Users Guide to Writing a Thesis in a Physics/Astronomy Institute of the University of Bonn

Hinweise und Tipps

zur

Produktion einer Bachelor/Master/Doktorarbeit

in der

Mathematisch-Naturwissenschaftlichen-Fakultät

der

Rheinischen Friedrich-Wilhelms-Universität Bonn

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Acknowledgements at the beginning should be a `\chapter*` so that they do not appear in the Table of Contents.

Contents

Introduction

LaTeX file: guide_intro.tex

When you want to start writing your thesis you usually ask a (more senior) colleague if he or she has a LaTeX framework that you can start with. He or she in turn had asked their (more senior) colleague for an example thesis several years earlier etc.! Maybe it is surprising that we are actually using LaTeX and not TeX to write theses!

LaTeX (or more precisely the packages that one can use in LaTeX) is actually in a state of continual development and improvement, so it certainly makes sense to review what packages are available, how they should be used and whether there are better ways of doing things than methods used 10 or more years ago.

The aim of this guide is to break with the tradition of just adapting what your predecessor used and provide up-to-date guidelines on the layout and packages that can or should be used for thesis writing. The guide should also provide you with enough information for you to concentrate on the content of your thesis, rather than having to spend too much time making it look nice!

You may ask why bother? First and foremost a thesis is something that you should be proud of! I therefore think it is actually worth devoting some effort to not only making it look good, but also to using correct and consistent notation when you write it. Figures and tables should be legible and understandable (including the size of the axis labels!). You should, however, not have to spend too much time working out how to make the thesis look the way you want it to. It is also good if you can avoid annoying or irritating your supervisor if he or she also thinks that GeV/c^2 should be written like this and not as GeV/c^2 or GeV/c^2 etc. or some mixture of the two.

The recommendations are based on experience I gained:

- preparing the lecture course „EDV für Physiker" for many years;

- editing the book "Physics at the Terascale", which was published in April 2011;

- rewriting and maintaining the ATLAS LaTeX document class and style files;

- regular reading of the „TeXnische Komödie", which is published by Dante (Deutschsprachige Anwendervereinigung TeX) 4 times a year;

- general interest in preparing good quality documents;

- reading quite a lot of theses!

This document does not attempt to explain how to write LaTeX. I assume a basic level of knowledge. The aim is more to give some practical tips and solutions to solve problems that often occur when you are writing your thesis. There are many books and online documents to help you get started, so many in fact that it is difficult to know where to start. My favourite is "Guide to LaTeX" from Kopka [KD04]. Be sure to read the Fourth Edition though. It was originally written in German where the title is „LaTeX: Eine Einführung". When you want to know what packages exist, what they can do and how to use them, consult "The LaTeX Companion" from M. Goossens et al. [MG04]. A fairly comprehensive online guide is the "A (Not So) Short Introduction to LaTeX2e." [Oet+], which is available in many languages. Help on getting started and a list of online documents can be found on the CTAN (Comprehensive TeX Archive Network) information page `http://tug.ctan.org/starter.html`. Other useful sources of information that I and others use are:

- `http://www.tex.ac.uk/faq`: This contains an extensive FAQ (maybe even a bit better than the German one maintained by Dante). An interesting feature is the "Visual FAQ" that serves as a rather unorthodox, but very intuitive kind of index: `http://www.tex.ac.uk/tex-archive/info/visualFAQ/visualFAQ.pdf`.

- `http://tex.stackexchange.com` often comes up in Google searches and contains a lot of very useful tips.

- `http://detexify.kirelabs.org/classify.html` contains a little online tool to find LaTeX names of symbols. It works quite well and can be a lot quicker than searching through the written documentation.

Not everyone knows about the `texdoc` command which should be available for Linux and macOS TeX installations. To get help on a package, you can simply give the command `texdoc geometry`, etc. Note that to see the KOMA-Script manual you have to know the name of the PDF file: `texdoc scrguide` or `texdoc scrguien` for the German and English versions, respectively. The AMS Math users guide also does not have a totally obvious name — try `texdoc amsldoc`. It contains a whole host of useful information on typesetting (complicated) equations.

The Physikalisches Institut is a member of Dante and so receives three copies of each issue of „der TeXnische Komödie", one of which is available in the department library in PI. The booklet often contains useful hints on typesetting. We also get a DVD every year with TeX distributions for Unix, macOS and Windows. Details on how to install a LaTeX distribution can be found in Appendix B.

If you write your thesis in English, questions are sure to occur on how things should be written in English, what is the correct punctuation and hyphenation, and what do you have to worry about when you construct sentences. I will not attempt to answer such questions here. "The guide to writing ZEUS papers" from Brian Foster [Fos] contains a wealth of useful information. Brian kindly gave me permission to package a PDF file of the note with this guide.

This document is structured as follows. Chapter 2 tells you how to get started with the files and the package. It also contains several tips and tricks that it is probably good to include early. It is sometimes not clear which version of the cover should be used when submitting and/or printing your thesis. Some instructions are given in Chapter 3. This is followed by Chapter 4, which lists the packages used in this document and says what they are good for. Chapters 5 and 6 give some guidelines for figures and tables. Chapter 7 discusses the tricky business of references and their formatting. Some hints on how

to solve common layout problems, which fonts one can use and how to handle multiple languages in a document are given in Chapter 8. In Appendix B I include some more information on the TeX setup I have used to test things. I have seen a glossary (list of acronyms) in a few theses and think this is a nice idea. Appendix C shows how you can create such a list. As big tables are often moved to the appendix, an example of how to create such tables is given in Appendix E.

While this guide is structured pretty much like a thesis, I have included a few extra features that are usually not needed in a thesis. The first is a link to the relevant LaTeX file at the beginning of each chapter. The guide also uses the listing possibilities of the tcolorbox package, to show you the LaTeX code directly, which means that you do not always have to look at the LaTeX file. I have added an index, as that is probably a useful complement to the table of contents.

Regular updates are made to the guide, so it is worth checking every so often to see if a new version is available. Corrections and suggestions for improvements are very welcome.

Tips and tricks

LaTeX file: guide_tips.tex

Over time I have collected quite a lengthy list of things you should "Do" and "Not Do" (at least in my head) that I think it is useful to write down early in the document, so that you may actually read them! In this chapter I first tell you how to get and use the style file and then give some tips. I have also started to add a list of common English mistakes, especially those made by German speakers!

2.1 How to use the ubonn-thesis style

My original idea with this document was that you also look at the LaTeX that is used to create it, in order to find out how things are done. I therefore do not always give you the LaTeX commands in the printed document, but assume that you would have a look at the LaTeX source. To help you with this, each chapter contains a link to the relevant file at the top. This link should work if you have compiled the guide yourself and are in the `guide` subdirectory of the **ubonn-thesis** directory tree. As of version 7.0 of the guide, I have started using the tcolorbox package that allows me to show both the LaTeX and the result automatically. Hence in more and more places you will find compiled LaTeX and the source code side by side. The files that make up this document are available in a Git repository and as a `tar` file. To get the latest Git version give the command:

```
git clone https://bitbucket.team.uni-bonn.de/scm/uni/ubonn-thesis.git
```

If you want to checkout a particular version you can give the command:

```
git clone --branch N.M \
  https://bitbucket.team.uni-bonn.de/scm/uni/ubonn-thesis.git
```

Note that you have to be in the University of Bonn network for the clone commands to work. The tar file (and the tag tree (as of version 1.5)) also includes the guide as a PDF file: `thesis_guide.pdf`. It can be obtained from:
http://www.pi.uni-bonn.de/teaching/uni-bonn-thesis and
http://www.pi.uni-bonn.de/lehre/uni-bonn-thesis.

Once you have the files, you can then give the command:

```
make new [THESIS=dirname] [TEXLIVE=YYYY]
```

to create a new directory with several files to help you get started. By default the directory name will be `mythesis`. If you want to write a thesis that uses the astronomy style of references (`authoryear` style and a bibliography at the end of each chapter) give the command "`make astro [THESIS=dirname]`". To compile your thesis switch to your new directory `cd mythesis [or dirname]` and try:

```
make thesis
```

See Section 2.2 for a list of the options that can be passed to the package. I no longer support versions of TeX Live older than 2015.

As of version 6.0, `make thesis` uses the `latexmk` command for compilation. `latexmk` looks at your logfile and decides how many times `pdflatex` etc. have to be run. If you use feynmf or feynmp you should use the commented out version of the `LATEXMK` variable that includes the `-shell-escape` option.[1] For details on how to compile a glossary with `latexmk` see Appendix C. If for some reason `latexmk` does not work you can use the command `make thesis11` instead. The tool `pplatex`[2] is supposed to provide a nicely formatted version of the LaTeX output on the command line.

My original idea was that the style file should work for all recent TeX installations. However, some of the packages I recommend have been changing quite a lot over the past few years. You should therefore set the TeX Live version you are using appropriately. The default setting is 2020.[3] For an an up-to-date version of MikTeX (2.9) you should probably use the current year. Things should compile without any changes if you use TeX Live 2016 or later. Look in the style file to see what changes are made depending on the year you use. You can change the TeX Live version when you make a new thesis by giving a command like "`make new TEXLIVE=2021`". If you switch TeX Live versions do a "`make clean cleanbbl cleanblx`" in between.

Note that as of version 2.1, the main file for the thesis (`mythesis.tex`), the `Makefile` and the style file (`ubonn-thesis.sty`) are copied into your `mythesis` subdirectory. This means that if you update the ubonn-thesis you can look for differences between the new style file and the one you have. It also implies that if you want the update to have an effect on your thesis you should copy the new versions of `ubonn-thesis.sty` and `ubonn-biblatex.sty` into the directory with your thesis. For more details see Section 2.10.

As of version 4.0 of the package, you specify the type of thesis and the stage as options to the `\documentclass` or to the ubonn-thesis package. These options select the appropriate title and cover pages. The following thesis types exist:

PhD a PhD thesis;
Master a Master thesis;
Diplom a Diplom thesis;

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[1] I got this information from https://tex.stackexchange.com/questions/374160/how-to-have-latexmk-always-use-shell-escape.

[2] Can be downloaded from https://github.com/stefanhepp/pplatex.

[3] Setting the TeX Live version to one that is lower than your installation should not cause any problems.

Bachelor a Bachelor thesis.

The following stages exist:

Draft you are still writing your thesis;
Submit you are ready to submit your thesis;
Final the final version of your thesis. For PhD theses this is the version that goes to ULB;
PILibrary final version of your thesis with an extra cover page including an abstract for the PI library.

See Chapter 3 for some more details about thesis submission.

If you change the stage of your thesis from say `Draft` to `Submit` you may encounter biblatex errors. These can be fixed by giving the command `make cleanall; make`.

If you are not a member of the „Physikalisches Institut" you should also change `\InstituteName`, `\inInstitute` and `\InstituteAddress`. The style file `ubonn-thesis.sty` already contains the appropriate definitions for PI, HISKP, IAP and AIfA.

All packages that are needed should be part of your TEX installation. If not you may have to install them or ask your system administrator to do so.

If you just want to make the cover pages, use the file `cover_only.tex`. Be sure to adapt the font selected in `ubonn-thesis.sty` to the font you actually used in your thesis. Be aware that not all font sizes are available in all font collections. If you used the default LATEX font in your thesis, then choose lmodern in the style file.

The main file for this guide is `guide/thesis_guide.tex` and it includes the LATEX files in the directory `./guide` and some of the Feynman graphs in the directories `./feynmf`, `pyfeyn`, `pyfeynhand` and `./tikz`. This guide should compile without changes for TEX Live 2017 or later. However, you can get rid of some diffcoeff warnings by setting the year to 2018 or later. For earlier versions set `\texlive` in `thesis_guide.tex` to the appropriate value.

2.2 Options that can be passed to ubonn-thesis

From version 3.0 onwards it is possible to change things in the style file by passing options to it. A few default packages also changed with this version. subfig → subcaption. I have oscillated between longtable → xtab. longtable seems to be more actively maintained and work a little bit better. The syntax `siunitx` and `siunitx=true` is equivalent. Use `siunitx=false` to turn off an option. The following options exist:

Option	Default	Description
PhD	false	A PhD thesis.
Master	false	A Master thesis.
Diplom	false	A Diplom thesis.
Bachelor	false	A Bachelor thesis.
Draft	true	Draft version of the thesis.
Submit	false	Version of the thesis to be submitted.
Final	false	Final version of the thesis (for PhD theses ready to go to ULB).

Continued on next page

Option	Default	Description
PILibrary	false	Final version including an extra cover page for the PI library.
thesistype	Unknown	Specify the thesis type.
thesisversion	Draft	Specify the stage of the thesis.
texlive	2020	Specify the TeX Live version. You can also use the older command `\newcommand*{\texlive}{2020}`.
twoside	true	Margins set for two-sided printing.
newtx	true	Use the newtx font packages (newer version of txfonts).
txfonts	false	Use a Times-Roman-like font.
palatino	false	Use a combination of Palatino, Helvetica and Courier fonts.
fontname	false	Use the font name rather than its filename for fonts with LuaLaTeX and XeLaTeX.
subcaption	true	A package for making sub-figures (and sub-tables) and captions for them.
subfig	false	A package for making sub-figures and captions for them.
subfigure	false	A package for making sub-figures and captions for them (deprecated).
tableheading	true	Table caption spacing set correctly for captions above the table.
longtable	true	Another package for tables that are longer than one page.
supertabular	false	Another package for tables that are longer than one page.
xtab	false	A package for tables that are longer than one page.
biblatex	true	Include biblatex.
siunitx	true	Use the siunitx package for typesetting units.
eVkern	false	Apply a kern of -0.1em to eV in order to move "e" and "V" closer together. This is not necessary if you use the newtx font package.
dcolumn	false	A package for helping to align things in tables.
cleveref	true	Turn on use of the cleveref package.
clevercaps	true	Capitalise Fig., Table etc.
derivative	false	A new package (released in 2021) with lot of useful commands for derivatives.
diffcoeff	false	A lot of useful commands for derivatives.
physics	false	Useful mathematical constructions for physics.
hepparticles	true	Standardised names and formatting for particle physics. This loads hepnicenames and heppennames.
hepitalic	true	Use italics rather than upright letters for particles.
mhchem	true	A nice package for chemical elements and processes.
bookmark	true	use bookmark package to improve bookmarks in PDF file.
feynmf	false	Include the feynmf package for Feynman graphs.
feynmp	false	Include the feynmp package for Feynman graphs.
titlesec	false	Use the titlesec package for formatting chapter titles.
astrobib	false	Adjust biblatex options to conform to the usual astronomy style.
refsection	true	Set things up for references to be at the end of each chapter.

Option	Default	Description
floatopt	true	Adjust settings that control the number and placement of floats.
todonotes	false	Turn on use of the todonotes package and define \mynote.
shownotes	false	Show the ToDo notes (also turns on todonotes).
showframe	false	Shows a frame around page elements for debugging purposes.
backend	biber	Specify the backend to use for biblatex. Possibilities are biber, bibtex or bibtex8.
bibencoding		Set the encoding for the bibliography (usually not needed).
bibstyle	numeric-comp	Specify the style to use for the references. Standard values are numeric-comp or alphabetic.

A few default option values are adjusted depending on the TeX Live version. See the ubonn-thesis style file to find out what is changed. The option twoside should probably be set to false for an online version of your thesis that is not going to be printed.

You can tweak the bibliography by passing various options to the ubonn-biblatex style file. These are detailed in Section 7.4.1.

If you use LuaLaTeX or XeLaTeX, the newtx and txfonts options select the TeX Gyre Termes font, while the palatino option selects the TeX Gyre Pagella font. The TeX Gyre font Heros is used as the sans-serif and Cursor as the monospaced font. Fonts are by default selected using the filename. If for some reason this does not work you can try the fontname=true option, which uses the font name instead.

Depending on the font you use, you may find that the "e" and "V" in eV, MeV etc. are too far apart. You can pass the option eVkern to ubonn-thesis in order to move them 0.1em closer together.[4]

2.3 Do

- Have 1–2 other people read your thesis well before you are supposed to submit it. Do not ask too many; everyone has their own opinions on how things should be written, how much detail should be included etc. and these opinions will not necessarily agree with each other!

- Write "nice" LaTeX. It makes it much easier to find mistakes in your document. If you like to use the keyboard rather than the mouse when moving round in a document, turn on "auto-fill-mode (emacs)" or its equivalent in any other editor, so that line breaks are inserted.

- Make sure every table and figure is referenced in the text. I get very irritated when I suddenly find a figure that is not described in the text. A useful package to check this is refcheck.[5] You need to run LaTeX one more time for it to work. It indicates both in the log file and the resulting PDF which figures, tables, equations and sections are referenced.

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[4] It is not needed if you use the newtx font package.

[5] There is a conflict if you use refcheck, subcaption and hyperref together. See http://tex.stackexchange.com/questions/273970/conflict-refcheck-subcaption-packages-for-label-with-underscores for a workaround.

- Use a units package to format numbers and their units. Recent versions of LaTeX include the siunitx package, which is a superior replacement of SIunits. I used to use SIunits, or rather hepunits which is built on top of SIunits, and defines common particle physics units such as GeV. Use of these packages is discussed in Section 2.5. An alternative is the units package.

- Define any complicated symbols once you use them more than once:

  > `\newcommand*{\etajet}{\ensuremath{\eta_{\text{jet}}}\xspace}`

  If you decide at a later date that jet should be a superscript rather than a subscript you only have to change this in one place!

  Note that Kopka [KD04] recommends using `\newcommand*` rather than `\newcommand` for short commands.

- If you use normal words in superscripts or subscripts (or anything else in math mode) enclose them in `\text`. You can also use `\mathrm` or `\textrm`. However, if you then use the same symbols in slides with a sans-serif font, the text may well continue to be in a serif font.
  Compare: A common jet energy cut at the LHC is now $p_T^{\text{jet}} > 20\,\text{GeV}$, while at HERA we typically used $p_T^{\text{jet}} > 6\,\text{GeV}$. The GeV in the first expression is in sans-serif. This is because the `\sisetup{detect-family=true}` option is set in ubonn-thesis.sty (see Section 2.5.1). I used the option `detect-family=false` for the `\SI` command in the 2nd expression. In the first expression I use `\text` for "jet", while I use `\mathrm` in the second expression.

- Use `\xspace` and `\ensuremath` in all commands where you would like to use a symbol both in text mode and in math mode. Without `\xspace` you have to make sure that you end every symbol with \ or {}, otherwise the space is used to signify the end of the symbol, e.g. in LaTeXwe have to pay attention otherwise the symbol and the next word run together.

- Decide how you want to write abbreviations for particles and stick to it — you should probably define the particle names in your style file and always use them (also for quarks). There are packages hepnicenames and heppennames, which use hepparticles.[6] These packages have many predefined particles and a standard convention for naming. It is easy to add further definitions. See Section 2.6 for some more details on how to write particles that are relevant for particle physics.

- Decide how you want to write coordinate axes and stick to it. Far too often I see text like: "The proton beam defines the Z direction, while the interaction point is denoted as (x_0, y_0, z_0). The polar angle is measured with respect to the z axis and $\cot\theta = p_Z/p_T$". Which is the best way of writing the coordinates? As x, y and z are often used for kinematic variables, there are arguments in favour of (X, Y, Z).

- Use `\enquote` from the csquotes package to quote text rather than using explicit quotation marks. This has the advantage that consistent quotation marks are used everywhere (also if they are nested)

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[6] Note that hepnicenames automatically includes heppennames, so it is sufficient to include hepnicenames to be able to use both sets of definitions.

and that they are also correct for the language (and dialect[7]) you are writing your thesis in. You can also see in Chapter 1 how this works, even when switching languages inside a paragraph.

- Use sizes that depend on the font size, em (width of "M") and ex (height of "x"), for spacing that should change with the text size. Use absolute sizes cm, mm, pt etc. where they are appropriate, e.g. title pages, boxes, etc. \quad and \qquad are also useful sizes in tables and equations.

- Add a \ (or {}) after abbreviations that end with a full stop such as e.g. if followed directly by text. If you do not, an end of sentence space is added rather than a normal interword space. Note that \ is not needed (but does no harm) after abbreviations that only consist of capital letters: compare "e.g. my name is Ian C. Brock" and "e.g. my name is Ian C. Brock", where \ was included in the second version. In this example the difference is small. However, if LaTeX increases the spacing between words to fill a line the effect is more obvious.

- If a capital letter ends a sentence you should add the command \@ before the full stop, e.g. \ldots as discussed in the chapter on QCD\@. which produces ... as discussed in the chapter on QCD. This is necessary, as otherwise only an interword space is used before the next sentence.

- Ask someone (me) if you cannot easily find out how to solve formatting problems. I once saw a thesis in German, where the author wanted to use commas instead of full stops in numbers and wrote numbers as \(2,\!47\) to produce 2,47 instead of 2, 47. There are usually much better solutions, e.g. \num{2.47} with the siunitx package produces 2.47 in English and 2,47 in German. In the end such solutions will save you time!

- Use punctuation in equations and "d", i.e. an upright "d" (if you are writing in British English) for derivatives, e.g.

$$\int y \, \mathrm{d}x \, .$$

This is also one of the the very few places, where it makes sense to put some spacing in by hand — normally you should leave this to TeX. The derivative package provides the command \odif{x}, while the diffcoeff package (as of version 3.0) provides the command \dl, and you can add space using a syntax such as \dl2x.[8] The physics package provides the command \dd{x}, which does the spacing for you.

```
\begin{equation*}
  \int y \dl2x\,.
\end{equation*}
```

- Pay attention to the alignment of numbers in tables. siunitx provides the S column specifier to help with this. Recent versions of siunitx provide the command \tablenum, which gives a lot of flexibility. Packages such as dcolumn also provide assistance.

---

[7] By default, British (UK) English uses 'British quoted text' for outer quotation marks, while American (US) English uses "American quoted text". In this guide (and in ubonn-thesis.sty) "American (US) quotes" are used even if you write in British (UK) English.

[8] The digit can be anything between 0 and 9 (negative values are also possible). 2 and 3 look to me to be sensible default values to use.

Not really a strict "Do": I highly recommend that you use an integrated environment for editing and compiling your thesis. If you are use macOS or Windows you probably get TeXShop or TeXworks by default. TEXstudio is based on Texmaker and is available for Linux, Windows and macOS. It used to be my preferred LATEX environment under all systems! In the past couple of years, I have switched to the Visual Studio Code editor instead. The main reason for this is so that I can use the same program for editing scripts, e.g. a `Makefile`, as I use for LATEX code. The `LaTeX Workshop` extension is being actively developed and is very nice. The `Spell Right` spelling checker works very well and I have also activated the use of `ChkTeX` to improve my LATEX syntax. Under Linux you can also use Kile or the way I used to work was to use `emacs` and AUCTeX. Note that the RefTeX mode in `emacs` also provides powerful tools for finding cross-references and the names of citations easily.

An increasingly popular alternative is Overleaf. If you want to write your thesis using Overleaf, you first have to upload a zip file of a skeleton thesis as a project. See Appendix B.1.3 for details on how to set things up and get started.

One advantage of such environments is that it is usually possible to switch between a position in your output file and the relevant place in the source code and vice versa. This makes it much quicker to fix things when you spot an error in your output PDF file. You can usually also step through the errors when you try to compile your file and fix them directly. In addition, they know which environments and mathematical symbols exist, which can speed things up if you have not been working with LATEX for the past 20 years!

More details on integrated environments and installing TEX for different systems can be found in Appendix B.

2.4 Do not

- Don't write symbols differently in math mode and in text. One of my pet hates is:

    The most famous equation in the world is:

    $$E = mc^2 \tag{2.1}$$

    where E is the energy of the particle and m is its mass,

  i.e. E and m are in math mode in the equation, but in text mode in the text where they are explained.

- Do not start a new paragraph when describing the elements in an equation. The equation above is described correctly. Wrong would be:

    The most famous equation in the world is:

    $$E = mc^2 \tag{2.2}$$

      where E is the energy of the particle and m is its mass.

  Using the paragraph options of this guide, you add extra vertical space. If your paragraphs are indented, "where" would also be indented.

  If you want to leave a blank line in your LATEX file for clarity, you should make it a comment line, i.e. "%".

- Another example of how not to write things is something like "The scale factor, SF, used to correct the MC is determined in an independent dataset using $SF = N_{data}/N_{MC}$". Note the wrong font and spacing of SF, $data$ and MC. All should be enclosed in \text: $SF = N_{\text{data}}/N_{\text{MC}}$.

- Do not include the directory (or at least the top-level directory) or the extension of the file in \includegraphics commands. Use \graphicspath instead to set up a list of directories that hold the figures. Let LaTeX or pdfLaTeX pick the extension for the figure, so that you can (in principle) easily switch between the two.

- Do not use the old font commands \rm, \tt, \sc etc. If you are running a recent version of TeX Live, you may have seen warnings of the form:

```
Class scrartcl Warning: Usage of deprecated font command '\sc'!
(scrartcl)              You should note, that in 1994 font command '\sc' has
(scrartcl)              been defined for compatibility to Script 2.0 only.
(scrartcl)              Now, after two decades of LaTeX2e and NFSS2, you
(scrartcl)              shouldn't use such commands any longer and within
(scrartcl)              KOMA-Script usage of '\sc' is definitely deprecated.
(scrartcl)              See 'fntguide.pdf' for more information about
(scrartcl)              recommended font commands.
(scrartcl)              Note also, that KOMA-Script will remove the definition
(scrartcl)              of '\sc' anytime until release of about version 3.20.
(scrartcl)              But for now, KOMA-Script will replace deprecated '\sc'
(scrartcl)              by '\normalfont \scshape ' on input line 94.
```

  If you have TeX Live 2016 or later, you will find that KOMA-Script has gone ahead with its threat and \sc etc. now give errors and compilation stops! Instead you should use \textsc etc. You should also use \mathcal{L} instead of {\cal L}. A nice, brief explanation of the differences can be found in „Das LaTeX2e Sündenregister", which you can find with the command texdoc l2tabu. The English variant is called "An essential guide to LaTeX2e usage: Obsolete commands and packages" and can be found with the command texdoc l2tabuen. I highly recommend you read this document to find out what constructs you should avoid in your documents. You can read the font guide by giving the command texdoc fntguide.

- Do not try to end paragraphs with \\. Outside tables, these should be used sparingly when for some reason you really have to start a new line. Just leave an empty line for a new paragraph.

- Do not draw conclusions or interpret figures in the caption. The caption should just describe what is in the figure. Interpretation belongs in the main body of the text.

- Do not start trying to format figure and table captions inside each caption — use the options available in KOMA-Script to set such things at the beginning of the document.

- Do not worry about overfull boxes, positions of figures and tables, etc. until you reach the final version of your thesis.

2.5 Units

As mentioned above, but I'll say it again just to make the point, one of my pet hates is inconsistent and poor typesetting and spacing of units. At least three standard packages exist to solve this problem: siunitx, SIunits and units. My favourite is siunitx as it offers many extra features in addition to the correct typesetting of numbers and their units. Information on the other (older) packages has been relegated to Appendix G.1.

2.5.1 siunitx package

This package is a more modern and complete package than either SIunits or units.

One very attractive feature is that it allows you to format computer-generated numbers such as `1.4E4` automatically:

```
\num{1.4E4}\\
\num[exponent-product=\cdot]{-3.4E-6}\\
\SI{2.99467E8}{\metre\per\second}\\
\SI[round-mode=places,round-precision=1]{2.99467E8}{\m.\s^{-1}}
```

1.4×10^4
$-3.4 \cdot 10^{-6}$
$2.99467 \times 10^8 \,\mathrm{m\,s^{-1}}$
$3.0 \times 10^8 \,\mathrm{m\,s^{-1}}$

Depending on the language or using the option `exponent-product` you can change the way exponents are output. It is even possible to set the number of decimal places using the rounding abilities. The last two examples only differ by the use of the `round-mode` and `round-precision` options, and even rounds correctly!

Another extremely nice feature of the package is that you can typeset numbers in a single way and then a full stop or a comma will be used as the decimal point, depending on which language you set for your document. This means that computer generated decimal numbers can be output with commas in a German thesis just by changing the language of your thesis — this for me is LaTeX at its best! For example:

```
\num{1.2345E-3}\\
\foreignlanguage{ngerman}{\num{1.2345E-3}}
```

1.2345×10^{-3}
$1{,}2345 \cdot 10^{-3}$

where the 1st example is in the default language of the document and the second says that this piece of text is in German (`ngerman` to be exact).

In keeping with LaTeX philosophy, you can specify a number and its error:

```
\num{2.88(32)}\\
\num[separate-uncertainty=false]{2.88(32)}\\
\num{2.88(32)E-3}
```

2.88 ± 0.32
2.88(32)
$(2.88 \pm 0.32) \times 10^{-3}$

The 1st example uses `separate-uncertainty` option (which I specify), while the 2nd uses the package default (given here as `separate-uncertainty=false`). Errors and powers can also be combined. You also give as an option how units with negative powers of units should be shown, e.g. per second. This can be changed for a single command.

Some examples are given below:

```
\(c\) is \SI{3E8}{\metre\per\second}\\
\(c\) is \SI[per-mode=fraction,
    fraction-function=\sfrac]{3E8}{\metre\per\second}\\
\(c = \SI[per-mode=symbol]{2.99E8}{\metre\per\second}\)\\
\(\hbar\) is \SI{1.054E-34}{\joule.\second}
```

c is $3 \times 10^8 \, \mathrm{m \, s^{-1}}$
c is $3 \times 10^8 \, \mathrm{m/s}$
$c = 2.99 \times 10^8 \, \mathrm{m/s}$
$\hbar$ is $1.054 \times 10^{-34} \, \mathrm{J \, s}$

The 1st example uses the default `\per`, while the 2nd example uses
`per-mode=fraction, fraction-function=\sfrac`. The 3rd example shows that it does not matter whether one is in math mode or not and uses `per-mode=symbol`. You use "." or "," to make a space between the units, as illustrated in the last example.

Angles are also very straightforward:

```
\ang{90}
```
90°

If you want to write something like 90(99) %, include the option `parse-numbers=false` with the `\SI` command, so that it does not try to interpret 90(99):

```
\SI[parse-numbers=false]{90(99)}{\%}
```
90(99) %

If you also want to use siunitx in slides, where one usually uses a sans serif font, you may at first be disappointed that siunitx uses a serif font for the units! Do not despair! You can use the command `\sisetup{detect-family=true}` to ensure that the package uses the current font (in all its aspects) rather than its default.

Have a look at the manual, `texdoc siunitx`, for many more examples. siunitx also contains useful

and powerful tools for typesetting tables and as mentioned above can be used to round numbers. These aspects are discussed in Chapter 6.

Note that the `\clight` symbol that is used in the macro `\MeVovercsq` to produce MeV/c^2 is defined as c_0 in siunitx version 2. As this is not the way it is usually written in particle physics I redefined it using:

```
\DeclareSIUnit\clight{\text{\ensuremath{c}}}
```

Two things that are currently not built in are separate statistical and systematic errors and asymmetric errors. From the author I got some suggestions on how to define such things. They are included in `guide_defs.sty` at present and can be added to `thesis_defs.sty`. Several new macros have been defined there: `\numerrt`, `\numpmerr` and `\numpmerrt` to write errors with a description, which are asymmetric and both, respectively. The corresponding macros for values and errors are `\SIerrt`, `\SIpmerr` and `\SIpmerrt`. For the macros whose names end with "t", you also have to provide the descriptive text. If you have two errors then use `\SIerrtt` or `\SIpmerrtt`, which have two or three more arguments, respectively. For the standard case of statistical and systematic errors, you can use the macros `\SIerrs` and `\SIpmerrs`. Examples of their use are:

```
\begin{align*}
  \sigma & = \SIerrs{3.42}{0.46}{0.32}{\pico\barn}\\
  \sigma & = \SIpmerr{3.42}{+0.46}{-0.32}{\pico\barn}\\
  \sigma & = \SIpmerrt{3.42}{+0.46}{-0.32}{\stat}{\pico\barn}\\
  \sigma & = \SIpmerrs{3.42}{+0.46}{-0.32}{+0.06}{-0.04}{\pico\barn}\\
  \sigma & =
    \SIpmerrtt{3.42}{+0.46}{-0.32}{\stat}{+0.06}{-0.04}{\sys}{\pico\barn}
\end{align*}
```

$$\sigma = (3.42 \pm 0.46\,(\text{stat.}) \pm 0.32\,(\text{sys.}))\,\text{pb}$$

$$\sigma = (3.42\,{}^{+0.46}_{-0.32})\,\text{pb}$$

$$\sigma = (3.42\,{}^{+0.46}_{-0.32}\,(\text{stat.}))\,\text{pb}$$

$$\sigma = (3.42\,{}^{+0.46}_{-0.32}\,(\text{stat.})\,{}^{+0.06}_{-0.04}\,(\text{sys.}))\,\text{pb}$$

$$\sigma = (3.42\,{}^{+0.46}_{-0.32}\,(\text{stat.})\,{}^{+0.06}_{-0.04}\,(\text{sys.}))\,\text{pb}$$

The last two examples use `\SIpmerrs` and `\SIpmerrtt` just to show that they can both give the same output. If you need even more complicated combinations of errors, or more errors, have a look at the definitions, e.g.

```
\begin{equation*}
  \sigma_{t\bar{t}} = (\num{164.6}%
  \valuesep\numerrt{8.7}{\stat}%
  \valuesep\numpmerrt{+6.4}{-5.3}{\sys}%
  \valuesep\numerrt{8.2}{lumi.})%
  \valuesep\si{\pico\barn}
\end{equation*}
```

$$\sigma_{t\bar{t}} = (164.6 \pm 8.7\,(\text{stat.})\,{}^{+6.4}_{-5.3}\,(\text{sys.})\, \pm 8.2\,(\text{lumi.}))\,\text{pb}$$

Version 3 of siunitx replaces \SI with \qty and \si with \unit. This version was released in June 2021, so it might take a while before you are affected by this change. The old macro names will continue to work.

2.6 Definitions in particle physics

At some point the CERN Computer Newsletter claimed that all particles should be written upright, e.g. Z boson, b quark. However, nowadays it seems to be much more common to use italics. This is also how the particles are written in the PDG. While ATLAS usually uses italics, CMS (and the CERN Courier) use upright letters.

If you use the hepnicenames, heppennames or hepparticles packages, you can use the option `italic` to switch from upright and italics. This is of course very nice! You just have to get used to the conventions used there for particle names. Many particles are available in hepnicenames, while heppennames is more complete. Note that there is a bug in the hepnicenames, heppennames and hepparticles packages as of TeX Live 2019. Upright particles are not printed. I have a solution to the problem, but it has not yet made it to the official version.

Some examples from heppennames:

```
\Pe, \Pl, \Pqt, \Paqt\\
\PZ, \PWpm\\
\PBz, \PBpm, \PacB\\
\PBz{}\PBz, \PBz\PBz
```

$e, \ell, t, \bar{t}$
$Z, W^{\pm}$
$B^{0}, B^{\pm}, B^{-}_{c}$
$B^{0}B^{0}, B^{0}\,B^{0}$

Some examples from hepnicenames:

```
\APelectron, \Plepton, \Ptop,
    \APtop\\
\PZ, \PWpm\\
\PBzero, \PBpm, \APBc\\
\PBzero{}\PBzero, \PBzero\PBzero
```

$e^{+}, \ell, t, \bar{t}$
$Z, W^{\pm}$
$B^{0}, B^{\pm}, B^{-}_{c}$
$B^{0}B^{0}, B^{0}\,B^{0}$

You can use commands like \HepParticle to define particles that are missing. There are also macros for antiparticles and supersymmetric particles. If you define particles yourself, I would recommend one

of the following definitions:

```
\newcommand*{\Zo}{\ensuremath{Z}\xspace}
\newcommand*{\Zo}{\ensuremath{\text{Z}}\xspace}
\newcommand*{\bbarQ}{\ensuremath{\bar{b}}\xspace}
\newcommand*{\bbarQ}{\ensuremath{\bar{\text{b}}}\xspace}
```

which produce Z, Z, $\bar{b}$, $\bar{\text{b}}$. Note that you are not allowed to include numbers in the names of commands, so \Z0 or \U1S are not valid commands. For $\overline{B}_c^{\pm}$ and other particles whose names are capital letters, it can be debated whether it better to use \overline than \bar. Compare $\overline{B}_c^{\pm}$ and $\bar{B}_c^{\pm}$. If you use upright letters the choice is maybe easier: $\overline{\text{B}}_c^{\pm}$ and $\bar{\text{B}}_c^{\pm}$ or $\overline{\text{K}}_S^0$ and $\bar{\text{K}}_L^0$. hepparticles tries to tweak the size of the bar to make it look good.

Another problem is that, depending on the font you use, the spacing between "e" and "V" on eV and its derivatives, e.g. GeV, can be larger than you would like. As this is font dependent the siunitx package does not try to fix this.[9] The ubonn-thesis package contains an option eVkern that introduces a -0.1em kerning, i.e. shift of "V" closer to "e" by 0.1em, which you can turn on if necessary.

2.7 Hints

xspace is great, but how do you write $B^0\bar{B}^0$ when you have defined the symbols \Bo and \Bobar with \xspace at the end. Here you need {} between the two commands, e.g. \Bo{}\Bobar produces $B^0\bar{B}^0$ while \Bo\Bobar produces $B^0\ \bar{B}^0$.

How should you write "between 10^4 and 10^5"? If you use math mode it looks like $10^4 - 10^5$, which is not really what you want. Although it is rather clumsy, the best way to do it is \(10^{4}\)--\(10^{5}\) which produces "10^4–10^5".

With siunitx and \num there is a built-in option. You simply write

`\numrange{3e4}{7e4}`	3×10^4 to 7×10^4

You can steer how often the units are written out:

```
\SIrange[range-units=repeat, range-phrase=--]{5}{7}{\GeV}\\
\SIrange[range-units=single, range-phrase=--]{5}{7}{\GeV}\\
\SIrange[range-units=brackets, range-phrase=--]{5}{7}{\GeV}
```
- -
5 GeV–7 GeV

5–7 GeV

(5–7) GeV

In a single range, such settings are rather long-winded! However, they can be applied to the whole document using the \sisetup macro.

---

[9] A discussion of this can be found in http://tex.stackexchange.com/questions/219854/can-i-declare-a-new-automatic-kern-for-ev-without-modifying-font-metrics.

A similar problem is how do you write "about 10%"? Again the simple solution $\sim 10\%$ or $\sim 10\%$ have too much space. In the file `thesis_defs.sty` two macros `\mysim` and `\mysymeq` are defined that add some negative space so that you can simply put everything in math mode: $\sim 10\%$ or $\simeq 0.2$. An alternative is to use `\SI` or `\unit`, as there should actually be some space between the number and the % sign, e.g. `\(\sim\)\SI{10}{\%}`, which produces $\sim 10\,\%$, is completely correct and does not need the use of `\mysim`.

What is the difference between `\textrm` and `\mathrm`? I used to worry about this and found a few examples (which I then forgot) where the font size was better using one or the other. Then I learnt about `\text`, converted all my predefined symbols to use `\text` rather than `\mathrm` or `\textrm`, and don't have to worry any more. Having played around with using a sans serif font in the main document I understand the differences better. `\text` uses the standard text font, while `\mathrm` and `\textrm` use the math font. In documents like your thesis, these are usually the same, so you do not see any difference. If your text font is sans serif, as in University of Bonn letters, and you use a serif math font, then you will see a difference. I can given an example for the definition of the transverse energy of the highest energy jet:

```
\(p_{\mathrm{T}}^{\mathrm{1^{\text{st}} jet}}\)\\
\(p_{\textrm{T}}^{\textrm{1}^{\text{st}}\textrm{ jet}}\)\\
\(p_{\text{T}}^{1^{\text{st}}\text{ jet}}\)
```

$$p_{\mathrm{T}}^{1^{\text{st}}\text{jet}}$$
$$p_{\mathrm{T}}^{1^{\text{st}}\text{ jet}}$$
$$p_{\mathrm{T}}^{1^{\text{st}}\text{ jet}}$$

As you can see from this example, the key difference is that `\mathrm` switches to an upright font, but keeps you in math mode — hence ignoring any spaces. `\textrm` switches to text mode (with a serif font) and therefore pays attention to spaces. You cannot use a superscript or subscript inside `\textrm`, as it is for text mode. The 3rd example uses `\text`, which is my preferred solution.

A perennial problem is bold math when it is needed in section headings etc. This is further complicated by the fact that the table of contents is usually not typeset using a bold font (except for chapter titles, or whatever the highest level(s) of sectioning are). One way to get this right in both cases is to give the heading twice, once with `\boldmath` for the real title and once without as the optional title for the table of contents. An alternative solution is to add the command `\def\bfseries{\fontseries\bfdefault\selectfont\boldmath}`. As of version 3.0 of ubonn-thesis this command is included, so `\boldmath` should no longer be needed. An illustration of how this works is given in Appendix F. Note that this fix does not work for LuaLaTeX and XƎLaTeX and so is not applied. Appendix F illustrates ways of getting around the problem.

For math mode the official LaTeX macro is `\(...\)`. `$...$` is the TeX primitive. It is therefore recommended to use `\(...\)` for inline equations etc., although it must be said that probably well over $90\,\%$ of people still use `$...$`. There still seem to be a few cases when `\(...\)` leads to errors. This sometimes happened for TeX Live versions from 2013 or earlier when used in figure or table captions.

2.8 Common English mistakes

Several constructs are often used by German (and other non-native) speakers that are not grammatically correct in English. Additions to the list are welcome. These are the ones I remember coming across so far:

- "He has been living here since five years." Correct: *"He has been living here for five years."* An example of the correct use of "since": "Since becoming ATLAS spokesperson he has implemented . . . ."

- "This allows to measure m_H very accurately." Correct: *"This allows m_H to be measured accurately."* See comment below about "fluff".

- "The table contains lots of informations." Correct: "The table contains a lot of information."

- "The table contains a lot of information, that is redundant." Correct: *"The table contains a lot of information that is redundant."* You do not need a comma before "that" in English.

- "The main topics to discuss include: Building a new detector; . . . " Correct: *"The main topics to discuss include: building a new detector; . . . "* In British English you should not capitalise the word after a colon. In American English it is often capitalised.

- "less" and "fewer": use "fewer" for things that you can count and "less" for things you cannot count: "less energy" and "fewer jets".

- "The interaction occurs with a highly energetic hadron." Correct: *"The interaction occurs with a high energy hadron."* One could argue that: *"The interaction occurs with a high-energy hadron."* is even better, as it makes clear that "high" is describing the energy of the hadron.

- "Energy is measured in the hadronic calorimeter." Correct: *"Energy is measured in the hadron calorimeter."* This is somewhat controversial. There are in fact ATLAS publications that use the term "hadronic calorimeter".

- "We are not sensible to this effect." Correct: *"We are not sensitive to this effect."*

- "We have to choose between Xenon (Xe) and Argon (Ar)." Correct: *"We have to choose between xenon (Xe) and argon (Ar)."*

- "We loose 50 % of the signal due to this cut." Correct: *"We lose 50 % of the signal due to this cut."*

A general comment (which also applies to theses in other languages) is that you should avoid "fluff". A statement that is often attributed to Mark Twain[10]:

> Substitute "damn" every time you're inclined to write "very"; your editor will delete it and the writing will be just as it should be.

---

[10] See https://quoteinvestigator.com/2012/08/29/substitute-damn/ for a discussion of the source.

This also ("damn!") applies to other similar words such as "also, really". Common usage of fluff is in statements like "very high energy", which can be properly written as just "high energy" without compromising content. What does the "very" add if it is not compared to anything? If it is compared, why not choose a better adjective?

Although a case can be made for name assignment used with "so-called", it makes more sense for proper assignment to use "called", "defined as" or "referred to as". "So-called" is typically used to indicate that a name assigned is not entirely true or in fact wrong. For example, one could say "wrongly identified and non-prompt leptons, so-called fake leptons, are estimated . . . " This is because non-prompt leptons are not fake leptons in reality, but are often grouped under the same "fake lepton" umbrella term. One should not use "so-called" to define or give a proper name. For example, "when charged particles pass through gasses, they induce charges in the gas material that can be measured, so-called ionization" is incorrect. Correct: "*The induction of charge in gasses in this manner is one definition of ionization.*" or "*when charged particles . . . can be measured, 'referred to as' or 'called ionization'.*"

To make matters more complex, "so-called" should not be confused with "so called", unhyphenated. This is no longer an adjective but it is now a combination of an adverb and a verb! In this way, "so called" essentially means "it is called this way because". For example, "*ATLAS is an general-purpose detector; it is so called because it has means to detect and measure the broadest possible range of signals.*"

One further important point: decide early on if you are going to write your thesis in American or British English. Typical American spellings include: center, flavor, color, hadronize. The British English spellings are: centre, flavour, colour, hadronise. Choose one or the other and do not mix them. Note that the conventions on punctuation and where it is placed relative to quotes are different in American and British English.

You should also decide how to capitalise your chapter and section headings. You can either capitalise just the first word (and proper names and acronyms), or every important word. Most journals have moved to the first option, but there are some that use the latter (most notably APS journals). Both are fine — just be consistent!

2.9 Line numbering

You probably do not need line numbers when writing your thesis (who knows?). However, as this is a very useful package that occasionally has some problems, I thought I would include some information here.

lineno is the package to use to get line numbers in your text, but sometimes a block of lines is not numbered — see Fig. 2.1a.

Such problems are associated with text that is close to math mode environments. Some of the problems can be solved by using a new version of the lineno package. However, this only works for "standard" LaTeX math environments: `displaymath`, `equation` and `eqnarray`, while it does not work for recommended amsmath environments such as `equation*`, `align(*)` and `alignat(*)`.

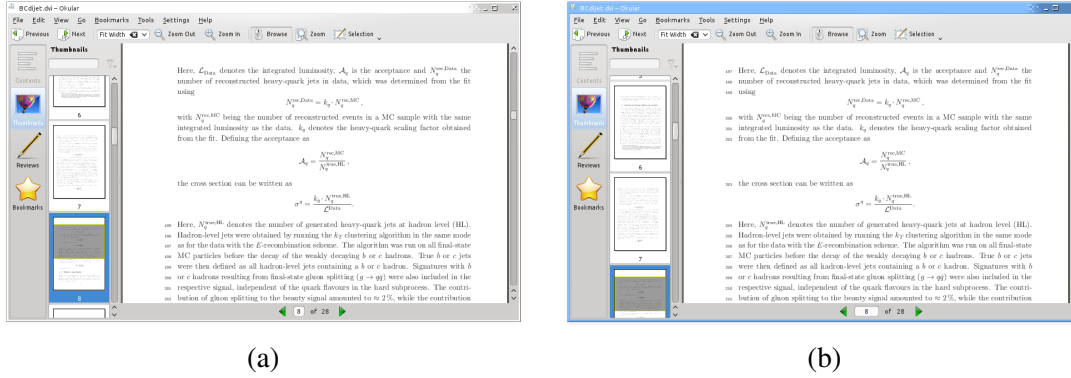The solution is to enclose the equation in `linenomath` environment, e.g.

Figure 2.1: Example of (a) a problem with line numbers and (b) its solution.

```
The total visible cross section for inclusive heavy-quark jet
production, \(\sigma^{q}\), with \(q\in\{b,c\}\) is given by
\begin{linenomath}
\begin{equation*}
  \sigma^{q} = \frac{N_{q}^{\text{rec,Data}}}%
    {\mathcal{A}_{q}\cdot\mathcal{L}_{\text{Data}}}.
\end{equation*}
\end{linenomath}
Here, \(\mathcal{L}_{\text{Data}}=\) denotes the integrated luminosity,
\(\mathcal{A}_{q}\) is the acceptance and \(N_{q}^{\text{rec,Data}}\) the
number of reconstructed heavy-quark jets in data, which was determined
```

Then the line numbering will be correct, see Fig. 2.1b. The ATLAS atlasdoc class contains a patch that gets round this problem.

2.10 Updating ubonn-thesis

When you make a new thesis skeleton (as of version 2.1) the files ubonn-thesis.sty and ubonn-biblatex.sty) are copied to your mythesis directory. As of version 6.0, your mythesis directory should be completely standalone and does not rely on any files in the parent directory. If you want to profit from updates to ubonn-thesis, you therefore need to copy the new version into mythesis again. The advantage of this scheme is that you can easily check what the differences are before you do the copy. More importantly, if you have made your own changes to the style file, it should be relatively easy to merge the two versions. Having all files in the mythesis subdirectory also makes it much easier for you to use your own version manager for your thesis.

What is therefore the best way to update ubonn-thesis? If you are using Git, then you first need to do a git pull in the ubonn-thesis directory. If you use a tar file, then you should unpack it and copy over your mythesis directory tree to the new ubonn-thesis tree. As of version 6.0, you can then use a command like make update THESIS=mythesis to copy the style files, the bib file with the standard references and the covers to your mythesis directory. You will be asked before existing files are overwritten. The Makefile is not updated in this process (as of version 9.1), as changes to it are

only rarely made, and you may have adapted it to your use. Have a look at `thesis_skel/Makefile` to see if there are any updates to the `Makefile` that you should also include.

If you are using Overleaf, you can try to download the project as a zip file, unpack it into a subdirectory of `ubonn-thesis`, apply the changes you want to make, make a zip file of it again and import the zip file of the project back into Overleaf. Otherwise, you will have to make any relevant changes by hand. Have a look at the `Makefile` to see which files I normally try to update.

As a side remark, I would also recommend that you put all Feynman graphs etc. in subdirectories of `mythesis`. You may have to change some variables that are set at the beginning of the `Makefile` so that this works if you use feynmf. If you use feynmp just add `\write18` statements. See Section 5.5 for some more details.

Submitting your thesis

LaTeX file: guide_submit.tex

Questions often come up when your thesis is finished and now you have to print it and submit it. Both the „Promotionsbüro" and the „Prüfungsamt" have instructions on what you have to do, but it is sometimes not clear what this means in terms of the cover pages offered by this thesis framework.

For the printed version of your thesis, you probably want hyperref links and the table of contents to be black. In order to do this, you should uncomment the \hypersetup command that is in the thesis main file, just after the \usepackage{thesis_defs}.

3.1 PhD thesis

3.1.1 Submission

1. Use the file PhD_Submit_Title.tex for the title pages. This is selected by passing the options PhD, Submit. to the \documentclass or the ubonn-thesis package. Leave the „Tag der Promotion" and „Erscheinungsjahr" blank.

2. You are required to also submit a CV and a summary of your thesis. A skeleton CV is provided as the file thesis_cv.tex, which you include at the end of your thesis. The summary should also be printed separately.

3. You have to print and bind five copies of your thesis for the Promotionsbüro. Nowadays these are usually in colour. One of these copies will go to the department library.

4. The first and second referees for your thesis often like to also have an extra copy of the thesis so that they can make comments when they read your thesis — ask them if they want one. You can usually save the institute some money and print these copies in black & white. Some referees even prefer to get the extra copy as a PDF file.

3.1.2 Printing the final version

1. Use the file PhD_Final_Title.tex for the title page. This is selected by passing the options PhD, Final. to the \documentclass or the ubonn-thesis package.

2. Do not include your CV.

3. There are probably some small corrections you or the referees found during the time between submission and your examination. These should be corrected before you submit your thesis to the university library (ULB).

4. Almost everyone submits their thesis electronically to the ULB. You also have to print two copies for them.[1] The ULB is quite strict on the quality of the binding etc. The university print shop is not able to fulfil the requirements, so you have to print these versions externally. When you do this do not forget to uncomment the `\hypersetup` command as mentioned above, if you want to print them in colour.

5. The department library (in the Physikalisches Institut) needs seven printed copies with the file `PhD_Cover.tex` as the cover and `PhD_Final_Title.tex` for the title pages. These are selected by passing the options `PhD, PILibrary` to the `\documentclass` or the ubonn-thesis package. You have to get the "BONN-IR-YYYY-nnn" number from the librarian. You should also include an abstract (in English) on the cover page. You can also use this abstract when you submit your thesis electronically to the ULB.

6. The department library version of the thesis is the one that you usually print if you need extra copies for your experiment or research group.

Note that when you want to get your degree certificate, you will get some forms from the Promotionsbüro that have to fill out. These forms have to be signed by your supervisor. One of the forms asks you if you have published significant parts of your thesis elsewhere. This means your actual thesis and not a paper that uses the results from your thesis. If you submit your thesis electronically to the ULB, then you should not fill out this form. It only applies if you actually publish your thesis elsewhere (which is allowed by the Promotionsordnung).

You can contact the ULB to get suggestions for print shops that can make copies of your thesis in good enough quality to be accepted by the university library.

3.2 Master/Diplom/Bachelor thesis

3.2.1 Submission

1. Use the file `Master_Submit_Title.tex`, `Diplom_Submit_Title.tex` or `Bachelor_Title.tex` for the title pages. These are selected by passing one of the options `Master`, `Diplom` or `Bachelor` to the `\documentclass` or the ubonn-thesis package. In addition, pass the option `Submit` to to the `\documentclass` or the ubonn-thesis package.

2. You have to print and bind three copies of your thesis to be submitted to the Prüfungsamt. Nowadays these are usually in colour.

3. The first and second referees for your thesis often like to have an extra copy of the thesis so that they can make comments when they read your thesis — ask them if they want one. You can usually

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[1] This used to be five, but was reduced in 2015.

save the institute some money and print these copies in black & white. Some referees even prefer to get the extra copy as a PDF file.

Note that a CV does not have to be included in a Master/Diplom/Bachelor thesis. This is only needed when you submit a PhD thesis.

3.2.2 MSc/Diplom theses for the department library

1. Use the file `Master_Cover.tex` for the cover and `Master_Final_Title.tex`[2] for the title pages. These are selected by passing the options `Master, PILibrary`[3] to the `\documentclass` or the ubonn-thesis package.

2. There are probably some small corrections you or the referees found during the time between submission and the completion of the referees' reports and grades. These should be corrected before you submit your thesis to the department library.

3. The department library (in the Physikalisches Institut) needs 1 printed copies with the file `Master_Cover.tex` as the cover. This is selected by passing the options `Master, PILibrary` to the `\documentclass` or the ubonn-thesis package. You have to get the "BONN-IB-YYYY-nnn" number from the librarian. You should also include an abstract (in English) on the cover page.

4. This version of the thesis is the one that you usually print if you need extra copies for your experiment or research group.

3.2.3 BSc theses

1. There are probably some small corrections you or the referees found during the time between submission and the completion of the referees' reports and grades. These should be corrected before you print some extra copies of your thesis if your group wants them.

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[2] Replace Master with Diplom as appropriate.

[3] or `Diplom, PILibrary`

Useful packages

LaTeX file: guide_package.tex

LaTeX has so many packages that it is often hard to find the correct or most useful ones. It is also not a good idea to just take one of your friend's theses and use his/her packages and conventions, as there is a steady and regular improvement in the packages available.

This chapter lists some useful packages — maybe also some that are not so commonly known. Here I only say what the package is used for. More detailed instructions on the usage can be found in the relevant chapters. I first list the packages used in this guide and then give a bit of information on other packages that may be useful.

From all that I have read, KOMA-Script seems to be the way to go for the overall classes. I have therefore based the ubonn-thesis style on this. You replace article, report and book by scrartcl, scrreprt and scrbook. For theses I think it is best to use scrbook, as this class also includes the commands `\frontmatter`, `\mainmatter` and `\backmatter` that set up page numbering etc. appropriately.

You should use KOMA-Script version 3.19 or higher. The `\KOMAoptions` command as well as some other macros are not available in earlier versions, so you would have to modify the style file.

4.1 Layout and language

There are quite a few packages related to layout and also to handling of text input and languages. As far as layout goes, KOMA-Script has many options with which you can already do a lot. You can either use the built-in typearea package to do the page layout, which also includes nice options to allow for the binding, or use the geometry package which also contains more than enough options. In the past I have used geometry, but I also see no reason not to just use typearea. Note that you should not include the typearea package, you should simply set the options using `\KOMAoptions`. Generally, all you need to do is specify DIV (set by default to 12), which divides the page into a number of divisions and BCOR (set by default to 5 mm), which leaves some space for the binding. The packages are listed in Table 4.1.

The package scrlayer-scrpage has superseded scrpage2. If your version of LaTeX is so old that it does not know about scrlayer-scrpage adjust the ubonn-thesis style file accordingly.

Table 4.1: Useful packages for layout.

geometry	Provides simple options for page layout such as `scale=0.75` to cover 75 % of the page.
typearea	Does much the same, but here you specify how many elements to split the page into, e.g. `DIV=12`. You do not have to include this package explicitly if you use KOMA‑Script.
setspace	Useful options to change spacing.
fontenc	The encoding used for fonts. Recommended is `T1`, which is given as an option. This package is not used/needed by LuaLATEX and XƎLATEX.
inputenc	Use either `utf8` or `latin1` so that you can input German letters such as ä, ü and ß directly. This package is not used/needed by LuaLATEX and XƎLATEX.
unicode-math	Main package for font setting with LuaLATEX and XƎLATEX. It internally calls fontspec.
babel	Language specific typesetting.
csquotes	Package for quoting things using the correct language-dependent quotation marks.
scrlayer-scrpage	Set headers and footer.
xspace	Avoid having to put "\ " or "{}" after a macro.

4.2 Appearance

It used to be the case that nearly all LATEX documents used the Computer Modern Fonts. That is no longer necessary. There are rather complete font sets that are also free that you can use instead. The default font for theses is newtx that is available as of TEX Live 2013. If you have this package, then I would recommend using it. txfonts is an older version of this package that can be used instead, if necessary. Some of the spacings in equations have been improved in newtx and there is a better balance of the sizes of serif, sans serif and typewriter fonts. Other fonts that look quite nice (e.g. Palatino) can also be used. The option `palatino` in ubonn-thesis can be used to select this. The option actually selects the font packages mathpazo, courier and helvet. Another alternative is a package such as pxfonts to get both text and math fonts in the same style. Some examples of other possible font packages are given in the style file. As mentioned above, certain fonts can be selected directly via options: `txfonts`, `newtx` or `palatino`. The fonts used by LuaLATEX and XƎLATEXcan be steered in the same way and use the appropriate TeX Gyre fonts.

Commonly used packages associated with fonts, tables and figures are listed in Table 4.2.

The cleveref package is a great package for specifying references to figures, tables, sections etc. You just give the command `\cref{fig:plot}` and it will add "Fig." or whatever you set to the figure number and an unbreakable space. You can correctly format a list of figures by including several comma-separated labels in the `\cref` command. Note that you should not include any whitespace between the labels. If you want capitalised "Fig." etc. pass the option `clevercaps` to ubonn-thesis (this is the default setting). Otherwise pass the option `clevercaps=false`. Note that you should include cleveref by passing `cleveref` as an option to ubonn-thesis. If you just try the usual `\usepackage{cleveref}` you may get things in the wrong language. This guide has been converted to use the cleveref package everywhere. Note that if you use `UKenglish` or `USenglish` and the cleveref package, and use `\cref` or `\Cref` in a figure caption to refer to another figure or table, the cross-reference will be in German in

Table 4.2: Useful packages for appearance.

siunitx	Typeset units properly with correct spacing.
graphicx	The package to use for including graphics.
biblatex	The package to use for formatting the bibliography.
rotating	Package to use for rotating tables etc. The \includegraphics command can rotate figures directly.
array	Adds extra column formatting capabilities.
longtable	Can produce tables that extend over more than one page.
booktabs	Help for producing nicer tables.
subcaption	As the name suggests make sub-figures (and sub-tables) and add separate captions for them.
cleveref	Provides "Fig.", "Table" etc. when you use the \cref{fig:plot} syntax.
mathtools	An extension package for amsmath that fixes some bugs and deficiencies there.
amsmath, amssymb	Included by mathtools. Extra math commands and symbols from AMS.
hepnicenames	A somewhat restricted list of predefined elementary particles.
heppennames	A more complete list of predefined elementary particles. Note that hepnicenames also loads heppennames. The packages are based on hepparticles, which you can use to define further particles.
mhchem	Nice package for typesetting chemical elements correctly.
bookmark	Fixes appendices displaying in PDF viewer index/outline under first appendix instead of under Appendix heading.
xfrac	Some more options for typesetting fractions.
xcolor	Add colour commands.
microtype	Small adjustments to word spacings.
ifthen	Provides the \ifthenelse command.

the list of tables/figures. The only way I have found to get round this problem is to remove any use of ngerman as a language in your thesis or to add english as a language to the document class and to edit the .lof and .lot files by adding a line: \babel@toc {english}{}\relax after other such lines and recompiling once using pdflatex etc. and not latexmk. The second is not a nice option, as you have to do this every time the .lof or .lot files change, or remember to do it just before you submit your thesis. If you want to have a list of figures/tables, the other alternative is not to use the cleveref macros in captions.

As alternatives to longtable, one can also use supertabular or xtab. The syntax of longtable is closer to that used in normal tables and does not need definitions outside the table. It is also maintained by the LATEX Project team. All these packages also have the advantage that you can specify header and footer text. If you use the longtable package, you have to terminate the \caption with \\. If you use the mpxtabuar environment from xtab you can include footnotes in a table. See the xtab documentation for more details. It is probably best to only use one of these three packages to avoid conflicts.

The package tabularray was released in 2021. It looks like it can do everything that the other packages can and more with a uniform syntax. I do not have experience with it so far (apart from skimming the documentation), but it looks to be very promising.

The package microtype declares itself to be responsible for "Subliminal refinements towards typo-

graphical perfection". Need I say more?

4.3 Other packages

Some other useful packages, some of which are included in `ubonn-thesis.sty` are listed in Table 4.3.

Table 4.3: Other useful packages.

IEEEtrantools	Contains useful environments for multiline equations.
feynmp	Draw Feynman graphs with Metapost.
axodraw	Draw Feynman graphs.
tikz	General drawing package that can also be used for Feynman graphs.
standalone	Allows you to have a document that you can directly compile for each figure and also input to another document.
hyperref	Adds `\url` command as well as ability to click on entries on table of contents etc.
todonotes	Nice package to add notes to your text. You can also use it to indicate missing figures.
background	Allows you to add things like DRAFT across the whole document page.
subfiles	Provides a nice alternative to `\include` and `\includeonly`.
tabularx	Allows fixed table width with flexible column widths.
floatrow	Add ability to define own floats.
diffcoeff	A lot of useful commands for derivatives.
derivative	A new package (released in 2021) with lot of useful commands for derivatives.
physics	Some useful extra maths commands, especially for differentials.
commath	Some useful extra maths commands — has not been updated for a while.
skmath	More maths commands that could be useful.
adjustbox	Add much more sophisticated clipping capabilities than offered by graphicx.
wrapfig	Allow text to flow around figures.
floatflt	Similar capabilities to wrapfig — allow text to flow around figures.
glossaries	Provide commands for creating a glossary. This is intended to replace the glossary package.
dcolumn	Very helpful for lining up columns on character strings such as a decimal point. siunitx offers similar and better functionality.
refcheck	Check whether labels are used, i.e. if figures and tables are actually referenced.
snapshot	Enables you to get a list of external dependencies (and the versions being used).
tcolorbox	Fancy coloured boxes. Also works very well for code listings.
pgfplotstable	Read in tables from CSV files and format them (even as graphs).
titlesec	Change the appearance of chapter and section headings. See below for more information.

While the mathtools and amsmath packages solve many problems that occur if you just use the normal LATEX math mode commands, there are some things that are not so nice with long and complicated multiline equations. mathtools provides some extensions to amsmath that solve some of the problems.

An alternative is the package IEEEtrantools, in particular the `IEEEeqnarray` environment. See Ref. [Oet+] or the package documentation for more details.

The packages physics, commath, skmath, diffcoeff and derivative provide some additional maths commands. Differentials etc. are particularly useful. Both the diffcoeff and derivative packages contain a lot of nice and flexible definitions associated with derivatives. They handle the spacing around things like dx well, if you use the `\odif{x}` (derivative) or `\dl x` (diffcoeff) construction. An alternative (but not updated for a long time) package is physics package contains a lot of nice and flexible definitions. However, an interesting StackExchange article[1] suggests that the package has its drawbacks and it has not been updated since 2012. The commath package has not been updated for a while. skmath does quite a lot more then commath and even modifies/enhances some standard commands. The diffcoeff has been around since 2016, while derivative package was released in 2021. Both look to be nice and well maintained. This guide uses diffcoeff, as derivative is too new. By default, the option `ISO` is passed to the diffcoeff package, so that an upright "d" is used in derivatives, e.g. df/dx.

The todonotes is a very nice package that enables you to add notes to your text. By default they will be put in the margin of your document. More details can be found in Section 4.4.

standalone is both a package and a document class. It allows you to have a standalone document for a tikz or feynmf figure and also input this file into another document. If you run pdfLATEX on the file it also automatically crops the resulting picture. This is one of those packages where you think "Why didn't someone create this years ago?". The tikz figures included in this guide make use of it.

If you want to know which LATEX packages are being used when you compile your thesis, you can use the snapshot package. Just add the line

```
\RequirePackage{snapshot}
```

before `\documentclass`. The dependencies can be found after running pdfLATEX (or whichever engine you run) in the file `mythesis.dep` (or whatever your main filename is). A file `mythesis.dep` can be found in the main directory of `ubonn-thesis`. This contains the list of dependencies (and their version numbers) from the version of TEX Live I used when last updating the package.

If you want to include code listings, you can use the packages tcolorbox or listings. I used listings for quite a while, but tcolorbox can be used for anything associated with boxes and has much more flexibility. This guide can has now been adjusted to use tcolorbox.

Use of the titlesec package gives a warning when using KOMA-Script; hence as of version 3.0 the chapter title formatting is done by hand in ubonn-thesis. You can switch back to using titlesec by giving the option `titlesec`.

Although I have not actually tried it, the pgfplotstable package has the ability to read in CSV files and then format them as tables, or even as graphs. There is a detailed description in the TEXnische Komödie issue (2/2020) on how this can be done. This could be a really nice way of formatting data and avoids the need to write out such tables including "&" and "\\". Various sorting options are also possible.

The subfiles package has been included at some point in the texlive-latex-extra collection. It is a convenient way to be able to compile single files in a document. This can also be done with `\includeonly`, but this requires changes to the document each time. With subfiles you can just run pdfLATEX(or whatever engine you are using) on a single file in your document). Have a look at http://en.wikibooks.org/wiki/LaTeX/General_Guidelines for example for more information.

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[1] https://tex.stackexchange.com/questions/471532/alternatives-to-the-physics-package

Note that there is a conflict if you use refcheck, subcaption and hyperref together. See http://tex.stackexchange.com/questions/273970/conflict-refcheck-subcaption-packages-for-label-with-underscores for a workaround.

It is often useful to indicate whether your thesis is in the draft stage. The thesis skeleton uses the package background for this.

A list of other packages that are commonly used is given in Table 4.4. They are not included in the list above, because they are either not really needed or have been superseded by other packages.

Table 4.4: Other packages that are often used, but I have already given alternatives.

hepunits	Typeset units properly with correct spacing.
units	Typeset units properly with correct spacing.
SIunits	Typeset units properly with correct spacing. hepunits uses this package, so it does not need to be added explicitly
fancyhdr	As the name suggests, do your own header and footer configuration. Within KOMA-Script it is recommended to use scrlayer-scrpage instead.
feynmf	Draw Feynman graphs with Metafont.
draftwatermark	Another package that allows you to add DRAFT to the background each page.
subfig	As the name suggests make sub-figures and add separate captions for them. *This package has apparently been deprecated.*
subfigure	As the name suggests make sub-figures and add separate captions for them. *This package is deprecated.*
color	Add colour commands — xcolor is needed to colour boxes around links.
float	As far as I can tell floatflt offers more options.
caption	Much more control on captions — as KOMA-Script also has many options, not sure this is necessary.
ziffer	Spacing with a comma as decimal separator is correct.
nomencl	Another package for creating a glossary.
listings	Code listings. I switched to tcolorbox.
fncychap	Another package for changing the style of the chapter heading.
quotchap	Another package for changing the style of the chapter heading.

As indicated, the ziffer package is advertised as providing the correct spacing after a comma in math mode if you use the comma as the decimal separator. Compare 2, 5 with 2,5 and 2,5. The first spacing is wrong. If you use the ziffer package it will be correct. However, it does seem to conflict with the use of the dcolumn package, so I cannot compile this guide if ziffer is included. Some workarounds are discussed in Section 8.3. In addition, the siunitx package contains the same functionality, which can simply be steered by changing the document language, as discussed in Section 6.2. Hence, ziffer is not really needed anymore.

4.4 ToDo Notes

As an example, the \mynote command is defined. If you turn on the option todonotes, the package will be loaded. With the option shownotes they will also be displayed.

The shownotes option also turns on todonotes.

Another nice feature of the todonotes package is that you can use \missingfigure{text} to indicate figures that you still want to include. See for example Fig. 4.1. You can get a list of your notes by adding the \listoftodos command somewhere.

The macro \todo has some problems inside floats. You should pass the option inline to \mynote if you want a comment inside a caption. If you also include a "List of Tables" or "List of Figures", then you have to provide a short caption as an option or move the note outside (after) the caption.

Missing figure

Still need to create the plot to be included here.
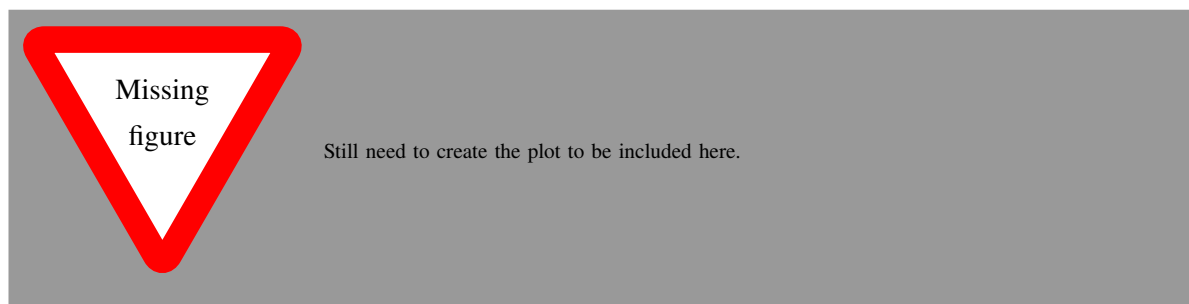
Figure 4.1: This figure still has to be added.

Use the option inline to include a note in a caption, as this is floating. A note that does not point to a block of text needs a blank first argument.

4.5 pdfLaTeX, LuaLaTeX or XeLaTeX

You may have heard that successors to the TeX engine are being planned and that LaTeX3 may at some point replace the current pdfTeX engine. This has been the case for many years, but so far it does not seem to be clear which development, if any, will replace pdfLaTeX. The two main directions are LuaLaTeXand XeLaTeX. The big advantage of these new developments is that they can use the installed fonts on your machine directly. LuaLaTeX also integrates a scripting language, Lua. As a result, it also does not have some of the restrictions of LaTeX or XeLaTeX, e.g. the number of open files for writing.

As of version 7.0 I have adapted the thesis style file able to be able to use both LuaLaTeX and XeLaTeX. The font specifications had to be changed. The main package that should be used is fontspec. However, there are several different packages that can be used to set the fonts for mathematics. I tried out unicode-math, mathfont (which only works with LuaLaTeX) and mathspec (which only works with XeLaTeX). While I got test files to compile using all three, unicode-math seems to be the furthest developed, and works with both LuaLaTeX and XeLaTeX, so it is the package I have used. You can enter Greek letters etc., such as π directly when using unicode-math, but you then have to find out how to enter them on your keyboard. unicode-math introduces the macros \symup, \symit, \symbf, \symsf, \symbtt for steering of boldface etc. in math mode. There are also the macros \symbfit, \symbfcal etc. The package recommends these macros as being preferable to the usual \mathbf etc. See the package documentation for more information.

Both the skeleton thesis and the thesis guide can be compiled with either pdfLaTeX, LuaLaTeX or XeLaTeX. You can compile the thesis using the commands make or make thesis for pdfLaTeX, make thesislua for LuaLaTeX, add make thesisxe for XeLaTeX. You can compile the thesis guide using the commands make guide for pdfLaTeX, make guidelua for LuaLaTeX, add make guidexe for XeLaTeX.

The fonts are selected using filenames rather than font names. This follows the recommendation of Will Robertson in a TUGboat article [Rob18]. Using filenames I am able to compile theses (and this guide) under both macOS and Linux. By default I use the TeX Gyre fonts — see Section 8.4.

On big advantage of LuaLaTeX and X$_{\exists}$LaTeX is that Greek letters can be entered directly instead of using the style \(\alpha\):

Greek letters entered directly are not shown as pdfLaTeX was used to compile the guide.

Figures and Feynman graphs

LATEX file: guide_figs.tex

This chapter discusses what you need to know to include graphics in your thesis. The basic command to use is `\includegraphics`. I found a pretty complete guide (in German) called `l2piqfaq` which can be obtained from `http://www.ctan.org/tex-archive/info/l2picfaq/german`. It contains a lot of detailed information and tricks. This chapter also contains some suggestions as to how to create Feynman graphs with a number of different packages.

5.1 Simple figures

A simple figure and its associated caption is straightforward to include. For example, the layout of the LHC and its experiments is shown in Fig. 5.1. Don't forget to use the package cleveref and macros such as `\cref` to reference the figures — see Section 4.2 for a few more details.

Note the use of `\centering` rather than the environment `\begin{center}` ... `\end{center}` to centre the figure. This avoid adding extra vertical space. It is also important that the `\label` be either inside the caption or after it. If your caption is more than 1 (or 2) lines, you should also give a short form that will appear in the "List of Figures".

One tricky question is how to best format the caption. This document uses a smaller font and no extra indentation. Often italics are used. I dislike this, as symbols are then formatted in different ways in the main text and in the caption. One can also reduce the width of the caption. The font for the caption can be specified using the `\setkomafont{caption}` command. You can specify how to label the figure by changing the `\figureformat` command. The captions in this document follow the standard KOMA-Script convention: if they are one line long they are centred; if they are longer they are left-adjusted. If you want them all to be left-adjusted set the `KOMAoptions{caption=nooneline}` in `ubonn-thesis.sty`. Some examples of the possibilities are included in the style file.

Another thing to consider is whether the caption text should be indented or not. For short captions, indentation is OK. I do not think it looks good for long captions. Hence the style file sets `\setcapindent{0pt}`.

```
\centering
\includegraphics[width=\figwidth]{CERN_all-experiments}
\caption[Sketch of the LHC ring, the position of the experiments and
  the surrounding countryside.]{Sketch of the LHC ring, the position
  of the experiments and the surrounding countryside. The four big
  LHC experiments are indicated. The location of the injection lines
  and the SPS are also shown.}%
\label{fig:LHC}
```
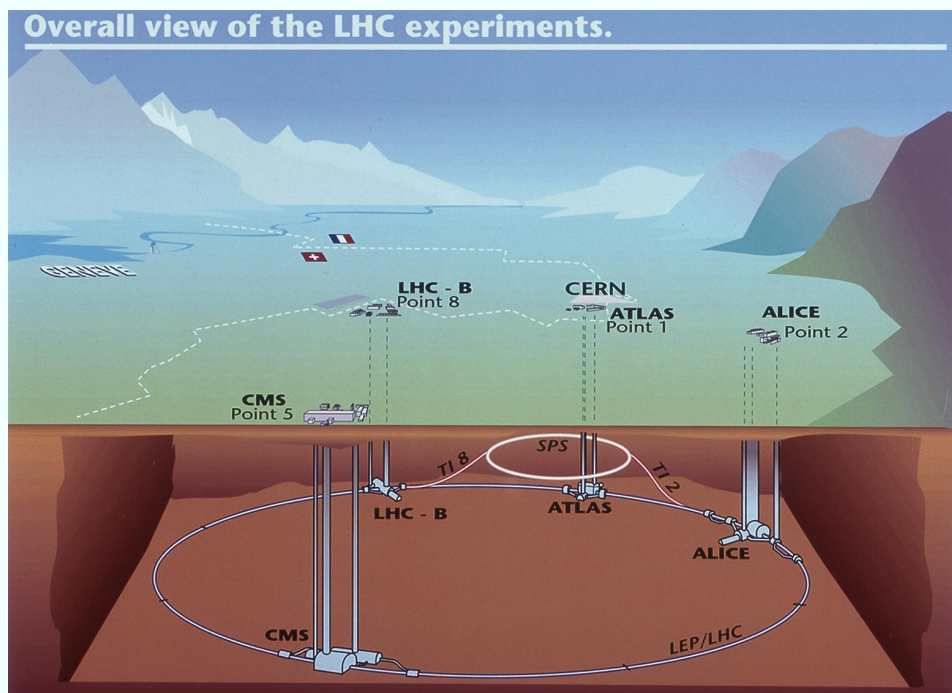

Figure 5.1: Sketch of the LHC ring, the position of the experiments and the surrounding countryside. The four big LHC experiments are indicated. The location of the injection lines and the SPS are also shown.

5.2 Fancier figures

Life gets more complicated if you want to include several plots in one figure, if you want the caption next to the figure, or if you want the text to "flow" around the figure. For the first case I like to use the `tabular` environment to place the plots, although there are other ways of doing it.

Another very nice way to add (a), (b) etc. to the figure is to use the `\put` command. This has the big advantage that you can display the letters in the figure without actually having to add them to the EPS/PDF file. Figure 5.2 shows how this is done. Note that the origin of the coordinate system is the bottom right-hand corner of the file that you have included (assuming that the `\put` command comes just after the `\includegraphics`). The units for the `\put` command are set with the `\setlength{\unitlength}` command, which is by default set to 1 mm in `ubonn-thesis.sty`. The same units are also used for Feynman graphs made with the feynmf and/or feynmp package — see Section 5.5.3.

```
\centering
\includegraphics[height=3cm]{gg_ttbar_1-BW}\quad
\includegraphics[height=3cm]{gg_ttbar_2-BW}\quad
\includegraphics[height=3cm]{gg_ttbar_3-BW}
\put(-130,14){(a)}
\put(-80,14){(b)}
\put(-35,14){(c)}
\caption{Adding letters to figures with \Macro{put}.}%
\label{fig:letters1}
```
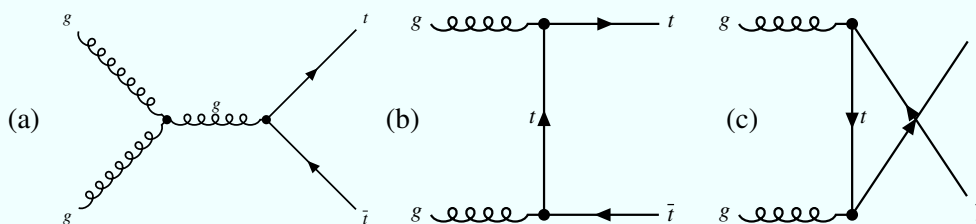

Figure 5.2: Adding letters to figures with `\put`.

Another way of achieving the same thing, but this time with the letter outside the figure is to use `tabular`. An example of this is shown in Fig. 5.3.

If you want to save space it is sometimes nice to put the caption next to the figure. While packages exist to do this, KOMA-Script has its own built-in `captionbeside` environment. The placement option comes after the caption itself and can be one of:

l Left of figure

r Right of figure

i Inner margin in two-sided layout

o Outer margin in two-sided layout

Note that this is an environment rather than a macro and that the figure itself is inside the environment.

```
\centering
\begin{tabular}{ccc}
\includegraphics[width=0.33\figwidth]{gg_ttbar_1-BW} &
\includegraphics[width=0.3\figwidth]{gg_ttbar_2-BW} &
\includegraphics[width=0.3\figwidth]{gg_ttbar_3-BW}\\
(a) & (b) & (c)
\end{tabular}
\caption{Adding letters to figures with \Env{tabular}.}%
\label{fig:letters2}
```
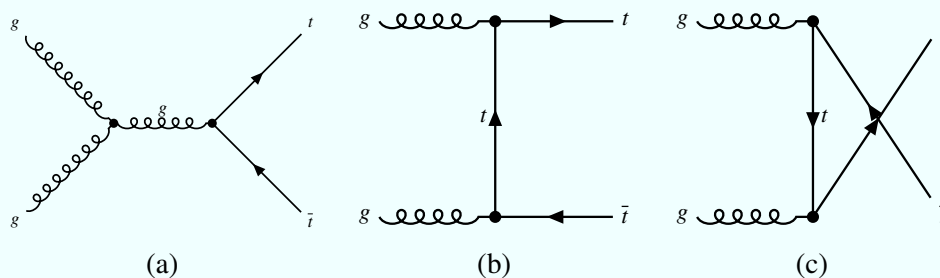

Figure 5.3: Adding letters to figures with `tabular`.

Also the placement does not seem to work exactly how it is advertised in the manual. I set the width equal to `\figwidth` and then the offset to `-\figwidth`.

```
\centering
\begin{captionbeside}{A small figure with a simple caption beside
    it.}[i][\figwidth][-\figwidth]
  \includegraphics[width=0.3\textwidth]{qq_ttbar-BW}
\end{captionbeside}%
\label{fig:qqtt}
```
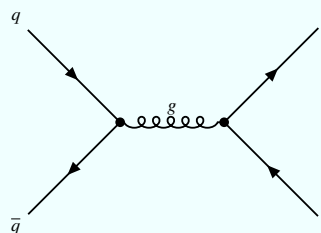

Figure 5.4: A small figure with a simple caption beside it.

If you want different (partial) captions for a figure then the subfig package used to be the way to go. An alternative, and successor, to subfig is subcaption. It works in much the same way as subfig. A nice tutorial on its use can be found in http://www.peteryu.ca/tutorials/publishing/latex_captions. Examples of the different subcaption macros can be seen in Figs. 5.5 and 5.7. You can see how to

reference the different parts of the figure in Section 5.5. If you want the captions of the sub-figures to also appear in the "List of Figures" you should include the package with the option `lofdepth`. For tables use the option `lotdepth`.

```
\centering
\begin{subfigure}[b]{0.5\figwidth}
  \includegraphics[width=0.5\figwidth]{ep_nc}
  \caption{NC scattering}\label{fig:nccc-nc}
\end{subfigure}
\qquad
\begin{subfigure}[b]{0.5\figwidth}
  \includegraphics[width=0.5\figwidth]{ep_cc}
  \caption{CC scattering}\label{fig:nccc-cc}
\end{subfigure}
\caption{Processes in $ep$ scattering.}%
\label{fig:nccc}
```


(a) NC scattering   (b) CC scattering
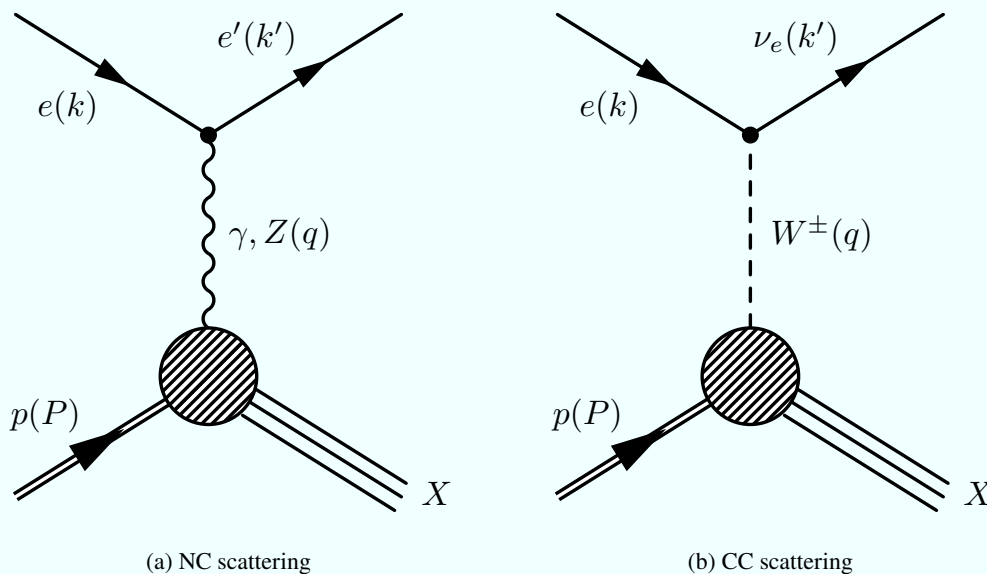
Figure 5.5: Processes in ep scattering.

If you run out of space (applies more often to proceedings than to theses) you can use the wrapfig package.

5.3 Figure formats

If you use plain LaTeX, you are pretty much stuck with encapsulated postscript (EPS) as your figure format. If you use pdfLaTeX, then you have much more freedom, with the notable exception that you

cannot include EPS files![1] I would still recommend that you always try to use a vector graphic format. What usually works well is to either create PDF directly or to create EPS and then convert from EPS to PDF.

The tool I use for conversion is `epstopdf`. Occasionally this fails; in that case `eps2eps` can help. It is important that the bounding box is set correctly in the EPS file before you run `epstopdf`.

If these fail, you can try the `convert` command which is part of `ImageMagick`. A more powerful tool is `inkscape` which is a successor to `xfig`. Professionals use Adobe Illustrator!

5.4 Placement

Even after many years of including figures into LaTeX files, I still think there is a fair amount of black magic involved in getting them into the place that you want them to be.

In general, you are advised to give LaTeX as much freedom as possible in the placing, so it is usual to use the options `[htbp]` for the placement. In particular, be very careful with using just `[h]` or `[H]` as the placement option. It very easily leads to LaTeX putting single lines of text either above or below a figure. One way to get rid of single lines is to remove the option `h`, as the figure must then be placed at the top or bottom of the page (or on a page of floats). You can also add an `!` in the list of options, which suspends spacing and number restrictions.

A nice summary of the logic behind the placement can be found in TeX/LaTeX Stack Exchange (click on the link!). A couple of points from there that are worth mentioning here:

- The order of the options `htbp` has no effect!

- If a float is placed in the middle of a paragraph, the reference point for deciding where it will appear is the next line break or page break in the paragraph, following the float.

- The order of figures (and tables) is fixed to the order that they are included in a document. However, the order of figures and tables relative to each other is not fixed.

The UK List of FAQ recommends changing several default LaTeX options so that there are fewer problems with figure and table placement. It is certainly worth reading that page for further advice. As it is very hard to really test how well these options work they can be turned on or off in ubonn-thesis via the option `floatopt=true|false`. The default value is set to `true`.

I used to think it was better to attach the figure to a paragraph. More recently it appears to me to be better to separate the figure from the paragraph. What I mean is illustrated below:

---

[1] This restriction has finally been lifted with TeX Live 2011. It simply converts the EPS files to PDF inline.

```
\Cref{fig:funny1} is attached to the paragraph.
%
\begin{figure}[htbp]
  \centering
  \includegraphics[width=\figwidth]{file}
  \caption{An odd plot that I don't understand.}
  \label{fig:funny1}
\end{figure}
%
The distribution shows something that I do not understand.

Given that this is not understood we went to the pub for a beer to
think about it a bit more.
```

```
\Cref{fig:funny2} is separated from the paragraph by a blank line.
The distribution shows something that I do not understand.

\begin{figure}[htbp]
  \centering
  \includegraphics[width=\figwidth]{file}
  \caption{An odd plot that I don't understand.}
  \label{fig:funny2}
\end{figure}

Given that this is not understood we went to the pub for a beer to
think about it a bit more.
```

However, it is hard to give a hard and fast rule here. As indicated above, the effect of these different ways of including a figure (and table) is the point in the text (reference point) that LaTeX uses to start trying to place the figure. In general, you should only try to tweak the position of figures and tables when your text is final, as a change in the text may well move some of the floats.

5.4.1 standalone package and class

The standalone package provides a great way of developing figures in small files and then inputting these files directly, without making any changes, into your thesis!

It is in fact both a package and a document class. It allows you to have a standalone document for a TikZ or feynmf figure and also input this file into another document. If you run pdfLaTeX on the file it also automatically crops the resulting picture. This is one of those packages where you think "Why didn't someone create this years ago?". The TikZ figures (as well as those made using TikZ-FeynHand) that I include in this guide (see subdirectories `tikz` and `pyfeynhand`) make use of this package. If you want to use it, make sure that you also include this package in your thesis.

5.5 Feynman graphs

You have lots of Feynman graphs you want to include, but how do you generate them? For a few years I used a Python package PyFeyn (https://pyfeyn.hepforge.org) that works quite nicely once you have it set up. However, the package does not seem to be actively developed any more and fixes are needed before it works with the latest PyX version, which is the drawing tool it uses. Hence, I am moving my graphs to a TikZ package, which means that they are created in a LATEX file. Two possibilities are TikZ-Feynman and TikZ-FeynHand. I have written a Python wrapper for TikZ-FeynHand, which hopefully allows me to combine the best of both worlds! The wrapper code and an example can be found in the pyfeynhand directory.

Before I started using Python packages, I followed the example of many people, where I found one way doing making graphs and never changed! I used Mn_Fit, mainly because I wrote it and therefore know inside out how it works. Examples can be found on my web page: http://pi.physik.uni-bonn.de/~brock/feynman. Alternatives include axodraw and the feynmf or feynmp packages.

The use of feynmf and feynmp is described in Section 5.5.3, while a few examples of usage of TikZ are given in Section 5.5.1. Usage of TikZ-FeynHand and my Python wrapper PyFeynhand can also be found in Section 5.5.1. Examples of Feynman graphs made with feynmf and feynmp can be found in the feynmf directory; those made with TikZ-FeynHand can be found in the pyfeynhand and tikz subdirectories; while those made with TikZ can be found in the tikz subdirectory.

Instructions on how to use axodraw may come at a later date — contributions would be welcome! Several people have claimed that jaxodraw is the way to go. This is a Java package which you can download from http://jaxodraw.sourceforge.net/. It has a Graphical User Interface (GUI) to axodraw and so is simple and straightforward to use.

```
This paragraph illustrates how to reference different parts of a
figure that uses the environment \Env{subfigure} from
the package \Package{subcaption}.
The NC and CC graphs shown in \cref{fig:nccc}, or more accurately
in \cref{fig:nccc-nc} and \cref{fig:nccc-cc} were made with \Package{feynmp}.
Another way of saying the same thing is that typical Feynman graphs
for \(ep\) scattering are shown in \cref{fig:nccc},
where \subref{fig:nccc-nc} shows a neutral current and \subref{fig:nccc-cc}
show a charged current process.
```

This paragraph illustrates how to reference different parts of a figure that uses the environment subfigure from the package subcaption. The NC and CC graphs shown in Fig. 5.5, or more accurately in Fig. 5.5(a) and Fig. 5.5(b) were made with feynmp. Another way of saying the same thing is that typical Feynman graphs for ep scattering are shown in Fig. 5.5, where (a) shows a neutral current and (b) show a charged current process.

5.5.1 Feynman graphs with TikZ (and Python)

There are (at least) two packages based on TikZ that exist to draw Feynman graphs: TikZ-Feynman and TikZ-FeynHand. If you want to use the automatic placement features of TikZ-Feynman you have to use

LuaLaTeX. Hence, I am inclined to use the TikZ-FeynHand package.[2] It does not seem to be possible to adjust the amplitude and frequency of boson and gluon oscillations explicitly. This has to be done using the `\setlength{\feynhandlinesize{1.0pt}}` command. This also, as the name suggest, changes the line thickness. After a bit of playing around 1.0pt seems to work well, with a Feynman graph size of about 2 2 cm^2.

I like using a scripting language, e.g. Python, to draw my graphs. I have therefore written a Python wrapper for TikZ-FeynHand. You can find the wrapper and a couple of example scripts in the `pyfeynhand` directory. The wrapper creates a LaTeX file, which can either be compiled or included directly in your document, as it uses the standalone package. Have a look at the `README.md` file in that directory for some more details.

Many more example graphs can be found in the Git repositories:
https://gitlab.cern.ch/atlasphys-top/singletop/PubUtils/FeynmanDiagrams/PyFeynHand ATLAS
https://bitbucket.team.uni-bonn.de/users/unp00039/repos/pyfeynhand Uni Bonn

Figure 5.6 shows two graphs from one of my favourite processes. These graphs are made using TikZ-FeynHand commands directly, while the TeX file was originally created using the Python wrapper.

Figures 5.7(a) and 5.7(b) show a graph for $t\bar{t}$ production, as well as one for top-quark decay that uses quite a lot of the bells and whistles available in TikZ-FeynHand and PyFeynHand. The resulting PDF files are included directly, while the graphs have been made using the command `make pyfeynhand`.

A diagram for μ decay using the TikZ-Feynman package is shown in Fig. 5.8. This uses the manual placement style so that I can compile the guide with `pdflatex`.

If you want to draw Feynman graphs using TikZ directly, you need to include some extra TikZ packages and libraries. In addition it makes sense to define things like gluons, photons and incoming and outgoing particles once, as these are objects that are often needed.

We can directly compare a scattering graph made with feynmp, TikZ and TikZ-FeynHand. This is shown in Fig. 5.9. As you can see the quality of the graphs is very similar. Further tweaking can probably make them almost identical. In the TikZ-FeynHand graph, I use lots of colours to illustrate how they work.

5.5.2 PyFeyn

As the name suggests, PyFeyn (https://pyfeyn.hepforge.org) is a Python package for drawing Feynman graphs. It combines the advantages of using a programming language to draw the graphs with the ability to use LaTeX and the same fonts as you use in your thesis for the text. I also wanted to improve my Python skills, so used this package quite a lot for my graphs.

The package hepnicenames is included by PyFeyn. If you want your particles to be written with italics, you have to add this option to `__init__.py` in the `pyfeyn` directory. As of TeX Live 2019 particles using the upright font do not seem to be printed properly, so you really have to write your particles with italics. This is due to a bug in hepparticles (which is the underlying package of hepnicenames). I have a fix of the bug, but it has not yet been propagated into the official package. Hence, in `__init__.py` of the package you have replace

```
pyx.text.default_runner.preamble(r"\usepackage{hepnicenames}")
```

---

[2] Note that the TikZ-FeynHand package was first included in TeX Live 2017.

```
\centering
\begin{subfigure}{0.5\figwidth}
  \centering
  \ifthenelse{\texlive > 2016}{%
    \input{../tikz/tdecay.tex}
  }{%
    \missingfigure{TeX Live version does not include TikZ-FeynHand}
  }
  \caption{\LaTeX\ file}%
  \label{fig:feyn:tdecay1}
\end{subfigure}
\qquad
\begin{subfigure}{0.5\figwidth}
  \centering
  \includegraphics[width=0.5\figwidth]{../tikz/tdecay}
  \caption{PDF file}%
  \label{fig:feyn:tdecay2}
\end{subfigure}
\caption{Feynman graphs made with the \Package{TikZ-FeynHand} package.
  This example uses the \Env{subfigure} environment from the
    \Package{subcaption} package.}%
\label{fig:feyn:tdecay}
```
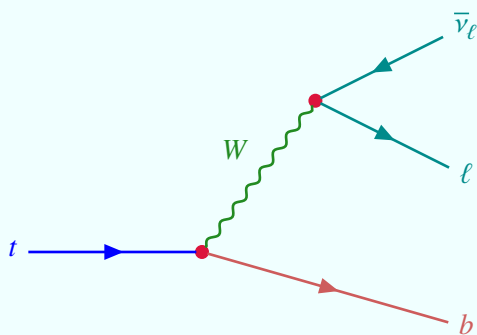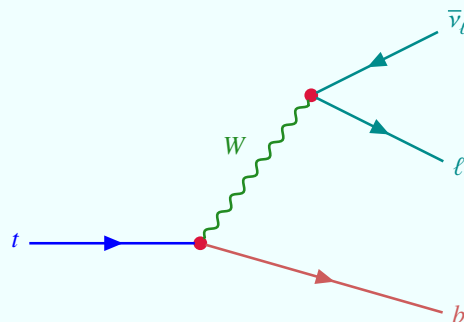

(a) LaTeX file   (b) PDF file

Figure 5.6: Feynman graphs made with the TikZ-FeynHand package. This example uses the subfigure environment from the subcaption package.

```
\centering
\subcaptionbox{\ttbar production\label{fig:pyfeynhand:ttbar}}
  [0.5\figwidth]{%
    \includegraphics{gg_ttbar_2}
}
\qquad
\subcaptionbox{Top-quark decay\label{fig:pyfeynhand:tdecay}}
  [0.5\figwidth]{%
  \includegraphics{tdecay}
}
\caption{Feynman graphs made with the \Package{PyFeynHand} wrapper.
  This example uses the \Env{subcaptionbox} macro from the
    \Package{subcaption} package.}%
\label{fig:pyfeynhand}
```
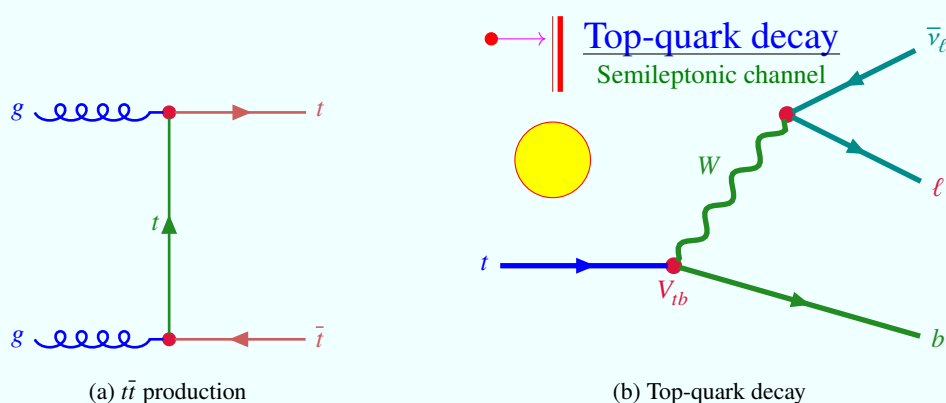

(a) $t\bar{t}$ production   (b) Top-quark decay

Figure 5.7: Feynman graphs made with the PyFeynHand wrapper. This example uses the `subcaptionbox` macro from the `subcaption` package.

by

```
pyx.text.default_runner.preamble(r"\usepackage[italic]{hepnicenames}")
```

PyFeyn does not work out of the box any more, unless you use a specific version of the PyX package. In order to install the package using Homebrew Python (set up with pyenv under macOS), I did:

```
pip install pyx==0.14.1
pip install pyfeyn
```

This installed the packages in ~/.pyenv/versions/3.8.2/lib/python3.8/site-packages/... etc. For older versions of PyX you may have to patch `pyx/dvi/vffiles.py` to use the newtx fonts: https://sourceforge.net/p/pyx/code/3678/. For the most recent version of PyX (0.15), you also have to patch PyFeyn to make it work. This means replacing `pyx.text.defaulttexrunner.text`

```
\centering
\begin{subfigure}{0.6\figwidth}
  \centering
  \input{../tikz/mudecay-feynman.tex}
  \caption{\LaTeX\ file}%
  \label{fig:feyn:mudecay1}
\end{subfigure}
\qquad
\begin{subfigure}{0.4\figwidth}
  \centering
  \includegraphics[width=0.4\figwidth]{../tikz/mudecay-feynman}
  \caption{PDF file}%
  \label{fig:feyn:mudecay2}
\end{subfigure}
\caption{Feynman graphs made with the \Package{TikZ-Feynman} package.
  This example uses the \Env{subfigure} environment from the
    \Package{subcaption} package.
  The example is taken from
    \url{https://www.overleaf.com/learn/latex/feynman_diagrams}.}%
\label{fig:feyn:mudecay}
```
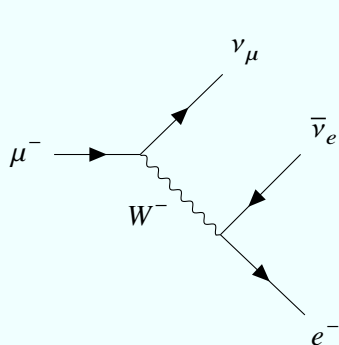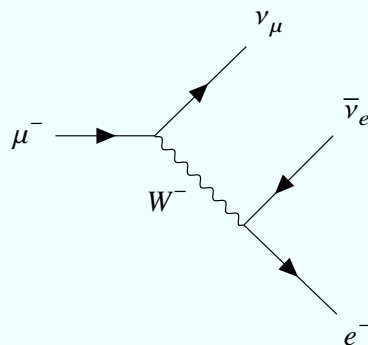

(a) LATEX file   (b) PDF file

Figure 5.8: Feynman graphs made with the TikZ-Feynman package. This example uses the subfigure environment from the subcaption package. The example is taken from https://www.overleaf.com/learn/latex/feynman_diagrams.

```
\centering
\subcaptionbox{feynmp\label{fig:feyn:feynmp}}
  [0.325\textwidth]{\fbox{%
    \input{../feynmf/moeller.tex}
    \write18{mpost moeller}
  }
}
\subcaptionbox{\TikZ\label{fig:feyn:tikz}}
  [0.325\textwidth]{\fbox{%
    \input{../tikz/moeller-tikz.tex}
  }
}
\subcaptionbox{TikZ-FeynHand\label{fig:feyn:feynhand}}
  [0.325\textwidth]{\fbox{%
    \ifthenelse{\texlive > 2016}{%
      \input{../tikz/moeller-feynhand.tex}
    }{%
      \missingfigure{TeX Live version does not include TikZ-FeynHand}
    }
  }
}
\caption{Feynman graphs drawn with \Package{feynmp}, \Package{\TikZ} and
    \Package{TikZ-FeynHand}.
  The frames around the boxes are for illustration only.
  As you can see the \Package{feynmp} box does not include the labels.
  This example uses the \Macro{subcaptionbox} macro from the
    \Package{subcaption} package.}%
\label{fig:feyn:cf}
```


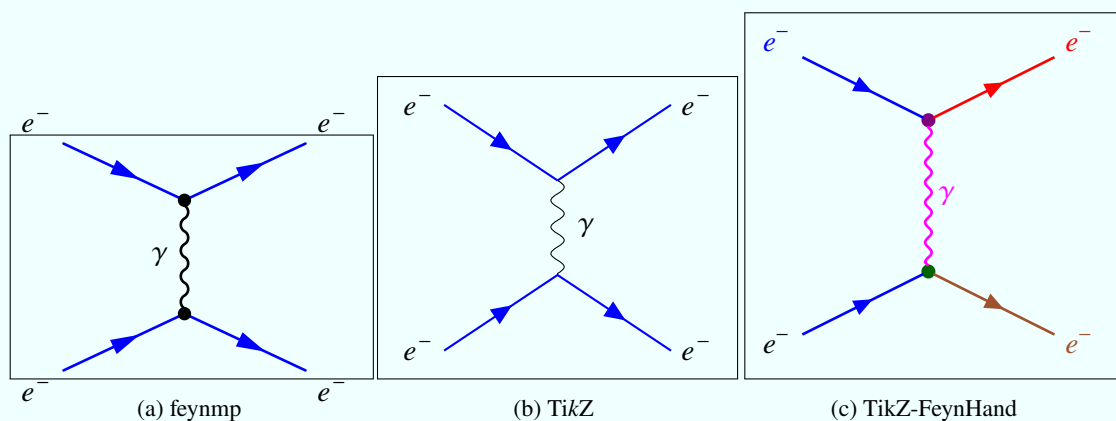(a) feynmp   (b) TikZ   (c) TikZ-FeynHand

Figure 5.9: Feynman graphs drawn with feynmp, TikZ and TikZ-FeynHand. The frames around the boxes are for illustration only. As you can see the feynmp box does not include the labels. This example uses the \subcaptionbox macro from the subcaption package.

by `pyx.text.defaulttextengine.text` in `deco.py` You have to adjust `__init__.py` in a similar way including the following lines:

```
if pyxversion >= Version("0.15.0"):
    pyx.text.set(pyx.text.LatexEngine)
elif pyxversion >= Version("0.13.0"):
    pyx.text.set(pyx.text.LatexRunner)
else:
    pyx.text.defaulttexrunner.set(mode="latex")
```

Given these difficulties, I have moved to TikZ-FeynHand, as discussed above.

While functions exist to draw a number of lines, I added my own wrapper functions that adjust the style as I wanted. Have a look at `pyfeyn/myPyFeyn/__init__.py` to see what default settings I use to get the font and colours that I want. Examples of Feynman graphs drawn using the package can be found in Fig. 5.10 and are included in the `pyfeyn` directory. If you want to get started with PyFeyn you can copy this directory into your thesis directory, e.g. `mythesis`.

```
\centering
\raisebox{0ex}{%
  \includegraphics[width=0.4\textwidth]{../pyfeyn/tZq_4FS_feyn}
}
\quad
\raisebox{2ex}{%
  \includegraphics[width=0.4\textwidth]{../pyfeyn/tZq_5FS_feyn}
}
\caption{Example Feynman graphs for the associated production
  of a top quark and a \PZ boson.}%
\label{fig:tZq-pyfeyn}
```
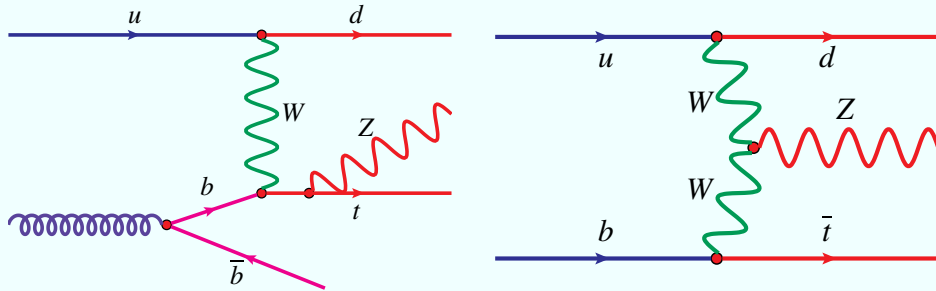

Figure 5.10: Example Feynman graphs for the associated production of a top quark and a Z boson.

5.5.3 FeynMP

In order to use the feynmp package, you have to put the commands to draw the graph in a LaTeX file and then process this file with LaTeX and either Metafont or Metapost.[3] You can either make a separate LaTeX file containing the Feynman graph or include the commands inside your normal LaTeX file. Metapost is a bit easier to use than Metafont. You should be able to just run mpost after (pdf)latex and then run pdflatex again twice. Note that you have to run mpost on all the files whose names are defined at the beginning of the fmffile environment.

Metafont is a bit trickier and details have been relegated to Appendix G.2. On Unix systems the feynmf perl script exists that runs both LaTeX and Metafont for you. This will produce a dvi file that you then then look at or use to make a Postscript/PDF file.

I think a better way to proceed is the following:

- make a separate LaTeX file for each of the Feynman graphs;

- input this file in your figure;

- use the Makefile described below to automatically run over one or all feynmp/feynmf LaTeX files by giving the command make feynmp or make feynmf.
  Check ./feynmf/feynmf_all.dvi or ./feynmf/feynmf_all.pdf to see if the graphs are OK;

- run LaTeX or pdfLaTeX;

- run bibtex or biber;

- run LaTeX or pdfLaTeX again, at least twice.

The last three steps are done with the command make thesis, make thesis11. The big advantage of this procedure is that the graphs are included "properly" in the thesis, their fonts should automatically match the fonts used in the thesis and you don't have to worry about converting and clipping. I have written a small script that is executed by the Makefile to do the third step. The script is run_mf for feynmf and run_mp for feynmp. These are included in the main directory ubonn-thesis. The scripts assume that all Feynman graphs are in a feynmf subdirectory. This can clearly be adjusted in the Makefile as necessary. To get started you can copy the feynmf directory from ubonn-thesis.

The run_mf script assumes that all files of type tex (except those that start with feynmf_) are Feynman graphs to process with feynmf. Note that it may be necessary to give the command make cleanfeynmf to get rid of temporary files before make feynmf if you change the sizes of things.

The run_mp script works a bit differently. It creates a temporary directory mpost_tmp in which it processes the figures (tex files) in the feynmf subdirectory. The resulting PDF files are copied back to the feynmf subdirectory.

You can also use the package standalone together with feynmp. The files in the feynmf directory contain commented out code that shows how this can be done. I do not do this by default for the guide, as I want to test making the Feynman graphs with feynmf. Note that the name in the fmffile environment (and the \write18 command) should be the same and different from the name of the LaTeX file. If you

---

[3] ubonn-thesis.sty now includes feynmp by default. If you want to use feynmf instead just change the name.

use this option, you should probably also adjust the `Makefile` target for `feynmp` to work in the same way as the target `tikz`. You have to run `pdflatex` twice on each file.

Figure 5.11 shows the same neutral current and charged current graphs, but this time inputting the appropriate feynmf commands directly. The graphs are enclosed in `\fbox` for illustration purposes only. The plots are made using feynmp, where an appropriate `\write18` statement is included in the LATEX source code, e.g. `\write18 mpost gluon`, after the figure, where the figure starts with `\begin{fmffile}{gluon}`.[4]

```
\centering
\fbox{\input{../feynmf/ep_nc.tex}}
  \write18{mpost ep_nc}
\qquad
\fbox{\input{../feynmf/ep_cc.tex}}
  \write18{mpost ep_cc}
\caption{NC and CC graphs for $ep$ scattering using \Package{feynmf}
  code directly.}%
\label{fig:nccc-feynmf}
```
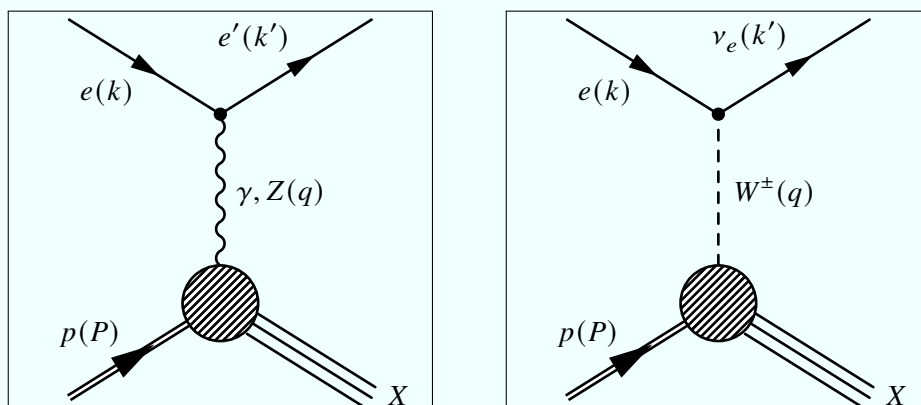

Figure 5.11: NC and CC graphs for *ep* scattering using feynmf code directly.

If `mpost` does not run automatically, you must execute the command `pdflatex -shell-escape mythesis` when you compile your thesis. This can be achieved by including the `EXTRACMD` definition that is commented out in the `Makefile`. In this guide I put the Feynman graph in its own file and the `\write18` statement in the main file so that I can test feynmf and feynmp with the same LATEX code. In your thesis, you should probably put the `\write18` statement in the file with the Feynman graph. If you use `latexmk` to compile you probably need to use the commented out version of the `latexmk` command in the `Makefile`.

As mentioned above, you probably want to first draw the graphs outside of your thesis to get them into the form that you need. If you give the command `make feynmf`, it will run `feynmf` on all `tex` files in the subdirectory `feynmf`. If you give the command `make feynmf file=ep_nc` it will run over

---

[4] If you use TEXstudio you may have to give the full pathname for `mpost`, e.g. `/usr/texbin/mpost`, as TEXstudio does not parse your `PATH` properly.

`./feynmf/ep_nc.tex` etc. As indicated above, the graphs can then be looked at in `feynmf_all.dvi` or
`feynmf_all.pdf`. You can use the same syntax for `make feynmp` and `make tikz`.

5.6 Ti*k*Z and PGF

pgfplots and Ti*k*Z are packages to help with creating graphics "inline". For 3D figures you also need tikz-3dplot. PGF is the backend, while Ti*k*Z is what the user interacts with directly. The manual contains all the information you should need, but was 1318 pages long at the last count, so it may not to be too easy to find what you want!

I do not have much experience with using these packages so far, except for Feynman graphs discussed above. Hence, this section will certainly not cover all possibilities. There may also be better ways of doing things than I illustrate here. The examples I give come from Andrii Verbytskyi or are adapted from questions and answers found on http://tex.stackexchange.com/. The examples included in this guide and a few more are collected in the `tikz` directory. If you want to get started with Ti*k*Z you can copy this directory into your thesis directory, e.g. `mythesis`.

Ti*k*Z is not included by default in a new skeleton thesis. See the commented out packages in a new thesis skeleton or `thesis_guide.tex` for the packages and Ti*k*Z libraries that you should include if you want to use it.

You often want to include a figure of your experiment's coordinate system in your thesis. One way to do this is illustrated in Fig. 5.12.

```
\centering
\input{../tikz/zeus_coords.tex}
\caption{The ZEUS coordinate system.}%
\label{fig:tikz:coord}
```
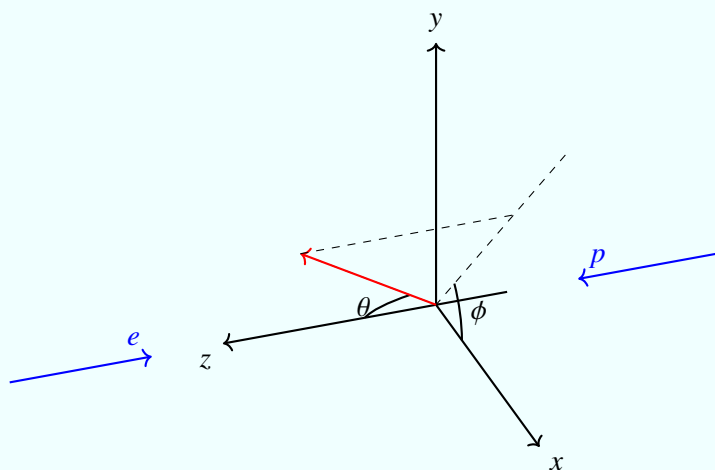

Figure 5.12: The ZEUS coordinate system.

It is also possible to make flow charts with Ti*k*Z. This is illustrated in Fig. 5.13.

There are many more possibilities, including plots which you would otherwise make with `root` or some other graphics program. An example plot showing the effect of systematic variations can be found in Appendix D. Making Feynman graphs with Ti*k*Z is covered in Section 5.5.1.

5.6.1 Accelerator lattices

If you want to include an accelerator lattice in your thesis you can try tikz-palattice[5]. Jan Schmidt used the package to make lattices of particle accelerators for his PhD thesis.

---

[5] `https://ctan.org/pkg/tikz-palattice` written by Jan Schmidt, who gave me a number of useful tips for this guide.

```
\centering
\input{../tikz/zeus_reconstruction.tex}
\caption[Event reconstruction and simulation in ZEUS]{Event reconstruction and
    simulation in ZEUS.}%
\label{fig:tikz:flow}
```
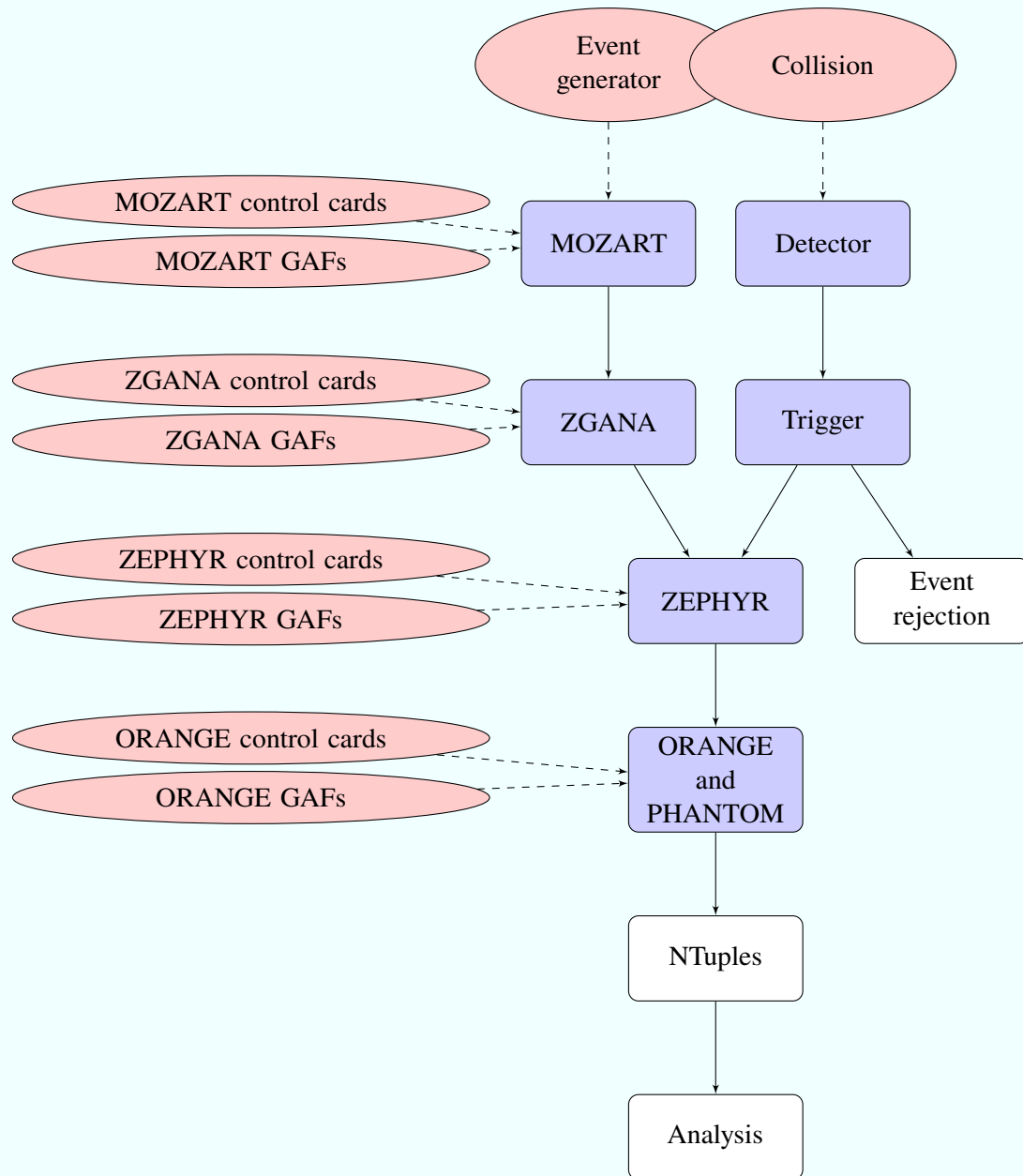

Figure 5.13: Event reconstruction and simulation in ZEUS.

Tables

LaTeX file: guide_tables.tex

You almost certainly have tables with results that you want to include in your thesis. You probably even know about the `tabular` environment, but what about fine-tuning to get the tables exactly in the form that you want? How do you line up the decimal points in a list of cross-sections and/or ± for the errors? How can you handle a table that goes over more than one page and what if it is so wide that you would like to rotate it by 90°?

Also, how can you make your tables look more professional with for example thick and thin lines in appropriate places? This is easy to solve — use the `\toprule`, `\midrule` and `\bottomrule` commands from the booktabs package. These commands also produce much better spacing between these lines and the rows above and below. The booktabs package gives you some advice on how good tables should look, as well as some guidelines on how to make your tables look better.

The `\rule` command is very useful for adding more space between rows. Kopka has several examples of its usage. You can also use `\arraystretch`, e.g. `\renewcommand{\arraystretch}{1.5}` to increase the spacing by 50 %. This command is often useful if table cells contain subscripts and/or superscripts. `\toprule` etc. mean that it is usually not needed in headers.

If you want columns of expandable width you can use the tabularx package. The environment `tabular*` has instead expandable intercolumn spacing.

It looks as if the package tabularray can be used for all tweaking of tables. It includes options related to amsmath, booktabs, longtable, siunitx and more. There are improved ways of spanning columns and rows, removing the need for `\multicolumn` and the multirow package. There are many options for also making colourful tables, adjusting spacing etc., while the defautl row spacing looks to be better than the standard one in the `tabular` and `array` environments. The package was only released in 2021, so you need a recent version of TeX Live to be able to use it.

Tables usually go inside the `table` environment so their position can "float". In this chapter I use some tables inside `table` and some inline.

Don't forget to use the package cleveref and macros such as `\cref` to reference the tables — see Section 4.2 for a few more details.

There are good arguments for the table caption being above the table, while the figure caption should be below the figure. Include the `\caption` command before the `tabular`, in order for the caption to be placed above. The spacing of the caption and the table is then optimal when the

option `captions=tableheading` is set in KOMA-Script. This can be achieved by setting the option `tableheading` (as of version 8.0), which is set to "true" by default. If you use this option, you should use `\centering` to centre the table and not the environment `center`. You can get the same spacing, without the `captions=tableheading` option, by using the macro `\captionabove` macro instead of `\caption`.

Trying to include footnotes in tables can be tricky. See Section 8.2 for some guidance on how this can be done.

6.1 Use of `\phantom`

Although extra packages can help, a very useful command is `\phantom`. This inserts white space corresponding to the width of the argument.

```
\centering
\begin{tabular}{cc | rr}
  \multicolumn{2}{c|}{Centred} &
  \multicolumn{2}{c}{Right justified} \\
  & Phantom & & Phantom\\
  \midrule
  0.76 & \phantom{0}0.76 & 0.76 & 0.76\\
  83.1 & 83.1\phantom{0} & 83.1 & 83.1\phantom{0}
\end{tabular}
\qquad
{\setlength{\extrarowheight}{0.5ex}
\centering
\begin{tabular}{cc|rr}
  \multicolumn{2}{c|}{Centred} &
  \multicolumn{2}{c}{Right justified} \\
  & Phantom & & Phantom\\
  \midrule
  0.76 & \phantom{0}0.76 & 0.76 & 0.76\\
  83.1 & 83.1\phantom{0} & 83.1 & 83.1\phantom{0}
\end{tabular}
}
```

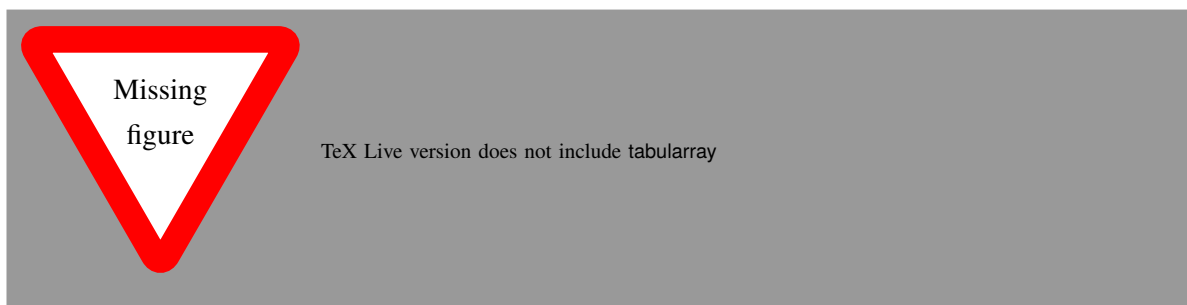| Centred		Right justified		Centred		Right justified	
	Phantom		Phantom		Phantom		Phantom
0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
83.1	83.1	83.1	83.1	83.1	83.1	83.1	83.1

The difference between the two tables is that the one on the right has the length `\extrarowheight` set to 0.5ex. The first two columns are centred, the last two are right justified. This is clearly a bit clumsy, but it does work!

6.2 Using siunitx and the S column option

The siunitx package contains some nice tools that make the correct alignment of numbers simpler.

Here are very similar tables to those in the previous section typeset using the tabularray package and the `tblr` and `booktabs` environments, respectively. The column widths are fixed to show the effect of the `table-number-alignment` option. The `vlines` option is used to show the effect of the alignment. Note that triple pairs of braces have to be used in these environments to guard non-numeric cells, such as column headings, if one is using the S column descriptor or the Q column descriptor with the `si` key. In the latter case, the `c` option applies to the alignment of the non-numeric cell content.

```
\begin{center}
  \begin{tblr}{
    vlines, columns={4em},
    colspec={
      Q[si={table-format=2.2, table-number-alignment=center},c]
      Q[si={table-format=2.2, table-number-alignment=right},c]
    }
  }
    \hline
    \SetCell[c=2]{c}{{{\Env{tblr}}}} & \\
    \hline
    {{{Centre}}} & {{{Right}}} \\
    \hline
    0.76 & 0.76 \\
    83.1 & 83.1 \\
    \hline
  \end{tblr}
  \quad
  \begin{booktabs}{
    columns={4em},
    colspec={*{2}{S[table-format=2.2]}}
  }
    \toprule
    \SetCell[c=2]{c}{{{\Env{booktabs}}}} & \\
    \midrule
    0.76 & 0.76 \\
    83.1 & 83.1 \\
    \bottomrule
  \end{booktabs}
\end{center}
```

Missing figure

TeX Live version does not include tabularray

A further simple example is shown in Table 6.1. In fact I show the table twice, once with the language set to default and once with it set to German. The `tabular` contents are identical, the second tabular is inside a `\foreignlanguage`.[1] Note the use of `table-format` to centre the temperatures as the heading is wider than the numbers.

Table 6.2 shows a more complicated table set using the tools. You can either enclose all numbers in `\tablenum` (or `\num`) or use the S column descriptor. If you use S, it usually centres the contents of the column. You can use the `table-number-alignment` option to change this. S and `\tablenum` cannot generally be mixed in a single column though. If you want to use `\tablenum` in an S column you have to enclose it in braces. You also need to do this with regular text, such as column headings — see Table 6.1. Note the use of `\sisetup{table-format=4.0}` to define a default format for numbers in an "S" column, or that are formatted using `\tablenum`.

The spacing of the captions in Tables 6.1 and 6.2 is the same, as the option `captions=tableheading` is set in this guide.

With `\tablenum` you can also specify the precision and format of each number is shown separately. `\tablenum` should be preferred over `\num` in tables, as you can use alignment options with it. With S you specify the format for the whole column. You should make sure that you specify the rounding mode in the preamble of the table (usually `figures` or `places` — you can also choose `off`).

If you know that you are going to make such a table, it is easy to use either of these options to write it out in this format using a program. Using `\tablenum` or `\num` solves the very common problem of your program writing out the results with too many significant digits and you have to correct them all by hand later (as well as every time they get updated)! It is possible to use to use S for simple numbers in tables and `\tablenum` for more complicated number typesetting. For asymmetric errors you could consider defining something similar to `\numpmerr`, which internally uses `\num`.

A common and closely related problem that occurs is that your analysis spits out a result such as $24.36789^{+0.36423}_{-0.45236}$. You copy and paste this into a table and then a referee (or your supervisor) complains that you clearly don't understand statistics, as you should never quote an error to 5 significant digits. You can go ahead and edit all the numbers by hand, but what do you do if you rerun your analysis and all the numbers change. Reformatting by hand is then an error prone and lengthy process. As discussed above, you can either use options such as `round-precision` in the S command or use the macro `\tablenum` or `\num` and option `dp/round-precision` to do the rounding for you.

Tables 6.3 and 6.4 shows and compares two different approaches on how this can be done, even for asymmetric errors. While the form may appear to be a bit clumsy at first, it is easy enough to get your program to write out the lines. You should use the options `round-mode` and `round-precision` to

---

[1] Umlaute etc. can normally be inserted directly. Such characters can be included directly in listings that use the `tcblisting` environment, if one uses with LuaLATEX and X∃LATEX for compilation. However, that does not work in the `tcblisting` environment if one uses pdfLATEX to compile the guide. Hence this example uses the old fashioned style \"{u} etc.

```
\captionabove{A table of viscosities in the default language and German.
  Typeset using the \Macro{captionabove} macro.}%
\label{tab:viscosity}
\centering
\begin{tabular}{lS[table-format=4.2]S}
  \toprule
  Liquid & {Temp.} & {Viscosity \(\eta\)}\\
  &  {[\si{\celsius}]} & {(\si{\metre\pascal\second})} \\
  \midrule
  Blood     & 37 & 4.0 \\
  Glycerine &  0 & 10000 \\
  & 20 & 1410 \\
  Oil (SAE 10) & 30 & 200 \\
  Water   &  0 & 1.8 \\
  & 20 & 1.00 \\
  Air     & 20 & 0.018 \\
  \bottomrule
\end{tabular}
\qquad
\foreignlanguage{ngerman}{%
\begin{tabular}{lS[table-format=4.2]S}
  \toprule
  Fl\"{u}ssigkeit & {Temp.} & {Viskosit\"{a}t \(\eta\)}\\
  &  {[\si{\celsius}]} & {(\si{\metre\pascal\second})} \\
  \midrule
  Blut     & 37 & 4.0 \\
  Glyzerin &  0 & 10000 \\
  & 20 & 1410 \\
  \"{O}l (SAE 10) & 30 & 200 \\
  Wasser   &  0 & 1.8 \\
  & 20 & 1.00 \\
  Luft     & 20 & 0.018 \\
  \bottomrule
\end{tabular}
}
```

Table 6.1: A table of viscosities in the default language and German. Typeset using the `\captionabove` macro.

Liquid	Temp. [°C]	Viscosity η (m Pa s)	Flüssigkeit	Temp. [°C]	Viskosität η (m Pa s)
Blood	37	4.0	Blut	37	4,0
Glycerine	0	10 000	Glyzerin	0	10 000
	20	1 410		20	1 410
Oil (SAE 10)	30	200	Öl (SAE 10)	30	200
Water	0	1.8	Wasser	0	1,8
	20	1.00		20	1,00
Air	20	0.018	Luft	20	0,018

```
\caption{A selection of cross-section measurements!
  Typeset using the \Macro{caption} macro.}%
\label{tab:xsect0}
\centering
\renewcommand{\arraystretch}{1.2}
\sisetup{round-mode = places}
\sisetup{table-format=4.0}
\begin{tabular}{
    S[table-format=+1.2] @{\,:\,}
    S[table-format=+1.2, table-number-alignment=center-decimal-marker]
    r@{\,}c@{\,}l@{\,}l
    S[table-format=5.0, round-precision=0]@{\,}l
    S[table-format=1.2, round-precision=2]}
  \toprule
  \multicolumn{2}{c}{\etajet} & \multicolumn{4}{c}{\diffetab}
  & \multicolumn{2}{c}{\diffnloetab} & \Cbhad \\
  \multicolumn{2}{c}{} & \multicolumn{4}{c}{[\si{\pico\barn}]} &
  \multicolumn{2}{c}{[\si{\pico\barn\per\GeV}]} & \\
  \midrule
  -1.6 & -1.1 & \tablenum[table-format=2.1, round-precision=1]{57.4} &
  \(\pm\) & \tablenum[table-format=1.1, round-precision=1]{9.4} &
  \(^{+13}_{-3}\) &  72 & \(^{+22}_{-13}\) & 0.704 \\
  -1.1 & -0.8 & \tablenum[round-precision=0]{121.3} &
  \(\pm\) & \tablenum[table-format=2.0, round-precision=0]{21.1} &
  \(^{+16}_{-16}\) & 182 & \(^{+50}_{-30}\) & 0.781 \\
  \multicolumn{9}{l}{\ldots}\\
  -0.2 & +0.1 & \tablenum[round-precision=0]{264.1} &
  \(\pm\) & \tablenum[table-format=2.0, round-precision=0]{22.0} &
  \(^{+28}_{-23}\) & 342 & \(^{+91}_{-55}\) & 0.808 \\
  +0.1 & +0.5 & \tablenum[round-precision=0]{316.0} &
  \(\pm\) & \tablenum[table-format=2.0, round-precision=0]{21.1} &
  \(^{+23}_{-17}\) & 346 & \(^{+96}_{-57}\) & 0.847 \\
  +0.5 & +1.4 & \tablenum[round-precision=0]{288.1} &
  \(\pm\) & \tablenum[table-format=2.0, round-precision=0]{15.4} &
  \(^{+20}_{-30}\) & 265 & \(^{+82}_{-48}\) & 0.926 \\
  \bottomrule
\end{tabular}
```

Table 6.2: A selection of cross-section measurements! Typeset using the `\caption` macro.

η^{jet}	$\dfrac{\mathrm{d}\sigma_b}{\mathrm{d}\eta^b}$ [pb]	$\dfrac{\mathrm{d}\sigma_b^{\text{NLO}}}{\mathrm{d}\eta^b}$ [pb GeV^{-1}]	C_b^{had}
$-1.60 : -1.10$	$57.4 \pm 9.4\,^{+13}_{-3}$	$72\,^{+22}_{-13}$	0.70
$-1.10 : -0.80$	$121 \pm 21\,^{+16}_{-16}$	$182\,^{+50}_{-30}$	0.78
$\ldots$			
$-0.20 :\ \ 0.10$	$264 \pm 22\,^{+28}_{-23}$	$342\,^{+91}_{-55}$	0.81
$0.10 :\ \ 0.50$	$316 \pm 21\,^{+23}_{-17}$	$346\,^{+96}_{-57}$	0.85
$0.50 :\ \ 1.40$	$288 \pm 15\,^{+20}_{-30}$	$265\,^{+82}_{-48}$	0.93

specify how the rounding should be done. In the first line of Table 6.3 I show what to do if you need to change the precision of a single number. As you can see this is rather trivial. However, then the alignment on the decimal point is no longer perfect. While this is probably OK for internal notes etc., theses or papers (should) have tougher requirements. Another way of achieving the same thing and avoiding the use of `round-mode` and `round-precision`[2] is shown in Table 6.4. Note the use of options for the S command and the use of `\num` enclosed in braces to format the row that requires a different precision.

While the rounding works very nicely, it slows down the compilation of your document. You can turn off any rounding (and all other parsing of numbers) by using `\sisetup` and the option `parse-numbers=false`: `\sisetup{parse-numbers=false}`. If you set this option inside a table, it will only be applied to that table.

It takes a while to learn what the different options mean and their consequences. I hope that these examples cover most problems and at least give ideas as to what is possible. In particular the Table 6.4 solution is very nice, as all numbers except the one that requires an extra digit are written without any special formatting!

Another example using siunitx tools that contains a similar problem is:

```
\centering
\begin{tabular}{
  S[table-number-alignment=center-decimal-marker]@{\(\,\pm\)}
  S[table-number-alignment=center-decimal-marker]|
  c
  S[output-decimal-marker={,}]@{\(\,\pm\!\!\)}
  S[output-decimal-marker={,}]
}
\toprule
\multicolumn{2}{c|}{English} &
\multicolumn{1}{c}{German1} &
\multicolumn{2}{c}{German2} \\
{Value} & {Error} & {Wert} & \multicolumn{2}{c}{Messung}\\
\midrule
0.76 & 0.14 & \num[output-decimal-marker={,}]{0.89(16)} & 0.89 & 0.16\\
83.1 &  7.6 & \num[output-decimal-marker={,}]{94.2(83)} & 94.2 & 8.3\\
\bottomrule
\end{tabular}
```

English		German1	German2	
Value ±Error		Wert	Messung	
0.76 ± 0.14		0,89 ± 0,16	0,89 ± 0,16	
83.1 ± 7.6		94,2 ± 8,3	94,2 ± 8,3	

As you can see, the "English" column formats things nicely using the S column descriptor. The "German1" column successfully converts the decimal point to a comma and also the parentheses with the error to ±. However, the alignment of the numbers is now messed up. The "German2" column looks

---

[2] The `round-mode` should be set in the preamble of the table and not for every number.

```
\caption{Another selection of cross-section measurements! Note the
  use of \Macro{sisetup} to keep the plus signs on the positive errors.
  This example uses \Macro{tablenum}.
}%
\label{tab:rounding1}
\centering
\renewcommand{\arraystretch}{1.2}
\sisetup{retain-explicit-plus}
\sisetup{round-mode = places}
\begin{tabular}{%
    S@{\,:\,}S
    r@{\,}@{\(\pm\)}@{\,}l@{\,}l
      }
  \toprule
  \multicolumn{2}{c}{\etajet} & \multicolumn{3}{c}{\diffetab} \\
  \multicolumn{2}{c}{} & \multicolumn{3}{c}{[\si{\pico\barn}]} \\
  \midrule
  -1.6 & -1.1 & \num[round-precision=3]{0.574} &
  \num[round-precision=3]{0.094} &
  \(^{\num[round-precision=3]{+0.035}}_{\num[round-precision=3]{-0.031}}\) \\
  -1.1 & -0.8 & \num[round-precision=2]{1.213} &
  \num[round-precision=2]{0.211} &
  \(^{\num[round-precision=2]{+0.162}}_{\num[round-precision=2]{-0.162}}\) \\
  \multicolumn{5}{l}{\ldots}\\
  -0.2 & +0.1 & \num[round-precision=2]{2.641} &
  \num[round-precision=2]{0.220} &
  \(^{\num[round-precision=2]{+0.283}}_{\num[round-precision=2]{-0.233}}\) \\
  +0.1 & +0.5 & \num[round-precision=2]{3.160} &
  \num[round-precision=2]{0.211} &
  \(^{\num[round-precision=2]{+0.232}}_{\num[round-precision=2]{-0.172}}\) \\
  +0.5 & +1.4 & \num[round-precision=2]{2.881} &
  \num[round-precision=2]{0.154} &
  \(^{\num[round-precision=2]{+0.201}}_{\num[round-precision=2]{-0.301}}\) \\
  \bottomrule
\end{tabular}
```

Table 6.3: Another selection of cross-section measurements! Note the use of `\sisetup` to keep the plus signs on the positive errors. This example uses `\tablenum`.

η^{jet}	$\dfrac{\mathrm{d}\sigma_b}{\mathrm{d}\eta^b}$ [pb]	
$-1.60 : -1.10$	0.574 ± 0.094	$^{+0.035}_{-0.031}$
$-1.10 : -0.80$	1.21 ± 0.21	$^{+0.16}_{-0.16}$
$\ldots$		
$-0.20 : +0.10$	2.64 ± 0.22	$^{+0.28}_{-0.23}$
$+0.10 : +0.50$	3.16 ± 0.21	$^{+0.23}_{-0.17}$
$+0.50 : +1.40$	2.88 ± 0.15	$^{+0.20}_{-0.30}$

```
\caption{Another selection of cross-section measurements! Note the
  use of \Macro{sisetup} to keep the plus signs on the positive errors.
  This example uses \enquote{S} columns.}%
\label{tab:rounding2}
\centering
\renewcommand{\arraystretch}{1.2}
\sisetup{retain-explicit-plus}
\sisetup{round-mode = places, round-precision = 2}
\begin{tabular}{%
    S[table-format=3.2, table-number-alignment=right]@{\,:\,}S
    S[round-mode = places, round-precision = 2,
    table-format = 1.3, table-number-alignment=right]
    @{\(\,\pm\,\)}
    S[round-mode = places, round-precision = 2,
    table-format = 1.3, table-number-alignment=left]
    @{\,}l
      }
  \toprule
  \multicolumn{2}{c}{\etajet} & \multicolumn{3}{c}{\diffetab} \\
  \multicolumn{2}{c}{} & \multicolumn{3}{c}{[\si{\pico\barn}]} \\
  \midrule
  -1.6 & -1.1 & {\num[round-precision=3]{0.574}} &
  {\num[round-precision=3]{0.094}} &
  \(^{\num[round-precision=3]{+0.035}}_{\num[round-precision=3]{-0.031}}\) \\
  -1.1 & -0.8 & 1.213 & 0.211 & \(^{\num{+0.162}}_{\num{-0.162}}\) \\
  \multicolumn{5}{l}{\ldots}\\
  -0.2 & +0.1 & 2.641 & 0.220 & \(^{\num{+0.283}}_{\num{-0.233}}\) \\
  +0.1 & +0.5 & 3.160 & 0.211 & \(^{\num{+0.232}}_{\num{-0.172}}\) \\
  +0.5 & +1.4 & 2.881 & 0.154 & \(^{\num{+0.201}}_{\num{-0.301}}\) \\
  \bottomrule
\end{tabular}
```

Table 6.4: Another selection of cross-section measurements! Note the use of `\sisetup` to keep the plus signs on the positive errors. This example uses "S" columns.

η^{jet}	$\dfrac{\mathrm{d}\sigma_b}{\mathrm{d}\eta^b}$	
	[pb]	
$-1.60 : -1.10$	0.574 ± 0.094	$^{+0.035}_{-0.031}$
$-1.10 : -0.80$	1.21 ± 0.21	$^{+0.16}_{-0.16}$
$\ldots$		
$-0.20 : +0.10$	2.64 ± 0.22	$^{+0.28}_{-0.23}$
$+0.10 : +0.50$	3.16 ± 0.21	$^{+0.23}_{-0.17}$
$+0.50 : +1.40$	2.88 ± 0.15	$^{+0.20}_{-0.30}$

better. I had to do some dirty tricks with the formatting of the intercolumn separator @{\,\pm\!\!} to get the spacing nice! This confirms my statement above that the S format is most useful for aligning simple numbers easily, while \tablenum is very nice for rounding to a given precision — note that you can use either the dp or sf options to achieve what you want.

If your header is wider than the content, you may also have to tweak a few things to get the correct alignment. A good way of doing this is to insert some \hspace* into the header. The table on the left of Table 6.5 is without \hspace, while the one on the right is with an \hspace of 2em. The tables contain vertical lines that I would normally not include to illustrate the alignment.

6.3 Using dcolumn

An alternative is the dcolumn package. You can also use this package to convert numbers written with "." as the decimal point into German-style numbers with ",".[3] You can line up measurements and errors by putting each of them in its own column. If your errors are symmetric you can put ± as the intercolumn separator:

```
\centering
\begin{tabular}{cD{.}{.}{3} | cD{.}{,}{2} | rl |
  D{.}{.}{2}@{\(\,\pm\,\)}D{.}{.}{2}}
  \multicolumn{2}{c|}{English} &
  \multicolumn{2}{c|}{German} &
  \multicolumn{2}{c|}{Val \(\pm\) Err} &
  \multicolumn{1}{c}{Val} & \multicolumn{1}{l}{Err}\\
  \midrule
  0.76 & 0.76 & 0,76 & 0.76 & 0.76 & \(\pm\) 0.14 & 0.76 & 0.04\\
  83.1 & 83.1 & 83,1 & 83.1 & 83.1 & \(\pm\) 4.2  & 83.1 & 4.2
\end{tabular}
```

English		German		Val ± Err		Val	Err
0.76	0.76	0,76	0,76	0.76	± 0.14	0.76	± 0.04
83.1	83.1	83,1	83,1	83.1	± 4.2	83.1	± 4.2

Tables 6.6 and 6.7 show quite a complicated table typeset in two different ways. The box below illustrates the typesetting used in Table 6.6.

---

[3] See Section 8.3 for hints on how to get around problems with the ziffer package.

```
\caption{Table illustrating how to centre numbers
  if the heading is wider than them.}%
\label{tab:heading}
\renewcommand{\arraystretch}{1.4}
\sisetup{round-mode=places, retain-explicit-plus}
\centering
\begin{tabular}{|S[table-format=5.0, round-precision=0]@{\,} l|}
  \toprule
  \multicolumn{2}{| c |}{\diffnloetab} \\
  \multicolumn{2}{| c |}{[\si{\pico\barn\per\GeV}]} \\
  \midrule
    72 & \(^{+22}_{-13}\) \\
    182 & \(^{+50}_{-30}\) \\
    255 & \(^{+69}_{-42}\) \\
  \bottomrule
\end{tabular}
\qquad
\begin{tabular}{|S[table-format=5.0, round-precision=0]@{\,}
  l@{\hspace*{2em}}|}
  \toprule
  \multicolumn{2}{| c |}{\diffnloetab} \\
  \multicolumn{2}{| c |}{[\si{\pico\barn\per\GeV}]} \\
  \midrule
    72 & \(^{+22}_{-13}\) \\
    182 & \(^{+50}_{-30}\) \\
    255 & \(^{+69}_{-42}\) \\
  \bottomrule
\end{tabular}
```

Table 6.5: Table illustrating how to centre numbers if the heading is wider than them.

$\dfrac{\mathrm{d}\sigma_b^{\mathrm{NLO}}}{\mathrm{d}\eta^b}$ $[\mathrm{pb\,GeV}^{-1}]$	$\dfrac{\mathrm{d}\sigma_b^{\mathrm{NLO}}}{\mathrm{d}\eta^b}$ $[\mathrm{pb\,GeV}^{-1}]$
$72\,^{+22}_{-13}$	$72\,^{+22}_{-13}$
$182\,^{+50}_{-30}$	$182\,^{+50}_{-30}$
$255\,^{+69}_{-42}$	$255\,^{+69}_{-42}$

```
  \centering
  \begin{tabular}{r@{ : }l|c|c|c}
    \toprule
    \multicolumn{2}{c|}{\pTjet} & \diffptb & \diffnloptb & \Cbhad \\
    \multicolumn{2}{c|}{(GeV)} & (pb/GeV) & (pb/GeV) & \\
    \midrule
    \(\phantom{1}\)6 & 11 &
    \(95.6\phantom{2} \pm 4.9\phantom{4}^{+9.8\phantom{2}}_{-7.0\phantom{2}}\) &
    \(109\phantom{.22}^{+31\phantom{.22}}_{-19\phantom{.22}}\) & 0.83 \\
    \multicolumn{5}{l}{\ldots}
  \end{tabular}
```

The next box illustrates the typesetting used in Table 6.7. Splitting values and uncertainties into separate columns makes the formatting and alignment easier. Table 6.7 is rotated by 90° to illustrate how that can be done.

```
  \begin{sideways}
  \(\begin{array}{r@{\,:\,}l |
    D{.}{.}{2}@{\,}r@{}D{.}{.}{2}@{\,}l |
    D{.}{.}{2}@{\,}l | c}
    \toprule
    \multicolumn{2}{c|}{\pTjet} & \multicolumn{4}{c|}{\diffptb} &
    \multicolumn{2}{c|}{\diffnloptb} & \Cbhad \\
    \multicolumn{2}{c|}{[\si{\GeV}]} &
    \multicolumn{4}{c|}{[\si{\pico\barn\per\GeV}]} &
    \multicolumn{2}{c|}{[\si{\pico\barn\per\GeV}]} & \\
    \midrule
      6 & 11 & 95.6 & \pm & 4.9  & ^{+9.8}_{-7.0}  &
      109  & ^{+31}_{-19} & 0.83 \\
      \multicolumn{5}{l}{\ldots}
  \end{array}\)
  \end{sideways}
```

Table 6.7 is certainly simpler to typeset and does not really use any tricks to line things up. Note the use of array rather than tabular, which means that the contents are typeset in math mode rather than text mode. For tables of numbers this is often preferred. You just have to enclose the array in \(...\) or \begin{math}...\end{math}. Close inspection of Table 6.7 table shows that it is, however, not perfect. It is questionable whether one wants to to write +0.5 or just 0.5. The fact that both p_T as well as η cross-sections are in a single tabular, but the numerical values are so different makes it difficult to line things up perfectly. An alternative, which uses the headers to fix the width of the columns is given in Tables 6.8 and 6.9. Note that these use sidewaystable rather than sideways inside table, which also rotates the caption. It also removes the vertical lines following the recommendations in the package booktabs.

This version of the table also adds a few extra bells and whistles. It uses a \rule of zero width to give a bit more space above and below the cross-sections. p{...} switches to paragraph mode, so \centering is needed to get centred headers. It adds a bit more space between the rows using \arraystretch. You have to play around a bit with the column widths. If you set one of them too

Table 6.6: Cross-section measurements using \phantom and normal column types!

p_T^{jet} (GeV)	$\frac{d\sigma_b}{dp_T^b}$ (pb/GeV)	$\frac{d\sigma_b^{NLO}}{dp_T^b}$ (pb/GeV)	C_b^{had}
6 : 11	$95.6 \pm 4.9 \; {}^{+9.8}_{-7.0}$	$109 \; {}^{+31}_{-19}$	0.83
11 : 16	$24.8 \pm 1.2 \; {}^{+1.8}_{-1.4}$	$29.1 \; {}^{+7.9}_{-4.7}$	0.89
16 : 21	$6.02 \pm 0.49 {}^{+0.6}_{-0.6}$	$7.1 \; {}^{+2.0}_{-1.2}$	0.92
21 : 27	$0.93 \pm 0.22 {}^{+0.31}_{-0.20}$	$1.87 {}^{+0.54}_{-0.34}$	0.95
27 : 35	$0.30 \pm 0.12 {}^{+0.14}_{-0.12}$	$0.46 {}^{+0.13}_{-0.08}$	1.05

η^{jet}	$\frac{d\sigma_b}{d\eta^b}$ (pb)	$\frac{d\sigma_b^{NLO}}{d\eta^b}$ (pb)	C_b^{had}
$-1.6 : -1.1$	$57 \pm 22^{+13}_{-3}$	72^{+22}_{-13}	0.70
$-1.1 : -0.8$	$121 \pm 21^{+16}_{-16}$	182^{+50}_{-30}	0.78
$-0.8 : -0.5$	$214 \pm 22^{+22}_{-12}$	255^{+69}_{-42}	0.79
$-0.5 : -0.2$	$233 \pm 21^{+28}_{-21}$	307^{+83}_{-50}	0.79
$-0.2 : \;\; 0.1$	$264 \pm 22^{+28}_{-23}$	342^{+91}_{-55}	0.81
$0.1 : \;\; 0.5$	$316 \pm 21^{+23}_{-17}$	346^{+96}_{-57}	0.86
$0.5 : \;\; 1.4$	$288 \pm 15^{+20}_{-30}$	265^{+82}_{-48}	0.93

Table 6.7: Cross-section measurements using dcolumn and array!

p_T^{jet} [GeV]	$\frac{d\sigma_b}{dp_T^b}$ [pb GeV^{-1}]	$\frac{d\sigma_b^{NLO}}{dp_T^b}$ [pb GeV^{-1}]	C_b^{had}
6 : 11	$95.6 \pm 4.9 \; {}^{+9.8}_{-7.0}$	$109 \; {}^{+31}_{-19}$	0.83
11 : 16	$24.8 \pm 1.2 \; {}^{+1.8}_{-1.4}$	$29.1 \; {}^{+7.9}_{-4.7}$	0.89
16 : 21	$6.02 \pm 0.49 {}^{+0.6}_{-0.6}$	$7.1 \; {}^{+2.0}_{-1.2}$	0.92
21 : 27	$0.93 \pm 0.22 {}^{+0.31}_{-0.20}$	$1.87 {}^{+0.54}_{-0.34}$	0.95
27 : 35	$0.30 \pm 0.12 {}^{+0.14}_{-0.12}$	$0.46 {}^{+0.13}_{-0.08}$	1.05

η^{jet}	$\frac{d\sigma_b}{d\eta^b}$ [pb]	$\frac{d\sigma_b^{NLO}}{d\eta^b}$ [pb]	C_b^{had}
$-1.6 : -1.1$	$57 \pm 22^{+13}_{-3}$	72^{+22}_{-13}	0.70
$-1.1 : -0.8$	$121 \pm 21^{+16}_{-16}$	182^{+50}_{-30}	0.78
$-0.8 : -0.5$	$214 \pm 22^{+22}_{-12}$	255^{+69}_{-42}	0.79
$-0.5 : -0.2$	$233 \pm 21^{+28}_{-21}$	307^{+83}_{-50}	0.79
$-0.2 : +0.1$	$264 \pm 22^{+28}_{-23}$	342^{+91}_{-55}	0.81
$+0.1 : +0.5$	$316 \pm 21^{+23}_{-17}$	346^{+96}_{-57}	0.86
$+0.5 : +1.4$	$288 \pm 15^{+20}_{-30}$	265^{+82}_{-48}	0.93

```
  \caption[Cross-sections using \Env{sidewaystable}, which also
    rotates the caption.]{Cross-sections using  \Env{sidewaystable},
    which also rotates the caption.
    Note the dirty trick used to
    get the \Cbhad values nicely in the centre of the column.}%
  \label{tab:xsect2a}
  \centering
  \renewcommand{\arraystretch}{1.2}
  \begin{math}
  \begin{array}{D{.}{.}{4.0}@{\,.\,:}D{.}{.}{.}D{.}{.}{3.1}
    D{.}{.}{2}@{\,}r@{}D{.}{.}{2}@{\,}l
    D{.}{.}{2}@{\,}l c}
    \toprule
    \multicolumn{2}{p{2.0cm}}{\rule[-1.5ex]{0pt}{4.0ex}\centering\pTjet} &
    \multicolumn{4}{p{3.0cm}}{\centering\diffptb} &
    \multicolumn{2}{p{2.2cm}}{\centering\diffnloptb} &
    \multicolumn{1}{p{1.5cm}}{\centering\Cbhad}  \\
    \multicolumn{2}{c}{[\si{\GeV}]} &
    \multicolumn{4}{c}{[\si{\pico\barn\per\GeV}]} &
    \multicolumn{2}{c}{[\si{\pico\barn\per\GeV}]} &  \\
    \midrule
       6 & 11 & 95.6 & \pm & 4.9  & ^{+9.8}_{-7.0}  & 109  & ^{+31}_{-19} & 0.83  \\
      11 & 16 & 24.8 & \pm & 1.2  & ^{+1.8}_{-1.4}  & 29.1 & ^{+7.9}_{-4.7} & 0.89  \\
    \multicolumn{9}{1}{\ldots}\\
      27 & 35 & 0.30 & \pm & 0.12 & ^{+0.14}_{-0.12} & 0.46 & ^{+0.13}_{-0.08} & 1.05  \\
    \bottomrule
  \end{array}
  \end{math}
```

Table 6.8: Cross-sections using sidewaystable, which also rotates the caption. Note the dirty trick used to get the C_b^{had} values nicely in the centre of the column.

p_T^{jet} [GeV]		$\frac{d\sigma_b}{dp_T^b}$ [pb GeV^{-1}]		$\frac{d\sigma_b^{\mathrm{NLO}}}{dp_T^b}$ [pb GeV^{-1}]	C_b^{had}
6 :	11	95.6 ± 4.9	$^{+9.8}_{-7.0}$	$109\ ^{+31}_{-19}$	0.83
11 :	16	24.8 ± 1.2	$^{+1.8}_{-1.4}$	$29.1\ ^{+7.9}_{-4.7}$	0.89
...					
27 :	35	0.30 ± 0.12	$^{+0.14}_{-0.12}$	$0.46\ ^{+0.13}_{-0.08}$	1.05

```
\caption[Cross-sections using \Env{sidewaystable}, which also
  rotates the caption.]{Cross-sections using \Env{sidewaystable},
  which also rotates the caption. Just for fun the numbers
  indicating the \(\eta\) range of the bins in the lower half have
  been converted to German format!
  Note also the dirty trick used to
  get the \Cbhad values nicely in the centre of the column.}%
\label{tab:xsect2b}
\centering
\renewcommand{\arraystretch}{1.2}
\begin{math}
\begin{array}{D{.}{,}{1}@{\,,:}D{.}{,}{1}
  D{.}{,}{5.0}@{\,}r@{}D{.}{,}{0}@{\,}l
  D{.}{,}{5.0}@{\,}l D{.}{,}{4}}
\toprule
\multicolumn{2}{p{2.0cm}}{\rule[-1.5ex]{0pt}{4.0ex}\centering\etajet} &
\multicolumn{4}{p{3.0cm}}{\centering\diffetab} &
\multicolumn{2}{p{2.2cm}}{\centering\diffnloetab} &
\multicolumn{1}{p{1.5cm}}{\centering\Cbhad} \\
\multicolumn{2}{c}{} & \multicolumn{4}{c}{[\si{\pico\barn}]} &
\multicolumn{2}{c}{[\si{\pico\barn}]} & \\
\midrule
-1.6 & -1.1 & 57 & \pm & 22 & ^{+13}_{-3} & 72 & ^{+22}_{-13} & 0.70 \\
-1.1 & -0.8 & 121 & \pm & 21 & ^{+16}_{-16} & 182 & ^{+50}_{-30} & 0.78 \\
\multicolumn{9}{l}{\ldots}\\
0.1 & 0.5 & 316 & \pm & 21 & ^{+23}_{-17} & 346 & ^{+96}_{-57} & 0.86 \\
0.5 & 1.4 & 288 & \pm & 15 & ^{+20}_{-30} & 265 & ^{+82}_{-48} & 0.93 \\
\bottomrule
\end{array}
\end{math}
```

η^{jet}		$\frac{\mathrm{d}\sigma_b}{\mathrm{d}\eta^b}$ [pb]	$\frac{\mathrm{d}\sigma_b^{\text{NLO}}}{\mathrm{d}\eta^b}$ [pb]	C_b^{had}
−1,6:	−1,1	$57 \pm 22\,^{+13}_{-3}$	$72\,^{+22}_{-13}$	0,70
−1,1:	−0,8	$121 \pm 21\,^{+16}_{-16}$	$182\,^{+50}_{-30}$	0,78
...				
0,1:	0,5	$316 \pm 21\,^{+23}_{-17}$	$346\,^{+96}_{-57}$	0,86
0,5:	1,4	$288 \pm 15\,^{+20}_{-30}$	$265\,^{+82}_{-48}$	0,93

Table 6.9: Cross-sections using sidewaystable, which also rotates the caption. Just for fun the numbers indicating the η range of the bins in the lower half have been converted to German format! Note also the dirty trick used to get the C_b^{had} values nicely in the centre of the column.

small it gets expanded anyway, so the two parts of the table would not line up. Just for fun the bottom half of the table uses "," instead of "." for the decimal point! Admittedly the header is a bit complicated, but the numbers are nice and easy to write!

6.4 Hiding columns

Sometimes you write out a table with so many columns that it does not fit on a page, even if you rotate it. In such cases you can of course reduce the number of columns by hand, but it would be much nicer to just "hide" some of the columns (as one often does in a spreadsheet). The array package, which is included by default, allows one to define new column types and you can use this feature to define a column that is not shown.

Following the idea found in https://texblog.org/2014/10/24/removinghiding-a-column-in-a-latex-table/ we define two new column types "H" and "E":

```
\newcolumntype{H}{>{\setbox0=\hbox\bgroup}c<{\egroup}@{}}
\newcolumntype{E}{>{\setbox0=\hbox\bgroup\let\pm\relax}c<{\egroup}@{}}
```

The "E" variant is for columns that include \pm. This idea can also be extended to other content if necessary. Tables 6.10 to 6.12 show the original table with variants hiding different columns.

Table 6.10: Simple table with columns that we want to hide.

```
\centering
\begin{tabular}{SSS[table-format=1.1(1)]
  S[table-format=3.1]@{\(\,\pm\,\)}
  S[table-format=2.1, table-number-alignment=left]
  S[table-format=3.1]@{\(\,\pm\!\!\)}S[table-format=1.1]}
  \toprule
  {Col.\ 1} & {Col.\ 2} & {Col.\ 3} &
  \multicolumn{2}{c}{Col.\ 4 with err.} &
  \multicolumn{2}{c}{Col.\ 5 with err.} \\
  \midrule
  1.1 & 2.1 & 3.1 \pm 0.2 & 4.1 & 0.1 & 5.1 & 0.3 \\
  1.2 & 2.2 & 3.2 \pm 0.3 & 4.2 & 12.2 & 5.2 & 0.4 \\
  1.3 & 2.3 & 3.3 \pm 0.4 & 4.3 & 0.3 & 5.3 & 0.5\\
  \bottomrule
\end{tabular}
```

Col. 1	Col. 2	Col. 3	Col. 4 with err.	Col. 5 with err.
1.1	2.1	3.1 ± 0.2	$4.1 \pm\ \ 0.1$	$5.1 \pm\ \ 0.3$
1.2	2.2	3.2 ± 0.3	4.2 ± 12.2	$5.2 \pm\ \ 0.4$
1.3	2.3	3.3 ± 0.4	$4.3 \pm\ \ 0.3$	$5.3 \pm\ \ 0.5$

Table 6.11: Simple table with columns 2 and 3 hidden. Note the use of the "E" column when the number contains an uncertainty.

```
\centering
\begin{tabular}{SHE
  S[table-format=3.1]@{\(\,\pm\,\)}
  S[table-format=2.1, table-number-alignment=left]
  S[table-format=3.1]@{\(\,\pm\!\!\)}S[table-format=1.1]}
  \toprule
  {Col.\ 1} & {Col.\ 2} & {Col.\ 3} &
  \multicolumn{2}{c}{Col.\ 4 with err.} &
  \multicolumn{2}{c}{Col.\ 5 with err.} \\
  \midrule
  1.1 & 2.1 & 3.1 \pm 0.2 & 4.1 & 0.1 & 5.1 & 0.3 \\
  1.2 & 2.2 & 3.2 \pm 0.3 & 4.2 & 12.2 & 5.2 & 0.4 \\
  1.3 & 2.3 & 3.3 \pm 0.4 & 4.3 & 0.3 & 5.3 & 0.5\\
  \bottomrule
\end{tabular}
```

Col. 1	Col. 4 with err.	Col. 5 with err.
1.1	4.1 ± 0.1	5.1 ± 0.3
1.2	4.2 ± 12.2	5.2 ± 0.4
1.3	4.3 ± 0.3	5.3 ± 0.5

Table 6.10 also illustrates different ways of including numbers with errors. Column 4 is the one that looks best to me.

Table 6.12: Simple table with column 4 (actually 4 and 5) hidden. The column heading, which is defined using \multicolumn, also needs to be typeset with column type "H".

```
\centering
\begin{tabular}{SSS[table-format=1.1(1)]
  H%S[table-format=3.1]@{\(\,\pm\,\)}
  H%S[table-format=2.1, table-number-alignment=left]
  S[table-format=3.1]@{\(\,\pm\!\!\)}S[table-format=1.1]}
  \toprule
  {Col.\ 1} & {Col.\ 2} & {Col.\ 3} &
  \multicolumn{2}{H}{Col.\ 4 with err.} &
  \multicolumn{2}{c}{Col.\ 5 with err.} \\
  \midrule
  1.1 & 2.1 & 3.1 \pm 0.2 & 4.1 & 0.1 & 5.1 & 0.3 \\
  1.2 & 2.2 & 3.2 \pm 0.3 & 4.2 & 12.2 & 5.2 & 0.4 \\
  1.3 & 2.3 & 3.3 \pm 0.4 & 4.3 & 0.3 & 5.3 & 0.5\\
  \bottomrule
\end{tabular}
```

Col. 1	Col. 2	Col. 3	Col. 5 with err.
1.1	2.1	3.1 ± 0.2	$5.1 \pm$ 0.3
1.2	2.2	3.2 ± 0.3	$5.2 \pm$ 0.4
1.3	2.3	3.3 ± 0.4	$5.3 \pm$ 0.5

References

LaTeX file: guide_refs.tex

Every thesis should also include a list of references, called the bibliography in LaTeX terminology. You "cite" a reference using the \cite command. For example, the book of Kopka [KD04] is my favourite LaTeX book. In general you should include a non-breaking space, i.e. "~" between the text and the \cite command. The reference comes in general before the punctuation.[1]

On a related topic, after some research, it appears to me that the footnote number should come after the punctuation, unless the footnote only refers to the last word of the phrase or sentence.

That is the easy part! Where do you get the references from and how do you format them? Sources of references are discussed in Section 7.6. There are two options for the formatting. Either you do it by hand, formatting \bibitem entries yourself or you use BibTeX. More precisely you should use the biblatex package, which is a replacement for traditional BibTeX. While biblatex and/or BibTeX may appear to be the more complicated option at the beginning, I strongly recommend that you use it.

In addition, you have to make sure that authors' names are printed consistently, you include the appropriate collaboration name, the title is formatted correctly and journals are given consistent abbreviations. Such topics are discussed in Section 7.3.

What about citing a series of articles? Can you include them in one reference or do you want to keep one article per reference? I give some hints on useful options and settings for biblatex below (Section 7.4.1). If you use traditional BibTeX (which I do not recommend), then you probably have to use the mcite package — see Appendix G.4. Just to take a silly example. The ZEUS collaboration publications in 2010 [ZA+10; Abr+10a; Abr+10b] were not as numerous as in previous years. If you use the standard \cite command and the unsrt option or its equivalent, you get a list of numbers. In the past one could use the mcite package to make the references nicer, put them all in one, write the list as [m–n] etc.

---

[1] This appears to always be the case in British English. In American English some sources used to specify that the \cite command comes after the punctuation. However, this seems to not be common, so I recommend to put it before the punctuation, regardless of the English variant you are using.

7.1 Formatting by hand

Don't! The number of references that you will need will probably grow fast. It is quite likely that at some point you will decide that they are not really formatted as you would like them to be. You will almost certainly add references when you correct your thesis. How do you make sure they are in the order you want? How do you make sure that only articles that you actually refer to are in the bibliography?

Suppose you want to use some of the references in your thesis in conference proceedings or a paper in a journal. Every place where you publish will have it's own preferred format for the references that almost certainly will not be the one you chose for your thesis.

If you insist on following this route, consult a book on LaTeX!

7.2 Using BibTeX and biblatex

I won't pretend that BibTeX is the most user-friendly way of handling references and there are several things that you have to pay attention to when you use it for your references.

The two big advantages of biblatex and/or BibTeX are: only references that you actually refer to appear in the bibliography; you can change the format (consistently) of all articles in the bibliography simply by changing the style!

The first step is to put your references in one or more `.bib` files. For this document they can be found in:

- `../guide/guide_refs.bib`;

- `../refs/standard_refs-biber.bib` or `../refs/standard_refs-bibtex.bib`;

- `../guide/refs/example_refs-utf8.bib` or `../guide/refs/example_refs-ascii.bib`;

- `../guide/refs/zeus_2009.bib` and `../guide/refs/zeus_2010.bib`.

For each article you specify things like its title, author, journal etc.

You then include these files into your LaTeX document and specify which style should be used. You also have to indicate where you want the bibliography to appear.

At this point you also have to decide which interface to the contents of the `.bib` files you want to use. You have a choice of the original BibTeX or the more modern biblatex. If you use biblatex you need something like:

```
% Use biblatex for the bibliography
\usepackage[backend=biber,
  style=numeric-comp, sorting=none, block=ragged, giveninits=true]{biblatex}

% Adjustments to output are in this style file:
\usepackage{ubonn-biblatex}

\addbibresource{../mythesis/thesis_refs.bib}
\addbibresource{../refs/standard_refs-biber.bib}
```

in the document preamble and \printbibliography where they should be printed.[2] Note that as of version 3.0 of the thesis package, the biblatex command is included in ubonn-thesis directly. To turn it off add the option biblatex=false.

If you use traditional BibTEX you need something like:

```
% Use BibTeX for the bibliography
\bibliographystyle{../refs/atlasBibStyleWithTitle.bst}
% \bibliographystyle{unsrt}
\bibliography{../mythesis/thesis_refs,%
  ../refs/standard_refs-bibtex}
```

at the point where the references should be printed. Note that LaTeX is sometimes picky about spaces in lists of files, so you either terminate each line in \bibliography with a % or include all files on one line.

Which should you use? Traditional BibTEX has been around for a long time and is therefore better known. However, it has many problems when it comes to sorting, handling more modern sources of information (e.g. the web), etc. By now biblatex is rather stable, so future changes should be minor. It supports things like online references and enables you to click on references using the preprint number or DOI to look at a reference. It is also easier to change the way your references look. I therefore strongly recommend that you use biblatex.

Another serious problem with BibTEX is that it cannot handle umlauts etc. properly. While I have said elsewhere in this document that you should use UTF-8 encoding so that you can enter ä etc. directly, this does not work with BibTEX. You can use the old syntax \"{a}.[3] This problem is completely solved if you use biblatex and the biber backend.[4] As indicated above, the references in the guide include two versions of the file with some example references:

- ./guide/refs/examples_refs-utf8.bib with UTF-8 encoding;
- ./guide/refs/examples_refs-ascii.bib without any umlauts.

If you try to compile the guide with the wrong file using BibTEX, you will get some errors as I have included some umlauts in the example references. The thesis skeletons use by default the package biblatex with the biber backend. See the skeleton thesis_skel/thesis_2009_skel.tex for the complete syntax if you want to use traditional BibTEX.

That's it? Well almost! First, you will have to make sure that the entry type that you use corresponds to the type of document that you are citing. Second, you will probably get some or all of your references from standard sources such as Spires,[5] Inspire or CDS, you will have to change the entries a bit so that they get formatted the way you want.

---

[2] If you use an older version of TEX Live you may have to replace giveninits by firstinits, although this should be done for you automatically if you set texlive correctly.

[3] In fact you have to write this as author = "Br{\"{u}}ning, Oliver" for it to work properly! As an aside, if you look at the LaTeX source code for this footnote, it might seem natural to use \verb for author = ... However, verbatim does not work in footnotes, unless you include other packages such as fancyvrb or cprotect.

[4] If for some reason you want to use biblatex with the bibtex8 backend you have to encode your .bib files with latin1 instead of UTF-8 if they includes umlauts and use the line:
\usepackage[backend=bibtex8,bibencoding=latin1]{biblatex}.

[5] I will refer to both as Inspire in this chapter.

7.3 BɪʙTᴇX entries

In this section I discuss how to format your BɪʙTᴇX databases, i.e. the `.bib` files. In the following section I talk about how you make your references look the way you want them to be in your thesis.

I maintain a complete set of ATLAS and CMS publications in BɪʙTᴇX format, which is regularly updated. You should certainly use these rather than trying to make your own collection, as all the titles have been checked and should be formatted correctly. These can be accessed via the atlaslatex package, which is either available from the ATLAS TWiki page: https://twiki.cern.ch/twiki/bin/view/AtlasProtected/PubComLaTeX. They are also kept separately on the TWiki page: https://twiki.cern.ch/twiki/bin/view/AtlasProtected/PubComRefs. Access to these pages is restricted to members of the ATLAS collaboration. ATLAS LᴬTᴇX has also been released as open source. Hence, a copy of the package can be obtained from the same place as the University of Bonn thesis package: https://www.pi.uni-bonn.de/lehre/uni-bonn-thesis, although this version may not be completely up to date.

7.3.1 Entry types

One question is what entry type you should use for what? I give here recommendations on what to use for biblatex. Some of the entry types that biblatex has are not part of BɪʙTᴇX.

@article This is easy — use it for articles published in journals, e.g. [ZA+10].

@book Just as easy — use it for books, e.g. [KD04].

@proceedings, @inproceedings The name says it all. Use `@inproceedings` for a paper in the proceedings and `@proceedings` for the whole volume.

@collection Use it for things such as the ATLAS Technical Design Report [Brü+04a] where the names that you find are the editors. Use `@incollection` for a single article in a collection.

@report Use it for conference and internal notes. This is probably also the best type to use for preprints. You can also use `@booklet` or `@online`.

@online Use it for things that are only available online, e.g. [Oet+].

@thesis The name says it all. `@phdthesis` and `@mastersthesis` also exist. If you are using biblatex you can and should specify the thesis type, e.g. `type = {PhD}`, see for example a PhD thesis [Lod12].

biblatex also knows about multivolume proceedings etc. See the manual for more details.

Note that Inspire will always give you a BɪʙTᴇX entry of type `@article`, so you should adjust it by hand according to what the document you refer to really is. CDS tries a bit harder, but you probably still have to set the entry type by hand.

As indicated above, biblatex knows about preprint archives, online references with a url etc. and can format the references so that you can click on a DOI or arXiv number. Details of how these are handled are well documented in the manual. In order to make use of these abilities you have to modify the Inspire format of the references a bit so that it is fully compatible with what biblatex expects for preprints etc. More details on this are given below.

What else do you have to be careful about? The first thing to know is that biblatex and BibTeX will try to format your author names and titles. Thus, if you want the title to remain in exactly the form you have typed it in include it in ""{Title}"", i.e. both double quotes and braces. If not, collaborations and accelerators tend to be converted to lowercase, e.g. "lhc" instead of "LHC". If you use an author such as "ATLAS Collaboration" it gets printed as "A. Collaboration". If part of a title should not have its case changed enclose it in {... }, e.g. ""The {ATLAS} Detector""

7.3.2 Entries from Inspire and CDS

Things like the LHC Design Report are by default called `@article` in Inspire [Bru+04] or `@book` in CDS [Brü+04b]. They are in fact best declared as `@collection` with the `author` field replaced by `editor` and a field indicating the `institution` instead of `publisher` [Brü+04c]. You can also add the CDS link as a `url` field.

Conference notes, e.g. from ATLAS, are defined as `@techreport` by CDS [11]. It is better to just call them `@report`. You should add an author, usually just `author = "{ATLAS Collaboration}"`, [ATL11a]. You may also have to change the month format to avoid error messages. For internal notes, also call them report and add `type = internal report` to the entry. Again you could add the CDS link as a `url` field. For preprints, I also think it is best to use the `@report` entry type.

Books need to be changed from `@article` to `@book` and it is better to give the ISBN in the `isbn` field [HM84a] rather than the `reportNumber` field as given in Inspire [HM84b].

Theses should used the `@thesis` entry type and then add a `type` field. Alternatively you can use `@mastersthesis` or `@phdthesis`.

In all cases you probably have to edit the titles a bit to get things like $\sqrt{s} = 7\,\text{TeV}$ printed properly. An open question is whether you should assume the use of a units package in the formatting of the title. If you want to make your `.bib` files usable by others, it is probably best to do the formatting by hand.

An example of a typical ATLAS paper as it comes from Inspire [Aad+11] needs a bit of work. The link to DOI and arXiv both work well [ATL11b]. Note that the LHC collaborations specify that the first author should not be included, i.e. `author = "{ATLAS Collaboration}"`,.

7.3.3 More on names

The best way to format author names so that they appear correctly whatever BibTeX style you use is `Surname, Name`. Any other syntax is likely to get mangled.

What about collaboration names? If you use Inspire as the source of your BibTeX entries, you will see that it has a field for the collaboration. This is often, but not always, formatted correctly. However, very few BibTeX styles, and as far as I know no biblatex styles, pay any attention to this field. The ones from Inpire listed below will work properly. The only other reliable alternative I have found is to use the following syntax:

```
@Article{Chekanov:2009qja,
    author    = "{ZEUS Collab.} and Chekanov, S. and others",
```

which then usually gets formatted as "ZEUS Collab., S. Chekanov et al.,". I went through and changed the references in `zeus_2009.bib` accordingly.

7.4 Formatting references

While BibTeX or biblatex format the references for you from the `.bib` files, you have to tell them what format you want! For a start, you have to choose between an alphabetic and a numeric scheme for the references. Most journals use a numeric style. This corresponds to style `unsrt` or a variant thereof using traditional BibTeX. If you use biblatex you include the package with option `numeric-comp` or `numeric`. `numeric-comp` produces more compact citations (e.g. [1–4,7,9]) than `numeric` (e.g. [1,2,3,4,7,9]).

For this guide (for a change) I use an alphabetic style: `alpha` with BibTeX or option `alphabetic` with biblatex. In the thesis skeleton I use a more usual unsorted numeric style.

7.4.1 biblatex styles

My experience with biblatex took off when I started rewriting the ATLAS LaTeX templates in 2014. The first official stable release of biblatex was 19 Oct 2010. Active and rapid development is still ongoing. Some things I recommend below may work a bit differently depending on which version you have. See Appendix B on how to install a newer version of TeX Live if you want a more up-do-date version of LaTeX.

Looking for numeric styles you can either use the built-in `numeric` or `numeric-comp`. The `numeric-comp` style is used by default in the thesis skeleton. I made a few adjustments that are included in the file `ubonn-biblatex.sty`.

You can change some of the settings in the style file by passing options to it. The syntax `articletitle` and `articletitle=true` is equivalent. Use `articletitle=false` to turn off an option. The following options exist:

Option	Default	Description
texlive	2020	Specify the TeX Live version. You can also use the older command `\newcommand*{\texlive}{2020}`.
block	ragged	Specify the justification of each reference;
backref	true	The bibliography lists where the reference is cited. This option is very useful when writing your thesis, but should probably be turned off for the final version;
maxbibnames	5	Numbers of authors to list before switching to "et al.";
articletitle	true	Show the titles of articles and reports;
titlequote	false	Enclose the title in quotes rather than using a slanted font;
boldvol	false	Show the volume in bold face;
showurl	true	Show the URL field;
showdoi	false	Show the DOI separately. Otherwise it is linked from the journal reference;
eprint	true	Show the arXiv entry;
address	false	Print the address, if given;
location	false	Print the location, if given.

You can fine tune things even more by using hooks that are available. For example, the way I turn off the URL field is to include the command:

```
\AtEveryBibitem{\clearfield{url}}
```

in the preamble or in the relevant style file given in the previous paragraph. It is not clear to me if you also need \AtEveryCitekey{\clearfield{url}}.

There are slowly more and more biblatex styles around, but not as many as traditional BIBTEX. It is, however, much easier to change things (usually you can just change an option) with biblatex than it was for traditional BIBTEX, so you can probably start with a standard file and just make adjustments in your preamble. I have found a number of very useful hints on how to make changes in http://tex.stackexchange.com/ — just search for biblatex. A fairly nice-looking style is ieee. After playing around a bit with the ieee style, I decided it is too new and has too many settings that depend on having a new version of biblatex for now.

If you include ubonn-thesis with the option astrobib, the references will be formatted in the style usually used in astrophysics publications. Version 3.0 contains a first version of this option. You can use the command make astro instead of make new to make a thesis skeleton with the appropriate options set and the template introduction uses typical citation commands. By default things are set up to have the reference at the end of each chapter. If you do not want this pass the option refsection=false to ubonn-thesis.

If it is available, biber is the preferred backend over bibtex or bibtex8. However, the backend is mostly relevant for sorting, so it probably does not matter which you use if you use an option that gives the references in the order that they were cited. biber is now rather mature and hence is the default.

If you want to find out where your references are actually cited, you can include the option backref=true. This is set to true by default. You should probably set it to false for the final version of your thesis.

If you get an error such as:

```
biber      thesis_guide
data source /tmp/par-62726f636b/cache-ab06f20732bfab23dfa35f56998ad4edca61bee1//inc/li
Compilation failed in require at Biber/Utils.pm line 21.
```

then you should delete the directory /tmp/par-... and try to run again. The directory name depends on the operating system you are using. Use the command biber --cache to find out where it is. If you are adventurous, the command rm -rf $(biber --cache) will do it all for you!

7.5 Errata

What is the best way to include errata? biblatex offers a nice mechanism for this using the related field. For example, Ref. [ATL15] has an erratum. This is achieved using the following:

```
@Article{EXOT-2013-13,
    author        = "{ATLAS Collaboration}",
    title         = "{Search for new phenomena in final states ...}",
    journal       = "Eur. Phys. J. C",
    volume        = "75",
    year          = "2015",
    pages         = "299",
    doi           = "10.1140/epjc/s10052-015-3517-3",
    reportNumber  = "CERN-PH-EP-2014-299",
    eprint        = "1502.01518",
    archivePrefix = "arXiv",
    primaryClass  = "hep-ex",
    related       = "EXOT-2013-13-err",
    relatedstring = "Erratum:",
}

@Article{EXOT-2013-13-err,
    author        = "{ATLAS Collaboration}",
    journal       = "Eur. Phys. J. C",
    volume        = "75",
    year          = "2015",
    pages         = "408",
    doi           = "10.1140/epjc/s10052-015-3639-7",
    reportNumber  = "CERN-PH-EP-2014-299",
}
```

This mechanism is used in `ATLAS.bib` and may at some point be extended to `CMS.bib` if I find a list of the CMS Errata.

The mechanism only works if the `biber` backend is used. Using the standard files with the `bibtex` backend and/or traditional BibTeX does not cause errors when compiling. However, the Errata are simply ignored.

7.6 Sources for references

As mentioned above, ATLAS keeps a checked list of ATLAS and CMS publications in BibTeX format. The ZEUS collaboration also kept a reasonably up-to-date list of ZEUS and H1 publications (as well as some others), and I assume that other collaborations keep similar lists.

Within experimental high energy physics the standard way to get a reference is to use Inspire (http://inspirehep.net).[6] You can get the appropriate Inspire entry by using the Inspire search engine. Alternatively if you know the arXiv preprint number you can go from its entry to Inspire directly.

To get the ZEUS references I used above I first tried the following command in Inspire:

```
find exp zeus and date 2009
```

---

[6] This has now replaced Spires (http://www.slac.stanford.edu/spires/). One problem with Spires was that it was very slow and regularly timed out when you perform searches.

This does not really give you the references you expect though! It seems much more reliable to use an author name so I used:

```
find a chekanov and date 2009
```

and then selecting BIBTEX format, saving the resulting page in a file and removing the `<pre>` and `</pre>` entries between references. This worked better, even though I got a whole load of ATLAS papers as well.

If you then try to use the references, you get complaints that something is not in math mode. You have to go through by hand and change things such as `Q^2` to `$Q^{2}$`.

7.7 Common wishes

It is possible that you would like to combine several articles into a single reference. The mcite package was designed to do this, but is not compatible with biblatex and hyperref. biblatex has another solution that it calls sets.

In `standard_refs-biber.bib` and `standard_refs-bibtex.bib` I have put in the three standard references for the Standard Model [Gla61]. They are combined by using `@Set` and the relevant keys. If you use `biber` this is all you have to do. If, however, you are using the `bibtex` or `bibtex8` backend, the `crossref` field must contain the same key as the first one in `entryset`.

One thing you should always do is include all references in a single `\cite`, e.g. there were quite a few ZEUS publications in 2009 [ZC+10a; ZC+09; ZC+10b] is better than [ZC+10a][ZC+09][ZC+10b]. If you want to get a list of references printed in the form "[m–n]", then with biblatex you should use the style `numeric-comp`. In 2009 there were many papers published by the ZEUS collaboration [ZC+10a; ZC+09; ZC+10b] as well as several articles from both the H1 and ZEUS collaborations[HA+10a; HA+10b]. See Appendix G.4 on how to do this with BIBTEX.

In some areas, it is more common to give a bibliography per chapter, rather than collecting all references at the end of the thesis. This is straightforward to achieve with biblatex. Simply add the option `refsection=chapter` when you include biblatex. This and more can be done by passing the option `astrobib` to ubonn-thesis. In addition you have give the command `\printbibliography[heading=subbibliography]` at the end of each chapter. The thesis skeleton contains such commands commented out. The command `make astro` uses a skeleton with a bibliography per chapter. The option `astrobib` also sets things up so that the natbib citation commands `\citep`, `\citet` and `\citealt` can be used, so that the citation appears as expected for astronomy publications. If you use `\citep` and an old version of biblatex, you may see an extra comma between the author name and the year in parentheses. This can been removed by uncommenting the lines:

```
% \ifUBN@astrobib
%   \renewcommand*{\nameyeardelim}{\addspace}
% \fi
```

in ubonn-biblatex.sty

You are nearing the end of your thesis and have to properly format all the references that you have. However, they are spread over several files and these files also contain many references that you do not use or want to correct. How best to proceed?

```
bibtool -x mythesis.aux -o refs.bib
```

will extract the entries that you use and in future you can use and correct `refs.bib`, which only contains the references that you actually cite.[7]

The `biber -tool` command can be used to manipulate `.bib` files. In this way it is possible to format all entries in the same way. There was a lengthy article in the TeXnische Komödie 2/2020 about this, but I have not actually tried it out.

---

[7] I got this tip from http://tex.stackexchange.com/questions/417/how-to-split-all-bibtex-referenced-entries-from-a-big-bibtex-database-to-a-copy. Do not forget to change `mythesis.tex` to use `refs.bib` instead of the previous sources.

Layout and language

LATEX file: guide_layout.tex

If you are not happy with the layout, fonts, etc. that are used in this guide or the thesis skeleton, this chapter includes some examples on how you can change things.

8.1 Page layout

See the beginning of the KOMA-Script guide for a detailed introduction on how a page should be laid out. Page geometry can be changed using either the typearea or the geometry package. In this guide I use typearea as it is closely tied into KOMA-Script. The basic command is to specify how many pieces to divide the page into. This guide uses `DIV=12` by default with a binding correction of `BCOR=5mm`. You can then let KOMA-Script and typearea sort out the rest. Note that typearea will issue a warning that you have "Bad type area settings" when using `DIV=12`. If you want to avoid this warning, you can set `DIV` to 11 or smaller, but then the amount of text on each page is reduced by quite a bit and your thesis will cover more pages.

The alternative is to use geometry, where by default I say that the text should cover about 75% of the page. In practice, I have found geometry easier to use if you want to specify exactly the layout, e.g. making single Feynman graphs with feynmf. typearea is probably to be preferred for documents on normal paper sizes.

The setspace package has a number of useful options to change spacing in a fairly easy way, if such options are not already available in KOMA-Script.

You can use the default settings for the printed version of your thesis. These include the KOMA-Scriptoptions `twoside=true`, `BCOR=5mm`. For a PDF version it is probably better to have the text centred on the page. As of version 8.0, you can pass the option `twoside=false` to `ubonn-thesis` in order to achieve this. As of this version the KOMA-Script option `titlepage=firstiscover` is set so that the cover/title page is centred.

For the library version of your thesis you should set the `PIlibrary` option. If the `twoside` option is turned on, this offsets the content of the library cover page by horizontally 1 cm with the aim of centring the content on the paper. This amount can be changed using the `coveroffset` option.

8.2 Footnotes

A few tweaks may well be useful in order to get footnotes looking the way you want them rather than using the default KOMA‑Script settings.

The default setting of KOMA‑Script is:

```
\deffootnote[1em]{1.5em}{1em}{\textsuperscript{\thefootnotemark}}
```

In this guide and in `ubonn-thesis.sty` I have changed this to:

```
\deffootnote{1em}{1em}{\textsuperscript{\thefootnotemark}\ }
```

The differences are:

- The optional argument is missing that sets the box width for the footnote mark (which is right-adjusted). In this case the width of the first required argument is used instead, which also defines how much all other lines are indented. Hence all lines in the footnote are now left-aligned, while in the default setting the first line is indented more than the others.

- In the last argument an extra space has been added so that the footnote mark is not quite so close to the text.

You might think that a nice way to write footnotes is:

```
We want to include a footnote
\footnote{
  This is the footnote text.
}
about what the footnote should look like.
```

We want to include a footnote ^{a} about what the footnote should look like.

_____
^{a}This is the footnote text.

This example uses the default footnote settings. As you can see this is not really satisfactory. You have a spurious space between the colon and the footnote mark ^{a}. If may even be the case that the footnote mark appears on the next line! To get the spacing correct and still have "nice" LaTeX you have to add some judicious % signs:[1]

_____
[1]It may be that the exact appearance of the footnotes vary a bit depending on your TeX Live version.

```
We want to include a footnote%
\footnote{\label{foot:one}
  This is the footnote text.
  it is longer than the previous one, but about nothing in particular.
  It goes over more than one line to make sure that we can also have a proper
  look at the effect of indentation.
  It also demonstrates that footnotes can be given a label,
  if they need to be referred to from elsewhere.
}
about what the footnote should look like.
The space between \enquote{\(^{a}\)} and \enquote{This} should not actually be
    there
with the default footnote settings.
If you look very carefully \enquote{This} is not properly left-aligned
with the line below.
```

We want to include a footnote[a] about what the footnote should look like. The space between "[a]" and "This" should not actually be there with the default footnote settings. If you look very carefully "This" is not properly left-aligned with the line below.

---

[a] This is the footnote text. it is longer than the previous one, but about nothing in particular. It goes over more than one line to make sure that we can also have a proper look at the effect of indentation. It also demonstrates that footnotes can be given a label, if they need to be referred to from elsewhere.

```
The same footnote with the \File{ubonn\_thesis.sty} default settings
demonstrates the effect of the changed spacing.%
\footnote{\label{foot:two}%
  This is a longer footnote about nothing in particular that goes
  over more than one line to make sure that we can also have a proper
  look at the effect of indentation.
  It also demonstrates that footnotes can be given a label,
  if they need to be referred to from elsewhere.
}
```

The same footnote with the `ubonn_thesis.sty` default settings demonstrates the effect of the changed spacing.[a]

---

[a] This is a longer footnote about nothing in particular that goes over more than one line to make sure that we can also have a proper look at the effect of indentation. It also demonstrates that footnotes can be given a label, if they need to be referred to from elsewhere.

In standard LATEX you can use `\footnotemark` to set the symbol for a footnote and refer to it. KOMA‑Script has a better solution for this. You define a `\label` inside the footnote and then refer to it via the label and `\footref`. You can see how to do this in footnote [a]. The cleverref package claims to also know about footnote label. However, if I use `\cref{foot:two}` to refer to it, Section 8.2, it points to the section and not the footnote. Using the `\footref` mechanism it is even possible to click on the reference if you use hyperref.

When a footnote contains a complete sentence, people still often forget to add a full stop at the end of it — try not to!

If you try to use footnotes in tables, you will probably have some problems. The ctable package allows you to include footnotes that are part of the table. It also supports booktabs, so it should be possible to keep the same format. If you use the package xtab you can use the environment `mpxtabular` instead of `xtabular` to get footnotes — see Appendix E for an example. If you use the longtable package, use `longtable` rather than `table` and `tabular` in order to easily include footnotes. Another package is tablefootnote which provides the command `\tablefootnote`. This is advertised to also work in sideways tables.

8.3 Thesis in German

babel is a powerful package for handling different languages. The languages to be used in a document can either be given as options to `\documentclass` or to babel. I choose to use `\documentclass` here so that the style file `ubonn-thesis.sty` is independent of the thesis language. If you give more than one language make sure that the default language comes last.

Your thesis is in German rather than English. What do you have to worry about? First, set the languages in the `\documentclass` to `UKenglish,ngerman` rather than the other way round.

Second, if you want to use a comma rather than a full stop for the decimal point you may notice that numbers are sometimes not written properly. In text mode they are OK, e.g. 91,1234, while in math mode there is a small space after the comma, e.g. 91, 1234.

If you use the siunitx package, you can simply specify the locale: `\sisetup{locale = DE}`. This is already done for you in `ubonn-thesis.sty` in such a way that if you select ngerman as the language of your document `\num{2.3}` will be printed as 2,3. I find this by far the best way to handle such things.

You can also do such things locally in a single table for example by using constructions such as "S[decimalsymbol=comma]" in the column description of a table to change full stops into commas — see Chapter 6.

Another way to avoid this problem by using the ziffer package. It is commented out in `ubonn-thesis.sty`. An alternative is to remove the comments on the TeX code snippet at the top of the file `thesis_defs.sty`:

```
\mathchardef\CommaOrdinary="013B
\mathchardef\CommaPunct    ="613B
\mathcode`,="8000   % , im Math-Mode aktiv ("8000) machen
{\catcode`\,=\active
 \gdef ,{\obeyspaces\futurelet\next\CommaCheck}}
\def\CommaCheck{\if\space\next\CommaPunct\else\CommaOrdinary\fi}
```

As far as I have able to tell this above code does just what one wants and so is probably better than trying to use ziffer.

I have spent some effort to try to get around the problems that occur if you try to use ziffer and dcolumn together. A way that seems to work is to use the full stop as the decimal point in columns that are formatted using dcolumn and then just change full stop to a comma, i.e. use the form `D{.}{,}{2}`. The table below illustrates this usage:

```
\begin{otherlanguage}{ngerman}
\begin{tabular}{l|
  D{.}{,}{4}@{\(\,\pm\,\)}
  D{.}{,}{4}}
  Teilchen &
    \multicolumn{2}{c}{Masse
    [\si{\GeVovercsq}]}\\
  \midrule
  \(Z\) boson & 91.0372 & 0.0002\\
  \(W\) boson & 83 & 0.035\\
  Top quark & 173.3 & 1.1\\
\end{tabular}
\end{otherlanguage}
```

Teilchen	Masse [GeV/c^2]
Z boson	$91{,}0372 \pm 0{,}0002$
W boson	$83 \pm 0{,}035$
Top quark	$173{,}3 \pm 1{,}1$

If you use ziffer and want to keep the decimal symbol, e.g. D{.}{.} or D{,}{,} this does not seem to work. Hence if you try to use ziffer with this guide you will get error messages.

The other question is whether to use the traditional TeX way of writing letter with umlauts: \"{u} to get ü, or \"a to get ä, or just to type in the character directly. I strongly recommend typing the characters directly. It makes your LaTeX much easier to read and spell-check. You can either switch your keyboard to German (this is simple under Windows, macOS, KDE or Gnome (Unity)) or set the compose key and then type the sequence Compose " a to get ä for example.

8.4 Fonts

Fonts to use for the various parts of a document can usually be set using the \setkomafont command. I have set a few such fonts in ubonn-thesis.sty. In particular I set the fonts for the title page so that it conforms more closely to the requirements for theses and also have a few more commented out examples there.

Which font should I use? http://tug.ctan.org/tex-archive/info/Free_Math_Font_Survey/ en/survey.html has a list of fonts that one can consider using. I have included commented out packages that use some of these in the style file. Good alternatives to newtx and txfonts (with the varg option) seem to be either lmodern or pxfonts. See Section 2.5 for some of the things you have to worry about if you use a font for which the text mode and math mode display numbers differently.

I have tried to compile the guide using XƎLATEX and LuaLATEX. After a few tweaks both work. You can use the command make guidexe to try to compile using XƎLATEX. You can use the command make guidelua to try to compile using LuaLATEX. The TeX Gyre fonts Pagella or Termes are used, depending on whether you pass the palatino option to the document class or not. The TeX Gyre font Heros is used as the sans-serif and Cursor as the monospaced font. The advantage of these tools is that you can use any font that you have installed on your computer. However, the number of (free) fonts that also have all the math symbols is very limited.

8.5 Other languages

If you have a few words in the foreign language just use `\foreignlanguage`,
e.g. `\foreignlanguage{ngerman}{Das Physikalische Institut der Universität Bonn}` to
produce Das Physikalische Institut der Universität Bonn. You might ask why bother? Hyphenation, in
particular, is not the same in different languages, so telling LaTeX which language the text is in certainly
helps. To change the language at a certain point in the document use `\selectlanguage`. To set a block
of text (inside an environment) use the `otherlanguage` environment. I used this in the title pages, as
(except for the cover page) they are in German. It certainly does no harm to specify the language of the
abstract within `\thesisabstract`.

The csquotes package advertises itself as the way to cope with quoting things in different languages.
The basic command to use is `\enquote` for quoting things in the current default language, while you use
`\foreignquote` to quote things in another language. For example, John said "I have too much to do
at the moment", while Johannes sagte „ich habe im Moment alle Zeit der Welt". Note that babel uses
ngerman for "new" German spelling, while csquotes options calls the same thing german. However,
this only affects the setting of options. If you use commands such as `\foreignquote` you can specify
ngerman as the language.

Having used csquotes for several years now, I find it a really nice way of quoting things properly in
the language you are writing your text in without having to worry about using the correct opening and
closing quotes, so I warmly recommend it.

8.6 Coloured links

In the default version of the thesis, links in the table of contents are coloured blue, citations are coloured
dark magenta and URLs are coloured dark green. These settings are in `ubonn-thesis.sty`.

For the printed version you probably do not want these things to be coloured. You can change the
hyperref options using the `\hypersetup` command as indicated in the main file of your thesis. Using
these changes, such links will be surrounded by a coloured box when viewed on the screen, while the
box will not be shown when the thesis is printed.

8.7 Chapter headings

The standard appearance of the chapter headings is not very exciting! You can make some changes with
the KOMA-Script options, but nothing very radical. A number of packages exist that can make larger
changes. I tried out fncychap, quotchap and titlesec. A variant of titlesec was used for this guide and
for theses (version 3.0). As combining titlesec with KOMA-Script is not recommended, the settings
are now done by hand by default. The problem with this version was that the bibliography was given a
chapter number, if it was part of `\mainmatter` rather than `\backmatter`. As of version 4.0, I use a
very similar style, but this time the changes are made using KOMA-Script adjustment as suggested by
the author.[2] This seems to work better. If you want to get back to the usual style, just comment out the
appropriate lines in `ubonn-thesis.sty`. See the documentation on titlesec on how to make further
adjustments.

---

[2] `http://www.komascript.de/chapterwithlines`

Changes and plans

LaTeX file: guide_appendix.tex

In this section I used to document briefly the major changes to this guide. This list has been moved to `CHANGELOG.md`, as they are quite long and this seems a more appropriate place to keep them.

Here is a list of ideas for more information that could be added to this guide:

- Add drawing of Feynman graphs with axodraw and/or jaxodraw.

- Add instructions on content of CV and summary for PhD thesis. A skeleton CV exists in the file `theis_cv.tex`.

- Look at and think about possible application of the changes, snapshot and gitver packages in theses.

T_EX setup and packages

LaTeX file: guide_appendix_texsetup.tex

Some packages that I recommend, and that are still subject to active development, are biblatex and siunitx. TikZ-Feynhand, diffcoef and derivative are new and very interesting packages. If you want to fully exploit their capabilities, you should make sure you LaTeX installation is as recent as possible — I recommend at least TeX Live 2020 and preferably later.

The institute is a member of Dante and I therefore receive a copy of the TeX Collection DVD every year. You can also download the installation you need from the TeX Users (TUG) group web page: `http://www.tug.org/texcollection`.

B.1 Integrated environments

As mentioned in Section [2.3](2.3), I highly recommend that you use an integrated environment for editing and compiling your thesis. All such tools allow you to define projects, which then know about which files should be included when compiling.

TeXstudio and Texmaker can be installed under Windows, macOS or Linux. I have tried TeXstudio in all three systems and it works nicely. It can be downloaded from `http://texstudio.sourceforge.net/`. Others report good experience with Texmaker (under Ubuntu). It is available as an Ubuntu package or from `http://www.xm1math.net/texmaker`. Texmaker and TeXstudio (TeXmakerX) split in 2009, so both packages contain a lot of similarities. Visual Studio Code[1] is a fast and powerful editor with a very nice extension for LaTeX documents. It is also available for Windows, macOS and Linux. Kile is quite popular, especially if you use the KDE desktop environment.

I used to use `emacs` and AUCTeX, as I can then use the same editor for everything. Note that the RefTeX mode in `emacs` also provides powerful tools for finding and inserting cross-references and the names of citations easily.

B.1.1 T_EXstudio

I used TeXstudio as my main tool for creating LaTeX documents starting in 2013. One very nice feature is that it works under macOS, Windows and Linux. It is fairly easy to adapt to your preferences. Additional

---

[1] `https://code.visualstudio.com`

keyboard shortcuts can be added and the editor can be customised. I usually change the `TAB` behaviour so that spaces rather than TABs are inserted.

If you use the integrated PDF viewer, it is very easy to switch between the PDF file and the LATEX source code, which is extremely helpful. You can also usually click on an error in the Message window and the cursor will jump to the right spot. This makes debugging and proofreading much easier.

You can configure TEXstudio to use `latexmk` by default. It is easy to switch between `biber` and `bibtex` using the Build preferences. If you want to use `latexmk` with TEXstudio under Windows, you may have to install Perl from e.g. https://strawberryperl.com/.

TEXstudio should also know about your citations. If you do not get a list of citations when you type `\cite`, you should first close the file and open in TEXstudio `Options` → `Configure TexStudio` → `Completion` and check `biblatex.cwl`.

You can also make a glossary from within TEXstudio. In order to do this you have to define a user build command. You can find such commands under: Options → Configure TeXstudio → Build. I defined a new command which I called "BuildWithGlossary". This executes `pdflatex, biber, makeindex, makeglossary, pdflatex, pdflatex`.

B.1.2 Visual Studio Code

I currently use Visual Studio Code as my editor for both LATEX and other programs. It is available for Windows, macOS and Linux. The big advantage is that you have one editor for both documentation and code. It works quite well for writing LATEX, but assumes that you know the LATEX commands that you want to include. Rapid development is ongoing, also for the LATEX extension LATEX Workshop that you should certainly install. If you have `chktex` installed you should also enable it, as it helps you to find errors and gives a lot of information on the quality of your LATEX.

B.1.3 Overleaf

If you want to write your thesis using Overleaf, you first have to upload it as a project there. The best way to do this is to create a new thesis skeleton as usual, specifying the version of TEX Live being run by Overleaf, e.g.:

```
make new TEXLIVE=2020 [THESIS=projectname]
```

Compress the directory into a zip file:

```
  zip -r projectname projectname
```

and upload it to Overleaf as a new project.

Overleaf should then be able to compile the skeleton thesis and you can start writing!

B.1.4 Kile

Many people use Kile as their environment for editing and compiling LATEX. I have not used it for a number of years, so some of the instructions I give here may be out of date.

If you use `bibtex` for your references then the default setup does not have to be changed. If you want to use the `biber` backend then you should integrate the command into Kile.

To do this you need to do the following: In Kile: `Settings → Configure Kile → Tools → Build` and then insert a new tool (Biber) on the left-hand side. It is probably best to define the class of the tool as BIBTEX. Then on the right-hand side in the `General` tab the command should be `biber` and the option `%S`. In the `Advanced` tab you should set the `Source extension` to `aux` and the `Target extension` to `bbl`.

I would then recommend adding a new configuration to the `QuickBuild` called `PDFLaTeX+Biber+ViewPDF` that executes the commands: `PDFLaTeX, Biber, PDFLaTeX, PDFLaTeX, ViewPDF`. This is also the series of commands that the `Makefile` executes.

I have not yet investigated how to also make the glossary from within Kile, but it should be possible to do it in the same way as you add a `biber` command.

B.2 macOS

For the past several years, I have been installing and running LATEX on a MacBook Pro. The standard package you start with is TEXShop. Together with BasicTEX this provides a basic environment. However, if you want to do more (like write a thesis), you should install TEX Live. There is a complete TEX Live installation called MacTEX that you can download from http://www.tug.org/mactex/. The Dante TEX Collection DVD also includes MacTEX, which is what the TEXShop web page recommends as the best combination to install. You can also install MacTEX using Homebrew. Install and run the TEX Live Utility to keep your installation up to date.

As discussed above, there are macOS versions of TEXstudio and Texmaker which you can try. I used to use TEXstudio. More recently I switched to using Visual Studio Code, which is a very nice editor with integrated LATEX and Git support.

B.3 (Ku|Xu|U)buntu

For my tests with Ubuntu I use Xubuntu 20.04 and TEX Live 2019. I also check that things work with older versions. The oldest version of TEX Live that I have access to is 2013.

If you want to write your thesis in British (UK) English you should make sure that that language is fully installed. If you want to write your thesis in German, then also install German as a language, even if your system is in English.

I explicitly installed the following packages in addition:

```
(k|x)ubuntu-restricted-extras
git #Used to be subversion
texlive
texlive-science
texlive-bibtex-extra
texlive-fonts-extra
texlive-latex-extra
biber
latexmk
texlive-lang-german
feynmf
```

I also had to install `texlive-metapost` and `tracklang` in order to compile the guide. If you want to use IEEEtrantools you have to install `texlive-publishers`, or the package IEEEtran. If you want to use LuaLATEX you also have to install `texlive-luatex` and if you want to use X∃LATEX you have to install `texlive-xetex`. You may also have to install `texlive-xetex` even if you only plan to use LuaLATEX. In older Ubuntu installations you may have to also install `texlive-math-extra`. In newer versions this package has been removed.

   If your LATEX installation is old, you may want to bring it up-to-date. For Ubuntu variants there is a simple solution. Just add TEX Live backports to your list of sources (use the `sudo apt-add-repository ppa:texlive-backports/ppa` command). You should then be able to give the command `sudo apt-get update; sudo apt-get upgrade`. Note that this variant will overwrite your current LATEX installation. An alternative is the method discussed in the following paragraphs, which allows you to have two (or more) different installations in parallel.

B.4 Fedora

For my tests with Fedora I used Fedora 33 which I downloaded from https://getfedora.org, which includes TEX Live 2019. Most LATEX packages come as separate Fedora packages, so the list of what you have to install is long.

   I installed the following packages using the command `dnf install ...`:

```
texlive
latexmk
texlive-newtx
texlive-mweights
texlive-siunitx
texlive-longtable
texlive-hep
texlive-mhchem
texlive-biblatex
texlive-background
texlive-cleveref
texlive-babel-german
texlive-hyphens-german
```

These are sufficient to compile the skeleton thesis. For the thesis guide I needed in addition:

```
texlive-standalone
texlive-physics
texlive-tikz-feynhand
texlive-tikz-feynman
texlive-tikz-3dplot
texlive-pgfplots
texlive-pgfopts
texlive-glossaries
texlive-import
texlive-bigfoot # needed for suffix
```

You will probably need at least some of these packages for your thesis.

LuaLATEX and XƎLATEX were either installed by default, or with one of the other packages.

For the tests that I conducted with a new installation on 2020-10-21, I got an error when trying to use the newtx fonts. After some searching, I was able to fix it using the commands: `sudo updmap -sys -syncwithtrees` and `sudo updmap -sys`.

B.5 Installing (a newer version of) TEX Live by hand

A TEXnische Komödie issue (3/2011) contained detailed instructions on how to install a newer version of TEX Live in parallel to the default version. For a while, I did this as standard practice on my laptop and it worked very well. Another useful source of information on how to install TEX Live can be found under http://tug.org/texlive/quickinstall.html.

A brief summary of how to do the installation by hand: you must have `perl-tk` installed. Go to a directory where you want the install script to be and then execute the following chain of commands:

```
wget http://mirror.ctan.org/systems/texlive/tlnet/install-tl-unx.tar.gz
tar zxvf install-tl-unx.tar.gz
cd install-tl-...
sudo ./install-tl -gui perltk
  Turn off some of the languages
  Make sure installation is in /usr/local/texlive
  Install
```

I installed the scheme `scheme-tetex` and added the collections: `BibTeX additional styles`, `Additional fonts` and `LaTeX additional packages`. If you want to use the package TikZ-Feynman you probably need to include `LuaTeX packages`. If you want to use XeTEX include `XeTeX and packages`. When the installation is complete (can easily take 1 to 2 hours):

```
cd ..
echo 'export␣PATH=/opt/texbin:${PATH}' > texlive.sh
sudo cp texlive.sh /etc/profile.d/
sudo ln -s /usr/local/texlive/2020/bin/x86_64-linux /opt/texbin
```

You probably have to login again to activate the new `PATH`. Check whether it is correct with

```
echo $PATH
```

If you have a 32-bit installation replace `x86_64-linux` with `i386-linux`. Note that the three commands set things up so that `/opt/texbin` is at the beginning of your `PATH` and that LATEX is then taken from there rather than the usual `/usr/bin`.

On my test Ubuntu installation, I installed a very basic TEX Live installation when setting up the system and then added several different TEX Live installations using this method. This works very well.

For updating, additions of packages etc., it is useful to define an alias in your `.bashrc` or `.bash_aliases`:

```
function sutlmgr () {
    if [[ -z "$@" ]]; then
      sudo /opt/texbin/tlmgr -gui
    else
      sudo /opt/texbin/tlmgr "$@"
    fi
}
```

You then give the command `sutlmgr` to start the TEX Live manager interface. You can use this interface to install new packages as well as to update the ones you have installed. If you want to update things, you should first click on "Load default" to load a repository and then you can do things such as "Update all installed".

B.6 Windows

I also tried to to make the guide and a skeleton thesis under Windows. My tests have been done with Windows 10. I simply downloaded the MiKTEX installer from http://miktex.org. This is discussed in Appendix B.6.1. You can also install TEX Live for Windows. Some hints on how to do this are given below (Appendix B.6.2).[2]

Once you have a TEX installation, you have to get the thesis style files and the guide. To do this I used `TortoiseGit` which is available from https://tortoisegit.org as the interface between Windows and `Git`.

To checkout the files, simply start Windows Explorer and go to the top-level directory where you want to do the checkout, right-click on the mouse and enter
`https://bitbucket.team.uni-bonn.de/scm/uni/ubonn-thesis.git` as the URL. If you do this you can stay at the cutting edge! If you want a particular version then specify the branch you want, e.g. "8.0". You can of course simply download the appropriate tar file from the PI webpages.

To set up your thesis, you have to do by hand what the `Makefile` does under Linux or install GNU Make. If you want to do it by hand, you should make a new directory `mythesis`, copy

---

[2] I have had success with the 2010 TEX Collection DVD from Dante to install proTEXt, which is based on MiKTEX. Newer versions should also work without problems. What the user sees is TEXworks which is deliberately supposed to look like the Mac's TEXShop.

`thesis_skel/thesis_skel.tex` to `mythesis/mythesis.tex`, and copy the rest of the files you need from `thesis_skel` into `mythesis`. In addition you should copy the style files `ubonn-thesis.sty` and `ubonn-biblatex.sty` into the `mythesis` directory.

To compile things, I ran the sequence pdfLaTeX, Biber, pdfLaTeX, pdfLaTeX to get the output file for the skeleton thesis. You should make sure that the BibTeX command in TeXstudio or TeXworks is set to `biber`, unless for some reason you want to use traditional BibTeX.

If you want to use `latexmk` with TeXstudio, you probably have to install Perl. I installed Perl from `https://strawberryperl.com`, rebooted and `latexmk` then worked.

If you want to install GNU Make you can try the following: You should install the "Minimal Gnu for Windows" from `http://www.mingw.org`. I downloaded and ran `mingw-get-setup.exe`. Once you have installed it you can run the "MinGW Installer" to install the software you want. I think you should install `msys-base` from "Basic Setup". This installs `make` and quite a lot of other typical Unix commands. Finally you have to add `C:\MinGW\msys\1.0\bin` to your `PATH`. One way to do this is with the command `setx PATH %PATH%;C:\MinGW\msys\1.0\bin` using a Windows Command Prompt, i.e. `cmd.exe`. You can also use the GUI in the System Administration to set environment variables. If you get `make` to work properly you start `cmd.exe`, navigate to the correct directory and give the usual commands to create and compile your thesis:

```
make new
make
```

If you run pdfLaTeX with the option `-enable-write18` and include appropriate `mpost` commands in your LaTeX file(s), as discussed in Section 5.5.3, Feynman graphs made using `feynmp` work well. With TeXstudio, you can simply include this option in the pdfLaTeX command: Options → Configure TeXstudio → Commands.

I have not invested any effort in trying to get `feynmf` working under Windows. The output files are produced, but I have not tried to run Metafont on them.

B.6.1 MiKTeX

I usually install TeX under Windows via a download from Internet. You should decide whether to install MikTeX for yourself or for all users. I think maintenance is easier if you just install it for yourself. Once the installation is finished, I also update all the packages using the MiKTeX Maintenance (Admin) → Update (Admin) program. Be patient — these updates always take a while!

With the minimal version of MiKTeX you are then asked whether to install the missing packages when first compiling a file that needs them. Note that such missing packages are installed in your local directory tree and not in the central directory tree. This means that if you want to update MiKTeX in the future you should run the MiKTeX Update both as Admin and as a normal user, if you installed MiKTeX for all users. Be patient if the first compilation of a document appears to hang. This usually means that new packages are being installed.

The last time I have installed TeX under Windows using a DVD was from the TeX Collection 2010 DVD. To do this I logged in as an Administrator and then opened the DVD. It opened a TeX Collection window and I then clicked on proTeXt Quick Install and installed MiKTeX (minimal version), Ghostscript and Ghostview for all users.

Note that the Dante TEX Collection 2011 DVD has dropped TEXnic Center within proTEXt and is using the TEXmakerX front-end instead. TEXmakerX has been superseded by TEXstudio. My comments on TEXnic Center have been relegated to Appendix G. There is also the package Texmaker.

B.6.2 TEX Live

You can install TEX Live instead of proTEXt. To do that you can either use the TEX Collection DVD or download TEX Live. If you download TEX Live you should unzip the file that you get and go to the directory `install-tl/install-tl-YYYYMMDD`. In that directory you should run `install-tl-advanced.bat` as Administrator if you want to install TEX Live in a system directory. I installed the "medium" scheme. The following extra collections were needed:

- BibTeX additional styles

- Generic additional packages

- LaTeX additional packages — needed for csquotes

- Natural and computer sciences

I also added the German documentation. Do not forget to toggle the option `All users` if you want more than one user to be able to use LATEX on your machine. If you forget one of the above collections, you can install the missing packages later.

While MiKTEX can install missing packages on the fly, this does not seem to be the case for TEX Live. To install extra packages you should start the TEX Live manager and before doing anything else you should load the default repository.

You can either use TEXworks as the front end or you can install TEXstudio or Texmaker.

B.7 Making the guide

Using the installations described above I was able to issue to following commands to produce the guide (assuming that you have TEX Live 2016 or later):

```
git clone https://bitbucket.team.uni-bonn.de/scm/uni/ubonn-thesis.git
cd ubonn-thesis
```

Set the `\texlive` variable appropriately in `guide/thesis_guide.tex`. Then the following worked:

```
cd guide
make guide|guidelua|guidexe
```

so all packages are there as well as at least the default font which I selected. If your version of TEX Live is older than 2020, you should set `\texlive` accordingly. Some figures or tables may not appear with versions of TEX Live earlier than 2017, as, for example, the TikZ-FeynHand package was only introduced then.

The default version of the guide uses `biber` for the `biblatex` package and includes `./guide/refs/example_refs-utf8.bib` which contains some umlauts.[3] You give the command `make guide` to compile, which uses `biber` rather than `bibtex` to process the `.bib` files.

The default version of the guide also compiles on ATLAS Bonn desktop computers (Debian 11 with TeX Live 2020). If you want to use feynmf instead of feynmp to compile the guide, you have to pass the option `feynmf` instead of `feynmp` to `ubonn-thesis.sty` and give the command `make feynmf` before `make guide`.

If you want to switch from `biber` to `bibtex` or `bibtex8` or vice versa, give the commands `make cleanguide cleanbbl cleanblx` before you try to compile the guide (or your thesis).

In order to edit LaTeX you need an editor such as `Visual Studio Code` or `emacs`, or a program such as TeXstudio or Texmaker or `kile` (and the associated `kile-doc`). These were discussed above.

TeXstudio knows about indexes and glossaries. You have to set up a user command to execute `makeindex` and `makeglossaries` as discussed in Appendix B.1. With the addition of these commands, you should also be able to compile this guide.

---

[3] The same references using normal ascii test (suitable for `bibtex`) can be found in `./guide/refs/example_refs-ascii.bib`.

Making a glossary or list of acronyms

LaTeX file: `run:./guide_appendix_glossary.tex`guide_appendix_glossary.tex

What is the difference between a glossary and a list of acronyms? They are in fact very similar. A list of acronyms is probably most appropriate for defining the abbreviations used for detector names, e.g. the electromagnetic calorimeter (EMC). A glossary is used for defining terms, e.g. "**transition radiation**: transition radiation can be emitted when a particle crosses the boundary between two media with different dielectric constants". A list of acronyms is probably a good idea to include in any thesis; a glossary may be helpful as well.

Several packages are available to help in the creation of a glossary:

glossaries A new glossary package that can do everything! This is what I use here.

nomencl Another glossary package that I used in the book "Physics at the Terascale".

glosstex Rather an old package that looks to be quite simple to use.

acronym A fairly extensive package for acronyms.

A short introduction to the first three packages can be found in the TeXnische Komödie 4/2012. acronym is a further package that provides quite a few commands associated with acronyms. It is probably sufficient if you only want to define acronyms and provide a list of them. I have not actually tried out the package, but as far as I can tell you should provide a definition of all acronyms at the place you want to output the list within an `acronym` environment.

The nomencl package is maybe the easiest to use for creating a simple list of acronyms. If you want to change the formatting or do anything other than create a simple list, it is probably worth investigating glossaries.

The nice thing about glossaries is that it works with hyperref so that you can even click on an acronym and find its definition. In this guide I included the package with the option `acronym`, in order to get both a glossary and a list of acronyms. I also included the option `toc`, so that the glossary and list of acronyms are included in the table of contents. You tell it to to make a glossary (and list of acronyms) by giving the command `\makeglossaries` in the preamble and you print the glossary (usually at the end of the document) with the `\printglossaries` command. I have not included these commands in the thesis skeleton, as the glossaries package is rather new and may not be available in older TeX installations.

In order to process the glossary, you need to run the command `makeglossaries filename`. This is included in the `Makefile` for the commands `make guide` and should be added to `make thesis` if you want to make a glossary for your thesis.

If you use the package xtab for long tables, then you should include glossaries with the option `nosuper` to avoid it loading supertabular. Use styles with a `long` rather than a `super` variant if you want such features.

If you have a glossary and want it to compile it using `latexmk` you should add the following lines to `~/.latexmkrc` or to `~/.config/latexmk/latexmkrc`:[1]

```
add_cus_dep( 'acn', 'acr', 0, 'makeglossaries' );
add_cus_dep( 'glo', 'gls', 0, 'makeglossaries' );
$clean_ext .= "␣acr␣acn␣alg␣glo␣gls␣glg";
sub makeglossaries {
  my ($base_name, $path) = fileparse( $_[0] );
  pushd $path;
  my $return = system "makeglossaries", $base_name;
  popd;
  return $return;
}
```

This code can be found in the file `latexmk/latexmkrc`.

I illustrate the use with the standard description of the ZEUS detector, which includes the abbreviations that are used in the rest of a ZEUS paper. As a first step you define the terms for the glossary and the acronyms. In this guide, the acronyms and the glossary entries are defined in the file `guide_glossary.tex`. These definitions must come before they are used. You can decide whether it is best to have them in a single file, or define them just before they are used. When they are printed at the end, they will be sorted alphabetically.

Once an acronym is defined, the first time the acronym is used, `\gls{acronym}`, the full text and the abbreviation is printed. Every time after that only the abbreviation is printed.

---

[1] I got this information from `https://tex.stackexchange.com/questions/1226/how-to-make-latexmk-use-makeglossaries`

C.1 ZEUS detector description

```
In the kinematic range of the analysis, charged particles were tracked
in the \gls{CTD} and the \gls{MVD}.
These components operated in a magnetic field of \SI{1.43}{\tesla}
provided by a thin superconducting solenoid.
The \gls{CTD} consisted of 72~cylindrical drift-chamber layers,
organised in nine superlayers covering the polar-angle region
$\ang{15} < \theta < \ang{164}$.
%
The \gls{MVD} consisted of a barrel (BMVD) and a forward (FMVD)
section. The BMVD contained three layers and provided polar-angle
coverage for tracks from \ang{30} to \ang{150}. The four-layer FMVD
extended the polar-angle coverage in the forward region to
\ang{7}. After alignment, the single-hit resolution of the MVD was
\SI{24}{\micro\metre}. The \gls{DCA} of tracks to the nominal vertex in
$X$--$Y$ was measured to have a resolution, averaged over the
azimuthal angle, of $(46 \oplus 122 / p_{T})\,\si{\micro\metre}$,
with $p_{T}$ in \si{\GeV}.
For \gls{CTD}-\gls{MVD} tracks
that pass through all nine \gls{CTD} superlayers, the momentum
resolution was $\sigma(p_{T})/p_{T} = 0.0029 p_{T} \oplus 0.0081
\oplus 0.0012/p_{T}$, with $p_{T}$ in \si{\GeV}.
```

In the kinematic range of the analysis, charged particles were tracked in the central tracking detector (CTD) and the MVD silicon tracker (MVD). These components operated in a magnetic field of 1.43 T provided by a thin superconducting solenoid. The CTD consisted of 72 cylindrical drift-chamber layers, organised in nine superlayers covering the polar-angle region $15° < \theta < 164°$. The MVD consisted of a barrel (BMVD) and a forward (FMVD) section. The BMVD contained three layers and provided polar-angle coverage for tracks from 30° to 150°. The four-layer FMVD extended the polar-angle coverage in the forward region to 7°. After alignment, the single-hit resolution of the MVD was 24 µm. The transverse distance of closest approach (DCA) of tracks to the nominal vertex in X–Y was measured to have a resolution, averaged over the azimuthal angle, of $(46 \oplus 122/p_T)$ µm, with p_T in GeV. For CTD-MVD tracks that pass through all nine CTD superlayers, the momentum resolution was $\sigma(p_T)/p_T = 0.0029 p_T \oplus 0.0081 \oplus 0.0012/p_T$, with p_T in GeV.

```
The high-resolution \gls{CAL} consisted of three parts: the forward
(FCAL), the barrel (BCAL) and the rear (RCAL) calorimeters. Each part
was subdivided transversely into towers and longitudinally into one
electromagnetic section (EMC) and either one (in RCAL) or two (in BCAL
and FCAL) hadronic sections (HAC). The smallest subdivision of the
calorimeter was called a cell.  The \gls{CAL} energy resolutions, as
measured under test-beam conditions, were $\sigma(E)/E=0.18/\sqrt{E}$
for electrons and $\sigma(E)/E=0.35/\sqrt{E}$ for hadrons, with $E$ in
\si{\GeV}.

ZEUS had quite a large assortment of tracking detectors. In the
forward direction there was the \gls{FTD} and the \gls{TRD}. The
\gls{TRD} was replaced by the \gls{STT} for the HERA~2 running
period.  In the middle of the detector, the \gls{CTD} was always
there, while the \gls{MVD} was also installed later.
```

The high-resolution uranium–scintillator calorimeter (CAL) consisted of three parts: the forward (FCAL), the barrel (BCAL) and the rear (RCAL) calorimeters. Each part was subdivided transversely into towers and longitudinally into one electromagnetic section (EMC) and either one (in RCAL) or two (in BCAL and FCAL) hadronic sections (HAC). The smallest subdivision of the calorimeter was called a cell. The CAL energy resolutions, as measured under test-beam conditions, were $\sigma(E)/E = 0.18/\sqrt{E}$ for electrons and $\sigma(E)/E = 0.35/\sqrt{E}$ for hadrons, with E in GeV.

ZEUS had quite a large assortment of tracking detectors. In the forward direction there was the forward tracking detector (FTD) and the transition radiation detector (TRD). The TRD was replaced by the straw-tube tracker (STT) for the HERA 2 running period. In the middle of the detector, the CTD was always there, while the MVD was also installed later.

Plots with Ti*k*Z

LATEX file: guide_appendix_tikz.tex

Figure D.1 shows how you can produce a plot showing the contributions of many different systematic uncertainties to a result. The code to produce this figure can be found in the File tikz/zeus_Ds_systematics.tex. This in turn reads in data from tikz/BRANCHINGSTRANGE0.dat, tikz/BRANCHINGSTRANGE1.dat and tikz/BRANCHINGSTRANGE_titles.dat
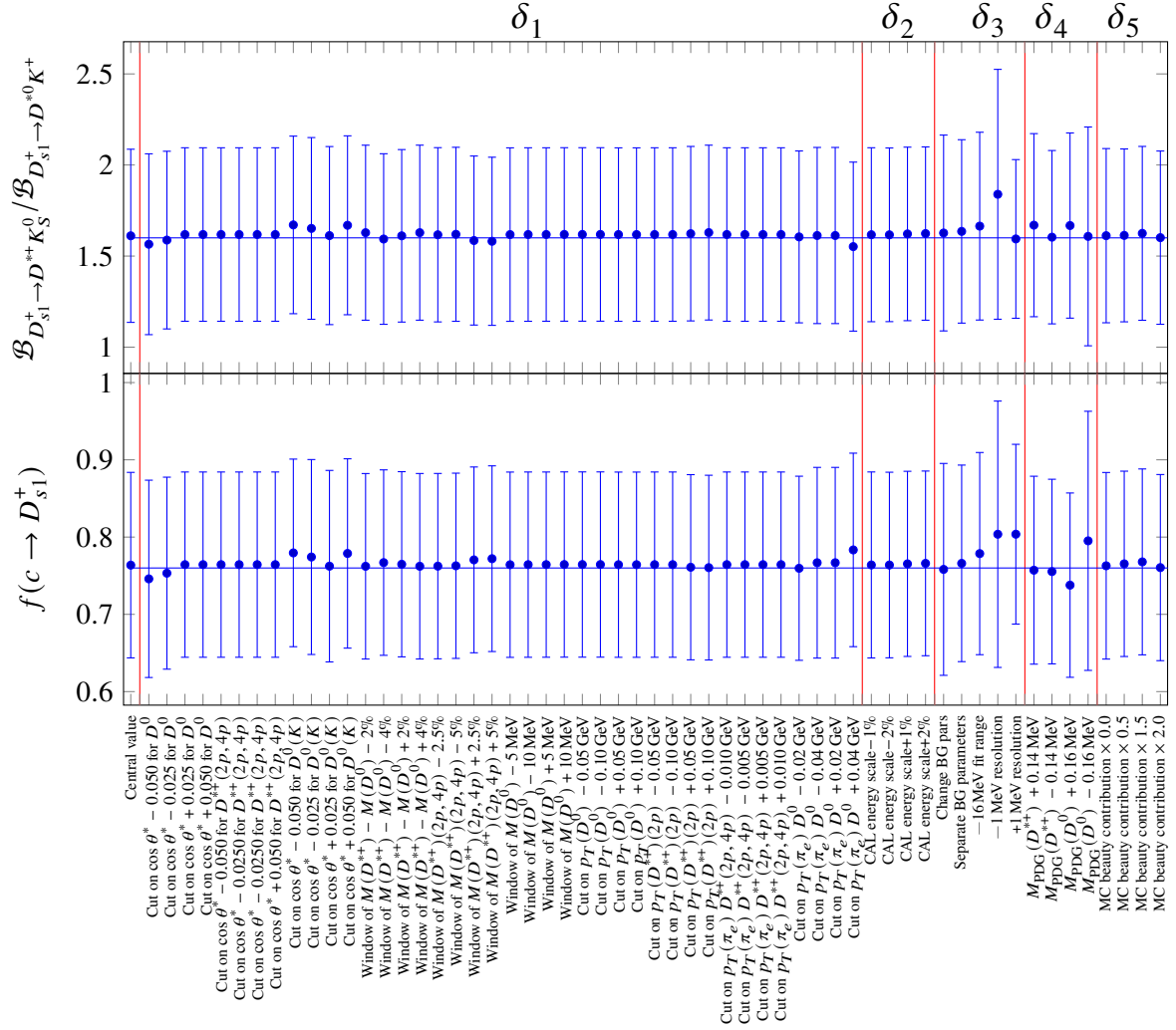
Figure D.1: The results of strange excited charm meson fragmentation fraction and branching ratio with systematic variations. The individual systematic variations are put into groups $\delta_1 - \delta_5$.

Long tables

LaTeX file: guide_appendix_longtable.tex

Long and complicated tables, such as tables containing the breakdown of the systematic error for each data point are usually put into the appendices. Code or data cards can also be included here. Examples of complicated typesetting have been given already in Chapter 6. In this appendix I give two examples of a table (Tables E.1 and E.2) that goes over more than one page using the xtab and longtable packages. Some features of the longtable package:

- A `longtable` is a combination of `tabular` and `table` in one environment.

- While footnotes do not work properly in a normal `tabular`, but they do work in `longtable`.

- You have to terminate the `\caption` with `\\`.

- If you want the caption to be at the end of the table you should include it in the `\endlastfoot` block.

Some features of the xtab package:

- Use the `mpxtabuar` environment to include footnotes in a table.

- You should specify the table header and footer outside the table itself.

- Do not include `xtabular` inside a `table` environment, as the table will then be output on one page, which is not what you want!

- A few things you can tweak to get the page breaks in the right place: According to the xtab documentation you should first try to play around with the variable `\xentrystretch`. The default value is 0.1. Decrease this to put more on a page and increase it to get less. You can even set it to a negative value! The value can be set per table. As an alternative you can use the `\shrinkheight` command.

As mentioned in Chapter 4, an alternative is the supertabular package.

The relevant parts of Table E.1 are:

```
\tablefirsthead{\toprule
  \multicolumn{1}{c}{Number} &
  \multicolumn{1}{c}{Letter} &
  \multicolumn{1}{c}{Greek} &
  \multicolumn{1}{c}{Explanation}\\
  \midrule
}
\tablehead{\midrule
  \multicolumn{1}{c}{Number} &
  \multicolumn{1}{c}{Letter} &
  \multicolumn{1}{c}{Greek} &
  \multicolumn{1}{c}{Explanation}\\
  \midrule
}
\tabletail{\midrule
  \multicolumn{3}{r}{Continued on next page}\\
  \midrule
}
\tablelasttail{\bottomrule}
\bottomcaption{The alphabet set using the \Package{xtab} package.}%
\label{tab:alphabet:xtab}
\xentrystretch{-0.15}
\begin{center}
  \begin{mpxtabular}{rccl}
   1 & a & \(\alpha\)  & The lowercase 1st letter in the alphabet\footnote{%
    \enquote{a} deserves a footnote}\\
    ...
    26 & Z & \(\omega\) & The uppercase 26th letter in the alphabet\\
  \end{mpxtabular}
\end{center}
```

The relevant parts of Table E.2 are:

```
\begin{longtable}{rccl}
  \caption{The alphabet set using the \Package{longtable} package.%
  \label{tab:alphabet:longtable}}\\
  \toprule
  \multicolumn{1}{c}{Number} &
  \multicolumn{1}{c}{Letter} &
  \multicolumn{1}{c}{Greek} &
  \multicolumn{1}{c}{Explanation}\\
  \midrule
\endfirsthead
  \midrule
  \multicolumn{1}{c}{Number} &
  \multicolumn{1}{c}{Letter} &
  \multicolumn{1}{c}{Greek} &
  \multicolumn{1}{c}{Explanation}\\
  \midrule
\endhead
  \midrule
  \multicolumn{3}{r}{Continued on next page}\\
  \midrule
\endfoot
  \bottomrule
\endlastfoot
    1 & a & & The lowercase 1st letter in the alphabet\footnote{%
    \enquote{a} deserves a footnote}\\
    26 & Z & & The uppercase 26th letter in the alphabet\\
\end{longtable}
```

Table E.1: The alphabet set using the xtab package. Greek letters are included using math mode, e.g. \alpha.

Number	Letter	Greek	Explanation
1	a	α	The lowercase 1st letter in the alphabet[a]
2	b	β	The lowercase 2nd letter in the alphabet
3	c	γ	The lowercase 3rd letter in the alphabet
4	d	δ	The lowercase 4th letter in the alphabet
5	e	ϵ	The lowercase 5th letter in the alphabet
6	f	ζ	The lowercase 6th letter in the alphabet
7	g	η	The lowercase 7th letter in the alphabet
8	h	θ	The lowercase 8th letter in the alphabet
9	i	ι	The lowercase 9th letter in the alphabet
10	j		The lowercase 10th letter in the alphabet[b]
11	k	κ	The lowercase 11th letter in the alphabet
12	l	λ	The lowercase 12th letter in the alphabet
13	m	μ	The lowercase 13th letter in the alphabet
14	n	ν	The lowercase 14th letter in the alphabet
15	o	o	The lowercase 15th letter in the alphabet
16	p	π	The lowercase 16th letter in the alphabet
17	q		The lowercase 17th letter in the alphabet
18	r	ρ	The lowercase 18th letter in the alphabet
19	s	σ	The lowercase 19th letter in the alphabet
20	t	τ	The lowercase 20th letter in the alphabet
21	u	υ	The lowercase 21st letter in the alphabet
22	v	ϕ	The lowercase 22nd letter in the alphabet
23	w	ξ	The lowercase 23rd letter in the alphabet
24	x	χ	The lowercase 24th letter in the alphabet
25	y	ψ	The lowercase 25th letter in the alphabet
26	z	ω	The lowercase 26th letter in the alphabet
1	A	A	The uppercase 1st letter in the alphabet
2	B	B	The uppercase 2nd letter in the alphabet
3	C	Γ	The uppercase 3rd letter in the alphabet
4	D	Δ	The uppercase 4th letter in the alphabet
5	E	E	The uppercase 5th letter in the alphabet
6	F	Z	The uppercase 6th letter in the alphabet
7	G	H	The uppercase 7th letter in the alphabet
8	H	Θ	The uppercase 8th letter in the alphabet
9	I	I	The uppercase 9th letter in the alphabet

[a] "a" deserves a footnote

[b] "j" deserves another footnote

Number	Letter	Greek	Explanation
10	J		The uppercase 10th letter in the alphabet
11	K	K	The uppercase 11th letter in the alphabet
12	L	Λ	The uppercase 12th letter in the alphabet
13	M	M	The uppercase 13th letter in the alphabet
14	N	N	The uppercase 14th letter in the alphabet
15	O	O	The uppercase 15th letter in the alphabet
16	P	Π	The uppercase 16th letter in the alphabet
17	Q		The uppercase 17th letter in the alphabet
18	R	P	The uppercase 18th letter in the alphabet
19	S	Σ	The uppercase 19th letter in the alphabet
20	T	T	The uppercase 20th letter in the alphabet
21	U	Υ	The uppercase 21st letter in the alphabet
22	V	Φ	The uppercase 22nd letter in the alphabet
23	W	Ξ	The uppercase 23rd letter in the alphabet
24	X	X	The uppercase 24th letter in the alphabet
25	Y	Ψ	The uppercase 25th letter in the alphabet
26	Z	Ω	The uppercase 26th letter in the alphabet

Table E.2: The alphabet set using the longtable package.

Number	Letter	Explanation
1	a	The lowercase 1st letter in the alphabet[1]
2	b	The lowercase 2nd letter in the alphabet
3	c	The lowercase 3rd letter in the alphabet
4	d	The lowercase 4th letter in the alphabet
5	e	The lowercase 5th letter in the alphabet
6	f	The lowercase 6th letter in the alphabet
7	g	The lowercase 7th letter in the alphabet
8	h	The lowercase 8th letter in the alphabet
9	i	The lowercase 9th letter in the alphabet
10	j	The lowercase 10th letter in the alphabet[2]
11	k	The lowercase 11th letter in the alphabet
12	l	The lowercase 12th letter in the alphabet
13	m	The lowercase 13th letter in the alphabet
14	n	The lowercase 14th letter in the alphabet
15	o	The lowercase 15th letter in the alphabet
16	p	The lowercase 16th letter in the alphabet
17	q	The lowercase 17th letter in the alphabet
18	r	The lowercase 18th letter in the alphabet
19	s	The lowercase 19th letter in the alphabet
20	t	The lowercase 20th letter in the alphabet
21	u	The lowercase 21st letter in the alphabet
22	v	The lowercase 22nd letter in the alphabet
23	w	The lowercase 23rd letter in the alphabet
24	x	The lowercase 24th letter in the alphabet
25	y	The lowercase 25th letter in the alphabet
26	z	The lowercase 26th letter in the alphabet
1	A	The uppercase 1st letter in the alphabet
2	B	The uppercase 2nd letter in the alphabet
3	C	The uppercase 3rd letter in the alphabet
4	D	The uppercase 4th letter in the alphabet
5	E	The uppercase 5th letter in the alphabet
6	F	The uppercase 6th letter in the alphabet
7	G	The uppercase 7th letter in the alphabet
8	H	The uppercase 8th letter in the alphabet
9	I	The uppercase 9th letter in the alphabet
10	J	The uppercase 10th letter in the alphabet
11	K	The uppercase 11th letter in the alphabet

Continued on next page

---

[1] "a" deserves a footnote

[2] "j" deserves another footnote

Number	Letter	Explanation
12	L	The uppercase 12th letter in the alphabet
13	M	The uppercase 13th letter in the alphabet
14	N	The uppercase 14th letter in the alphabet
15	O	The uppercase 15th letter in the alphabet
16	P	The uppercase 16th letter in the alphabet
17	Q	The uppercase 17th letter in the alphabet
18	R	The uppercase 18th letter in the alphabet
19	S	The uppercase 19th letter in the alphabet
20	T	The uppercase 20th letter in the alphabet
21	U	The uppercase 21st letter in the alphabet
22	V	The uppercase 22nd letter in the alphabet
23	W	The uppercase 23rd letter in the alphabet
24	X	The uppercase 24th letter in the alphabet
25	Y	The uppercase 25th letter in the alphabet
26	Z	The uppercase 26th letter in the alphabet

Table E.2: The alphabet set using the longtable package.

A famous equation is $E = mc^2$

LaTeX file: guide_appendix.tex

This chapter was included to show how one can get bold mathematics in a chapter/section title, but not in the table of contents. The code used in this chapter heading when running LuaLaTeX of XƎLaTeX is:

```
\chapter{A famous equation is \texorpdfstring{$\symbfit{E = mc^{2}}$}{E =
    mc^2}}%
```

The code used in this chapter heading when running pdfLaTeX is:

```
\chapter{A famous equation is \texorpdfstring{$E = mc^{2}$}{E = mc2}}%
```

When using pdfLaTeX, no special handling of titles should be necessary. This is because the following line is included in ubonn-thesis.sty:

```
\def\bfseries{\fontseries\bfdefault\selectfont\boldmath}
```

No optional title for a chapter is needed as the chapter title is typeset in bold face in the table of contents.

The macro `\texorpdfstring` is used to avoid hyperref warnings of the type:

```
Package hyperref Warning: Token not allowed in a PDF string (Unicode):
(hyperref)                 removing 'superscript' on input line 12.
```

F.1 A slightly less famous equation $F = ma$

The code used in this section heading when running LuaLaTeX of XƎLaTeX is:

```
\section{A slightly less famous equation \texorpdfstring{$\symbfit{F = m
    a}$}{F = ma}}%
```

The code used in this section heading when running pdfLaTeX is:

```
\section{A slightly less famous equation \texorpdfstring{$F = m a$}{F = ma}}%
```

The title here does not include \boldmath, as the bold font series turns on bold math by default for pdfLaTeX. For LuaLaTeX and XƎLaTeX \symbfit is used to get bold face. However, a section title is typeset in a normal font when writing a book or report in the table of contents. This is handled correctly by pdfLaTeX. When using LuaLaTeX or XƎLaTeX the title is the table of contents is boldface, which is not what we want.

F.2 Cross-section is given by $\sigma = N/\mathcal{L}$

The code used in this section heading when running LuaLaTeX of XƎLaTeX is:

```
\section[Cross-section given by \texorpdfstring{$\sigma = N /
    \symcal{L}}{sigma = N / L}$]%
  {Cross-section is given by \texorpdfstring{$\symbf{\sigma = N
    /}\symbfcal{L}$}{sigma = N / L}}%
```

The code used in this section heading when running pdfLaTeX is:

```
\section[Cross-section given by \texorpdfstring{$\sigma = N /
    \mathcal{L}}{sigma = N / L}]%
  {Cross-section is given by \texorpdfstring{$\sigma = N / \mathcal{L}$}{sigma
    = N / L}}%
```

This attempt includes a Greek and a calligraphic letter to make sure they work as well. It includes the section title as a short form and a regular form, as this is necessary when running LuaLaTeX of XƎLaTeX.

Old or obsolete information and instructions

LATEX file: guide_appendix_obsolete.tex

With time things change! Some of the instruction or packages that I recommended at an earlier time are superseded. Operating systems and TEX installations also change with time. In order to avoid cluttering up the main chapters of the guide with outdated or obsolete information, such things are collected in this appendix.

Tips chapter

G.1 Units

Instead of SIunits, I used to use hepunits, which is based on SIunits but includes units commonly used in particle physics such as GeV and pb. Unfortunately the syntax of the hepunits and units packages is different even though they use the same macro name. In hepunits you write `\unit{10}{\GeV}`, while in units you write `\unit[10]{\GeV}`. The siunitx package is more modern and older versions were supposed to have compatibility modes for both SIunits and units, but I had problems getting them working. It uses the macros `\SI` and `\num` rather than `\unit`.

G.1.1 SIunits/hepunits packages

Before I found siunitx these used to be my preferred units packages. This section therefore gives examples on how to use hepunits and what you should be careful about. As siunitx has got stricter about what it allows for a syntax, I have had to cheat in the LATEX code several times to show the effect.

Even though `\xspace` is used for some units in hepunits it does not appear to have the usual effect. Hence, if you use units in normal text it is probably wise to terminate them with "\" or "{}". Compare

- The GeVis a heavily used unit in particle physics and cross-sections measured in pbor nbare quite common. Masses can be given in either MeV/c^2or MeV.

- The GeV is a heavily used unit in particle physics and cross-sections measured in pb or nb are quite common. Masses can be given in either MeV/c^2 or MeV.

In the first bullet the units were not terminated, while in the second they were.

Note that Slunits typesets the value in text mode and the unit in math mode. You only have to worry about this if you want to use math mode symbols e.g. 10^8 in the value. Three different ways of writing the velocity of light are:

- c is \unit{\(3 \cdot 10^{8}\)}{\metre\per\second}
- c is \unit{3\(\cdot\)\power{10}{8}}{\metre\reciprocal\second}
- c is \unit{3 \(\cdot\) \power{10}{8}}{\metre\usk\reciprocal\second}
- Written in displaymath or preferably equation*:

  \begin{equation*}
    c = \unit{$3 \times \power{10}{8}$}{\metre\usk\reciprocal\second}
  \end{equation*}

If you try these examples you will see differences in the spacing. The first example gives the best result. Two different ways of handling the value are used in the second and third examples, either without or with space between the number and \(\cdot\). In the fourth example, where you use \unit in math mode, you still need to enclose the value in $...$ if it includes characters from math mode. Conversely if for some reason you want normal text in your units, you should put it inside \text, e.g. the velocity of light is 3×10^8 metres per second. If you forgot the \text command using

\unit{\(3 \cdot \power{10}{8}\)}{metres per second} you would get: $3{\cdot}10^8 \, metrespersecond$ or if you tried to write the units yourself you would get $3 \times 10^8 \, ms^{-1}$.

If you have negative powers then you can play around with the \power command and the usual superscript:

- $\hbar$ is \unit{\(1.054 \times 10^{-34}\)}{\joule\usk\second}

- $\hbar$ is \unit{1.054 \(\times\) \power{10}{-34}}{\joule\usk\second}

- $\hbar$ is \unit{1.054 \(\times\) \power{10}{\(-34\)}}{\joule\usk\second}

Note the use of \usk to get a bit of space between the units. In the second example the minus sign appears as a dash, "-", rather than "−", which is too small. Hence, if you use \power you should put the power in math mode.

Just to complicate things further, if you use the Palatino font for example, then the standard TeX font is used in math mode. You thus have to decide from the very beginning whether numbers should **ALL** be in text or in math mode. This is clearly one of the disadvantages of using a font for which the math mode is different from the text mode. ATLAS uses either the newtx or txfonts package, which do not have this problem. This is why I use newtx in this guide. If you compile the guide with a different font and the numbers 1234.56 and 1234.56 look the same then you do not have to worry! Recent versions of this guide contain a Palatino font combination that works in both text and math mode — see the style file. There are other ways to get around the problem with Palatino. You can try either the pxfonts or the mathpazo packages — for my taste the sans serif font used in pxfonts looks a bit better.

For ranges with Slunits and \unit you can write \unit{\power{10}{4}--\power{10}{5}}{}, which would look almost correct, but leaves some space for the unit! If you want to write between 5 and 7 GeV, then \unit works well: \unit{5--7}{\GeV}.

Figures chapter

G.2 More on feynmf

I relegate this section to the chapter on obsolete instructions, because I think it is much easier to just use feynmp than feynmf. You can combine feynmp with standalone for a very convenient way to develop and include Feynman graphs, as discussed in Section 5.5.3.

If you use feynmp you can just give the command `make feynmp` and it will produce PDF files of all the `tex` files in the `feynmf` subdirectory.

If you do not want to include the feynmf commands for Feynman graphs in the thesis (or input the file containing them), you can try to make encapsulated Postscript (or PDF) files that contain a single Feynman graph and then include these as usual in your thesis.

If you want to use feynmf you can start with the `feynmf` command on the `tex` file containing the graph.[1] This produces a `dvi` file that you then have to convert to Encapsulated Postscript and/or PDF. This is not totally trivial.

The best way is to specify the options to the geometry package so that the page size corresponds to the Feynman graph. For a graph with size (50, 50), as specified at the beginning of the `fmfgraph*` environment (within `\unitlength` in mm), the following wrapper works well:

```
\documentclass{article}
%
\usepackage[papersize={60mm,56mm},text={58mm,52mm},centering]{geometry}
\usepackage{feynmf}
\usepackage{color}
%
\pagestyle{empty}
\begin{document}
\setlength{\parindent}{0pt}
\setlength{\parskip}{0pt}
\setlength{\unitlength}{1mm}
\begin{center}
\fbox{\input{figs/feynmf/ep_nc.tex}}
\end{center}
\end{document}
```

I also had success with the command chain:

```
feynmf ep_nc
dvips ep_nc
ps2epsi ep_nc.ps
```

and then you can include `ep_nc.epsi` in your LATEXfile.[2] To get PDF you need one more step:

---

[1] Note that the example files that are included in this document tree are missing the `\documentclass` and `\usepackage` commands.

[2] By default LATEX will not find `.epsi` files with the `\includegraphics` command. Rename them to `.eps` instead or add `.epsi` to the list of file types that `\includegraphics` can handle.

```
epstopdf ep_nc.epsi
```

An alternative with explicit Metafont calls is:

```
pdflatex ep_nc
mf '\mode=localfont; input ep_nc;'
pdflatex ep_nc
pdflatex ep_nc
```

The trouble with this is that the Feynman graph is not clipped, unless you have specified the page size appropriately as discussed above.

References chapter

G.3 Traditional BIBTEX styles

I strongly recommend that you use biblatex and biber, but if you insist. . .

If you use references directly from Spires or Inspire, then it is probably best to use one of the style files that is compatible with their format. A list can be found on http://www.slac.stanford.edu/spires/hep/refs/bibstyles.shtml. I have used utphys a few times and it works OK. I see that there are also style files available there for common HEP journals, which could save quite a bit of work. The big advantage of utphys is that it also knows about the arXiv and preprints.

The equivalent of biblatex's ieee style in BIBTEX is ieeetr. It also knows about arXiv and preprints. However, it does not know about collaborations.

There are also standard ATLAS style files that work fairly well: atlasBibStyleWithTitle.bst and atlasBibStyleWoTitle.bst These are included in the refs directory.

G.4 Using mcite

As mentioned above, the mcite package used to be a good way of combining several articles into a single references and also getting them to be printed out in the form "[m–n]", rather than "[l,m,n]" or "[l],[m],[n]". How do you achieve this? Just put all the articles in a single \cite and prefix those that should be lumped together with a "*",

e.g. \cite{Chekanov:2009wt,*Aaron:2009wg,*Aaron:2009sma}. The problem is that this package does not appear to be compatible with the hyperref package, so you have to choose between the two. Given the ability that the hyperref package offers to jump directly to sections, equations, references referred to in a document, I guess most of you will go with hyperref rather than mcite.

As mentioned above the biblatex package offers a more modern alternative and different ways of achieving the same results! It is also not compatible with mcite.

A modified version mcite is used by ZEUS in its LaTeX4ZEUS environment, which is why I include a short description here.

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Glossary

LaTeX the typesetting program that is used for this guide.

csquotes a very nice package for using consistent quotes that is language sensitive.

siunitx the best package around for typesetting units.

Acronyms

CAL uranium–scintillator calorimeter. 100

CTD central tracking detector. 99, 100

DCA transverse distance of closest approach. 99

FTD forward tracking detector. 100

MVD MVD silicon tracker. 99, 100

STT straw-tube tracker. 100

TRD transition radiation detector. 100

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Acknowledgements

There is plenty of discussion as to where the acknowledgements should go in a thesis. The two most common places are just after the title and dedication or right at the end. For the purpose of this guide I include both options.

Acknowledgements at the end should be in \chapter so that they appear in the Table of Contents.