Comments on Lab Reports

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This document lists the criteria which I use to rate the lab reports. It is not a replacement for the guidelines in the official experiment description, but an addition.

General Form of the Lab Report Imagine this: You have to do the experiment again, but after such a long time that you forgot most of the theory and the practical execution.
Write the lab report in such a way, that it allows you to get quickly back into the topic and remember how the measurements were performed.
Maybe there is one exception to this analogy: It is part of the task to completely write the report on your own, while in the above mentioned case it would be useful to copy existing texts, like the script or other lab reports. While this might be okay for personal notes, in a lab report it is not! See also "quoting of sources" about plagiarism.
Write it in a precise language, but still take care that it is easy to read. For example: Don't make sentences too long.

Also, write the report in a way that I can easily see that you understood what you were doing. Not so good example: "We verified with the oscilloscope, that the amplifier was not in saturation for the 1275 keV line."
Better: "We identified the 1275 keV on the scope and verified that it had the pulse shape as smaller pulses. So the amplifier was not in saturation for this line."
Don't only write the conclusion, write how you reached it. Don't only write what you did, but also how you did it. Still, try to stay brief, only mention the key aspects.

Technical Terms Get familiar with technical terms (German: Fachbegriffe) and use them properly. In a long-term view it helps to make your texts precise and easily understandable.
Example: Today, I came to work using this machine which has this levers on which you step to make the round rubber coated elements turn.
That is not wrong, but it is much easier understandable to say: I came to work by bicycle.

Quoting of Sources There are different reasons, why one should indicate that one uses "something" from "someone else".

In this context, something could be: Measurement result, a picture, data, ...
Someone else could be: A textbook, a scientific paper, a web page, a person, ...

Reasons are:

- To ensure confirmability of your scientific line of argument.
  In my opinion, this is the most important reason from a scientific point of view. If conclusions are drawn in a scientific text, it has to be possible to verify every single piece in the line of argument. See also the topic "Scientific Argumentation".

- To declare that a specific achievement is not your own.
  It is plagiarism if you don't declare it and has a high chance for the report being rated with a "5".

- To give a good impression. Example: You use a plot in which a peak corresponding to the Higgs boson can be seen. I guess no one will assume that you measured that within the lab curse. Still it gives a good impression if you are able to tell in which paper this plot was published.
  Another example: In a theoretical introduction, you should not write a textbook. It gives a good impression in a lab report or a thesis when you show that you know in which textbook a detailed introduction on the topic can be found. In a thesis, these kind of references might also help other scientists reading it. Also, there might be overlap with the other reasons.

Types of Sources As reliability I define the probability that the statement given by the source is false. While there is supposedly no source with a zero probability for giving a false statement, the probability can be assumed to vary for different types of sources.
For example a statement given in a textbook is more reliable than something written on Wikipedia. Something someone just said has an even lower reliability.
The degree of reliability has to match the degree of how crucial the validity of the statement is.
For example, it is not relevant whether the gain of a photomultiplier is 10^5 or 10^6 when this value occurs in no calculation anyway. So here a high reliability is not required.
Example for the opposite: In an experiment, you investigate the decay from an excited nucleus. It decays from some spin / parity in the initial state, to some different quantum numbers in the final state. This is crucial information. The whole analysis rests on that piece of information being correct. So, only a high reliability source is adequate.

Another aspect in choosing the right source is what is available.
Example: In an experiment, the atomic emission spectrum of hydrogen is measured. To rate the results, a comparison with a high reliability source should be made.
However, there might also be information that you only can quote as "the supervisor said so". For example that the light source in the experiment actually

contains Hydrogen.

A few examples for sources, high reliability:

- Textbooks
- Scientific papers, which were published in reviewed journals

Good reliability:

- PhD theses
- a scientific text that uses high reliability sources
- scientific text from an unreviewed platform

Medium reliability:

- Theses: MSc, BSc, Diploma

Low reliability:

- something someone said (a.k.a. private communication)

As the quality of Wikipedia articles varies a lot, those cannot be used as a high reliability source. However, good articles refer high quality sources. So Wikipedia may be used to find a high reliability source.

Scientific Argumentation Science involves the search for truth. The number of statements that can be considered true can be extended for example by observations or logic conclusions.
Therefore, logic conclusions have to fulfill a degree of precision known from mathematical proves.
In a line of argumentation, the following types of statements can occur:

- Assumptions. You assume that something is true without having (initially) proof of it. In some cases assumptions have to be made which are not proven and will not be proven within your text. This is okay as long it becomes clear that the statement actually is an assumption.
- Conclusions. You combine previously made statements by statement logic.
- Observations. You phrase or describe an observation or measurement. When doing so, take care to not mix it with the conclusion type of statement.

This list is not necessarily complete.
Your report does not need to have a strict form like a programming language or mathematical equations. Still it should become clear for each statement which type it is.

Results Ideally, at the end of the analysis of your measurement, you should be able to draw a conclusion like: The results confirm the theoretical prediction, or the results deviate from the theoretical prediction.
These cases can be split up further, which I will illustrate with a very simple experiment. Theory: When throwing a coin, heads and tails have the same probability. Experiment: Throw a coin and count the cases.

- The measured data can be described with the theoretical prediction and the accuracy of the measurement excludes other outcomes with a high probability.
  Applied to the example: You have thrown the coin 1000000 times, 500207 times it showed head, 499793 times tails. The outcome supports the assumption of equal probability. The deviation is within the probably range, while probabilities e. g. like 20% or 80% seem extremely unlikely. In the lab report, you should give a quantitative statement about how likely or unlikely something is.

- The data can be described by the prediction. However, the accuracy of the data is so low, that the result is not significant.
  Example: you threw the coin 4 times, of which 2 times the result was head. Although the result matches the prediction perfectly, the data is not worth a lot. If one side of the coin would actually have a chance of 70%, the experiment would have the same outcome in 26% of cases.
  Although it is a bit more involved to calculate the other way round (getting the likelihood of the true probability of either of the sides of the coin under the requisite of the measured data), it gets plausible already now, that this experiment will not give much knowledge.

- Similar is the case that the result seems to be off, but the accuracy is so low that the deviation does not have any meaning.
  Example: you threw the coin 4 times. In one case, it showed heads. The best guess for the probability of the coin showing heads, based on this data, is 25%. However other probabilities are similarly likely. So, this experiment does not yield much knowledge.
  However, there is often something to learn in these kind of experiments. Maybe only, that the desired quantity cannot be measured like that.

- The data cannot be described by the prediction. The accuracy is good enough to falsify the prediction with a very high chance.
  Example: you threw the coin 30 times and it showed head only 2 times. The probability for this to happen is $8 \cdot 10^{-7}$, assuming both sides are equally probable.

Take care to correctly classify your results according to these possible outcomes.

When doing the experiment, I encourage you to do something differently than advised in the experiment description, if it seems reasonable to do it differently.
Here it is very important: Explain, why you performed it differently. Did your changed method yield good results? Or turned it out to be the wrong decision?

Common Mistakes Let's again consider the plot showing the gamma-gamma invariant mass of the recent measurements at LHC.

Statement example 1: This peak is the Higgs boson.
Comment: No, it is a peak. Only in a casual conversation, a statement like that might be okay.
Conclusion: Take care to use precise language in your lab report!
Statement example 2: This peak is prove that there is a Higgs boson.
Comment: I'm not an expert for theoretical elementary particle physics, but I guess it's not as easy as that. A peak in the invariant mass spectrum is visible. It is consistent with the Standard Model prediction of a Higgs boson.
Conclusion: Be careful on statements. Try to think like a mathematician about your line of argument. Does a result really prove a set assumptions? Remember, A implies B does not yield that also B implies A!

Omitting Data Points In some cases it can be reasonable or even necessary to omit data points. In other cases it might be scientifically incorrect or even deception to omit data points. I will try to give an idea which case applies under which circumstances.

Example a: The experiment was configured in the wrong way, which had an influence on the data.
What to do: Omit the data point directly. Don't even mention it in the report.

Example b: All data points are lying perfectly on a straight line. With one exception: One point is far off.
What to do: Mention in the report that you assume that something went wrong. Maybe you don't even know what exactly. Depending on the actual circumstances: Maybe make one analysis using the data point and another one omitting it. If you decide to do so: Argue why it seems reasonable to omit the far off data point.

Example c: Similar to example b. You realized quite early that the data point is off. You tried to reproduce the measurement settings as precisely as possible, however, you are unable to reproduce the data point.
What to do: Depending on the actual circumstances it makes sense to mention the data point in the report but to not use it in the analysis as you were not able to reproduce it.

Example d: The data is not fitting the theoretical prediction. However, removing some "outliers" allows to fit the predicted behavior and resulting parameters agree with the reference values.
What to do: Do not omit these data points!! Changing the database just to make the data fit the prediction is bad practice. It is comparable to making up data or faking results. Any report that does this has a high chance to be rated with a 5.