

III. Physikalisches
Institut A

RWTHAACHEN
UNIVERSITY

Experimental Techniques in Particle Physics (WS 2020/2021)

Organisation and Introduction

Prof. Alexander Schmidt

The Team

Prof. A. Schmidt



RWTH, Experimental
Particle Physics,

CMS Experiment (CERN),

MADMAX Experiment
(DESY)

**Lecture + Data
Analysis Exercises**

Dr. S. Metzger



Fraunhofer Institute for
Technological Trend
Analysis

Radiation Effects in
Electronics and Opto-
Electronics

Lecture

Dr. A. Nowack



RWTH, Experimental
Particle Physics,

Grid-, Cloud, HPC
Computing

**GEANT
simulation
course**

Dr. J. Steinmann



RWTH, Experimental
Particle Physics,

T2K Experiment,
Juno Experiment

**FPGA
programming
course**

The Team

Dr. A. Pozdnyakov

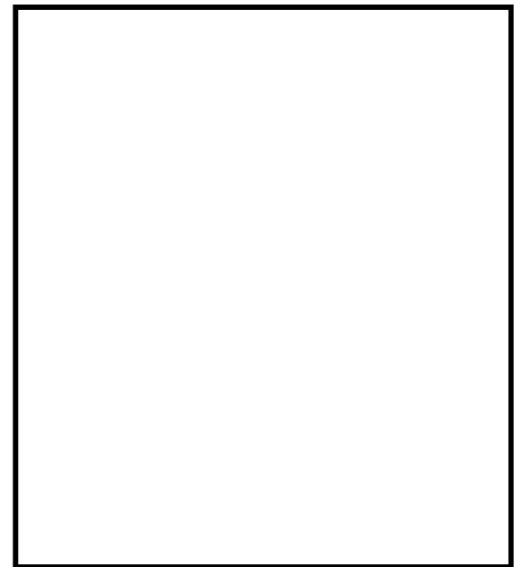


RWTH, Experimental
Particle Physics,

CMS Experiment (CERN),

**Data Analysis
Exercises**

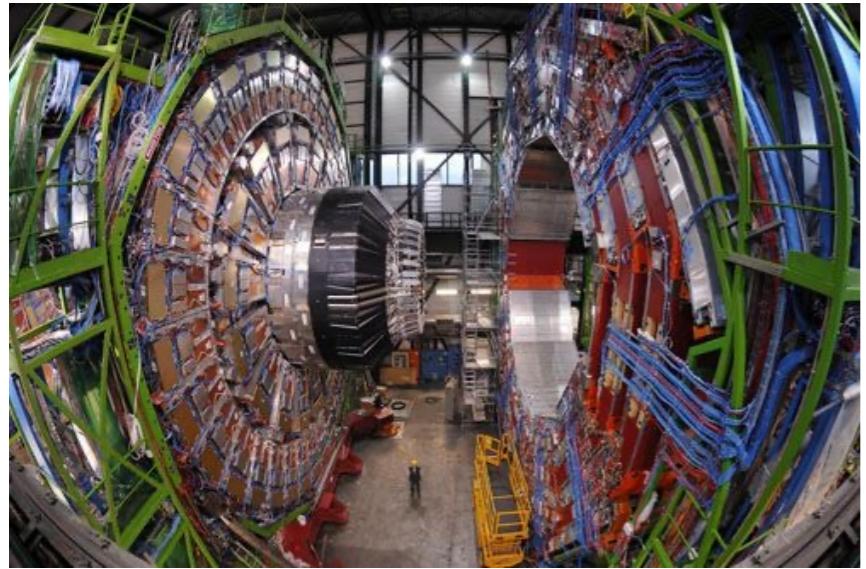
V. Sarkisovi



student assistant

**Data Analysis
Exercises**

Structure



lecture + data analysis exercises

time and location:
Tuesday, 14:30

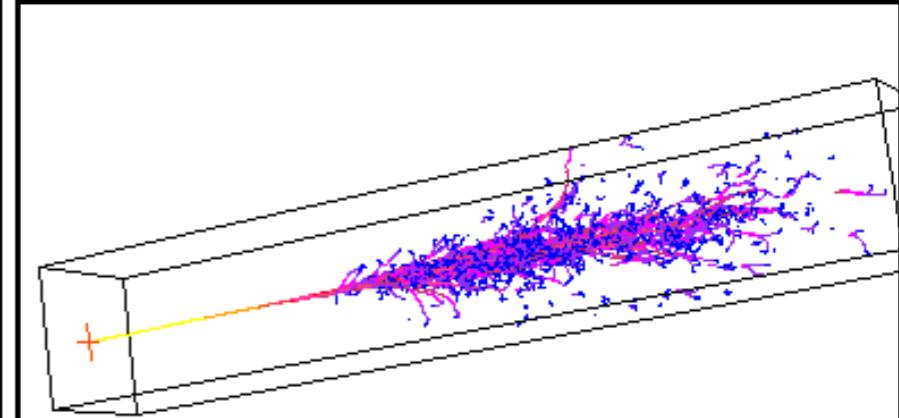
- basic principles of detectors and their technology
- **hands-on examples**
- **data analysis methods and examples**
- **analysis of real LHC data**



**practical course:
FPGA programming**

time and location:
Wednesday, 14:30,

- learn how to program fast electronics
- real-time data processing



**practical course:
GEANT 4 simulation**

time and location:
Thursday, 14:30,

- simulate interaction of radiation with matter
- Monte Carlo simulation
- used in physics, medicine, biology, etc...

Structure

- after the lecture and courses, there is extra time to work on the material yourself, with the help of the supervisors

13.18519	W	⌚	<u>Experimental Techniques in Particle Physics</u>  	6	VU	  	0/1	<u>Schmidt A,</u> <u>Metzger S,</u> <u>Nowack A,</u> <u>Steinmann J</u>	133920 Englisch	Online-Veranstaltung	27.10.20 14:30 - 16:00
13.18520	W	⌚	<u>Self-Learning Sessions to Experimental Techniques in Particle Physics</u> 	6	UE	  		<u>Schmidt A,</u> <u>Metzger S,</u> <u>Nowack A,</u> <u>Steinmann J</u>	133920 Englisch	Online-Veranstaltung	27.10.20 16:30 - 18:00

- you will NOT have to hand in any solutions for homework
- 10 ECTS credits
- admission to the exam will be based on regular presence in the courses
- we need to fix a date and time for the written exam (Klausur)
 - suggestion: **16.02.2020, 14:30** (one week after the last lecture)

Resources

- all material will be available through moodle
- if you don't have access, please let us know

The screenshot shows the RWTHmoodle interface for a course titled "Experimental Techniques in Particle Physics (VU) [13.18519]". The left sidebar contains navigation links for Participants, Grades, Download center, Sections (with General, Lecture, FPGA, Geant4), Activities (with Forums), Dashboard, Calendar, Private files, and My courses. The main content area displays the course general information, including prerequisites for the Geant4 & FPGA tutorial, a lecture section with details about the first lecture, and sections for announcements, videostreaming, latest announcements, and upcoming events.

RWTHmoodle

English (en) Schmidt, Alexander Turn editing on

(VU) Experimental Techniques in Particle Physics

Participants

Grades

Download center

Sections

General

Lecture

FPGA

Geant4

Activities

Forums

Dashboard

Calendar

Private files

My courses

(VU) Experimental

Experimental Techniques in Particle Physics (VU) [13.18519]

Dashboard / My courses / (VU) Experimental Technique...

General

Announcements

Prerequisites for the Geant4 & FPGA tutorial

- Login for CIP pool: If you need a new account contact edv-support@physik.rwth-aachen.de with your details (full name, RWTH ID, RWTH email address).
- SSH key for the connection to CIP pool: See the [instructions](#) and send your public SSH key to edv-support@physik.rwth-aachen.de via GigaMove.
- X2Go on your computer: You can download X2Go [here](#). Use the settings described [here](#) in order to connect to the host "portal-intern.physik.rwth-aachen.de" via the proxy server "tunnel.physik.rwth-aachen.de".

Lecture

The first lecture will be Tuesday, 27.10.2020, 14:30

The link to connect through zoom is the following: <https://rwth.zoom.us/j/94827607276?pwd=RGYvRzdUbWhzNFZOb0szSUpDOXQ4UT09>

We will discuss the organisational details and the content of the course during the first lecture.

Quickmail

[Compose New Email](#)

[Signatures](#)

[View Drafts](#)

[View History](#)

Videostreaming (Opencast)

[Add video](#)

No videos available

[Go to overview...](#)

Latest announcements

[Add a new topic...](#)

(No announcements have been posted yet.)

Upcoming events

Experimental Techniques in Particle Physics [VU]

Tuesday, 27 October, 2:30 PM » 4:00 PM

Overview

what are “experimental techniques” ?

- everything you do in an experiment
- there are many experiments
- example experiment at the LHC
 - proton-proton interactions (physics processes)
 - interaction of particles with detector material
 - response of the various detectors (silicon, calorimeters, muon chambers)
 - trigger (several stages)
 - data acquisition
 - data processing
 - data quality monitoring
 - event reconstruction
 - physics analysis and statistical interpretation

how do particles (Higgs bosons?) find their way into the computer?

Preliminary schedule of the lecture

(may slightly change according to your preferences)

today: organisation/introduction/overview/technical setup
(C++ programming, ROOT analysis tool) (Prof. Schmidt)

03.11.: sources of radiation (Dr. Metzger)

10.11. / 17.11.: basic principles of interaction of particles with matter
(with practical hands-on examples) Part I + II (Prof. Schmidt)

24.11.: overview of detectors (Dr. Metzger)

01.12.: gas detectors

08.12.: principles of silicon detectors (Dr. Metzger)

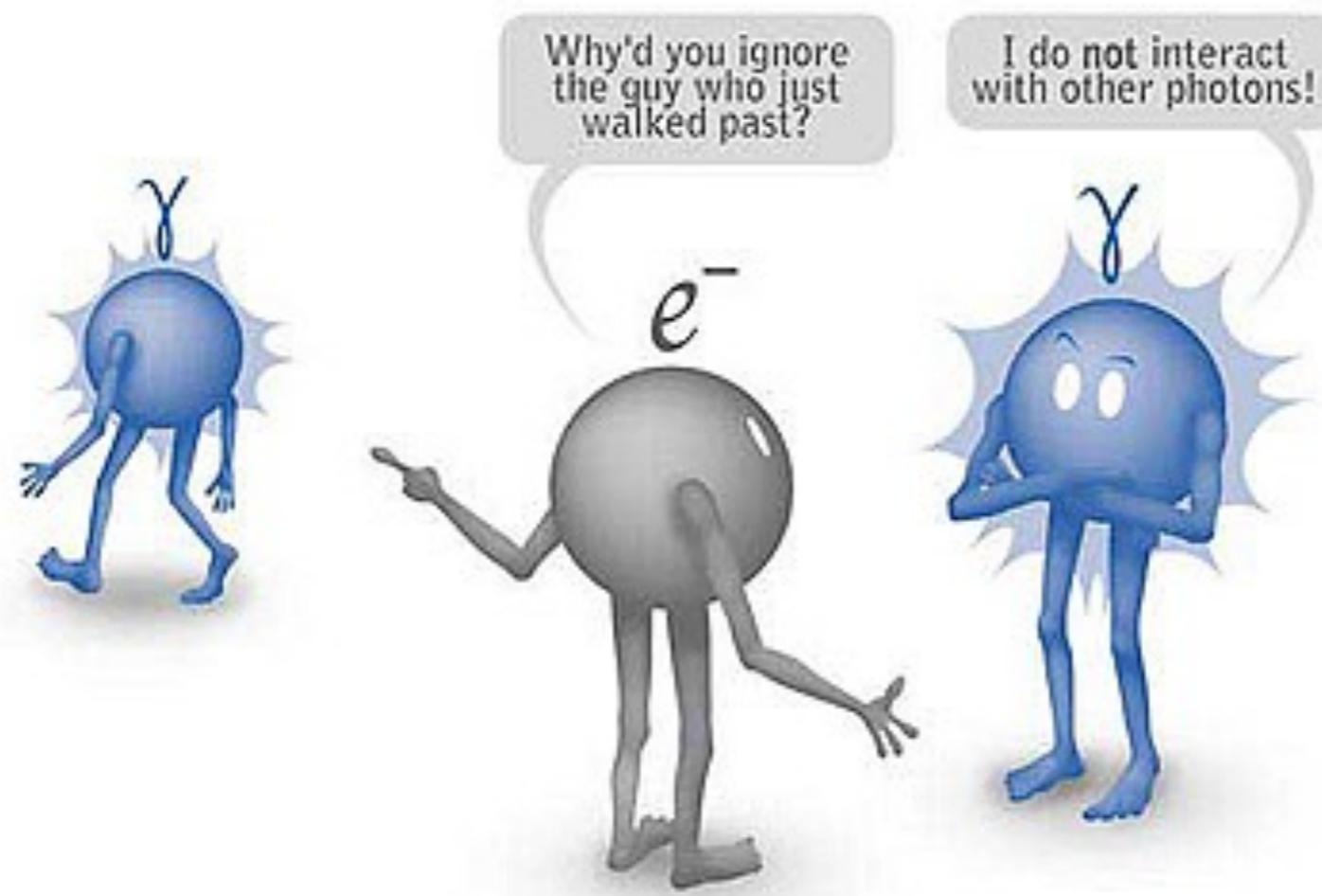
15.12.: advanced topics on silicon detectors, calorimeters
(Prof. Schmidt)

22.12. / 12.01.: detector readout electronics (Dr. Metzger)

19.01. / 26.01. / 02.02. / 09.02.: advanced statistics and data analysis
topics. Analysis of LHC data, hands-on tutorial (Prof. Schmidt)

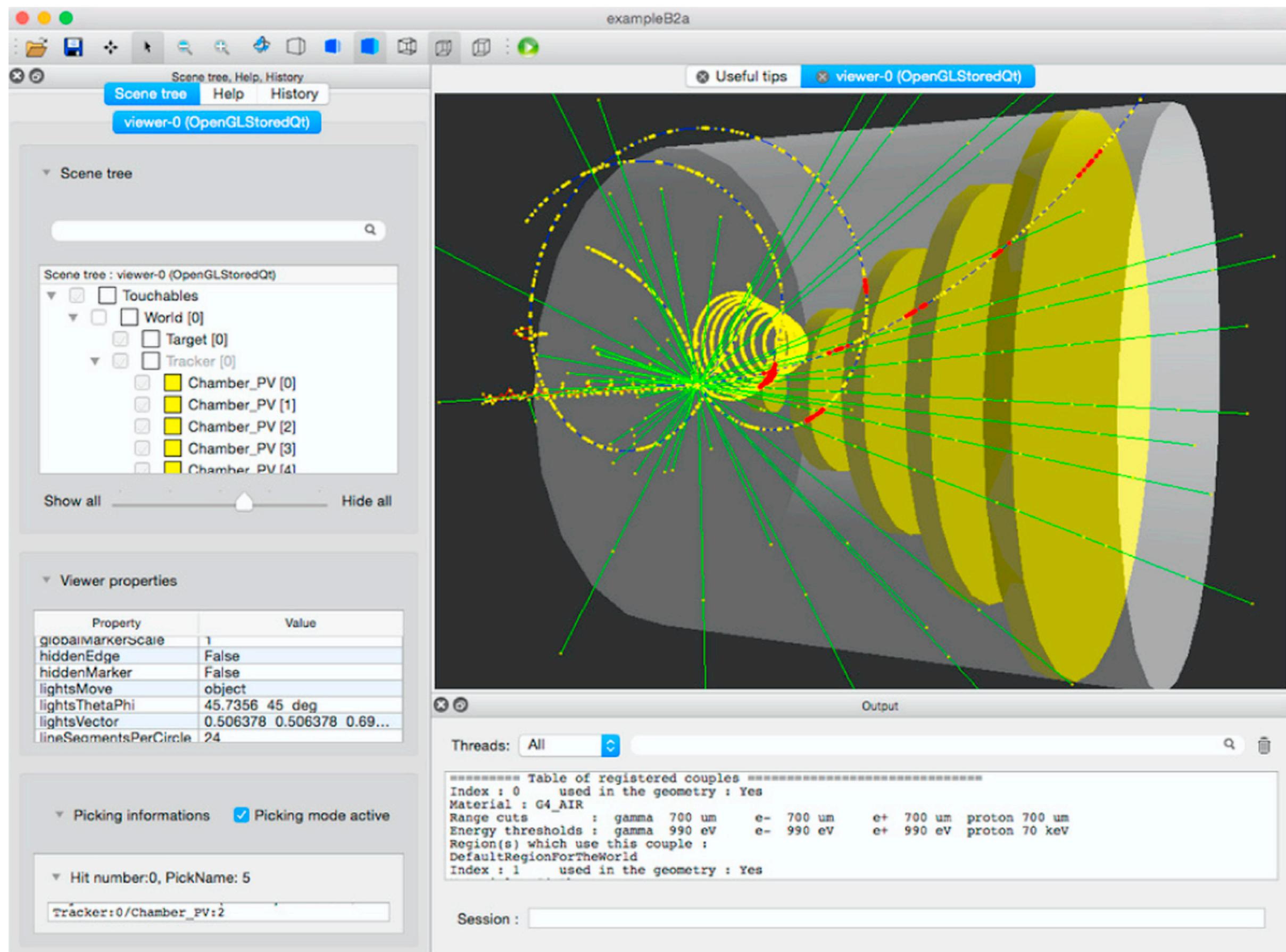
GEANT 4

- particles can only be detected through their **interaction** with “something”
- the **interaction** is registered by the detector, not the particle itself
- one has to deduce the information about the particle from the **interaction**
- the detector consists of various types of material



- detailed understanding of **interaction of particles with matter** is fundamental for experiment
- GEANT 4 is a flexible toolkit to obtain precise descriptions of such interactions in arbitrary geometries

GEANT 4



GEANT 4

- it does Monte Carlo simulation
- you do the same thing twice and get very different results
- is a toolkit in C++ programming language (you need to understand C++)
 - performs motion of particles in fields and matter
 - simulates interaction of particles with matter (detector)
- GEANT4 does **not** simulate high energy proton-proton collisions
 - need to use event generators for that (pythia, sherpa...)
- GEANT4 is **not** an executable program/file.
 - it is a collection of libraries organized in classes (C++)
- GEANT4 is **not** an analysis program.
 - use other analysis tools (e.g. ROOT), to be learned in our tutorial

Chain of a HEP experiment simulation

- back to our example experiment at the LHC:
 - proton-proton interactions (physics processes): **theory, not covered here**
 - interaction of particles with detector material: **GEANT4**
 - response of the various detectors (silicon, calorimeters, muon chambers)
examples and exercises in the lecture
 - trigger (several stages): **FPGA**
 - data acquisition
 - data processing
 - data quality monitoring
 - event reconstruction: **examples and exercises in the lecture**
 - physics analysis and statistical interpretation: **examples and exercises in the lecture**

FPGA

Lecture

Overview about detectors

GEANT4

Simulation of detectors

FPGA

Readout of detectors

- **What this tutorial cannot do?**

- Improve your soldering skills
- Make you an electrical engineer
- Make you an FPGA „expert“

- **What this tutorial can do?**

- Help you understanding electrical engineers talking about FPGA / Programmable Logic
- Help you programming a basic firmware
- Get an overview of programmable logic
 - Problems and their solutions
 - Features and how they can be used

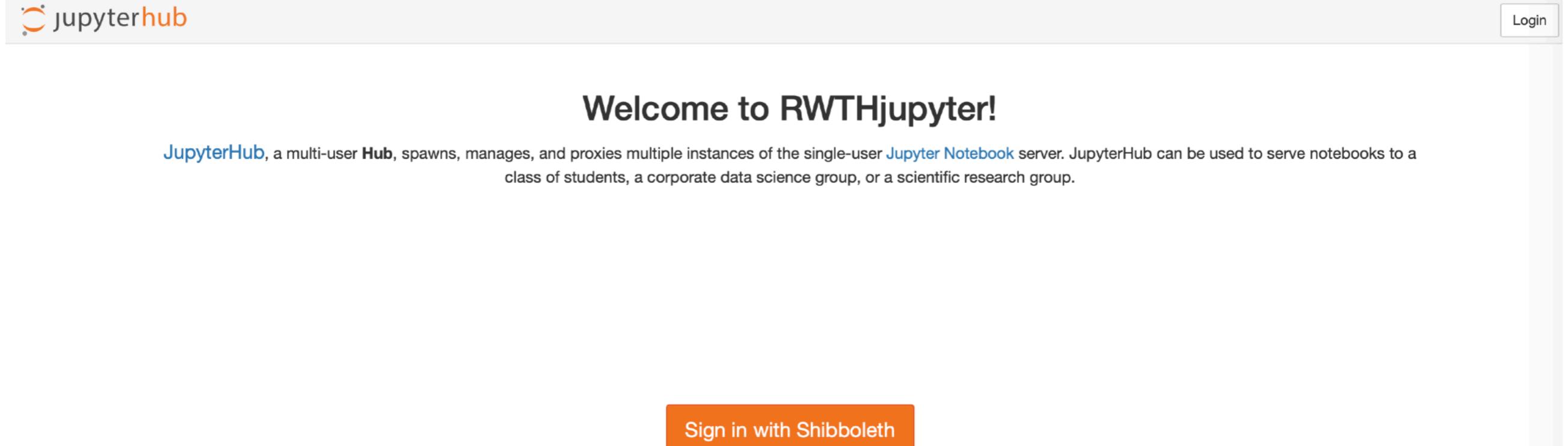
Data Analysis Software



- a modular scientific software toolkit
- it provides all the functionalities needed to deal with big data processing, statistical analysis, visualisation and storage
- it is mainly written in C++ but integrated with other languages such as Python (we should use it in plain C++ as you need C++ anyway in the GEANT tutorial)
- all LHC experiments use it as fundamental analysis software
- some of you learned how to use it during your Bachelor Thesis?
<https://root.cern.ch> has extensive documentation and tutorials
- we use the remaining time today to test it

Jupyter Hub at RWTH

- go to <https://jupyter.rwth-aachen.de> with a web-browser on your computer
- log-in with your RWTH TIM ID



The screenshot shows the JupyterHub login interface. At the top left is the "jupyterhub" logo. At the top right is a "Login" button. The main heading is "Welcome to RWTHjupyter!". Below it is a descriptive text: "JupyterHub, a multi-user Hub, spawns, manages, and proxies multiple instances of the single-user Jupyter Notebook server. JupyterHub can be used to serve notebooks to a class of students, a corporate data science group, or a scientific research group." A large orange button in the center contains the text "Sign in with Shibboleth".

The RWTHjupyter cluster is provided in collaboration between the [Institute for Automation of Complex Power Systems](#) and the [IT Center](#) of the [RWTH Aachen University](#).

Contact: [RWTHjupyter Admins](#)
[Documentation](#)

[Imprint](#)

Jupyter Hub at RWTH

- select DAPP

- [LCPP] Laboratory Class in Particle Physics (Boson)**
Mathematics, Computer Science and Natural Sciences - M.Sc.
- [IDA] Image Data Analysis**
Electrical Engineering and Information Technology - M.Sc. ET/TI/IT
- [DAPP] Data Analysis Class in Particle Physics**
Mathematics, Computer Science and Natural Sciences - M.Sc.
- [PMT] Praktikum Medizintechnik**
Electrical Engineering and Information Technology - B.Sc. ET/TI/IT
- [Sys2] System Theory II**
Electrical Engineering and Information Technology - B.Sc. ET/TI/IT

Start

- wait until everything is set up
- you will receive a home directory where you can work

Jupyter Hub at RWTH

File Edit View Run Kernel Tabs Settings Help

+

Index.ipynb index.md

Python 3

Home > dapp

Name Last Modified

- ex1-decay-data 27 minutes ago
- ex2-bethe-bloch 2 days ago
- Plots 2 days ago
- tutorial-root 5 minutes ago
- tutorial-terminal 27 minutes ago
- Index.ipynb 2 days ago
- Dockerfile 2 days ago
- fix-permissions 2 days ago
- jupyter_notebook_... 2 days ago
- LICENSE 2 days ago
- pythia-root.patch 2 days ago
- README.md 2 days ago
- requirements.txt 2 days ago
- start-notebook.sh 2 days ago
- start-singleuser.sh 2 days ago
- start.sh 2 days ago

Data Analysis Class in Particle Physics

Andrey Pozdnyakov, Valentina Sarkisovi, Alexander Schmidt

Quickstart: Jupyter

- Run single cells: ►-Button or Shift+Enter
- Run all cells of a notebook: Menu Run>Run All Cells
- To restart the kernel (delete all variables): C-Button
- Backup data:** It is recommended to download the edited files via the fileviewer on the left side. (Right-click the file, then ↴Download).

Contents

File	Description
tutorial-root	A few notebooks to go over basic functionality of ROOT software
tutorial-terminal	How to use terminal (for beginners)
ex1-name	Exercise 1: Name (Lecture 1)
ex2-bethe-bloch	Exercise 2: Bethe Bloch equation (Lecture 2 and 3)
ex3-name	Exercise 3: Name
ex4-name	Exercise 4: Name
ex5-name	Exercise 5: Name
ex6-name	Exercise 6: Name
ex7-name	Exercise 7: Name

[]:

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Jupyter Hub at RWTH

- go to folder tutorial-terminal
- open with Markdown (right click)

The screenshot shows the Jupyter Notebook interface. On the left, a file viewer displays a list of files in the 'tutorial-terminal' directory, including 'index.md' (modified 29 minutes ago). A context menu is open over 'index.md', with 'Open With' selected, showing options like 'Editor' and 'Markdown Preview'. The main notebook area shows a Markdown cell titled 'Analysis Class in Particle Physics' by 'Johanna, Valentina Sarkisovi, Alexander Schmidt'. The cell content includes a section 'Quickstart: Jupyter' with instructions and a 'Contents' section. A table below lists files and their descriptions. The top bar shows tabs for 'Index.ipynb', 'Python 3', and the kernel status.

File Edit View Run Kernel Tabs Settings Help

+ 📂 ⌛ ⌁ C

Index.ipynb X

Python 3

Name Last Modified

M index.md 29 minutes ago

index.md

- Open
- Open With
- Open in New Browser Tab
- Rename
- Delete
- Cut
- Copy
- Duplicate
- Download
- Shutdown Kernel
- Copy Shareable Link
- Copy Path
- Copy Download Link
- Paste

Index.ipynb

Analysis Class in Particle Physics

by, Valentina Sarkisovi, Alexander Schmidt

Quickstart: Jupyter

- Run single cells: ►-Button or Shift+Enter
- Run all cells of a notebook: Menu Run>Run All Cells
- To restart the kernel (delete all variables): C-Button
- Backup data:** It is recommended to download the edited files via the fileviewer on the left side. (Right-click the file, then ↴Download).

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ex4-name	Exercise 4: Name
ex5-name	Exercise 5: Name
ex6-name	Exercise 6: Name
ex7-name	Exercise 7: Name

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Jupyter Hub at RWTH

The screenshot shows the Jupyter Notebook interface. On the left, there's a sidebar with icons for file operations like creating new files, moving, copying, and deleting. Below that is a file browser showing a directory structure: `home > dapp > tutorial-terminal`. A file named `index.md` is selected, showing its last modified time as "31 minutes ago". The main area has a menu bar with File, Edit, View, Run, Kernel, Tabs, Settings, and Help. There are three tabs open: "Index.ipynb" (active), "index.md", and "Terminal 2". The content area displays a Markdown document:

Welcome to the tutorial!

Before we proceed to familiarization with commands, one should know that the file has to be opened with the help of "Markdown preview". In general, a command in Linux is an instruction given by a user telling a computer to do something. A short list of the most basic Linux commands is presented in this tutorial that will help users execute tasks easily and effectively.

First of all, let's open the terminal in Jupyter. This can be done by clicking on "File" → "New" → "Terminal". Now the terminal is open and we can see what some of the listed commands do.

1. **pwd command**

If you want to know full path of the current working directory you are in, use the **pwd** command. Let's type it in the terminal and see the output.

2. **ls command**

You can display the contents of a directory by simply typing the **ls** command in terminal. It is also possible to see the content of another directory if you type **ls** and then the directory's path. For example, **ls /home/username/dapp** will view the content of **dapp**.

ls command has different options, some of them are listed below:

- **ls -a** lists all files including hidden file
- **ls -S** sorts by file size
- **ls -t** sorts by time and date
- **ls -R** lists all the files in the subdirectories as well
- **cd command**

In order to navigate through the Linux files and directories, one should use the **cd** command. Mainly, there are two scenarios: either you want to navigate through a subdirectory of the current directory, or you want to switch to a completely new directory. The example for the first case is as follows: let's say you are in **/home/user/** and you want to go to **dapp**, a subdirectory of **user**. To do so, you have to type in terminal following command: **cd dapp**. As for the second scenario, for example you want to switch to **/home/username/dapp** from some other directory, then you have to type **cd** followed by the directory's absolute path: **cd /home/username/dapp**.

There are some commands that help you navigate quickly:

Jupyter Hub at RWTH

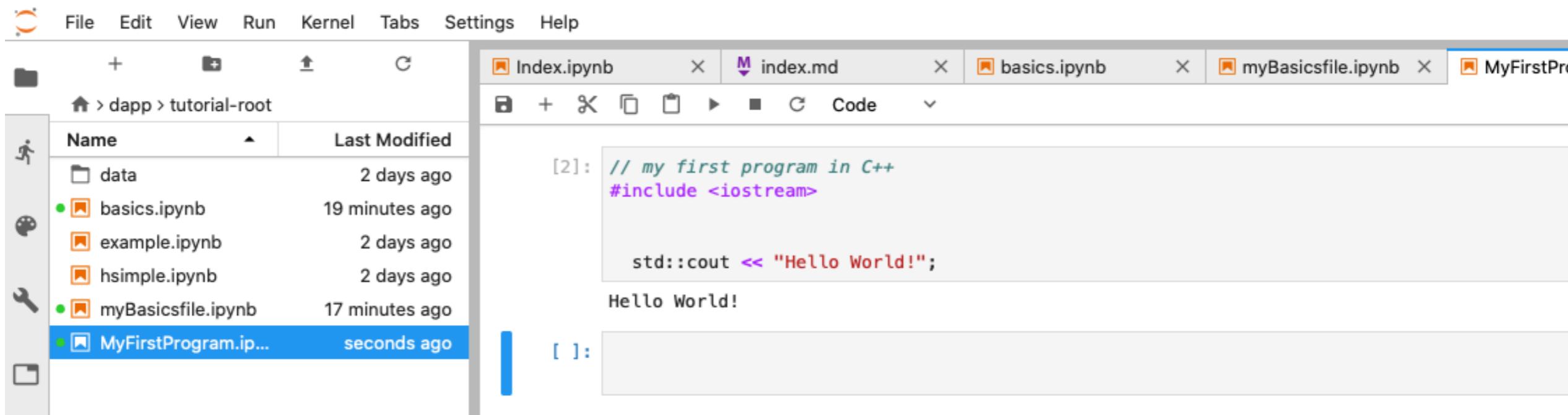
- go to folder tutorial-root and start basics.ipynb

The screenshot shows the Jupyter Notebook interface. On the left is a sidebar with icons for File, Edit, View, Run, Kernel, Tabs, Settings, and Help. Below the sidebar is a file browser showing a directory structure: dapp > tutorial-root. Inside this directory are several files: data (modified 5 minutes ago), basics.ipynb (selected and modified a minute ago), example.ipynb (modified 5 minutes ago), and hsimple.ipynb (modified 5 minutes ago). The main area displays the contents of the basics.ipynb notebook. The title of the notebook is "basics.ipynb". The content starts with a note: "Note: this is a simplified version of the tutorial from here: <https://github.com/root-project/NotebookPrimer/tree/master/notebooks>". The first section is titled "Install ROOT?". It contains text: "For this tutorial and the while class it is **not necessary** to install ROOT on your personal computer. However, if you are interested to explore more advanced options of this software, give it a try: <https://root.cern/install/>". Below this, there is another note: "If you decided to install root, you can launch it with `root` command in your terminal, then follow the rest of the instructions. Otherwise, just run the cells inside this notebook." The next section is titled "1. ROOT as calculator". It contains text: "You can use the ROOT interactive shell instead of a calculator. For example:". Below this, four code cells are shown, each with its output:

```
[1]: 1+1  
(int) 2  
[2]: 2*(4+2)/12.  
(double) 1.000000  
[3]: sqrt(3.)  
(double) 1.7320508  
[4]: 1>2  
(bool) false
```

Jupyter Hub at RWTH

- this may be difficult if you don't know C++
- do a C++ tutorial first:
<http://www.cplusplus.com>
- create a new notebook though the + sign (new launcher), and select ROOT C++
- give it a name
- try some code



The screenshot shows the Jupyter Notebook interface with a C++ kernel session. The top navigation bar includes File, Edit, View, Run, Kernel, Tabs, Settings, and Help. The left sidebar displays a file tree under 'dapp > tutorial-root' with files like 'data', 'basics.ipynb', 'example.ipynb', 'hsimple.ipynb', 'myBasicsfile.ipynb', and 'MyFirstProgram.ip...'. The main area shows a list of open notebooks: Index.ipynb, index.md, basics.ipynb, myBasicsfile.ipynb, and MyFirstProgram.ipynb. The 'MyFirstProgram.ipynb' tab is active, showing a code cell output:

```
[2]: // my first program in C+
#include <iostream>

std::cout << "Hello World!";

Hello World!
```

Jupyter Hub at RWTH

- note that Jupyter Hub is good for quick and fast things
- it is not appropriate for large scale software development or high-performance applications
- it also has some limitations for ROOT, for example interactive graphics
- you can install ROOT on your laptop, see the documentation
- or simply login via ssh to
`ssh -Y -l yourTID login18-1.hpc.itc.rwth-aachen.de`
- and fire up root
`source /cvmfs/sft.cern.ch/lcg/app/releases/ROOT/6.22.02/x86_64-centos7-gcc48-opt/bin/thisroot.sh`
`root`

Next steps

- please fill the questionnaire about your state of knowledge in moodle until next week

I am attending or have attended the following courses:

- Bachelor Vertiefungsfach: Particle Physics
- Master: Particle Physics I
- Master: Particle Physics II
- Deep Learning in Physics Research
- Accelerator Physics
- Astronomy and Astrophysics
- Statistics and Data Analysis

I know the following programming languages

- C++
- Python
- Fortran
- R
- Java
- PHP
- Julia
- Other

- next week, we will see if you are able to solve very simple problems with ROOT
- until then, please follow the tutorials in Jupyter
- the tutors will be connected today to help you getting started

Warning

- we have never done this class fully online....
- let's try to make it work
- give feedback about ideas how to improve it