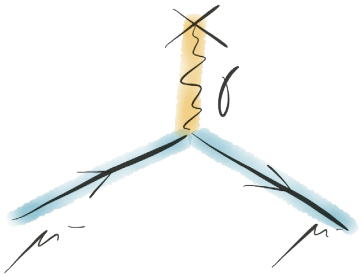
Introduction and course overview

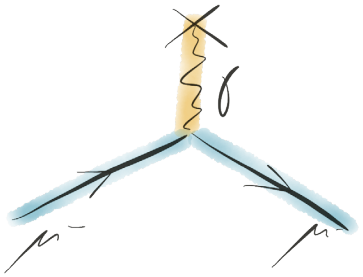
Particle Physics, Summer Term 2016

Niklaus Berger

Kernphysik, Johannes-Gutenberg Universität Mainz



Organisational matters



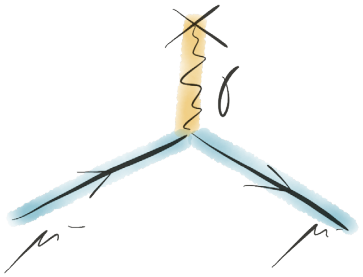
Schedule

- Lectures:
  Monday 12-14
  Wednesday 8-10

- Seminar room I, Kernphysik

- Wednesday sessions will also contain exercises

- If you have not done so yet:
  Sign up with Jogustine before this Friday!

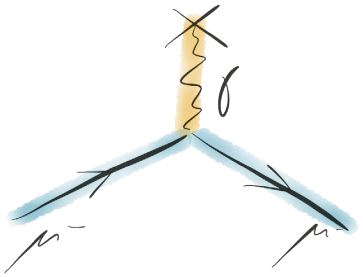


Material

- Website of the lecture:
  http://agberger.kph.uni-mainz.de/76.php

- Will upload all slides, exercises

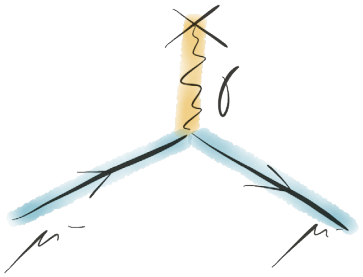
- Take notes of what happens on the blackboard
  (My own notes are typically not very readable)



Books

- Modern Particle Physics
  Mark Thomson
  ISBN: 978-1107034266
  570 pages
- Introduction to Elementary Particles
  David Griffiths
  ISBN: 978-3-527-40601-2
  470 pages
- Quarks and Leptons: An Introductory Course in Modern Particle Physics
  Francis Halzen und Alan D. Martin
  ISBN: 978-0471887416
  396 pages

- All good introductions to the subject with fairly complete calculations
- Griffiths more chatty, Halzen and Martin more concise
- Thomson up to date with Higgs and Neutrinos
- More theory than experiment: We will cover experiment in the lecture



Exercises

Calculating things:

- Will be handed out Mondays
- Hand in Monday after
- Discussion on Wednesday

Reading papers:

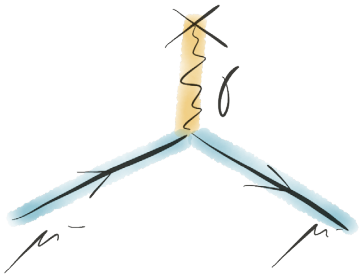
- Give at least a week to read
- Typically with a list of questions
- Discussion on Wednesdays

State on sheets how much time they took

Requirements:

- Put an appreciable effort into at least 75% of problems and reading assignments
- Feel free to collaborate on problems
- No more than tree names per answer sheet
- Read the papers yourselves

Exercise- and discussion leaders:
Dr. Alexandr Kozlinskiy
Dr. Frederik Wauters

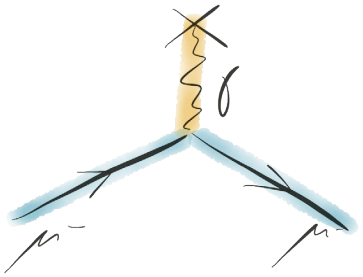


Exam

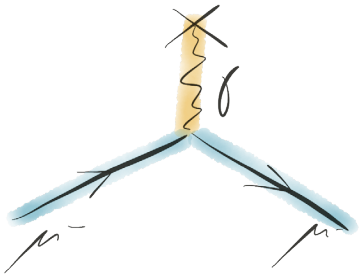
- 30-45 minute oral exam
- The lecture is either a "Topical Course" (Spezialvorlesung) or
- A "Advanced Course" (Vertiefungsvorlesung)

- In the first case, exam will be jointly with your other topical course

- Sign up for the exam using Jogustine towards the end of term (Prüfungsanmeldephase)



Your lecturer...



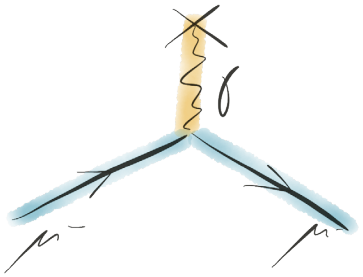
Niklaus Berger

- Ph.D. from ETH Zürich, working on the H1 experiment in Hamburg
  Electron-proton scattering
  Trigger electronics (FPGAs) and track reconstruction

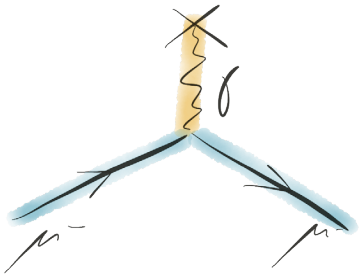
- Postdoc at IHEP in Beijing, working on the BES III experiment
  Electron-positron scattering
  Data analysis, partial wave analysis, computing with graphics cards (GPUs)

- Postdoc and junior research group leader in Heidelberg, working on the Mu3e experiment
  Muon decays
  Silicon pixel detectors, track reconstruction, fast readout electronics

- Professor at the institute of nuclear physics in Mainz since 2104, working on Mu3e, BES III and P2 at MESA
  Parity violating electron-proton scattering, tracking detectors

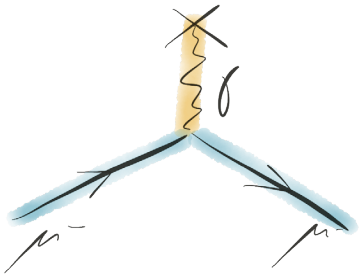


Content of the course



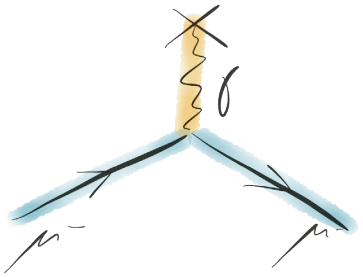
Particle physics:

What is stuff made of and how does it stick together?



Particle physics:

What are the fundamental constituents of matter and how do they interact?

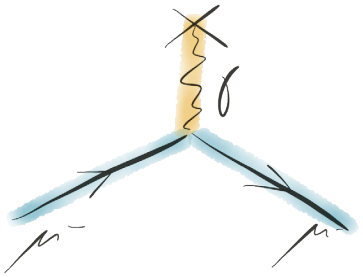


The Standard Model of Particle Physics

- We have a theoretical framework working extremely well:
  Quantum Field Theory (QFT)

- We have a specific particle and field content describing everything around us (except gravity):
  The Standard Model (SM)

- Content of the course:
  The Standard Model and the supporting experimental evidence



Successes of the Standard Model

Extremely precise:

Magnetic moment of the electron:

- Theory:

  g_e = -2.002 319 304 363 56 (154)

  (Aoyama et al., PRL 109, 111807 (2012))

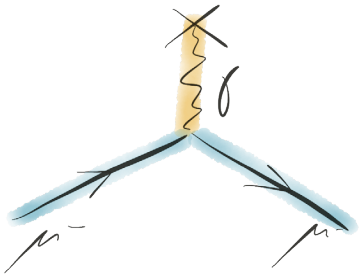
- Experiment:

  g_e = - 2.002 319 304 361 53 (53)

  (Hanneke et al. PRL 100, 120801 (2008))

Very predictive:

- Higgs boson predicted in the seventies, found 2012
- Top quark mass predicted well before the discovery
- Third generation predicted well before discovery



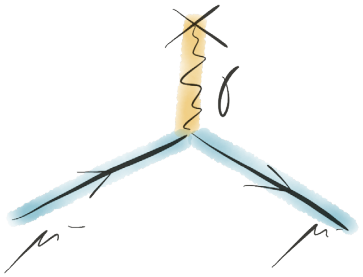
What we will cover

- Tools of the trade (partly repetition):
  Natural units
  Relativistic kinematics
  Particle decays
  Particle scattering
  Cross-sections

- Dirac equation to Quantum Electrodynamics (QED)
  Antiparticles
  Interaction by exchange
  Electron-positron scattering

- Bound states
  Electron-proton scattering
  Proton structure
  Symmetries, quarks and hadrons

- Quantum chromodynamics (QCD)
  The strong force and colour
  Asymptotic freedom and confinement



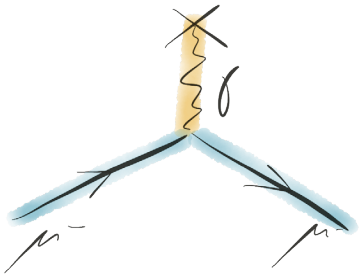
What we will cover

- The weak interaction
  Parity and chiral structure
  Charged and neutral currents
  Weak interactions of leptons

- Flavour physics
  Oscillation phenomena
  Neutrino oscillations
  Kaon, B- and D- meson oscillations
  CKM and PMNS matrices
  CP violation

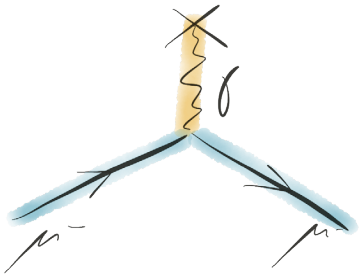
- Electroweak unification and the Higgs
  Properties and decays of the W, Z and Higgs bosons
  Unifying QED and the weak interaction
  Spontaneous symmetry breaking

- Tests of the Standard Model and beyond
  Precision tests of the Standard Model
  Problems of the Standard Model
  Beyond the Standard Model



What we will not cover (other related lectures)

- Quantum Field Theory
- String Theory
- Effective Field Theory
- Theoretical Particle Physics
- Lattice Gauge Theory
- Amplitudes and Precision Physics at the LHC
- Functional Methods and Exact Renormalization Group
- Modern Methods in Theoretical High Energy, Particle and Nuclear Physics
- Precision experiments at low energy
- Statistics, data analysis and simulation
- Particle Detectors
- Accelerator Physics
- Astroparticle Physics
- Theoretical Astroparticle Physics
- Advanced Particle Physics
- Advanced Subatomic Physics
- Advanced Astroparticle- and Astrophysics
- Advanced Accelerator Physics



Where do you stand?

If you want to really do it...

ETH zürich

PAUL SCHERRER INSTITUT PSI

UNIVERSITÄT HEIDELBERG ZUKUNFT SEIT 1386

JG|U JOHANNES GUTENBERG UNIVERSITÄT MAINZ

Practical Course in Particle Physics

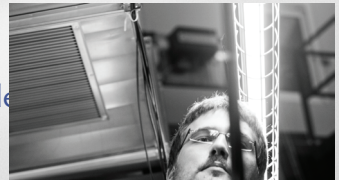
at the Paul Scherrer Institut (PSI, Switzerland), Summer 2016

Perform a real particle physics experiment at a PSI beam-line.

Learn experimental particle physics hands-on.

Join a group of 10-12 students from ETH Zürich and Heidelberg and Mainz Universities for one week of preparartions in Heidelberg and two weeks of beam time at PSI.

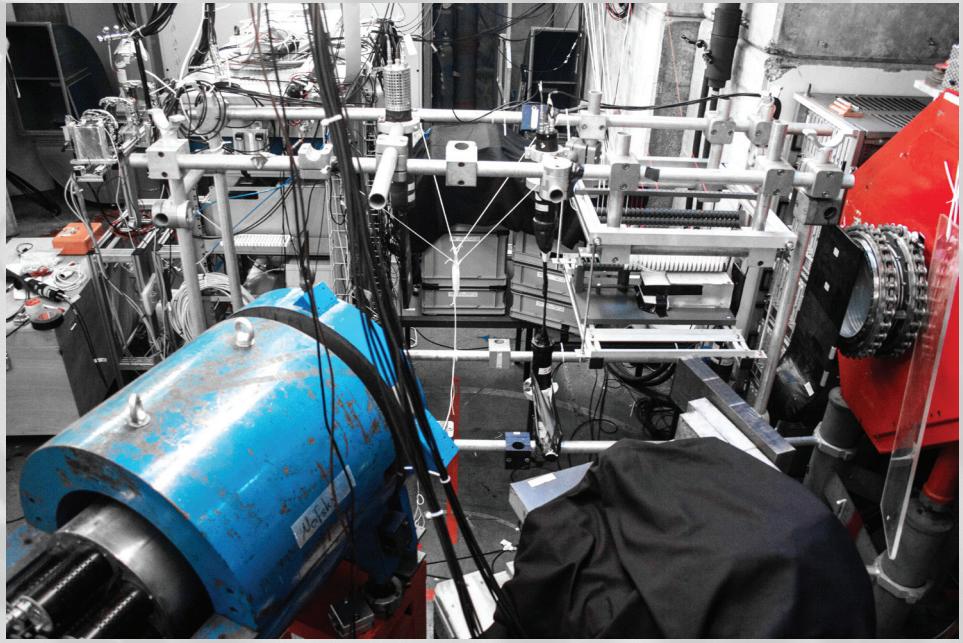
Design and build your experiment from available detector components, take data during a 24/7 beam time. Analyse the data and write up the results.

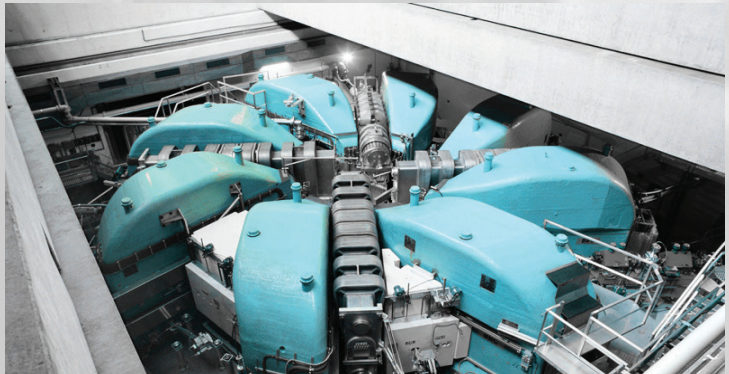


detector components, take data during a 24/7 beam time. Analyse the data and write up the results.

Example measurements:

- Branching ratio $B(\pi \to e\nu)/B(\pi \to \mu\nu)$
- Panofsky ratio $B(\pi^- p \to n\pi^0)/B(\pi^- p \to n\gamma)$
- Lifetimes and decay parameters of muons and pions





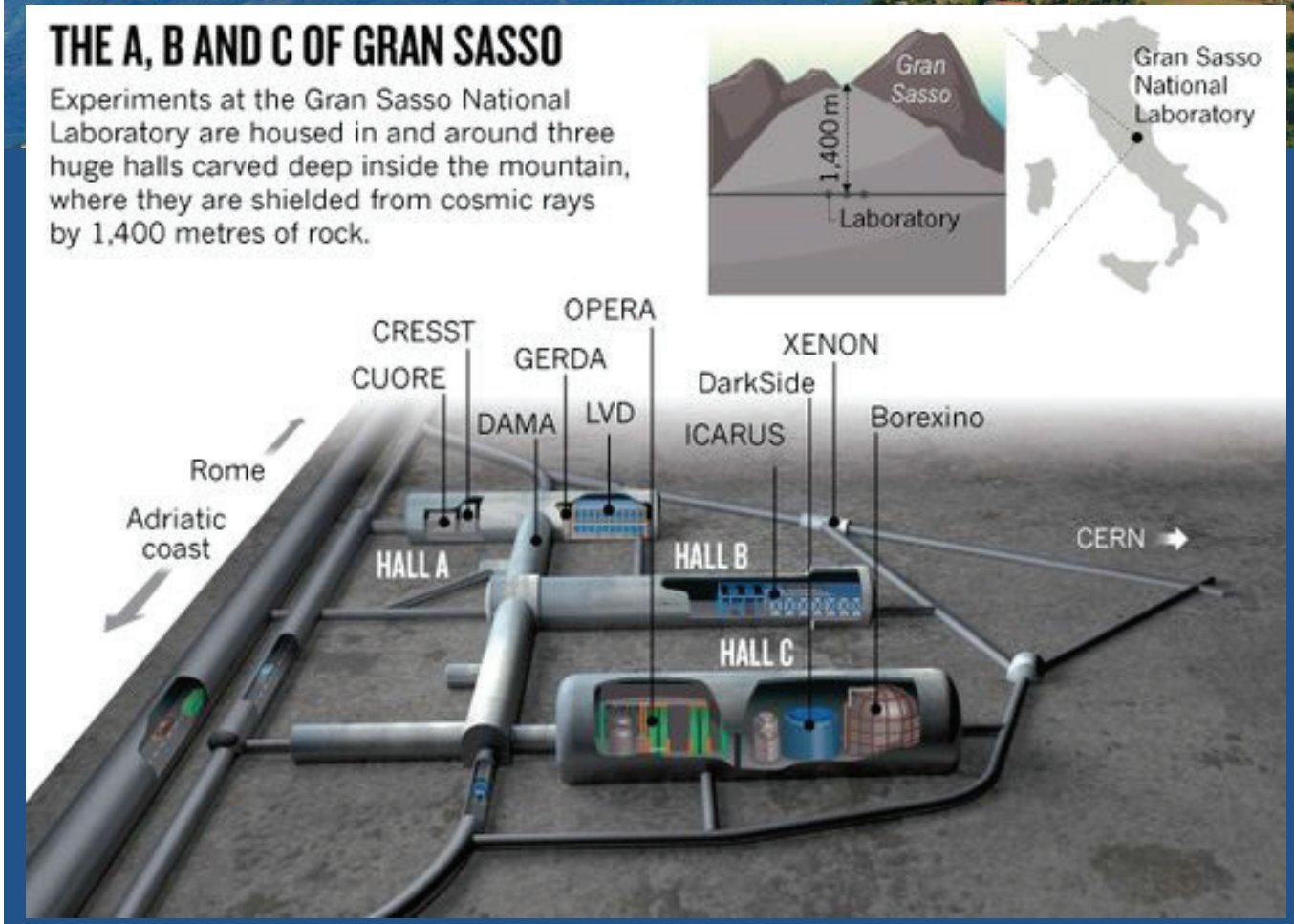
Next course: 22.8.-9.9.2016

Please contact:

Niklaus Berger (niberger@uni-mainz.de)

Exkursion zum Gran Sasso Untergrundlabor

9.–11. Juni 2016



- Hin- und Rückflug Frankfurt-Hahn – Rom
- Besuch des größten Untergrundlabors Europas
- Vorstellung der Experimente zur Suche nach Neutrinos und Dunkler Materie durch die Wissenschaftler vor Ort
- Besuch auf dem Dach des Labors, dem 2000m hohen Campo Imperatore
- Bei Interesse: e-mail an wurmm@uni-mainz.de, Anmeldung bis zum 22.4.