Particle Physics beyond the Standard Model

- LUH goes CERN -

Leibniz Universität Hannover

+ few external participants

SoSe 2022, August 8 – 12, 2022 @CERN, Geneva, Switzerland

Jun.-Prof. Dr. Elina Fuchs

CERN, Department of Theoretical Physics, Senior Research Fellow & TH coordinator of the CERN Quantum Technology Initiative (QTI)

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Homepage

QUANTUM TECHNOLOGY INITIATIVE

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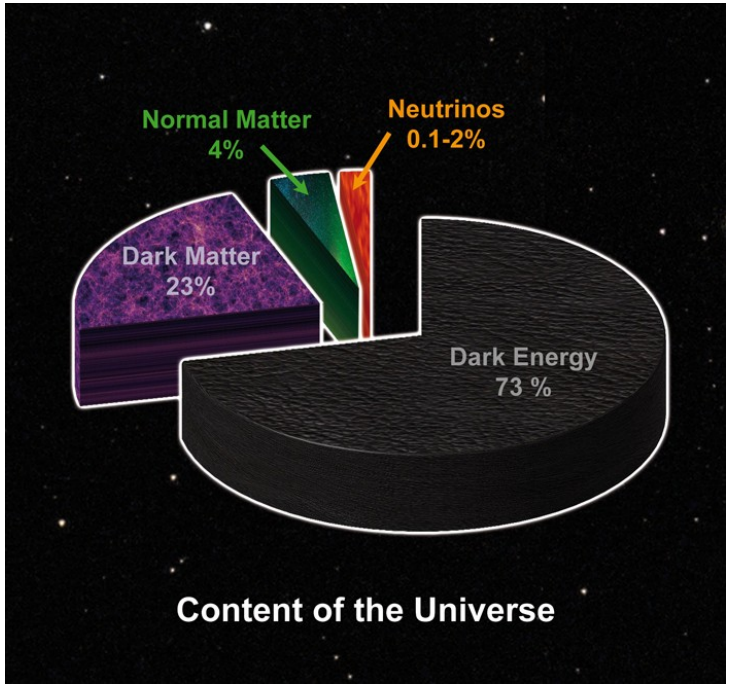
PTB

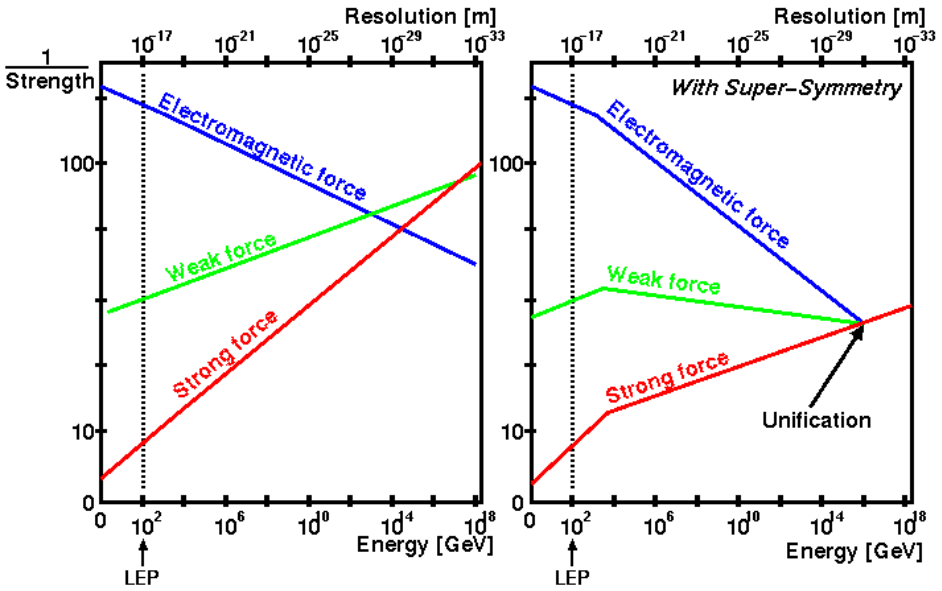
QuantumFrontiers

mat

Motivation: fundamental questions

- What are the fundamental building blocks of nature?
- How can we describe the interactions consistently?
- Are there more than 4 interactions? Are they unified at high energies?
- What is Dark Matter? Dark Energy?
- Are there explanations for the measured values of free parameters in the SM (masses, mixing angles, ….)
- What are the best experimental & theoretical tools to derive robust predictions for processes in models beyond the Standard Model (BSM) and to test them?





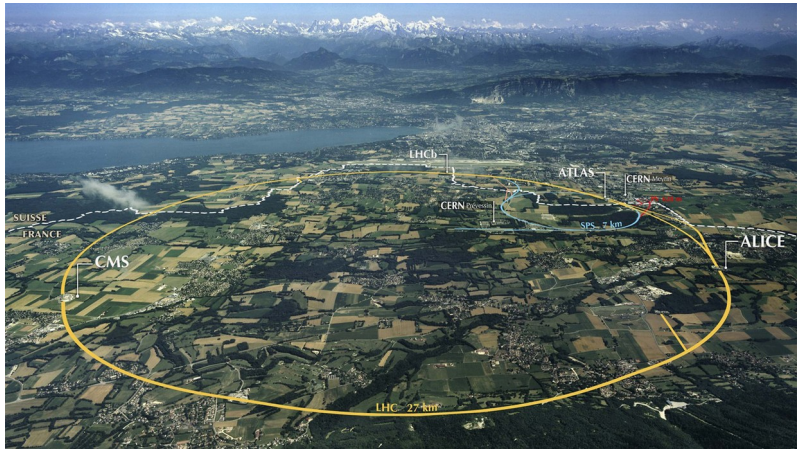
Big thanks to

- Tanja Wießner @ LUH-ITP secretariat
- Michelle Connor, Julie Sal Gobbo, Marie Gauthier @ CERN-TH secretariat
- Elena Gianolio @ CERN-TH IT
- Jodie Millet-Ursin, Jenna Laroche @ CERN Hostel
- Prof. Dr. Luis Santos @ LUH-ITP (head)
- Prof. Dr. Ulrich Derenthal @ LUH-MaPhy Fakultät (dean)
- Prof. Dr. Julia Gillen, Dr. Ines Katenhusen @ LUH-VPL (Vice President for Teaching and Academic Programs)
- … and all participants for their interest.

This excursion is generously supported through “Studienqualitätsmittel” (SQM, funds for the improvement of the quality of teaching).
Normally, LUH students have to pay out of pocket for an excursion and only receive some modest subsidy. Due to the pandemic, some funds were not used and this excursion receives a good portion of them such that your train tickets and hostel are fully covered.

Questionnaire

- Who has been to CERN before?
- Who arrived yesterday?
- Who took the night train?
- Who will depart on Friday with the train at 14:15 (or earlier)?
- Who is in the BSc, MSc, PhD?
- Who knows the gauge group of the strong interaction?
- Who knows the mass of the Higgs boson?
- Who knows the superpartner of the top quark?
- Who intends to do an exam and obtain the 2 ECTS?

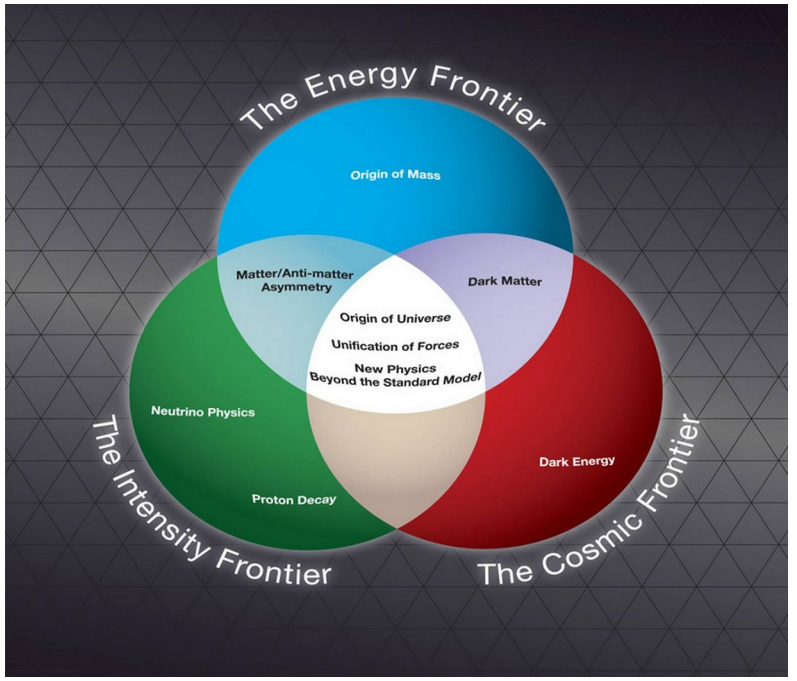


Interrail
Eurail

Disclaimers

- The topic of Particle Physics beyond the Standard Model is very broad
  → impossible to cover everything comprehensively in 1 week
  → will show selection of topics, some only as short overview
  → BSM lecture again next summer (30.5.-3.6.) with possibly slightly different topics
  → planned BSM student seminar with distributed talks

- Personal disclaimer: my father is currently in the ICU with sepsis. The unexpected past days interrupted my preparations, therefore not all details are prepared as I would have liked to. I ask you for your understanding.
  → I might need to travel. In that case, the lectures of Friday would already take place on Wednesday/Thursday, about which I would inform you via StudIP and the indico schedule.



Topics

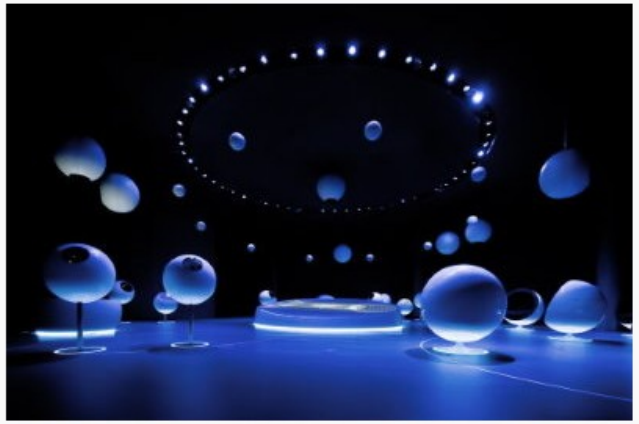
Topic				real hours	exercise
Introduction				0.25	
Review SM				1.25	1.00
Shortcomings SM I				1.00	
Detection methods				0.50	
Shortcoming SM II				0.50	
Extended H sectors				1.00	
SUSY				1.00	1.00
composite Higgs				0.50	
New approaches Hierarchy problem				0.75	
Extra dimensions				0.50	
DM models				1.50	1.00
EFT				0.50	1.00
Direct searches and precision tests at colliders				0.50	
10 years with the Higgs boson				0.50	
Future colliders				0.25	
Low-energy precision searches				1.50	
Feedback and Conclusion				0.25	
Sum	**16.25**			**12.25**	**4.00**

lectures

Tutorial: exercises to be solved in class and continued in the remaining hours

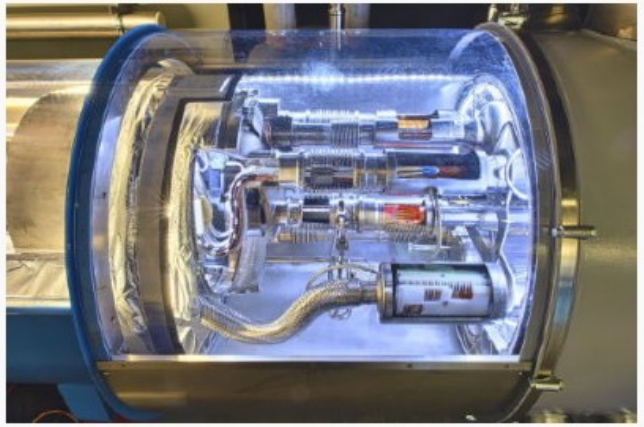
Special events

- Building our own cloud chambers and detecting cosmic rays: *today*
- Guided tour to the synchrocyclotron & ATLAS visitor center
- Visit at the Microcosm
- Visit at the Universe of Particles in the Globe
- Group picture: *today before lunch at the blue accelerator pipes on the grass next to the canteen*



Particles all around us

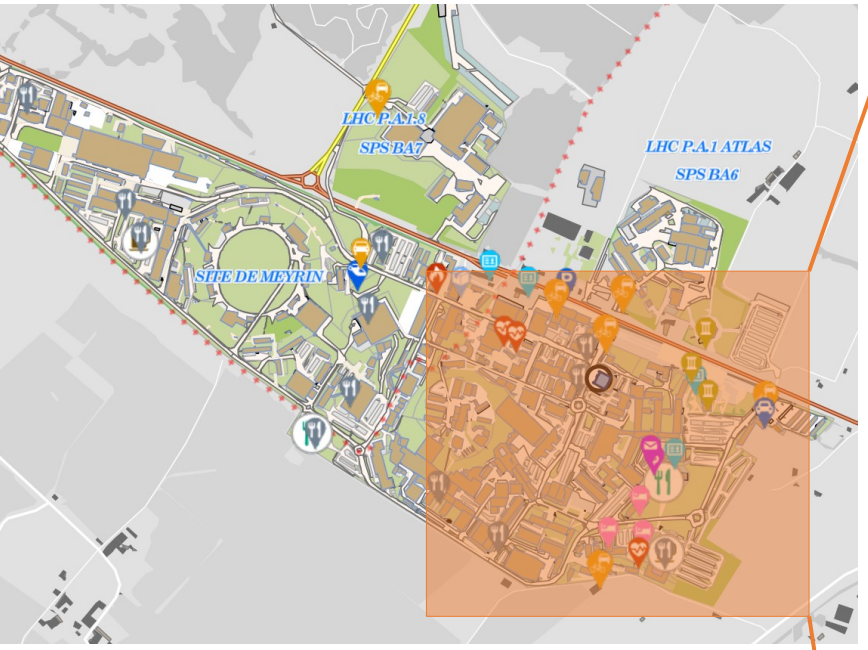
Enjoy the inspiring atmosphere on the ground floor of the Globe of Science and Innovation. Enter the world of particles and see with your own eyes the tracks left by cosmic rays, discover the first web server and find out more about CERN's experiments in our interactive exhibition.



Inside the Large Hadron Collider

Take a selfie in the tunnel! Microcosm's scale mock-up of a section of CERN's biggest accelerator includes real pieces of equipment. Learn about the technical challenges and find out how ingenious engineering can create solutions that evolve into innovative technologies for the benefit of everyone.

Slide credit: Agnese Mariotti



FACILITIES @ CERN

ENTRANCE B

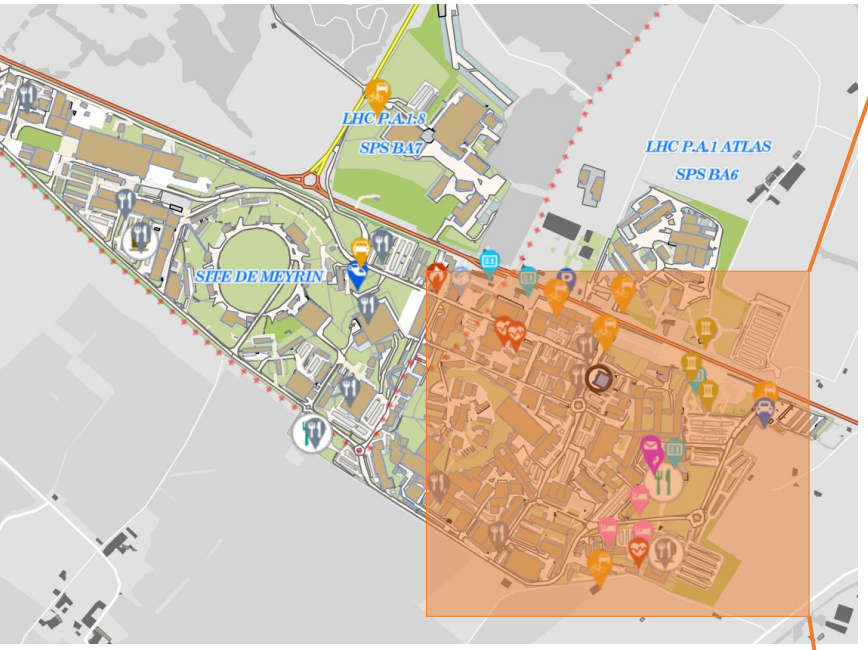
Seminar room (4/S-030)
Bldg. 4, Floor S, Room 030

Restaurant R1
(Bldg. 501)

Hostels
(Bldg.s 38, 39, 41)

- Kitchen
- Laundry room
- Canteen

Slide credit: Agnese Mariotti



IMPORTANT APPOINTMENTS

ENTRANCE B

Monday afternoon
Get access cards (Bldg. 55)

Tuesday @ 8:55
SynchroCyclotron visit (Bldg. 300)

Monday
Workshop @ S'Cool Lab (Bldg. 143)

Meeting point, either:
- Reception (Bldg. 33) @ 15:55
- Seminar room @ 15:45

Slide credit: Agnese Mariotti

SUPERMARKETS

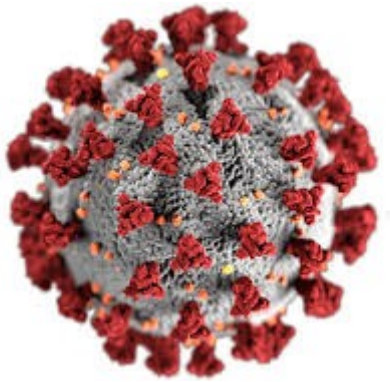
Organisation of the lecture

- The lecture will be mostly at the blackboard. In addition, I will present slides with summaries of experimental results.
- I will upload photos of the notes on the black board and the slides on StudIP.
- If you would like to have latexed lecture notes, you can volunteer to type one chapter each. This will be an excellent possibility to review the topics, especially as a preparation for an exam. I will then edit and complete the notes and provide them on StudIP.
- If you want to take an exam, you need to reach 50% of the homework (can be submitted within 2 weeks after the lecture) and present an exercise during this week.

Administration

- Need to sign presence sheet
- Reimbursement of your travel costs:
  - Send email with IBAN & BIC to Tanja Wießner tanja.wiessner@itp.uni-hannover.de
  - Bring her the original of your train ticket in an envelope with your name to Appelstr. 2, building 3701, room 239
- Needs to be completed by 31/08/2022
- Reimbursement to your bank account within 6 months, most likely much faster

Covid



- (self-)test at the start and on Wednesday
- Please wear a mask in the seminar room
- technical service wrote me about the ventilation in this room 4/S-030:
  - “This room is equipped with fresh air ventilation 400/1000 m3/h (small speed/ high speed), tuned at high speed in summer, and with additional cooling units. No need to open the windows.”
- Read the CERN rules: https://hse.cern/covid-19-information
- If you develop symptoms, self-declare on https://tramed.web.cern.ch/ (if possible as a guest?) and/or take a self-test

Hoping that all will stay healthy!

Quick round of introduction

About myself

Until 2006: Hannover

2006-2012: **B.Sc., M.Sc.**

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

Erasmus UNIVERSITY OF HELSINKI

M.Sc. thesis DESY.

summer student 2009 DESY. 2010 Fermilab CERN

2012-2015: **PhD** DESY.

Summer 2014 CERN

2015-2019: **Postdoc/Minerva Fellow**

מכון ויצמן למדע WEIZMANN INSTITUTE OF SCIENCE

Minerva Stiftung

2019-2021: **Postdoc/Feodor-Lynen Fellow**

Fermilab THE UNIVERSITY OF CHICAGO

Alexander von Humboldt Stiftung/Foundation

Since 6/2021: **Senior Research Fellow & QTI-TH coordinator**

CERN QUANTUM TECHNOLOGY INITIATIVE

Since 6/2021: **Junior Professor**

Leibniz Universität Hannover

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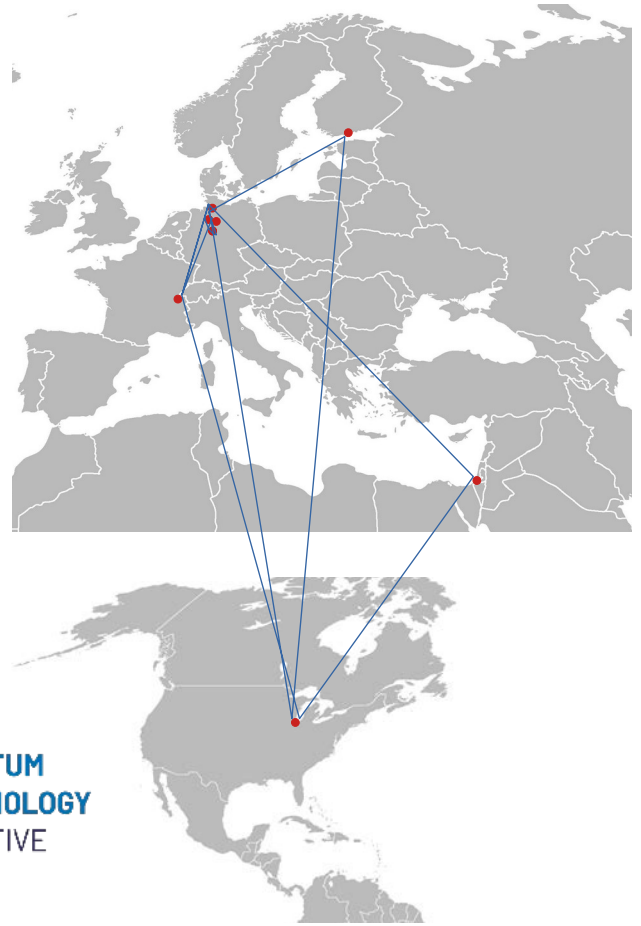

Research: Phenomenology beyond the SM at colliders and at low energies

→ Higgs physics, CP violation, baryogenesis, new low-mass particles and their effects on atoms and ions

Literature recommendations

- SM: lecture notes by Roman Kogler, SoSe 2022
- Griffith book
- Gunion, Haber, Kane, Dawson: The Higgs Hunter's Guide
- BSM lecture notes by Matthew McCullough (CERN)
- TASI lecture notes, especially

TASI lecturer	Topic
Liantao Wang	Quick introduction
Heather Logan, Christoph Englert	Higgs
Ayres Freitas	SM precision
Timothy Cohen (CERN)	EFT
Paddy Fox	SUSY & WIMPs
Anson Hook	Axions
Michelangelo Mangano (CERN)	Future colliders

Goals: At the end of this lecture, you will

1. remember the Standard Model (SM) and its shortcomings,
2. have an overview of models that extend the SM by including additional particles and interactions, in particular
   - extended scalar sectors
   - supersymmetry
   - extra dimensions
   - alternative solutions to the hierarchy problem
3. know different types of Dark Matter candidates
4. have an idea of how to parametrize unknown New Physics at energy scales far above the electroweak scale as an Effective Field Theory
5. be aware of New Physics scenarios that predict very light new degrees
6. have an overview of experimental searches and measurements at the high-energy and high-precision frontiers