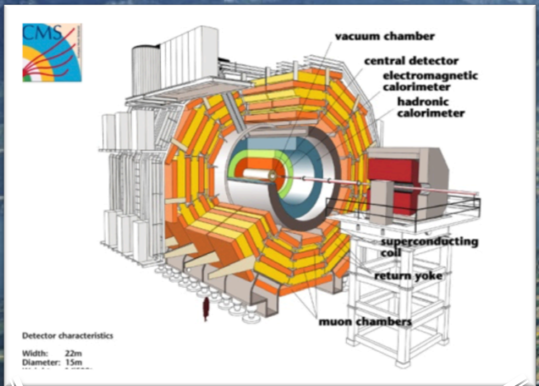
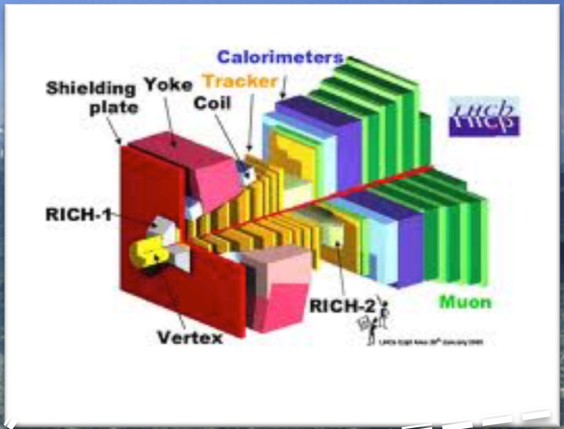
Prof. Dr. Florencia Canelli and Prof. Dr. Kilminster (CMS)
Prof. Dr. Nicola Serra (LHCb, SHiP), Prof. Dr. Ueli Straumann (LHCb)
Universität Zürich

Bachelor/Master projects at the LHC 2017

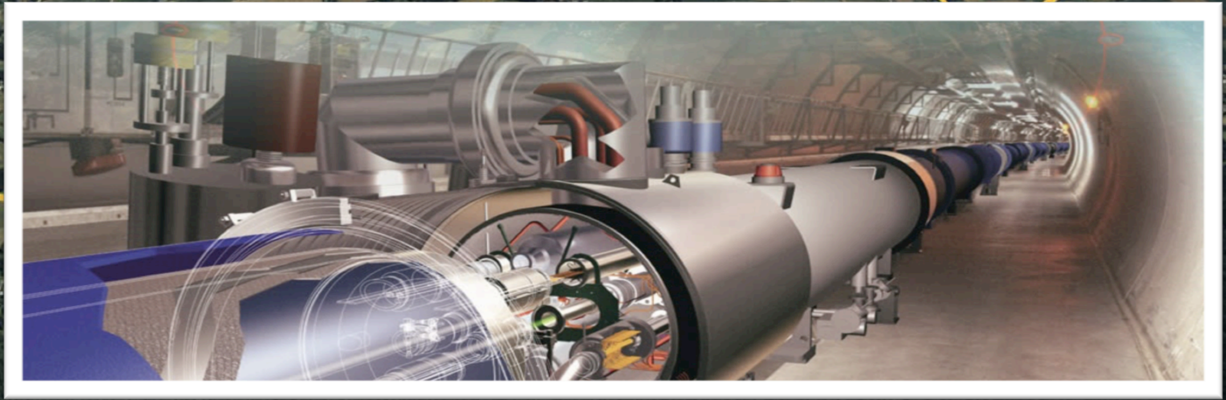




LHCb
ATLAS
CERN Meyrin
CERN Prévessin
SUISSE
FRANCE
CMS
ALICE

Experimental particle physics

- Analysis of data, *physics results !*
- Operation of detector, *need to collect data efficiently*
- Detector development, *always designing the next one*



Large Hadron Collider at CERN
Collides protons at 13 TeV
28 km circumference
1.9 K cooling
10^8 pp collisions/s

Experimental research at LHC

Physics:
- Get deeper insight on the Standard Model of particle physics
- Search for something that has never been looked for

Ideal requirements: KTI and II, python/C++

Learn most advance analysis tools:
- artificial neural networks, multivariate analysis techniques

and many software skills
- Data analysis tools (ROOT)
- Programming (C++, Python)
- Distributed computing (GRID)
- Statistical analysis tools

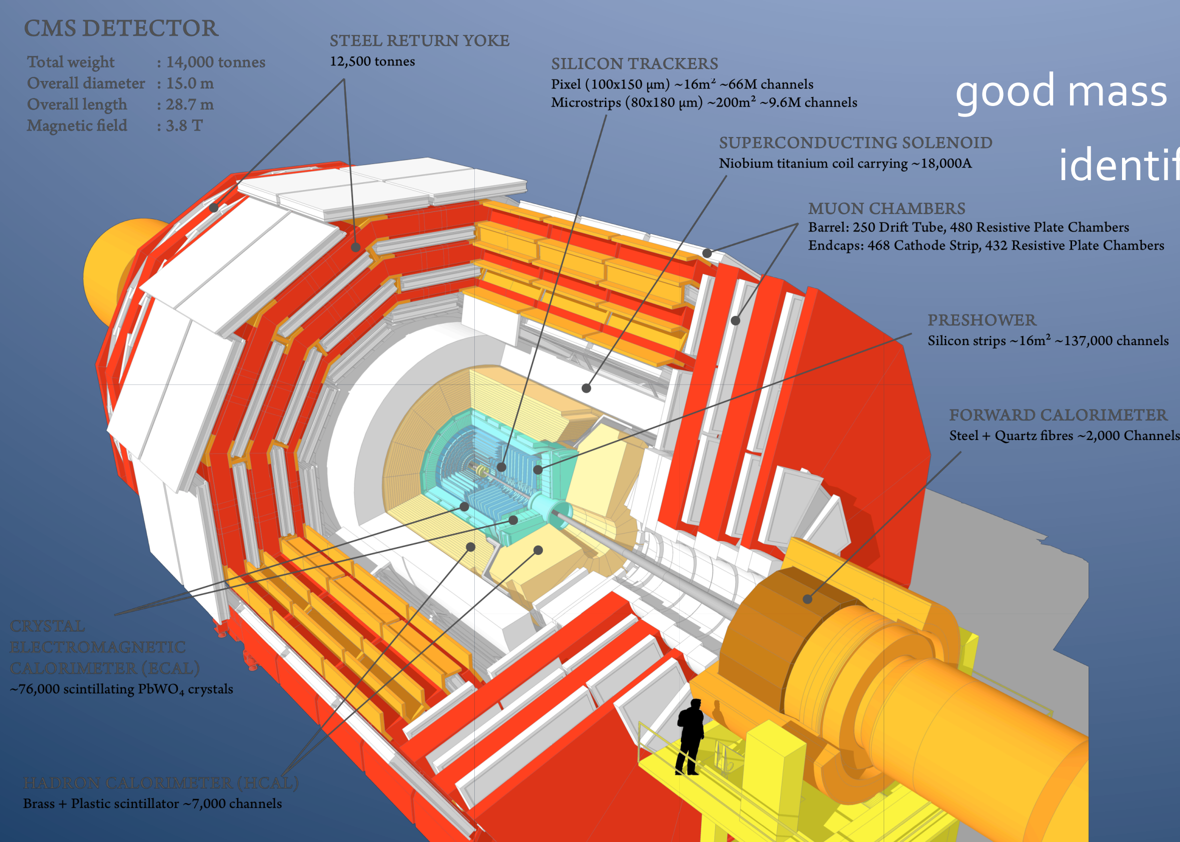
Design and develop new type of detectors/experiments
- Operate and calibrate the most sensitive detectors of the LHC
- Test detector in a beam of particles

Work in an international collaboration
- collaborate with other groups/universities
- visit CERN

Presentation of results
- within our group
- topic meetings with other universities
- within CMS collaboration meetings
- SPS/conference (masters)
- Write a public document (paper or note)

CMS Experiment

Prof. Dr. Florencia Canelli
Prof. Dr. Ben Kilminster



multi-purpose detector

good mass resolution to discover new particles

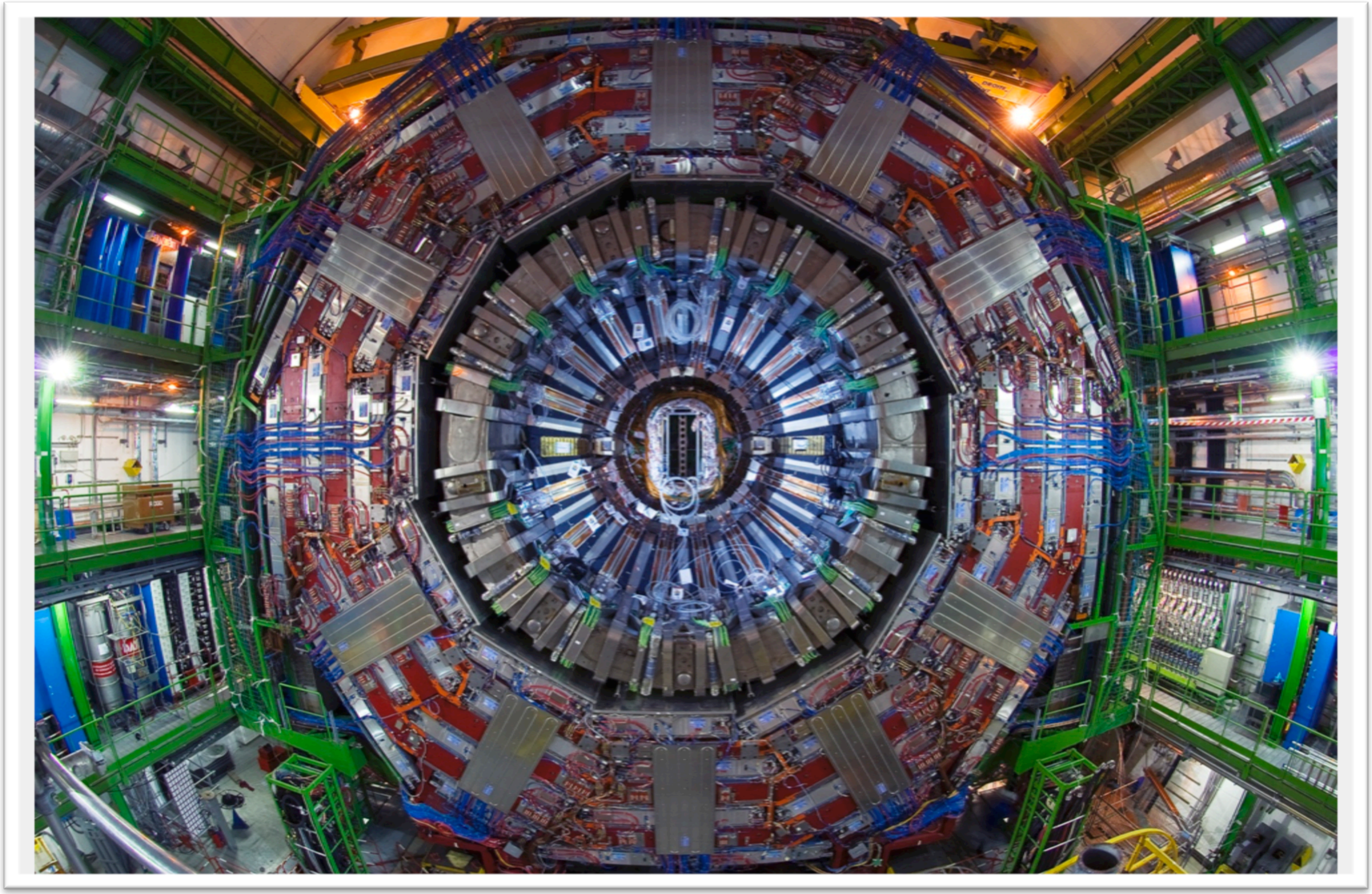
identifying missing energy of dark matter

~2500 scientists

15 000 tons

Currently taking data !

CMS Experiment



UZH@CMS Group 2017

Faculty: F. Canelli, B. Kilminster

Senior scientists: P. Robmann, L. Caminada (jointly w/ PSI)

Postdocs: Y. Takahashi, A. Zucchetta, A. de Cosa, C. Seitz, S. Donato

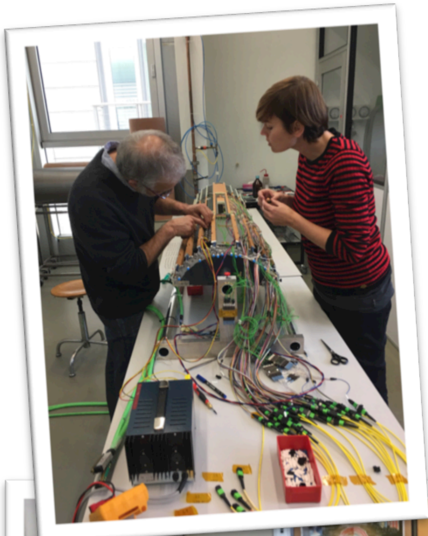
PhD Students: C. Galloni, I. Neutelings, T. Arrestead, D. Salerno, G. Rauco, V. Mikuni, D. Brzhechko, K. Schweiger

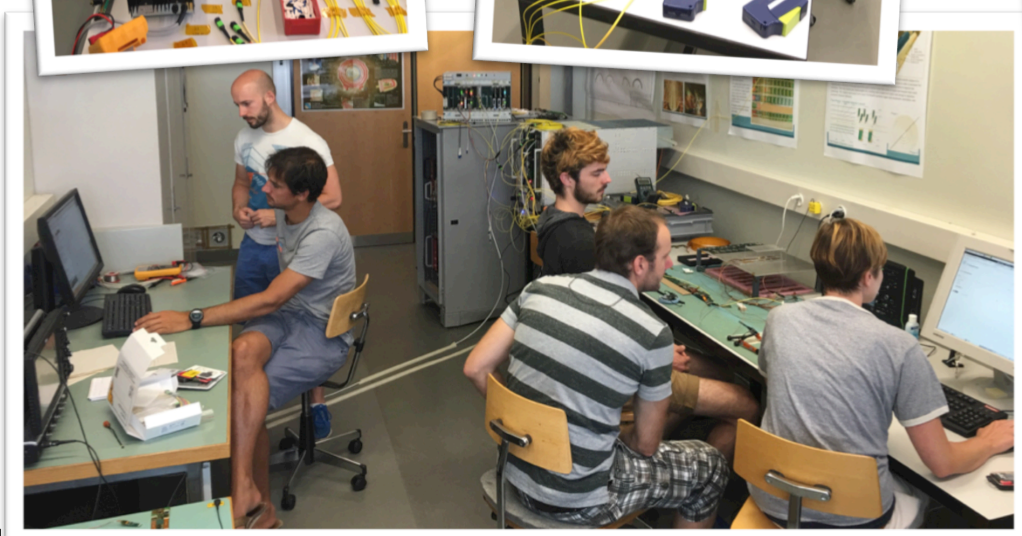
Master students: M. Gienal

Undergraduate students: P. Bärtschi, R. Bürgler

CMS Pixel Detector

Our main area of detector development. This year we finished building a new 100 M channel silicon pixel detector for CMS (installed on 02/2017)
Starting R&D on an even better system … Many hardware projects will be available





Pixel detector: High-precision tracking close to the interaction point to allow for reconstruction of primary vertices and secondary vertices of long lived particles (b-quarks, c-quarks, tau leptons)

CMS – Available projects

Our groups are involved in detector hardware, calibration and operation, and data analysis

There are many available research projects in all these areas

- 3-12 months duration
- Data analysis and hardware topics
- Projects details in the next slides

More information :
http://www.physik.uzh.ch/groups/cms

Questions ? Contact us !

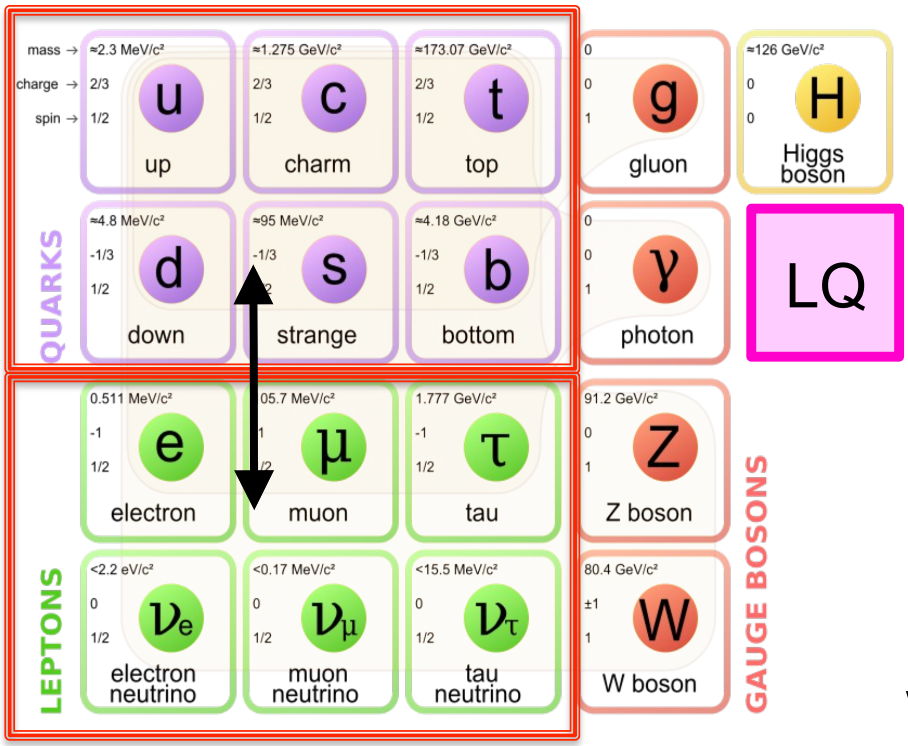
canelli@physik.uzh.ch
bjk@physik.uzh.ch

kilminster@physik.uzh.ch

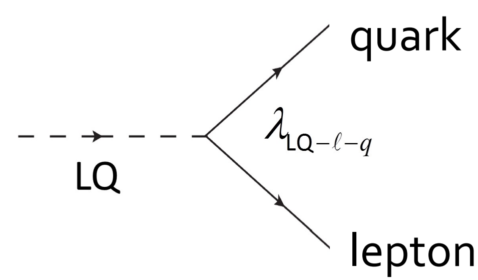
Projects in B. Kilminster's group

1. Leptoquark search

Why do quarks and leptons have similar structure ?



Maybe there is a new boson (called the Leptoquark; LQ) that connects the quark and lepton



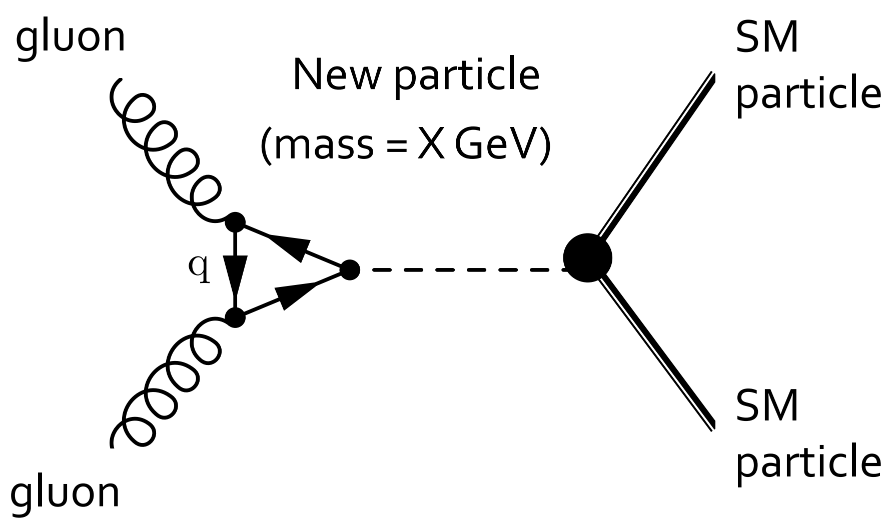
In fact, recent B-anomalies reported by LHCb prefers leptoquark with mass ~TeV

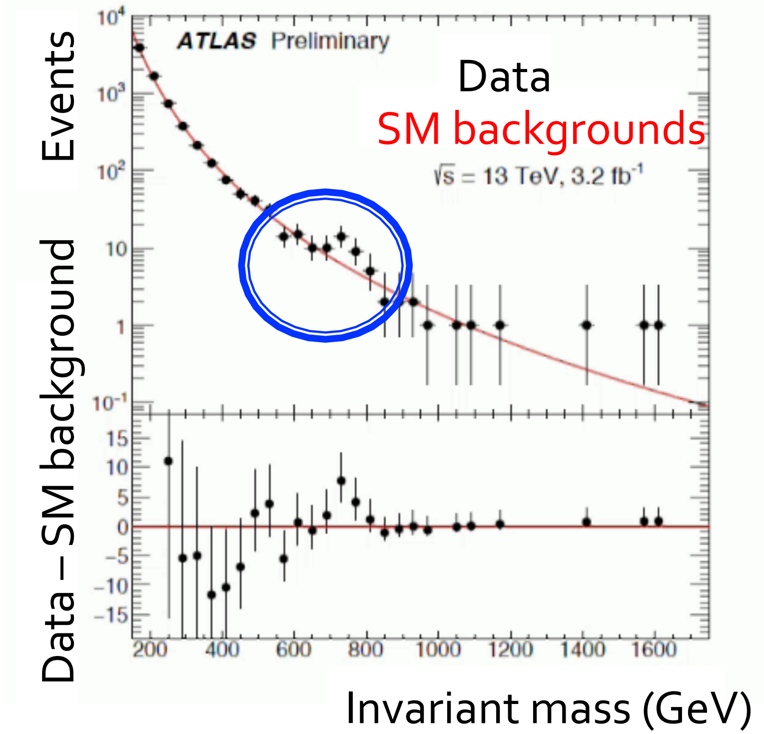
We *just* started new searches to directly detect them at the CMS

Lots of new ideas & developments are to come in coming few years, for which you are welcome to join !

2. What goes bump in the night ?

If new particles exist beyond what we know now, we'll observe a "**bump**" in the invariant mass distribution, over standard model backgrounds





- We have seen some bumps, and we want to look farther …
- Student will join a team effort to investigate bumps
- You can be the first person to **find a new particle at the LHC !**

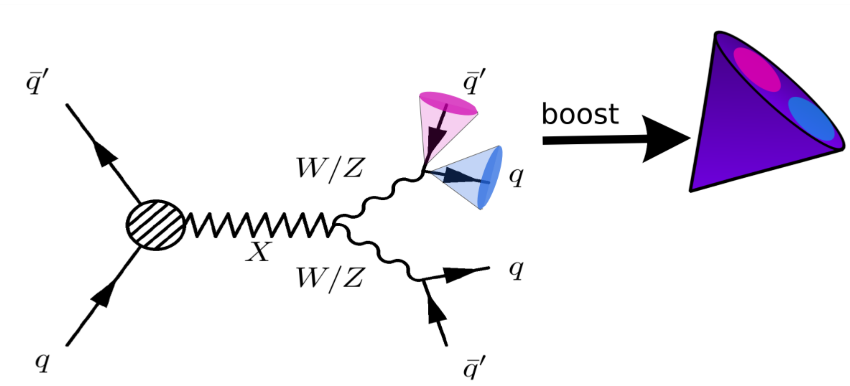
CMS: Kilminster

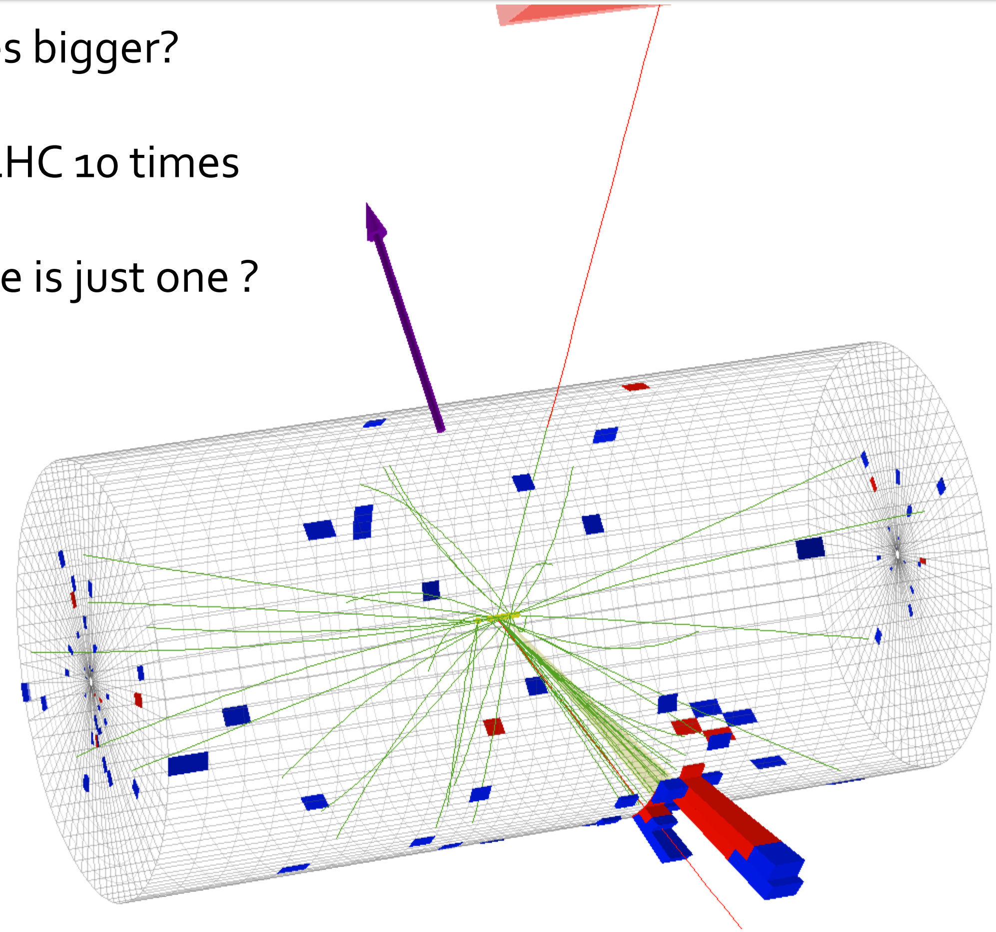
3. Boosted resonance search

Why is the Higgs boson mass not 1016 times bigger?

Answer predicts particles produced at the LHC 10 times more massive than anything known

Or additional Higgs bosons… who said there is just one ?



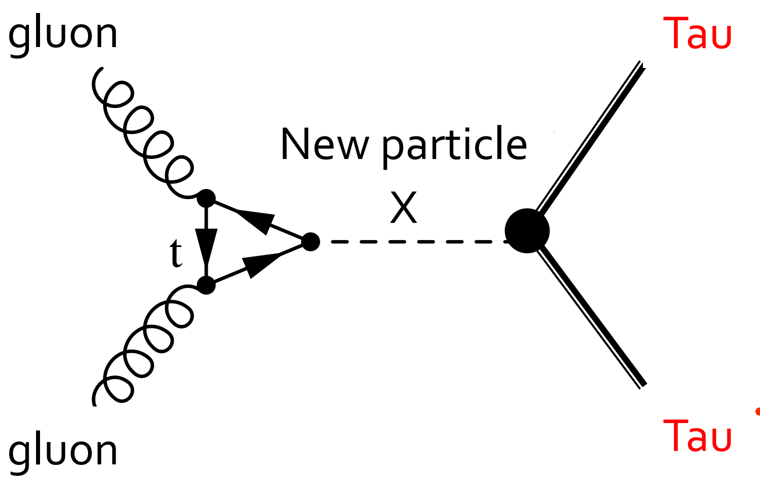


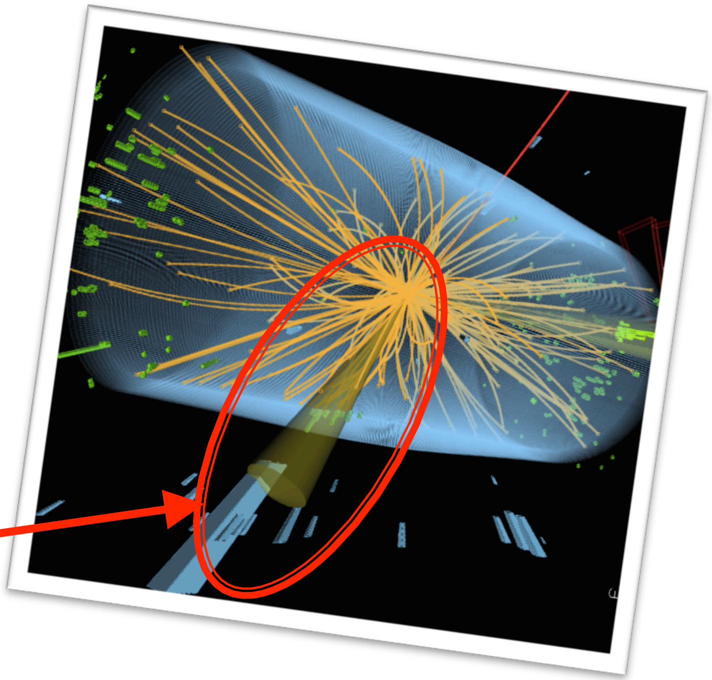
The student will have the chance to:

- Search for a new particle never previously tested
- Learn and apply advanced techniques such as multiariate and machine-learning tools
- Discover new forces (maybe)?

4. Sophisticated tau identification

In many new-physics models, new particle preferentially decays into a **tau pair**





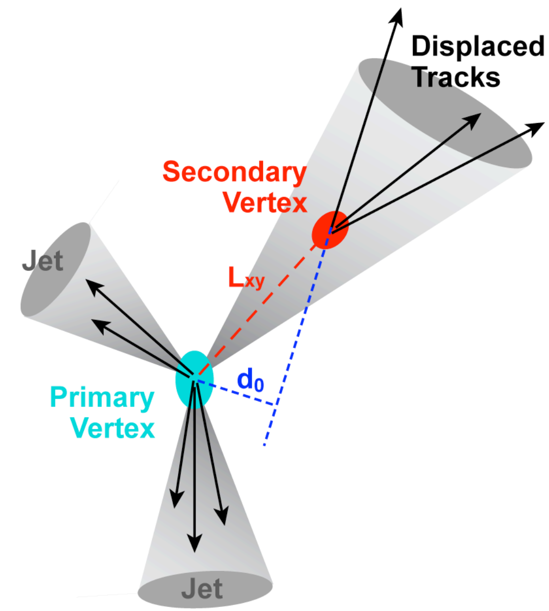
However, tau is the most difficult particle to identify due to its complicated decay

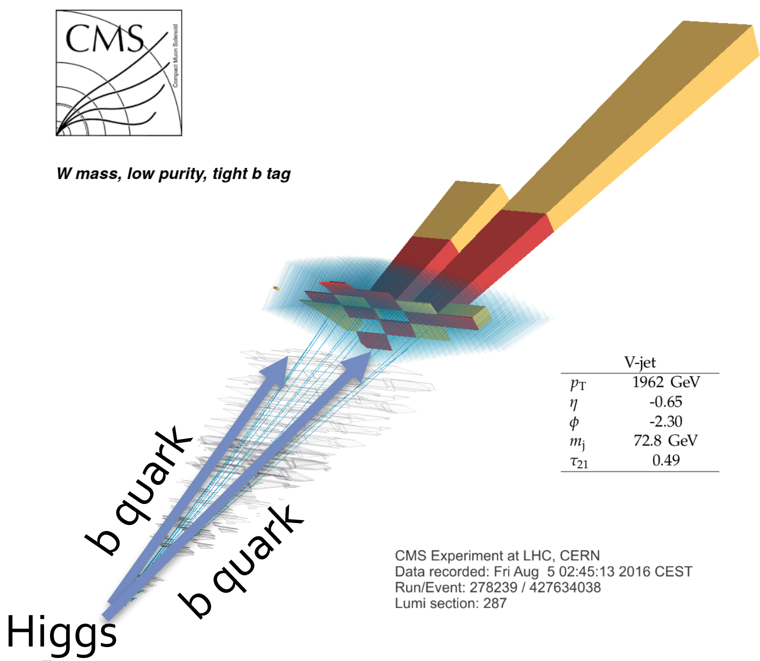
Exploit state-of-the-art **machine-learning techniques** to improve tau identification capability

5. B-tagging identification

New particles will also decay to b quarks :

- B hadrons decay after a measurable distance (~ 1 mm) as measured by a pixel detector
- Problem : b-tagging techniques not optimized for high-mass new particles





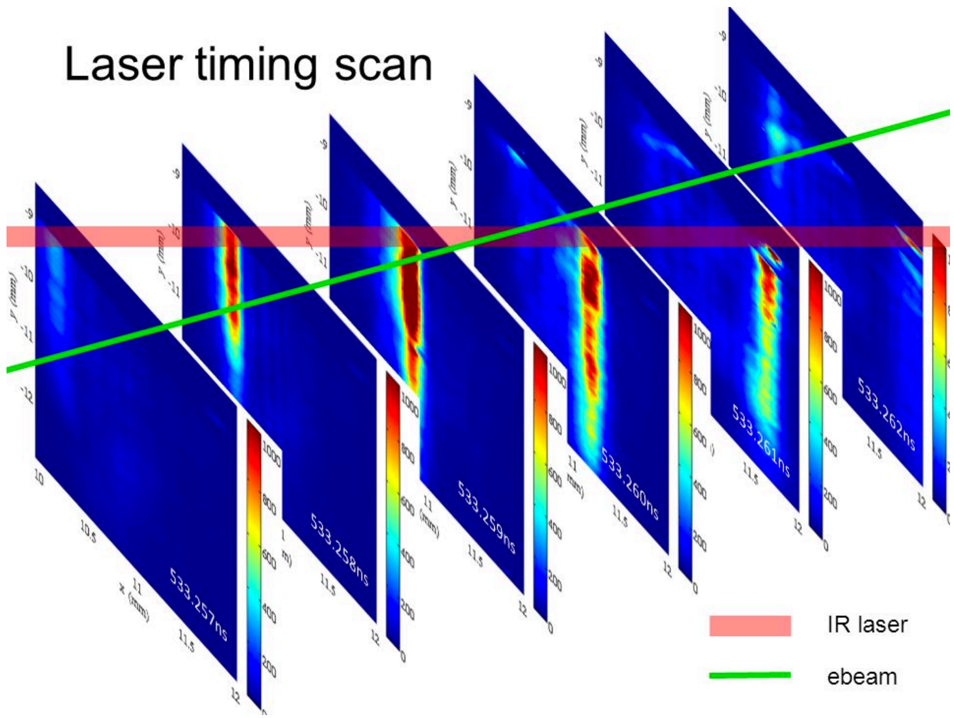
Develop a never-before utilized method of b-tagging algorithm

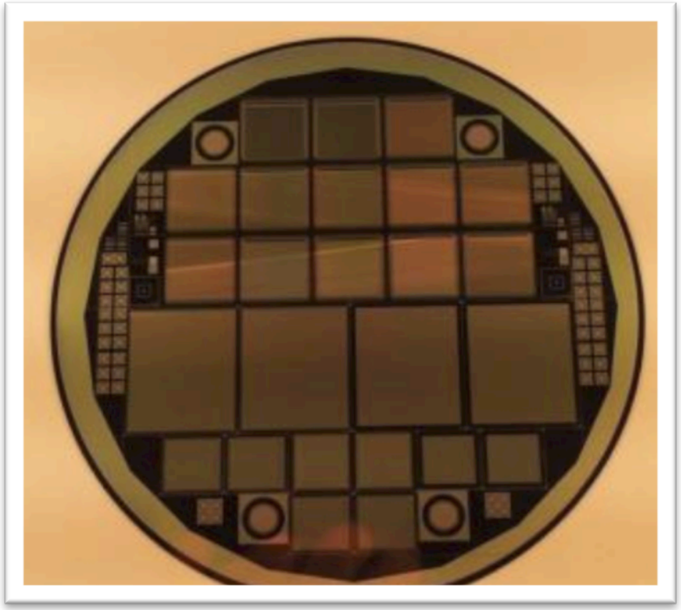
- Takes advantage of the 100-million channel pixel detector built @UZH
- Learn and develop multivariate analysis and machine learning tools

6. New type of timing detector

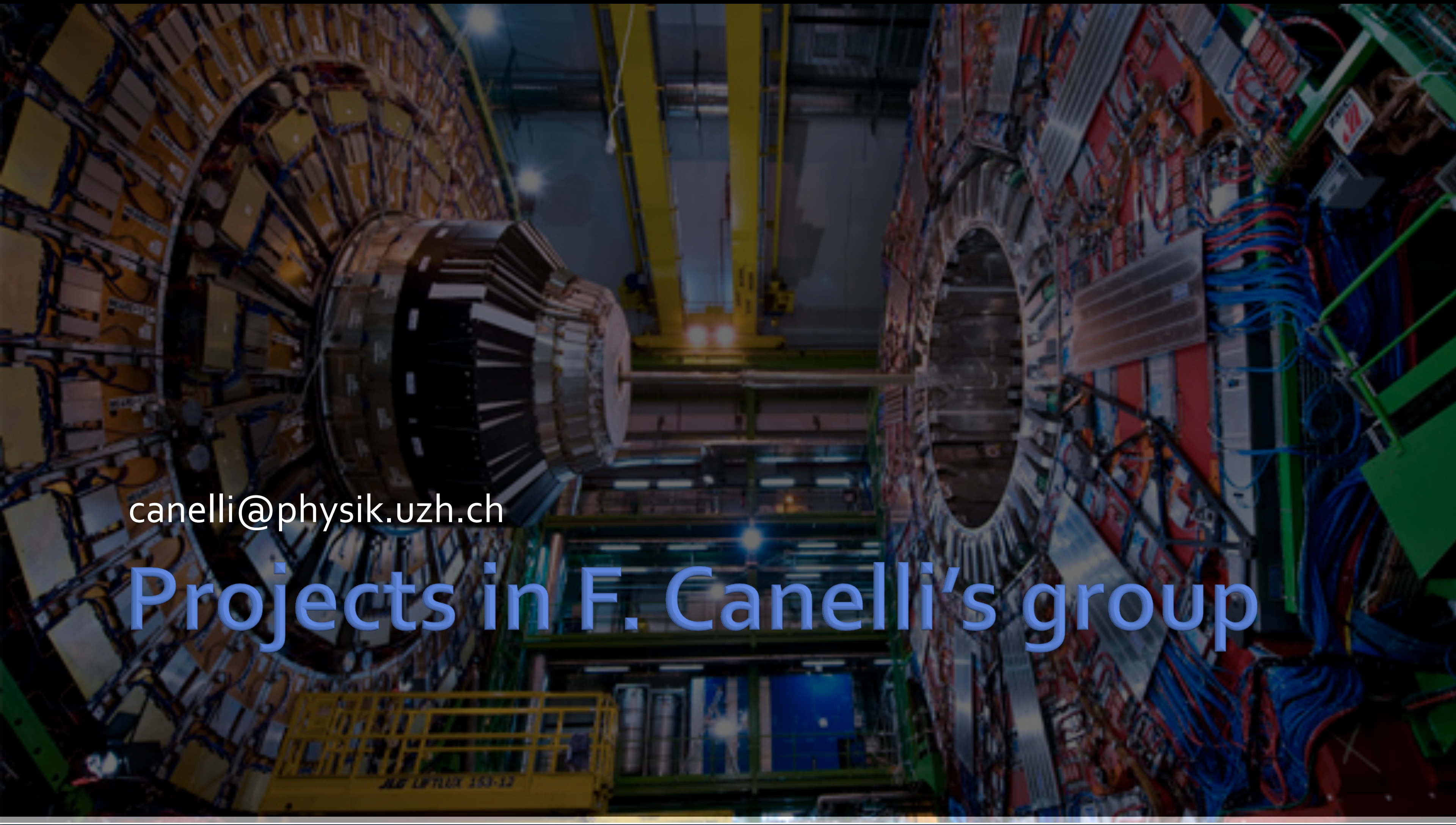
Our group is developing a new detector that can measure time and position extremely precisely

- 30 micro-meter position
- 30 picosecond (10^{-12}) precision
    - (Light travels only 1 cm in 30 ps)





- Measure the properties and test these detectors in a particle beam
- Help become an expert in a new technology that will have a range of scientific and commercial applications in the future



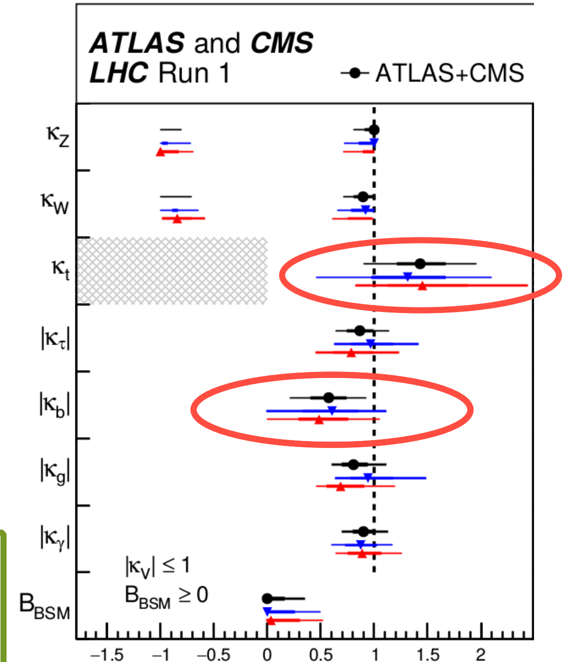
canelli@physik.uzh.ch

Projects in F. Canelli’s group

1. Search for top and Higgs production

Higgs production in association with a top quark pair (ttH) offers an unique direct probe for Higgs-top coupling

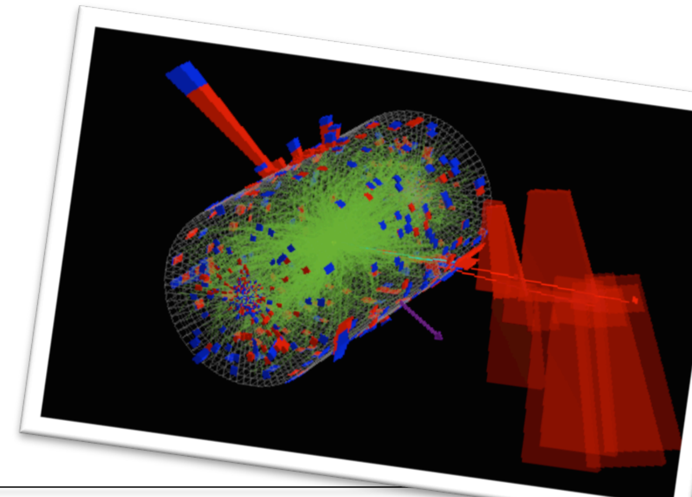
- Fully hadronic ttH (t→bqq, t→bqq, H→bb)
  - Hadronic Higgs decay (H → bb):
    - large branching ratio (58%);
    - H → bb has not yet been observed
  - Hadronic top decay (t → bqq):
    - large signal yield and large QCD background



Available projects

- improvement of signal/background discrimination (Matrix Element Method);
- develop methods for rejection and estimation of QCD background;
- study of b-tagging algorithms;
- measurement of the trigger efficiency;

Can start any time, ideal project duration 6-12 months

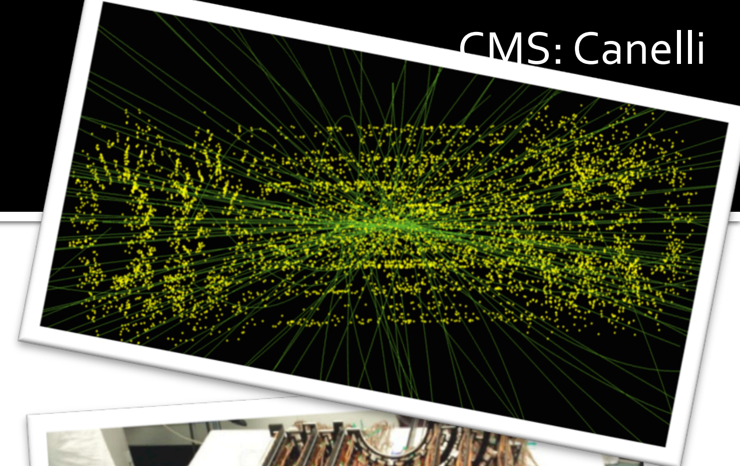


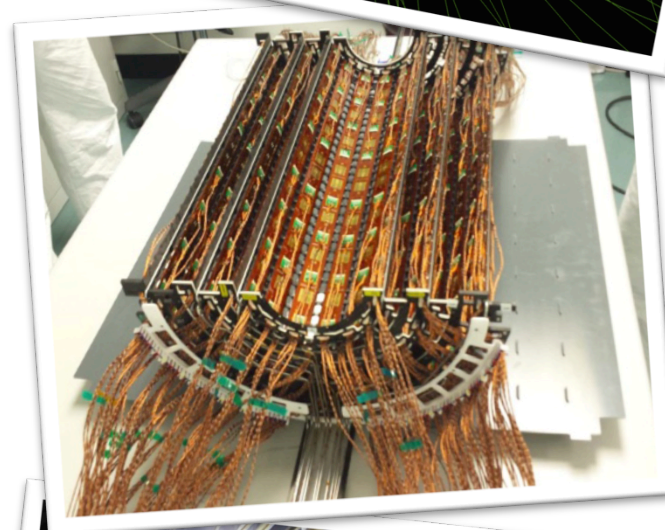
2. Pixel Detector

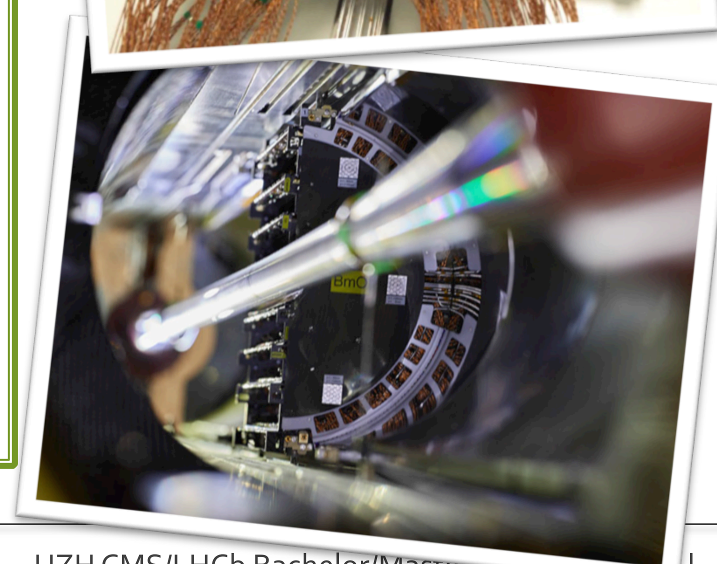
- Pixel detector provides high-precision 3D measurement of particle trajectories
- Upgraded detector installed in 2017
- UZH involved in all aspects of pixel work: construction, operation, calibration, monitoring, maintenance, R&D for future upgrades…

Available projects

- Monitoring of detector performance (6-12 months, can start any time);
- Detector calibration (3 months, requires presence at CERN);
- Simulation studies for future upgrades (6-12 months, can start any time);
- Testing of electronic components for future upgrades (6-12 months, at PSI. starting from mid 2018);

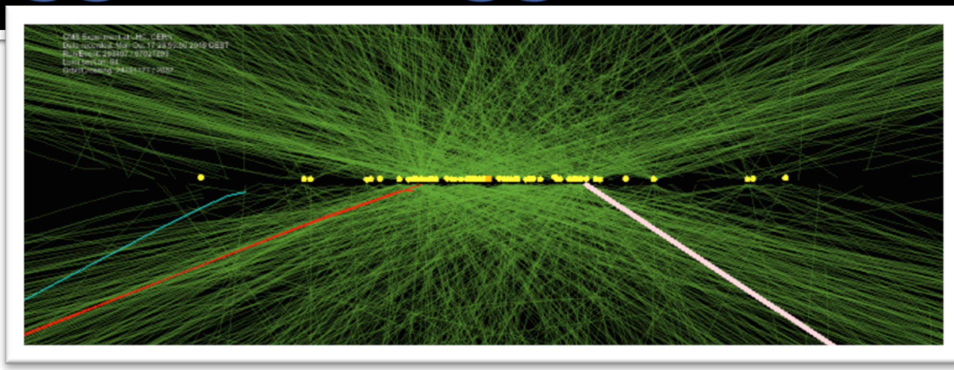






CMS: Canelli

3. Trigger for Higgs and New Physics



In 2017, the LHC reached record high instantaneous luminosities

- it delivered up to **60 simultaneous pp collisions** (pile-up) at ~20 MHz,
- even larger luminosity is expected for 2018!

Only ~1 kHz of events can be actually stored

- we use triggers to select online events using a fast event reconstruction

We need to improve our trigger performance under such high pile-up conditions

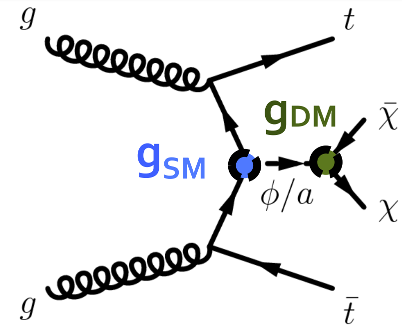
- missing transverse energy and b-tagging play a key role in the search for the Higgs and New Physics

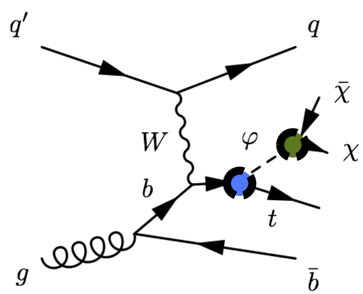
Available projects

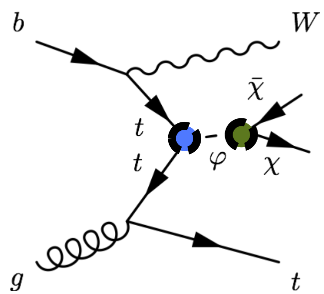
- optimization of online b-tag performance (~3 months)
- study and development of techniques to reject pile-up jets (~3 months)
- improvement on the missing transverse energy reconstruction (noise filter) (~3months)

4. Dark matter searches with top quarks

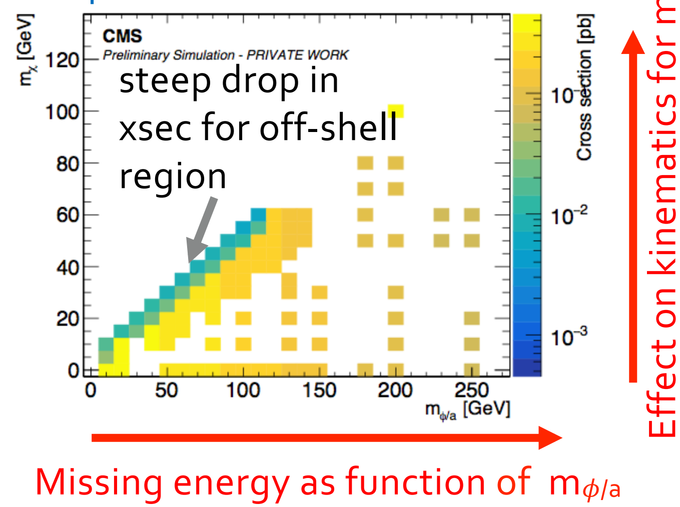
- New physics scenarios predict new mediator particles to couple preferably to heavy quarks
- This new mediator decays into a pair of DM particles
- Rate of single top + DM can be significantly enhanced with respect to tt + DM production in new physics scenarios







Example: Pseudo scalar model

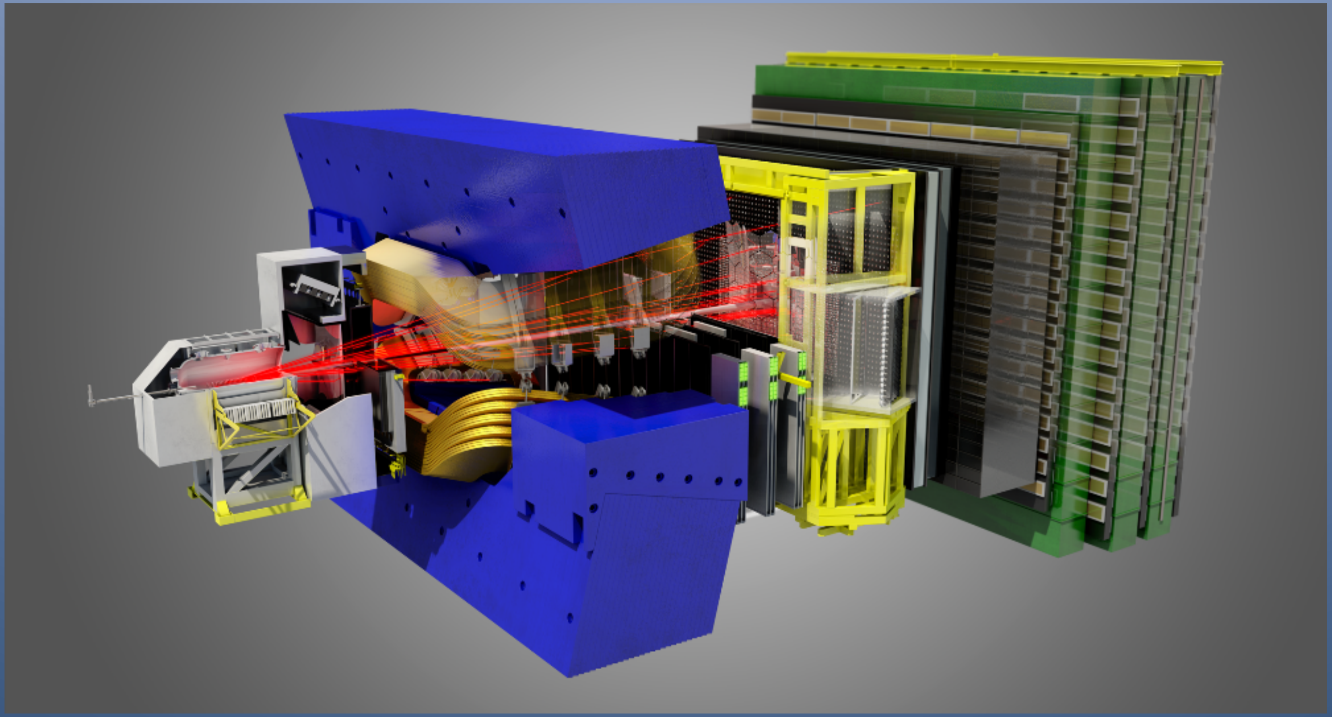


Available projects

- Study phenomenological implications of the new single top + DM model
  - Use state of the art event generators
  - Determine NLO cross sections
  - Test effect of different coupling and mass parameters
- Use data collected by CMS during 2016 to interpret the results
- Projects timeline ~3 month

LHCb Experiment

Prof. Dr. Nico Serra, Prof. Dr. Ueli Straumann
Dr. Katharina Müller, Dr. PD Olaf Steinkamp



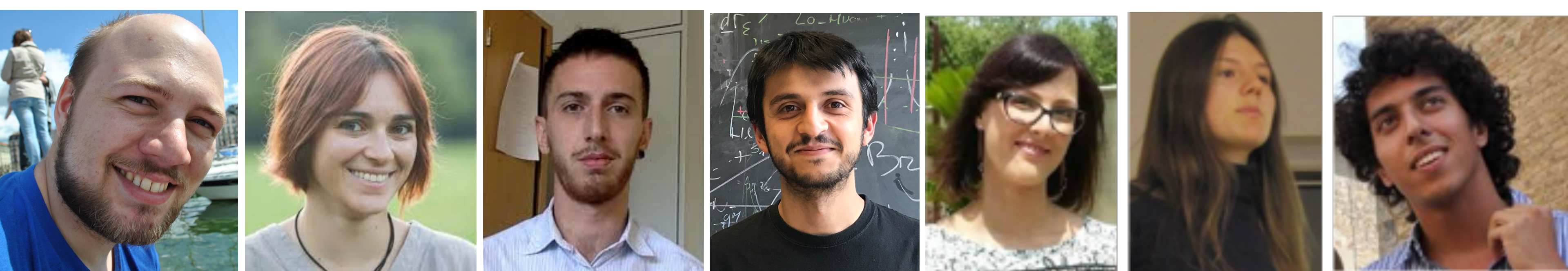
Detector specialized to measure decays of B-meson

UZH@LHCb Group 2017

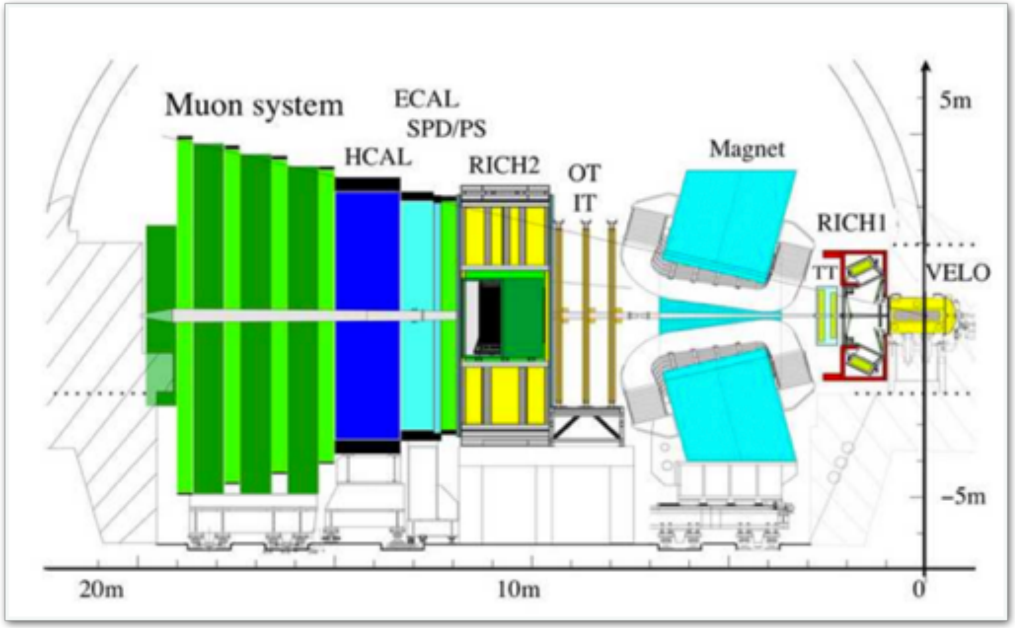
Senior Staff

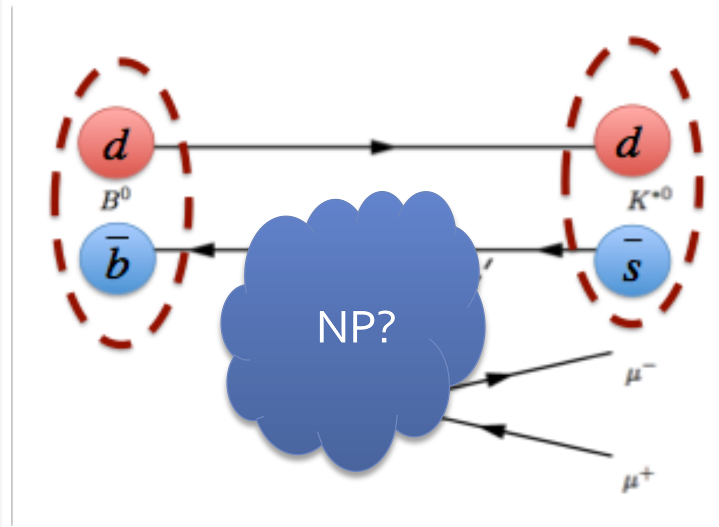
Postdocs

Ph.D. Students



LHCb Experiment

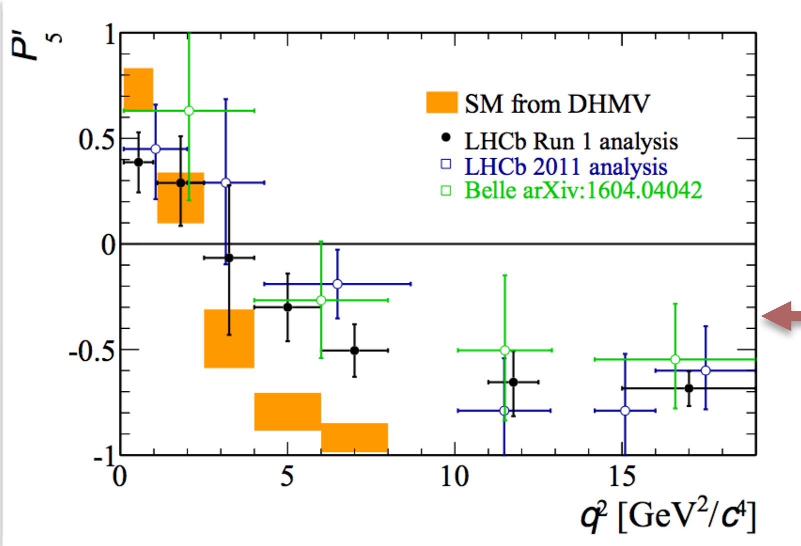




Experiment to perform precise measurements of B-meson decays

- Indirectly inferring the existence of new heavy particles by comparing with the Standard Model prediction
- Heisenberg uncertainty principle allows for the indirect search for new physics produced by virtual particles at energies orders of magnitude larger than the C.M. energy at LHC

LHCb - The Flavor Anomalies

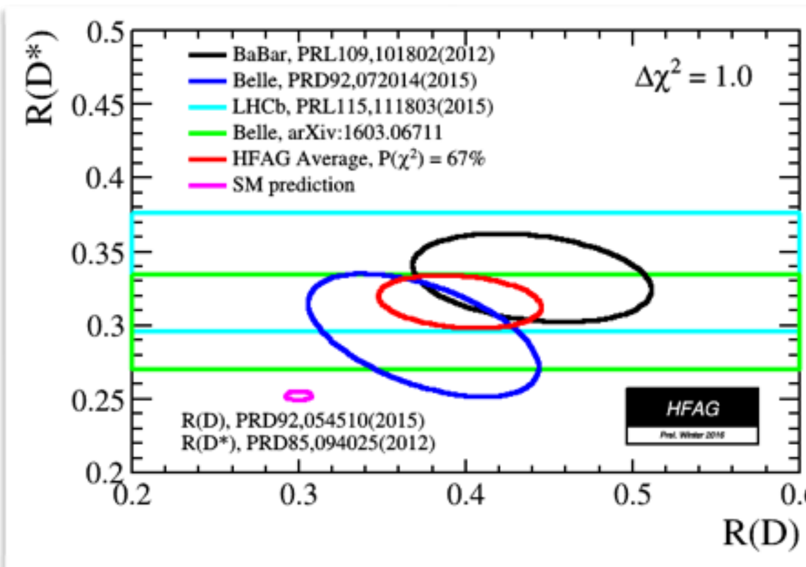


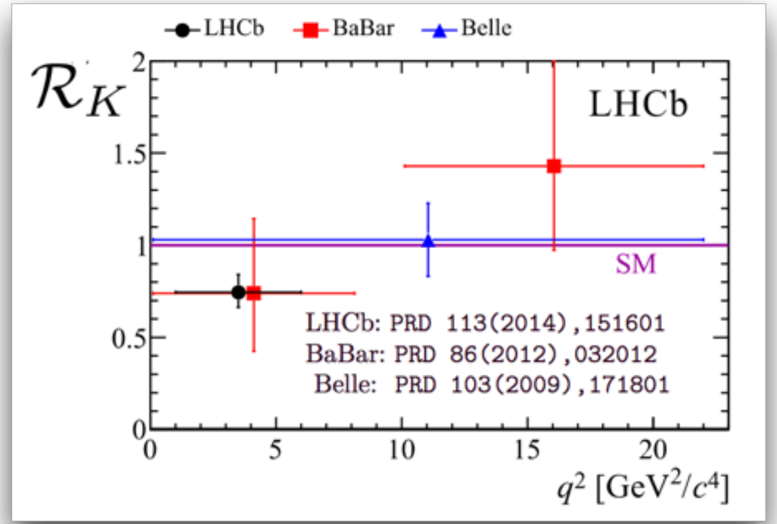
A set of measurements in the flavor sector at LHCb (and some other experiments) show coherent deviations with respect to SM predictions

This discrepancy could be caused by new particles (not present in the SM) contributing to the decays

- The UZH group @ LHCb group is one of the main groups working on these anomalies (e.g. we discovered the P5' anomaly)

Master/Bachelor Thesis Available





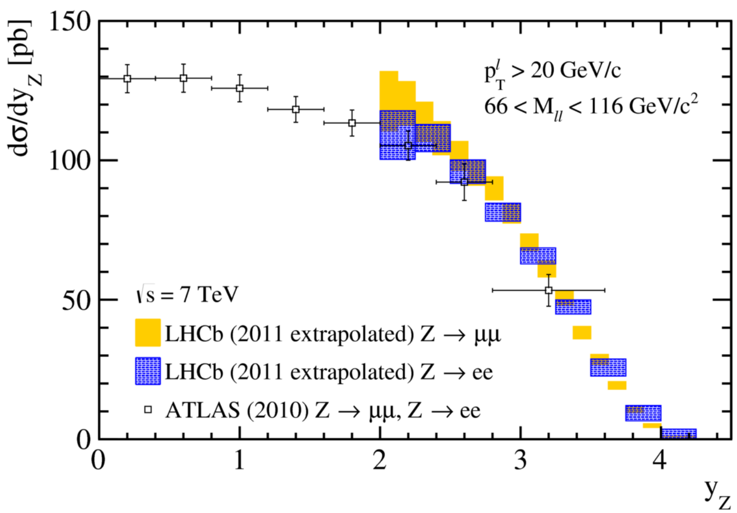
LHCb: Müller

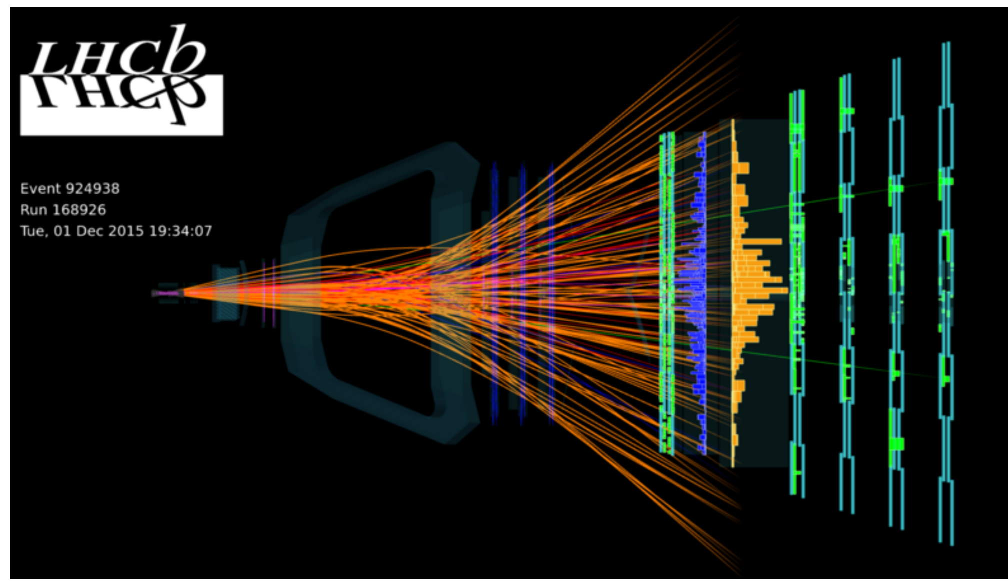
Forward Electroweak

LHCb has unique coverage in the forward region, complementary to ATLAS and CMS

- This makes it a general purpose detector in the forward region
- Possible measurements of Z and W production or Drell-Yan cross section

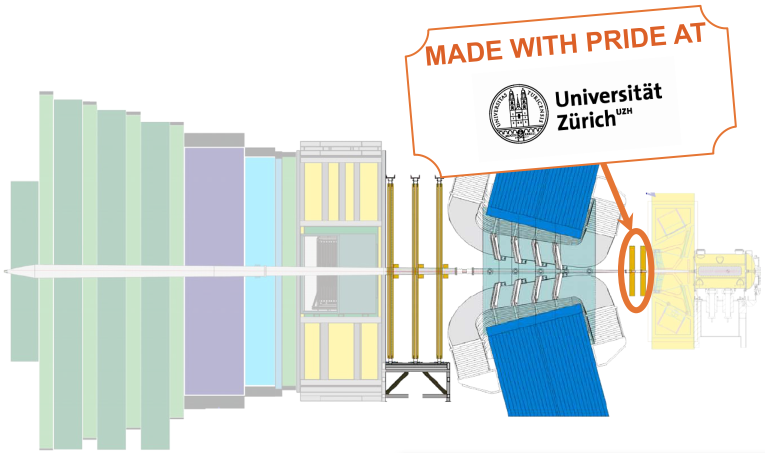
Master/Bachelor Thesis Available

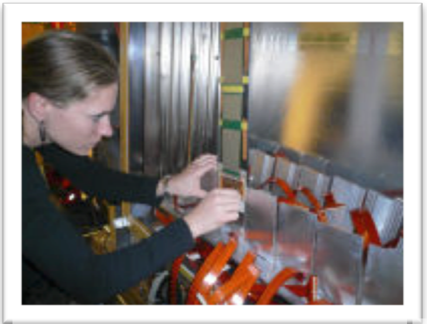




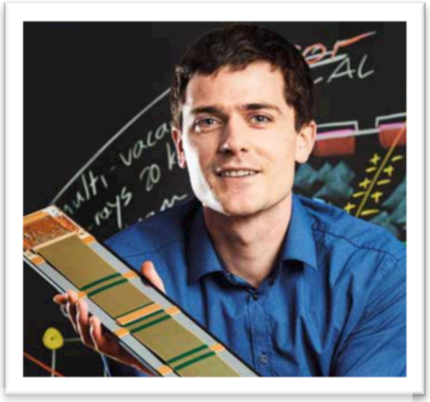
Important to control uncertainties on many direct New Physics searches

LHCb Upgrade(s)





Angela Büchler
(PhD thesis)



Christian Elsasser
(Bachelor/Master/PhD thesis)

"Tracker Turicensis" (= Zurich tracker) designed and built by our group (Steinkamp/Straumann)

important **LHCb Upgrade** in 2019/2020: new detectors with 40 x faster readout, better radiation hardness

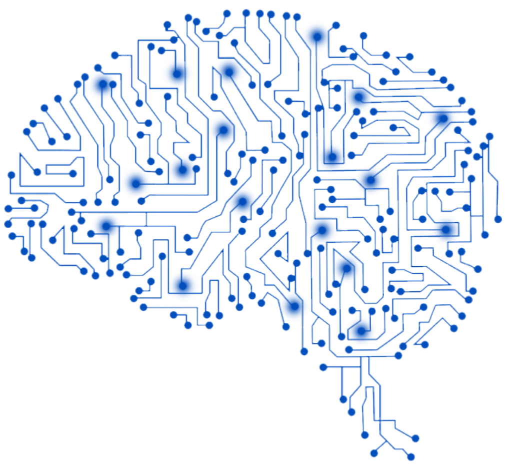
- our group involved in design, testing and commissioning of readout electronics

NEW: planning for **future upgrades**: collect data even faster than after first upgrade

- our group starting to get involved in development of new detector technologies (using silicon semiconductors) and novel algorithms for event reconstruction (using deep learning and machine-learning technologies)

Master/Bachelor Theses Available

Deep Learning



Deep Learning has revolutionised the field of Machines Learning in the last decade, we are studying

- Selections for signal against various backgrounds using low level information
- Unsupervised Learning with Autoencoders
- Tracking with Recurrent Neural Networks
- Event Reconstructions with Convolutional Neural Networks

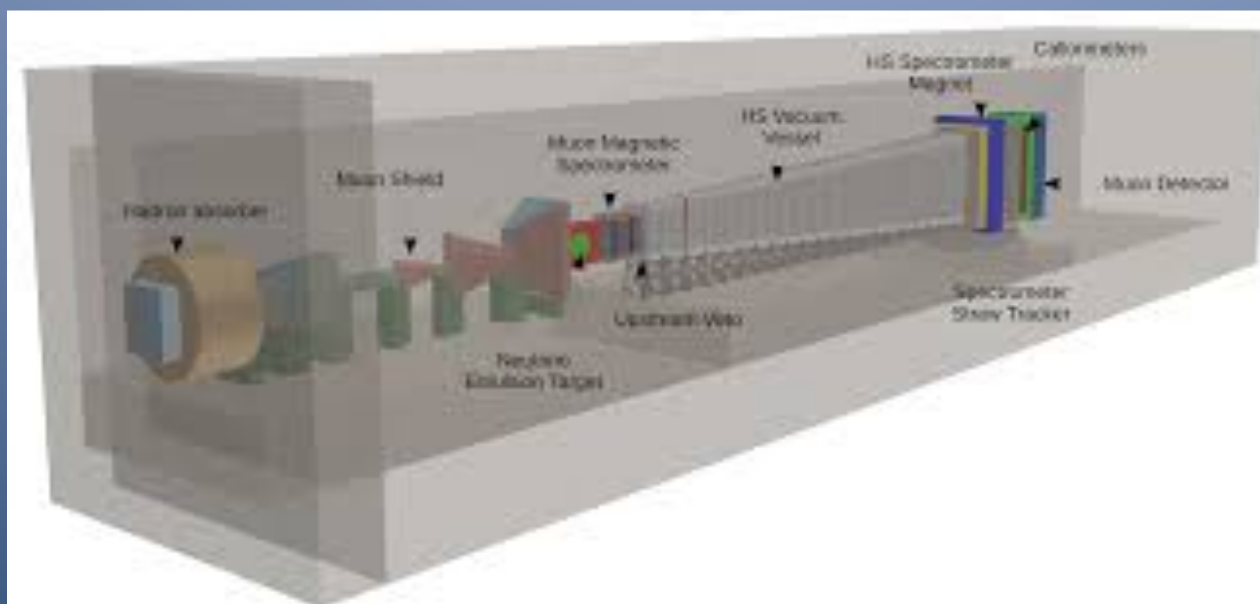
More advanced thesis (only master with previous experience)

- Generative Adversarial Networks or Variational Autoencoders for Simulation
- Reinforcement Learning for Optimization problems

Master/Bachelor Thesis Available

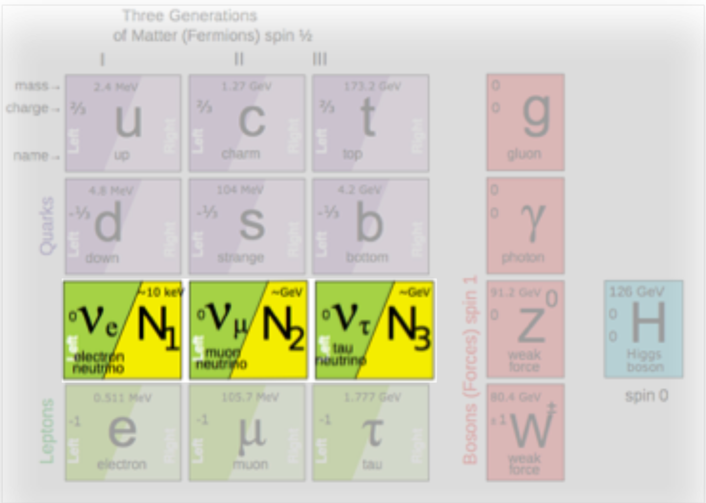
SHiP Experiment

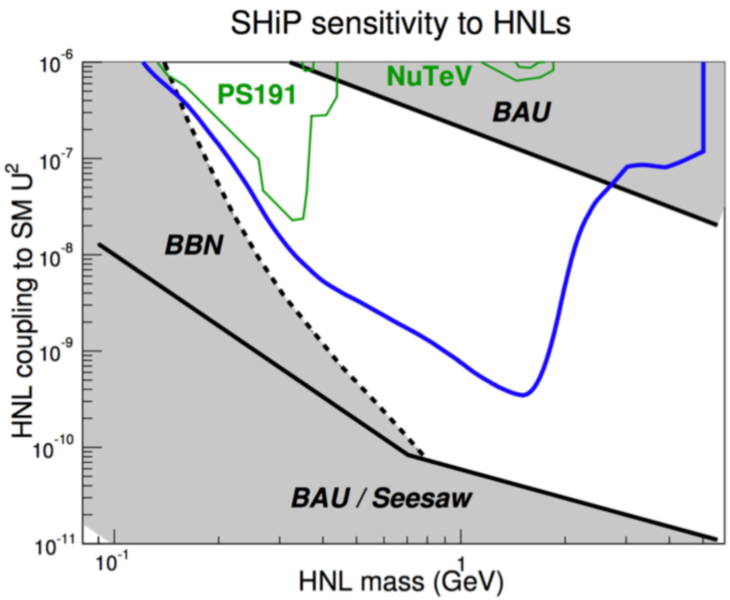
Prof. Dr. Nicola Serra



Search for Hidden Particles

SHiP Experiment





Proposal for a new fixed target experiment at CERN

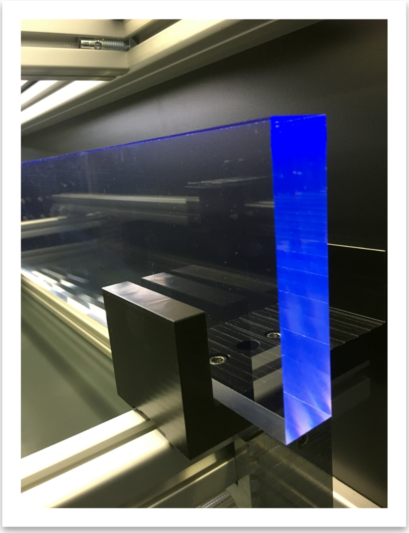
- Search for new very-weakly-interacting long-lived particles, e.g. sterile neutrinos, light supersymmetric particles, and vector portals to hidden sectors
- UZH one of the main proponents of the experiment

Master/Bachelor Thesis Available

SHiP design

Hardware:

- Timing detector for the to veto the combinatorial muon background
- SHiP laboratory at UZH (system set up, timing measurements)



Master/Bachelor Thesis Available

Detector design, optimization and analysis:

- Study of background and optimization of the detector
- Study of signal signatures and implications for New Physics
- Studies to extend the facility to search for $\tau \rightarrow 3\mu$