Skills You Learn

Physics:

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

Learn the most advance analysis tools:

- Artificial neural networks, multivariate analysis techniques, deep learning

and many software skills

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

Design and develop new type of detectors

- Operate and calibrate the most sensitive detectors of the LHC
- Test detectors 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 / publication

Ideal requirements: KT1 and 2, python/C++

- What is the Universe made of?
- Do we really live in only 3 dimensions?
- How did antimatter disappear?
- Are there more particles left to find?

Particle physicists study Nature at its most fundamental level by observing particle collisions. By understanding the properties of the various types of particles and the forces that govern their interactions, we can learn about the origins of the Universe itself.

Our groups are involved in analysis of data and designing, building and operating detectors

There are many available research projects in all these areas with 3-12 months duration

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

Questions ? Contact us !

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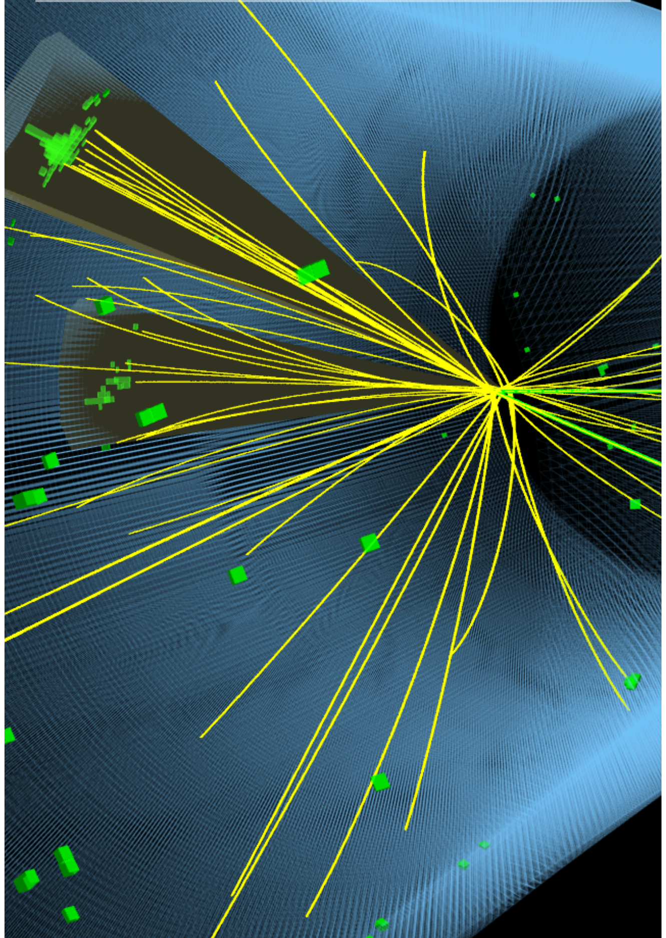
Bachelor/ Master Projects at CMS 2018



Prof. Dr. Florencia Canelli
&
Prof. Dr. Kilminster
Universität Zürich

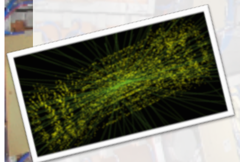
HARDWARE PROJECTS

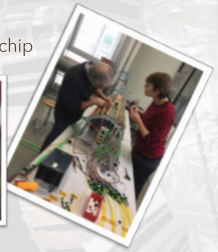
Pixel Detector

- The pixel detector provides high-precision 3D measurement of particle trajectories
- Phase 1 detector installed in 2017, phase 2 detector to be installed in 2024
- 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)
- 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 2019)
- Characterisation of the phase-2 readout chip





New type of timing detector

- Our group is developing a new detector that can measure time and position extremely precisely
  - 30 micro-meter position resolution and 30 picosecond (10^{-12}) precision
    - Light travels only 1 cm in 30 ps

Available project:

- Measure the properties and test these detectors in a particle beam

MACHINE LEARNING

With the rapid development and availability of machine learning (ML) libraries like Keras and TensorFlow, the recent years have seen an explosion of deep neural networks in high-energy physics. Based on the idea that, given enough examples to train on, a computer can learn to recognise and reproduce almost any distribution, machine learning has proven that it can do so with very high accuracy and on unprecedentedly small time scales. It is no wonder they are taking over more and more tasks in a field that deals with data amounts corresponding to 1700 years of HD video and need to process data on time scales of the order of micro seconds!

Tasks like producing simulated data, distinguishing between different types of particles and analysing large datasets can nowadays be done by a machine learning algorithm in a fraction of the time that it took to perform these tasks before the rise of deep learning. With this being the very beginning of the machine learning revolution, deep learning is one of the fastest growing fields of research both in science and in the private sector. Now is the perfect time to get involved and do some deep learning on your own!

PHYSICS ANALYSIS PROJECTS

Higgs Boson and Top Quark Physics

At the LHC, single top production is done through electroweak interactions. The large luminosity and energy from the LHC allow the study of rare processes, production of a Z boson in association with a top quark being one of the most interesting one. This process is characterised, by a final state with a Z boson, a top quark and an additional quark (tZq). The precise measurement of this process can be used as a probe for physics beyond the standard model.

The precise measurement of the associated production of top quarks + b-jets is an interesting and challenging task. The theory description of this process requires an accurate knowledge of Quantum Chromodynamics, together with input from data collected by experiments. Knowing the ttbb topology also allows us to gain insight into other process like the ttH(bb).

Measuring the properties of the Higgs boson is an important test of the Standard Model of particle physics. "The full strength of the Higgs interaction can only be directly measured when the Higgs boson is produced in association with top quarks (ttH). Furthermore, the Higgs boson can decay into many different particles. The work in this group focuses on ttH with the Higgs decaying to bottom quarks. This is a very challenging final state and requires sophisticated methods to separate the very rare signal events from the overwhelming background.

Searches

Leptoquarks

Why do quarks and leptons have similar structure? Maybe there is a new boson called the leptoquark that connects the quark and the lepton. In fact, LHCb recently reported anomalies in the decays of B-hadrons, which might indicate the existence of a leptoquark with a mass in the TeV-scale. We have started new searches to directly detect its decay at CMS. In particular, we exploit the decay signature of one b quark and one tau lepton that can be found in proton-proton collision data.

Boosted resonances

Is there a reason why the the electroweak (100 GeV) and the gravitational scales (10^{18} GeV) are so different? Is there only one Higgs boson or are there more? Theories beyond the standard model try to address these questions, and in many cases, predict the existence of new particles with masses of a few TeV, that in many models couple and decay to SM particles, such as fermions or bosons.

The intermediate boson will then have a large momentum, and the final decay products will be collimated such that they have a small angular separation due to the large Lorentz-boost. Special reconstruction techniques have been developed to study such processes, which can be directly investigated at the LHC. Collision data would manifest the presence of the new resonances as a localised excesses on a smoothly falling background distribution.

Dijet / Dark Matter

Other new resonances could be gravitons, string resonances, and dark matter that decay to a pair of quarks or gluons. This pair creates 2 collimated sprays of particles called jets (dijets). The big sample of pp collisions allows the search for events not only with two jets, but require an additional jet - the initial state radiation (ISR) jet. This technique allows us to cover a mass region that was not covered by previous CMS searches.

Vector-Like Quarks (VLQs)

VLQs are hypothetical colour-charged fermions and are predicted in many models beyond the standard model. Top-like and bottom-like VLQs, denoted by T and B, are assumed to have electric charges of magnitude 2/3 and 1/3 of the electron charge, respectively. The T and B quarks may decay to a W, Z, or Higgs boson and a third-generation quark. The wide range of possible VLQ types, decay modes, and production mechanisms defines a broad search program at CMS.

Physics object reconstruction

Tau identification

Many new-physics models predict new particles that preferentially decay to a pair of tau leptons. However, the tau lepton itself has a very short lifetime and can decay in many different ways. Therefore we need a dedicated identification algorithm of tau decays that is well understood and well modeled by our simulations.

B-tagging identification

Identifying particles is one of the major challenges in particle physics. The identification of B hadrons relies on the fact that such particles decay after a measurable distance (~1mm) within the pixel detector. Sophisticated algorithms combine this information with other measurements to search for B hadrons in every collision and have played a key role in recent observations at the LHC. However, these algorithms need further development for extreme conditions, e.g. when looking for new heavy particles.

Available projects

Data Analyses:

- Search for new particles that couple to quarks and/or gluons in a very low mass regime, requiring special triggers and data collection techniques
- Search for the most massive standard model particle production process, 4 top quarks, in the entirely unexplored all-jets channel
- Investigating a novel method to measure the decay width of the top quark
- Development of a method to identify the charge of jets produced by b or anti-b quarks
- Investigating a novel method to directly measure the mixing between top and down quarks
- Study of jet-shape observables with the potential to reduce backgrounds to associated production of a Higgs boson with a top quark pair
- Search for Vector Like Quarks T in the tTq production mode
- Measurement of the Standard Model tZq cross section
- Phenomenological study of heavy-flavour enriched beyond-standard-model dark jets (enhancement of coupling to third generation quarks)
- Search for leptoquark production
- Feasibility study of studying lepton universality via $R_\varphi = B(B_s \to \varphi\mu\mu)/B(B_s \to \varphi ee)$
- Measuring Higgs and Z boson couplings to strange quark

Sophisticated Analyses Algorithms:

- Optimisation of the matrix-element method in the study of associated production of a Higgs boson with a top quark pair
- Using machine learning to boost the matrix element method
- Use of advanced machine-learning techniques to reduce the impact of systematic uncertainties on measurements
- Use of machine learning techniques to calibrate complex triggering algorithms
- Exploit state-of-the-art machine-learning techniques to improve tau identification capability, extending also to low-p_T
- Develop multivariate analysis and machine learning tools for b-tagging identification
- Apply advanced techniques such as multivariate and machine-learning tools to search for boosted resonances