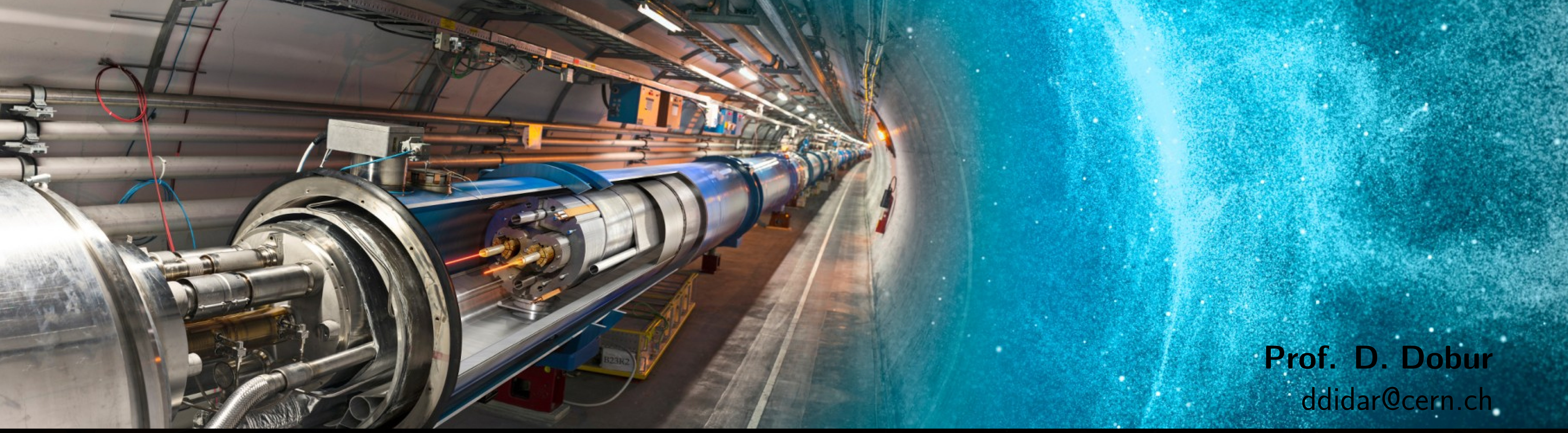

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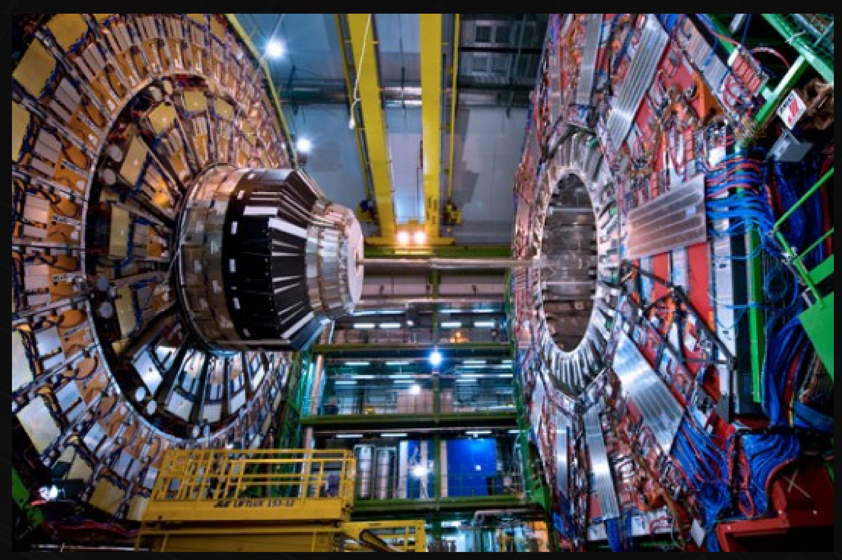
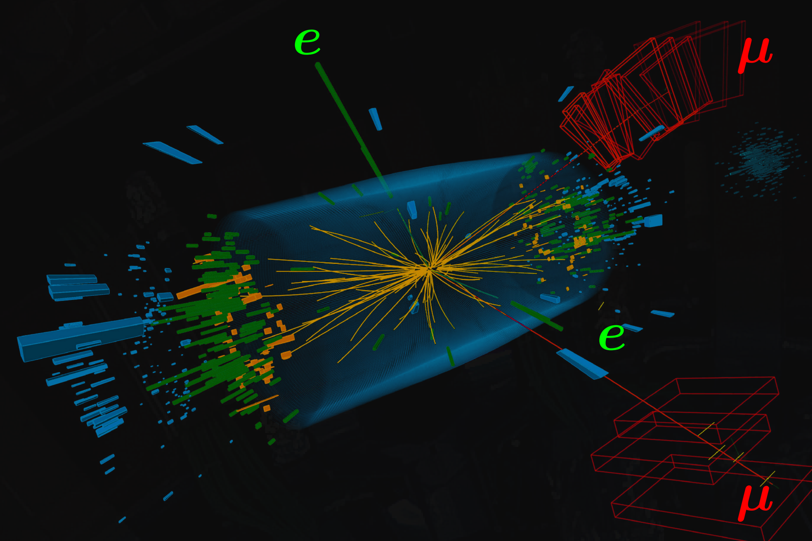
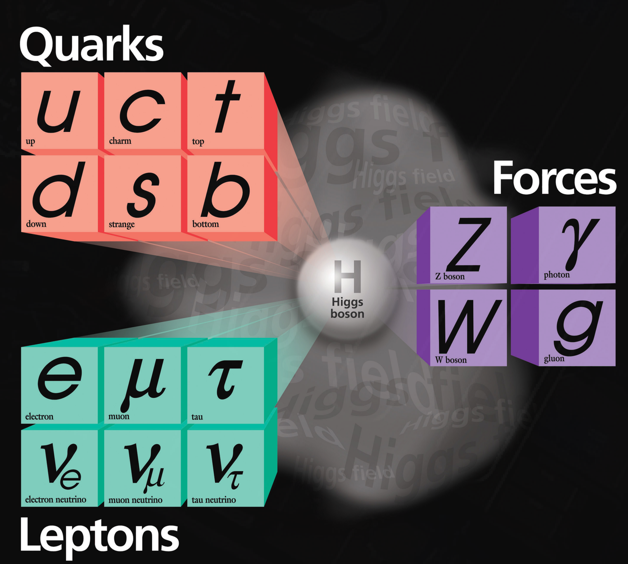
CMS: Expedition into the high-energy frontier

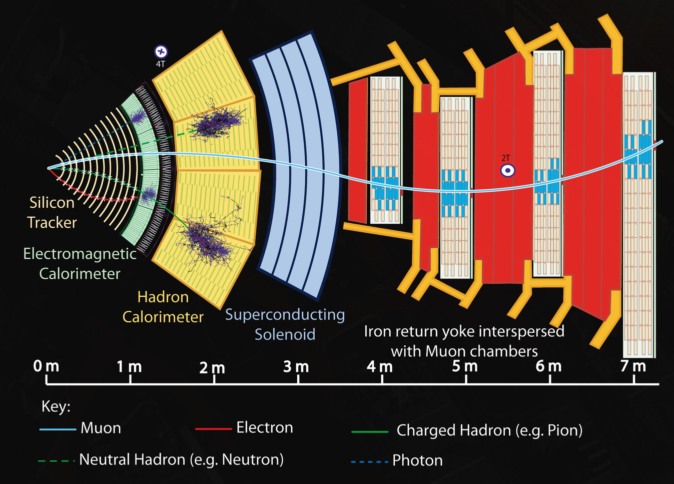
The **Compact Muon Solenoid (CMS) experiment** is a particle-physics experiment at the **Large Hadron Collider** (LHC), the world's most powerful particle accelerator located at CERN, Geneva. CMS is designed to detect a wide range of particles and phenomena produced in the LHC's high-energy proton-proton collisions. During its first years of operation, CMS achieved many new precision results on the Standard Model and limits on new physics beyond the Standard Model, as well as the long awaited discovery of the Higgs boson. Recently CMS started to take data at **unprecedented centre-of-mass energy of 13 TeV**, and at a rate of 40 million collisions per second, much more data is to be expected in the coming year.



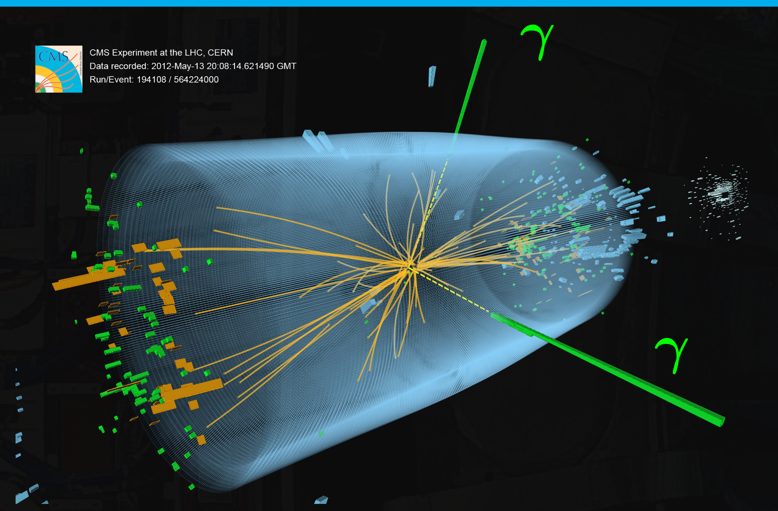


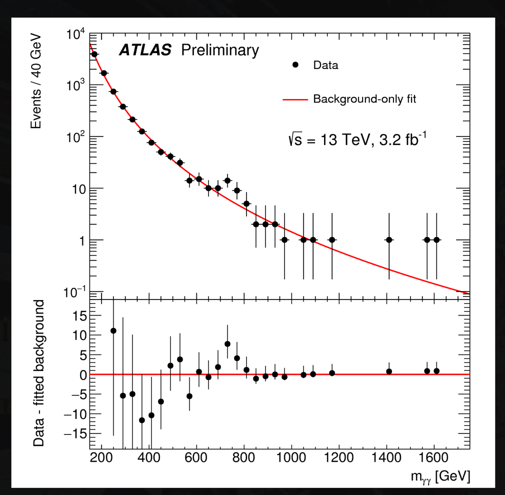
The CMS experiment is one of the largest international scientific collaborations in history, involving 4300 particle physicists, engineers, technicians, students and support staff from 191 universities and institutes in 43 countries.





Multiple observations and the everyday experience of gravity hint at the fact that the Standard Model (SM) is not the ultimate theory of nature. Why is the Higgs boson so light? Why is matter so abundant compared to antimatter? Why is gravity so much weaker than the other forces? How can neutrinos be so light? New data, never before explored, might hold keys to unlocking these secrets about the fundamental nature of nature itself! Data collected in the ongoing Run II, at the never aforetime reached energy of 13 TeV, will provide a matchless opportunity for joining this expedition into the high energy frontier. There are several available thesis subjects focussed on analysing the many uncharted dwellings in the LHC's data, all complementary to the research being performed in the Gent CMS group.





The analysis of the 2015 data shows an interesting "bump "in the $M(\gamma\gamma)$ spectrum that hints to a new particle with a mass of $\sim$750 GeV. If the upcoming data confirms this hint, a new era in the history of particle physics might begin. You can take part in this exciting journey with your master thesis and witness the dawn of a new age.

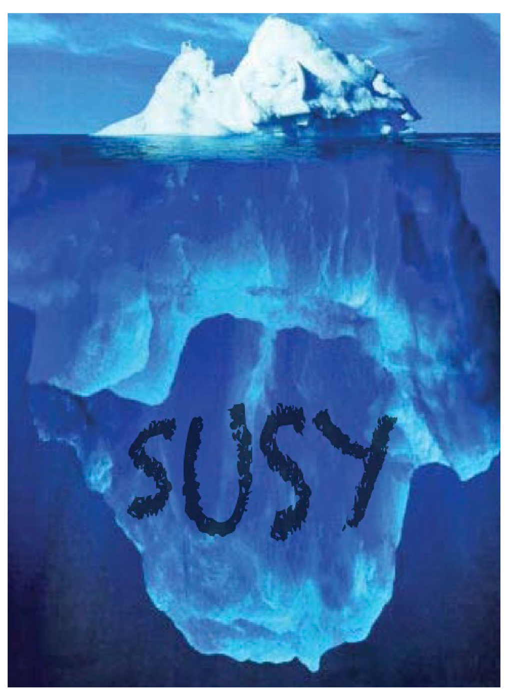
The Ghent CMS team is involved in several analyses at CMS, which include supersymmetry searches and top quark physics, and plans to search for Heavy Majorana neutrinos. Master students are welcome to join in one of our analyses groups where they get the opportunity to explore the large amounts of new data. Under the daily supervision of our CMS team, you will acquire the necessary knowledge to identify particles, select the events of interest and to use big data analysis techniques. You get the opportunity to gain experience in an international collaboration, and present/discuss results at CERN.

Searches for supersymmetry

Among many theories going beyond the standard model is Supersymmetry (SUSY). It can be used to address the problem of dark matter, and cure the hierarchy problem that afflicts the SM. SUSY is a spacetime symmetry relating fermions and bosons. In a supersymmetric theory there are an equal number of bosonic and fermionic degrees of freedom which naturally leads to cancellations between the divergent mass corrections to the Higgs boson's mass. Every fermion would therefore have a bosonic partner in SUSY models and vice versa. To achieve a cancellation of the chiral anomaly arising from the fermionic partner of the Higgs, atleast one other scalar doublet is required, leading to the presence of 5 or more scalar Higgs bosons. In order to protect the proton from decaying, R-parity conservation is introduced, leading to the stability of the lightest supersymmetric particle. So the requirement of a stable proton can lead to an excellent dark matter candidate in SUSY.

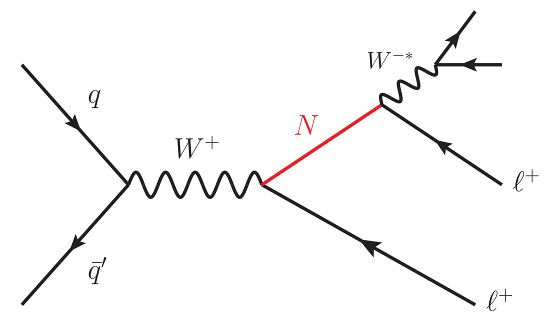
The discovery of supersymmetric particles would mark a revolutionary leap in the field of particle physics and our understanding of nature. Several searches, approaching the problem from different angles, are proposed.

- Search for supersymmetry in three leptons and missing energy final states
- Search for supersymmetry using same-sign dileptons and missing energy
- Search for the stop, the supersymmetric partner of the top quark



Searches for Majorana neutrinos in W boson decays

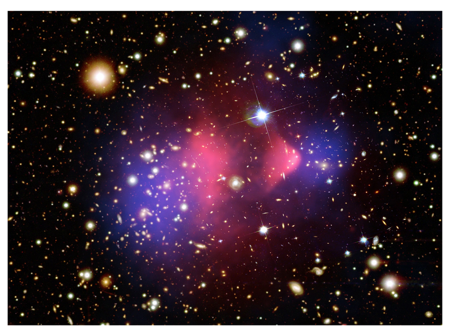
Only recently, the Nobel prize was awarded for the discovery of neutrino oscillations, a phenomenon strongly suggesting that neutrinos are in fact massive particles. Sev- eral experiments have however constrained this mass to be extremely small, below the eV scale. It might be conceived as unnatural that the Higgs mechanism would be responsible for their masses as the Yukawa couplings would have to be many orders of magnitude smaller than those of the other SM particles. By introducing heavy, so-called Majorana neutrinos, in the SM, the mass of the left-handed neutrino can be pushed down below the eV scale while retaining a Yukawa coupling constant similar to those of other SM particles. This is known as the see-saw mechanism. If they exist in nature, Majorana neutrinos might also be searched for in the LHC's proton-proton collisions. W bosons, which are copiously produced at the LHC, may decay to a heavy Majorana neutrino, due to it's coupling to the neutrino, and a charged lepton. This leads to characteristic signatures, which can be efficiently distinguished from known Standard Model processes. In Run I no discovery was made, but the expected 6-fold increase of the integrated luminosity to be collected in Run II, and the monumental increase in collision energies forebode a bright future for these searches.

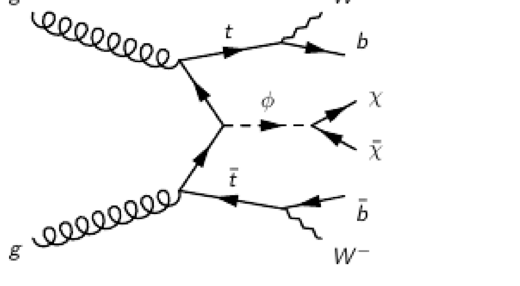


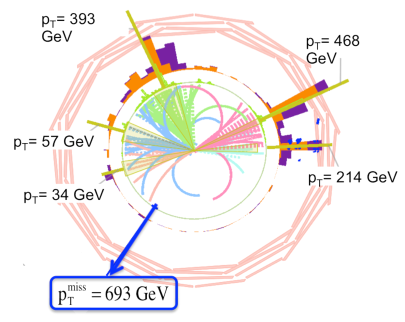
- Search for Majorana neutrinos in 3 prompt lepton final states
- Search for Majorana neutrinos in 3 lepton final states of which two originate from a displaced vertex
- Search for Majorana neutrinos in final states with two same-sign leptons (one prompt and one displaced) and two displaced jets

Search for dark matter production with top quarks

Yet another mystery the SM is unable to cope with is the elusive dark matter, the existence of which has been presumed to explain a profusion of astronomical observations over the past few decades. Among many other observations, the most prominent is perhaps the Bullet Cluster where two galaxy clusters are colliding. In this collision, the observable matter lags behind the bulk of the mass, as observed by the weak gravitational lensing effect, making a very strong case for dark matter's existence. Many modern observations show that the largest part of all the mass present in the known universe must consist of this enigmatic form of matter, which is not accounted for in the particle spectrum of the standard model.







- Search for direct dark matter in top quark pair events events

Precise measurements in top quark sector

The heaviest particle in the Standard Model is the top quark. As such, its properties are very sensitive to the existence of new physics beyond the Standard Model. Since it couples so strongly to the Higgs boson, a precise determination of its mass as well as its production rate (cross section) is an important check on the scalar sector. Top quarks are dominantly produced in top-antitop pairs, and produce 0, 1 or two leptons with two b-quarks in their decays and missing energy due to neutrinos. The properties of the top quark can be measured using any of these decay channels. We propose a subject on measuring the rates of top-quark pair production in association with W and Z bosons.

- Precision measurement of top quark pair production in association with W and Z bosons