Final Report FWO Research Project G.0017.04N

"Contribution to the design and construction of a detector for the CMS experiment at the Large Hadron Collider (LHC) at CERN"

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Content:

Chapter 1

General challenges for particle physics at the start of the project

After the discovery of the top quark at the Tevatron in Fermilab (Chicago, U.S.) and the precise measurements of the W and Z bosons at the LEP accelerator in CERN (Geneva, Switserland), the Standard Model of particle physics was promotor to become one of the most important theories in modern physics. This relativistic quantumfield theory is based on the symmetries we observe in the nature of the interactions between fundamental or elementary particles. The descriptions and predictions of the properties of particle interactions are tested profoundly and with great success via a long series of experiments. Nevertheless this success it was known at the beginning of this decennium that the Standard Model had many fundamental problems. The mass of the fundamental particles is described by a mechanism invoking a spontaneous symmetry breaking resulting in the prediction of the presence of a new scalar boson that we have never discovered. With an empirical observation of this Brout-Englert-Higgs particle we can complete the Standard Model. Its search is therefore the essential motivation in the design of contemporary collider experiments. There is however a list of alternative models which provide an explanation of the phenomena of Electroweak symmetry breaking. In some of these models a Technicolor interaction is introduced based on the mechanism present in Quantum Chromodynamics. With a study of particle interactions at higher energies we should be able to discover the phenomena responsible for this spontaneous breaking of the Electroweak symmetry and to study its properties.

When relying only on the particle content of the Standard Model, the enormous amount of Dark Matter observed in the universe cannot be explained. This yet unknown matter dominates the baryonic matter and had an important impact in the formation of our early universe. When invoking a new symmetry, namely supersymmetry, in the fundamental theory which is broken at the TeV scale, we can enrich the particle spectrum of our theory and therefore postulate new particles that can be responsible for the Dark Matter. Previous particle accelerators in the sub-TeV energy range did not unravel phenomena related to this supersymmetry. Depending on the nature of the supersymmetry and its breaking mechanism, the phenomena of a broken supersymmetry should become visible in particle collisions in the TeV energy range. Also this provides an argument to study particle interactions in the TeV energy range.

The conceptual hierarchy problem in the Standard Model between the energy scale of the Electroweak interactions (10^2 GeV) and the Planck scale (10^{19} GeV), is a motivation to expect new phenomena in the TeV energy range. It is shown than when postulating extra dimensions in the theoretical description the hierarchy problem can be reduced. The phenomena of these extra dimensions in which the fundamental particles can interact, have not yet been observed. Access to the TeV energy range could shed light on this part of the theoretical thoughts.

With a precise determination of the properties of top quarks we can test the intrinsic correctness of the Standard Model. At larger interactions energies is becomes easier to produce the massive top quarks in larger quantities. Therefore with a new accelerator operational in the TeV energy range we can obtain a more profound indirect insight in the elements of the Standard Model which are strongly connected to the spontaneous breaking of the Electroweak symmetry. A statistical test of the empirical observations to the indirect predictions of the Standard Model, will reveal a goodness-of-fit probability of the theory including the Brout-Englert-Higgs mechanism.

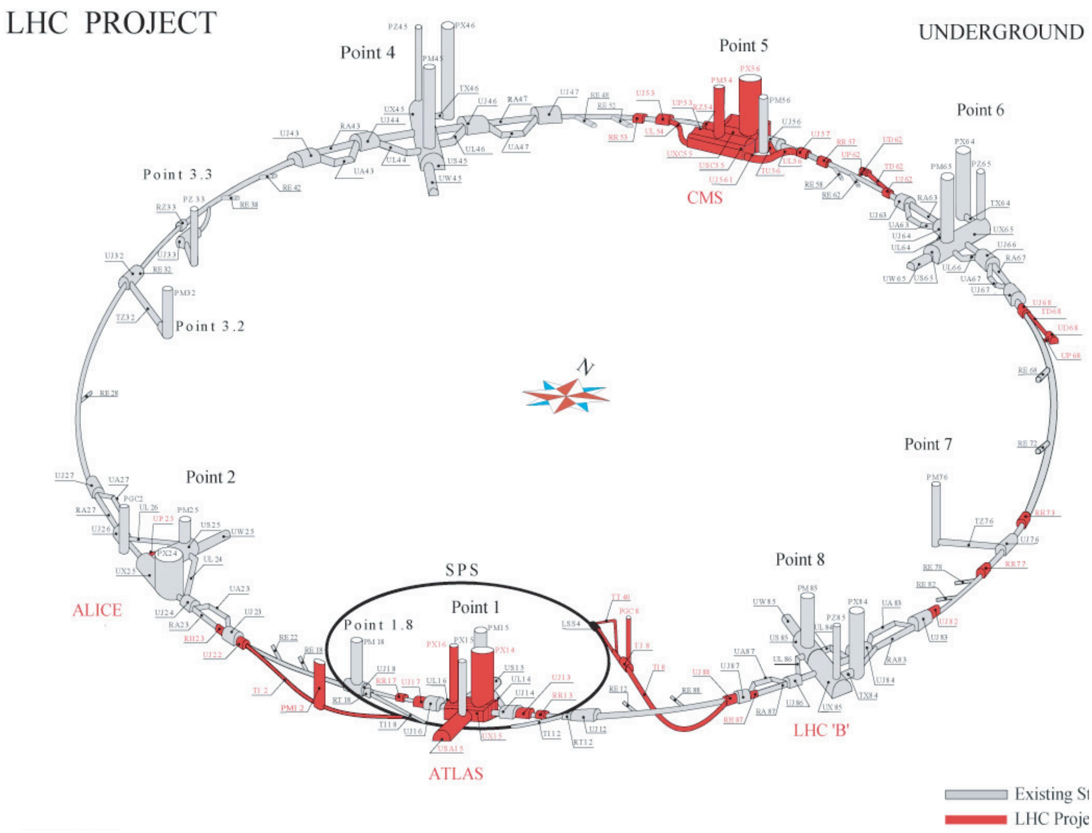
This list of arguments, of which the most important ones are summarized above, lead at the end of previous decennium to the motivation to construct an accelerator able to collide particles in the 10^4 GeV regime. The scale of the centre-of-mass energy has to be compared to the one of the LEP accelerator, about 10^2 GeV, and the Tevatron accelerator, about 10^3 GeV. To achieve these collision energies and a very high luminosity, a proton accelerator was built at CERN capable to accelerator protons up to 7 TeV. In the centre-of-mass of the collision this should result in 14 TeV collisions. The large underground infrastructure of the previous LEP accelerator was used to install the Large Hadron Collider or LHC at CERN.

Chapter 2

Proton collisions with the Large Hadron Collider at CERN

During the period of this project the Large Hadron Collider was in its final stages of construction and commissioning. At the end of the project period we have seen the first high energy collisions between protons obtaining a new energy frontline in particle physics collisions. Two proton beams travel in opposite direction around the 27 km circumference ring hosted about 50 to a 175 meter below ground in the old LEP tunnel. In total 1232 superconductive dipole magnets keep the charged protons on their path, while 392 quadrupole magnets keep the beams in the ultrahigh vacuum pipe focussed towards the four collision points where the detector experiments are build. The Niobium-Titanium magnets operate at a temperature of 1.9 K in superfluid Helium and conduct electricity without resistance at this temperature opening the possibility to create 8.3 Tesla magnetic fields. It is expected that about 100 tons of superfluid Helium is needed to cool all magnets which is unprecedented. The protons will be bunched in about 2800 packages to get a crossing of two bunches each 25 ns at the interaction points. Before injecting the protons in the LHC, they are prepared by CERN's accelerator complex consisting out of a series of systems and reaching proton energies of 450 GeV. After that the machine ramps up to its full 7 TeV beam energy in about 28 minutes. As of today we have reached 3.5 TeV per beam, therefore a centre-of-mass energy of 7 TeV. With these energies we will study the particle interactions for the next two years. According to the current planning in 2012 a shutdown is scheduled to upgrade the accelerator to allow for 14 TeV collisions at high luminosities.

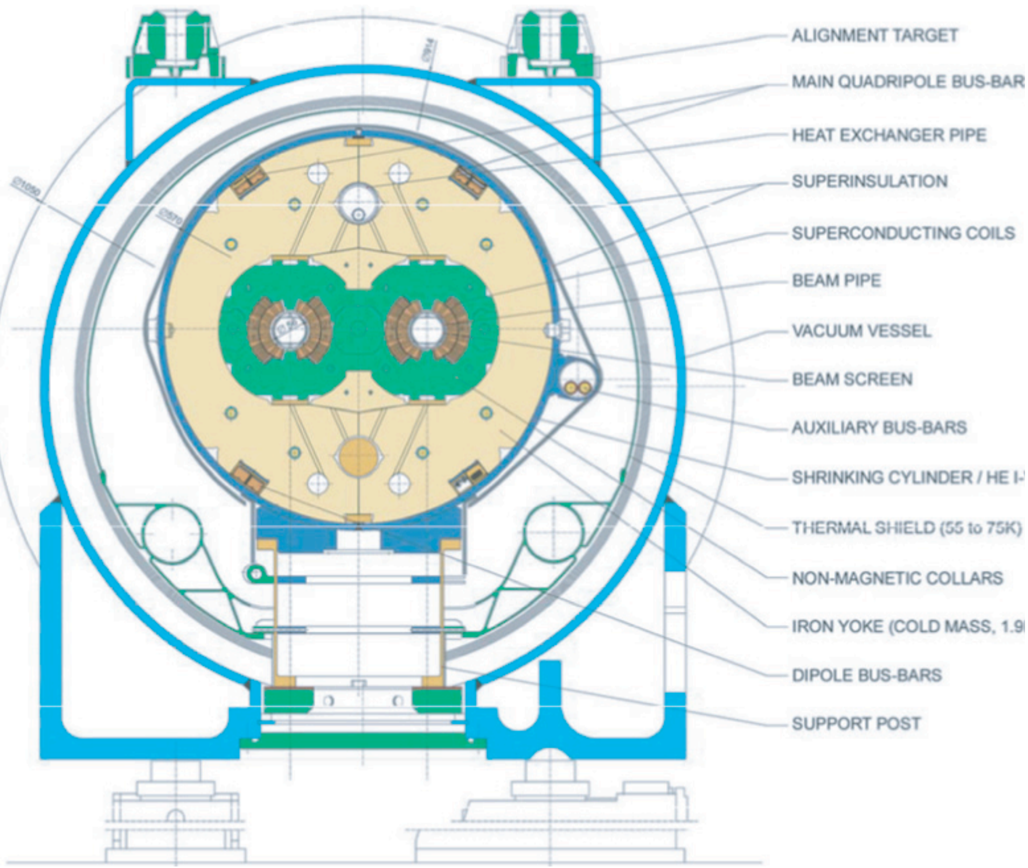
Although the energy stored in one single proton collision is tiny on macroscopic scales, this energy becomes large when integrated over all protons in the beam. The total amount of energy stored in each of the proton beams in the ring is about 360 MJ which is equivalent to a high speed train at about 150 km/h. While the beam is radiating off billions of particles, the magnets few centimetres away need to be kept at 1.9 K. These energetic particles could quench or even destroy a magnet. The energy of few particles could already quench a magnet and change its superconductive nature to a normal phase releasing a huge amount of energy within a second. The magnet would heat up from -271°C to about 700°C. To protect the magnets and the detector experiments at the interaction points from damage, a detailed beam dump system is being developed to protect the LHC from itself. When a quench begins the heat of that magnet is being dissipated over the whole 35 ton magnet of 14.3 m. Also energy is send to large resistors where about 8 ton of steel in heated to 300°C in 2 minutes. If really the whole beam crosses a dipole magnet, the magnet will be destroyed and has to be replaced with one of the about 30-40 spares. Dumping the whole beam can happen on the request of the operators by using fast kicker magnets which redirect the beam. Before dumping the beam in an 8 m long and 1 m in diameter cylinder of graphite composite its intensity is diluted by magnets. Graphite is chosen for its high melting point and therefore the block can hold for the whole duration of the experiment.



Schematic overview of the underground infrastructure of the LHC laboratory. The main experiments will be hosted in caverns indicated by point 1, 2, 5 and 8. The other areas will be used for accelerator components like collimators and RF cavities. (courtesy CERN)

The LHC is divided in 8 arc sections connected with straight lines to host experiments and accelerator equipment. At one of the straight sections (point 4) two independent sets of radio-frequent superconducting cavities operate at 400 MHz. For each beam there are 8 single cell cavities providing 2 MV and therefore a field gradient of 5.5 MV/m. All sections were expected to be cooled down to the operation temperature by the summer of 2008. At the end of the summer of 2008 the access to the experimental caverns and the tunnel was closed after which protons can be injected and the commissioning of the accelerator with proton beams will start.

At the end of 2008 we have succeeded in injecting and circulating particles in the accelerator. Unfortunately a shortcut in the connections between the superconducting magnets invoked an electric arc penetrating the cryogenic system. This resulted in severe damage to the accelerator and a rescheduling of the planning. In 2009 the damage was repaired including an upgrade of the safety elements to prevent another failure. At the end of 2009 the accelerator restarted successfully and was able to accelerator protons first to collision energies of 2.36 TeV. Early 2010 the energy record was extended to collisions of 7 TeV.



Cross section of an LHC dipole magnet, indicating both beam pipes surrounded by the superconducting coils. All is contained in a vacuum vessel and a thermal shield in which the iron yoke of the magnets is cooled to 1.9 K. (courtesy CERN)

Chapter 3

The Compact Muon Solenoid detector

Particle detectors evolved to very complex multi-layer systems with several millions of read-out channels. The data acquisition (DAQ) systems have evolved accordingly with the main reason for evolution the ever increasing particle rate in the final state of the collisions together with the usual custom detector electronics. More events to be looked at in less time and also more complex event topologies, gives strong requirements on the read-out and trigger systems of our detectors. The DAQ system of the detector collects all the signals of the millions of detector channels and allows the trigger system to analyze this data. In general the cross section of Standard Model processes is increasing when going to higher centre-of-mass energies. The processes of interest to be discovered (eg. Brout-Englert-Higgs boson, supersymmetry, etc.) have a much lower cross section compared to the Standard model processes. But as they require the creation of particles at higher mass scales their cross section usually increases more rapidly compared to Standard Model processes with the centre-of-mass energy. In general only 1 out of 10^{11} events exhibits the effect of a particle interaction beyond the Standard Model, see Figure.

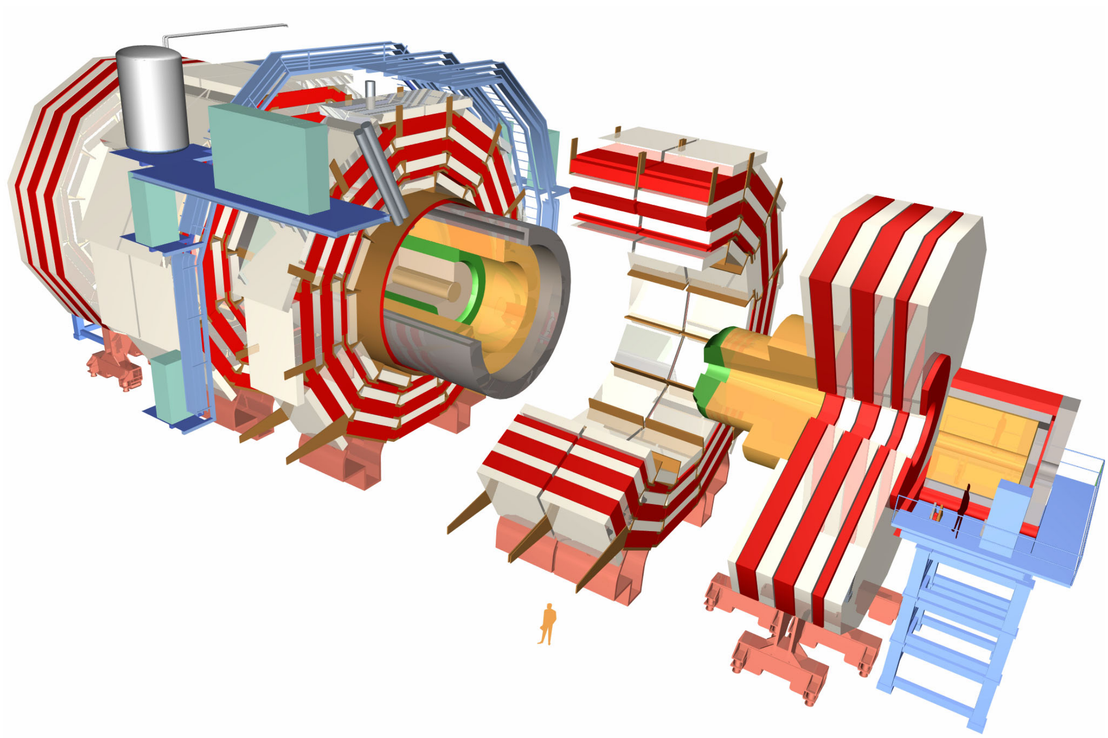
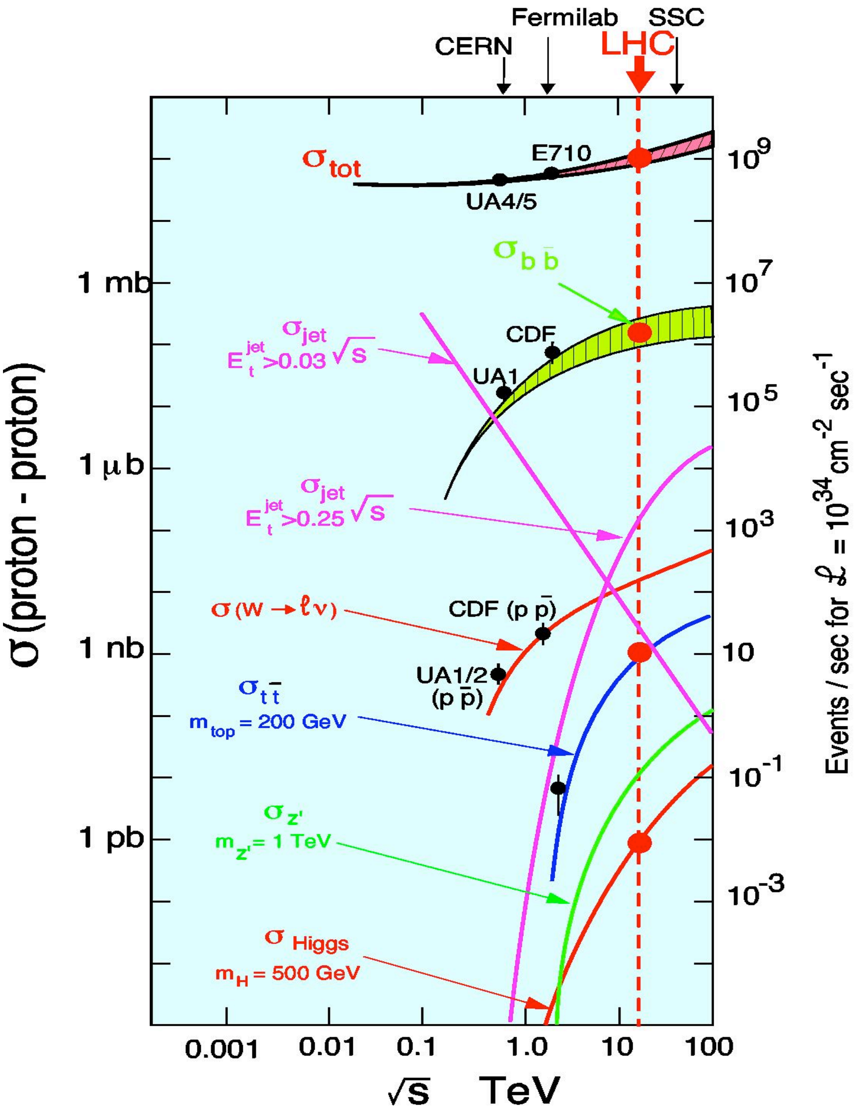


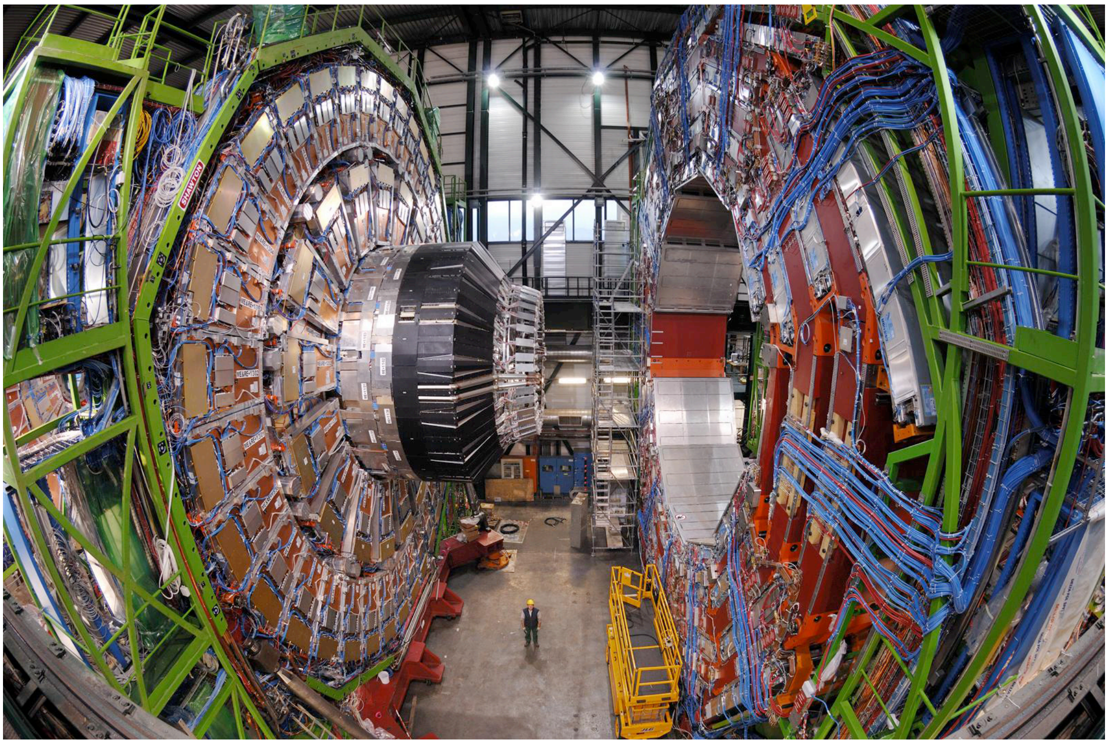
Illustration of the CMS detector

The CMS detector is a multi-purpose detector with a design focused on the search for the Brout-Englert-Higgs boson and other potential new particles. A sketch of the detector layout is shown in the figure above. To achieve this a high performance system to detect and measure muons was needed, a high resolution for the measurement of electrons and photons, a high granular tracking device and the calorimeter part of the detector needed to be as hermetic as possible. The high performance tracking can be achieved by means of a powerful magnet to bend the charged particles. A solenoid of 13 meter long and 7 meter in diameter was constructed to produce a 3.8 Tesla homogenous field.



Cross section of several processes in proton-proton collisions as a function of the centre-of-mass energy. The event rate is indicated per second for a luminosity of 10^{34} $cm^{-2}s^{-1}$. The cross sections of the accessible processes which are measured at previous accelerators are shown. Clearly the probability to create an interaction to produce a Brout-Englert-Higgs boson is orders of magnitude smaller than the one to produce to processes with jets or top quarks.

The final design for the CMS Tracking system is based on silicon technology. Both the pixel at the very core of the detector and the Silicon Strip detectors are based on silicon and produce about 75 million separate electronic readout channels. The radius of the Silicon Strip Tracker is 130 cm. The device is subdivided in a barrel and endcap sector each consisting out of divers sizes of detector modules. A total of about 16000 detector modules provide about 10 million readout channels. The charge on each microstrip is read out and amplified by an Analogue Pipeline Voltage (APV25) chip. Four or six such chips are housed within a "hybrid", which also contains electronics to monitor key sensor information, such as temperature, and provide timing information in order to match "hits" with collisions. The APV25 stores the signals in a memory for several microseconds and then processes them before sending to a laser to be converted into infrared pulses. These are then transmitted over a 100m fibre optic cable for analysis in a radiation-free environment. The tracker uses 40,000 such fibre optic links providing a low power, lightweight way of transporting the signal. Much of the technology behind the tracker electronics came from innovation in collaboration with industry. The Belgian groups were very active in the design and construction of the CMS Tracking device.



Picture of the CMS detector under construction at the LHC Point-5 site.

The Electromagnetic Calorimeter (ECAL) is positions just outside the Tracker radius and consists out of about 75 thousand scintilating crystals. Lead tungstate is used as scintillating material which produces a fast signal. The crystals have a surface of 2.2 cm x 2.2 cm in the barrel, and 3 cm x 3 cm in the endcaps. The Hadron Calorimeter is a sampling calorimeter alternating layers of absorber and fluorescent material. Optic fibres collect the light pulse which is amplified by photodetectors. The CMS muon system is built with divers techniques: drift tubes and about 2 million cathode strip chamber wires mainly to measure the particles' position and resistive plate chambers for trigger purpose. The UGent team has been very active in the commissioning of the RPC-detectors. The muon system is aligned with the central Tracking system to within one sixth of a millimetre in order for the detectors to work together in the reconstructino of muons.

The trigger system consists out of several layers of consecutive online rejection of events. At a bunch crossing rate of 40 MHz and an average of about 3-20 collisions per bunch crossing, about 0.1 to 1 GHz of collisions will be produced in the detector. The total size of one event is on average about 1 MB. In the CMS experiment a two step approach is being deployed. The first Level-1 hardware trigger will select only those events for which locally in the detector a pattern is present of particles with relatively large transverse momentum or with a clear identification of interest. The parameters of these trigger algorithms are tuned to select only a rate of 100 kHz of events. The electronic delay buffers are finite and require the Level-1 decision to be made in 3 μs time, therefore relying on simple algorithms, small amounts of data and local decisions. During this time the signal cannot be transported to far. The control room with all processors is located underground very nearby the detector, but shielded however from the radiation. Most of the latency time of 3 μs is used for the transportation of the signal through cables. Upon a positive decision from the Level-1 trigger algorithms the full event is read-out and build by the DAQ system. At this stage there is still 1 TB/s of information. To reduce this, all these events are being processed in a second stage High-Level Trigger by a farm of thousands of commercial processors. More complex algorithms are explored to reduce the event rate to 100 Hz, which is finally put on disk for further analysis. The processing time allowed for these algorithms depends on the amount of processors deployed in the computing farm. It was an important challenge to define optimal settings for this triggering process because it decides which data we will be available to analysis and which will be rejected and therefore lost forever. With only a tiny fraction of interesting events featuring new phenomena, the trigger thresholds were well studied prior to the first collisions.

The data that will make it to the disks is distributed in a worldwide hierarchical network of computing infrastructures. The offline analyses themselves are performed at the computing centre which will host the particular dataset the analysis is intended for. To allow the physicist to run his or her software analysis within this distributed system, GRID related tools are being used. The LHC Computing Grid (LCG) has been developed to support the experiments at the LHC to handle huge amount of data and large data rates.

Chapter 4

Funding of the project

For the period 2004-2009 the FWO granted funding to this project to hire scientific and technical personnel. The budgets allocated are summarized in the table below. These tables also include the annual running budgets and the budgets allocated to equipment.

Universiteit Antwerpen

Year	Running	Equipment	ATP	budget	WP	budget	Total
2004	5.000,00	40.000,00					45.000,00
2005	25.000,00				1	53.800,00	78.800,00
2006	45.000,00				2	107.600,00	152.600,00
2007	45.000,00				2	107.600,00	152.600,00
2008	45.000,00				2	112.000,00	157.000,00
2009	45.000,00				2	113.600,00	158.600,00
							744.600,00

Universiteit Gent

Year	Running	Equipment	ATP	budget	WP	budget	Total
2008	15.000,00						15.000,00
2009	15.000,00						15.000,00
							30.000,00

Vrije Universiteit Brussel

Year	Running	Equipment	ATP	budget	WP	budget	Total
2004	9.000,00	75.000,00			1	52.700,00	136.700,00
2005	93.500,00		4	177.600,00	2	107.600,00	378.700,00
2006	123.500,00	75.000,00	5	222.000,00	2	107.600,00	528.100,00
2007	123.500,00		5	222.550,00	2	107.600,00	453.650,00
2008	123.000,00		3	140.700,00	2	112.000,00	375.700,00
2009	123.000,00		3	142.800,00	2	113.600,00	379.400,00
							2.252.250,00

Chapter 5

Scientific results

During the period of this project our groups were active on divers fronts, from the design and construction of the detector, to the preparation of the full data analyse methods to study the proton collisions. Our main responsibilities in the construction of the CMS detector are situated in the design, assembly and testing of the Silicon Strip Tracker. Mainly the UA and VUB teams contributed to this effort. Towards the end of the project the UGent group contributed to the construction of the Resistive Place Chambers for muon detection. Our contributions to the development of object reconstruction techniques are divers and cover most of the object classes needed to perform the physics program of the CMS Collaboration. Also in the development of full analyse methods to study the proton collisions our efforts are divers. We contributed in the preparation of most items in the foreseen physics program resulting in a wide range of expertise. This will prove to be essential when studying in detail the real collisions to be accumulated over the next years. Below our main activities during the period of this project are summarized.

1. Design and construction of the CMS Silicon Strip Tracker

The IIHE (ULB/VUB) took the following responsibilities: coordination of the design and production of 17000 frame components to support the Silicium detector modules and 17000 pitch adapters, assembly of 6000 frames, assembly of around 1700 modules for the forward wheels of the tracker using a high precision positioning machine (gantry), mounting of modules on 42 support structures in the shape of a sector of a wheel (so-called petals), and detailed long term tests of the modules and the petals. The procurement of the pitch adapters was successfully terminated in 2004. Concerning the module frame components, all were delivered to the assembly centres in Italy, in Pakistan and at the IIHE. Carbon fiber plates from the different batch production were checked to be within specification concerning the thermal conductivity property. Around 5000 frames of 8 different geometries were assembled at the IIHE in the year 2004. The storage of detector components, their shipping among the various laboratories of the collaboration and their registration in the data base was well organised. Brussels was one of the eight centres having a gantry positioning machine in order to assemble modules, with a precision of around 10 microns. Detailed calibration and tests were undergone during the year 2004 and around 2000 modules from the four different geometries were assembled in the following years. The production had to stop at the end of the summer of 2004 because of a problem found on the hybrid production process in the industry. It restarted in March 2005.

Another important responsibility from the IIHE (ULB/VUB) group is the assembly and the long term test of 42 petals. A module test station was built at the UA in order to develop the software related to the long term test. A clean room was constructed in the IIHE for this purpose. The petal assembly set-up was installed during the year 2004 and assembled petals in the following years. A first petal was assembled successfully beginning of 2005. In parallel, the petal test set-up is being installed with the help of the UA. The IIHE (ULB/VUB) also participated to the development of the optical electronic system to be used in these tests. The IIHE (ULB/VUB) team made significant contributions to the online and offline data quality monitoring of the CMS Tracking system.

The UA team was responsible for the long term test setups of the Si-strip modules of the CMS tracker. During this project, the set-up was expanded to accommodate larger structures on which multiple modules were mounted. The UA group was the main responsible for this project, in close collaboration with UCL and the University of Karlsruhe. The UA's main contributions were the software design and implementation while Karlsruhe defined the mechanical and electrical infrastructure. UCL supplied the steering software for the individual apparatus. The end product was a fully automated test setup in which tracker structures were tested at various temperatures for several days.

During the process of module testing, more functionalities were added to the software in order to study defects to the delivered structures in greater detail, since some anomalies were not reproducible by manual measurements. The setup was finally copied and installed in 6 other European labs and in 2 American institutes. In this phase the expertise of the UA group was regularly called upon when unusual results were encountered. Both personal and remote interventions occurred regularly in Brussels, UCL and Aachen. On request of the CMS collaboration, the US setups were also visited and their host labs consulted. The electronics of one of the American setups had to be replaced as a result of these inspections. A database of anomalies and faults was kept of all setups in order to trace and detect fundamental design errors. Wim Beaumont recently achieved a CMS lifetime achievement award for his extraordinary contributions to the general testing of the silicon tracker modules. Ref. T. Bergauer, W. Beaumont, E.A. De Wolf et al., *'Petal Integration for the CMS Tracker End Caps'*, CERN-CMS NOTE-2008-028, describes completely the full test procedure.

In addition, general technical support was supplied by the UA group in function of the tracker integration at CERN.

Early 2008 the Tracker system was successfully included within the complete CMS detector in the underground cavern at LHC Point-5 site at CERN. The performance of the Tracking system was determined by use of cosmic radiation detected by the Tracker. After the short period of LHC beam operation in September 2008, the CMS Collaboration conducted a month-long data-taking exercise known as the Cosmic Run At Four Tesla (CRAFT) in late 2008. The objectives of the CRAFT exercise were to test the solenoid magnet at its operating field (3.8 T), with the CMS experiment in its final configuration underground, to gain experience operating CMS continuously for a sufficiently long period, and to collect a large sample of cosmic triggers in order to study the performance of the CMS subdetectors. These results gave confidence that the CMS experiment was ready for LHC beam operation in late 2009. A set of 23 publications summarize these results.

Late 2009 the first collisions are produced at energies exceeding 2 TeV. An illustration of such an event can be found in the figure below. The hits measured by the Silicon Strip Tracker are indicated and the Tracking system is working efficiently in proton collisions.

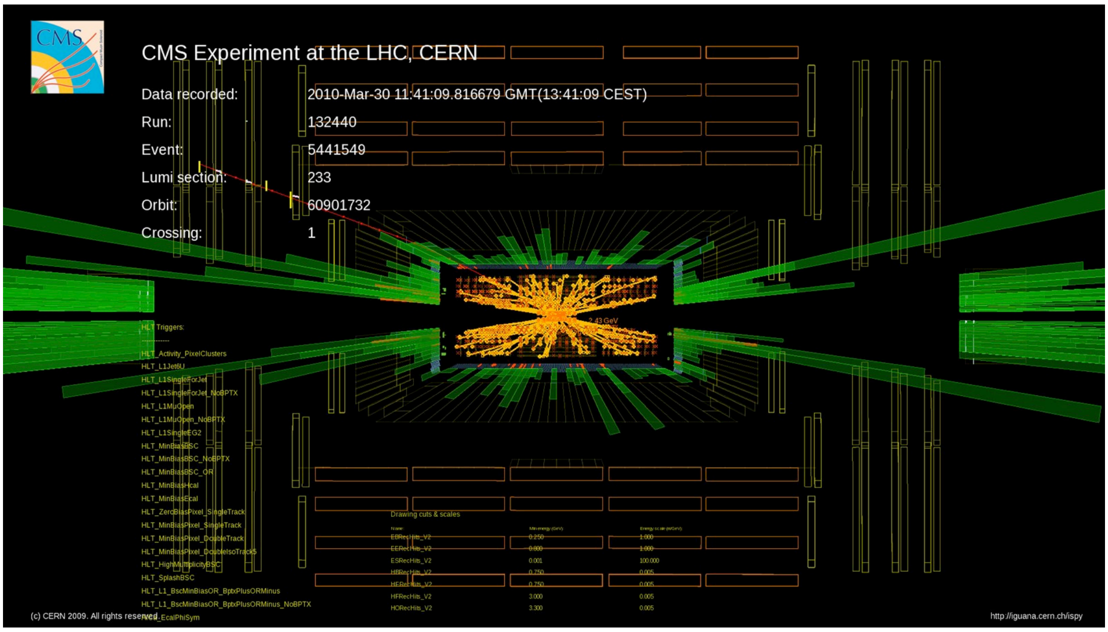


Illustration of a proton-proton collision as observed by the CMS detector.

2. Design and implementation of reconstruction methods

Several reconstruction methods need to be developed and tested to be able to study the physics in the proton collisions. Our groups have participated significantly in the reconstruction of vertices, leptons, jets, missing transverse energy, etc. The environment of the object to reconstruct in the event is dense and divers as illustrated in the figure of a simulated proton collision in the CMS detector.

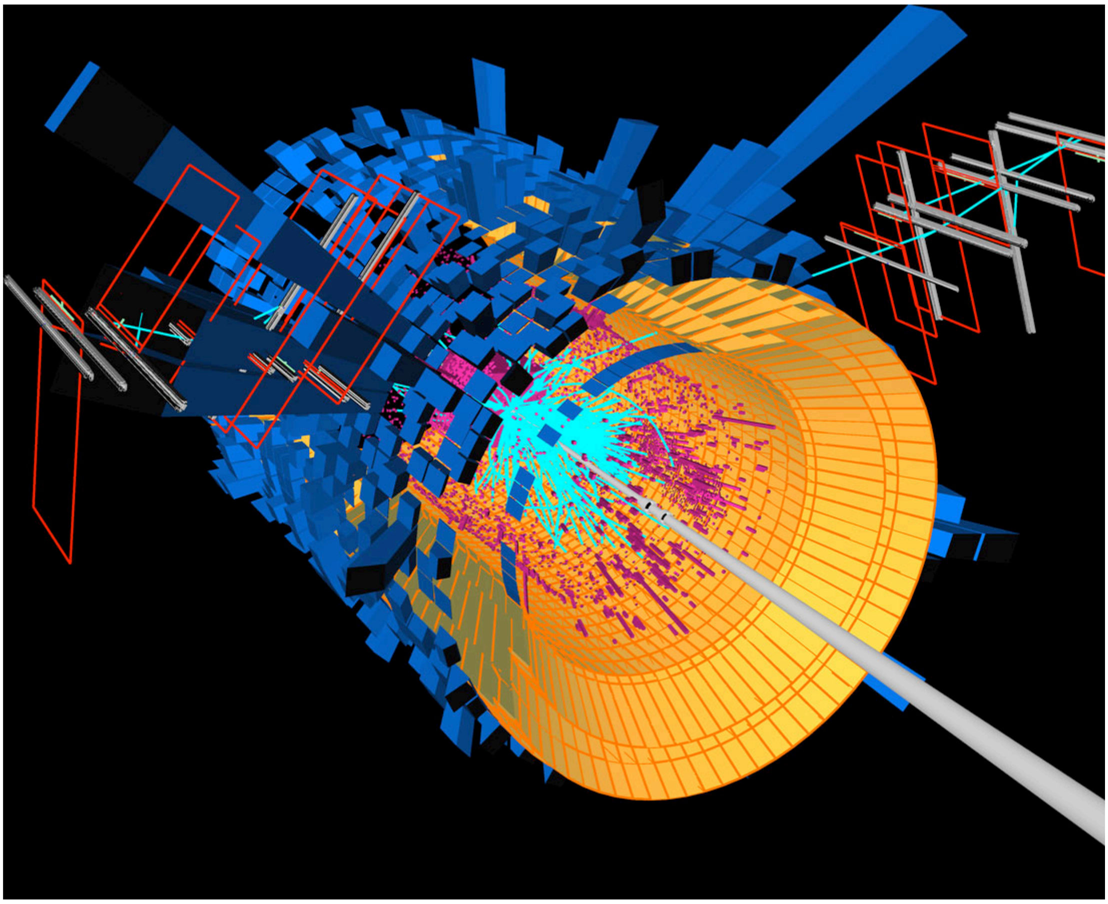


Illustration of the complexity of a proton-proton collision in which a pair of top quarks is produced, CMS detector simulation. (courtesy Steven Lowette)

The reconstruction of vertices is important to constrain the direction of the individual particles, and also to identify secondary decay vertices and to remove cosmic and beam background. The latter is an essential element for the identification of for example b-quark jets in which the B mesons produce a displaced vertex. The IIHE (ULB/VUB) group contributed to the studies of vertex finding and fitting techniques. Tests were performed to optimize the numerical tools and to identify which techniques performs better in divers situation.

The reconstruction of hadronic jets is a crucial ingredient for most of the physics analyses to be performed with the CMS experiment. Members of the IIHE (ULB/VUB) have studied the optimization of a series of jet algorithms. Also calibration tools are developed to correct the jet energy scale of the reconstructed jets via event-by-event kinematic fits using the top quark mass and W boson mass constraints in top quark decays. This resulted in the potentially most precise calibration tool within the CMS experiment.

Identification tools for b-quark jets are developed by members of the IIHE (ULB/VUB) and methods to measure from the data the efficiency of these so-called b-tagging methods. They use the Vtb=1 constraint in the decay of the top quark, and selected on this basis a jet sample purified in b-quark flavoured jets.

Kinematic fit tools are developed by members of the IIHE (ULB/VUB) based on Lagrange multipliers in a least-square method. Possible non-linear constraints like mass constraints between the reconstructed objects in the final state are linearized via Taylor expansions. It was shown that the application of the kinematic fit provided a clear improvement in the measurement of the top quark mass for example.

Lepton isolation techniques are developed by the IIHE (ULB/VUB) based on a series of observable properties of the reconstructed lepton. Likelihood ratio tools are applied to optimize the performance of the methods, resulting in a better determination of the cross section of processes in which isolated leptons appear, for example from the decay of W bosons.

The UGent group works on the reconstruction algorithms for missing transverse energy. Most of the events where SUSY particles are produced will contain a lot of missing energy. To distinguish between such events and processes with e.g. neutrinos necessitates a very good reconstruction of the event. The existing algorithms are under evaluation and optimized where possible.

All above studies resulted in divers publications and conference contributions. Most of the information is summarized in the Physics Technical Design Reports of the CMS Collaboration.

3. Design and implementation of data-analyse techniques

The main goal of the CMS experiment is to study the physics in the proton interactions provided by the LHC. Members of our groups have contributed and in most cases lead parts of these activities within the CMS Collaboration. The data-analyses techniques are developed and tested on the basis of simulated collision events produced with Monte-Carlo tools.

The search for a heavy charged Higgs boson through the decay into a top-antibottom quark pair was studied. These new yet unobserved particles are predicted by the Minimal Supersymmetric Standard Model. For the first time a full detailed study provided insight in the potential to discover these particles with the CMS experiment. It was shown that the Standard Model background should be known much better from both the theoretical and experimental point of view to extend the discovery potential.

The search for Kaluza-Klein recurrences of the Z boson and the photon through the decay into an electron-positron pair was studied in the framework of models beyond the Standard Model including extra dimensions. Important in this study was to overcome the reconstruction difficulties of high energetic electron or positron in the CMS Electro-Magnetic calorimeter. The punch-through energy was recovered by dedicated reconstruction algorithms, and hence extended the discovery potential of these resonances.

An important part of our attention was devoted to the study of collision events in which top quarks appear. The production cross section of top quark pairs is very high and an enormous collection of millions of top quarks are expected to be accumulated by the CMS experiment over the first year of running. This dataset opens a new window to study this heaviest Standard Model particle with unprecedented precision. Analyses techniques are developed to measure the mass and the cross section of these processes.

Techniques are developed to identify supersymmetric phenomena via the appearance of leptons with the same electric charge in the final state of the proton collisions. The Standard Model background was studied for this topology and the potential to discover supersymmetric signals was obtained.

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Our groups have participated to software developments related to and supporting the physics analyses activities. The Fast Monte-Carlo simulation (FAMOS) of the response of the muon detector and the electromagnetic calorimeter is an example where members of our groups contributed.

We also contributed to the central computing activities in the CMS Collaboration. During 2 years the IIHE (ULB/VUB) was one of the 5 production teams to run Monte Carlo simulations of collisions events. With this team we produced about half a billion simulated events. This team also contributed to the test of data transfer between the different TIER sites of the CMS Collaboration. The non performant links were debugged and improved. The deployment of the CMS main software on the about 40 European TIER centres was also a crucial task of the IIHE (ULB/VUB) team. Recently we also participated to the development of monitoring tools for the efficiency of the GRID system deployed in the CMS Collaboration. On this basis new analysis operation tools are developed to improve the efficiency. The work related to computing by the IIHE (ULB/VUB) team lead to several conference contributions and some publications.

The IIHE (ULB/VUB) team also contributes significantly to the deployment of the LHC Computing Grid (LCG). A cluster of 110 processors with 2 TB disk space has been installed already in 2005, and passed at that time the certification tests of the European Grid Program EGEE. Today a fully commissioned TIER-2 infrastructure is deployed by the IIHE (ULB/VUB) and used by all members of the CMS Collaboration, especially the Belgian members.

4. Evolution towards complementary FWO projects and the Big Science program

This project was the most important one for the Flemish participation to CERN's main experiment, namely the Large Hadron Collider. With the opportunities given each of the UA, UGent and VUB groups have reinforced themselves with new hiring at the professor level. At the UA, Prof. Pierre Van Mechelen and Prof. Nick Van Remortel joint the group, at the UGent Prof. Martin Grunewald joint and at the VUB Prof. Jorgen D'Hondt and recently Dr. Freya Blekman was assigned the new research professor position. During the period 2004-2009 this project was complemented with a divers range of other parallel projects. For example the creation of the Big Science budget line and the IUAP Fundamental Interactions provided excellent opportunities for our groups.

The funding program during last decennium was successful in preparing the Flemish research groups for particle physics research with the Large Hadron Collider at CERN. We have obtained international recognition of our activities and are in an excellent position to validate our preparation efforts in the study of the proton collisions from 2010 onwards. It is of paramount importance to continue and even enhance the funding program of our groups during the data-taking period. It is only with a combination of all funding programs during the lifetime of a modern accelerator experiment that the validation of the financial and scientific efforts is optimal.

Chapter 6

Collaborations

Within Flanders the three participating universities have collaborated in a natural way. The contributions to the Tracker construction from the UA and VUB groups have been done in close collaboration. This close collaboration is extended to the whole of Belgium, where also the UCL, ULB and UMH participated to the construction of the Tracker. At the IIHE (ULB/VUB) for example we have used the same infrastructure of clean rooms and we have worked in technical teams where all personnel is combined into one single group.

Also in the preparation of the physics analyses we have a close collaboration for example through the IUAP network of Fundamental Interactions. The exchange of post-docs between the Belgian teams has created a dynamic research team in which expertise on diverse topics came together. This resulted in several joint publications.

The collaboration within Belgium was enhanced by the hiring of several new professors during the period of this project. At almost all the Belgian universities participating to the CMS experiment, a new professor (or equivalent) has been hired during the period 2004-2009. This has strengthen our international reputation and created a platform for new collaborations between our universities.

Our impact in the CMS Collaboration is larger than the 2% of the persons we represent as Belgium. This can be seen not only by the relative amount of publications the Belgium teams have written, but also by the relative fraction of responsibilities we have taken. Several of our members were elected to be part of the management or coordination group of the CMS experiment. This can be as coordinator of parts of the technical work to be done, or as coordinator of a large group of physicists preparing the physics analyses or reconstruction tools. As an example Prof. Albert de Roeck, a part-time professor of the UA group, was elected as deputy spokesperson of the experiment in 2010.

Among the about 170 institutions connected to the CMS experiment, we have in a natural way collaborated with many of them. For example for the design and construction of the Silicon Strip Tracker we have collaborated with most of the German, French, Italian, Austrian institutions in the CMS Collaboration.

Today the CMS Collaboration connects 1689 physicists, 752 PhD students, 696 engineers, and 661 other collaborators from 173 institutions from 38 countries. Among them 6 institutions from Belgium hosting a total of individual 101 collaborators, representing about 2.5% of the total collaboration.

Chapter 7

Communication of the results

Members of our groups were accumulated a long series of presentations during national and international conferences or workshops for the period of the project. A significant part of them was on invitation and with published proceedings. Usually the presentations were given by name of the full CMS Collaboration, hence the presenter was selected within the collaboration to represent the scientific results obtaine. Hundreds of presentations were given during international CMS workshops at CERN of elsewhere. Many of us were invited to take part in the organization of workshops and conferences, either as session convenors, chairpersons or effectively in the organizing board of the event.

Our researchers wrote diverse articles in magazines aimed to reach the general society. An example is EOS magazine in collaboration with Scientific American. Also with a long series of general presentations for wide audiences, we have reached thousands of people in the broad society.

We were able to reinforce our communication to the society in September 2008 with a national press conference for the start of the LHC experiment. This was the start of a very successful campaigne in the media on the theme of the Large Hadron Collider. Both the written and the audio-visual press have taken the concept of the most powerfull accelerator at CERN and promoted it to a general and widespread project known in our society. With this kind of communication we have reached several times the full Flemish population.

Prof. Jorgen D'Hondt is the national representative in the European Particle Physics Outreach Group (EPPOG) of CERN that discussed the general outreach in Europe for particle physics. This group organizes for example the annual Masterclasses in particle physics throughout Europe. Our institutions have participated to these and reach with this about 50 secondary school students per year, per institute.

Chapter 8

Scientific and technical collaborators

For the design and construction of elements of the CMS detector we hired several scientific and technical personnel. The construction of the CMS Silicon Strip Tracker at the IIHE (ULB/VUB) was the largest technical project of the institute during this decennium. The following persons were hired by means of the FWO budgets allocated to this project. The UGent team had received no funding for personnel on this project.

Universiteit Antwerpen

Wim Beaumont – Bijzonder wetenschappelijk medewerker (01/01/2005 – 31/01/2010): responsible for the realisation and coordination of Si-strip long term test stations and specialist on data acquisition and slow control software.

Marco Cardaci - Doctoraatsbeurs (01/01/2006 – 31/12/2009): contribitions to the Jet/Met analysis tools and study of cluster splitting merging in Si-tracker modules by means of the CMS detector simulation based on GEANT4.

Vrije Universiteit Brussel

Olivier Devroede – Bijzonder wetenschappelijk medewerker (1/02/2004 – 31/05/2004): responsible for the construction and maintenance of the TIER-2 computing infrastructure at the IIHE (ULB/VUB)

Chunxu Yu – Subsidie aan geleerden (1/06/2004 – 30/09/2004): studied the deformation of Silicon Strip Tracker modules at low temperatures

Stijn De Weirdt – Bijzonder wetenschappelijk medewerker (1/11/2004 – 30/06/2008): IT expert in charge of the initial construction of the TIER-2 computing infrastructure at the IIHE (ULB/VUB)

Steven Lowette – Doctoraatsbeurs (1/01/2005 – 30/09/2005) en Bijzonder wetenschappelijk medewerker (01/10/2005 – 20/12-2006): PhD obtained by studying the design and implementation of b-tagging identification tools and by performing the first study of data-analyse techniques to search for charged Higgs bosons

Ilaria Villella – Doctoraatsbeurs (1/11/2006 – 31/10/2007; 1/01/2008 – 30/10/2008; 1/01/2009 – 30/10/2009): study of the angular distributions of the observed objects in the decay of top quark pair events, and this with the aim of measuring the W boson helicity and the possible spin correlations between the top and anti-top quarks

Jan Heyninck – Bijzonder wetenschappelijk medewerker (1/02/3008 – 31/05/2008): PhD obtained by performing a study to quantify the potential to measure the top quark sector with the CMS experiment

Matthias Mozer – Subsidie aan geleerden (1/07/2008 – 30/09/2009): study of the reconstruction of high energetic electron-positron pairs in proton collisions and the search for heavy resonances with this decay topology, inlcluding studies of trigger and reconstruction requirements

Michael Maes – Doctoraatsbeurs (1/01/2010 – now): study of the measurement of the cross section of the top quark pair process with a multi-dimensional fit including the CKM matrix element Vtb and the b-tagging efficiency

Stijn Blyweert – Doctoraatsbeurs (1/01/2010 – now): study and search of possible fourth generation quarks heavier than the top quark and measurement of the jet energy scale corrections

Annie De Coster – Technisch personeel (1/01/2005 – 30/06/2009): important contribution in the design and construction of support frames for the Silicon Strip Tracker modules, and testing the electronic circuits on these frames

Marleen Goeman – Technisch personeel (1/01/2005 – 31/12/2009): important contribution for the assembly of Silicon Strip Tracker modules by means of a semi-automatic assembly robot, also in charge of all transportation of Tracker components at the IIHE (ULB/VUB)

Luc Van Lancker – Technisch personeel (1/01/2005 – 28/02/2009): important contribution as an engineer to the design, construction and maintenance of the semi-automatic assembly robot used to assemble the Silicon Strip Tracker modules

Bram Meerschaut – Technisch personeel (1/01/2005 – 31/12/2006): important contribution for the assembly of Silicon Strip Tracker modules by means of a semi-automatic assembly robot

Hans De Nil – Technisch personeel (1/01/2006 – 31/12/2007): important contribution to the verification of the readout electronics of the Silicon Strip Tracker modules and the optical inspection of the electronic connections

The Belgian team represents about 2% of the full CMS Collaboration. The three Flemish universities involved host about half of this team. The general Flemish contribution to the CMS experiment, in the period 2004-2009, is foreseen by the following lists of persons. Below all members of our team involved in the CMS experiment are listed for completeness. The allocated running budgets supported the whole team.

Universiteit Antwerpen

- Prof. Eddi De Wolf, Prof. Albert De Roeck, Prof. Pierre Van Mechelen, Prof. Nick van Remortel
- Dr. Leonardo Benucci, Dr. Karel Cerny, Dr. Evelyne Delmeire , Dr. Majid Hashemi, Dr. Xavier Janssen, Dr. Benoit Roland, Dr. Lali Rurua, Dr. Edward Sarkysyan-Grinbaum, Dr. Deniz Sunar, Dr. Tomas Sykora, Dr. Alexander Zhokin, Wim Beaumont
- PhD students: Marco Cardaci, Ludivine Céard, Luca Mucibello, Silvia Ochesanu, Marion Ripert, Romain Rougny, Michele Selvaggi, Hans Van Haevermaet, Thomas Maes, Filip Moortgat
- Internship: Harish Chandra

Universiteit Gent

- Prof.Dirk Ryckbosch, Prof.Martin Grunewald
- Dr.Michael Tytgat, Dr.Nikolaos Zaganidis, Dr.Sylvia Costantini, Dr. Jeremie Lellouch
- PhD students: Filip Thyssen, Piet Verwilligen, Lukas Vanelderen, Benjamin Klein, Sinead Walsh, Andrey Marinov, Joseph McCartin

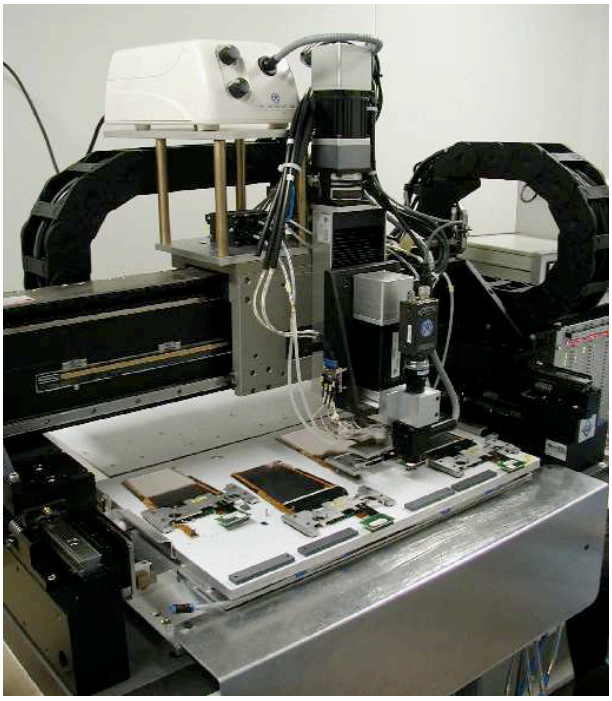
Vrije Universiteit Brussel

- Prof. Jorgen D'Hondt, Prof. Stefaan Tavernier, Prof. Walter Van Doninck, Prof. Fred Udo
- Dr. Volker Adler, Dr. Stephanie Beauceron, Dr. Olivier Devroede, Dr. Matthias Mozer, Dr. Chunxu Yu
- PhD students: Stijn Blyweert, Jan Heyninck, Alexis Kalogeropoulos, Steven Lowette, Joris Maes, Michael Maes, Petra Van Mulders, Ilaria Villella
- Technical personnel: Jan Debruyne, Annie De Coster, Hans De Nil, Stijn De Weirdt, Marleen Goeman, Robert Goorens, Sven Hannaert, Bram Meerschaut, Abdelhak Ouchene, Daisy Pirnay, Luc Van Lancker, Christian Wastiels
- Jobstudents: Yue Cao, Philippe Dehasque, Sofie Jaspers, Xu Ping, Jarl Verledens, Marian Vincent, Yue Yi

Chapter 9

Equipment

Most of the equipment budget is used to support the construction of the Silicon Strip Tracker elements for which we were responsible and the initial construction of the TIER-2 computing infrastructure. The budget was used to purchase the support frames of the detector modules. Every collaborating institute in the Tracker sub-collaboration of the CMS experiment, did invest a significant budget to purchase the infrastructure needed to construct the Tracker. The picture below shows part of the Gantry Robot system built for assemble the Silicon Strip Tracker modules at the IIHE (ULB/VUB). For the TIER-2 system, the budget was allocated to the CPU and hard disk elements needed in this GRID based computing infrastructure. The TIER-2 system is essential is our research to design and test analysis methods to study the proton collisions.

Picture of a Silicon Strip Tracker module and the Gantry robot deployed a the IIHE (ULB/VUB) to assemble its components.

Chapter 10

Scientific publications

Unless indicated, most of the publications are joint publications between the promoters. Joint publications are intrinsic to the character of an international collaboration like the CMS Collaboration. Also the publications of the design and the construction of the Silicon Strip Tracker are joint publications in a natural way. In the general publication strategy of large international collaborations at collider experiments the so-called internal notes represent valuable publications usually after a thorough evaluation within the collaboration. On the Spires webarchive it can be found that the CMS Collaboration has 711 entries, including journal papers, reports, proceedings, books, etc.

1. Publications in journals mentioned in the ISI Web of Science (a1)

1. Performance studies of the CMS Strip Tracker before installation, Adam, W; Bergauer, T; Dragicevic, M, et al., JINST 4:P06009,2009.
2. M.G. Albrow, et al., 'The FP420 R&D project: Higgs and New Physics with forward protons at the LHC', JOURNAL OF INSTRUMENTATION 4:T10001, 2009
3. Alignment of the CMS silicon strip tracker during stand-alone commissioning, Adam, W.; Bergauer, T.; Dragicevic, M., et al., JINST 4:T07001 July 2009
4. Stand-alone cosmic muon reconstruction before installation of the CMS silicon strip tracker, Adam, W.; Bergauer, T.; Dragicevic, M., et al., JINST 4:P05004,2009.
5. The CMS experiment at the CERN LHC, Chatrchyan, S; Hmayakyan, G; Khachatryan, V, et al., JINST 3:S08004,2008.
6. The CMS tracker operation and performance at the magnet test and cosmic challenge , Adam, W.; Bergauer, T.; Dragicevic, M., et al., JINST 3:P07006,2008.
7. CMS physics technical design report, volume II: Physics performance, Bayatian, GL; Chatrchyan, S; Hmayakyan, G, et al., J.Phys.G34:995-1579,2007. JUN 2007
8. The CMS tracker system, D'Hondt, J, Conference Information: Nuclear Science Symposium/Medical Imaging Conference, Date: OCT 23-29, 2005 Fajardo PR 2005 IEEE Nuclear Science Symposium Conference Record, Vols 1-5 Pages: 1084-1087 2005
9. Vertex reconstruction in CMS, Waltenberger, W.; Chabanat, E.; D'Hondt, J., et al.
   Nuclear Instruments & Methods in Physics Research, Section A (Accelerators, Spectrometers, Detectors and Associated Equipment) Volume: vol.549, no.1-3, Pages: 188-191 1 Sept. 2005

10. The effect of highly ionising particles on the CMS silicon strip tracker, Adam, W; Bergauer, T; Friedl, M, et al., Nucl.Instrum.Meth.A543:463-482,2005
    Sensitivity of Robust Vertex Fitting Algorithms, J. D'Hondt et al., IEEE Transactions on Nuclear Science Journal Vol.51, N°5 (2004) 2037-2044
11. CMS Monte Carlo production in the WLCG computing grid. Jose M. Hernandez *et al.* 2008. 10pp. Published in J.Phys.Conf.Ser.119:052019,2008.
12. CMS Monte Carlo production operations in a distributed computing environment. A. Mohapatra *et al.* FERMILAB-CONF-08-312-CD, 2008. 2pp. 18th Hadron Collider Physics Symposium 2007 (HCP 2007) 20-26 May 2007, La Biodola, Isola d'Elba, Italy. Published in Nucl.Phys.Proc.Suppl.177-178:324-325,2008.
13. The CMS data transfer test environment in preparation for LHC data taking. G. Bagliesi *et al*. Oct 2008, 8p. Published in Nuclear Science Symposium Conference Record, 2008. NSS '08. IEEE
14. Transverse momentum and pseudorapidity distributions of charged hadrons in pp collisions at sqrt(s) = 0.9 and 2.36 TeV, by CMS Collaboration (Vardan Khachatryan *et al.*). CMS-QCD-09-010, Feb 2010, published in JHEP 1002:041,2010.
15. The CMS high level trigger. By CMS Trigger and Data Acquisition Group (W. Adam *et al.*). Dec 2005. 107pp. Published in Eur.Phys.J.C46:605-667,2006.
16. Development of RE1/1 RPCs for the CMS muon trigger system. S. Park *et al.* 2009. 3pp. Published in Nucl.Instrum.Meth.A602:665-667,2009.

Below a list of publications from the CMS Collaboration on the studies of the detector performance using particles from cosmic rays.

1. Commissioning of the CMS experiment and the cosmic run at four tesla, CMS Collaboration, 2010 J. Inst. 5 T03001
2. Performance of the CMS Level-1 trigger during commissioning with cosmic ray muons and LHC beams, CMS Collaboration, 2010 J. Inst. 5 T03002
3. Performance of the CMS drift-tube chamber local trigger with cosmic rays, CMS Collaboration, 2010 J. Inst. 5 T03003
4. Fine synchronization of the CMS muon drift-tube local trigger using cosmic rays, CMS Collaboration, 2010 J. Inst. 5 T03004
5. Commissioning of the CMS High-Level Trigger with cosmic rays, CMS Collaboration, 2010 J. Inst. 5 T03005
6. CMS data processing workflows during an extended cosmic ray run, CMS Collaboration, 2010 J. Inst. 5 T03006
7. Commissioning and performance of the CMS pixel tracker with cosmic ray muons, CMS Collaboration, 2010 J. Inst. 5 T03007
8. Commissioning and performance of the CMS silicon strip tracker with cosmic ray muons, CMS Collaboration, 2010 J. Inst. 5 T03008

9. Alignment of the CMS silicon tracker during commissioning with cosmic rays, CMS Collaboration, 2010 J. Inst. 5 T03009
10. Performance and operation of the CMS electromagnetic calorimeter, CMS Collaboration, 2010 J. Inst. 5 T03010
11. Measurement of the muon stopping power in lead tungstate, CMS Collaboration, 2010 J. Inst. 5 P03007
12. Time reconstruction and performance of the CMS electromagnetic calorimeter, CMS Collaboration, 2010 J. Inst. 5 T03011
13. Performance of the CMS hadron calorimeter with cosmic ray muons and LHC beam data, CMS Collaboration, 2010 J. Inst. 5 T03012
14. Performance of CMS hadron calorimeter timing and synchronization using test beam, cosmic ray, and LHC beam data, CMS Collaboration, 2010 J. Inst. 5 T03013
15. Identification and filtering of uncharacteristic noise in the CMS hadron calorimeter, CMS Collaboration, 2010 J. Inst. 5 T03014
16. Performance of the CMS drift tube chambers with cosmic rays, CMS Collaboration, 2010 J. Inst. 5 T03015
17. Calibration of the CMS drift tube chambers and measurement of the drift velocity with cosmic rays, CMS Collaboration, 2010 J. Inst. 5 T03016
18. Performance study of the CMS barrel resistive plate chambers with cosmic rays, CMS Collaboration, 2010 J. Inst. 5 T03017
19. Performance of the CMS cathode strip chambers with cosmic rays, CMS Collaboration, 2010 J. Inst. 5 T03018
20. Aligning the CMS muon chambers with the muon alignment system during an extended cosmic ray run, CMS Collaboration, 2010 J. Inst. 5 T03019
21. Alignment of the CMS muon system with cosmic-ray and beam-halo muons, CMS Collaboration, 2010 J. Inst. 5 T03020
22. Precise mapping of the magnetic field in the CMS barrel yoke using cosmic rays, CMS Collaboration, 2010 J. Inst. 5 T03021
23. Performance of CMS muon reconstruction in cosmic-ray events, CMS Collaboration, 2010 J. Inst. 5 T03022

2. Publications in journals but not in category a1 (a2)

1. Top Quark Physics at the LHC, Jorgen D'hondt, Jul 2007. 6pp., proceedings of Symposium on Hadron Collider Physics 2006 (HCP 2006), Durham, North Carolina, 22-26 May 2006.
2. CMS physics technical design report: Addendum on high density QCD with heavy ions, by CMS Collaboration (David G. d'Enterria, (Ed.) *et al.*). CERN-LHCC-2007-009, Mar 2007. 169pp. , J.Phys.G34:2307-2455,2007.
3. Potential of standard model measurements with CMS, by CMS Collaboration (J. D'Hondt *for the collaboration*). 2005, prepared for EPS International Europhysics Conference on High Energy Physics (HEP-EPS 2005), Lisbon, Portugal, 21-27 Jul 2005, PoS HEP2005:295,2006.
4. The top quark as a calibration tool at the LHC. H. Bachacou, P. Van Mulders, . ATL-PHYS-CONF-2008-022, ATL-COM-PHYS-2008-096, CERN-

CMS-CR-2008-058, 2009. 8pp. Published in Nuovo Cim.123B:1197-1204,2008.
5. Estimation of the jet energy scale corrections using top quark events. P. Van Mulders, . CERN-CMS-CR-2008-052, Jul 2008. 3pp. Published in Nuovo Cim.123B:1325-1326,2008.
6. Measurements of the b-tag performance from data in CMS. Joris Maes, Brussels Vrije U., . CERN-CMS-CR-2008-059, Aug 2008. 4pp. Published in Nuovo Cim.123B:1305-1307,2008.
7. Observability of same-charge lepton topologies in fully leptonic top quark pair events in CMS. S. Lowette, (Vrije U., Brussels) . 2007. 8pp. Prepared for Physics at LHC, Cracow, Poland, 3-8 Jul 2006. Published in Acta Phys.Polon.B38:469-476,2007.
8. Observability of heavy charged MSSM Higgs bosons in the H+- ---> t b decay in CMS. S. Lowette, (Brussels U.) . 2005. Prepared for Conference on Physics at LHC, Vienna, Austria, 13-17 Jul 2004. Published in Czech.J.Phys.55:B831-B836,2005.
9. Distributed Analysis in CMS, A. Fanfani et.al., Published in Journal of Grid Computing, 1572-9814, 2010
10. Triggers for new physics at the LHC. Matthias Ulrich Mozer, (Brussels U., IIHE) . 2009. 3pp. Published in J.Phys.Conf.Ser.171:012101,2009.
11. QCD factorization in diffraction. Matthias Ulrich Mozer, (Vrije U., Brussels) . 2008. 3pp. Prepared for International Europhysics Conference on High Energy Physics (EPS-HEP2007), Manchester, England, 19-25 Jul 2007. Published in J.Phys.Conf.Ser.110:022033,2008.
12. The CMS RPC system overview. By CMS Collaboration (N. Darmenov *et al.*). 2010. 6pp. Published in AIP Conf.Proc.1203:43-48,2010.
13. Assembly and quality certification for the first station of CMS endcap RPCs (RE1). Z. Aftab *et al.* 2006. 5pp. Prepared for 8th Workshop on Resistive Plate Chambers and Related Detectors, Seoul, Korea, 10-12 Oct 2005. Published in Nucl.Phys.Proc.Suppl.158:103-107,2006. Also in *Seoul 2005, Resistive plate chambers and related detectors* 103-107
14. Cosmic ray test certification of the first 100 CMS endcap RPCs and the corresponding construction database. A. Ball *et al.* 2006. 4pp. Prepared for 8th Workshop on Resistive Plate Chambers and Related Detectors, Seoul, Korea, 10-12 Oct 2005. Published in Nucl.Phys.Proc.Suppl.158:99-102,2006. Also in *Seoul 2005, Resistive plate chambers and related detectors* 99-102
15. Production and the quality control for the CMS endcap RPCs. Z. Aftab *et al.* 2006. 5pp. Prepared for 8th Workshop on Resistive Plate Chambers and Related Detectors, Seoul, Korea, 10-12 Oct 2005. Published in Nucl.Phys.Proc.Suppl.158:16-20,2006. Also in *Seoul 2005, Resistive plate chambers and related detectors* 16-20
16. The CMS Data Transfer Test Environment in Preparation for LHC Data Taking, Bagliesi, G; Bauerdick, L; Belforte, S, et al. Conference Information: IEEE Nuclear Science Symposium/Medical Imaging Conference, Date: OCT 19-25, 2008 Dresden German 2008 IEEE Nuclear Science Symposium and Medical Imaging Conference (2008 NSS/MIC), VOLS 1-9 Pages: 2750-2757 2009

3. Publications in national journals with reading committee (a3)

1. Physicalia Magazine 26(2004)4,411-420, "Physics at the Large Hadron Collider", J. D'Hondt

4. Publications in journals not in a1, a2 or a3 (a4)

a. Publications within the CMS Collaboration with reading committee

1. CMS NOTE-2009-002, CMS Tracker Alignment at the Integration Facility, W. Adam,et al.
2. CMS NOTE-2009-003,Track Reconstruction with Cosmic Ray Data at the Tracker Integration Facility , W. Adam, et al.
3. CMS NOTE-2009-005, Reception Test of Petals for the End Cap+ of the CMS Silicon Strip Tracker, R. Bremer , et al.
4. CMS NOTE-2009-009, Integration of the End Cap TEC+ of the CMS Silicon Strip Tracker, V. Adler,et al.
5. CMS NOTE-2009-013, Distributed Analysis in CMS, A.Fanfani,et al.
6. CMS NOTE-2009-021, Commissioning the CMS Silicon Strip Tracker prior to Operations with Cosmic Ray Muons, Bouhali,et al.
7. Adiguzel, et al., 'Production of quartz plates for CMS-CASTOR Experiment', CERN-CMS NOTE-2008/035.
8. CMS NOTE-2008-032, Performance studies of the CMS Strip Tracker before installation. ,W. Adam, et al.
9. CMS NOTE-2008-028, Petal integration for the CMS tracker Endcaps, T. Bergauer et al.
10. M. Cardaci et al., 'CMS Search Plans and Sensitivity to New Physics using Dijets', CERN-CMS NOTE-2008-019.
11. CMS NOTE-2007-02,CERN-LHCC-2006-039,CERN-LHC-G-124, Prospects for diffractive and forward physics at the LHC, M. Albrow et al.
12. CMS NOTE-2007-006, CMS computing, software and analysis challenge in 2006 (CSA06) summary, The CMS Collaboration
13. CMS-NOTE-2006-013, Offline calibration of b-jet identification efficiencies., S. Lowette et al.
14. CMS-NOTE-2006-023, Fitting of event topologies with external kinematic constraints in CMS., J. D'Hondt et al.
15. CMS-NOTE-2006-024, Electron and muon reconstruction in single leptonic t anti-t events., J. D'Hondt et al.
16. CMS-NOTE-2006-025, Light quark jet energy scale calibration using the W mass constraint in single-leptonic t anti-t events., S. Lowette et al.
17. CMS-NOTE-2006-032, Vertex fitting in the CMS tracker., T. Speer et al.
18. CMS-NOTE-2006-064, Measurement of the cross section of single leptonic t anti-t events., J.D'Hondt et al.
19. CMS-NOTE-2006-065, Observability of same-charge lepton topology in di-leptonic ttbar events, J. D'Hondt et al.

20. CMS-NOTE-2006-066, Top quark mass measurement in single leptonic t anti-t events, J. Heyninck et al.
21. CMS-NOTE-2006-109, Charged MSSM Higgs boson observability in the H+- → t b decay, S. Lowette et al.
22. CMS-NOTE-2005-009, Thermal conductivity measurement of the silicon sensor support frames of the CMS tracker, B. Clerbaux, F. Udo, C. Vander Velde, M. Vancaldenhoven, L. Van Lancker
23. CMS-NOTE-2005-025, Design and test beam performance of substructures of the CMS tracker end caps, R. Brauer_ et al.

The following Physics Analysis Summary pages, are reports fully reviewed within the CMS Collaboration with reading committee. There are the baseline communication of physics results from the CMS Collaboration to the external scientific community. These results are for example shown at international conferences.

1. JME-09-008: Calorimeter Jet Quality Criteria for the First CMS Collision Data (July 2009)
2. JME-09-010: Performance of Track-Corrected Missing ET in CMS (July 2009)
3. JME-09-007: Measurement of the Jet Energy Resolutions and Jet Reconstruction Efficiency at CMS (July 2009)
4. JME-09-005: Determination of the jet energy scale using Z->e+e− + jet pT balance and a procedure for combining data-driven corrections (July 2009)
5. JME-09-004: Jet energy calibration with photon+jet events (July 2009)
6. JME-09-002: Jet Plus Tracks Algorithm for Calorimeter Jet Energy Corrections (July 2009)
7. BTV-09-001: Algorithms for b Jet Identification in CMS (July 2009)
8. JME-09-001: A Cambridge-Aachen (C-A) based Jet Algorithm for boosted top-jet tagging (July 2009)
9. JME-09-009: Jet energy correction using Z-->mumu Jet PT balance (June 2009)
10. JME-08-002: Jet Corrections to Parent Parton Energy (May 2009)
11. JME-09-003: Offset Energy Correction for Cone Jets (May 2009)
12. JME-08-003: Determination of the Relative Jet Energy Scale from Dijet Balance (May 2009)
13. PFT-09-001: Particle–Flow Event Reconstruction in CMS and Performance for Jets, Taus, and ETmiss (April 2009)
14. JME-08-001: Performance of Jet Reconstruction with Charged Tracks only (September 2008)
15. PFT-08-001: Tau Reconstruction using the Particle Flow Technique (July 2008)
16. JME-07-002: Plans for Jet Energy Corrections at CMS (July 2008)
17. BTV-07-003: Effect of misalignment on b-tagging (July 2008)
18. JME-07-003: Performance of Jet Algorithms in CMS
19. JME-07-001: Performance of missing ET reconstruction
20. BTV-07-001: b tag efficiency from System 8 & Ptrel Method

21. BTV-07-002: Measuring uds mistag rate of b tag using negative tags
22. EGM-07-001: Measuring Electron Efficiencies with Early Data
23. TOP-09-009: Study of the top-pair invariant mass distribution in the semileptonic muon channel at 10 TeV (July 2009)
24. TOP-09-001: Probing the heavy flavor content of the t-tbar dilepton channel at 10 TeV (July 2009)
25. TOP-09-010: Expectation for a measurement of the t-tbar production cross section in the muon+jets final state using a multivariate technique (July 2009)
26. TOP-09-002: Expectations for observation of top quark pair production in the dilepton final state with early data at 10 TeV (Jun 2009)
27. TOP-08-001: Di-lepton ttbar cross section with 10 pb^-1
28. TOP-08-002: Di-lepton ttbar cross section with 100 pb^-1
29. TOP-09-003: Plans for an early measurement of the t-tbar cross section in the muon+jets channel at 10 TeV (Jul 2009)
30. TOP-08-005: Semi-leptonic (muon) ttbar cross section with 10 pb^-1
31. TOP-09-004: Plans for an early measurement of the t-tbar cross section in the electron+jets channel at 10 TeV (Jul 2009)
32. TOP-09-005: Prospects for the measurement of the single-top t-channel cross section in the muon channel with 200 pb−1 at 10 TeV (Jul 2009)
33. TOP-09-007: Plan for a B(t->Wb)/B(t->Wq) measurement in t-tbar semi-leptonic decays at 10 TeV (Jul 2009)
34. TOP-08-004: Di-lepton ttbar tau channels (en route to)
35. TOP-07-004: Jet Energy Scale from top events
36. EWK-09-006: Study of the ratio of W + jets to Z + jets at 10 TeV (July 2009)
37. EWK-08-006: Study of Z production in association with jets 10 TeV (July 2009)
38. EWK-09-005: Study of the Z->ee differential cross section as a function of Z rapidity at 10 TeV (July 2009)
39. EWK-09-004: Towards a Measurement of the Inclusive W->enu and gamma!*/Z->e+e Cross Sections at 10 TeV (July 2009)
40. EWK-09-003: Muon Differential Cross Section and Charge Asymmetry in Inclusive pp -> W(mu-mu) + X Production at 10 TeV (Jun 2009)
41. EWK-09-002: Prospects for measuring the WW production cross section at 10 TeV (Jun 2009)
42. EWK-09-001: Measurement of the W and Z cross section with muons at 10 TeV (Mar 2009)
43. EWK-08-002: W charge asymmetry (Sep 2008)
44. EWK-08-003: Observation of WZ production (Sep 2008)
45. EWK-08-001: Measurement of Z boson production in association with two b-jets (July 2008)
46. EWK-08-005: Measurement of the W and Z cross section with electrons (July 2008)
47. EWK-07-002: Measurement of the W and Z cross section with muons
48. QCD-09-003: Dijet Azimuthal Decorrelations -- at 10 TeV (July 2009)
49. QCD-08-002: Study of jet transverse structure using the second moment of the jet profile in transverse momentum -- at 10 TeV (July 2009)

50. QCD-08-001: Initial Measurement of the Inclusive Jet Cross Section at 10 TeV (July 2009)
51. QCD-09-002: Charged hadron multiplicity in minimum bias events (June 2009)
52. QCD-08-004: Pseudorapidity distribution of charged particles in minimum-bias collisions (October 2008)
53. QCD-08-005: Transverse momentum distribution within jets (October 2008)
54. QCD-08-003: Hadronic Event Shapes at CMS (July 2008)
55. QCD-07-002: Zero bias and HF-based minimum bias triggering
56. QCD-07-001: Measurement of charged hadron spectra
57. QCD-07-003: Measurement of the Underlying Event
58. HIG-08-003: Search for Higgs to ZZ* (January 2009)
59. HIG-08-006: Search for Higgs to WW* (January 2009)
60. HIG-08-008: Higgs to tau-tau (October 2008)
61. HIG-08-001: qqH production, with H-->tau-tau
62. EXO-08-010: Search for First Generation Leptoquarks (July 2009)
63. EXO-09-010: Search for Second Generation Scalar Leptoquarks (July 2009)
64. EXO-08-013: Search for Low Mass b' Production (July 2009)
65. EXO-09-003: Searching for Majorana Neutrinos in the Like-Sign Dilepton Final State at 10 TeV (July 2009)
66. EXO-08-008: Search for Exotic Partners of the Top Quark (July 2009)
67. EXO-09-012: Search for A Fourth Generation b' Quark in tW Final State at 10 TeV (July 2009)
68. EXO-09-007: Search for Technicolor (July 2009)
69. SUS-09-001: Search strategy for exclusive multi-jet events from supersymmetry (July 2009)
70. EXO-09-011: Search for Scalar and Tensor Unparticles in the Diphoton Final State (July 2009)
71. EXO-09-009: Search for Randall-Sundrum Gravitons in the Diphoton Final State (July 2009)
72. EXO-09-004: Search for large Extra Dimensions in the diphoton final state (June 2009)
73. SUS-09-004: Data-Driven Background Estimates for SUSY Di-Photon Searches (July 2009)
74. EXO-09-008: Search for heavy narrow t-tbar resonances in muon-plus-jets final states with the CMS detector (July 2009)
75. EXO-09-006: Search for high-mass resonances decaying into an electron pair -- at 10 TeV with 100 pb−1 (July 2009)
76. EXO-09-013: Search for Mono-Jet Final States from ADD Extra-Dimensions at 10 TeV (July 2009)
77. SUS-09-002: Discovery potential and measurement of a dilepton mass edge in SUSY events at 10 TeV (July 2009)
78. EXO-09-002: Search for High-Mass Resonances Decaying into Top-Antitop Pairs in the All-Hadronic Mode (July 2009)
79. EXO-09-001: Searching for Stopped Gluinos during Beam-off Periods (May 2009)
80. EXO-08-009: Search for a b' (October 2008)

81. EXO-08-011: Search for extra dimensions with monojets (October 2008)
82. EXO-08-005: MUSIC -- deviations between data and Monte Carlo simulation (September 2008)
83. SUS-08-005: SUSY search with dijet events (September 2008)
84. SUS-08-001: Dilepton+Jet+MET channel: Observation and Measurement of x2 --> x1 ll (July 2008)
85. SUS-08-002: Data driven estimation of the Z->invisible background for the early SUSY searches (July 2008)
86. EXO-08-001: Search for Z'-->ee (July 2008)
87. EXO-08-004: Search for W'-->enu (July 2008)
88. SBM-07-002: Search for Z' --> mumu
89. SBM-07-001: Searches for New Physics using high ET dijet events
90. EXO-08-003: Search for Heavy Stable Charged Particles
91. BPH-07-001: Study of B_s -> μ+μ− (Jul 2009)
92. BPH-09-001: Measurement of Differential Production Cross Sections and Lifetime Ratio for Exclusive Decays of B+ and B0 Mesons in pp Collisions at 10 TeV (Jun 2009)
93. BPH-08-004: Study of b-bbar correlations using J/psi + muon events (Mar 2009)
94. BPH-07-002: Feasibility study of a J/psi cross section measurement with early CMS data (July 2008)
95. HIN-07-002: Analysis of photon-jet events in pb-pb collisions
96. FWD-08-001: Single jet spectrum in HF and dijets with large eta separation (October 2008)
97. FWD-08-002: Observation of dijet events with forward rapidity gap (October 2008)
98. DIF-07-001: Exclusive dilepton production
99. DIF-07-002: Single diffractive W production

b. Publications within the CMS Collaboration without reading committee

1. CMS AN-2008/101, High level triggers for high energy electrons at low luminosity, D. Evans, et al.
2. CMS AN-2008/077, The High Energy Electron Pair Analysis: An Experience of Integration and Improvements, M. Mozer, et al.
3. CMS AN-2008/048, Search for high mass resonance production decaying into an electron pair in the CMS experiment, D. Evans, et al.
4. CMS AN-2008/045, Electron ID at High Energies, D. Newbold, et al.
5. CMS AN-2008/044, Study of backgrounds to high-mass di-electron (Dell-Yan) final states, D. Bandurin, et al.
6. CMS AN-2008/029, Recovery of high pt electrons from large mass pairs, lost in CMS ECAL cracks and in case of a missing endcap, Sh. Elgammal, et al.
7. CMS IN-2008/009, Description of CSA07 SUSYBSM Skims, M. U. Mozer, M. Tytgat
8. CMS AN-2008/004, Search for massive resonance production decaying into an electron or a photon pair, J. Brooke, et al.

9. CMS AN-2007/016, Dijet resonance analysis with CMSSW 1.2.0, M. Cardaci, B. Bollen and R. Harris
10. CMS AN-2007/031, Towards a measurement of the inclusive $W\rightarrow\mu\nu$ and $Z\rightarrow\mu\mu$ cross sections in pp collisions at 14 TeV, N.Adam et al.
11. CMS- AN-2007/037, Search for the Higgs boson in the WW$^{(*)}$ decay channel with the CMS Experiment, C.Charlot et al.
12. CMS-AN-2007-039, CMS search plans to new physics using dijets, M. Cardaci et al.
13. CMS-CR-2005-008, Top physics at the LHC, S. Lowette
14. CMS-AN-2005-071, Selection of toppair events with CMS, M. Grunewald et al., J. D'Hondt, S. Lowette, …
15. CMS-AN-2005-030, Offline calibration of bjet identification efficiencies, S. Lowette, J. D'Hondt, J. Heyninck and P. Vanlaer
16. CMS-AN-2005-027, Light quark jet energy scale calibration using the W mass constraint in singleleptonic ttbar events, J. D'Hondt, J. Heyninck, S. Lowette and S. Kasselman
17. CMS-AN-2005-025, Design and test beam performance of substructures of the CMS tracker end caps, R.Brauer et al.
18. CMS-AN-2005-024, Electron and muon reconstruction insingle leptonic tt bar events, J. D'Hondt, S. Lowette and J. Heyninck
19. CMS-AN-2005-024, Electron and muon reconstruction insingle leptonic tt bar events, J. D'Hondt, S. Lowette and J. Heyninck
20. CMS PAS SBM-07-001, CMS Search plans and sensitivity to new physics using dijets, CMS Collaboration
21. CERN-LHCC 2007-01, The CMS magnet test and cosmic challenge (MTCC phase I and II), CMS Collaboration
22. CERN-LHCC 2007-010, CMS computing, software and analysis challenge in 2006 (CSA2006), CMS Collaboration
23. CERN-LHCC 2007-14, CMS expression of interest in the SLHC, CMS Collaboration
24. CERN-LHCC 2007-021, CMS-AN 2007-009, CMS high level trigger, D.Acosta et al.
25. CERN-LHCC-2006-001, CMS-TDR-008-1, 2006, CMS physics: Technical design report, by CMS Collaboration
26. CMS Analysis Operations. J. Andreeva et.al., presented at CHEP 2009, CMS CR-2009/088
27. Debugging Data Transfers in CMS, G. Bagliesi, presented at CHEP2009, CMS CR -2009/093
28. CMS-AN-2009/032, Multi-jet background in semi-leptonic top quark pairs, G.Hammad,et al.
29. L. Benucci, et al., 'Search for Mono-Jet from ADD Extra-Dimensions in different LHC energy scenarios', CERN-CMS AN-2009/003.
30. L. Benucci, et al., 'Search for Mono-Jet Final States from ADD Extra-Dimensions', CERN-CMS AN-2008/073.
31. B. Bollen, et al., Dijet Resonance Analysis with CMSSW_1_2_0, , CERN-CMS AN-2007/016.
32. W. Beaumont et al., 'LtStruct Package for the Longterm Test of Tracker Substructures', CERN-CMS IN-2006/047
33. W. Beaumont et al., 'Defect Analysis of the CMS Silicon Strip Detectors', CERN-CMS IN-2004/043

5. Books as author or co-author (b1)

1. The CMS Collaboration, CMS Physics TDR: Volume 1 (PTDR1), Detector Performance and Software (CERN/LHCC/2006-001, CMS TDR 8.1, 2 Feruary 2006)
2. The CMS Collaboration, CMS Physics TDR: Volume 2 (PTDR2), Physics Performance (CERN/LHCC/2006-021, CMS TDR 8.2, 26 June 2006), J. Phys. G: Nucl. Part. Phys. 34 995-1579
3. The CMS Collaboration, High Density QCD with Heavy Ions PTDR Addendum (CERN/LHCC/2007-009, CMS TDR 8.2-Add1, 5 March 2007), J. Phys. G: Nucl. Part. Phys. 34 (2007) 2307-2455
4. The CMS Collaboration, CMS Computing TDR (CTDR), (CERN/LHCC-2005-023, 20 June 2005)

6. Chapters in books (b2)

7. Books as editor (b3)

8. Proceedings not in category a (no abstracts) (c1)

1. Standard Model Handles and Candles Working Group: Tools and Jets Summary Report. C. Buttar *et al.* Mar 2008. 94pp. Temporary entry Published in *Les Houches 2007, Physics at TeV colliders* 121-214 e-Print: arXiv:0803.0678 [hep-ph]
2. Top Quark Physics at the LHC. Jorgen D'hondt, (Vrije U., Brussels) . Jul 2007. 6pp. in the proceedings of Symposium on Hadron Collider Physics 2006 (HCP 2006), Durham, North Carolina, 22-26 May 2006. e-Print: arXiv:0707.1247 [hep-ph]
3. Les houches physics at TeV colliders 2005, standard model and Higgs working group: Summary report. C. Buttar *et al.* Apr 2006. 234pp. Contributed to Les Houches Workshop on Physics at TeV Colliders, Les Houches, France, 2-20 May 2005. e-Print: hep-ph/0604120
4. Heavy charged MSSM Higgs bosons in the H+- ---> t b decay in CMS. S. Lowette, J. Heyninck, P. Vanlaer, (Brussels U., PNTPM) . CMS-CR-2004-031, Aug 2004. 8pp. Prepared for the proceedings of the 3rd Les Houches Workshop: Physics at TeV Colliders, Les Houches, France, 26 May - 6 Jun 2003.
5. The Higgs working group: Summary report 2003. By Higgs Working Group Collaboration (K.A. Assamagan *et al.*). FERMILAB-CONF-04-504-E, Jun 2004. 169pp. 3rd Les Houches Workshop: Physics at TeV Colliders, Les Houches, France, 26 May - 6 Jun 2003. Published in *Les Houches 2003, Physics at TeV colliders* 1-169 e-Print: hep-ph/0406152
6. Top physics at the LHC. S. Lowette, (Brussels U.) . Feb 2005. 5pp. Prepared for Lake Louise Winter Institute: Fundamental Interactions,

Lake Louise, Alberta, Canada, 20-26 Feb 2005. Published in *Lake Louise 2005, Fundamental interactions* 209-213
7. LHC searches for high-mass resonances decaying to leptons or photons. Matthias Ulrich Mozer, (Vrije U., Brussels) . Apr 2008. Prepared for 16th International Workshop on Deep Inelastic Scattering and Related Subjects (DIS 2008), London, England, 7-11 Apr 2008. Published in *London 2008, Deep inelastic scattering* 114
8. Diffractive dijets in DIS and PHP. Matthias Ulrich Mozer, (Vrije U., Brussels) . Apr 2007. 4pp. Prepared for 15th International Workshop on Deep-Inelastic Scattering and Related Subjects (DIS2007), Munich, Germany, 16-20 Apr 2007. Published in *Munich 2007, Deep-inelastic scattering, vol. 2* 667-670
9. Data Quality Monitoring of the CMS Tracker. By CMS Tracker Collaboration (V. Adler *for the collaboration*). CMS-CR-2009-344, Nov 2009. 5pp. Presented at 2009 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS MIC 2009), Orlando, Florida , 25-31 Oct 2009. e-Print: arXiv:0911.5240 [physics.ins-det]
10. The Standard Model and beyond, an overview, J.D'Hondt, in the proceedings of Journees Jeunes Chercheurs 2004, Ile De Berder, Bretagne, France
11. P. Van Mechelen, 'Forward and low-x physics program with CMS at the LHC', Proceedings of the 16th International Workshop on Deep-Inelastic Scattering and Related Topics, London, UK, April 7-11 2008, PROGRESS IN HIGH ENERGY PHYSICS, Volume 2, 2008.
12. O.A. Grachov, et al., 'Measuring photons and neutrons at zero degrees in CMS', Proceedings of 19th International Conference on Ultra-Relativistic Nucleus-Nucleus Collisions: Quark Matter 2006 (QM2006), Shanghai, China, 14-20 Nov 2006, INTERNATIONAL JOURNAL OF MODERN PHYSICS E16:2137-2142,2007.

9. PhD manuscripts, thesis, internal reports, abstracts (c2)

Dr. Filip Moortgat (UA, 2004), "Discovery potential of MSSM Higgs bosons using supersymmetric decay modes with the CMS detector"

Dr. Marco Cardaci (UA, 2009), "ADD extra dimensions searches with monojet events and resonance searches with dijet events with the CMS detector"

Dr. Steven Lowette (VUB, 2007), "The CMS Top Quark Physics Potential with 1/fb of data"

Dr. Jan Heyninck (VUB, 2008), "B-Tagging as a Tool for Charged Higgs Boson Identification in CMS"

1. P. Van Mechelen, 'Large Hadron Collider - Present status and future prospects', BPS General Scientific Meeting, 1 April 2009, Hasselt, Belgium
2. W. Beaumont, 'Design of the CMS-CASTOR subdetector readout system by reusing existing designs'

TWEPP-09: Topical Workshop on Electronics for Particle Physics, Paris, France, 21 - 25 Sep 2009

3. P. Van Mechelen, 'Forward Physics at the LHC', 3rd International Conference on Hard and Electromagnetic Probes of High Energy Nuclear Collisions, June 8-14 2008, Ila Da Toxa, Spain
4. M. Cardaci, 'Searches for new physics using dijet events at the LHC', Moriond QCD 2008, 08/03/2008 - 15/03/2008,La Thuile,Italy
5. P. Van Mechelen, 'Experimental Results on Diffraction', Hadron Collider Physics Symposium, May 26- June 1 2008, Galena (IL), USA
6. P. Van Mechelen, 'Low x phenomenology with CASTOR', Meeting on Diffraction and Forward Physics at HERA and the LHC, October 25-26 2007, Antwerpen, Belgium
7. P. Van Mechelen, 'Proton-proton physics studies at the LHC with CMS/Castor', Workshop on Low x Physics, August 29-September 1, 2007, Helsinki, Finland

Chapter 11

List of PhD's

In the period of this project in total 4 PhD's connected to the CMS experiment are successfully defended at our universities. Every year the CMS Collaboration selects between about 170 participating institutions the best PhD which is awarded the CMS Thesis Award. Several of our PhD students have obtained this price: Dr. Filip Moortgat (UA) in 2004, Dr. Steven Lowette (VUB) in 2008 and Dr. Jan Heyninck (VUB) in 2009. They are elected among about 500 ongoing PhD projects within the CMS Collaboration. The awarded persons are celebrated extensively within the CMS Collaboration and obtain an honourable position within the general field of particle physics.

Universiteit Antwerpen

Dr. Filip Moortgat (CMS Thesis Award in 2004)
Promoters Prof. Eddi De Wolf and Prof. Daniel Denegri
"Discovery potential of MSSM Higgs bosons using supersymmetric decay modes with the CMS detector"

Dr. Marco Cardaci, 21 december 2009 – ***this project***
Promoters Prof Pierre Van Mechelen en Prof. Albert De Roeck
"ADD Extra Dimension searches with monojet events and resonance searches with dijet events with the CMS detector"

Vrije Universiteit Brussel

Dr. Steven Lowette (CMS Thesis Award in 2007) – ***this project***
Promoters Prof. Jorgen D'Hondt and Prof. Stefaan Tavernier
"The CMS Top Quark Physics Potential with 1/fb of data"

Dr. Jan Heyninck (CMS Thesis Award in 2008) – IWT beurs and ***this project***
Promoter Prof. Jorgen D'Hondt
"B-Tagging as a Tool for Charged Higgs Boson Identification in CMS"

Stijn Blyweert (2009-...) – ***this project***
Promoter Prof. Jorgen D'Hondt
Study and search for possible fourth generation quarks

Alexis Kalogeropoulos (2009-...) – FWO project G.0464.07
Promoter Prof. Jorgen D'Hondt

Study of the kinematic properties of top quark pair events via goodness-of-fit tools to perform a statistical test of the consistency of the Standard Model predictions

Joris Maes (2006-…) – IWT beurs
Promoter Prof. Jorgen D'Hondt
Study of a new and data-driven measurement of the b-tagging efficiency via top quark pair events

Michael Maes (2009-…) – ***this project***
Promoter Prof. Jorgen D'Hondt
Study of a multi-dimensional measurement of the cross section, the b-tagging efficiency and the CKM element Vtb in top quark pair events

Petra Van Mulders (2006-…) – IWT beurs
Promoter Prof. Jorgen D'Hondt
Study of a new and data-driven measurement of the jet energy scale corrections via top quark pair events

Ilaria Villella (2006-…) – ***this project***
Promoter Prof. Jorgen D'Hondt
Study of the angular distributions in top quark pair events to measure the spin correlations between the top and anti-top quark