Compact Muon Solenoid Times

7 NOVEMBER, 2011

Editorial

Dear friends,

A very productive proton-collisions run of 2011, which yielded many interesting results, came to an end around 10 days ago. The LHC and CMS are now feverishly preparing for upcoming lead-ion collisions, which promise to provide us with more fascinating data into what our Universe was like in its early seconds. If last year is anything to go by, these collisions will open new windows and enhance our understanding of fundamental particle physics.

In this edition of the CMS Times, we look back at the proton collisions of this year, highlighting only a few of the many successes CMS has achieved.

We also include a summary of a CMS paper on electroweak physics, which was accepted for publication in *Physical Review D*.

With kind regards,

CMS Times Editorial Team

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CMS Profile

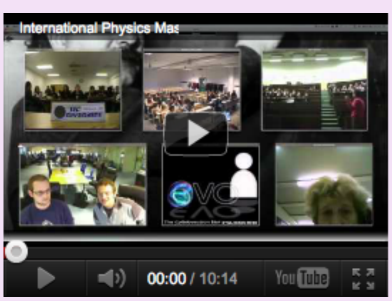
IPPOG International Physics Masterclasses

The international physics masterclasses allow high-school students to spend a day at a research institute and analyse real data from high-energy physics experiments. Conducted under the aegis of the International Particle Physics Outreach Group (IPPOG), the events are held in 24 countries with about 8000 students participating in nearly 120 nearby universities.

Lectures by particle physicists are followed by data analysis, and at the end of the day the students get to participate in an international videoconference to discuss their results.

In March 2011, for the first time, the physics enthusiasts performed analyses on LHC data, collected by three of the LHC experiments — ALICE, ATLAS and CMS.

We spoke to students and teachers, as well as members of the organisation team, who told us their motivation behind participating and what they gained from the Masterclasses of 2011.



Links

CMS Outreach, Visits and Media

From *NewScientist*, 1 November:

LHC to probe early universe in best detail yet

The Large Hadron Collider will spend four weeks probing the conditions of the early universe in better detail than ever before, as it takes a break from the hunt for the Higgs boson...

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From *Physics World*, 2 November:

LHC trials proton–lead collisions

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From *Wired Science*, 21 October:

Hints of New Physics Crop Up at LHC

Preliminary findings from CERN's Large Hadron Collider may have uncovered experimental evidence for physics beyond the Standard Model...

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From *symmetry breaking*, 31 October:

Graffiti Art Reflects an Experiment's Excitement on the Walls

The three concrete blocks CERN installed to contain waste at the CMS experiment were ugly and needed paint, according to Niels Dupont-Sagorin, who is in charge of safety at the site...

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2011 proton collisions come to an end

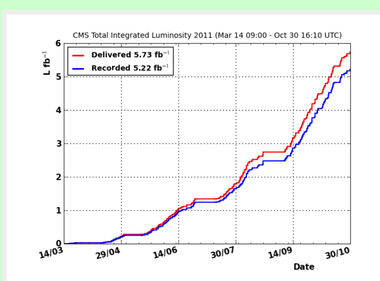
At about half-past five in the evening on Sunday, 30th October, an e-mail from Run Coordination to the CMS collaboration said:

> *At 17:00 today the LHC dumped the last proton beams for the year to start the machine development period and to prepare for the ion running. This means that we have come to the end of the proton operation for 2011.*

And what a fantastic year of proton collisions it was! The LHC delivered around 5.73 fb^{-1} (inverse femtobarns) of data to CMS — of which CMS recorded about 5.22 fb^{-1} — surpassing by far expectations from before the start of the run.

"At the beginning of the year, they [the LHC] had first said they could deliver 1 fb^{-1}, and then they learned a few things early so they revised it to 3," said Joe Incandela, spokesperson-elect and current deputy spokesperson for CMS. "But it was clear by summer that we'd reach 5 or 6."

"If I go back to the LHC Performance Workshop in Chamonix in January, I was asking them to give me five," said CMS spokersperson Guido Tonelli, gesturing a high-five. "I was pushing to get 5 fb^{-1} because it will allow us to enter the region in which we might say something really important about the Higgs boson."



Luminosity from the 2011 proton-collisions run

The vast quantity of data accumulated by CMS in 2011 did not come without its challenges. "It took a lot of effort, for example, for the Trigger to balance

It isn't sufficient just to collect collision data — these data must be rapidly processed and analysed, in time for international conferences, where the results will be scrutinised by other physicists. While the usual timeline to process a few inverse femtobarns is many months, CMS has produced well-understood results for the EPS-HEP and Lepton Photon conferences within weeks.

"The speed at which we have been able to deploy in producing results on the Higgs boson and the quality of these results is striking," said Tonelli.

CMS has also produced excellent results relating to Supersymmetry, although no signs of it have been observed so far in any of the channels explored. According to Incandela, "This non-appearance of signals is already having a huge impact on understanding SUSY and dark matter."

None of this, of course, would have been possible without the incredible performance of the LHC, which provided stable beams for 1364 hours in 2011.

Recounting the time he was asked if he was disappointed with the LHC for not having manifested Supersymmetry thus far, Incandela noted, "Of course I'm not disappointed! The LHC is doing what it's supposed to do. This is why we have experiments — the theories could be wrong."

Ryd had some well-deserved praise for the efforts involved in running the CMS detector: "We have been able to follow the luminosity evolution of the machine without any major problems. I'm happy that we are able to operate CMS at high efficiency with a crew of basically five people in the Control Room with a lot of support from on-call people."

Some records from the 2011 proton run:
Peak instantaneous luminosity: 3.55 x 10^{33} Hz/cm^2 in fill 2256 (26th October)
Delivered luminosity in one fill: 123 pb^{-1} in fill 2219 (16th October)
Maximum luminosity in one day: 136 pb^{-1} (13th October)
Maximum luminosity delivered in one week: 538 pb^{-1} in week 41
Maximum luminosity delivered in one month: 1614 pb^{-1} in October

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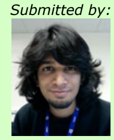
CPU utilisation and the rate of recording data," pointed out CMS Run Coordinator Anders Ryd. "Although CMS had a general infrastructure problem with the cooling in August, overall the proton run was pretty good."

Incandela added: "The fact that we've recorded nearly 91% under tough conditions is phenomenal."

These data will help CMS refine not just the Higgs searches but also those involving, for example, Supersymmetry and Exotica (new physics beyond the Standard Model). "Having recorded so much data will eventually allow us, if there are fluctuations, to have a better understanding of what is happening. If there are the first hints of new physics signals, they could manifest themselves," said Tonelli.

Submitted by:

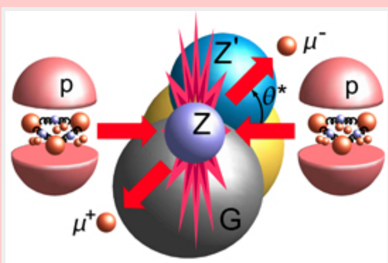


Achintya Rao

The Weak Mixing of Light and Heavy

The source of energy for most of the life on our planet originates from proton-proton collisions at the core of the Sun, which occur at an energy (or temperature) about a billion times less than the collision energy of the LHC. Due to emission of heavy weak bosons, which must initiate this fusion, the process is slow and allows the Sun to supply us with energy for billions of years. In the end this energy is carried to us by massless photons (γ bosons). It is believed that in the early moments of the Universe all electroweak bosons were equal and massless, but as the Universe cooled, it had to make a spontaneous choice and this symmetry was broken as the neutral electroweak W and B bosons mixed to produce the now known γ and Z. The degree of their mixing is called the weak mixing angle θ_W. Why the weak bosons acquire mass, while photons remained massless, is the key question to be answered by the LHC. The Higgs mechanism, which postulates the Higgs field, is one possible explanation.

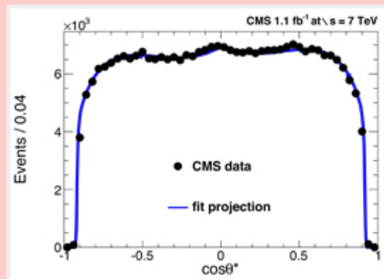
While this idea of electroweak symmetry breaking is only a hypothesis, it provides a very precise relationship of the W and Z boson masses and the weak mixing angle. Moreover this mixing angle becomes the only unknown parameter which determines the relative strength of interaction of all matter particle (quarks, leptons) with Z or γ, extending the pure electric charge strength in electromagnetic interactions with γ. All these relationships have been verified at experiments at the CERN LEP collider, housed in the same underground tunnel as the LHC more than a decade ago, as well as at the SLAC Linear Collider (SLC). At these electron-positron colliders, the angular distributions of the pairs of matter-antimatter particles produced in decay of γ or Z bosons allowed the mixing angle θ_W to be measured to a 0.1% precision.



An event of proton-proton collision with a new particle produced and decayed to two muons. The angle θ* of the decay is defined with respect to the incoming quark direction.

At the proton-antiproton Tevatron collider, similar measurements were performed more recently in the quark-antiquark annihilation process. At the proton-proton LHC collider, the ambiguity of the quark direction from interacting protons makes the above angular distribution impossible to measure directly. Thus, the CMS experiment had to develop more elaborate techniques. The analysis followed the LEP measurement idea and Tevatron hadron environment implementation, but went deeper into the proton structure to deduce the quark assignment based on the mass and boost of a created system ($\gamma \rightarrow \mu^+\mu^-$ or $Z \rightarrow \mu^+\mu^-$).

The approach became a synergy of the multivariate techniques developed for the Higgs polarisation analysis at the LHC and B-meson polarisation with interference analyses at the B-factories. The philosophy of the developed likelihood analysis was to first produce a phenomenological model of the process and then introduce detector effects into the model, all written analytically and tested against detailed numerical simulation.



Angular distribution of cos(θ*) for about 300000 two-muon events analysed.

The CMS measurement of the weak mixing angle parameter has about 1% precision with the summer 2011 data, which is a proof of principle that this kind of analysis can be done at the LHC. The precision of this analysis, which is now accepted for publication in the Physics Review journal, with this amount of data is a pleasant surprise. This measurement confirms the standard model picture in a completely new process of quark-antiquark annihilation into a muon-antimuon pair, while LEP, SLC, and Tevatron tested this with electron-positron pair in either the initial or the final state. The analysis technique allows great flexibility in the model with new free parameters to be included, such as interference of the γ and Z with possible new gauge bosons. Moreover, application of the angular analysis tools boosts sensitivity in the direct search for the Higgs boson.

The nature of electroweak symmetry breaking and the mixing of the light photons and heavy Z bosons that is essential to our existence remains a mystery. At the LHC, we may finally be able to explain this, but this requires elaborate techniques to boost sensitivity in data analysis. The measurement of the weak mixing angle at CMS is an interesting example which presented a new set of challenges, but its techniques have roots in experiments from LEP and SLC to the Tevatron and to the B-factories.

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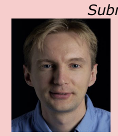 

Andrei Gritsan and Nhan Tran

Web-cam latest images (click picture to enlarge)