News

LHC Update: Luminosity Milestones, End of Year Run Trouble, Back with Gusto & Heavy Ion Collisions

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Abstract

This news article contains LHC updates for the period of Ocotober 10, 2010 to October 30, 2010 which appeared in viXra Log at http://blog.vixra.org .

Key Words: LHC, Update, luminosity milestone, end of year run, trouble, heavy ion collision.

October 14, 2010: LHC Reaches 100/μb/s target for 2010

The Large Hadron Collider has reached its official 2010 target for peak luminosity of 100/μb/s or $10^{32}/cm^2/s$. Massive Congratulations are due to all the teams at CERN who have worked incredibly hard this year to achieve this success!

This luminosity is 3.15/fb/year. The target next year is to collect 1/fb of data, but it is not possible to run at peak luminosity continuously so an extra margin is required. If they can run for 40% of the time during the running time allocated they really need peak luminosities of about 200/μb/s so they still have a little ground to make up.

The 100/μb/s has been reaches with 248 bunches by pushing to tighter emittances and better intensities. The next physics run will be with 300 bunches.

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There are still three more weeks of proton running this year, so with the official target passed they can relax and use the time remaining for whatever seems most useful. That will include running to collect physics data before the winter break, pushing the number of bunches a little higher, and running various tests and scans that help them understand the machine better.

One last thing they might possibly try is something extra to improve luminosity. There are options to squeeze the beams to a lower beta* of 2m, or reduce the bunch separation to 75 ns or even 50 ns, but these might take time and result in less data collected for this year. If they don't do these things now there should be time next year.

Whatever they, this year's proton physics runs will be counted a great success.

Update (16 Oct 2010): In a short run last night with 312 bunches the peak luminosity was increased to about 135/μb/s. The filling scheme is 150ns_312b_295_16_295_3x8bpi19inj which means 312 bunches per beam with a 150ns minimum separation between bunches, 295 collisions per turn in ATLAS, CMS and LHCb, 16 collisions per turn in ALICE and 19 injections of up to 3 trains of 8 bunches at each go.

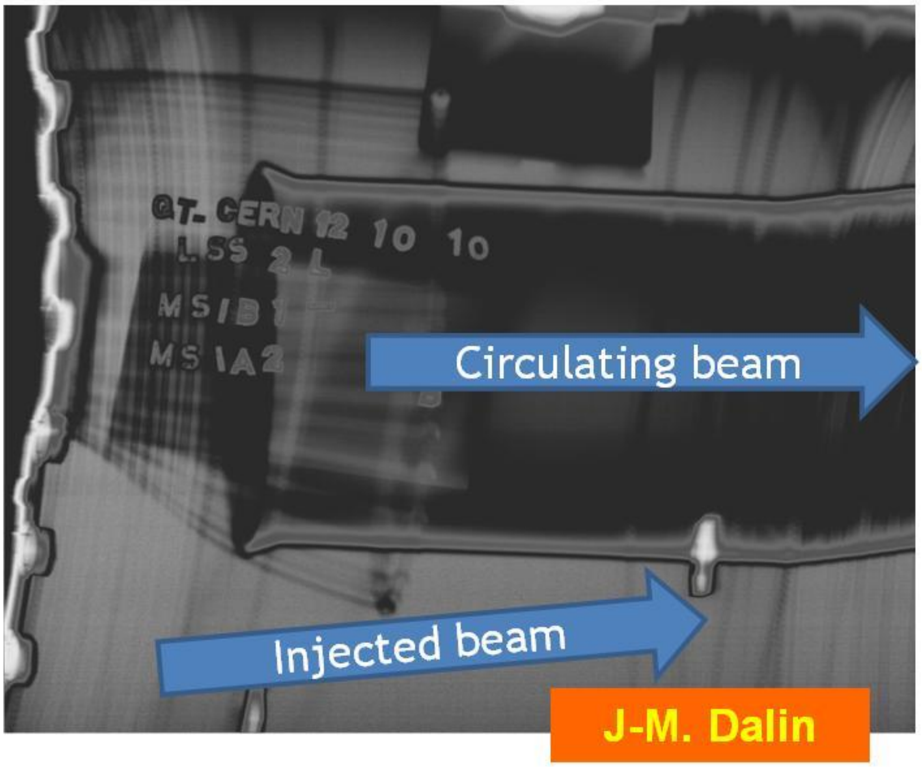
Tentative plans are to move to 360 bunches after three good runs at 312. Then they hope to try out a 50ns bunch spacing and 32 bunch injections so that they can go to 400 bunches or higher. They are also still hoping to collect 50/pb before stopping pp physics. Current total delivered is just over 20/pb. Whether they can get there, (or even go beyond) depends on how many running problems come up in the two weeks they have left, but with the goals for 2010 already met, anything extra is icing on the cake.

October 21, 2010: LHC end of run troubles

As the Large Hadron Collider approaches its end of proton-proton physics for 2010, the CERN bulletin reports on some of the problems that have hit the final runs. One particularly frustrating issue concerns beam losses at the time of injection. X-rays of the injection point have revealed a "non-conformity" in the mounting of the interconnection.

Despite this they managed to reach peak luminosities of 148/μb/s last week, but not without difficulty. To run efficiently at this luminosity and higher they need to remove the obstruction so the collider has been closed down for four days while they try to fix it. This is a blow for their hopes to collect 50/pb this year. So far they have about 20/pb, but there are now just 13 days of running left until they start setting up for Heavy Ion physics on 5th November.

How much more data the experiments can get in time to show at the winter conferences will depend on how fast they can get back up to speed after this technical stop.



Update 24-Oct-2010: The technical stop is now over and beams are once again colliding with 312 bunches giving peak luminosities of 152/μb/s. The plan now is to move to 360 bunches as soon as possible. After that they may just continue running at that level for the remaining 12 days to see how much physics data they can collect, or they may try injecting with 50ns bunch spacing and push for even higher bunch numbers.

Update: ATLAS collected 4.3/pb on this run! Next run increases to 368 bunches.

October 25, 2010: LHC Back With Gusto

Following a four-day technical stop to fix a restriction at the injection point, the Large Hadron Collider is back up and running with even more power. A few days before the stop they passed the target luminosity of 100/μb/s, but this morning they reached 206/μb/s. This is much better than expected and they are not finished yet.

Six weeks ago they had collected 3.6/pb and were at the end of a three-week commissioning phase for bunch trains. I predicted then that by the end of the pp run they would be collecting that much data in a single run. Yesterday they collected 4.2/pb in a single run of 10.5 hours with 312 bunches. In another run with 368 bunches still ongoing this morning, they have collected 3.8/pb in just 6.5 hours.

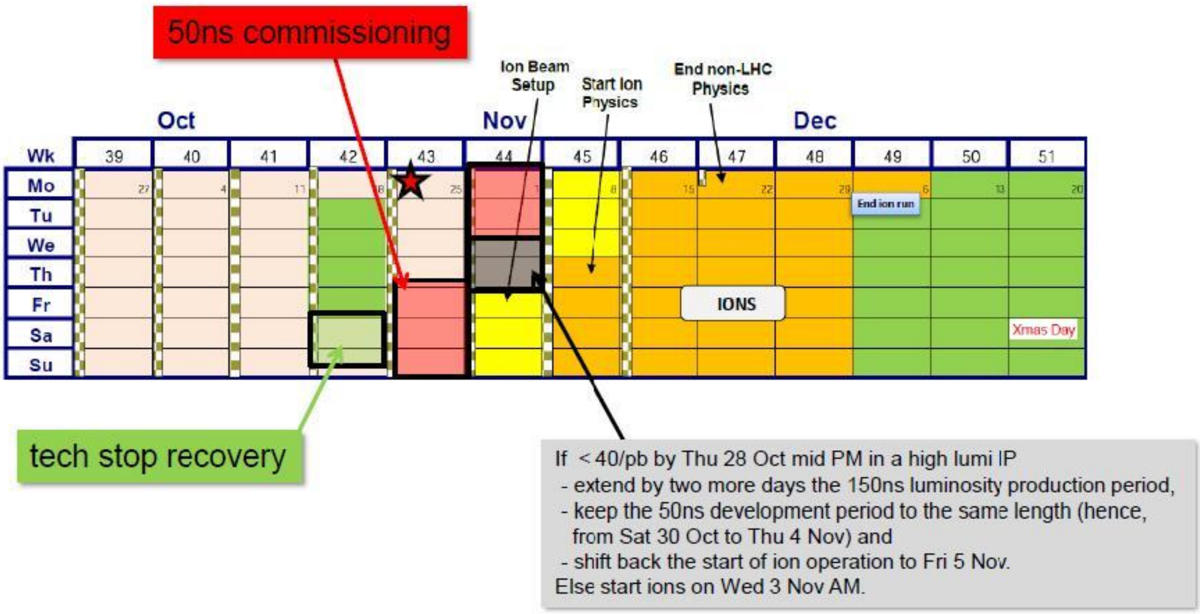
With 12 days left they could easily collect another 50/pb or more, but they have a long list of measurements and tests that need to be done. In fact their aim now is to switch to higher density bunch trains and push towards even higher luminosities. Going for higher intensities now is a good idea because new problems keep cropping up as they step up (e.g. the injection restrictions, UFOs and electron cloud background were only found at high intensity.) If they know about these things now then they have time to fix them properly while the machine is shut down during December to February.

Next year they aim to collect 1/fb of data per experiment. They can reasonably expect to have 200 days of running with pp collisions, so they need to be able to deliver 5/pb per day. The luminosities they have now reached mean that they can achieve this quite comfortably. In fact they have scope to increase luminosity by a considerable factor with tighter bunch trains and smaller beta*. When you do the maths, even peak luminosities approaching 1/nb/s are starting to look possible for early next year. How far they choose to go is up for discussion at a technical meeting in Evian in December.

This means that the target of 1/fb could be reached much sooner than expected in 2011. They will then have several options: They could close down early to ready the LHC for nominal energies of 7 TeV ahead of schedule, they could carry on and collect more data during the year, or they could aim for slightly higher proton energies straight away. Operation at 4.5 TeV per beam next year is a possibility already being considered.

Update: The latest fill ended with 6/pb collected by ATLAS.

On this version of the plan from a meeting this afternoon, they intend to run with the current 368 bunch scheme for three more days. This should take the collected data up to the 50/pb that the experiments were hoping for. If all goes well they can then spend the last week trying out 50ns separations which will allow them to push the bunch numbers over 400 for even higher luminosity.



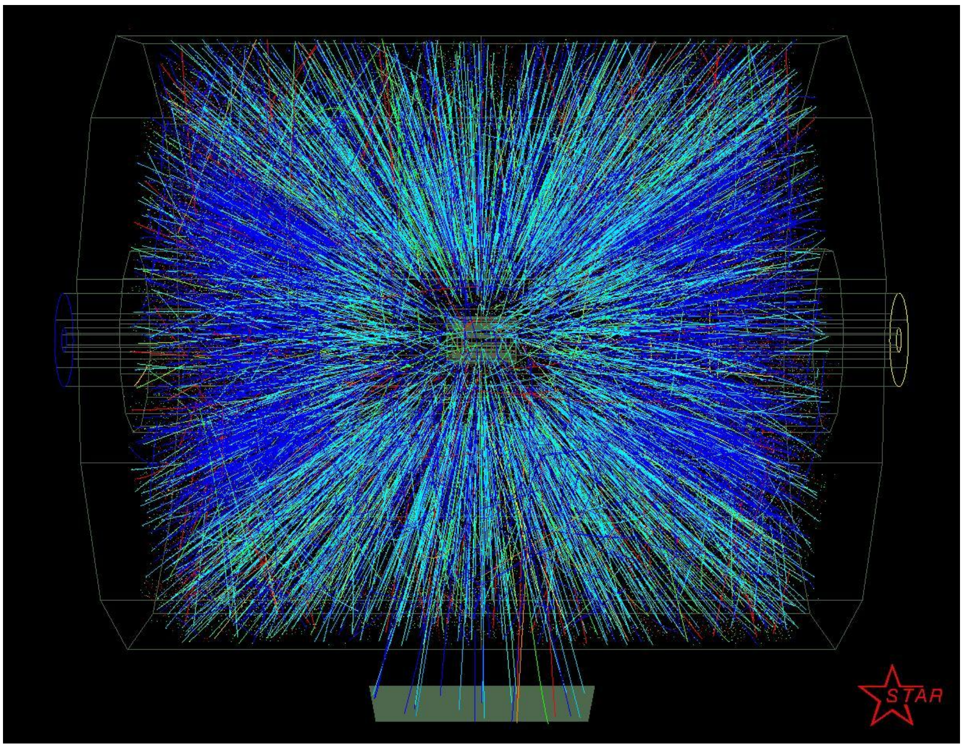
October 29, 2010: LHC Heavy Ion Collisions

In about a weeks time the Large Hadron Collider will stop proton-proton physics for this year and the physicists working on ATLAS, CMS and LHCb will work hard on their 50/pb of data to try to figure out if supersymmetry exists in nature. Meanwhile the LHC will continue running for another month colliding lead ions instead of protons. The main experiment designed to take advantage of these heavy-ion collisions is ALICE, but ATLAS and CMS will also take a look.

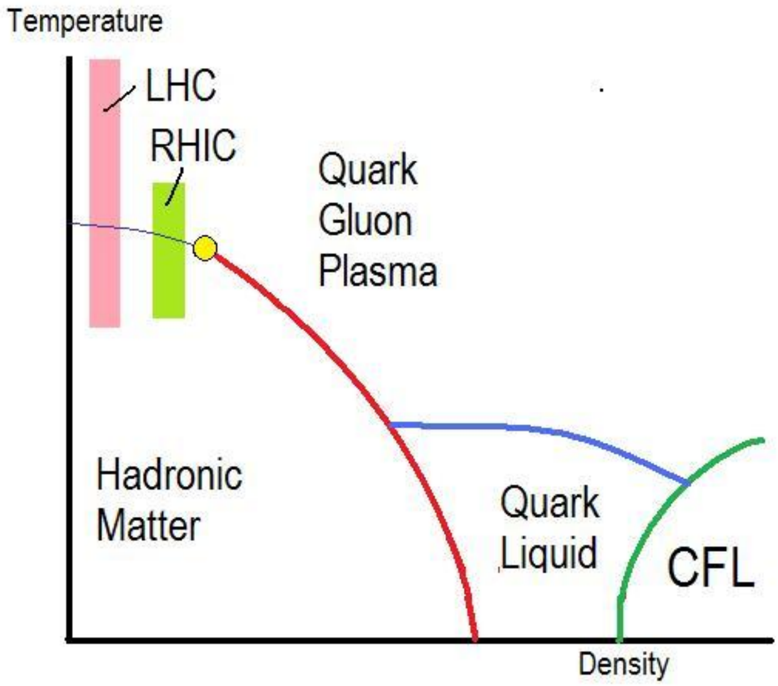
One of the exciting features of the Heavy-Ion collisions will be the total amount of energy in each collision. I don't know how high they will actually get in this first series of runs but the target seems to be about 2.7 TeV per nucleon. Lead nuclei have 207 nucleons so the total centre of mass-energy could be as high as 1100 TeV. That is enough energy to create a million protons. The LHC is about to become the worlds first Petatron collider.

Sadly this does not mean they will be exploring the particle spectrum at such high energies. When heavy ions collide it is more like lots of small collisions between the quarks and gluons in the nuclei so the energy does not get concentrated into the production of any single heavy particles. Instead you can get lots of lighter particles that can form a very hot plasma ball. The interactions involved are dominated by QCD so this experiment is mostly a study of QCD phenomena.

If you want an idea of what such a collision will look like have a look at what has been seen at the RHIC collider. Here is a typical example with thousands of particles produced. The RHIC uses energies of 500 GeV per nucleon so we can expect something like 5 times as many particles at the LHC.



The aim of these experiments is to find out something about the phase diagram of QCD. According to various theories it probably looks like this



All the stuff to the bottom right is what happens in neutron stars at very high densities of matter. There is not much possibility of recreating such conditions in any experiment because they only way to produce the densities required are by using the enormous pressures due to gravity that occur inside neutron stars.We will have to rely on astronomical observations to probe those regions of the phase diagram. RHIC and the LHC are better suited to looking at the top left where the enourmous collision energies produce a plasma at very high temperature.

The hadronic matter phase is what we are used to at low temperature and at most nuclear density. Here the quarks are confined inside hadrons and mesons. At higher temperatures and densities theory predicts that the quarks will enter a deconfined phase where hadrons do not form. Instead the quarks and gluons just form a liquid-like plasma where they can flow around freely. You can cross from the hadronic phase to the quark gluon plasma over a first order phase transition (the thick red line) where the two phases mix just like gas and liquid in boiling water. However, at lower densities you can pass from one phase to another without going through the phase transition. A similar thing happens with water turning to steam at high pressure. The first order phase transition stops at a critical point and one objective of RHIC has been to try to find this point experimentally. This requires running with lower energy, not higher energy, so the LHC is not looking for the same thing.

Instead the LHC will be able to explore the crossover region where there is a smooth change from confined to deconfined matter, but there is something else in this region. Another phase transition is though to be crossed over, but it is a second order phase transition, not first order. This is the phase transition for chiral symmetry breaking.

The QCD Lagrangian has an approximate symmetry known as chrial symmetry that relates different flavours of quarks and left and right chiral states. The symmetry is broken by any quark mass but the up and down quark masses are small enough for this symmetry to be a good approximation. The symmetry is also broken by the electric charges, but this is also a relatively small effect. The spontaneous symmetry breaking leaves a residual symmetry which is isospin and it generates Goldstone bosons such as the pion. The pion would be massless if the symmetry was exact. At high temperatures the chiral symmetry is restored, so there must be a transition. Lattice calculations suggest that it is around temperatures corresponding to 170 MeV.

With symmetry breaking phase transitions it is not possible to have a cross-over region if the symmetry is exact. A symmetry is either broken or not. You can’t go smoothly from one phase to another. However, chiral symmetry is not exact in QCD so the phase transition will not be sharp. It is though to coincide with the deconfining phase transition up to the critical point and then continue across to the zero density axis as shown on my diagram. Actually it could separate before the critical point, we don’t know for sure.

When the LHC starts Ion-collisions at ramped energies it will be a leap ahead of where the RHIC has been looking. It has been said that it is one of the largest jumps in energy for a specific type of accelerator ever taken. The regions explored are thought to be similar to the conditions in the big bang a little after inflation stopped. It will be very interesting to see what happens.