News

LHC Update: Luminosity Milestones at LHC III & Remaining Runs in 2010

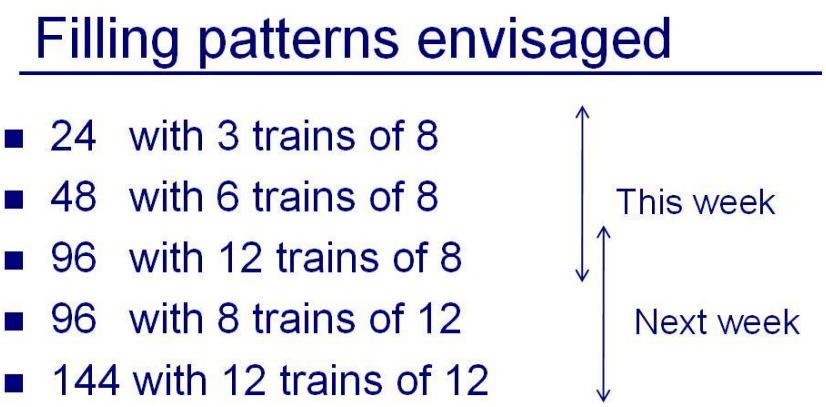
Philip E. Gibbs*

Abstract

This article contains LHC updates for the period of September 12, 2010 to October 9, 2010 which appeared in viXra Log at http://blog.vixra.org .

Key Words: LHC, Update, luminosity, milestones, LHC collisions.

September 20, 2010: LHC 2010 Crescendo Finale



The Large Hadron Collider is nearly ready to start the last phase of running for proton beam physics during 2010. For the past three weeks they have been commissioning the running parameters necessary for this last stage.

The new settings include a 150ns separation between proton bunches in each beam. Previous runs have been performed with a longer spacing of 1000ns, but to get enough bunches in the ring they now need to be packed much closer. The closer packing means that the bunches are more likely to interact with each other as they approach the collision point. This is avoided by increasing the angle at which they cross. To speed up the operations they are also ramping up the beam energy in the LHC more quickly.

All these changes have required a lot of setting up and it has taken about twice as long as expected. This means that they have less time for the next stage during which they hope to gain another factor of 10 in luminosity. At that point the number of collisions seen in each run could be as high as the entire 3.6/pb already collected since the LHC started. This requires them to increase the number of

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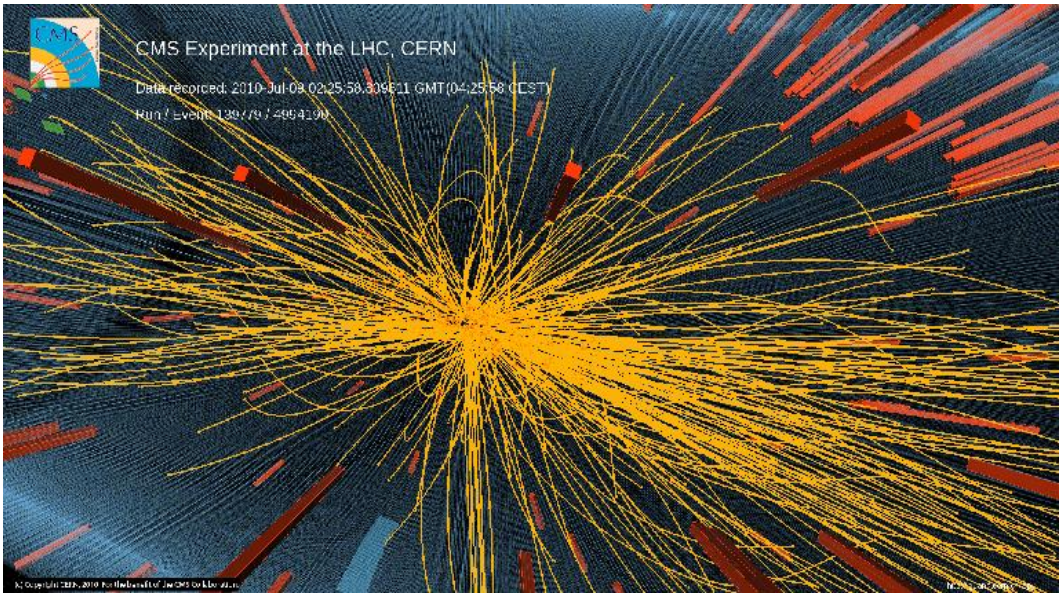
bunches in the ring from 52 to 384, and they have just five weeks left to do it before the LHC is reconfigured for heavy ion collisions.

To achieve this level they will start with 24 bunches some time in the next few days. This will quickly be doubled to 48 if all is well. From then on they will add 48 new bunches at each step until they hit the limit with the current settings at 384 bunches. This will take 7 steps and they will have about 5 weeks in which to do it, meaning they have to step up the number of bunches once every five days. This is faster than previous rates of increase, but it should be possible provided there are no hitches. The only commissioning interruptions will be some work to set up for the heavy ion collisions to come afterwards. To move on to each new step they want at least three good runs with a total of 20 hours of stable beams.

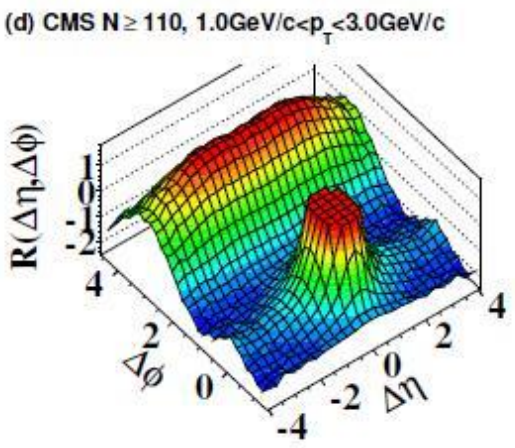
In November they will change mode to perform the heavy ion collisions that will help to understand QCD at high temperatures. That will be followed by a shutdown over the Xmas period and then they will be ready to start serious proton physics data collection during 2011.

September 21, 2010: Quark-Gluon Plasma Seen in Proton Collisions – Maybe

The CMS collaboration has released this image of a collision showing more than 100 charged particles from a single collision event. It could be the result of a quark-gluon plasma previously seen only in Heavy-Ion collisions. It also makes a good desktop wallpaper. Click to get the hi-res version.



The CMS analysis of these events looks at the correlations between particles flying off at different angles. The resulting plots look like this:

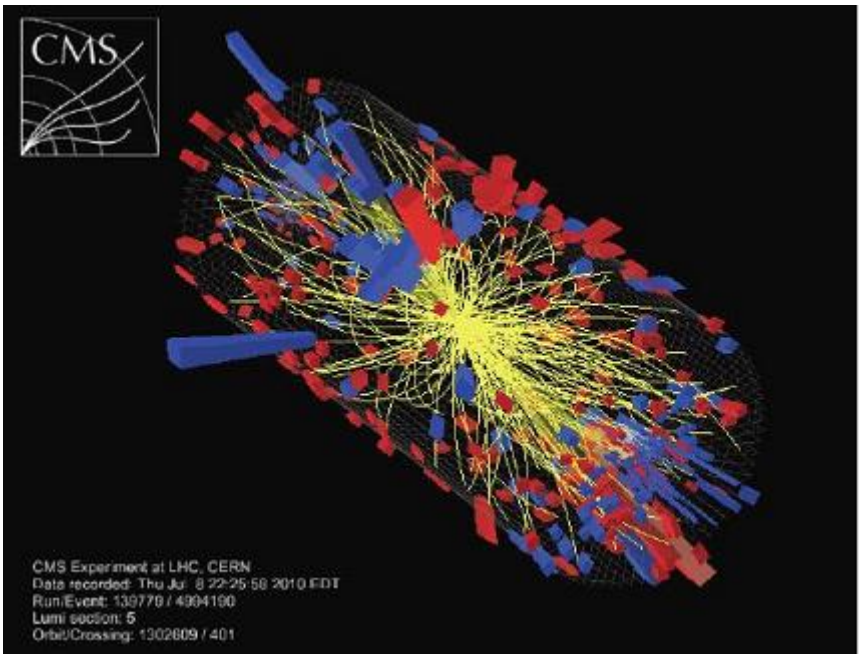


In this plot Δη is a measure of how far apart the particles are in terms of the polar angle away from the beam axis. Δϕ is the difference in the azimuthal angle in radians. In this plot the peak which has been cut-off at the front shows particles on a similar trajectory and is an expected observation. The ridge along the back is at a separation of 180 degrees in azimuthal angle. It extends over a range of the polar angle and is not predicted in the standard Monte-Carlo simulations based on QCD. The smaller ridge at zero azimuthal separation is not expected either. The effect intensifies for events with larger numbers of particles.

The interpretation offered by CMS is that some kind of clusters are formed, which then radiate particles isotropically. Such clusters could be droplets of quark-gluon plasma, but other explanations might be possible. Similar results have been observed at RHIC when Copper ions were collided but it is a surprise to see this with single protons.

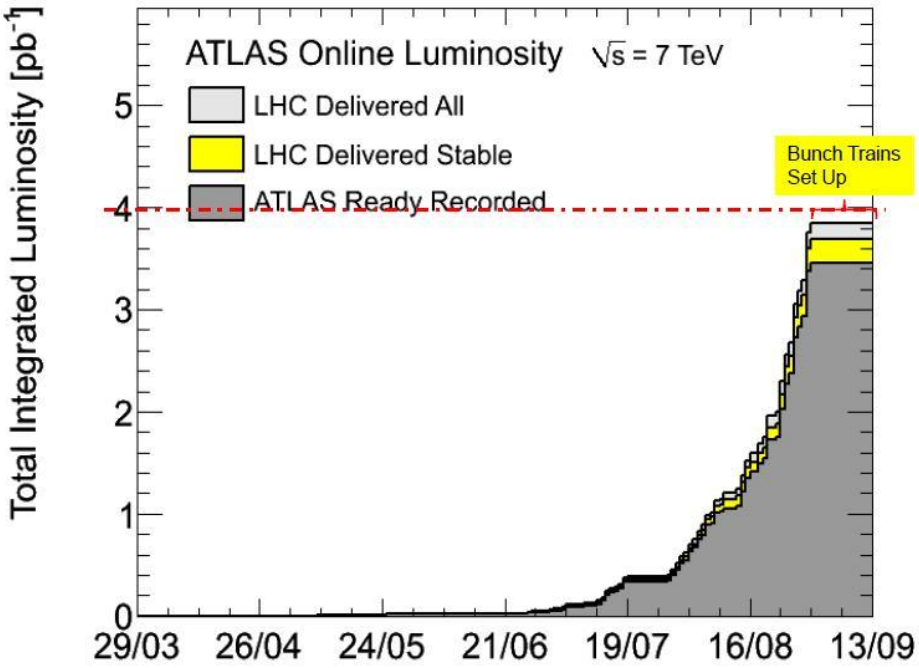
The results presented are based on the only first inverse picobarn (1/pb) of data taken. So far 3.6/pb has been collected and much more will be generated in the next five weeks as the luminosity is pushed up by another factor of 10. Following that, the LHC will also turn to heavy-ion collisions using lead nuclei. The ALICE experiment is optimized for exploring the effects of these events, but CMS and ATLAS will also be used. Today's report from CMS shows that interesting results could come from unexpected places.

For more analysis see the detailed CMS publication, The Reference Frame and Quantum Diaries Survivor.



September 22, 2010: LHC September Update

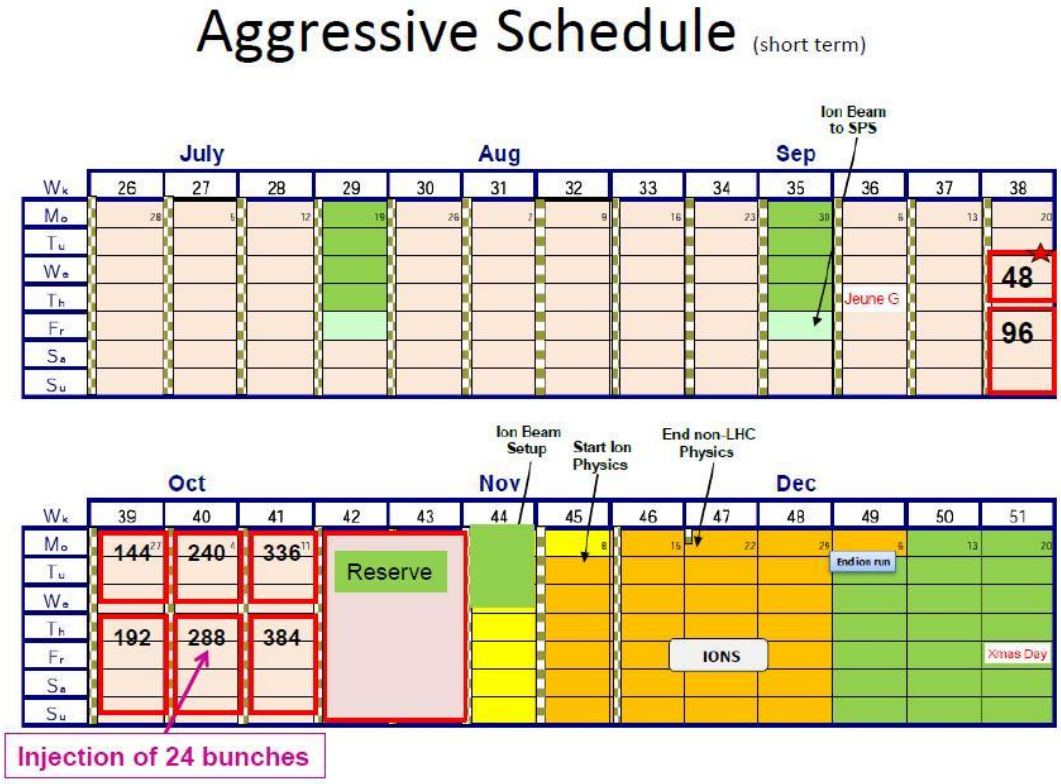
Steve Myers who is the director of the LHC beams has just delivered an optimistic update on the ongoing LHC commissioning process. This comes at a critical moment as they are about to move out of a prolonged commissioning phase with a restart of physics runs expected today.



Myers expressed some frustration over the time taken to do the setting up of the machine when parameters are changed. He said he felt like renaming the LHC as the large Loss-Map non-Collider because they have to keep doing runs to map where the protons are lost round the beam pipe.

However, that process is now finished ready for the next series of runs and there was good news about beam performance. The bunches can now be separated by just 150 ns which will allow up to 384 bunches in each beam. The crossing angle is set at 170 micro-radians and they found that they only had problems when this reduced to about 80 micro radians. This means they may have room to use a smaller bunch spacing later without changing the crossing angle.

Control of beta-beating in the beams is also better than expected. They use 100 quadrapole magnets to keep the bunches in good shape and this has been very effective. The beam aperture measured at 450 GeV is especially good and this may mean that they can use more squeeze to increase luminosity without adding more bunches.

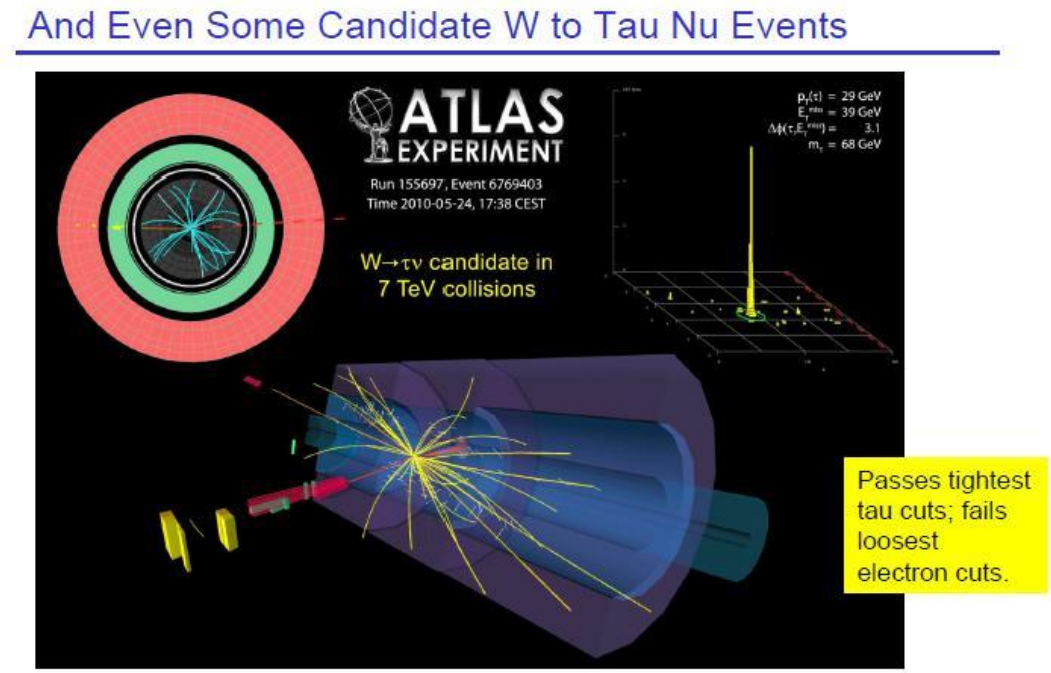


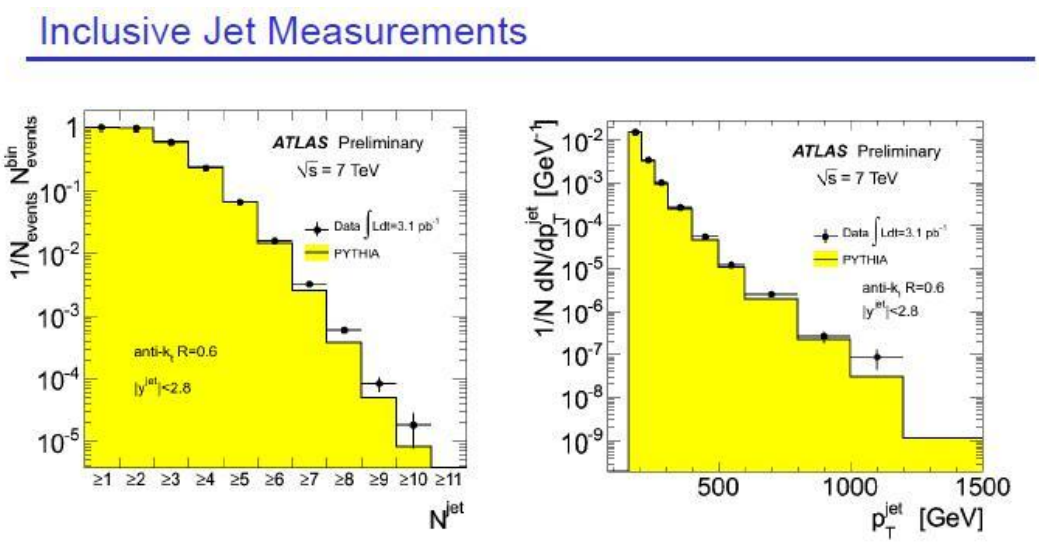
In a review of the protection systems it was concluded that they are working very well. Myers suggested that this allows him to increase the number of bunches in the ring more quickly over the next few weeks. In a previous plan the number was to increase by 48 bunches each week. Now he is suggesting doing this twice a week. This will make up for time lost over the last few weeks. It might also allow for two weeks of running with 384 bunches, during which time they may even attempt to squeeze the beams further. Currently they use a beta* of 3.5m but if they can reduce it to 2m they can more easily reach the target of 1/fb desired for next year's runs.

However, they must still be cautious and this aggressive schedule can only be realized if each run ticks all the boxes indicating that everything is under control. The number of bunches injected in each bunch train will start at 8, then be increased to 12 and then 24. Twelve bunches is already the safe intensity limit above which the collider can be damaged if they lose control. When they inject twice this limit at one go the risk increases.

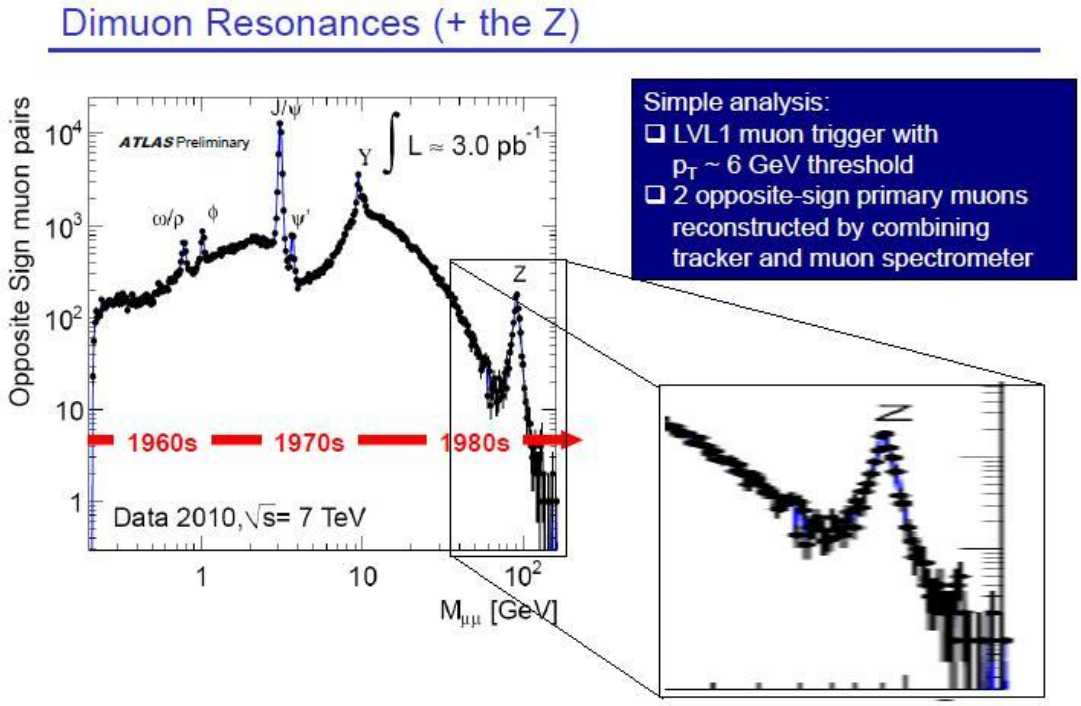
During questions Myers also said that next year they may attempt to reduce the bunch spacing to 75ns or even 50ns. This would allow 2 or 3 times more bunches and the same factors for increase of luminosity. If Myers' optimism proves to be justified they could even exceed the 1/fb target for 2011.

Following Myer's update this morning there were presentations from CMS and ATLAS which present results using up to 3/pb of data for the first time. At recent conferences they have only shown up to about 1/pb. Some of the plots are really exciting and you can get the full set of slides at http://indico.cern.ch/conferenceDisplay.py?confId=105780 Here is just a selection from ATLAS





They see up to 10 jets and agreement with the monte carlo is considered surprisingly good.



I've added a zoom to this slide so we can peer into the noise.

During questions after his ATLAS talk, Thomas Le Compte was asked why he had not shown di-photon plots. He said he could not comment but that these results were of interest to lots of people …

September 22, 2010: LHC Stable Beams Are Back

The Large Hadron Collider has reached stable beams again for the first time in about three weeks. The wait has been due to changes in beam parameters needed to take the collider to yet higher luminosities.

The current filling scheme is 150ns_24b_16_16_16_8bpi which means a 150 nano second space between bunches injected in 3 trains of 8 making 24 bunches per beam. There are 16 collisions per turn in each experiment.

Tomorrow, if all goes well, they will return to 48 bunches to match previous luminosity records before attempting to rapidly increase the luminosity by a further factor of ten in just 1 month.

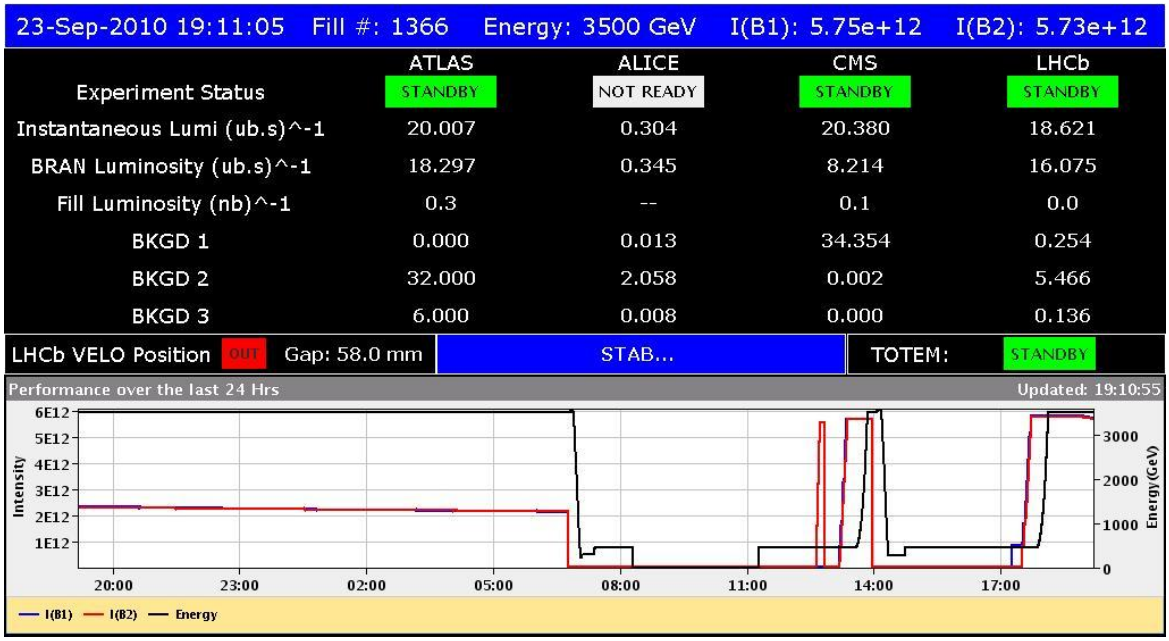
Update: In fact the next fill will use the scheme 150ns_56b_47_16_47_8bpi. This means they will inject 7 trains with 8 bunches per injection to provide 56 bunches per beam. There will be 47 collisions per turn in CMS, ATLAS and LHCb, and 16 per turn in ALICE. This could give luminosity up to 14/µb/s which would surpass the previous record of 10/µb/s. They expect to inject early tomorrow morning when the current fill will be terminated.

September 23, 2010: LHC Luminosity Reaches 20/microbarn/second

After a successful physics run overnight which collected 160/nb of integrated luminosity, the LHC has increased its luminosity again to double the previous record set a month ago. The latest run with 56 bunches per beam reached 20/µb/s at start surpassing expectations by successfully injecting higher intensity bunches.

The plan now indicates that they will further double the luminosity very soon by using 104 bunches, probably on Saturday. At that point they will be able to collect about 1/pb of data in each run. This is the first steps in a planned rapid increase of luminosity for the Large Hadron Collider over the next few weeks. This could provide up to 50/pb of data for this year which could be enough to reveal new physics in the ATLAS, CMS and LHCb detectors.

The Large Hadron Collider has passed a new luminosity milestone with a peak of 10.1/µb/s (or 10.131 Hz/cm2 or 0.32/fb/year) recorded in the CMS detector. This was achieved at the start of a run with a new filling scheme using 50 proton bunches per scheme today. This figure is one tenth of the target luminosity for the end of this year that is needed to get them ready for collecting 1/fb during 2012.



Update: The first 56 bunch run ran for 14 hours before the luminosity dropped to about half its starting value. At that point the run was ended after collecting 680/nb taking the total recorded to about 4.4/pb. 680/nb is about twice the amount used at the ICHEP conference so it is easy to see how they will soon have much stronger results.

They will attempt one more similar run this evening before doubling the luminosity again with a 104 bunch fill in which 93 bunches collide per turn. This will be injected in 13 trains of 8 bunches. After that they will have to switch to longer trains of 12 bunches because they don't want to do more than about 16 injections for any run.

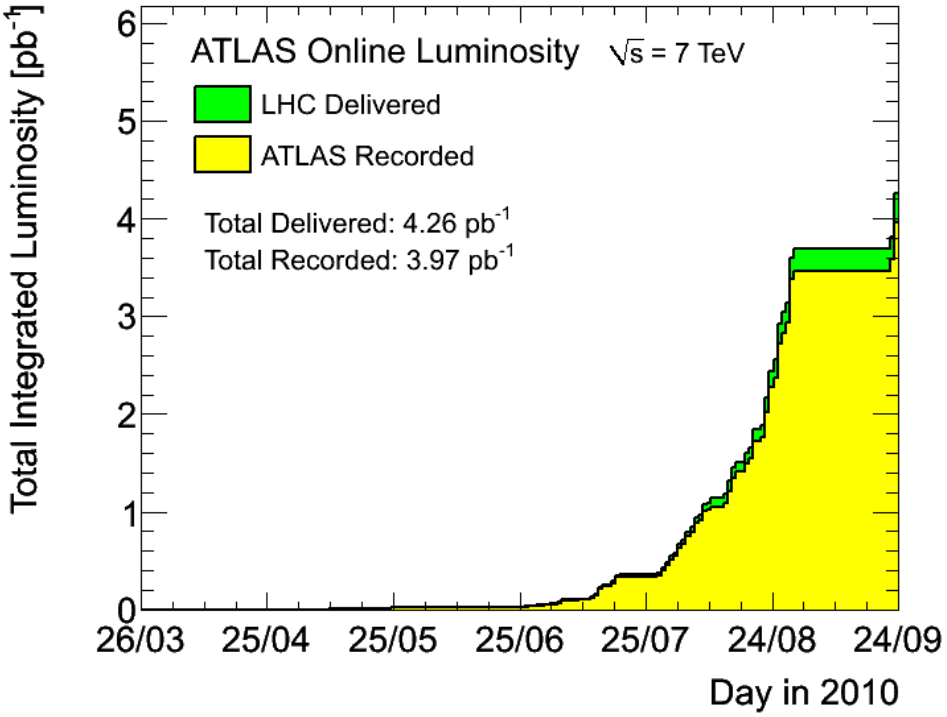
The stability of the beams is now proving to be exceptionally good so there is optimism that they can reach and even exceed the set targets for this year. In fact this fill was so good that CERN Director General Rolf-Dieter Heuer sent out a back-slapping message about it which you can find on the US LHC blog.

September 25, 2010: LHC Passes 1/fb/year Peak Luminosity

After yesterday's great run at the Large Hadron Collider that CERN DG Rolf Heuer described in management speak as "a game-changing fill", they have done it again today. With 104 bunches and over 10 trillion protons per beam the peak luminosity has been pushed up to 36/µb/s which nearly doubles the record for the second day in a row. This is also 1.13/fb/year which is significant because their target is to collect 1/fb during 2012. Of course they will need to go higher to reach that target because the peak luminosity cannot be maintained continuously, but another factor of 5 or so should suffice and that is now looking quite achievable.

With just a few weeks left of proton physics this year, the recent pace of development has been faster than at any point since they first started to ramp up the luminosity. If this run continues to a

healthy completion tomorrow morning they should be able to collect 1/pb in a single run. It is only a few weeks since they celebrated collecting 1/pb in total.



Update: The fill did indeed surpass 1/pb for CMS, LHCb and ATLAS taking the total delivered past 5/pb

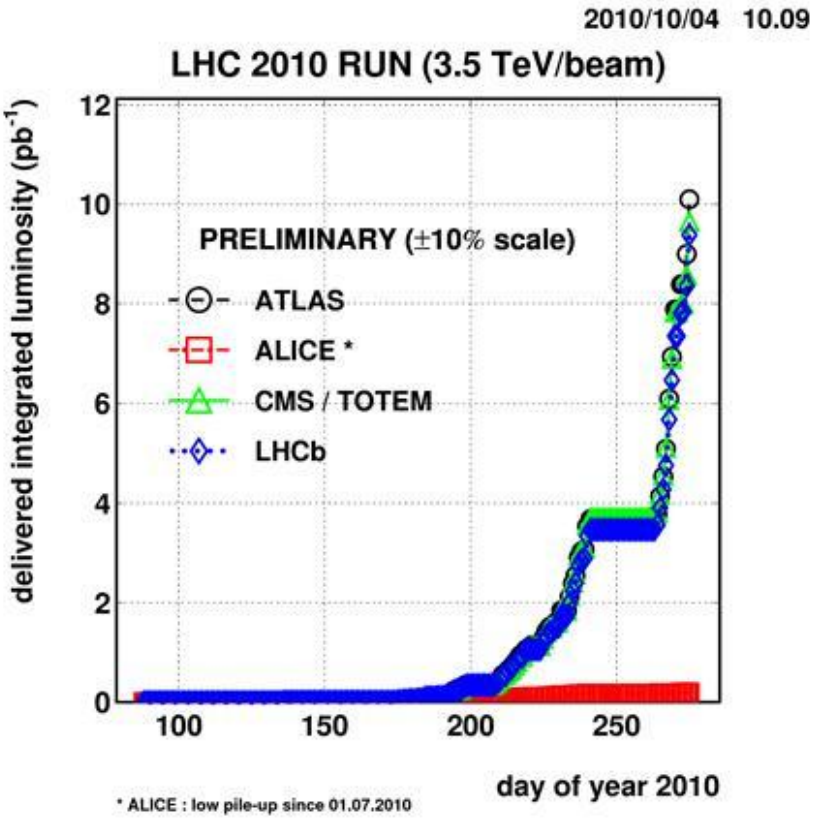
Update (30.sep.2010): There was a short run last night with 152 bunches reaching a new record luminosity of about 48/µb/s. This is nearly half way to the target luminosity for 2010 but hopefully the second half will be much quicker than the first.

October 3, 2010: LHC at 50/µb/s

Today the Large Hadron Collider reached a luminosity of 50/µb/s for the first time having fallen just short of that target a few days ago. That means that after 6 months of running at 3.5 TeV per proton they have now reached half of the planned target for 2010. Adding the other half to reach 100/µb/s should be a lot quicker, probably just 2 to 4 weeks. If they can't do it that quickly they will run out of time for this year.

The latest runs with 152 bunches per beam have not run as long as the controllers would have liked. In each case the beams have been dumped prematurely due to a variety of faults including "UFOs". These are thought to be flakes of dust from the beam pipe that fall into the way of the beams triggering losses and an automatic dump to protect the systems. This shows just how difficult the process of getting the LHC up to speed can be.

Despite running for only 6 hours the latest run still produced another 1/pb of accumulated luminosity, bringing the total to 10/pb. The next luminosity increase using 200 bunches per beam should start this week.



Update (4 oct 2010): The first run with 200 bunches per beam is now underway with intial luminosity of 68/µb/s which is 2.1/fb/year

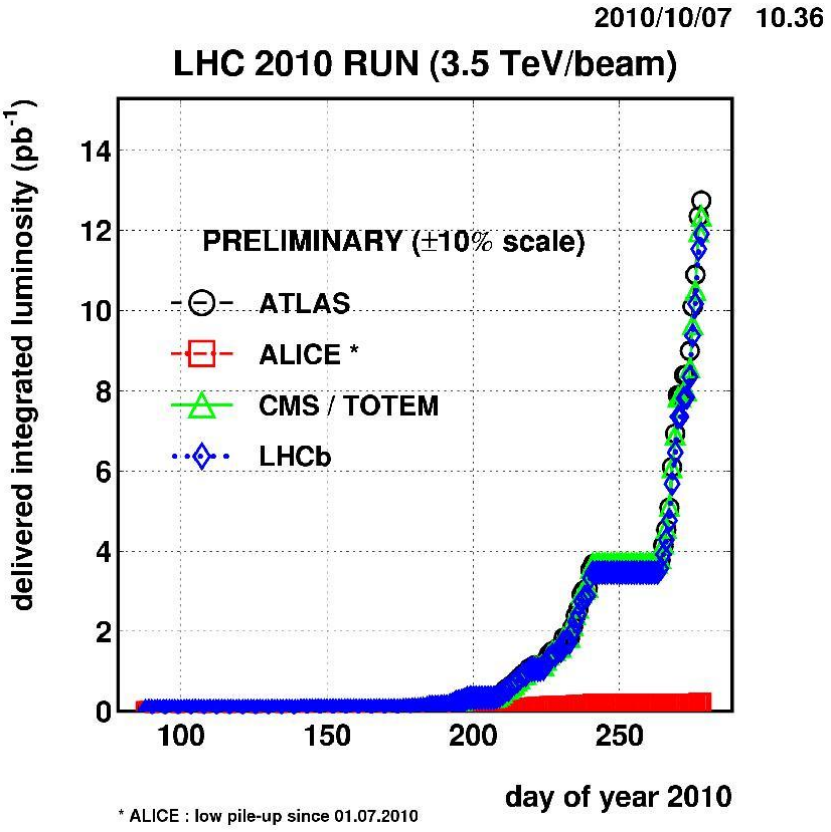
Update (5 oct 2010): The run is still going after 12 hours with 2/pb delivered.

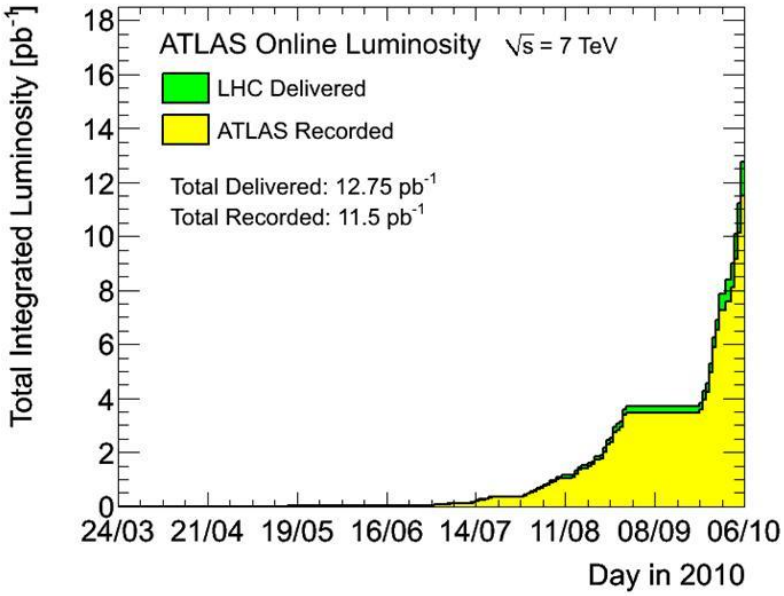
October 7, 2010: LHC Ready for 248 Bunches

The Large Hadron Collider is now ready for its next step up to 248 bunches which should raise the peak luminosity to 85/µb/s. That will be one more step away from this years target of 100/µb/s which will require 296 bunches.

To progress at each step when they add another 48 bunches, they need three fills and 20 hours of stable beams. At 152 bunches they had a rough time and ended up with only 16 hours, but they decided that was OK because that's 20 in octal (I'm not making it up). The latest run at 200 bunches has gone very well with one run of 14 hours delivering 2/pb. Two shorter runs take the total time to over 20 hours so they are preparing for the next step.

To inject 248 bunches they need to switch to injecting 24 bunches in one go. If all goes well they should be ready to set the new record tonight. There is no sleep for the LHC.



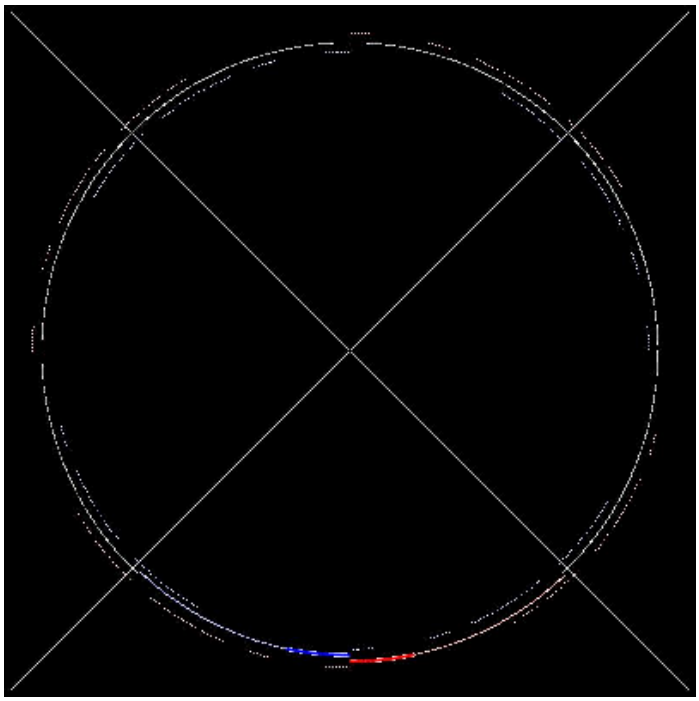


The plot above shows the delivered luminosity for each experiment which is now between 12/pb and 13/pb for the big three. However, the experiments do not collect everything that is delivered.

The plot below shows that ATLAS has collected 11.5/pb. I don't have the equivalent plot for the other but it is likely that CMS and LHCb are also past the 10/pb mark at least.

Update (8 Oct 2010): 248 bunches now running with peak luminosity in ATLAS of around 88/µb/s

In case you want to see what 248 bunches per beam looks like here is a picture taken from the LHC filling schemes page. The current fill pattern is 150ns_248b_233_16_233_3x8bpi15inj.txt



In Other News:

September 18, 2010: Tevatron to Carry On

The Physics Advisory Committee at Fermilab have announced their decision to continue running the Tevatron until 2014. It is easy to see why they want to do that: This year's published results have strengthened the case for a light Higgs sector. In the mass range up to 150 GeV the rival Large Hadron Collider does not have such a big advantage and won't make the Tevatron obsolete until around 2014 when it's higher energy and luminosity will finally trump the Tevatron at all mass scales. In the meantime the Tevatron will double its current database of collision events which currently stand at around 9/fb, although Most of the results shown this year only used about 6/fb, so by the time they finish they will be using about three times the data. That should be enough to give a clear signal for where the Higgs mass lies. If there is a more complex Higgs sector with charged multiplets they should have a good indication of that too. According to Fermilab other exciting measurements include the search for supersymmetric Higgs bosons at large tanβ, measurement of the forward-backward asymmetry of the top quark, and the di-muon charge asymmetry in neutral B decay, as well as further improvement in the measurement of the top-quark and W-boson masses.

Any of these things would be an exciting discovery beyond standard model physics and would completely change the Tevatron's place in history, so it is no surprise they want to go on, but in the grander scheme of things it is not such a good move. By 2014 the LHC will be surpassing the Tevatron and could well beat them to the most interesting discoveries. At best the Tevatron will share some of the glory unless the LHC has another significant failure that pushes back their schedule. Meanwhile, other experiments and developments at the Tevatron will not be able to progress so well, both because their budget suffers and because the Tevatron is needed to power them. This includes NOvA, LBNE, Mu2e, and Project X. For longer term progress in high energy physics it would be better if Fermilab concentrated on those efforts.

Meanwhile at CERN the planning council has approved a five-year plan that makes some significant cutbacks in their projects. During 2012 while the LHC is off-line for maintenance, they have now decided that all other experiments on the CERN complex will also be halted. This will push back future plans while allowing the medium term LHC goals to be unaffected. Studies for the next Linear Collider will be slowed and some planned upgrades to the LHC will also be delayed. This is seen as a short-term cutback due to harsh economic times but it could easily turn into a series of pullbacks from cash-strapped governments who are beginning to question the wisdom of expensive research with no direct payback.

It has been suggested that the LHC plans are ambitious with still an order of magnitude of improvements in luminosity to reach the 100/μb/s target by end of October. Even if they achieve this they will need another factor of two next year to be able to collect the 1/fb they want during 2011. But the LHC commissioning process has in fact been going very well with most targets they have set being reached or exceeded so far. Sometimes they face setbacks as they work to push the machine to new heights, but time can be made up as luminosity increases. For the last three weeks the LHC has made no physics runs while preparations are made for the next stage of running. In the next few days they will be colliding again with three major improvements. The separation between proton bunches will be reduced from 1000 μs to just 150 μs and a larger crossing angle of 100 μrad will be used at the collision points to keep the bunches apart before they meet. The speed at which the magnets can be ramped up to increase the beam energy has also been improved by a factor of three to give a significantly better turn round time between runs. With these changes it should be possible to step up the beam luminosity by adding more bunches in a veritable crescendo of activity before they switch to heavy ion physics in November.

The results of the next few years at the Tevatron and LHC will be critical for the future of fundamental physics. If the Tevatron and LHC find supersymmetry it will show that the theorists have been on the right lines for the lats few decades after all and we will see business as usual once again. If only the standard model is found the superstring doubters will come out in greater force and the impact on theoretical physics research around the world could be devastating, even though supersymmetry at the weak scale is not a definitive prediction. Other scenarios are possible if unexpected discoveries are made.