News

LHC Update: Continuing Success, New Particle? But D0 Sees No Bump

Philip E. Gibbs*

Abstract

This news article contains LHC updates for the period of May 29, 2011 to June 30, 2011 which appeared in viXra Log at http://blog.vixra.org. CDF plots show a small excess around the 110GeV – 120GeV region, but the size is not significant and the positions are not quite consistent. Will we look back on these graphics in a few months time as the first signals of the Higgs or as statistical flukes? Sadly the D0 experiment sees no bump in boson+dijet at Fermilab, dismissing the 4.1 sigma result of CDF. After a tough week for LHC, it is reaching new records and doing bunch splitting.

Key Words: LHC, Tevatron, new particle, Higgs, new record.

May 31, 2011: Rencontres de Blois

Leonardo de Vinci spent many of his latter days in the Loire Valley and if you visit Ambrois you may still see his ghost parading for the tourists. While he was there he contributed a number of beautiful designs into the châteaux of the region including this spiral staircase at the Royal Chateau de Blois. There is an even more spectacular example in the nearby picturesque Chateau de Chambord where he used a double helix design so that people can pass from one floor to another without meeting, but it is at Blois where this week we find a conference to discuss some new findings in particle physics and cosmology.

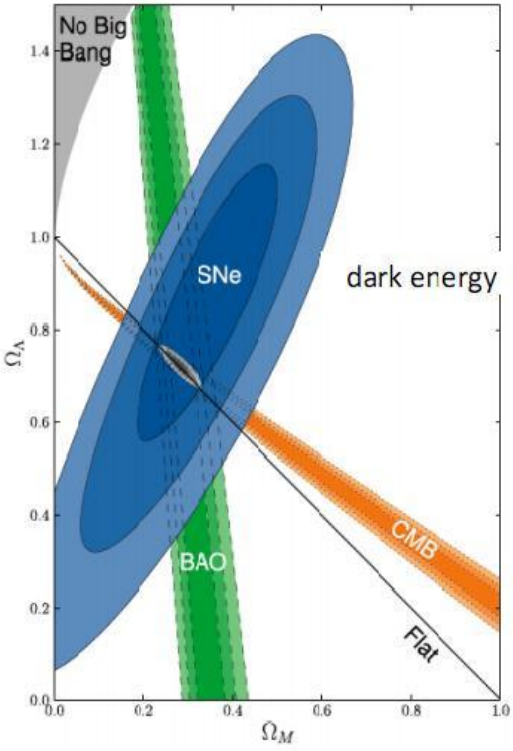
Dark Matter in Cosmology

Yesterday included a talk by Joe Silk, prof of astronomy at Oxford, who summarised our understanding on the cold dark matter model including dark energy and dark matter. Simulations of galactic cluster and structure formation favour a model where dark matter is made of weakly interacting cold particles. The mass should be in the range 10GeV to 10TeV. The lighter end seems at odds with accelerator experiments which should have produced such particles unless they have a very low cross-section for production from interaction with standard model particles. However, some of the detectors build to directly detect passing

* Correspondence: Philip E. Gibbs, Ph.D., Independent Researcher, UK. E-Mail: phil@royalgenes.com

WIMPs have found evidence for 7 GeV particles. They have even seen an annual variation in the signal consistent with a cosmological origin. Dark Matter particles may also annihilate to produce a cosmic halo of positrons and electrons that space observatories such as PAMELA may have detected. From the slides Silk seems to have neglected to mention the results from Xenon100, now in theory the most sensitive dark matter detector, which is at odds with other results because it sees nothing. Over all it is a very exciting time for dark matter with the hope that the LHC will resolve the matter by producing the expected particles in proton collision.

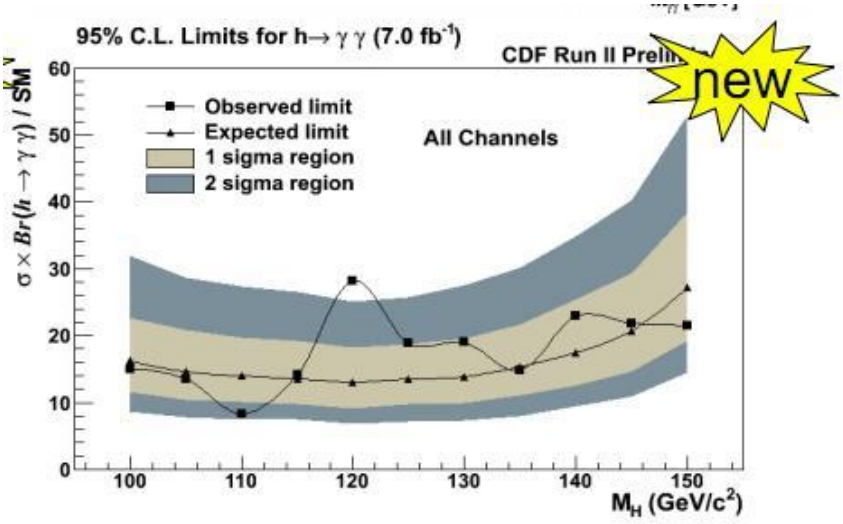
Silk also looked at dark energy results and provided this awe-inspiring plot of how different observations constrain the two parameter space of cosmological models.

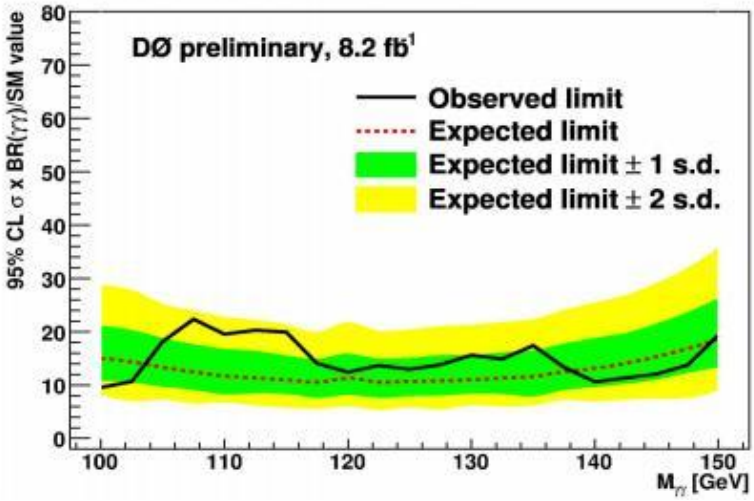


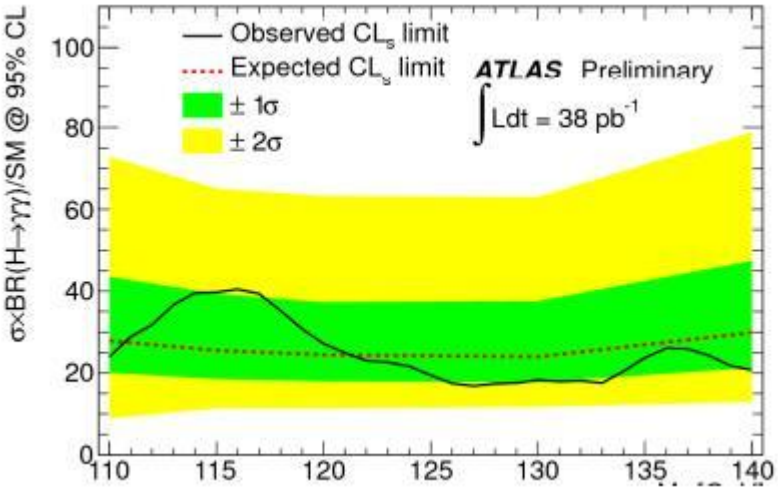
The blue SNe area is from the supernova data that first indicated the acceleration of the universe. This was followed by the CMB cosmic microwave background analysis that produced an orthogonal constraint to pin down the cosmological parameters to a narrow region consistent with a flat universe. This year a third source of data came from measurements of galactic structures giving the BAO band in excellent agreement with earlier data. This is also sufficient to show that dark energy is well modeled by a cosmological constant rather than a variable that changes with time. The effect of the constant is to have less impact in the early universe, while now it accounts for 73% of the non-gravitational energy of the universe. As the universe ages the cosmological constant will continue to increase its domination. Despite this observational triumph its theoretical origin remains mysterious and should be tied up with theories of quantum gravity not yet understood.

Searches for the Higgs Boson

Later in the afternoon Giovanni Punzi delivered a talk that has already caused a stir around the blogosphere, see here, here, here, here. First take a look at some of his collected plots for Higgs searches.

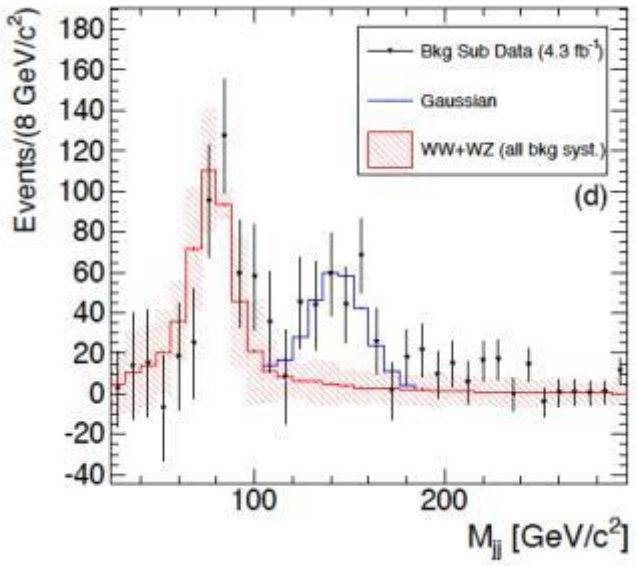




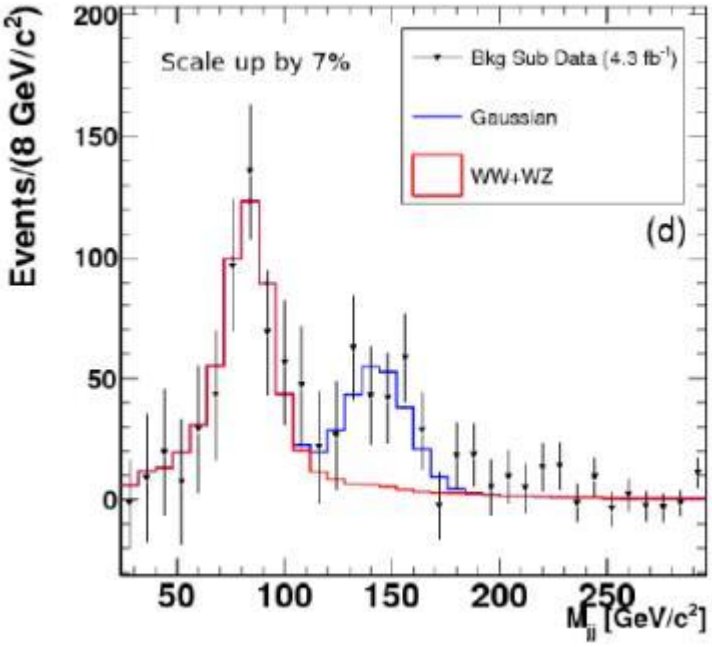


All these plots show a small excess around the 110GeV – 120GeV region, but the size is not significant and the positions are not quite consistent. Will we look back on these graphics in a few months time as the first signals of the Higgs or as statistical flukes?

The real interest today is in observations from jets at CDF. Here is a plot from a few weeks back that appeared to show a mystery bump. This was widely poo-poo'ed by commentators including myself who said that it could be a statistical fluke or a background effect.



Now they have fought back with a second plot from a completely independent run of data

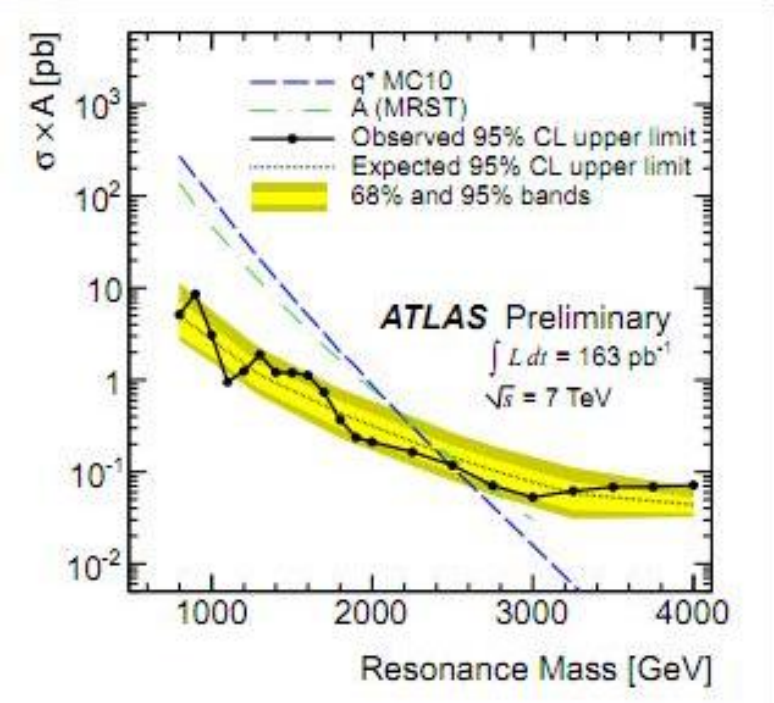


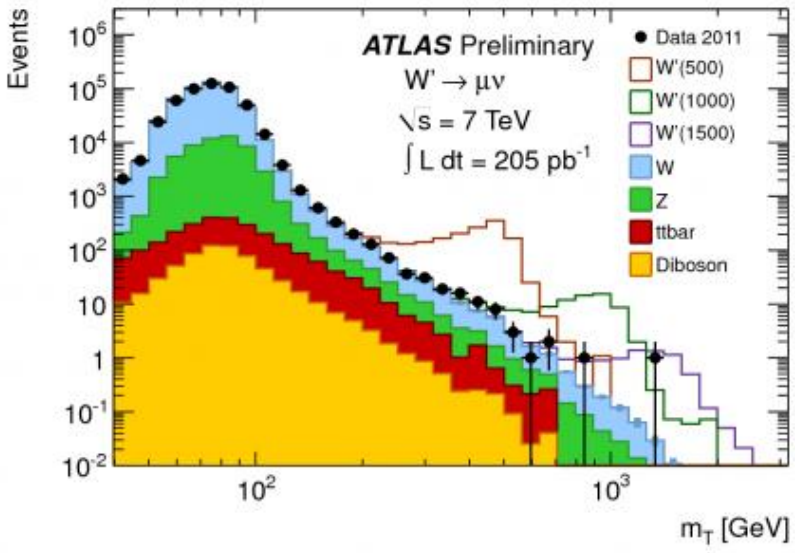
It shows exactly the same thing! This rules out a statistical fluke at about the 5 sigma level. CDF has also responded to suggestions that it could be due to incorrect scaling of the background, showing that this cannot account for the excess when modelled carefully. Finally they rule out a standard model effect from top quarks. We are left to conclude that it must be a real new effect due to a particle of 150 GeV that is not part of the standard model. the big question is whether it is also seen at D0 and will the LHC confirm it?

June 2, 2011: ATLAS publish searches with 205/pb

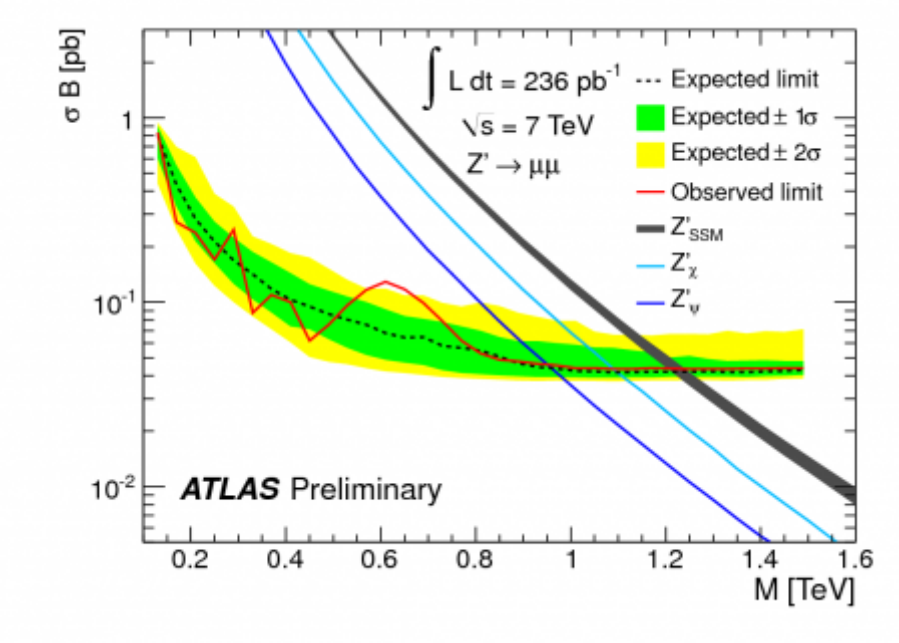
Up to this point most publications from the LHC experiments have been based on the 2010 data of up to 43/pb. Today ATLAS have published their most advanced results yet in two conference notes using 163/pb of 2011 data and 42/pb of 2010 data for a total of 205/pb. The first note looks at the Dijet Mass distribution using just the 2011 data, and the second looks for one muon and missing transverse momentum with 205/pb. No results inconsistent with the standard model are seen but these papers are significant as a sign that we can expect to see a lot more publications from these amounts of data shortly.

The 163/pb of data for 2011 was collected around the 26th of April so the analysis has taken about five weeks. The total recorded data in each of ATLAS and CMS is now around 600/pb

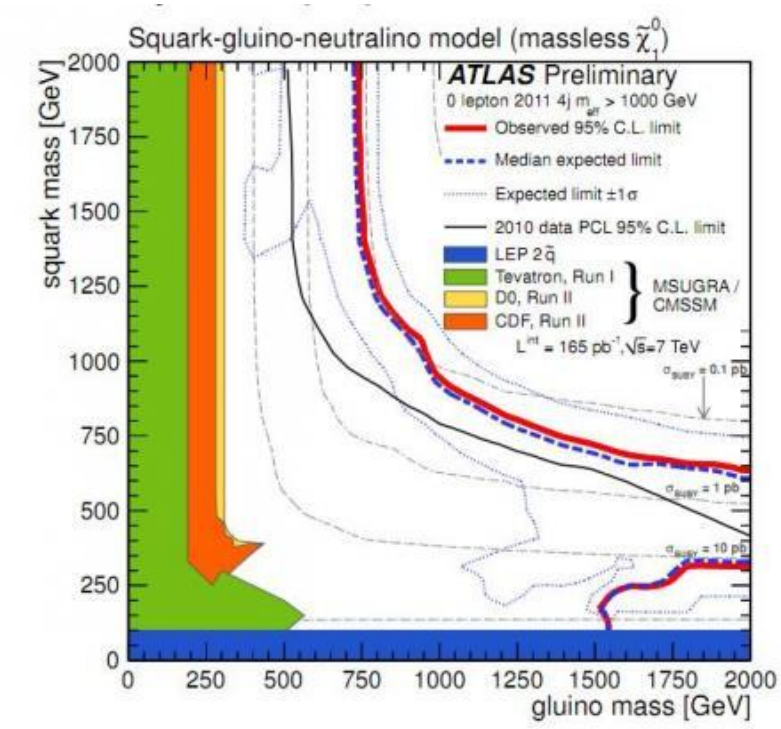




Update 3-Jun-2011: There is now a third conference note on a search for dilepton resonances using up to 236/pb



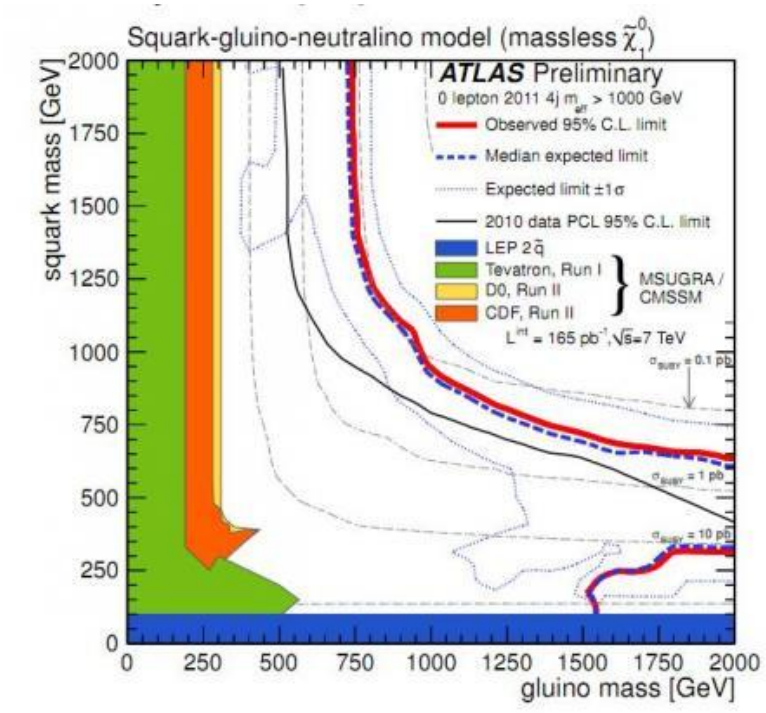
Update 4-Jun-2011: A fourth note reporting a search for squarks and gluinos using 165/pb is now online.



June 4, 2011: ATLAS squark and gluino search with 165/pb extends SUSY exclusions

A new conference note from ATLAS using 165/pb of data has extended exclusions for SUSY. Previous published results used 36/pb of 2010 data. These new findings will be

reported at the Physics at LHC conference next week. With 691/pb delivered, further search results will be possible very soon.



Gluino masses below 725 GeV are excluded in the simplest models. The new limit of the excluded region is the thick red line on this plot. The odler limit using just the 2010 data is the thinner black line. The no-go zone has extended about 200 GeV to the right.

It is disappointing for many phenomenologists that no SUSY signal has yet appeared, but SUSY has a large parameter space and it will take much more data to really rule out the theory completely. It seems likely that if SUSY is not found then something else will prove to be the solution for physics at the TeV scale. The data from the LHC to be accumulated over the next two years will tell us how the Higgs sector looks. Whether it is SUSY or not, it is likely to be something of interest.

June 7, 2011: New Particle Physics, on the way?

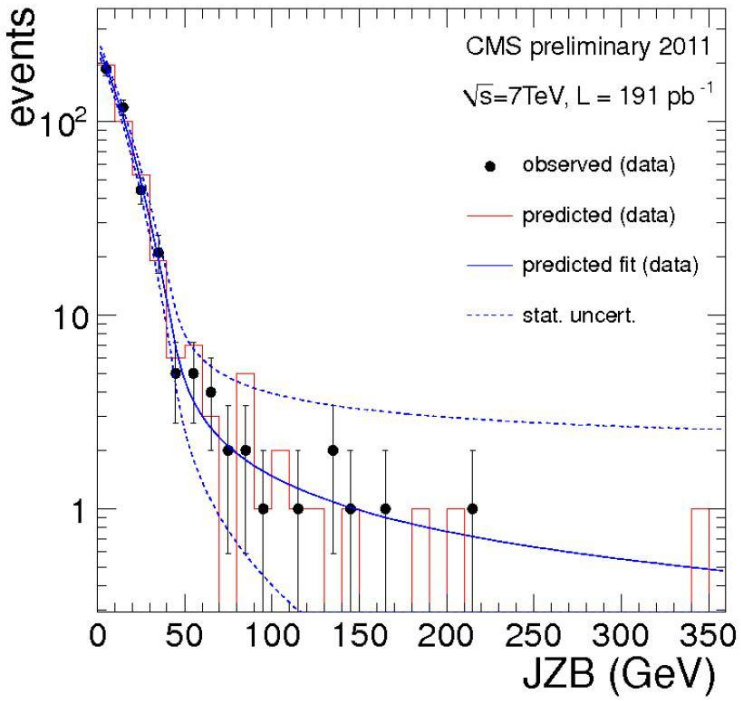
The PHLC2011 conference is underway with the promise of new reports from CMS and ATLAS using around 200/pb of data. The conference notes released by ATLAS so far suggest that only better exclusion limits will be found unless they are holding back some surprises. Today CMS have also shown their first paper using 190/pb from 2011 data. It also provides new exclusions.

From before the conference the main excitement came from the Tevatron where CDF have shown a 4-sigma bump at 150 GeV in decays producing W bosons and two jets. Dorigo remains firmly sceptical while Jester reports that detailed analysis of the events are consistent

with a new particle just below 300 GeV that decays into a W-boson and the lighter unknown particle at 150 GeV. A study by D0 using similar data will be a crucial indicator of whether this effect is here to stay. They are expected to report on Friday at Fermilab.

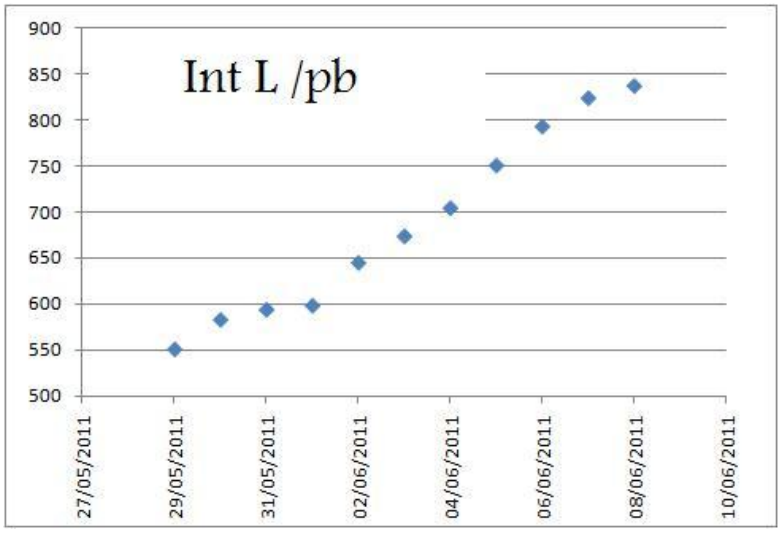
Before then we will have a number of new search reports at PLHC2011, mostly on Thursday and Friday, but also today we have a special seminar from Jon Butterworth on behalf of ATLAS that just might have news (Update: It doesn't).

So by the end of the week particle physics could look very different, and if it is all an anti-climax we just have to wait for the next big conference EPS-HEP2011 where at least 1000/pb of LHC data will be on show at the end of July. My betting is that will be the one to watch out for.



June 9, 2011: Another LHC Update

For the past 11 days the Large Hadron Collider has been running with a 1092 bunch filling scheme adding 325/pb to the total data delivered. Based on an average peak luminosity of 1.13/nb/s this gives a Hübner Factor of 0.3 which is very respectable for this early stage of the run.

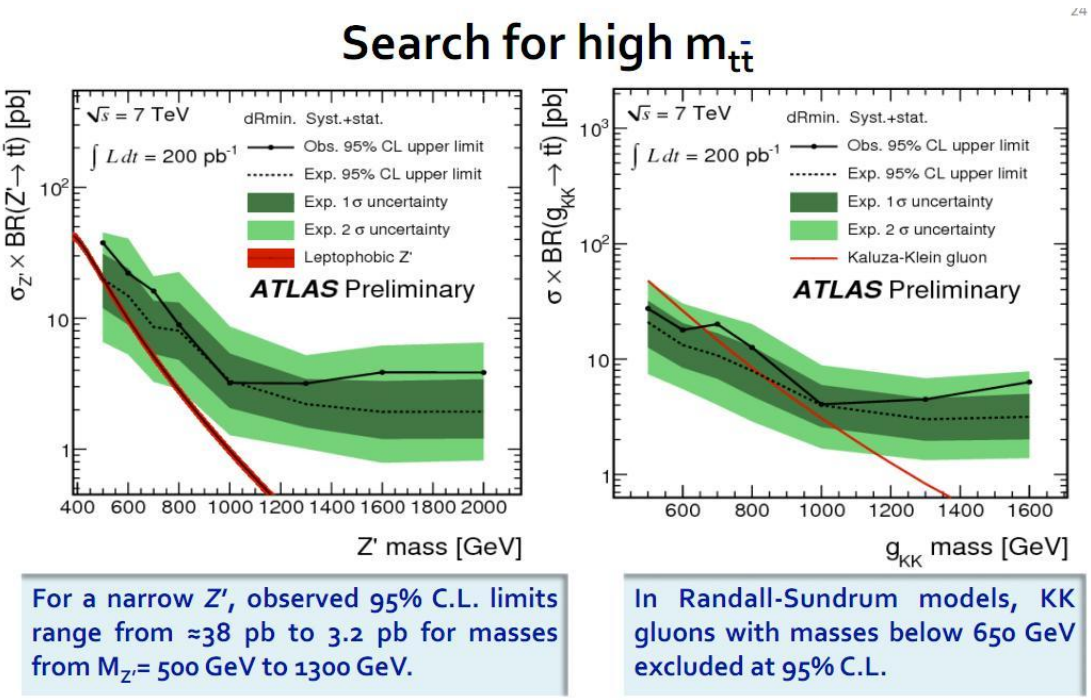


During this time the beams have been dumped frequently by problems such as software errors that are being rapidly fixed. UFOs have been another major headache. These are thought to be dust particles that fall into the beam. There is so far no sign of their numbers dropping as the beam zaps them up, but the dump thresholds can be changed in the worst hit areas to reduce the number of UFOs that cause a run to be aborted. This means that overall the run efficiency should improve and the expectation should be for a somewhat better Hübner Factor once they settle into the longer run.

The first successful fill with 144 bunch injection ran last night. The longer train length means a few more bunches can be fitted into the ring. They just need two long fills with this filling scheme before they can step up to 1226 bunches in each beam, so higher luminosities should be with us soon.

The schedule for the rest of the year has been modified to replace the four planned maintenance breaks with just three breaks, but slightly longer in duration. The immediate effect is that the next stop moves back from 16th June to 29th June, allowing more data to be collected in time for the big HEP-EPS conference at the end of July.

This week it has been the Physics at LHC conference in Perugia that has been grabbing most attention. There have already been some new limits shown, such as seen on these plots from a talk today on ATLAS top physics by Marina Cobal.



The talks on the final day tomorrow are the ones most likely to declare any new observations rather than just exclusions using the 240/pb on offer. Indications from conference notes already released suggest that we should not expect too much. A lot of the talks have not explored beyond the 40/pb dataset from 2010.

A pessimist would say that they have concentrated on the best-hope channels for presentations at this conference so the absence of new observations beyond the standard model here means that nothing new is showing up yet. An optimist, however, might say that they have only been able to approve the less interesting searches in the time available. All the best results may be in the places where no new data was shown this week because they will want to wait a little longer for more data to get conclusive results. We wont have long to wait until the EPS-HEP conference where 1000/pb of data should be on the table.

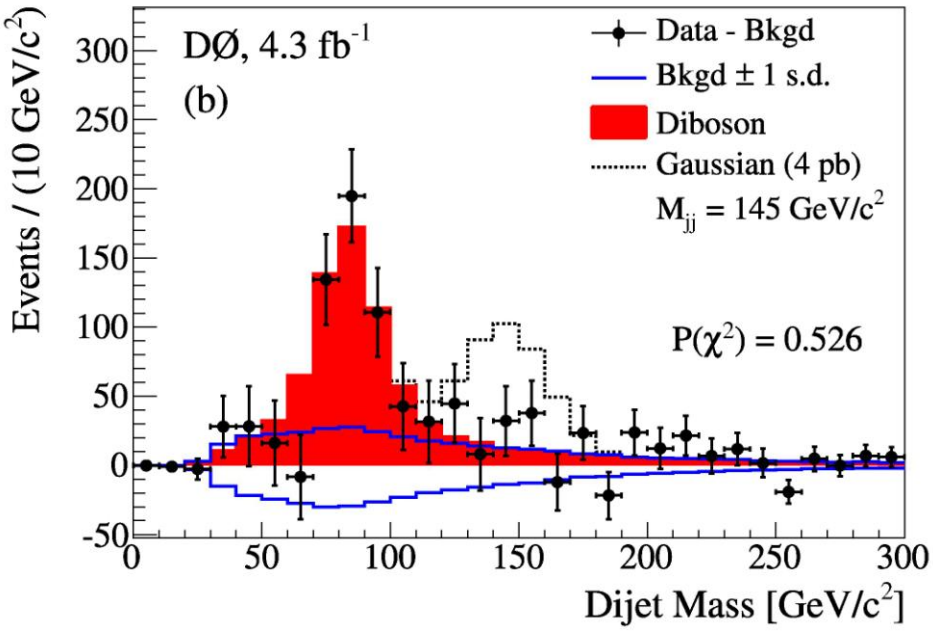
Meanwhile the main buzz is about the CDF bump at 150 GeV. Tomorrow there should be a seminar at Fermilab from the D0 group to tell us whether or not they also see the bump. It will be webcast here. Another version of the talk will be seen at PLHC on Saturday. Woit has already passed on a rumour that says the answer will be negative. Even if he is right, this will leave open the question of how the bump seen by CDF can be explained. The results should be consistent so the two groups will need to compare their analysis methods to find out what went wrong.

Update 9-Jun-2011: I have checked all of the talks at PLHC 2011. There are 10 talks from ATLAS and one from CMS where new searches using 2011 data up to 236/pb are presented. They all correspond to notes already published last week so we know that only new exclusions limits are found. No new physics is forthcoming this week from the LHC, unless they slip in an extra last minute talk.

June 10, 2011: D0 sees no bump

Sadly the D0 experiment sees no bump in boson+dijet at Fermilab, dismissing the 4.1 sigma result of CDF.

This has already been reported here, here, here, and here. The original paper is here.

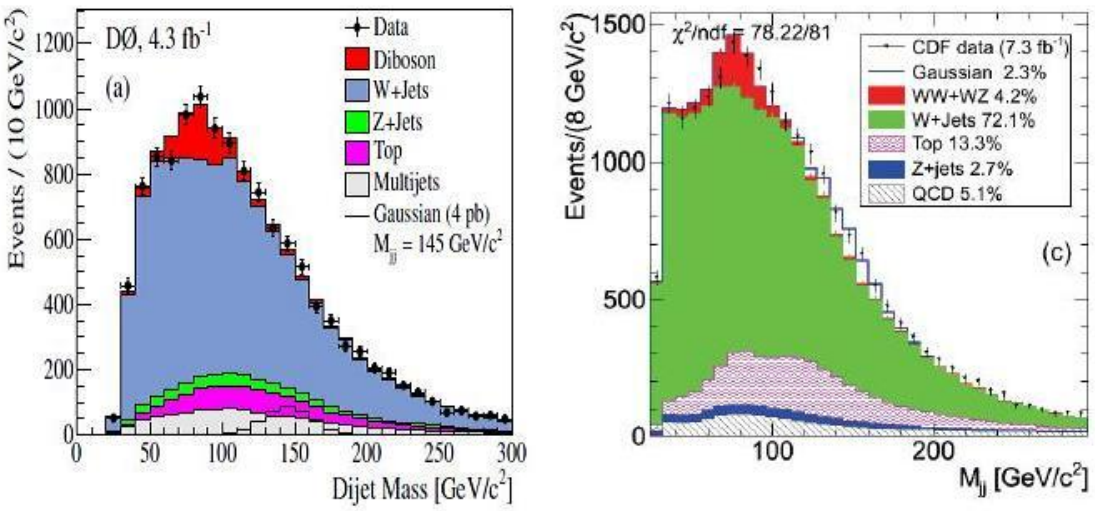


Now the two experiments need to get together to work out which is wrong and why. It is not a sure conclusion that D0 is right but it seems more likely that someone would see an effect that isn't there by mistake than that someone would fail to see an effect that is there. This gives D0 a strong psychological advantage.

To find out what went wrong they have to compare the raw plots and the background as seen in these plots.

The differences are too subtle to see from just the visual image, and it does not help that they used different bins. There does appear to be significant differences in the backgrounds while the data look quite similar. If that is the case then the problem is purely theoretical and they just need to compare their background calculations. However, the detectors are different so perhaps the backgrounds should not look exactly the same. Only the people directly involved have enough details to get to the bottom of it.

I hope they will work it out and let us know because it would be nice to see that their understanding of their results can be improved to give better confidence in any similar future results.

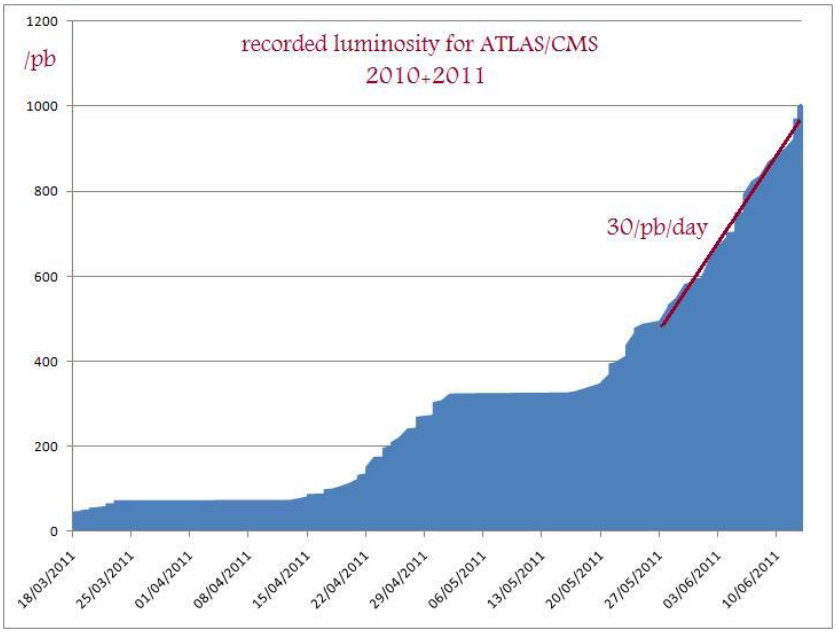


By the way, you can still vote for us on 3QuarksDaily

June 13, 2011: Large Hadron Collider provides 1 inverse femtobarn for CMS and ATLAS, already!

Today at 21:10 hours European Time the Large Hadron Collider passed an important milestone when it reached 1/fb of integrated luminosity delivered to each of the large experiments CMS and ATLAS. The third major proton experiment LHCb which limits its luminosity has around 0.35/fb. These figures include the 47/pb delivered in 2010, but after another one or two good runs the total for 2011 alone will also surpass the one inverse femtobarn milestone.

Update 14-Jun-2011: With another good run today the total delivered for CMS passed the 1/fb mark for 2011 data alone at about 20:25.



This is an impressive achievement for the worlds most powerful particle accelerator at CERN which had originally expected to collect this amount of data only by the end of 2011. Better than expected performance now means that it records about 30/pb worth of collision data each day on average. With about 120 days of proton physics left this year, the beam operations team can expect to deliver at least 4.4/fb this year if they continue at this rate.

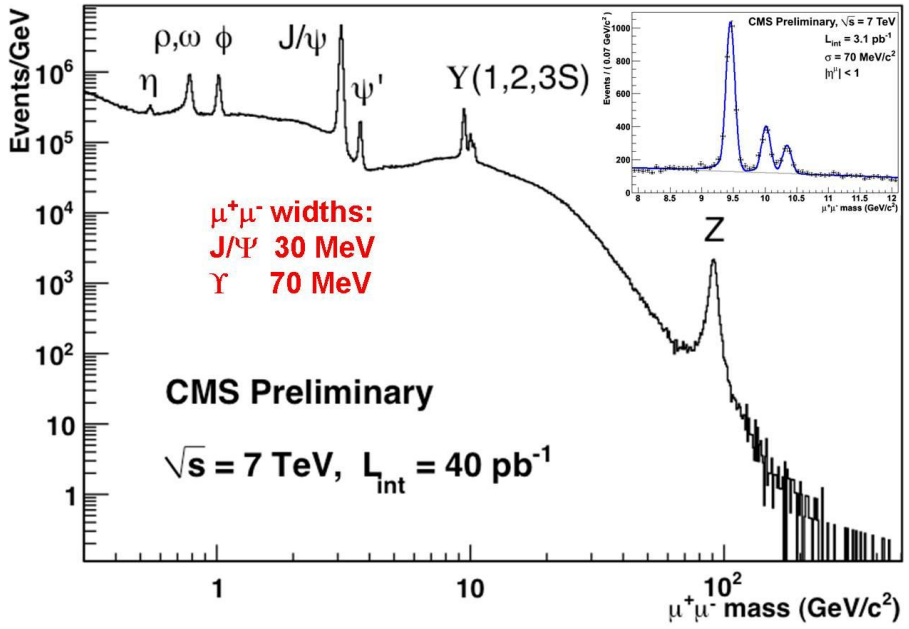
Potential luminosity increases

There is still some potential to increase this figure if they can continue to increase the number of protons circulating in the rings. The current quantity of 1092 proton bunches circulating in each direction will shortly be increased to 1236 and then finally 1380 once they overcome difficulties with power to the RF systems. This will increase the luminsity by 25%. Another goal will be to increase the efficiency by keeping the collider in Stable Beams for longer. Recent figures show that this state is only achieved for around 40% of the time due to a variety of technical issues. As these are sorted the figure may go up to 60% or even higher to give 50% more data. If this can be done quickly it would bring the expected total for 2011 up to around 7/fb. At 1380 bunches the rings are full to capacity with current bunch spacing so further improvements this year are only possible if the bunch intensity can also be increased, but this is not yet planned. 5/fb to 7/fb is already a spectacular number to aim for and they may not want to put these numbers in danger by taking such risks.

Expected conference announcements

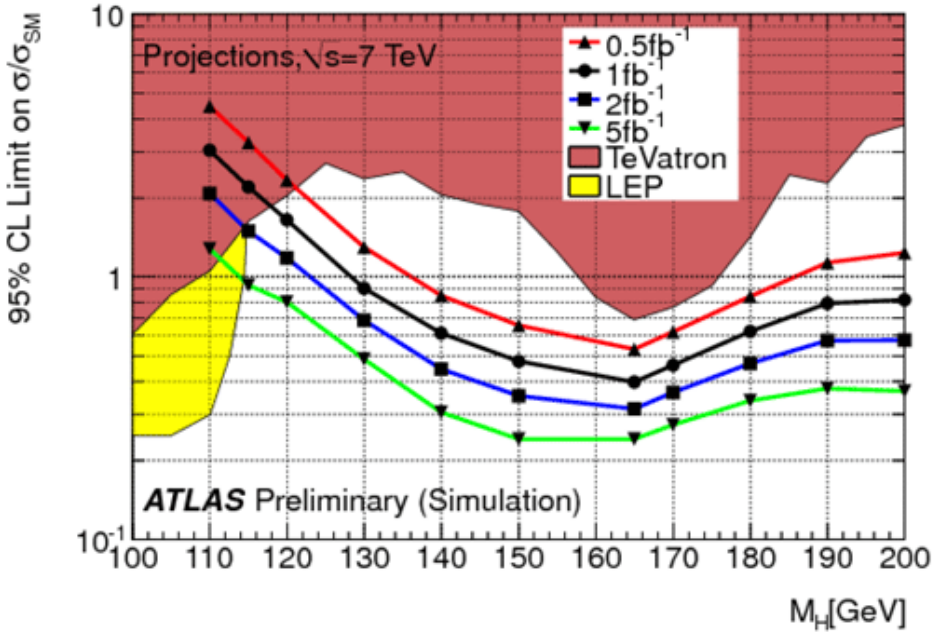
The amounts of useful data recorded by the experiments is typically 90% to 95% of the amounts delivered. In a few days these figures will also pass 1/fb and this should be in time for the next big particle physics conference EPS-HEP2011 at the end of July. At last weeks PLHC2011 conference we already saw a few results using 200/pb, one fifth of the current standing. However, there are many standard searches for which we have still only seen plots using the 40/pb collected last year. For example the classic dimuon resonance curve has not yet been shown in updated form for either ATLAS or CMS. This could be because it was too

dull to show. The dimuon signal is very clean but it is not expected to be the first place where new physics will appear. On the other hand, it may not have been shown for the opposite reason. If it had an inconclusive signal of a new resonance then they would surely want to wait for more data before showing it.



When will the Higgs be seen?

To get a better impression of just how significant the quantities of data now being collected are, it is useful to look at the projected Higgs Limits as shown in this figure.



With 1/fb of data there will either be a signal or an exclusion for the Higgs boson above 130 GeV. If it is excluded then it will be known to lie between the 115 GeV limit previously set by LEP and a new limit of 130 GeV. This is highly significant because the standard model on its own predicts that the vacuum would be unstable if the Higgs has a mass less than 135 GeV. New particles such as those predicted by supersymmetry would be needed to restore stability. In other words, this exclusion expected from 1/fb would be indirect evidence of physics beyond the standard model at the electro-weak scale. The EPS-HEP conference is likely to be a historic event where they will either describe the first signals for the Higgs Boson or the first good evidence for new BSM physics. If you want to attend today is the last day to register at the standard fee or 350 Euro!

If EPS-HEP is an anti-climax, the next big particle physics conference is Lepton-Photon 2011 during the last week of August. Another femtobarn of data will be available for analysis in time for that. There are smaller workshops and seminar opportunities going on all the time so a new discovery can come at any moment, but the physicists do like to time their results for these big events.

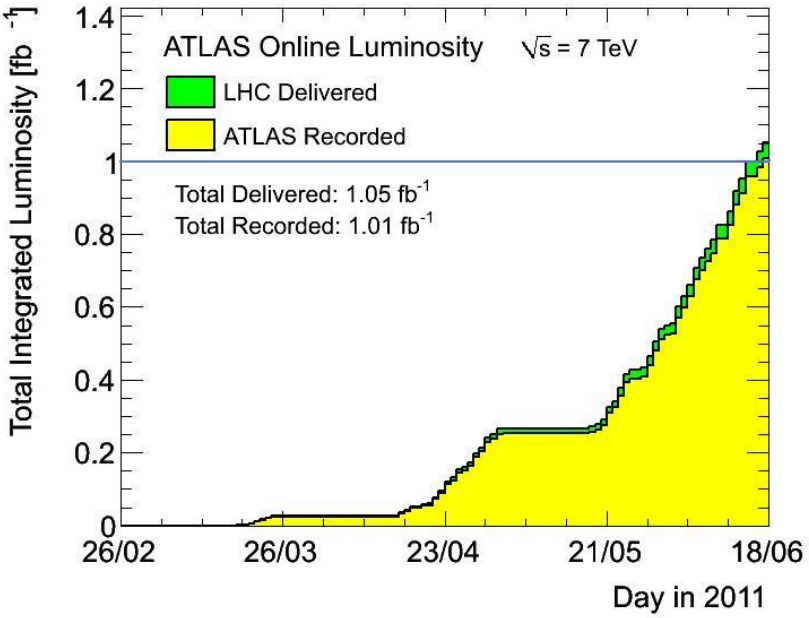
By the end of the year the situation will be even more dramatic. About 5/fb should be available, enough to exclude the Higgs boson at all masses, or more likely to discover it. If it is indeed a light Higgs there is a good chance that some other new particles will be discovered too.

What if it does not show up?

The calculations that are used to calculate the exclusion limits are themselves based on assumptions that the Higgs will decay according to the predictions of the standard model. If the standard model is ruled out by not seeing the Higgs then these calculations will themselves be invalid. For example, a possibility is that there are heavy unknown particles into which the Higgs could decay. If these new particles produce jets that are hidden in the sea of background QCD it may be much harder to detect it. Another even weirder possibility is that the Higgs boson just isn't there. If nature is devious enough we could still see no new particles this year.

June 18, 2011: LHC Status Report

last week we celebrated 1 inverse femtobarn (1/fb) of integrated luminosity delivered to ATLAS and CMS. Of that data ATLAS has recorded about 95% and CMS about 92% so with a little more added ATLAS have now recorded over 1/fb.



The milestones have been celebrated with a CERN press release

Last week the LHC Control group held an Open meeting to report on progress of the beams and experiments. Slides and videos are available for some of the talks including the Machine Status Report by Steve Myers who revealed that during the last Machine Development period the bunch intensity was tested up to 195 billion protons, going well beyond the 170 billion ultimate intensity limit. The intensity currently in use is about 120 billion, but there is hope that this may be increased later in the year.

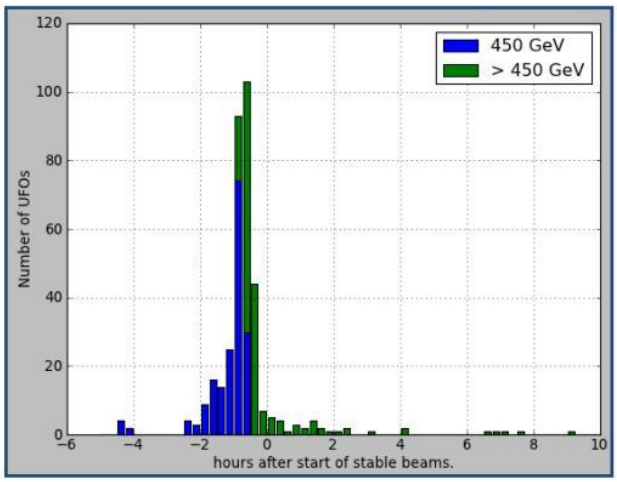
Although the LHC has delivered 1/fb in record time as a result of its better than expected early performance, there is some frustration that technical problems are holding it back from achieving even better results. A string of difficulties has been making it hard to get the beams circulating while other glitches cause the beams to be dumped early. The time in stable beams has been about 36% since they started running with 1092 bunches and it should be possible to do better than that.

Unidentified Falling Objects

In his talk Myres gave some more information about UFOs. These are mysterious rapid beam loss events thought to be caused by particles falling into the beam path. They can trigger the protection mechanisms to dump the beams. Studies have shown that they most often occur at the injection points and almost always shortly after injection causing problems before they get to stable beams. Surprisingly their frequency is not increasing with further intensity advances. They were 110 of these UFO events last year and already 5000 this year, but only the strongest cases can trigger a beam dump.

An extensive report on UFOs can be found here

Most of the UFOs around the MKIs occur before going to stable beams.



RF Power Couplers

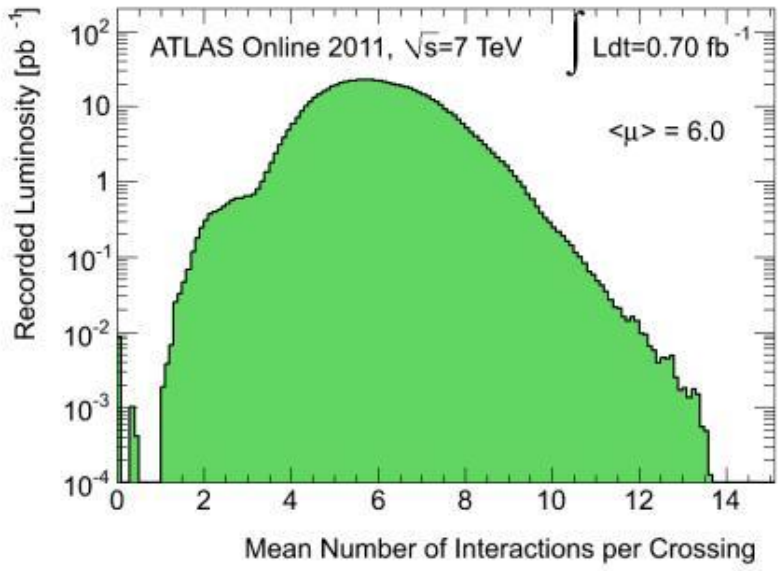
Another series of problems concerns the RF components. The couplers can take 200 kW of power and currently are being loaded up to 190 kW. This figure increases with beam intensity. If one of the ceramic couplers breaks it would put the LHC out of action for five to six weeks. These and other concerns have been preventing them from raising the bunch number to the next step of 1236 bunches. There is also a special report on the RF power issues and how they have been addressed. With the situation coming back under control it is hoped that the next luminosity step can still be taken this weekend.

Mini-Chamonix

In order to decide how to proceed for the rest of the year there will be a "mini-Chamonix" meeting on the 15th July. There We may hear more about addressing these and other problems as well as prospects for any further luminosity increases e.g. by raising bunch intensity.

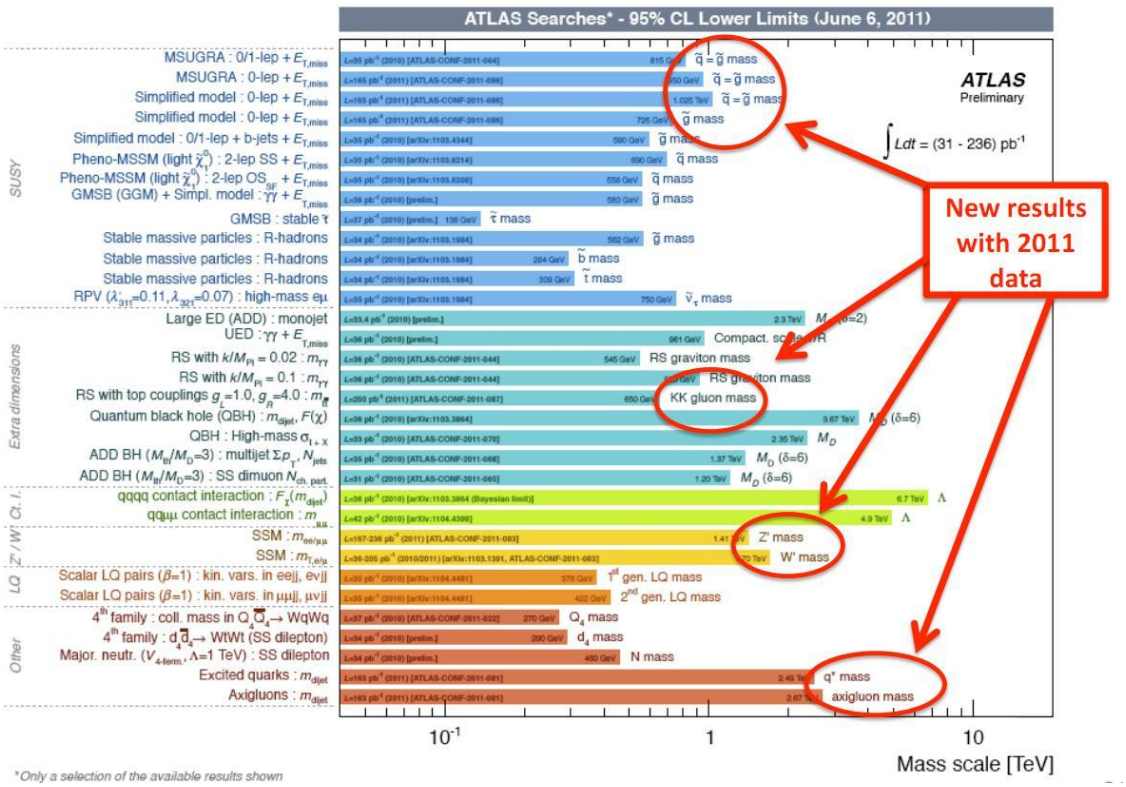
Status Reports of the Experiments

At the LPCC meeting there were also reports from the individual LHC experiments. CMS has produced 80 papers using LHC data while ATLAS has about 190 and there are also good initial results from LHCb and ALICE. With the luminosity increasing at faster than expected rates there has been more pileup of events in the detector than anticipated. ATLAS reports an average of 6 events for each bunch crossing. There is significant impact on the calorimeter reconstruction resulting in increased systematic uncertainties in the analysis. Low transverse momentum jet events are the worst affected, but it is a small price to pay for so much extra data. Pileup will get worse if the bunch intensity is raised further.



Summary of Physics Results

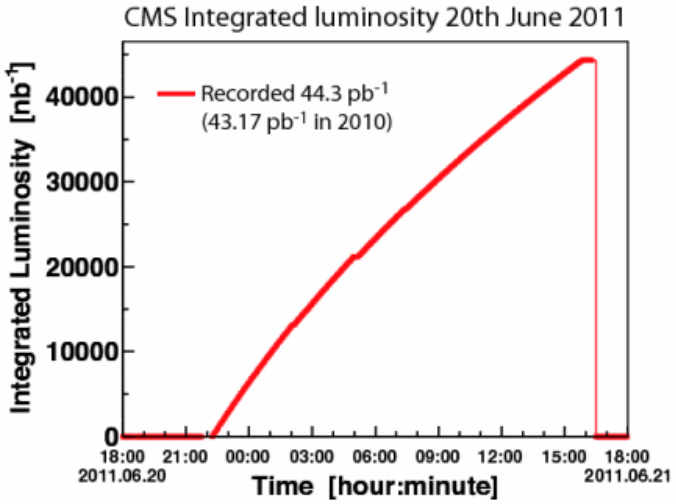
Most of the physics results published so far have used just the 40/pb of data collected in 2010 with just a handful using up to 240/pb . A selective summary of results from ATLAS is shown on this slide (click to see full-sized). Within a few weeks we will have many more results including some using the 1/fb now collected. the EPS-HEP conference at the end of July is the next major opportunity for physics presentations.



June 24, 2011: Tough Week for the LHC

Today the Large Hadron Collider has taken another step up in luminosity by increasing the number of proton bunches per beam from 1092 to 1236. The first run at this new intensity equaled the previous luminosity record. They may beat it in subsequent runs by pushing up the bunch intensity. One more step up is required to reach this years maximum possible bunch count of 1380 bunches per beam. It may be too late to reach that step before the next technical stop.

The advance comes at the end of a tough week with only one run during a period of five days. At least that one run was itself a record with integrated luminosity for a single run of 47.7/pb in ATLAS. For CMS the total delivered was 46.3/pb but they issued a special note to say that they had also recorded 44.3/pb, more than the entire amount recorded during 2010.



The main reason for the delay this week was problems with cryogenics caused by clogged oil filters and possibly worsened by a lightning strike and/or an industrial strike. When any one of the 8 major cryongenic plants fails it can easily take two days to get it fixed and return the superconducting magnets to their working temperature of 1.9 degrees Kelvin. There were two such outages this week with this record run in between.

Update 27-Jun-2011: The situation has improved in the last few days culminating in a run today lasting about 20 hours that delivered a record 62/pb. The luminosity was still above half its peak value at the end of the run demonstrating just how good the luminosity lifetimes are. The next run will attempt 1380 bunches, the maximum possible with 50ns spacing. They have just one day left before machine development time takes over, followed by a technical stop.

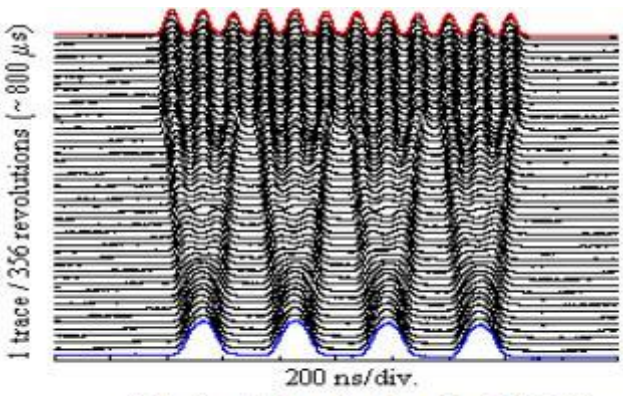
June 28, 2011: New LHC Records and bunch splitting

Yesterday the Large Hadron Collider produced a record run lasting 20 hours and delivering a record 62/pb. The run ended with a programmed dump for the first time in a while. They then turned the machine round in just four hours for a new run with 1380 bunches for the first time. This is the maximum bunch number that will be used for physics runs this year.

At this significant point in the LHC commissioning process it is worth reflecting just how much of an achievement it is to run with so many bunches. For comparison, the Tevatron runs with just 36 bunches per beam. Of course the LHC is bigger so it is possible to get more bunches in, but it is only four and a bit times bigger. To get 1380 bunches in they have to pack them much closer together. In the Tevatron the bunches run about 175 meters apart on average but in the LHC they are on average 20 meters apart.

This improvement in the design of the LHC over previous hadron colliders is just as important as the increase in energy. Hadron collisions are messy processes and to get the full information out the physicists will need to look for very rare events with clear signals of unusual processes. By time the LHC has run its full length it will have collected thousands of inverse femtobarns of data to explore the Higgs sector in the best possible detail. To achieve this it has to run with lots of bunches and with high quality, low emittance beams.

You can't just inject individual proton bunches into an accelerator very close together because there is a limit to how fast the kicker magnets can change as they inject the bunches into the ring. As the energy increases the magnets have to produce more powerful fields and it gets harder to pack the bunches together. The injection process uses a series of increasingly powerful rings to put together the bunches in trains (see my earlier post about the injection chain). The early stages have lower energy so the bunches can be slotted closer, but the rings are smaller and fill up quickly. You can build up as you go along but this is not enough to get the bunches as close together as they need them.



Splitting of 4 bunches into 12 at 1.4 GeV.

The trick that made this possible was invented in the 1990's using the PS accelerator at CERN which is now part of the injection chain for the LHC. They first considered a procedure of debunching the protons in the ring, so that they could then reform new smaller bunches, but they found that this ruined the good emittance properties of the beams. The solution was to split the bunches by starting with a low-frequency RF signal in the ring and

gradually boosting one of its harmonics to higher amplitude. If you raise the second harmonic the bunches split in two and if you raise the third harmonic it splits them in three. In the PS they start with 6 big bunches. These are first split in three to provide 18 bunches. The bunches are then accelerated to a higher energy before being further split into two. The 36 bunch trains are moved to the larger SPS ring and gathered into 144 bunch trains which are further accelerated before being injected into the main LHC ring. Later, possibly next year, they will split the bunches one more time in the PS to double the number of bunches again.

I've no idea who worked out how to do this bunch splitting but they are just some of the many unsung heroes of the LHC.