Key Questions

• What is the origin of Electroweak Symmetry Breaking? Origin of Mass?
• Where is all the Anti-Matter?
• Were the fundamental forces once unified?
• Are there extra dimensions? Dark Matter?

New particles should appear at the TeV scale, in reach of the LHC
Overall view of the LHC experiments.
LHC Experiments

• ATLAS/CMS:
  • Electroweak Symmetry Breaking
  • Supersymmetry
  • Extra Dimensions, Exotics

• LHCb:
  • CKM Measurements
    • (Matter/Anti-Matter Imbalance)
  • Precision tests of the standard model

• ALICE:
  • Properties of the Quark-Gluon Plasma
LHC Experiments

• **ATLAS/CMS:**
  - Electroweak Symmetry Breaking
  - Supersymmetry
  - Extra Dimensions, Exotics

Also smaller experiments: Totem, Alpha

• **CKM Measurements**
  - (Matter/Anti-Matter Imbalance)

• **Precision tests of the standard model**

• **ALICE:**
  - Properties of the Quark-Gluon Plasma
LHC Experiments

• **ATLAS/CMS:**
  - Electroweak Symmetry Breaking
  - Supersymmetry
  - Extra Dimensions, Exotics

• **LHCb:**
  - CKM Measurements
    - (Matter/Anti-Matter Imbalance)
  - Precision tests of the standard model

• **ALICE:**
  - Properties of the Quark-Gluon Plasma
LHC Beginning & Beyond

- **2009**: LHC start up, $\sqrt{s} = 900$ GeV
  - $\sqrt{s} = 7-8$ TeV, $L = 6 \times 10^{-33}$ cm$^2$s$^{-1}$, bunch spacing 50 ns

- **2010**
  - Go to design energy, nominal luminosity
  - $\sqrt{s} = 13-14$ TeV, $L = 1 \times 10^{-34}$ cm$^2$s$^{-1}$, bunch spacing 25 ns (likely to be more)

- **2011**
  - Injector & LHC Phase I upgrade to full design luminosity
  - $\sqrt{s} = 14$ TeV, $L = 2 \times 10^{-34}$ cm$^2$s$^{-1}$, bunch spacing 25 ns (likely to be more)

- **2012**
  - HL-LHC Phase-2 upgrade, crab cavities?, IR
  - $\sqrt{s} = 14$ TeV, $L = 5 \times 10^{-34}$ cm$^2$s$^{-1}$, bunch spacing 25 ns
  - Plan for 50% more

- **2013**
  - ~25 fb$^{-1}$

- **2014**
  - ~50 fb$^{-1}$

- **2015**
  - ~300 fb$^{-1}$

- **2016**
  - ~3000 fb$^{-1}$

- **2017**

- **2018**

- **2019**

- **2020**

- **2021**

- **2022**

- **2023**

- **2030?**
• 2009-today: Run 1 : 7-8 TeV centre of mass energy. Peak Luminosity $6.66 \times 10^{33}$ cm$^{-2}$s$^{-1}$

• 2013-2014 : Shut down to prepare machine for design energy (14 TeV) and nominal luminosity ($10^{34}$cm$^{-2}$s$^{-1}$)

• 2015-2016 : Operation at design
LHC Peak Luminosity

- [http://lpc.web.cern.ch/lpc/lumiplots.htm](http://lpc.web.cern.ch/lpc/lumiplots.htm)

Estimated for 2012
CMS Total Integrated Luminosity, 2012, p-p, \( \sqrt{s} = 8 \) TeV

Data included from 2012-04-04 23:57:30 to 2012-06-18 11:01:36 UTC

LHC Delivered: 6.65 fb\(^{-1}\)

CMS Recorded: 6.15 fb\(^{-1}\)
Impressive Luminosity Race with an Amazing Finish!

6.6 fb\(^{-1}\) delivered until MD/Ts2 !!
An extremely successful week 24

- Very stable operation with
  - $\sim 6.5 \times 10^{33}$
  - $1.5 \times 10^{11}$ ppb
- 1.33 fb-1 recorded in one week!!
- 51% of the time in stable beams
- Total 18.7% 'down time'
  - MKI waiting for cool down: 13h40'
  - Injectors: 6h30'
  - Waiting for experiments: 3h28'

Peak Stable Luminosity Delivered
<table>
<thead>
<tr>
<th></th>
<th>Fill 2710</th>
<th>12/06/06, 15:52</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luminosity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deliverer</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.76 x 10^{33} cm^{-2} s^{-1}</td>
<td></td>
</tr>
<tr>
<td></td>
<td>237.32 pb^{-1}</td>
<td></td>
</tr>
<tr>
<td></td>
<td>250.94 pb^{-1}</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1390.14 pb^{-1}</td>
<td></td>
</tr>
</tbody>
</table>

Tuesday, 26 June 12
LHC Collision Conditions

**ATLAS Online Luminosity**

- **ATLAS Online Luminosity**
  - $\sqrt{s} = 7$ TeV
  - $\sqrt{s} = 8$ TeV

**Mean Number of Interactions per Crossing**

- Recorded Luminosity [pb$^{-1}$]
  - $\beta^* = 1.0$ m, $<\mu> = 11.6$
  - $\beta^* = 1.5$ m, $<\mu> = 6.3$

**LHC Highlights - 26 June, 2012 - Geoffrey Taylor**

Tuesday, 26 June 2012
Re-discovery of the SM

ATLAS Preliminary
\[ \int L \, dt = 0.035 - 4.7 \, fb^{-1} \]
\[ \sqrt{s} = 7 \, TeV \]

- Theory
- Data 2010
- Data 2011
A Higgs Search (H\textrightarrow{}WW*) @ ATLAS

- ATLAS

\( \sqrt{s} = 7 \text{ TeV}, \int L \, dt = 4.7 \text{ fb}^{-1} \)

\( H \rightarrow WW^{(*)} \rightarrow l\nu l\nu + \text{0 jets} \)

- ATLAS

\( \sqrt{s} = 7 \text{ TeV}, \int L \, dt = 4.7 \text{ fb}^{-1} \)

\( H \rightarrow WW^{(*)} \rightarrow l\nu l\nu + \text{1 jet} \)

- ATLAS

95\% CL Limit on \( \sigma \sigma_{\text{SM}} \) for the Higgs boson

\( \int L \, dt = 4.7 \text{ fb}^{-1} \)

\( \sqrt{s} = 7 \text{ TeV} \)

The tum spectrum has been reweighted to the next-to-next-to-leading gluon–gluon fusion process. The Higgs boson transverse momentum is obtained from MC simulation using the next-to-leading order Pythia (NLO) matrix-element generator.

The use of a 2nd order polynomial was shown to be sufficient for the five event classes. The dijet-tagged class. Both photons in the barrel, and for the combination of the four other classes, are also shown in the analysis, together with the magnitude of the variation of the source that has been applied.

Table 3 shows the local and signal significance evaluation is carried out in steps binned and an unbinned evaluation of the likelihood. The correlation of the signal model is shown in the second column.

Separate sources of systematic uncertainties accounted for in this analysis. The magnitude of the variation of the source that has been applied.

The diphoton mass scale is insensitive to the choice of background model fitting function.

Table 3 shows the local and signal significance evaluation is carried out in steps binned and an unbinned evaluation of the likelihood. The correlation of the signal model is shown in the second column.
Discovery?

• Finding the Higgs is a discovery!
• Not finding the SM Higgs is a discovery!

• LHC will elucidate spontaneous symmetry breaking. How do the W and Z get their mass? Let alone all other elementary particles?
It took ~30 years to experimentally restrict the SM Higgs mass to be above 114 GeV. CMS and ATLAS independently eliminated another ~475 GeV of the range in 2011.

"Expected" exclusion 114.5 - 543 GeV
Observed exclusion 127.5 - 600 GeV
Higgs Search Limits: ATLAS

Excluded at 95% CL

110 < mH < 122.5 GeV (except 117.5-118.5)
129 < mH < 539 GeV

One window left open?

Have a new peak at ICHEP 2012
A standard model Higgs?

- Is the particle we are calling a Higgs, a real Higgs? A real Higgs would decay to $WW^*$ much more often than it decays to $\gamma\gamma$
- Decay to two photons proceeds via indirect decay. If it happens more often than expected
  - Higgs couplings to top and $W$ don’t match prediction OR
  - Unknown heavy particles are mediating the decay
- Must proceed to measure decays to fermions: leptons and quarks ($H \rightarrow \tau\tau$ & $H \rightarrow bb$)
Retrospective

- In 2008 ATLAS performed studies involving state of the art simulations in a rigorous effort to prepare for the start of data taking at the LHC
- Culminated in a ~1850 page document it reported what was expected to be searched for or measured and to what exclusion or precision at collision energy of 14 TeV
  - (arXiv:0901.0512 - citations > 700)
- In 2012 we can look back and measure our progress with respect to expectation
  - (Higgs is the best case study)
Higgs Expectations @ 14 TeV

<table>
<thead>
<tr>
<th>√s (TeV)</th>
<th>σ(gg→H) (pb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>14</td>
<td>50</td>
</tr>
</tbody>
</table>
Factor 2.5-3 less Higgs events at 7-8 TeV than at 14 TeV - at 125 GeV expected significance was 4 sigma with luminosity of 10/fb.

With ~15/fb at 7-8 TeV, the significance is greater than 5 sigma. Basically in three years of data-taking analyses have improved by a factor of 2. Remarkable achievement!
Higgs Expectations @ 14 TeV

<table>
<thead>
<tr>
<th>$\sqrt{s}$ (TeV)</th>
<th>$\sigma(gg\rightarrow H)$ (pb)</th>
</tr>
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<td>8</td>
<td>20</td>
</tr>
<tr>
<td>14</td>
<td>50</td>
</tr>
</tbody>
</table>
Physics Beyond the SM

• Has the LHC ...
  • made dark matter?
  • made weird heavy particles? Black holes?
  • found sources of CP asymmetry that help bridge the gap between the minuscule amount in the SM and that observed in the Universe

• No evidence for any of it yet, but as David Gross said at EPS2011 “we’re only at the beginning of a long journey”. We expect to accumulate 100 times more data, so let’s be optimistic.
For narrow $Z$'s, 95%CL limits range from 9.3-0.95 pb in the range $m_{Z'} = 500$ GeV -1300 GeV.

The excluded mass region for a leptophobic topcolour $Z'$ boson (Kaluza-Klein gluon excitation in the Randall-Sundrum model):

$m_{Z'} < 880$ GeV  \hspace{1cm} (m_{g_{KK}} < 1130$ GeV).
Di-jet Resonance Searches

- Test of QCD & Large sensitivity to new physics
- Resonances decaying into two quarks or gluons, excited quarks
- ATLAS 36/pb. Exclude 95% C.L. $0.60 < m(q^*) < 2.64$ TeV. CMS similar analysis with 2.9/pb
SUSY constraints

0-lepton jet+MET channels most sensitive to gluino and squark production (Simplified Model - assumes only squarks gluino & LSP)
Changing neutralino mass and allowing for richer SUSY particle content weakens constraints (more room to search)
**ATLAS Mass Reach for SUSY**

### ATLAS SUSY Searches* - 95% CL Lower Limits (Status: March 2012)

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Search Type</th>
<th>p &lt; 3 TeV</th>
<th>p &gt; 3 TeV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MSUGRA/CMSSM</strong>: 0-lep + j's + E_T,miss</td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-032)</td>
<td>1.40 TeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>MSUGRA/CMSSM</strong>: 1-lep + j's + E_T,miss</td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-041)</td>
<td>1.20 TeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>MSUGRA/CMSSM</strong>: multijets + E_T,miss</td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-037)</td>
<td>850 GeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>Pheno model</strong>: 0-lep + j's + E_T,miss</td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-033)</td>
<td>1.38 TeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>Pheno model</strong>: 1-lep + j's + E_T,miss</td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-033)</td>
<td>940 GeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>Gluino med. \tilde{\chi}^0 \rightarrow \tilde{\chi}^0 + j's + E_T,miss</strong></td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-041)</td>
<td>810 GeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>GMSB</strong>: 1-lep + j's + E_T,miss</td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-033)</td>
<td>990 GeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>GMSB</strong>: 2-\tau + j's + E_T,miss</td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-033)</td>
<td>1.10 fb^{-1} (ATLAS-Coll. 2012-005)</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>GGM</strong>: \gamma + E_T,miss</td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-032)</td>
<td>990 GeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>Gluino med. \tilde{\chi} \rightarrow \tilde{\chi} \rightarrow j' + j's + E_T,miss</strong></td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-033)</td>
<td>805 GeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>Gluino med. \tilde{\chi} \rightarrow \tilde{\chi} \rightarrow j' + j's + E_T,miss</strong></td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-033)</td>
<td>900 GeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>Gluino med. \tilde{\chi} \rightarrow \tilde{\chi} \rightarrow j' + j's + E_T,miss</strong></td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-033)</td>
<td>710 GeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>Gluino med. \tilde{\chi} \rightarrow \tilde{\chi} \rightarrow j' + j's + E_T,miss</strong></td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-033)</td>
<td>650 GeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>Gluino med. \tilde{\chi} \rightarrow \tilde{\chi} \rightarrow j' + j's + E_T,miss</strong></td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-033)</td>
<td>830 GeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>Gluino med. \tilde{\chi} \rightarrow \tilde{\chi} \rightarrow j' + j's + E_T,miss</strong></td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-033)</td>
<td>390 GeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>Direct \bbbar \rightarrow \tilde{\chi} \rightarrow j' + j's + E_T,miss</strong></td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-033)</td>
<td>310 GeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>Direct \ttbar \rightarrow \tilde{\chi} \rightarrow j' + j's + E_T,miss</strong></td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-033)</td>
<td>170 GeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>Direct \ddbar \rightarrow \tilde{\chi} \rightarrow j' + j's + E_T,miss</strong></td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-033)</td>
<td>110 GeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>Direct \ddbar \rightarrow \tilde{\chi} \rightarrow j' + j's + E_T,miss</strong></td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-033)</td>
<td>562 GeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>Direct \ddbar \rightarrow \tilde{\chi} \rightarrow j' + j's + E_T,miss</strong></td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-033)</td>
<td>562 GeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>Direct \ddbar \rightarrow \tilde{\chi} \rightarrow j' + j's + E_T,miss</strong></td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-033)</td>
<td>294 GeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>Direct \ddbar \rightarrow \tilde{\chi} \rightarrow j' + j's + E_T,miss</strong></td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-033)</td>
<td>309 GeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>Direct \ddbar \rightarrow \tilde{\chi} \rightarrow j' + j's + E_T,miss</strong></td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-033)</td>
<td>810 GeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>Direct \ddbar \rightarrow \tilde{\chi} \rightarrow j' + j's + E_T,miss</strong></td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-033)</td>
<td>136 GeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>Stable massive particles (SMP)</strong></td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-033)</td>
<td>1.32 TeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>SMP</strong>: R-hadrons</td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-033)</td>
<td>760 GeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>SMP</strong>: R-hadrons</td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-033)</td>
<td>1.77 TeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>SMP</strong>: R-hadrons (Pixel det. only)</td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-033)</td>
<td>1.77 TeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>GMSB</strong>: stable \tilde{\tau}</td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-033)</td>
<td>185 GeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>RPV</strong></td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-033)</td>
<td>185 GeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>MSUGRA/CMSSM</strong>: BC1 RPV</td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-033)</td>
<td>185 GeV</td>
<td>3-lep + E_T,miss</td>
</tr>
<tr>
<td><strong>Hypercoloured scalar gluons</strong>: 4 jets, \sma = \smass</td>
<td>L = 4.7 fb^{-1} (ATLAS-Coll. 2012-033)</td>
<td>185 GeV</td>
<td>3-lep + E_T,miss</td>
</tr>
</tbody>
</table>

*Note: Preliminary results, status as of March 2012.*
ATLAS Mass Reach for Exotics

Similar results for CMS for SUSY and Exotics
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEXO
Is SUSY beyond reach?

- Pre-LHC: SUSY predicted particles at the Terascale
- Today: SUSY is directly being pushed beyond the Terascale > 1 TeV
- Precision flavor physics e.g LHCb (Belle, Babar elsewhere) > 10 TeV
- Naturalness requires SUSY to have fairly light stops to cancel “un-naturally” large corrections to the Higgs mass
Precision Tests of the Standard Model
LHCb

- Sensitive probe of new physics.
- Virtual loops
- Measurement of the Isospin asymmetry in $B \rightarrow K \mu^+ \mu^-$ turned up an asymmetry which no one expected
- Awaiting SM prediction

More on LHCb results in upcoming talk
Exact mechanism that causes confinement remains unknown

Is the mechanism that confines quarks inside protons responsible for most of the mass in matter?
Properties of qg-Plasma

- QCD predicts the existence of quark-gluon plasma at high energy density
- Azimuthal distribution of particles in the plane perpendicular to the beam direction (azimuthal anisotropy)
- Higher Harmonic Anisotropic Flow Measurements of Charged Particles in Pb-Pb collisions at sqrt(s) = 2.76 TeV
- Fourier coefficients

\[ v_n = \langle \cos[n(\phi - \Psi_n)] \rangle \]

- First measurements of particle flow v3, v4 and v5!
- PRL 107, 032301 (2011)
Ultra-relativistic heavy ion collisions are expected to produce hot and dense QCD matter.

High pT quarks or gluons are expected to lose energy or have their parton shower modified in the medium of high color-charge density. May lead to modified jet yields or structure, phenomenon known as “jet quenching”
2012 LHC Goals

- Allow ATLAS and CMS to independently discover the Higgs before the shutdown (LS1)
- Run with Pb-p collisions at the end of 2012
- Machine studies with 25 ns bunch spacing and pileup to ensure smooth operation after LS1
- Data needed for Higgs discovery

<table>
<thead>
<tr>
<th>Year</th>
<th>Data(/fb)/Beam E(TeV)</th>
<th>Significance (σ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>5 / 3.5</td>
<td>2.5</td>
</tr>
<tr>
<td>2012</td>
<td>11.5 /4.0</td>
<td>5</td>
</tr>
</tbody>
</table>
Impressive Luminosity Race with an Amazing Finish!

6.6 fb$^{-1}$ delivered until MD/TS2 !!

LHC Highlights - 26 June, 2012 - Geoffrey Taylor
LHC Lowlights
Summary

LHC start up, $\sqrt{s} = 900$ GeV

$\sqrt{s} = 7$ to 8 TeV, $L = 6 \times 10^{33}$ cm$^{-2}$s$^{-1}$, bunch spacing 50 ns

Go to design energy, nominal luminosity

$\sqrt{s} = 13$ to 14 TeV, $L = 1 \times 10^{34}$ cm$^{-2}$s$^{-1}$, bunch spacing 25 ns

(likely to be more)

Injector & LHC Phase I upgrade to full design luminosity

$\sqrt{s} = 14$ TeV, $L = 2 \times 10^{34}$ cm$^{-2}$s$^{-1}$, bunch spacing 25 ns

(likely to be more)

HL-LHC Phase-2 upgrade, crab cavities?, IR

$\sqrt{s} = 14$ TeV, $L = 5 \times 10^{34}$ cm$^{-2}$s$^{-1}$, bunch spacing 25 ns

Plan for 50% more
• Remarkable that with ~1/2 design energy (but with great progress on the luminosity front) the LHC has achieved so already.

• With plans for massive increases in data at higher energies in the future the LHC will without doubt be extremely productive.
Nevertheless, at less than two weeks from the start of the ICHEP conference, the news from the experiments is exciting. As I reported to Council, the hints that were reported in the 2011 data last December are still present in the 2012 data. Furthermore, refinements of the analysis of the 2011 data have confirmed the hints reported in December. It is too early for the experiments to say whether the significance is enough to claim a discovery, but whatever the news, it will be reported at CERN on Wednesday 4 July with a live two-way video link to the scientists gathering in Melbourne for ICHEP2012.