

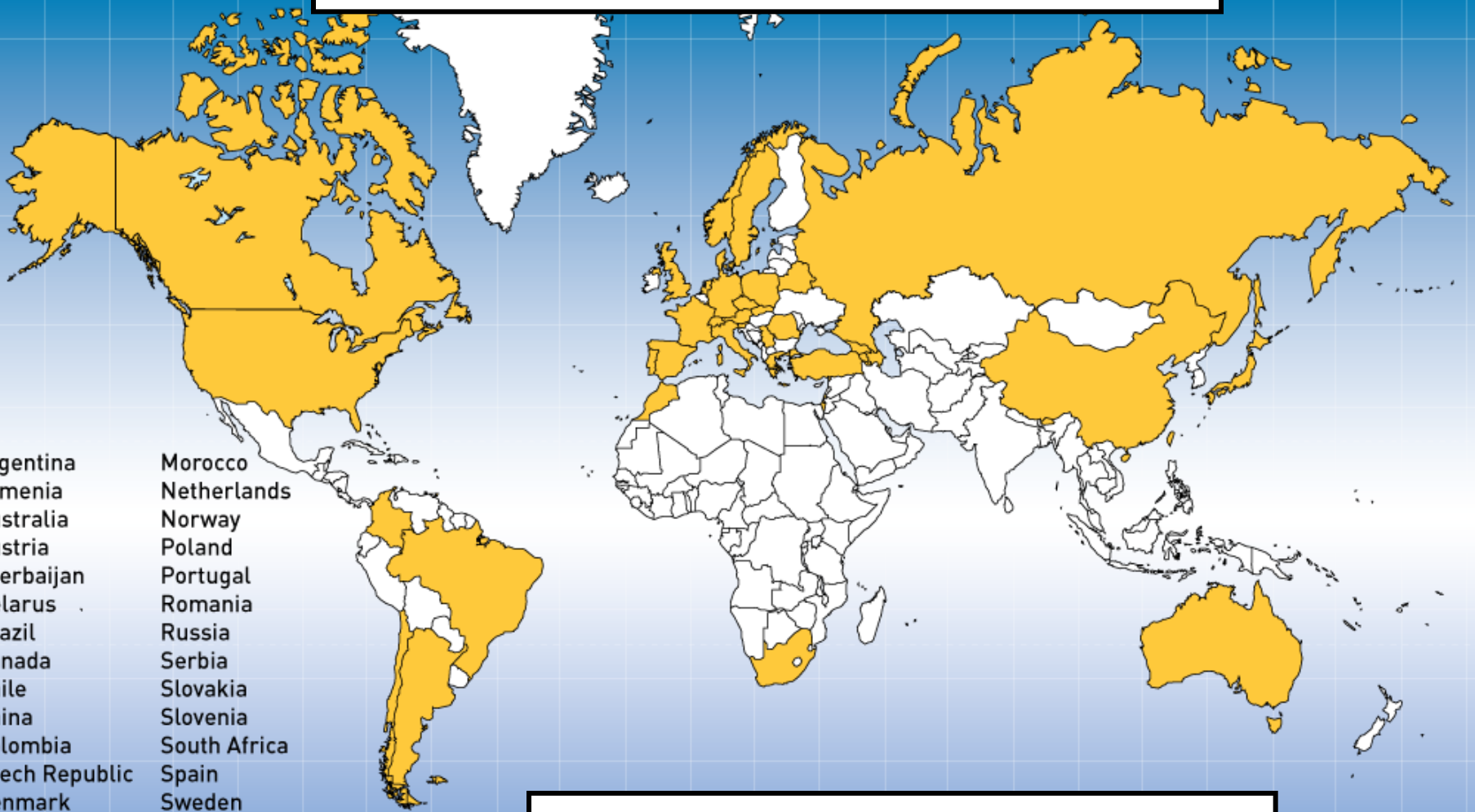
A 3D cutaway illustration of the ATLAS detector. The central part shows a particle collision event with a red cylindrical calorimeter and a central detector core. A white starburst pattern of tracks radiates from the collision point. The detector is surrounded by various colored layers: purple and blue for the inner tracking regions, green for the calorimeters, and yellow and blue for the outer calorimeter and muon systems. Large orange pipes are visible at the top. The entire scene is set against a background of blue and purple geometric shapes.

ATLAS Highlights in 2011

Imma Riu
on behalf of the ATLAS Collaboration
IFAE Barcelona
16 December 2011



ATLAS International Collaboration



- Argentina
- Armenia
- Australia
- Austria
- Azerbaijan
- Belarus
- Brazil
- Canada
- Chile
- China
- Colombia
- Czech Republic
- Denmark
- France
- Georgia
- Germany
- Greece
- Israel
- Italy
- Japan
- Morocco
- Netherlands
- Norway
- Poland
- Portugal
- Romania
- Russia
- Serbia
- Slovakia
- Slovenia
- South Africa
- Spain
- Sweden
- Switzerland
- Taiwan
- Turkey
- UK
- USA
- CERN
- JINR

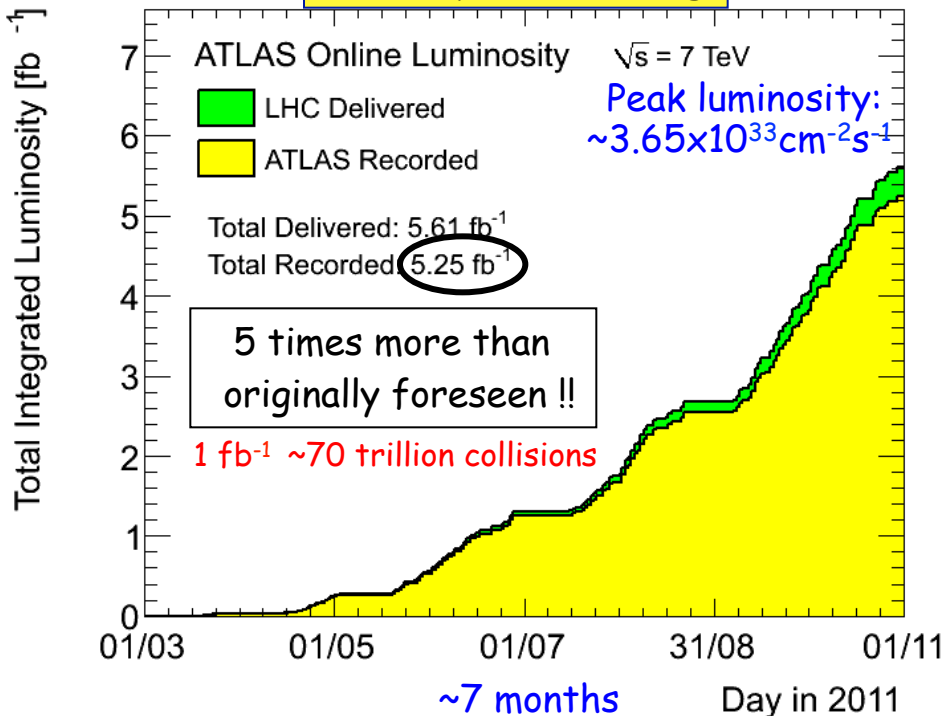
38 Countries
173 Institutions
~3000 Scientists (~1000 PhD students)



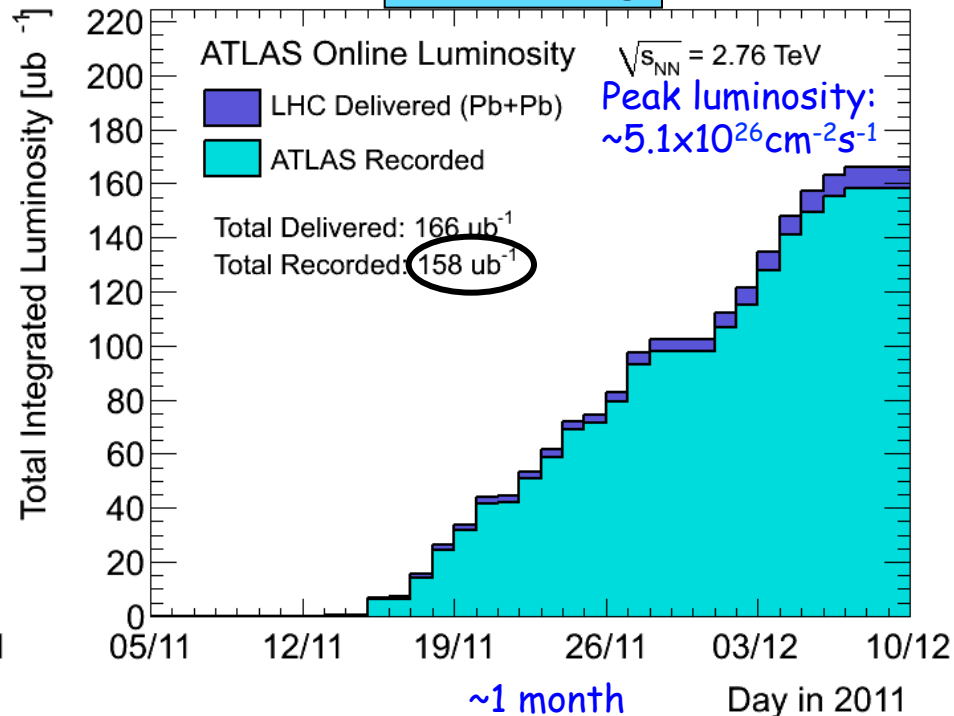


ATLAS collected data in 2011

Proton-proton running



Pb-Pb running



- >100 times more proton-proton collisions:
 - 45 pb^{-1} in 2010
 - 5250 pb^{-1} in 2011
- Excellent recording efficiency: ~94%

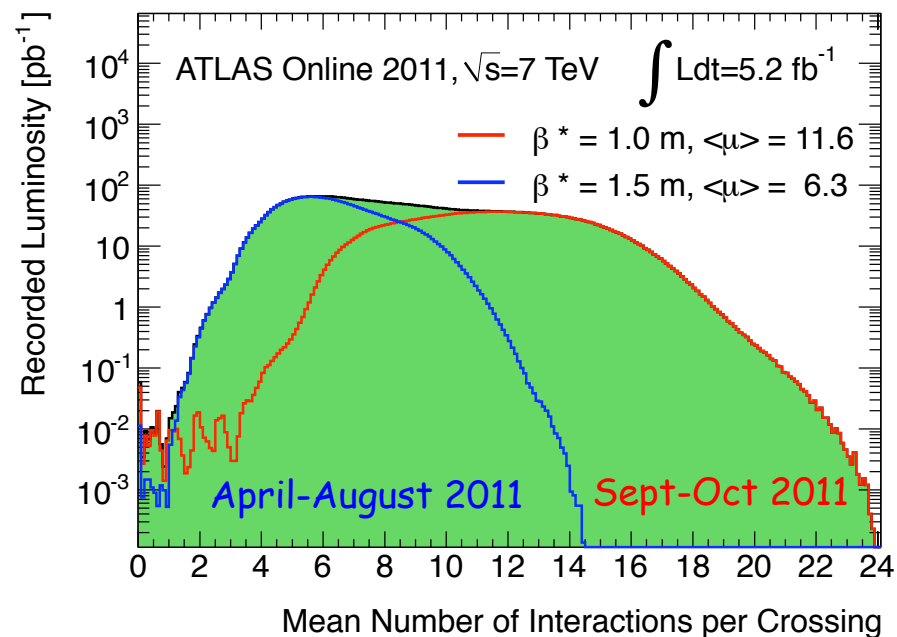
- 17 times more Pb-Pb collisions:
 - 9 μb^{-1} in 2010
 - 158 μb^{-1} in 2011
- Excellent recording efficiency: 95%

~90-96% of good quality data for physics analysis

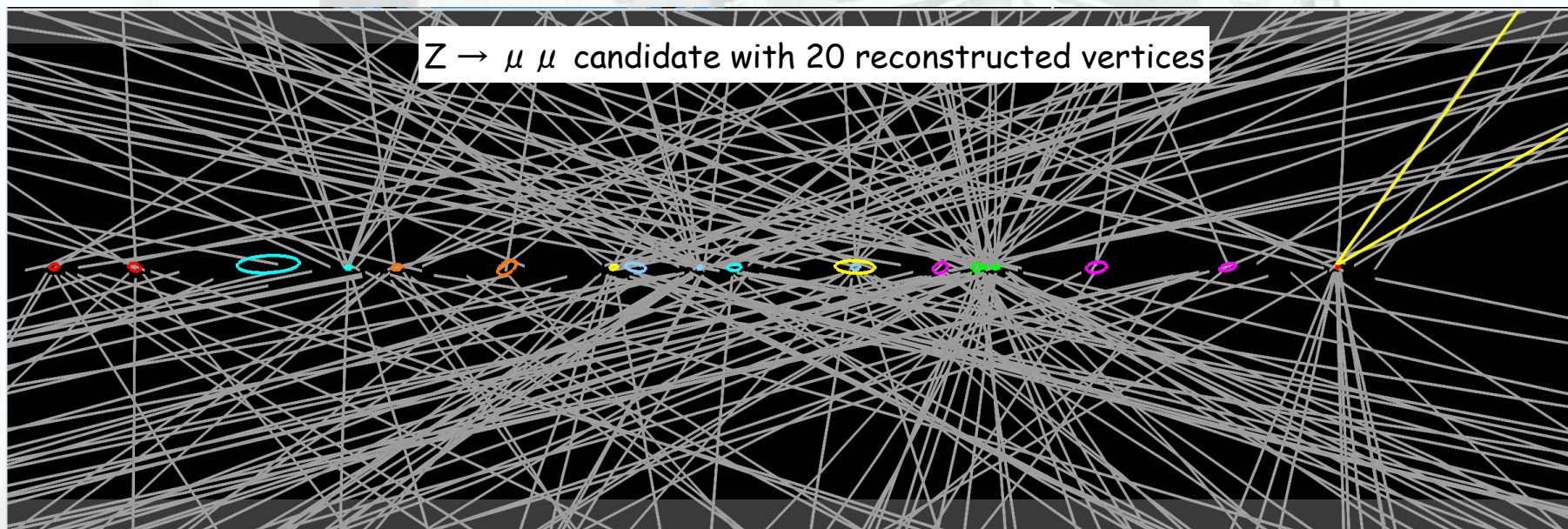


The challenge of pile-up

- Pile-up:
 - Number of simultaneous interactions per crossing
 - Challenges the selection, computing resources and reconstruction of physics objects
- Result in 2011:
 - Observed events with as many as 23 simultaneous interactions:
 - Larger than expected at this early stage



$Z \rightarrow \mu \mu$ candidate with 20 reconstructed vertices





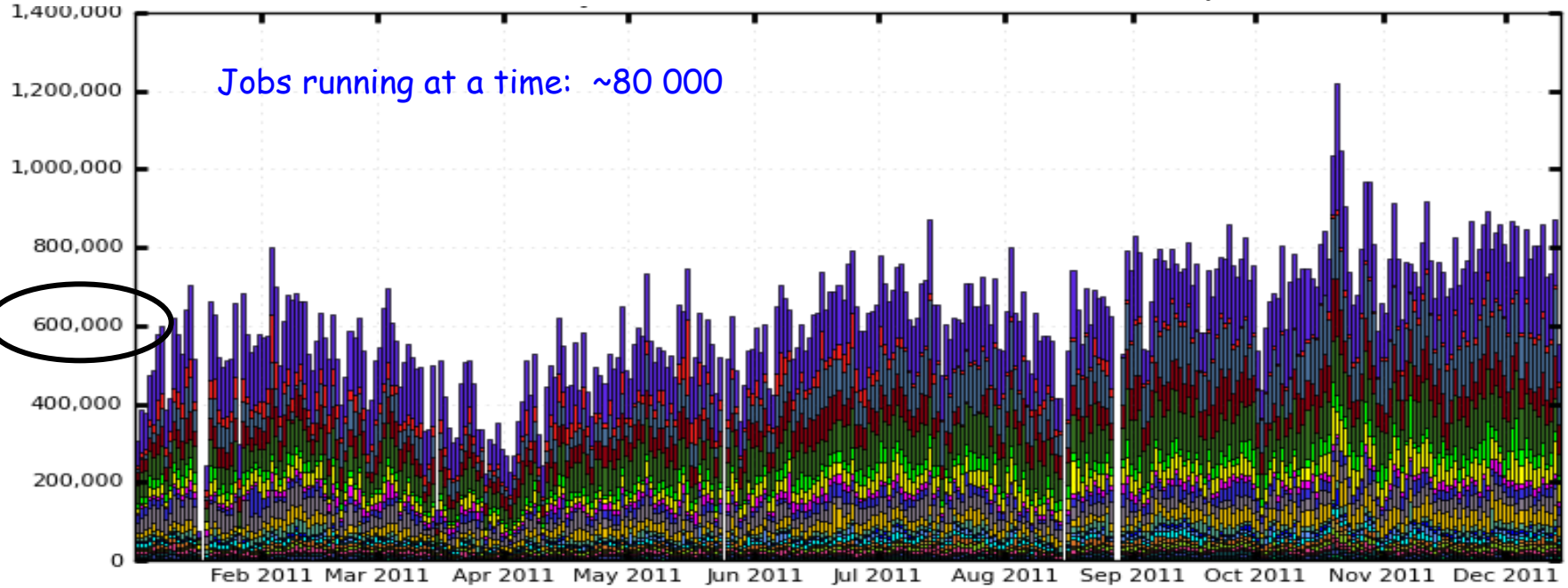
ATLAS physics

- Reminder:
 - ATLAS is a general-purpose experiment
- Main Physics goals:
 - Comprehensive measurement of known physics processes:
 - Lays the foundation for searches
 - Investigation of the origin of mass of particles:
 - Existence of the Higgs boson?
 - Any other mechanism?
 - Investigation of the origin of Dark matter:
 - ~25% of the universe consists of dark matter
 - Origin of this matter? Super Symmetry (SUSY)?
 - Look for new physics at a TeV scale:
 - Existence of extra-dimensions? New forces?
 - New unexpected physics?



Operating computing resources

Simulation production, event reconstruction and physics analysis jobs per day in the Grid



Month in 2011

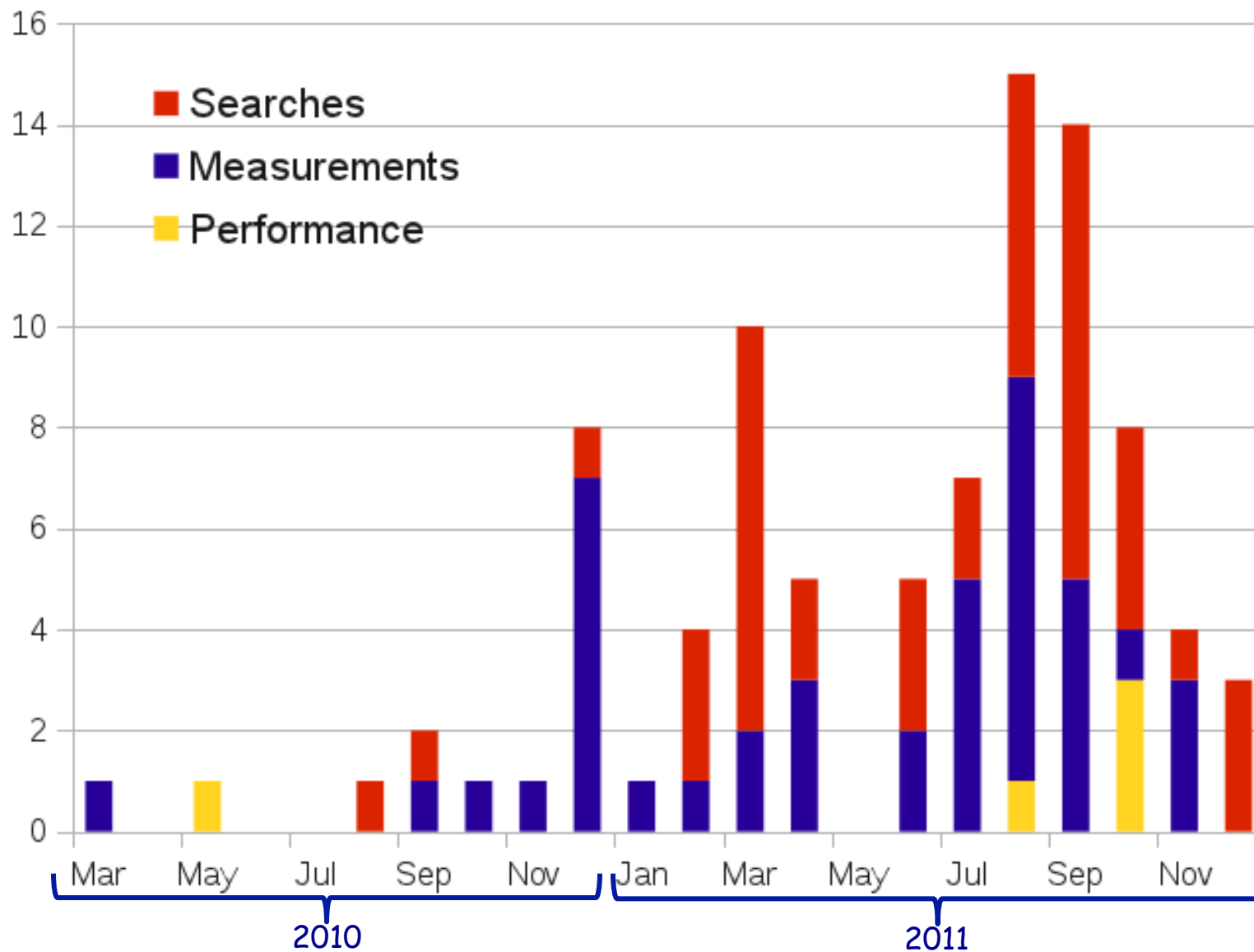


Maximum: 1,221,295 , Minimum: 0.00 , Average: 608,002 , Current: 554,101

Truly international collaborative effort in computing resources to perform physics analysis.
The Worldwide LHC Computing Grid is instrumental to deliver fast physics results.



ATLAS publications





ATLAS publications

- ATLAS papers submitted for publication:
 - In 2010: 16 papers
 - In 2011: 75 papers until today

- Conference notes:
 - 265 since the start of data taking (~50 to summer conferences)

Jet cross-section measurement

The European Physical Journal volume 71 - number 2 - february - 2011

EPJ C Feb 2011

Recognized by European Physical Society

Particles and Fields

Inclusive jet differential cross section as a function of jet p_T integrated over the full region $|\eta| < 2.8$ for jets identified using the anti- k_r algorithm with $R = 0.4$. The data are compared to NLO pQCD calculations to which soft QCD corrections have been applied. From the ATLAS Collaboration: Measurement of inclusive jet and dijet cross sections in proton-proton collisions at 7 TeV centre-of-mass energy with the ATLAS detector

Societ  Italiana di Fisica Springer

SUSY searches in the 2l channel

The European Physical Journal volume 71 - number 7 - july - 2011

EPJ C July 2011

Recognized by European Physical Society

Particles and Fields

Exclusion in the mSUGRA/CMSSM (m_0 , $m_{1/2}$) plane for $\tan\beta = 3$, $A_0 = 0$ and $\mu < 0$, together with existing limits. The expected (dashed line) and observed (full line) 95% CL exclusion limits are shown for the opposite-sign (red line) and same-sign (blue line) analyses. From the ATLAS Collaboration: Search for supersymmetric particles in events with lepton pairs and large missing transverse momentum in $\sqrt{s} = 7$ TeV proton-proton collisions with the ATLAS experiment

Societ  Italiana di Fisica Springer

Search for di-photon events

The European Physical Journal volume 71 - number 10 - october - 2011

EPJ C October 2011

Recognized by European Physical Society

Particles and Fields

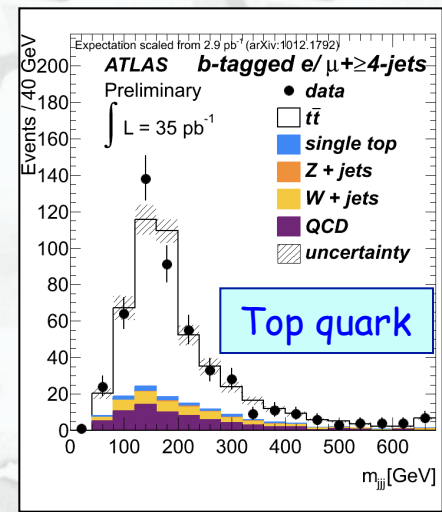
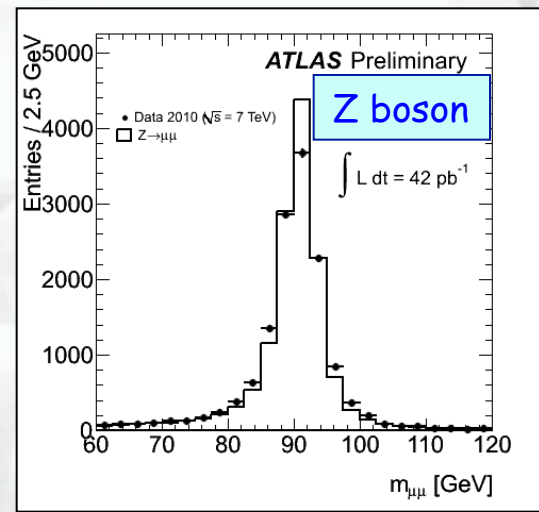
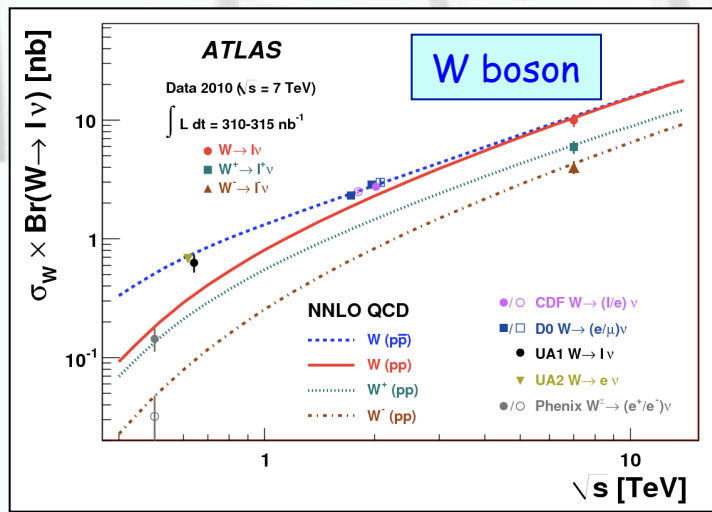
Spectrum of the missing transverse energy in diphoton events as measured by ATLAS at the LHC, compared to the background expected from Standard Model processes (QCD, W decays) as well as to signals expected from a model of gauge-mediated supersymmetry breaking (GMSB) and a model with one universal extra dimension (UED). From the ATLAS Collaboration: Search for diphoton events with large missing transverse energy with 36 pb^{-1} of 7 TeV proton-proton collision data with the ATLAS detector

Societ  Italiana di Fisica Springer

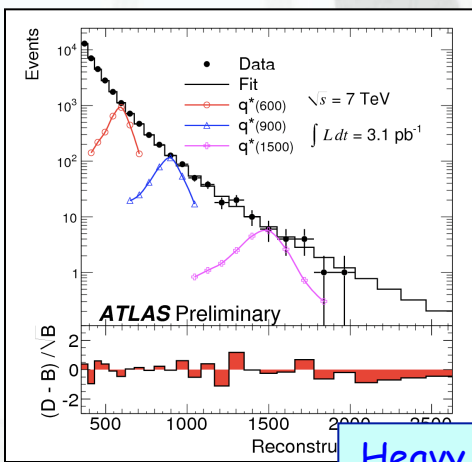


Reminder – ATLAS results in 2010 –

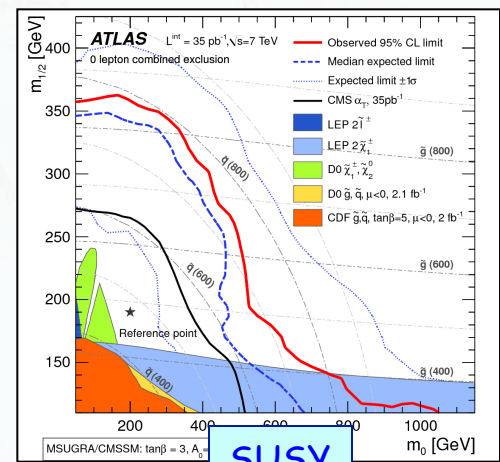
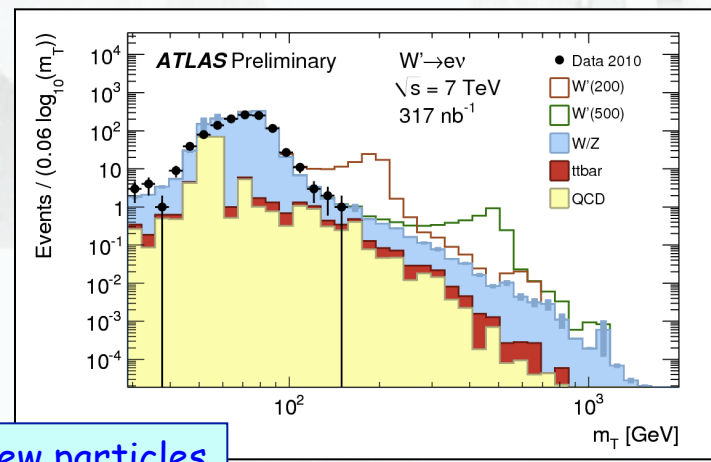
Re-establish the signals from the already known particles of the Standard Model



New physics searches at the reach of statistics



Heavy new particles





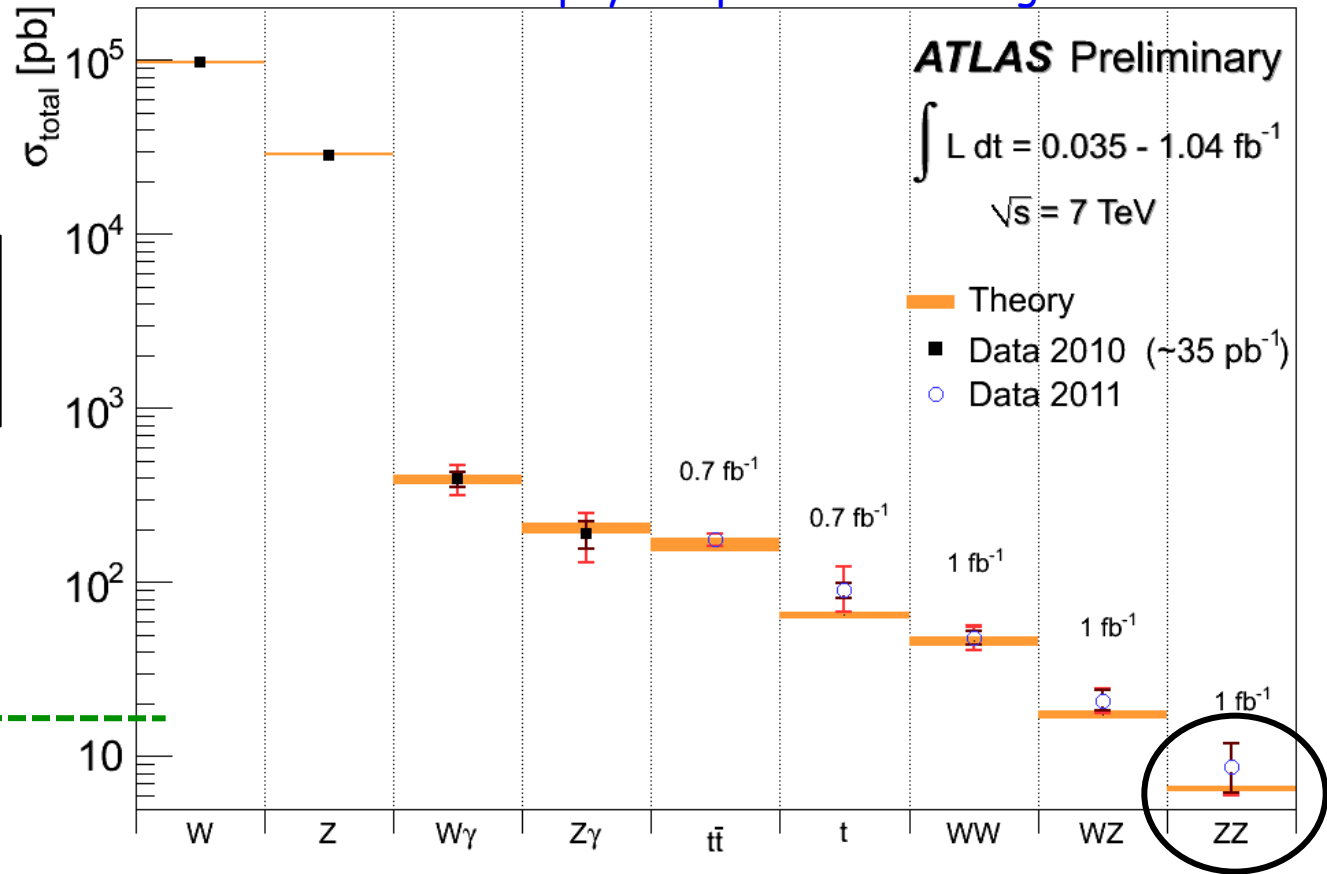
Standard Model cross-section measurements in 2011

Production cross-sections of physics processes background to searches

Events after selection cuts

$\sim 30\text{M}$ $W \rightarrow \mu \nu, e \nu$
 $\sim 3\text{M}$ $Z \rightarrow \mu \mu, e e$
 $\sim 60\text{k}$ top-pairs

$\sigma(pp \rightarrow H)$
 $m_H = 130\text{ GeV}$



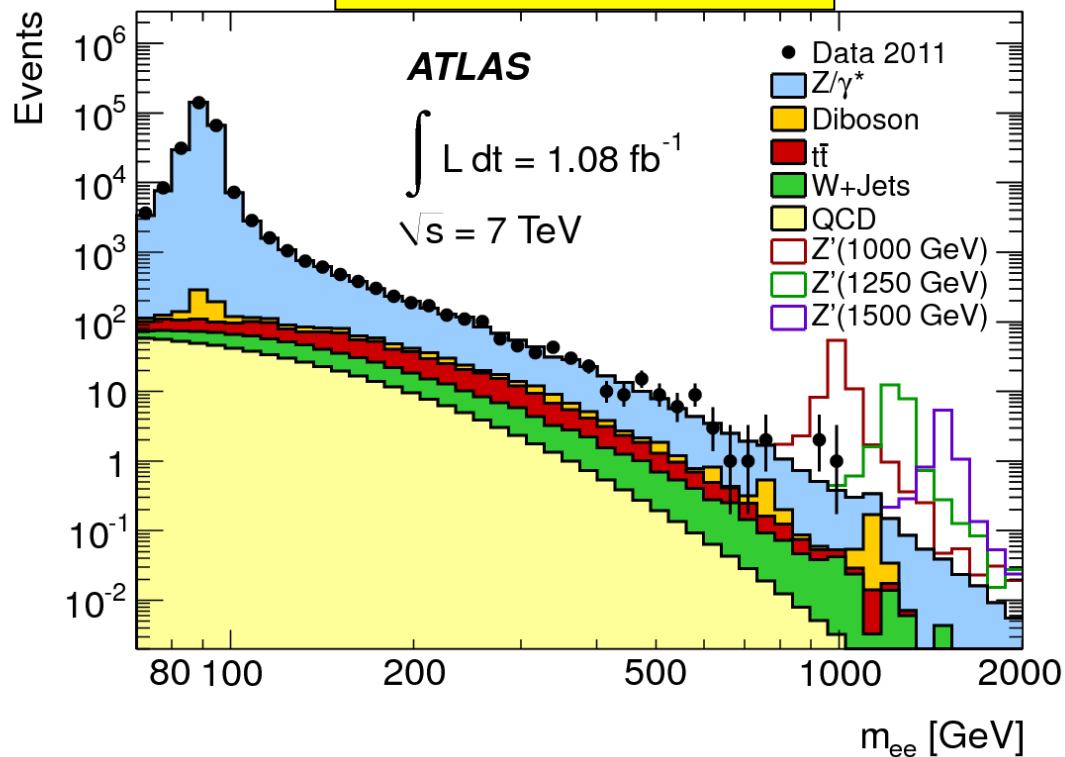
- The amount of data allowed measurements of “rare” physics processes:
 - In ~ 70 trillion pp collisions, ~ 40 ZZ \rightarrow 41 events are produced
- Good agreement with the Standard Model expectations



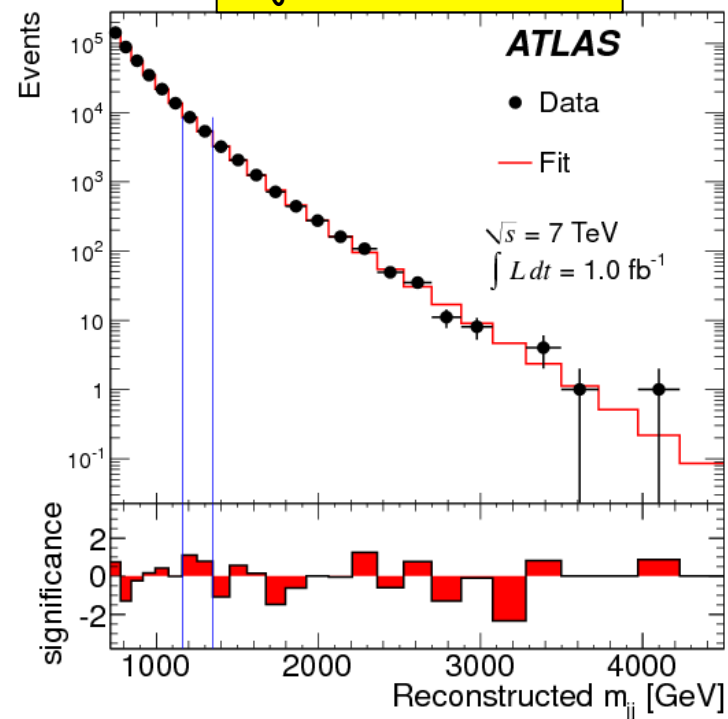
Search for heavy new particles – resonances –

- Search for peaks in different spectra
 - Reached very high masses: ~ 4 TeV (m_{jj}) and 1 TeV (m_{ee})

2 electrons invariant mass



2 jets invariant mass

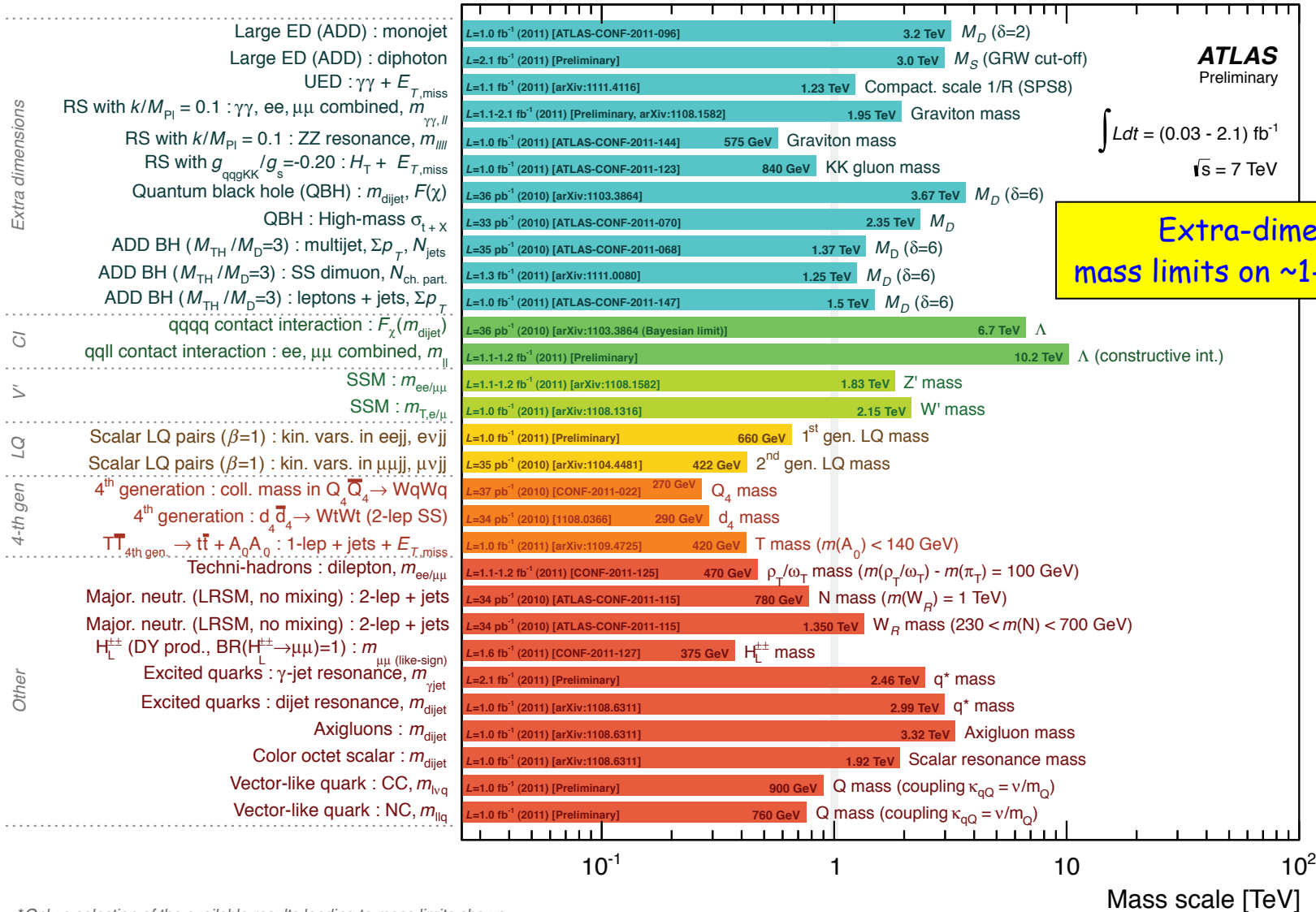


This allows to put more stringent lower mass limits to heavy new particles



New exotic physics search result summary

ATLAS Exotics Searches* - 95% CL Lower Limits (Status: Dec. 2011)



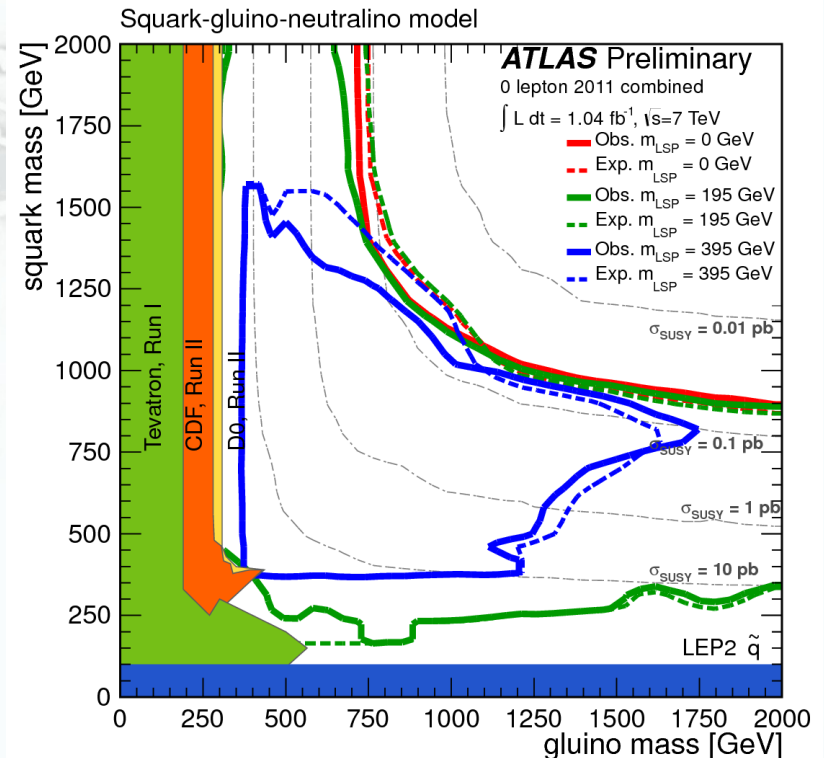
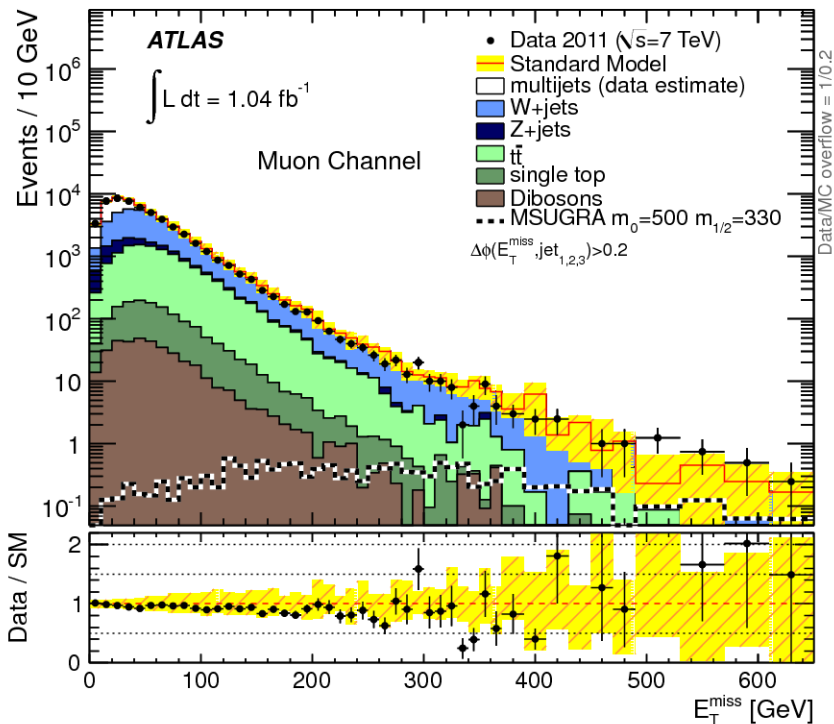
Extra-dimensions:
mass limits on ~1-3 TeV range

*Only a selection of the available results leading to mass limits shown



SUSY search results

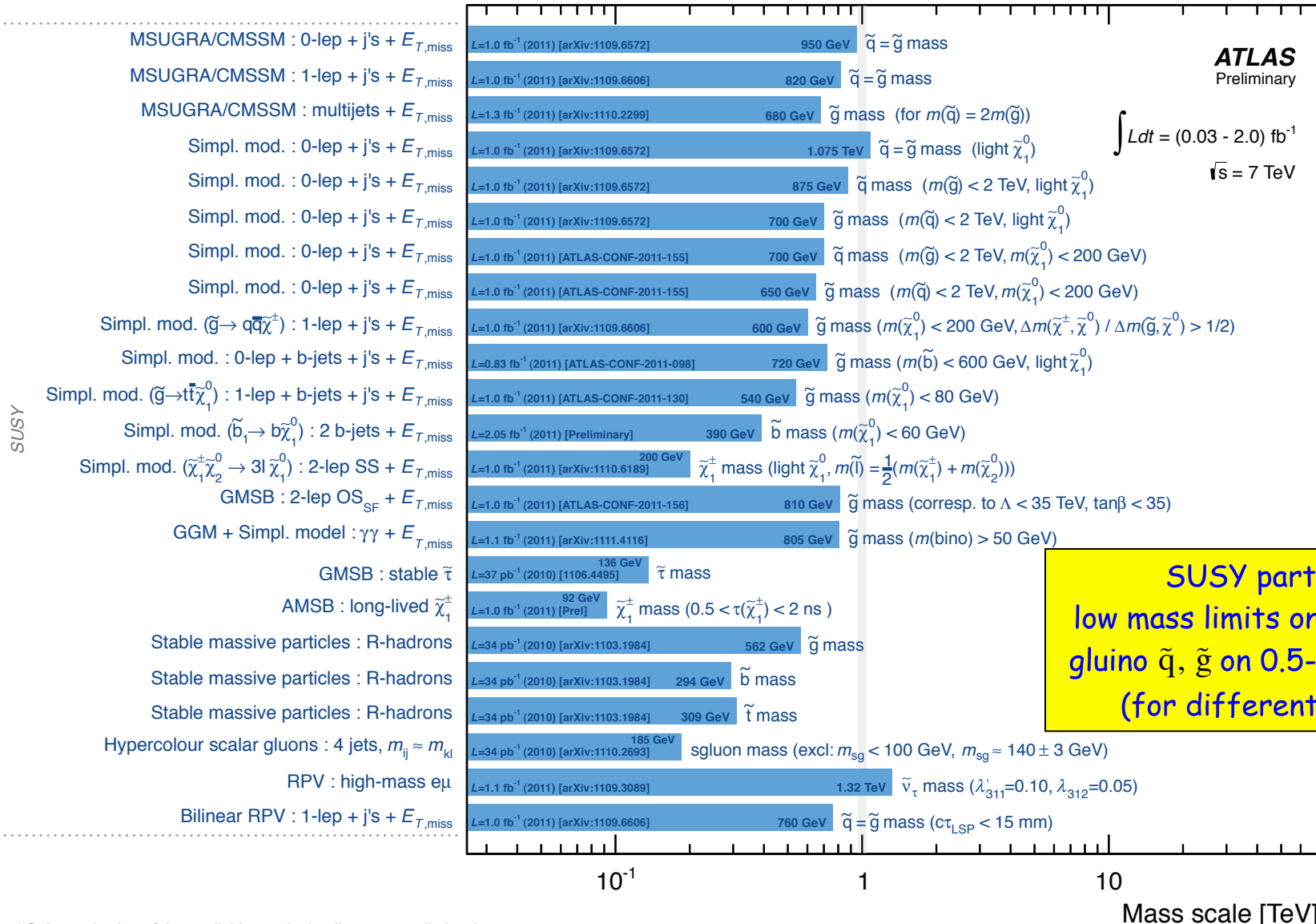
- Searching for SUSY:
 - Sum all energy in the detector
 - Compute the energy balance in the plane transverse to the beam axis (E_T^{miss})
 - Might be due to neutrinos (known that mostly don't interact) or maybe SUSY
- E_T^{miss} distribution well described within 5 orders of magnitude:
 - Very good understanding of the detector !
- Limits on different SUSY particle masses are extracted
- Plot of the exclusion region for squark and gluino masses





SUSY search result summary

ATLAS SUSY Searches* - 95% CL Lower Limits (Status: Dec. 2011)



ATLAS Preliminary

$\int L dt = (0.03 - 2.0) \text{ fb}^{-1}$
 $\sqrt{s} = 7 \text{ TeV}$

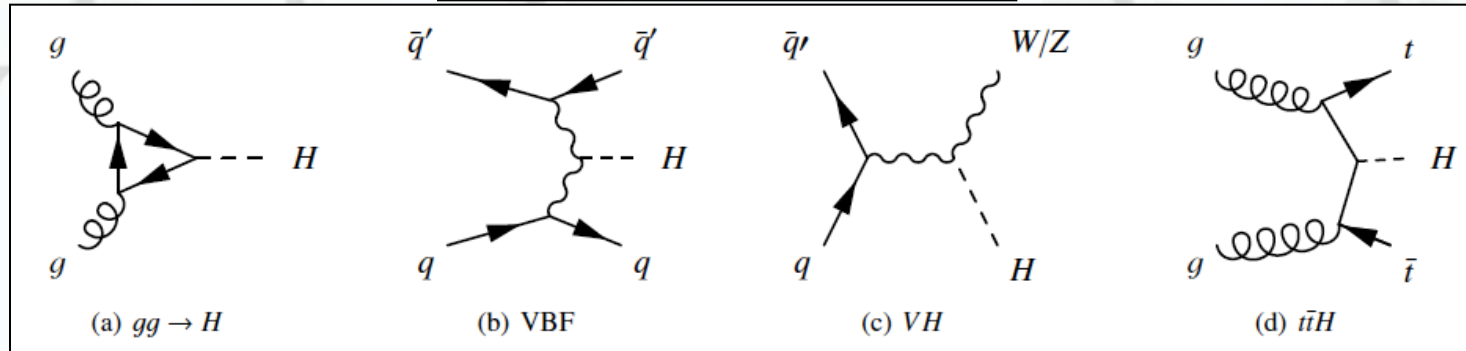
SUSY particles:
low mass limits on squark and gluino \tilde{q}, \tilde{g} on 0.5-1 TeV range
(for different models)

*Only a selection of the available results leading to mass limits shown

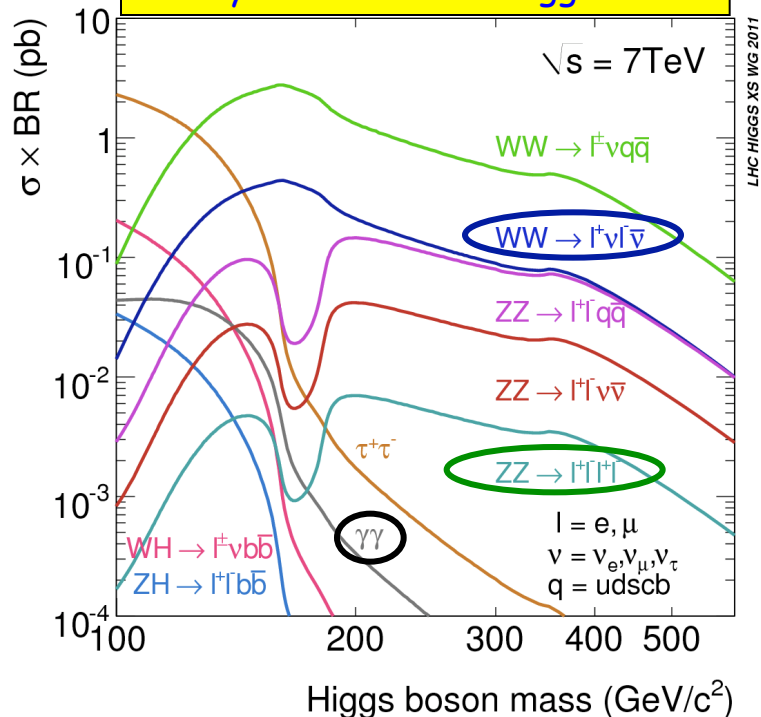


The Higgs boson search in ATLAS

Higgs boson production at LHC



Decay modes of the Higgs boson

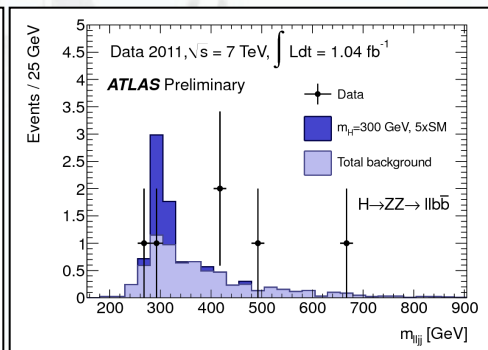
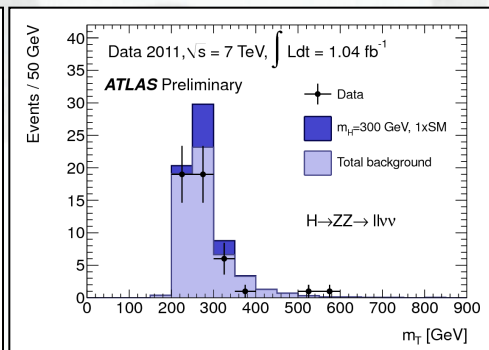
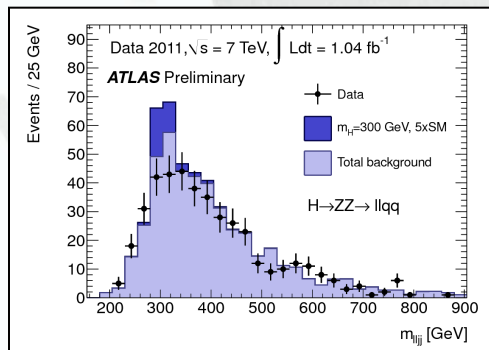
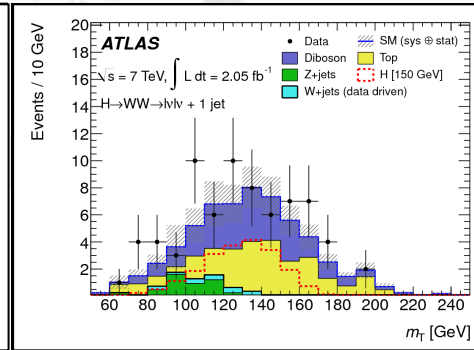
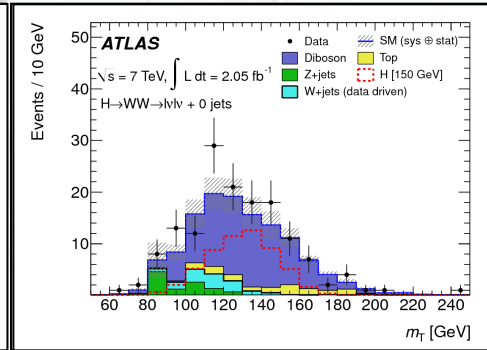
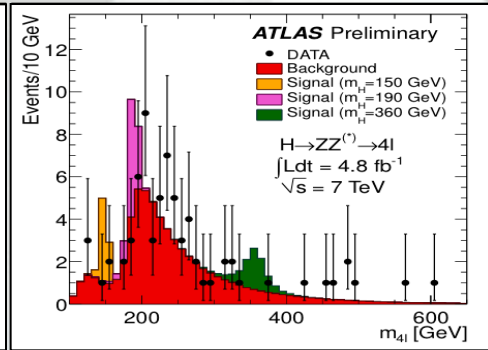
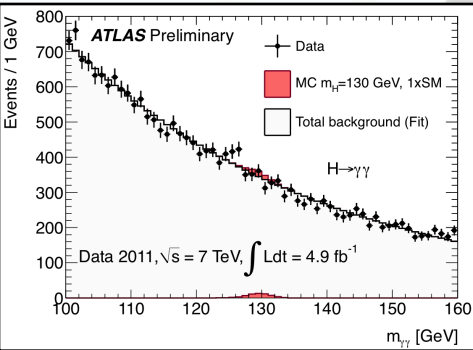
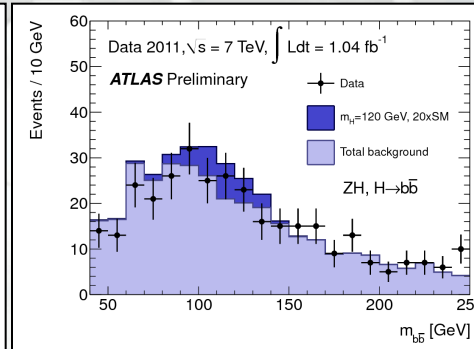
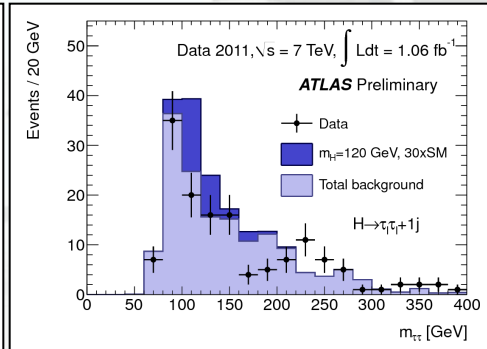
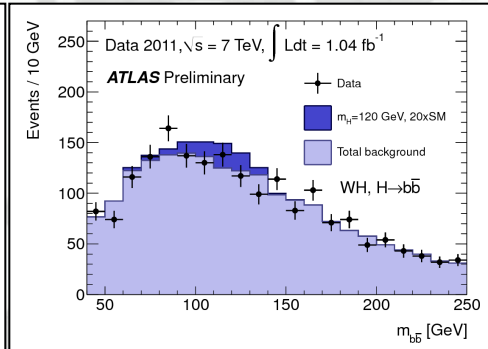
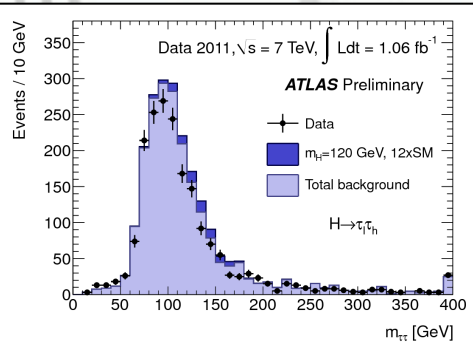


- Sensitivity of a channel to find the Higgs depends on the mass of the Higgs boson, e.g.
 - If $m_H < 130 \text{ GeV}$: $H \rightarrow \gamma\gamma$
 - If $125 < m_H < 180 \text{ GeV}$: $H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$
 - If $125 < m_H < 300 \text{ GeV}$: $H \rightarrow ZZ^{(*)} \rightarrow \mu\mu\mu\mu$
- Results obtained from analysis of each decay mode are combined to constrain the Higgs mass



ATLAS analysis of 11 Higgs channels

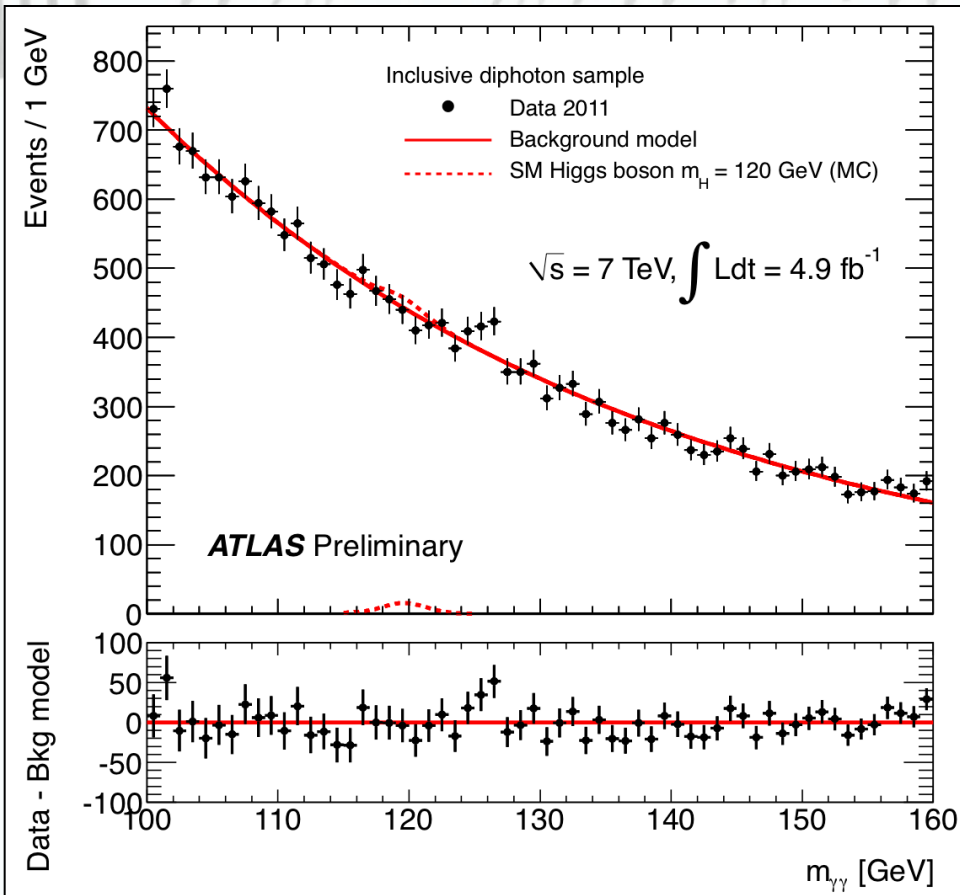
Results shown 13th December 2011



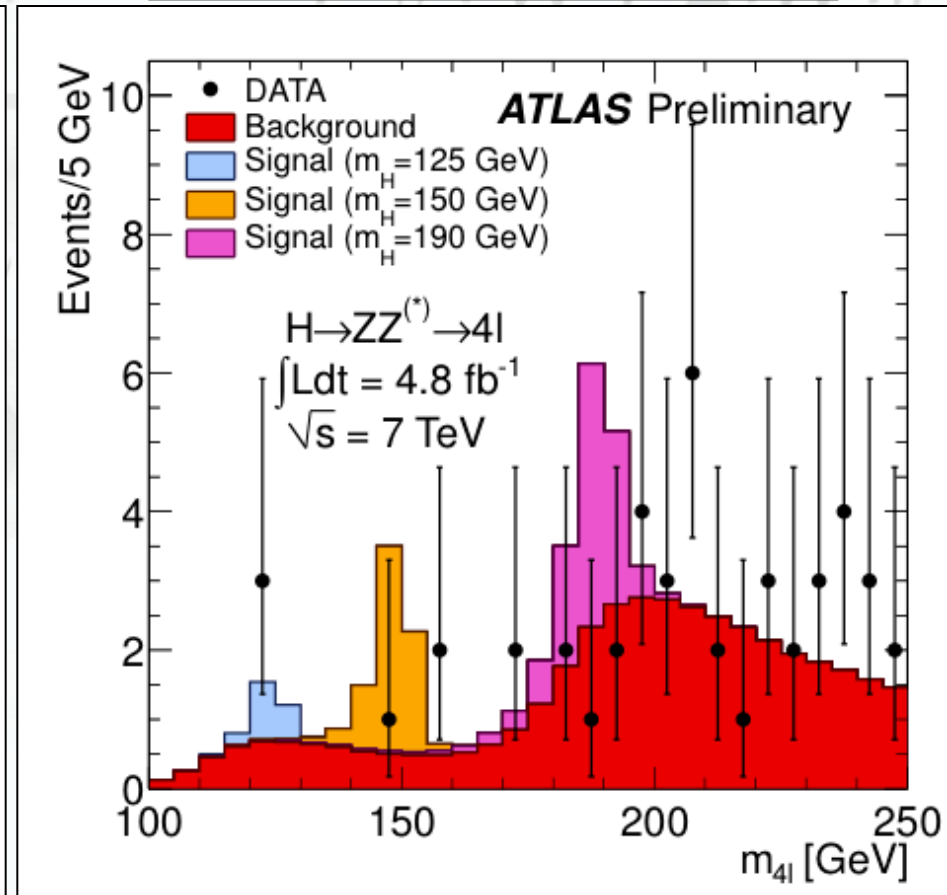


A closer look to two of the channels

H → γγ channel analysis result



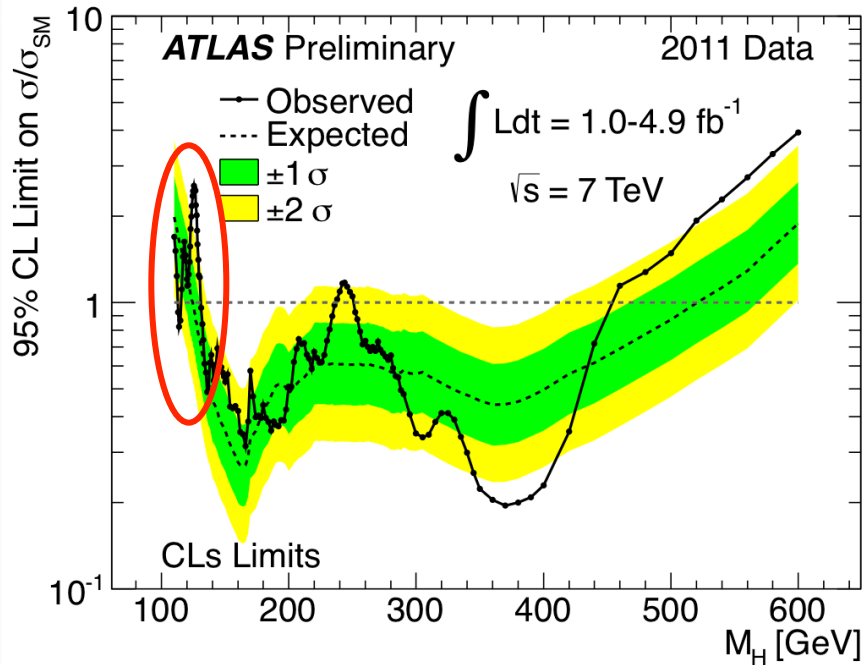
H → ZZ(*) → 4l channel analysis result



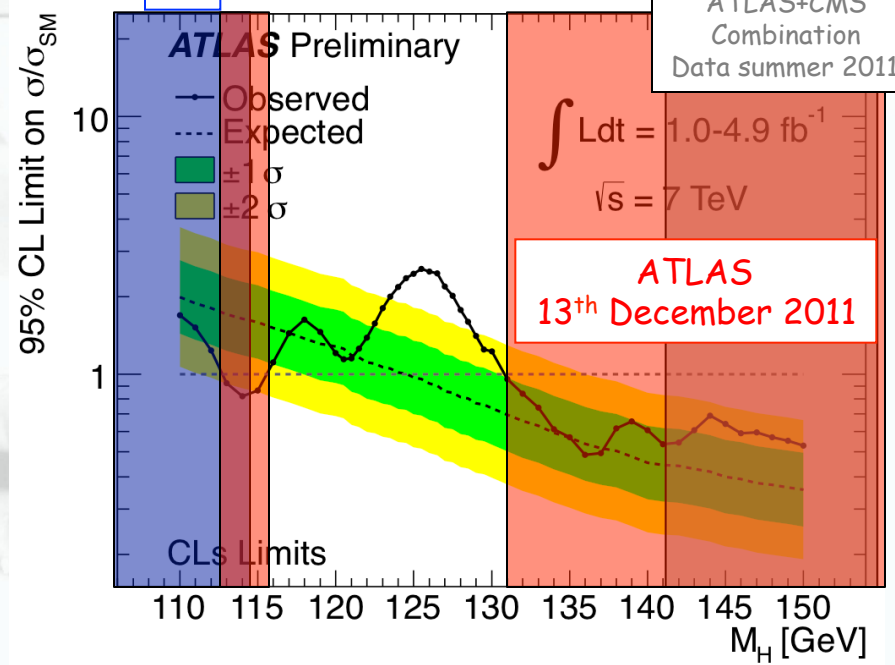


ATLAS exclusion of Higgs masses

Higgs masses with $\sigma / \sigma_{SM} < 1$ excluded at 95%CL



Zoom in the low Higgs mass region



Excluded at 95% CL

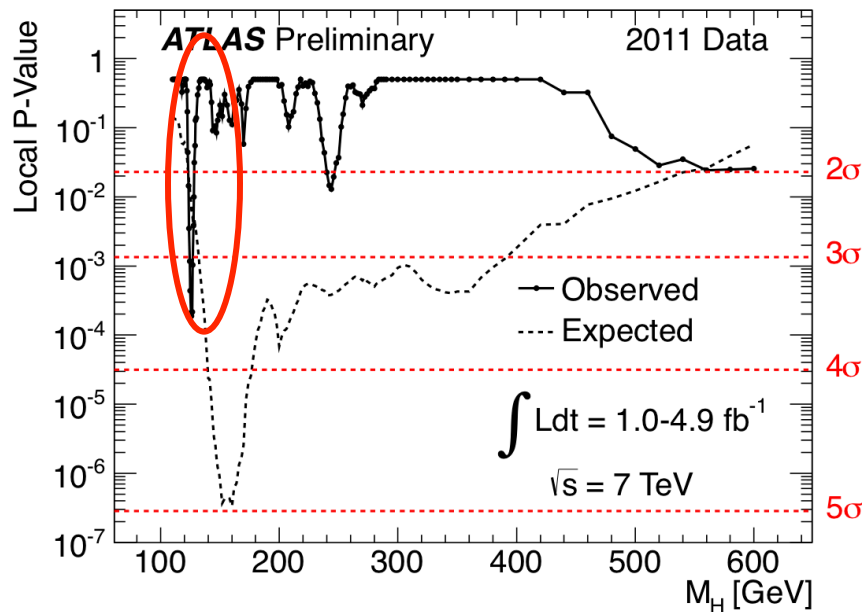
$114.4 < m_H < 115.5 \text{ GeV}$
 $131 < m_H < 453 \text{ GeV}$, except 237-251 GeV

Most likely Higgs mass region at 95% CL: $115.5 - 131 \text{ GeV}$

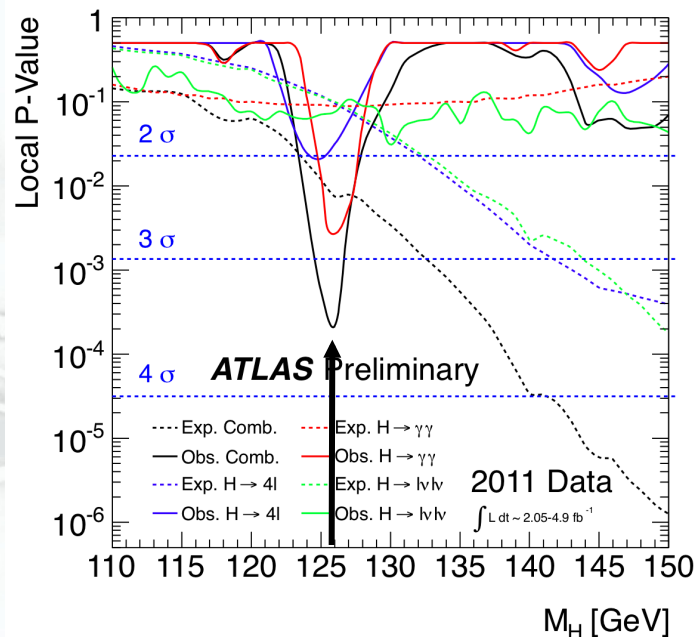


Data and background only expectation consistency

Probability that the data is compatible with background only expectation



Zoom at the low Higgs mass region



- Maximum deviation from background only expectation observed at $m_H \sim 126$ GeV:
 - Local probability (p_0 value) = 0.019%
 - Global probability = $\sim 1\%$
 - Includes the probability for such an excess anywhere in a mass range (LEE)
- Local excess significance = 3.6σ
- Global excess significance = $\sim 2.3 \sigma$



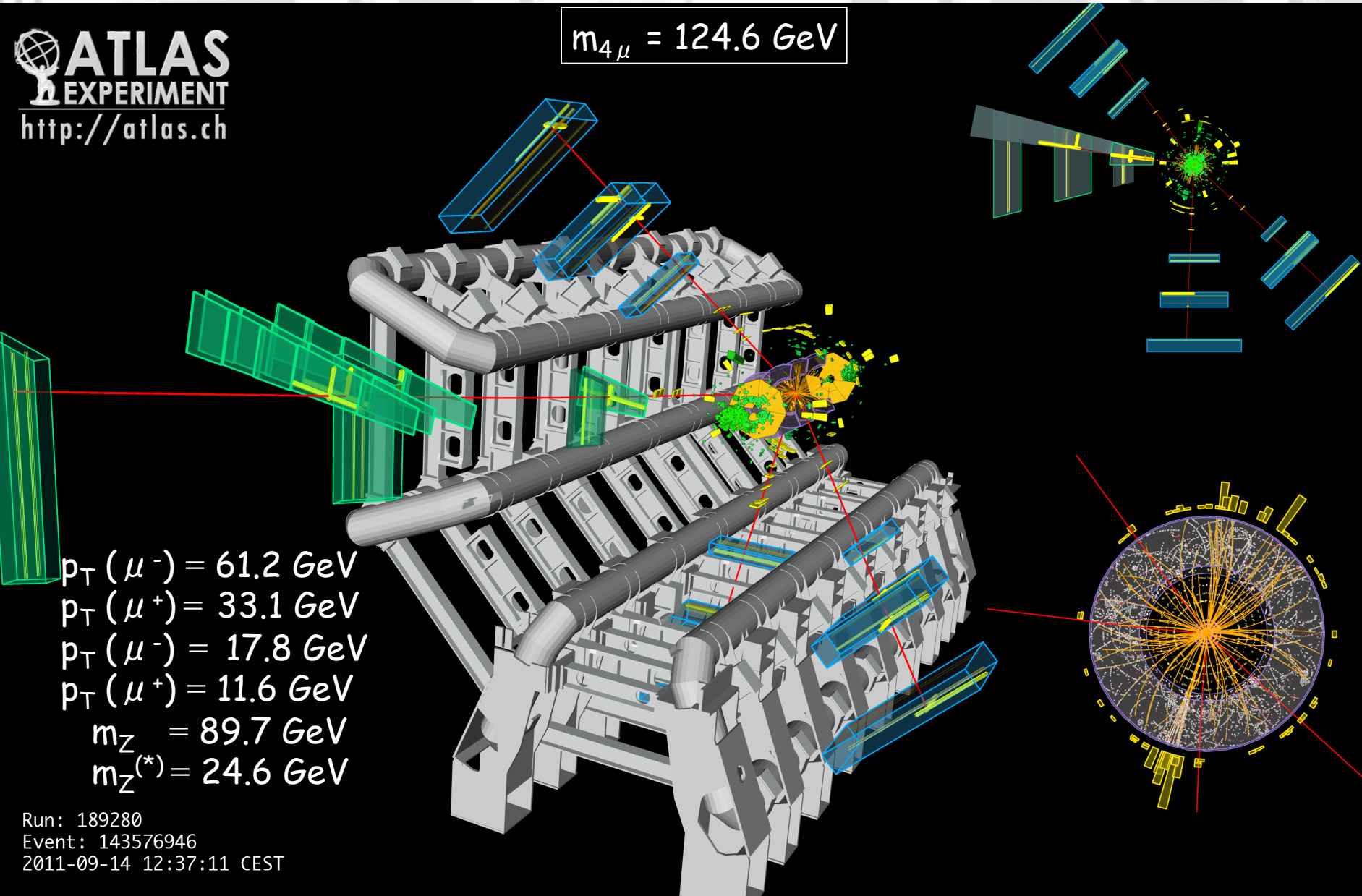
4 μ candidate

ATLAS
EXPERIMENT
<http://atlas.ch>

$$m_{4\mu} = 124.6 \text{ GeV}$$

$p_T(\mu^-) = 61.2 \text{ GeV}$
 $p_T(\mu^+) = 33.1 \text{ GeV}$
 $p_T(\mu^-) = 17.8 \text{ GeV}$
 $p_T(\mu^+) = 11.6 \text{ GeV}$
 $m_Z = 89.7 \text{ GeV}$
 $m_Z^{(*)} = 24.6 \text{ GeV}$

Run: 189280
Event: 143576946
2011-09-14 12:37:11 CEST



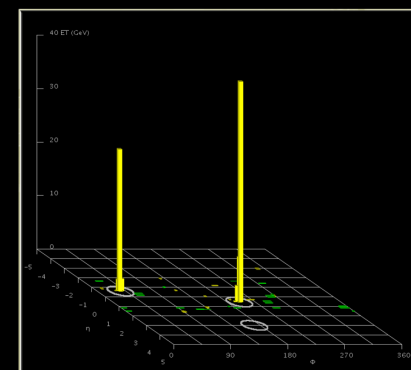
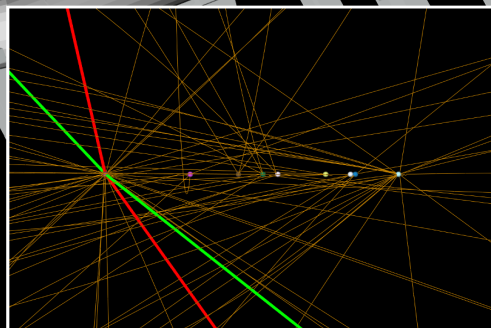
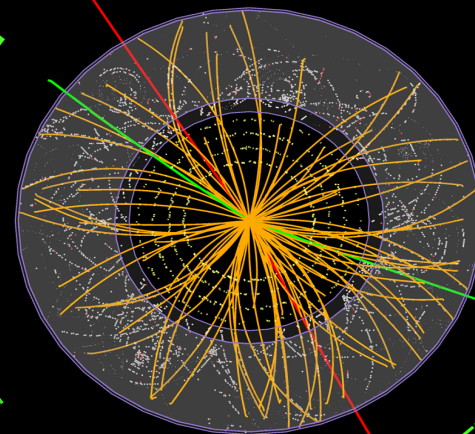


2e2μ candidate

ATLAS
EXPERIMENT
<http://atlas.ch>

$$m_{2e2\mu} = 124.3 \text{ GeV}$$

$p_T(e^+) = 41.5 \text{ GeV}$
 $p_T(e^-) = 26.5 \text{ GeV}$
 $p_T(\mu^-) = 24.7 \text{ GeV}$
 $p_T(\mu^+) = 18.3 \text{ GeV}$
 $m_{ee} = 76.8 \text{ GeV}$
 $m_{\mu\mu} = 45.7 \text{ GeV}$

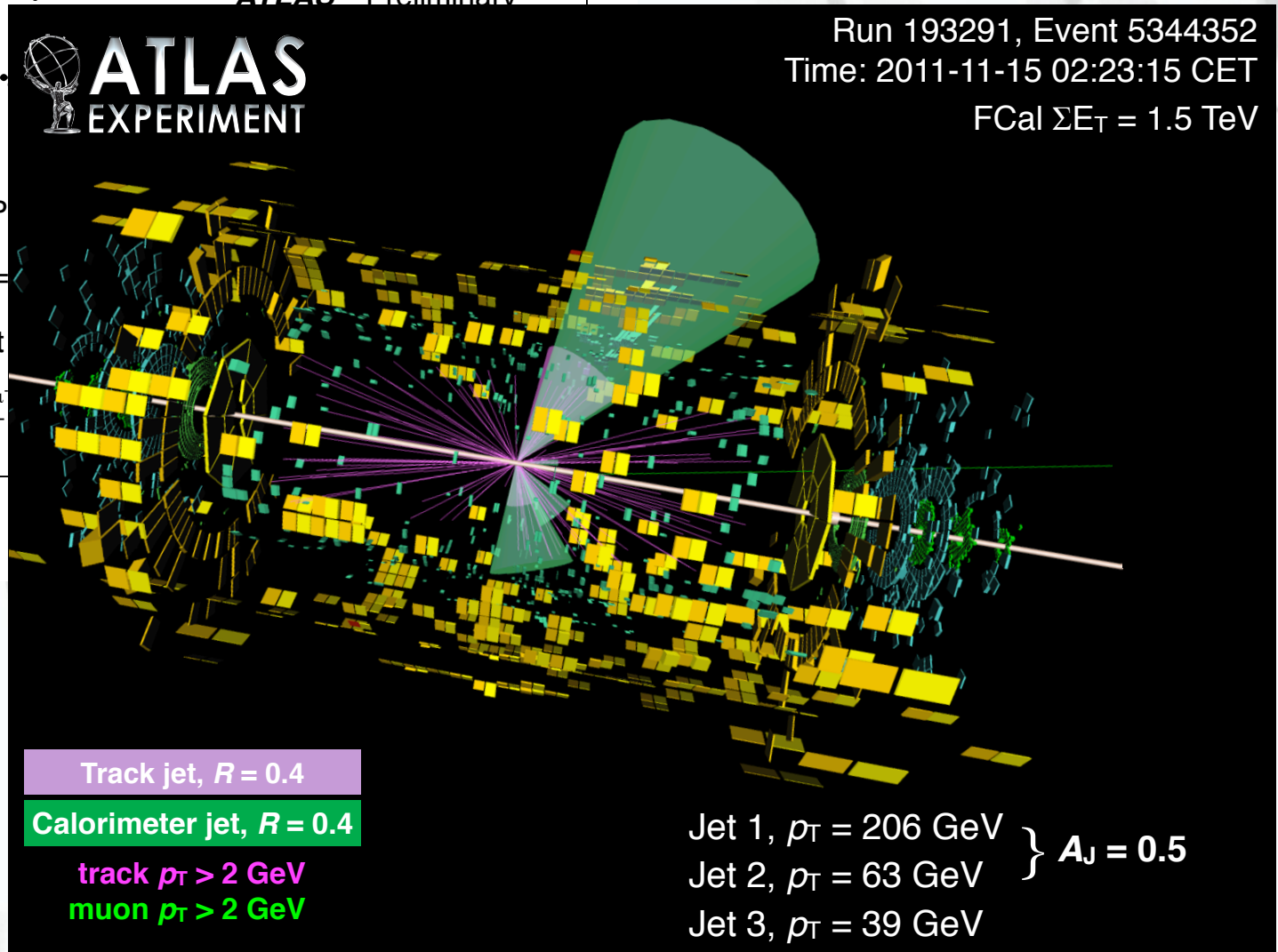
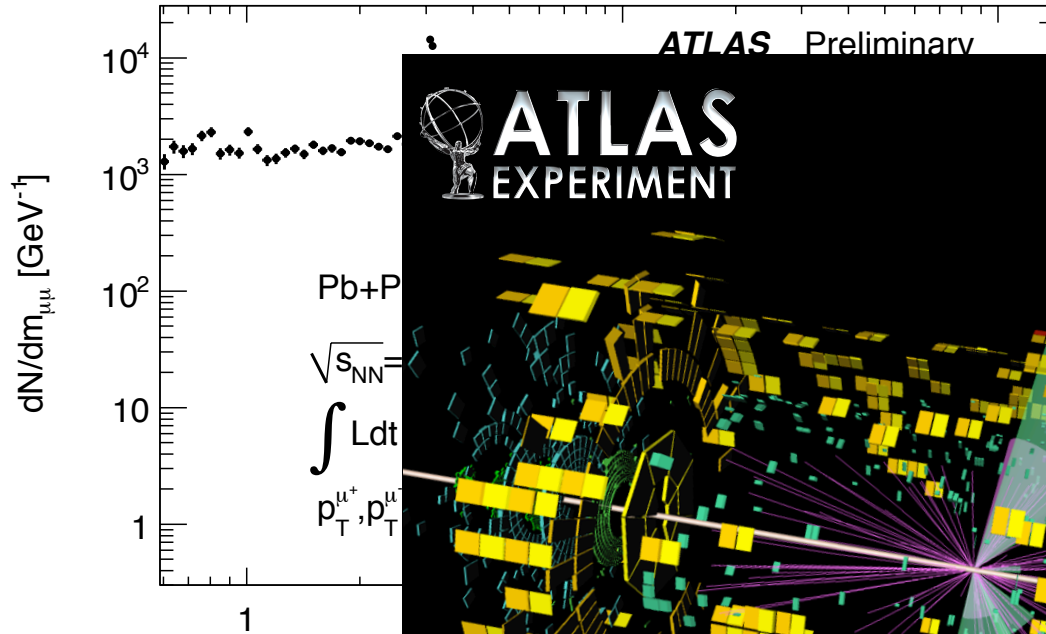


Run: 182796
Event: 74566644
2011-05-30 07:54:29 CEST



First look at PbPb data taken in 2011

$m_{\mu\mu}$ spectra: J/Ψ , Z particles clearly seen





Conclusions

- Overall, a **fantastic** year thanks to an excellent LHC performance!
- The ATLAS collaboration **has achieved to** do:
 - Multitude of detailed measurements of many known processes in the LHC energy regime.
 - Many searches for new physics including SUSY particles, very heavy bosons, extra-dimensions and many others and put unprecedented limits to many of them.
 - A **search for the SM Higgs boson** in many channels and has restricted the most probable region at the 95% CL to 115.5-131 GeV.
- An excess of events has been observed at **126 GeV** with a local/global significances of 3.6σ / $\sim 2.3\sigma$
 - **Is this the Higgs?** We don't know yet – we need more data –.
- Looking forward for an **exciting new year!**

THANK YOU!



BACKUP



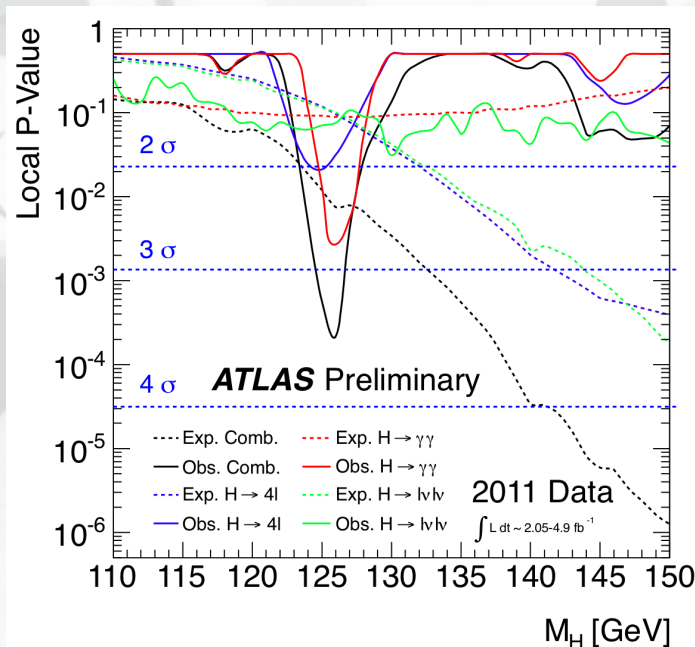
Summary of present Higgs searches in ATLAS

Channel	m_H range (GeV)	Int. lumi fb^{-1}	Main backgrounds	Number of signal events after cuts	S/B after cuts	Expected $\sigma/\sigma_{\text{SM}}$ sensitivity
$H \rightarrow \gamma\gamma$	110-150	4.9	$\gamma\gamma, \gamma j, jj$	~ 70	~ 0.02	1.6-2
$H \rightarrow \tau\tau \rightarrow ll+\nu$	110-140	1.1	$Z \rightarrow \tau\tau, \text{top}$	~ 0.8	~ 0.02	30-60
$H \rightarrow \tau\tau \rightarrow l\tau_{\text{had}}$	100-150	1.1	$Z \rightarrow \tau\tau$	~ 10	$\sim 5 \cdot 10^{-3}$	10-25
$W/ZH \rightarrow bbl(l)$	110-130	1.1	$W/Z+\text{jets}, \text{top}$	~ 6	$\sim 5 \cdot 10^{-3}$	15-25
$H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$	110-300	2.1	$WW, \text{top}, Z+\text{jet}$	~ 20 (130 GeV)	~ 0.3	0.3-8
$H \rightarrow ZZ^{(*)} \rightarrow 4l$	110-600	4.8	ZZ^*, top, Zbb	~ 2.5 (130 GeV)	~ 1.5	0.7-10
$H \rightarrow ZZ \rightarrow ll \nu\nu$	200-600	2.1	$ZZ, \text{top}, Z+\text{jets}$	~ 20 (400 GeV)	~ 0.3	0.8-4
$H \rightarrow ZZ \rightarrow ll qq$	200-600	2.1	$Z+\text{jets}, \text{top}$	2-20 (400 GeV)	0.05-0.5	2-6
$H \rightarrow WW \rightarrow l\nu qq$	240-600	1.1	$W+\text{jets}, \text{top}, \text{jets}$	~ 45 (400 GeV)	10^{-3}	5-10



Higgs results

Consistency of the data with background only expectation



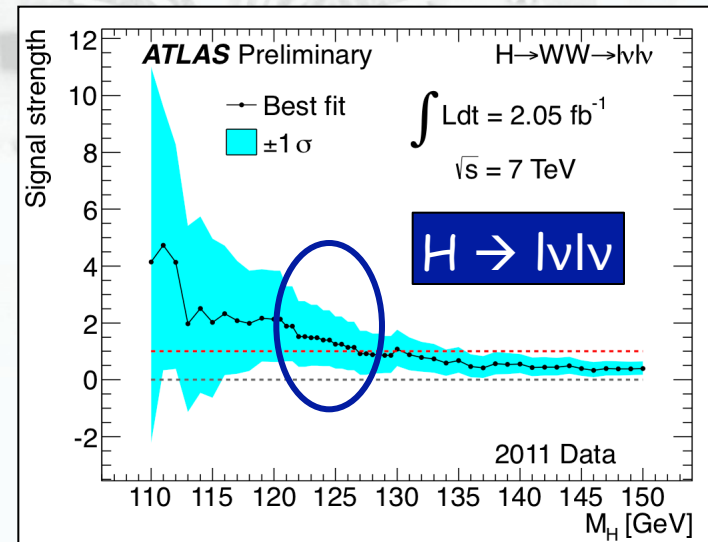
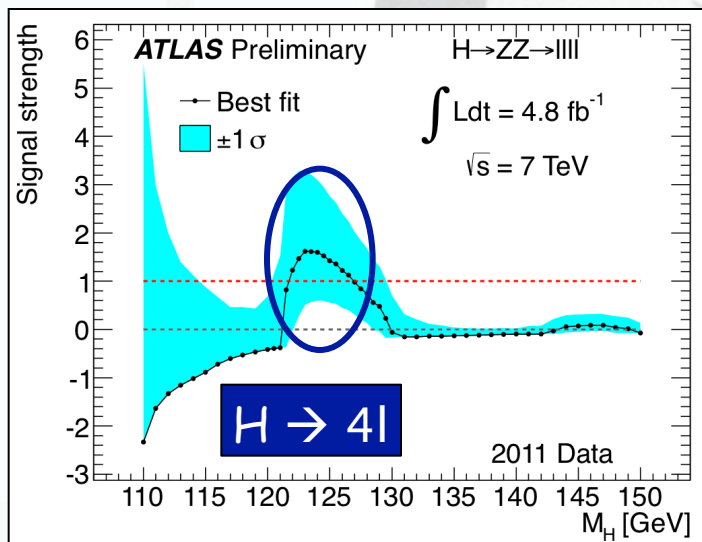
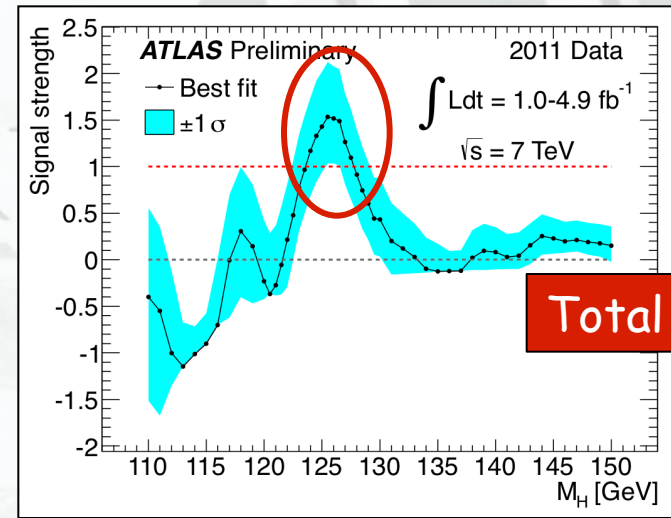
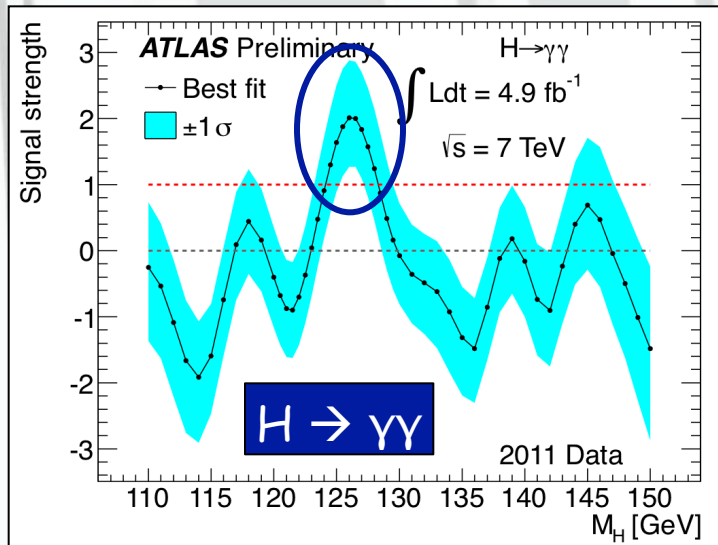
Local p_0 -value: $1.9 \cdot 10^{-4}$
→ local significance of the excess: 3.6σ
~ 2.8σ $H \rightarrow \gamma\gamma$, 2.1σ $H \rightarrow 4l$, 1.4σ $H \rightarrow l\nu l\nu$

Expected from SM Higgs: $\sim 2.4\sigma$ local ($\sim 1.4\sigma$ per channel)

Global p_0 -value : 0.6% → 2.5σ LEE over 110-146 GeV
Global p_0 -value : 1.4% → 2.2σ LEE over 110-600 GeV



Compatibility of the observation with the expected strength of a SM Higgs signal



The observed excess is slightly larger (2 ± 0.8) than expected in the $H \rightarrow \gamma\gamma$ channel and compatible within 1σ for the other channels and the combined result