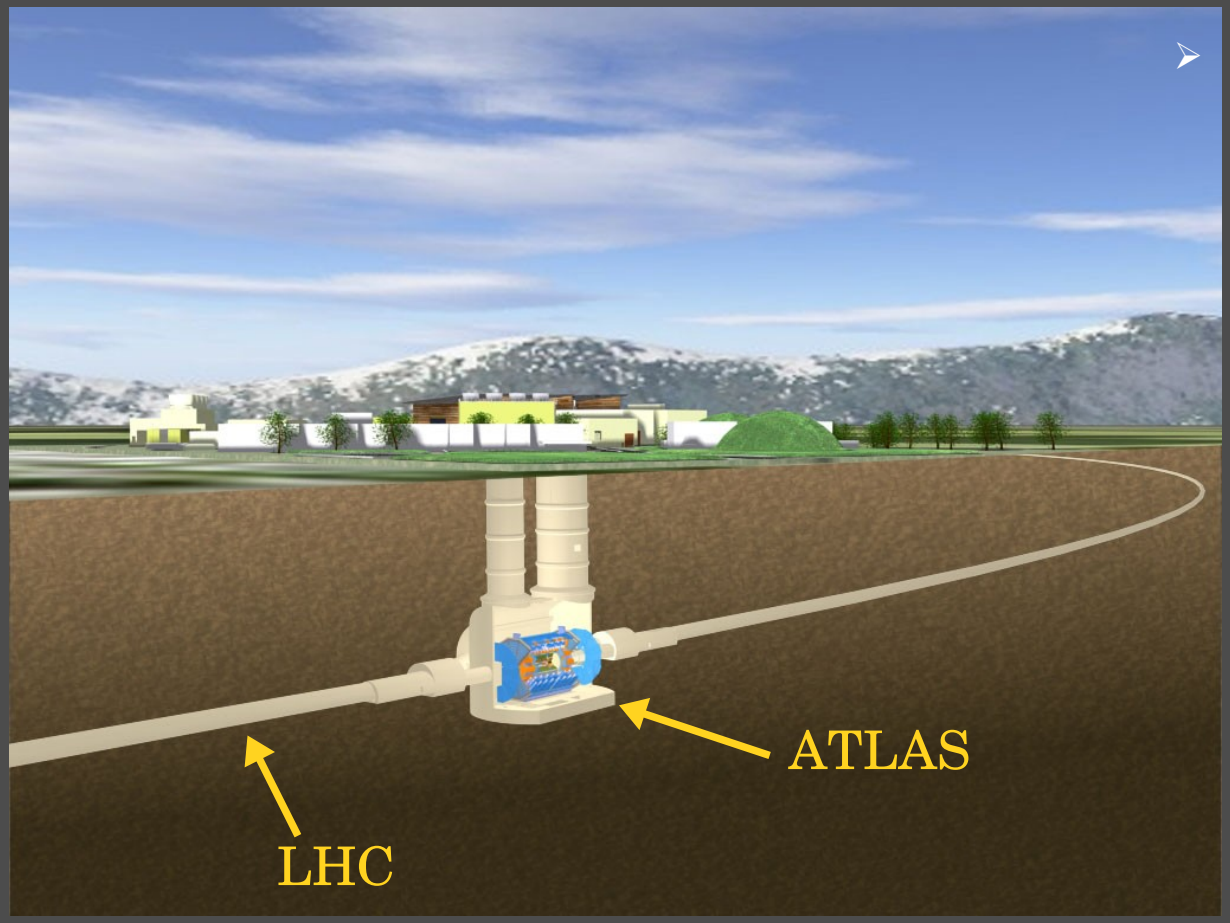
ATLAS Physics Results

Patricia Conde Muíño

Jornadas do LIP (21-23 Abril 2012)

ATLAS

- ATLAS is one of the four LHC experiments at CERN



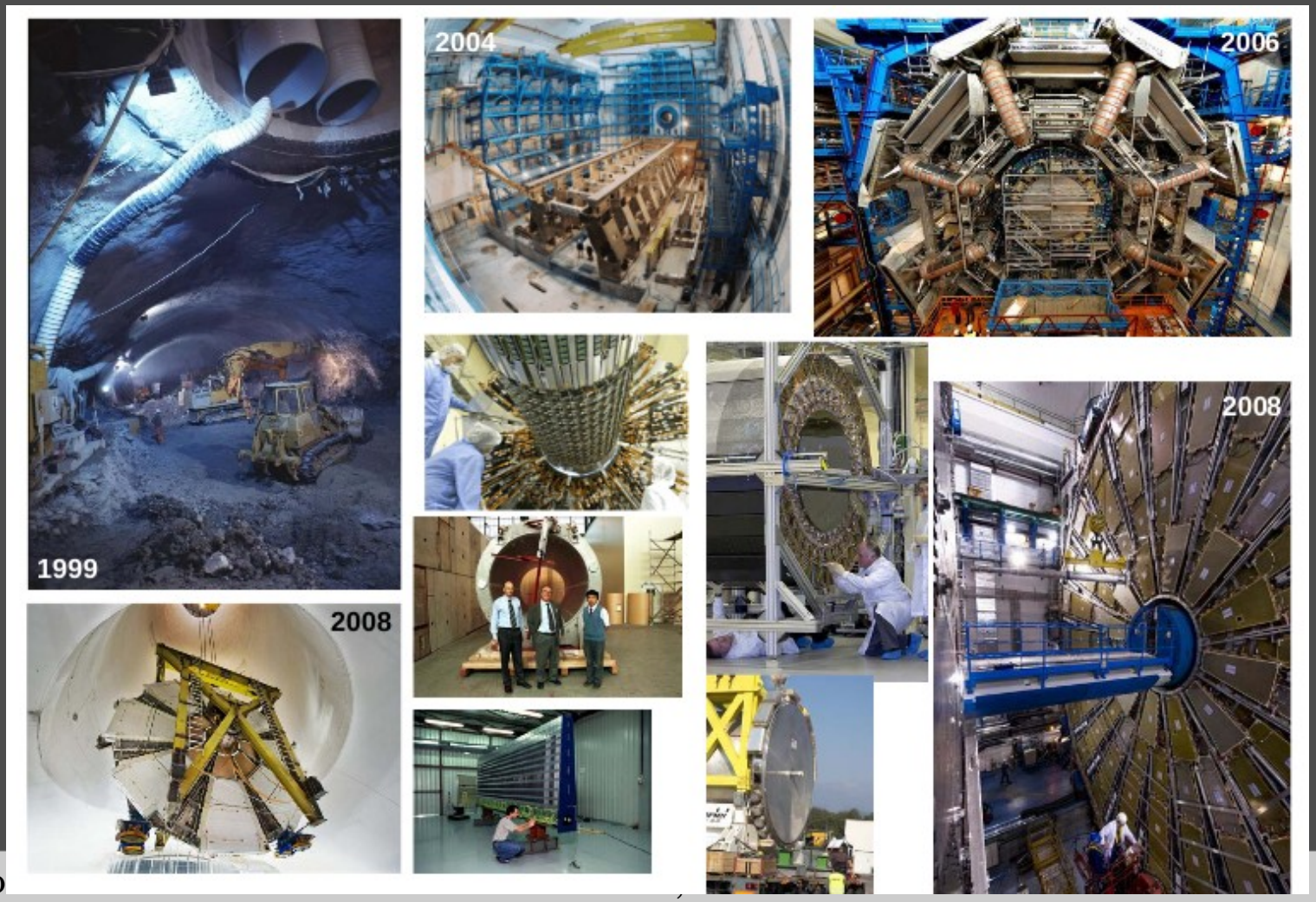
- LHC
  - pp & heavy ion colliding beams
  - 2010-11:

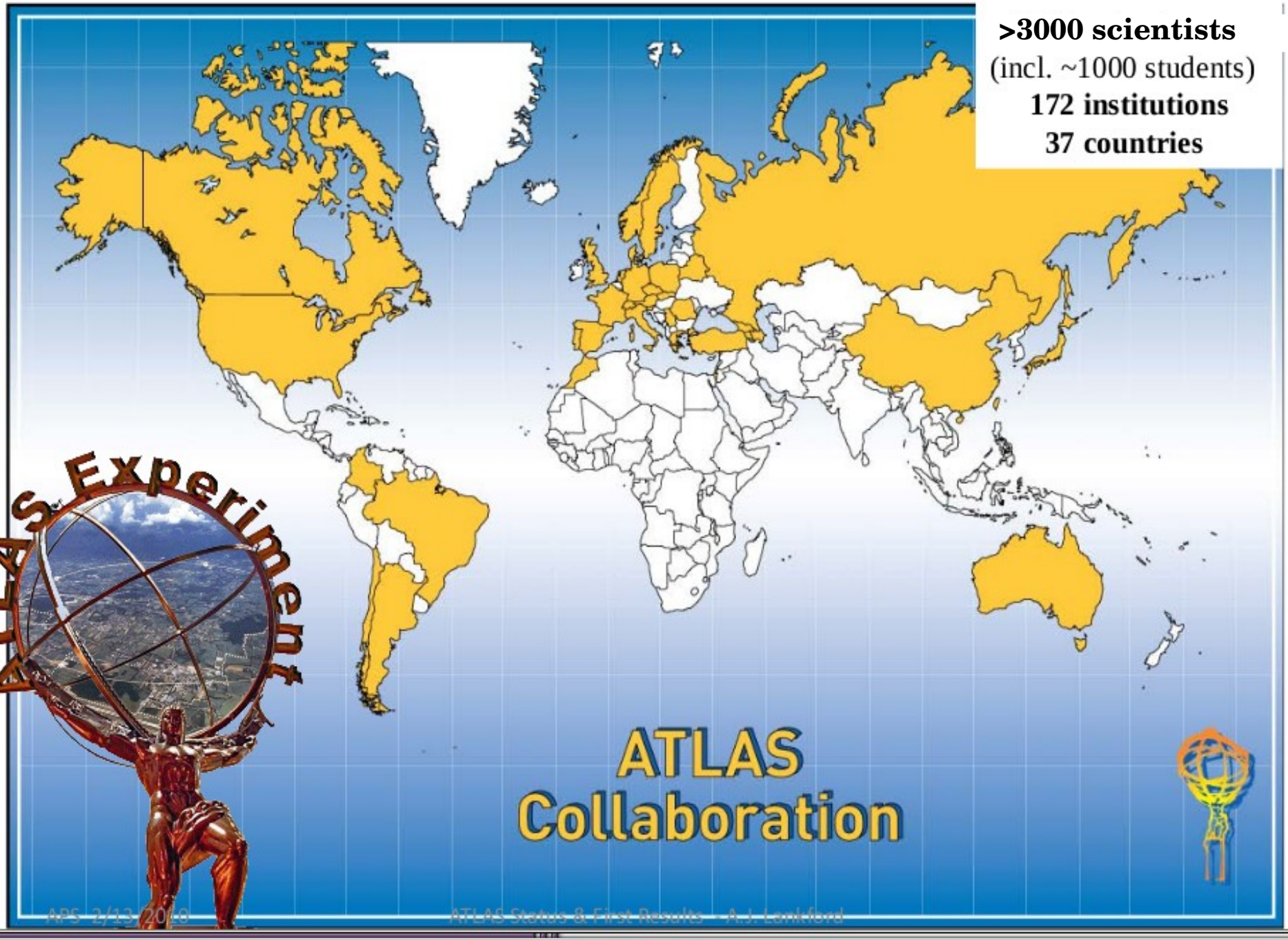
    $\sqrt{s}$ = 7 TeV
  - 2012:

    $\sqrt{s}$ = 8 TeV

ATLAS in pictures

- More than 20 years of continuous work



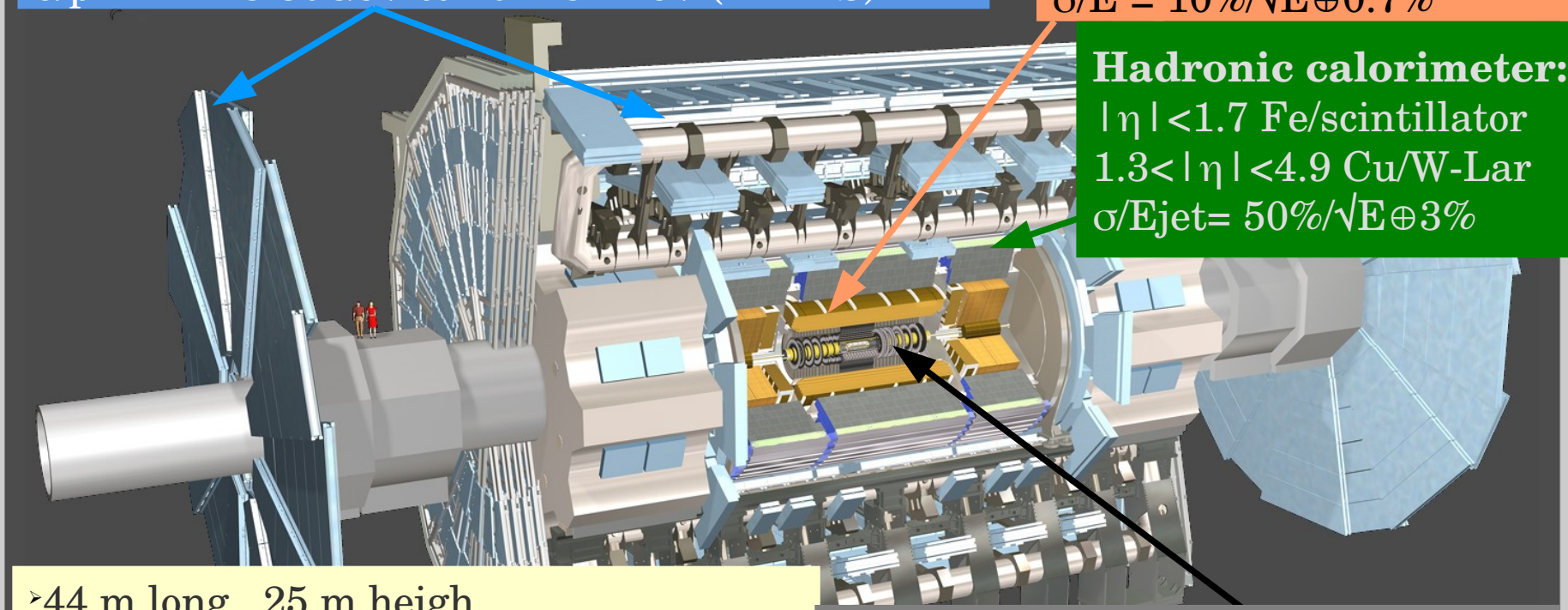

>3000 scientists
(incl. ~1000 students)
172 institutions
37 countries
ATLAS Experiment
ATLAS
Collaboration

The ATLAS detector

Muon Spectrometer: $|\eta|<2.7$
Air-core toroids and gas-based muon chambers
σ/pT = 2% @ 50GeV to 10% @ 1TeV (ID+MS)

EM calorimeter: $|\eta|<3.2$
Pb-LAr Accordion
$\sigma/E = 10\%/\sqrt{E} \oplus 0.7\%$

Hadronic calorimeter:
$|\eta|<1.7$ Fe/scintillator
$1.3<|\eta|<4.9$ Cu/W-Lar
$\sigma/Ejet = 50\%/\sqrt{E} \oplus 3\%$



- 44 m long, 25 m heigh
- $\approx 10^8$ electronic channels
- 3-level trigger reducing 40 MHz collision rate to 300 Hz of events to tape

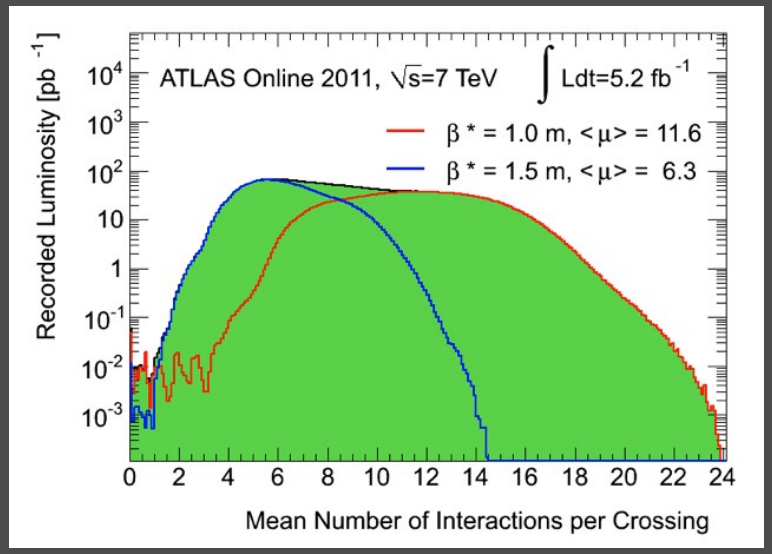
Inner Tracker: $|\eta|<2.5$, B=2T
Si pixels/strips and Trans. Rad. Det.
σ/pT = 0.05% pT (GeV)$\oplus$ 1%

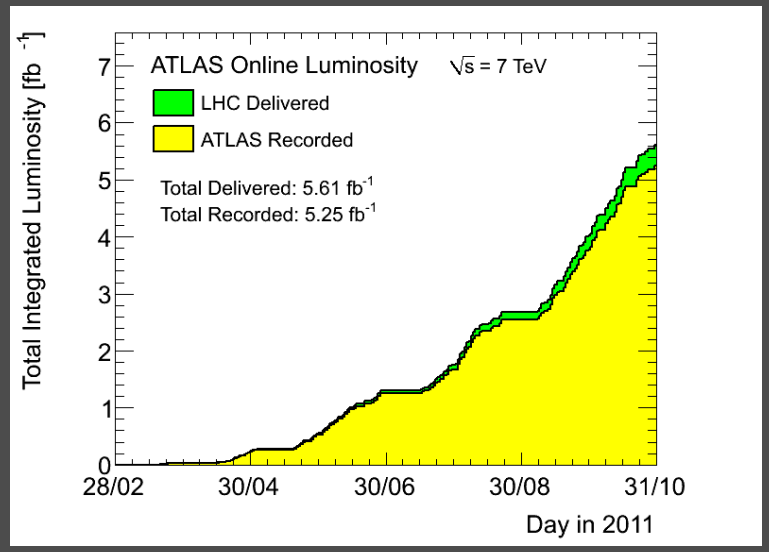
LHC

Working wonderfully since Nov. 2009

7 TeV pp collisions in 2010-2011

- 5.61 fb^{-1} recorded in 2011
  - ~ half of total luminosity at Tevatron
- Peak luminosity: 3.65×10^{33} $cm^{-2}s^{-1}$
- Average number of interactions up to 24 last year

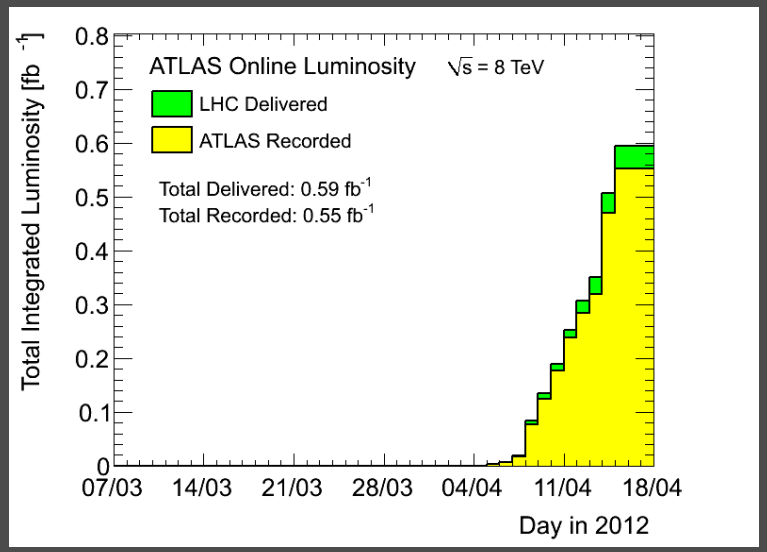


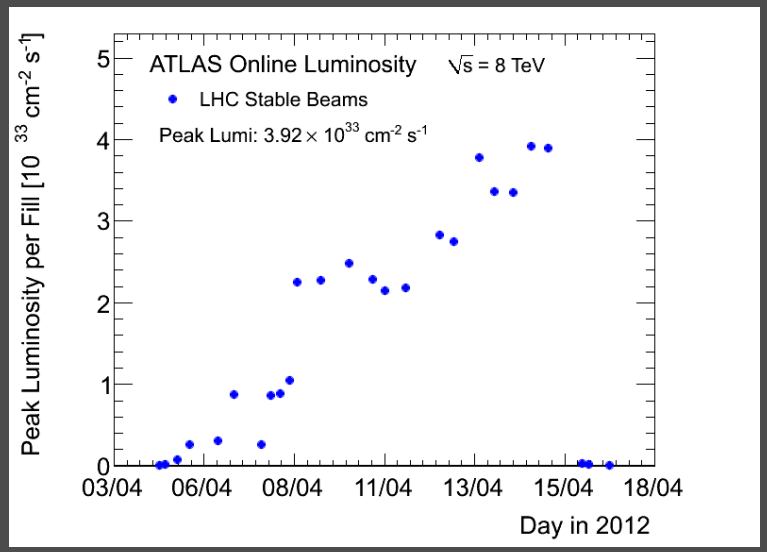


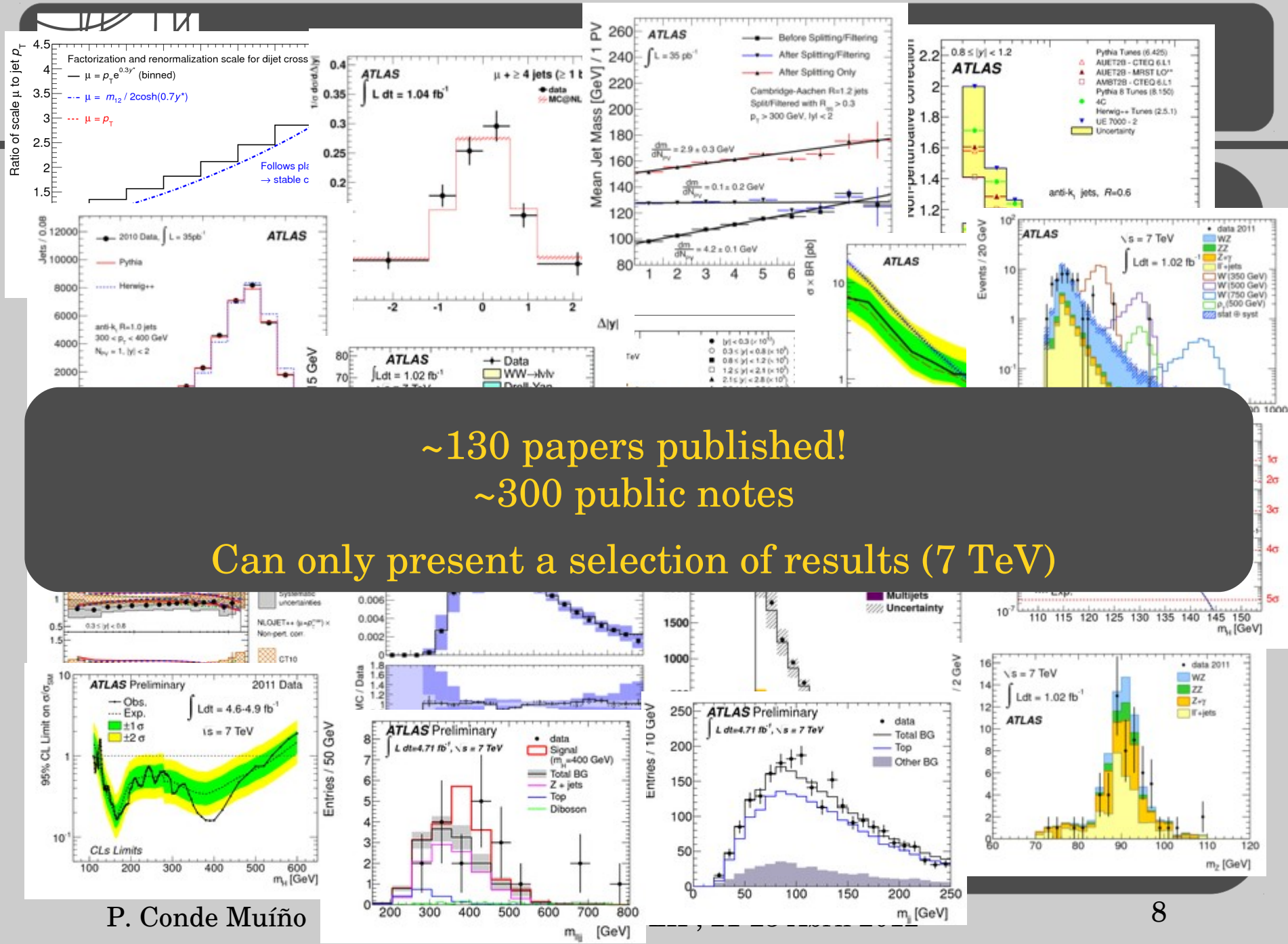
LHC this year

8 TeV pp collisions

- Started delivering pp collisions with stable beam on 6th April
- Very fast and smooth increase in luminosity
- 0.59 fb^{-1} delivered up to now
- Peak luminosity already higher than last year



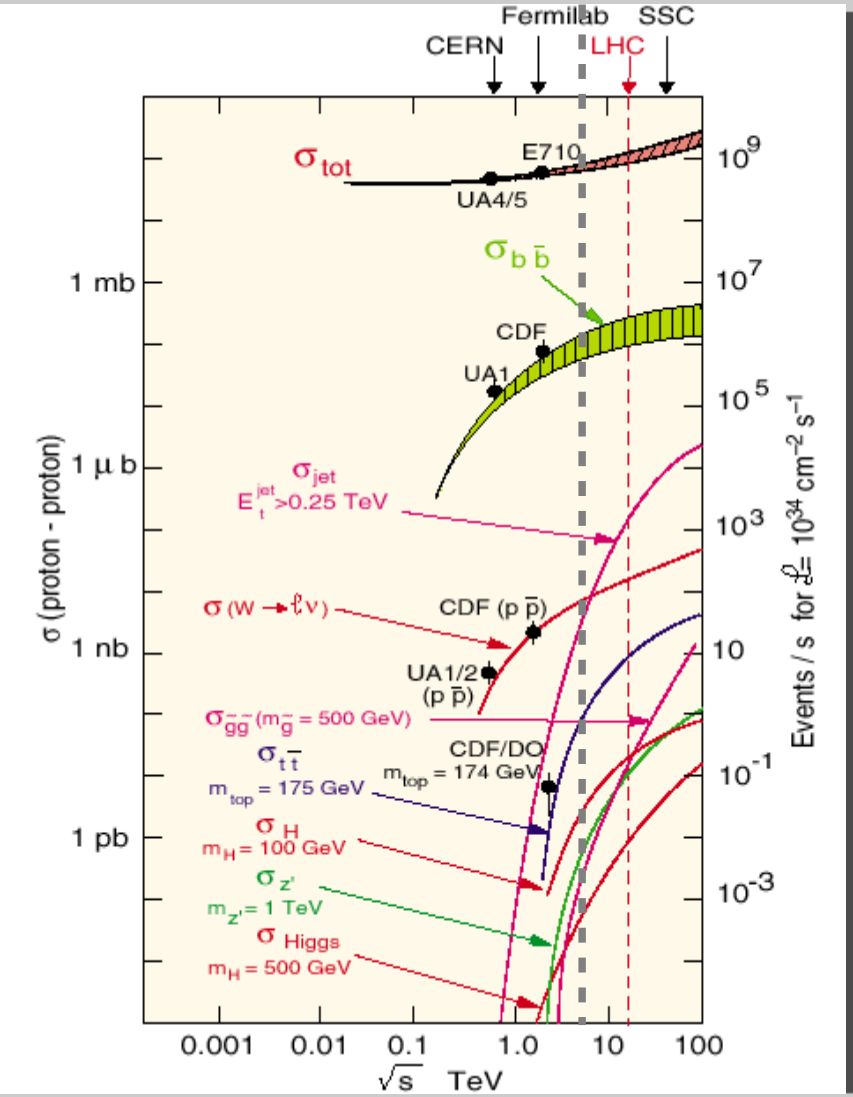




~130 papers published!
~300 public notes

Can only present a selection of results (7 TeV)

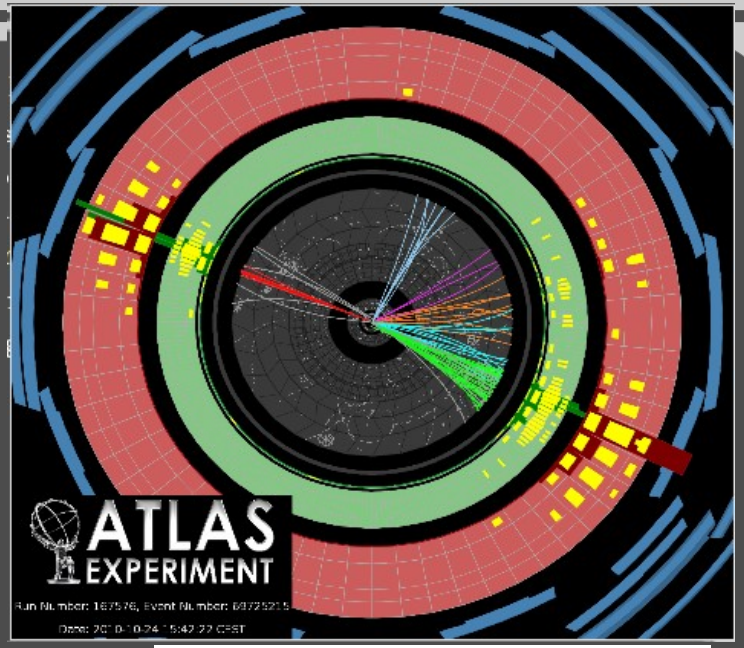
Physics processes at the LHC

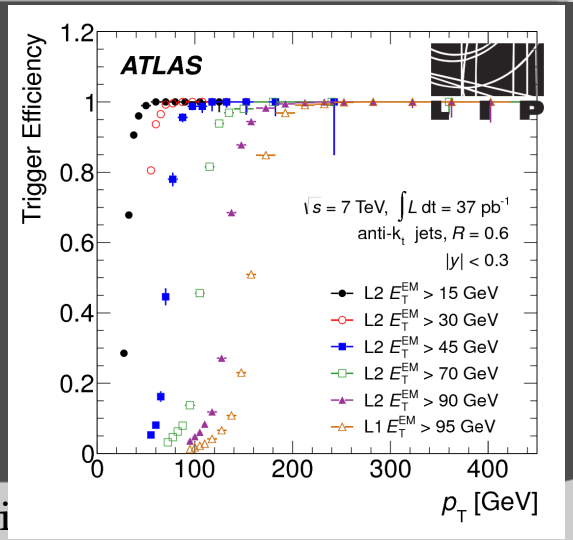


- QCD
  - Jet production, jet properties
  - Searches for di-jet resonances
- Electroweak boson production and properties
- Top quark
  - Precision measurement of cross section, mass, polarization, FCNC decays, ...
- Di-boson production
  - Anomalous triple gauge couplings
- Higgs searches

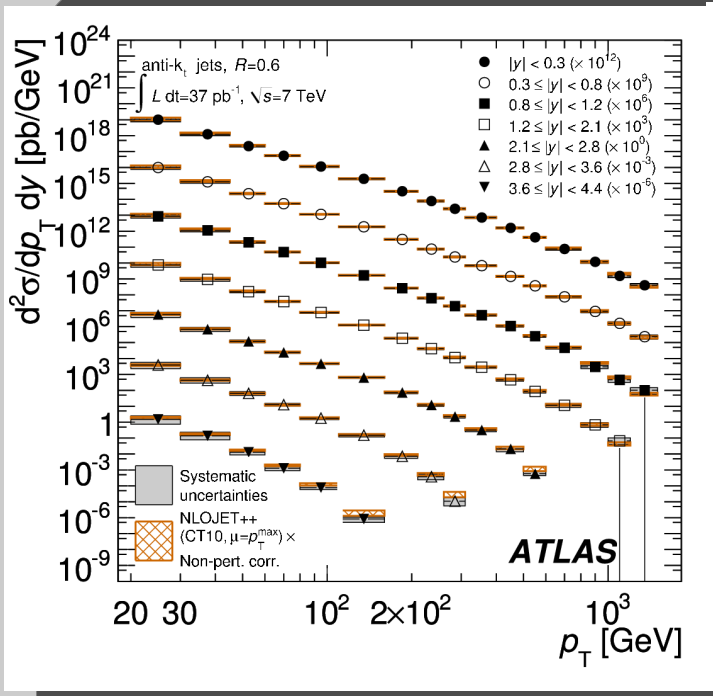
Jet cross section

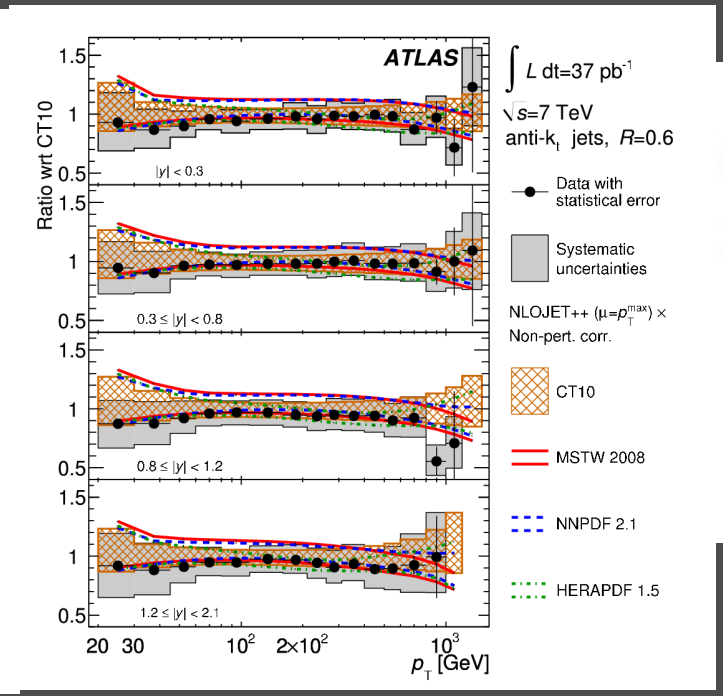
- Dominant high p_T process at LHC:
  - Information on proton structure
  - Understand strong interaction
  - Search for physics beyond SM
- Measurement includes forward jets
  - Sensitive to different dynamics
  - Better coverage than Tevatron experiments!
- Jet algorithm definition
  - Anti-kT with R=0.6 (and R=0.4)
- Results corrected for detector effects
  - Trigger efficiency
  - Reconstruction and calibration

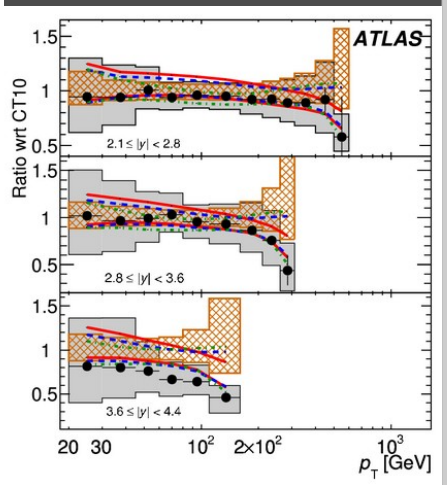




Inclusive jet cross section

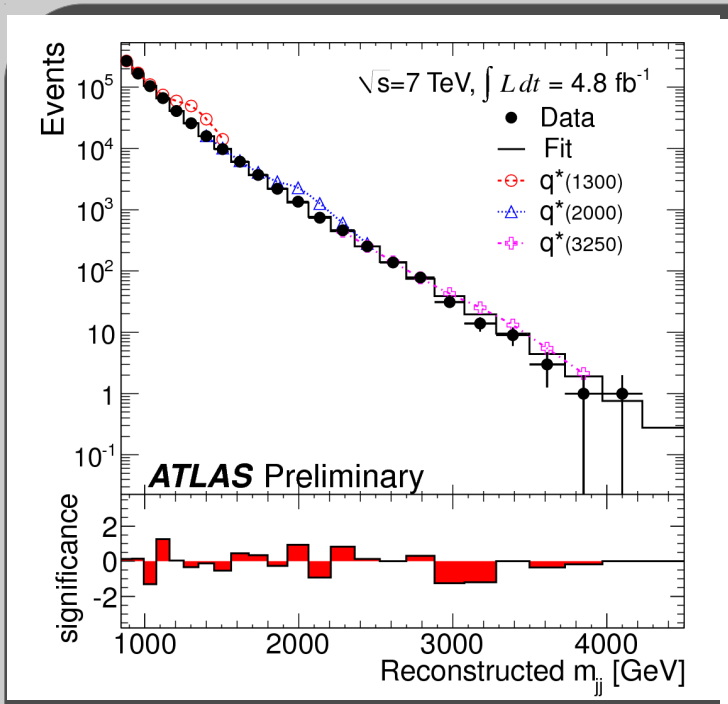


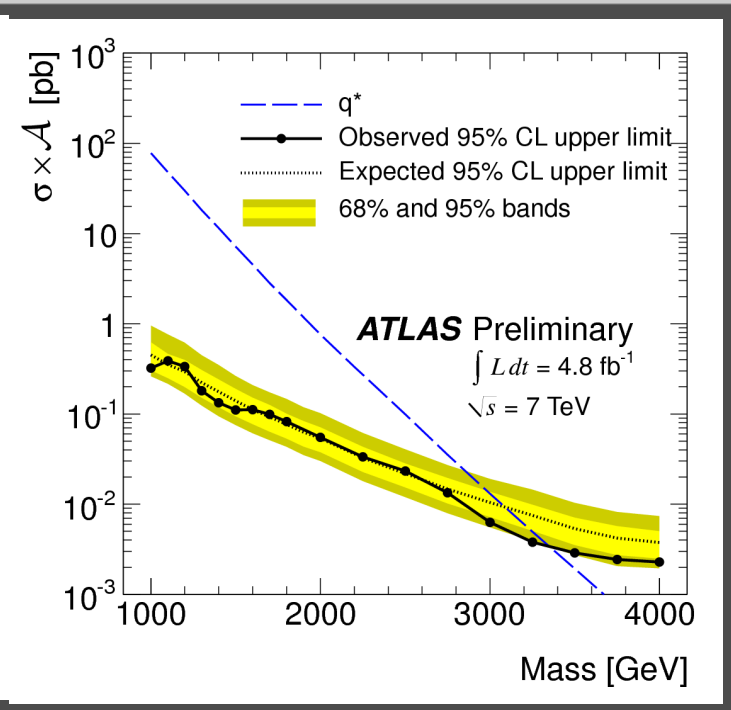




- Exploring a new kinematic regime in energy and rapidity
  - Forward region never measured with such precision in a Hadron Coll.
- These results constitute a comprehensive test of pQCD in a large kinematic regime

Search for di-jet mass resonances

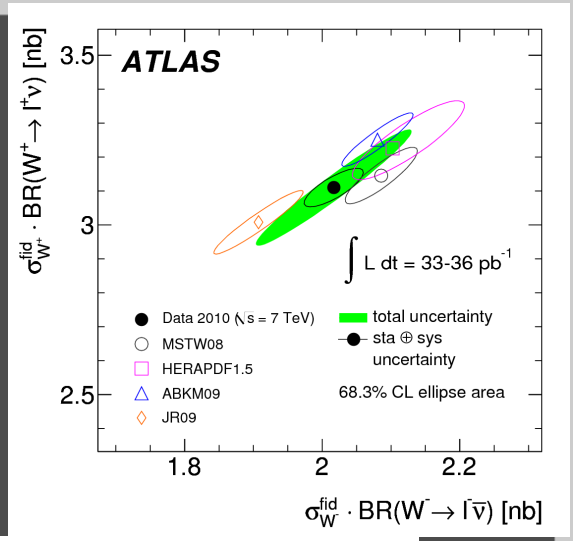


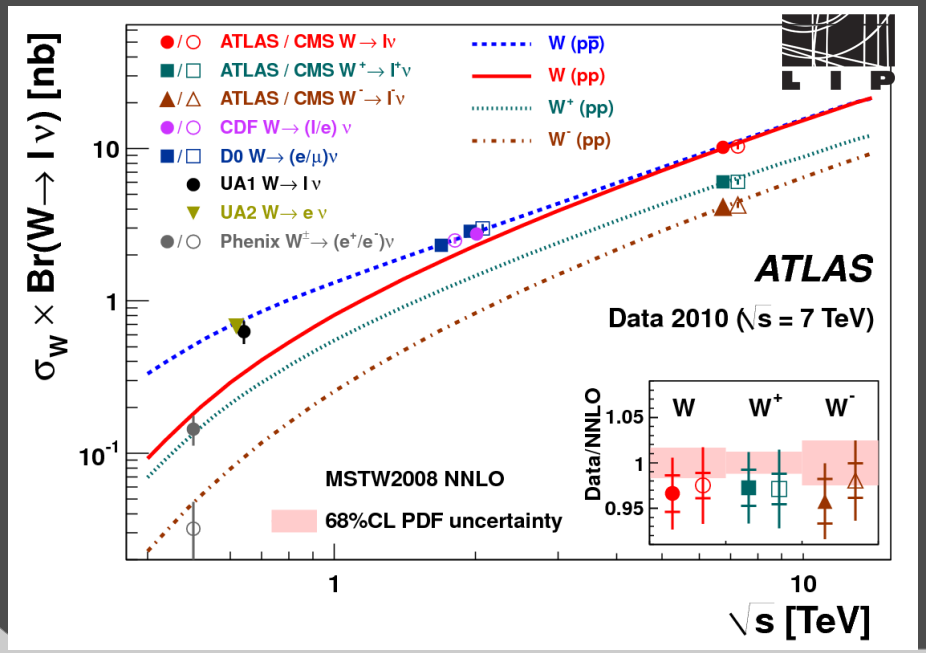


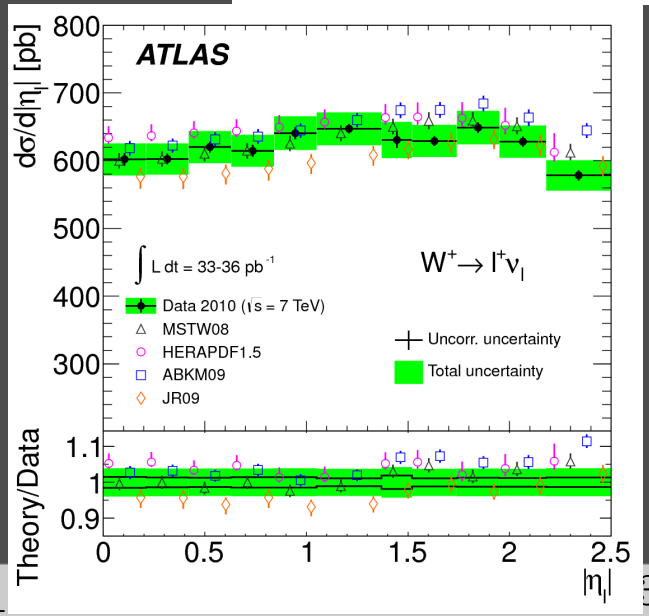
- SM extensions predict new particles decaying to two partons
  - Excited quarks q*: manifestation of quark compositeness
- Excluded exited quarks up to 3350 TeV
  - Tests quark compositeness down to scale ~ 3×10^{-20} m

W/Z boson production

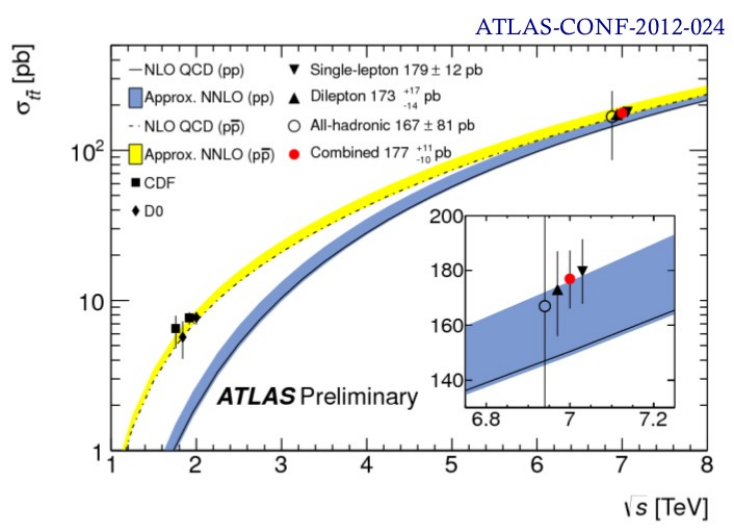
- W/Z total/differential cross sections known to NNLO in QCD perturbative theory
  - input EW parameters known to high accuracy
  - Main uncertainty comes from proton PDFs



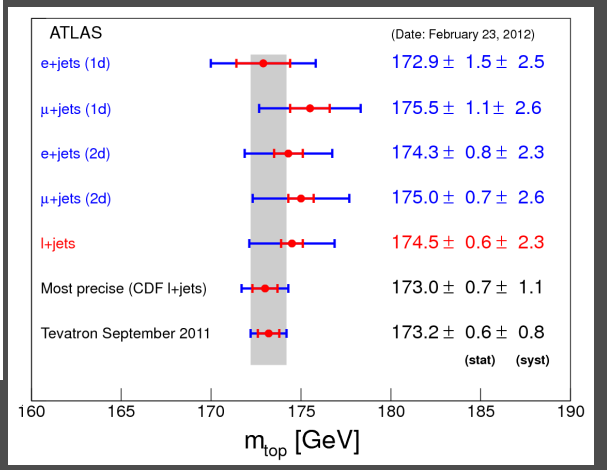




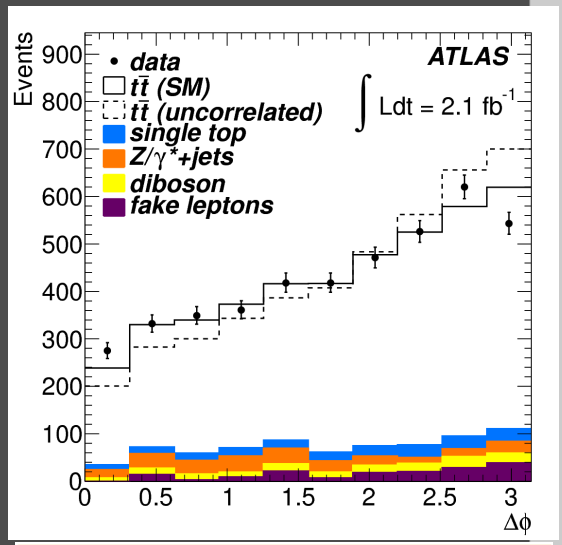
Top quark measurements



- Mass



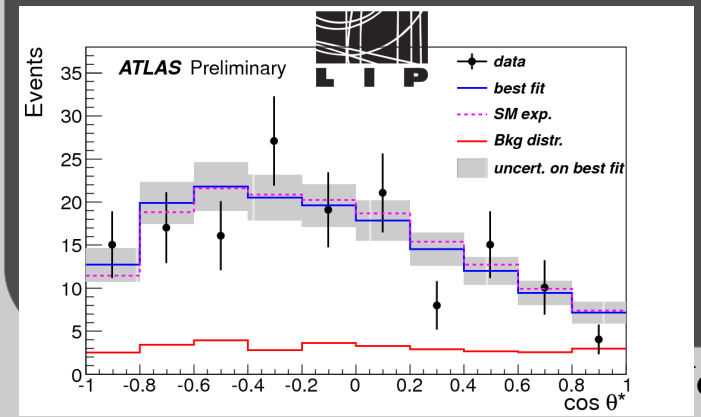
- Spin correlations



$A_{helicity} = 0.34^{+0.15}_{-0.11}$ in agreement with SM ($A^{SM}_{helicity} = 0.32$)

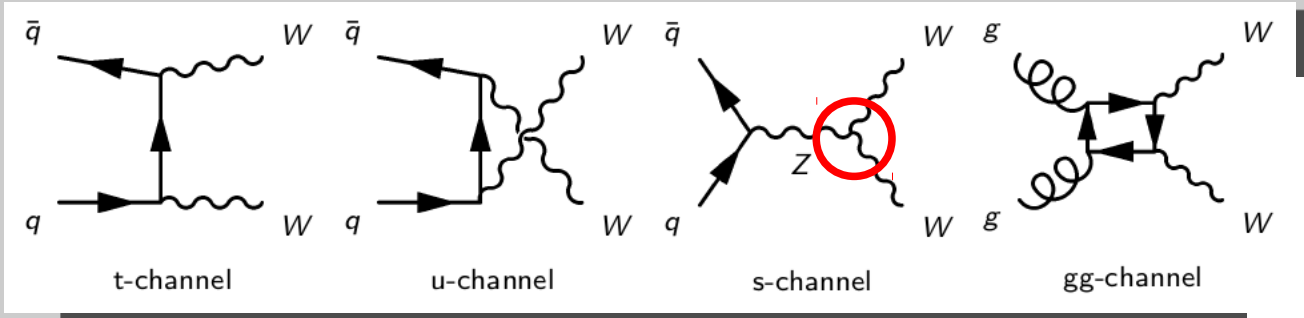
Uncorrelated spins disfavoured @ 3σ

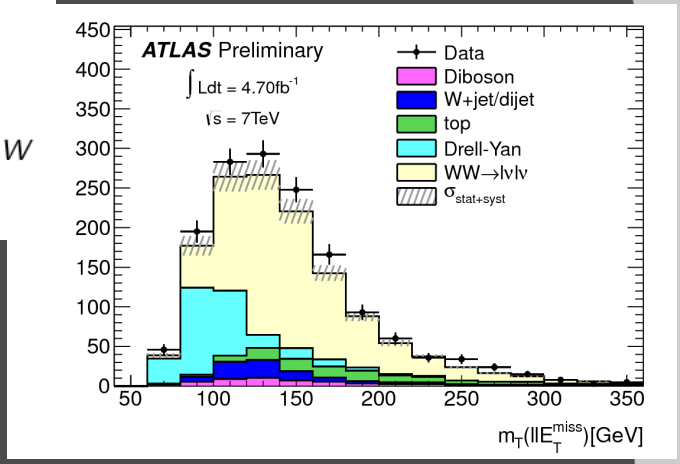
- W polarization
  - reflects the V-A coupling
  - In agreement with SM



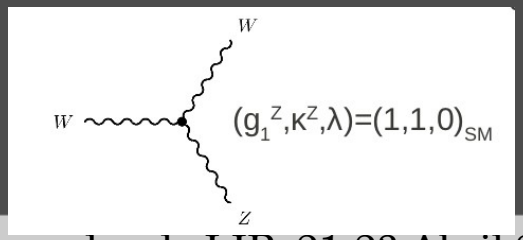
- And more...
  - See presentation by N. Castro

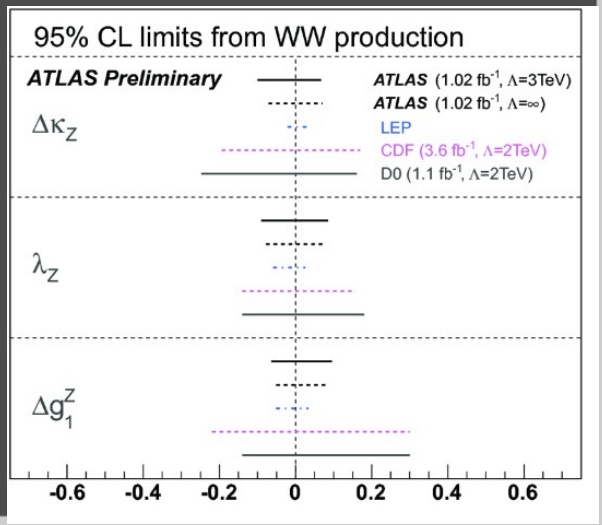
Di-boson production





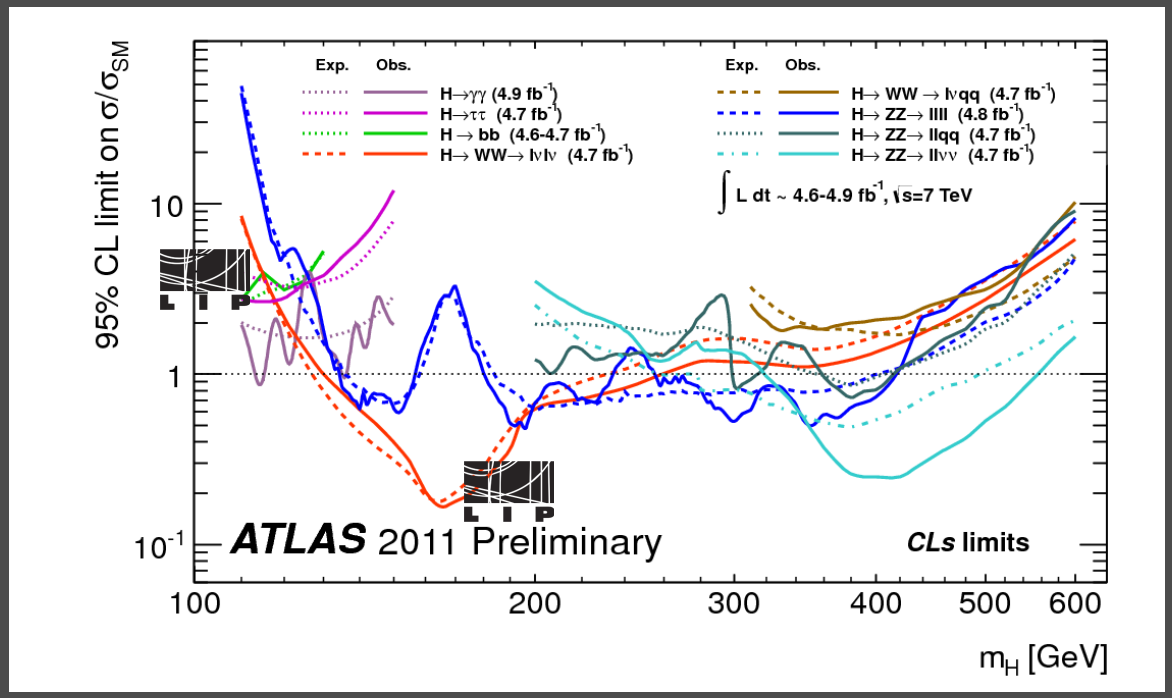
- Standard model predicts Triple Gauge Couplings, fully constraint by EW symmetry
  - WWγ and WWZ vertices are predicted,
  - ZZγ and ZZZ are forbidden
- Beyond SMphysics could modify di-bosons cross sections and kinematics
- ATLAS measured WW, WZ, ZZ, Wγ, Zγ production



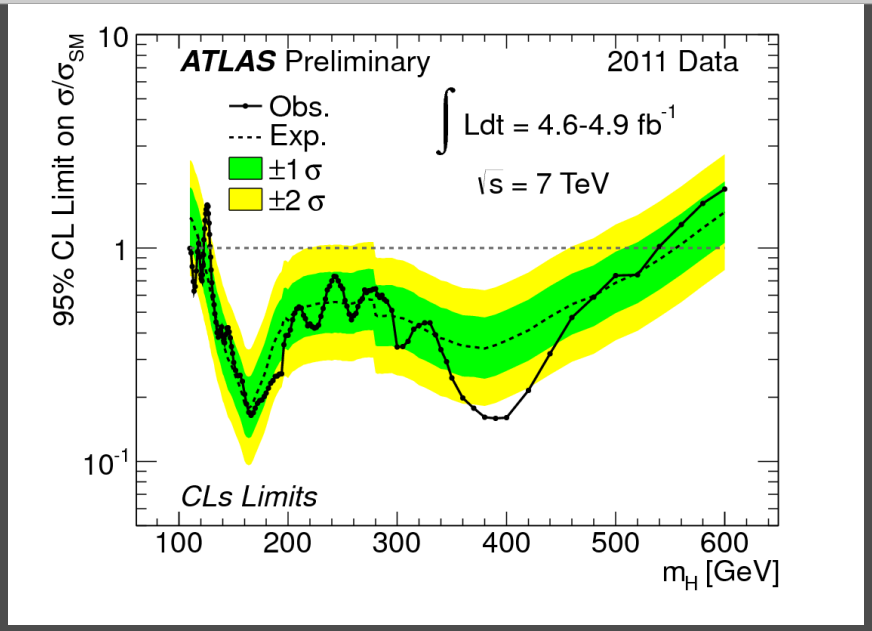


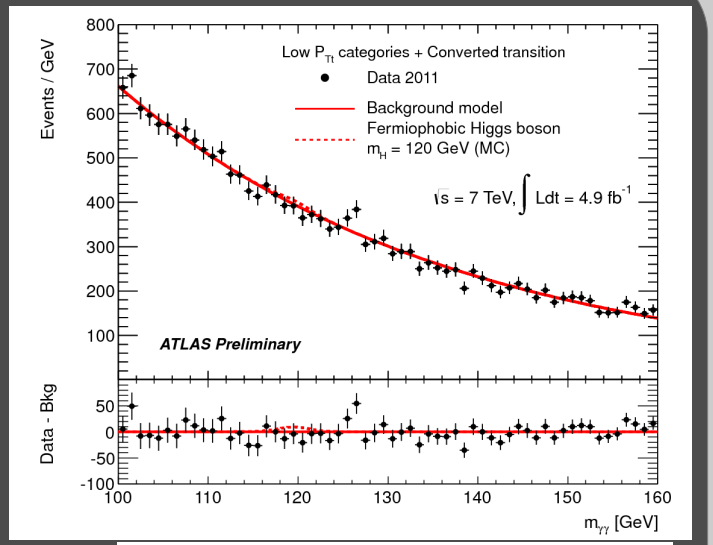
Higgs Searches

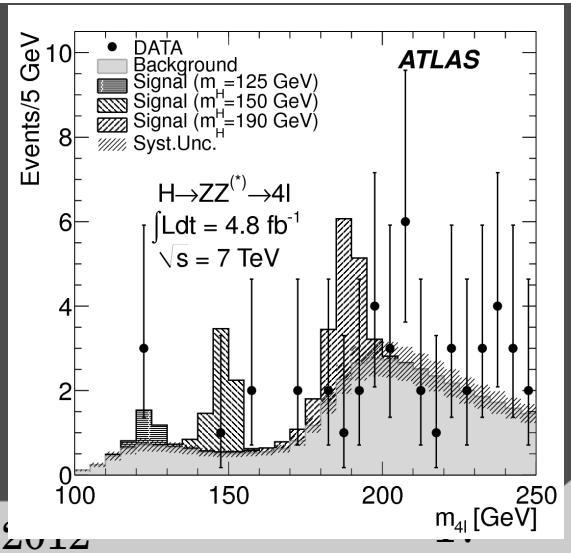
- ATLAS has searched for the Higgs boson in 12 different channels



Higgs searches

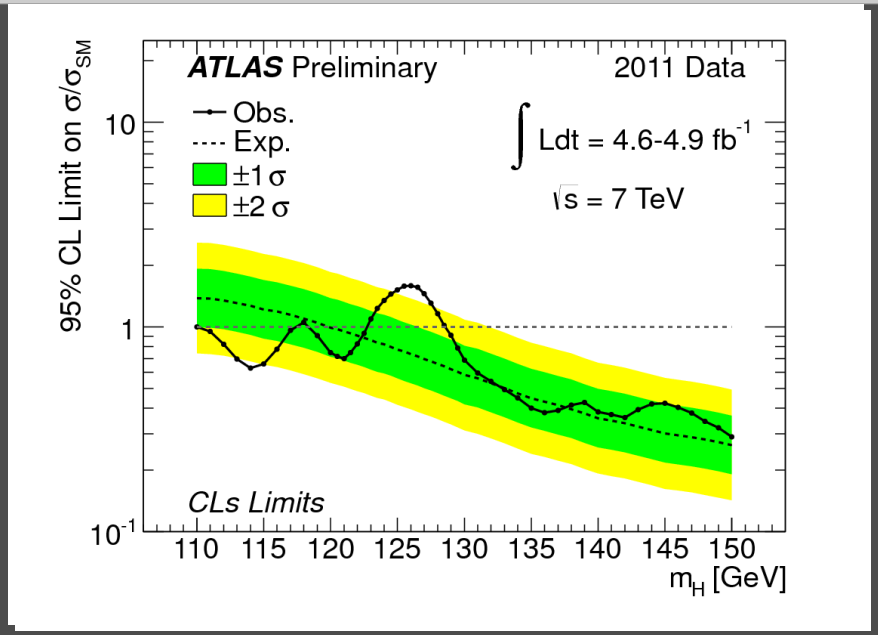


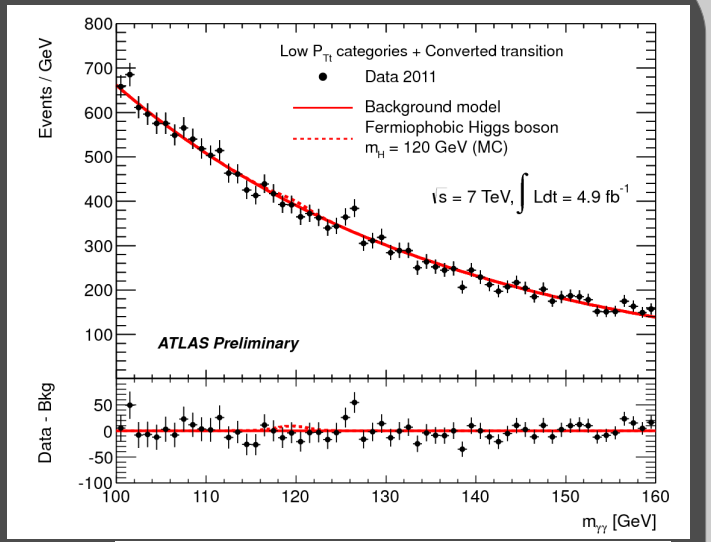


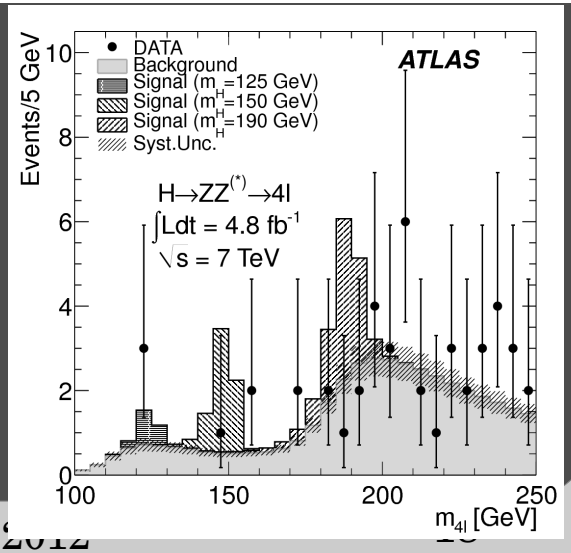


- All channels using full 2011 luminosity
- Expected exclusion @ 95%CL [120-555] GeV
- Observed: [110-117.5] – [118.5-122.5] – [129-539] GeV

Higgs searches

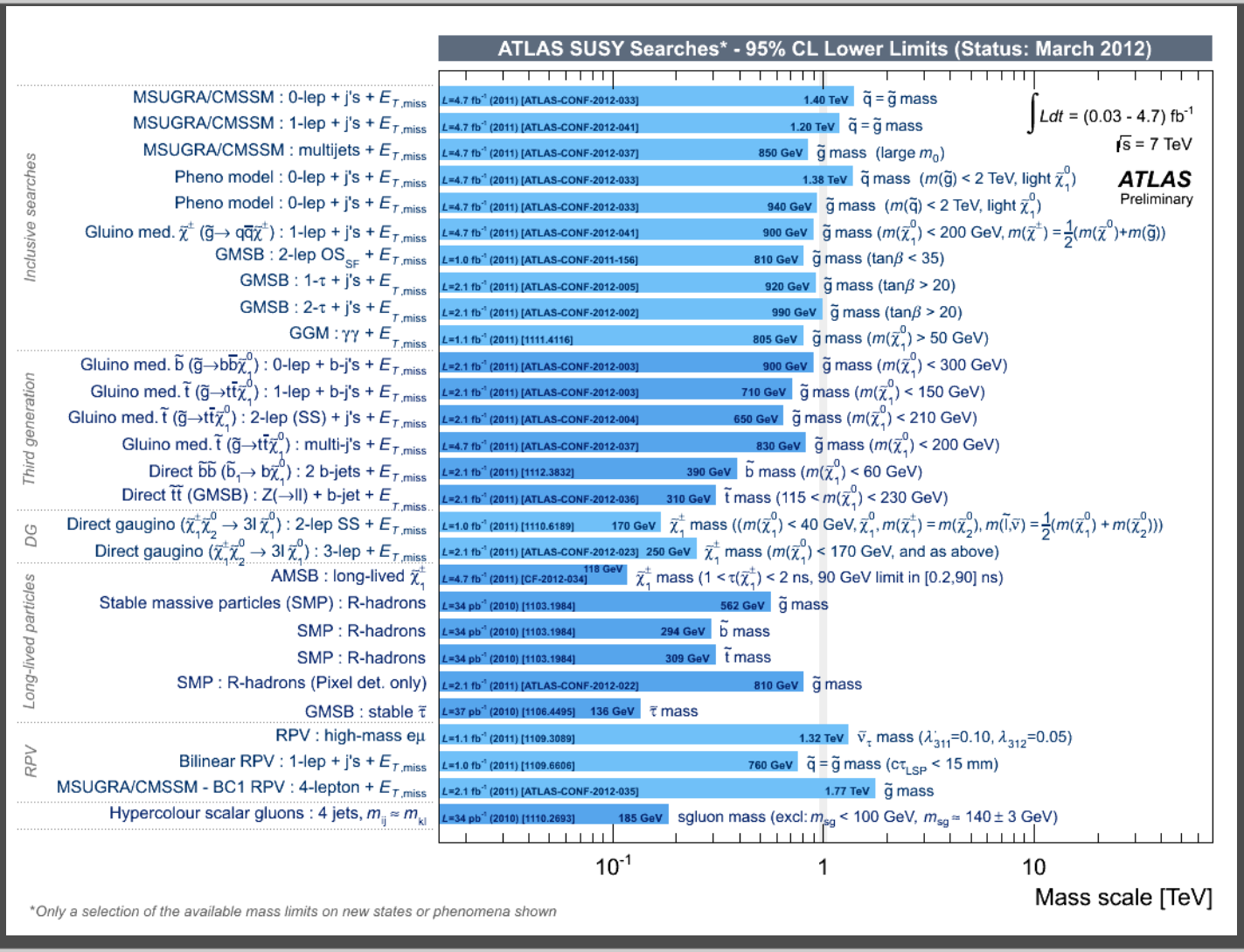




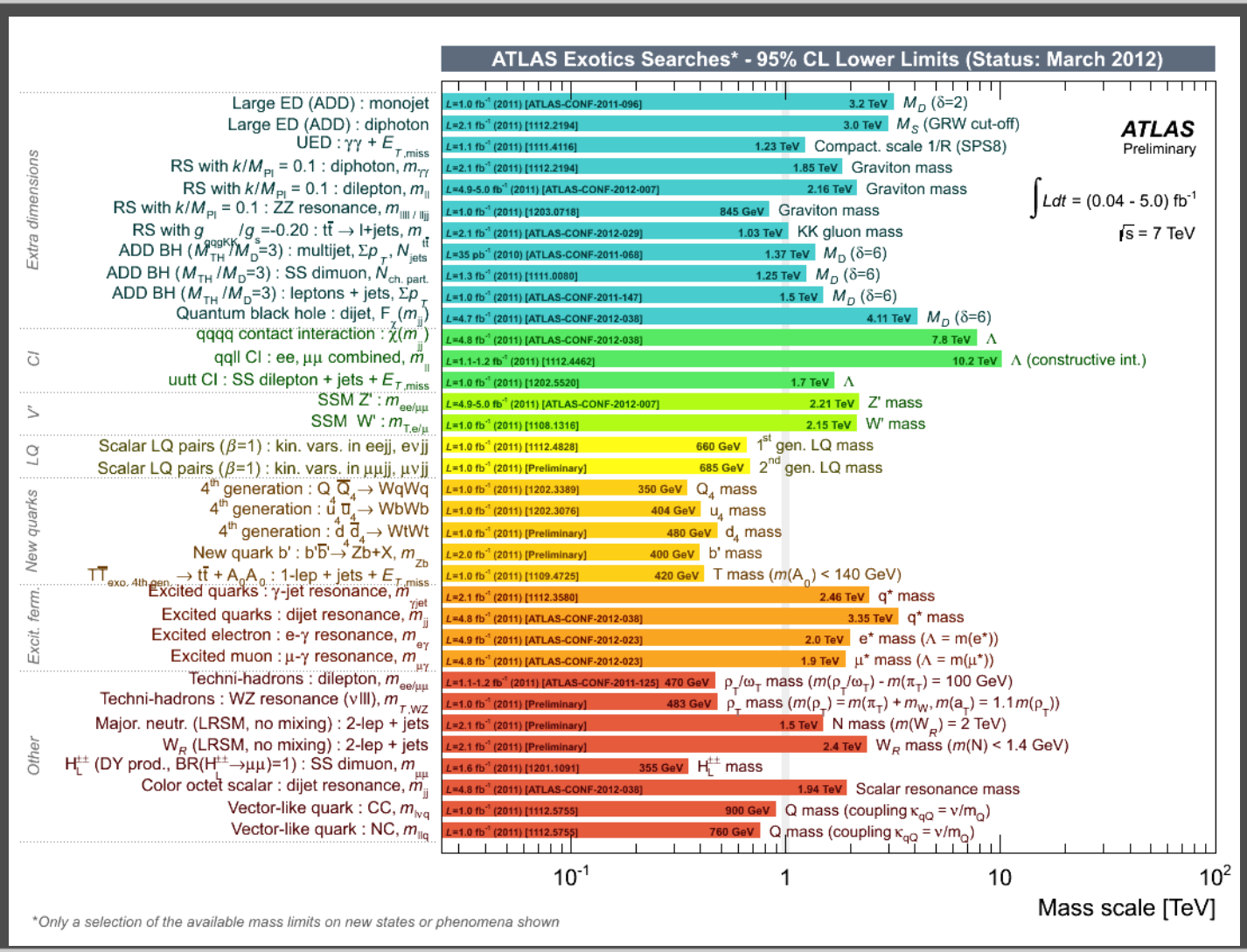


- All channels using full 2011 luminosity
- Expected exclusion @ 95%CL [120-555] GeV
- Observed: [110-117.5] – [118.5-122.5] – [129-539] GeV

SUSY searches

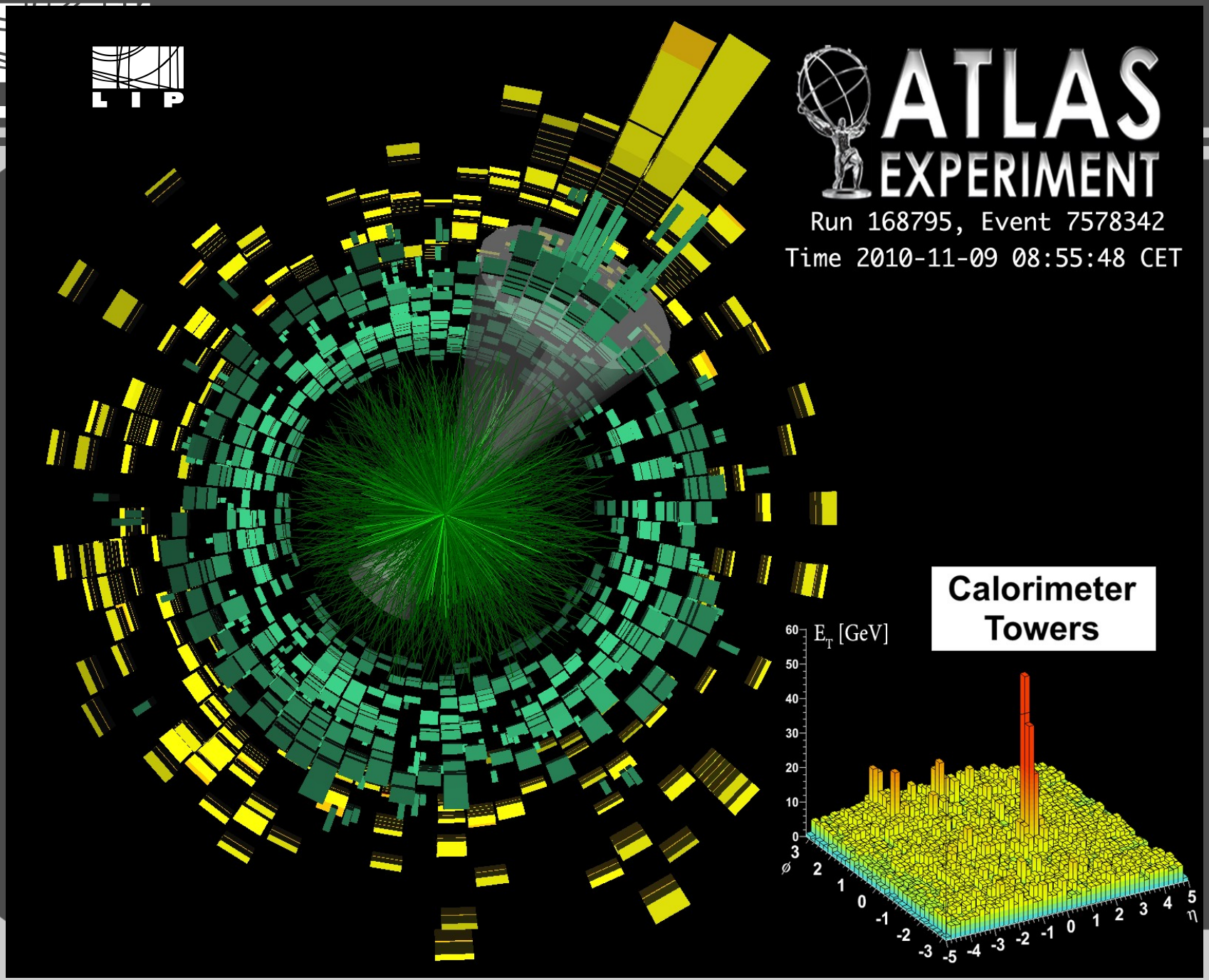


Exotic searches



Summary and conclusions

- The LHC has collected 5 fb-1 of pp collisions at 7 TeV
- The ATLAS experiment has used this data to study a long list of physics topics
- In general, measurements in agreement with SM
- No sign of new physics yet
- Starting to find indications that the Higgs boson may be there!
- A lot more data expected this year at 8 TeV!


LIP
ATLAS
EXPERIMENT
Run 168795, Event 7578342
Time 2010-11-09 08:55:48 CET
Calorimeter Towers
E_T [GeV]
60
50
40
30
20
10
0
φ
3
2
1
0
-1
-2
-3
-5
-4
-3
-2
-1
0
1
2
3
4
5
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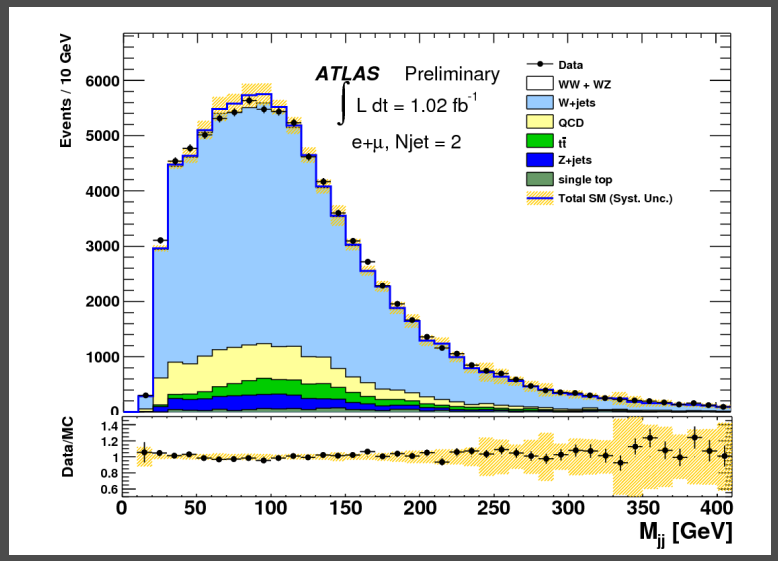
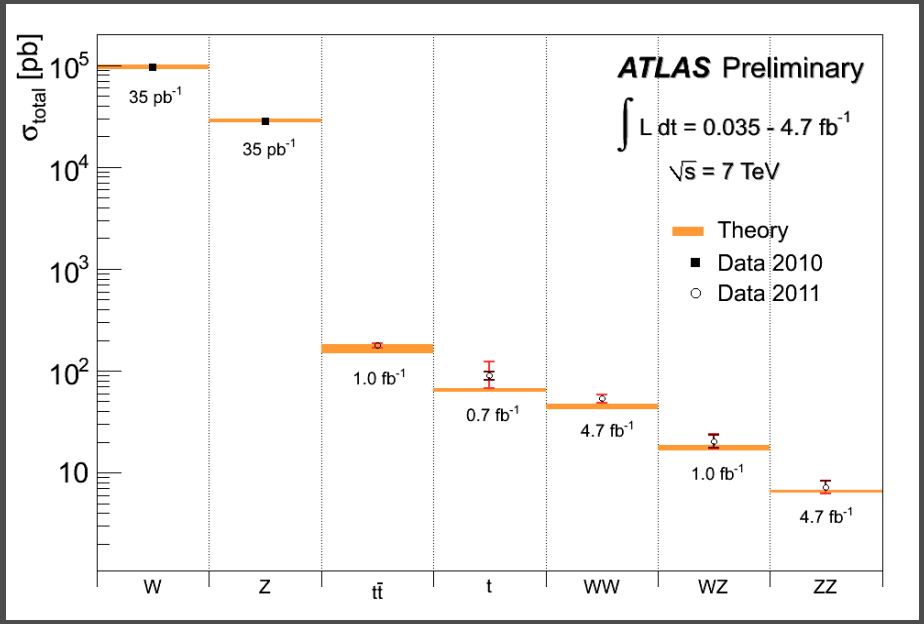
Thank you!

Acknowledgements

QREN QUADRO DE REFERÊNCIA ESTRATÉGICO NACIONAL PORTUGAL 2007.2013
COMPETE PROGRAMA OPERACIONAL FACTORES DE COMPETITIVIDADE
FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

Wjj


ATLAS Preliminary
∫ L dt = 1.02 fb-1
e+μ, Njet = 2
Data
WW + WZ
W+jets
QCD
tt̄
Z+jets
single top
Total SM (Syst. Unc.)
Events / 10 GeV
Data/MC
Mjj [GeV]

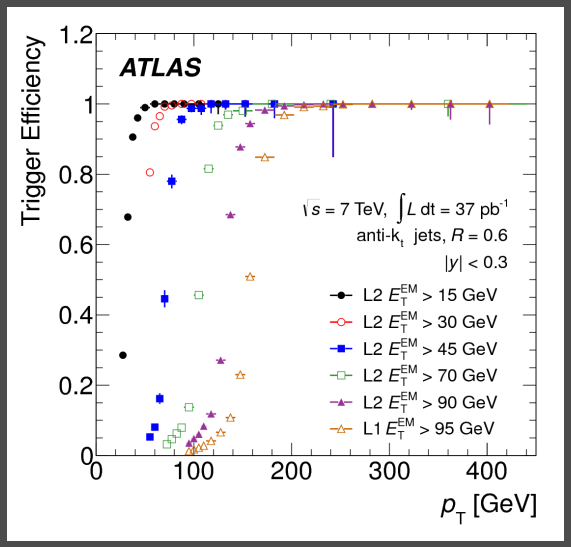

ATLAS Preliminary
∫ L dt = 0.035 - 4.7 fb-1
√s = 7 TeV
Theory
Data 2010
Data 2011
σtotal [pb]
10^5
10^4
10^3
10^2
10
35 pb-1
35 pb-1
1.0 fb-1
0.7 fb-1
4.7 fb-1
1.0 fb-1
4.7 fb-1
W
Z
tt̄
t
WW
WZ
ZZ

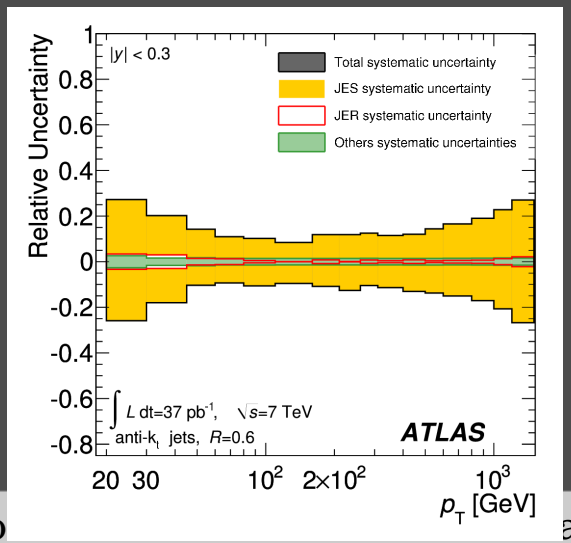
Corrections and systematic uncertainty

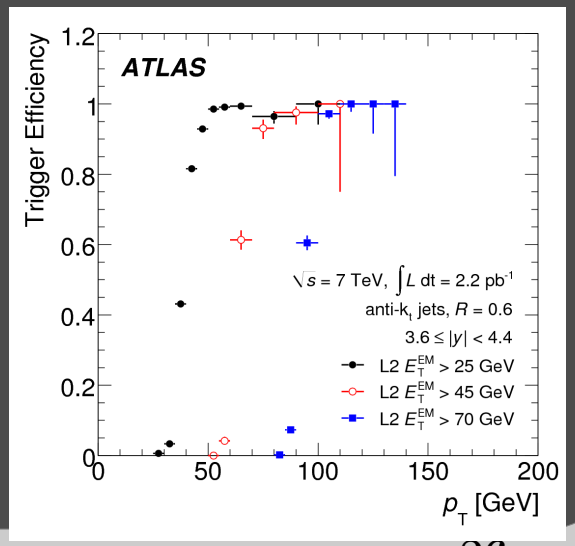
- Trigger efficiencies
  - Jet trigger efficient to provide unbiased, high statistics jet samples in all p_T bins
- Unfolding:

$$N^{\mathrm{ptcl},i} = \sum_j N_{\mathrm{reco},j} \times \epsilon_{\mathrm{reco},j} A^{\mathrm{ptcl},i}_{\mathrm{reco},j} / \epsilon^{\mathrm{ptcl,i}}$$

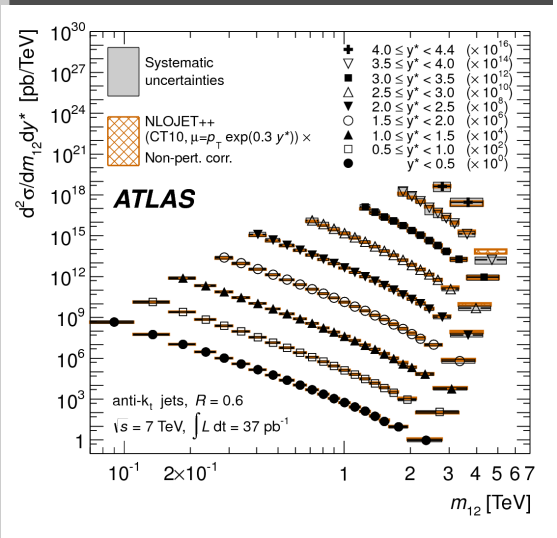
- Systematic uncertainties

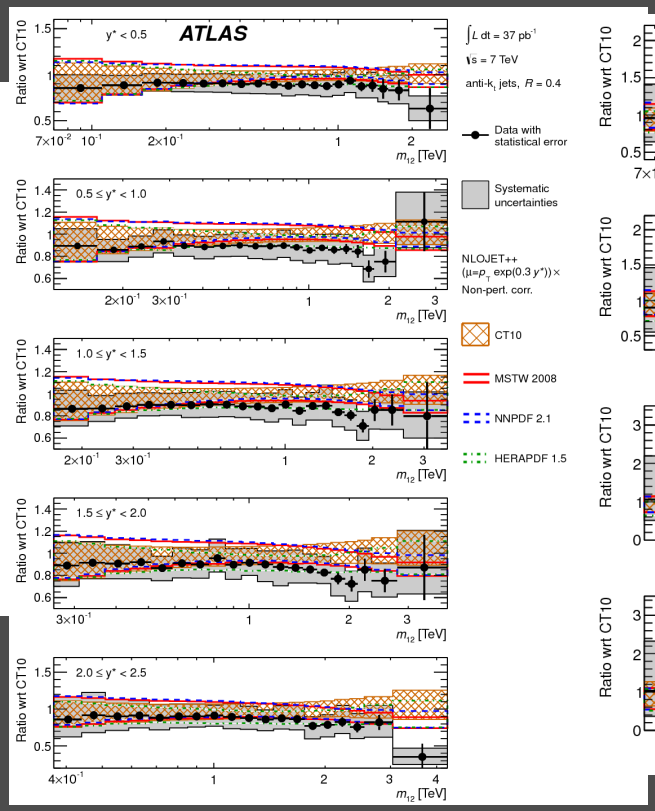


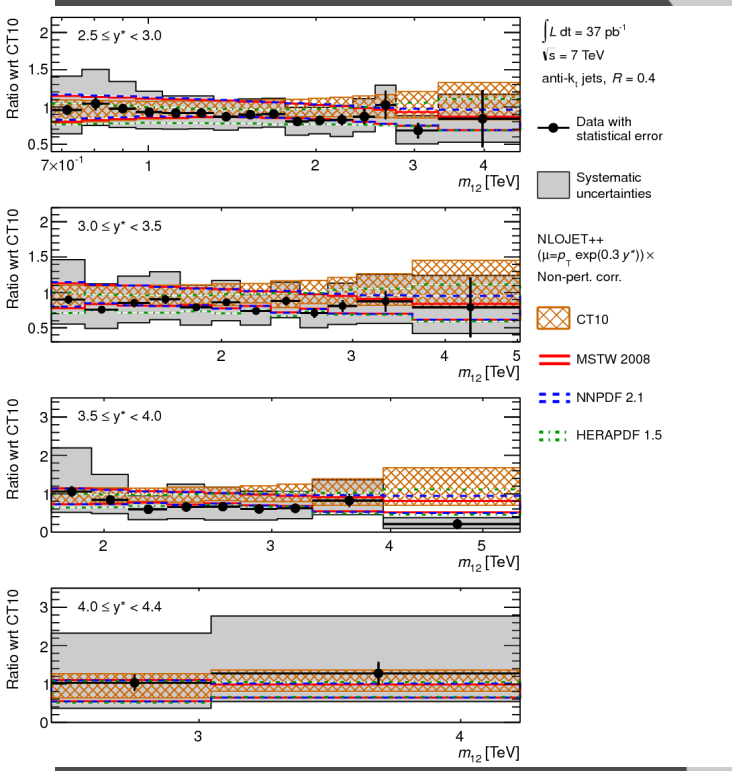




Di-jet cross sections



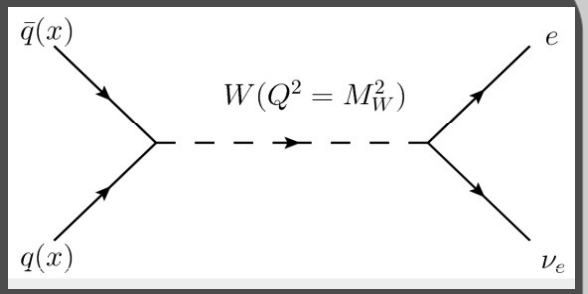


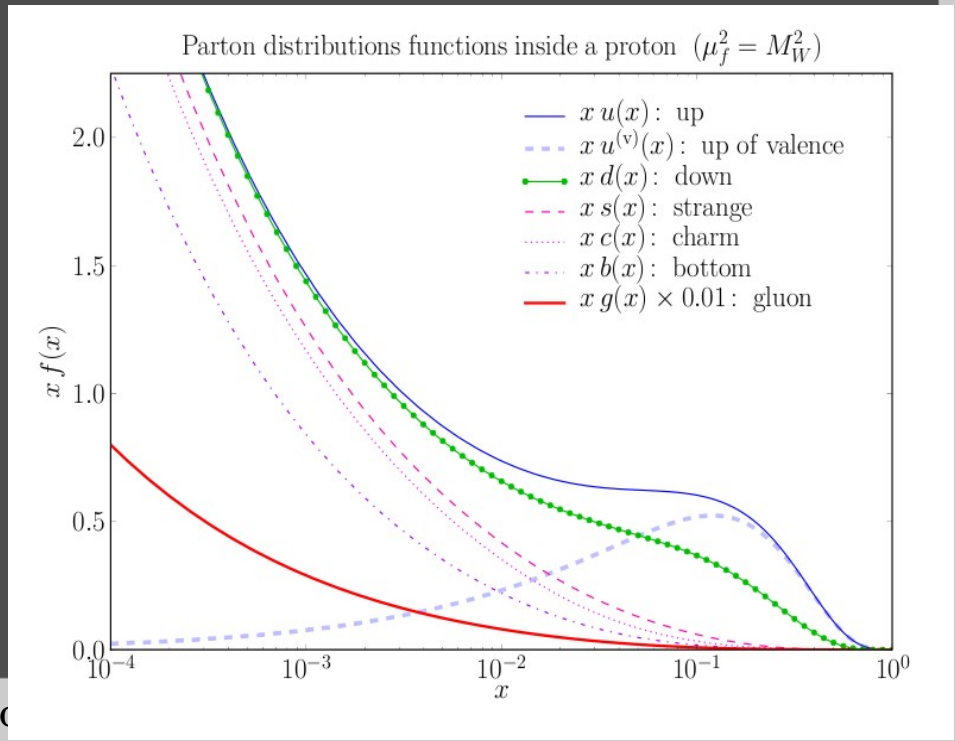


Model, and Analysis Strategy	95% C.L. Limits (TeV)	
	Expected	Observed
Excited quark, mass of q^*		
Resonance in m_{jj}	3.09	3.35
Resonance in $F_\chi(m_{jj})$	2.97	2.58
Colour octet scalar, mass of s8		
Resonance in m_{jj}	1.95	1.94
Quantum Black Hole for $n = 6$, M_D		
$F_\chi(m_{jj})$	4.14	4.11
11-bin χ , $m_{jj} > 2.6$ TeV	4.23	3.96
Contact interaction, Λ, destructive interference		
$F_\chi(m_{jj})$	8.2	7.6
11-bin χ , $m_{jj} > 2.6$ TeV	8.7	7.8

W/Z boson production

- W/Z total/differential theoretical cross sections known to NNLO in QCD perturbative theory
  - input EW parameters known to high accuracy
  - Main uncertainty comes from PDFs
- Experimentally very clean
- W^+/W^- asymmetry provides information on
  - The quark content of the p
  - Fraction of momentum carried by the quarks



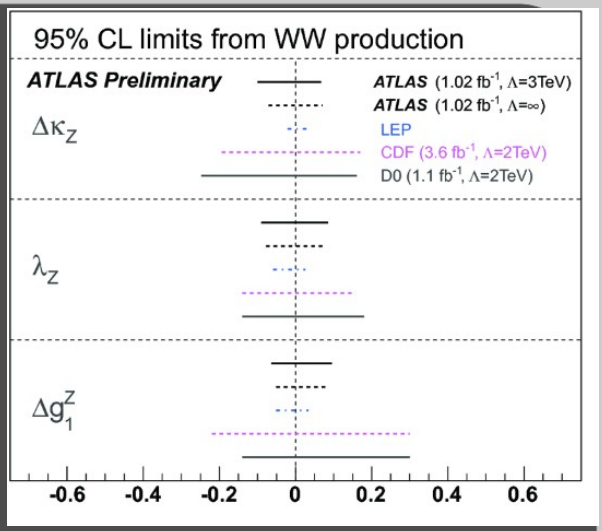


Limits on anomalous TGC

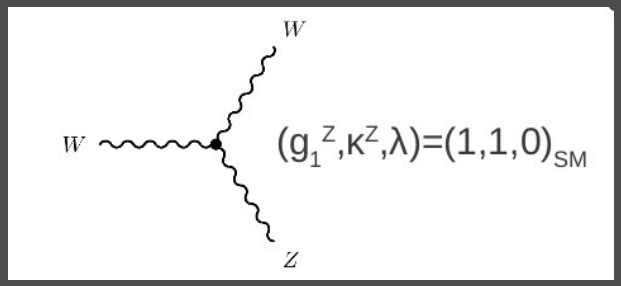
- Di-boson cross sections compatible with SM predictions

$$\sigma^{TOT}(W^+W^-)=53.4\pm2.1_{stat}\ \pm4.5_{sys}\ \pm2.1_{lumi}\ pb$$

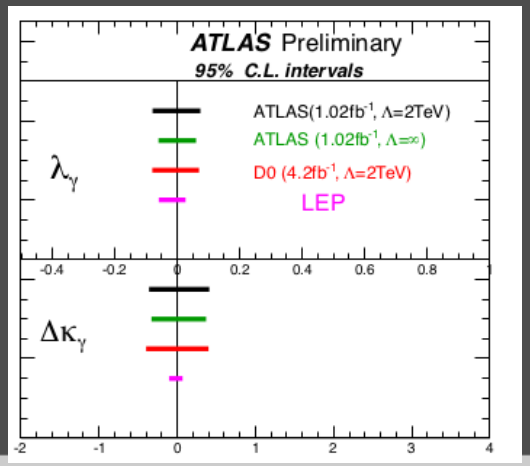
$$\sigma^{SM}(W^+W^-)NLO=45.1\pm2.8\ pb$$

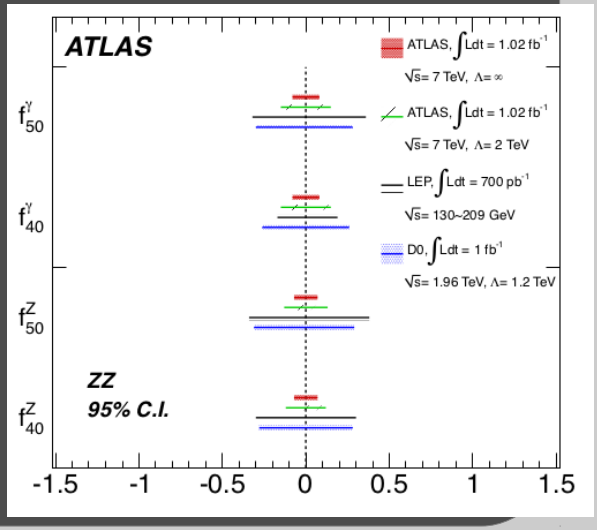


Limits imposed on anomalous triple Gauge boson couplings



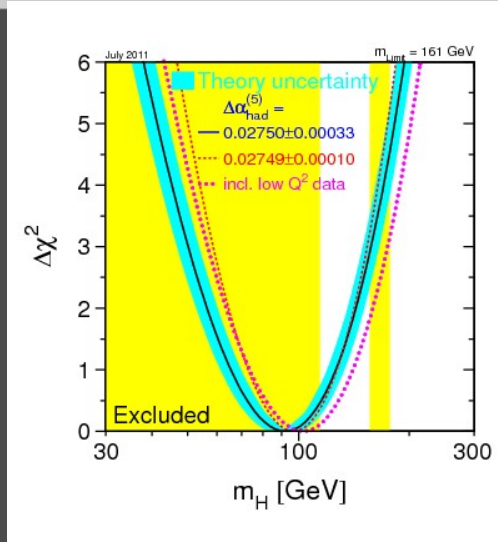
$$\alpha(\hat{s})=\frac{\alpha_0}{(1+\hat{s}/\Lambda^2)^2}$$

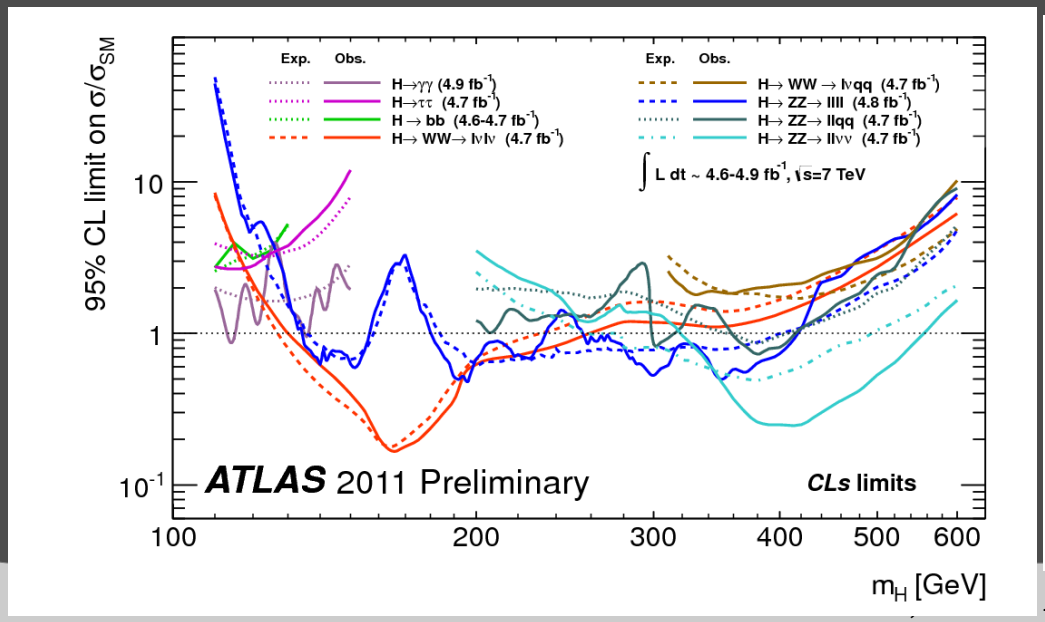


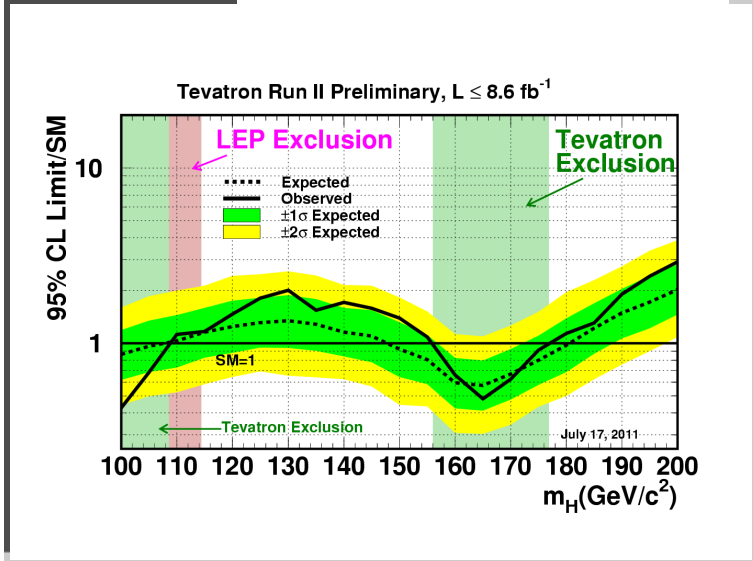


Higgs searches

- Fit to electroweak data: $m_H = 92^{+34}_{-26}$ GeV
- LEP, TEVATRON exclusion limits
  - LEP excludes m_H<114.4 GeV
  - Tevatron excludes 156 < m_H < 177 GeV
- ATLAS has searched for the Higgs boson in 12 different channels



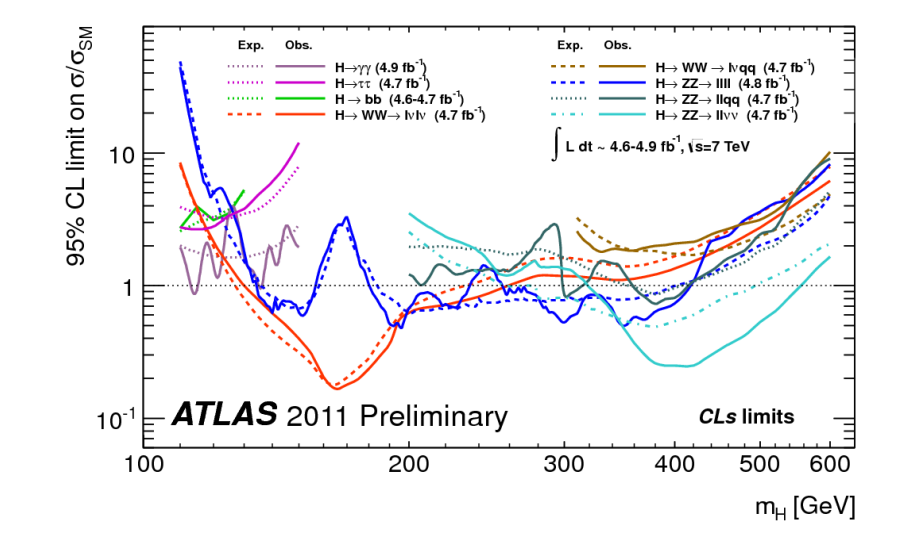


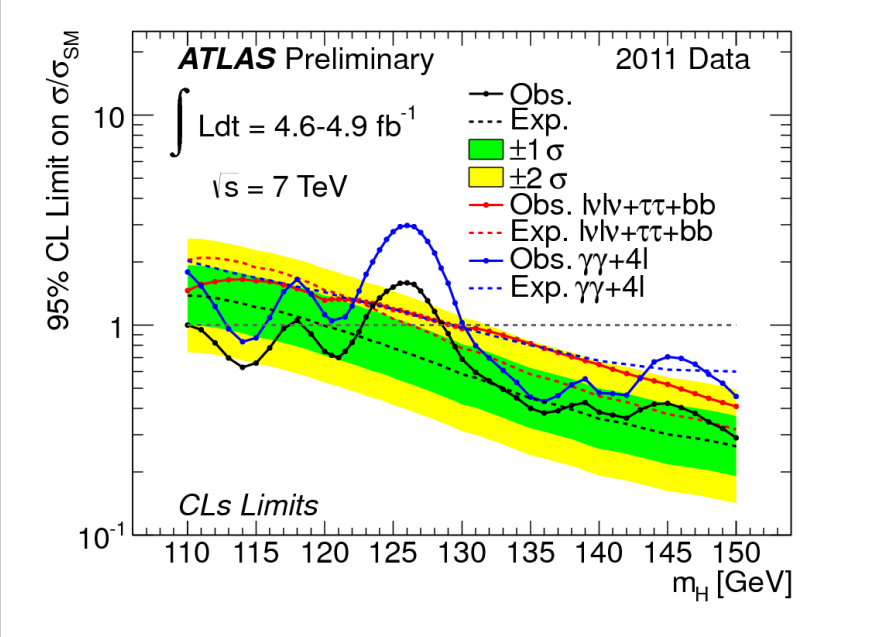


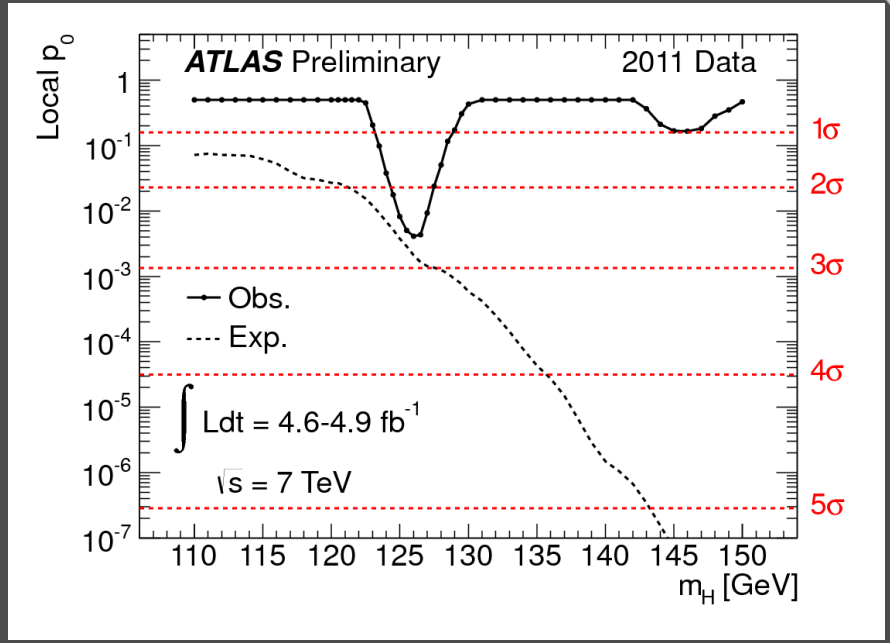
Higgs searches

Channel	Mass range m_H (GeV)	Luminosity (fb^{-1})
$H\to\gamma\gamma$	110-150	4.9
$H\to ZZ^{(*)}\to 4l$	110-600	4.8
$H\to WW^{(*)}\to l\nu l\nu$	110-600	4.7
$H\to\tau\tau\to ll4\nu$ $H\to\tau\tau\to l\tau_{had}3\nu$ $H\to\tau\tau\to\tau_{had}\tau_{had}2\nu$	100-150	4.7
$WH\to l\nu bb$ $ZH\to llbb$ $ZH\to\nu\nu bb$	110-130	4.7
$H\to ZZ\to ll\nu\nu$	200-600	4.7
$H\to ZZ\to lljj$	200-600	4.7
$H\to WW\to l\nu jj$	300-600	4.7

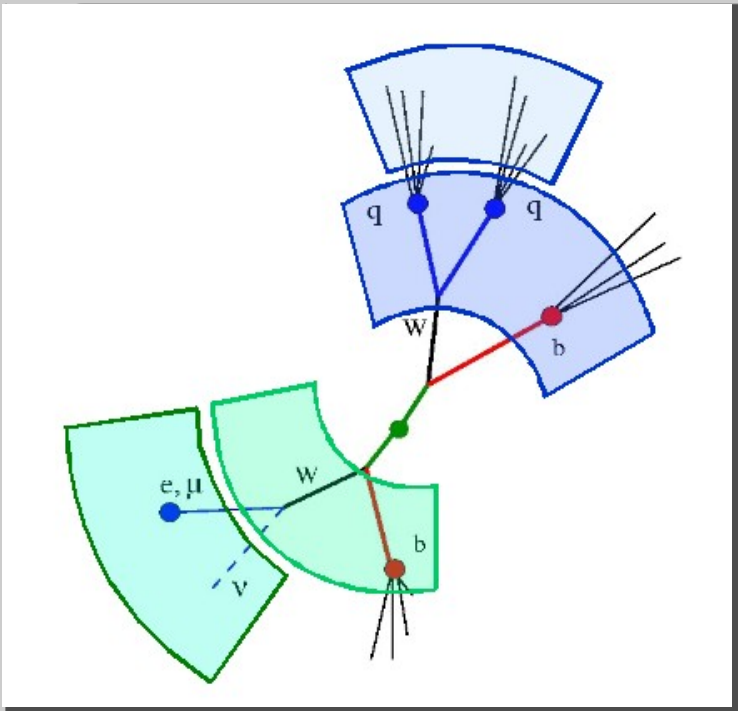
CERN-2011-002; arXiv:



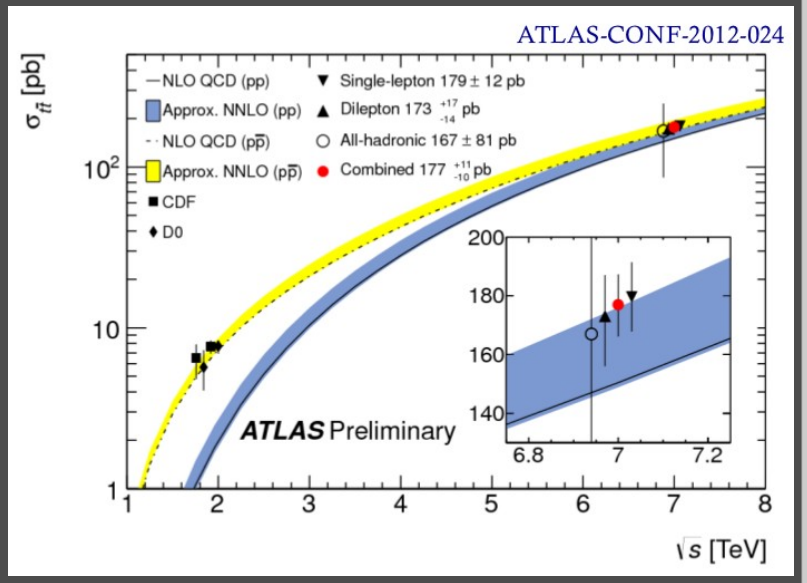

ATLAS Preliminary
2011 Data
∫ Ldt = 4.6-4.9 fb-1
√s = 7 TeV
Obs.
Exp.
±1 σ
±2 σ
Obs. lνlν+ττ+bb
Exp. lνlν+ττ+bb
Obs. γγ+4l
Exp. γγ+4l
CLs Limits
95% CL Limit on σ/σSM
mH [GeV]


ATLAS Preliminary
2011 Data
Local p0
Obs.
Exp.
∫ Ldt = 4.6-4.9 fb-1
√s = 7 TeV
1σ
2σ
3σ
4σ
5σ
mH [GeV]

Top quark measurements at ATLAS



- LHC is a top quark factory
  - σ_{tt} ~20× Tevatron, backg.~8× Tevatron
- Predicted cross section @7TeV
  - $\sigma(tt)_{\text{approx NNLO}} = 165^{+11}_{-16}$ pb.



- Top signatures:
  - High p_T leptons, missing E_T, b-jets