General Update on the ATLAS EXPERIMENT

Jon Butterworth

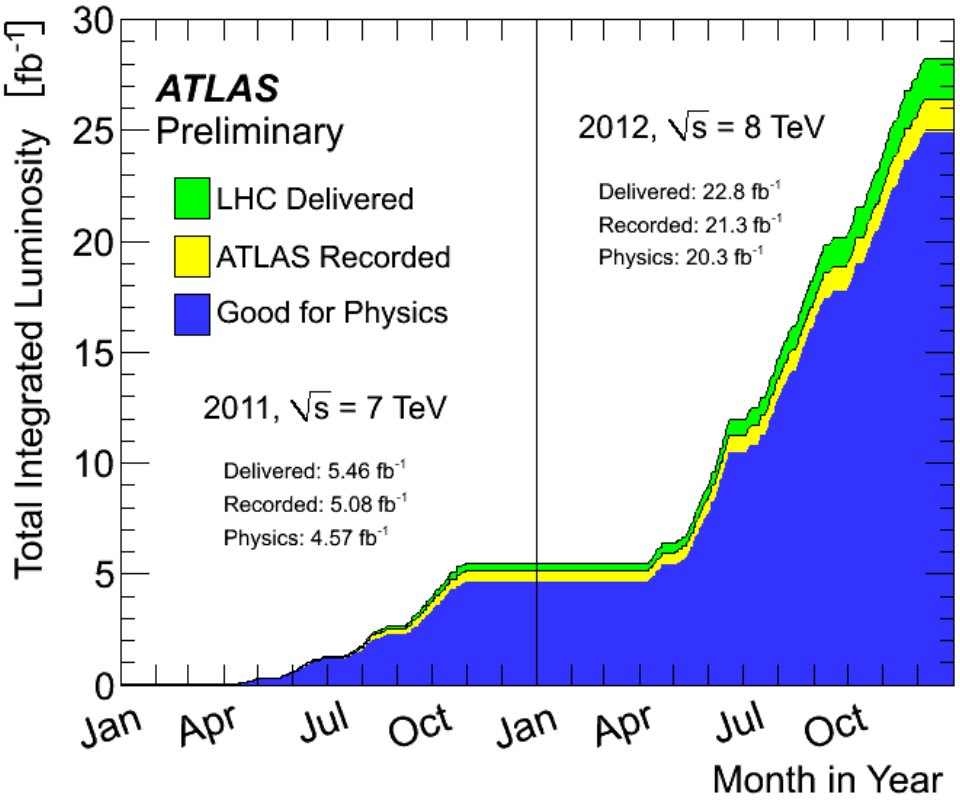
HiggsTool, 13/4/2016

(personal selection, not on behalf of ATLAS)

Physics at the LHC

- Energy reach
  - New particles
  - Shorter distance scales
- High luminosity and excellent detectors
  - Cover the phase space opened
  - Study rare events
- Energy opens more phase space
  - High multiplicities
  - QCD & EW radiation in events with objects at the electroweak scale
  - Boosted electroweak scale objects, rich perturbative structure inside jets
- Surprises?

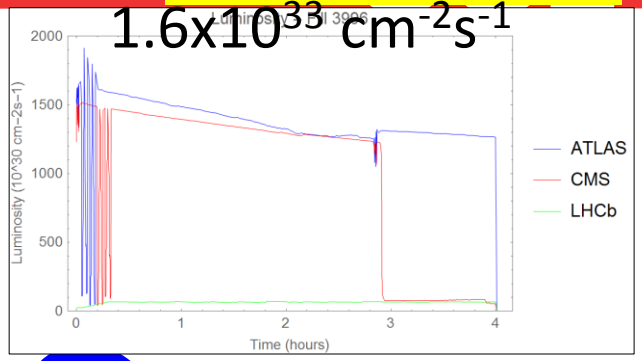
Run 1 was good…



- >400 papers submitted (still coming)
  - Wide range of precision measurements
  - Extensive searches, with one of two interesting anomalies
  - A new particle, confirmation of our understanding of mass

From Mike Lamont, LP2015

1.6×10^{33} cm^{-2}s^{-1}



5th April first beam

10th April: 6.5 TeV for the first time

July 14th: 476b (50 ns)

APRIL

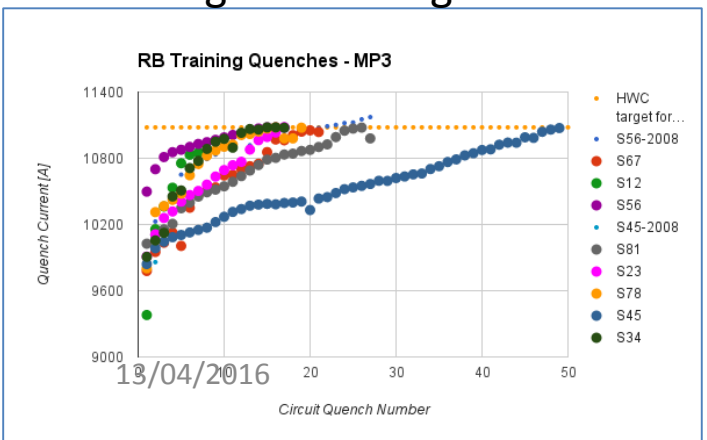
MAY

JUNE

JULY

AUGUST

Finish magnet training

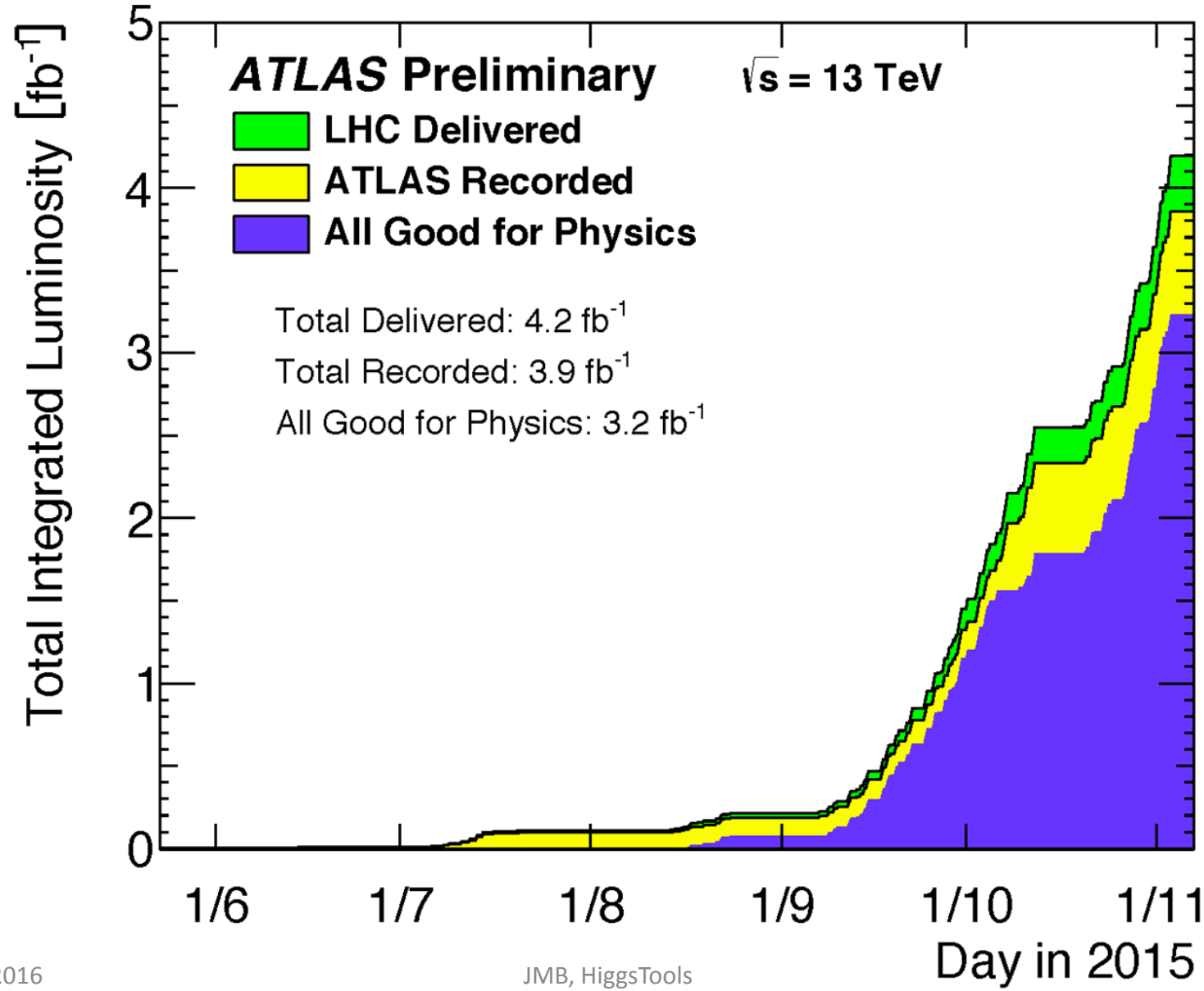


3rd June: First Stable Beams

25 ns
219 bunches

2015

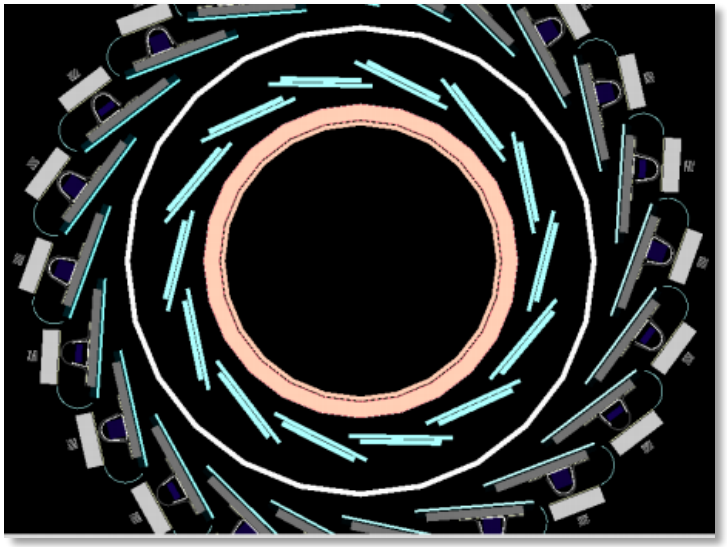
The story so far…



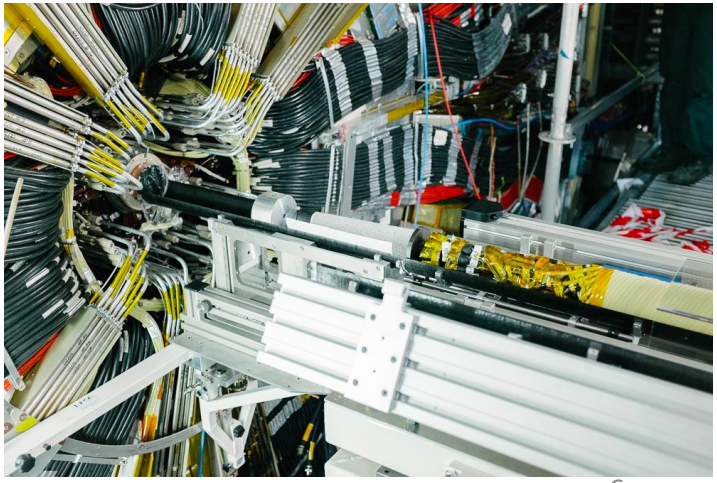
Detector Upgrades: Reminder

From Beate Heinemann, LP2015

- Infrastructure:
  - New beampipe, improvements to magnet & cryogenic system
- Detector consolidation
  - Muon chambers completion (|η|=1.1-1.3) and repairs, improved readout of various systems (L1 rate 100 kHz), repair of pixel modules and calorimeter electronics, new pixel services, new luminosity detectors, new MBTS detector
- 4th silicon pixel detector layer (IBL)
  - Innermost Pixel detector layer at R=3.3 cm from beam
- Trigger improvements
  - New Topological L1 trigger, new central trigger processor, coincidence between Tile and muons, restructuring of high-level trigger, new Fast TracK Trigger (FTK), improved L1 calorimeter trigger
- Software
  - Many improvements to simulation, reconstruction, grid and analysis software

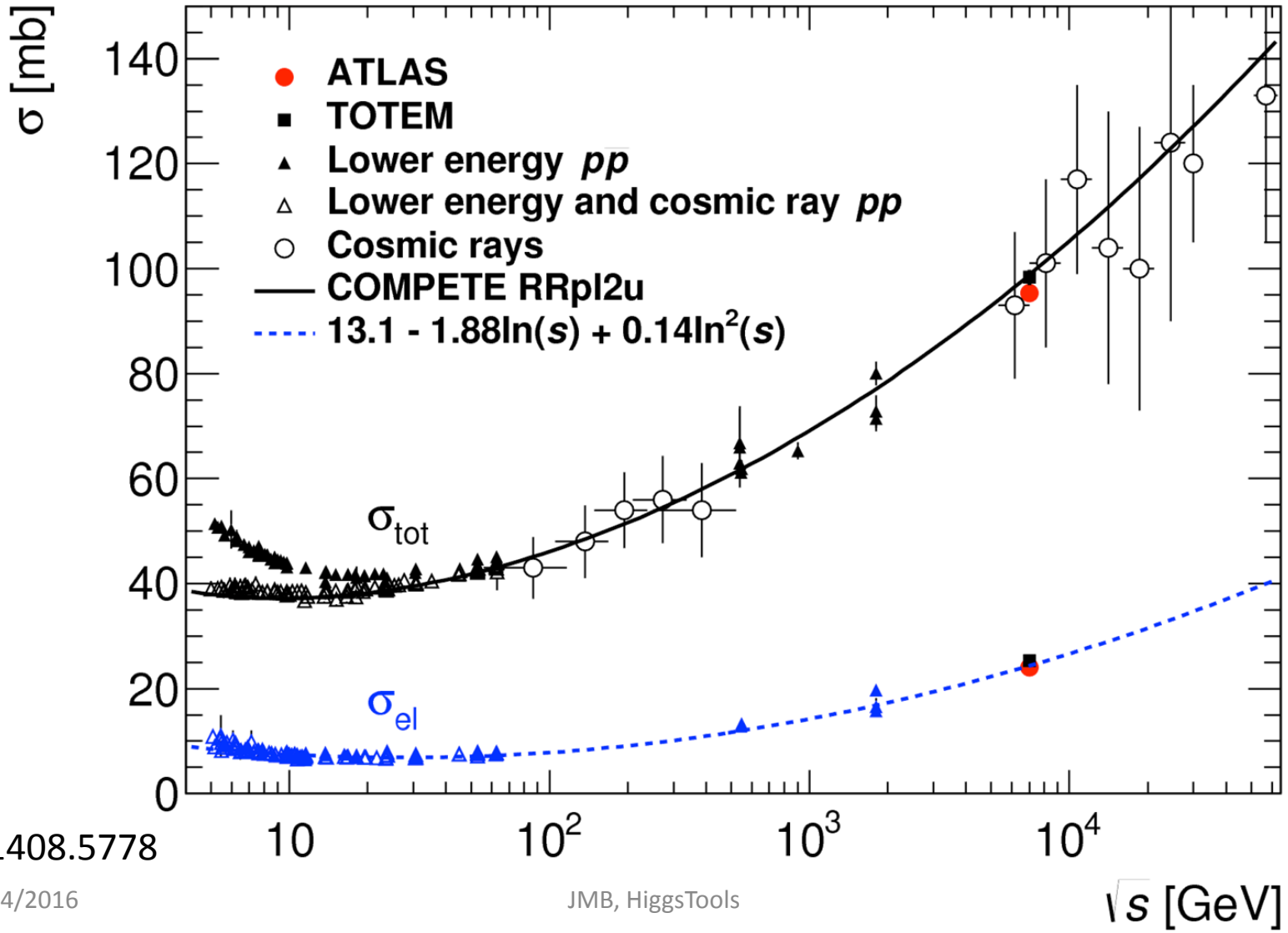


IBL Insertion: May 2014



Total Cross Section

- Forward detectors (ATLAS/ALFA, CMS/TOTEM)

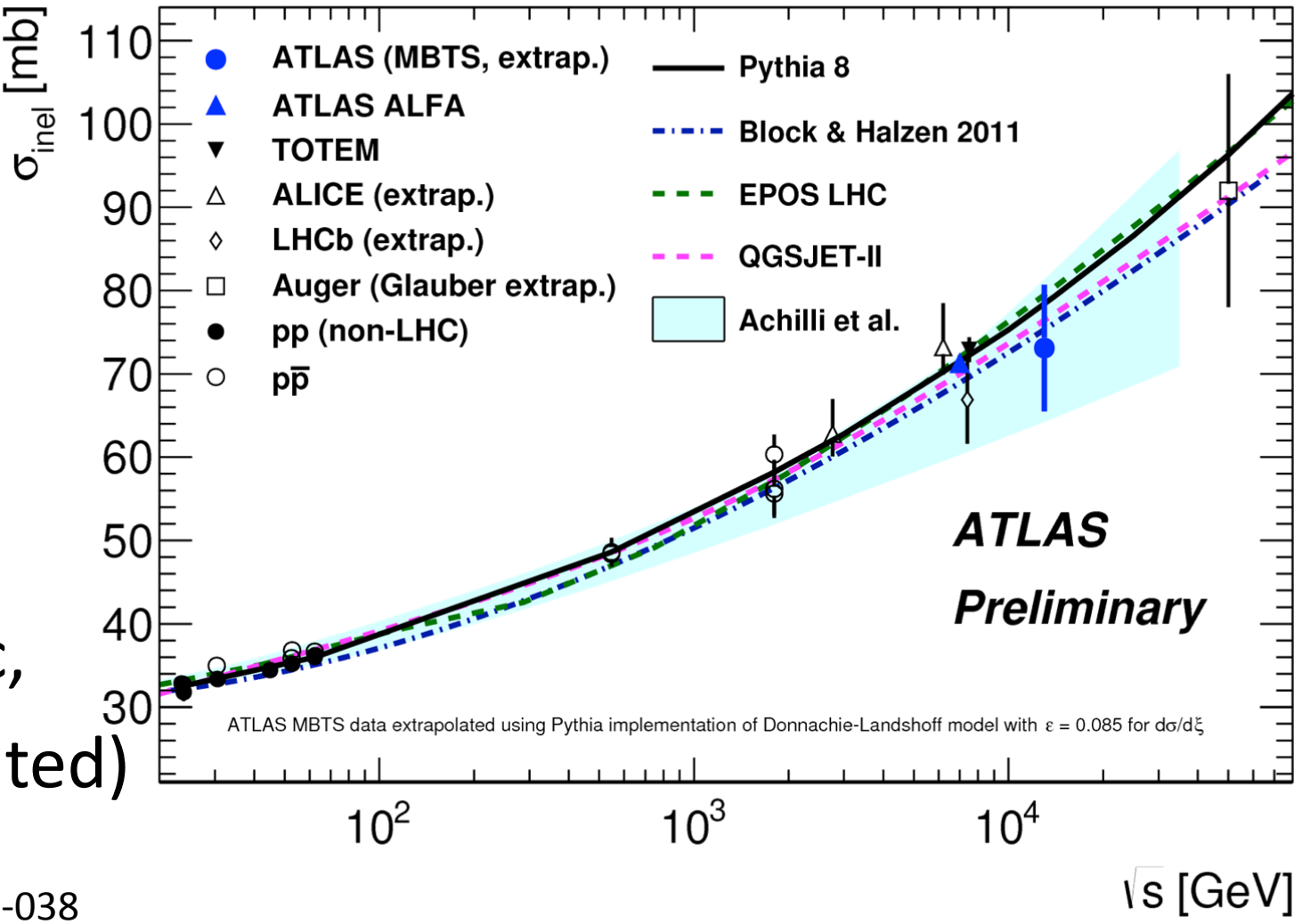


arXiv:1408.5778

Total Cross Section

- Forward detectors (ATLAS/ALFA, CMS/TOTEM)

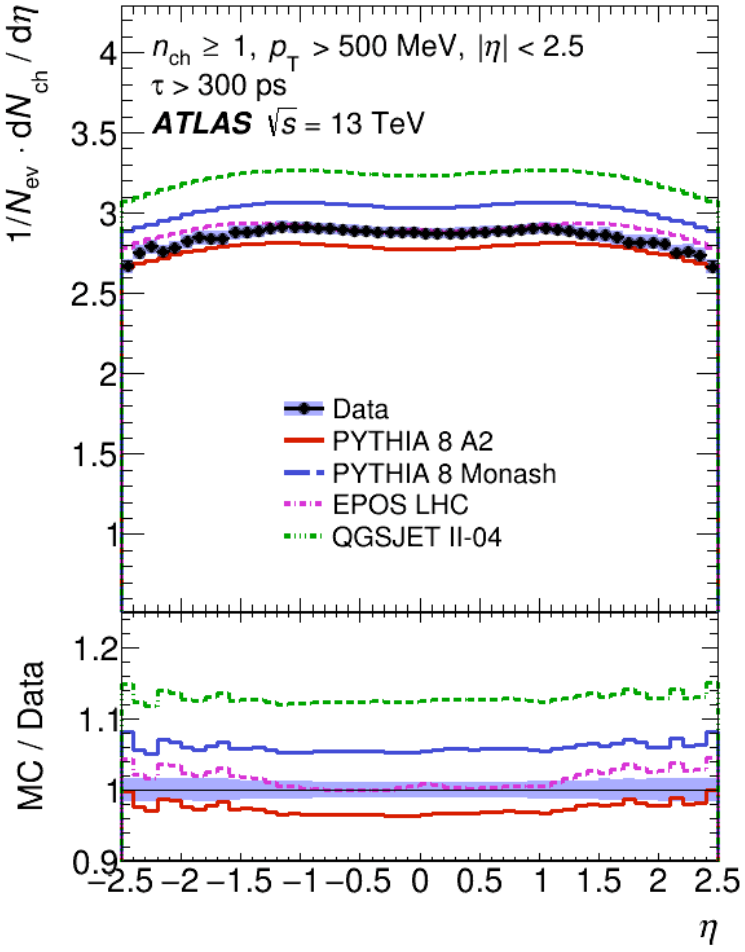
13 TeV MBTS (inelastic, extrapolated)

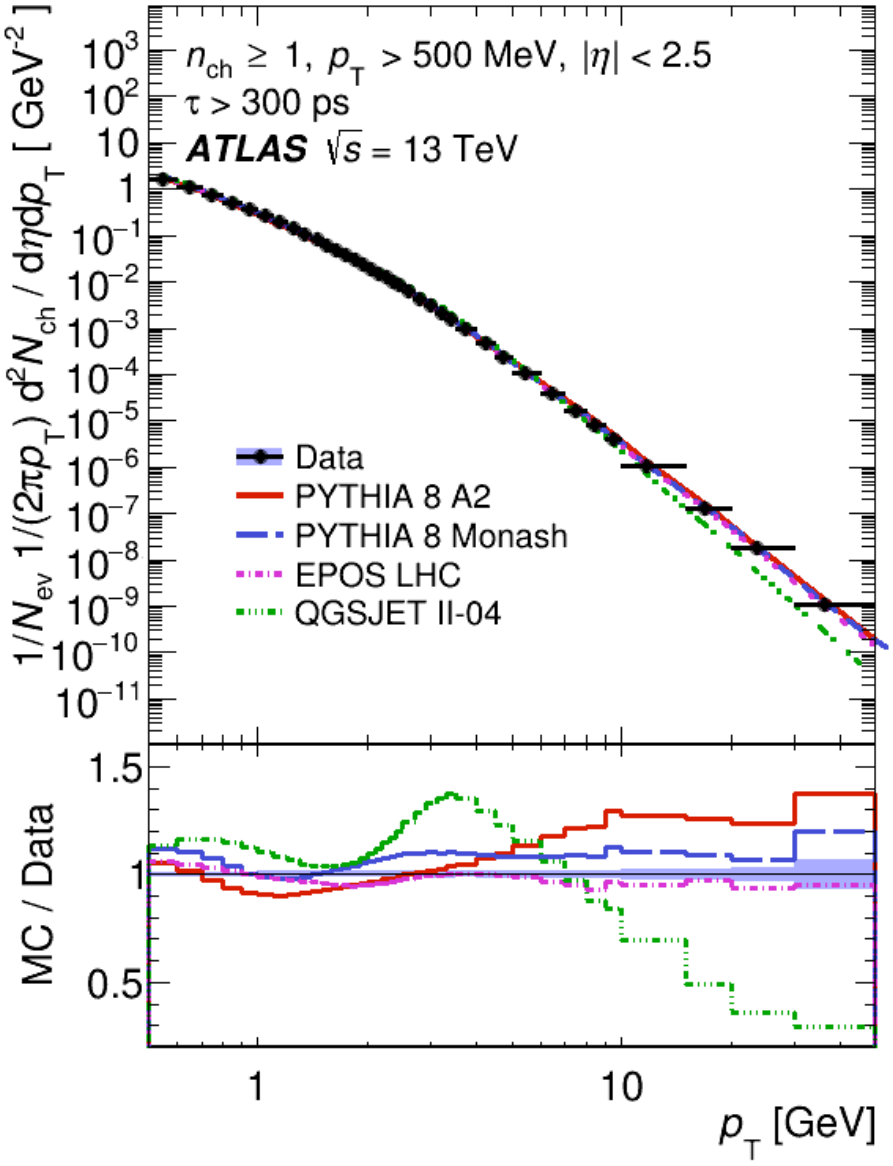


ATLAS-CONF-2015-038

Particle Production

- 13 TeV data, ‘minimum bias’ **arXiv:1602.01633**





Particle Production

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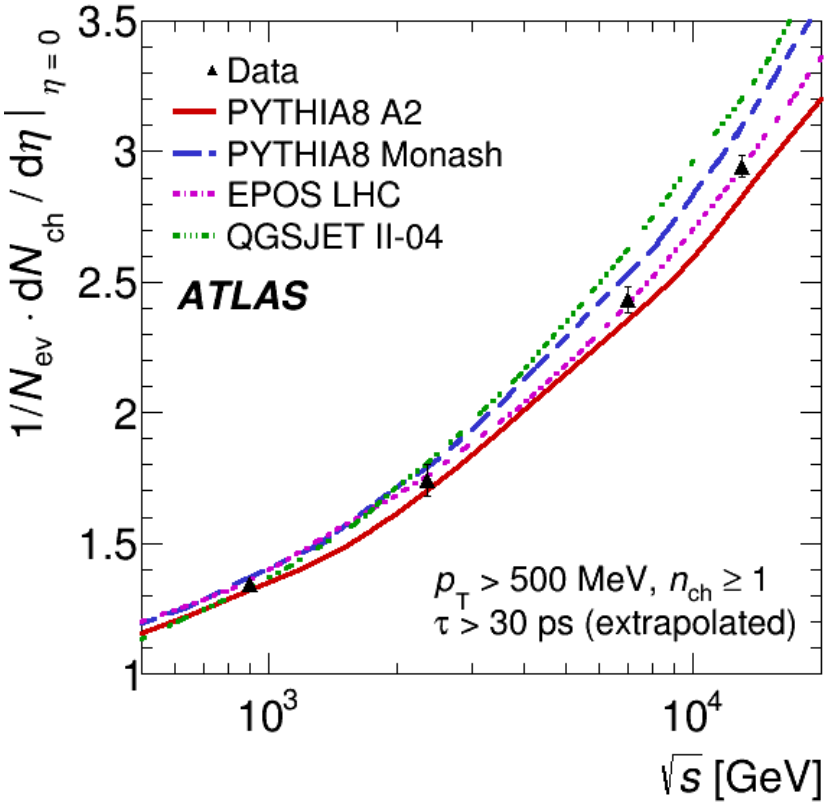
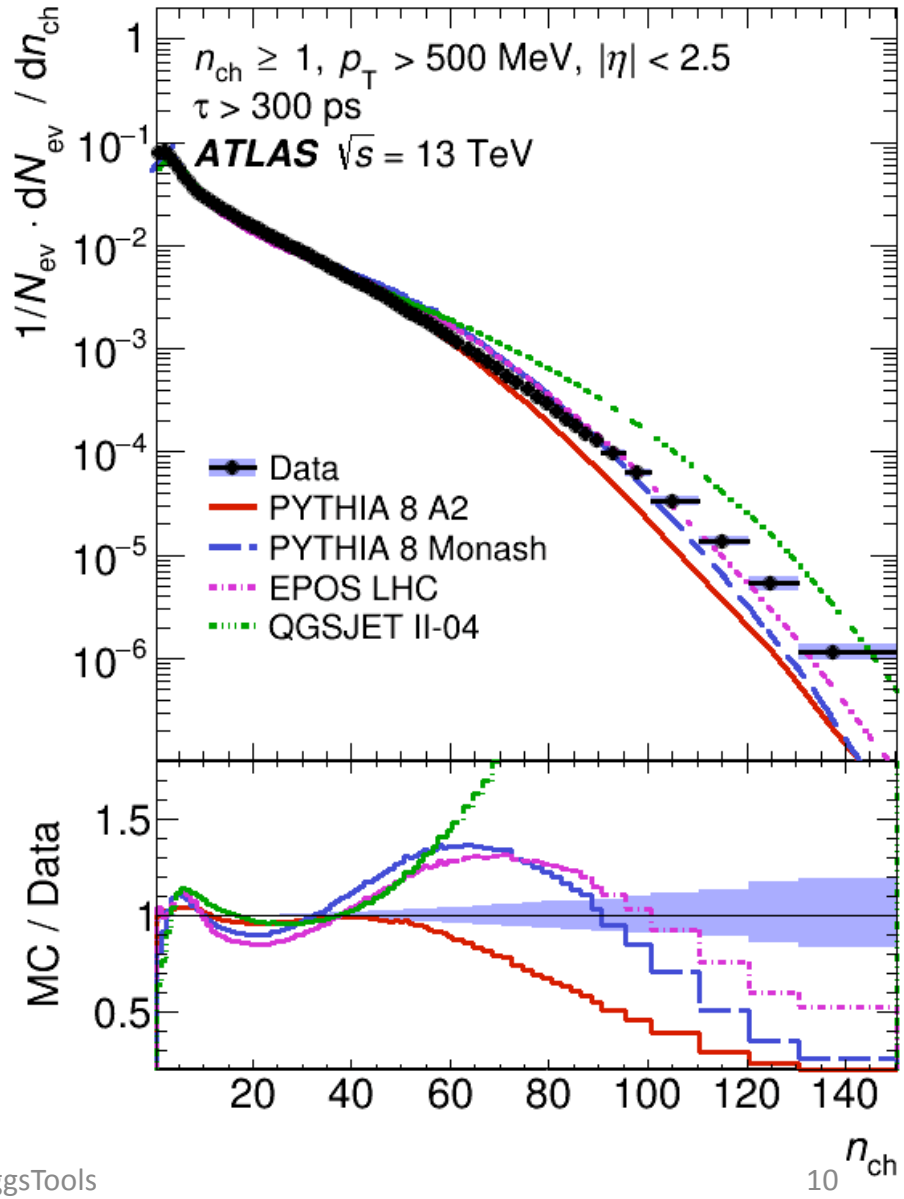
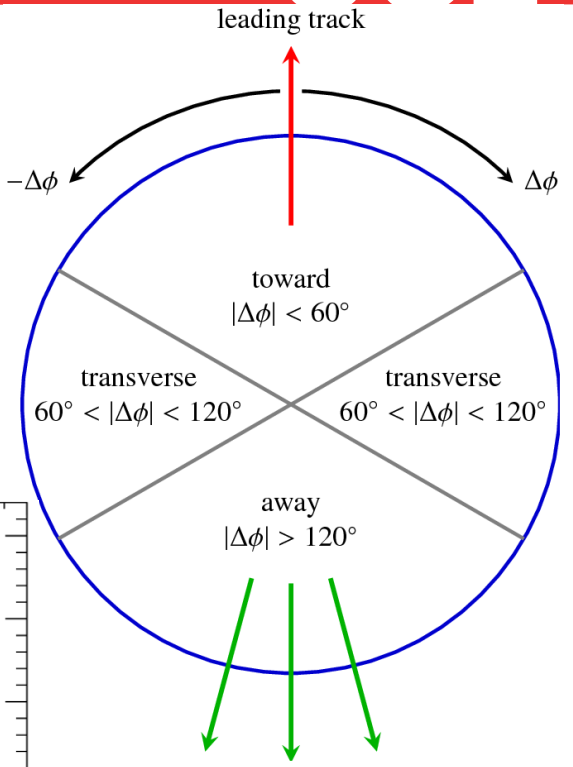


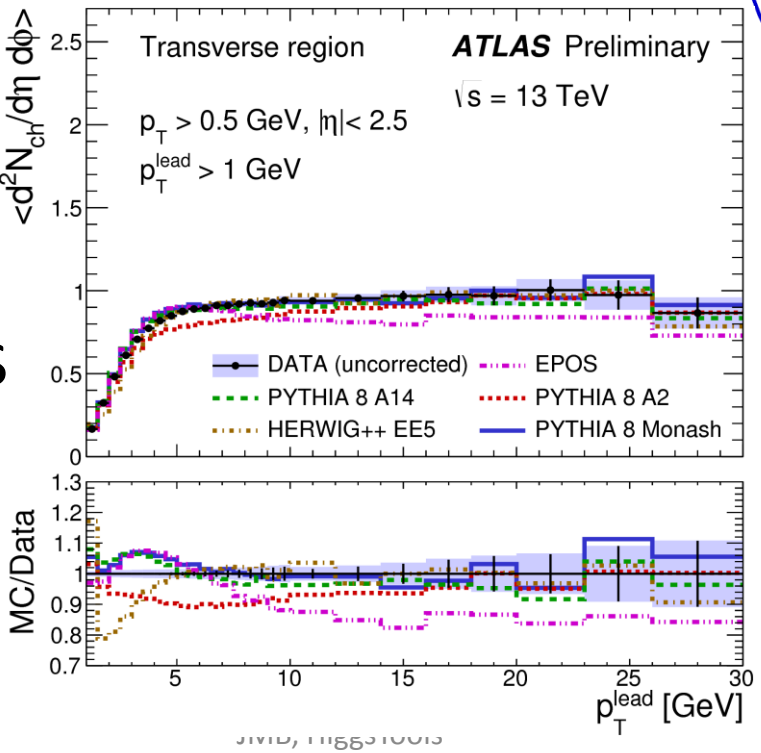


Underlying Event

- Use an object (track, jet, Z…) to select events with a hard process, and to define regions:
  - e.g. leading track →

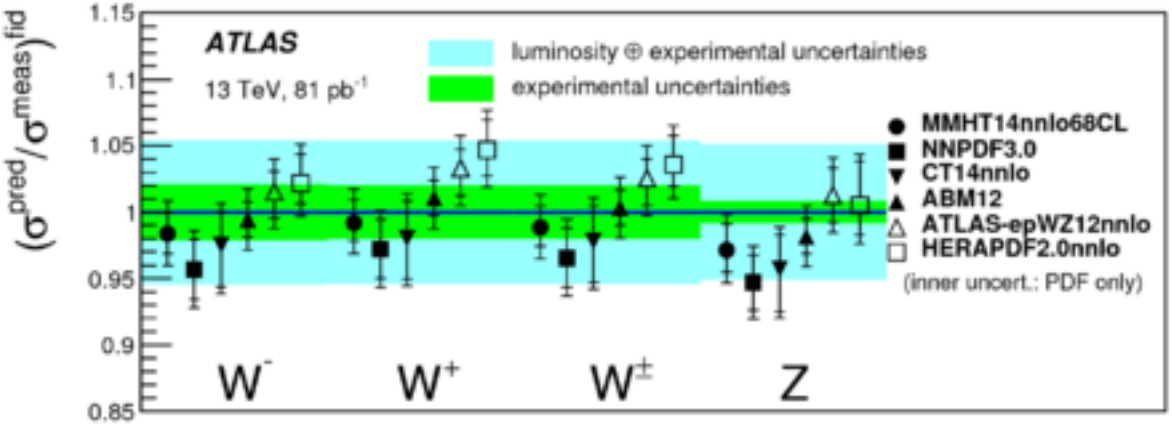


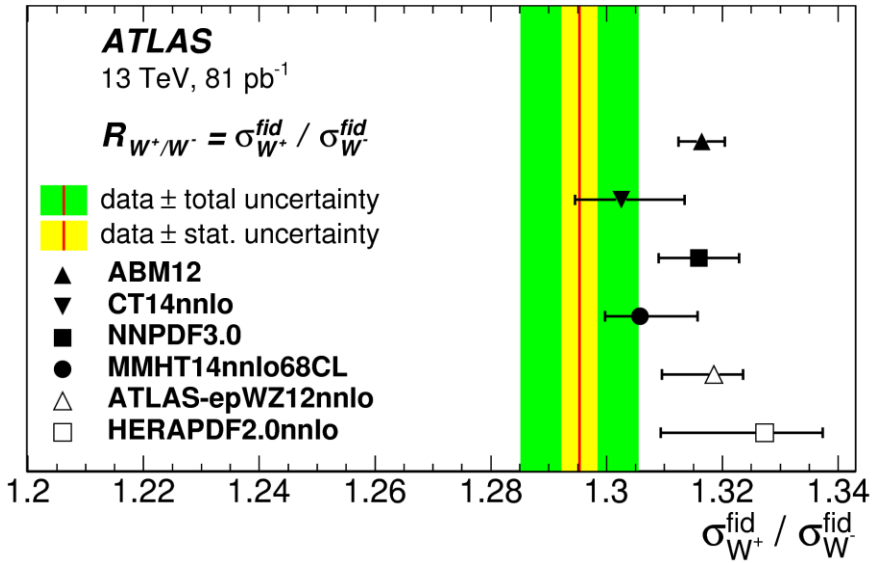
- Extensive library of fully-corrected result in Rivet, used to tune MC generators
- This example, ATLAS 13 TeV detector level, rapid check of modelling in a new energy regime

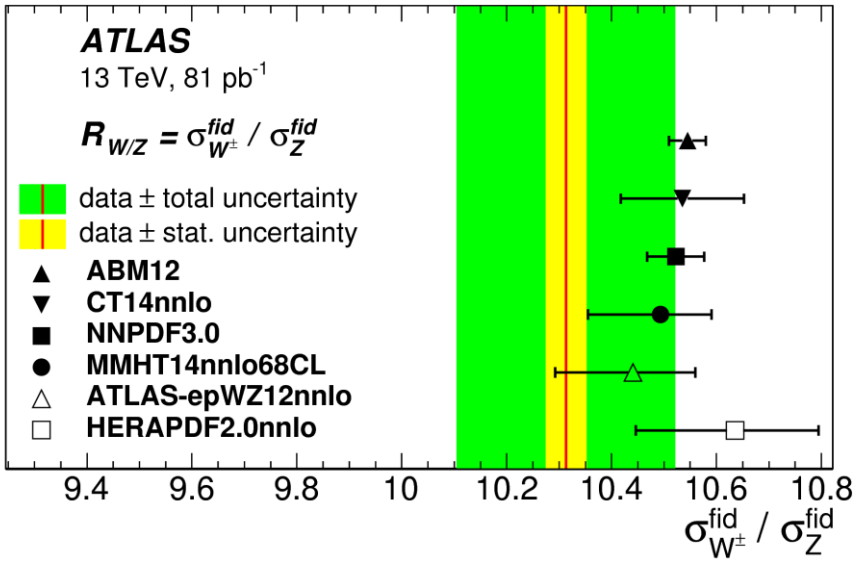


ATLAS-CONF-2015-028

W, Z and Proton Structure



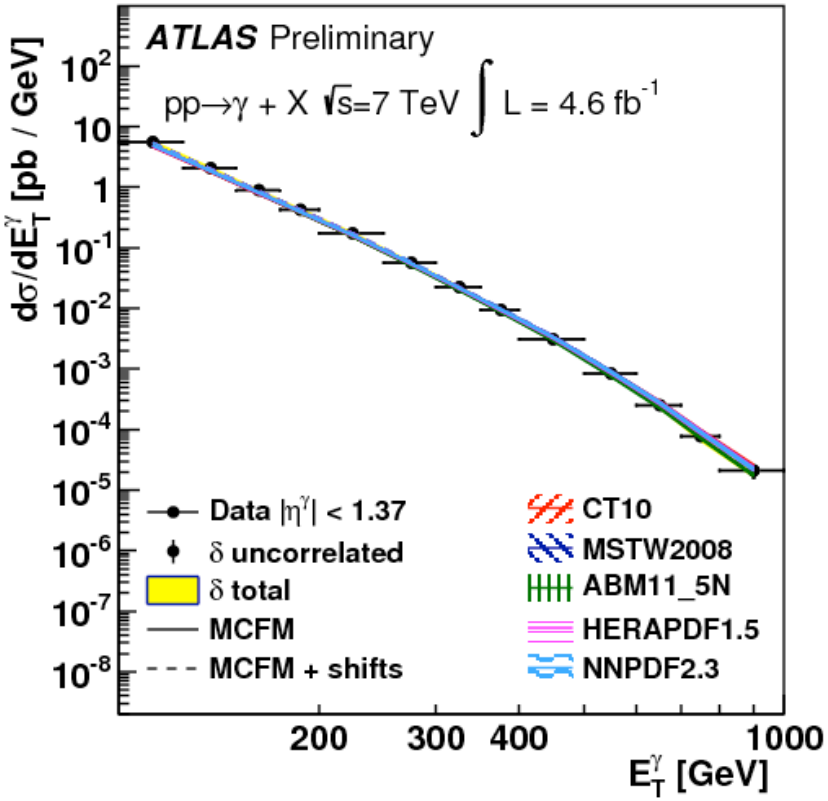


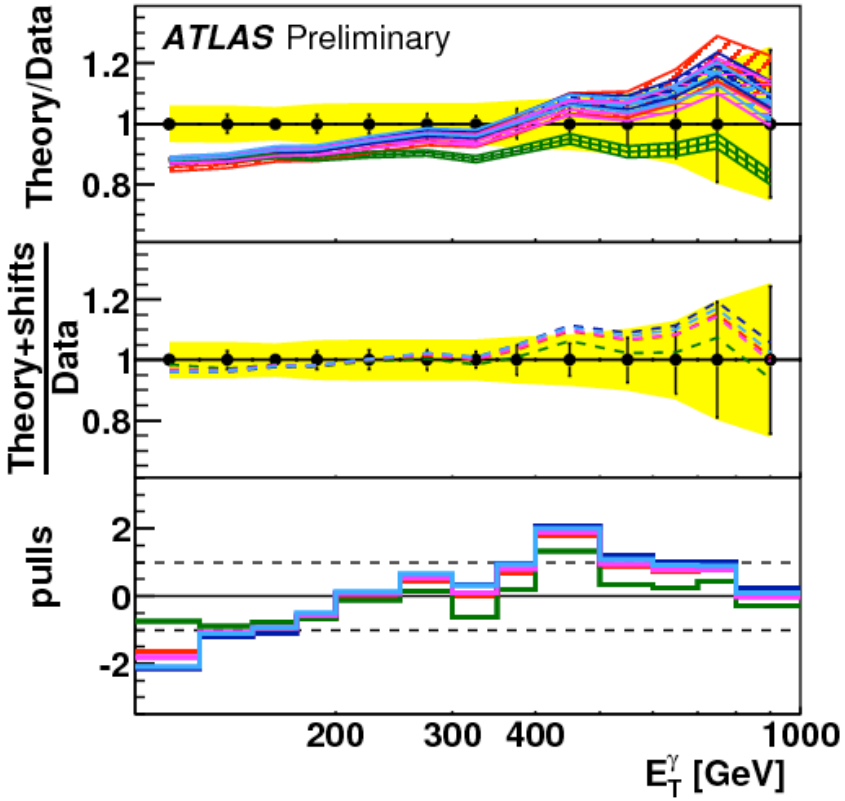


arXiv:1603.09222

Photons & Proton Structure

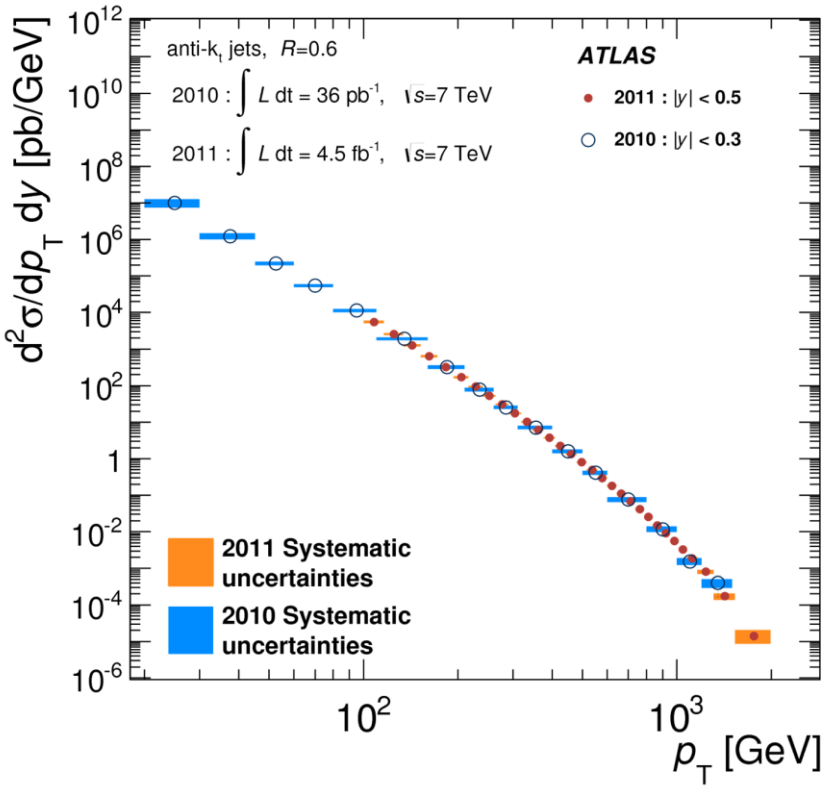
ATL-PHYS-PUB-2013-018

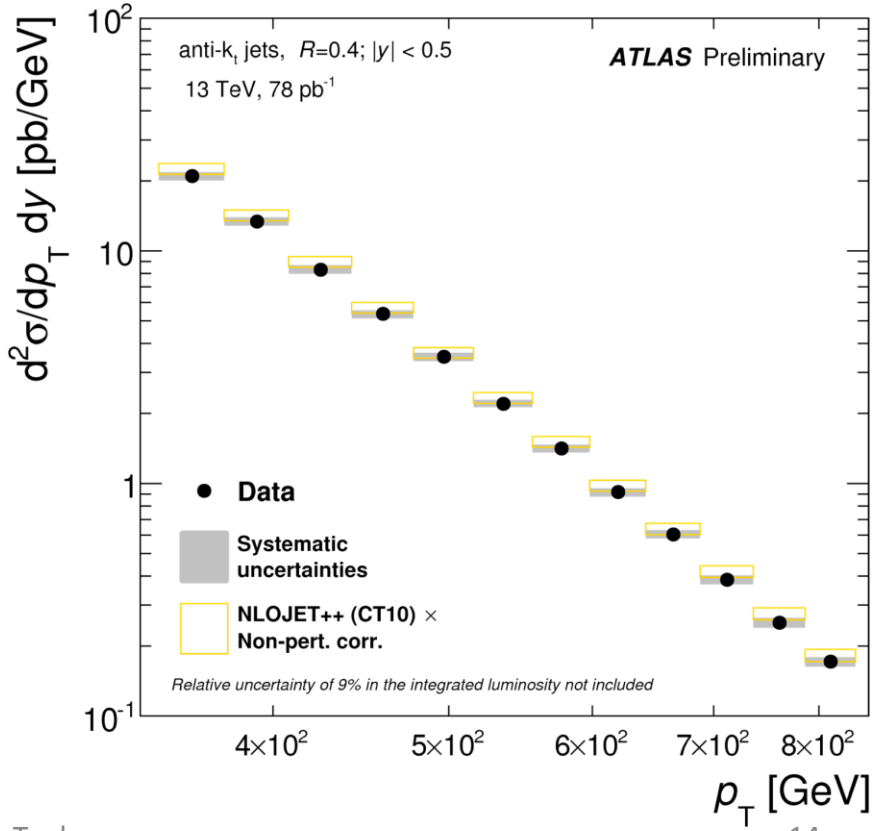




Jet production

- Jets measured over a very wide kinematic range (20 GeV < p_T < ~2 TeV)
- Strong coupling and PDF constraints





Angular coefficients of lepton pairs in Z events

ATLAS STDM-2014-10
Phys. Lett. B750 (2015) 154

in Z rest frame:

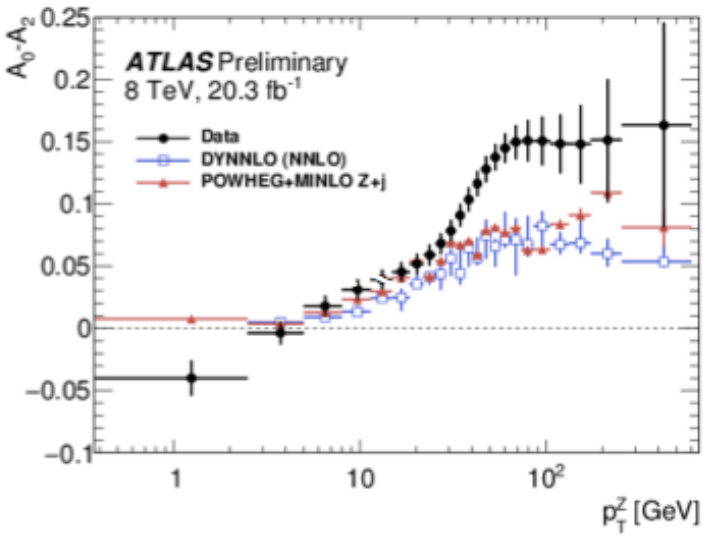
$$\frac{d^2\sigma}{d\cos\theta^* d\phi^*} \propto \left[(1+\cos^2\theta^*) + A_0\frac{1}{2}(1-3\cos^2\theta^*) + A_1\sin(2\theta^*)\cos\phi^* + A_2\frac{1}{2}\sin^2\theta^*\cos(2\phi^*) + A_3\sin\theta^*\cos\phi^* + A_4\cos\theta^* + A_5\sin^2\theta^*\sin(2\phi^*) + A_6\sin(2\theta^*)\sin\phi^* + A_7\sin\theta^*\sin\phi^*\right].$$

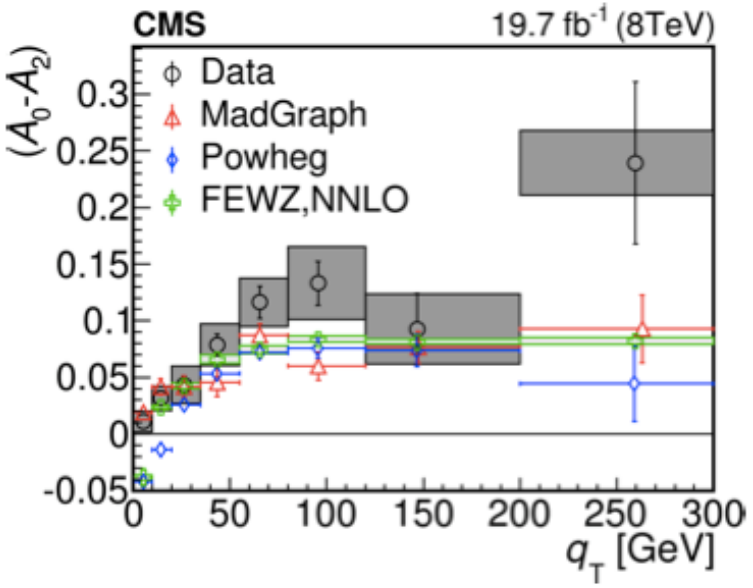
θ* and φ* : polar and azimuthal angles of negative lepton in the rest frame of Z

A_0 -A_7 eight angular coefficients, A_0 -A_2 related to polarization of Z

→ A_5 -A_7 measured for the first time by ATLAS

A_0−A_2:very sensitive to higher order effects: Lan-Tung Relation (NLO) predicts it to be 0

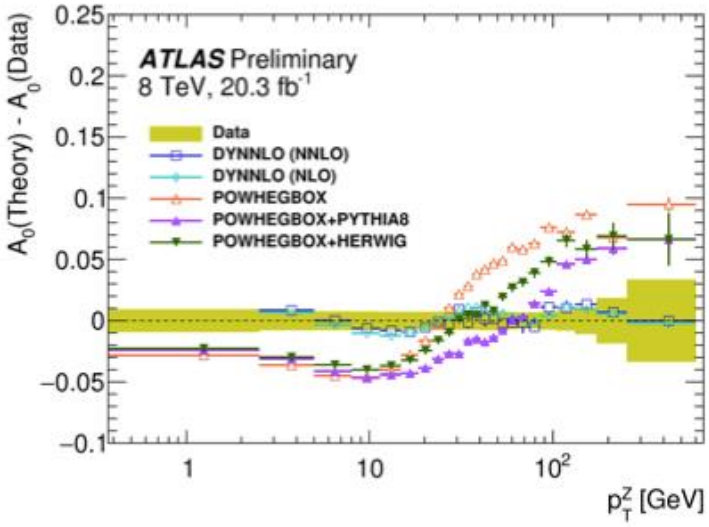


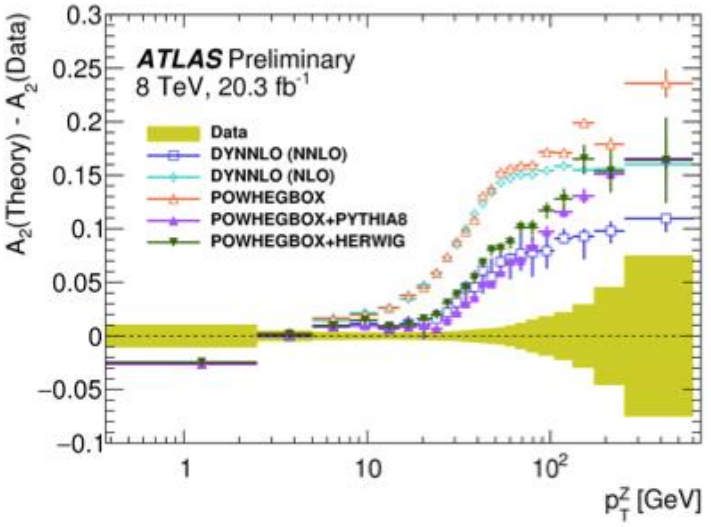


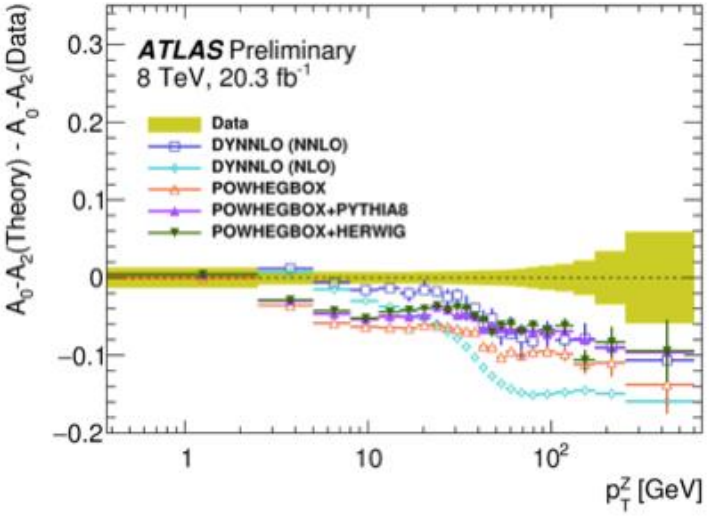
A_0−A_2significant difference to O(α^2_s)

→ higher-order corrections needed

Comparison with theory



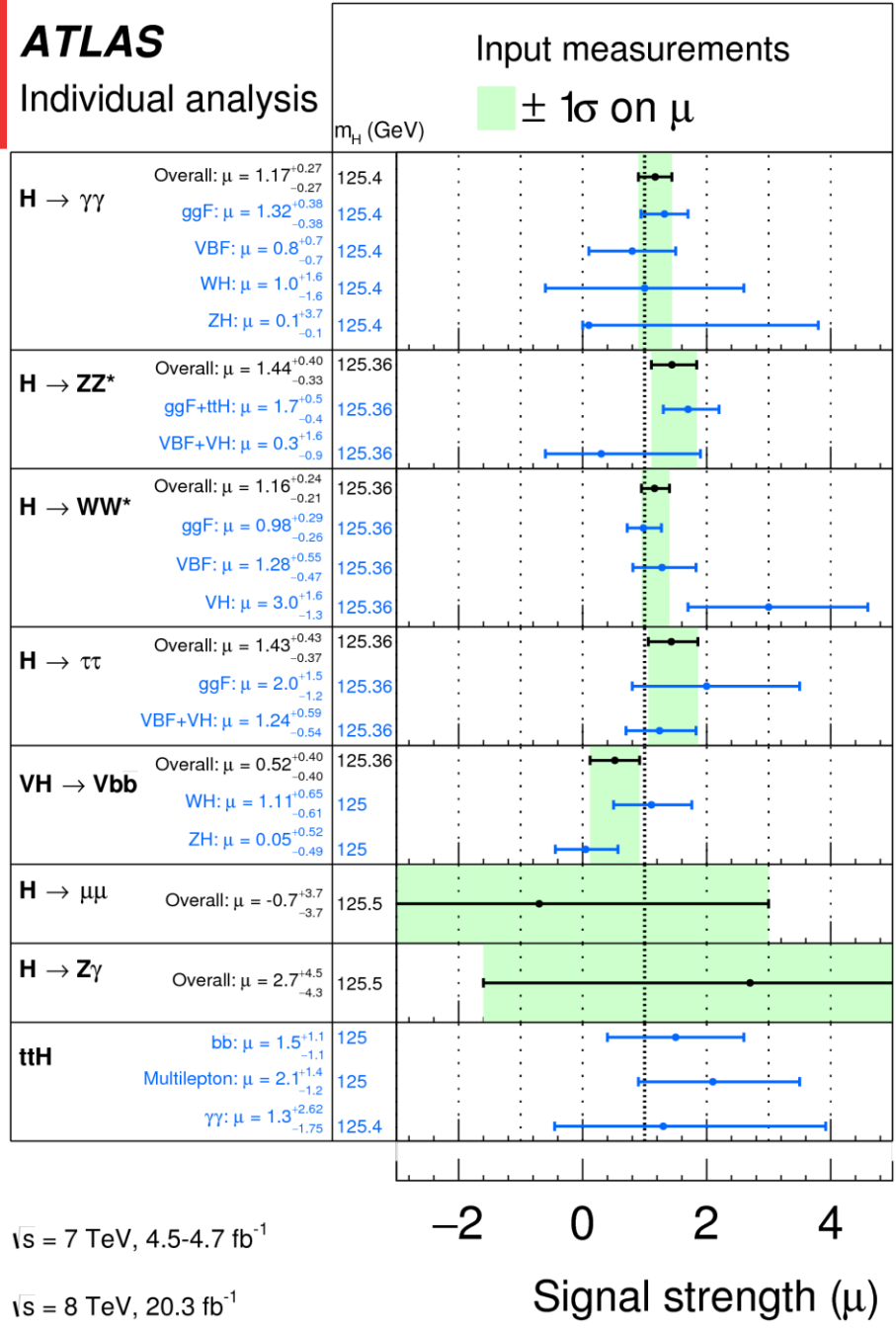




- For A_0 PowHeg shows worse result due to cutoffs in b-quark mass and treatment of Sudakov form factors
- A_2 show sensitivity to parton shower implementation (Pythia8 vs Herwig)

Higgs

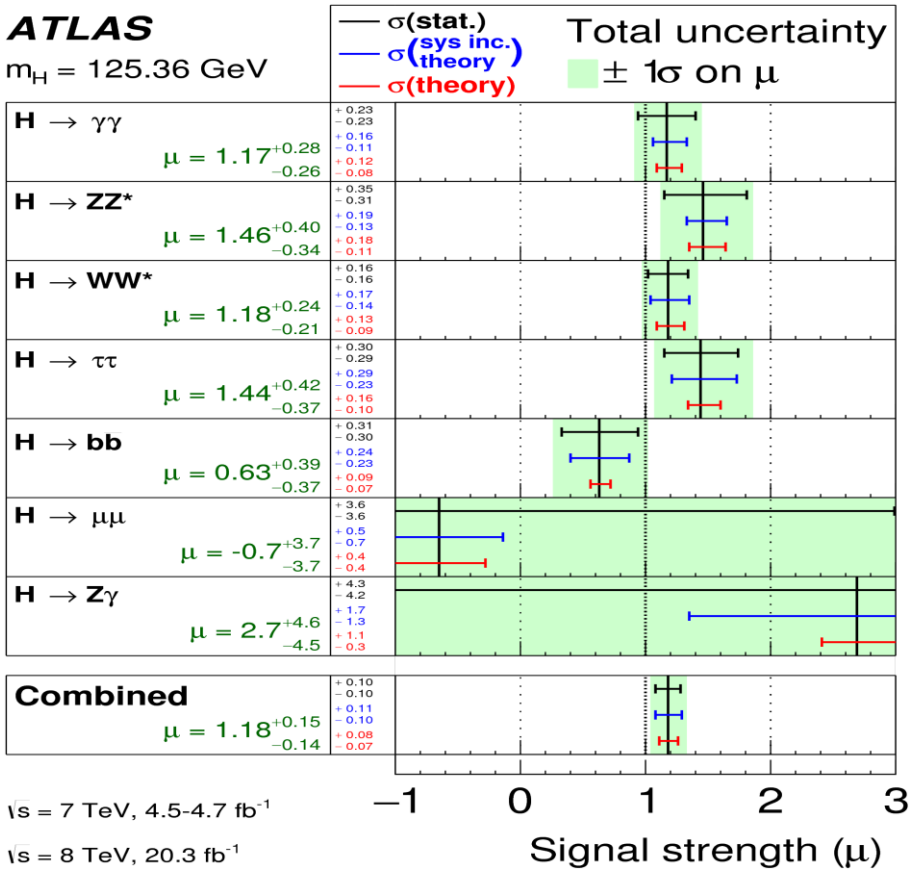
- Couplings/decay rates

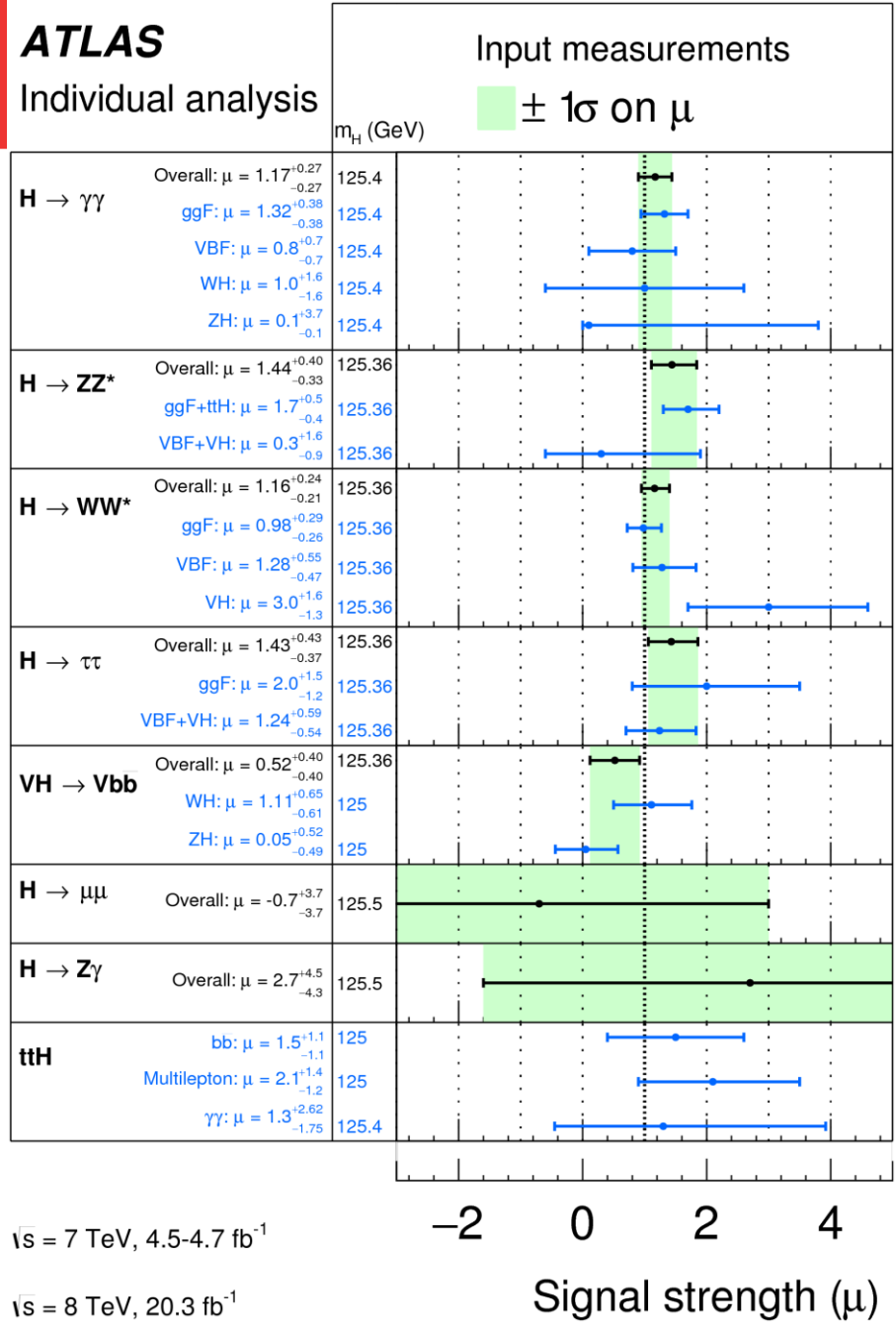


arXiv:1412.8662
arXiv:1507.04548

Higgs

- Couplings/decay rates



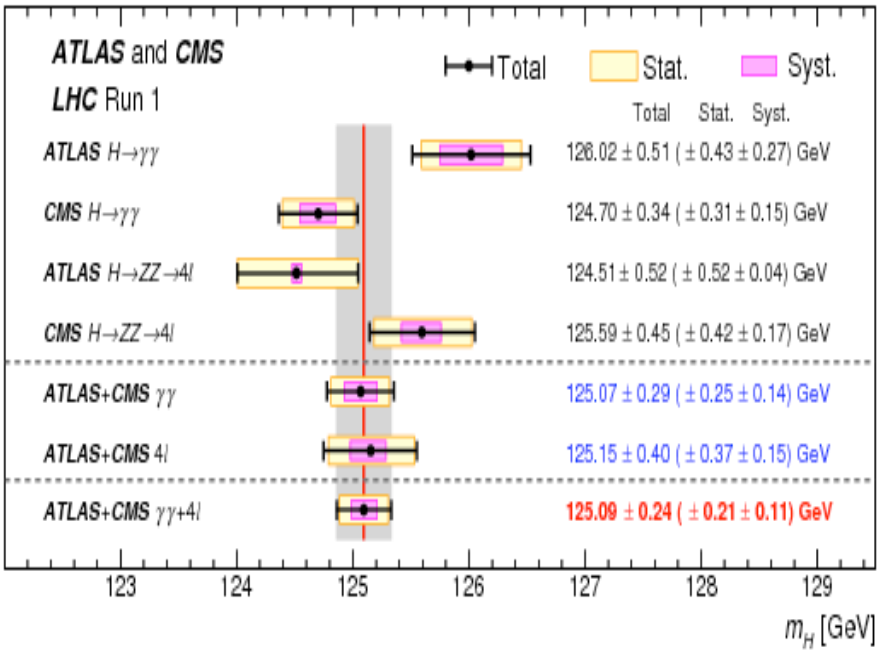


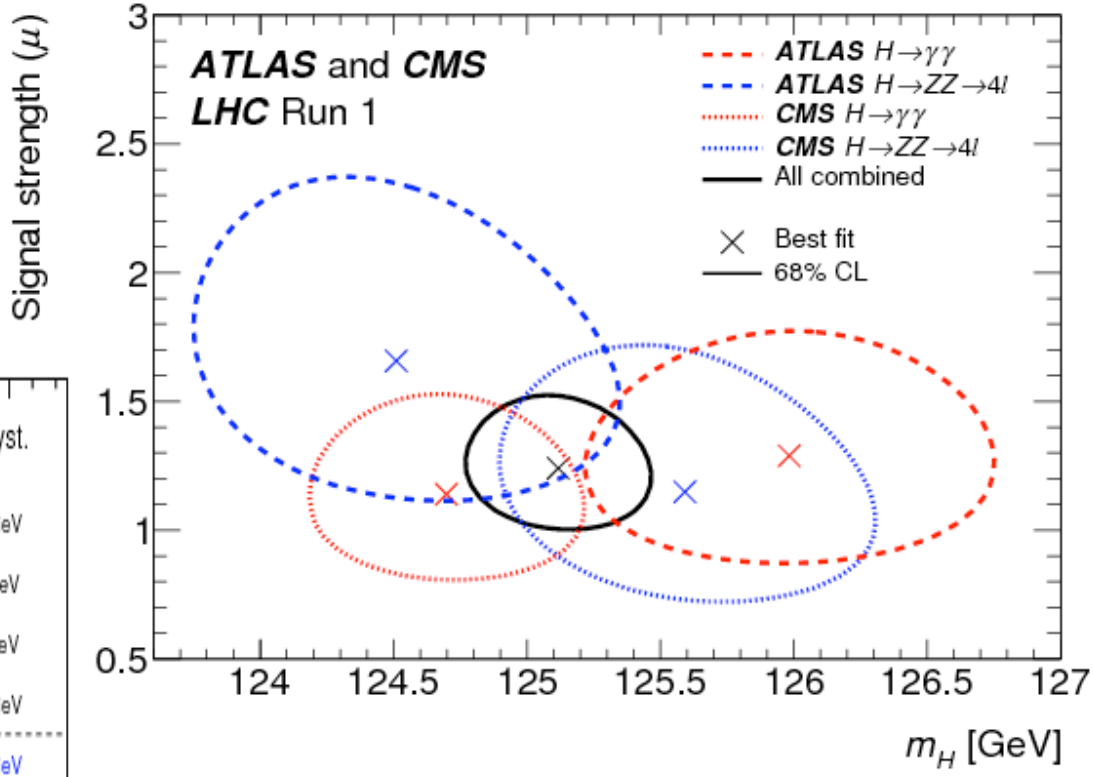
arXiv:1412.8662

arXiv:1507.04548

Higgs

- Mass

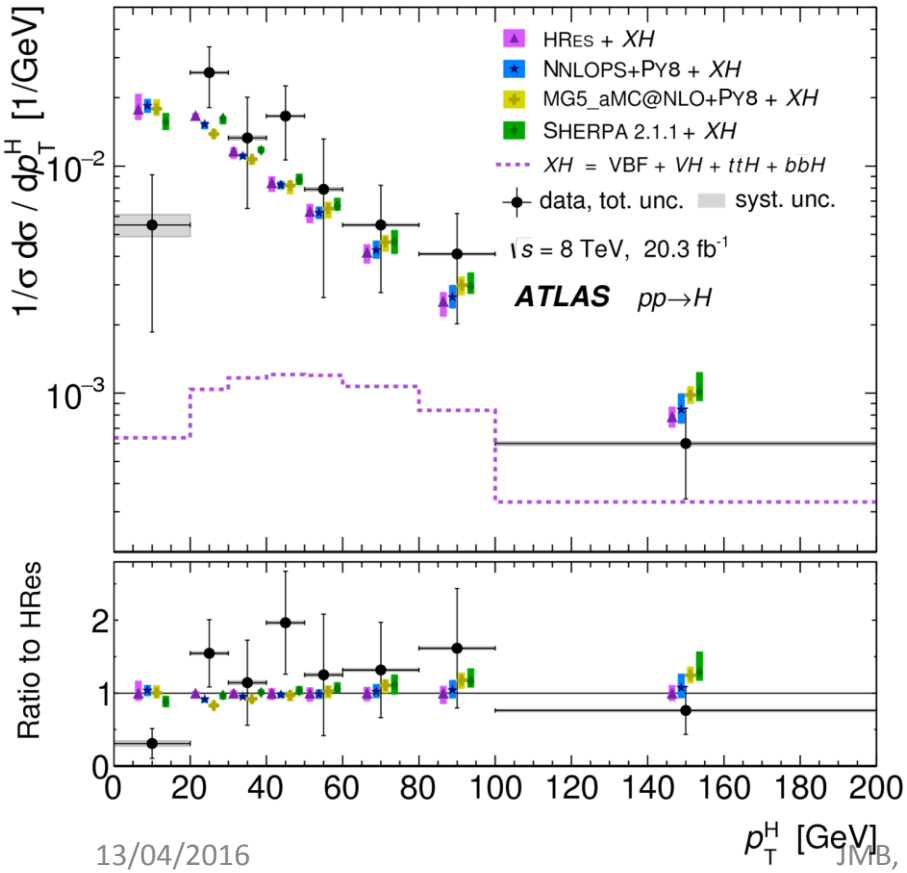


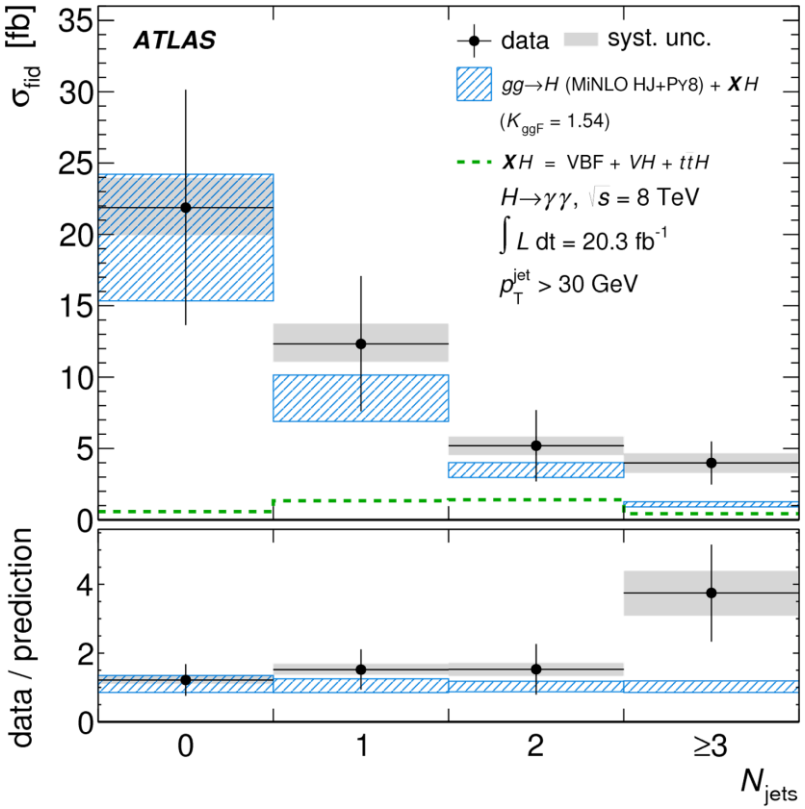


arXiv:1503.07589

Higgs

- Differential and fiducial cross sections



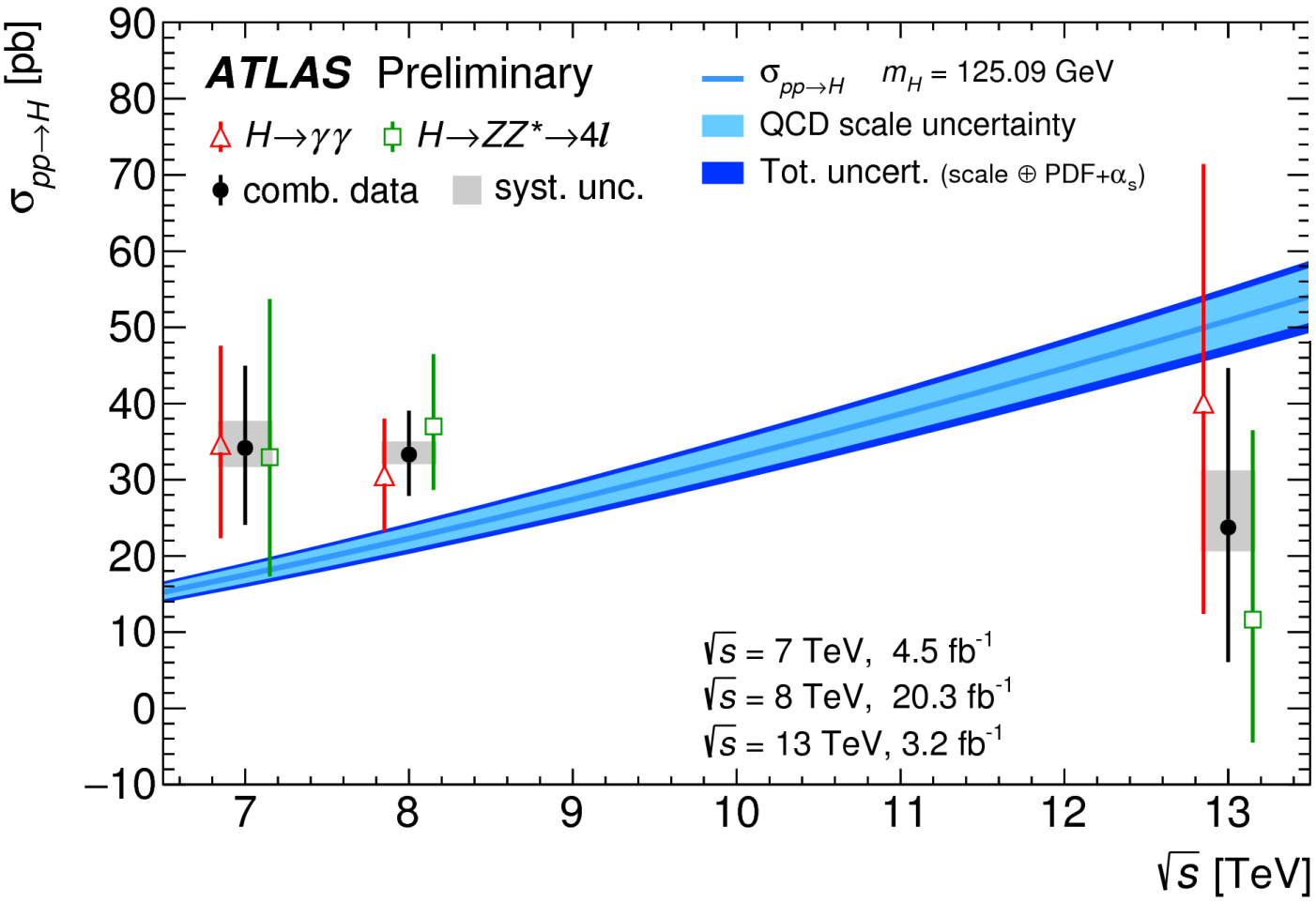


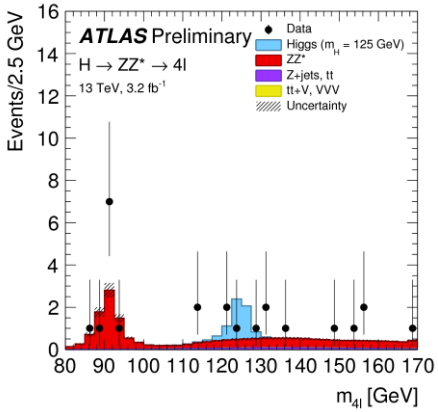
arXiv:1407.4222
arXiv:1408.3226
arXiv:1504.05833

Higgs

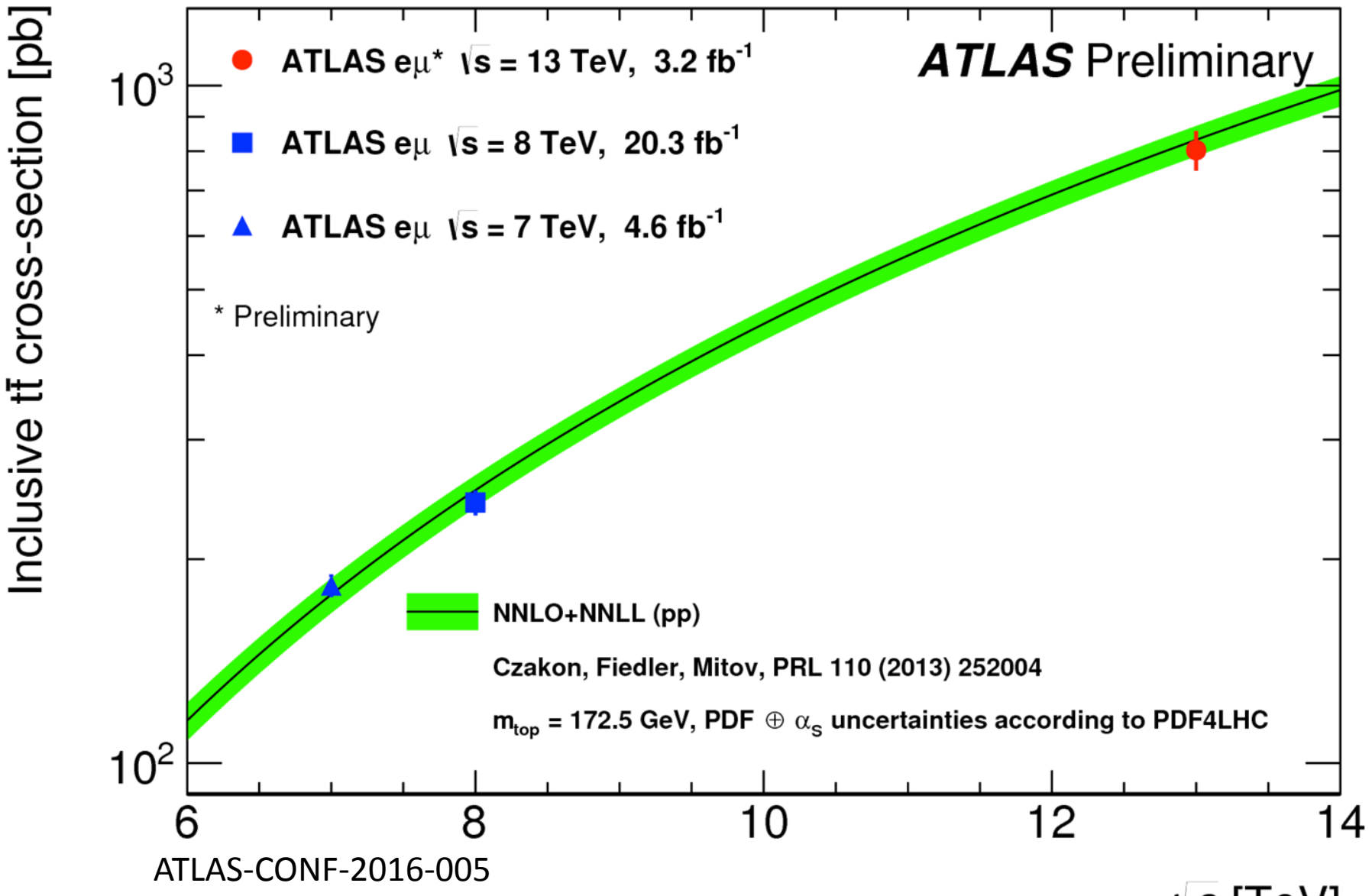
- Couplings/decay rates
- Mass
- Differential and fiducial cross sections
- Spin, CP, etc…
- Searches for more bosons
- Di-Higgs searches

Higgs @ 13 TeV


ATLAS Preliminary
$H\to\gamma\gamma$ $H\to ZZ^*\to 4l$
comb. data syst. unc.
$\sigma_{pp\to H}$ m_H = 125.09 GeV
QCD scale uncertainty
Tot. uncert. (scale ⊕ PDF+α_s)
$\sqrt{s}$ = 7 TeV, 4.5 fb^{-1}
$\sqrt{s}$ = 8 TeV, 20.3 fb^{-1}
$\sqrt{s}$ = 13 TeV, 3.2 fb^{-1}
$\sigma_{pp\to H}$ [pb]
$\sqrt{s}$ [TeV]


ATLAS Preliminary
Data
Higgs (m_H = 125 GeV)
ZZ*
Z+jets, tt
tt+V, VVV
Uncertainty
H → ZZ* → 4l
13 TeV, 3.2 fb^{-1}
Events/2.5 GeV
m_{4l} [GeV]

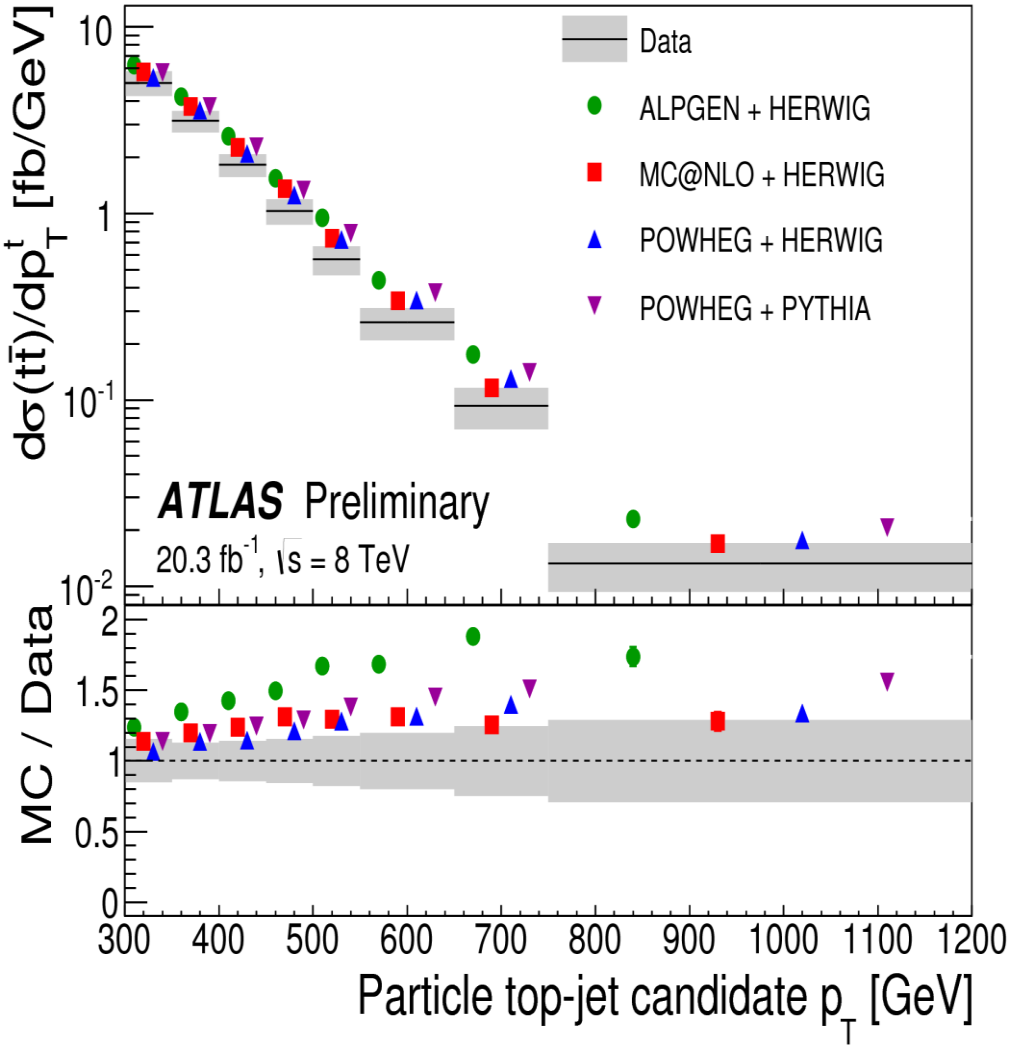
Top



ATLAS-CONF-2016-005

Top

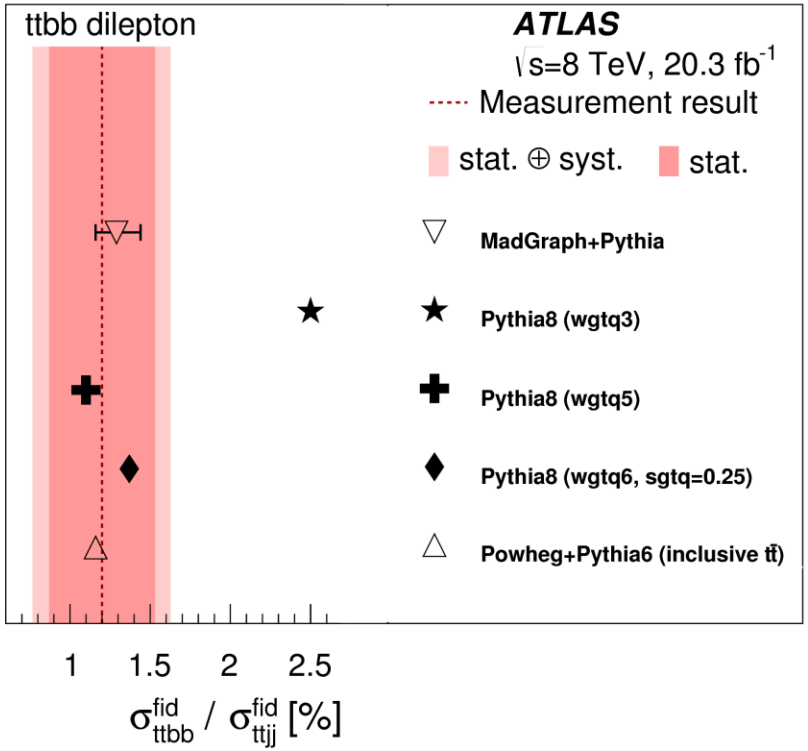
- Many precision measurements.
- Starting to include fiducial & differential results:
  - Build cross sections out of final-state particles
  - Top-jet cross sections from ATLAS & CMS



ATLAS-CONF-2014-057

Top

- Many precision measurements.
- Starting to include fiducial & differential results:
  - Build cross sections out of final-state particles
  - Top-jet cross sections from ATLAS & CMS
  - Top + (b) jets



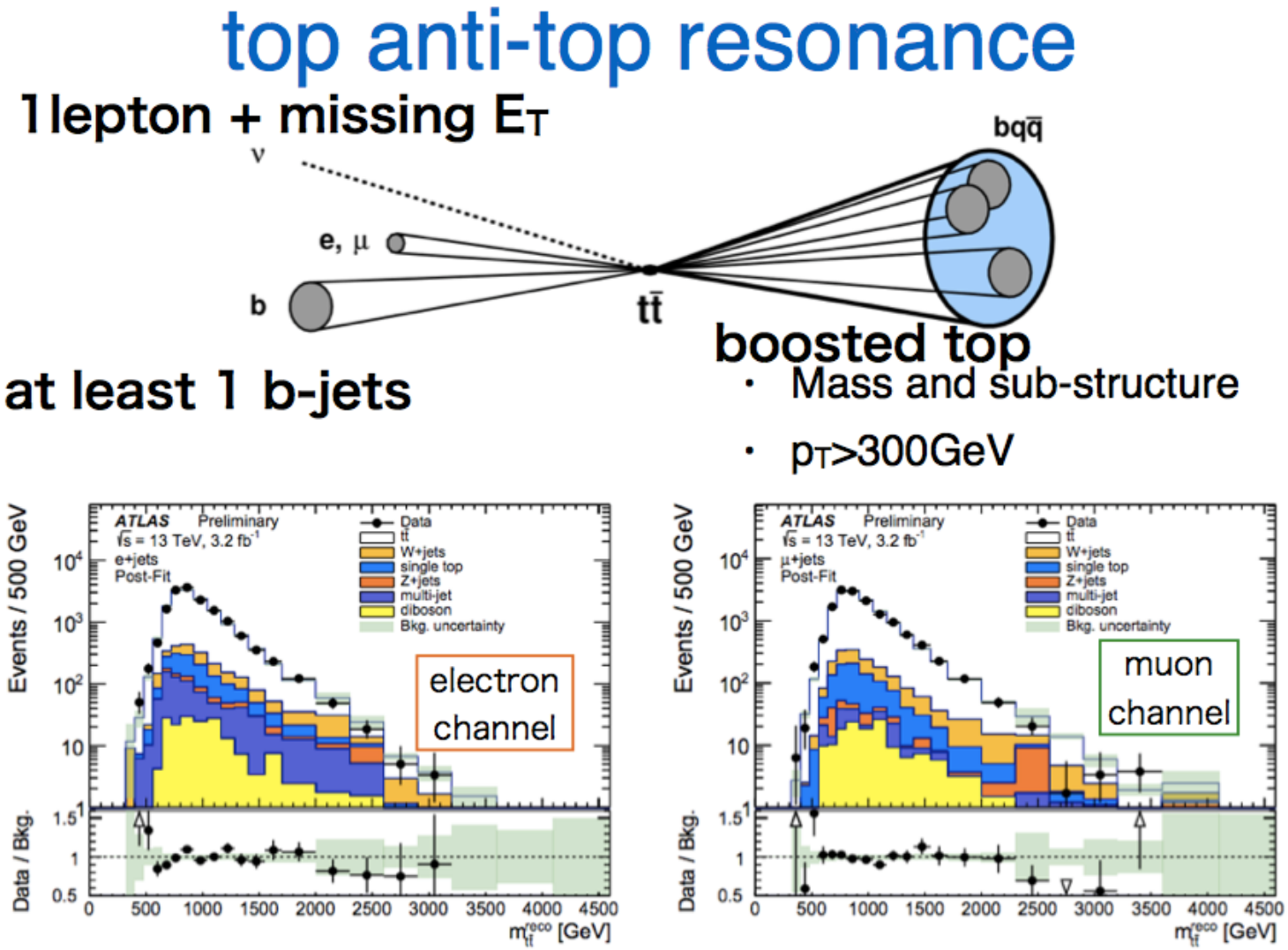
arXiv:1508.06868

Inside jets

- Understanding jet substructure is critical for physics above the electroweak symmetry breaking scale (examples – previous top results, resonance searches, boosted hadronic W/Z)
- Fortunately QCD is up to the job, as are the experiments.
- See Boost 2015 for status… Measurements in dijets, W+jets, hadronic W, Z->bb…

Inside jets… Searching

- Many searches for SUSY and other BSM signatures
- (slide from T.Nobe, La Thuile)



Inside jets… Searching

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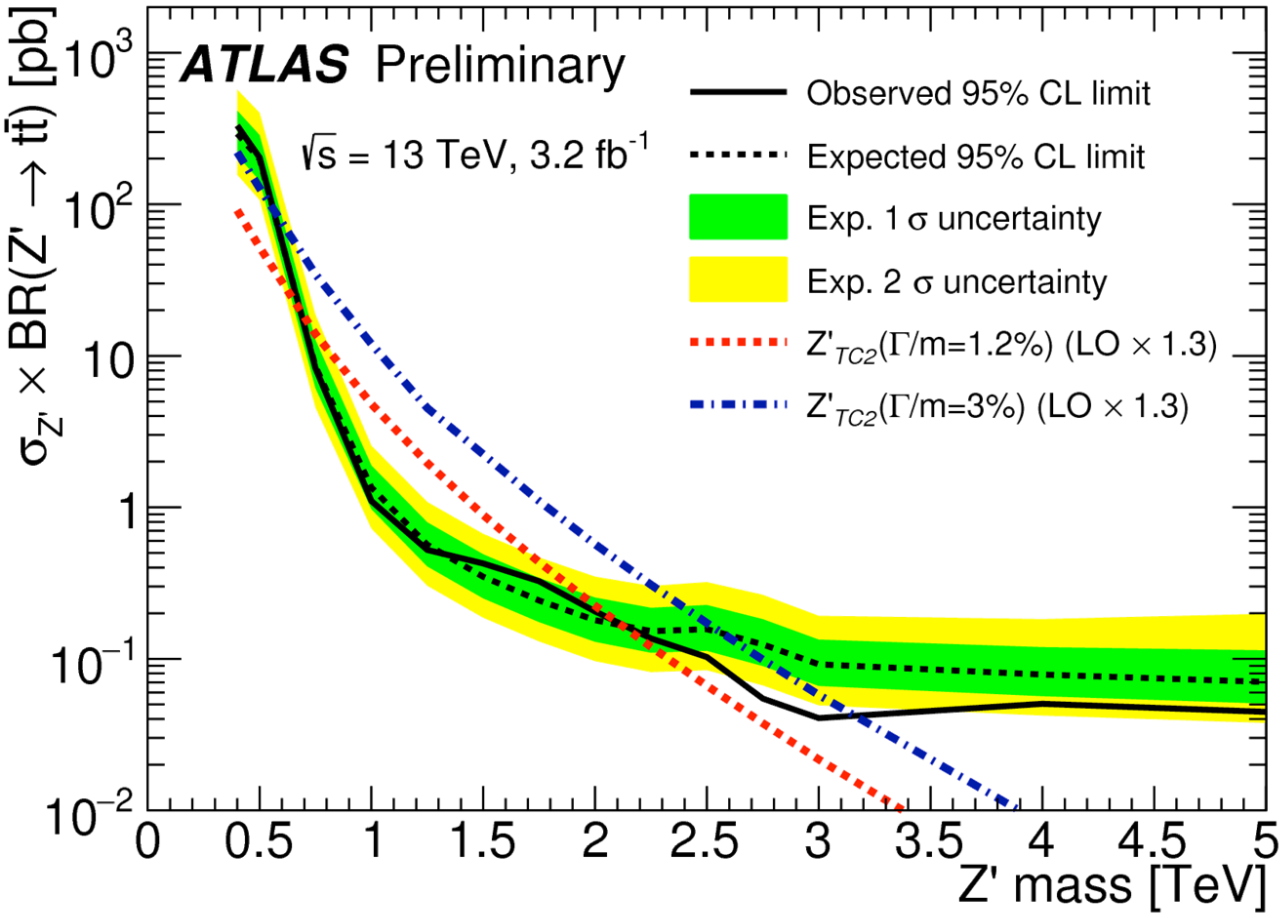
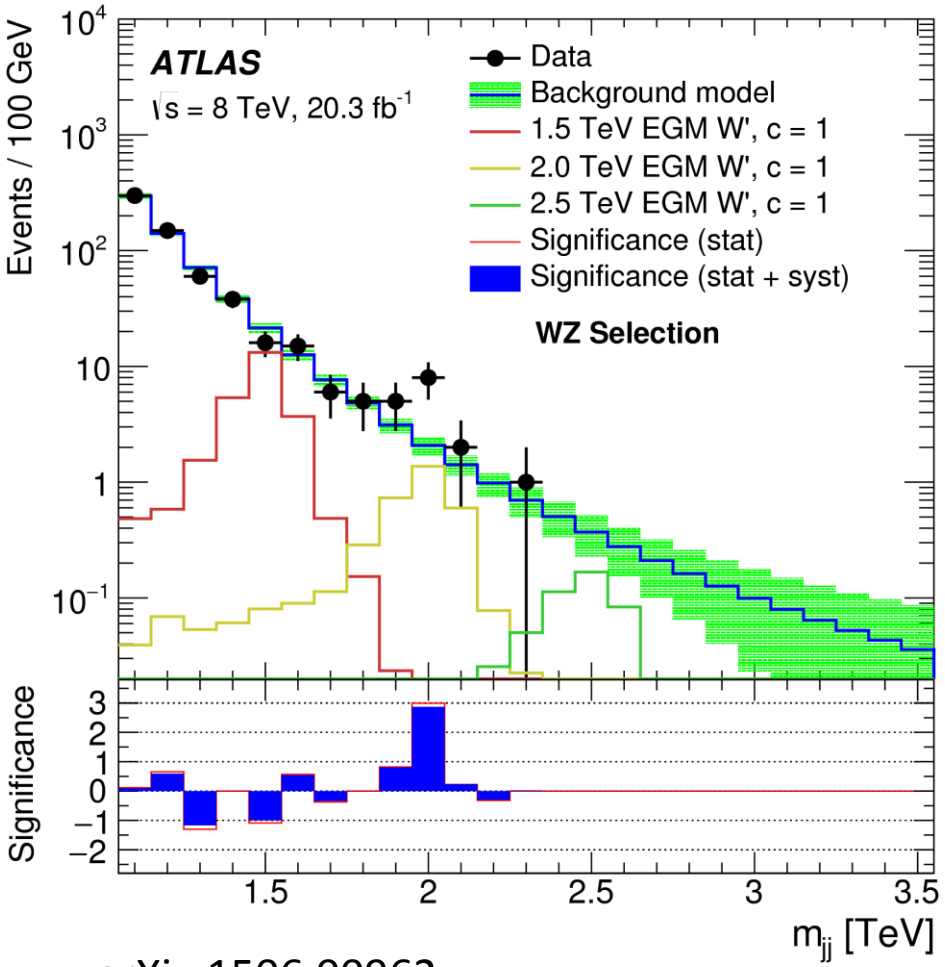


Inside jets

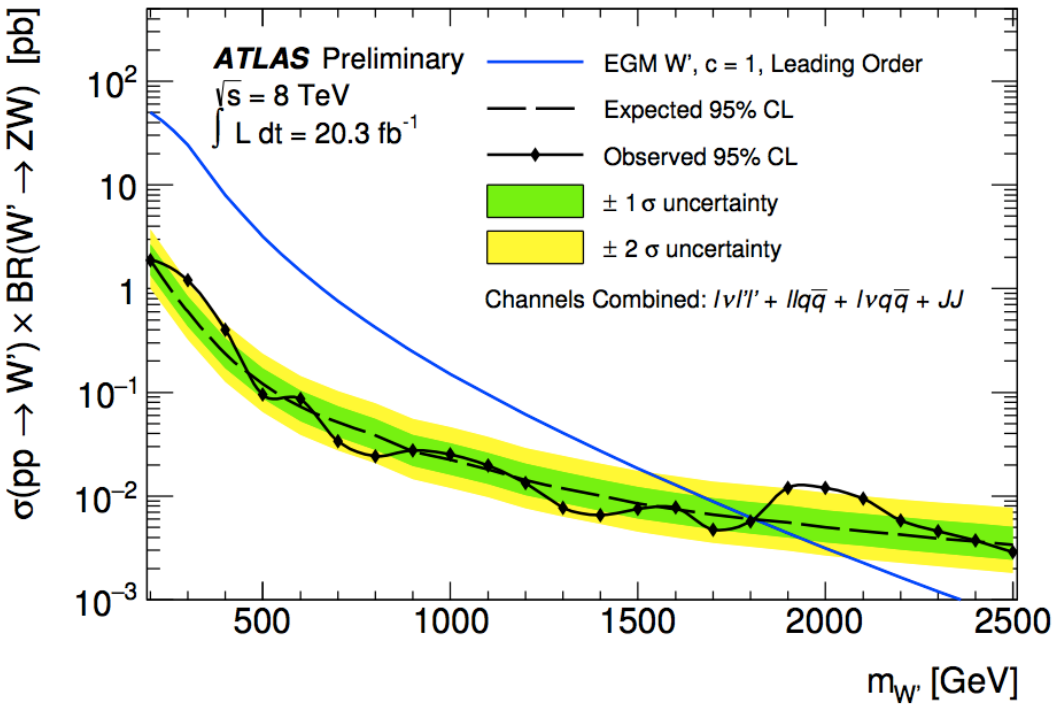
- Example – fully hadronic, boosted WW/WZ/ZZ
- Hints also from CMS, but also some tension with (semi-leptonic results)



arXiv:1506.00962

Combination with leptons

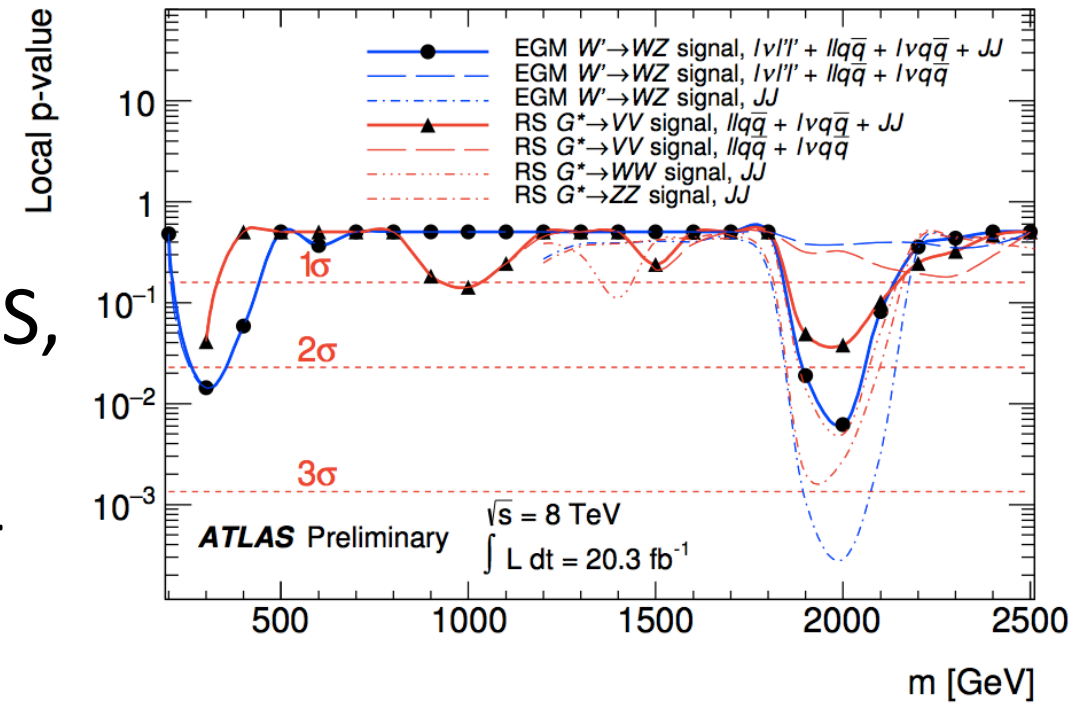
- Example – fully hadronic, boosted WW/WZ/ZZ
- Hints also from CMS, but also some tension with (semi-leptonic results)
- New ATLAS combination with (semi)leptonic channels



ATLAS-CONF-2015-045

Combination with leptons

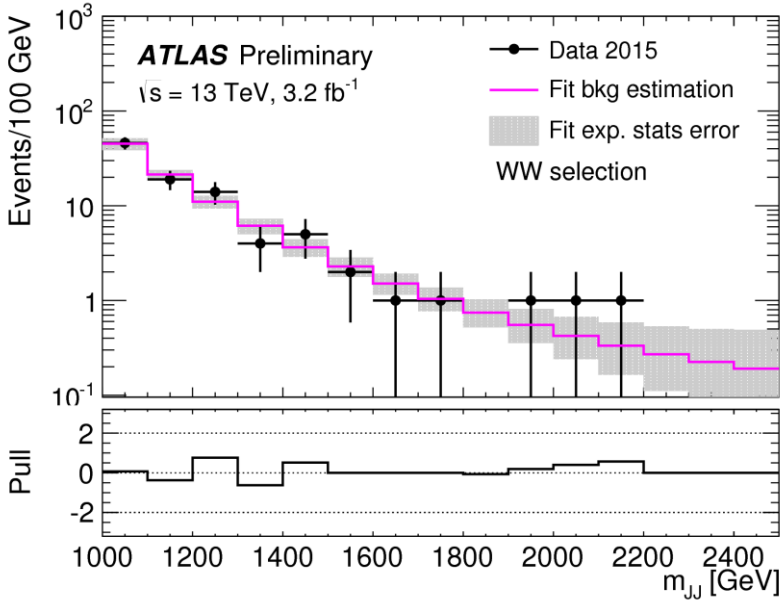
- Example – fully hadronic, boosted WW/WZ/ZZ
- Hints also from CMS, but also some tension with (semi-leptonic results)
- New ATLAS combination with (semi)leptonic channels

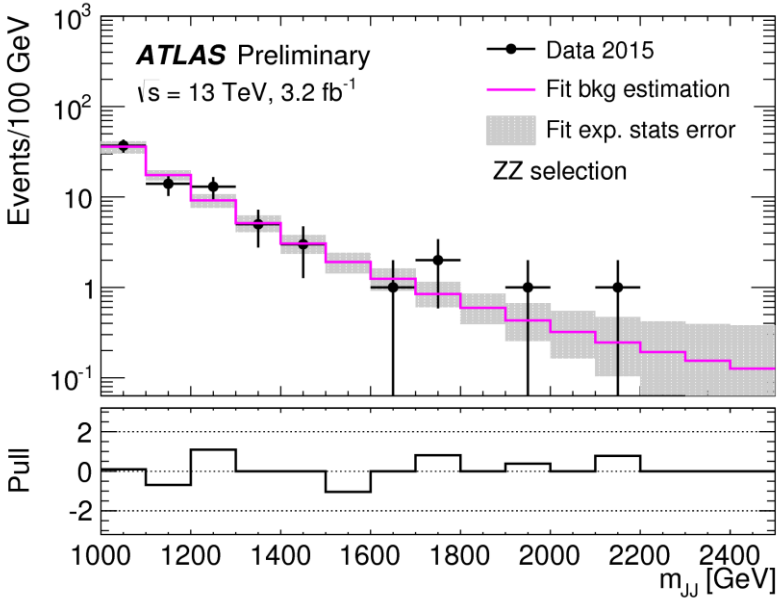


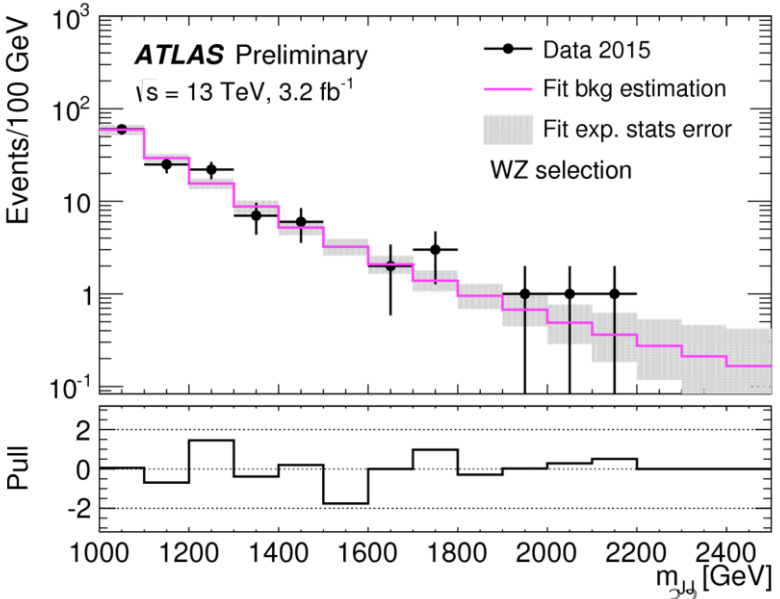
A provocative reminder… we are in unknown territory!

ATLAS-CONF-2015-045

13 TeV Dibosons (jj)

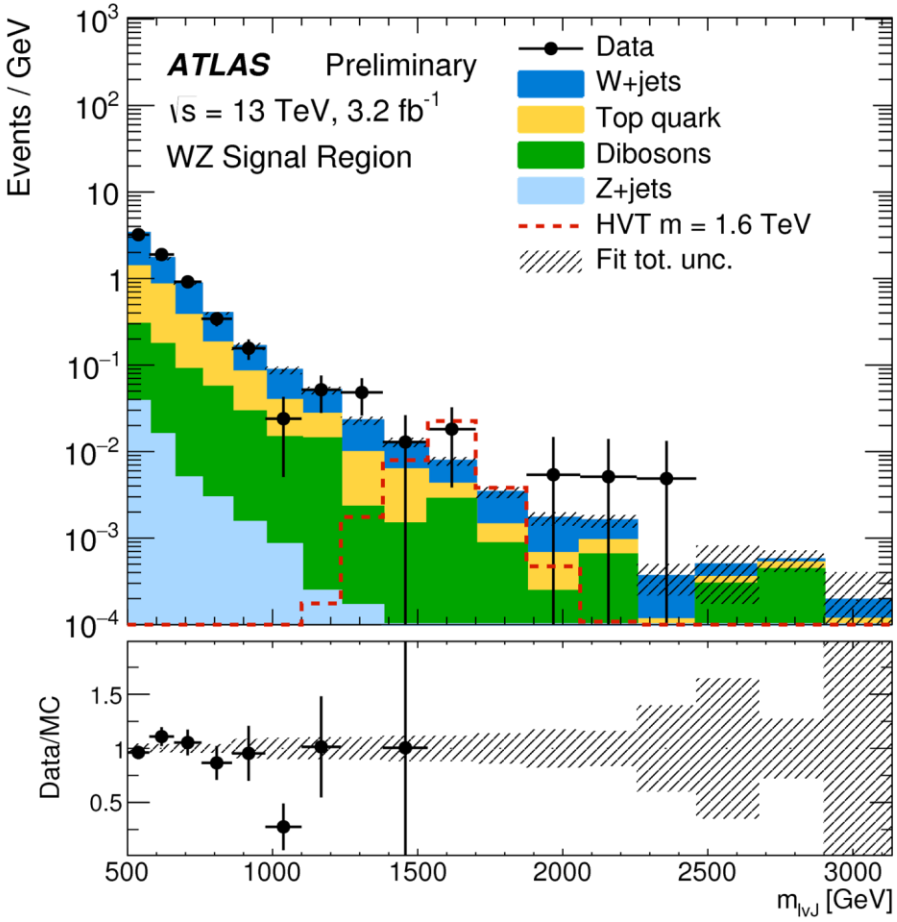


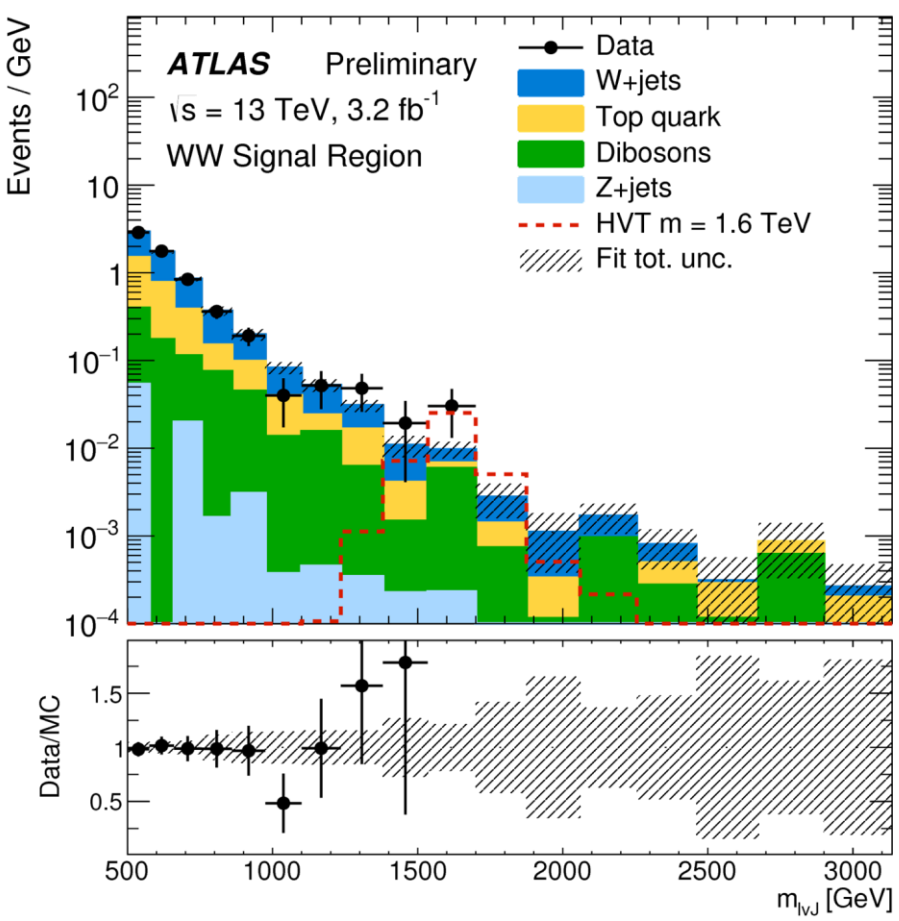




Not quite as exciting… but still pending more data

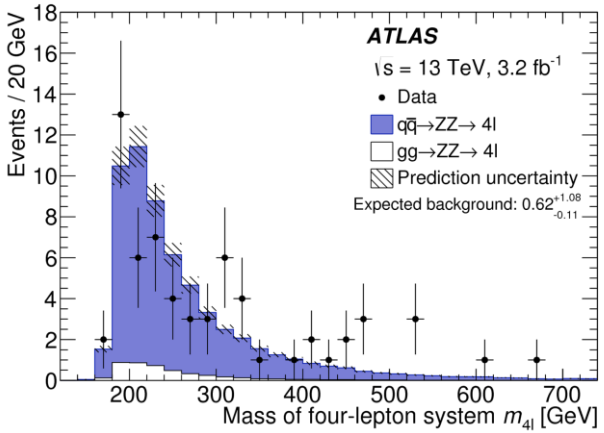
13 TeV Dibosons (lvj)

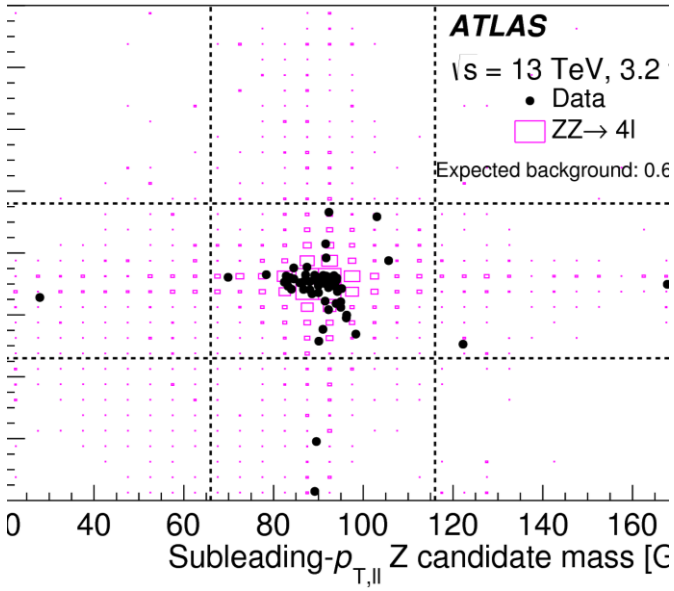


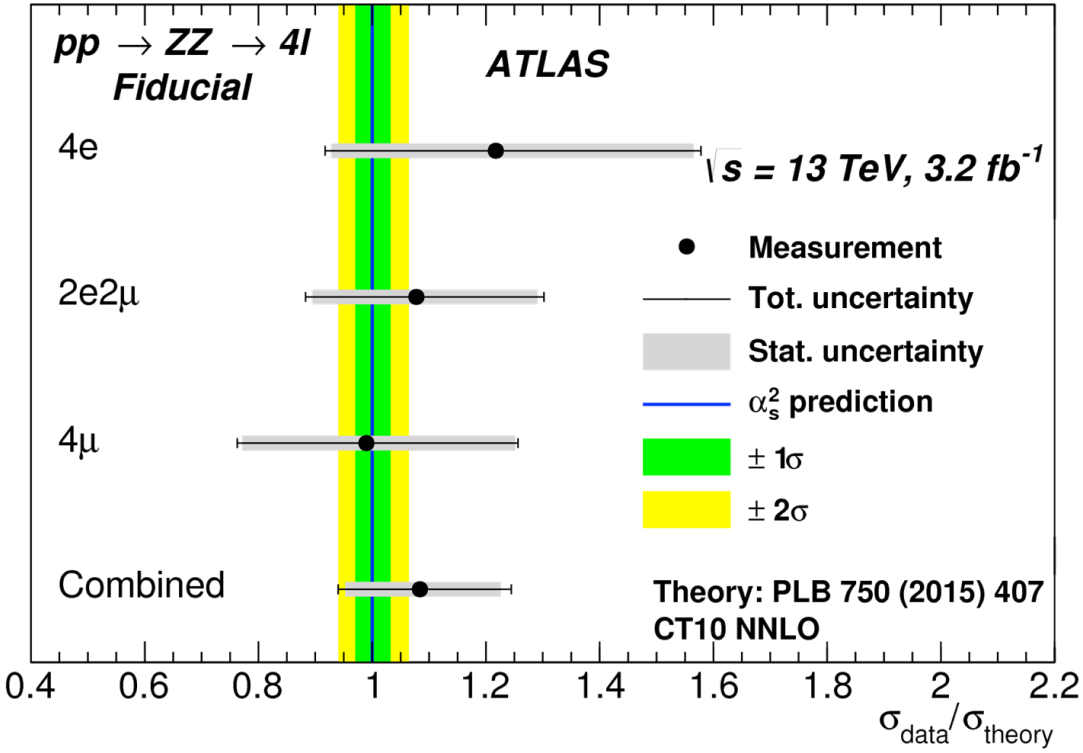


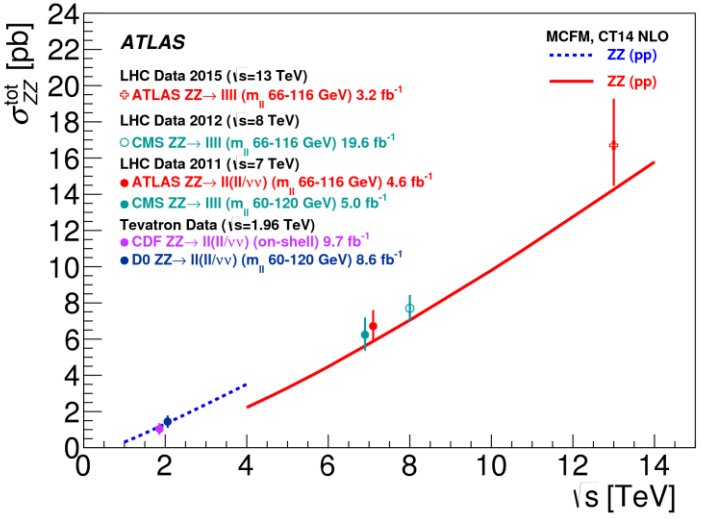
Not quite as exciting… but still pending more data

13 TeV Dibosons: ZZ (4l)





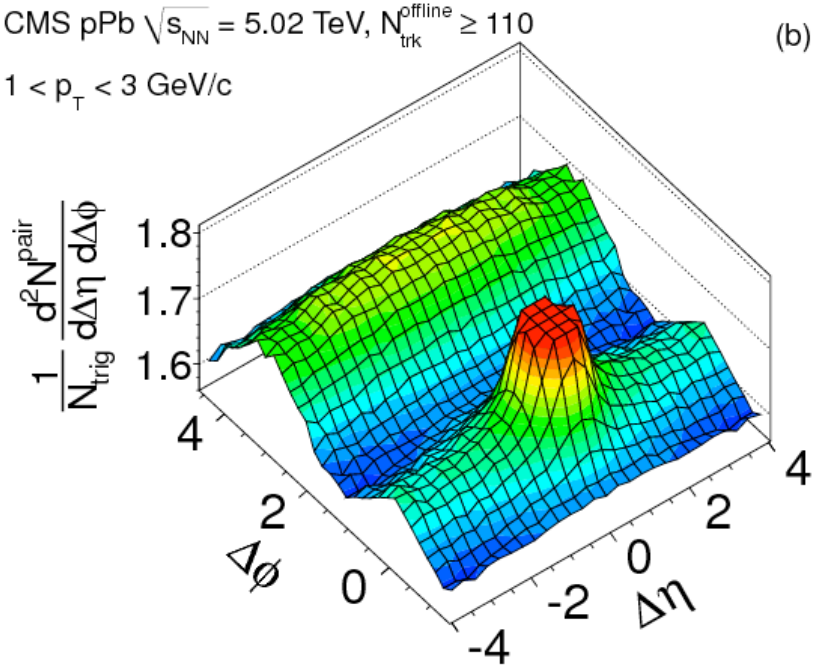




Correlations, Bulk Behaviour?

- Same-side ridge in high multiplicity events, seen by CMS early in Run 1

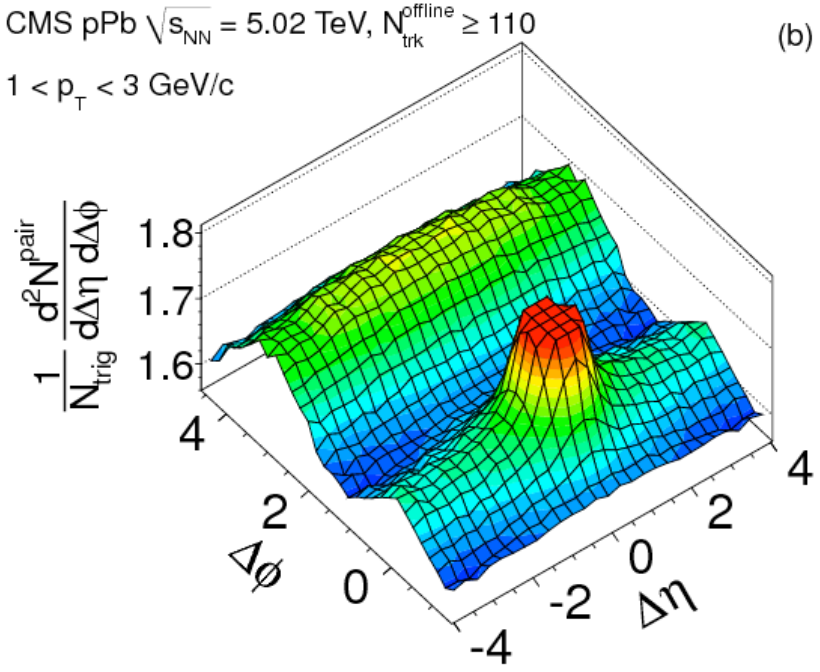
arXiv:1009.4122



Correlations, Bulk Behaviour?

- Same-side ridge in high multiplicity events, seen by CMS early in Run 1
- Also seen by ATLAS now at 13 TeV…

arXiv:1009.4122



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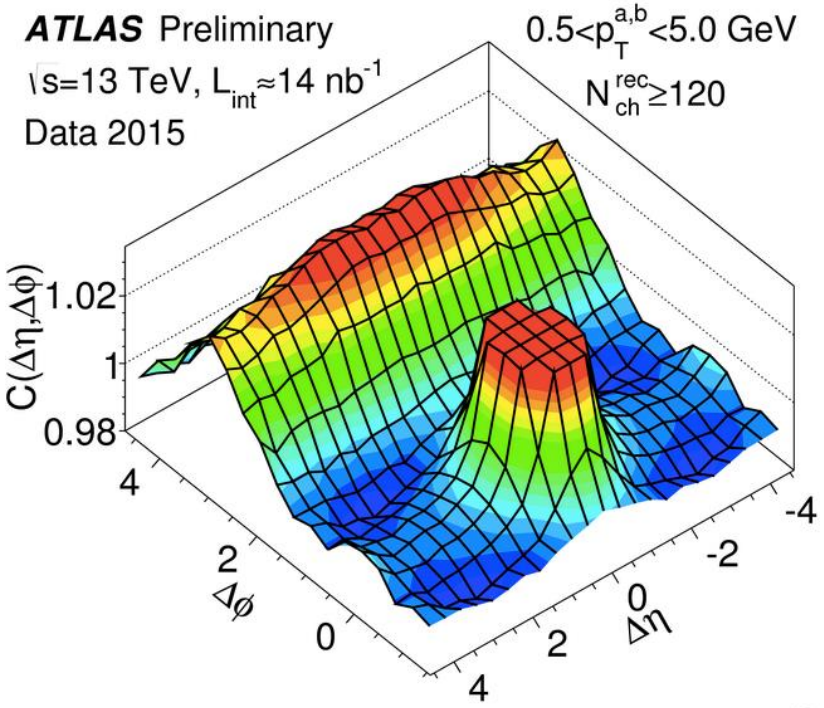
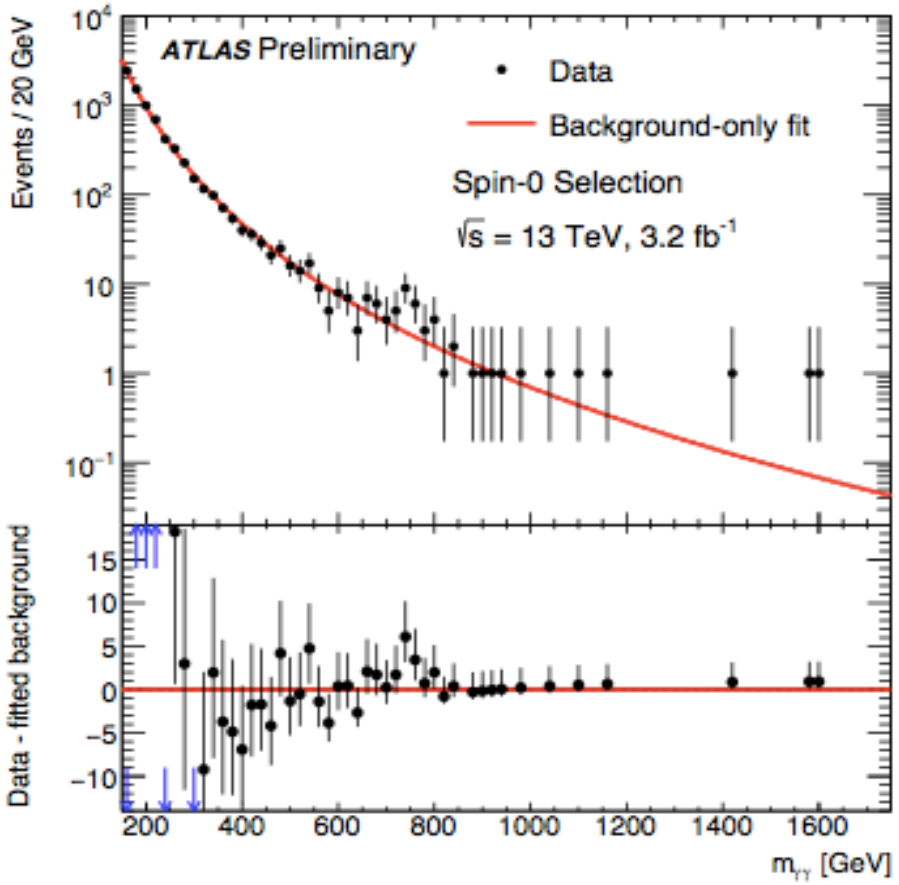


Diphotons

Results

SPIN-0 ANALYSIS

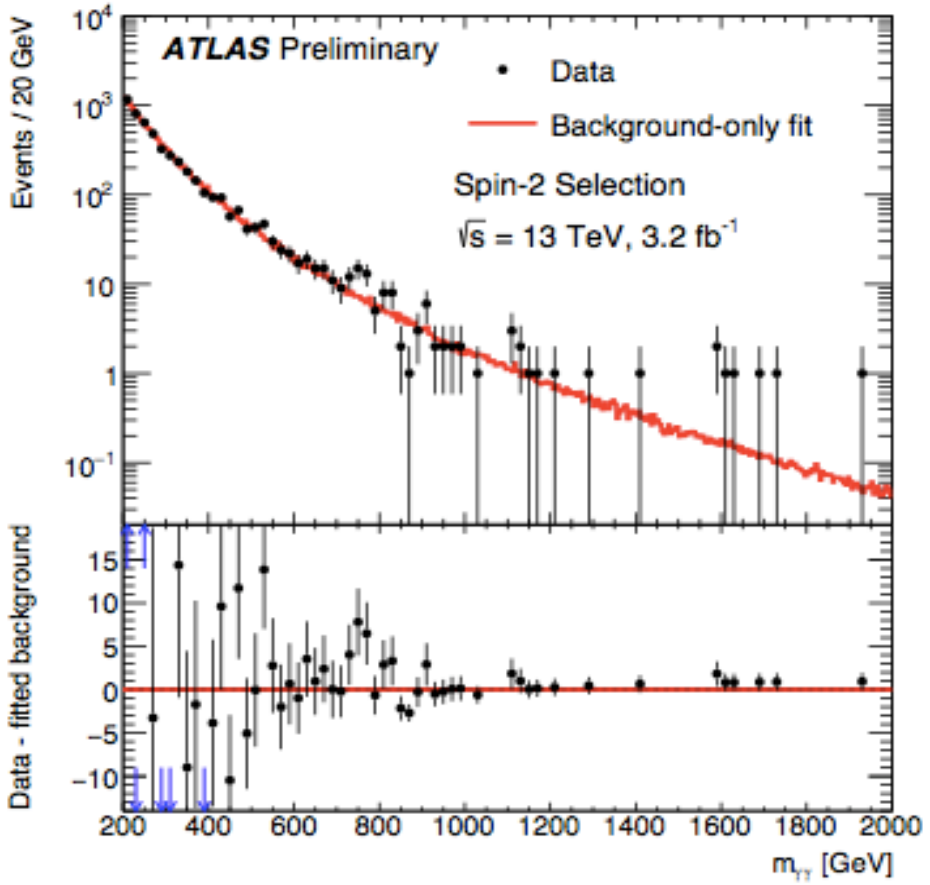
background-only fit



2878 events (m_{YY} > 200 GeV)

SPIN-2 ANALYSIS

background-only fit

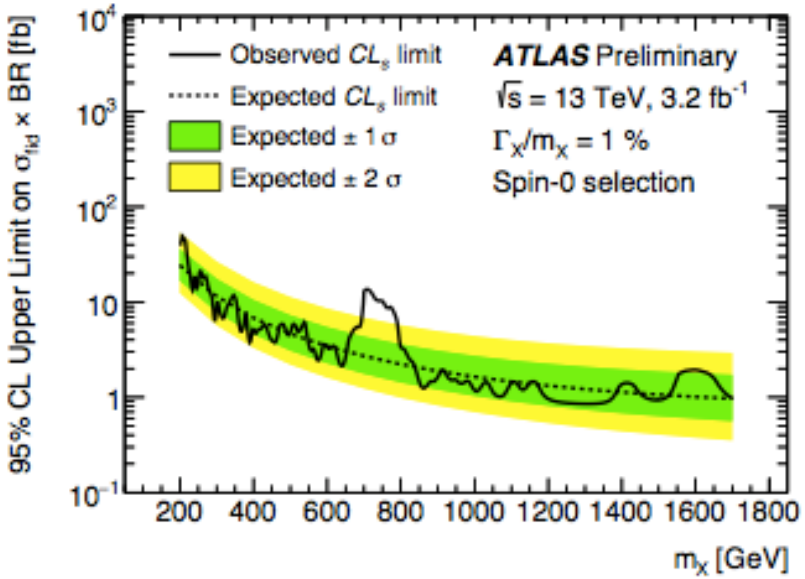


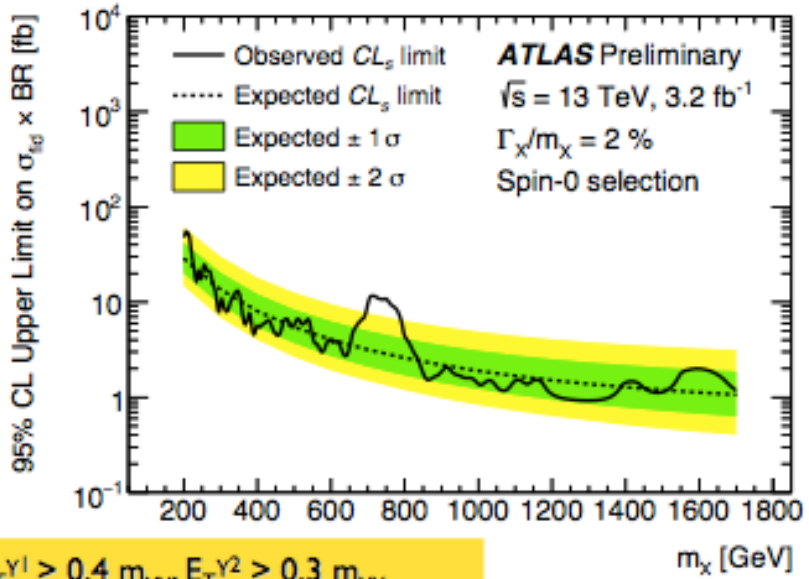
5066 events (m_{YY} > 200 GeV)

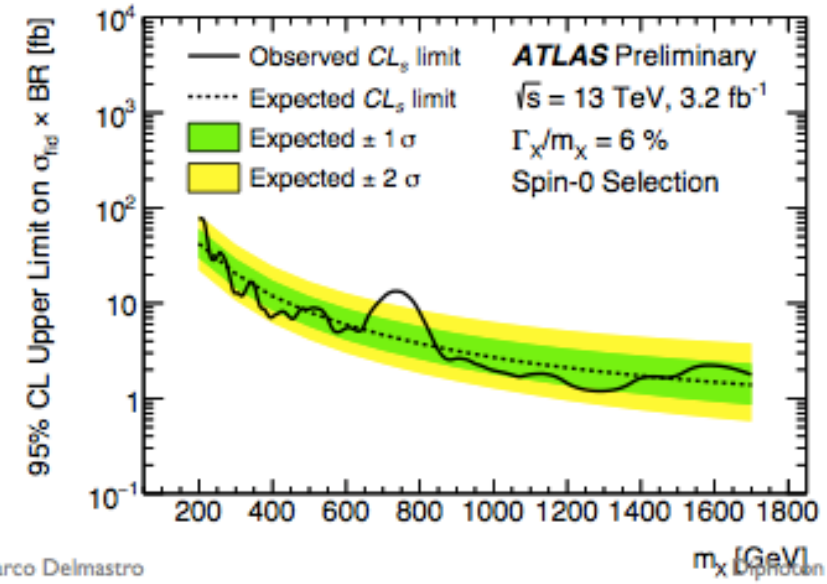
Diphotons

Limit on fiducial cross-section

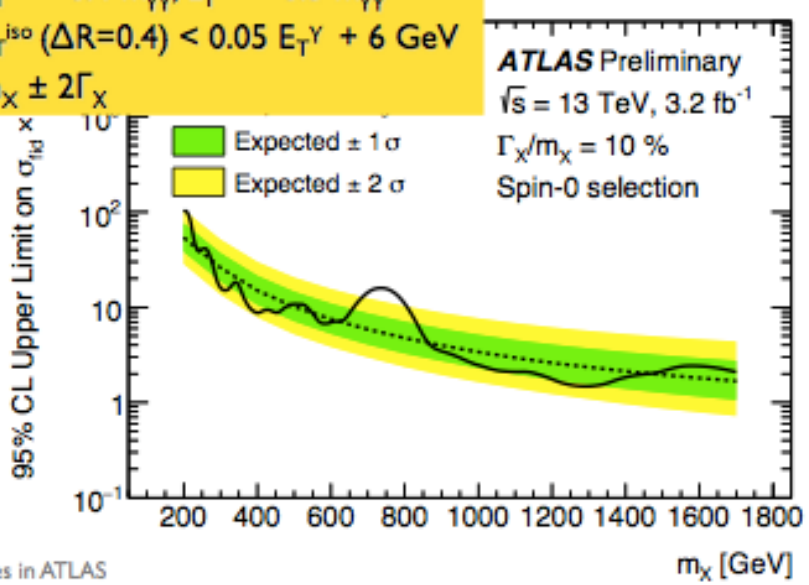
SPIN-0 ANALYSIS







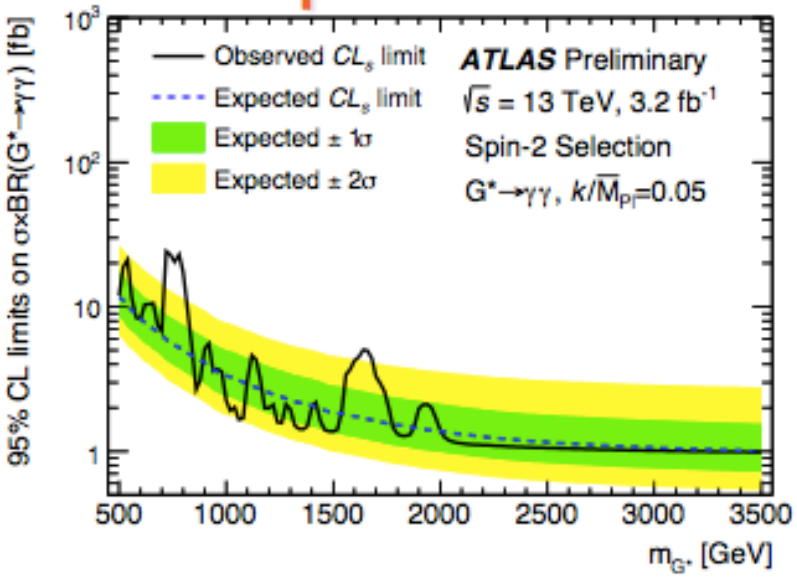
$E_T^{\gamma 1} > 0.4\ m_{\gamma\gamma}$, $E_T^{\gamma 2} > 0.3\ m_{\gamma\gamma}$
$E_T^{iso}\ (\Delta R=0.4) < 0.05\ E_T^{\gamma} + 6$ GeV
$m_X \pm 2\Gamma_X$

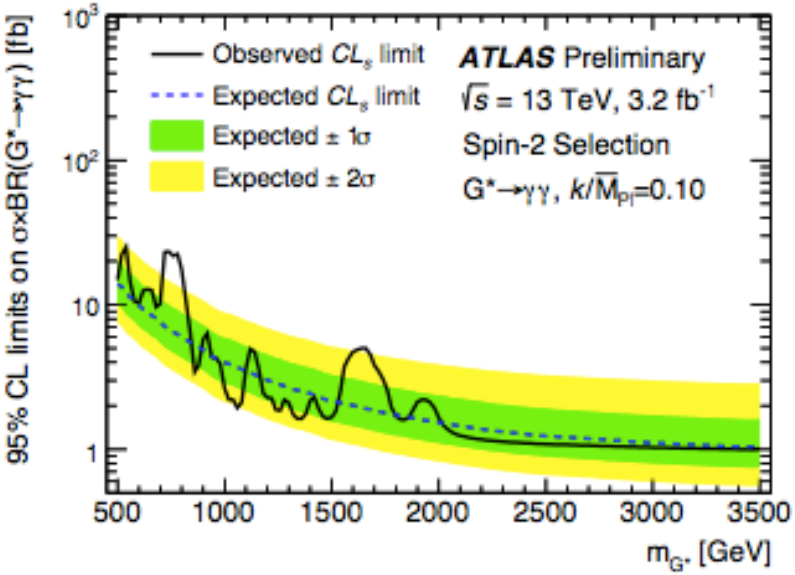


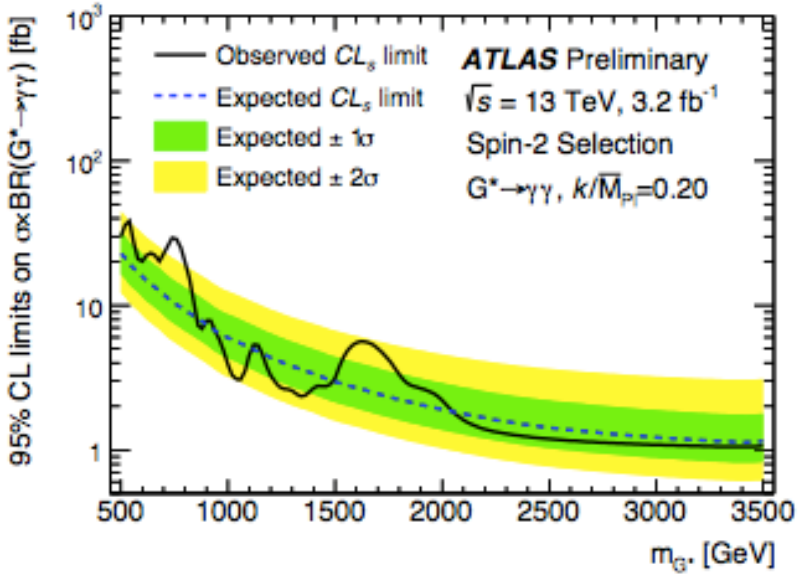
Diphotons

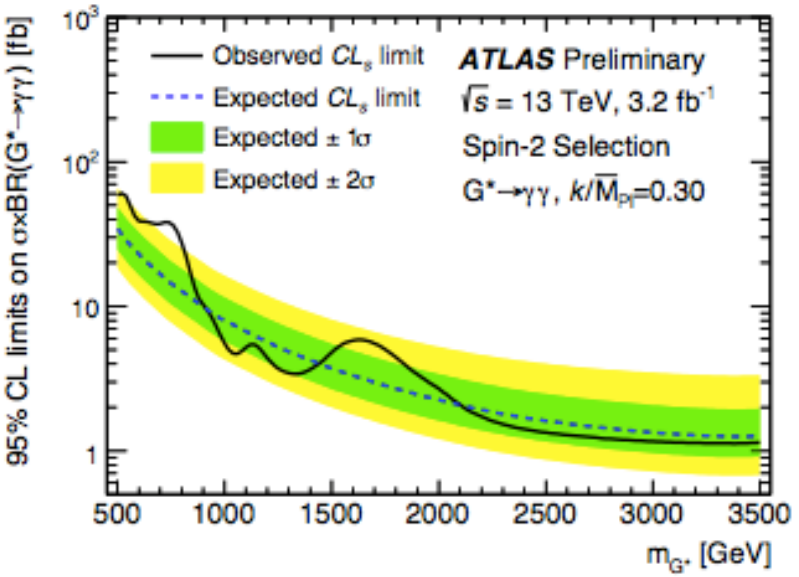
Limit on production cross section

SPIN-2 ANALYSIS







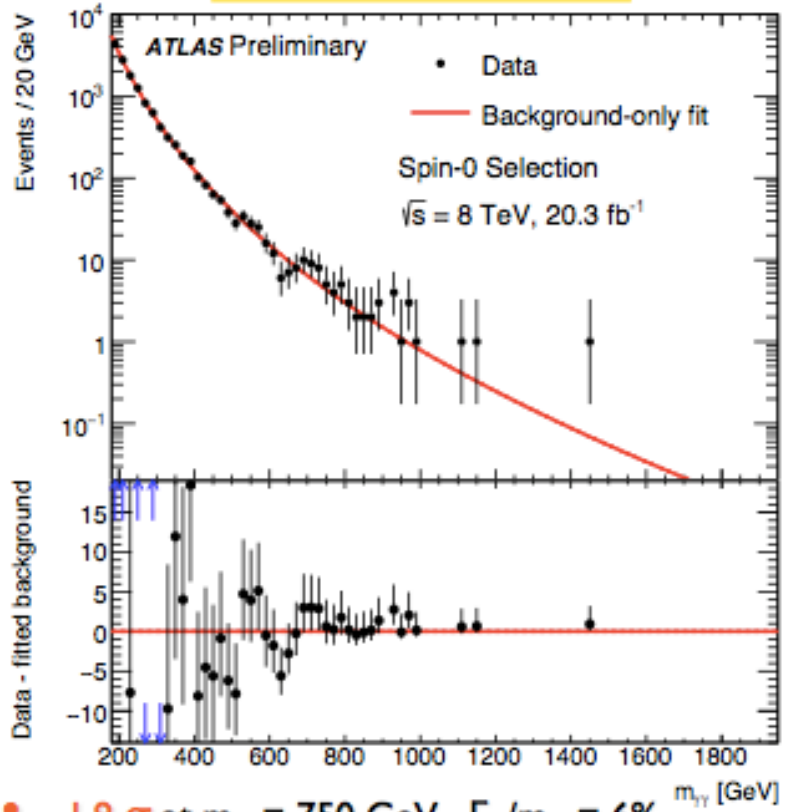


Diphotons

Compatibility with 8 TeV data

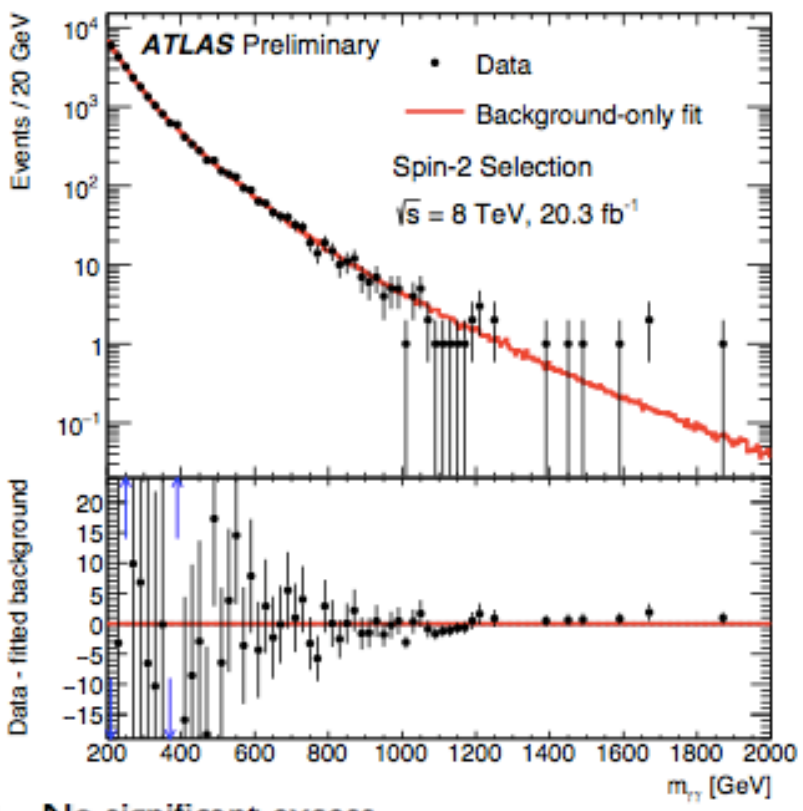
- 8 TeV data re-analyzed: latest Run 1 γ calibration + same Run 1 selections + 13 TeV analysis methods

SPIN-0 ANALYSIS



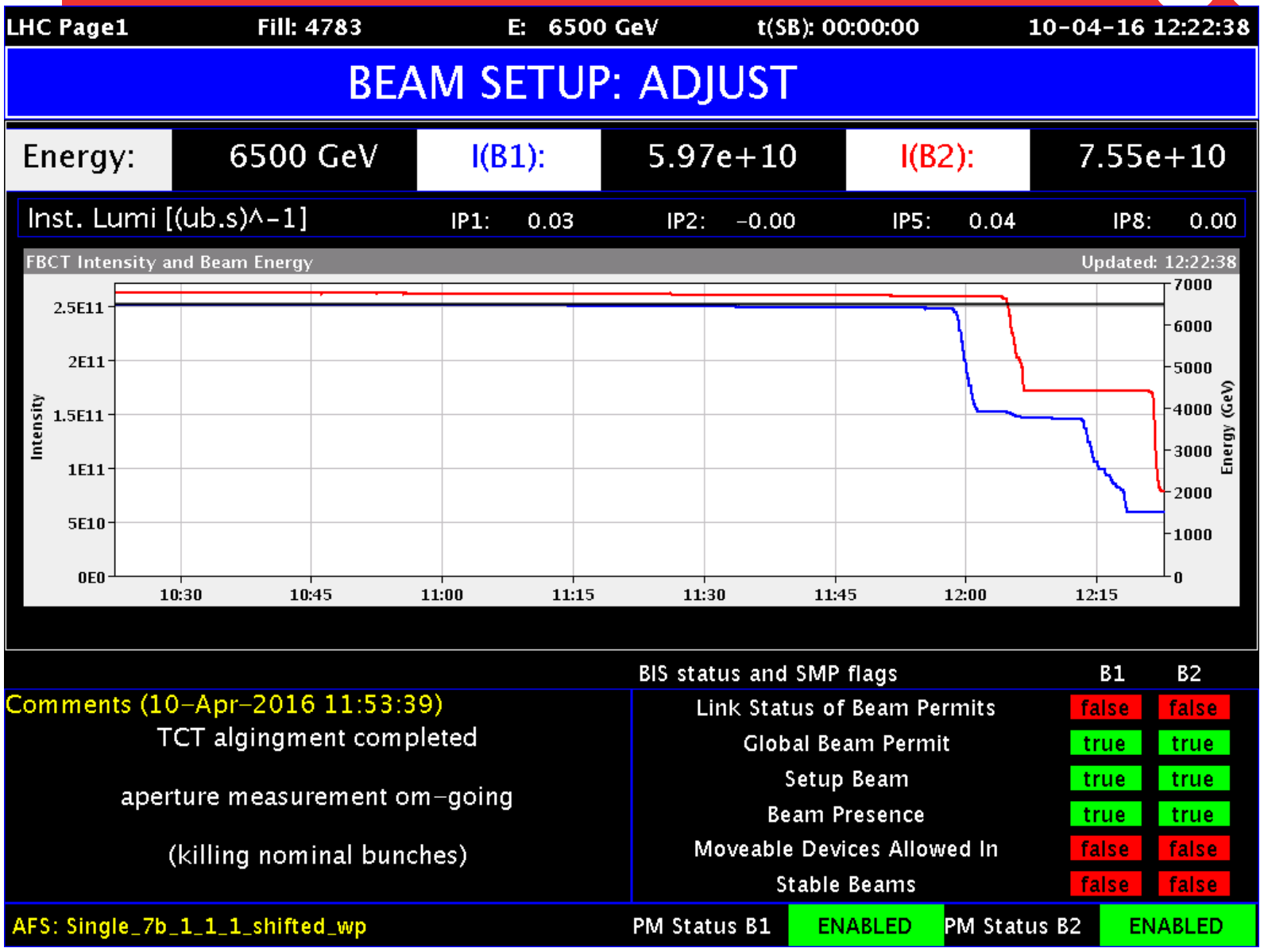
- 1.9 σ at m_X = 750 GeV , Γ_X/m_X = 6%
- Compatibility with 13 TeV scalar
  - ✓ gg (scaling: 4.7) → compatibility: 1.2 σ
  - ✓ qq (scaling: 2.7) → compatibility: 2.1 σ

SPIN-2 ANALYSIS

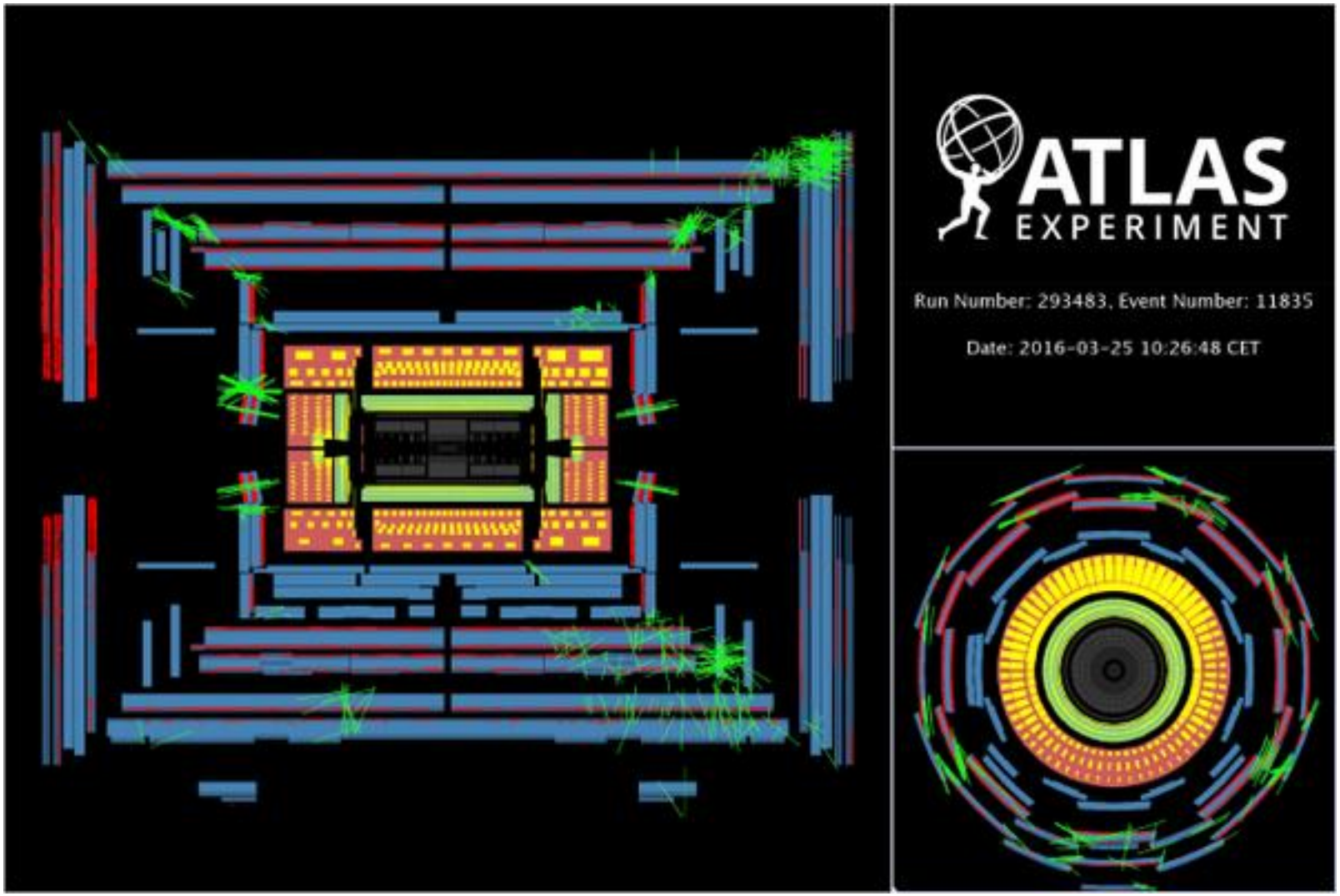


- No significant excess
- Compatibility with 13 TeV graviton
  - ✓ gg → compatibility: 2.7 σ
  - ✓ qq → compatibility: 3.3 σ

Now…


LHC Page1
Fill: 4783
E: 6500 GeV
t(SB): 00:00:00
10-04-16 12:22:38
BEAM SETUP: ADJUST
Energy:
6500 GeV
I(B1):
5.97e+10
I(B2):
7.55e+10
Inst. Lumi [(ub.s)^-1]
IP1: 0.03
IP2: -0.00
IP5: 0.04
IP8: 0.00
FBCT Intensity and Beam Energy
Updated: 12:22:38
Intensity
Energy (GeV)
2.5E11
2E11
1.5E11
1E11
5E10
0E0
7000
6000
5000
4000
3000
2000
1000
0
10:30
10:45
11:00
11:15
11:30
11:45
12:00
12:15
Comments (10-Apr-2016 11:53:39)
TCT algingment completed
aperture measurement om-going
(killing nominal bunches)
BIS status and SMP flags
B1
B2
Link Status of Beam Permits
false
false
Global Beam Permit
true
true
Setup Beam
true
true
Beam Presence
true
true
Moveable Devices Allowed In
false
false
Stable Beams
false
false
AFS: Single_7b_1_1_1_shifted_wp
PM Status B1
ENABLED
PM Status B2
ENABLED

Now…


ATLAS
EXPERIMENT
Run Number: 293483, Event Number: 11835
Date: 2016-03-25 10:26:48 CET

Summary

- Looking forward to the rest of this year…