Status and Recent Highlights

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LHCP, 13. June 2016

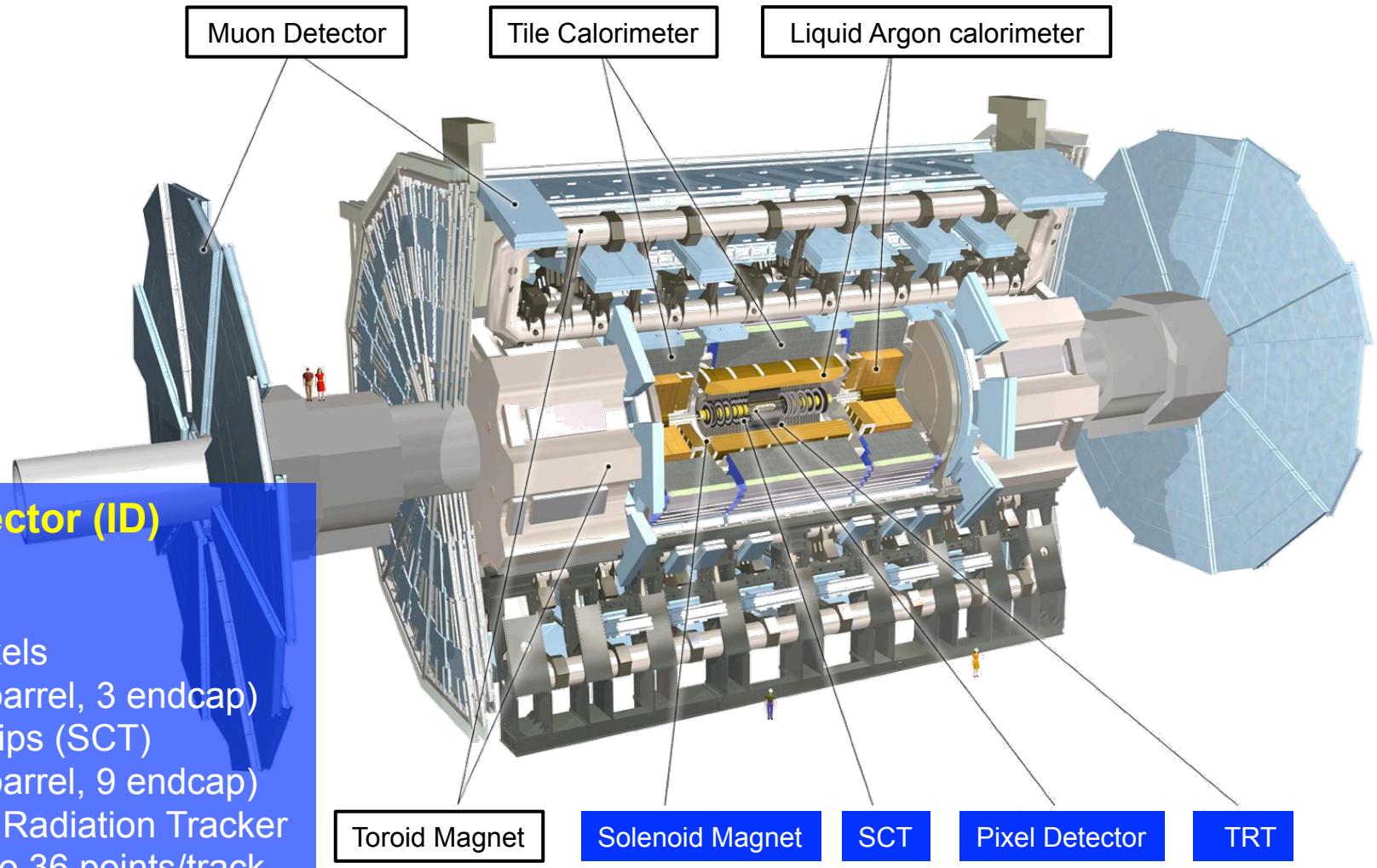
Outline

- The ATLAS detector
- 2016 start-up and detector performance
- Recent physics highlights

For upgrade please see
ATLAS upgrade and potential, A. Henriques, Saturday morning

… and of course the many physics plenary and parallel talks
for more details on the results shown here (and many more)

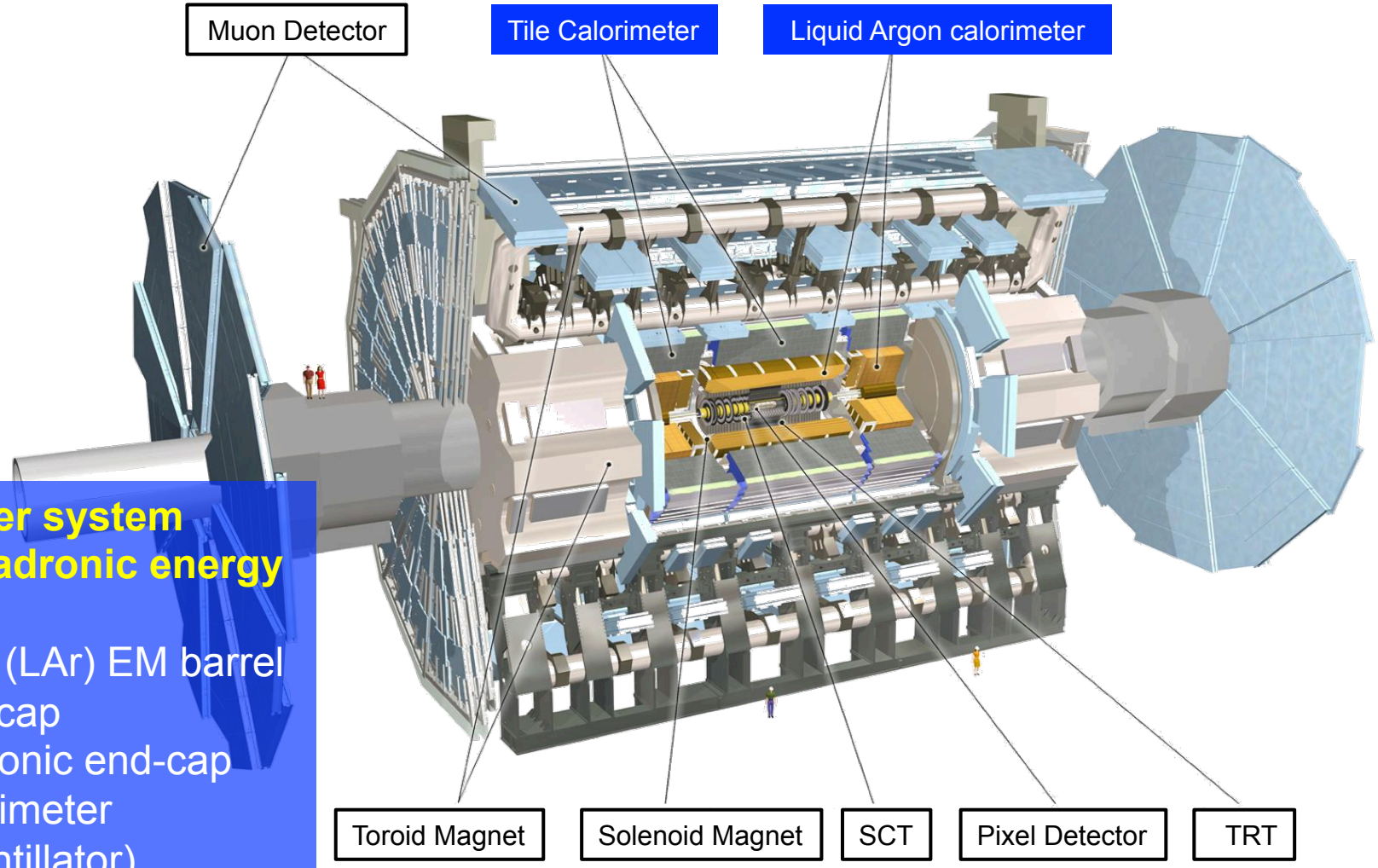
The ATLAS Detector



Inner Detector (ID)
Tracking

- Silicon Pixels
  (4 layers barrel, 3 endcap)
- Silicon Strips (SCT)
  (4 layers barrel, 9 endcap)
- Transition Radiation Tracker
  (TRT) up to 36 points/track
- 2T Solenoid Magnet

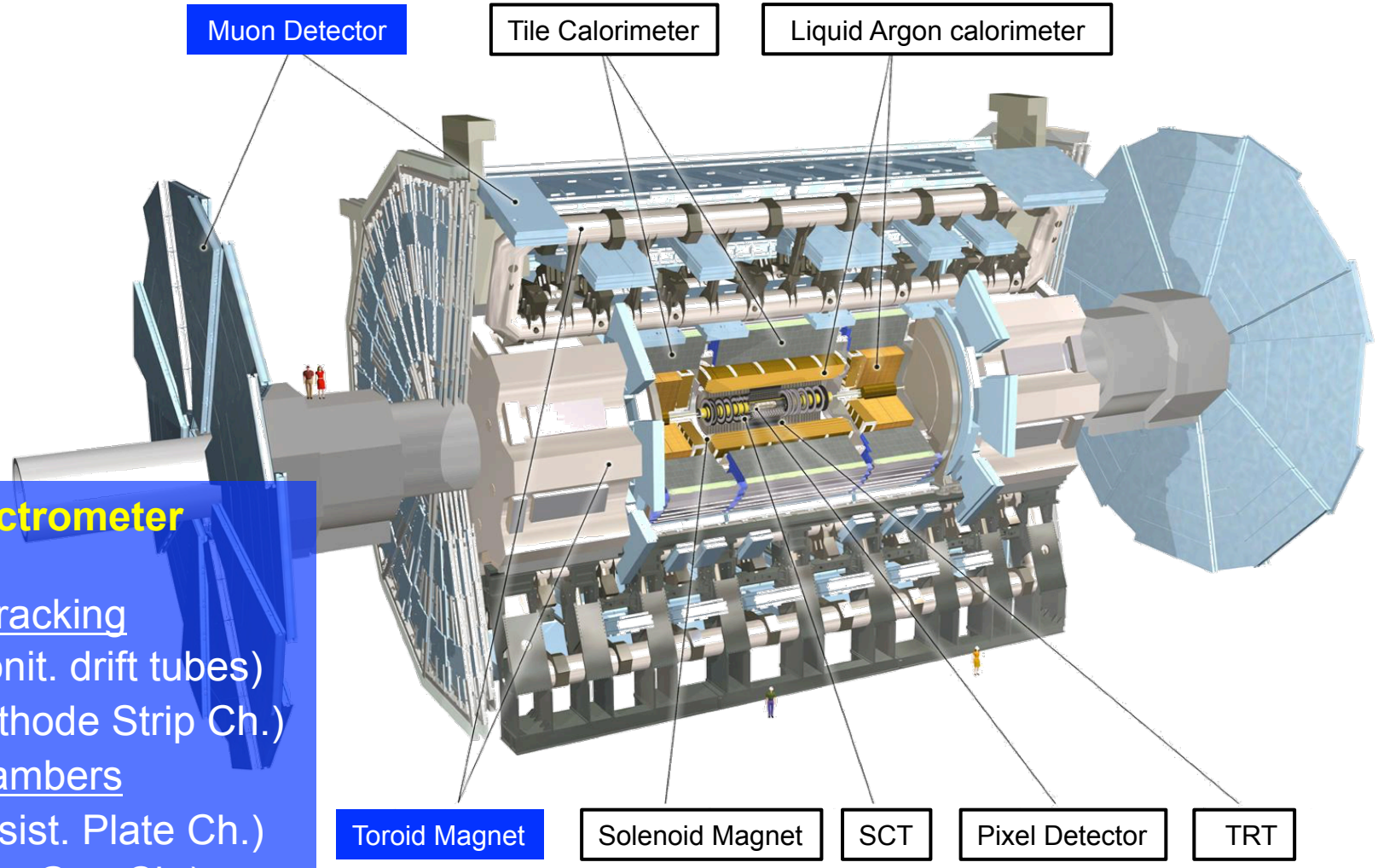
The ATLAS Detector



Calorimeter system
EM and Hadronic energy

- Liquid Ar (LAr) EM barrel and end-cap
- LAr Hadronic end-cap
- Tile calorimeter (Fe – scintillator) hadronic barrel

The ATLAS Detector



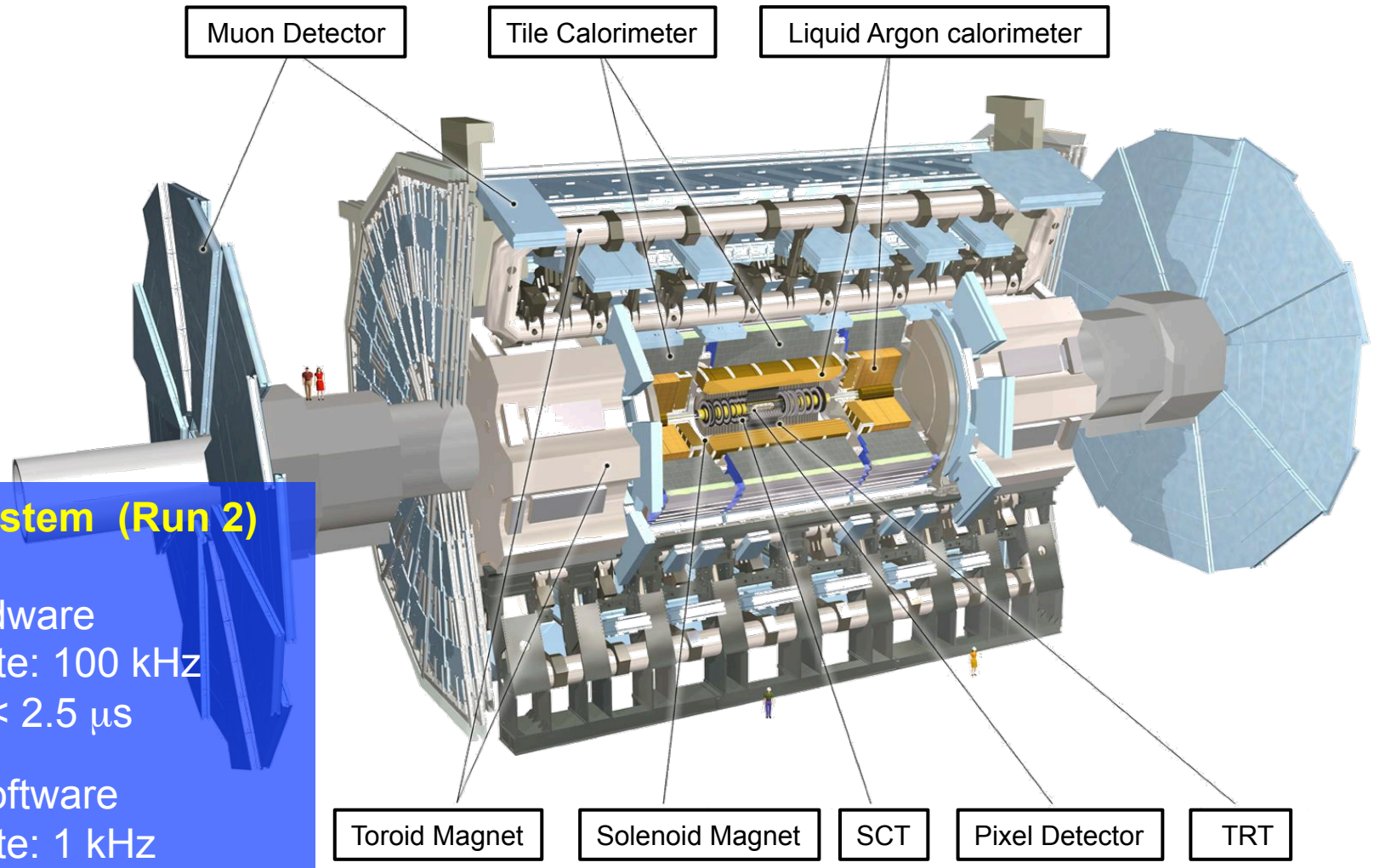
Muon spectrometer
μ tracking

Precision tracking
- MDT (Monit. drift tubes)
- CSC (Cathode Strip Ch.)

Trigger chambers
- RPC (Resist. Plate Ch.)
- TGC (Thin Gap Ch.)

- Toroid Magnet

The ATLAS Detector



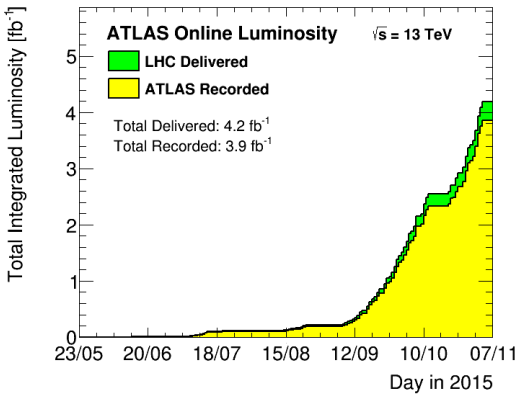
Trigger system (Run 2)

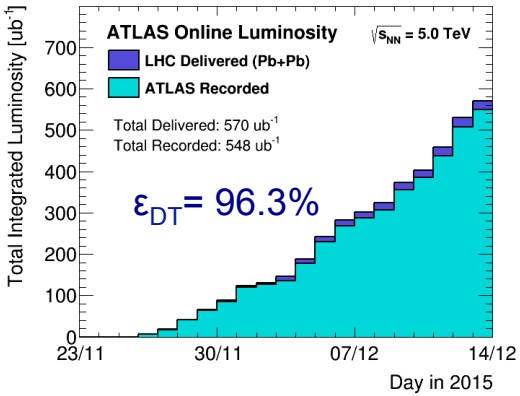
- L1 – hardware
  output rate: 100 kHz
  latency: < 2.5 μs
- HLT – software
  output rate: 1 kHz
  proc. time: ~ 550 ms

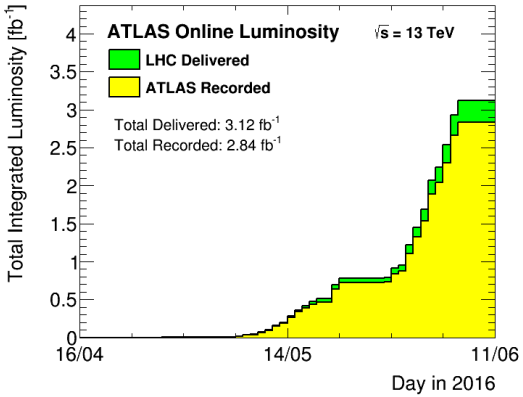
ATLAS data taking from 2015 to 2016

- 2015 pp data taking @ 13 TeV
  - A total of 4 fb^{-1} was delivered
  - ATLAS data-taking efficiency 92.0% (93.5% in 2012)
- 2015 Heavy Ion data
  - Intense period in Nov-Dec:
    - 5.02 TeV pp reference data (28pb^{-1}, ε_{DT}= 96.9%)
    - $\sqrt{s}$ NN = 5.02 TeV Pb-Pb data: 548 μb^{-1}
- 2016 data taking
  - Quiet beams Apr 12th / First stable beams Apr 23rd
  - Intensity luminosity ramp-up is ongoing
    - Up to 2028 colliding bunches in ATLAS
    - L_{peak} ~ 0.88 x 10^{34} $cm^{-2}s^{-1}$
    - Recorded 2.8 fb^{-1}, data taking efficiency 91%

ATLAS has been successfully re-commissioned and is operating smoothly







Many thanks to the LHC teams!

Detector Status 2016

Subdetector	Number of Channels	Approximate Operational Fraction	
Pixels	92 M	98.2%	
SCT Silicon Strips	6.3 M	98.7%	
TRT Transition Radiation Tracker	350 k	97.2%	
LAr EM Calorimeter	170 k	100%	
Tile calorimeter	5200	100%	+0.8%
Hadronic endcap LAr calorimeter	5600	99.6%	
Forward LAr calorimeter	3500	99.7%	
LVL1 Calo trigger	7160	100%	
LVL1 Muon RPC trigger	383 k	99.8%	+13k ch.
LVL1 Muon TGC trigger	320 k	100%	
MDT Muon Drift Tubes	357 k	99.7%	
CSC Cathode Strip Chambers	31 k	98.4%	
RPC Barrel Muon Chambers	383 k	96.6%	+13k ch.
TGC Endcap Muon Chambers	320 k	99.6%	
ALFA	10 k	99.9 %	
AFP	188 k	98.8 %	

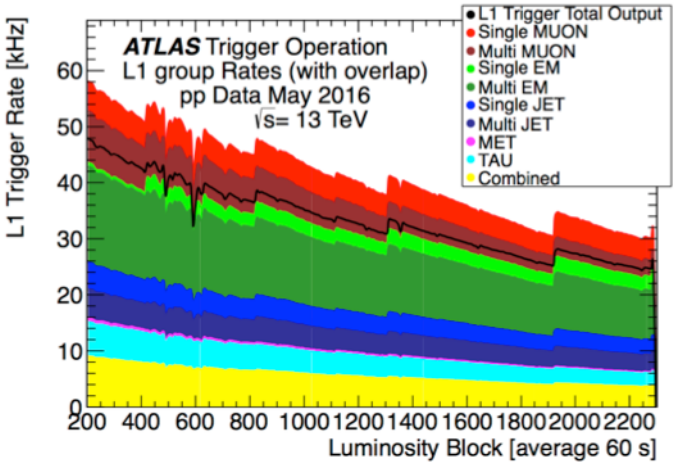
changes w.r.t. 2015

Notes:

- For the Pixel status: 3-Layers Pixel (80 M channels) - 98%; IBL (12 M channels) - 99.5%
- Now includes the 36 new trigger towers for Sector 12 and 14 on the outer layer.
- For Tilecal we indicate the number of cells (including gap and crack counters) that is more accurate for the status
- Detectors with fewer than 100 channels are not reported

May 2016

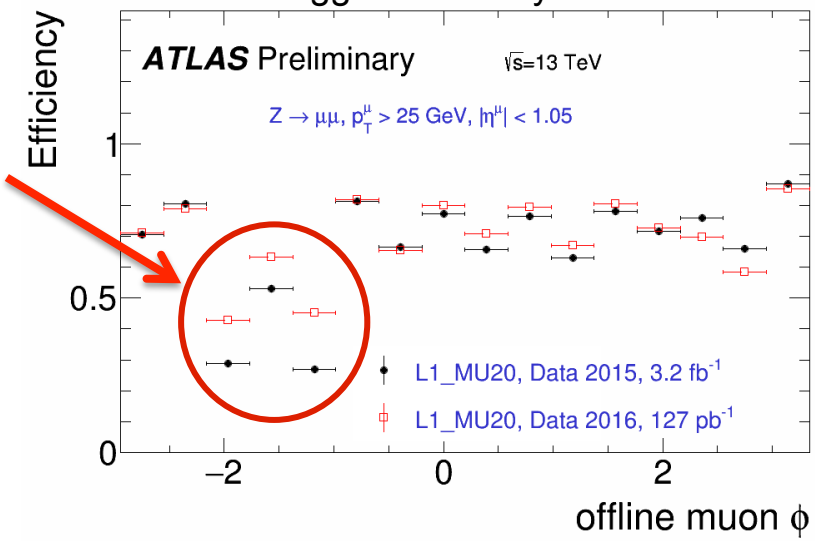
- Trigger and DAQ
  - Prepared for luminosities up to 1.2 x 10^{34} $cm^{-2}s^{-1}$
  - Most bandwidth still given to *generic* triggers
    - e.g. single isolated e/μ with p_T > 24-26 GeV
  - Multi-object and dedicated triggers added

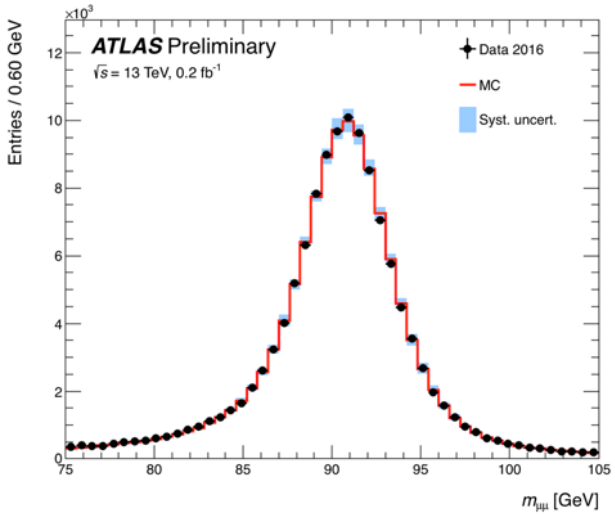


Muon spectrometer

- Barrel trigger chambers (RPC)
  - Additional chambers improve acceptance in 'feet' region (4% of total)
- Endcap trigger chambers (TGC)
  - Optimisation of coincidences → ~8% rate reduction for L1 MU20
- Precision chambers (MDT/CSC)
  - Working well for precision tracking
  - 2015 alignment applied to 2016 data

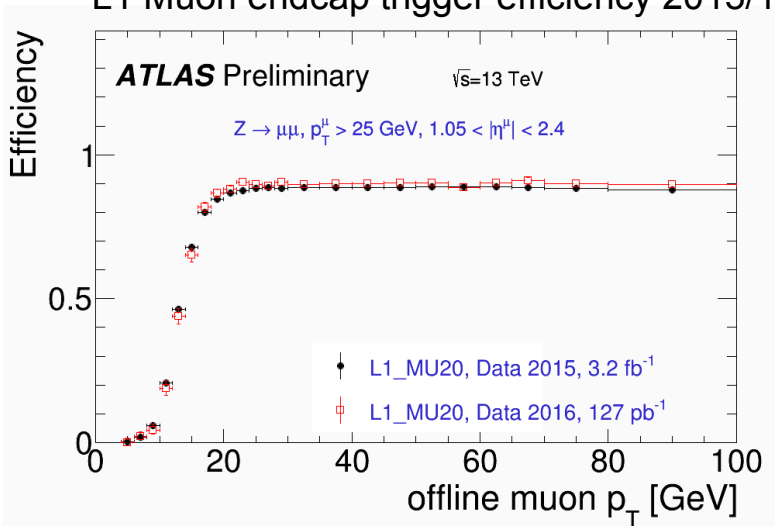
L1 Muon trigger efficiency barrel 2015/16





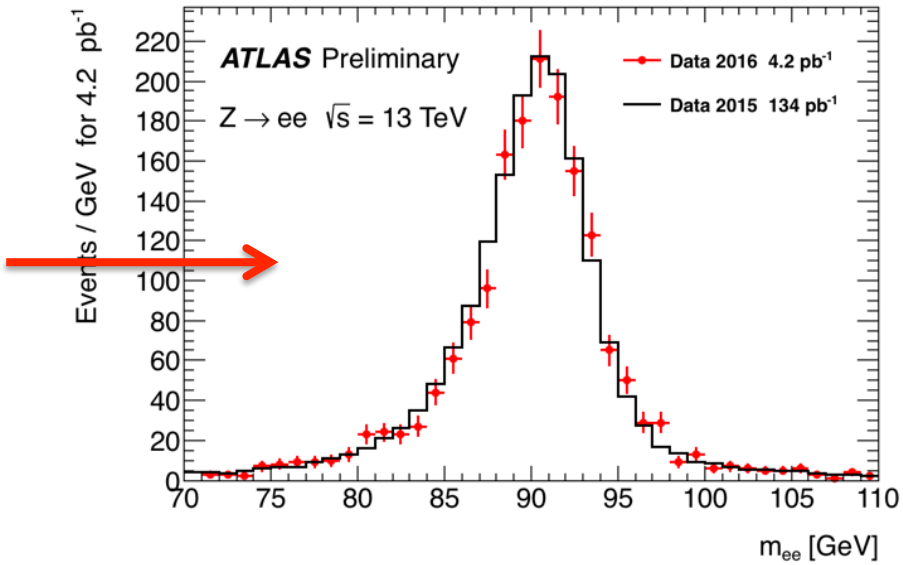
Di-muon invariant mass of $Z \rightarrow \mu^+\mu^-$

L1 Muon endcap trigger efficiency 2015/16



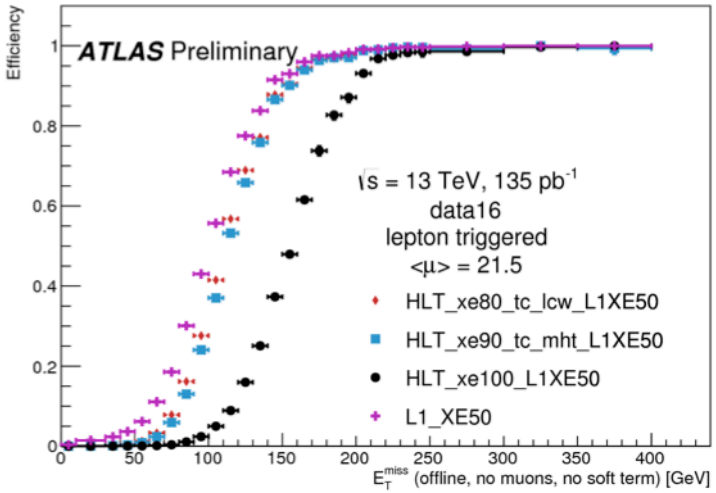
Calorimeters

- LAr calorimeter
  - Operating smoothly
  - Very good LAr purity stablitily
  - Energy scale in the 2016 data is consistent with 2015
- Tile calorimeter
  - Recovered two dead modules and four partially operational drawers → 100% coverage



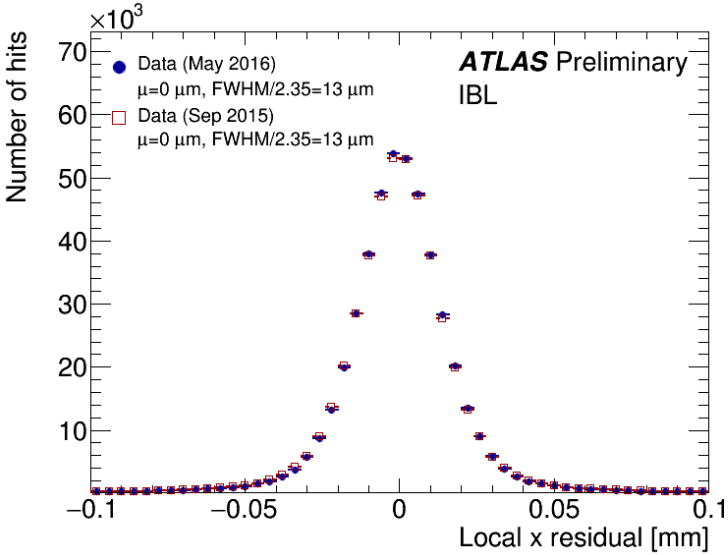
- Example of using calorimeter objects in trigger
  - Three different ETmiss high-level trigger algorithms, using
    - Calibrated cluster
    - Reconstructed jets
    - Cells on EM energy scale

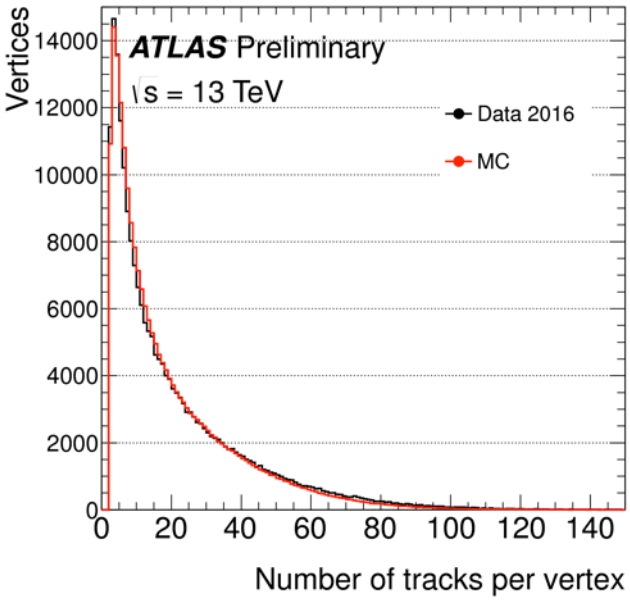
E_T^{miss} triggers



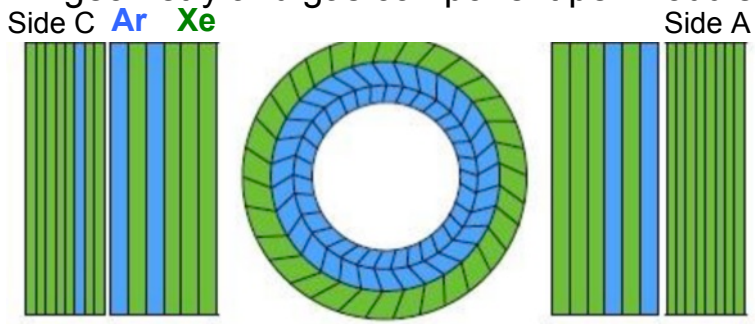
Inner tracking

- Pixel system
  - Readout was upgraded to handle higher pileup w.r.t. the 2015 operation
  - ID alignment is automated, updates before bulk reconstruction
- Semi Conductor Tracker
  - Nearly 99% of the modules are included with good data quality
- Transition Radiation Tracker
  - New gas configuration to reduce loss of xenon
    - Particle-ID re-optimised
      → Negligible impact on physics





TRT geometry and gas component per module

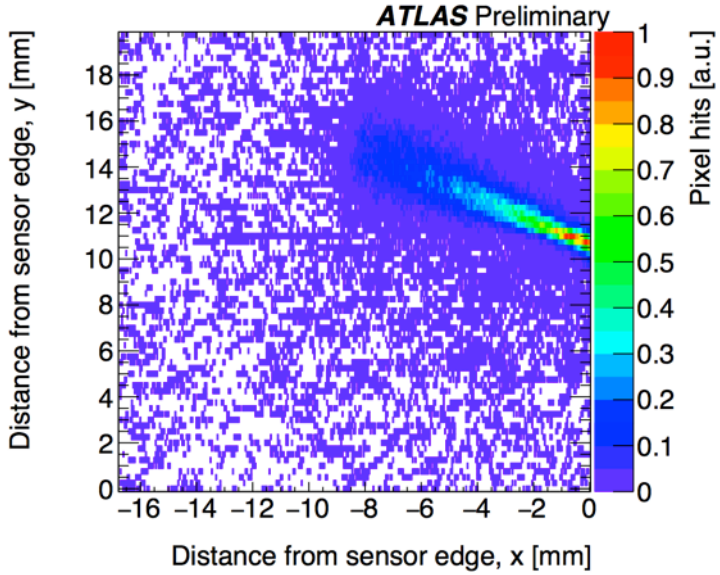


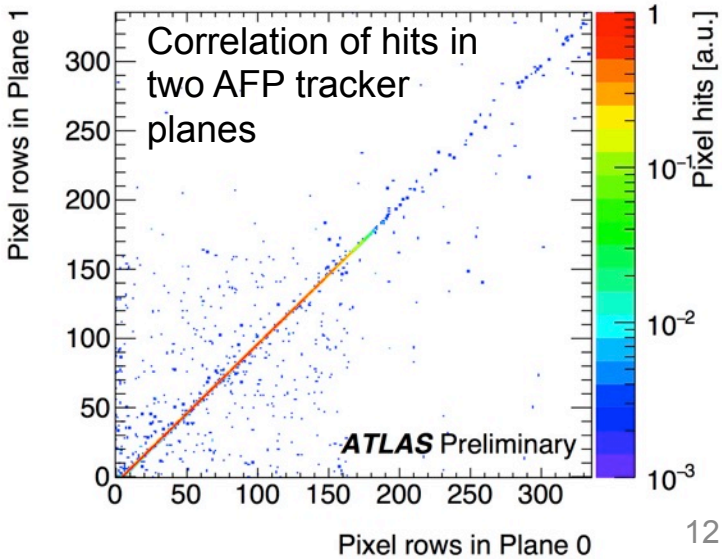
Forward Detectors

- New Detector AFP: ATLAS Forward Protons (200 m from IP)
  - Roman pots for one arm were installed and integrated in DAQ
  - Hit-pattern plot shows expected "band" of diffractive protons
  - Second arm installation in 2016/2017 shutdown

- The other forward detectors, LUCID, ALFA, and ZDC are also fully operational

raw pixel hits in AFP tracker plane





ATLAS is well advanced in establishing the 2016 detector performance

Finalising Run-1 analyses

- $B_{d/s} \rightarrow \mu^+\mu^-$
  - 25 fb^{-1} of the 7/8 TeV data in Run-1
  - Consistent with the SM at 2.0 σ
  - Also consistent with zero

$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = \left(0.9^{+1.1}_{-0.8}\right) \times 10^{-9}$$
$$\mathcal{B}(B^0 \to \mu^+\mu^-) < 4.2 \times 10^{-10} \quad \text{at 95\% CL}$$

- Top quark mass Eur. Phys. J. C (2015) 75:330
  - Top quark mass in the l+jets and di-lepton channels using 4.6 fb^{-1} @ 7 TeV
    - Di-lepton channel: 1-dim template in average invariant mass of the l+b-jet pairs
    - l + jets: 3-dim template determining mass with global jet energy scale factor (JSF) and and a relative b-to-light-jet energy scale factor (bJSF)

… latest news: from 20.2 fb^{-1} @ 8TeV (di-lepton):

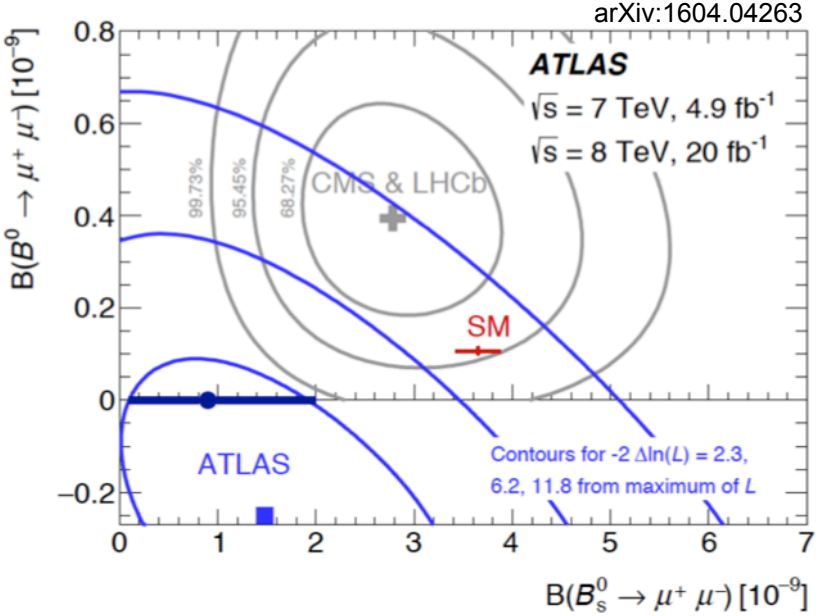
$$m_{\text{top}} = 172.99 \pm 0.41\ (\text{stat}) \pm 0.74\ (\text{syst})\ \text{GeV}$$

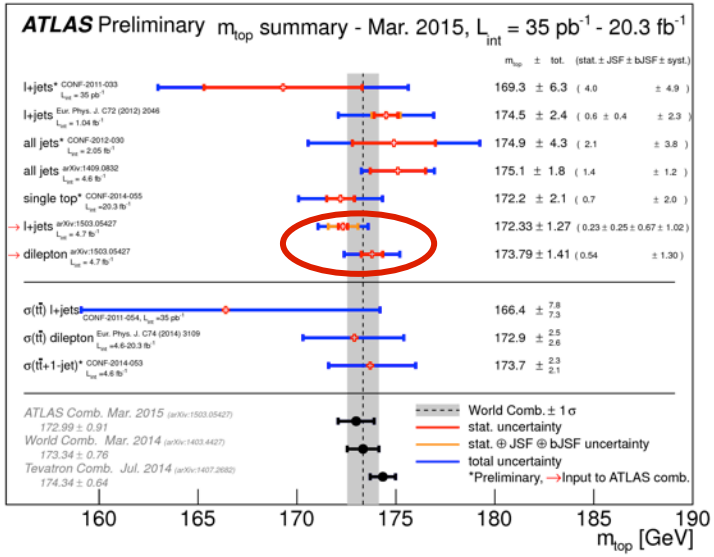
and combined with the 7 TeV data:

$$m_{\text{top}} = 172.84 \pm 0.34\ (\text{stat}) \pm 0.61\ (\text{syst})\ \text{GeV}$$

arXiv:1606.02179 → relative precision of 0.4%

arXiv:1604.04263





Run-2: Top quark cross section

- Measured in the eμ channel
  - $t\bar{t} \rightarrow e\mu\nu\bar{\nu}b\bar{b}$ 3.2 fb^{-1} @ 13 TeV
  - Count events with exactly one (N_1) and exactly two (N_2) b-tagged jets

Integrated Luminosity

b-jet efficiency

$$N_1 = L\sigma_{t\bar{t}}\,\epsilon_{e\mu} 2\epsilon_b(1 - C_b\epsilon_b) + N_1^{\mathrm{bkg}}$$

$$N_2 = L\sigma_{t\bar{t}}\,\epsilon_{e\mu} C_b \epsilon_b{}^2 + N_2^{\mathrm{bkg}}$$

Background events

pre-selection efficiency

tagging correlation $C_b = \epsilon_{bb}/\epsilon_b{}^2$

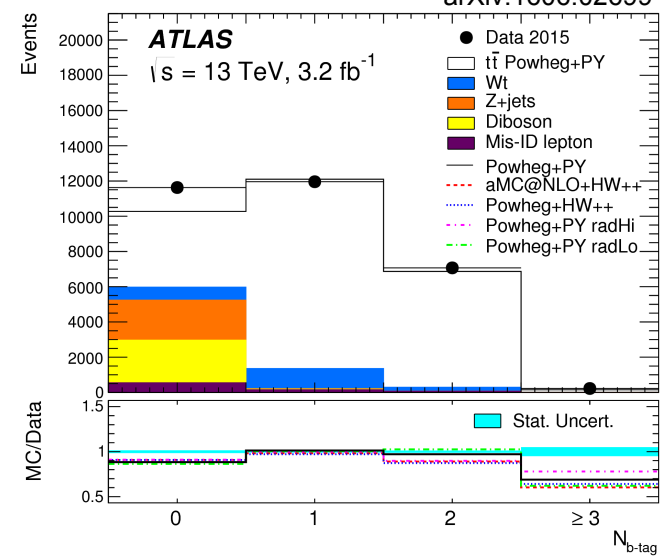
  - Solve for σ_{tt} and ε_b

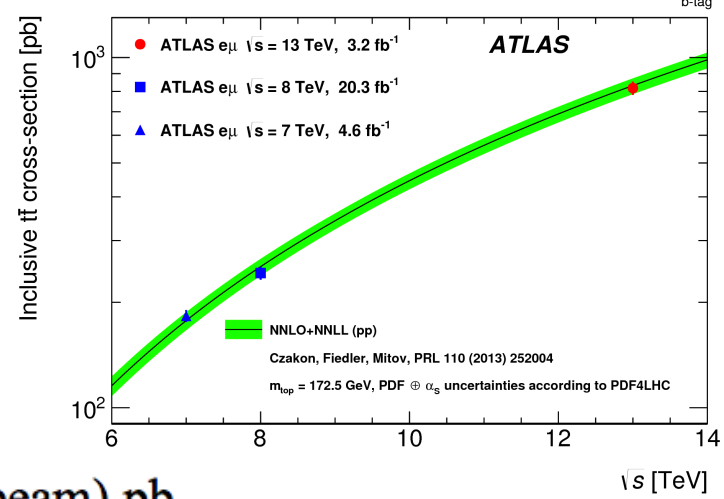
$$\epsilon_b = 0.559 \pm 0.004 \pm 0.003$$

$$\sigma_{t\bar{t}} = 818 \pm 8\ (\mathrm{stat}) \pm 27\ (\mathrm{syst}) \pm 19\ (\mathrm{lumi}) \pm 12\ (\mathrm{beam})\ \mathrm{pb}$$

$$\sigma_{t\bar{t}}^{\mathrm{fid}} = 11.32 \pm 0.10\ (\mathrm{stat}) \pm 0.29\ (\mathrm{syst}) \pm 0.26\ (\mathrm{lumi}) \pm 0.17\ (\mathrm{beam})\ \mathrm{pb}$$

arXiv:1606.02699



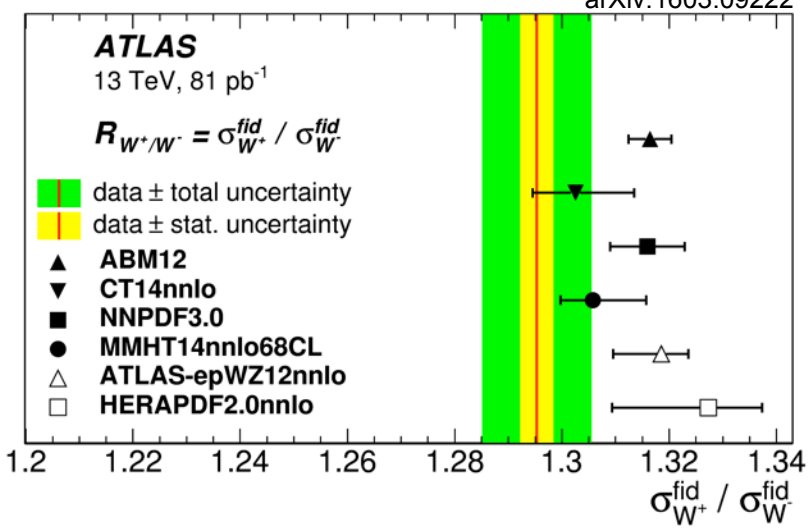


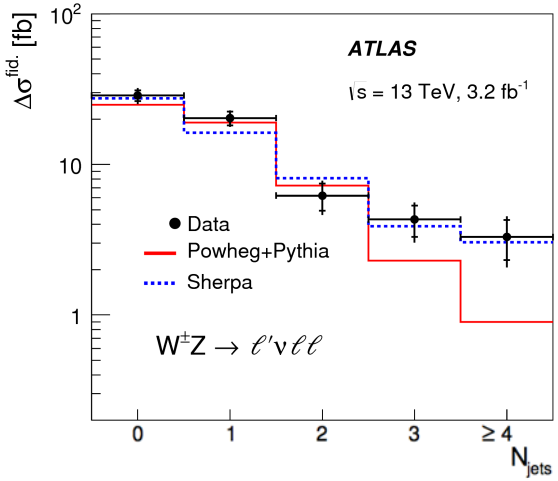
Using latest luminosity uncertainty: 2.1%

W, Z measurements @ 13 TeV

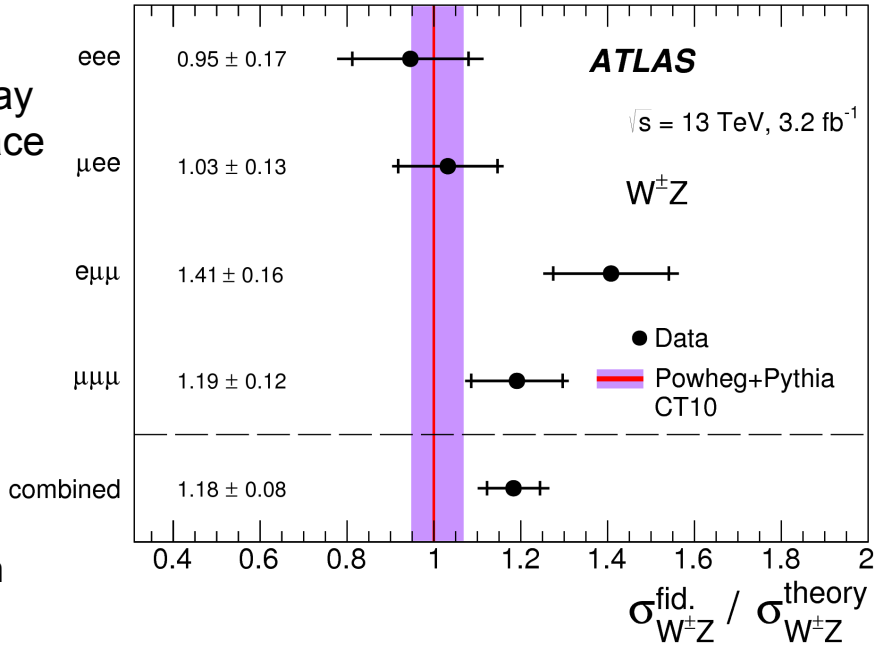
- Recent additions include
  - W and Z cross sections & ratios @ 13 TeV
    - E.g. ratio of W^+ to W^- fiducial cross sections
    - Measured to a precision of 0.8%
    - 1-2σ lower than the various predictions based on different PDFs
  - $W^{\pm}Z$ cross sections
    - Further important test of the SM EW sector
      - Measured in 3.2 fb^{-1} @ 13 TeV
      - Fiducial cross sections in e and μ decay modes extrapolated to total phase space
      - Ratios of 8 and 13 TeV and W^+Z/W^-Z

arXiv:1603.09222





$\sigma(W^{\pm}Z)$ vs N_{jets}
Test of QCD for diboson production processes

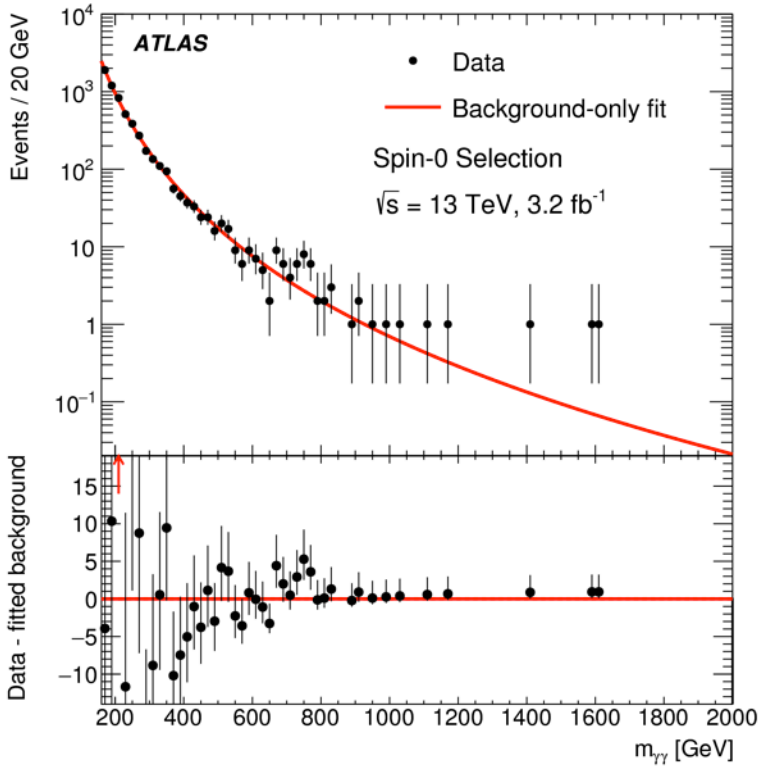
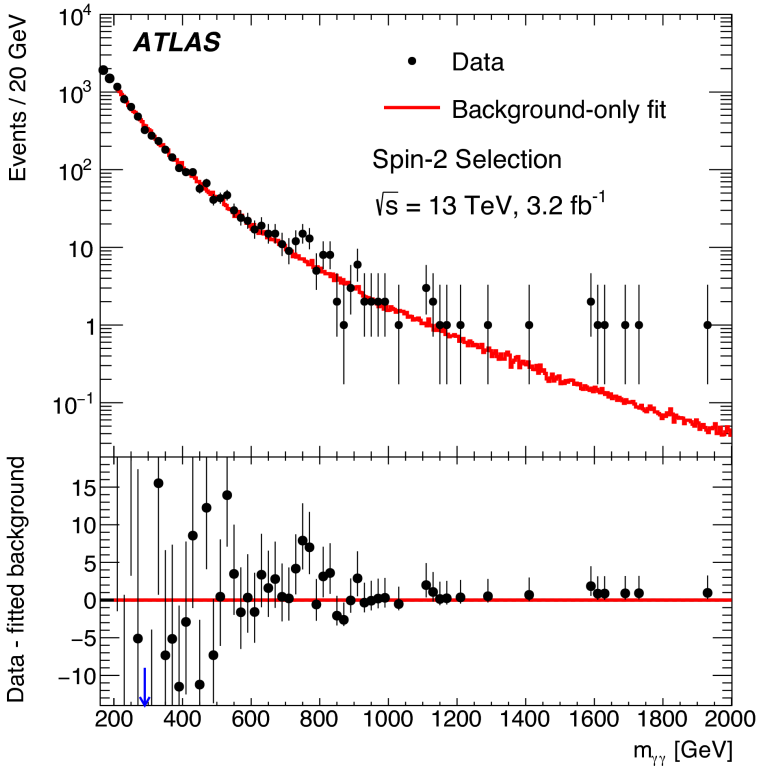


Using latest luminosity uncertainty: 2.1%

Search for di-photon resonance: $m_{\gamma\gamma}$ spectrum

- Search for excess in di-photon invariant mass spectrum

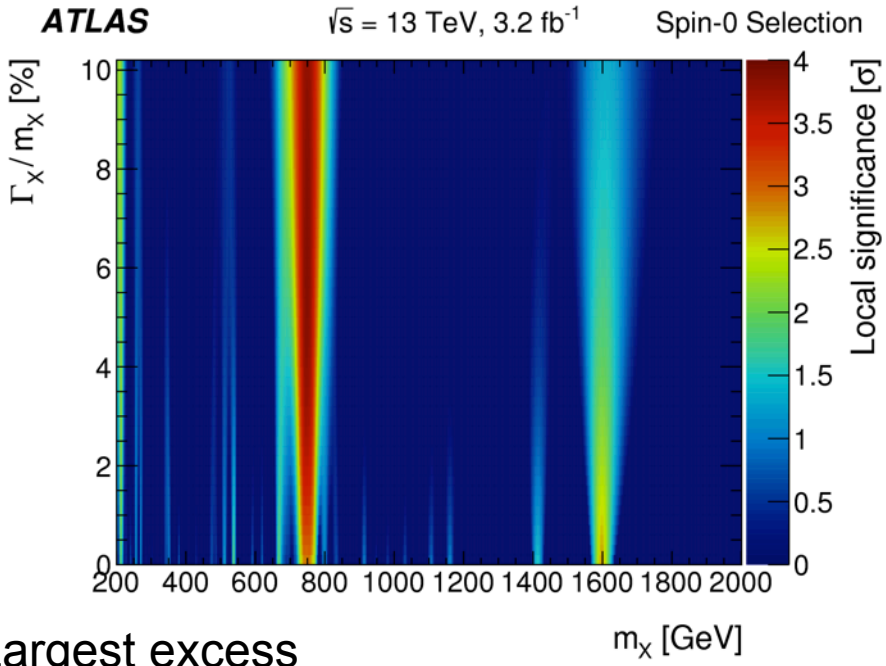
arXiv:1606.03833

Analysis	Spin-0	Spin-2
Target	Extended Higgs sector	KK-graviton
Selection	2 isolated-γ's: $E_T/m_{\gamma\gamma}$> 0.3, 0.4	2 isolated-γ's: $E_T(\gamma_{1,2})$>55, 55 GeV
$m_{\gamma\gamma}$ spectrum		

Using 3.2 fb^{-1} of $\sqrt{s}$ = 13 TeV data collected in 2015

Search for di-photon resonance: significance

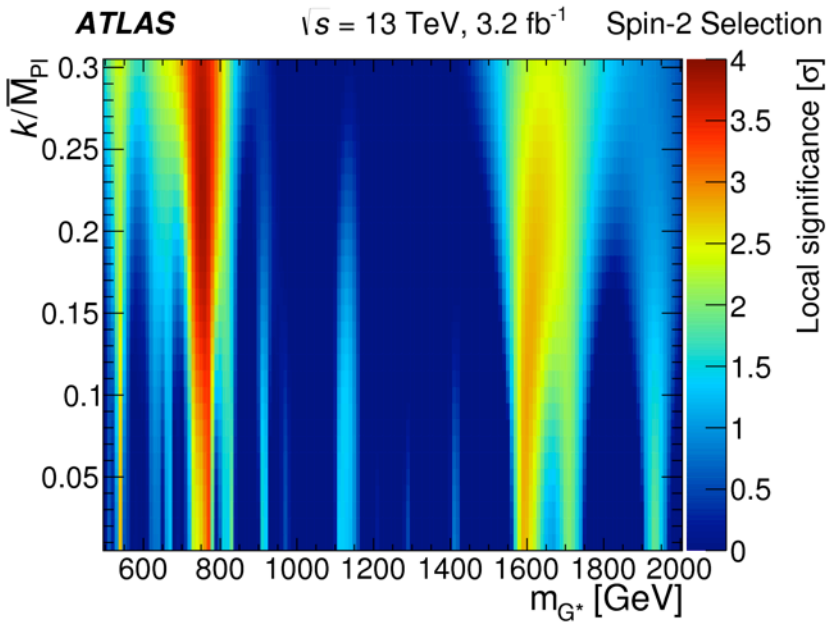
Spin-0



Largest excess
Best fit mass: 750 GeV, width: 45 GeV
- Local: 3.9 σ, global: 2.1 σ

Spin-2

arXiv:1606.03833



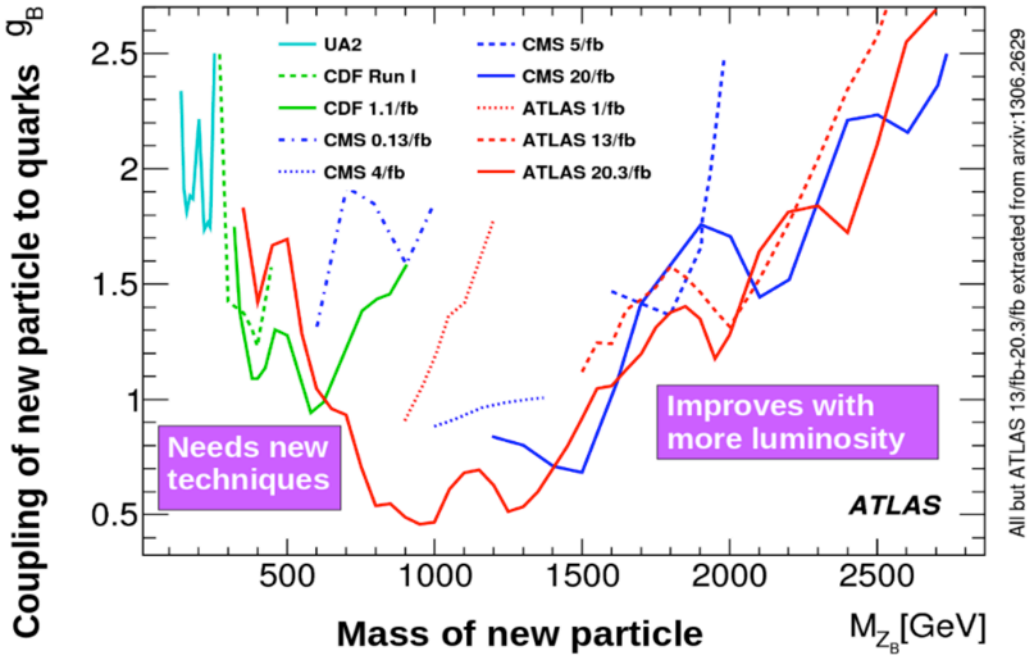
Best fit mass: 750 GeV, width: 57 GeV
- Local: 3.8 σ, global: 2.1 σ

- Significances intriguing but not compelling at this point

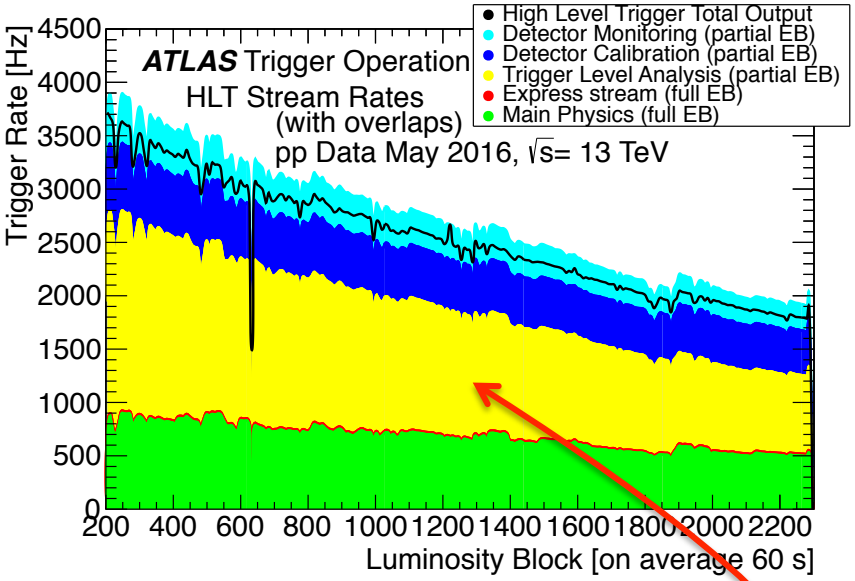
→ One analysis we are watching carefully in 2016

Trigger Level Analysis

Coupling-mass plane for a Leptophobic Z' model



High Level Trigger output rates

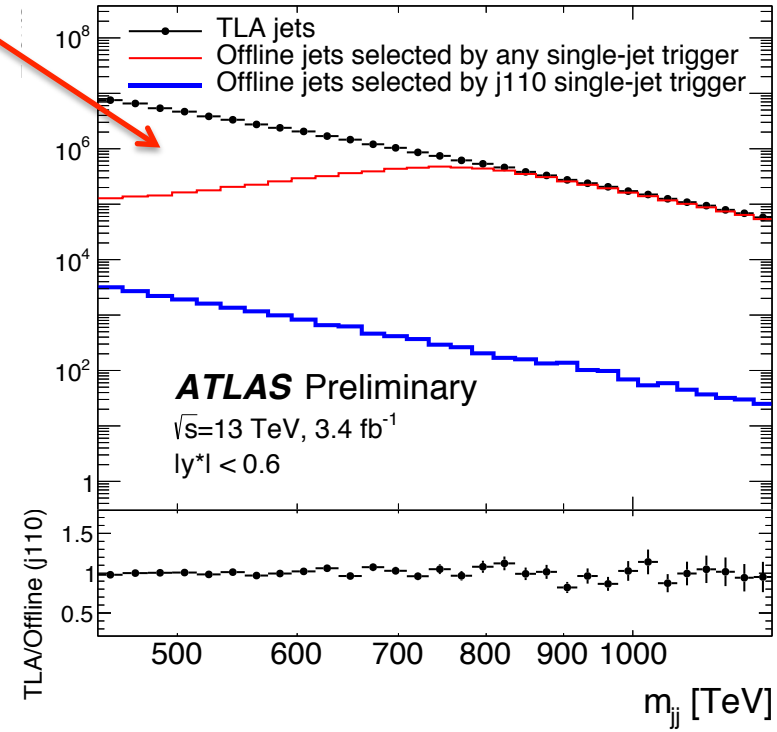


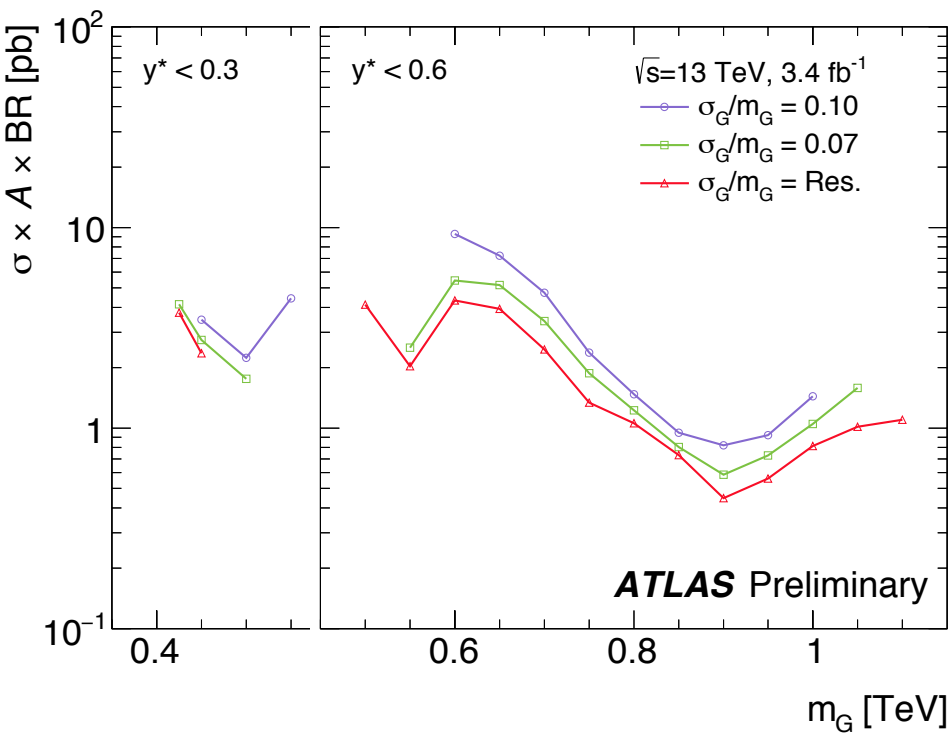
- Searches for light (< 1 TeV) di-jet resonances motivated e.g. by Leptophobic Z' models
  - Sub-TeV searches limited by available trigger bandwidth
  - Avoid limitation using partially built events with only the information needed for the search (5% of full event size) → additional 2kHz event rate

Trigger Level Analysis

- TLA selection fills the gap at low m_{jj}
- SM backgrounds estimated by fitting binned m_{jj} distribution to empirical function
  - Significance of any localized excess evaluated with BumpHunter algorithm

ATLAS-CONF-2016-030

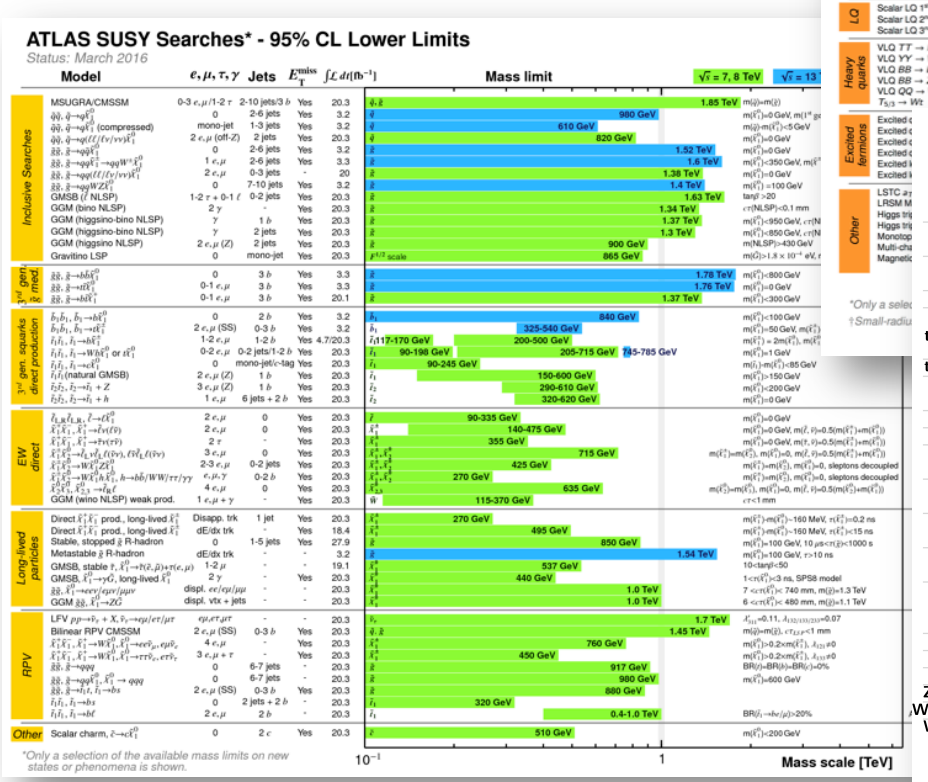


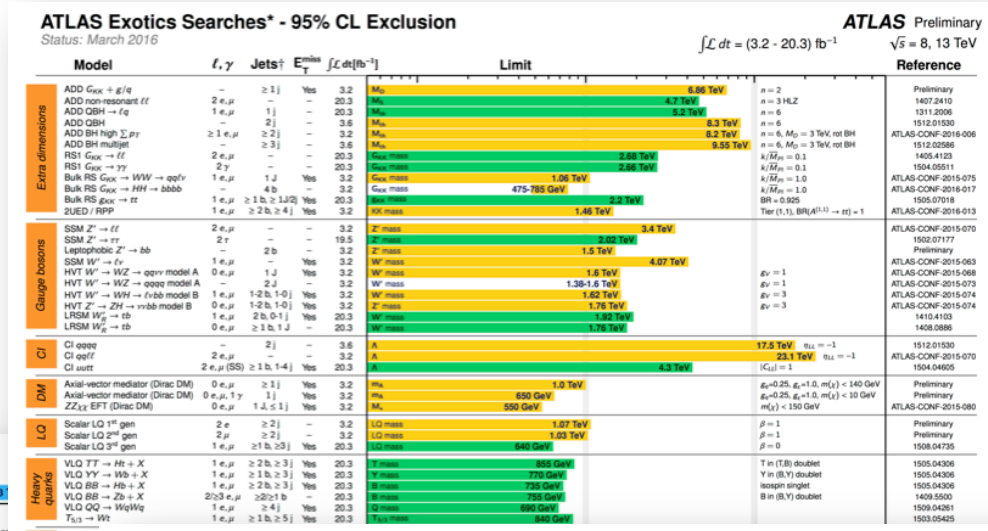


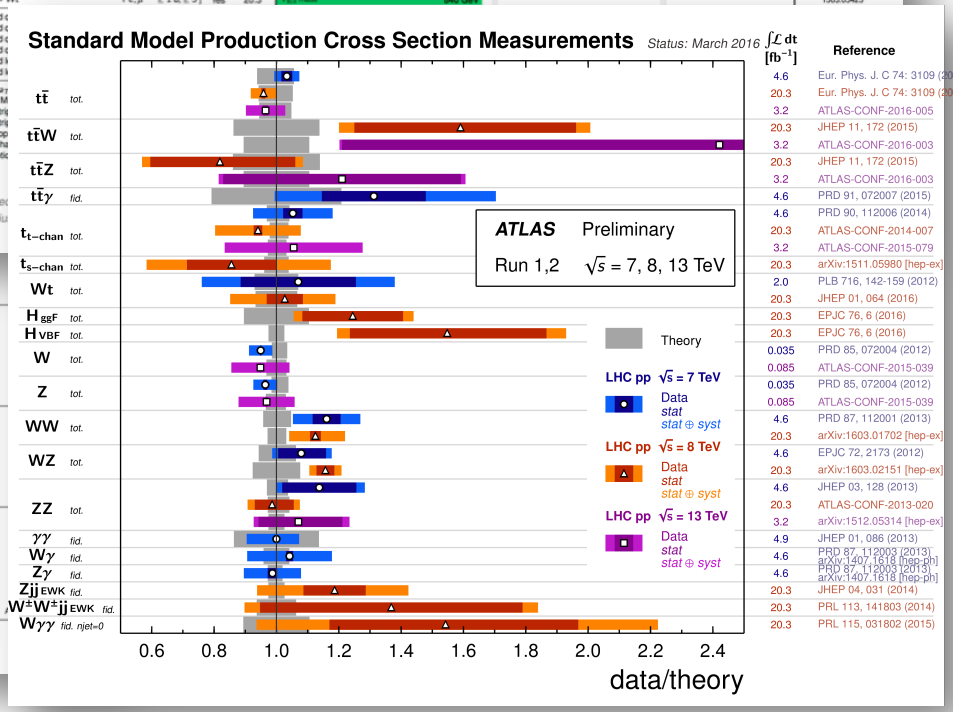
Limits are set on $\sigma \times A \times BR$ of a leptophobic Z' simplified model and on generic Gaussian resonances

A large number of other results ....

- Many other results are available and coming out
  - Stay tuned for many more interesting talks this week

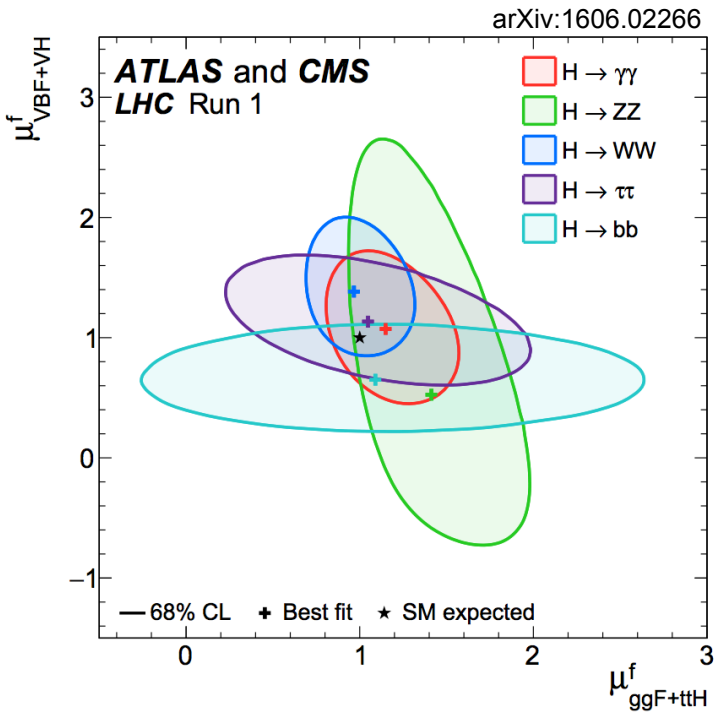






Conclusions

- ATLAS is up and running taking 2016 data
  - Much of the detector performance for this year has been (re-)established → ongoing activity
- Computing and software is operating well
- Steady output of physics results
  - Still Run-1 analyses being finalised, Run-2 results increasingly taking over



ATLAS/CMS Higgs combination paper submitted to JHEP last week

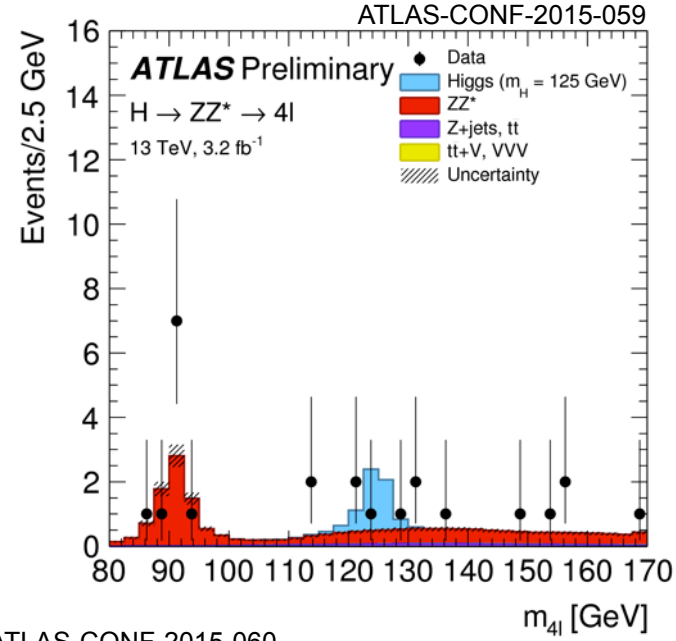
ATLAS is very much looking forward to this year of high luminosity production
and any surprise the data might have for us

Additional material

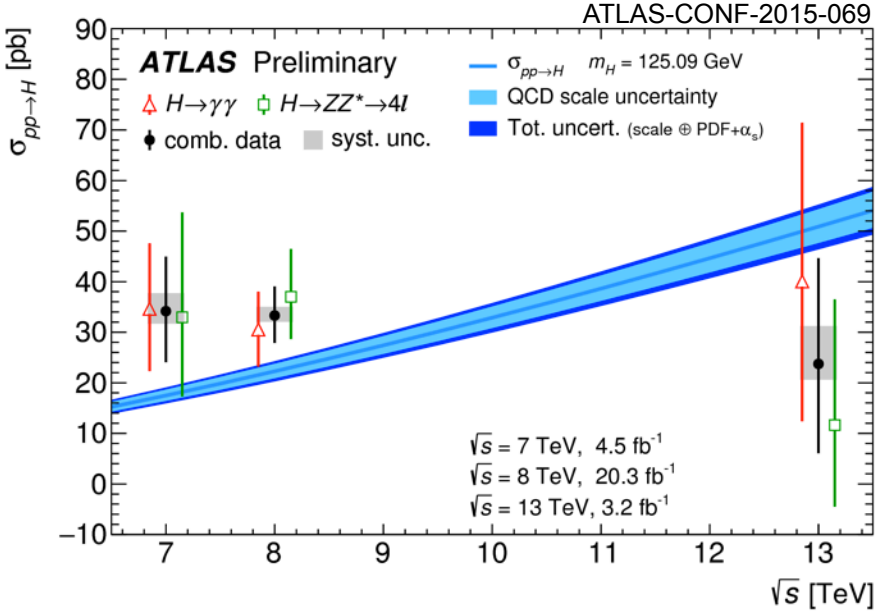
Looking for H(125) @13 TeV

- Using 3.2 fb^{-1} @ 13 TeV
- Diphoton channel:
  - Observe 1.5σ significance, expect 1.9σ
- Four-lepton channel:
  - Observe 0.7σ significance, expect 2.8σ
- Combined compatibility with SM
  - … is around 1.3σ

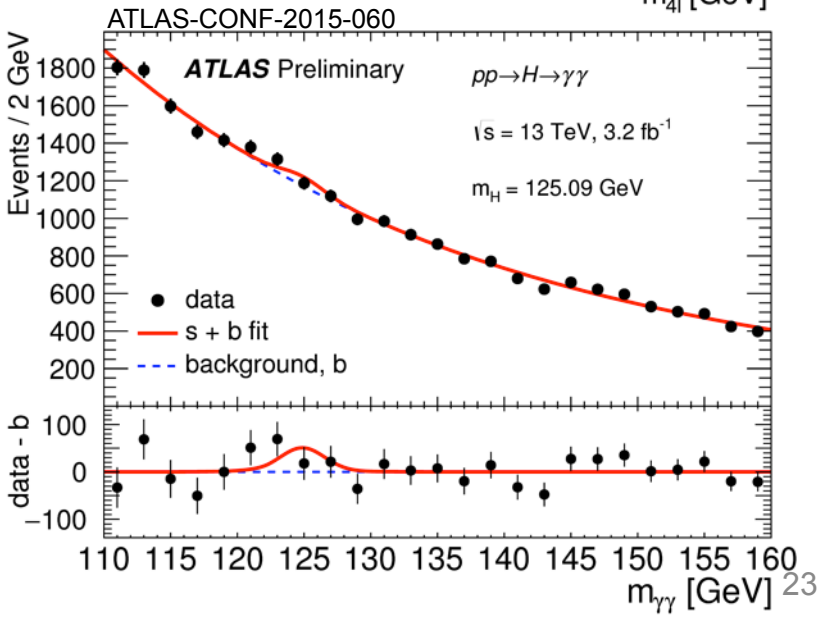
ATLAS-CONF-2015-059



ATLAS-CONF-2015-069

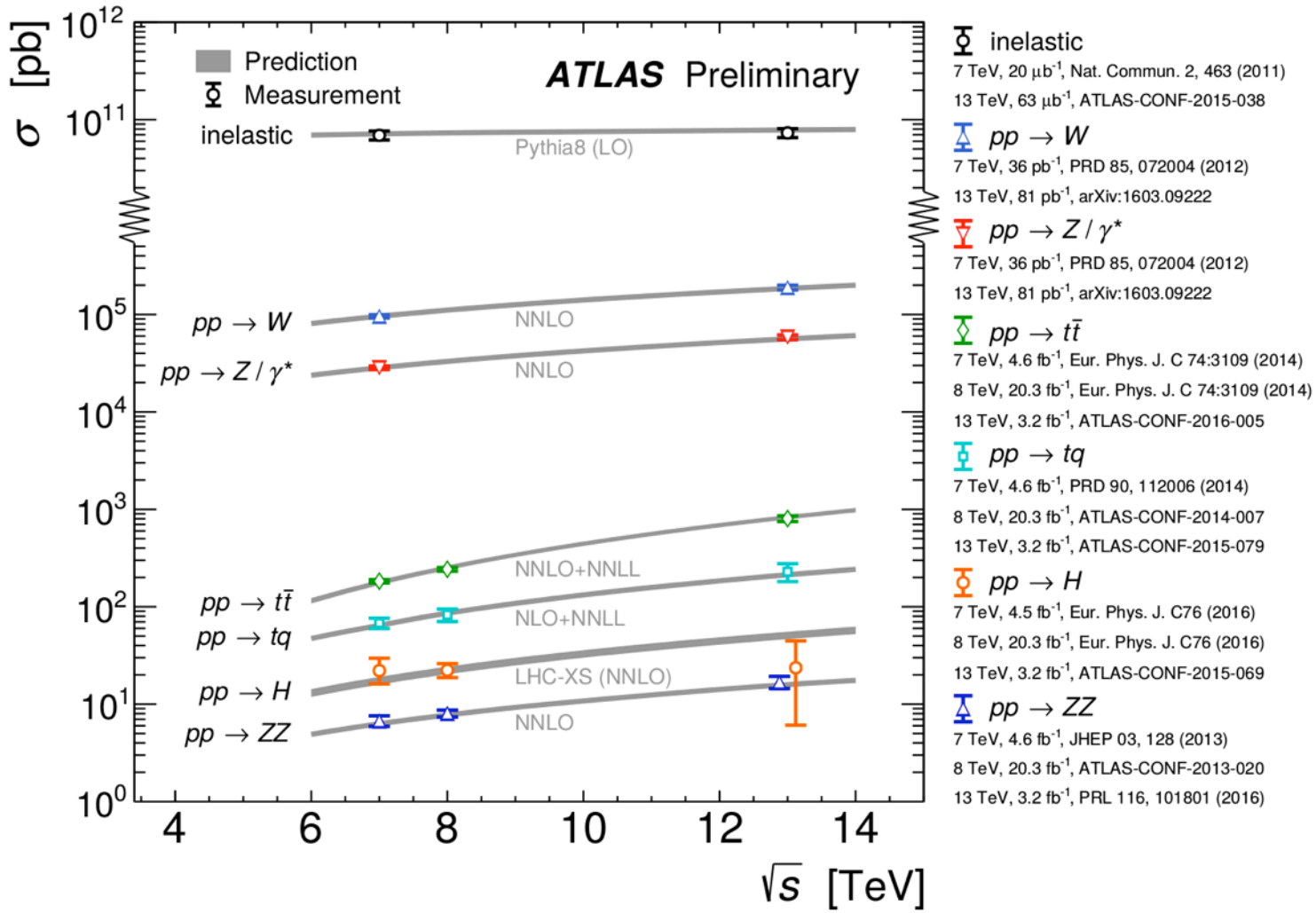


ATLAS-CONF-2015-060



W, Z measurements @ 13 TeV

- A wide range of cross section measurements has been performed



(Z) → ℓℓ + jets + missing E_T

- SUSY targeted search
  - Modest excess at Run-1
    → 3σ when $m_{ll} \sim m_Z$
- Modest excess in 2015
  - 2.2 σ on and off m_Z
  - With intermediate E_T

To be watched in 2016

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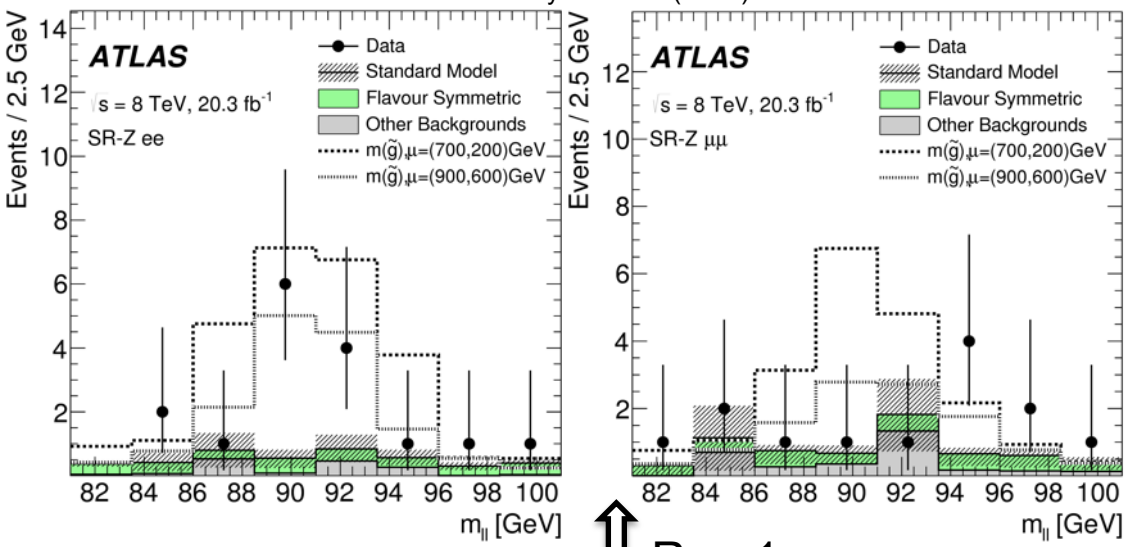
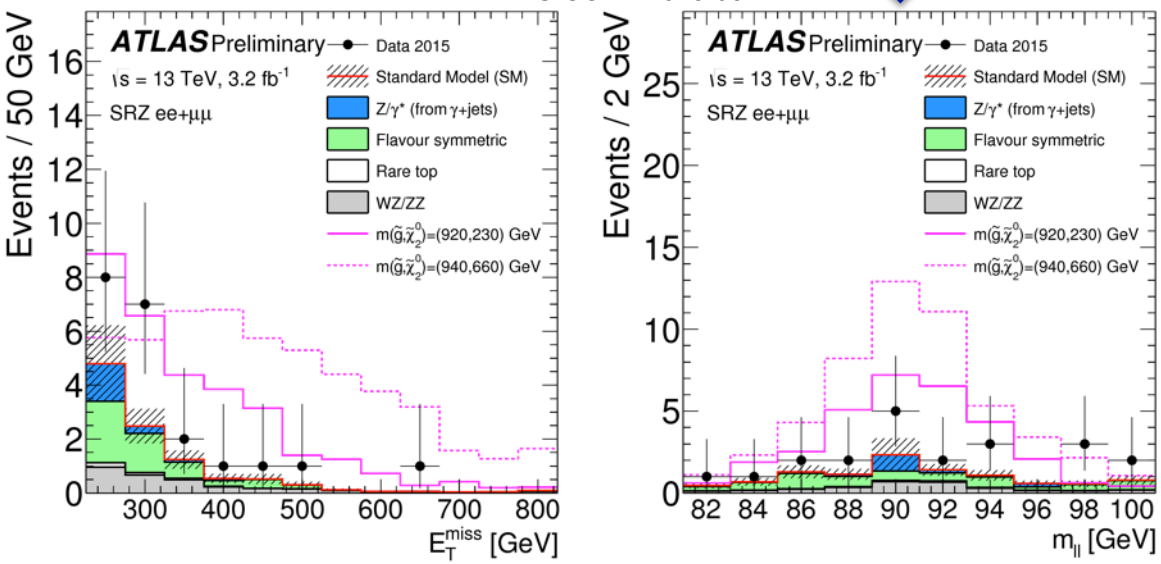


Run 1

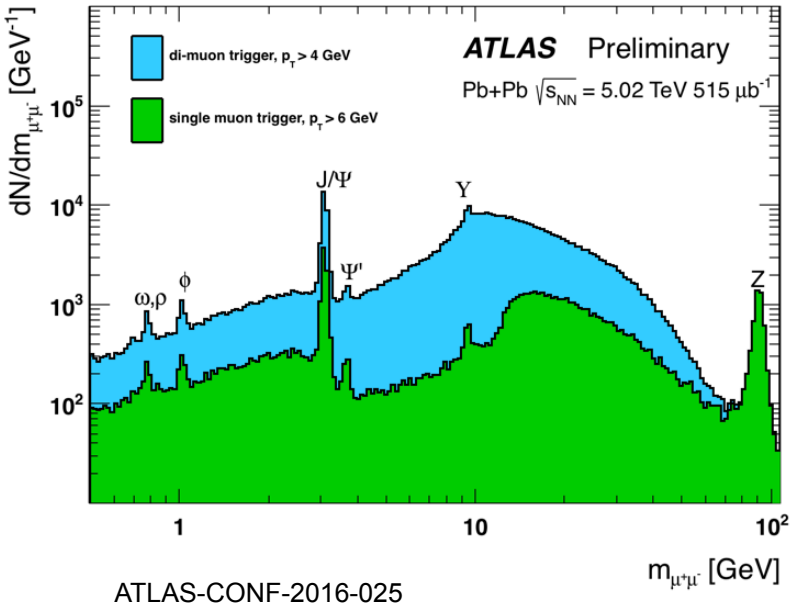
Run 2 (2015)

ATLAS-CONF-2015-082



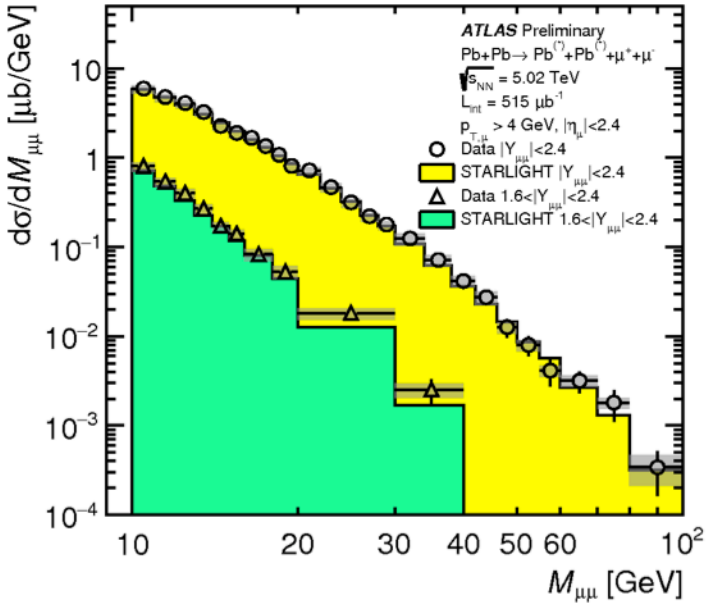
Heavy Ion: Pb+Pb data in 2015

- Recorded 550 μb^{-1} of Pb+Pb data at $\sqrt{s_{NN}}$ = 5.02 TeV
  - Big increase in hard-probe statistics
  - Jet events with p_T from 100-1000 GeV
  - Analyses ongoing with first results now available on:



- High-mass di-muon pairs in ultra-peripheral Pb-Pb collisions
  - Studying the strong EM field surrounding nucleus
    - induces interactions at large impact parameters where strong interaction is not active
  - Well-described by STARLIGHT calculations of Pb + Pb → $\mu^+ + \mu^- + Pb^{(*)} + Pb^{(*)}$

ATLAS-CONF-2016-025



Search for di-photon resonance: significance, spin-2

arXiv:1606.03833

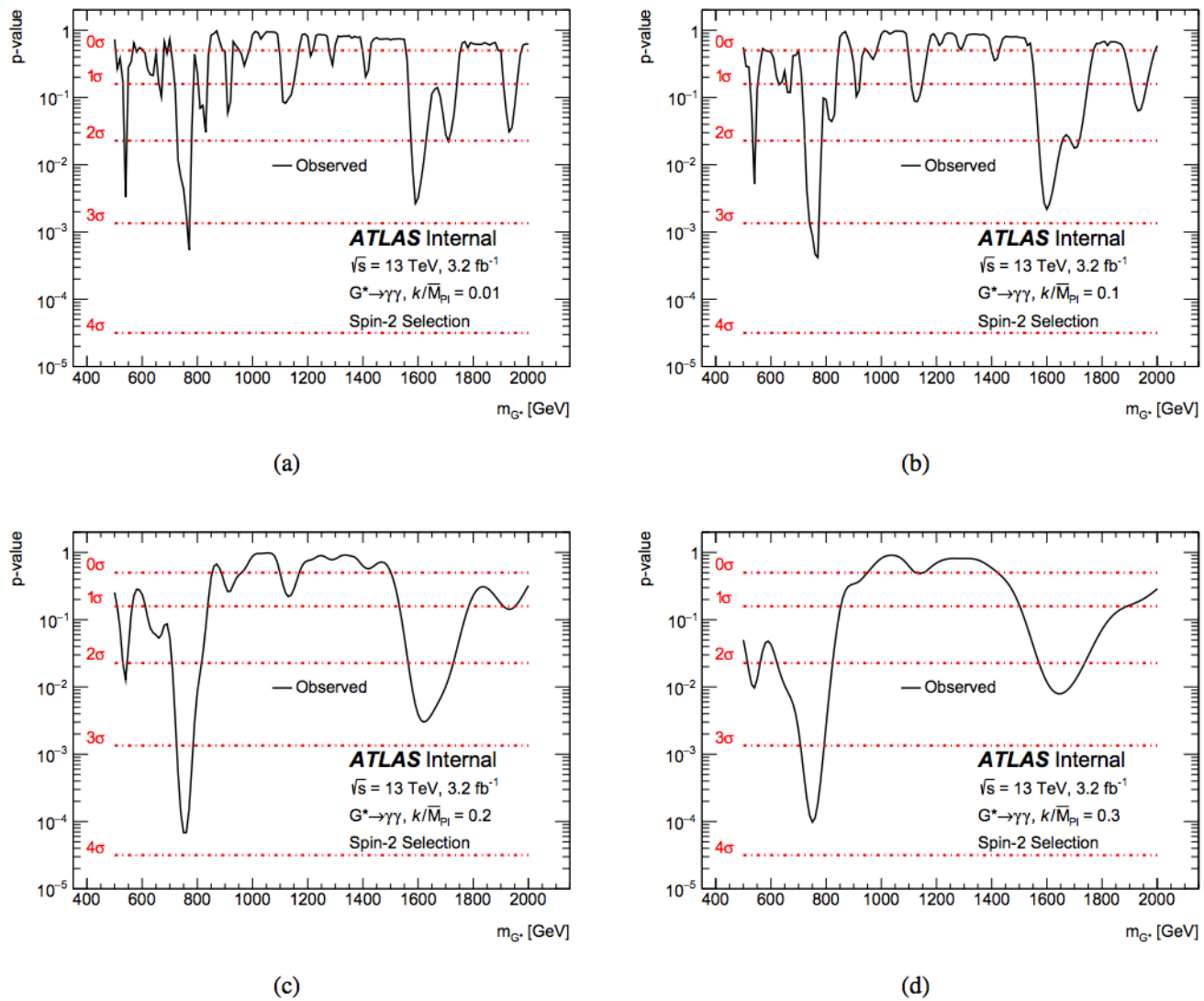


Figure 15: Compatibility with the background-only hypothesis as a function of the assumed RS graviton mass for different values of $k/\overline{M}_{\mathrm{Pl}}$ for the analysis optimized for a spin-2 resonance search.

Search for di-photon resonance: significance, spin-0

arXiv:1606.03833

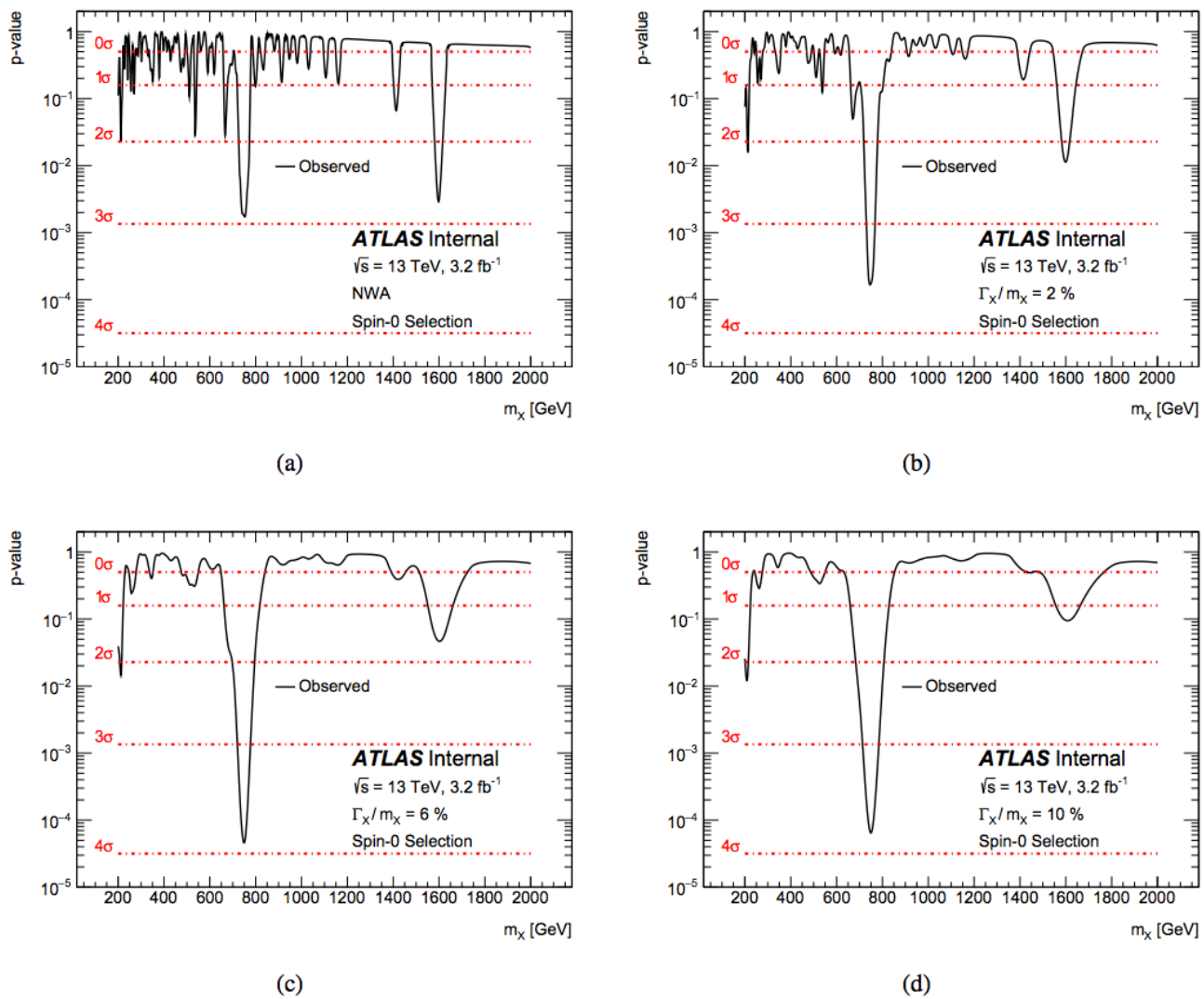


Figure 16: Compatibility with the background-only hypothesis as a function of the assumed signal mass m_X for different values of the relative width Γ_X/m_X for the analysis optimized for a spin-0 resonance search.