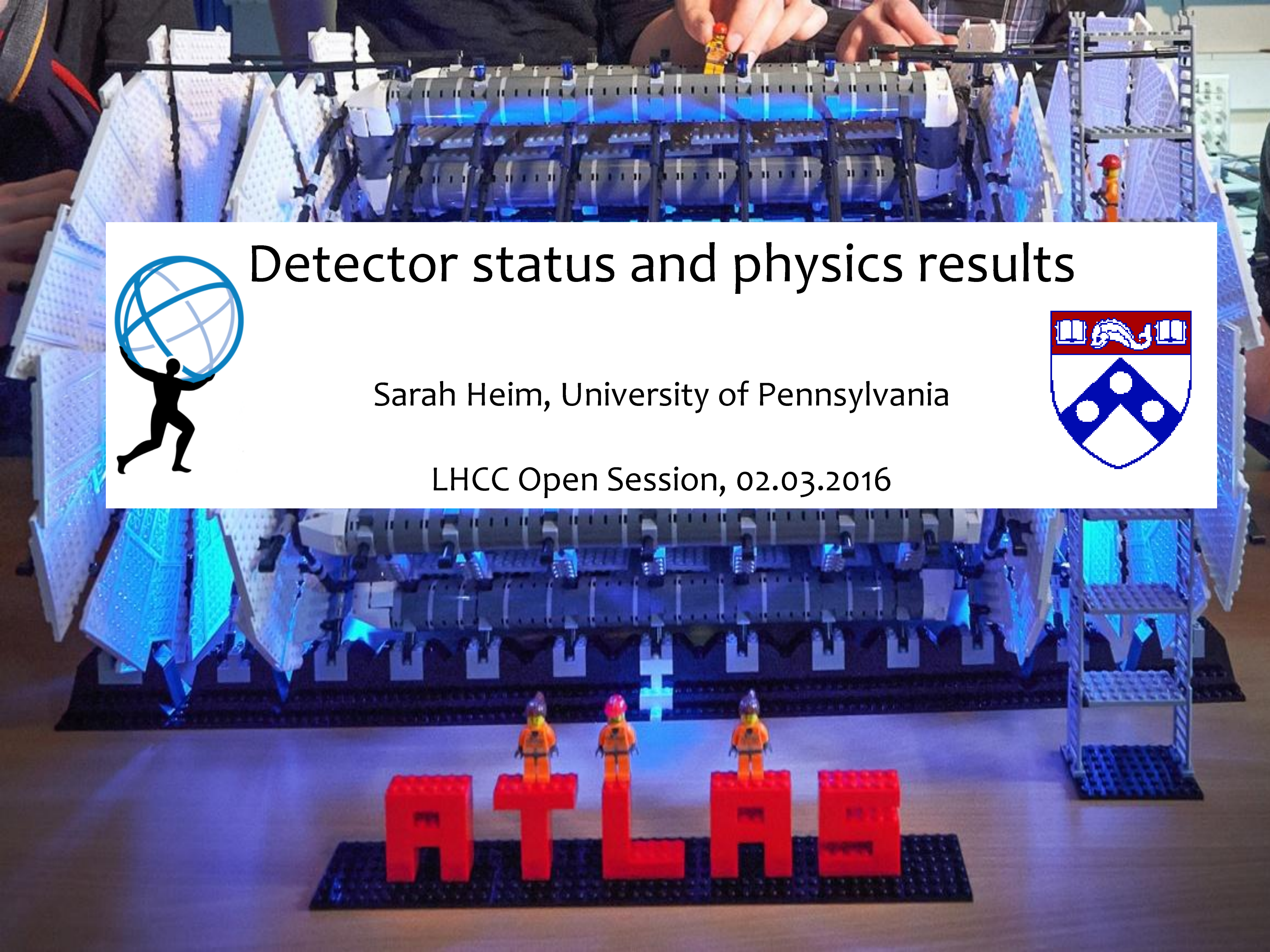
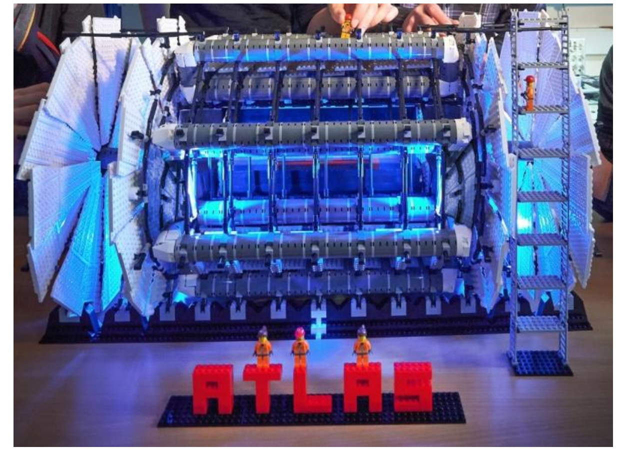


Detector status and physics results

Sarah Heim, University of Pennsylvania

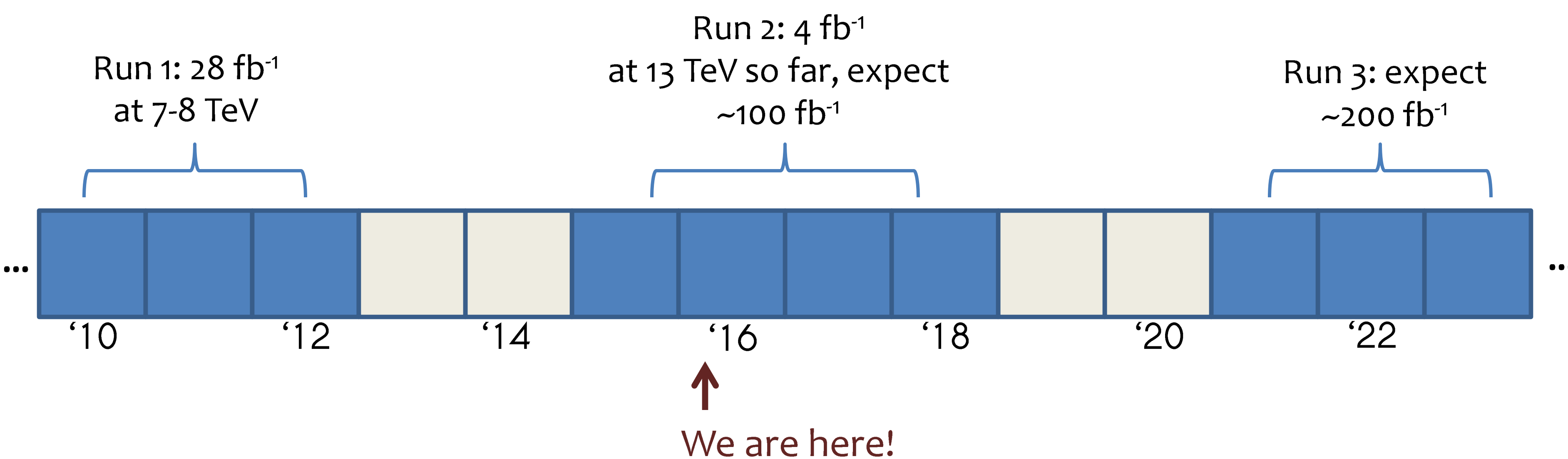
LHCC Open Session, 02.03.2016

What I am going to talk about



- ✓ Selection of latest proton-proton results
- ✓ Detector preparation for collisions in 2016

Extract of LHC run schedule



Recent physics results based on Run 1 data

Milestone: ATLAS has now submitted more than 500 papers on collision data to peer-reviewed journals!

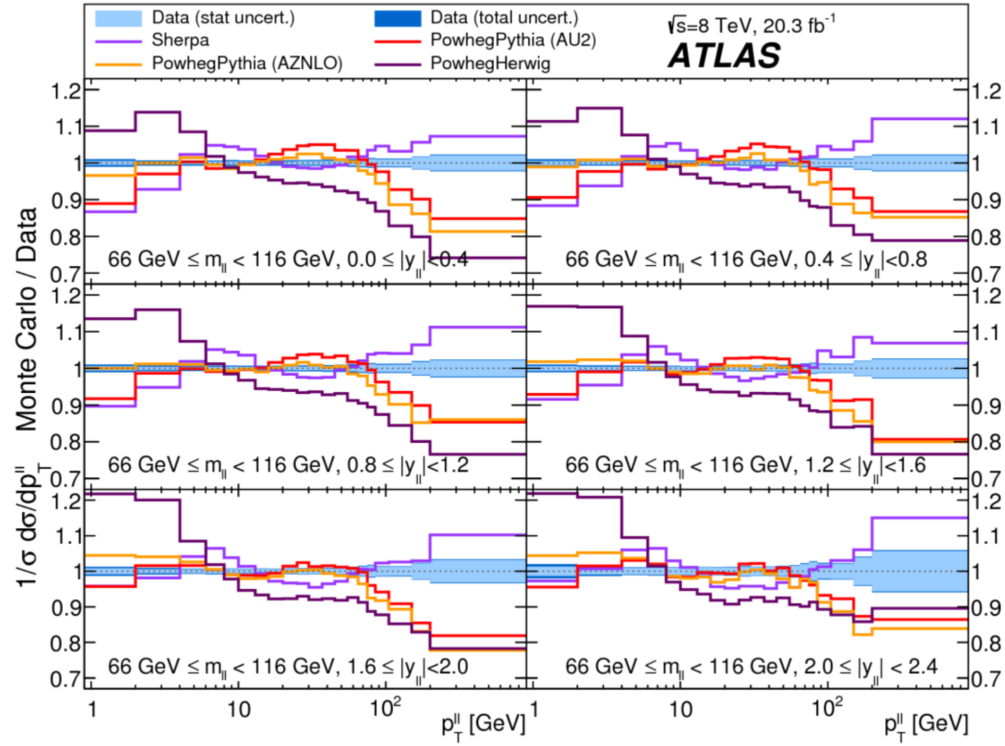
Since last LHCC in December:

- submitted 7 Run 2 papers and 24 Run 1 papers
- in total now 513 papers

~50 precision Standard Model measurements on the 25 fb^{-1} from Run 1 are still in the pipeline

Example of recently released results: Measurements of Z/γ^* p_T distributions

arXiv:1512:02192, submitted to EPJC



Physics results based on 2015 data

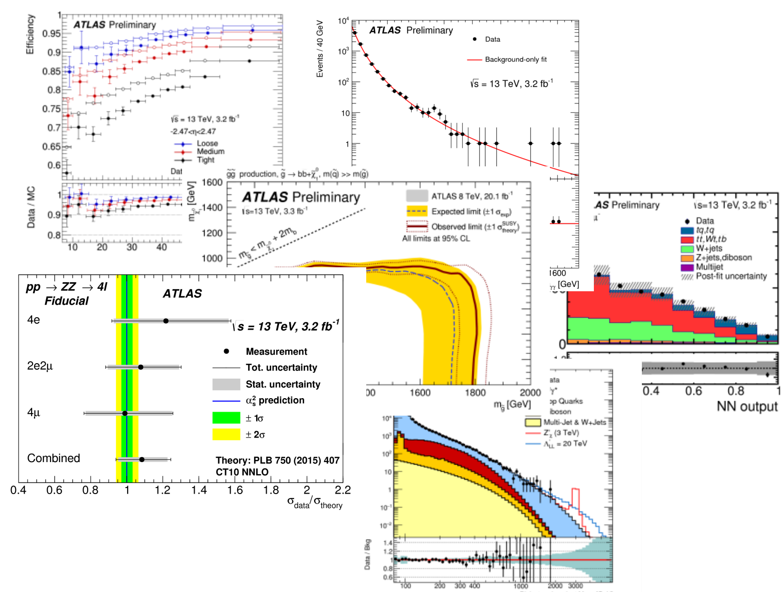
Already public/submitted:

- 8 papers
- 24 Conference notes

→ most presented by Marumi Kado at the CERN seminar December 15th

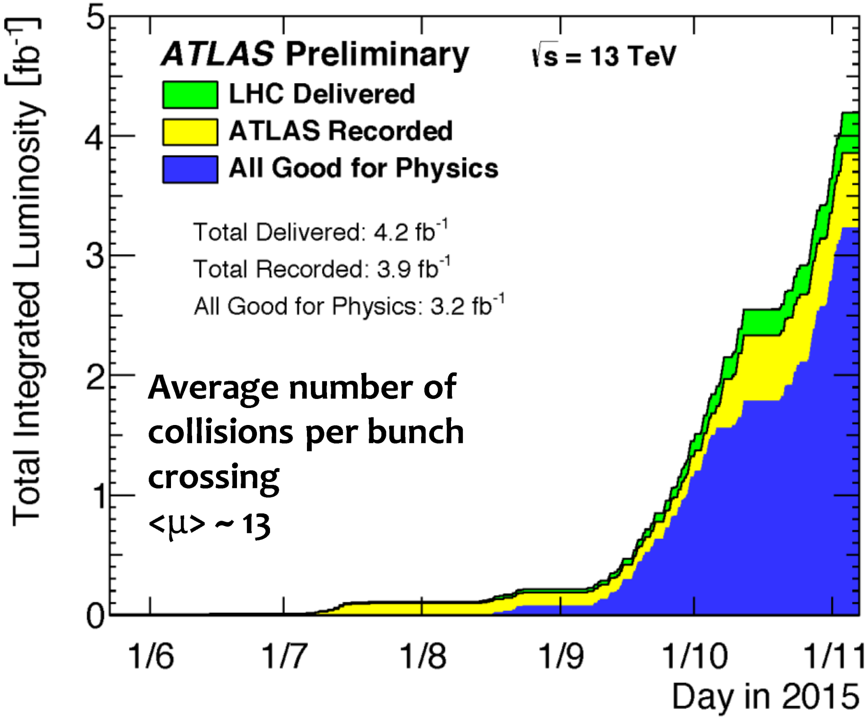
This talk: a selection of

- Detector performance studies
- Standard Model measurements
- New physics searches



2015 data taking

Proton-proton run



Average number of collisions per bunch crossing
<μ> ~ 13

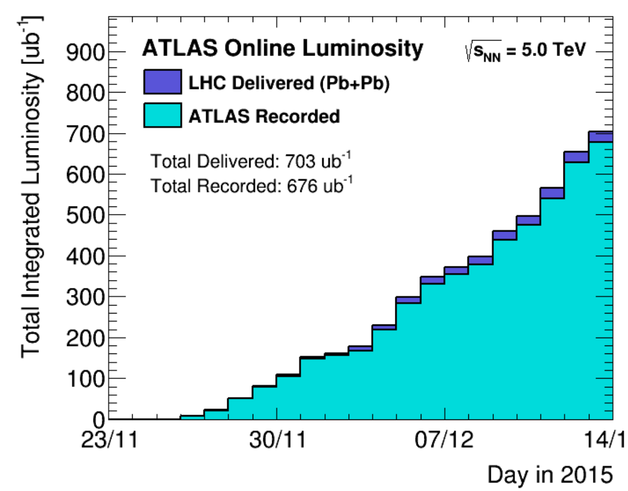
- 3.5 fb^{-1} of 25 ns data good for physics
- 3.2 fb^{-1} if IBL (new innermost Pixel layer) is required

→ Data quality efficiency: 87% - 93%

- excellent trigger performance and stability

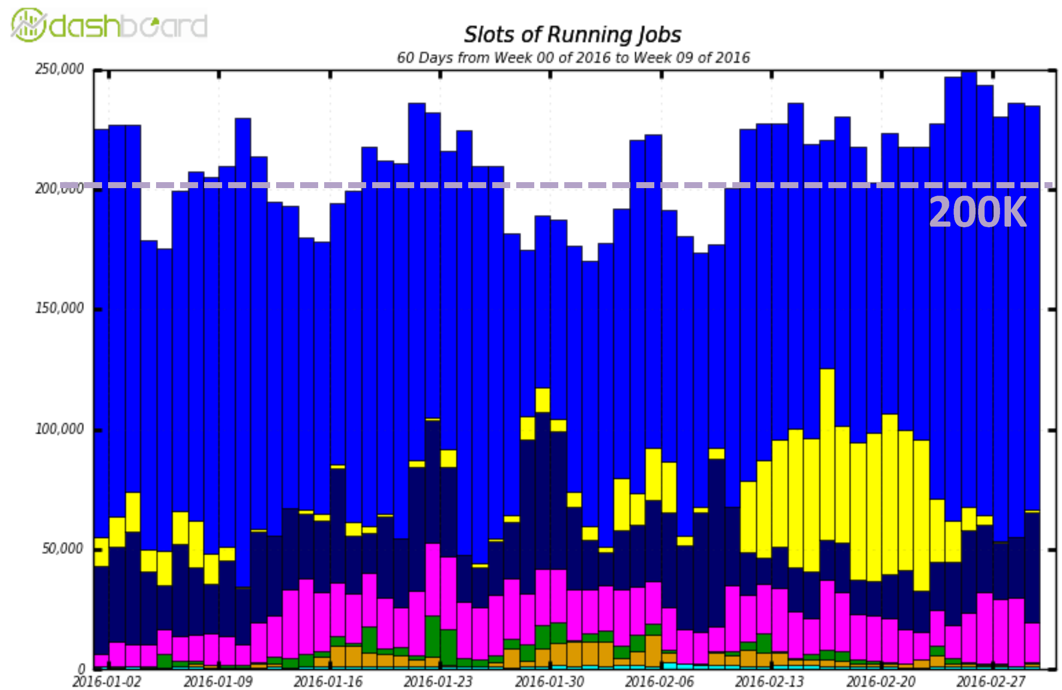
Heavy ion run very successful, as well!

- sqrt(s_{NN}) = 5.02 TeV
- 0.67 nb^{-1} recorded



Reprocessing of 2015 pp data, 2016 reconstruction

Reprocessed 2015 data (2 billion events) with same reconstruction as 2016 data taking within 2 weeks without crashes



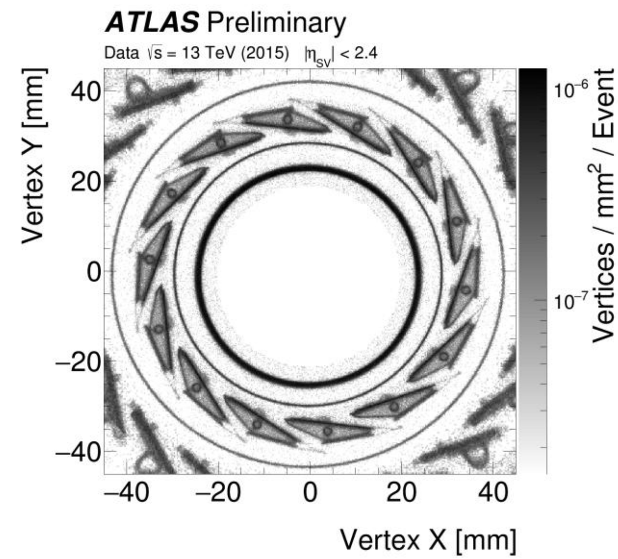
MC simulation, MC reconstruction
Reprocessing, User analysis

Improvements to reconstruction:

- lumi-by-lumiblock alignment
- local occupancy measurement using the TRT
- improved Tau identification
- improved Flavor tagging MVA

Detector performance and object reconstruction

ATLAS-PHYS-PUB-2015-050



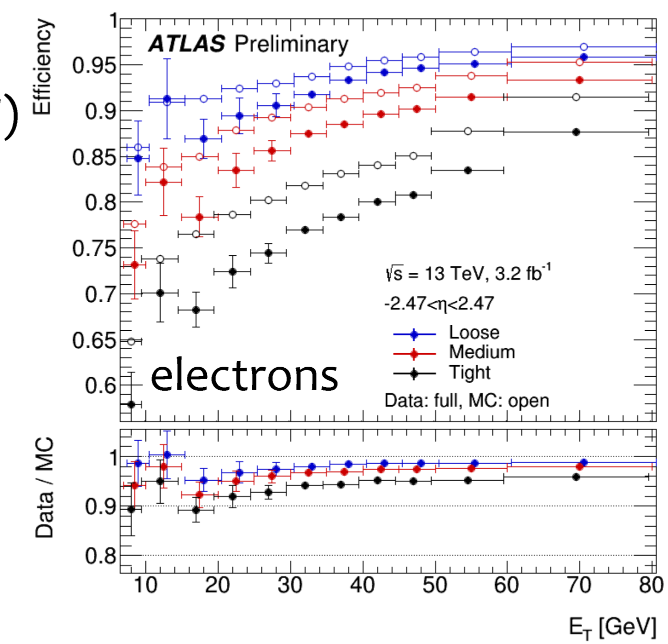
Improved tracking performance thanks to IBL

Crucial for all following results:

Excellent understanding of the detector!

Efficiencies, energy scale, resolution:

determined in data, used to correct simulation



Electrons

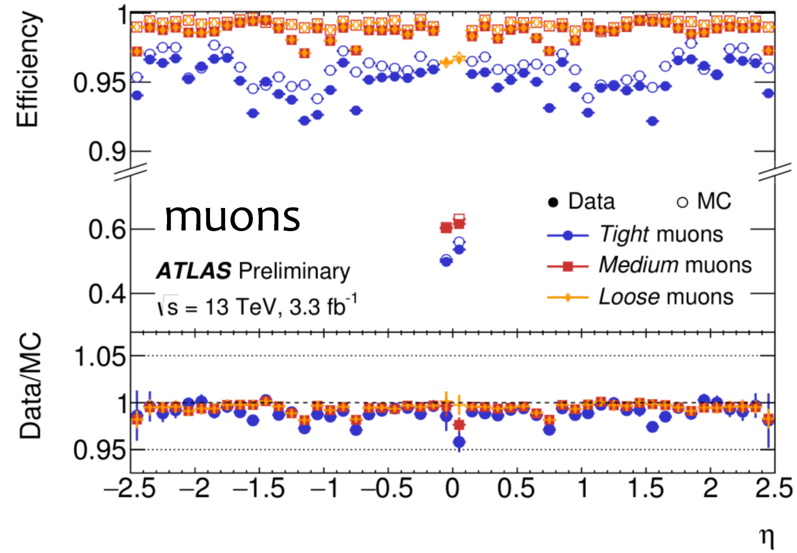
- data efficiencies measured using Tag & Probe (Z, J/Ψ)

Photons

- efficiencies based on Run 1, MC corrections, checks in data

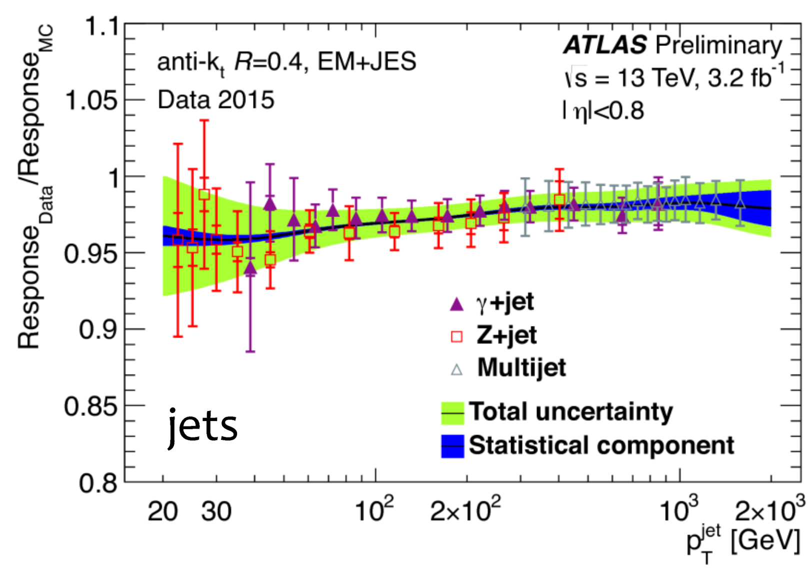
For both: calibration based on Run 1, MC corrections, cross checked in data

Detector performance and object reconstruction



Muons

- data efficiencies measured using Tag & Probe (Z, J/Ψ)
- Resolution and momentum scales for the inner and muon detectors were measured in data



Jets

- energy scales and resolutions extracted from data for results to be released in March/April

MET

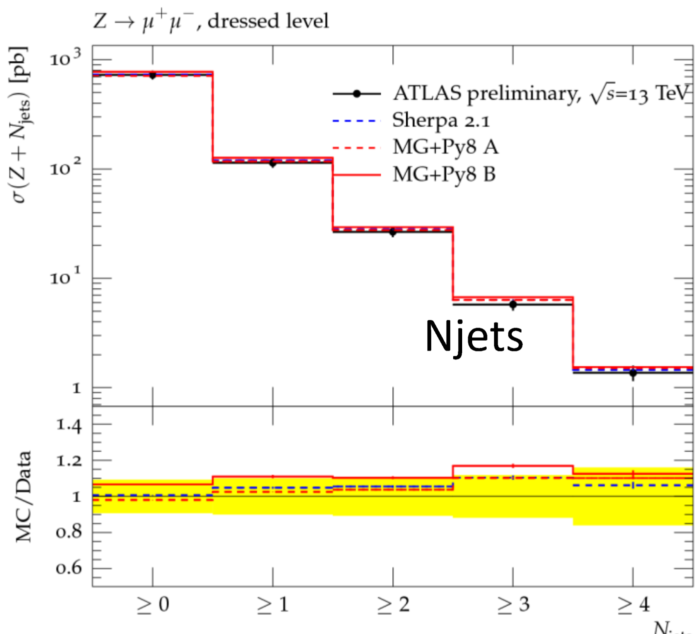
- uncertainties derived from data for results to be released in March/April

Modeling for MC simulations

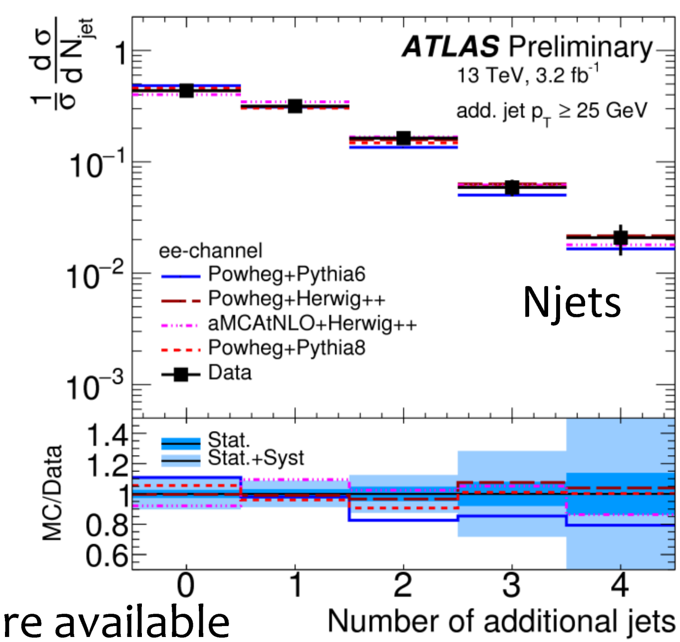
- physics modeling also crucial for all analyses
- ATLAS is now using latest MC generators where possible, extensive checks were performed to find optimal setup
- huge documentation effort lately (released for ATLAS/CMS MC workshop)
- two examples, comparison to unfolded 13 TeV data:

ATLAS-PHYS-PUB-2016-01
ATLAS-PHYS-PUB-2016-02
ATLAS-PHYS-PUB-2016-03
ATLAS-PHYS-PUB-2016-04
ATLAS-PHYS-PUB-2016-05

V + jets: Sherpa 2.1.1 NLO (2 partons, LO up to 4 partons)

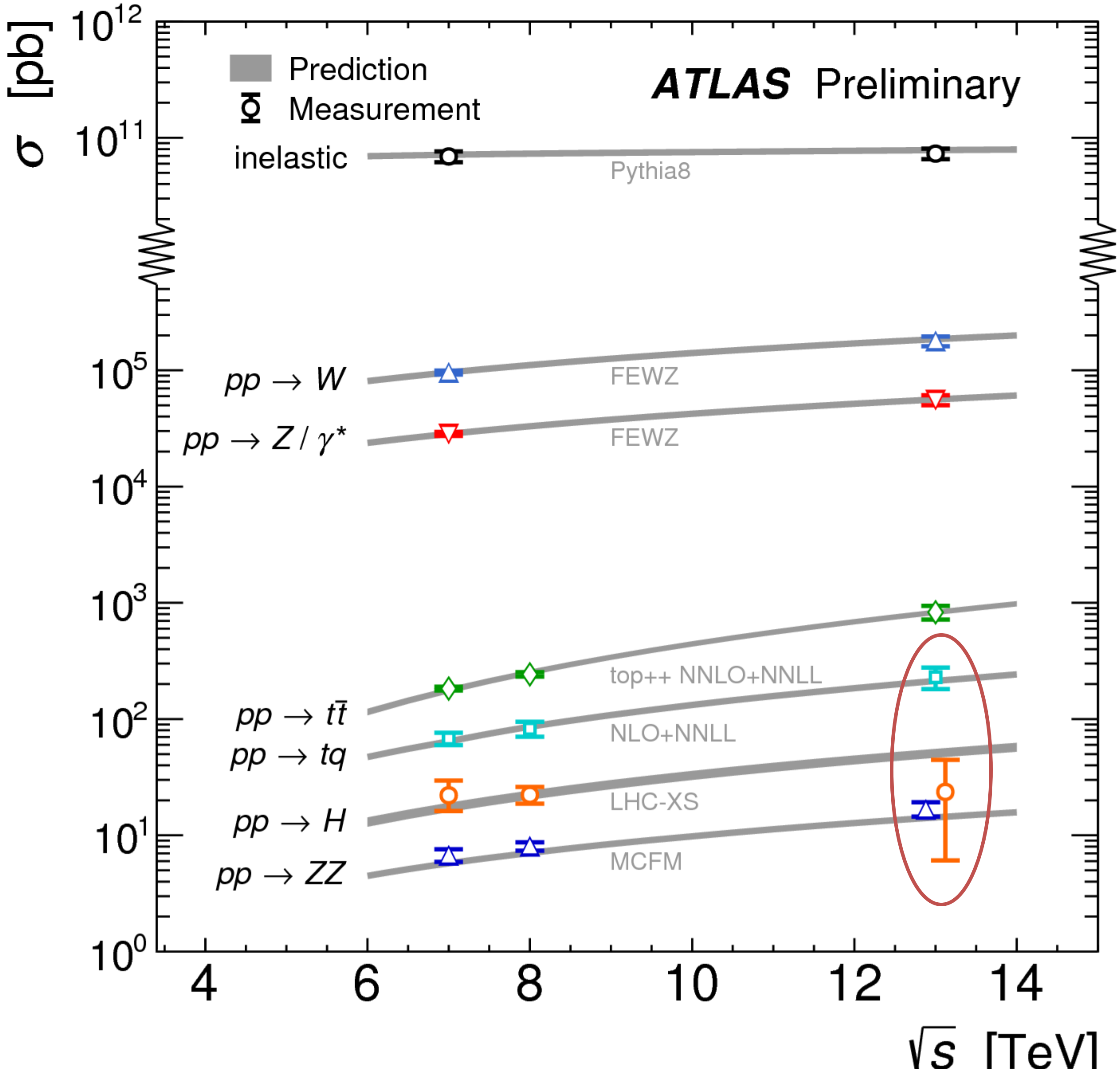


Top pair production
Powheg-Box v2 (NLO)



Normalized to higher order cross sections, where available

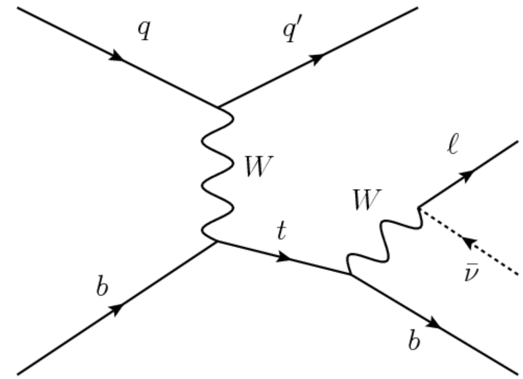
2015 Physics results - measurements



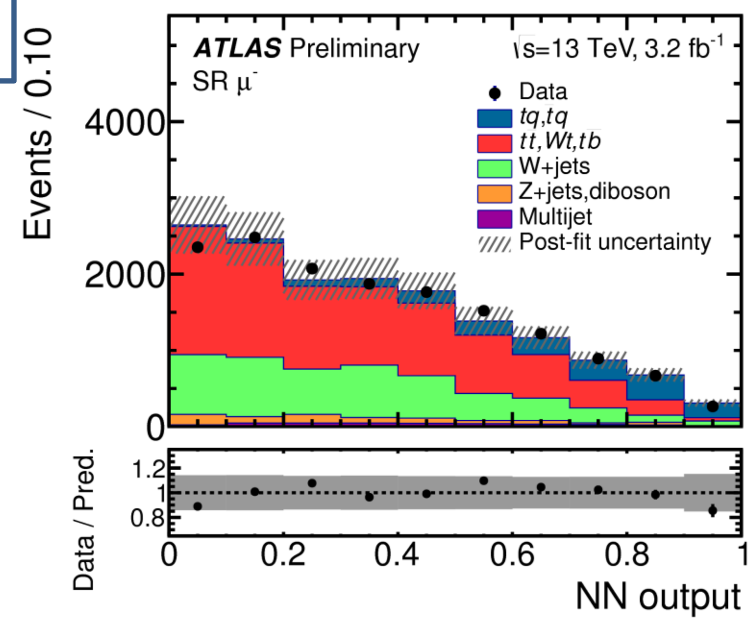
2015 Measurements - single top quark production

ATLAS-CONF-2015-079

Cross section measurement in the t-channel, separately for t and $\bar{t}$, using events with 2 jets, 1 b-tag, 1 muon



$$\sigma_{tq} = 133 \pm 6(\text{stat}) \pm 24(\text{sys}) \pm 7(\text{lumi})\ \text{pb}$$
$$\sigma_{\bar{t}q} = 96 \pm 5(\text{stat}) \pm 23(\text{sys}) \pm 5(\text{lumi})\ \text{pb}$$



Compared to NLO predictions:

$$\sigma_{tq} = 136.0^{+5.4}_{-4.6},\ \sigma_{\bar{t}q} = 81.0^{+4.1}_{-3.6}$$

Measurement of the CKM matrix entry Vtb (assumptions: Vtb >> Vts,Vtb and 100% decays to Wb, SM-like left-handed coupling)

$$|f_{\text{LV}} \cdot V_{tb}| = 1.03 \pm 0.11$$

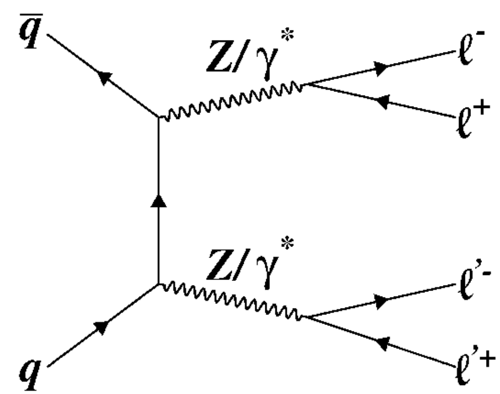
$$\begin{bmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{bmatrix} \begin{bmatrix} |d\rangle \\ |s\rangle \\ |b\rangle \end{bmatrix} = \begin{bmatrix} |d'\rangle \\ |s'\rangle \\ |b'\rangle \end{bmatrix}$$

2015 Measurements – ZZ production

arXiv: 1512:05314, submitted to PRL

ZZ production cross section measurement

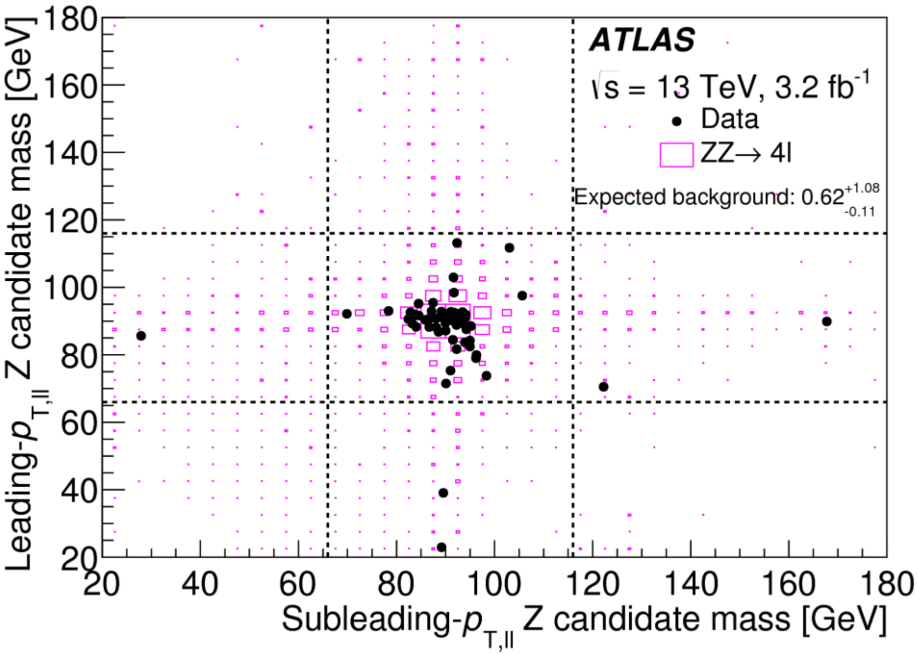
- 2 same flavor, opposite sign lepton pairs with masses consistent with the Z boson mass

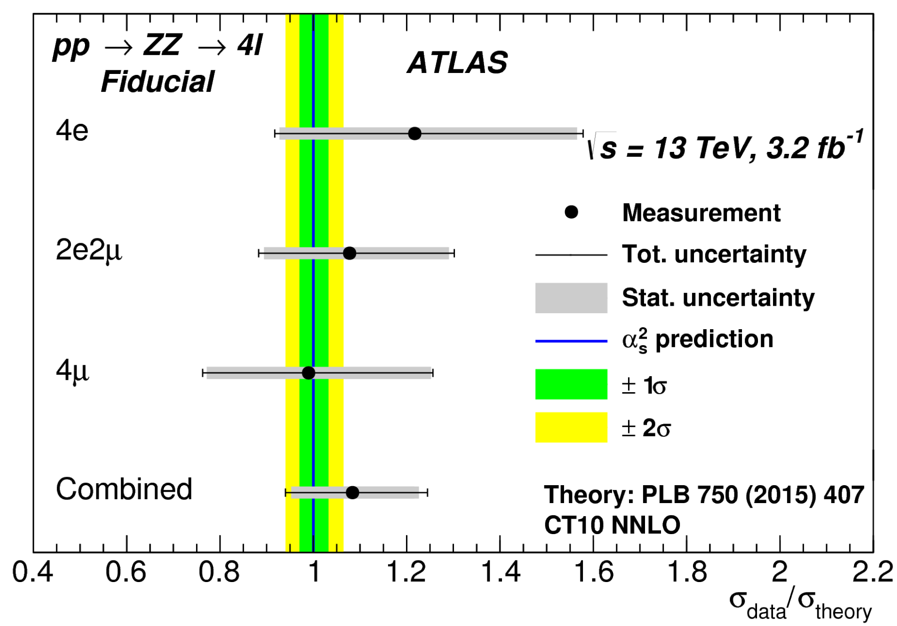


$$\sigma_{ZZ} = 16.7^{+2.2}_{-2.0}(\text{stat})^{+0.9}_{-0.7}(\text{sys})^{+1.0}_{-0.7}(\text{lumi})\ \text{pb}$$

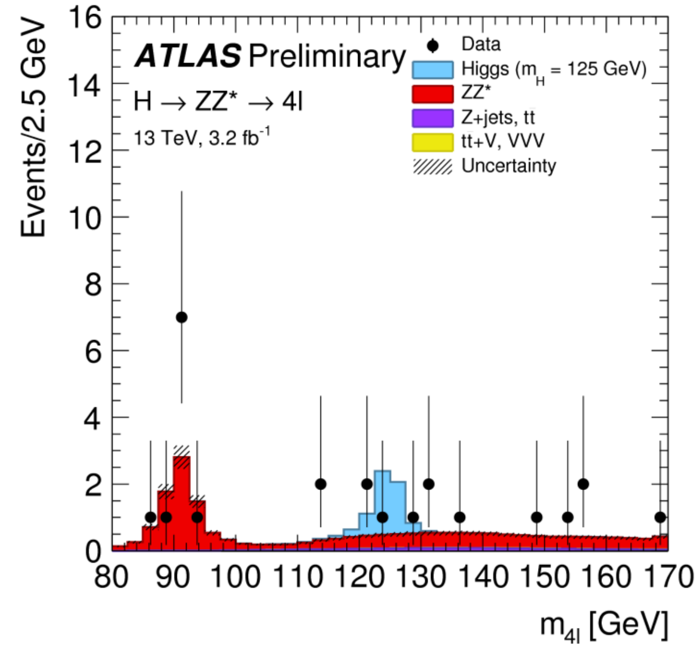
NNLO prediction: $\sigma_{ZZ} = 15.6 \pm 0.4$ pb

(smaller: gg → ZZ production)





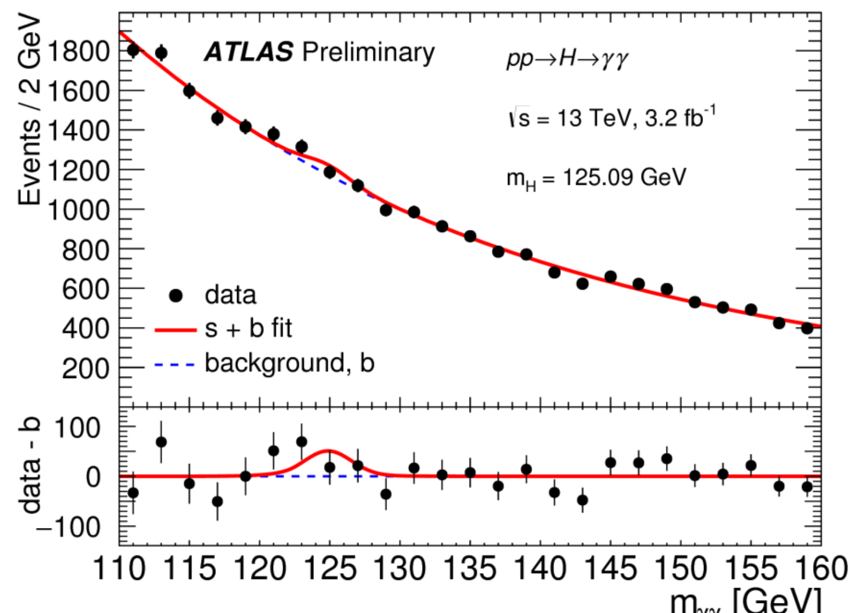
2015 Measurements – glimpsing the Higgs boson again?



In the two discovery channels

- 4l and γγ
- fully inclusive analyses
- still very statistically limited:

$$N_{4\ell} = 1.0^{+2.3}_{-1.5}$$
$$N_{\gamma\gamma} = 113 \pm 74(\text{stat})^{+43}_{-25}(\text{sys})$$



Combined observed significance: 1.4 σ

(expected: 3.4 σ)

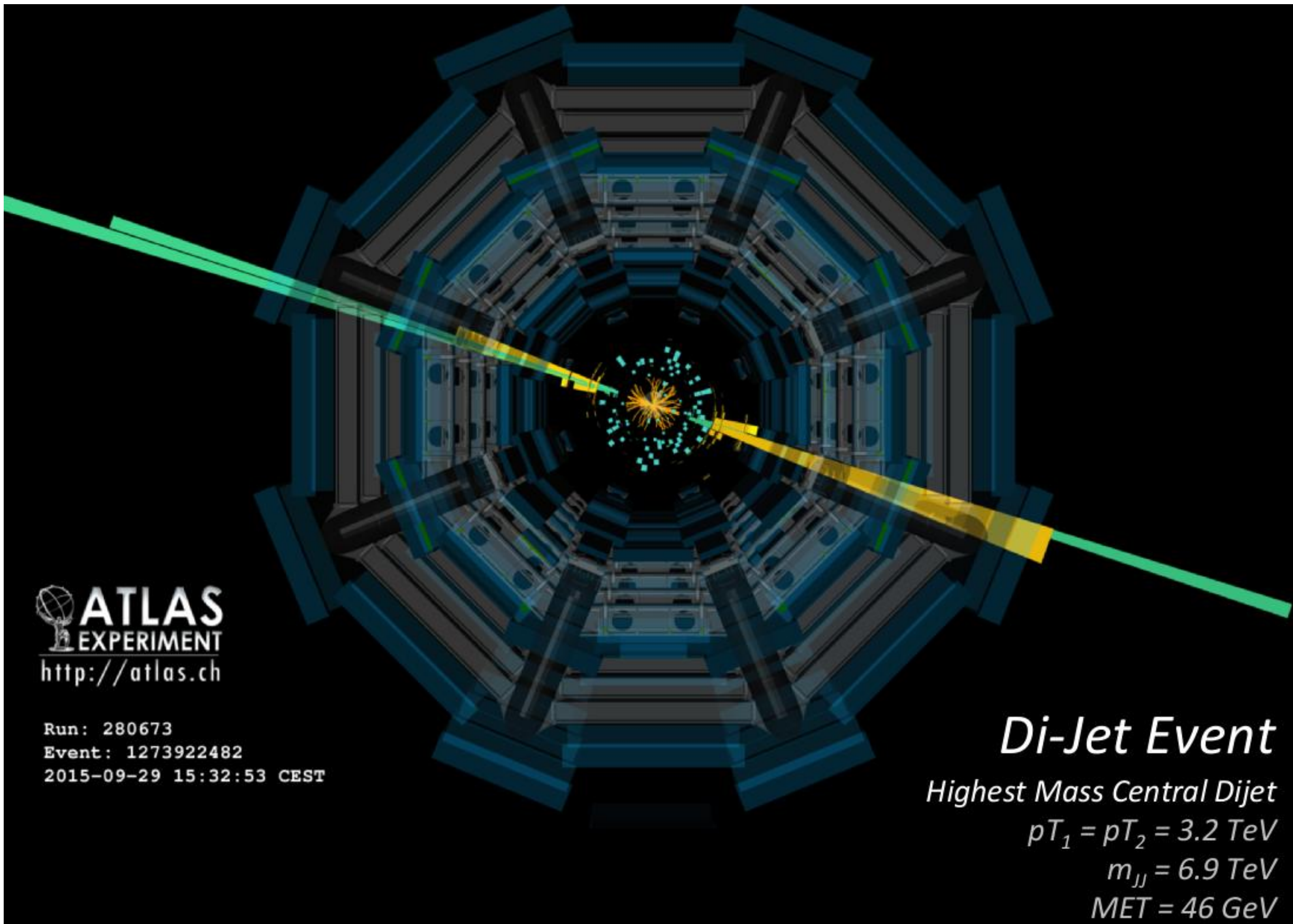
Compatibility with SM: 1.3 σ

ATLAS-CONF-2015-59
ATLAS-CONF-2015-60
ATLAS-CONF-2015-69

2015 Physics results - searches

Benefitting from 13 TeV proton-proton collision energy:

large cross section increase for high mass states!



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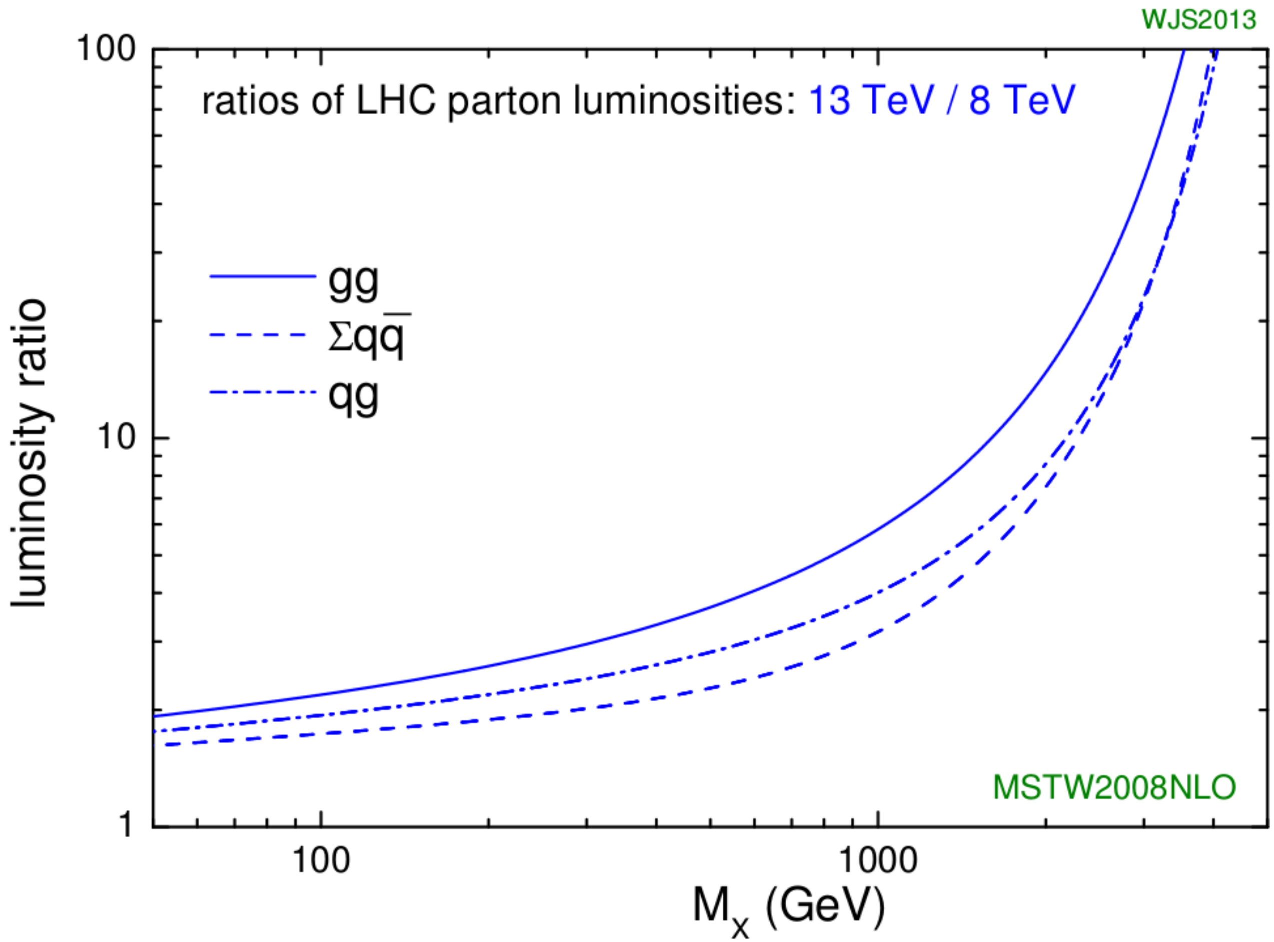


2015 Searches – two photons

ATLAS-CONF-2015-081

Event selection (similar to SM Higgs)

- 2 photons, $p_T/m_{\gamma\gamma} > 0.3, 0.4$
- p_T dependent isolation

→ photon purity ~90%

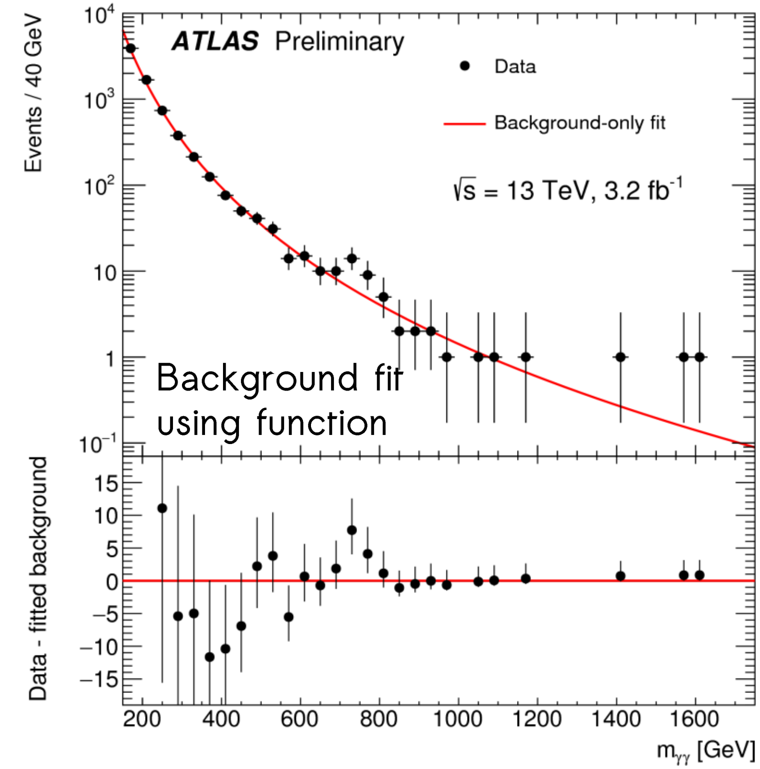
Fit function chosen by optimizing fit quality and minimizing fake signal in NLO simulation

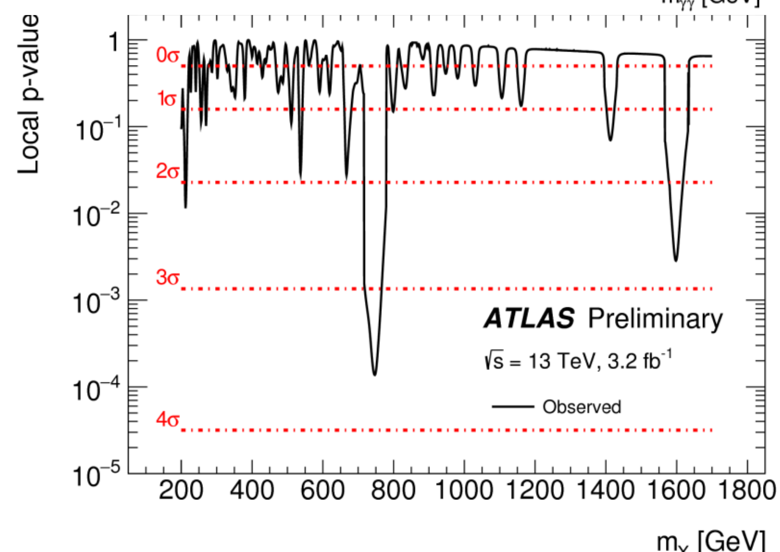
Excess found in the diphoton invariant mass spectrum (search optimized for scalar resonance):

Local significance (NWA): 3.6 σ

for 45 GeV width: 3.9 σ local

Global significance (0.2-2 TeV): 2.0 – 2.3 σ



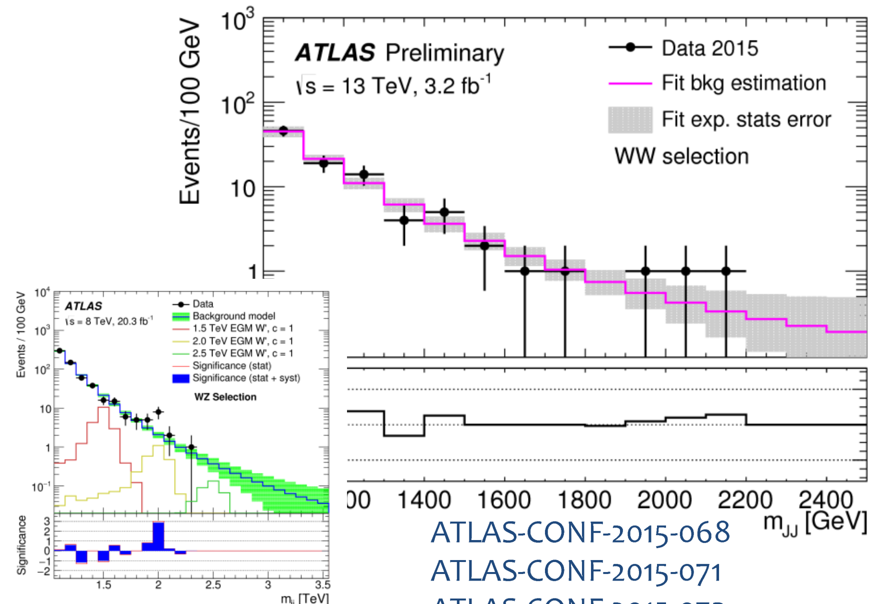


2015 Searches – two heavy bosons (WW, WZ, ZZ)

- leptonic and hadronic decays: 4l, llqq, vvqq, qqqq, lvqq
- for high resonance masses: two jets can be merged to one fat jet

→ using substructure techniques

- Run 1 excess (m_{JJ} ~ 2 TeV, 2.5 σ global) not repeated, not conclusive yet
- exclusion limits set for HVT, graviton and scalar scenarios



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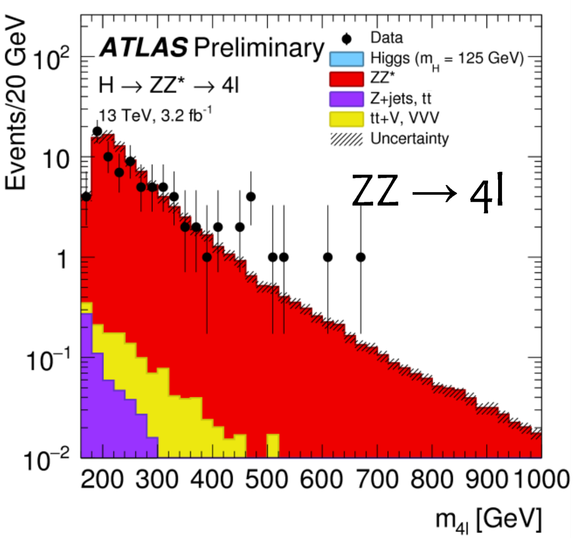
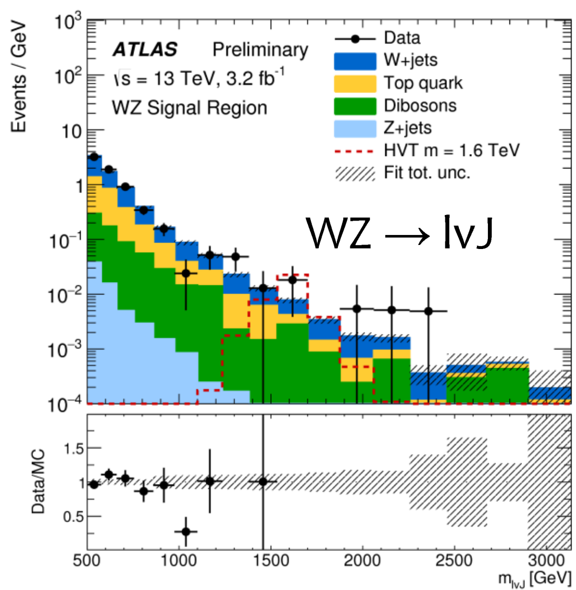
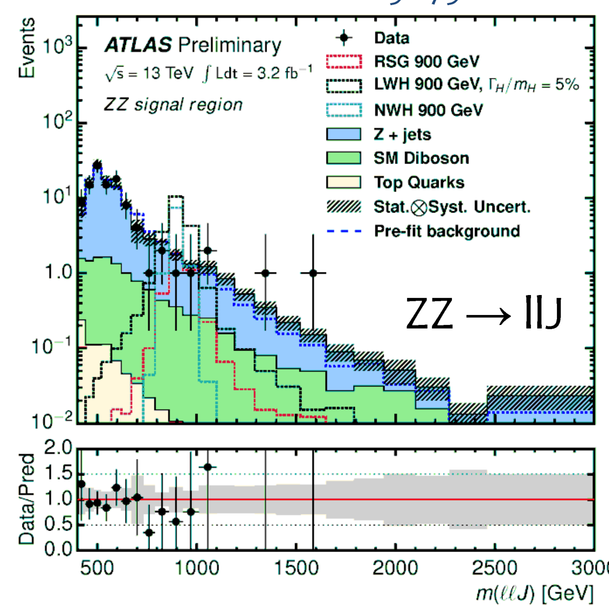
ATLAS-CONF-2015-071
ATLAS-CONF-2015-073
ATLAS-CONF-2015-074
ATLAS-CONF-2015-075







2015 Searches – two leptons

ATLAS-CONF-2015-070, ATLAS-CONF-2015-072

Search for high mass resonances

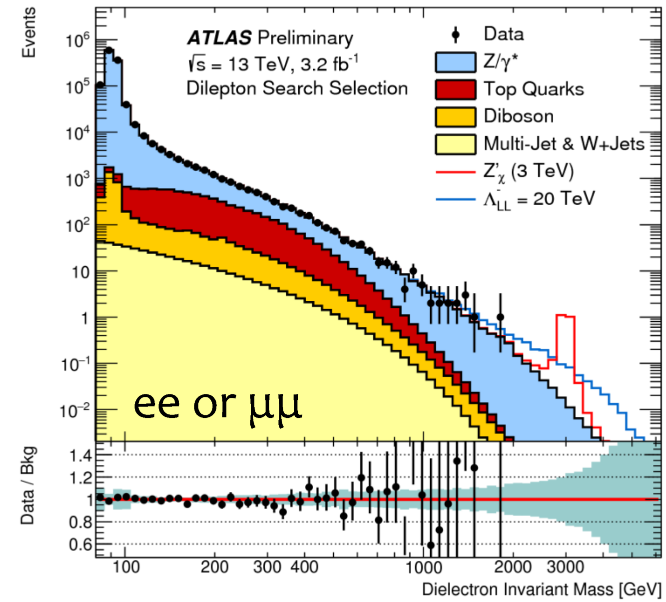
- in both flavor conserving and flavor violating final states
- no significant excess is found

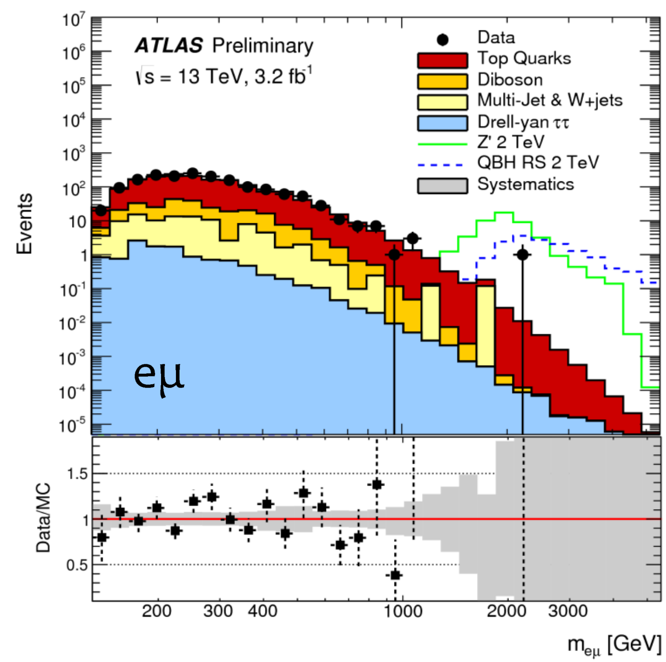
ee or μμ:

- limits set on Z'$_{SSM}$ at 3.4 TeV (2.9 TeV in Run 1) as well as on llqq contact interaction scale

eμ:

- limits set on LFV Z'$_{SSM}$ at 3.0 TeV (2.5 TeV in Run 1) as well as on threshold mass for quantum black holes

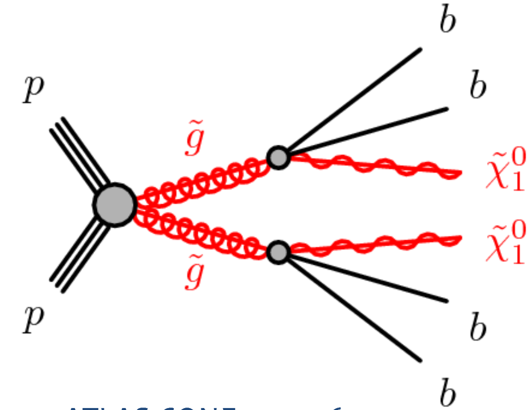




2015 Searches – jets plus missing transverse momentum

Early SUSY searches for gluinos/squarks: For $m_{g/q} \sim 1.5$ TeV, the production mode ratio between 13 and 8 TeV is 35!

- many signal regions depending on jet multiplicity (2-10), and number of b-jets
  - increasing complexity of decay chain
  - sensitivity to sbottom quarks
- no significant excess found



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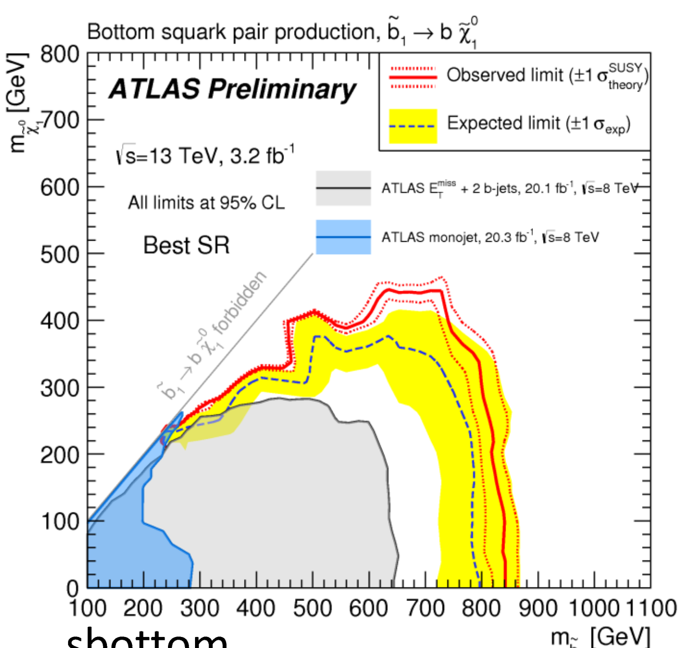
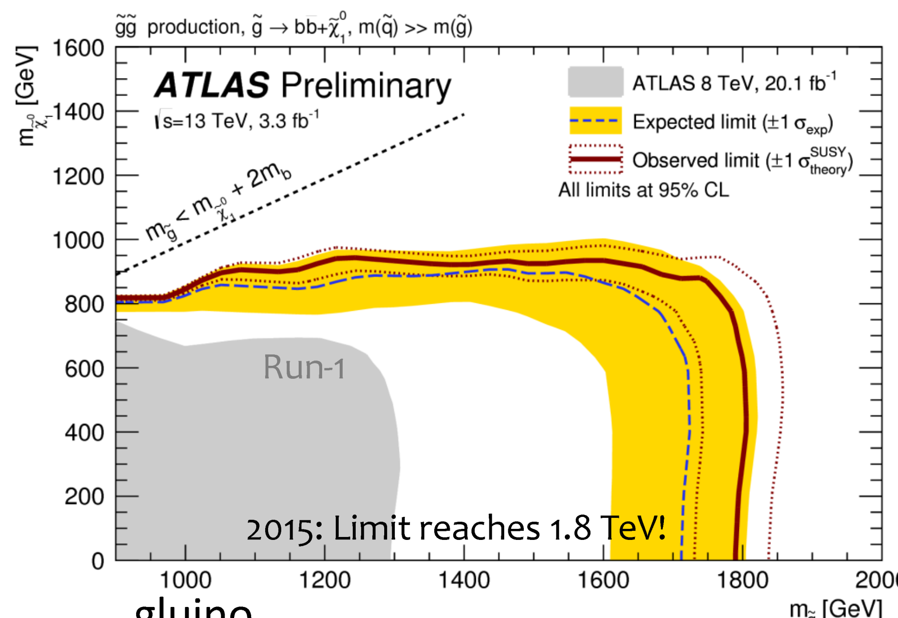
ATLAS-CONF-2015-066
ATLAS-CONF-2015-067
ATLAS-CONF-2015-077



sbottom



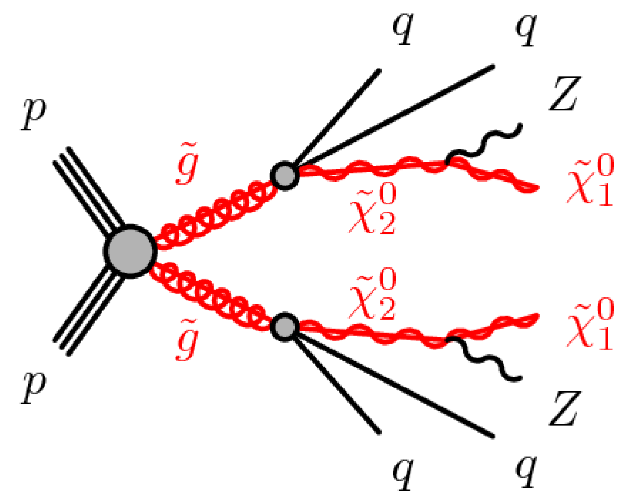
gluino

2015 Searches – dileptons plus missing transverse momentum

ATLAS-CONF-2015-082

Z + jets + MET signature: 3 σ excess in Run 1

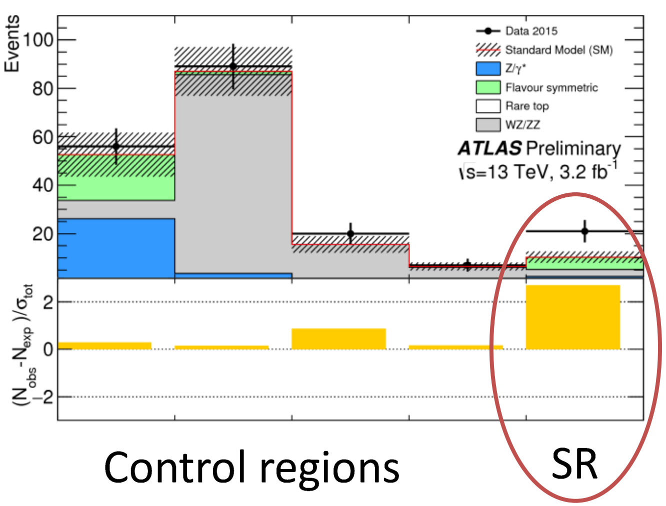
(ATLAS only)

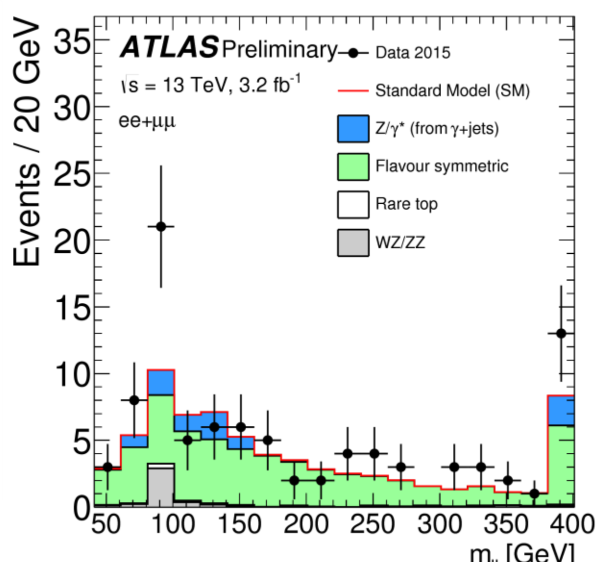


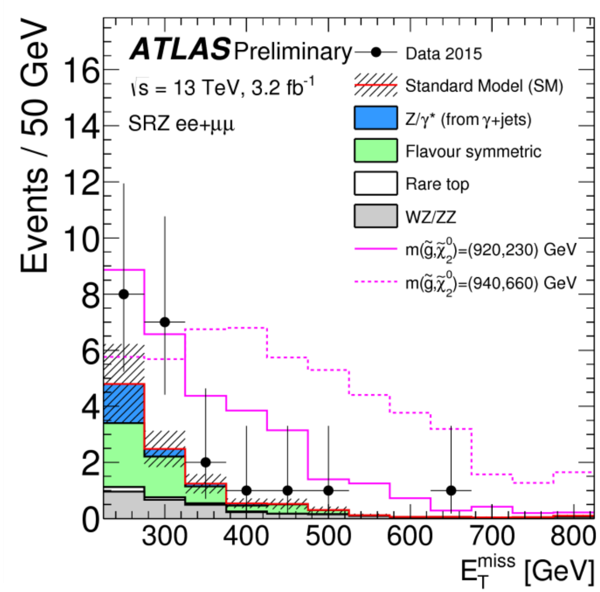
Z candidate (ee or μμ), 2 jets,

MET > 225 GeV, H_T > 600 GeV

Run 2: 2.2 σ excess observed (μ ~ e)







End of year technical shutdown

Subsystem used the time

for repairs and upgrades

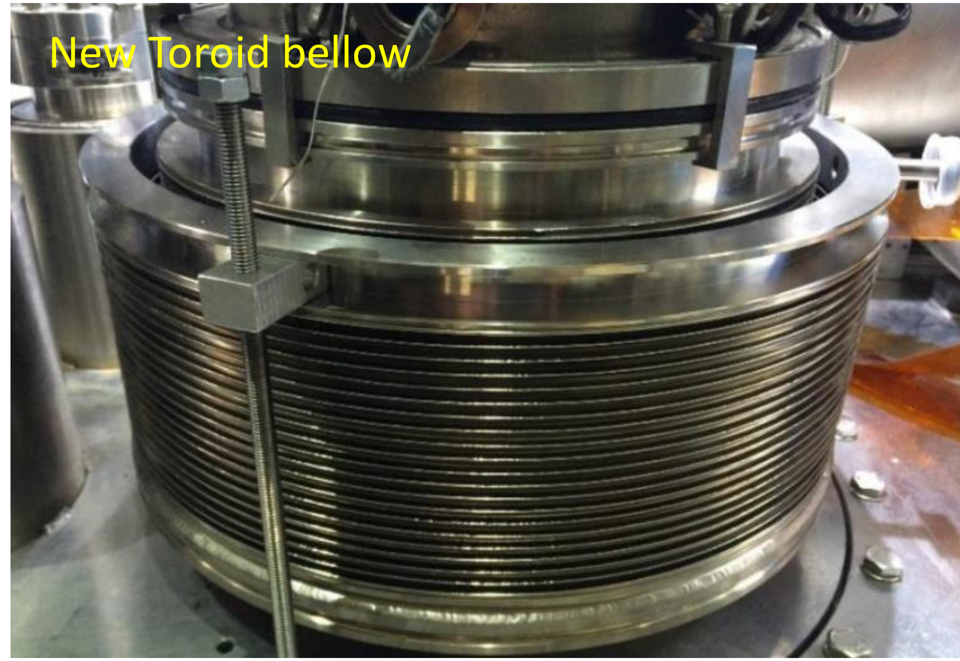
Detector was opened on both sides

C-side:

- Toroid bellows repairs

→ done, toroid cooling down,

closed again



A-side:

- leak in Tile water cooling system

    - wrong connector found and fixed

- opportunity for maintenance on

other systems

→ closing again

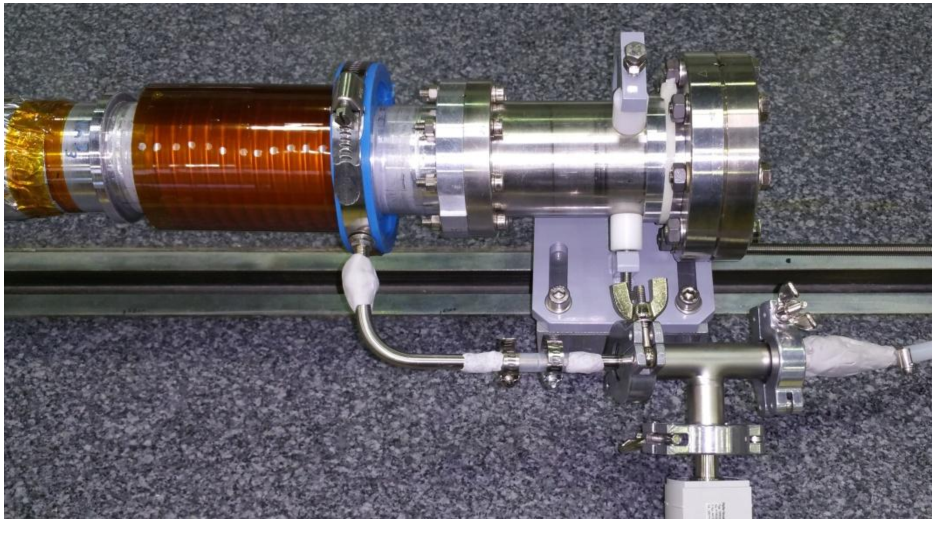
Many thanks to the CERN technical support for the great help!

End of year technical shutdown: Beam pipe

Last weeks' surprise: Inspection on beam pipe revealed dimple on C-side

- created during LS1 or this shutdown
- initial tests found no leak, but to be safe:
  - on advice of LHC/vacuum experts, install collar/clamp

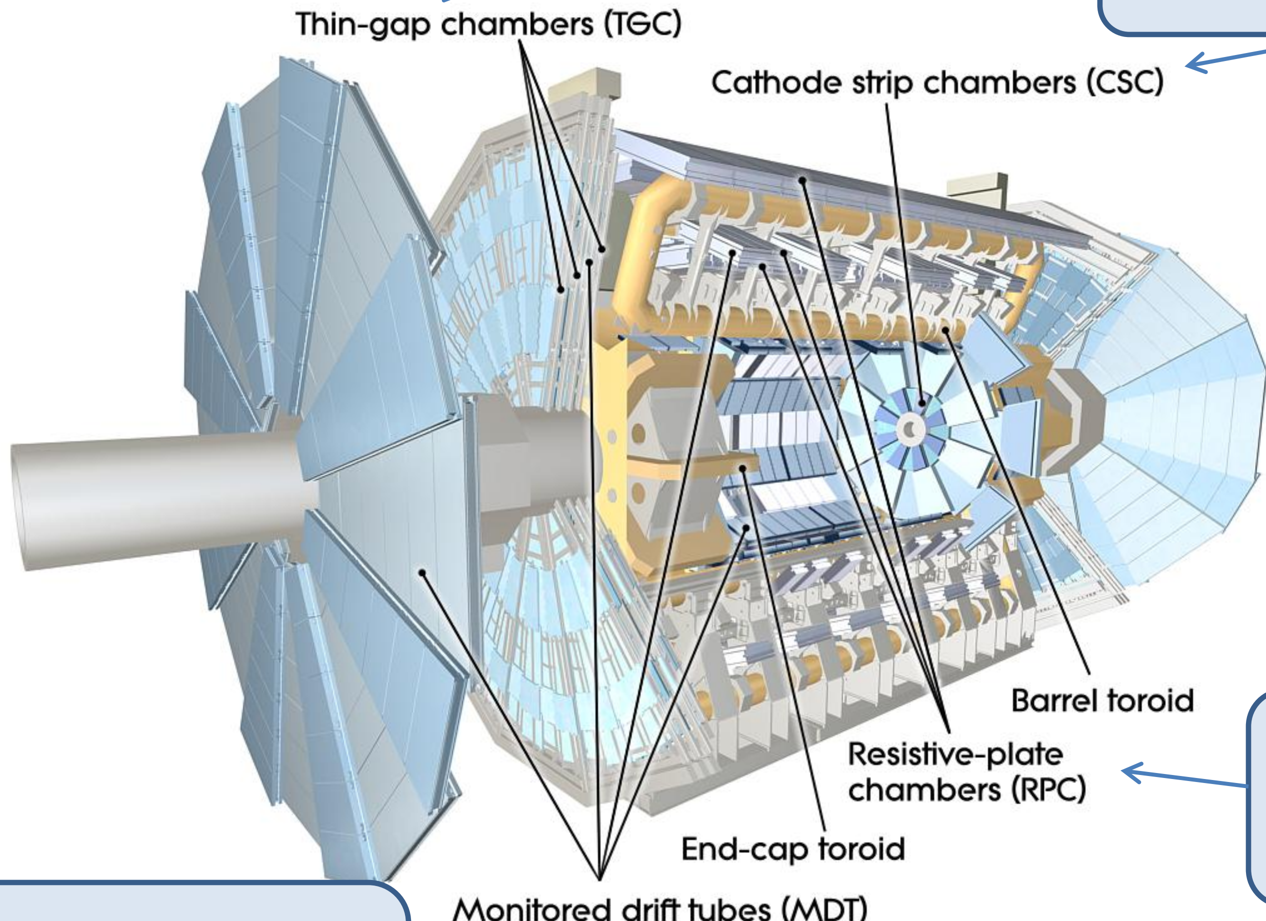
→ a few additional days needed to reopen Toroid, intervene and close C-side again



End of year technical shutdown – Muon systems

Chamber replacement

Improvements to new readout system's firmware



Repairs on leaks in gas inlets ongoing

Fix of
- gas leaks
- front-end electronics
- alignment sensors

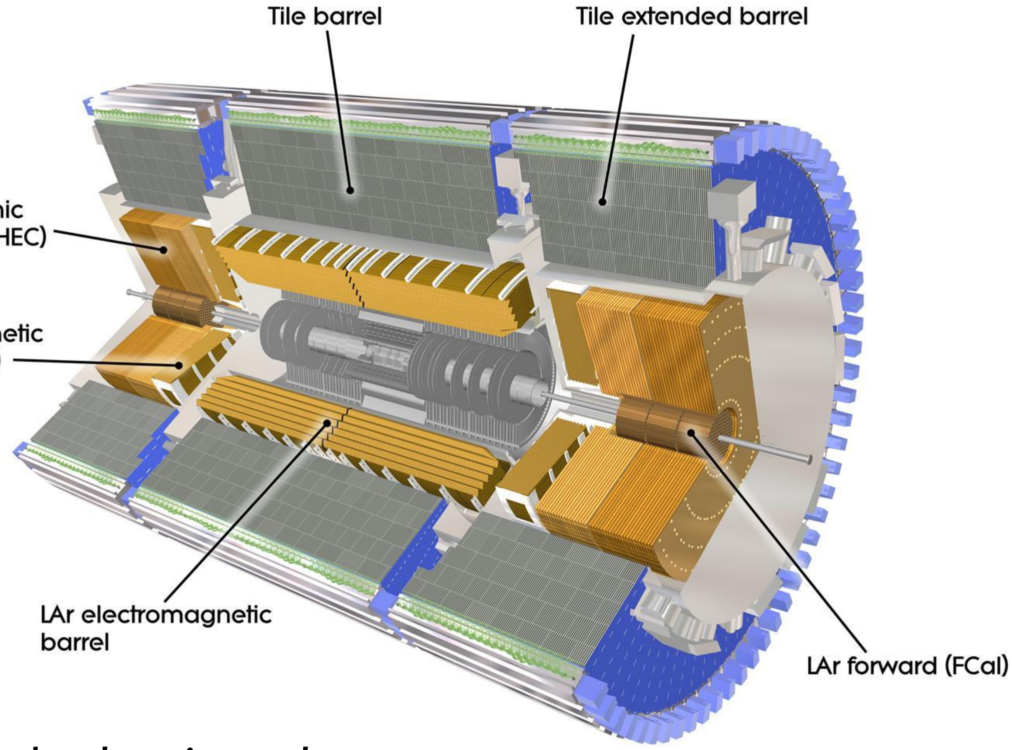
→ Mostly standard maintenance work

End of year technical shutdown - Calorimetry

Tile

- (air) leak in water cooling fixed
- fixed 2 dead modules

→ all modules operational again



Liquid Argon

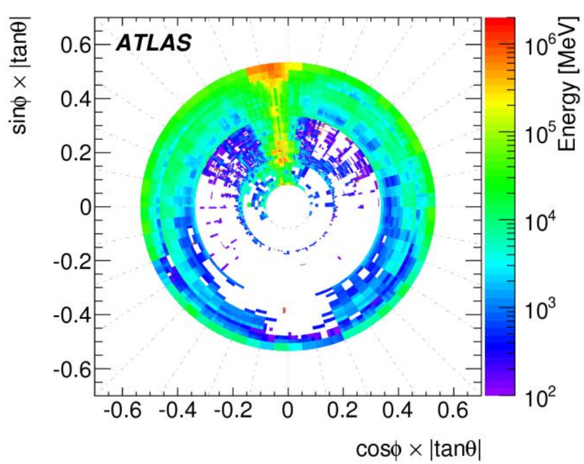
- completed installment of current-controlled high voltage modules in hadronic end cap

→ significant reduction of high voltage trips

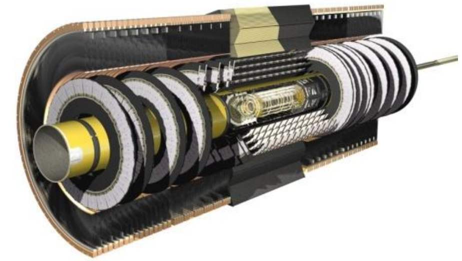
- plan to only run purity monitoring during technical stops or longer breaks between runs

→ significant reduction of noise bursts

→ Both fixes will allow for even smoother running!



End of year technical shutdown – Inner Detector



Transition radiation tracker (TRT)

- updates to HW and SW addressing 1.7% data quality inefficiencies
- more gas leaks opened in 2015, requires:
  - calibration and tuning of gas system
  - decision on Xenon/Argon strategy

Data quality efficiencies		
TRT	SCT	Pixel
98.3%	99.4%	93.5%

due to IBL-off runs

Semiconductor Tracker (SCT)

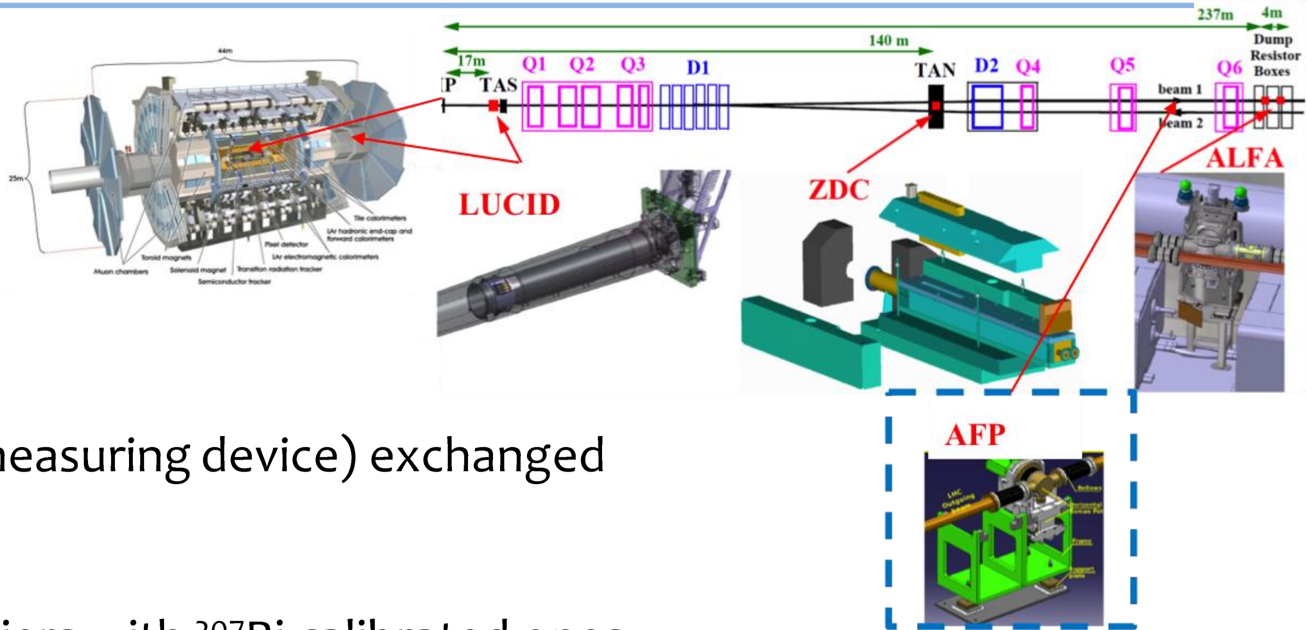
- nominal cooling and powering reestablished after shutdown, recalibrated
- progress on off-detector firmware to address 0.6% data quality inefficiency

Pixel

- upgrades to 2nd layer (reached limit of bandwidth)
  - fixed by replacing electronics (using IBL-type electronics), tested successfully
- IBL (very successful first year)
  - low voltage current increase due to irradiation, close to safety limit
  - tests in lab ongoing

  → effect depends on temperature and dose rate, strategy being developed

End of year technical shutdown – Forward detectors



ALFA

- new electronics, firmware, software for movement system
- noisy LVDT (distance measuring device) exchanged

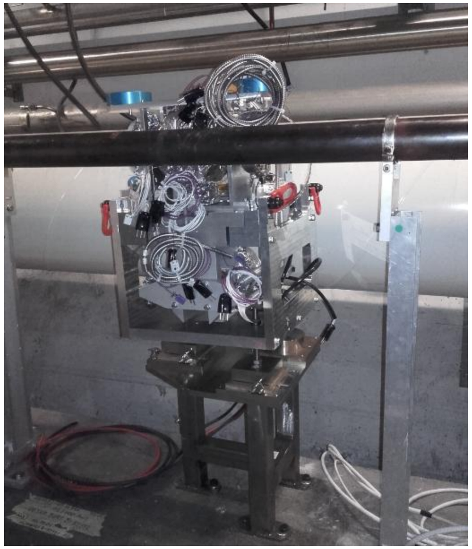
LUCID

- replaced photo multipliers with ^{207}Bi calibrated ones

ZDC

- taken out of the pit for refurbishments
- will be back for heavy ion collisions end of the year

New: AFP (ATLAS Forward Protons)



- goal: study diffractive processes
- installation of 1 arm ongoing, commissioning in March-May

→ very smooth process so far, great success for the AFP team!

Data Acquisition and preparations for first collisions

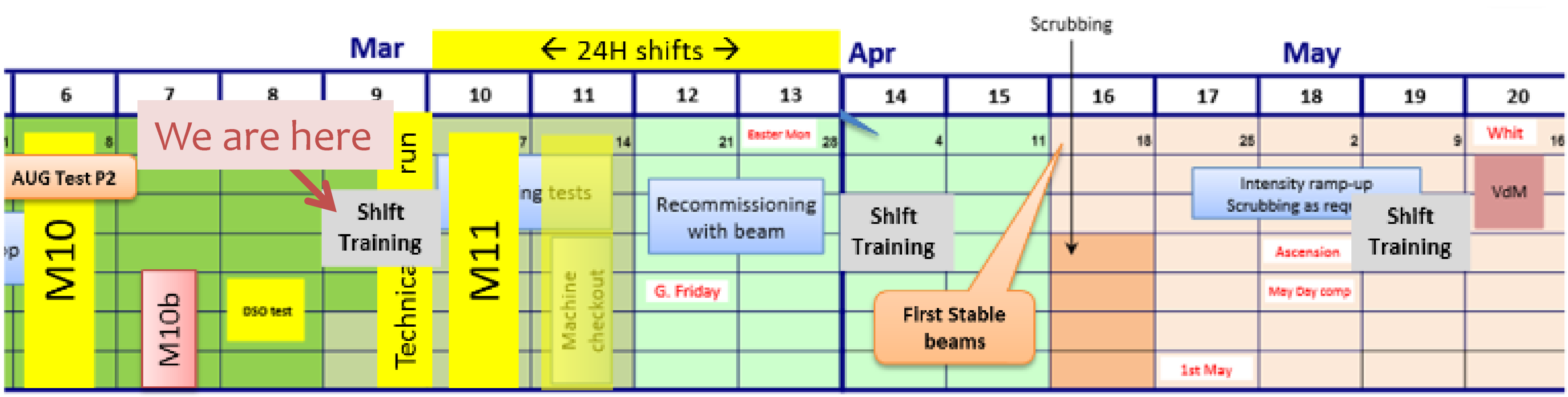
Data Acquisition

- new PC-based Region-of-Interest Builder has been installed and tested successfully
- FTK (full scan tracking at 100 kHz) to be commissioned for the barrel in 2016, hardware arriving at CERN

Detector milestone week February 8th was very successful

- all systems took part
- cosmic data taken, high rate tests successful: noise runs at 100 kHz

Next milestone week (March 7th) will transition into routine data taking



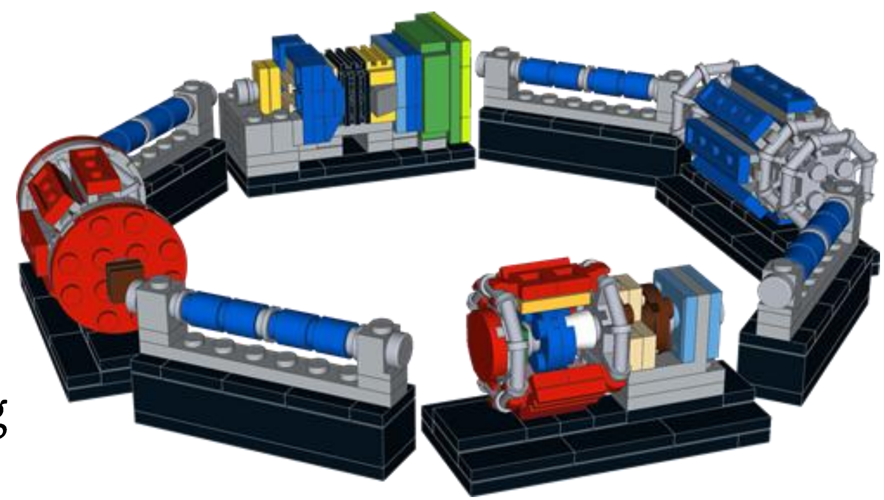
Concluding remarks

2015 was a very successful year for ATLAS

- excellent detector performance
- 13 TeV CM energy allowed for many interesting physics results

→ great start of Run 2!

Many thanks to the CERN technical support (TE-VSC), the central workshop and of course to the LHC team for the work, the great collaboration, and the beautiful data!



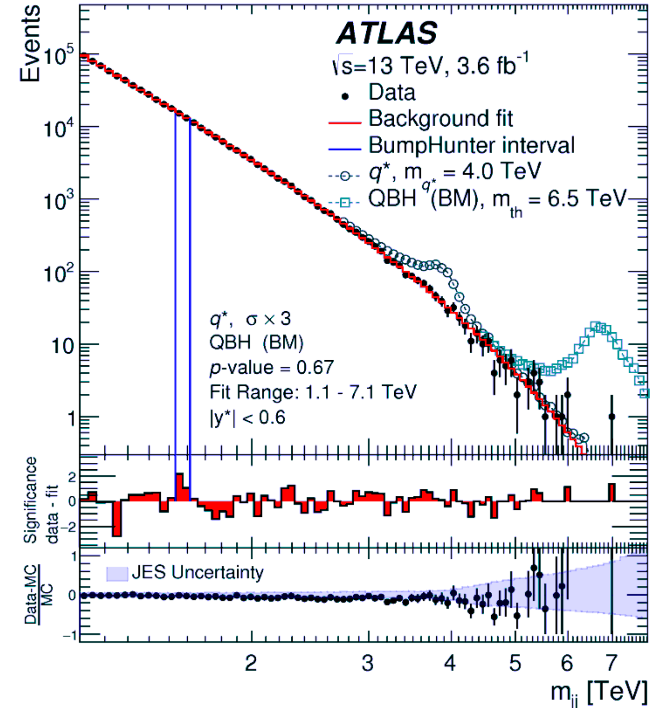
ATLAS is getting ready for 2016 data taking and we are looking forward to more data!

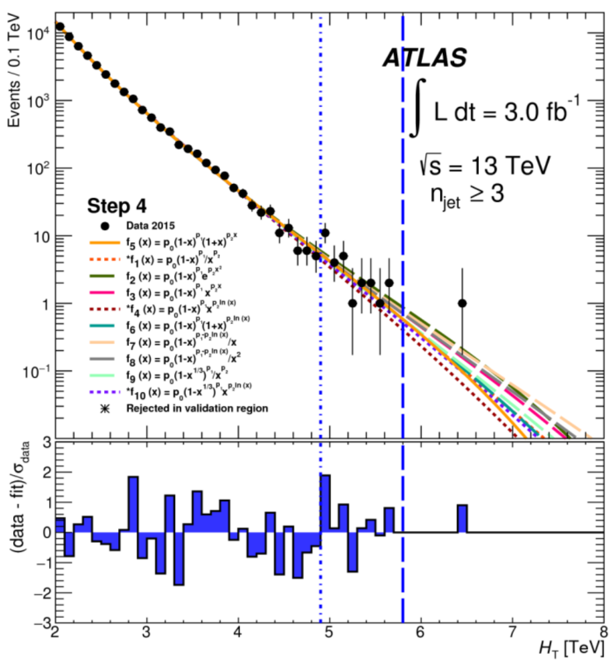
Backup slides

Backup slide: 2015 Searches – jets

Search for resonance decaying to two jets

- Use of dijet spectrum, angular distributions
- No significant excess
- Limits set on quantum black holes (~8 TeV threshold mass), excited quarks, W'/Z' models





Search for thermal black holes

- Signal regions: 3-8 jets
- Signal at high HT
- Bootstrap method: incremental data sets used for control regions
- No significant excess, limits on threshold mass 9-10 TeV (was ~6 in Run 1)

Backup slides: TRT gas scenarios

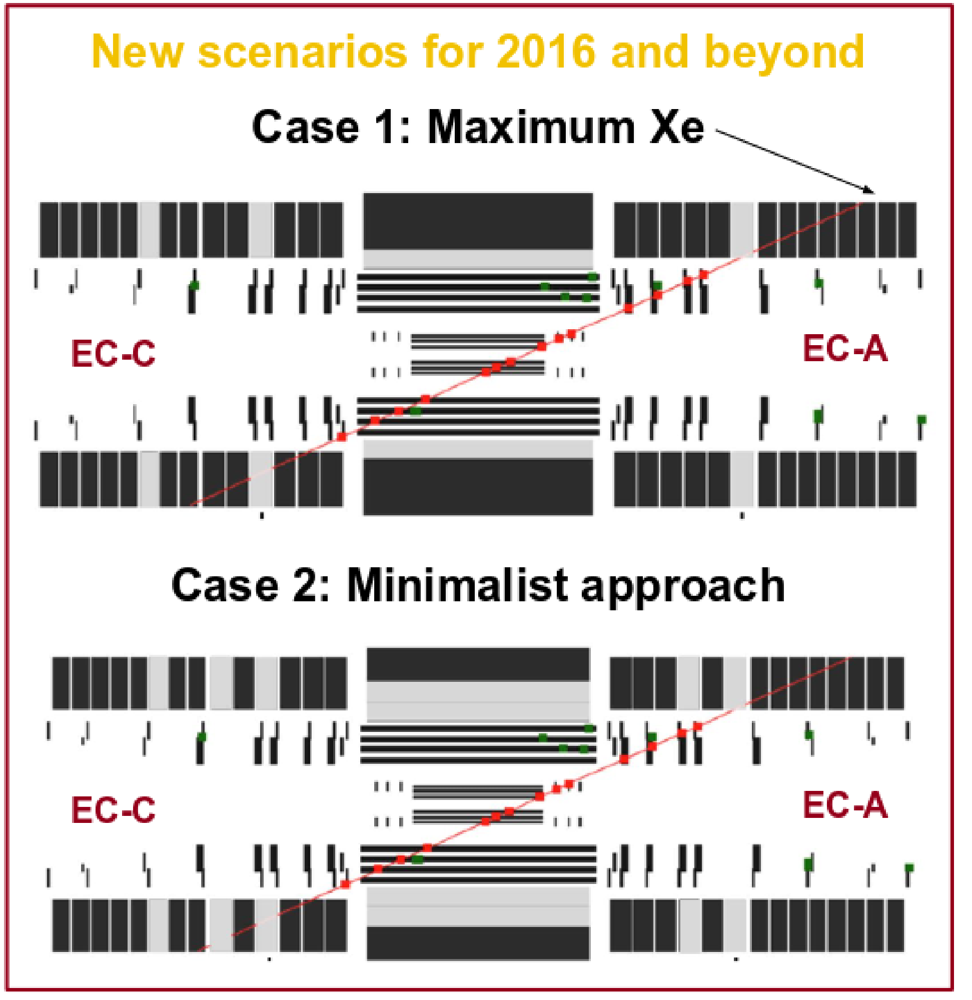
2 scenarios under evaluation

Case 1

- Requires 51m3 Xe in 2016
- Not maintainable with higher luminosity

Case 2

- Requires 12 – 17 m3 Xe in 2016
- Allows for storage of Xenon
- Possibly stable until end of Run 2
- Will impact electron/photon vs hadrons discriminiation

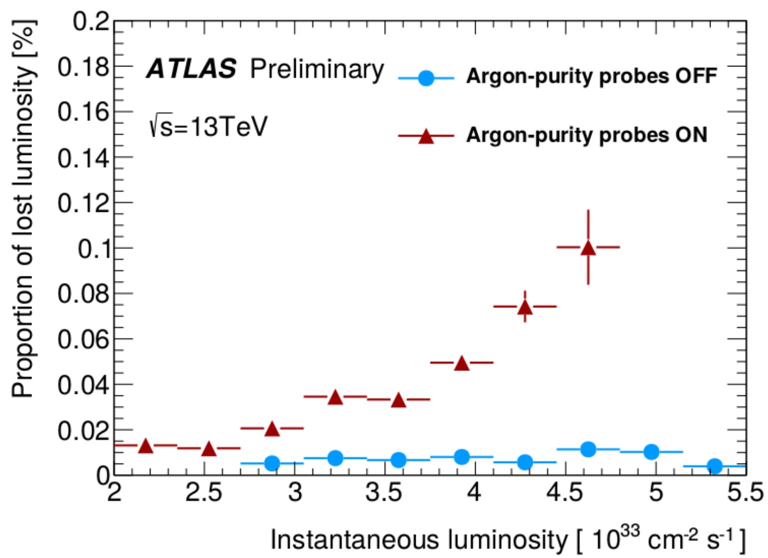


Backup slides: Liquid Argon Calorimeter

High voltage trips

- Very **small number of HV trips** in the EM in 2015
- New current controlled modules tremendously improved situation in EMEC
- Trips now dominated by HEC
- Decided to buy new current controlled modules for HEC (order went out, to be installed end of February

Noise bursts



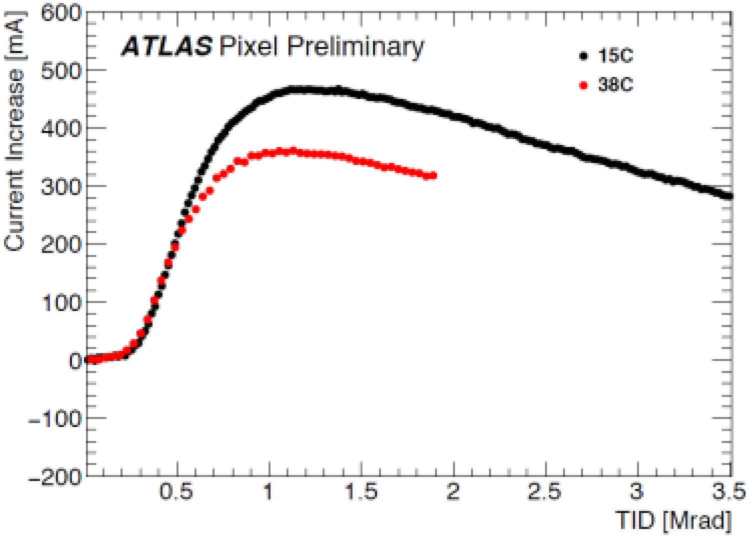
Bkp: Pixels, effects in the FE-I4 readout chip related Total Ionization Dose

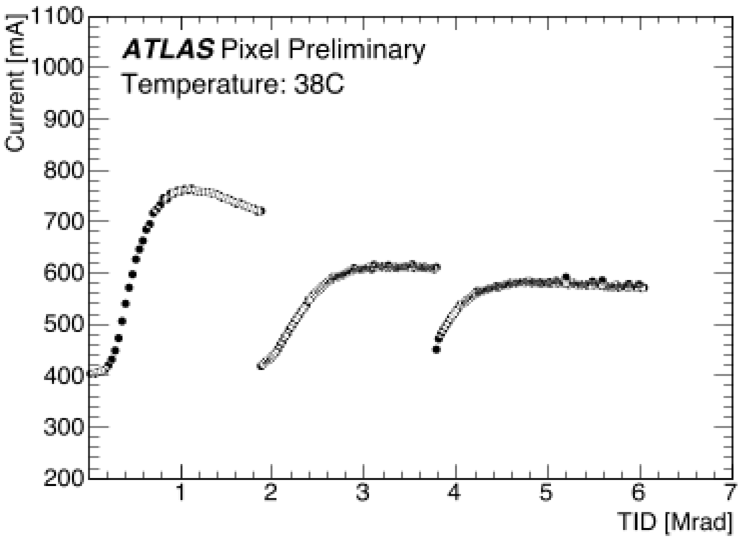
Consequences for operation:

Current increase reaching safety limits. When the limit is reached, 2 cases:
- Change FE state: Ready -> Standby
- Power down this module group

Drift of the FEI4 tuning (Threshold, TOT).
- Need to regularly check tuning in between fills and readjust if necessary

Current status quo:
- **Origin of LV current increase:** NMOS transistor trap defects that are built-up at the Si-SiO2 interface which is inducing leakage current
- **Temperature dependency** confirmed by several tests
- **Successive irradiation and annealing** is measured in lab and is expected to reduce the amplitude of the next peak
- **Model is under parameterization** to be able anticipate future behavior
- Irradiator was purchased for dedicated FEI4 lab measurements with realistic operational conditions





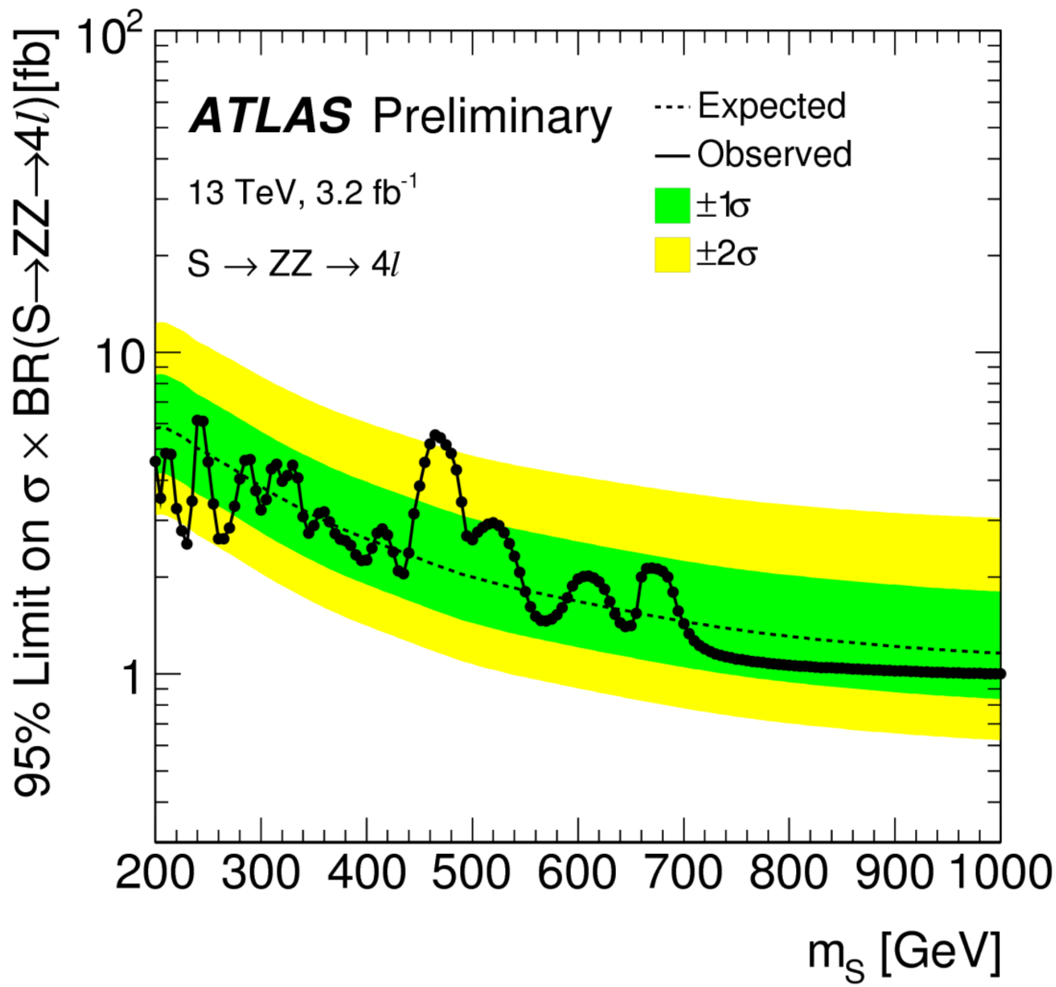
Backup slides: Diphoton search

- Fit function $$f(z) = p_1(1-z)^{p_2} z^{p_3}$$ $$z \equiv m_{\gamma\gamma}/\sqrt{s}.$$

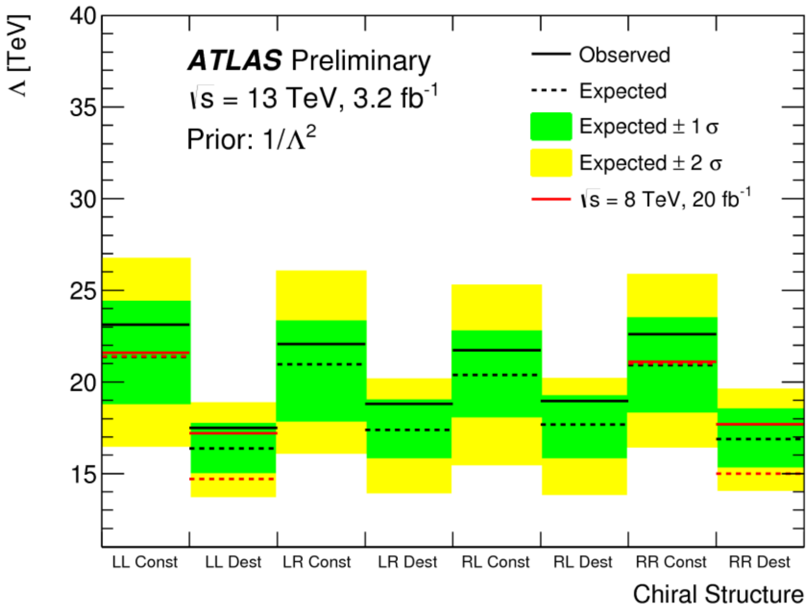
- Background-only MC: Sherpa, Diphox

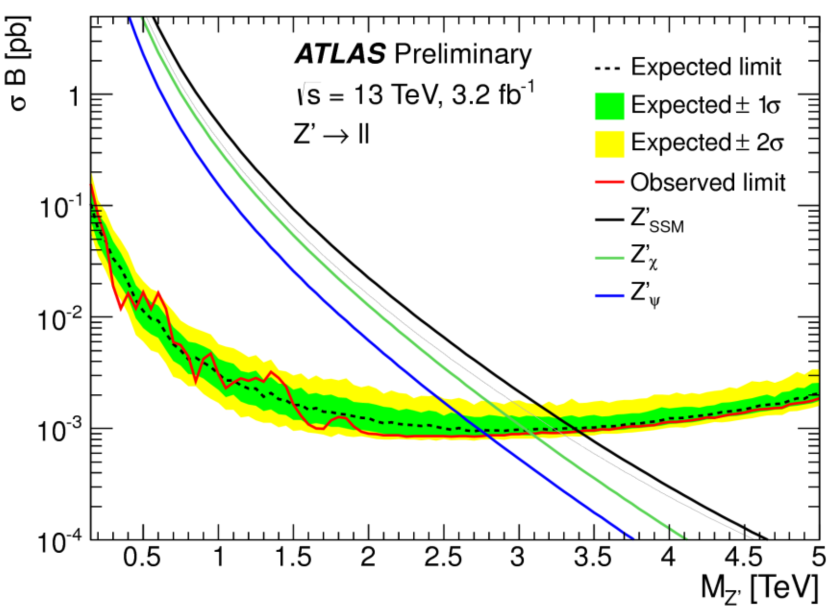
- Compatibility with 2012 results (parton luminosity ratio: 4.7):
  - 2.2 σ for NWA
  - 1.4 σ for 6% width

Backup slides: Diboson search (4l)

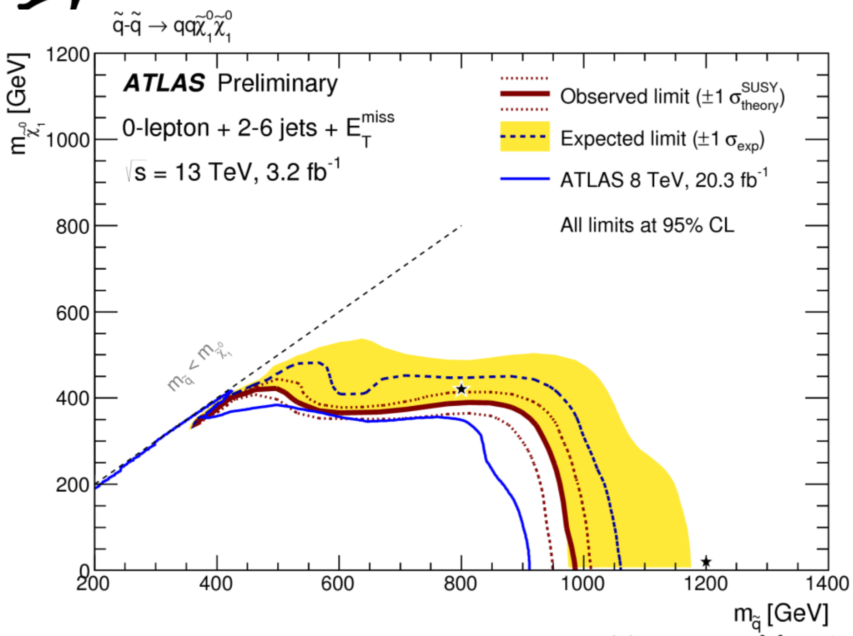


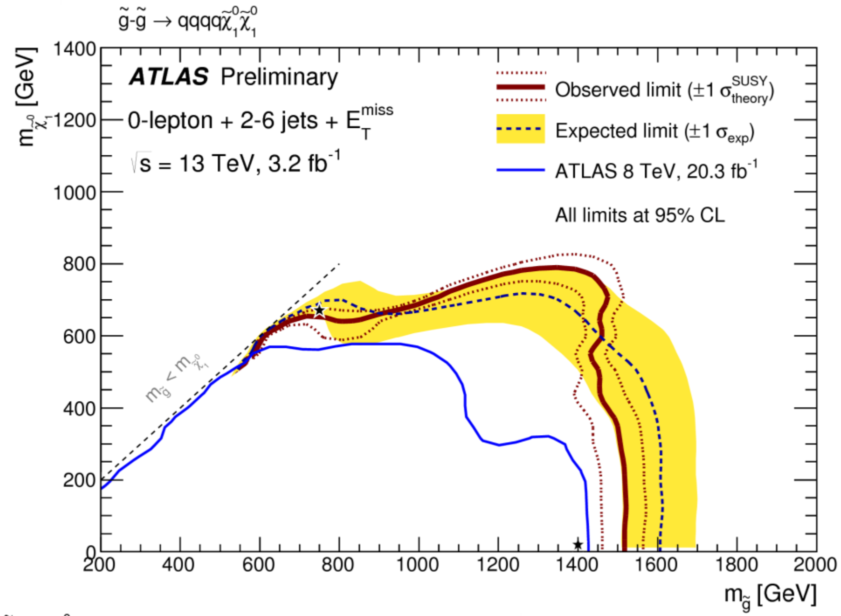
Backup slides: Dilepton search

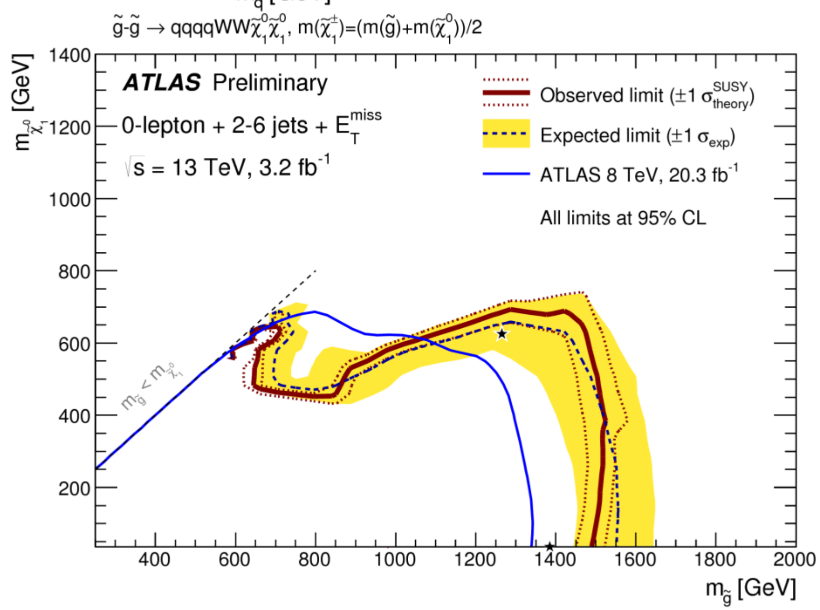




Backup slides: SUSY searches

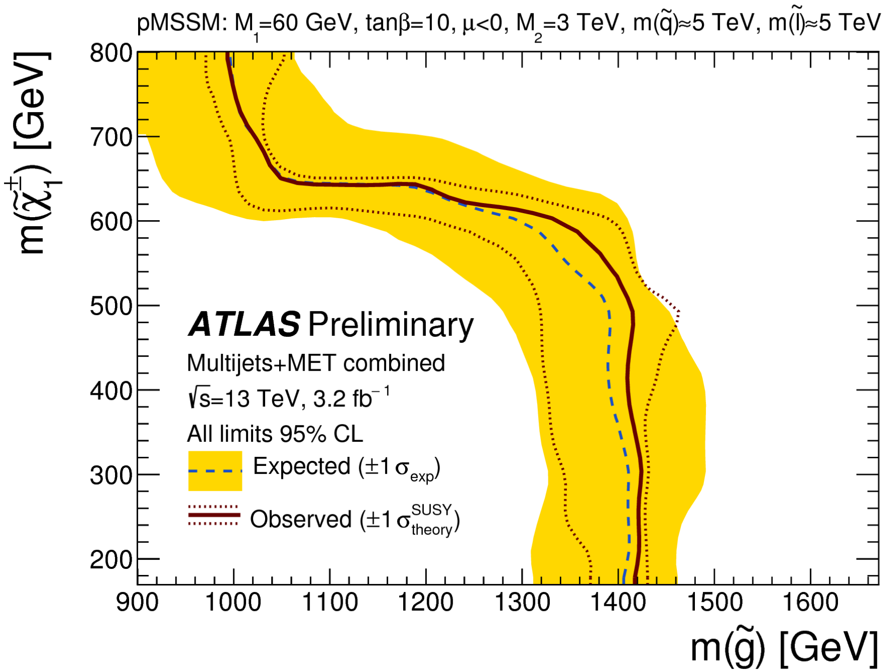




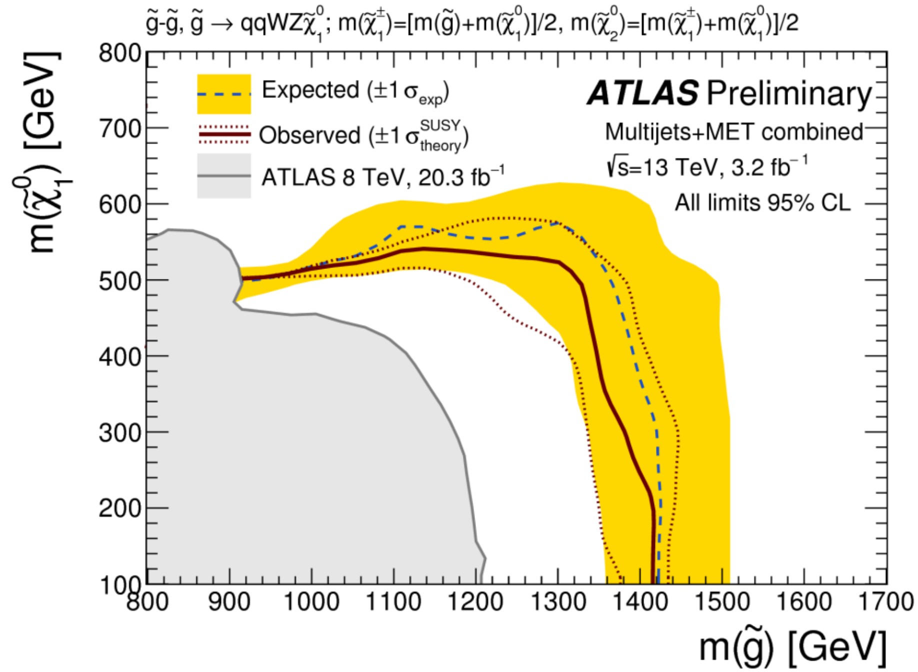


Simplified models (R-parity conserved, neutralino LSP)

Backup slides: SUSY searches



pMSSM slice model



Cascade decay model