ATLAS RUN-2:
Primi risultati e prospettive

Run Number: 265545, Event Number: 5720351

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101⁰ Congresso della Societa' Italiana di Fisica

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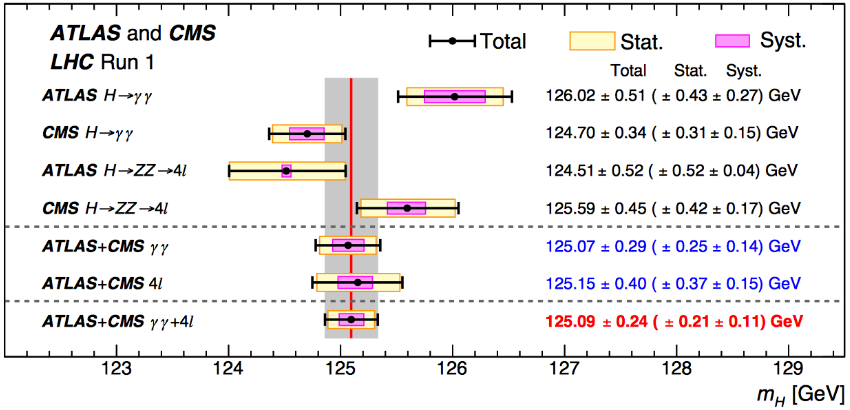
Legacy from Run-1

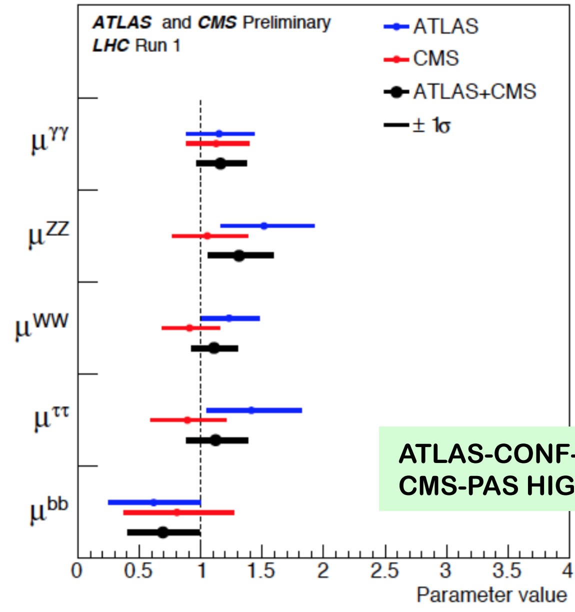
Phys. Rev. Lett. 114, 191803

- Run-1 data taking completed in Feb. 2013
  - Excellence performance of LHC machine and ATLAS detector
  - Data collected: ~ 5fb^{-1} at 7 TeV, ~ 20fb^{-1} at 8 TeV
  - Data-analysis still on-going
- 465 publications to date
  - Higgs boson observation and main properties measured
  - 198 measurement papers
  - 232 (null) search result papers
  - 26 papers on performance of detector, reconstruction and simulation
- Many ATLAS+CMS combined physics results, e.g.
  - March 2015 : Higgs Mass
    - measured with <0.2% precision
  - September 2015: Higgs Couplings
    - sensitivity improved by almost √2

ATLAS and CMS combined Higgs Mass



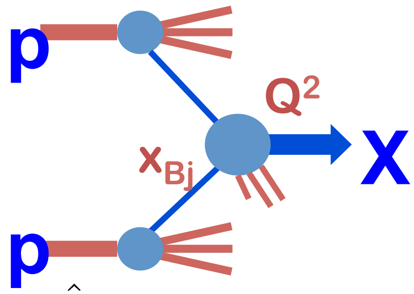
ATLAS and CMS decay signal strengths



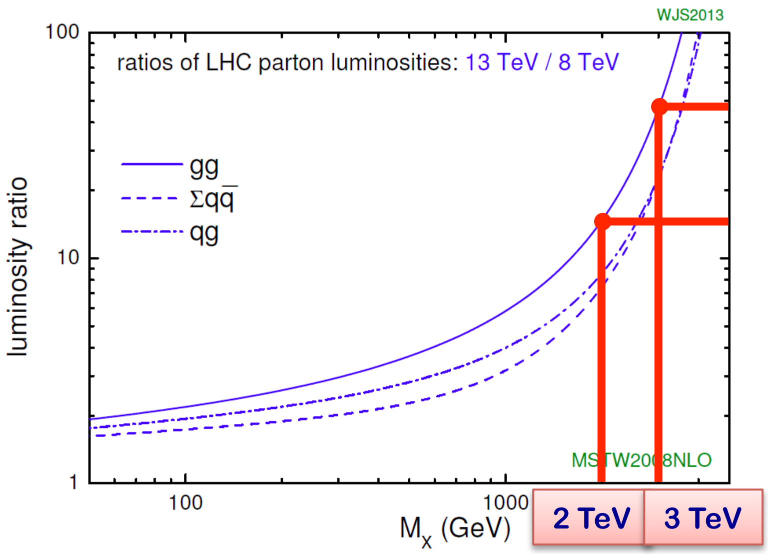
ATLAS-CONF-2015-044
CMS-PAS HIG-15-002

LHC Run-2

- **LHC machine**
  - Large increase in cross sections due to $\sqrt{s}$ increase from 8 to 13 TeV
    - Max Luminosity : 1.3×10^{34} cm^{-2} s^{-1}
    - More than 100 pb^{-1} by end of 2018
  - Priority for 2015 run
    - Establish proton-proton collision at 13 TeV with 25 ns and *low* β * (from 80 to 60 or 40) to prepare production runs in 2016-2018. $\sigma^* \propto \sqrt{\beta^*}$



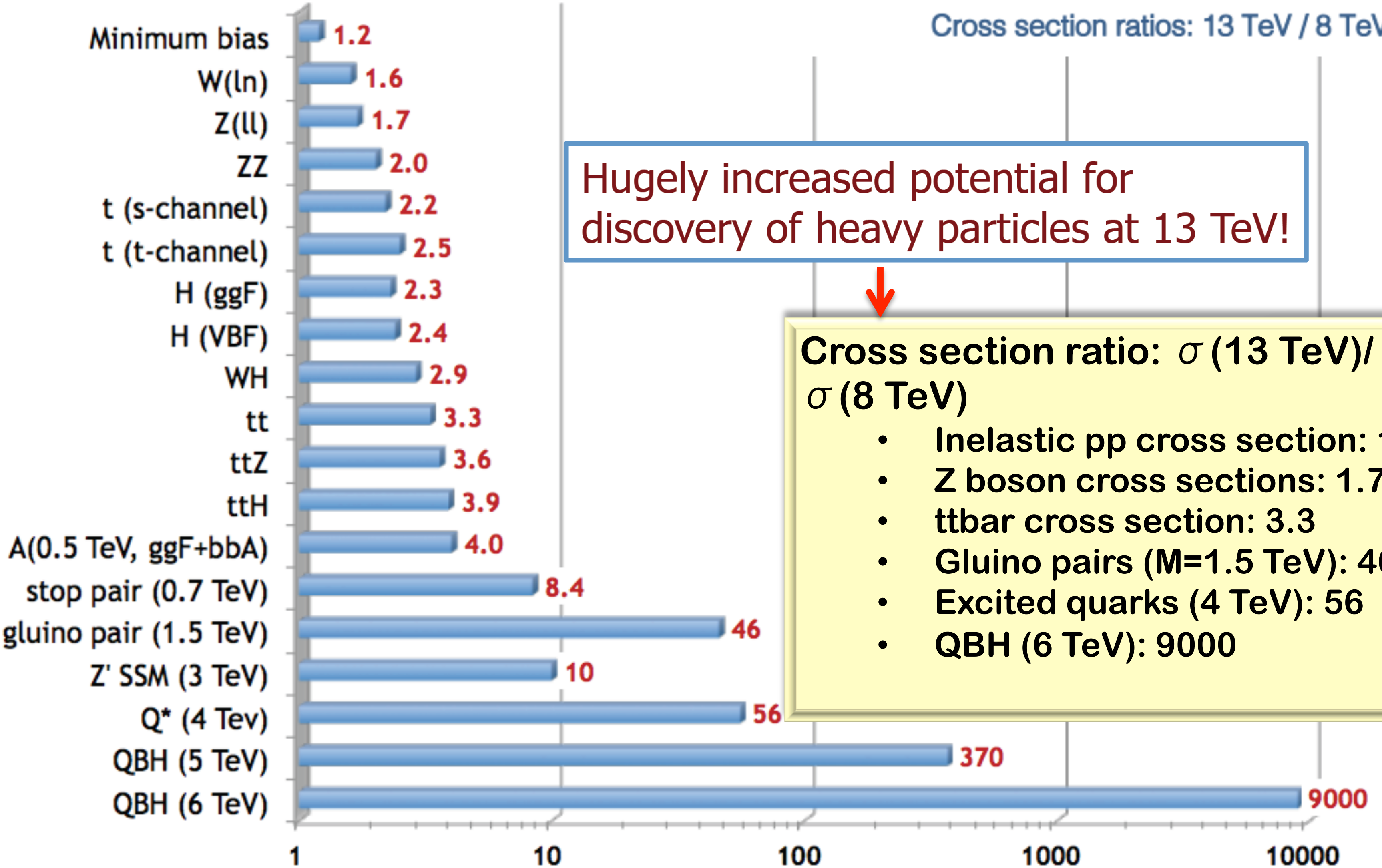
$$\hat{s} = x_p \cdot x_{\bar{p}} \cdot s$$



A factor 10 to 50 higher luminosity for 2< M_x< 3 TeV

- **ATLAS experiment**
  - Search for new Physics Beyond Standard Model
    - Excellent discovery potential
  - SM Precision measurements at 13 TeV
    - Higgs, top, W/Z, B, …
  - Study of rare processes
    - ttH, 4-top, VBS, …

Physics Potential for Run2



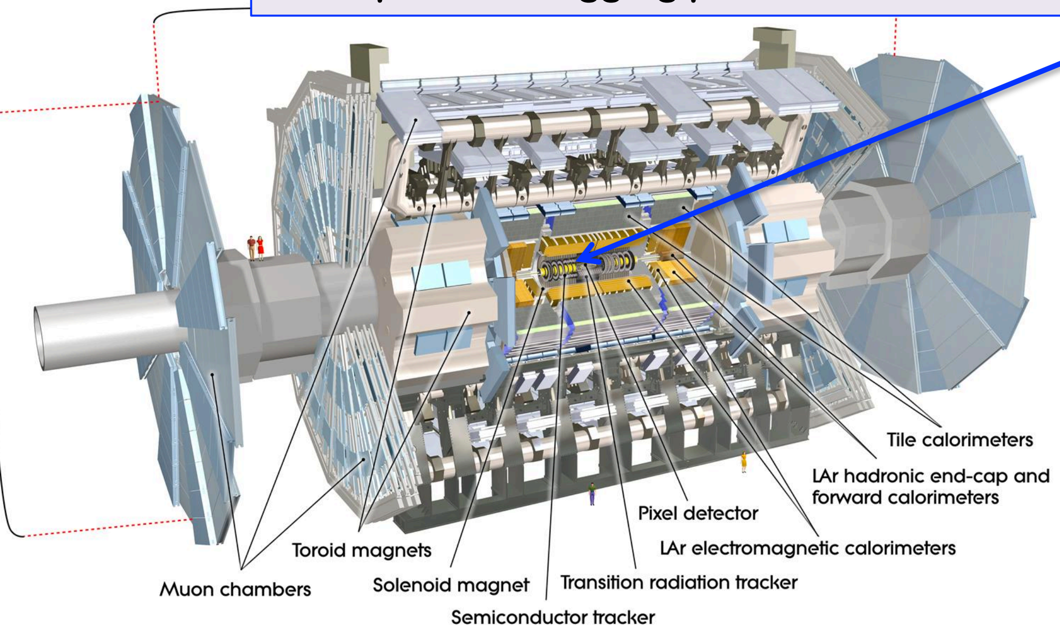
Hugely increased potential for discovery of heavy particles at 13 TeV!

Cross section ratio: σ(13 TeV)/ σ(8 TeV)

- **Inelastic pp cross section: 1.2**
- **Z boson cross sections: 1.7**
- **ttbar cross section: 3.3**
- **Gluino pairs (M=1.5 TeV): 46**
- **Excited quarks (4 TeV): 56**
- **QBH (6 TeV): 9000**

ATLAS Upgrade during LS1

Insertable B-Layer (IBL), 4th silicon pixel detector layer
- 2 cm x 2 cm FE-I4 Pixel Chip, 130 nm CMOS process
- Innermost Pixel detector layer at R=3.3 cm from the beam
- Improves b-tagging performance

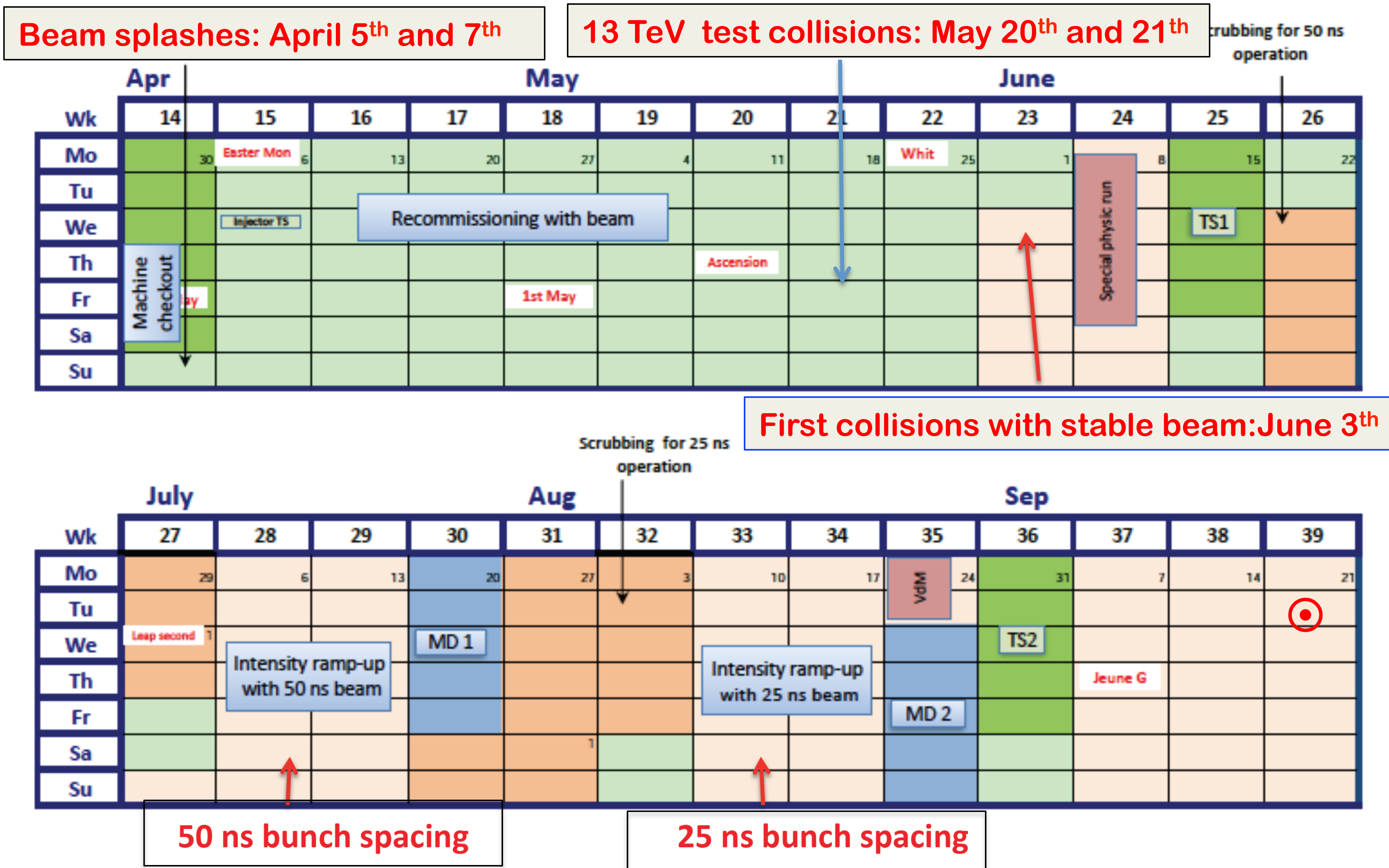


Trigger improvements
- New Topological L1 trigger,
- new central trigger processor,
- restructuring of high-level trigger, new Fast TracK Trigger (FTK)

Software
- Many improvements to simulation, reconstruction, analysis software

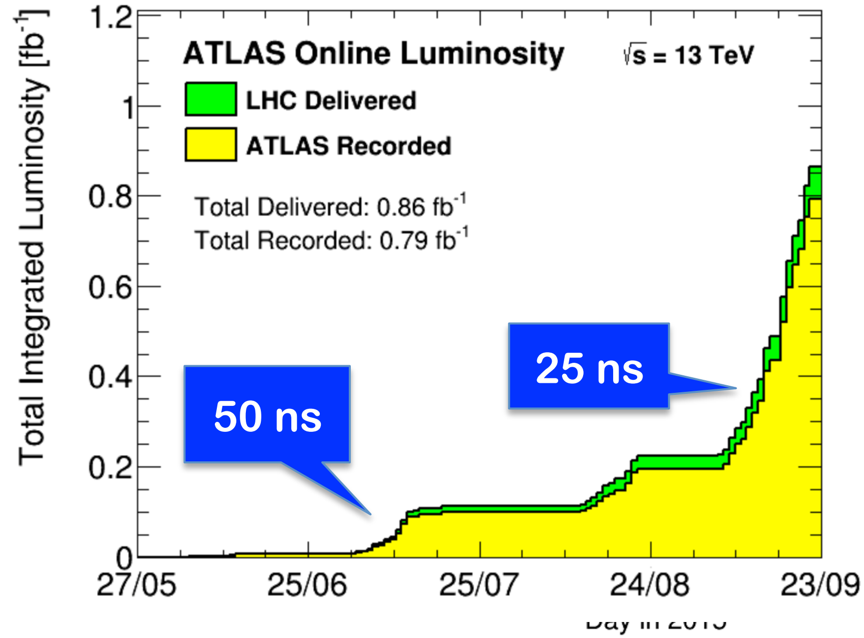
Overall detector consolidation
- Muon chambers completion ($|\eta|$=1.1-1.3) and repairs
- improved readout of various systems, (L1 rate up to 100 kHz)
- repair of pixel modules and calorimeter electronics
- new pixel services, new luminosity detectors, new MBTS detector

LHC schedule in 2015



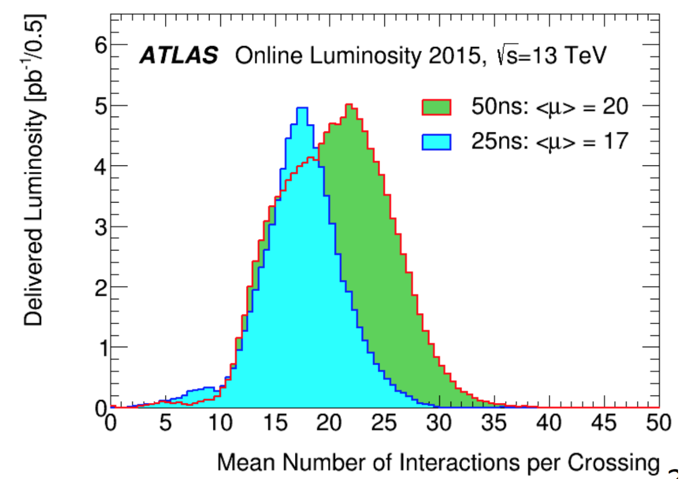
Run-2 Data taking

- **Integrated luminosity recorded: 0.86 fb^{-1}, $L_{max}=2.7\times10^{33}cm^{-2}s^{-1}$**
- **Average Pileup: $\mu \cong 20$ for 50ns, $\mu \cong 17$ for 25ns**
  - Special runs taken with low pileup ($\mu \ll 1$) for soft QCD studies
- **Data taking efficiency: ~90%**
  - 93.3% of recorded data good for physics analyses

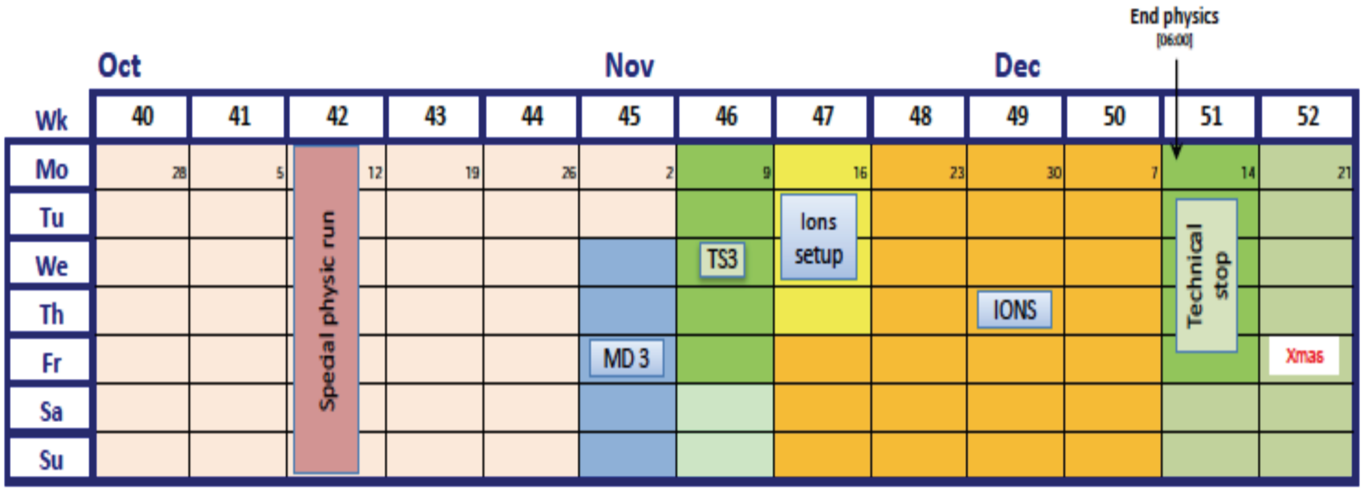


ATLAS pp run: June-July 2015										
Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
97.3	99.6	100	98.4	100	100	100	100	100	100	99.3
All good for physics: 93.3%										

Luminosity weighted relative detector uptime (in percent) and good quality data delivery during 2015 stable beams in pp collisions at √s = 13 TeV between 3 June and 16 July – corresponding to 91 pb^{-1} of recorded data.



Outlook for the rest of 2015 and beyond



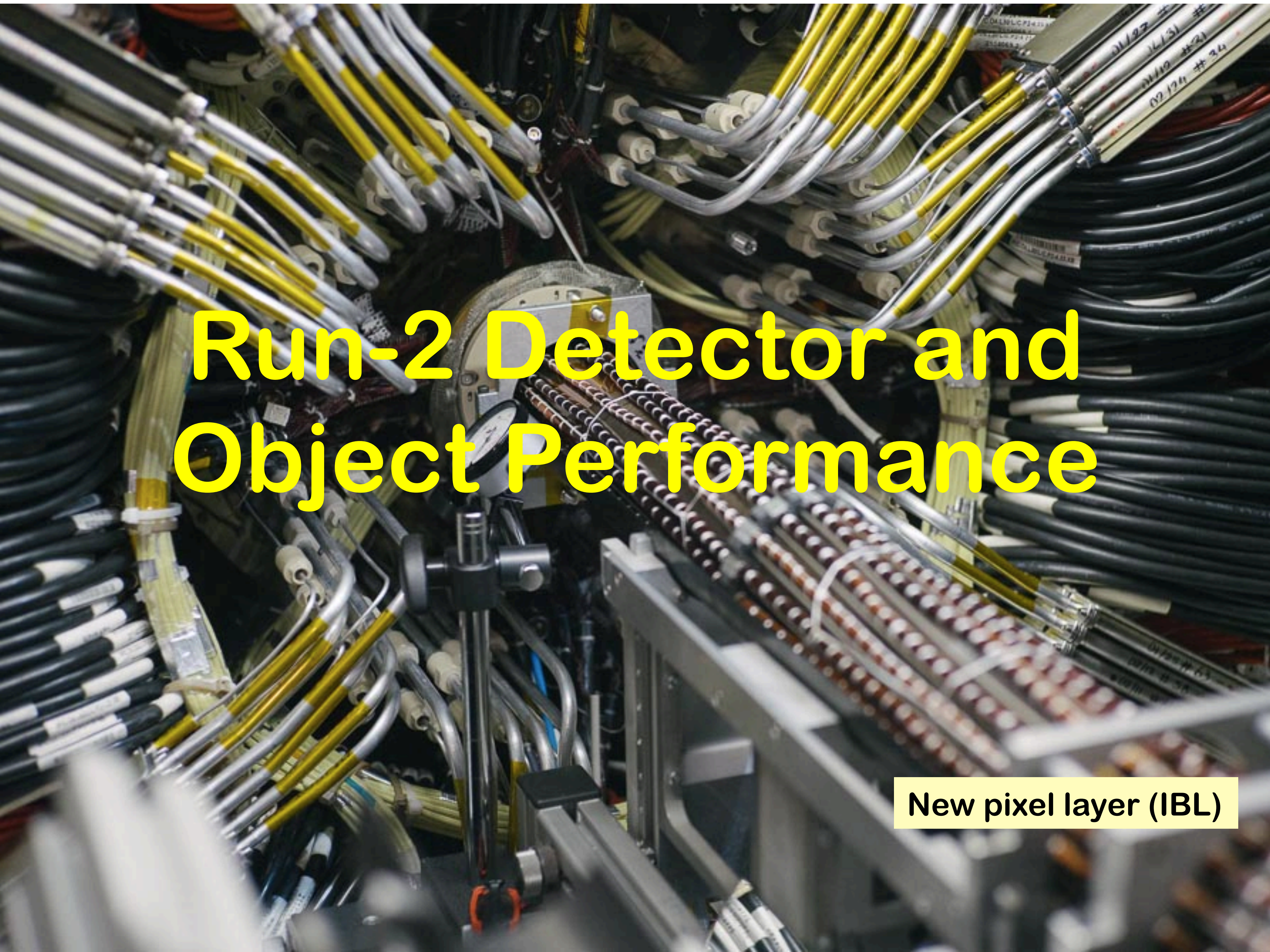
	Nc	Beta *	ppb	EmitN	Lumi [cm^{-2}s^{-1}]	Days (approx)	Int lumi	Pileup
50 ns	476	80	1.1e11	1.8	1.6e33	14	0.1 fb^{-1}	27
2015.1	1200	80	1.2e11	3.5	3.6e33	50	~2.3 fb^{-1}	21
2015.2	1200	60	1.2e11	2.3	5.6e33	47	~3.4 fb^{-1}	33

	Peak lumi E34 cm^{-2}s^{-1}	Days proton physics	Approx. int lumi [fb^{-1}]
2015	~0.5	65	3
2016	1.2	160	30
2017	1.5	160	36
2018	1.5	160	36

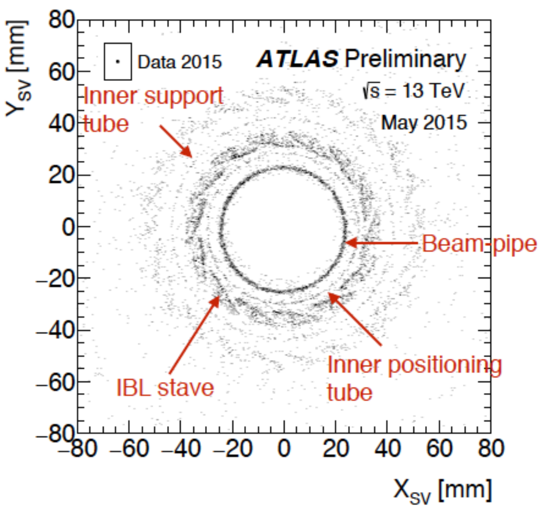
Latest news: Intensity ramp up with 25 ns bunch spacing

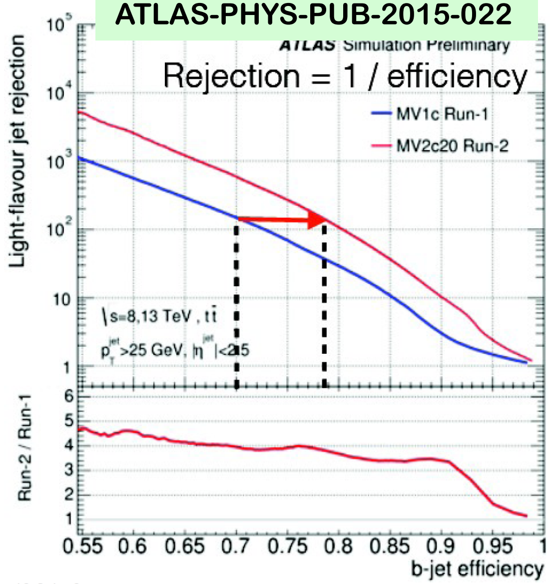
- 1033 bunches per beam, 144 bunch trains
- Bunch populations 1.0-1.1 x 10^{11}
- Now progress in smaller steps

Run-2 Detector and Object Performance

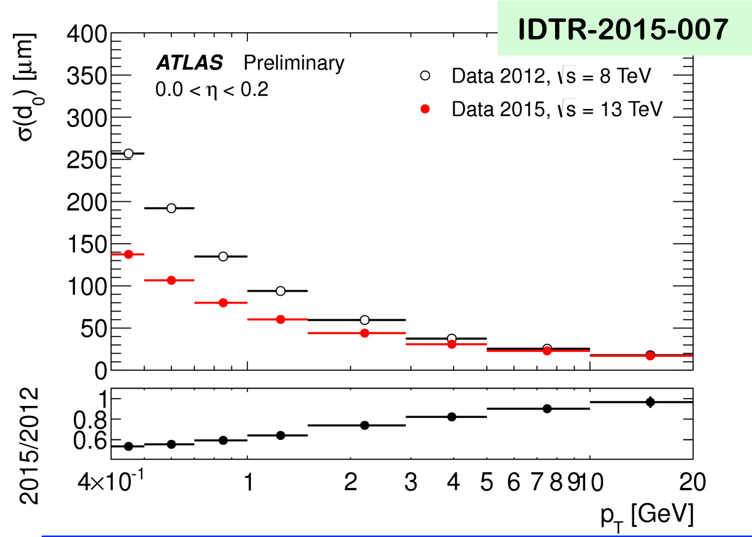


Tracking and vertexing performance

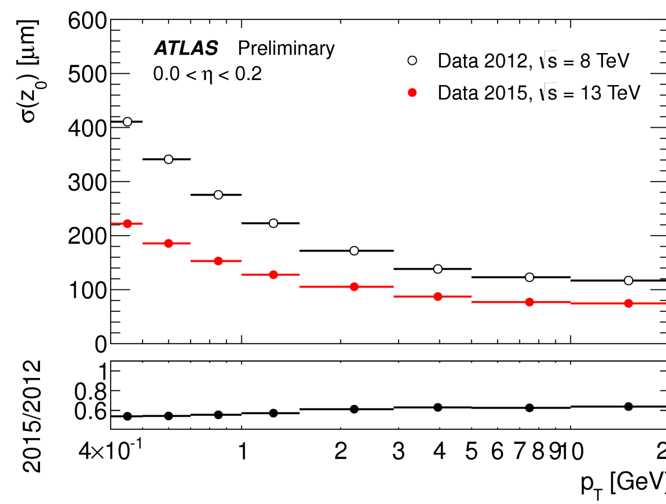




Transverse impact parameter resolution



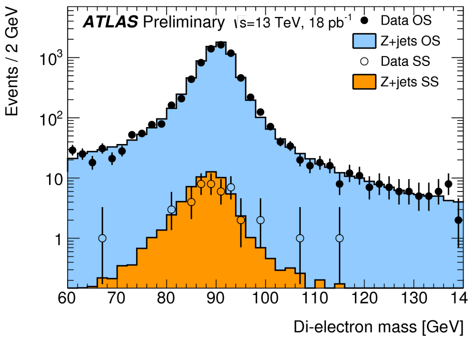
Longitudinale impact parameter resolution

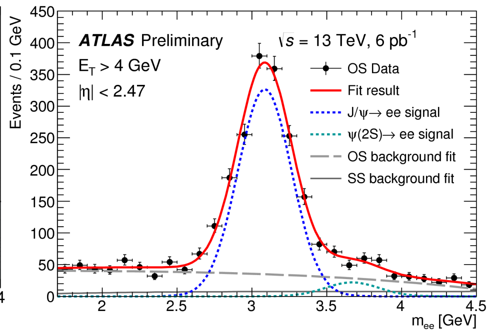


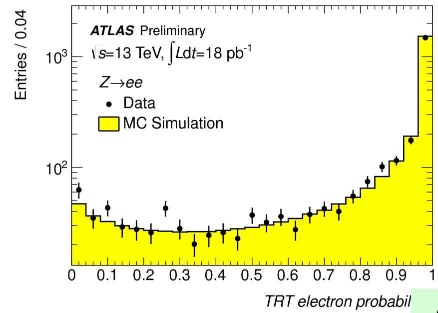
- **IBL fully operational**
  - **Material mapped using photon conversions and hadronic interactions in situ**
- **Significant improvement in impact parameter resolution**
  - **Reduced multiple scattering**
  - **Reduced size of pixels in longitudinal direction (400 μm => 250 μm)**
- **Improved b-tagging**
  - **~ +10% relative improvement in b-jet efficiency for same light-jet rejection**

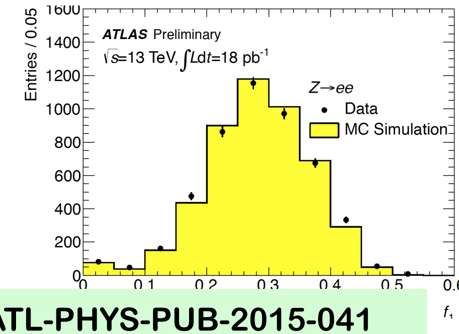
Electron identification efficiency

PLOTS-EGAM-2015-003

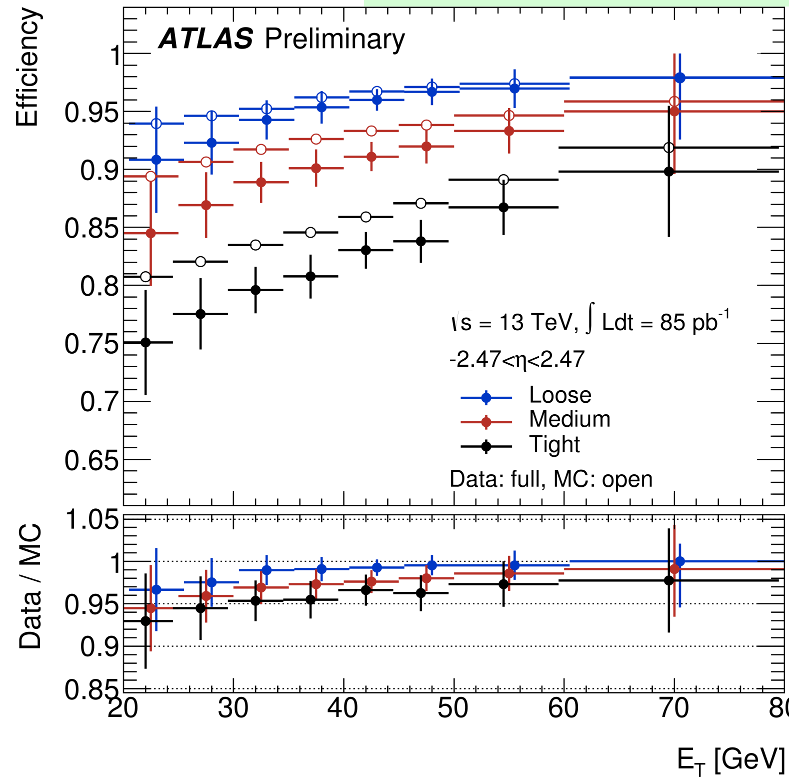








ATL-PHYS-PUB-2015-041

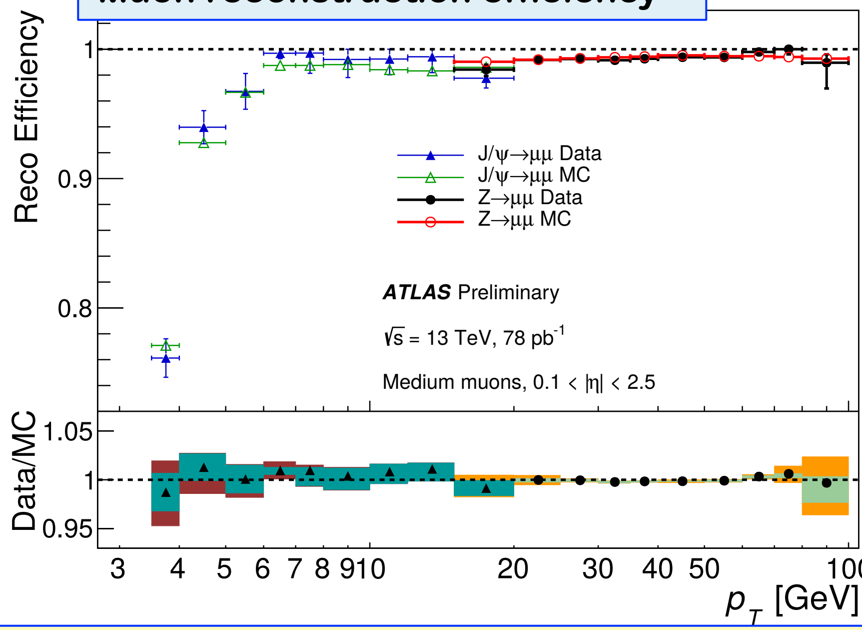


- Z's and J/psi's used to evaluate electron energy scale
  - Mean and resolution already well understood
- Electron identification
  - Based on many variables combined in a likelihood (shower shape, track properties,etc)
- Electron efficiencies between 75% and 95%
  - Three different identification criteria defined: loose, medium and tight
  - Differences between data and MC corrected by in-situ calibration

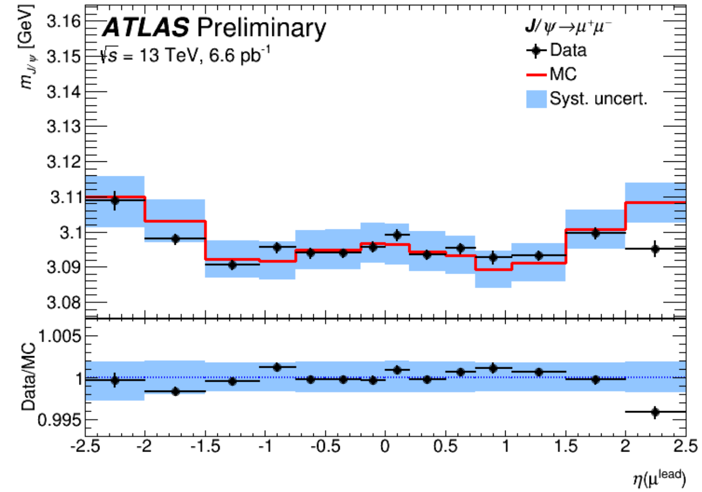
Muon performance

ATL-PHYS-PUB-2015-037

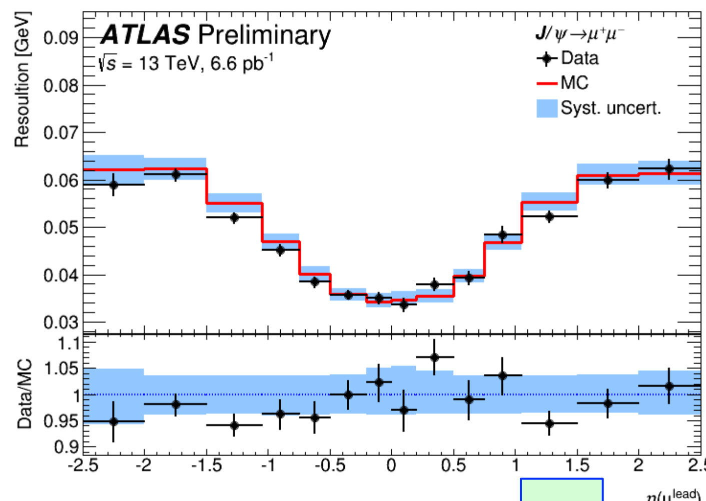
Muon reconstruction efficiency



Mean value of the $J/\psi \rightarrow \mu\ \mu$ inv mass



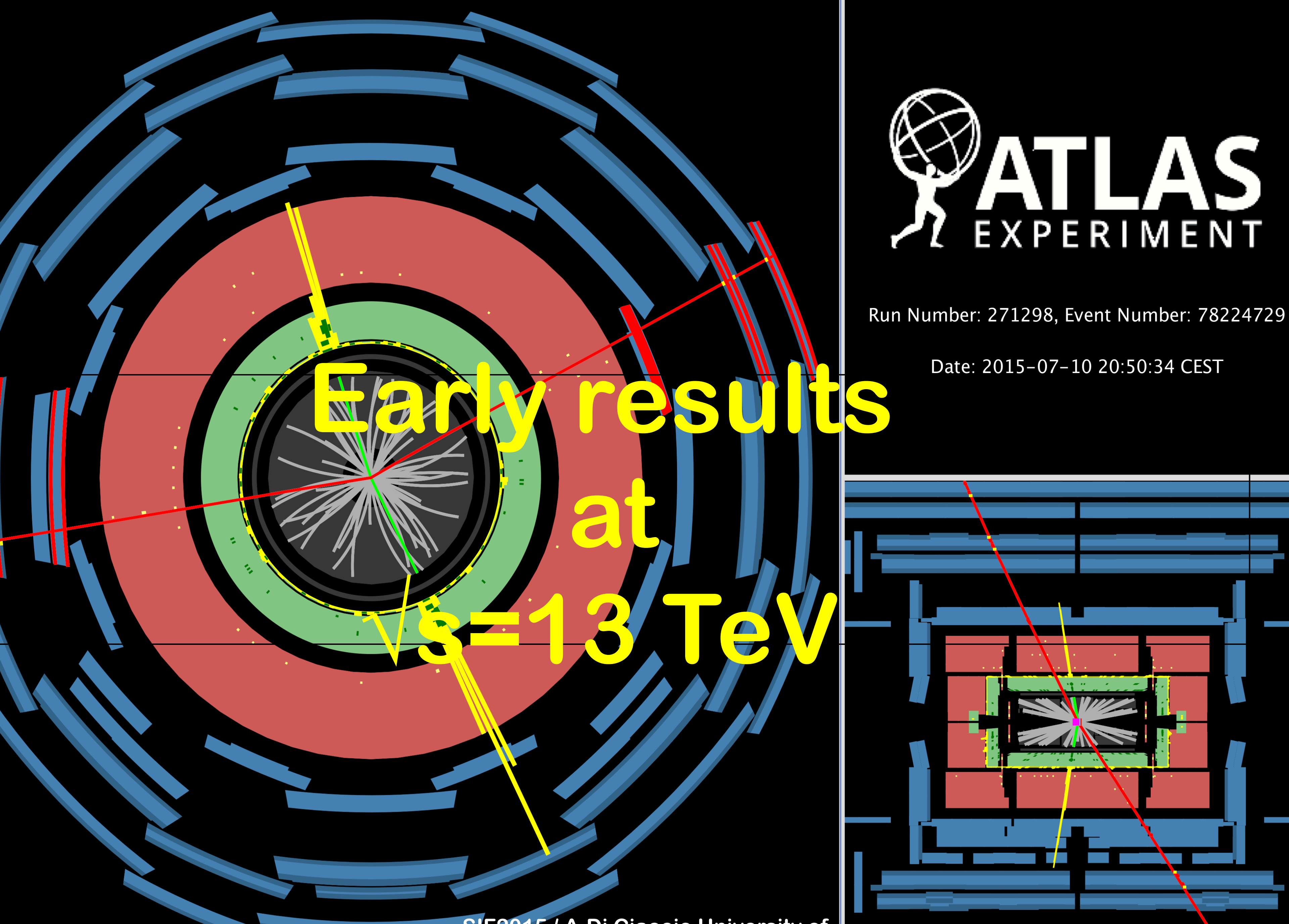
Resolution using the $J/\psi \rightarrow \mu\ \mu$ peak



η

- **High reconstruction efficiency**
  - Well modeled by simulation
- **Muon momentum scale**
  - Combines Inner Detector and Muon Spectrometer information
  - Resolution and scale extracted in data using Z and J/Ψ peak
- **Performance**
  - Momentum scale already understood with precision of 0.2%
  - Resolution also understood to within 5% in the momentum range of the J/Ψ

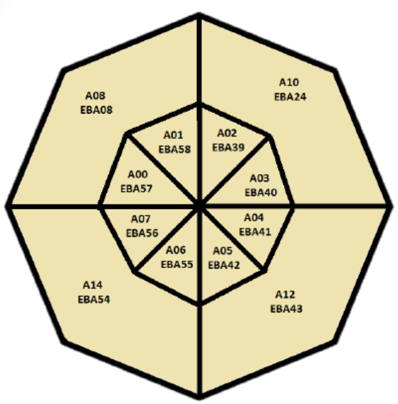
Early results at $\sqrt{s}$=13 TeV

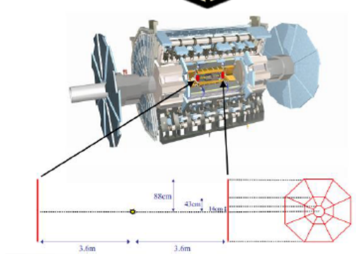


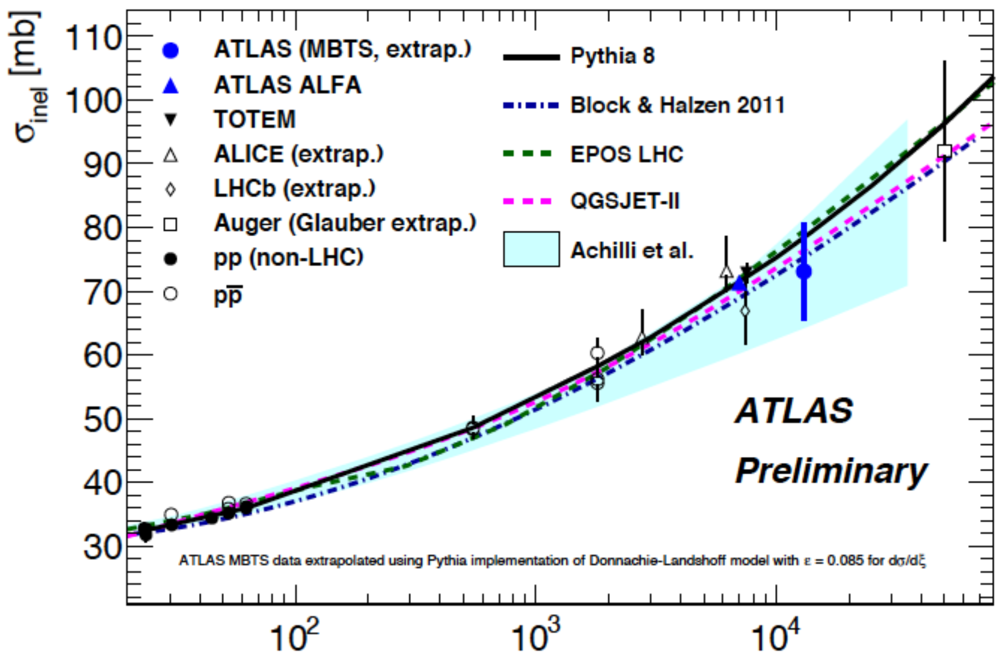
Inelastic pp Cross Section at 13 TeV

- **Inelastic cross section measured at 13 TeV**
  - using just 63 μb^{-1} of data (recorded in low luminosity running period)
- **New MBTS detectors installed during shutdown**
  - Trigger on one MBTS
  - 2cm thick discs of highly efficient polystrene scintillators mounted at z=±3.6 m
  - Pseudorapidity range: $2.07<|\eta|<3.86$

ATLAS-CONF-2015-038







$\sigma_{fid} = 65.2 \pm 0.8\ (\text{exp.}) \pm 5.9\ (\text{lum.})\ \text{mb}$

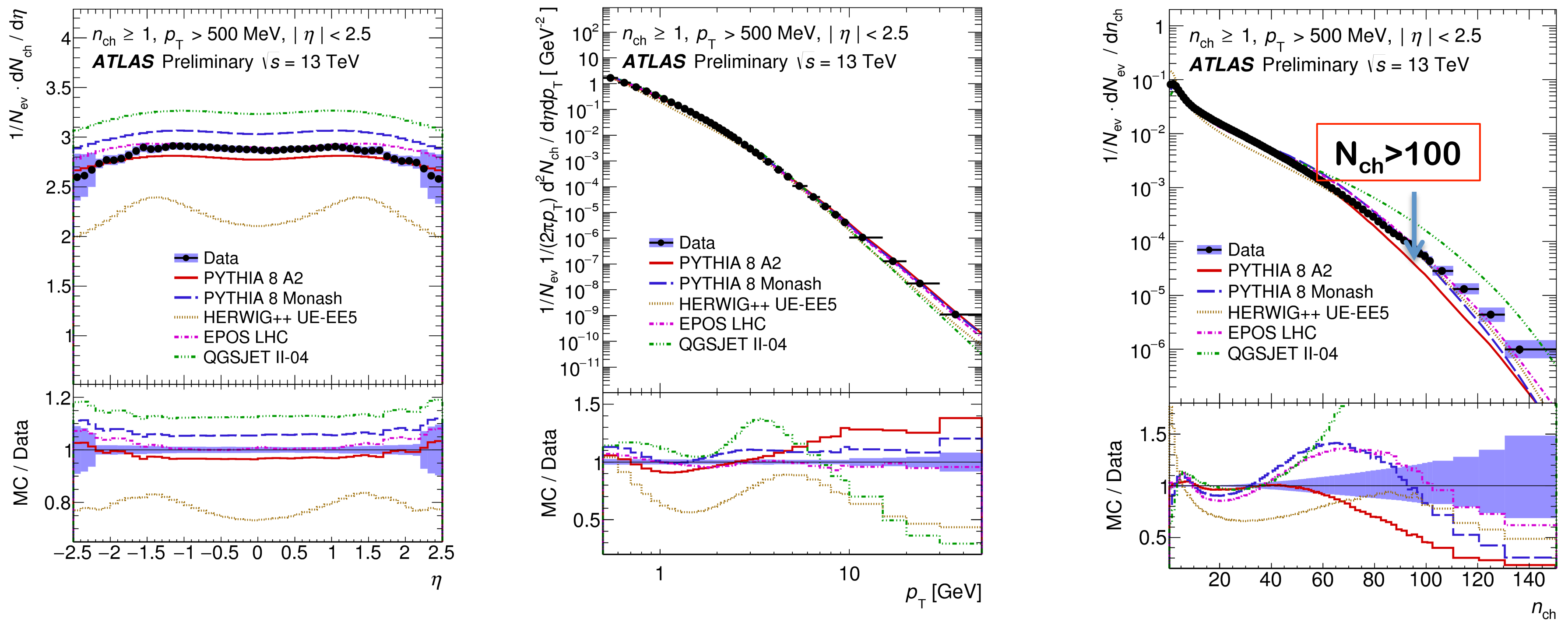
$\sigma_{inel} = 73.1 \pm 0.9(\text{exp.}) \pm 6.6(\text{lum.}) \pm 3.8(\text{extr.})\ \text{mb}$

Syst.error dominated by luminosity measurement

Minimum Bias charged particle differential cross-section

ATLAS-CONF-2015-028

- **Event selection:**
  - Triggered by MBTS trigger (ε >99%)
  - Requirements:
    - ≥1 track with p_T>0.5 GeV and | η |<2.5, Vertex (≥2 tracks with p_T>0.1 GeV)

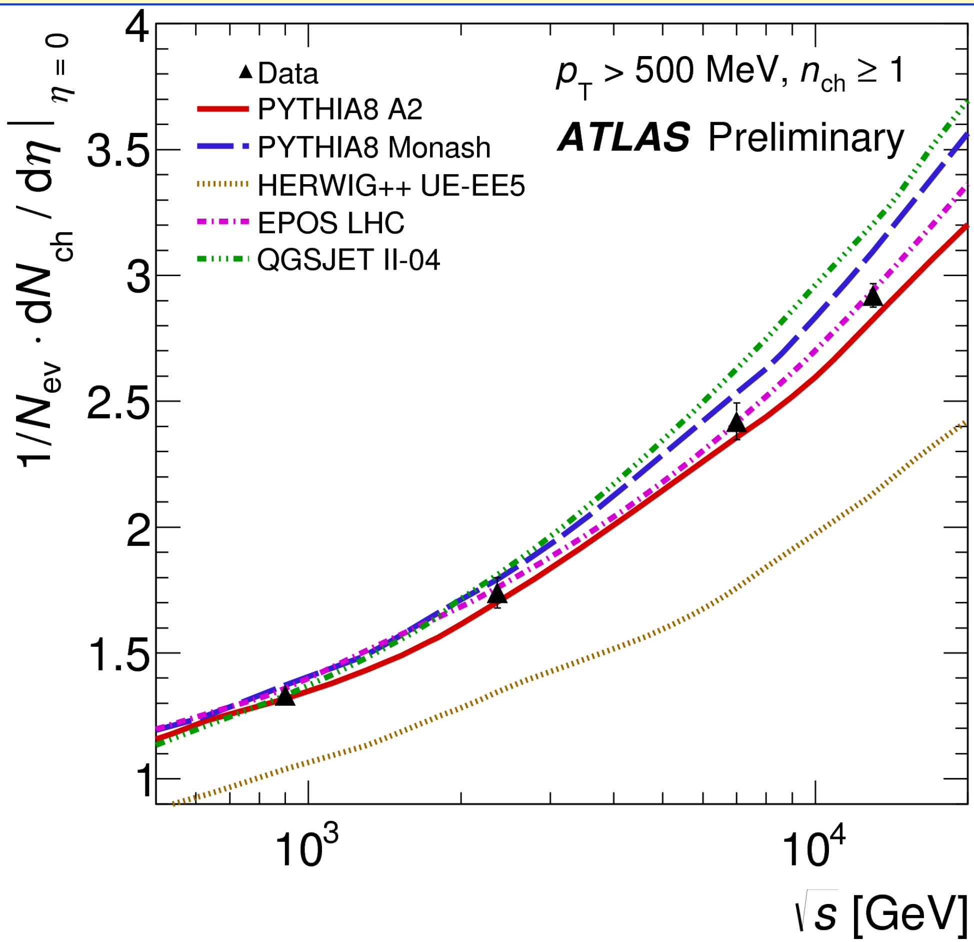


- **Measurements compared to variety of MC models**
  - These MC are used to model pileup pp interaction
- **Pythia tunes and EPOS in better agreement with the data**

Multiplicity in Minimum Bias Events

ATLAS-CONF-2015-028

Charged particle multiplicity for p_T>0.5 GeV at η =0 versus $\sqrt{s}$



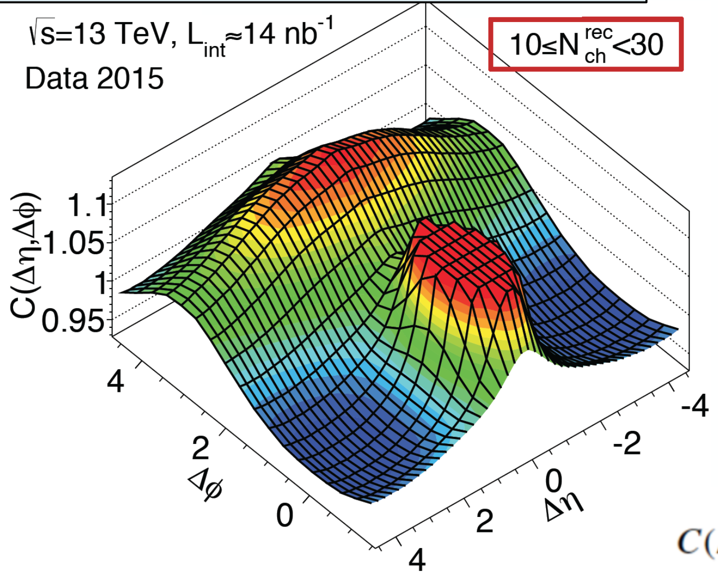
Pythia tunes (used for our pile-up simulation) and EPOS in better agreement with the data

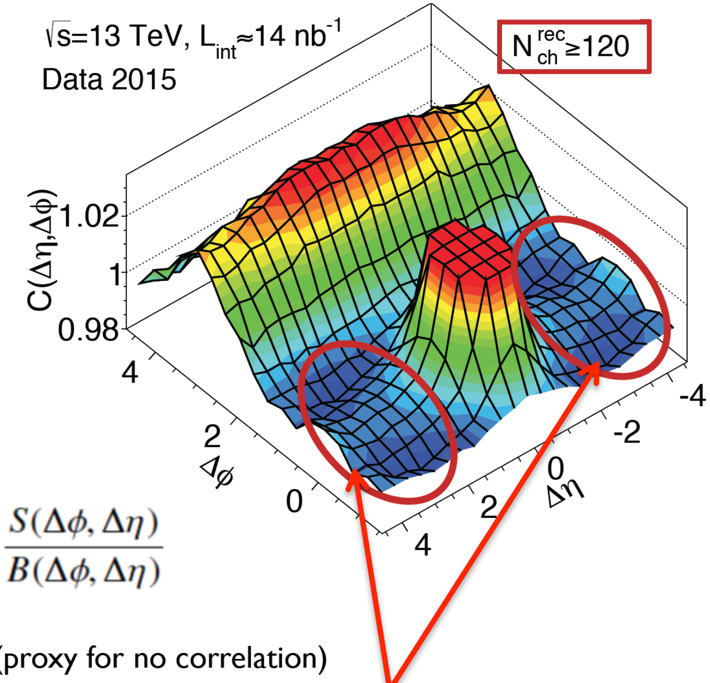
Large-range Correlations

- Dedicated high multiplicity trigger > 60 tracks
- Define correlation function between any two particles a and b

two particle correlation in $\Delta\eta$ and $\Delta\phi$=0

ATLAS-CONF-2015-027





$$C(\Delta\eta, \Delta\phi) = \frac{S(\Delta\phi, \Delta\eta)}{B(\Delta\phi, \Delta\eta)}$$

S=same event
B=mixed event (proxy for no correlation)

- High N_{ch} events show correlations at large $\Delta\eta$ and $\Delta\phi$=0
- Observe "ridge" opposite to jet peak
- Effect present strongly in p-A and A-A collisions
  - First observed on p-p collisions by CMS at √s=7 TeV

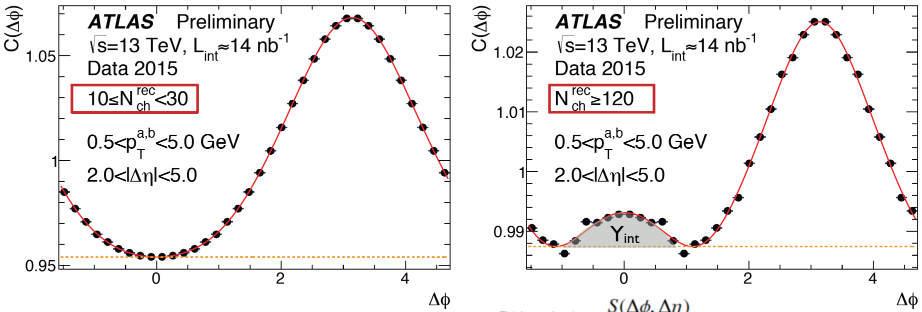
The Ridge at 13 TeV pp collisions

- **Studied integrated yield for for 2<|Δ η|<5**

$$Y(\Delta\phi) = \left(\frac{\int B(\Delta\phi)\mathrm{d}\Delta\phi}{N^a \int \mathrm{d}\Delta\phi}\right) C(\Delta\phi)$$

with $$C(\Delta\phi) = \frac{\int_2^5 \mathrm{d}|\Delta\eta|\ S(\Delta\phi, |\Delta\eta|)}{\int_2^5 \mathrm{d}|\Delta\eta|\ B(\Delta\phi, |\Delta\eta|)} \equiv \frac{S(\Delta\phi)}{B(\Delta\phi)}$$

ATLAS-CONF-2015-027



$$C(\Delta\eta, \Delta\phi) = \frac{S(\Delta\phi, \Delta\eta)}{B(\Delta\phi, \Delta\eta)}$$

S=same event
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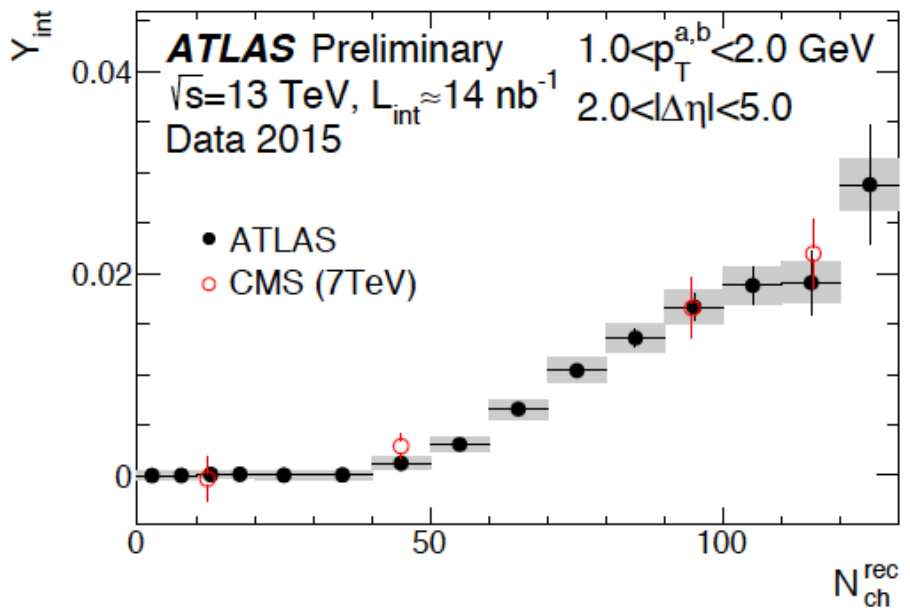
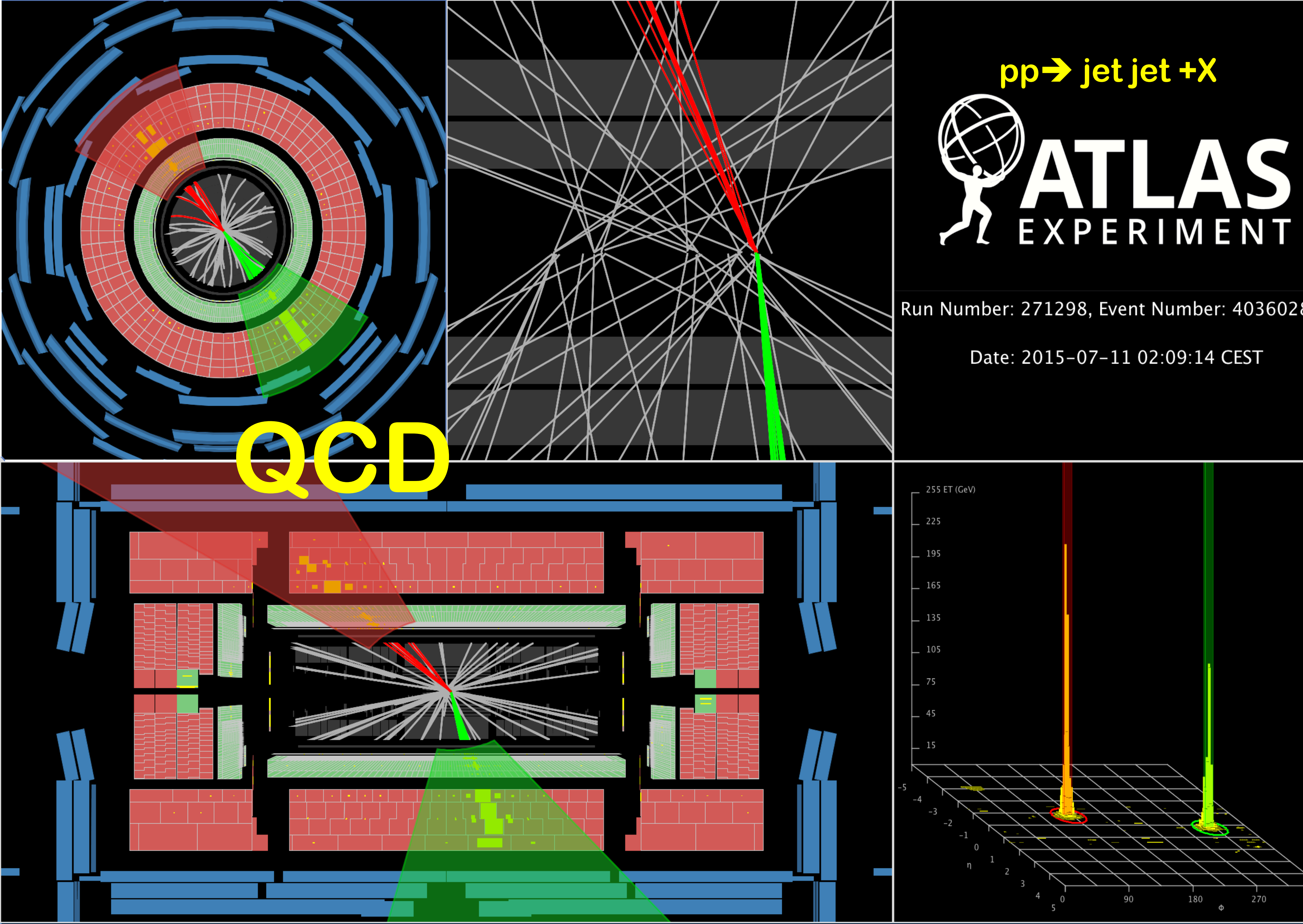
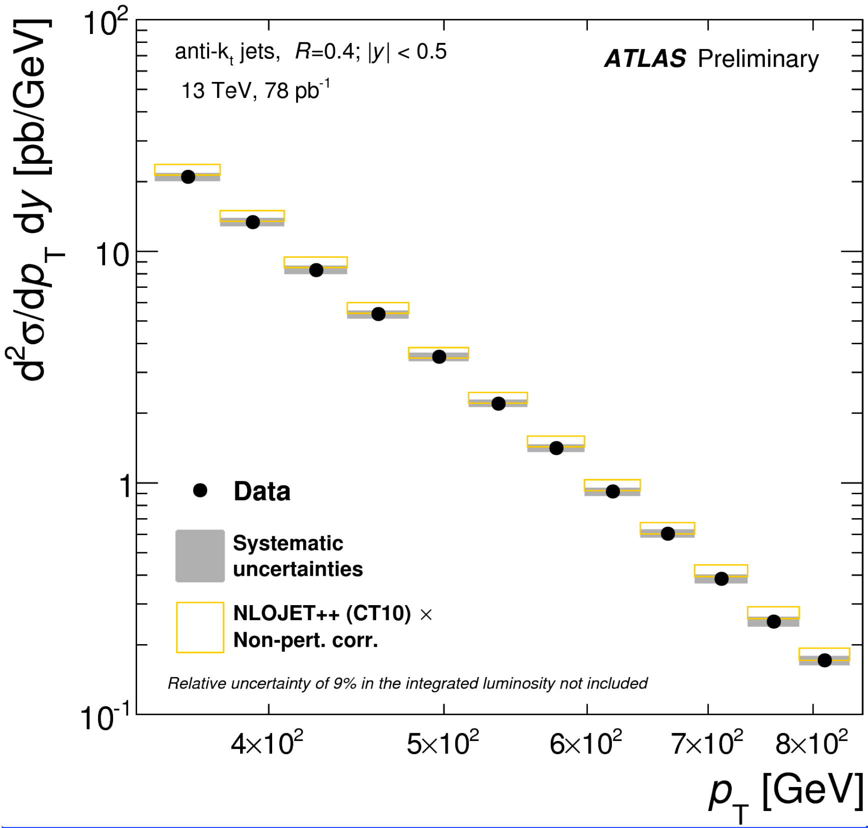


- **Relative strength of "ridge "**
  - **Same N(trk) dependence as at 7 TeV and 13 TeV**
  - **consistent with CMS**

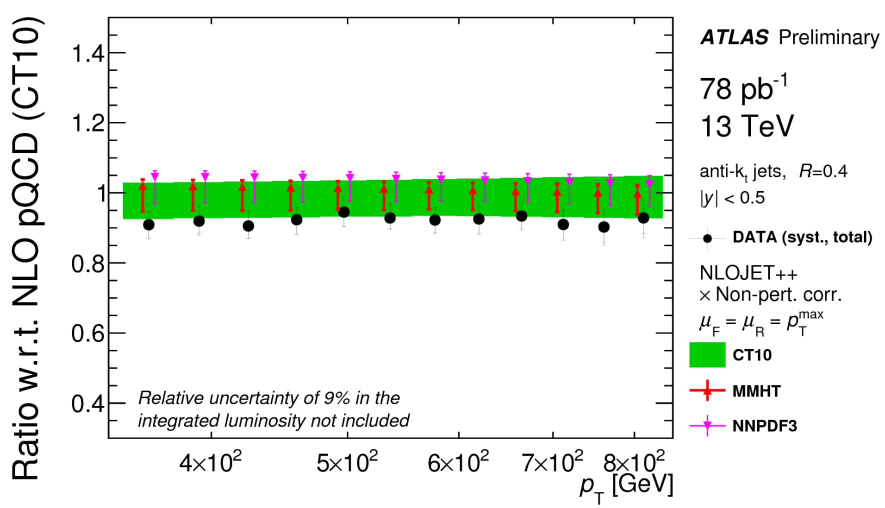


pp→ jet jet +X
ATLAS
EXPERIMENT
Run Number: 271298, Event Number: 403602
Date: 2015-07-11 02:09:14 CEST
QCD
255 ET (GeV)
225
195
165
135
105
75
45
15
η
φ
0
90
180
270

Inclusive jet cross-section

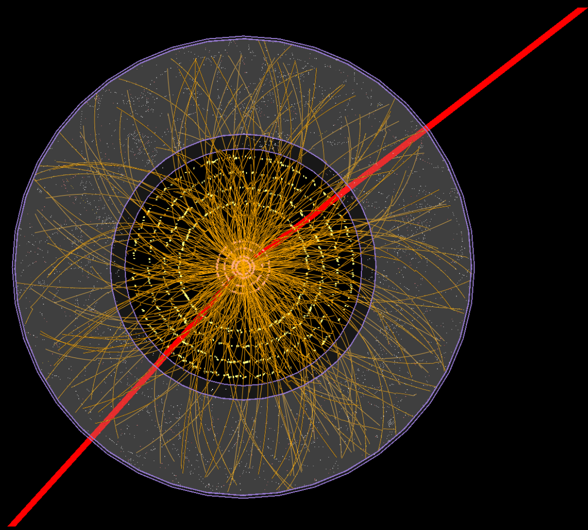


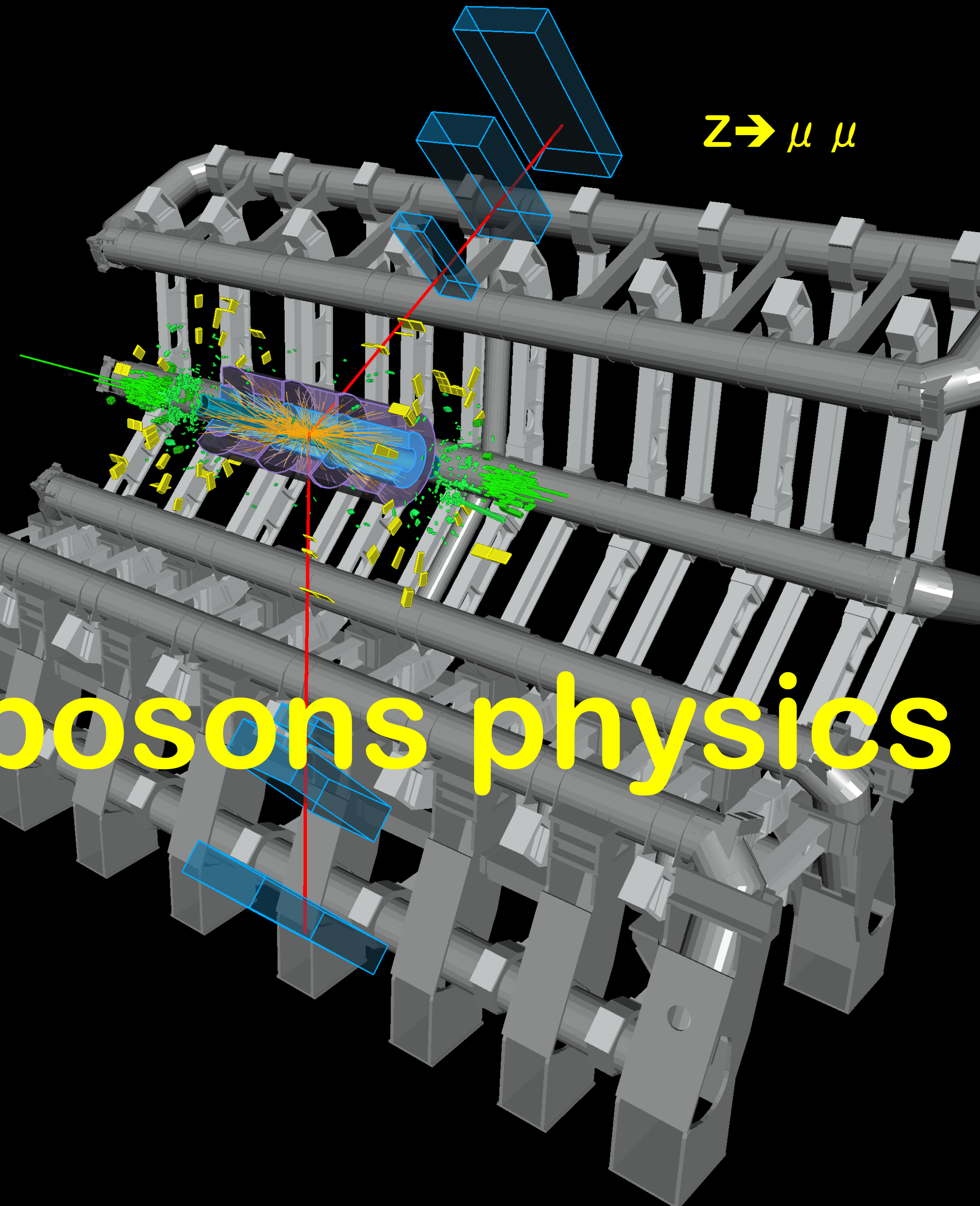
ATLAS-CONF-2015-034



- Jets reconstructed with anti-k_T algorithm, R=0.4, |y|<0.5
- Cross section measured using only 78 pb^{-1}
  - Largest uncertainty: luminosity (+-9%)
  - Good agreement with fixed-order NLO calculation and several PDFs

W and Z bosons physics





ATLAS EXPERIMENT

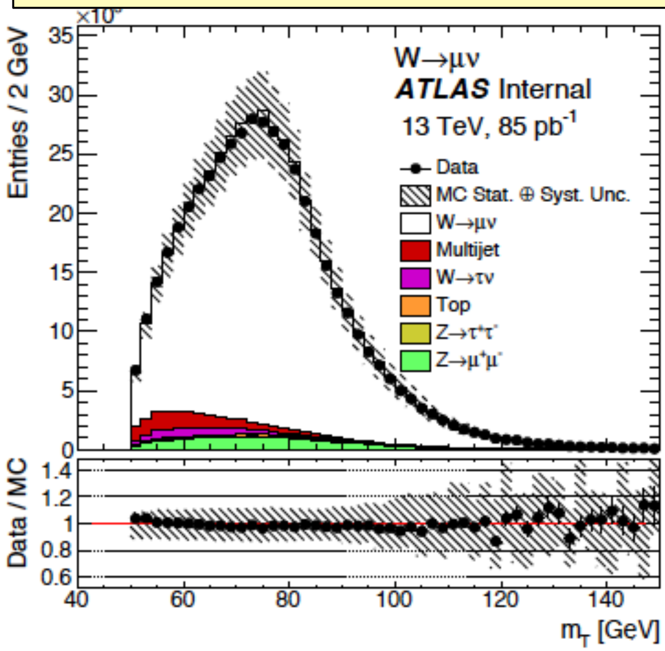
Run: 267638
Event: 242090708
2015-06-14 01:01:14 CEST

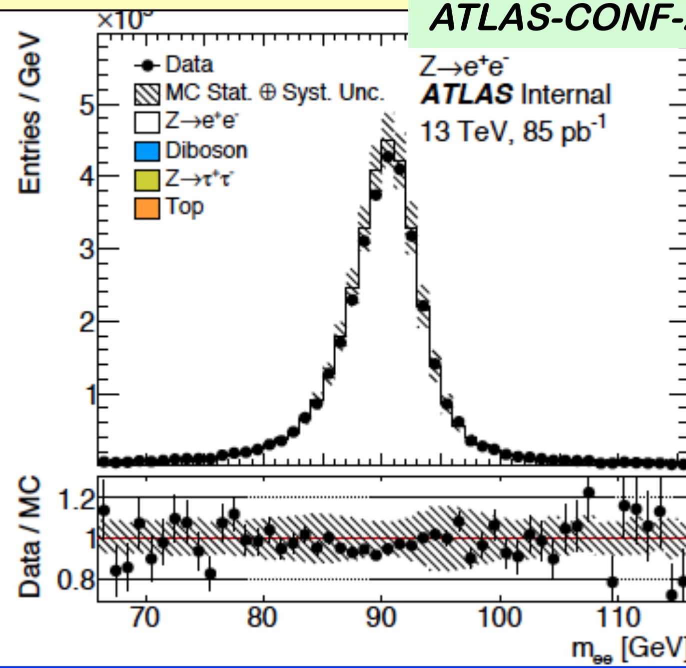
W and Z boson measurements

Selection:

- Isolated electron or muon: p_T>25 GeV
- W bosons: E_T^{miss}> 25 GeV, m_T>50 GeV
- Z bosons: Require two opposite-charge leptons 66 GeV<m(ll)<116 GeV

ATLAS-CONF-2015-039



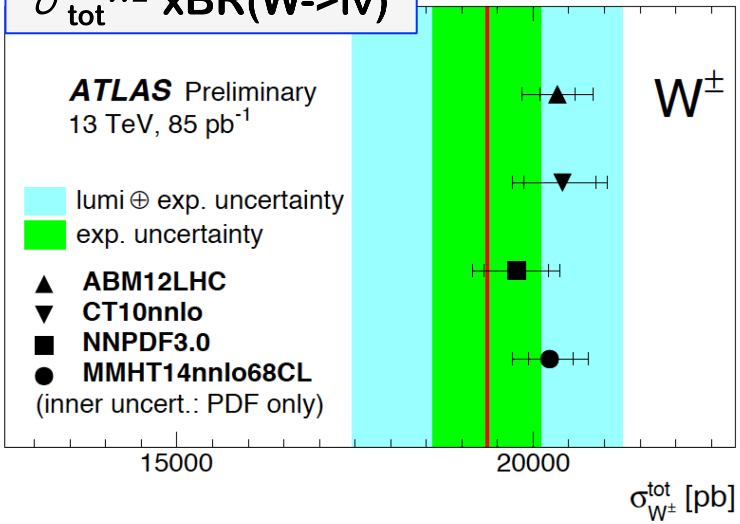


- **About 1 million W candidates selected and 100k Z candidates**
- **Measured: fiducial cross section and total cross section**

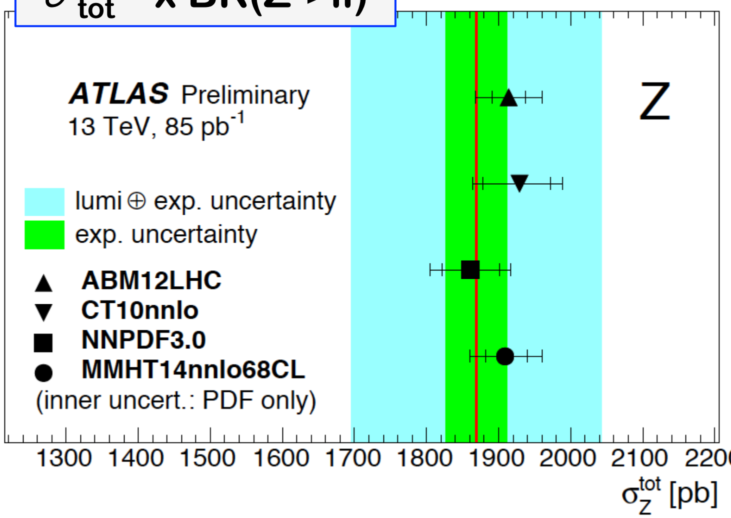
Inclusive W and Z Cross Sections

ATLAS-CONF-2015-039

$\sigma_{tot}^{W\pm}$ xBR(W->lν)



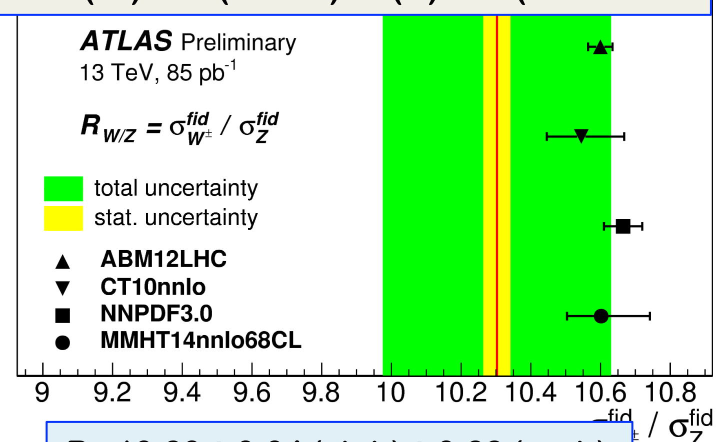
σ_{tot}^{Z} x BR(Z->ll)



$$\sigma_W^{\rm fid} \cdot BR(W \to \ell\nu) = \sigma_W^{\rm tot} \cdot BR(W \to \ell\nu) \cdot A_W = \frac{N_W^{\rm sig}}{C_W \cdot \mathcal{L}}$$

- Measurements agree with predictions at NLO EW and NNLO QCD with different PDFs
  - Precision limited by luminosity uncertainty of ±9% and lept. efficiency
  - Measurement uncertainties (without luminosity) already of the same magnitude as the theoretical uncertainties due to PDFs and higher order corrections

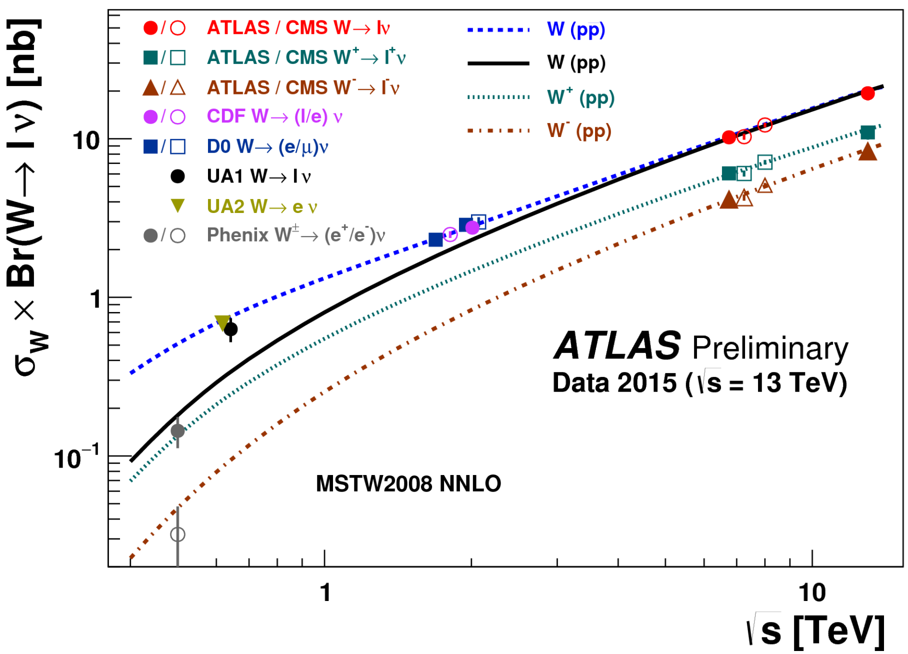
R= σ (W)xBR(W->lν)/ σ (Z)xBR(Z->ll

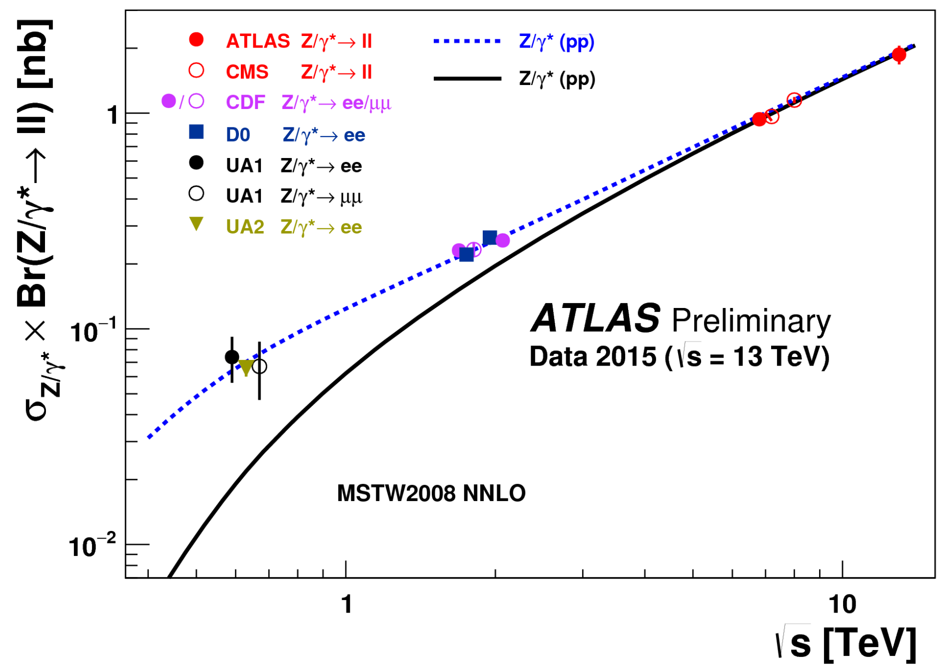


R= 10.30 ± 0.04 (stat.) ± 0.33 (syst.)

Dependence of σ (W) and σ (Z) on √s

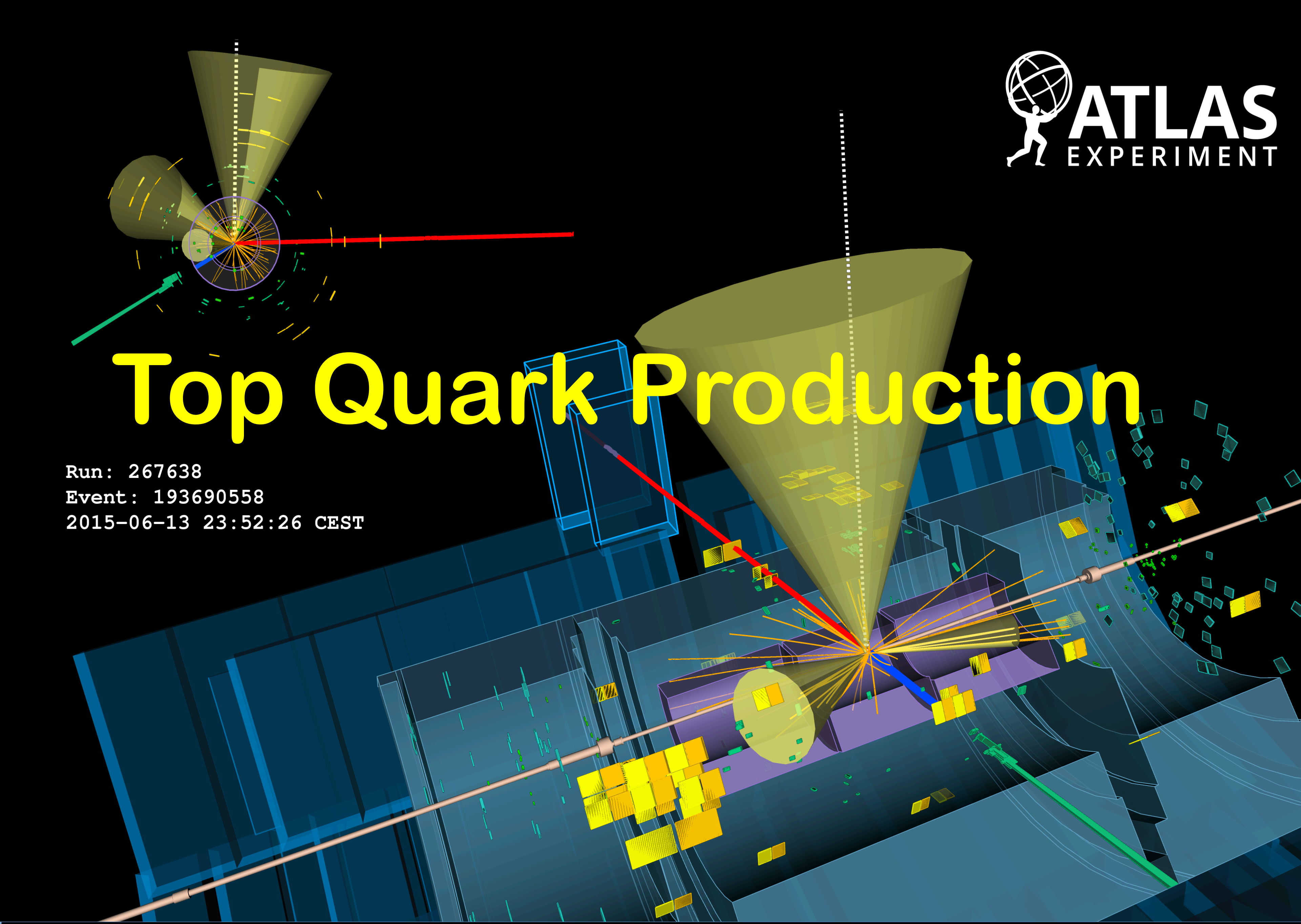
ATLAS-CONF-2015-039



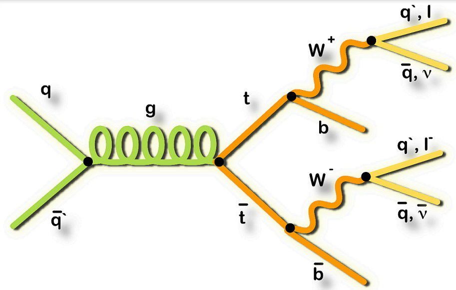


- Cross sections increase by factor ~2 for both W's and Z's compared to 7 TeV

Top Quark Production



Top cross section: dilepton channel

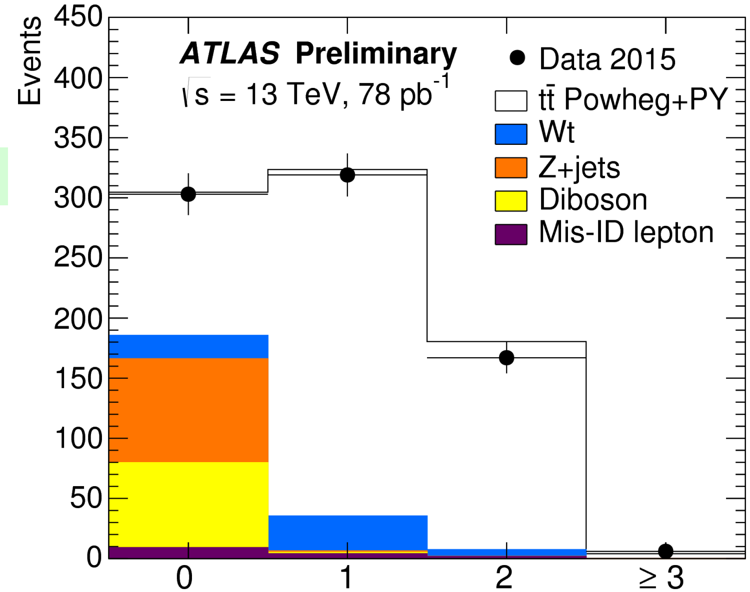


ATLAS-CONF-2015-033

- **Event selection:**
  - Isolated e and μ with p_T>25 GeV
  - One or two b-jets
    - N_1: 1 b-jet
    - N_2: 2 bjets
- **Solve equations for cross section and fraction of b-jets found (ε_b)**

$$N_1 = L\sigma_{t\bar{t}}\,\epsilon_{e\mu}2\epsilon_b(1 - C_b\epsilon_b) + N_1^{\mathrm{bkg}}$$
$$N_2 = L\sigma_{t\bar{t}}\,\epsilon_{e\mu}C_b\epsilon_b^2 + N_2^{\mathrm{bkg}}$$

b-tagged jets in preselected e μ events



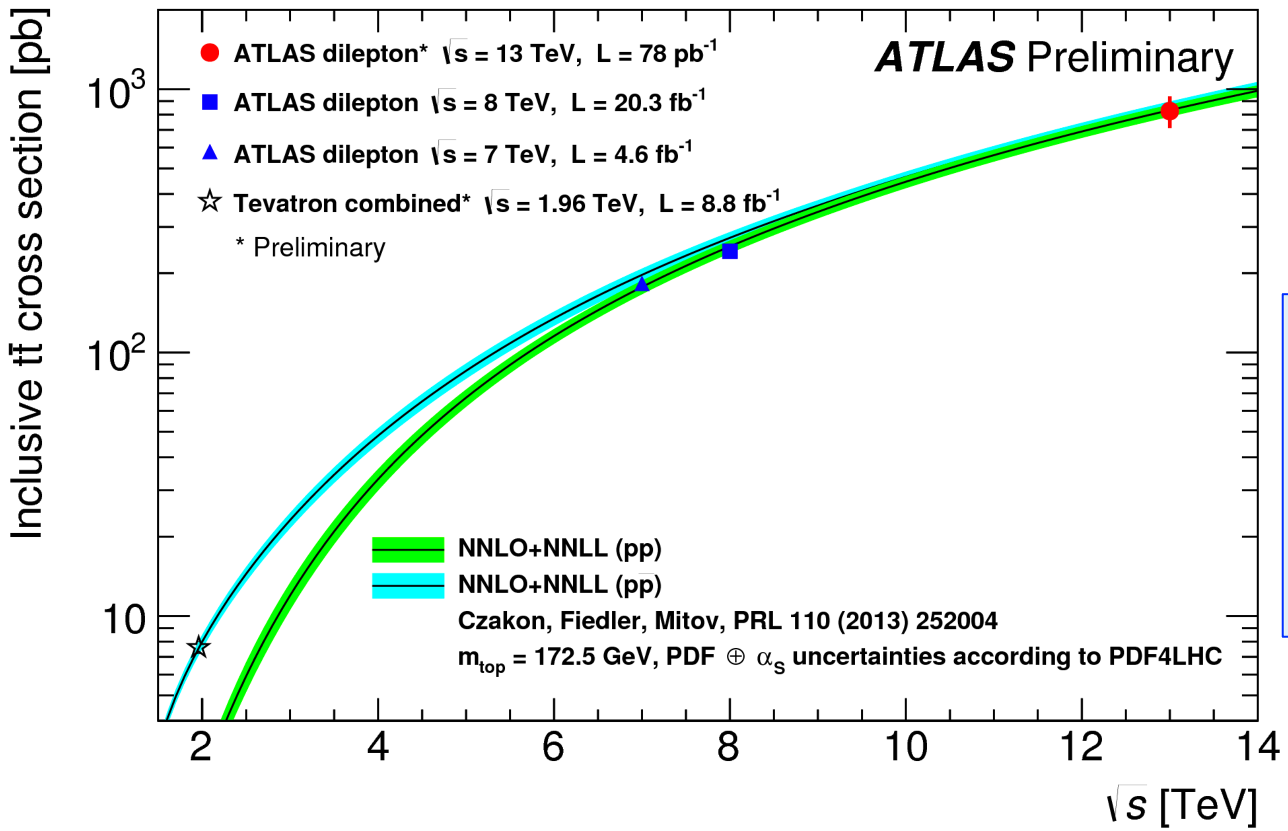
Event counts	N_1	N_2
Data	319	167
Wt single top	29.0 ± 3.8	5.6 ± 2.0
Dibosons	1.1 ± 0.2	0.0 ± 0.0
$Z(\rightarrow \tau\tau \rightarrow e\mu)$+jets	1.3 ± 0.7	0.1 ± 0.1
Misidentified leptons	6.0 ± 3.9	2.8 ± 2.9
Total background	37.3 ± 5.5	8.5 ± 3.5

Data: ε_b=52.7±2.6(stat.)±0.6 (syst.)%
MC: ε_b= 54.3%

Top cross section (e μ channel) vs $\sqrt{s}$

ATLAS-CONF-2015-033

- Large increase of cross section as expected
  - σ(13 TeV)/σ(8 TeV)≈3.4 and σ(13 TeV)/σ(7 TeV)≈4.5

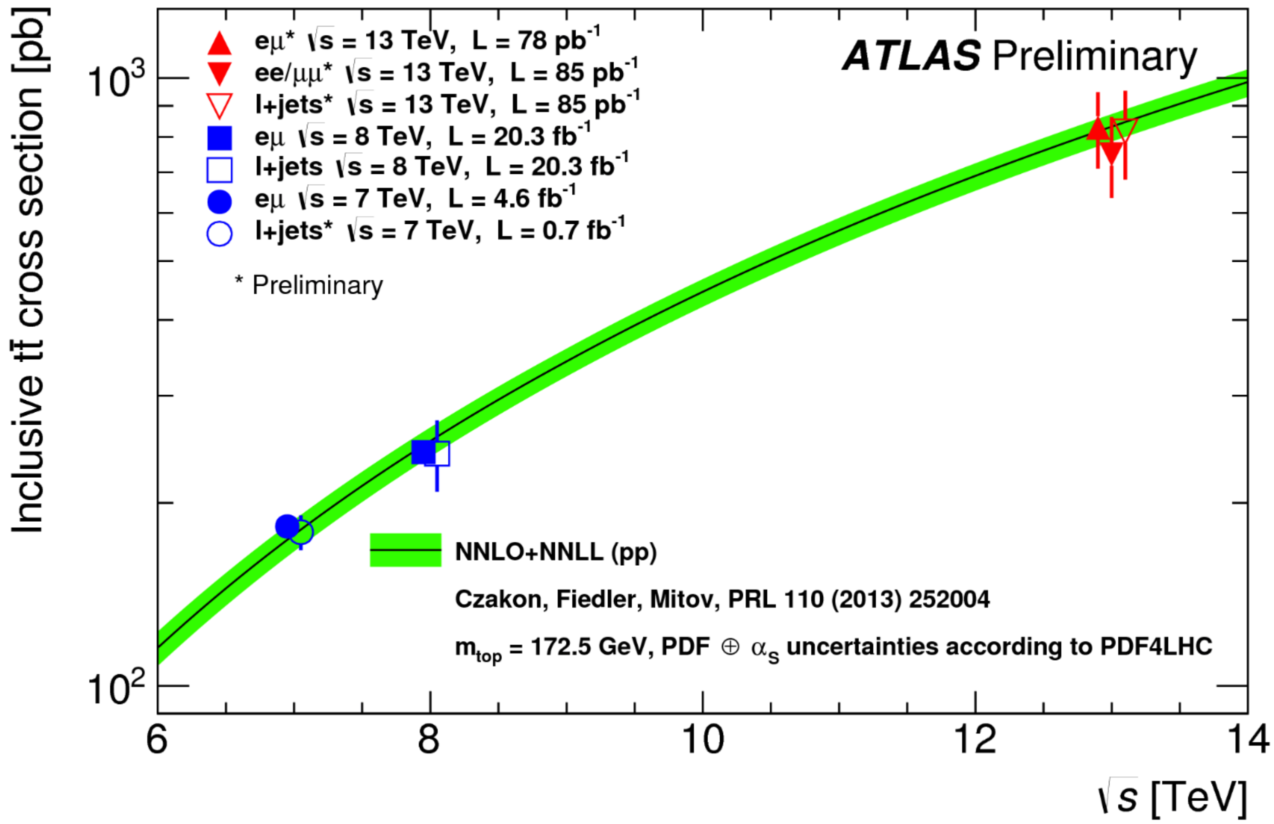


Largest uncertainties:
- Luminosity (10%)
- Theor. Modeling (5%)
- (NLO MC choice, hadronization model, PDF sets)
- Elect. efficiency

$$\sigma_{t\bar{t}} = 825 \pm 49\ (\text{stat}) \pm 60\ (\text{syst}) \pm 83\ (\text{lumi})\ \text{pb}$$

Top cross section: single lepton, dilepton(e μ , μ μ ,ee)

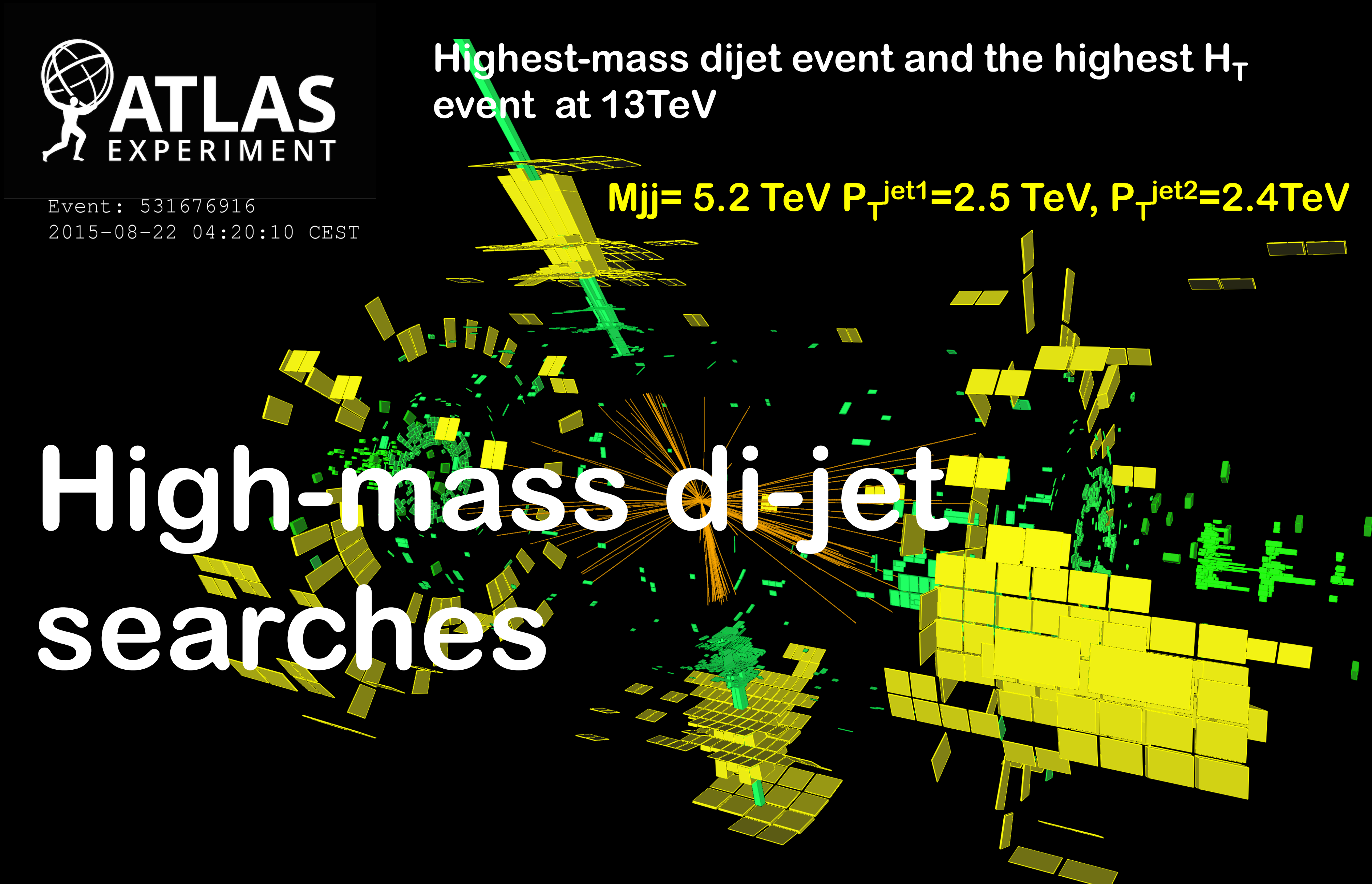
ATLAS-CONF-2015-049



ATLAS measurements at 7, 8 and 13 TeV in agreement with NNLO+NNLL calculations

Highest-mass dijet event and the highest H_T event at 13TeV

Mjj= 5.2 TeV P_T^{jet1}=2.5 TeV, P_T^{jet2}=2.4TeV



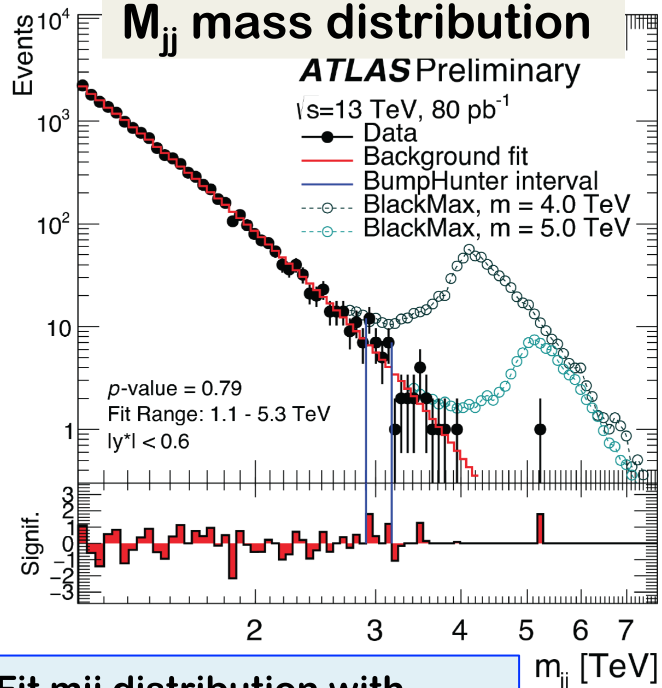
High-mass di-jet searches

New phenomena in di-jet search

New Resonance search

80 pb^{-1}
jets: anti-k_t , R = 0.4
≥ 2 jets, p_T > 410, 50 GeV

M_{jj} mass distribution

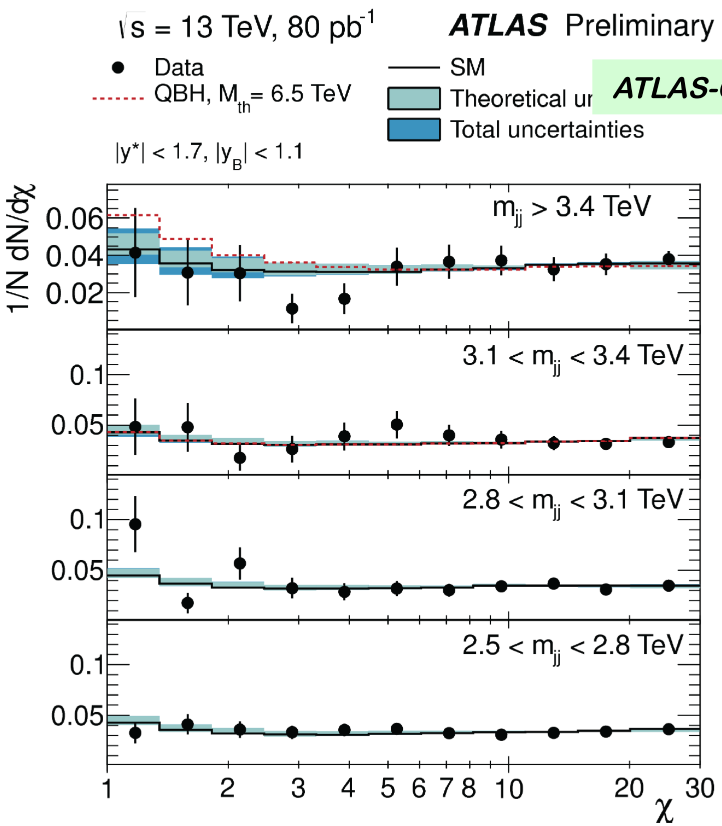


- **Fit mjj distribution with analytic function**
- **Compare fit with observed data using BumpHunter**

No significant excess found

Deviation in angular variables χ

ATLAS-CONF-2015-042



$$\chi = e^{2|y^*|} \sim \frac{1+\cos\theta^*}{1-\cos\theta^*} \qquad y^* = \frac{1}{2}(y_1 - y_2)$$

No significant deviation observed

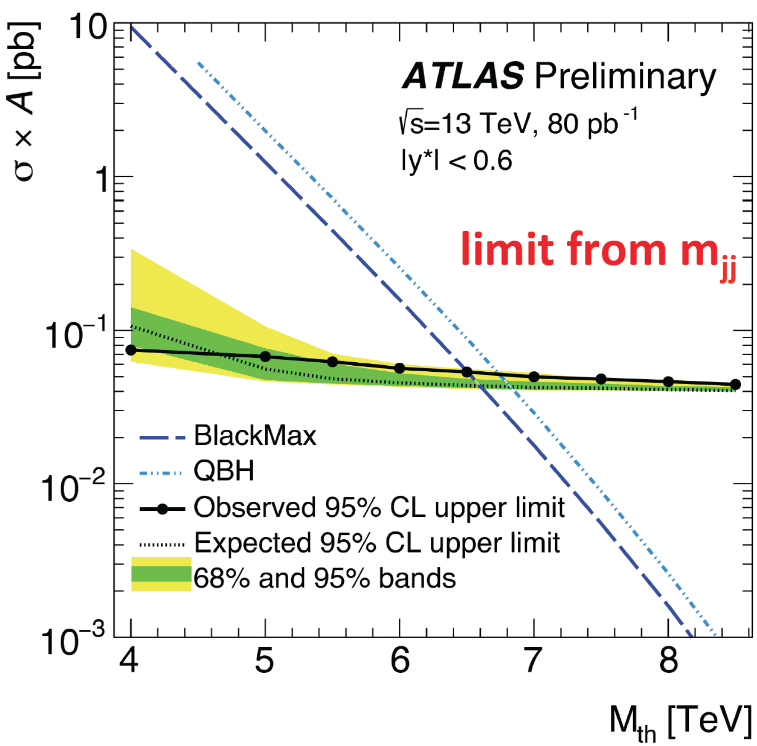
Interpretation in a model of extra-dimensions and QBH

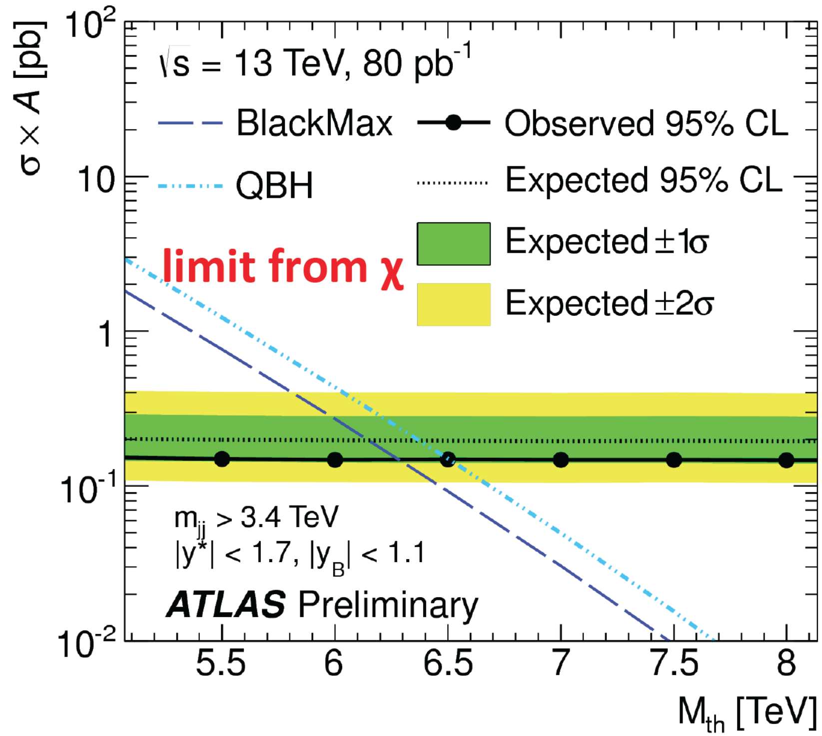
ATLAS-CONF-2015-042

M_D = Plack scale in extra-dimensions

Assume n=6, $M_D = M_{th}$

M_{th}: threshold scale for black hole production





The resonant search excludes :

- $M_{th} < 6.8$ TeV at 95% CL using QBH
- $M_{th} < 6.5$ TeV at 95% CL using BlackMax

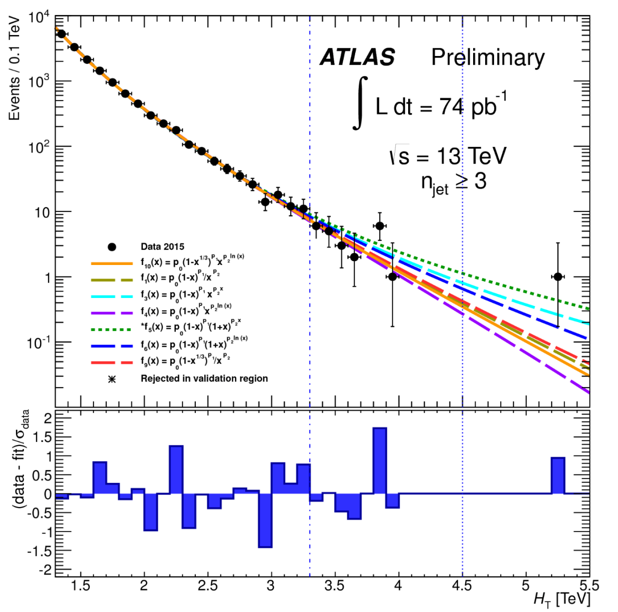
The angular search excludes:

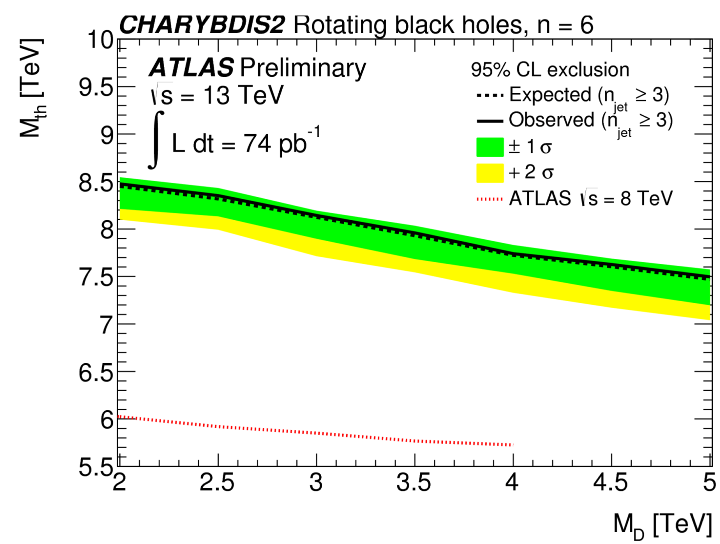
- $M_{th} < 6.5$ TeV at 95% CL using QBH
- $M_{th} < 6.4$ TeV at 95% CL using BlackMax

Multi-jet search for thermalizing QBH

ATLAS-CONF-2015-043

- Non resonant search
  - $N_{jet} \geq 3$, $P_T > 50$ GeV
- Look for an excess in H_T (HT scalar sum of pT of all jets of pT>50 GeV), $H_T > 1$TeV
  - Data-driven background fits in control region (CR)
  - Check in validation (VR)
  - Compared to events in signal region (SR)



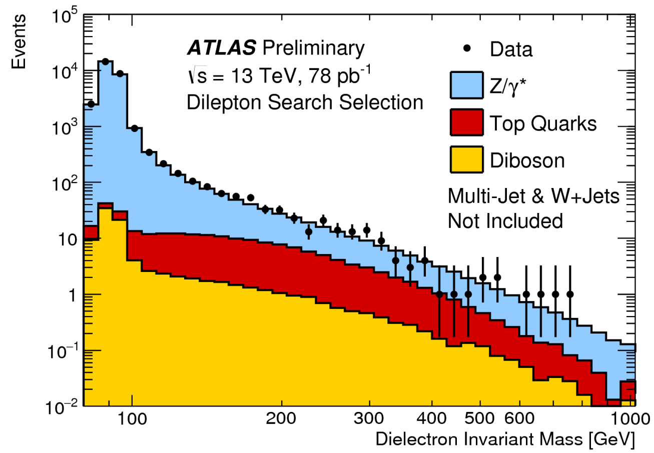


No significant deviations observed in any signal region

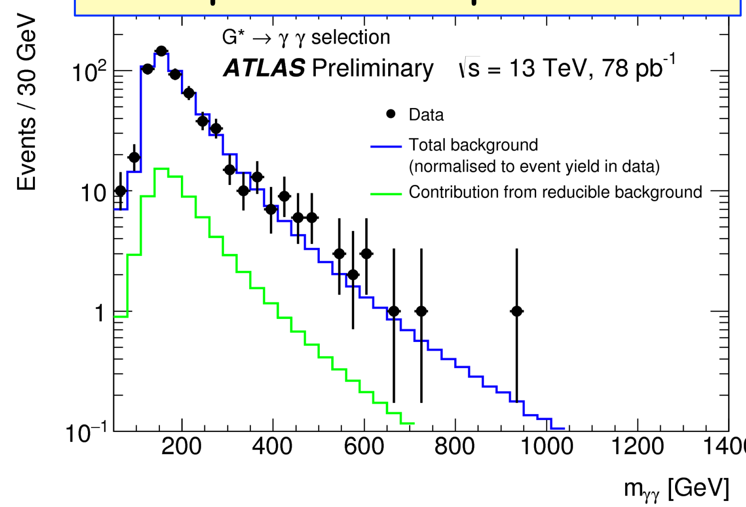
- Set 95% CL limits on models of low scale gravity (n=6) using CHARYBDIS2 Model
- Improvement of 2-2.5 TeV on exclusion limit with respect to Run-1 result

Many New Physics Searches on going…

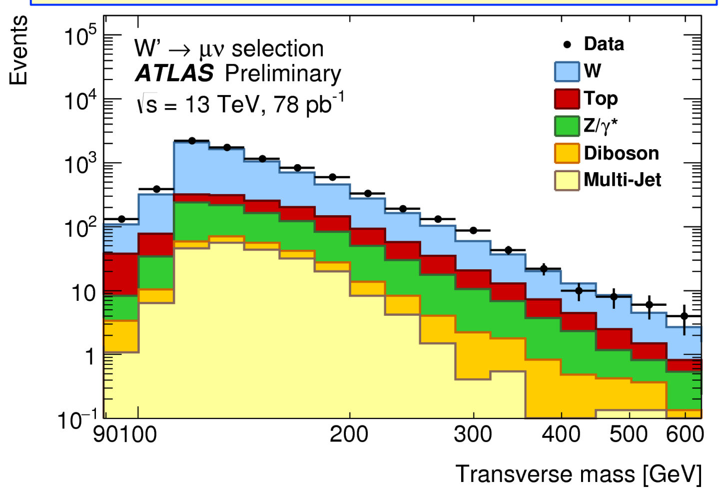
Z' search:Dilepton mass spectrum



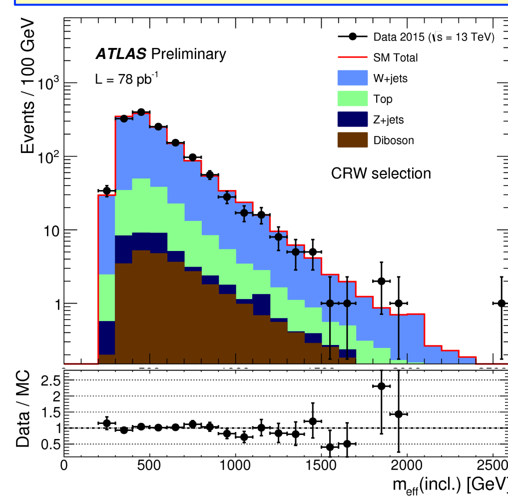
G* : Diphoton mass spectrum



W' search : Lepton + missing ET



Control-region for SUSY search

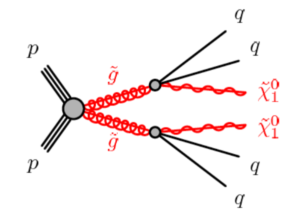


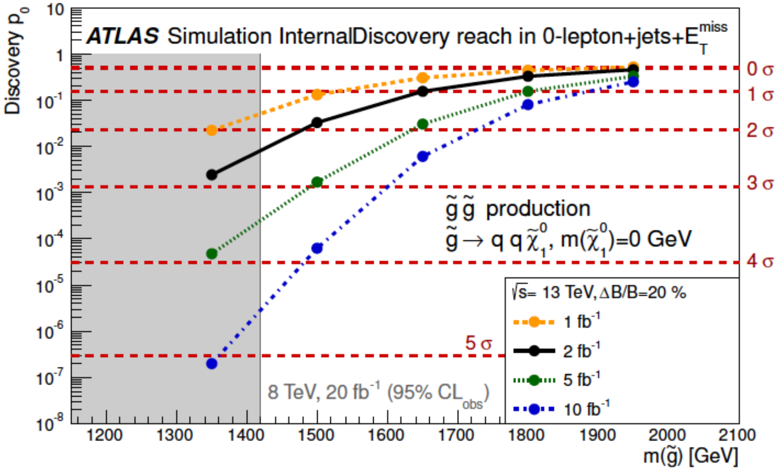
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/Summer2015-13TeV

Conclusions and Outlook

- ATLAS has successful start data-taking at Run-2 and commissioned all its sub-detectors.
  - Re-establishing understanding of high momentum objects
    - Fundamental keys for the future precision measurements
- First results on several SM processes and searches at 13 TeV with <100pb^{-1}
  - SM precision measurements important to understand background for searches of new physics
- ATLAS is fully ready for possible new discoveries and to perform precision physics at 13 TeV!

➔Stay tune, the best has still to come..





- Could find evidence(3 σ) for gluino mass up to ~1.5 GeV already with 5 fb^{-1}

Back-up

Resonances decaying to VV

- **Major new tool: jet substructure**