ATLAS at the dawn of Run2

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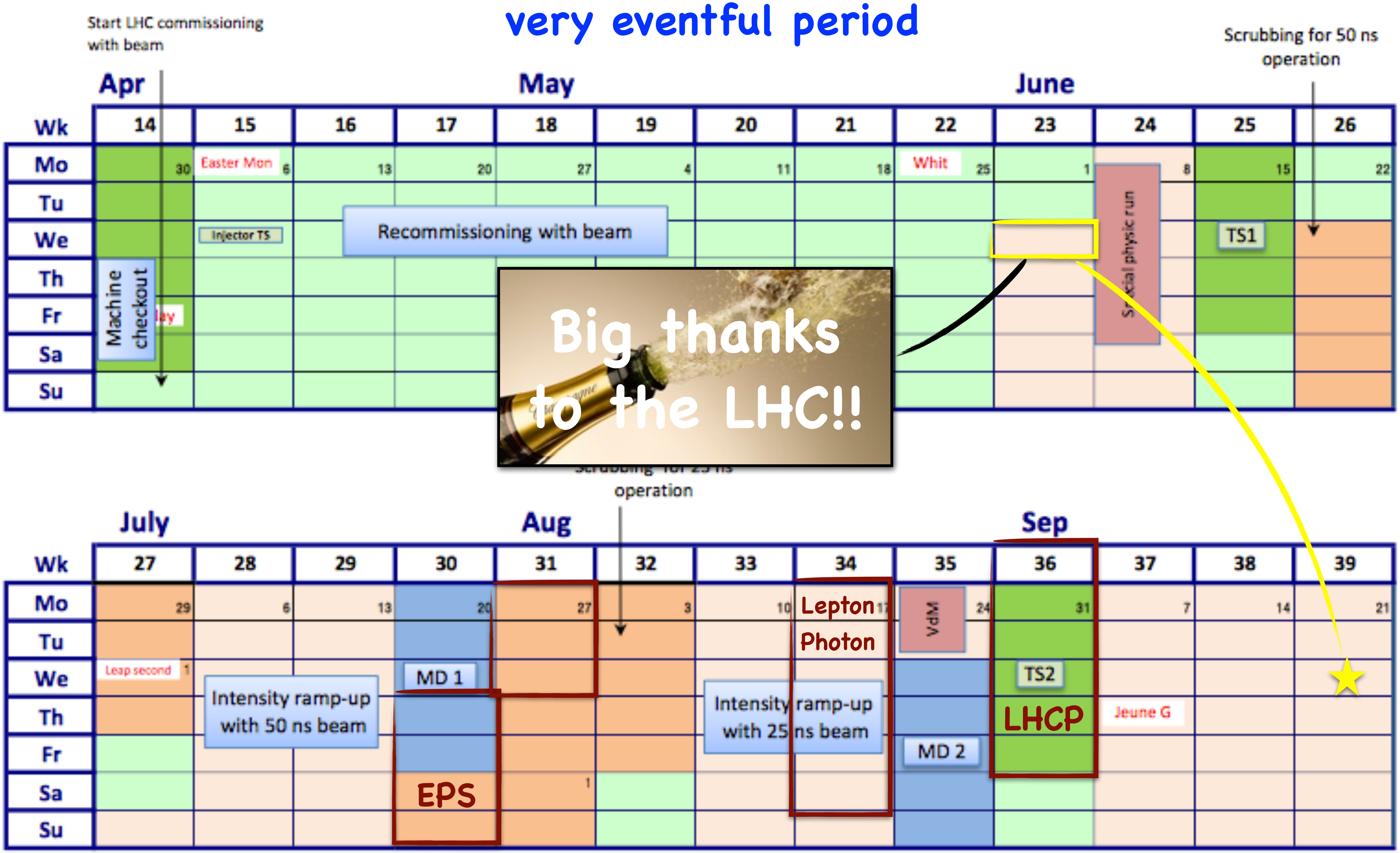
University of Toronto

LHCC Meeting Open Session
23.9.2015 CERN

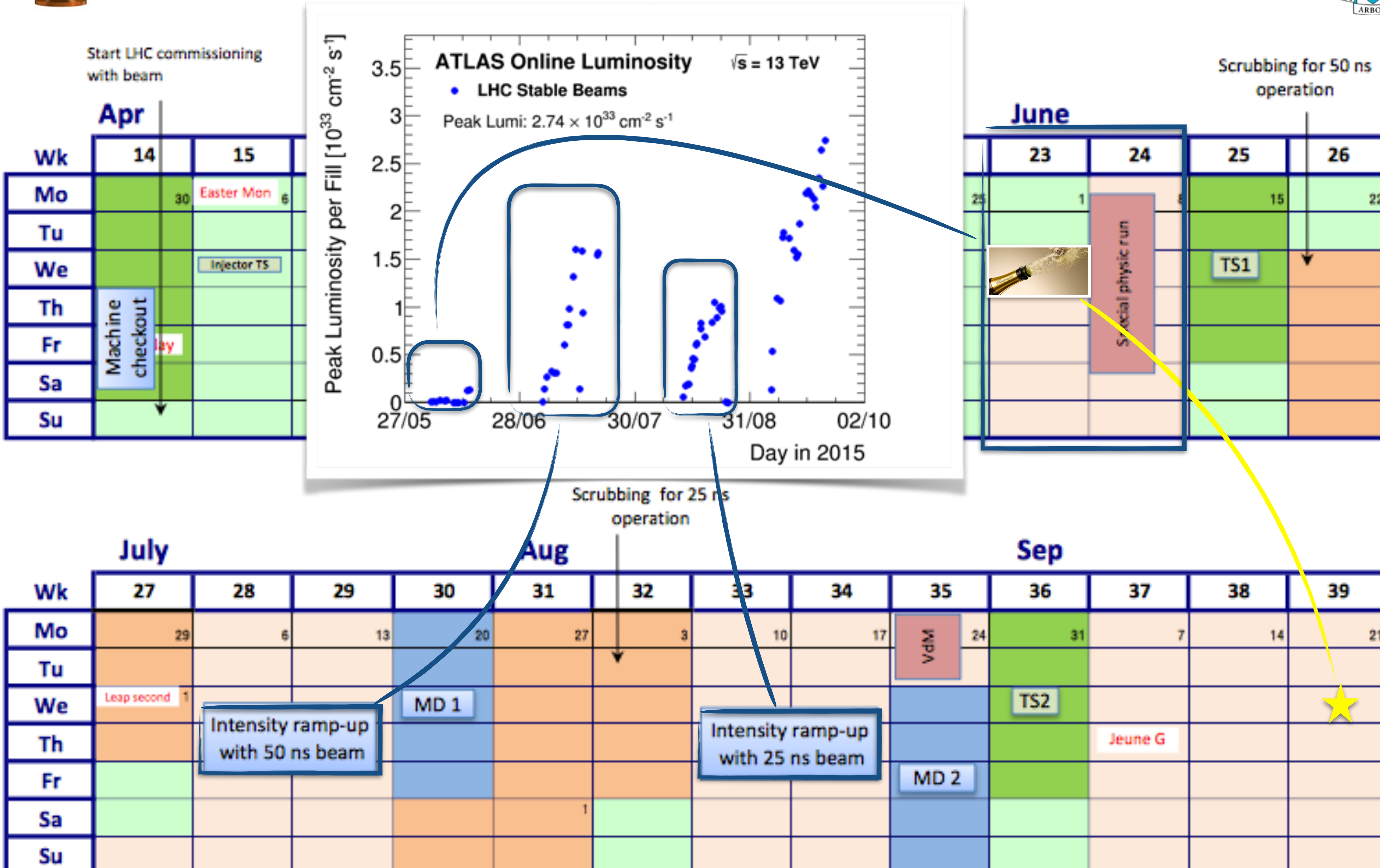
Detector Operation | Trigger | Computing & Software | Data Preparation | Physics

LHC Timeline

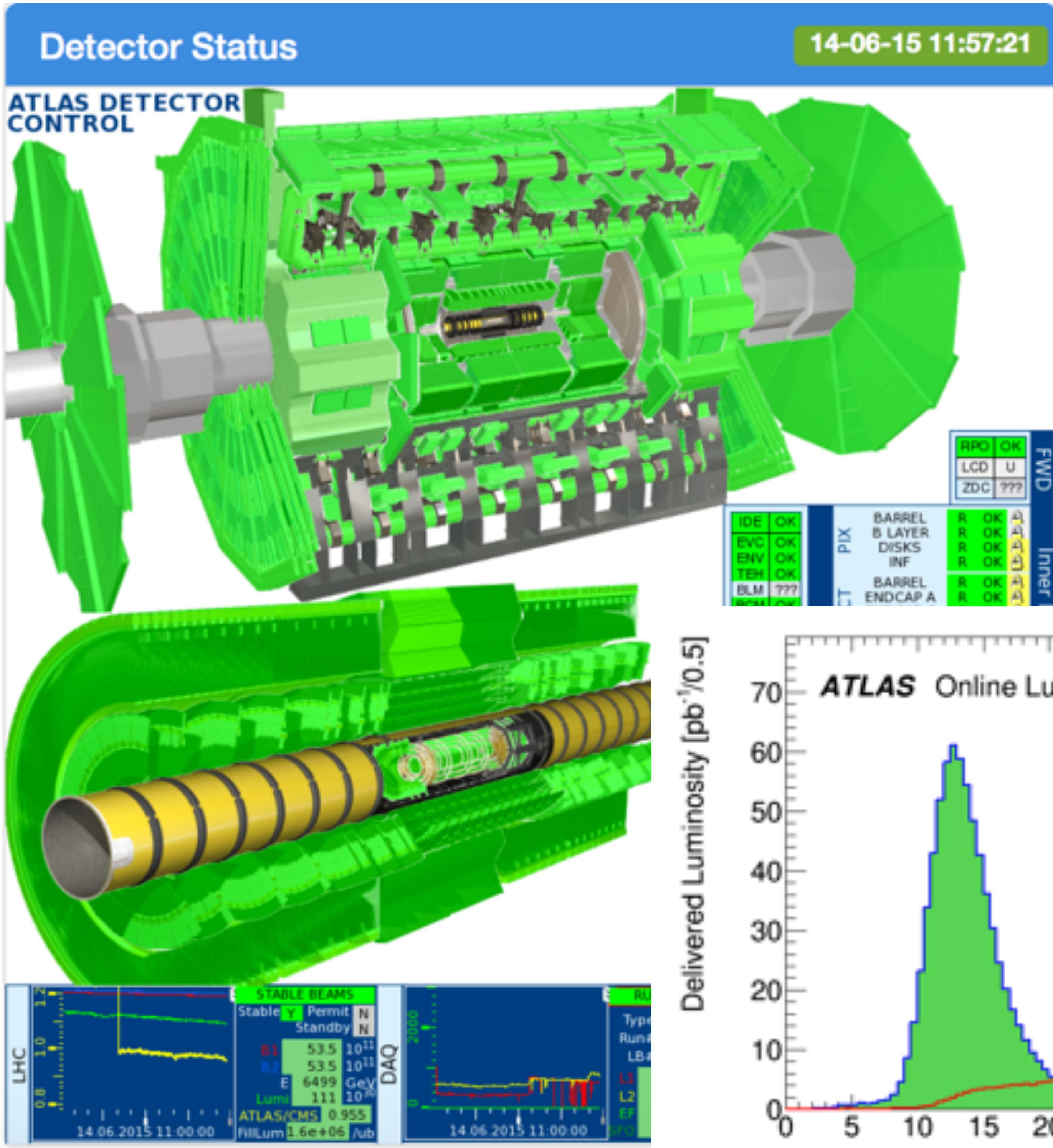
very eventful period

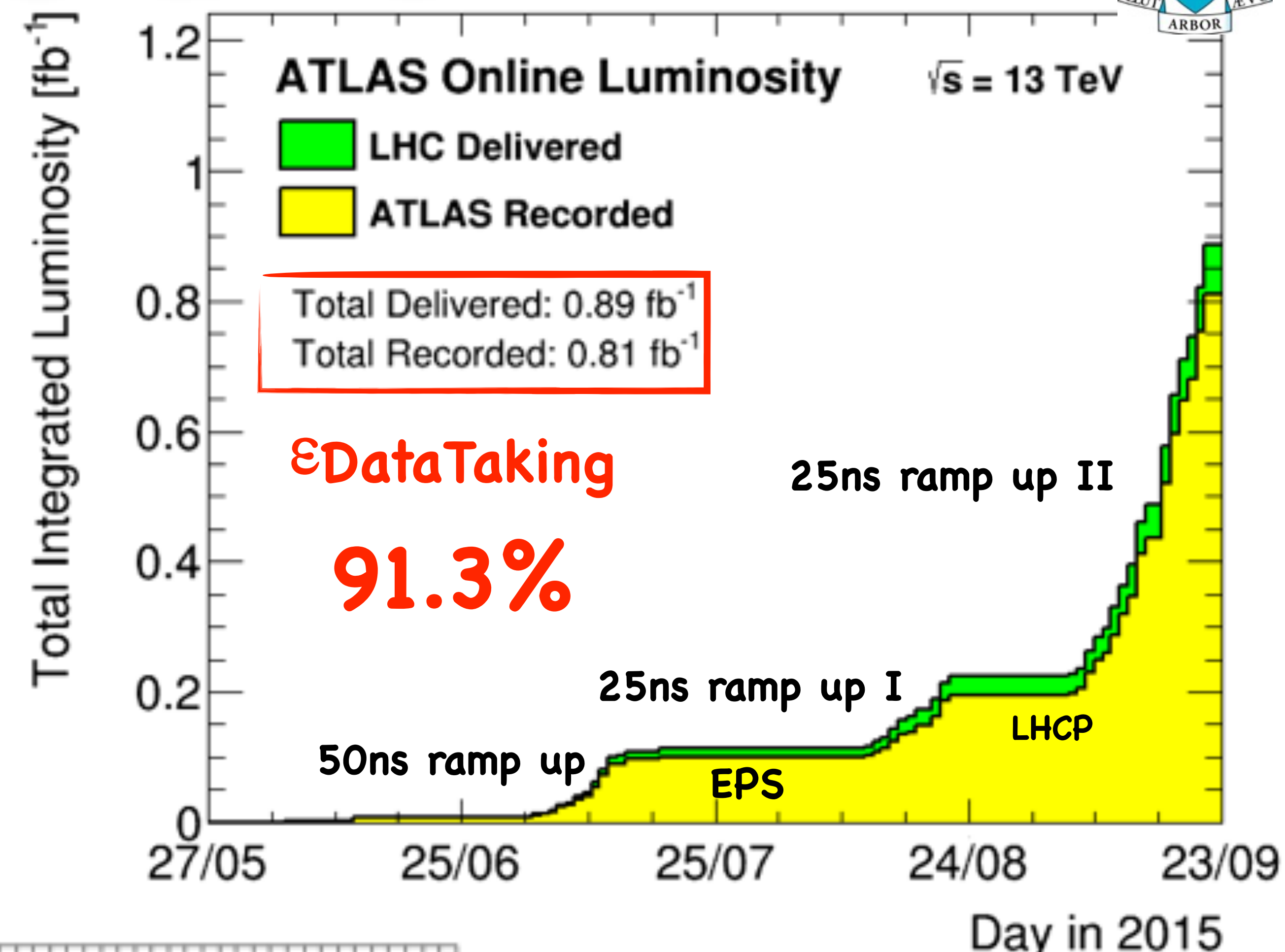


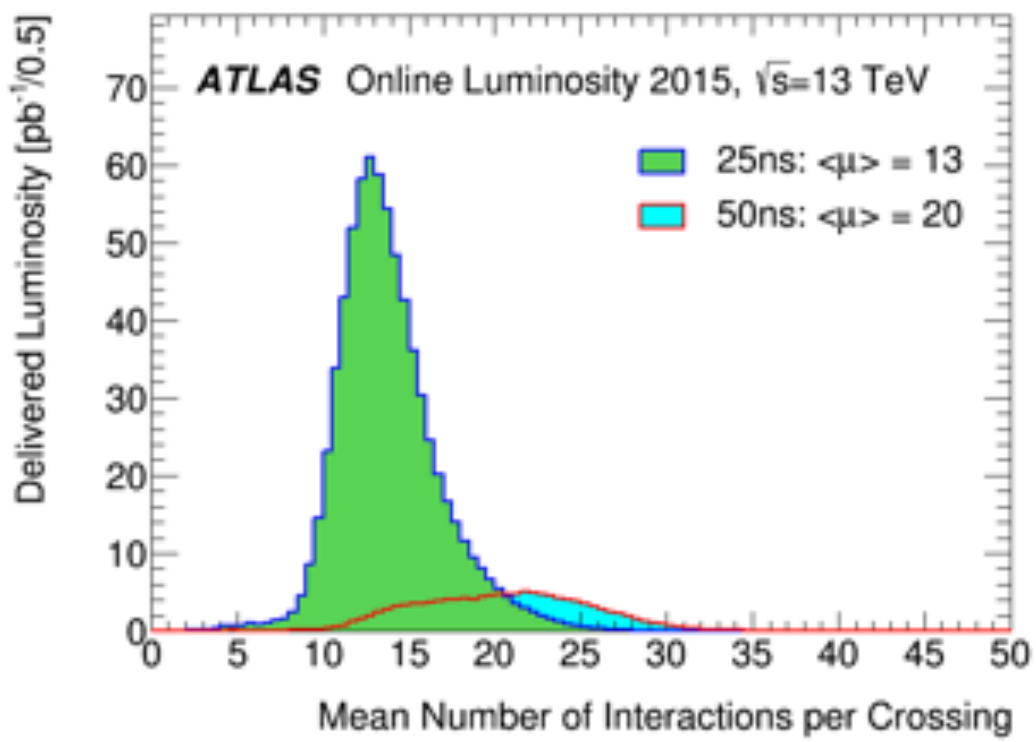
LHC Timeline



ATLAS Status

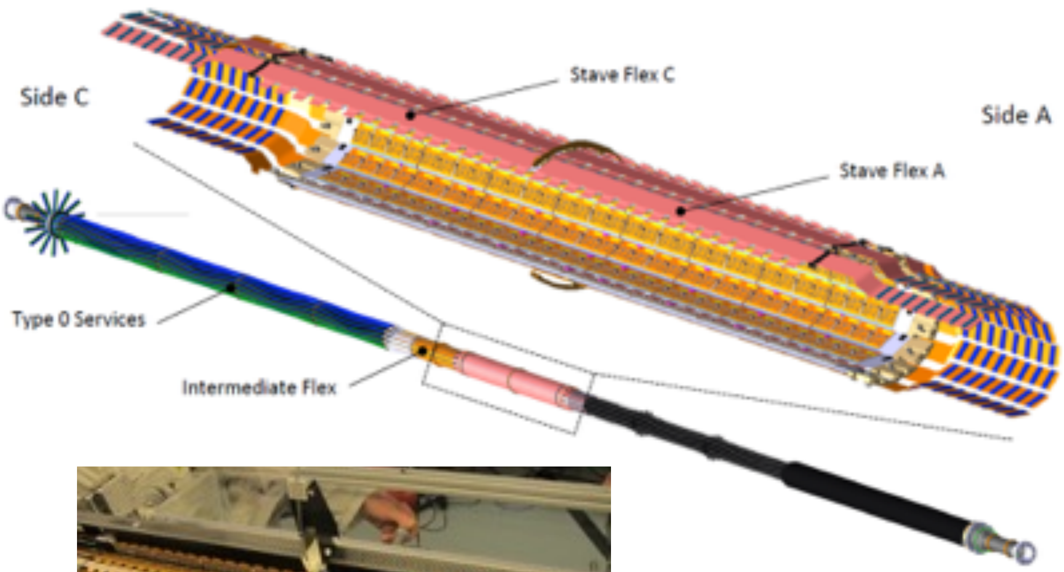






- μ values still similar to Run1 values
- EPS and LHCP datasets ~100 pb^{-1} each
- early lumi systematics from LHCf run … **9%**

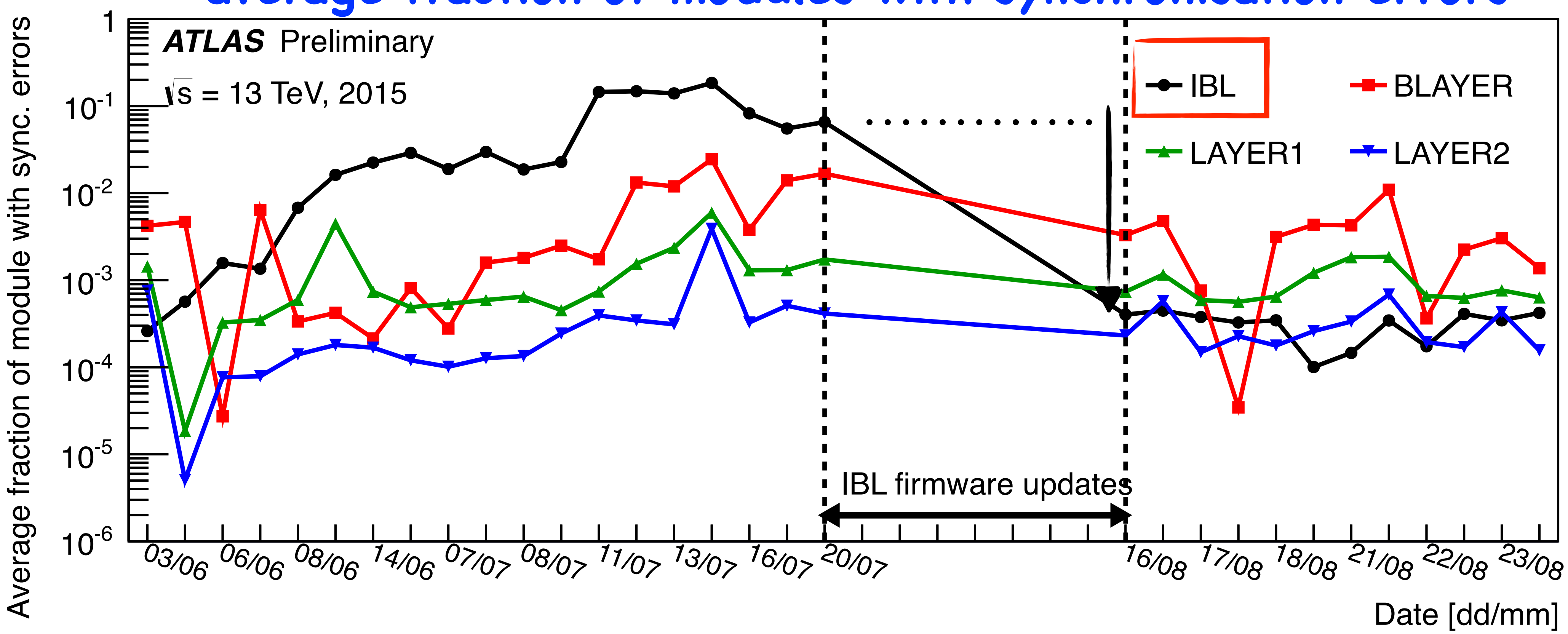
Inner Detector



- Pixel/IBL operational since Week1
- **IBL significantly improves the performance** of the Pixel
  - operational stability thanks to firmware upgrades and mainly before 25 ns runs (3 order of magnitude less errors)

IBL = the 4th and innermost Pixel layer installed in LS1

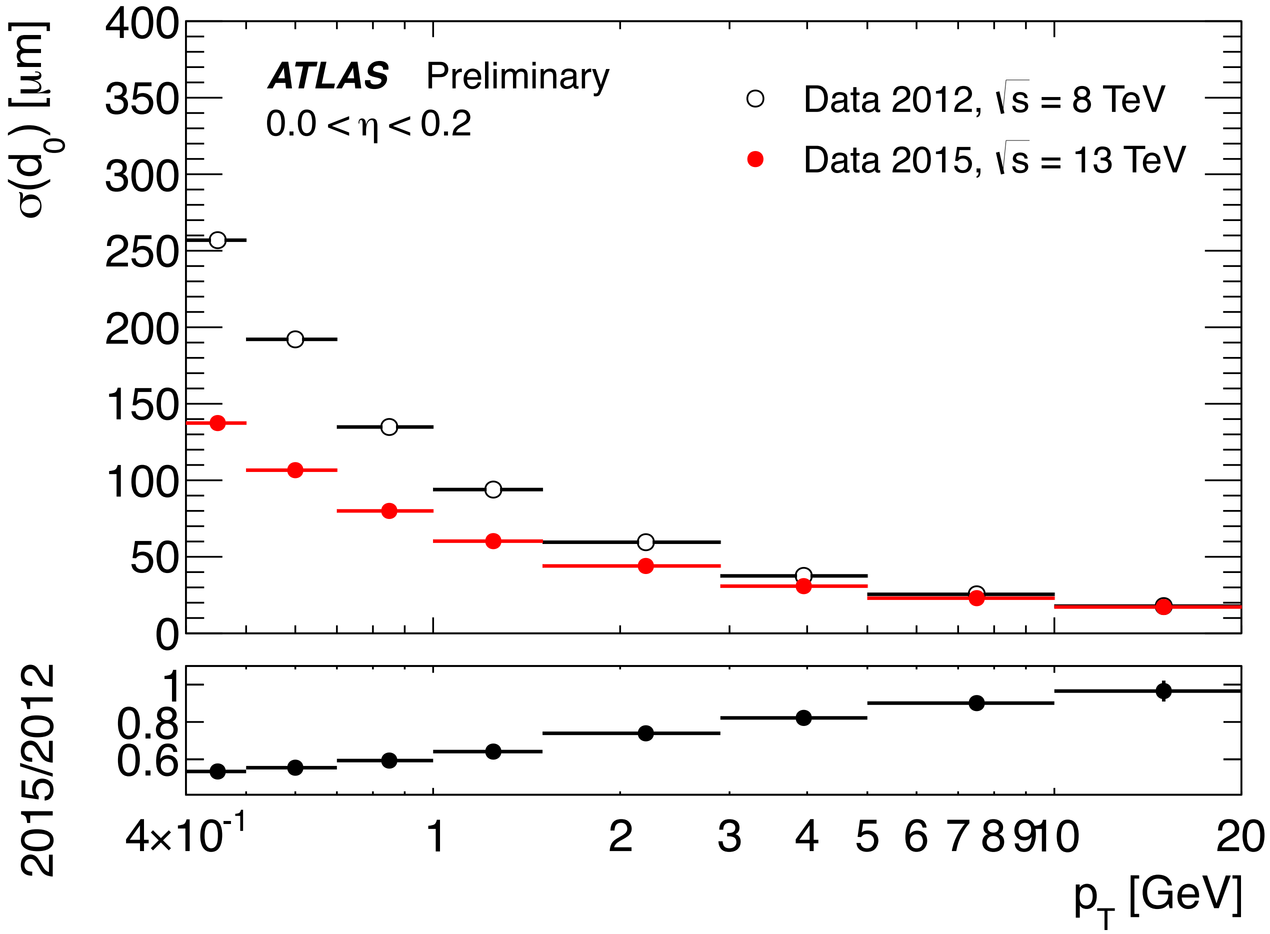
average fraction of modules with synchronisation errors



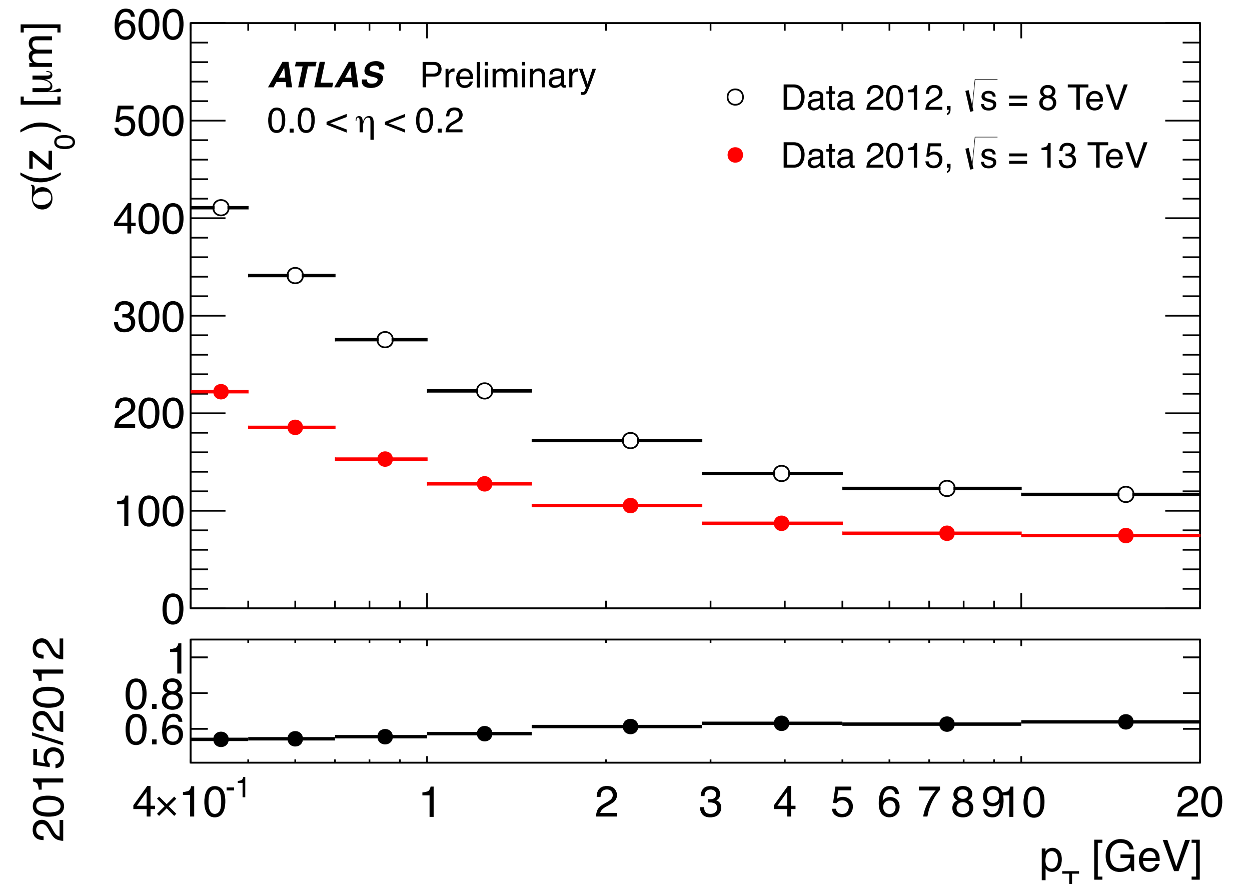
SCT and **TRT** are operating smoothly and are preparing for high μ runs

Tracking

ATL-PHYS-PUB-2015-018

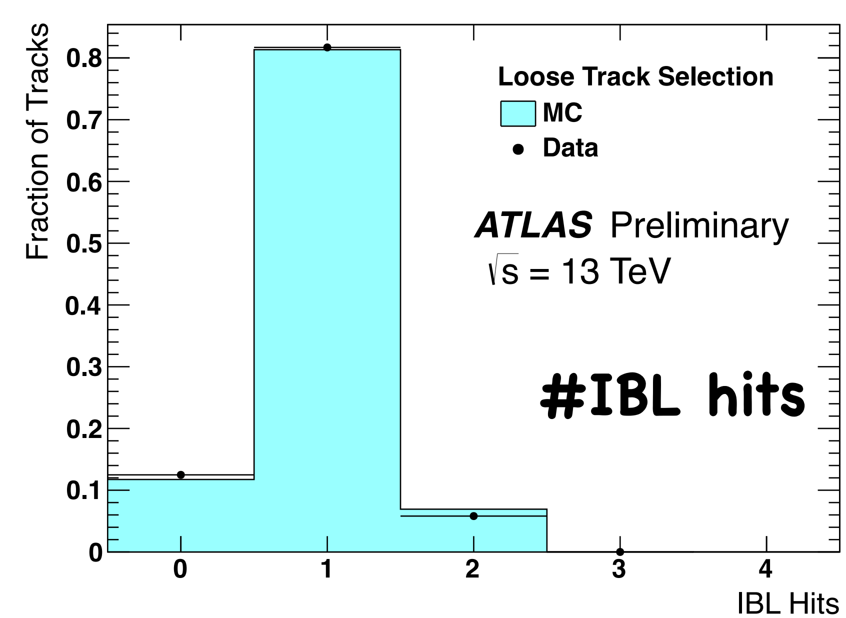


transverse impact parameter resolution in 2015 (+IBL) and 2012



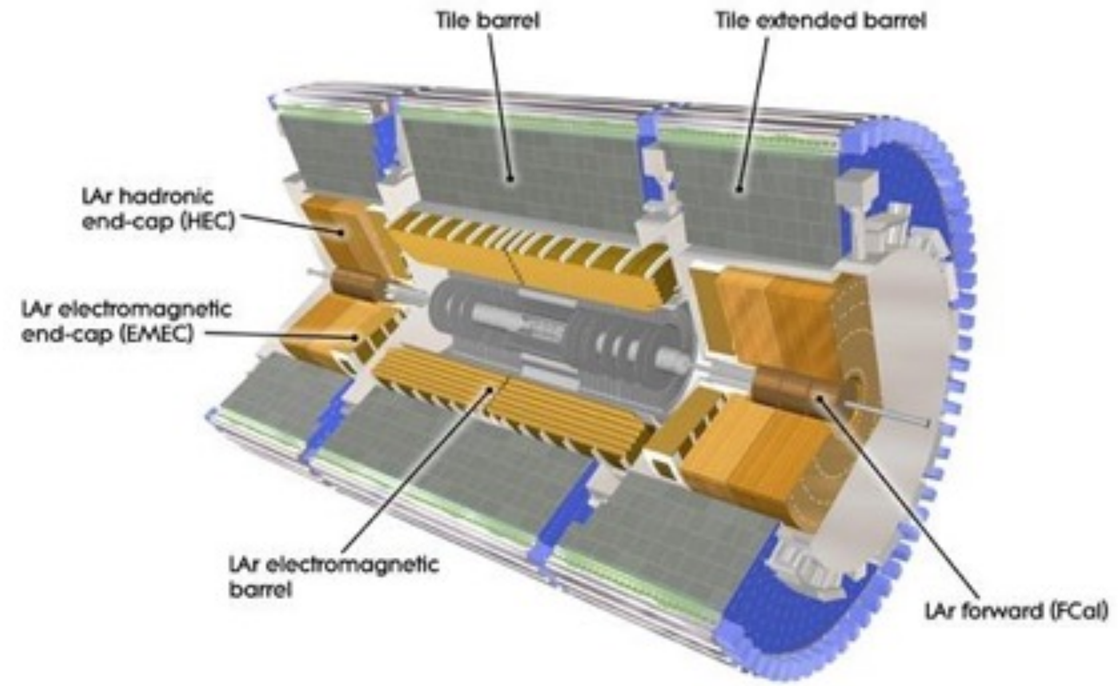
longitudinal impact parameter resolution in 2015 (+IBL) and 2012

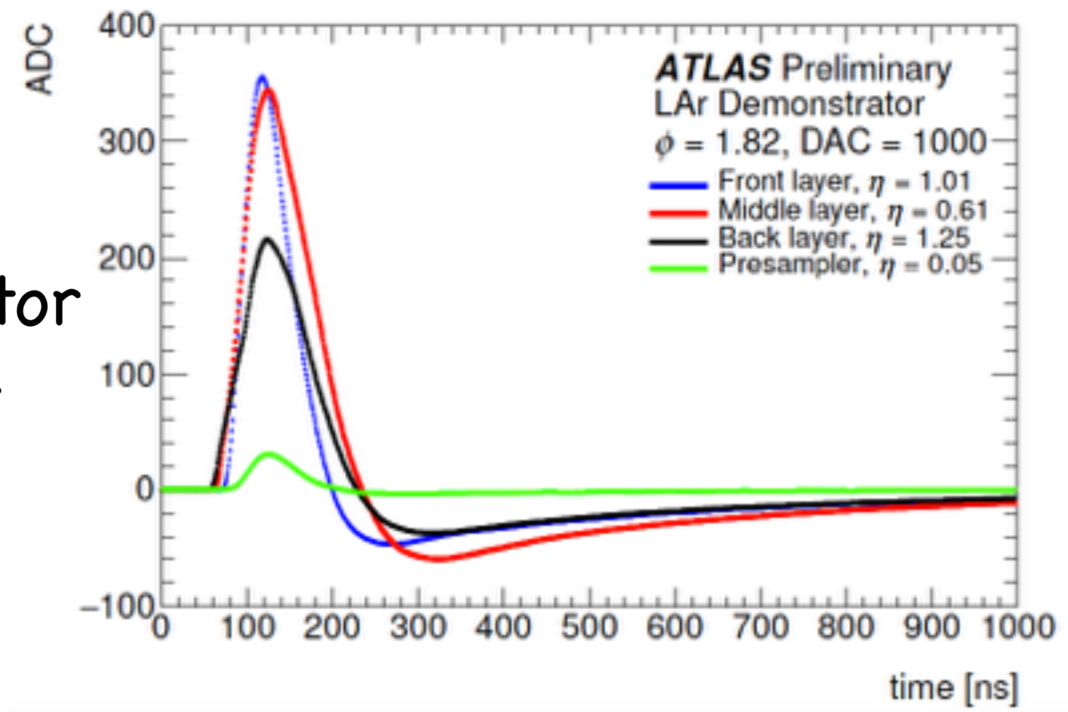
- large gain in resolution through IBL
- generally good agreement between data and MC



Calorimetry

- very smooth operations for 50 and 25ns
- LAr:
  - noise burst flagging running @ HLT level (very energetic with high Q factor over a few μs, looked up in a 100ms sliding window)
  - LAr Phase-I trigger upgrade demonstrator boards ($1.767 < \varphi < 2.160$, $|\eta| < 1.4$, super cells record data) installed

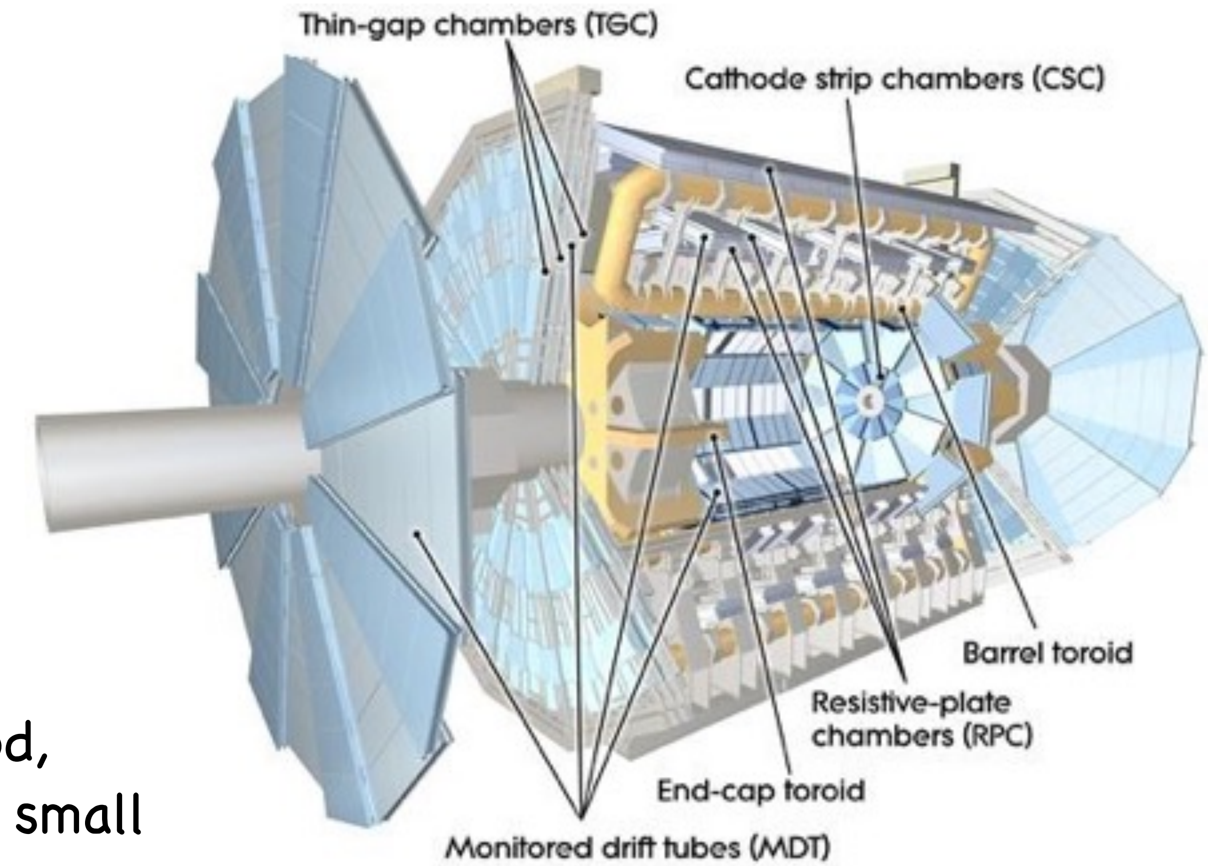




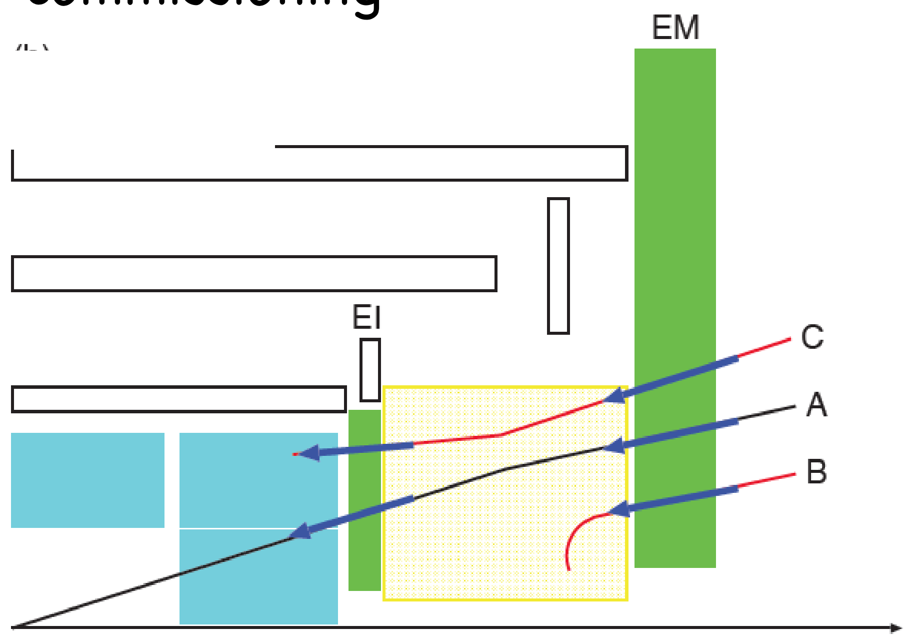
- Tile:
  - no LVPS trips (unlike in Run1), 2 dead modules
  - Using all calibration systems to preserve the scale
  - new MBTS counters were inter-calibrated based on the minimum bias current measurements from Tile

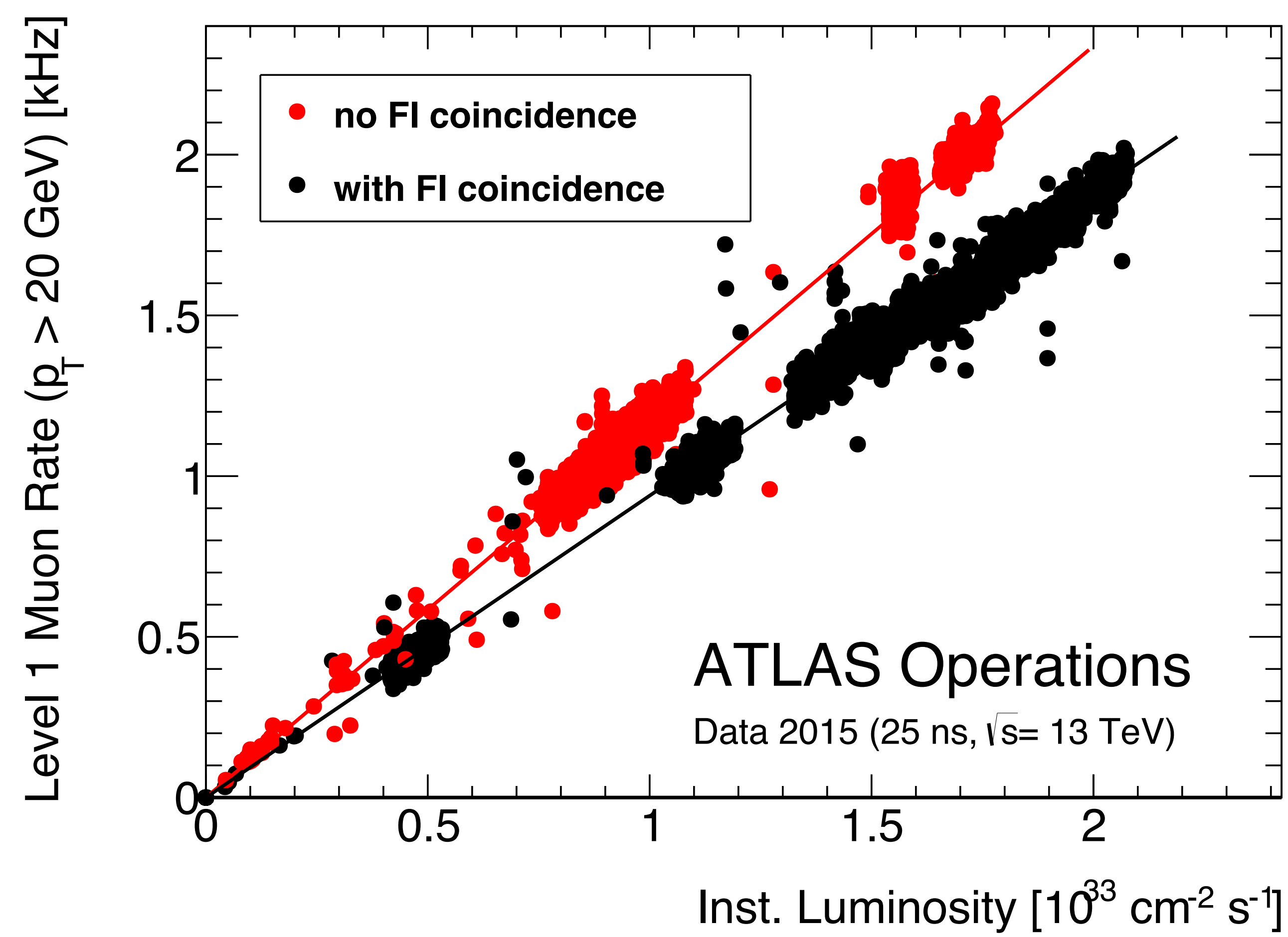
Muons

- alignment performed with toroid magnet off
  - 30M muon tracks collected (target resolution of **10% @ 1 TeV**)
  - initial alignment from July available
- overall performance of the muon systems is very good, operational teams are focusing on troubleshooting of small issues

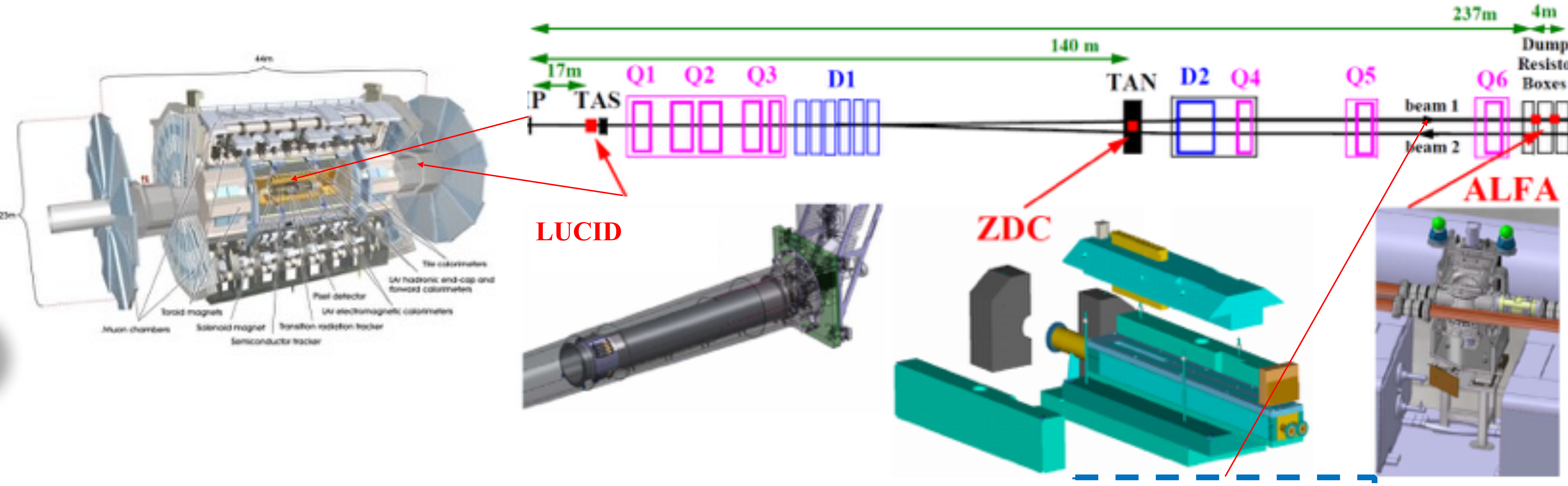


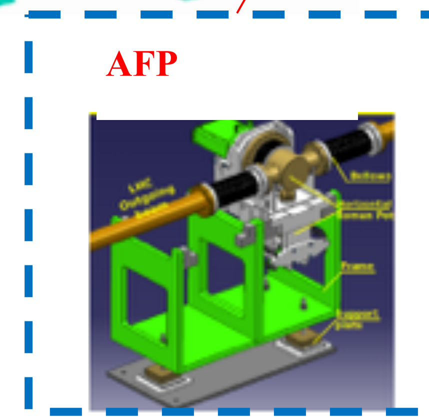
- **TGC** deployed the inner coincidence (reduction of muon trigger rates in the ECs.)
  - additional Tile-muon coincidence under commissioning





FWD

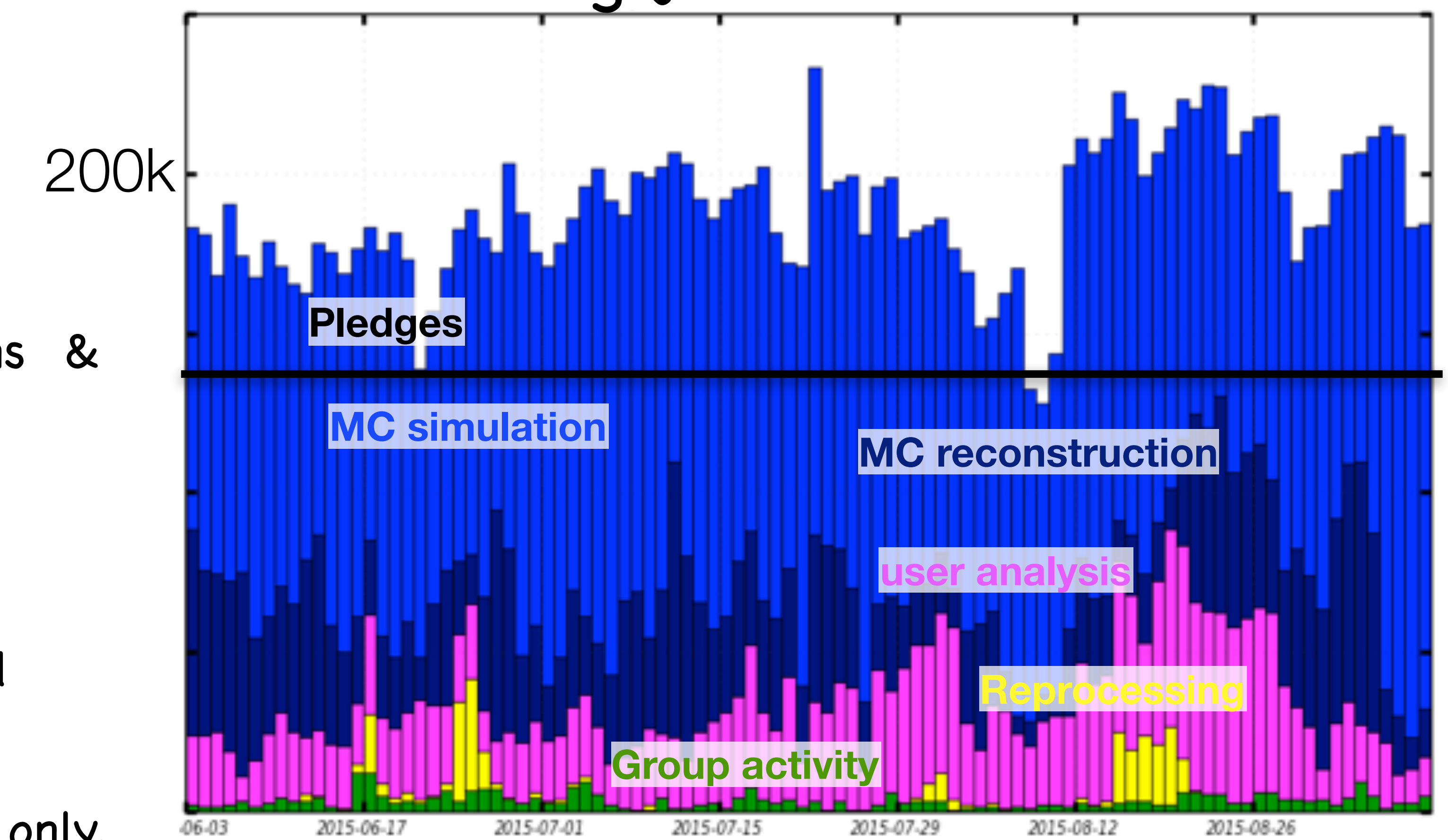




- ALFA - will be used in the special ß*=90m run; elastic and diffractive physics
- LUCID - newly installed, very well performing and providing online and offline luminosity for ATLAS
- ZDC - test beam (SPS) showed need for refurbishment of EM modules; will take part in the next LHC Heavy Ion run (installation during TS3) - centrality measurement
- AFP - Roman Pot installation approved by LMC on August 26th. Aiming to install infrastructures and possibly two stations in the Year End Technical Stop 2015/2016, soft QCD, hard diffraction

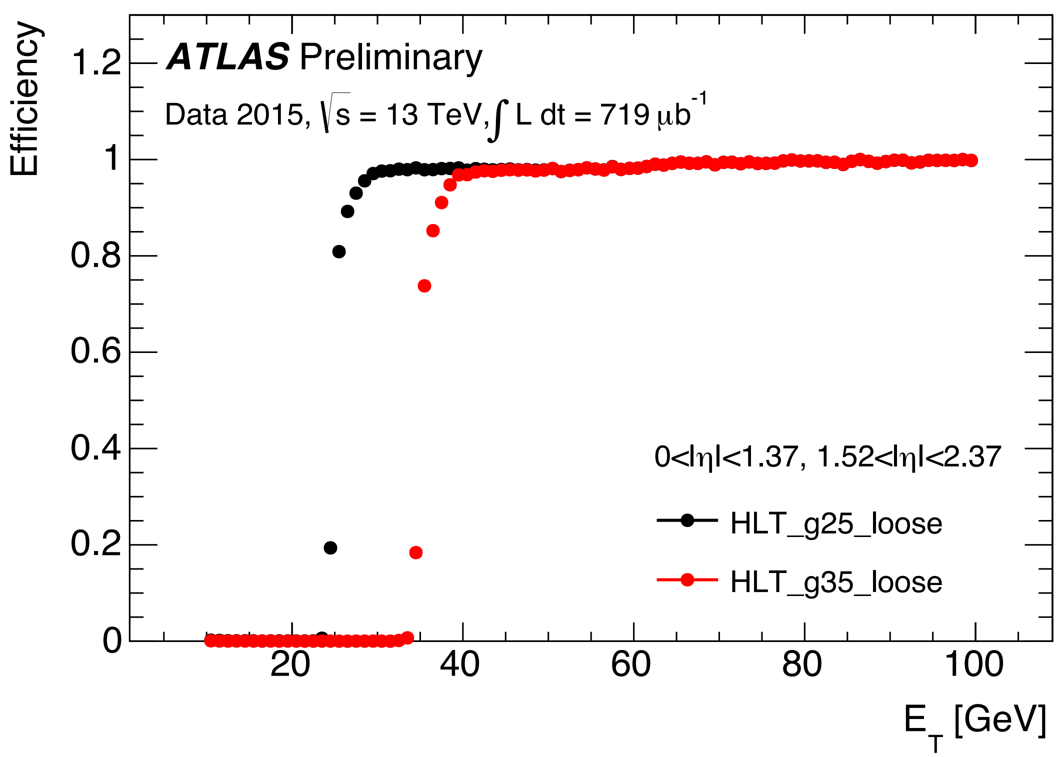
Computing

Running jobs last 3 months

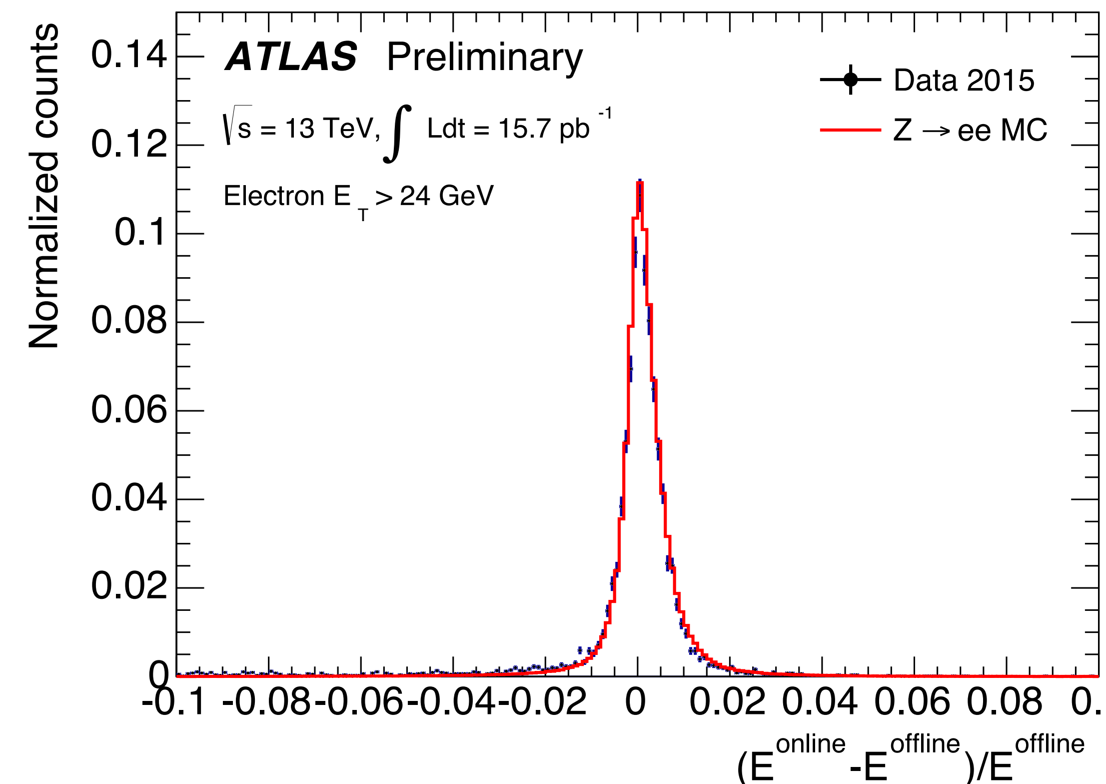


- **Grid utilisation at full**
  - MC simulation:
    - 2.8B simulated events produced
    - 5B events reconstructed for 50 ns & 25 ns conditions
- No issue with data transfer and data processing
- parts of2015 data have been reprocessed twice
- Major software update for summer 2016 only.
- **New analysis model:** group data format DxAOD made using a train model
  - Production of 83 DxAOD species on the grid via 17 trains
  - Within 24h after data reconstruction at Tier-0
  - **Successful and popular**

Trigger Performance

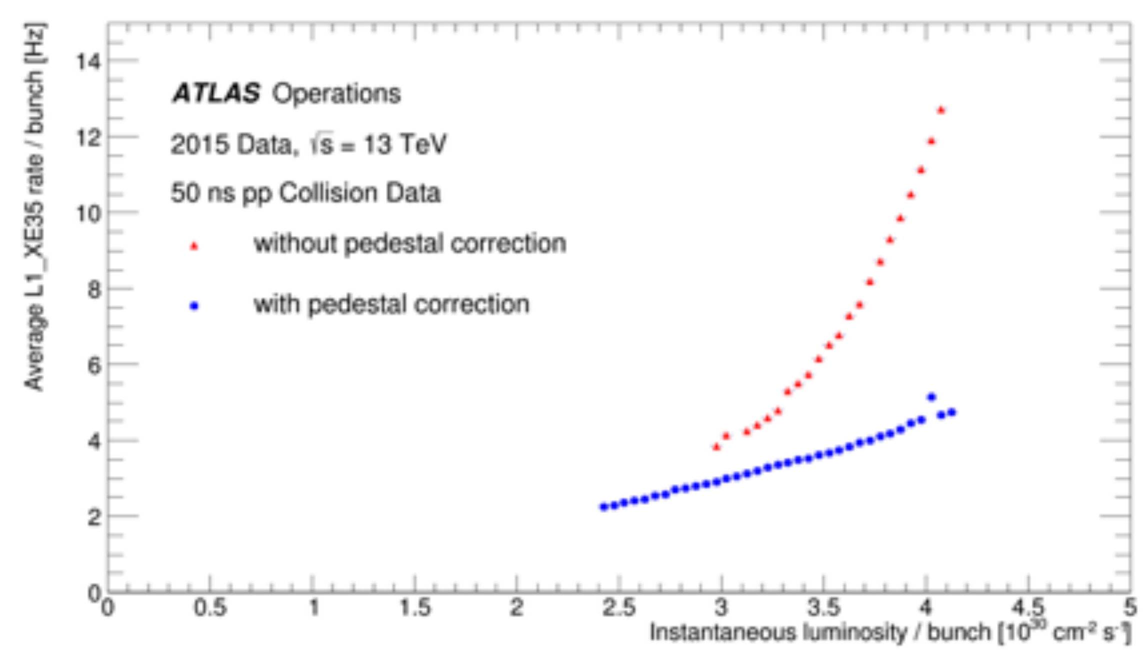


$\varepsilon_{\text{Single-}\gamma\text{-trig}}$ **with E_T > 25/35 GeV measured with L1_EM7**



online-offline resolution for HLT E_T > 24 GeV trigger, medium ID applied

- L1 trigger menu ~500 items, HLT ~2000 items
- pedestal correction minimising pile up effects and linearising trigger rate for the L1Calo MET > 35 GeV trigger shows dramatic improvement for the rate

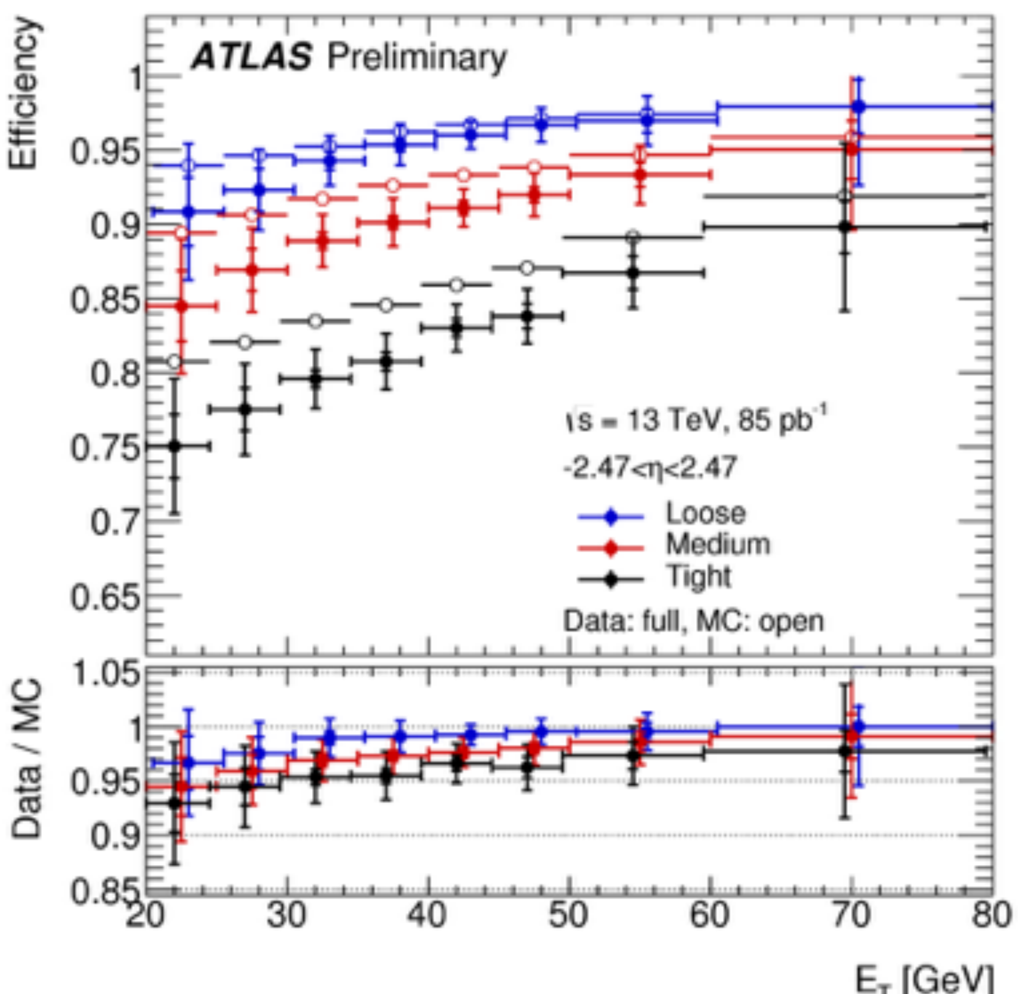


Object performance

- Prepared so-called 'pre-recommendations' for physics object calibrations based on MC and Run-1 data. These pre-recommendations, verified with early 13 TeV data, were used in initial physics analyses presented at EPS-HEP in July.
- Since then, data driven recommendations were determined for electron and muon identification efficiencies and calibrations, as well as jet calibrations (in-situ corrections). The calibrations of the other physics objects are ongoing

Electrons and Photons

ATL-PHYS-PUB-2015-041



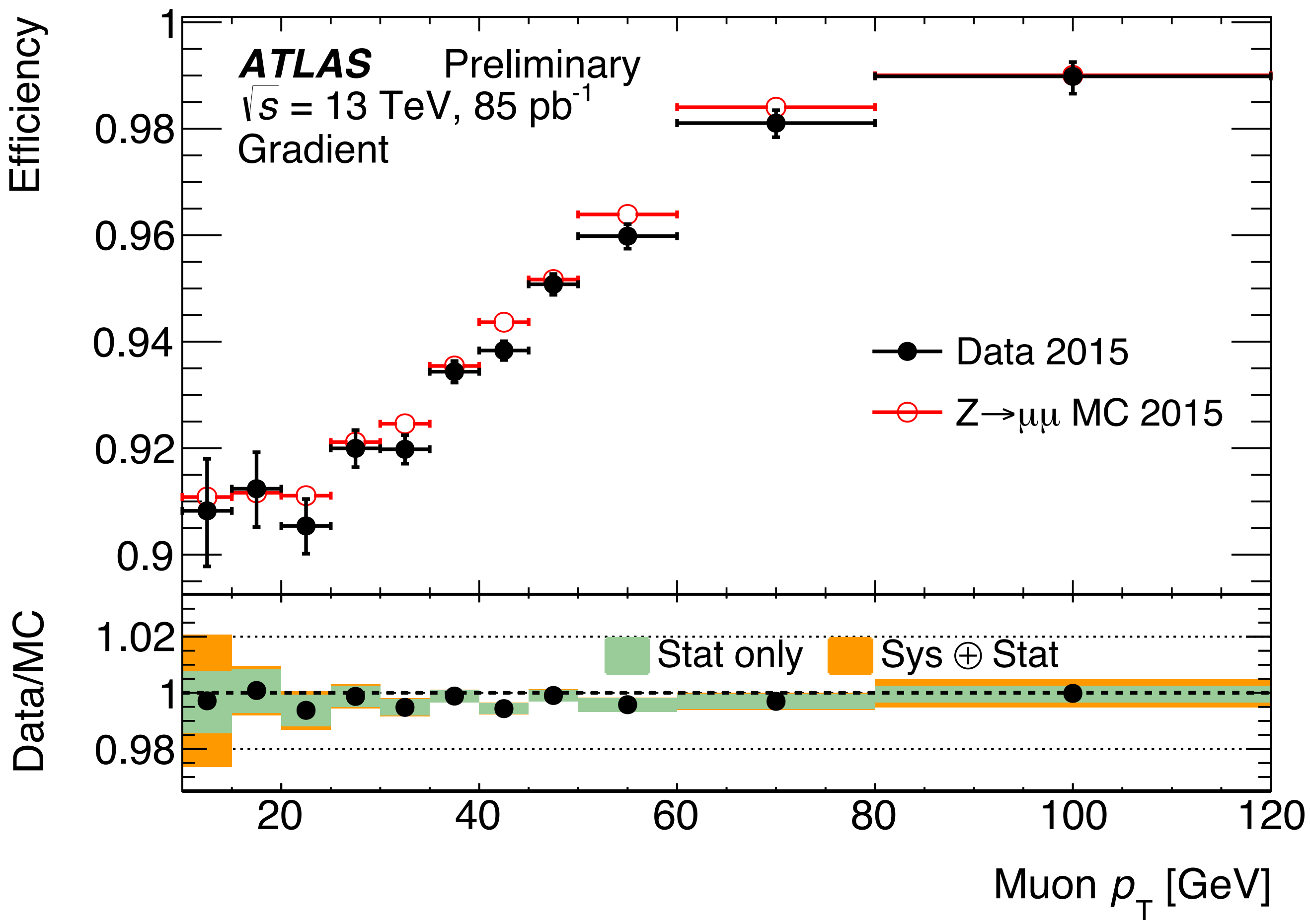
Electron identification (likelihood) efficiency

Data/MC

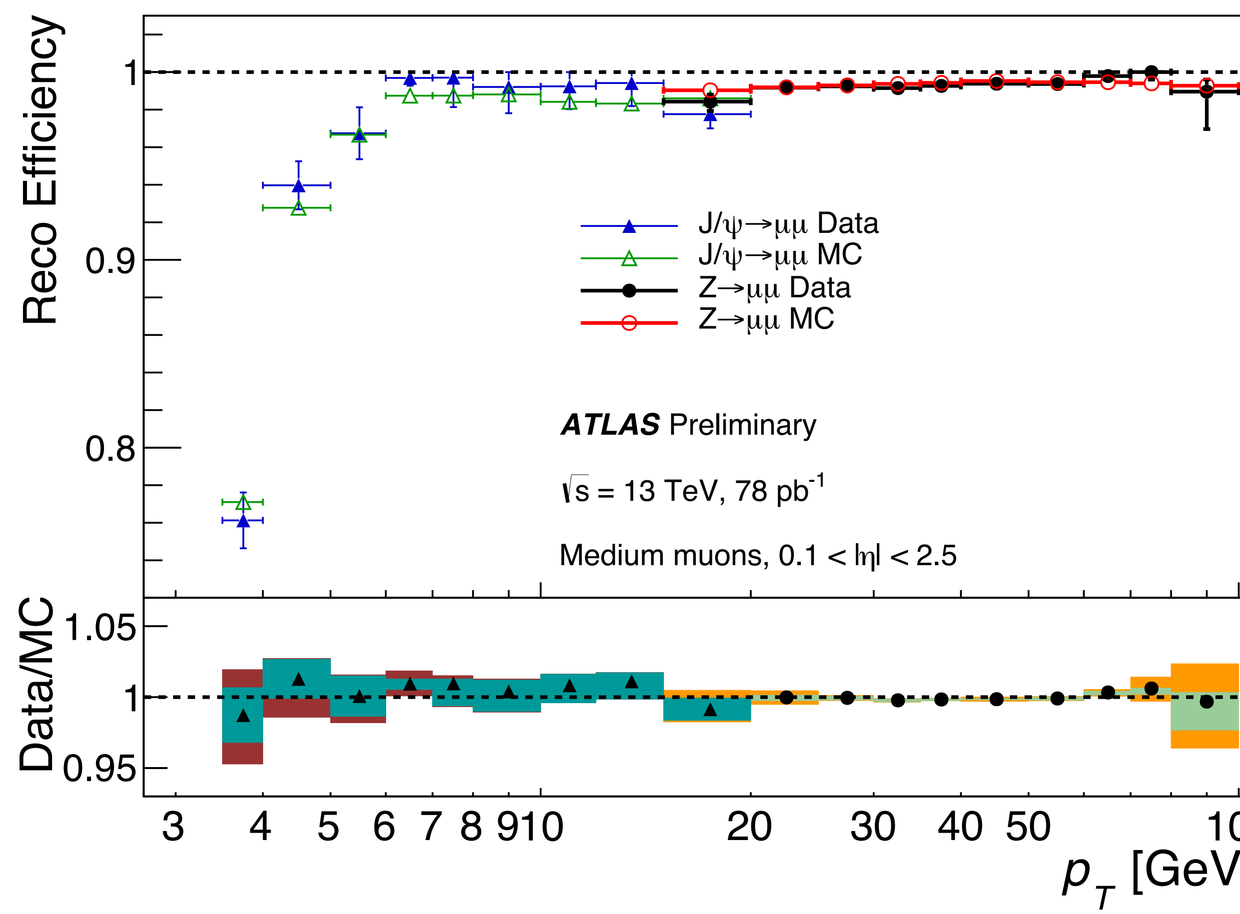
- Data/MC disagreement in Electron ID is due to (known) GEANT mis-modelling of shower shapes
- quite flat as a function of in-time pile up
- scale factors from data applied to MC

Muon reconstruction

- based on 50 ns data (85 pb^{-1})   ATL-PHYS-PUB-2015-037
- improved acceptance ($1.0 < |\eta| < 1.4$) and reconstruction algorithm



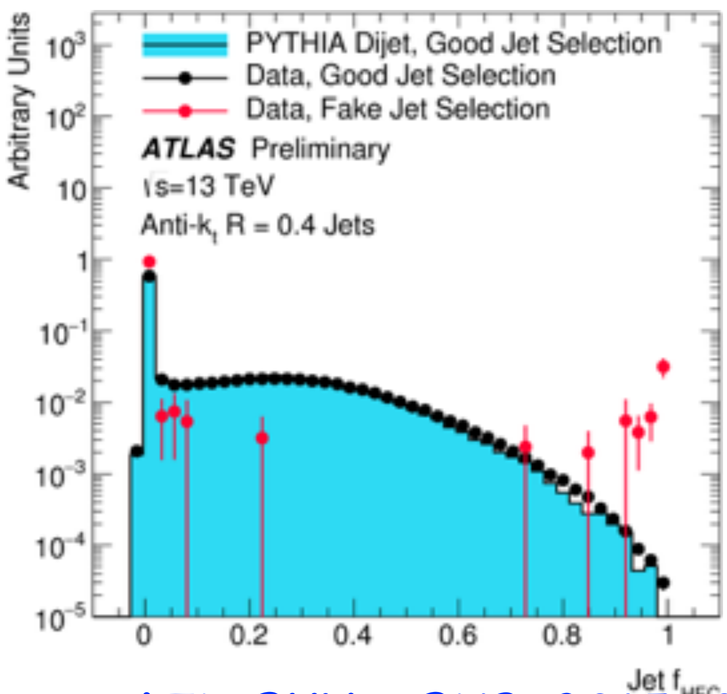
Efficiencies of the combined track-based and calorimeter-based **isolation** for the Gradient working point



excellent **data/MC agreement** for reconstruction efficiency, but large δ_{stat}

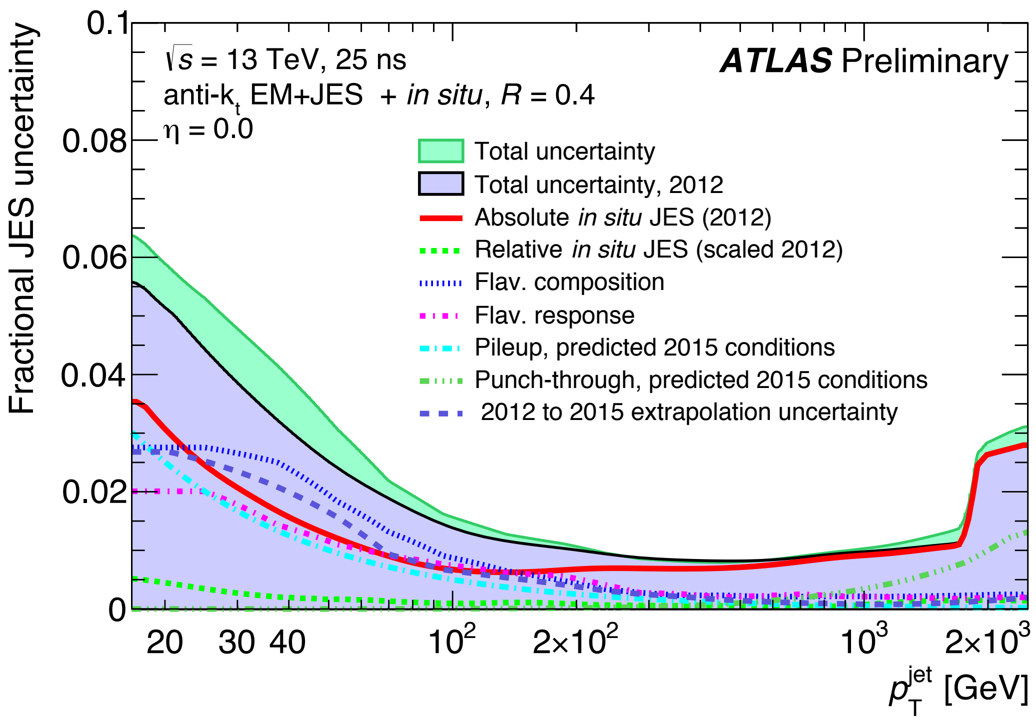
Jets

ATLAS-CONF-2015-029



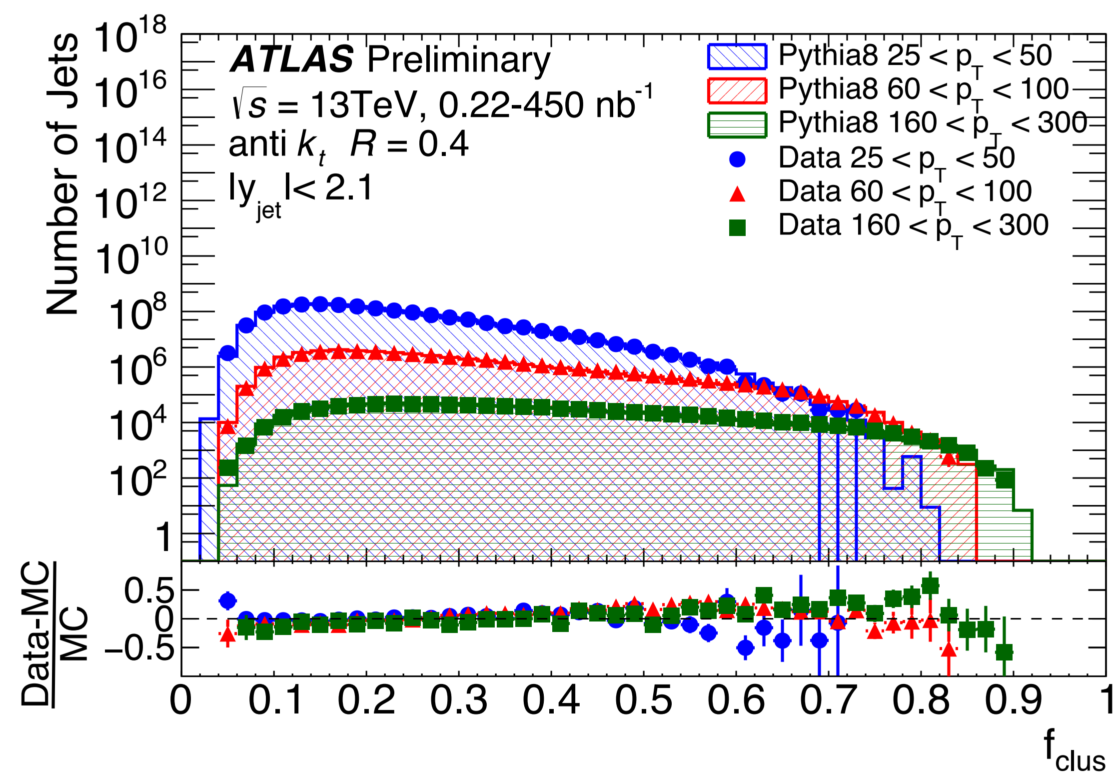
- jet cleaning defined - selection of good jets based on calorimeter criteria (beam background, noise, cosmics)
- JES and JER preliminary recommendations (based on simulations) delivered for early analyses, AntiKt4TopoEM, validated on data
- good shape agreement in data/MC -> validated inputs to more sophisticated methods (GSC, substructure…)

ATL-PHYS-PUB-2015-015



25ns JES uncertainties

ATL-PHYS-PUB-2015-036

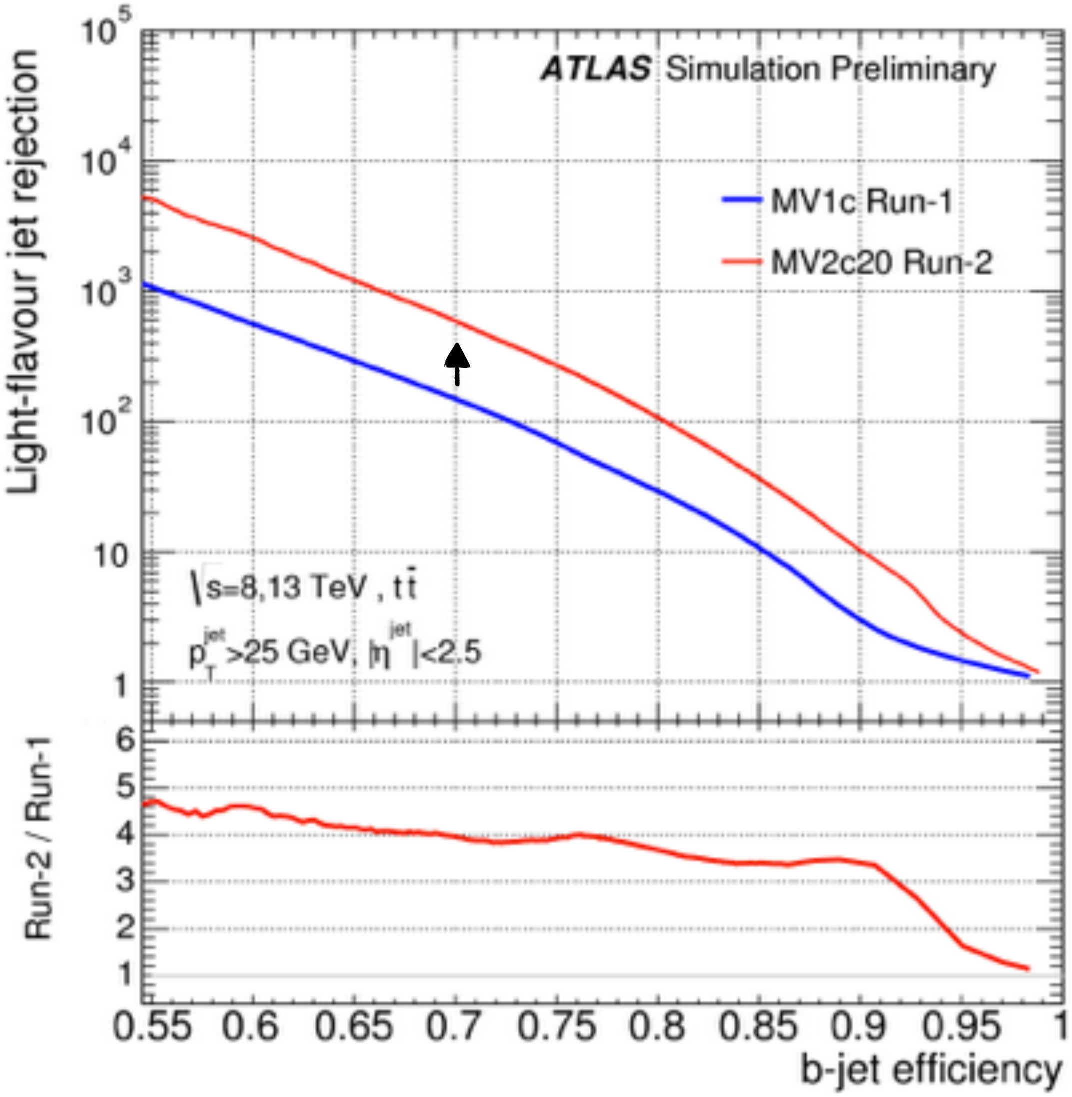


leading cluster energy fraction

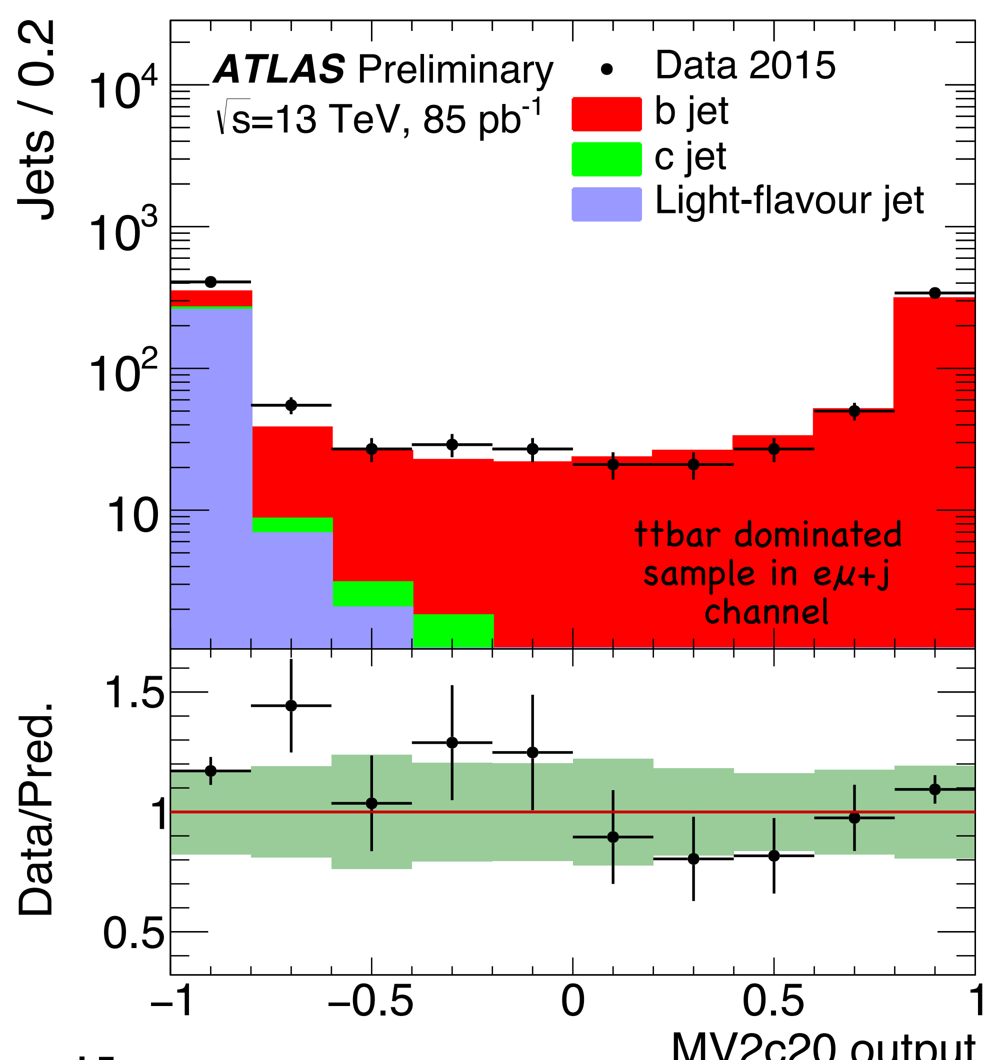
Flavour Tagging

- Several enhancements between Run-1 and 2 will impact flavour tagging
  - Improved tracking (including IBL) and flavour tagging algorithms
- Significant improvement predicted in both light-flavour (factor ~4!) and c-jet rejection (~1.6)

ATL-PHYS-PUB-2015-022



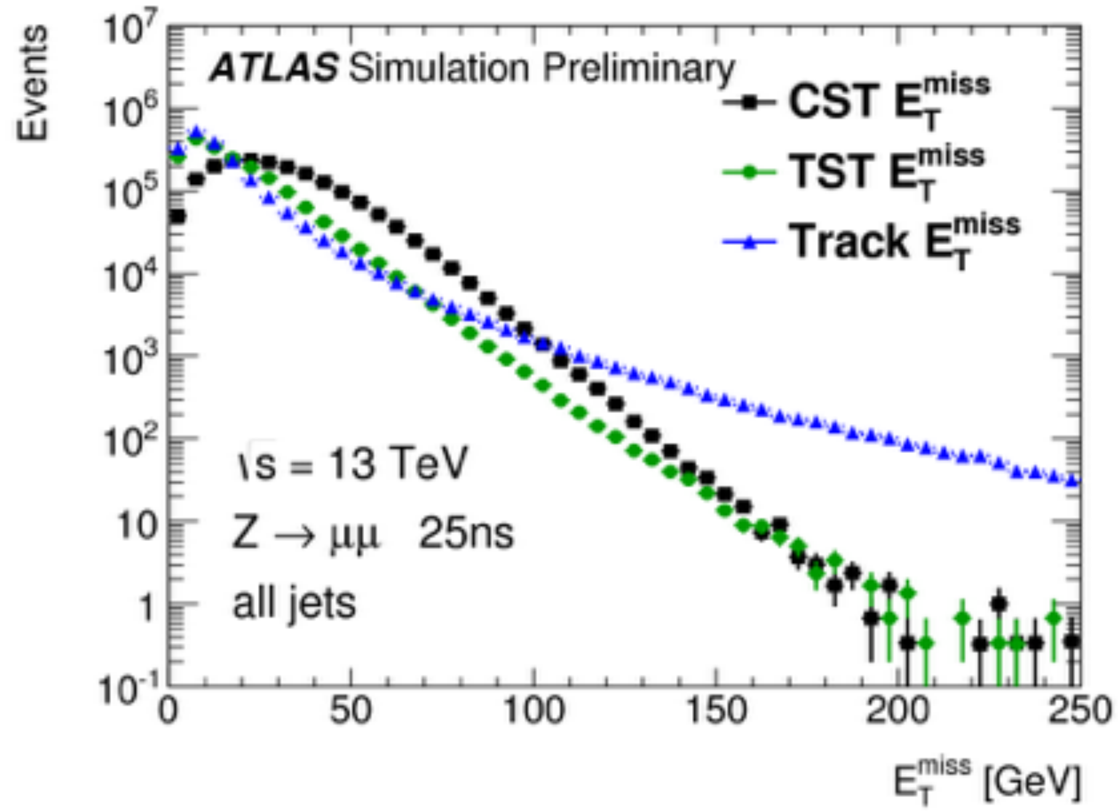
ATL-PHYS-PUB-2015-039



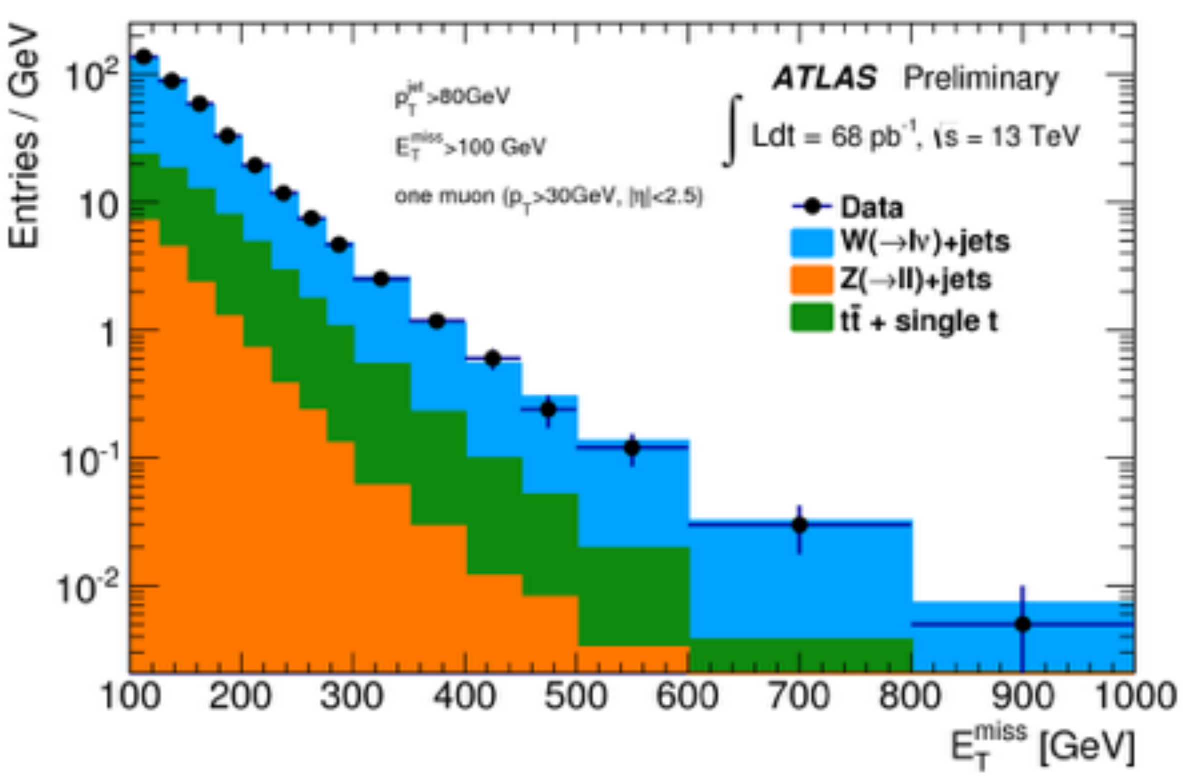
- Flavour tagging MVA output shows good data-MC agreement
- Full data-based calibration underway

Missing E_T

ATL-PHYS-PUB-2015-023

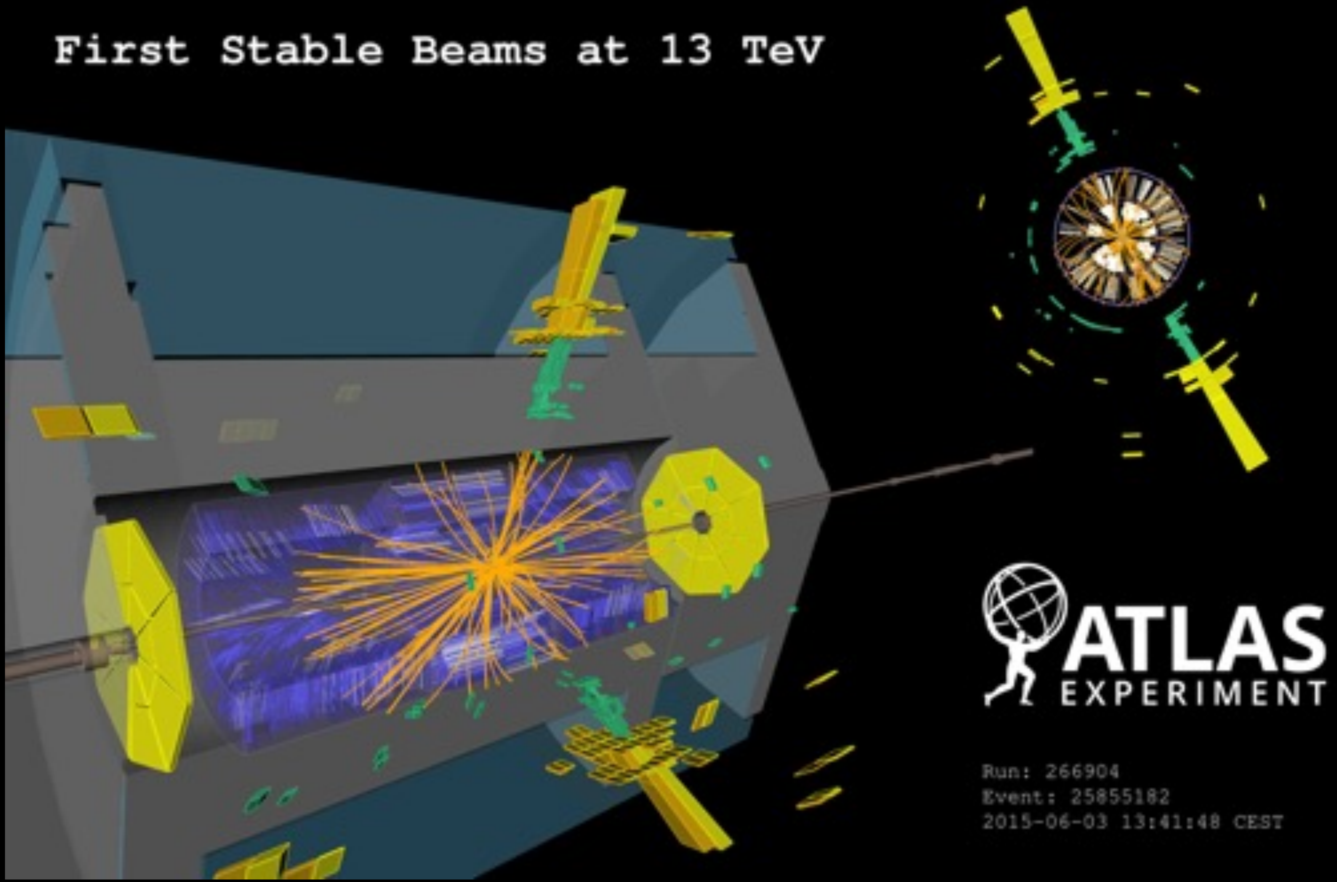


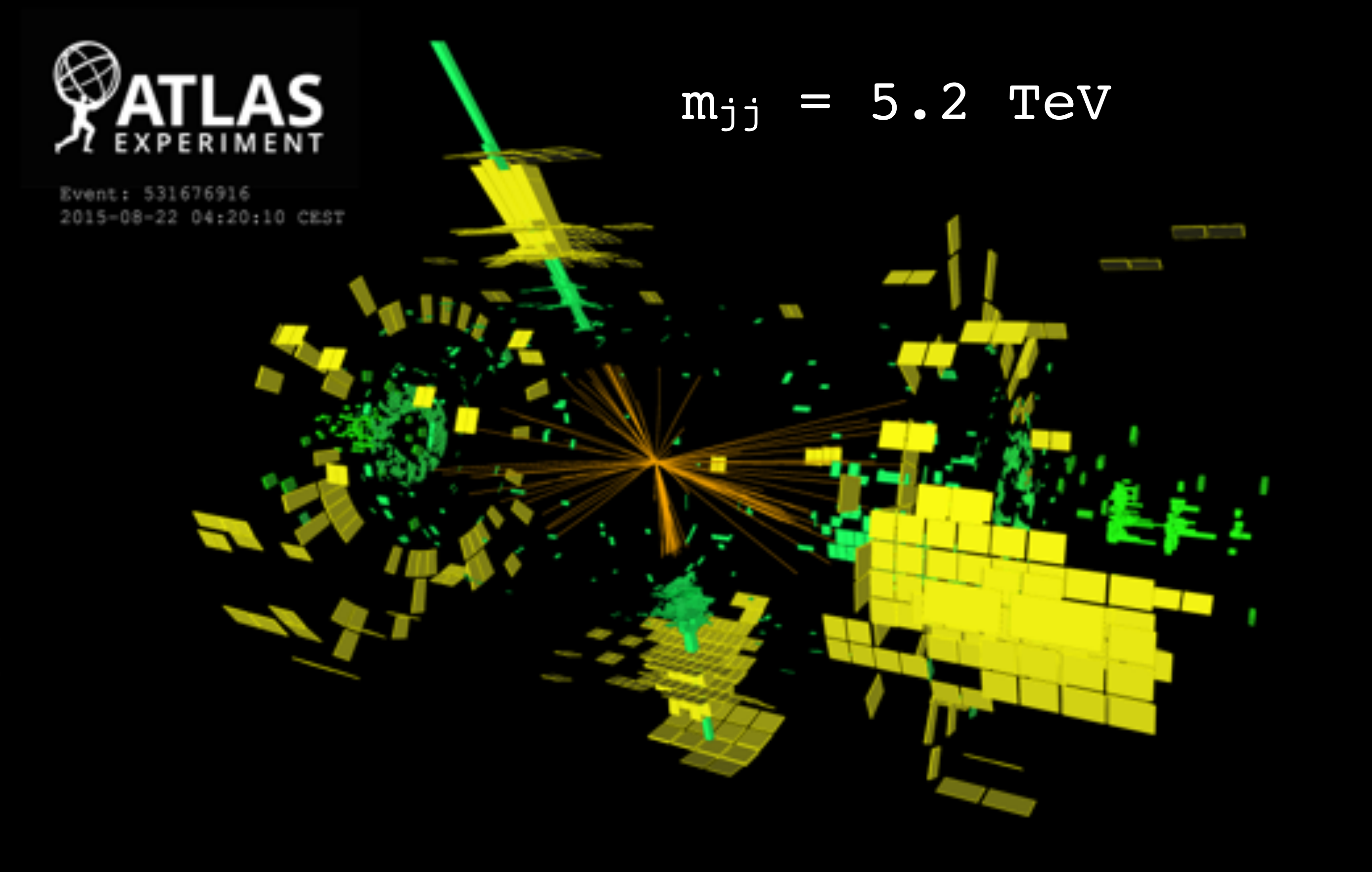
performance plot from mono-jet search

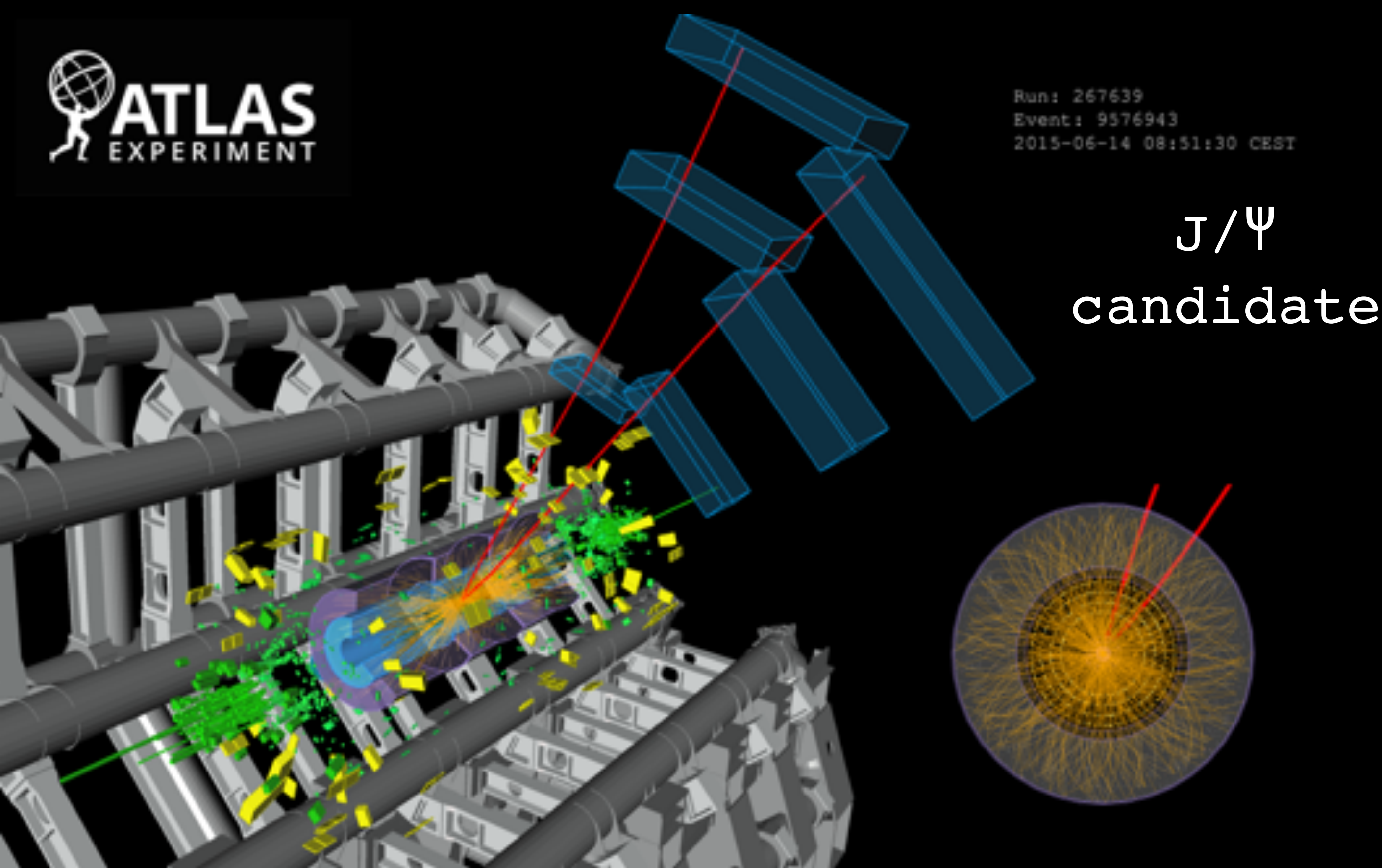


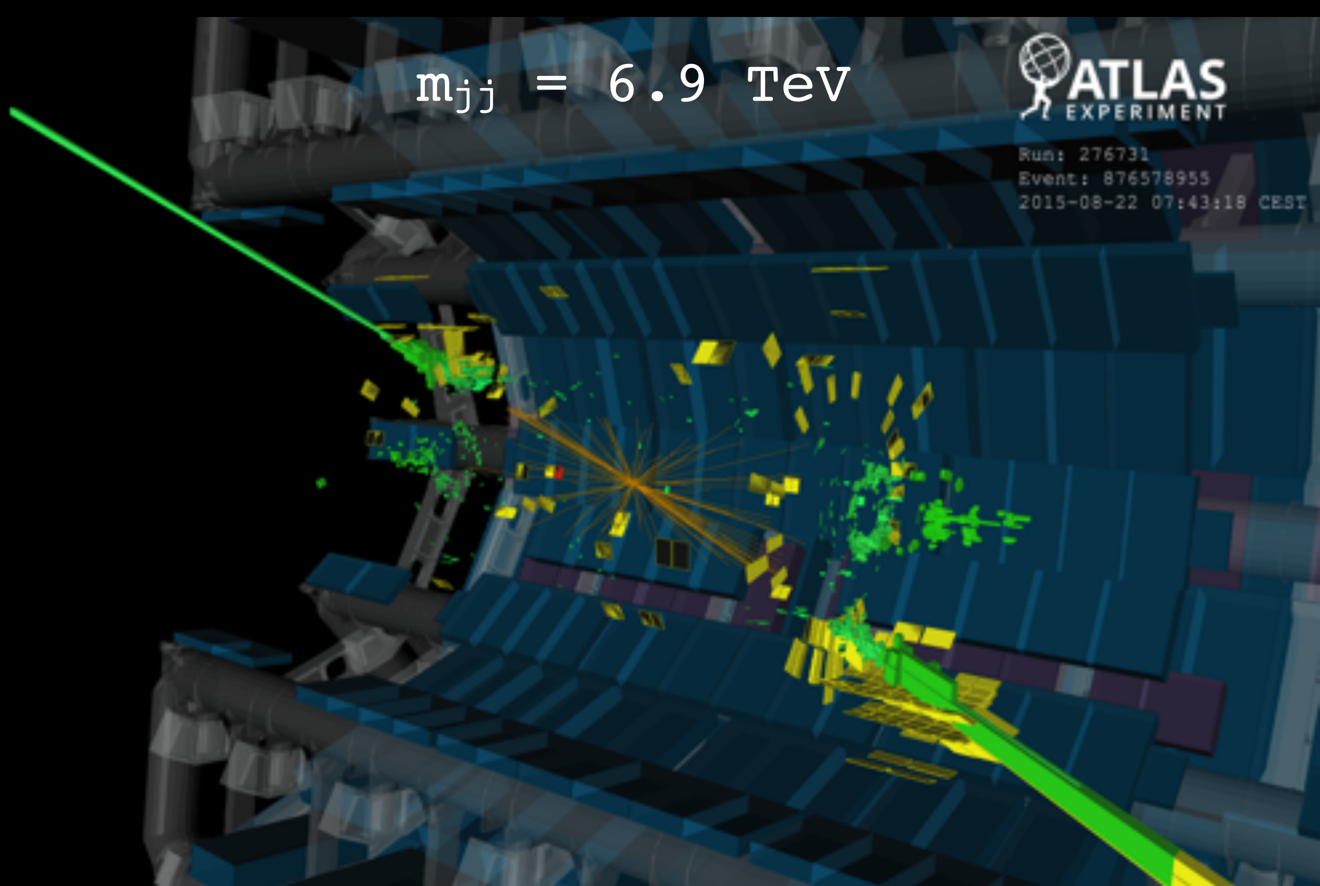
- new techniques developed during LS1, use tracking information
  - TST (track soft term), Track MET
  - reduces pile up sensitivity
- systematics derived from MC, will be updated soon
- validated against data in ATL-PHYS-PUB-2015-027

Physics – Measurements and Searches





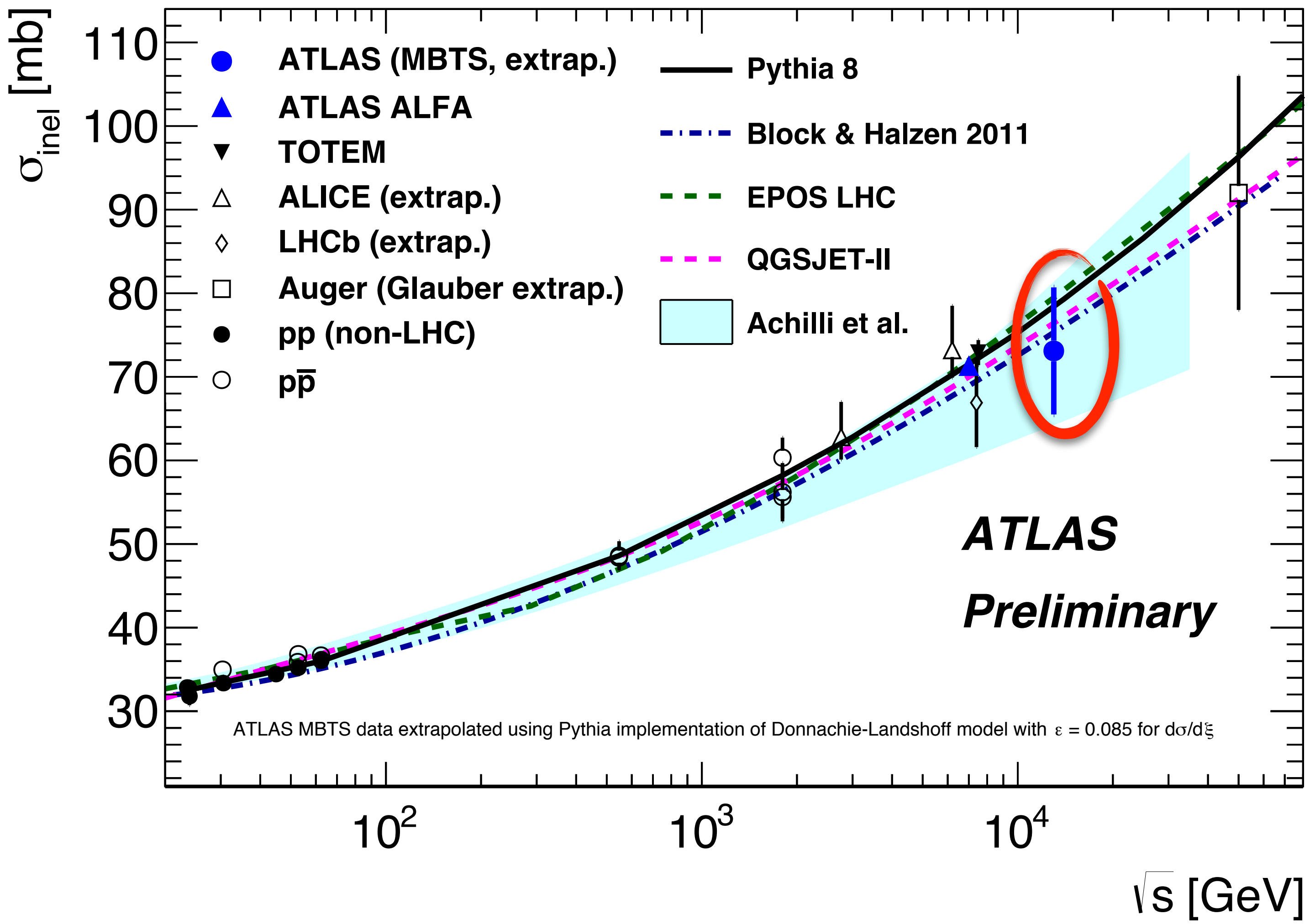




Inelastic pp Cross Section

ATLAS-CONF-2015-038

- MBTS triggers (counting experiment, highly efficient) runs taken in June
  - fiducial volume: 2.08<|η|<3.86 <-> Mx > 13 GeV -> extrapolation
  - $\sigma_{inel} = \sigma_{SingleDiff} + \sigma_{DoubleDiss} + \sigma_{CentralDiff} + \sigma_{NonDiff}$



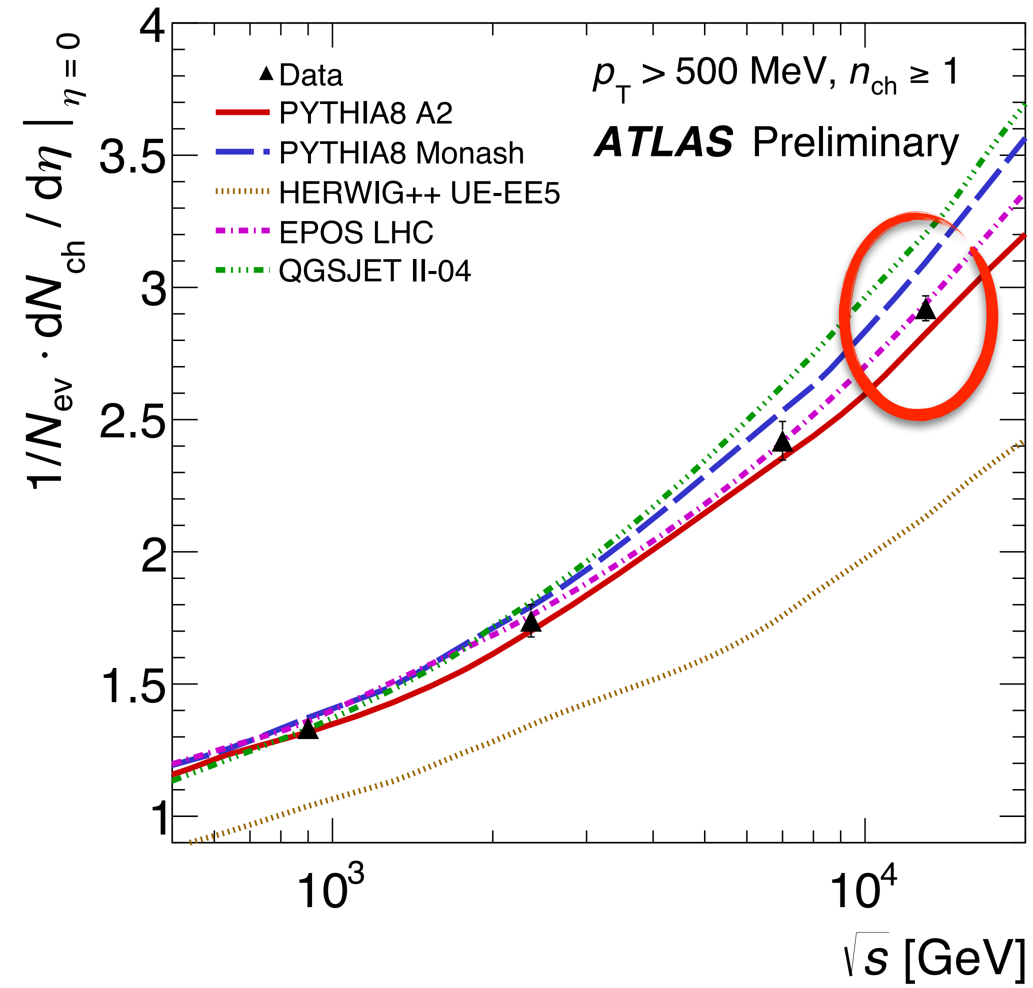
constraints on diffractive dissociative component through single sided event vs inclusive selection (25-30% depending on model)

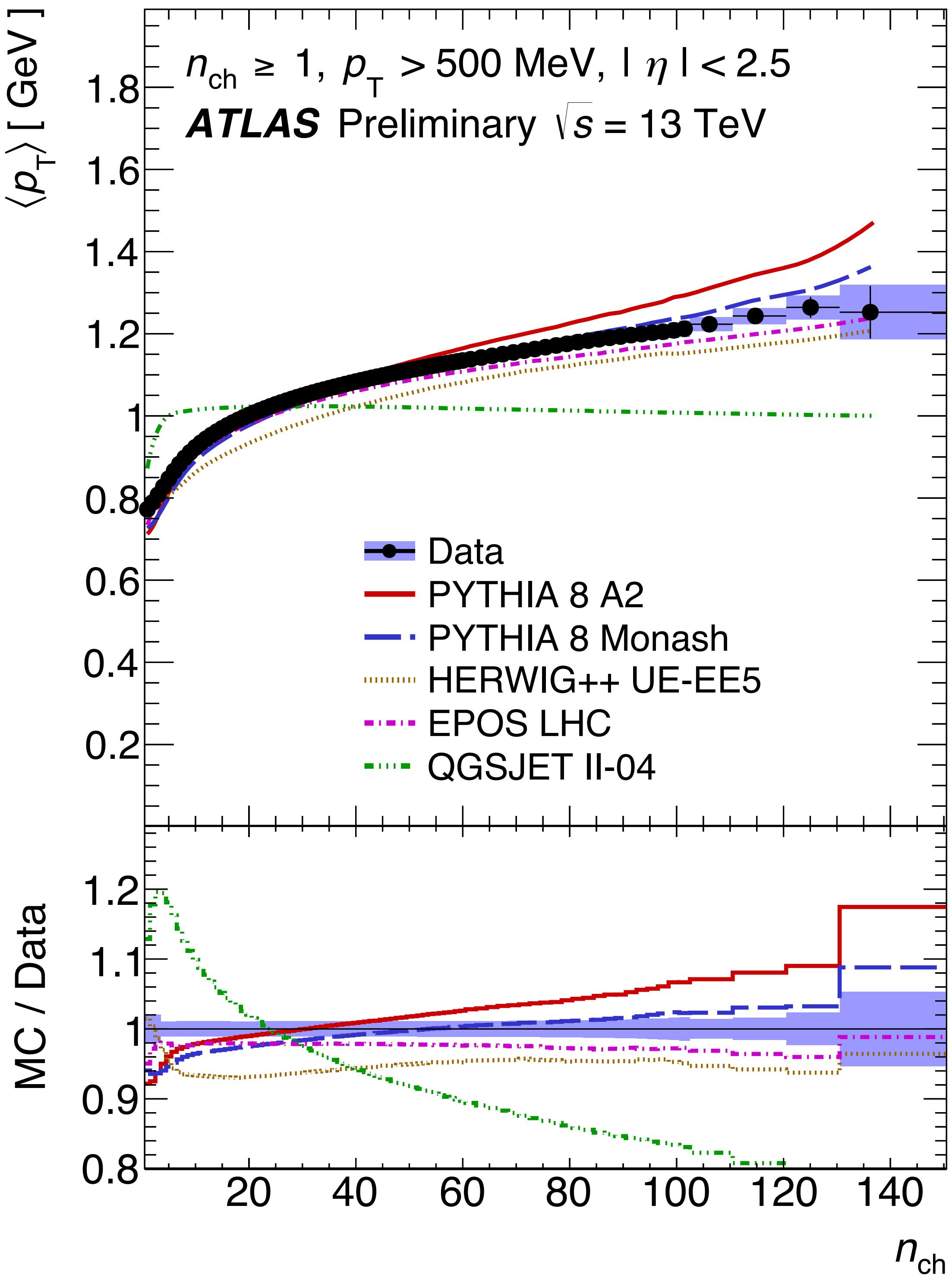
σ_{fid} = **65.2** ±0.8 (exp.)±5.9 (lum.) mb

σ_{tot} = **73.1**±0.9(exp.) ±6.6(lum.)±3.8(extr.) mb

Charged Particle spectra and UE

ATLAS-CONF-2015-028





- measurement of unfolded spectra of charge particle multiplicity, also differentially in η and pT
  - comparison to model prediction
- allowed to validate the tune (Pythia A2) used for the pileup modelling in the 13 TeV MC that was derived from Run-1 data
- 'leading track underlying event' analysis (ATL-PHYS-PUB-2015-019) has allowed to validate the underlying event tune (Pythia A14) used in the simulation of hard scattering processes, also derived from Run-1 data

The Ridge

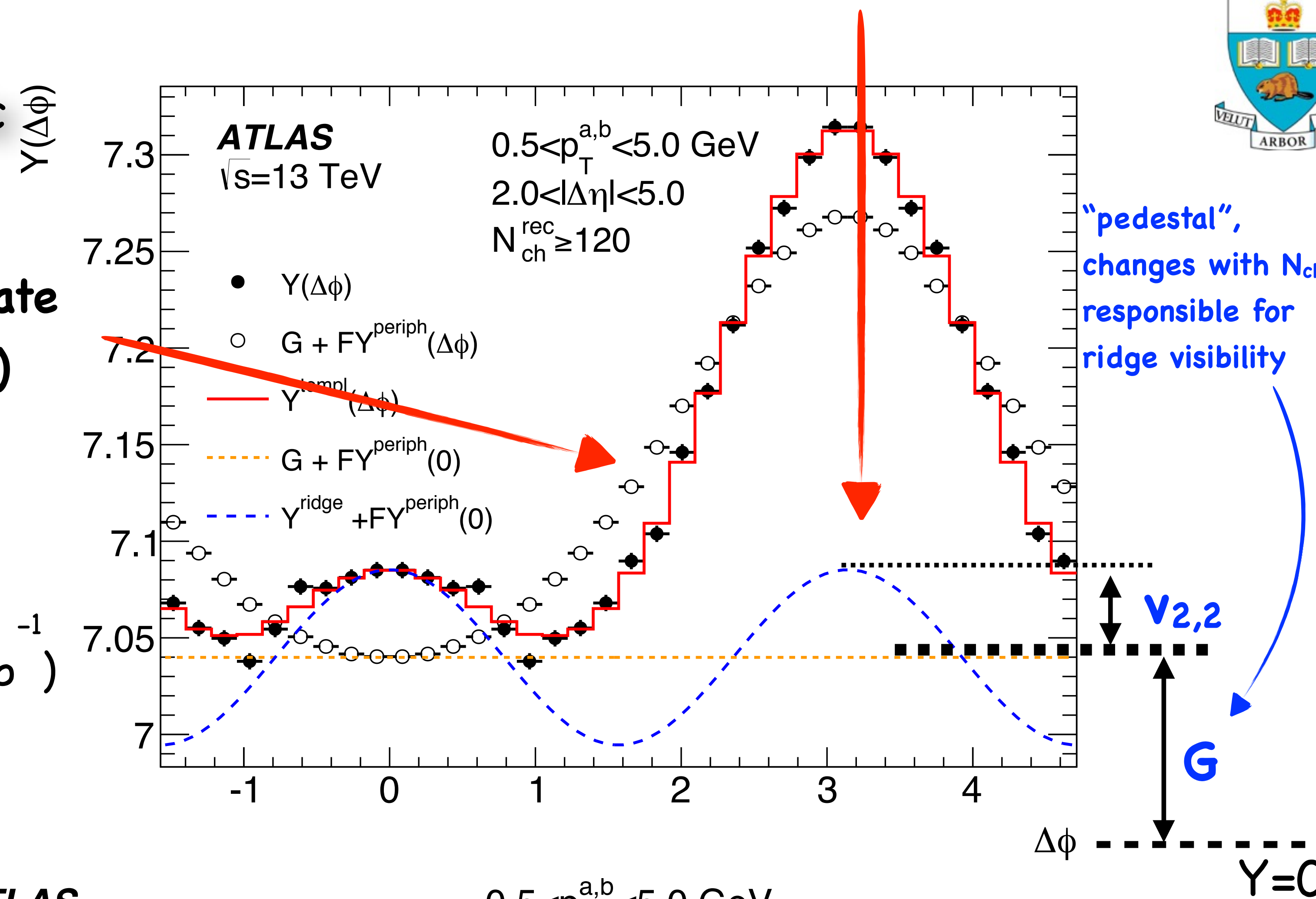
Observation of long-range elliptic anisotropies in pp collisions

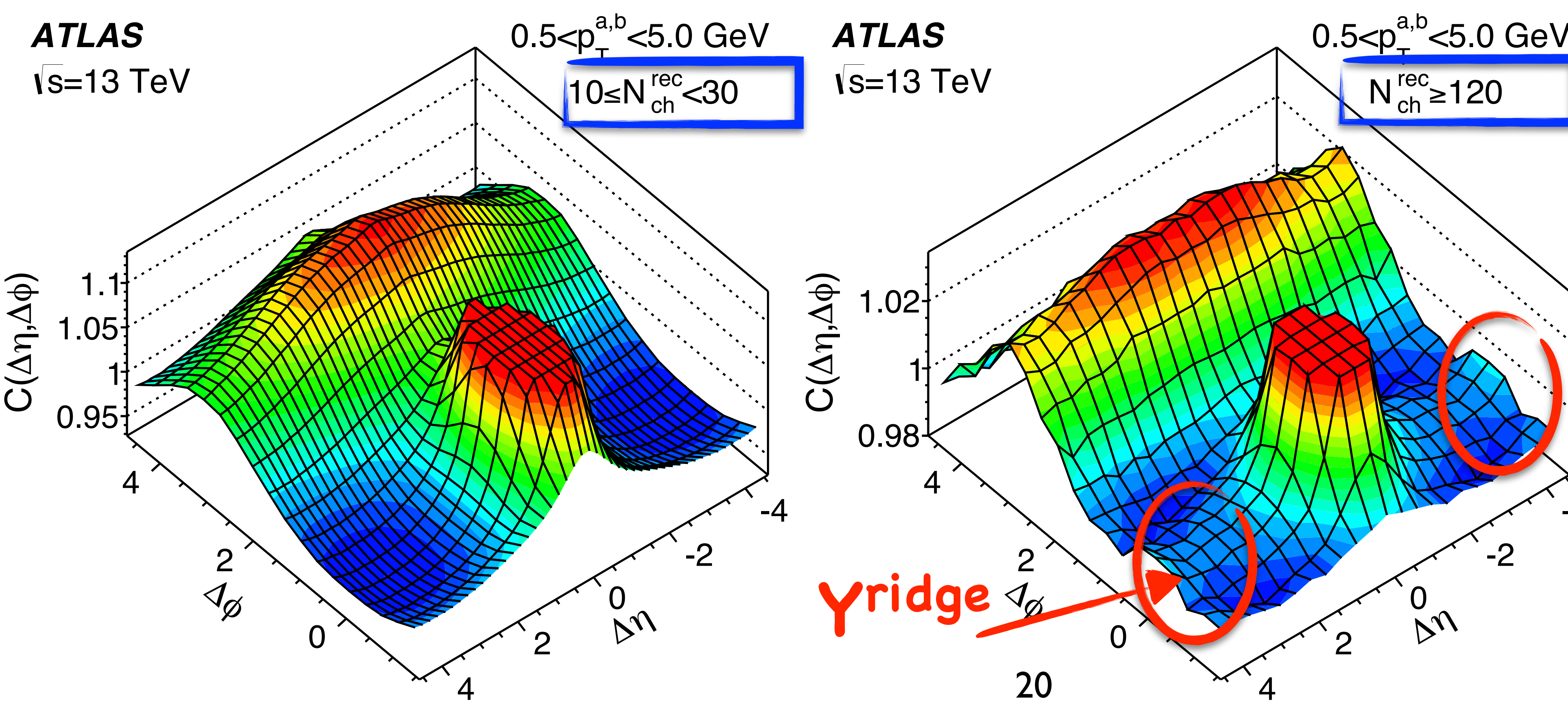
[arXiv:1509.04776](https://arxiv.org/abs/1509.04776)

- first ATLAS Run2 paper!
- long range correlations at high $\Delta\eta$ and $\Delta\Phi=0$ measured at two $\sqrt{s}$ points - 2.76 TeV (Run1 - 4pb^{-1}) and 13 TeV (Run2 - 14nb^{-1})
- at large N_{ch}, quantifiable through Y^{ridge}

fit ridge modulation $G(1+v_{2,2}\cos(2\Delta\Phi))$

low N_{ch} template (~$\sin(\Delta\Phi)$)





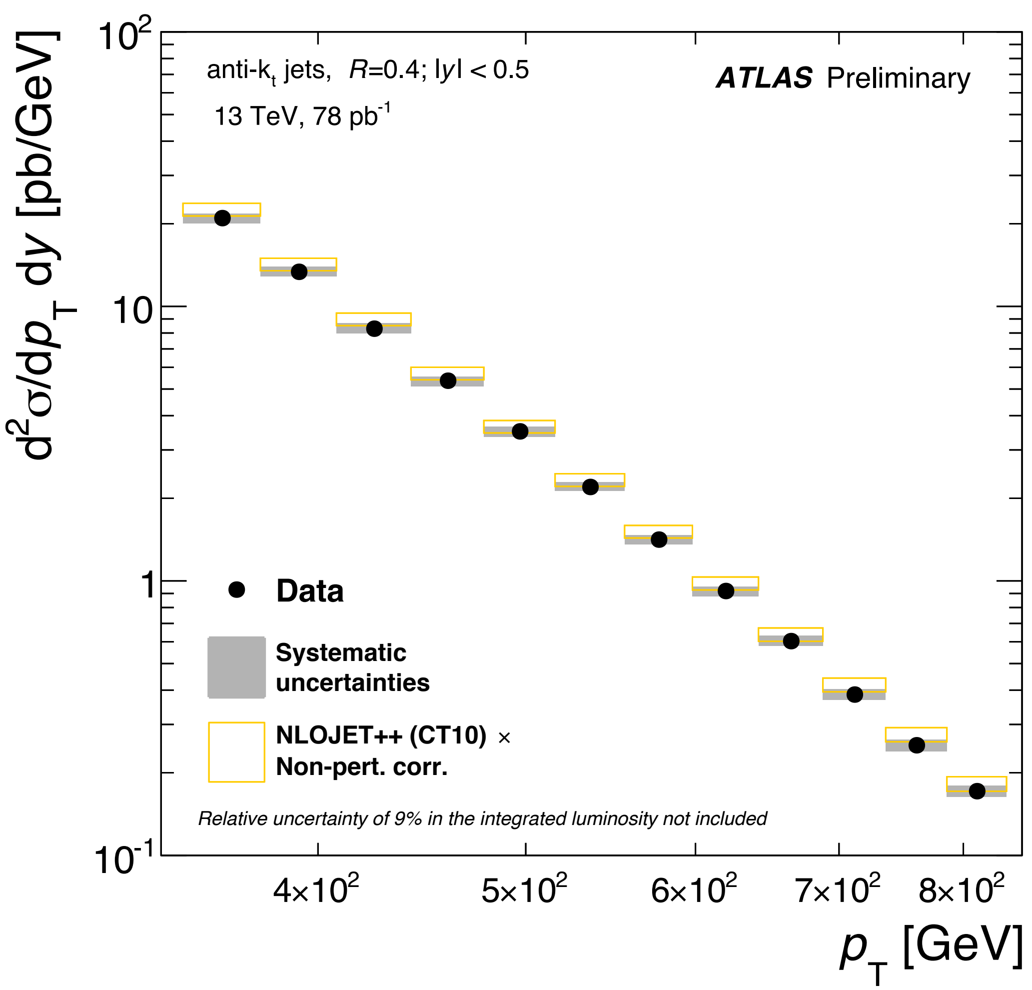
- ridge modulation factorises (shows global modulation of per-event single particle distributions)

- ~independent of $\sqrt{s}$ and N_{ch}, only of p_T

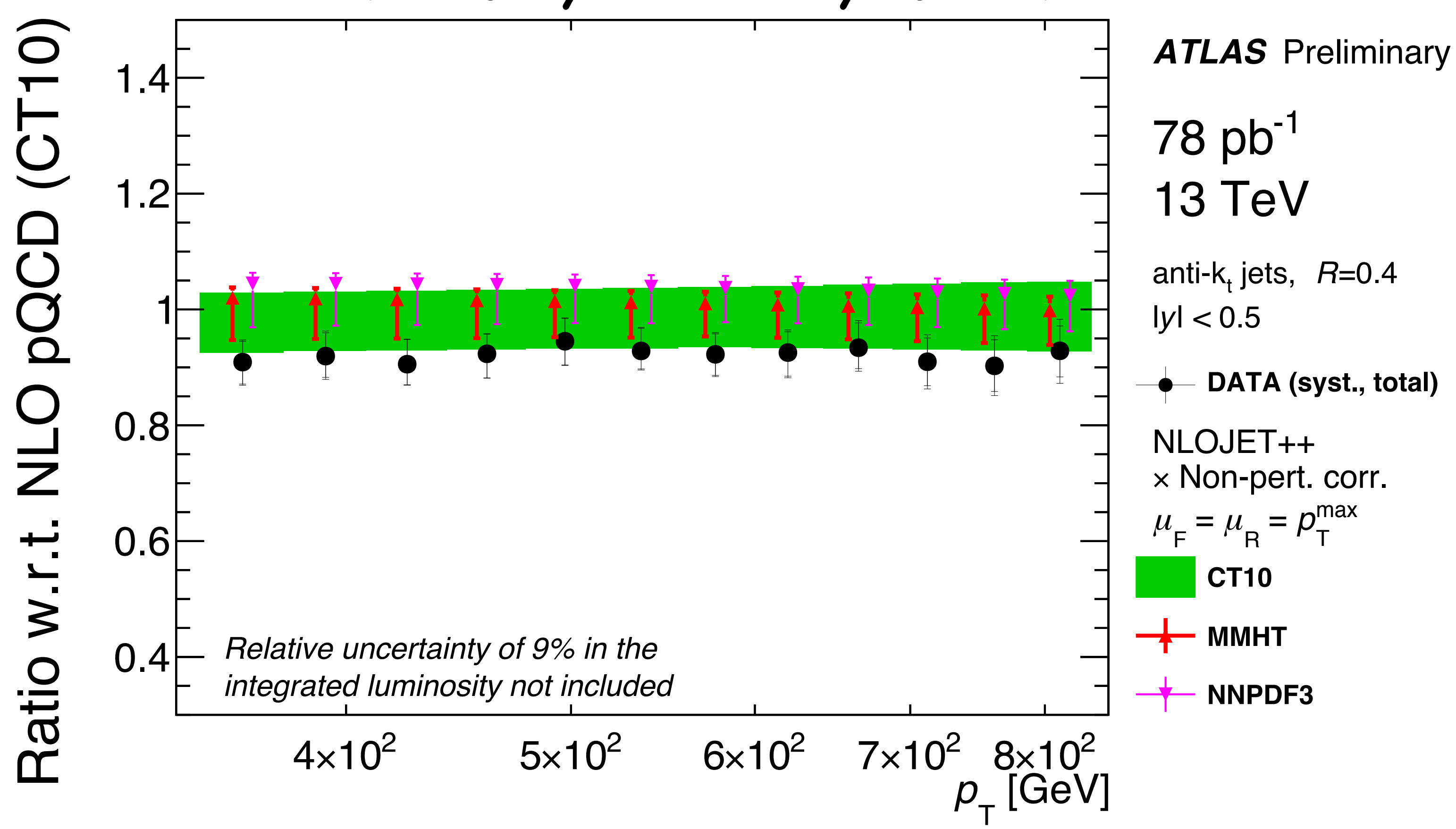
Inclusive jet measurement

ATLAS-CONF-2015-034

- lowest p_T unprescaled trigger (346 < p_T < 838 GeV) in central region |y| < 0.5
- cross section compared to fixed order NLO (NLOJET++) with several PDFs - CT10, NNPDF3, MMHT



luminosity uncertainty not included

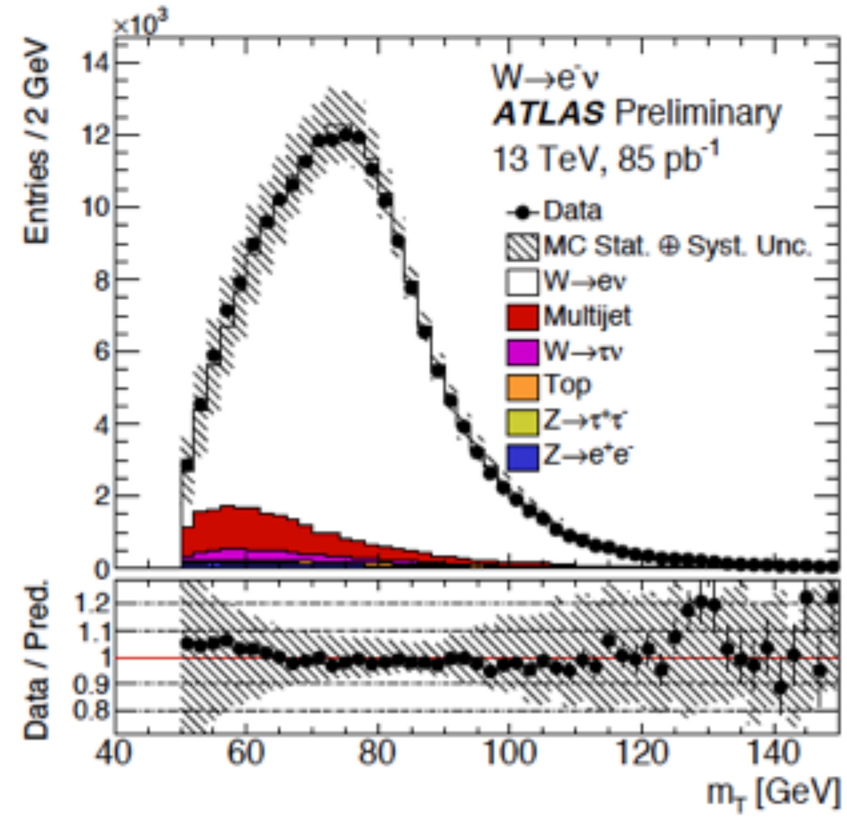


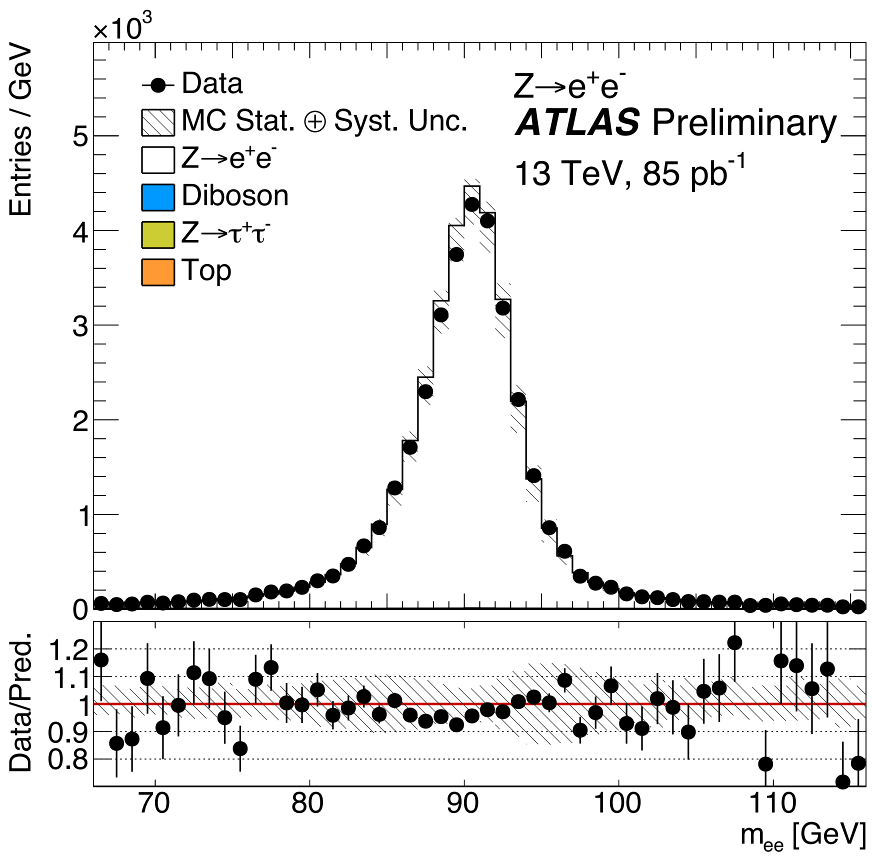
good agreement with pQCD calculation

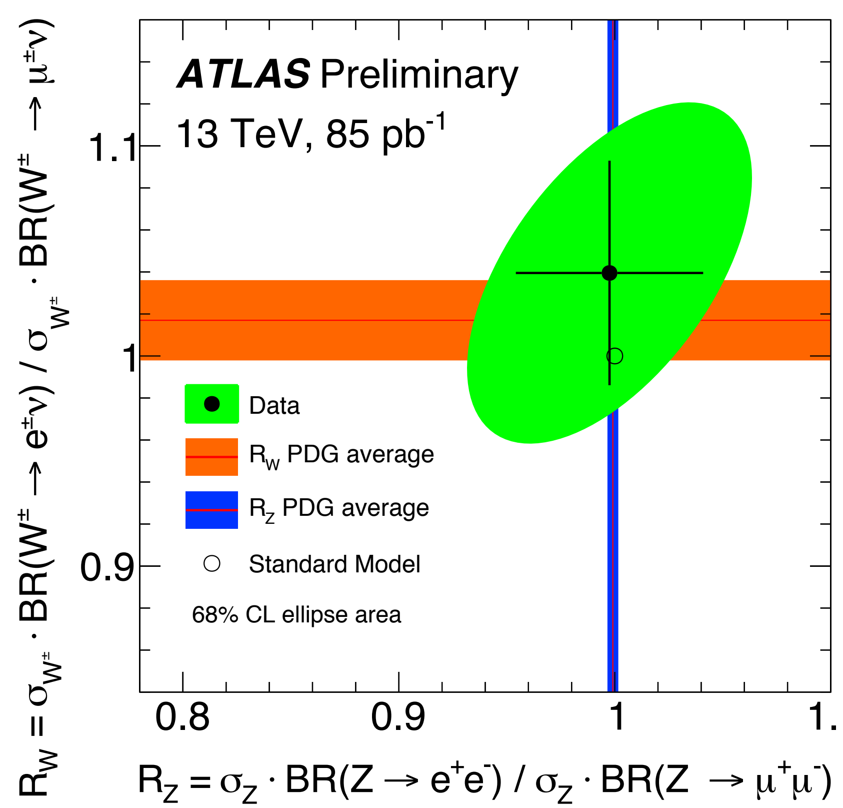
W/Z Boson Cross Sections

ATLAS-CONF-2015-039

- 50 ns run, L = 85pb^{-1}
- single lepton triggers with p_T > 24 (20) GeV for e (μ) -> final selection p_T^{lep} > 25 GeV
- W: MET > 25 GeV, m_T > 50 GeV ~1 M evts
- Z: 66 < mll < 116 GeV ~80K evts

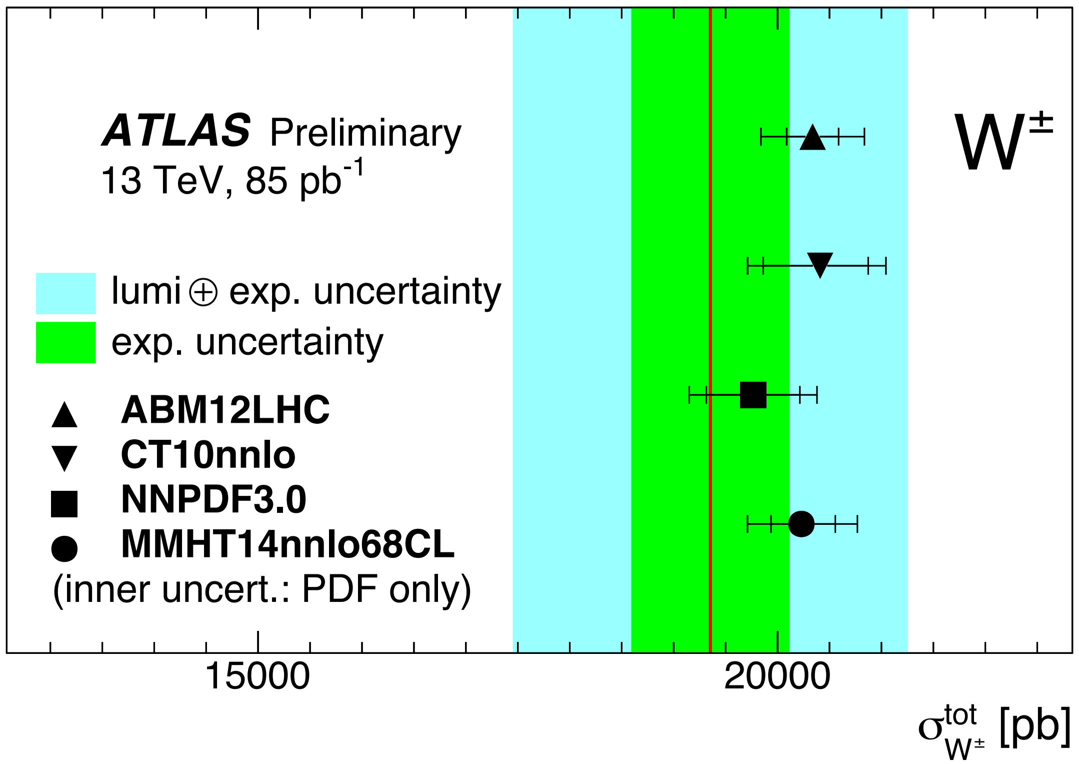


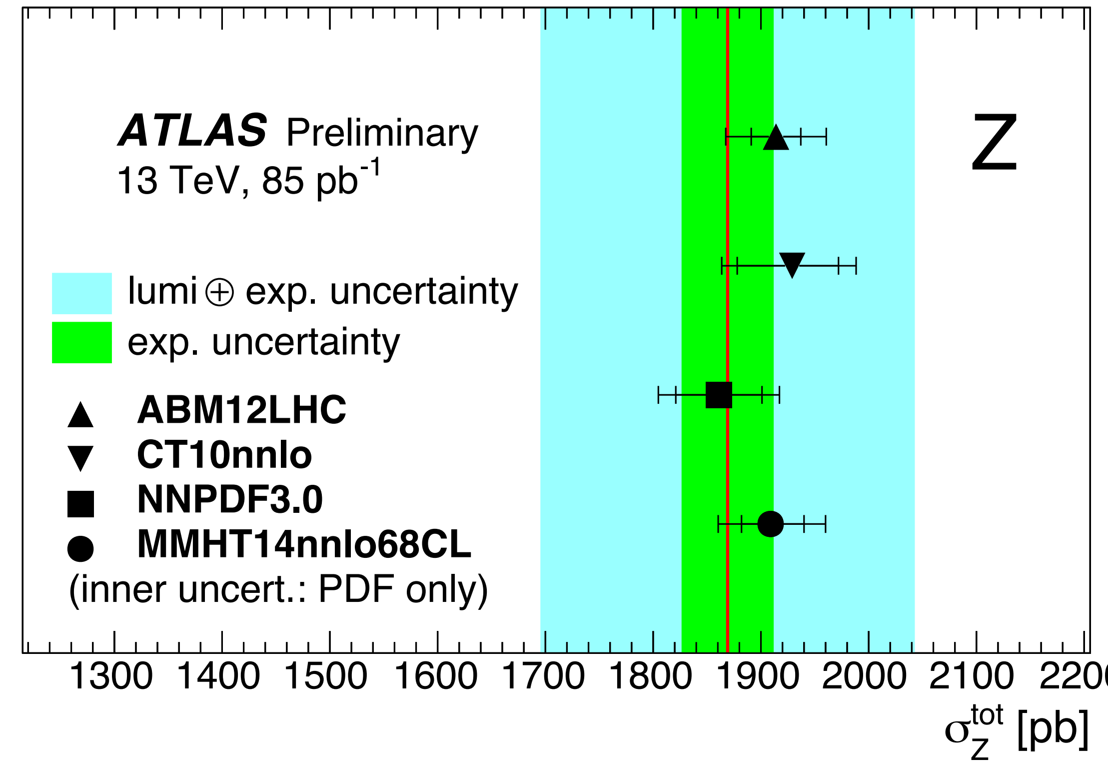




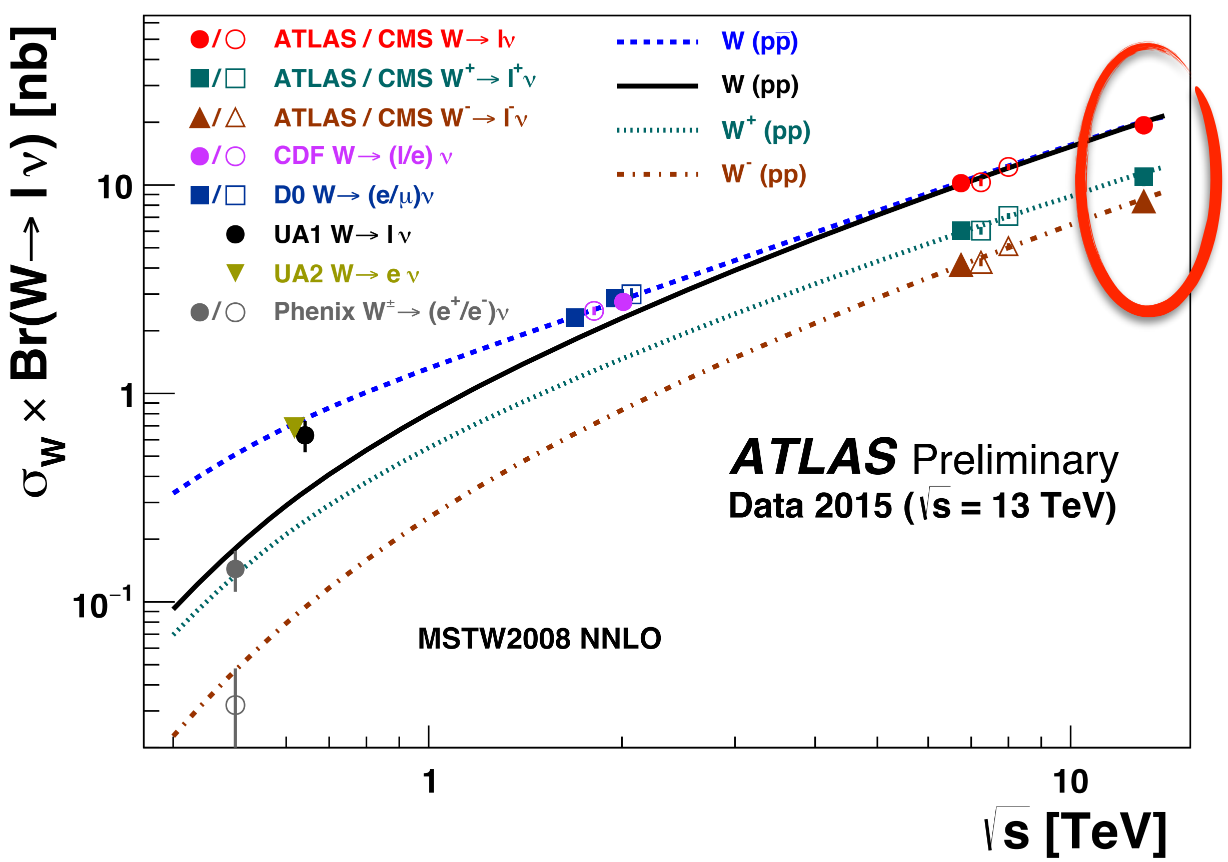
- dominant systematics:
  - luminosity
  - lepton efficiences
  - backgrounds
  - JES

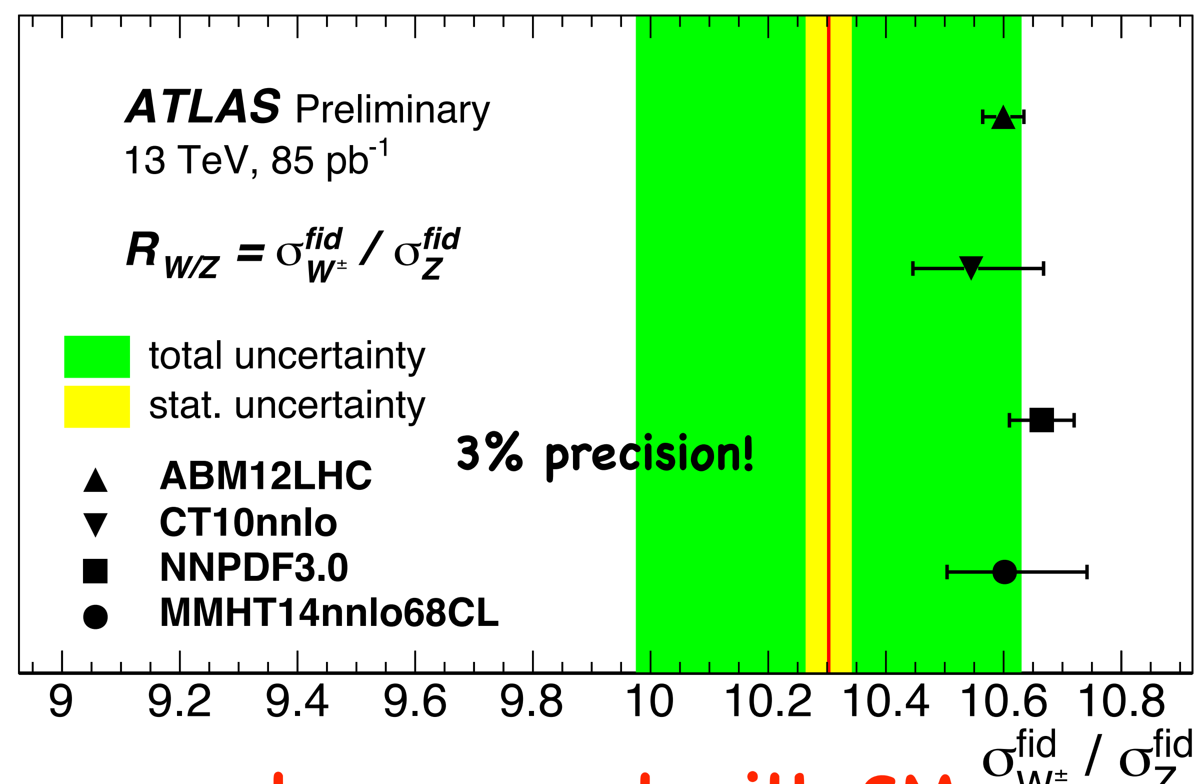
W/Z Boson Cross Sections





ATLAS-CONF-2015-039





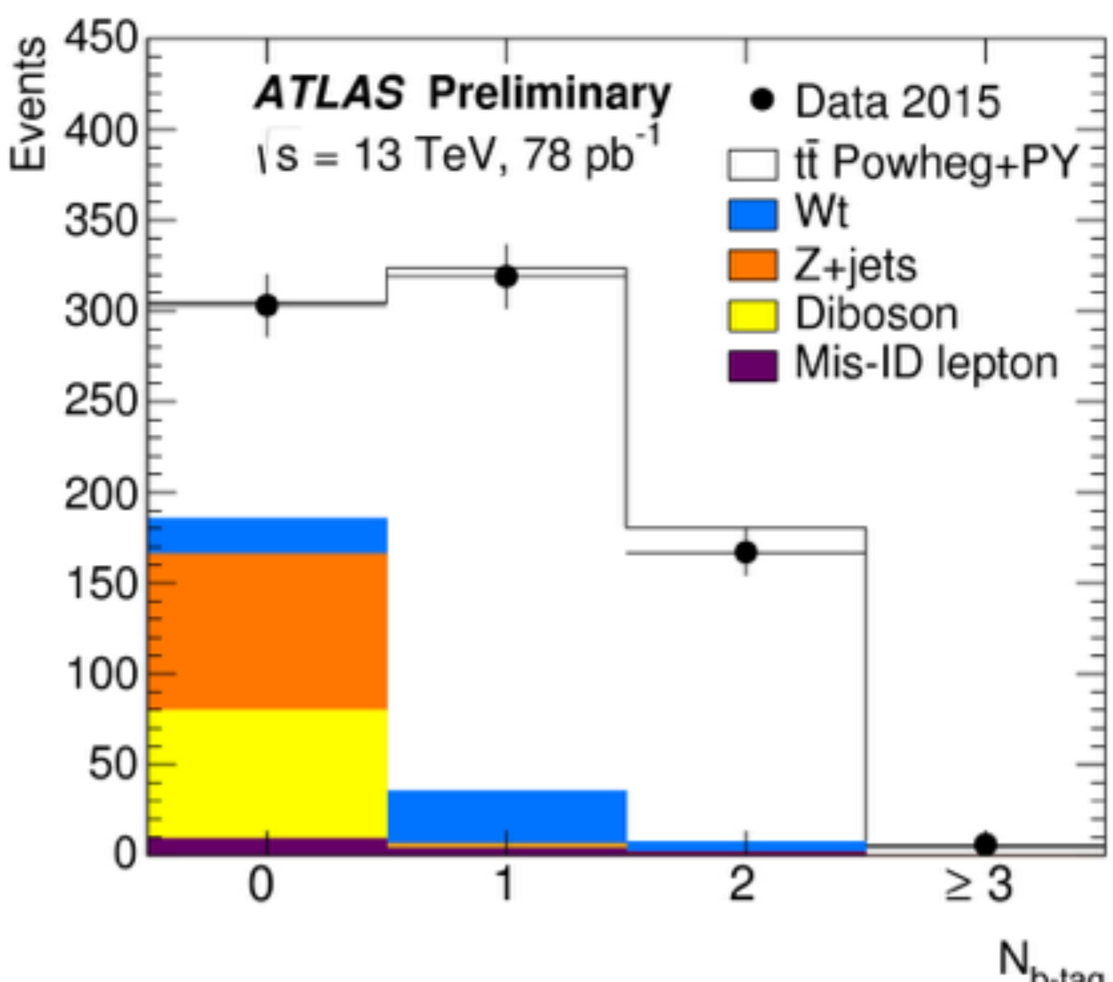
good agreement with SM

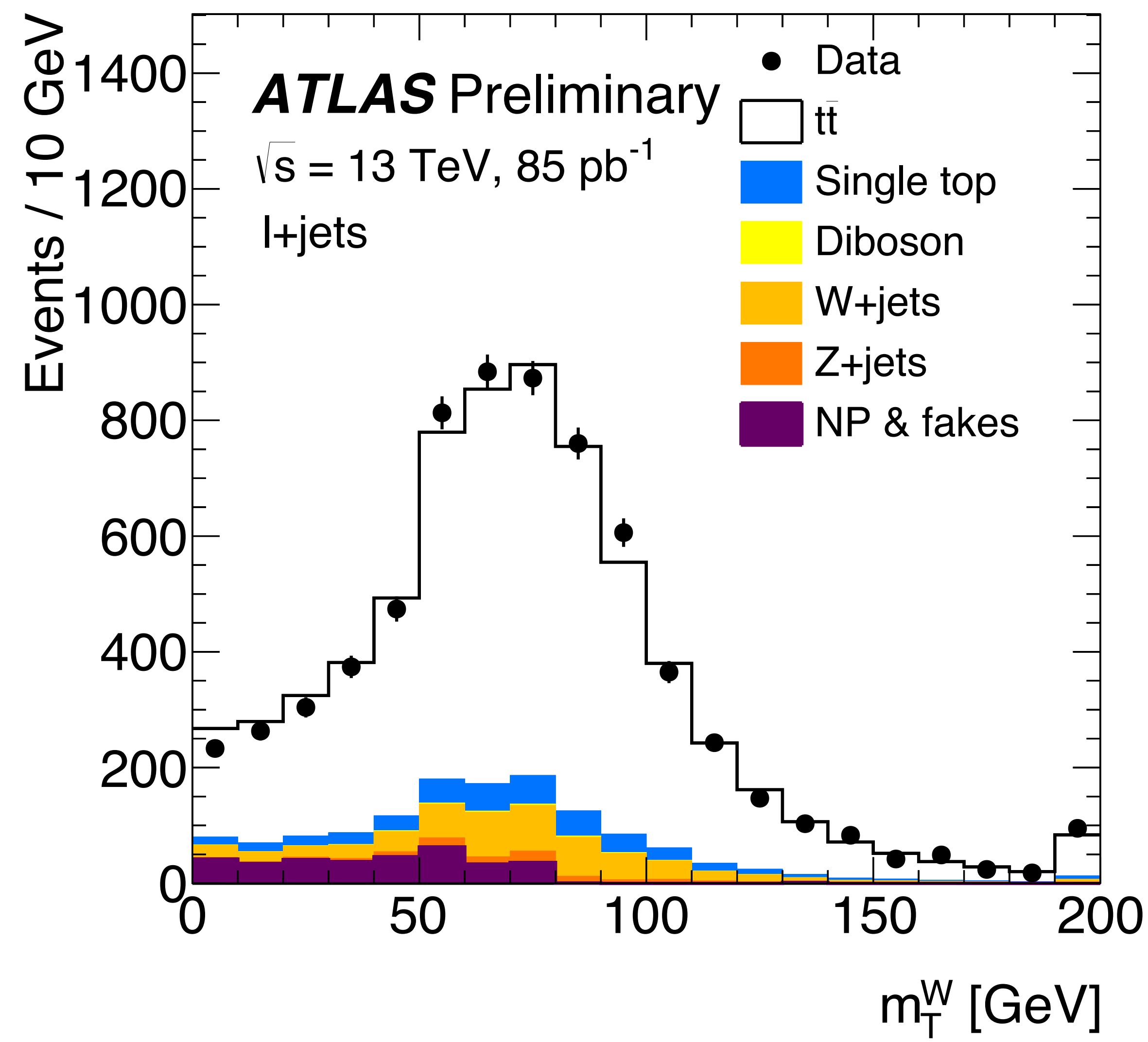
Z+j XS measured in ATLAS-CONF-2015-041

top cross section

ATLAS-CONF-2015-049

- single lepton triggers > 25 GeV
- exactly 2 leptons with opposite charge
- 60 < m_{ll} < 81 GeV || m_{ll} > 101 GeV; MET > 30 GeV
- exactly one or two b-Tagged jets (MV2c20 70%)



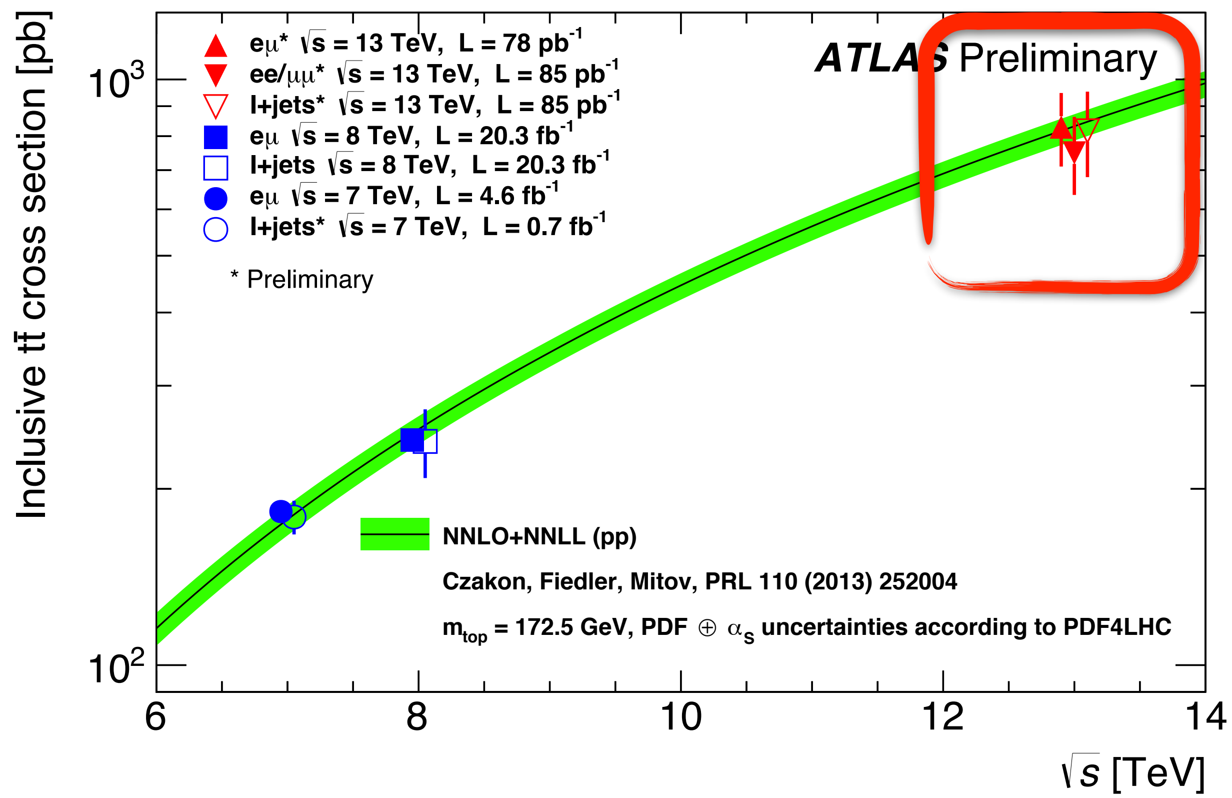


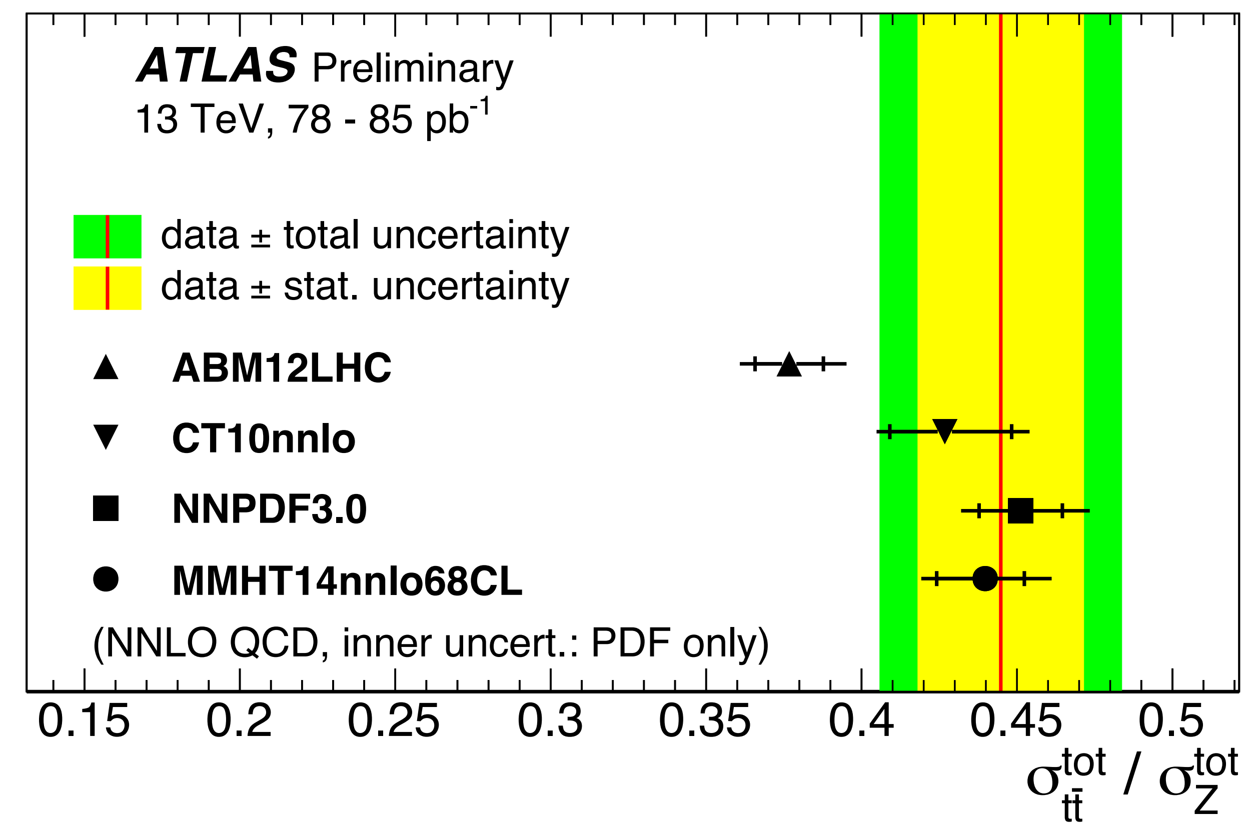
pure in top

good agreement with SM backgrounds

top cross section

ATLAS-CONF-2015-049





agreement within uncertainties

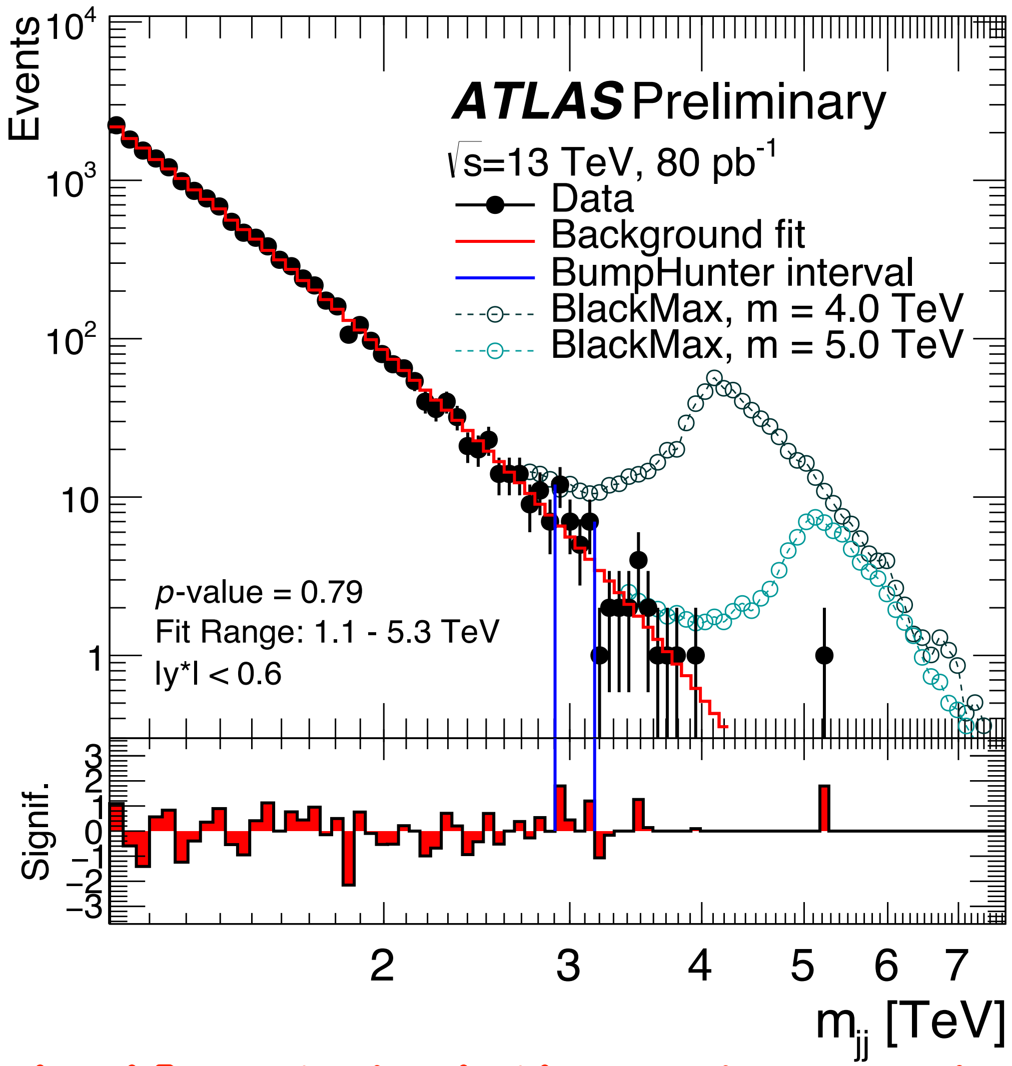
σ_{tt} = **829** ± 50 (stat) ± 56 (syst) ± 83 (lumi) pb.

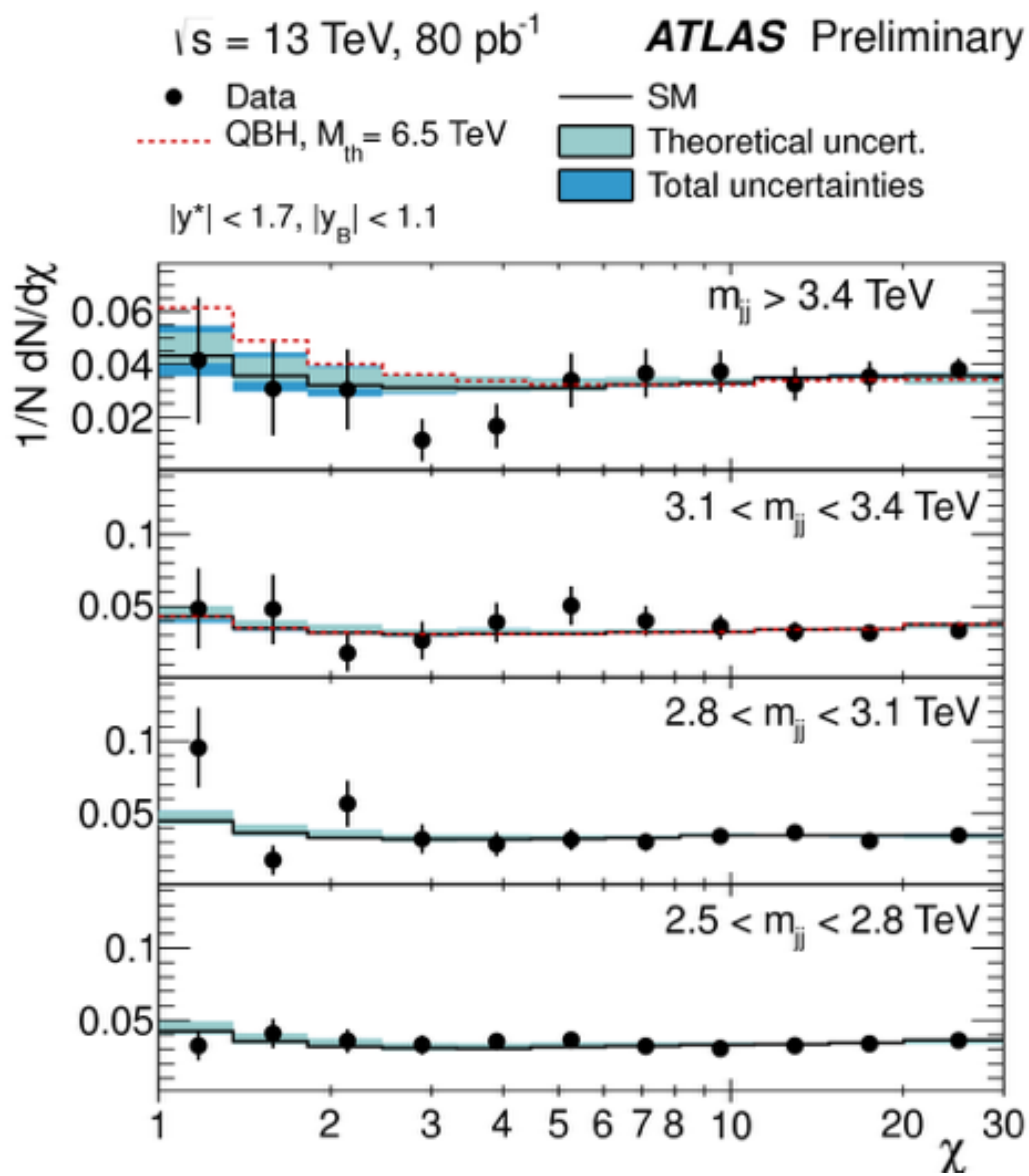
$R_{tt/Z}$ = 0.445 ± 0.027 (stat) ± 0.028 (syst) = **0.445 ± 0.039**

Dijet searches

ATLAS-CONF-2015-042

- High-p_T searches do not use July data due to a trigger problem
- central production, highest p_T (> 360 GeV)
- di-jet invariant mass spectrum (> 1.1 TeV)
- Quantum Black Holes models





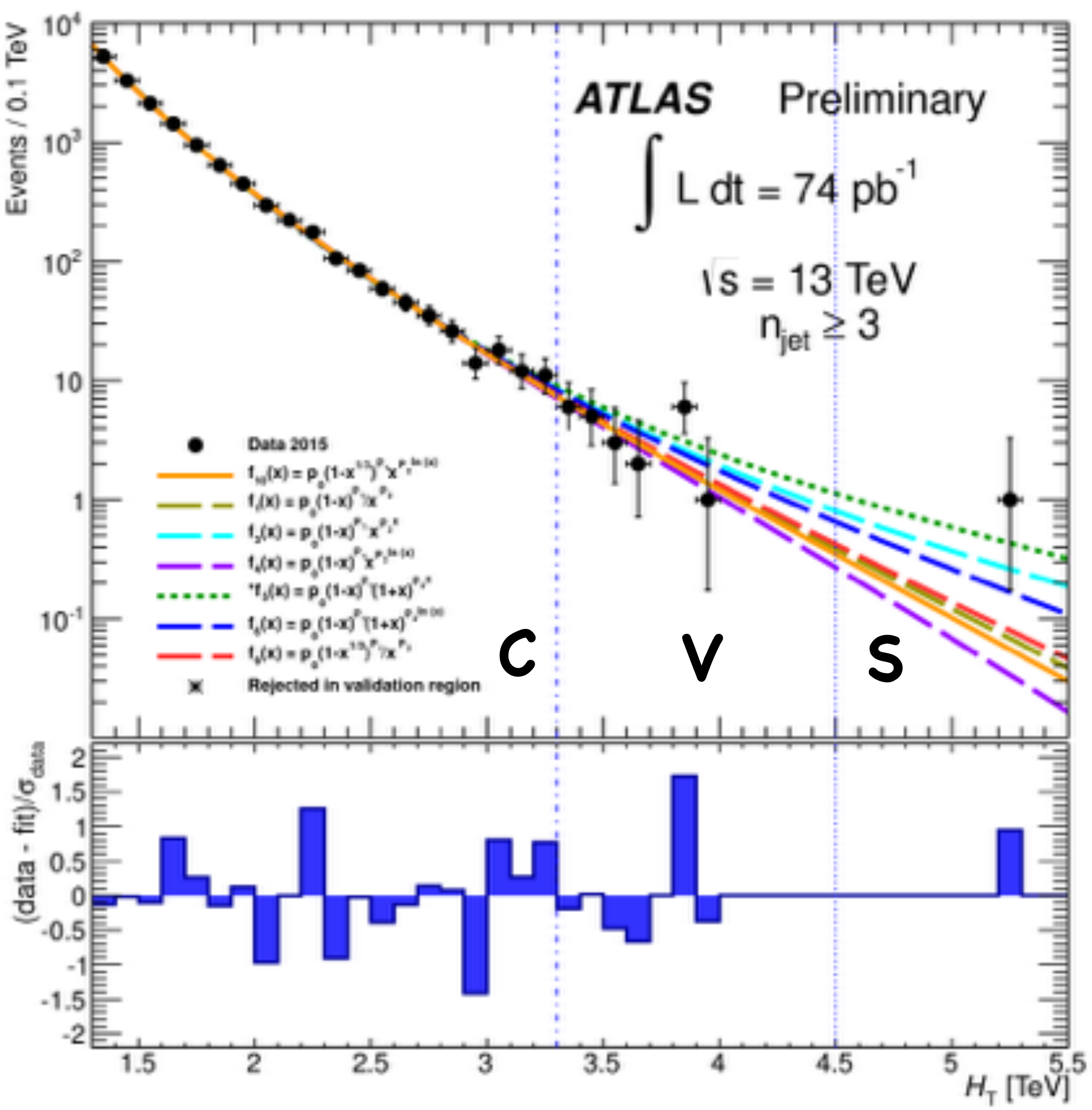
χ ~ difference in rapidities

no significant deviations observed, limit extended to 6.5 TeV (+1TeV wrt Run1)

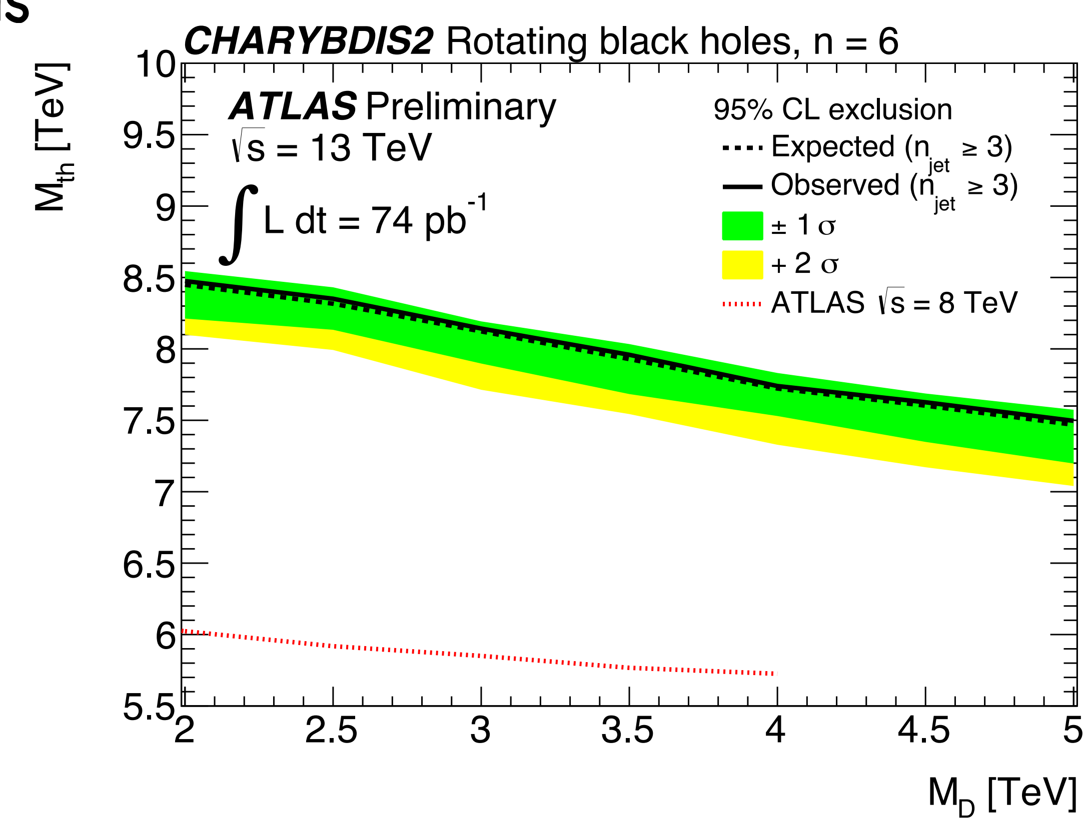
Multijet searches

ATLAS-CONF-2015-043

- at least 3 jets, H_T > 1 TeV
- Control (fitted) -> Validation -> Signal region
- models with additional space-time dimensions



Lepton+jet searches - ATLAS-CONF-2015-046 - show also consistency with SM

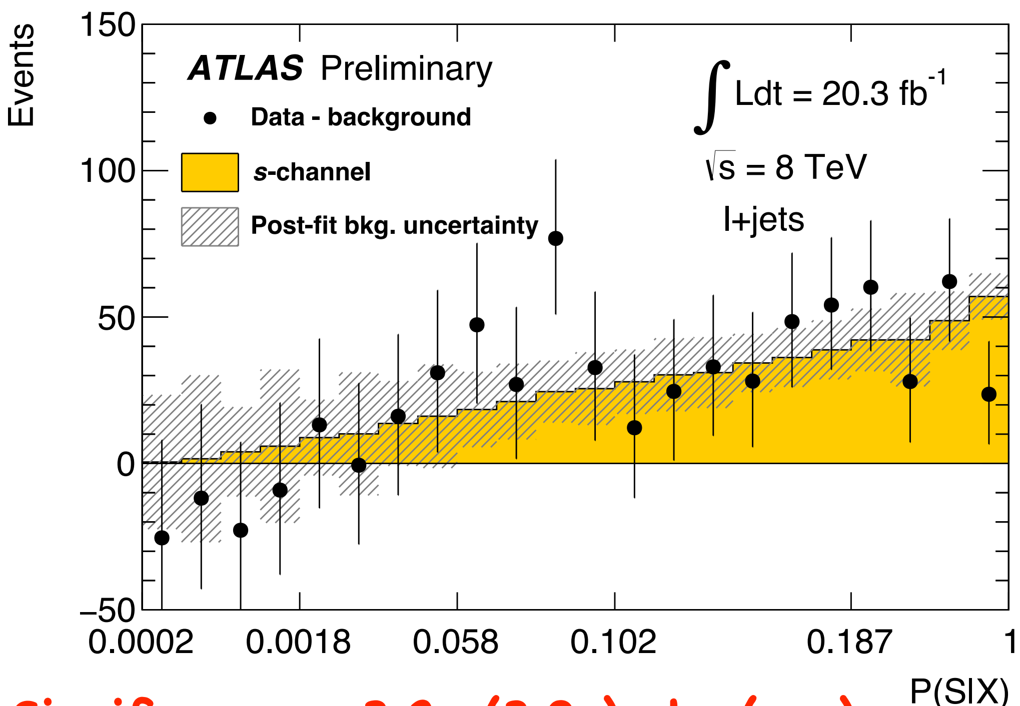


Limits are significantly extended wrt Run1, yet no evidence for deviations from SM was observed

Brief selection of latest Run1 Highlights

ATLAS-CONF-2015-047

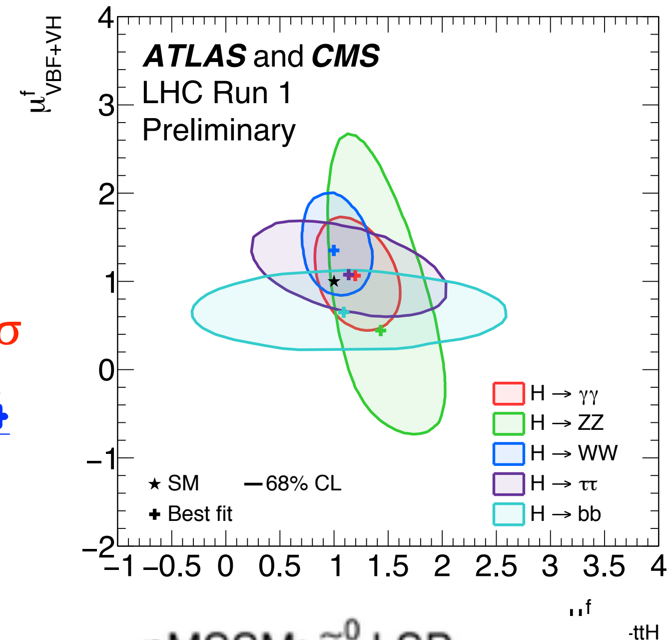
- 8 TeV analysis (20.3fb^{-1}), single lepton triggers
- single top s-channel production, leptonic W decays, Matrix element method



Significance = 3.2σ (3.9σ) obs (exp)

$\sigma = 4.8^{+2.5}_{-2.2}$ pb

- Run1 ATLAS+CMS coupling combinations
- H-> ZZ,WW,γγ,ττ,bb & μμ
- $\mu = 1.09^{+0.11}_{-0.10}$



Significance (VBF) = 5.4σ

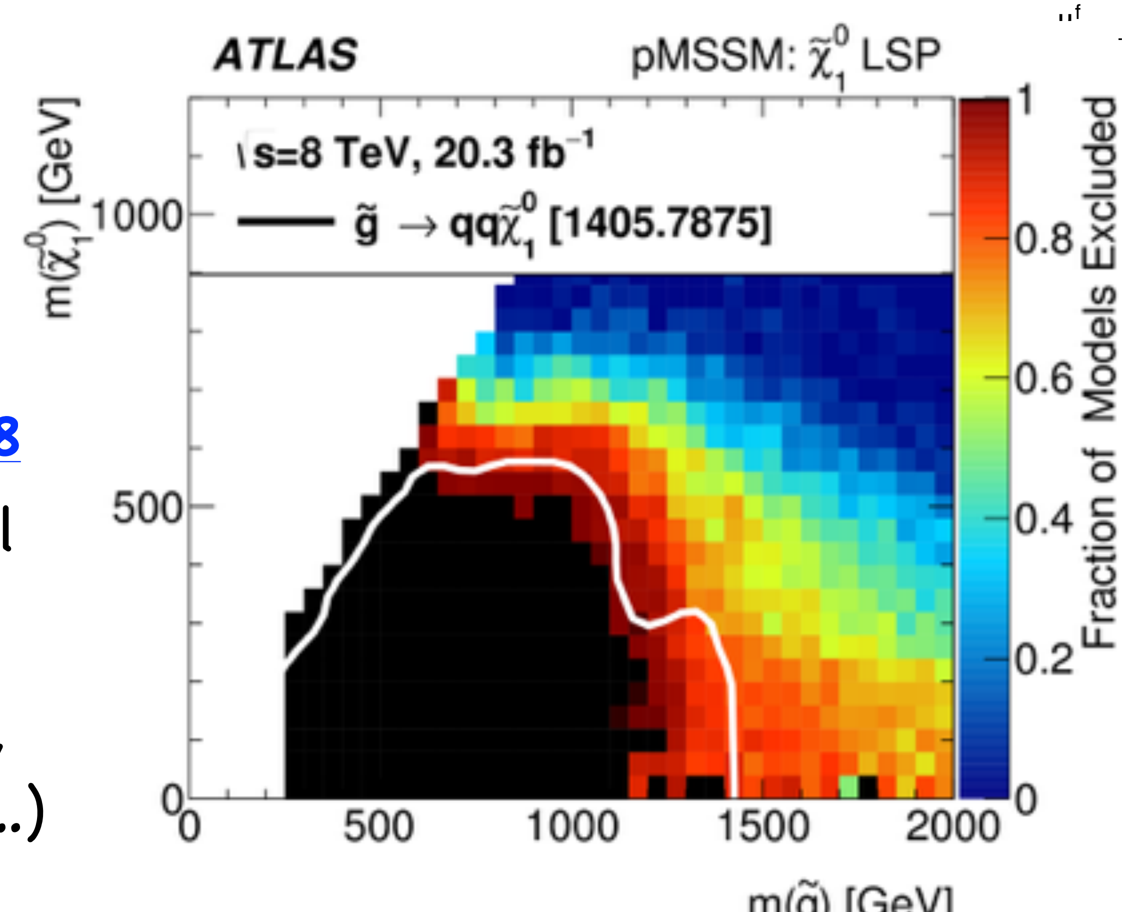
Significance (H->ττ) = 5.5σ

ATLAS-CONF-2015-044

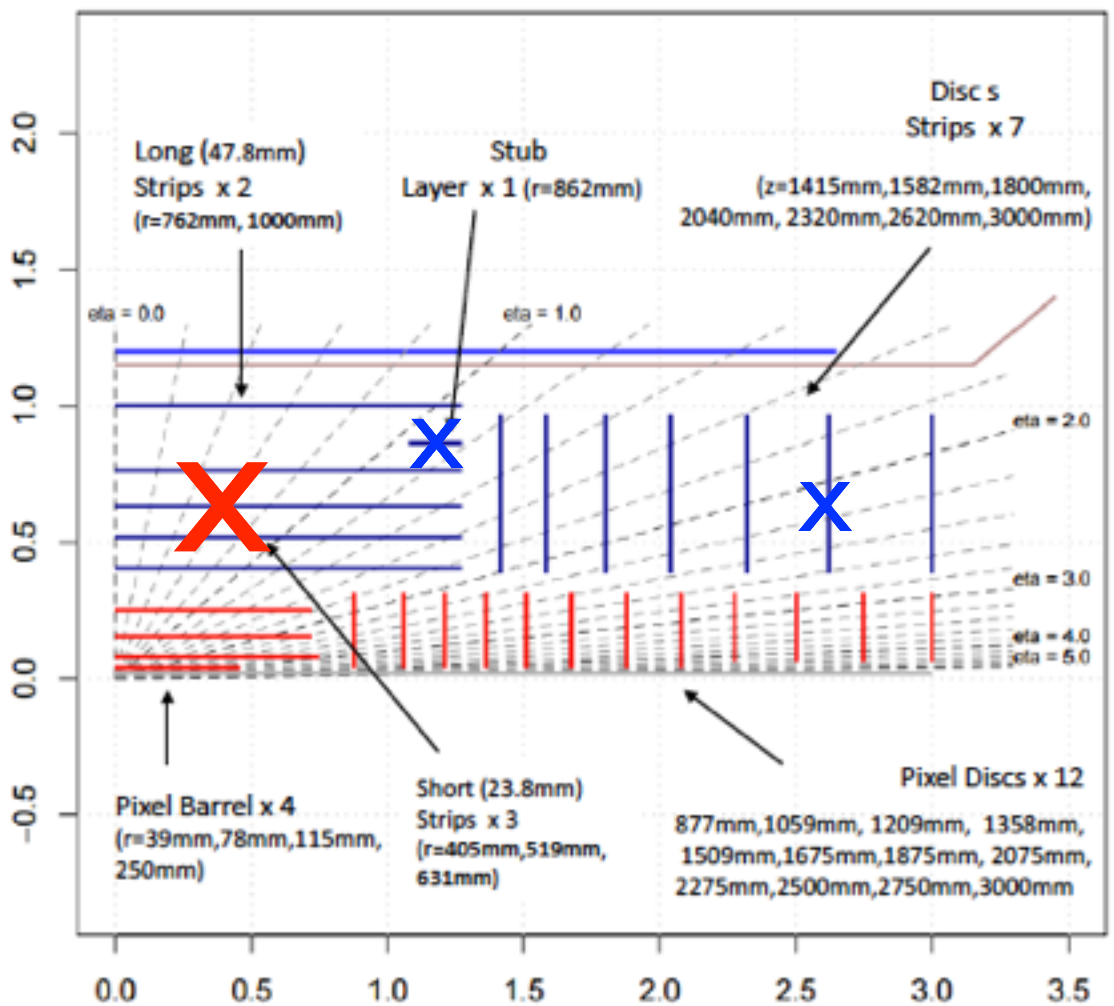
CMS-PAS-HIG-15-002

arXiv:1508.06608

- SUSY Run1 summary on phenomenological MSSM (19 parameteres)
- 22 ATLAS searches considered (Inclusive, 3rd generation of squarks, EW produced,...)



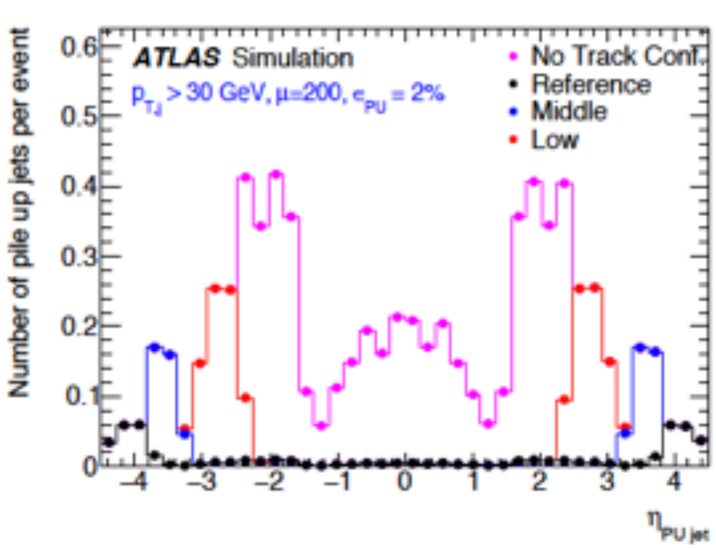
Into the future...



- 3 Scoping Scenarios for μ=200 and L=3ab^{-1} :
  - **275MCHF - "Reference"**
    - ITk up to $|\eta|$ = 4.0, sFCAL, timing detectors...
  - **235MCHF - "Middle"**
    - ITk up to $|\eta|$ = 3.2, central region degradation
  - **200MCHF - "Low"**
    - ITk up to $|\eta|$ = 2.7, significant central region degradation

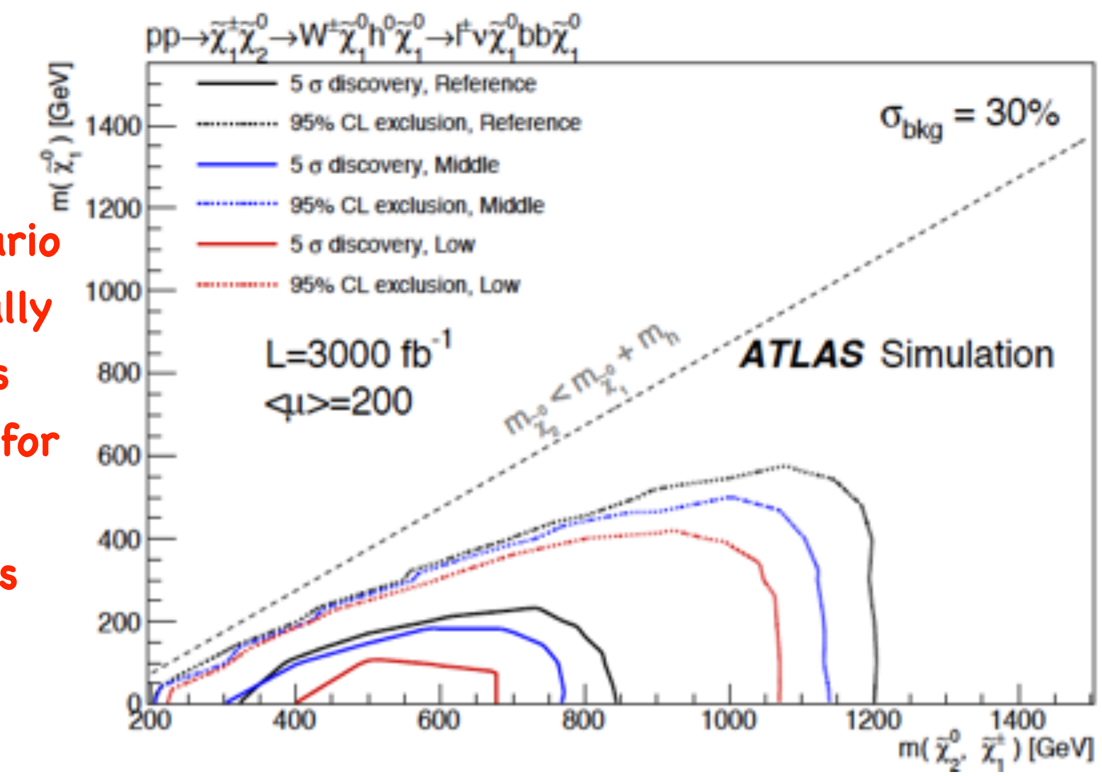
HWW VBF, ~100% degradation from Ref->Low

Scoping Scenario	without theo. unc.		with theo. unc.	
	$\Delta\mu/\mu$	Z_0-value (σ)	$\Delta\mu/\mu$	Z_0-value (σ)
Reference	0.14	8.0	0.20	5.7
Middle	0.20	5.4	0.25	4.4
Low	0.30	3.5	0.39	2.7



distribution of pile up jets (> 30 GeV) and **effect of PU mitigation** in the tracker range

Low scenario dramatically reduces potencial for SUSY searches



Summary

- Huge thanks to the LHC team for the good start and rapidly increasing luminosity!
- ATLAS has restarted successfully
  - Detector is in good shape and running quite smoothly
  - recorded now 0.8 fb^{-1} with a data-taking efficiency of 91%
- Detailed performance studies ongoing, demonstrating already a good understanding of the 2015 data
- Exploring the landscape of physics at 13 TeV with measurements of inclusive, jet, W, Z and top production processes
- Sensitivity to beyond-the-SM physics starts to extend beyond Run-1
- Eagerly awaiting more data in 2015!

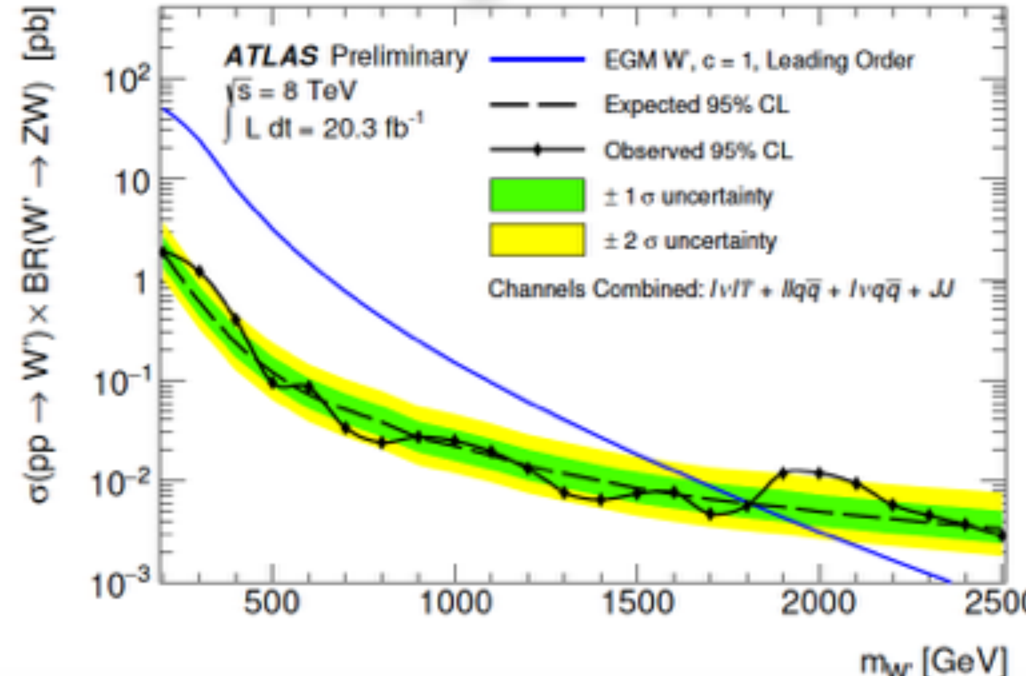
Full list of 13 TeV results can be found here

backup

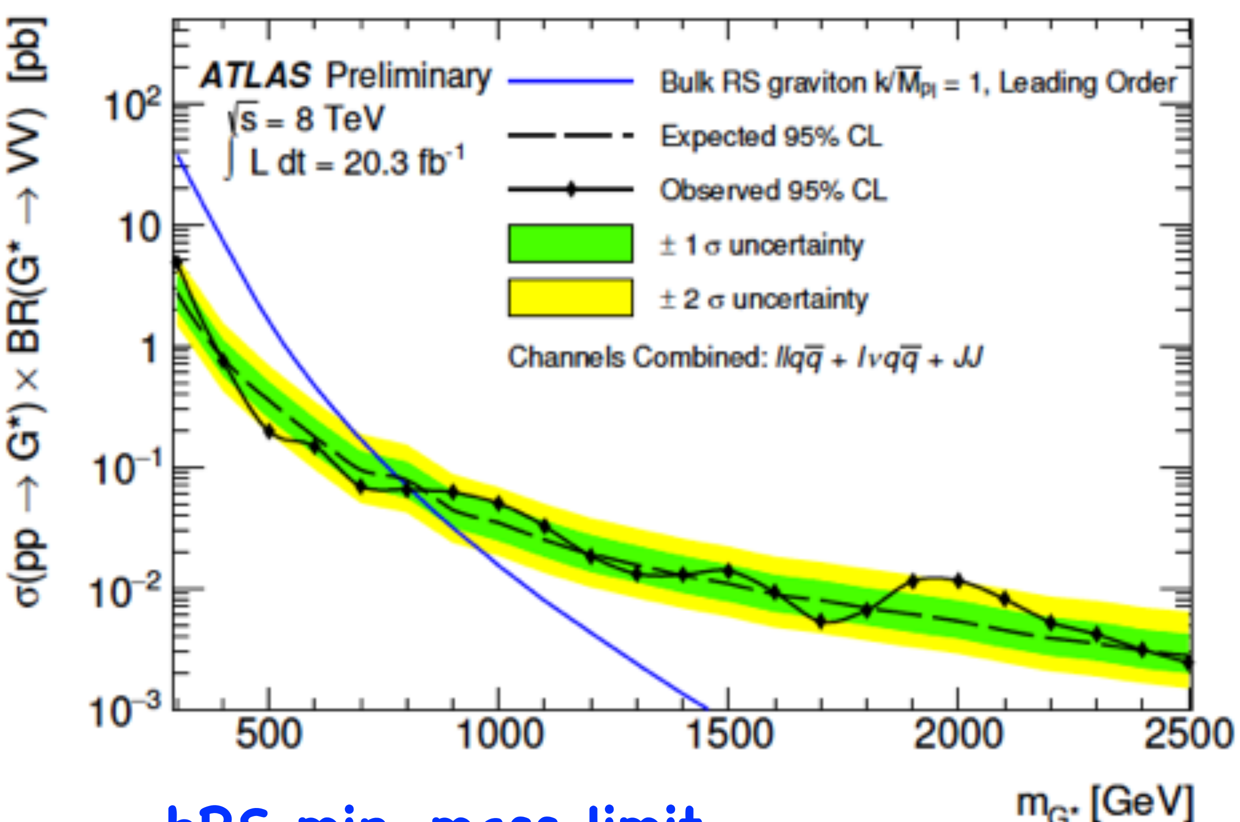
Run1 Searches for new heavy bosons

ATLAS-CONF-2015-045

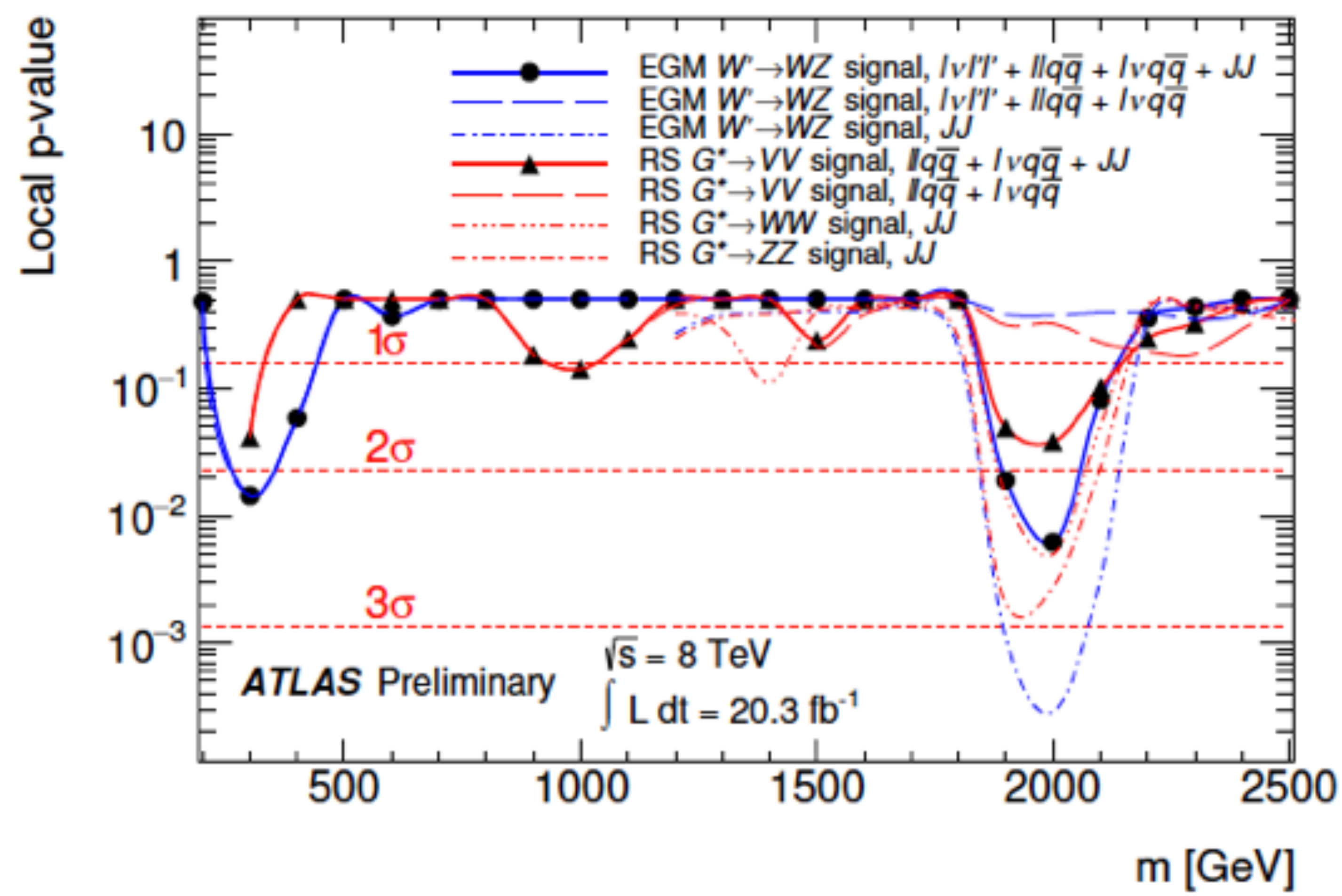
- lvl'l', llqq, lvqq and JJ final states
  - J … CA R=1.2 jets -> groomed (mass drop)
- Extended Gauge Model (EGM, W')
- bulk-Randall-Sundrum (RS, G*)



EGW min. mass limit = 1.81 TeV (exp = obs)



bRS min. mass limit = 790 (810) GeV exp (obs)



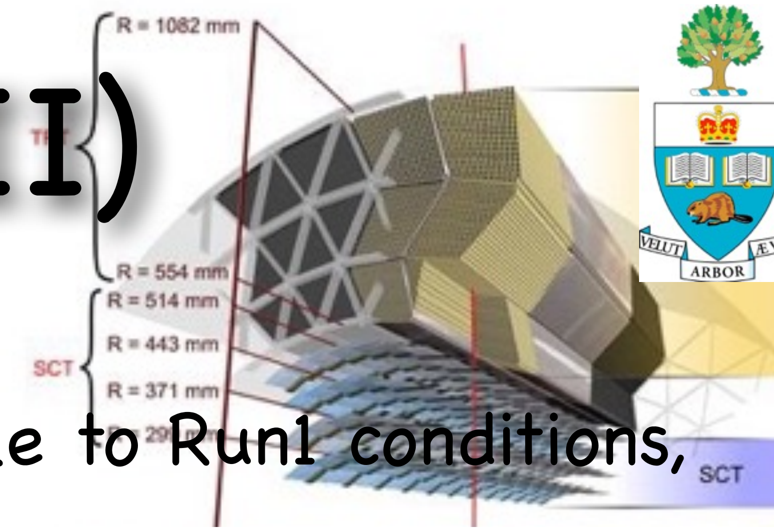
ATLAS Status

ATLAS pp run: June-August 2015										
Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
98.5	99.7	100	99.1	100	100	99.3	100	100	100	99.6

Luminosity weighted relative detector uptime (in percent) and good quality data delivery during the stable beams in pp collisions at 13 TeV between June-August 2015, corresponding to 173 pb^{-1} recorded luminosity.

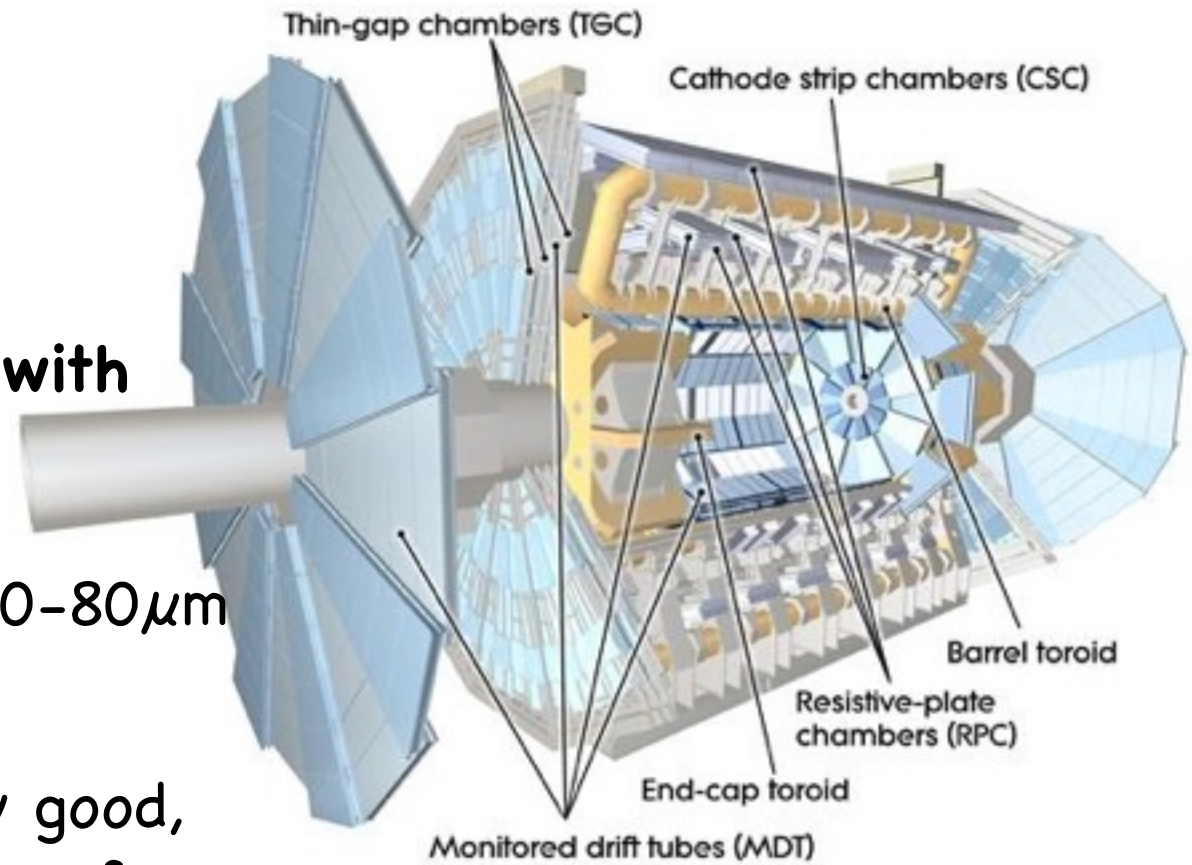
period	date	bunch spacing	μ_{Max}	L_{peak} [$10^{32} cm^{-2} s^{-1}$]	$L_{recorded}$ [pb^{-1}]	L_{total} [pb^{-1}]	
A	3.6.-14.6.	50ns	27.6	1.4	7.9	7.9	
B	9.6.-13.6.	2000ns	0.3	4.5×10^{-3}	0.0145	7.9	
C	4.7.-20.7.	50ns	27.4	16.0	101	109	EPS dataset
D	12.8.-23.8.	25ns	29.4	10.5	105	214	LHCP dataset

Inner Detector (II)

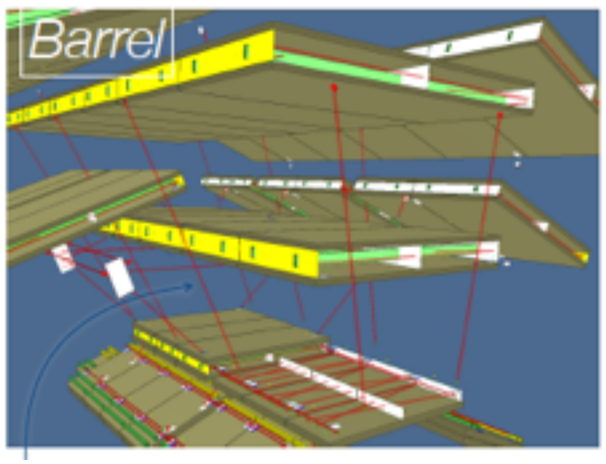


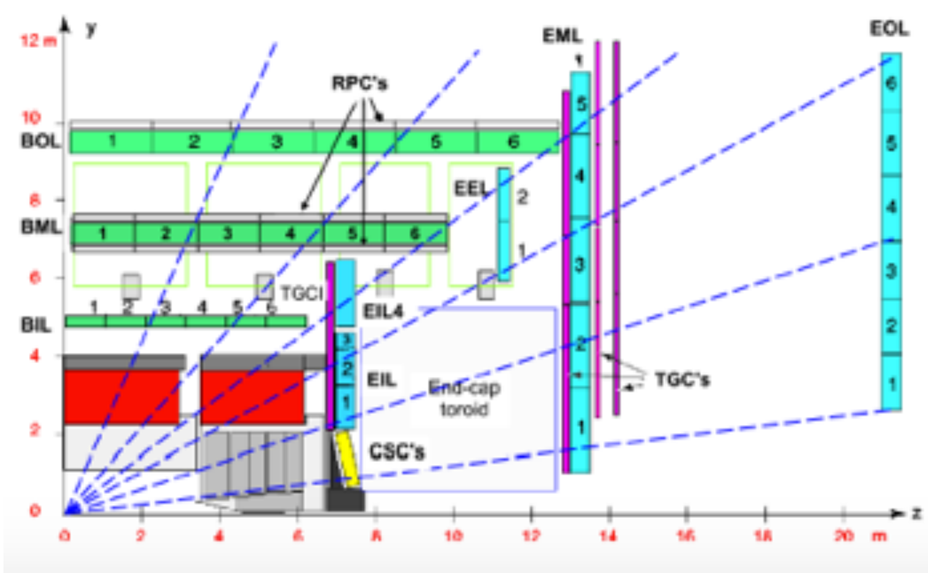
- **SCT** - Noise, gain and operating voltage comparable to Run1 conditions, Excellent data taking efficiency
  - SCT vetoing signals from "previous" BX causes inefficiencies during 25 ns running (negligible effect on the data)
- **TRT** operates smoothly and provides high DQ, preparing HW and SW tools to run with high μ and 25ns
  - HV Protection system against overshoot at the beam dump implemented.
    - No discharges in the detector since
  - Significant ROD repair effort and ROD FW upgrade made. (10% spares, able to operate @ 100kHz)
    - due to leaks in exit pipes (50-70l/day, no new ones in Run2), Ar is used in parts of the detector instead of Xe, Kr is under testing

Muons



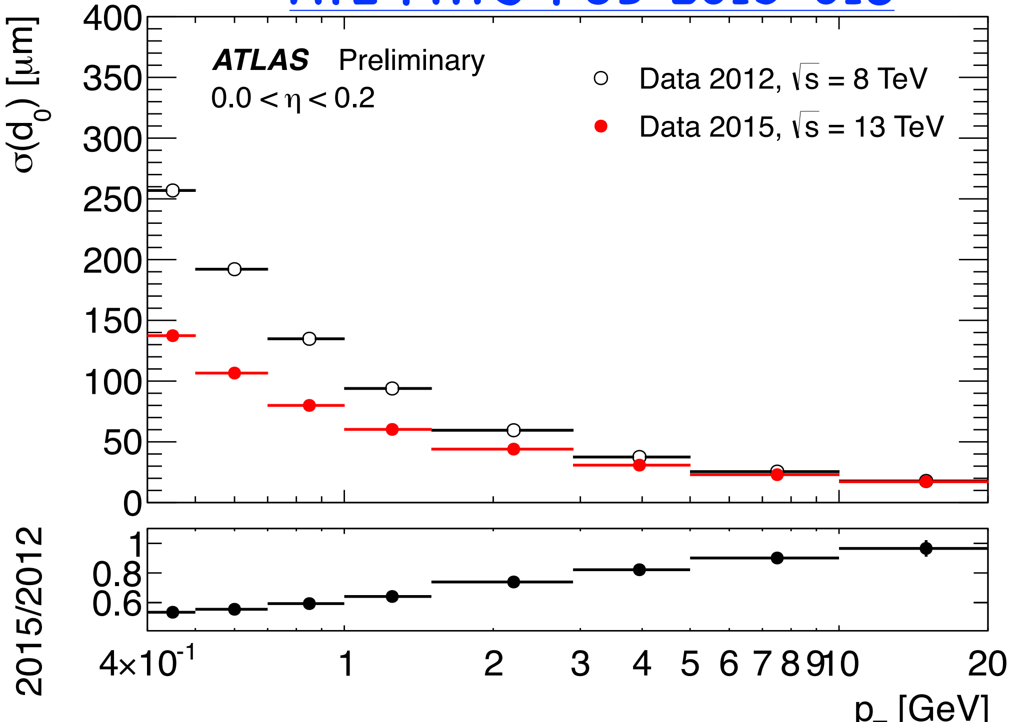
- **alignment performed in July and August runs with toroid magnet off**
  - resolution of **10% @ 1 TeV** needs resolution 20-80μm (10^{-6} scale!), ~30M muon tracks ~collected
- overall performance of the muon systems is very good, operational teams are focusing on troubleshooting of small issues
- **CSC** - two planes OFF, 5 reduced HV
- **MDT** - noise burst study ongoing (origin in one chamber)
- **RPC** - new chambers installed in LS1 and equipped with electronics in LS1; still need some development and commissioning work
- **TGC** are ready to deploy the inner coincidence (reduction of muon trigger rates in the ECs.);timing verified (scan), Tile-muon coincidence under commissioning

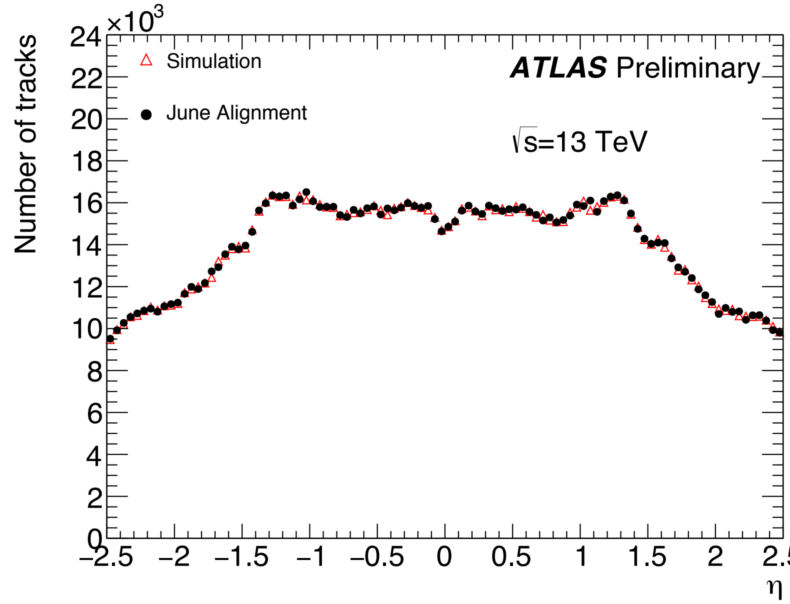


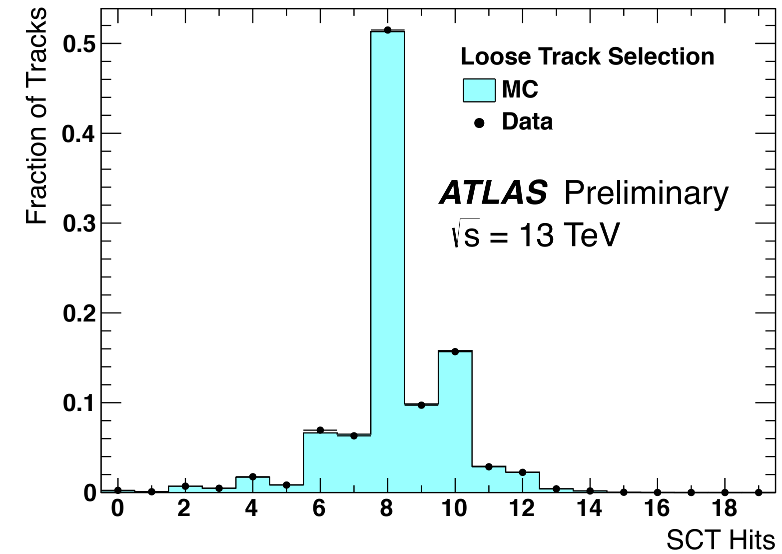


Tracking

ATL-PHYS-PUB-2015-018



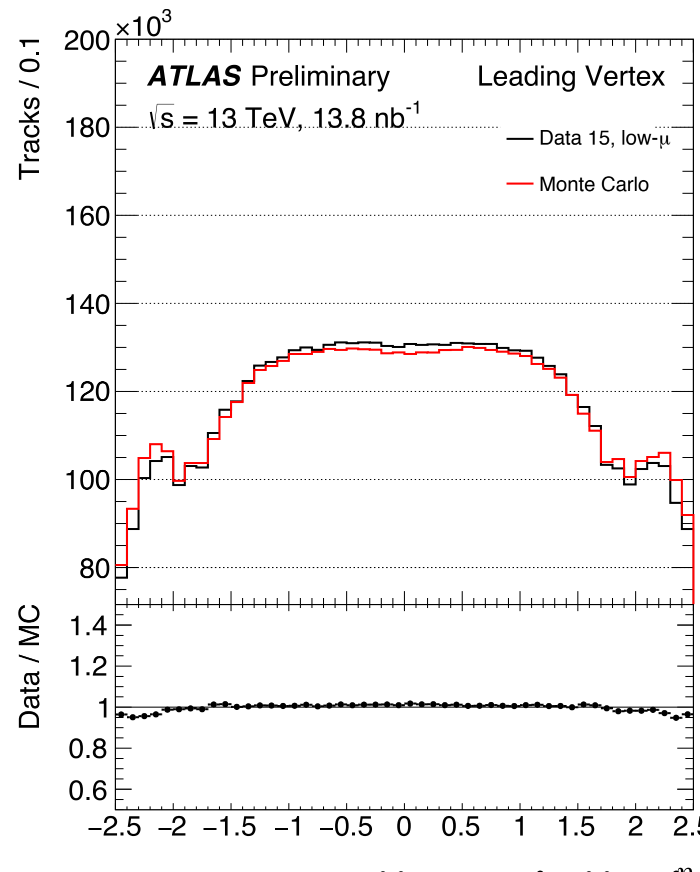


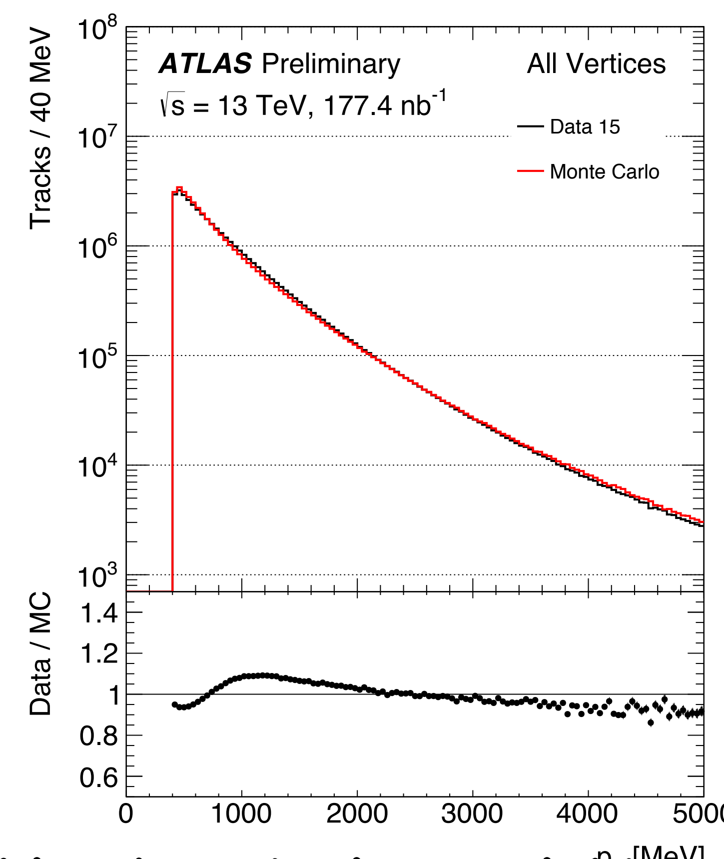


very well modelled alignment & #IBL hits

transverse impact parameter in 2015 (+IBL) and 2012

- huge gain through IBL
- generally good agreement between data and MC



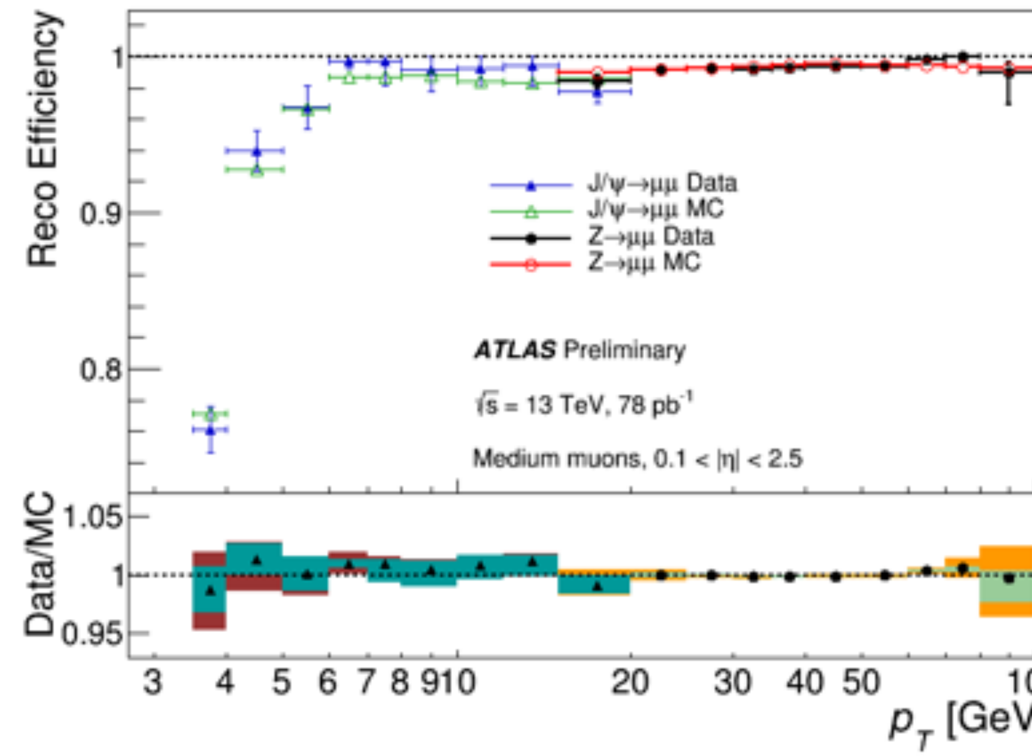


very well modelled combined vertexing variables

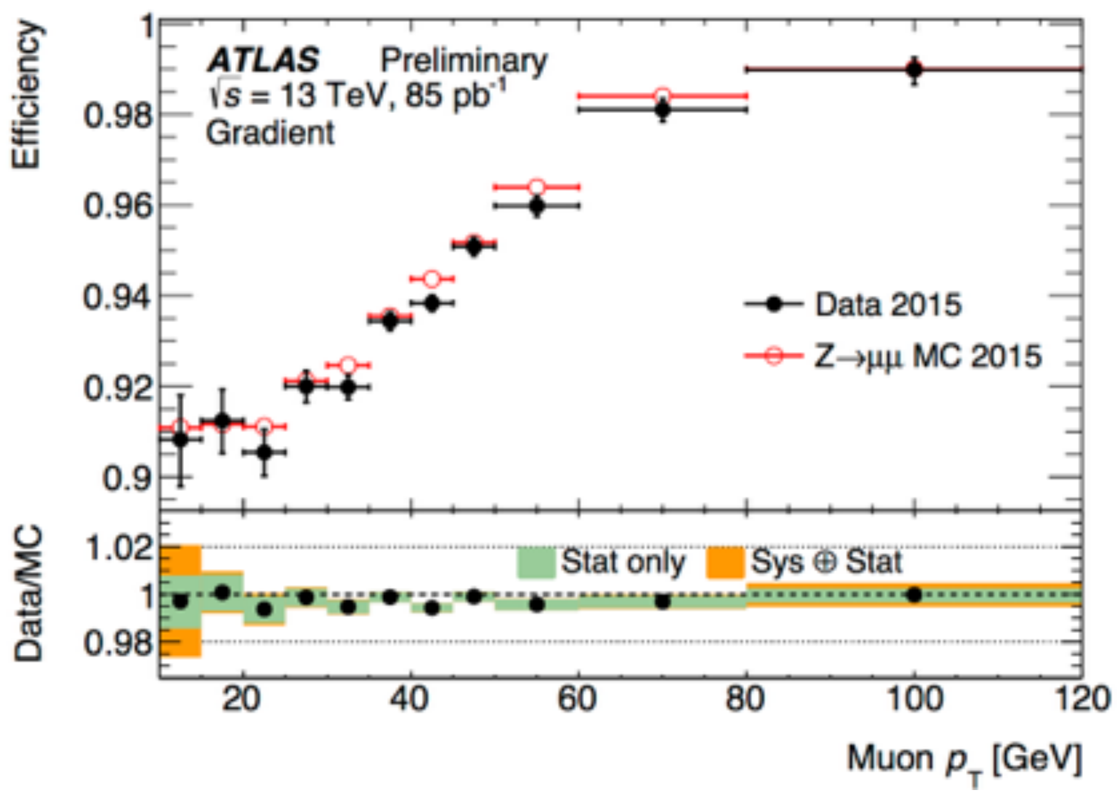
Muon reconstruction

ATL-PHYS-PUB-2015-037

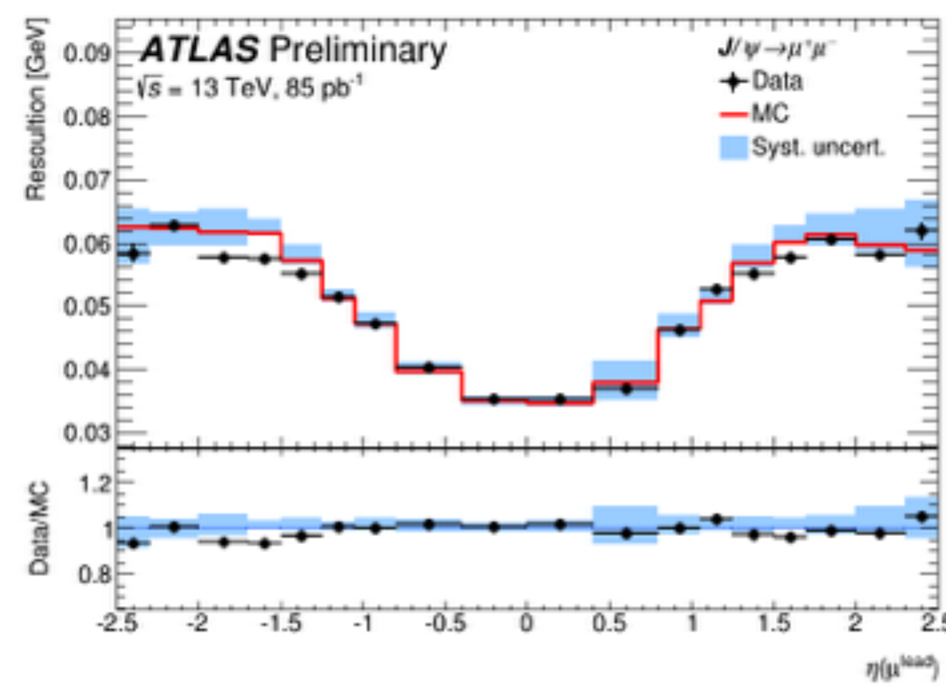
- based on 50 ns data (85 pb^{-1})
- improved acceptance ($1.0 < |\eta| < 1.4$) and reco algorithm



excellent agreement, but large δ_{stat}



Efficiencies of the combined track-based and calorimeter-based isolation for the Gradient working point



mass resolution:

J/Ψ: 35-60 MeV

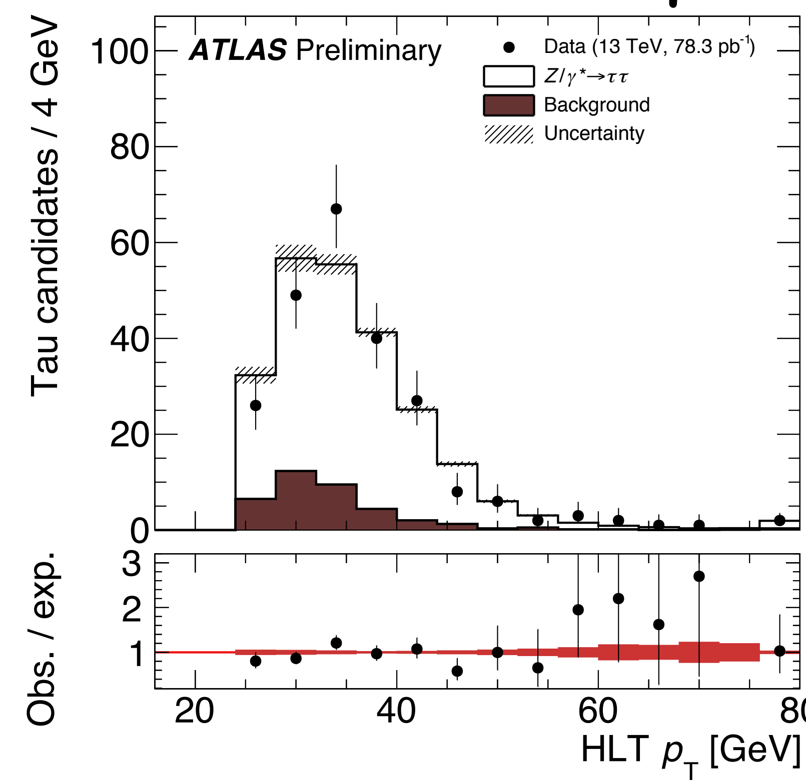
Z:1.5-2.0 GeV

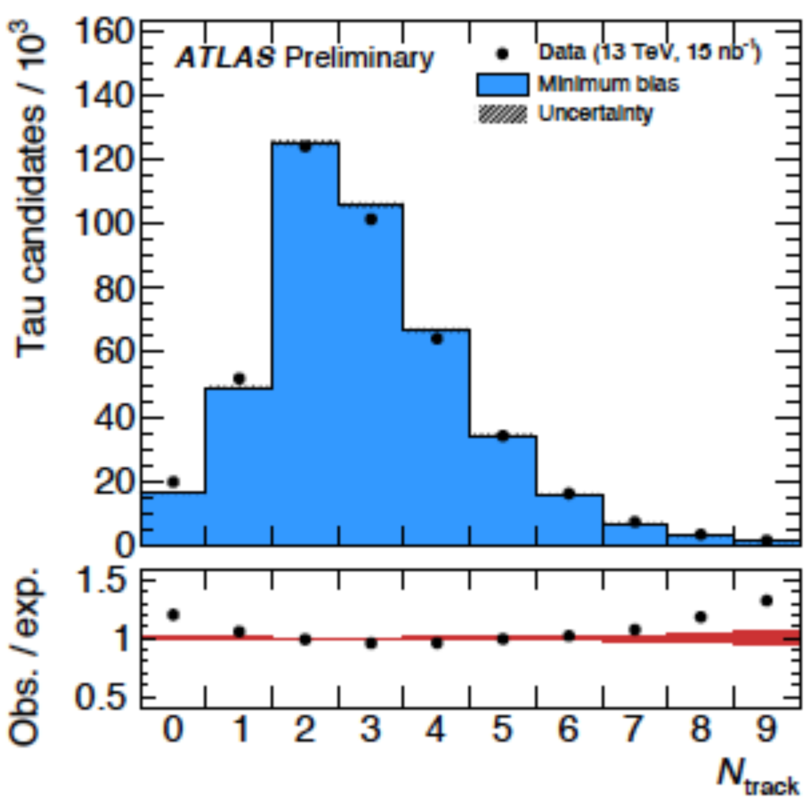
taus

ATL-PHYS-PUB-2015-025

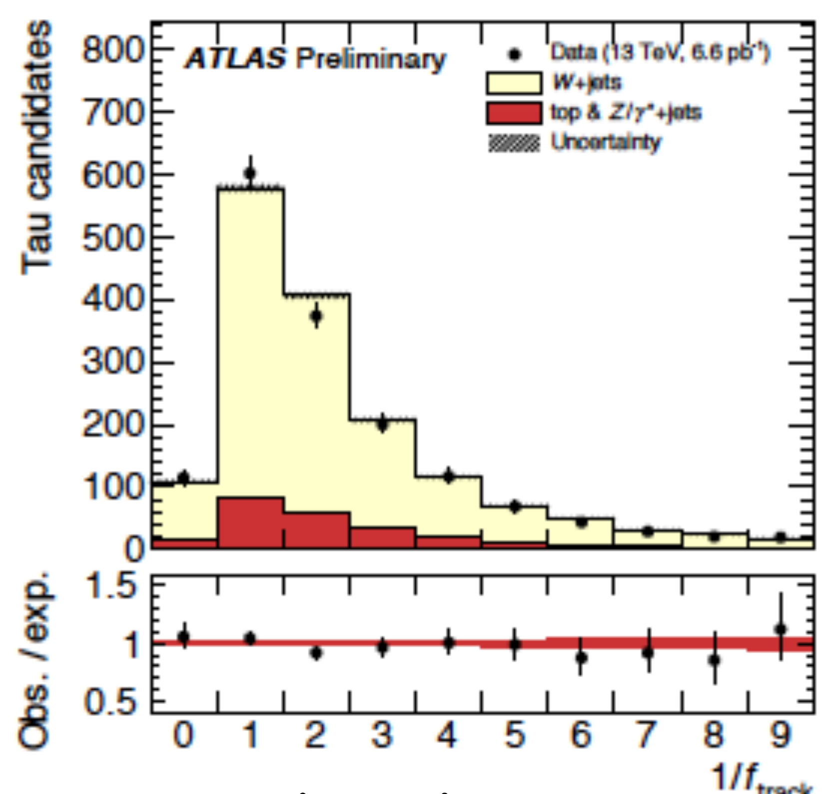
- identification based on BDT
- data samples: low μ runs (MBTS trigger) and high μ (e,μ and τ triggers)

enriched Z->ττ sample

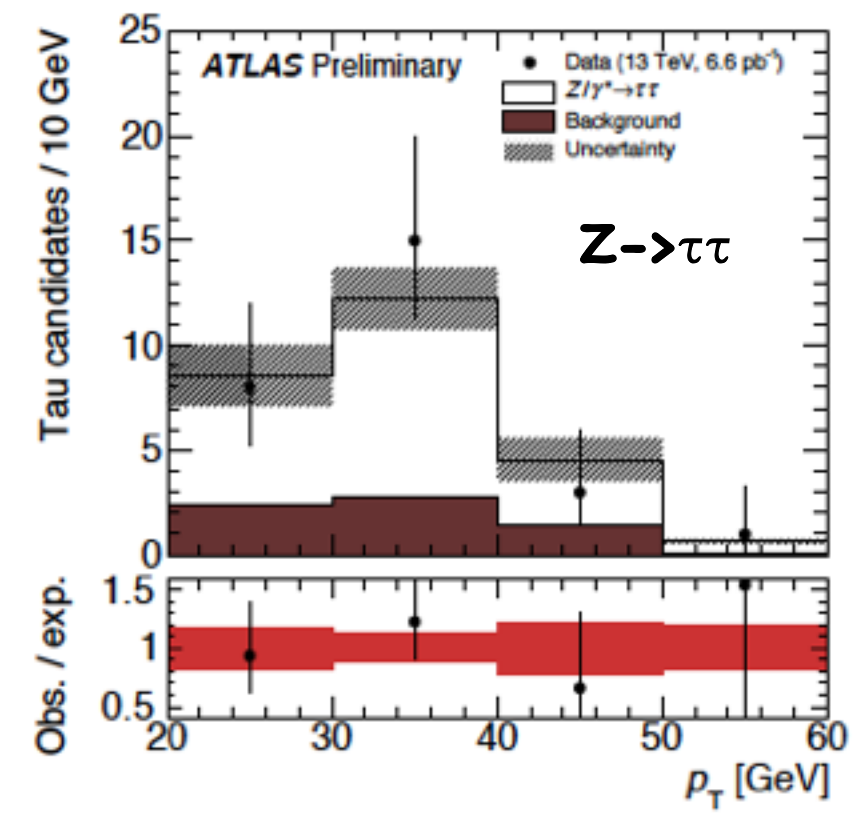




minimum bias



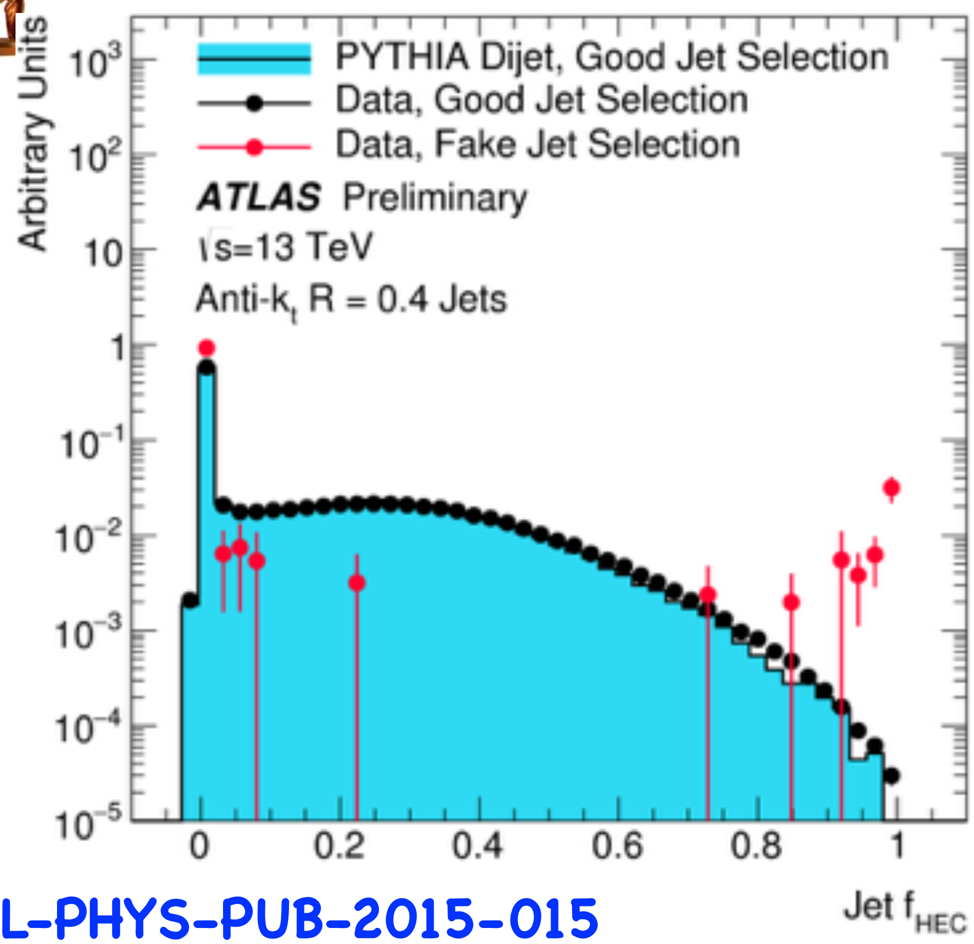
W(->μν)+jets



good modelling by MC and understanding of the detector

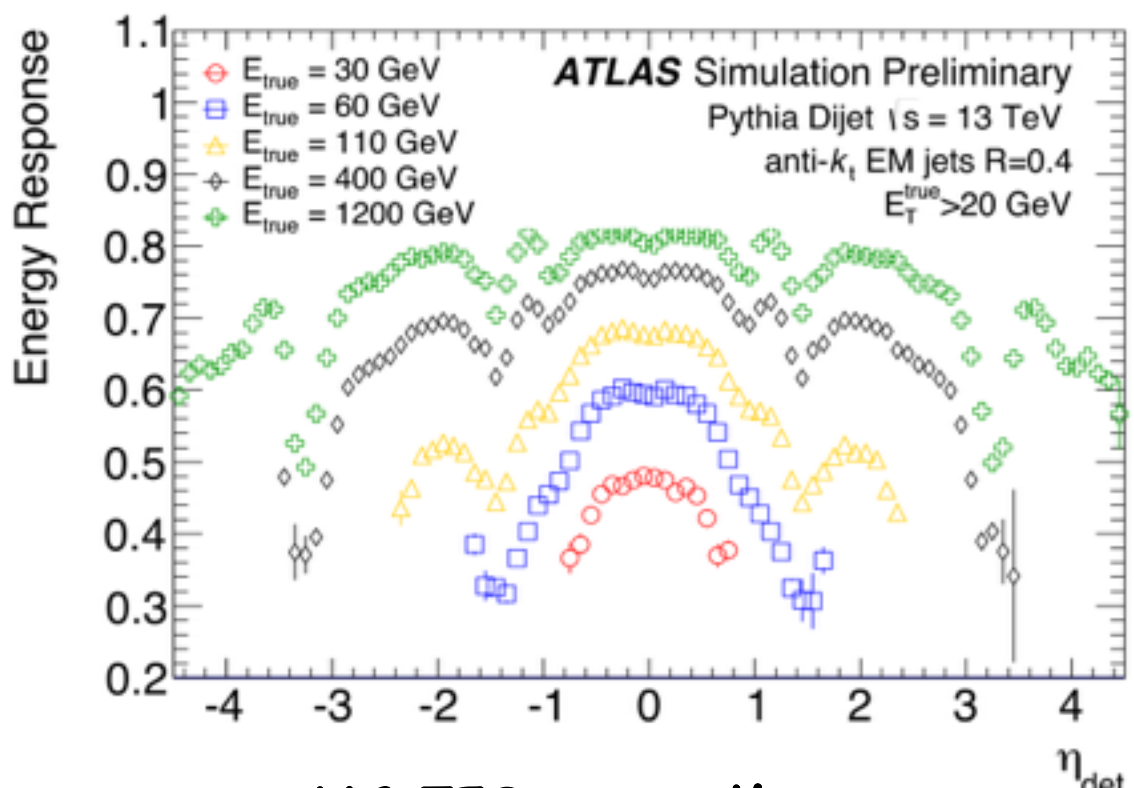
Jets (I)

ATLAS-CONF-2015-029

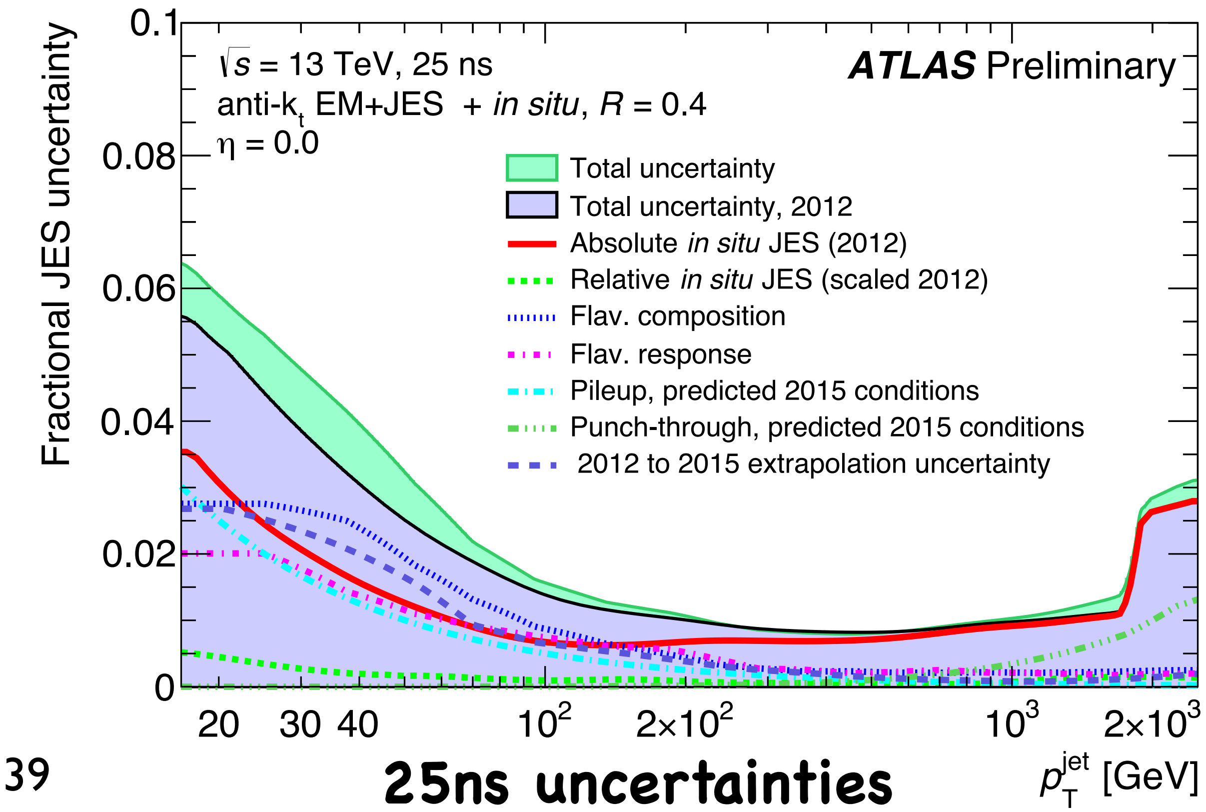


- jet cleaning - selection of good jets based on calorimeter criteria (beam background, noise, cosmics)
  - criteria for analyses defined
- JES and JER preliminary recommendations (based on simulations) delivered for early analyses, AntiKt4TopoEM

ATL-PHYS-PUB-2015-015



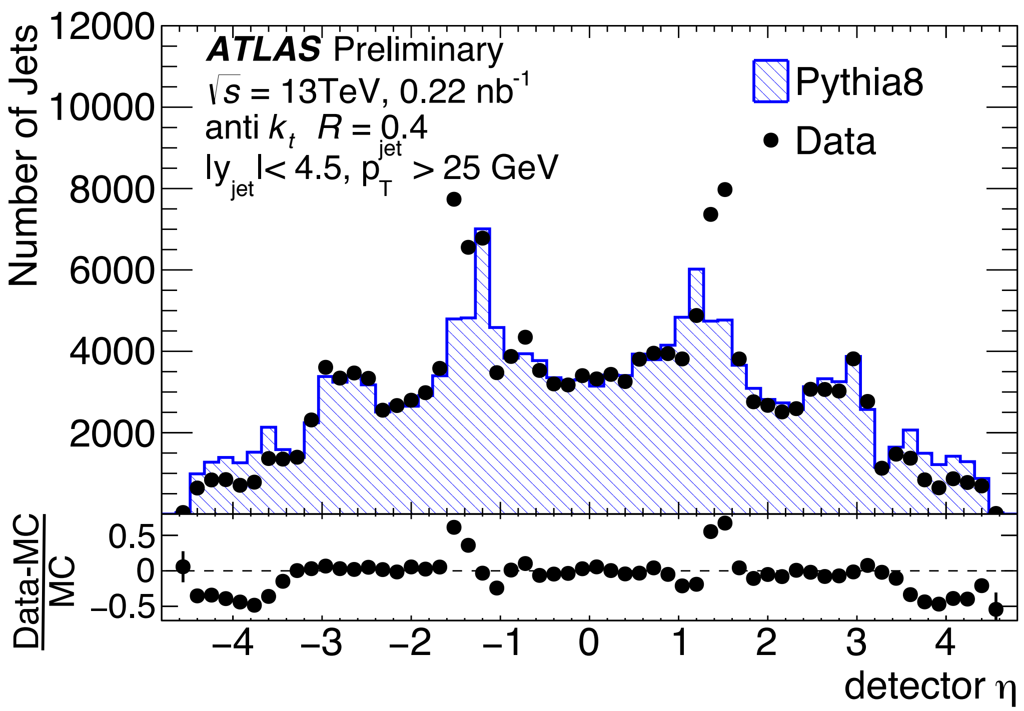
MC JES correction



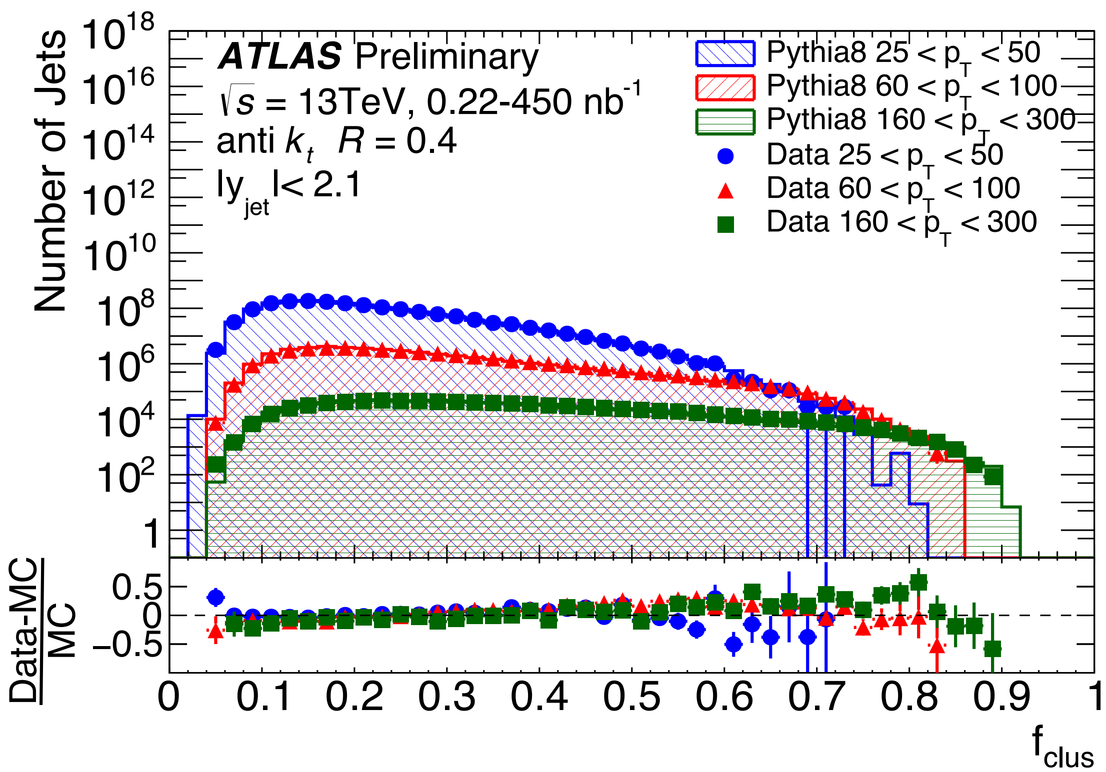
25ns uncertainties

Jets (II)

ATL-PHYS-PUB-2015-036

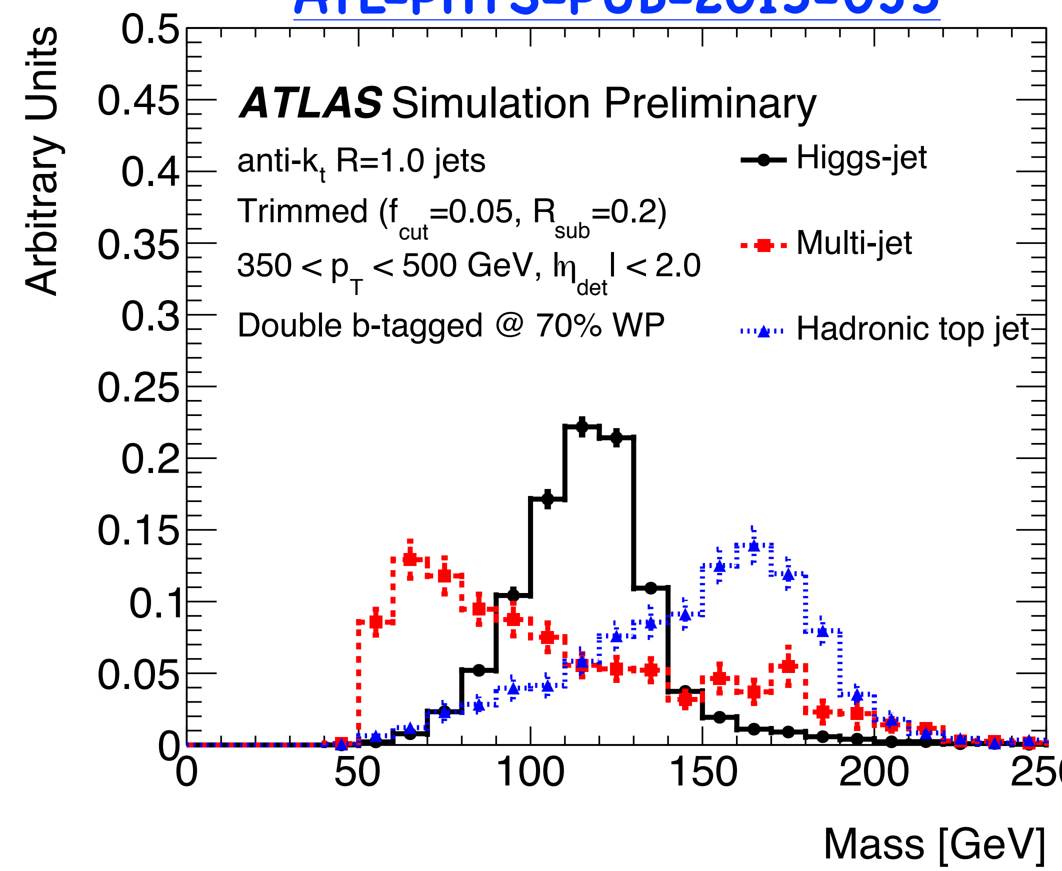


- preliminarly calibrated jets
- MC normalized to data
- good shape agreement -> validated inputs to more sophisticated methods (GSC, substructure...)



leading cluster energy fraction

ATL-PHYS-PUB-2015-035



Higgs(->bb) Tagger, large R jets

arXiv:1509.04776

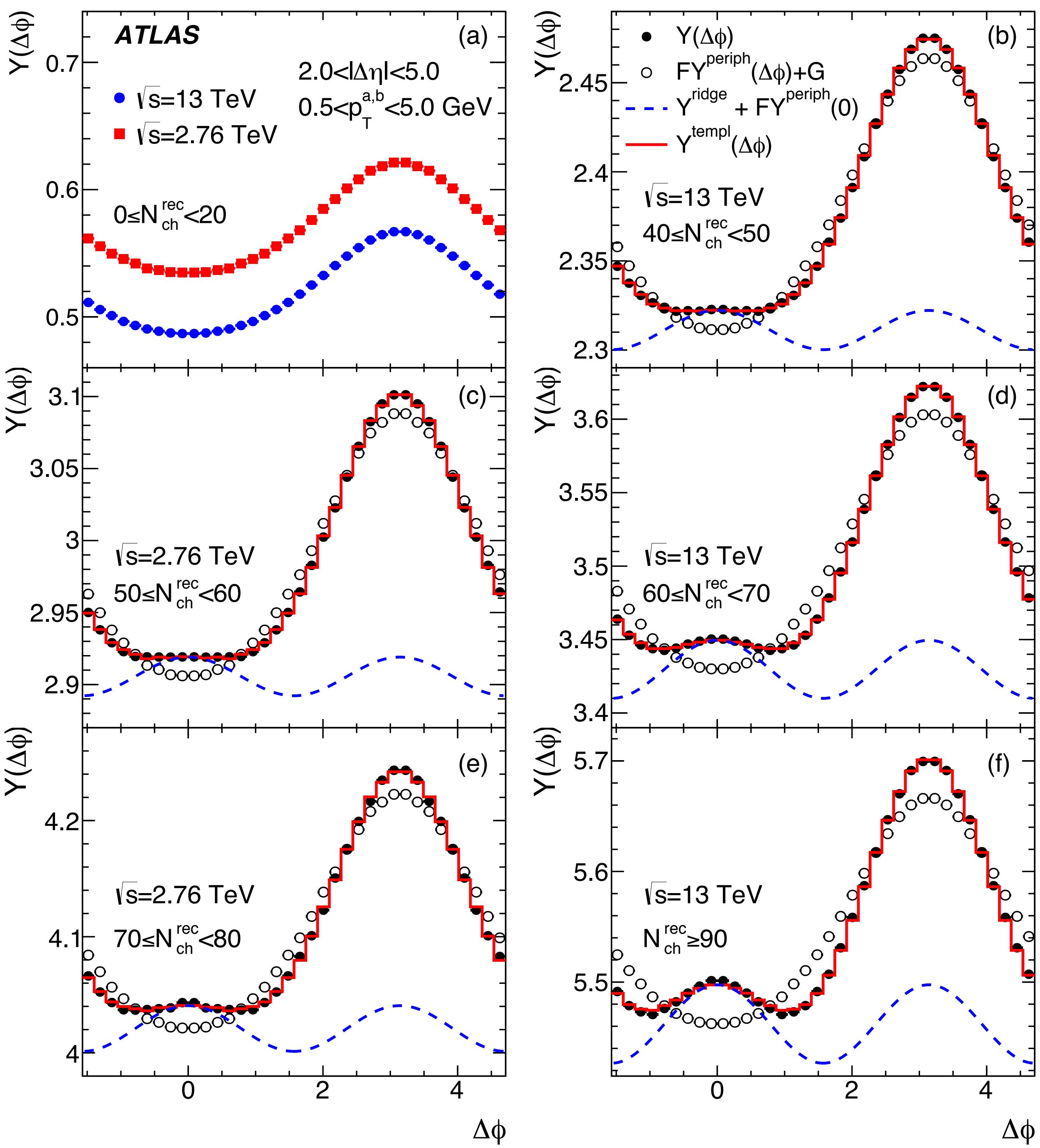
The Ridge

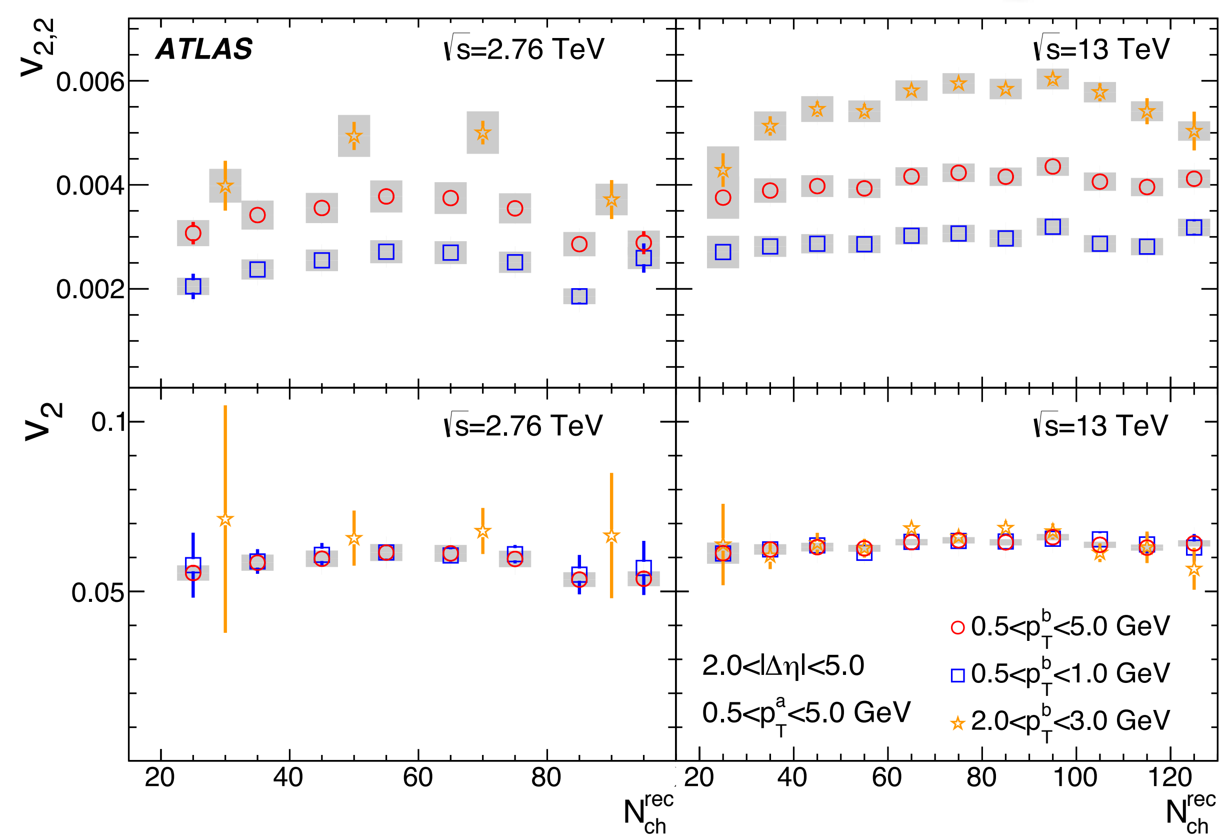
Observation of long-range elliptic anisotropies in pp collisions

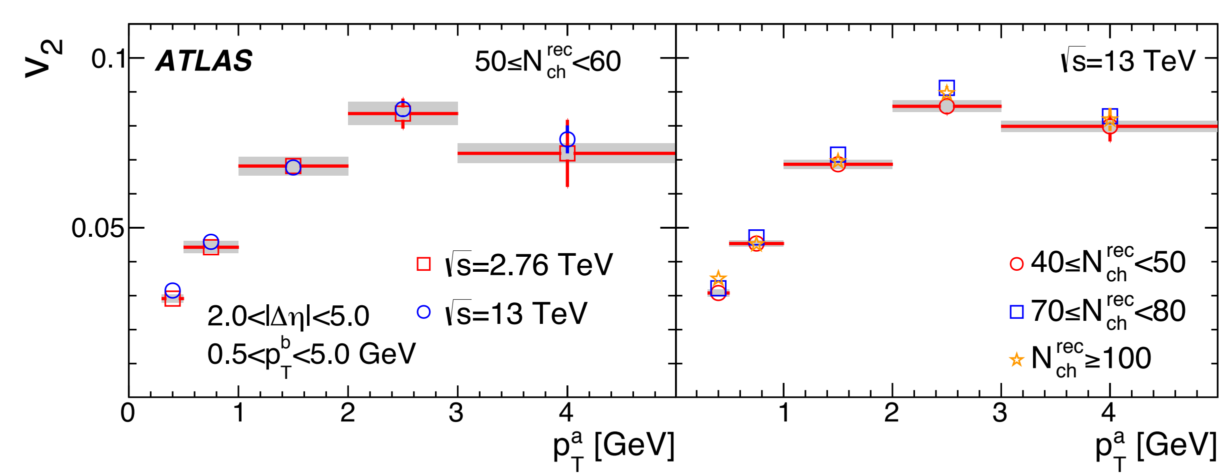
$$Y^{\mathrm{templ}}(\Delta\phi) = F\, Y^{\mathrm{periph}}(\Delta\phi) + Y^{\mathrm{ridge}}(\Delta\phi)\,,$$

$$Y^{\mathrm{ridge}}(\Delta\phi) = G\,(1 + 2v_{2,2}\cos(2\Delta\phi))\,,$$

$$v_2(p_{\mathrm{T}1}) = v_{2,2}(p_{\mathrm{T}1}, p_{\mathrm{T}2}) / \sqrt{v_{2,2}(p_{\mathrm{T}2}, p_{\mathrm{T}2})}\,,$$

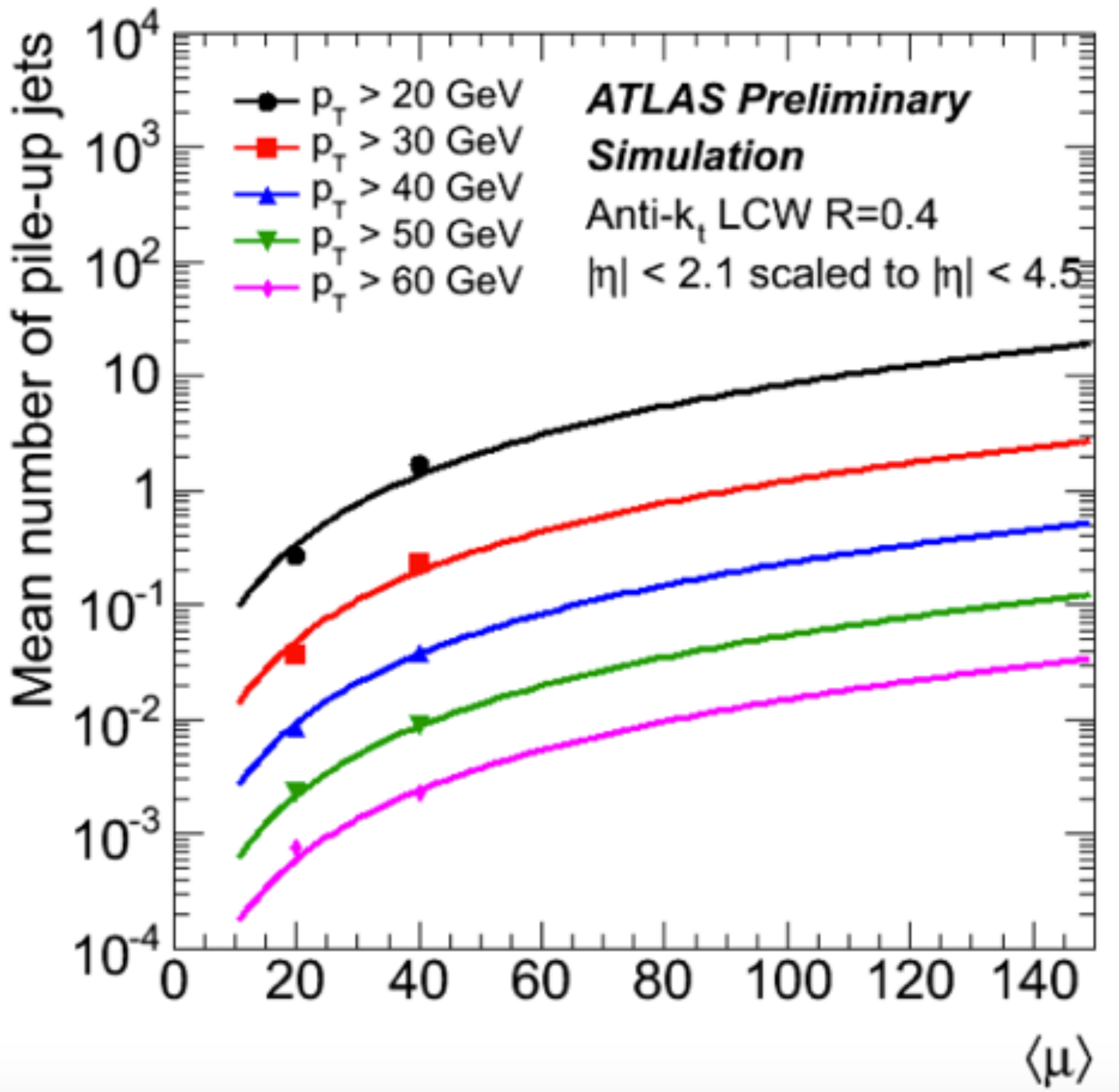






Pile up jets in Run1 vs HL-LHC

ATLAS-PHYS-PUB-2013-004

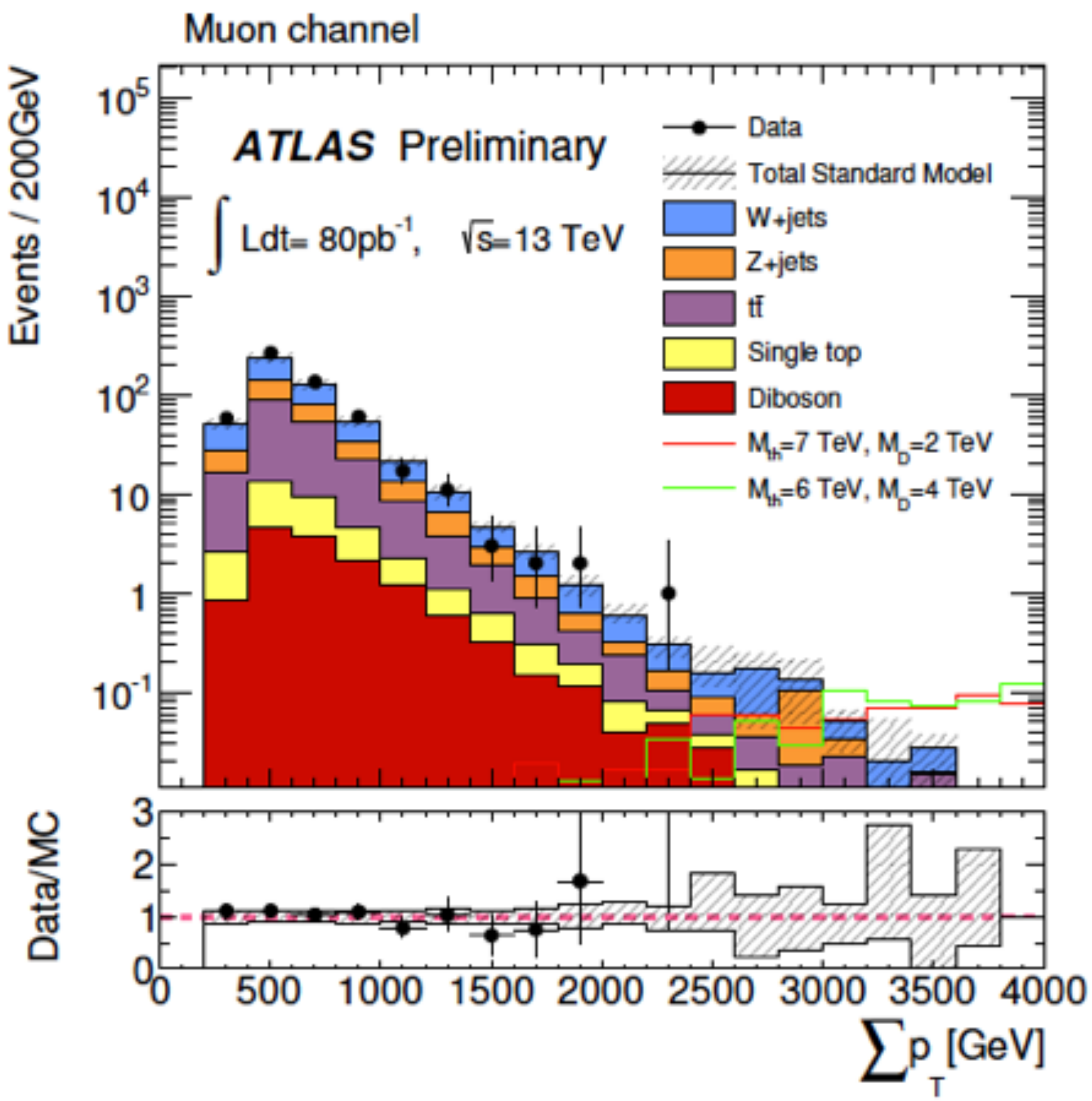


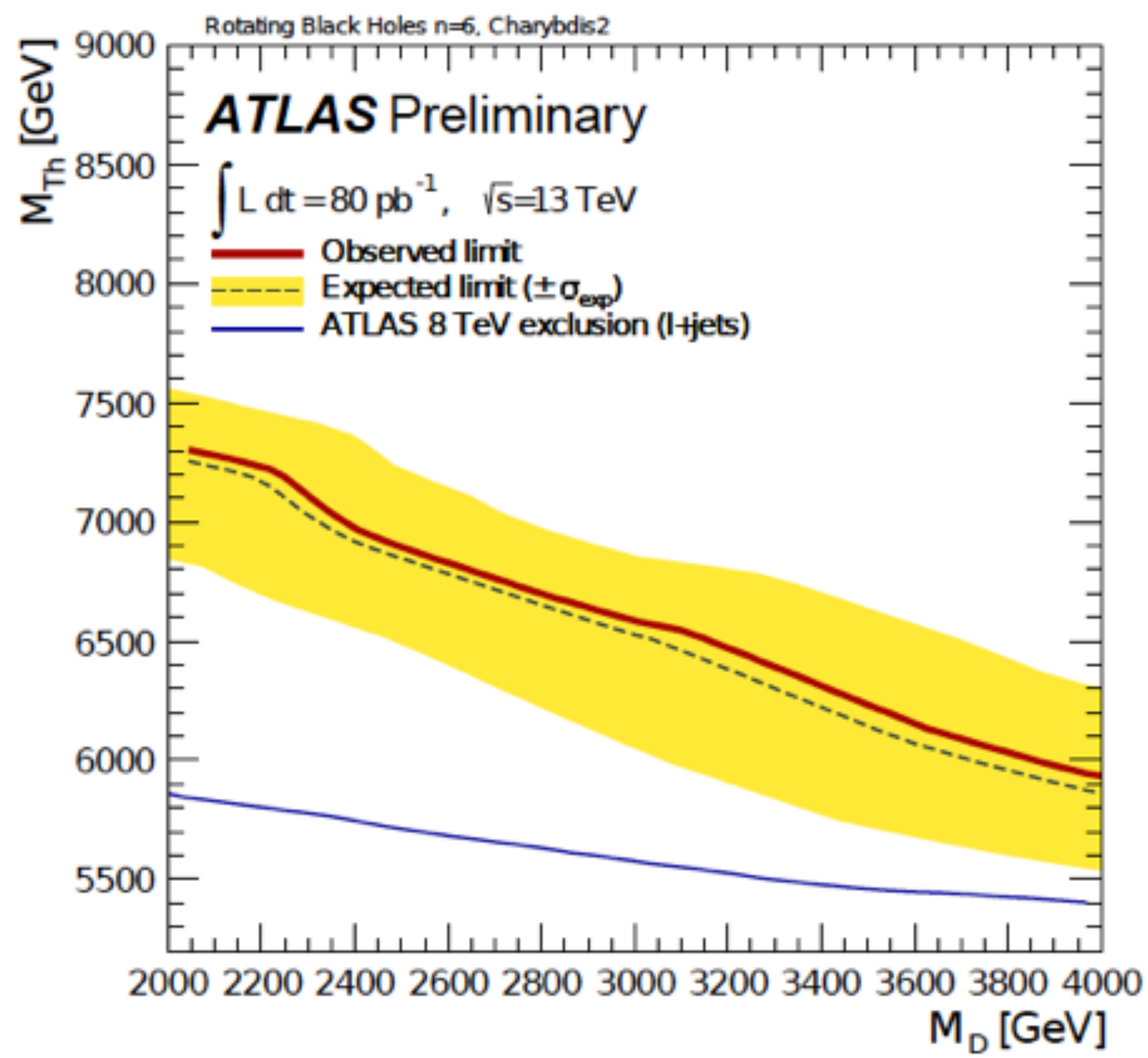
- pile up jet multiplicity in Run1 and HL-LHC conditions:
  - $<\mu>$ = 20 for p_{Tj} > 30 GeV ... $<n_j^{PU}>$ ~0.04
  - $<\mu>$ = 200 for p_T > 30 GeV ... $<n_j^{PU}>$ ~7.4

Lepton+jet searches

ATLAS-CONF-2015-046

- single lepton trigger p_T > 50 GeV
- SRs: p_{Tl} > 100 GeV + additional l/j with p_T > 100 GeV, $\sum p_T$ > 2 TeV/3TeV
- bkg: W+j, Z+j, ttbar -> CRs





no evidence for deviations from SM was observed