ATLAS Status

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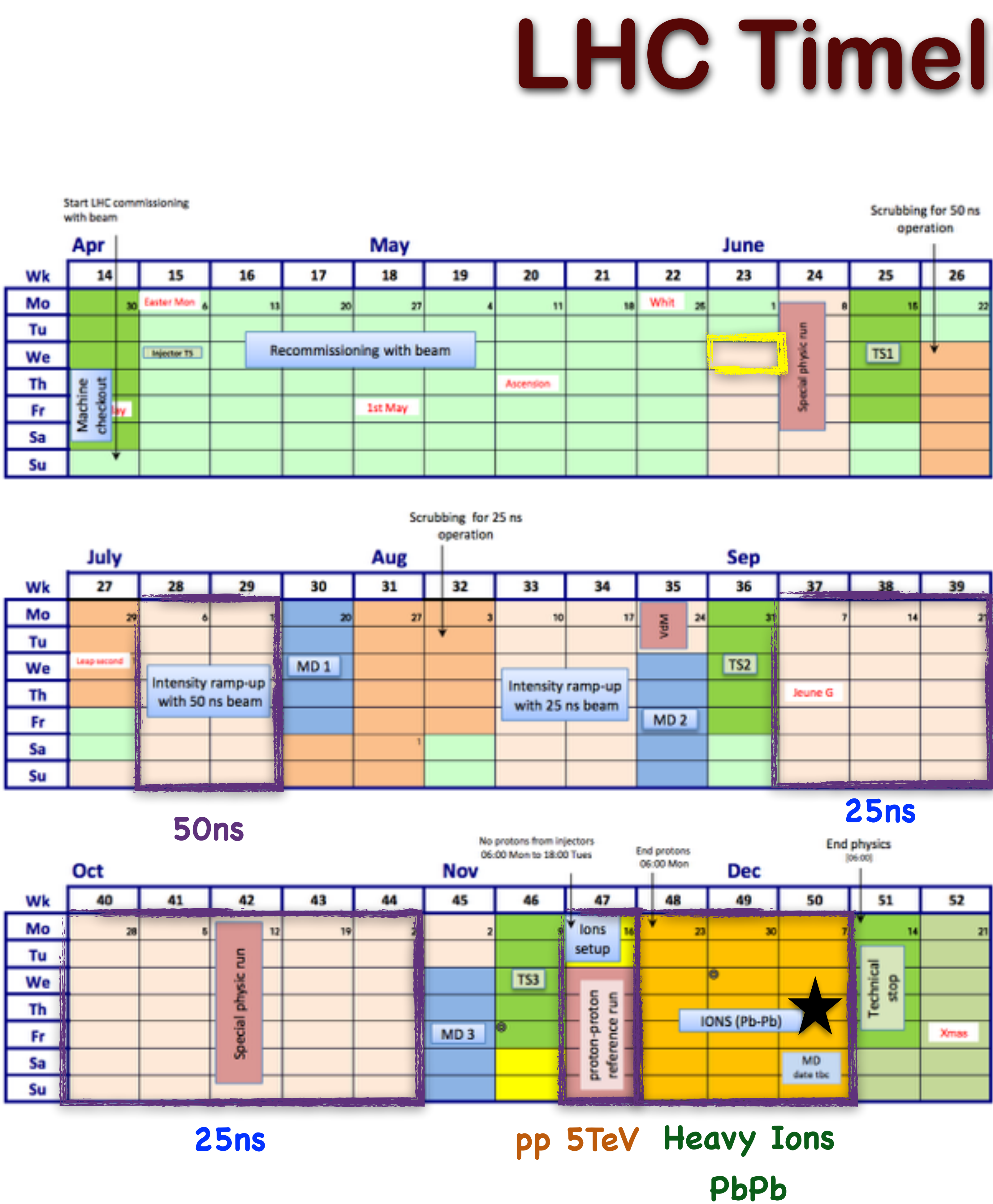
University of California Irvine

ATLAS Collaboration

HEPAP Meeting
12.10.2015

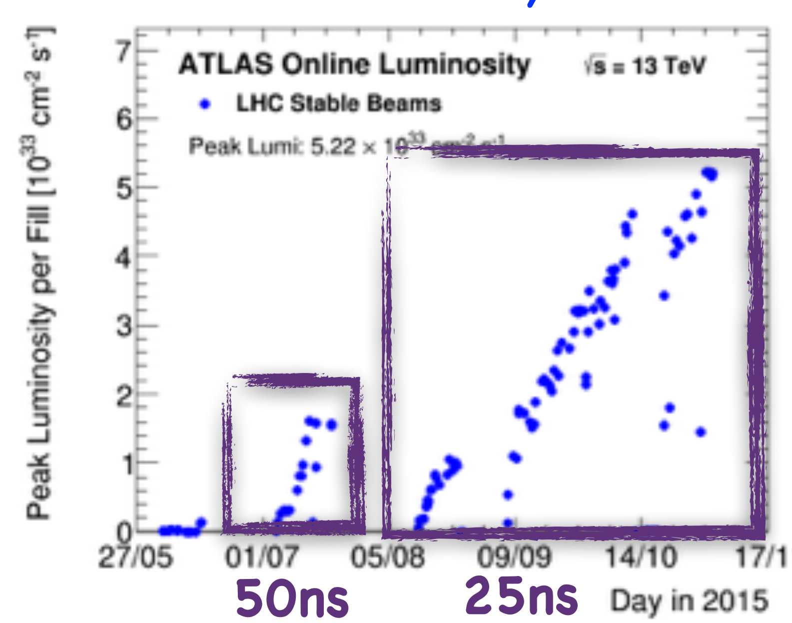
LHC Timeline



Diverse running conditions

- 13 TeV 50ns & 25ns collisions
  - Ramp up from few up to 2400 bunches
- pp reference $\sqrt{s}$=5.02 TeV
- Heavy Ions $\sqrt{s_{NN}}$=5.02 TeV

Peak Luminosity vs time



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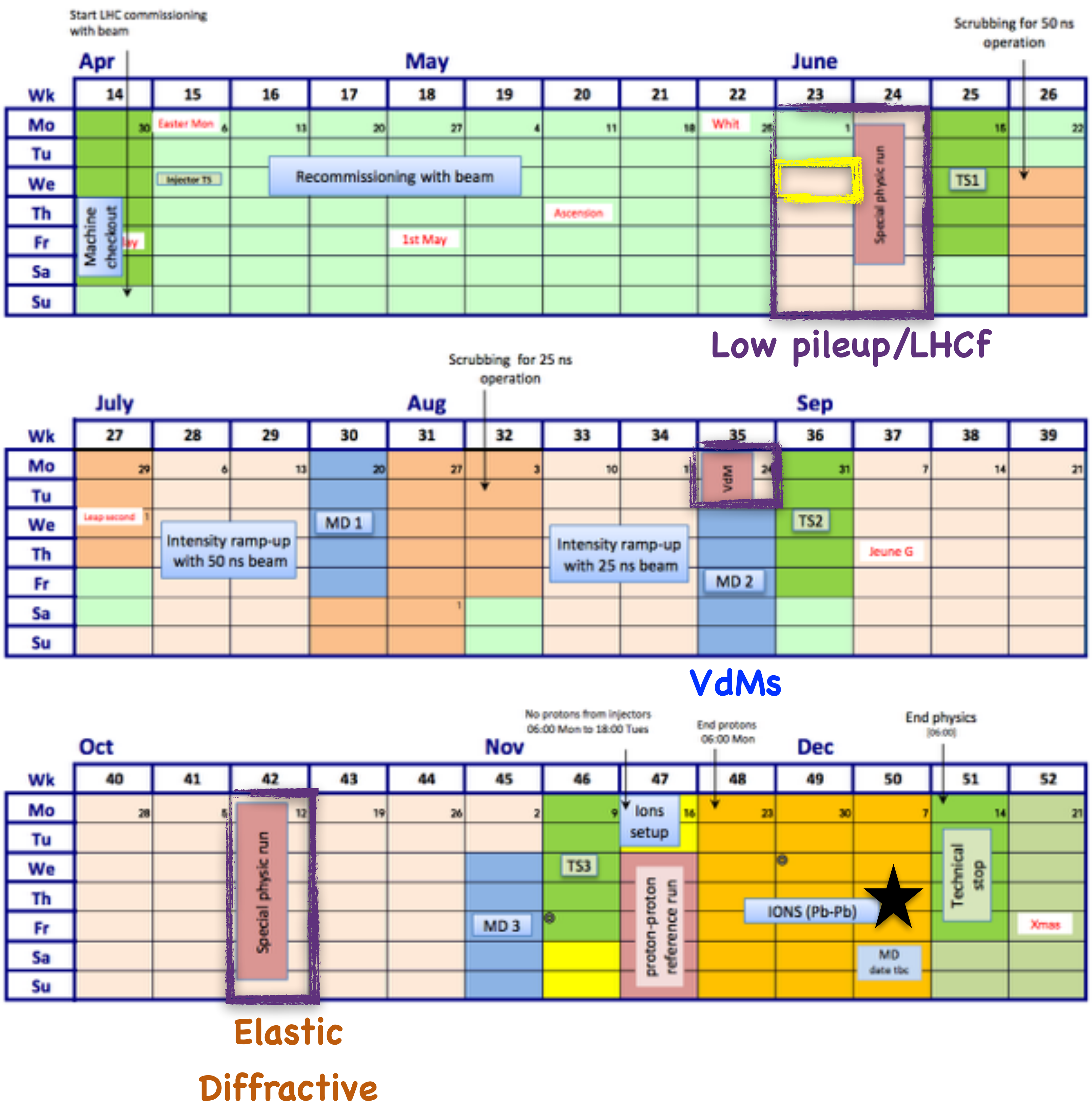

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- Low pileup runs (low μ)
- Special combined trigger/running with LHCf
- VdMs scans
- Elastic and diffractive running with ALFA roman pots

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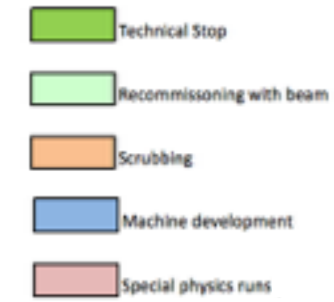

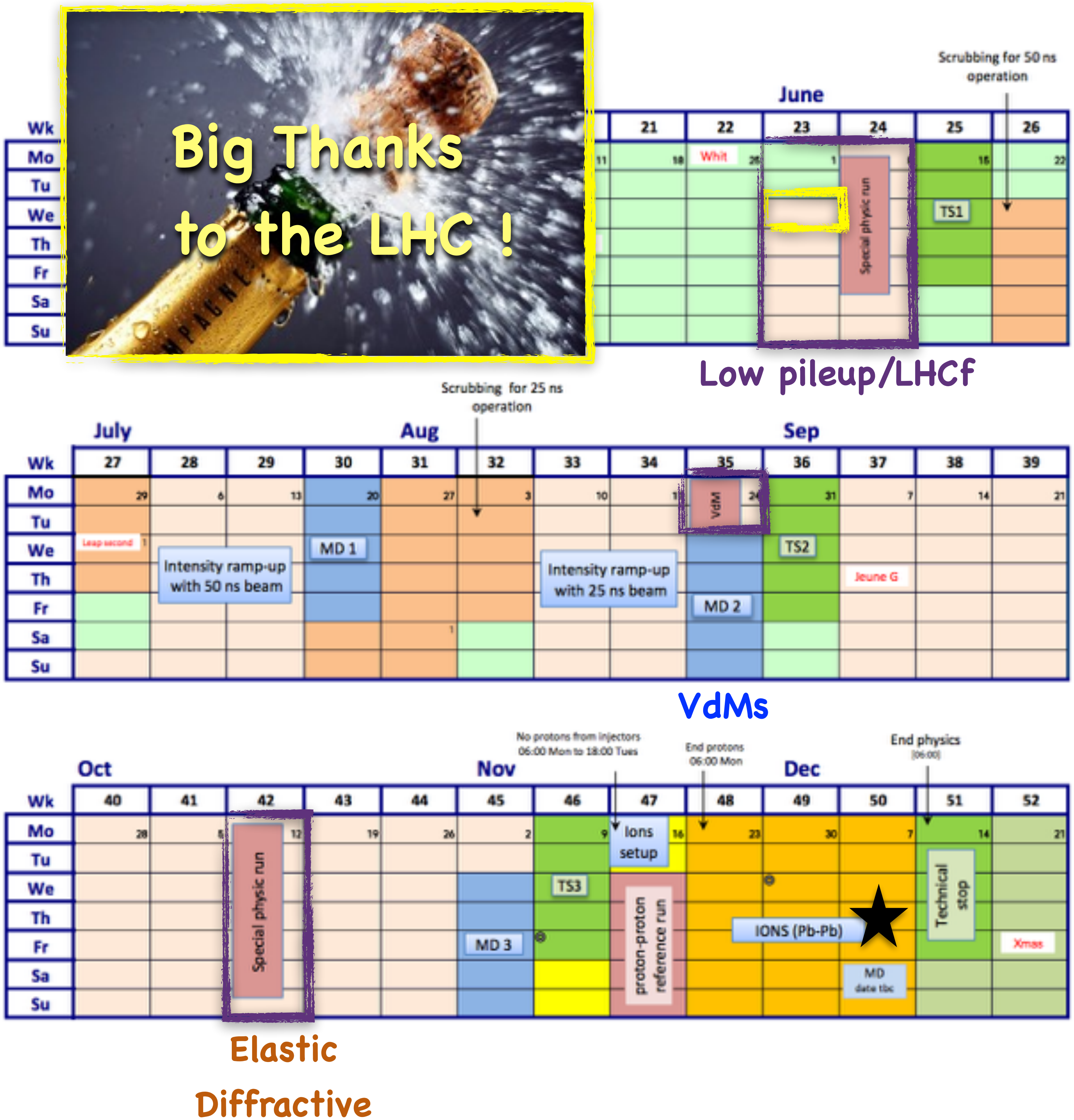

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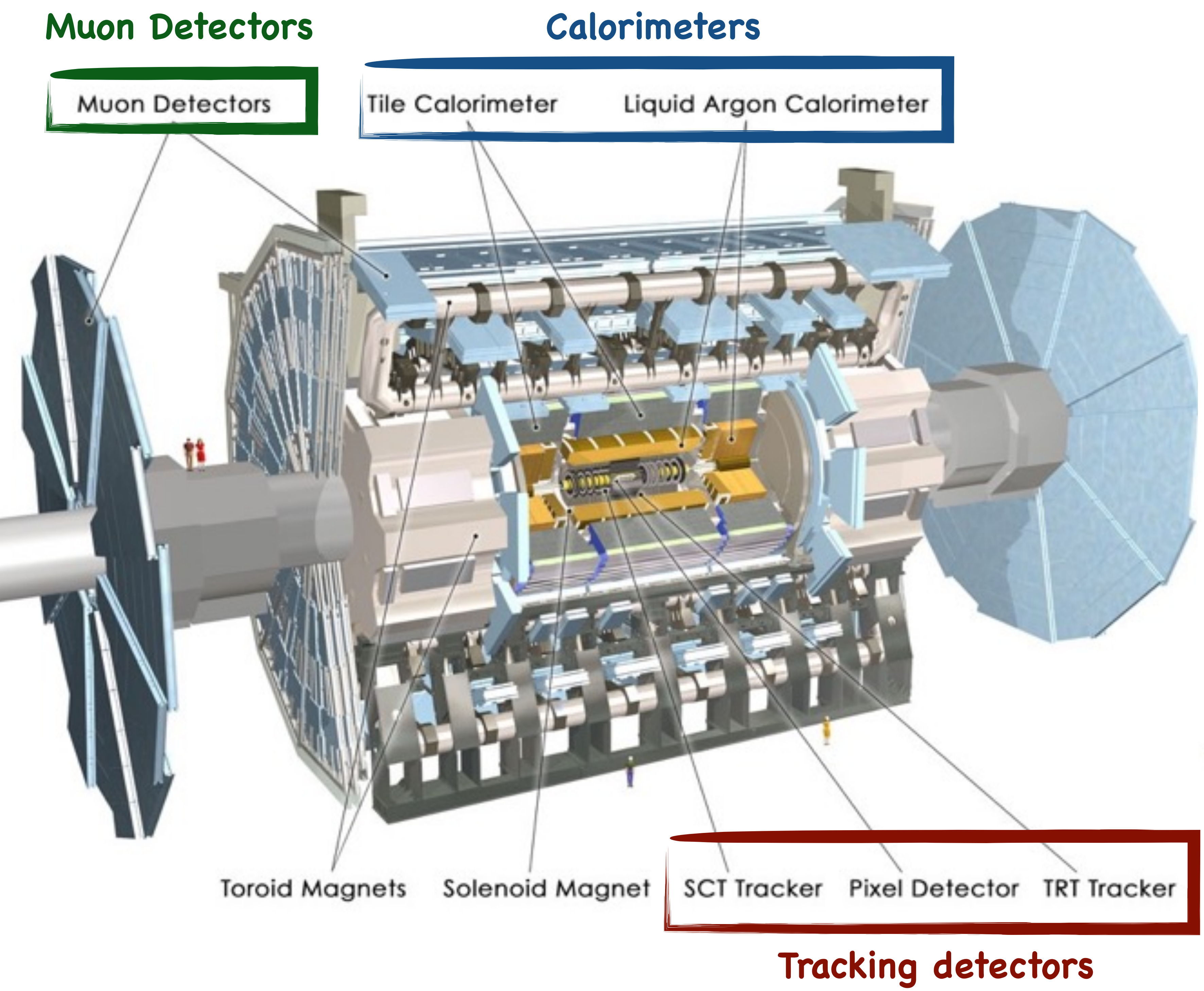
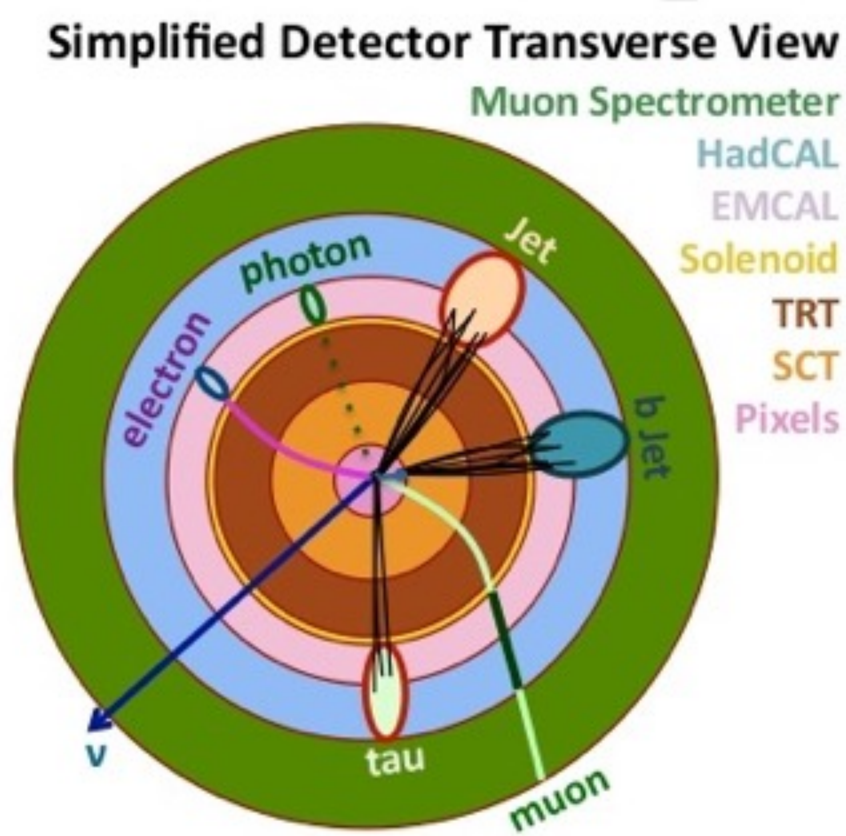
The ATLAS Detector



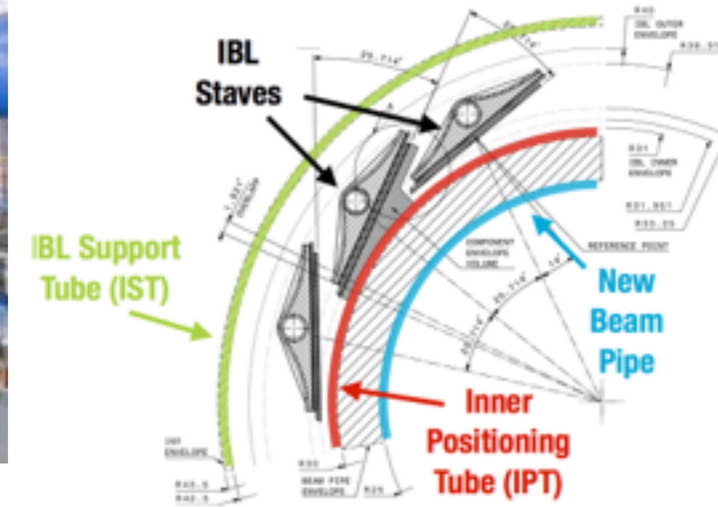


- ✓ High precision silicon and micro-tube tracking
- ✓ Fine-granularity, longitudinally segment calorimeter
- ✓ Air-core toroid muon spectrometer

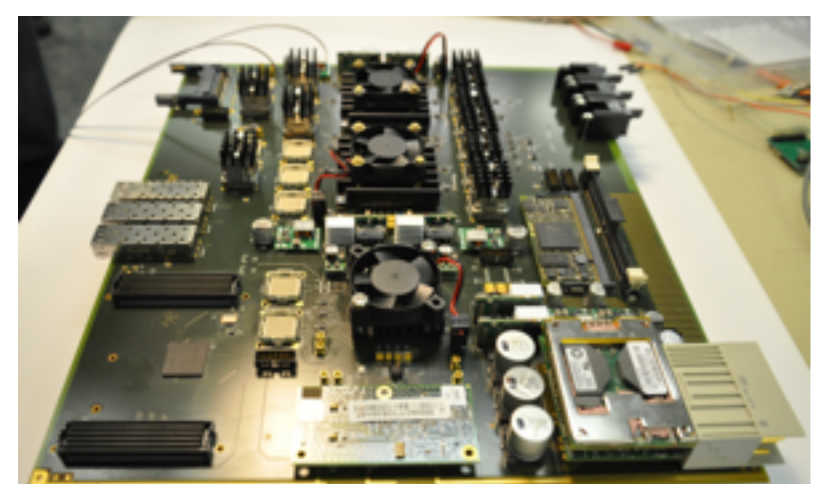
ATLAS Upgrades During LS1

- **Infrastructure:**
  New beam pipe, improvement to magnet & cryogenic system
- **Detector consolidation:**
  Completion ($|\eta|$=1.1-1.3) and repairs of muon chambers. Repair of pixel modules and calorimeter electronics. New pixel services. New luminosity detector (LUCID). New MBTS detector.
- **Insertable 4th pixel layer (IBL):**
  New innermost pixel layer at R=3.3cm from beam.
- **Various trigger upgrades:**
  To improve triggering capabilities and trigger purity (eg topological trigger)
- **Software:**
  Many improvements to simulation, reconstruction, grid and analysis software.

TGC final layer

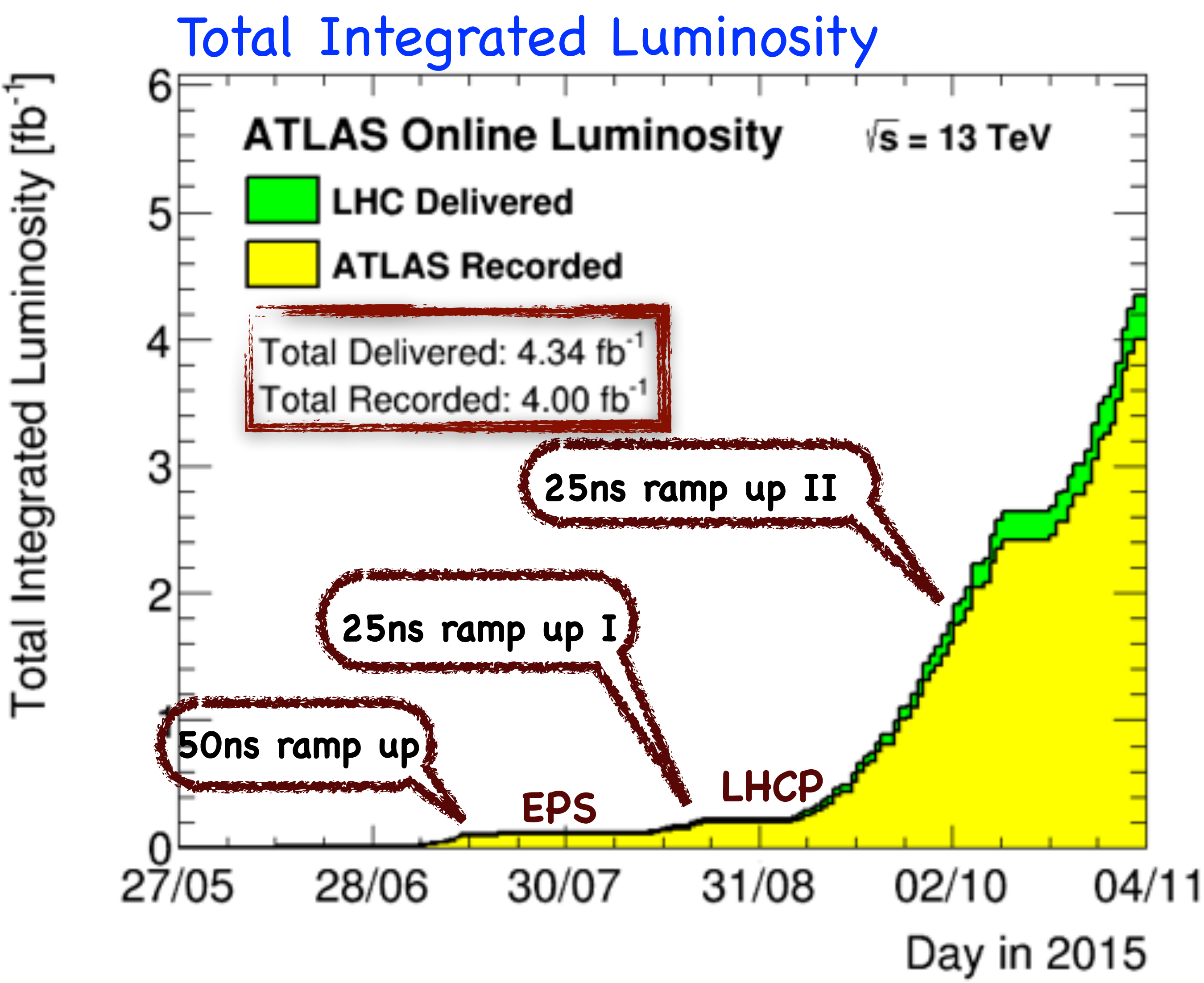


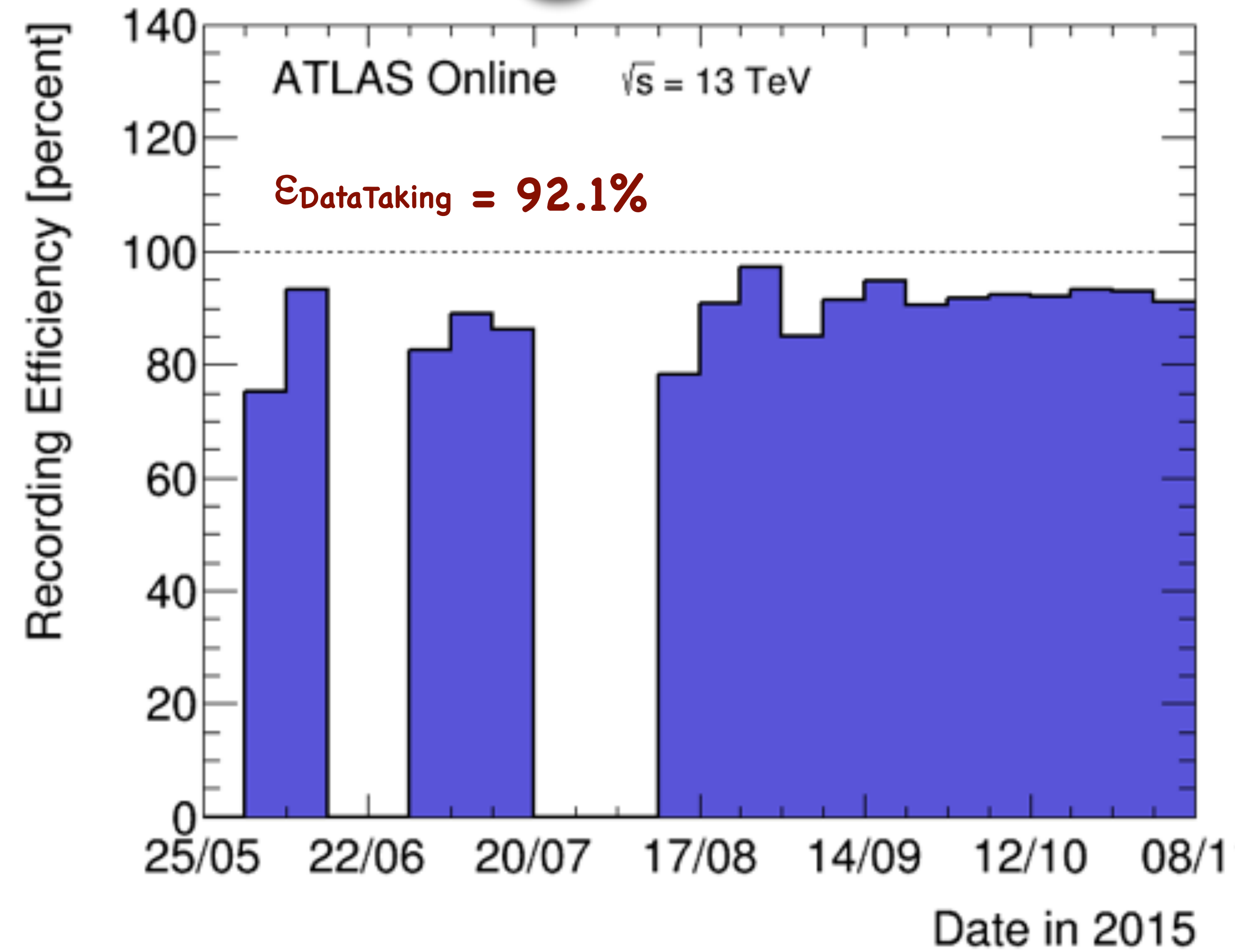
IBL insertion May 2014



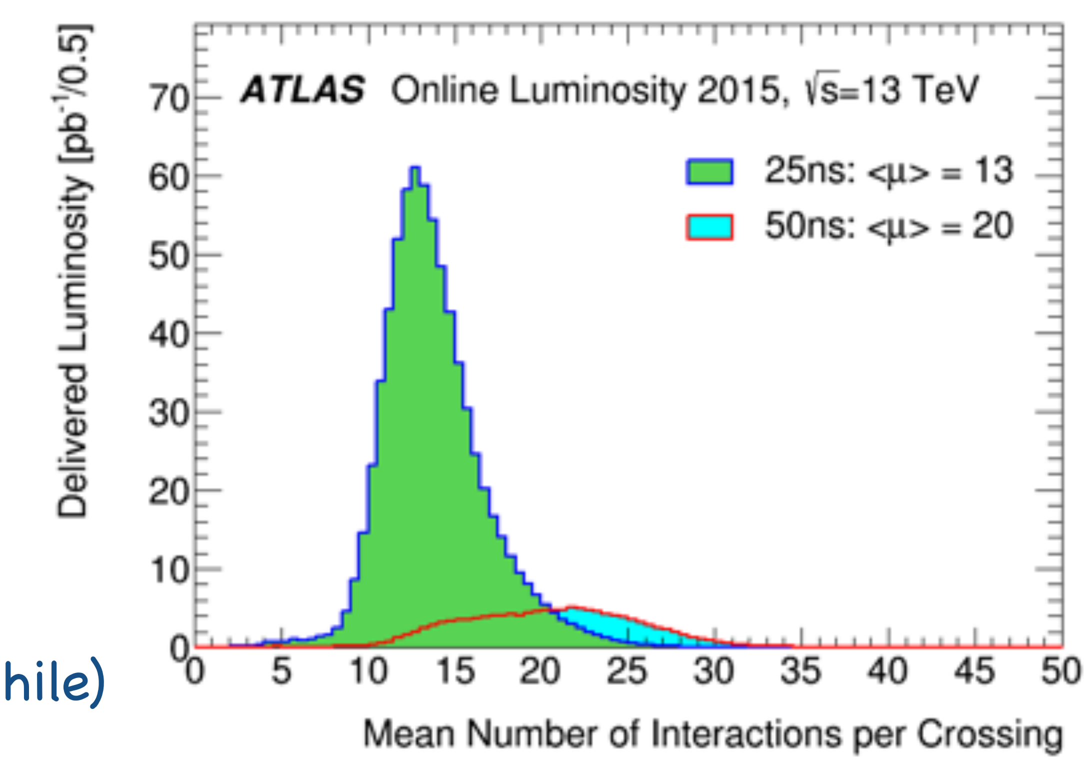
L1 Topo board

2015 Data Taking





- EPS and LHCP datasets ~100 pb^{-1} each
- 2015 dataset: 3.2 fb^{-1}
  - $\langle\mu\rangle$ at 25ns slightly lower than Run-1
  - Preliminary luminosity systematics for 2015 data 5%

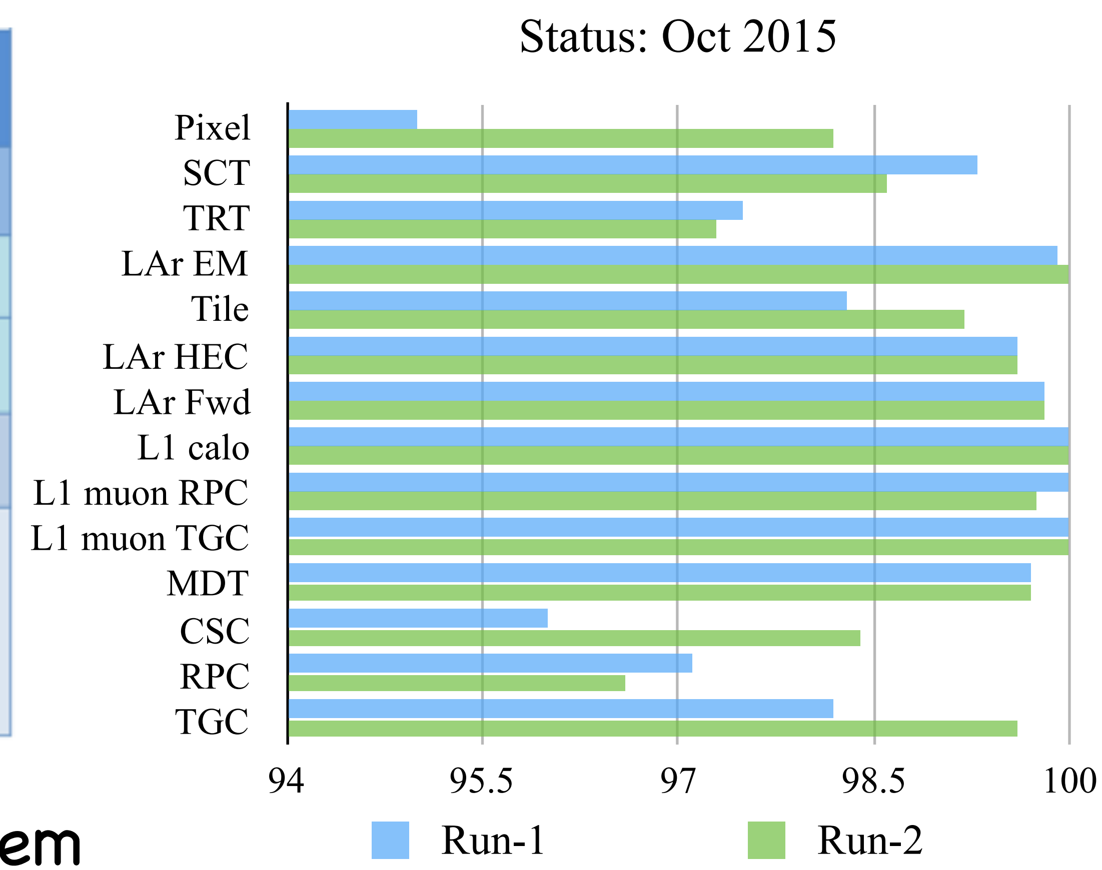


Run-1: 1.8% for 2011 and 1.9% for 2012 (but it took a while)

ATLAS Detector in 2015

ATLAS pp 25ns run: August-November 2015										
Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
93.5	99.4	98.3	99.4	100	100	100	100	100	100	97.8
All Good for physics: 87.1% (3.2 fb^{-1})										

Luminosity weighted relative detector uptime and good data quality (DQ) efficiencies (in %) during stable beam in pp collisions with 25ns bunch spacing at $\sqrt{s}$=13 TeV between August-November 2015, corresponding to an integrated luminosity of 3.7 fb^{-1}. The lower DQ efficiency in the Pixel detector is due to the IBL being turned off for two runs, corresponding to 0.2 fb^{-1}. Analyses that don't rely on the IBL can use those runs and thus use 3.4 fb^{-1} with a corresponding DQ efficiency of 93.1%.



More than 96% of channels working in each system

Significant improvements w.r.t Run-1 in most systems

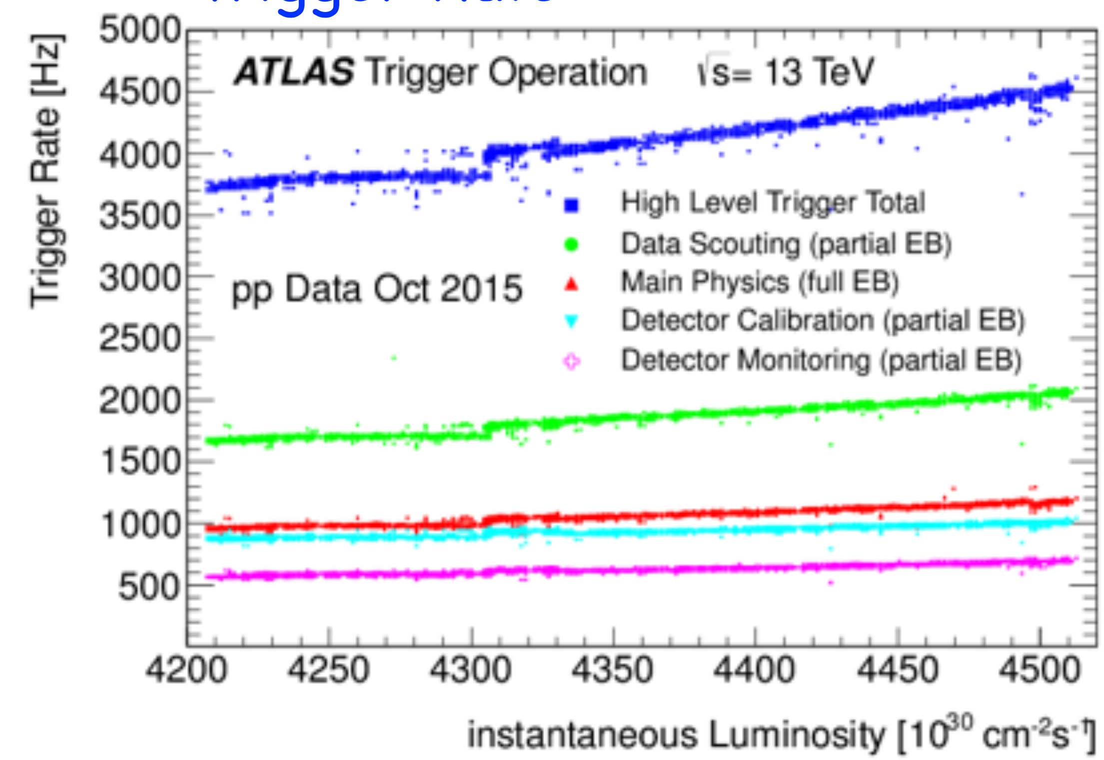
Overall good data taking efficiency for 25ns

- 87.1%
- 93.1% for analyses not relying on IBL

Learnt to operate new detector

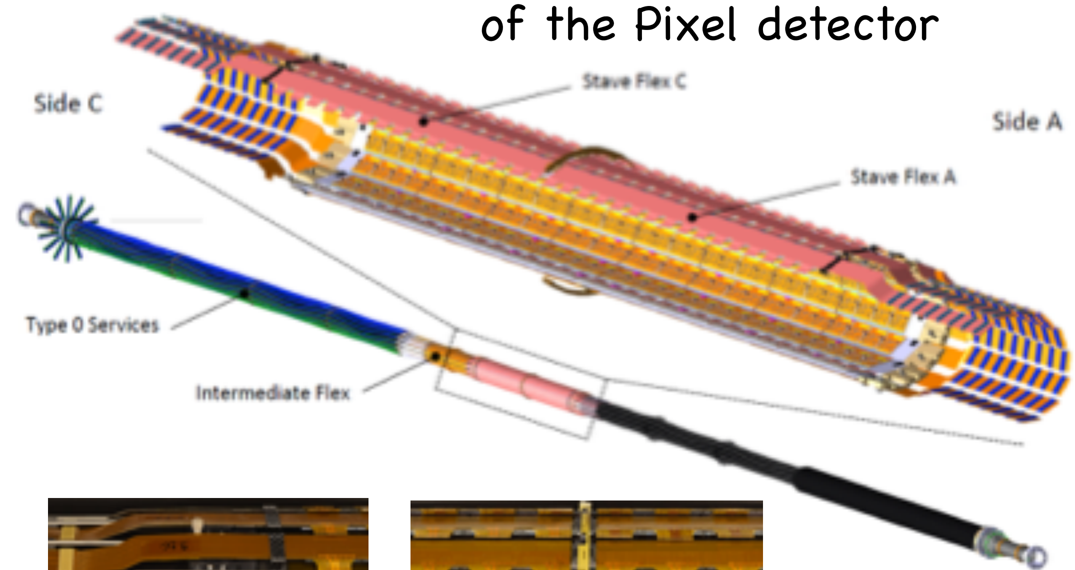
Monitoring and adjusting trigger following the LHC intensity ramp up

Trigger Rate



Inner Detector

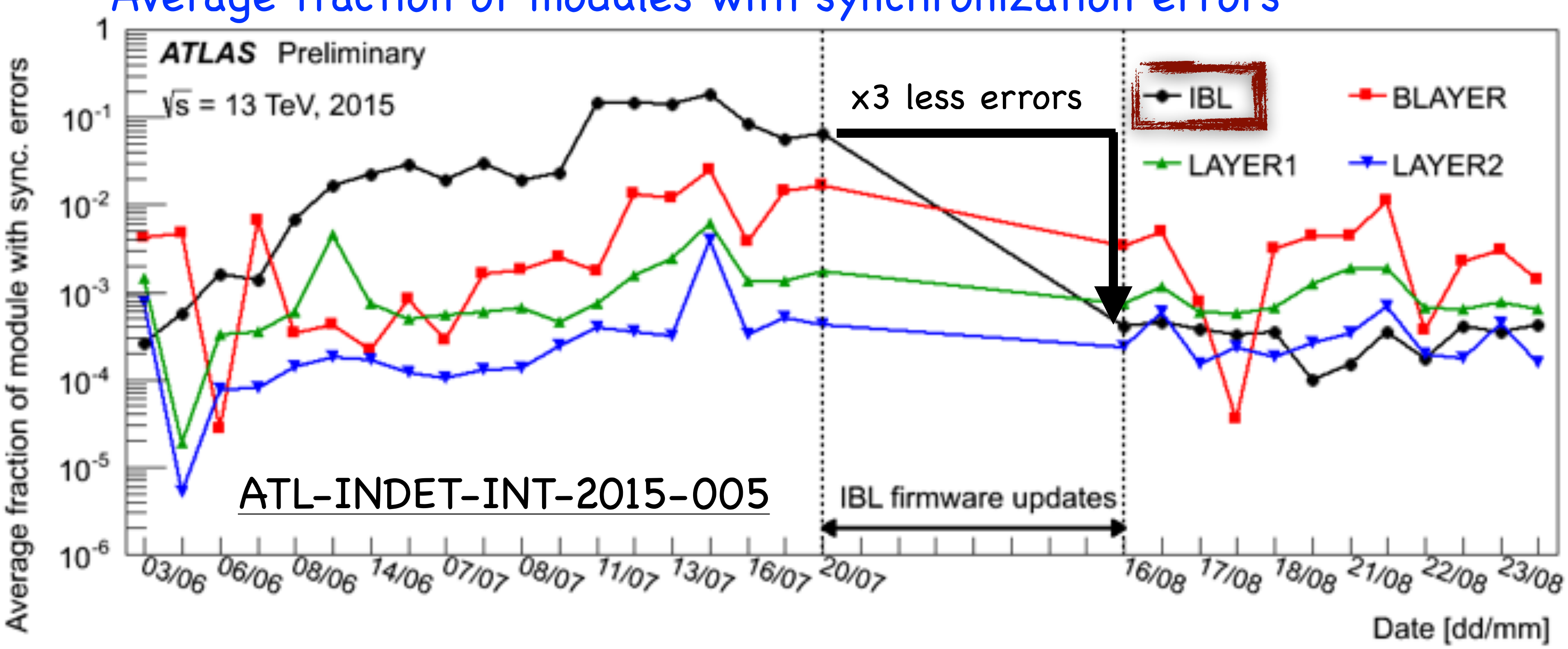
IBL: the 4th and innermost layer of the Pixel detector



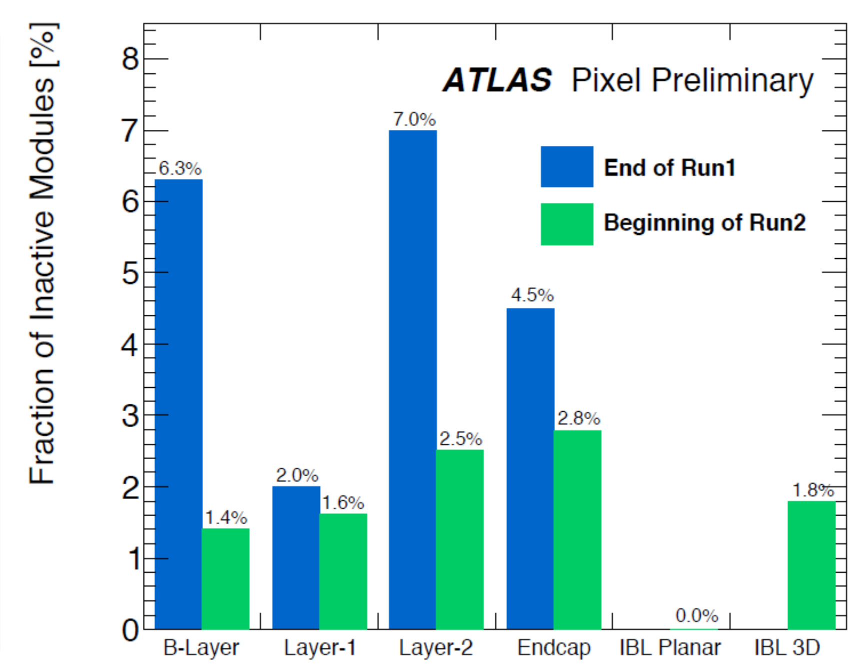
Pixel and IBL operational since Week 1

- **Significant improvement of the performance of the Pixel thanks to firmware upgrades**
  - Operational stability thanks to firmware upgrades (3 order of magnitude less errors)
  - Larger faction of active modules

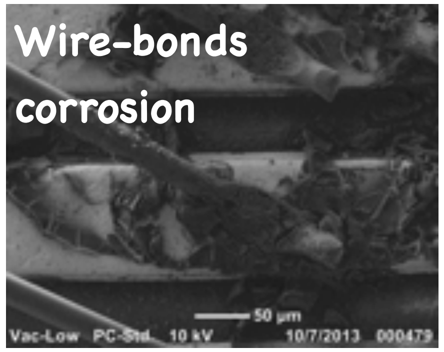
Average fraction of modules with synchronization errors



Fraction of inactive modules



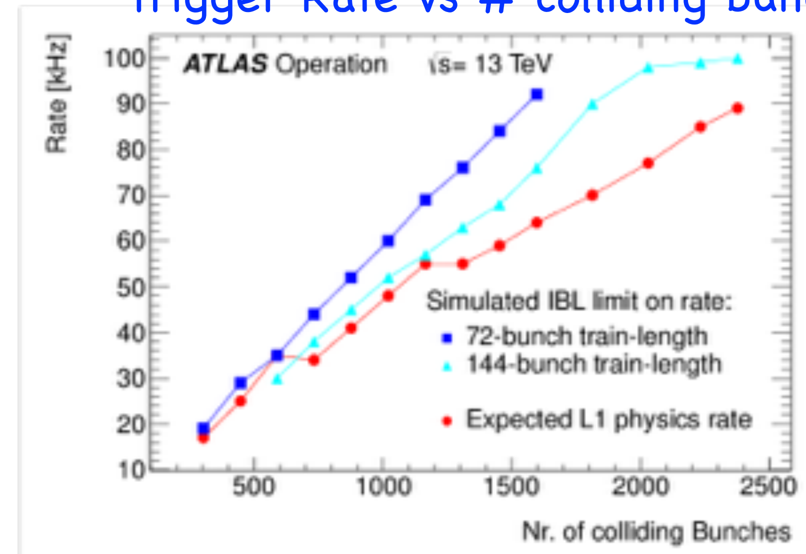
IBL



Corrosion

- Fixed before installation

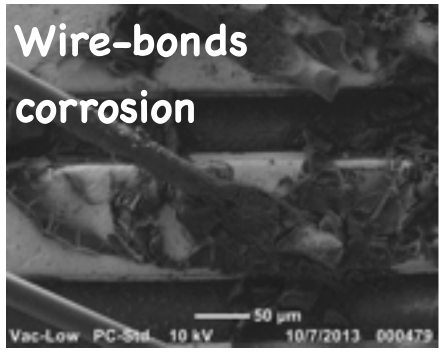
Trigger Rate vs # colliding bunches



Wire bond resonance danger

- Careful trigger rate optimization for partially filled machine to avoid fixed frequency trigger

IBL



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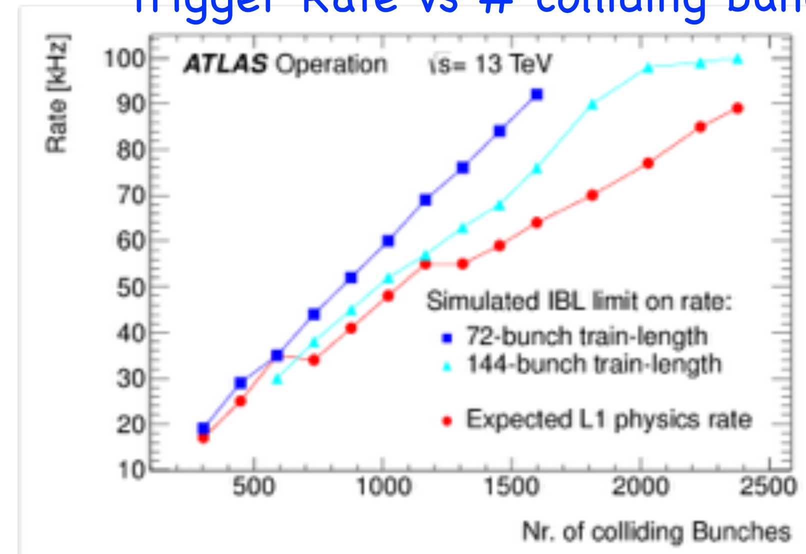
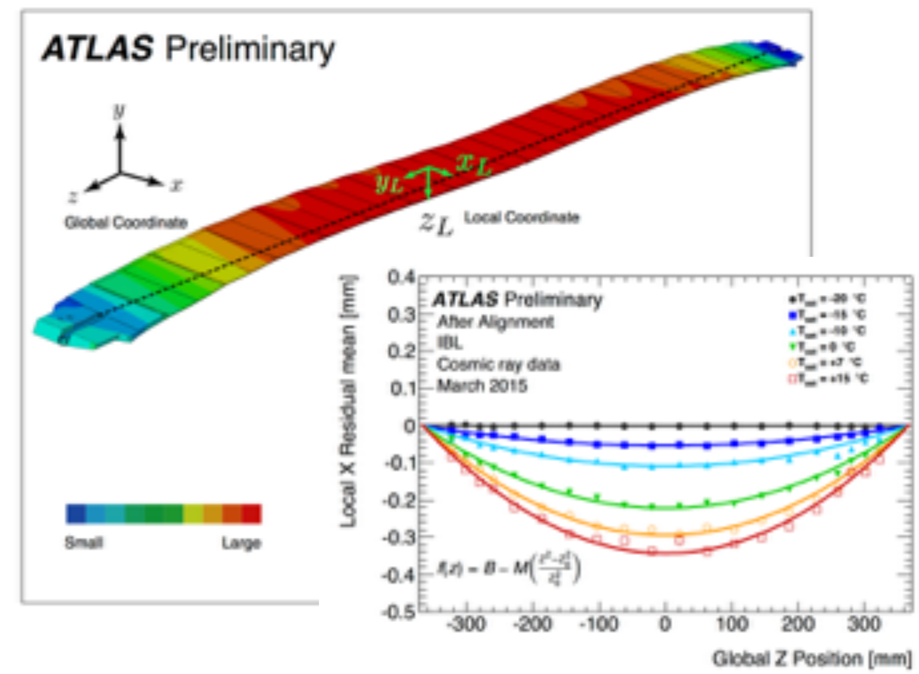
Stave bowing

- Discovered with cosmic ray alignment
- Direct impact on tracking performance
- Run by run alignment correction necessary to recover the physics performances.
- Temperature and cooling stability OK until September

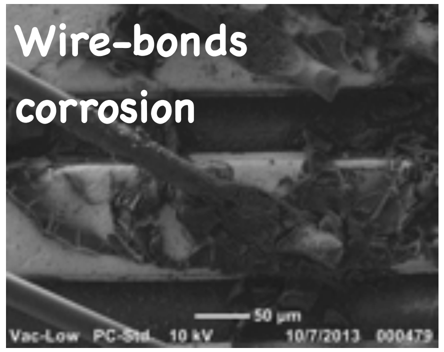
Trigger Rate vs # colliding bunches



ATL-INDET-PUB-2015-001



IBL



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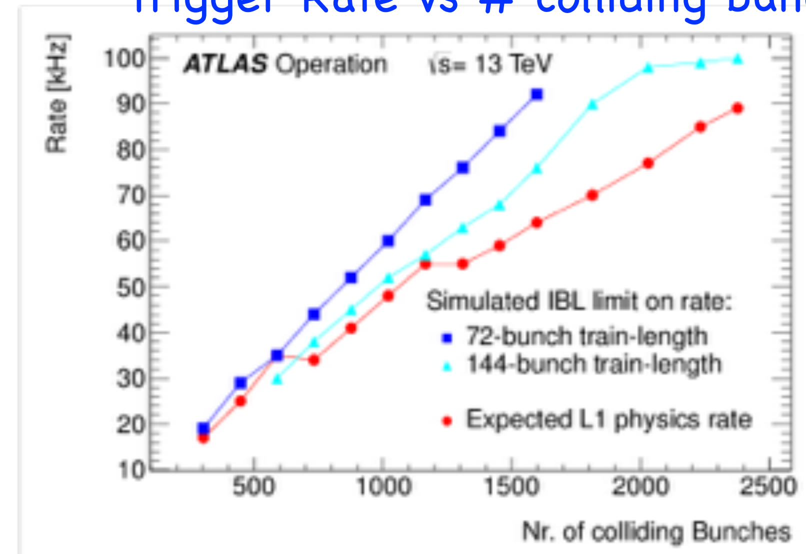
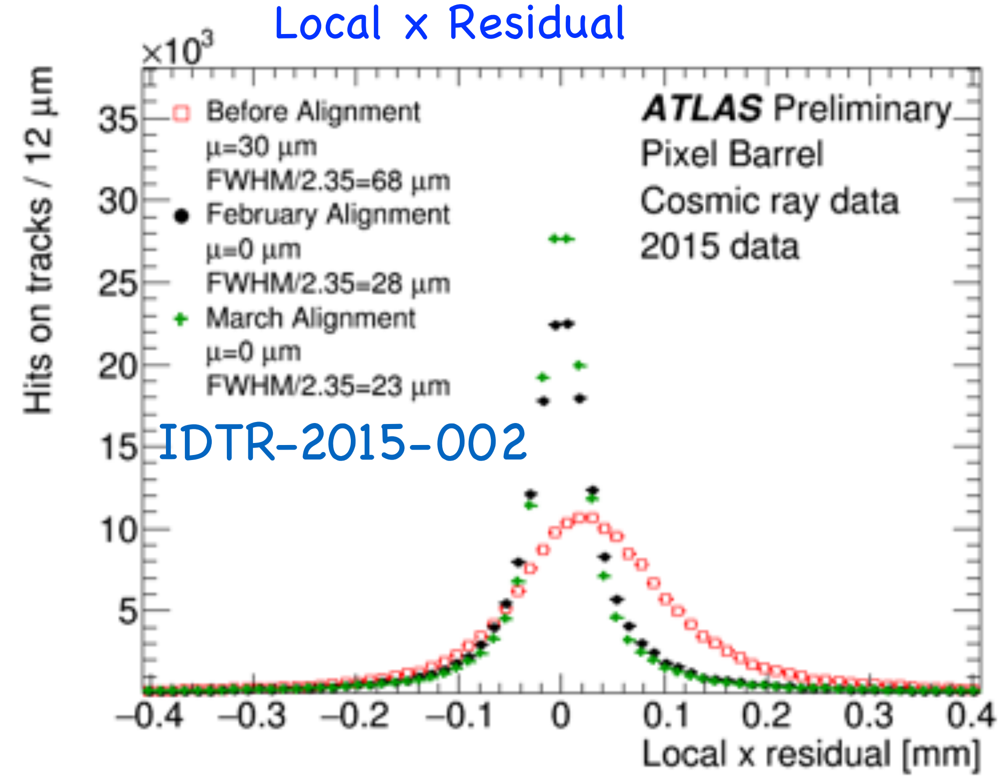
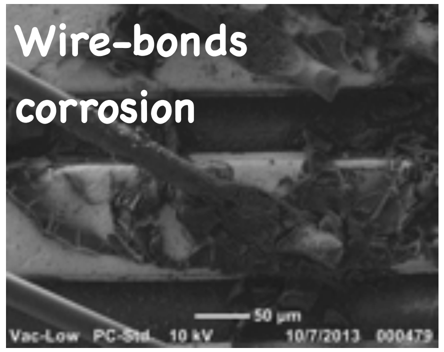


Local x Residual



IBL



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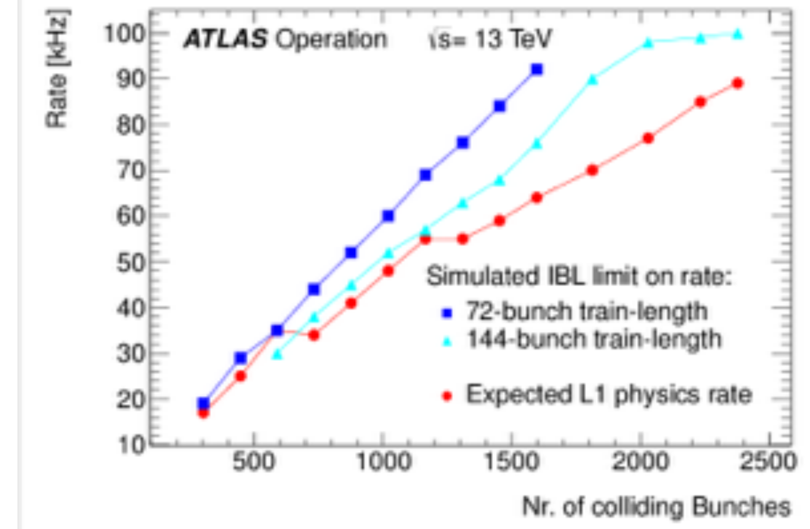
Low Voltage Front End current drift

- Observed drift of IBL calibration parameters and low voltage current consumption with increasing integrated luminosity

Trigger Rate vs # colliding bunches



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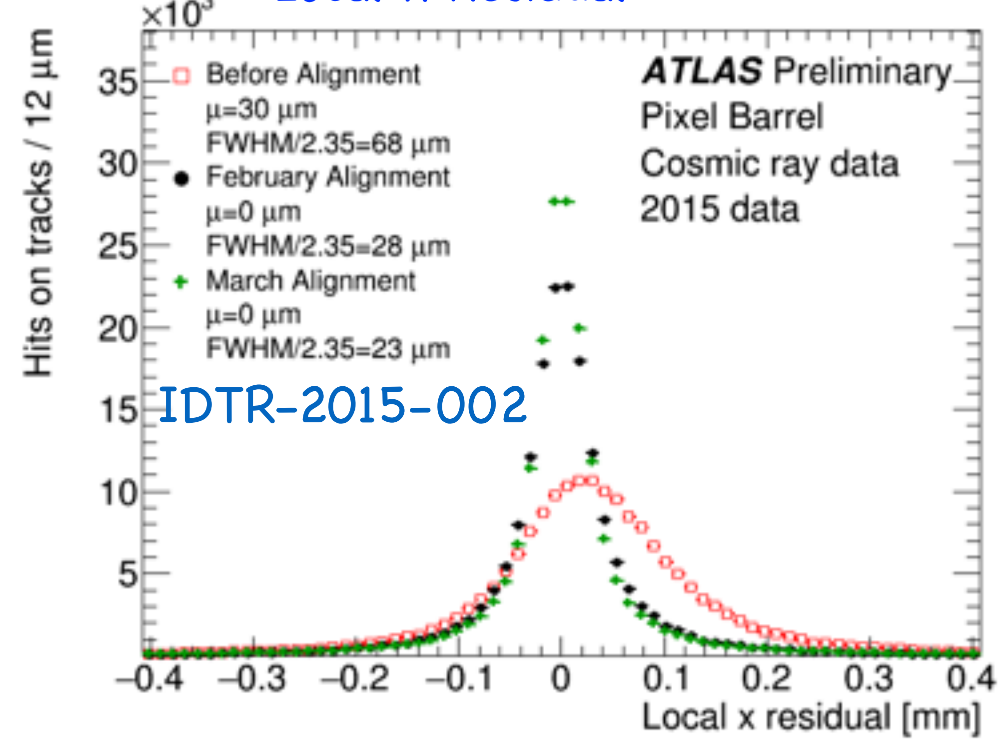
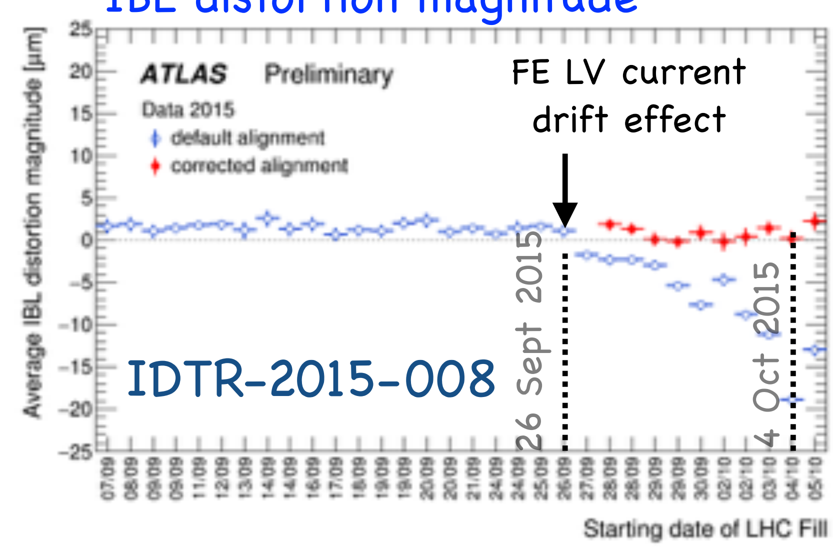


IBL distortion magnitude

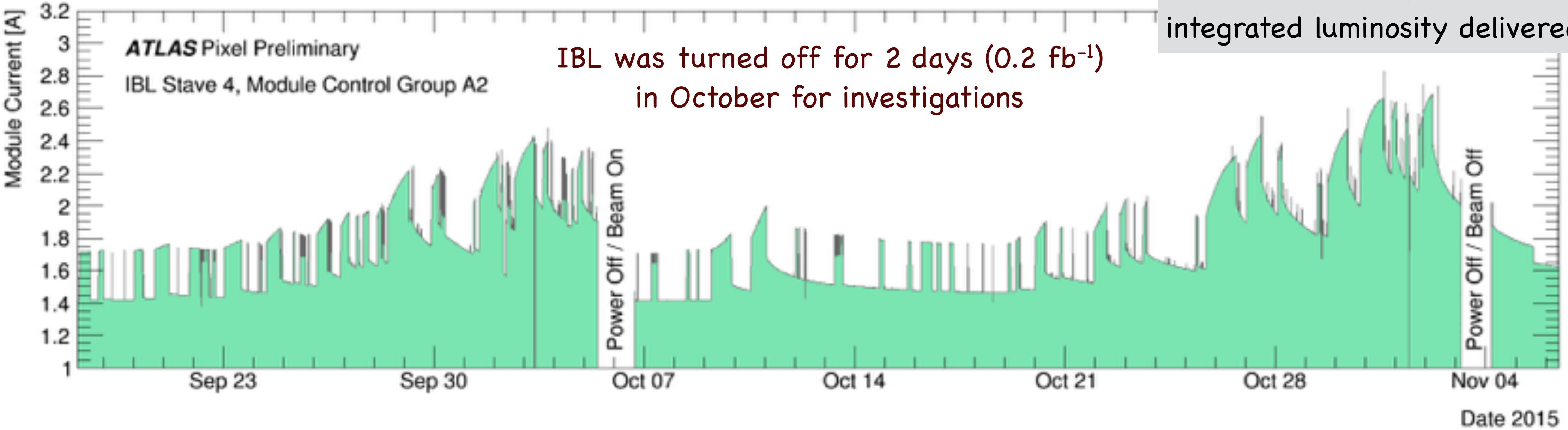


IBL: LV Front End current drift

Module current

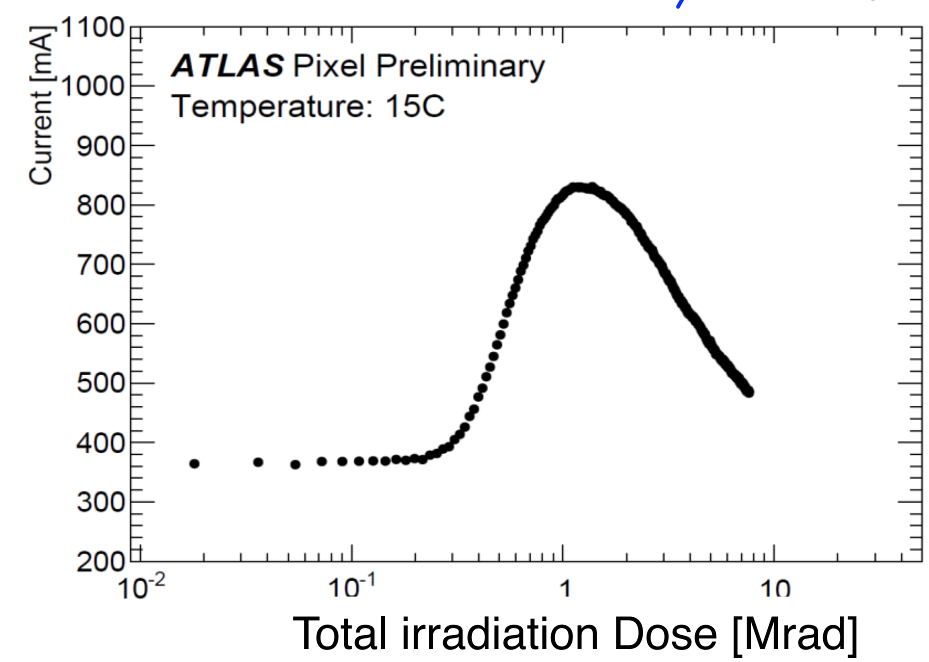
ATL-INDET-PUB-2015-002

~1.3 Mrad for 4.3/fb^{-1} of integrated luminosity delivered

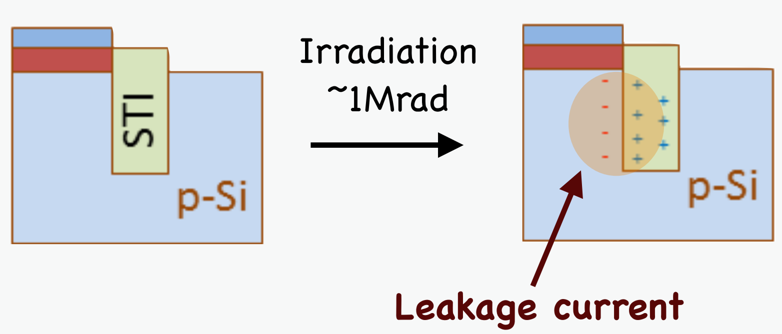


- **Effect understood to be a Front End transistors leakage due to defects built-up at the Silicon Oxide (STI) interface and cumulated by ionizing dose**
  - Known features but not tagged during construction
  - Almost invisible at low dose rate
- **Lab investigations are on-going for next year operation**

Lab measurement – FE X-ray irradiation



N-MOS transistor cross-section

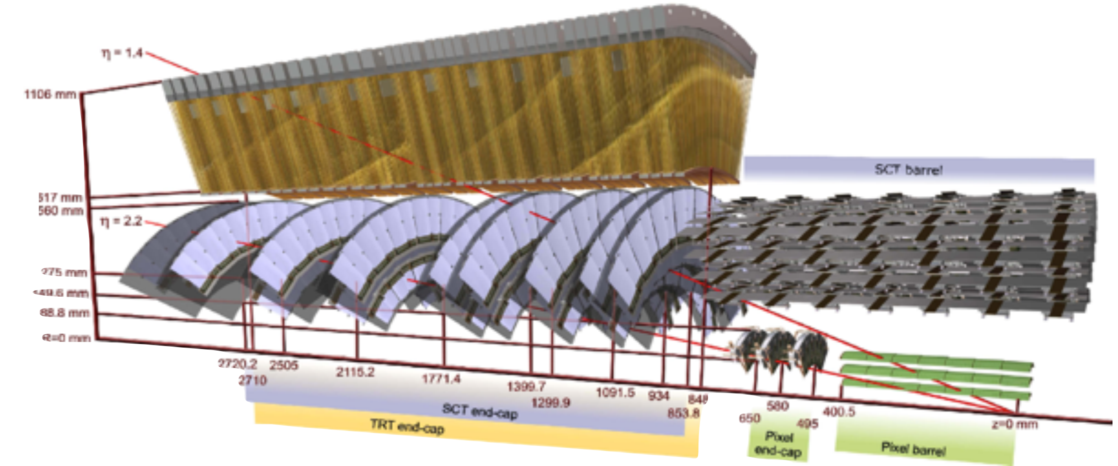


Consequences

- Temperature increase
- Electrical failure risks

Issue expected to be relaxed after few Mrad

SCT & TRT

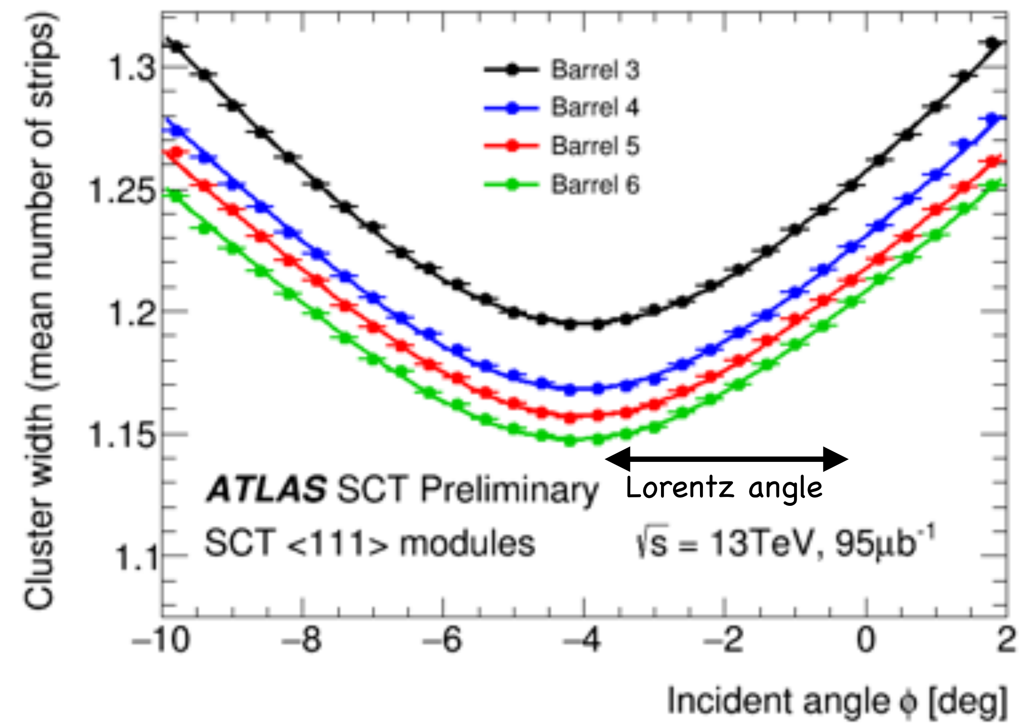


Stable and reliable throughout 2015

SCT

- Si leakage currents continue to closely match expectations from radiation damage
- Noise, gain and operating voltage comparable to Run-1
- Some minor DQ and data taking inefficiency due to ReadOut firmware requiring further tuning

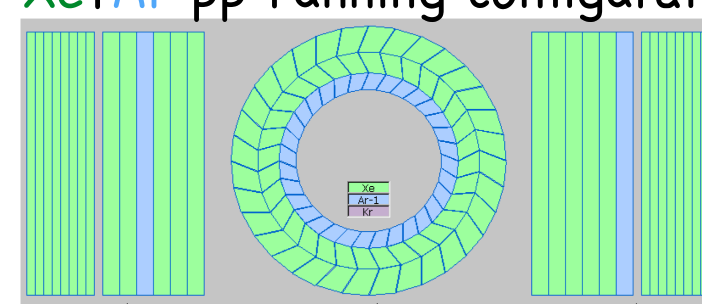
Cluster width SCT-2015-002



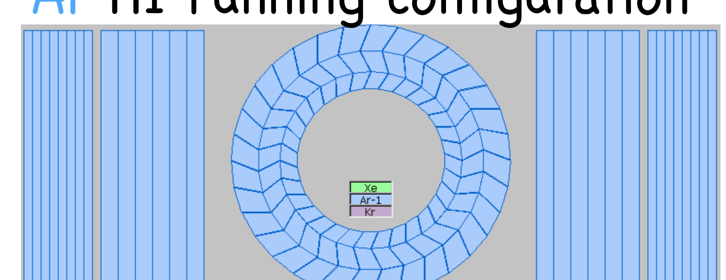
TRT

- Proved to sustain 100kHz limit at 50% occupancy
- Xe gas leak developed in the exhaust active gas pipes (no new ones in Run-2)
  - Losses at the end of pp operation ~150L/day
  - Measures to reduce the Xe leak rate will be taken during Year End Technical Stop
- Scenarios with more modules running with Ar-mixture are under study. Aiming to minimize performance losses.

Xe+Ar pp running configuration



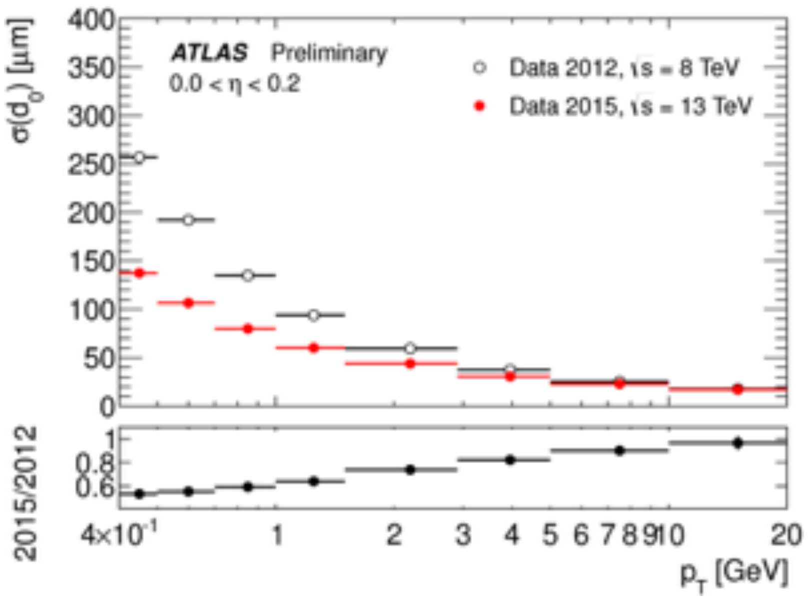
Ar HI running configuration

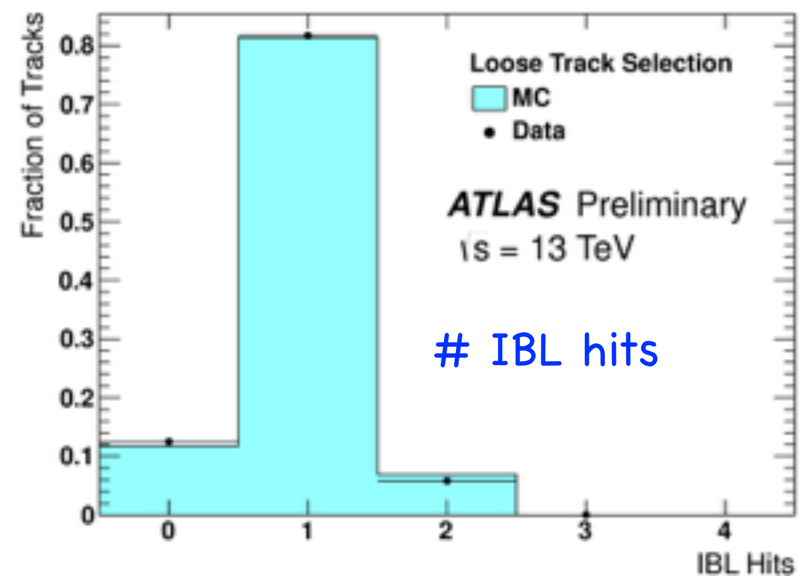


Impact Parameter Resolution

ATL-PHYS-PUB-2015-018

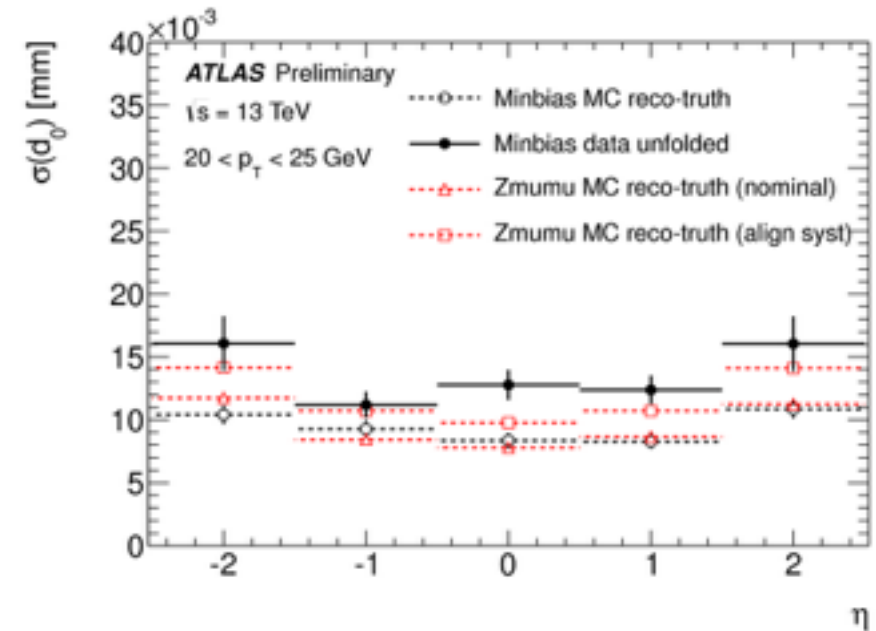
Transverse impact parameter resolutions in 2015 (+IBL) and 2012





ATL-PHYS-PUB-2015-051

Unfolded transverse impact parameter resolution compared to the expectation from minimum bias and $Z \to \mu\mu$ simulation.



- **Large gain in resolution through IBL.**
  Enhance tracking close to interaction point

- **Good agreement between data and MC**
  - d_0, z_0 resolutions in both simulation agree with each other to within 20%

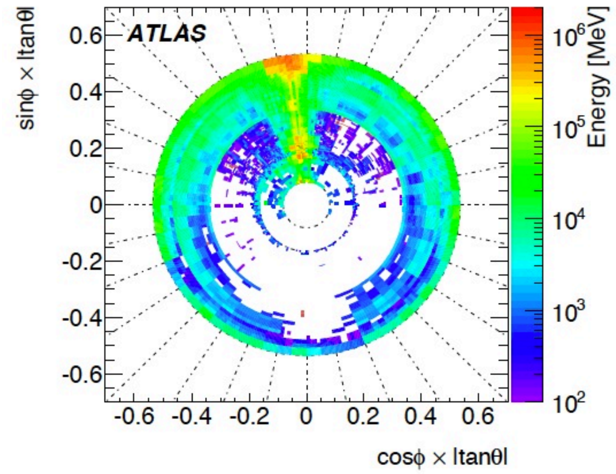
Calorimeters

Very smooth operations throughout 2015

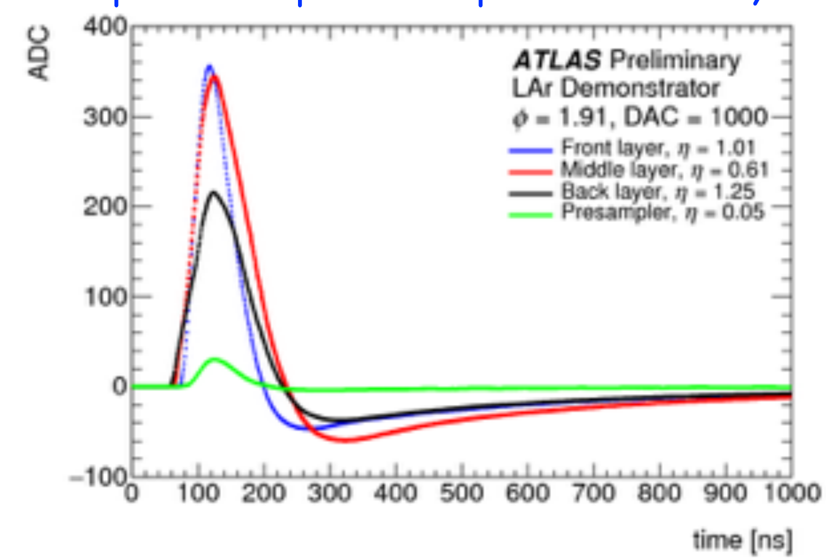
LAr:

- Noise burst flagging running @ HLT level
- New current control HV for EMEC installed during LS1
  - Tremendously reduce HV trip in EMEC.
  - Install new current controlled modules for HEC in YETS[†]
- LAr Phase-I trigger upgrade demonstrator boards installed ($1.767<\varphi<2.160$; $|\eta|<1.4$)
  - Readout implemented this year. Data taking during physics and calibration runs.

LAr noise burst

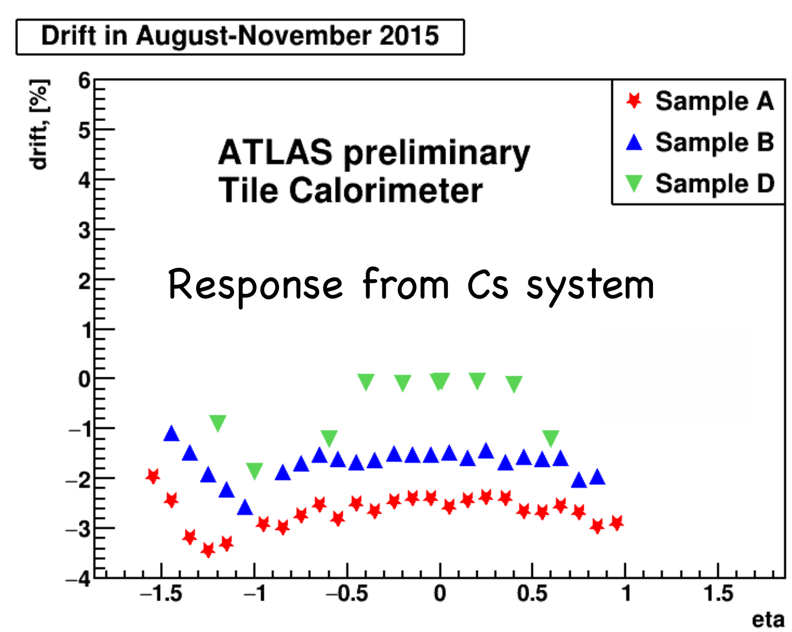


Super cells pulse shape for each layer



Tile:

- No LVPS trips (unlike in Run-1). 2 dead modules
- Using all calibration systems to preserve the scale
- New MBTS counters were inter-calibrated based on the minimum bias current measurement from Tile.
- Commissioning of the Tile-Muon trigger for $1.0<|\eta|<1.3$ is in its final stage

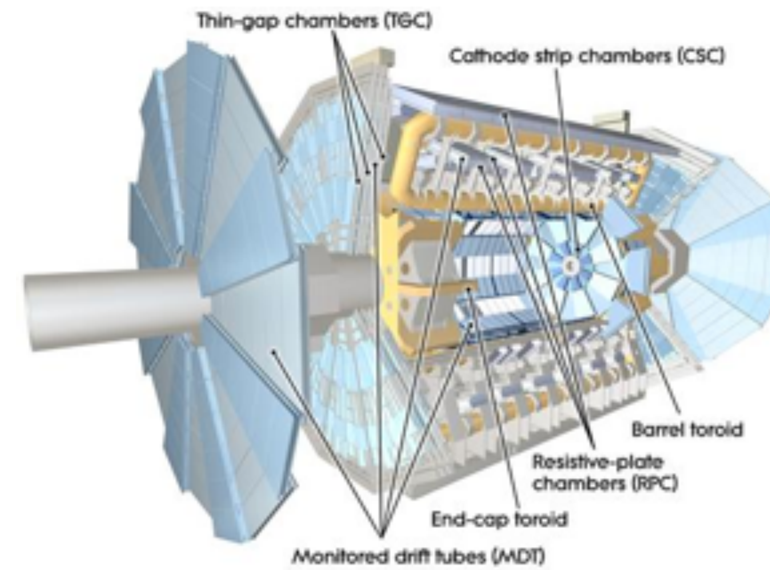


Known drifts from PMTs under illumination. Recovery when there is no collisions

YETS: Year End Technical Stop

Muon Detectors

Very smooth operations throughout 2015



RPC

- Commissioning of new trigger towers (feet region) ongoing
  - All towers included in trigger and readout since Sept

TGC

- Deployed the inner coincidence
  - Reduction of muon trigger rates in the Endcap

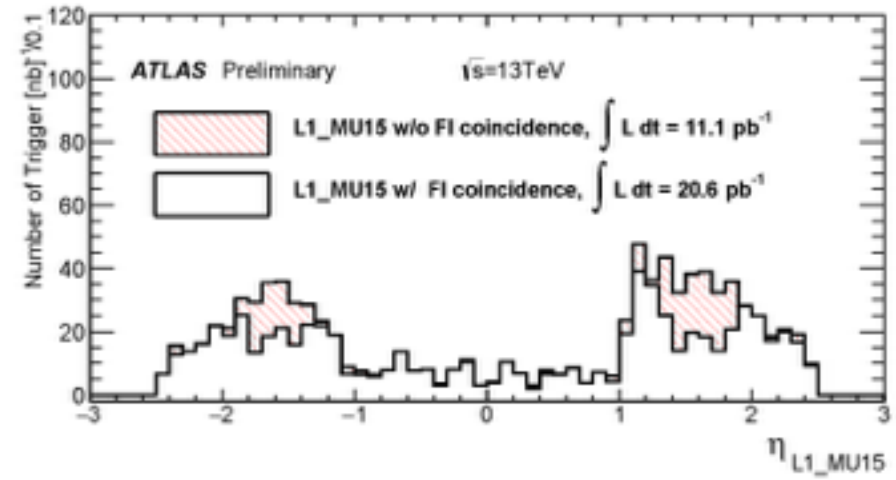
CSC:

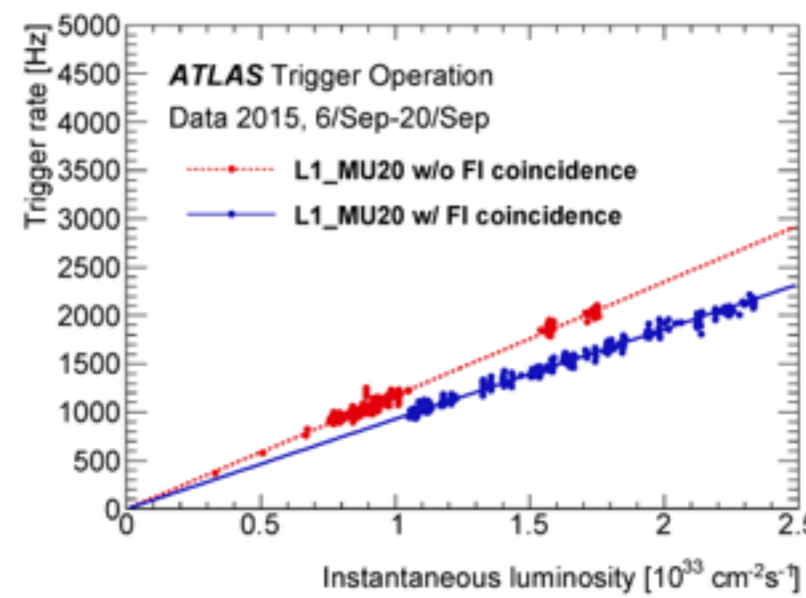
- New readout operating nicely
  - Tested up to L1 rates of 100kHz

Alignment performed with toroid off

- Target resolution of 10% for 1 TeV μ

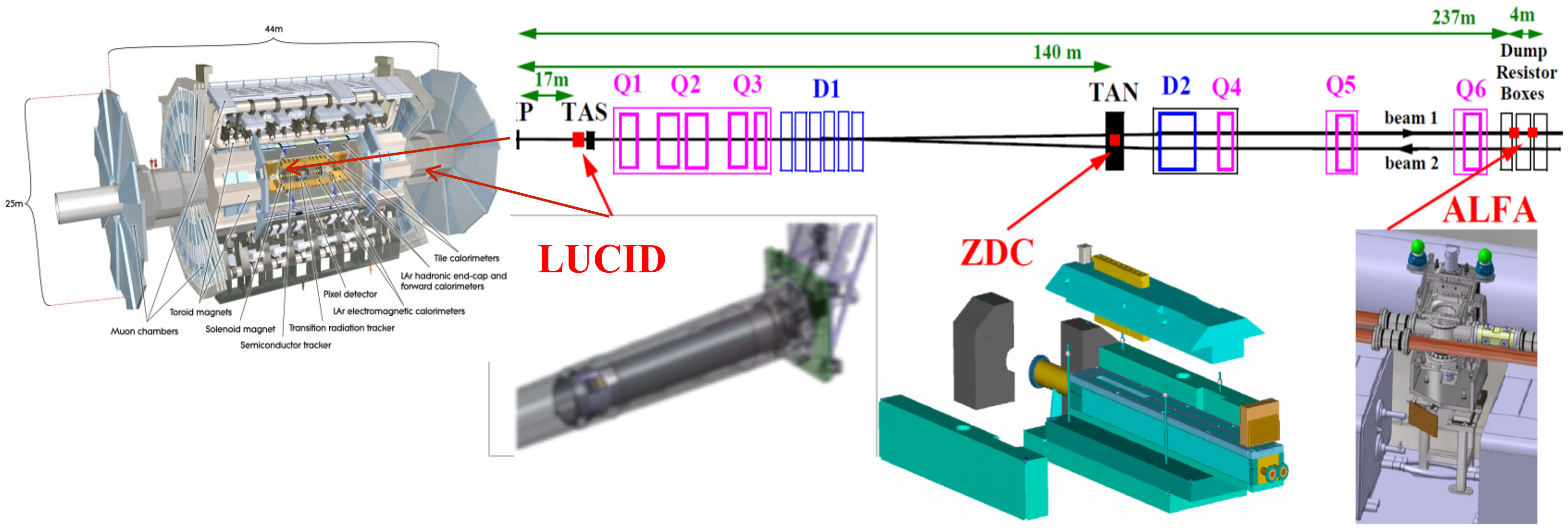
RoIs distribution w & w/o FI coincidence



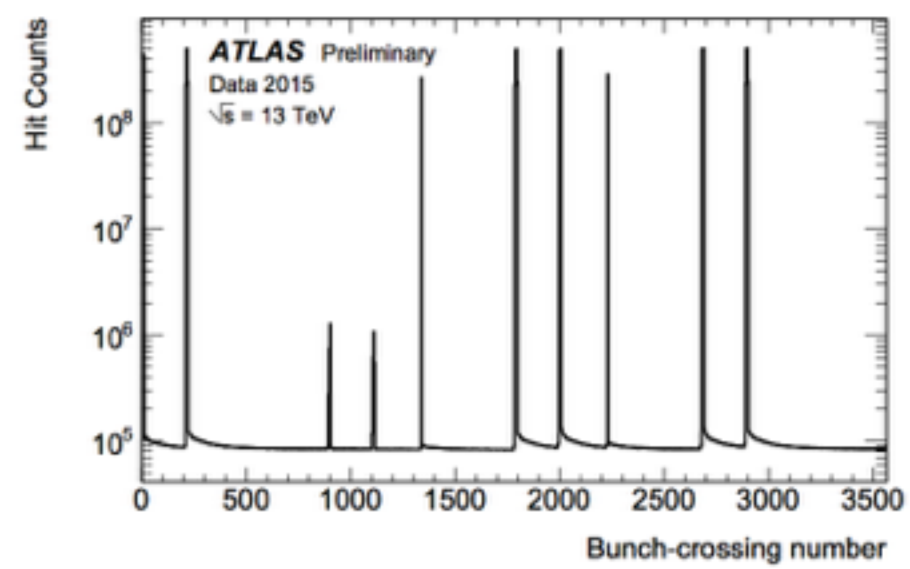


21% reduction in trigger rate with FI coincidence

Forward Detectors



LUCID Hit counts



LUCID

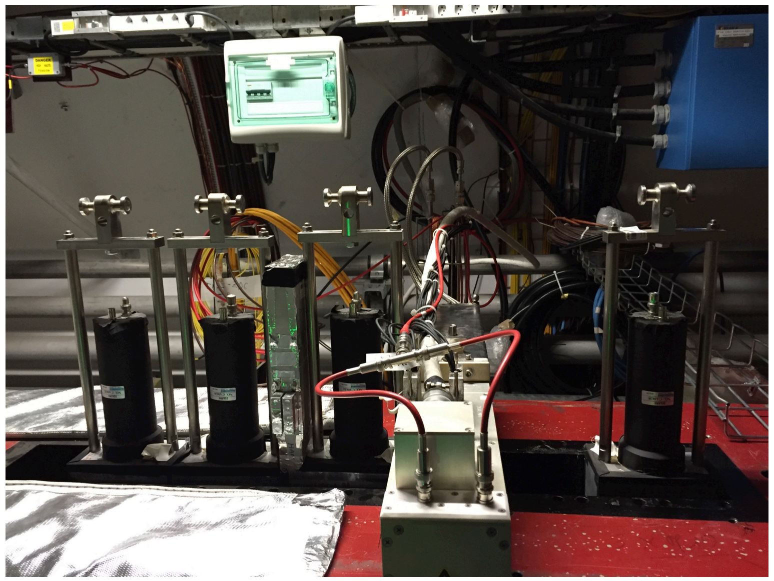
- Newly installed. Working well as a luminosity monitor

ZDC

- Detector refurbished. Taking data successfully during the Heavy Ions run

ALFA Data taken between October 12th and 18th

- Total cross section
- Diffractive physics



Trigger/DAQ

TDAQ system redesign for Run-2 and bringing many improvements

- Run-2 pp data taking over 90% efficiency

~1.5k High Level Trigger (HLT) selections seeded by ~400 different Level-1 items

- Primary triggers (usually unprescaled)
- Background triggers (usually prescaled)
- Alternative trigger (use different algorithms)
- Backup triggers (tighter selections)
- Calibration triggers (providing partially built events)

Peak rate:

- Level-1: 70 kHz (100 kHz max)
- HLT: 1.4 kHz

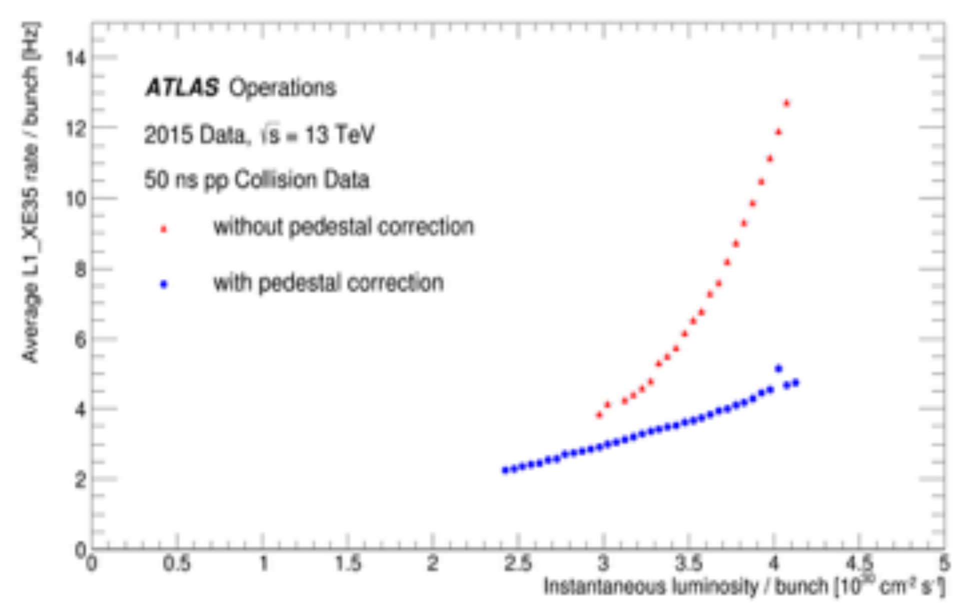
Menu items and prescale strategy maintained though out 2015.

- Ensure continuity of trigger selections for physics analyses.

Pedestal correction

- Minimize pileup effects and linearize trigger rate for L1Calo MET > 35 GeV trigger
  - Shows dramatic improvement in rate.

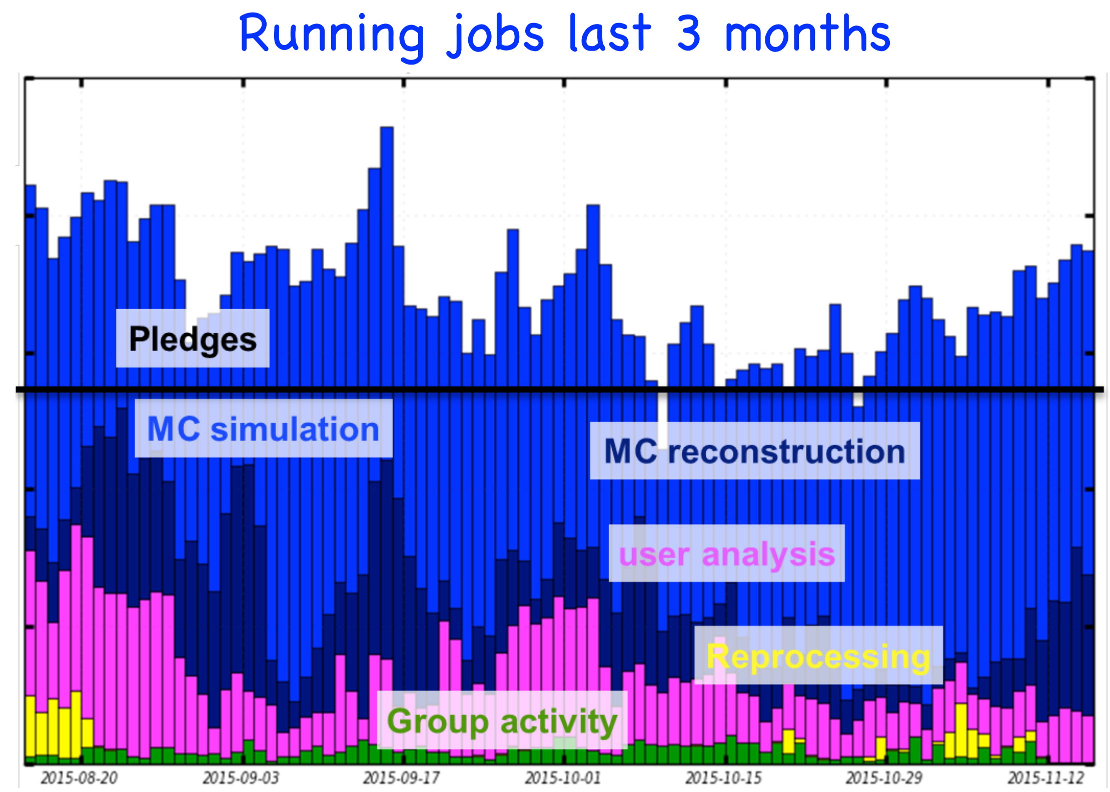
L1_XE35 rate w & w/o pedestal



Computing

Grid utilization at full capacity

- No issue with data transfer and data processing



Tier-0 farm used for Grid processing when no data processing activity

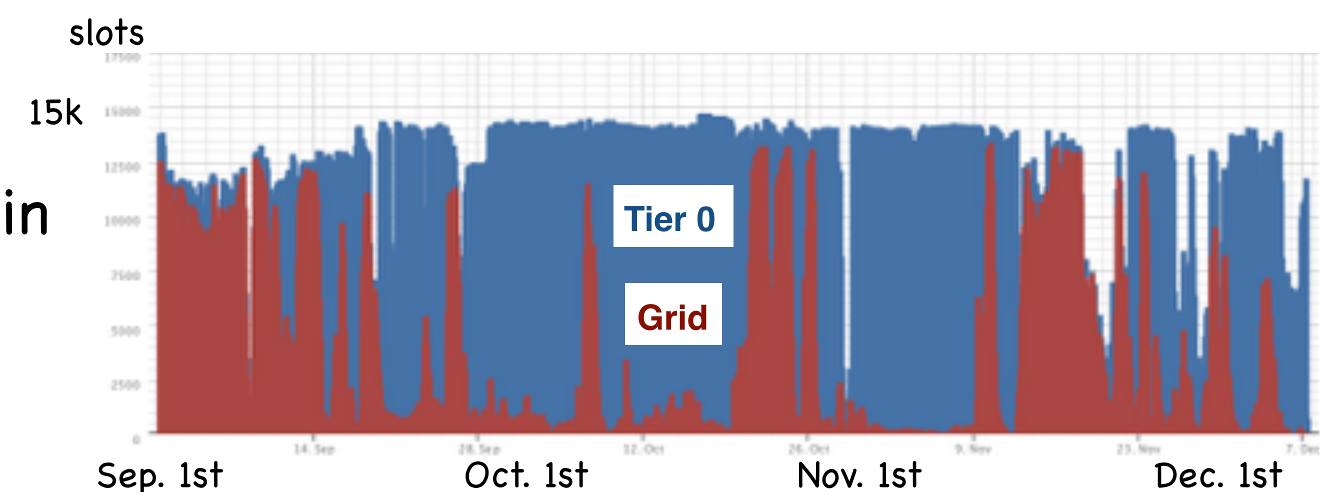
- Spill-Over of Tier-0 jobs to Tier-1 sites validated

Reprocessing of 2015 data/MC planned for end of 2015/early 2016

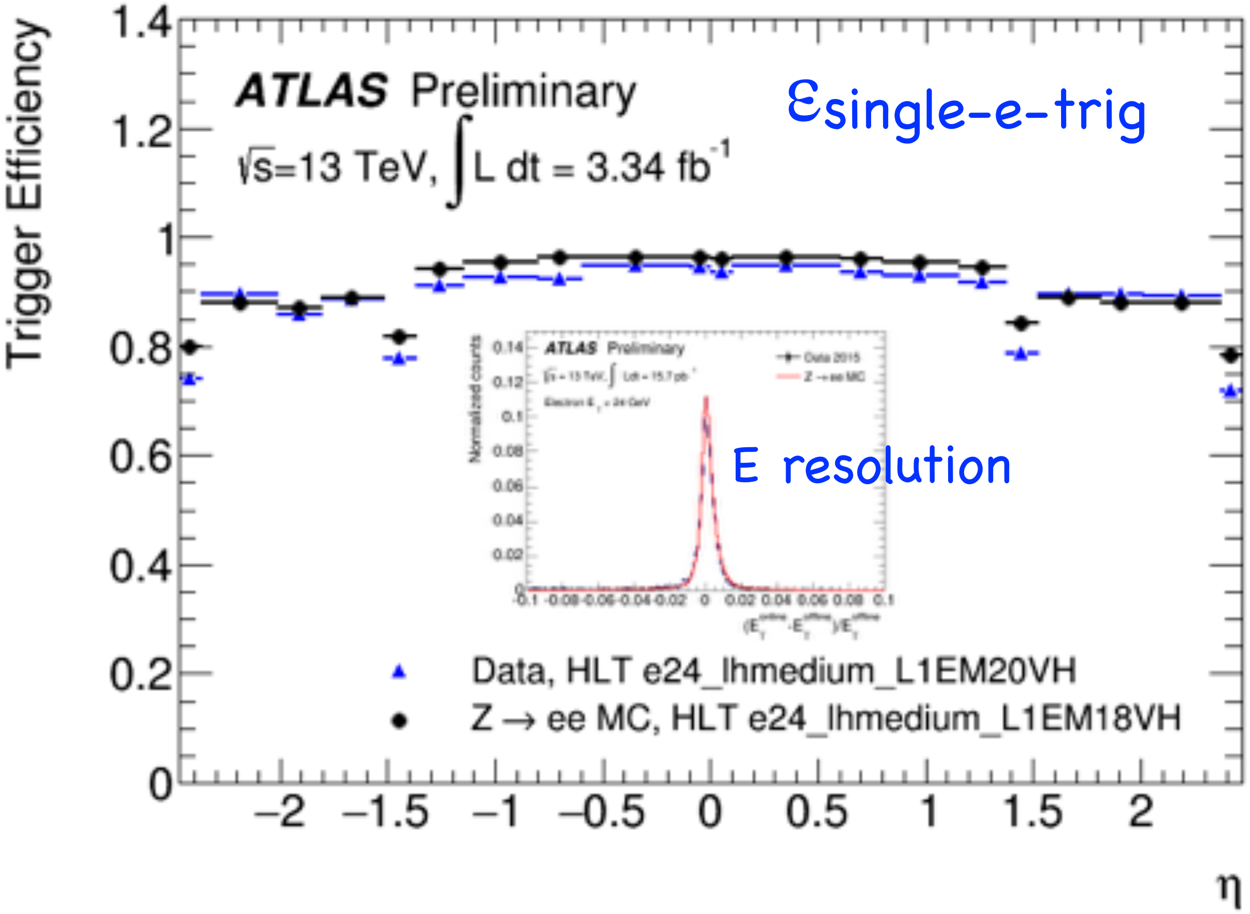
- Major software update for summer 2016 only

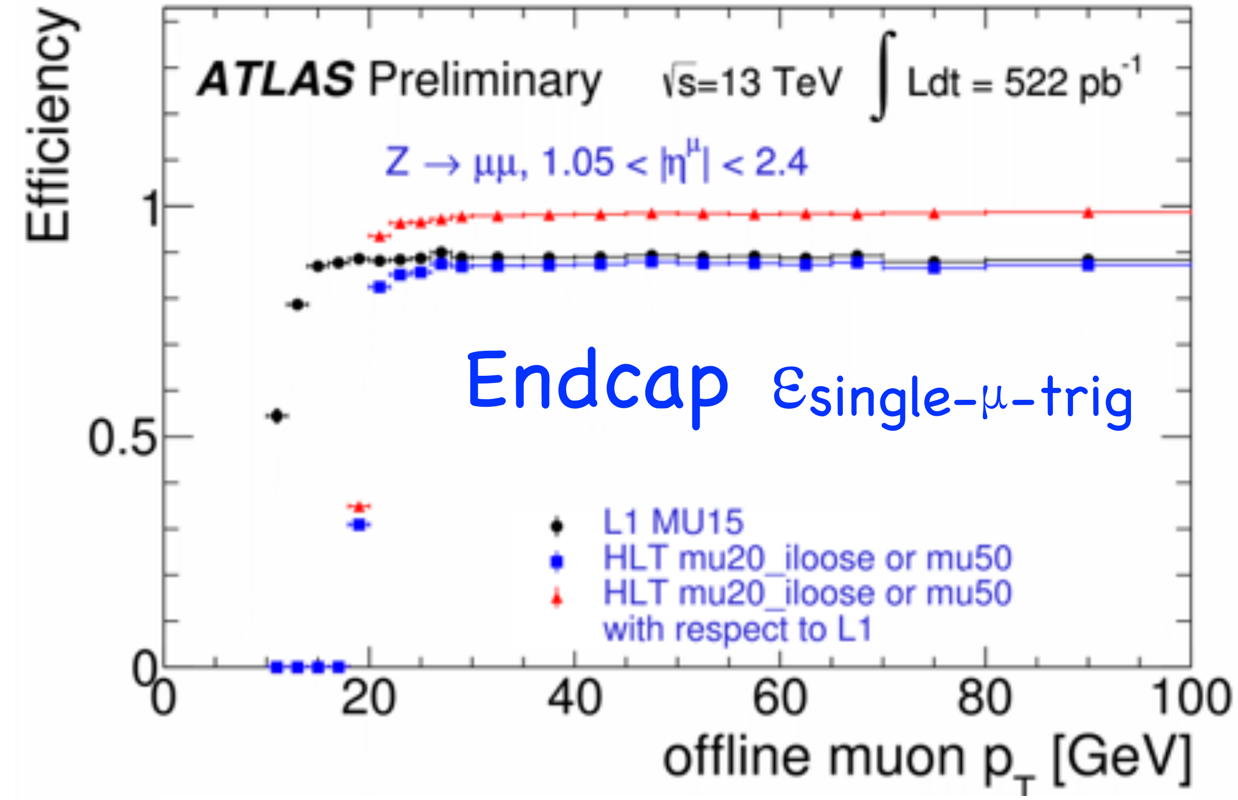
New analysis model:

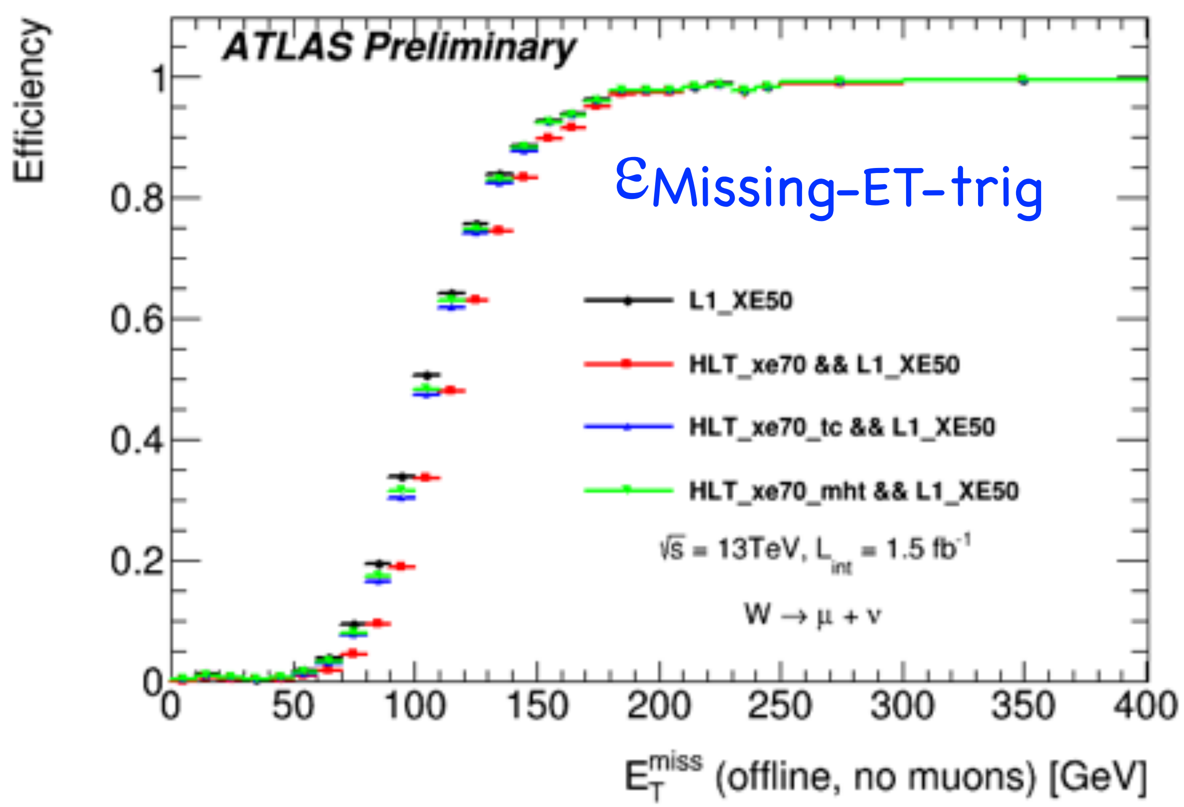
- Physics groups data format produced within 24h after Tier-0 data processing

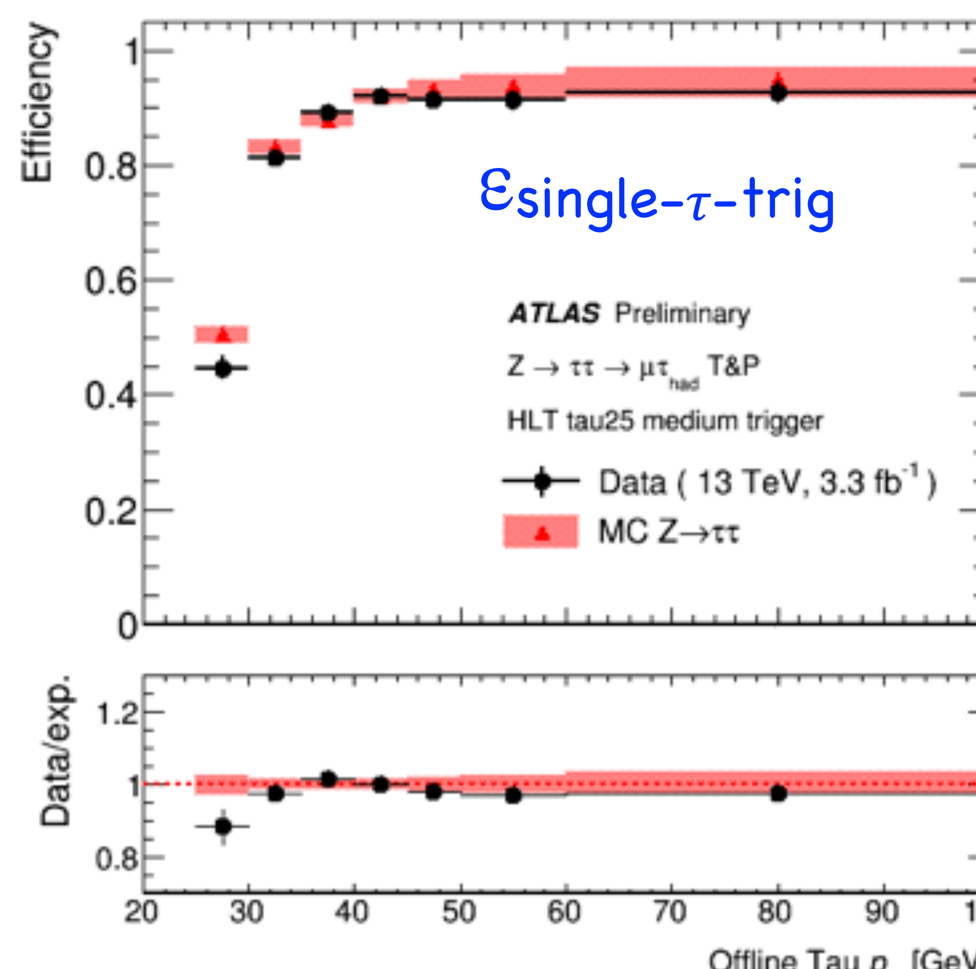


Trigger Performance





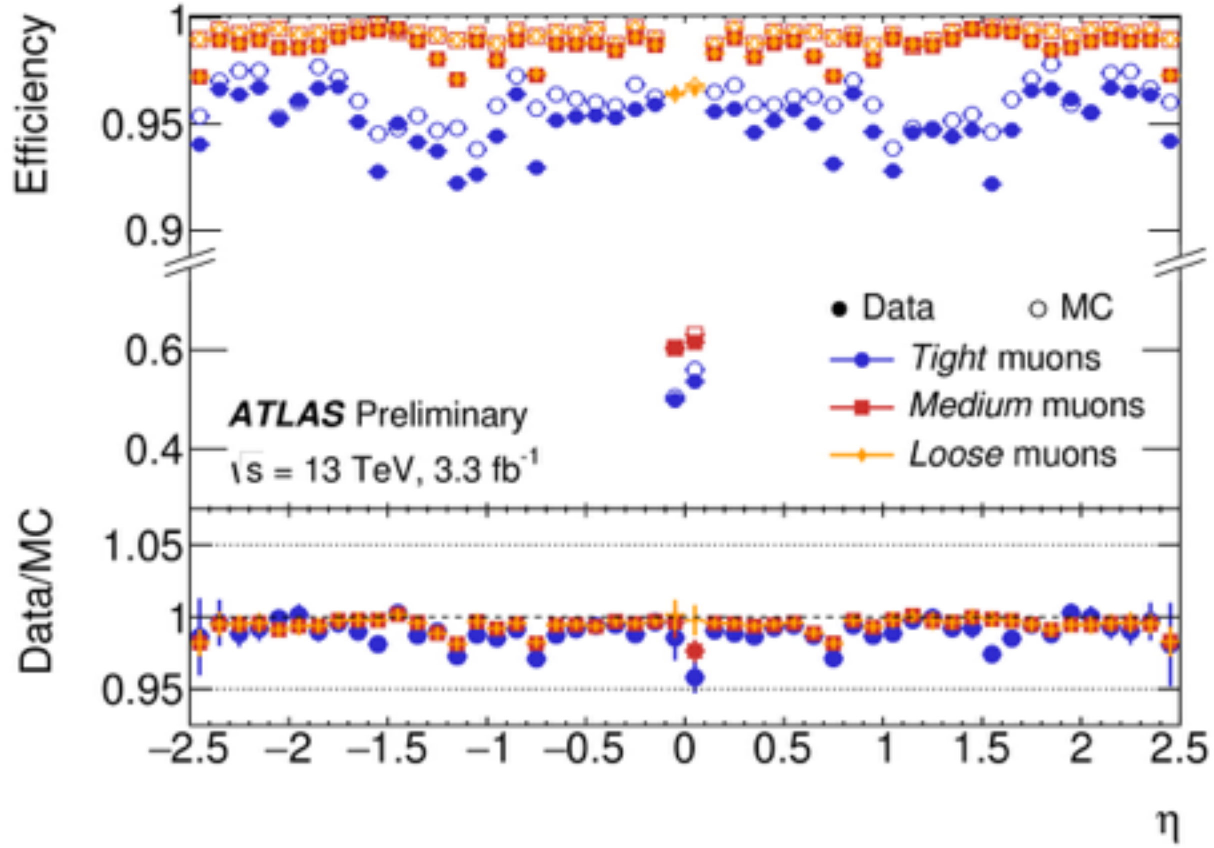




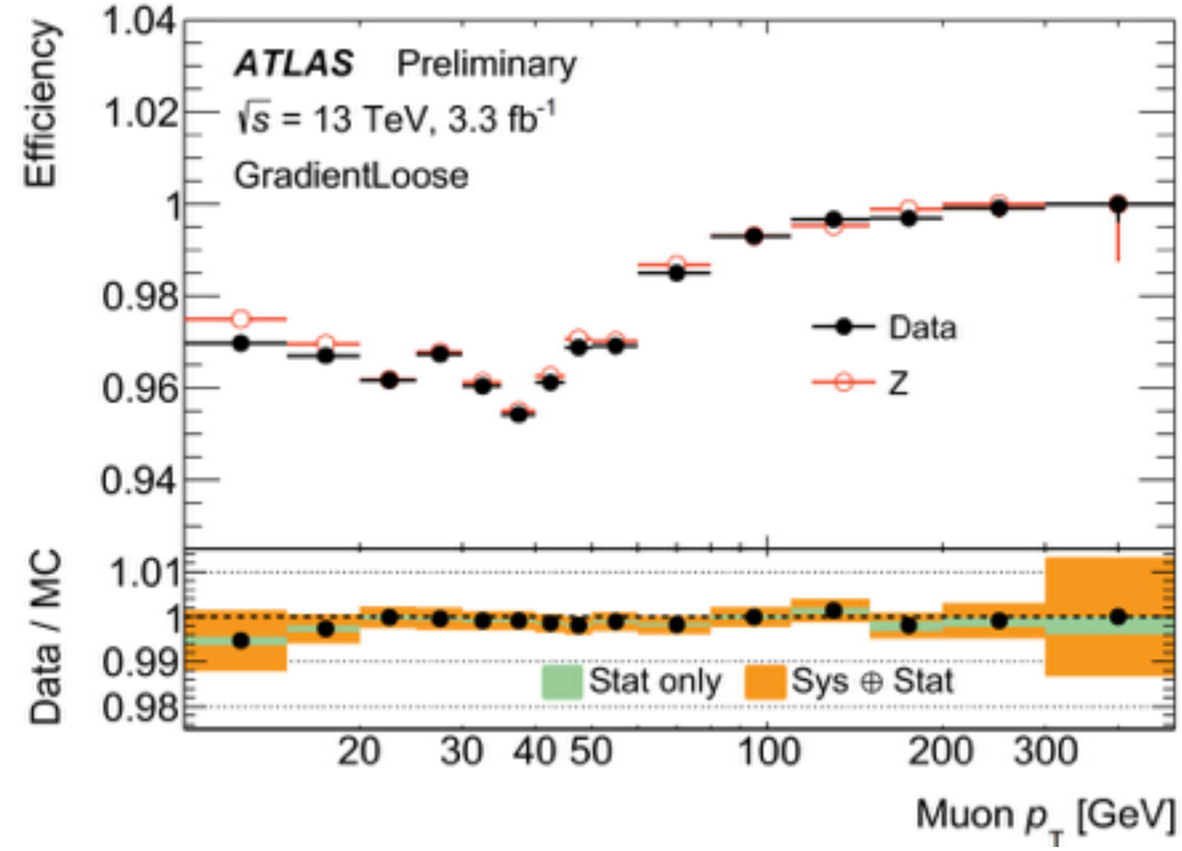
MUON-2015-004

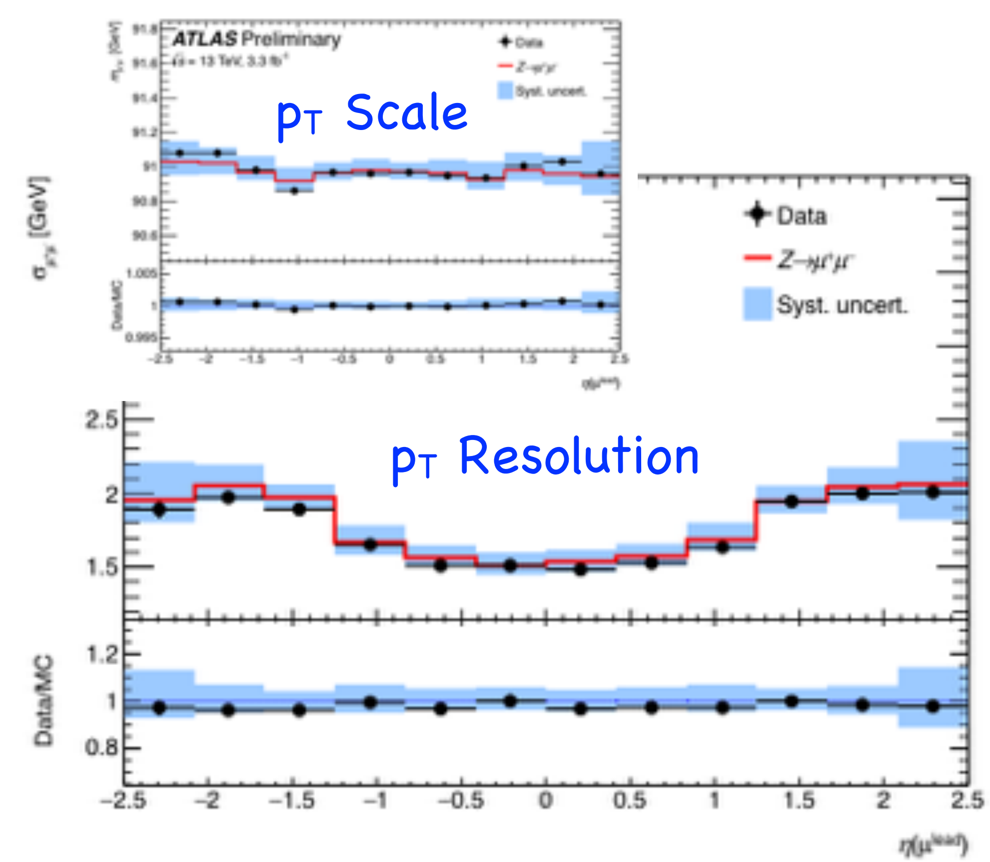
Muons

Muon reconstruction efficiency



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

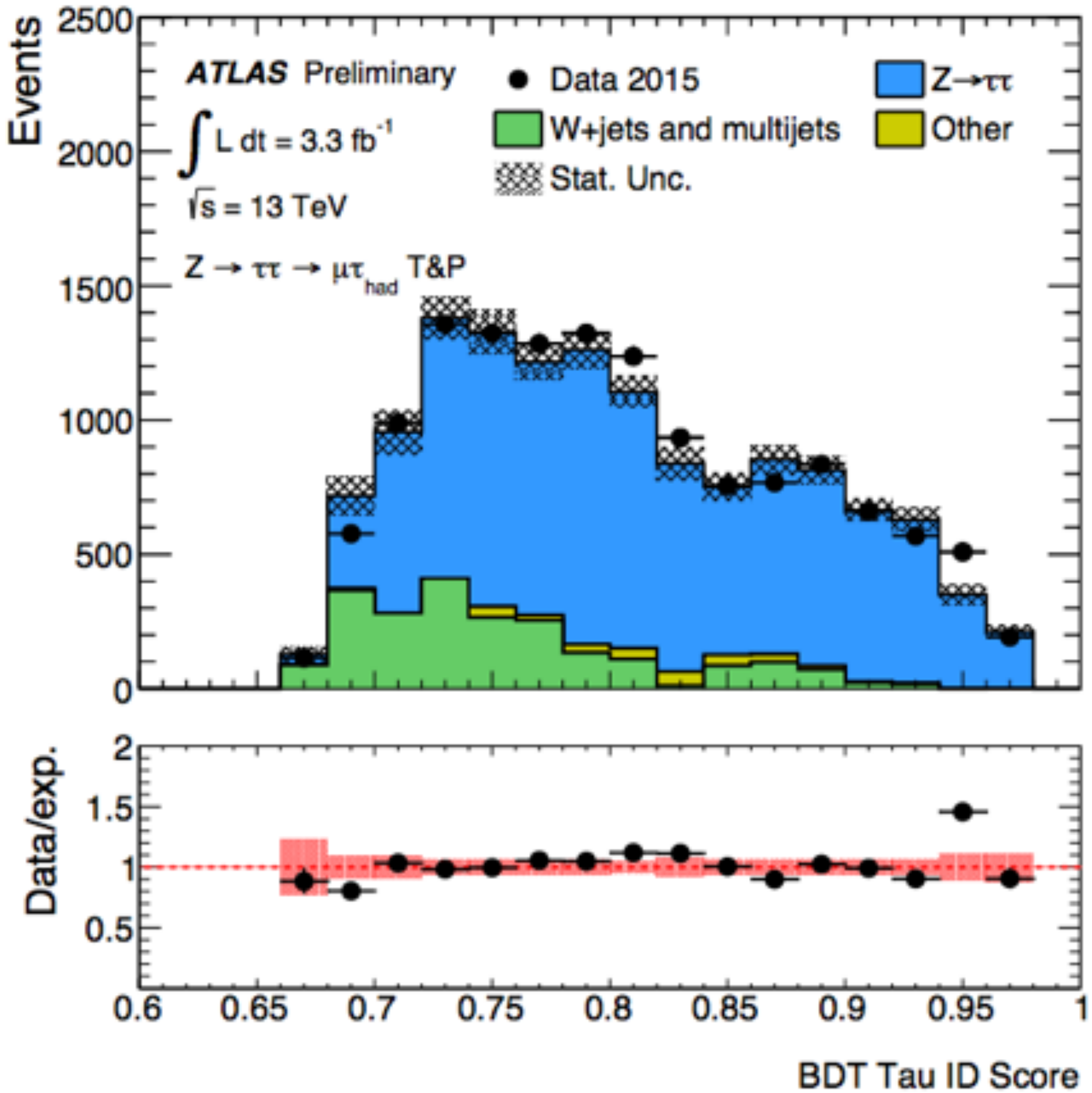




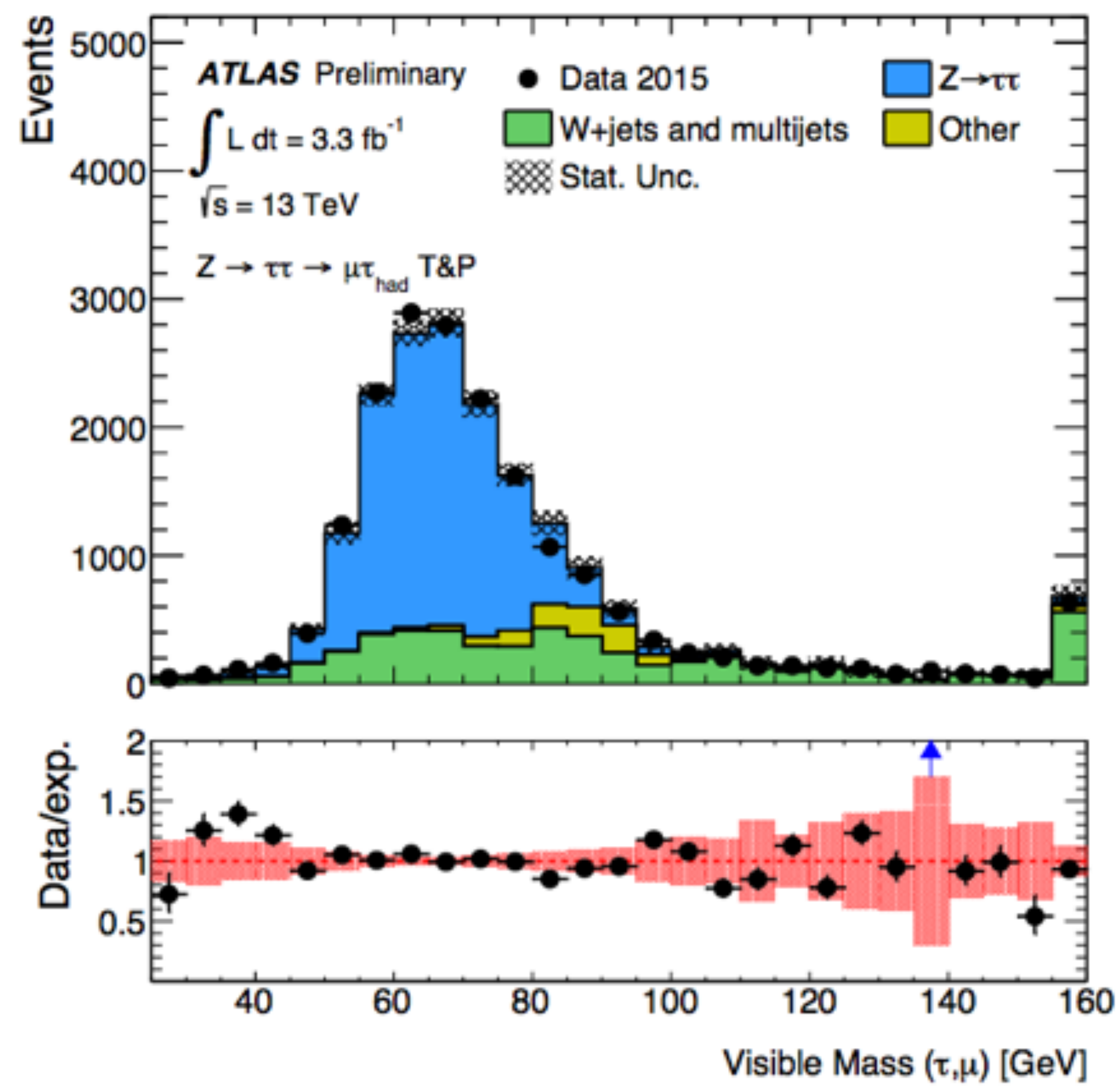
- **Muon performance with full 2015 dataset**
- **Good agreement between data and simulation**
  - Correction factors applied to correct remaining differences

Taus

BDT Tau Identification score

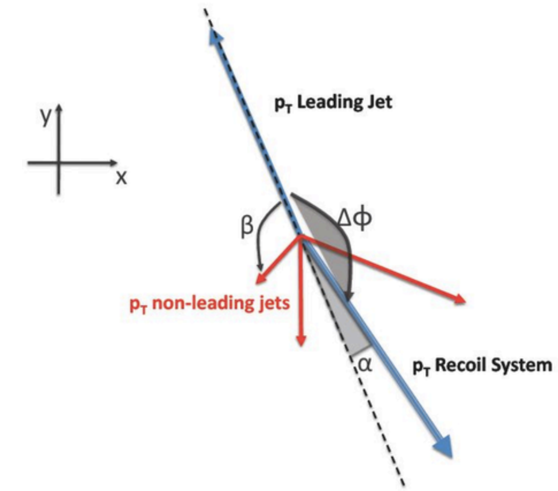


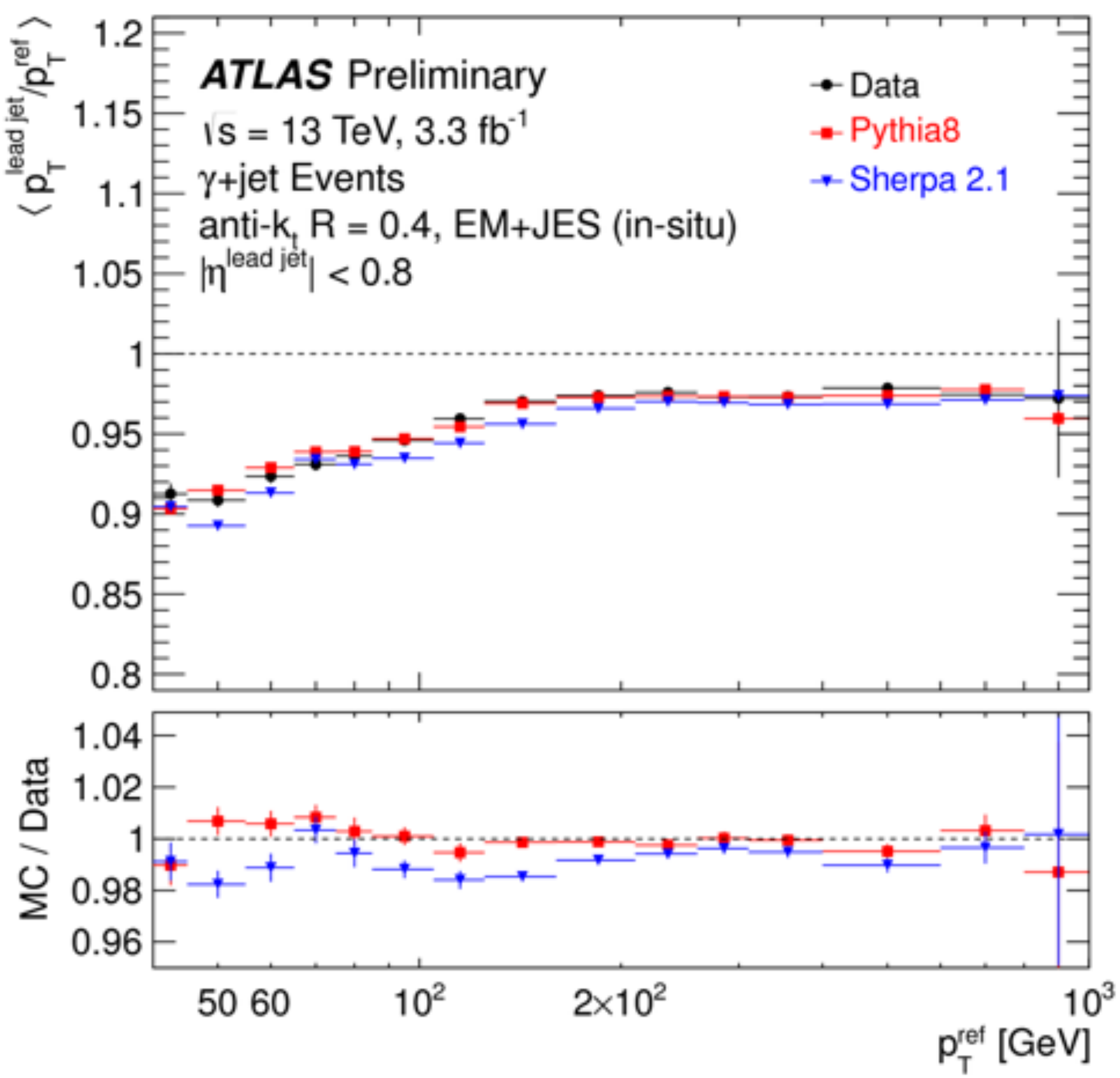
Visible mass of the $\mu\tau_{had}$ Z candidates

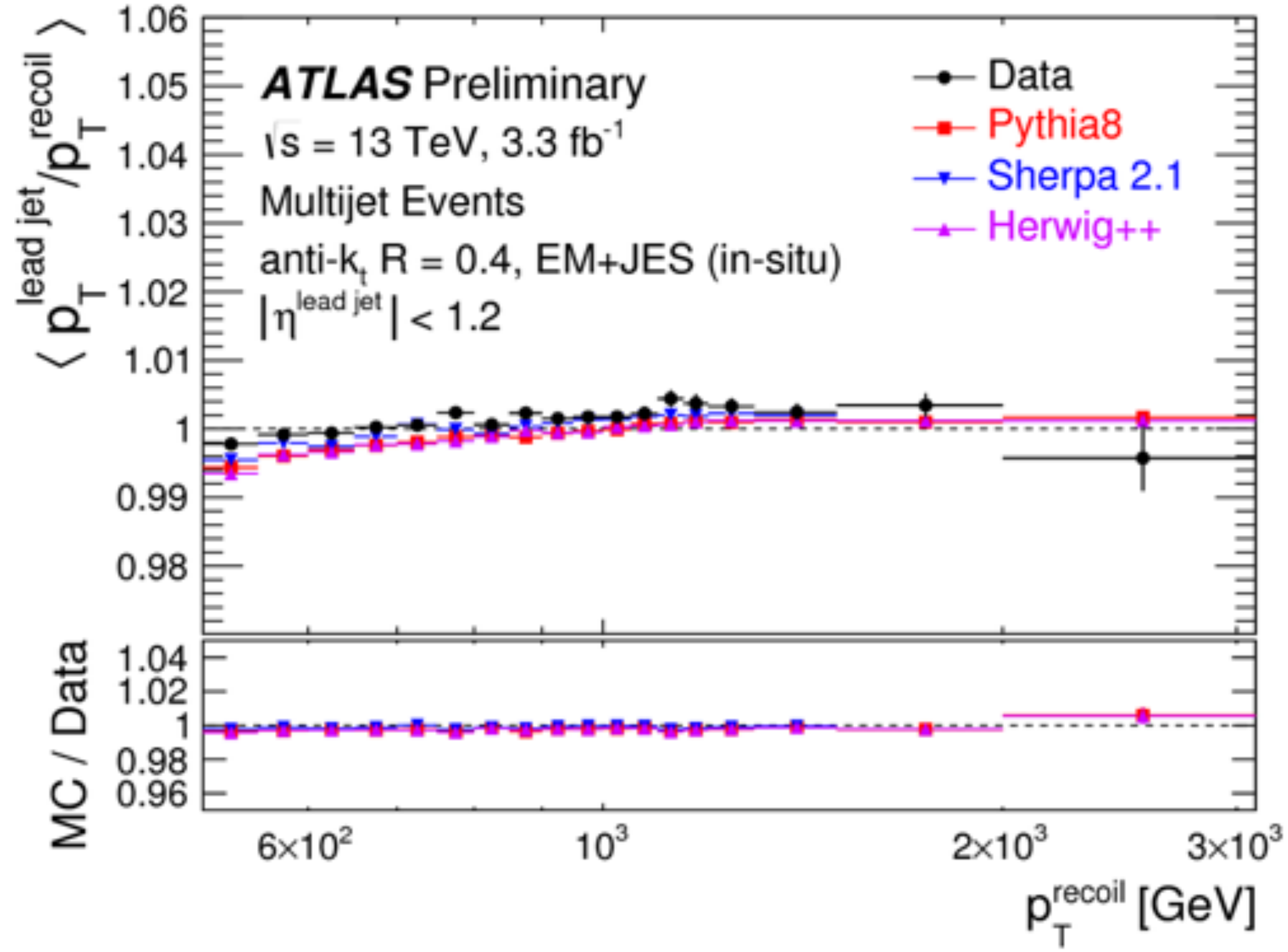


- **Hadronically decaying taus identified using boosted decision tree online and offline**
  - Performance measure using $Z\rightarrow\tau\tau\rightarrow\mu\tau_{had}$ candidates
  - Good agreement between data and simulation

Jet Energy Scale



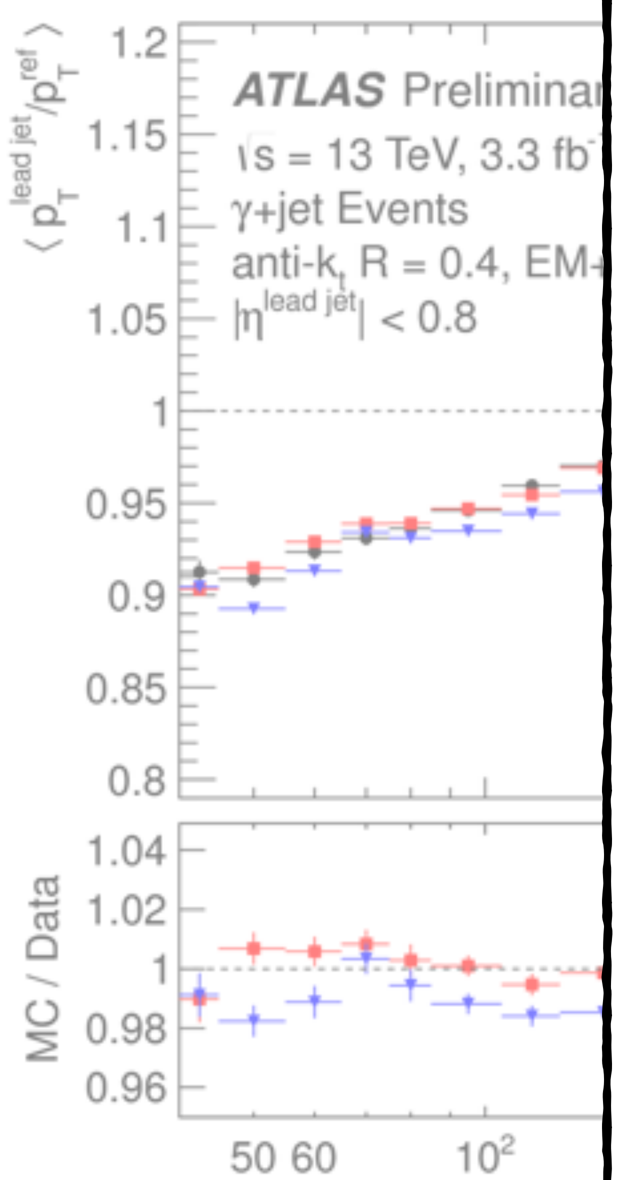


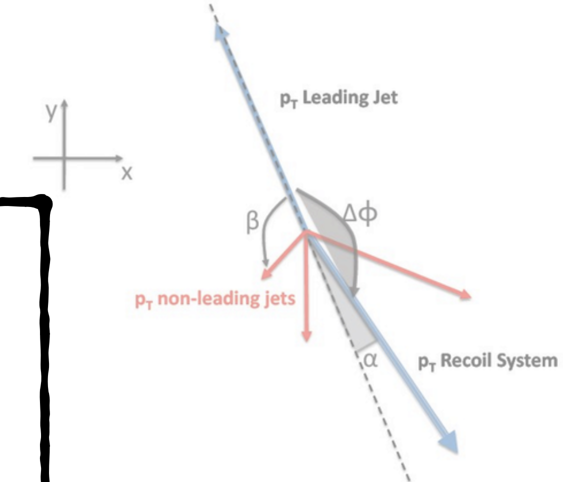


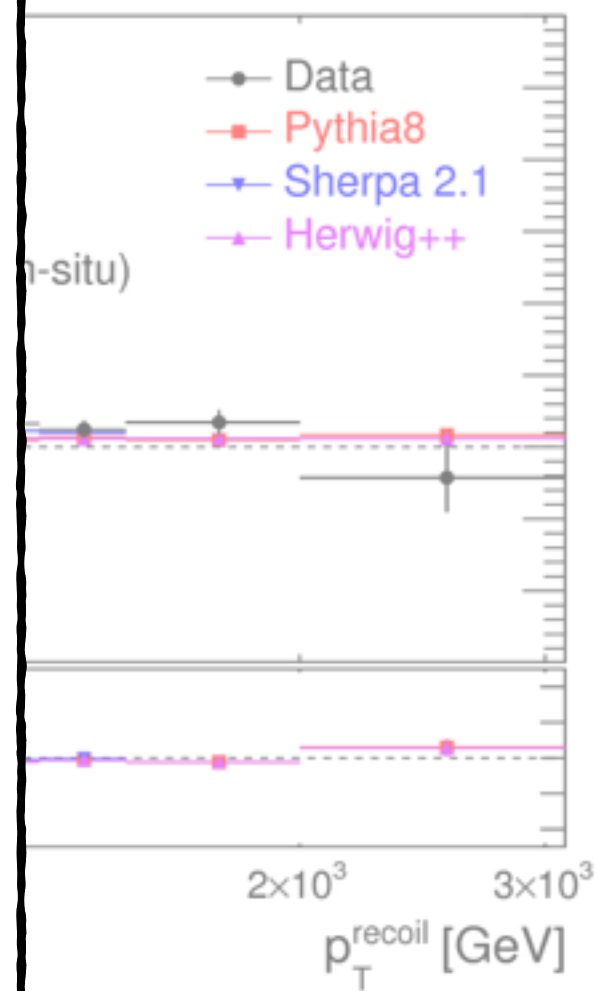
- **Jet energy scale studied in-situ with full 2015 dataset**
  - Photon-jet balance
  - Multi-jet balance

- **Agreement between data and simulation better than 2% up to 3TeV**

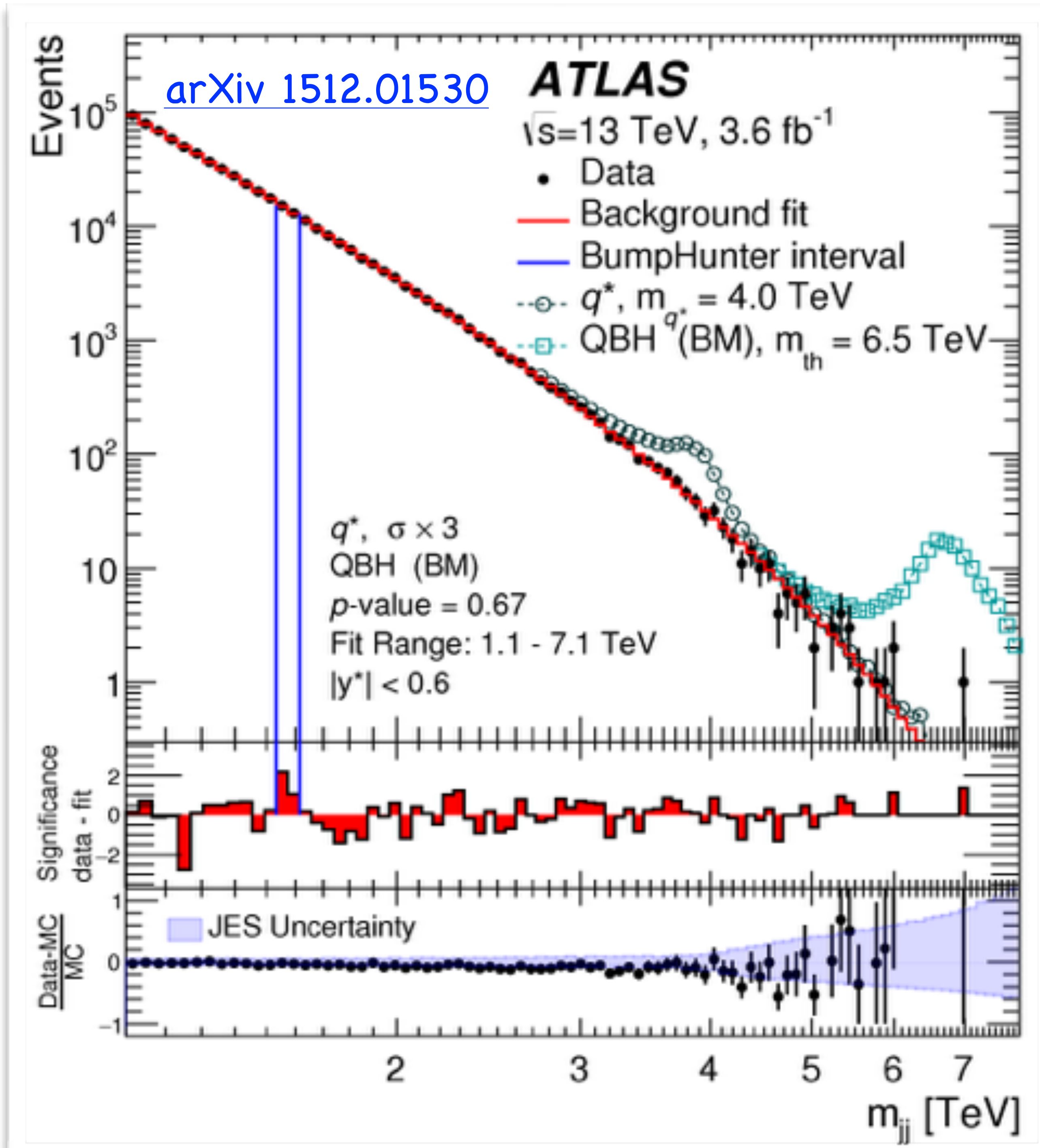
Jet Energy Scale







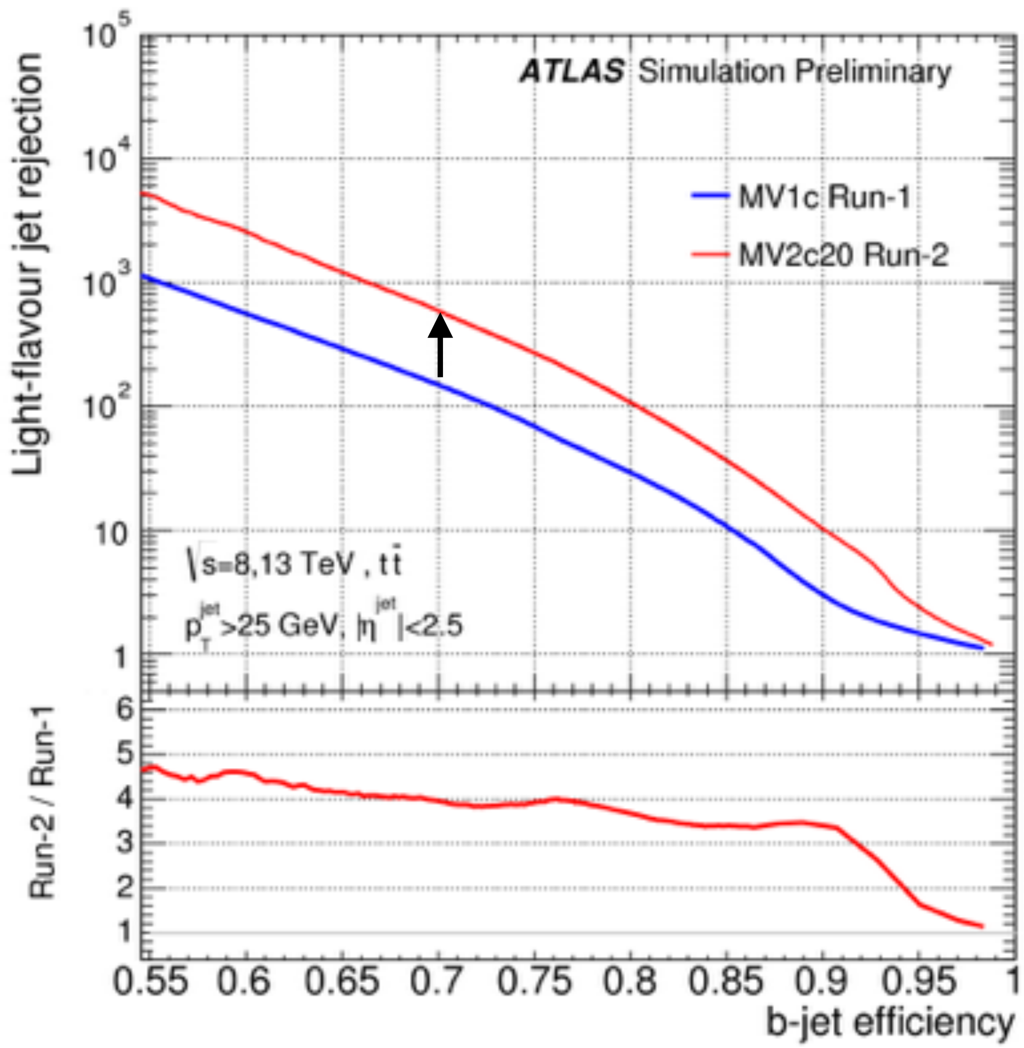
Di-jet mass search



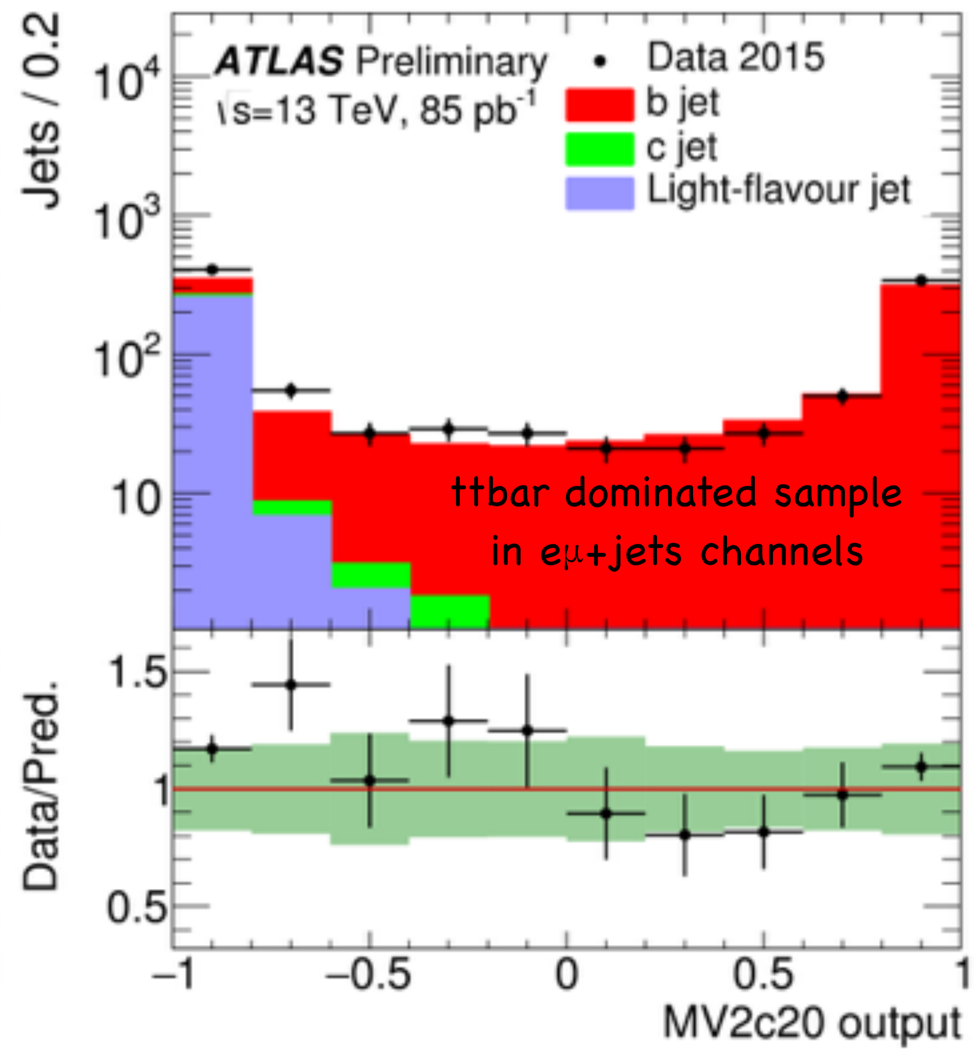
- Jet energy scal
  - Photon-jet bal
  - Multi-jet balar
- Agreement between data and simulation better than 2% up to 3TeV

Flavour Tagging

ATL-PHYS-PUB-2015-022



ATL-PHYS-PUB-2015-039



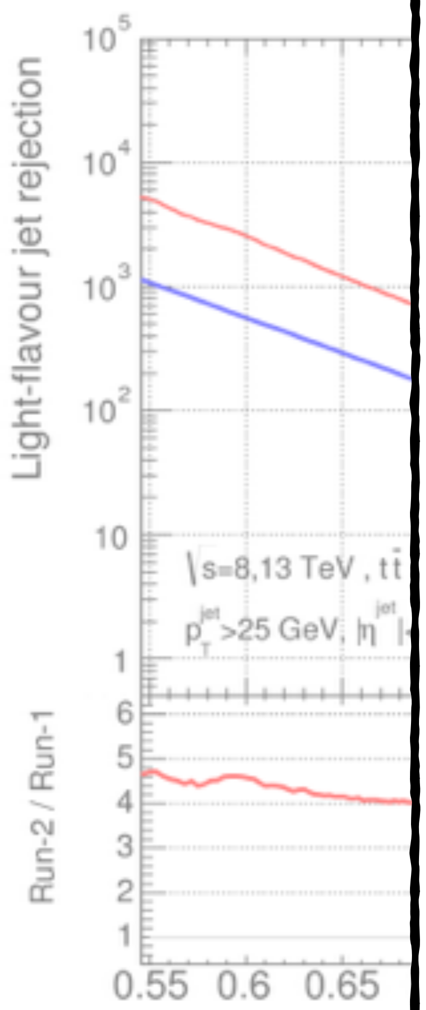
Flavor tagging MVA
Good data/MC agreement

Full data-based calibration of b, c and light jets underway

- **Several enhancements between Run-1 and Run-2 impact flavor tagging**
  - Improved tracking (including IBL) and flavor tagging algorithms
- **Improvement in light flavor (~x4) and c-jet (~x1.6) rejection**

Flavour Tagging

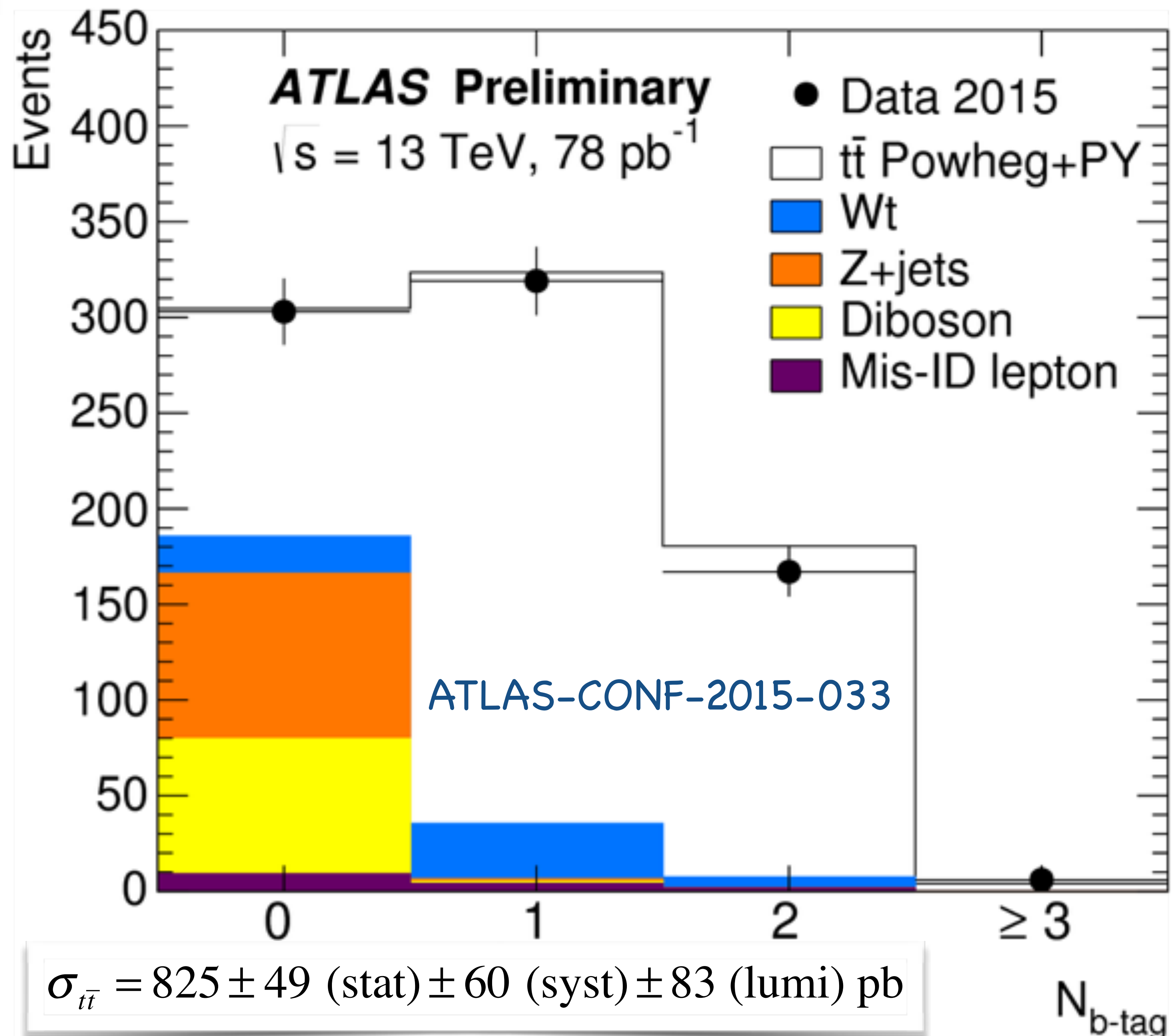
ATL-PHYS-PUB-2015-022



… tagging MVA
… data/MC agreement

… ata-based calibration
… c and
… jets underway

Top Cross-Section Dilepton (eμ) channel



ATLAS-CONF-2015-033

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

- Several e… … tagging
  - Improve…
- Improvem…

Summary

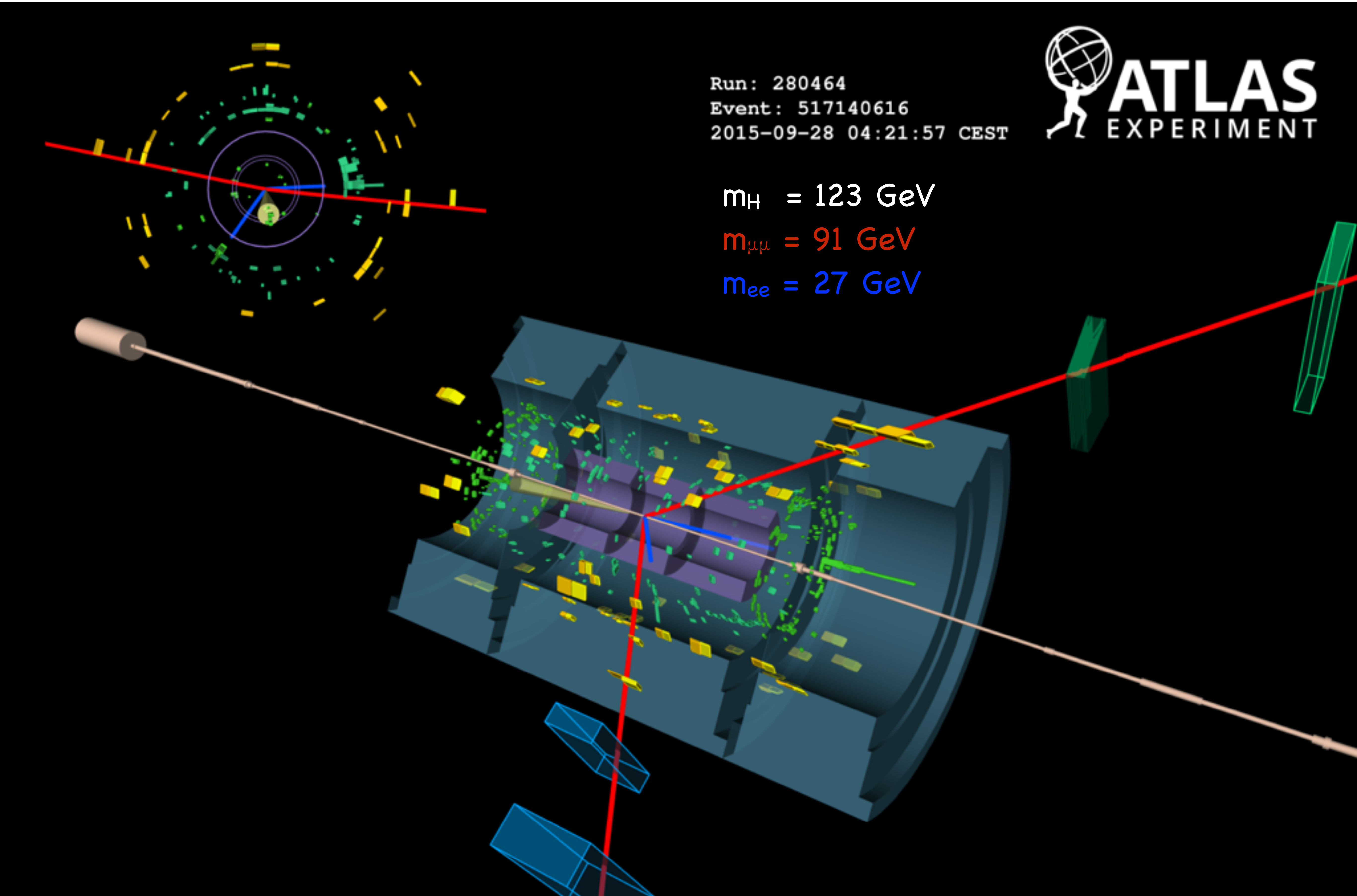
- **ATLAS successfully completed the LS1 upgrades**
  - Nearly all components are now commissioned and used.
- **Restart after long shutdown and data taking through out 2015 has been very successful.**
  - Despite some challenges, data taking efficiency and system stability has already reached a level comparable to the last part of Run-1
  - Possible only with the dedications of the subsystem experts and shifters, often working all around the clock
- **Detailed performance studies demonstrate good understanding of the 2015 data**

Huge thanks to the LHC team for a good start and rapidly increasing luminosity!

Eagerly waiting more data in 2016 to carry on exploration of the 13 TeV physics landscape.

Looking forward to sensitivity beyond the SM to extend beyond Run-1.

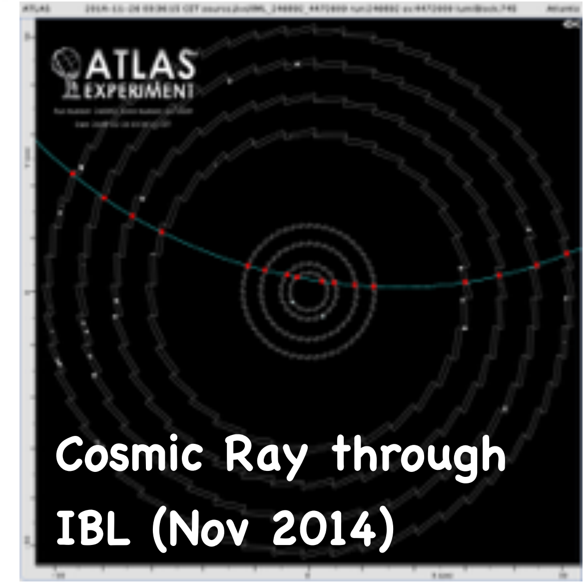
$H \rightarrow ZZ \rightarrow 2\mu 2e$ candidate



BACKUP

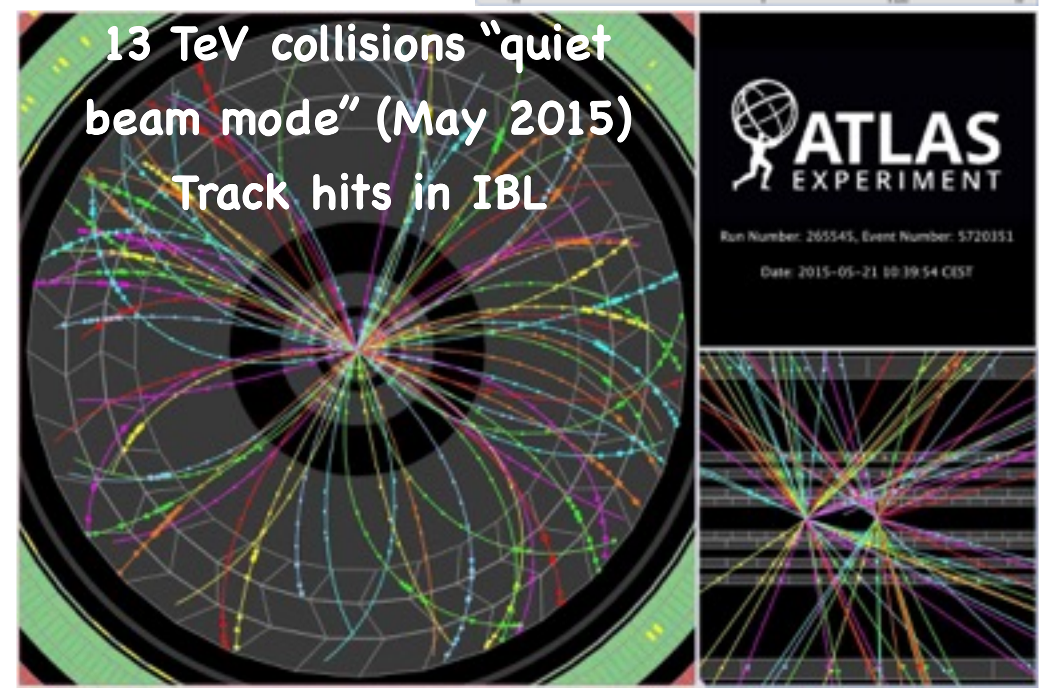
Commissioning for Run -2

- **Cosmic Runs every few weeks with full detector since Sept. 2014:**
  - Integrate all systems into new DAQ, exercise system etc…
  - Initial alignment studies for IBL.



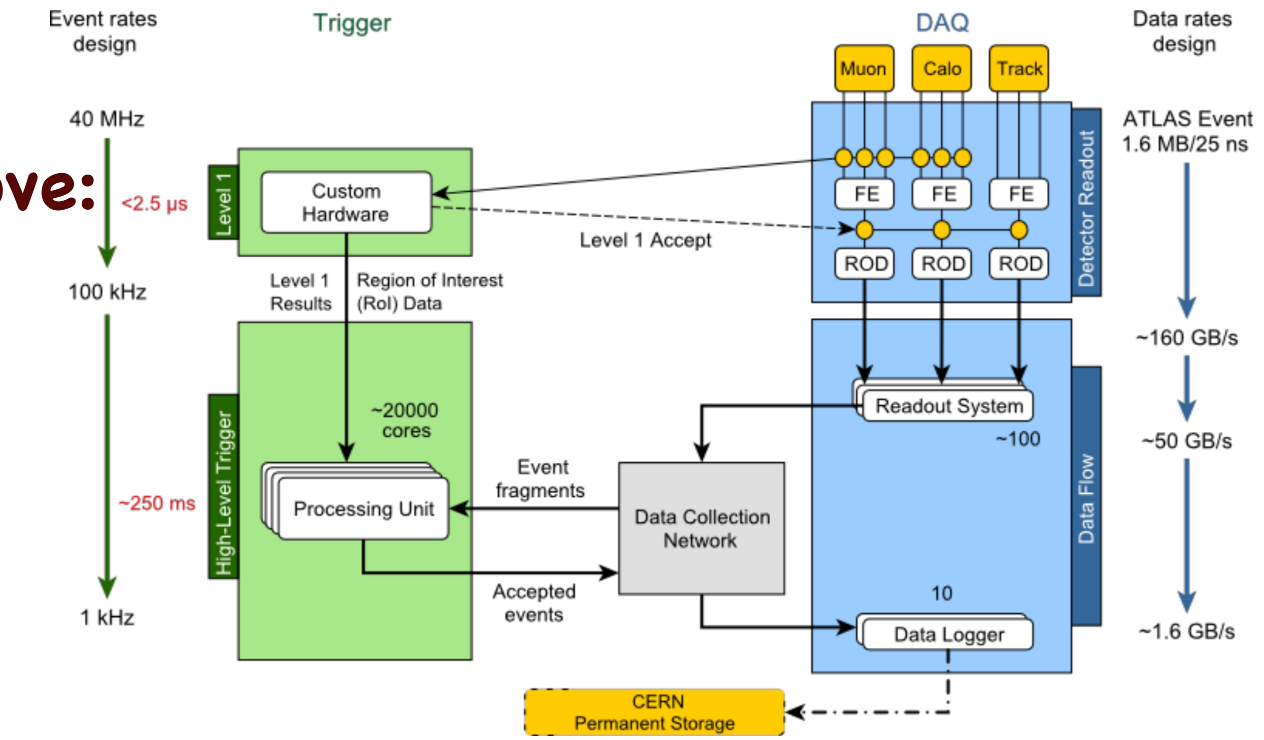
- **Beam Splashes (04/05 & 04/07):**
  - Timing of calorimeters.

- **900GeV collisions (May 5^{th} & 6^{th}):**
  - Pixel and IBL tuned on during "quiet beam".
  - 7M collision events.



- **13 TeV test collisions (May 20^{th} & 21^{st}) :**
  - Pixel and IBL tuned on during "quiet beam".
  - 21M collision events.

Trigger/DAQ System in Run-2

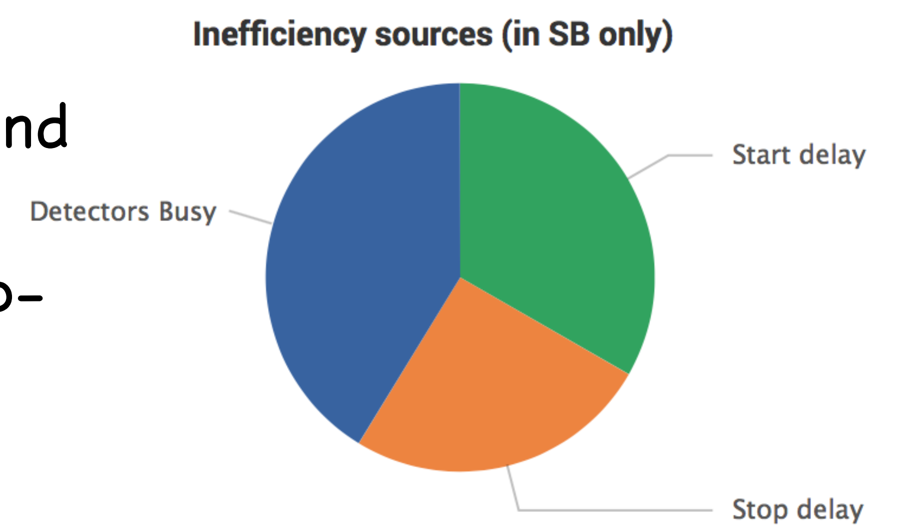


TDAQ system redesign for Run-2 to improve:

- Read-Out Buffers
- Data flow network performance
- High Level Trigger (HLT)
- Online calibration farm
- Trigger rate up to 100 kHz at L1, on average 1kHz HLT

Run-2 pp data taking over 90% efficiency:

- HLT farm ~25k cores.
  - Partially used for simulation jobs during Technical Stop and Machine Development periods
- Largest busy contribution from holding triggers while "stop-less" recovering



YETS and 2016 plans

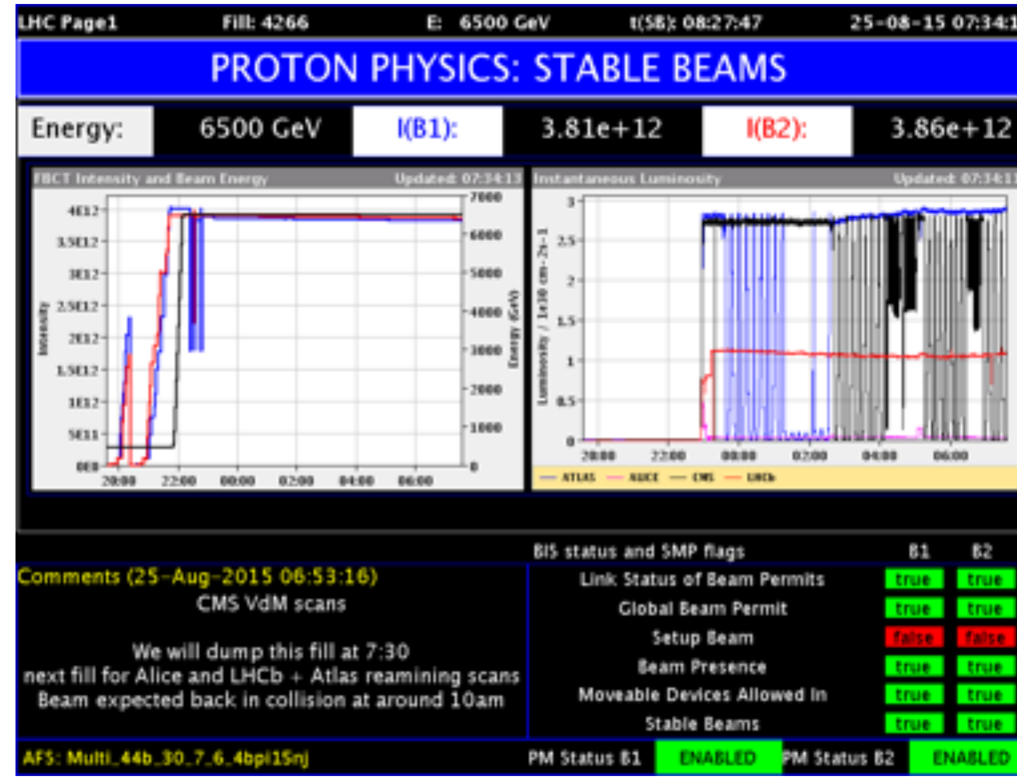
- PC-based Region of Interest Builder (faster and more flexible)

Trigger Menu

Trigger	Typical offline selection	Trigger Selection Level-1 (GeV)	Trigger Selection HLT (GeV)	Level-1 Peak Rate (kHz) $L = 5 \times 10^{33}$ cm^{-2}s^{-1}	HLT Peak Rate (Hz) $L = 5 \times 10^{33}$ cm^{-2}s^{-1}
Single leptons	Single iso μ, $p_T > 21$ GeV	15	20	7	130
	Single e, $p_T > 25$ GeV	20	24	18	139
	Single μ, $p_T > 42$ GeV	20	40	5	33
	Single τ, $p_T > 90$ GeV	60	80	2	41
Two leptons	Two μ's, each $p_T > 11$ GeV	2×10	2×10	0.8	19
	Two μ's, $p_T > 19, 10$ GeV	15	18, 8	7	18
	Two loose e's, each $p_T > 15$ GeV	2×10	2×12	10	5
	One e & one μ, $p_T > 10, 26$ GeV	20 (μ)	7, 24	5	1
	One loose e & one μ, $p_T > 19, 15$ GeV	15, 10	17, 14	0.4	2
	Two τ's, $p_T > 40, 30$ GeV	20, 12	35, 25	2	22
	One τ, one μ, $p_T > 30, 15$ GeV	12, 10 (+jets)	25, 14	0.5	10
	One τ, one e, $p_T > 30, 19$ GeV	12, 15 (+jets)	25, 17	1	3.9
Three leptons	Three loose e's, $p_T > 19, 11, 11$ GeV	15, 2×7	17, 2×9	3	< 0.1
	Three μ's, each $p_T > 8$ GeV	3×6	3×6	< 0.1	4
	Three μ's, $p_T > 19, 2 \times 6$ GeV	15	18, 2×4	7	2
	Two μ's & one e, $p_T > 2 \times 11, 14$ GeV	2×10 (μ's)	2×10, 12	0.8	0.2
	Two loose e's & one μ, $p_T > 2 \times 11, 11$ GeV	2×8, 10	2×12, 10	0.3	< 0.1
One photon	one γ, $p_T > 125$ GeV	22	120	8	20
Two photons	Two loose γ's, $p_T > 40, 30$ GeV	2×15	35, 25	1.5	12
	Two tight γ's, $p_T > 25, 25$ GeV	2×15	2×20	1.5	7
Single jet	Jet ($R = 0.4$), $p_T > 400$ GeV	100	360	0.9	18
	Jet ($R = 1.0$), $p_T > 400$ GeV	100	360	0.9	23
E_T^{miss}	$E_T^{miss} > 180$ GeV	50	70	0.7	55
Multi-jets	Four jets, each $p_T > 95$ GeV	3×40	4×85	0.3	20
	Five jets, each $p_T > 70$ GeV	4×20	5×60	0.4	15
	Six jets, each $p_T > 55$ GeV	4×15	6×45	1.0	12
$b-$jets	One loose b, $p_T > 235$ GeV	100	225	0.9	35
	Two medium b's, $p_T > 160, 60$ GeV	100	150, 50	0.9	9
	One b & three jets, each $p_T > 75$ GeV	3×25	4×65	0.9	11
	Two b & two jets, each $p_T > 45$ GeV	3×25	4×35	0.9	9
$b-$physics	Two μ's, $p_T > 6, 4$ GeV plus dedicated b-physics selections	6, 4	6, 4	8	52
Total				70	1400

Luminosity Measurement

- **Preliminary Luminosity Calibration**
  - 9% from June 10th LHCf run (very conservative)



- **Luminosity calibrated in dedicated beam scans**
  - So-called "van-der-Meer scan" (VdM)

- **For high precision, a set of scans is required**
  - Takes about 2 days for 4 experiments

- **Scan was taken on Aug. 25th**
  - ATLAS+CMS to understand relative observed difference.

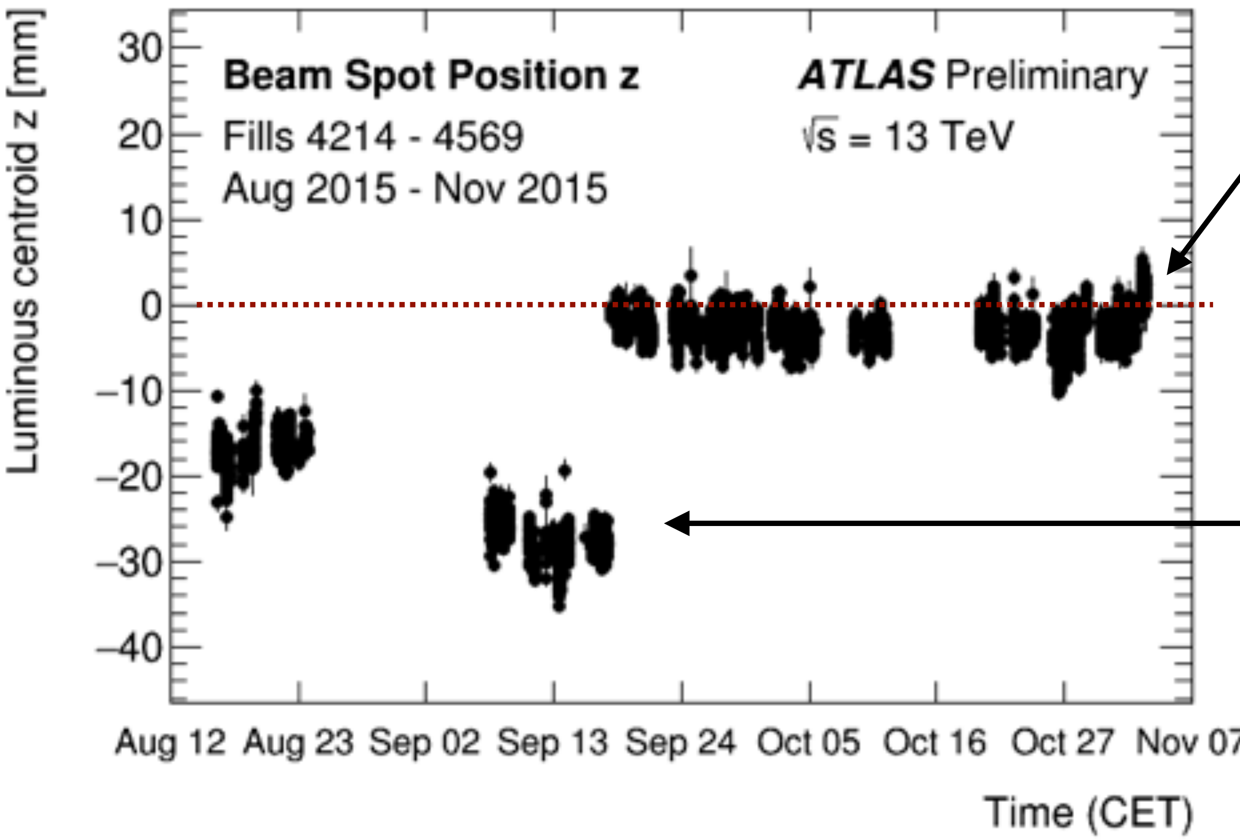
- **Dominant systematics:**
  - Quality of the VdM data
  - Consistency of the various luminosity monitors

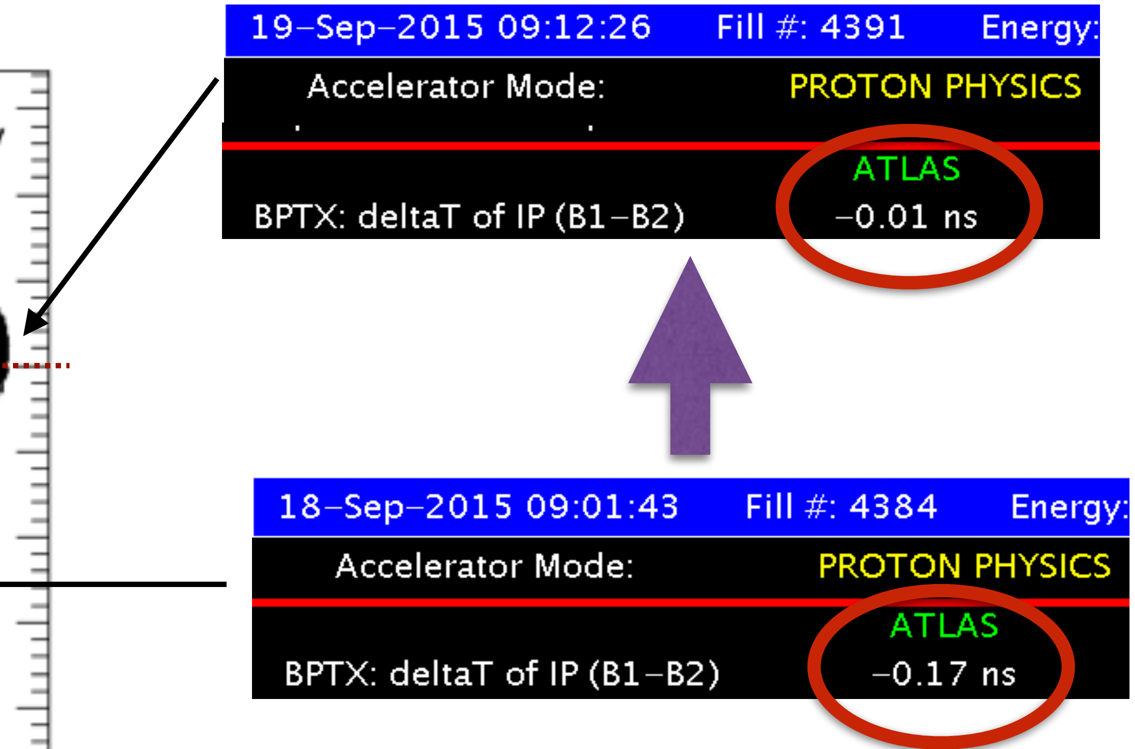
Preliminary systematics
for 2015 data
5%

Run-1: 1.8% for 2011 and 1.9% for 2012 (but it took a while)

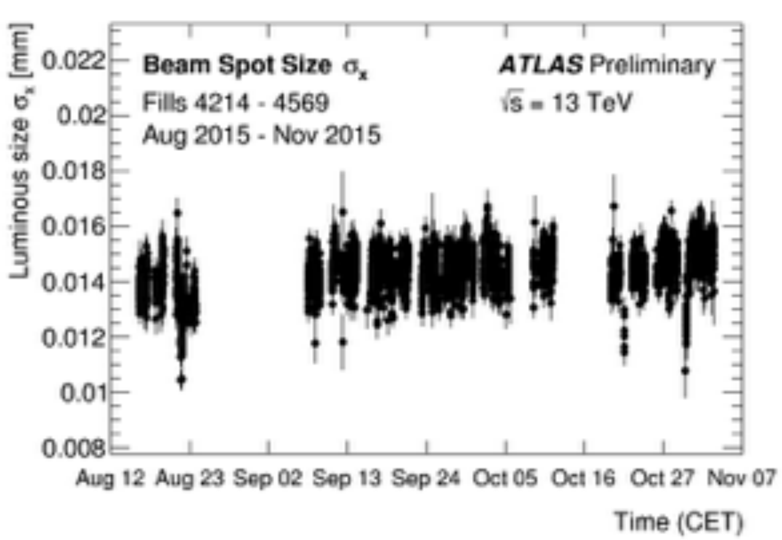
Beam Spot Public Results

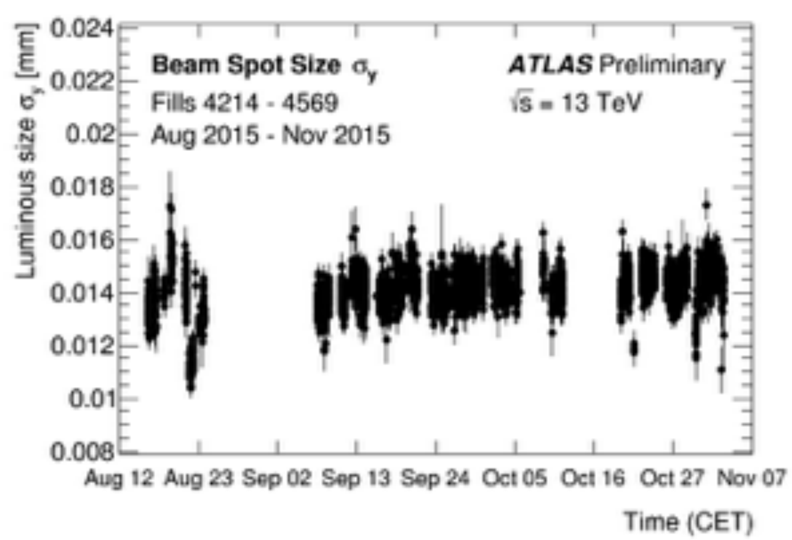
Beam Spot

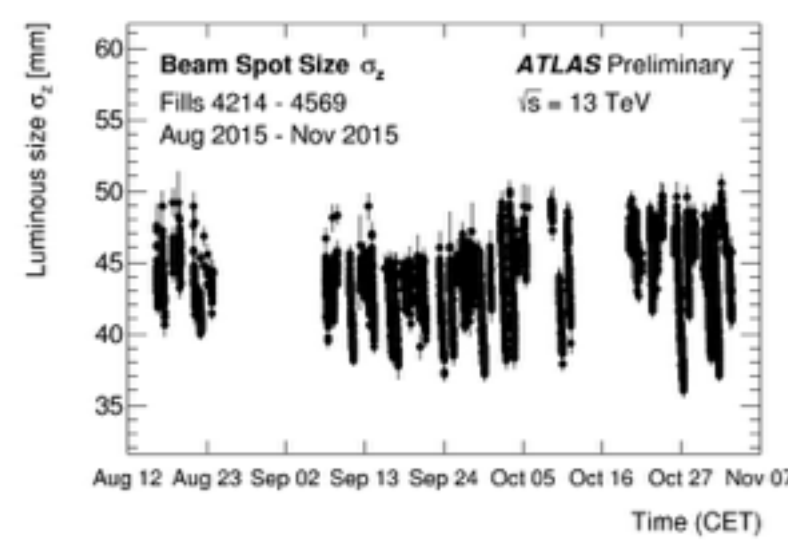




- Very stable beam spot for all 2015
- Tune beam once to bring collisions in nominal position
- Very stable x, y, z beam sizes





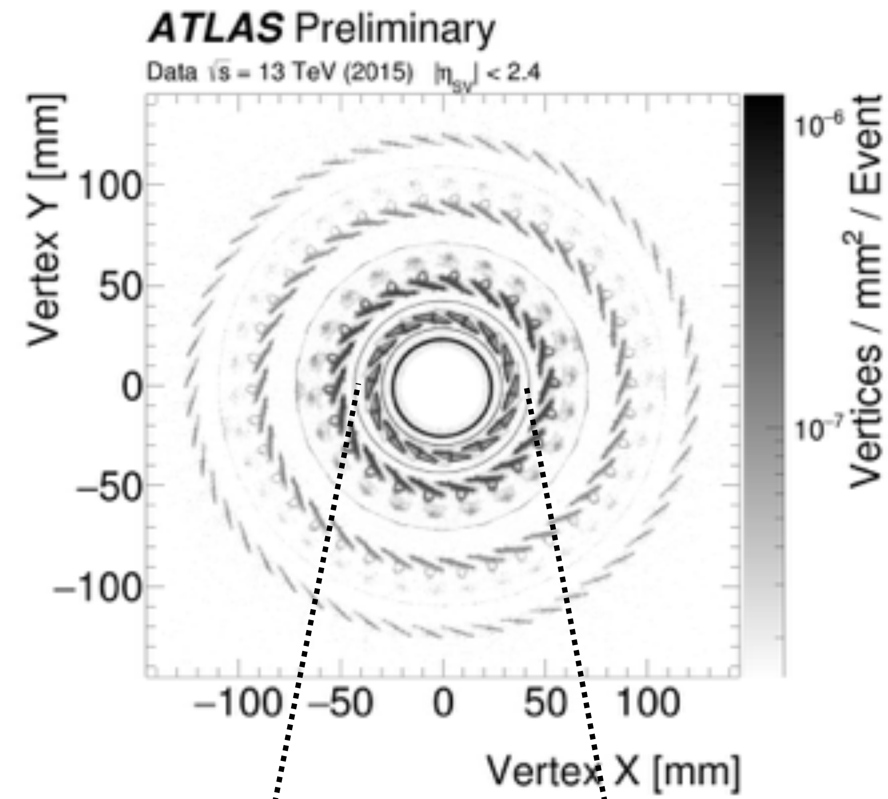


Inner Detector Material

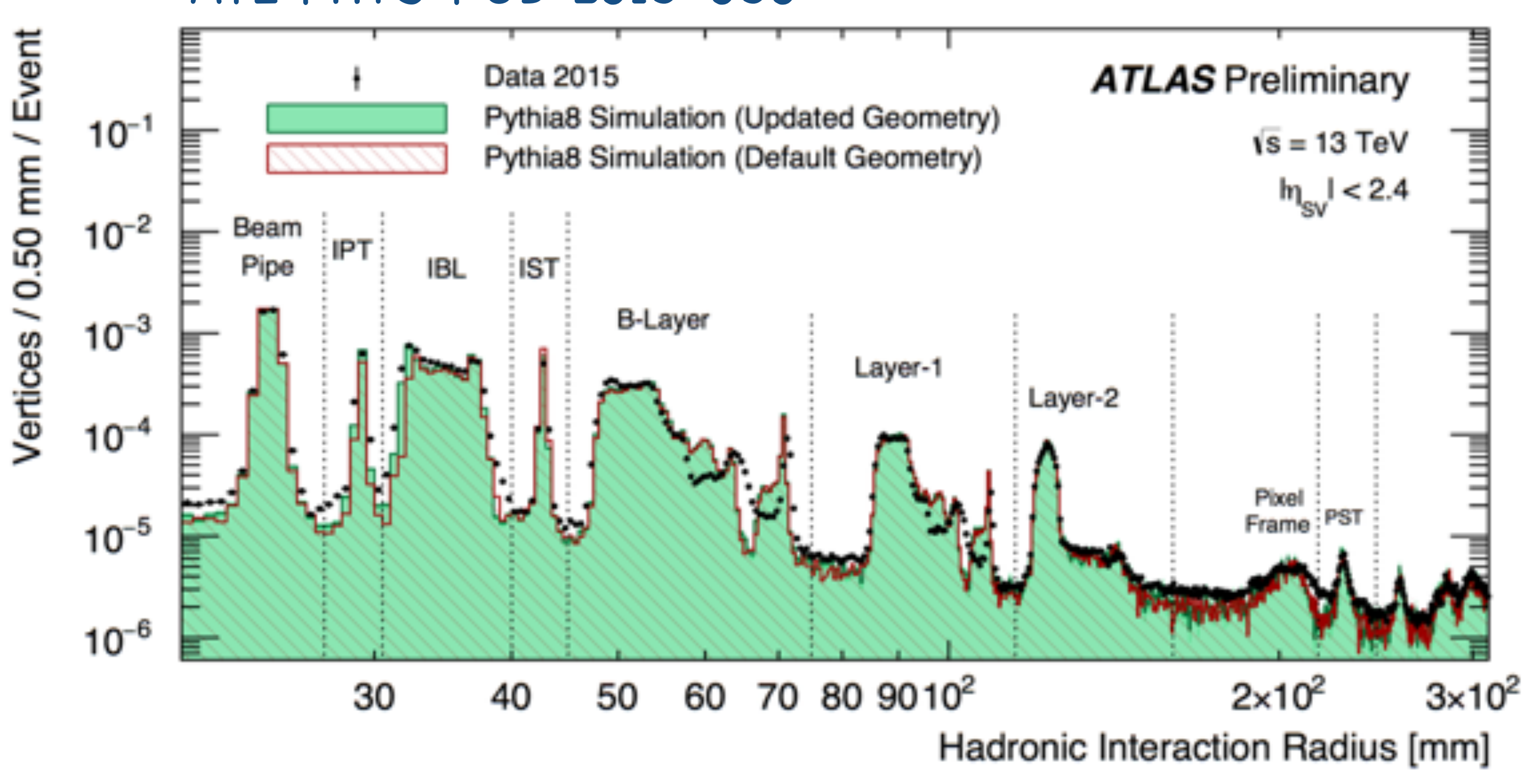
Detailed mapping of the material in Pixel detector using:

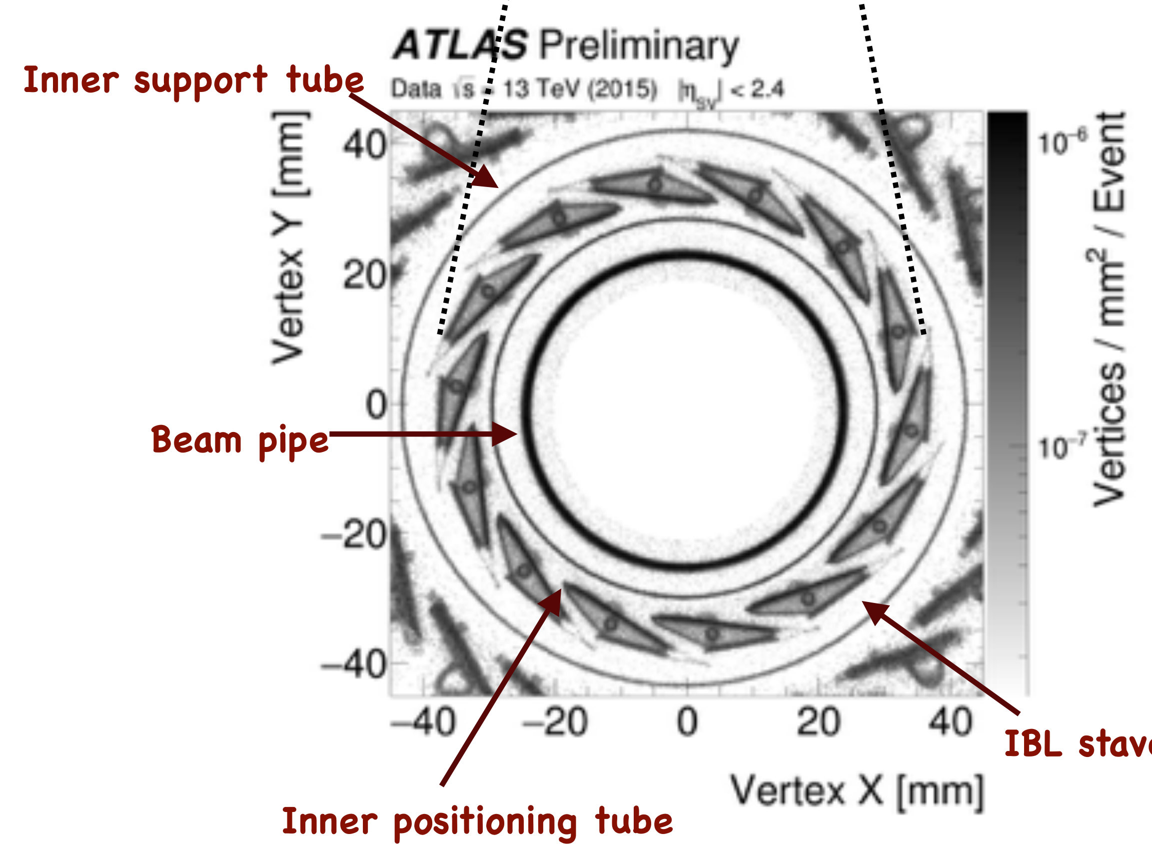
- Hadronic interactions
- Photon conversions

Simulation updated after comparison to improve geometry description



ATL-PHYS-PUB-2015-050

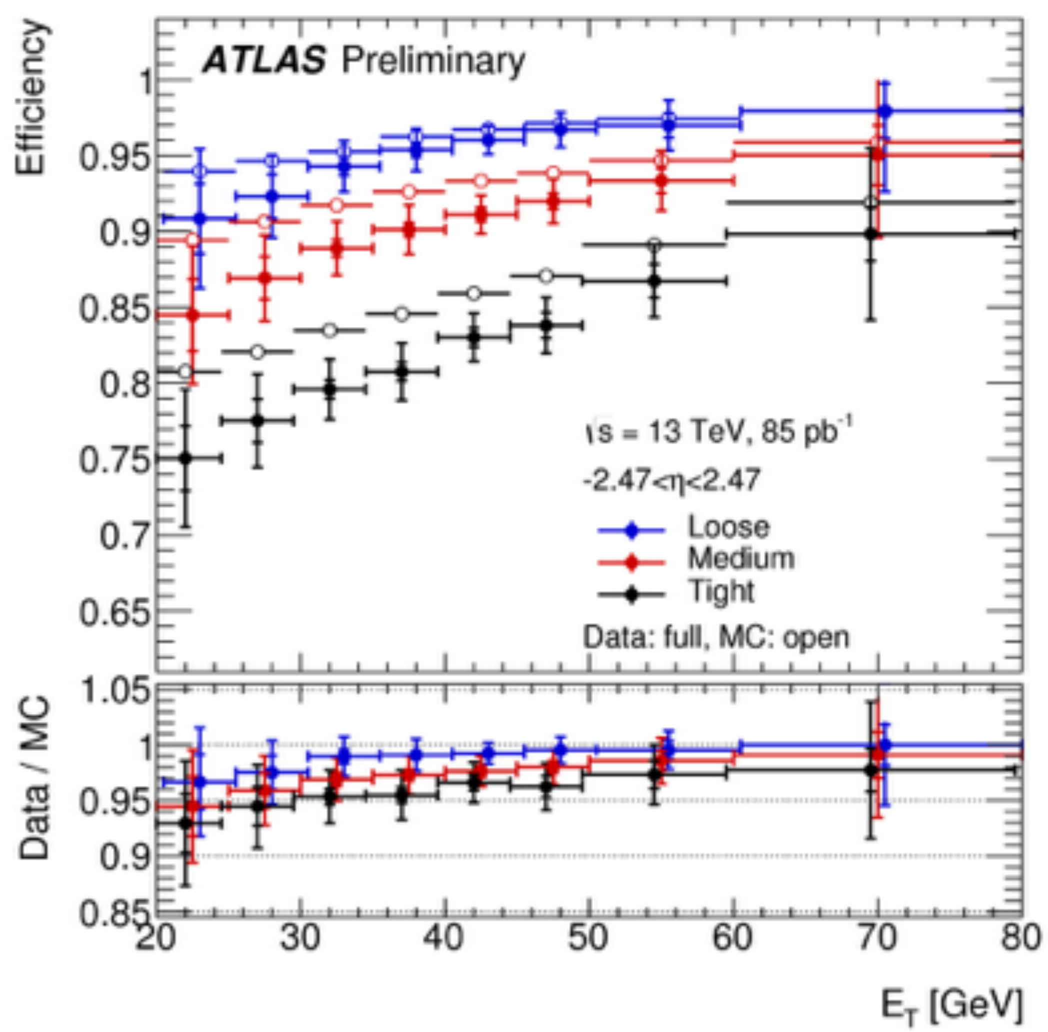




Electrons and Photons

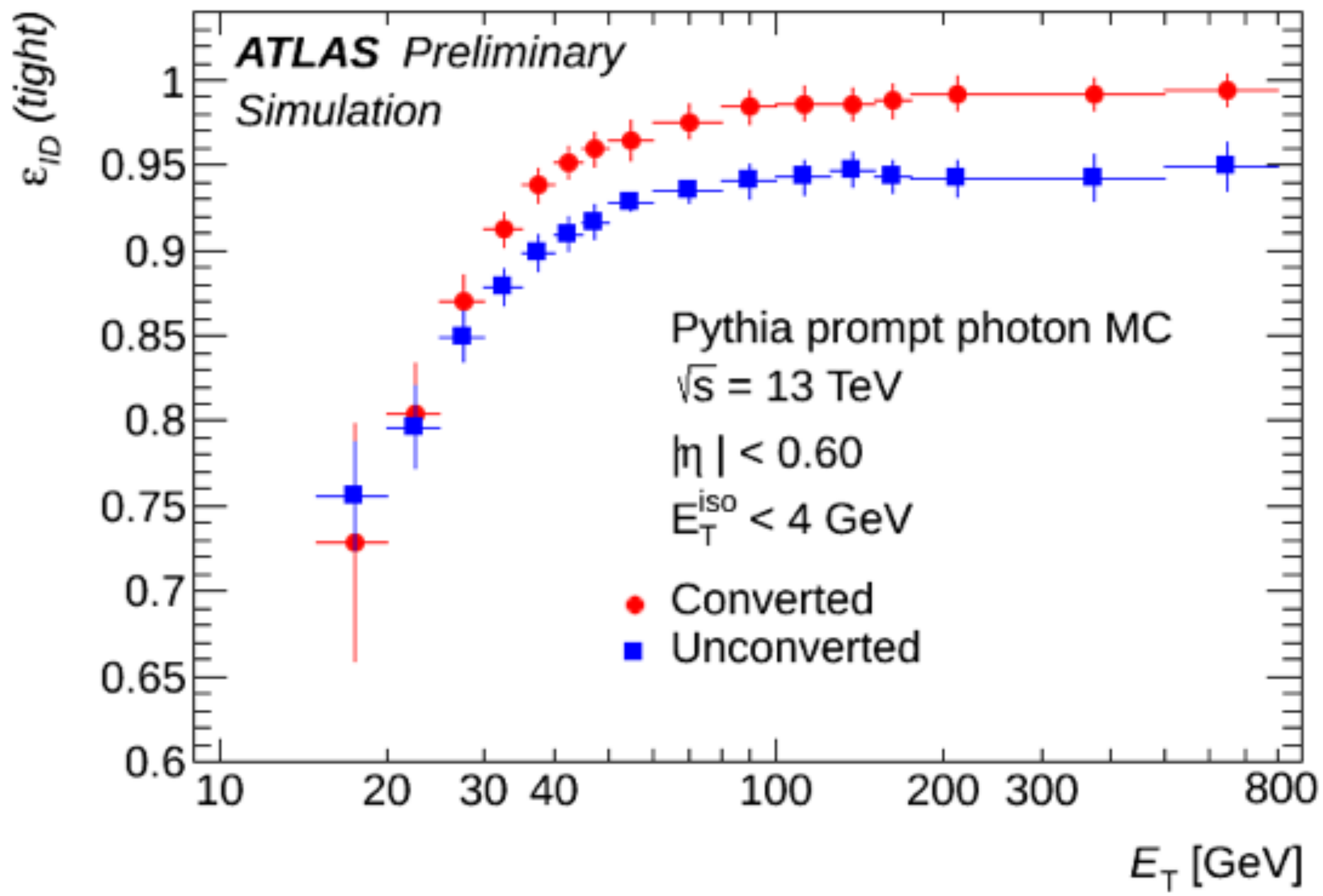
ATL-PHYS-PUB-2015-041

Electron identification efficiency



EGAM-2015-002

Photon identification efficiency



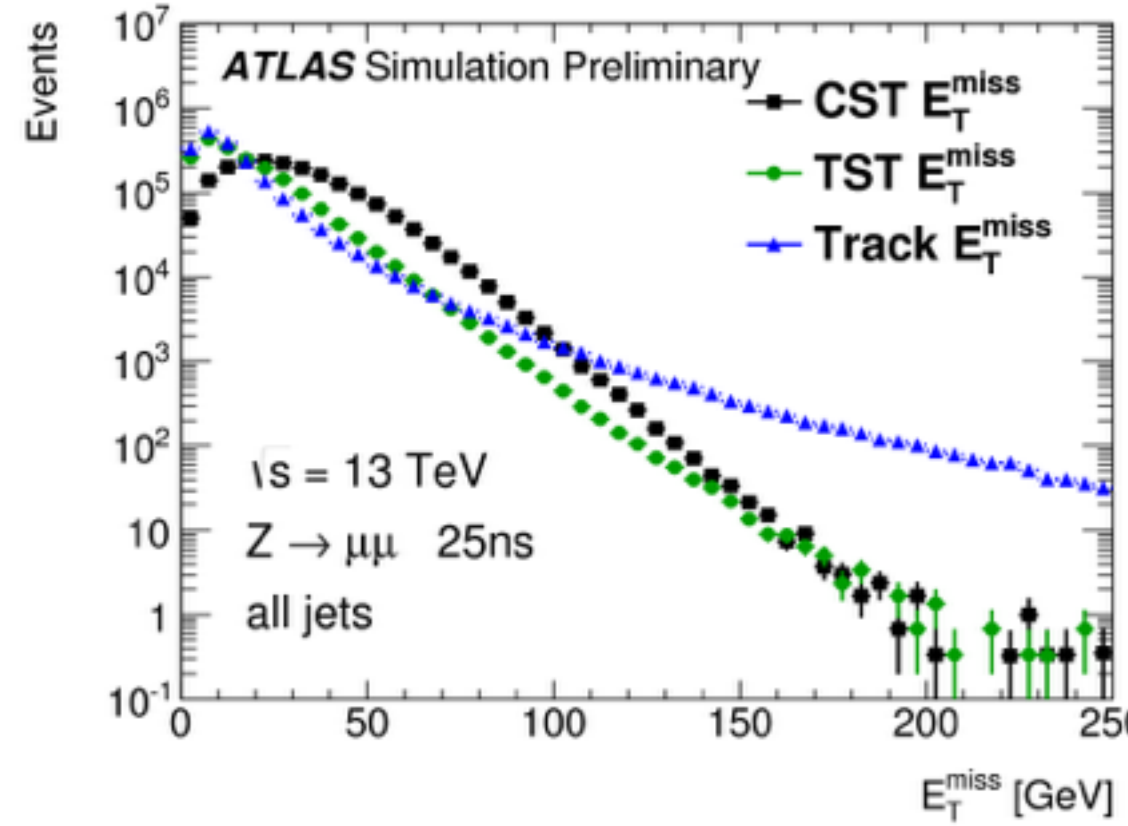
- **Likelihood electron identification performance with full 2015 dataset**

- **Good agreement between data and simulation**
  - Lower efficiency in data than MC mostly arises from a known mismodelling of calorimetric shower shape
  - Correction factors applied to correct remaining differences

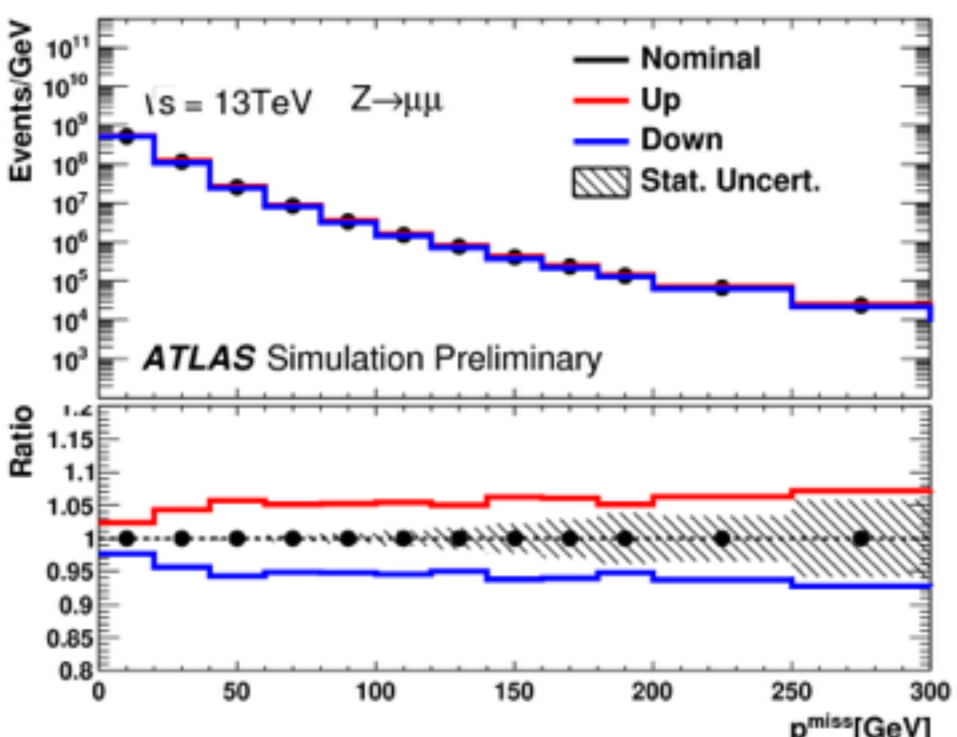
Missing Transverse Momentum

- **New technique developed during LS1 using tracking information**
  - Track Soft Term (TST)
  - Track MET
  - Reduces pileup sensitivity
- **Systematics derived from MC, will be updated soon**

ATL-PHYS-PUB-2015-023



ATL-PHYS-PUB-2015-027



Performance plot from mono-jet search