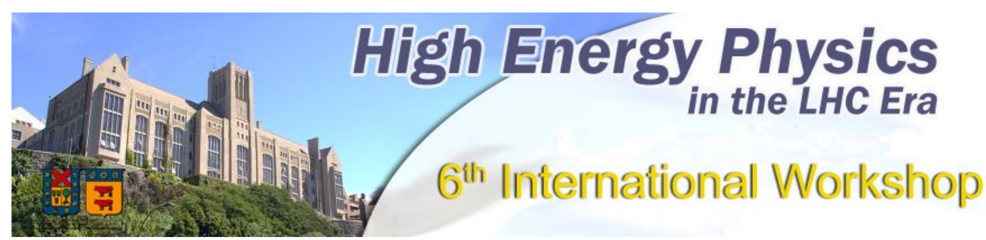
Run-2 ATLAS Trigger and Detector Performance

Frank Winklmeier
University of Oregon

on behalf of the ATLAS Collaboration



https://indico.cern.ch/e/hep2016

Valparaiso, Chile
8th January 2016

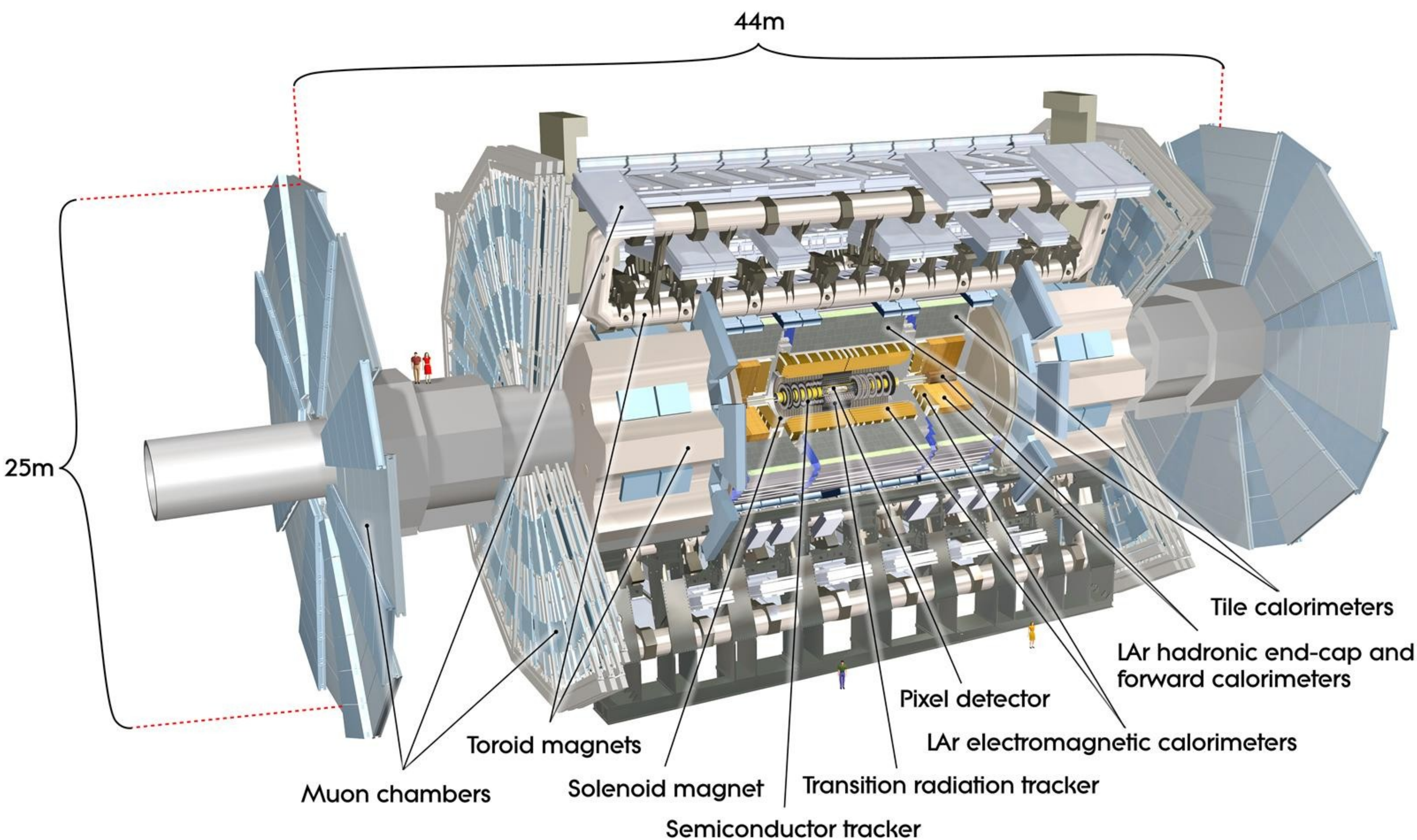
ATLAS EXPERIMENT

Content

- Detector and Trigger performance
    - Upgrades done during Long Shutdown 1 (LS1, Feb'13 – Apr'15)
    - Detector Performance in 2015
    - Trigger Performance in 2015
    - Outlook for 2016

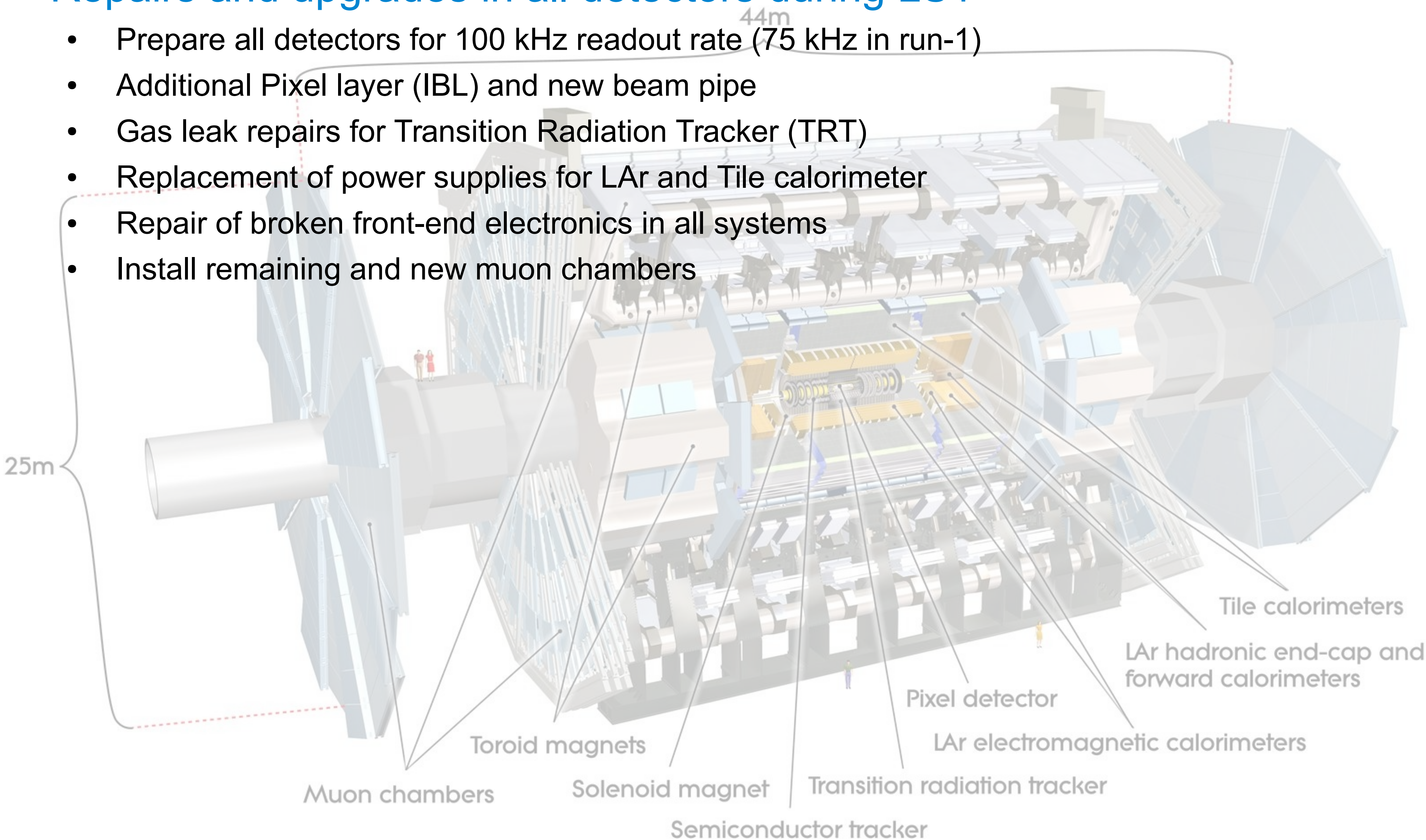
- Physics and Upgrade covered in
    - Wednesday
        - Hernan Wahlberg, First Atlas Results from Run2
    - Saturday
        - Giulio Aielli, ATLAS Upgrades for the Next Decades
    - + many other talks in parallel sessions

The ATLAS Detector



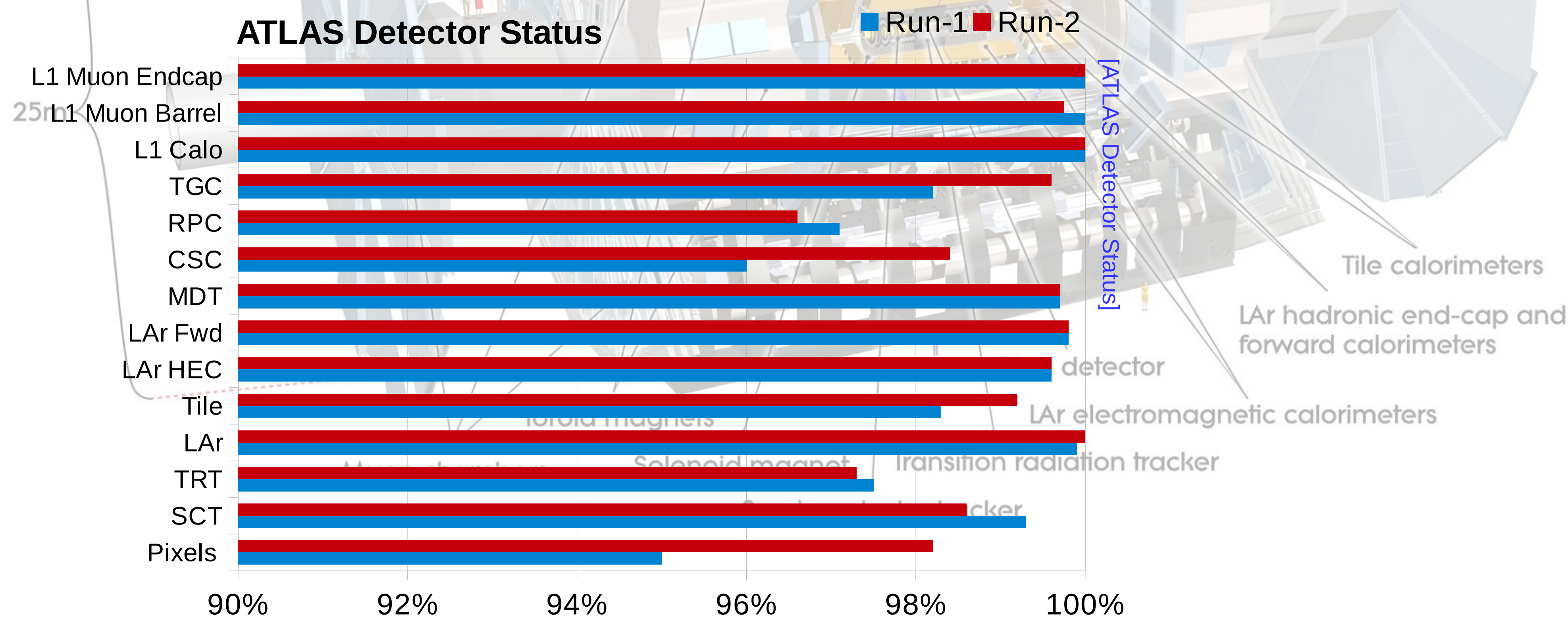
The ATLAS Detector

- Repairs and upgrades in all detectors during LS1
  - Prepare all detectors for 100 kHz readout rate (75 kHz in run-1)
  - Additional Pixel layer (IBL) and new beam pipe
  - Gas leak repairs for Transition Radiation Tracker (TRT)
  - Replacement of power supplies for LAr and Tile calorimeter
  - Repair of broken front-end electronics in all systems
  - Install remaining and new muon chambers



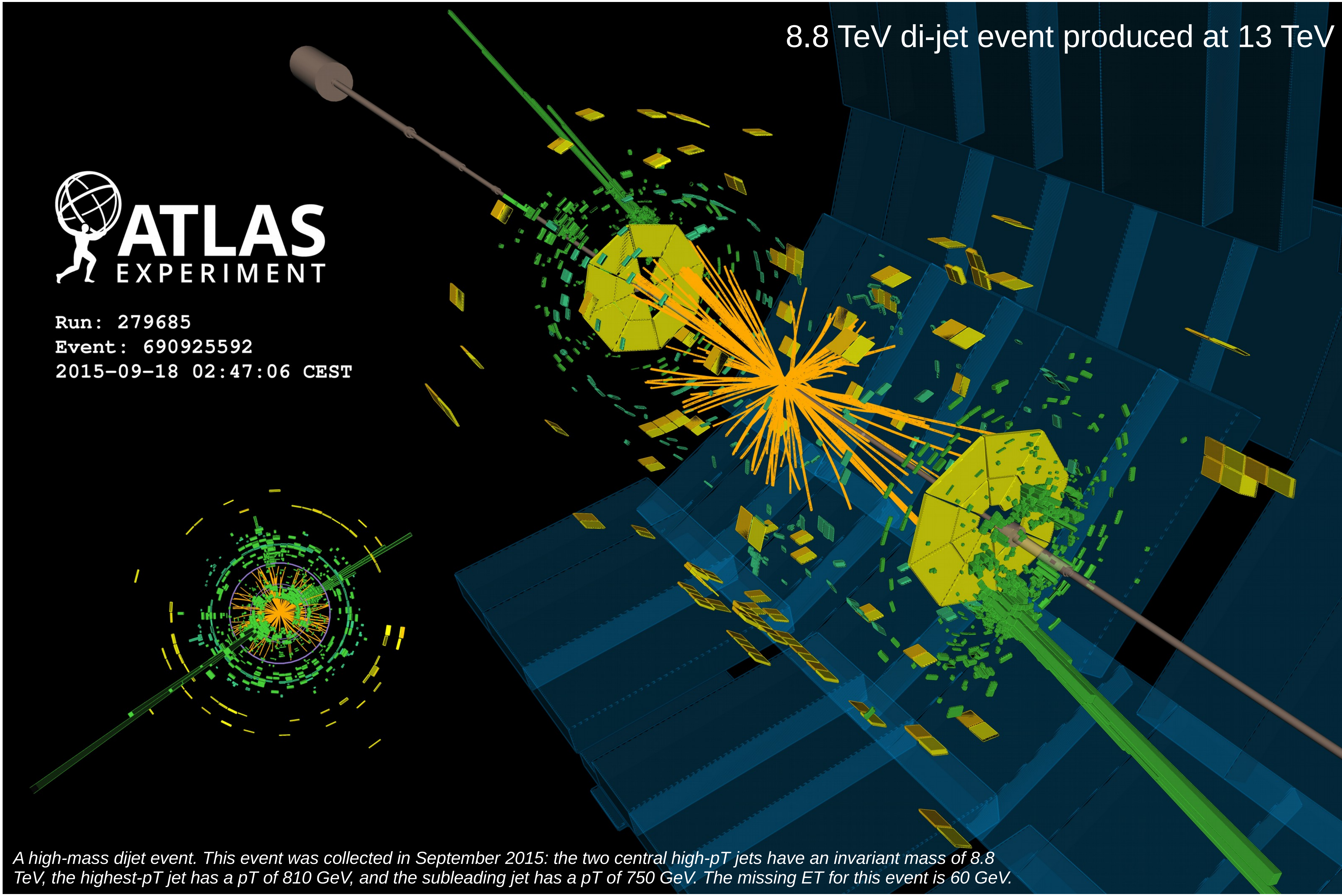
The ATLAS Detector

- Repairs and upgrades in all detectors during LS1
  - Prepare all detectors for 100 kHz readout rate (75 kHz in run-1)
  - Additional Pixel layer (IBL) and new beam pipe
  - Gas leak repairs for Transition Radiation Tracker (TRT)
  - Replacement of power supplies for LAr and Tile calorimeter
  - Repair of broken front-end electronics in all systems
  - Install remaining and new muon chambers
- Fraction of operational channels



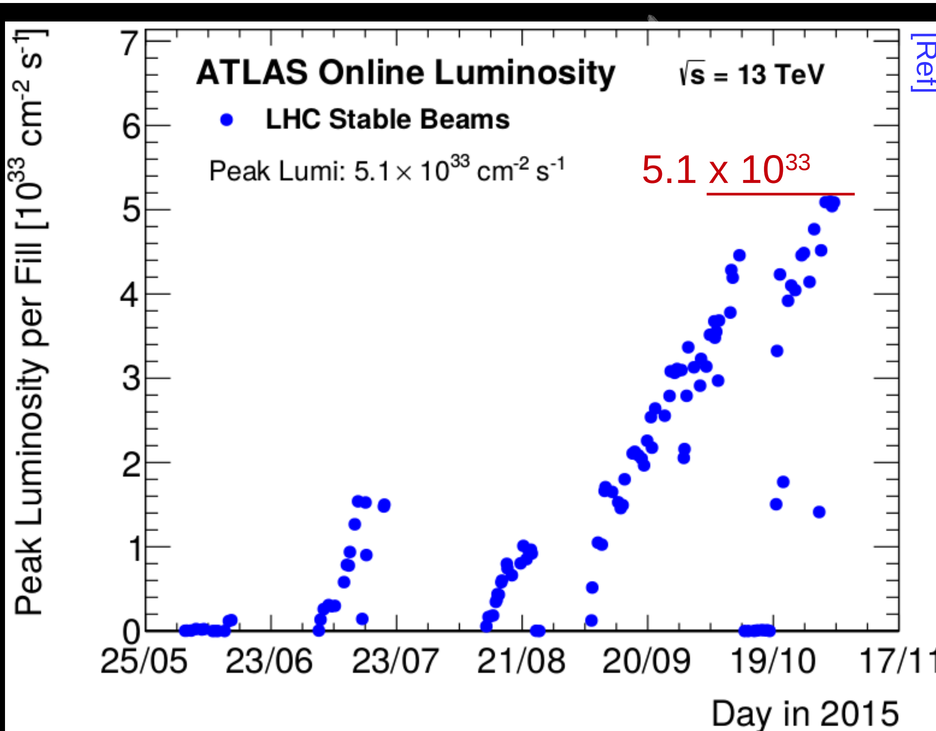
A new era for proton-proton collisions

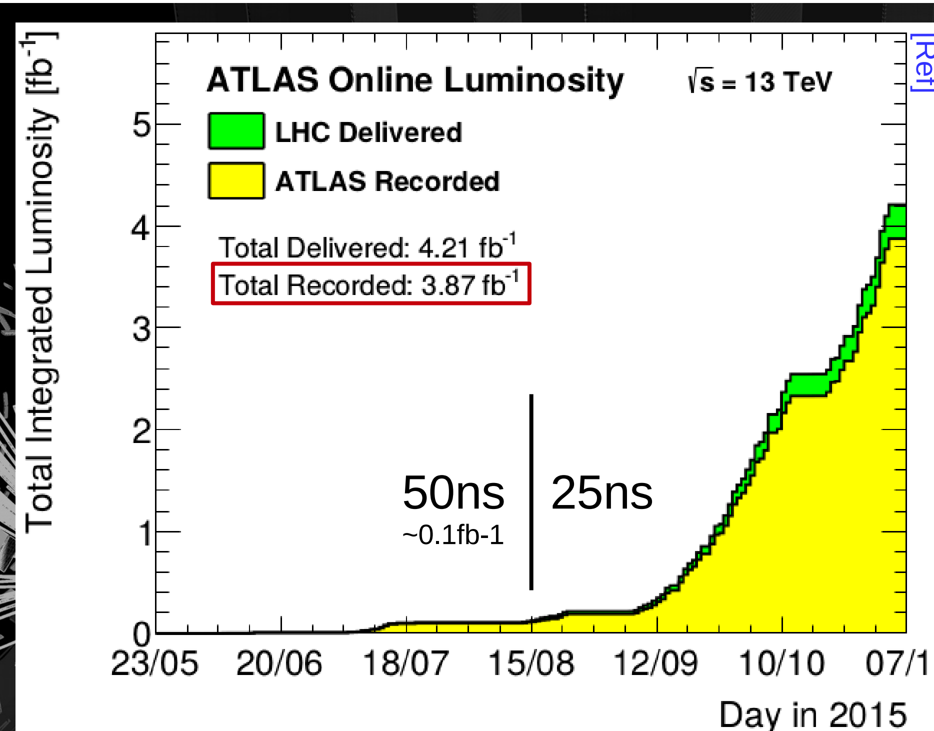
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/EventDisplayPublicResults



A high-mass dijet event. This event was collected in September 2015: the two central high-pT jets have an invariant mass of 8.8 TeV, the highest-pT jet has a pT of 810 GeV, and the subleading jet has a pT of 750 GeV. The missing ET for this event is 60 GeV.

A new era for proton-proton collisions





Run-1 vs Run-2	Run-1 (8TeV)	Run-2 (13TeV)
Peak lumi [cm^{-2} s^{-1}]	7.7 x 10^{33}	5.1 x 10^{33}
mean pileup	21	13
Integrated lumi [fb^{-1}]	22.8	4.2
Data-taking eff.	93%	92%

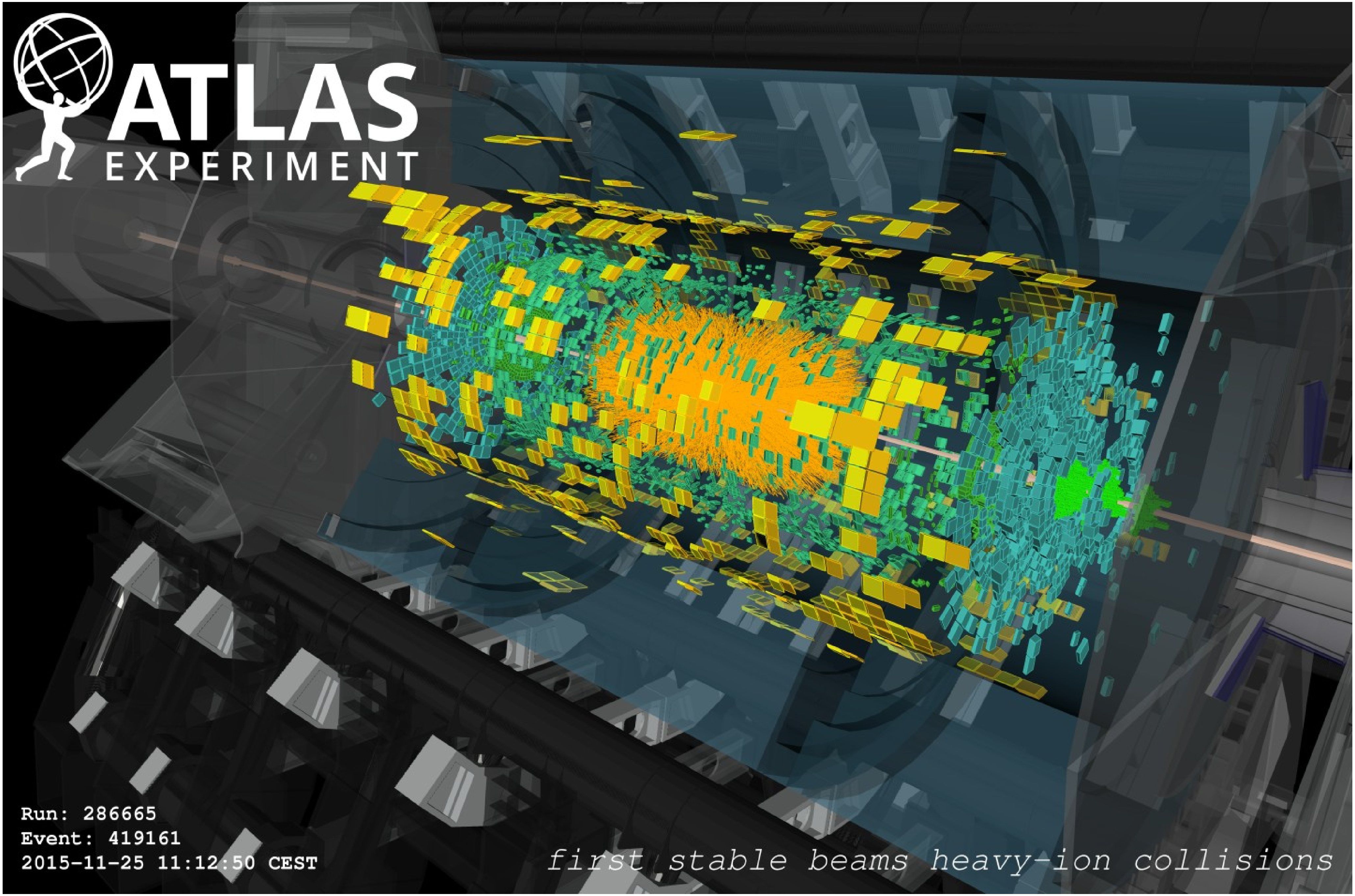
ATLAS pp 25ns run: August-November 2015

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})										

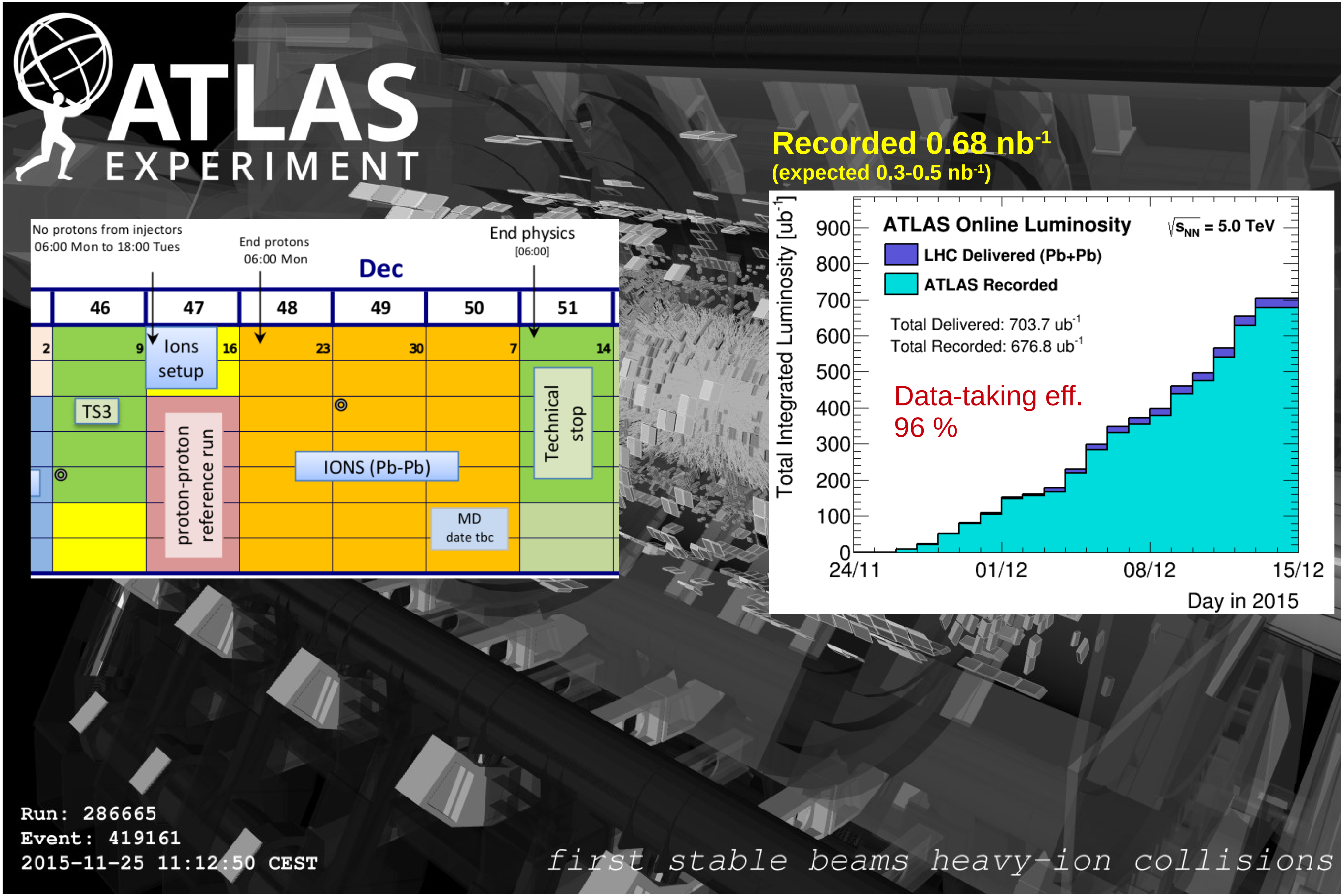
Luminosity weighted relative detector uptime and good data quality (DQ) efficiencies (in %) during stable beam in pp collisions with 25ns bunch spacing at √s=13 TeV between August-November 2015, corresponding to an integrated luminosity of 3.7 fb^{-1}. The lower DQ efficiency in the Pixel detector is 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%. [Ref]

Heavy-Ion data-taking

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/EventDisplayPublicResults

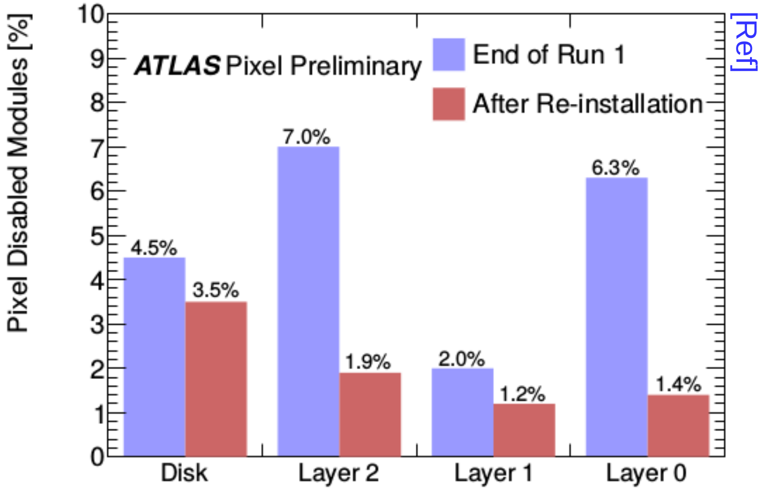


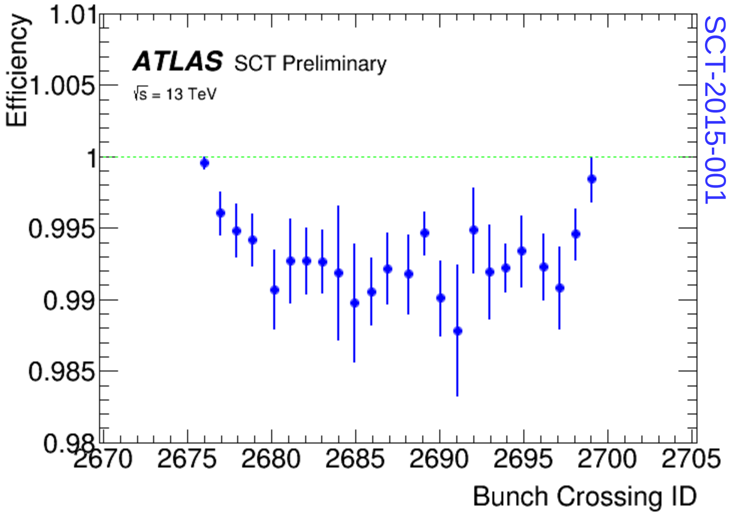
Heavy-Ion data-taking



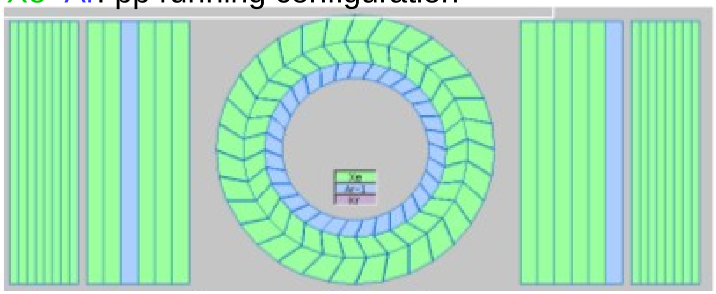
Inner Detector – Pixel, SCT and TRT

- Pixel
  - Operating smoothly
  - Overall status of Pixel improved compared to end of Run-1
  - New innermost layer (IBL) → see next slides
- Silicon Strip Tracker (SCT)
  - Stable and reliable throughout 2015
  - Performance comparable with Run-1
  - Very small drop in hit efficiency for 25ns beams
    - This is expected for bunches within a train
    - Intrinsic hit efficiency can be seen in first bunch
    - No impact on tracking performance
- Transition Radiation Tracker (TRT)
  - Proved to sustain 100 KHz at 50% occupancy
  - Still suffering from gas leaks
    - Currently ~150 liters per day
    - Xe gas replaced by (cheaper) Ar in the worst gas loops
  - Negligible impact on electron identification
  - For HI run changed full detector to Ar gas mix



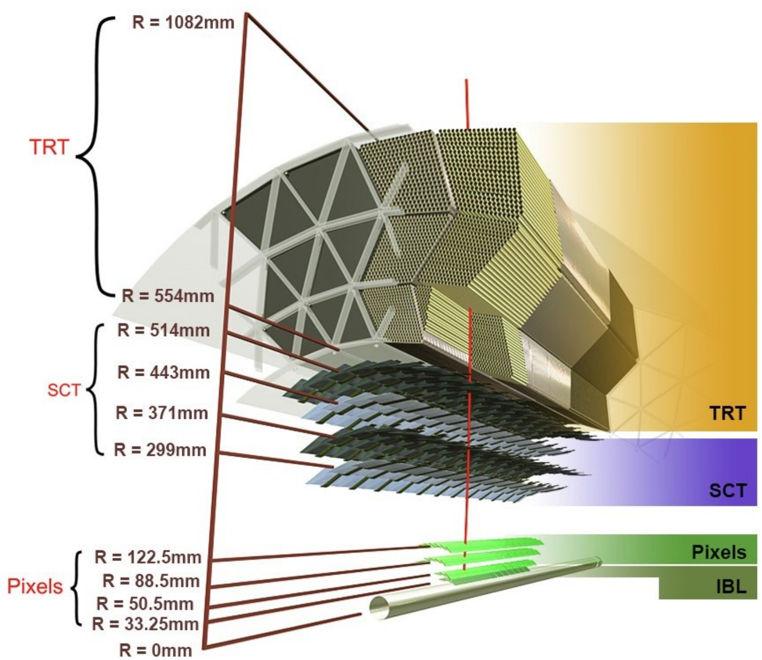


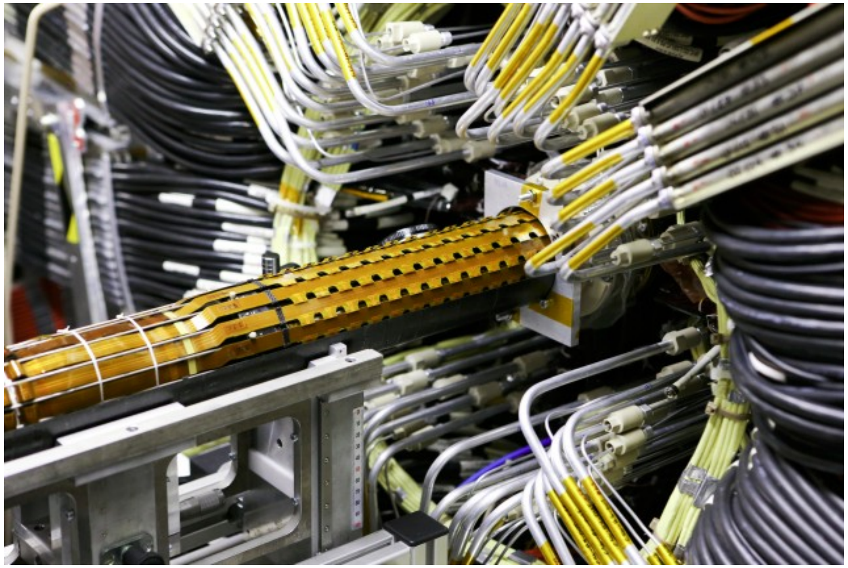
Xe+Ar: pp running configuration



IBL – Insertable B-Layer

- New innermost layer for the ATLAS Pixel detector
  - Increases the number of pixel layers from 3 → 4
    - 6M additional channels, 50×250 μm² pixel size (compared to 50×400 for Pixel)
    - 8×40 μm² resolution
  - 3.3 cm from the beam line including a new (smaller) beam pipe
  - Required complete removal of the ATLAS Pixel volume during Long Shutdown 1
  - Provides better tracking for ATLAS
  - But of course also some operational issues as with any new detector

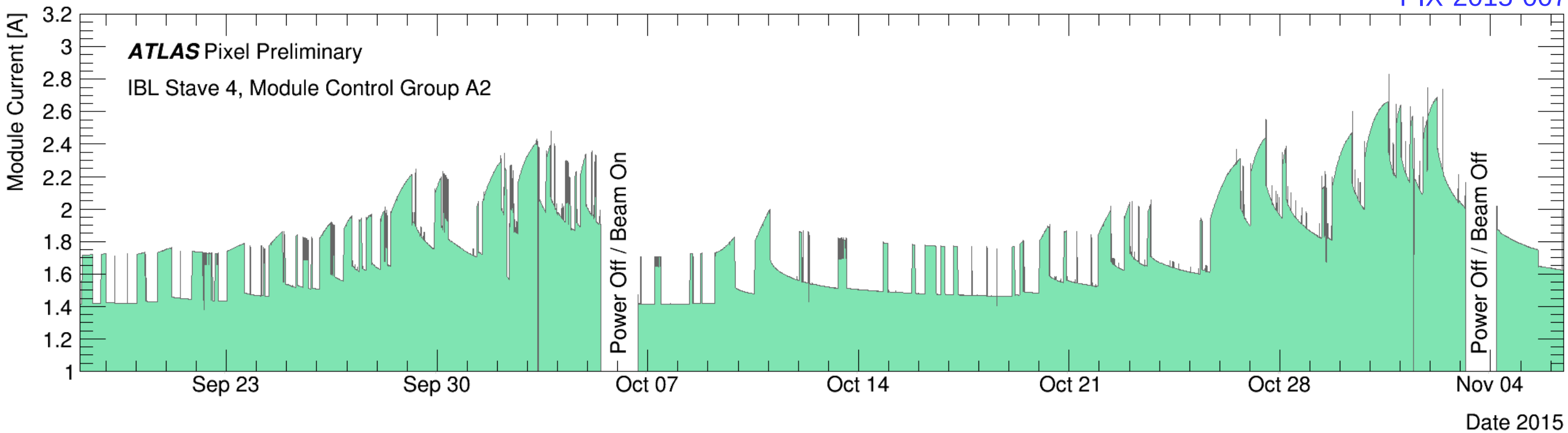




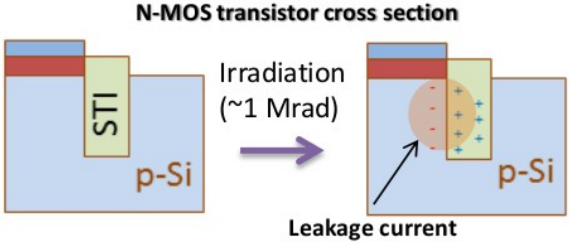
IBL – Front-End current drift

- Increase of FE current observed during data-taking
  - Stopped IBL for 2 days in October for investigations

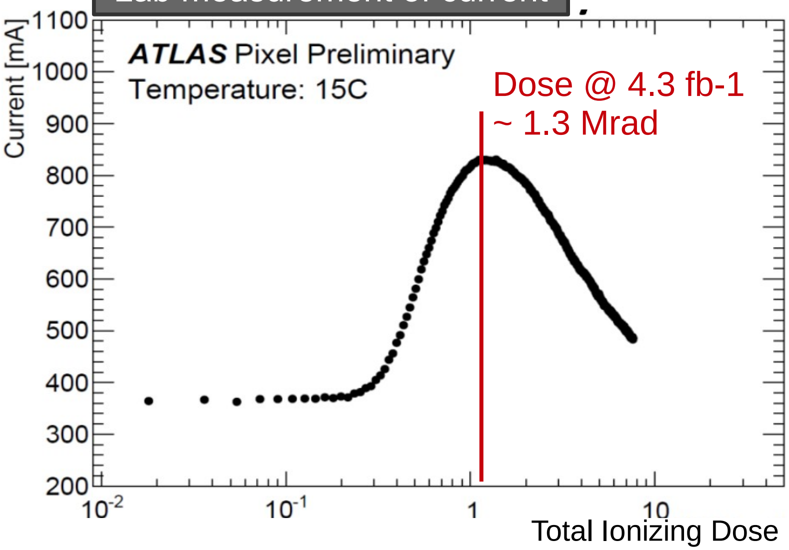
PIX-2015-007



- Effect is due to irradiation
  - Understood to be a N-MOS transistor leakage due to defects built-up at the Silicon Oxide (STI) interface and cumulated by ionizing dose
  - Lab test confirms that effect will significantly reduce after a few additional Mrad of irradiation



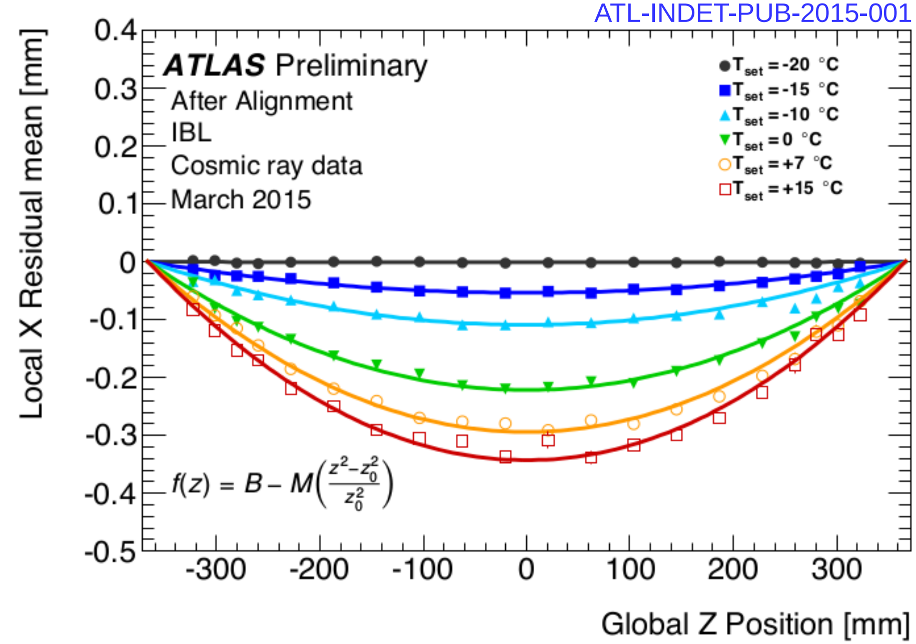
Lab measurement of current



IBL – Mechanical Distortions

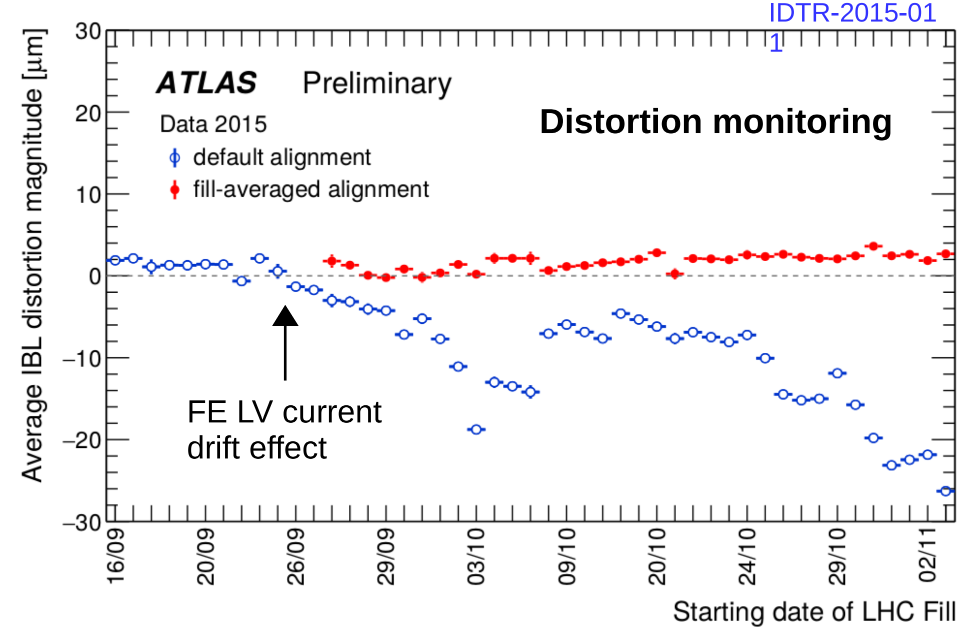
- Distortions due to temperature variations
  - Bowing of ~10μm/K observed during cosmic ray commissioning in early 2015
  - Under normal operations conditions temperature is stable within 0.2K
    - No impact on tracking performance
  - Became a problem with the current drifts of the previous slide

ATL-INDET-PUB-2015-001



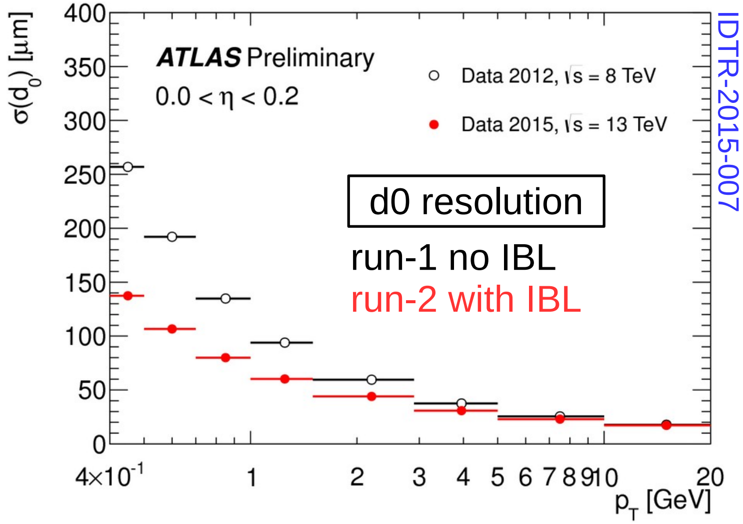
- Run-by-run alignment
  - Correction applied on a run-by-run basis before bulk reconstruction
  - No significant effects on impact parameter resolution are observed
  - Not easily possible in the High-Level Trigger
    - For the moment mitigating effect by applying larger error scaling

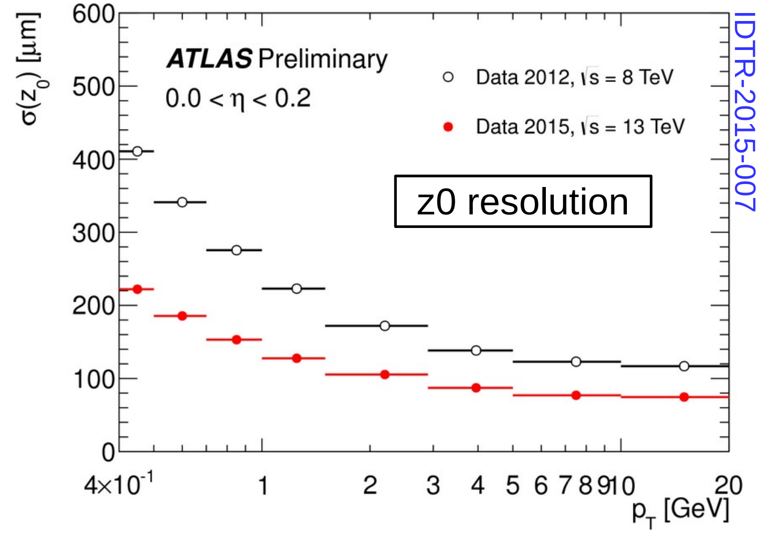
IDTR-2015-01
1



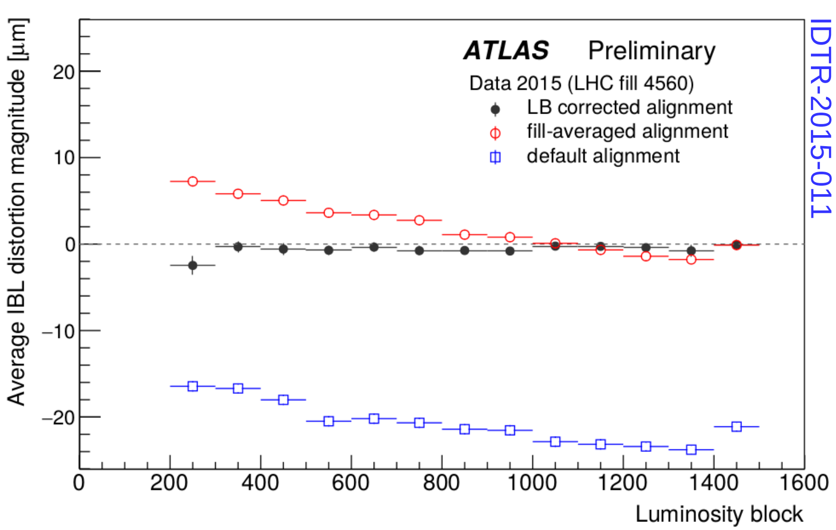
IBL – Performance

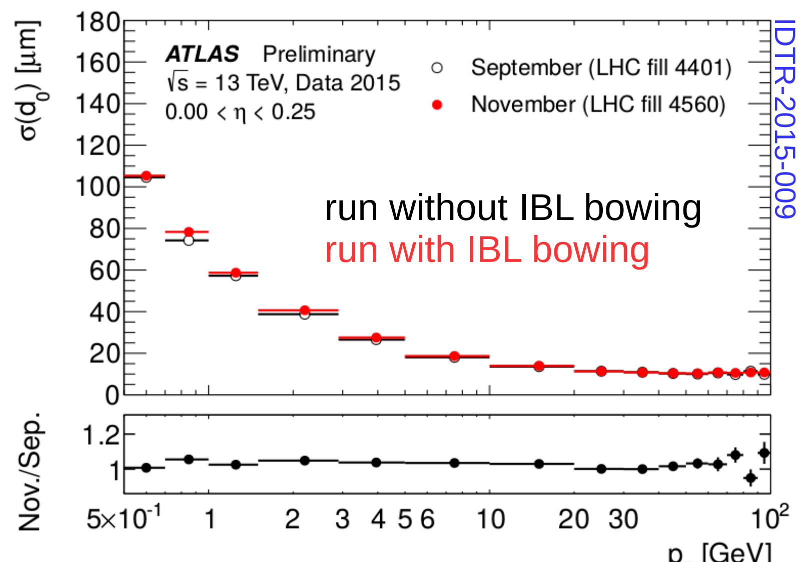
- IBL significantly improves impact parameter resolution
  - About a factor two gain in impact parameter resolution for low-pT tracks





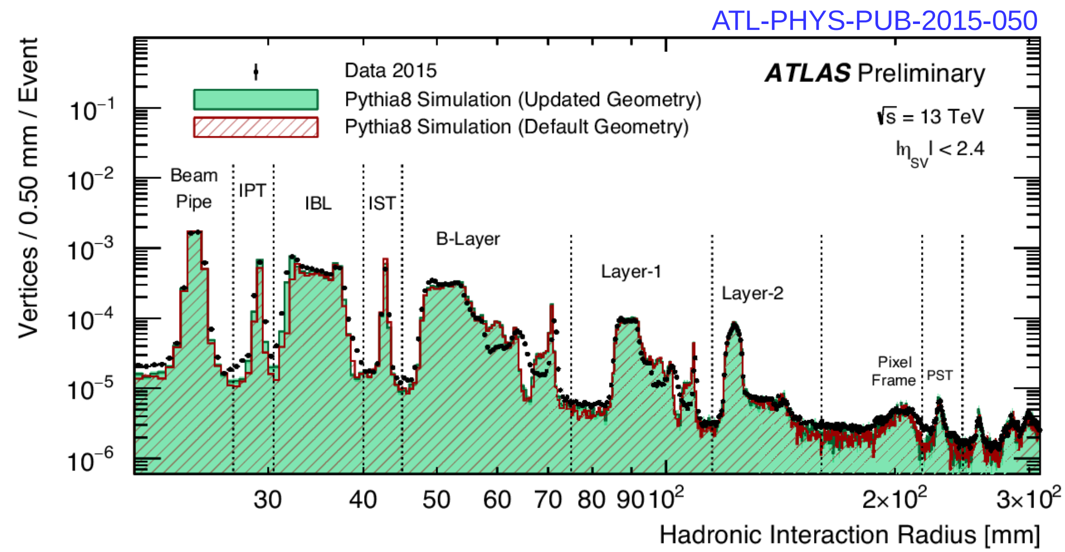
- Impact of IBL distortion
  - No significant impact after alignment correction



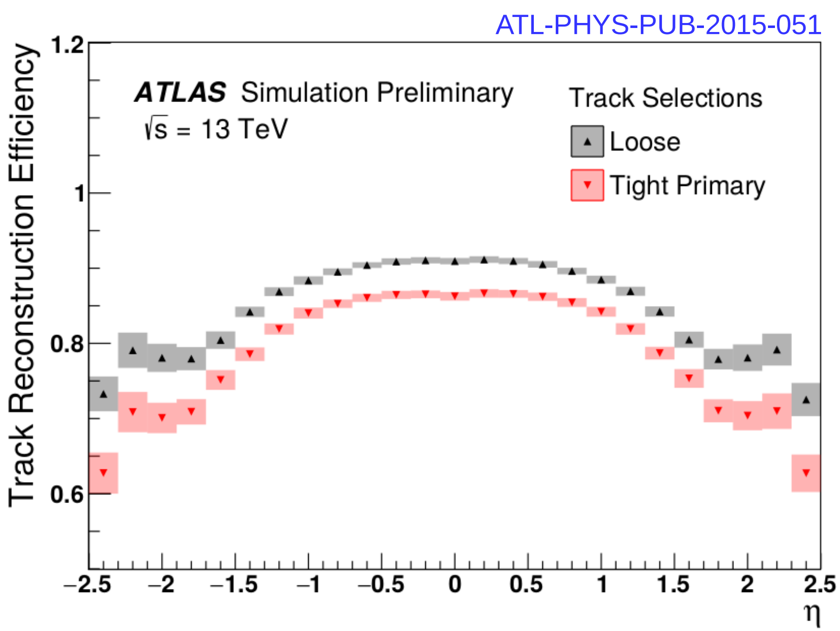


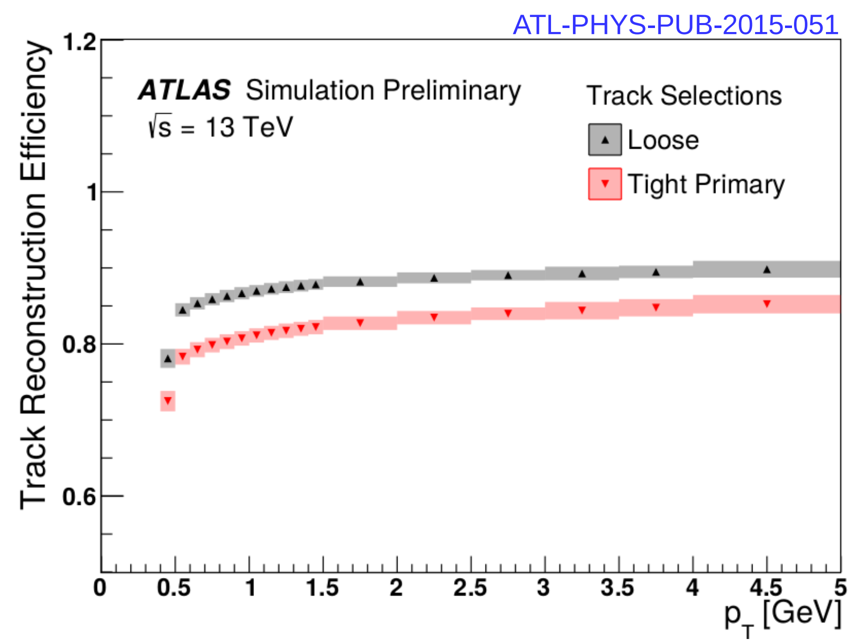
Tracking Performance and Material

- Material map of the Pixel detector
  - Using hadronic interactions
  - Using photon conversions
  - Simulation updated with improved geometry



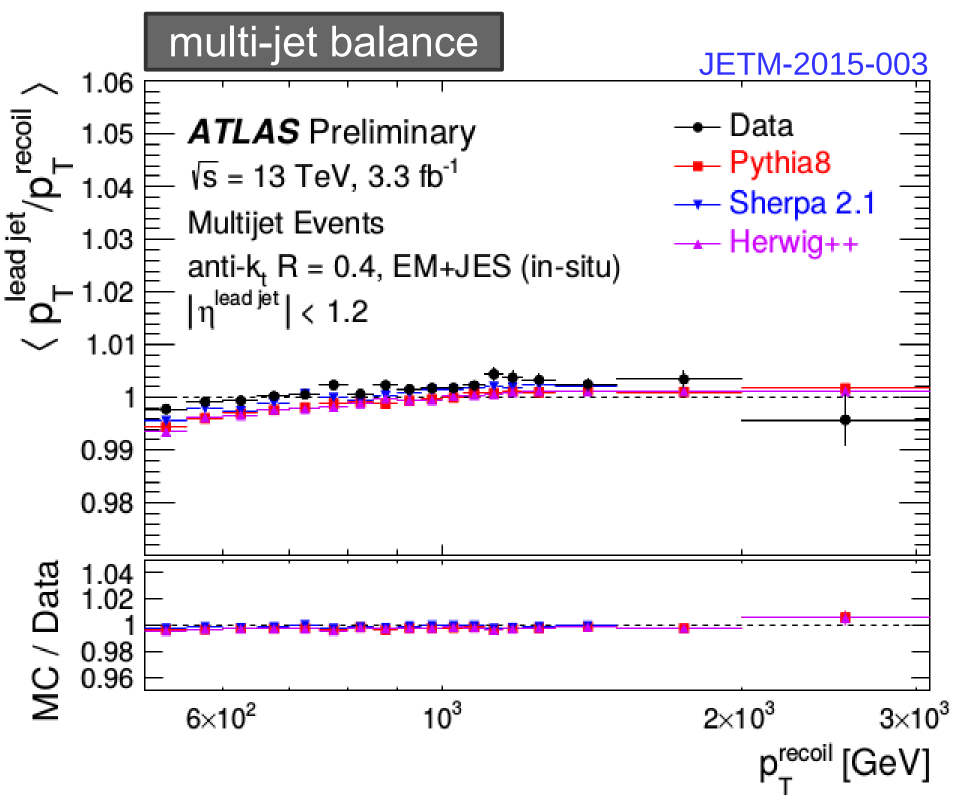
- Tracking efficiency
  - 90% (85%) efficient for *Loose* (*Tight Primary*) selections for tracks above 5 GeV

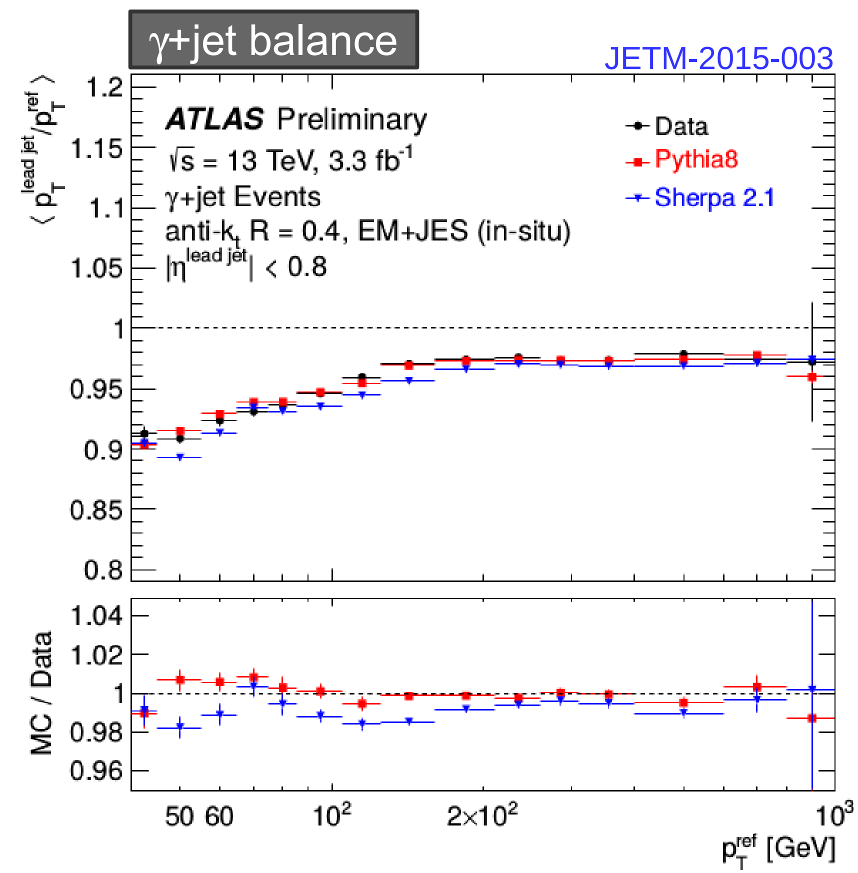




Calorimeters and Jet reconstruction

- Very stable operations for both LAr and Tile calorimeter
  - Good for physics: 99.4% (LAr) and 100% (Tile) based on Data Quality
  - LAr using 4 instead of 5 sample readout to achieve 100 kHz
  - Performing even better than during run-1
- In-situ jet energy-scale with full 2015 dataset
  - Agreement between data and MC better than 2% up to 3 TeV

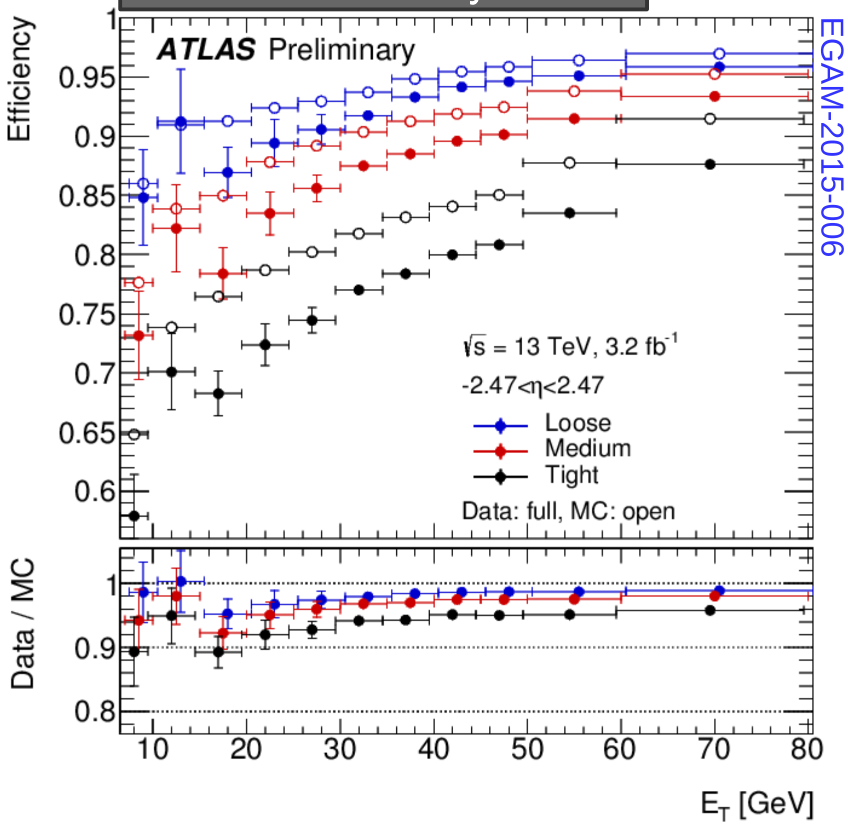




E/gamma reconstruction performance

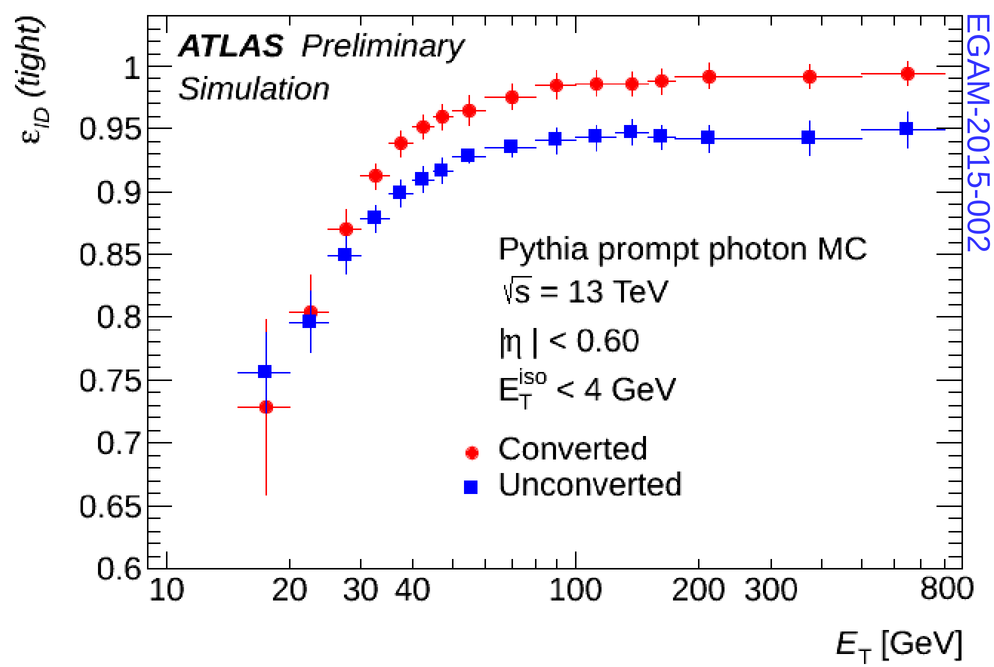
- Electron ID
  - Likelihood (LH) combining LAr shower shapes, tracking, track-cluster matching and TRT PID
  - LH improves background rejection by ~50% compared to cut-based ID with the same efficiency
- Photon ID
  - Using cut-based selection

Electron efficiency from Z



The lower efficiency in data than in MC mostly arises from a known mismodelling of calorimetric shower shapes in the GEANT detector simulation

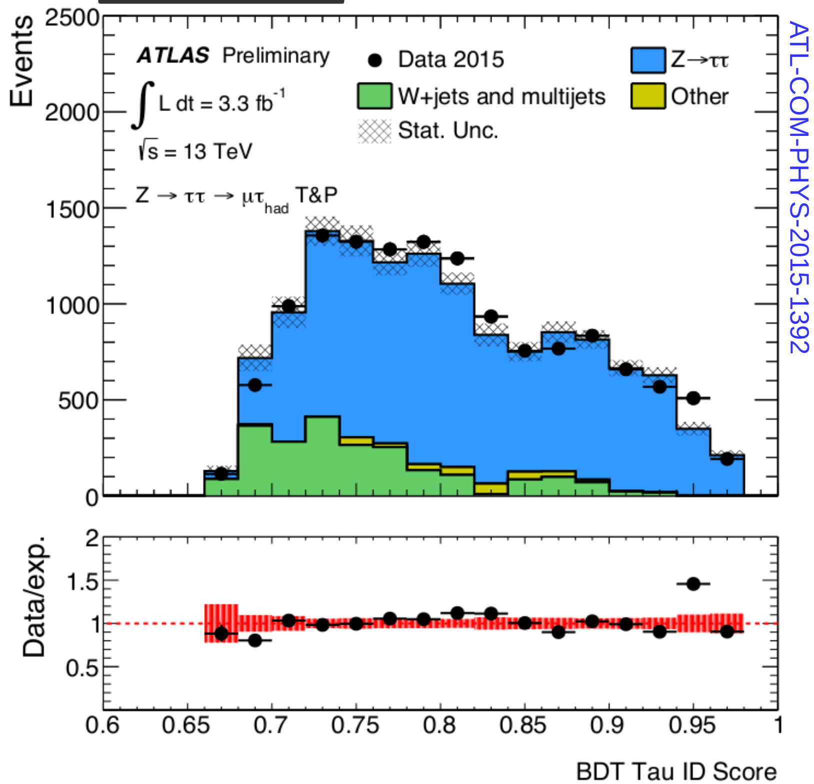
Photon reconstruction (MC)



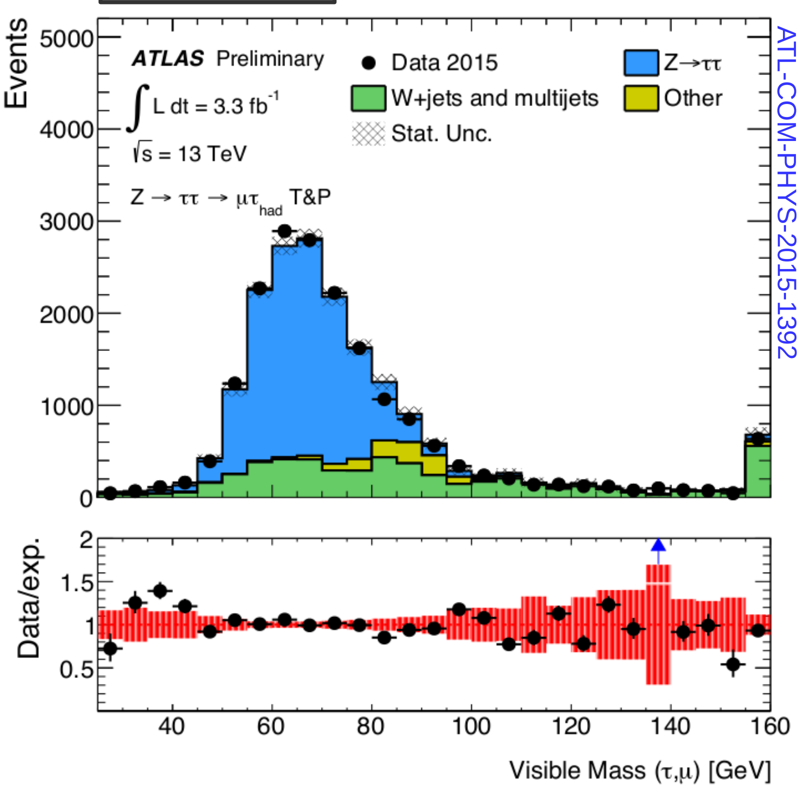
Tau reconstruction performance

- ## Tau reconstruction
  - Tau identification performed both at trigger and offline level using a multivariate discriminant combining calorimeter, tracking and lifetime observables [ATL-PHYS-PUB-2015-045]
  - Performance measured on $Z \rightarrow \tau\tau$ candidates
  - Good agreement between data and MC

Tau BDT



$Z \rightarrow \tau\tau$

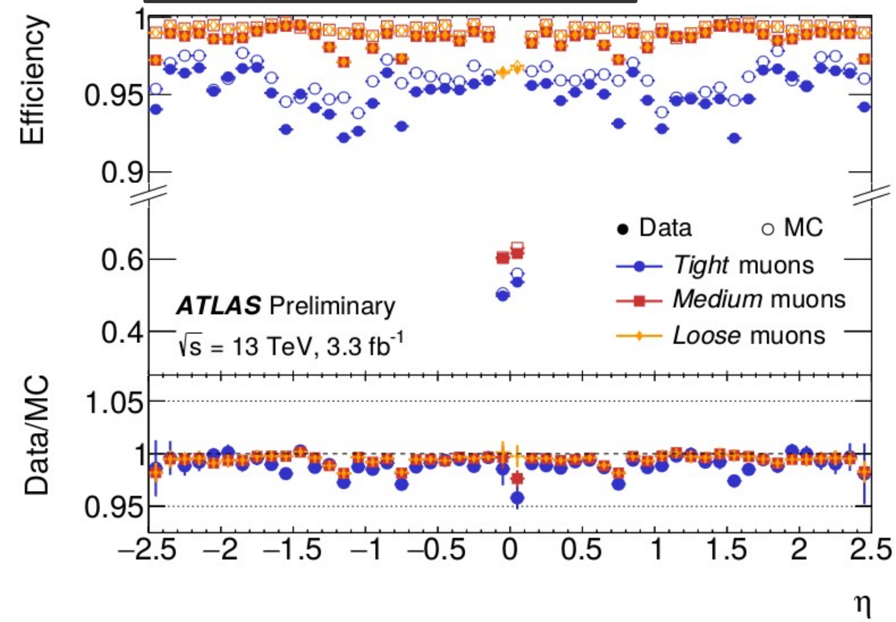


Muon Detector and Performance

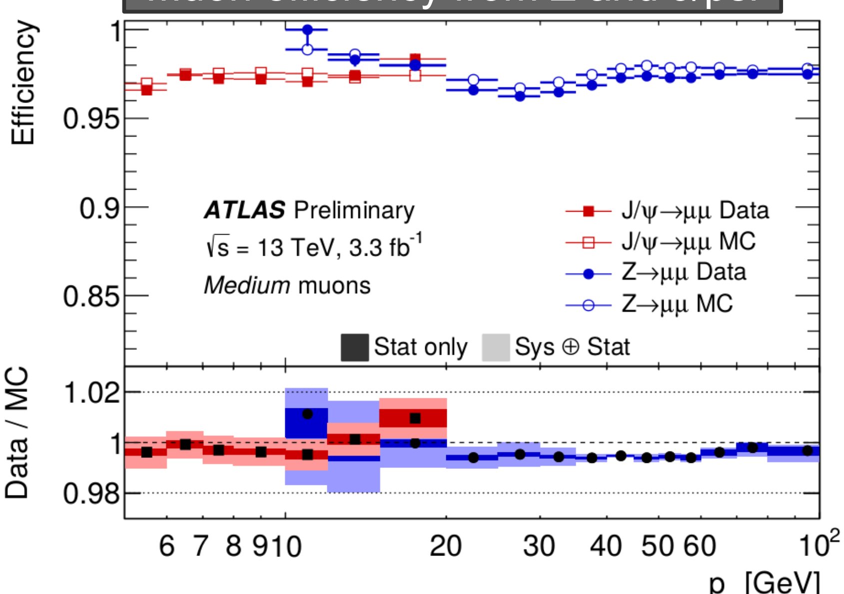
MUON-2015-004

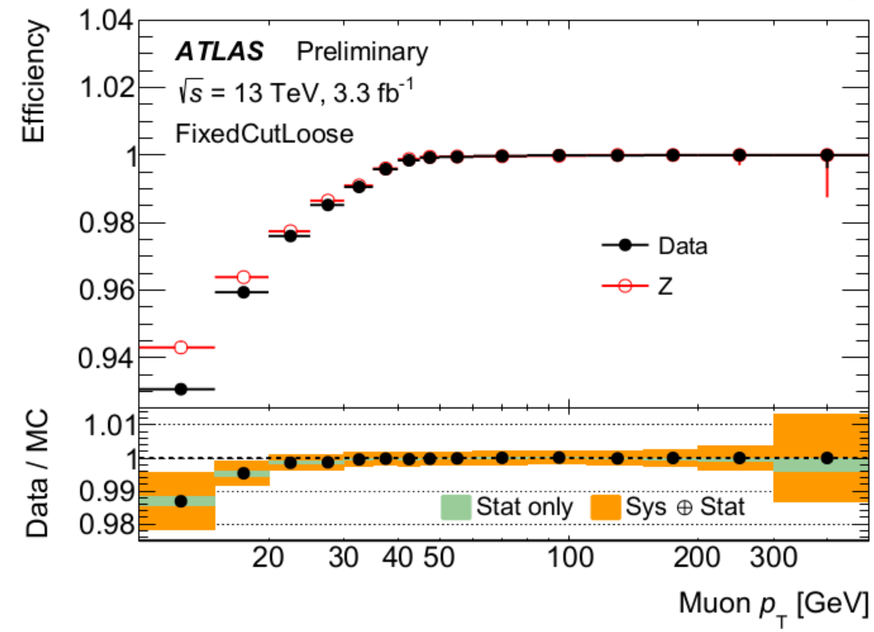
- All Muon detectors operating well
  - Readout operational at 100 kHz
  - Alignment already good to O(50μm) in the barrel and O(100μm) in the endcap
- Performance studied with 2015 dataset
  - Three main working points
    - Tight, medium, loose
  - Good agreement between data and MC
    - Remaining differences accounted for by scale factors

Muon efficiency from Z



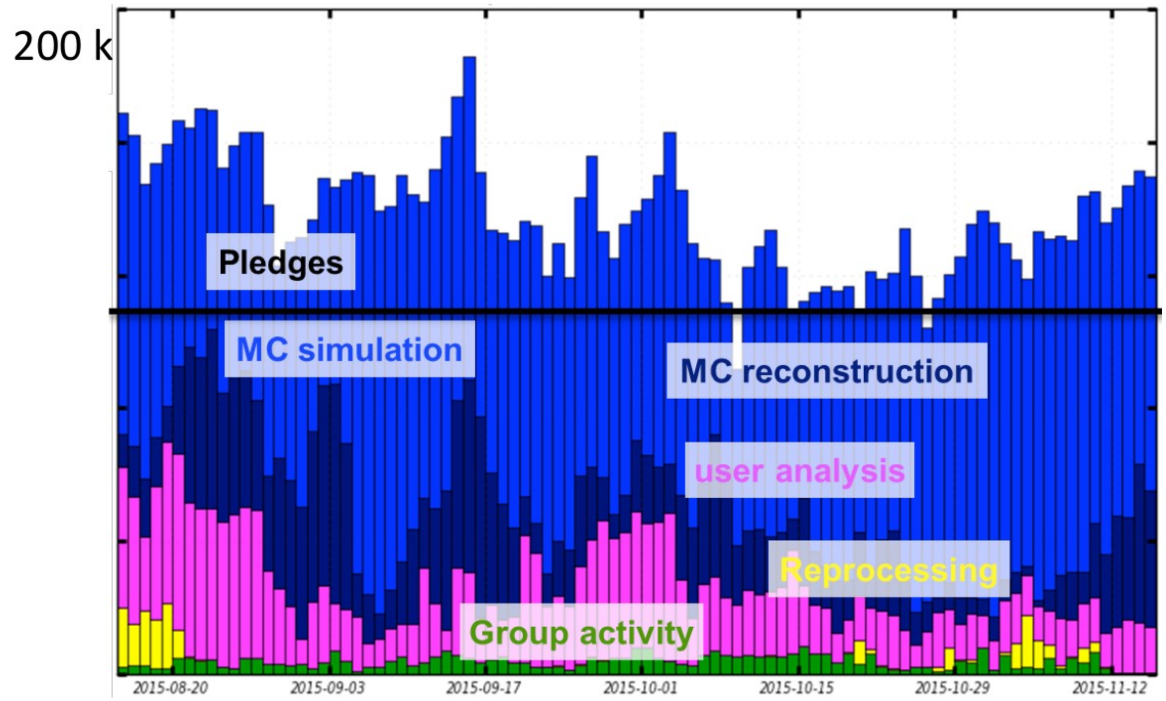
Muon efficiency from Z and J/psi





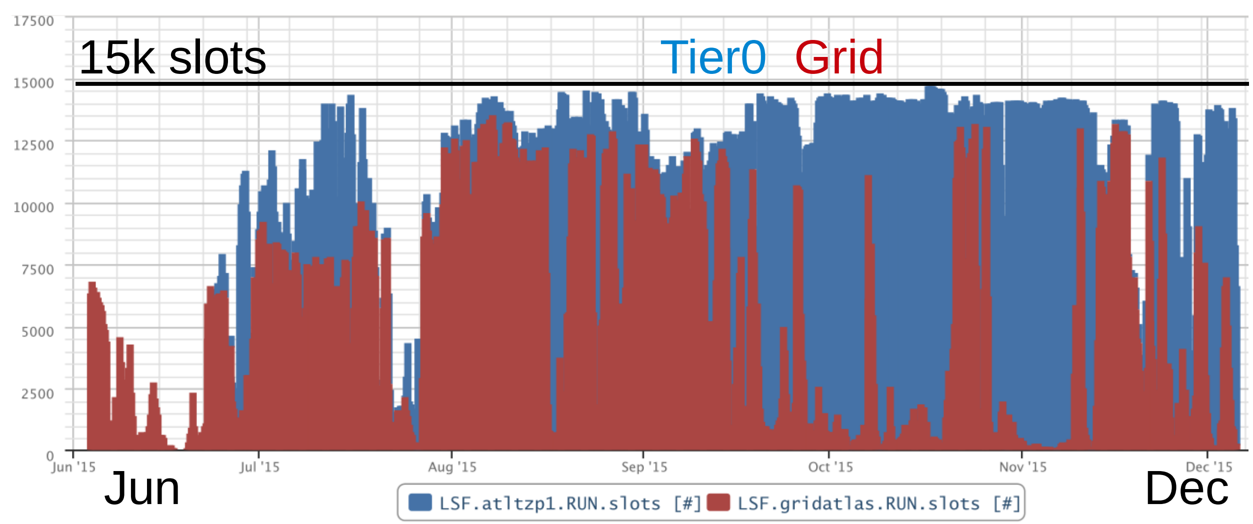
Computing and Analysis

- Grid utilized at full capacity
  - Smooth operations
  - Running up to 200k jobs
  - Dominated by MC production

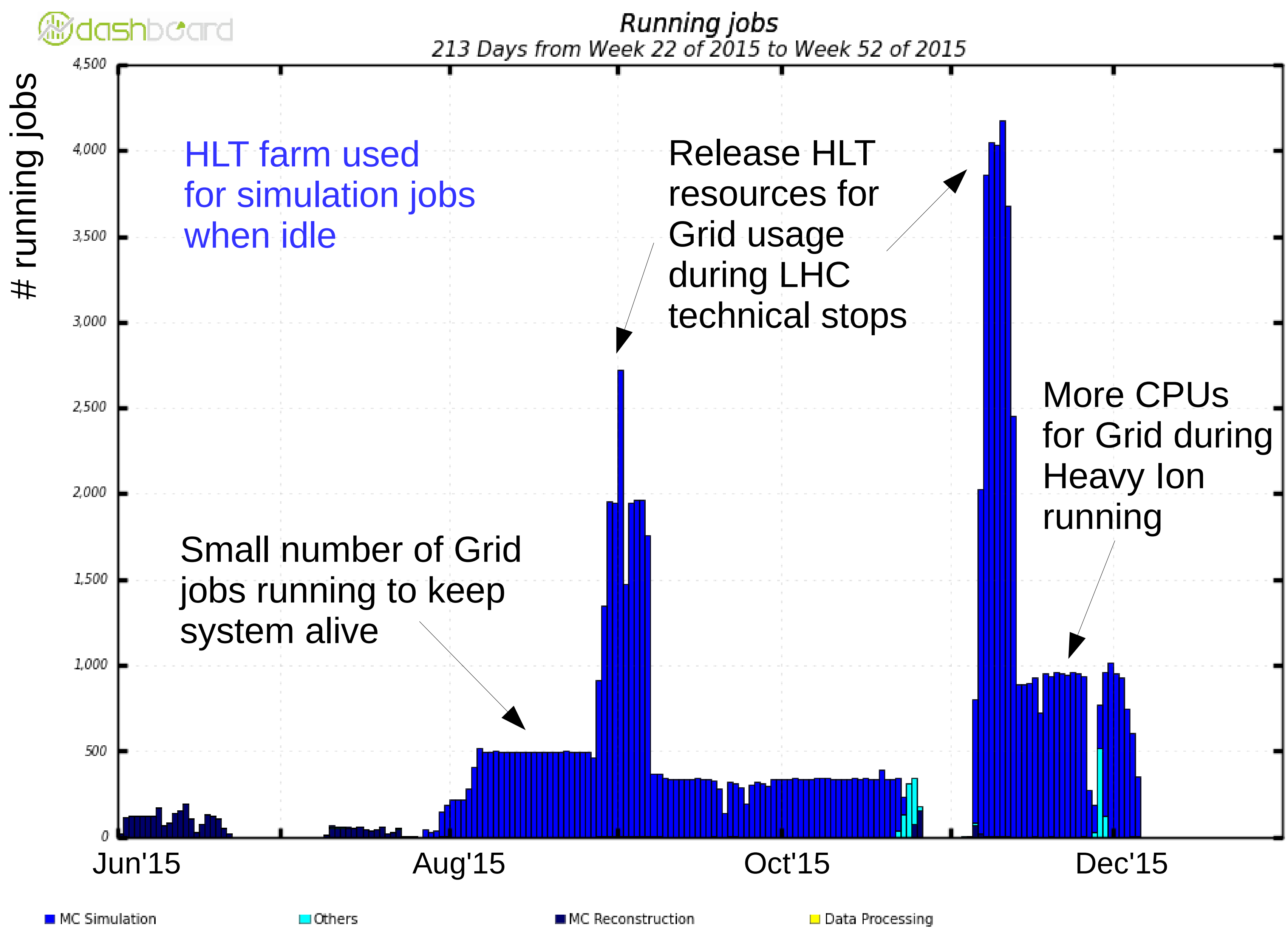


- Tier0 reconstruction
  - 15k jobs slots
  - Used for Grid jobs if not utilized by Tier0

- Analysis dataset production
  - New analysis model (xAOD) working extremely well
  - Producing O(100) analysis specific derived datasets



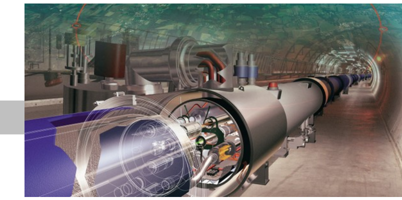
High-Level Trigger farm usage for Grid jobs

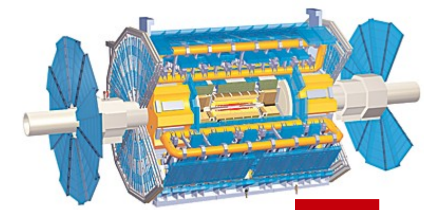


These are opportunistic resources. Data-taking, testing and commissioning always has priority!

Trigger Performance

Trigger environment in Run-2

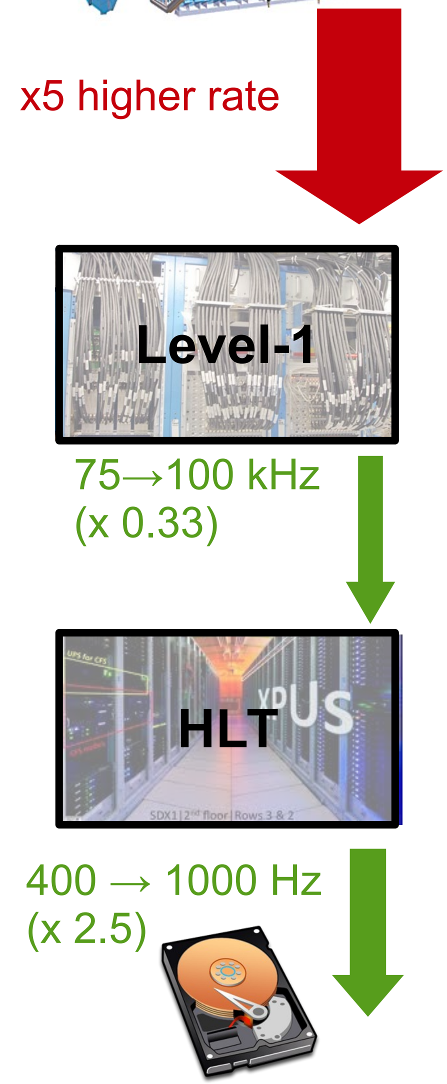




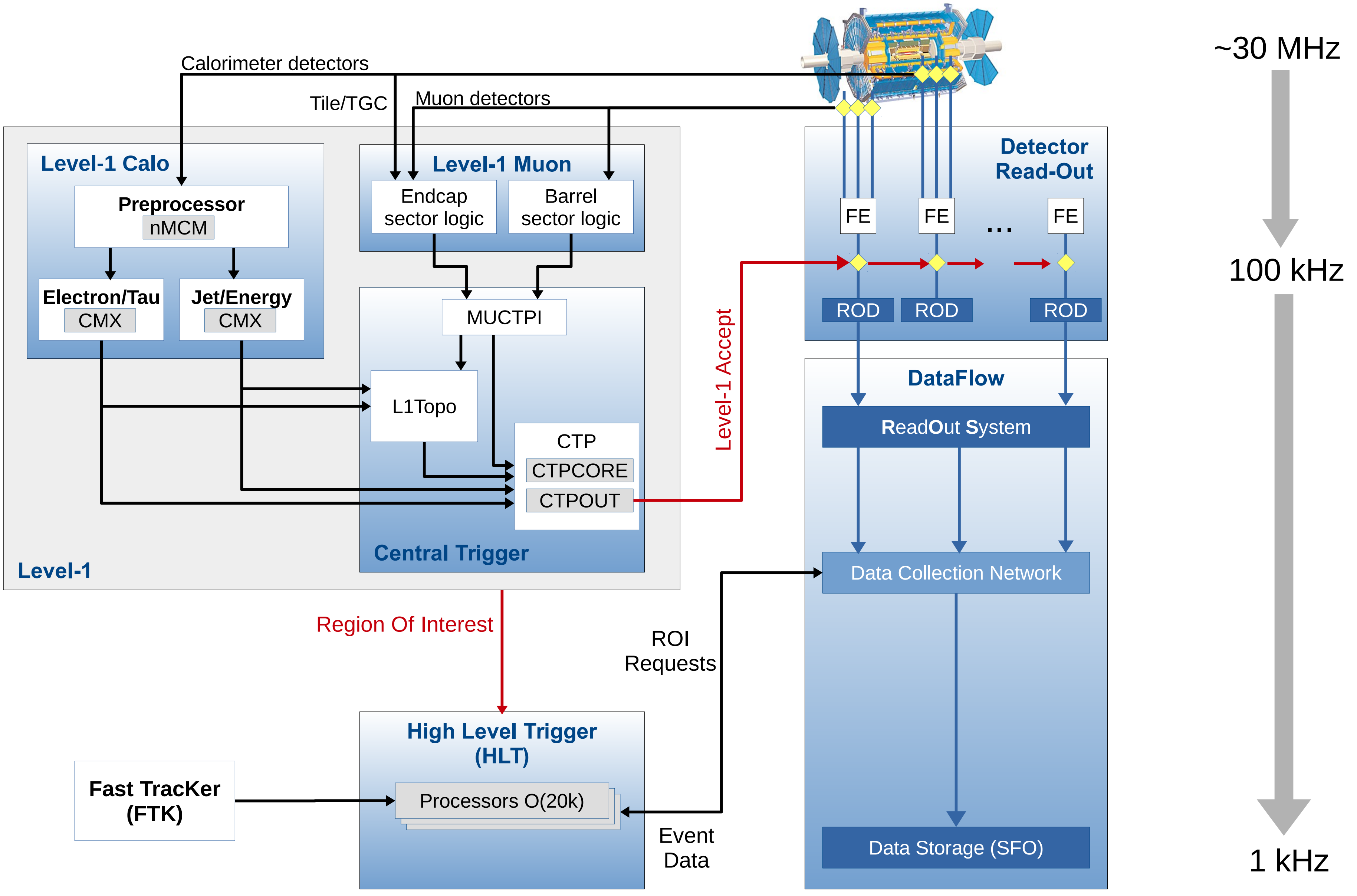
- LHC
  - Energy increase 8→13 TeV results in 2-2.5 times higher trigger rates
  - Peak luminosity increase 0.8→1.7e34 results in ~2 times higher trigger rates

- Options to cope with increase in trigger rates
  - Increase output rate → challenge for offline computing
  - Increase trigger thresholds → loose potentially interesting physics
  - Reduce fake (non-physics) triggers
  - Increase trigger rejection power → better hardware/software

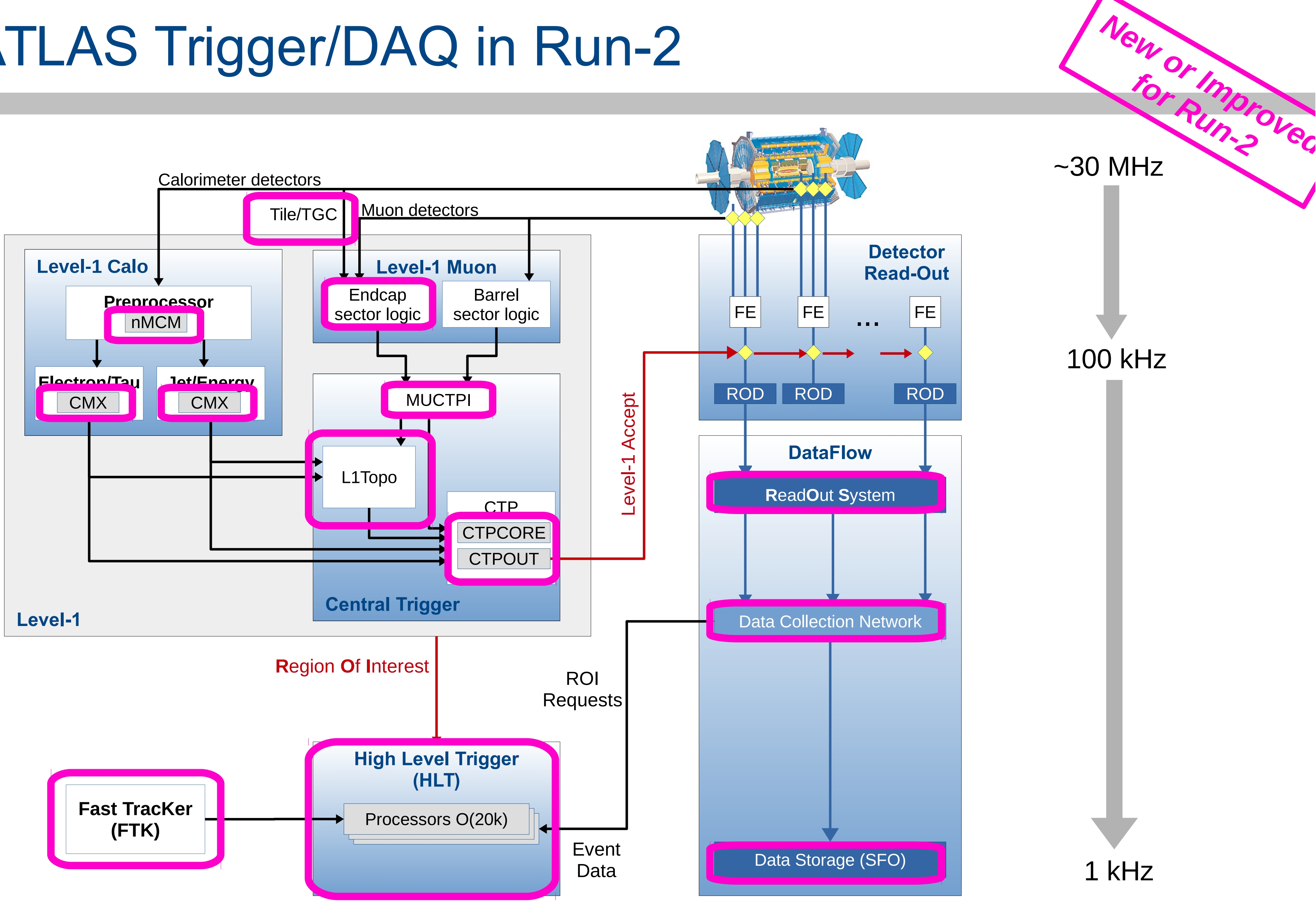
- Will show some of the improvements on the next slides...



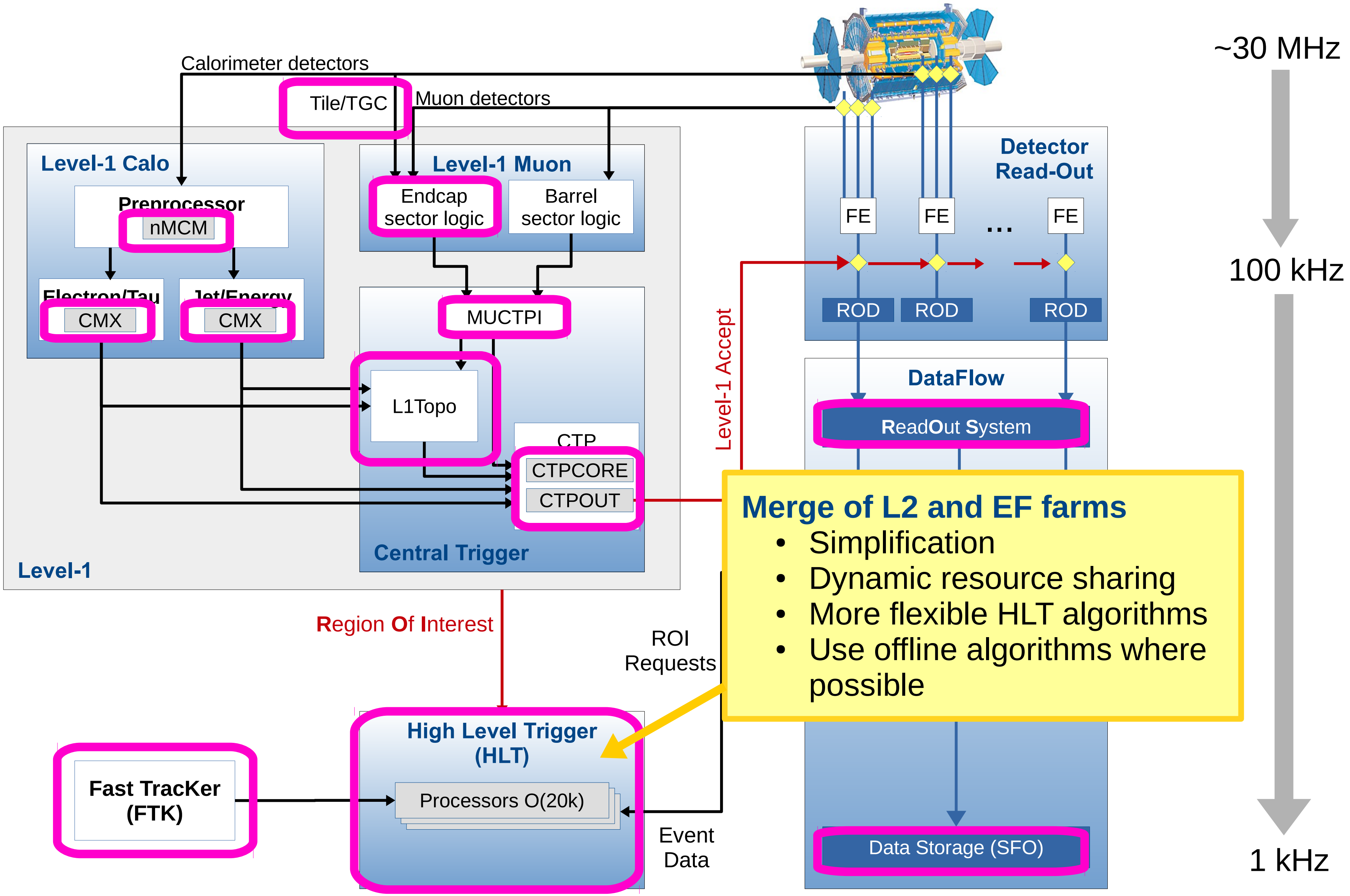
ATLAS Trigger/DAQ in Run-2



ATLAS Trigger/DAQ in Run-2



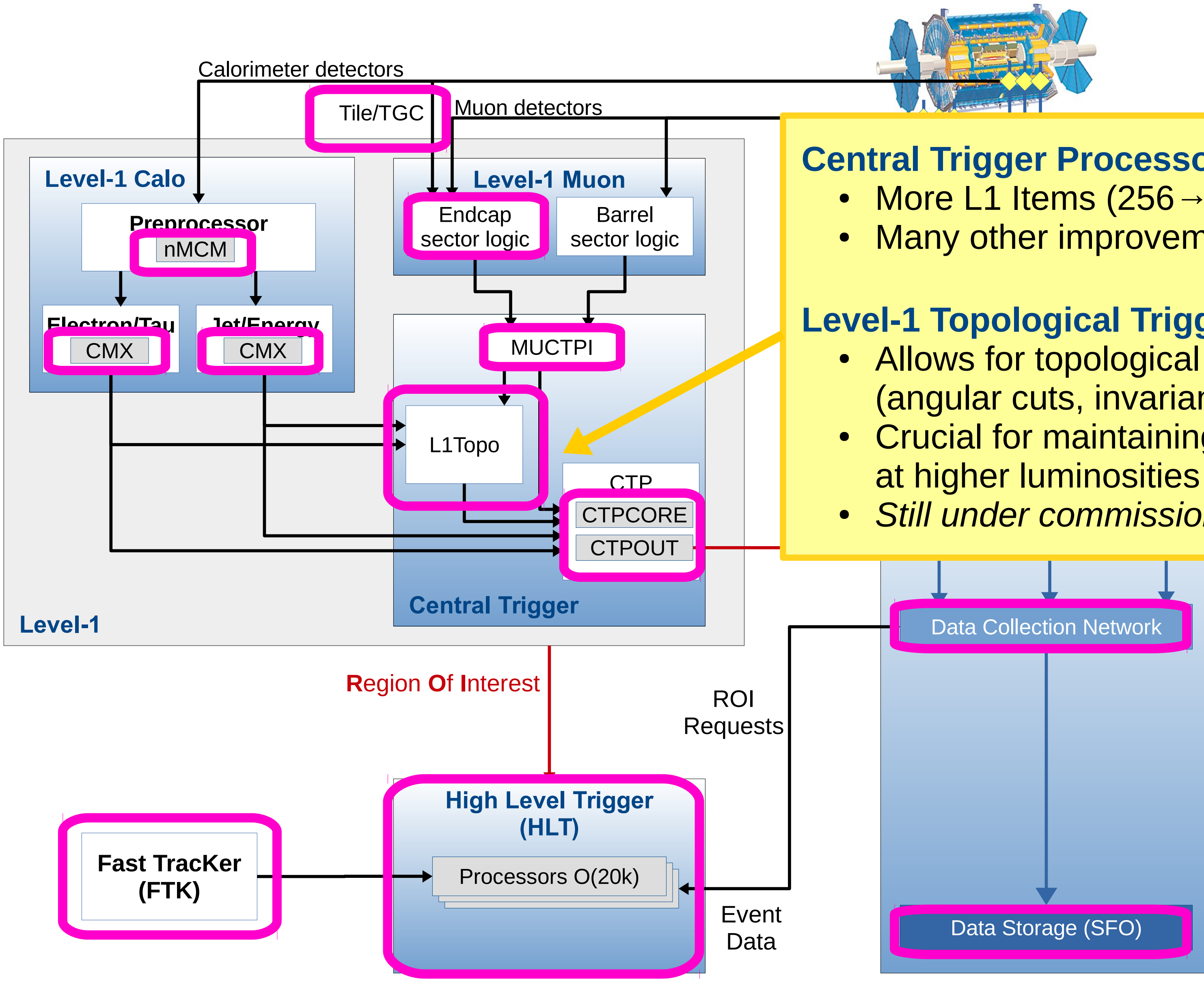
ATLAS Trigger/DAQ in Run-2



Merge of L2 and EF farms

- Simplification
- Dynamic resource sharing
- More flexible HLT algorithms
- Use offline algorithms where possible

ATLAS Trigger/DAQ in Run-2



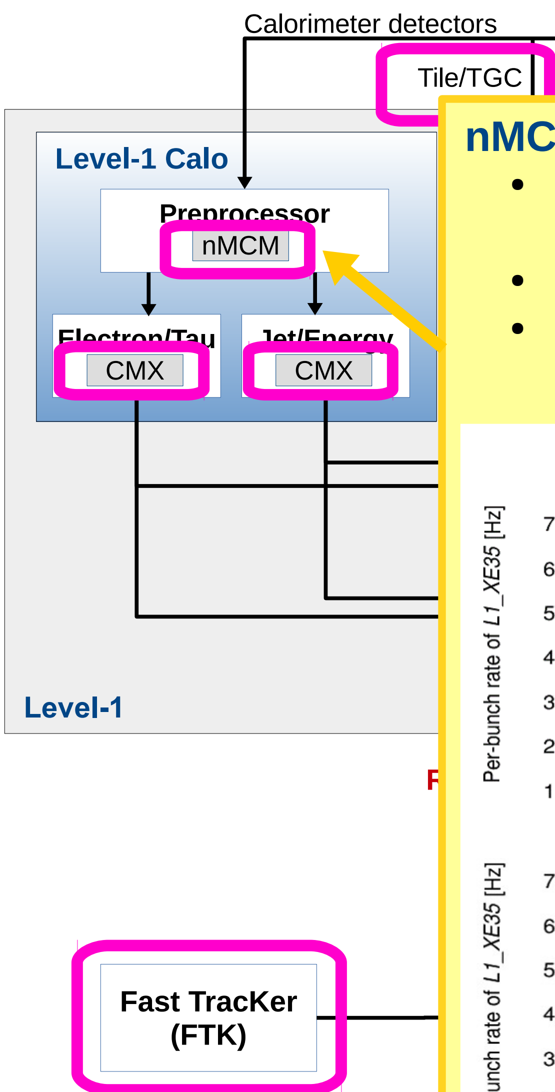
Central Trigger Processor (CTP)

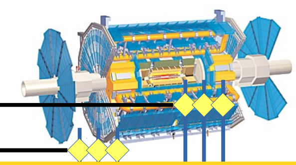
- More L1 Items (256→512)
- Many other improvements...

Level-1 Topological Trigger

- Allows for topological selections at L1 (angular cuts, invariant mass, combinations, ...)
- Crucial for maintaining low trigger thresholds at higher luminosities
- *Still under commissioning*

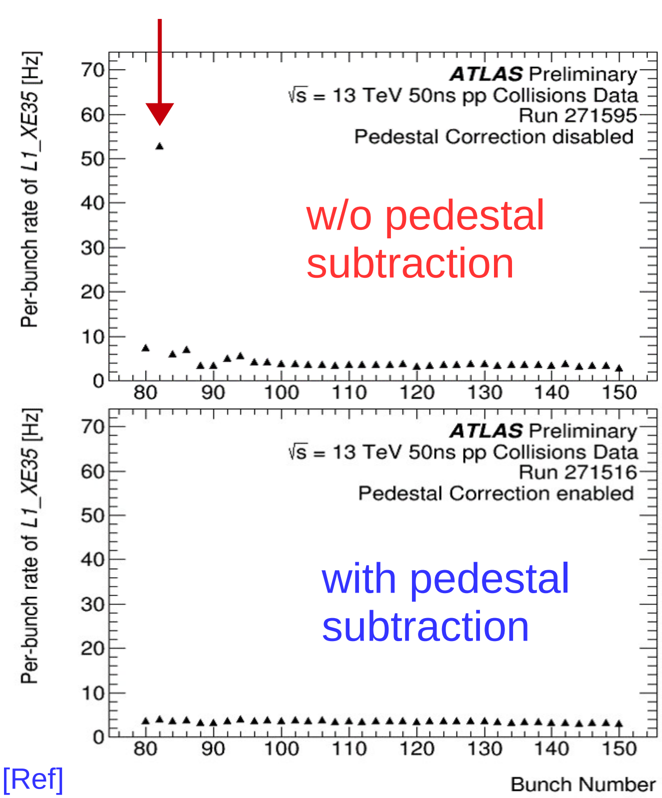
ATLAS Trigger/DAQ in Run-2



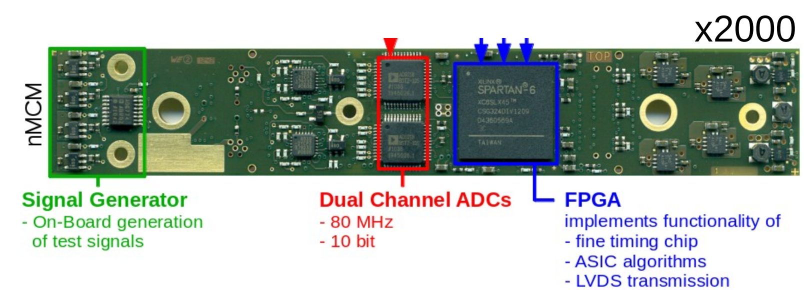


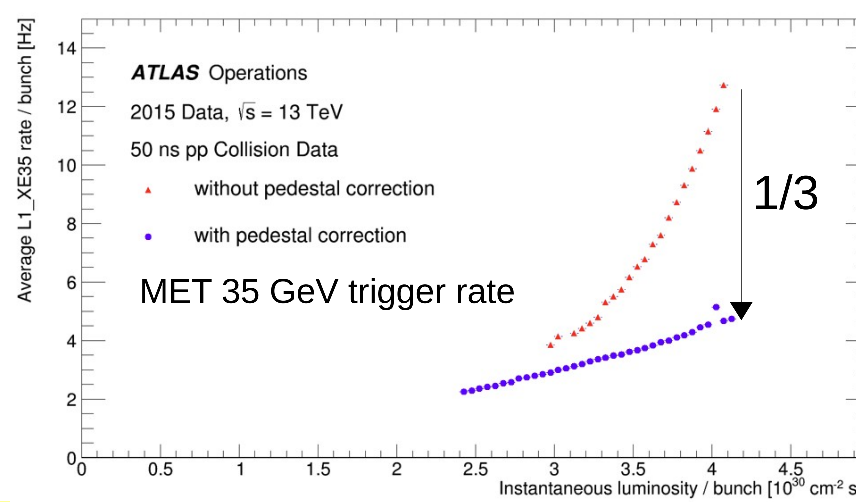
nMCM – *new Multi-Chip Modules*

- Major limitation during Run-1 were the high MET rates at the start of the bunch train (due to LAr pulse shape)
- nMCM allows for more flexible signal processing (ASIC→FPGA)
- Dynamic pedestal correction depending on position in bunch train resulting in dramatic rate reduction and linear lumi-scaling for MET triggers

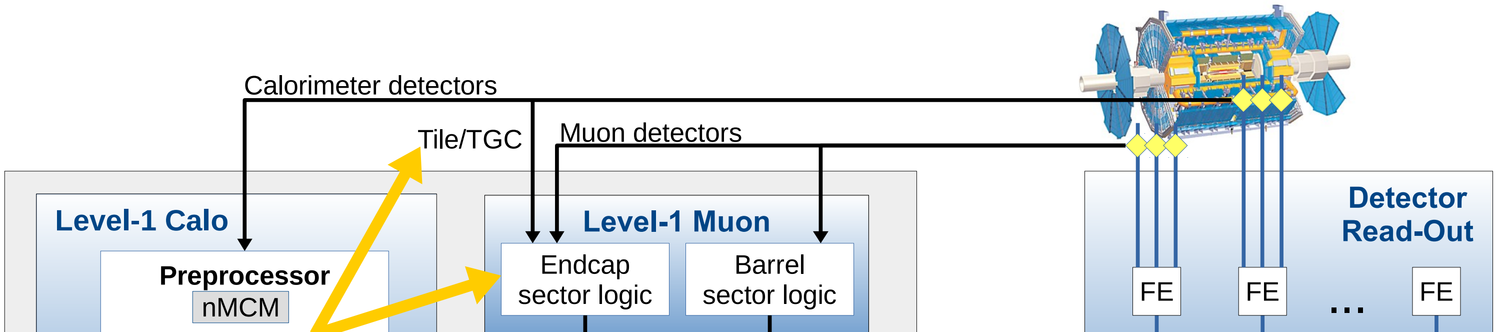


[Ref]



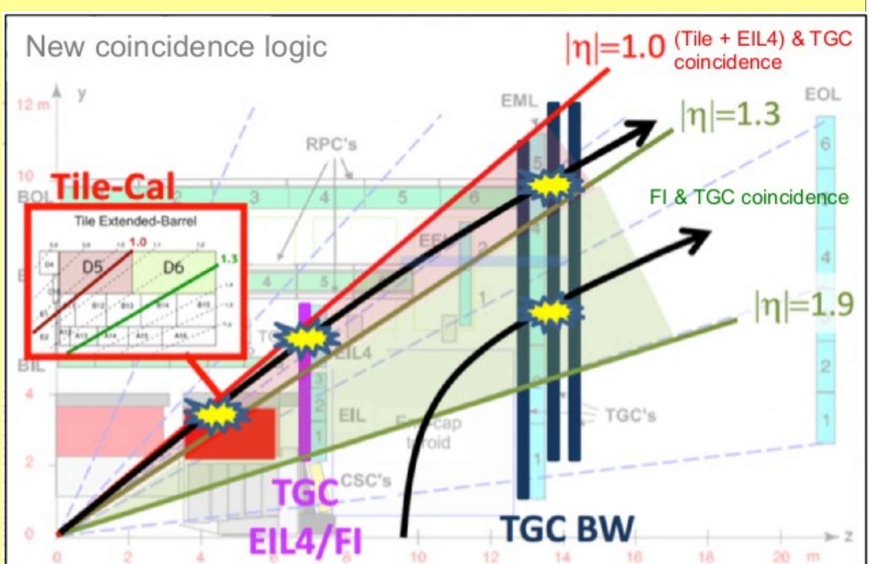


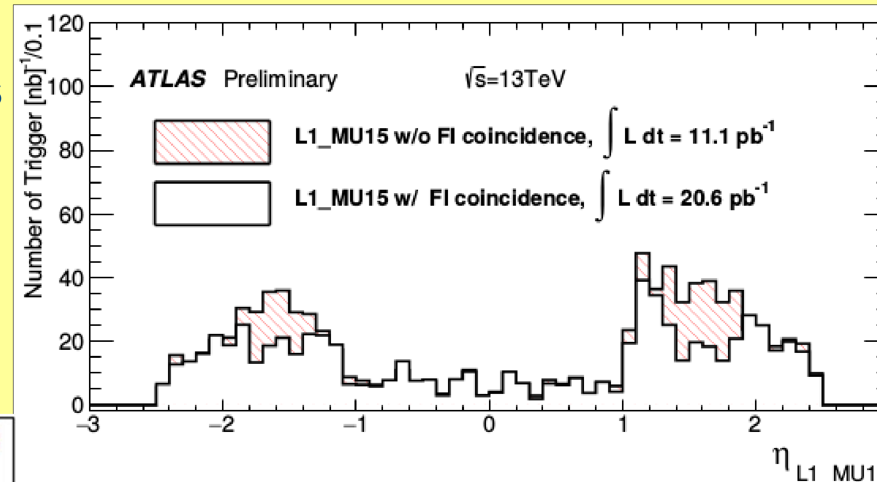
ATLAS Trigger/DAQ in Run-2

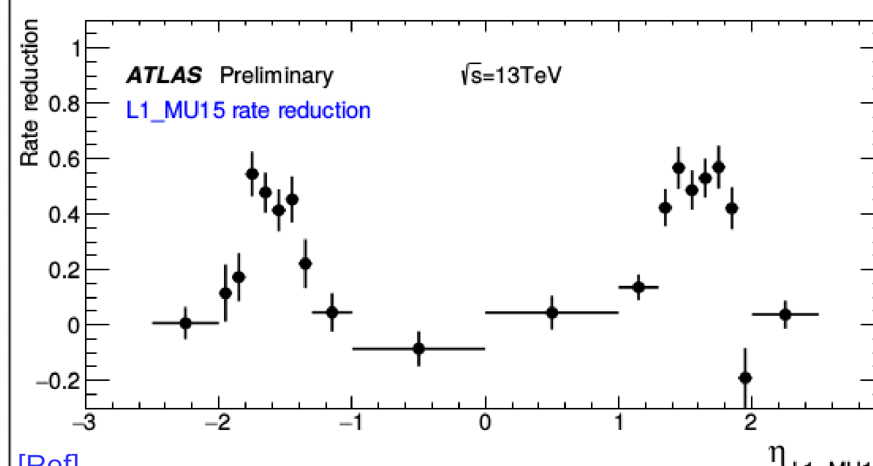


New coincidences to reduce rate in muon endcap trigger due to fakes

- Tile D-layer and TGC *(ongoing)*
- TGC inner layer *(ready)*

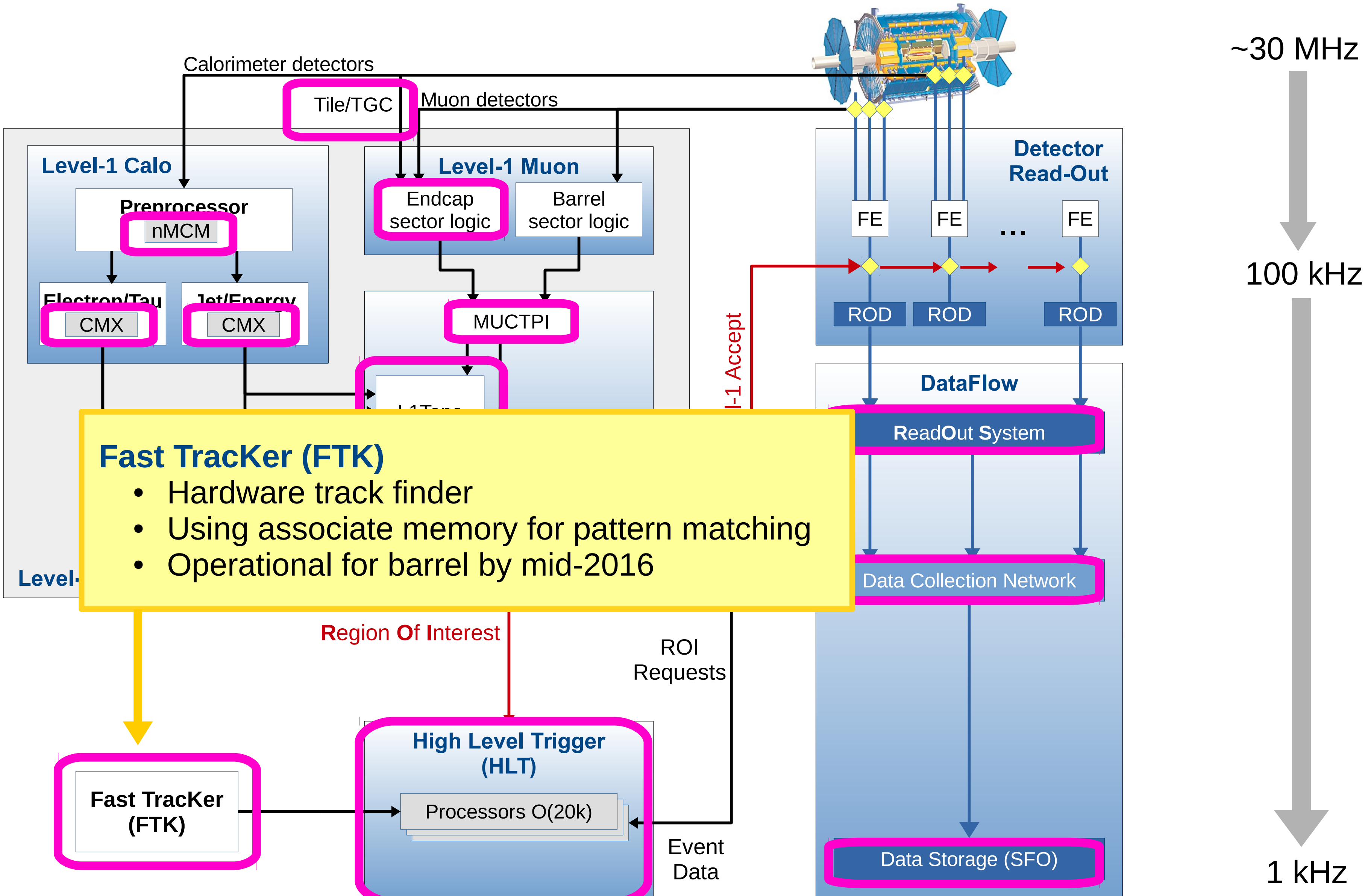






[Ref]

ATLAS Trigger/DAQ in Run-2



Fast TracKer (FTK)
- Hardware track finder
- Using associate memory for pattern matching
- Operational for barrel by mid-2016

Trigger Menu and Rates at 5e33

[Ref]

Trigger	Typical offline selection	Trigger Selection		Level-1 Peak Rate (kHz)	HLT Peak Rate (Hz)
		Level-1 (GeV)	HLT (GeV)	$L = 5 \times 10^{33}$ $\mathrm{cm}^{-2}\mathrm{s}^{-1}$	
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

Trigger Menu and Rates at 5e33

[Ref]

Trigger	Typical offline selection	Trigger Selection: Level-1 (GeV)	Trigger Selection: HLT (GeV)	Level-1 Peak Rate (kHz), $L = 5 \times 10^{33}\ \mathrm{cm^{-2}s^{-1}}$	HLT Peak Rate (Hz), $L = 5 \times 10^{33}\ \mathrm{cm^{-2}s^{-1}}$
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
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

- In total 400 L1 triggers and 1500 HLT triggers
  - Primary triggers, usually unprescaled
  - Support and background triggers, usually prescaled
  - Alternative triggers, using different algorithms
  - Backup triggers, using tighter selections
  - Calibration triggers, usually providing partially built events
- Aim was to keep primary physics triggers stable during 2015
  - Ensures continuity of trigger selection for physics analysis
  - At cost of slightly higher output rate than planned

Trigger Menu and Rates at 5e33

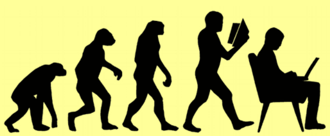
[Ref]

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	$15, 2 \times 7$	$17, 2 \times 9$	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	$18, 2 \times 4$	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

Trigger Menu and Rates at 5e33

[Ref]

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
	$p_T > 2 \times 11, 11$ GeV	[illegible]	[illegible]	[illegible]	[illegible]
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

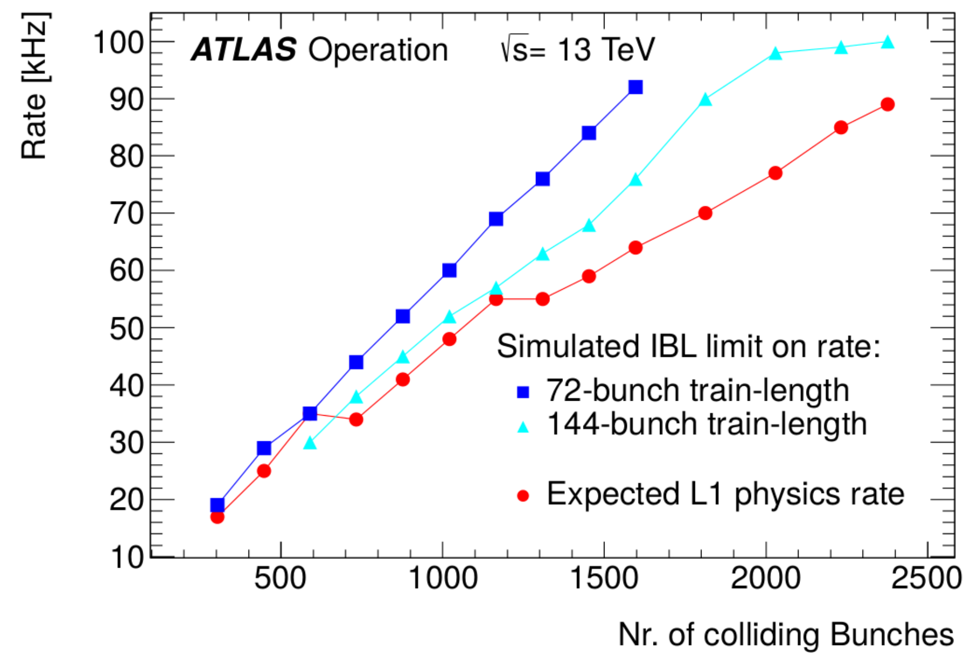


Trigger Menu Evolution is prepared for up to 2e34

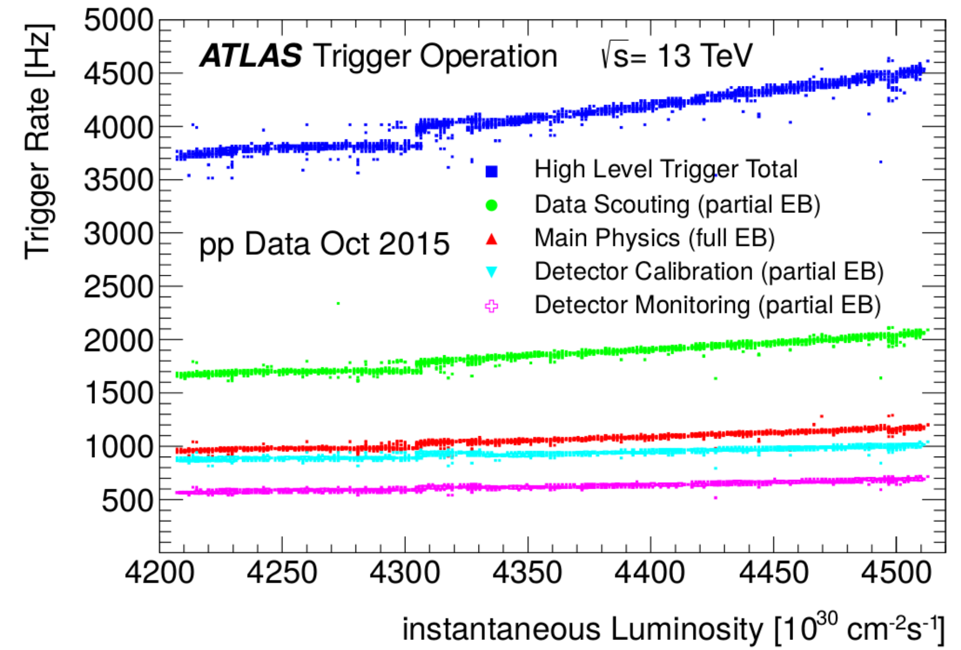
Trigger rates during Run-2

[Ref]

- Level-1 trigger rate
  - ATLAS can run at 100 kHz
  - However, at low number of bunches, dangerous resonance frequencies could damage the IBL wire-bonds
  - Automatic fixed frequency veto protects IBL
  - Physics trigger menu not affected by this rate limitation

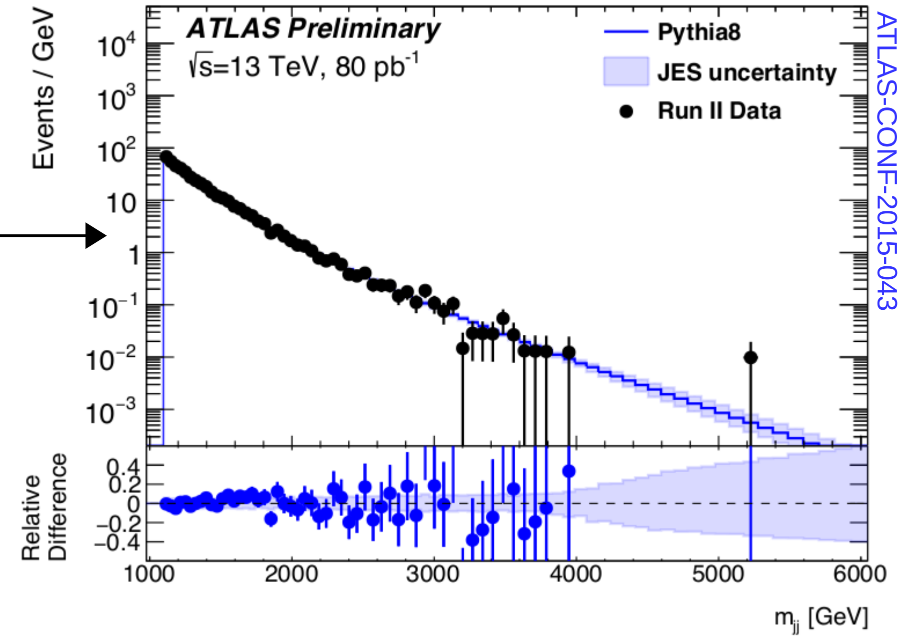


- HLT trigger rate
  - 1 kHz physics output rate
  - 4 kHz total output rate due to additional (partial event) rates from
    - Calibration and monitoring events
    - Data Scouting events
    - Bandwidth ~1.5 GB/s (80% for physics)

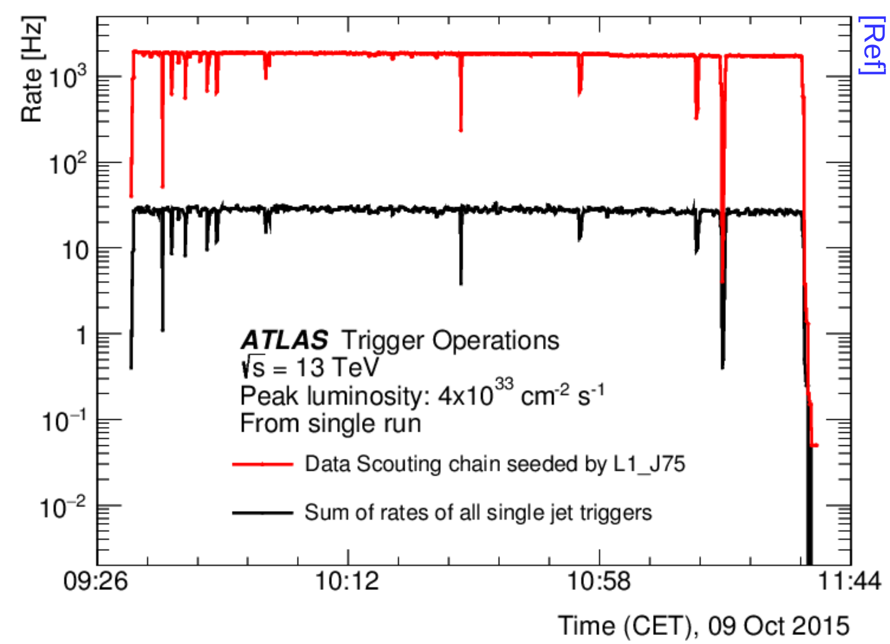


Trigger-Level Analysis / DataScouting

- Di-jet resonance search
  - Lowest unprescaled single jet is 360 GeV
  - Limits reach of standard di-jet resonance search
    - Current standard analysis applies m_{jj} > 1.1 TeV to avoid kinematic bias



- Trigger-Level Analysis
  - Only store reconstructed HLT jets instead of full ATLAS event
  - Can store much higher event rates
    - 2 kHz vs 200-300 Hz
  - Allows significant lower reach in di-jet masses
  - Look forward to first results at Moriond

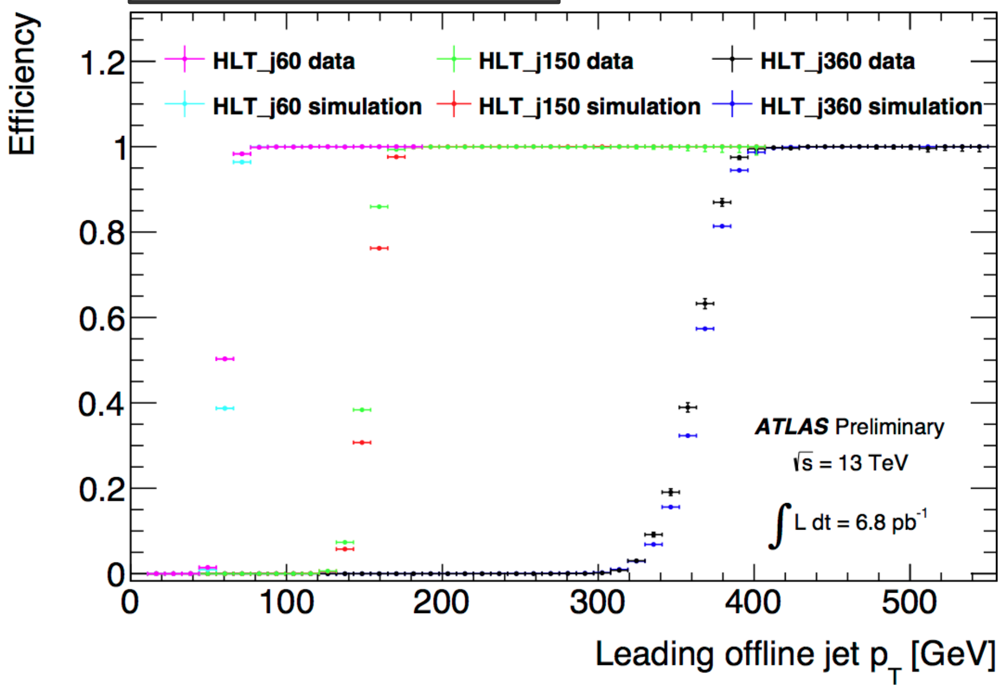


Jet Trigger Performance

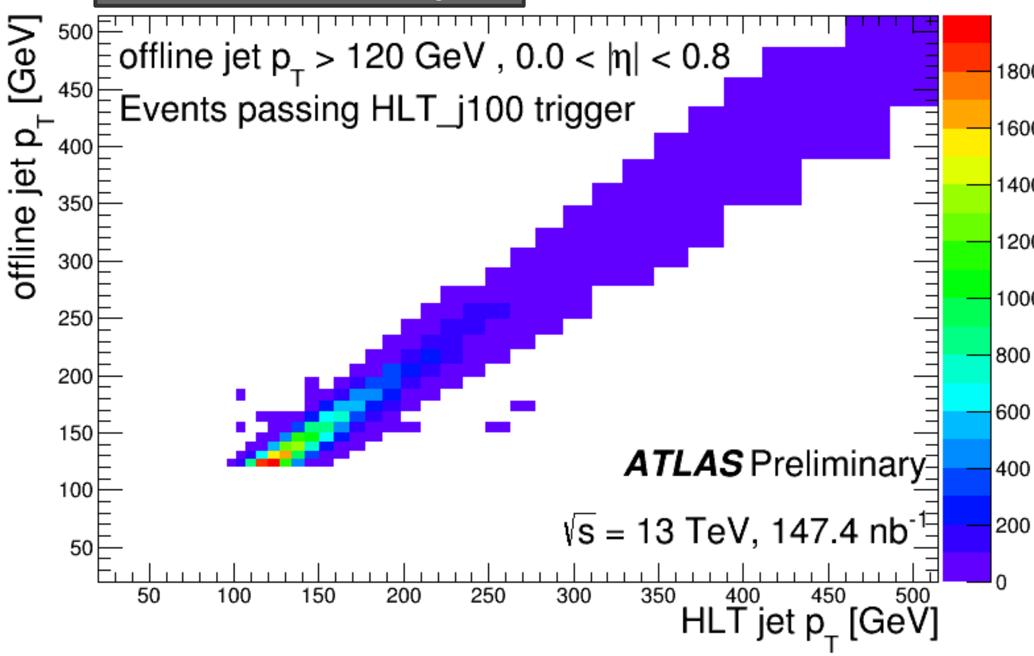
[Ref]

- Jet trigger improvements for Run-2
  - Using topo-cluster based offline jet reconstruction of the entire calorimeter
    - As opposed to two-step (partial → full) reconstruction in run-1
  - Implemented jet area pileup suppression
  - Good agreement between online/offline jet energy scale

HLT turn-on curves



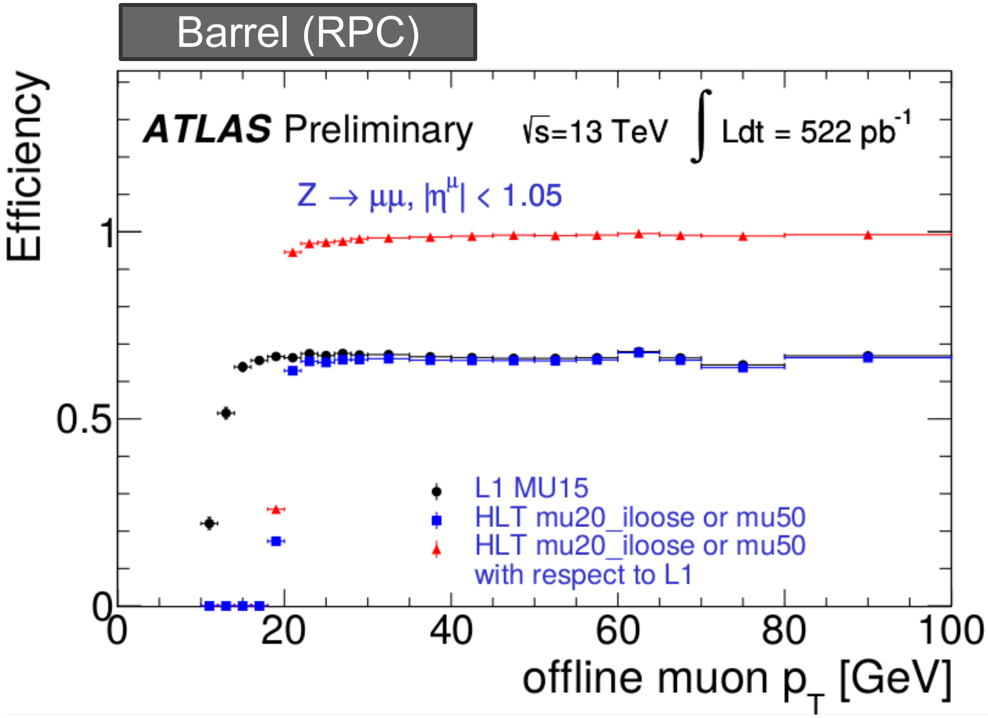
Online vs Offline jets

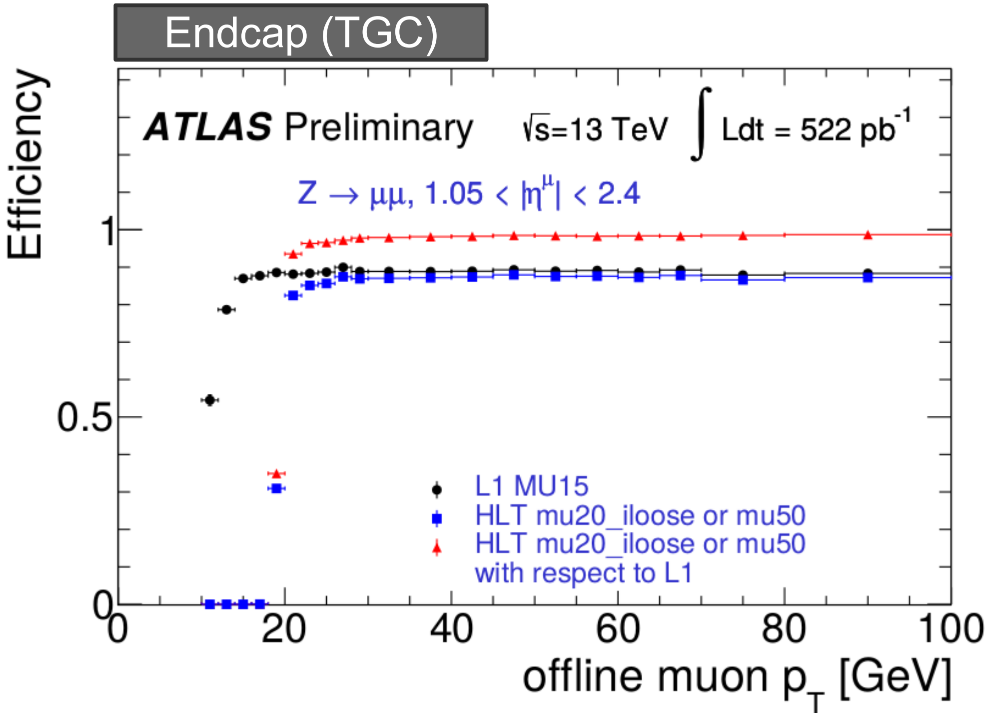


Muon Trigger Performance

[Ref]

- Barrel (RPC) and Endcap (TGC) muon trigger
  - Low barrel L1 trigger efficiency due to geometrical trigger chamber coverage
    - Worst in the ATLAS feet region
  - HLT close to 100% efficient compared to L1
  - Factor 3 speed improvement in muon full scan finding
    - To prevent efficiency loss from L1 for di-muon trigger signatures

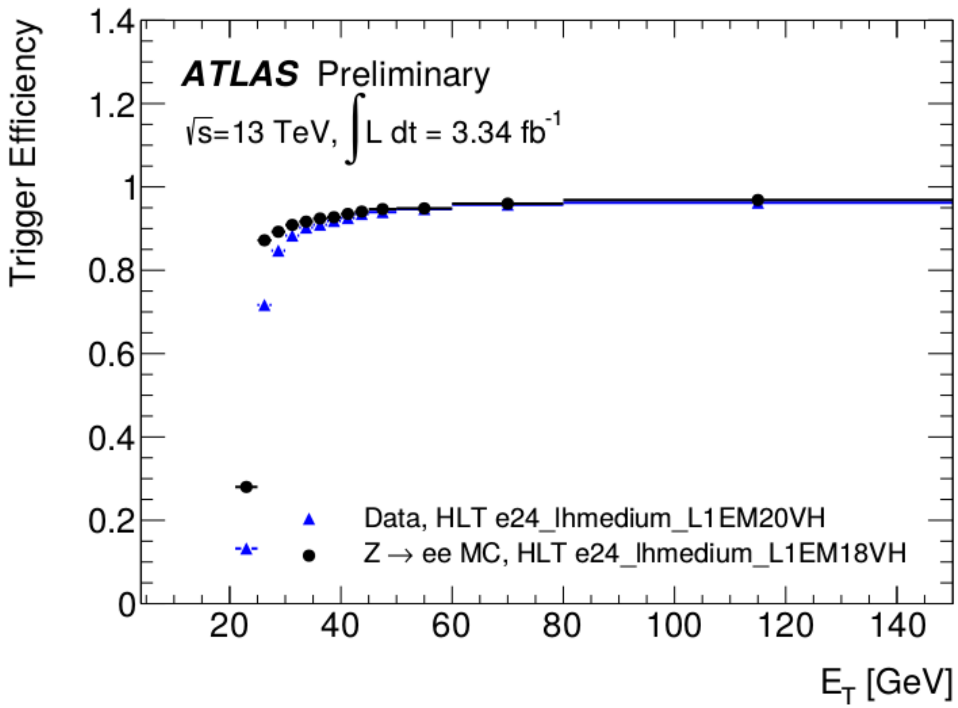


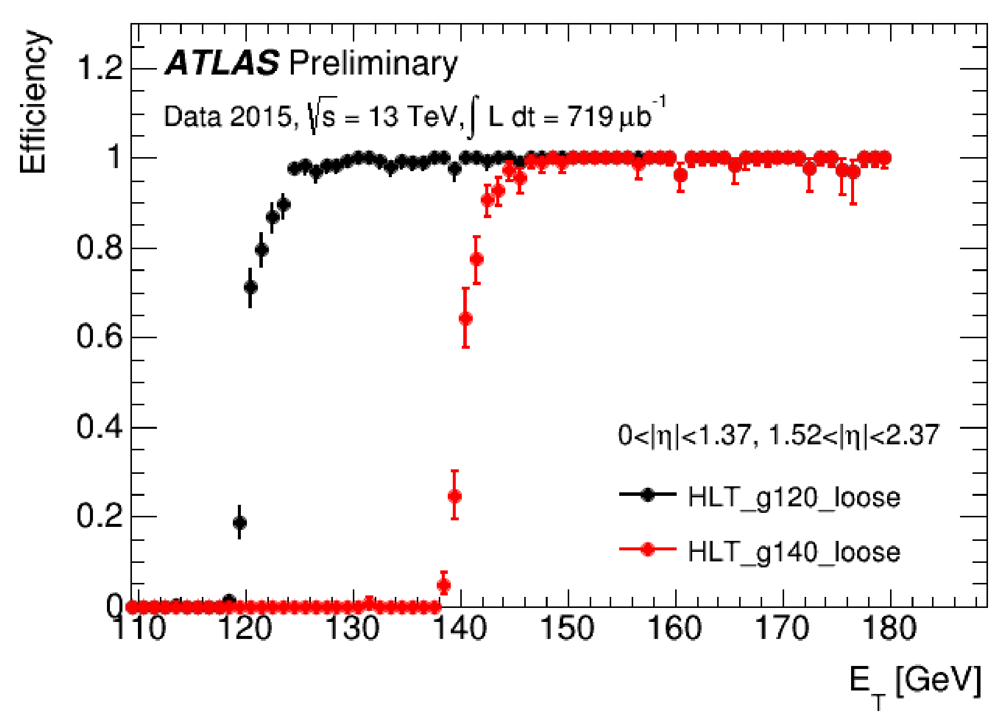


Electron and Photon Trigger Performance

[Ref]

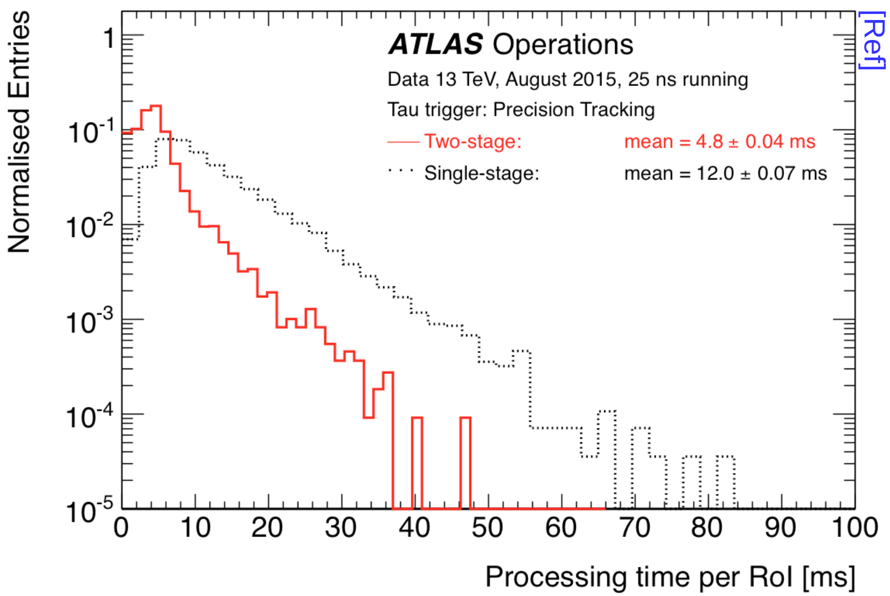
- Improvements for Run-2
  - New fast tracking algorithms
  - MVA energy calibration
  - Likelihood-based identification used for electrons (was cut-based in Run-1)
- Performance in Run-2
  - Single (isolated) electron triggers with minimum threshold of 24 GeV
  - Medium electron identification criteria (will move to tight selections for higher luminosities)
  - Photon triggers close to 100% efficient at threshold

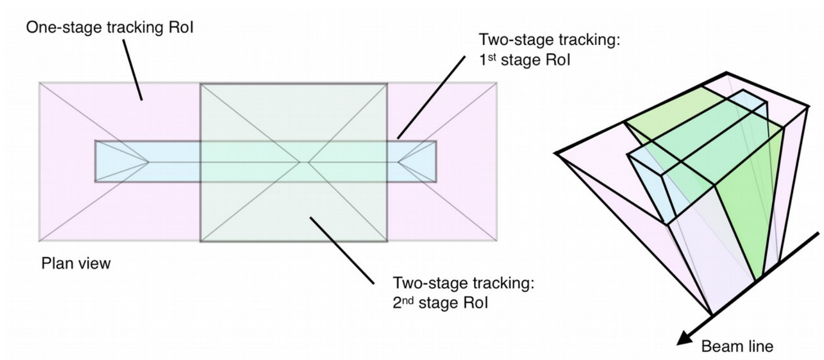


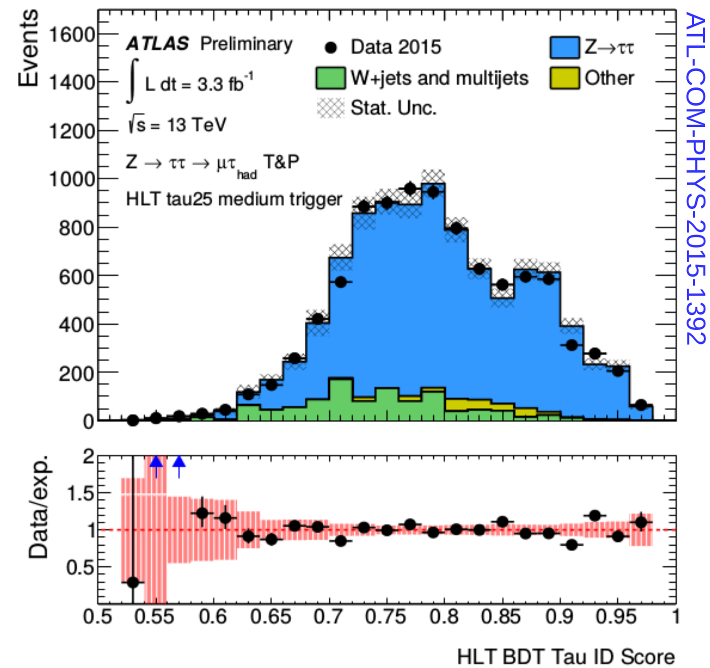


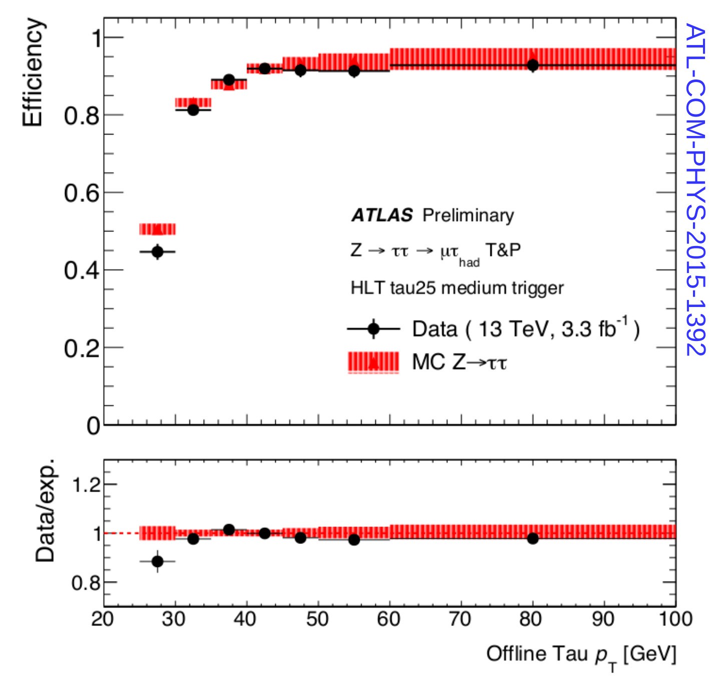
Tau Trigger Performance

- Tau trigger based on offline BDT
  - Ensure performance close to offline
  - Tracking performed in two-stages with narrowing regions to save CPU







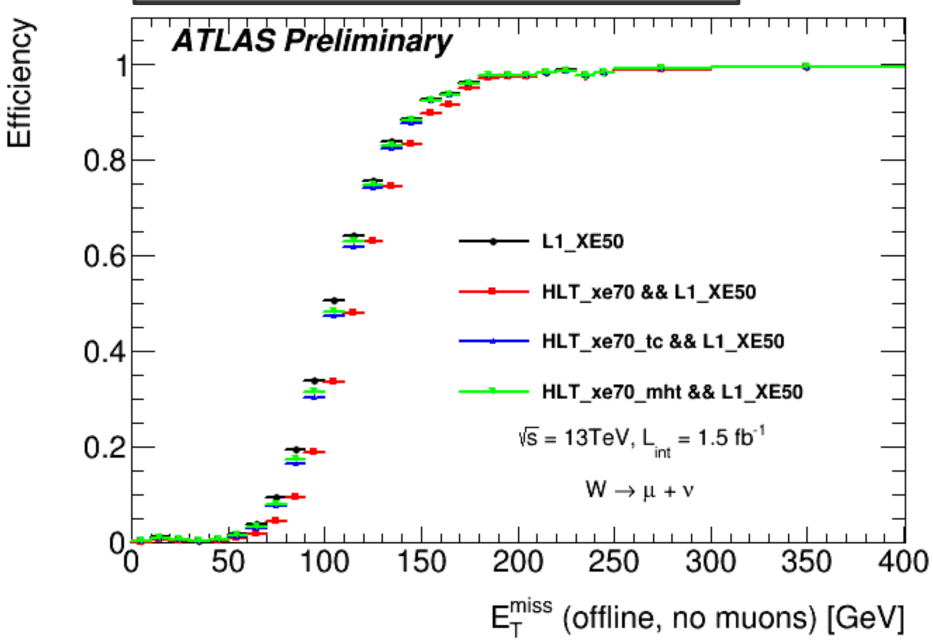


Missing Energy Trigger Performance

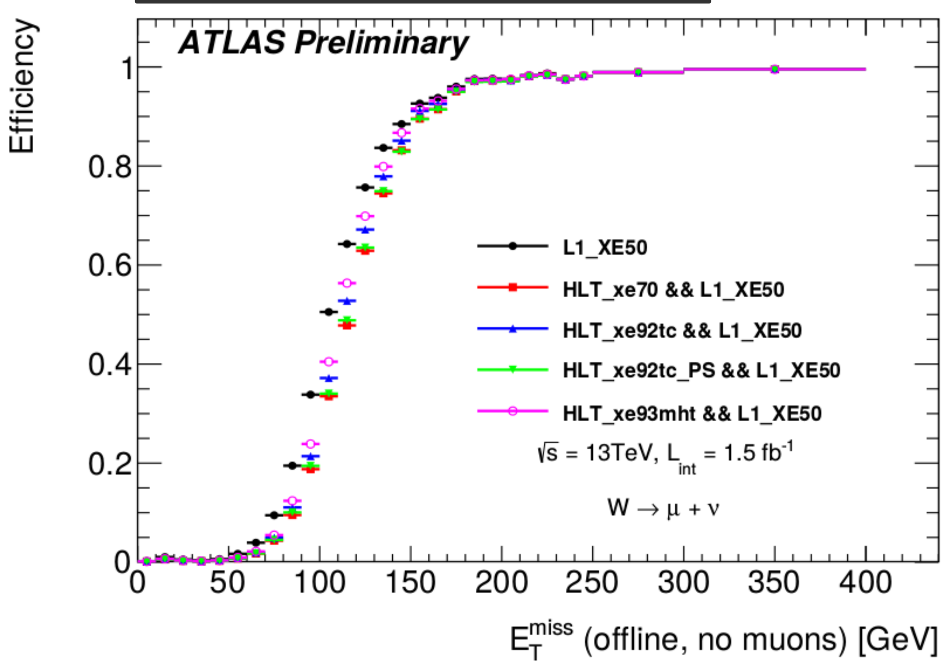
[Ref]

- Several 'flavours' of MET in use at the trigger
  - Default cell-based algorithms with two-sided two-sigma noise suppression
  - Topo-cluster based algorithm (tc)
  - Jet-based algorithm with soft object correction (mht)
  - + variants with different calibration and pileup subtraction
- Best performing MET algorithm is analysis dependent
  - Will maintain most of them as negligible impact for total rate and CPU cost
  - Important to compare performance for equal rate triggers

MET turn-ons for equal threshold

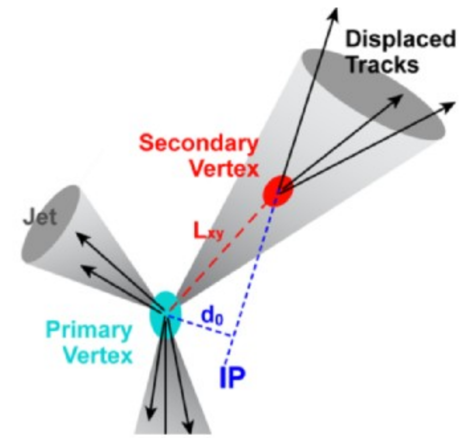


MET turn-ons for equal rates

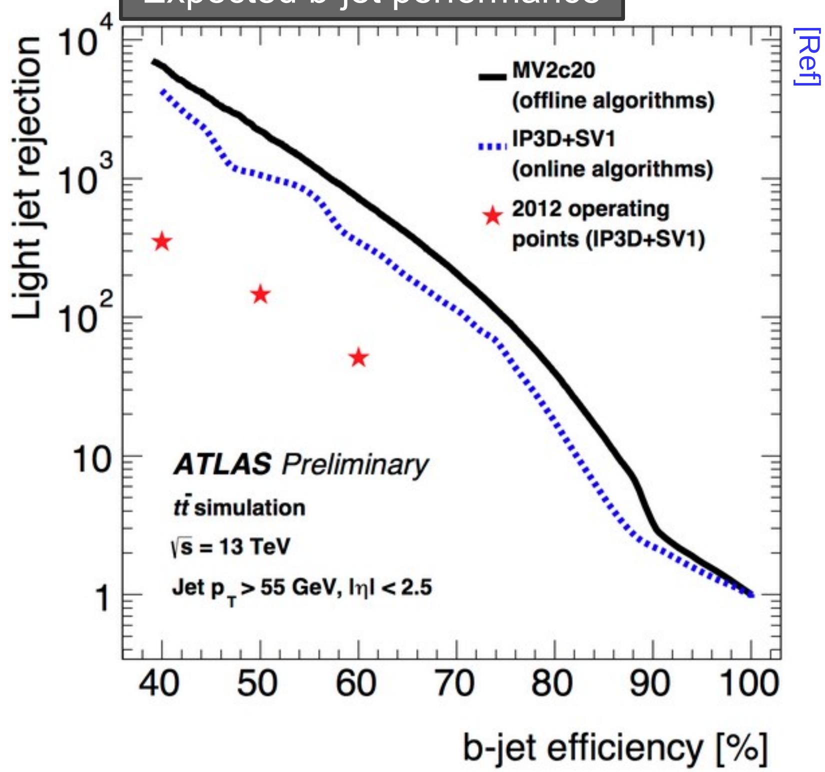


Expected performance of the b-jet Trigger

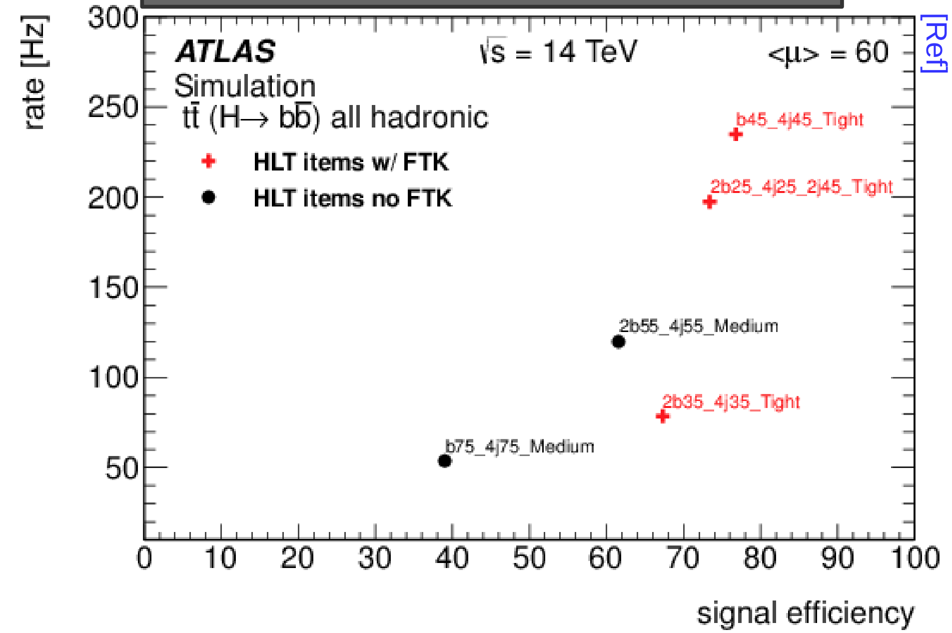
- Run-2 b-jet trigger has been completely rewritten
  - Use same tagging algorithm as offline (MV2c20)
  - Track finding and primary/secondary vertexing heavily optimized for CPU
  - Will make heavy use of L1Topo and FTK
    - Reduce input rate by applying topological selection already at L1
    - Use FTK tracks for primary vertex finding



Expected b-jet performance

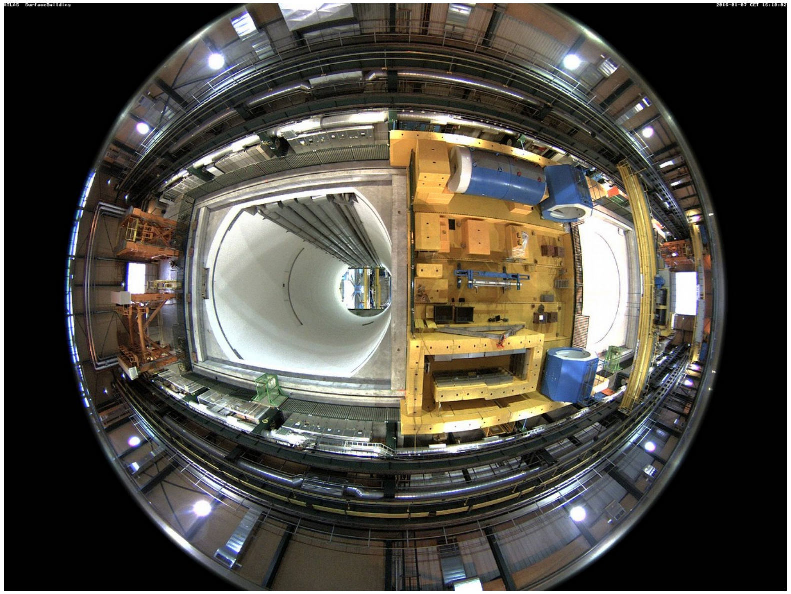


Expected b-jet performance using FTK



Plans for Year-End-Technical-Stop and 2016

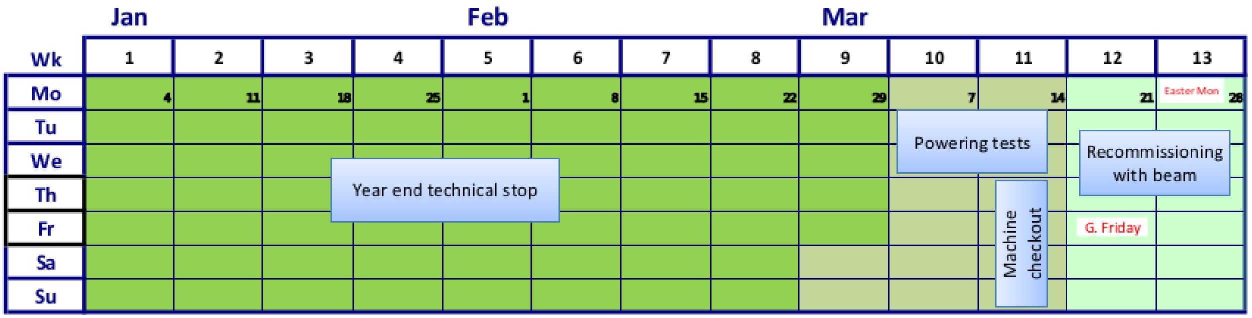
- Repairs and upgrades continue
  - New readout readout system for 2nd layer of Pixel detector
    - To prepare for higher pileup
  - Repair a damaged bellow of the toroid endcap magnet
    - Requires opening of one side of ATLAS
  - Standard maintenance work on all detectors



One access shaft to ATLAS cavern open (Jan 7th)

- Full reprocessing of 2015 data and MC underway
  - Allows for a coherent Run-2 dataset

- During 2016 full commissioning of
  - Fast Tracker (FTK)
    - Provides full event tracking for the HLT
  - L1Topo
    - Topological selection at L1



Conclusions

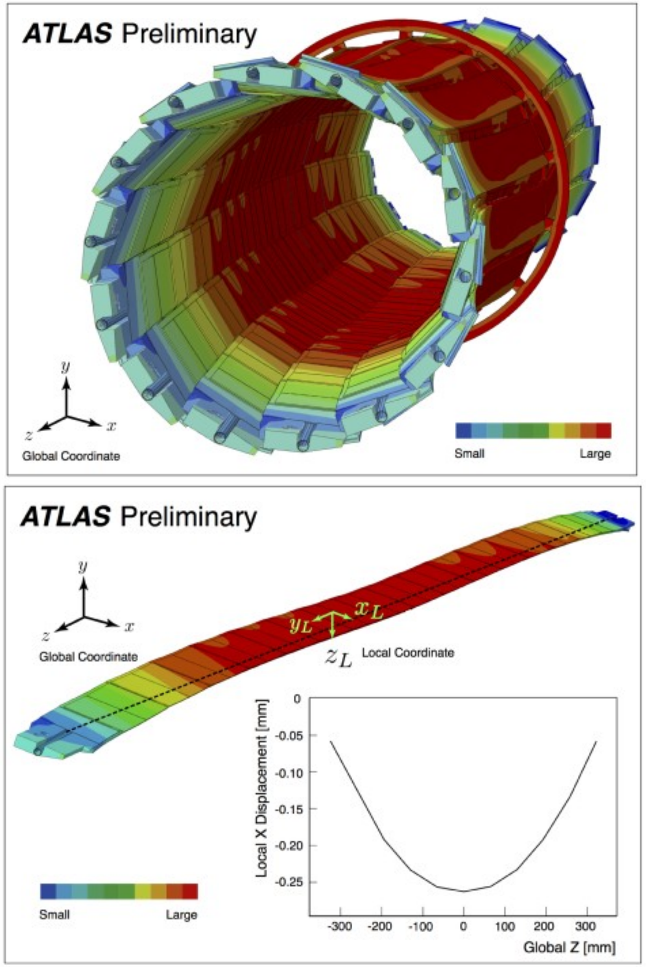
- The restart after the long shutdown and data taking through out 2015 has been very successful
- Despite the challenging conditions, the data taking efficiency and system stability has already reached a level comparable to the end of Run-1
- ATLAS is ready for more data and higher luminosities in 2016
- Many physics results are presented this week

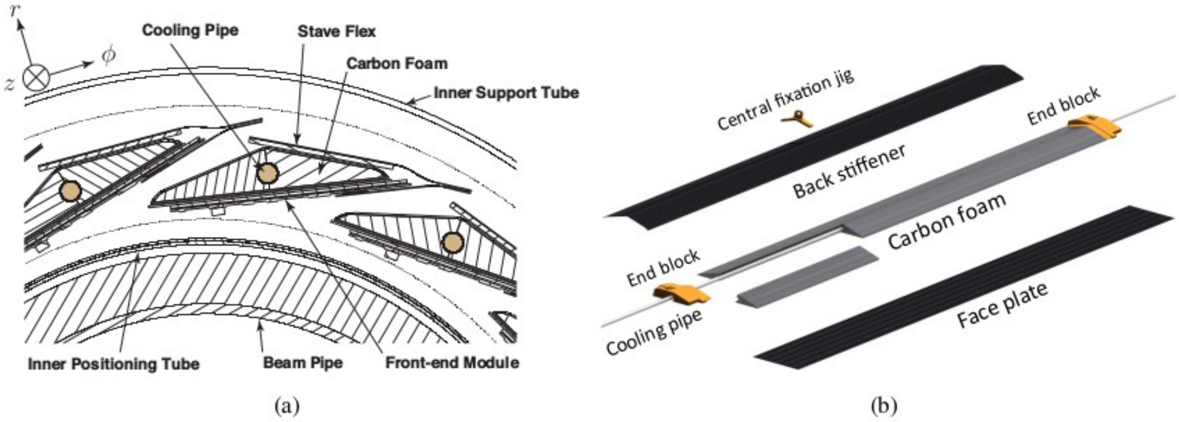
Backup

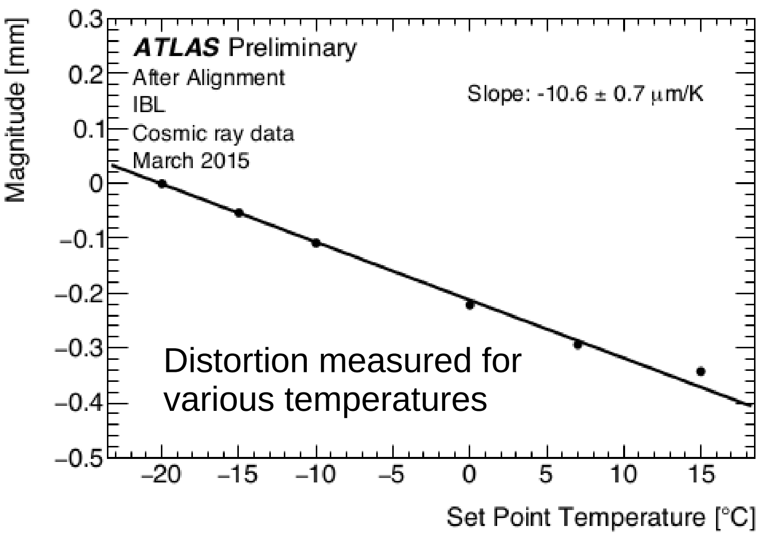
IBL – Bowing due to temperature variations

- Detailed investigation of IBL bowing
  - Full report available: https://cds.cern.ch/record/2022587
  - Bowing occurs in the -phi direction due to different thermal expansion coefficients of the bare stave and the polyimyde flex bus line

FEA simulation of bowing

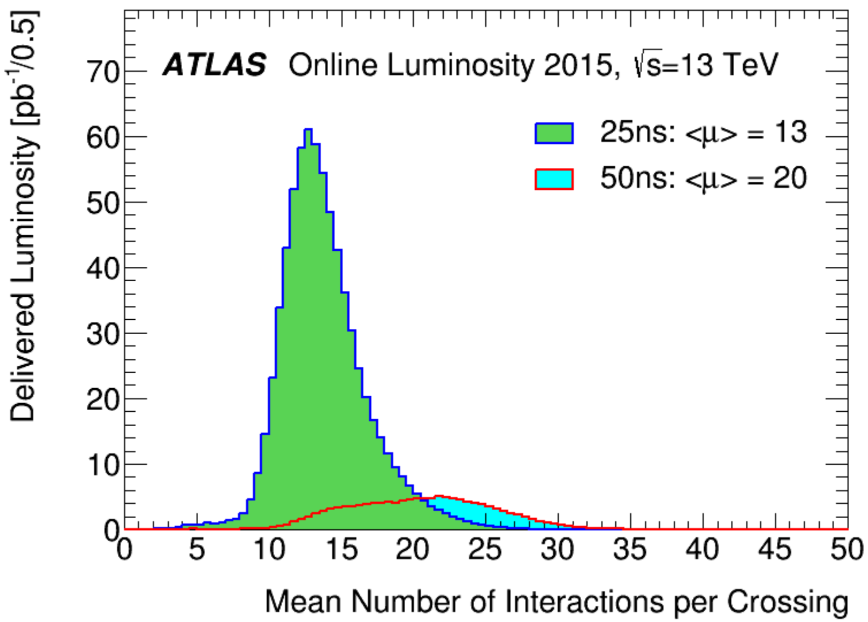


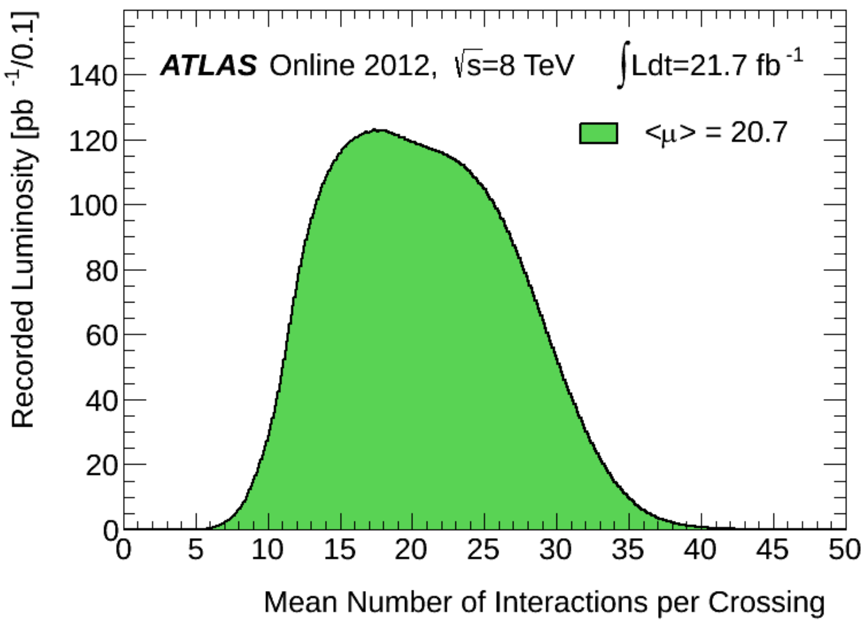


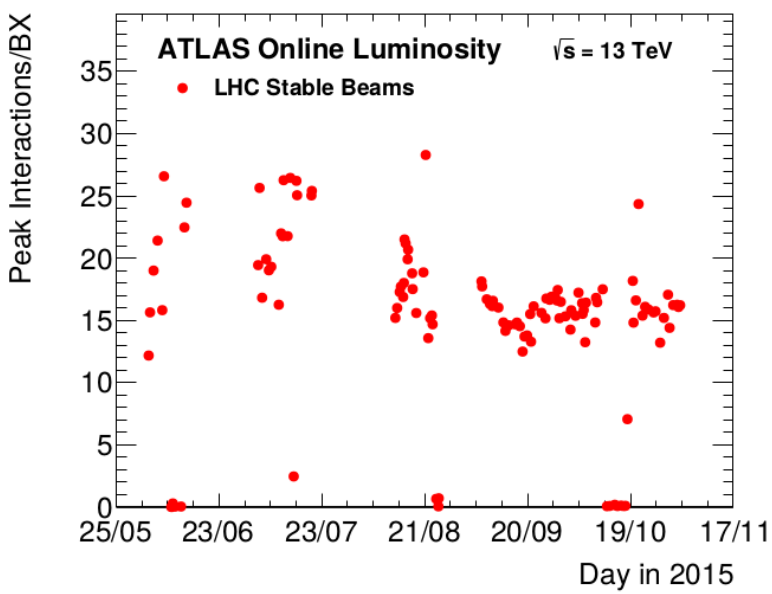


Pileup distributions

- Mean number of interactions for 25ns, 50ns in run-1 and run-2

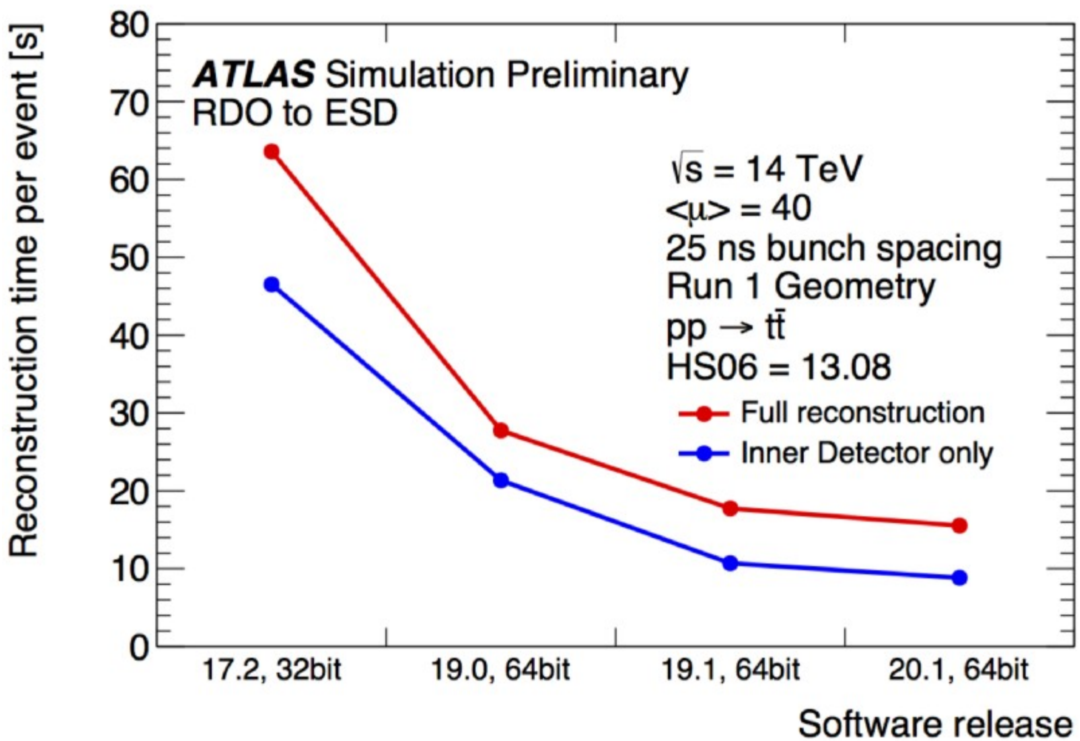




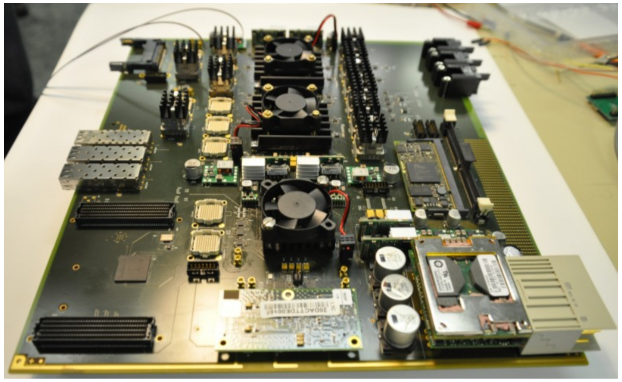


Reconstruction improvements

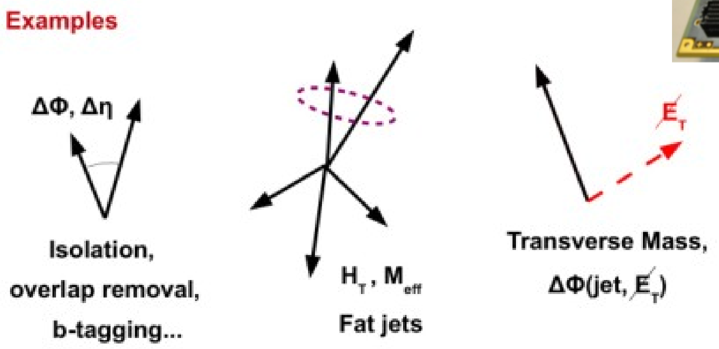
- Reduction in reconstruction time during LS1
  - More than factor of 3 speed improvements, mainly in ID tracking
  - Crucial for handling the higher HLT output rate and higher pileup later in Run-2



Level-1 Topological Processor/Trigger

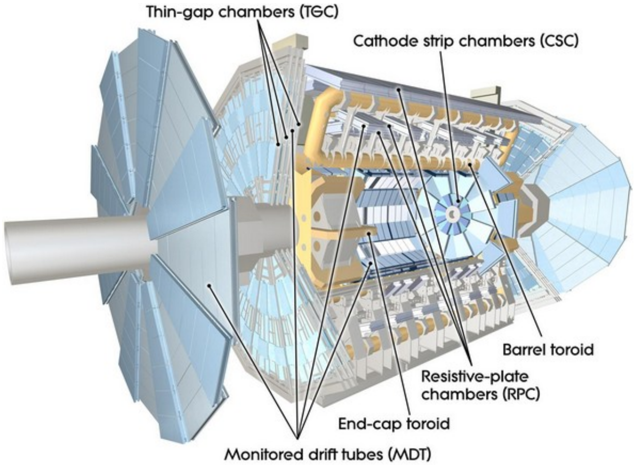


- Completely new piece of Level-1 hardware
  - Programmable trigger selections (FPGA)
  - Receives input from L1Calo and L1Muon
  - Applies selection on trigger objects
- Possible selections
  - Angular cuts (DR, Df, Dh)
  - Invariant mass cuts
  - Object refinements
  - etc.
- Essential for higher lumino



  - Will allow us to keep the L1 thresholds low while not exceeding 100 kHz
- In commissioning...
  - Very complex piece of hardware
  - First trigger algorithms working as expected
  - Will be used during 2016 data-taking

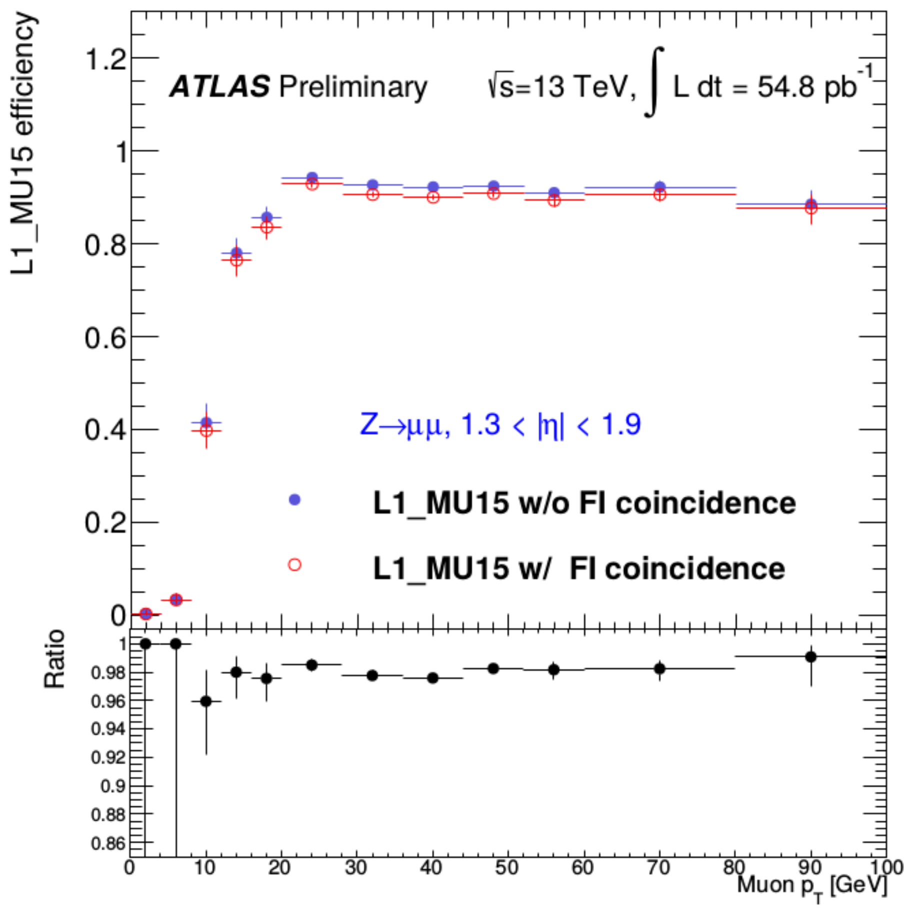
Muon Detectors

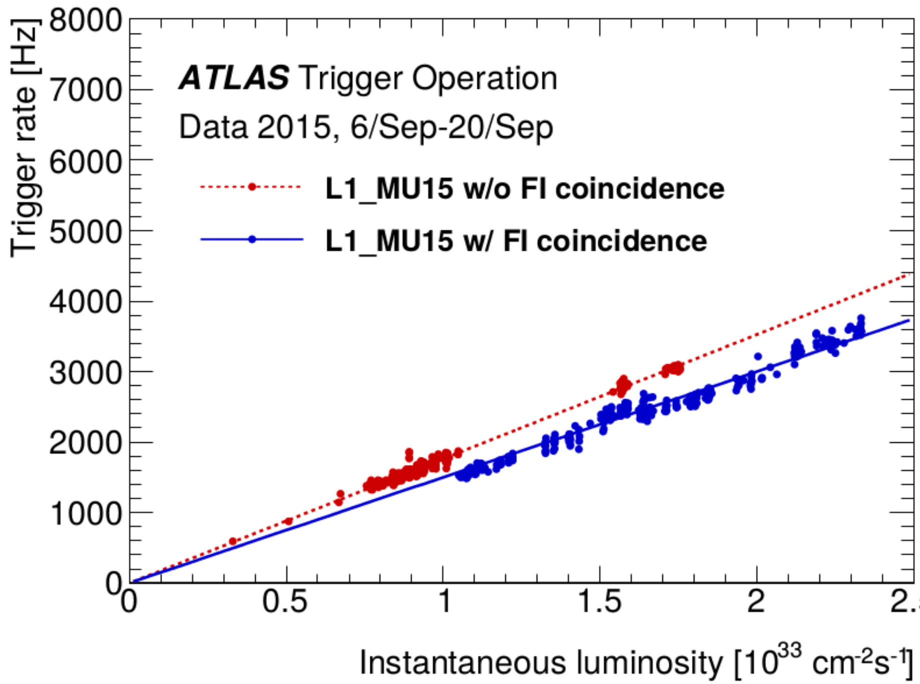


- CSC
  - New ATCA-based readout operating nicely at 100 kHz
    - Absolutely essential for trigger operations in Run-2
  - Several layers show sparking during collisions
    - two chambers show several broken wires (1 out of 4 layers lost)
    - Low voltage has been reduced slightly to prevent sparking
- RPC
  - Extensive repair campaign for gas leaks in LS1
  - Commissioning of new trigger towers (feet region) is ongoing
- TGC
  - Added Inner station coincidence to reduce trigger rates (see later)
  - Implemented veto for noise bursts (relevant for lumi > 5e33)
- MDT
  - Double-link readout for innermost stations to prevent saturation during Run-1
  - Alignment based on Toroid-off run taken in July during LHC ramp up
    - Preliminary alignment already good to O(50µm) in the barrel and O(100µm) in the endcap

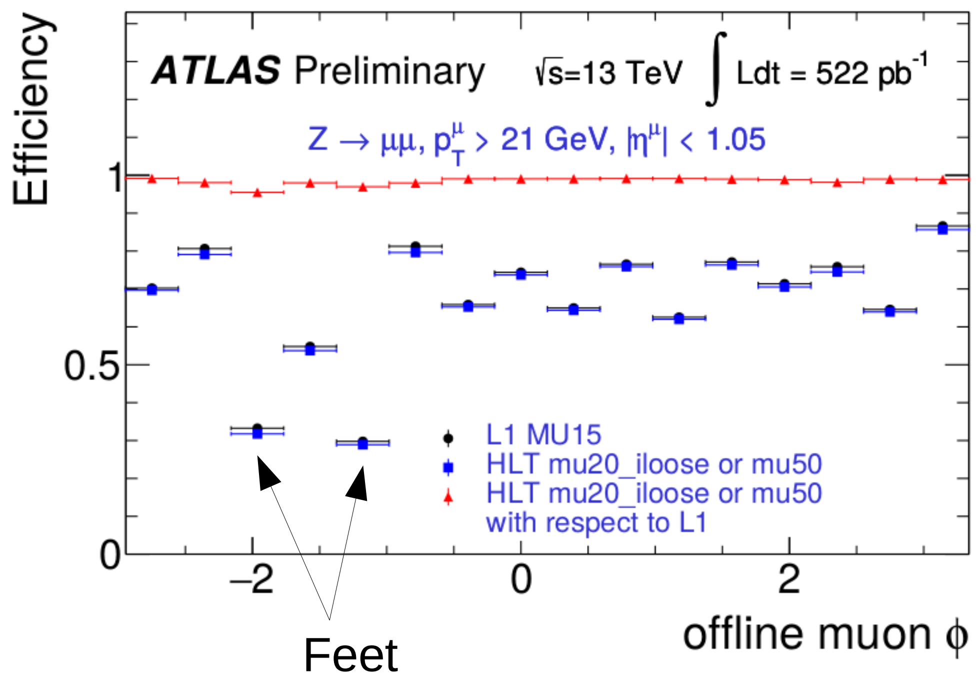
TGC EI/FI coincidence logic

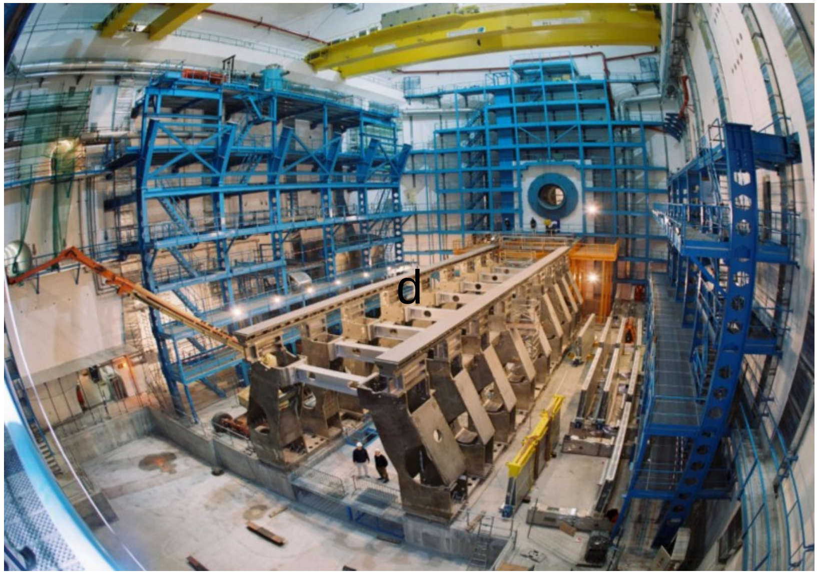
- Significant rate reduction with minimal loss in efficiency
  - >98% efficient with 15% rate reduction at 2.5e33 (more at higher lumi)



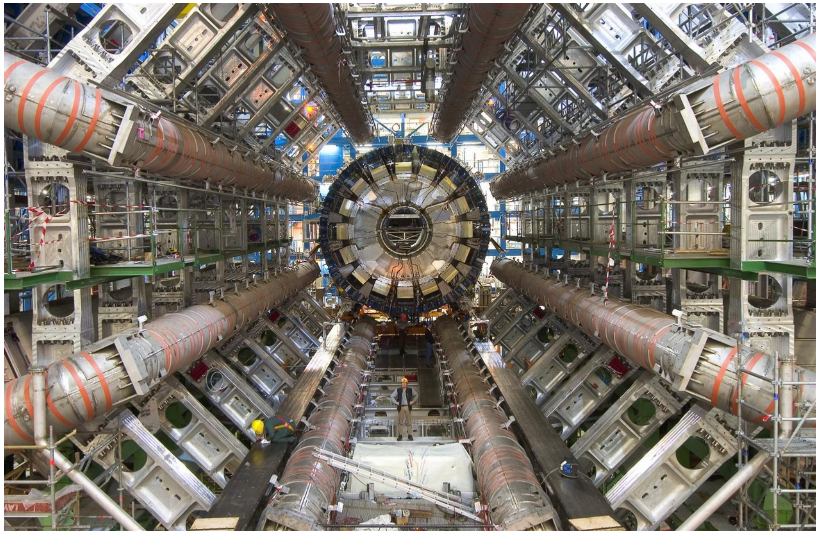


Muon barrel trigger efficiency





The feet of ATLAS (2004)



ATLAS support structure (2005)

- RPC chambers in feet region
  - Trigger electronics installed and commissioned
    - Was post-poned to LS1 during construction phase
  - Will be fully operational for 2016 data-taking
    - Will increase trigger efficiency in this region to 60-70%