# The *ATLAS* Trigger System: Ready for Run II
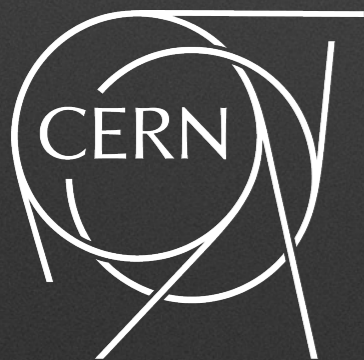
Patrick Czodrowski
for the *ATLAS* collaboration

EPS HEP - Wien
24 July 2015

CERN

UNIVERSITY OF ALBERTA
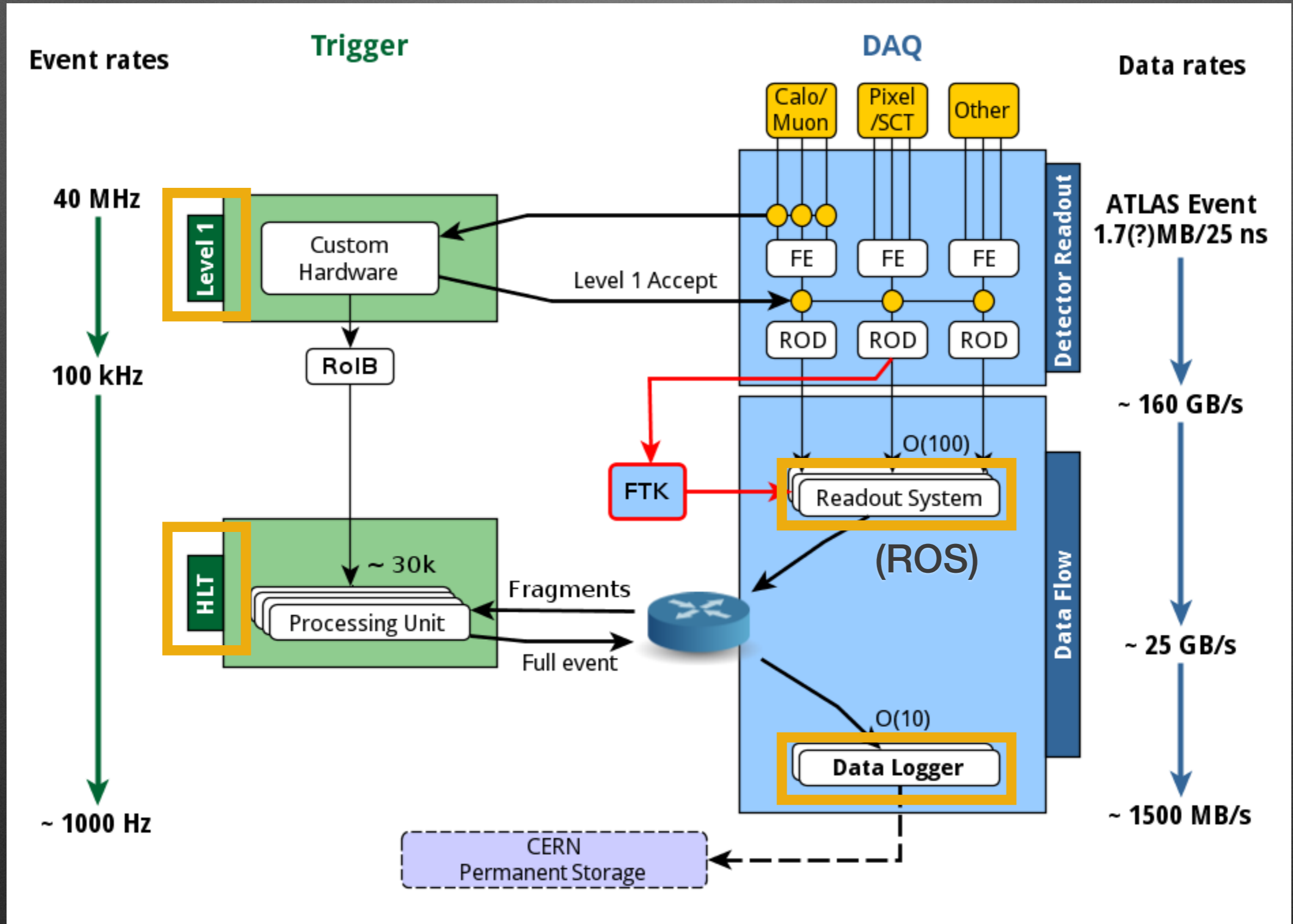
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ATLAS

# Facts and Figures

- **Run I was a success for *ATLAS* and its trigger system!**

  - selected data with high efficiencies for a plethora of physics programs and results

- **Run II presents an unprecedented challenge - the rates are expected to increase by a factor of 5 - 6!**

| | bunch spacing | $\sqrt{s}$ | inst. lumi [ $cm^{-2}s^{-1}$ ] | collisions per bunch x-ing |
|---|---|---|---|---|
| Run I (2012) | 50 ns | 8 TeV | $8 \times 10^{33}$ | 25 - 30 |
| Run II | 25 ns | 13 TeV | $1.7 \times 10^{34}$ | 25 - 50 |

- **To face these harsh conditions the trigger system underwent an enormous upgrade program during the long shutdown**

- **The work and results of the effort of hundreds of experts will be summarized in the following - setting the stage for another success story**

# *ATLAS* Trigger & DAQ

# Introducing the new *ATLAS* Trigger

**Level 1 (L1):** rate reduction 40 MHz → 100 kHz

- Fast custom-made electronics determine Regions of Interest (RoI) from calorimeter and muon signals (relatively coarse), can perform topological combinations

~ 500 independent trigger lines

**Max rate: 70 kHz → 100 kHz !**

**Latency = 2.5 µs**

**High-Level Trigger (HLT):** rate reduction 100 kHz → ~1 kHz

- Runs either on the RoIs only or on the full event info with a fast near-offline reconstruction quality on an off-the-shelf CPU farm
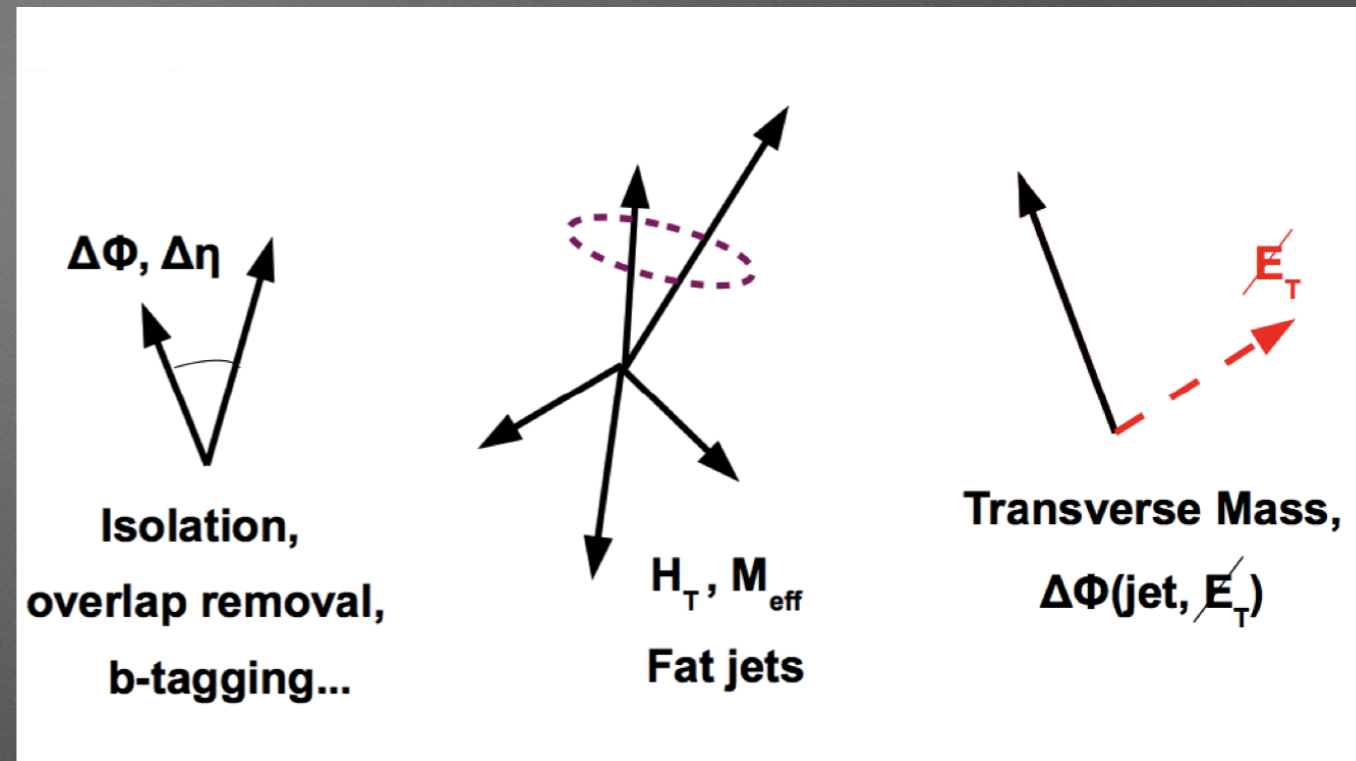
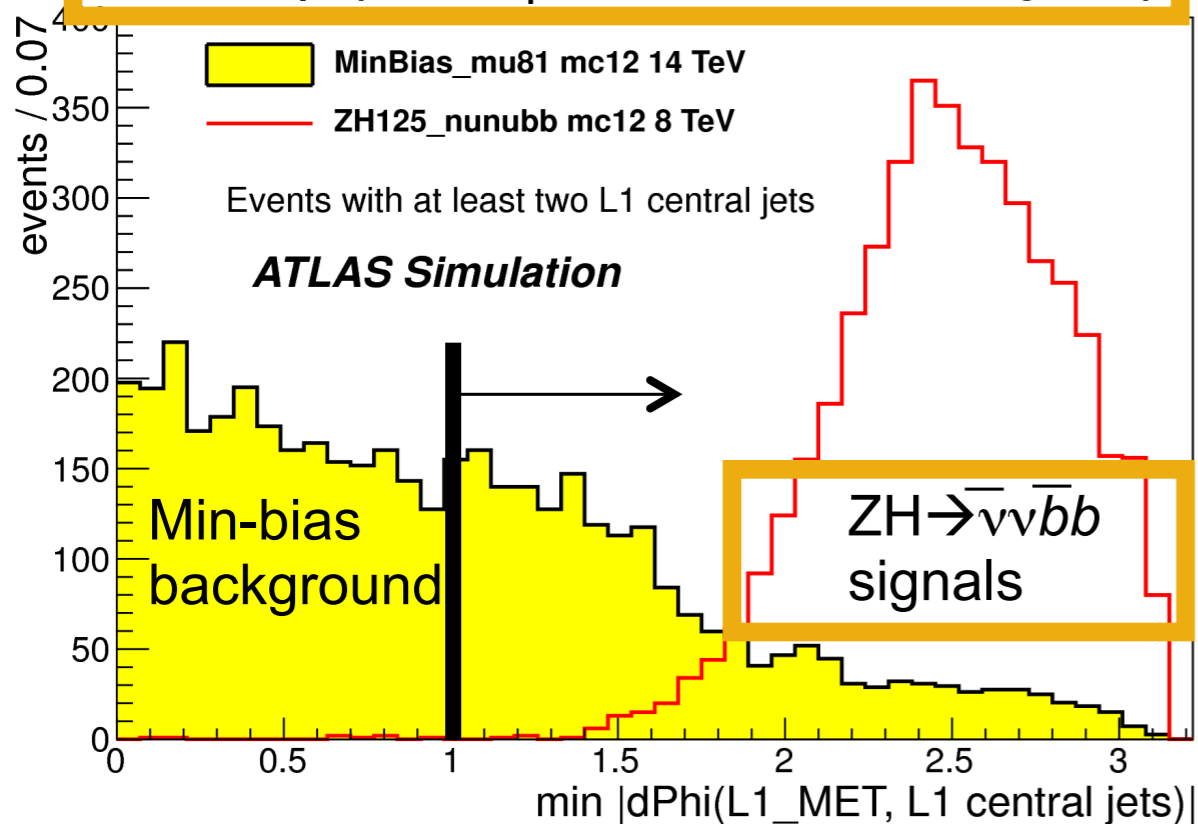~ 1000 independent trigger lines

**Max rate: 600 Hz → 1.5 kHz !**

**Latency ~ 0.2 s**

# L1 Topological Module (new!)

- **L1Topo is being commissioned:**



Isolation, overlap removal, b-tagging... | $H_T$, $M_{eff}$ Fat jets | Transverse Mass, $\Delta\Phi$(jet, $E_T$)



Isolation, overlap removal, b-tagging... | $H_T$, $M_{eff}$ Fat jets | Transverse Mass, $\Delta\Phi$(jet, $E_T$)

## min $\Delta\phi$ (L1 $E_T^{miss}$, L1 central jets)



MinBias_mu81 mc12 14 TeV

ZH125_nunubb mc12 8 TeV

Events with at least two L1 central jets

*ATLAS Simulation*
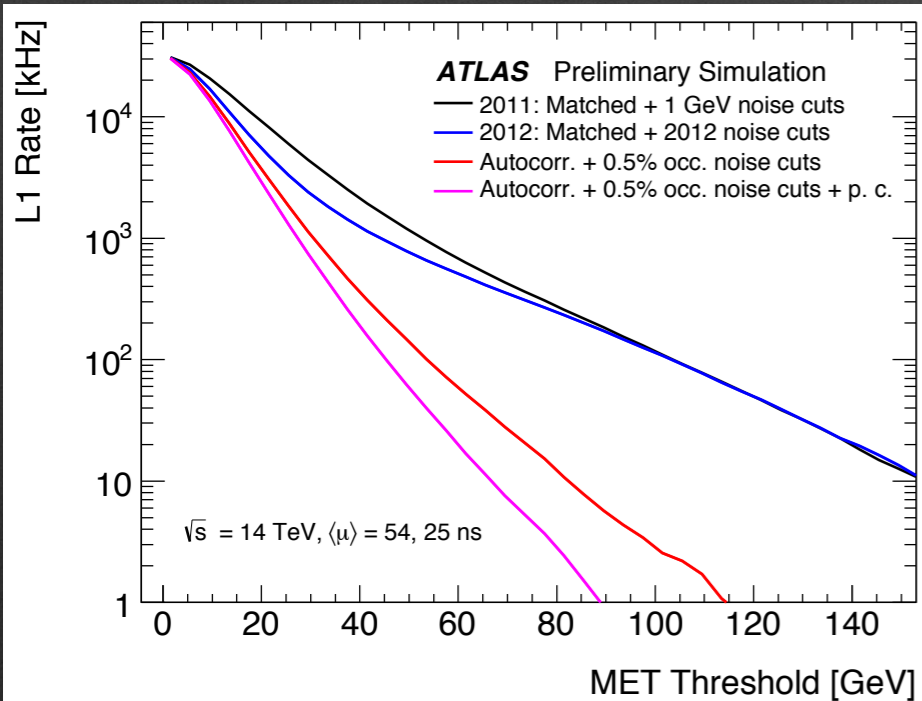
Min-bias background

ZH→$\bar{\nu}\nu\bar{b}b$ signals

- Features a plethora of combinatorial possibilities of (latency-optimized) algorithms for physics analyses

- Examples: angular cuts, invariant and transverse mass as well as scalar sum of $p_T$ - to just name a few

- Very helpful to keep the thresholds low

5

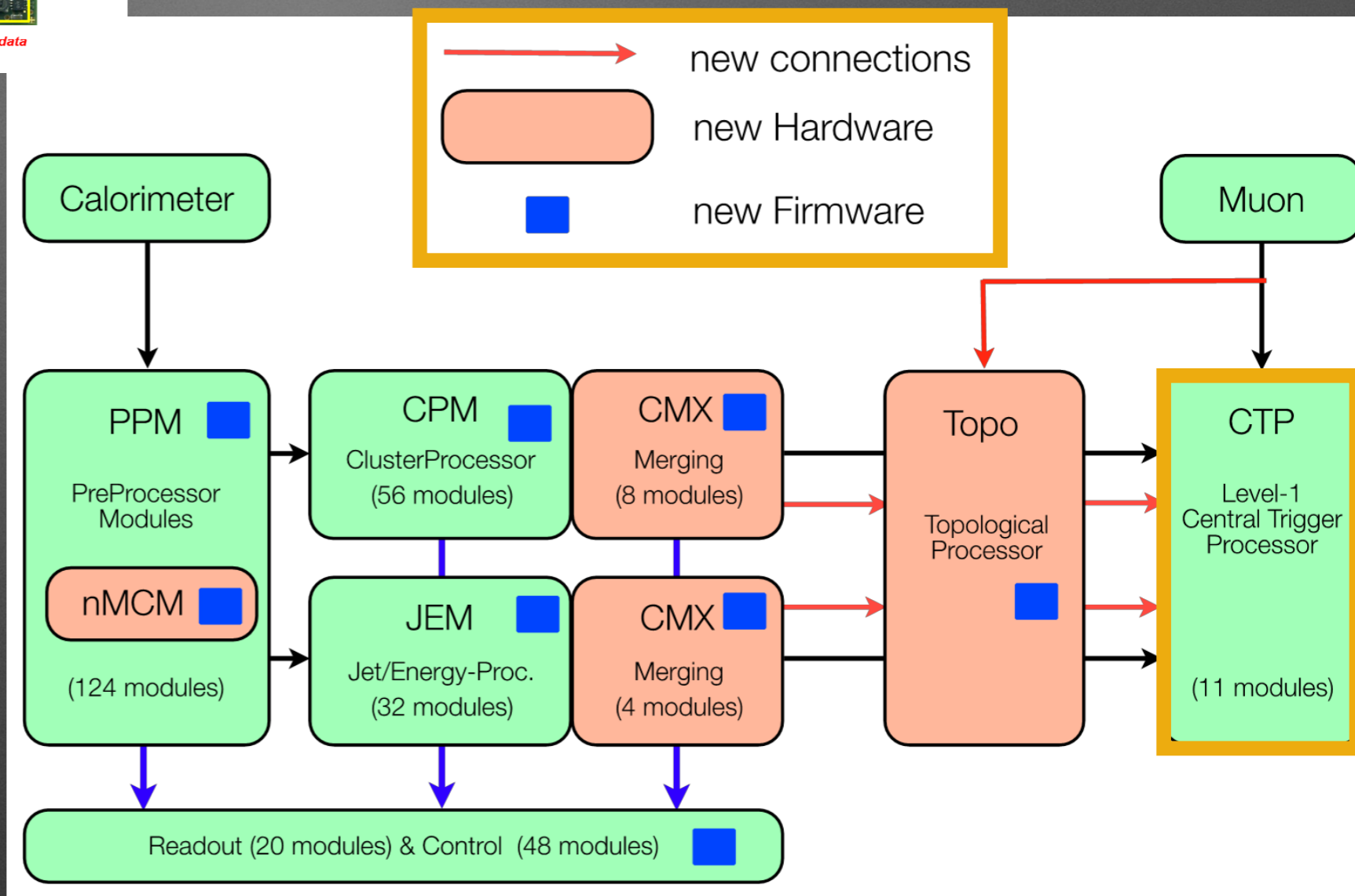# What's new for L1Calo?



**x2000**

**One example update (out of of many): Multi-Chip Modules**

- Enhanced flexible signal processing for dynamic pedestal subtraction (rate reduction esp. for missing $E_T$ trigger)
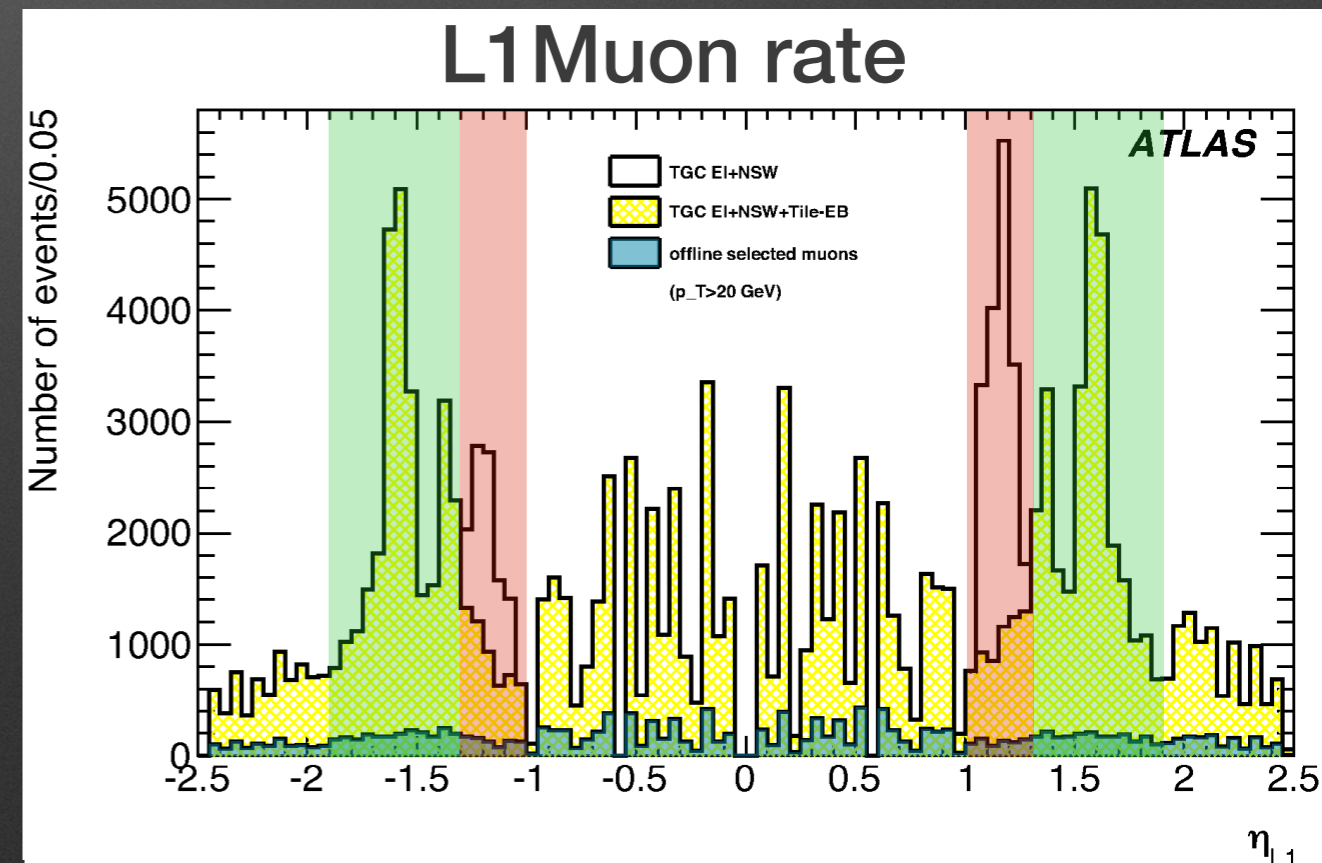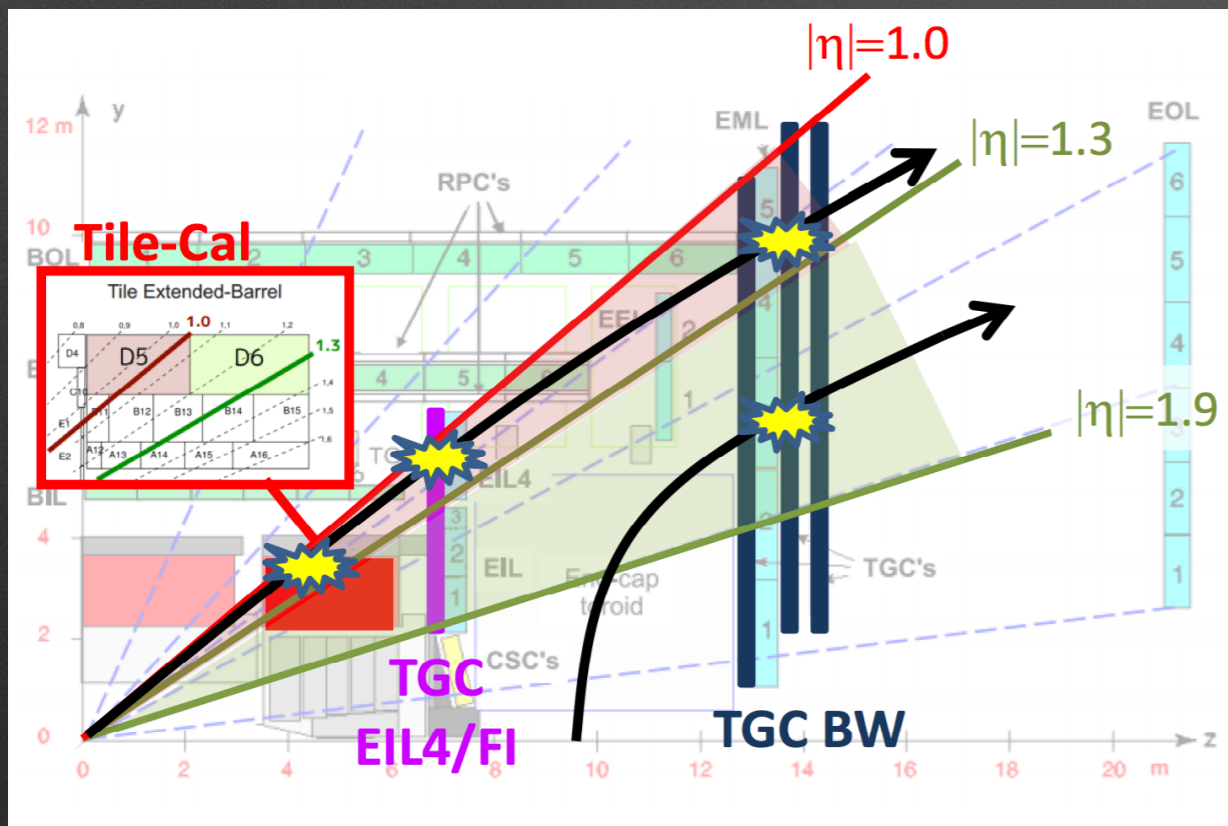


## The updated L1Calo for Run II:



new connections

new Hardware

new Firmware

**Calorimeter**

**Muon**

**PPM** ■
PreProcessor Modules
(124 modules)

**nMCM** ■

**CPM** ■
ClusterProcessor
(56 modules)

**CMX** ■
Merging
(8 modules)

**JEM** ■
Jet/Energy-Proc.
(32 modules)

**CMX** ■
Merging
(4 modules)

**Topo**
Topological Processor ■

**CTP**
Level-1 Central Trigger Processor
(11 modules)

Readout (20 modules) & Control (48 modules) ■

**Further features an increase of definable thresholds ( 28 → 57 )**

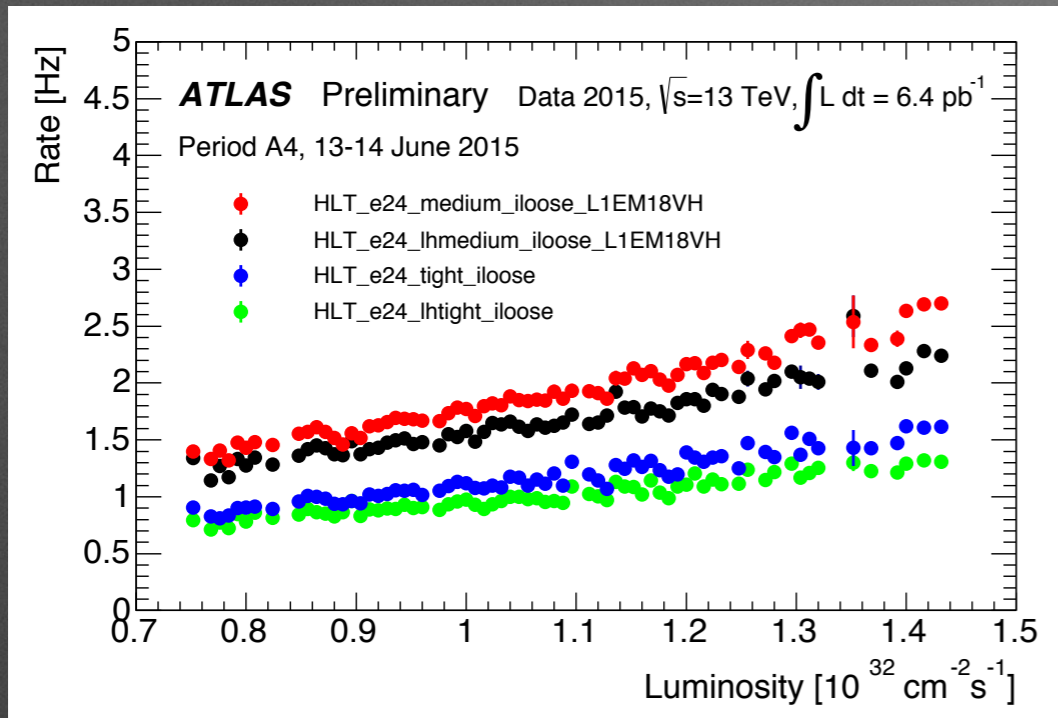- Increased selection flexibility!

# L1Muon News

- **New additional trigger chambers installed at the "feet" of the detector**

- **Communication improved - the new coincidence logic:**

  - Coincidences set up with the new Inner Muon Chambers as well as with the extended barrel of the Tile Calorimeter

  - Goal: reduce by a factor of 2 the low-$p_T$ proton pollution in the forward region observed in Run I !

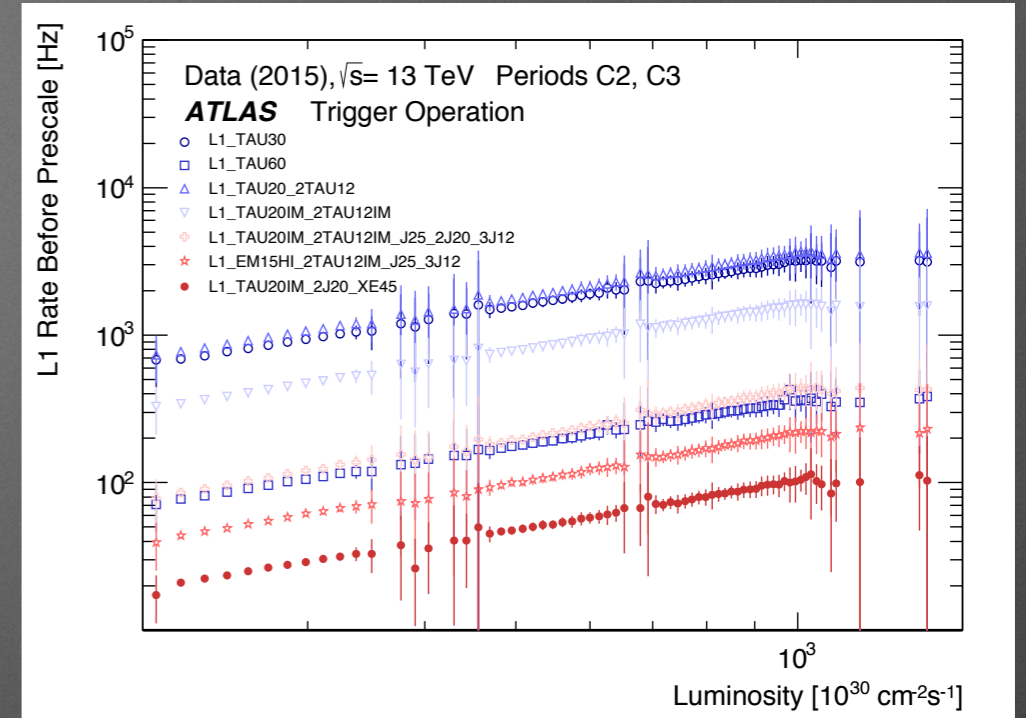# Level 2→ HLT ←Event Filter

- **The new merged HLT (vs. Level 2 + Event Filter split in Run I):**
  - Reduces complexity - nevertheless more flexibility
  - More efficient resource-wise and reduces duplicate data-fetching
  - Processes one event per ~0.2 s on average

- **Software Improvements:**
  - Adopt offline techniques where feasible
    - Trigger / offline object harmonization increases the physics acceptance after analysis selection is applied
    - Reduces online / offline code duplication
  - Increased use of global reconstruction
  - Advanced multiprocessing to fully utilize available hardware
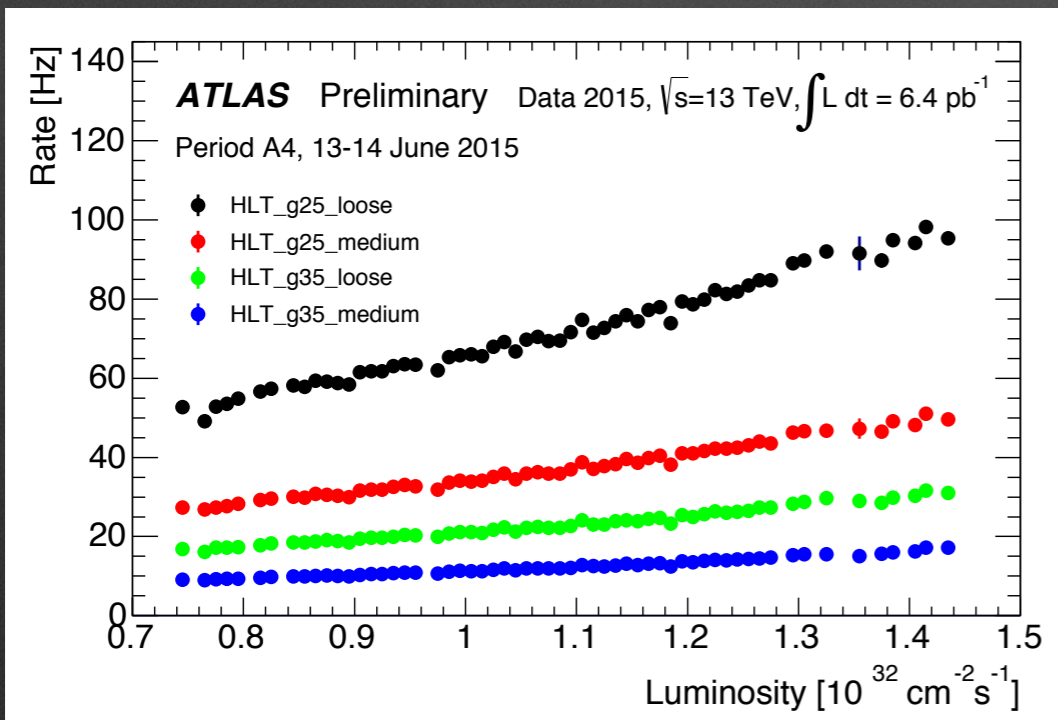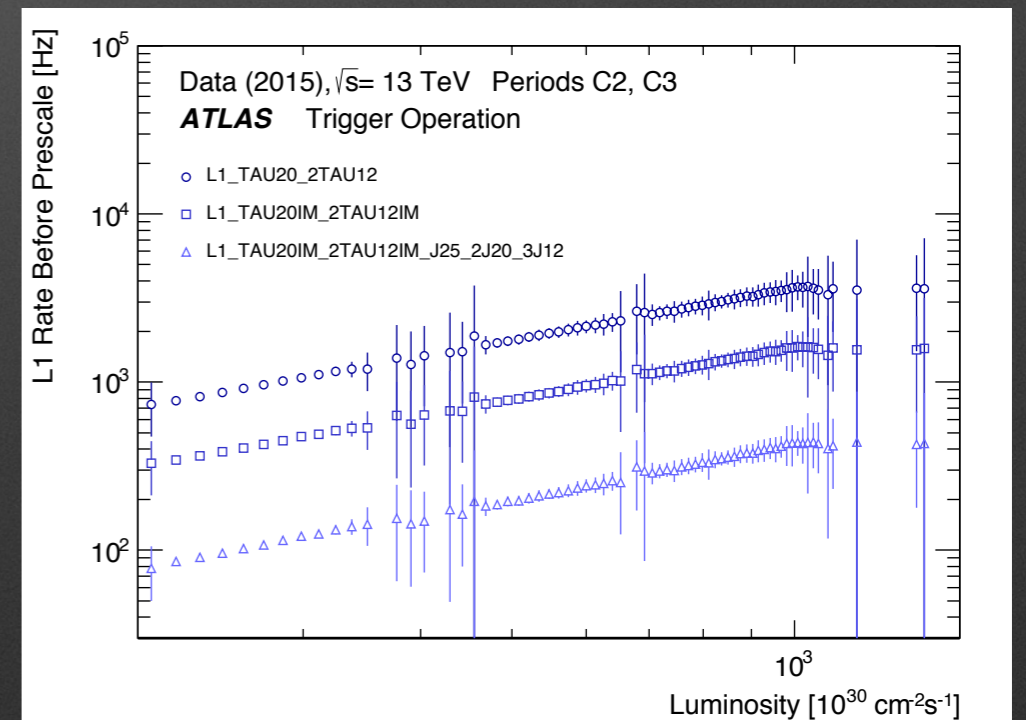
# Trigger Operation



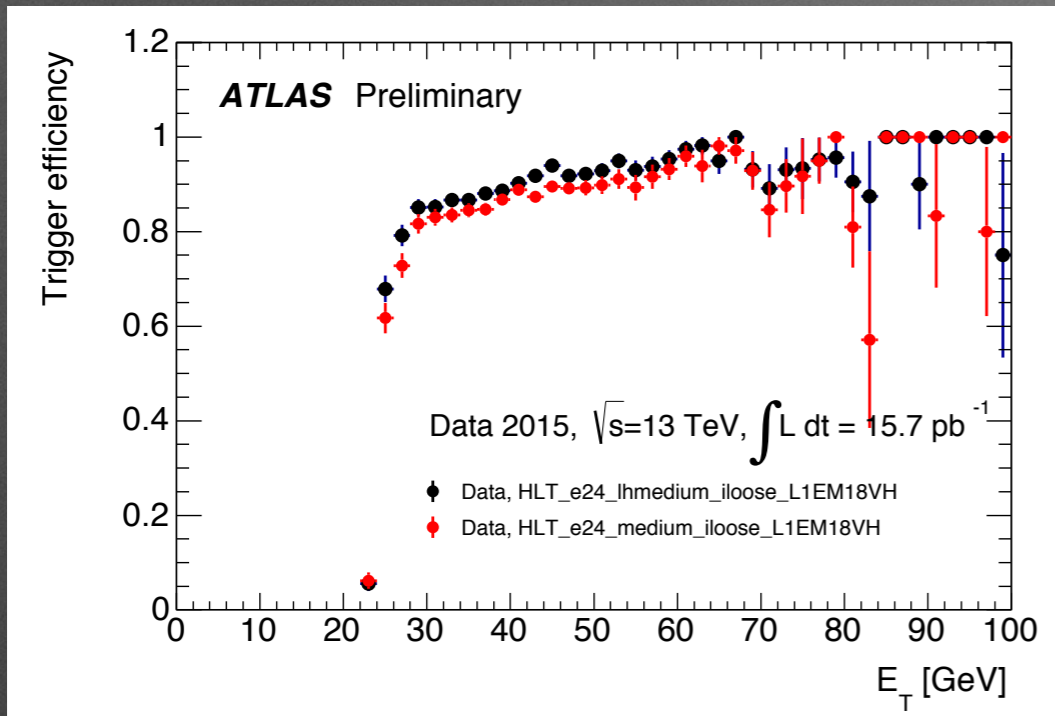Electron HLT trigger rates



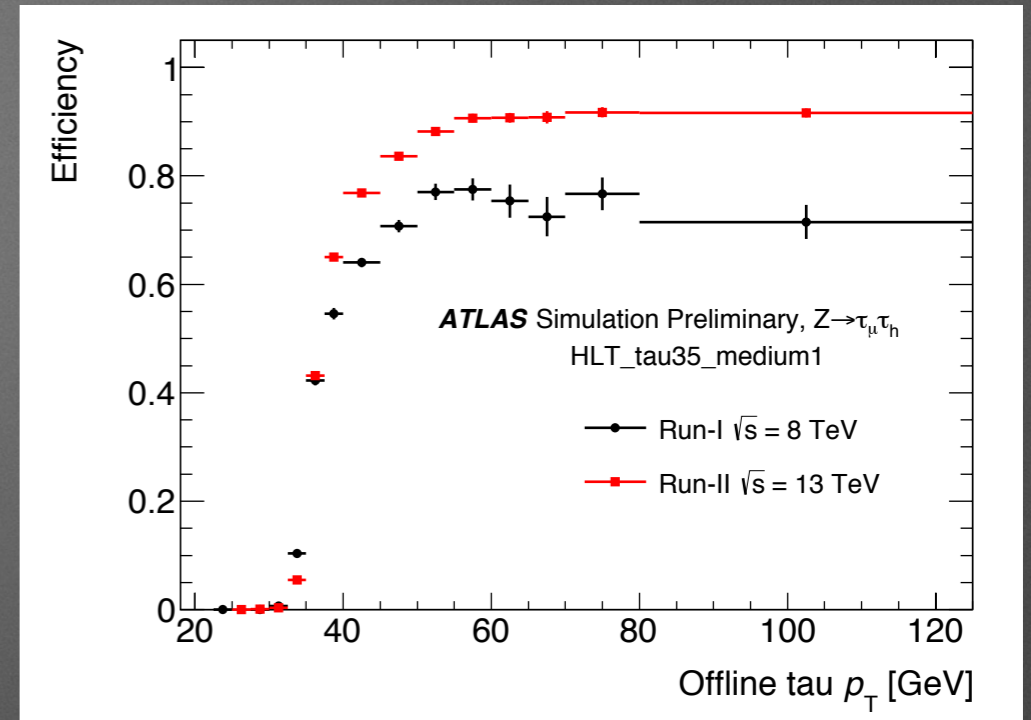Tau L1 trigger rates



Photon HLT trigger rates
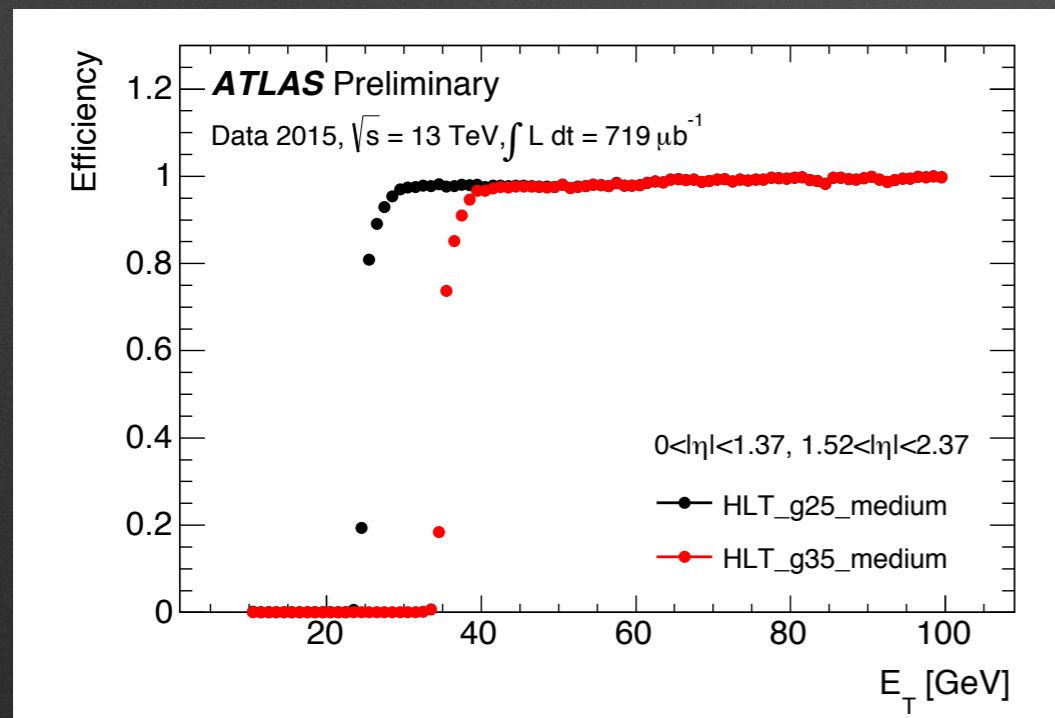


Di-tau L1 trigger rates

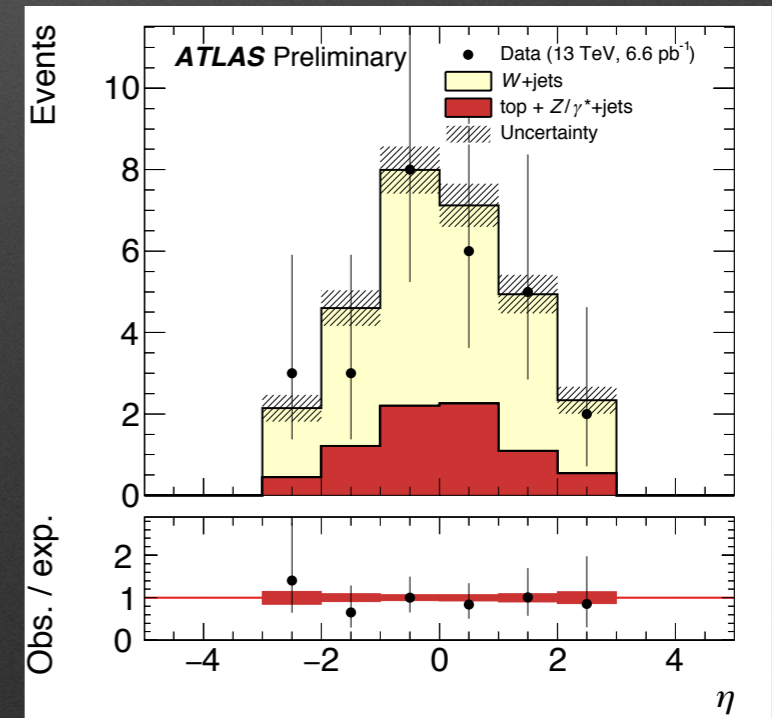# Trigger Performance


Electron HLT triggers


Tau HLT triggers (Run I vs. II)


Photon HLT triggers


"Fake" taus from *W*+jets

# The *ATLAS* Trigger System is ready for Run II

- Thanks to the dedicated effort of a large number of experts during the long shutdown the *ATLAS* Trigger System is now ready for the challenges Run II brings and will improve its already outstanding Run I performance in terms of:

  - Rate reduction

  - Efficiency

  - Coverage

  - Stability

  - and most important: enhanced physics analysis acceptance

**Looking forward to more data to come!**

# Further Trigger contributions

## Talks (in this session - today):

*Hardware-based tracking at trigger level for ATLAS: The Fast Tracker (FTK) Project*

Johanna Gramling

*An FPGA-based Test-Bench for the design verification of the FTK AM chip*

Francesco Crescioli

## Posters:

*The ATLAS Transverse Momentum Trigger Evolution at the LHC towards Run II*

Allen Mincer & Catrin Bernius

*The Upgrade&Performance of the ATLAS Electron&Photon Triggers towards Run II*

Sebastien Kahn

*The ATLAS Jet Trigger for LHC Run II*

Nuno Anjos

*The Upgrade and Performance of the ATLAS Tau Triggers towards Run II*

Andrew Karamaoun

*The ATLAS Muon Trigger: Run I and Initial Run II Performance*

Kota Kasahara

*Real-time flavour tagging selection in ATLAS*

Jeff Hetherly

*Dedicated Trigger for Highly Ionising Particles at ATLAS*
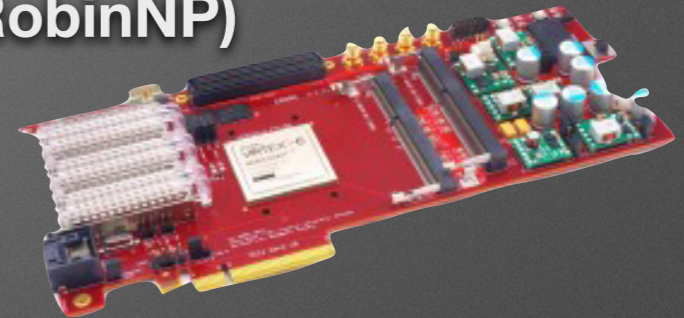
Akshay Katre

Thank you for your attention!

Enjoy the presentations yet to come!

# DAQ news

- **Network**
  - data flow network and control network more redundant + active backup solutions
- **Readout System (ROS) upgraded to new FPGA board (RobinNP)**
  - PCI-X ➔ PCI Express
  - higher density of optical link connectors
  - larger memory buffer
  - New higher performance ROS PCs (can run at up to 100 kHz)
    - 2 x 1 Gbit/s ➔ 4 x 10 Gbit/s Ethernet per PC
- **Data Logger**
  - from Run I: 3 internal Raid5 raid arrays of 8 disks each
  - to RUN II: directly-attached storage unit with multiple front-ends and redundant data paths for fault tolerance and resilience
  - copy files to permanent storage in the background

*ATLAS* data flow was considerably simplified compared to Run I

Every component either upgraded hardware-wise, or rewritten taking advantage of modern designs

# The ATLAS Level-1 Trigger

# ATL-DAQ-PROC-2015-016