Ready for Run 2: The ***ATLAS*** Trigger System

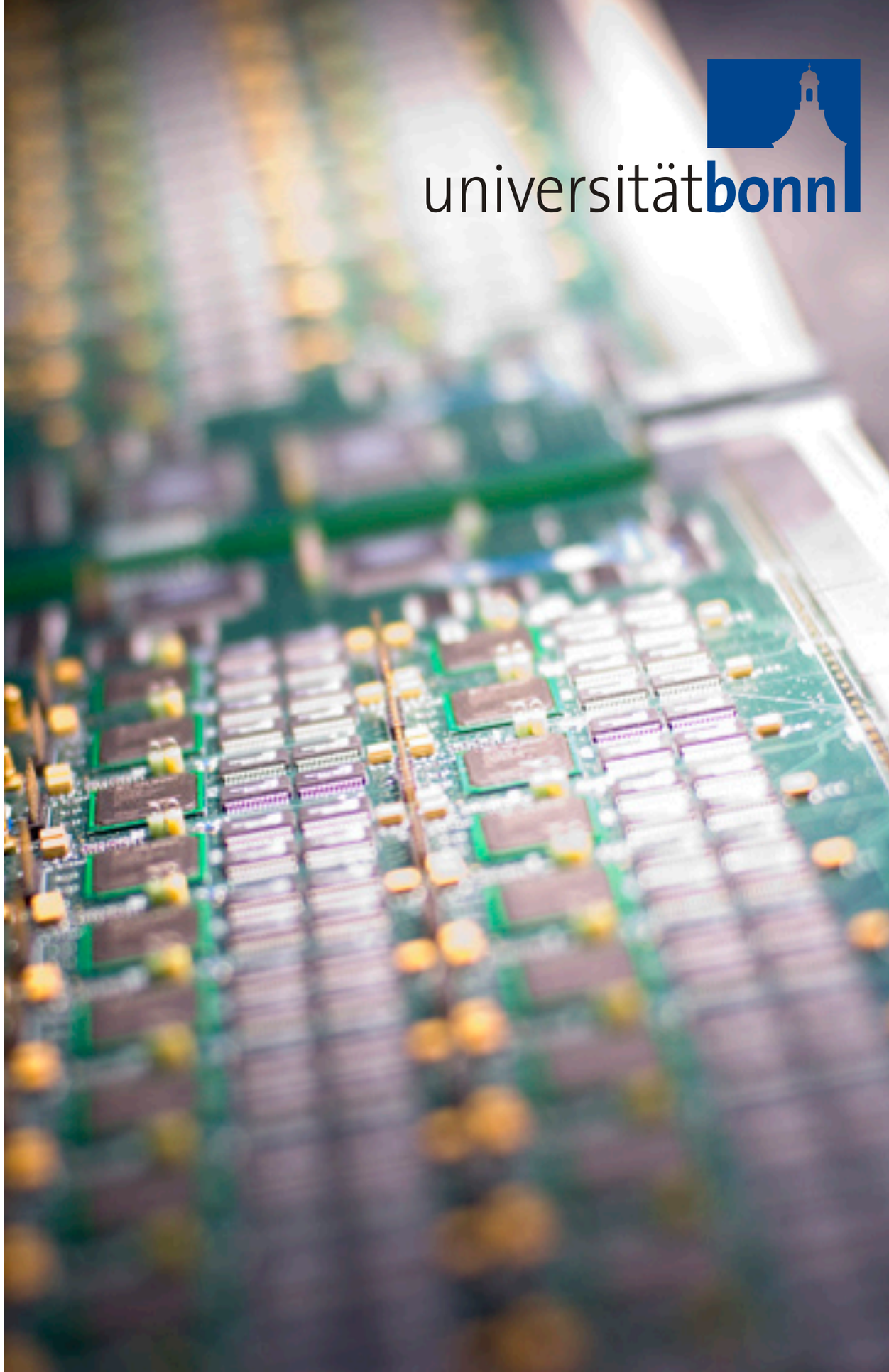
Florian Bernlochner
University of Bonn, Germany

*on behalf of the **ATLAS** collaboration*

LISHEP Conference, Brazil

ATLAS EXPERIMENT

universitätbonn



From *Run 1* towards *Run 2*

Run 1 was a success for ***ATLAS*** and its trigger system:

—| interesting data events selected with high efficiency to produce many interesting physics results.

—| E.g. Discovery of the Higgs boson, many SM and searches results.

Run 2: higher instantaneous luminosity and centre-of-mass energy presents a unprecedented challenge.

—| Rate increase by a factor of **5 to 6!**

	bunch spacing [ns]	√s [TeV]	inst. luminosity [cm^{-2} s^{-1}]	max.collisions per bunch crossing
Run 1: 2012	50	8	8×10^{33}	40
Run 2: 2015 onward	50 - 25	13	1.7×10^{34}	50-80

To face these harsh conditions, the trigger system underwent an enormous upgrade program during the upgrade period.

The work and results of this effort of hundreds of experts will be summarized in the following.

The new ***ATLAS*** Trigger Architecture

In the shutdown period: **transition** from

➠ 3-level trigger **(L1→L2→HLT)** to a 2-level **(L1→HLT)** approach (more on slide 7)

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

- fast custom-made hardware trigger that determines *Regions-of-Interests* (ROIs) using calorimeter and muon system signals. Can perform topological combinations.

O(500) trigger items

Run 1 versus Run 2: **70 kHz → 100 kHz**

Latency < 2.5 µs

High-level Trigger (HLT): necessary rate reduction 100 kHz → 1 kHz

- software based trigger on CPU farm; runs fast analyses on *Regions-of-interests* or *full detector readout* using granularity and calibrations close to offline definitions.

O(1000) trigger items

Run 1 versus Run 2: **600 Hz → up to 1.5 kHz**

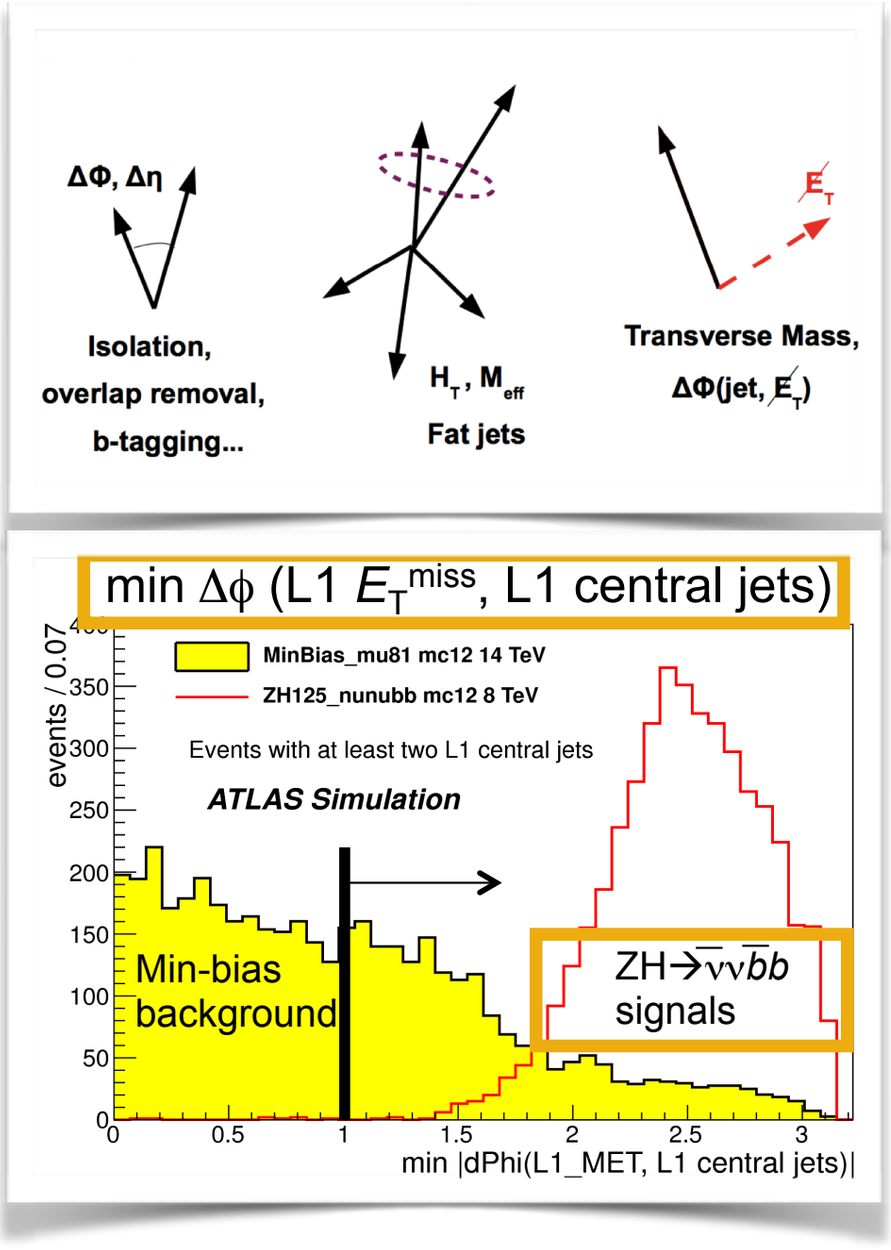
Latency ~ 0.2 s

Level 1 Topological Triggers

New for Run 2

Level 1 topological triggers: conceptually new for ***ATLAS***

- Combines trigger objects from L1 calorimeter and muon systems
- Can calculate event or signature kinematics or angular relations in real-time.
- FPGAs return a topological decision within *100 ns.*



Allows to combine many physics signatures to optimize selection for interesting physics events.

- E.g. angular cuts, invariant and transverse masses can be calculated, or scalar or vectorial p_T sum of jets.

Key concept for Run 2 to keep enabling physics analyses to probe difficult terrain.

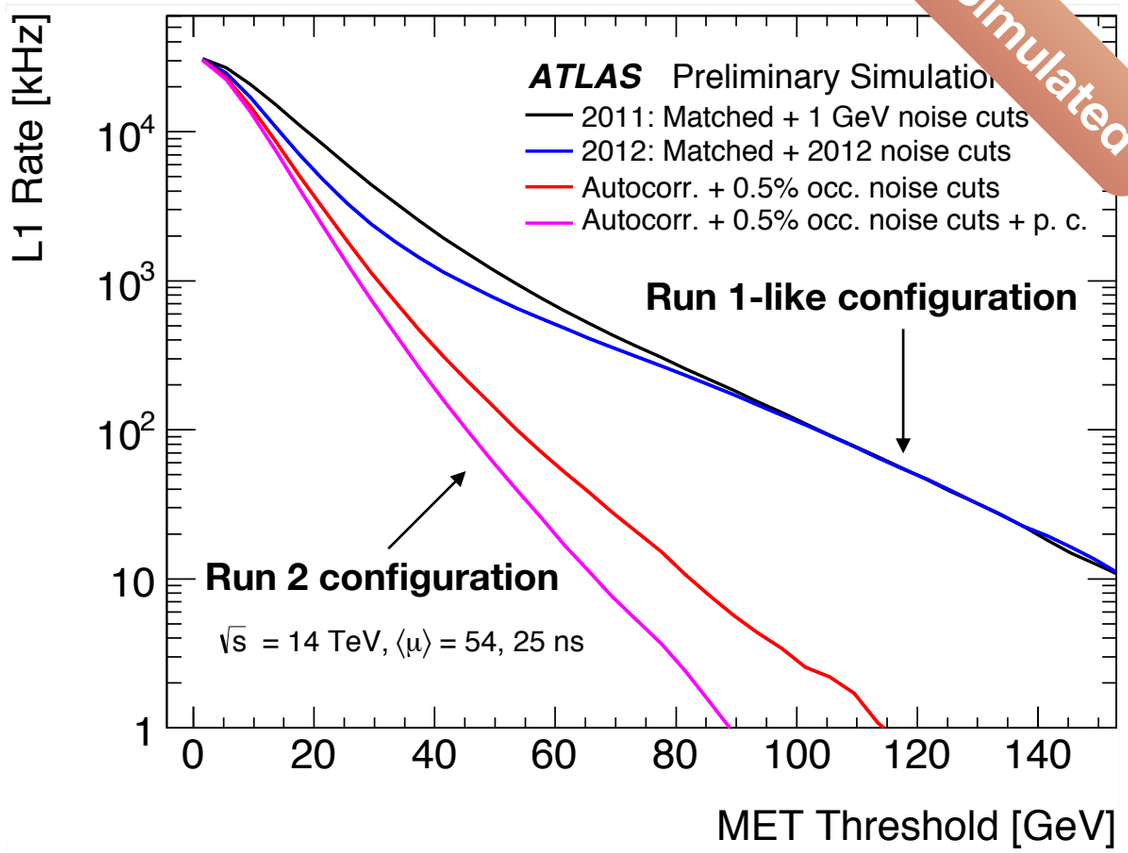
Level 1 Calorimeter readout

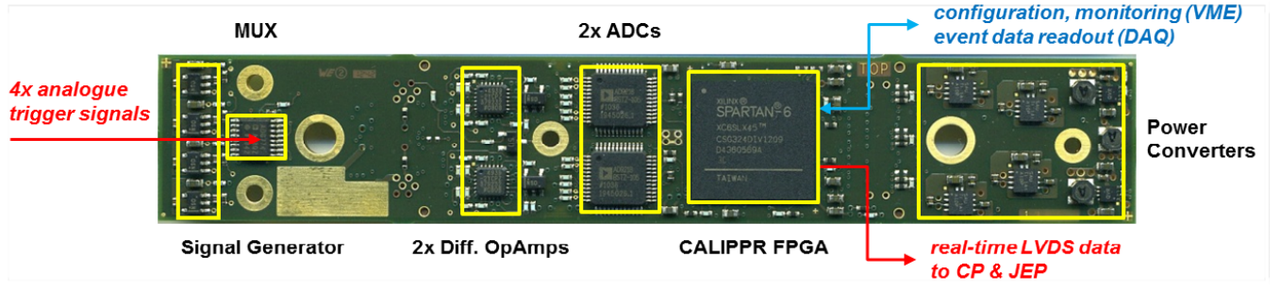
New for Run 2

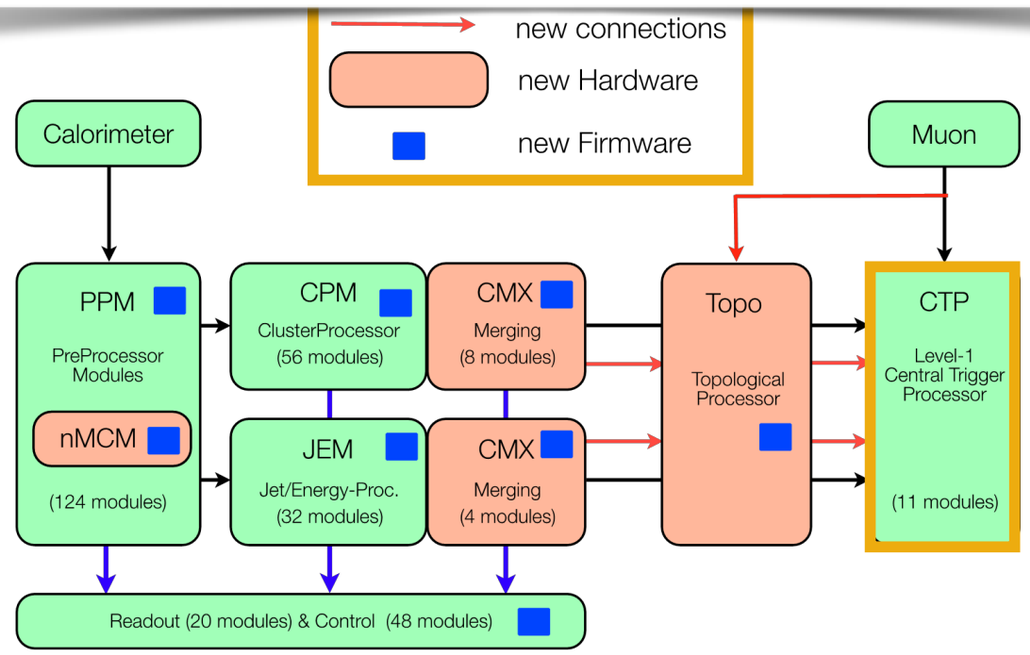
Level 1 Calorimeter readout improvements: new Multi-Chip Module (MCMs).

- Enhanced flexible signal processing for dynamic pedestal subtraction based on global cell occupancy. Great reduction in rates for global and ROI based triggers, e.g. *missing E_T*.

Simulated







Another key aspect for Run 2 to keep thresholds low for physics.

Level 1 Muon System

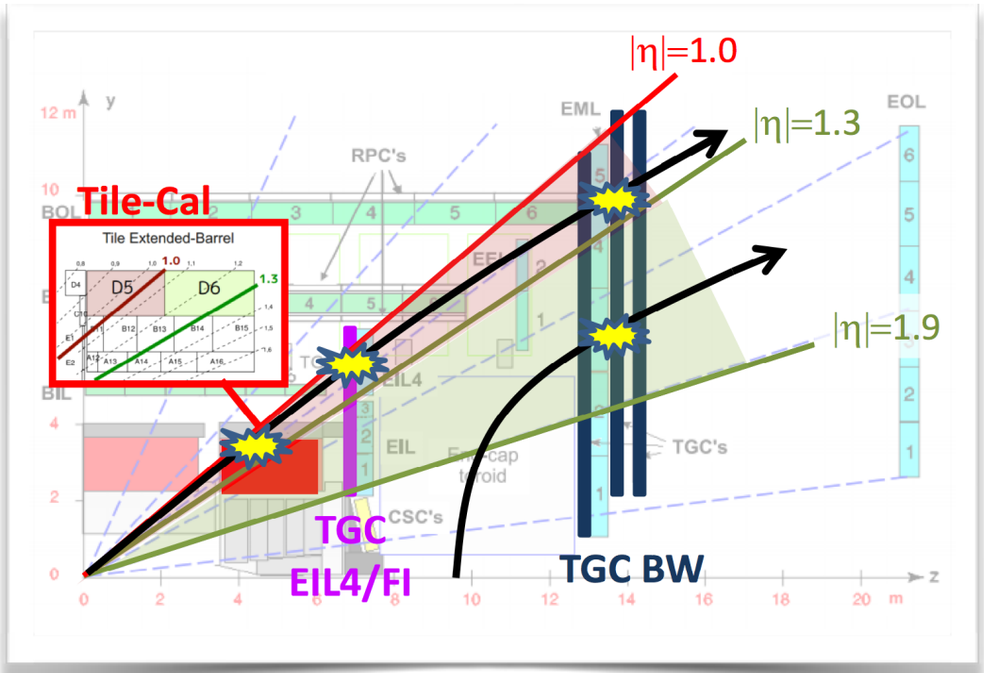
New for Run 2

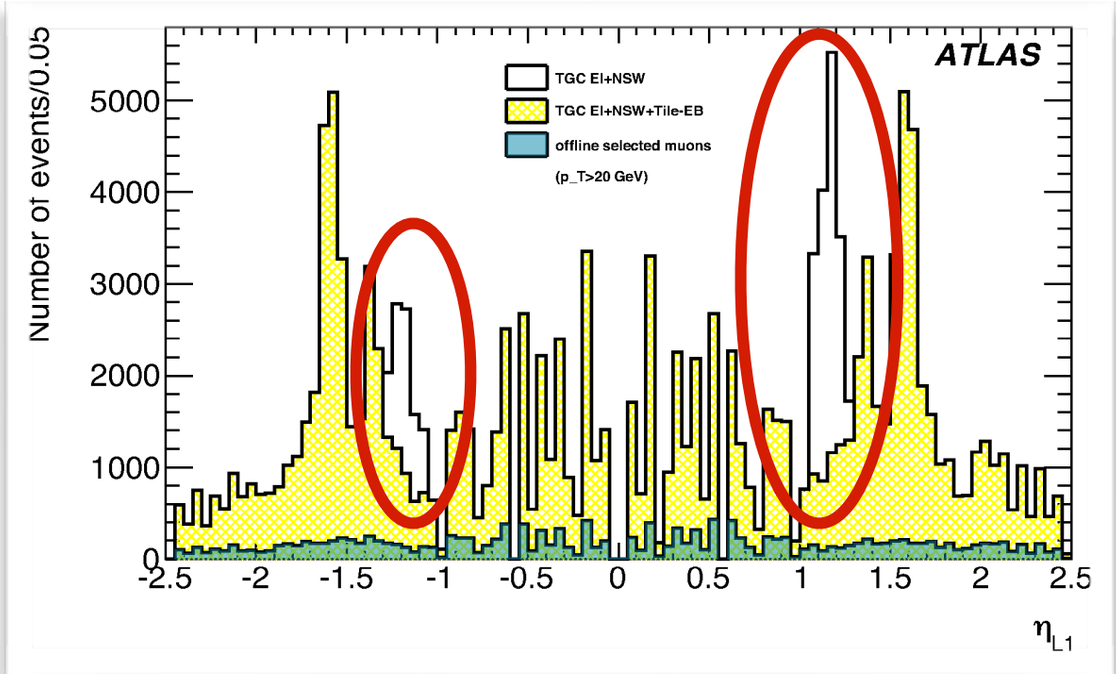
New additional trigger chambers installed at the bottom of the detector.

- Increases muon acceptance.

Trigger logic improved — new coincidence logic setup:

- Coincidences with new inner muon chambers as well as with the extended barrel of the tile calorimeter.
- Decreases the low p_T proton pollution in the forward region by a factor of 2.



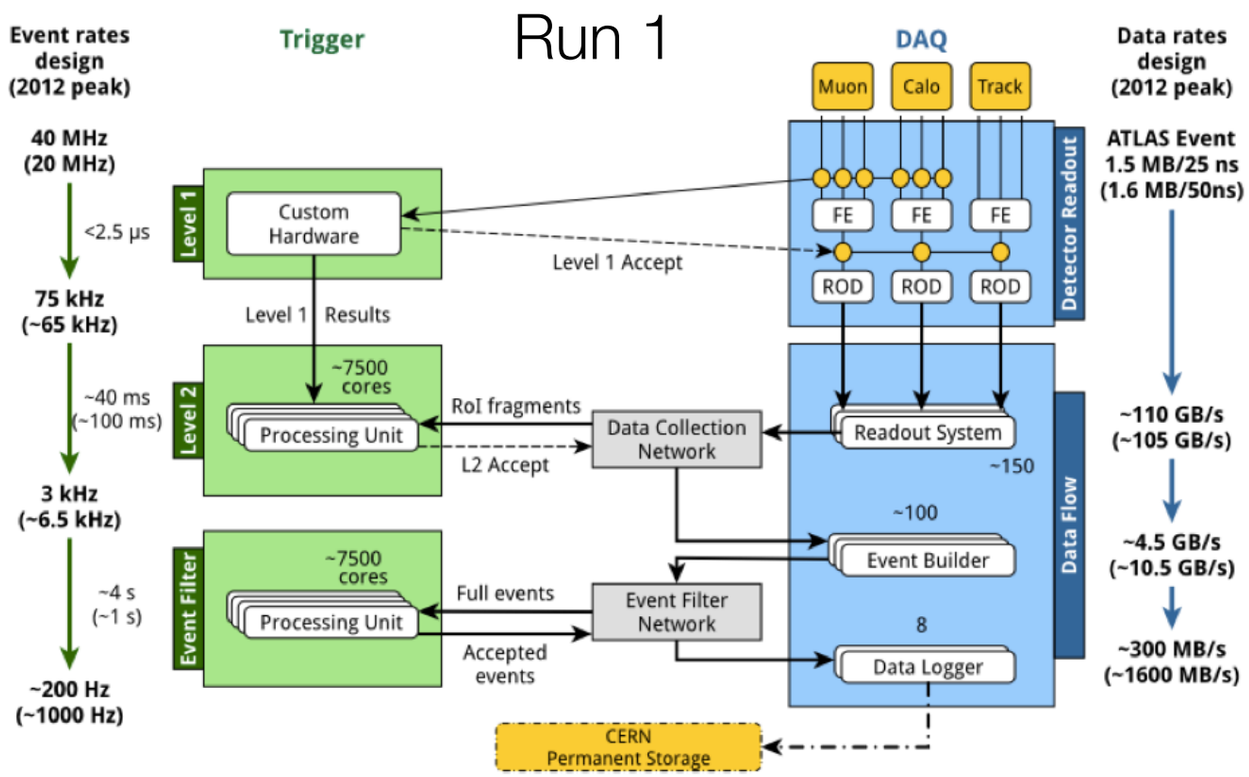


New integrated High level Trigger System

New for Run 2

New merged High-level Trigger (HLT):

- Reduces complexity and increases flexibility.
- More combined resources with respect to
  vs two clusters).
- Processes one event at a time (average of



Streamlined software:

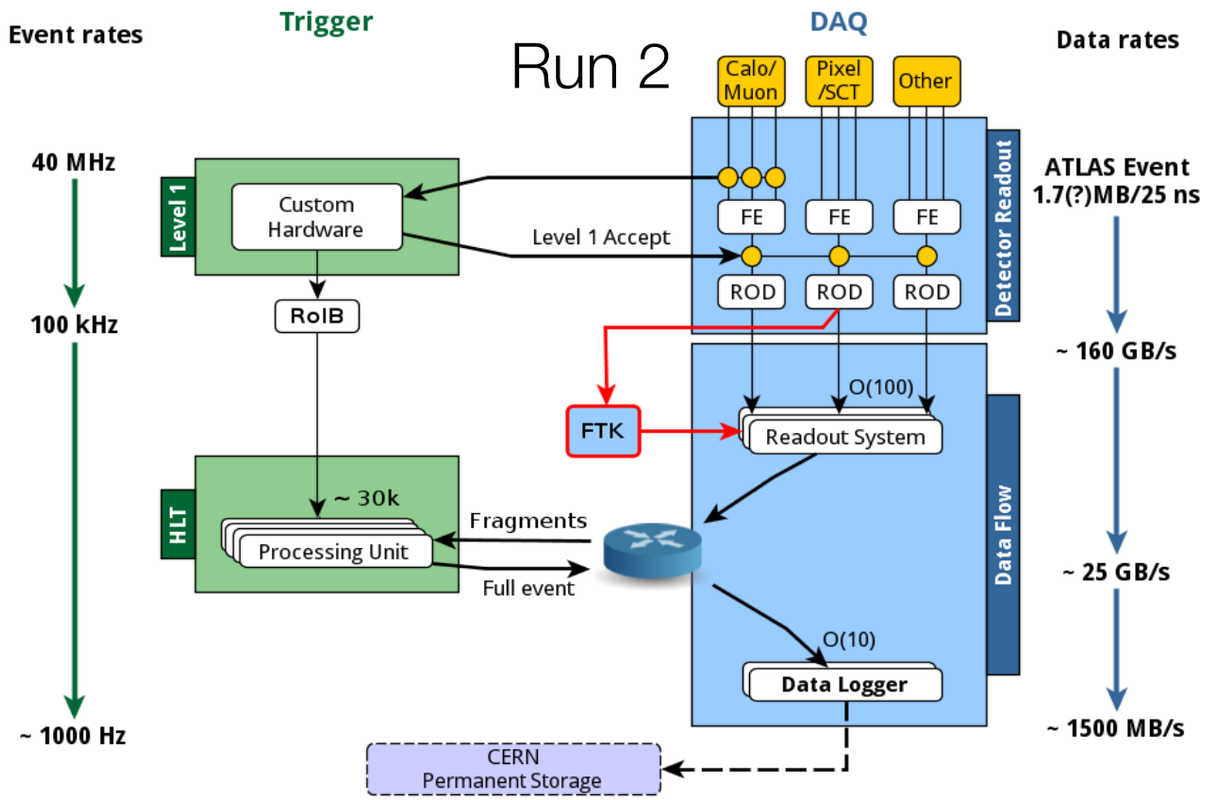
- Adopted offline techniques and algorithms where possible.
  - Offline / Trigger object harmonization simplify efficiency determinations.
- Less code duplication between online & offline algorithms.
- HLT processes forked into a single mother process, enables maximal memory sharing.

New integrated High level Trigger System

New for Run 2

New merged High-level Trigger (HLT):

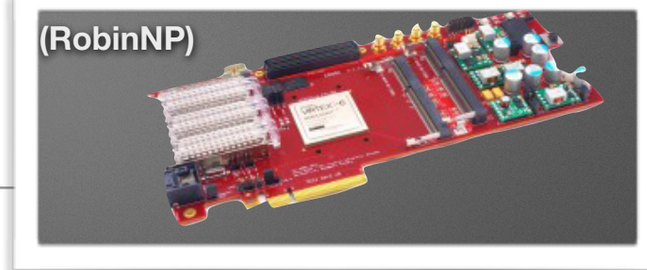
- Reduces complexity and increases flexibility.
- More combined resources with respect to *Run 1 (one CPU cluster vs two clusters).*
- Processes one event at a time (average of **~0.2 s / event**).



Streamlined software:

- Adopted offline techniques and algorithms where possible.
  - Offline / Trigger object harmonization simplify efficiency determinations.
- Less code duplication between online & offline algorithms.
- HLT processes forked into a single mother process, enables maximal memory sharing.

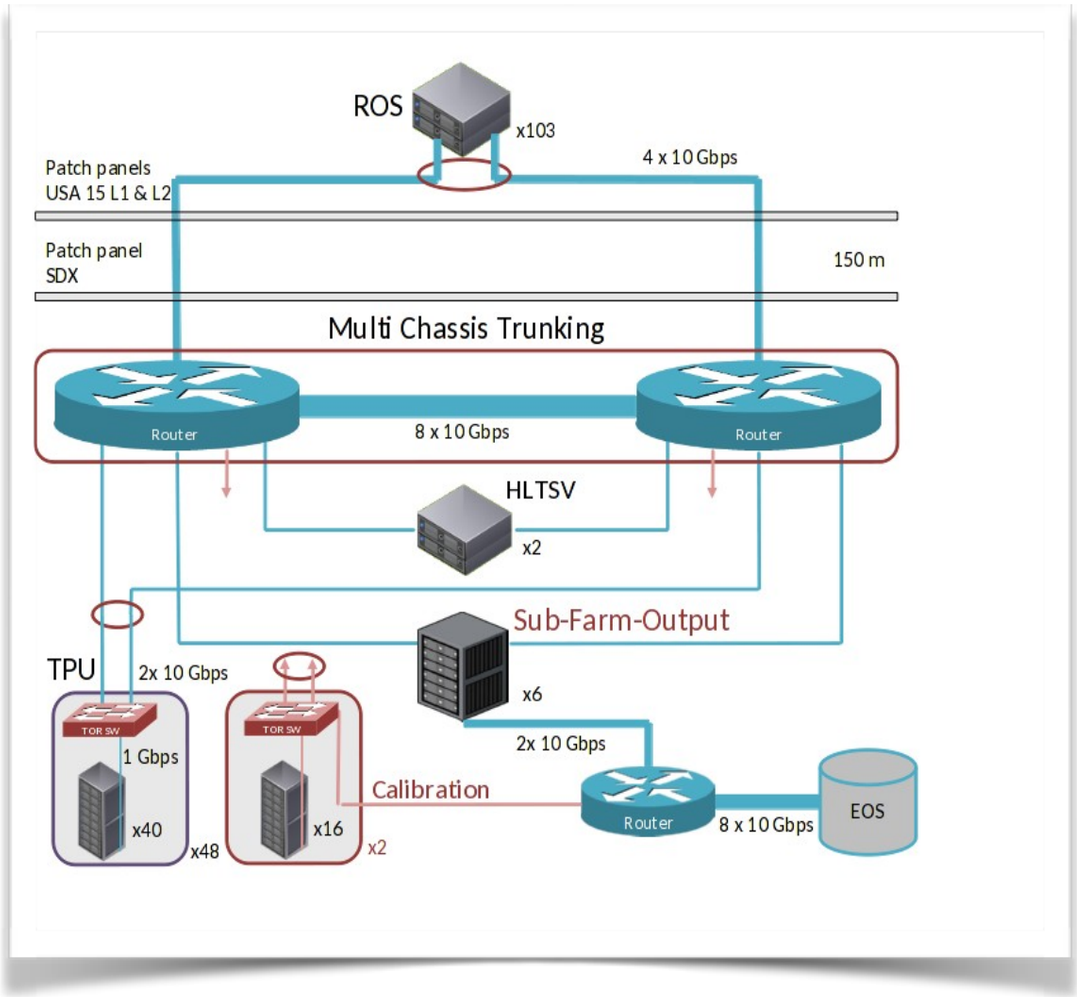
Data Acquisition (DAQ)



New for Run 2

Network:

- Added more redundancy to the data flow and control network.
- Readout system (ROS) upgraded to new board (RobinNP).
  - PCI-X upgraded to PCI express:
    - —| higher density of optical link connectors.
    - —| larger memory buffer.
- Updated Readout System PCs:
  - —| 2 x 1 Gbit/s → **4 x 10 Gbit/s (Ethernet).**
  - —| ROS with unsaturated input can run at 50 kHz.



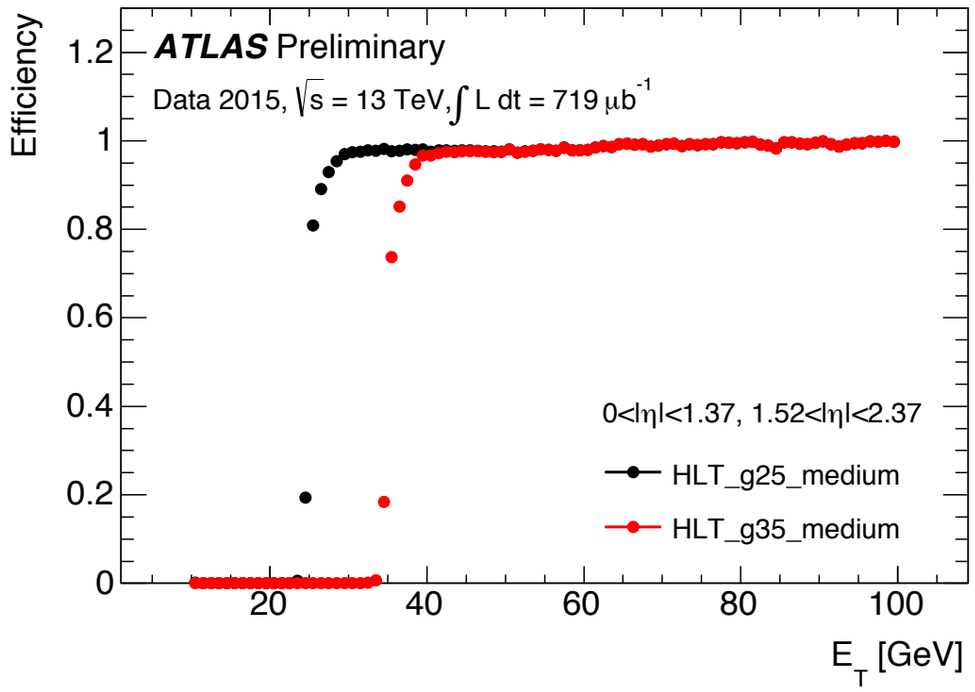
ATLAS data flow was considerably simplified with respect to Run 1

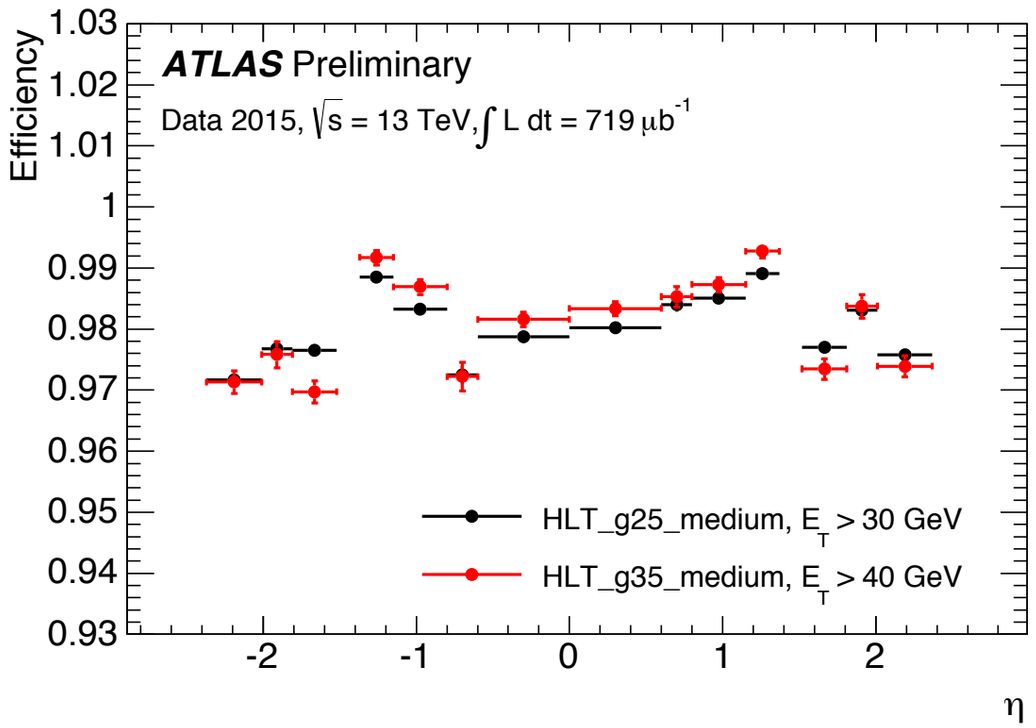
Every component either upgraded hardware-wise or rewritten taking advantage of more modern designs.

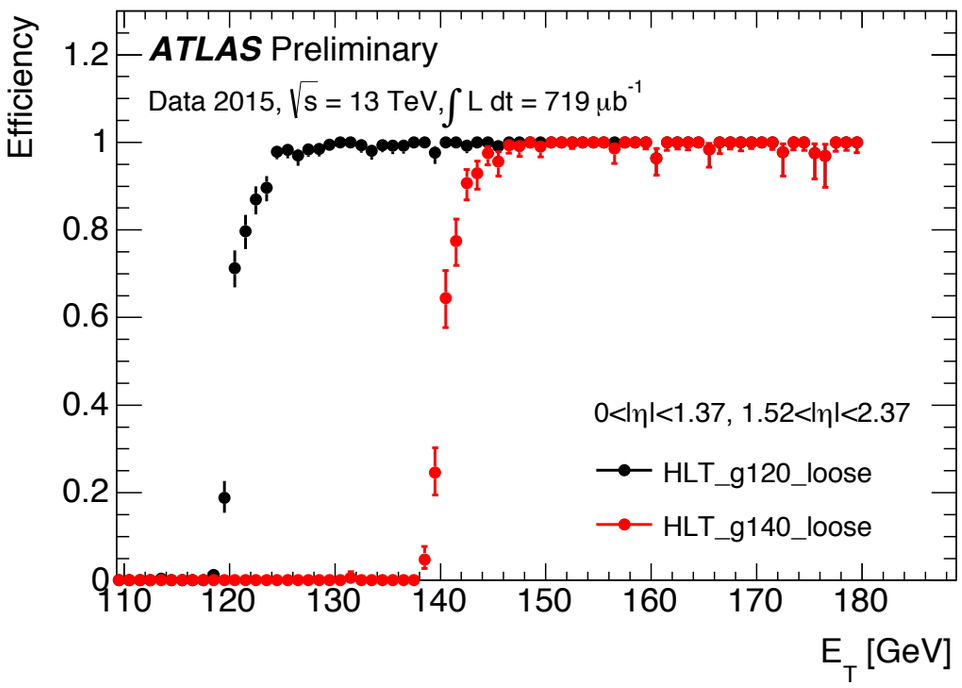
First results with 13 TeV (with 50 ns bunch spacing)

Photons

Single photon *turn*-on and *Pseudo-Rapidity coverage*







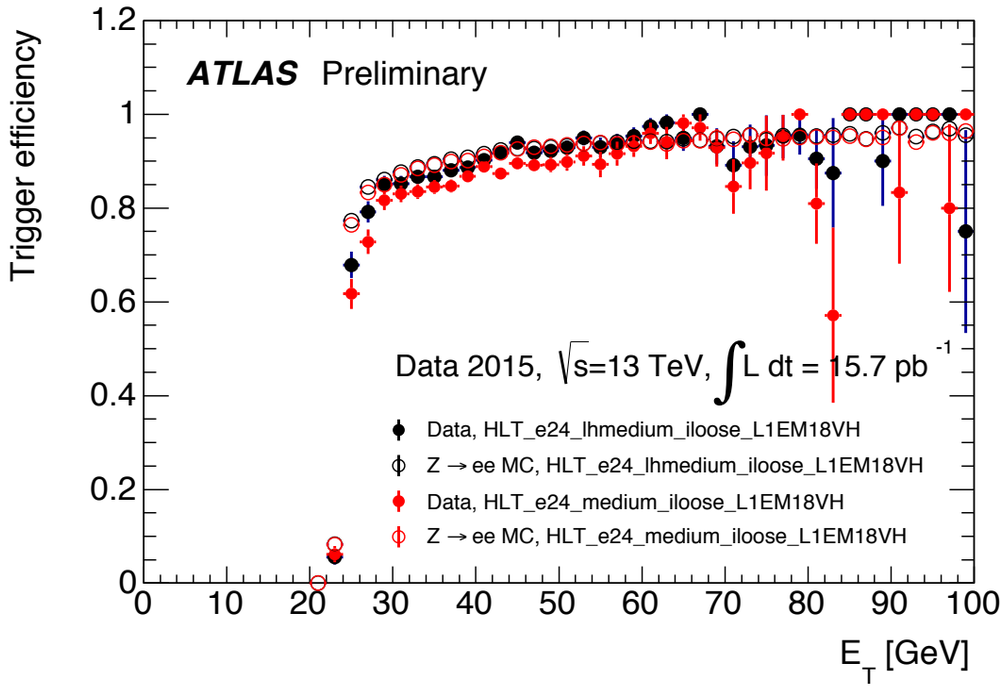
Perform as expected; back-bone triggers of Higgs to diphoton and mono-gamma analyses.

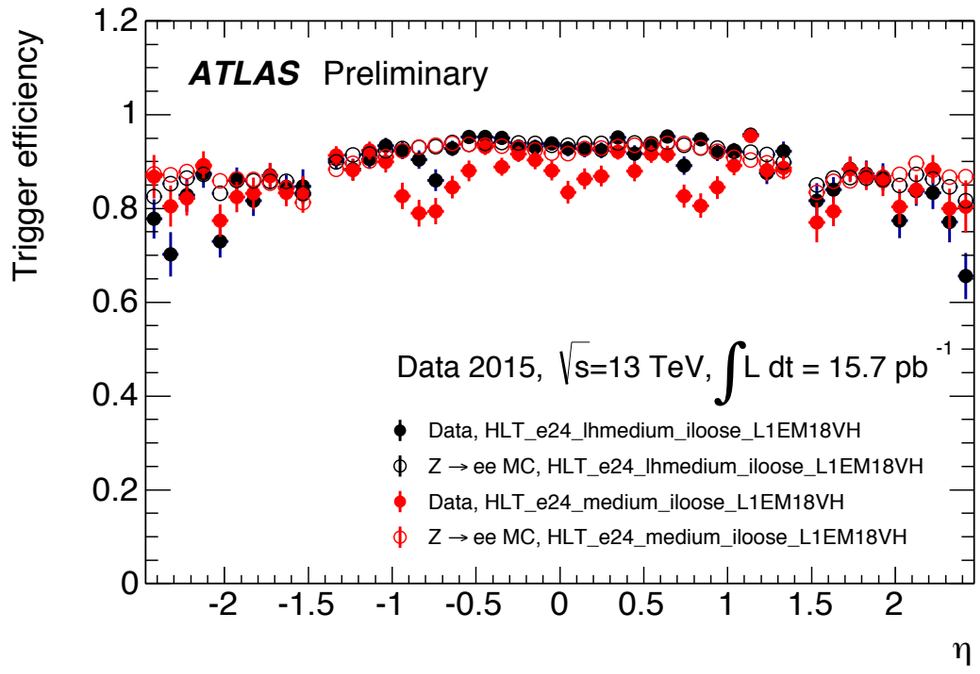
More plots see Carlos Chavez Barajas talk from Wednesday

First results with 13 TeV (with 50 ns bunch spacing)

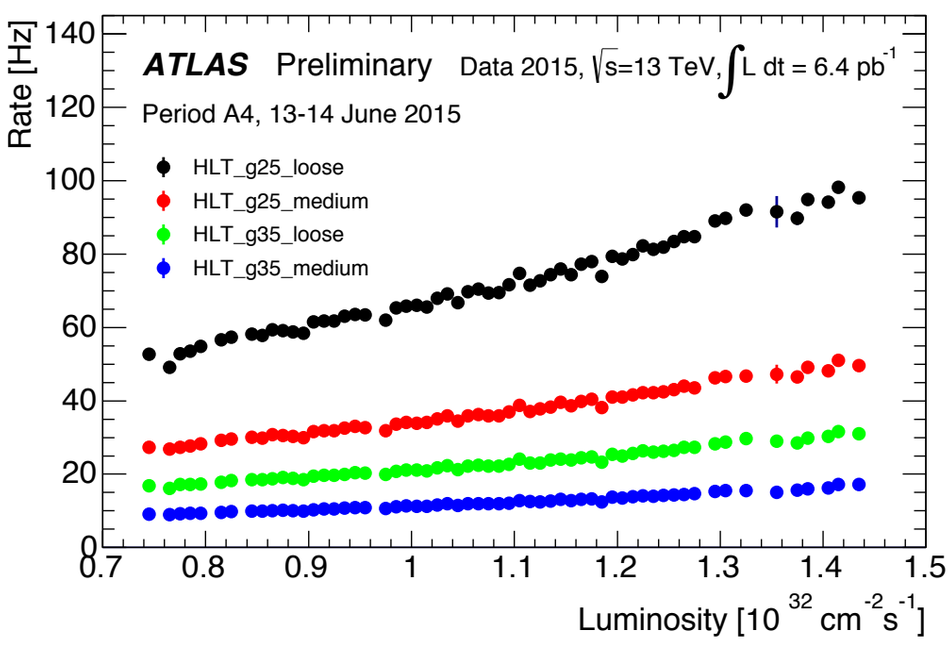
Electrons & Rates

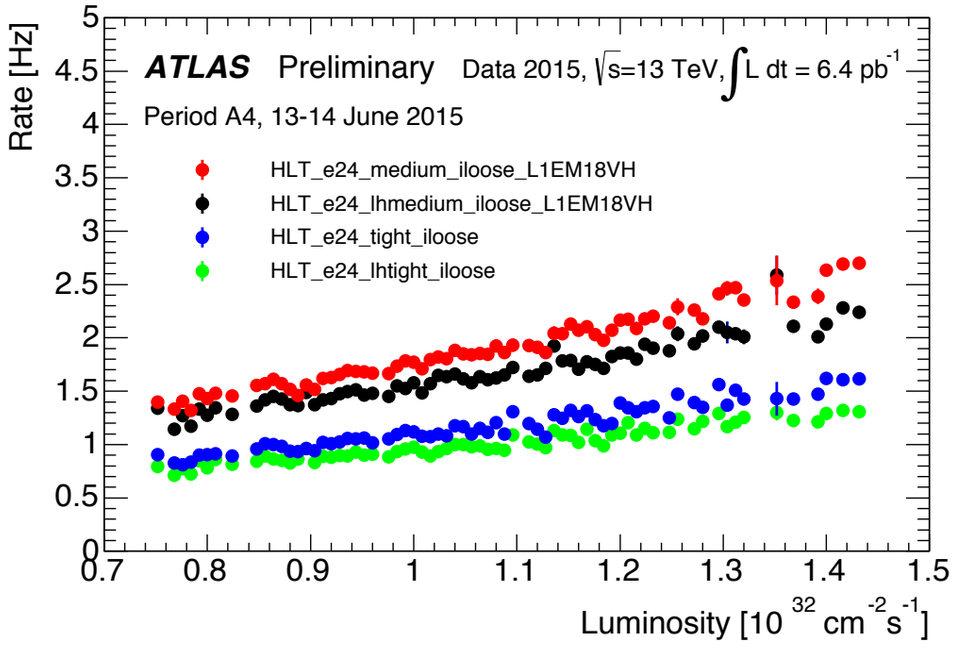
Single electron *turn*-on and *Pseudo-Rapidity coverage*





Trigger rates for Photon and Electron triggers:

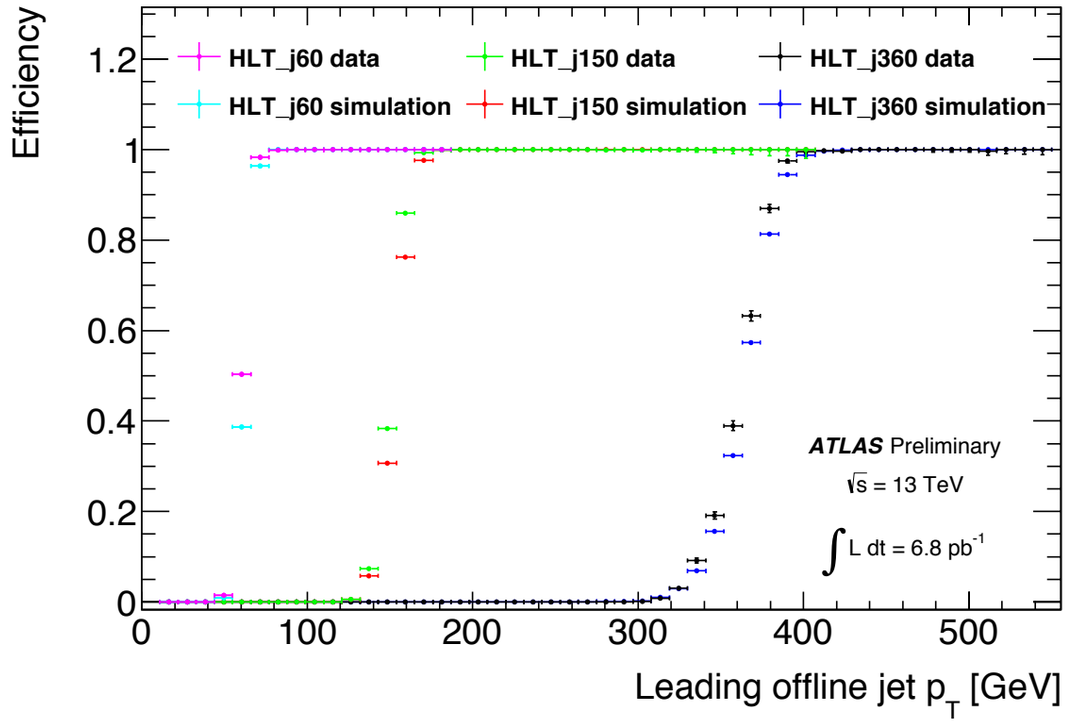


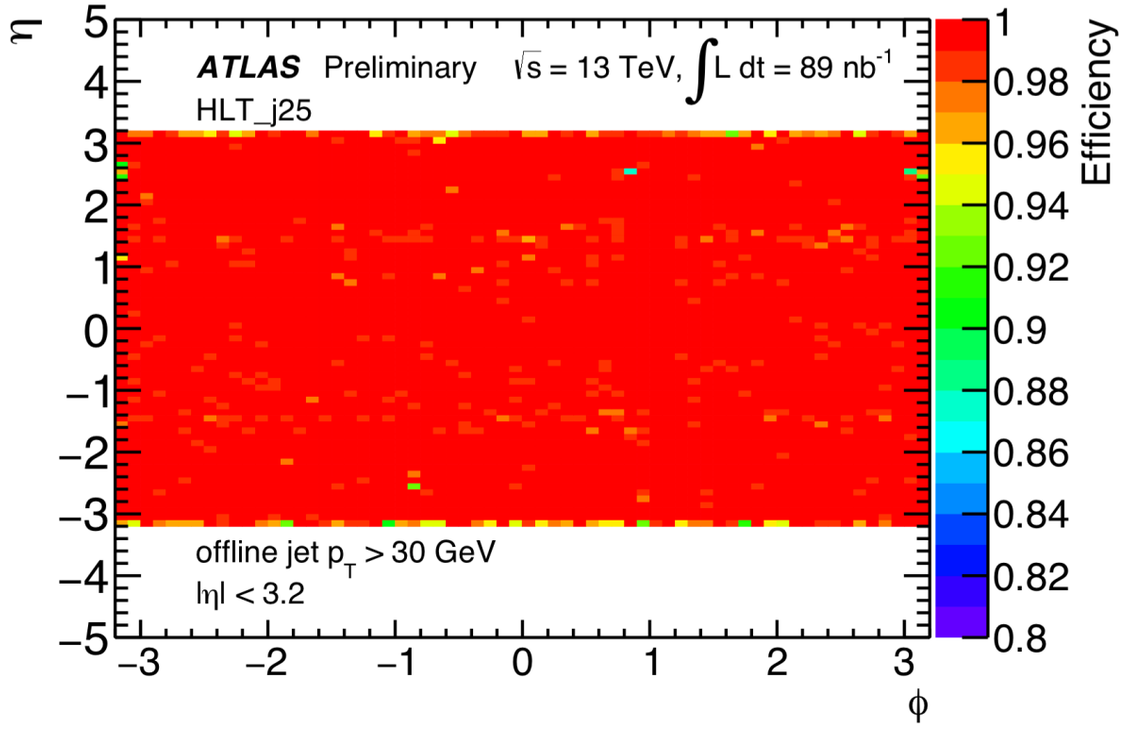


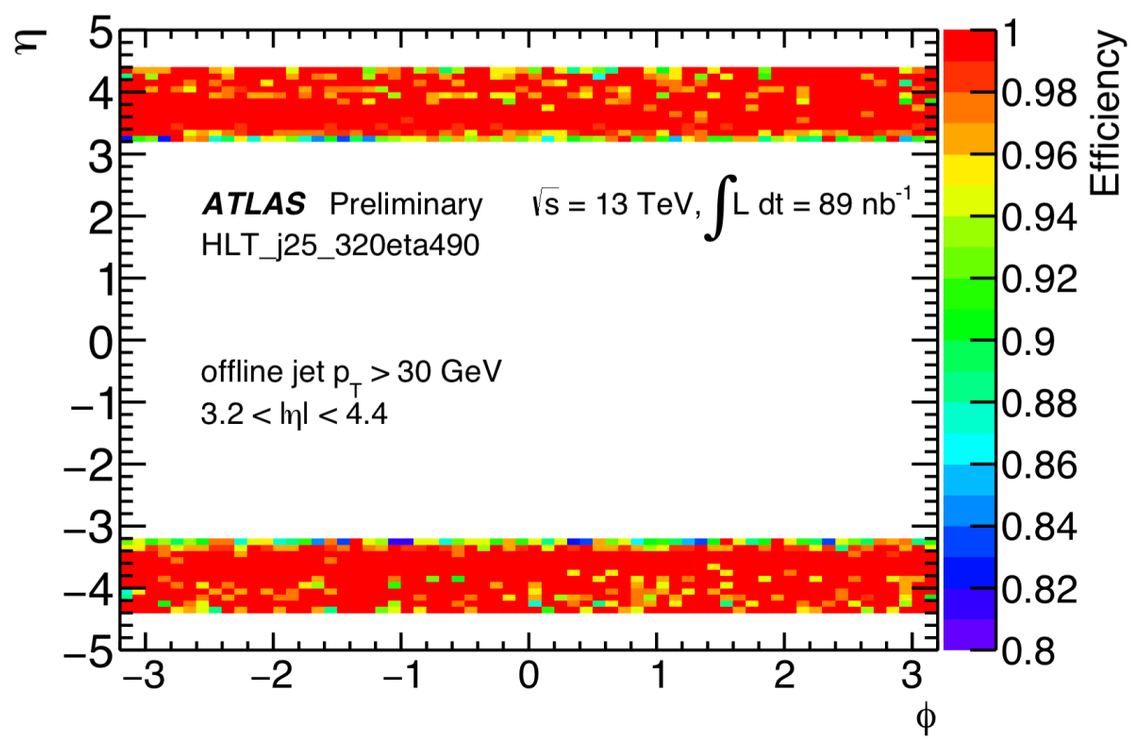
First results with 13 TeV (with 50 ns bunch spacing)

Jets

Jet Trigger *turn-on curves* and *efficiency maps*





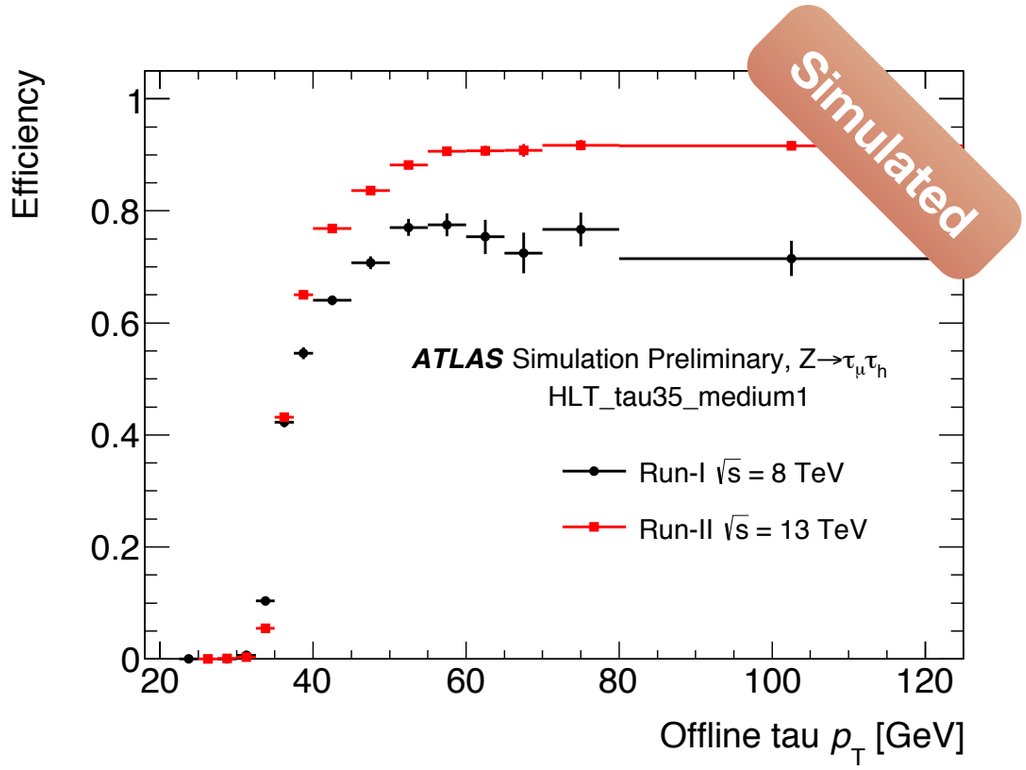


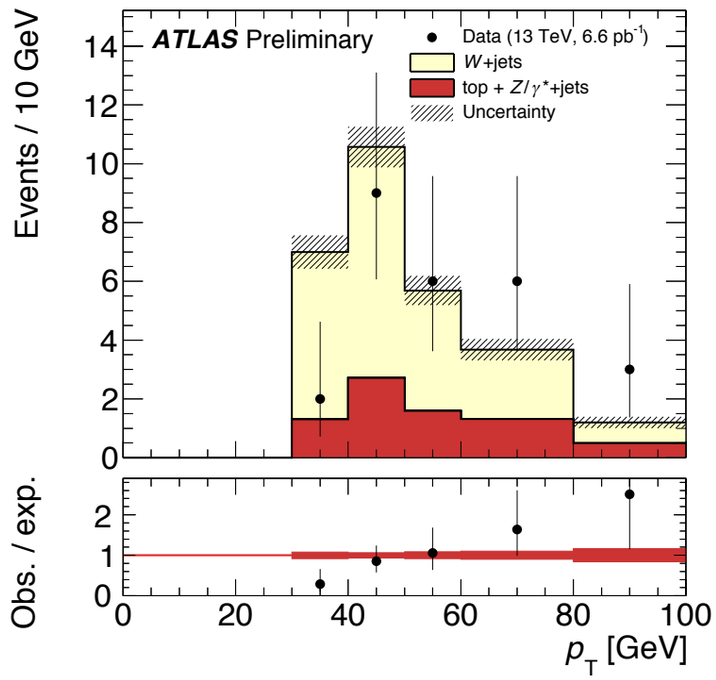
Excellent performance due to porting much offline code to the High-level trigger system. Now apply jet-area-dependent ambient energy correction.

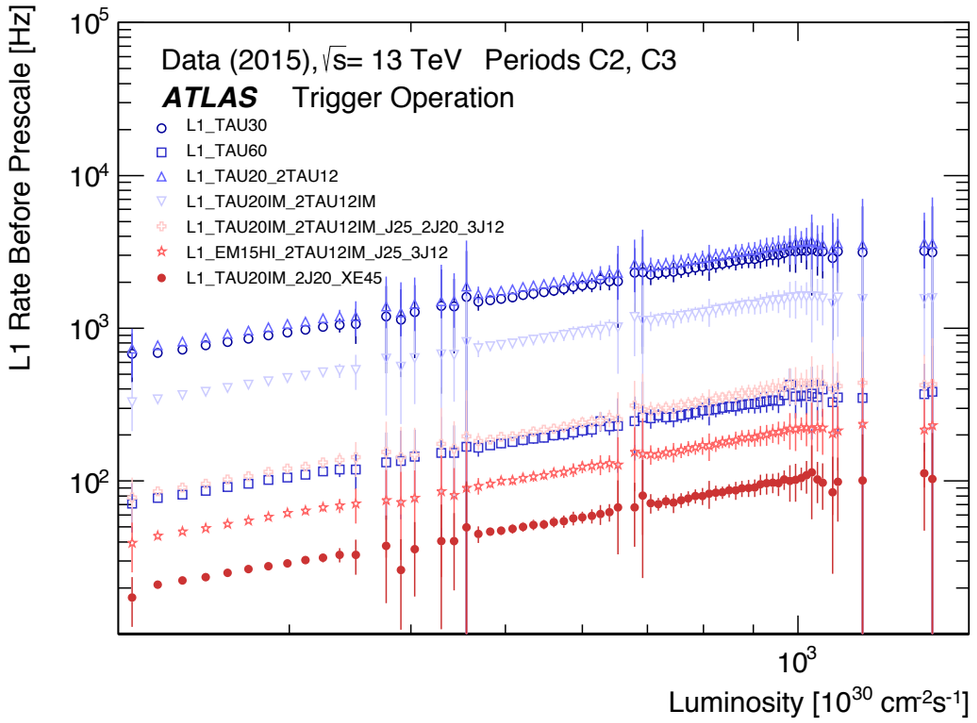
First results with 13 TeV (with 50 ns bunch spacing)

Tau

Simulated turn-on and first results on rates and first selected taus.







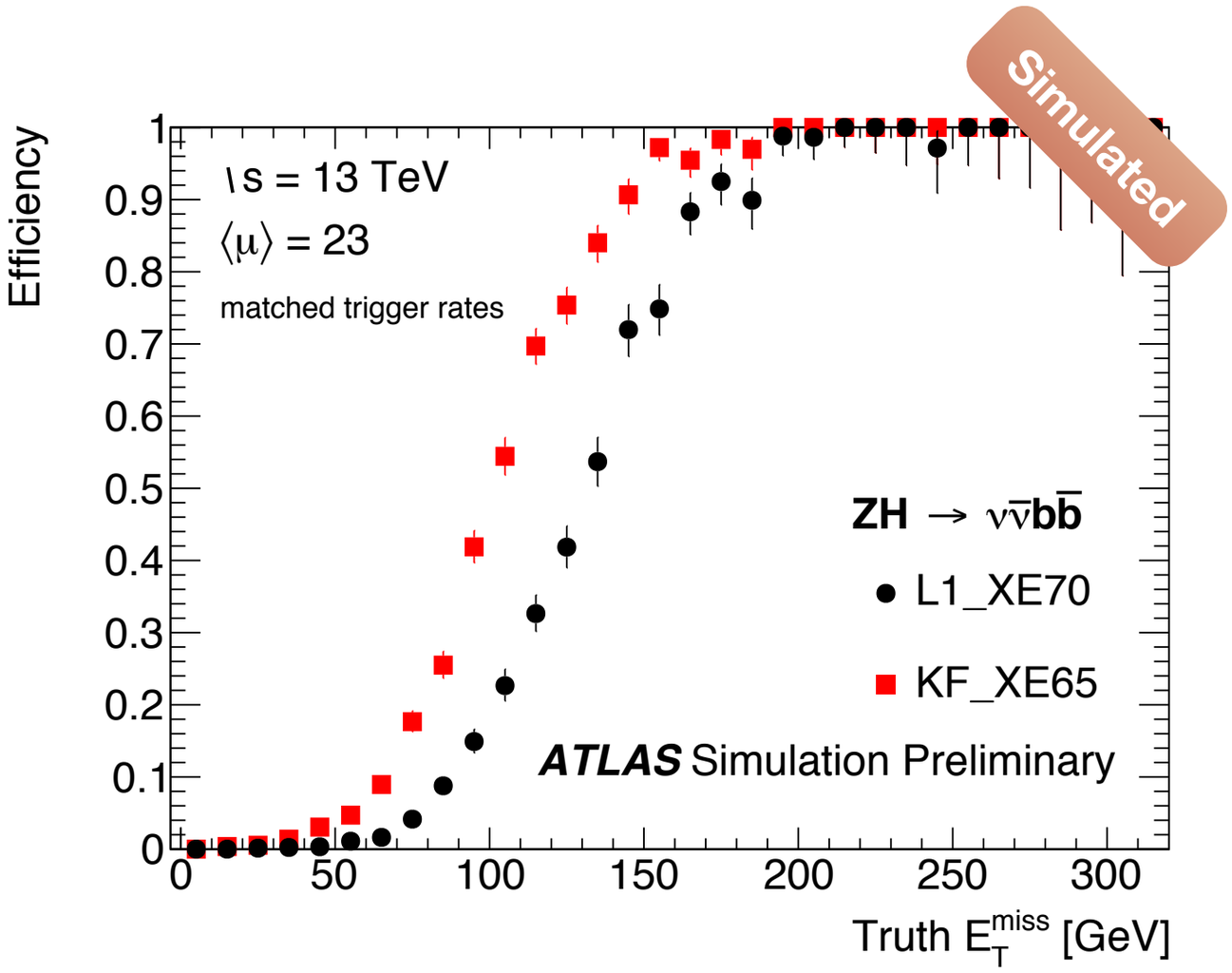
Expect big improvement on tau efficiencies thanks to more precise calibration, faster tracking and porting over the offline identification requirements to the high level trigger.

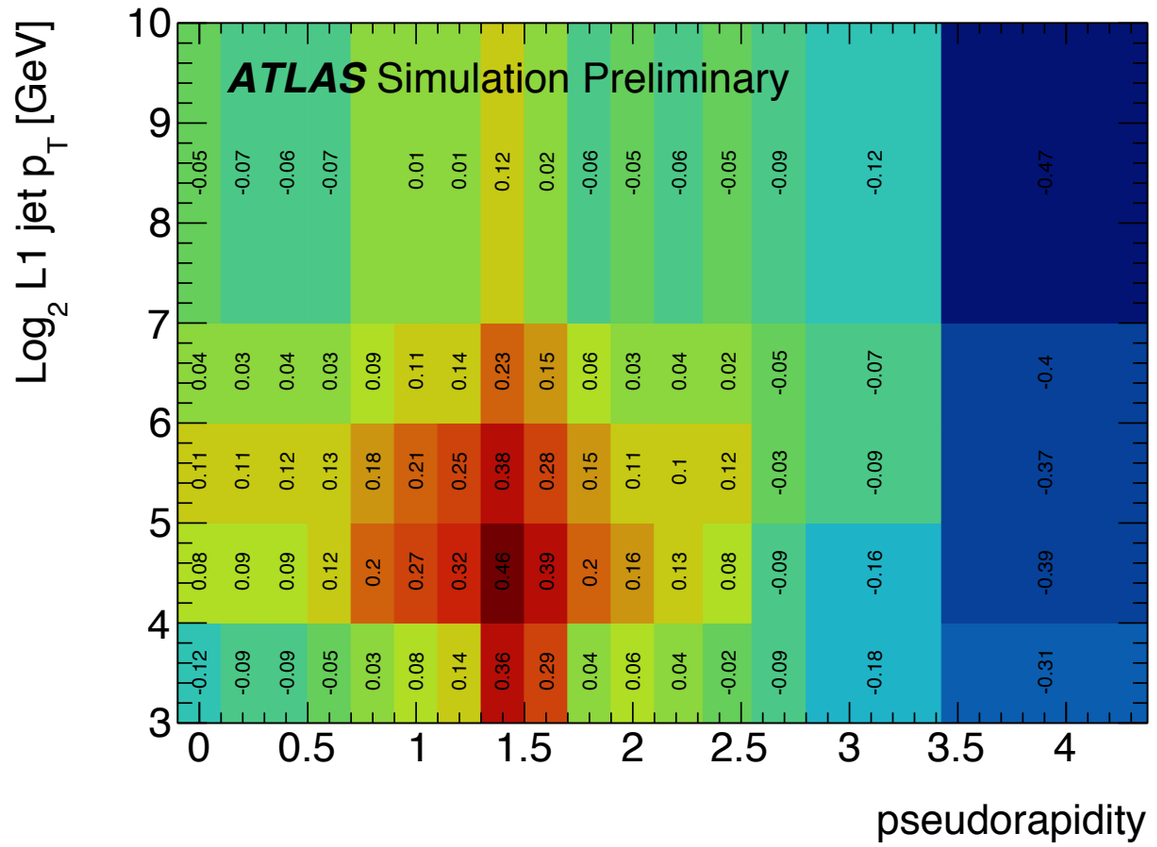
Simulated Performance with 13 TeV

MET

New L1 topological trigger that applies pile-up subtraction and calibration

$$\vec{E}_T^{\,\mathrm{KF}} = \vec{E}_T^{\,\mathrm{L1}} + \sum_i w_i \times \vec{E}_T^{\,\mathrm{jet}\,i}$$





Summary of most important changes for all trigger signatures at a glance

Signature	Changes
Electrons	Improved tracking and isolation.
Photons	Better fake separation at the high level trigger, will allow to keep thresholds low for physics.
Muons	New additional trigger chambers boost acceptance, better coincidence logic reduce fakes
Taus	Improved calibration, faster tracking and selection closer to offline definition
Missing Transverse Energy	L1 calibration with topological processor; pile-up subtraction algorithms
Jets	Offline and Online definition of jets in synch, jet area subtraction

Is the ***ATLAS*** trigger system ready for Run 2?

Yes!

Thanks to the *relentless effort of hundreds of experts* during the shutdown the ***ATLAS*** trigger system was made ready to face the challenges Run II will bring.

All set goals in terms of

- Rate reduction
- Efficiency
- Coverage
- Stability

were reached and we are looking forward for a smooth data taking!