Performance of the Missing transverse energy triggers for the ATLAS detector.

ASP2024 students online presentation

Directed by: Imane Zahir

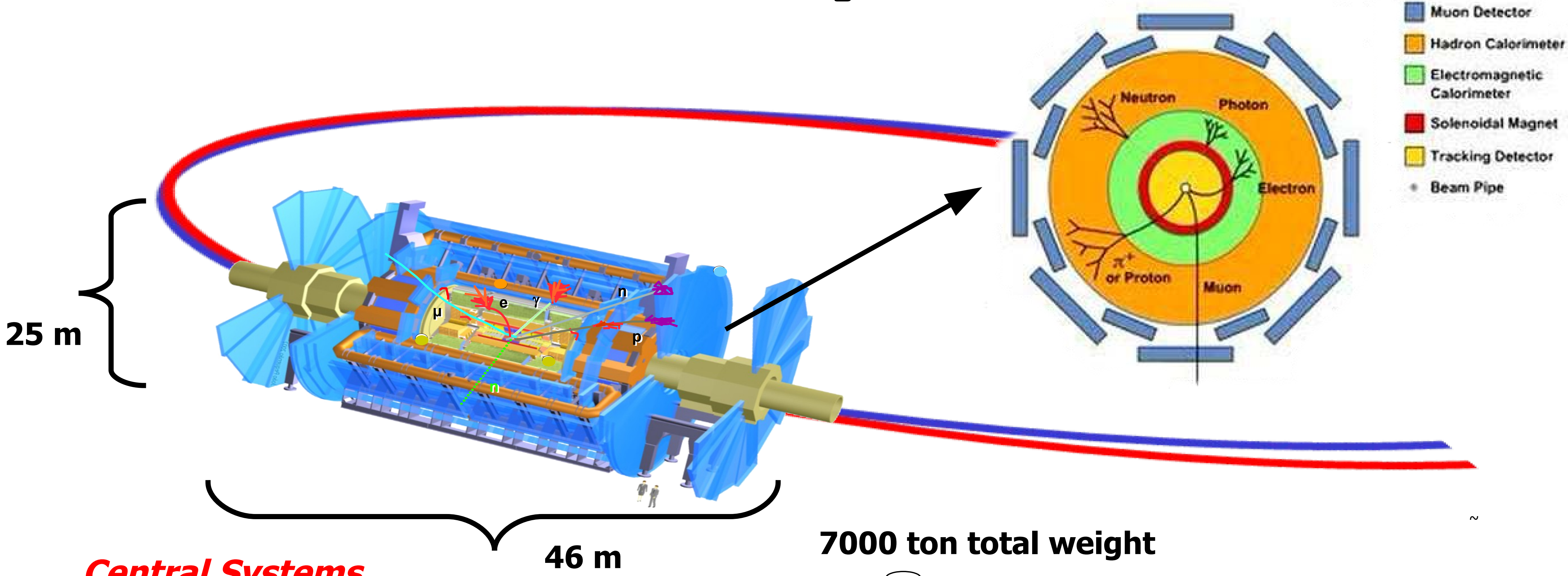
Supervised by: Pr. Driss BENCHEKROUN

Outline :

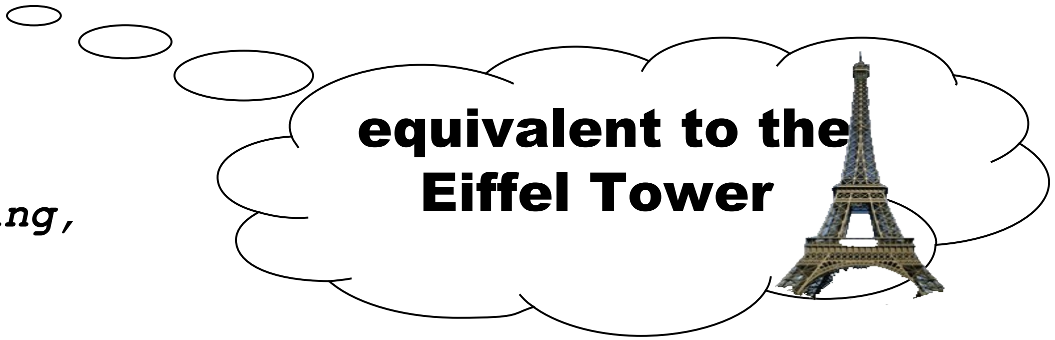
- ➔ ***The ATLAS experiment.***
- ➔ ***ATLAS Trigger system.***
- ➔ ***Overview of MET Trigger in ATLAS.***
- ➔ ***2023 Data Taking***
- ➔ Phase-1 jFEX Performance.
- ➔ Conclusion.

The ATLAS experiment at the LHC

The ATLAS experiment



7000 ton total weight



Central Systems

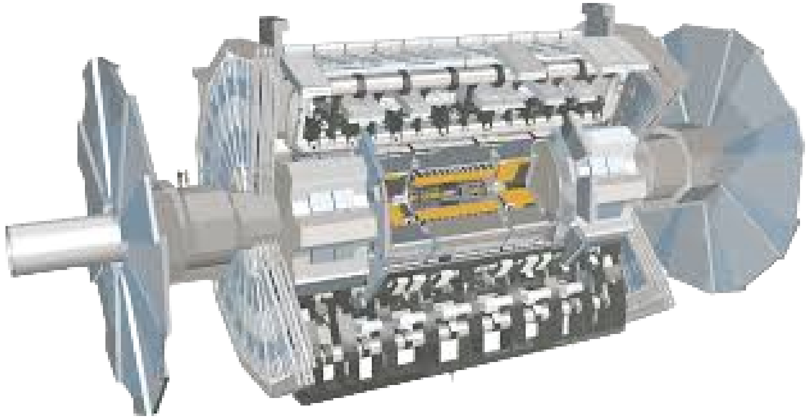
- Detector Control System (DCS)
- Detector Safety System (DSS)
- Trigger and Data Acquisition (TDAQ)

Services

– Power, gas, cooling, cryogenics , …

Magnets

ATLAS trigger system



40 MHz

Level-1 Trigger (L1)

A hardware-based trigger that quickly analyzes data from the calorimeters and muon detectors.

100 kHz

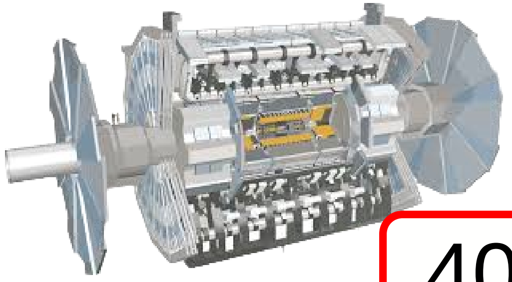
High Level Trigger (HLT)

A software-based system that performs more detailed event reconstruction using data from the full detector.

100 kHz

2-Level Trigger System

ATLAS trigger menu



40 MHz

100 kHz

100 kHz

Trigger Menu:

To select events useful for

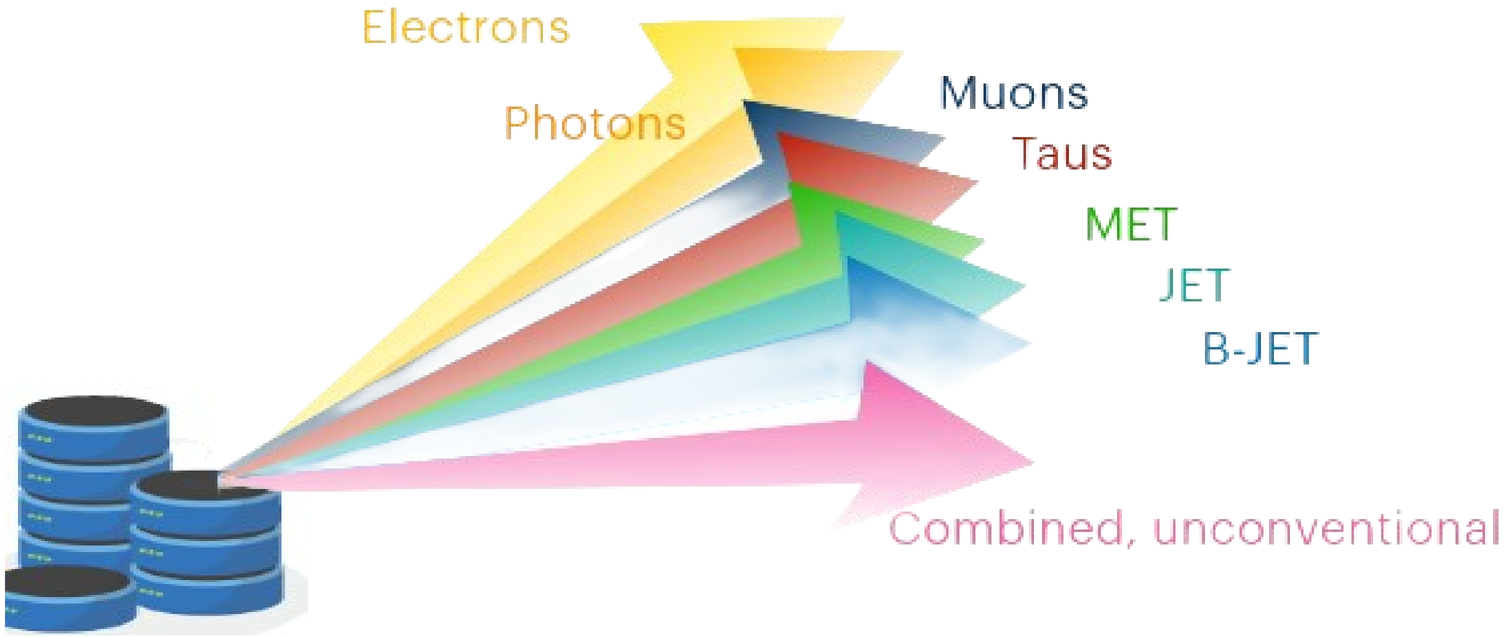
Searches for new physics

Standard Model measurements

Offline calibrations

Trigger scale factors

Trigger performance studies



Overview of MET Trigger in ATLAS

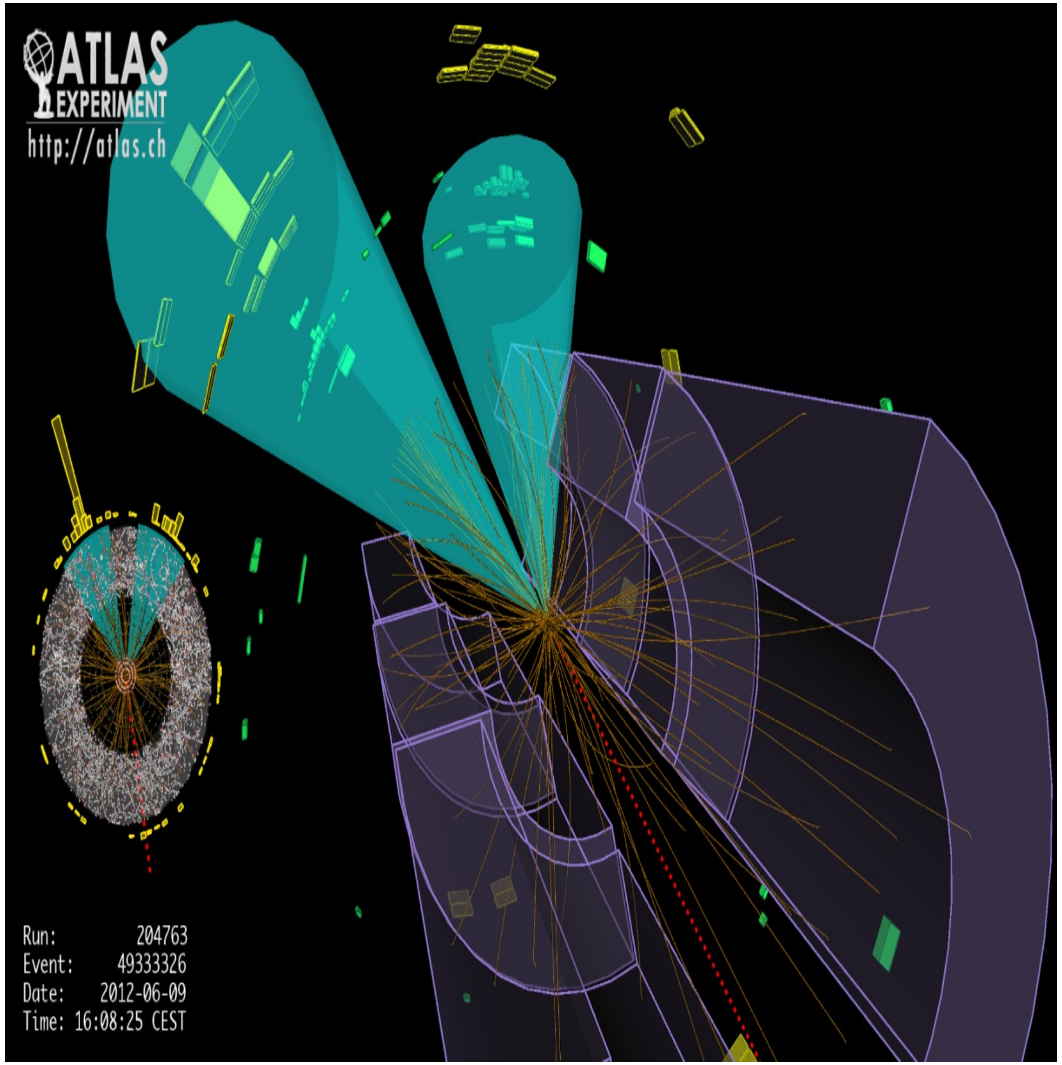
- Missing transverse energy (E_T^{miss}, MET) is an important aspect for many physics analyses requiring a significant amount of MET in their selection

$$\vec{E}_T^{miss} = -\sum \vec{p}_T^{detected}$$

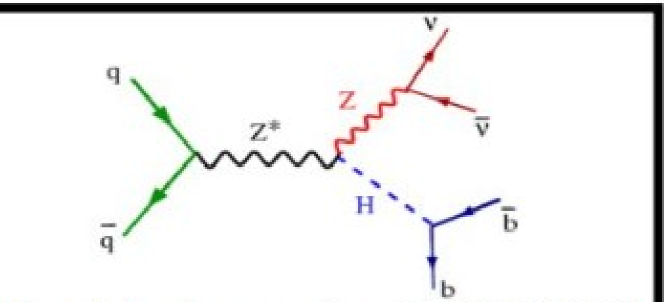
- A dedicated MET trigger is required to quickly and accurately identify such events by requiring transverse momentum conservation.

- Calculating MET requires the cooperation of different subsystems ⟶ tracking, calorimetry, particle-flow objects (PFO).

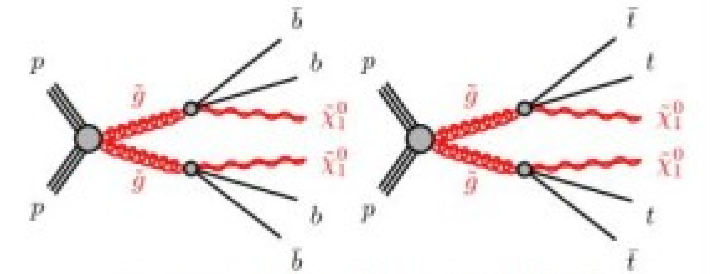
- Calculating MET for trigger is different than other trigger processes where the goal is to maintain high



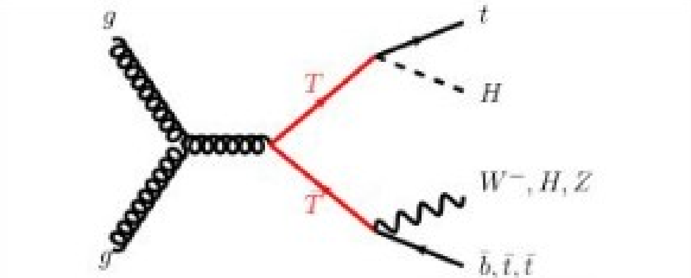
Why a Trigger for E_T^{miss} ?



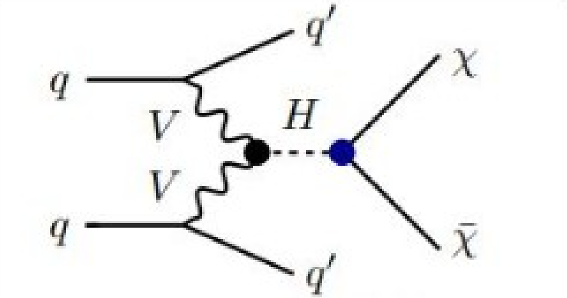
H → bb observation [1708.03299]



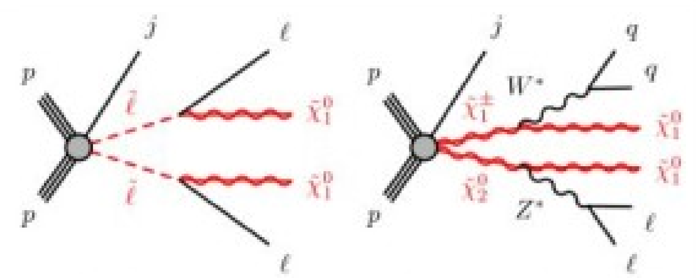
Strong SUSY [1711.01901]



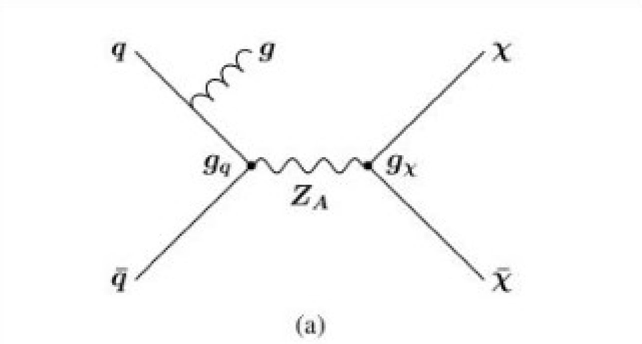
Vector-like quarks [1803.09678]



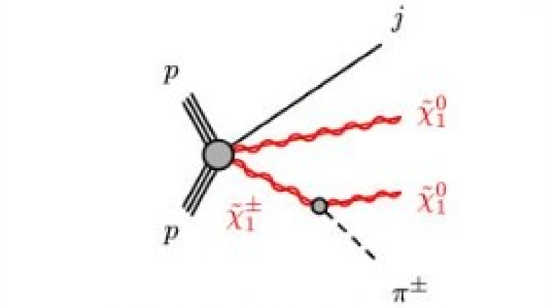
H→invisible [1809.06682]



Electroweak SUSY [1712.08119]



Dark matter [1711.03301]

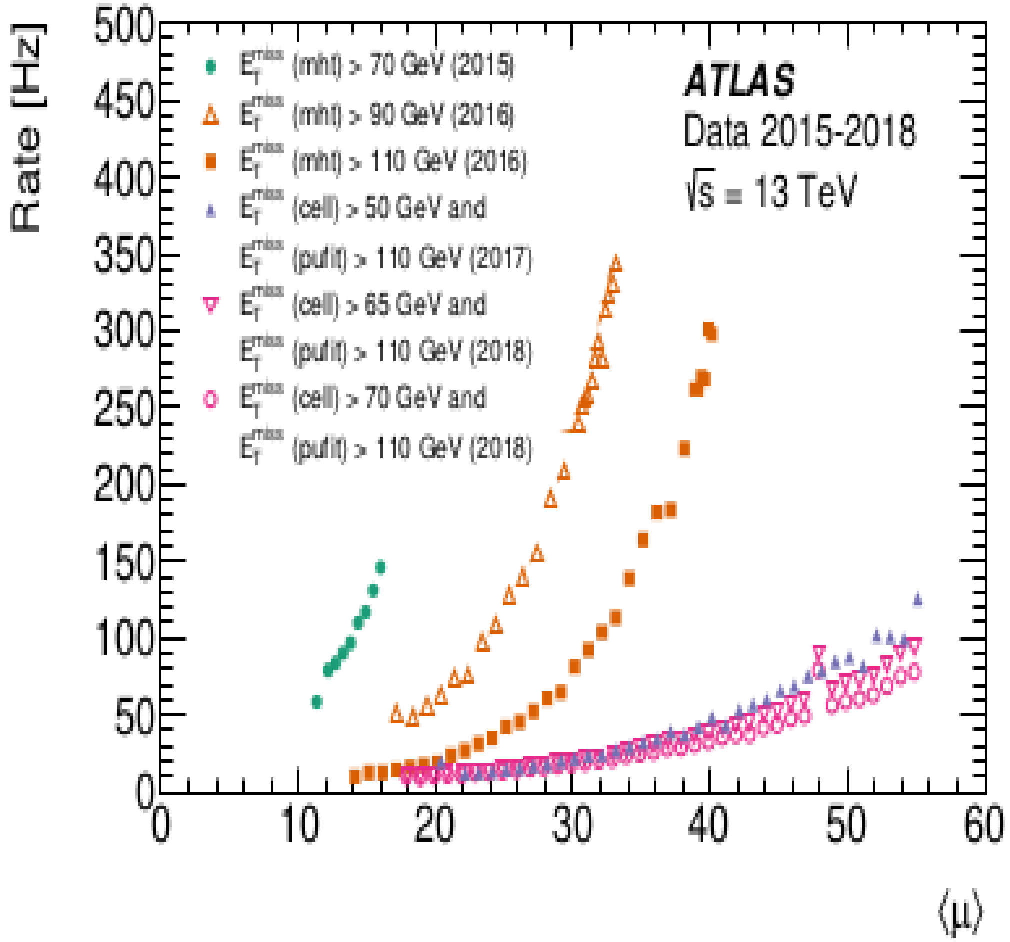


LLPs [1506.05332]

Challenges of Pileup

What makes it complicated?

- MET Trigger rates are particularly sensitive to increasing ***pile-up***
  - E_T^{miss} increases ~exponentially with $\langle\mu\rangle$
    → pile-up is public enemy no. 1!
- Requiring sophisticated techniques to reduce contributions from pile-up.
- Maintaining a reasonable data-taking rate.
- We have new methods to deal with the challenges of increasing pile-up:
  - Increased thresholds to manage pile-up.
  - Coupled this with algorithms (PUFit) to reduce pile-up effects.



[Run-2 MET Trigger Performance]

MET Trigger Algorithms

Run-2: algorithms uses calorimeter inputs only

- cell: MET computed by adding cells above a certain noise threshold.
- tcpufit: pufit algorithm applied to topoclusters to remove pile-up contribution.

Run-3: algorithms now include tracking info

- pfopufit, mhtpufit: pufit algorithms applied to jets and PFOs respectively.
- trkmht: sum over all jets passing JVT, soft term from tracks also included.

Run-3 + beyond: MET through machine learning efforts

- neural-network (nn): machine-learning based approach through the combination of multiple MET algorithms.
- ongoing: multiple projects looking into implementing machine learning into improving MET trigger.

```
chains['MET'] += [
    ChainProp(name='HLT_xe65_cell_xe90_pfopufit_L1XE50', l1SeedThresholds=['FSNOSEED']*2, stream=
    [PhysicsStream,'express'], groups=PrimaryLegGroup+METGroup, monGroups=['metMon:shifter','caloMon:t0']),
    # ATR-25512
    ChainProp(name='HLT_xe65_cell_xe100_pfopufit_L1XE50', l1SeedThresholds=['FSNOSEED']*2,
    groups=PrimaryLegGroup+METGroup, monGroups=['metMon:t0']),
    ChainProp(name='HLT_xe75_cell_xe100_pfopufit_L1XE50', l1SeedThresholds=['FSNOSEED']*2,
    groups=PrimaryLegGroup+METGroup, monGroups=['metMon:t0']),

    # ATR-27220 / ATR-26920
    ChainProp(name='HLT_xe65_cell_xe90_nn_L1XE50', l1SeedThresholds=['FSNOSEED']*2, groups=SupportLegGroup
    +METGroup+['RATE:CPS_XE50'], monGroups=['metMon:shifter']),
    ChainProp(name='HLT_xe65_cell_xe105_nn_L1XE50', l1SeedThresholds=['FSNOSEED']*2, stream=[PhysicsStream,
    'express'], groups=SupportLegGroup+METGroup+['RATE:CPS_XE50'], monGroups=['metMon:shifter']),

    ChainProp(name='HLT_xe75_cell_xe65_tcpufit_xe90_trkmht_L1XE50', l1SeedThresholds=['FSNOSEED']*3,
    groups=SupportLegGroup+METGroup+['RATE:CPS_XE50'], monGroups=['metMon:shifter']),
    ChainProp(name='HLT_xe60_cell_xe95_pfsum_cssk_L1XE50', l1SeedThresholds=['FSNOSEED']*2,
    groups=SupportLegGroup+METGroup+['RATE:CPS_XE50'], monGroups=['metMon:shifter']),
    ChainProp(name='HLT_xe55_cell_xe70_tcpufit_xe90_pfsum_vssk_L1XE50', l1SeedThresholds=['FSNOSEED']*3,
    groups=SupportLegGroup+METGroup+['RATE:CPS_XE50'], monGroups=['metMon:shifter']),
    ChainProp(name='HLT_xe65_cell_xe105_mhtpufit_em_L1XE50', l1SeedThresholds=['FSNOSEED']*2,
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    ChainProp(name='HLT_xe65_cell_xe100_mhtpufit_pf_L1XE50', l1SeedThresholds=['FSNOSEED']*2,
    groups=SupportLegGroup+METGroup+['RATE:CPS_XE50'], monGroups=['metMon:shifter']),
    ChainProp(name='HLT_xe55_cell_xe70_tcpufit_xe95_pfsum_cssk_L1XE50', l1SeedThresholds=['FSNOSEED']*3,
    groups=SupportLegGroup+METGroup+['RATE:CPS_XE50'], monGroups=['metMon:shifter']),
    ChainProp(name='HLT_xe65_cell_xe95_pfsum_vssk_L1XE50', l1SeedThresholds=['FSNOSEED']*2,
    groups=SupportLegGroup+METGroup+['RATE:CPS_XE50'], monGroups=['metMon:shifter']),
```

Cf Charlie Chen talk at ATLAS weekly

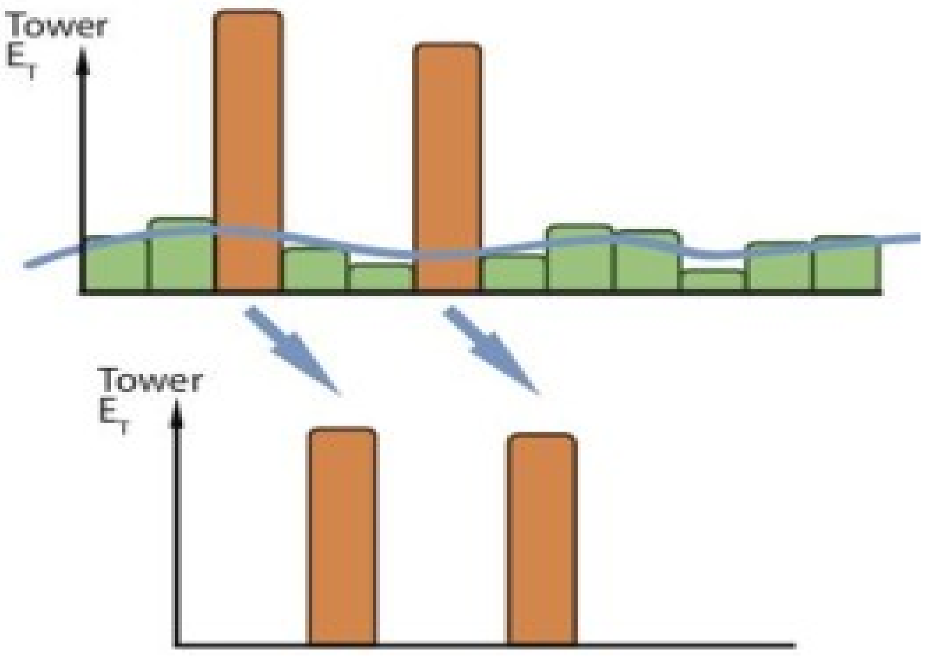
Pufit Optimization

- PUfit is an effective algorithm to reduce pile-up contributions to MET by performing a fit over calorimeter topoclusters.
- **Basic procedure:**

  1. Divide event into pieces.
  2. Mark as either pileup (PU) or hard scatter (HS).
  3. Derive corrections to the HS pieces based on the assumptions:

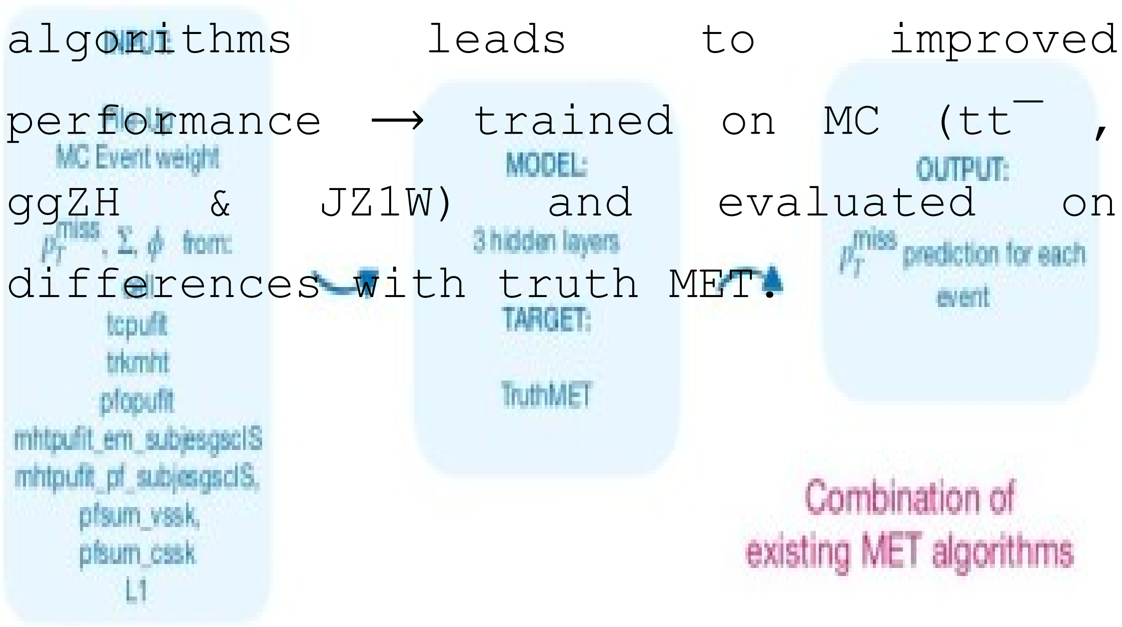
     i. Total MET from pileup should be 0

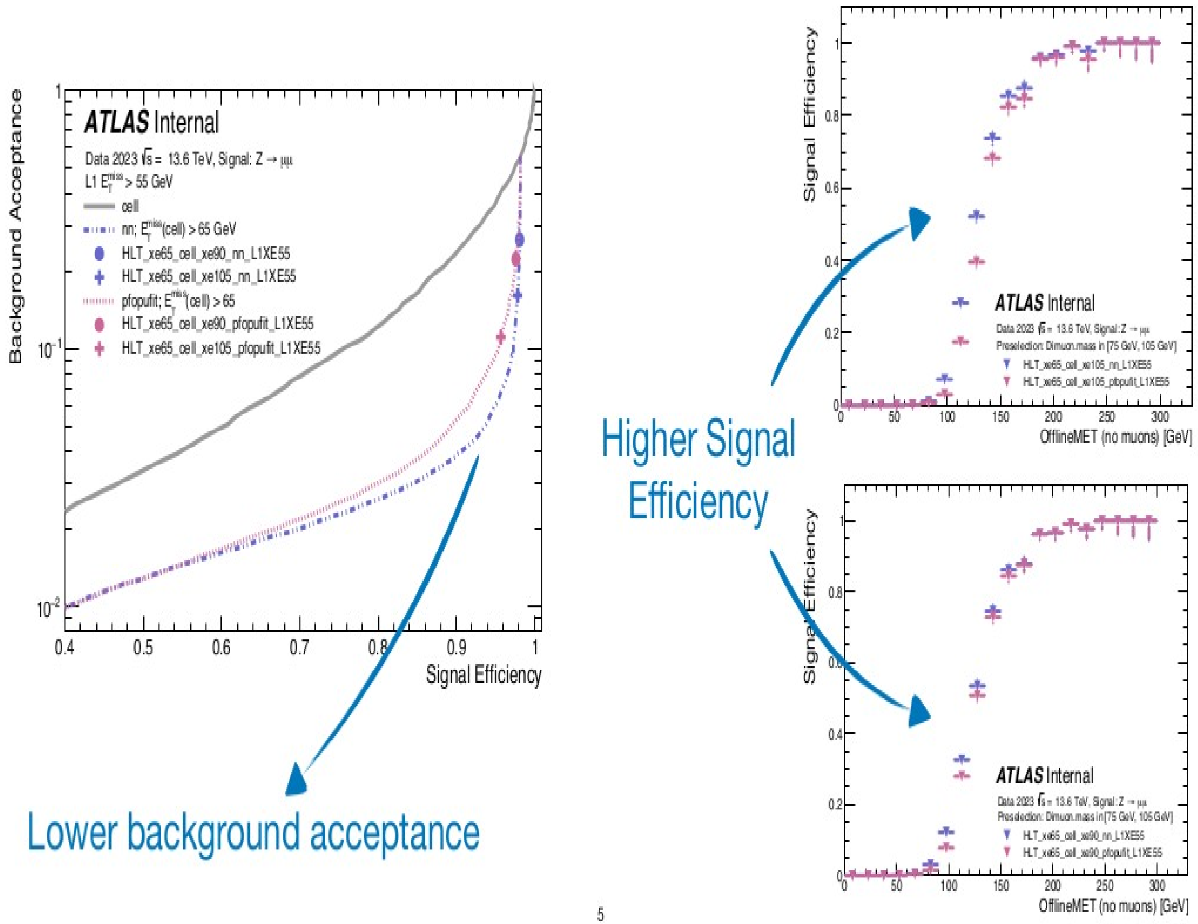
     ii. Pileup should be evenly distributed



Neural Network MET

- NN triggers are currently deployed at P1, and are recommended by the team as the primary trigger for analyses for 2024.
- The combination of multiple MET algorithms leads to improved performance → trained on MC ($t\bar{t}$, ggZH & JZ1W) and evaluated on differences with truth MET.





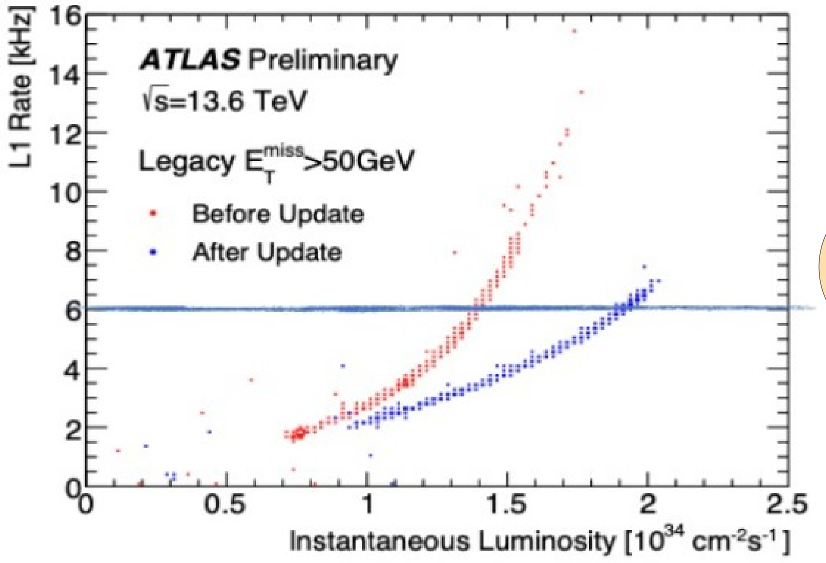
[nnMET]()

2023 Data Taking

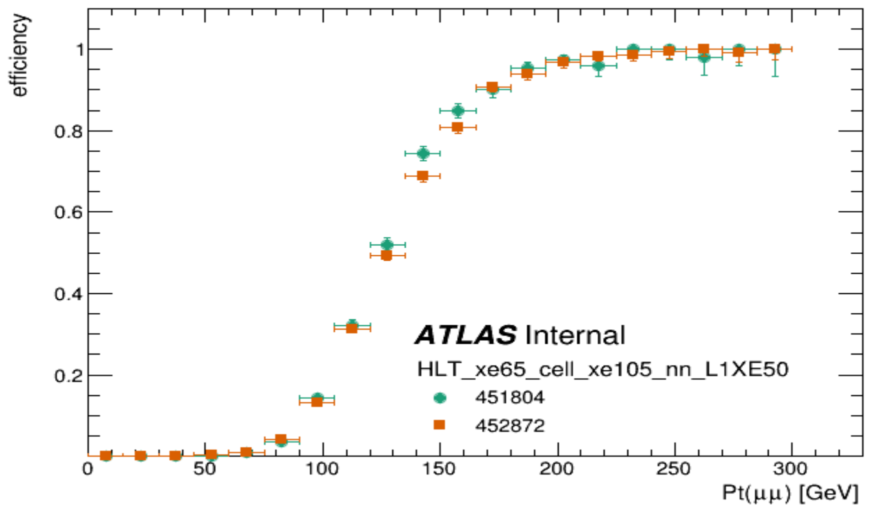
- *Trigger rates sensitive to pile-up increase.*
- *XE50 rate doubled in 2023 fills, reaching more than 10 kHz by 2400 b.*
- *A significant rate reduction is necessary to define operational requirements.*

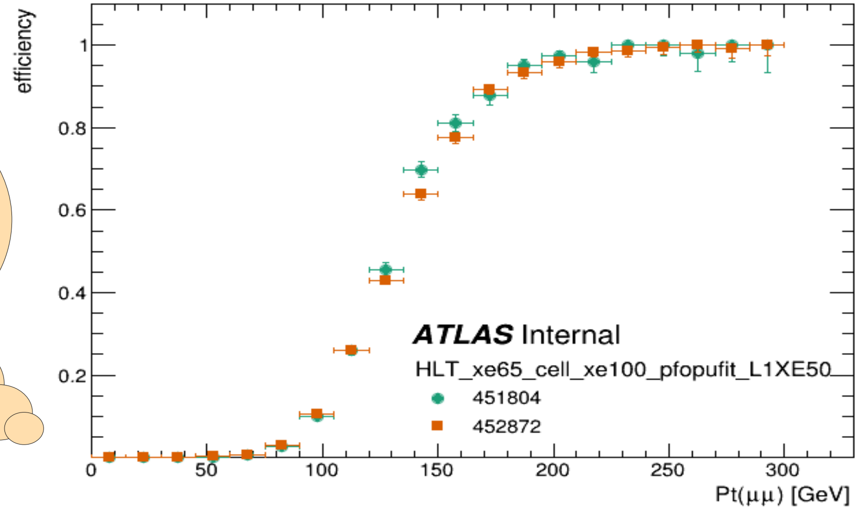
There are severale strategies to decrease the rate :

  - *Increase the L1 threshold from L1XE50 to L1XE55.*
  - *Tune the L1 calo noise cut (Avoided L1XE50 → L1XE55).*



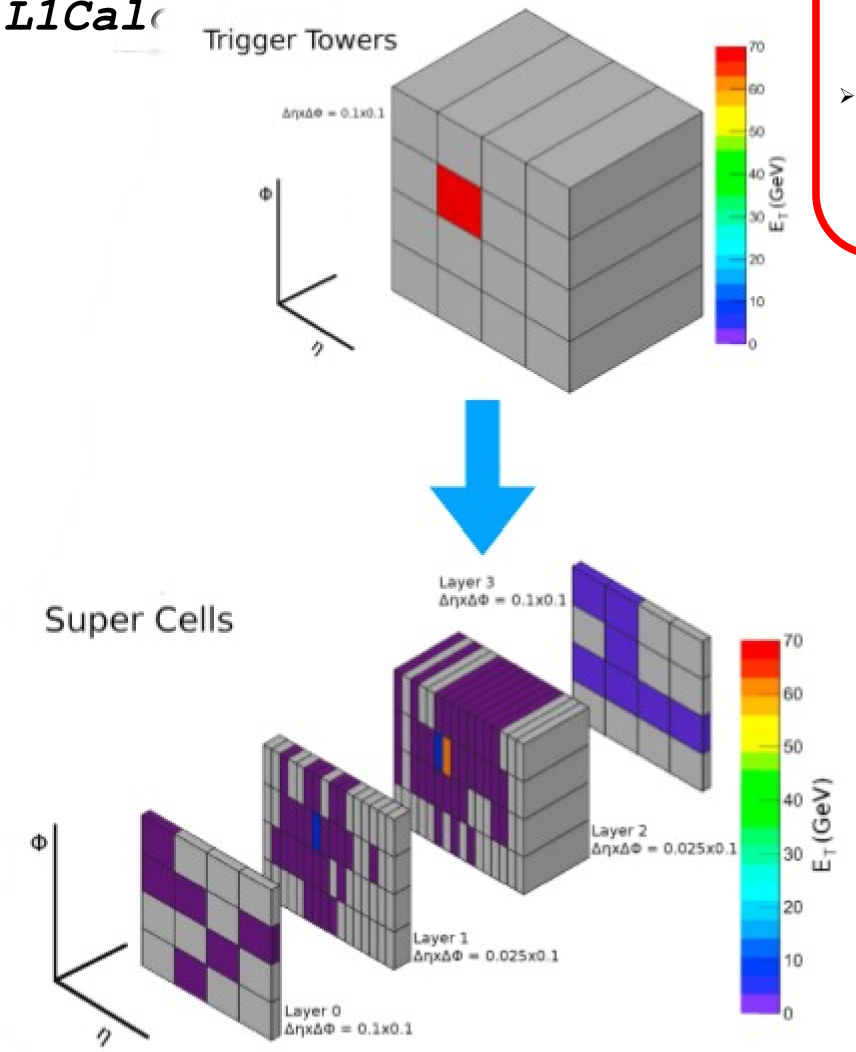
After noise bug fix, performance of these primary triggers were shown to return back to run-2 levels.



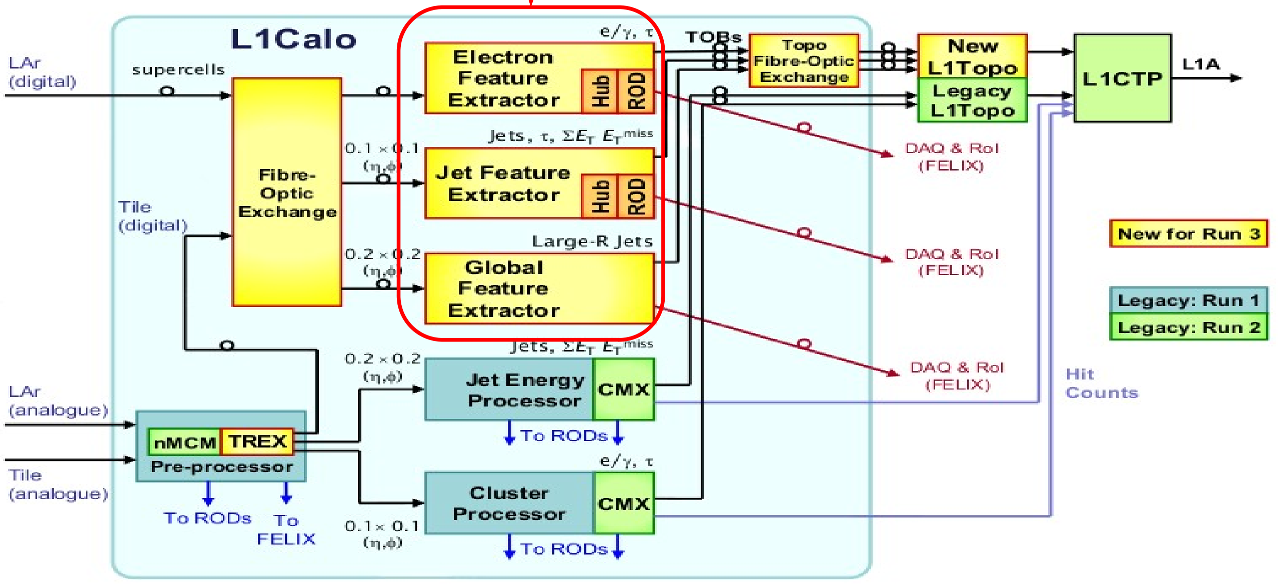


Phase-1 FEX Introduction

Increased granularity at L1Calo



- Phase-1 upgrade introduce new Feature Extractor hardware.
- Legacy L1Calo & Phase I upgrades run in parallel during commissioning at the beginning of Run 3.



Phase-I FEX Introduction

The Global Feature Extraction (gFEX) module runs global event algoritms such as « missing E_T ».

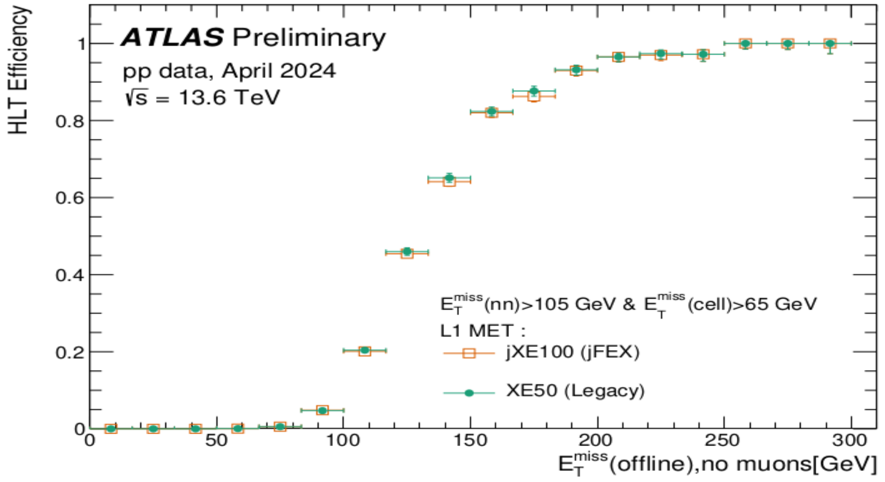
- Designed to provide large-radius jet triggers,MET,pile-up estimation,and other global observables for trigger.
- The Gfex is designed to enhace the selectivity of the L1 trigger and increase sensitivity to key physics channels.

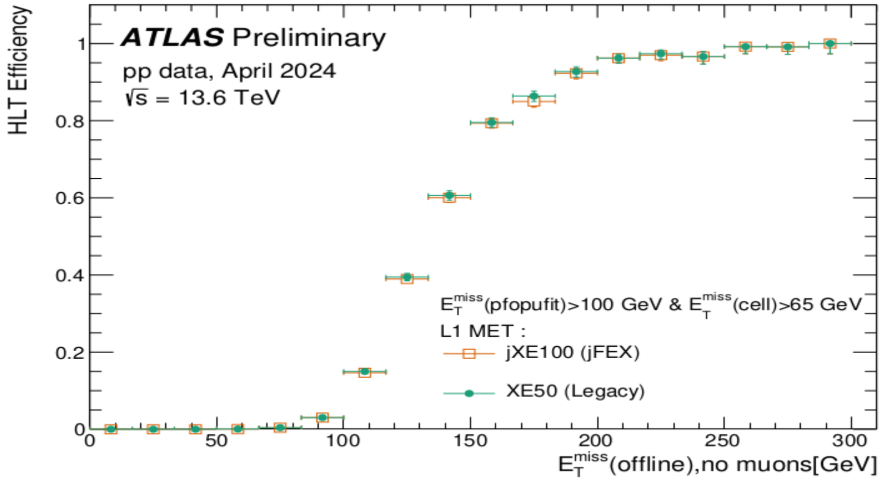
The jet Feature Extraction (jFEX) module calculates global variables like the total transeverse energy ΣE_T and the missing transverse energy E_T^{miss}.

- jFEX is designed to identify small-R jet , large tau ,forward electron , ΣE_T and E_t^{miss} TOBs based on inputs from Latome and TREX.

Phase-I jFEX Performance

- *Here HLT Efficiency curves for two primary trigger chains seeded by the Phase-I jet feature extractor (jFEX) compared with chains seeded by the L1Calo legacy system.*
- *Measured as a function of offline reconstructed E_T^{miss} with muons treated as invisible.*
- *Events taken from data with a Z →μμ selection .*
- *At < μ > ~ 60 :*
  - *For nn : Trigger rates for HLT MET chains seeded by jFEX L1 selection are approximately 20% lower than those seeded by the Legacy L1Calo selection.*
  - *For pfopufi : Trigger rates for HLT MET chains seeded by jFEX L1 selection are approximately 5% lower than those*

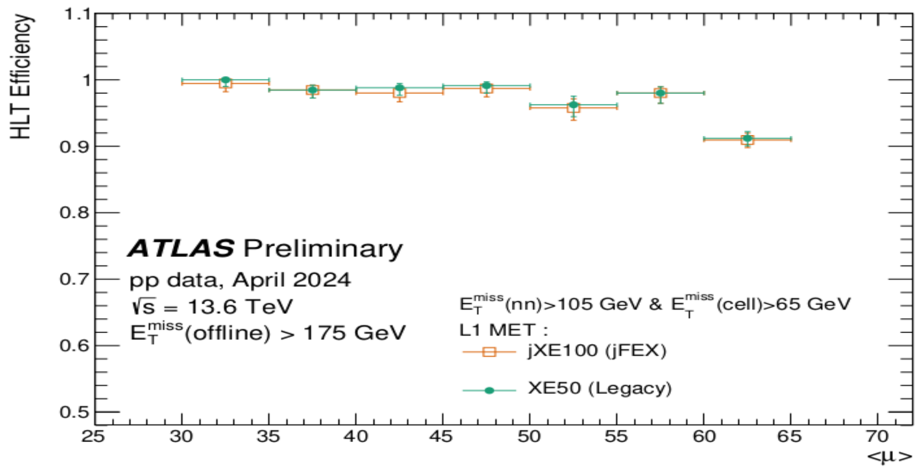


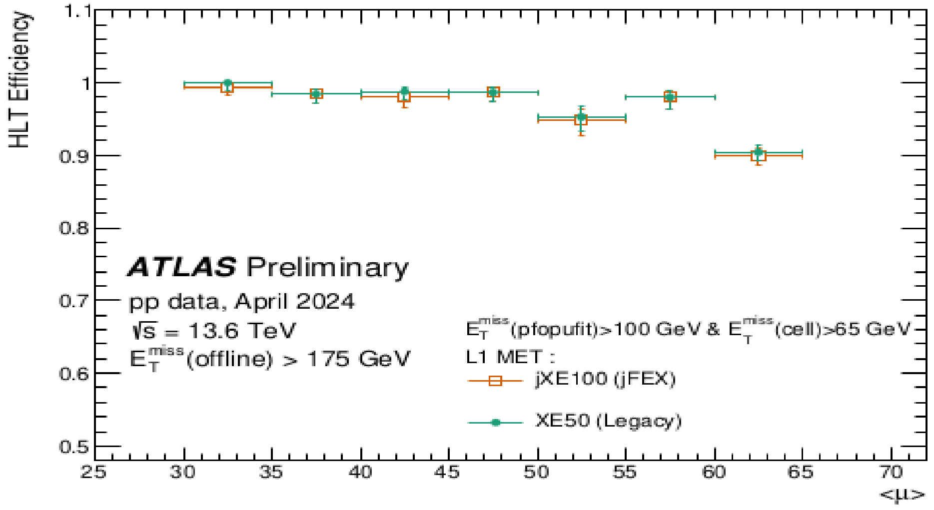


Cf my talk at ATLAS weekly

Phase-I FEX Performance

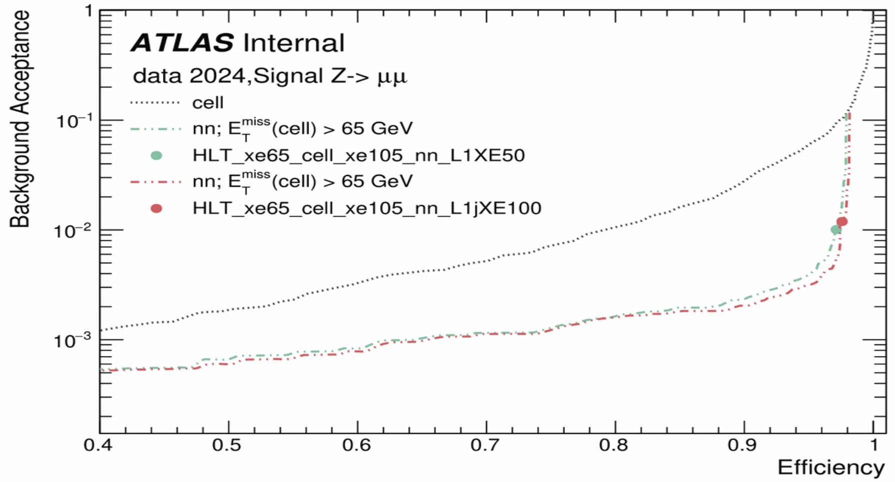
- ***Efficiency measured as a function of number of simultaneous interactions < μ >.***
- ***Events taken from data with a Z →μμ selection requiring offline E_T^{miss} >175GeV.***
- ***Same behaviour wrt trigger chains sedded by jFEX and Legacy L1Calo***

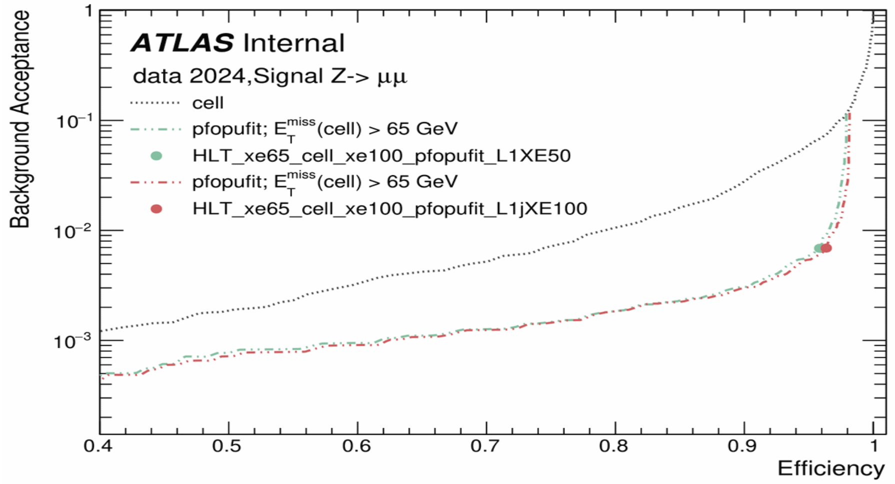




Phase-I FEX Performance

- Here the Background rejection vs. signal efficiency curves for two primary trigger chains seeded by the Phase-I jet feature extractor (jFEX) compared with chains seeded by the L1Calo legacy system.
- The signal efficiency on the x axis is evaluated using physics_main dataset, whith Z -> μμ event selection and a cut of 150 GeV is applied to the offlineMET.
- The background acceptance on the y axis is evaluted using EB dataset with EBWeight applied.
- We see a relative similare efficiency rejection power for Both trigger chains.





L1 Legacy calo system disabled

jet Feature Extraction (jFEX) module

Conclusion :

MET triggers has progressed quickly since the start of run-3 to present.

- Calorimeter only (run-2) ⟶ adding tracking +nn Algorithm (run-3)
- previous primary MET algorithm of pfopufit is replaced by nn .
- Significant progress made in studying signel efficiency for legacy system, allows us to continue to use L1XE50 as the baseline untile the phased out.
- jFEX algorithm closely matches legacy performance.
- jFEX MET shows resistance to pile-up and rate reduction
- L1XE50 legacy MET removed in May 2024.
- Future focus: Commission gFEX based .

Thanks!