# TrackMET and ATLAS Run2 xAOD Trigger for $ZH \rightarrow \nu\nu bb$

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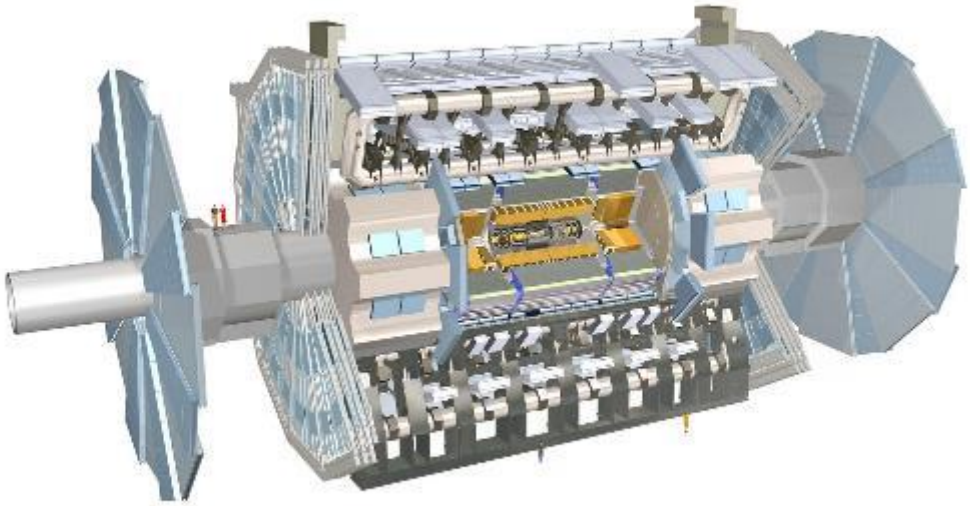
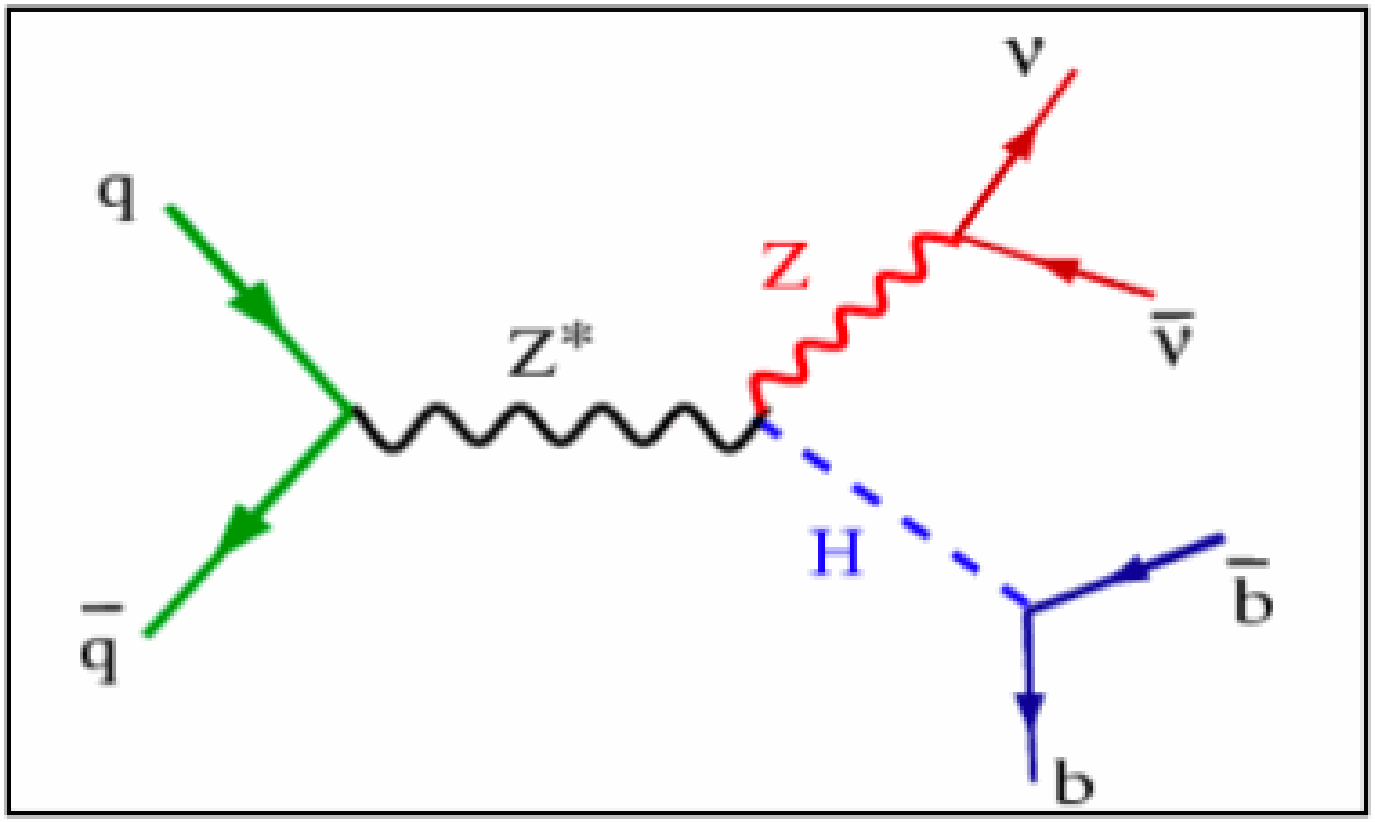
# Overview



# ZH→νν̄bb̄



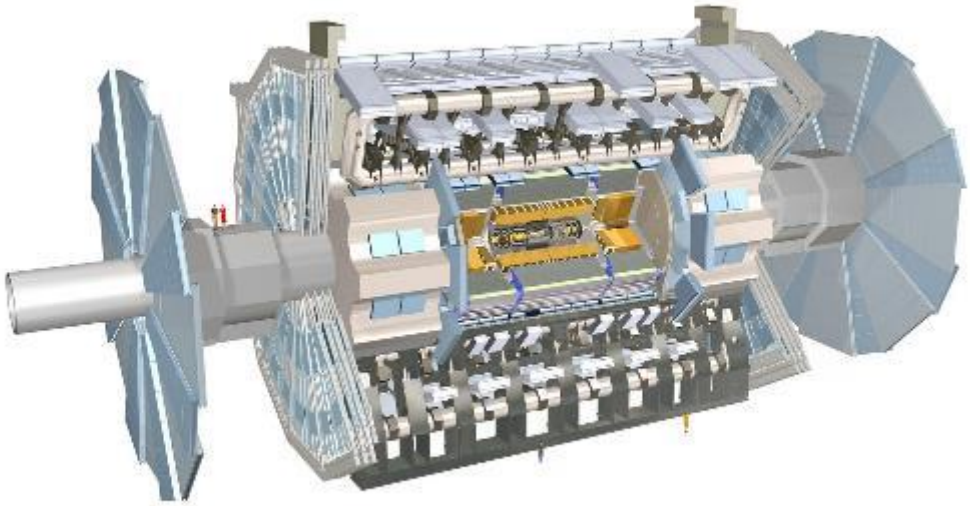
# What have I done?

- ✓ Performance study of the TrackMET vs CaloMET in Run2
- ✓ Selection cut study to reject QCD background events
- ✓ Look at different trigger configuration specific for Hbb analysis (eg. $ZH \rightarrow \nu\nu bb$)
- ✓ Look at the efficiency curves as a function of offline MET
- ✓ Estimate MET threshold for event selection for 100% efficiency

# What Remains (If feasible)

- Continue the trigger MET study to help performance for the $ZH \rightarrow \nu\nu bb$ analysis
- Learn trigger detailed implementation for future analysis
- Help the development of Run2 TrackMET
- Validate trigger menu from samples

# TrackMET



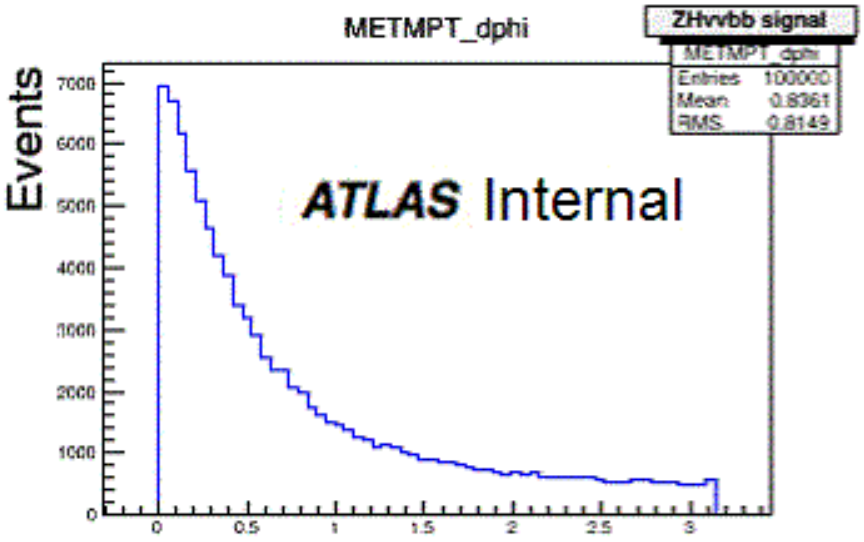
# TrackMET

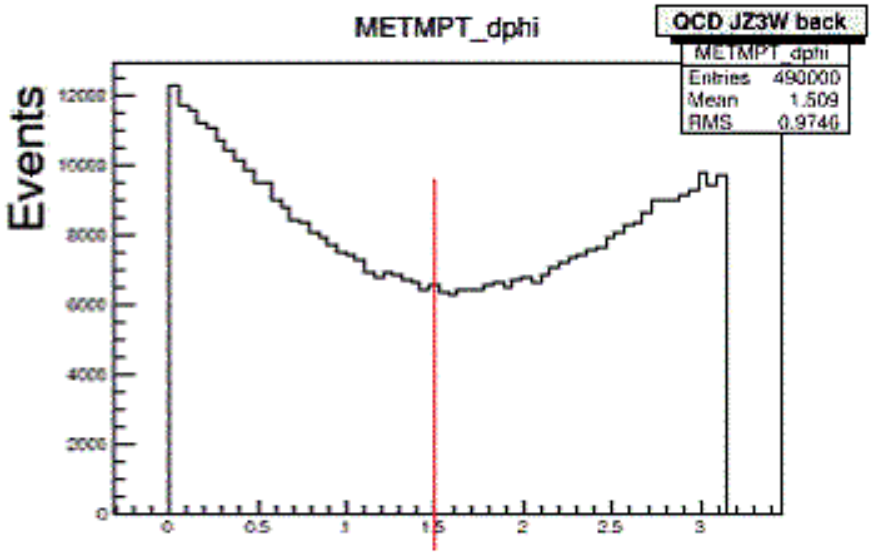
- Tool developed as alternative for calorimeter-based MET
  - Tracker and calorimeter are independent measurement, different systematic effect
- Currently being migrated for xAOD
- Useful to reject QCD backgrounds

# TrackMET?

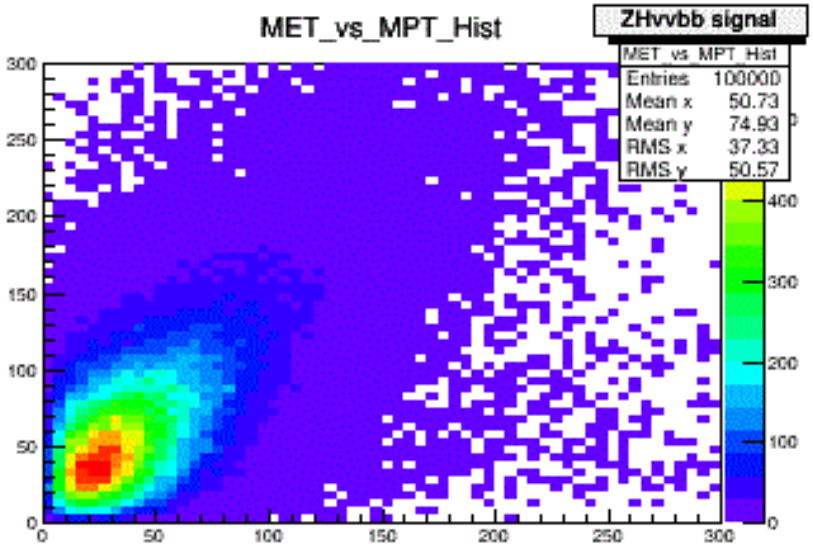
- Can associate tracks to primary vertex,
  - Calculate MET and SumPt based on primary vertex of the event ,thus more correlated to true MET of the main physics process– important in pileup case
- Will deteriorate less than calorimeter based variables as instantaneous luminosity increase
- Has less effect due to cosmic muon and beam background
- Some analysis it is used:
  - BSM: H->ZZ->vvqq
  - SM: ZH->vvbb, H->WW->lvlv
  - ZH->bbxx(invisible)
- Disadvantages :
- -See only charged particles
- -Smaller geometrical coverage (|eta|<2.5 Compared to calorimeter $|\eta|$<4.5)
- -Momentum resolution get worse in higher Pt (expected in Run2, need a way to fix that)

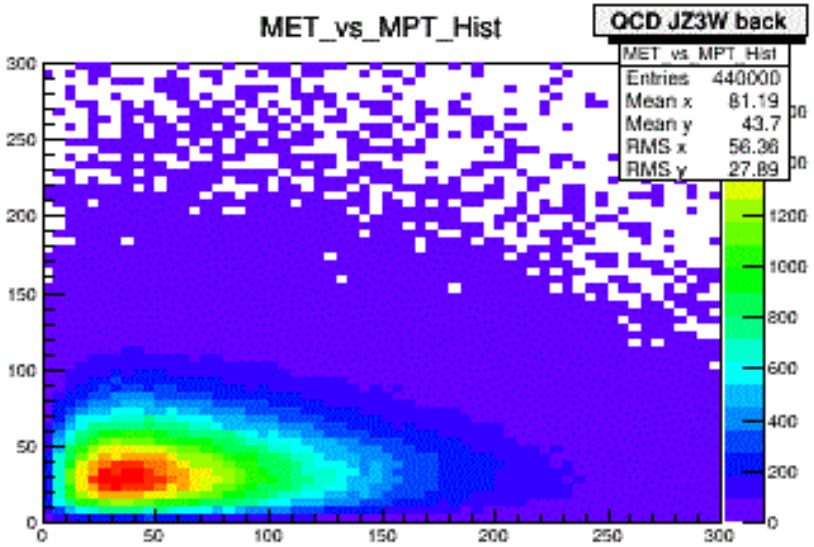
# METphi_vs_MPTphi



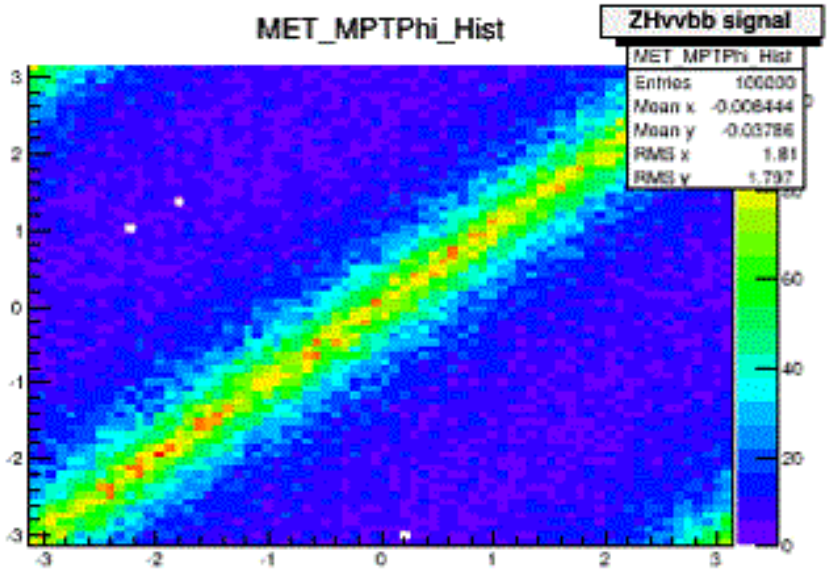



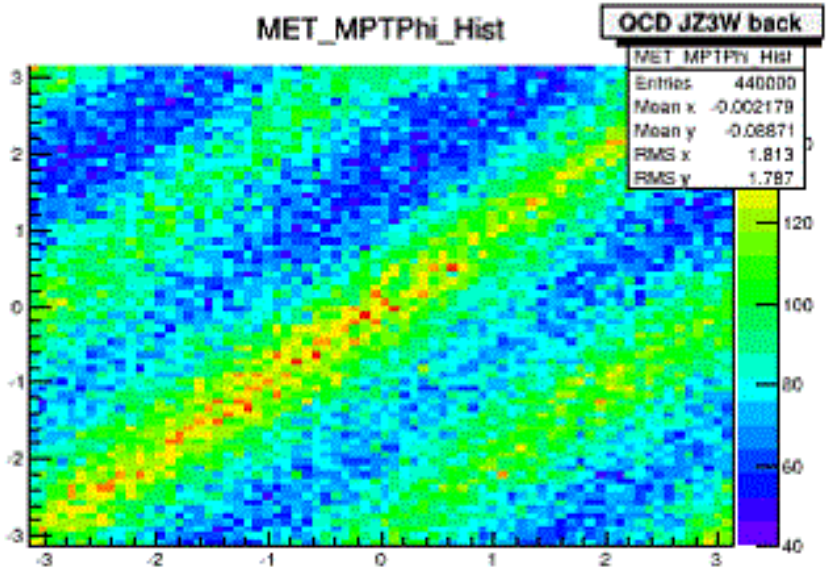
# METvsMPT (nonPV)



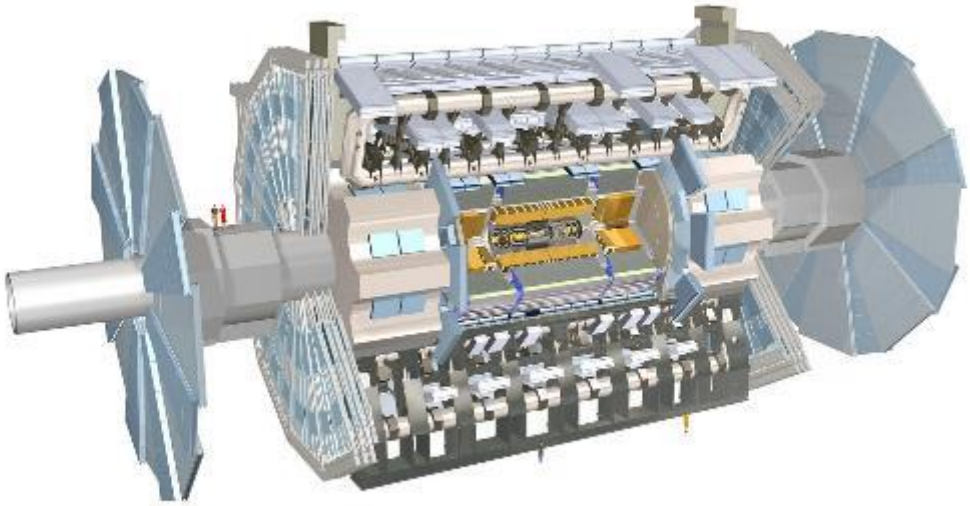



# METphivsMPTphi



# Trigger Side

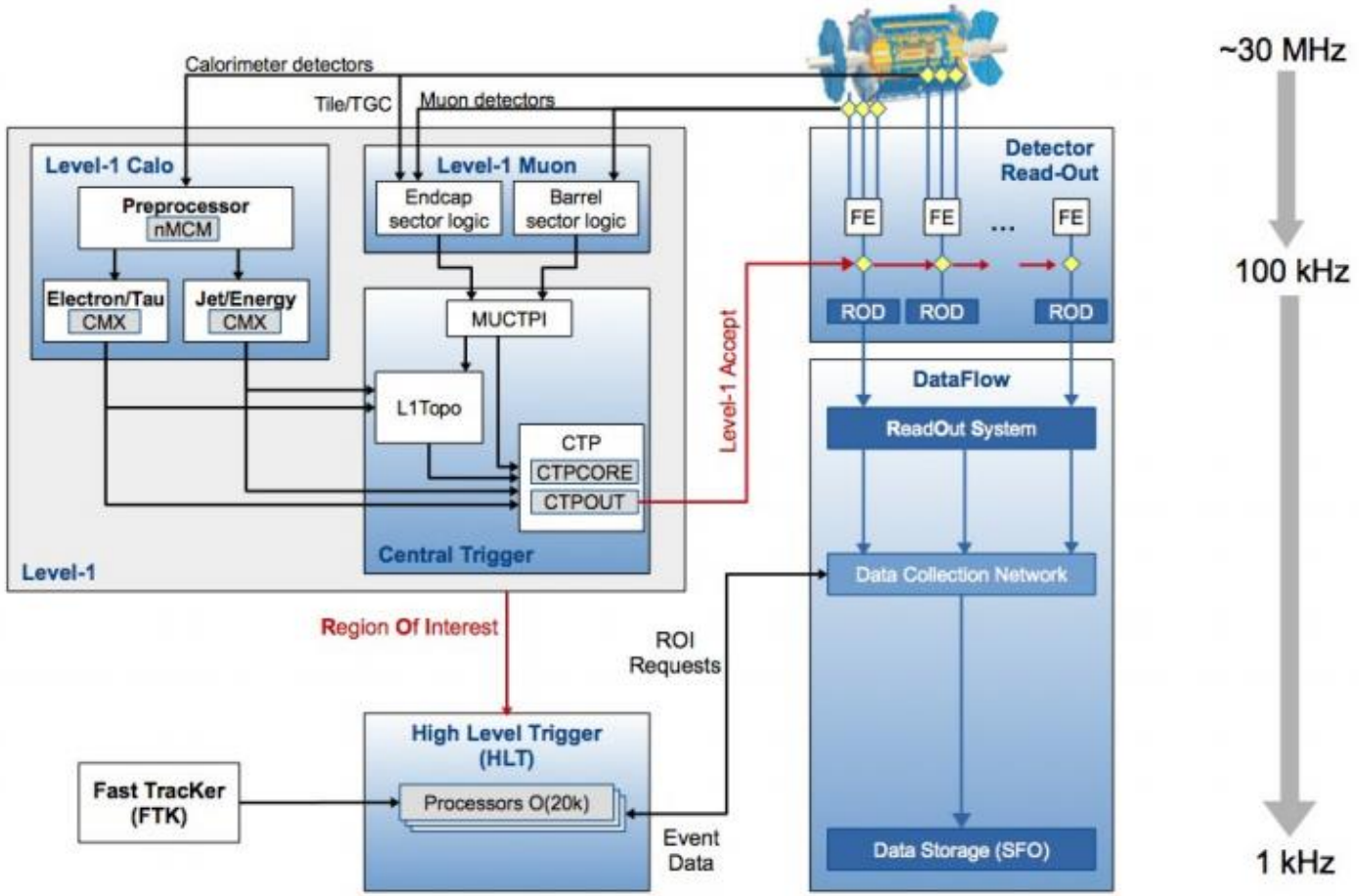


# Trigger Side

- L1 triggers: L1_XE50, L1_XE70, …
- L1 topo trigger: L1_J40_DPI-J20s2XE50
- HLT triggers: HLT_xe100
  HLT topo triggers:
  HLT_j80_xe80_dphi1_L1J40_DPHI-J20s2XE50
- Inclusive: L1_XE50, L1_XE70, HLT_xe100

- Meant to complement the TrackMET study by identifying which MET threshold gives maximum discrepancy power

# ATLAS Trigger System (Run2)



# ATLAS Trigger System

## What is a trigger sytem?

System that uses simple criteria to quickly decide events in particle detector to keep when small fraction of total can be recorded

## Real-world limitations

Data Storage, CPU Capacity (time) and collision rates

## How?

Searches for “interesting events” (decay of rare particles) which occur at relatively low rates, and identify events that should be saved for further analysis

Trigger has large number (hundreds) of hypothesis independently: *trigger chains*

## Why?

It is often the case that people check the trigger objects to match the offline reconstruction

## Offline vs Online

Trigger reconstruction (online) happens during data-taking, once data taken the trigger information is fixed for all times

# ATLAS Trigger System

## The Technicality

Job: Select few hundred events of interest/second for permanent storage

- Run 1: 20MHz→ 700Hz => rejection factor of 30 000

First level trigger (L1)

- Synchronous at 40MHz with fixed latency 2.5$\mu s$
- Identifies Region-of-Interest (RoI) in muon spectrometer and/or calorimeter with coarse resolution

High Level Trigger (HLT)

- Handles complexity with custom fast software on commercial CPUs
- Access full resolution of ALL detectors
- Access both partial events (L2 RoIs (Run1)) and full event (Event Filter(Run1))

# ATLAS xAOD

Software

- Trigger Decision Tool (TDT)
- xAODTrigConf
- xAODTrigger (EmTauRoI, Jet, etc)
- xAODTrigEgamma
- xAODTrigMissingET

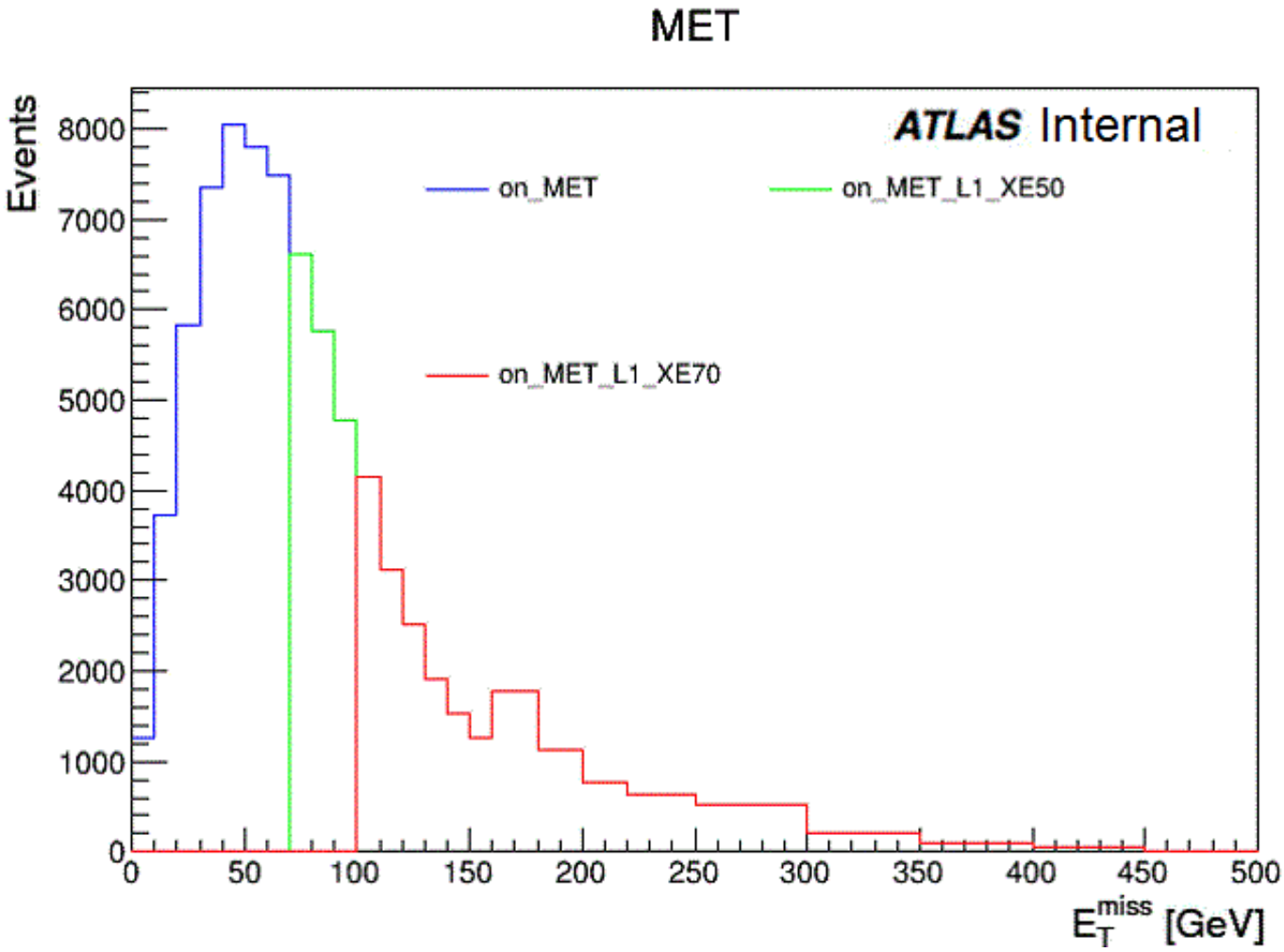
# Efficiency Curves

- Reconstructed events at offline level do not perfectly match the real data (online)
- Measure of ‘goodness’ of trigger

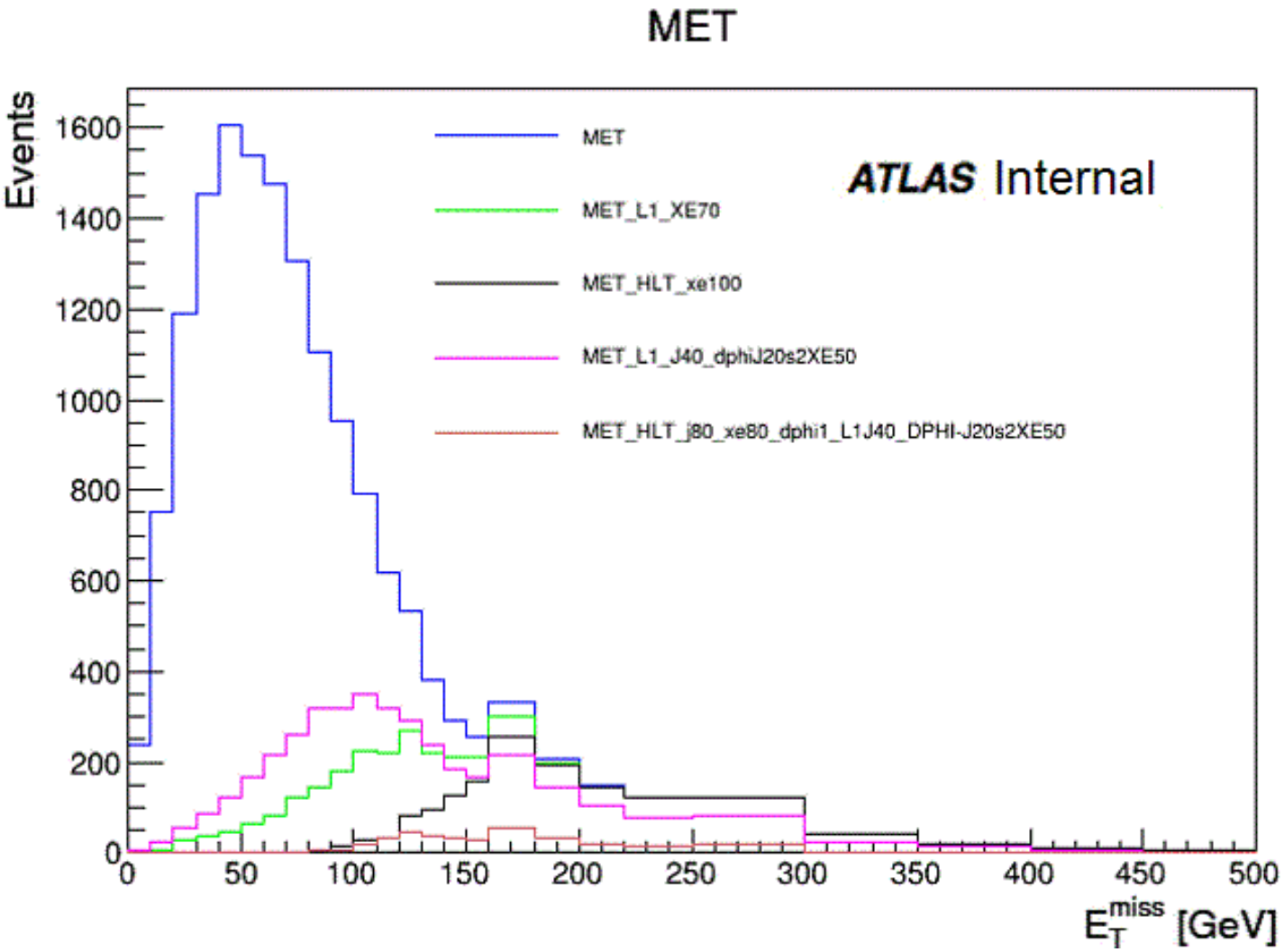
$$Eff. \sim \frac{Events\ pass\ trigger}{Total\ events}$$

- Nomenclature:
  - XE, xe, J, dphi, …
  - L1_XE70, HLT_xe100, L1_...

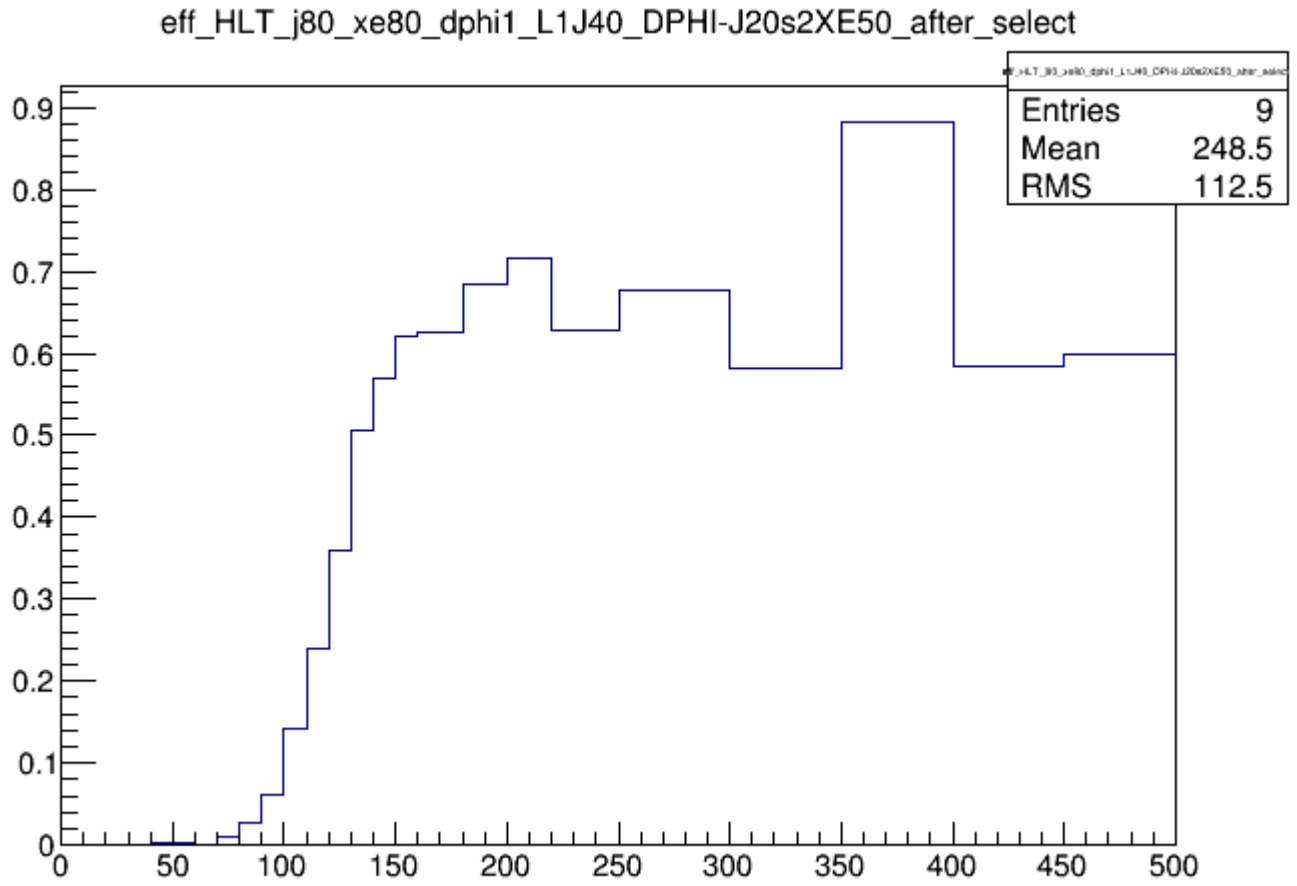
# $t\tilde{t}$ (online MET trig)



# $t\tilde{t}$ (offline MET trig)



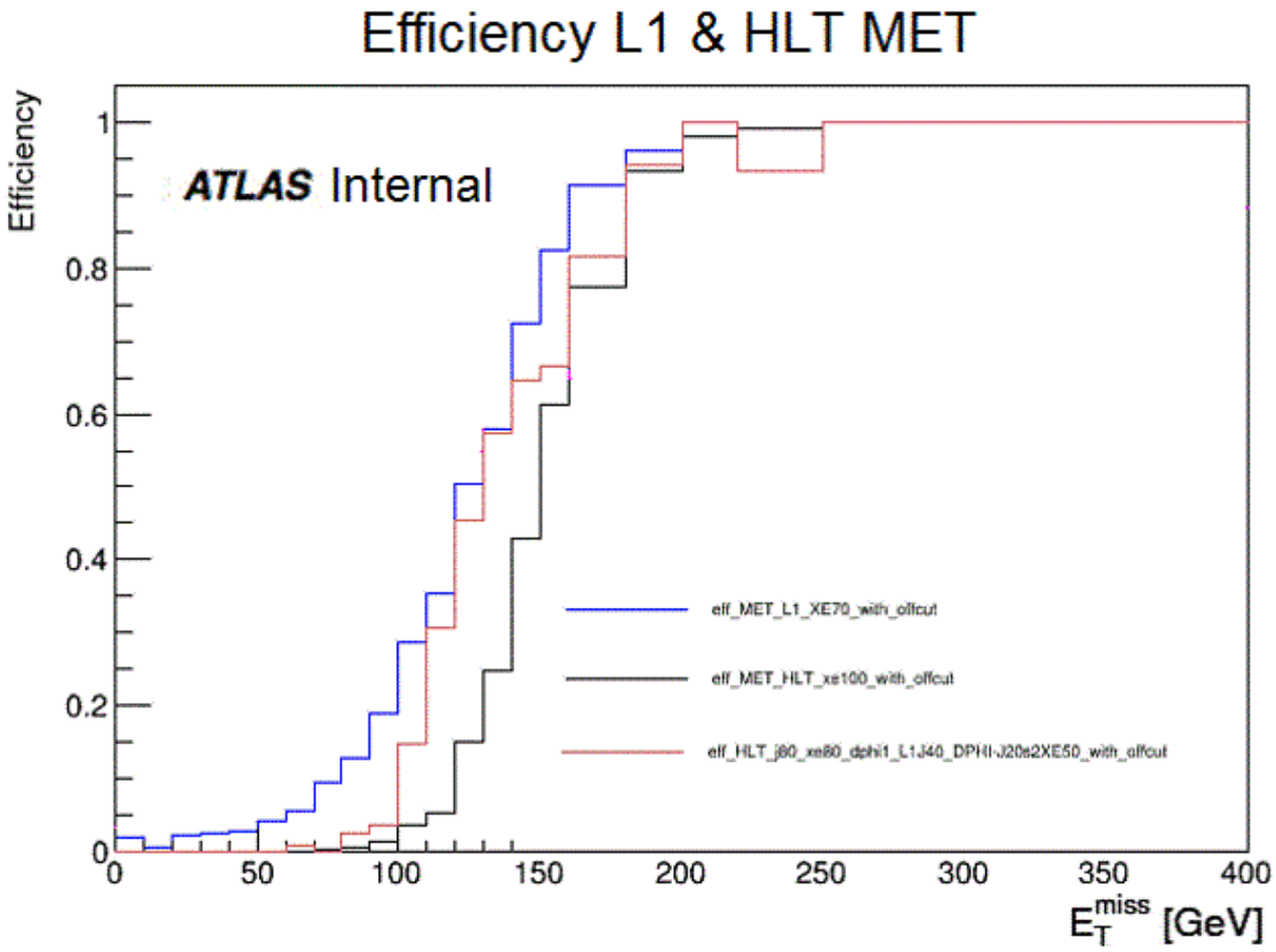
# $t\tilde{t}$ Efficiency (HLTtopo w/o offline cut)



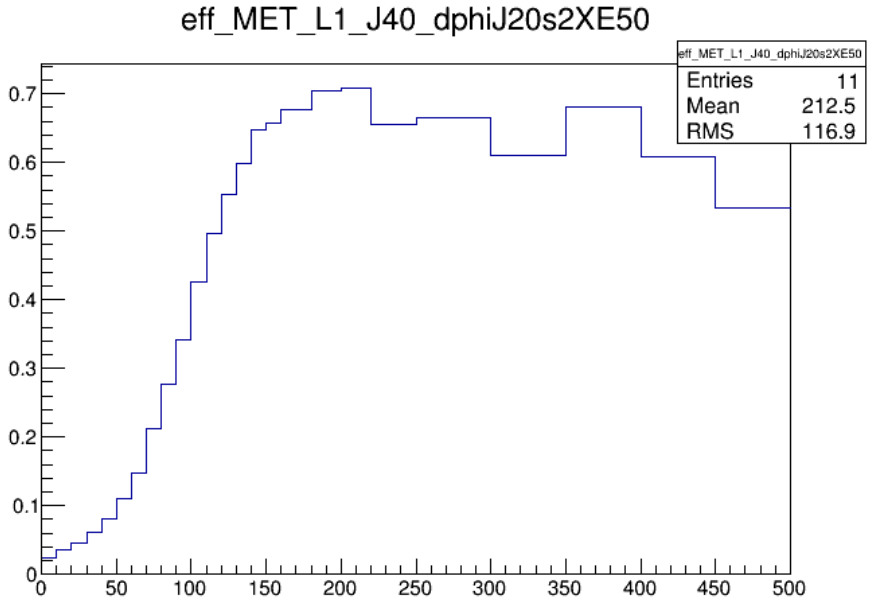
# Trigger offline cut

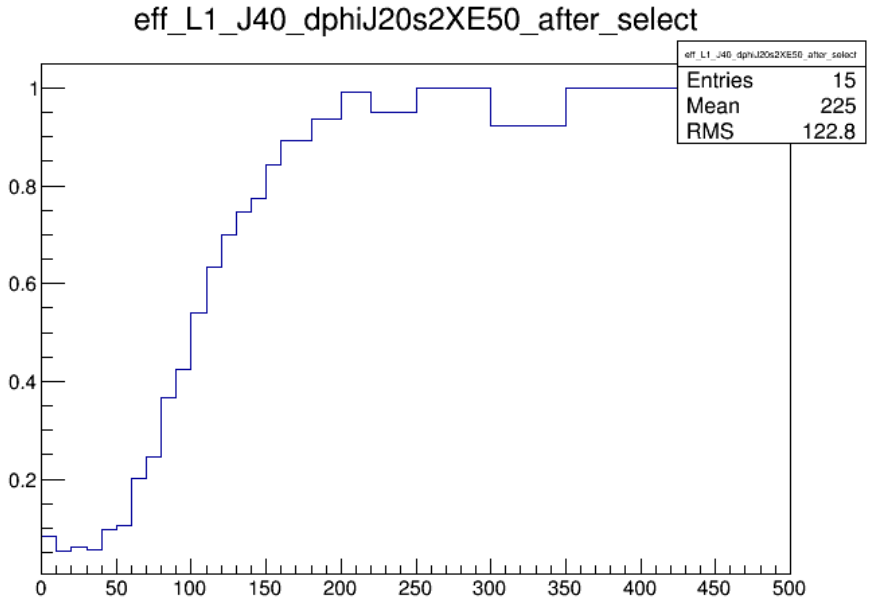
- At least two jets
  - $P_T$>20GeV
  - $|\eta|$ < 2.5
    - Leading jet with $P_T > 45GeV$
    - Min$\Delta\emptyset(MET, jet) > 1.5$

# $t\tilde{t}$ Efficiency (after offline cut)

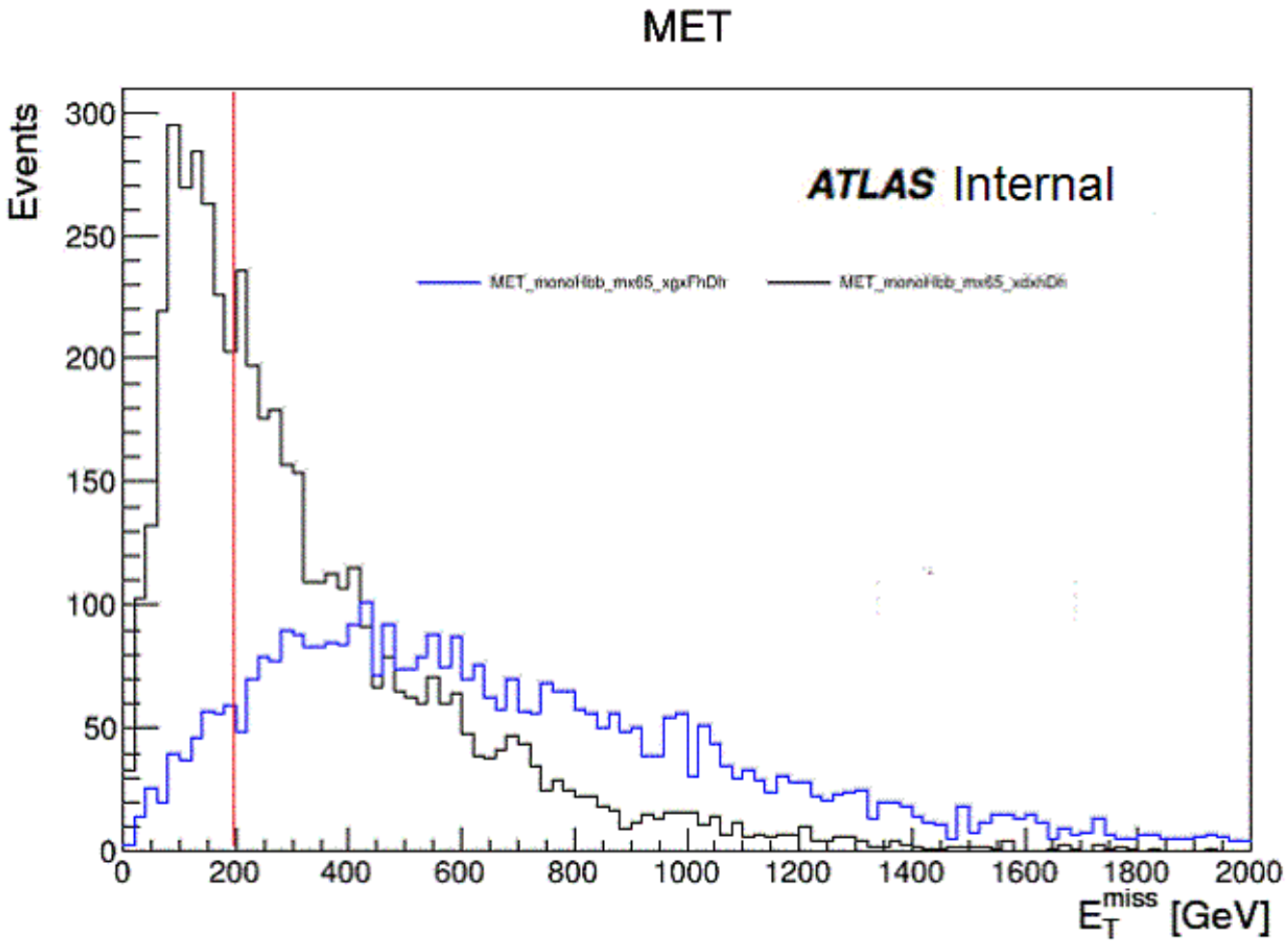


# $t\tilde{t}$ Efficiency (L1topo trigger)



# Monohiggs sample
# $(pp \rightarrow hxx \rightarrow bbxx)$



# Conclusion

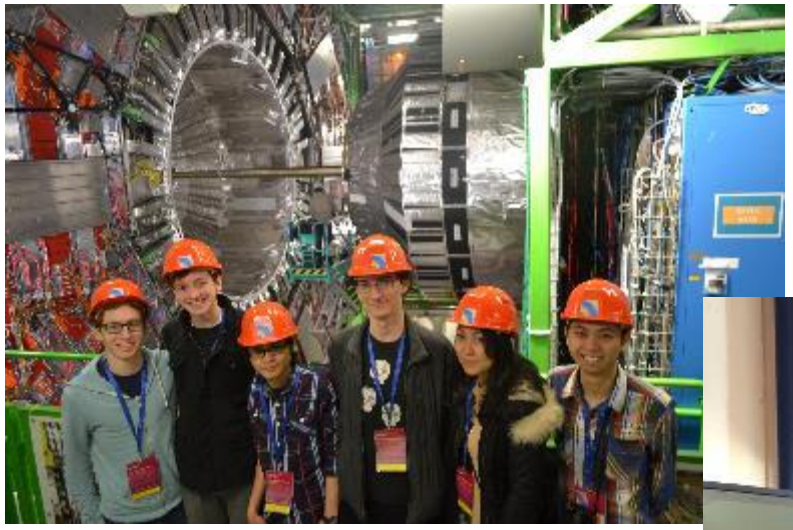
- TrackMet could help in rejecting processes which are source of fake MET, such as QCD
- It can be a powerful tool in W/Z analysis, and any other processes with real MET.
- Trigger study in Run2 useful for looking at the efficiency of MET signature trigger
- Study of trigger efficiency plots could help analysis in getting the optimum event selection by finding MET threshold

# Special thanks…


# And Lounsbery Foundation…

# Questions???

# Fun Time



# Backup

# ATLAS Trigger System

**Trigger is your first step of analysis**

For analysis, understanding which *trigger chain(s)* to work with is important. (First selection step of signal and background data)

Can use tools provided by trigger group to check outcome of hypothesis and analyze trigger objects

Important for analysis: Matching offline reconstruction to trigger objects

# ATLAS Trigger System

## Online vs Offline

Trigger reconstruction (online) happens during data-taking, once data taken the trigger information is fixed for all times.

## Expectation vs Reality

Expectation: In ideal-world we want trigger to reconstruct events same way as it is done Offline

Reality: In real-world limitations make it impossible (there would always be mismatch between online and offline reconstruction)

Trigger decision and reconstructed event objects is stored as part of ATLAS Raw Data (produced during Online data taking)

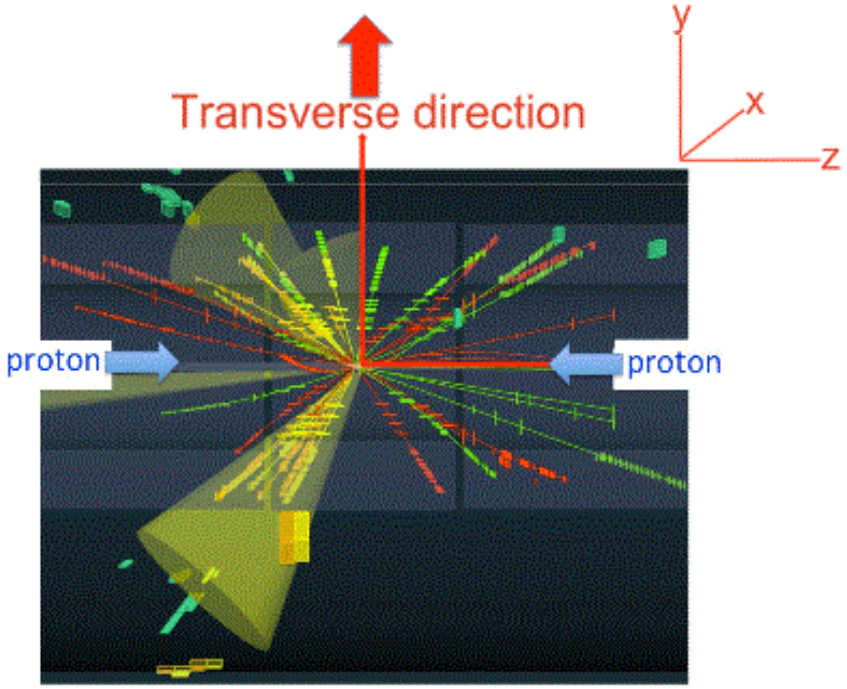
# Missing Transverse Energy

- In p-p collision at the LHC, a significant, unmeasured amount of energy escapes in z-direction.
- Total initial and final momentum is zero in transverse direction
- Imbalance of energy in transverse direction signals presence of weakly/non-interacting particles such as neutrinos

$$E_T = \sqrt{(p_x^{miss})^2 + (p_y^{miss})^2}$$

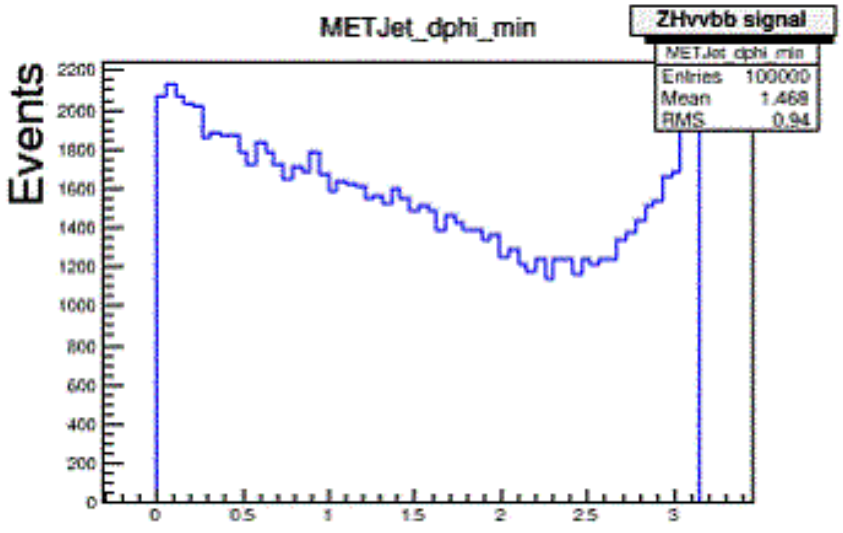
$$p_x^{miss} = -\sum_{i=1}^{N_{contrib}} p_{x,i}$$

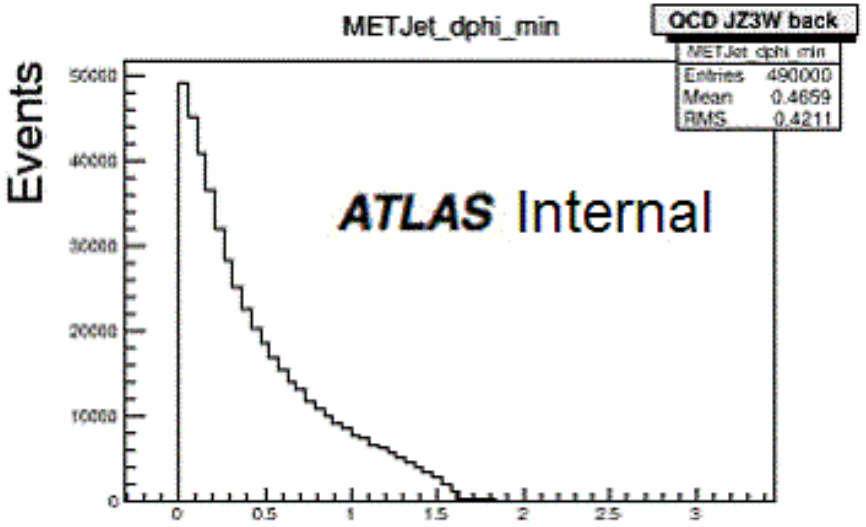
$$p_y^{miss} = -\sum_{i=1}^{N_{contrib}} p_{y,i}$$




- xAOD Missing ET

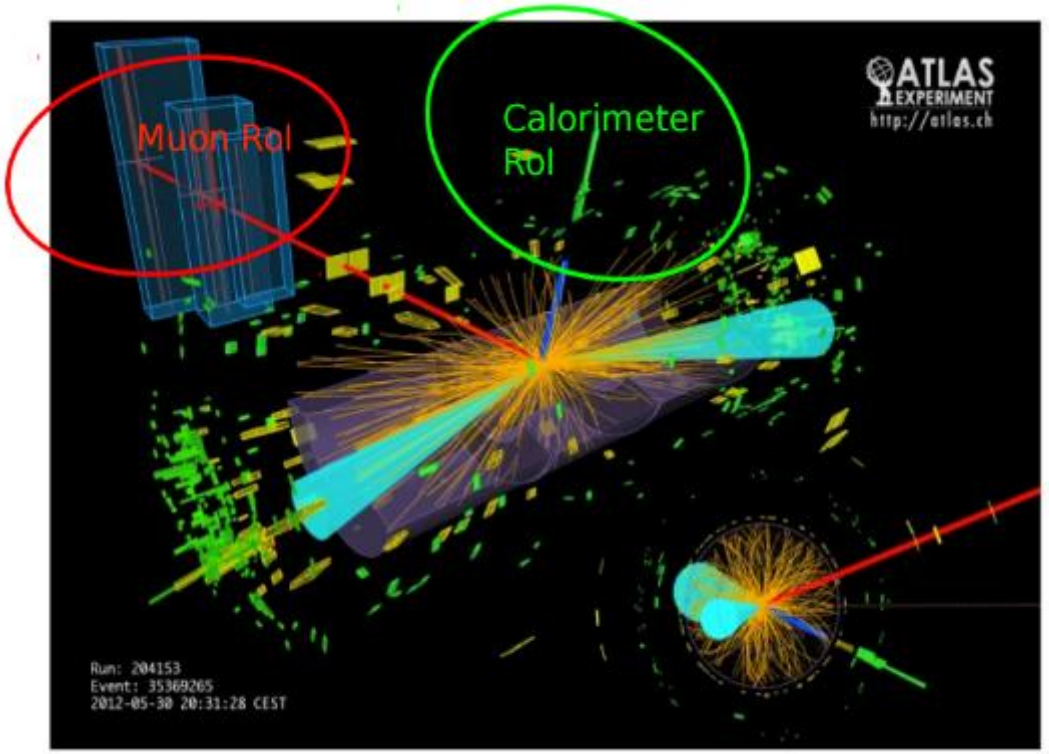
# METJEt_dphi_min



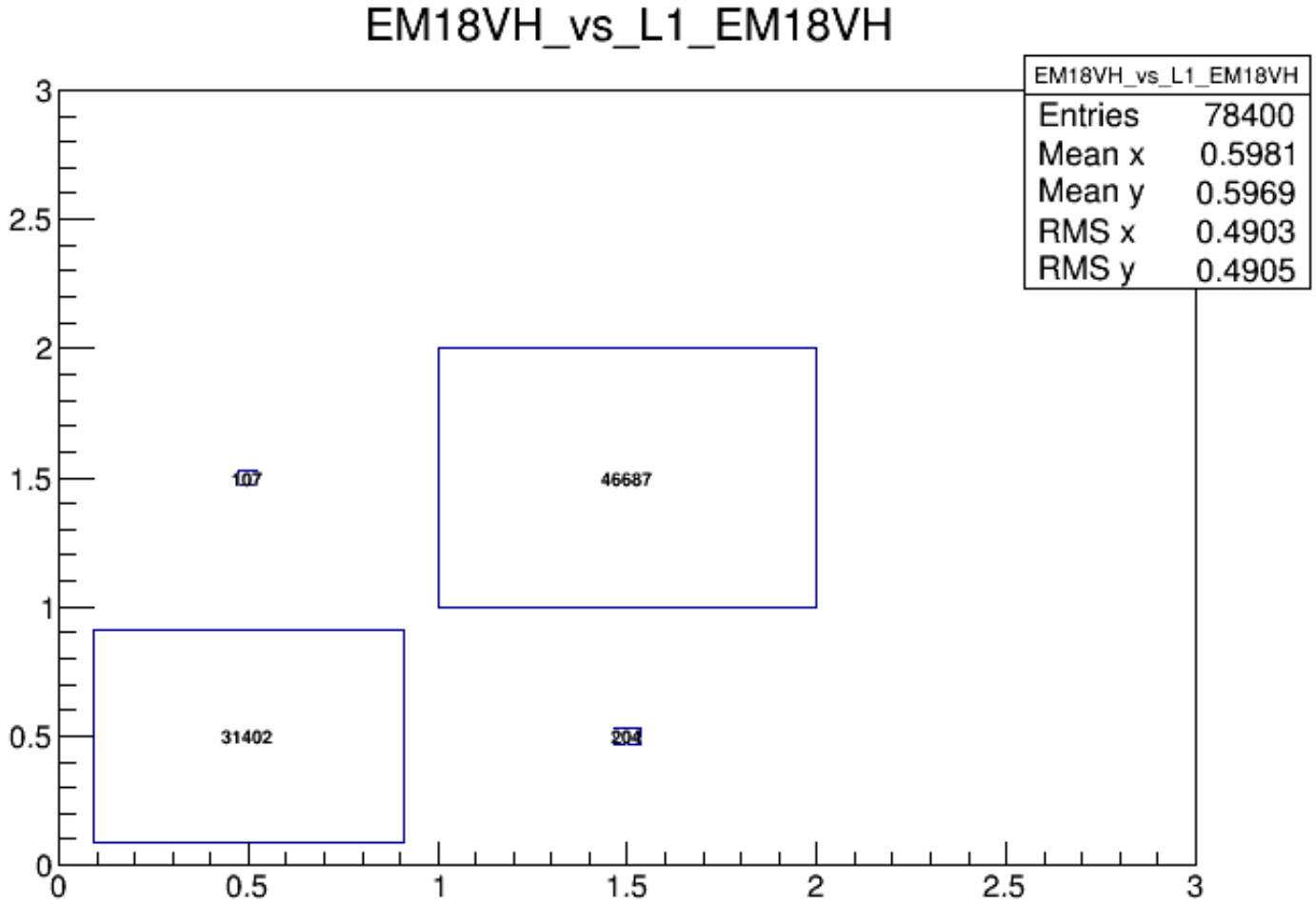



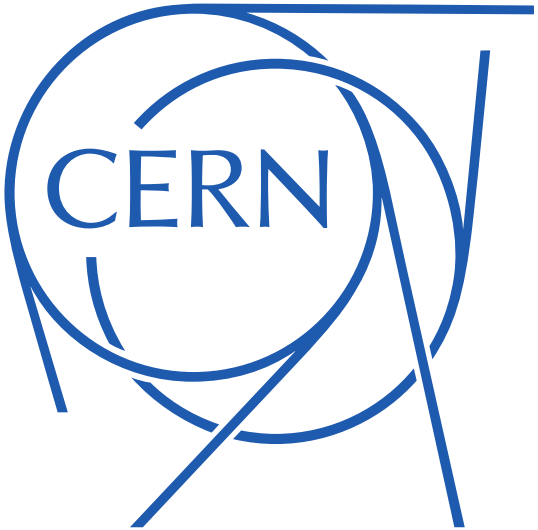
# RoIs

- RoI=Region of Interest
- LVL1EmTauContainer



# Trigger emulation vs flag
## (EM18VH vs L1_EM18VH)

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