SLHC Calorimeter Trigger Algorithms & Simulation

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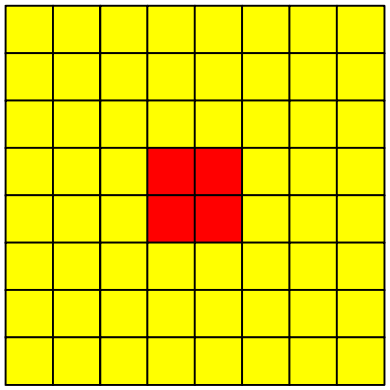
Calorimeter Trigger Requirements

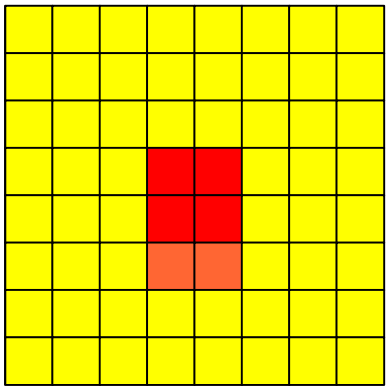
- Provide equal or better performance for Egamma , Taus and Jets by keeping the rates low in the presence of PileUp (for Phases I. II)
- Provide the best possible position resolution for matching between the calorimeter and the tracker (for Phase II)
- Exploit the latest technologies to create fast flexible and reconfigurable hardware to be adaptable to any conditions

Calorimeter Trigger signatures

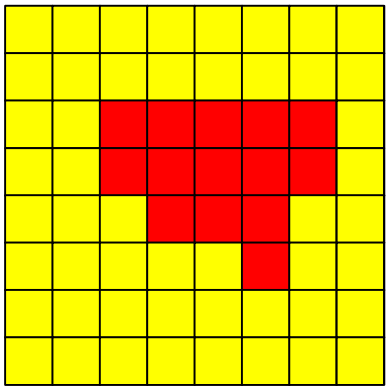
Electrons/Photons



Taus



Jets



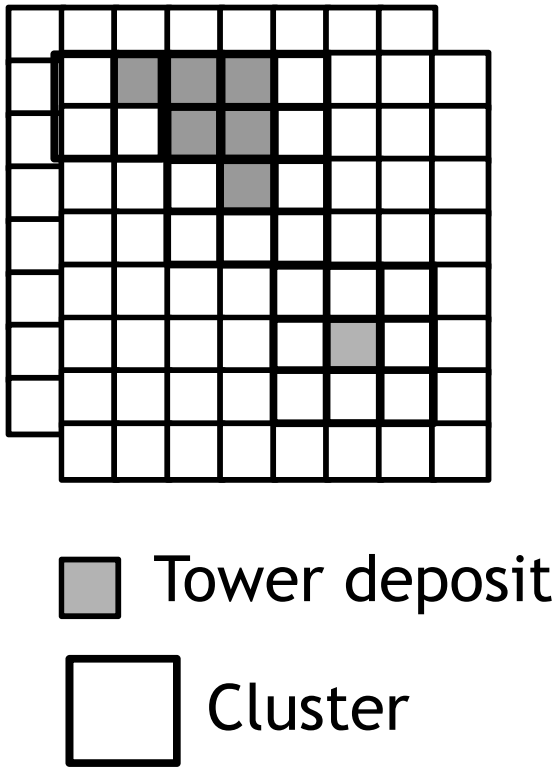
- Electrons and photons deposit most of the energy in a 2x2 cluster
- Taus deposit most of their energy in a 2x2 cluster however there is often leakage due to bending and three prong decays
- Jets correspond to a uniform energy deposit around a maximum

Calorimeter Trigger Algorithm

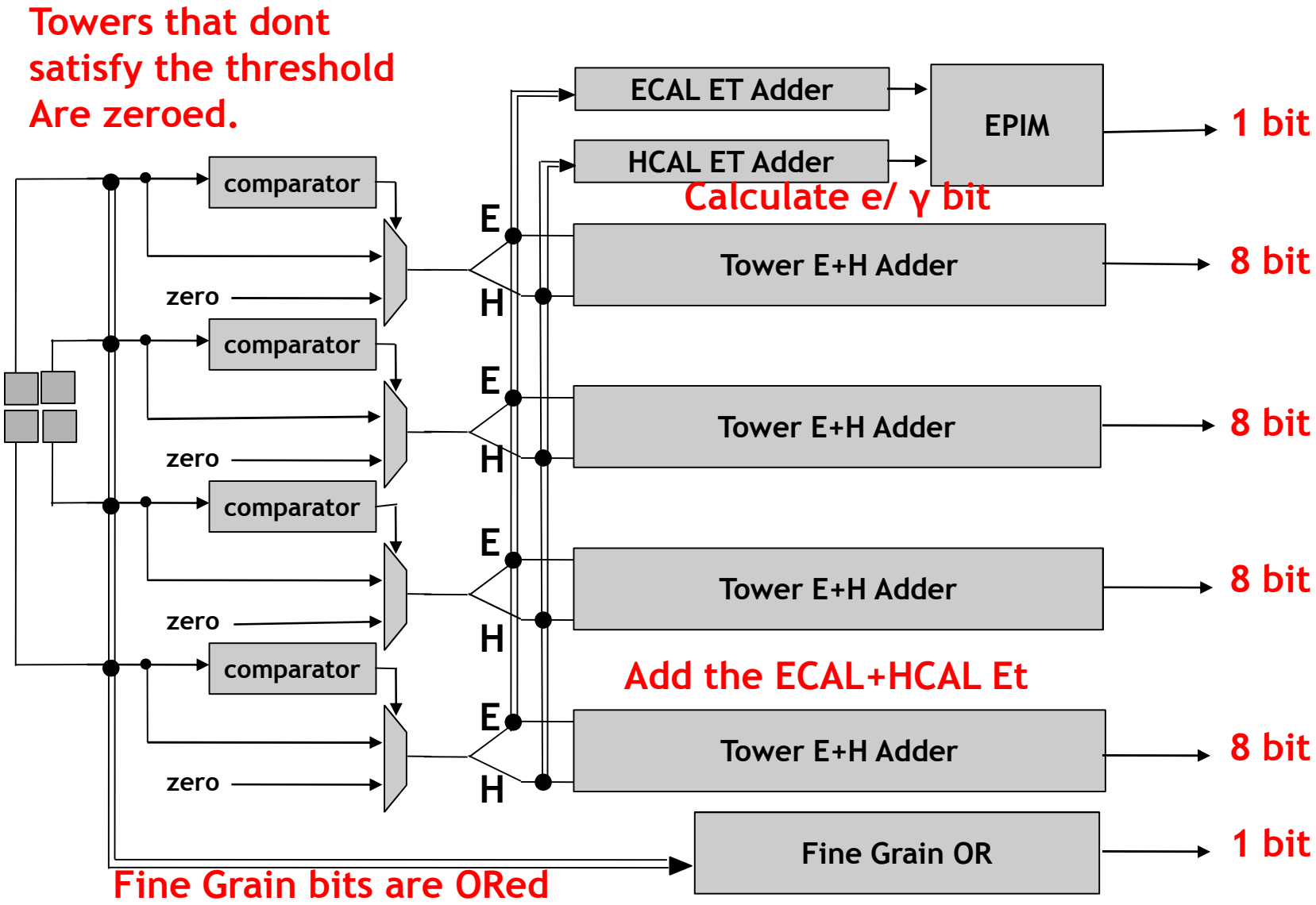
- Particle Cluster Finder
  - Reconstructs 2x2 overlapping clusters (overlap by one tower)
  - Applies Electron ID
- Cluster Overlap Filter
  - Removes overlap and locates local maxima
  - Weighs the cluster and gives high position granularity
- Particle Isolation
  - Calculates isolation around interesting clusters
- Jet Reconstruction
  - Sums clusters and creates jets
- Particle separation and sorting
  - Creates output collections sorts and outputs the highest ones
- MET/MHT/SumEt calculation

Particle Cluster Finder

- Applies thresholds on the towers
- Creates a 2x2 cluster at each position on the lattice
- The clusters are overlapping by one tower in eta/phi
- Calculates Electron/Photon ID bit
  - Denotes if the cluster is Photon/Electron like
- Applies OR of the finegrain bits
- Sums the ECAL and HCAL energy for each tower of the cluster



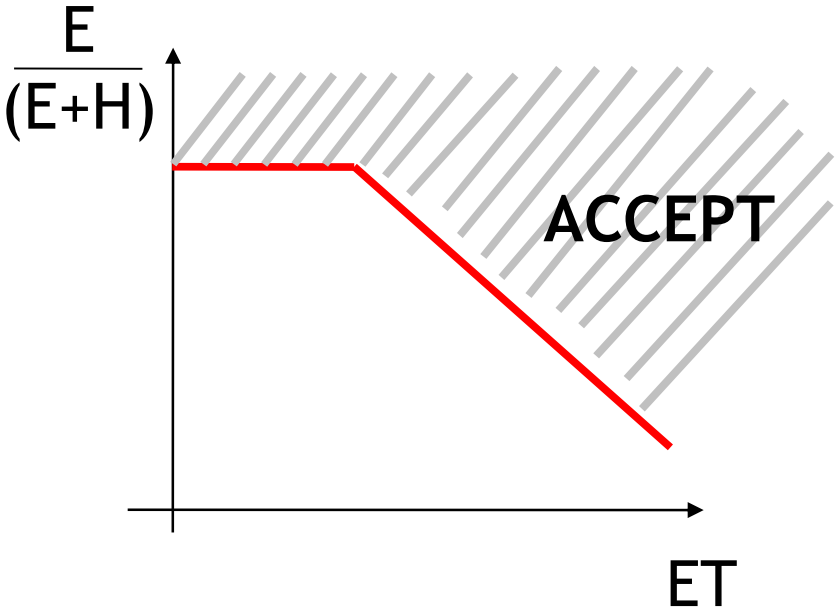
Particle Cluster Finder Logic



Electron Photon ID (EPIM)

- Applies calorimeter based electron ID by comparing ECAL/HCAL deposits
- Requirement 1: Flexibility
  - A lot of different cuts can be applied
    - E/(E+H) > value
    - H/E < value
    - Cuts that change at ET ranges
- Requirement 2: Firmware Stability
  - Re-synthesizing is painful (might even affect clock speed or overall resources)
- All the above lead in LUT based implementation

Example used in simulation



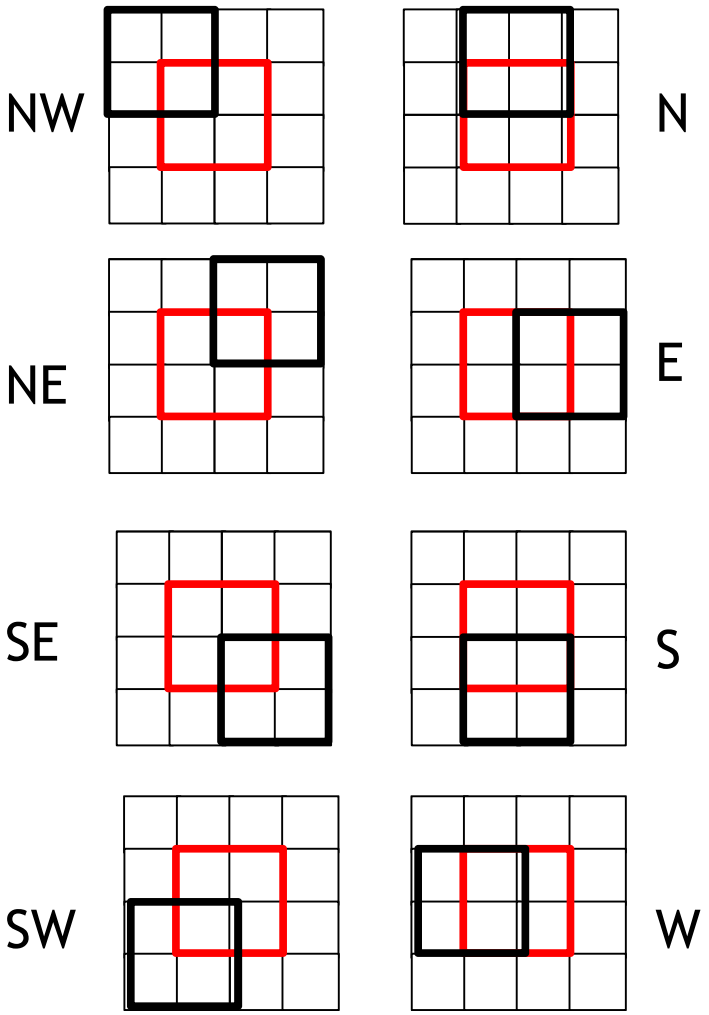
Electron ID should relax In High Pt to reduce trigger bias (and catch TeV electrons From Z' :-))

Cluster Overlap Filter

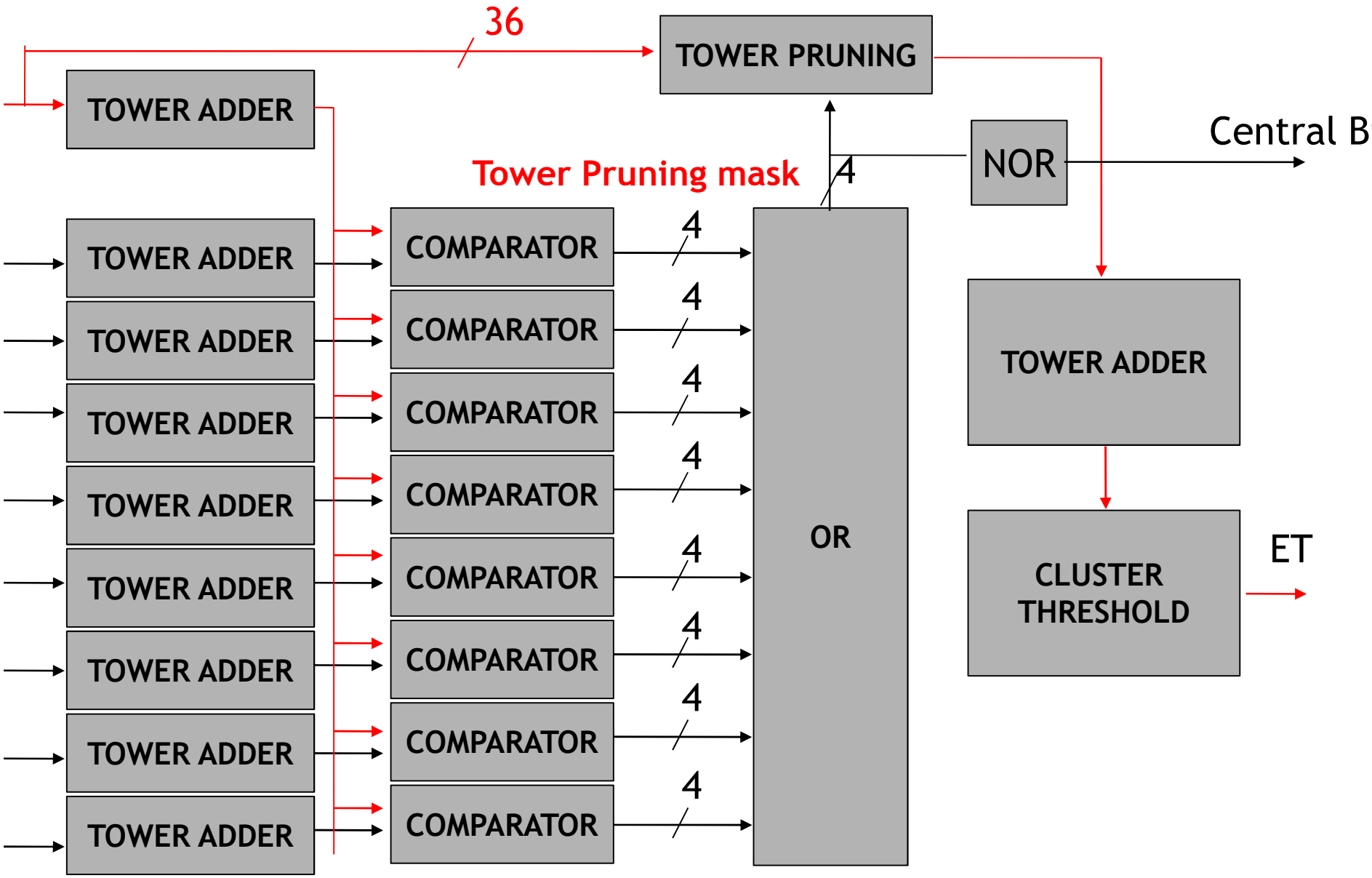
Cluster to be filtered

Neighboring Cluster

- **Compare Cluster ET with neighbor ET**
  - **If main cluster is less energetic remove the overlapping towers**
- **After pruning Sum all the towers to cluster ET**
- **Apply a threshold to the resulting cluster**
- **Assign a bit to the clusters that were not pruned**
  - **Local Maxima!**

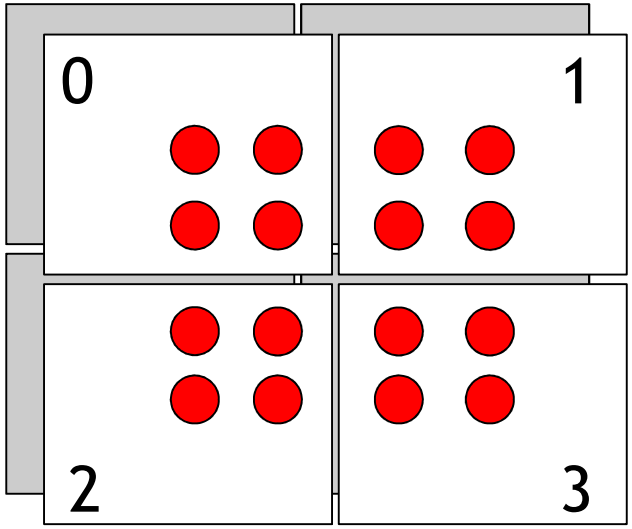


Cluster overlap filter logic

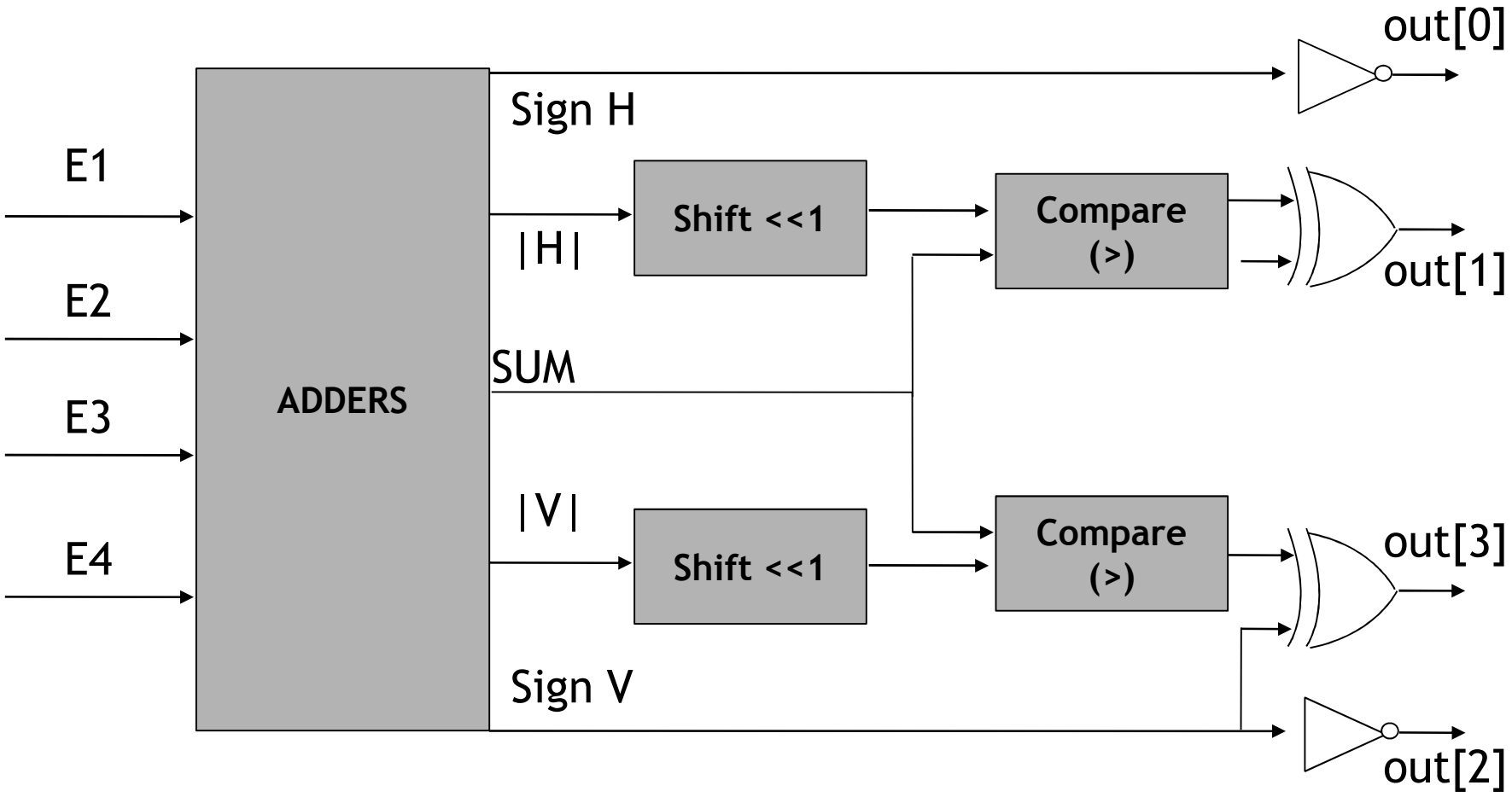


Cluster weighting

- Weights the cluster to provide maximum position resolution
  - Results in one of the depicted 16 points in cluster
- Algorithm
  - Calculate horizontal and vertical energy sums
    - H = E1+E3-E0-E2
    - V = E2+E3-E0-E1
    - S = E1+E2+E3+E4
  - Hpos = H/S, Vpos = V/S
- No division is needed
  - i.e 0<Hpos<0.5, 0.5<Hpos<1.0
  - -1<Hpos<-0.5 -0.5<Hpos<0

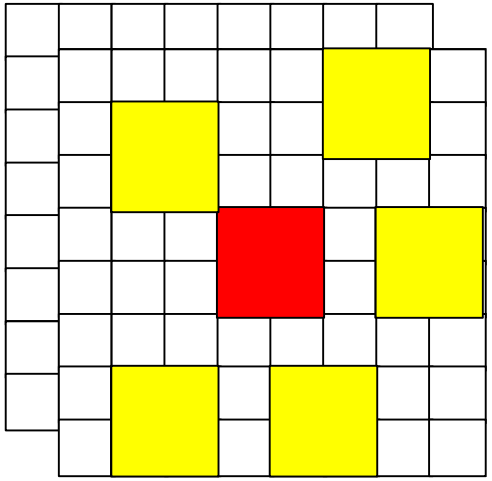


Cluster Weighting logic



Cluster Isolation

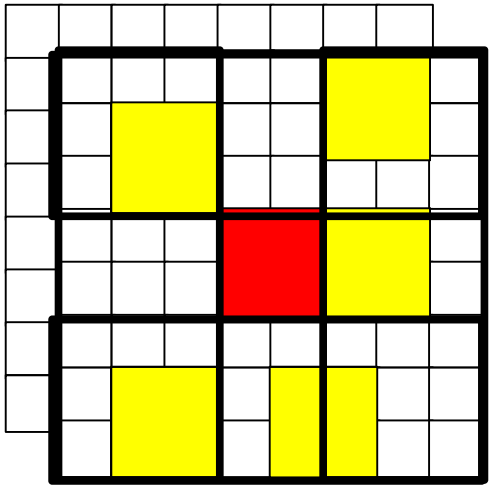
- Runs on a 8x8 lattice
- Counts the number of Clusters over a threshold around the central cluster.
  - Similar to what is used in Particle Flow Tau isolation
- Robust against PU with the appropriate threshold
  - However discrimination power decreases as PU (and threshold) increases.



To be implemented in firmware

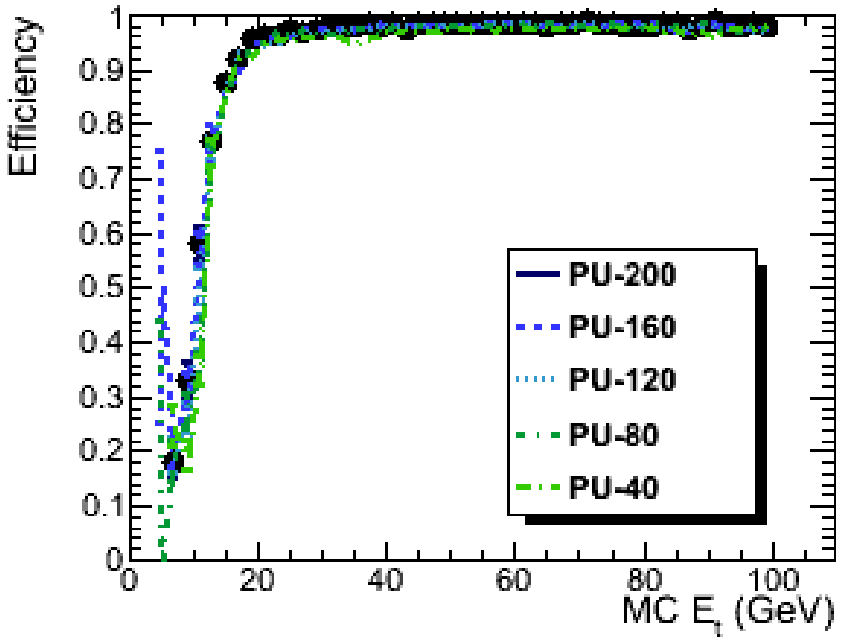
Jet Finder

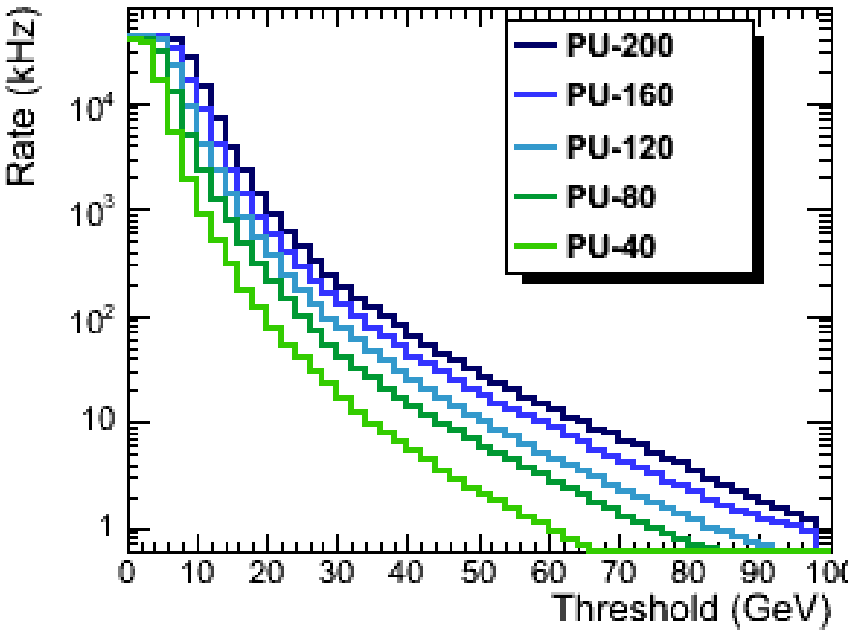
- Runs on overlap filtered clusters around a local maximum
- Calculates three sums
  - LR = LEFT-RIGHT
  - UD =UP-DOWN
  - ET = Sum of all
- Applies weighting
  - LR/ET<c AND UD/ET<c
  - No division used but shift and compare
  - i.e ET> LR<<shift_amount



To be implemented in firmware

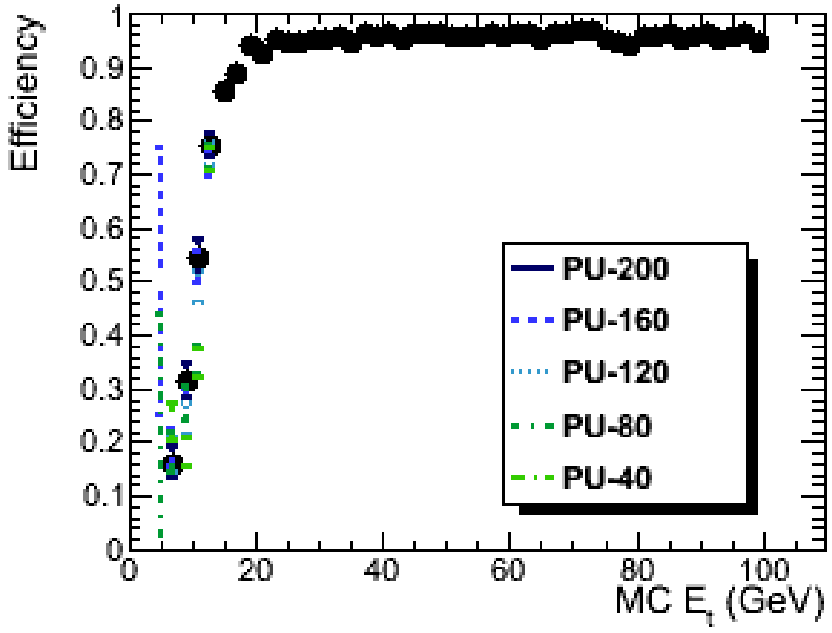
EGamma performance

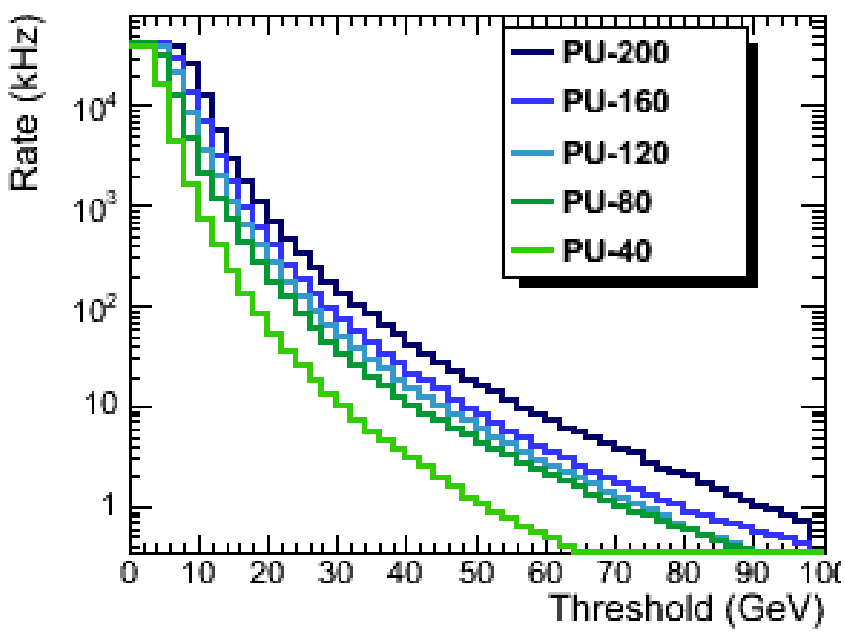




- This is non isolated Egamma
- Rate increases drastically in higher luminosity
- E/(E+H) cut is affected by PU (HCAL fraction increases)

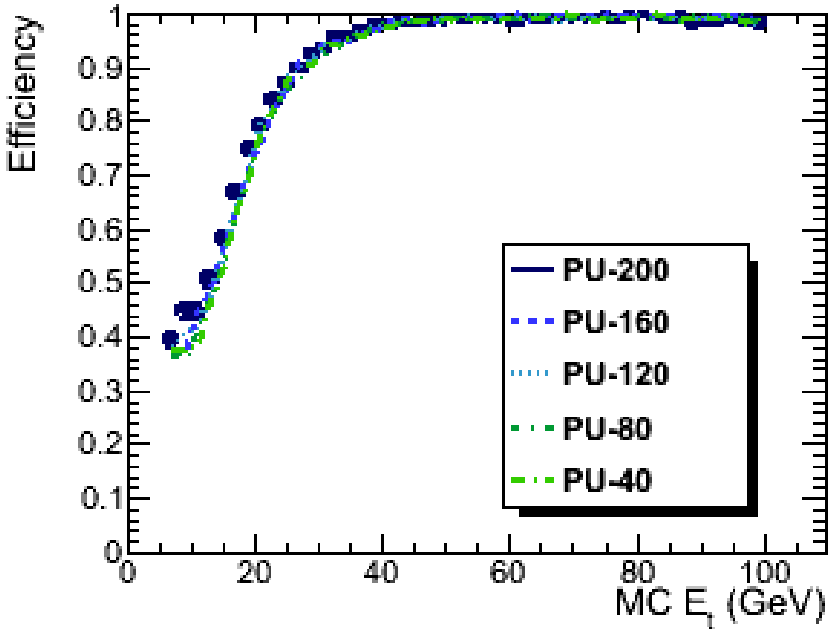
Isolated EGamma Performance

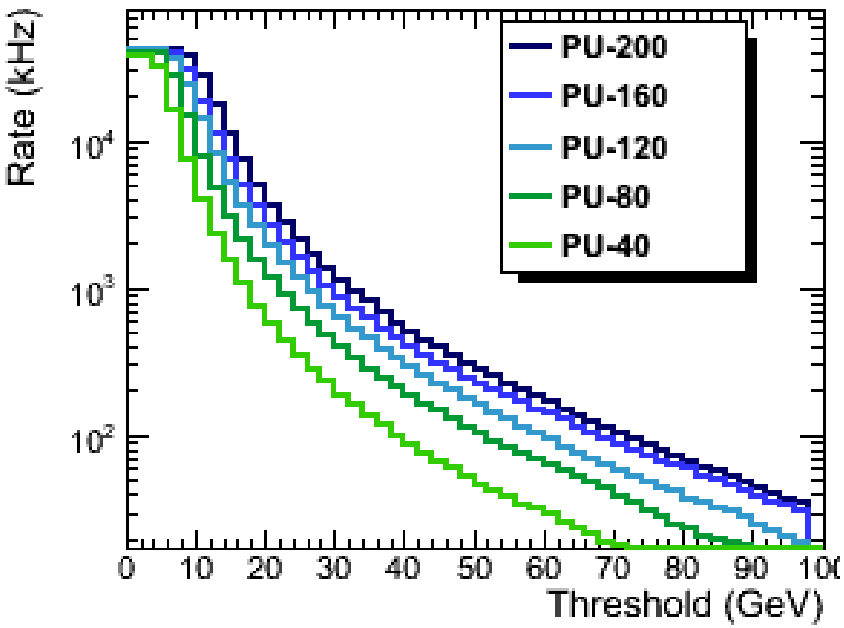




- Factor 0f 2 to 3 rate reduction by isolation
- Isolation performance drops ta very high PU

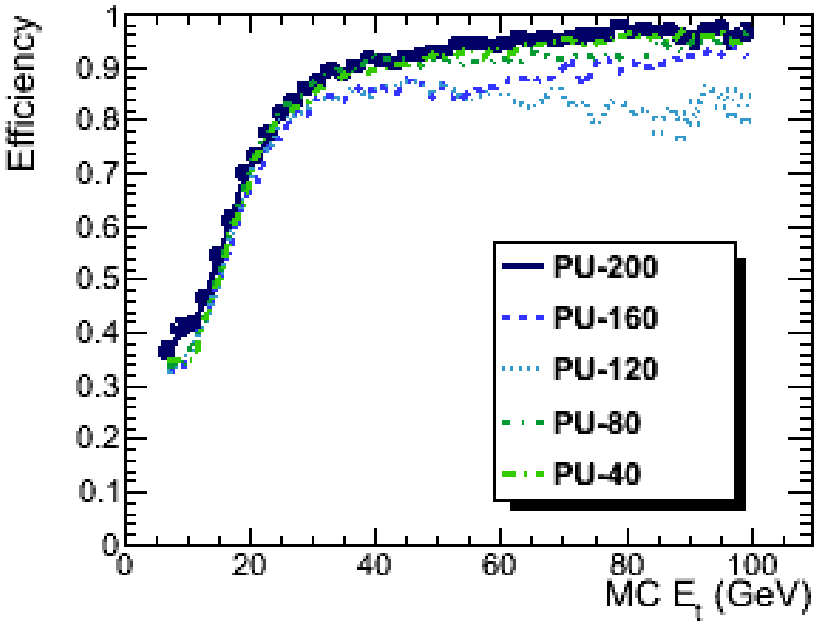
Tau performance

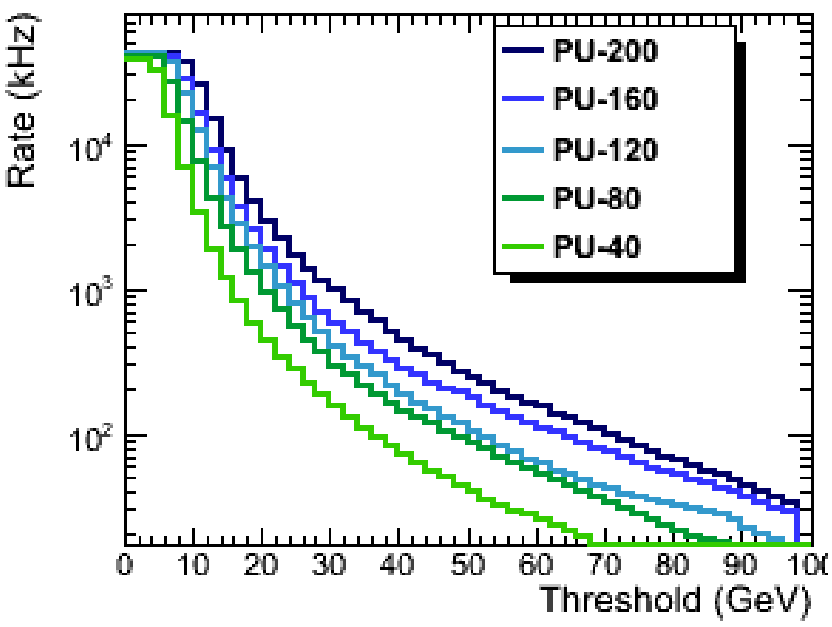




- Nice turn on curve for non isolated taus
- Single tau rate is high(it is even high in the low lumi menus)
  - Single tau trigger only usefull for heavy Charged Higgs
    - High threshold
  - Lepton +Tau triggers more useful

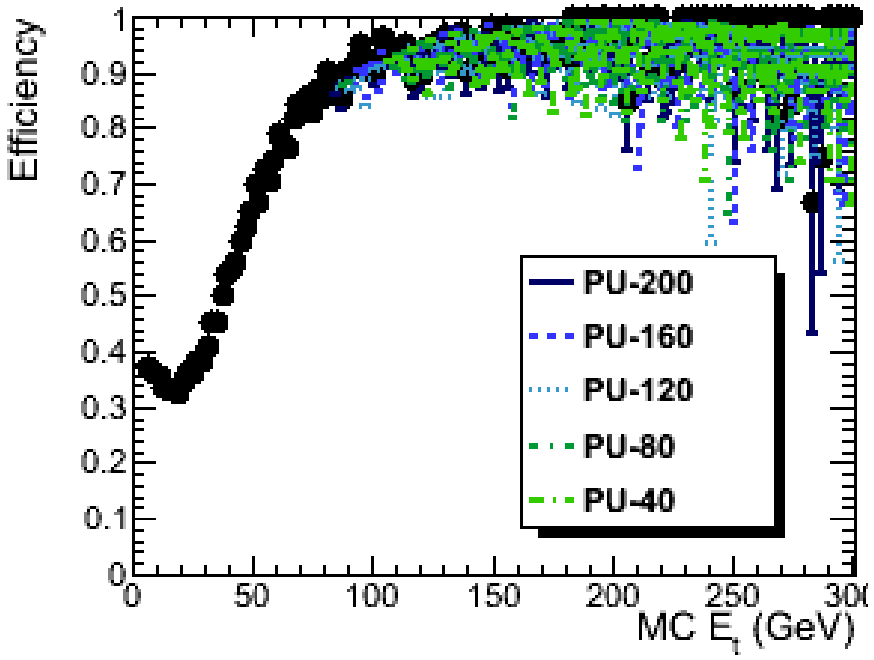
Isolated Tau Performance

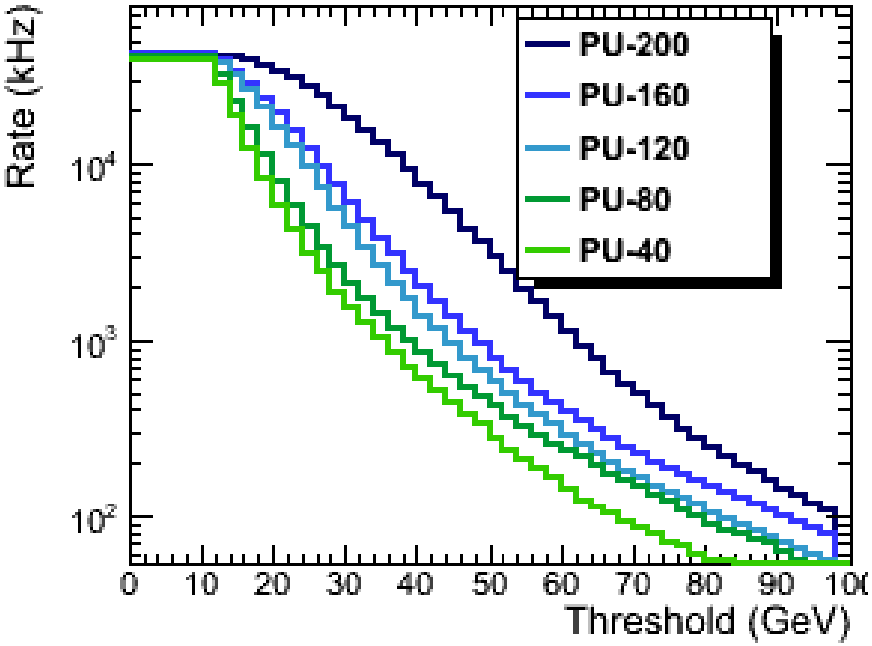




- Rate can be reduced by isolation for a loss of ~10% in efficiency
  - At 40 PU single tau can have a threshold of 70 GeV @ ~10KHz
  - Not bad for heavy H->taunu

Jet Performance





- Jets sensitive to very high PU
- Single jet threshold > 100 GeV [uncorrected]

Conclusions, Plans & Issues

Initial set of algorithms chosen work

- Meet rate limitation to tolerate factor of 2 increase in luminosity with sufficient efficiency for objects of interest
  - Additional handle at GT with better position of objects
- Calorimetric isolation is becoming inefficient as expected
  - Track matching and isolation are needed at >2x luminosity

Plans

- Complete algorithm development (MET …)
- Continue to work with FPGA firmware evaluators
- Integrate with system design

Issues

- Limited manpower (Kevin Flood left CMS, Mike Bachtis is busy with LHC/RCT, Ian Ross is busy with coursework, exams …)
- Need some support at the level of 50% for Postdoc or student