



τ , Jet, Missing E_T Simulation

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Algorithms Description

- τ , Jet, Missing E_T

Rates and Efficiency turn-on

- 95% efficiency point
- Improving the turn-on

Physics Efficiencies

- How do we save SUSY H(200 GeV) decays to 2 hadronically decaying τ particles?

HF-Trigger Mapping

- 20° sectors in ϕ for missing E_T
- Jet counting in HF



Generator level jet rate

"Perfect" calorimeter and "perfect" trigger and no pileup @ 10^{34}

- All generator level stable particles other than muons and neutrinos are used to find jets using LUCCLUS algorithm.

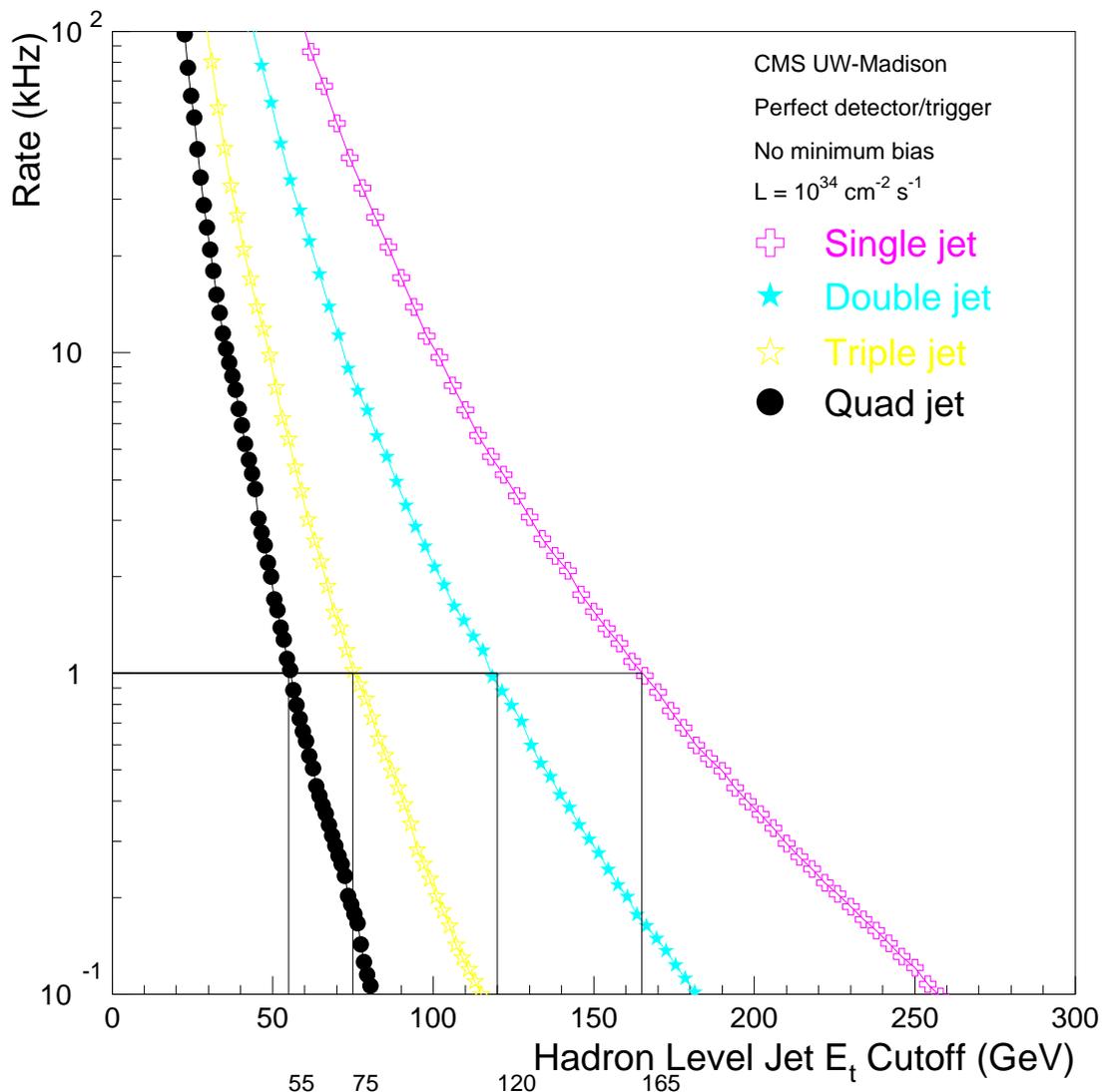
Bandwidth

- Level-1 output target for jets is about 3 kHz.
- Rate to tape is 100 Hz.

What is a reasonable target for jet threshold?

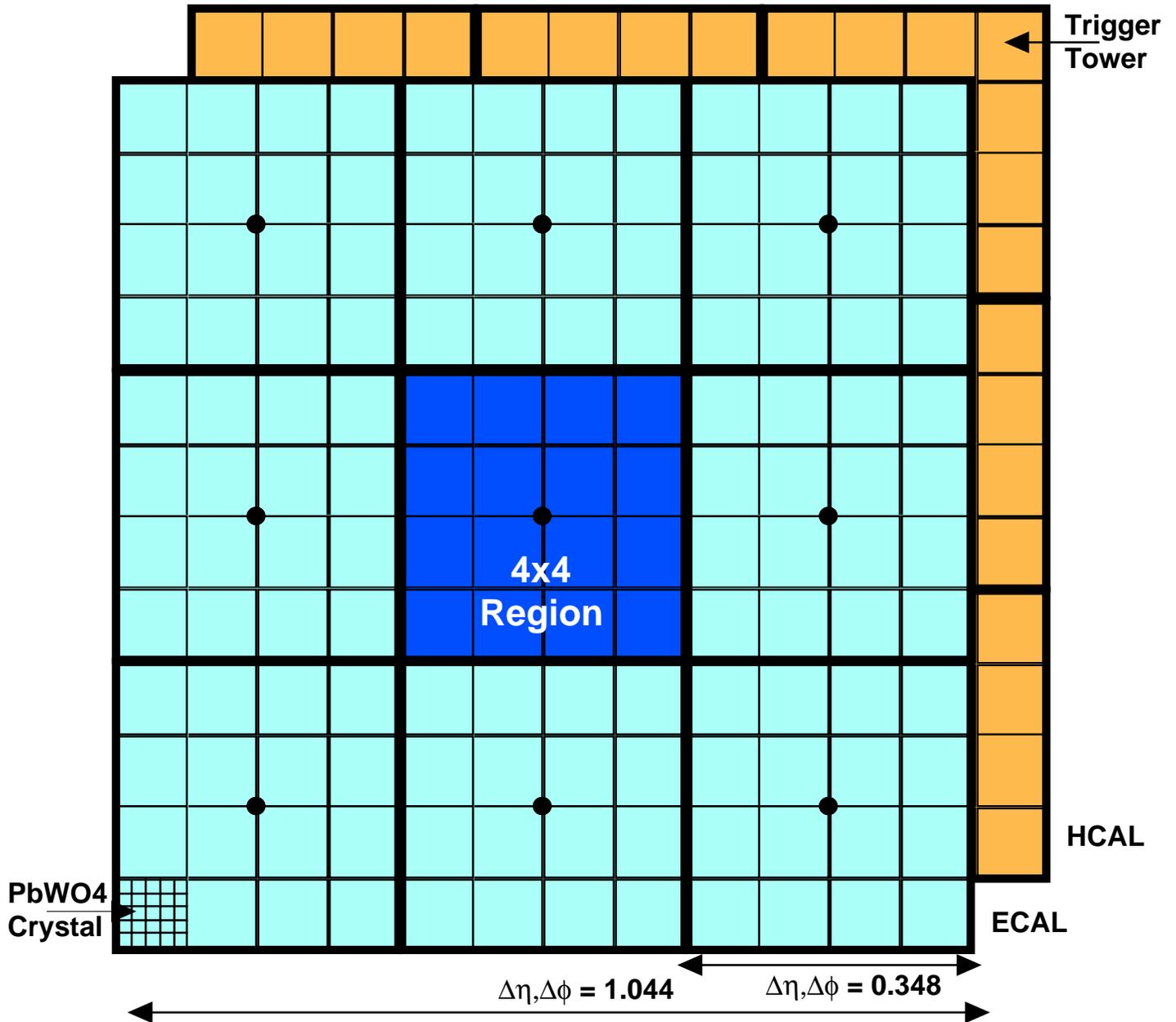
- Single jet threshold > 165 GeV
- Double jet threshold > 120 GeV

QCD jet rate - Generator level





Jet / Missing E_T algorithms



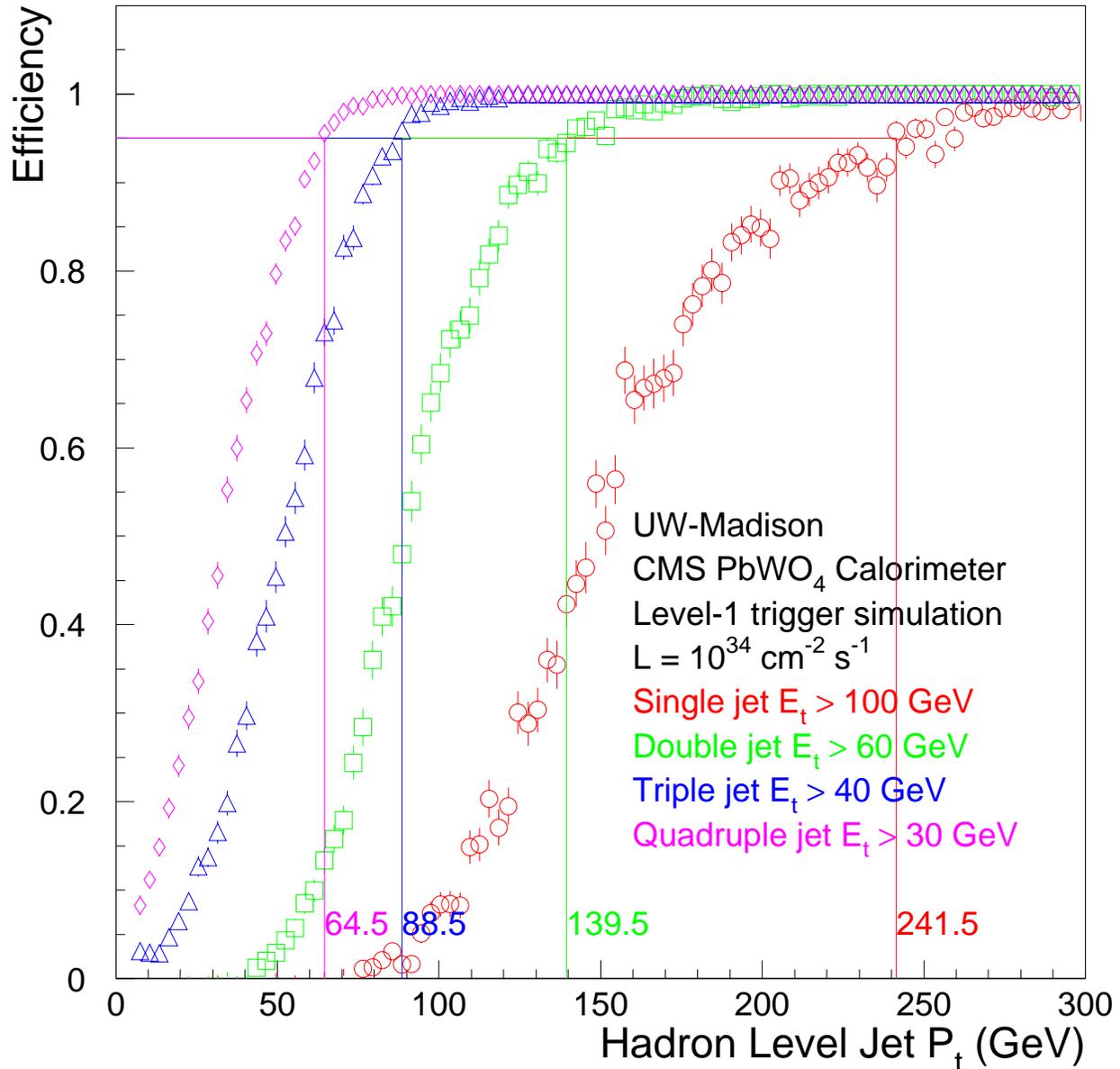
Baseline Algorithm

- Jet E_T is given by the sum of ECAL and HCAL trigger tower E_T in a non-overlapping 4x4 region
- Jet candidates are sorted to find highest energy jets
- Count 4x4 regions above threshold (Ability to handle high jet multiplicity)
- Missing E_T
 - 4x4 E_T is converted to E_X and E_Y using LUT and added over all η .



Jet trigger efficiency

QCD jet efficiency - 4x4 algorithm



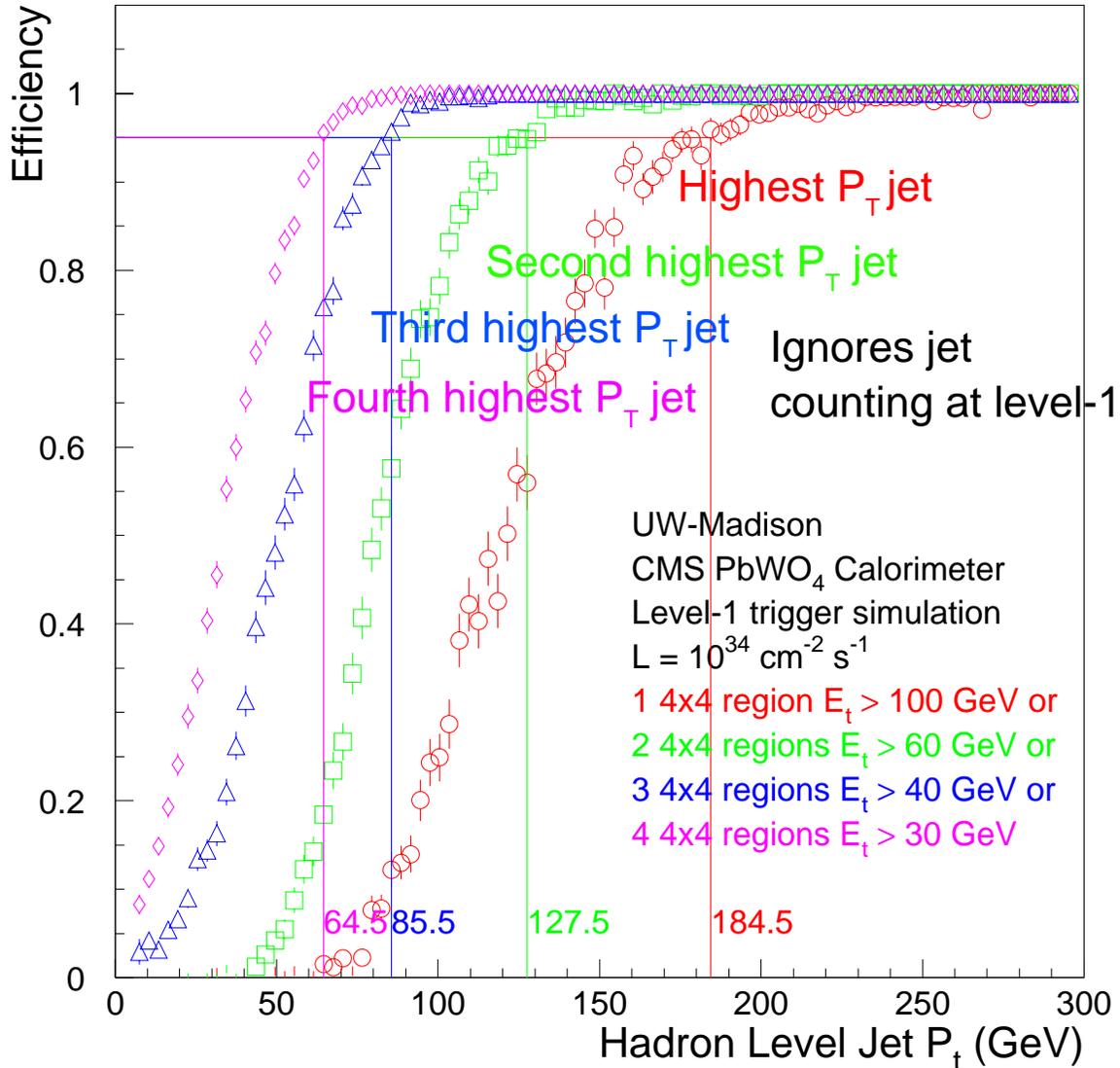
Efficiency for single, double, triple and quadruple jet triggers is plotted versus generated hadron level jet P_T

For multi-jet triggers cuts are cumulative, i.e., double jet trigger cuts are one 4x4 jet region > 100 or two 4x4 jet regions above 60 GeV. It plotted versus smallest of the hadron level jets P_T

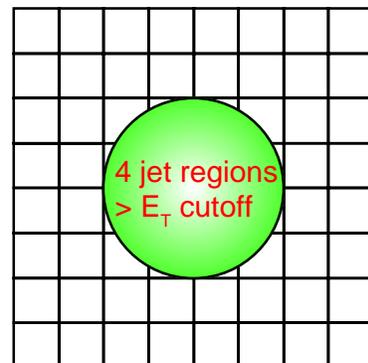
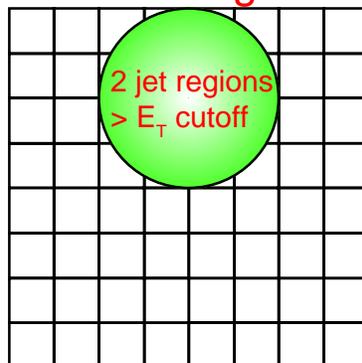
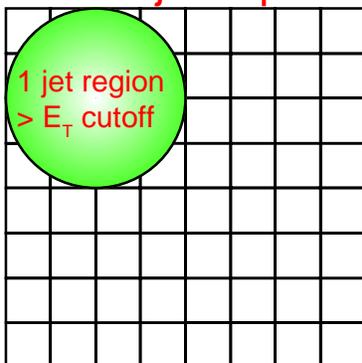


Combined jet trigger efficiency

QCD jet efficiency - 4x4 algorithm (all four jet cuts)



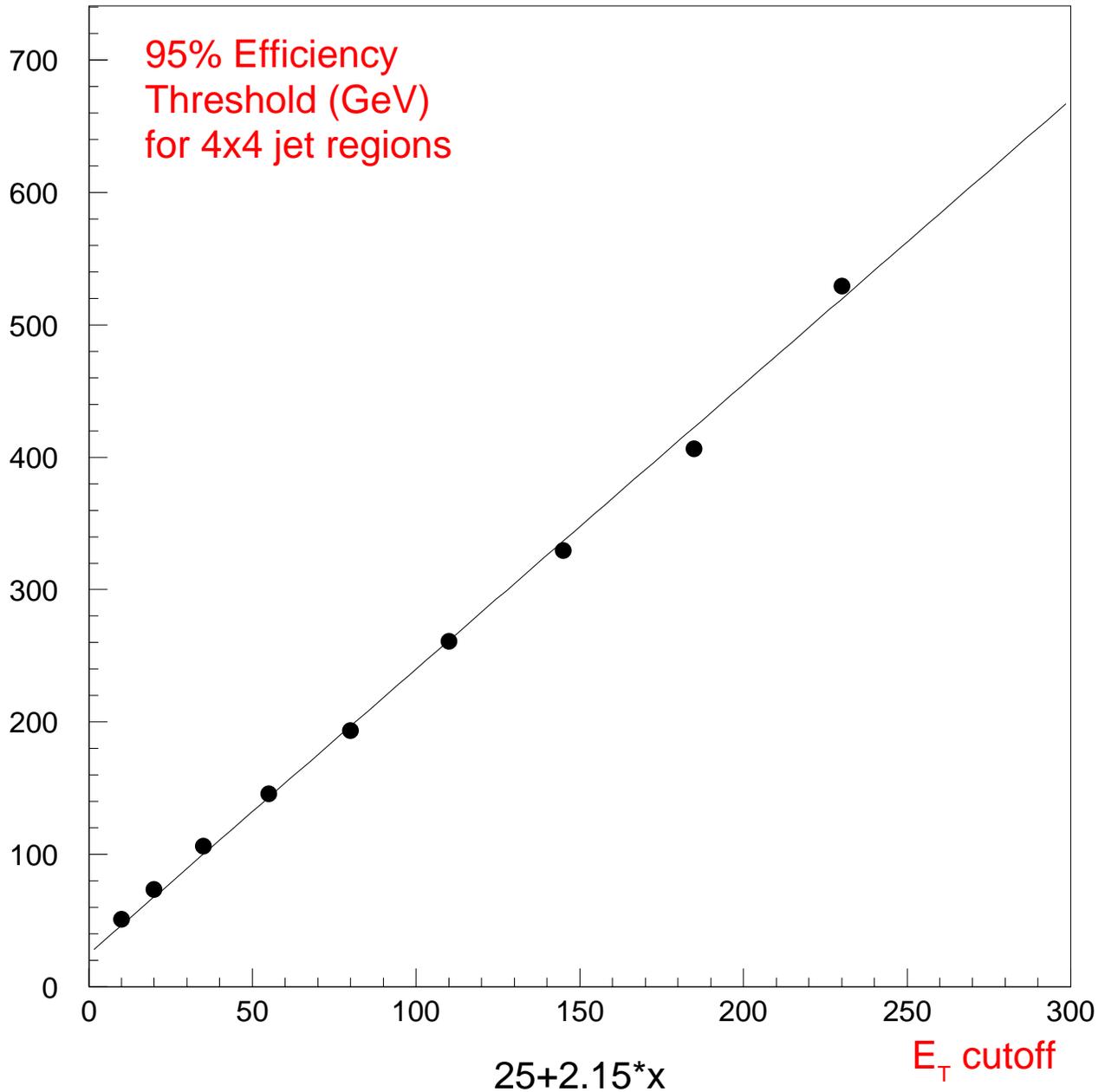
Combined jet trigger efficiency : Multi-jet trigger helps recover jets split between 4x4 regions.





4x4 Jet calibration

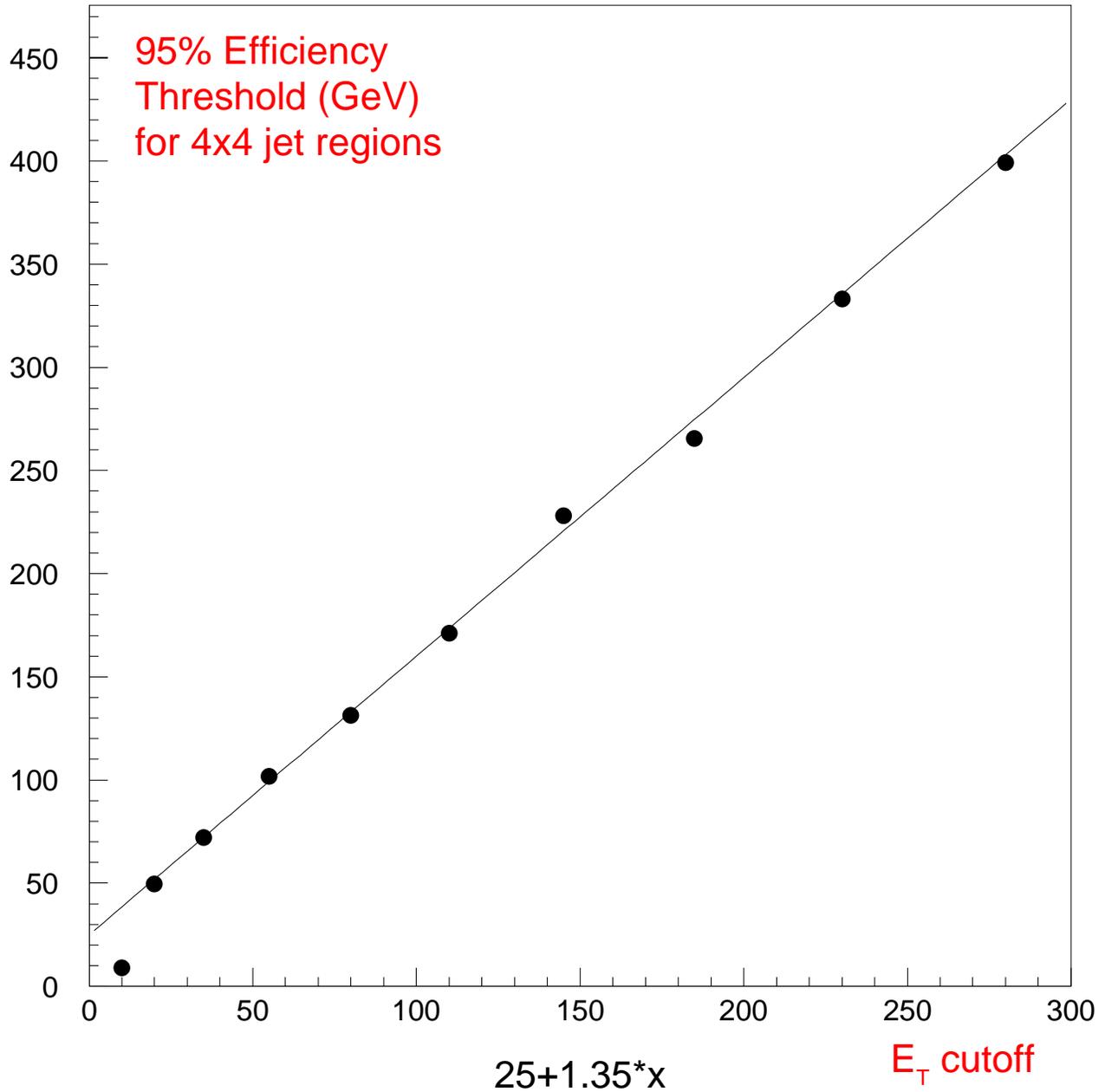
(individual 1,2,3 and 4 jet triggers)





4x4 Jet calibration

(combined 1, 2, 3 and 4 jet triggers)

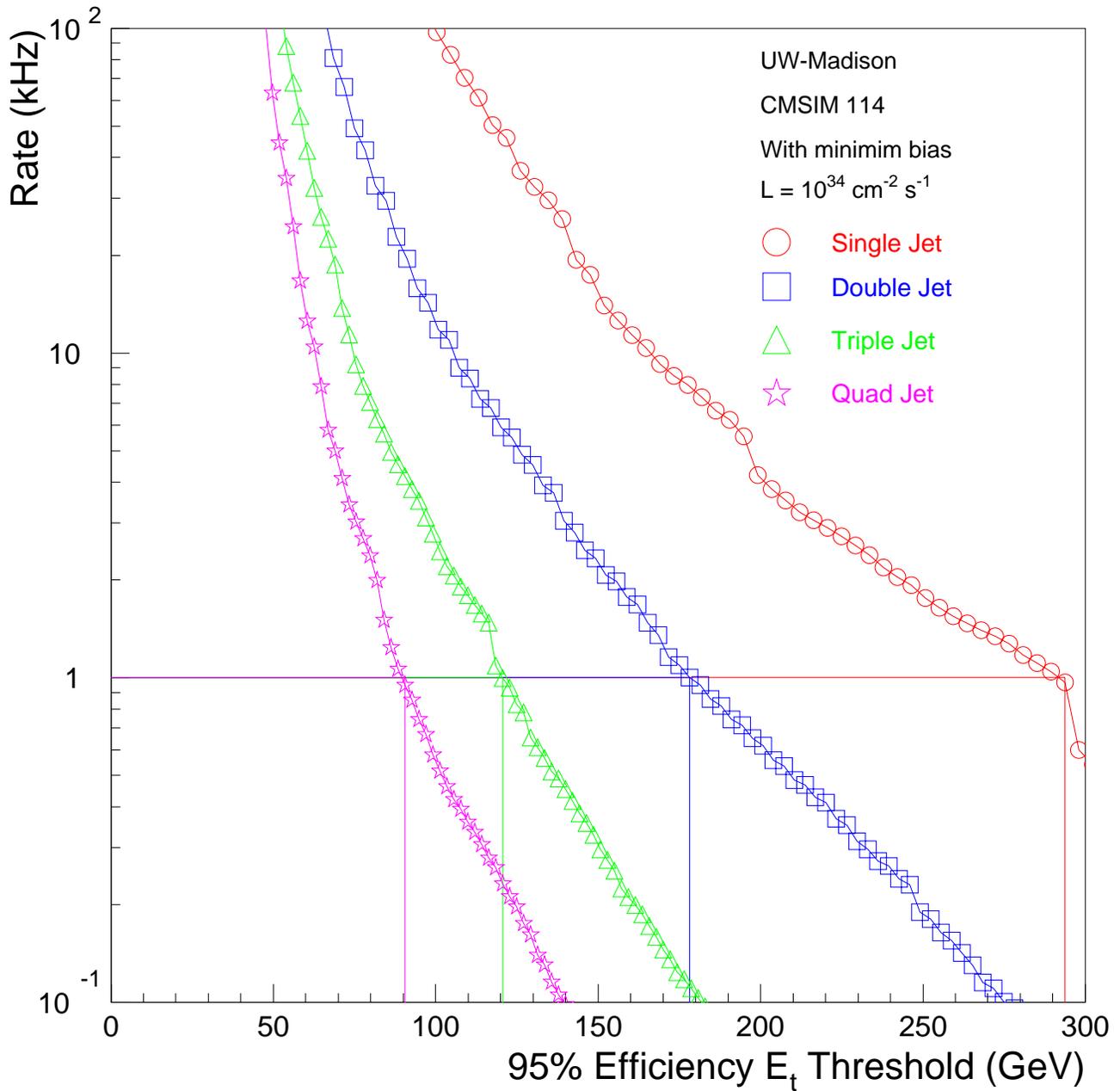




4x4 Jet trigger rate

(individual 1,2,3 and 4 jet triggers)

4x4 Jet trigger rate (separate cuts)

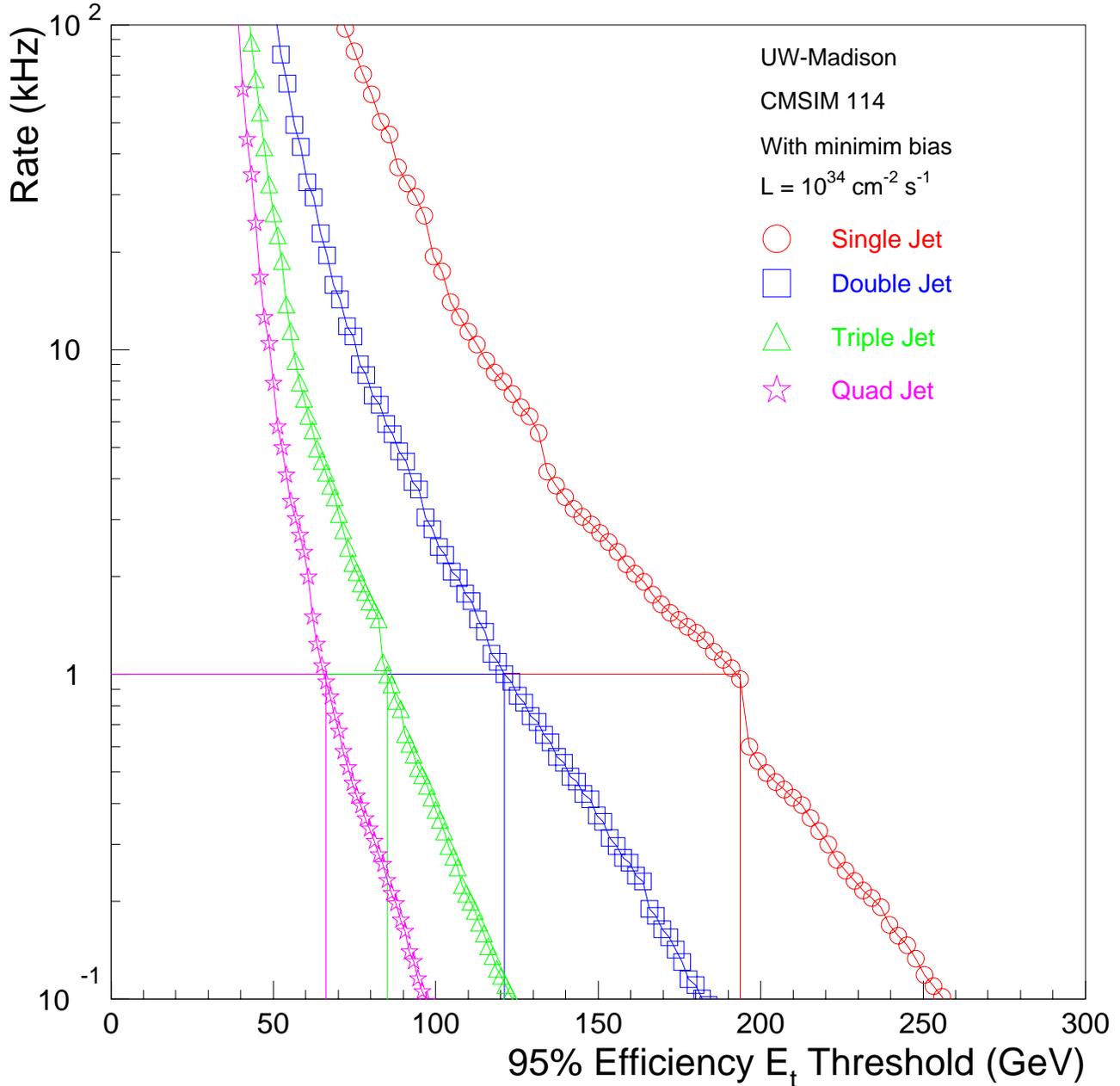




4x4 Jet trigger rate

(combined 1, 2, 3 and 4 jet triggers)

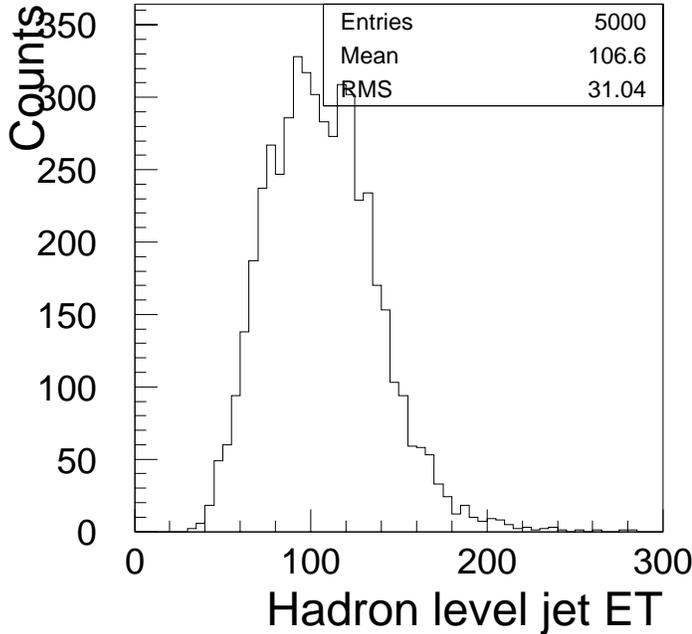
4x4 Jet trigger rate (all cuts)



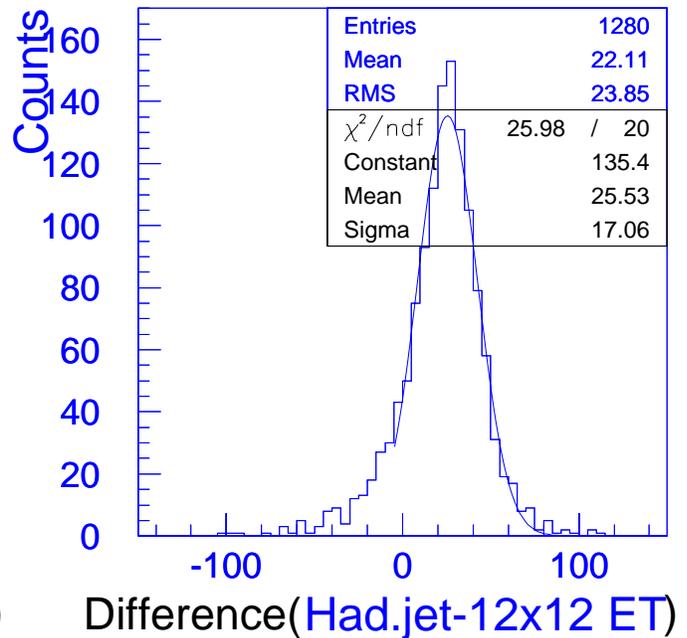
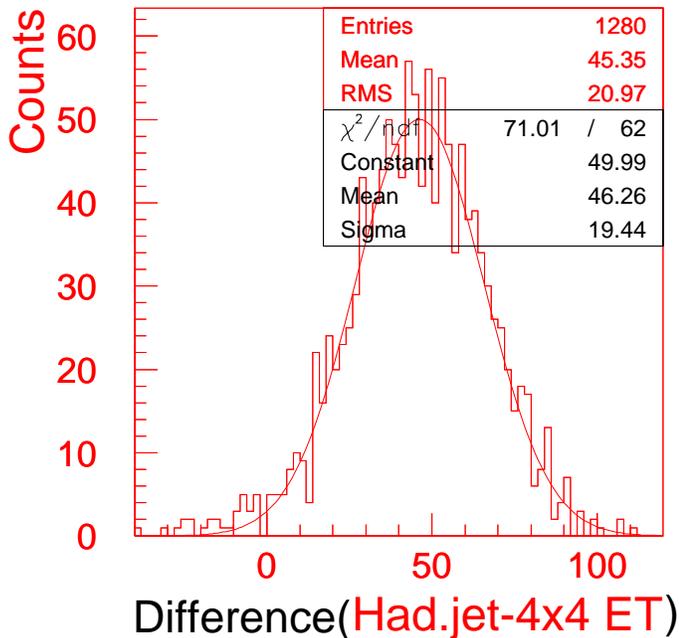


Comparison to 12x12 Algorithm

Jet Energy Resolution



For 10% around mean,
ET difference of
highest hadron level jet and
highest non-overlapping 4x4 sum
or highest overlapping 12x12 sum
is histogrammed and fitted
with gaussian



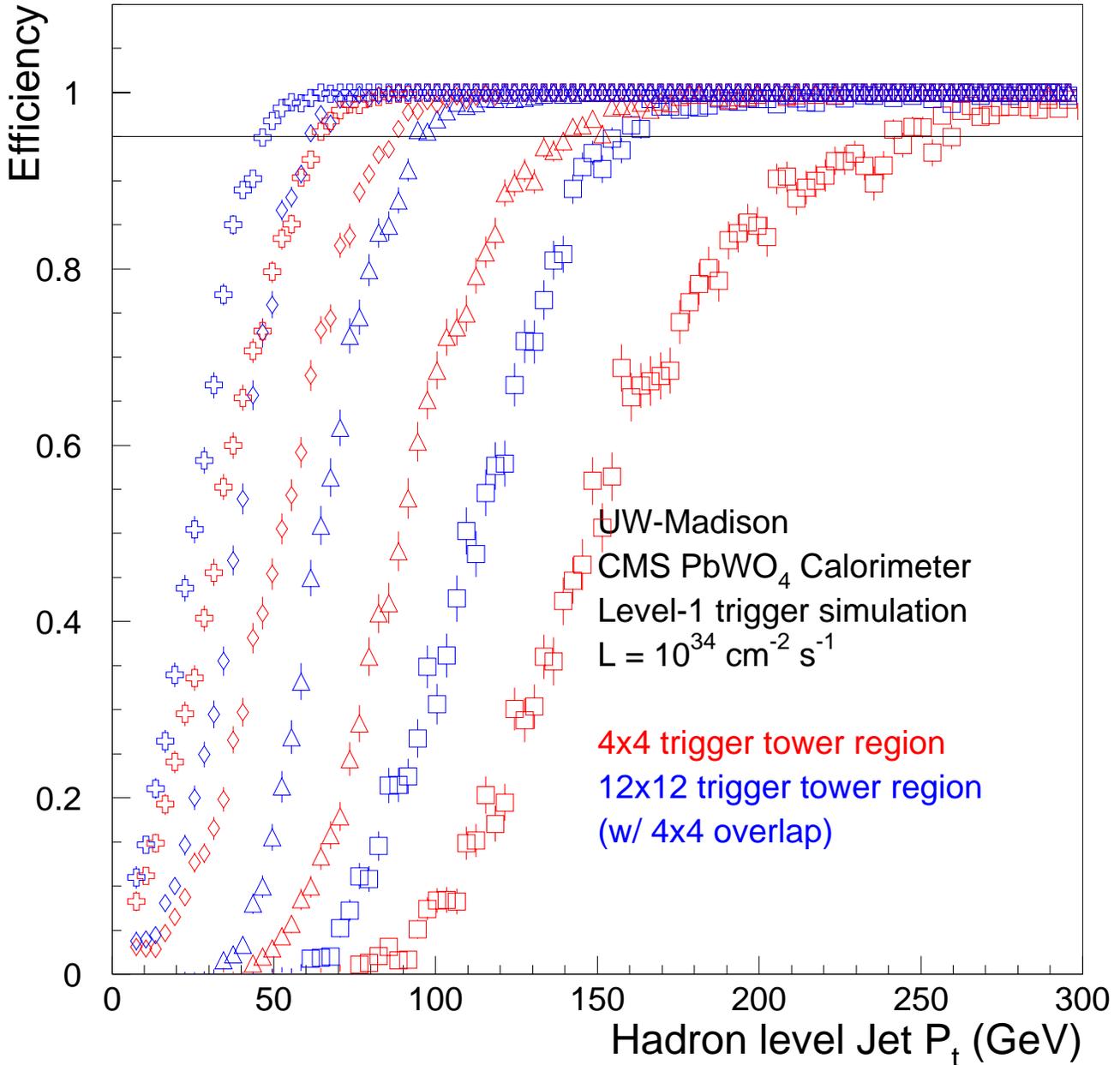
Level-1 jet energies compared to hadron level jets

- Not all energy is collected in the 4x4 jet region
- Some improvement in resolution due to 12x12 overlaps



Comparison to 12x12 Algorithm

Jet Efficiency Comparison



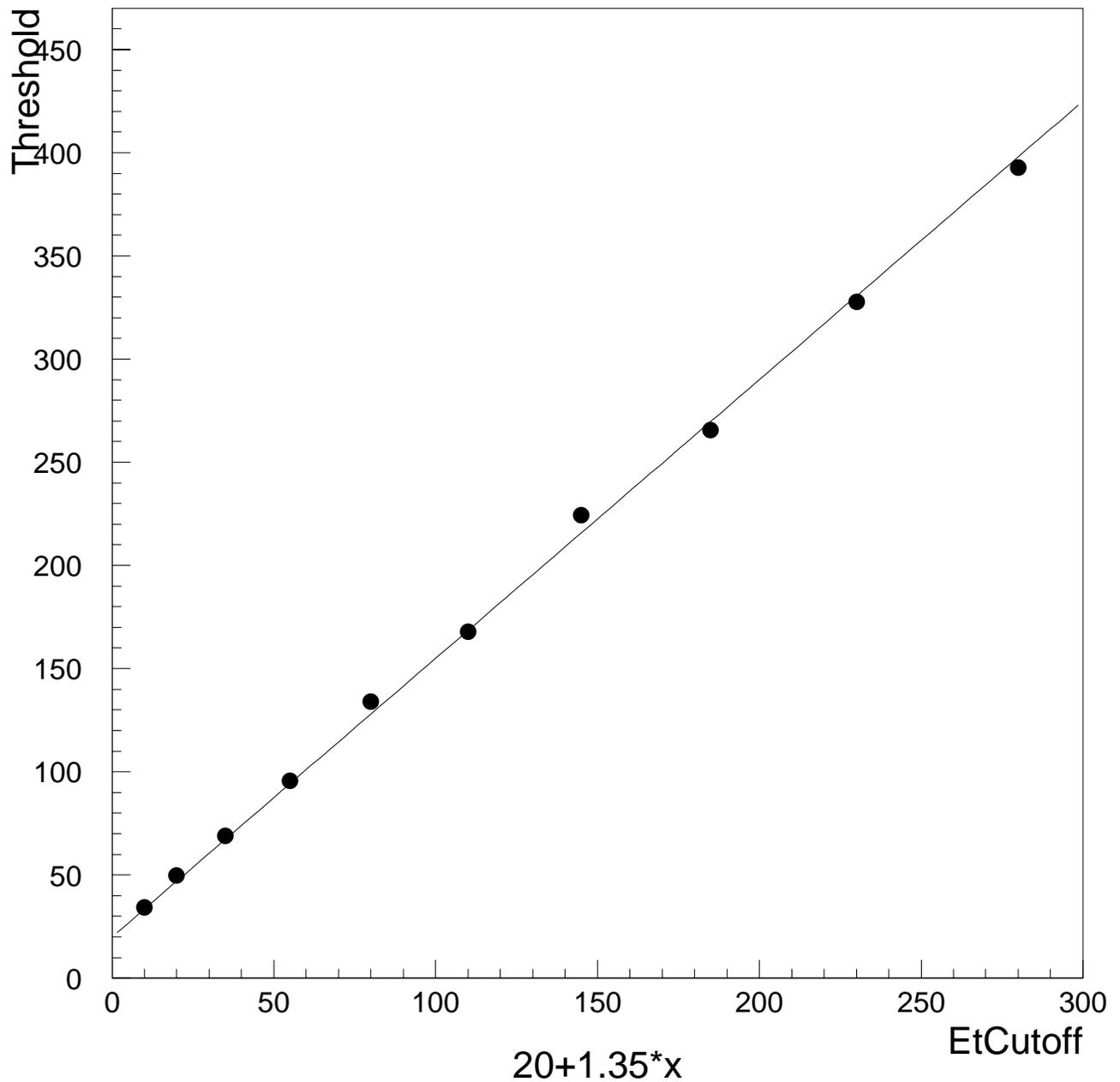
Efficiency turn-on for 12x12 algorithm is sharper than that for 4x4 algorithm.



12x12 Jet calibration

(individual 1,2,3 and 4 jet triggers)

12x12 jet calibration

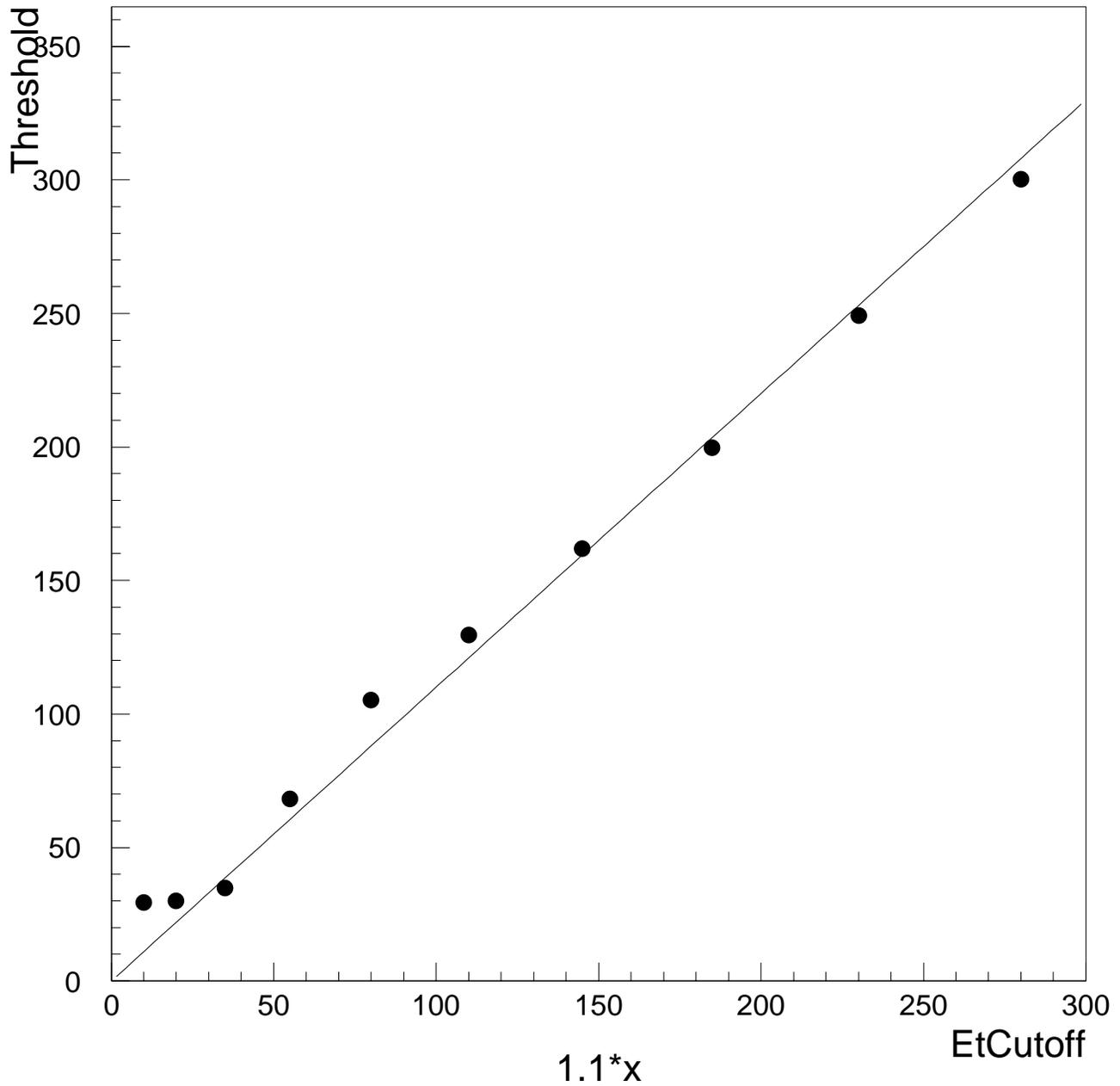




12x12 Jet calibration

(combined 1, 2, 3 and 4 jet triggers)

12x12 jet calibration

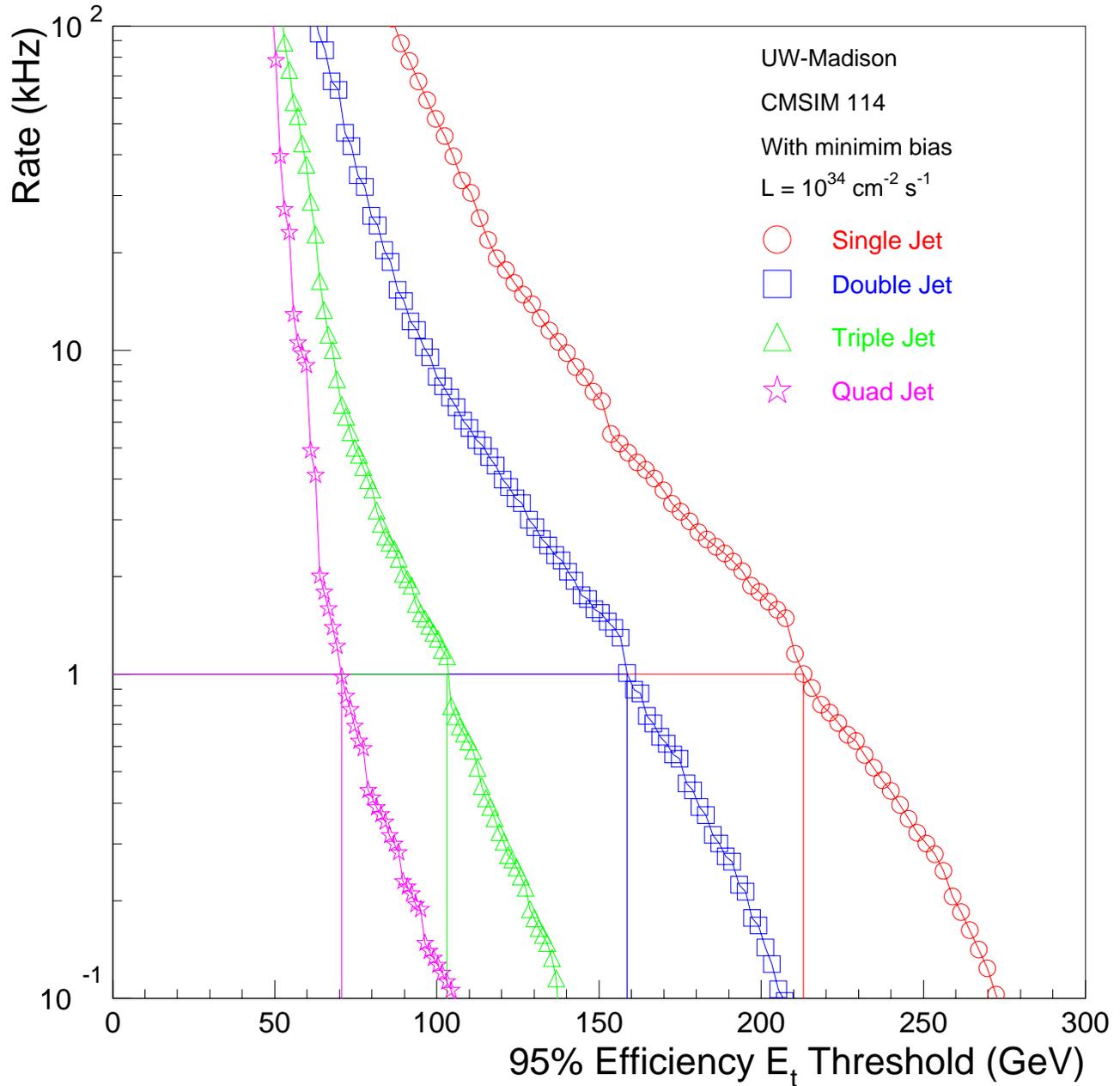




12x12 Jet trigger rate

(individual 1,2,3 and 4 jet triggers)

12x12 Jet Trigger rate with jet counting

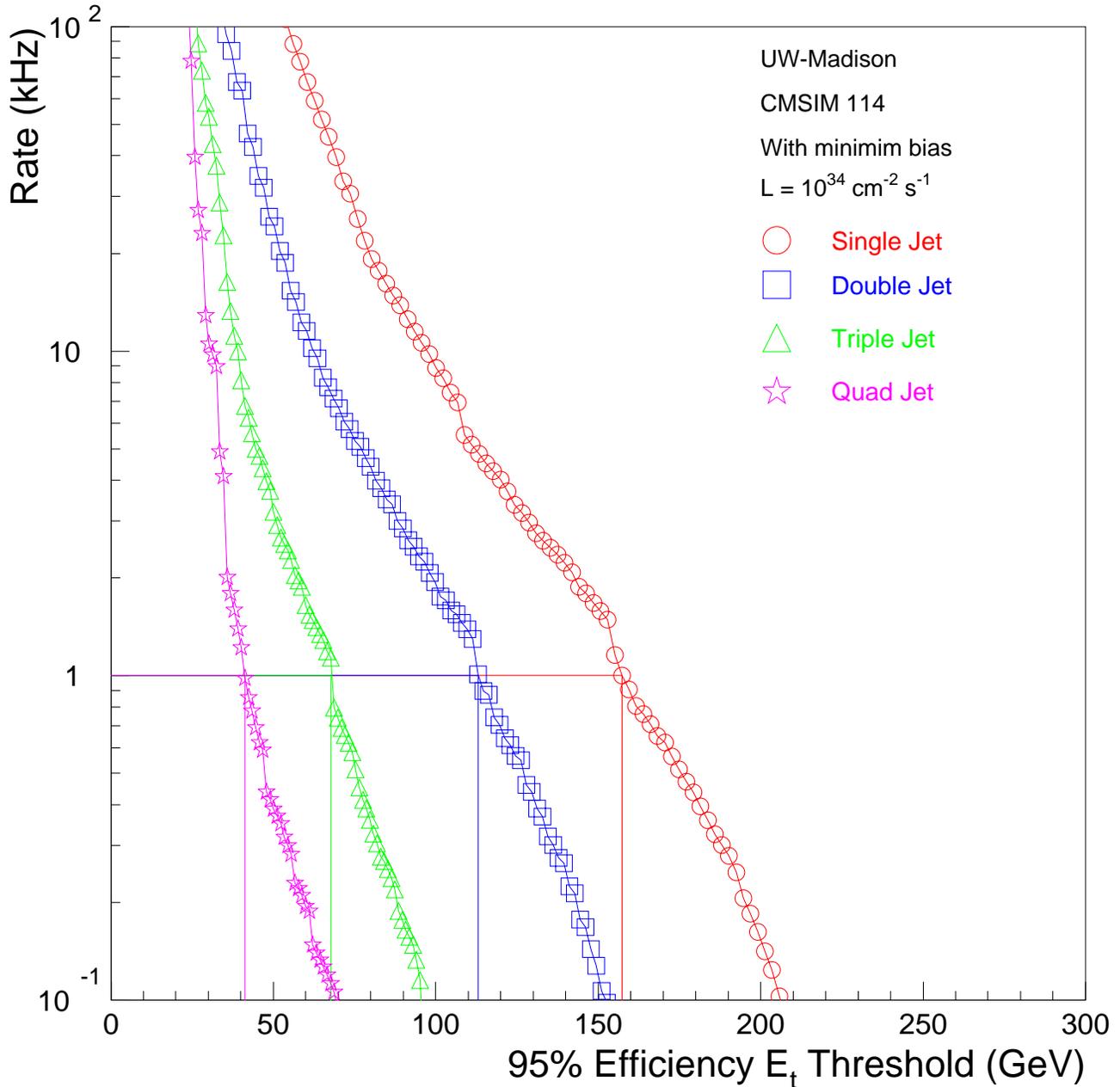




12x12 Jet trigger rate

(combined 1, 2, 3 and 4 jet triggers)

12x12 Jet trigger rate without jet counting





Comparison Summary

Generator vs 12x12 vs 4x4

1 kHz rate thresholds (GeV)	Single	Double	Triple	Quadruple
Generator level (100% efficiency)	165	120	75	55
12x12 individual triggers (95% efficiency)	212	158	103	70
4x4 individual triggers (95% efficiency)	295	177	120	90
12x12 combined triggers (95% efficiency)	157	112	67	40
4x4 combined triggers (95% efficiency)	192	120	85	67

Generator level

- Hadron level jet finder LUCCLUS
- No minimum bias

4x4 Algorithm

- Fixed windows
- Minimum bias included

12x12 Algorithm

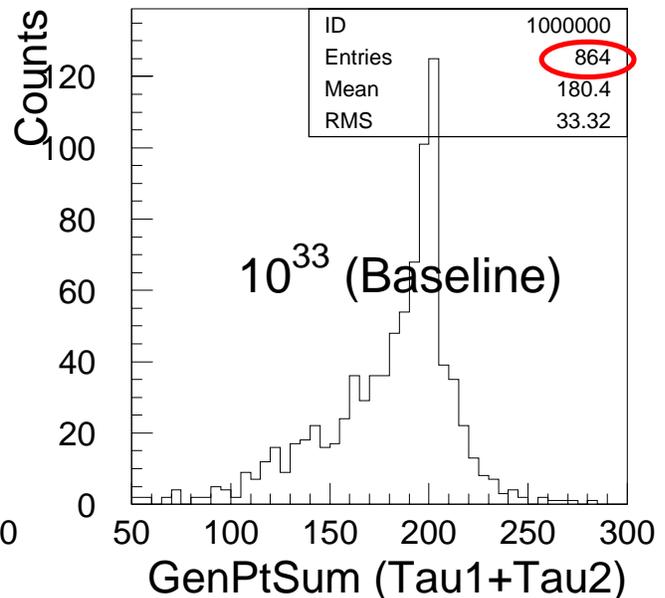
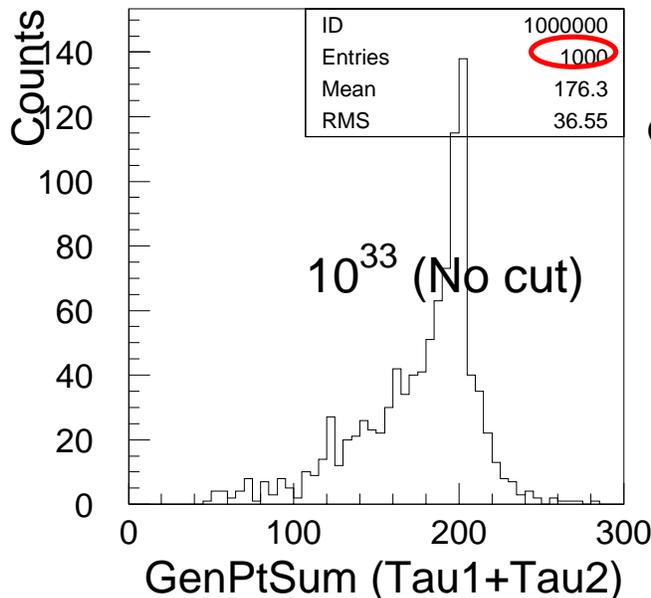
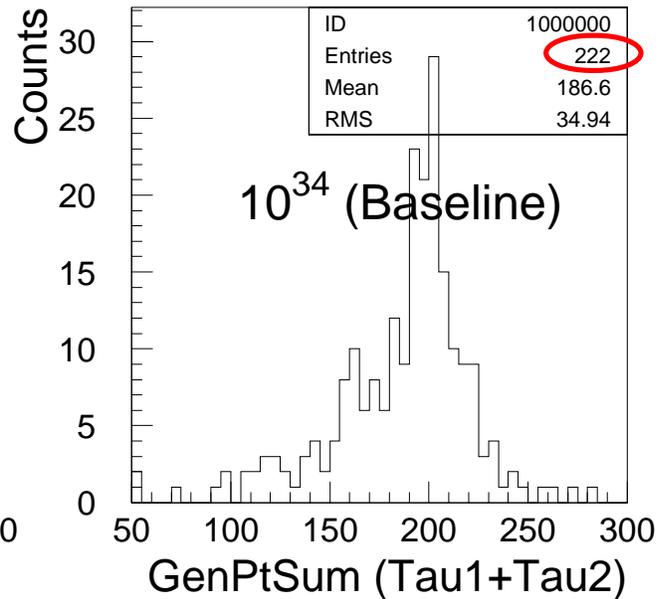
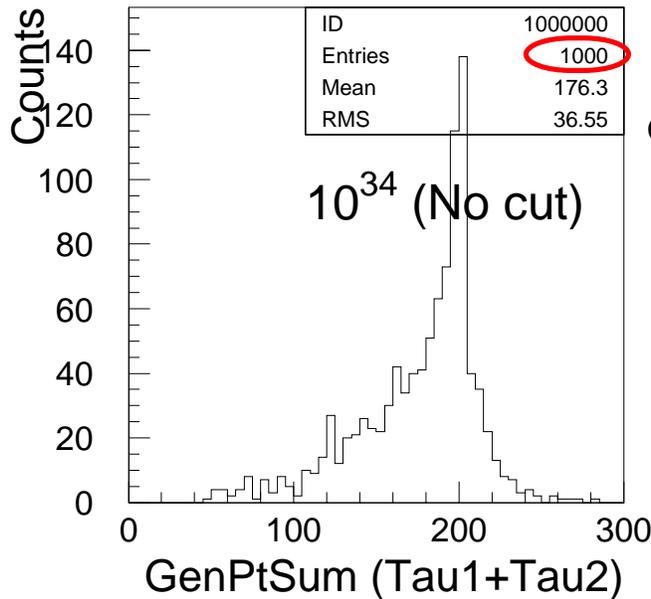
- Windows sliding in 4x4 steps
- Minimum bias included



SUSY H(200 GeV) tau decays

tau decays into hadrons

Baseline efficiency for susyham200t15 at 10^{34} , 10^{33}

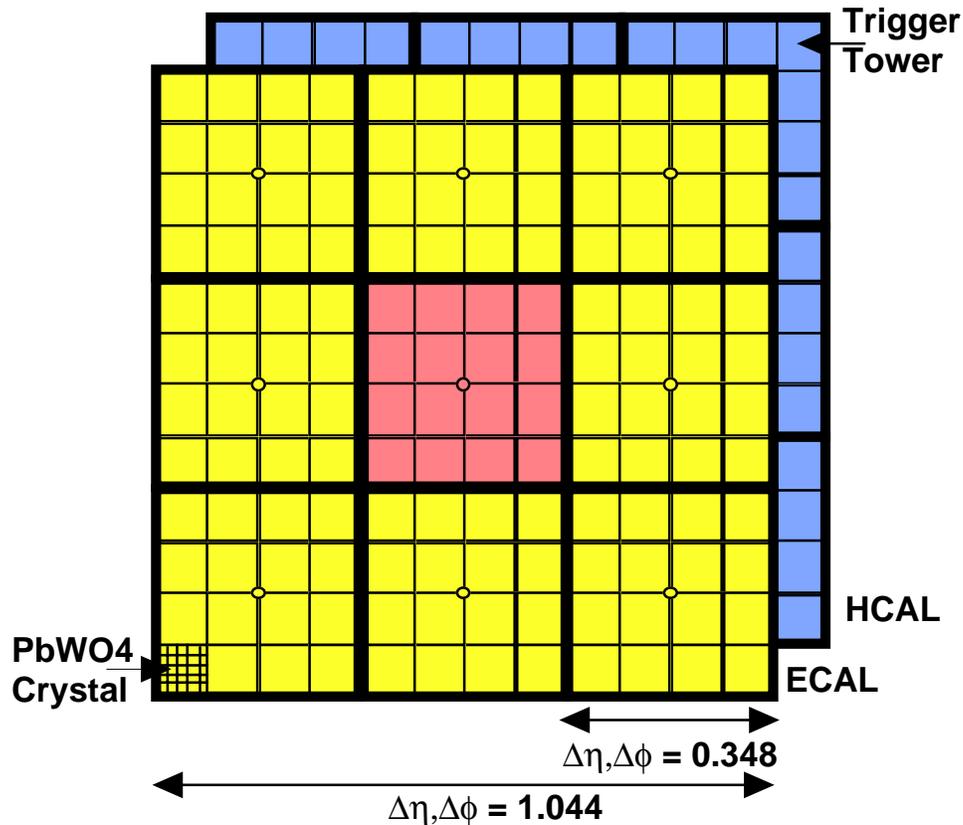


Baseline algorithm

- Efficiency due to 1, 2, 3 and 4 jet + other triggers
- Agrees with my old and Sasha's ORCA results



New τ , jet, E_T algorithms



Primitives

- 4x4 E_T sums of ECAL and HCAL trigger towers
- τ veto bit set if number of active ECAL and HCAL trigger towers in 4x4 region ($E_T^{ECAL} > 2$ GeV or $E_T^{HCAL} > 4$ GeV) is greater than 2

Jet Algorithm (sliding window of 4x4)

- Jet E_T is given by the sum of 12x12 trigger towers overlapping sliding steps of 4x4 with the requirement that central 4x4 is greater than neighbors
- Jet candidates are sorted to find highest energy jets
- Count 4x4 regions above threshold (Handle high jet multiplicity)

τ Algorithm (sliding window of 4x4)

- τ E_T is same as Jet E_T
- τ veto bit should be false in all nine 4x4 regions

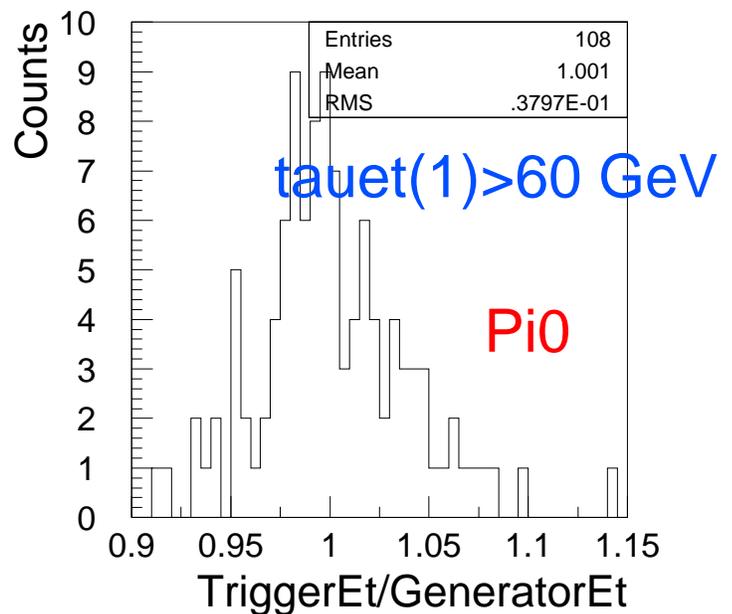
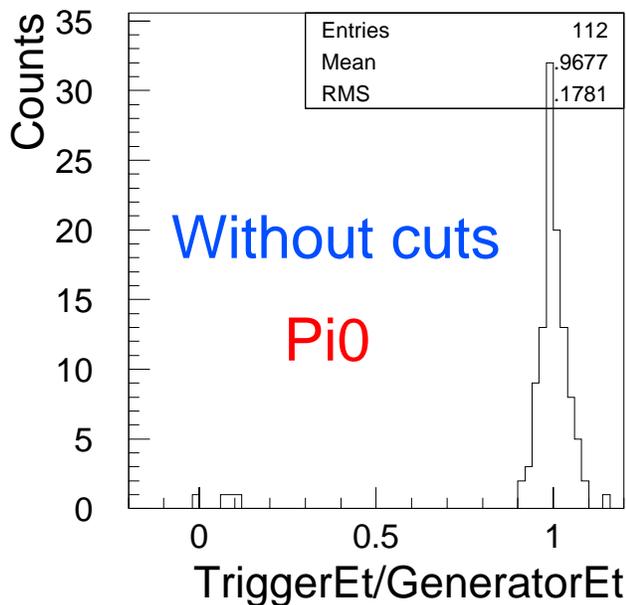
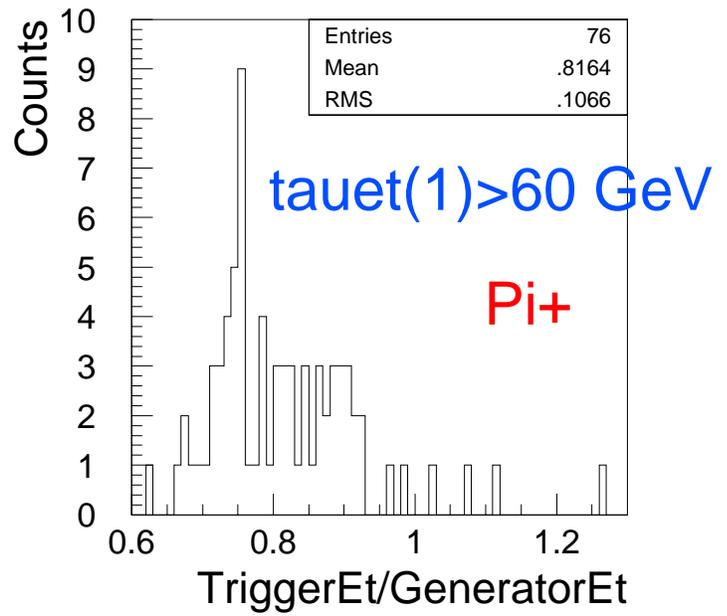
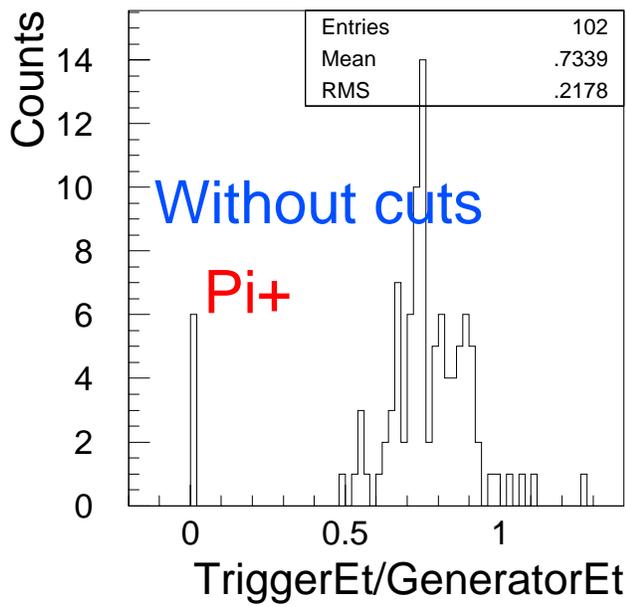
Missing E_T

- 4x4 E_T is converted to E_x and E_y using LUT and added over all η .

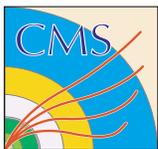


τ Trigger

Single π^+ and π^0 with minimum bias

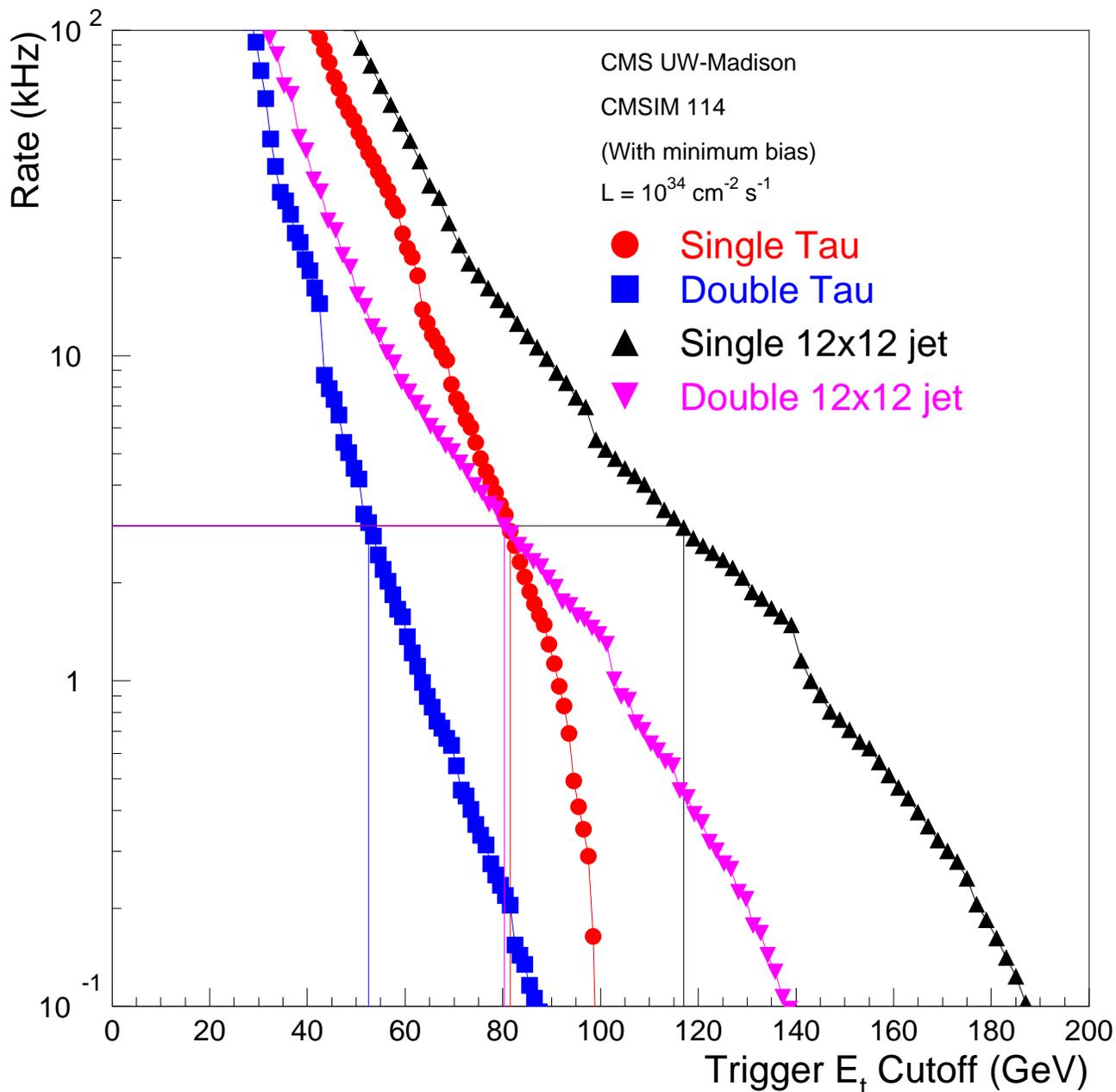


**Most of single pions (charged and neutral)
 $P_T > 80$ GeV are selected by this τ ID requirement**



τ Trigger Rate

Tau and jet trigger rates



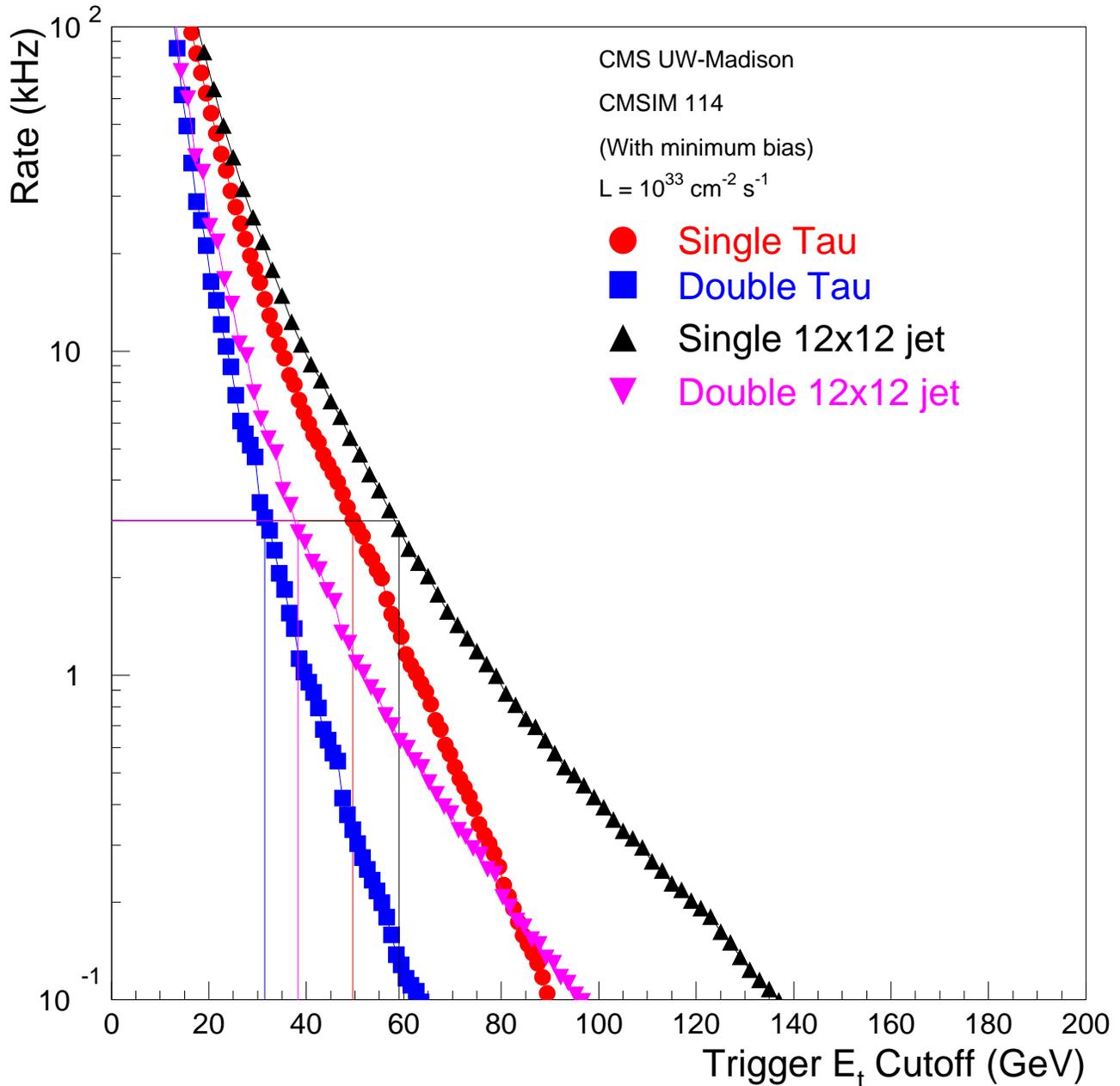
12x12 jet and τ rate comparison

- Substantial reduction in rate - not tuned yet
- All the τ energy is included in 12x12 - turn-on not effected by trigger.



Low Luminosity τ Rate

Tau and jet trigger rates



12x12 jet and τ rate comparison

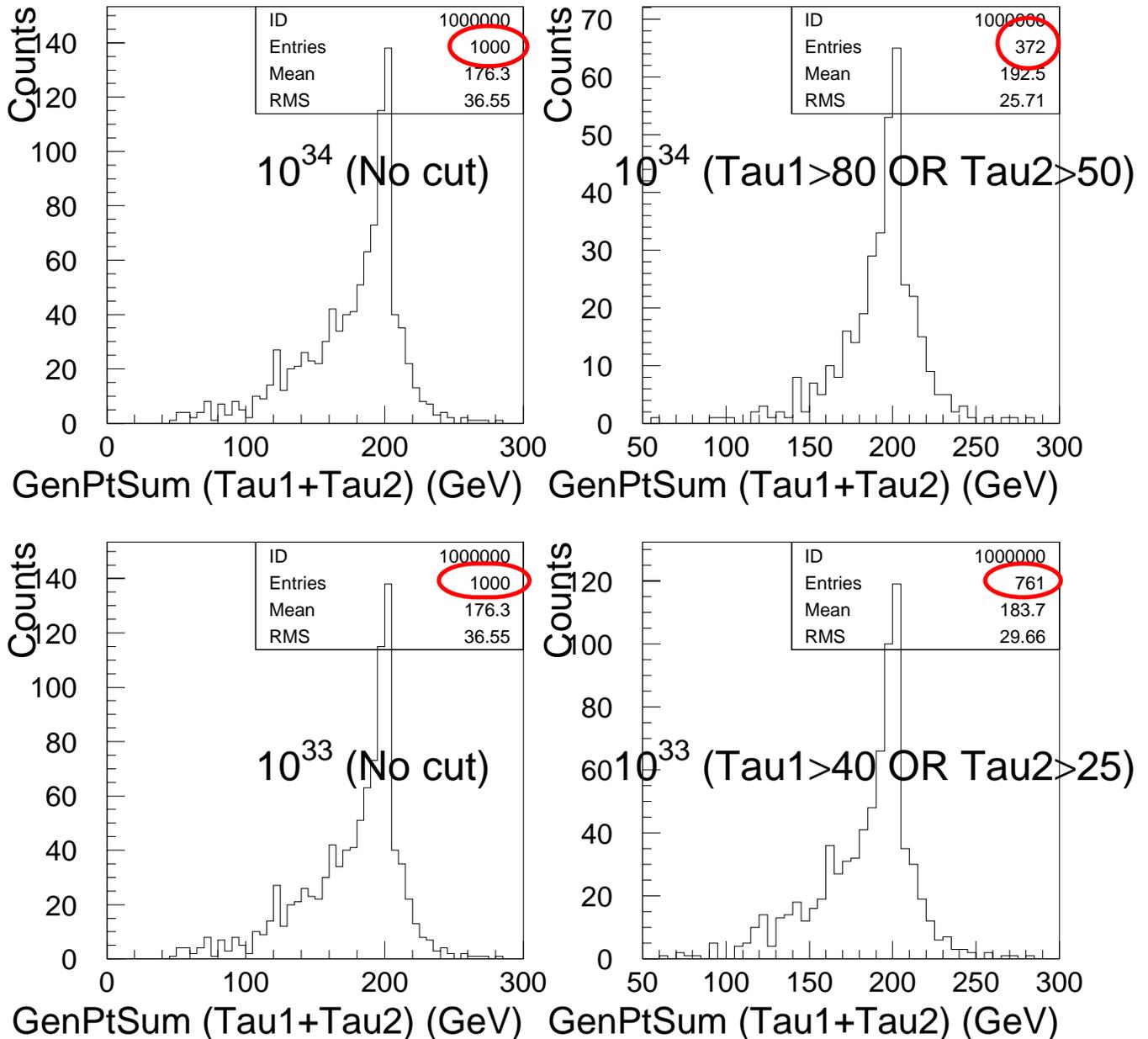
- Substantial reduction in rate
- Further tuning of cuts possible



SUSY H(200 GeV) tau decays

tau decays into hadrons

Tau trigger efficiency for susyham200t15 at 10^{34} , 10^{33}



37% efficiency in identified tau channels compared to 22% efficiency at high luminosity

- Comparable to expected offline analysis efficiency
- Cuts can be tuned further - aim for 50% efficiency, Tau1 > 70 GeV



HF Mapping and Jet Counting

HCAL group requests 20° mapping in ϕ matching with HB/HE jet segmentation

- Propose to restore descoped 20th crate
- No changes needed in trigger design itself
- Have sufficient channels to cover potential expansion to even higher η

Jet counting

- HF jets defined by tower over threshold
- Separately count $+\eta$ and $-\eta$ jets
- Jet counting also available in HB/HE in addition to top 4 ranking jets

Simulation

- HF needs to be included in level-1 trigger simulation
- Jet counting is also not implemented in level-1 trigger simulation
- Planning to have results for inclusion in draft TRIDAS TDR in May
- Help needed



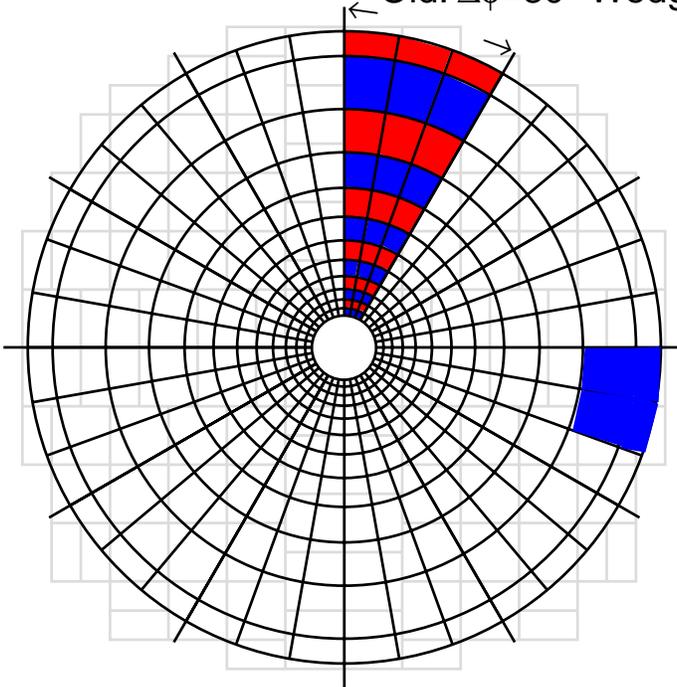
New HF-Trigger Tower Map

New: 2 CMS HF Calorimeters mapping onto 12 32-Channel Receiver Cards

Old: 2 CMS HF Calorimeters mapping onto 6 32-Channel Receiver Cards

Old: $\Delta\phi=30^\circ$ Wedge \Rightarrow half Receiver Card - 12 Channels

Each Receiver Card handles two 30° Wedges, one forward and one backward at same ϕ (using 24 out of 32 available channels)



*New: $\Delta\phi=20^\circ$ Wedge \Rightarrow quarter Receiver Card - 6 Channels
Each Receiver Card handles two 20° Wedges, one forward and one backward at same ϕ (using 12 out of 32 available channels)*

Readout segmentation: $36\phi \times 12\eta \times 2z \times 2F/B$

New Trigger Tower segmentation: $18f \times 6h \times 2F/B$

Old Trigger Tower segmentation: $12\phi \times 12\eta \times 2F/B$



Summary

Physics group requests

- SUSY Higgs (200 GeV) decays to hadronic tau modes is now considered an important channel to explore at high luminosity
- Desire to use only events passing level-1 triggers with better than 95% efficiency
- Desire NOT to use combined single, multi-jet triggers - prefer individual triggers

Considering jet/tau trigger changes

- Sharpen turn-on curve
- Identify tau like jets
- New algorithms compatible with existing designs
- Additional simulation (in ORCA?) needed to validate algorithms before detailed hardware work commences
 - Help from HLT groups will be appreciated

Additional hardware needed

- Working on conceptual design
- Looks feasible but additional work is needed to define the exact scope of these additions