Status and Plans for HLT Studies by the Jet/MET Physics Group

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http://home.fnal.gov/~sceno/jpg/Default.html

Milestone and Tasks

July'00 Milestone:

- **Demonstrate that data coming from Level-1 trigger can be reduced by a factor of ~10 using calorimeter information.**

Tasks

- **Software tools**
  - Verify ORCA4
  - Create ntuple-files
- **Understand offline performance for jet/met/tau at 10E34.**
- **Develop algorithms for Level 2 (and implement in ORCA).**

HLT algorithm

Jets

- Improve Et resolution and Et scale
  - improved jet axis with finer granularity (1x1 instead of 4x4 towers)
  - LSB: L1(Et=0.5~1.0GeV) -> L2(Et=0.2GeV)
  - energy calibration (non-linearity, pile-up energy)
- Reduce low Et fake jets due to min-bias pile-up
  - jet shape & smaller window size

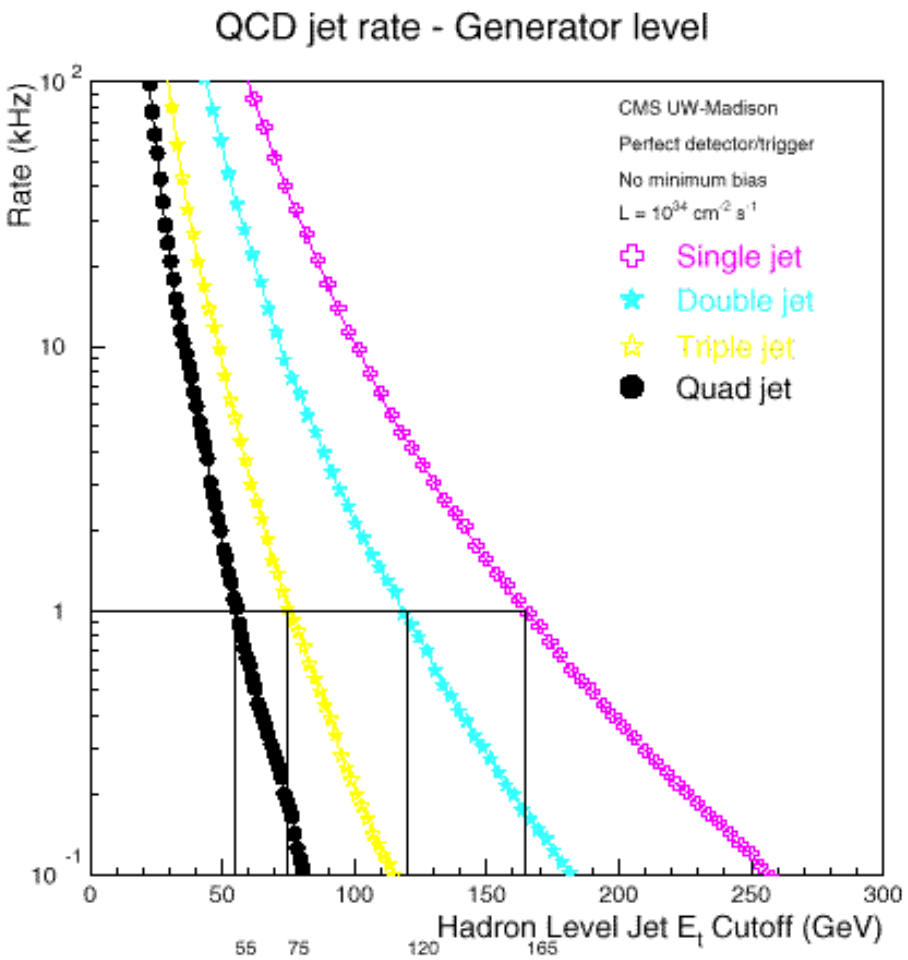
MET

- Improve resolution
  - energy calibration (non-linearity)

Tau

- improve shape cuts at L2
- use tracker information for isolated charged tracks at L3.

QCD Jet Rates



Very High rate!

1 kHz = acceptable L1 rate for jets

- **1 jet 165 GeV**
- **2 jets 120 GeV**
- **3 jets 75 GeV**
- **4 jets 55GeV**

Trigger Output (max):

- **L1 75 kHz**
  - (3 kHz for Jets)
- **L2 1 kHz**
- **L3 100 Hz (to tape)**

How to stay below 100 Hz ?

Guideline: 20Hz for Jets, MET, combination.

Low Et Physics

Draft list of processes where low Pt jet trigger could be required

#	Process	Typical physics cuts	Trigg. L1 (95% eff.?)
1	W (l ν) + H (b $\bar{b}$)	1 l (I), $E_t > 20$, $\|\eta\| < 2.5$ 2 bj, $E_t > 25$, $\|\eta\| < 2.5$ $E_t^{miss} > 20$	E > 15 or M > 15 $\|\eta\| < 2.5$ 2 J > 25 $\|\eta\| < 2.5$
2	t $\bar{t}$ (l ν +X) + H (b $\bar{b}$)	1 l (I), $E_t > 20$, $\|\eta\| < 2.5$ 4 bj + 2 j, $E_t > 25$, $\|\eta\| < 2.5$ $E_t^{miss} > 20$	E > 15 or M > 15 $\|\eta\| < 2.5$ 2 J > 25 $\|\eta\| < 2.5$
3a 3b	h,H,A (τ τ) → l + h + X + tag. jet(s)	1 l (I), $E_t > 20$, $\|\eta\| < 2.5$ 1 hj, $E_t > 40$, $\|\eta\| < 2.5$ $E_t^{miss} > 20$ 1- 2 j, $E_t > 25$, $2 < \|\eta\| < 4.5$	E > 15 or M > 15 $\|\eta\| < 2.5$ T > 40 $\|\eta\| < 2.5$ J > 25 $2 < \|\eta\| < 4.5$
4a 4b	h,H,A (τ τ) → h + h + X + tag. jet(s)	2 hj, $E_t > 60$, $\|\eta\| < 2.5$ $E_t^{miss} > 40$ 1- 2 j, $E_t > 25$, $2 < \|\eta\| < 4.5$	2T > 60 $\|\eta\| < 2.5$ J > 25 $2 < \|\eta\| < 4.5$
5	qqH → W (l ν) W (q q) + tag. jet(s)	1 l (I), $E_t > 50$, $\|\eta\| < 2.5$ 1-2 j, $E_t > 40$, $\|\eta\| < 2.5$ $E_t^{miss} > 150$ 1- 2 j, $E_t > 25$, $2 < \|\eta\| < 4.5$	E > 30 or M > 30 $\|\eta\| < 2.5$
6	t $\bar{t}$ (l ν +X)	1 l (I), $E_t > 20$, $\|\eta\| < 2.5$ 2 bj + 2 j, $E_t > 25$, $\|\eta\| < 2.5$ $E_t^{miss} > 20$	E > 15 or M > 15 $\|\eta\| < 2.5$ 2 J > 25 $\|\eta\| < 2.5$
7	q + t (l ν +X) + b	1 l (I), $E_t > 20$, $\|\eta\| < 2.5$ 1 bj, $E_t > 25$, $\|\eta\| < 2.5$ 1 j, $E_t > 25$, $2 < \|\eta\| < 4.5$ $E_t^{miss} > 20$	E > 15 or M > 15 $\|\eta\| < 2.5$ J > 25 $\|\eta\| < 2.5$ J > 25 $2 < \|\eta\| < 4.5$

Notations: l(I) - isolated lepton, bj - b-jet, hj - "tau-like-jet", j - light quark jet,
L1 trigger objects: E - isolated e/γ cluster, M - muon, J - jet, T - isolated " tau-like" cluster,
collimated in ECAL, values of Et for L1 thresholds correspond to efficiency of about 95%

Low Et Jets + others (by V.Gavrilov)

Et (jet) Threshold 25 GeV

Need estimation of physics rates.

L1 Jets/MET Trigger Table

Trigger Type	Trigger E_T Cutoff (GeV)	95% Efficiency Threshold (GeV)	90% Efficiency Threshold (GeV)	Incremental Rate (kHz)
Sum E_T	400			0.3
Missing E_T	80		200	0.9
Electron	27	35	33	5.3
Dielectron	14	22	20	1.3
Single jet	100	155	142	1.0
Dijet	60	106	100	0.7
Trijet	30	70	65	1.3
Quadjet	20	52	49	1.0
Jet + Electron	50 & 14			0.3
Cumulative Rate (kHz)	12.1			

Table 1: E_T cutoffs, 95% and 90% efficiency turn-on thresholds and incremental rate are shown for a variety of triggers at $\mathcal{L} = 10^{34}$ cm^{-2} s^{-1}.

Pure Jets trigger good for mass scale above 300-400GeV

but,

Higgs study (and others) need to cover 100-200GeV region, too.

=> How low Et can we go?

=> Need to combine with other objects (leptons, b-tag).

Software Tools (1)

CMSIM116

- GHEISHA / ECUTS=0.1MeV(em),10MeV(had)
- Geometry
  - Old eta segmentation - mismatch to EE crystals.
    - (o) 1.740-1.831-1.934-2.049-2.181-2.336-2.520-2.704-3.0
    - (n) 1.740-1.830-1.930-2.043-2.172-2.322-2.500-2.650-3.0
  - z position of Endcap: EE-HE-ME boundary
    - magnet on/off- 2.5cm shift
  - Not realistic material for cables, support structure etc. For Tracker and EE.
- No time jitter
    - TOF in 10nsec unit in Hit
    - No time jitter due to variation in clear fiber length
- HF Shower Library - small statistic

=> Need to update before next production!

Software Tools(2)

ORCA4

- **New pile up mechanism**
- **Calorimeter: restructured + bug fix**
  - Segmentation: some changes
    - **long.- 2 in HB & HE (towers 15-17 in HE added to HB)**
    - **eta - mismatch to EE crystals in eta 1.74-3.00**
    - **phi- 10 deg in eta > 1.74 (split to two for trigger tower)**
  - Readout simulation (same as before)
    - **no time jitter / small noise in HCAL / QIE pulse shape**
- **L1 simulator**
  - seamless 12x12 sliding window up to eta 5
  - HF included for MET
  - New tau algorithm
- **Jet Finder**
  - iterative cone (among many algorithms)

Software Tools(3)

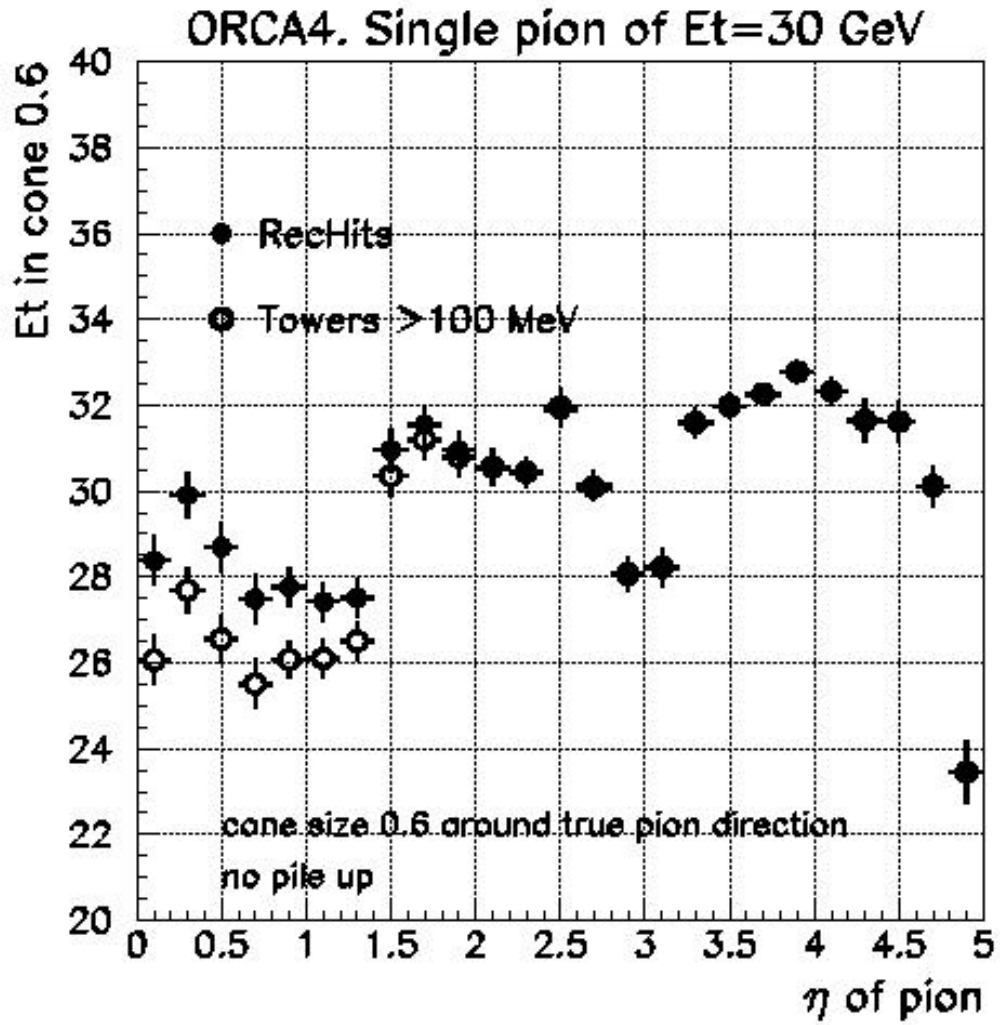
Ntuple maker

- **used for studies on-**
  - trigger (L1&HLT) / HCAL electronics / physics
- **multiple versions of ntuple files**
  - one for Jet/MET
    - **kine, L1 jets/met/tau, E+H towers, jets, met**
  - one for electron/photon

=> need a unified one for all physics objects!

- **Desirable features**
  - easy to expand (e.g. add obj's & re-reco. obj's ...)
  - easy to customize
- **limitation with ntuple?**
  - need to move to a new tool?

ORCA4: RHIT and E+H Towers for single pion



Energy Scate:

ECAL- with electron

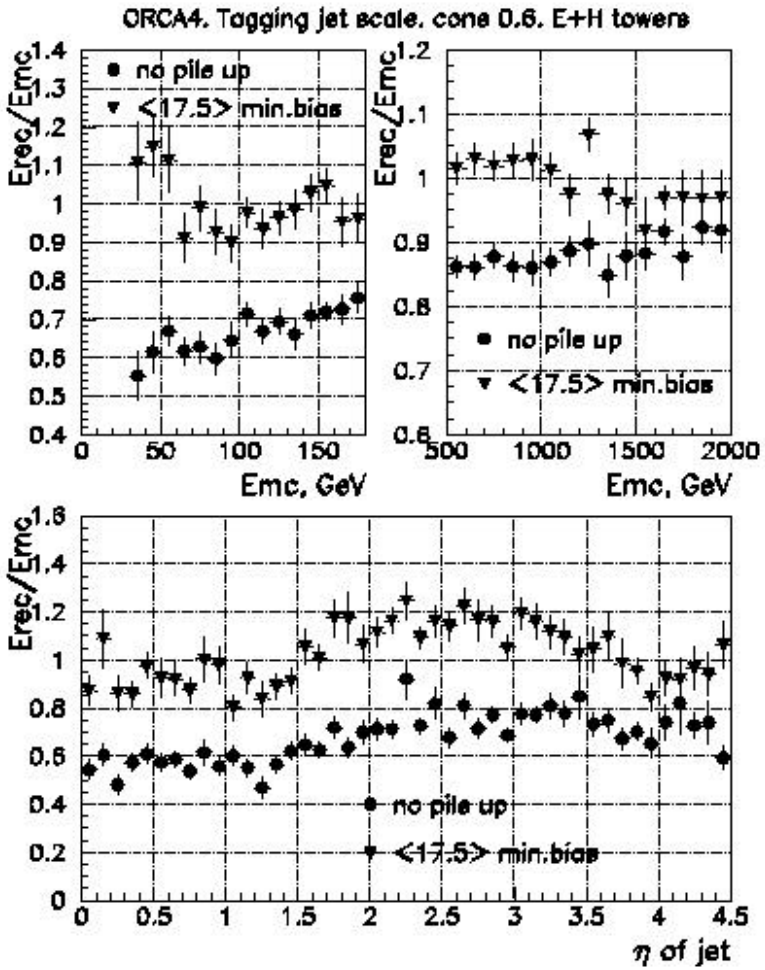
HB/HE- Et 50GeV pions not interact in ECAL

HF- 1TeV jets

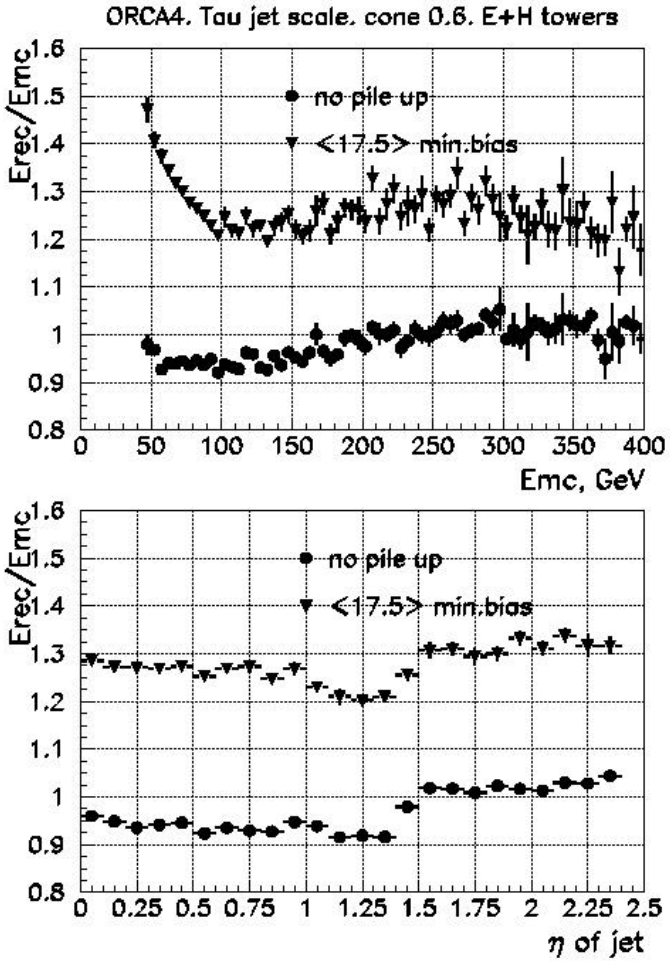
(A.Nikitenko)

ORCA4: Jet Finder (simple cone)

Tagging jets



Tau jets



(A.Nikitenko)

Data Sample

QCD: 15-470GeV

Et	events
10-15	100k
15-20	127k
20-30	196k
30-50	103k
50-80	42.7k
80-120	16.1k
120-170	11.5k
170-230	1.28k
230-300	1.28k
300-380	1.28k
380-470	1.28k

Total 600K

Min-bias 119k

Signal

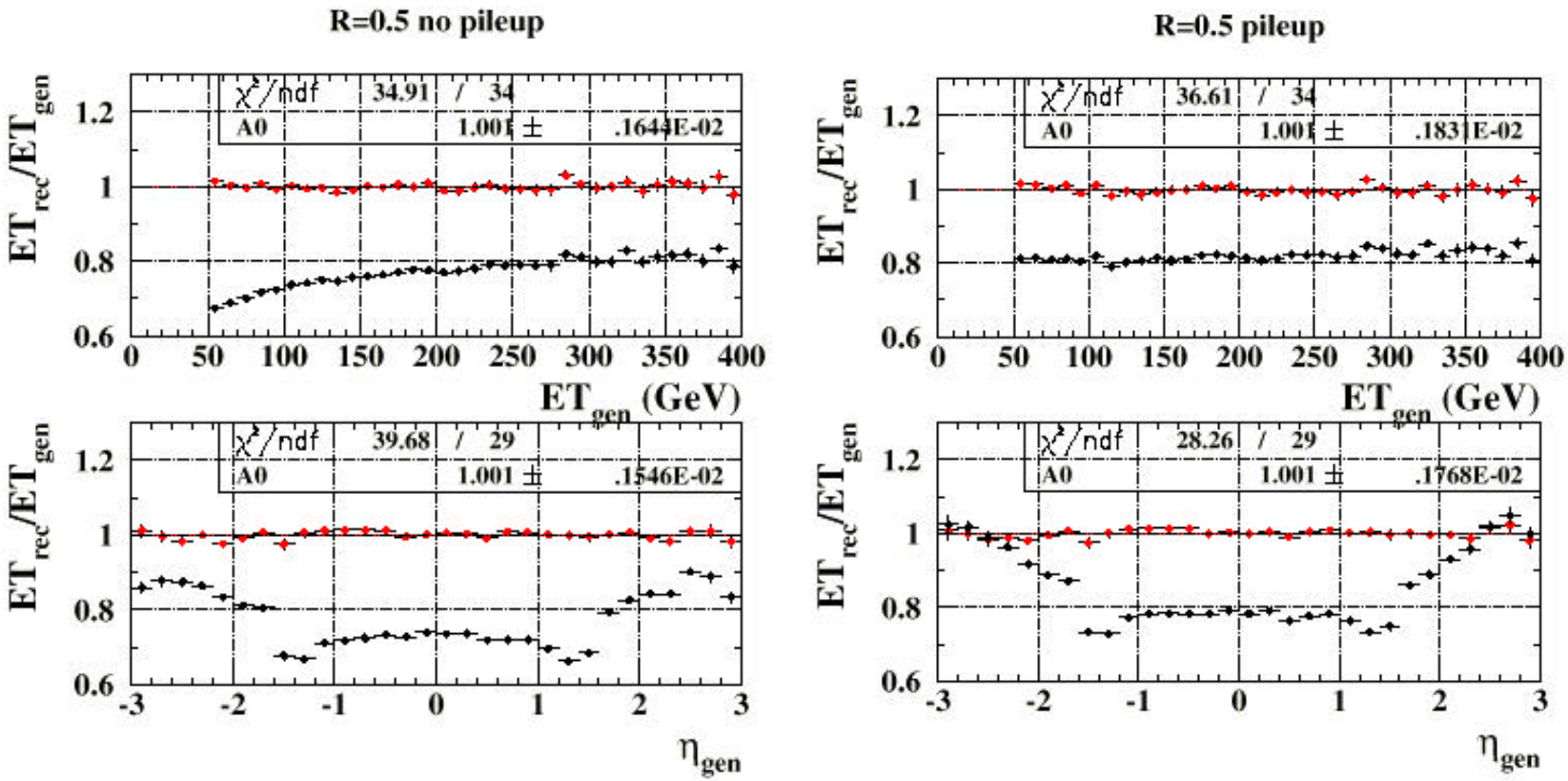
- ttH(110), H->bb 4.1k
- qqH(135), H->tau+tau
  - e+j 3.0k
- h(200)->tau+tau
  - ej/emu/jj 4.0,4.0,4.5k
- h(500)->tau+tau
  - jj 6.5k
- Sugra 4.8k

Single particle

- pion (5,30) 3.9,2.8k
- elec.(?)

Jet Energy Correction

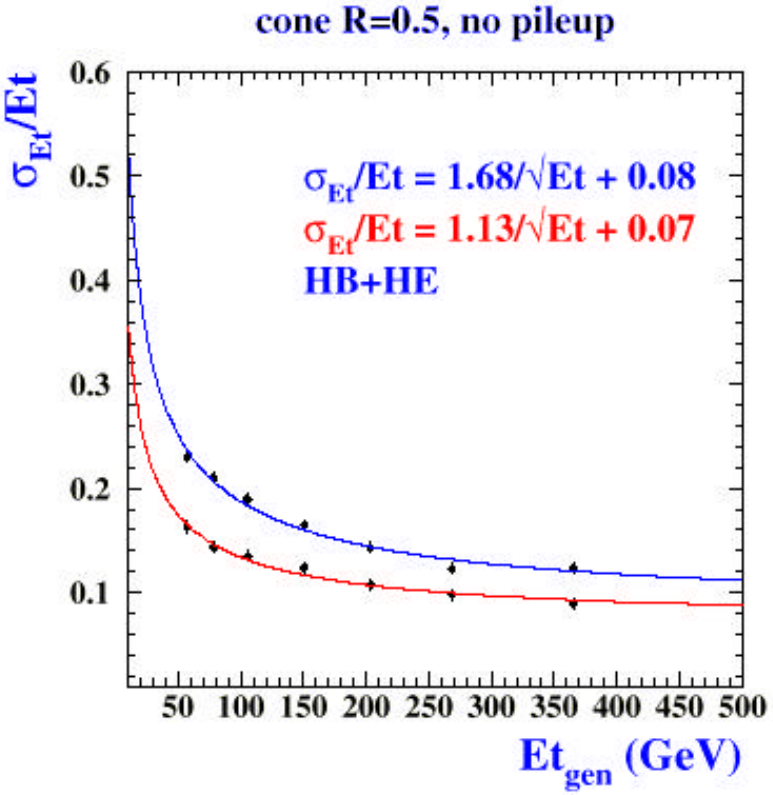
Et-eta dependent correction for QCD jets

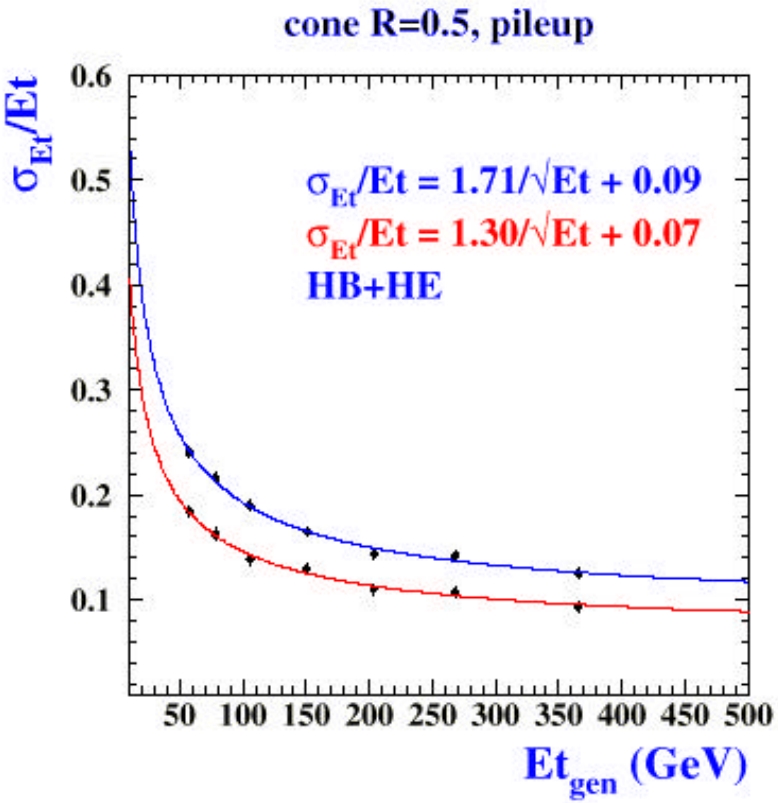


(S.Arcelli) => Need additional maps for L1 jets, tau-jets and b-jets.

Jets Resolution
Before/after energy correction

(Average over eta range < 3.0)



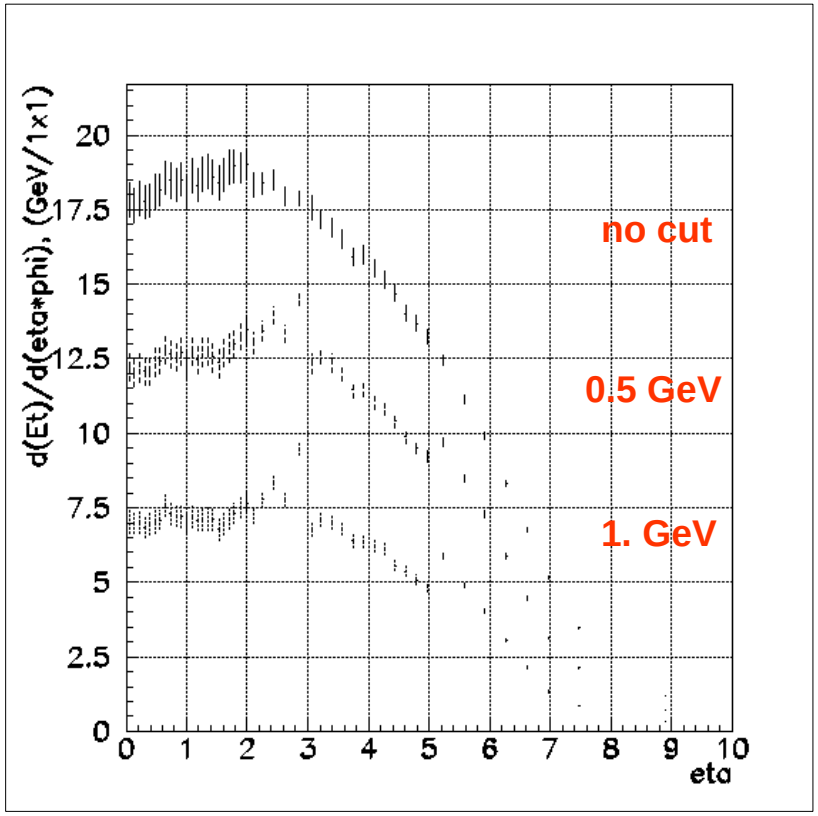


(S.Arcelli)

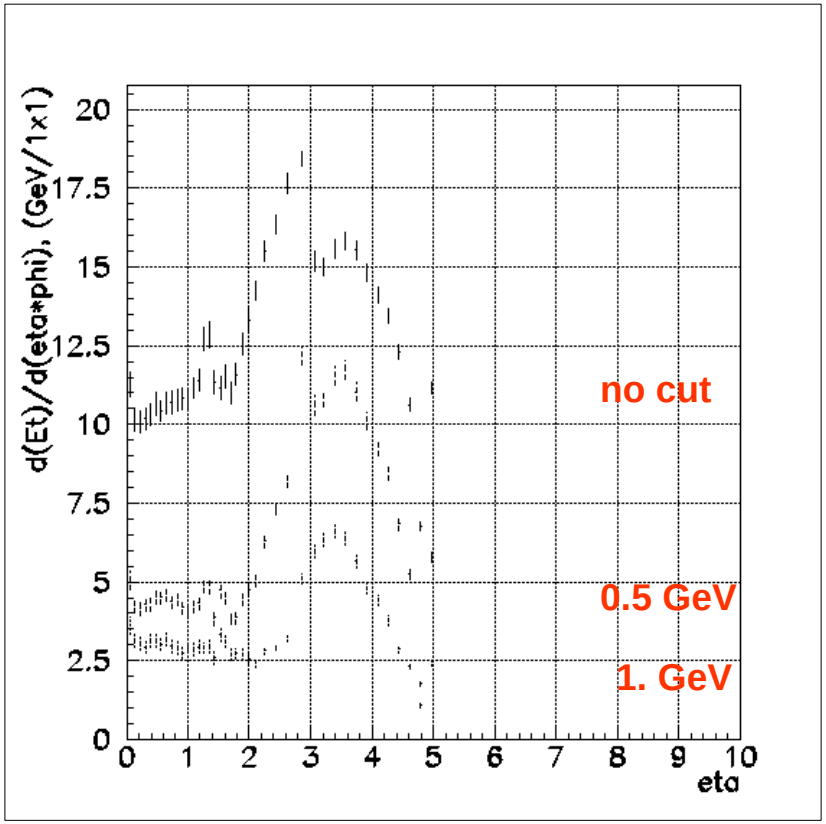
Pile-up Effects
(in-time only)

X-sec = 55mb >>> 17.3 min-bias/crossing at 10E34

Particle level



Calorimeter



~17GeV in unit (eta x phi)

(equiv. to radius 0.56)

(Cuts: on Tower)

Window Algorithm
(with pile-up energy subtraction)

WINDOW ALGORITHM

The modified window-type jet finding algorithm was used to search "jet-like" clusters above the average energy.

1. All possible rectangular windows (including overlaps) with given radius $R = \sqrt{\Delta\eta^2 + \Delta\varphi^2}$ (window size = $2R$) in calorimeter map in $\eta - \varphi$ space were constructed.

2. The window energy was calculated as sum of transverse energy cells E_c over all n_c cells included into this window minus background energy per cell:

$$E_{wind} = \sum_{n_c} \{E_c - [\overline{E_c}(\eta) + D_c(\eta)]\},$$

where $\overline{E_c}(\eta)$ — the average transverse energy, $D_c(\eta) = \sqrt{(\overline{E_c^2}(\eta) - \overline{E_c}(\eta)^2}$ — dispersion in cell as function η.

3. The loop on windows starts from the window with maximum transverse energy.

4. The non-overlapping windows with energy $E_{wind} > 2\sqrt{\Sigma\, D_c(\eta)^2}$ are considered as candidates for the jets.

5. Cell with maximum of transverse energy in window is chosen and considered as a center of this jet.

6. Cells of the window within radius R around jet center are collected.

7. $\overline{E_c}(\eta)$ and $D_c(\eta)$ are recalculated using cells which are not covered by jets.

8. The jet energy is calculated as energies of collected cells minus mean background energy per cell:

$$E_{jet} = \Sigma\{E_c - [\overline{E_c}(\eta) + D_c(\eta)]\}.$$

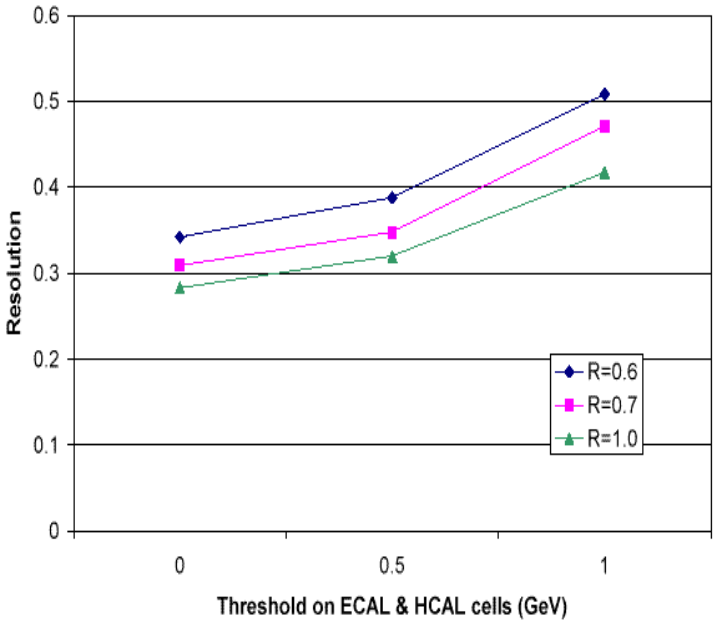
9. We also use criterium on intrinsic structure of a jet, which allow to cut background more effectively. Only jets with the energy density $E(0.7R)/E_{jet} > 0.7$ in center $r < 0.7R$ region of jet are accepted.

-Developed originally for jets in heavy ion collisions- (I.Vardanyan)

20 GeV Jets at 10E34

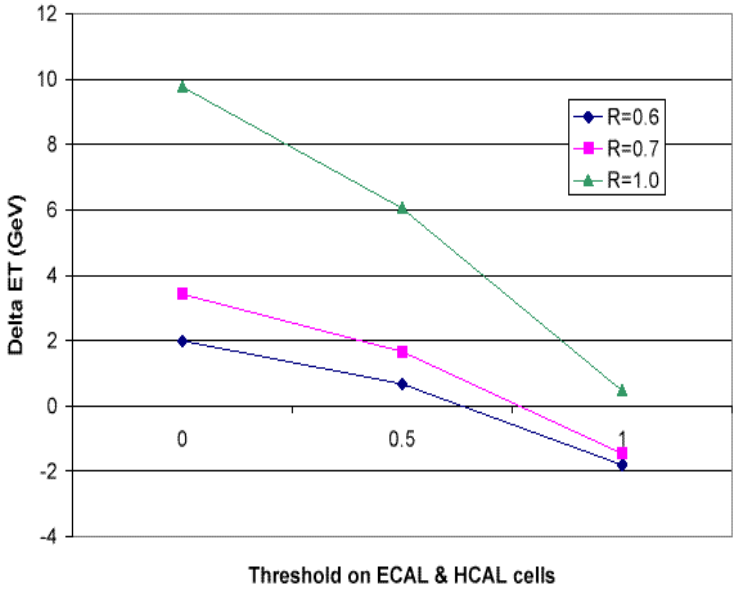
Effect of pile-up and Et threshold on towers
(Window Algorithm with in-time pile-up energy subtraction)

Resolution



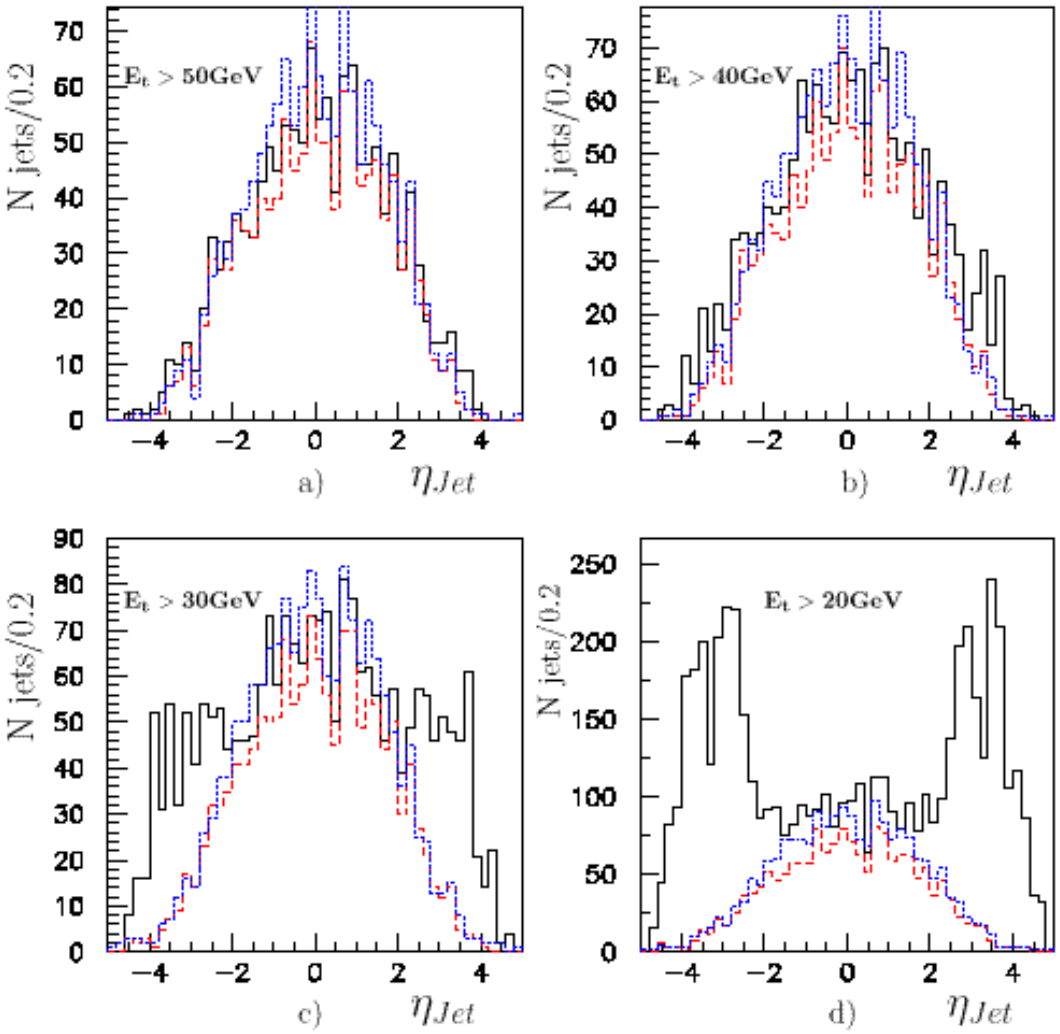
Energy offset due to pile-up

Delta Et = (reco with pile-up and thr.cuts)
-(reco with no pile-up and no thr.cut)



(I.Vardanyan)

Low Et Jets and Pile-up



(A.Krokhotine)

Reco with pile-up

Reco w/o pile-up

Generated

(R<0.7)

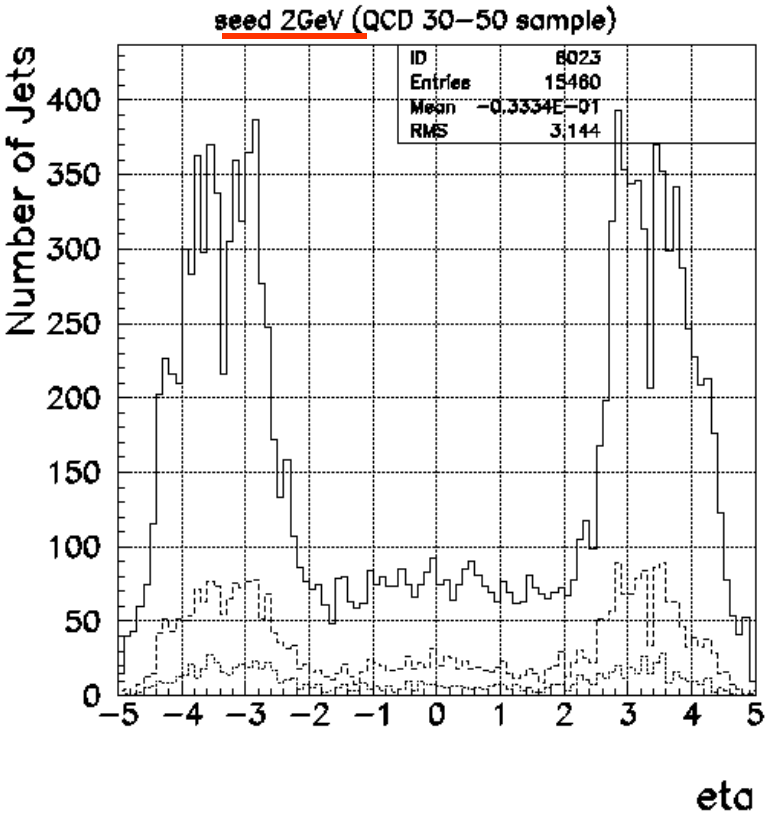
Fake jets < 40GeV

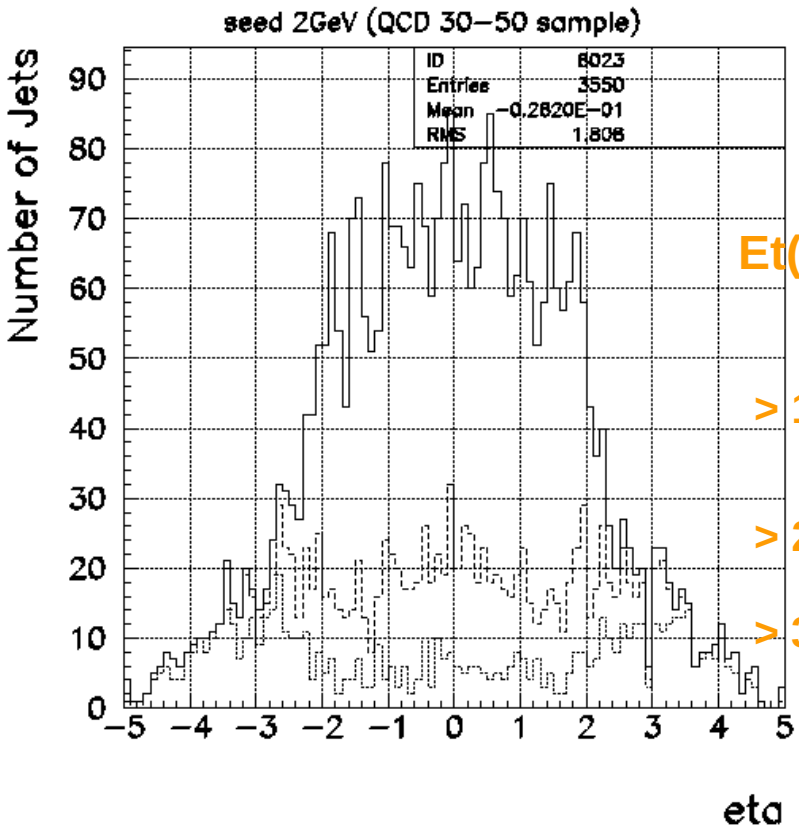
=> core of jets

=> smaller cone

Seed Cut

No cut **2 GeV / (0.087x0.087)**





Et(reco)

> 10 GeV

> 20 GeV

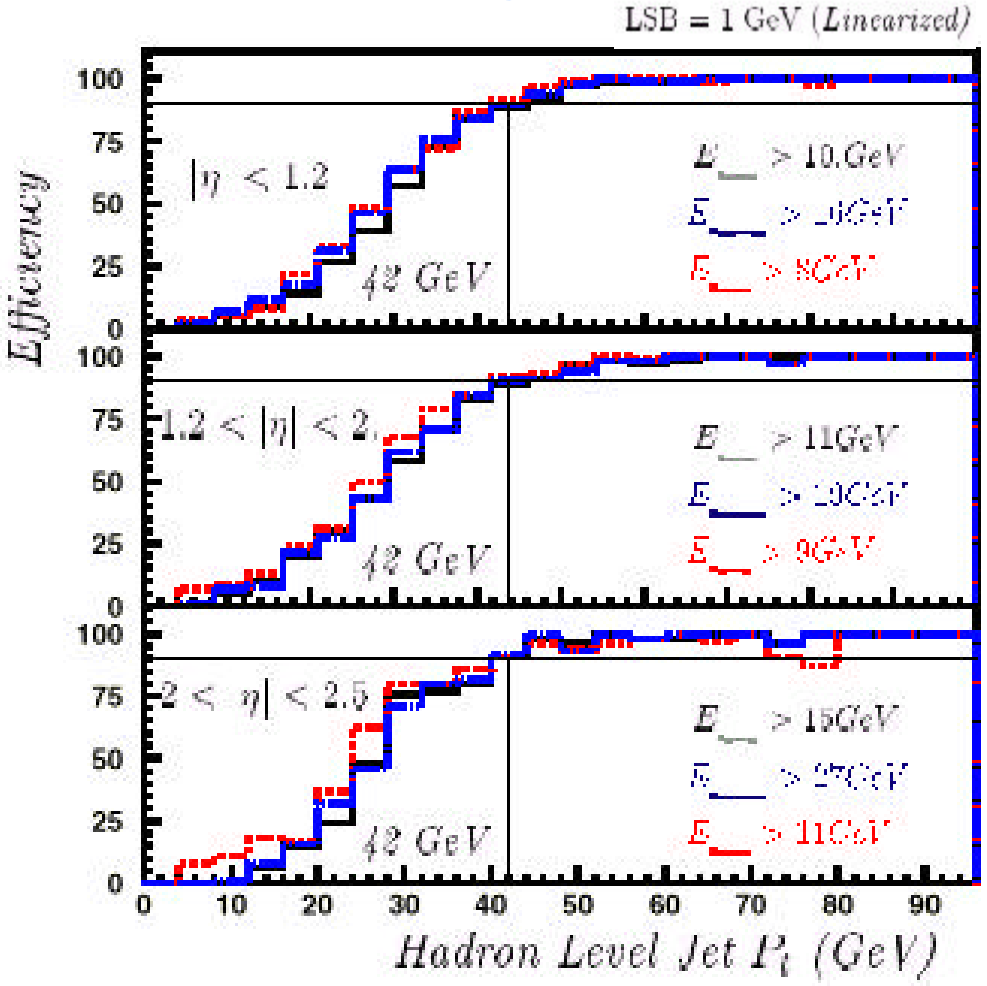
> 30GeV

Suppression of fake jets!

… but a rate calculation shows remaining fakes still too much for trigger.

Window size for Low Et Jets

Efficiency



(A.Krokhotine)

Sliding windows mad of 2x2 towers.

Rejection

of in-time pile-up events for 2 jets in eta<2.5

6x6	4.4
12x12	2.7
4x4	3.7

HLT Jets Algorithm

L2

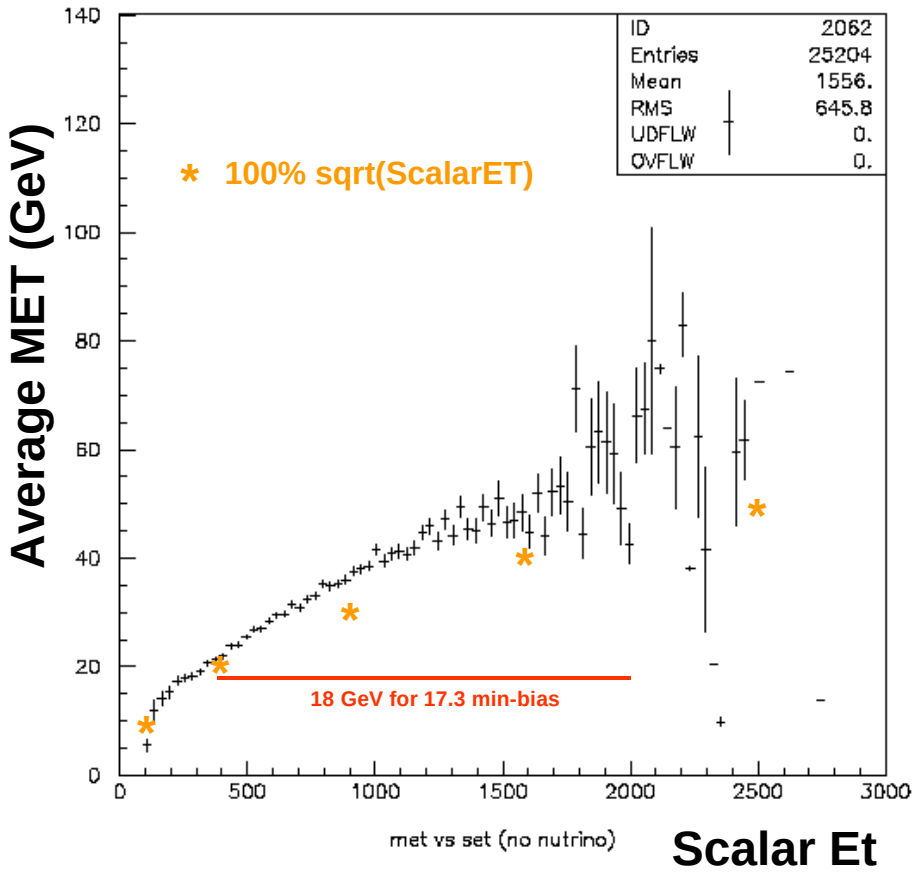
- Improve Et resolution and Et scale
  - improved jet axis with finer granularity (1x1 instead of 4x4 towers)
  - LSB: L1(Et=0.5~1.0GeV) -> L2(Et=0.2GeV)
  - energy calibration (non-linearity, pile-up energy)
- Reduce low Et fake jets due to min-bias pile-up
  - jet shape
  - smaller window size
- Combine with leptons and MET
  - cuts on correlation, e.g. delta-eta, delta-phi...

L3

- b-tagging

Offline MET Resolution

QCD Jets with no neutrino/muon
(no pile-up)



$Ex = \Sigma$ (Ex-tower)
$Ey = \Sigma$ (Ey-tower)

Any way to improve this?

e.g.

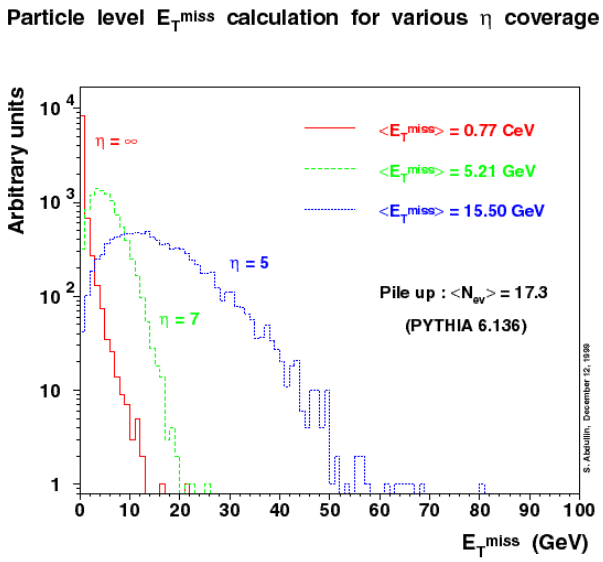
$Ex' = Ex + \Sigma\ (\Delta(Ex\text{-jet}))$
$Ey' = Ey + \Sigma\ (\Delta(Ey\text{-jet}))$

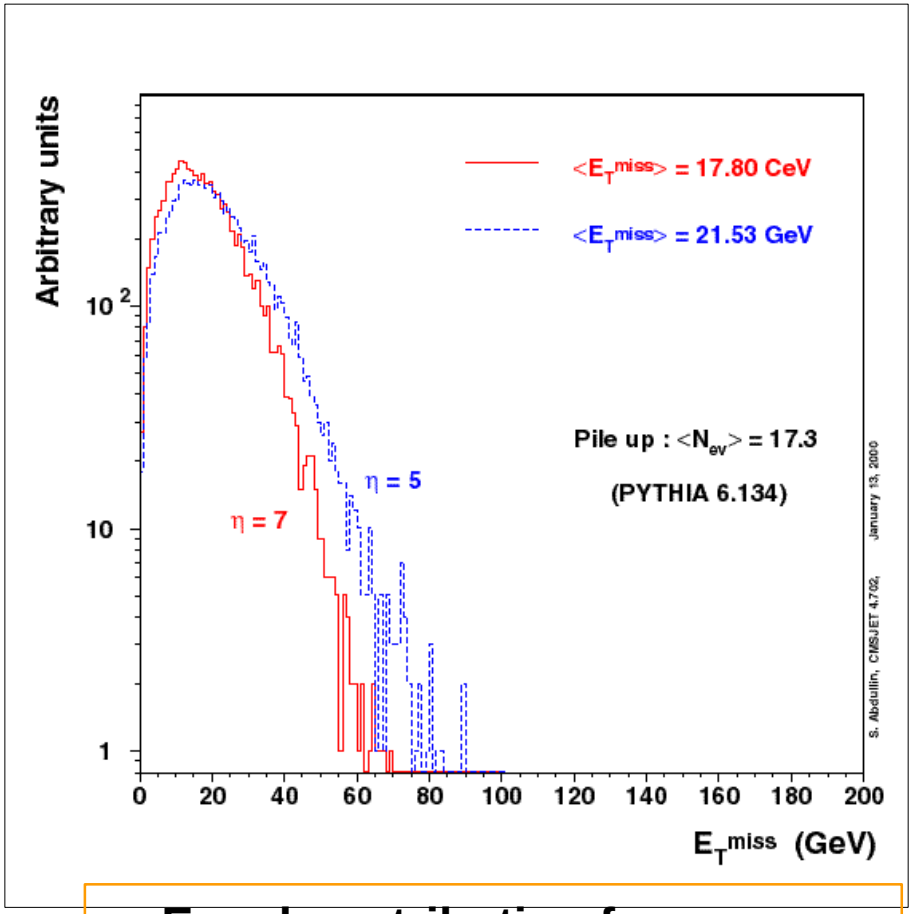
Does this work?

MET with Pile-up (eta 5 vs 7)

(CMSJET simulation)

(S.Abdullin)





MET (GeV)	gen.	cmsjet	
eta		res.	all(*)
5	15.49	19.36	21.53
7	5.21	12.92	17.80

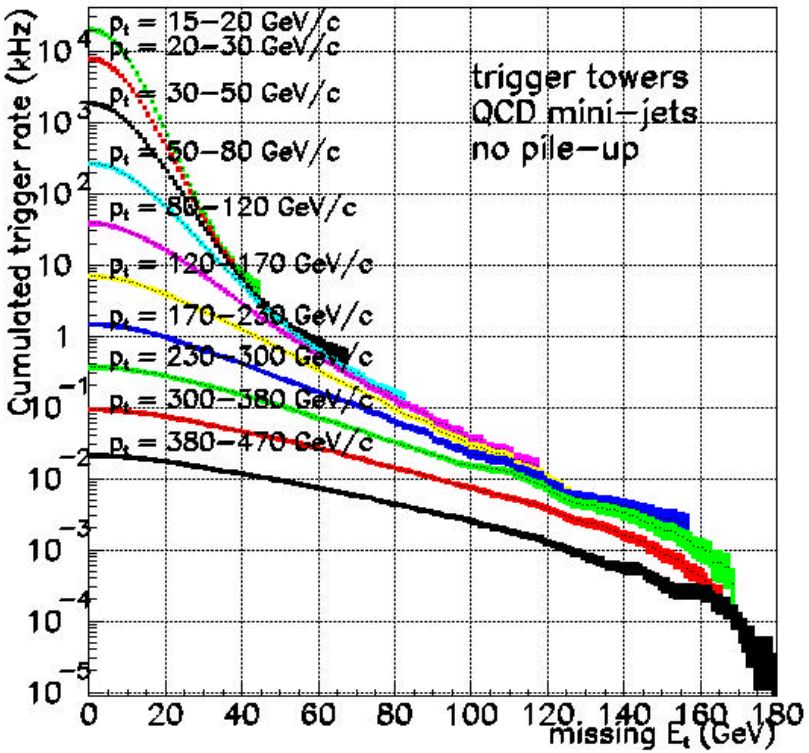
(all = res. & B-field & vtx smearing)

~ Equal contribution from eta 5-7, resolution and B-field

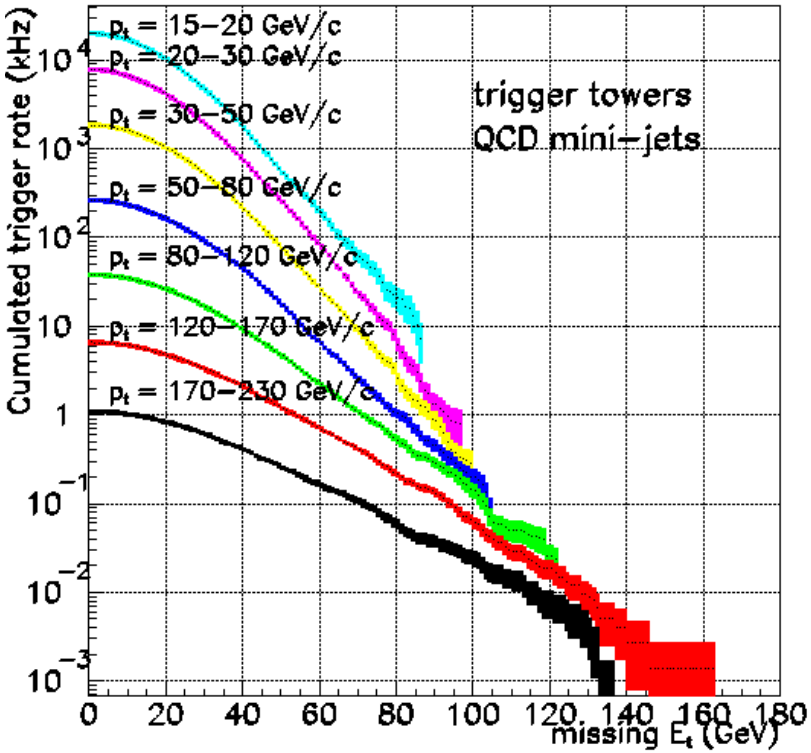
(15GeV) (12GeV) (9-12GeV)

Rates with Pile-up

No pile-up



In-time pile-up



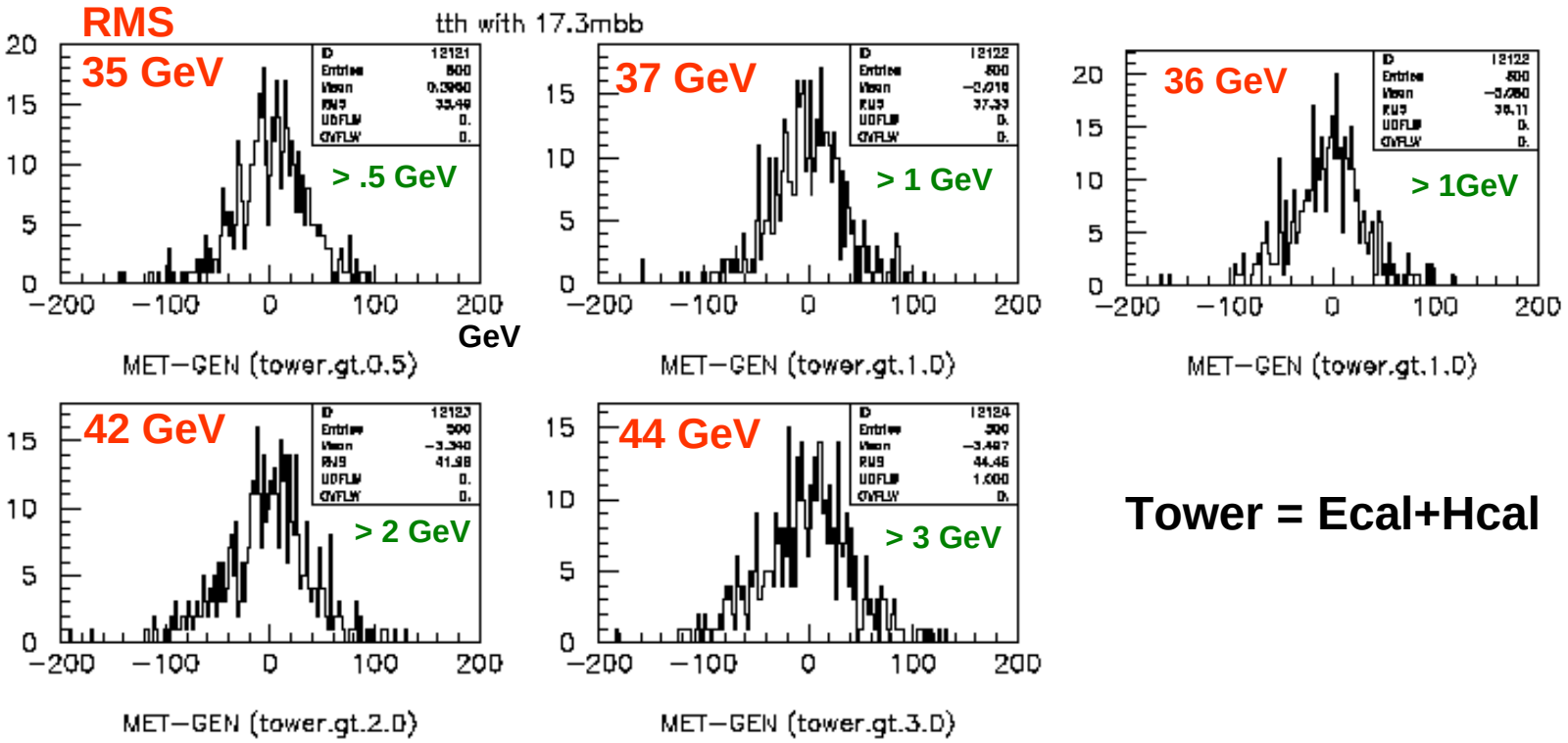
Huge rate below MET < 100 GeV due to min-bias at 10E34.

(P.Hidas)

MET for Signal Events with Pile-up and Tower Threshold

With 17.3 min-bias events

No min-bias



Tower = Ecal+Hcal

>> Not much pile-up effect with this resolution!

>> Resolution gets worse as threshold increase.

HLT MET algorithm

L2

- Try to Improve resolution
  - energy calibration (non-linearity)
- Combine leptons and jets to control rates at lower threshold.
- ???

L3

- ???

Improvement of Tau id efficiency

L2.0 calo Tau Trigger with old L1 jet triggers

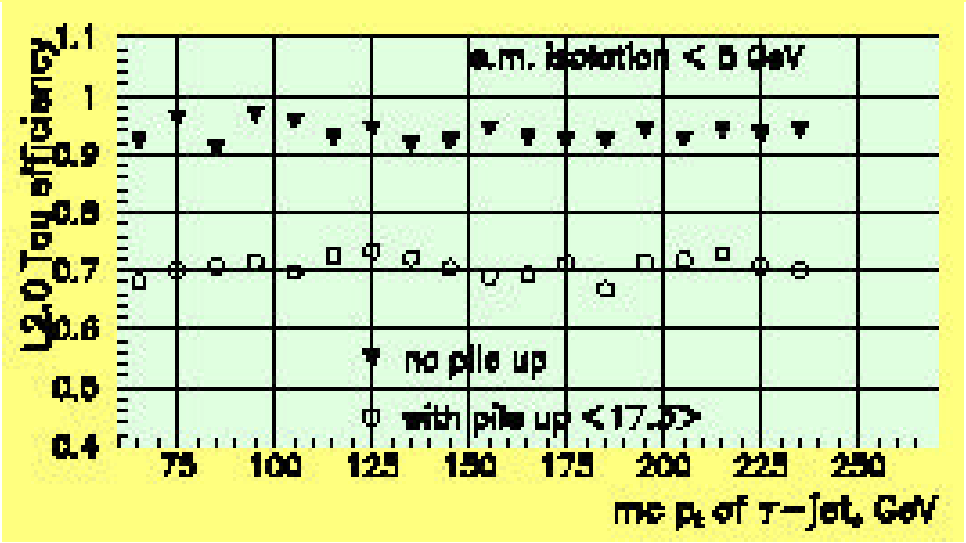
1. Reconstruct Jet in a region located on L1 J1 Region (J1 - highest E_t jet)

2. OLD - Calculate e.m. collimation parameter $P_{col}=\Sigma E_t^{cr}(R<0.13) / \Sigma E_t^{cr}(R<0.4)$

2. NEW ! - Calculate e.m. isolation parameter $P_{isol}= E_t^{cr}(R<0.4) - \Sigma E_t^{cr}(R<0.13)$

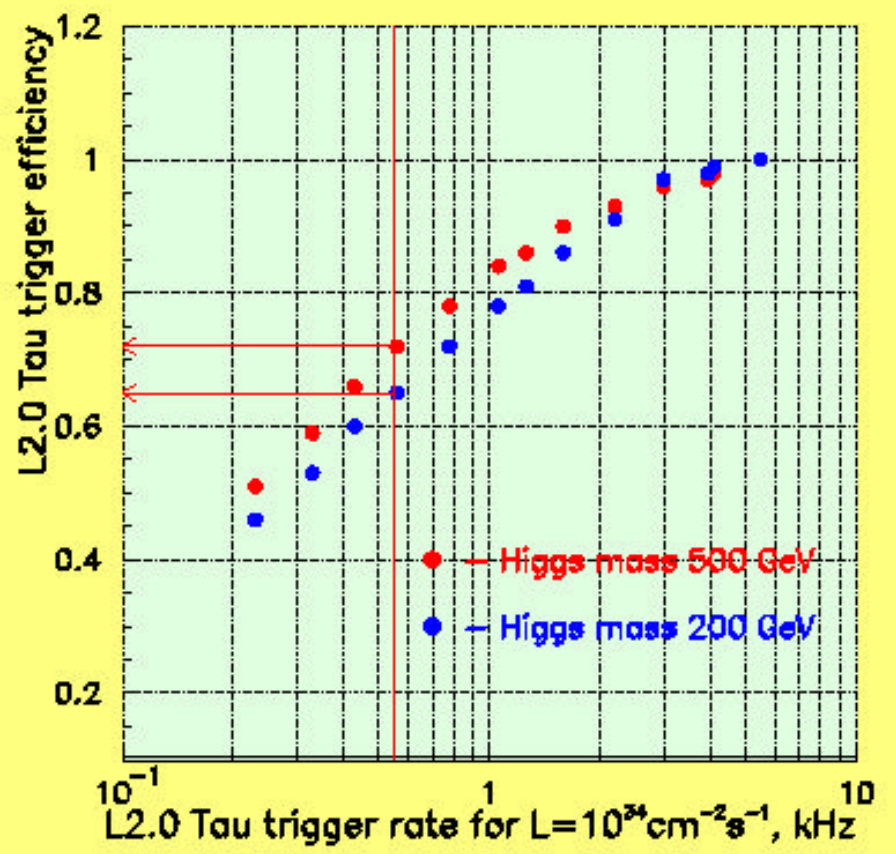
3. Accept Jets with $P_{isol} < P_{isol}^{cut}$

Usage of P_{isol} instead of P_{col} removes strong p_t dependence of tau-id efficiency



(A.Nikitenko)

L2.0 Tau: Efficiency and Rate



Efficiency for H->ττ->jj events passed TP L1 1-4 J Triggers and off-line selections : 1prong τ-jets of E_t>60 GeV

and rate of L2.0 Tau Trigger running on highest Et L1 Jet from L1 1-4 J Triggers

L1 1-4 J Trigger rate is 5.5 kHz

(A.Nikitenko)

Possible L2.0 Calorimeter Trigger with new L1 tau trigger

1. Reconstruct Jet in a region located on L1 Tau1 Region (Tau1 - highest E_t tau-jet)

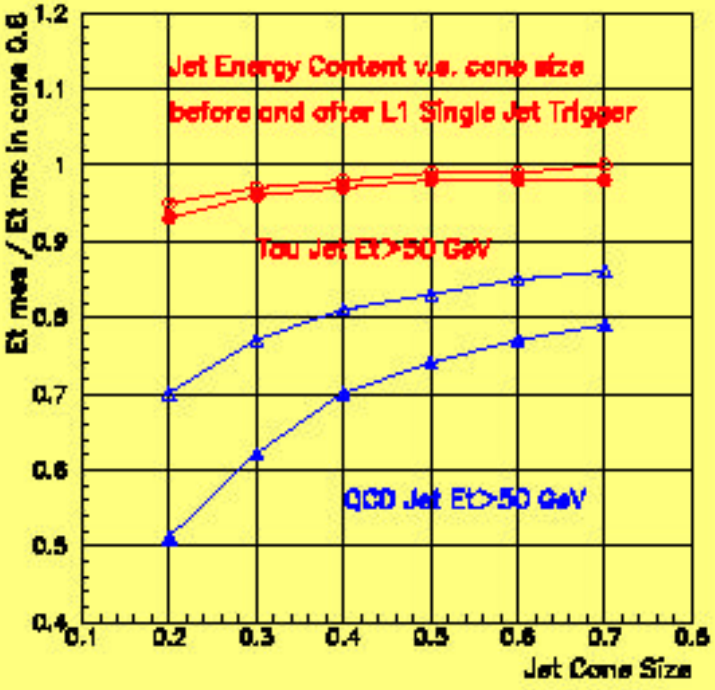
2. Calculate e.m. isolation parameter $P_{isol} = E_t^{cr}(R<0.4) - \Sigma E_t^{cr}(R<0.13)$

3. Accept Jets with $P_{isol} < P_{isol}^{cut}$

- Old L1 jet trigger preselected narrow jets in the turn on portion

- New L1 tau-trigger will do the same : select narrow jets

DO NOT EXPECT THE DEGRADATION OF THE L2.0 PERFORMANCE WITH NEW L1



(A.Nikitenko)

HLT Tau algorithm

L2

- isolation cuts

L3

- track match for isolated charged track

Plans for July Milestone

1) redo L1 rates

2) construct maps for eta-Et dependent jet energy correction for offline (L2) and L1
3) do L1/L2 jet rates with jet energy correction

4) see effect of jet energy correction on offline MET
5) do L2 MET rates with jet energy correction, if 4) works.

6) calculate L2 tau rejection rate with new L1 tau trigger.

7) support e+jets by the egamma group

8) start developing a common ntuple for jets/met/tau, electrons/gamma and muons.

After July Milestone

1) tracker information for L3 tau trigger.

2) proper HCAL electronics simulation.
(pulse shape, time jitter etc.)

3) optimize offline MET calculation
4) optimize handling of low Et jets (Et<40GeV)
5) improve jet energy calibration and pile-up energy subtraction

6) migrate to a common ntuple.

7) production with new cmsim (updated geometry, larger HF shower library, etc.)

Summary

We have better understanding of offline jets/MET performance at 10E34.

- **We will try some of offline algorithms at L2, and calculate rates and efficiencies for July Milestone with ORCA4 MC data.**

Triggering on low Et Jets and low MET is a real challenge at 10E34.

- **It is highly desirable to have a flexible system from L1 through HLT which accepts new golden algorithms in future.**

Tracker will be a key for L3 tau trigger and b-jets trigger.