Jets and $\not\!\!E_T$ at HLT

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Introduction

- Overview of the High Level Trigger Framework
- Status of the HLT Filter Objects
- Jet and $\not{E}_T$ Distributions
- Jet Reconstruction Timing Studies
- A Preliminary Look at L1 GCT Emulator Output
- “Triggered” Jet $\mathbf{p_T}$ Distribution

High Level Trigger Framework

- Each HLT trigger path is a sequence of modules, e.g.

```
path HLT1MET = {l1extra & l1s1MET &
                pre1MET & met, hlt1MET91}
```

- Processing of the trigger path stops once a module returns false.
- Two HLT Objects
  - `TriggerResults` reports the status (`NotRun, Pass, Fail, Exception`) of the HLT trigger paths, as well as the HLT module and pathname information.
  - `HLTFilterObjectWithRefs` provides references back to the objects (jets, for example) which satisfied the HLT filter requirements.

For more details visit the HLT twiki page:
https://uimon.cern.ch/twiki/bin/view/CMS/HighLevelTrigger

HLT Filters

- Currently available HLT filters reside in the `HLTrigger/HLTexample` directory.
- Generic templated filter algorithms as of CMSSW_1_0_0 are:
  - `HLTSinglet.cc`
  - `HLTDoublet.cc`
  - `HLTSmartSinglet.cc`
  - `HLTGlobalSums.cc`
- Specific instances of `HLTSinglet.cc`:
  - `HLT1CaloJet`
  - `HLT1CaloMET`
  - `HLT1Muon`
  - `HLT1Photon`
  - `HLT1Electron`
- `HLTDoublet.cc` is used to make kinematic cuts between two HLTSinglet objects; e.g., acoplanarity between `HLT1CaloJet` and `HLT1CaloMET` objects.

Filter Parameters

- `HLTSinglet.cc`:
  - Require $N \geq N^{cut}$ objects with $\mathbf{p_T} \geq \mathbf{p_T}^{min}$ and $abs(\eta) \leq \eta^{max}$.
- `HLTDoublet.cc`:
  - Require $N \geq N^{cut}$ di-objects satisfying
    - $\Delta\phi$ (acoplanarity),
    - $\Delta\eta$, and/or
    - mass requirements.
- `HLTSmartSinglet.cc`:
  - Single cut on ANY method defi ned by the templated class.
- `HLTGlobalSums.cc`:
  - Require a MET observable within specifi ed maximum and minimum values. Observables are:
    - $\sum_{CaloTower} E_T$,
    - $\not{E}_T$ signifi cance $\equiv \not{E}_T/\sqrt{\sum E_T}$, and
    - $E_{||}$, the longitudinal component of $\sum_{CaloTower} \vec{E}$.

Status of HLT Filter Objects

- Electron and Photon
  - Single and double photon; single electron
  - Isolation algorithms implemented
- Muon
  - Basic single and double μ fi lters with and without isolation
- Tau
  - Basic single and double τ fi lters
  - $\tau + e$, $\tau + \mu$
- b-jet
  - First working version “almost there”
- Jets and $\not{E}_T$
  - Status on next slide

Efforts are underway to implement the use of Level-1 seeds in the fi lter algorithms and to develop partial data unpacking and reconstruction

HLT JetMet Trigger Menu

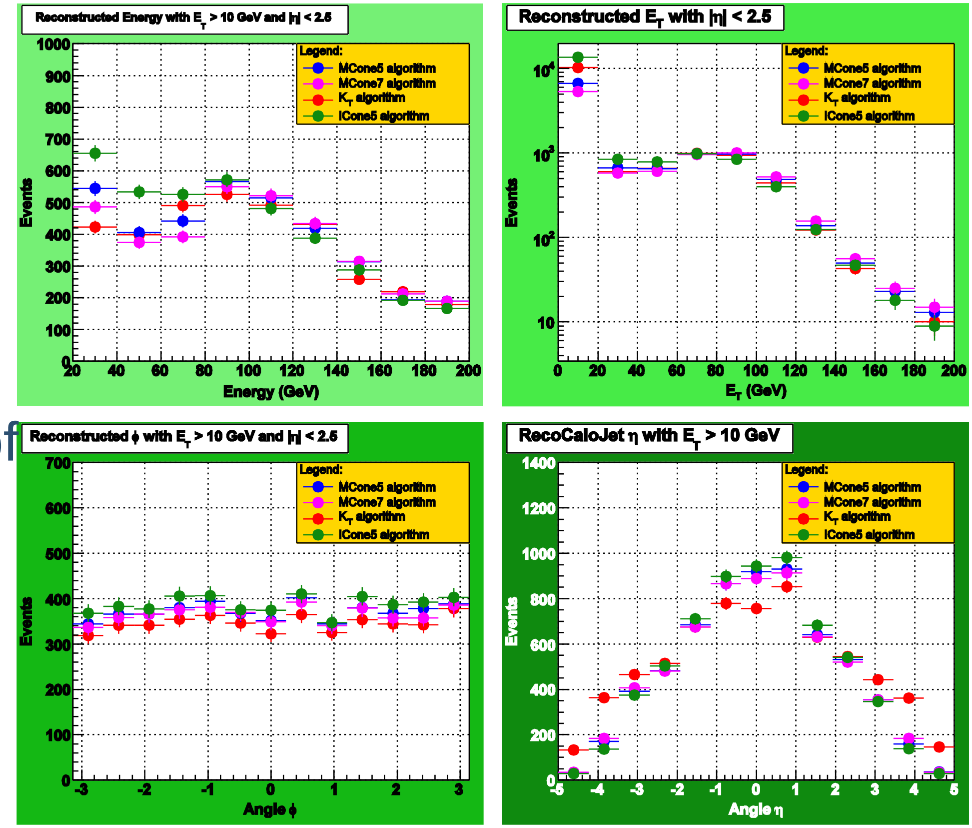
Trigger	Level-1 Prescale	HLT Threshold (GeV)	HLT Rate (Hz)	CMSSW availability
SINGLE-JET	1	400	4.8 ± 0.0	✓
DOUBLE-JET	1	350	3.9 ± 0.0	✓
TRIPLE-JET	1	195	1.1 ± 0.0	✓
QUADRUPLE-JET	1	80	8.9 ± 0.2	✓
$\not{E}_T$	1	91	2.5 ± 0.2	✓
jet + $\not{E}_T$	1	180,80	3.2 ± 0.1	✓
acoplanar 2 jets	1	200,200	0.2 ± 0.0	✓
acoplanar jets + $\not{E}_T$	1	100,80	0.1 ± 0.0	✓
2 jets + $\not{E}_T$	1	155,80	1.6 ± 0.0	✓
3 jets + $\not{E}_T$	1	85,80	0.9 ± 0.0	✓
4 jets + $\not{E}_T$	1	35,80	1.7 ± 0.0	✓
H_T + $\not{E}_T$	1	350,80	5.6 ± 0.2	X
H_T + e	1	350,20	0.4 ± 0.1	X
SINGLE-JET	10	250	5.2 ± 0.0	✓
SINGLE-JET	10^3	120	1.6 ± 0.0	✓
SINGLE-JET	10^5	60	0.4 ± 0.0	✓

from PTDR vol. II for $\mathcal{L} = 2 \times 10^{33}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$

Jet Distributions

Agata Smoron

- Framework supports three basic jet algorithms:
  - MidPoint Cone
  - Iterative Cone
  - k_T
- Signifi cant effort has been expended on the validation of the jet software in CMSSW.

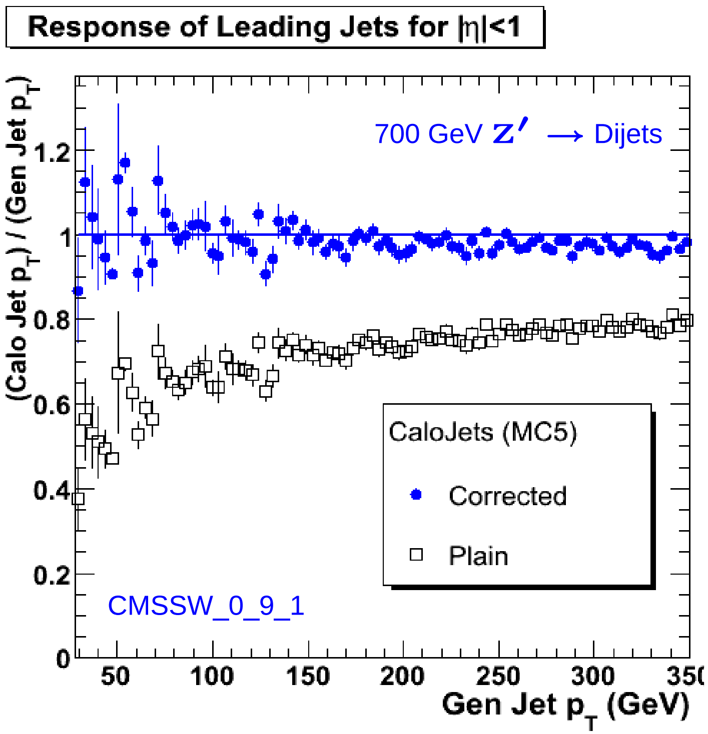


QCD Jet Sample

$120 < \hat{p}_T < 170$ GeV

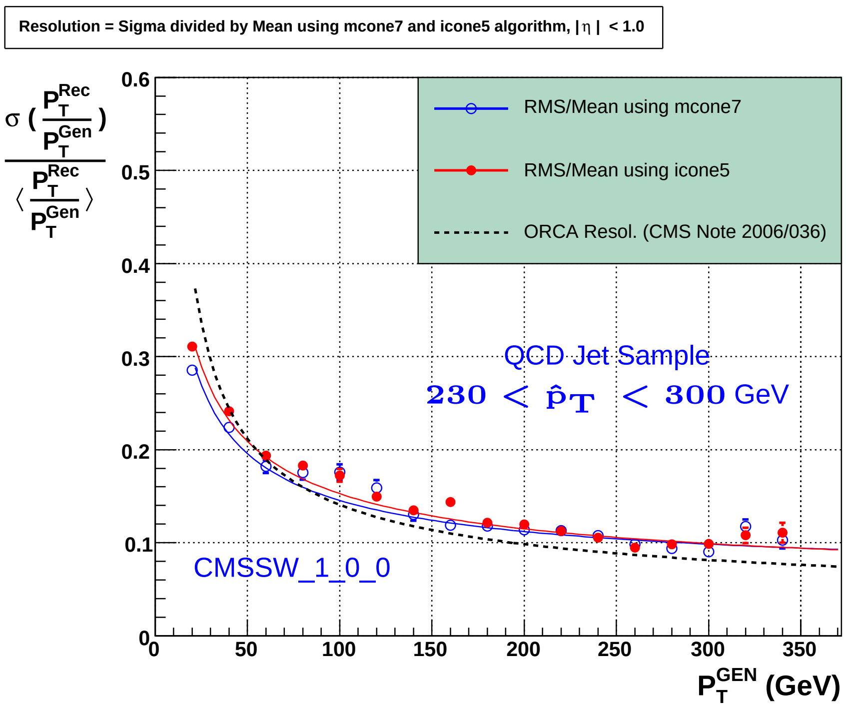
Jet Distributions (cont.)

Rob Harris



Jet Response

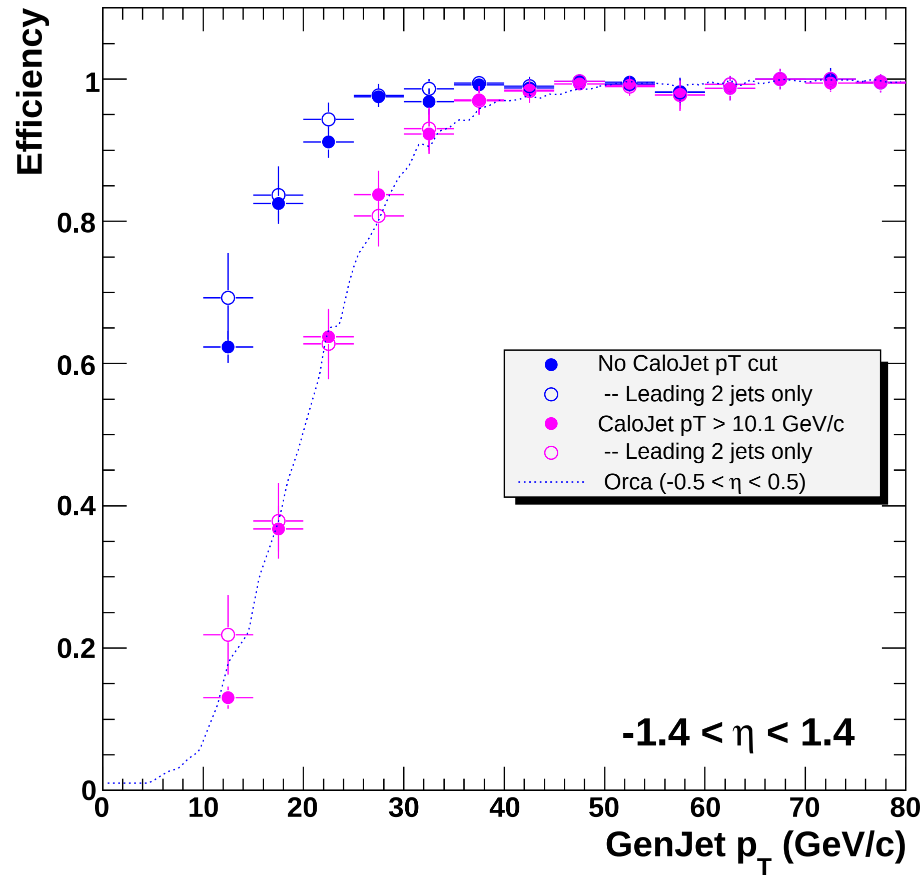
Agata Smoron



Jet Resolution

Jet Efficiency

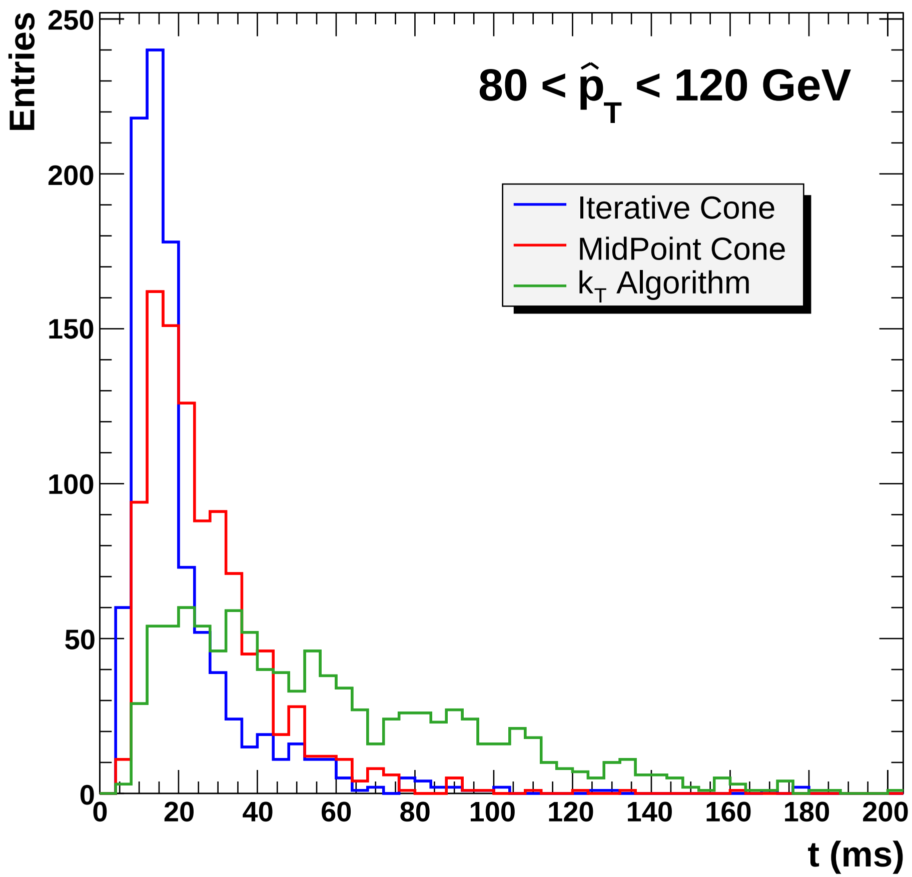
- $\Delta R^{gen-calo} < 0.3$ matching criteria.
- Previous studies from ORCA (CMS Note AN2006/036) found that the jet fi nding effi ciency wa 50% at E_T^{Gen} = 20 GeV for E_T^{Rec} = 10.1 GeV and CaloTower $E_T > 0.5$ GeV for jet fi nding.



Iterative-cone jets with $\Delta R < 0.5$

Jet Timing Studies

- Studies are still very preliminary. Absolute timing values should not be taken too seriously. For now compare only the relative values.
- Using CMSSW_1_0_1 for reconstruction.
- Studies performed with a 2.67 GHz Pentium 4 processor.



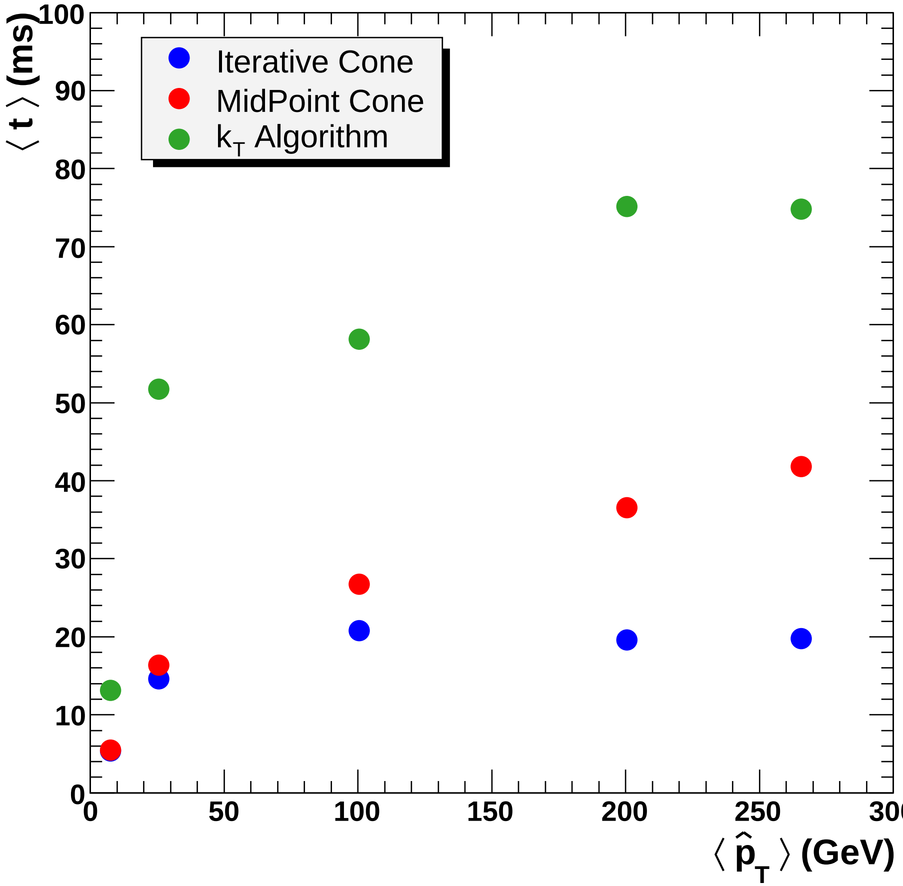
Jet Producer

Note: CMS currently uses an old implementation of the k_T jet algorithm. A much faster implementation is available.

Jet Timing Studies (cont.)

- Timing comparisons for several different Monte Carlo samples.

$$0 < \hat{p}_T < 15 \text{ GeV}$$
$$20 < \hat{p}_T < 30 \text{ GeV}$$
$$80 < \hat{p}_T < 120 \text{ GeV}$$
$$170 < \hat{p}_T < 230 \text{ GeV}$$
$$230 < \hat{p}_T < 300 \text{ GeV}$$



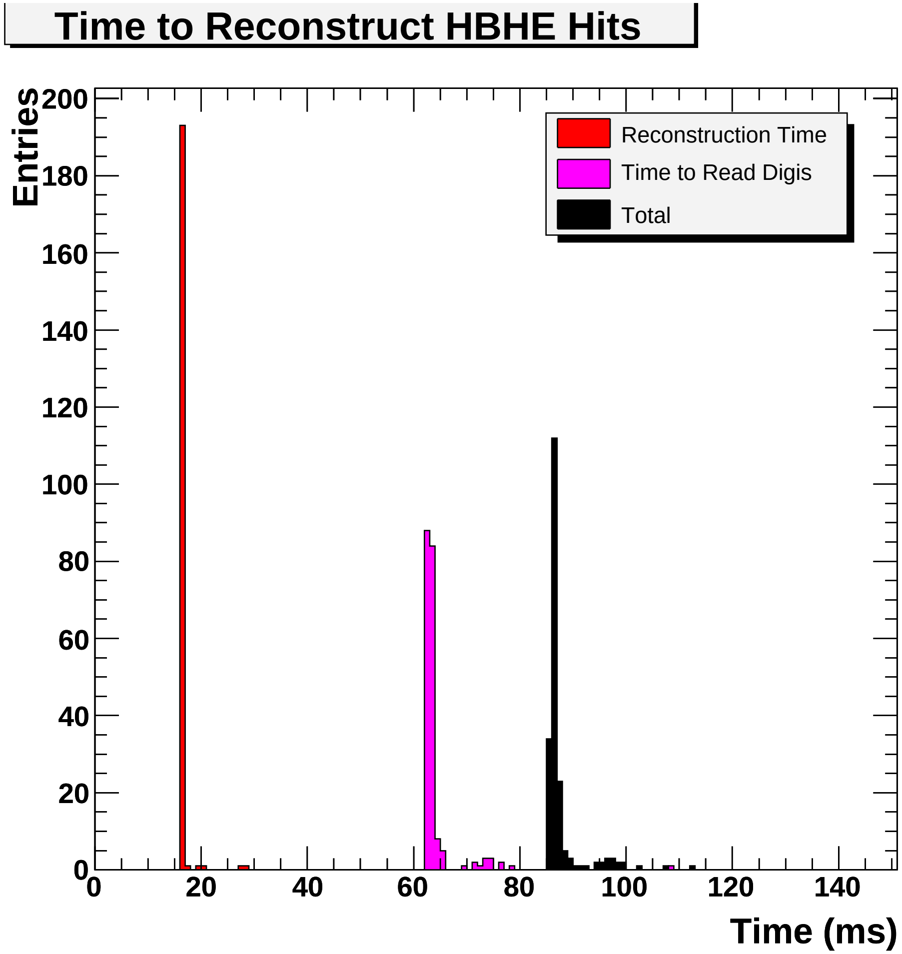
Jet Producer

Jet Timing Studies (cont.)

- Timing for the jet producers reflects only last element in the reconstruction chain:
  Unpacking ⇒ HCAL and ECAL hits ⇒ CaloTowers ⇒ Jets
- Data Unpacking (David Lange)
  - MC samples contain "digis". In order to measure "unpacking time". We need to fi rst convert digis to "raw" info ("digi2raw"), then measure how long it takes to convert back to digis ("raw2digi")
  - raw2digi: virtually all subdetectors are implemented see: https://twiki.cern.ch/twiki/bin/view/CMS/RawToDigiDigiToRawStatus
  - digi2raw: missing for most systems (Exception: tracker making a lot of progress)

HBHE Hit Reconstruction

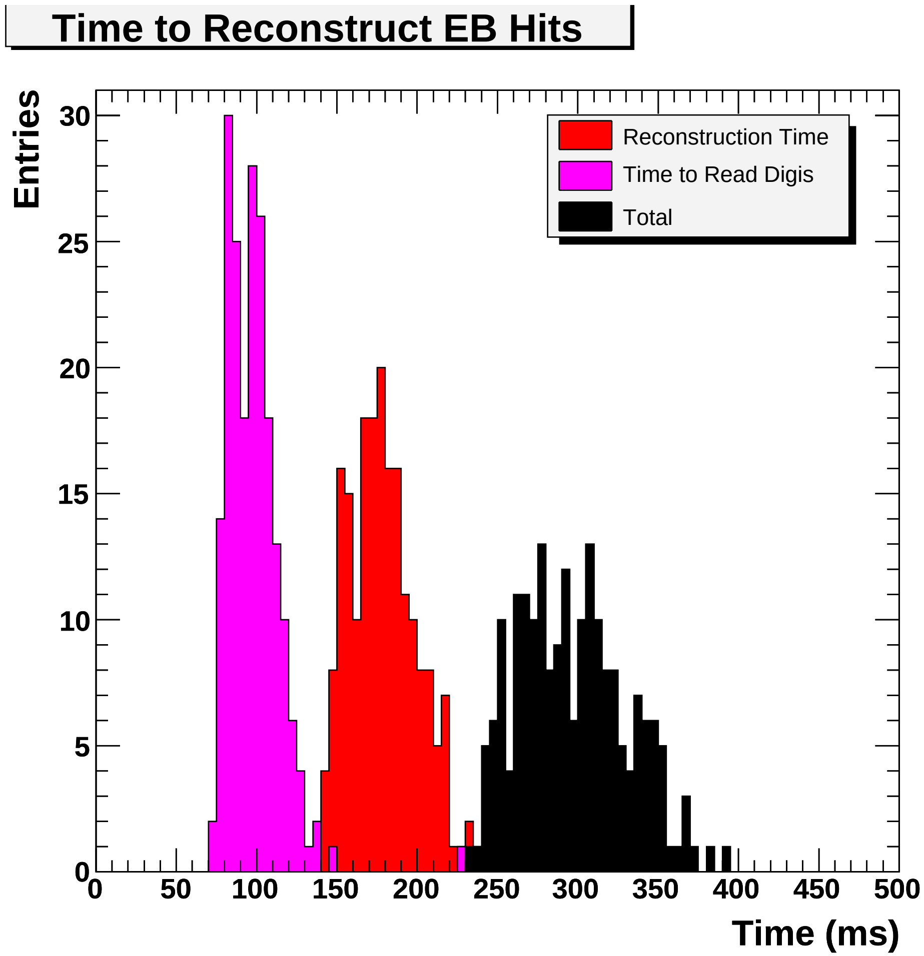
- Using CMSSW_1_1_0 for reconstruction.
- Studies performed with a 2.4 GHz Intel Xeon processor.
- HBHE digis read in from existing rootfi le. Time may not indicative of the online time.
- No zero suppression. All HBHE digis read (5184 channels).



QCD MC Sample – $50 < \hat{p}_T < 80$ GeV

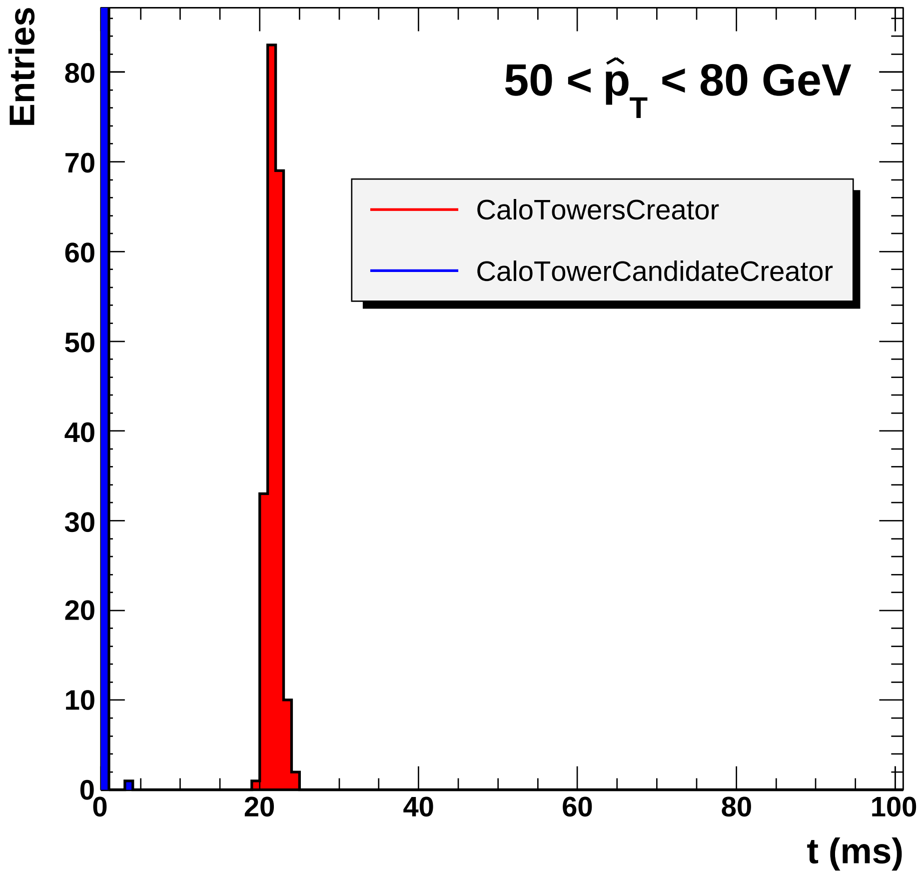
EB Hit Reconstruction

- Using CMSSW_1_1_0 for reconstruction.
- Studies performed with a 2.4 GHz Intel Xeon processor.
- EB digis read in from existing rootfi le. Time may not indicative of the online time.
- Digis **are** zero suppressed. Avg. 3162 channels / 61200 read.
- Reconstruction time dominated by module: `EcalWeightUncalibRecHitProducer`



QCD MC Sample – $50 < \hat{p}_T < 80$ GeV

- Using CMSSW_1_1_0 for reconstruction.
- Studies performed with a 2.4 GHz Intel Xeon processor.
- `CaloTowerCreator` reads in reconstructed HCAL and ECAL hits and produces the output CaloTowerCollection.
- `CaloTowersCandidate-Creator` just reformats this collection for later use.

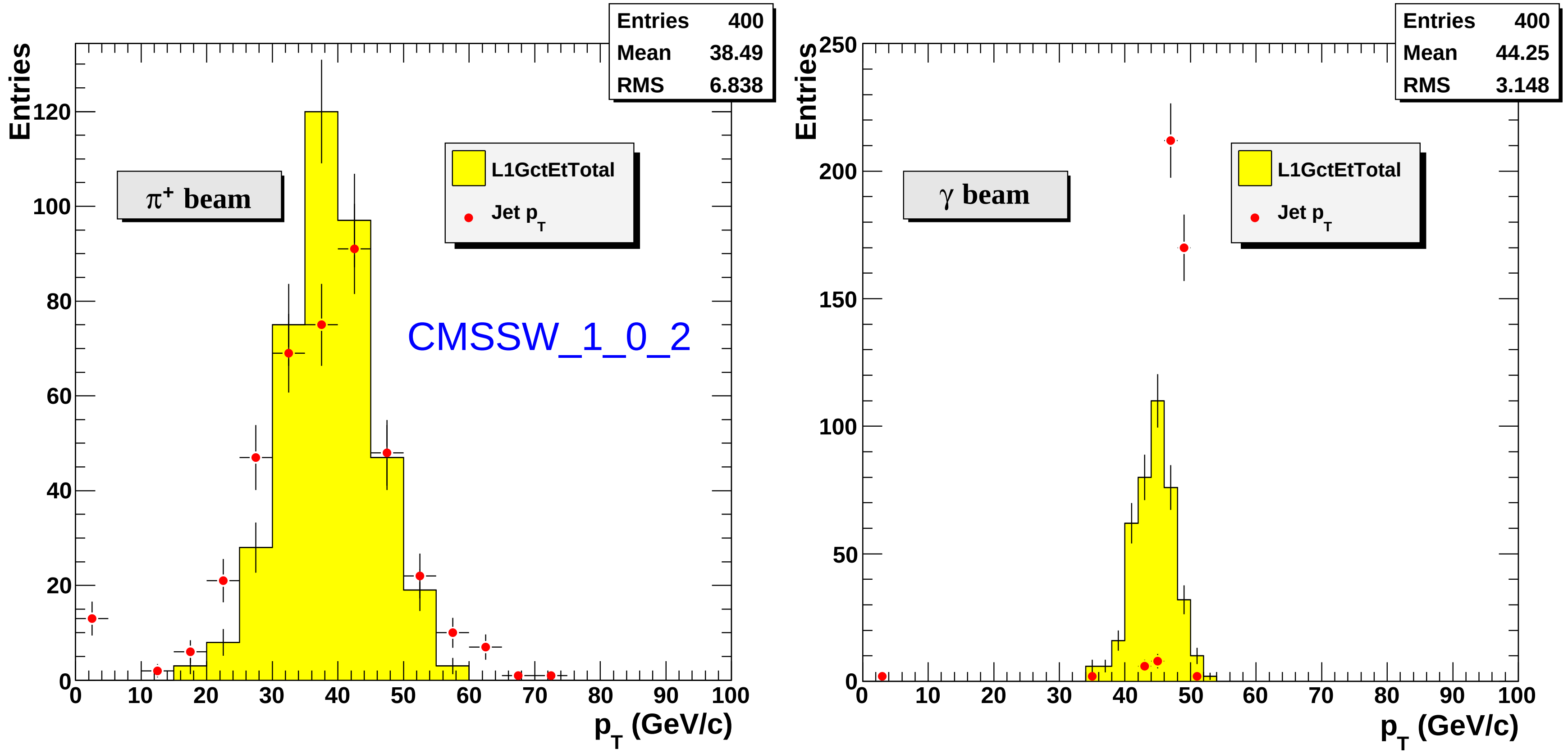


QCD MC Sample – $50 < \hat{p}_T < 80$ GeV

Level 1 Emulator Studies

50 GeV p_T Particle Gun MC

$-1.1 < \eta < 1.1, 0 < \phi < 2\pi$



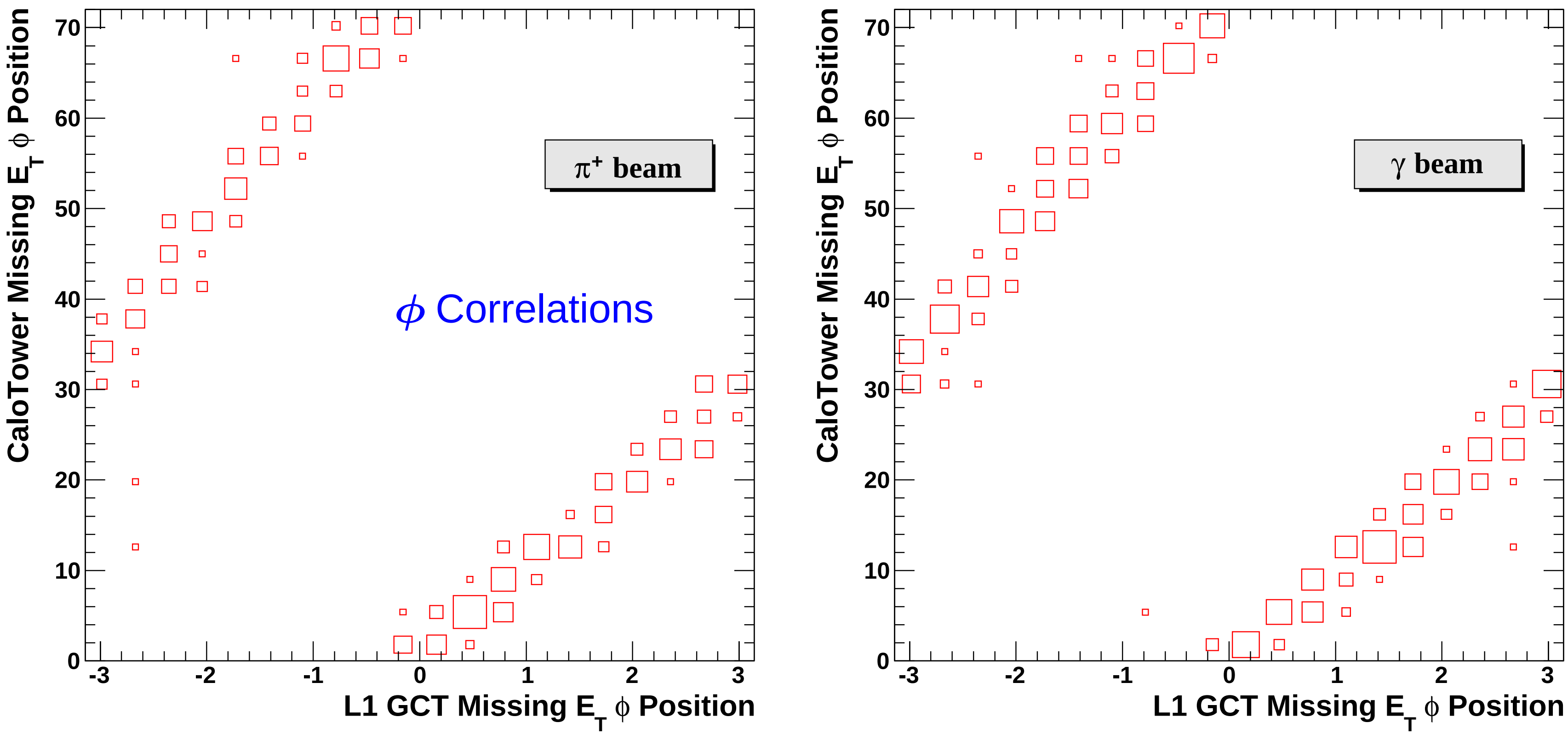
L1 GCT output scaled by a factor of 3

Jets use midpoint cone algorithm with $R = 0.5$

Level 1 Emulator Studies (cont.)

50 GeV p_T Particle Gun MC

$-1.1 < \eta < 1.1,\ 0 < \phi < 2\pi$

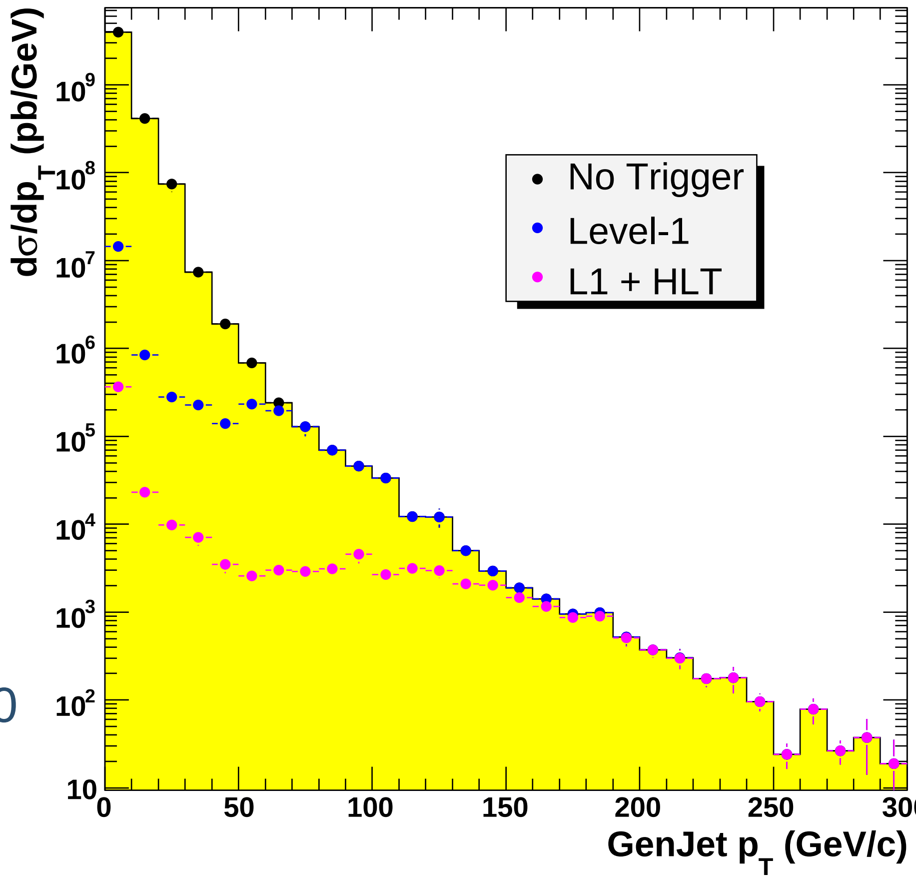


L1 GCT output scaled by a factor of 3

Jets use midpoint cone algorithm with $R = 0.5$

“Triggered” Jet p_T Spectrum

- Level-1 GCT emulator output is still not fully understood (any day now)
- For now, using Werner Sun’s pseudo L1 seeds which are created using generator level MC information.
- Level-1 p_T threshold = 60 GeV.
- HLT Single jet p_T threshold = 120 GeV.



Upcoming Plans

- Implement $\mathbf{H_T}$ and missing $\mathbf{H_T}$ filters.
  (Need an $\mathbf{H_T}$ producer in CMSSW. Should be available shortly.)
- Continue with jet timing and efficiency studies.
- Use real level-1 emulator once it is verified.
- Verify the HLT Jet and $\not{E}_T$ trigger rates reported in PTDRv2.
- Begin development of the Jet and $\not{E}_T$ trigger menus.
- Study cross-triggers (e.g. $\not{E}_T$ + leptons).
- Use CSA06 HLT Soup for high statistics studies.
- Find out if there are any additional jet or $\not{E}_T$ filters needed.