PRS: Physics Reconstruction and Selection
HCAL/JetsMET group

Status of JetsMET

Shuichi Kunori
U. of Maryland
18-May-2001
HCAL - Jets/MET

S.Eno / S.Kunori - Coordinator

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

Dates:
End 2002 DAQ TDR (end 2001 for HLT section)
End 2004 Physics TDR

Organization:
HCAL simulation – Sunanda Banerjee (TIRF)
   CMSIM/GEANT4/FAST
   Verify shower model in G4.
Calibration & Monitoring – Olga Kodolova (MSU)
   energy scale of jets, MET, tau
   -> from detector construction/commission to in-situ calibration.
HCAL in ORCA – Salavat Abdoullin (Maryland)
   readout simulation + …
Physics objects with HCAL – Sasha Niketenko (CERN/ITEP)
   jets, MET & tau
Currently, the DAQ TDR has one chapter dedicated to the High Level Trigger

- It should describe:
  - Amount of data per detector (occupancies, etc)
  - Readout scheme (zero-suppression, selective readout etc)
  - Basic raw data format (time samples)
  - Basic reconstruction
  - Lvl-2 algorithms
  - Lvl-3 algorithms
  - Performance of all object identification
  - Basic trigger table that includes all discovery channels
  - Basic rate plots. We MUST have a credible scenario to get to the $O(100)$ Hz level

For both low and high luminosity

We will cover all of these!
Main Issues

Many physics analyses require

- low $E_T$ jets:
  - from top, $W$, Higgs
  - from $WW$ fusion

  part of signal
  background rejection (e.g. jet veto)

- High luminosity

  pile-up energy
  low ET jets from overlapping events
  fake jets due to pileup.

- $\tau$ jet
- $b$ jet (tag)

- Correct energy scale from low $E_T$ to very high $E_T$
- Better resolution for Jet/MET

$E_T$ range

20GeV-2TeV
Single Top - Kinematics

Measurement of
- $V_{tb}$ / top decay properties / background to new physics

- $P_T$ (lepton) vs $\eta$
  - $P_T > 20$ GeV
  - $\eta < 2.5$

- $E_T$ (b-quark) vs $\eta$
  - $E_T$ in 20-100 GeV
  - $\eta < 2.5$

- MET
  - $> 20$ GeV

- $M_T (l+\nu)$
  - $50-100$ GeV

- $E_T$ (tagging jet) vs $\eta$
  - $E_T > 50$ GeV
  - $\eta$ in 2.5-4.0
Forward tagging jets & Higgs Couplings measurement


Although $\sigma(VBF) \sim \sigma(GF)/3$, VBF process may play a big role in measurement of higgs properties in addition to discovery potential.

Accuracy expected with 200 fb$^{-1}$ of data with ATLAS+CMS detectors at LHC

- measure $H\gamma\gamma$, $H\tau\tau$, $Hgg$ couplings at 10% level
- $hWW$ coupling ($|\sin(\beta-\alpha)|$) can be measured at 5% level
\( \tau \) jet

**5\( \sigma \) contours for the main discovery channels at high \( \tan\beta \)**

Branching ratios for \( H^+ \)

- \( \tau \nu \) decay
  - 1 prong \( \tau \) decay (\( \tau \) jet)
    - \( \tau^+ \rightarrow \pi^+\nu \) 12.5%
    - \( \tau^+ \rightarrow \rho^+\nu \rightarrow \pi^+\pi^0\nu \) 26%
    - \( \tau^+ \rightarrow a_1\nu \rightarrow \pi^+\pi^0\pi^0\nu \) 7.5%

**CMS**

- \( \tau^+ \rightarrow bH^+ H^+ \rightarrow \tau\nu \)
- \( A, H \rightarrow \tau\tau, 30 \text{ fb}^{-1} \)
- lepton + \( \tau \) jet

- \( \tau \nu \) \( \rightarrow \)

- \( \tan\beta = 30 \)
- \( \tan\beta = 3 \)

- No stop mixing
τ jets

tau jet:
  narrow (one prong) jet

L1/L2:
  use only calorimeter
  L1: 0.087x0.087
  L2: individual crystal

L2.0 Tau trigger

1. reconstruct a Jet*
2. calculate e.m. isolation:
   \[ P_{\text{isol}} = E_{\text{cal}}(R < 0.4) - E_{\text{cal}}(R < 0.13) \]
3. accept event if \( P_{\text{isol}} < P_{\text{cut}} \)

\[ \text{gg->bbA, A->} 2\tau -> h^+ + h^- + X \]
tau jets at L3

1. Tracks are reconstructed with 3 pixel layers only within a cone given by L2.0 jet axis.

2. Isolation cuts: tracks in a big cone (0.3-0.4) vs. a small cone (~0.1), PT(tr)>1-2GeV

(Nikitenko & Kotlinski : cms116 analysis)
**Pion Response: Linearity**

**ECAHL+HCAL: Non compensating calorimeter**

**CMS Simulation**

ET=3 GeV pion in 0<|\eta|<5

- E=3 GeV
- 1.5 GeV
- 3.0 GeV

**96'H2 Test Beam Data**

\[ E = E_C + \alpha \times H_1 + H_2 + H_0 \]

- \( e/\gamma \)
- \( \pi \) interacting in HCAL only
- \( \pi \) interacting in ECAL or HCAL
- no weighting
- passive weighting
- dynamic weighting

**E= 3 7 30 82 227 GeV**

P= 0 200 400 GeV
Jet Response and Correction #1

(S. Arcelli)

Et-eta dependent correction for QCD jets

No pileup

$$\text{Et(corr)} = a + b \times E_T^{\text{rec}} + c \times E_T^{\text{rec}}^2$$

With pileup

$$\text{Et(corr)} = a + b \times (E_T^{\text{gen}} + E_T^{\text{pu}}) + c \times (E_T^{\text{gen}} + E_T^{\text{pu}})^2$$

Offline jets resolution, $|\eta|<5$

$$\sigma_{E_T/E_T} = 1.49/\sqrt{E_T^{\text{gen}}} + 0.08$$
$$\sigma_{E_T/E_T} = 1.05/\sqrt{E_T^{\text{gen}}} + 0.06$$

Offline jets with pileup

$$\sigma_{E_T/E_T} = 1.37/\sqrt{(E_T^{\text{gen}} + E_T^{\text{pu}})} + 0.08$$
$$\sigma_{E_T/E_T} = 1.50/\sqrt{E_T^{\text{gen}}}$$
Dijet Mass Resolution

No pileup

M(bb) in ttH

With pileup

W(jj)

Top(jjj)

Before correction

Jet energy correction

without: 19%

with: 14%

CMSJET 15%

(S.Arcelli & V.Drollinger)

After correction

(R.Kinunnen)

ORCA4: resolution1 = 14.0%
Energy scales for MET

Corrections
Type 1: Jet corr.
Type 2: Jet corr. + out of cone corr.

Out of cone corr. uses weights for jet(30GeV) corr.
Corrected MET for mSUGURA
Jets+MET at low lumi

Mean offset

σ(reco MET\text{\tiny MC} - MC MET\text{\tiny MC}), \text{GeV}

L=10^{30}\text{cm}^{-2}\text{s}^{-1}

σ(reco MET\text{\tiny MC} - MC MET\text{\tiny MC}), \text{GeV}

MC MET < 50 GeV

150 < MC MET < 200 GeV

300 < MC MET < 350 GeV

reco MET - MC MET, GeV

reco MET - MC MET, GeV

reco MET - MC MET, GeV

new/GeV

new/GeV

new/GeV
Higgs mass in bbA, $A \rightarrow 2\tau \rightarrow 2j$

**before correction**

- $M_A = 500$ GeV, $\tan\beta = 20$
- $E_t > 60$ GeV
- $\Delta\phi_{\tau\tau} < 175^\circ$
- $E_{\tau\tau} > 0$

**after correction**

- $M_A = 500$ GeV, $\tan\beta = 20$
- $E_t > 60$ GeV
- $\Delta\phi_{\tau\tau} < 175^\circ$
- $E_{\tau\tau} > 0$

<table>
<thead>
<tr>
<th>bbA, A→2τ→2j</th>
<th>no corrections</th>
<th>type1 corrections</th>
<th>type2 corrections</th>
<th>CMSJET</th>
</tr>
</thead>
<tbody>
<tr>
<td>$&lt;M_H&gt;$</td>
<td>438.3 GeV</td>
<td>500.3 GeV</td>
<td>511.0 GeV</td>
<td>500.0 GeV</td>
</tr>
<tr>
<td>$\sigma / &lt;M_H&gt;$</td>
<td>19.7 $%$</td>
<td>18.9 $%$</td>
<td>16.8 $%$</td>
<td>13.4 $%$</td>
</tr>
<tr>
<td>$\varepsilon_{\text{reco}}$ (corr.) / (no corr.)</td>
<td>1</td>
<td>1.53</td>
<td>1.80</td>
<td></td>
</tr>
</tbody>
</table>
Jet correction method #2

Jet Corr. #1

\[ \alpha \times (EC+HC) \]
- corr. for jet energy scale
- \( \alpha \) depends on jet(Et,\( \eta \))

Jet Corr. #2

\[ \alpha \times EC + \beta \times H1 + \gamma \times H2 \]
- optimize jet resolution
  (and jet energy scale)
- \( \alpha, \beta, \gamma \) depends on jet(Et,\( \eta \))

(A.Oulianov)
### Jet Correction method #2

#### Table 1: Optimum weights and energy resolutions for ET=80 GeV jets

<table>
<thead>
<tr>
<th>eta range</th>
<th>eb</th>
<th>hb1</th>
<th>hb2</th>
<th>ee</th>
<th>he1</th>
<th>he2</th>
<th>RESOLUTION CMSIM120 weights + energy corrections</th>
<th>RESOLUTION optimum weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 0.4</td>
<td>1.48</td>
<td>1.12</td>
<td>1.12</td>
<td></td>
<td></td>
<td></td>
<td>0.143</td>
<td>0.136</td>
</tr>
<tr>
<td>0.4 - 0.8</td>
<td>1.49</td>
<td>0.95</td>
<td>1.19</td>
<td></td>
<td></td>
<td></td>
<td>0.141</td>
<td>0.134</td>
</tr>
<tr>
<td>0.8 - 1.1</td>
<td>1.49</td>
<td>1.08</td>
<td>1.19</td>
<td></td>
<td></td>
<td></td>
<td>0.144</td>
<td>0.137</td>
</tr>
<tr>
<td>1.25-1.45</td>
<td>1.47</td>
<td>0.98</td>
<td>1.40</td>
<td>1.89</td>
<td>1.26</td>
<td>1.54</td>
<td>0.136</td>
<td>0.133</td>
</tr>
<tr>
<td>1.7 - 2.0</td>
<td></td>
<td>1.44</td>
<td>1.04</td>
<td>1.15</td>
<td>1.15</td>
<td></td>
<td>0.134</td>
<td>0.128</td>
</tr>
<tr>
<td>2.0 - 2.4</td>
<td>1.32</td>
<td>1.03</td>
<td>1.15</td>
<td></td>
<td></td>
<td></td>
<td>0.123</td>
<td>0.120</td>
</tr>
</tbody>
</table>

#### Table 3: Optimum weights and energy resolutions for ET=120 GeV jets

<table>
<thead>
<tr>
<th>eta range</th>
<th>eb</th>
<th>hb1</th>
<th>hb2</th>
<th>ee</th>
<th>he1</th>
<th>he2</th>
<th>RESOLUTION CMSIM120 weights + energy corrections</th>
<th>RESOLUTION optimum weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 0.4</td>
<td>1.40</td>
<td>0.93</td>
<td>1.16</td>
<td></td>
<td></td>
<td></td>
<td>0.124</td>
<td>0.119</td>
</tr>
<tr>
<td>0.4 - 0.8</td>
<td>1.41</td>
<td>1.13</td>
<td>1.13</td>
<td></td>
<td></td>
<td></td>
<td>0.132</td>
<td>0.126</td>
</tr>
<tr>
<td>0.8 - 1.1</td>
<td>1.40</td>
<td>1.16</td>
<td>1.16</td>
<td></td>
<td></td>
<td></td>
<td>0.125</td>
<td>0.121</td>
</tr>
<tr>
<td>1.25-1.45</td>
<td>1.44</td>
<td>0.82</td>
<td>1.37</td>
<td>1.85</td>
<td>0.55</td>
<td>1.73</td>
<td>0.125</td>
<td>0.119</td>
</tr>
<tr>
<td>1.7 - 2.0</td>
<td>1.37</td>
<td>0.91</td>
<td>1.14</td>
<td>0.122</td>
<td>0.116</td>
<td></td>
<td>0.116</td>
<td></td>
</tr>
<tr>
<td>2.0 - 2.4</td>
<td>1.29</td>
<td>0.70</td>
<td>1.17</td>
<td>0.117</td>
<td>0.113</td>
<td></td>
<td>0.113</td>
<td></td>
</tr>
</tbody>
</table>
Correction method #3a (single pion)  
(V. Genchev)

Method #3

\[ E_{nl}^{\text{rec}} = \sum_{i=1,4} f_i(\vec{A}, E_i)E_i, \]

i: longitudinal segmentation

Method #1

\[ E^{\text{rec}} = \sum_{i=1,4} C_i E_i, \]

Minimize

\[ \chi^2 = \frac{1}{(M-N+1)} \sum_{j=1,M} W_j (E_j^m - E_{nl,j}^{\text{rec}})^2, \]

with cmsim.

Linearity is restored to 3% in 10-1000GeV for single pion!
Correction Method #3b
(single pion)

\[ E = \frac{1}{e_E} (\frac{e}{\pi})_E R_E + \frac{1}{e_H} (\frac{e}{\pi})_H R_H \]

\[ F_0 = \frac{E_0}{E} \approx 0.1 \ln(E) \]

\[ \frac{e}{\pi} = \frac{e}{h}/[1+(e/h-1)F_0] \]

\((e/h)_{\text{HCAL}} \approx 1.39\) (NIM paper)

To find \(e/h\) for ECAL, measure \(e/\pi\) at different energies for showers where there is a substantial energy (> 30% of the beam energy) in ECAL.

\((e/h)_{\text{ECAL}} \approx 1.60\)

Linearity is restored to a few %. The resolution is Gaussian to a high level of accuracy with ~ NO constant term and a 120% stochastic coefficient

Next: identify em cluster and had cluster in jet using transverse shower shape (in crystals) and reco-ed tracks and apply this to had cluster.
Effect of Threshold on low \(E_T\) jet and MET

Electronics noise and occupancy define the threshold.

- \(0.5 \text{ GeV/tower} \) at \(10^{34}\)

Lower threshold is better!

(A.Krokhotine) (S.Nikitenko)

\[
\begin{align*}
\sigma_{NEW} &= 0.271 \\
\sigma_{OLD} &= 0.363
\end{align*}
\]
Front end electronics simulation

\[ E = \sum (\text{Signal buckets})_i - \frac{\sum (\text{pre buckets})_j}{n} \]

Electronics noise 200MeV/25nsec/ch \( \rightarrow \) 500MeV/(3+3) buckets/ch

\( \rightarrow \) Looking for better method for energy calculation
Algorithm for L1 through Offline (1)

L1 – calorimeter only (coarse segmentation)
  • Resolution improvement
    • Equalize calorimeter response with simple correction
      • $a \times (EC+HC)$, $a$ depends on jet(ET,h)
      • $a \times EC + b \times HC$, $a,b$ depends on jet(ET,h)
  • Fake Jets/Pileup jets rejection
    • Threshold cut on a central tower in jets (seed cut)

L2 – calorimeter only (fine segmentation)
  • Resolution improvement
    • Better energy extraction from ADC counts
    • Em/had cluster separation using transverse shower shape in crystals
  • Fake jet/Pileup jet rejection
    • Use of transverse shower shape
Algorithm for L1 through Offline (2)

L3 – calorimeter plus pixel

- Resolution improvement
- Pileup energy subtraction
  - Estimation of energy flow from pileup events using pixel hits/tracks.
- Fake jets/Pileup jets rejection
  - Vertex information and jet pointing using pixel hits/tracks.

Offline – calorimeter plus fully reco-ed tracks

- Resolution improvement
- Fake jets/Pileup jets rejection
  - Jet and MET will be reconstructed with Tracks, EM clusters and HAD clusters.
  - All tracks down to $E_T \sim 700$ MeV have to be reconstructed at $10^{34}$!
- Physics correction – e.g. correction for IFR/FSR.
  - In-situ calibration!
Long way to go, but promising...