Performance of “Momentum Imbalance” Measurement Using the CMS Detector at the LHC

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The Joint Spring Meeting of the Texas Section of the American Physical Society (TSAPS), the Texas Section of the American Association of Physics Teachers (TSAAPT), and Zone 13 of the Society of Physics Students (SPS), Austin, Texas, March 18-20, 2010
Supersymmetry (SUSY) introduces a set of new particles by symmetrizing the theory between fermions and bosons.

\[
\text{SM Leptons/Quarks} \quad \text{... \ Spin-1/2 particles} \\
\text{Gauge bosons} \quad \text{... \ Spin-1 particles}
\]

\\

\[
\text{Slepton/Squatks} \quad \text{... \ Spin-0} \\
\text{Gauginos} \quad \text{... \ Spin-1/2}
\]

\[\Rightarrow\text{ Doubling the number of elementary particles!!!}\]

**What we gain?**

Roy Montalvo

MET at the LHC
Supersymmetry (SUSY) is expected to be observed at TeV scale for three aspects.

- **Elegant solution** to solve the problem associated with the Higgs mass
- **Connecting** the Standard Model with an ultimate unification of the fundamental interactions
- **Consistent with** the lightest neutralino ($\tilde{\chi}_1^0$) as dark matter candidate

The LHC is the machines to probe the TeV scale.
**Discoveries with “Missing ET”**

**Standard Model’s CV**

<table>
<thead>
<tr>
<th>Year</th>
<th>Degree</th>
<th>Discovery</th>
<th>Location</th>
<th>Year</th>
<th>Degree</th>
<th>Discovery</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973</td>
<td>B.S.</td>
<td>Neutral current</td>
<td>@ CERN SPS (400 GeV $p$)</td>
<td>1983</td>
<td>M.S.</td>
<td>“W/Z discovery”</td>
<td>@ CERN SppS (540 GeV $pp$)</td>
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<tr>
<td>1995</td>
<td>Ph.D.</td>
<td>“Top discovery”</td>
<td>@ Fermilab Tevatron (1.8 TeV $pp$)</td>
<td>20??</td>
<td></td>
<td>Evidence of SUSY-like new physics in the jets + MET final state</td>
<td>at the LHC</td>
</tr>
</tbody>
</table>

**Missing $E_T$ (MET) - inferring neutrinos**

**MET - inferring new physics**

(if the dark matter is like a heavy neutrino.)

**Cosmology $\otimes$ LHC = [Exciting Motivation] $\otimes$ [Right Place&Timing]**

Roy Montalvo  
MET at the LHC
Experimentally, we measure a momentum imbalance in transverse plane and call it “missing transverse energy” \( E_{T}^{\text{miss}} \) or \( E_{T} \).
**Large Hadron Collider**

**LHC is Back!**

*(Nov. 23, 2009)*

- CMS
- ALICE
- ATLAS
- LHCb

19:20 pm

CMS

17:59 pm

LHCb

14:22 pm

CMS

**E_{beam} = 450 GeV**

**p**

**p**

**7 TeV in 2010**

**14 TeV in 2013**

Roy Montalvo

MET at the LHC
The CMS (21 m x 15 m x 15 m, 12,500 tonnes) is one of two super-fast & super-sensitive detectors, consisting of 15 heavy elements, collecting debris from the collision and converting a visual image for us. “Particle” Telescope at CERN vs. Hubble Space Telescope in outer space.
Re-discoveries & MET Monitoring

We proposed to monitor MET events as Prompt Feedback in December 2008.

We designed and tested our MET monitoring (METmon) code using the December 2009 proton-proton collision data.
MET Monitoring Scheme

900 GeV pp Data

Express Stream Data

Monitoring Code

“Anomalous” Events

Comparisons!! Rates, Discrimination, Efficiencies, MET Tails

Compare w/ Monte Carlo

“Clean” Events

Physics Cuts

HDP
Nhits NADC Timing

RBX
Nhits NADC Timing

JetMET
MET MET Φ Jet ET Jet EMF CHP

HDP
Nhits NADC Timing

RBX
Nhits NADC Timing

JetMET
MET MET Φ Jet ET Jet EMF CHP

Data and MC agree well.
Our METmon provided key visuals online to detect any anomaly during the December 2009 operation.

This is in the CMS Prompt Feedback system for the coming 7-TeV pp operation.
Summary

MET is very sensitive to a status of detector (e.g., noise, dead channels).

As a part of the CMS commissioning tasks, we proposed a powerful MET monitoring (METmon) framework.

We designed and successfully tested our METmon framework using 900 and 2360-GeV proton-proton collision data in December 2009.

Further improvements are underway for commissioning at 7 TeV this year.