Understanding MET at CMS in view of SUSY

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Introduction

- MET measures the energy imbalance in the plane transverse to the beam axis
  - consequence of the law of energy conservation

- Sources
  - particles escaping detection (SM and beyond)
  - detector resolution $\Rightarrow$ energy mismeasurement
  - detector malfunction, beam halo, cosmic rays

- Useful quantity to commission the detector

- Provides a great discriminant in the search for new physics
CMS detector

Azimuthal angle: $\phi$
Polar angle: $\theta$
Pseudorapidity: $\eta = -\ln \tan(\theta/2)$
MET algorithms in CMS

Generic definition \( \vec{\not{E}}_T = - \sum_{\text{particles}} (p_x \hat{i} + p_y \hat{j}) \)

Depending on what is used as “particles” we have:

- **CaloMET** = based on calorimeter towers
  - traditional definition
- **tcMET** = tracks replace matched calorimeter towers
  - take advantage of the better tracker momentum resolution
- **pfMET** = based on Particle Flow reconstruction
  - improved resolution due to particle identification
- **MHT** = based on reconstructed jets
  - more robust against detector noise and pile-up effects
Cleaning-up the events

Select good collisions

• ≥ 1 well identified primary vertex
• vertex z-position < 15 cm away from center of detector
• > 25% fraction of high-purity tracks if $N_{\text{tracks}} < 10$
  • removes events where bunches of particles cross detector longitudinally

Beam Halo removal

• identify muons going parallel to the beam
• use CSC muon detectors
• $1 - 2 \times 10^{-5}$ fraction removed
  • will increase with beam intensity

CMS preliminary 2010
\( \sqrt{s} = 7 \text{ TeV} \)
Remove anomalous signals based on:

- unphysical charge sharing between channels
- timing and pulse shape information

This excludes 0.003% of all minimum bias events
• Good agreement with simulated minBias events using Pythia 8
  • Monte Carlo simulation normalized to data

• CaloMET(left), tcMET(middle), pfMET(right)

• Events with MET > 60 GeV studied in more detail

• Cleaning procedures can and will be improved
Data vs Simulation - DiJets

- Event topology closer to those used in searches
  - require two leading jets $P_T > 25$ GeV, $|\eta| < 3$
- Simulation is more reliable for this production
  - Good agreement between data and simulation in this sample as well
Energy scale corrections

- **Non-compensating calorimeter leads to energy under-measurement** (CaloMET is affected the most)

- **type-I correction** $\Rightarrow$ vector sum of transverse momentum of jets
  - apply jet energy corrections using dijet ($\eta$ dependence) and photon + jet (absolute scale) events
  - use jets with EM fraction $< 0.9$ and $P_T > 20$ GeV

- **type-II correction** $\Rightarrow$ soft jets unaccounted in type-I and unclustered energy
  - from simulated $Z \rightarrow$ ee events
Compare the resolutions for CaloMET, tcMET and pfMET in data and simulation

- require two leading jets $P_T > 25$ GeV, $|\eta| < 3$
- MET resolution = $\sigma$ of Gaussian fit to calibrated $\text{MET}_{x,y}$
  - calibrate MET to photon ET in photon+jets events
- show dependence on SumET calculated with particle flow algorithm
  - pfSumET calibrated particle level using Pythia

pfMET has best resolution

Data & simulation agree well
Many searches for new physics beyond SM use multijet samples
MET seems unaffected by jet multiplicity
Search channels are defined based on event content ⇒ less model dependent

- fully hadronic = jets + MET
- lepton + jets + MET
- dilepton + MET
- trilepton + MET
- photons + MET

Focus on estimating the SM background using data-driven methods

Results with first data in SM dominated regions

**MET is used for background modeling and for discrimination**
**QCD suppression**

- **QCD background can play a major role in the hadronic searches**
  - small intrinsic MET, but high cross-section and resolution effects make up for it
- **Use angle between MHT and jets to suppress it:**
  - $\Delta\phi^* > 0.5$ could efficiently reduce QCD
    \[
    \Delta\phi^* \equiv \min_{j\neq k} \left( |\Delta\phi(\vec{p}_k, - \sum_{j\neq k} \vec{p}_i)| \right)
    \]
- Similar behavior between samples with 2 jets and $\geq 3$ jets

$\sqrt{s} = 7$ TeV, 12 nb$^{-1}$

CMS preliminary

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Control QCD and fake MET

- Look at the imbalance between tracks in the transverse plane = MPT
  - neutrals are missing so the magnitude of MPT will be wrong, but the orientation is useful
  - For QCD expect angle between MPT and MHT be flat, while peaking at 0 for real MET
  - Useful to suppress/predict QCD as well as to reduce the calorimeter noise
Predicting QCD contribution

- Build MET templates from multijet events
- Bin in HT and \( N_{\text{jets}} \)

- Test this in photon+jets events (\( P_T^{\gamma} > 15 \) GeV)
- Use PF reconstruction
- Good agreement between observation and prediction
  - \( N^{\text{OBS}} = 11, N^{\text{PRE}} = 12.5 \)

\[ \text{MET} (\text{GeV}) \]

\[ \text{Events} / 5 \text{ GeV} \]

\[ \text{CMS preliminary, 65 nb}^{-1} \text{ at 7 TeV} \]

- \( \gamma + \geq 3 \) jets data
- Template prediction
QCD in diphoton+MET events

- Select a sample with 2 non-isolated photon candidates
- Weigh sample such that $P_T$ of diphoton system matches that of the signal sample
- Normalize the MET distribution to the yield in the signal region with MET < 10 GeV

- **Good agreement between observation and prediction**
  - $N^{\text{OBS}} = 4$ (MET > 20 GeV)
  - $N^{\text{PRE}} = 4.2 \pm 1.5$ (MET > 20 GeV)
Conclusions

- CMS has a good understanding of MET
- remarkable agreement between data and simulation
- performant reconstructing algorithms
- SUSY searches use a variety of tools to measure MET
- focus on data-driven approaches
- alternative methods cross-checking each other
- good description of SM contribution
- More data on the way ⇒ expect improved results