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CMS Performance Note

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MET Performance in 2012 Run A CMS Data

CMS Collaboration

Abstract

This note includes plots indicating the current state of the MET performance in 2012 for Data and MC.

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Content

- Detailed studies of the performance of the Missing Transverse Energy (MET) reconstruction are published in [1]

- In this note we present studies of the MET performance in the $\sqrt{s}$ = 8 TeV dataset collected by CMS in Spring 2012 (2012 Run A), corresponding to 0.7 fb^{-1}

  (the integrated luminosity of the full 2012 ICHEP dataset = 5.1 fb^{-1}; the full dataset has on average higher pile-up (PU) multiplicities)

  - Comparison of MET distributions in data with simulation in events with $Z \rightarrow \mu\mu$
  - MET resolution and response in $Z \rightarrow \mu\mu$ events as a function of pile-up multiplicity and the Z boson transverse momentum q_T

- Results presented in this note extend Study of MET performance in 2011 data documented in [2]

Comparing 2011 and 2012 data

NOTE: when comparing MET resolution in 2011 and 2012 data,
it is important to keep in mind that not only PU conditions changed,
but also

- Improved the ECAL and HCAL energy reconstruction to reduce the effects of out-of-time pileup interactions
  - HCAL: 100ns time window in 2011, 50ns time window in 2012.
  - ECAL: Reject out-of-time energy deposits not only in the barrel but also in the endcap

- Specific MET corrections against PU applied in 2012
  (“Type-0” and “systematic x/y shift” corrections)

$Z \rightarrow \mu\mu$ event selection

- Ideal test-bed to study the MET resolution
  - Clean final state, small background contributions
  - No intrinsic MET, only resolution effects

- Data is collected using double-muon triggers
  - Muons are required to satisfy the identification criteria listed in [3]
  - Two OS muons within $|\eta|<2.1$, $P_T^{\mu}>20$ GeV, and $60<M_{\mu\mu}<120$ GeV

- At least one of the muons isolated, isolation corrected for PU effects
  - $I_{\mu}=\sum P_T^{charged}(\Delta z<2mm)+max(P_T^{h0}+P_T^{\gamma}-\Delta\beta, 0)$; where $\Delta\beta=0.5\bullet\sum P_T^{charged}(\Delta z>2mm)$
  - Isolation requirement: $I_{\mu}<0.10\bullet P_T^{\mu}$

- The composition of the data samples is estimated using MC samples
  - MadGraph5 samples for $Z \rightarrow \mu\mu$, $t\bar{t}$ and di-boson (*WW*, *WZ*, *ZZ*)
  - PYTHIA6.4 samples for QCD multi-jet production

Event reconstruction

- Events are reconstructed with the Particle Flow technique [4]
  - MET computed as the negative vectorial sum of all particles candidates

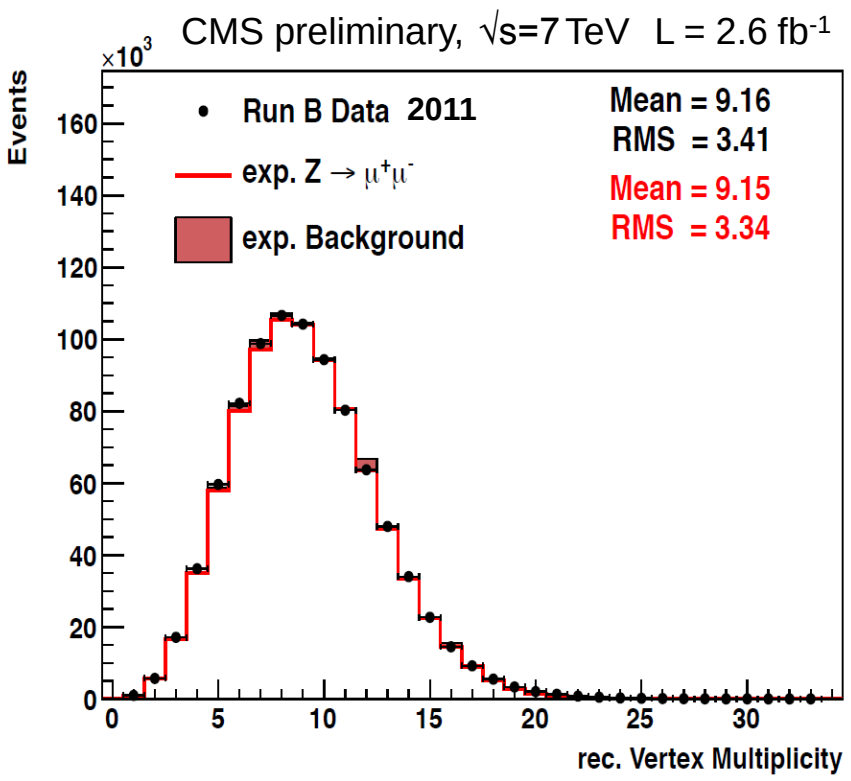
- MET reconstructed in simulated samples is corrected for JES:

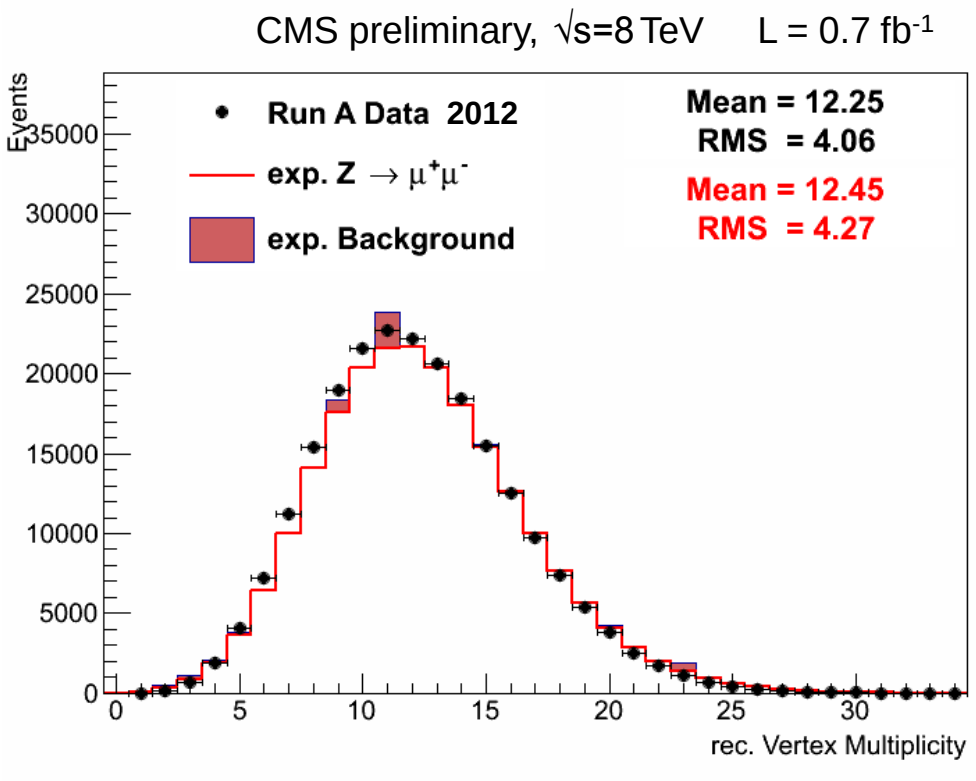
$$\not{E}_x^{corr} = \not{E}_x^{raw} + \Delta_x$$
$$\not{E}_y^{corr} = \not{E}_y^{raw} + \Delta_y \qquad \Delta_i = \Sigma P_i^{calibrated} - P_i$$
$$\not{E}_T^{corr} = \sqrt{\not{E}_x^{corr2} + \not{E}_y^{corr2}}$$

i=x, y, and the sum extends over all jets with JES corrected momenta $P_T > 10$ GeV.
  - Jet energies are corrected by applying *L1Fastjet, L2* and *L3* corrections [5]

- Events containing signatures of instrumental noise are rejected from the analysis, as described in [1]

PU multiplicities in 2012 compared to 2011

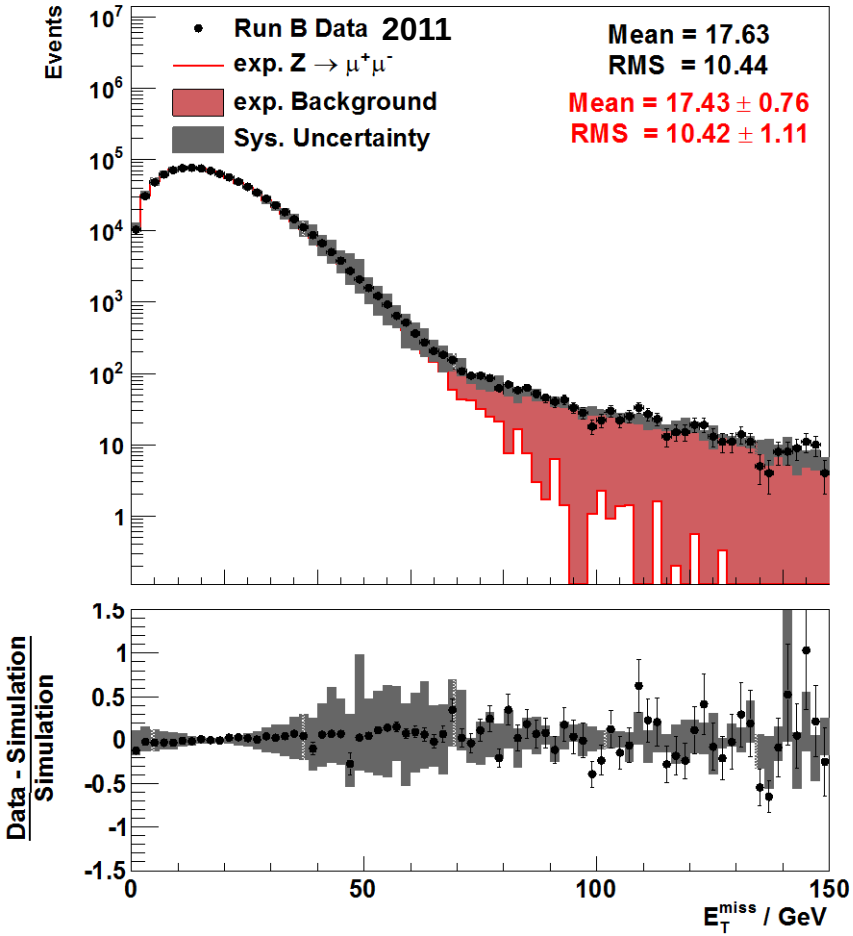




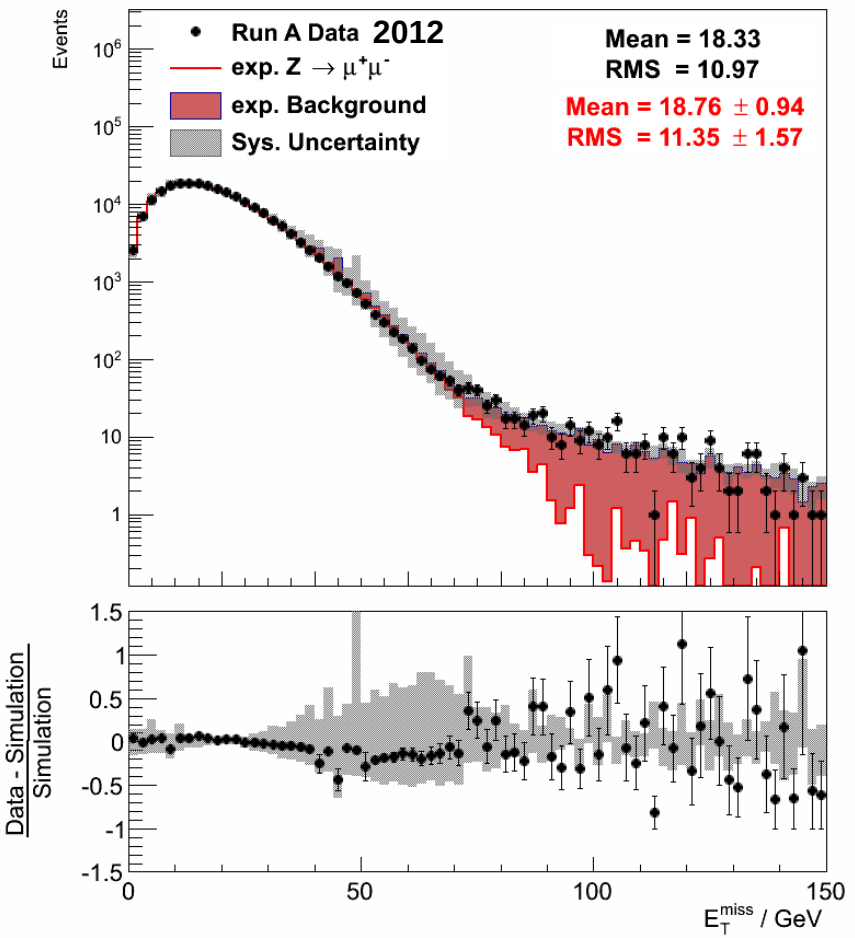
- About 30% increase in PU in 2012 Run A compared to end of 2011 data-taking (2011 Run B)
  - Simulated events are reweighted to match PU in data
  - We use a "*3D* reweighting" to match the PU distributions in the colliding bunch, as well as the previous and next bunches (for out-of-time PU)
- Larger difference in PU multiplicity for full 2012 wrt. full 2011 dataset

MET in $Z \rightarrow \mu\mu$ events

CMS preliminary, $\sqrt{s}$=7 TeV L = 2.6 fb^{-1}



CMS preliminary, $\sqrt{s}$=8 TeV L = 0.7 fb^{-1}

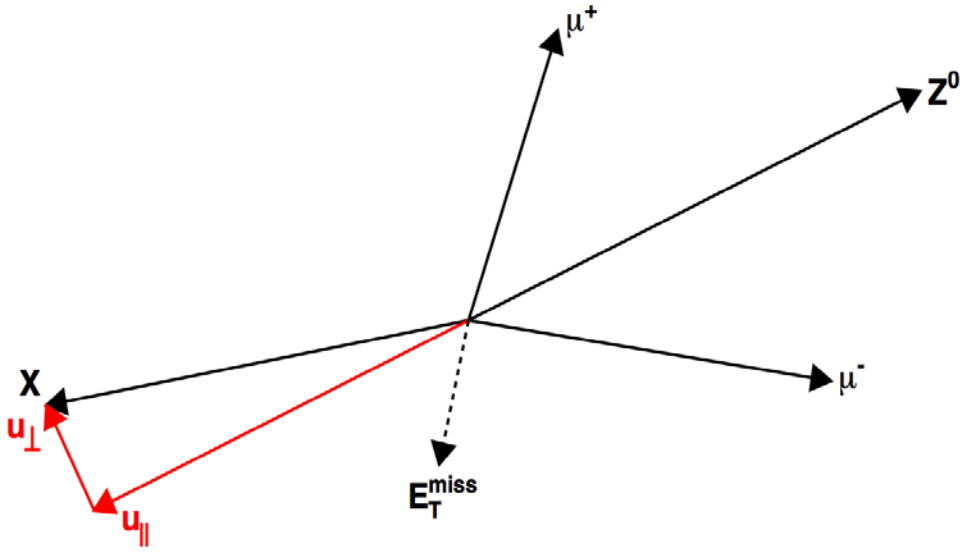


- MET distributions agree well between data and simulation
  - Simulation is corrected for jet energy scale. Additionally, jet energy resolution in simulation is smeared to match that observed in data [5].
- Small degradation in Resolution due to PU

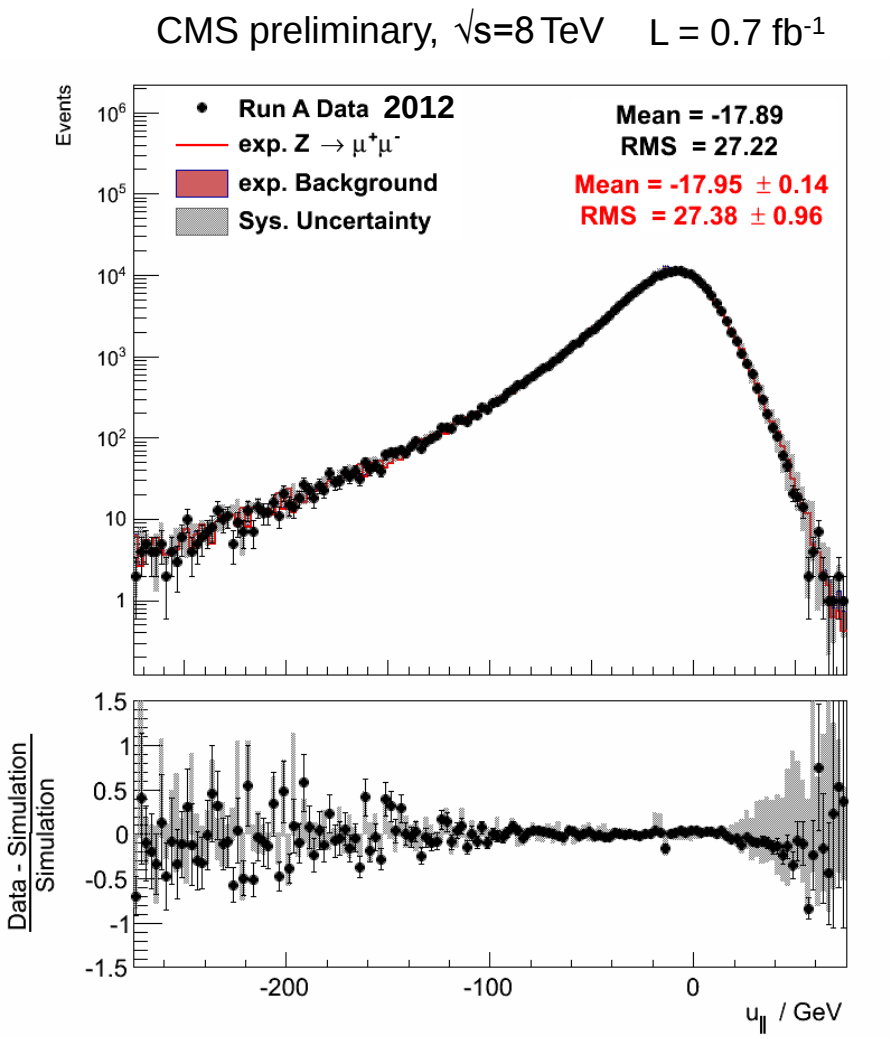
MET response and resolution in Z→μμ

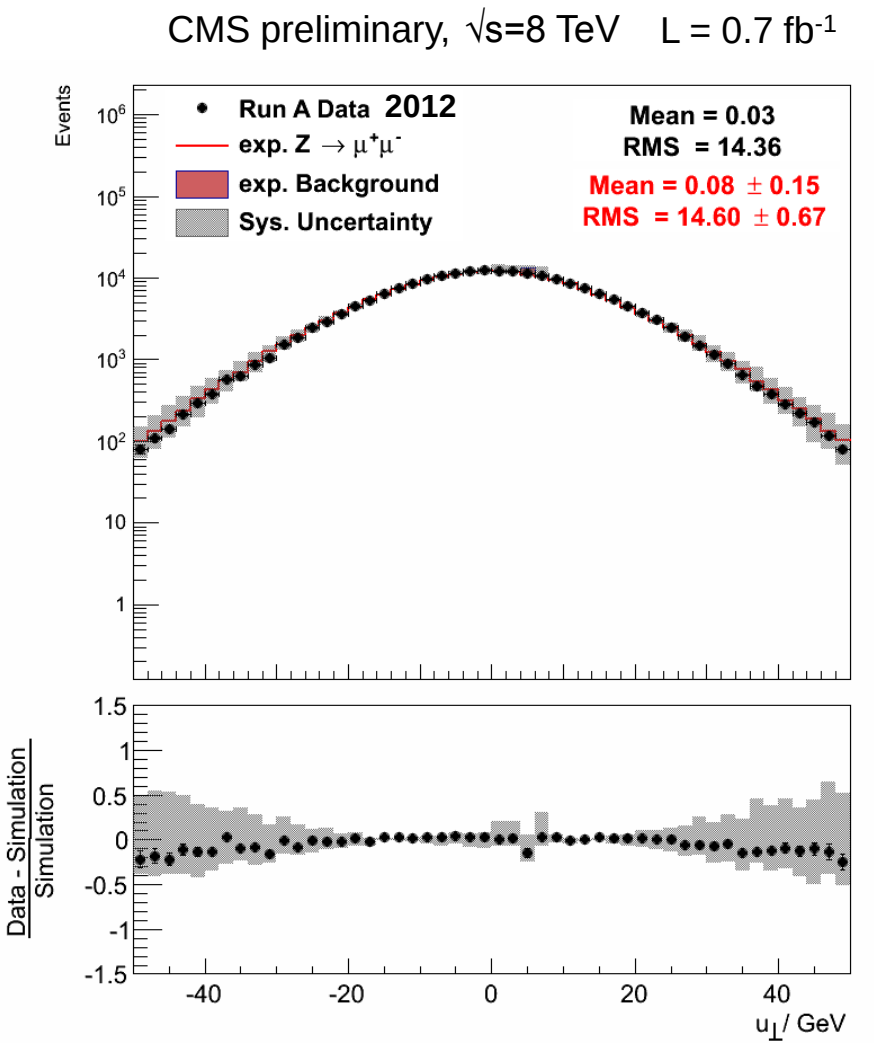
- The momentum of the *Z* boson is denoted as $\mathbf{q_T}$
- The transverse momentum ∑ of all particles' P_T except the boson: $\mathbf{u_T}$
  - In a perfectly measured event u_T would balance transvers momentum of the *Z*
  - $\vec{q}_T + \vec{u}_T + \vec{\not{E}}_T = 0$

- Determine the MET scale and resolution
  - The mean of the distribution of $\mathbf{-u_{||}/q_T}$ is a measure of the MET *response*
  - The RMS widths of $\mathbf{-u_{||}\text{-}q_T}$ and $\mathbf{u_\perp}$ are used to measure the MET *resolution*



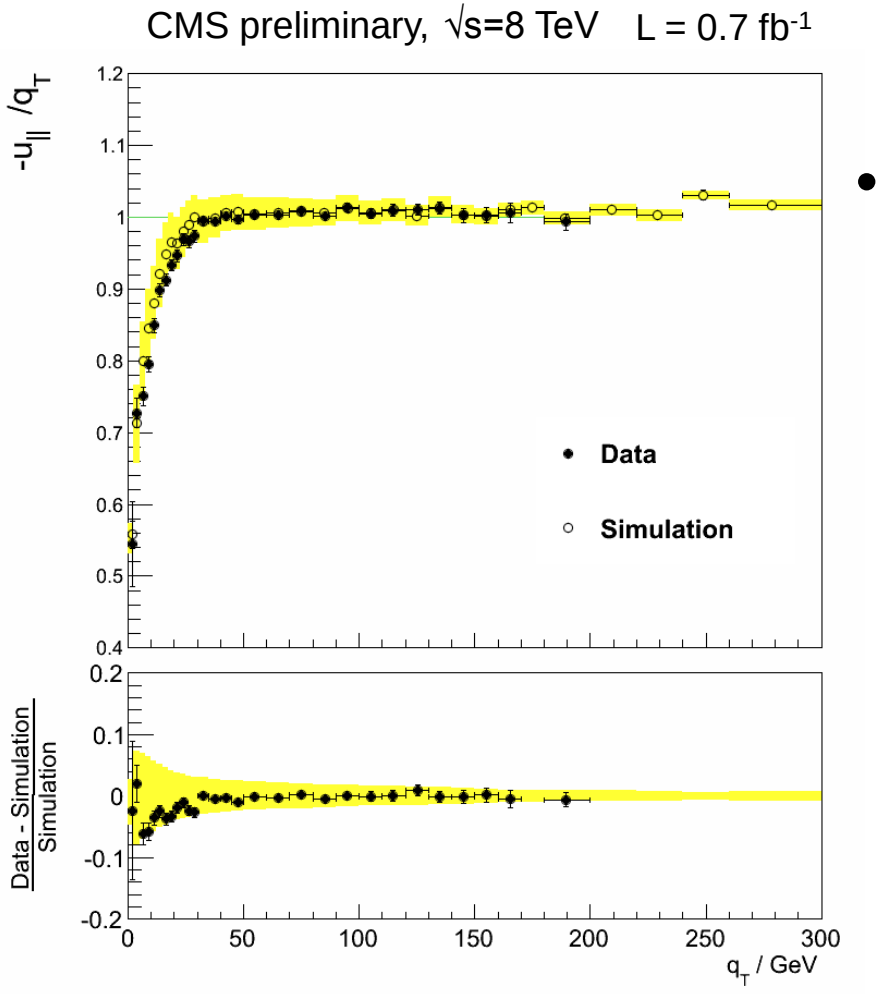
Recoil measured in Z→μμ events





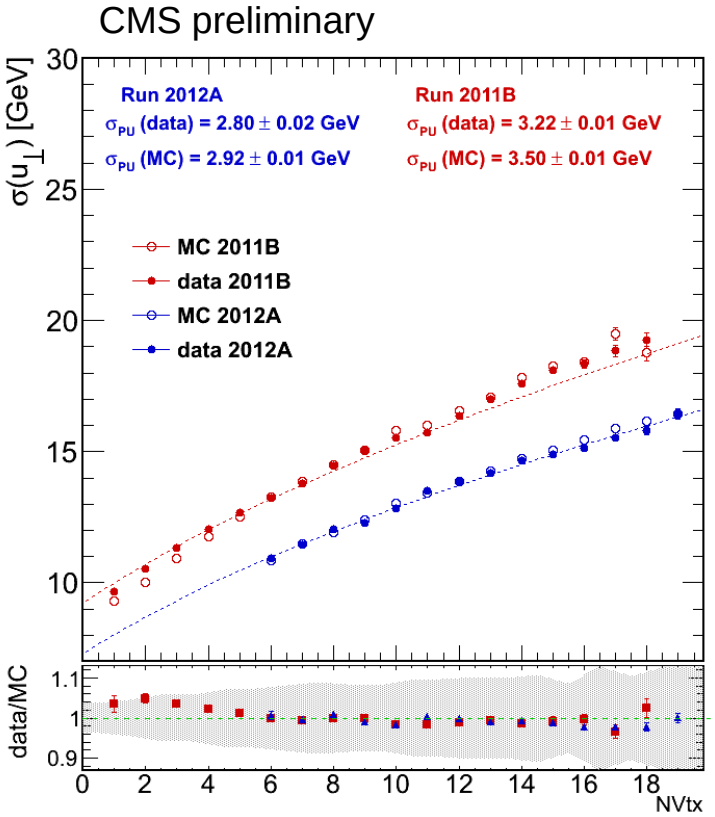
- Parallel and perpendicular recoil components agree well with the simulation.

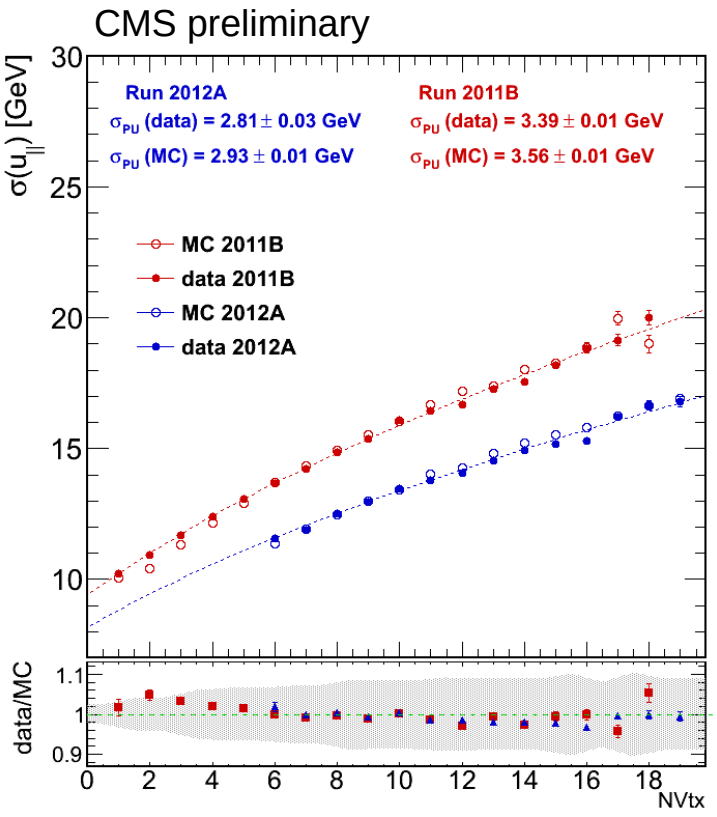
MET response in Z→μμ events



- MET response is close to unity after Type 1 MET corrections
  - ~1-2% overestimation of the response is expected: larger fraction of quark jets than in the sample used to derive the JES corrections

MET resolution VS NVtx in $Z \rightarrow \mu\mu$ events





Fit function used : $\sqrt{c^2 + \frac{Nvtx}{0.7} * \sigma_{PU}^2}$

- Resolution for fixed NVtx is better in 2012A due to changes in energy reconstruction (see page 3)
- The distributions are fitted to extract $\boldsymbol{\sigma_{PU}}$ which represents the degradation in resolution caused by PU events
  - PU introduces an additional smearing of ~2.5-3.5 GeV on MET resolution (in quadrature)
  - The "***c***" component of the fit represents average resolution in events with no PU

References

1. *CMS Collaboration, "*Missing transverse energy performance of the CMS detector*",* **JINST 6 (2011) 09001** (arXiv:1106.5048).
2. *CMS Collaboration,* "MET Performance in 2011 CMS Data", CMS DP 2012/003.
3. *CMS Collaboration*, "Measurements of Inclusive W and Z cross sections in pp Collisions at √s=7 TeV", **JHEP 01 (2011) 080** (arXiv:1012.2466).
4. *CMS Collaboration*, "Particle-Flow Event Reconstruction in CMS and Performance for Jets, Taus, and Missing ET*",* CMS PAS **PFT-09-001** (2009).
5. *CMS Collaboration,* "Determination of jet energy calibration and transverse momentum resolution in CMS", **JINST 6 (2011) P11002** (arXiv:1107.4277).