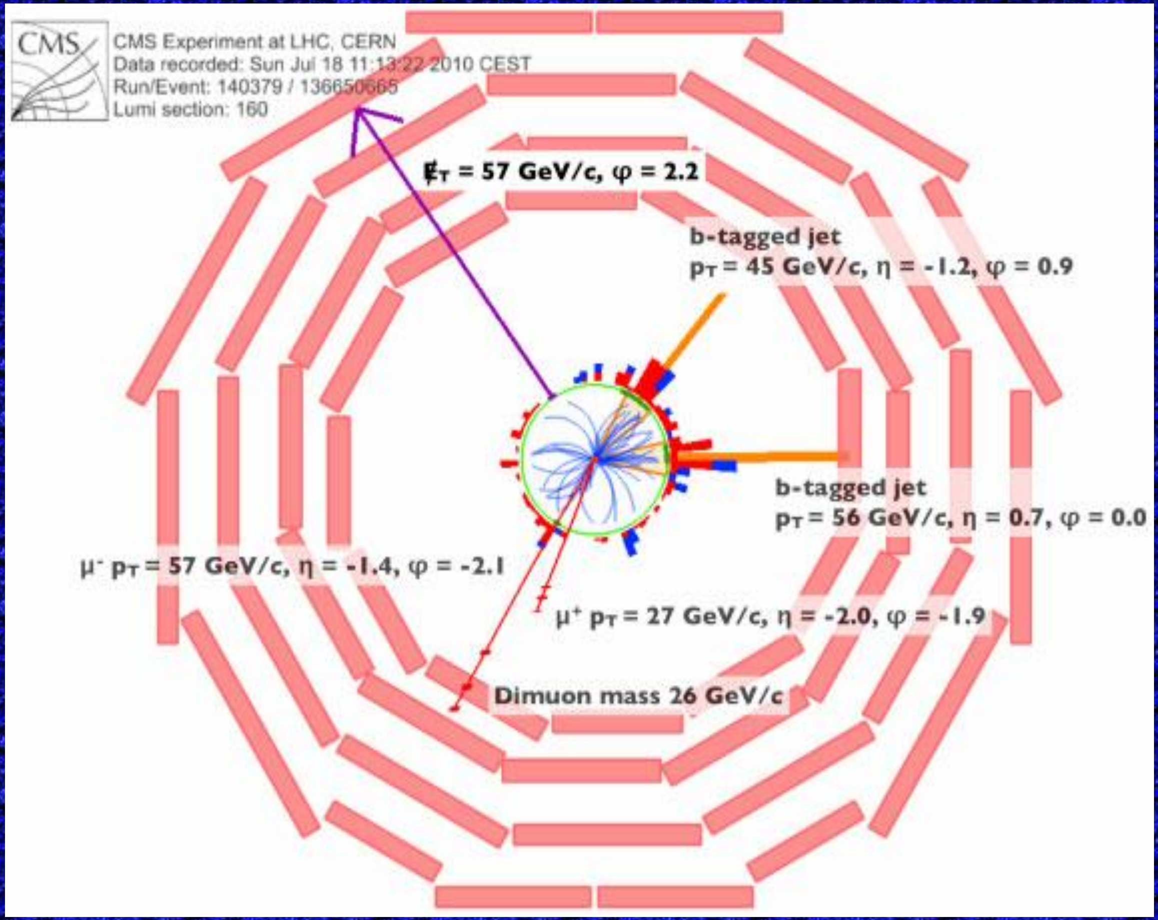
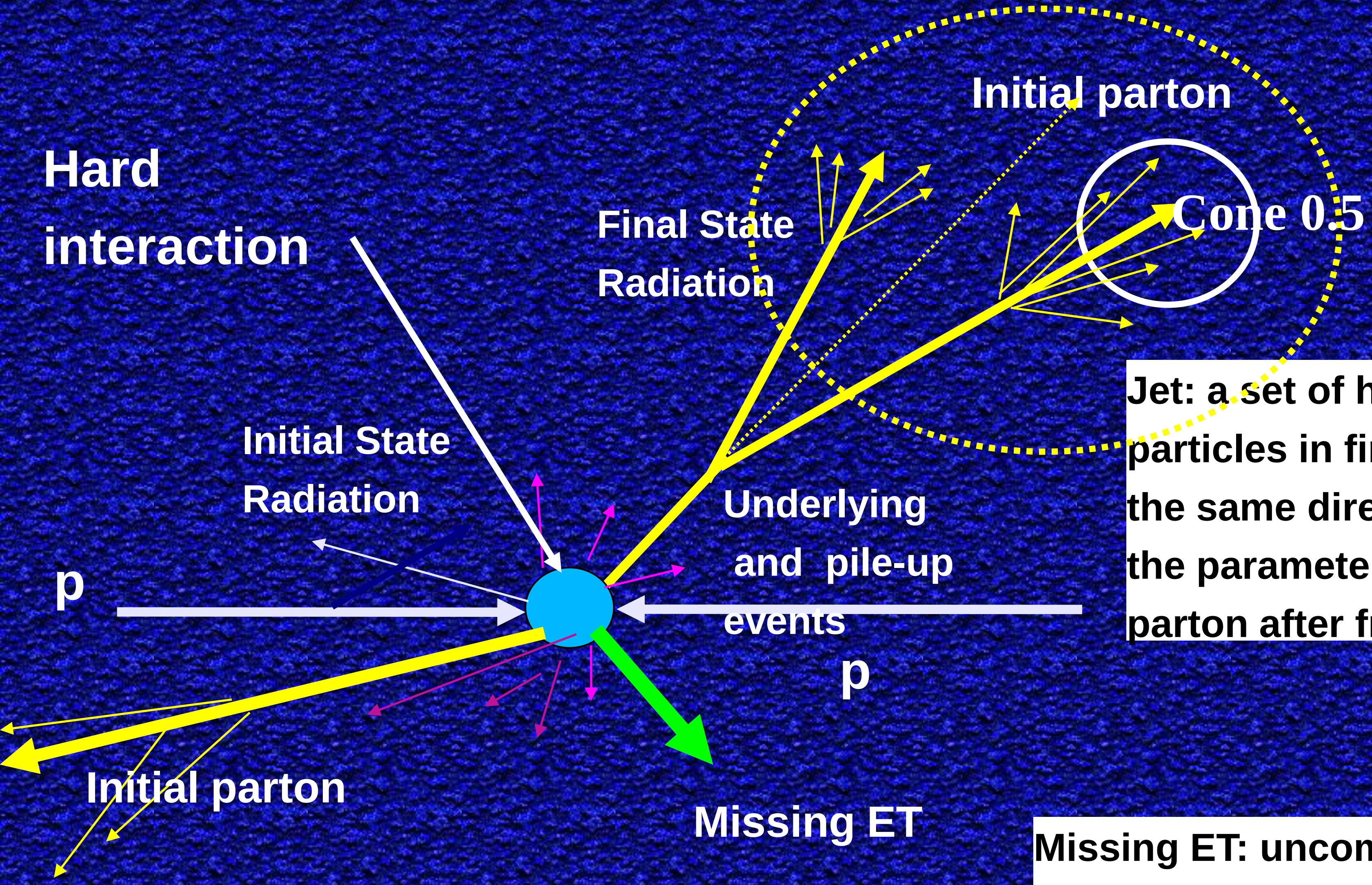
Jets and Missing Transverse Energy Reconstruction with CMS Detector



Olga Kodolova (SINP MSU) for the CMS Collaboration

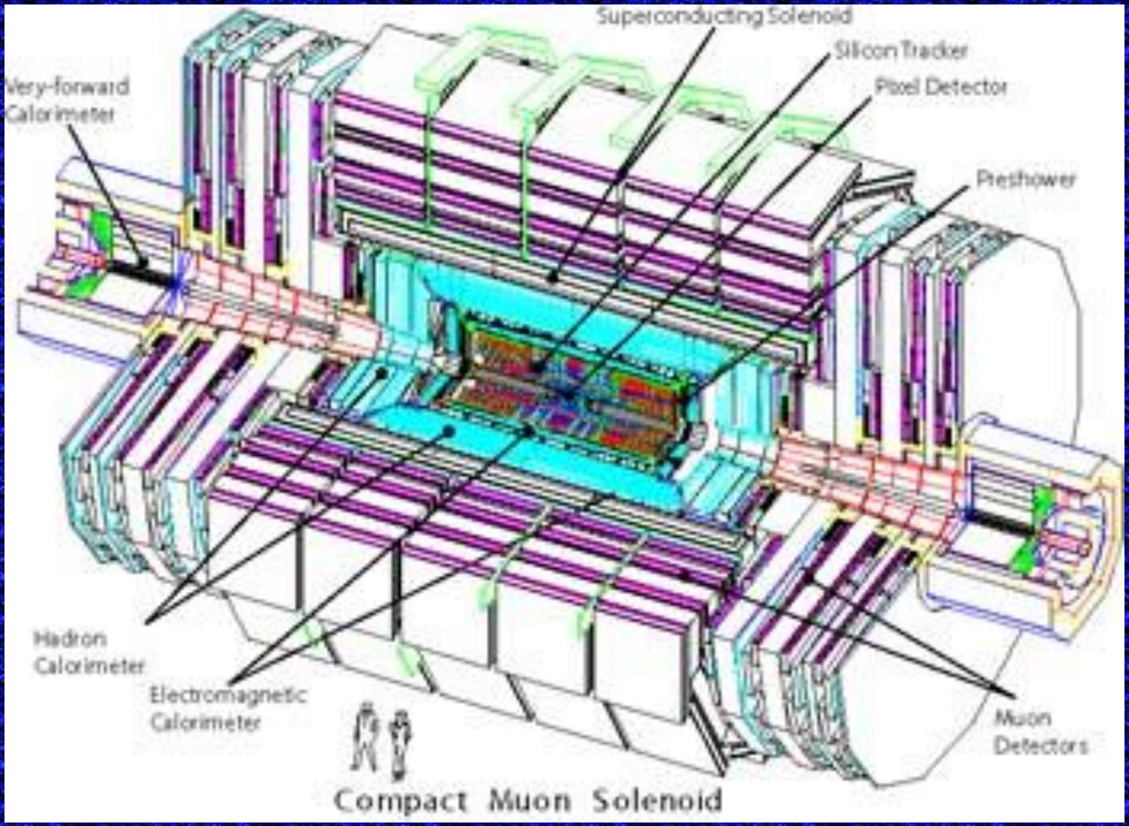
Jets and Missing ET (MET)



Jet: a set of high-momentum particles in final state flying in the same direction reflects the parameters of the initial parton after fragmentation

Missing ET: uncompensated transverse energy in the event Reflects the presence of the weakly interacting particles

CMS detector for Jets and MET



All subsystems are used for Jets and MET Measurements

4 Tesla magnetic field

Tracker $|\eta|<2.5$

Central calorimeters: $|\eta|<3$

electromagnetic (ECAL)
crystal $PbWO_4$

hadronic (HCAL: HB+HE+HO)
sampling calorimeter
scintillator and
brass absorber plates

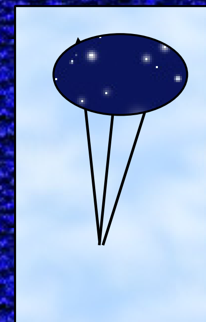
Very-Forward
calorimeter $3<|\eta|<5$
quartz-fiber and iron

muon system $|\eta|<2.4$

Reconstruction of Jets and MET

Default Jet clustering Algorithm: AntiKt R=0.5

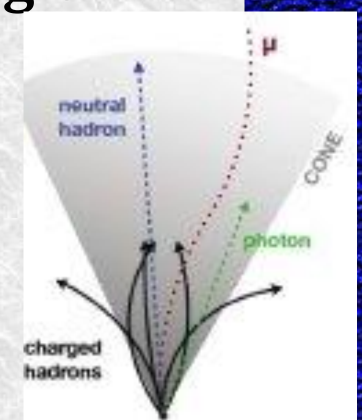
Calorimeter jets (CaloJets):
Jet clustered from Calorimeter Towers
Subdetectors: ECAL, HCAL
CaloMET



Tracker jets:
Jet clustered from Tracks
Subdetectors: Tracker

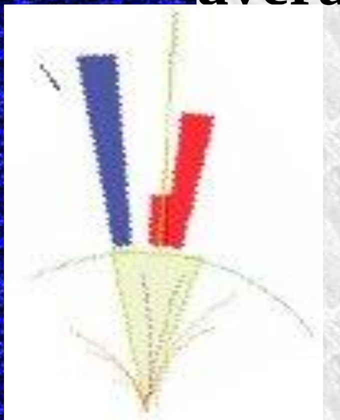
ParticleFlow jets (PFJets):
Jet clustered from Particle Flow objects (a la generator level particles) which are reconstructed basing on cluster separation.
Subdetectors: ECAL,HCAL, Tracker, Muon

PFMET



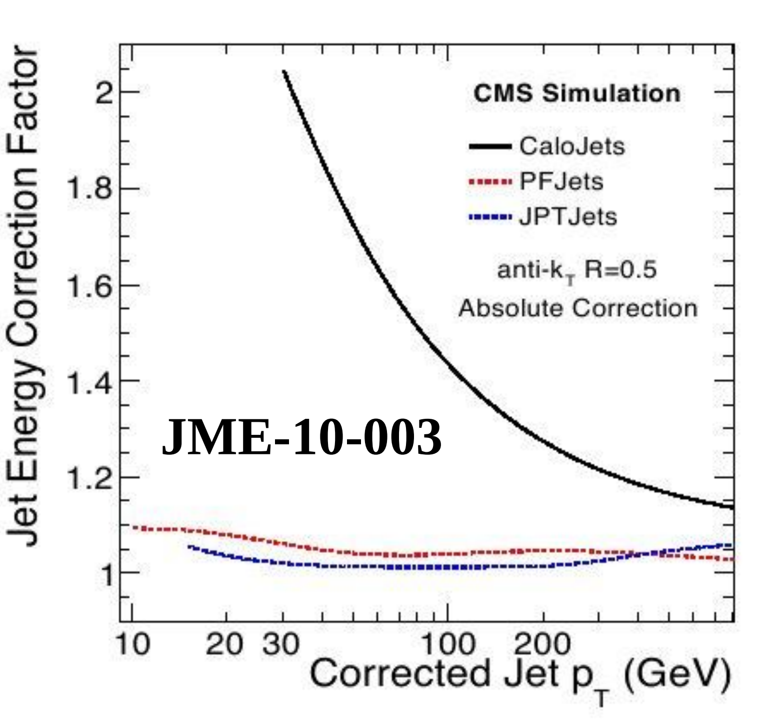
All subdetectors participate in reconstruction

JetPlusTrack jets (JPTJets):
Starting from calorimeter jets tracking information as added via subtracting average response and replacing with tracker measurements.
Subdetectors: ECAL,HCAL, Tracker, Muon
TcMET



Factors influencing on energy scale and resolution:

why we need corrections



From detector performance:

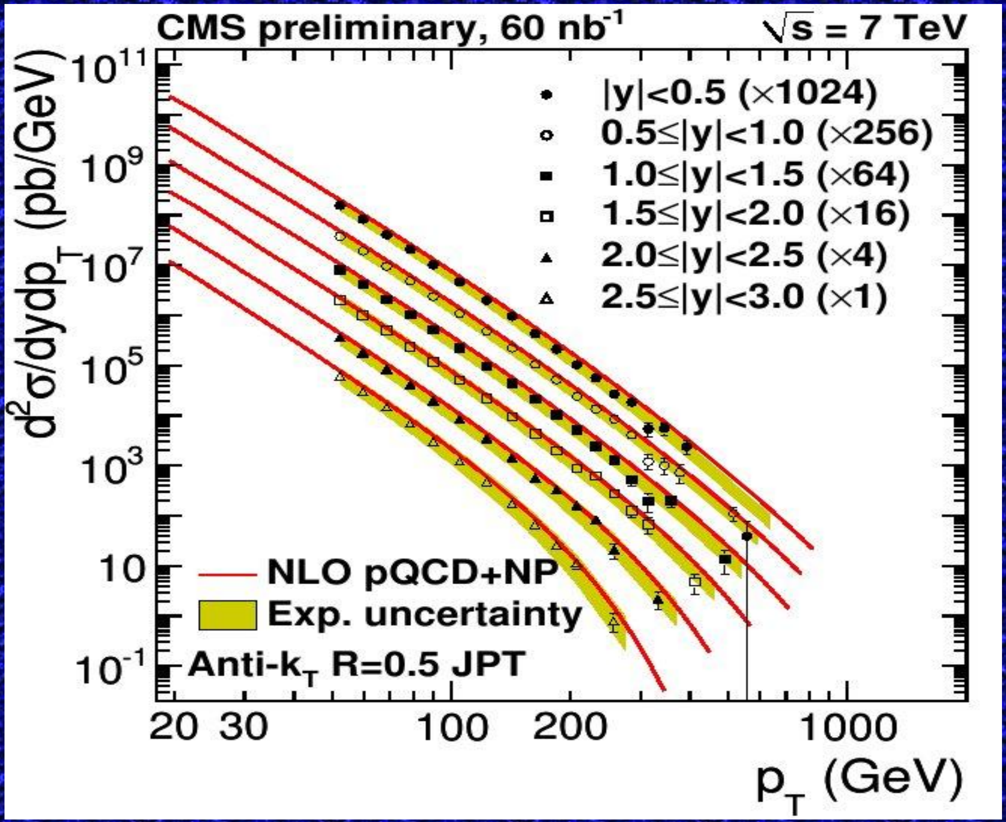
- Calorimeter response to the particles
- Magnetic field
- Electronic noise/tower thresholds
- Dead materials and cracks
- Longitudinal leakage for high-Pt jets
- Shower size, out of cone loss

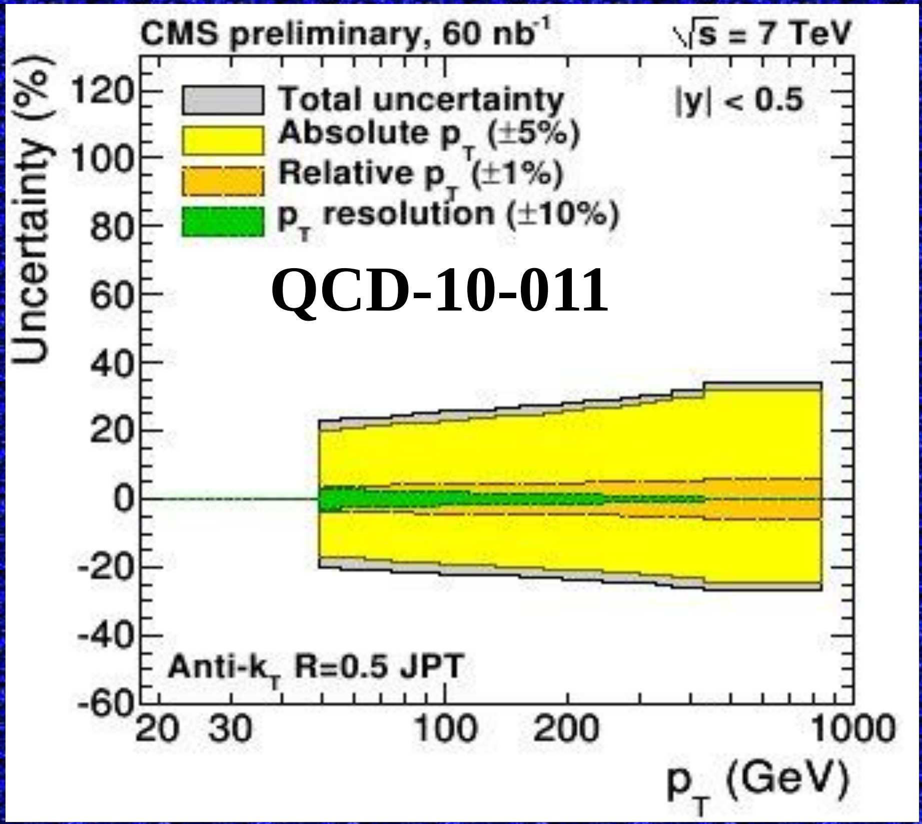
Note 1: use of tracker detectors decreases the value of the residual corrections.

Note 2: The better we know our response function the more exact measurements deconvolution we can perform

Effect of JEC uncertainty on physics measurements:

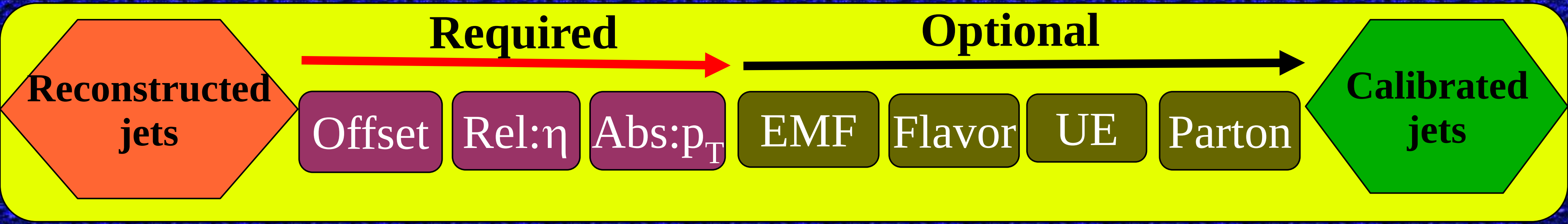
why we need the precise knowledge of JES





5% of JES uncertainty translates into >~10% of the systematical uncertainty to the differential cross-section measurements.
Scale under control is the key of the importance for a lot of discovery channels.

Jet energy corrections schema



Factorized approach for jet energy corrections

Required corrections:

- "Offset" - removes unwanted contribution from noise and Pileup
- "Relative" - removes variation of response vs η relative to the central region (in-situ: dijet p_T balance)
- "Absolute" - removes variation of jet response vs jet p_T (in situ: Photon+jet p_T balance, MPF method)

Two sources of the correction coefficients:

Monte-Carlo simulations

In-situ measurements with physics process

Relative corrections in situ: dijet balance

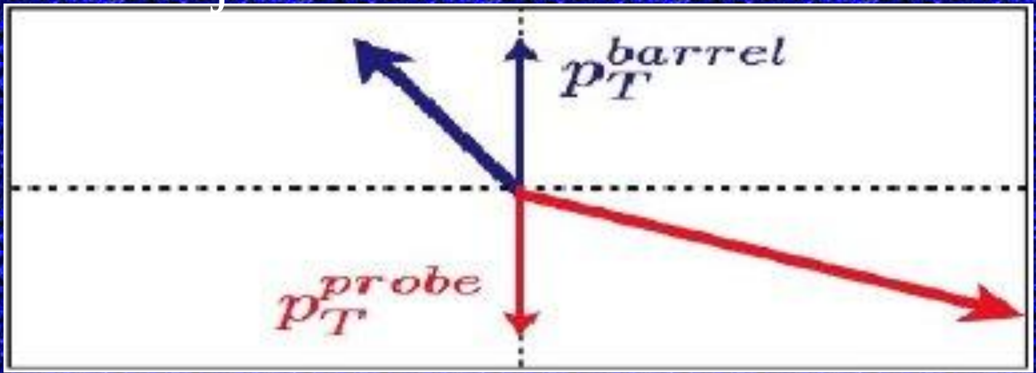
Relative jet energy corrections remove the jet response variation in h.
A priori estimate of uncertainty: +-2% x |η|

$$p_T^{dijet} = \frac{p_T^{probe} + p_T^{tag}}{2}$$

$$B = \frac{p_T^{probe} - p_T^{Tag}}{p_T^{dijets}}$$

$$R = \frac{2 + \langle B \rangle}{2 - \langle B \rangle}$$

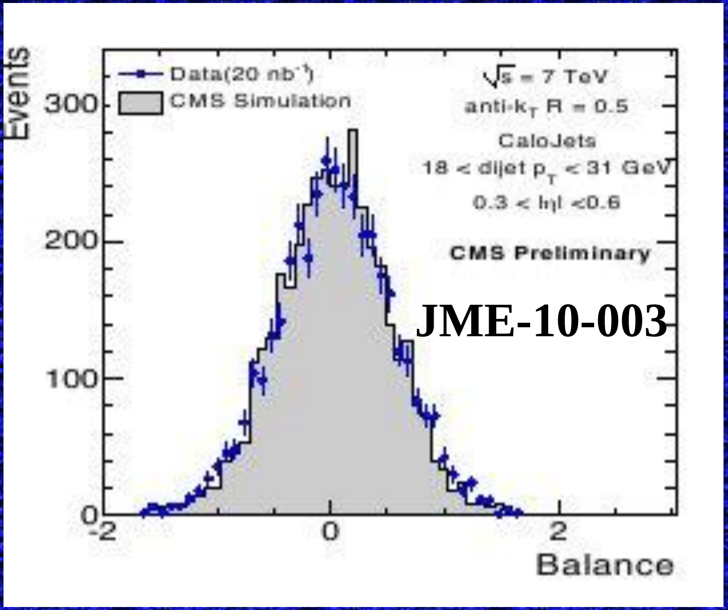
Barrel jet



Probe jet

Dijets selection

- At least two jets, one jet in barrel
- Azimuthal separation ΔΦ>2.1
- Third jet veto PT3rd/PTdijet<0.2



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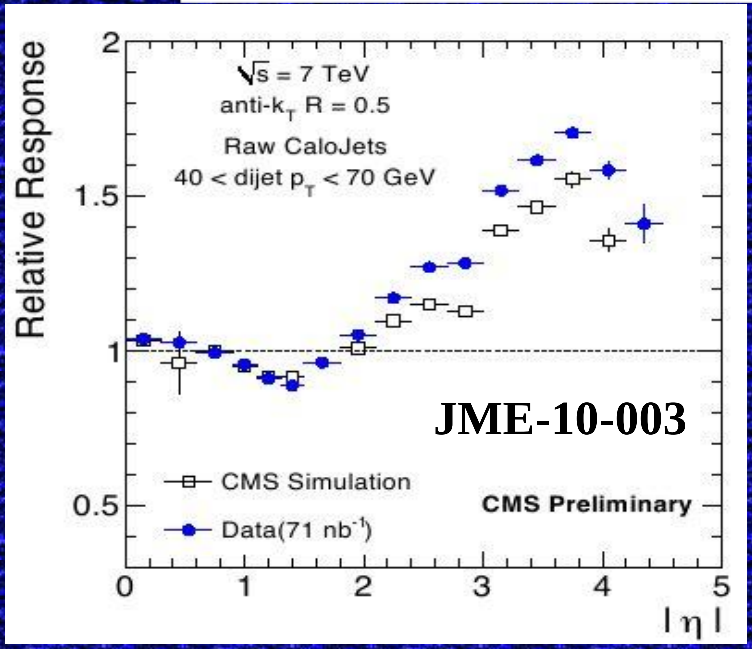
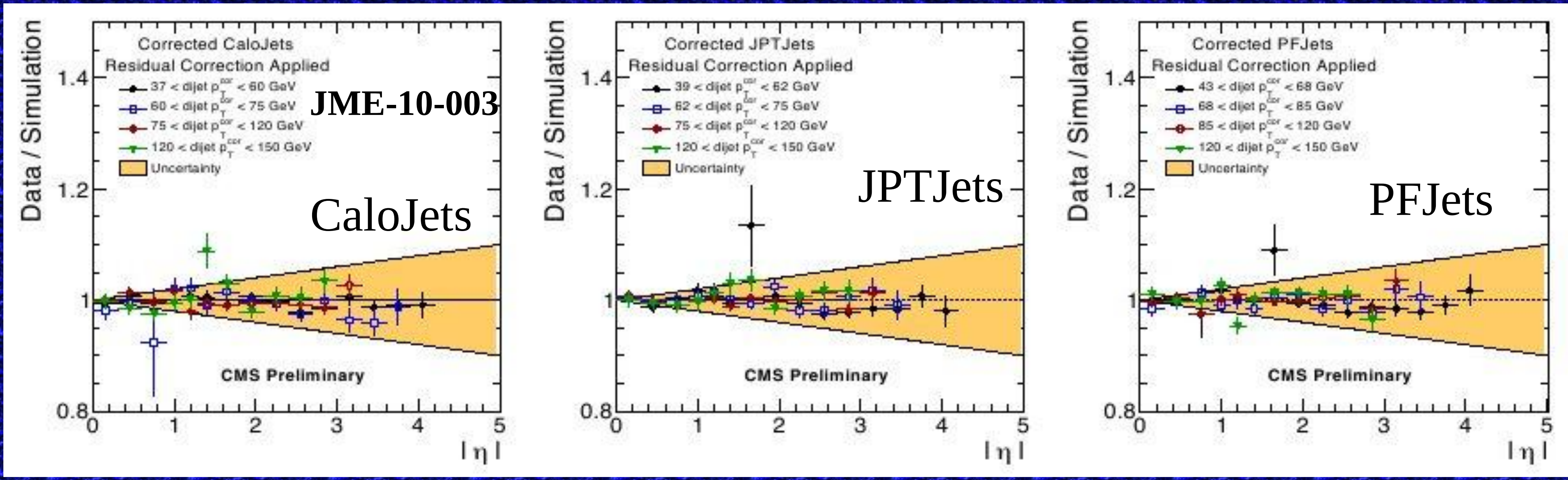
Relative corrections in situ: uncertainty

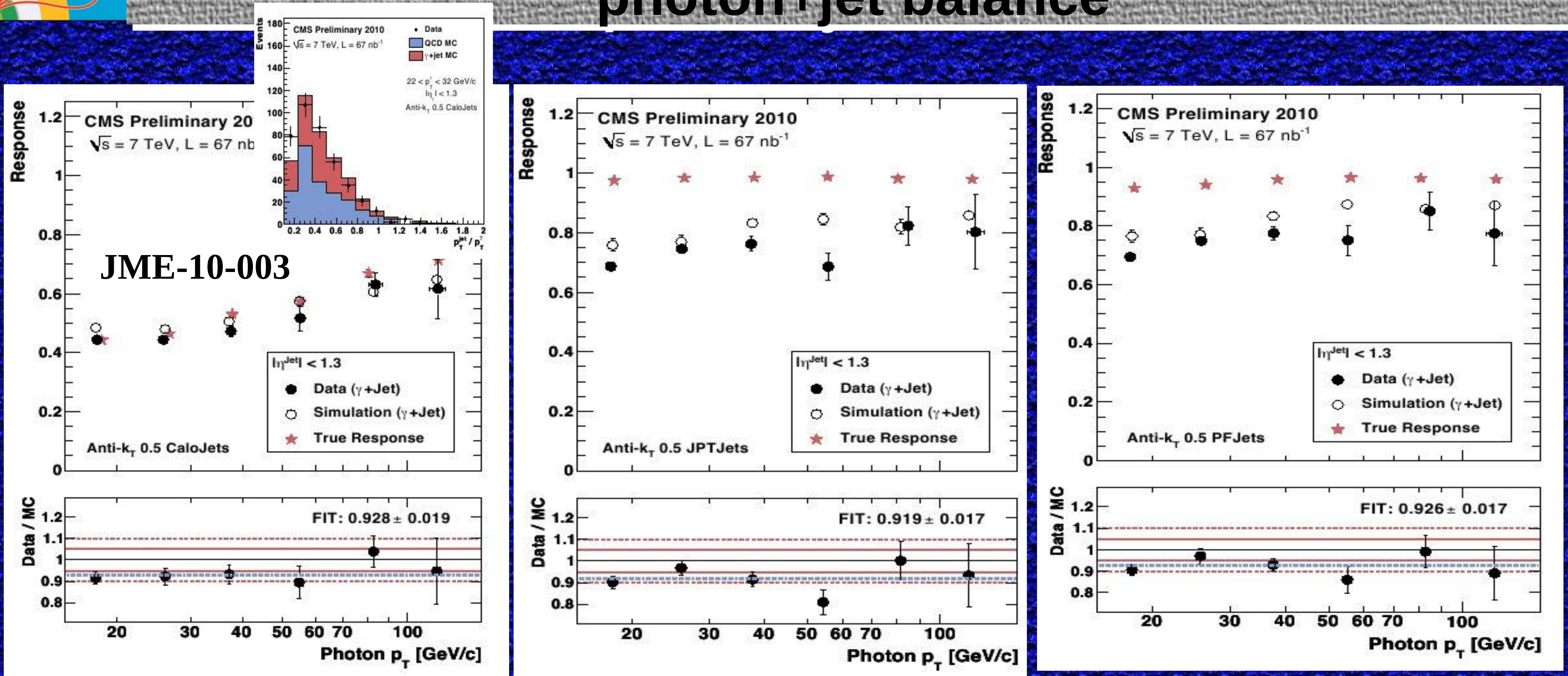


Good agreement between data and MC within |η|<2.
Relative response in data ~10% higher for |η|>2

After applying the residual correction data and MC are in agreement with +-2% x |η| for 3 Algorithms: CaloJets, JetPlusTrack, Particle Flow



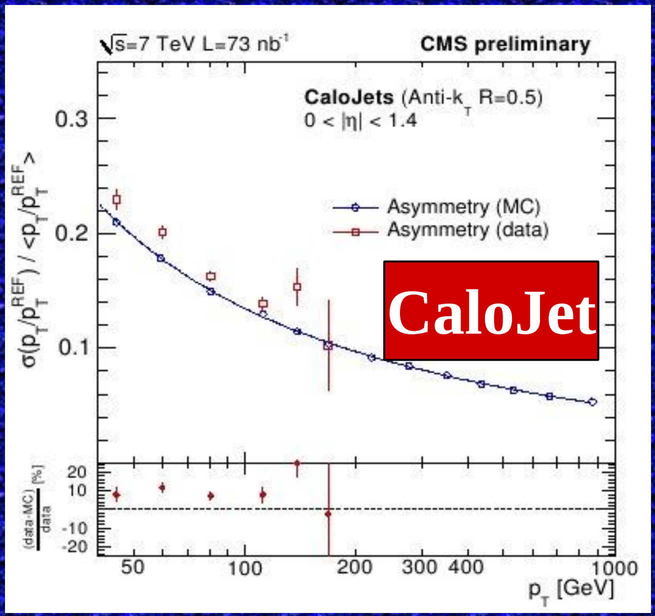
Absolute corrections in situ: photon+jet balance

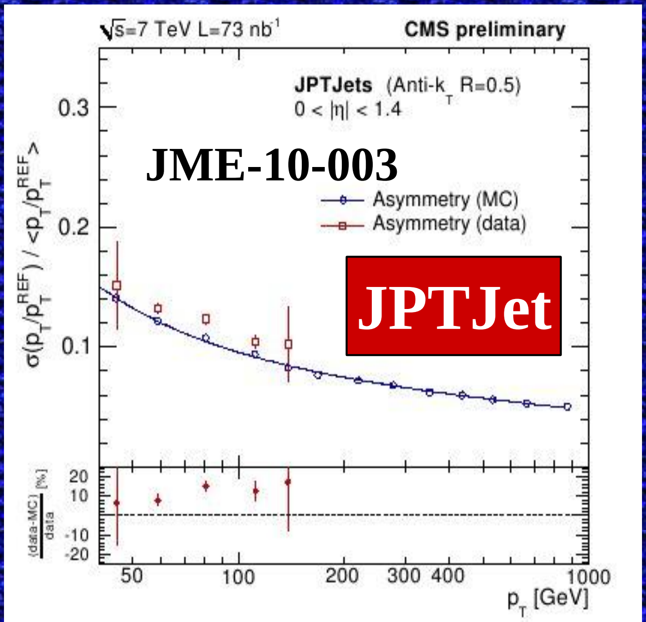


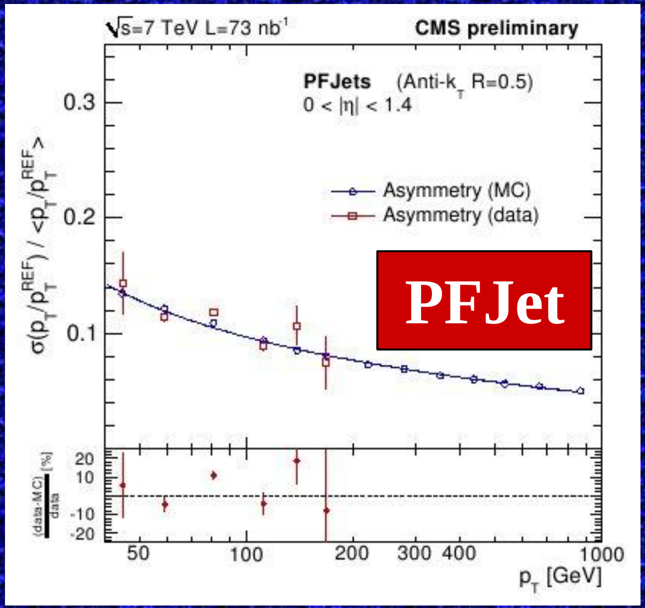
- Use of back-to-back photon+jet events candidates (Well measured "photon" object in ECAL)
- "Photons" are selected by photon trigger, isolated photons with p_T>15 GeV and |η|<1.3 (barrel ECAL)

Estimate of uncertainty of 5% for Tracker-based jets (TrackJets,PFjets, JPTJets) And 10% for CaloJets.

In situ measurements of jet p_T resolution







Dijet assymetry method:

Define p_T assymetry for the two leading jets in back-to-back dijet events:

$$A = \frac{p_T^{jet\ 1} - p_T^{jet\ 2}}{p_T^{jet\ 1} + p_T^{jet\ 2}}$$

Data/MC agreement within ~10%

For the approximately equal jets:

$$\sigma(p_T)/p_T = \sqrt{2}\ \sigma_A$$

MET

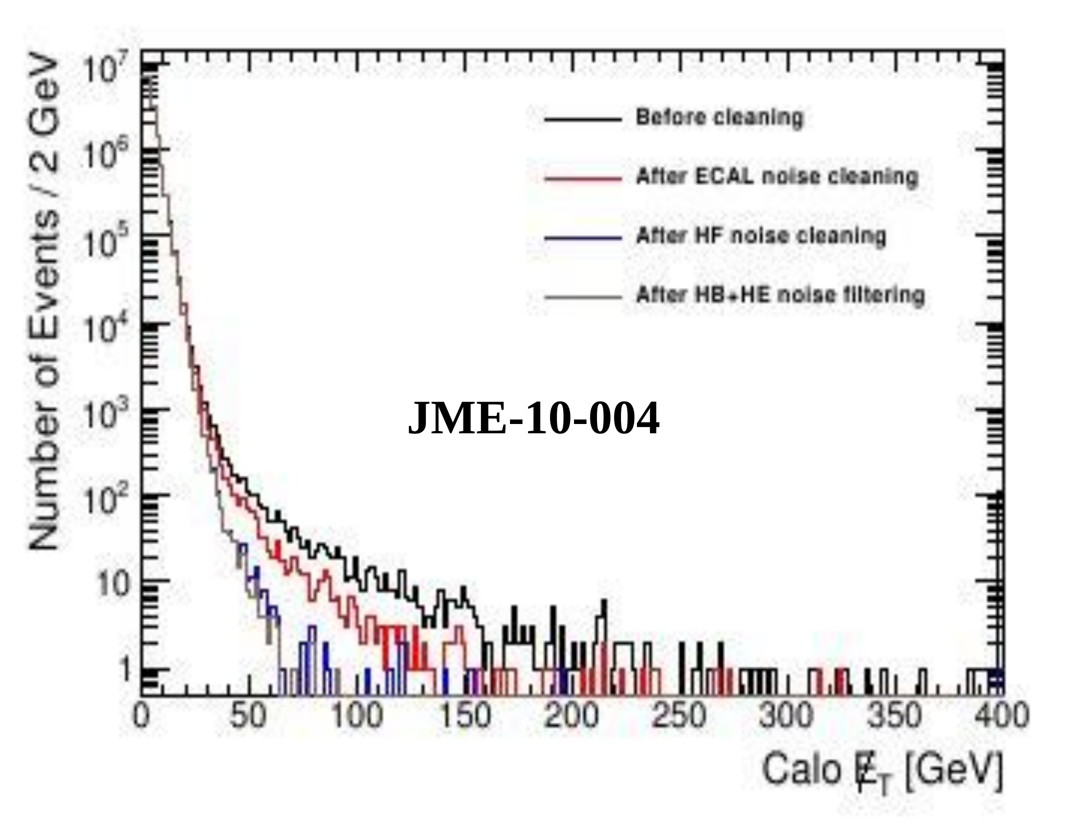
Cleaning MET tails

No large Missing-ET for Minimum bias/QCD jets events is supposed

Cleaning strategy is based on the identification of the anomalous events with use of:

- Unphysical charge sharing of neighboring channels

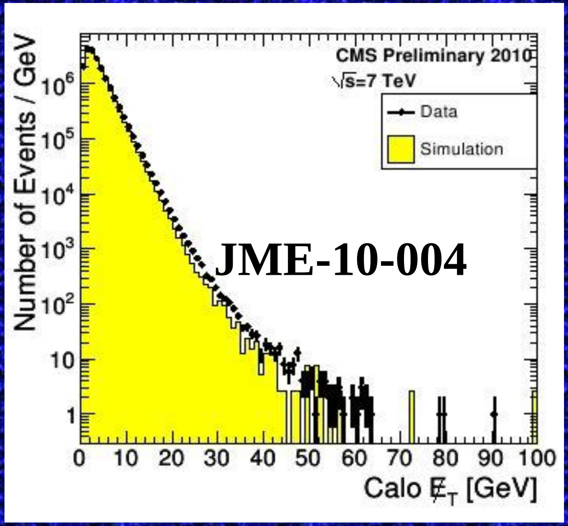
- Timing/pulse shape information

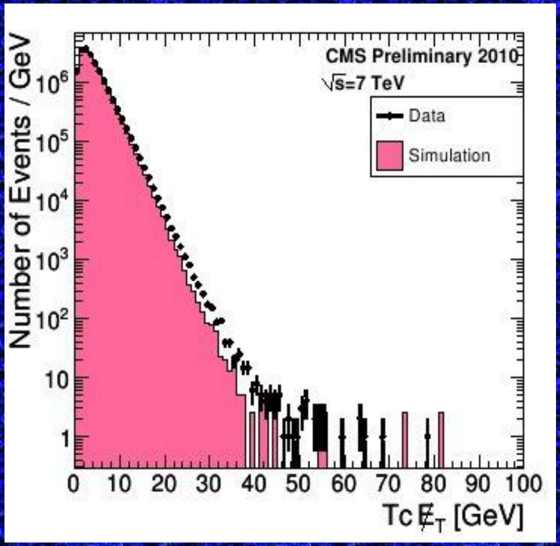


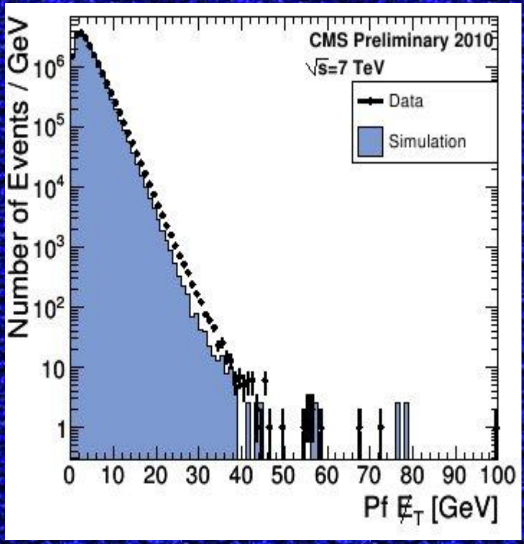
The nature of identified parasitic anomalous events: particles that hit the transducers or rare random discharges.

MET in Data vs MC

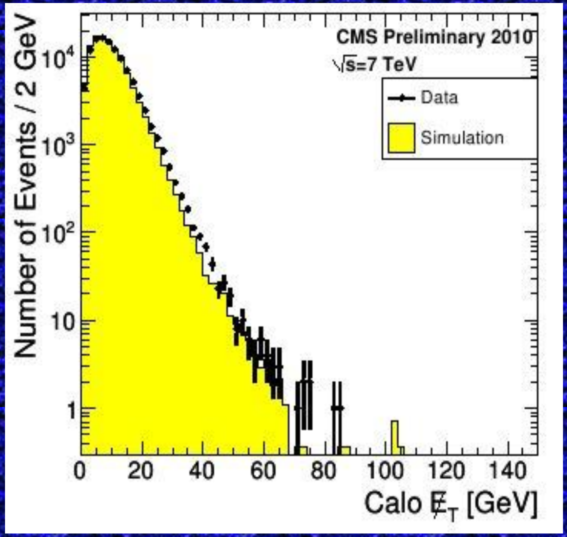
Minimim Bias events

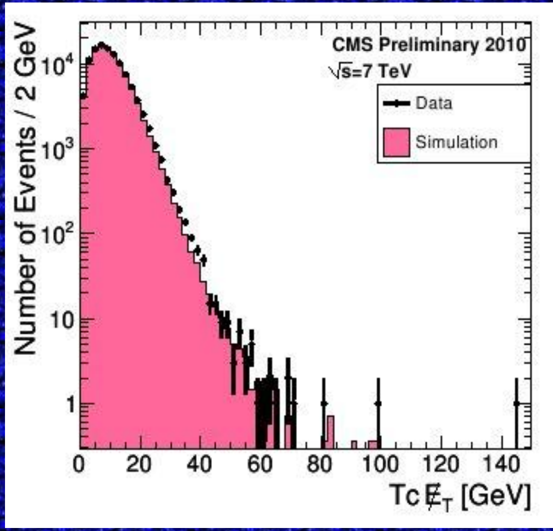


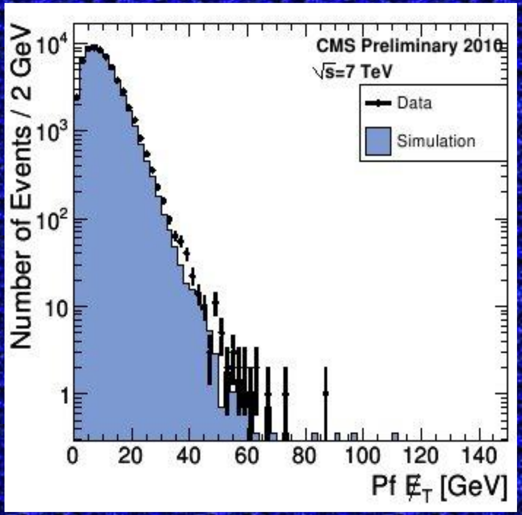




Dijets events







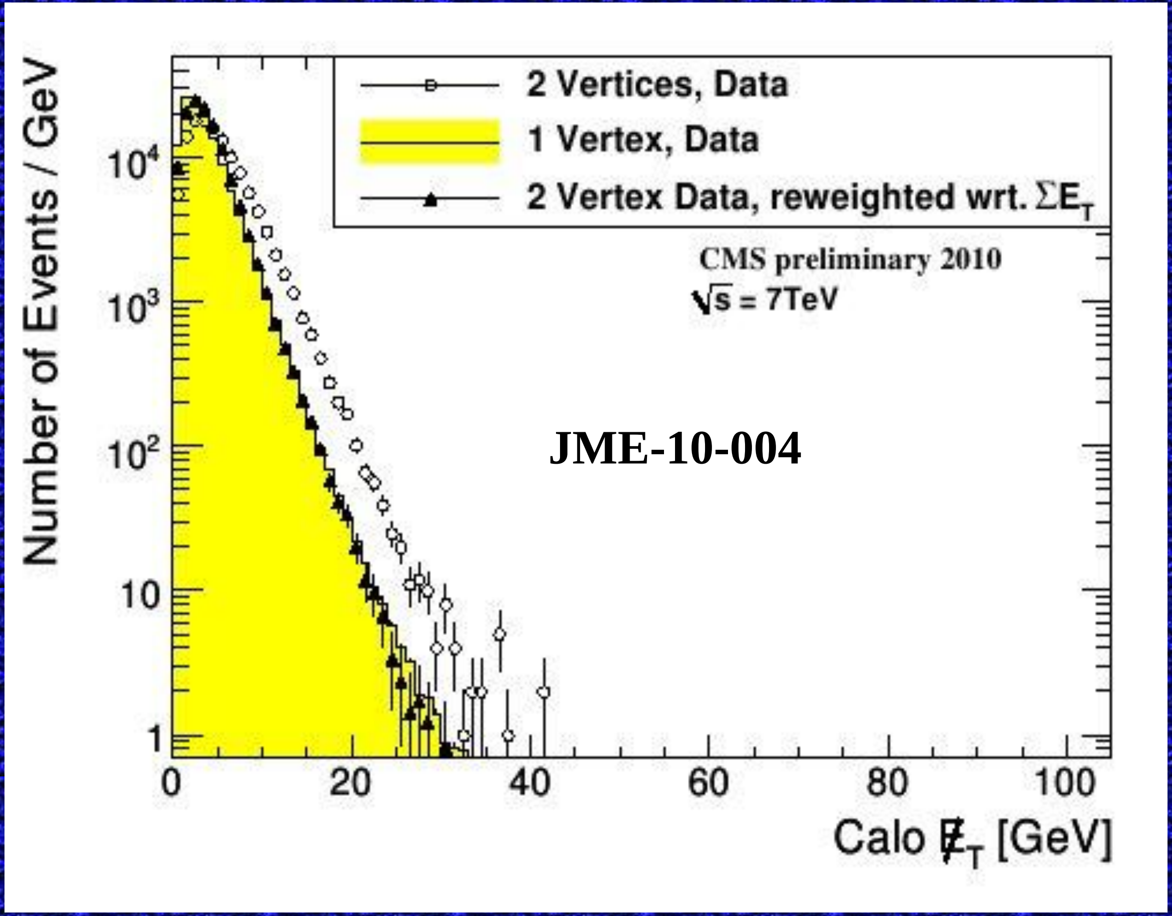
MET in the presence of pile-up events

MET distribution in 1 and 2 vertex events with Minimum bias triggered events

MET distribution is wider in 2-vertex events

Re-weight 2-vertex events to match SumE$_T$ distribution to that of 1-vertex events

After re-weighting MET distributions with 1 and 2 vertex events agrees



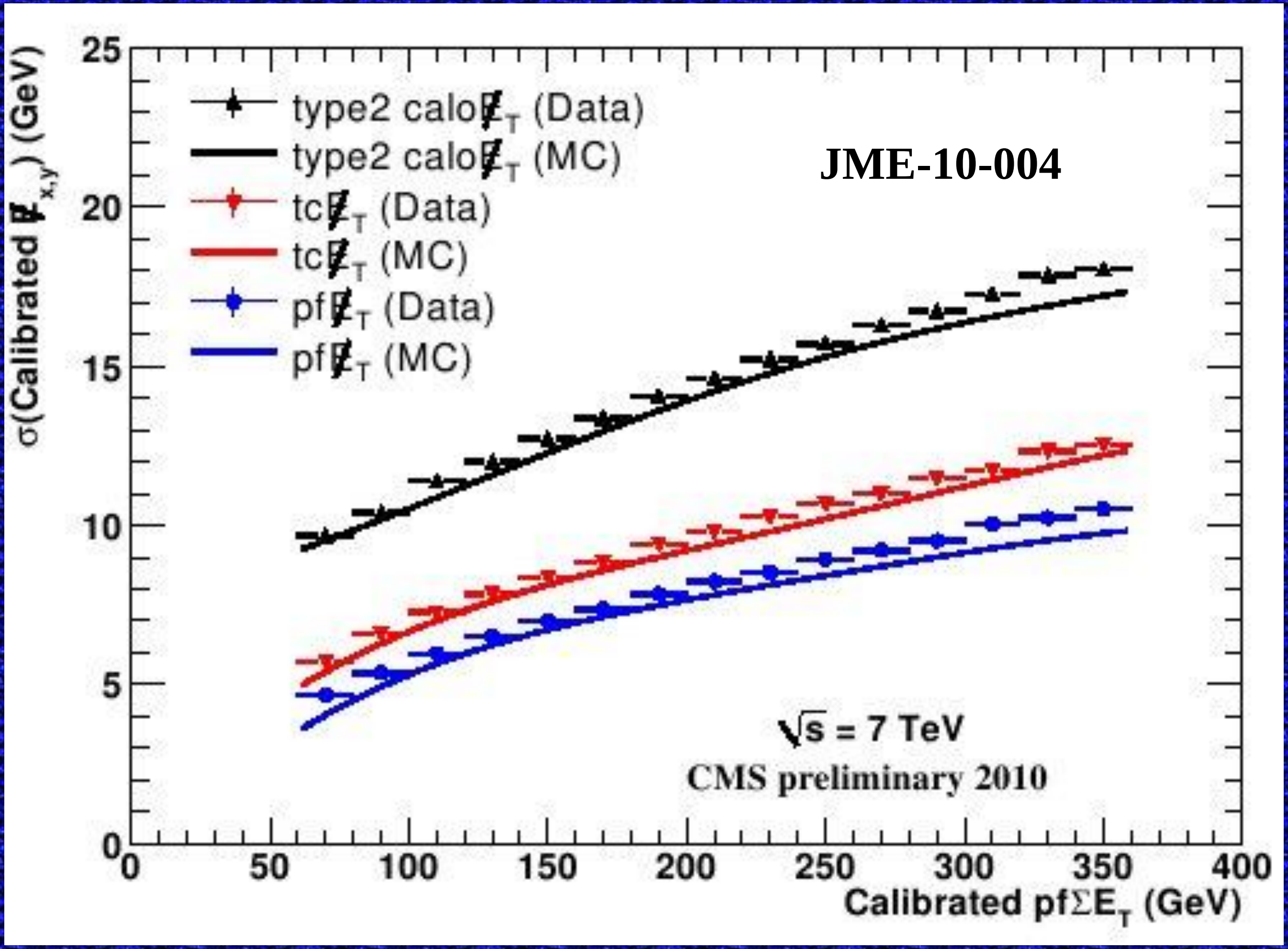
Widening of MET distribution in 2-vertex events is due-to increase of energy

MET resolution vs Sum ET

Calibrated MET resolution for 3 different types of algorithms vs pf SumEт;
Calo MET, tcMET, PfMET

Pf SumET was calibrated
To the generator level
SumET

MET calibration was
done with photon+jet
events



Summary

First results on jet and Missing transverse energy performance is presented. Use of combination of the different subdetectors improves both energy and spatial resolutions significantly.

Jets

- Good agreement between Data and Monte-Carlo for jet energy scale and resolution
- Observations support estimates of systematics:
  - 10%(5%) Jet energy scale deviation for calorimeter jets (jets using tracking detectors) in barrel region
  - The additional 2% uncertainty per rapidity unit
  - 10% of pt resolution uncertainty

MET

- Acceptable agreement between Data and Monte-Carlo
- Advanced tail cleaning
- Commissioning of MET within pile-up environment

References

CMS DP-2010/014: "Jet and MET Commissioning Results from 7 TeV Collision data"

JME-10-003: "CMS jet performance at sqrt(s) = 7 TeV"

JME-10-004: "Missing transverse energy performance in Minimum bias and jet events from Proton-proton collisions at sqrt(s) = 7 TeV"

JME-10-008: "Single particle response in the CMS calorimeters"

QCD-10-011: "Measurement of the Inclusive jet cross-section in pp collisions at sqrt(s) = 7 TeV"

Back-up slides

Anti-Kt jet clustering algorithm

$$R_{ij}^2 = (y_i - y_j)^2 + (phi_i - phi_j)^2$$

$$d_{i,j} = \min(k_{T,i}^{-2}, k_{T,j}^{-2}) \frac{R_{ij}^2}{R^2}$$

Rather new development in the jet clustering algorithmic family

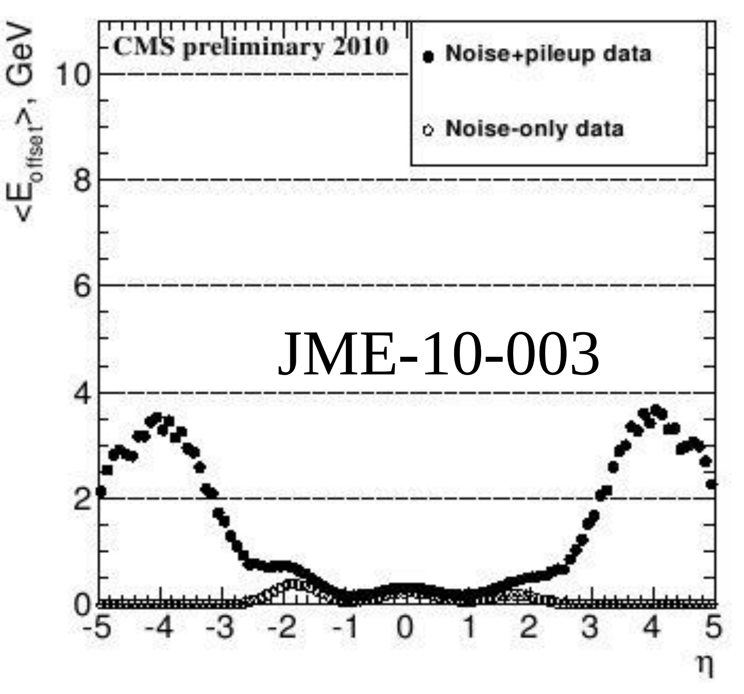
Belongs to kT family

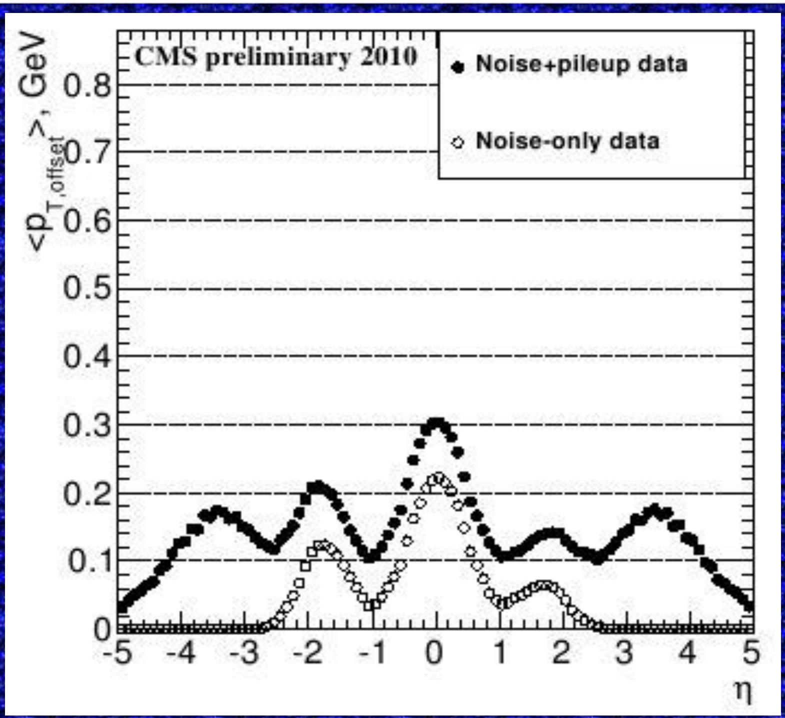
Merging 4-vector pairs basing on the transverse momentum weighted distance in the y-f plane
Clustering terminates when the weighted distance between objects is Greater then the specific value R (which is of the order of unity)

Tends to cluster jet around the hardest object

Is suitable for theoretical calculations due-to intrinsic infrared and collinear safety

Offset corrections





Offset due-to calorimeter noise

Is below 300 (400) MeV in energy (pT)

Well simulated

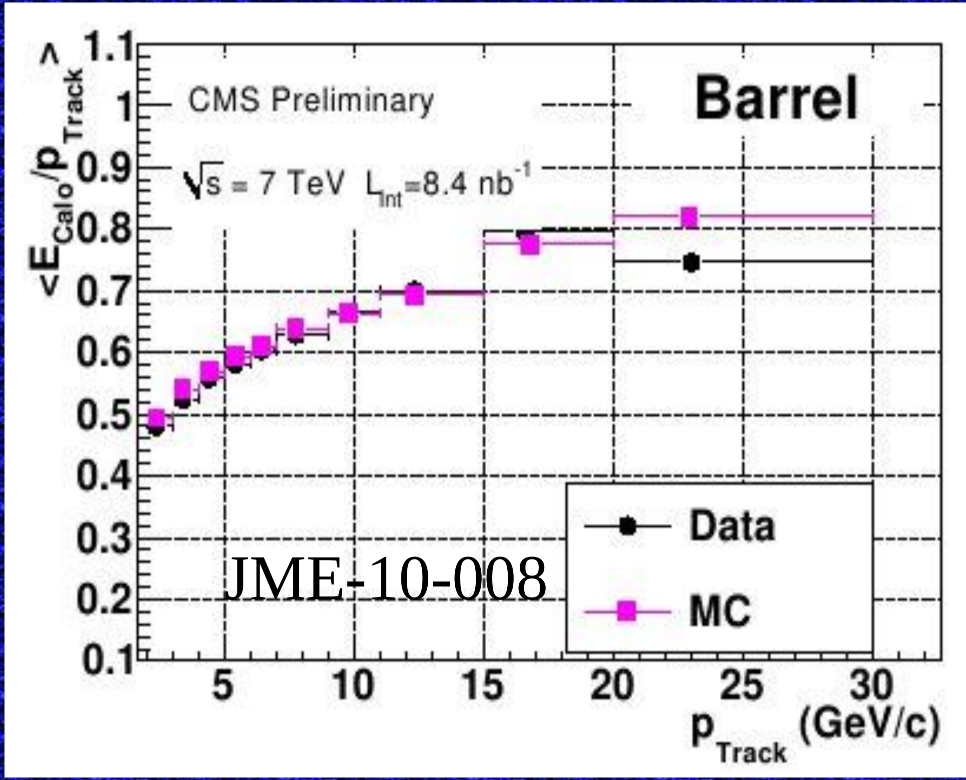
Offset due-to pileup events

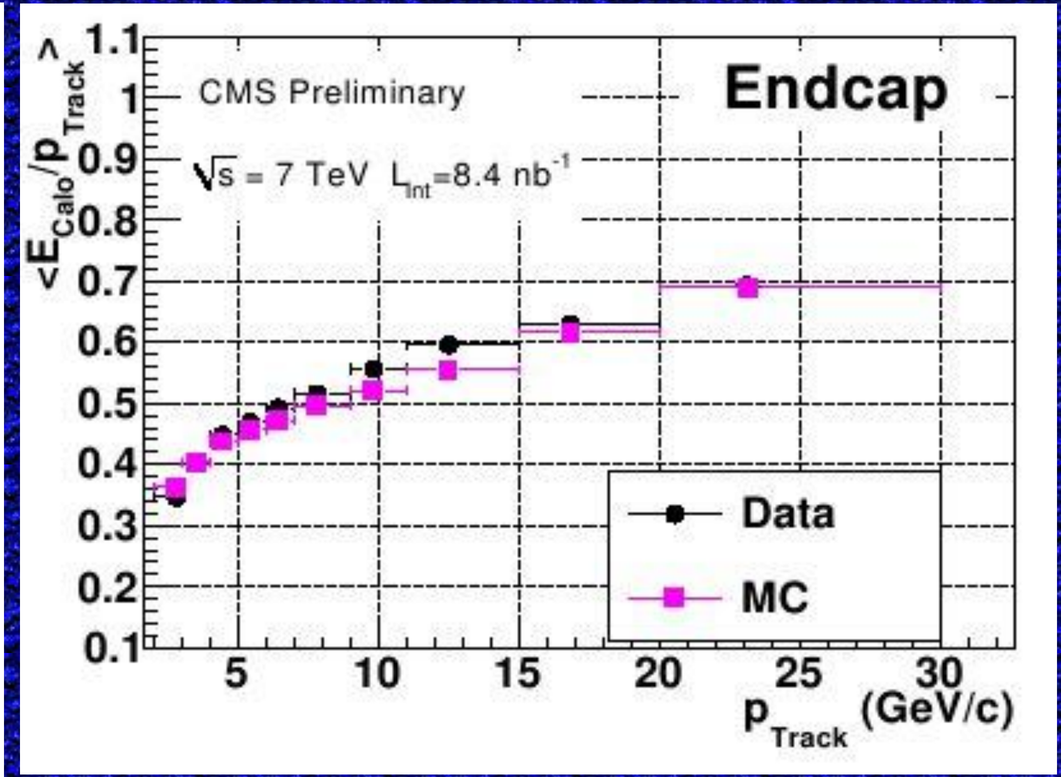
Up-to 7 GeV in HF (below 350 MeV in pT)

PYTHIA (D6T) gives descent description of pile-up

Probability of >=2 vertex events in the recent data is ~50% (10% in In earlier plots)

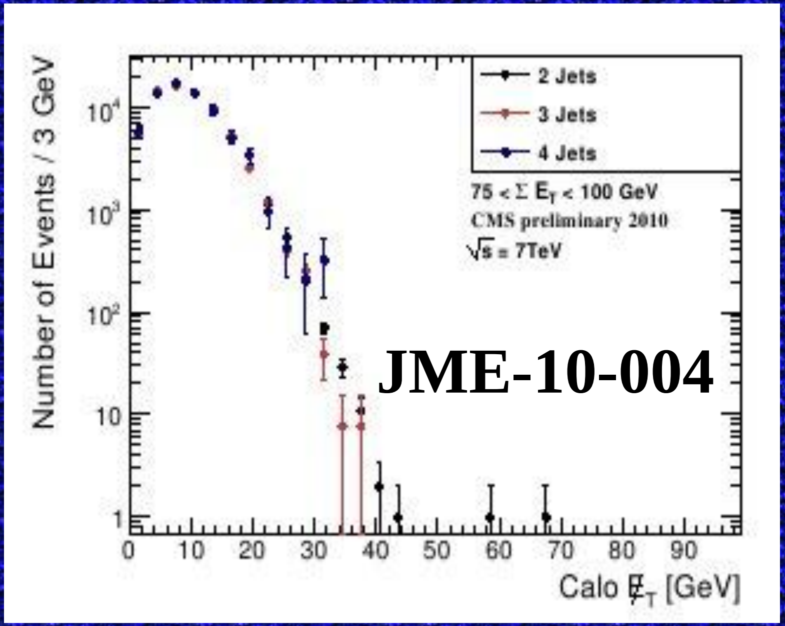
Single particle response

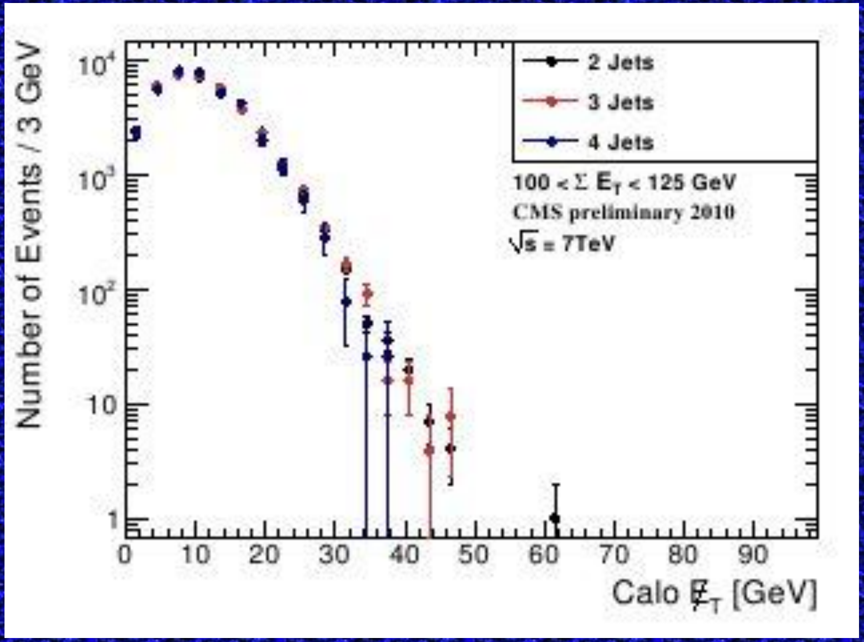




Mean response in Data and Monte-Carlo agrees within 2-3% in barrel Region. In endcap the simulated response is ~4% lower then in Data.

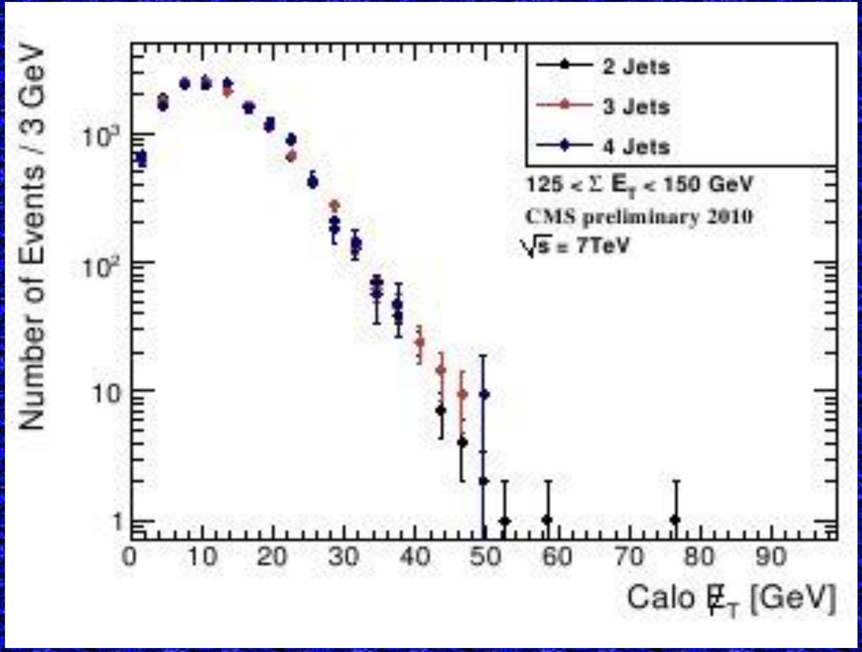
MET in multijet events





Uncorrected MET for the different SumEt ranges for 2,3,4 jets.
At least 2 jets with |h|<3 and pT>20 GeV.

No significant dependence on Jet multiplicity.

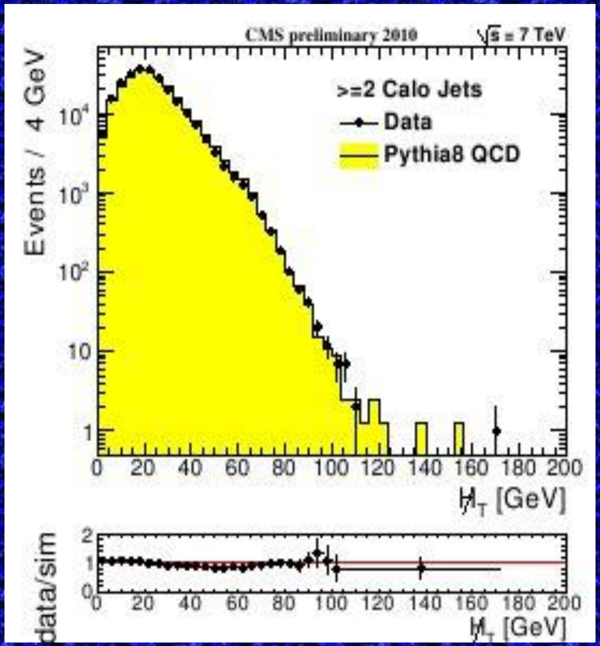


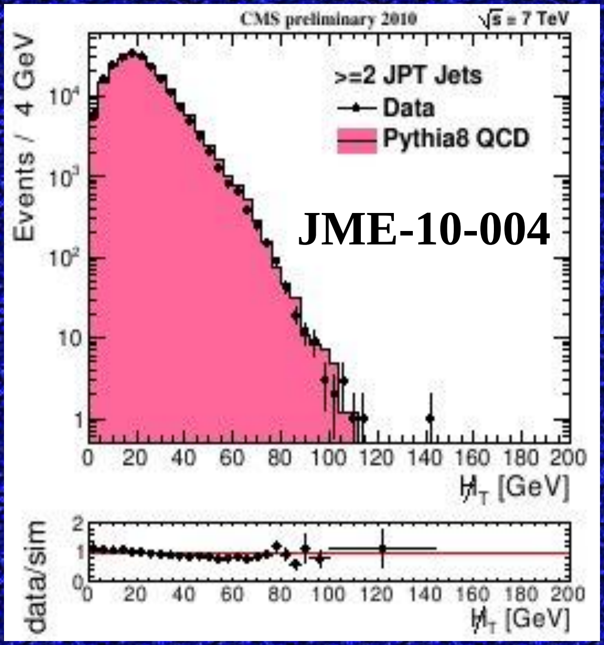
HT and MHT

HT and MHT is used in various new physics searches

$$H_T = \sum p_T^{jet}$$

$$MH_T = |-\sum p_T^{jet}|$$





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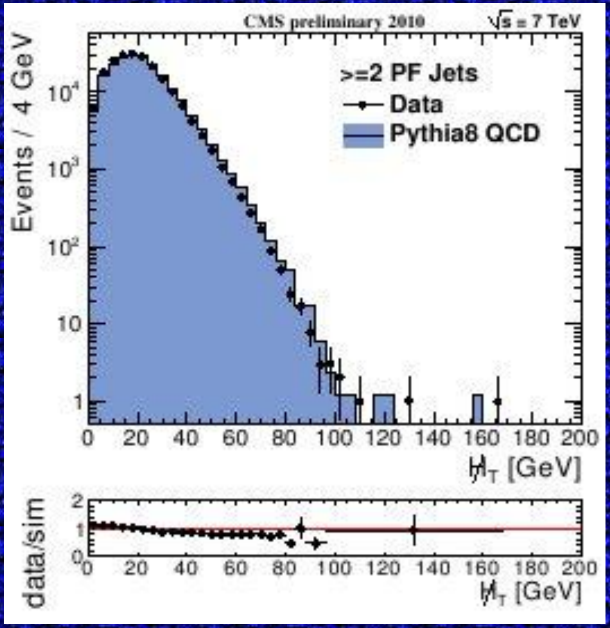

Good agreement between data and Monte-Carlo