Performance of the Particle Flow Algorithm in CMS

On behalf of the CMS collaboration

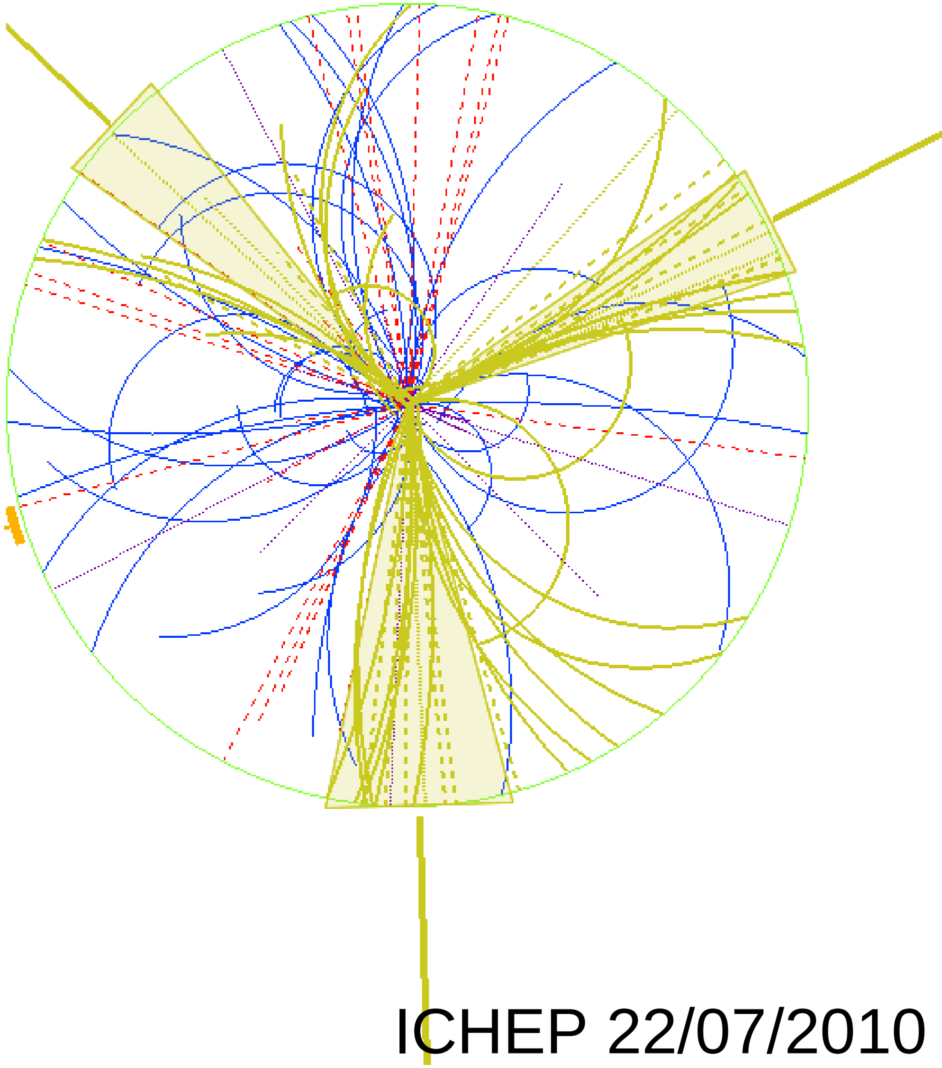
Outline

The particle-flow algorithm: overview

Performance on simulation

Commissioning on data

Conclusion



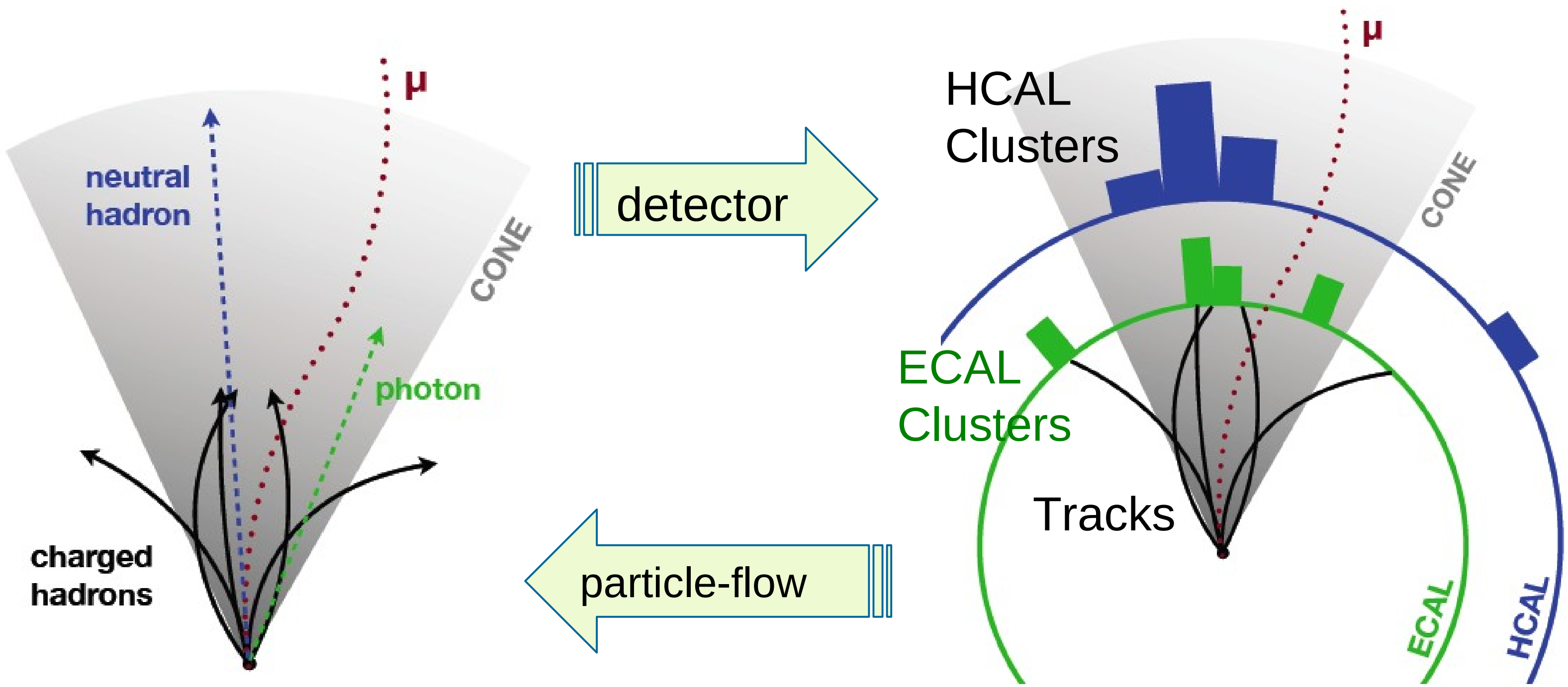
Material

CMS-PAS-PFT-10-002
CMS-PAS-PFT-10-003
CMS-PAS-PFT-09-001

F. Beaudette – CERN/LLR

ICHEP 22/07/2010

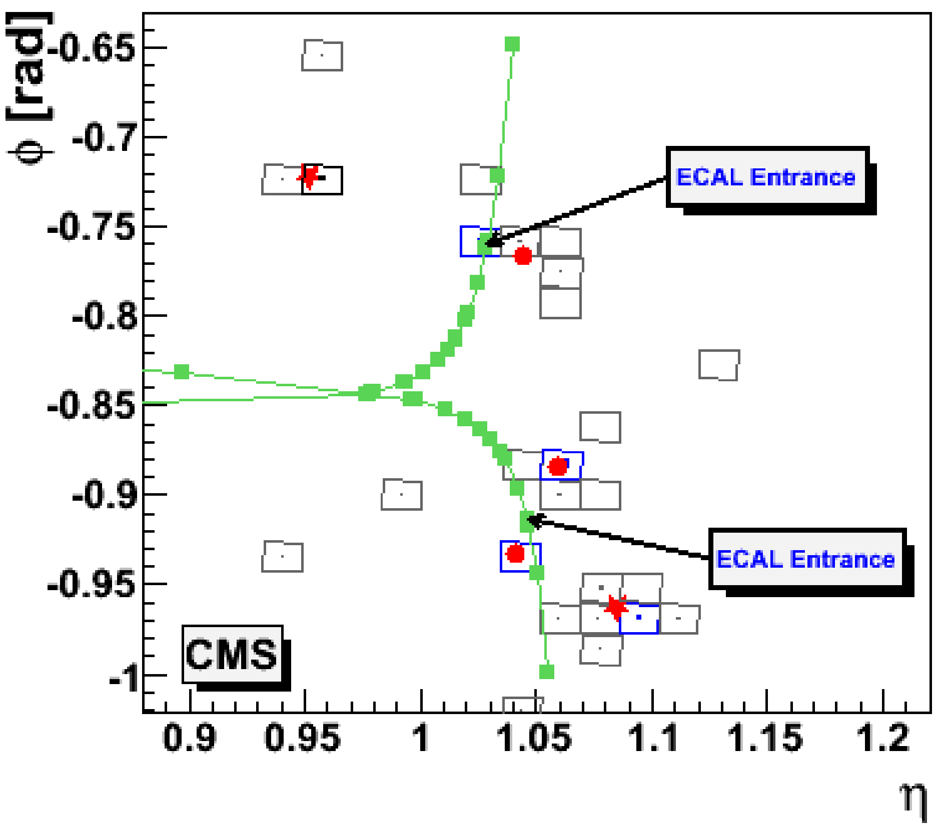
Overview: the Particle Flow algorithm



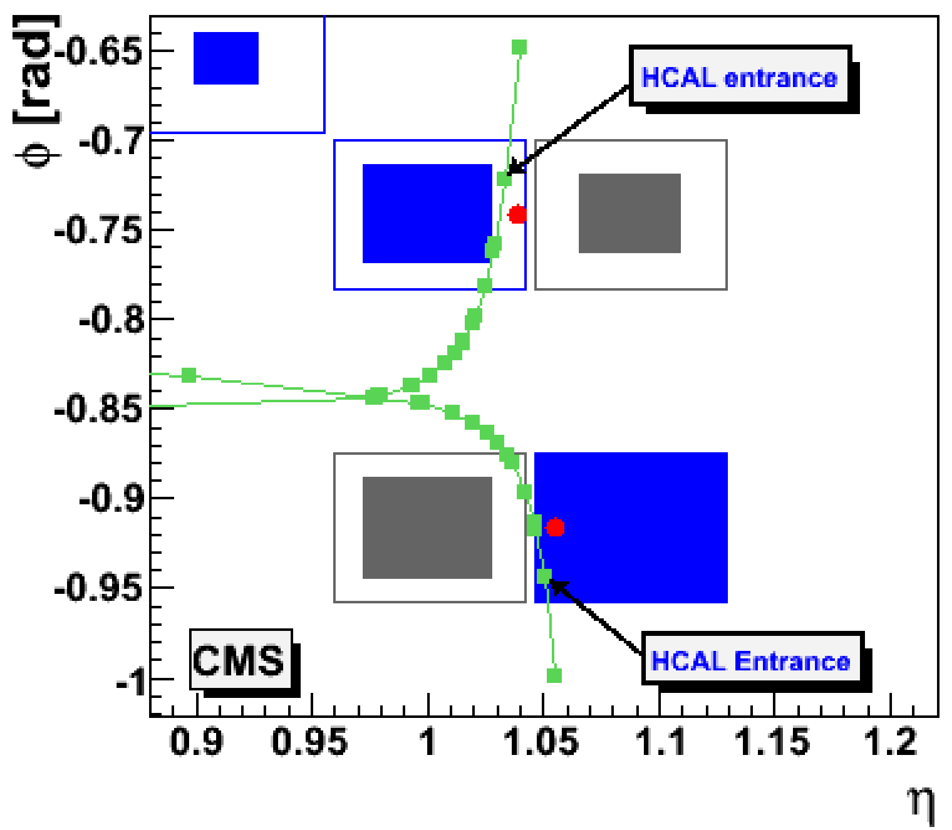
The list of individual particles is then used to build jets, to determine the missing transverse energy, to reconstruct and identify taus from their decay products, to tag b jets …

Track-cluster link

ECAL surface

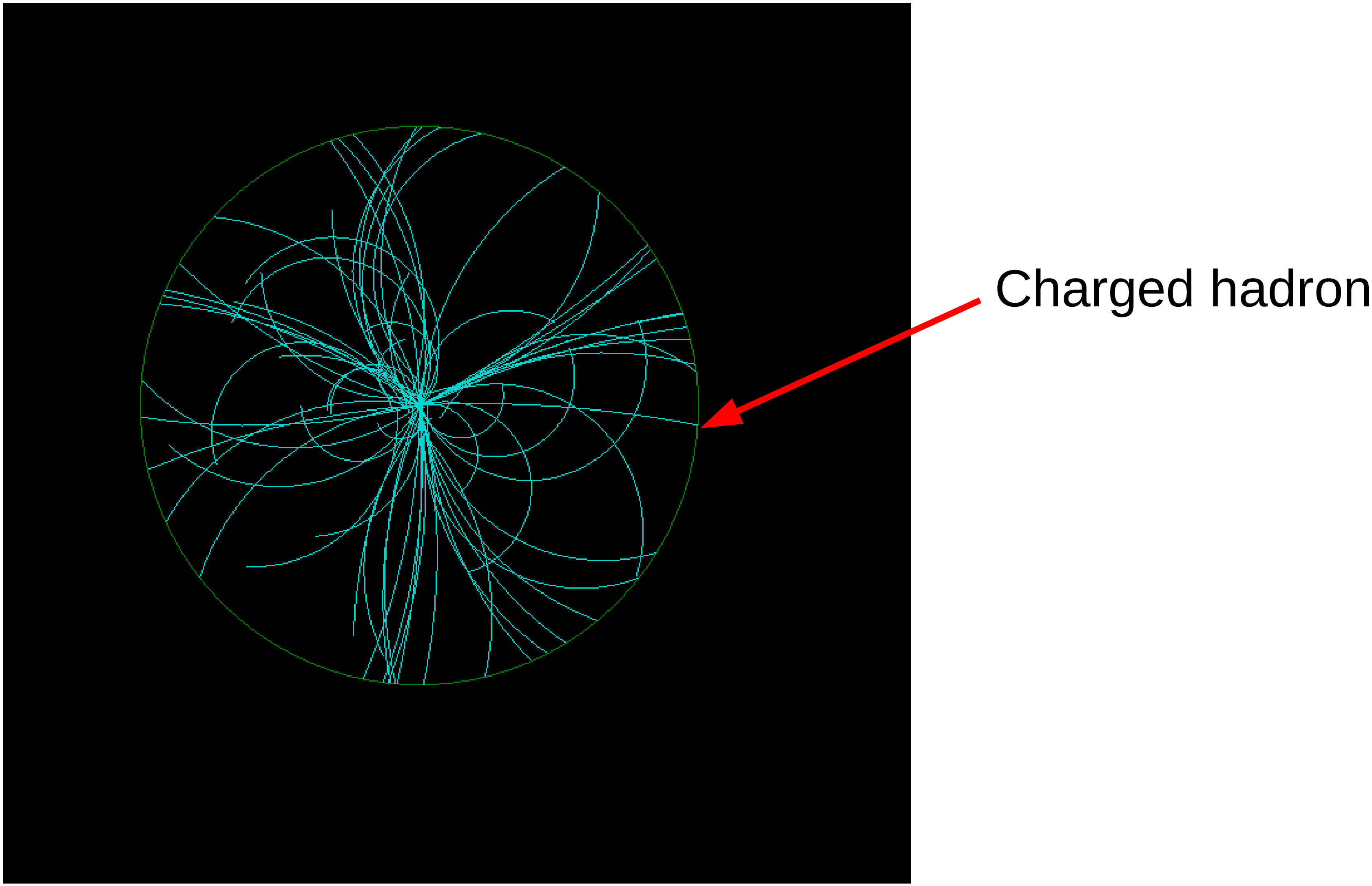


HCAL surface

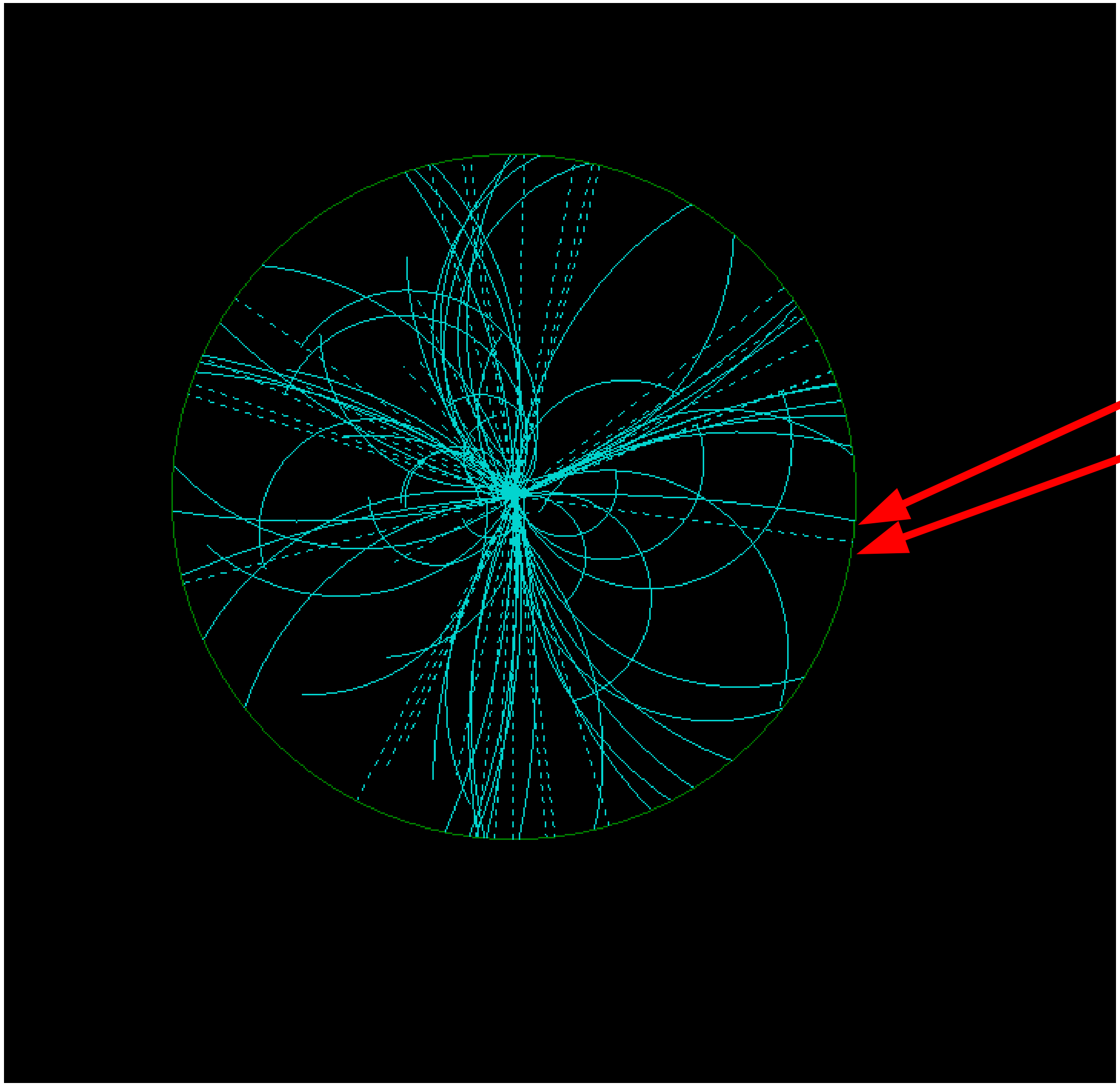


- Two photons (ECAL clusters not linked to any track) plus a $\pi-$ and a $\pi+$

Event Display, transverse view (2.36 TeV data)

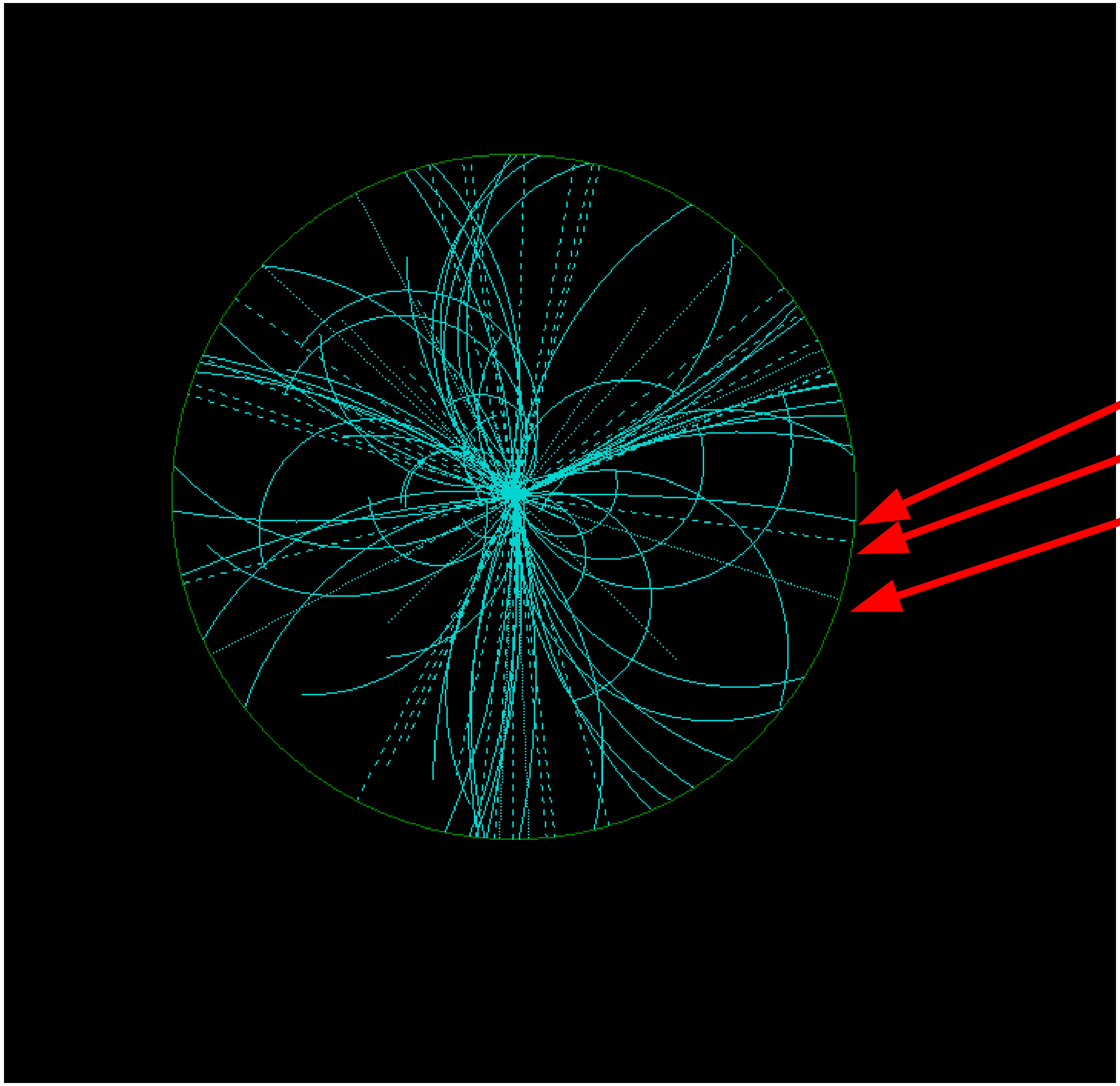


Event Display, transverse view (2.36 TeV data)



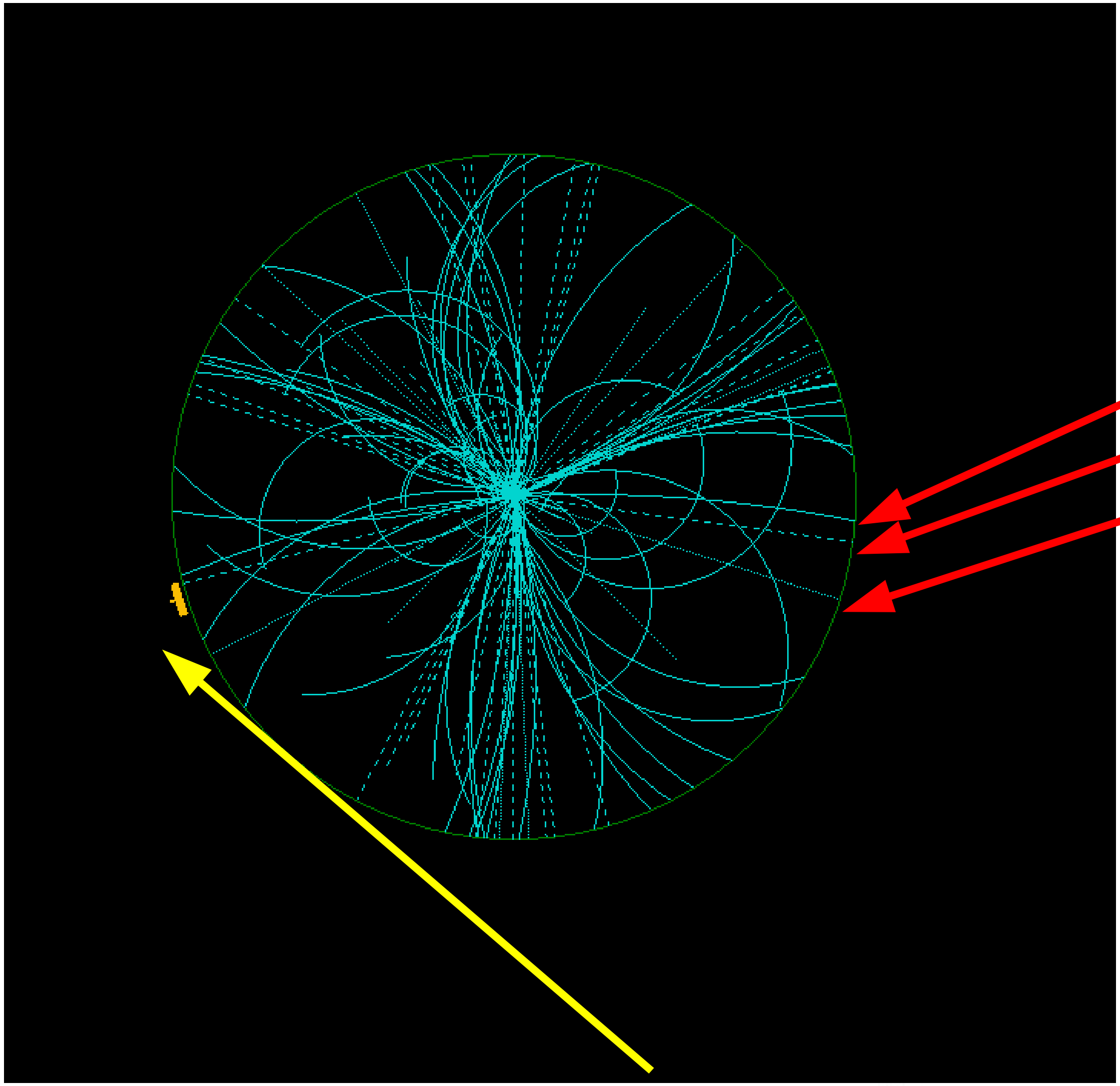
Charged hadron
Photon (dashed line)

Event Display, transverse view (2.36 TeV data)



Charged hadron
Photon (dashed line)
Neutral hadron (dotted line)

Event Display, transverse view (2.36 TeV data)

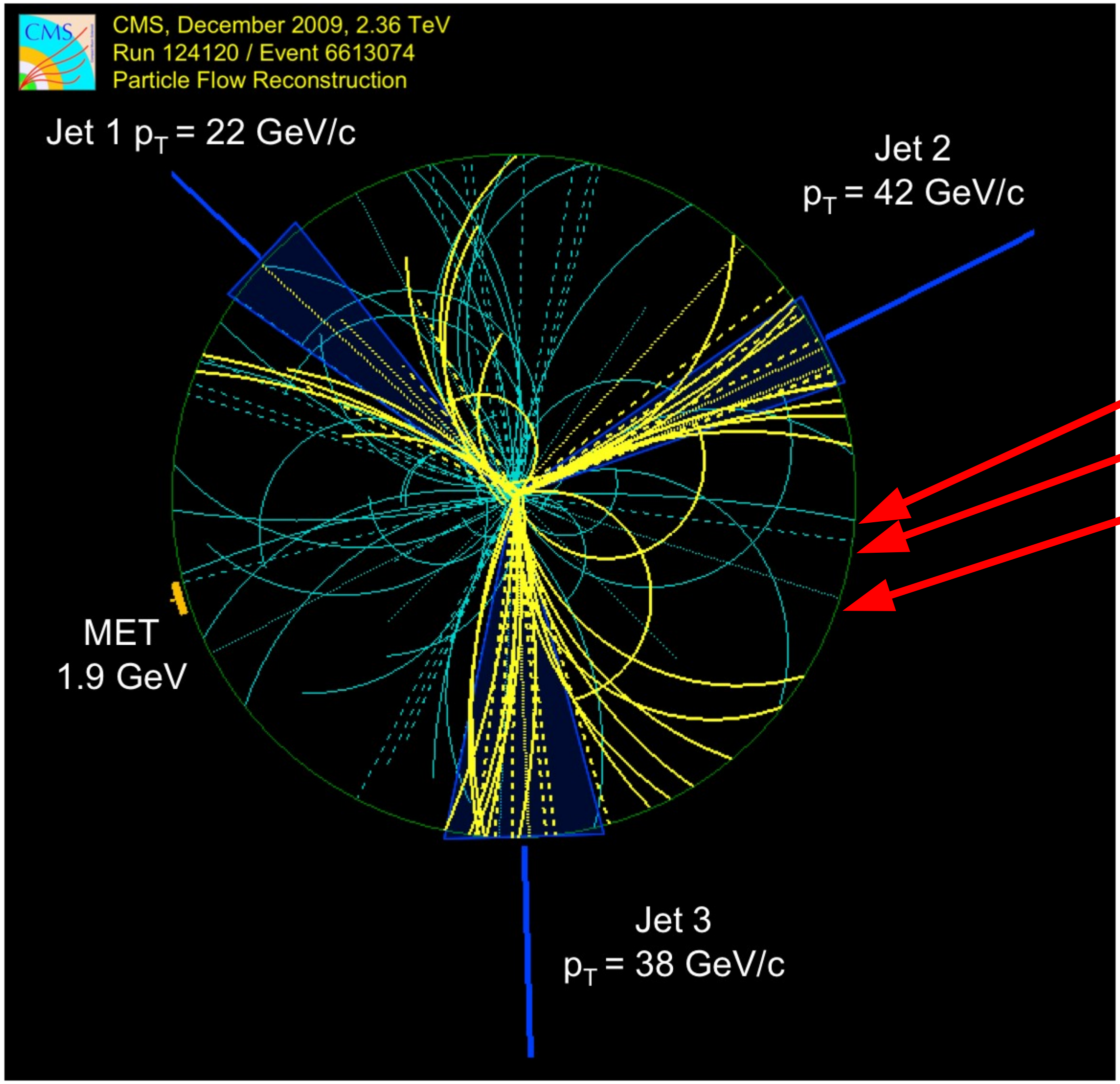


Charged hadron
Photon (dashed line)
Neutral hadron (dotted line)

$\text{Sum}E_T$: 178 GeV
MET : 1.9 GeV

$$\overrightarrow{\text{MET}} = -\sum_{i=0}^{N_{particles}} \vec{E}_T^i$$

Event Display, transverse view (2.36 TeV data)



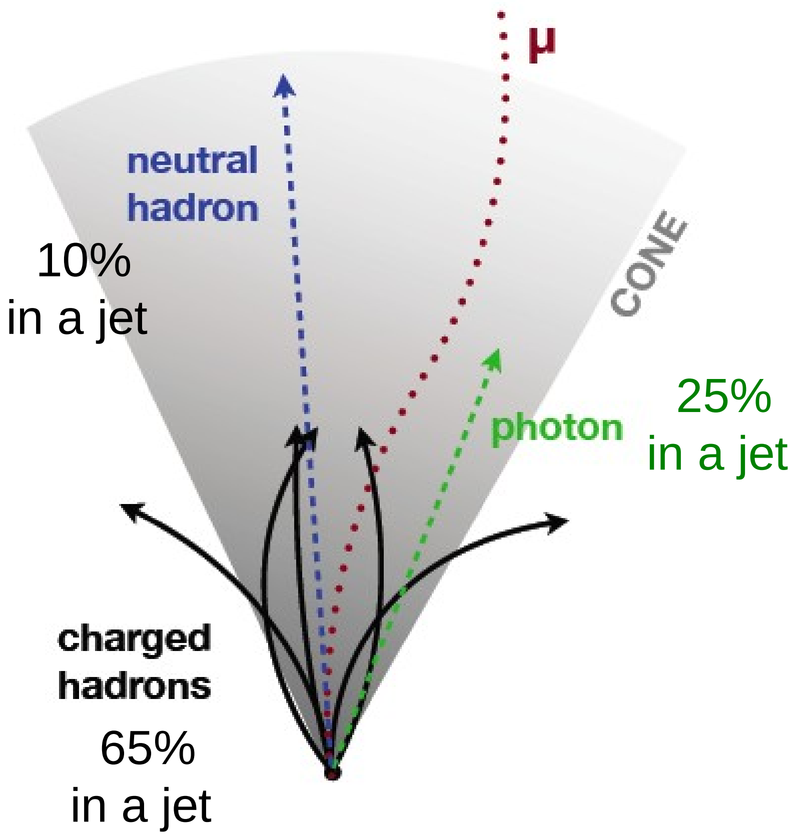
Particles clustered in jets

Jet

Charged hadron
Photon (dashed line)
Neutral hadron (dotted line)

$SumE_T$: 178 GeV
MET : 1.9 GeV
Jet Algo: anti-Kt R=0.5
Three jets with p_T> 20GeV/c

Expectations for the jet energy response & resolution

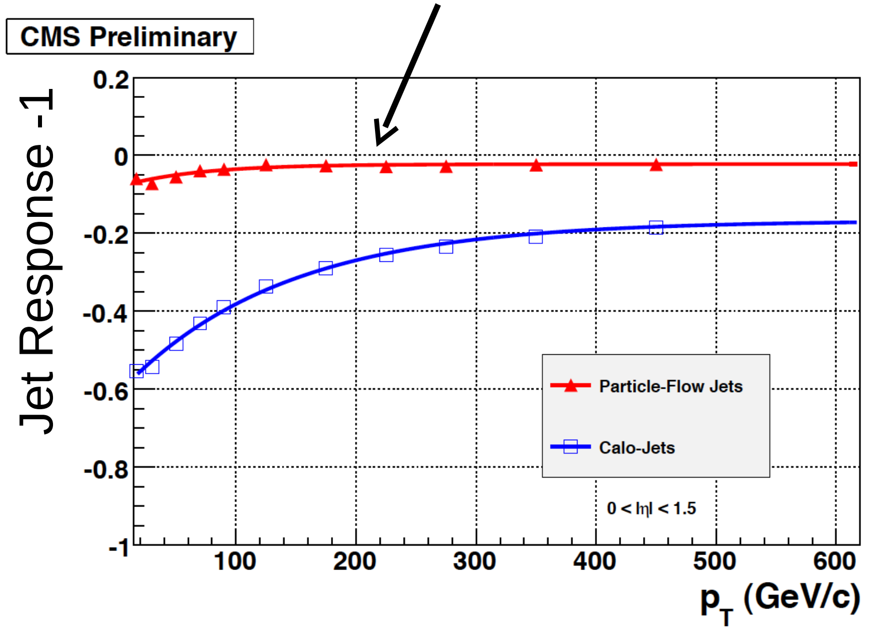


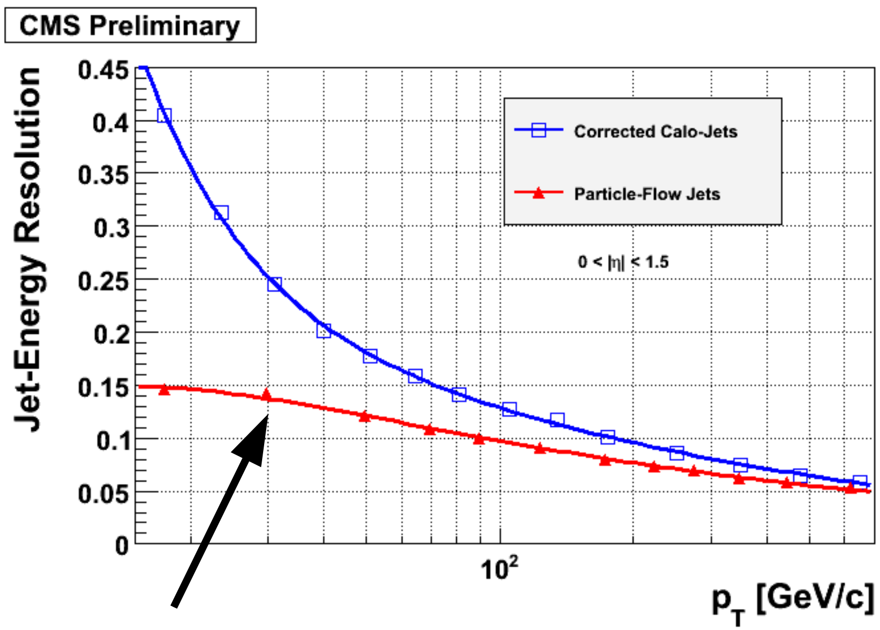
- About 90% of the jet energy is carried by charged-hadrons and photons
- Even in high-p_T jets, the average p_T of the stable particles is around 10 GeV/c

Jet energy response & resolution

simulated QCD-multijets events
barrel: $|\eta| < 1.5$

95-97% of the p_T reconstructed, over the whole range





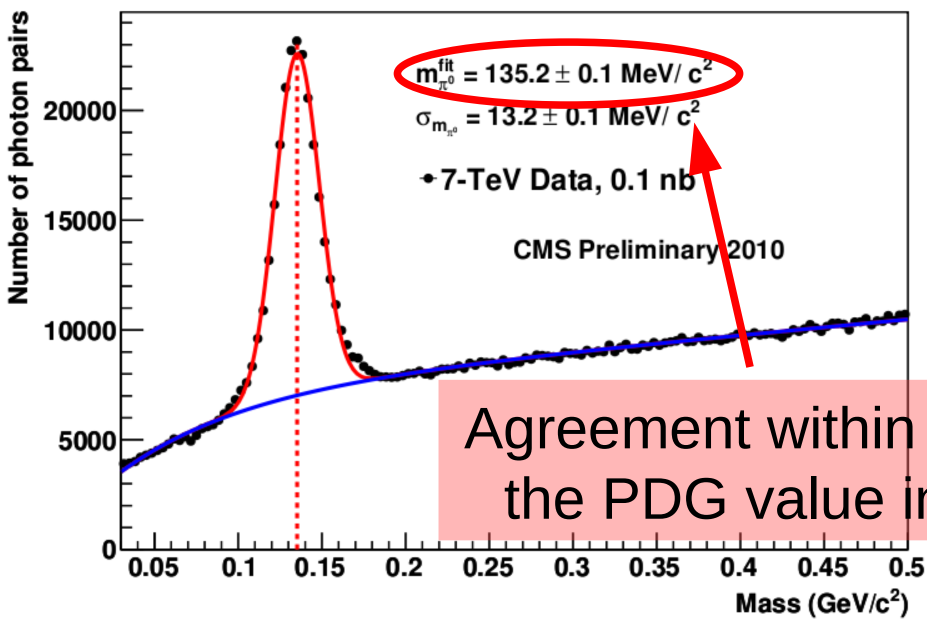
Very large improvement at low pT, thanks to the tracks

Commissioning

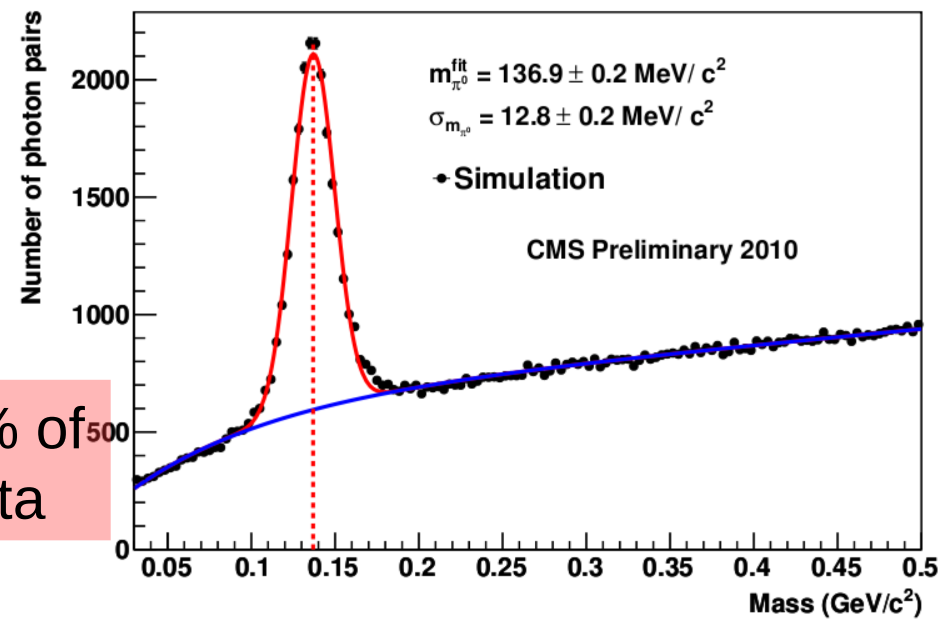
Photons

Commissioning with $\pi^0 \to \gamma\gamma$

Data



Simulation

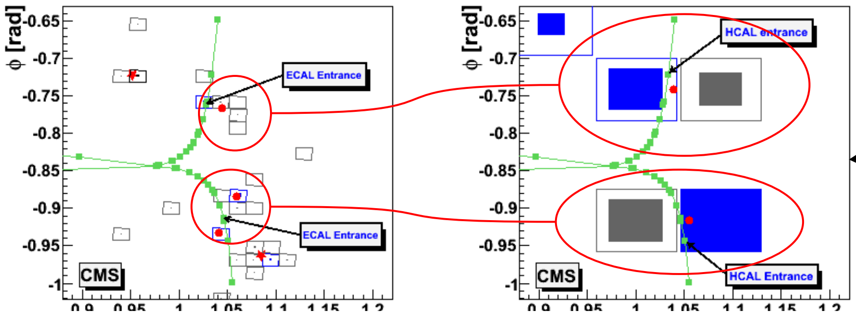


Agreement within ~1% of the PDG value in data

- Demonstrates the suitability of the absolute ECAL calibration

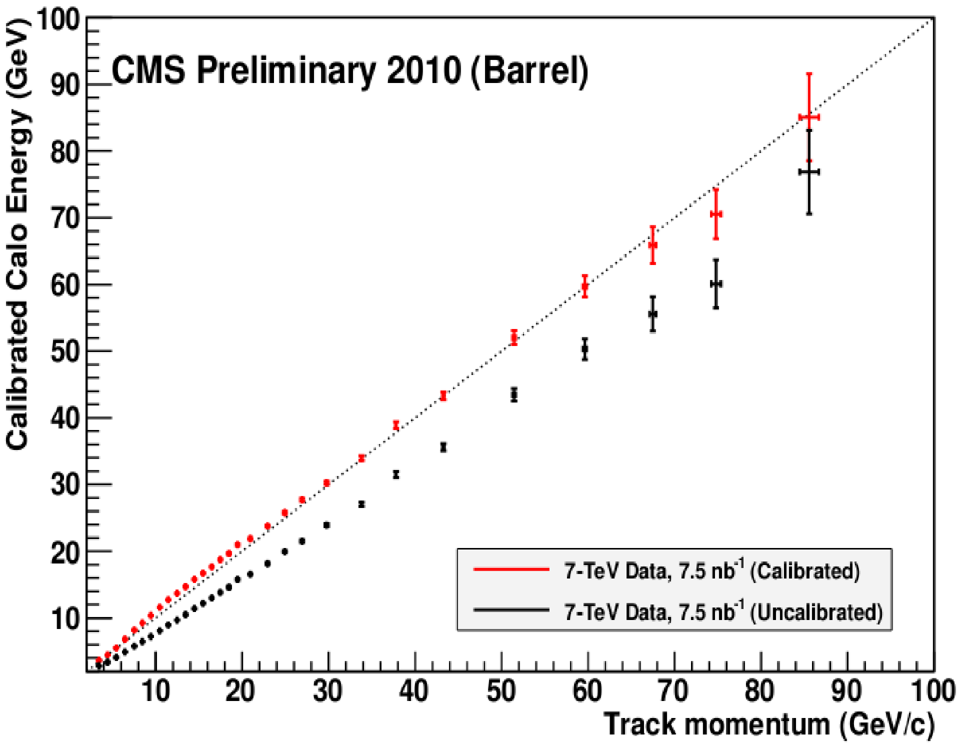
Calorimeter response to hadrons

ECAL surface HCAL surface



Obtained with charged hadrons

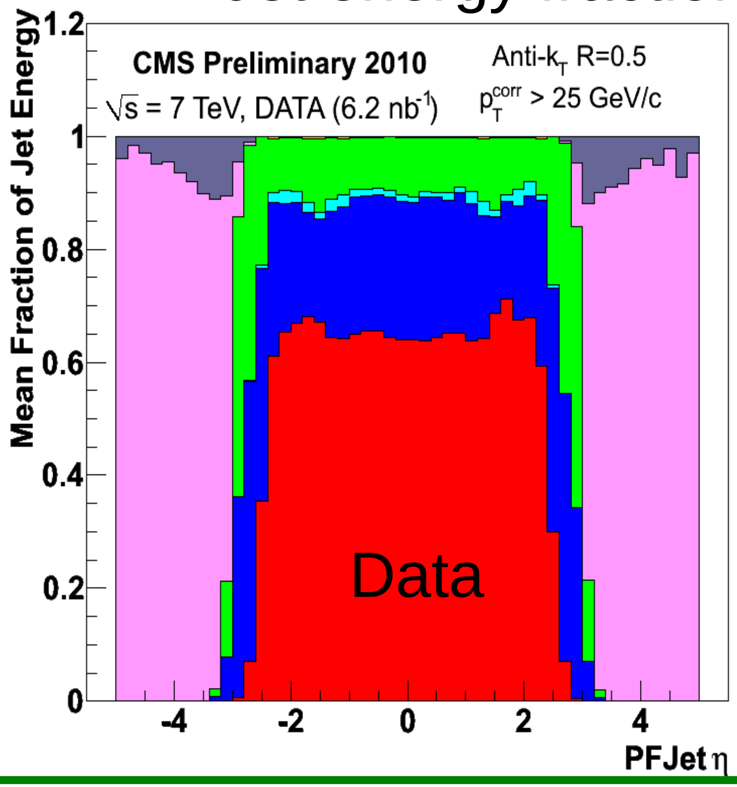
Calorimeter response is important for neutral hadrons

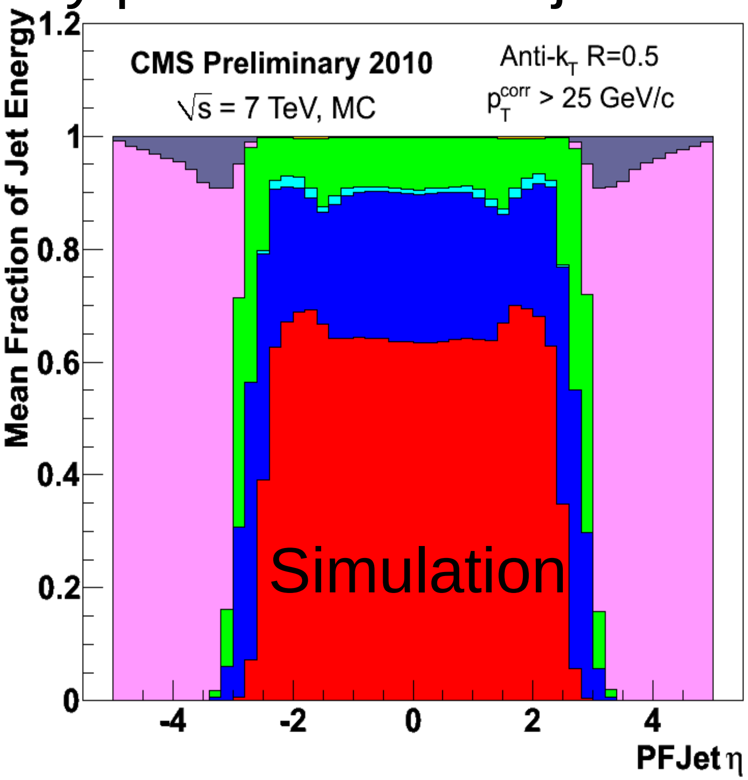


The calorimeter response to hadrons is well simulated.
The hadron response in the calorimeters is adequate at the 5% level
(similar agreement in the end-caps)

Jet composition

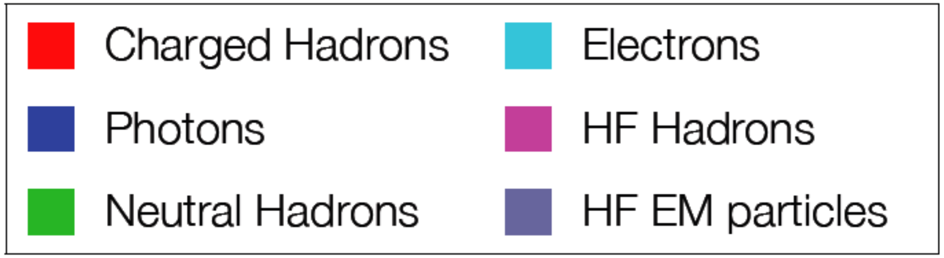
Jet energy fraction carried by particles within jets





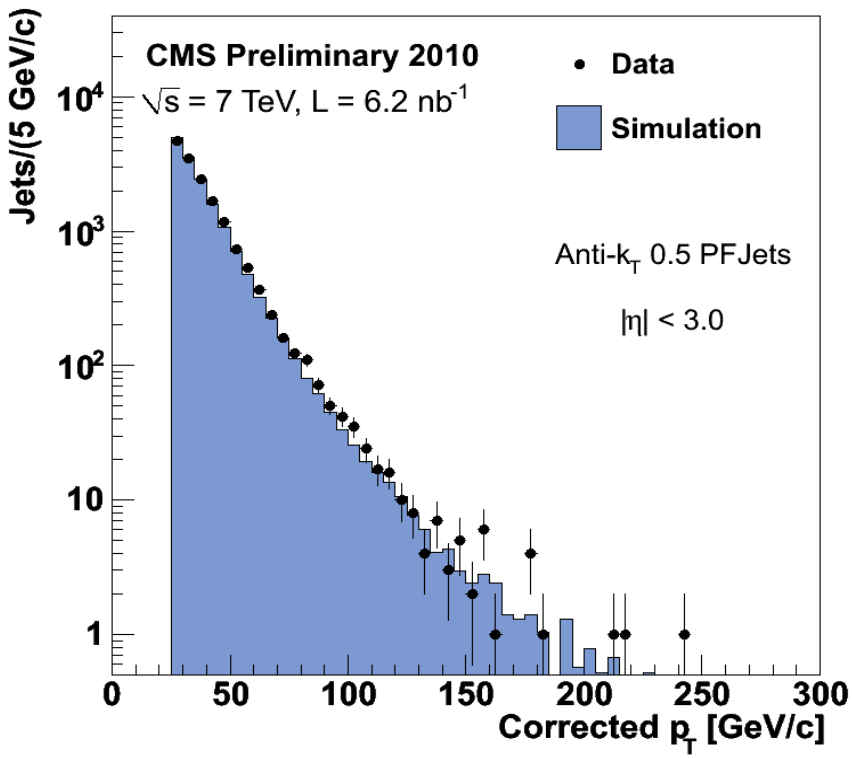
Particle energy scale uncertainty:
65% charged hadrons: high precision
25% photons: 1%
10% neutral hadrons: 5%

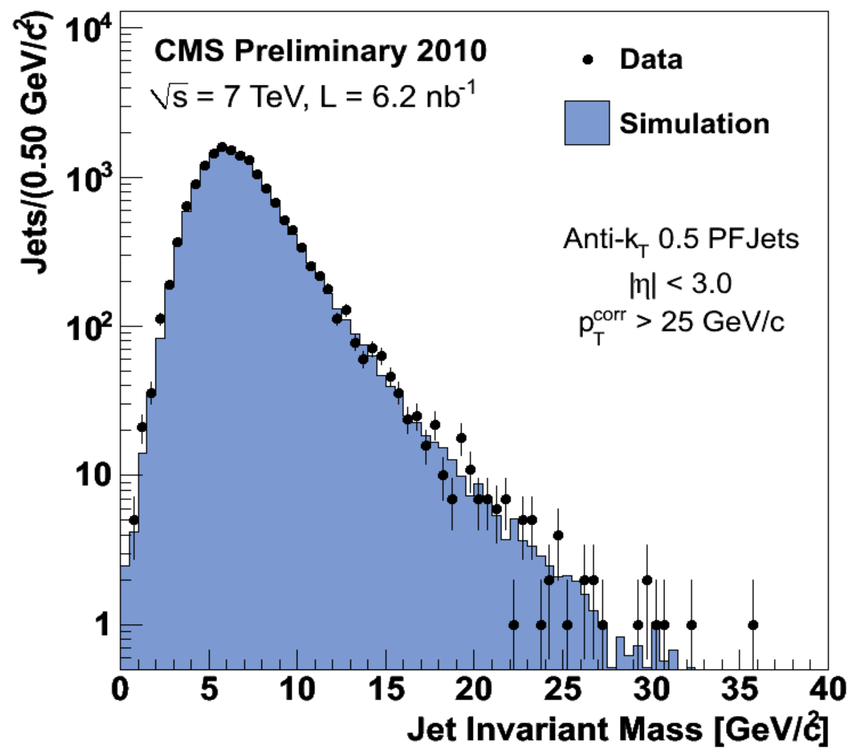
Legitimate JES systematic uncertainty target ~ 1%



Jet kinematics

- Require at least 2 jets with pT>25 GeV and $\Delta\phi>\pi-0.5$ and fill histograms with these 2 jets





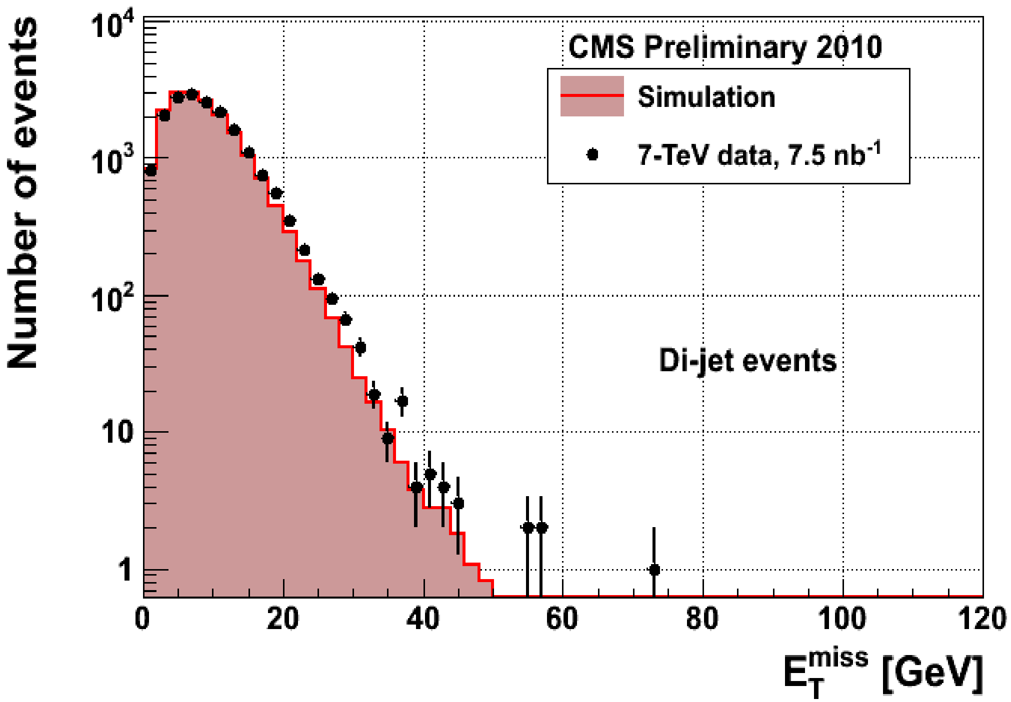
Jet spectrum reproduced over several order of magnitudes

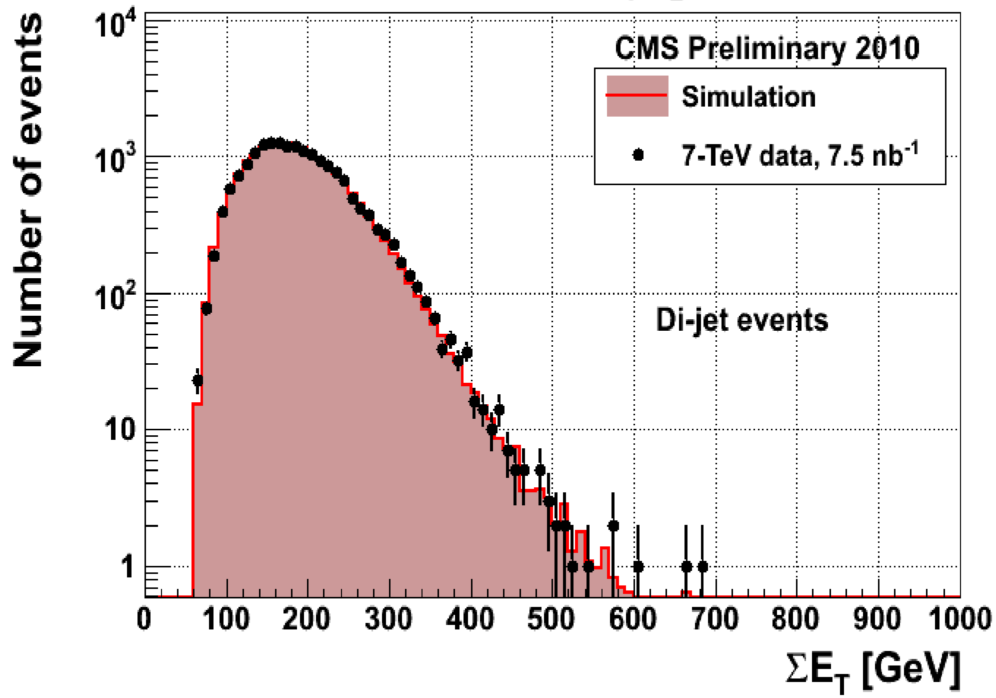
E_T^{miss} & ΣE_T

$$\overrightarrow{E_T^{miss}} = -\sum_{i=1}^{N_{particles}} \overrightarrow{E_T}^i$$

Di-jet events

$$\Sigma E_T = \sum_{i=1}^{N_{particles}} E_T{}^i$$



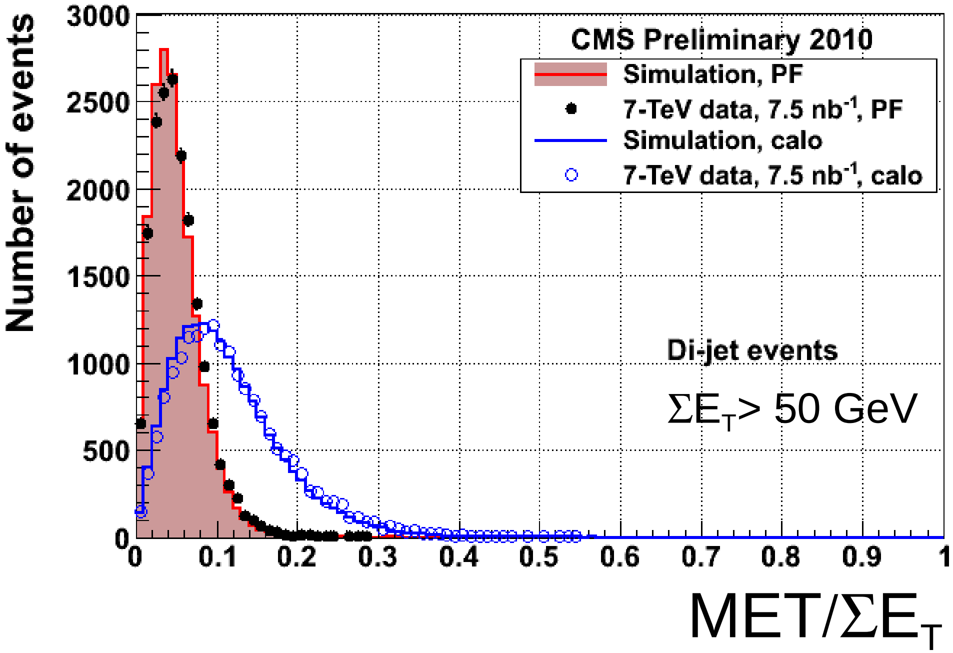


- Agreement over 3 orders of magnitude for the E_T^{miss}
- Even more challenging: ΣE_T (where no cancellation can occur)

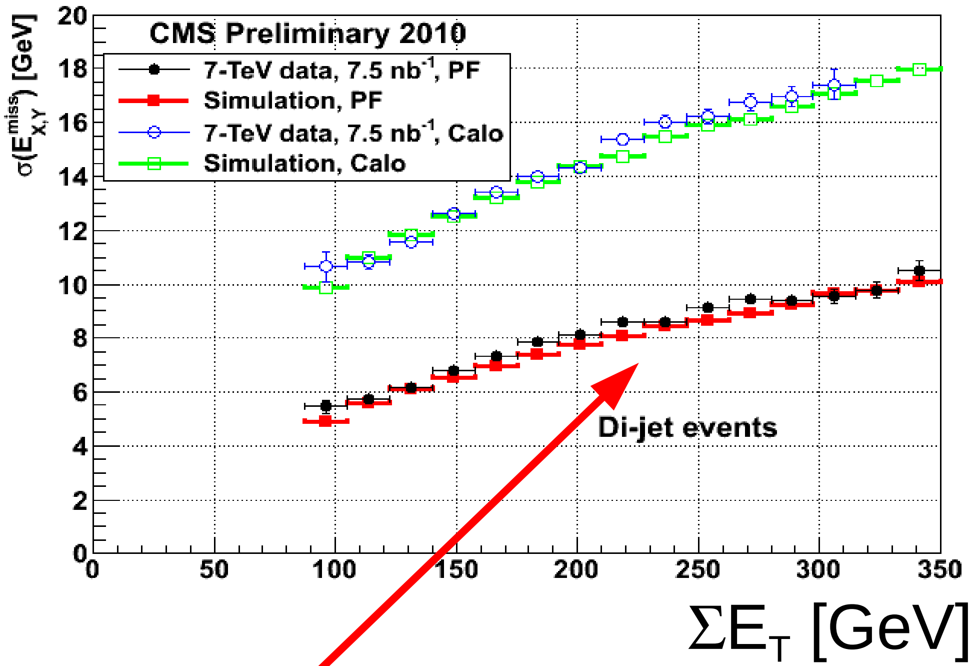
- All together, a remarkable agreement is obtained for these quantities, known to be challenging to reproduce at hadron colliders
  - robustness of the algorithm
  - a precise detector simulation

E_T^{miss} resolution

Poor-man E_T^{miss}-significance



σ of $E_{T\ x,y}^{miss}$ component



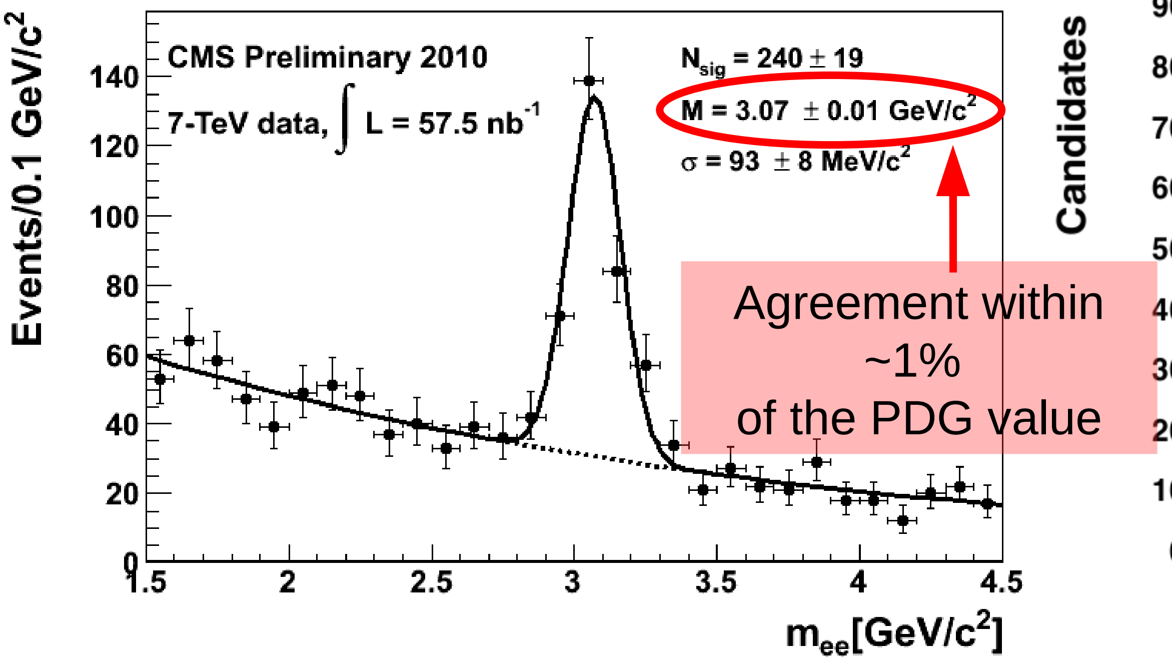
The E_T^{miss} resolution is improved by a factor ~2 wrt the calorimeter-based E_T^{miss}

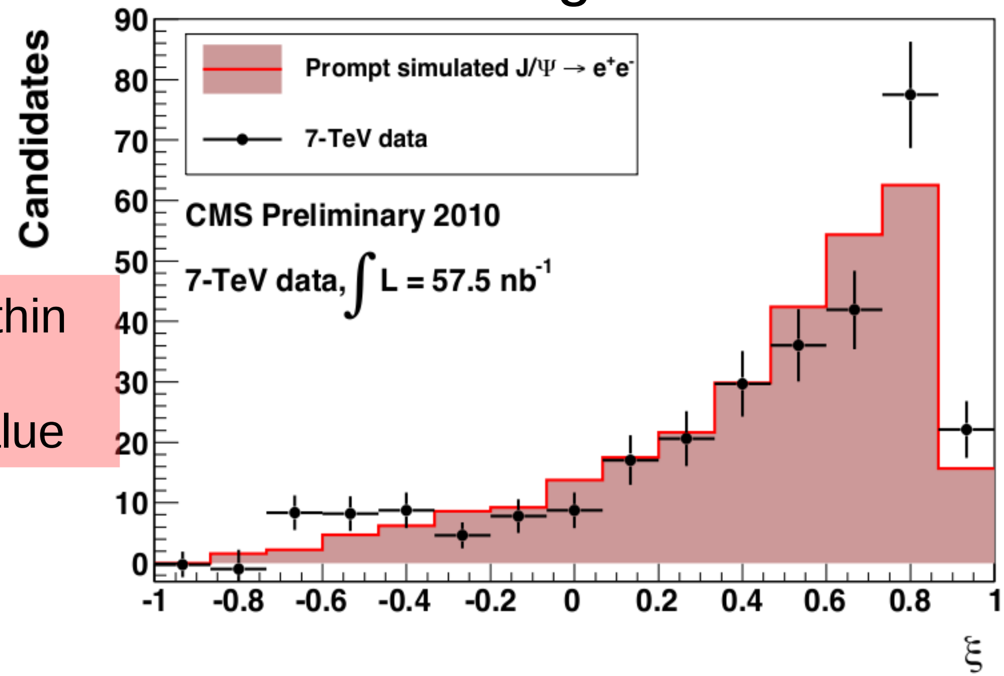
Stochastic term of $\sigma_{x,y}$ in the 50-60% range

Electrons

A dedicated electron reconstruction algorithm has been developed to cope with low p_T and non-isolated electrons

A sample of $J/\Psi \rightarrow ee$ is used for the commissioning





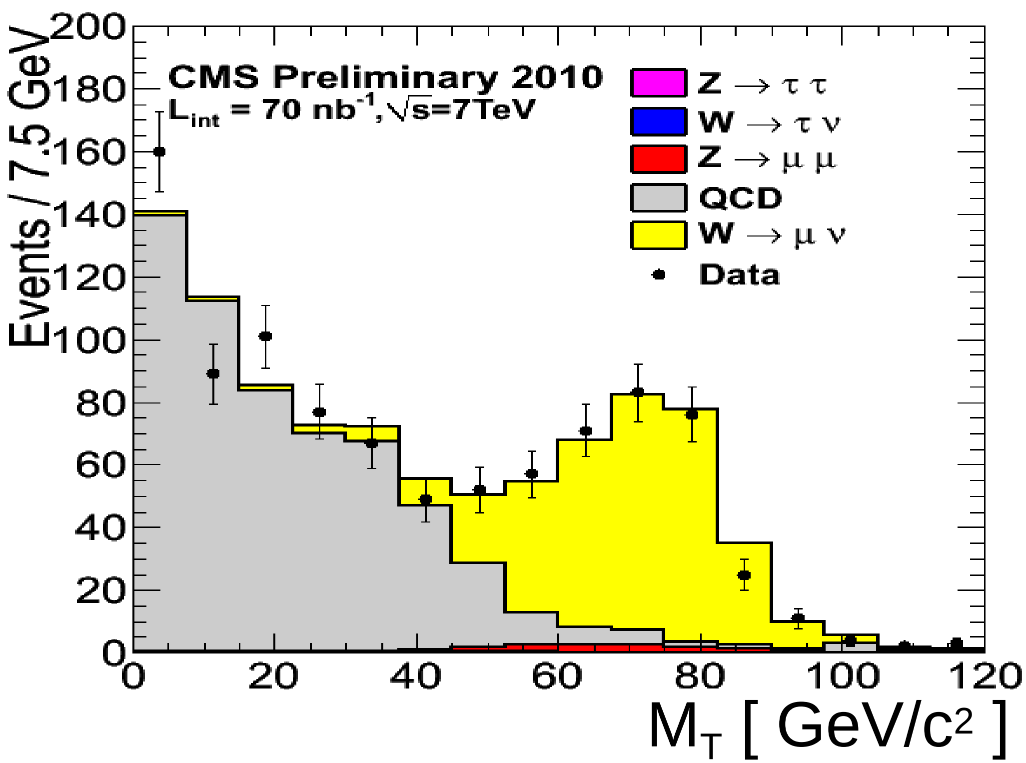
With a simple selection, a nice $J/\Psi \rightarrow ee$ peak is obtained

The electron quality multivariate estimator agrees between data and simulation

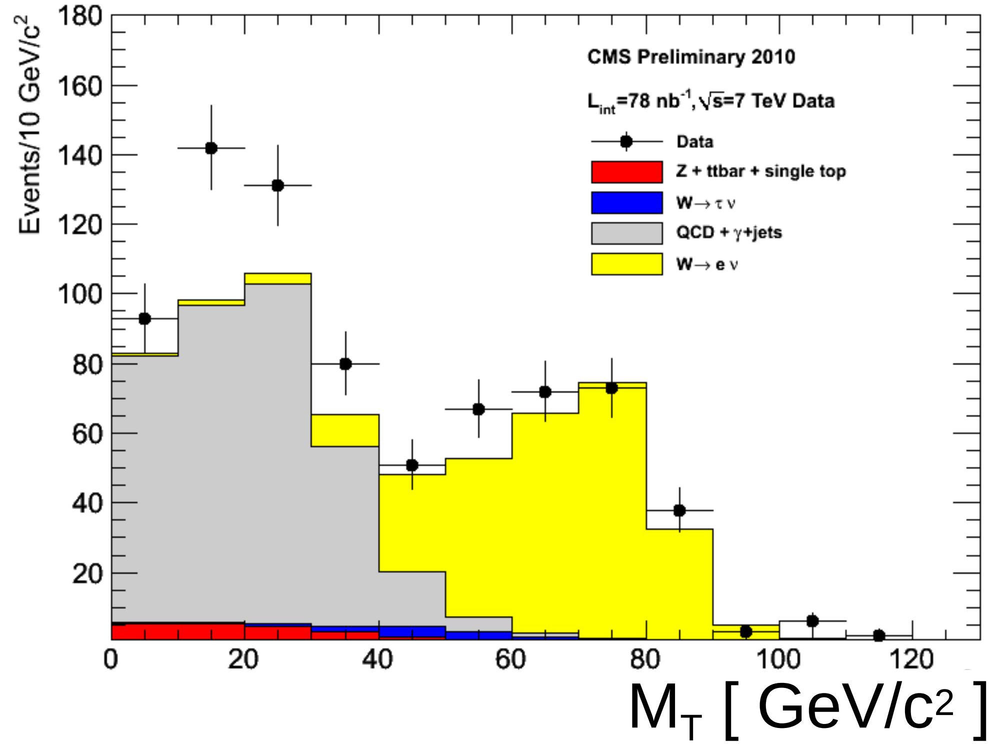
High p_T muons, electrons and E_T^{miss}

W leptonic decays are an ideal source for high pT leptons and neutrinos

W→ μ ν No muon isolation applied



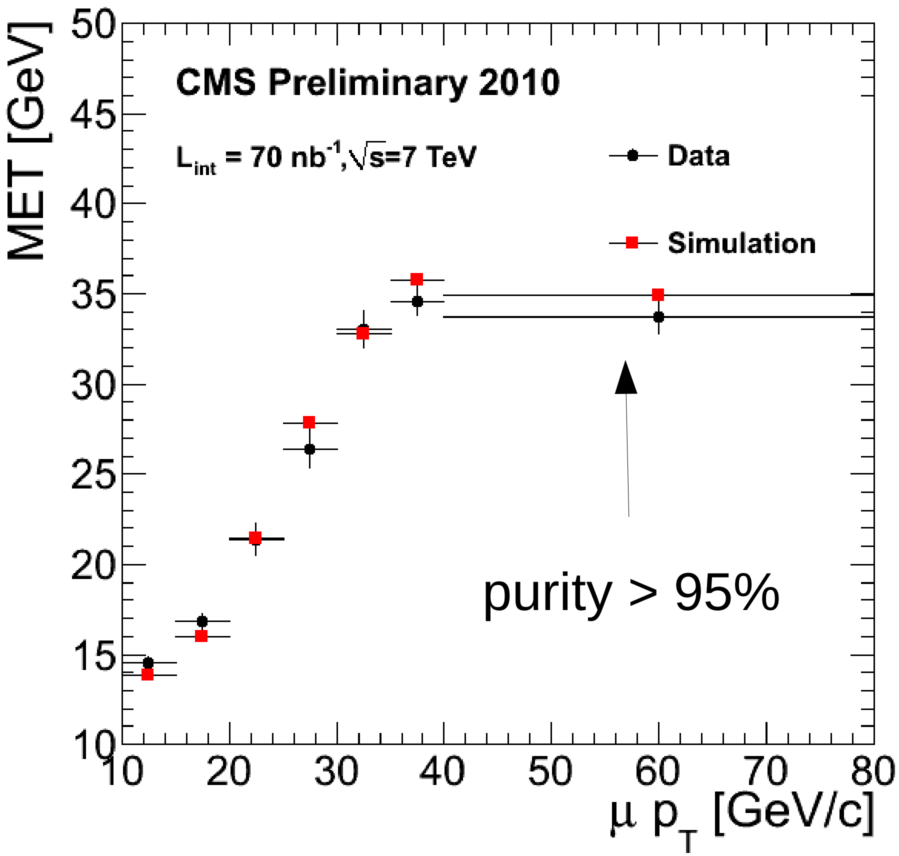
W→ e ν Electron isolation applied

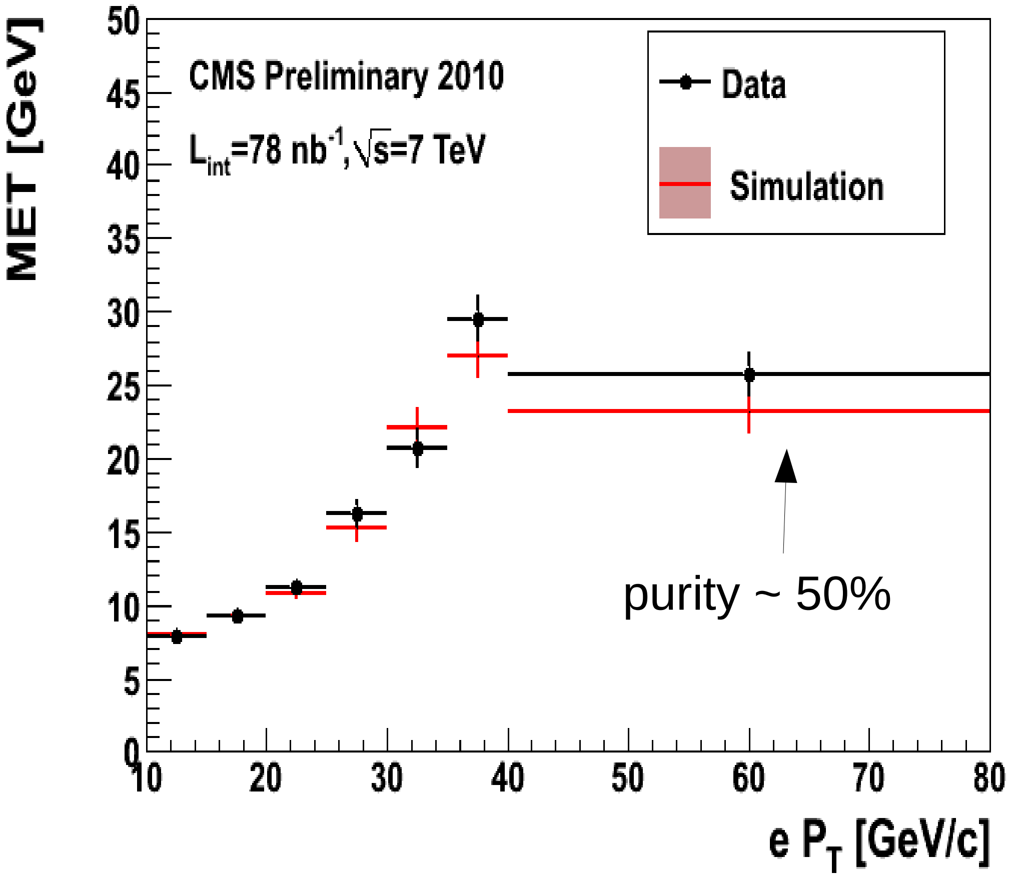


- Good agreement for the signal
- The agreement between data and simulation demonstrates the reliability of the Particle Flow E_T^{miss} and lepton reconstruction

High p_T leptons and E_T^{miss}

Average E_T^{miss} as a function of the leading isolated lepton p_T





To get agreement on these plots

- the E_T^{miss} should be correctly reproduced in the simulation
- the W/multi-jet event yields should be correctly reproduced

Conclusion

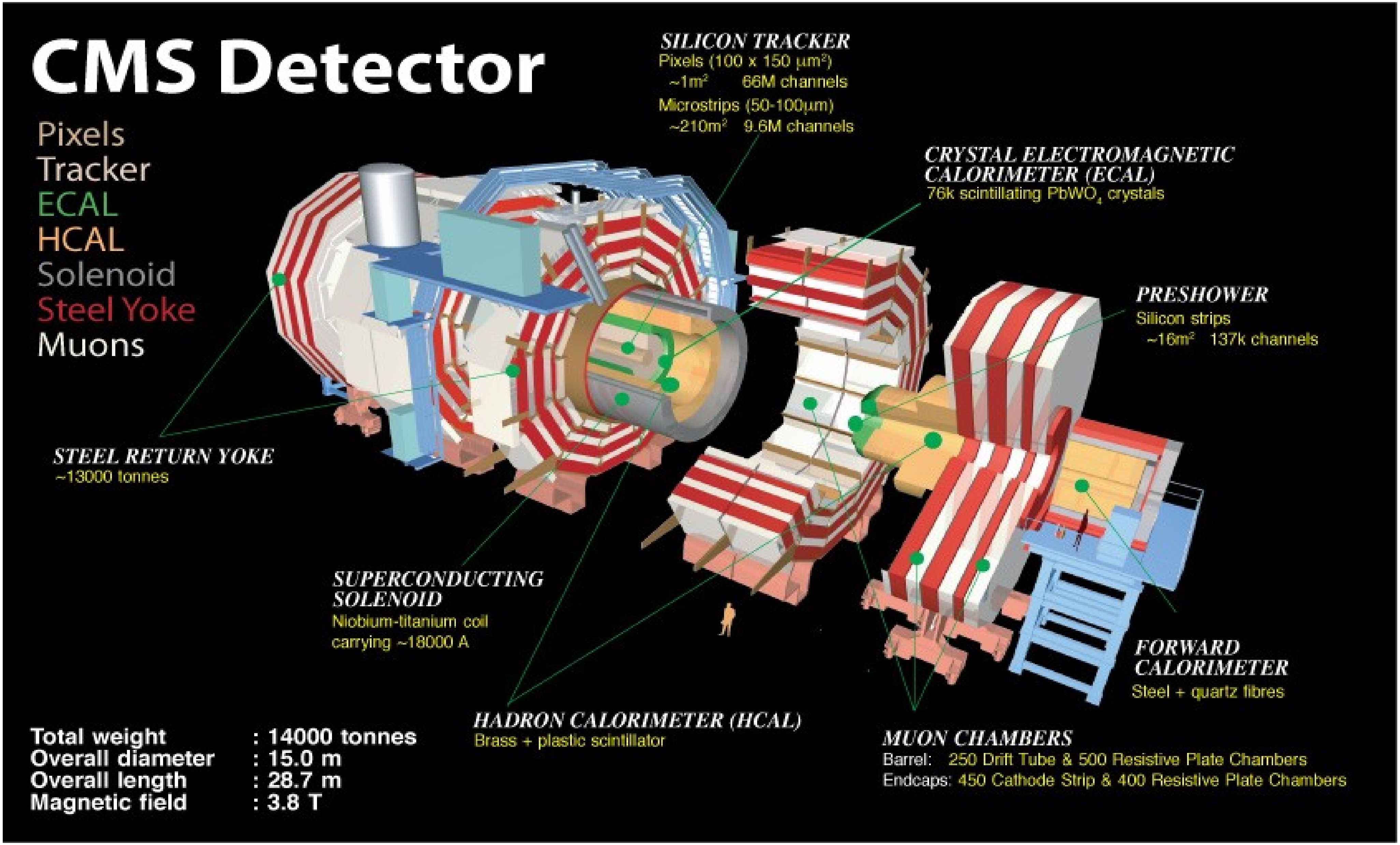
- Combining the various CMS sub-detectors, the particle-flow event reconstruction allows for a much better reconstruction of the jets, the E_T^{miss}, (and τ)
  - up to 3 times better resolution in jets
  - on average 2 times better resolution in E_T^{miss}

- The particle flow algorithm commissioning is ongoing and going well
  - the energy scale of jets, E_T^{miss}, electrons, photons, muons is under control at the percent level

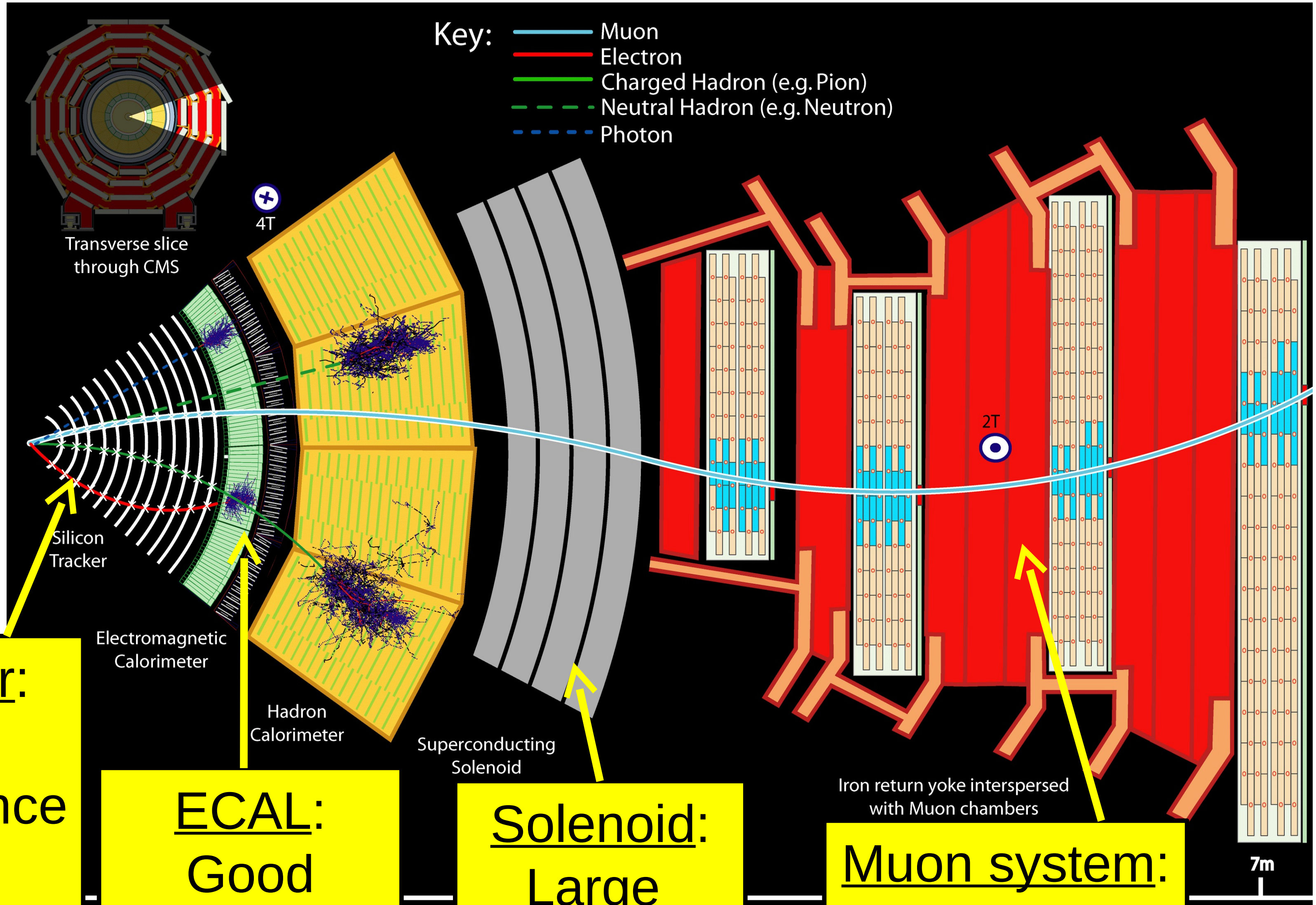
- The particle-flow event reconstruction is keeping up with the LHC challenge
  - the algorithms proves to be robust and reliable

Backup slides

The CMS Detector



Why Particle Flow in CMS



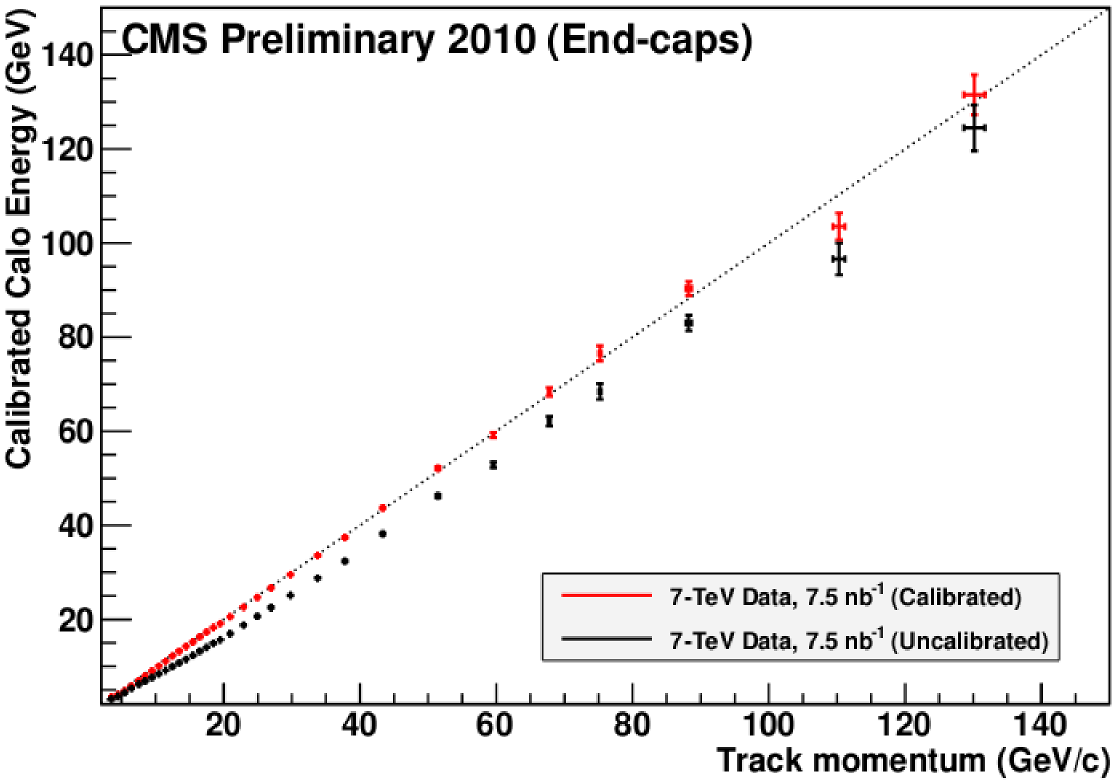
Tracker: large acceptance and efficiency

ECAL: Good granularity

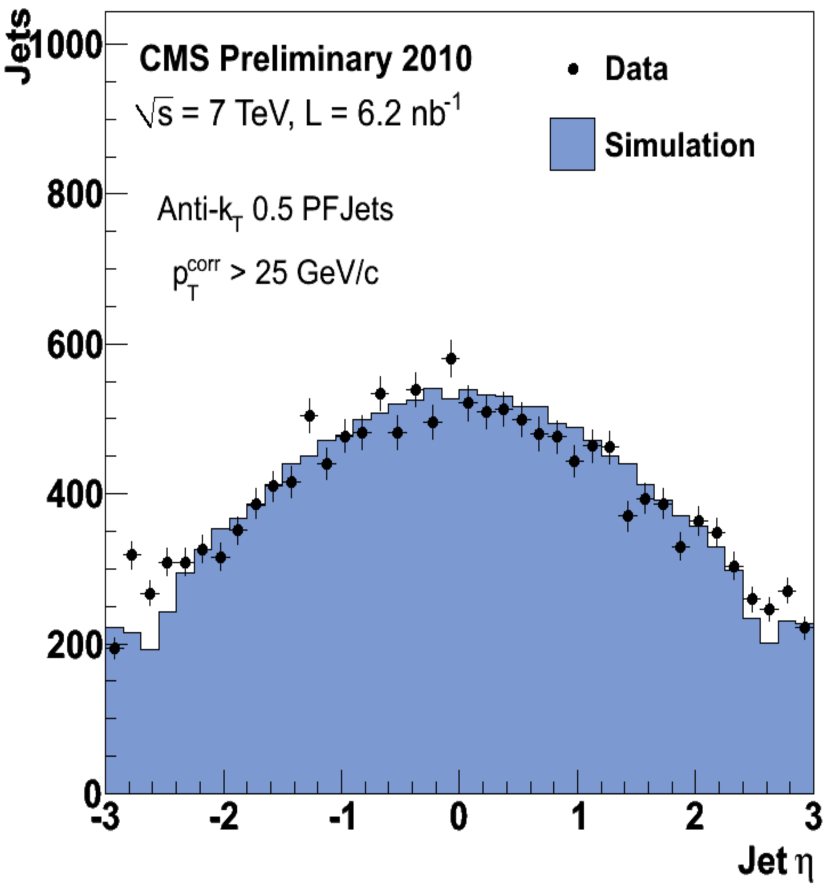
Solenoid: Large field

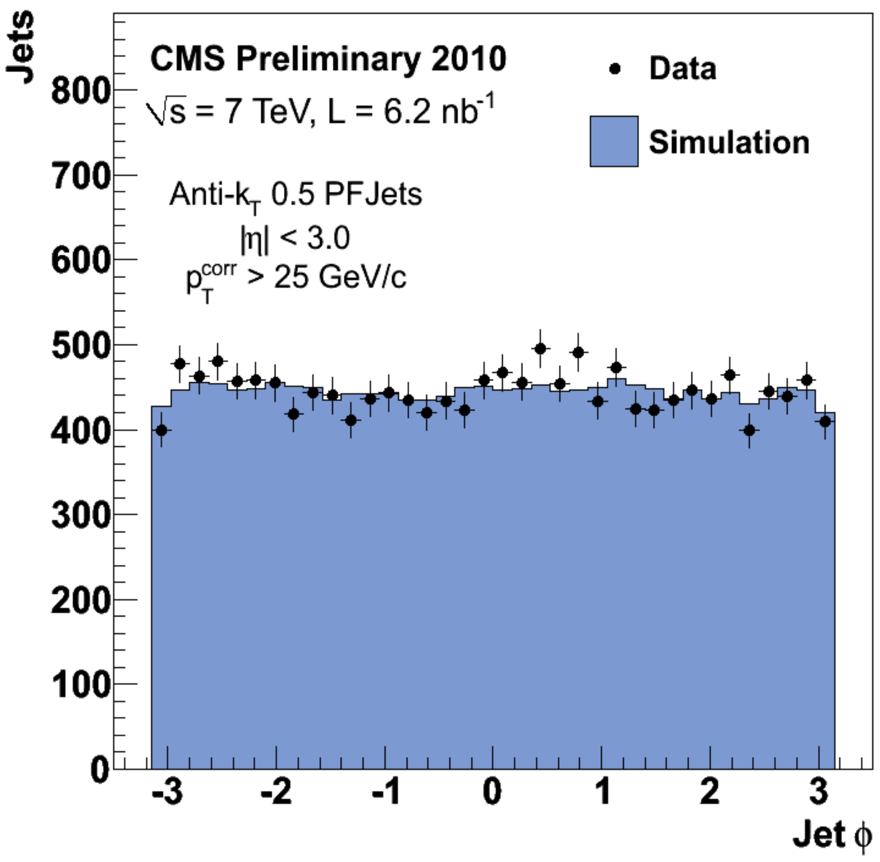
Muon system: Excellent efficiency

Hadron calibration - End-caps

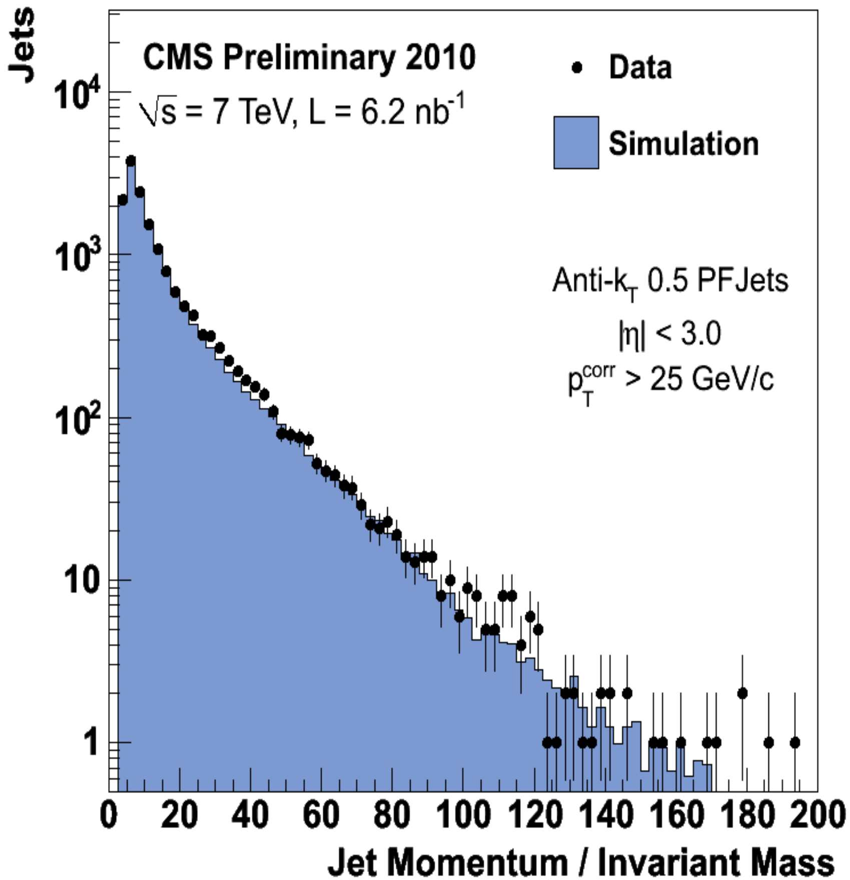


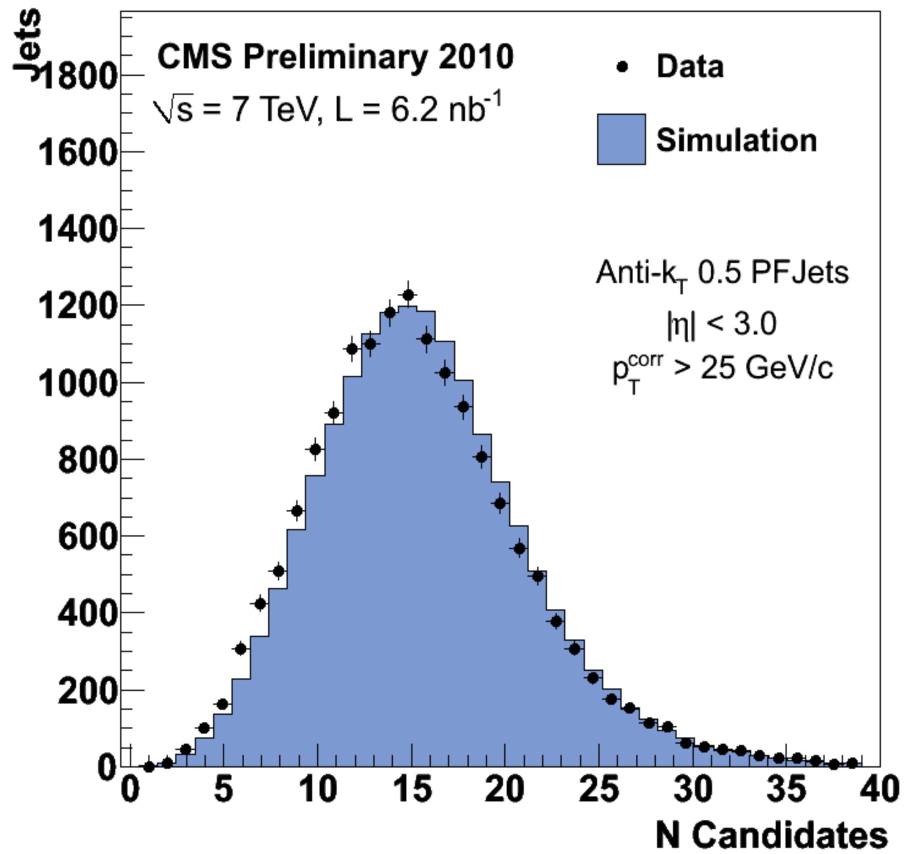
Jet variables





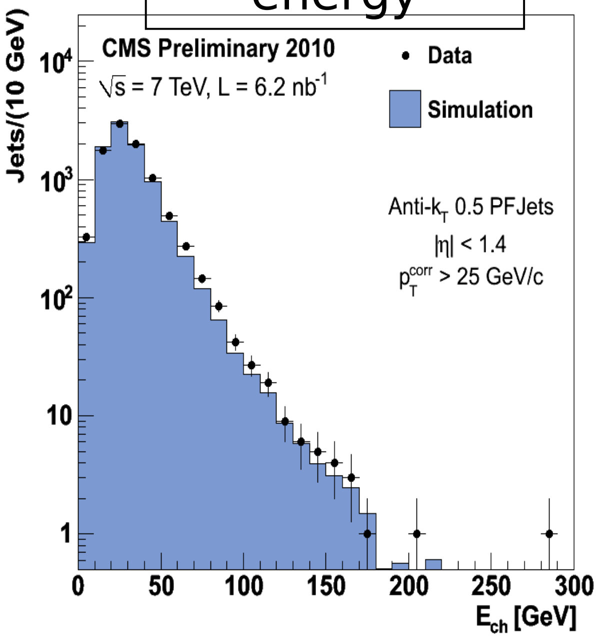
Jet variables



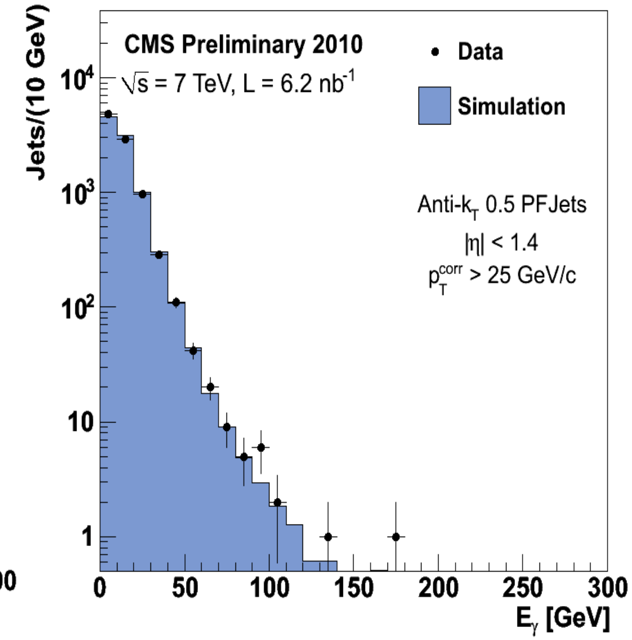


Barrel

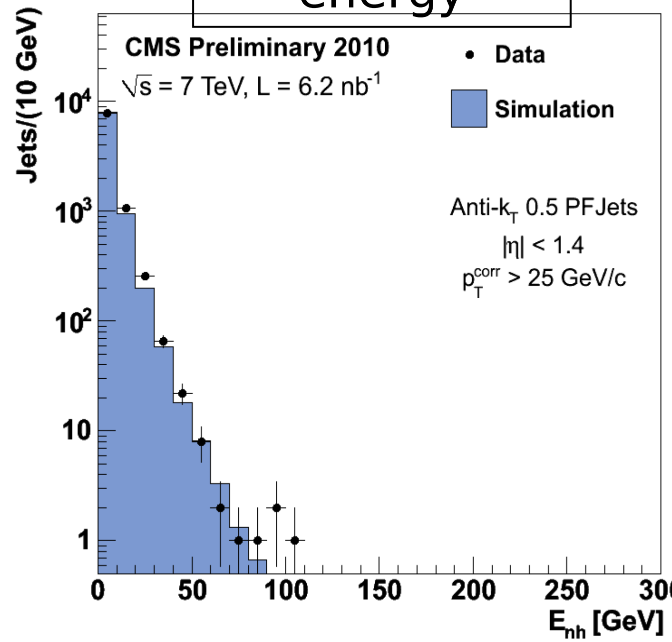
Charged hadron energy



Photon energy

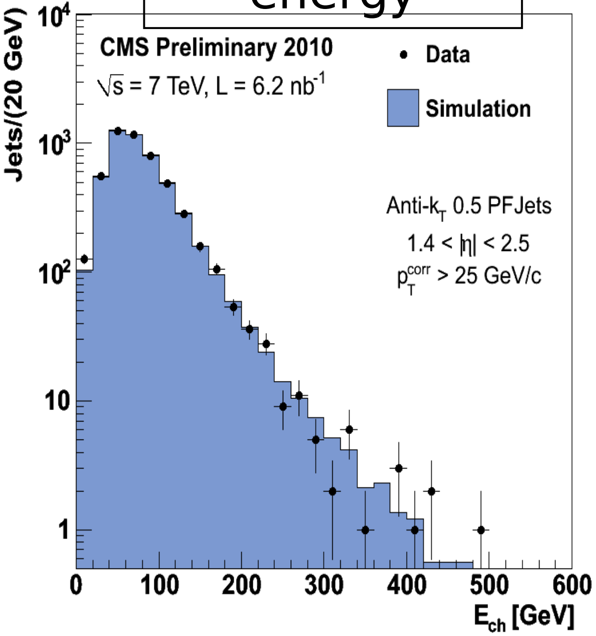


Neutral hadron energy

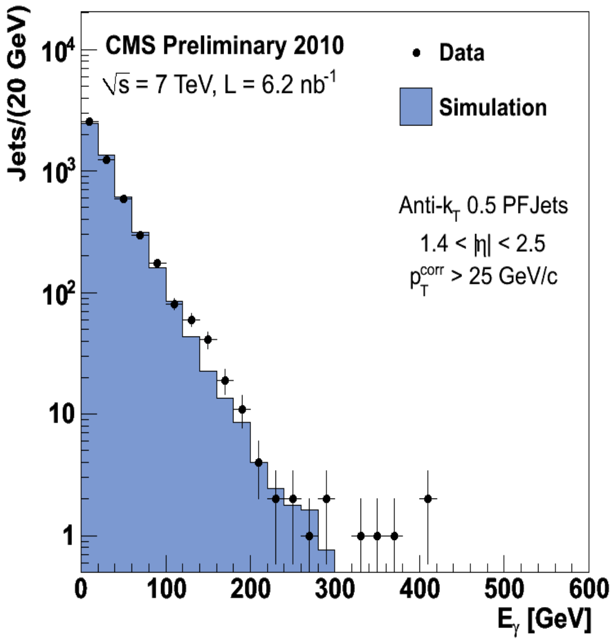


End-caps

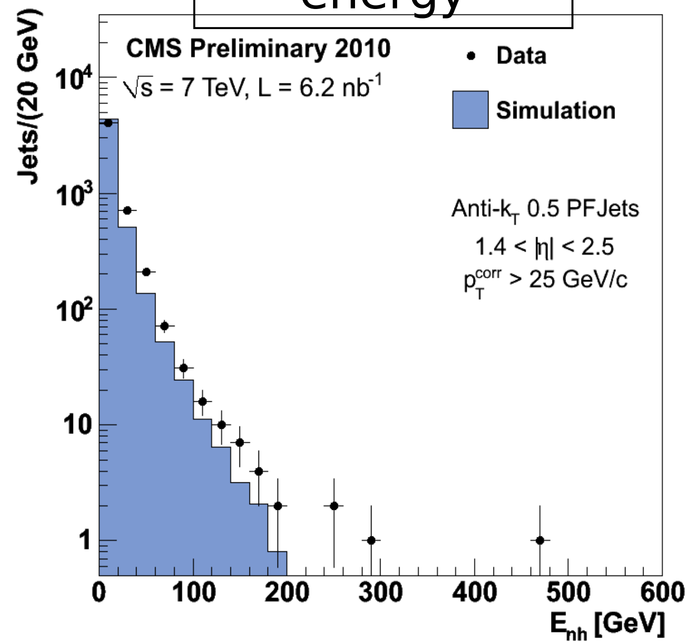
Charged hadron energy



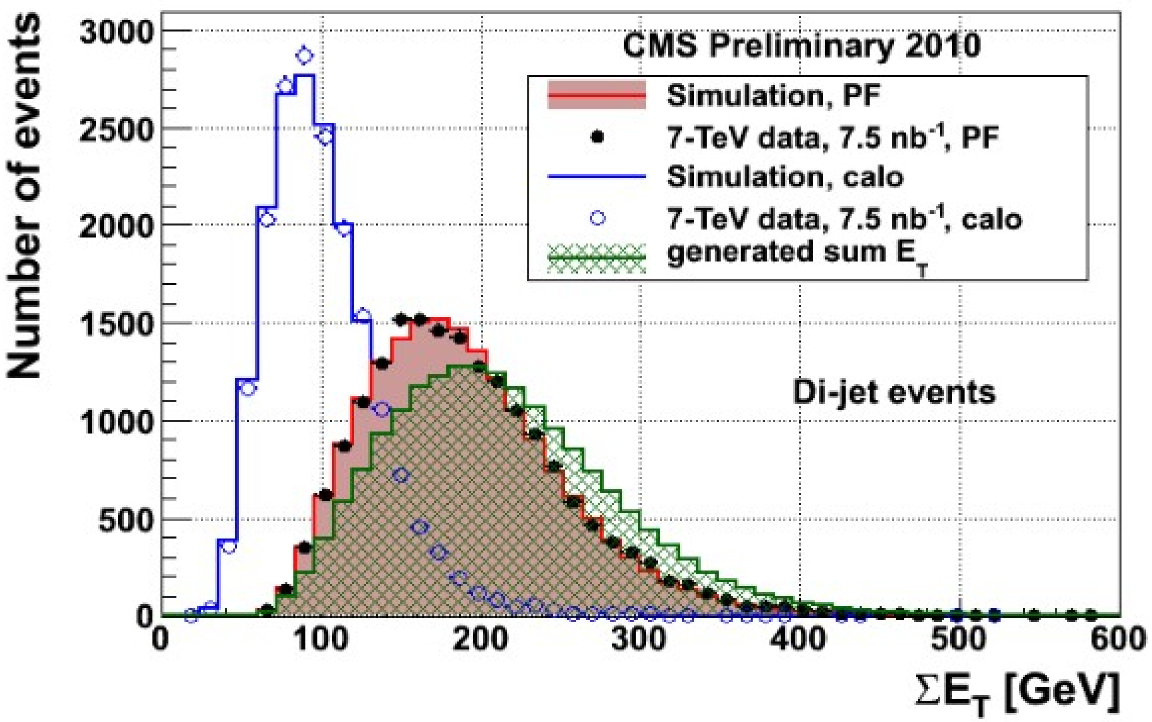
Photon energy



Neutral hadron energy

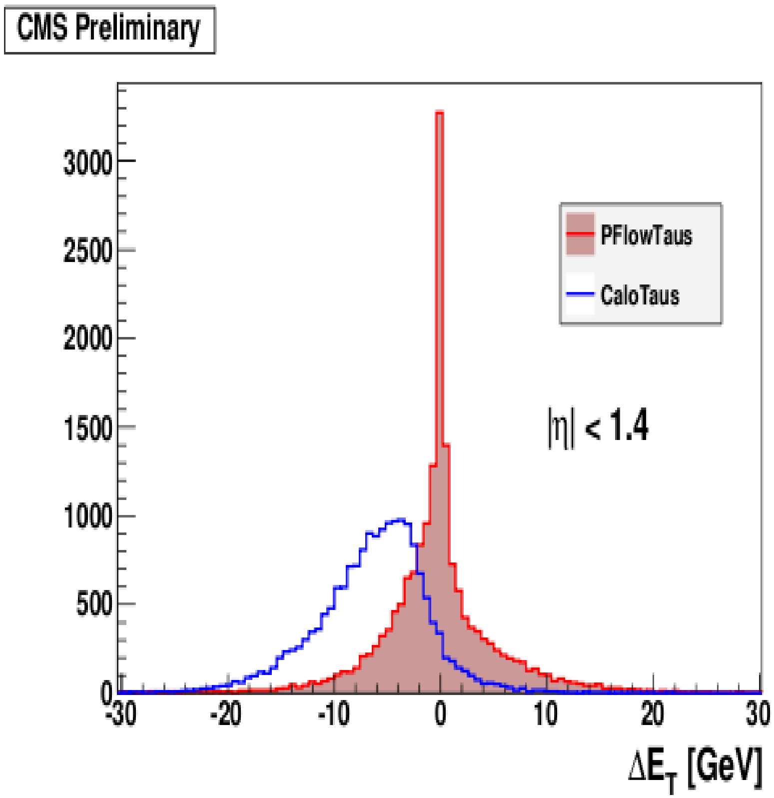


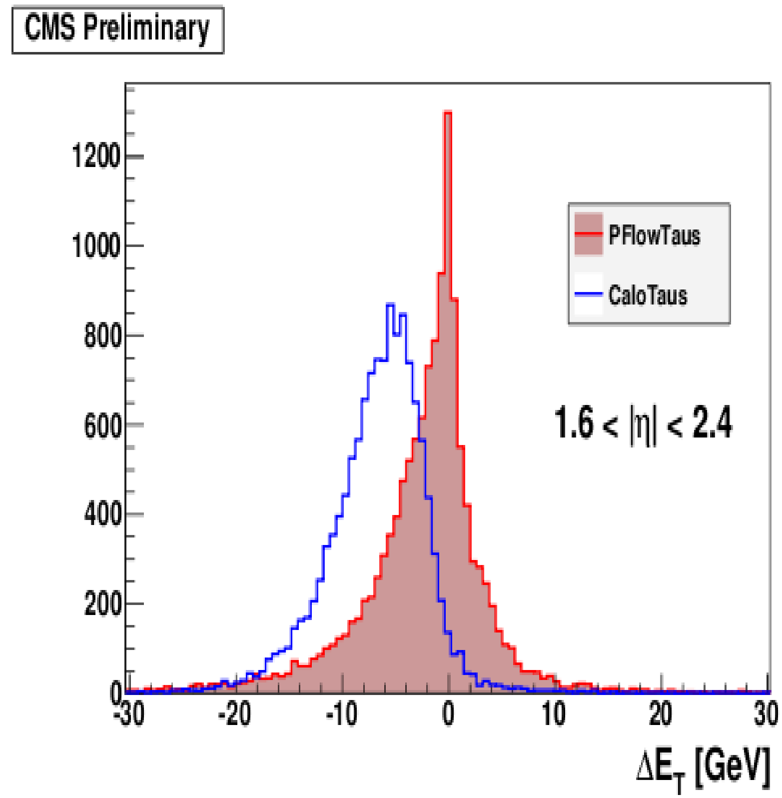
SumEt



CMS Preliminary 2010
Simulation, PF
7-TeV data, 7.5 nb-1, PF
Simulation, calo
7-TeV data, 7.5 nb-1, calo
generated sum E_T
Di-jet events
Number of events
ΣE_T [GeV]
0
500
1000
1500
2000
2500
3000
100
200
300
400
500
600

Tau reconstruction





Tau visible energy