Calibration of the ZEUS calorimeter for hadrons and jets

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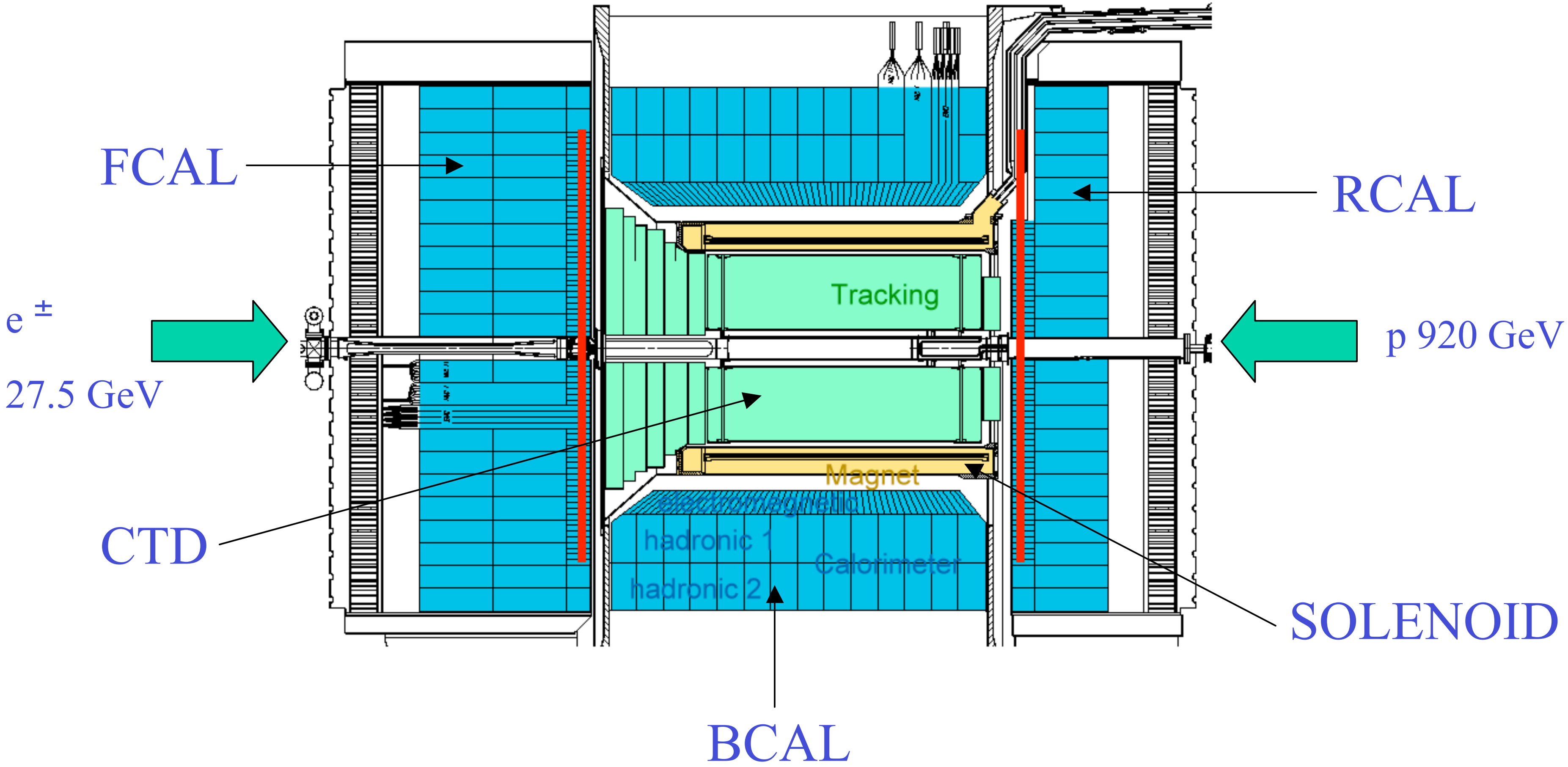
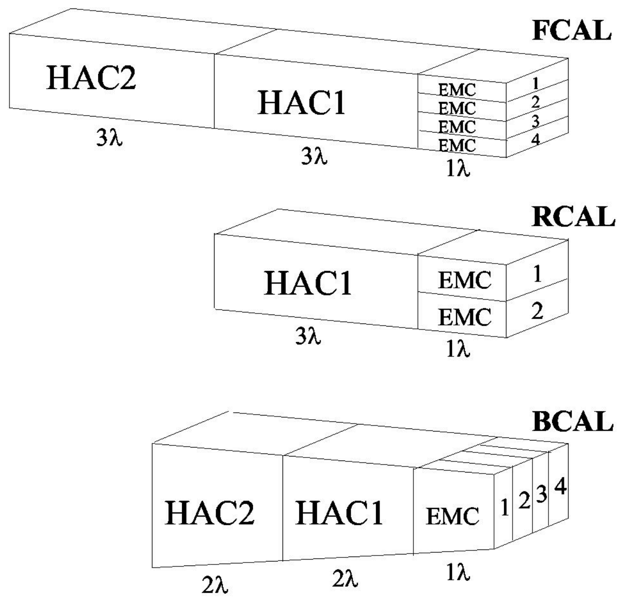
Outline

- Clustering
- Energy Flow Objects
- Backsplash
- Calibration for inclusive hadronic final states
- Calibration for jets
  - EFOs and momentum balance
  - Tracking and jet momentum balance
- Summary

The ZEUS detector



The ZEUS calorimeter - geometry



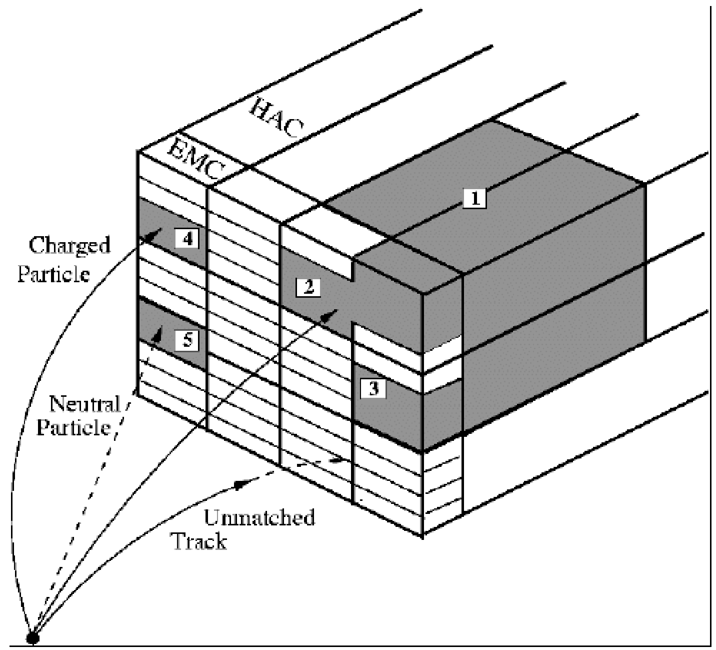
- EMC cells
  - 5x20 cm^2 (10x20 cm^2 in RCAL)
  - 1 interaction length
- HAC cells
  - 20x20 cm^2
  - 3 interaction lengths (2 in BCAL)
- Readout 2 PMTs per cell
- Imbalance gives position

Clustering

- Try to remove effects of CAL granularity
- Ideally one cluster corresponds to one particle
- First combine cells in 2D locally i.e. in EMC sections, HAC1 and HAC2 sections separately
- Combine 2D clusters in EMC with others in HAC1 and HAC2 sections of CAL
- Probability distribution for combining from single particle MC events
- 3D CAL clusters -> "islands"

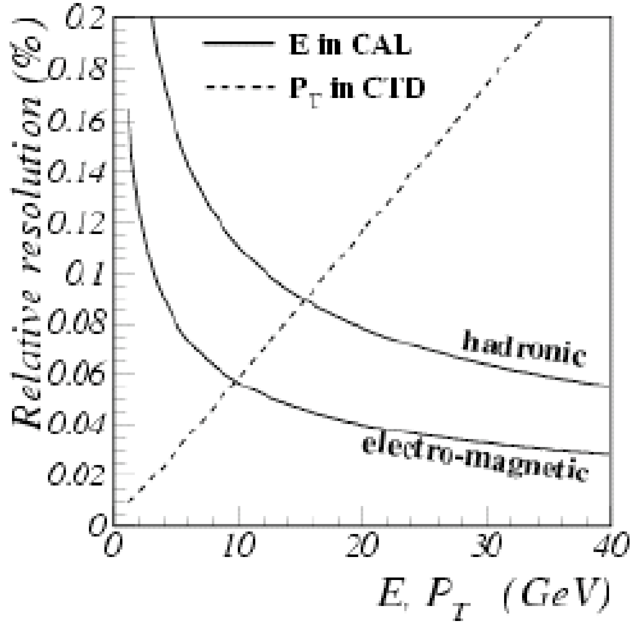
Energy Flow Objects

- Combine CAL and tracking information
- Optimise for best energy and position measurement
- For unmatched tracks use P_{trk} (assume π mass)
- No track: use CAL
- CAL objects with one or more tracks more complicated.....



Energy Flow Objects

- Consider whether CAL or CTD has better resolution
- Try to use track position even if energy is from CAL
- Treat muons separately using tracking information



Overall improvement in resolution of reconstructed quantities of ~20% when tracking information is used

Backsplash

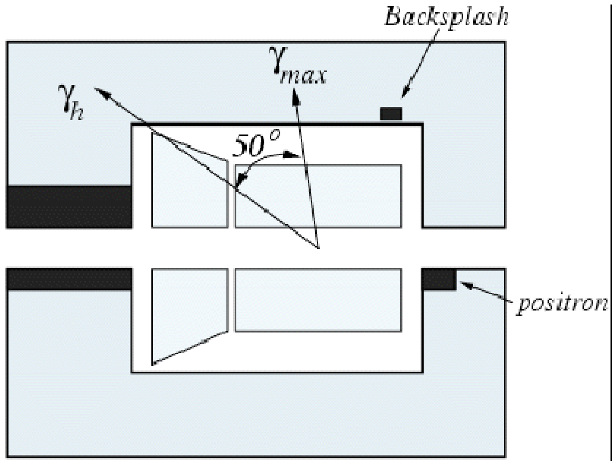
- Energy deposits far from the trajectory of the original particle
  - Backsplash (albedo effect) from the face of the CAL
  - Showering in dead material

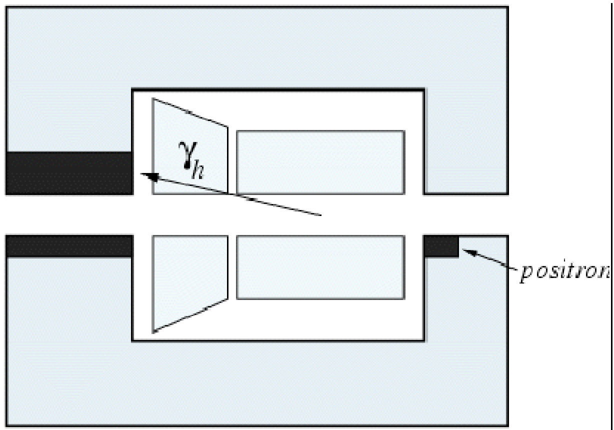
- In the ZEUS detector we see this effect for particles travelling in the forward direction

- Leads to a large bias in the reconstruction of the hadronic angle for forward hadronic energy

Backsplash

- Use MC to study these effects
- Remove low energy CAL deposits without a matched track >50° away from the hadronic angle
- Essentially unbiased reconstruction of hadronic angle in NC/CC DIS
- For high Q^2 events more complicated form to remove more as a function of angle

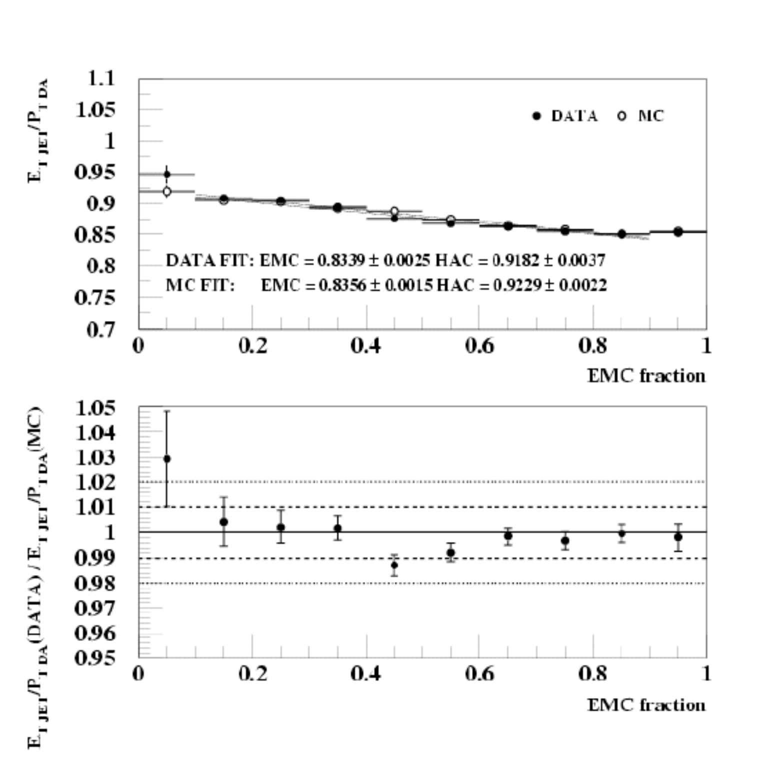


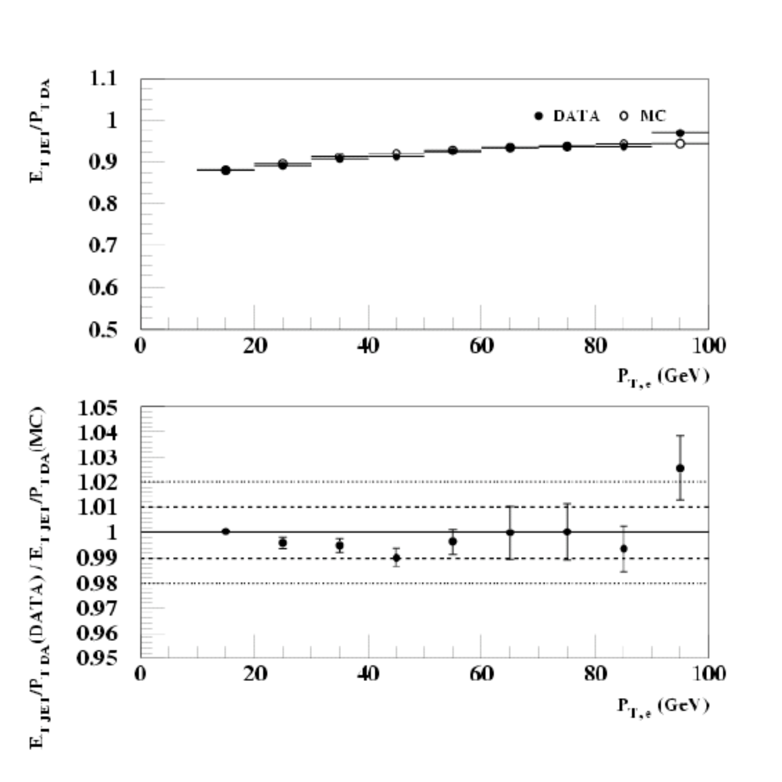


Inclusive Hadronic Final States

- Use NC DIS data to calibrate for hadronic $P_T > 10$ GeV
- Single jet NC DIS events
- Isolate jet in FCAL or BCAL
- Balance hadronic P_T with electron P_T and DA P_T (proton remnant P_T is negligible)
- Check agreement between data and MC in several variables
- Set systematic uncertainties

Inclusive Hadronic Final States





- Hadronic energy calibration in FCAL and BCAL ±1%

Inclusive Hadronic Final States

- Hadronic energy in RCAL is low
- Proton remnant P_T is not negligible
- Use events with large rapidity gap (diffractive)
- No proton remnant in CAL
- Unfortunately low statistics
- Agreement between data and MC ± 2%

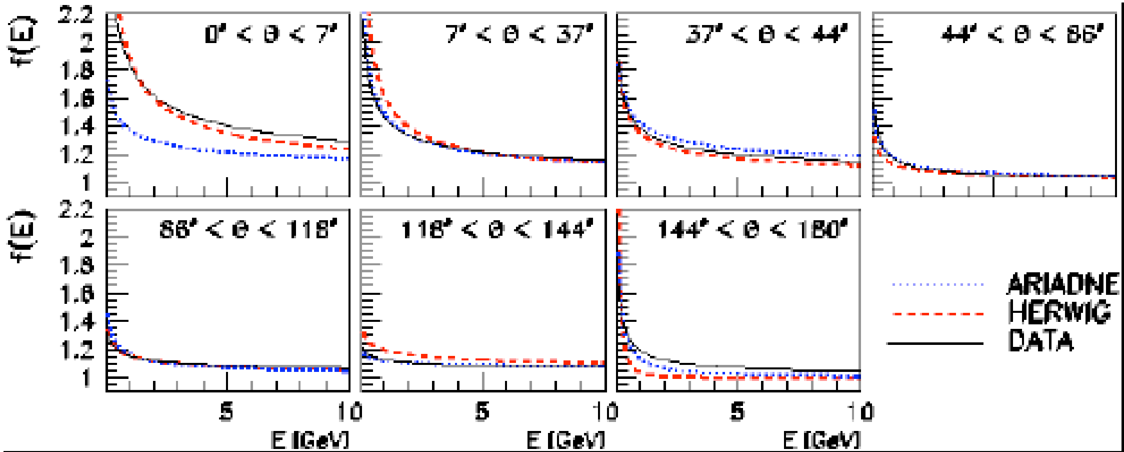
Jet Energy

- Method I
  - Use Energy Flow Objects
  - Derive dead material correction using NC DIS events
  - Apply to jets reconstructed from EFOs

- Method II
  - Use jets reconstructed from CAL cells
  - Derive dead material correction from MC and charged tracks in CTD
  - Balance jet in central region with jet outside tracking to give full detector correction

Jet Energy - Method I

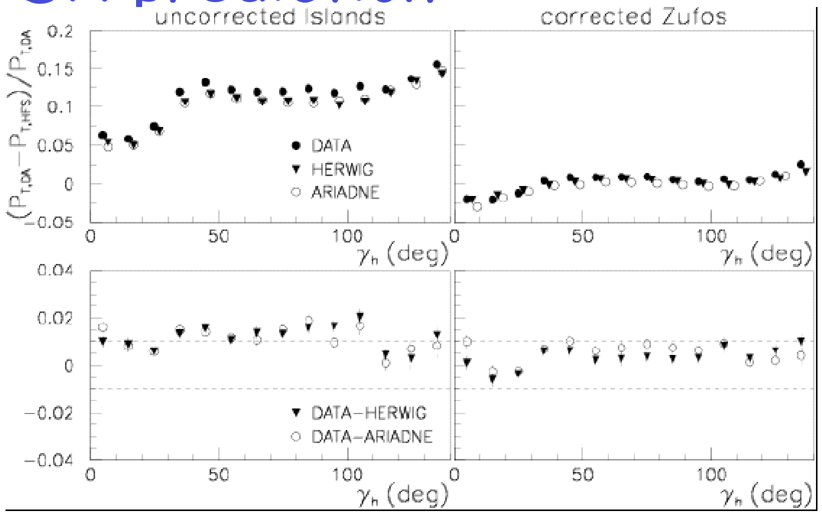
- Minimise difference between transverse momentum and longitudinal momentum of the hadronic system (using EFOs) and the DA prediction



- Set of optimised correction functions for energy loss in bins of polar angle
- Different corrections for data and MC

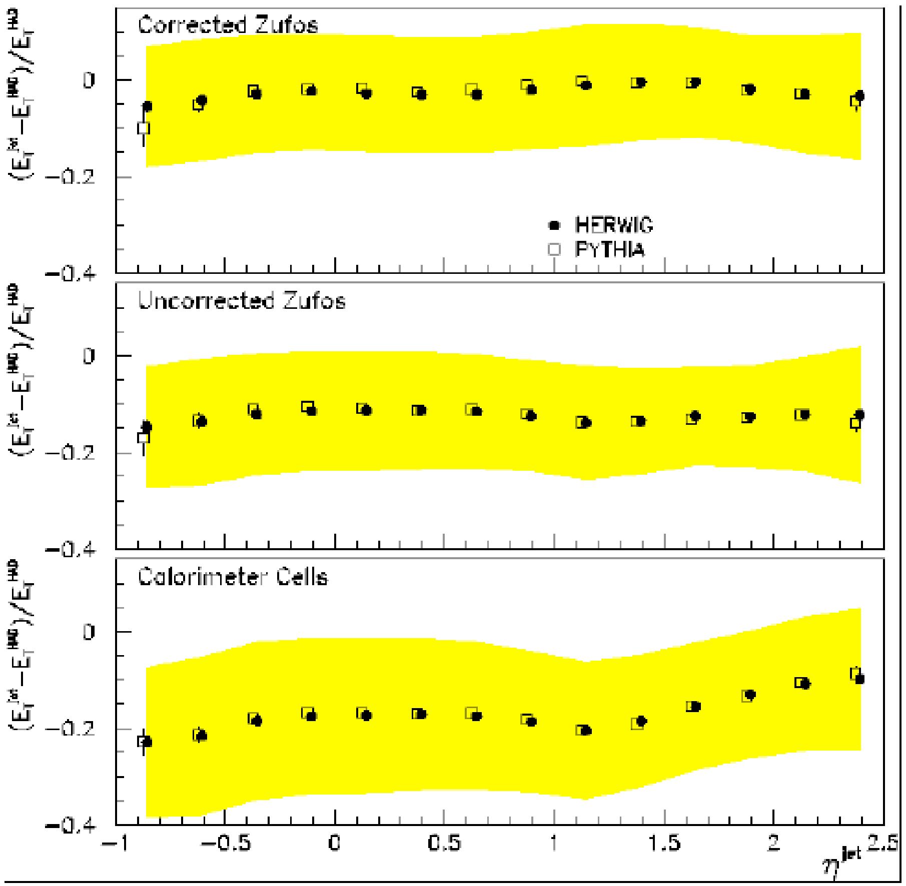
Jet Energy - Method I

- Check relative difference between corrected EFO P_T and DA prediction



- P_T well reconstructed using EFOs
- Data and MC differences within ±1%

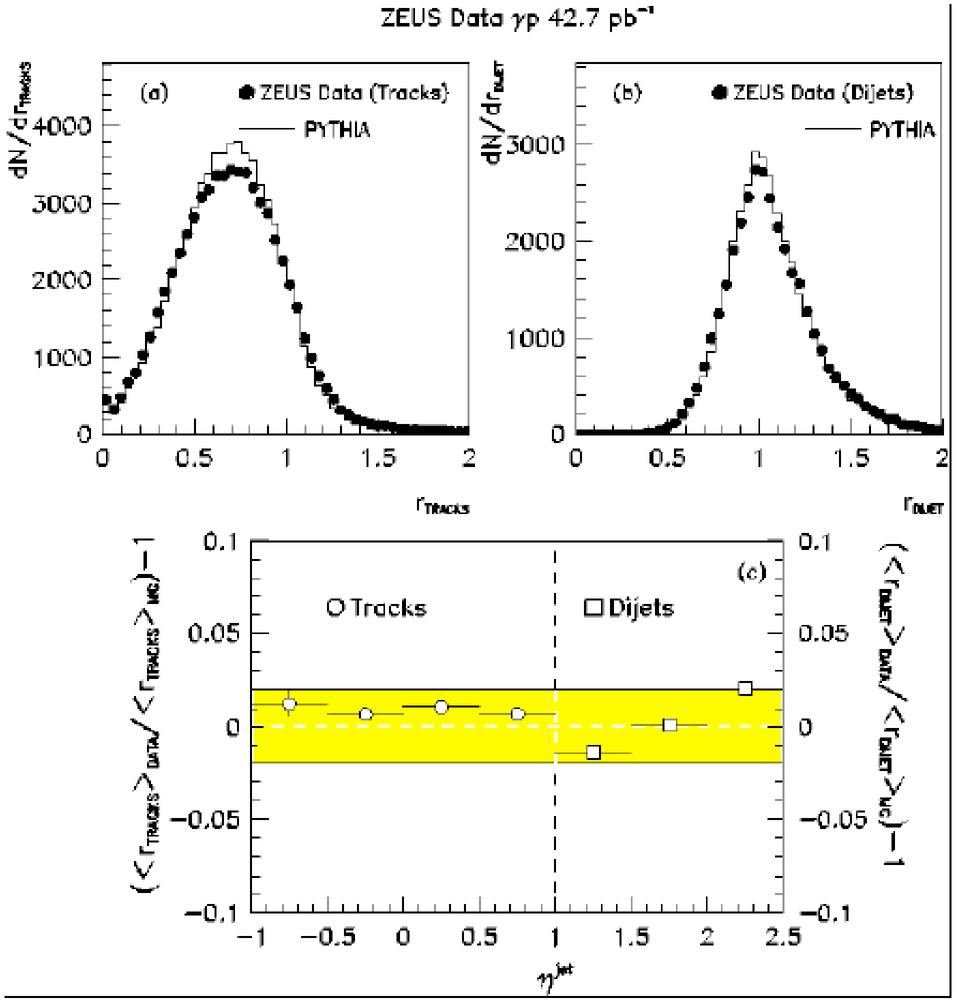
Jet Energy - Method I



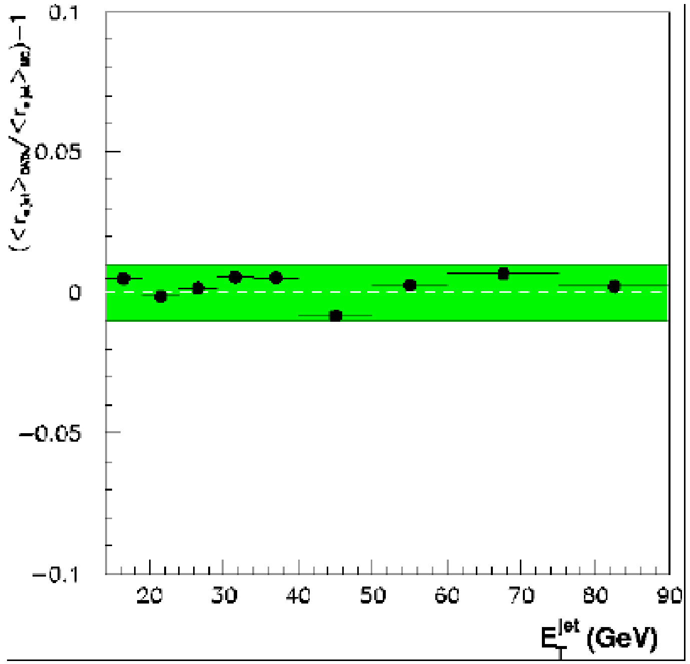
- Check how well the absolute values compare to MC truth
- Using independent PhP MC
- Clear improvement over no correction
- Absolute energy scale good to 2-3% over most of η range

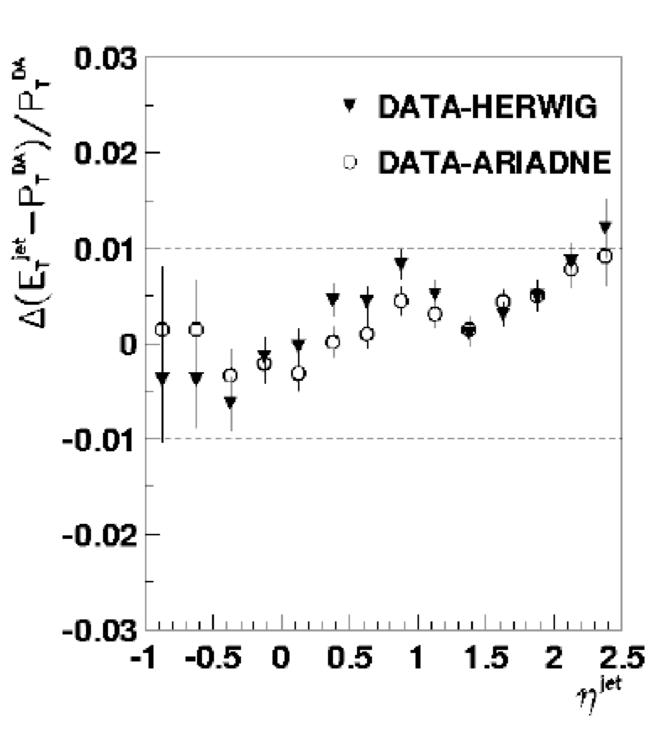
Jet Energy - Method II

- In barrel region compare E_T from CAL and charged tracks
- Use tracks to correct CAL E_T
- Balance corrected jet with other jet in forward region
- Relies on simulation of charged tracks
- Ratio shows correction is ~2%



Jet Energy





- Jet in NC DIS as function of E_T and η
- Jet energy scale uncertainty ±1%

Summary

- Clustering algorithm to remove effects of detector granularity
- Combine tracking and CAL information to form EFOs optimised for the best energy and position resolution
- Remove bias from backsplash

Summary

- Use EFOs and best knowledge of dead material to reconstruct hadronic final state
- Two independent corrections for jet events
- Energy scale uncertainty ±1% (±2% in RCAL)
- Reduced systematic uncertainty in physics results