Jet Resolution Improvement Techniques

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D0

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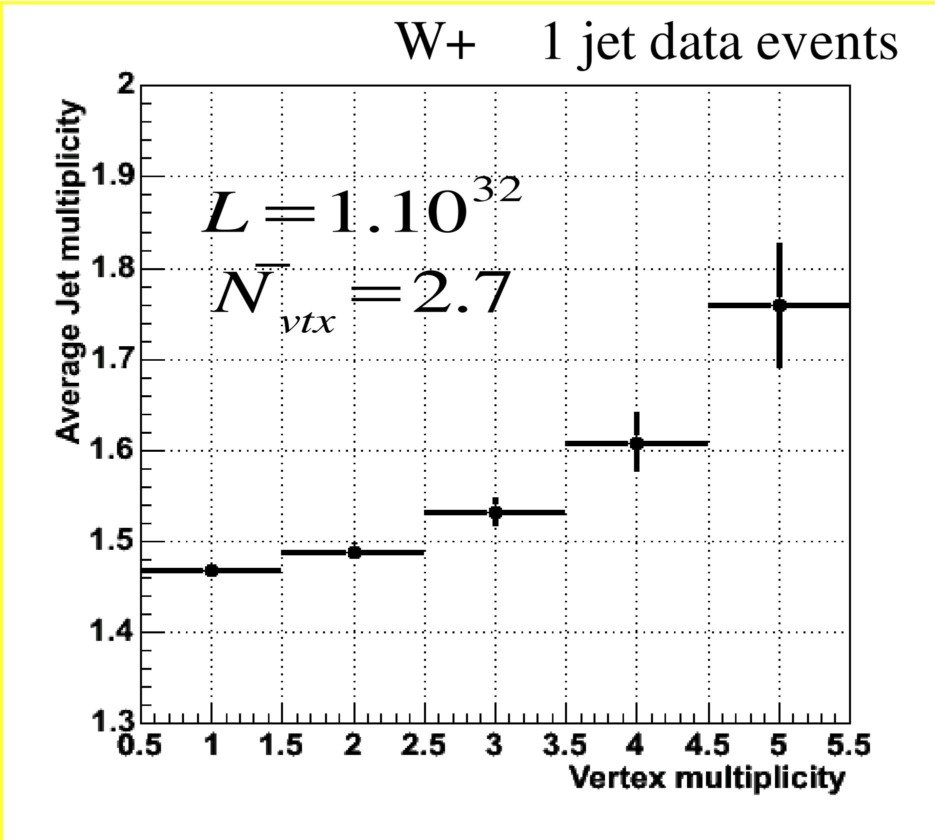
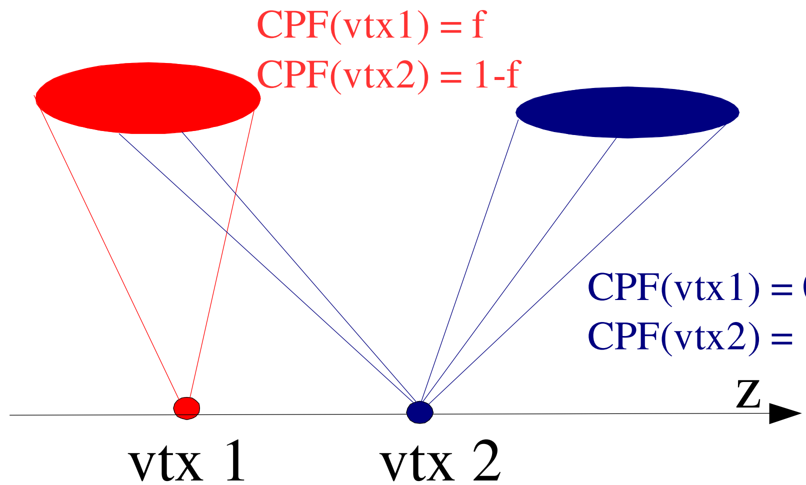
Outline

- Jet reconstruction at high luminosity:
  - Algorithm for calorimeter jet and vertex association.

- Improving jet energy resolution using tracks:
  - TrackCalJet algorithm overview.
  - Studies in simulated events:
    - Zbb mass resolution.
  - Studies in photon + jet data events:
    - jet energy resolution and response.

Jet Multiplicity at High Luminosity





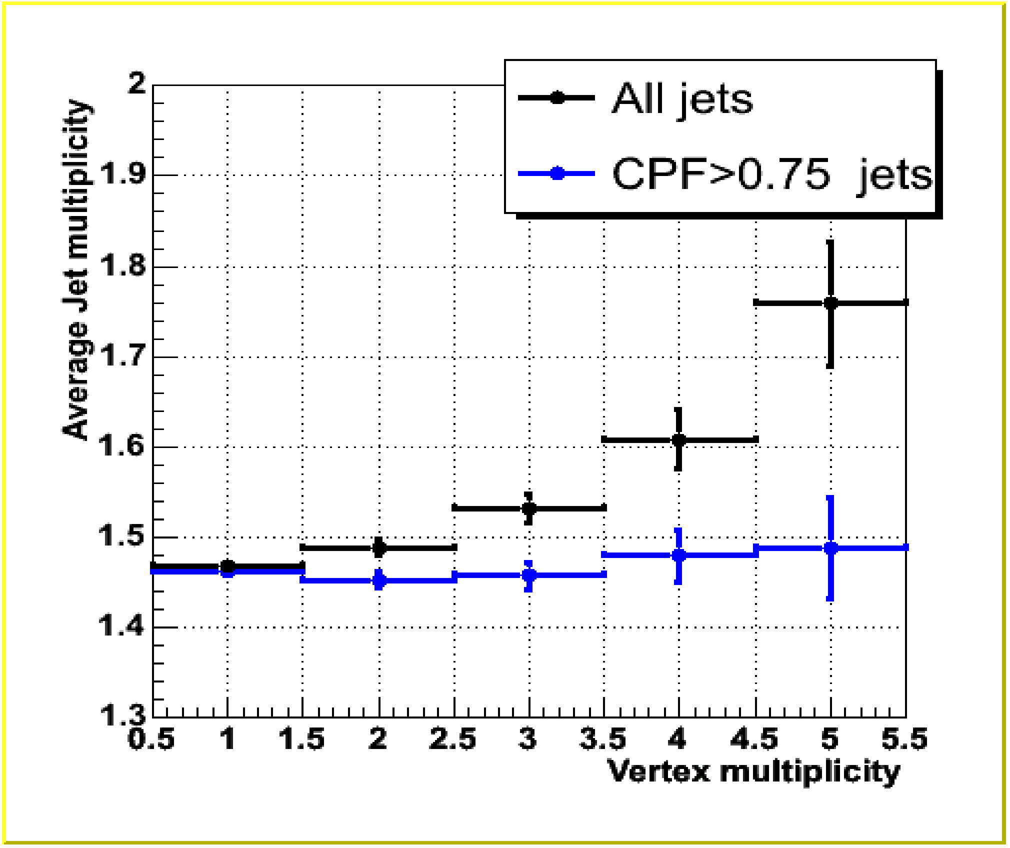
Goal: Associate Jets to Vertices.

$$CPF(jet) = \sum p_T^{track}(jet, vtx) / \sum_i p_T^{track}(jet, vtx_i)$$

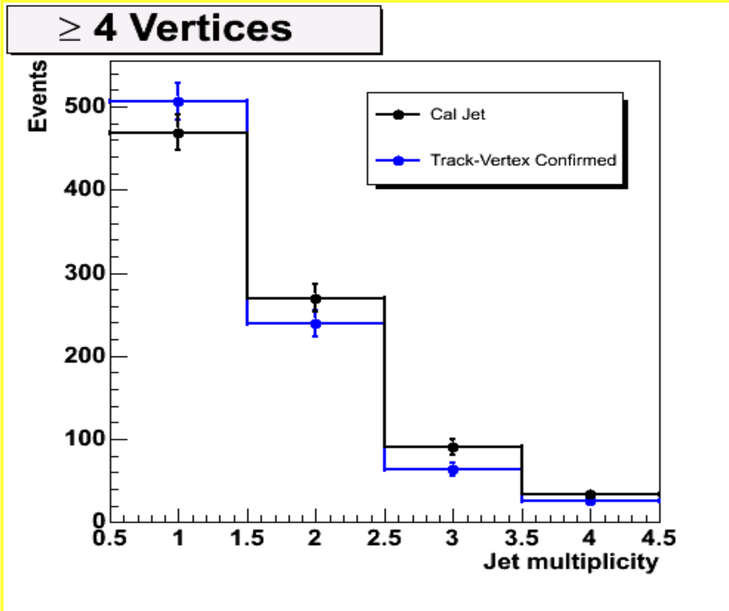
- At DZero, the beam spot has a width of 25cm in Z.
- Average jet multiplicity increases with number of primary vertices.
- Jet kinematics is distorted at low pT (extra low-pT jets)

→ this effect will be much more important at the LHC.

Jet Multiplicity vs. Number of Vertices



The dependence of jet multiplicity on the number of interactions is significantly reduced for jets with more than 75% of its energy coming from the hard scatter vertex.



Jet-Vertex algorithm allows to identify (remove) soft jets arising from min-bias interactions.

Improving Jet Energy Resolution Using Tracks (I)

Cal-Jet energy resolution has three (four) main contributions:

- Electronics noise term ~1/E
- Stochastic response ~1/sqrt(E)
- Constant term
  - non-uniformity of calibrations
  - non-linearity, magnetic field effects
- Absolute energy scale (denominator in sigma/E)

Addressed by Tracks

Idea:
- Reconstruct calorimeter-based jets (R=0.5)
- Use track momentum measurements to set an accurate scale for hadron response for *each* hadron in the jet.

CMS JetPlusTrack Algorithm

The Tevatron is an excellent opportunity to understand and optimize this technique on real collider data.

Improving Jet Energy Resolution Using Tracks (II)

Cal-Jets:

$$Resolution = \frac{k\,\sigma(E_{cal})}{k\,E_{cal}}$$

Normally Jet Energy Scale *(k)* does not affect resolution.

k does not take into account the non-linear response of individual particles in jets.

TrackCalJets:

Do not rescale the raw calorimeter energy measurement.
Replace contributions to *k* from charged hadrons by the tracker momentum scale:

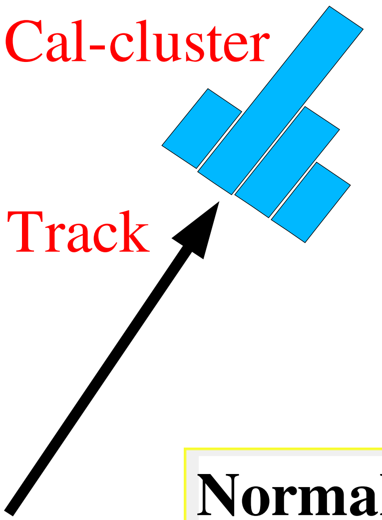
$$Resolution = \frac{\sigma(E_{cal}) \oplus \sigma(p_{trk})}{E^{trk}_{cal}}$$

Small contribution cal-JES still needed

Measured with Tracks

$$E^{trk}_{cal} = E(e/\gamma) + E(neutral\quad hadrons) + E(charged\quad hadrons)$$

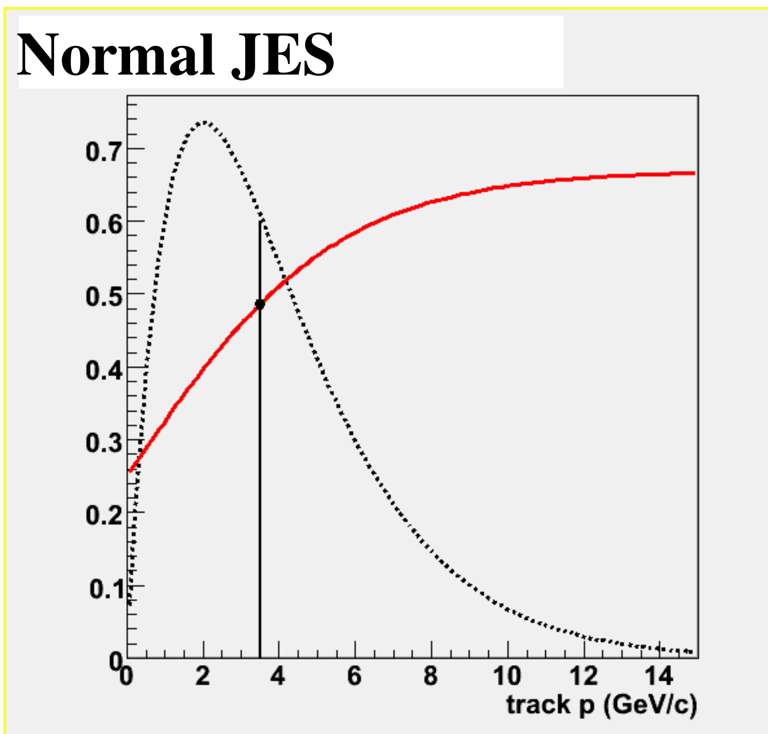
Why Does it Work?

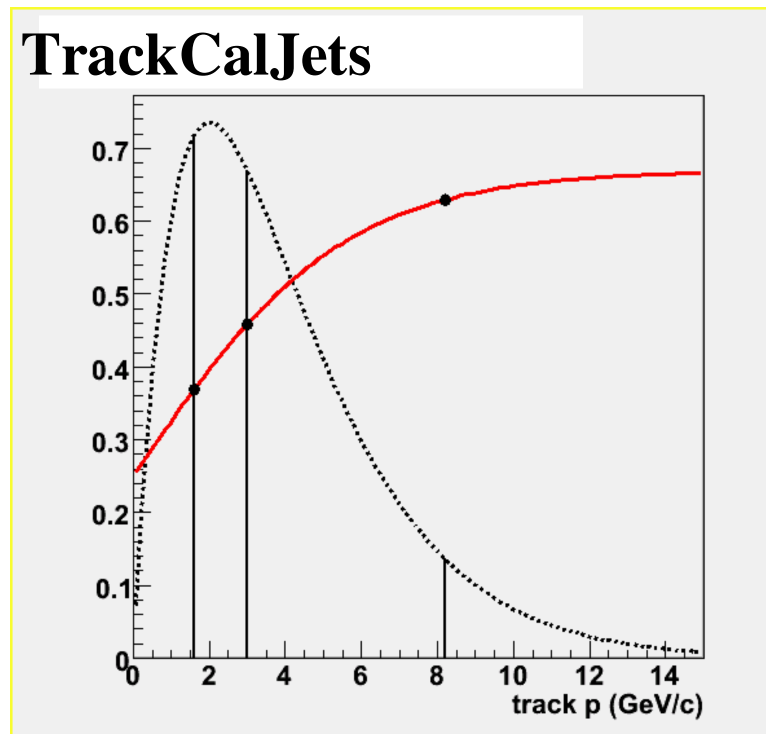


$$E_{cal}^{trk} = E(e/\gamma) + E(neutral\quad hadrons) + E(tracks) - E(cal)_{tracks}^{expected}$$

Normal JES: Average non-linear response assuming particle multiplicity and momentum spectrum

TrackCalJets: Sum individual contributions using the tracks of *each* jet.





TrackCalJet Algorithm Overview

Propagate tracks to the calorimeter surface.

dca(xy) < 0.5cm, dca(z) < 1.0 cm.

Classify tracks:

R(vtx)<0.5, R(cal)<0.5 : IN jet

R(vtx)<0.5, R(cal)>0.5 : Out-of-cone

For each IN-jet track:

$$E_{trkjet} = E_{caljet} + \left(1 - Ecal_{track}^{expected}\right) E_{track}$$

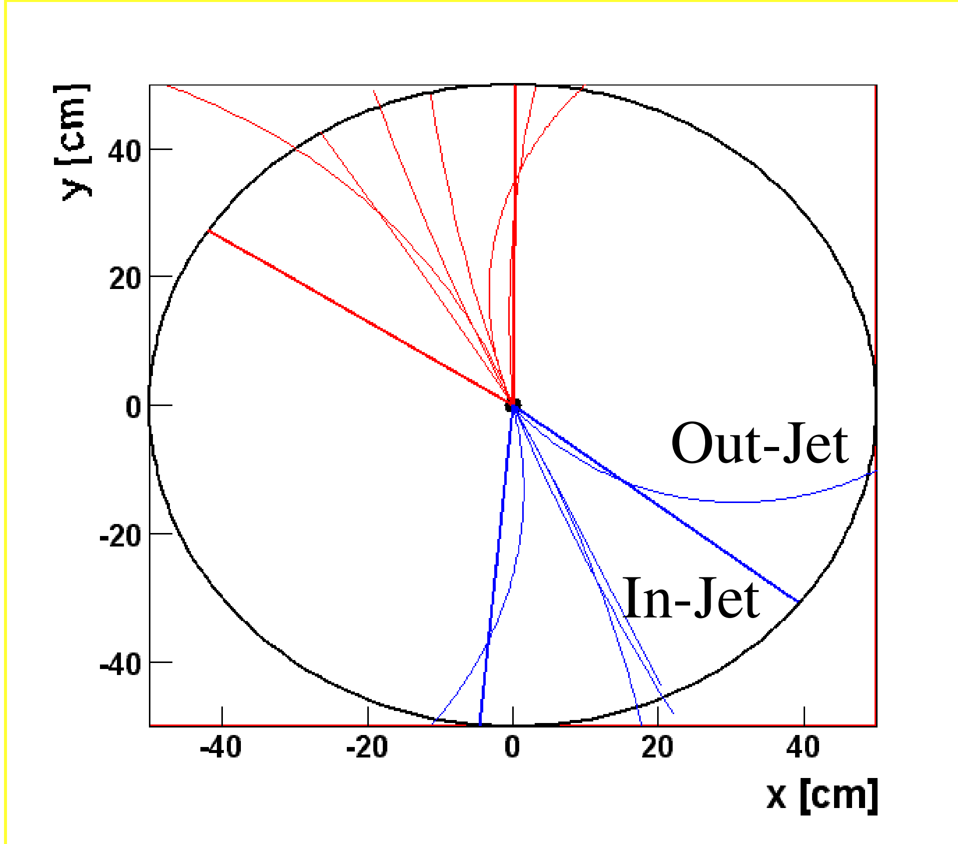
For each Out-of-cone track:

$$E_{jet} = E_{trackjet} + E_{track}$$

where:

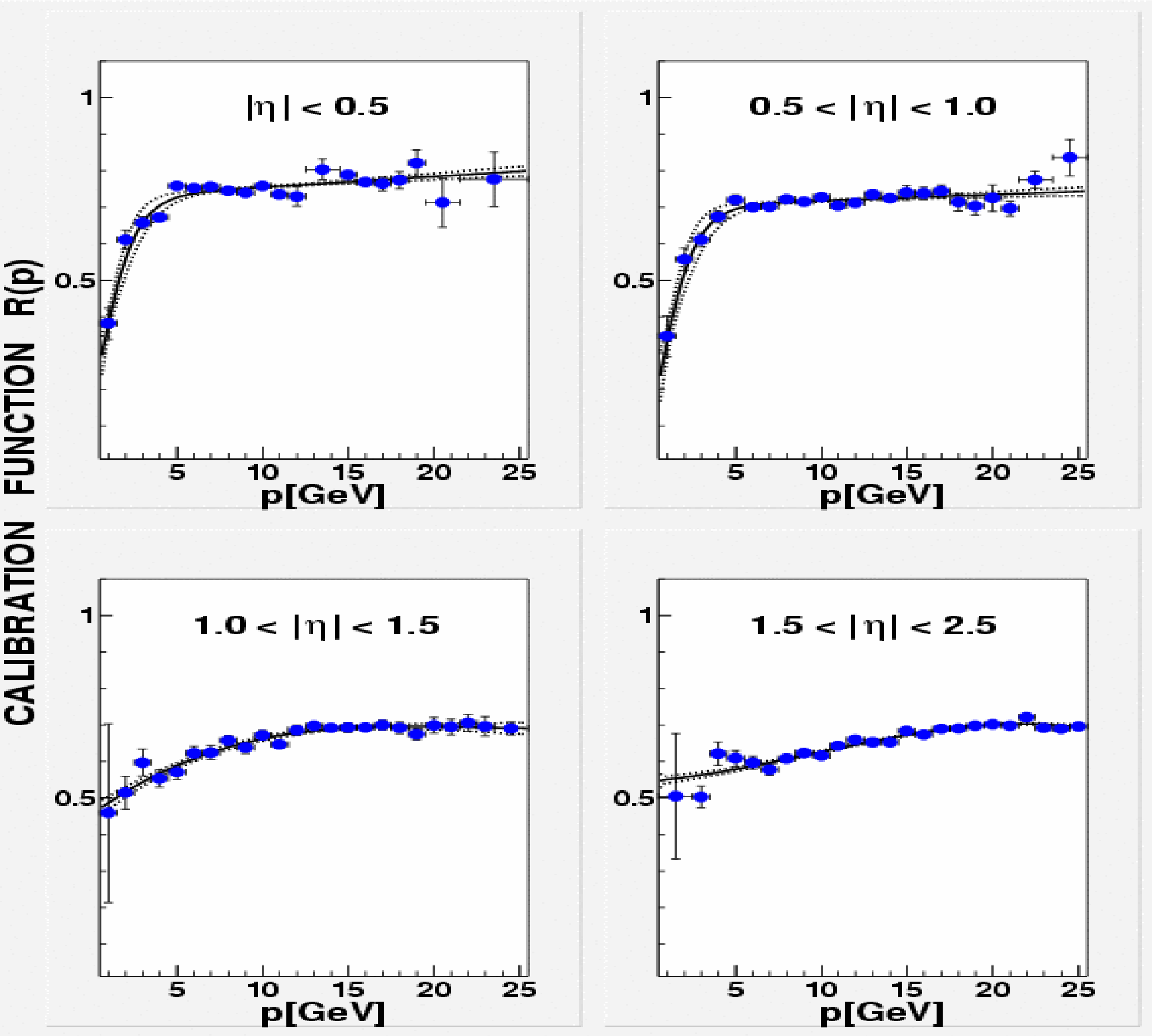
$$Ecal_{track}^{expected} = R^{cal}\left(E_{track}\right) = E^{cal} / E^{track}$$

is the single pion *average* calorimeter response.



CMS JetPlusTrack Algorithm

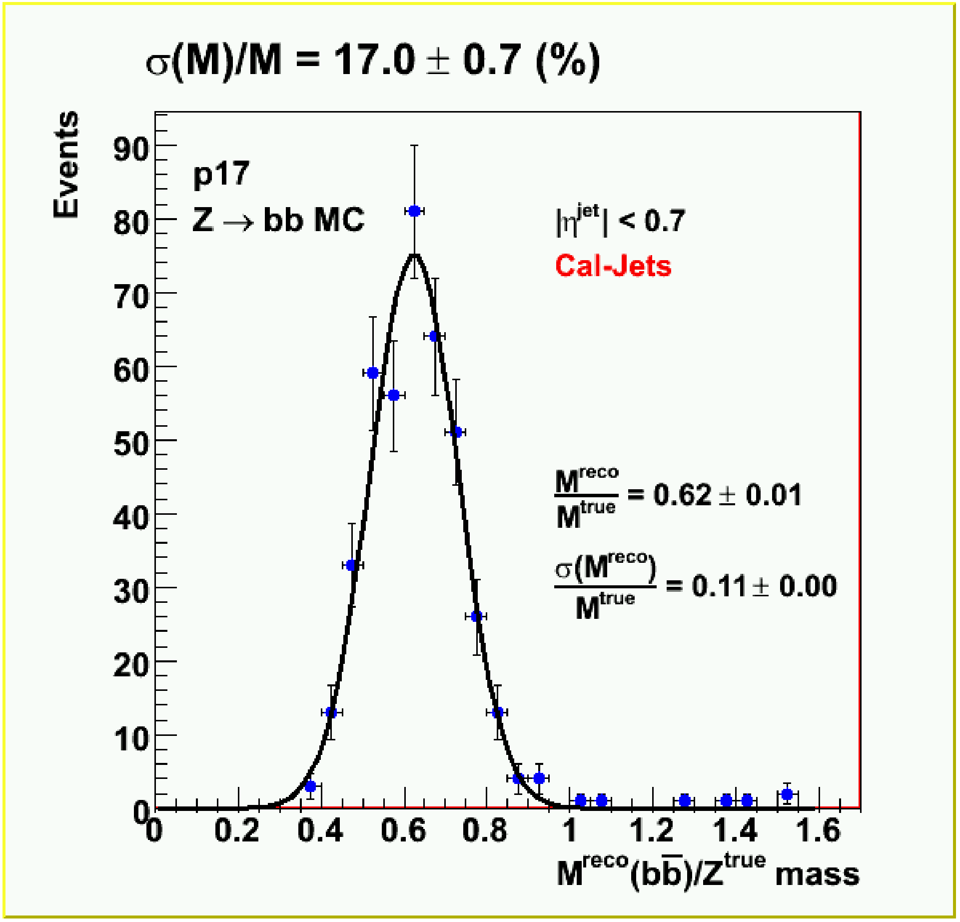
Single Pion Response in the Simulation

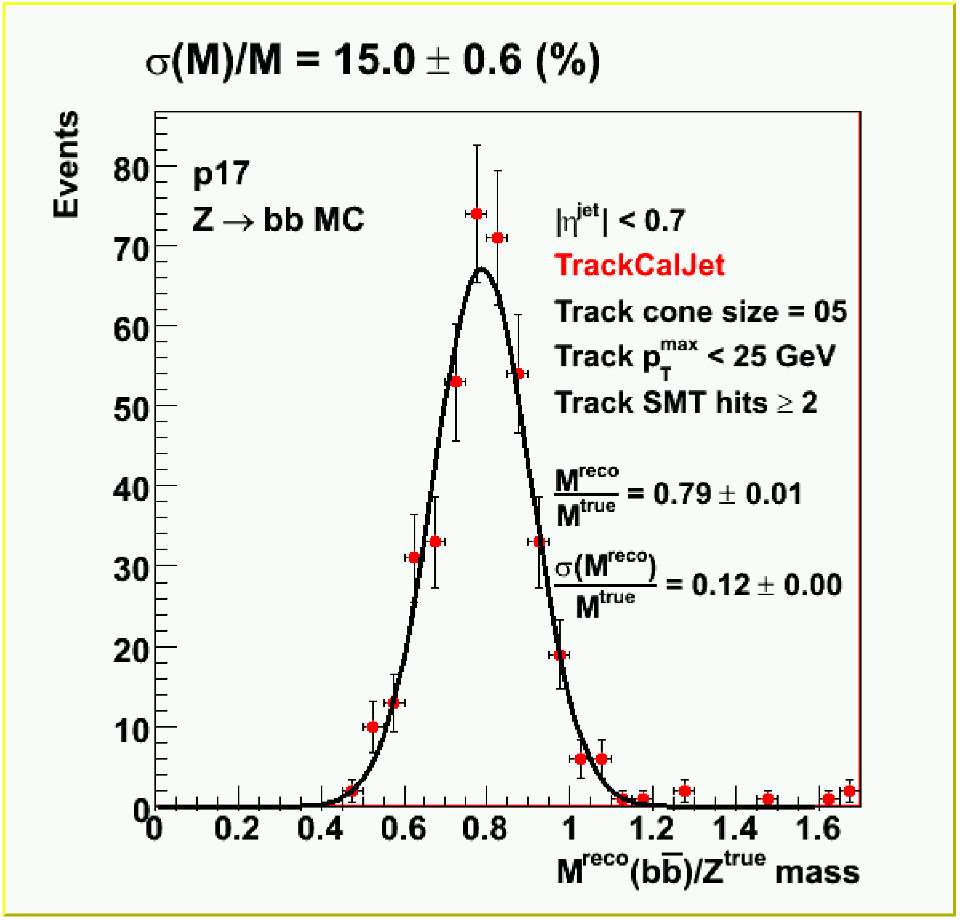


Single particle response measured in single pion Monte Carlo.

Currently studying minimum-bias data, and developing a dedicated trigger for high energy pions.

Zbb Mass Resolution in the Simulation

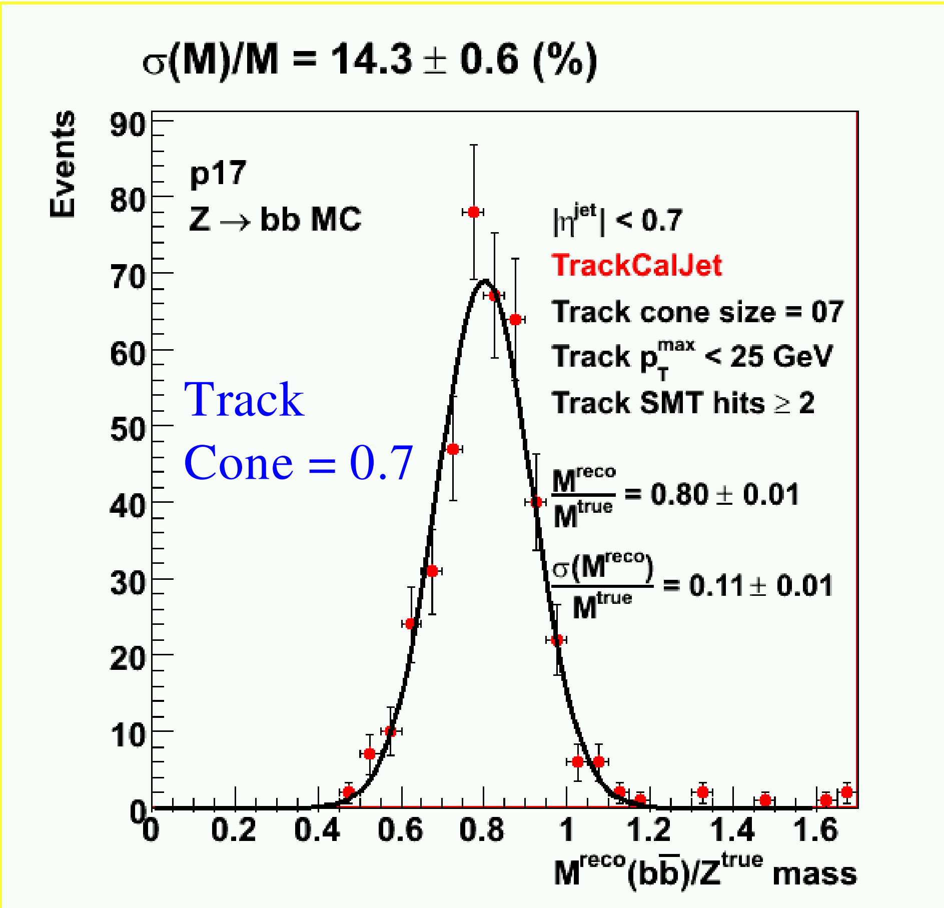


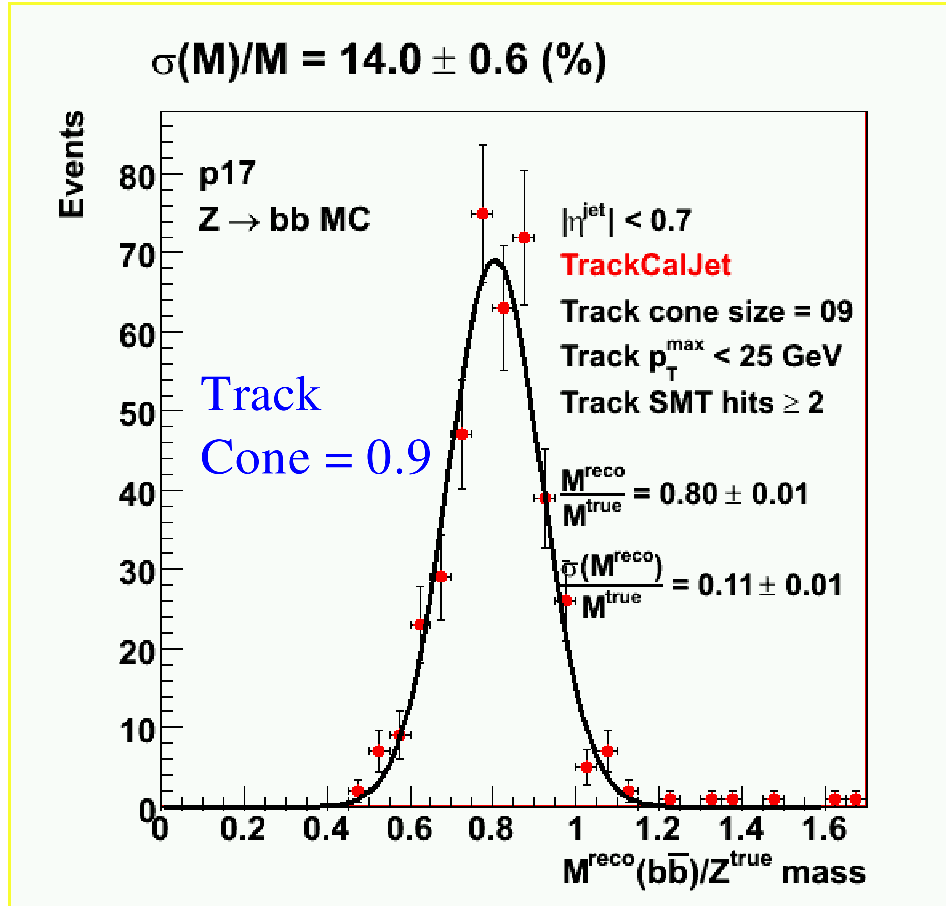


Response is significantly improved with the use of tracks.

12% Improvement on mass resolution.

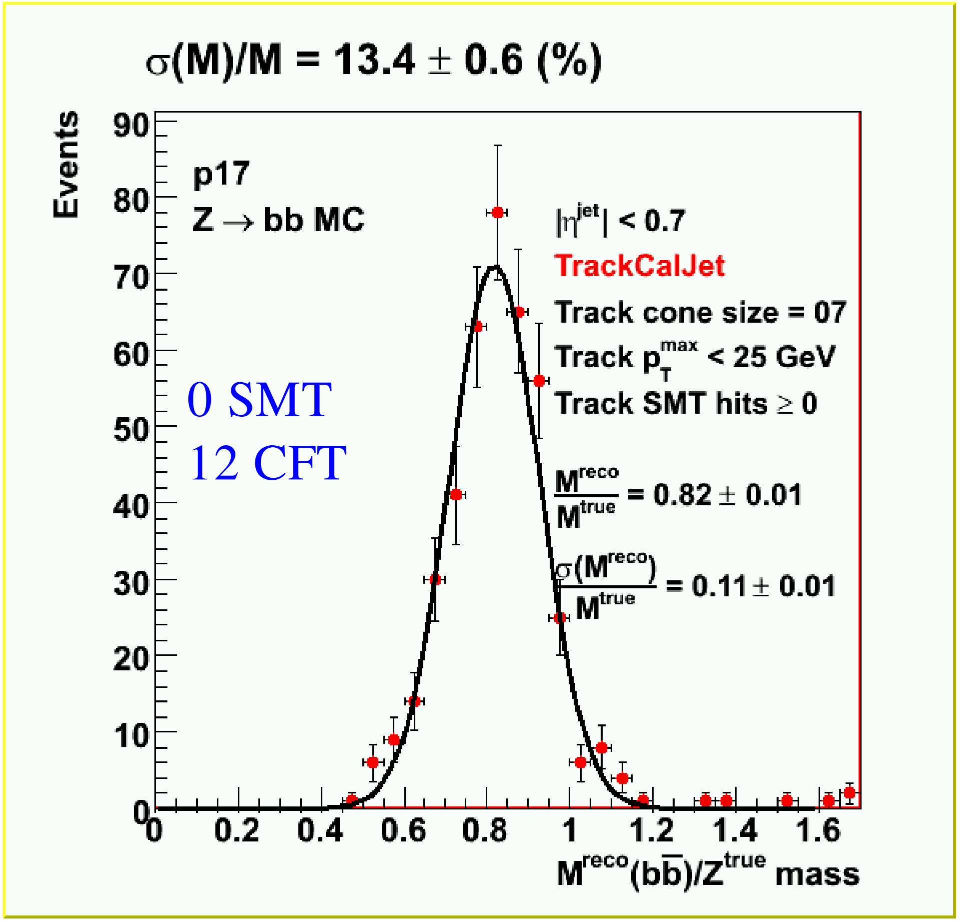
TrackCalJet Algorithm Optimization: Track Cone Size

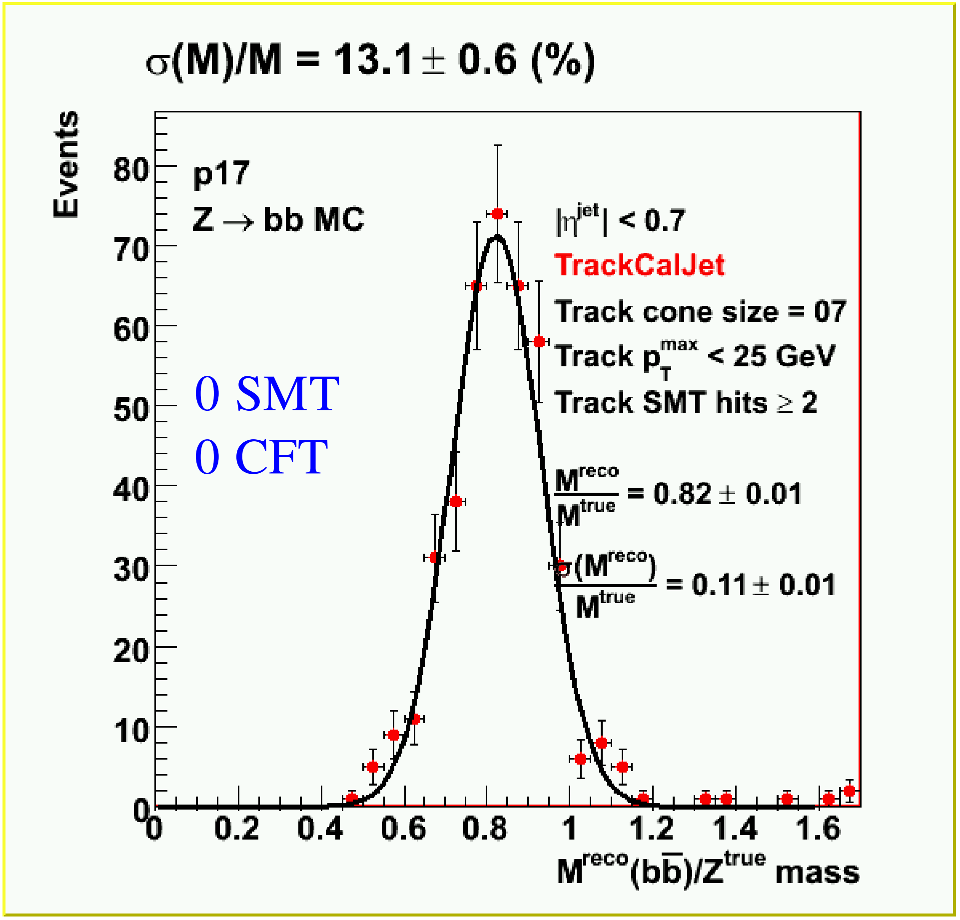




17% Improvement on Zbb mass resolution by using a larger cone size for tracks: Important for Higgs searches, in 2-jet events.

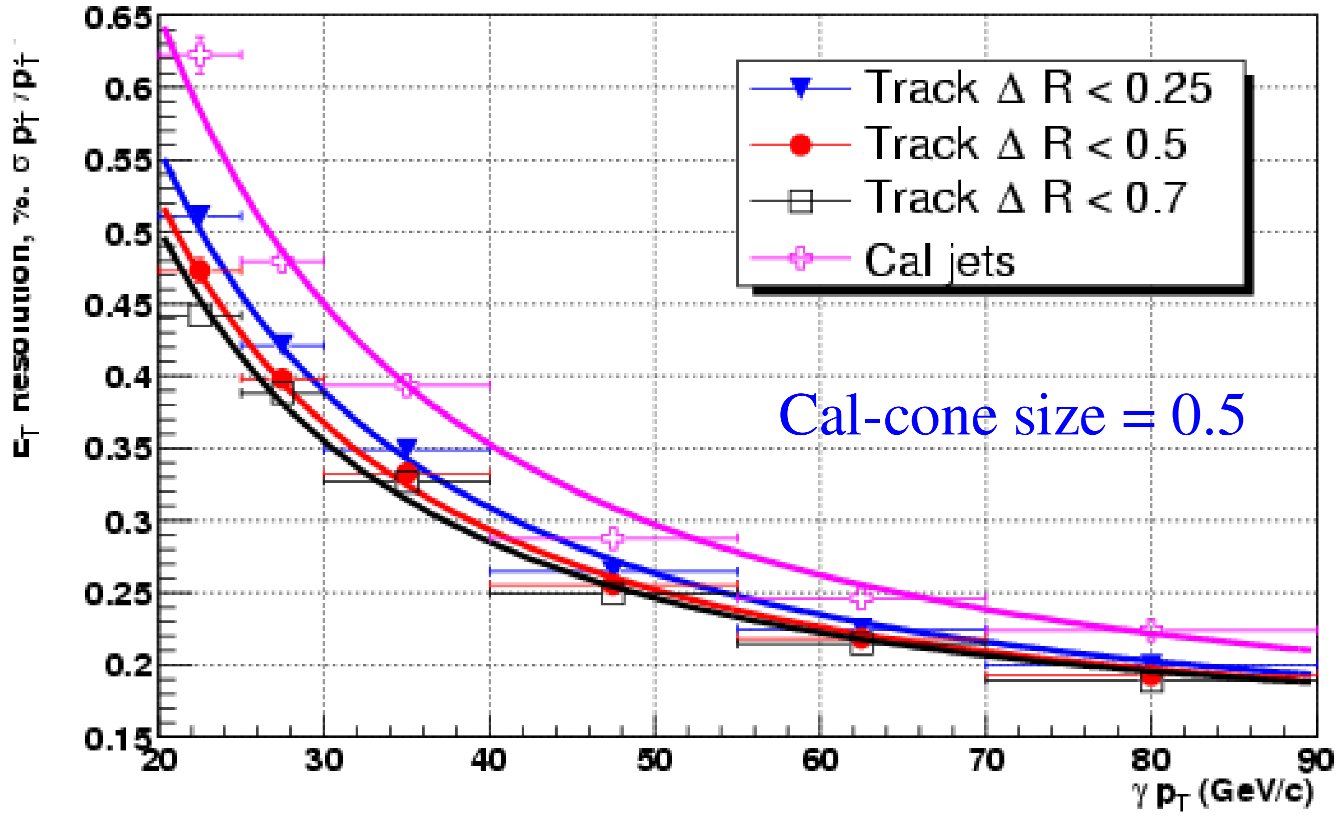
TrackCalJet Algorithm Optimization: Track Quality: SMT/CFT hits





20% Improvement on Zbb mass resolution by using all tracks in the jet: Need to be re-optimized in the data.

Jet Resolution in photon + jet Data

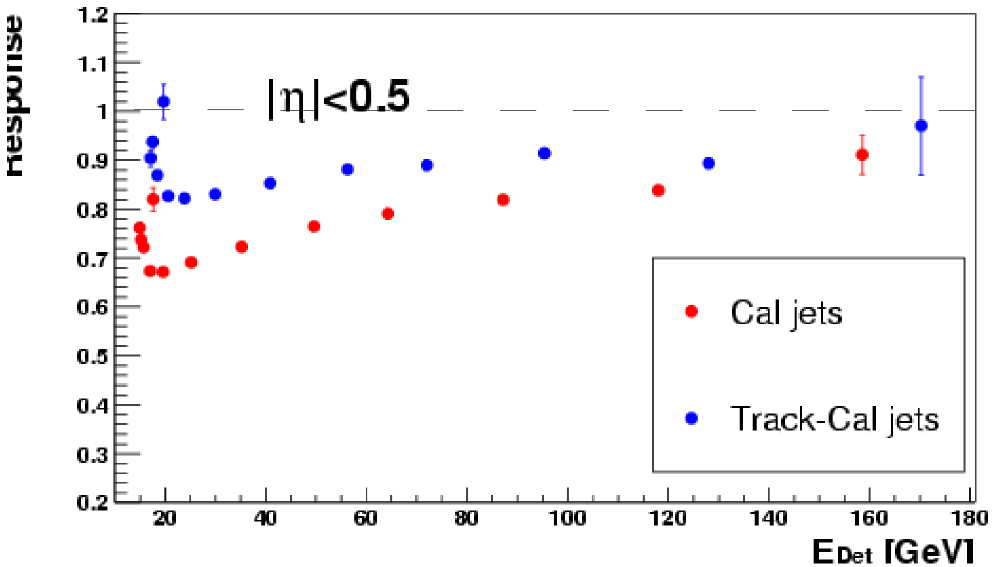


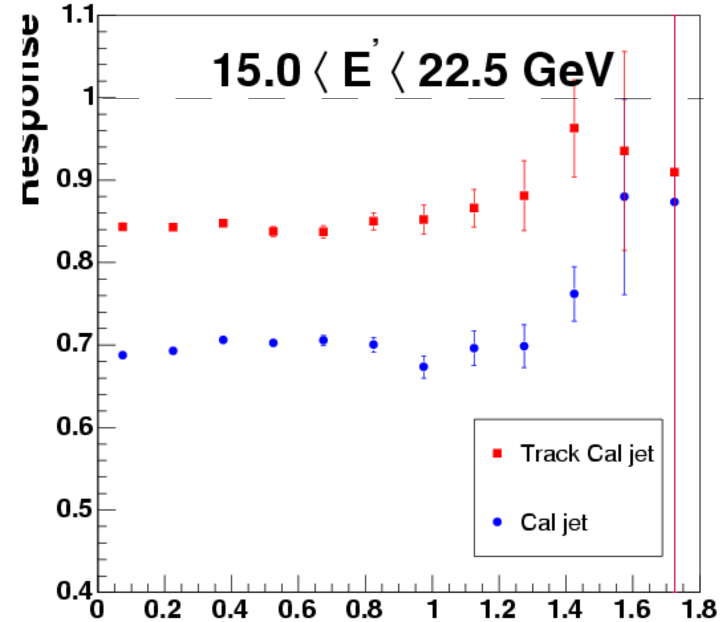
10-20% Resolution improvement in data at 40 GeV.

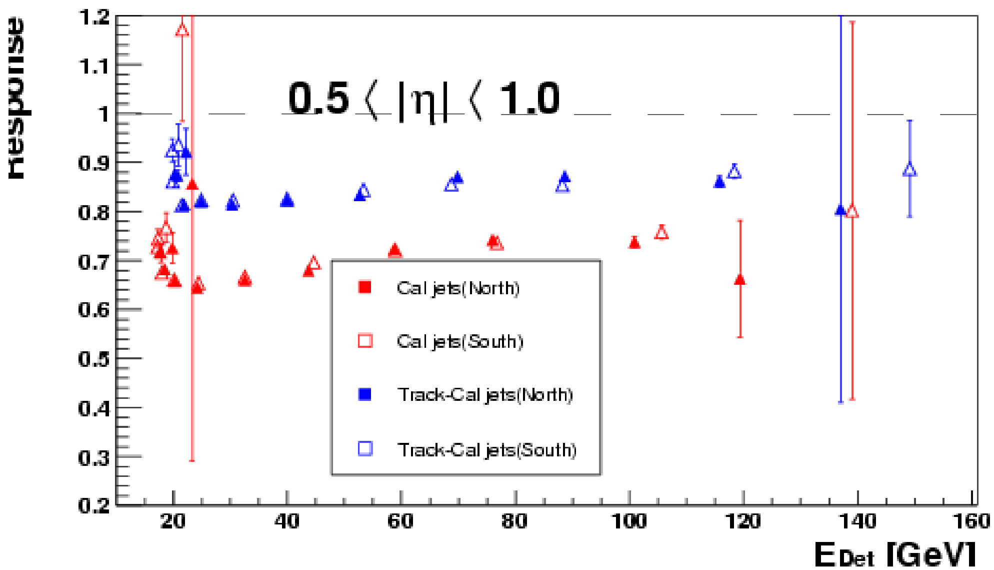
Higher improvement at lower jet energies.

Jet resolution improves by using larger track-cone sizes.

TrackCalJet Energy Scale: Response (I)



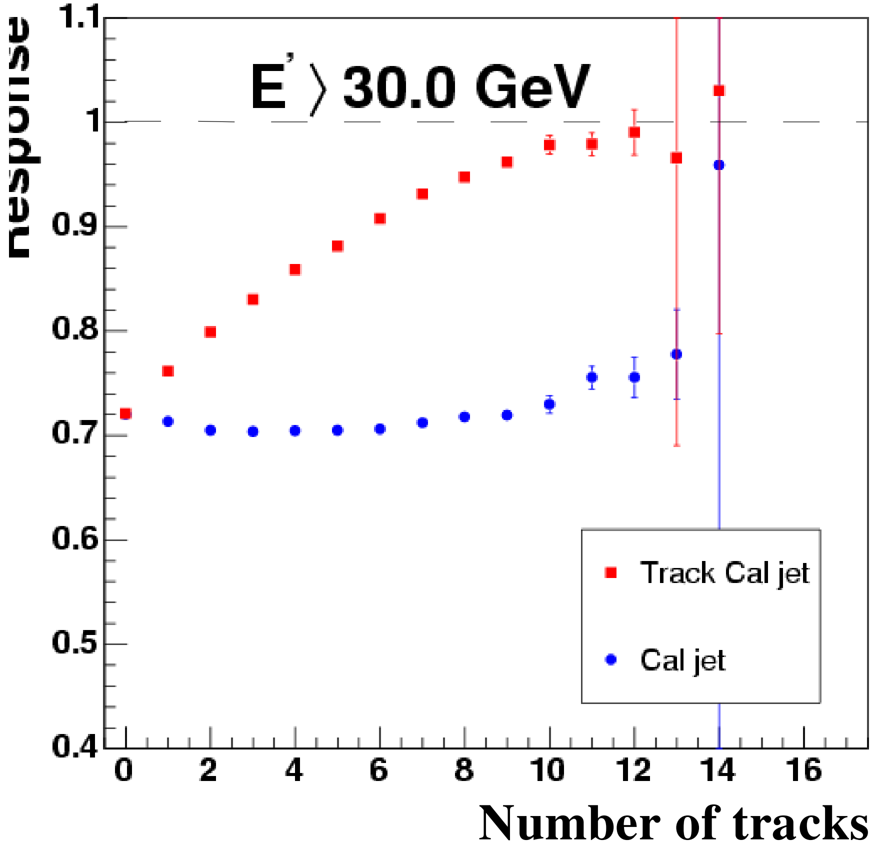




Response measured in photon +jet data.

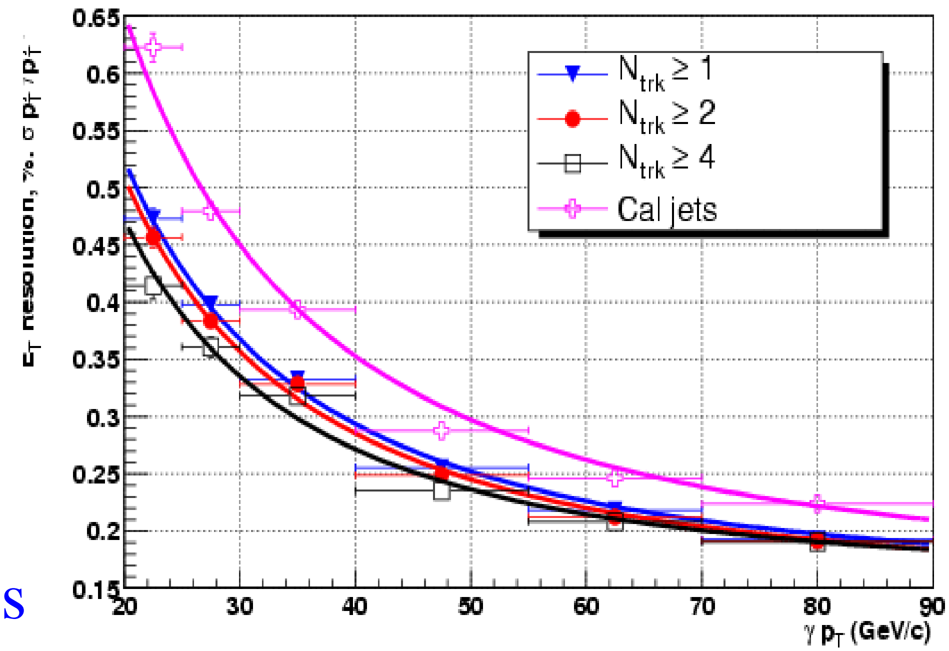
Tracking acceptance: |eta|<1.5

TrackCalJet Energy Scale: Response (II)



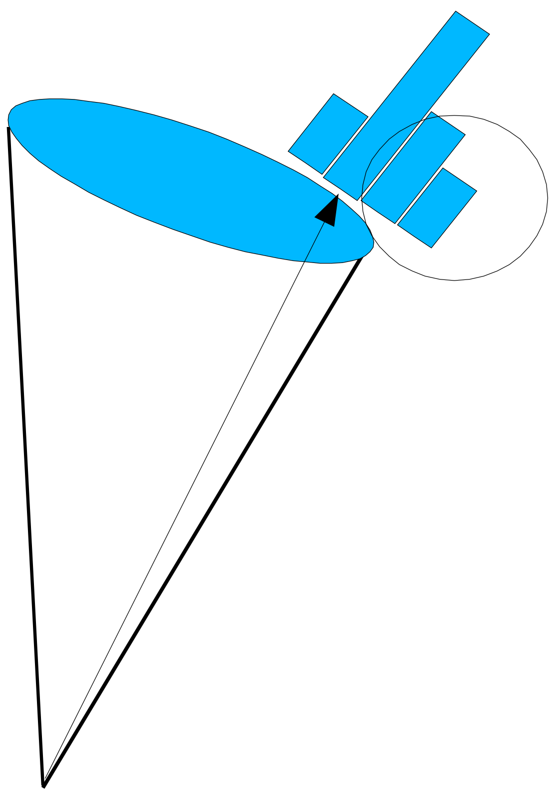
TrackCalJet Response is derived as a function of jet p_T and track multiplicity.

Jets which have large charged content get larger track correction.



Jet resolution also improves as a function of number of tracks.

TrackCalJet Future Improvements (I)
Showering Correction



Tracks close to the boundary of the jet, will not deposit all their energy inside the calorimeter cone.

Current TrackCalJet version assumes all pion energy is contained in the jet, i.e. it is over-subtracting energy:

$$E_{trkjet} = E_{caljet} + \left(1 - Ecal_{track}^{expected}\right) E_{track}$$

Next version of the algorithm will consider this effect introducing a showering correction:

$$E_{trkjet} = E_{caljet} + \left[1 - f\left(\Delta R_{(trk,\,jet)}\right) Ecal_{track}^{expected}\right] E_{track}$$

Expect improvement on both response and resolution.

Summary and Conclusions

Jet reconstruction at high luminosity:

- Additional min-bias interactions produce extra soft jets.
- Jet-Vertex association algorithm allows to discriminate between jets arising from the hard scatter vertex and additional minimum bias interactions: Improves jet momentum.

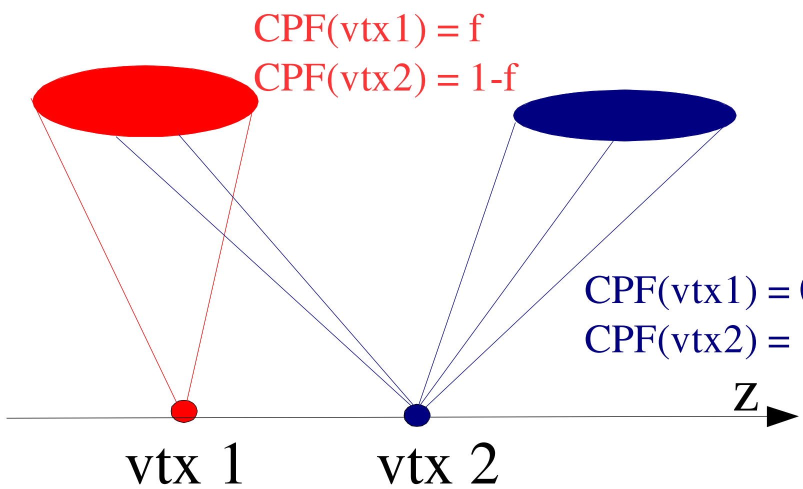
Improving jet energy resolution using tracks:

- CMS technique for combining tracks and vertices has been implemented at DZero.
- 10-20% jet resolution improvement in photon+jet data and MC.
- Increasing the track-cone size further improves the jet resolution.

- Currently finalizing jet energy scale. Expect to use this algorithm for DZero 2006 physics results.

Backup slides

Jet-Vertex Identification



Goal: Associate Cal-Jets to Vertices.

<u>Algorithm:</u>

- Select tracks matched to vertices and jets:

  $\Delta Z(trk_j, vtx_i) < 1.0cm$, $\Delta R(trk_j, jet_i) < 0.5$

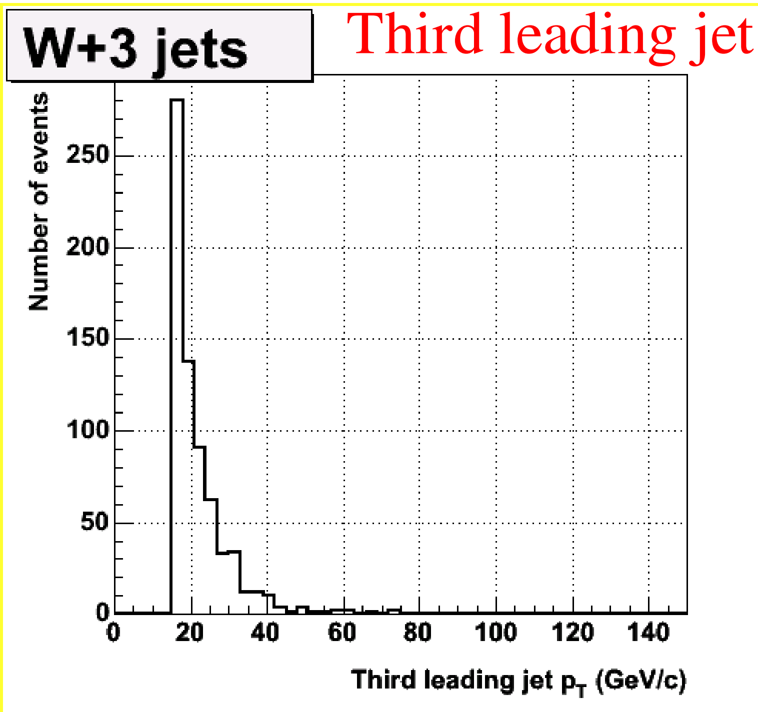
- For each jet, calculate the fraction of track energy associated to each vertex:

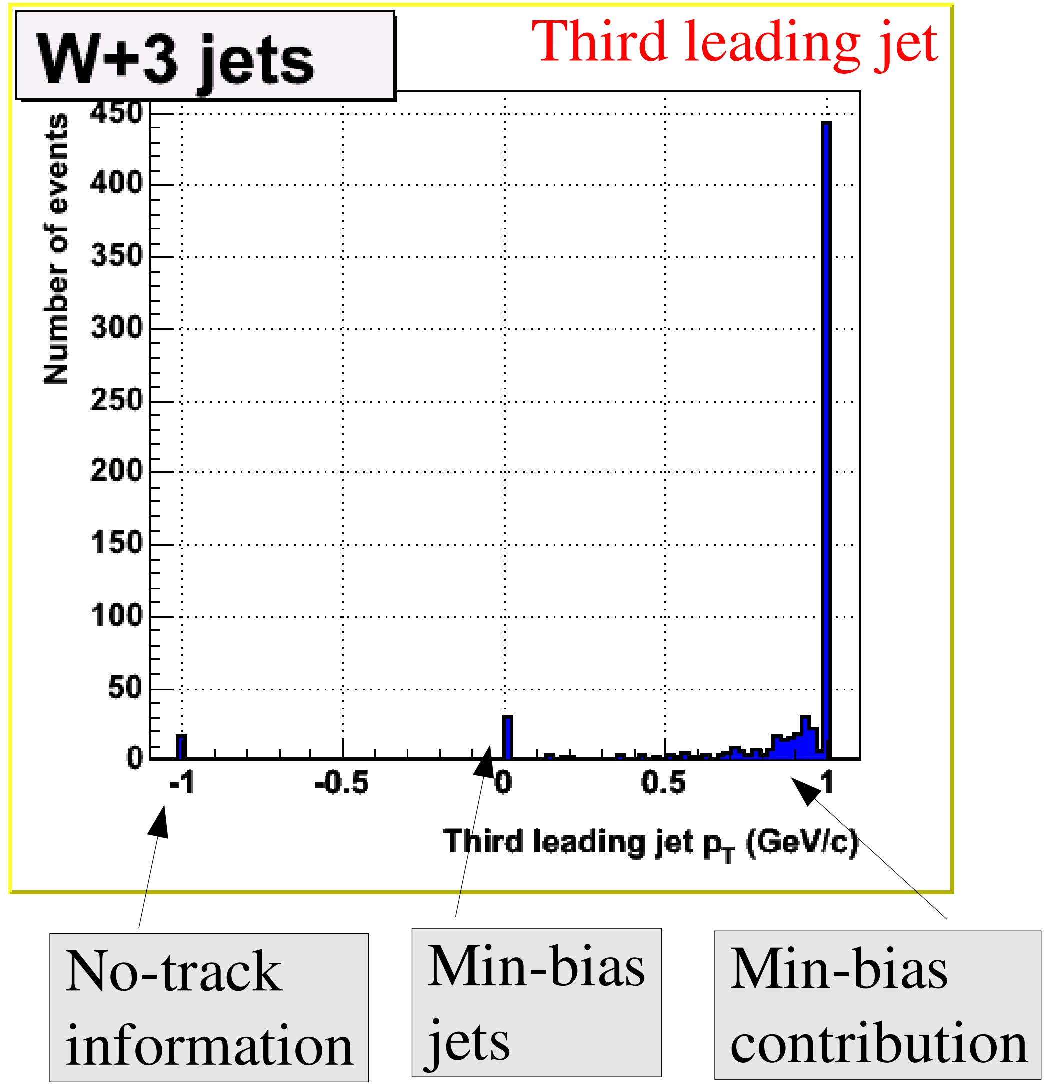
$$CPF(jet_j, vtx_i) = \sum_{trk} p_T^{track}(jet_j, vtx_i) / \sum_i \sum_{trk} p_T^{track}(jet_j, vtx_i)$$

  associate *jet j* to the vertex *i* for which $CPF(jet_j, vtx_i)$ is maximum.

CPF is the charged particle energy fraction of jet *j* from vertex *i*.

CPF in W+3 jet Events





The 3rd leading jet is more likely to be associated to a min-bias interaction.