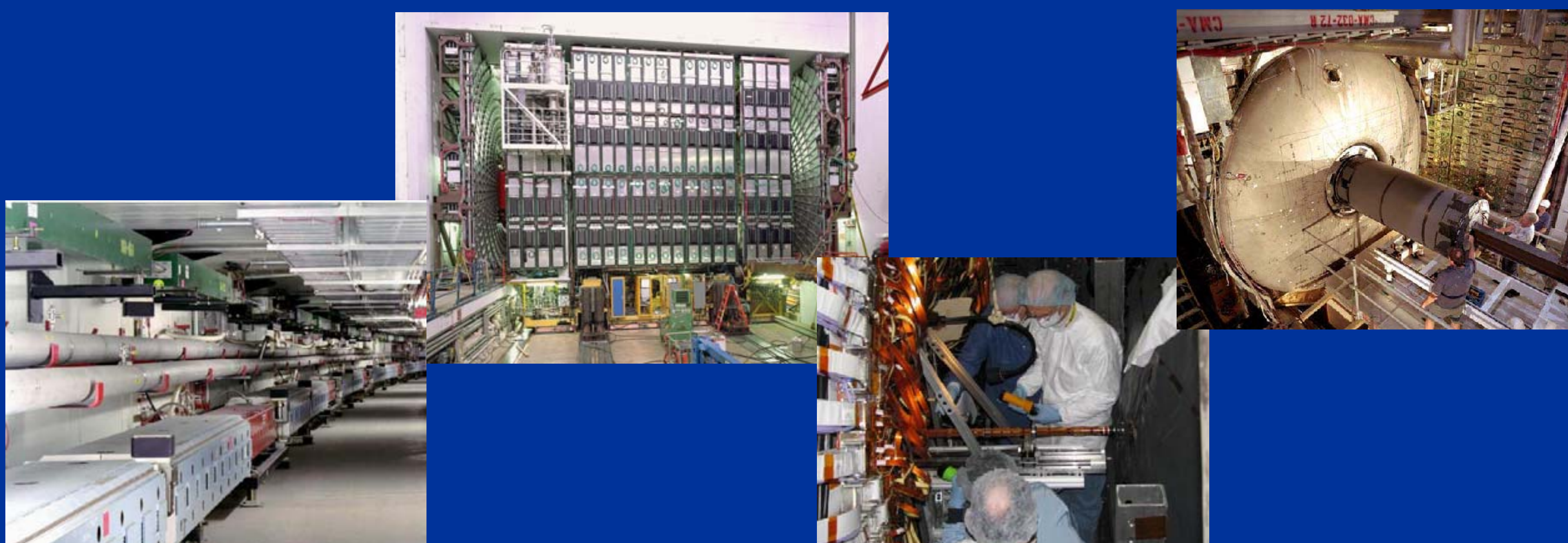
Pheno 06 Symposium, Madison

Studies of the D0 Calorimeter Response Using Isolated Charged Hadrons



Petra Haefner

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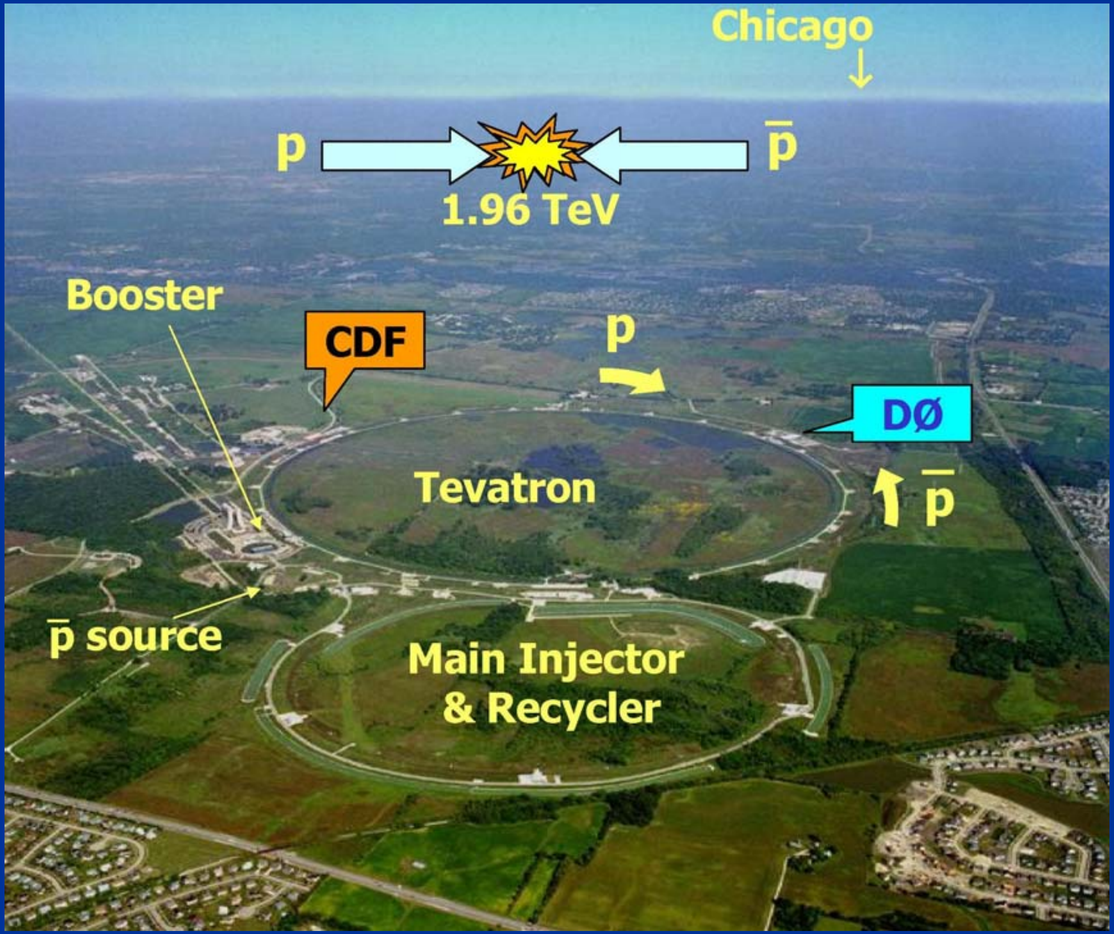
The Tevatron Collider



proton-antiproton collisions

Run I (1992-1996)

E_{CM} = 1.8 TeV

$\int L\,dt \cong 100\ pb^{-1}$

Run IIa (2002-2006)

E_{CM} = 1.96 TeV

$\int L\,dt \cong 1.2\ fb^{-1}$

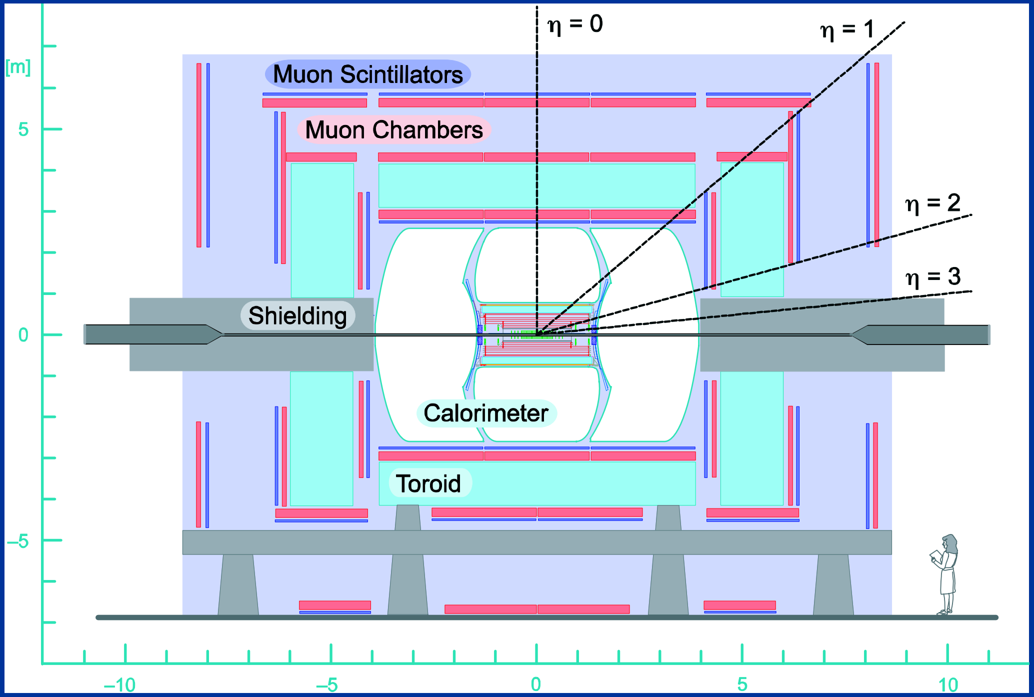
Run IIb (2006-?)

E_{CM} = 1.96 TeV

in preparation

$\int L\,dt \cong 4 - 8\ fb^{-1}$ (expected)

The D0 Detector



coordinate system:

pseudorapidity $\eta = -\ln(\tan \theta/2)$

radius r

polar angle φ

(track) distance $\Delta r = \sqrt{(\Delta\varphi)^2 + (\Delta\eta)^2}$

"standard" collider detector configuration

silicon microvertex & tracking detector within solenoid (2 T)

LAr calorimeter

- high granularity
- excellent resolution

muon chambers

- large coverage ($\eta < 2.0$)

three trigger levels

- Level 1 1.5 kHz
- Level 2 850 Hz
- Level 3 50 Hz

The Calorimeter

sampling calorimeter

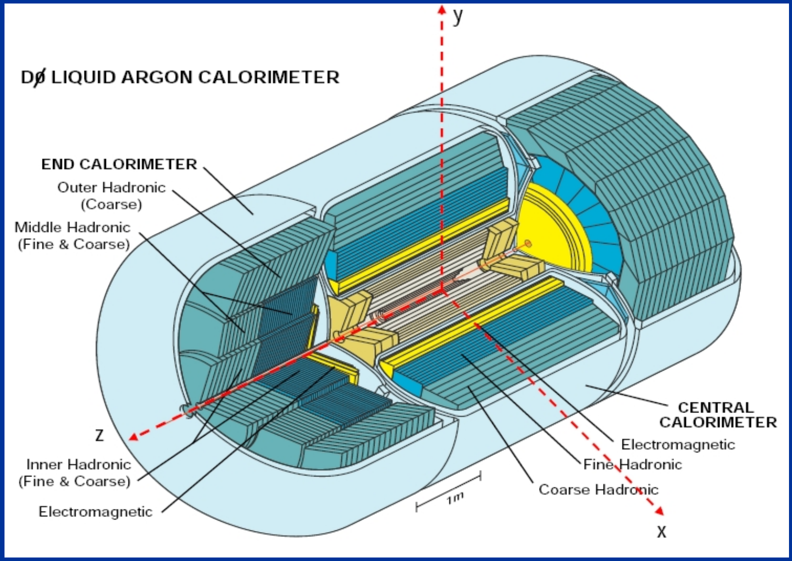
- uranium as absorber
- liquid argon as active material
- high granularity
- longitudinal shower shape

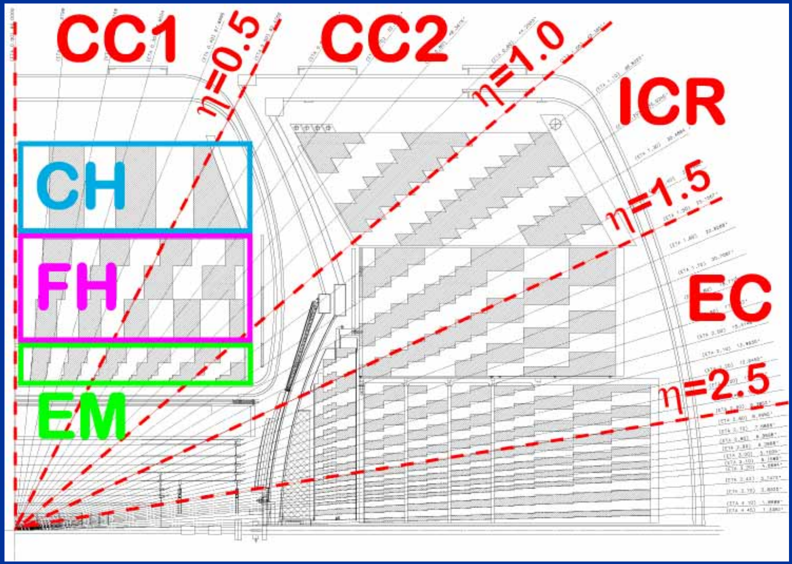
divided into 3 cryostats

- 1 Central Calorimeter
- 2 EndCaps
- Inter Cryostat Region

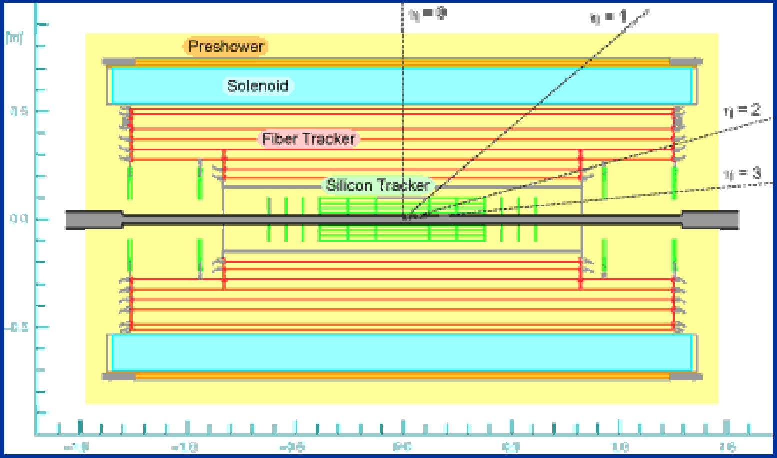
17 layers in 3 detector regions

- Electro Magnetic
- Fine Hadronic
- Coarse Hadronic





The Tracking System



Central Fiber Tracker

measurement of charged particle momentum & direction

- dca resolution

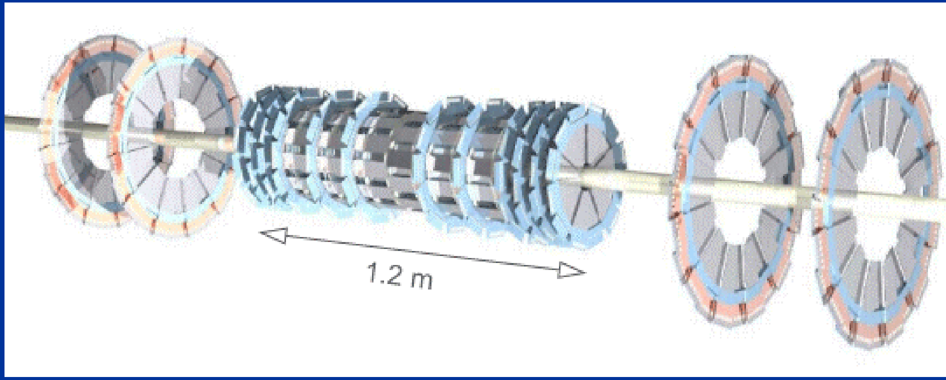
$$\sigma_{dca} = 8.5 + \frac{37.0}{p_t} (\mu m)$$

two tracking subdetectors

Silicon Microstrip Tracker

measurement of charged particle origin

- distinguish primary vertices (important at high luminosity)
- identify b jets, τ decays (secondary vertices)
- reject cosmic muon background



Single Hadron Response

select isolated charged hadrons in collision data and measure their energy deposit in the calorimeter as input for:

- D0 detector simulation
- ➢ in situ (hadronic) calorimeter calibration

- improved jet algorithm using track info
- ➢ improve jet energy resolution

- physics analysis
- ➢ determine systematic uncertainties

Hadronic Calorimeter Calibration

Hadronic Response

calorimeter response to EM objects

- easy to calibrate with isolated electrons stemming from $Z \rightarrow ee$ or $J/\Psi \rightarrow ee$
- main energy loss in EM calorimeter

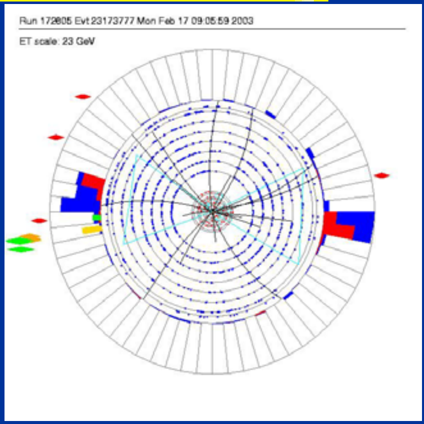
calorimeter response to hadrons (pions, kaons, protons)

- no clean probe of isolated hadrons exists
- no clean (enough) sample of isolated hadrons
  (no test beam data available for D0 Run II)
- energy loss in EM / FH / CH calorimeter

feedback to detector simulation development

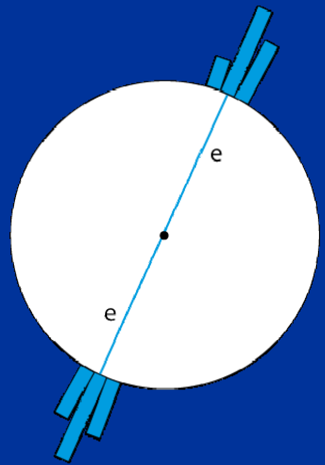
- energy loss in dead material?
- optimal layer weights?
- collected signal fraction in Run II integration time?

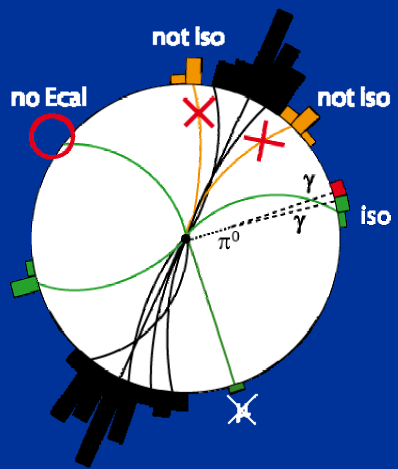
Comparison EM / HAD Calibration



DiEM events

- very clean event signature
- easy to calibrate mass fit
- high statistics



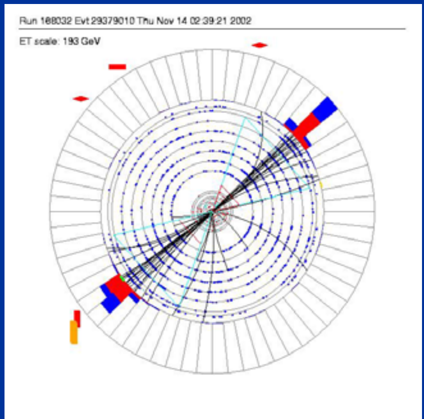


DiJet events

- hadronic W, Z decays swamped by QCD
- no mass constraint
- study single hadrons

Single Hadron Response

- need to find isolated particles
- backgrounds from neutral particle decays
- very low statistics (especially at higher E)



Improved Jet Algorithm

Jet Energy Resolution

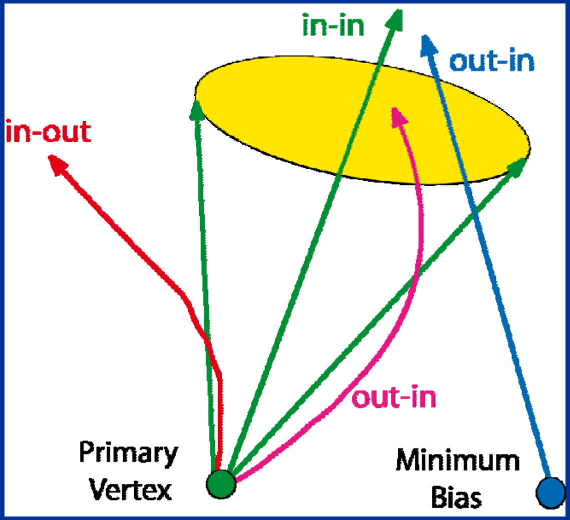
$$\frac{\sigma(E)}{E} \sim \frac{a}{\sqrt{E}} \oplus \frac{b}{E} \oplus c$$

3 main contibutions:

- stochastic term
  jet fragmentation
  sampling fluctuations
  EM fraction fluctuations
- noise term
  electronic noise
  multiple interactions
- constant term
  dead material
  magnetic field
  non-compensation

improved Track-Jet- Algorithm

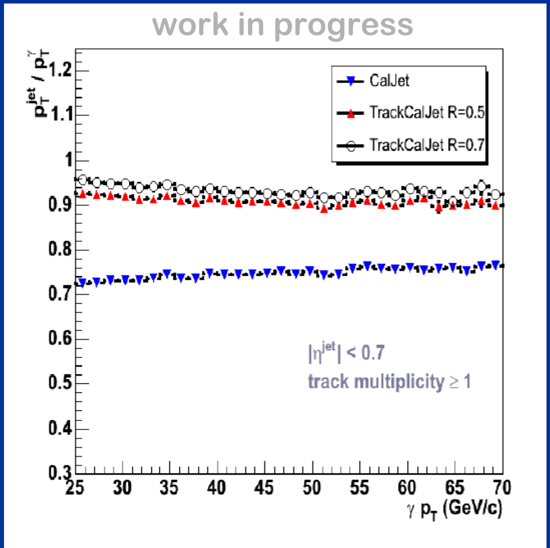
- improve jet energy resolution by improving absolute energy scale
- propagate tracks to CAL surface
- calculate η, φ of path at each layer
- subtract expected energy deposit in CAL from E_{jet}
- add E_{track} instead
- correct E_{jet} for in-out / out-in tracks

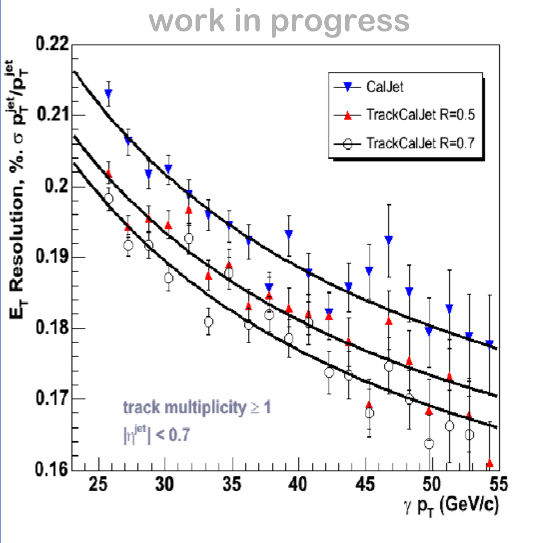


Petra Haefner

Algorithm Performance

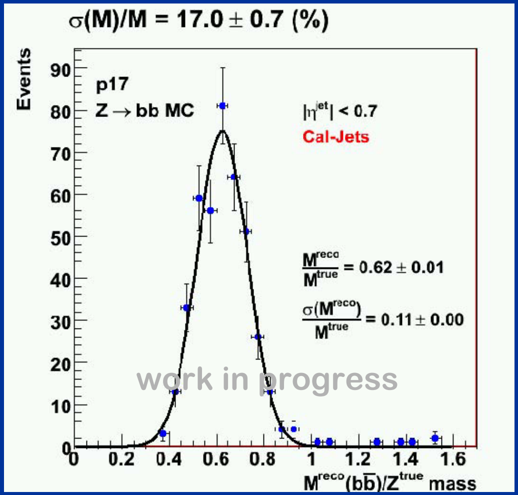
Petra Haefner   Pheno06, Madison   05/15/2006

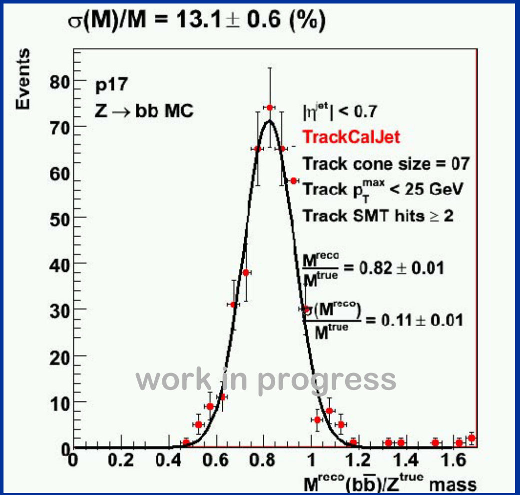




implemented in latest D0 software

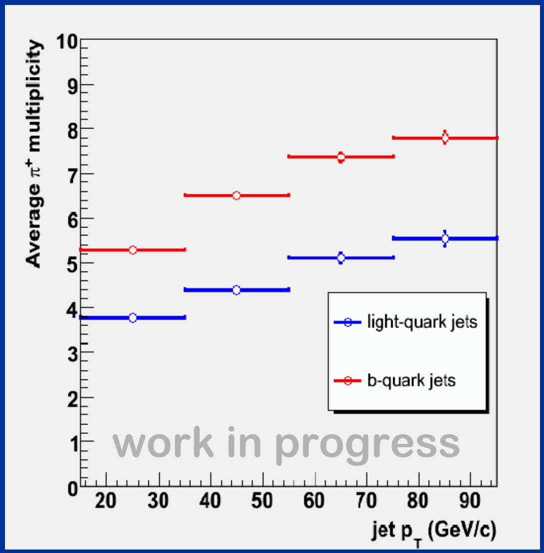
- cancel some sources of fluctuations
- 10 % jet resolution improvement in γ+jet data (before JES corrections)
- 20 % improvement on $Z \rightarrow bb$ mass resolution (important for Higgs search)
- 10 % improvement on $W \rightarrow jj$ mass resolution (important for top mass)
- larger cone size $\rightarrow$ further improvement

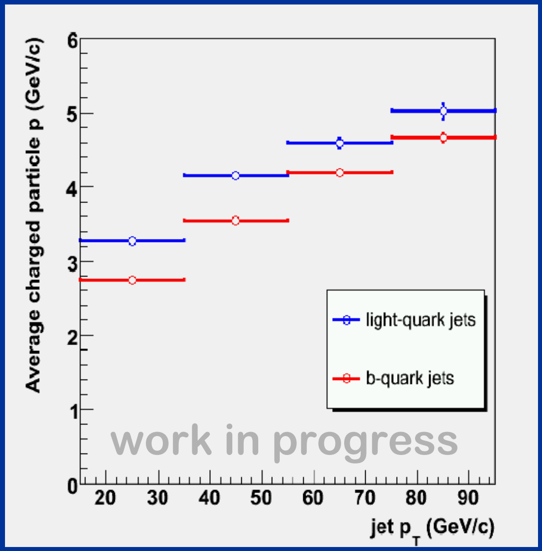




Systematic Uncertainties

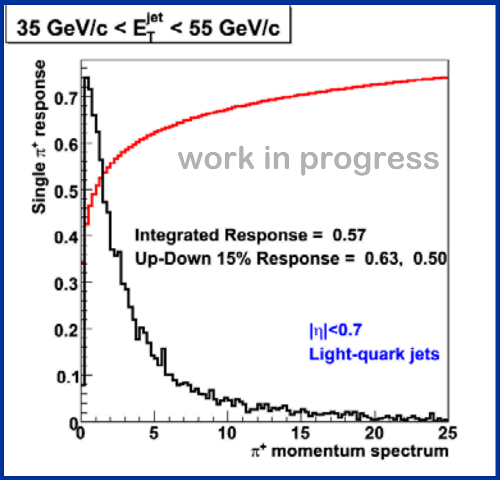
b Jet vs. light Jet Spectra

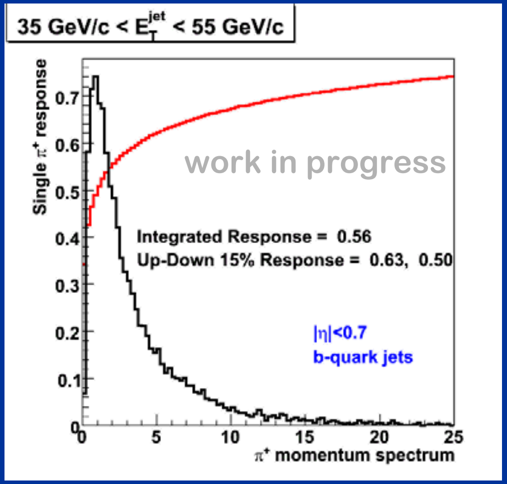




uncertainties on the b / light quark jet response from

- different hadron composition (b jets: more soft π^+)
- different hadron momentum spectrum in b/ light jets (b jets: softer)
- different e / h ratio
- uncertainty on energy scale ratio
- first results: no significant differences in b / light jet ratio





Single Hadron Response Results

Data / MC Samples

problem:

- strong track isolation cuts leave only very low statistics
- calibration of all hadronic layers and several η regions requires high statistics over a large energy range

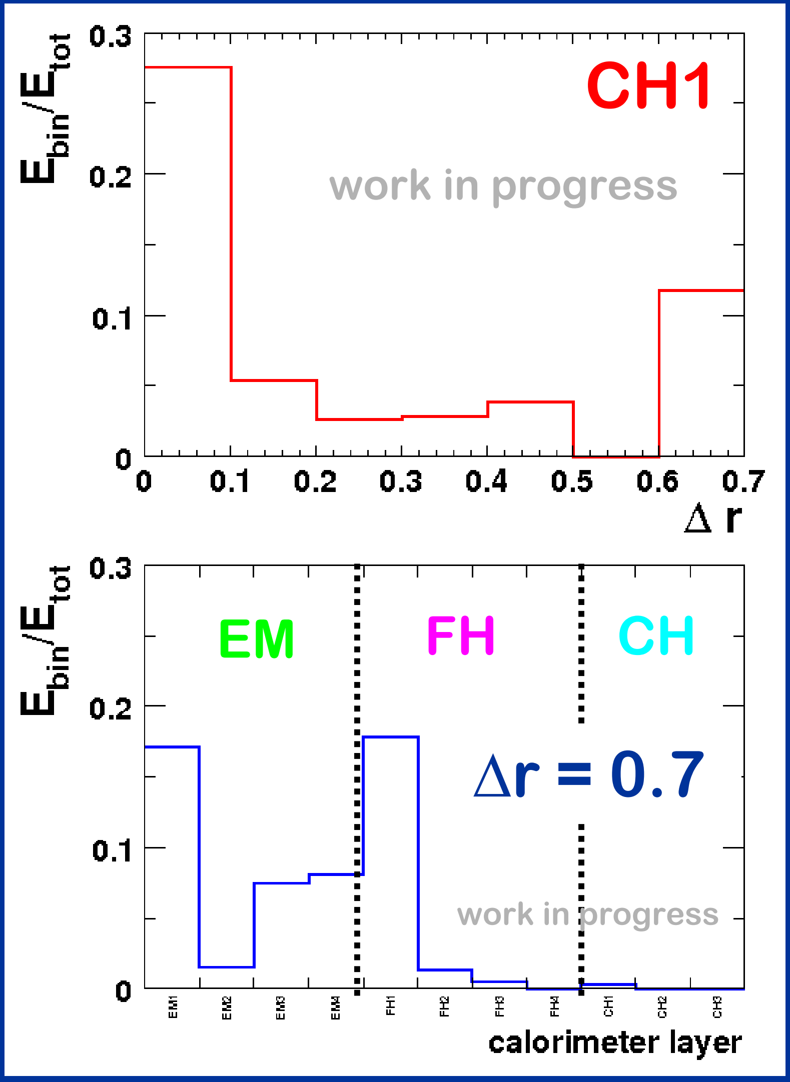
solution:

- dedicated trigger for higher percentage of useful data
- collect events with isolated tracks with $p_t \geq 5$ (10) GeV

simulation:

- dedicated samples for isolated pions / kaons / hadrons
- special sample without dead material
- special samples with different integration times

Shower Profiles (CC1, MC)



lateral profile

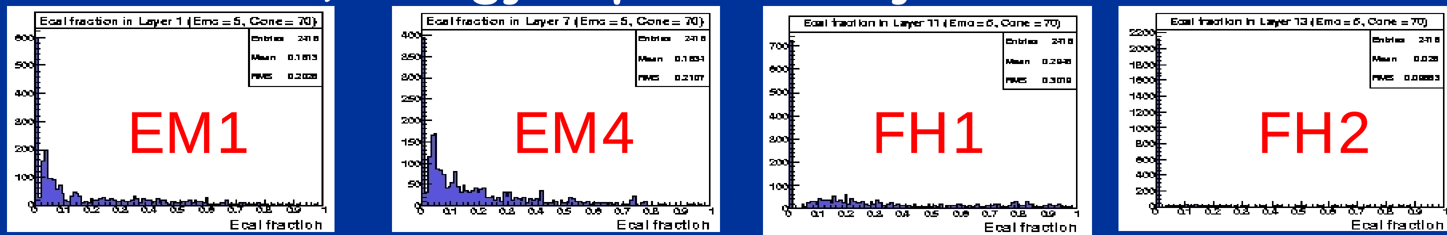
- E_{cal} vs. cone size, normalized to true E_{MC}
- E_{cal} in hollow cone, integrated over CAL layers
- very broad shower profiles (at energies < 5 GeV)

longitudinal profile

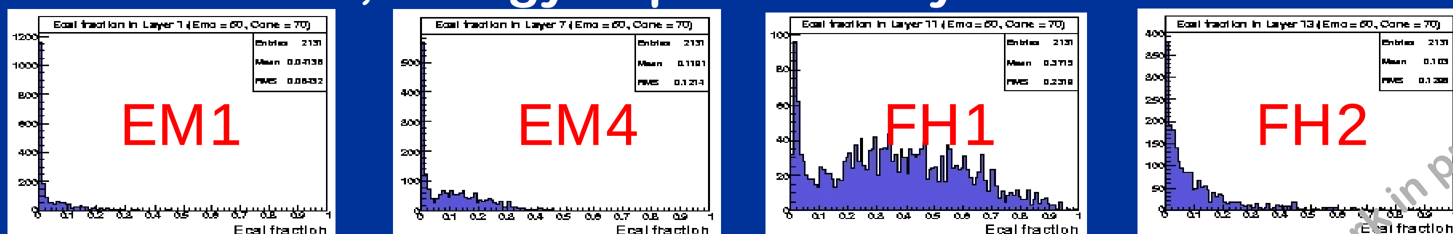
- E_{cal} vs. CAL layer , normalized to true E_{MC}
- most energy deposited in EM
- smaller fraction in FH
- hardly any deposit in CH

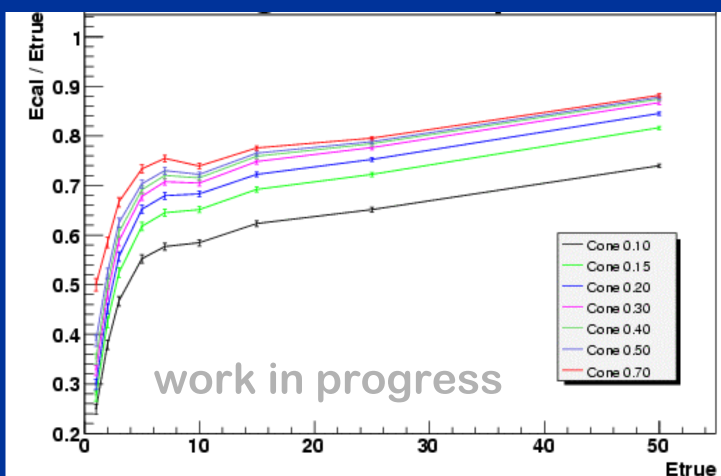
Single Pion Results MC (I)

5 GeV Pions, energy deposit mainly in the **EM** CAL



50 GeV Pions, energy deposit mainly in the **FH** CAL

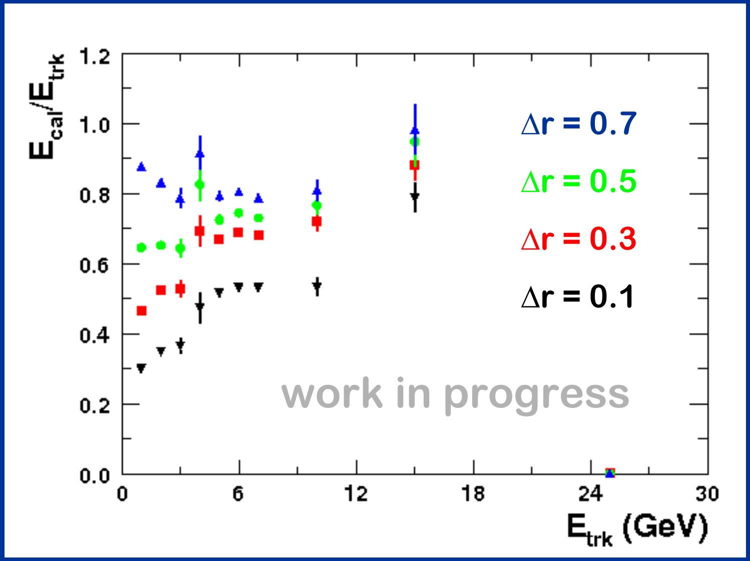




- strong cutoff at low energies
- due to dead material & zero suppression
- clear dependence on cone size due to broad energy profiles
- typical response ~ 75% @ 10 GeV

Single Hadron Response in Data

- only O(450k) events reconstructed and analysed
- O(16M) events taken with two trigger versions
  - small data set shows method is working
  - still too low statistics for reliable results
  - work in progress!



Towards a final response...

take care of calorimeter noise

- not subtract it several times
- quantify in MC studies (~ 5-10% @ E < 10 GeV)

subtract neutral background

- study single hadron vs. MinBias MC

effects of zero suppression and dead material

- study and correct for these effects
- dedicated MCs produced

Summary & Outlook

- single hadron response allows in situ calibration of the hadronic calorimeter
- can be used to improve jet algorithm
- serves as input for physics systematics calculations

- main issue: low statistics
  (due to required strong track isolation)
- developed special trigger for isolated charged hadrons
- ➤ enhance statistics at energies above 5 (10) GeV

- triggered data taken before shutdown
- first preliminary results on small subsample shown
- full data set will follow soon (16 M events)
- ➤ will allow response studies in finer eta bins
- ➤ will allow to derive response for higher energies