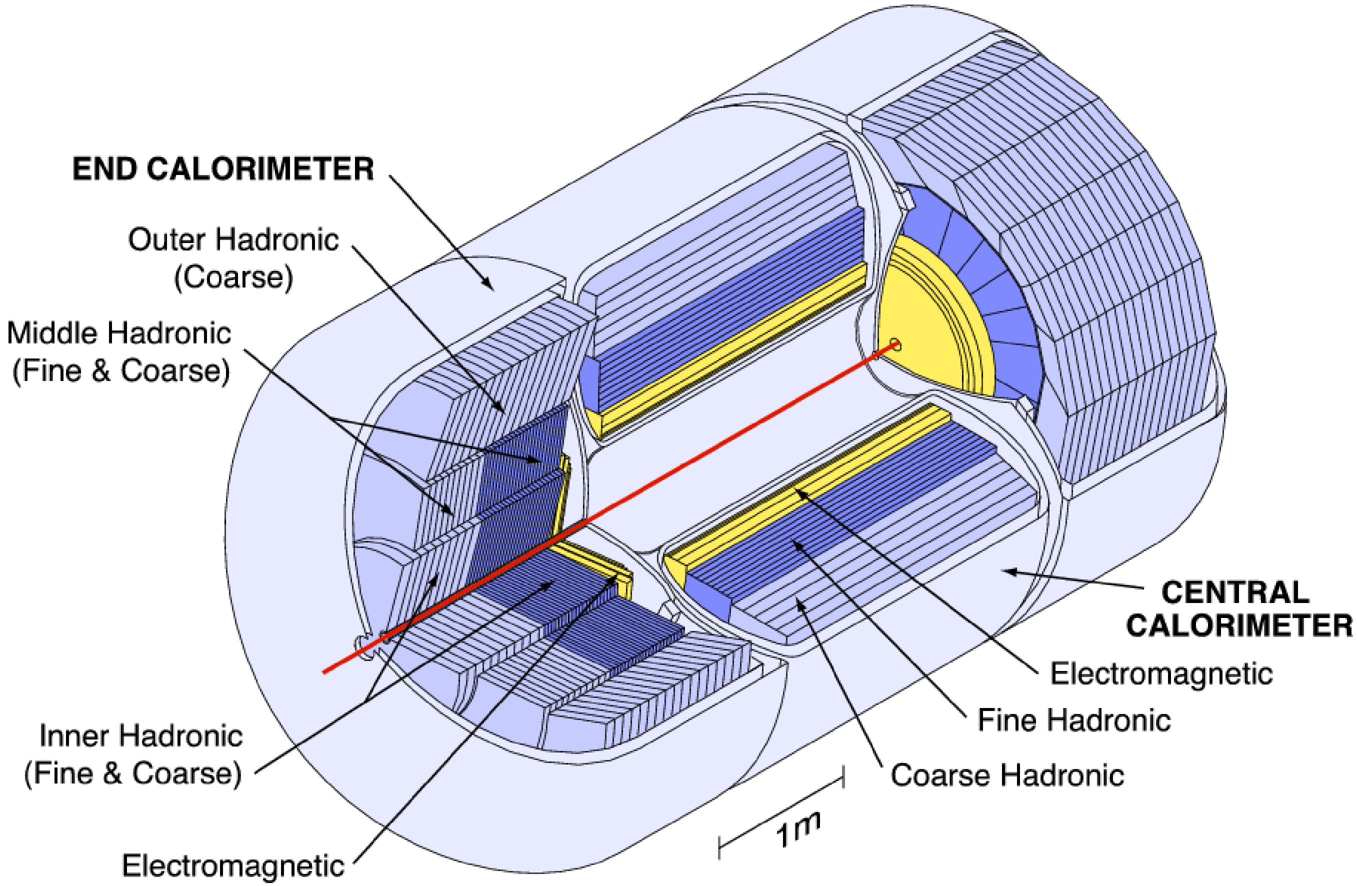
Jets in D0

Laurent Duflot

LAL Orsay

The D0 calorimeter



- Good granularity:
  - 0.1x0.1 in ηxϕ
  - 4 EM layers
  - 4 (5) HAD layers
- Deep
  - ~ 20 X_0
  - 7 to 8 int. length

- Integrated EM+hadronic U/LAr sampling calorimeter (Fe/LAr or Cu/LAr)
- Compact and hermetic : coverage up to $|\eta|<4.2$
- Complemented with scintillator detector in the inter-cryostat region
- About 4 X_0 in front of central calorimeter

A few words on electronics

- Beam crossing every 396ns
- About 5 interactions per crossing average in RunIIa high luminosity
- Short shaping time means calorimeter not really compensating as in RunI
- Electronics sensitive to pileup from the 3 previous beam crossings
- Typical noise RMS from
  - few MeV in EM layers
  - up to 300MeV in the “Coarse Hadronic” layers (large cells)
- Specific algorithms were developed to remove “hot cells” at reconstruction level
- So the “noise” for jets is a combination of
  - electronic noise
  - radioactivity from U (rather small in RunII)
  - pileup
  - multiple interactions and underlying event

Jets Algorithms: a bit of history

- The reference document for the algorithms implemented in D0 is the RunII QCD workshop report from 2000.
- Lots of different algorithms were implemented (all can be used at parton/particle, cell/tower or cluster level):
  - D0 Run I cone algorithm
  - “Improved Legacy Cone Algorithm” aka “RunII midpoint”
  - various flavors of kT algorithms

In the end, only the RunII cone was ever used

- RunI algorithm only used in the beginning as a reference

- kT algorithm seemed to show greater sensitivity to noise, pileup and multiple interactions
- Did not show any clear improvement for e.g. dijet mass resolution
- Deriving the Jet Energy Scale is a huge project and we did not really have enough manpower

Improved Legacy Cone Alg. or Midpoint

- Use preclusters formed with "simple cone" as seeds
- Grab objects in cone of radius $\Delta R^2=\Delta y^2+\Delta\phi^2$ (rapidity, not pseudo-rapidity) around seed and iterate until the cone axis is stable: protojets [almost all analyses use R=0.5]
- Use also "midpoint" (barycenter) between couples of protojets as seeds to find new protojets

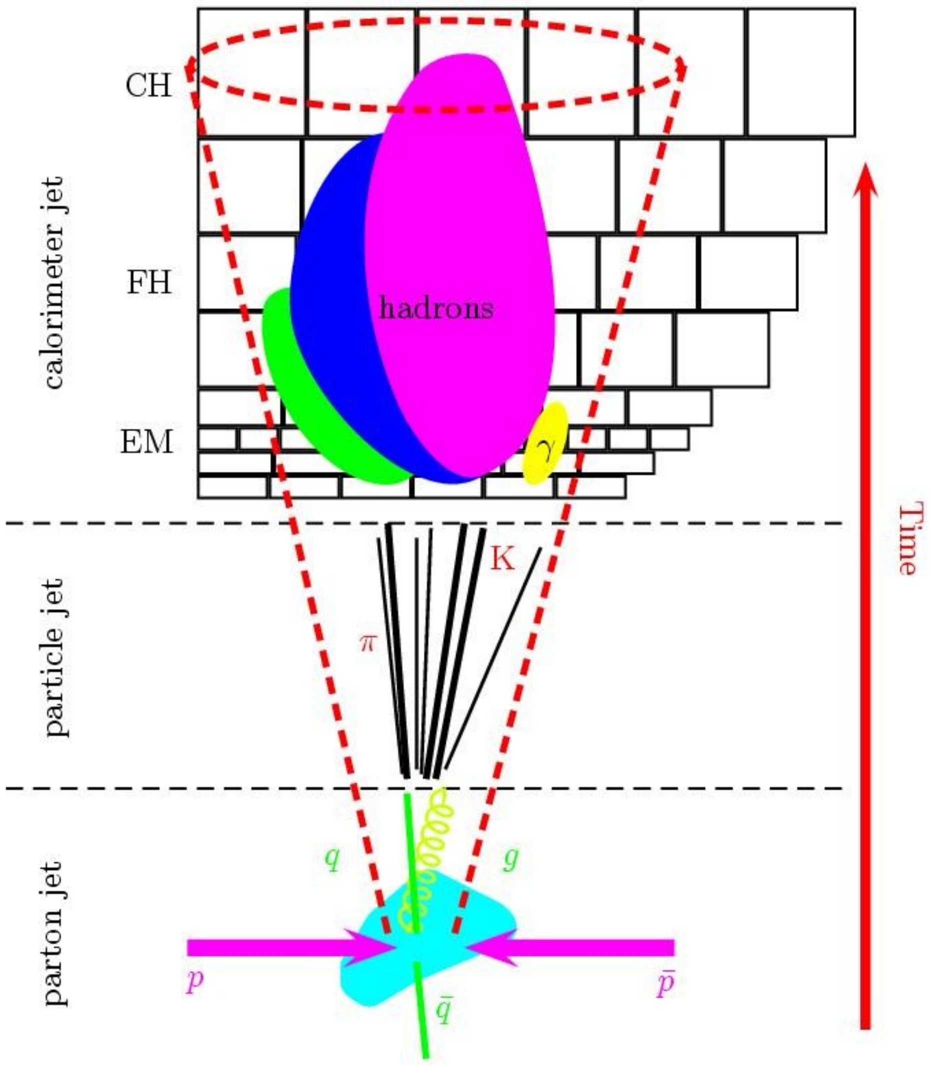
- Have to treat overlapping protojets: split or merge
- if more that 50% of pT jet is also in a higher pT jet, the lower pT jet is merged
- otherwise assign common objects to closest jet

- Object is : MC parton, MC particle, calorimeter tower [calorimeter clusters not used]

Remarks

- Typical parameters for calorimeter cone jets reconstruction
  - find seeds with “simple cone” jets pT>1GeV/c seed with tower>0.5GeV (skipping “Coarse Hadronic” cells)
  - accept jets with pT>6GeV
  - good jet criteria based on EM and Coarse Hadronic fractions, confirmation with L1 readout
- The jet efficiency can be derived with a tag-and-probe method
  - using dijet events, where one jet is required to pass all criteria for good jet and satisfy the single-jet trigger criteria and a track-jet is found opposite
  - using γ+jet events
- The jet finding inefficiency is significant at low pT, so in most analyses jets above 15 or 20 GeV (after correction for Jet Energy Scale) are used.

Jet Energy Scale



- We have chosen to correct the jet back to particle level and not parton level
- We correct the jet energy (and not pT as e.g. in CDF)

JES correction

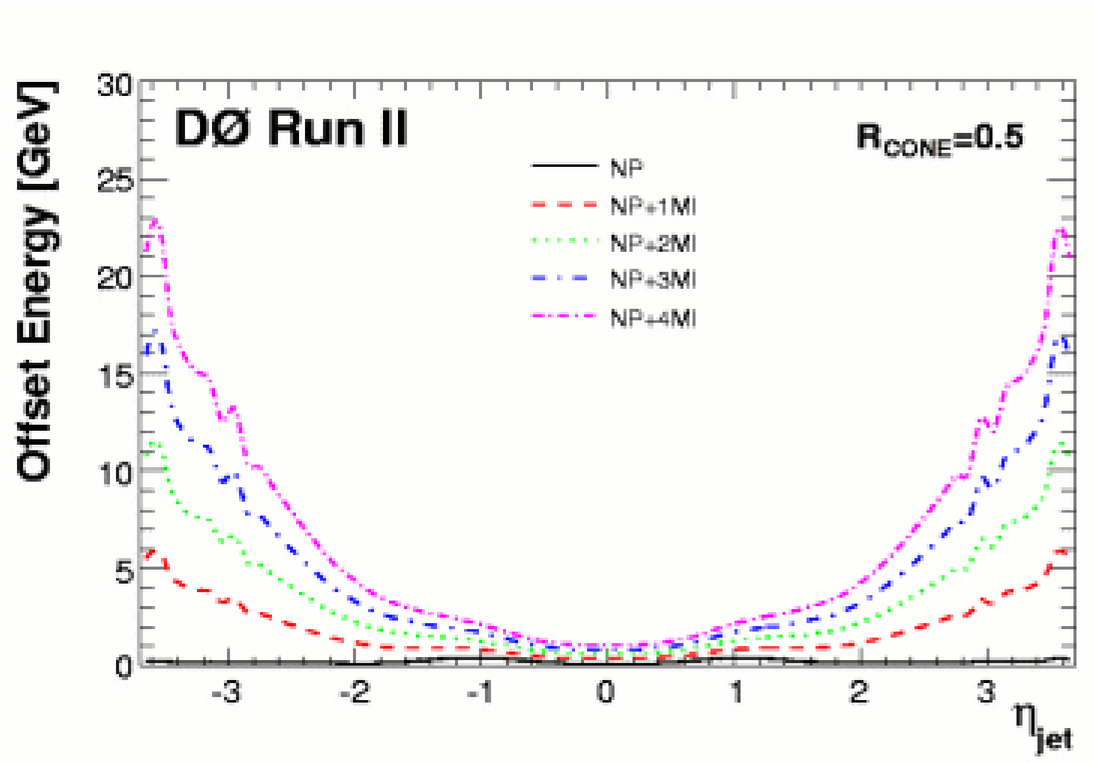
$$E_{jet}^{ptcl} = \frac{E_{jet}^{raw} - O}{F_\eta \cdot R \cdot S} \cdot k_{bias}$$

E_{jet}^{ptcl}:	corrected jet energy
E_{jet}^{raw}:	uncorrected jet energy
O:	offset energy correction
F_η:	relative response correction (η-intercalibration)
R:	absolute response correction
S:	showering correction
k_{bias}:	correction for remaining biases

Offset correction

- Electronic, uranium radioactivity and pileup noise measured with zero bias triggers (random beam crossings)

- Multiple interactions:
  - measure energy density as function of luminosity and number of primary vertices in minimum bias triggers
  - Difference between N and 1 primary vertices is the MI contribution



Absolute response correction

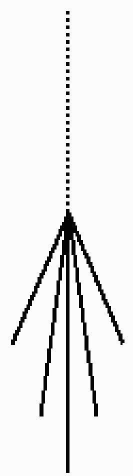
- Transfer the EM scale (derived from Zs) to jets using γ+jet events
- The Missing E_T Projection Fraction method uses the balance of the photon and jet pT.

- Tight γ+jet event selection to avoid biases
  - exactly one photon candidate $|\eta|<1.0$
  - exactly one jet $|\eta|<0.4$
  - back to back $\Delta\phi>3.0$ to suppress unclustered energy contributions
- QCD background estimated using different photon selection and bias corrected for

The MPF method

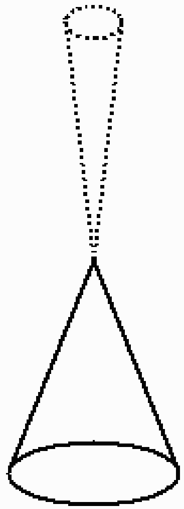
Missing E_T Projection Fraction Method: γ+jet

<u>Particle Level</u>



$$\vec{p}_{T,\gamma} + \vec{p}_{T,had} = \vec{0}$$

<u>Detector Level</u>

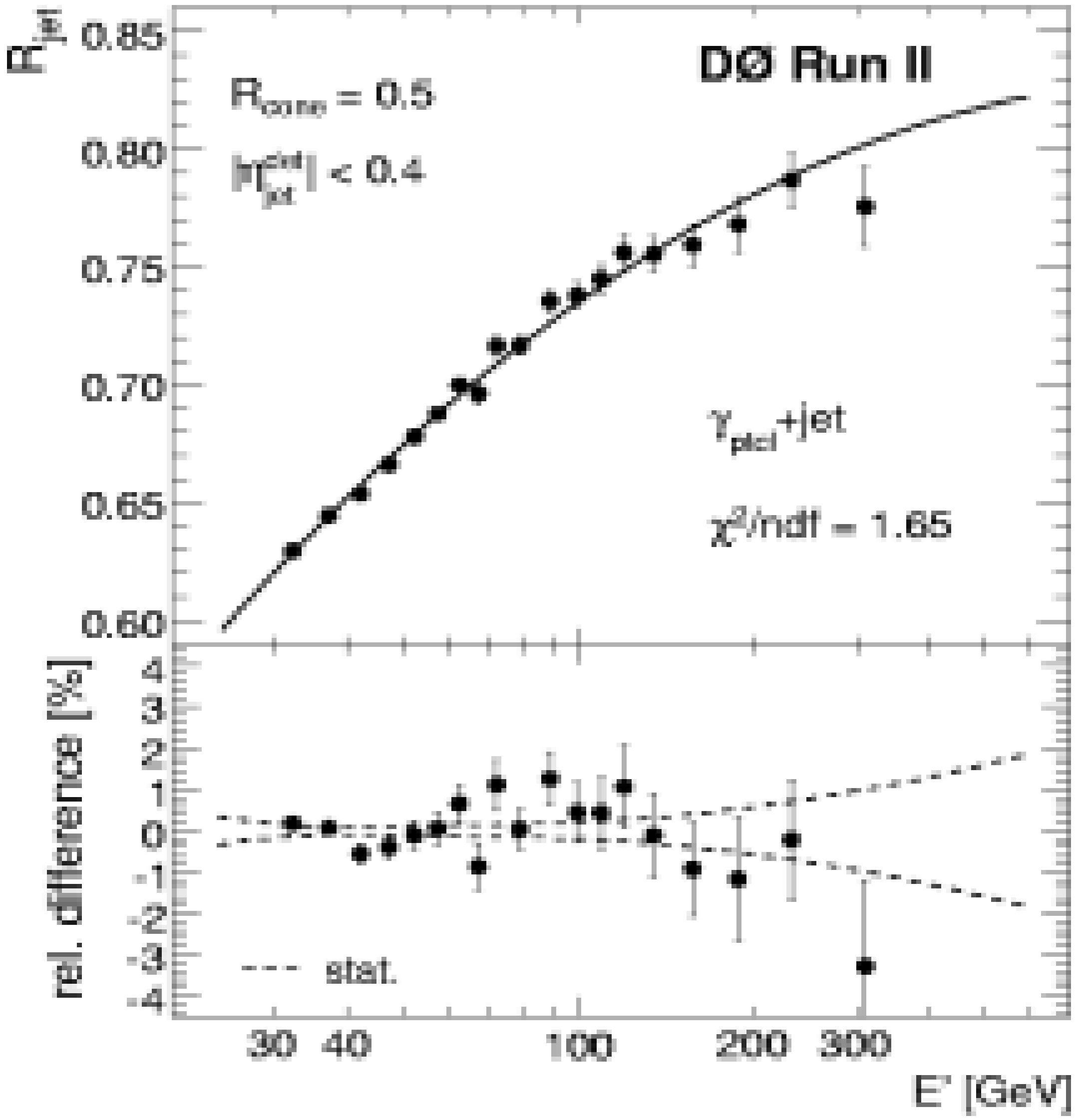


$$\vec{p}_{T,\gamma} + R_{had}\vec{p}_{T,had} = -\vec{\not{E}}_T$$

$$R_{had} = 1 + \frac{\vec{\not{E}}_T \cdot \vec{p}_{T,\gamma}}{\vec{p}_{T,\gamma}^{\,2}}$$

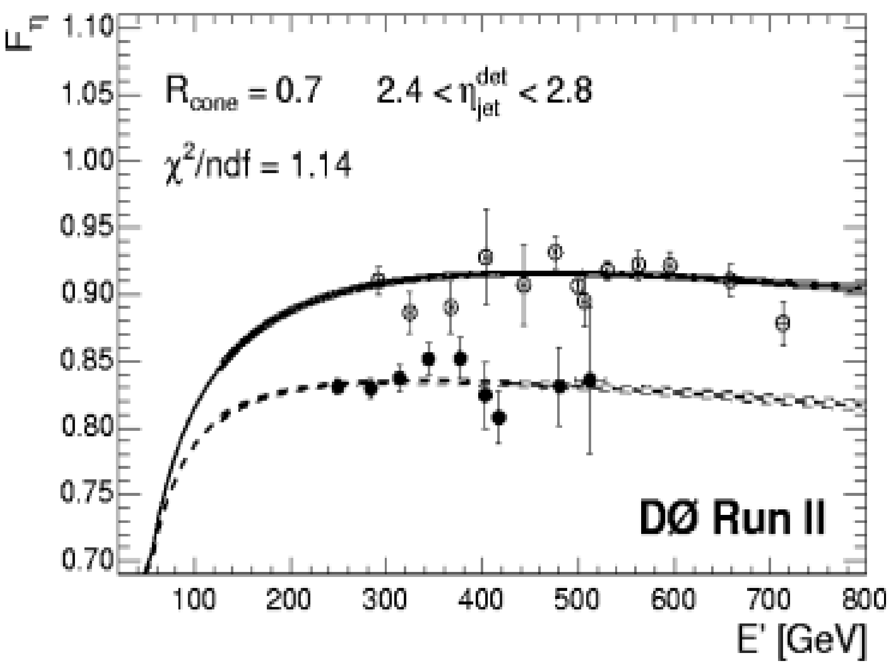
For back-to-back events : $R_{jet} \approx R_{had}$

Absolute response correction



Relative response in η

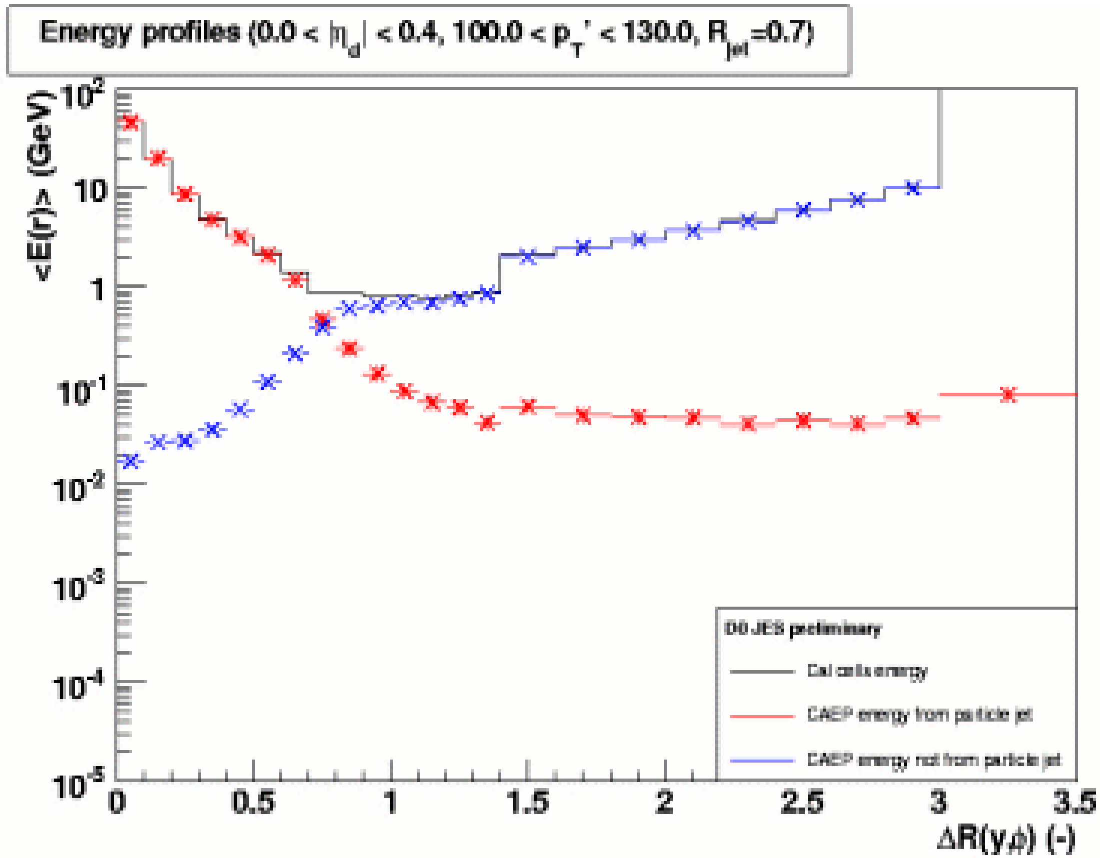
- The response measurement with γ+jets has large enough statistics for central jets, calibrate forward jets wrt central jets using γ+jets and di-jets events using the MPF.



- However jets in γ+jets and di-jets events have different compositions: quark vs gluon jets
- The response for gluon jets is smaller because of the softer fragmentation combined with the lower response for soft pions (material, compensation)
- Need to correct for that effect in deriving the relative response

Showering correction

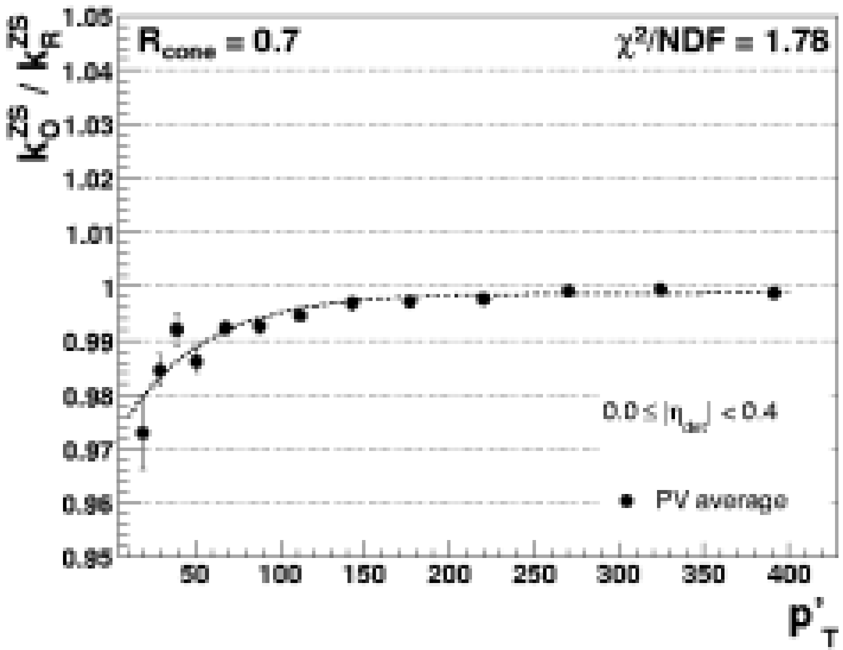
- The magnetic field can bend particles outside / inside the calorimeter cone.
- Particle showers in the calorimeter have a non negligible size, so a particle hitting the calorimeter inside the cone can deposit some energy outside the cone and vice versa.
- Templates derived from MC are fitted to the data to derive the effect and correction



MC energy profile from particles belonging (red) or outside (blue) particle jets in γ+jets events simulated at "zero" luminosity

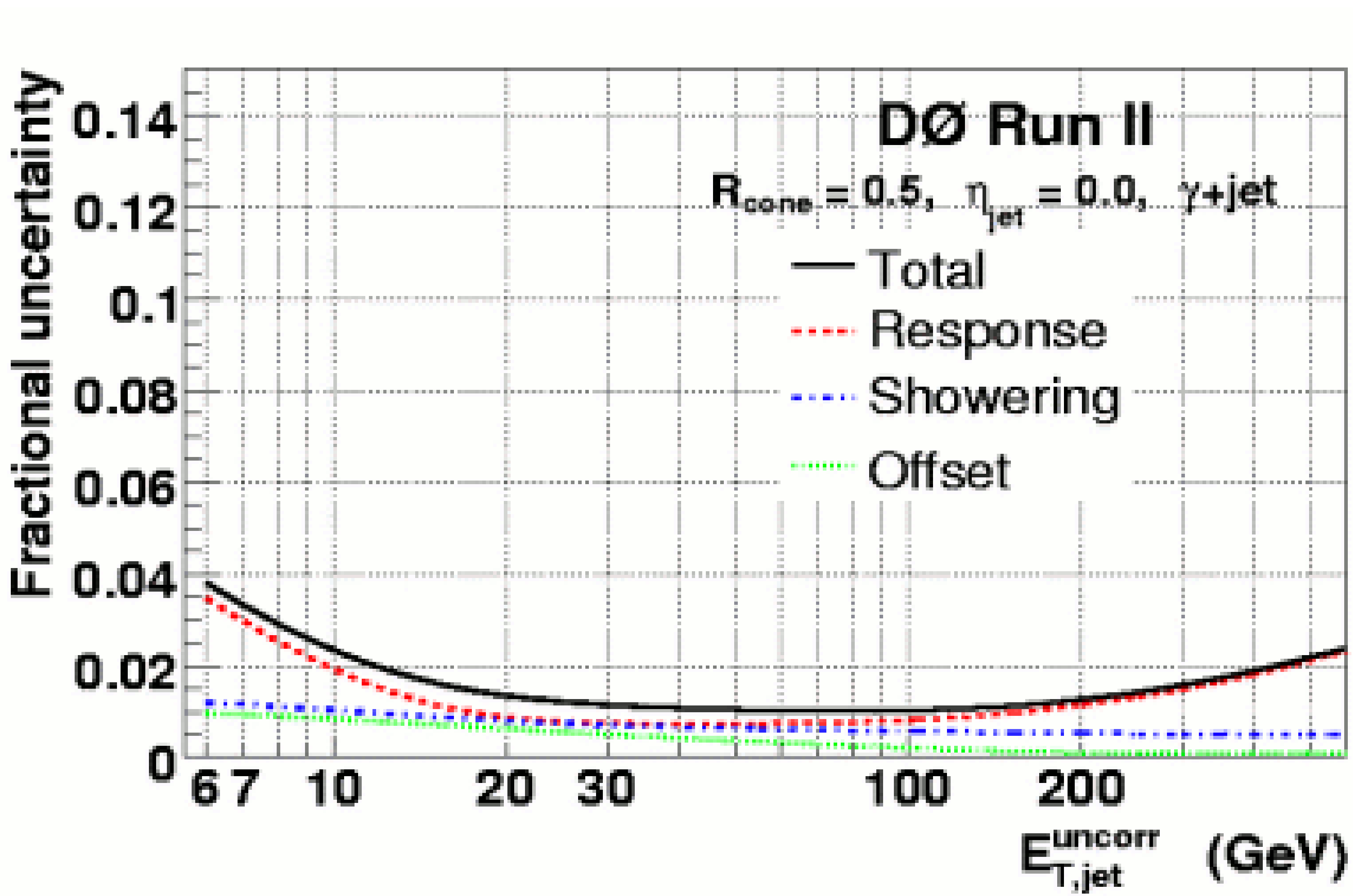
Bias corrections

- We do not readout/reconstruct all cells in the calorimeter but apply a zero suppression (N sigma of the noise). The offset correction takes that into account but cells in the jet area get additional contributions that increase their probability to pass zero suppression wrt cells in zero bias and min-bias events used to derive the offset. The same effects biases the response as in γ+jets events the photon is less affected than a jet.



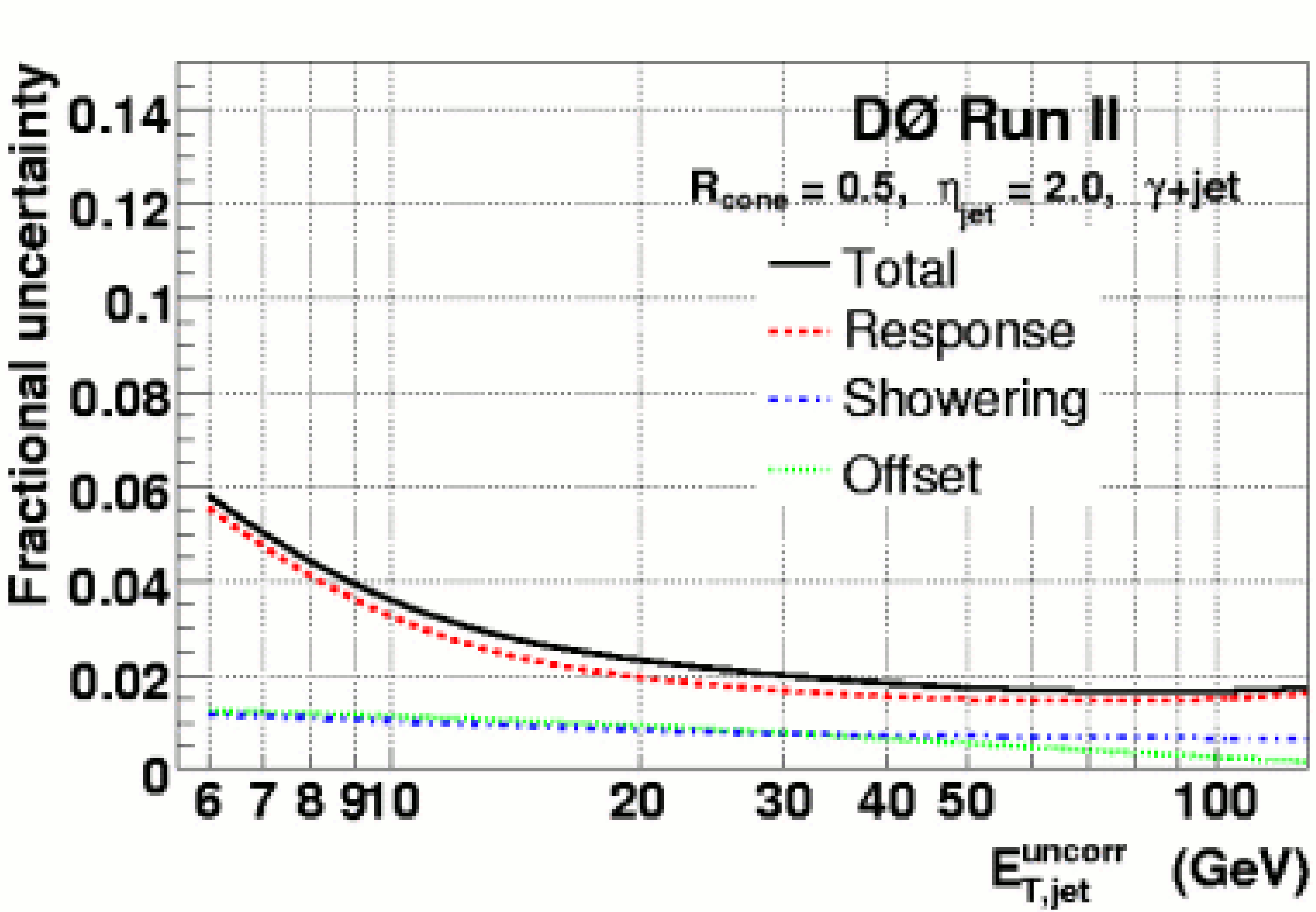
- Other sources of biases come from the event selection and event topology.

JES uncertainties



Fractional uncertainties at *η*=0 as a function of raw jet pT

JES uncertainties



Fractional uncertainties at η=2 as a function of raw jet pT

Remarks

- As noted before, quark and gluon jets in fact have a different response, hence a different jet energy scale can be derived based on MC studies. That can be used for according to physics process at play.
- The JES correction also need to be properly propagated to the missing E_T calculation to reduce fake ME_T and improve the resolution
- There are ongoing studies to improve jet energy resolution (of primary importance for low mass Higgs searches):
  - use of the preshower detectors in the JES
  - use of jet shapes
  - combine calorimetric and tracking informations
  - ....

Remarks

- The same techniques and samples are used to measure jet efficiencies and resolutions and derive corrections to improve the agreement between simulation and real data.
- In most analyses, the absolute scale is not fundamental but rather the relative scale between simulation and real data (e.g. a cut at 50 GeV should have the same effect in MC and data). The relative scale between MC and data have been derived and benefit from partial cancellations of systematics.

Summary and conclusions

- Although several different jet algorithms were available from the beginning, it turned out that only one is really used in D0. The main reason is that it takes a lot of time and effort to understand efficiencies, quality and derive a JES for a given algorithm.
- For the same reason, recent developments like fast seedless cone algorithms are not used.
- Deriving a good JES (i.e. small enough uncertainties) is a very long and tedious process.