Missing ET Reconstruction @ DØ

Patrice Verdier
Institut de Physique Nucléaire de Lyon

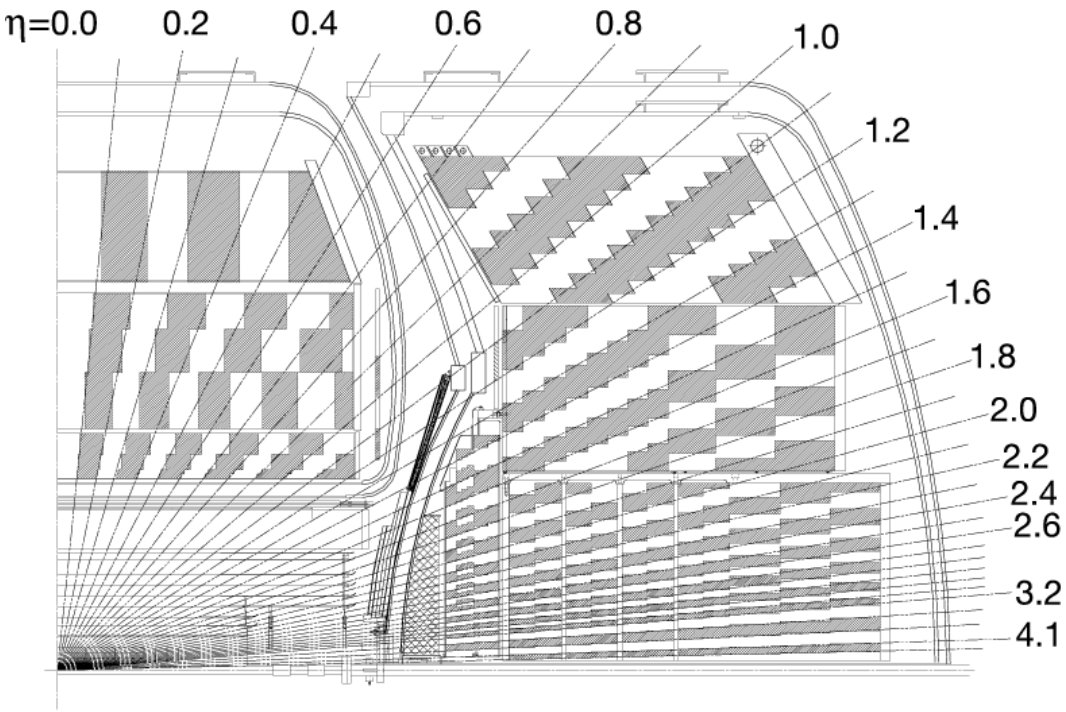
Top Workshop IN2P3: From Dzero to ATLAS
LPSC – October 9/10th, 2006

DØ Calorimeter and MET Definition

- Raw Missing ET and Scalar ET definitions:

$$MET_{x,y} = -\sum_{Ncells/Towers} E_{x,y}$$

$$SET = \sum_{Ncells/Towers} E_T$$

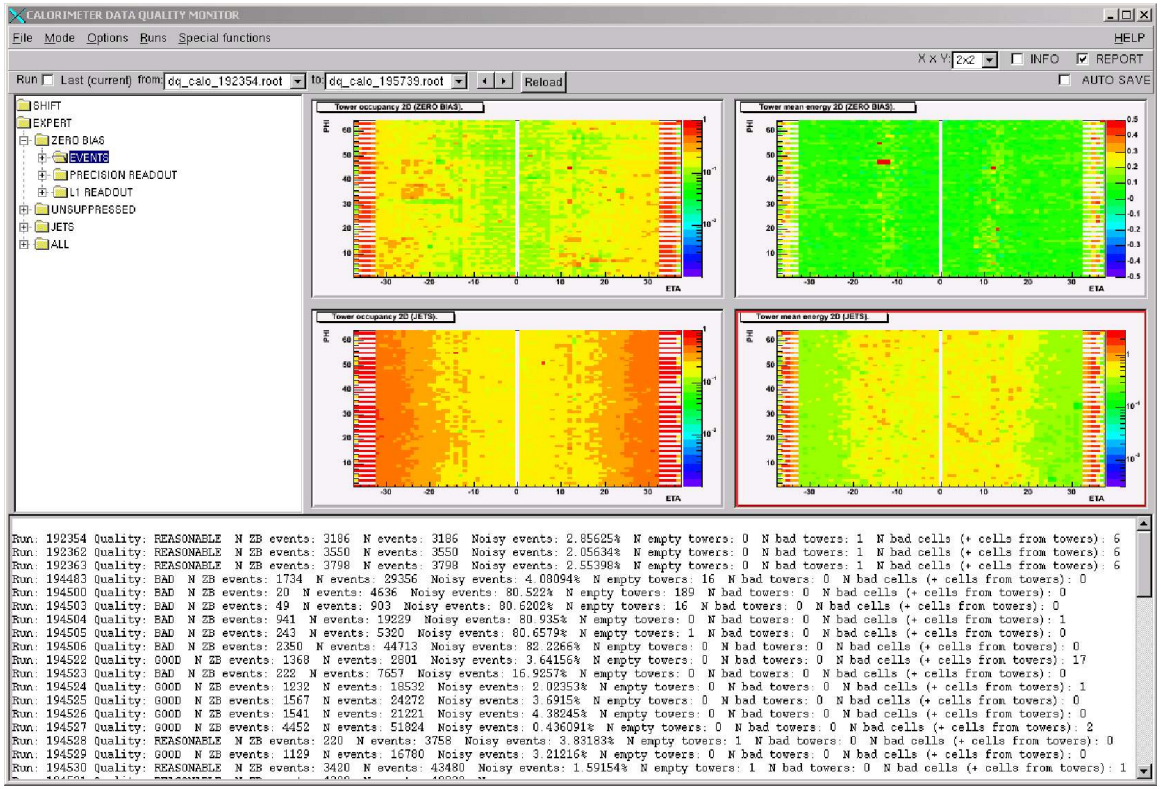


- DØ Calorimeter:
  - fine granularity : ~55,000 cells
  - 1280 trigger towers (size = 0.2 × 0.2) at L1 and L2 of the trigger system
  - Precision readout used at L3 and offline
- Raw missing ET can be computed :
  - From cells or towers (L1 or precision readout)
  - With/without Et threshold
  - With/without eta threshold
  - Including or not some part of the detector (Intercryostat region, Coarse hadronic)

- To apply correctly the MET corrections (discussed later), the raw MET used as the starting point of the final corrected MET as the be the one which include all calorimeter cells without any Et and eta thresholds

Online/Offline Monitoring

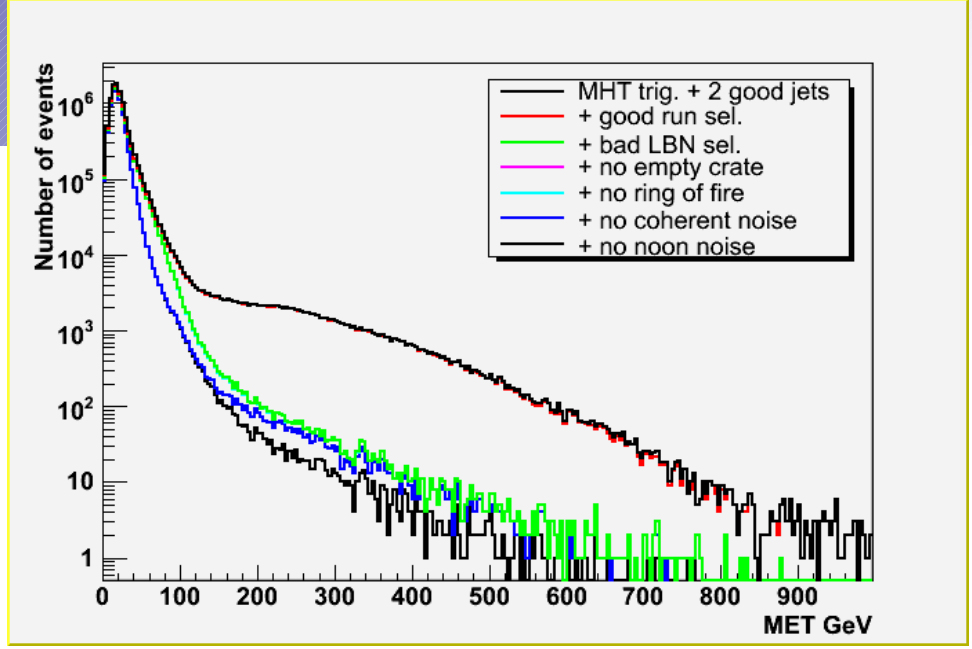
- Online Monitoring in the control room:
  - all runs (event between stores)
  - trigger and offline quantities
  - by cells/Towers/objects (jets,MET)
  - monitoring by trigger/topology
  - connected to alarms in the control rooms for the shifters
  - this is the first tool for DQ diagnostic
  - identify cells/towers for offline treatment (=> in the CAL DB)
- This is much more than a simple « histogram maker » !

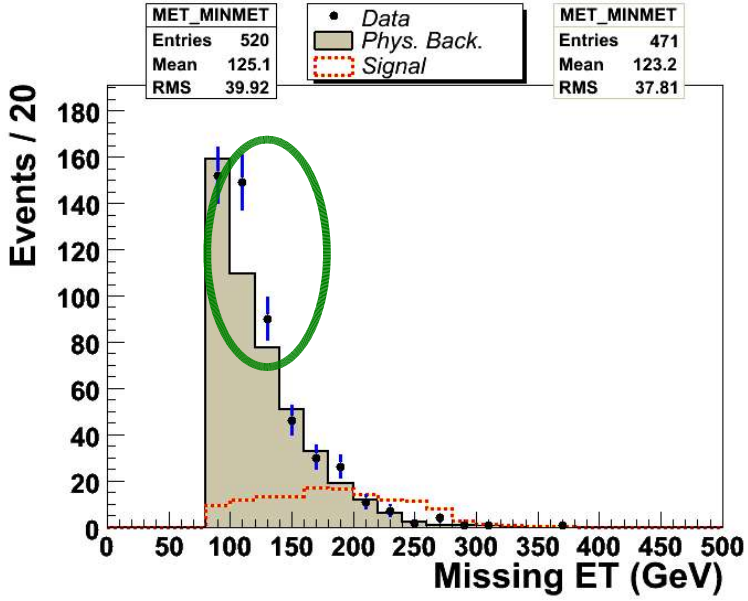


- Offline Monitoring :
  - A program (« histogram maker ») to determine DQ for each sub-detector is ran on all reconstructed data, just after the reconstruction program (raw to μDST)
  - For the calorimeter, DQ is done is three steps
    - by run (2 to 4 hours)
    - by LBN (“Luminosity Block Number” = 1 minute)
    - by event to flag/remove events with well identified noise pattern
- But :
  - Some problems are very rare and are discovered only at the very last step of a physics analysis

MET and DQ

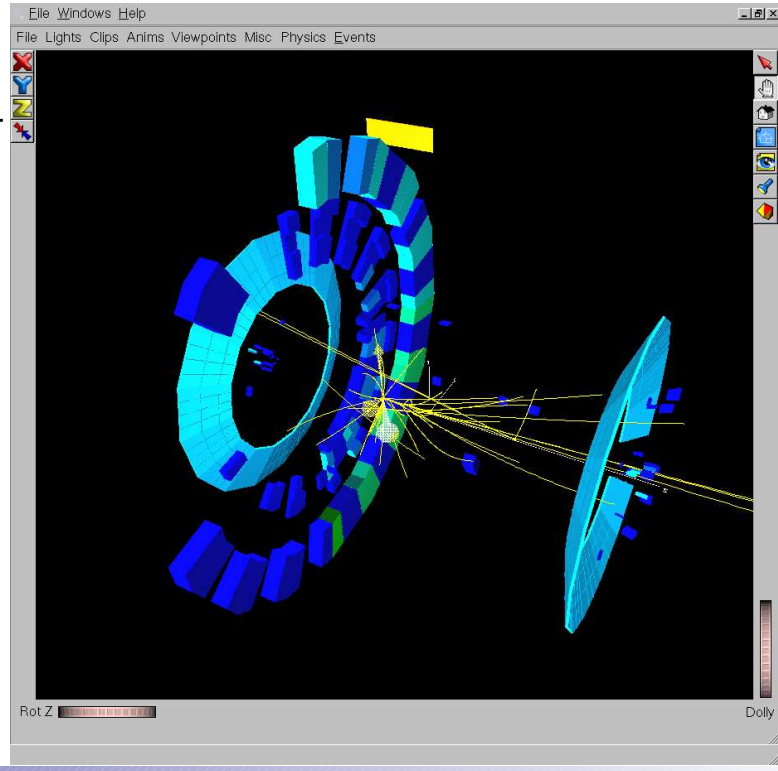
- Most of the problems in the calorimeter operations "c reate" missing ET
- In case of problem, it is very easy to fill the trigger bandwidth with missing ET triggers
- Coherent noise in DØ calorimeter has not been observed on the electronic test stand. Some problems are discovered only when we start taking data in "real" conditions:
  - coherent noise
  - beam
- Our best data samples to find problems in the calorimeter:
  - Jets+MET triggers





Some problems are as rare as the new physics we are searching for:

Almost at the end of an analysis searching for large MET, a bump is observed.
Only ~3000 events like this one in all RunIIa data (more than 2 billions of events recorded).
Those events do not come in burst, and are randomly distributed vs time.
No way to identify that problem in the control room



MET and the Trigger System

- During RunIIa :
  - No MET triggers at L1 and L2
  - use MHT instead at L2 and L3

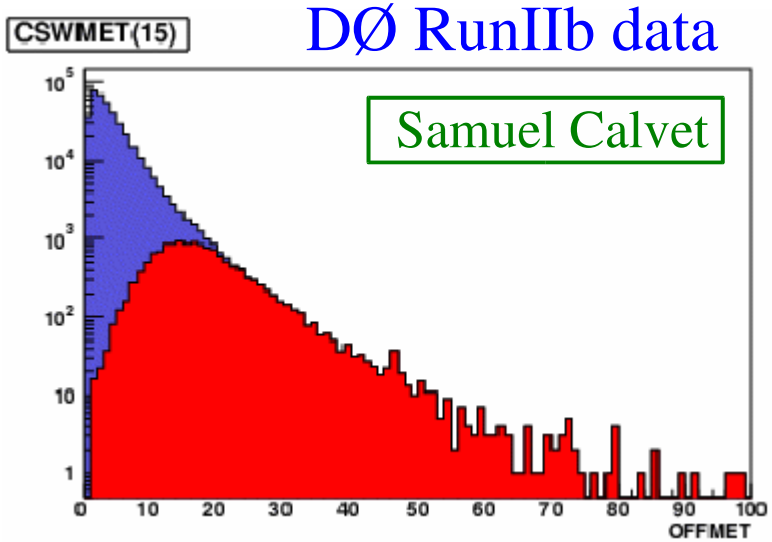
$$MHT = \left| \sum_{jets} \vec{p}_T \right|$$

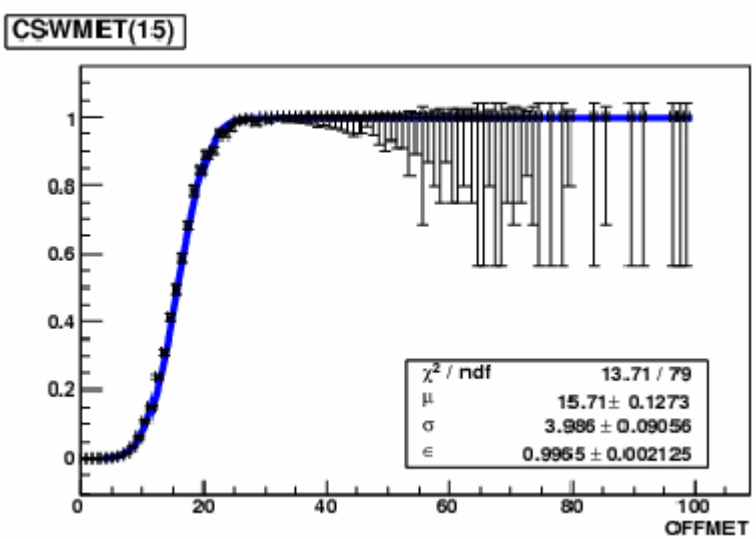
- Optimal Choice:
  - All towers except the ICR towers
  - threshold of 8 ADC counts (1 GeV) both on the EM and HAD part of each tower
- Trigger efficiencies have to be measured wrt to the same offline MET definition, but using the precision readout

- Since RunIIb :
  - New L1Cal trigger system
  - Sliding window algorithm @ L1 “a la ATLAS”
  - And we can now trigger on MET @ L1
- Before RunIIb start up, the L1 MET definition to be used was intensively tested on benchmark signals (for efficiency), and on RunIIa data with an emulation of the Run2b L1Cal system (for trigger rate determination):
  - Different Et/eta thresholds on trigger towers
  - Including or not the ICR region
- We want stable MET trigger conditions wrt :
  - instantaneous luminosities (pile up)
  - detector non uniformities
  - noise

DØ RunIIb data

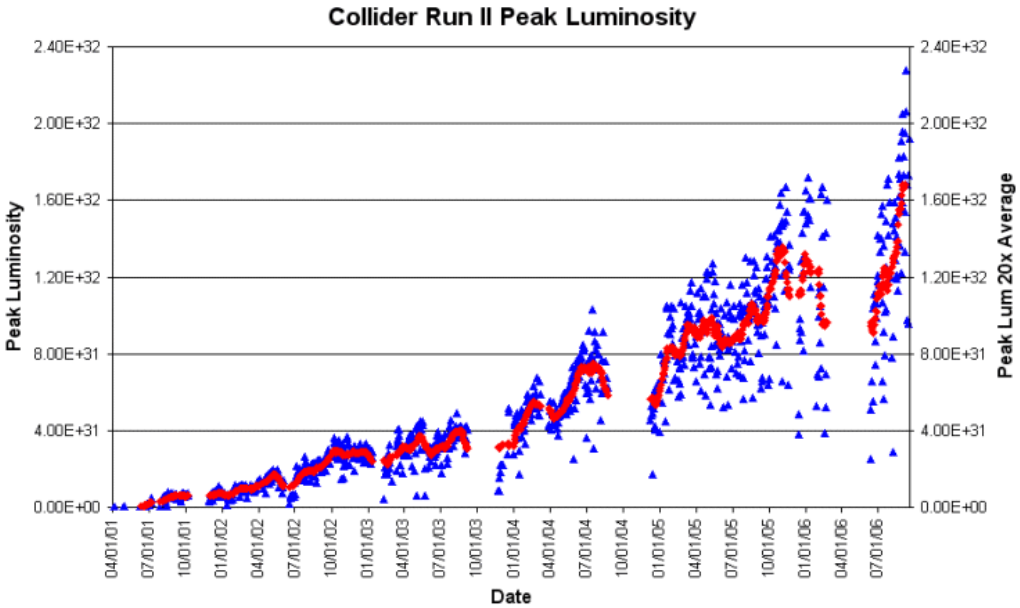
Samuel Calvet



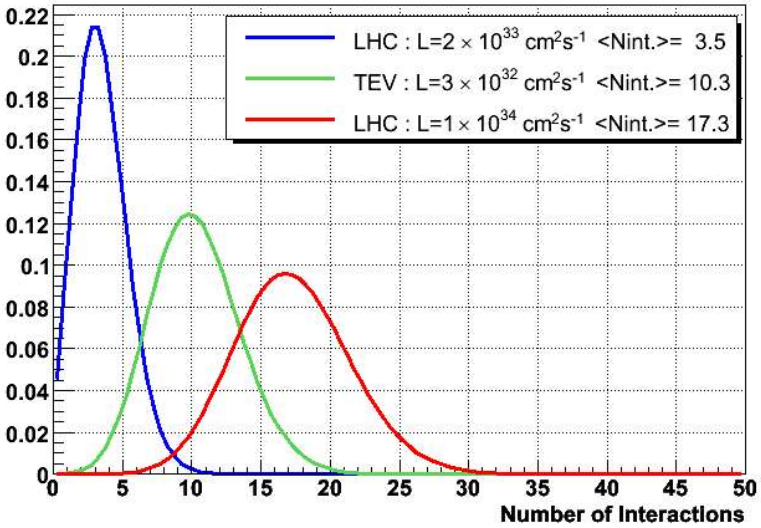


MET and Luminosity

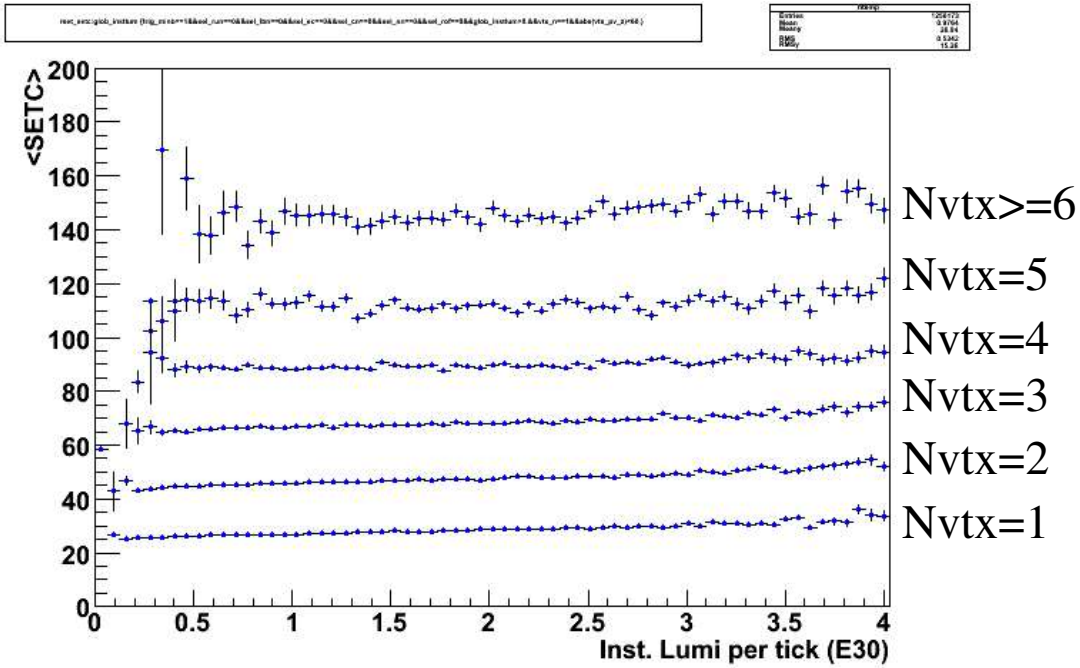
- DØ : 222E30 cm^2s^{-1} September 20th, 2006

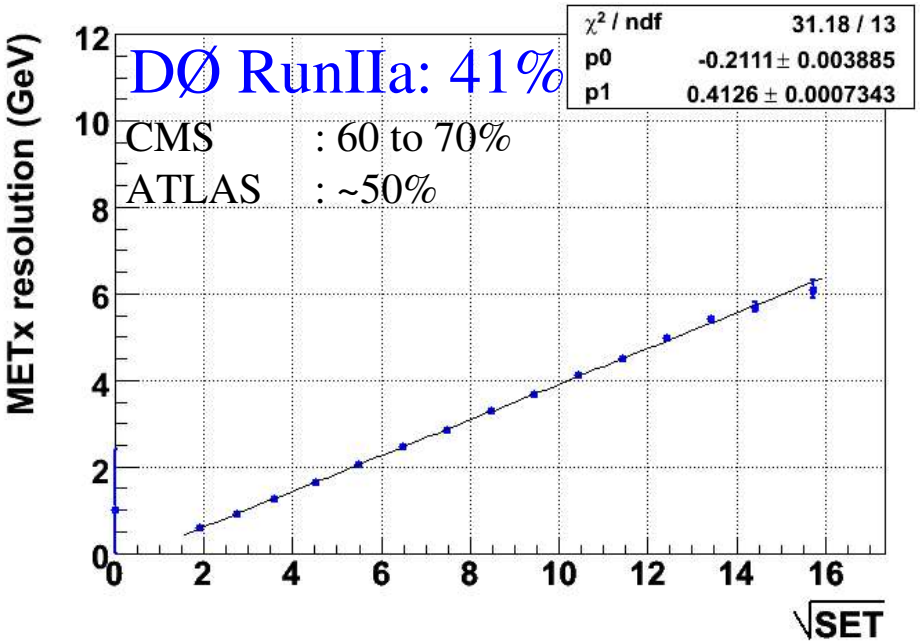


- We are already at high luminosity :
  - The RunIIb goal is to reach 300E30 cm^2s^{-1}
  - at this instantaneous luminosity, the average number of interaction per beam crossing is ~10 (beam crossing time = 396 ns)
  - Large effects on calorimeter object reconstruction



Missing ET resolution in min bias events



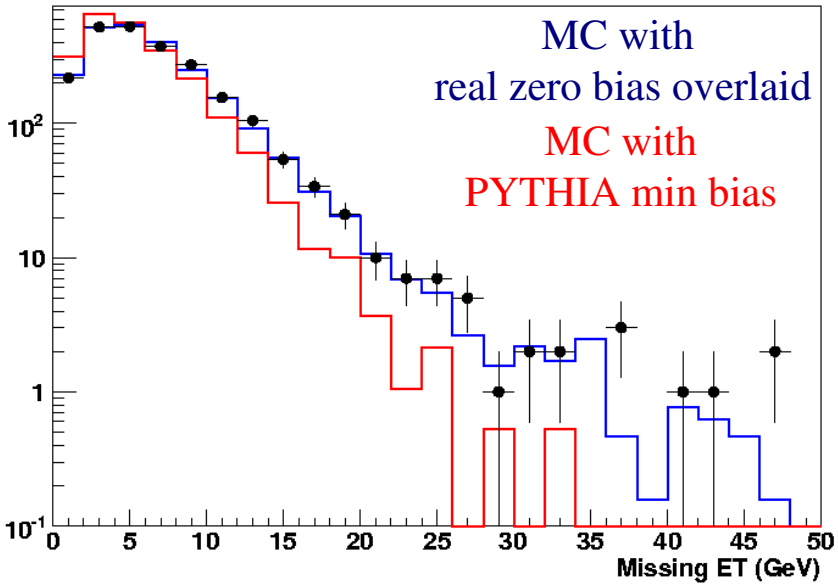


- zero bias and min bias events are very useful to understand the detector performance, the effect of zero suppression or other high level zero suppression (we use in DØ a neighboring algorithm “a la H1”). Those studies have to be done as soon as possible
- We expect a linear relation between the METx,y resolutions and sqrt(SET)
- This is the case, and the MET resolutions are good, after 4/5 years spent :
  - to understand the noise (internal and external) and non linearities in the calorimeter electronic
  - developing noise suppression algorithm
  - to calibrate the EM and HAD parts of the calorimeter
  - understanding the amount of dead material in front of the calorimeter
  - reprocessing the data
- MET resolution in min bias event is good : 41%
- On average, ~20 GeV of Scalar ET per reconstructed primary vertex
- @ high instantaneous luminosity: we start to have events with more energy in the calorimeter due to additional interactions than due to the hard process (even for a ttbar pair)

Underlying interactions and MC

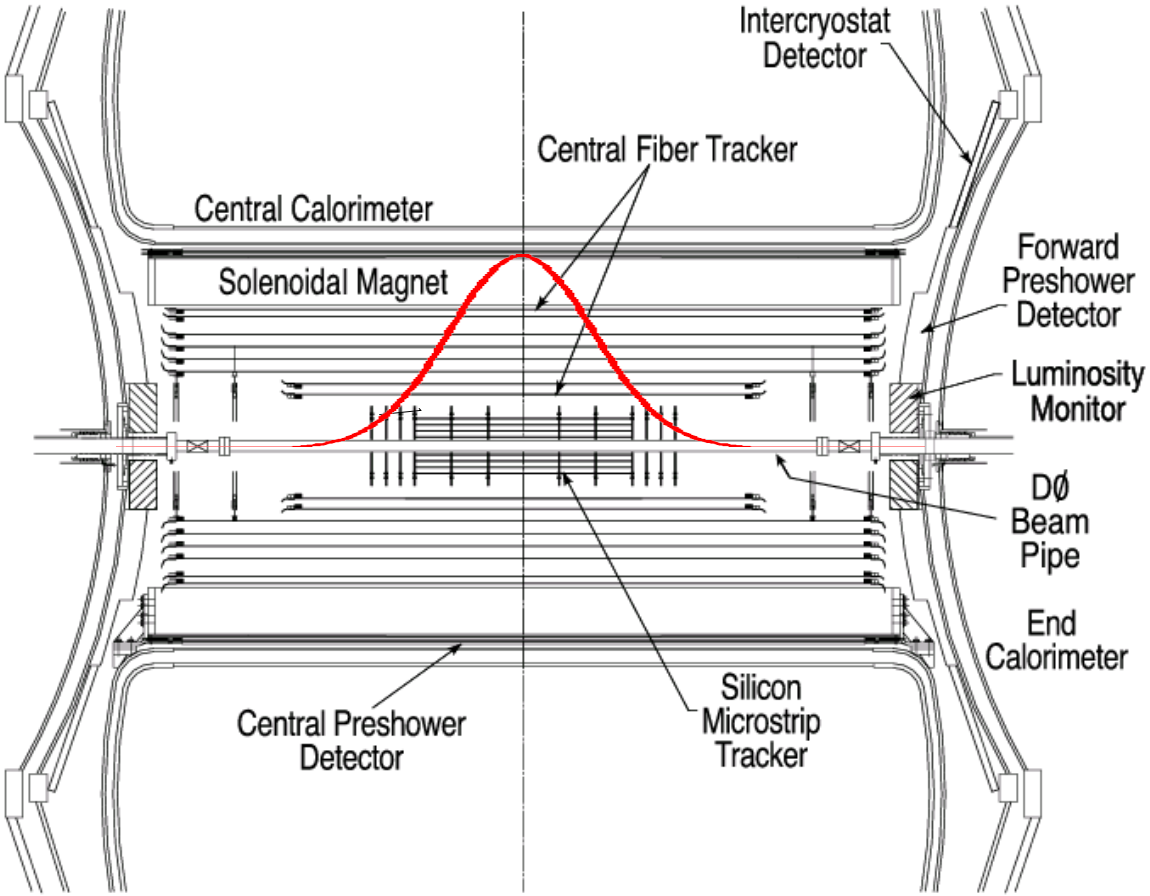
- In DØ, PYTHIA modeling of underlying events was not satisfactory :
  - The MET tail in topology without real MET was not correctly reproduced
- The decision has been taken to overlay in the MC real zero bias events recorded by DØ
- A much better agreement is observed between data and MC (example here for Z->ee events)
- But, it is technically complicated to that properly:
  - We want to overlay unsuppressed zero bias events (particularly important for electrons). DØ is collecting 0-suppressed and unsuppressed zero bias events (for the calorimeter) all the time
  - Offsite MC farms must have a large sample of zero bias for MC production
  - The instantaneous luminosity profile of overlaid zero bias events must matched the one of the data sample we want to analyze

Z->ee: data vs MC

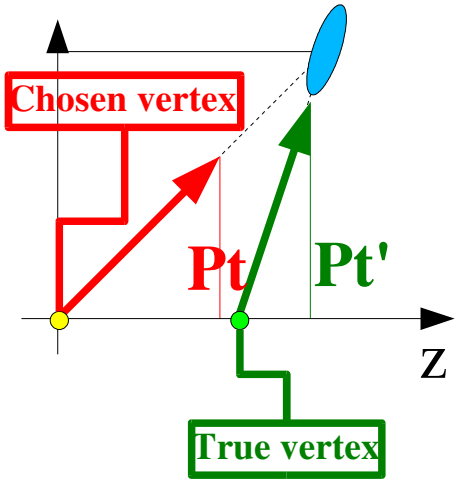


Its is particularly important to understand correctly the MET tail in Z->ll events for tt->blνblν

Mis-vertexing

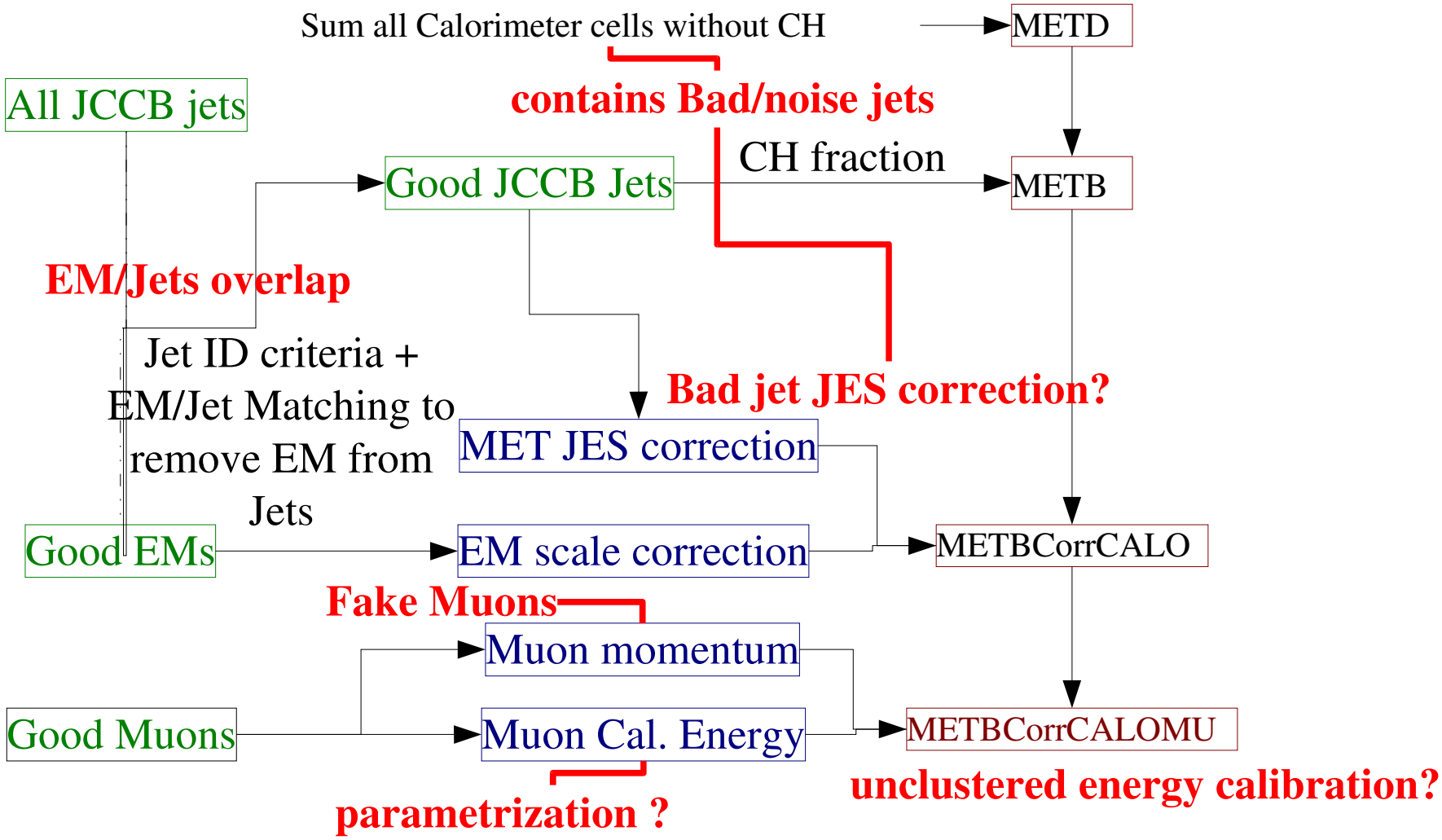


At the Tevatron, the gaussian width of the interaction region is ~23 cm. Jets, electrons, missing ET reconstruction is done with respect to THE best primary vertex. If the wrong vertex is chosen, the bias can be very large. This effect is often the main source of QCD background in physics analyses



- <u>Develop "Jet track confirmation" algorithms (which are also a vertex confirmation). And then, there are two strategies :</u>
  - Reject events with identified mis-vertexing (=> determine carefully the inefficiency)
  - Re-vertexing of all objects: Jets/EMs and MET => For MET, we need to compute the missing ET in phi rings wrt PV=(0,0,0)

Missing ET Corrections (I)



- Very easy to create fake MET. Example:
  - dijet event with a leading pi0 in only one jet and you apply EM scale correction on jet1, and JES correction on jet2
- The best MET you want is from a full Eflow algorithm

Missing ET Corrections (II)

$$Enew = \frac{(E - Off)}{R * Sh}$$

$$Ecalnew = \frac{(E - Off)}{Sh}$$

$$Delta\ Et = \frac{(Ecalnew - Enew)}{\cosh(eta)}$$

- <u>MET_JES correction :</u>
  - In DØ, JES is obtained from photon+jet events using the MPF method. There are 3 corrections:
    - Response (R)
    - Showering (Sh)
    - Offset (Off)
  - For the missing ET JES correction, we only want to propagate the response
    - Delta Et is the Et increment to be added vectorially to event missing Et in the direction of jet
  - By the way : for JES determination, we need the MET corrected only for the photon energy scale (and not the JES).

- Propagating EM scale and JES to MET improves the MET resolution, especially because the JES takes into account all remaining detector non-uniformities

- <u>Known problems:</u>
  - There is a cut of on uncorrected jet pT (6 GeV in DØ)
  - JES is valid above a pT threshold and below an eta threshold
  - If the EM scale and JES corrections are large, this creates discontinuities in the missing ET distribution

MET for top measurements

- MET is used in the observable for top properties measurement :

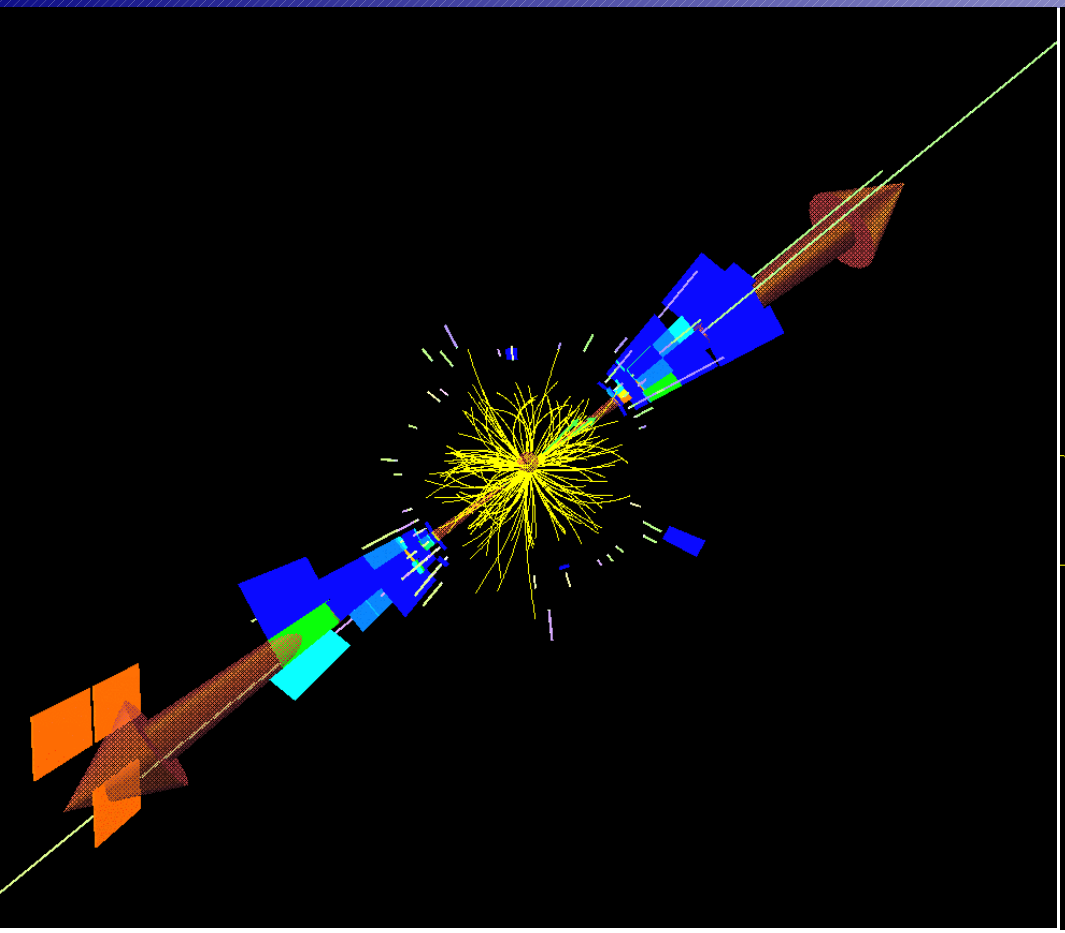
Example: the neutrino weighting method

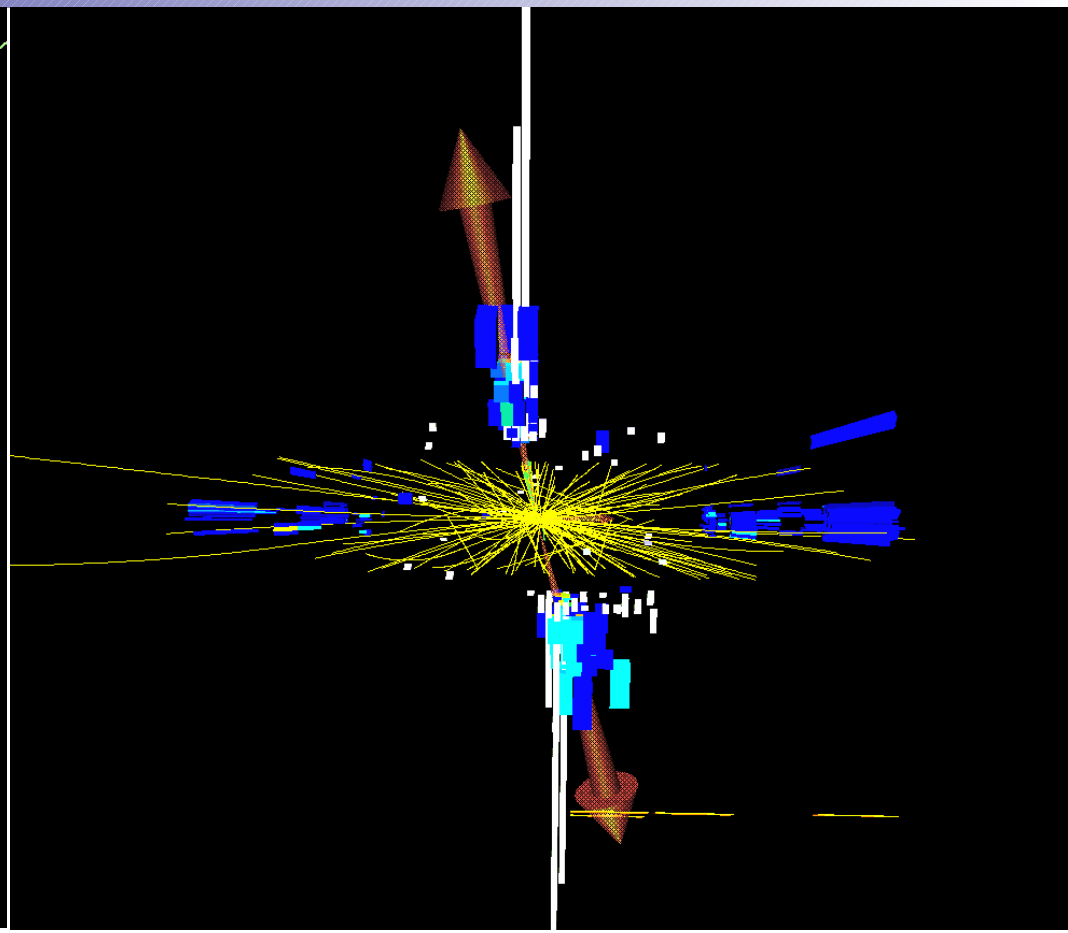
$$w = \frac{1}{Niter} \sum_{Niter}^{i=1} e^{\frac{-(E_{x,i}^{calc} - E_x^{obs})}{2\sigma_{METx}^2}} e^{\frac{-(E_{y,i}^{calc} - E_y^{obs})}{2\sigma_{METy}^2}}$$

- Which MET resolution do you need in this formula:
  - The missing ET resolution of the event (which include jet/EM resolutions) ?
  - The missing ET resolution of the unclustered energy ?
- How to assign a systematic uncertainty on the measured top mass due to the MET resolution ?

- Missing ET is a variable highly correlated with the neutrino transverse energy, but you have several other things which enters into the missing ET:
  - Noise (internal and external)
  - pileup (study the random influence of pileup on top measurements: mass, cross sections)
  - vertex
- And which can modify its reconstruction:
  - e/p response
  - cracks
  - amount of material in front of the calorimeter
- A model of unclustered energy for top mass measurement is needed. Look how the W mass is measured

QCD event





- Dijet mass = 1.2 TeV

	E	Pt	eta	phi
jet 1	627.	613.7	-0.189	0.649
jet 2	636.	614.0	0.249	3.781
jet 3	23.	15.9	0.450	1.655

- MET = 6.9 GeV !!!

We would like to, but the MET resolution is not as good as that in DØ !