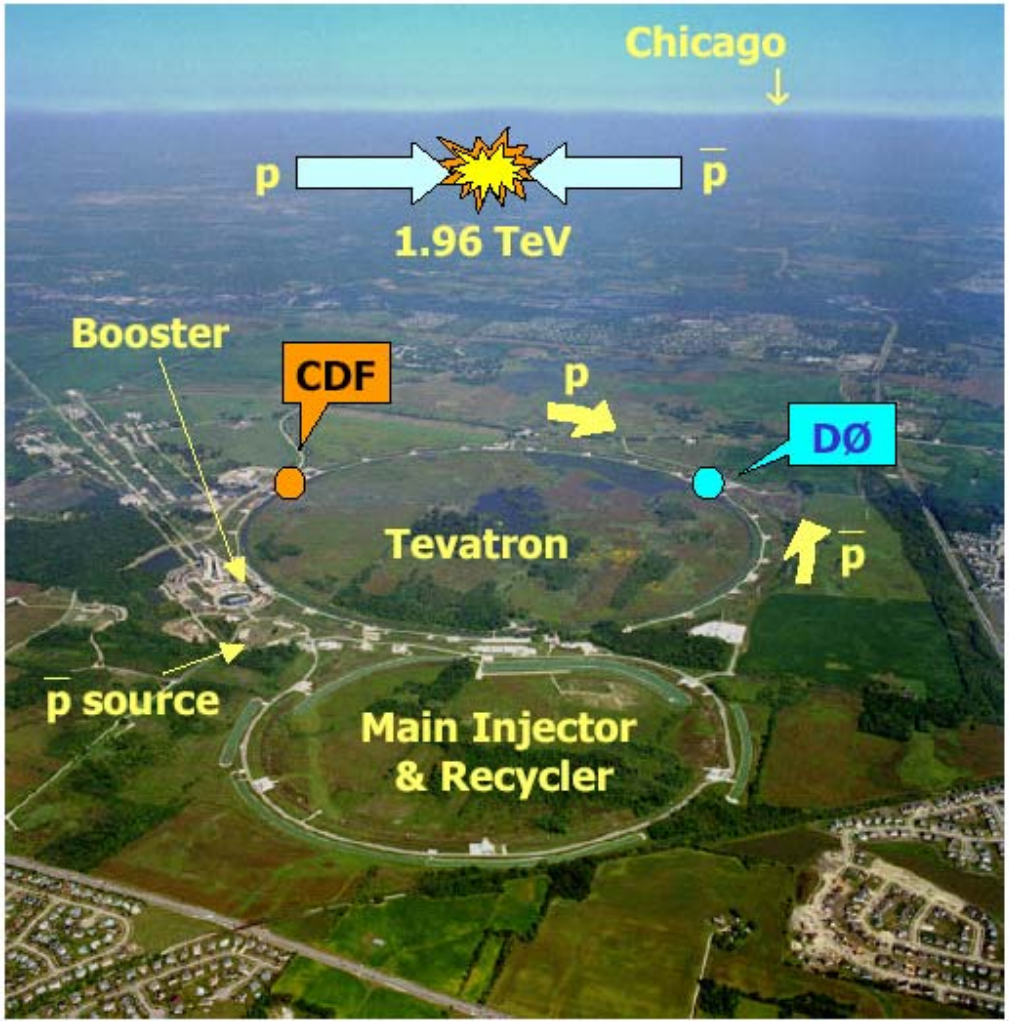
Lepton ID at the Tevatron



For the CDF and D0 Collaboration

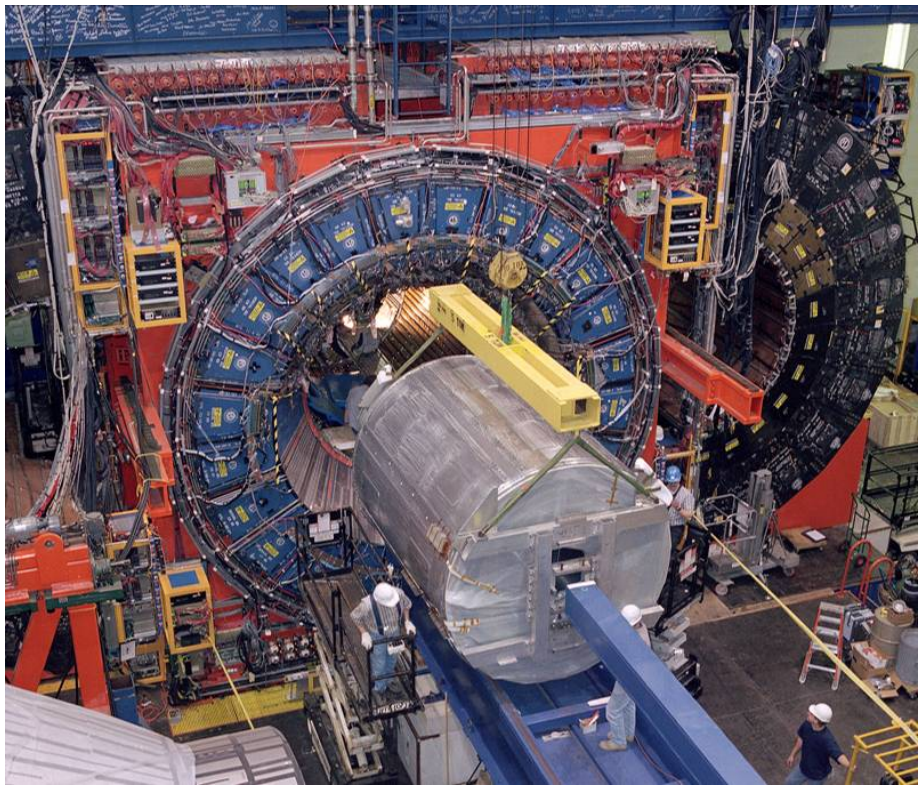
Xiaojian Zhang
University of Illinois,
Urbana-Champaign

Outline

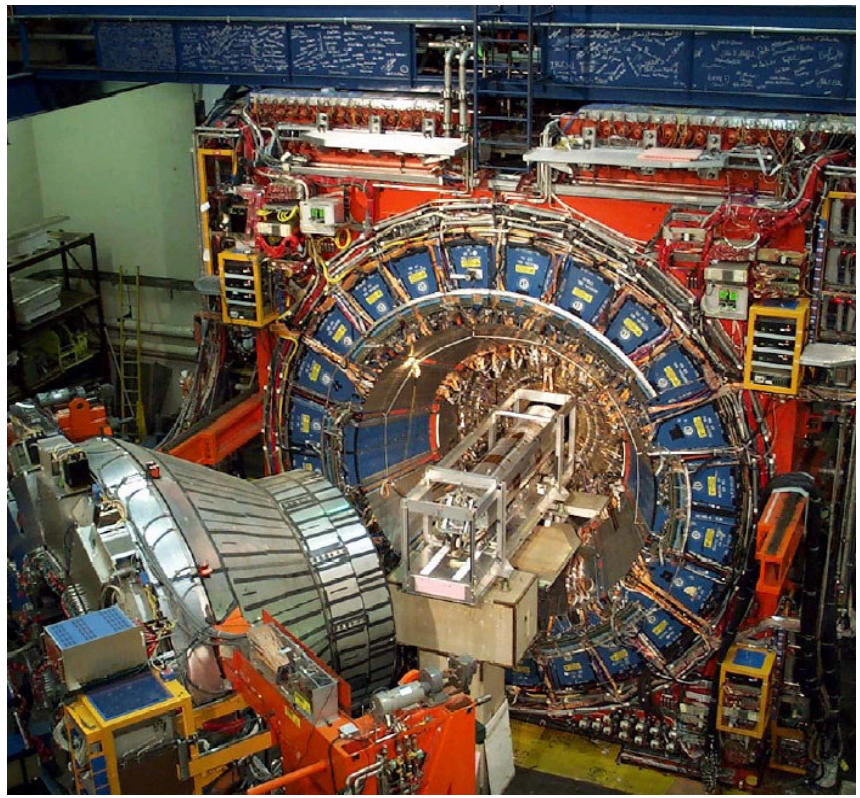
1. CDF & D0 Detectors
2. Lepton Identification
3. Lepton ID efficiency
4. Lepton Fake Rate
5. Detector Calibration
6. Conclusion

Detector pictures

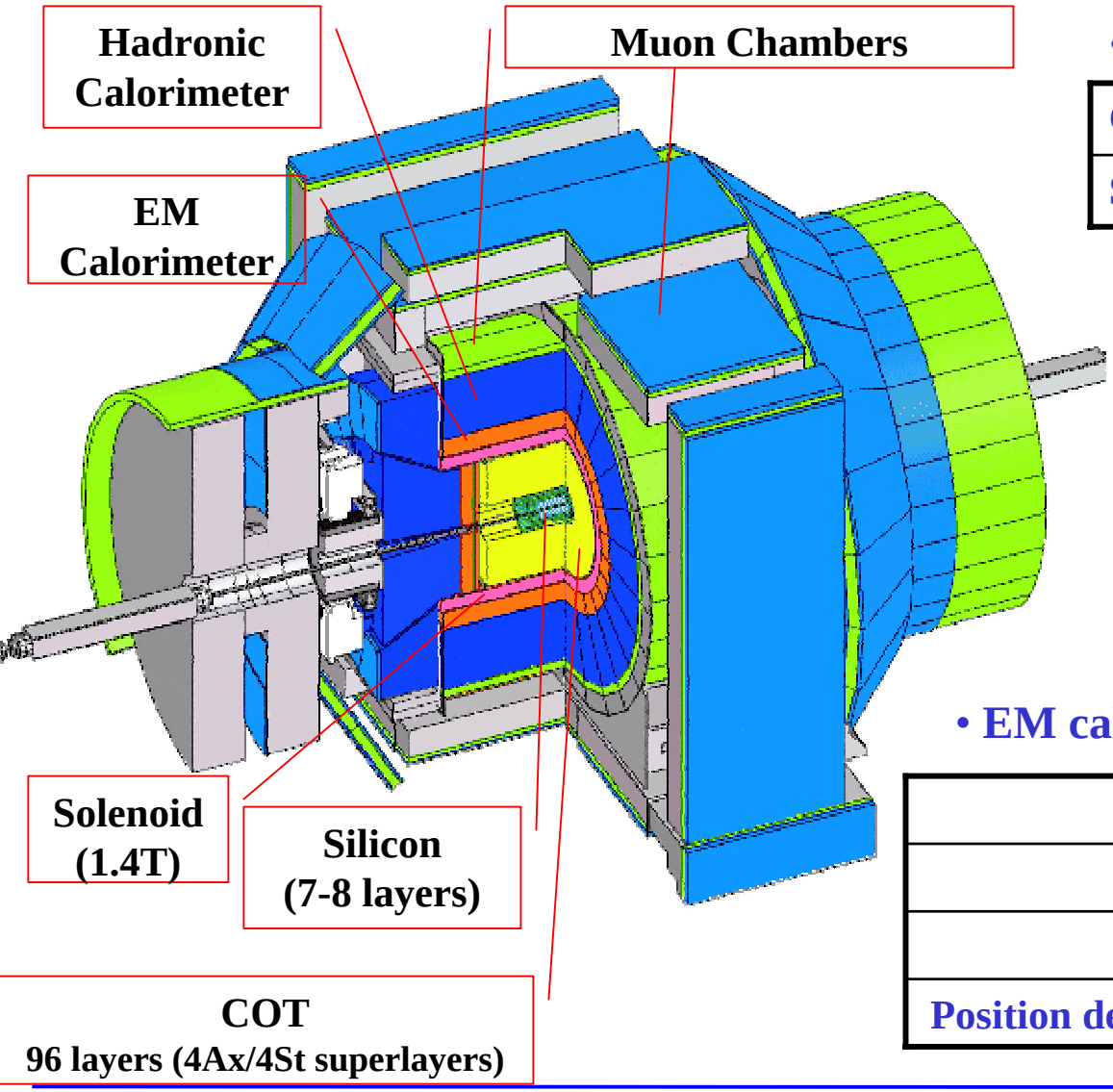
CDF



D0



CDF detector



- **Tracking system**

Central tracker	$\lvert\eta\rvert \le 1.0$, R ~1.4m
Si tracker	$\lvert\eta\rvert \le 2.0$

$$\eta = -\ln(\tan\frac{\theta}{2})$$

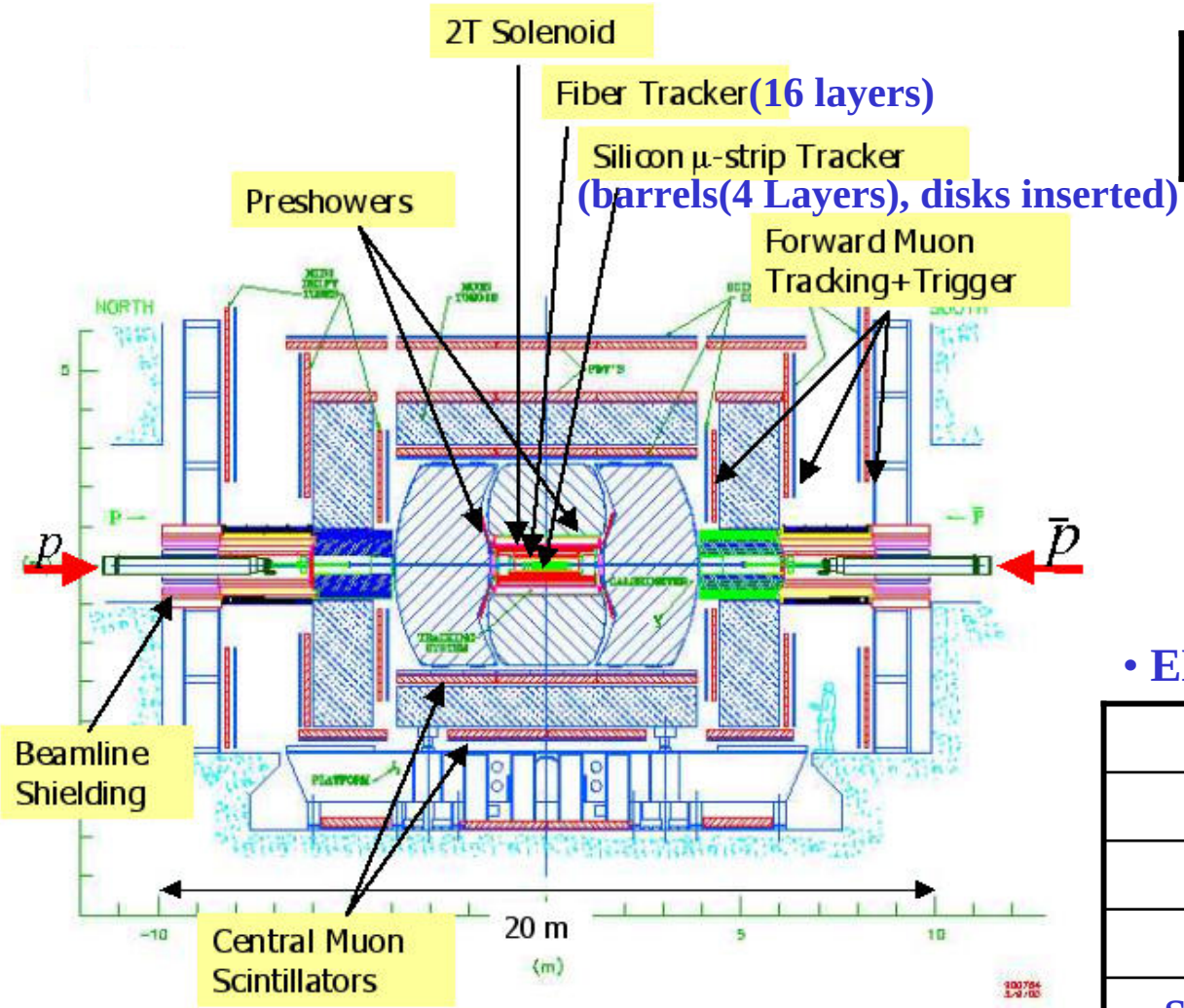
- **Muon system**

Drift chamber/ Scintillator
$\lvert\eta\rvert \le 1.5$ (CMU/CMP, CMX, BMU)
# of layers: 4/4, 8, 4

- **EM calorimeter**

Scintillator/lead
$0.11\times0.26(\eta\times\phi)$
~20 radiation length
Position detector(Strip and wires) at shower max

D0 detector



- **Tracking system**

Central tracker	$\lvert\eta\rvert \leq 1.7$, R ~0.5m
Si tracker	$\lvert\eta\rvert \leq 3.0$

- **Muon system**

Drift tube/ Scintillator
$\lvert\eta\rvert \leq 2$ (central, forward)
3 layers of tubes(3-4 planes/layer)
Toroid between layer 1 and 2

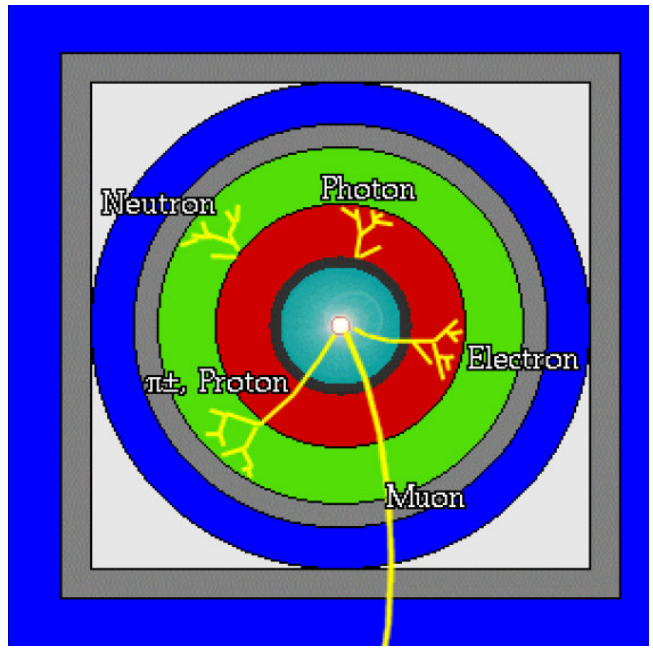
- **EM calorimeter**

Liquid Argon/Uranium
0.1×0.1 ($\eta\times\phi$)
~20 radiation length
Preshow: Scintillating strips
Shower max:3rd layer (0.05×0.05)

Identify leptons

- Extremely important for the Tevatron experiments
  - ✓ used in most analysis: top, EWK, Higgs, New Physics
- Identified by using the interaction with materials

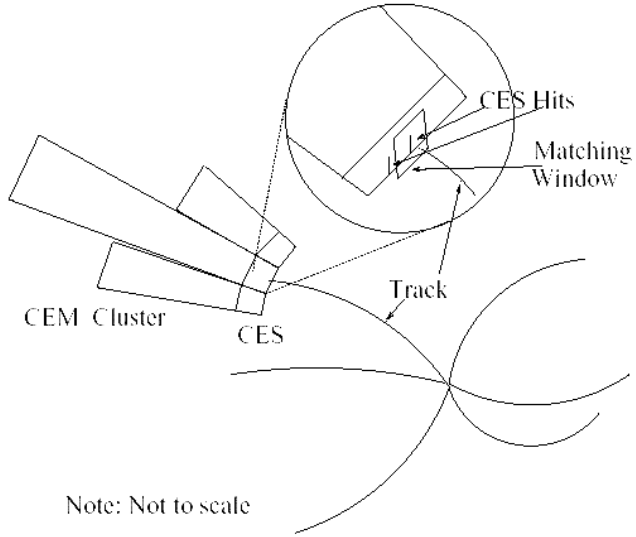
	Characteristics	property
Electron	Mainly bremsstrahlung	Calorimeter cluster+tracking
Muon	Minimum E loss	Muon stub hits+tracking
photon	E loss though conversion	Calorimeter cluster+No track matching

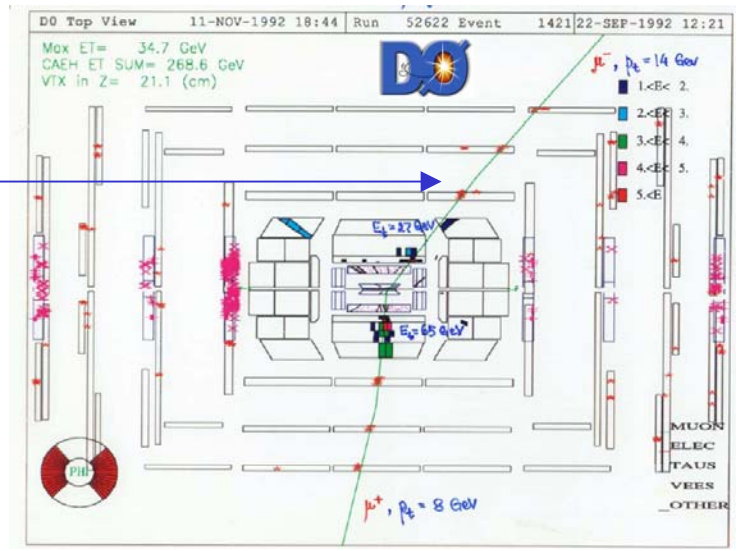


- <u>Goal</u>
  - High ID efficiency
    - ✓Get more events of interests.
  - Low fake rate
    - ✓ Improve the sensitivity of findings.

Lepton Reconstruction

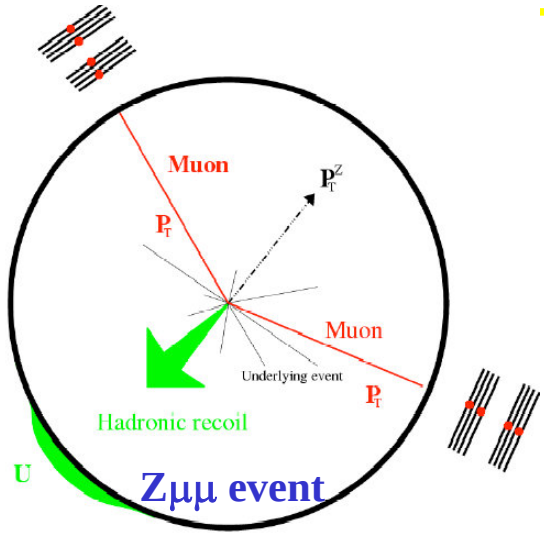
- Electron
  - ✓ Cluster towers
  - ✓ Extrapolate track to the cluster
    - ✓ Reverse order in FWD region
  - ✓ Apply ID cuts (discussed next…)
- Muon
  - Muon stub
  - CDF:
    - ➢ CMUP(CMU&CMP), CMX, BMU
  - D0:
    - ➢ Tight, medium, loose muon
    - ➢ Measure local muon pT
  - Match to track (3D)
- Photon
  - same as electron but vetoing associated track

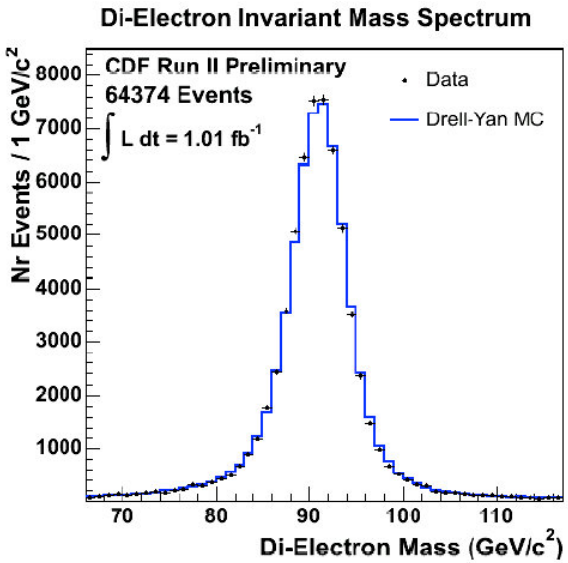




Measure the ID efficiencies

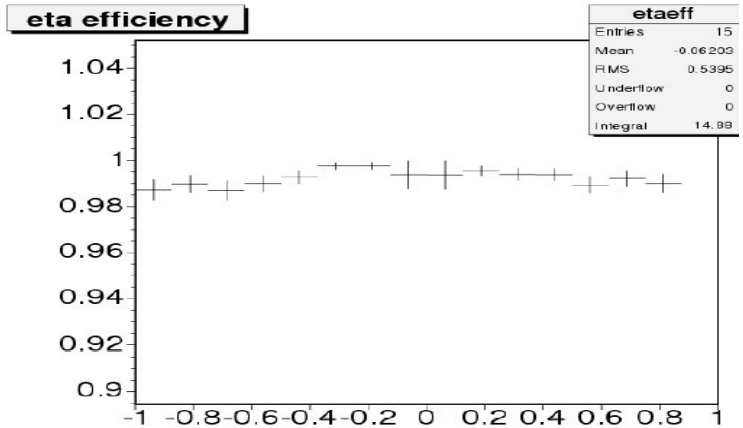
- **Resonance samples** (decay to di-e, di-μ)
  - Z, Upsilon, Jpsi provide ID ε vs a full range of Et/pt
  - Put "tight" cut on the triggered leg
  - Use the other leg as a probe (apply ID cuts)
- **DY process**
  - important to isolation cut study
- **Backgrounds**
  - Backgrounds under mass peak
  - bbbar, ccbar, jet fakes in DY
  - Remove converted electrons
- **Special treatment for photon**

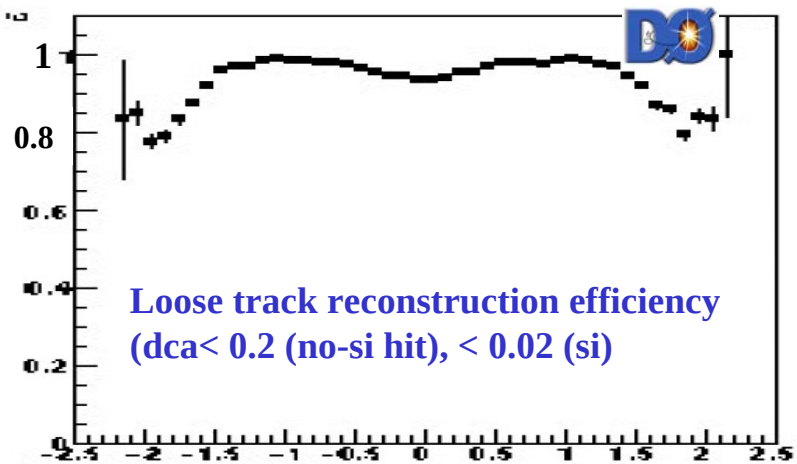




ID requirements

- **Basic cut:**
  - Fiducial
  - Muon: impact parameter, cosmic veto
  - Eletron: conversion removal
- **Isolation cut**
  - ✓CDF: ET(R<0.4)/Et(l)
  - ✓D0: ET(R=0.2-0.4)/ET(R<0.4)
  - ✓Very good at electron fake from jets
- **ID cuts**
  - ✓Muon
    - ✓Calorimeter Energy deposition (EM,HAD)
    - ✓Track matching variable 3D (Δx, Δ z)
  - ✓ Eletron
    - ✓Ratio of E_{EM} and E_{HAD}
    - ✓Shower shape
    - ✓ Track matching
    - ✓ E/P





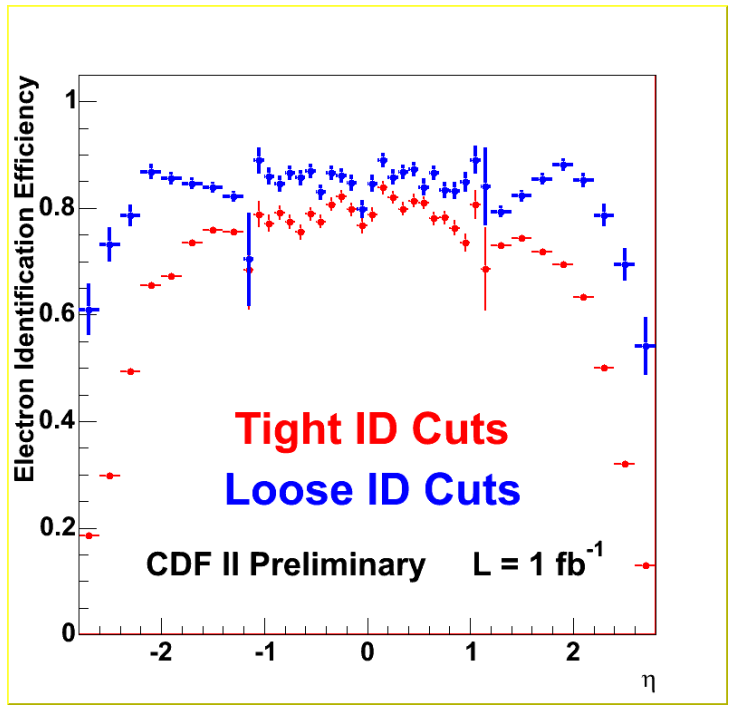
Loose track reconstruction efficiency (dca< 0.2 (no-si hit), < 0.02 (si)

Physics η

Detail of the ID efficiencies next…

High PT electron ID Efficiency (I)

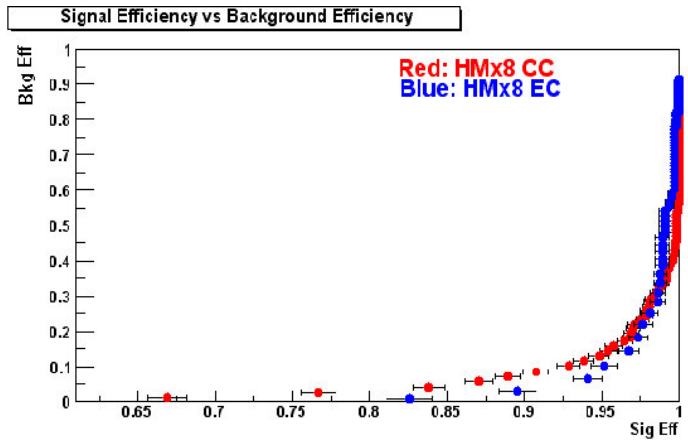
- Zee events from high pt e triggered dataset (Et > 18 GeV)
- Tight ID cuts at CDF
  - ✓ Iso ≤ 0.1
  - ✓ E_{HAD}/E_{EM} : <0.055+(0.00045×E)
  - ✓ Lshr ≤ 0.2
  - ✓ E/P: ≤ 2 (pT<50 GeV)
  - ✓ Track matching (ΔX*q, ΔZ)
  - ✓ Conversion veto
- Background subtractions
  - ✓ Same sign method in central region
  - ✓ Side band method in forward region
    - ✓ due to large charge fake rate

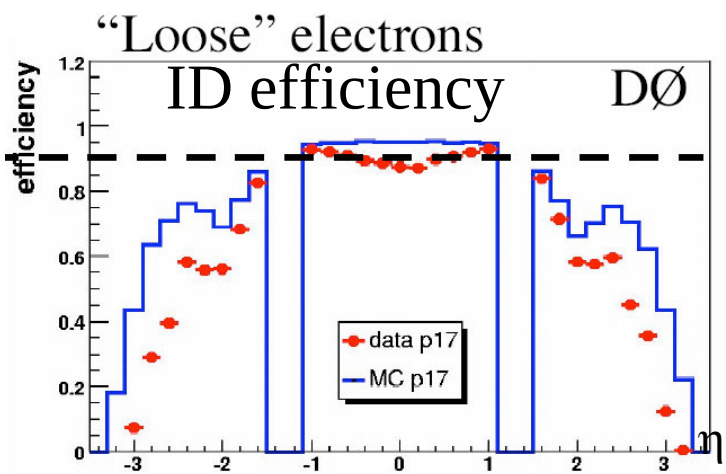


High PT Electron ID Efficiency (II)

- **Likelihood method at D0**
  - Replaces previous track matching method
  - To take advantage of more pieces of information
- **Pre-selection**
  - EM cluster (R =0.2)
  - Iso < 0.15
- **Parameters in likelihood function**
  - EM-track matching χ^2 (3D)
  - H-Matrix: (longitudinal & lateral shape)

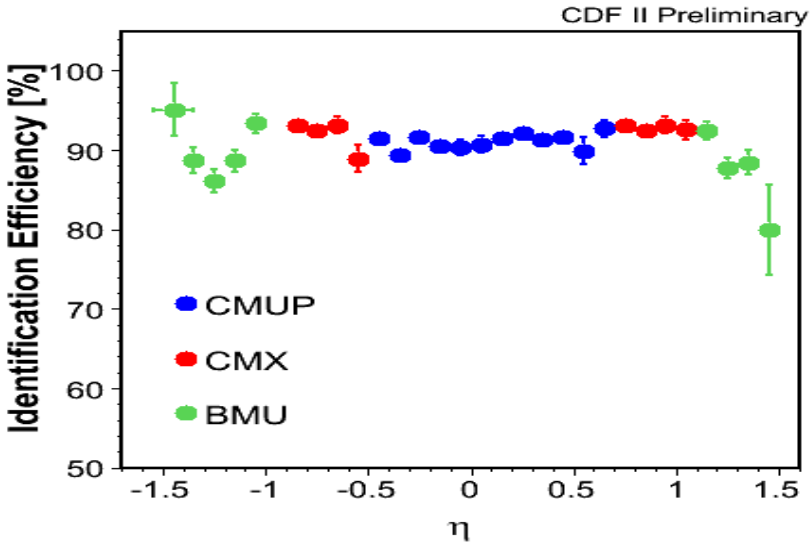
    χ^2 based on 8 parameters
  - f_EM
  - ET/pT
  - Distance Closest Approach
  - Distance in R to second closest track to cluster.
- **Other advanced technique:**
  - Neural Network: fairly confident of control samples

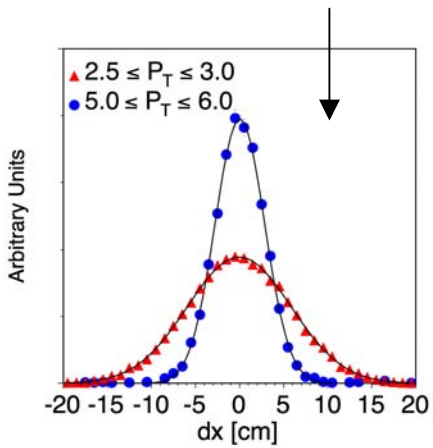




High PT Muon ID

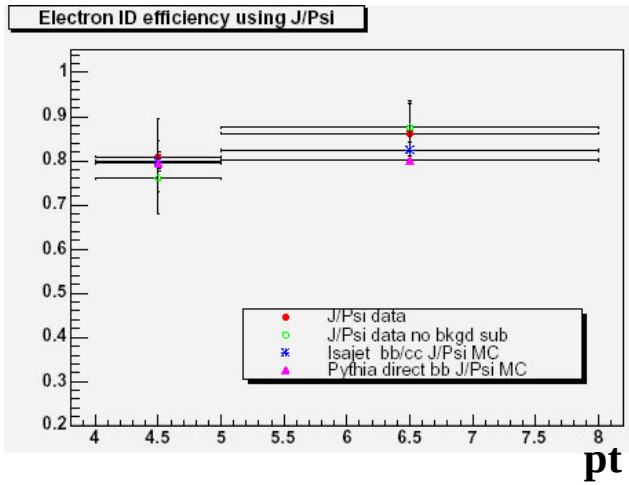
- Zμμ events from high pT μ triggered sample
  - Very pure sample
  - No bgd subtraction needed
- ID cuts
  - Iso < 0.1 (better to be pT dependent)
  - E_{EM} < 2+max(0,(p-100)*0.0115)
  - E_{HAD} < 6+max(0,(p-100)*0.0115)
  - Matching to track:

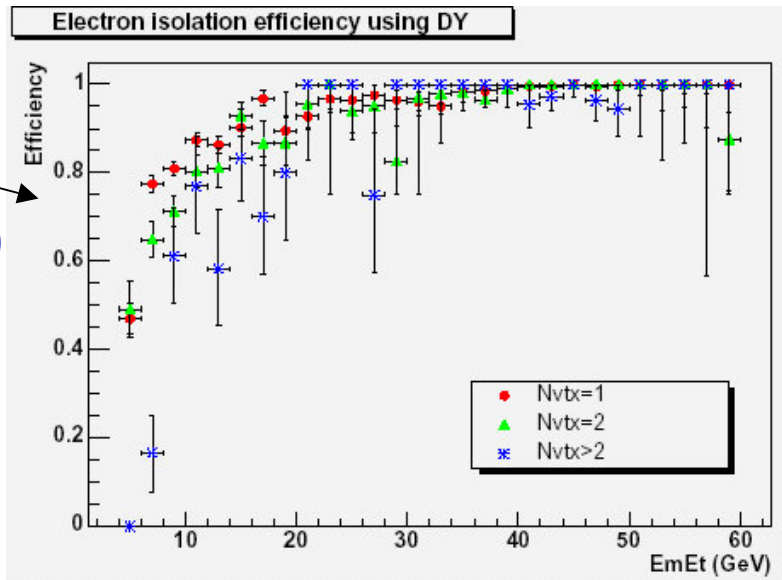




Low and Medium ET Electron ID

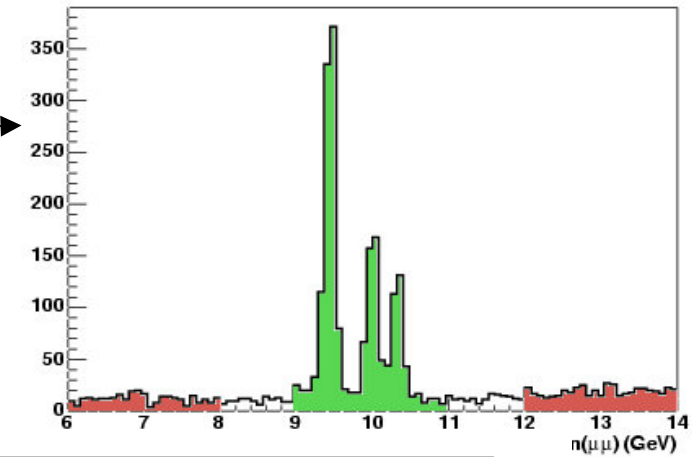
- **Similar cuts as high Et electron**
- **ID efficiency**
  - Inclusive 8 GeV eletrons data
  - Reconstruct Jpsi (clean signal)
    - Background subtraction (conversion, SS)
    - Boosted jpsi, not good for iso eff. study
- **Isolation efficiency**
  - Di-electron triggered data
  - Select DY events, cut on
    - Mee : always from resonance peak
    - dphi: separated di-electrons
  - SS method to subtract background (bbbar, ccbar, etc)
  - One probe leg, the tag leg passes all ID cuts.

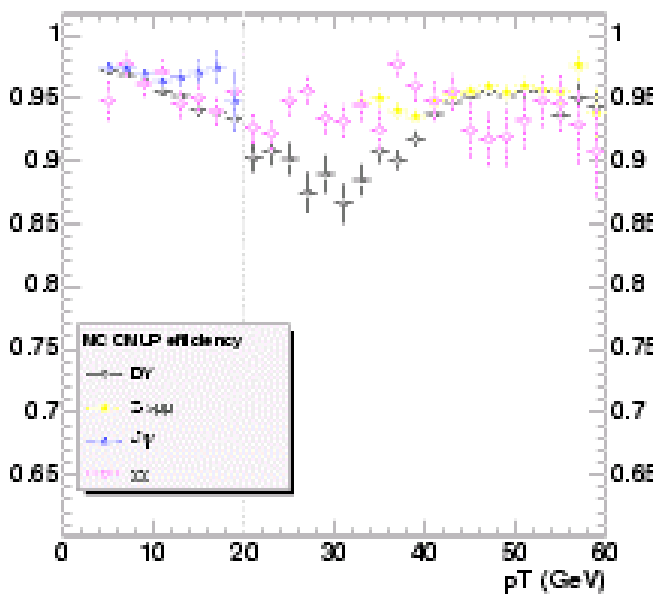


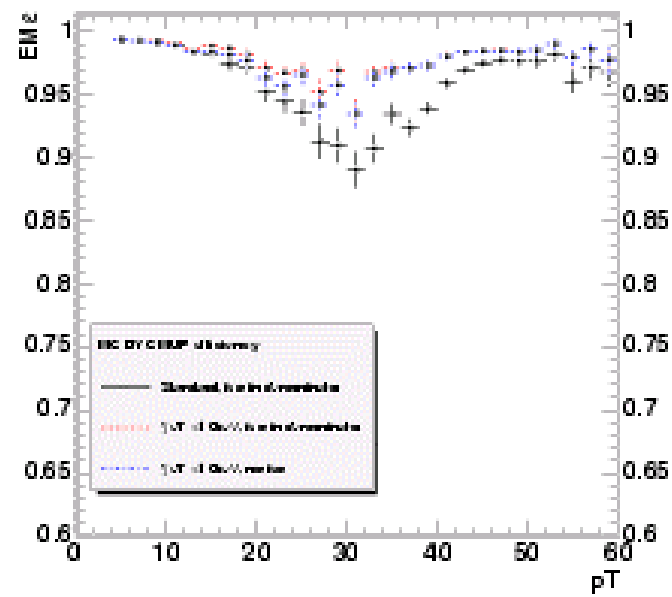


Low and Medium PT Muon ID

- **Similar approach as done in the electron part**
  - **upsilon events help too**
- **different ID cut values from high pT mu**
  - **Had_E < 3.5+pT/8**
  - **EM_E < 2**

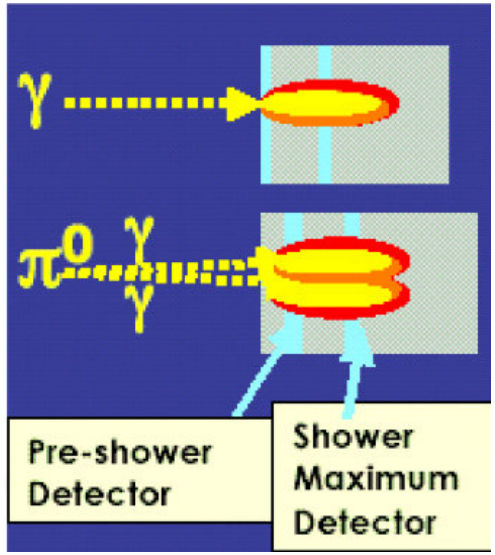




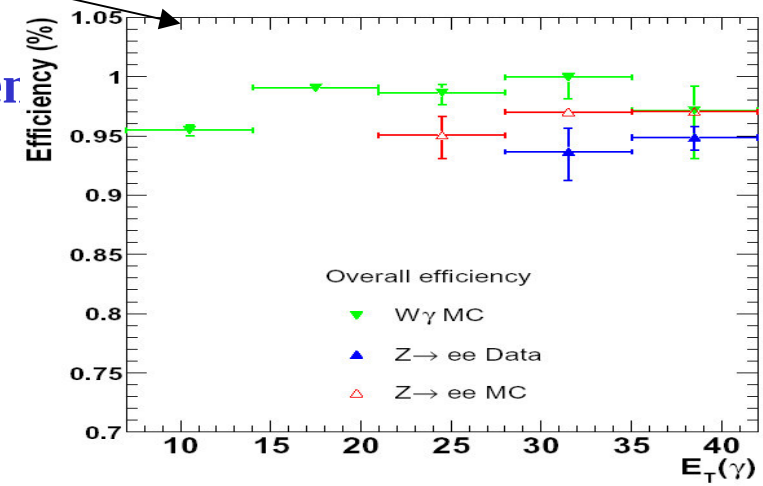


Photon ID

- **ID efficiency**
  - ✓ Strategy: use e to simulate photon
  - ✓ E_{HAD}/E_{EM} : same as electron ID cut
  - ✓ N3D ≤ 1 (if N3D =1, pT<1+0.005*Et)
  - ✓ sum of track pT < 2+0.005*Et (0.4 cone)
  - ✓ cut on 2nd CES cluster energy
  - ✓ Many samples available in data
    - ✓ conversion : medium pT
    - ✓ Zee : high pT

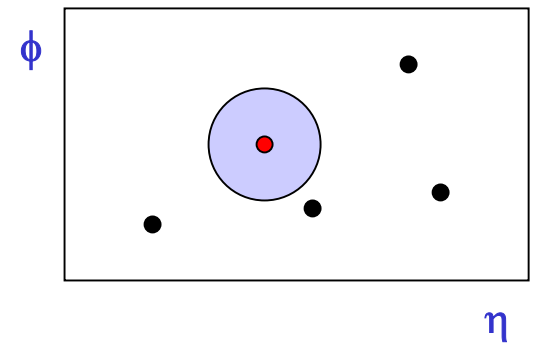


- **Isolation efficiency needs special treatmen**
  - ✓ Discussed in next slide…

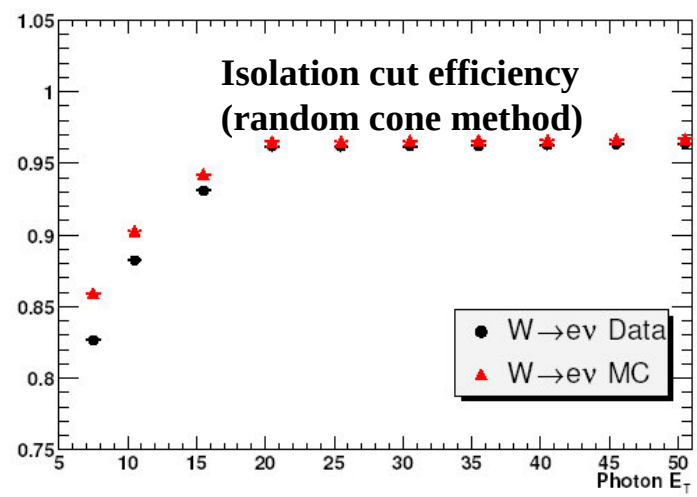


Photon Isolation Efficiency

- No ideal resonance sample available
  - ✓ $\pi 0$, eta -> $\gamma\ \gamma$ are not good
    - ✓ soft photons
    - ✓ or di-photon two close to each other.
- Hard to get pure photon sample
  - ✓ has iso pre-requirement



- One approach used at CDF:
  - ✓ "Random Cone Method"
  - ✓ Throw random cone in η-ϕ space in an event
  - ✓ assume a virtual γ in the cone
  - ✓ randomly assign Et to the virtual photon
  - ✓ Apply isolation cut to the cone
    - o Et_cone/Et_photon < 0.1
  - ✓ Measured in Wenu, minbias, jet20 sample.

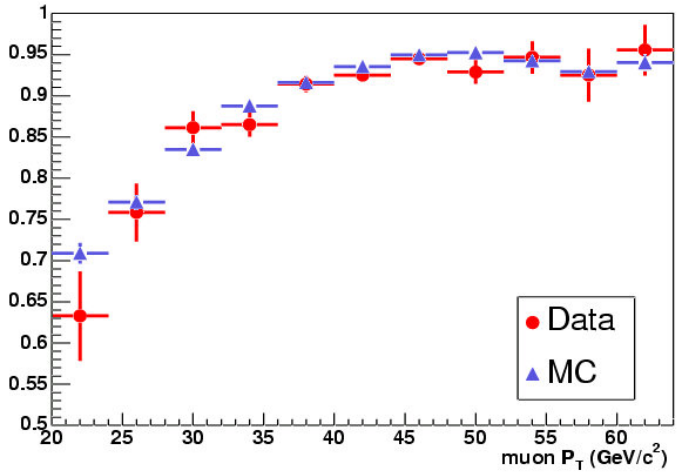


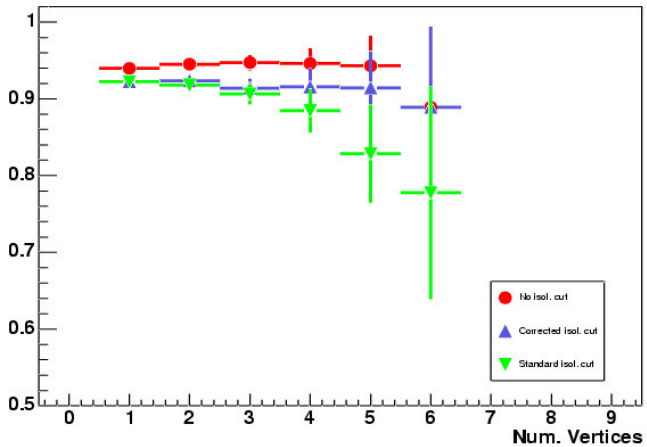
Efficiency dependence

- **Dependence on**
  - **pt, phi**
  - **Eta (cause by tracking efficiency)**
  - **luminosity**
    - **More Z vtx at higher luminosity**
    - **Worse isolation efficiency**
- **Corrections:**
  - **CDF is studying the corrected isolation cut**

$$(E_T^{isol.} - 0.35 \cdot (N_{vtx} - 1))/P_T < 0.1$$

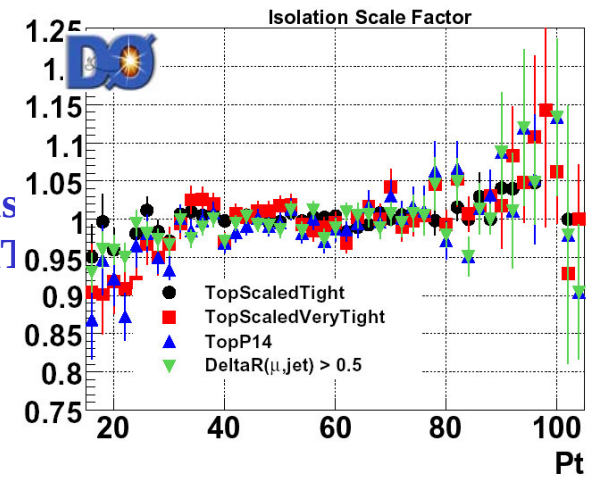
  - **Provide fitting function and convolute**

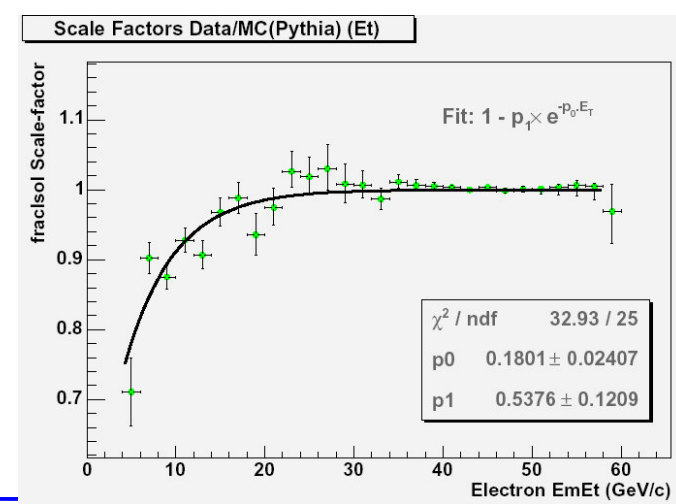




Scale Factors

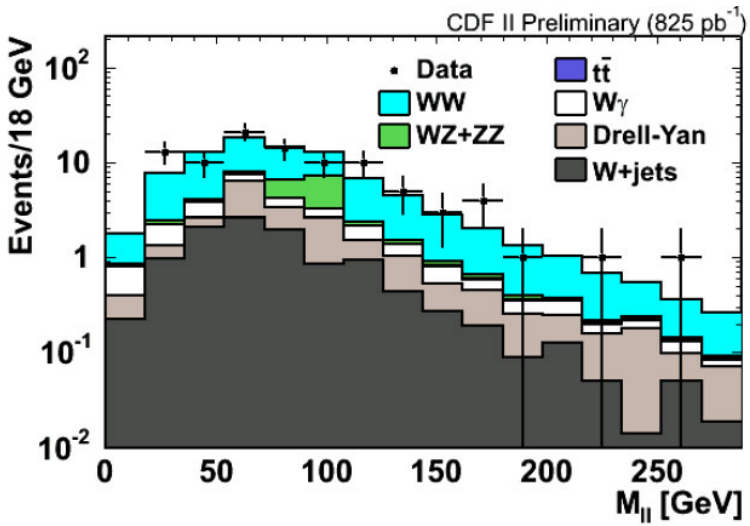
- **Scale factor: $S = \varepsilon_{DATA}/\varepsilon_{MC}$**
  - The detector simulation is never perfect
  - Increase of broken channels as the experiments proceed
  - Gain, timing shifts in electronics (monitoring them discus
  - Take into account of the difference between MC and DAT
- **Apply to MC prediction**
  - Corrected acceptance: Acc_MC*S
  - Correct the predicted backgrounds from MC
  - dependence on Et, eta
    - provide fit function and convolute
- **The error of the Scale factor propagate to the final measurement.**
  - error on the scale factor enters final analysis result,
  - e.g. 6-8% in ttbar cross-section





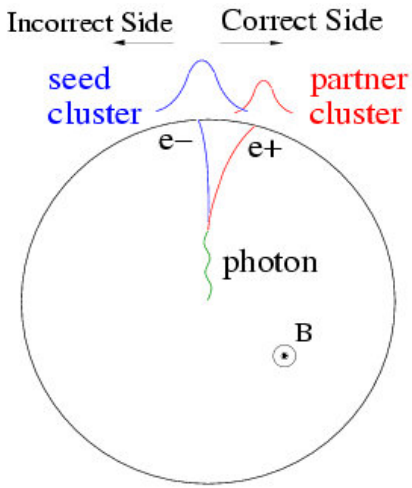
Fake Electron/Muon

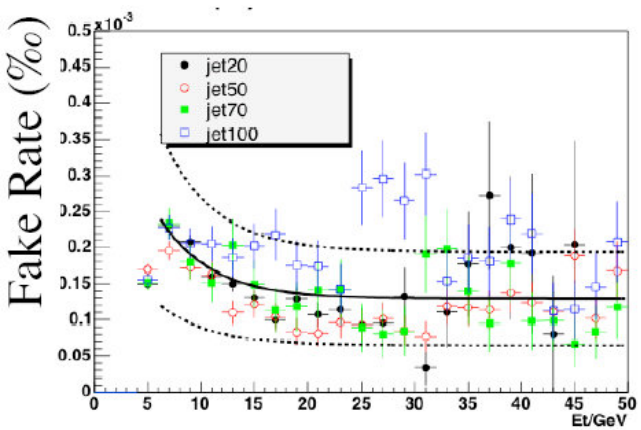
- **Main source of background for low energy leptons**
  - ✓Jets can fake leptons (large cross-section!)
    - ✓e: jets containing pion/eta/kaon
    - ✓muon: penetration, decay in flight, detector cracks
  - ✓Semileptonic decay form heavy flavor events
  - ✓Conversion, penetration, DIF, etc.
- **Lower fake rate lead to precision measurement**
  - •Major systematic error in WW cross-section
    - •5.5% systematic error (out of 8.0% in acceptance)
  - •5% systematic error in SUSY trilepton search



Fake Electron

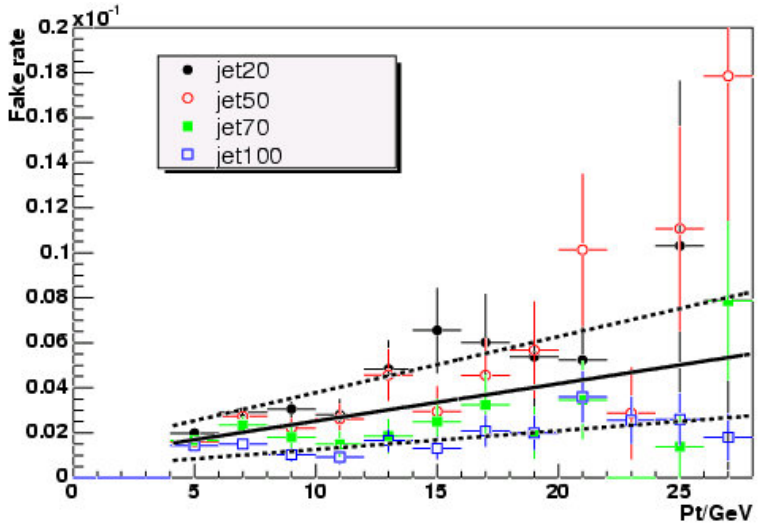
- **Fake definition**
  - fake rate per jet
  - measured in jet samples (j20, j50, etc)
  - denominator: # of jets (with Et/eta cut, depending on region.)
  - numerator: electron that passes lepton ID cuts (DR< 0.4)
  - ~1 in 10,000 tight jets
- **Identify conversion and removal**
  - CES cluster at "correct side", 2 phi wedge away
  - close distance between the two tracks in transverse plane
    - Dxy < 0.1/0.2 (tight/loose)
  - close distance in z of the two cluster
    - $\Delta\cot(\theta) < 0.02/0.04$
  - removal efficiency: ~70% - 85% depending on cuts

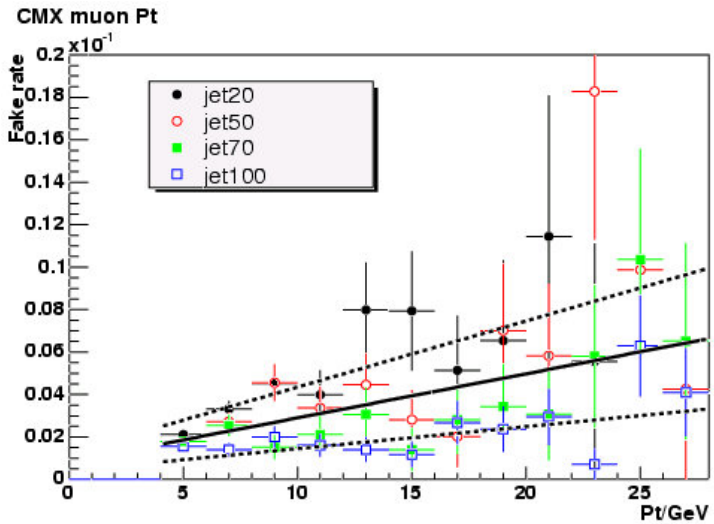




Fake Muon

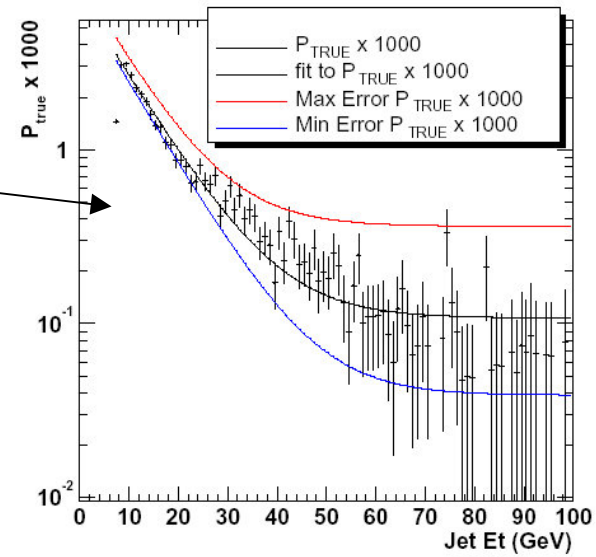
- **Measured in Jet sample**
  - Fake rate per track in the jet
  - ~ 2 per 1000 tracks.
- **Muon**
  - denominator:
    - Track passing quality cut.
    - Fiducial to sub-detector,
    - E/P < 1 remove e contamination, iso cut
  - Numerator
    - Muon stub matched to track

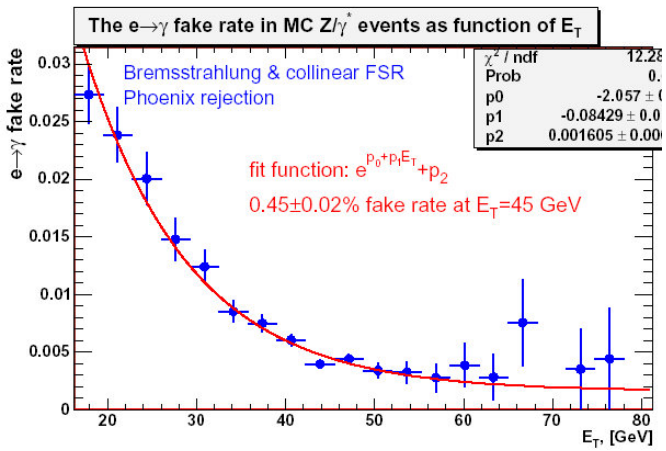


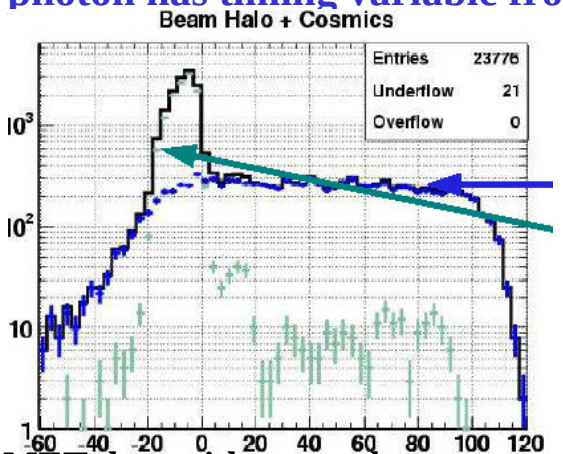


Fake Photon

- **Fake sources**
  - Jet fakes photon (per jet)
  - electron fakes photon
    - missing track, brems
  - from cosmic
  - beam halo dominate fakes in FDW region
- **Fake rate largely depends on Et**
  - Due to the sum trk pt cut
- **EM timing system**
  - reject cosmic and beam halo
  - real photon has timing variable from 0-20



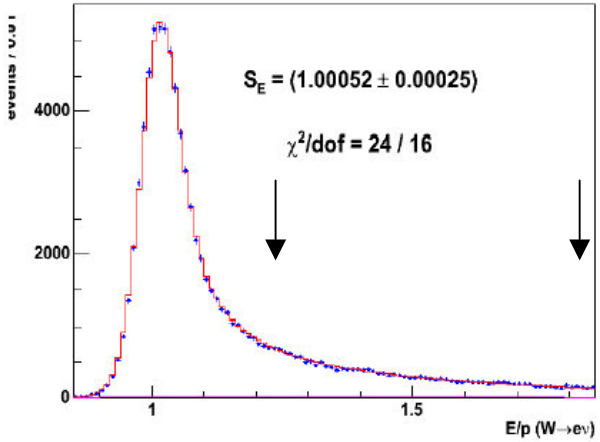


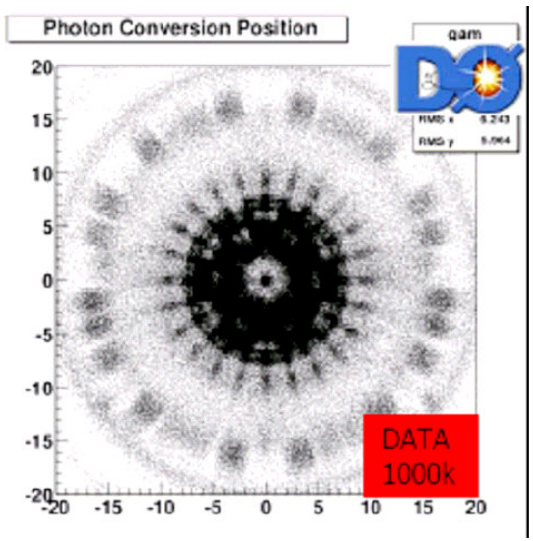


Photon+MET data with no tracks

Calibration

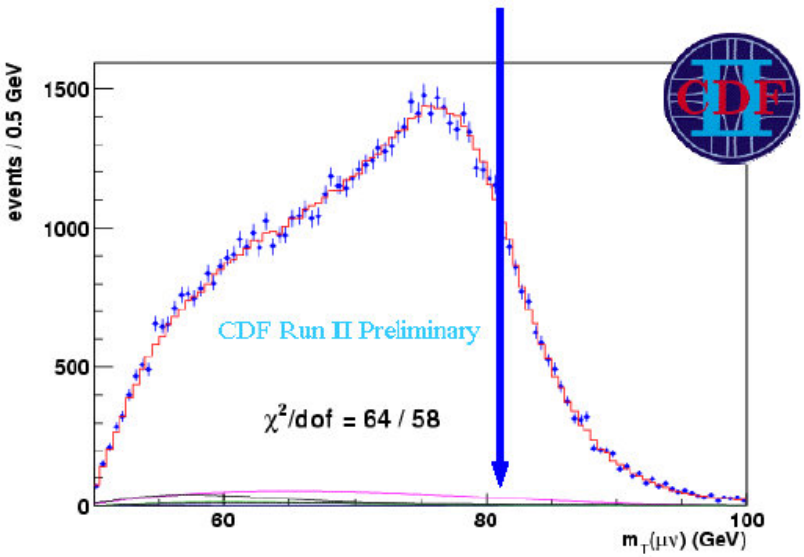
- **Momentum scale**
  - **Understand materials in tracking volume**
  - **Utilize radiative tail of E/P from electrons**
  - **Gives average material distribtion**
  - **Use muon track to estimate type of material**
  - **X-ray detector w/ gamma conversion**
- **Energy Calibration**
  - **next slide…**

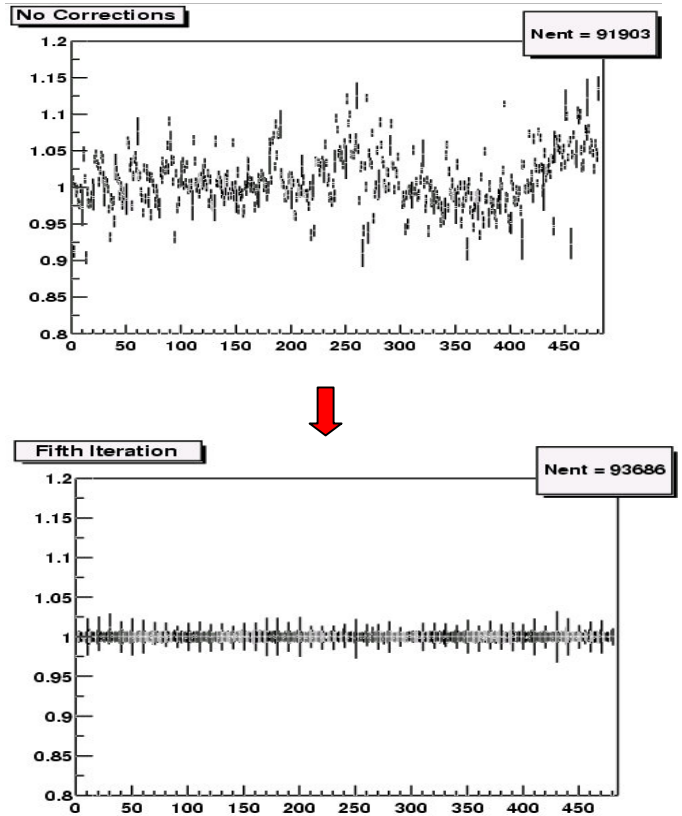




Energy Calibration

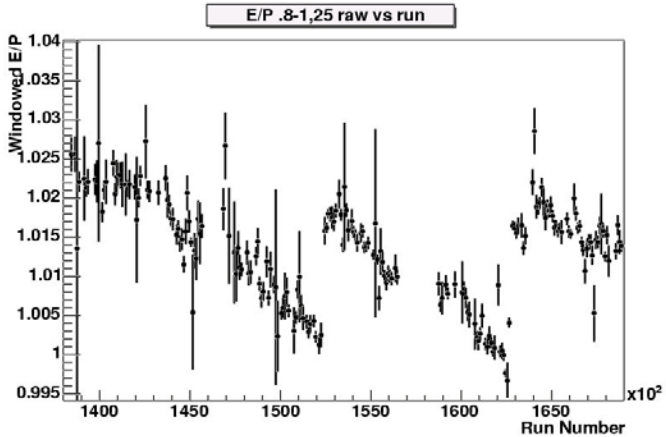
- E/P peak is heavily used at CDF
  - ✓ 8 GeV inclusive electron data
  - ✓ Offline correction factor tower by tower
- W → eν events
  - ✓ Absolute energy scale
- Finally calibrated with Zee peak
  - ✓ Energy resolution (width)
  - ✓ cross-check of energy scale (mass)
- Most important for precise W mass measurement



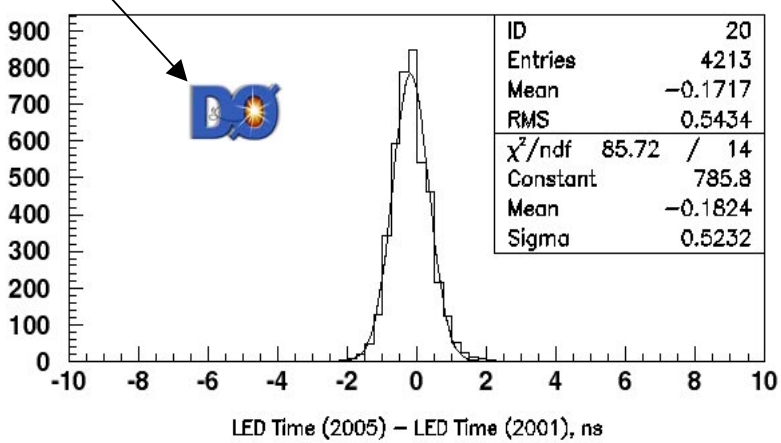


Calibration monitoring

- **Calorimeter system**
  - **PMT gain changes: causing non-uniform in eta-phi**
  - Fine tuning CEM tower using E/P peak
- **Muon system**
  - Timing shift in the scintillator detector
  - Gain change in the drift chamber calibration done at D0



- **Monitoring continues over the duration of RunII.**



Conclusion

- Lepton ID is very important at in collider physics
  - The identification method is well established
  - Improvements in working progress
- ID efficiency around 80-90%
- Fake rate about 1 in 1,000 –10,000
- Need good understanding of
  - Detector material
  - Minbias event
  - Valuable experience for the coming LHC experiments.