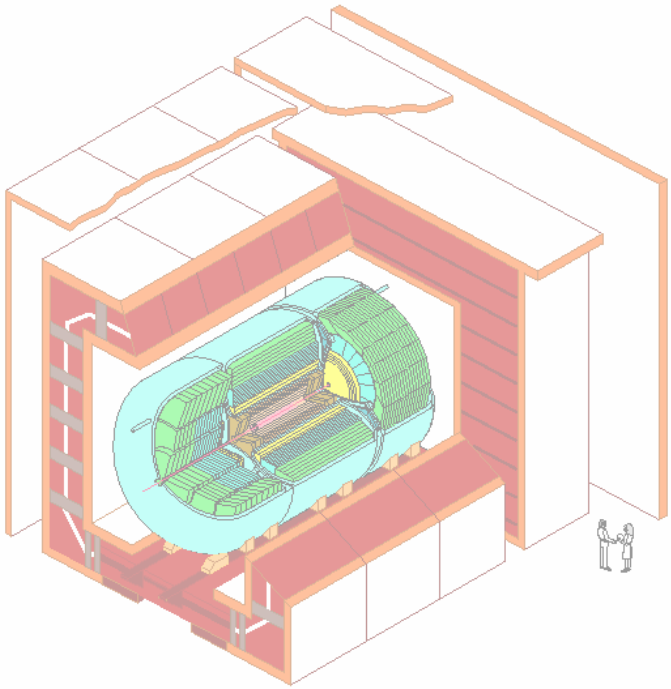
# Recent results on searches for new Phenomena from DØ



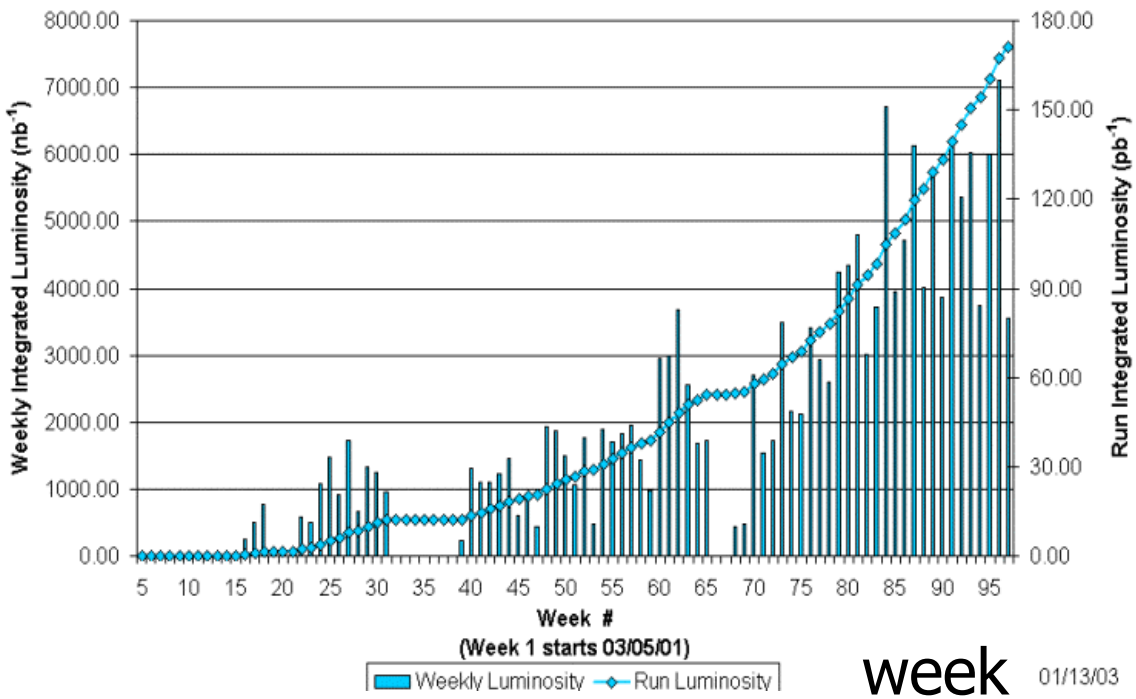


Gerard SAJOT for the D0 collaboration

# outline

- The tools for searches are performing well (e $\mu$ $\tau$ identifications, b tagging…)
- New Phenomena searches
  - supersymmetry (jets+m$E_T$, multilepton, GMSB $\gamma\gamma$+m$E_T$)
  - Exotics (2nd generation leptoquarks)
  - Large Extra Dimensions (dielectron/diphoton, dimuons)
- Conclusions

# Luminosity and data sample




week

4-6 $pb^{-1}$

per week

**Peak luminosity**

$3.7 \times 10^{31}\ cm^{-2}s^{-1}$

Better than RunI

**$\int L.dt$ on tape for physics**

**~ 50 $pb^{-1}$**

**(data september 2002- january 2003)**

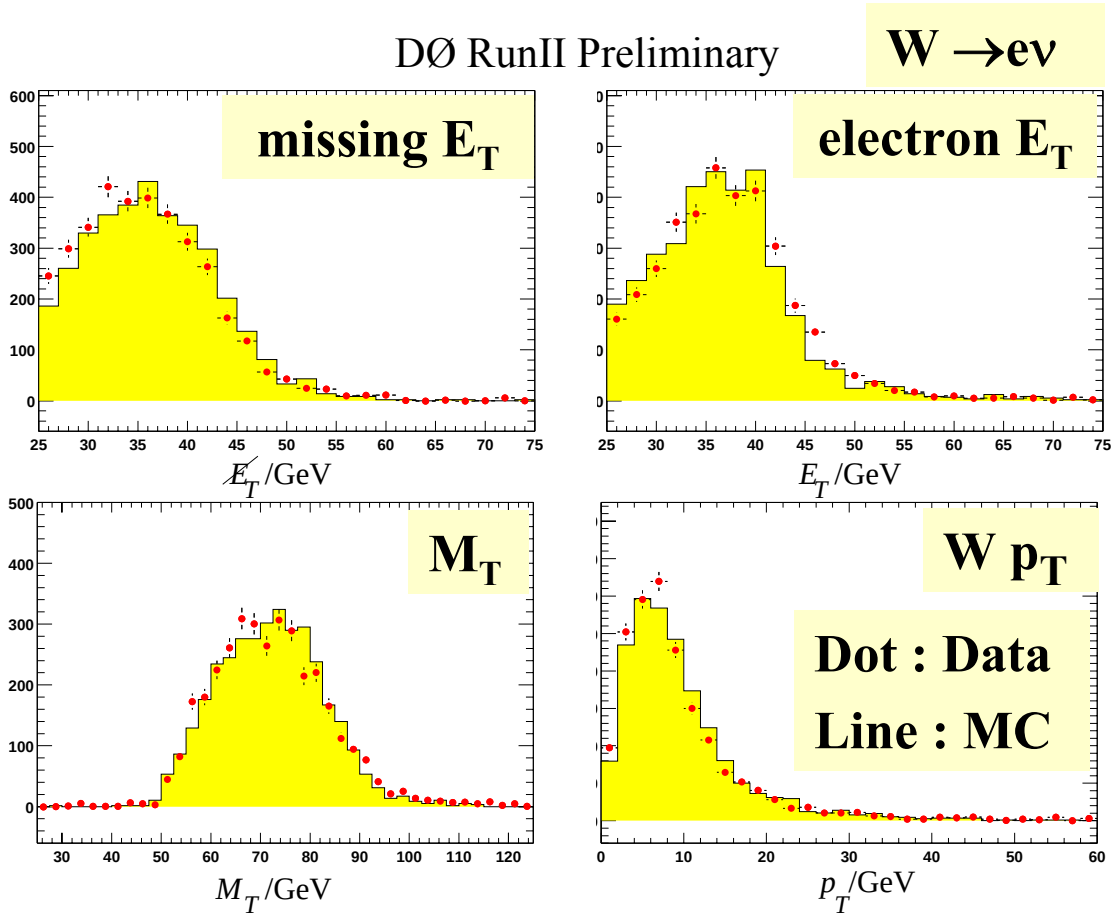
~0.5 X Run I

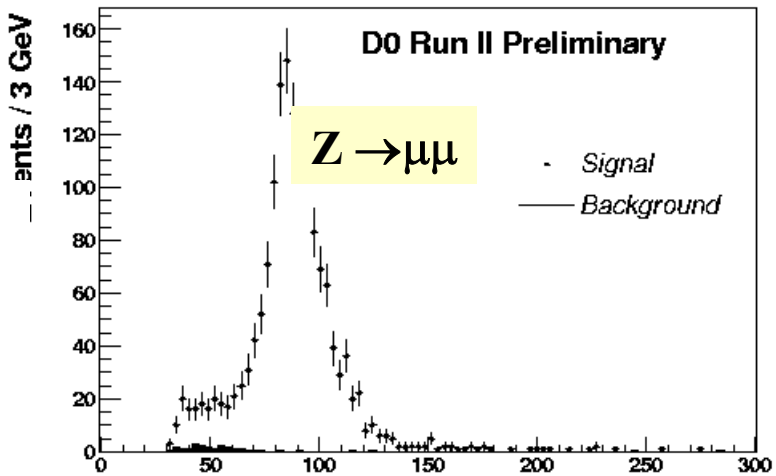
**Higher production cross sections : 1.8->1.96 Tev**

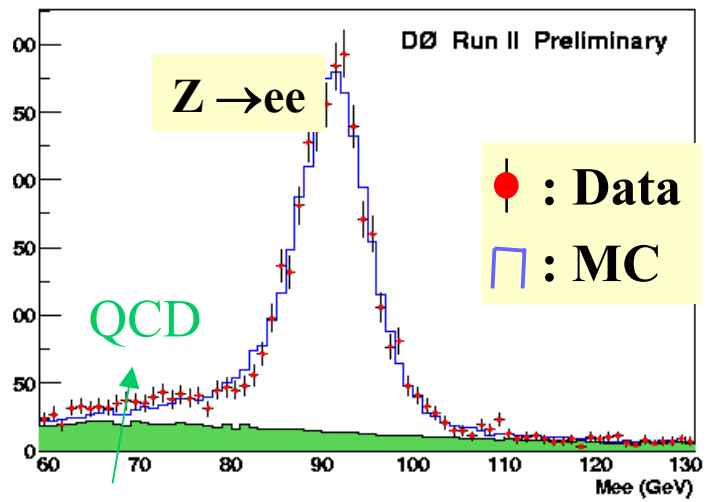
# Certification of the identification tools on SM Physics …and more

# Electron and muon identification

- W characteristics are represented by MC
- Clear mass peak of Z(ee) and Z(μμ)

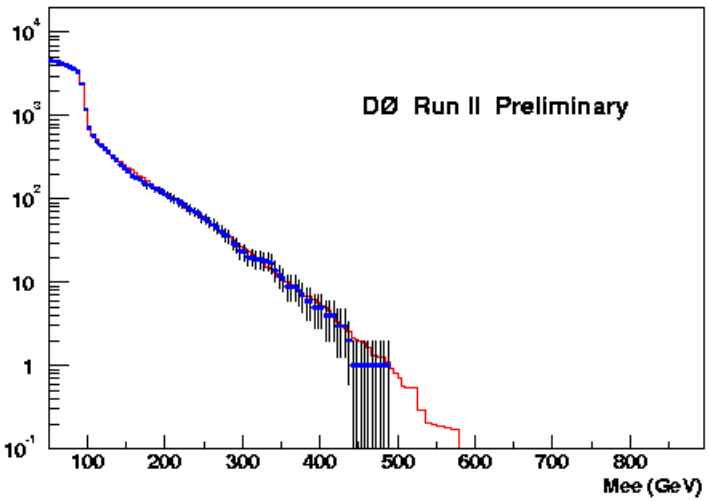


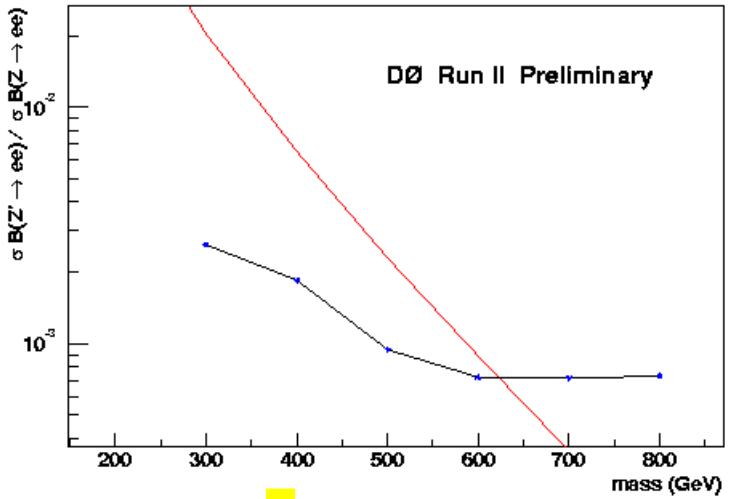



# Z' mass limit

Assuming SM-like coupling to femions



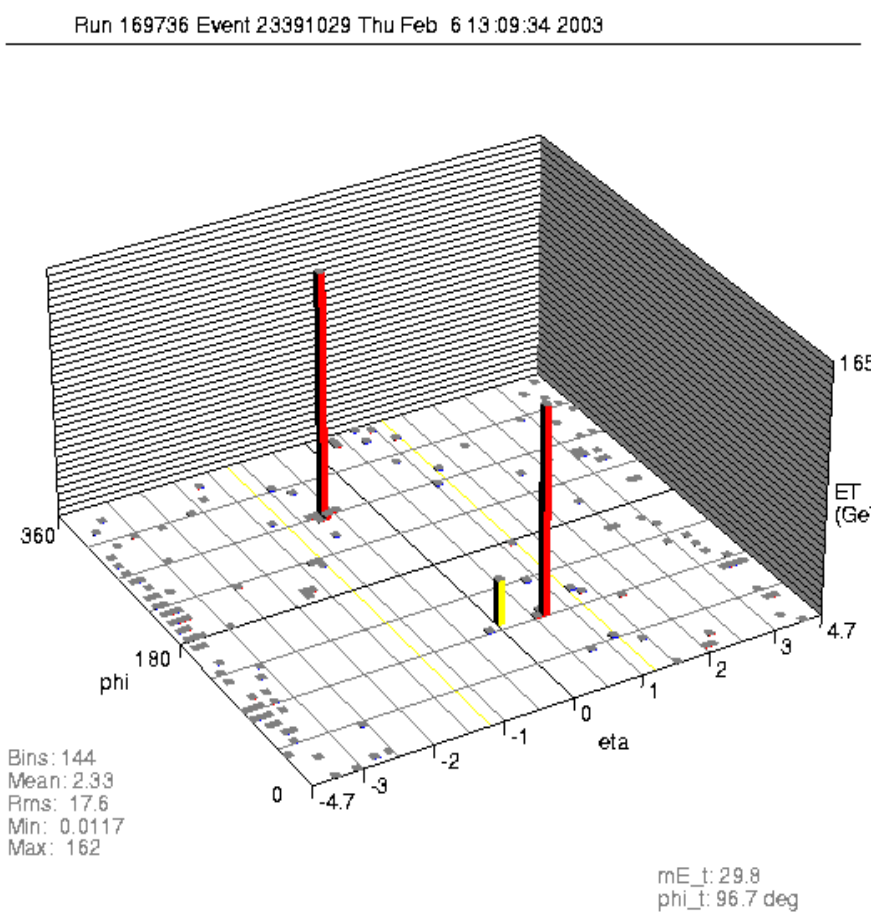



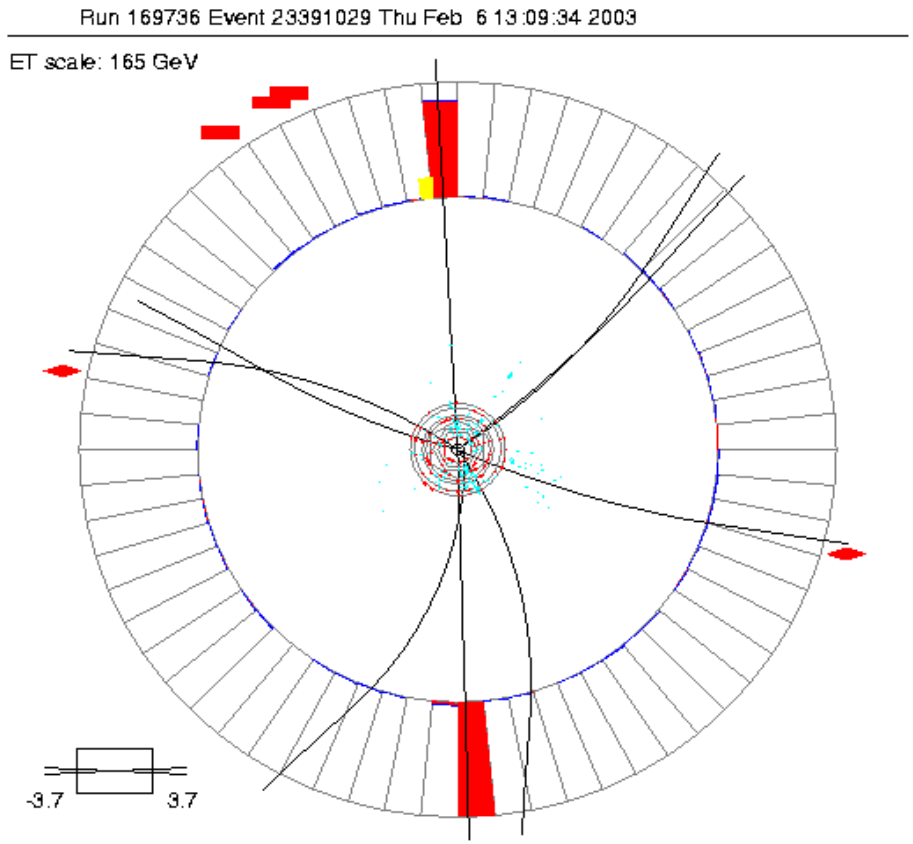

Integrated spectrum
(Mee above that mass)
Data (dot) background (line)

95% CL upper limit
$M_{Z'}$>620 Gev

Run I $M_{Z'}$ > 690 GeV

# Event with highest Mee invariant mass



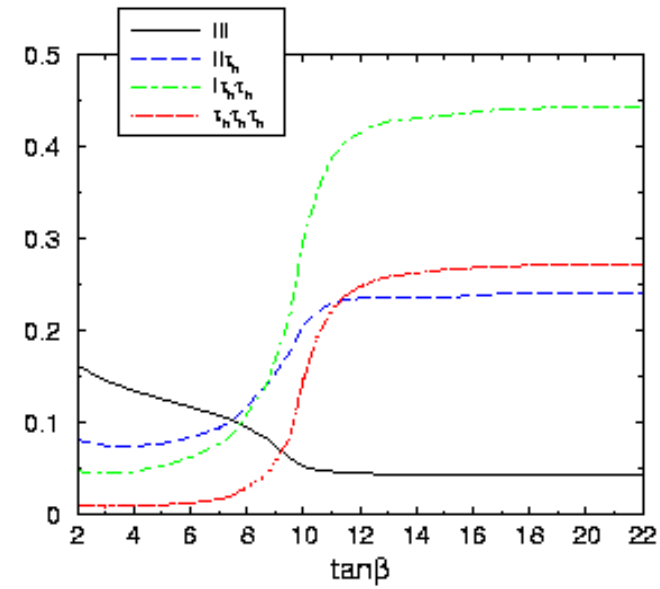

$M_{ee/\gamma\gamma} = 394$ GeV

# $\tau$ identification

- $\tau$'s are often a significant part of the beyond the Standard Model phenomenology
  - Trilepton SUSY searches,
  - third generation leptoquarks,
  - Higgs searches …

- Need a SM channel to study properties of identification (method, efficiency…)

- 2 searches at DØ are seeing evidence for the decay $Z \rightarrow \tau^+\tau^-$
  - e and hadronic $\tau$ decays
  - $\mu$ and hadronic $\tau$ decays



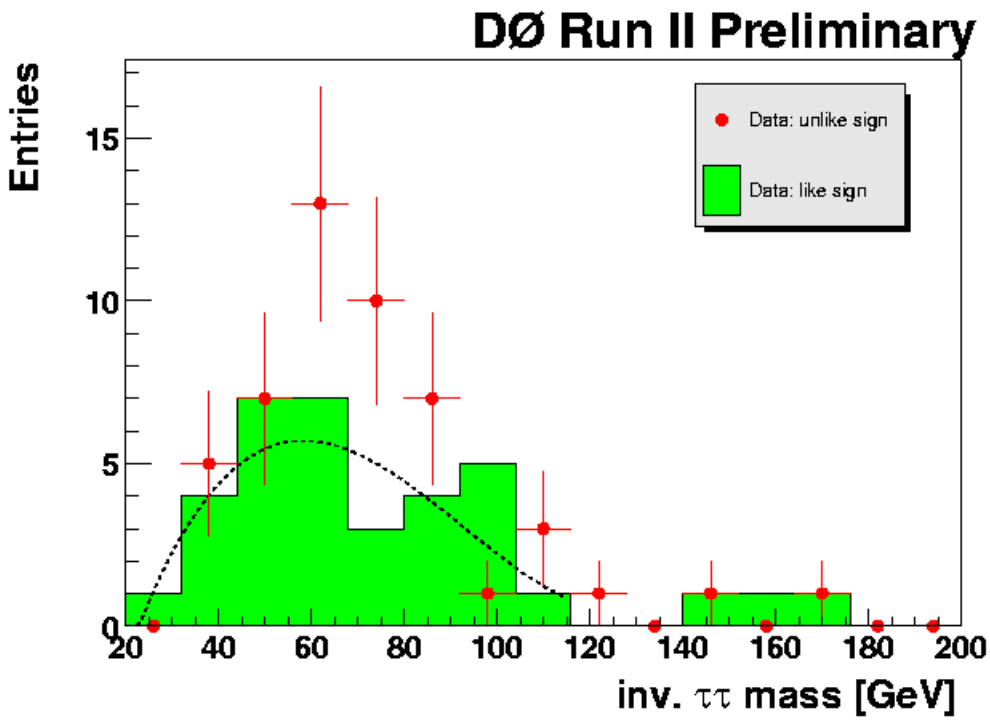

$Br(\tilde{\chi}_1^{\pm}\ \tilde{\chi}_2^0)$->e,$\mu$,$\tau_h$

# $Z \rightarrow \tau^+\tau^- \rightarrow e\tau_h$

**Selection :**

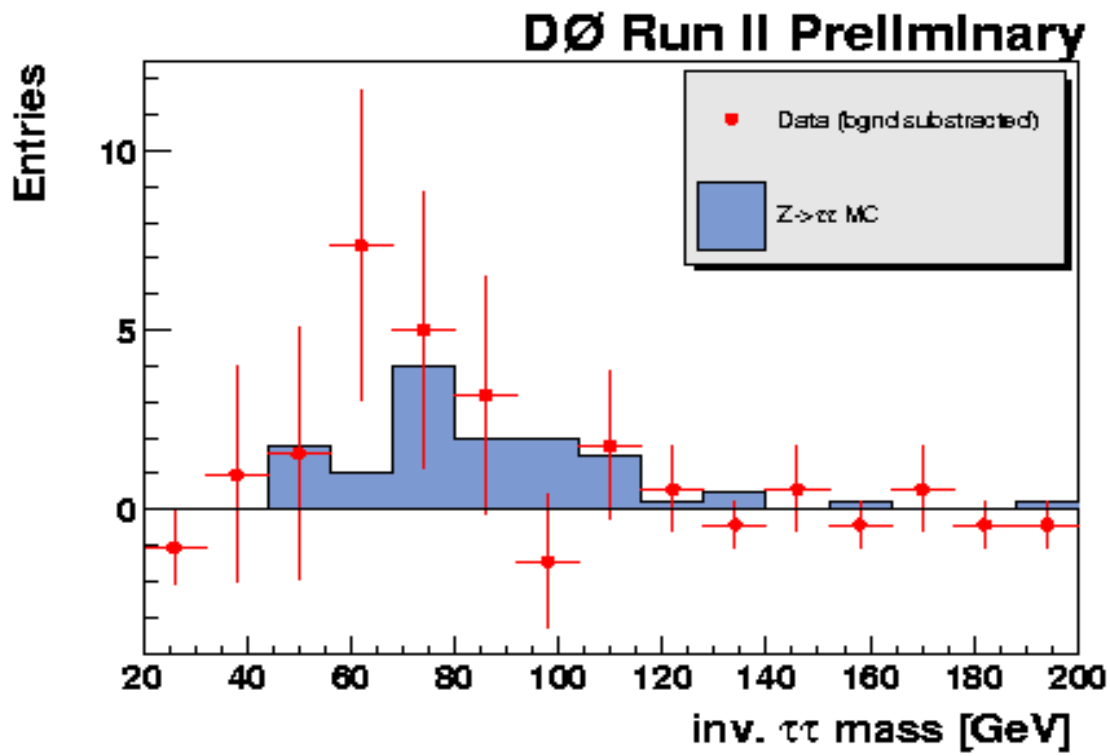
- isolated e $p_T$ > 15 GeV;
- $\tau$ candidate (jet) $p_T$> 7 GeV
- $M_T(e\nu)$ < 60 GeV (suppress W+jet
- $M_{e\,\tau}$ < 60 GeV (suppress Z+jets)

Neural net used to tighten $\tau$ ID
(don't consider 3-prong decays)




Use like sign distribution
as background estimator

# $Z \rightarrow \tau^+\tau^- \rightarrow e\tau_h$



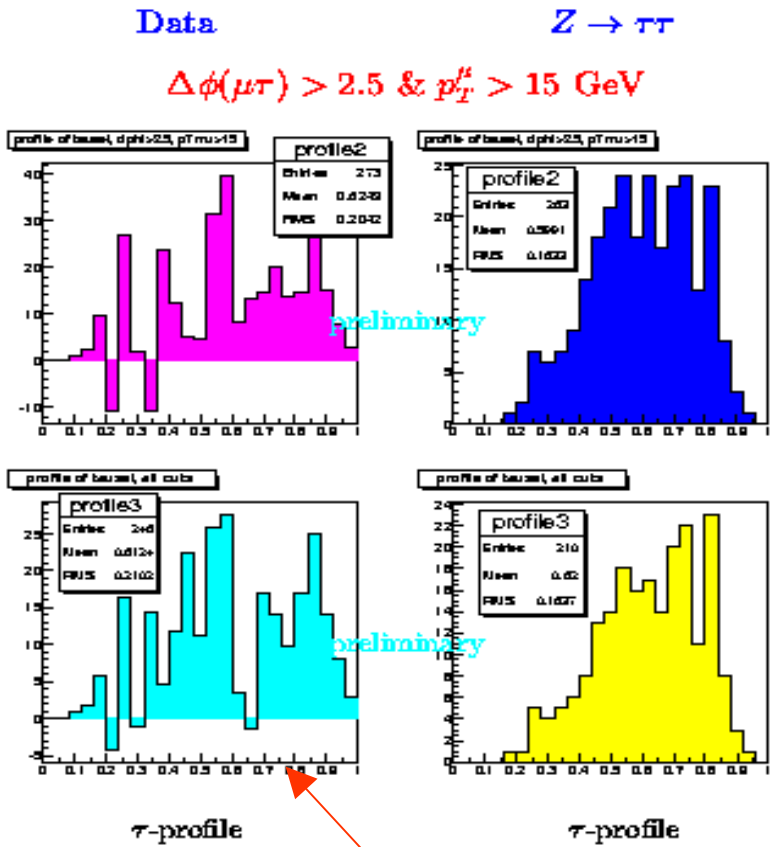

Data:
Opp sign 49 evts
Like sign 35
Diff 14 ± 9
Signal MC norm to 50 pb-1:
13 ± 4

Distribution in invariant ττ mass, calculated using collinear approximation

# $Z \rightarrow \tau^+ \tau^- \rightarrow \mu\tau_h$

**Selection:**

- isolated tight $\mu$, $p_T$ >15 GeV
- jet flagged as a $\tau$ candidate $E_T$ > 7GeV
- $\Delta\phi^{\mu\tau}$ >2.5
- 1 track $\tau$



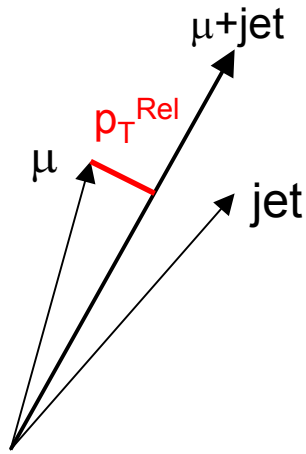

$\tau$ profile= ($\Sigma$ 2 highest $E_T$ towers)/$E^{\tau}_T$

$\Delta\phi(\mu\tau) > 2.5$ & $p_T^{\mu} > 15$ GeV & 1 track $\tau$

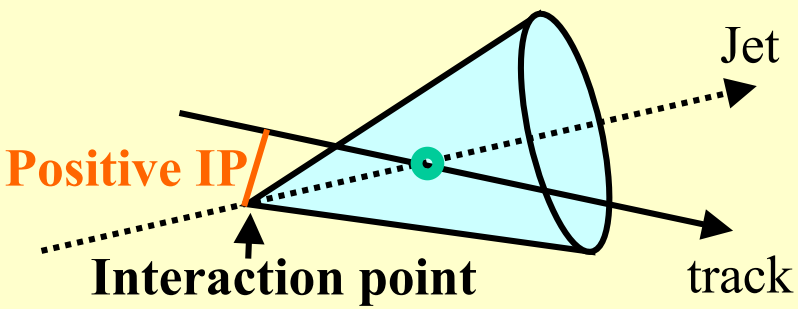
***Enhancement at high profile***

# b-tagging

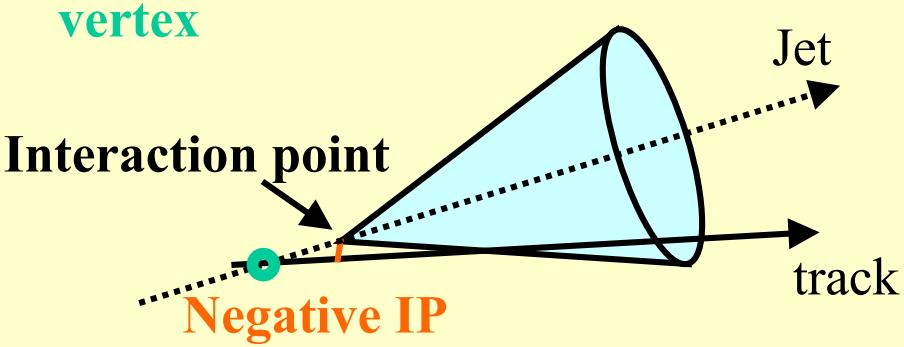
- b-tagging explores IP significance method
- Lepton from semileptonic decay of b is very useful



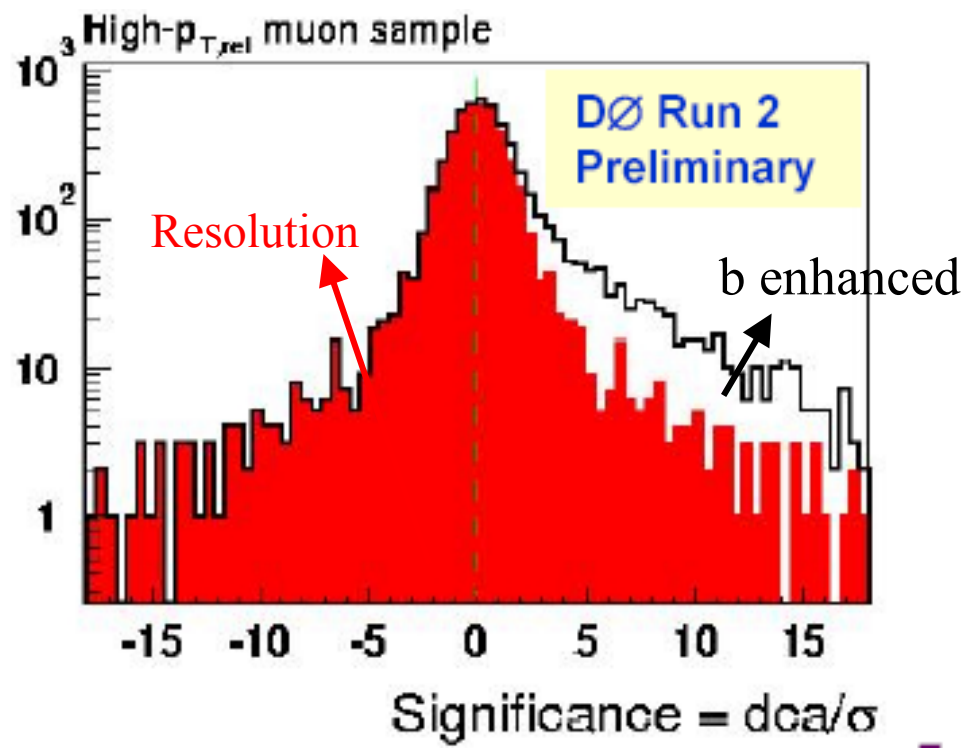

- Impact Parameter > 0
→track crosses jet axis after primary vertex




- Impact Parameter < 0
→track crosses jet axis before primary vertex



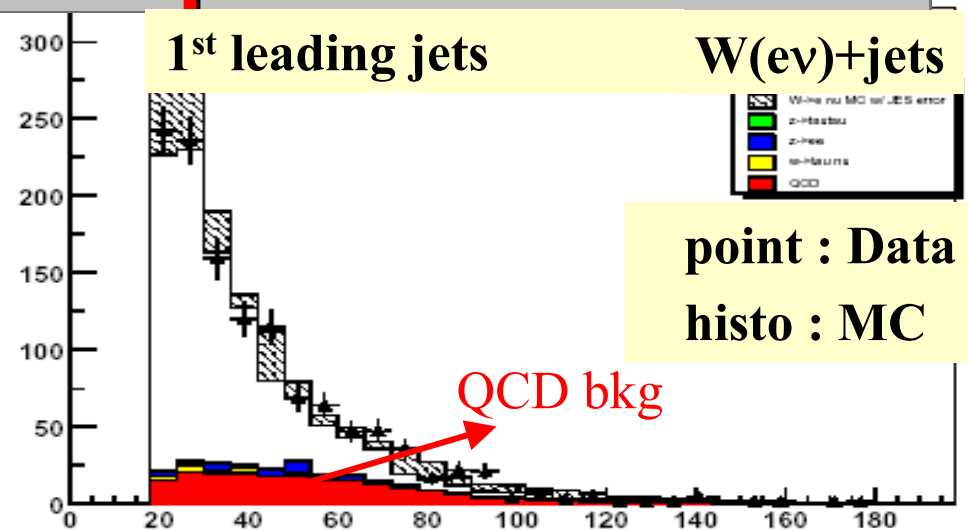

μ + jet sample

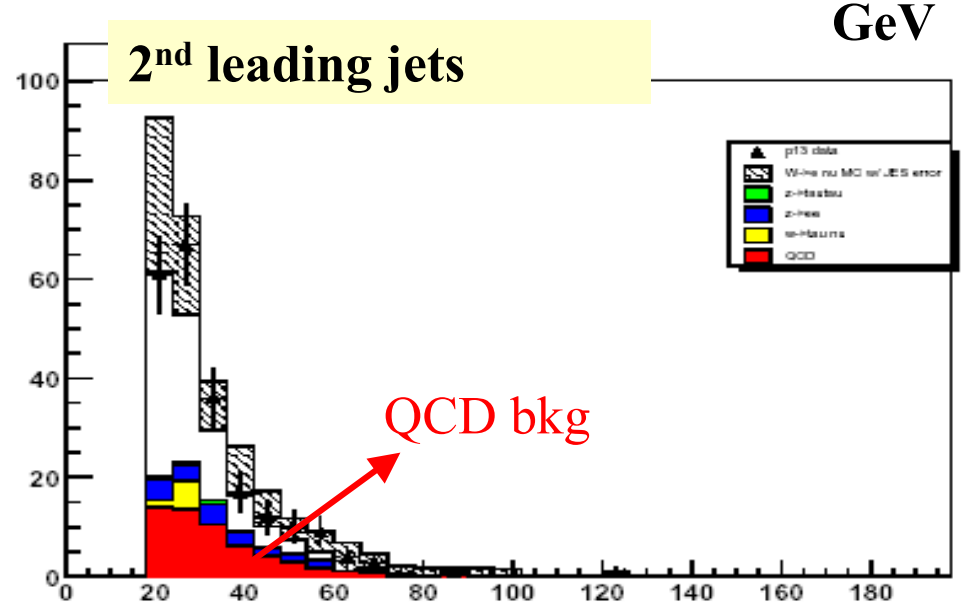



**Significance = IP/$\sigma_{IP}$**

# W+jets production

- Selection : **35 pb$^{-1}$**
  - W($\rightarrow$ e$\nu$)
    - Isolated e : $p_T$ > 20 GeV
    - |h| < 0.8
    - Missing $E_T$ > 25 GeV
  - W($\rightarrow\mu\nu$)
    - Isolated $\mu$: $p_T$ > 25 GeV
    - |h| < 1.5
    - missing $E_T$> 20 GeV
  - Jets
    - $p_T$ > 20 GeV
    - |h| < 2.5
- MC: PYTHIA
- MC normalized with DATA by area
- Error includes stat. error and dominant syst. error from Jet Energy Scale

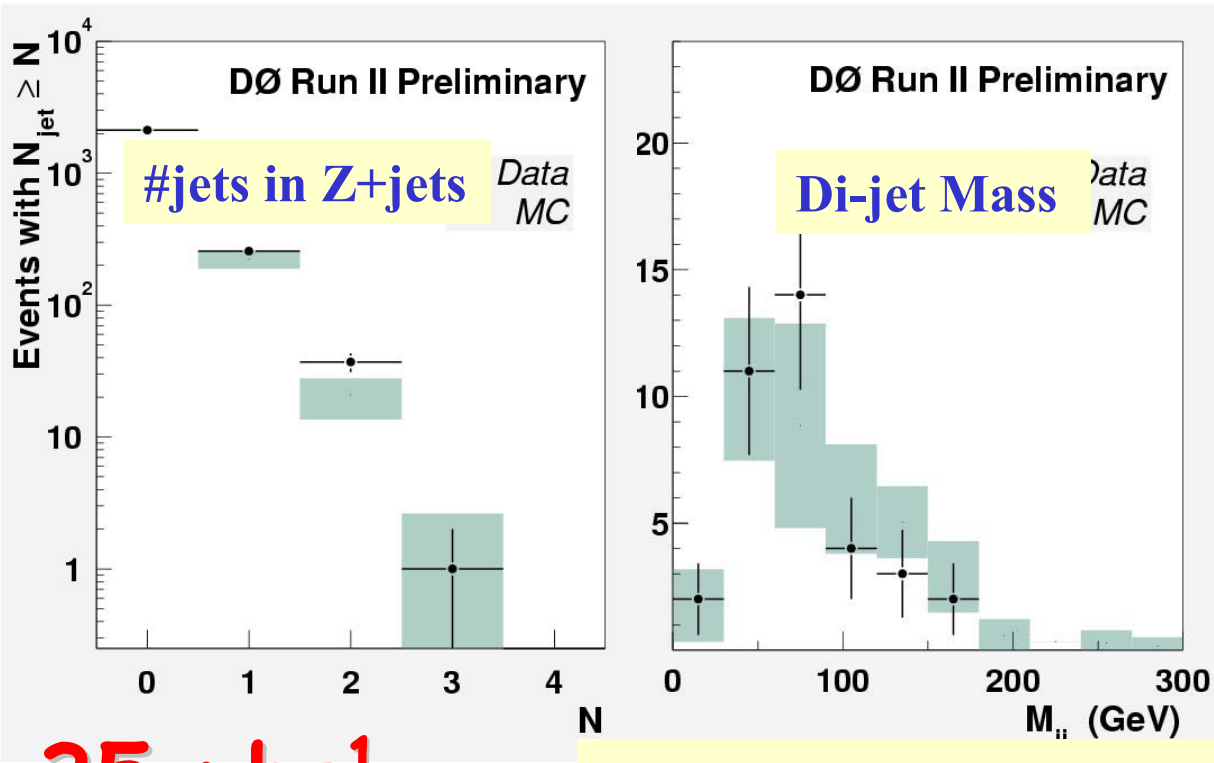


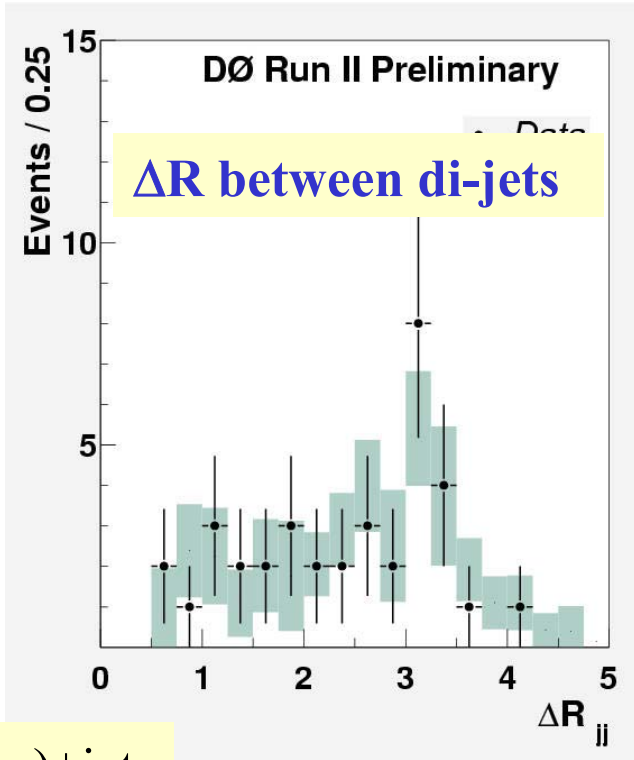




First step towards study of W($\rightarrow$leptons)H($\rightarrow$ bb) decay process

# Z+jets production

- Number of jets in Z + jets final states
- Reconstructed di-jet mass and $\Delta R(=\sqrt{\Delta\phi^2 + \Delta\eta^2})$ between j




**35 pb$^{-1}$**

Combined Z(ee)+jets and Z(μμ)+jets

First step towards study of Z(→leptons)H(→ bb) decay process

# Search for New Phenomena in Run II Data

# $\tilde{q}$ and $\tilde{g}$ search : Jets +m$E_T$

- Standard SUGRA ~ 4 $pb^{-1}$
- Squark - gluino pair production (signal was estimated for sbottom pairs)
- Cascade decays end
  - in quarks and/or gluons
  - LSP (neutralino) escapes detection

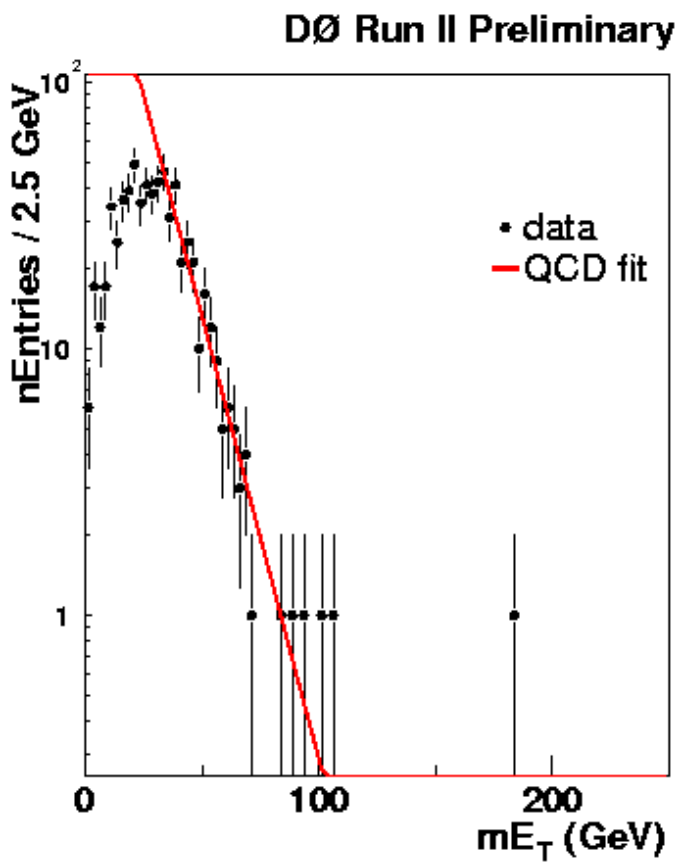
- Selection : 2 jets + mET

  Many instrumental background $\tilde{g}$ ⟶ "cleaning"
  - Trigger:
    - high $p_T$ jet > 65 GeV
  - Offline:
    - $p_T$ of leading jet > 100 GeV (insures trigger eff)
    - mET calculated adding all calorimeter towers with E>200 MeV
  - Background estimations:
    - PYTHIA-generated and fully simulated samples for physics backgrounds (real $ME_T$),
    - fit to low $ME_T$ region for QCD background (mismeasured $ME_T$)

# Jets +$mE_T$

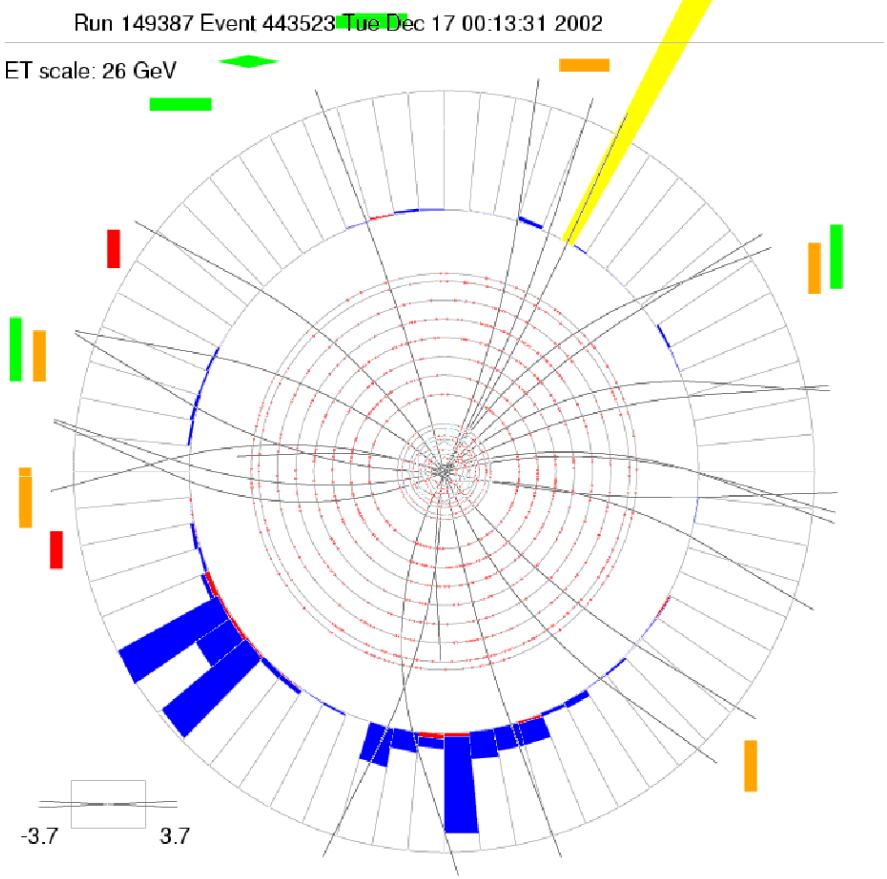
**Preliminary results**
**$P_T$ leading jet > 100 GeV**

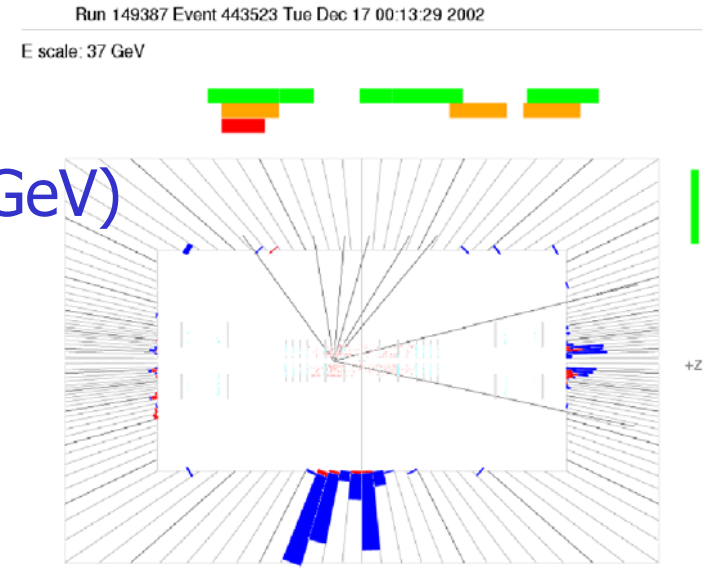
| # evts / $ME_T$ bin | QCD fit | Total bkg | Data | 95% CL $\varepsilon \times \sigma$ (pb) |
|---|---|---|---|---|
| > 70 GeV | 17.4 ± 7.9 ± 2.7 | 18.4 ± 7.9 ± 2.7 | 7 | 4.2 |
| > 80 GeV | 8.5 ± 5.0 ± 1.7 | 9.5 ± 5.0 ± 1.7 | 6 | 3.8 |
| > 90 GeV | 4.2 ± 3.0 ± 1.0 | 5.1 ± 3.0 ± 1.0 | 4 | 3.1 |
| > 100 GeV | 2.0 ± 1.7 ± 0.6 | 2.7 ± 1.7 ± 0.6 | 3 | 2.7 |

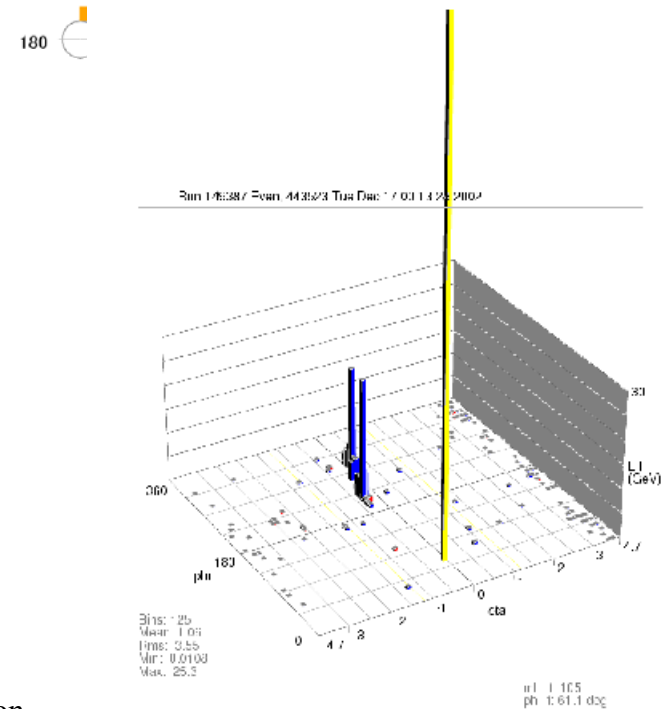


# Jets +m$E_T$

Views of the highest $\not{E}_T$ event (180 GeV)



# eμ inclusive search

- Rich discovery potential : model-independant
- Low SM background :

  WW, ttbar, $Z/\gamma^* \to \tau\tau$

  - Particle ID in D0 improved / RunI

**Very simple cuts:**

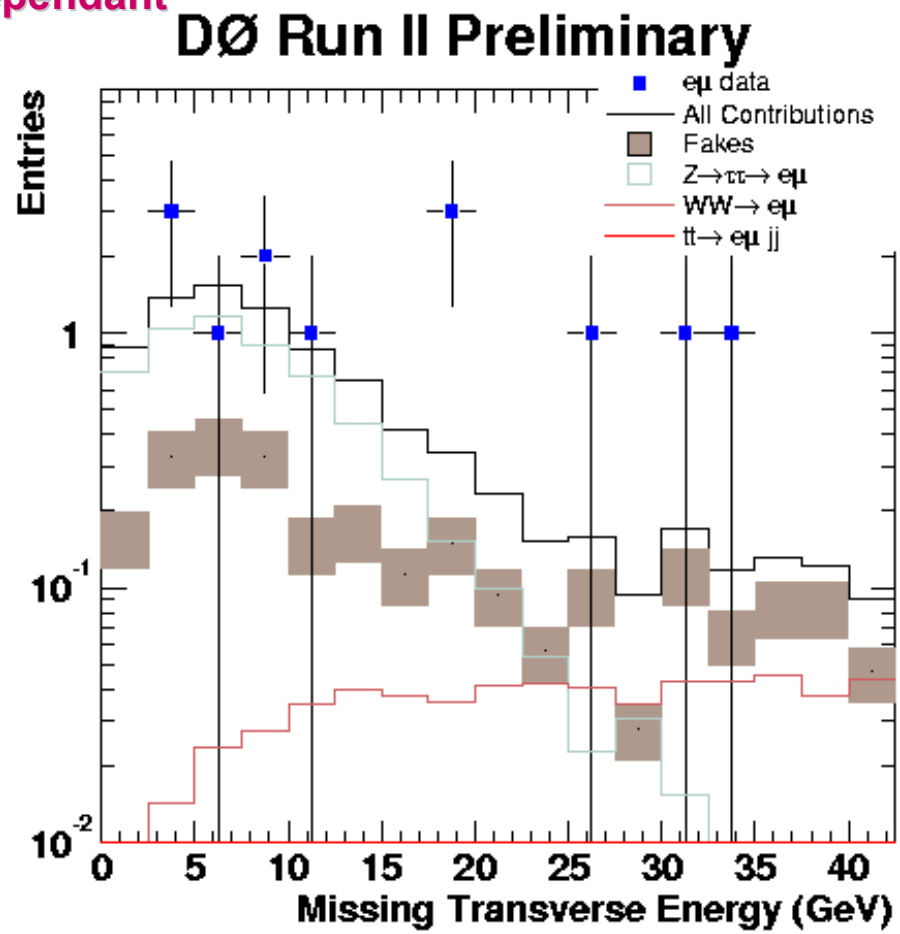
**1 e $p_T$ > 15 GeV**

**1 μ $p_T$ >15 GeV**

**Backgrounds :**

**- Instrumental from data**

**- Physics from simulation**

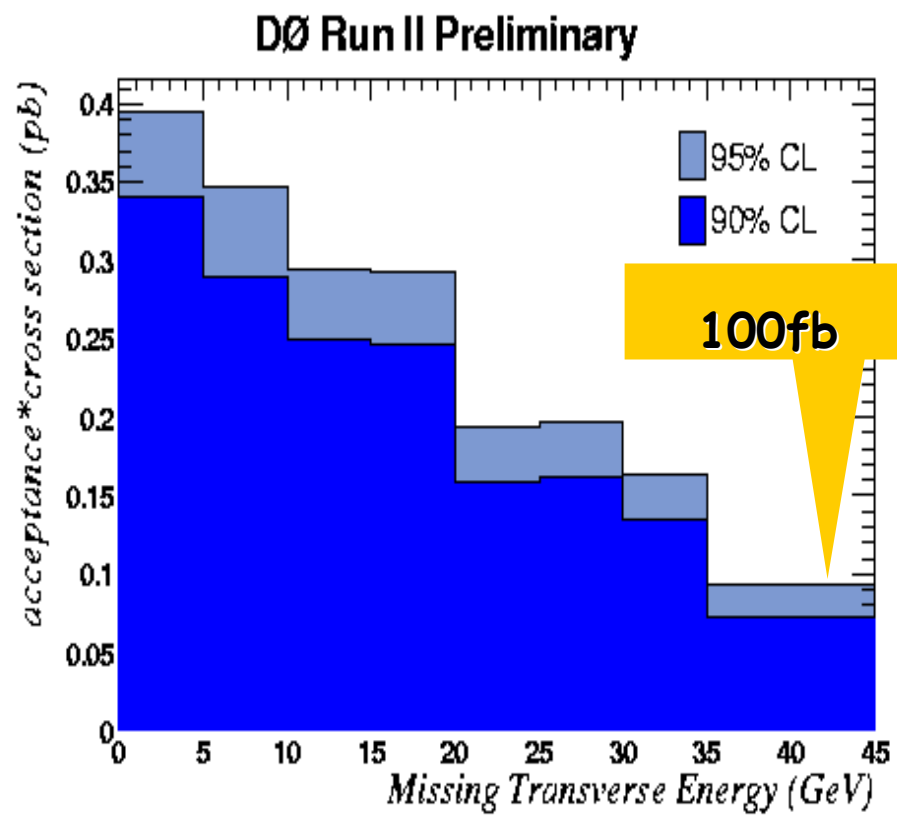



**Run II preliminary**

# eμ inclusive search

| $mE_T$ Cut | DATA | TOT BKG |
|---|---|---|
| > 0 | 13 | 9.6 ± 0.6 ± 2.6 |
| > 5 | 10 | 7.3 ± 0.6 ± 2.6 |
| > 10 | 7 | 4.6 ± 0.6 ± 2.6 |
| > 15 | 6 | 3.0 ± 0.6 ± 2.6 |
| > 20 | 3 | 2.3 ± 0.6 ± 2.6 |
| > 25 | 3 | 1.9 ± 0.6 ± 2.6 |
| > 30 | 2 | 1.6 ± 0.6 ± 2.6 |
| > 40 | 0 | 1.4 ± 0.6 ± 2.6 |
| > 45 | 0 | 1.1 ± 0.6 ± 2.6 |

~ 50% $Z \rightarrow \tau\tau$




Run II preliminary

~30 $pb^{-1}$

# Chargino Neutralino in 3 leptons

- **Signal**

$$p\bar{p} \longrightarrow \tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \longrightarrow lee\nu\tilde{\chi}_1^0\tilde{\chi}_1^0$$

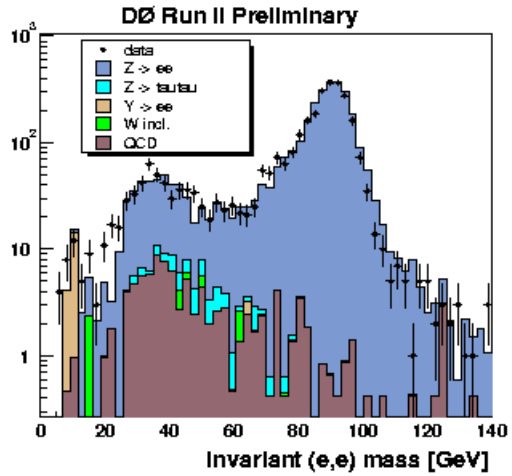
$$p\bar{p} \longrightarrow \tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \longrightarrow le\mu\nu\tilde{\chi}_1^0\tilde{\chi}_1^0$$

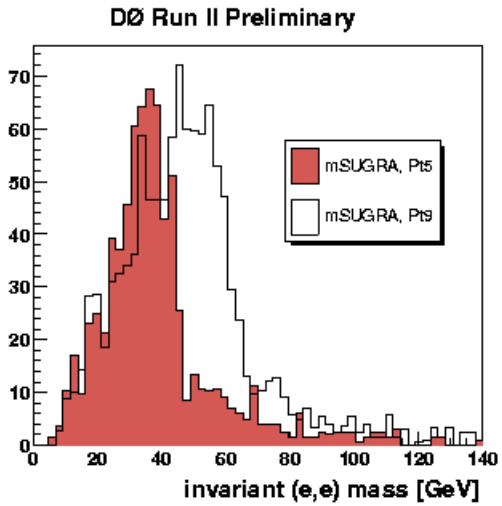
**2 points in Minimal SUGRA m $\tilde{\chi}_1^{\pm} \approx$ 2m $\tilde{\chi}_1^0 \approx$ 90 and 125 GeV**

- **Selection eel**
  1) At least 2 electrons (leading e $p_T$>15 GeV
     2nd e $p_T$>10 GeV)
  2) 10<Mee<70 GeV
  3) $M_T$(e,mET)>15 GeV
  4) A third isolated track $P_T$>5 GeV,$|\eta|$<3.0
  5) mET>15 GeV

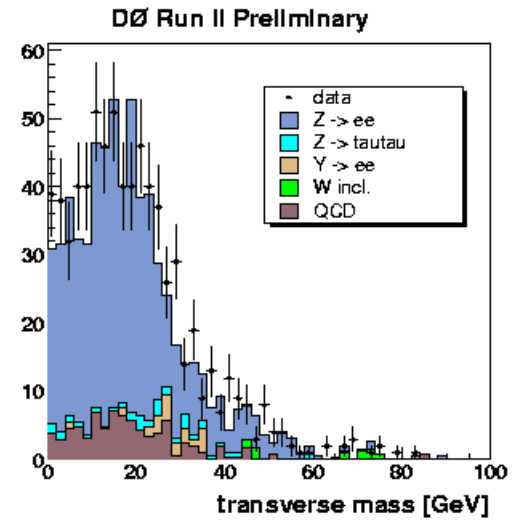
# Chargino Neutralino in eel

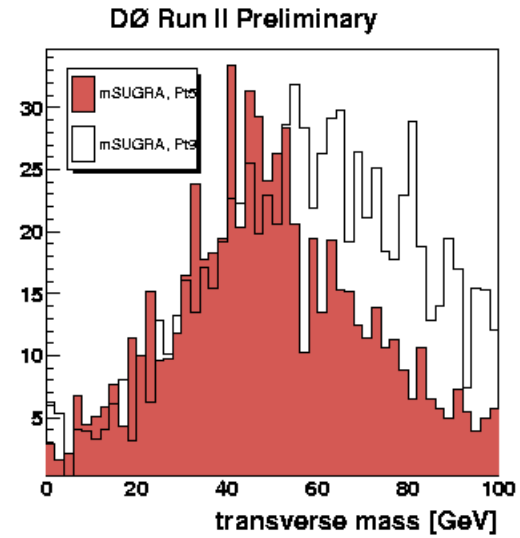
## After cut 1




## After cut 1 and 2




| | |
|---|---|
| Data | 3 |
| DY/Z->ee | 3.0 ±1.3 |
| Upsilon->ee | 0 ± 0 |
| W->eν | 0 ± 0 |
| Z->ττ | 0 ± 0 |
| QCD | 0.23 ± 0.23 |
| Total backg | 3.2 ± 1.4 |

**QCD= misidentified e's**

**Run II preliminary**

# GMSB

- LSP is a light (<< 1eV) gravitino
- Phenomenology driven by nature of NLSP
- "Bino" NLSP :

$$\tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$$

**Signature 2 $\gamma$ + mET**

- Model : "Snowmass slope" (2001 workshop)

$\Lambda$ parameter determining scale of SUSY masses
**N** number of messengers (-> N=1)
**$M_m$** messenger mass scale (-> $M_m$=2 $\Lambda$)
**tan $\beta$** ratio of v.e.v. of the 2 higgs doublets (at EW scale) (-> tan $\beta$ =15)
**sign($\mu$)** sign of higgsino mass term (-> $\mu$ > 0)

# GMSB : $\gamma\gamma$ + $mE_T$

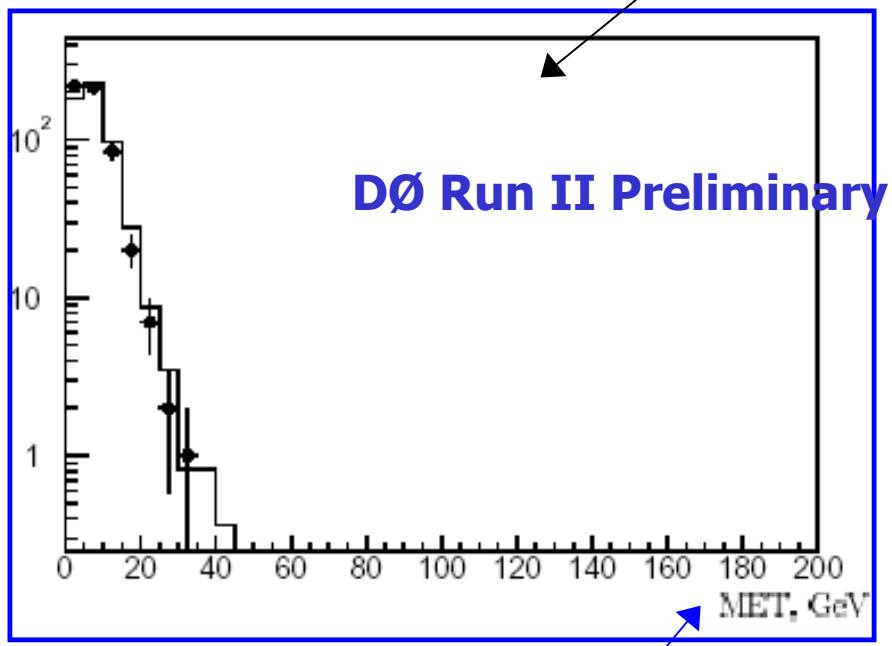
- **Cuts :**

  $pT_\gamma$ > 20 GeV, track veto
  $\Delta\varphi(Jet, mE_T) < 2.5$, $\eta < 1.1$
  $M_{\gamma\gamma} \not\subset$ 80-102 GeV, $\gamma$ pointing

- **Background :**
  - True $mE_T$
    $W\gamma$, Wj, Zee, tt, WW, WZ…
  - Instrumental
    QCD, Drell-Yan…

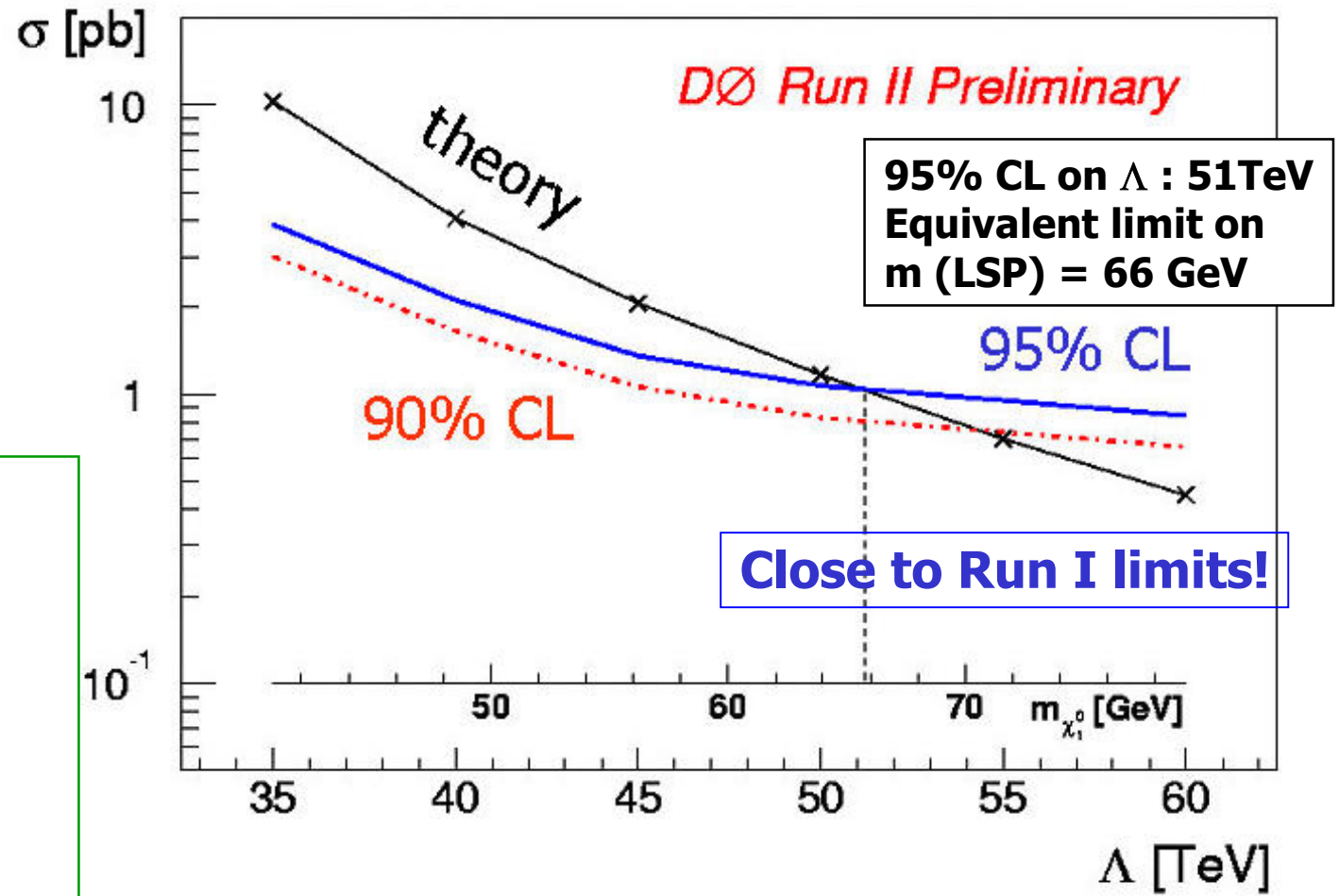
**m $E_T$ distribution of 2 $\gamma$ events**
- points : data
- hist : QCD background

**normalized at $mE_T$<20 GeV**




$mE_T$

# GMSB : $\gamma\gamma$ + $mE_T$

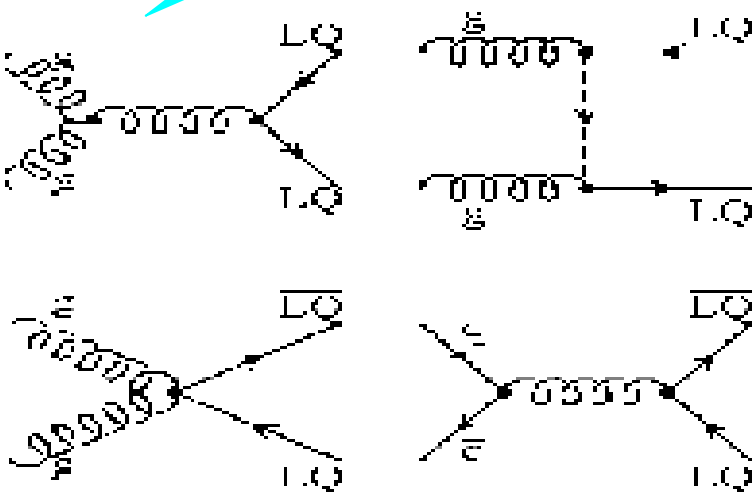



Theory = "Snowmass Slope"
$M=2\Lambda$
$N_5=1$
$\tan\beta=15$
$\mu>0$

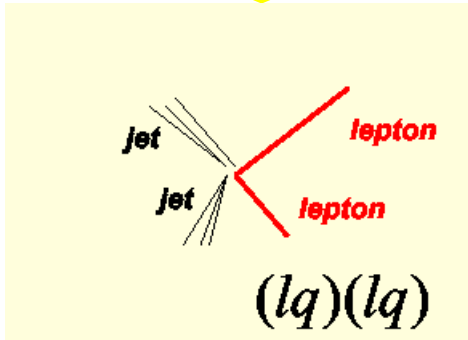
# Leptoquarks

- Particles coupled to quarks and fermions
- Carry both lepton and color quantum numbers
- Predicted in extended gauge sectors and composite models

Gluon splitting dominant at Tevatron




Present search
Second generation LQ
($\mu\mu jj$)
Assuming $\beta$=1



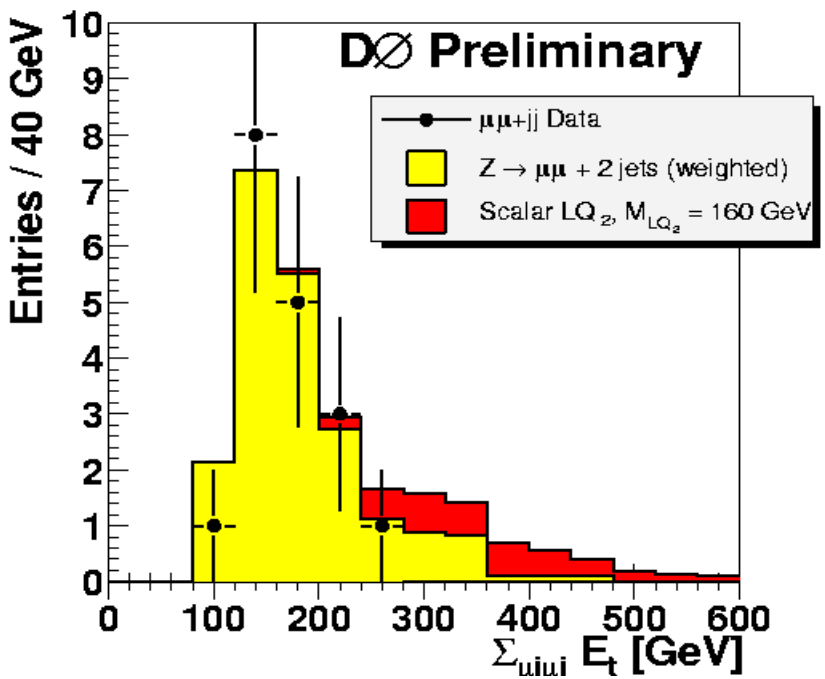
# 2nd generation LQ in μμ+2jets

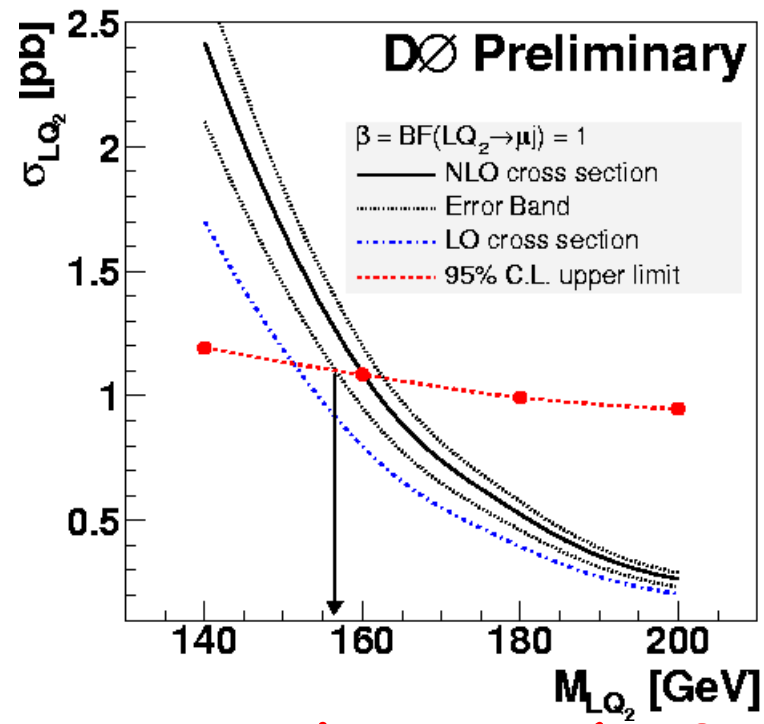
- **Event selection :** 2 isolated μ $p_T$>15 GeV opposite sign

  2 jets $E_T$>20 GeV

  $M_{\mu\mu}$ >110

- **Background :** Drell-Yan/Z, ttbar, WW




**Run II preliminary (~30 $pb^{-1}$)**

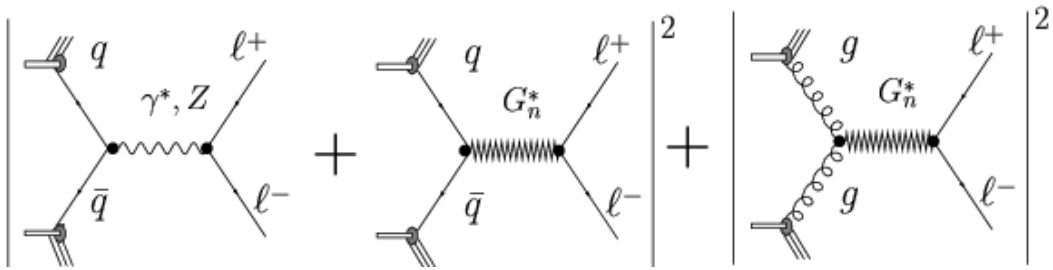
$M_{LQ2}$>157 GeV

**RunI (100 $pb^{-1}$) $M_{LQ2}$>200 GeV**

# Search for Large Extra Dimensions

- **Assume :**
  - SM particles confined in 3D-brane
  - gravity propagates in extra-dimensions
- **Look for :**

  excess of high mass dielectron, diphoton events over SM expectation, from coupling to KK gravitons

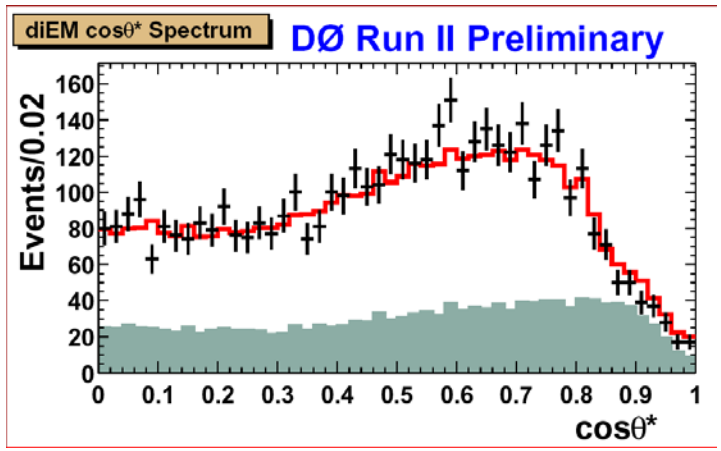


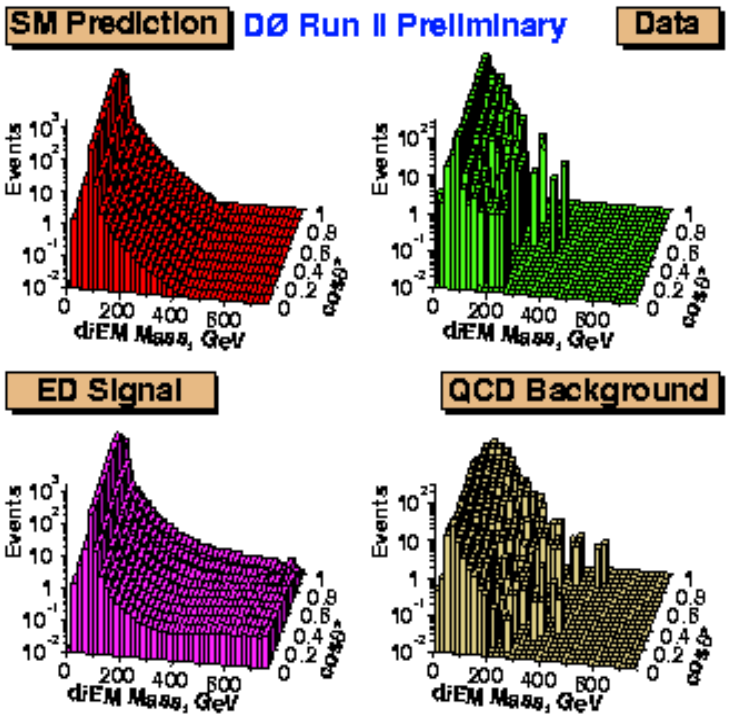

$$\frac{d^2\sigma}{dM\, d\cos\vartheta} = f_{SM} + f_{\text{int}}\,\eta_G + f_{KK}\,\eta_G^2 \qquad \text{where} \qquad \eta_G = F/M_S^{-4}$$

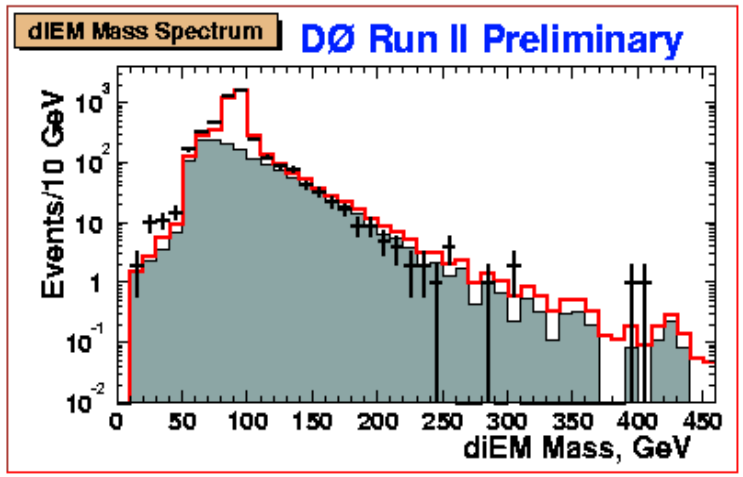
- **Studies in the di-EM (e/γ) and di-μ channels**
- **Two variables**
  - Invariant mass
  - Cos θ* ( where θ*= scattering angle in the rest frame )

# LED in the ee/γγ channel

- **Event selection :**
  - 2 electromagnetic objects (e/γ) $E_T$> 25 GeV
  - $mE_T$< 25 GeV
- **Background :**
  - Drell-Yan, Direct γγ production ( from MC)
  - EM mis-identification (from data)

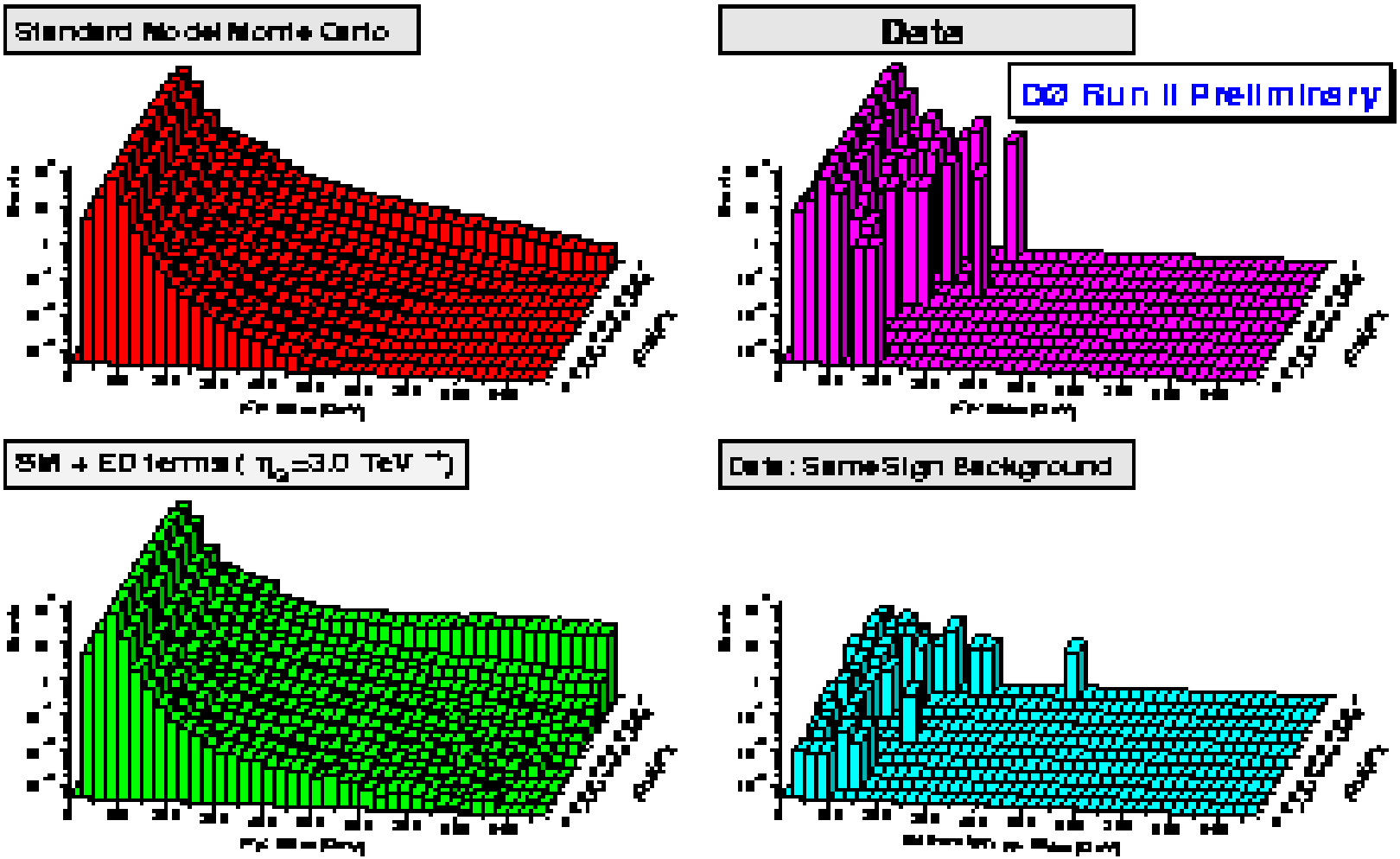


# LED in the μμ channel

- Event selection :
  - 2 μ $p_T$> 15 GeV, $m_{\mu\mu}$> 40 GeV



# LED preliminary results

- Fit the distributions in the $M_{inv}$-cos$\theta$* plane to determine the value of $\eta_G$ (expected to be zero in SM)

- Translate 95% CL upper limits on $\eta_G$ to 95% CL *lower* limits on $M_S$, the fundamental Planck scale (in TeV)

| Formalism | GRW | HLZ for n=: 2 | 7 | Hewett $\lambda$= 1 |
|---|---|---|---|---|
| di-EM (~50 $pb^{-1}$) | 1.12 | 1.16 | 0.89 | 1.00 |
| di-MU (~30 $pb^{-1}$) | 0.79 | 0.68 | 0.63 | 0.71 |

->di-EM limit close to Run I
->di-MU limit new channel
Both similar to individual LEP limits

# Conclusions

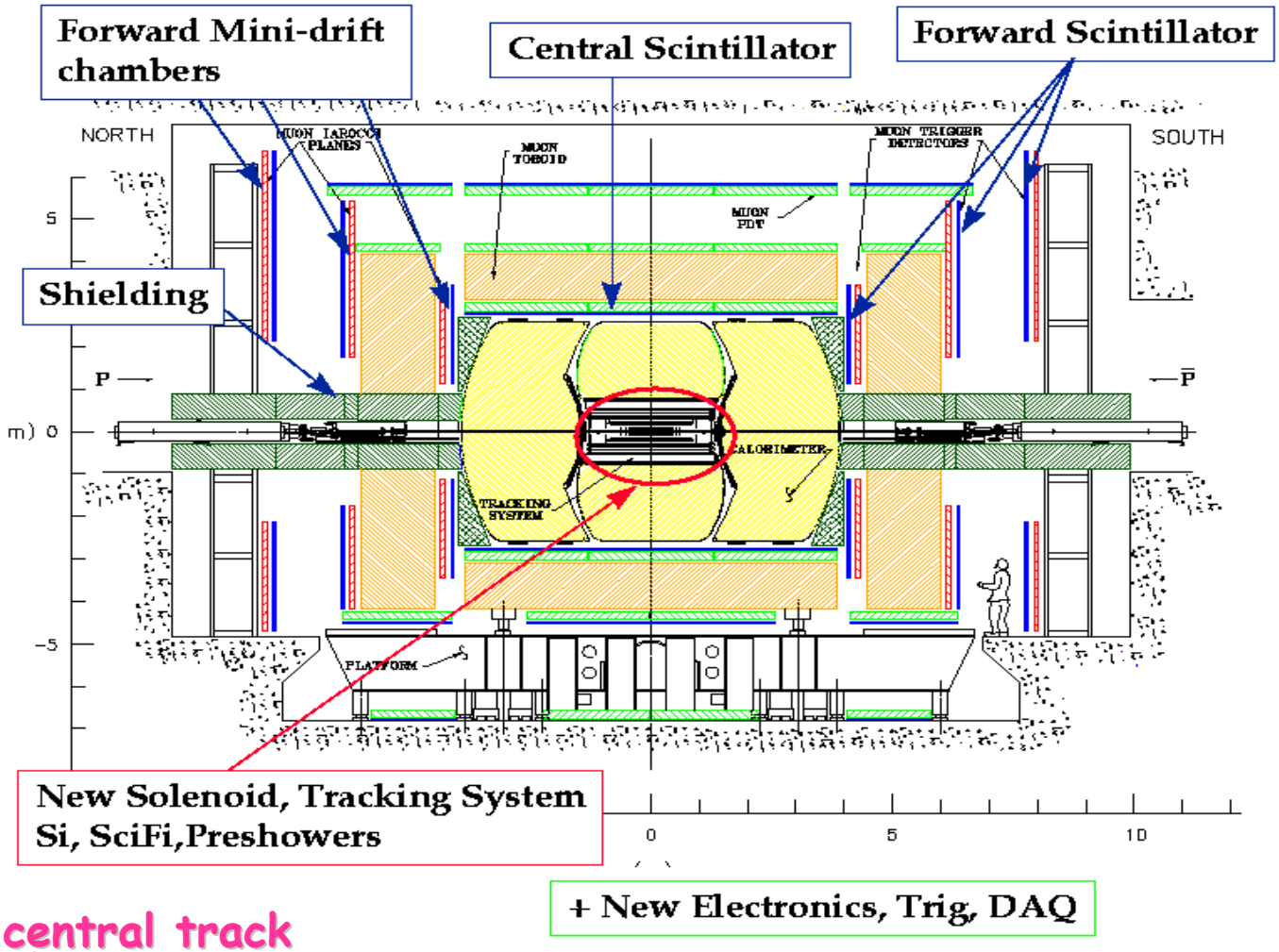
- D0 continues to search for many different signatures for new physics.
- The effects of increased center-of-mass energy and an improved detector can now be seen in improved sensitivity (compared to Run I).
- We anticipate with excitement the rise of the discovery potential as Run II 's dataset accumulates.

# backup

# DØ upgrade/status

## D0 upgrade

- tracking
  - Silicon vertex
  - Fiber tracker
- solenoid
  - 2 T magnetic field
- Preshower
- Muons detector
- Electronics
- Trigger system




D0 still commissioning central track and displaced vertex trigger

# $Z \rightarrow \tau^+ \tau^- \rightarrow \mu\tau_h$

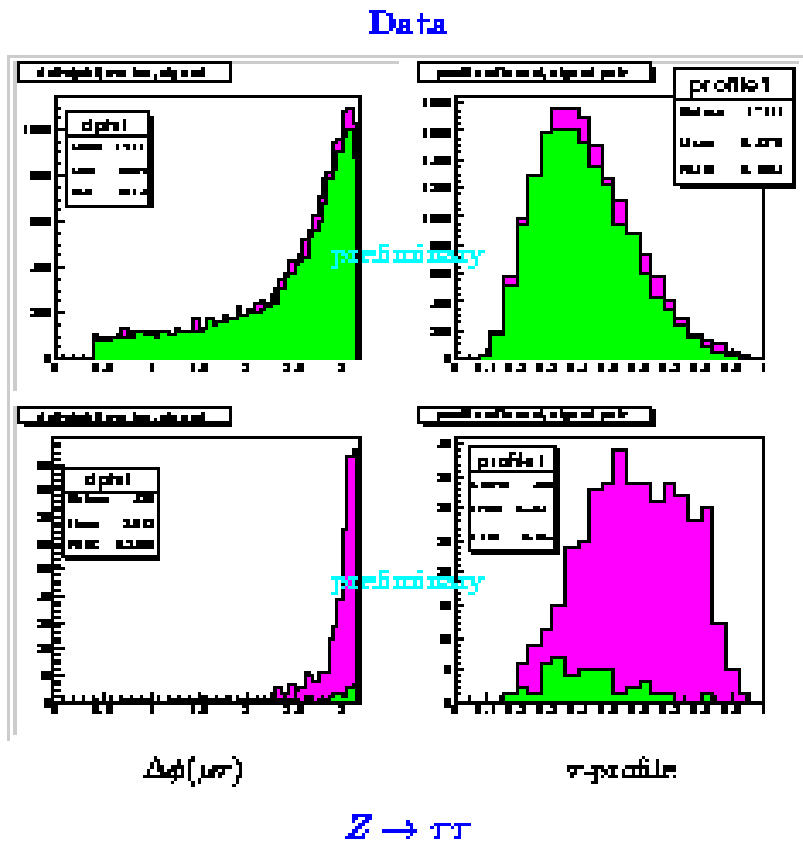
opposite sign $\mu$ $\tau$

equal sign $\mu$ $\tau$

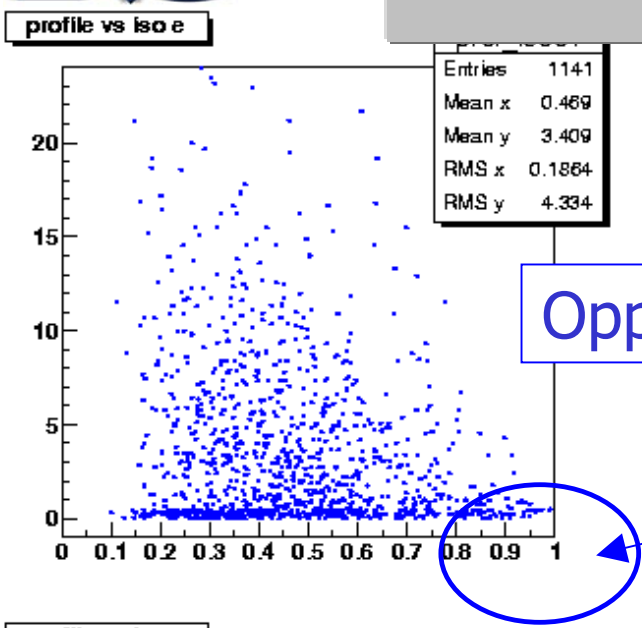
**DØ Run II Preliminary**

## Selection:

- isolated tight $\mu$, $p_T$ > 7GeV
- jet flagged as a
- $\tau$ candidate $E_T$ > 7GeV
- $\Delta\phi^{\mu\tau}$ >0.4



# $Z \rightarrow \tau^+ \tau^- \rightarrow \mu\tau_h$

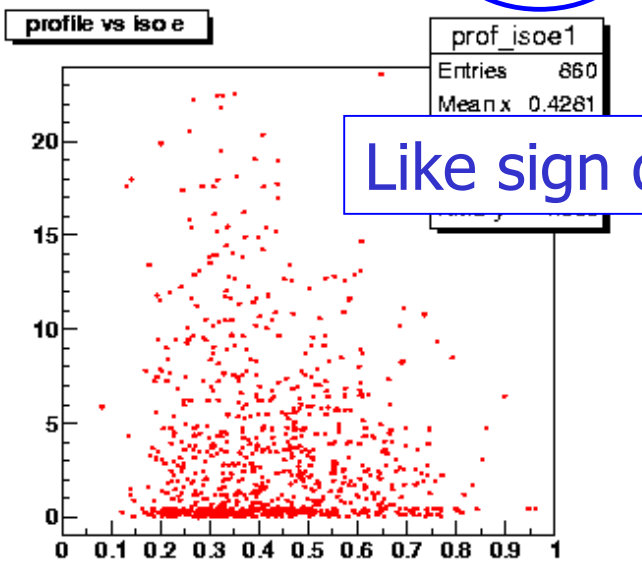



Opposite sign data

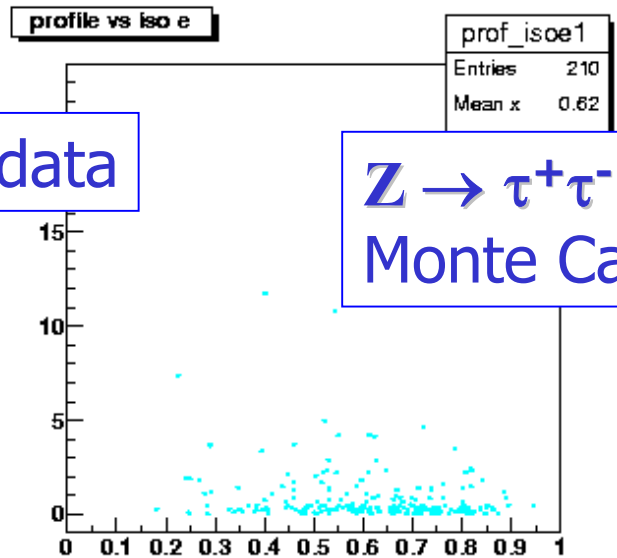
Plot isolation vs profile:

Isolation = Energy of trks, excl tau trk, in 0.7 cone
Profile = E twr(1+2)/Etot

***Enhancement at high profile***




Like sign data

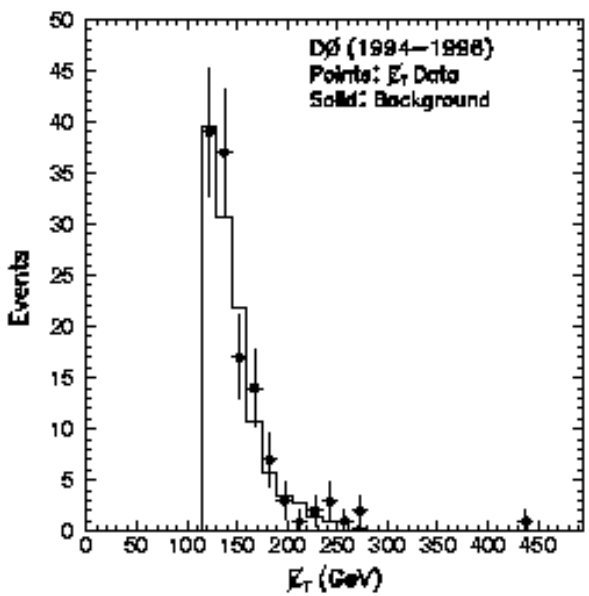



$Z \rightarrow \tau^+\tau^-$
Monte Carlo

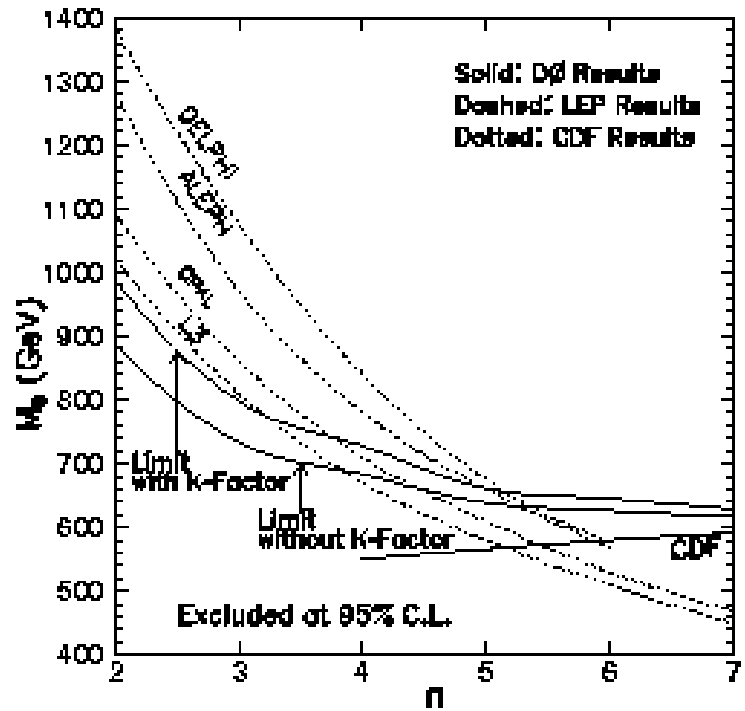
# LED in Monojet +$mE_T$

- **Search for Real Graviton emission**
  - First analysis in jet/+ $mE_T$
  - LEP and CDF : $\gamma + mE_T$
- **Background**
  - $Z(\nu\nu)$ , W, QCD

RunI
94-96 data




0.9 TeV




0.6 TeV