New Phenomena Results from DØ in Run II

- **Run II vs Run I**
- **A new capability for DØ:** $Z \rightarrow \tau^+\tau^-$
- **Reports from 7 new Run II analyses**
  - Chargino/Neutralino Search : Trilepton mode
  - GMSB SUSY Search : $2\gamma + \not{E}_T$
  - SUGRA Search : Jets + $\not{E}_T$
  - Limits on New Physics in an e-μ Search
  - Search for 2nd Gen LQ : 2 μ + 2 jets
  - Search for Large Extra Dimensions : di-EM channel
  - Search for Large Extra Dimensions : di-μ channel
- **Conclusions**

Run II vs Run I

- We have higher production cross sections: 1.96 TeV
  - Always nice for searches
- Most analyses in this talk utilize around 30-50 pb^{-1} (Run I total was ~120 pb^{-1})
  - Variation in trigger availability
  - Variation in data quality cuts for particular physics object
- We aren't using the full suite of Run II triggers yet
  - Still commissioning central track and displaced vtx triggers

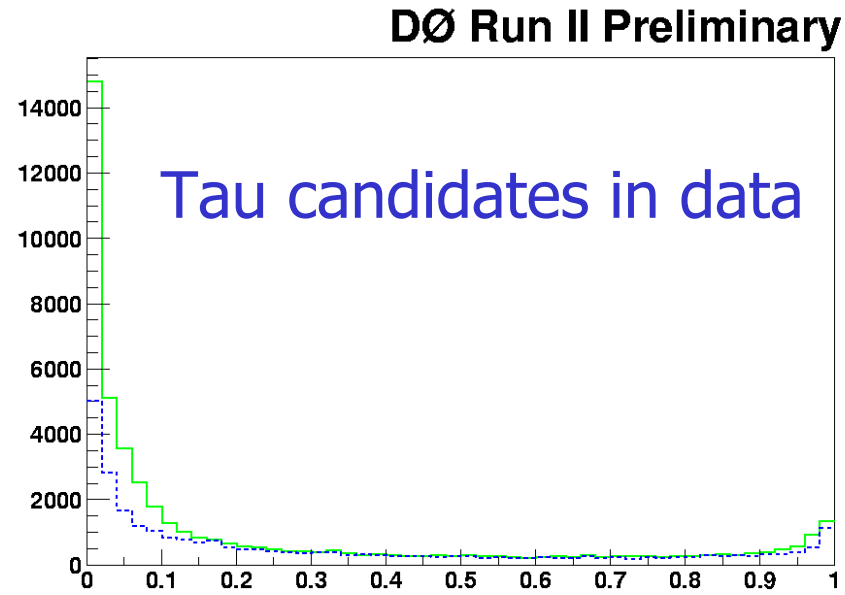
$Z \to \tau^+\tau^-$ - A Significant Analysis for Searches

- τ'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 give confidence in modeling, detection efficiency, …
- 2 searches at DØ are seeing evidence for the decay $Z \to \tau^+\tau^-$, for the first time at Tevatron
- One analysis searches for e and hadronic τ decays, the other for μ and hadronic τ decays

$Z \rightarrow \tau^+\tau^-$ (electron + hadronic mode)

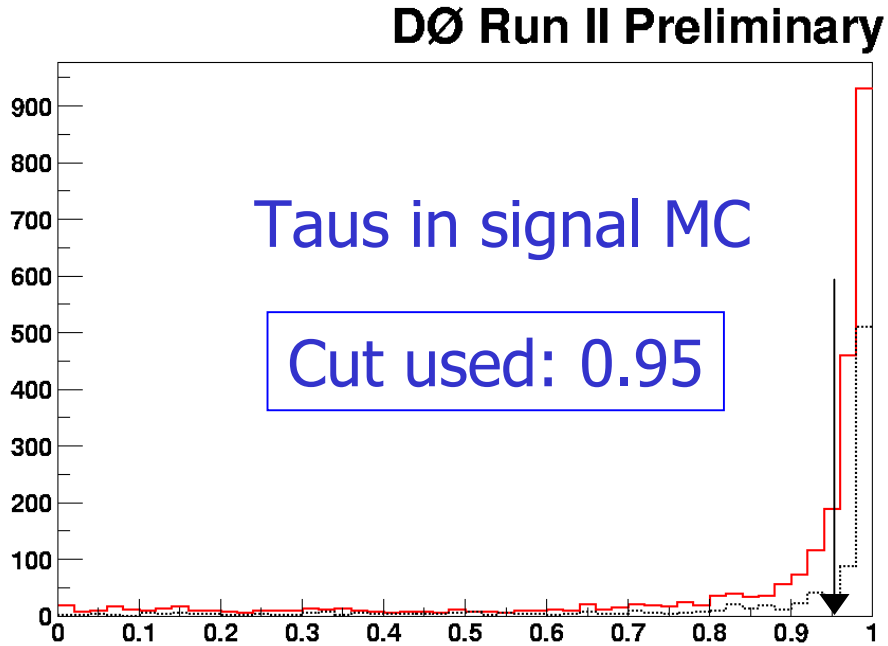
- **Method: Use collinear approximation to calculate $M_{\tau\tau}$**
  - **preselect electron sample with E_T > 12 GeV; require jet which is a τ candidate**
  - **daughter particles from τ are assumed to give τ direction; measured $\not{E}_T$ used to project neutrino momentum along τ direction**
  - **requires cut in $\Delta\phi$ in order to keep reasonable resolution (significant efficiency loss)**
  - **for bkg rejection, $M_T(e\nu)$ < 60 GeV; $M_{e\,\tau}$ < 60 GeV**
  - **neural net used to tighten τ ID : don't consider 3-prong decays**
  - **use like sign distribution as background estimator**

$Z \rightarrow \tau^+\tau^-$ (electron + hadronic mode)

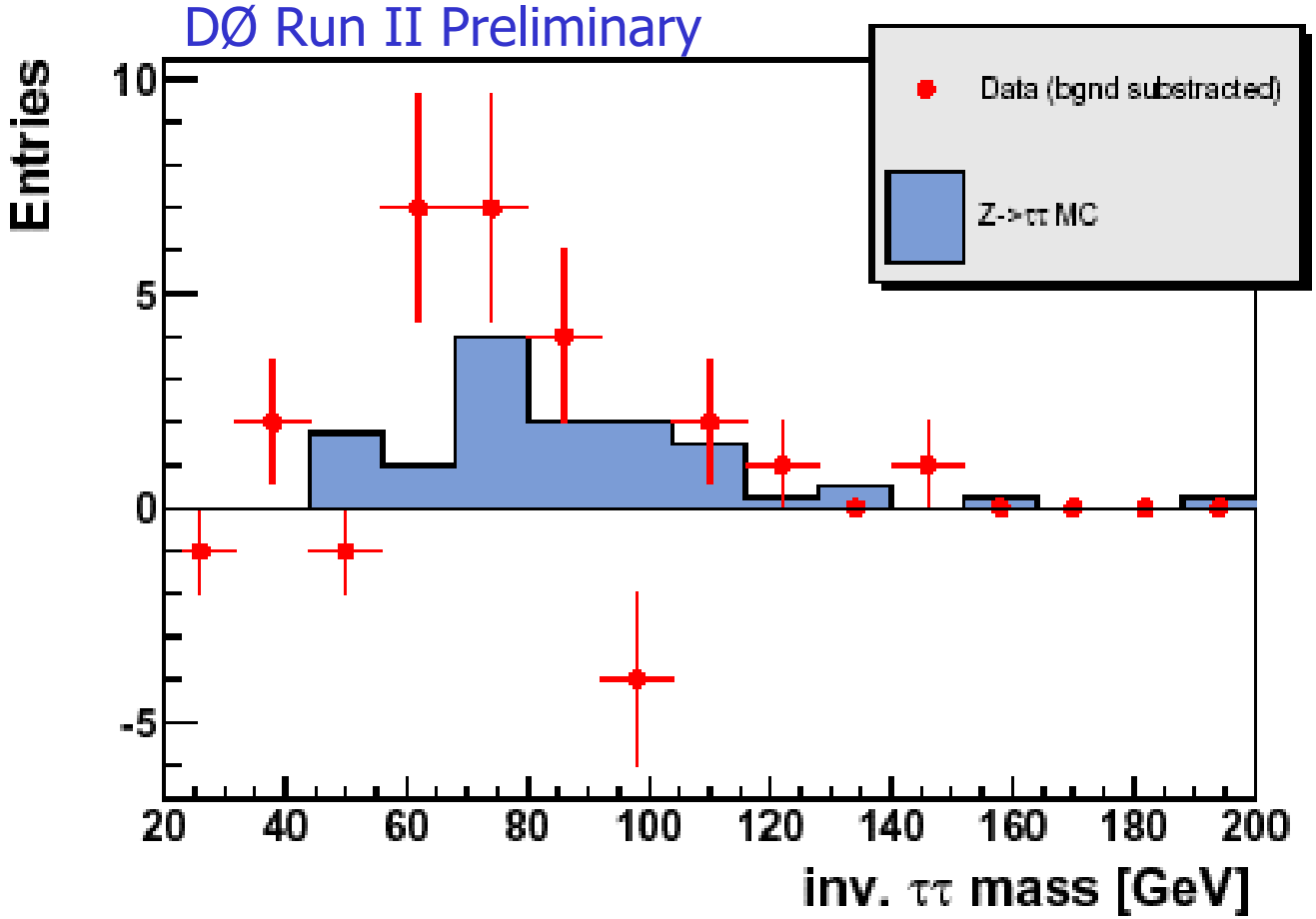


Neutral Net Outputs:
Net 1 is for $\tau \rightarrow \pi^{\pm}\nu$
Net 2 is for $\tau \rightarrow \pi^{\pm}\pi^{0}\nu$

Neutral Net Variables:
Net 1: EM12fr, ring iso, profile, trk iso, Et/pt
Net 2: ring iso, profile, trk iso, Et/pt, e1e2, dalpha



$Z \to \tau^+\tau^-$ (electron + hadronic mode)



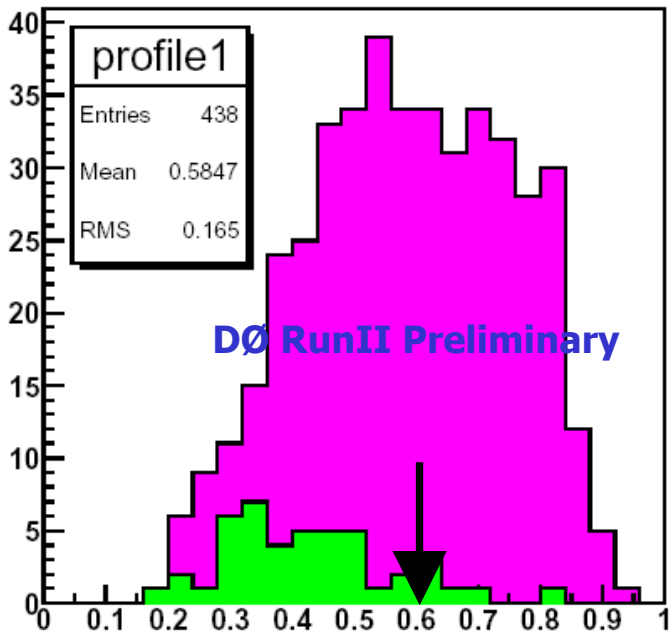
Data:
Opp sgn 49 evts
Like sgn 35
Diff 14 ± 9
Signal MC norm to 50 pb-1:
13 ± 4

Distribution in invariant $\tau\tau$ mass, calculated using collinear approximation, (opp sign - like sign)

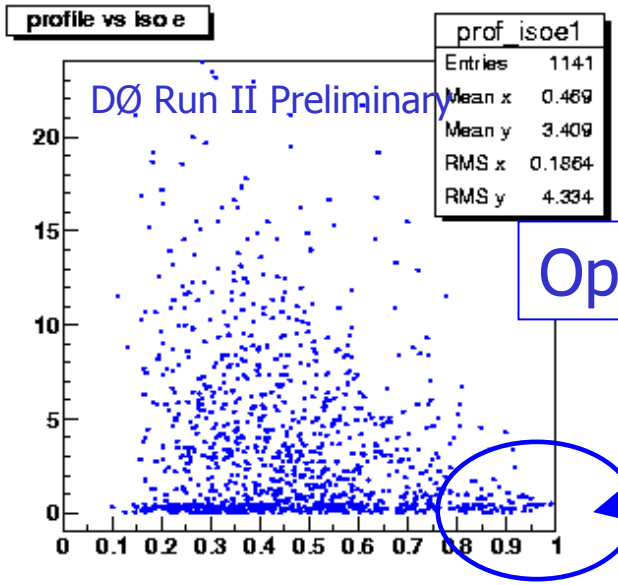
$Z \rightarrow \tau^+\tau^-$ (muon + hadronic mode)

- **Successive cuts to enhance tau signal, starting from single mu sample**
  - **central, isolated tight muon, p_T > 7GeV, and a jet flagged as a τ candidate w/ E_T > 7GeV, and the two objects with ($\Delta\phi$ >0.4)**
  - **increase $\Delta\phi$ cut to 2.5, increase τ E_T cut to 15 GeV, require isolated single trk matching τ**
    - **plot profile (sum of two leading ET towers/total ET)**
    - **normalize low end of profile dist to obtain factor in QCD sample between opp and same sign: 1.04**
  - **require profile > 0.6**

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



$Z \rightarrow \tau^+\tau^-$ (muon + hadronic mode)

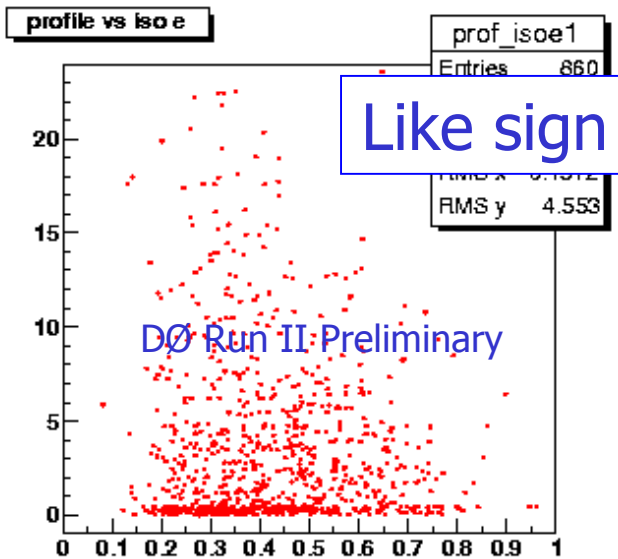


Opposite sign data

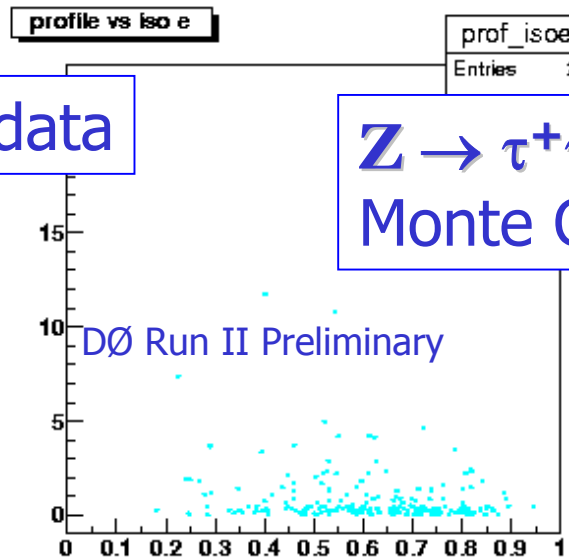
Plot isolation vs profile:

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

Analysis 1: Chargino/Neutralino Search

- **Model: mSUGRA, tan β = 2, μ < 0; chargino/neutralino pair production with both decaying to leptons**
- **This analysis: 2e + lepton + $\not\!\!E_T$**
  - **Triggers: 2e - single and diEM triggers**
  - **Preselection: 2 EM objects with E_T > 7 GeV**
  - **Selection: EM ID; $E_T(e_1)$ > 15GeV, $E_T(e_2)$ > 10GeV, both w/ trk match; 10GeV < M_{ee} < 70GeV; $M_T(e)$ > 15 GeV; 3rd lepton requirement: add'l trk p_T > 5 GeV, well isolated from other 2 leptons (0.4 in η and ϕ); η < 3; $\not\!\!E_T$ > 15GeV**
  - **Background estimation: SM processes w/ real $\not\!\!E_T$ from PYTHIA + full det sim; QCD bkg from data w/ inverted ID cuts**

Chargino/Neutralino Search - cont'd

	Sum Bkg	Data
ID + kinem + trk	3216 ± 43	3132
$10 < M_{ee} < 70$	660 ± 19	721
$M_T > 15$	96 ± 8	123
3rd trk	3.2 ± 2.3	3
$ME_T > 15$	0.0 ± 1.4	0

Result for ee + lepton

- efficiency 3-6 % for 2 mSUGRA pts
- excludes (σ x BR) = 3.5-2.2 pb

~40 pb^{-1}

Analysis 2: GMSB SUSY Search

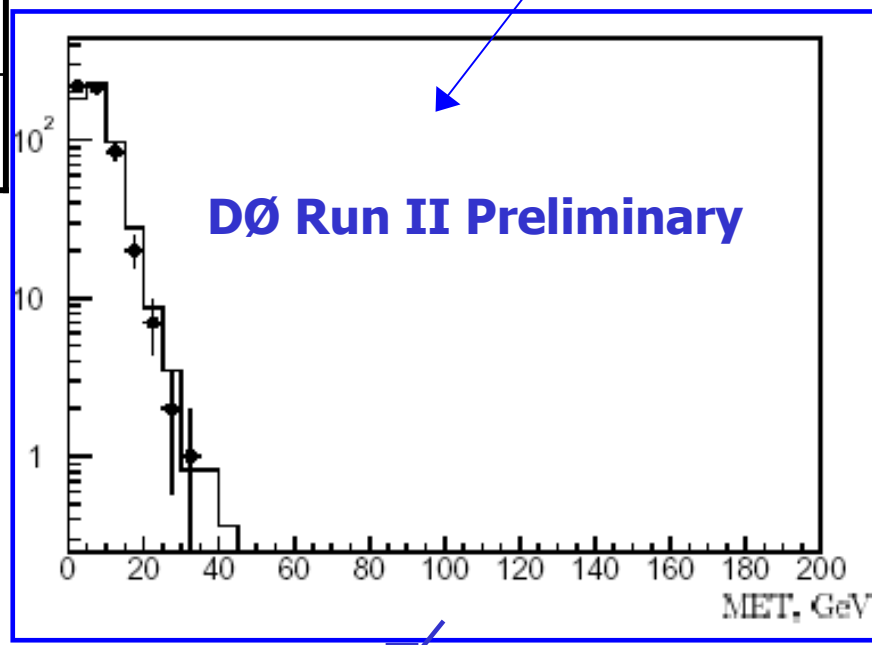
- **The model: Gauge-Mediated Symmetry Breaking SUSY with neutralino NLSP, characterized by Λ, the scale of SUSY breaking. Params used: M = 2 Λ, N_5 = 1, tan β = 15, sign(mu) positive**
- **This analysis: 2γ + $\not\!\!E_T$**
  - **3 Triggers: 1 or 2 EM objects (>97% eff for 2γ w/ E_T>20GeV)**
  - **Select 2 EM obj: central η, standard EM ID, no matched trks, E_T > 20 GeV**
  - **Topological and data quality cuts chosen to minimize QCD background and non-gaussian tails for $\not\!\!E_T$**
    - **no jets in InterCryostat region**
    - **leading jet and MET more than 2.5 radians apart**
  - **MET calculated using cells (cells in jets, for outer region)**

GMSB SUSY Search - cont'd

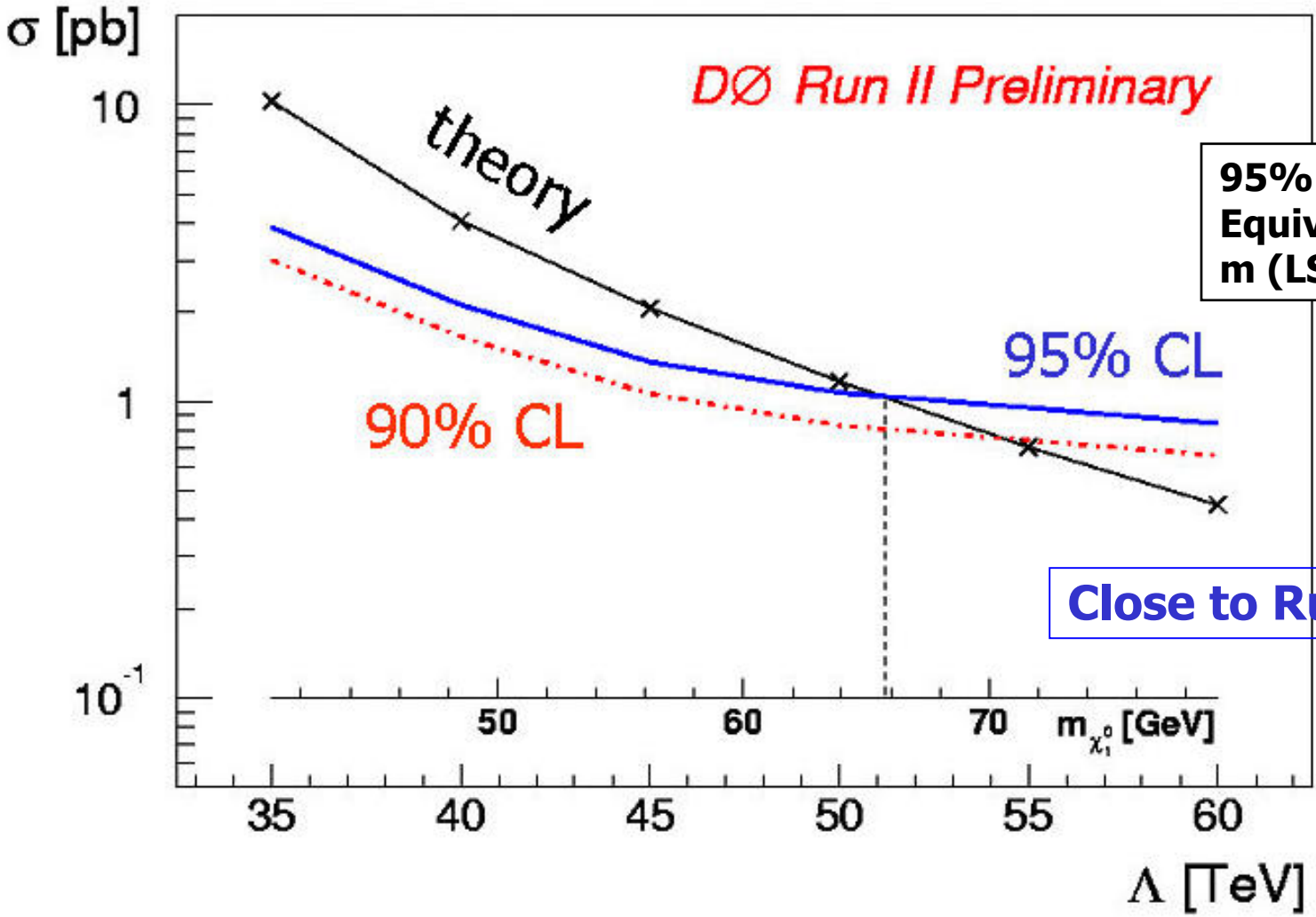
Sample / MET bin	QCD - dominated Data Sample	2 γ data	QCD Data Sample Normalized
< 20	5841	535	Normalized to be equal
> 25	65	3	6.0 ± 0.8
> 30	27	1	2.5 ± 0.5
> 35	18	0	1.6 ± 0.4

QCD background sample obtained by inverting EM quality cuts

Missing E_T distribution of 2 γ data (points) compared with normalized QCD background (hist)



GMSB SUSY Search - cont'd



95% CL on Λ : 51TeV
Equivalent limit on m (LSP) = 66 GeV

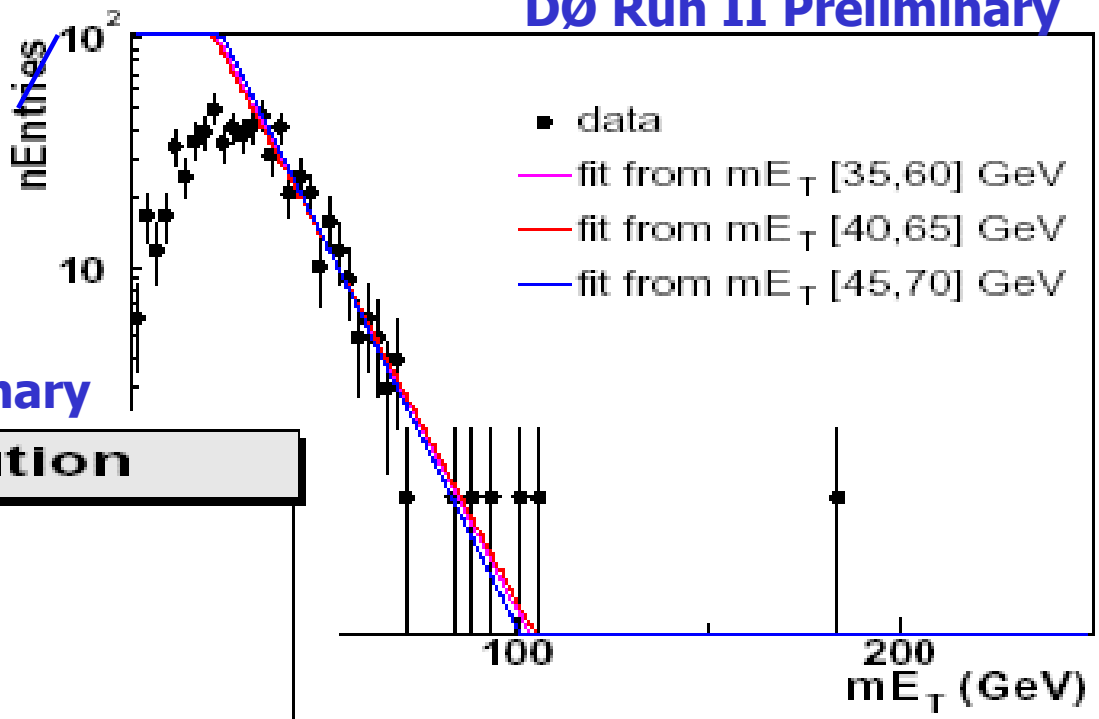
Close to Run I limits!

Analysis 2: Jets + $\not\!\!E_T$ Search

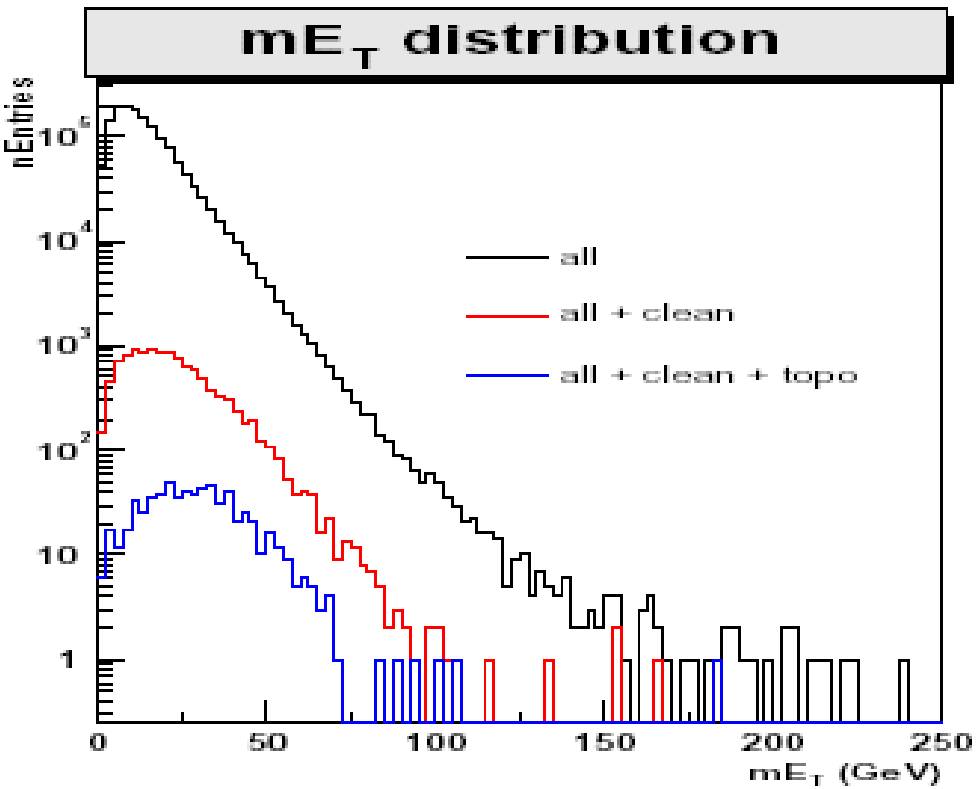
- Standard SUGRA, neutralino LSP
- Squark - gluino pair production; in particular, signal was estimated for sbottom pairs
- This analysis: 2 jets + $\not\!\!E_T$
  - Trigger: single, central high p_T jet > 65 GeV
  - ID: cone 0.7 jets, ME_T from cal towers, JES corrections
  - Selections: Jet quality cuts, electrons removed, angular separation cuts on 2 leading jets, and each of 3 leading jets with ME_T; data quality cuts; p_T of leading jet > 100 GeV (insures trigger eff)
  - 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 + $\not\!\!E_T$ Search - cont'd

DØ Run II Preliminary

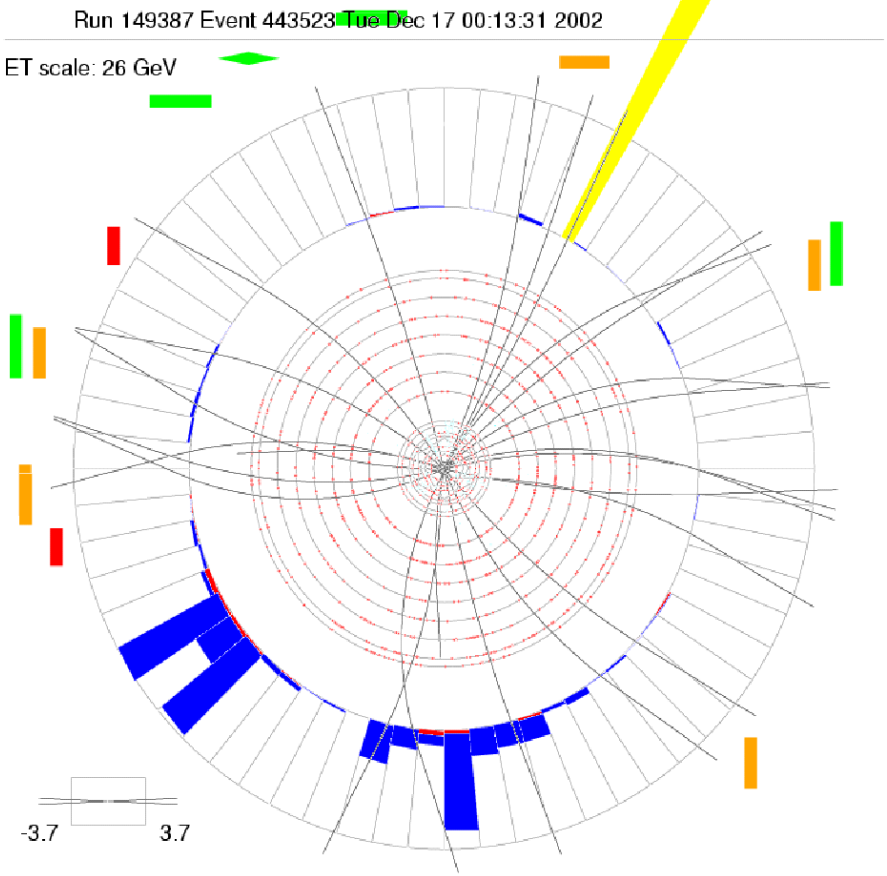


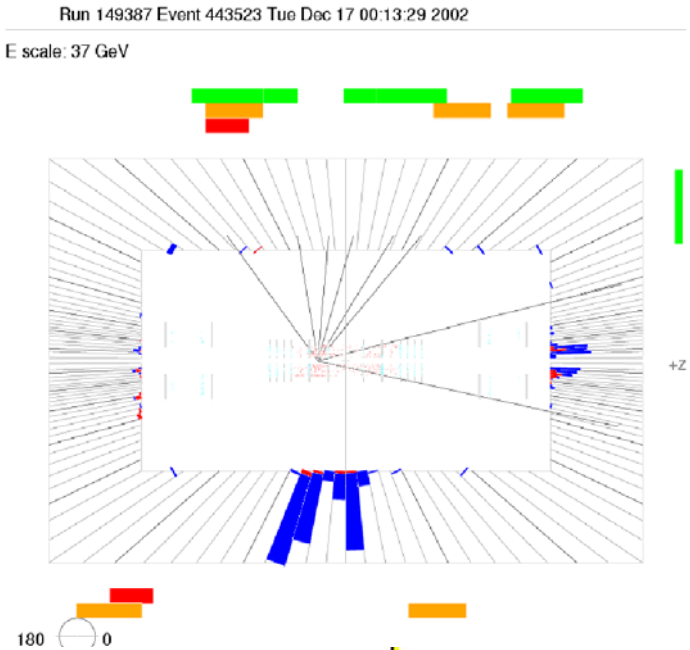
DØ Run II Preliminary

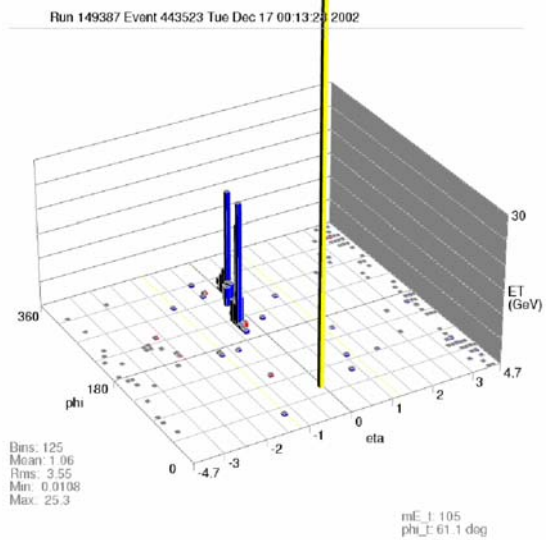


Jets + $\not{E}_T$ Search

Views of the highest $\not{E}_T$ event







Jets + $\not\!\!E_T$ Search - cont'd

# evts / ME_T bin	QCD fit	Total bkg	Data	95% CL ε X σ (pb)
> 70 GeV	$17.4 \pm 7.9 \pm 2.7$	$18.4 \pm 7.9 \pm 2.7$	7	4.18
> 80 GeV	$8.5 \pm 5.0 \pm 1.7$	$9.5 \pm 5.0 \pm 1.7$	6	3.76
> 90 GeV	$4.2 \pm 3.0 \pm 1.0$	$5.1 \pm 3.0 \pm 1.0$	4	3.12
> 100 GeV	$2.0 \pm 1.7 \pm 0.6$	$2.7 \pm 1.7 \pm 0.6$	3	2.69

- **Use result to set model-ind cross section limit for jets +$\not\!\!E_T$**

~30 pb^{-1}

Analysis 4: Limits on New Physics in e μ + X Channel

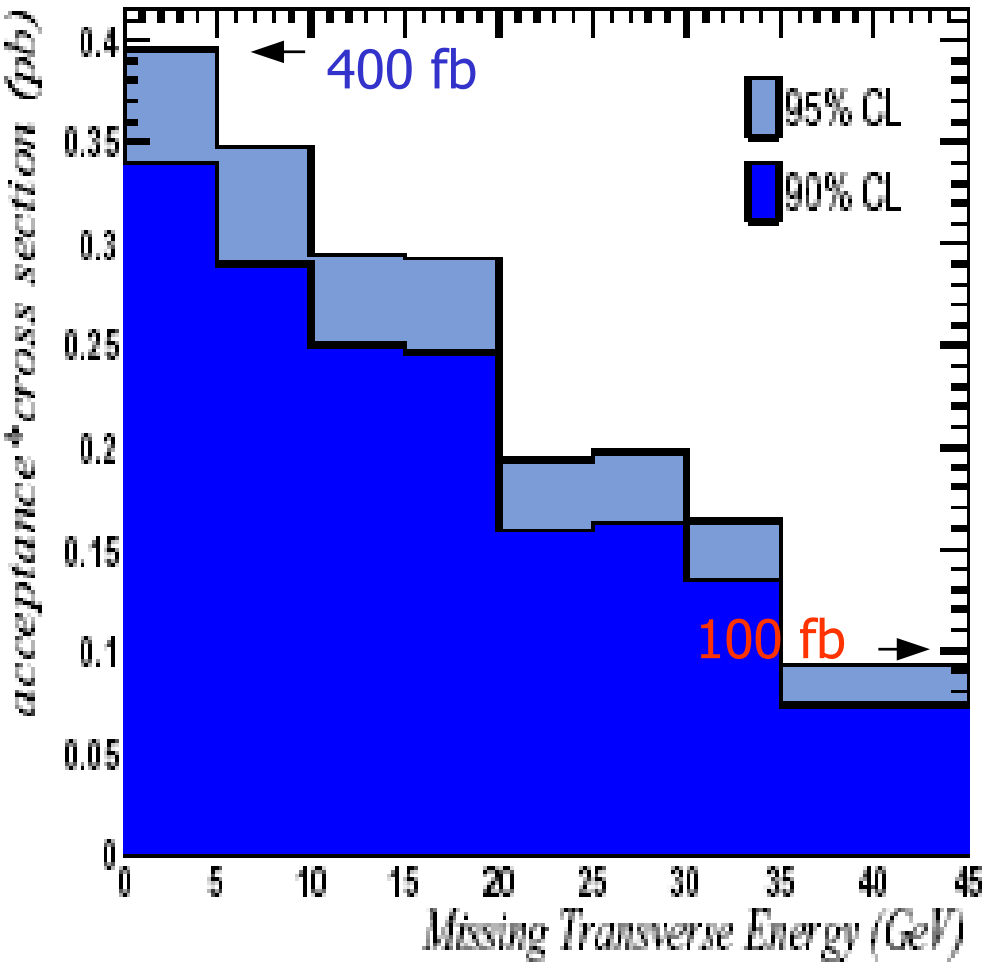
- Seek a channel with low background, high discovery potential and try to provide model-independent limit on NP cross section
- This analysis: e μ + X
  - Trigger: 1 elec w/ $E_T > 20$ GeV, 1 μ w/ $\eta<2$
  - Selection: muon ID'd with scint info, central trk match, isolation using both cal and trk info, cosmic veto. Electron ID'd w/ isolated EM cluster, trk match. p_T for e and μ > 15 GeV
  - Background identification: misID probability measured from data; SM contributions from PYTHIA generation + full GEANT detector sim (WW, $Z \rightarrow \tau^+\tau^-$, $t\bar{t}$)

Limits on New Physics in e μ + X Channel - cont'd

$\not{E}_T$ 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% $Z \rightarrow \tau\tau$

Cross Section Limits vs $\not{E}_T$ cut

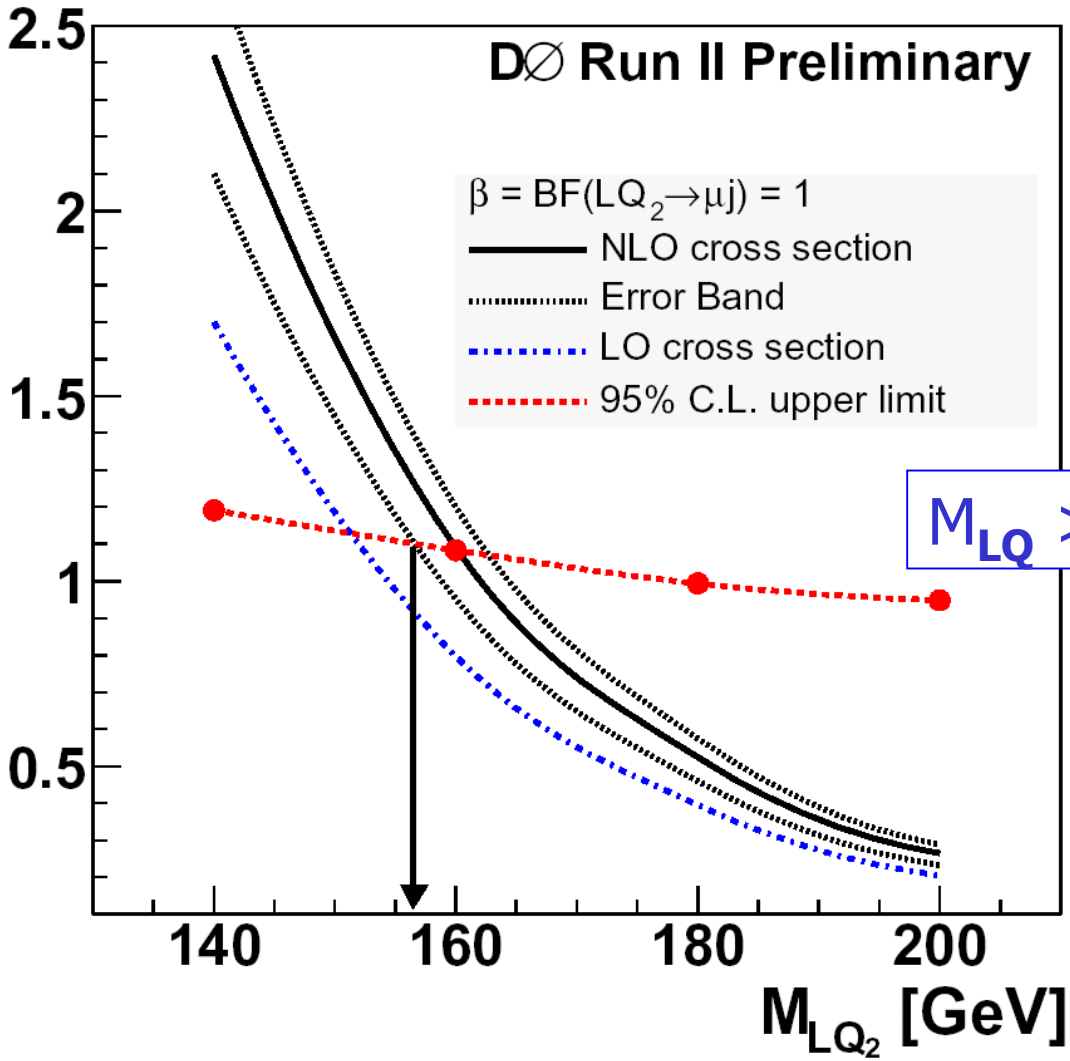


~30 pb^{-1}

Analysis 5: 2nd Generation Leptoquark Search

- **Model: Scalar LQ pair production, 100% BF to charged lepton**
- **This analysis: 2μ + 2jets, no $\not{E}_T$**
  - **Trigger: 2 μ at Level 1, 1 μ at Level 2, no further rejection at Level 3**
  - **Preselection: 2 isolated(use both cal & trk info) μ's (central trk match, minimal req on # hits in muon sys), p_T > 15 GeV, opp charge, $\mu\,\mu$ mass > 60 GeV**
  - **Compare w/ leading order simulation for D-Y; correct for observed jet multiplicity in $\mu\,\mu$ mass window [60-110GeV]**
  - **LQ sample selection: require 2 cone 0.5 jets, E_T > 20GeV, η < 2.4, standard jet ID, $\mu\,\mu$ mass > 110 GeV**

2nd Generation Leptoquark Search - cont'd

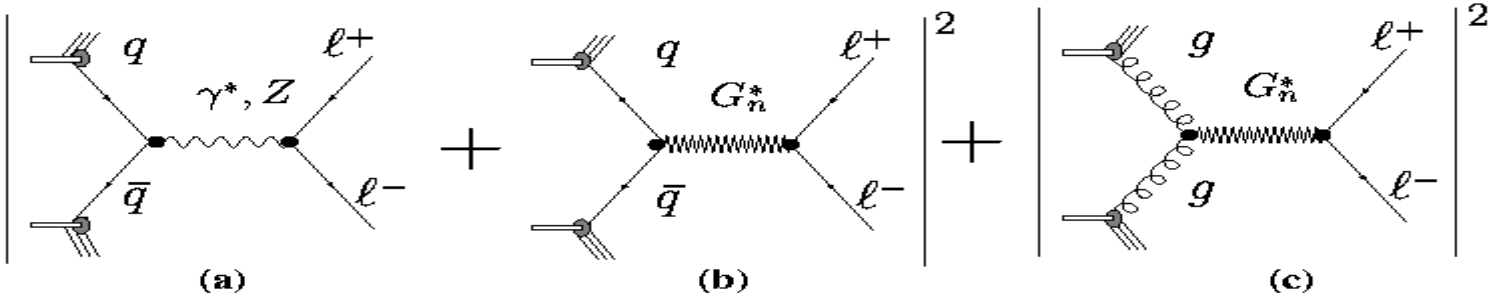


$M_{LQ} > 157$ GeV

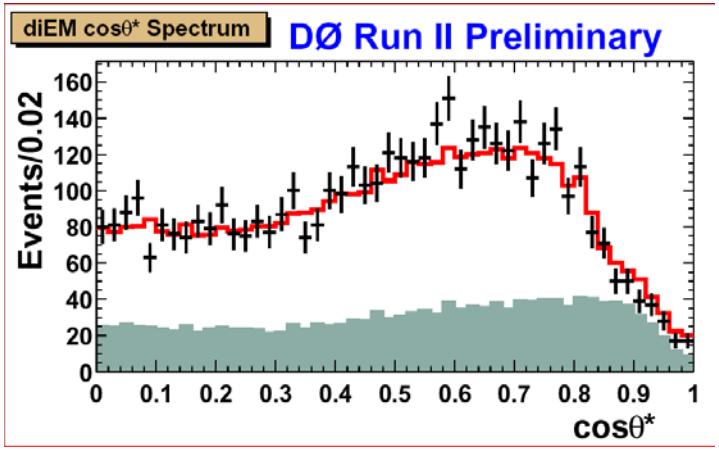
~50 pb^{-1}

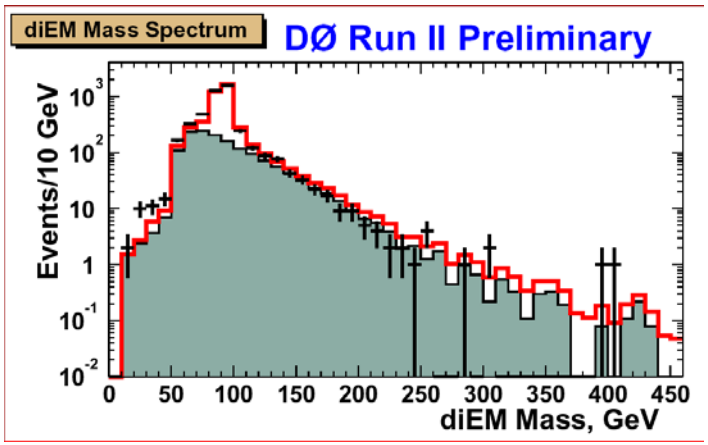
Analysis 6: Large Extra Dimensions Search w/ Electrons and Photons

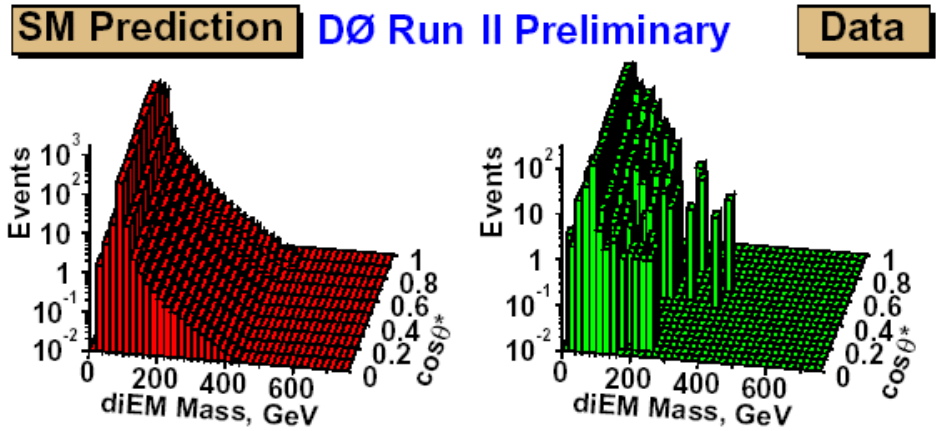
- Model framework: string theory w/ SM restricted to D3-brane, gravity propagating in extra dim's. Signature arises from virtual graviton diagrams contributing to dilepton and diboson production. (Figure below)
- This analysis: ee and $\gamma\gamma$ channels combined
  - Triggers: single or di-EM triggers
  - Selection: $E_T > 25$ GeV for both EM objs, $\not{E}_T < 25$ GeV, EM quality and data quality cuts.
  - Background estimation: fast MC for D-Y and diphoton production, estimate from data for misID background

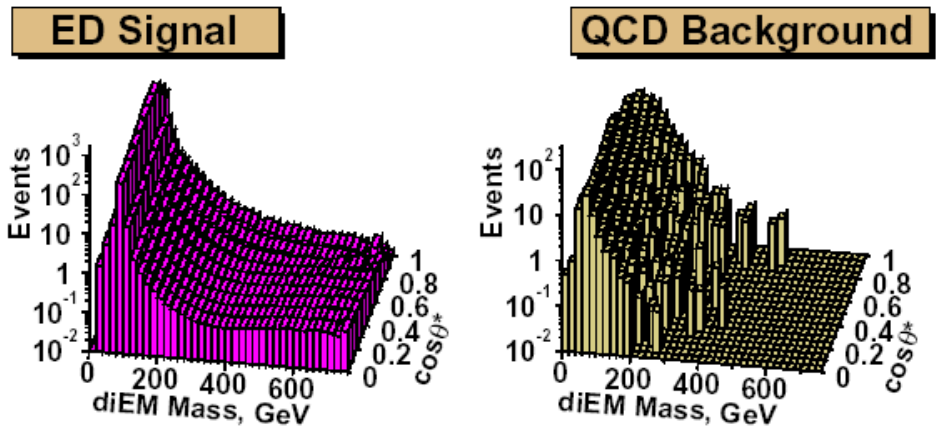


Large Extra Dimensions Search w/ Electrons and Photons - cont'd









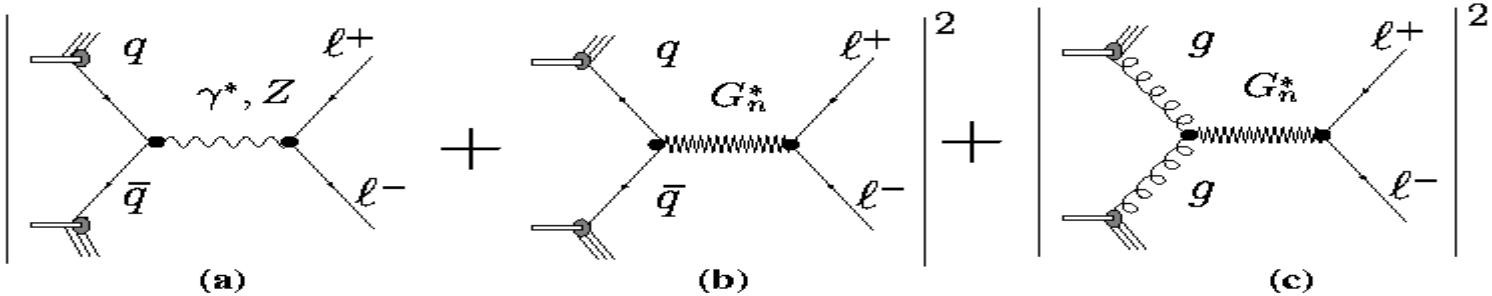
Fit to 2-D distributions to extract SM, interference, and direct gravity terms; use topologies w/ at least 1 EM obj in central calorimeter

~30 pb^{-1}

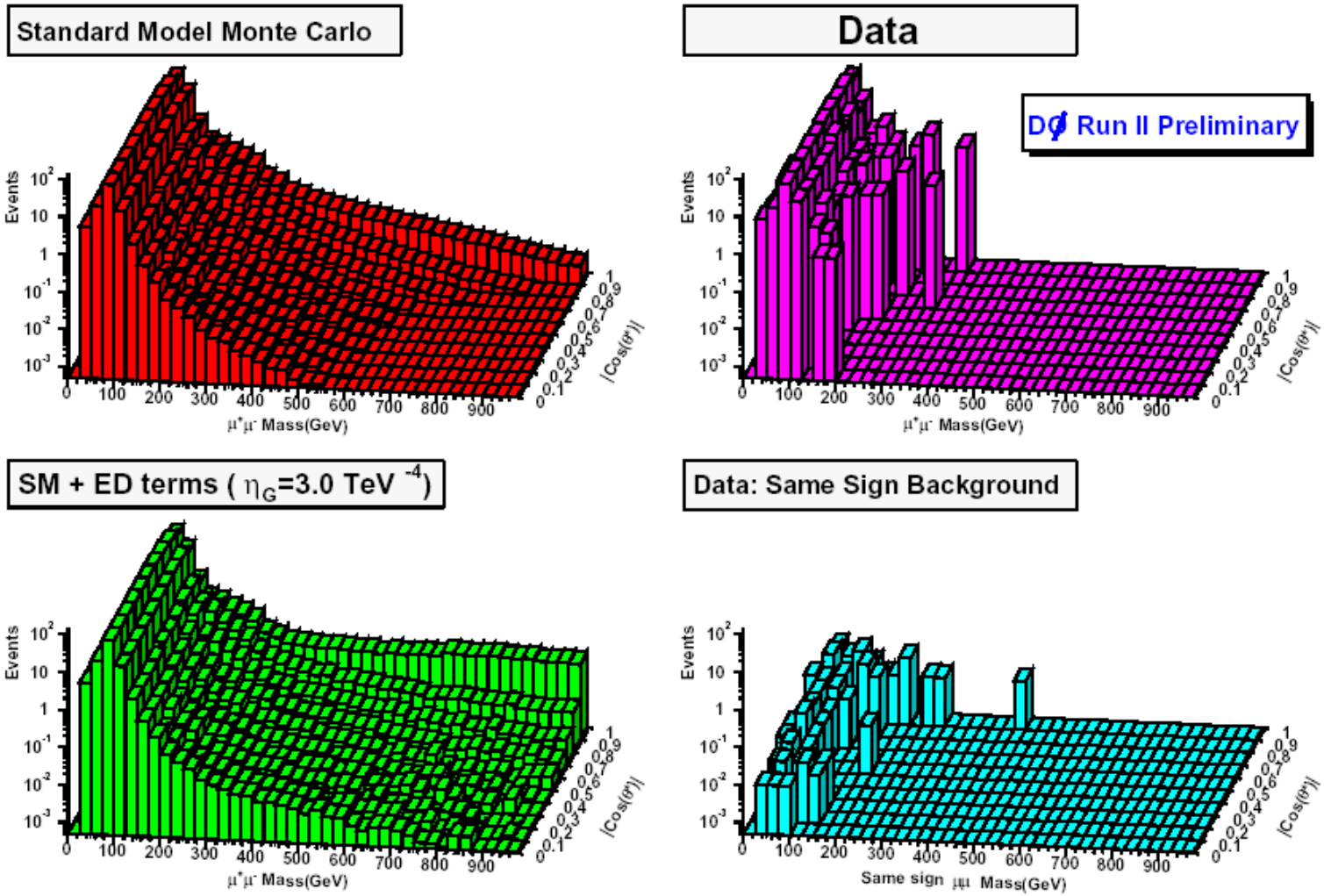
Analysis 7: Large Extra Dimensions Search w/ Muons

New Channel!

- **Model framework: same as LED/EM search**
- **This analysis: $\mu\mu$ channel**
  - **Trigger: 2 μ at Level 1, 1 μ at Level 2, no further rejection at Level 3 (fully eff for kinematic cuts used)**
  - **Selection: 2 μ w/ cent trk match, p_T > 15 GeV, cosmics removed, iso using cal and trk info, M$\mu\,\mu$ > 40 GeV (~1200 events)**
  - **Background estimation: fast MC for D-Y production, estimate from data for misID background**



Large Extra Dimensions Search w/ Muons - cont'd



Large Extra Dimensions Searches - Results

- **Fit value of η_G : expected to be zero in SM**

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

di-EM analysis: η_G = 0.0 $\pm$ 0.27 TeV^{-4}

di-μ analysis: η_G = 0.02 $\pm$ 1.35 TeV^{-4}

- **Extract 95% CL upper limits on η_G**
- **Translate to 95% CL *lower* limits on Planck scale M_S, in TeV, using different assumptions about F**

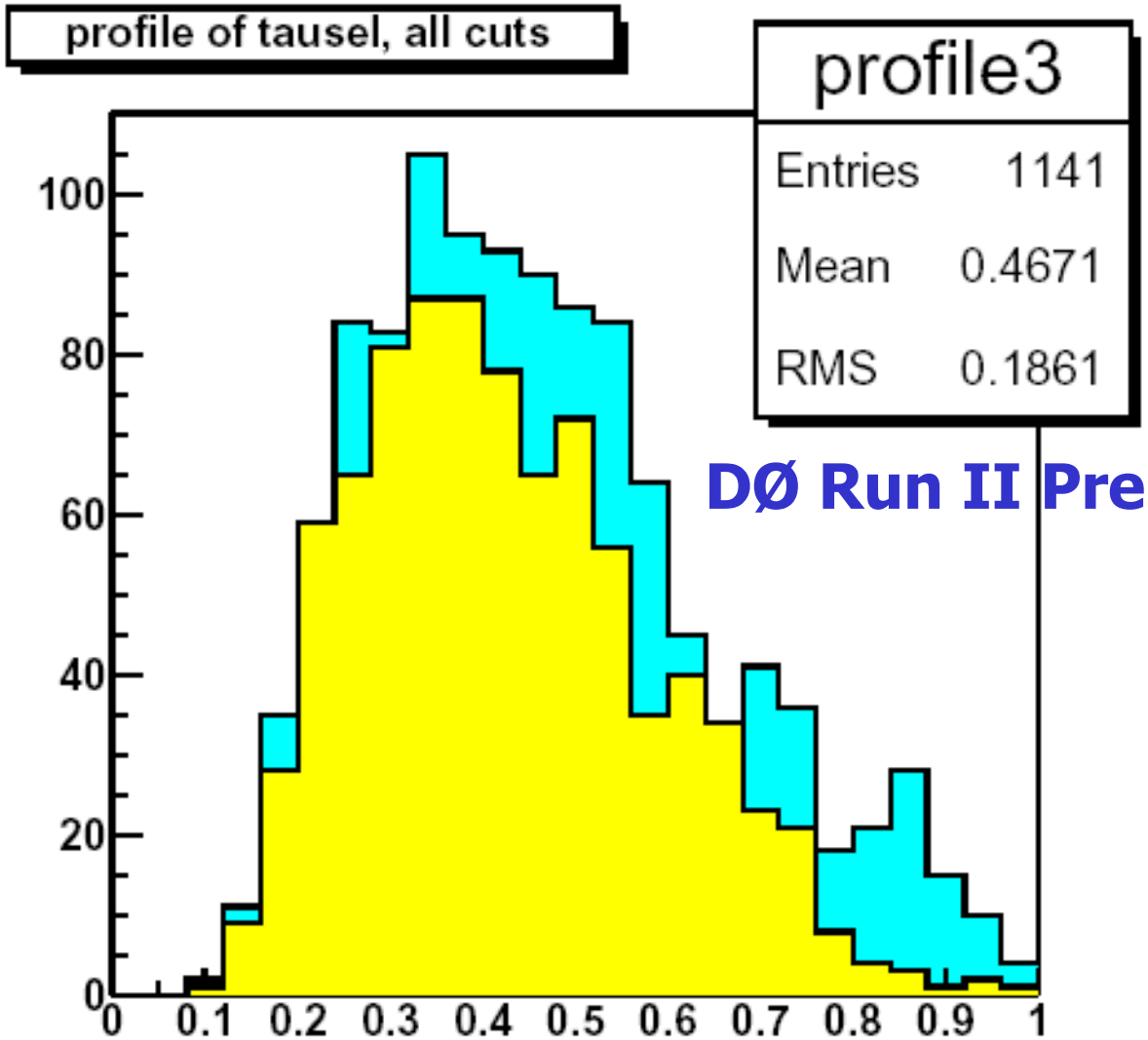
	GRW	HLZ for n=: 2	7	Hewett $\lambda = +1$
diEM	1.12	1.16	0.89	1.00
diMU	0.79	0.68	0.63	0.71

diEM limit close to Run I
diμ limit new channel

Conclusions

- DØ continues to pursue searches for New Phenomena vigorously, including new search channels (LED w/ 2μ).
- DØ's search reach and capabilities are expanding, as we add, for example, τ ID. More luminosity will very soon take us beyond Run I.
- We anticipate with excitement the rise of the discovery potential as Run II 's dataset accumulates

$Z \rightarrow \tau^+\tau^-$ (muon + hadronic mode) - backup



DØ Run II Preliminary

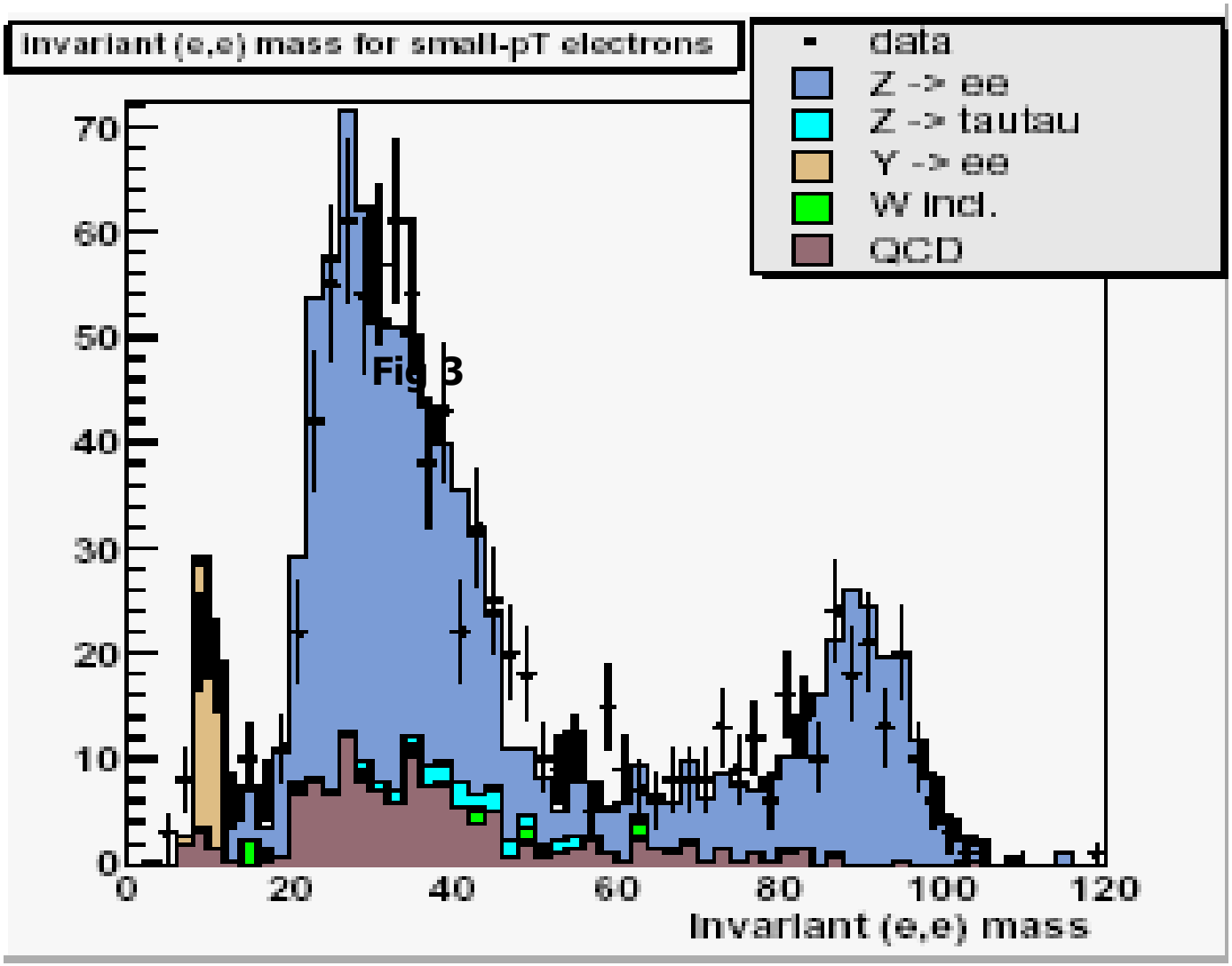
$Z \to \tau^+\tau^-$ (muon + hadronic mode)

- **Resulting event counts**

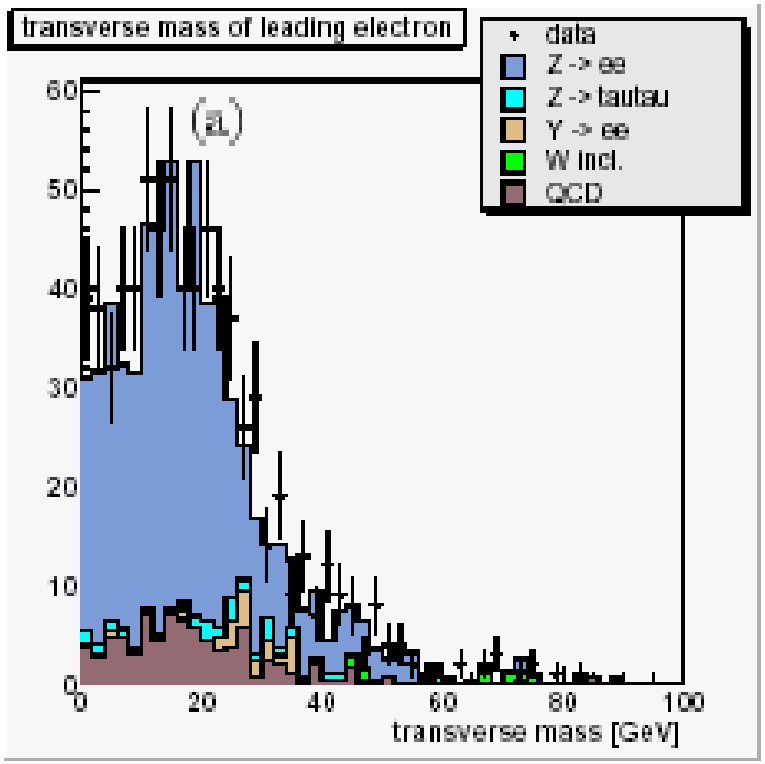
Number of $\mu\ \tau$ events applying succesive cuts

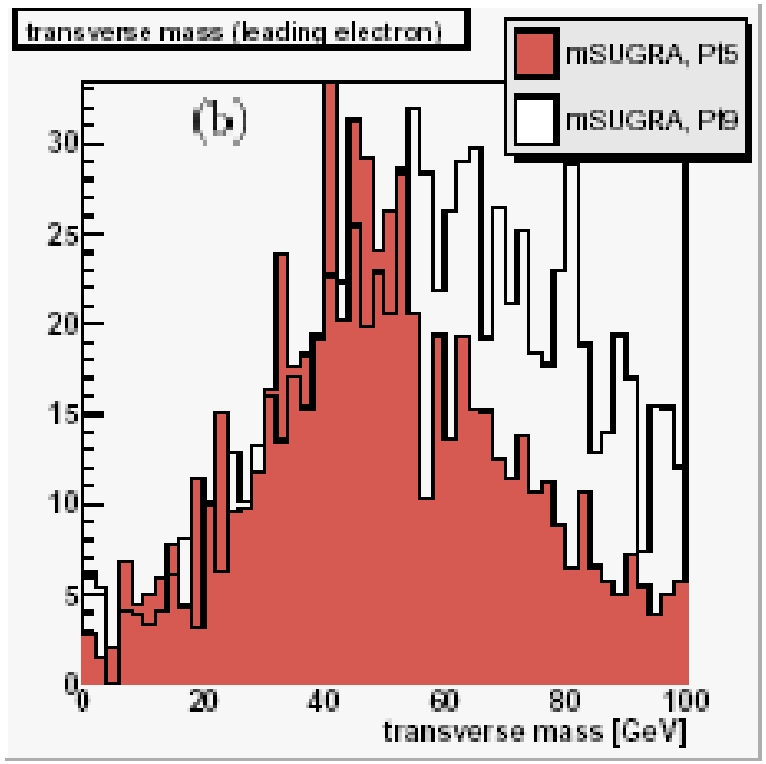
Cuts	DATA			$Z \to \tau\tau$
	$\begin{matrix}+- \\ -+\end{matrix}$	$\begin{matrix}++ \\ --\end{matrix}$	opp - 1.04* eq	50 pb^{-1} $\begin{matrix}+- \\ -+\end{matrix}$
$p_T^\mu > 7$ GeV	25138	22999	$1218^{+}_{-}220$	$405^{+}_{-}40$
$p_T^\mu > 15$ GeV	3209	2719	$381^{+}_{-}70$	$212^{+}_{-}30$
$\lvert\phi_\mu - \phi_\tau\rvert > 2.5$	1893	1557	$273^{+}_{-}59$	$200^{+}_{-}30$
1 prong	1141	860	$246^{+}_{-}45$	$151^{+}_{-}20$
prof.>0.6	355	210	$136^{+}_{-}24$	$100^{+}_{-}15$

Chargino/Neutralino Search - backup

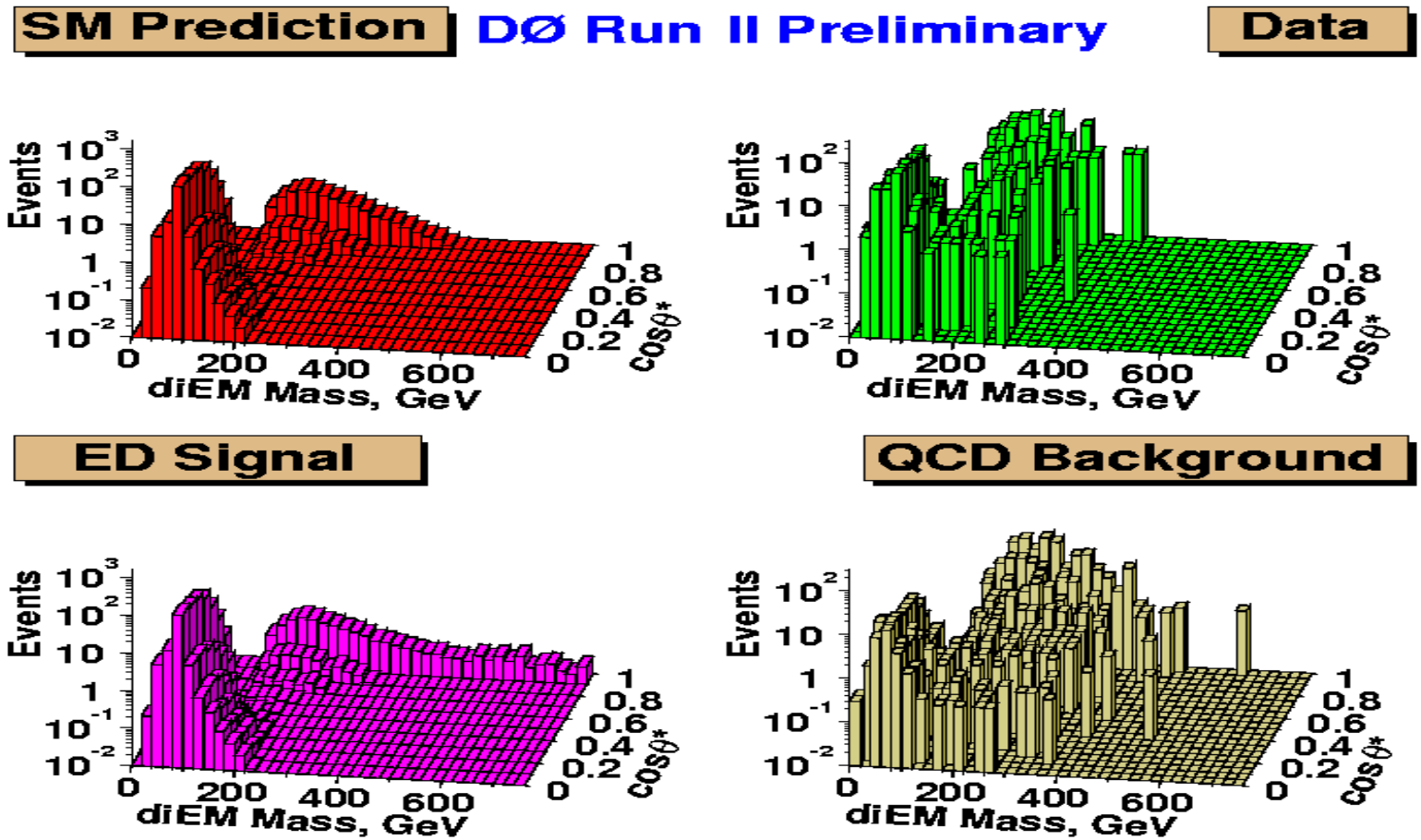


Chargino/Neutralino Search - backup





Large Extra Dimensions Search w/ Electrons and Photons - backup



Large Extra Dimensions Searches - backup