Searches for New Physics in Lepton Final States

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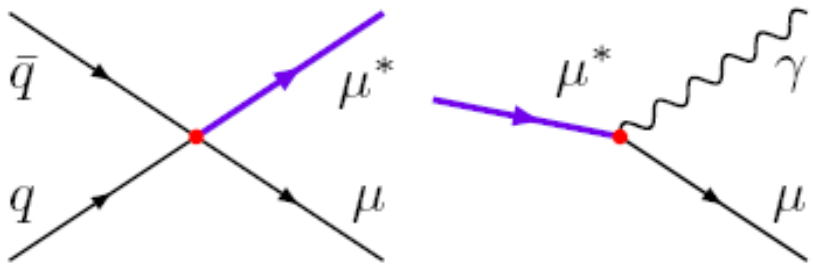
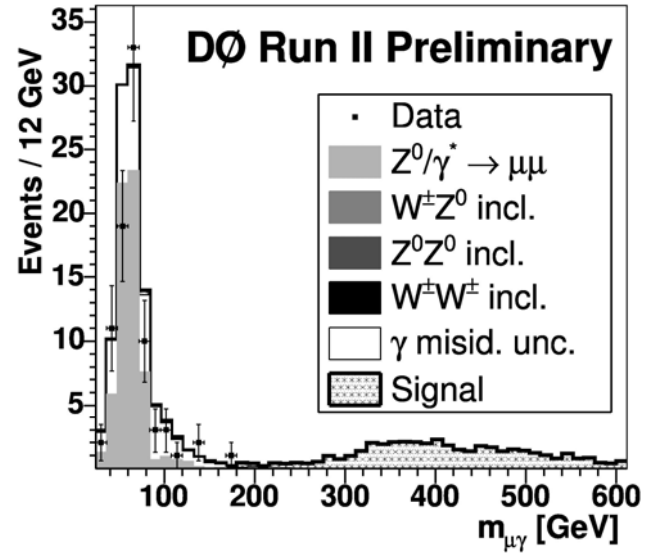
Moriond Electroweak Interactions and Unified Theories
March 16, 2006

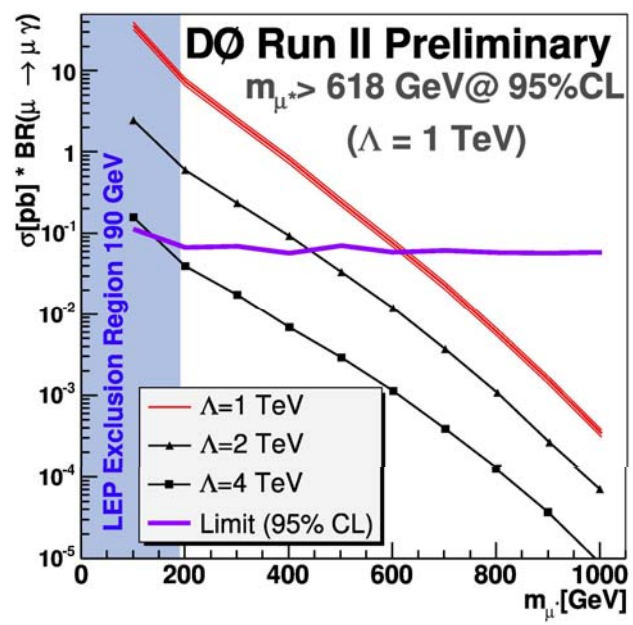
Excited Muons

- *Do leptons have structure?*
- μ* produced in qqμμ contact interactions (CI)

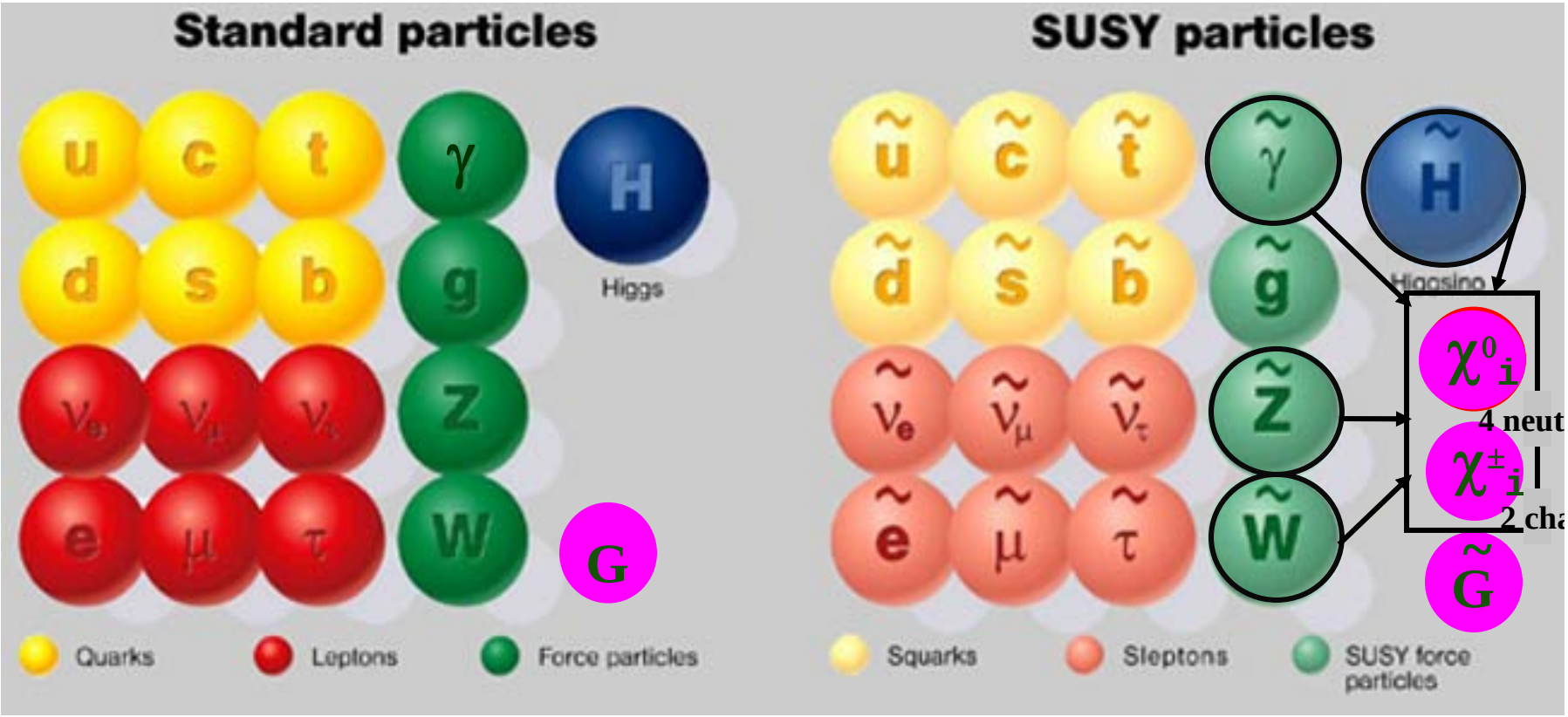




- μ* decay via CI or EWK:
  - **Look for μμγ.**
- Backgrounds:
  - **Drell-Yan: 65±8 events,**
  - **Diboson: ~ 1 event**
  - **Fakes (jet misID as γ) ~ 39 ±5 events**
- Observed 90 events
- CDF, *no CI decays*: M_{μ^*} <850 GeV (95%CL)



Supersymmetry



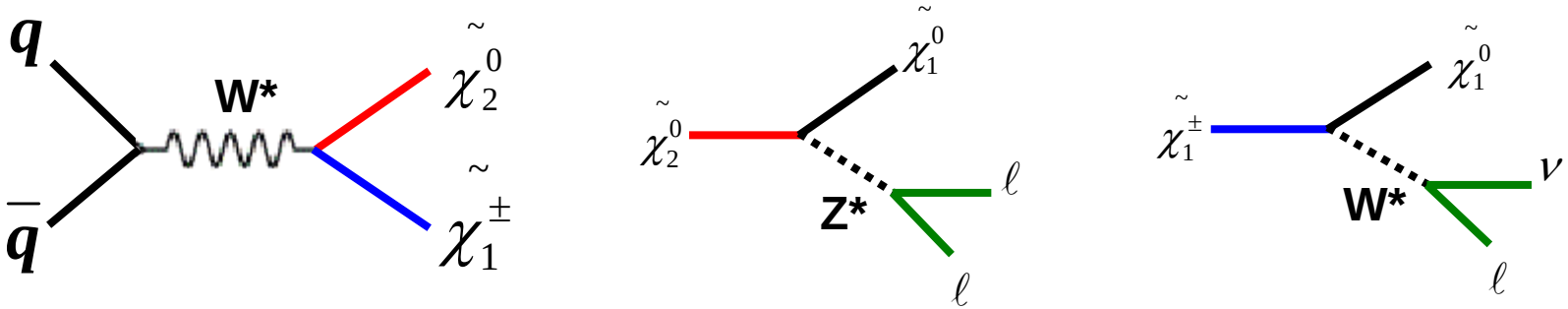
- Supersymmetry: SM fermion ⇔ SUSY boson; SM boson ⇔ SUSY fermion
- Needed to cancel divergences in Higgs mass Δm_H^2.

R-Parity Quantum Number--> $R_p = (-1)^{B+L+2s}$ **+1 (SM particles)**

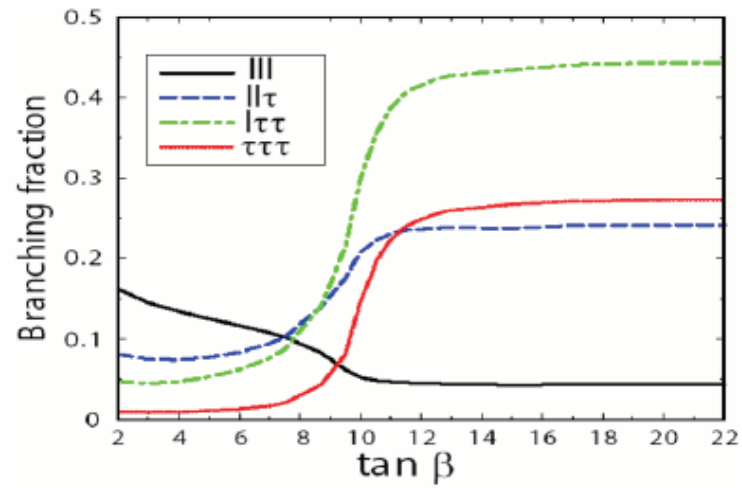
-1 (Susy particles)

Chargino/Neutralino

- Supersymmetry: SM fermion ⇔ SUSY boson; SM boson ⇔ SUSY fermion
- SUSY fermions W, Z, γ, H mix to form charginos and neutralinos:
  - **Chargino:** χ_1^+, χ_2^+, χ_1^-, χ_2^-
  - **Neutralino:** χ_1^0, χ_2^0
  - **LEP constraints: m(χ+) > 103.5 GeV/c²**



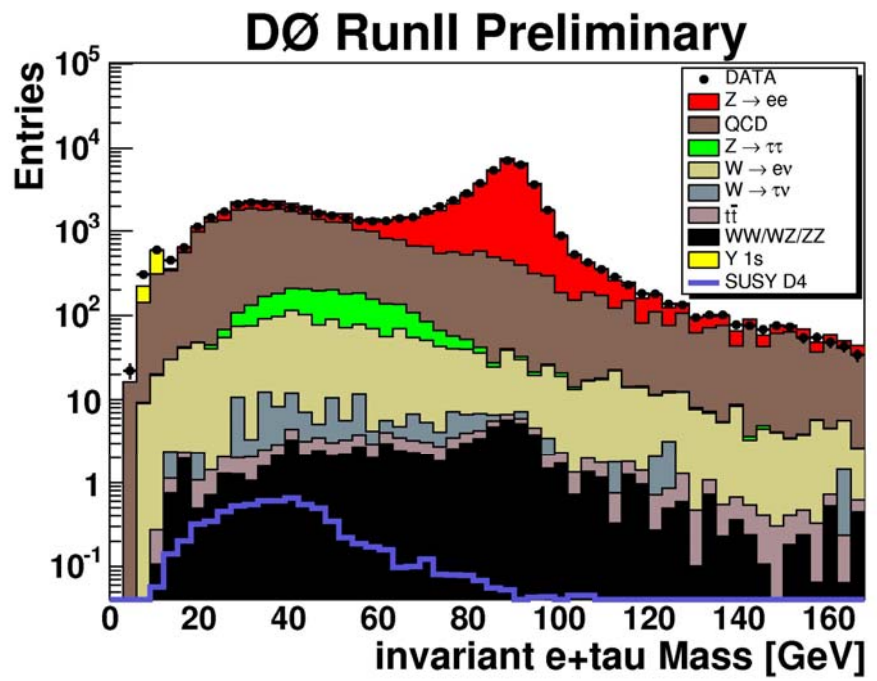
- Striking signature at the Tevatron: 3 leptons + large E_T
- Experimentally: low background + easy to trigger
- Small cross-section and acceptance



Chargino/Neutralino (D0)

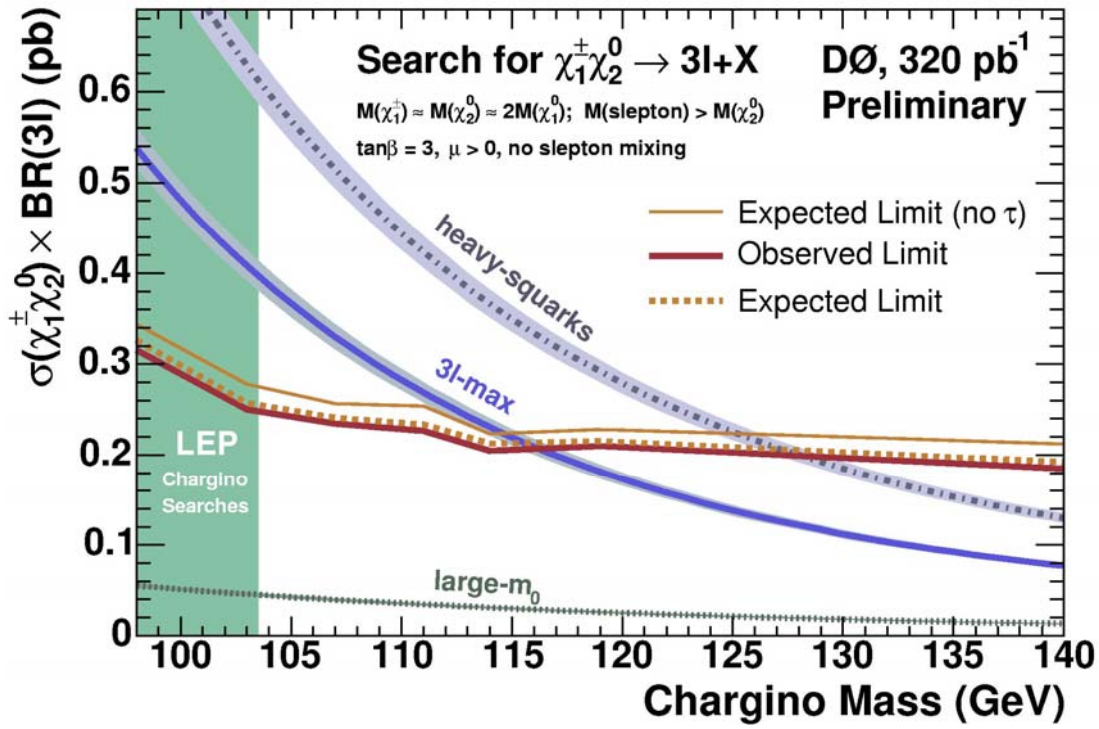
- Electrons and muons combined in *Phys. Rev. Lett.* ***95*** *151805 (2005).*
- Added τ channels: six analyses: 2l(e, μ, τ) + track, $\mu^{\pm}\mu^{\pm}$ (like sign)
  - Impose E_T and topological cuts (M_{ll}, $\Delta\Phi$, M_T)
- Backgrounds:
  - Drell-Yan dilepton production
  - Jets faking leptons
  - W, Dibosons, tt

Selection	SM expected	OBSERVED
ee+l	0.21±0.12	0
eμ+l	0.31±0.13	0
μμ+l	1.75±0.57	2
$\mu^{\pm}\mu^{\pm}$	0.64±0.38	1
eτ+l	0.58±0.14	0
μτ+l	0.36±0.13	1
SUM	3.85±0.75	4



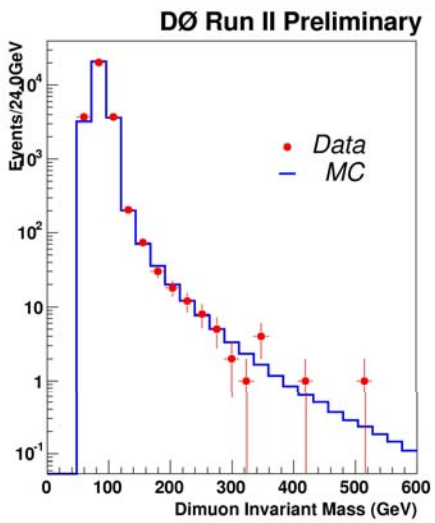
Chargino/Neutralino - Results

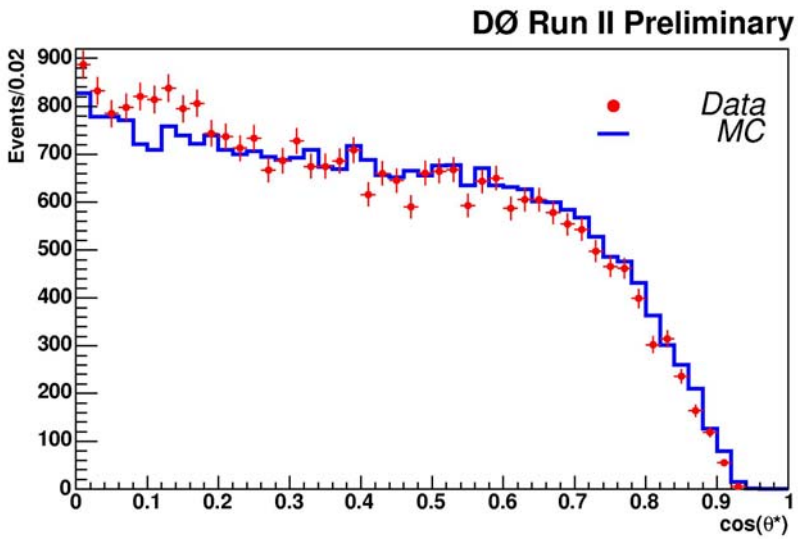
- mSUGRA: $m(\chi^{\pm}) \approx m(\chi^0_2) \approx 2\, m(\chi^0_1)$
  - **3l-max: m(l) ≥ $m(\chi^0_2)$**
  - **No slepton mixing**
- $\sigma \cdot BR < 0.2$pb (95%CL)
  - $m(\chi^0_2)$ **>116 (117) GeV/c²**
- Heavy squarks:
  - $m(\chi^0_2)$ **>128 (132) GeV/c²**
- Large m_0: no sensitivity



Started testing beyond LEP exclusion, but LEP less model-dependent

qqll Contact Interactions





Model	Λ^+(TeV)	Λ^-(TeV)
LL	4.19	6.98
RR	4.15	6.74
LR	5.32	5.10
RL	5.31	5.17
LL+RR	5.05	9.05
LR+RL	6.45	6.12
LL-LR	4.87	7.74
RL-RR	5.07	7.41
VV	6.88	9.81
AA	5.48	9.76

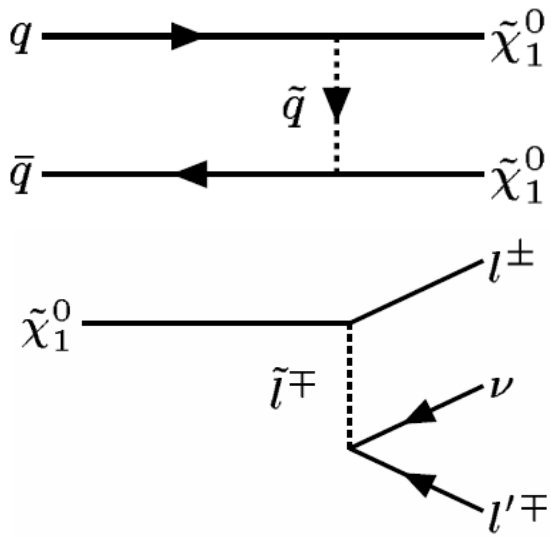
- Contact Interactions qqμμ:
  - Using both mass $M_{\mu\mu}$ and angular information cosθ*
- Tightest constraints on Λ_{CI}

Interaction	LL	LR	RL	RR	VV	AA
Λ^+_{qe} limit (TeV/c^2)	3.7	4.7	4.5	3.9	5.6	7.8
Λ^-_{qe} limit (TeV/c^2)	5.9	5.5	5.8	5.6	8.7	7.8

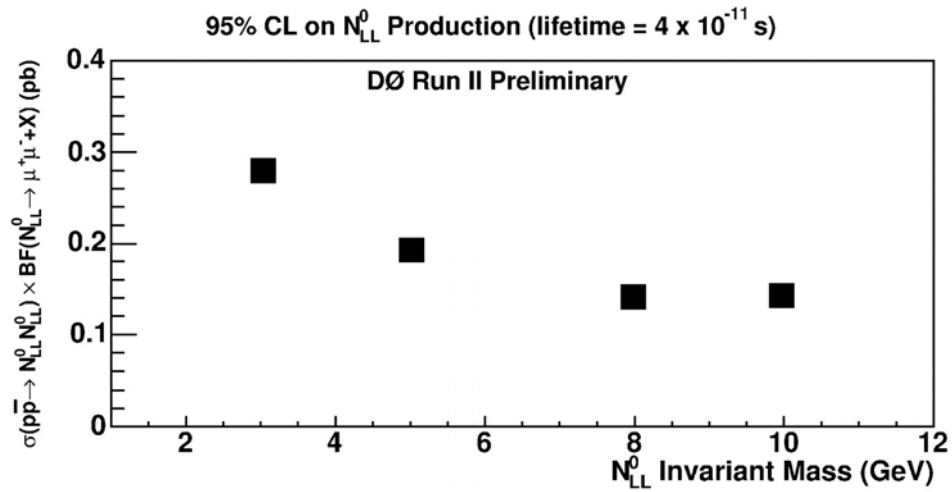
CDF limits for qqee CI scales

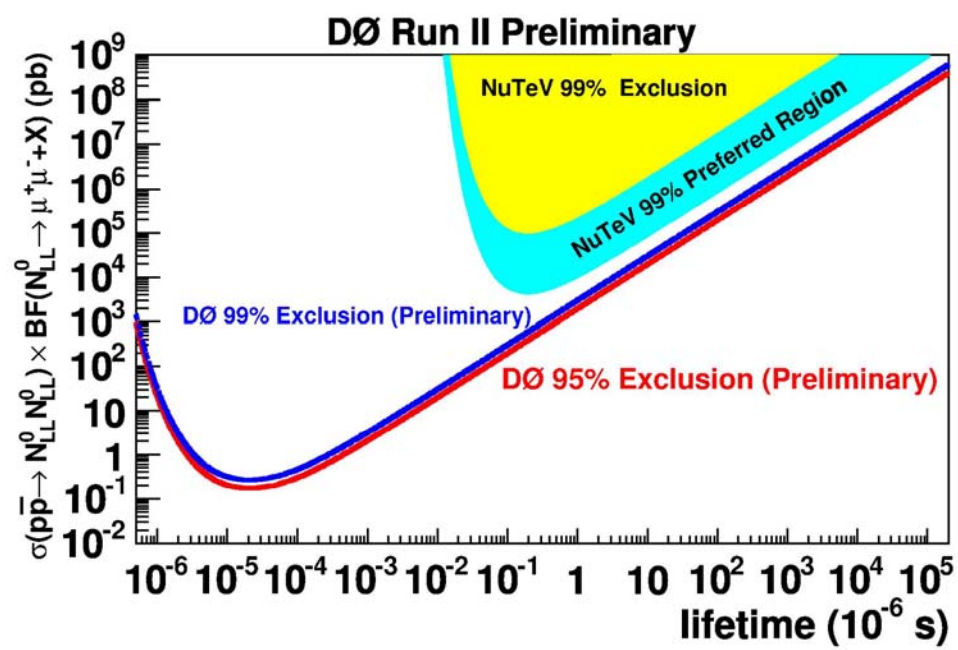
Neutral Long Lived Particles

- 3 intriguing events seen at NuTeV
- Looking for N_{LL}^0 decays to dimuons
- Decays at least 5cm from primary interaction



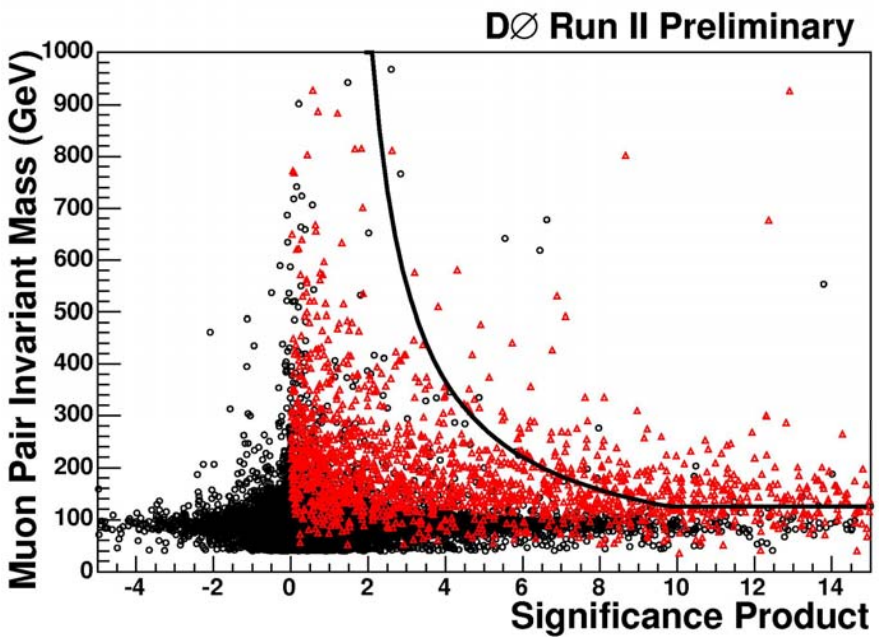
- MSSM with R_P violation
- λ_{122} determines the lifetime
- Excludes this SUSY interpretation of the NuTeV events

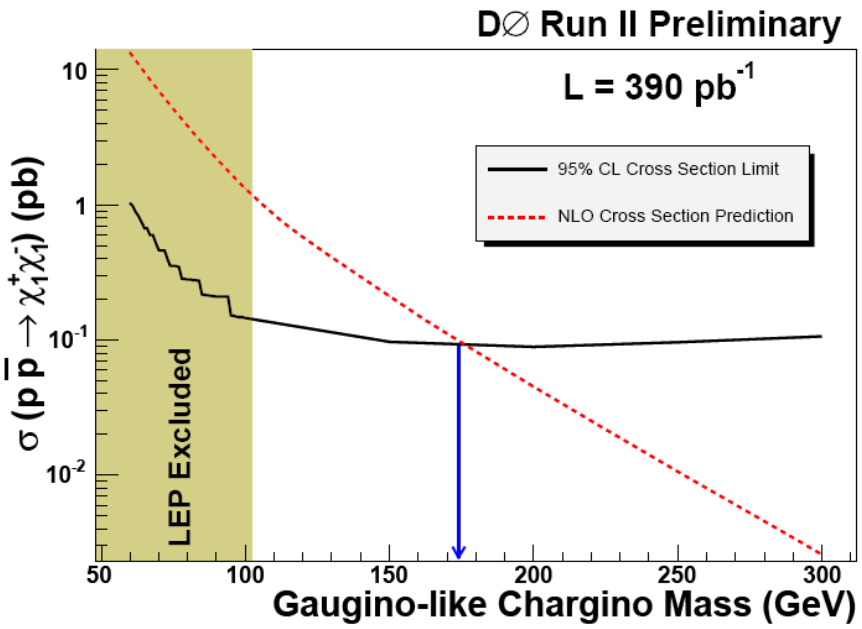




Charged Massive Particles

- Charged Massive Stable Particles
  - **GMSB – NSLP =lightest neutralino or lightest stau**
  - **Stable = long enough to escape the detector**
  - **Invariant mass and speed inconsistent with dimuon production**
  - **Significance = (1-speed)/σ(speed).**



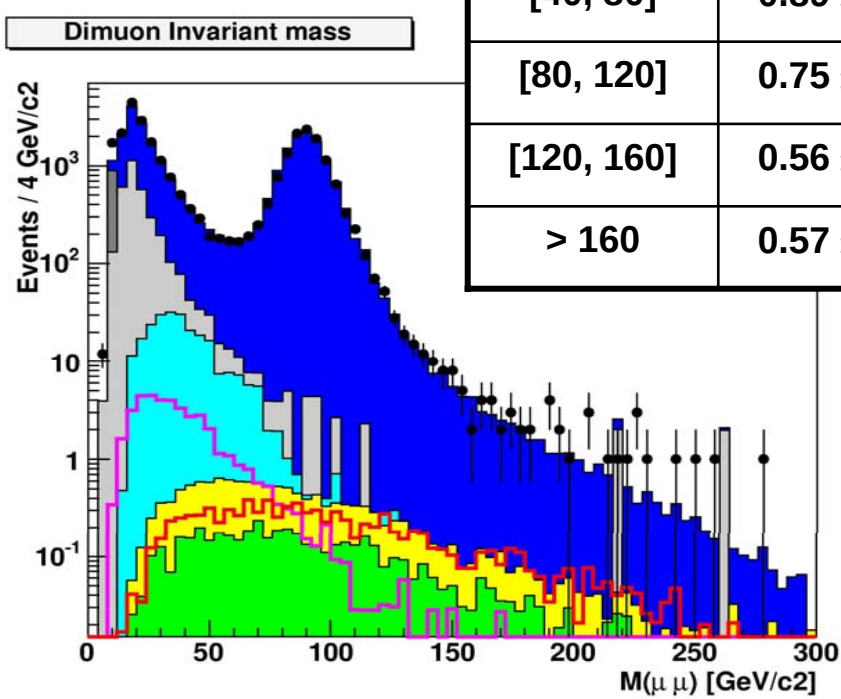


Gaugino(Higgsino)-like chargino: m($\chi\pm$) > 174 (140) GeV/c^2 (95%C.L.)

Lightest Scalar Top Search

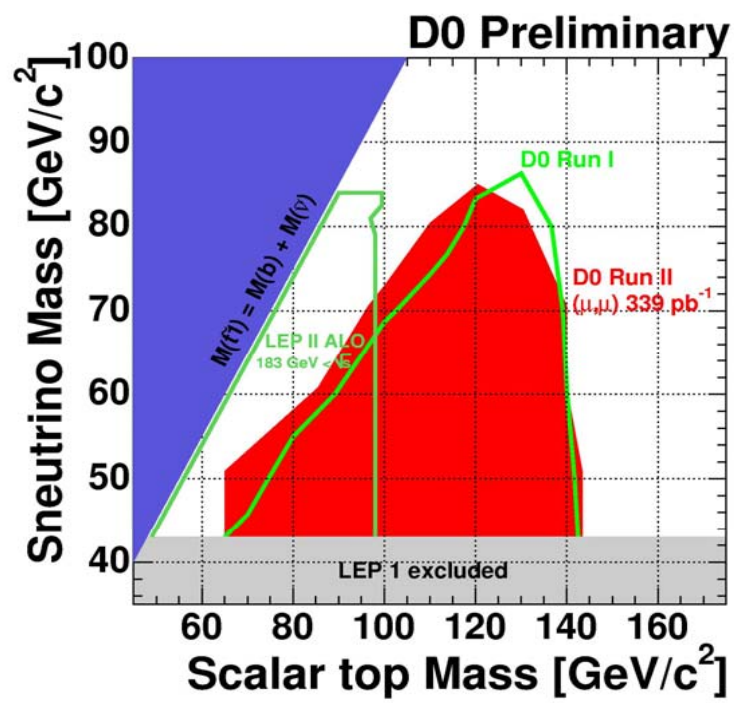
- Pair production, RPV decay $\tilde{t}_1\overline{\tilde{t}_1} \longrightarrow b\bar{b}\ \mu^+\mu^-\ \tilde{\nu}\overline{\tilde{\nu}}$
- Other decay channels severely constrained. Need m(ν) ≈ m(W)
- Backgrounds: Drell Yan dimuon, QCD multijet, Υ(1S), WW, ttbar

H_T bin (GeV)	Background	Data
[0, 40]	0.11 ± 0.03	0
[40, 80]	0.89 ± 0.43	0
[80, 120]	0.75 ± 0.13	0
[120, 160]	0.56 ± 0.07	1
> 160	0.57 ± 0.08	0



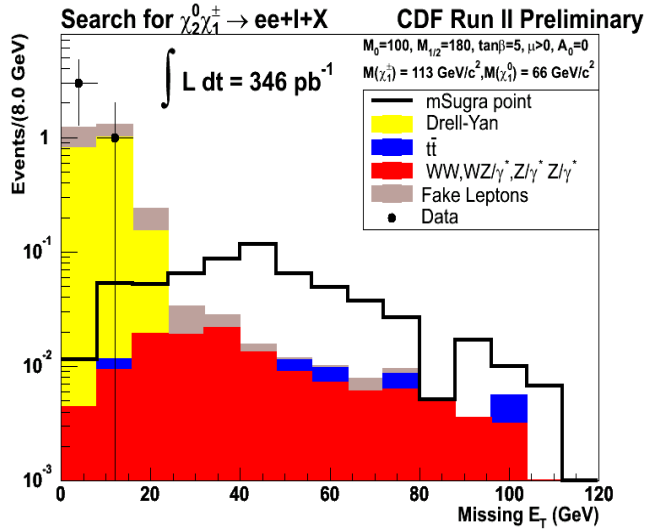
assume:

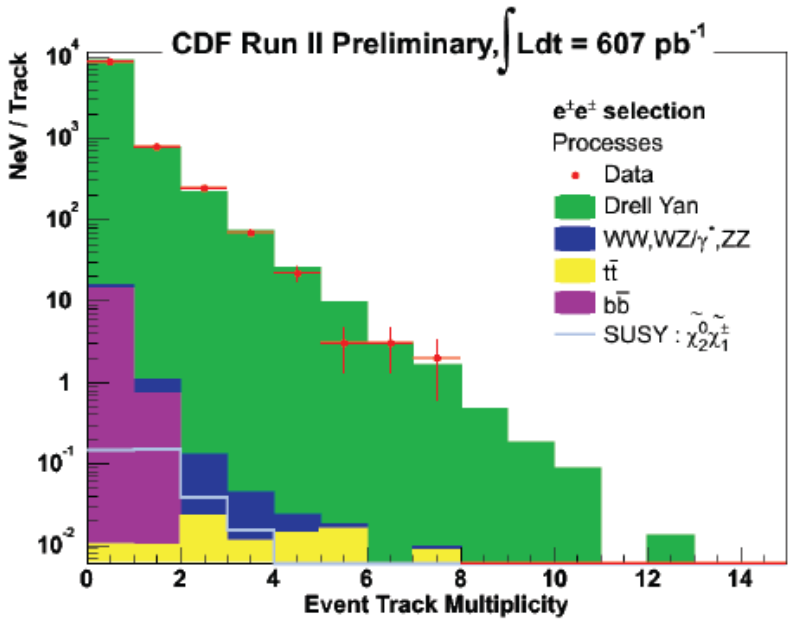
$BR(\tilde{t}_1 \rightarrow bl\tilde{\nu}) = 100\%$

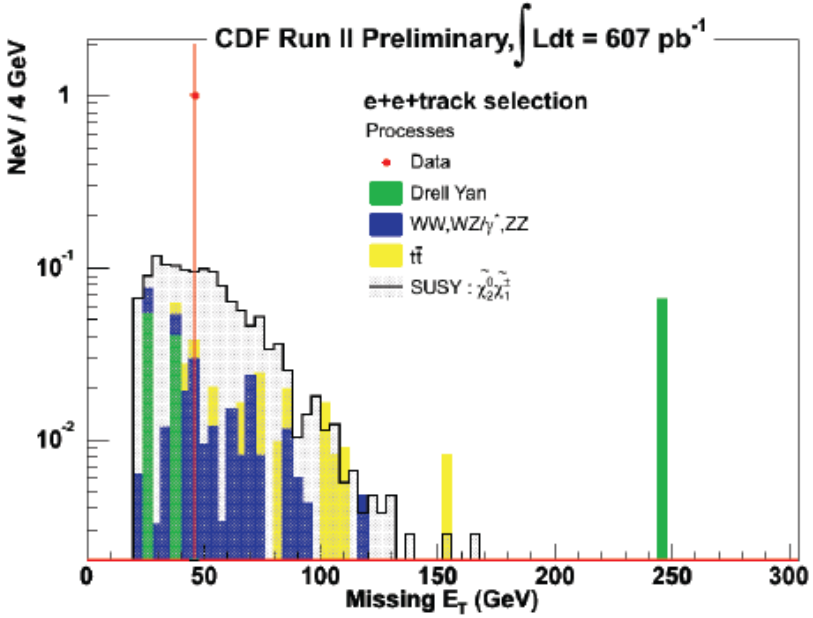


Chargino/Neutralino

Channel	L (pb^{-1})	Predict S / B	Observe
ee+l	*346*	*0.5 / 0.16*	*0*
ee+track	*607*	*1.2 / 0.5*	*1*
μe+l	680	1.0 / 0.8	0
μμ+l	745	1.6 / 0.6	1
μμ+l (low P_T)	312	0.5 / 0	0
Likesign Dilepton	704	x.x / 6.8	9



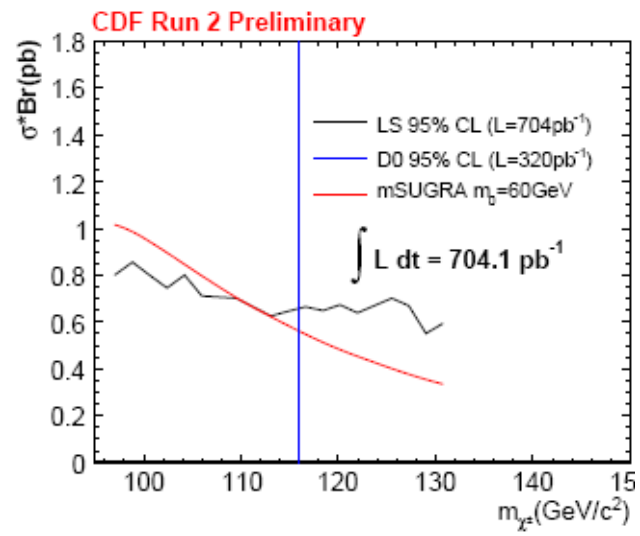




Chargino/Neutralino

Likesign Dilepton

(ee, μμ, μe)

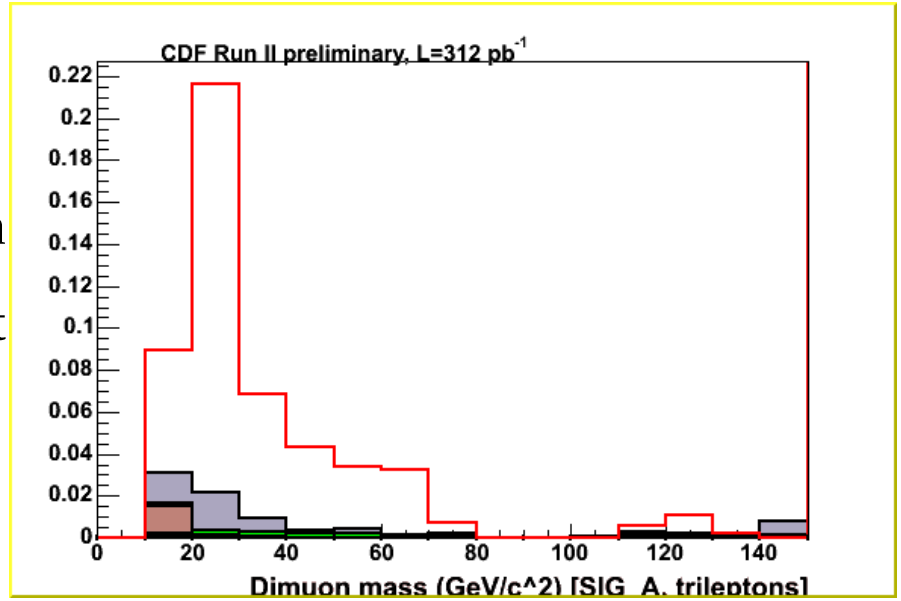


High-P_T Dimuon

Obs: 1 event

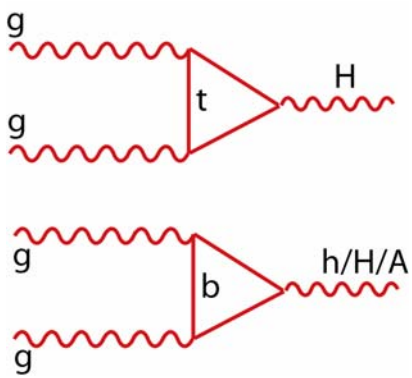
Low-P_T Dimuon

Obs: 0 event

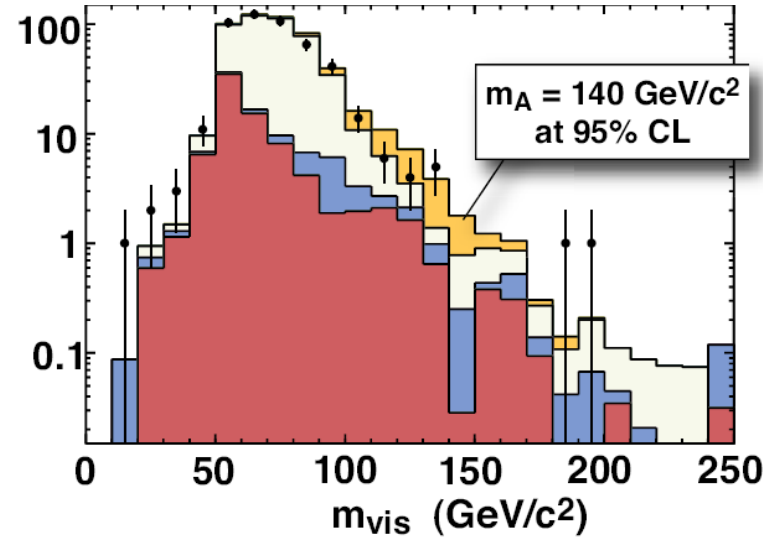


MSSM Higgs: $A \rightarrow \tau\tau$

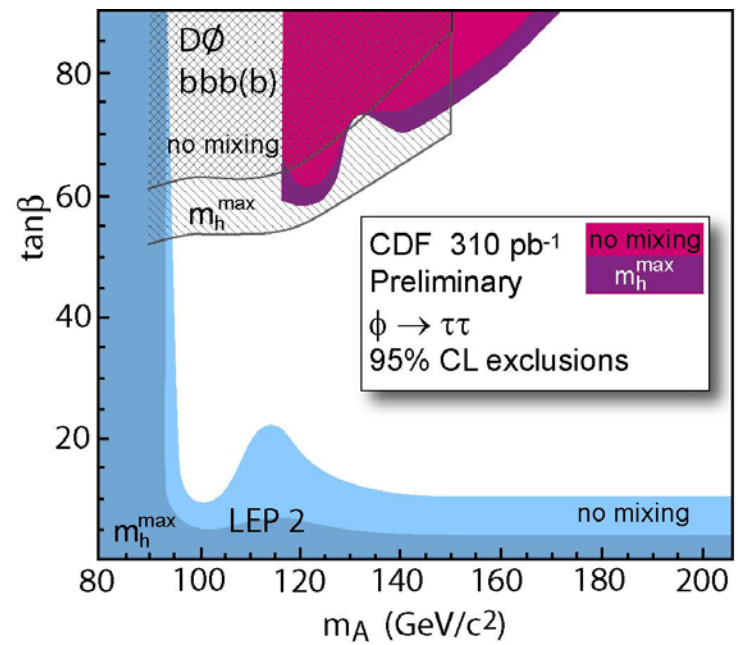
- Enhanced production of A at hadron colliders



$\sigma(pp \rightarrow H/A/h) \propto \tan^2\beta$



- A decays: bb (~90%) , $\tau\tau$ (~8-9%)
  - **Huge backgrounds associated with bb make limits comparable**

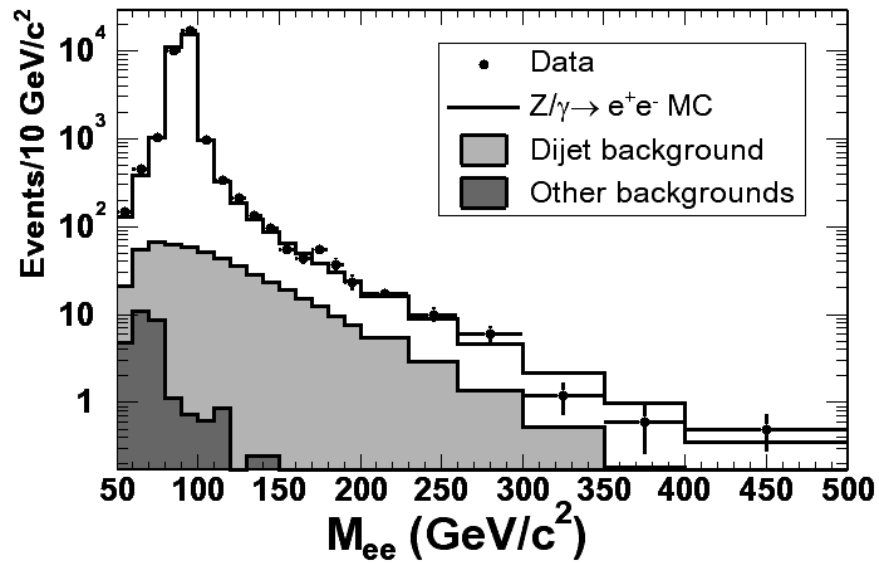


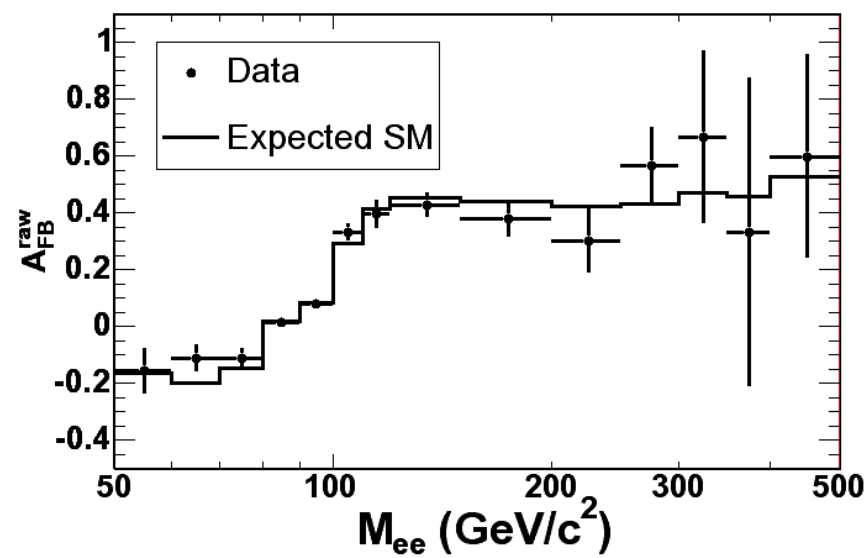
- One tau decays leptonically, the other one hadronically
- Backgrounds: $Z \rightarrow \tau\tau$, jet $\rightarrow \tau$ fakes
- Observe 11 events (expect 8.4)

Z′ Search

- Most extensions to SM predict new gauge interactions
  - **Neutral or singly charged bosons**
  - **Constraints on Z^0-Z′ mixing from LEP**
- Search for decays: $Z' \rightarrow e^+e^-$
  - **Use dielectron mass M_{ee} and $\cos\theta^*$**

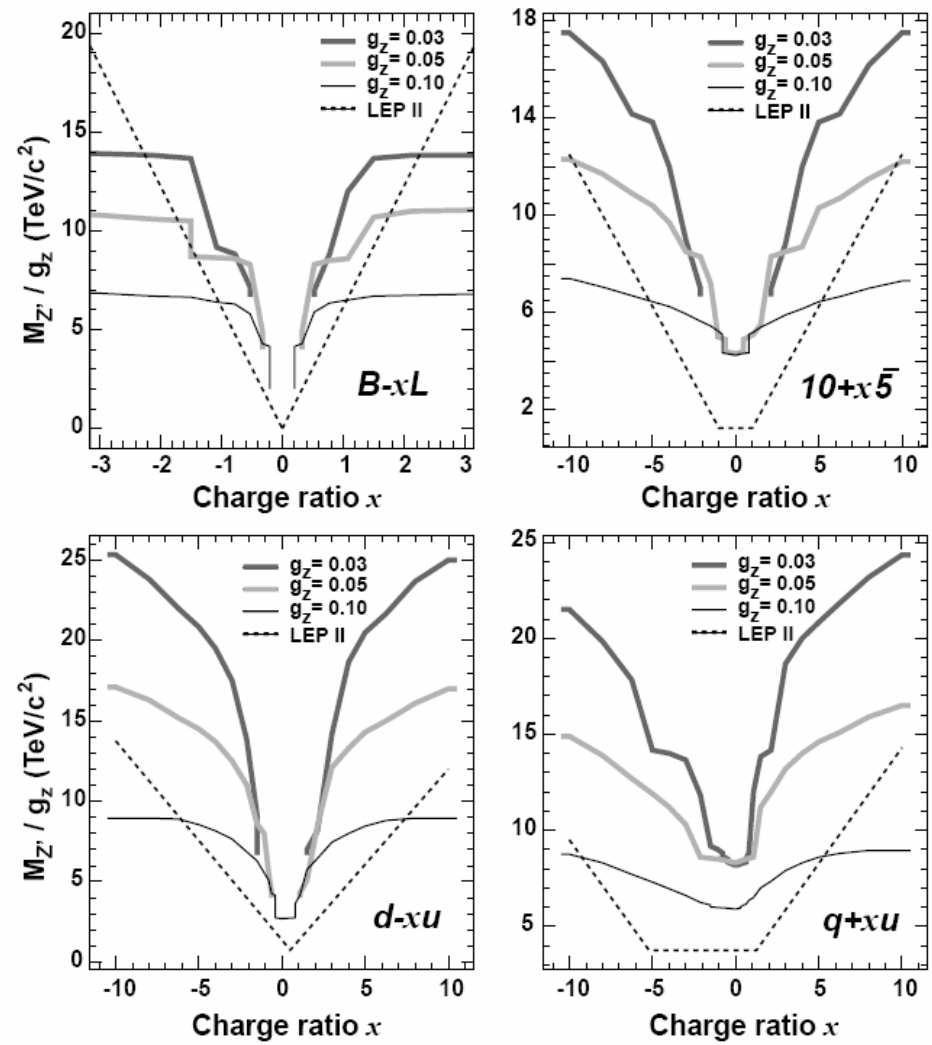
Z′ Model	M_Z Limit (GeV)
Seq. Z′	850
E6 Z_χ	740
E6 Z_ψ	725
E6 Z_η	745
E6 Z_I	650





Generic Z′ exclusion

- Adding angular information helps:
  - **More important as luminosity increases**
  - **At 448 pb-1: use cosθ* ≡ +25% data (seq. Z')**
- 2004 paper by *Carena et al* defines 4 model classes (***Phys.Rev.D70:093009,2004***):
  - **B-xL, q+xu, 10+x5, d-xu**
  - **Within each class, Z' defined by: mass MZ', strength gz, parameter x**
- Bonus:
  - **Comparisons to LEP II possible.**



RPV SUSY

- A Signature Based Search for New Physics in Dileptons+X
- A study of anomalous production of Z-bosons with high P_T

$H^{++}H^{-}$