

Exotica Searches from DØ

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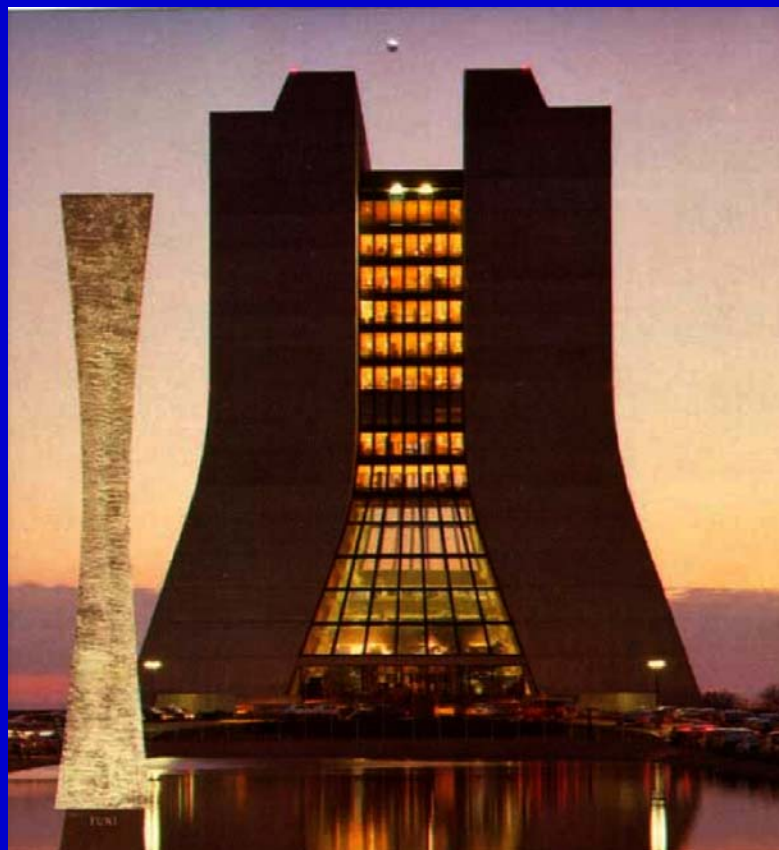


MC4BSM-4, UC Davis, April 3-4, 2009



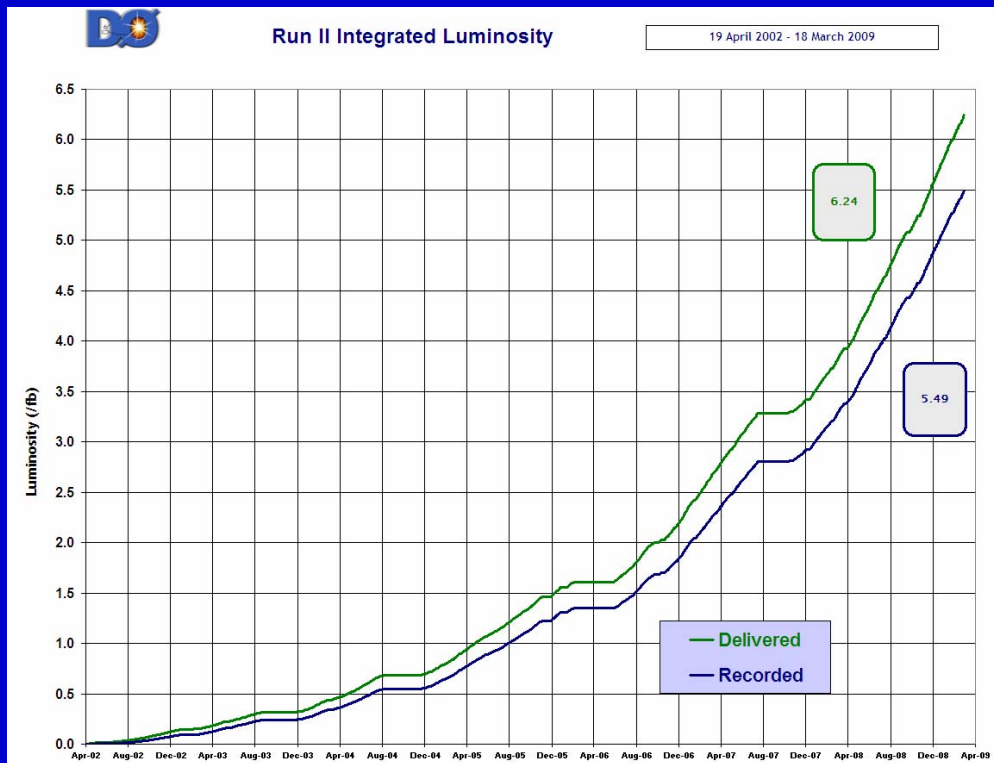
Outline

- **Standard SUSY**
 - squarks and gluinos
 - trileptons
- **Non-standard SUSY**
 - RPV sneutrinos
- **Standard Non-SUSY**
 - ED, LED
 - compositeness
 - leptoquarks/T-odd quarks
- **Exotic BSM**
 - stopped gluinos
 - NLLP in dimuons
 - CMSP
- **General Searches**
 - MIS

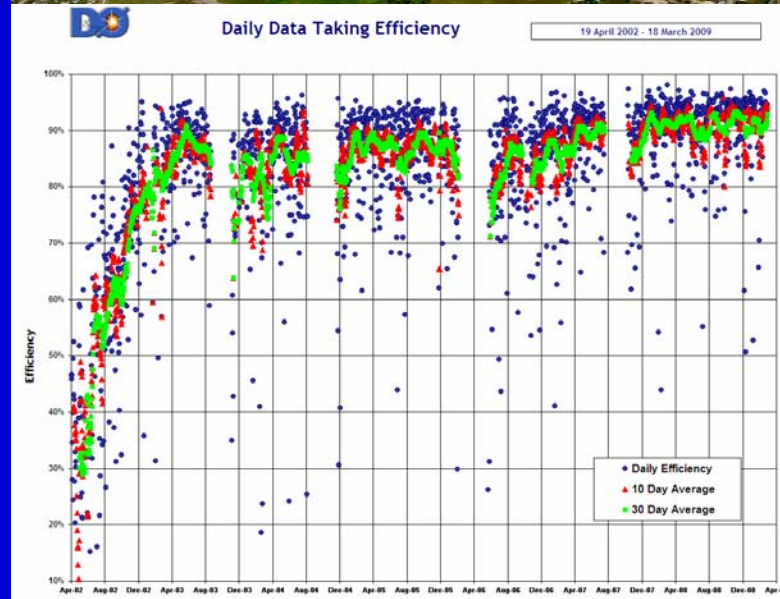
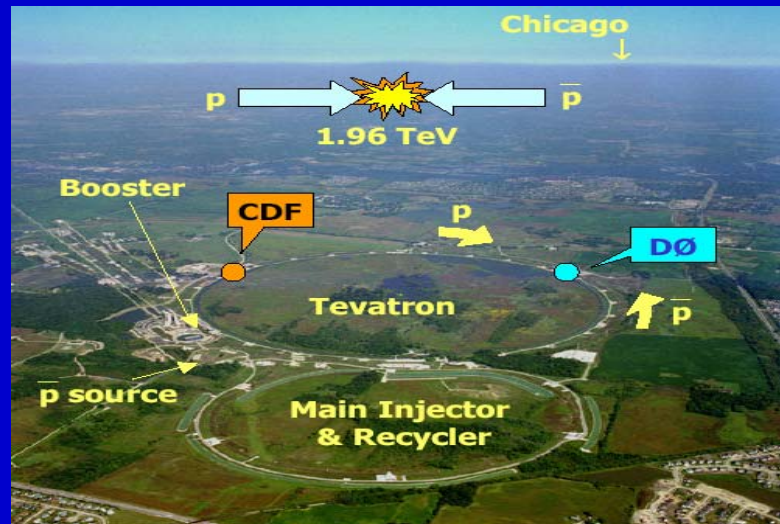




Fermilab Operations

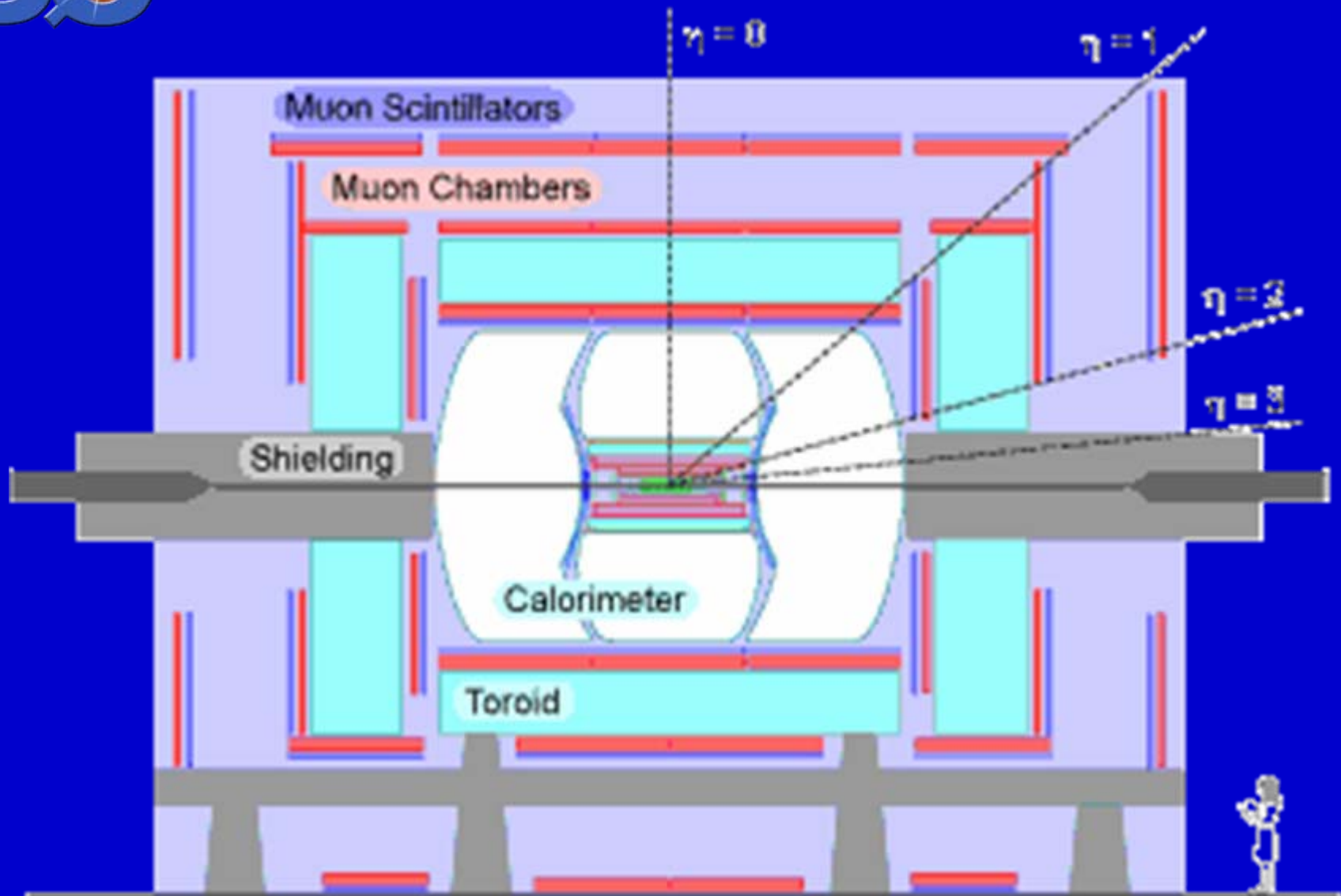


>6 fb⁻¹ delivered
>5 fb⁻¹ recorded
>90% efficiency





The DØ Detector





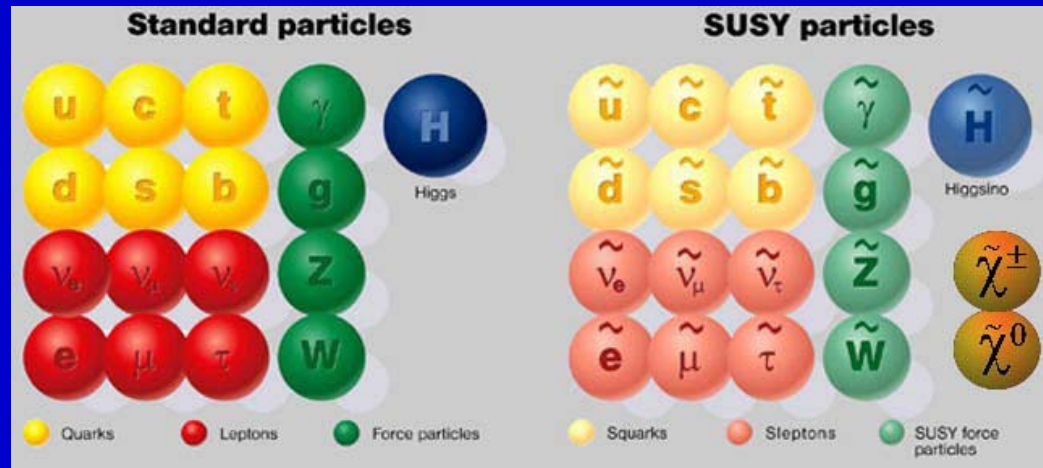
Standard SUSY

Squarks and gluinos

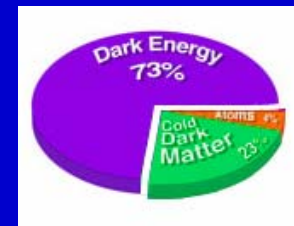
Trileptons



Supersymmetry



- **Supersymmetry is one of our most theoretically investigated BSM models**
- **Also numerous experimental searches**
- **But we often explore only part of SUSY phase space**
- **Examples:**
 - models with reduced parameters (GMSB, mSUGRA, etc)
 - models with R-parity conservation – dark matter candidate

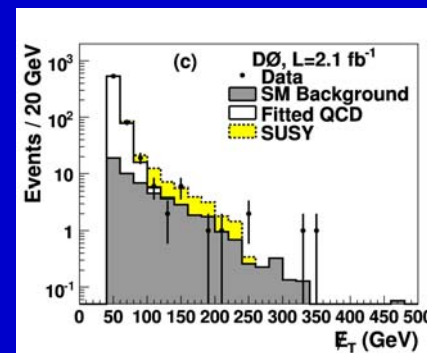
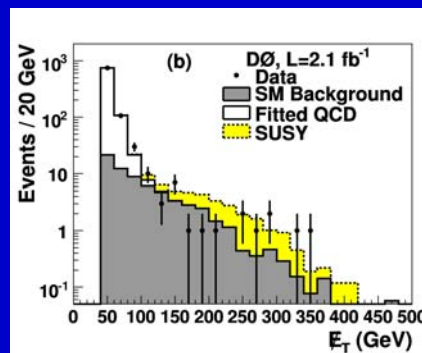
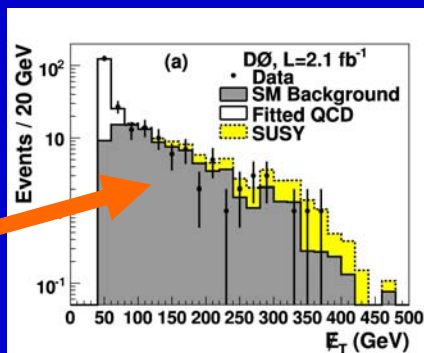
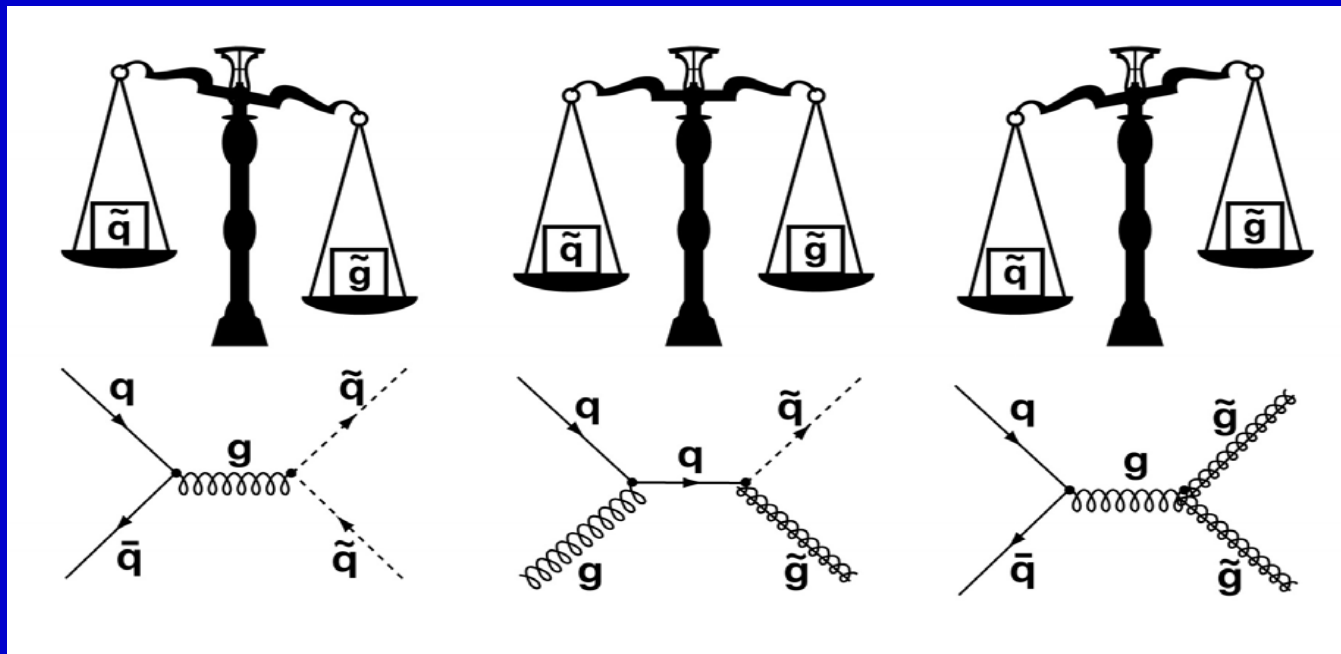




Squarks and Gluinos

2.1 fb⁻¹

- Large cross section
- High p_T jets + MET
- mSUGRA
- Don't want to depend upon QCD simulation
- Find region with SM QCD ≈ 0



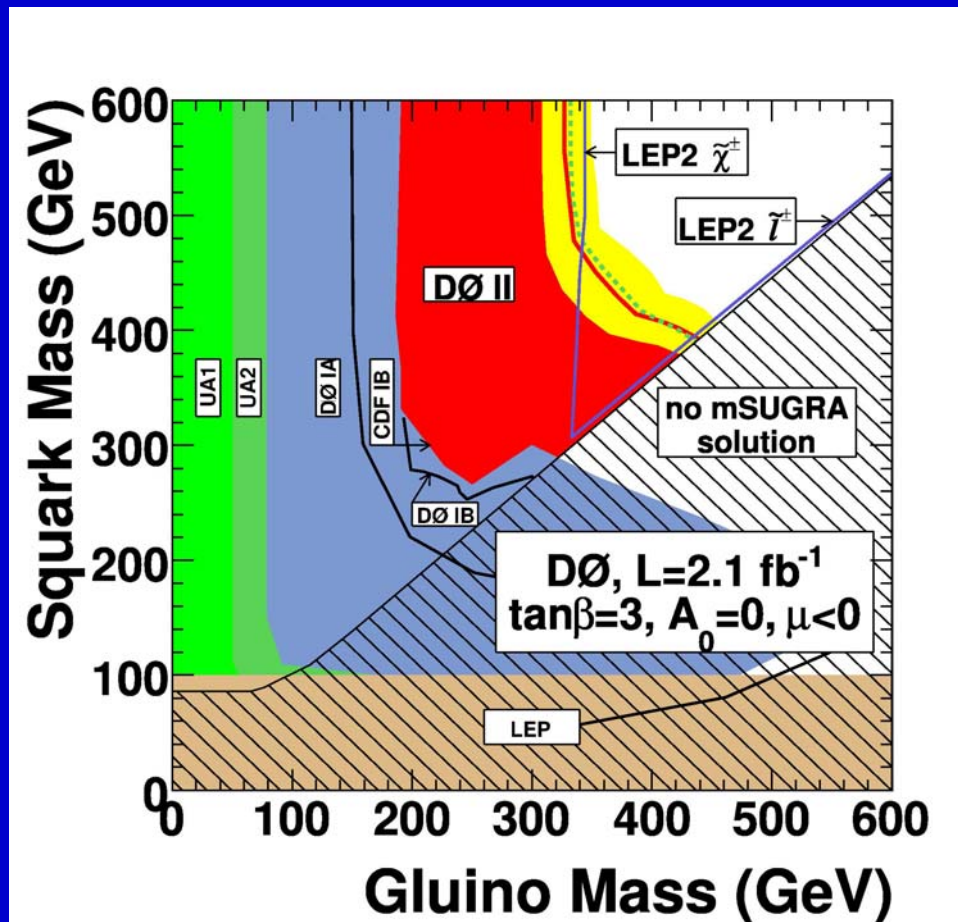


Squarks and Gluino Limits

2.1 fb⁻¹

	Expected	Data
“di-jet”	11.1 ± 3.1	11
“3-jets”	10.7 ± 3.2	9
“gluino”	17.7 ± 5.6	20

- Excellent limits by removing SM QCD events
- Remaining events described by other SM processes

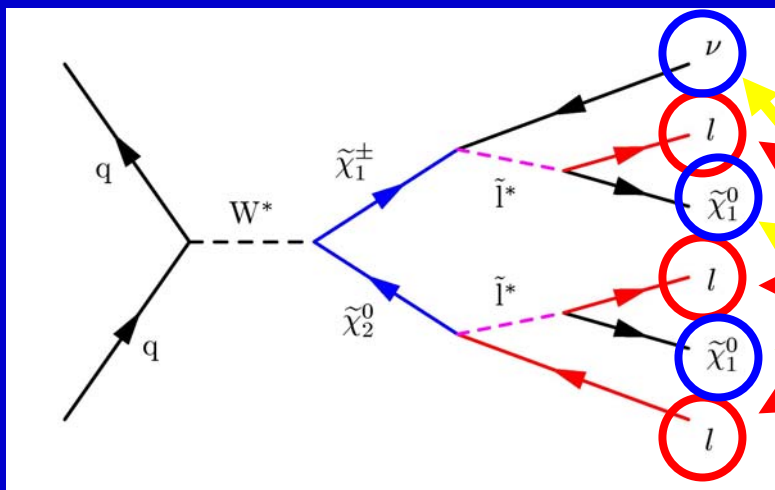


PLB 660, 449 (2008)

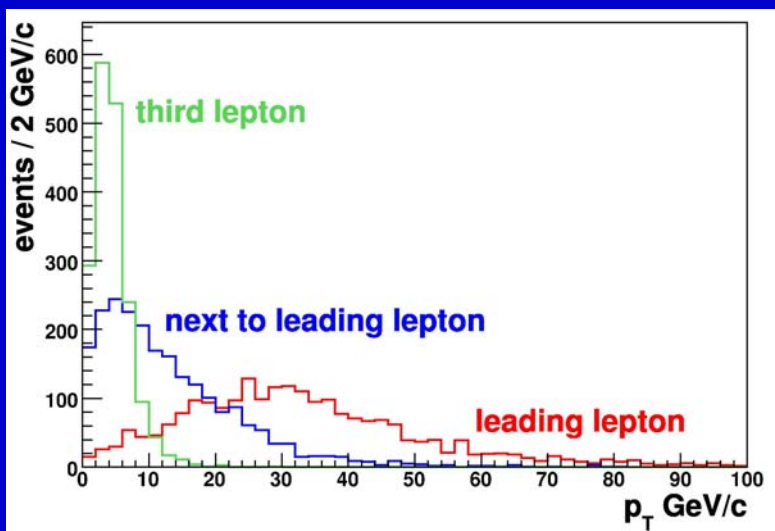


Trileptons

2.3 fb⁻¹



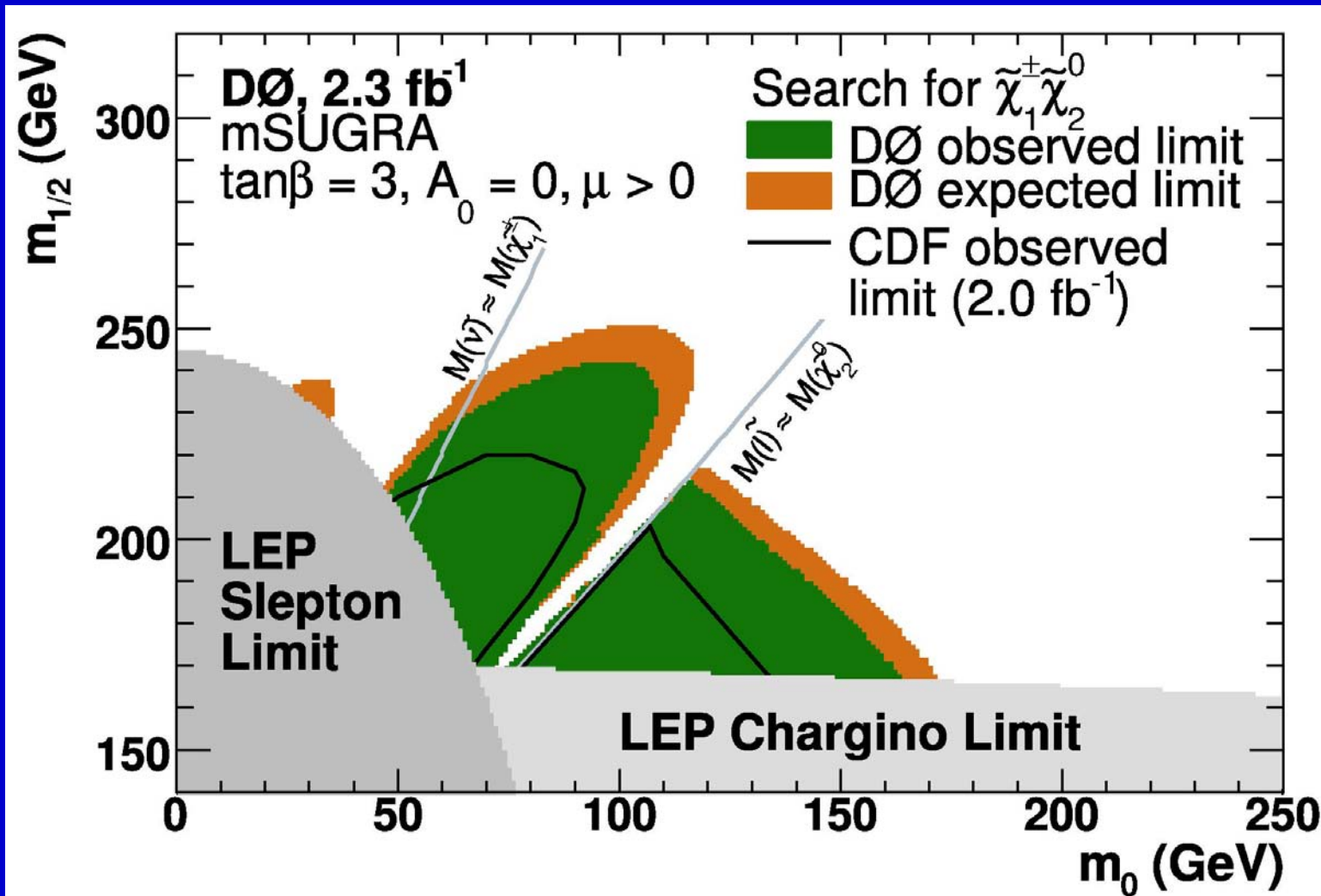
- Associated production of chargino + neutralino
- Signature is
 - three leptons
 - missing energy
- “Golden” channel
 - small SM contributions
- mSUGRA
- some areas of SUSY space are challenging
- find two leptons plus an isolated track





Trilepton Limits

2.3 fb⁻¹



arXiv.org:0901.0646



Other Standard SUSY Searches

- **stop in dileptons**
- **stop in c+MET**
- **stop in top admixture**
- **sbottom**
- **GMSB in diphotons**



Non-Standard SUSY

RPV sneutrinos



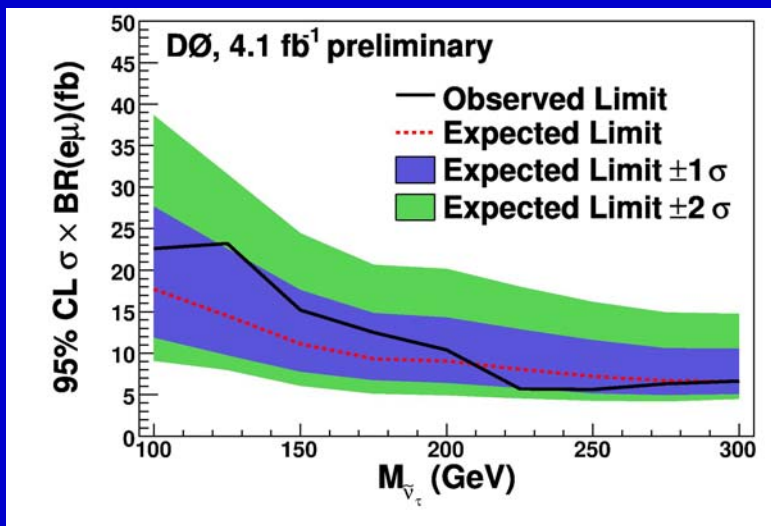
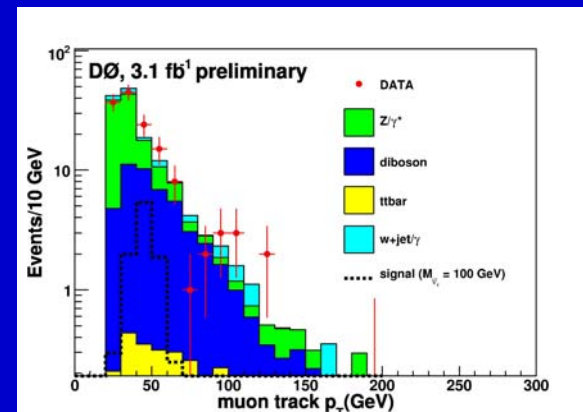
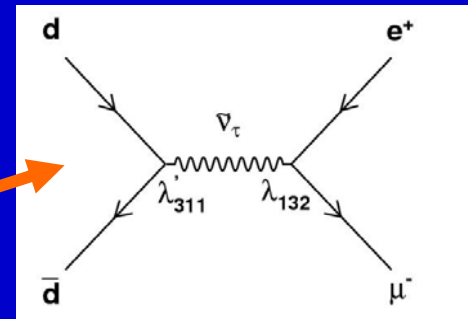
RPV Sneutrinos

4.1 fb⁻¹

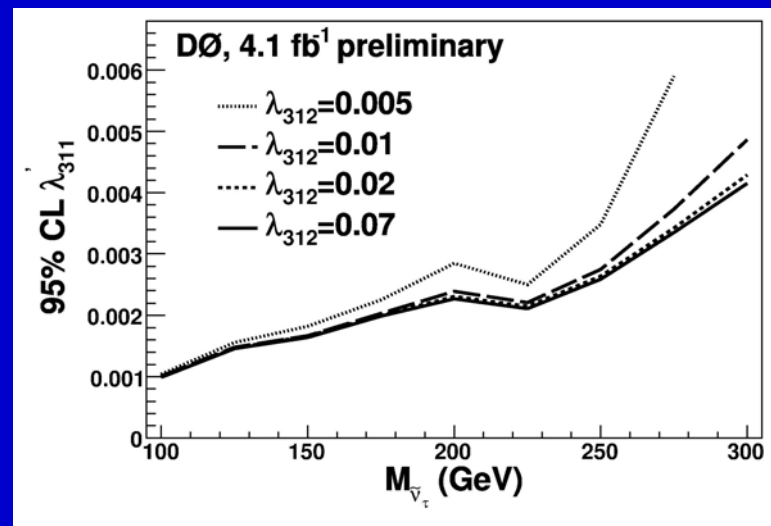
- If R-parity is not conserved
- Search in e+mu final state
- No evidence of signal

Background: 144.9 ± 8.3

Data: 143



Limits on cross-section times BR and couplings





Other Non-Standard SUSY

- **RPV violation in trileptons**
- **Slepton production**
- **See some other searches later in this talk**



Standard Non-SUSY Signatures

Extra dimensions

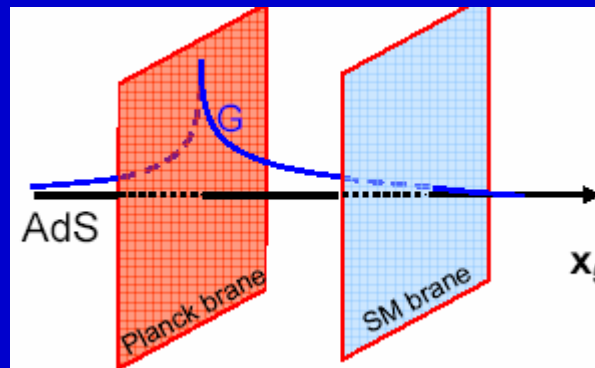
Leptoquarks

T-odd Quarks

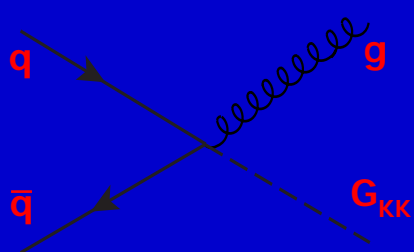


Extra Dimensions

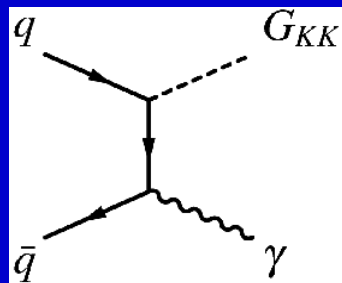
- Extra dimension models generally address the weakness of gravity



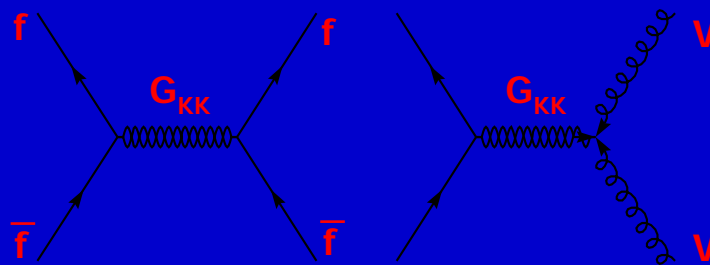
- Can produce experimental signatures



mono-jet or mono-photon



fermion pairs

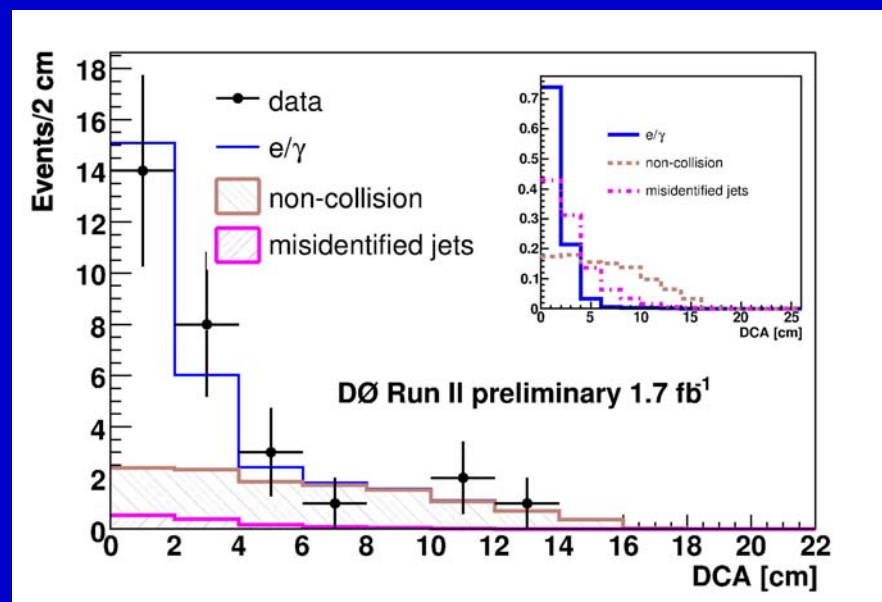
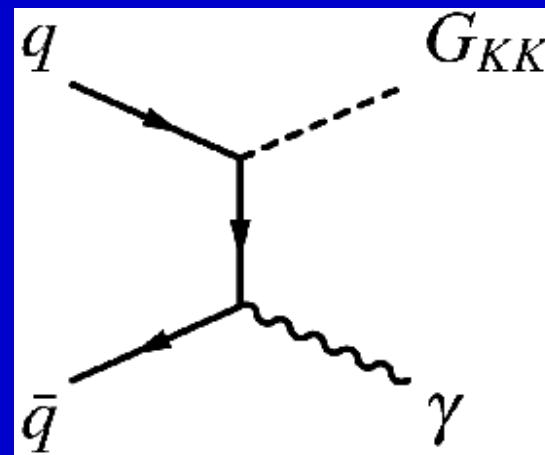




LED in Monophoton

2.7 fb⁻¹

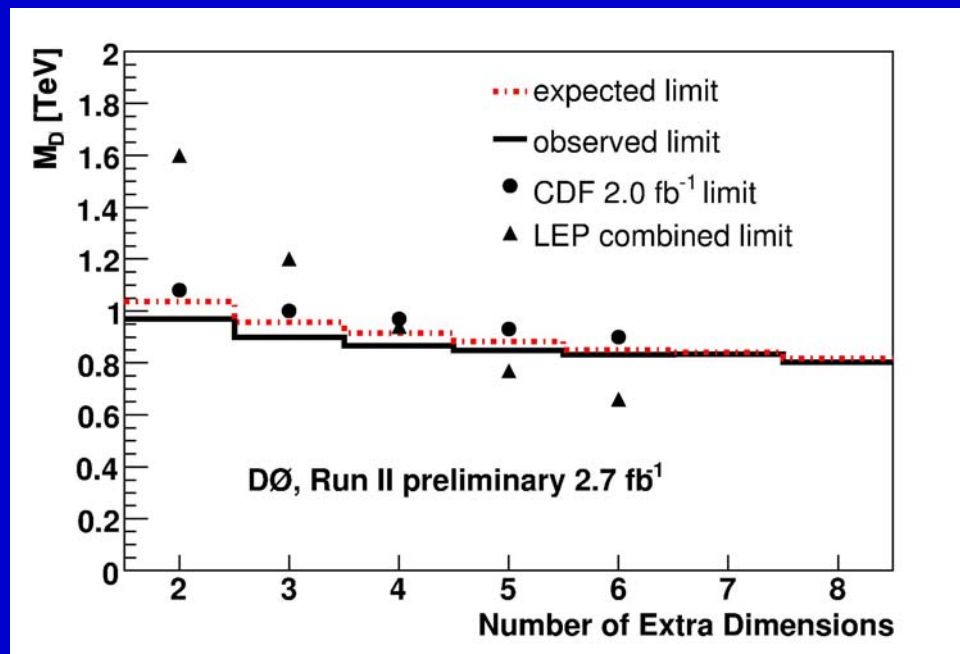
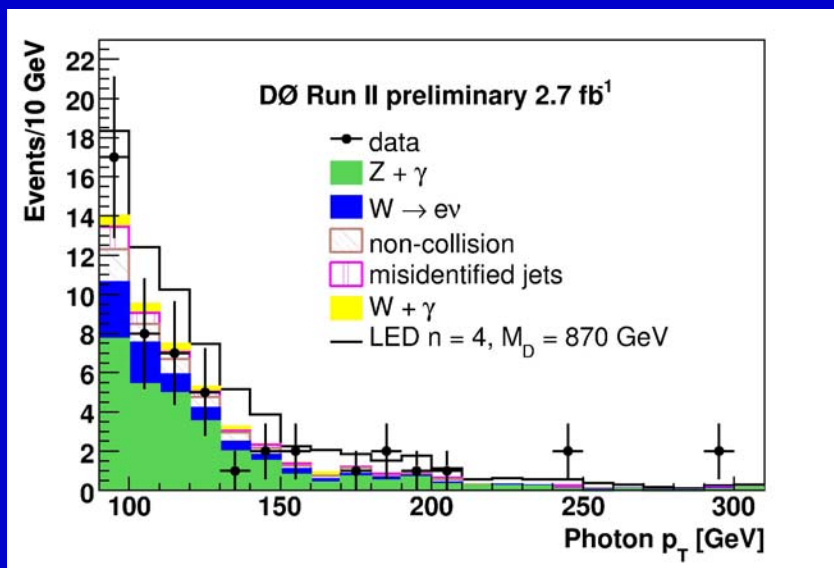
- Search for evidence of Kaluza-Klein gravitons
- Single photon and large missing ET
- Challenging backgrounds
 - $Z\gamma \rightarrow \nu\nu\gamma$ (irreducible)
 - $W \rightarrow e\nu$
 - mis-identified jets
 - cosmics
- Control non-physics backgrounds via DCA distribution





LED in monophoton

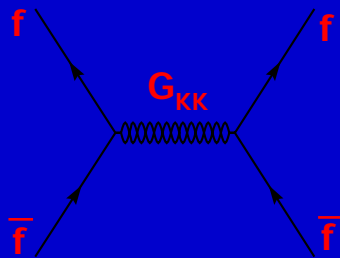
2.7 fb⁻¹





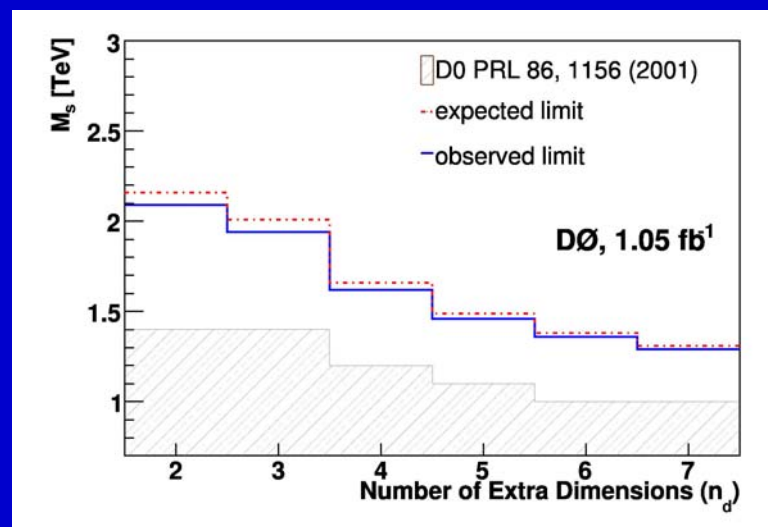
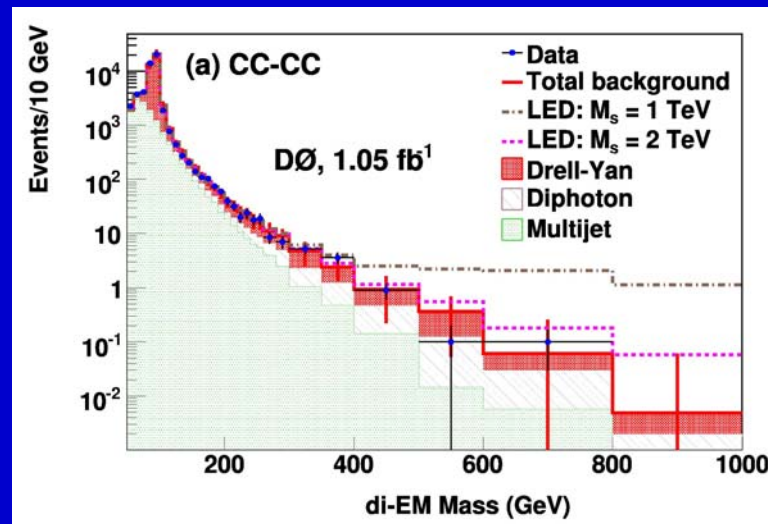
LED in di-EM

2.3 fb⁻¹



- ED can lead to an enhancement in fermion production and a modification of angular distribution
- Search in di-electron + diphoton high mass tail

PRL 102, 051601 (2009),





Dijet Angular Distributions

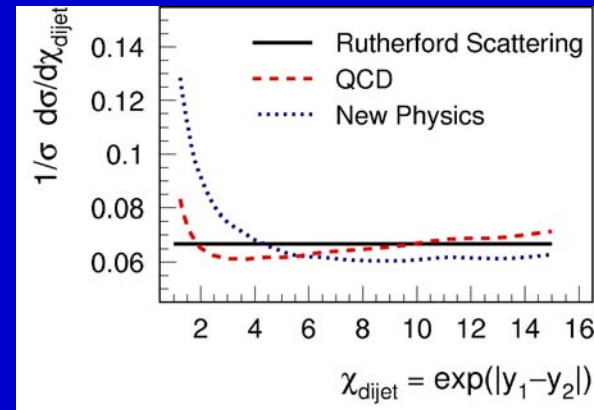
0.7 fb⁻¹

- Investigate dijet angular distributions
- New physics would modify from SM
 - compositeness
 - ADD extra dimensions
 - TeV⁻¹ extra dimensions
- Measure χ_{dijet} as a function of M_{jj}

$$\chi_{dijet} = \exp(|y_1 - y_2|)$$

- use simulation for corrections to particle jets
- look for new physics

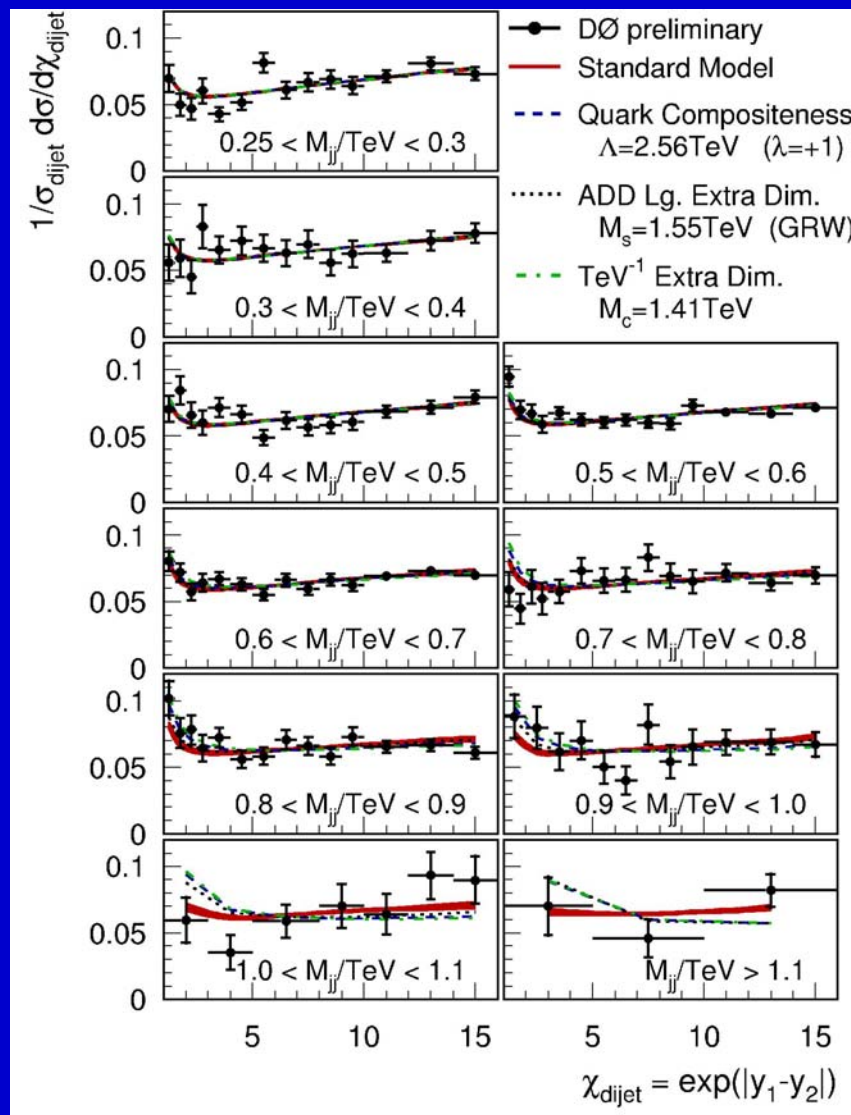
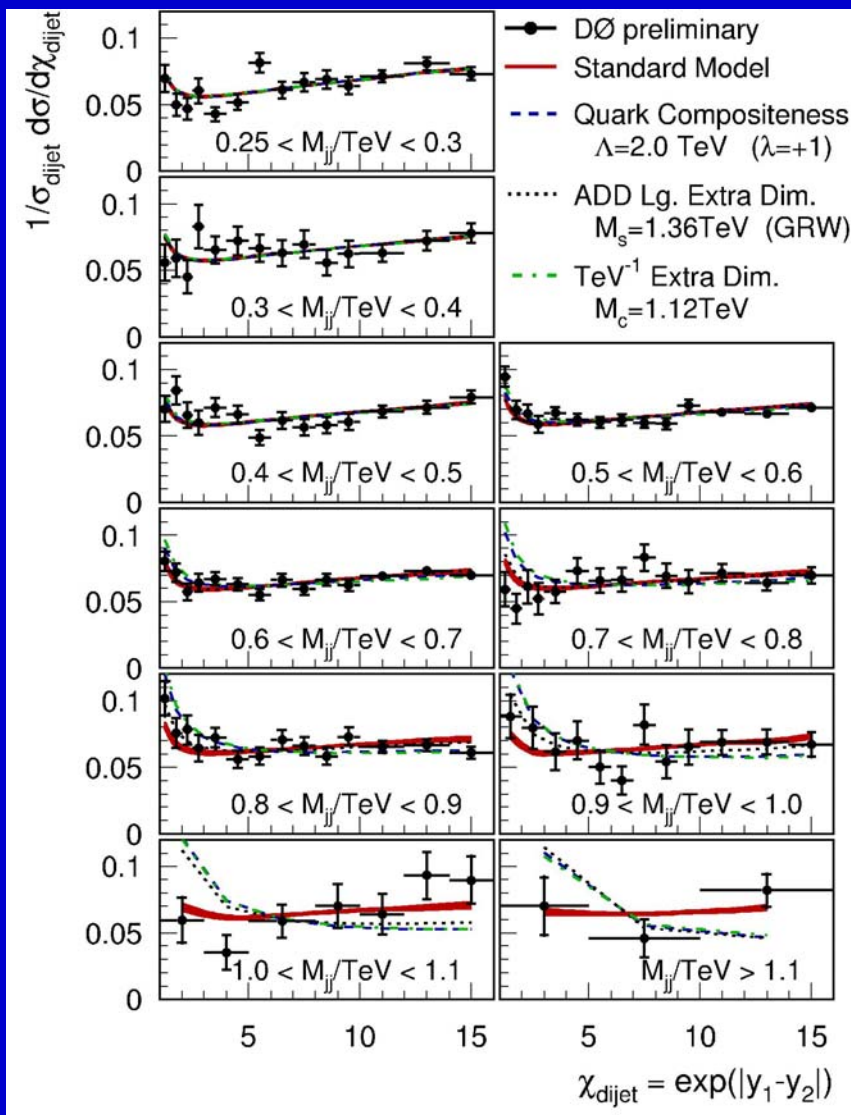
$$\sigma_{NP} = f_{SM} + \eta \times f_{Int} + \eta^2 \times f_{NP}$$





Dijet Angular Distributions

0.7 fb⁻¹





Limits from Dijets

0.7 fb⁻¹

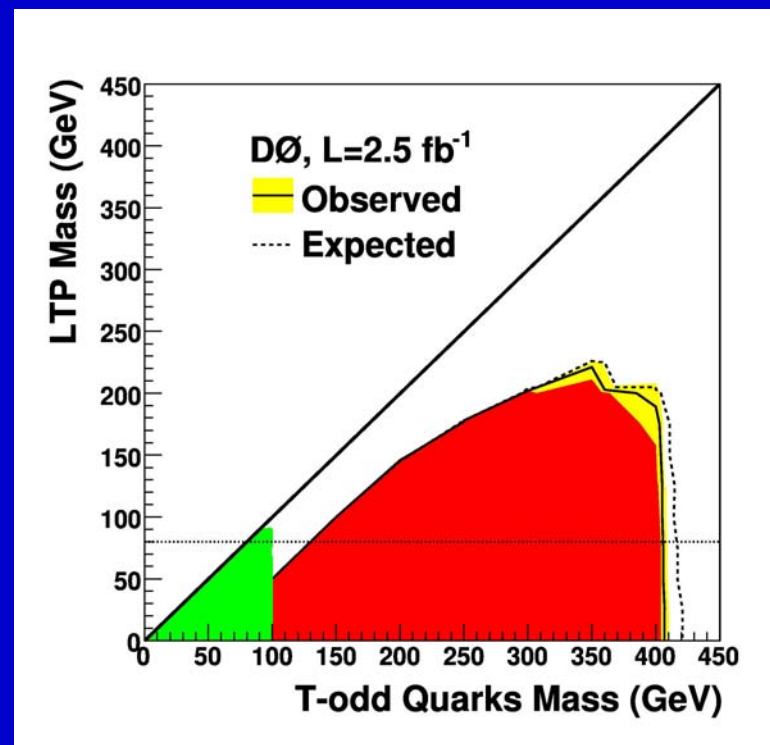
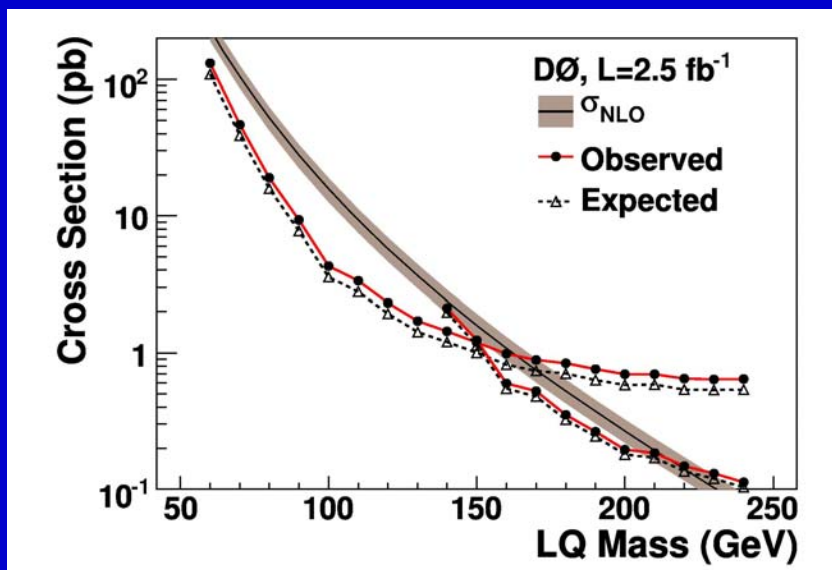
	Expected (TeV)	Observed (TeV)
Compositeness (Λ)		
$\lambda = +1$	2.75+0.43-0.35	2.58
$\lambda = -1$	2.78+0.36-0.41	2.54
TeV⁻¹ ED (M_C)	1.64+0.23-0.25	1.42
ADD LED (M_S)		
GRW	1.49+0.12-0.14	1.56
HLZ n=6	1.25+0.11-0.10	1.31

- *Bayesian limits with prior flat in η*
- *other limits available*



T-odd Quarks/Leptoquarks

- Some little Higgs models postulate a new symmetry
 - T-parity
- T-odd quarks could produce signal in jets+MET
 - convert squarks and gluinos search
- Could also be leptoquarks decaying to νq



PLB 668, 357 (2008)



Other Standard Non-SUSY Signatures

- **Leptoquarks**
 - 1st generation in $e\bar{e}j$ and $e\nu j$
 - 2nd generation in $\mu\bar{\mu}j$ and $\mu\nu j$
 - 3rd generation in $\mu\bar{j}\tau j$ and $\nu b\nu b$
 - all generation in $\nu j\nu j$ (previous slide)
- **Extra gauge bosons**
 - $W' \rightarrow e\nu$
 - $W' \rightarrow tb$
 - $Z' \rightarrow ee$ or $\mu\mu$
- **Excited quarks and leptons**
- **Compositeness in ee and $\mu\mu$**



Non-standard Signatures

Stopped Gluinos

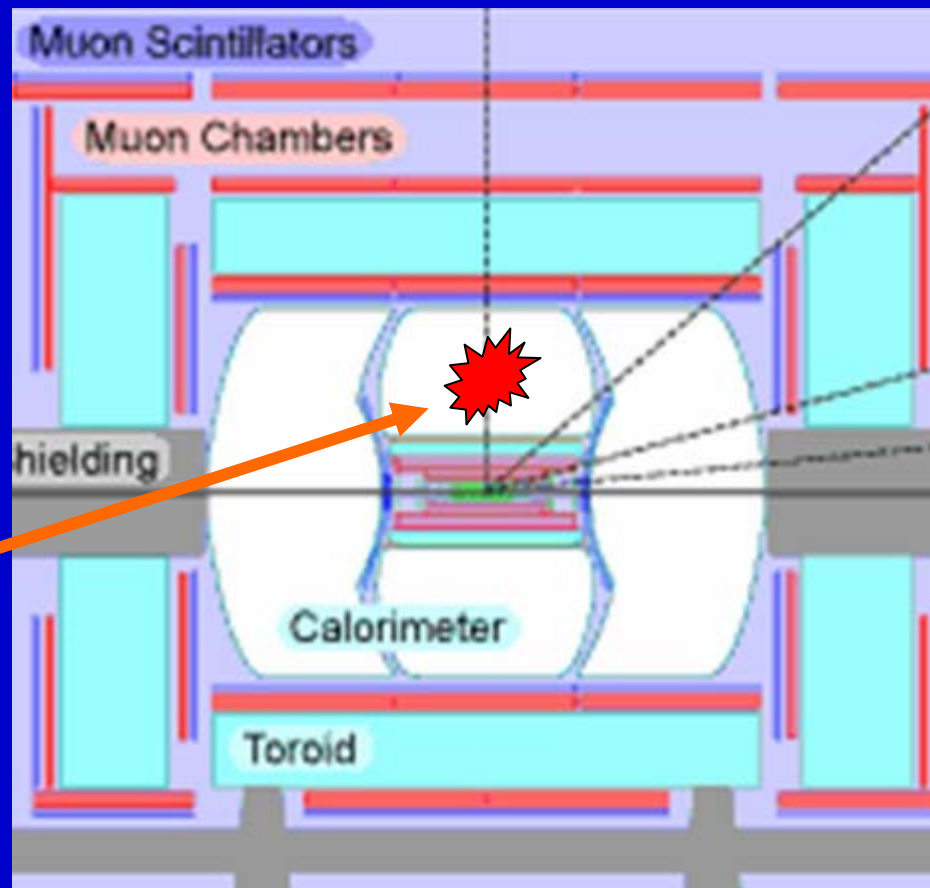
Long-lived Particles

Charged, massive stable particles



Stopped Gluinos

- **Split supersymmetry**
- **Glino hadronizes**
- **Stops within calorimeter**
- **Decays sometime later to neutralino + gluon**
 - minutes, hours, days
- **Look for calorimeter activity not associated with interaction**
 - Veto on reconstructed primary vertex
 - “Wide” showers

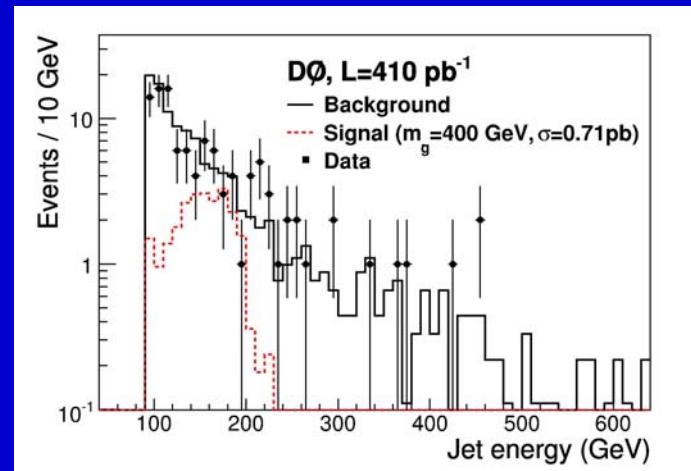




Glino Signal Simulation

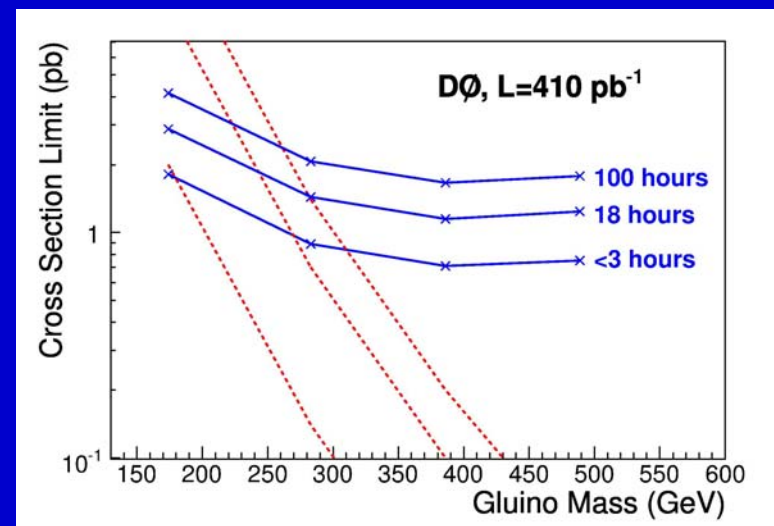
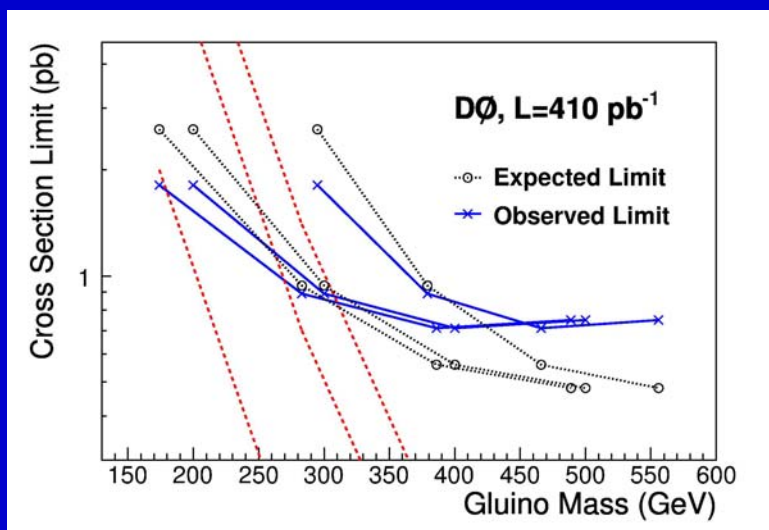
0.4 fb⁻¹

- $Z+g \rightarrow \nu\nu + g$
 - randomly oriented in calorimeter
 - $\sin\theta$ distribution
- depends on gluino mass, neutralino mass, and gluino lifetime



dependence on neutralino mass

dependence on lifetime





Neutral Long-lived Particles

0.4fb⁻¹

- Search for events with **VERY** detached di-muon vertices: 5-20 cm in x-y plane

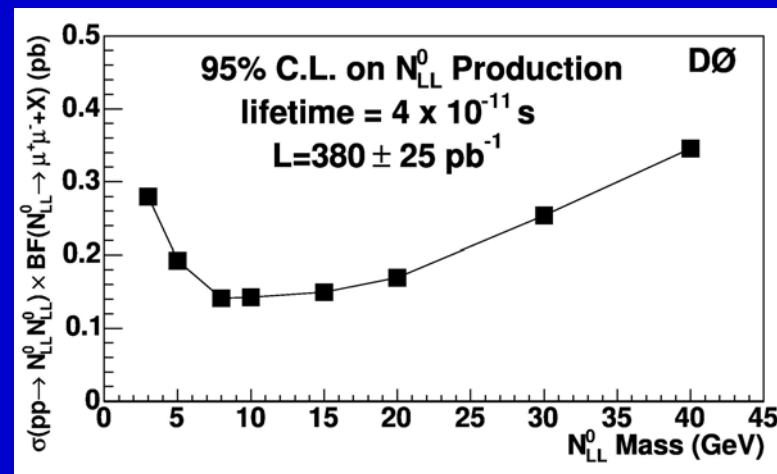
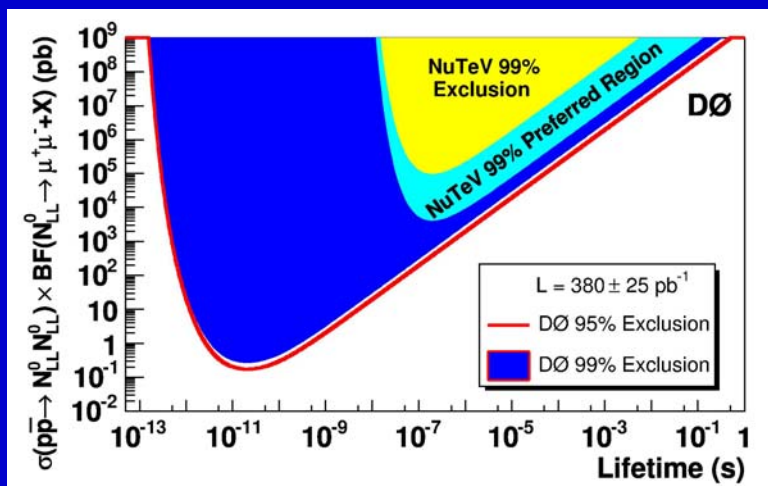
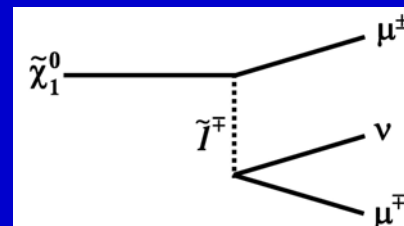
- study vertexing with K_S

- Possible signatures

- RPV SUSY or hidden valleys

PRL 668, 357 (2008)

- No events observed with 0.75 ± 1.1 events expected



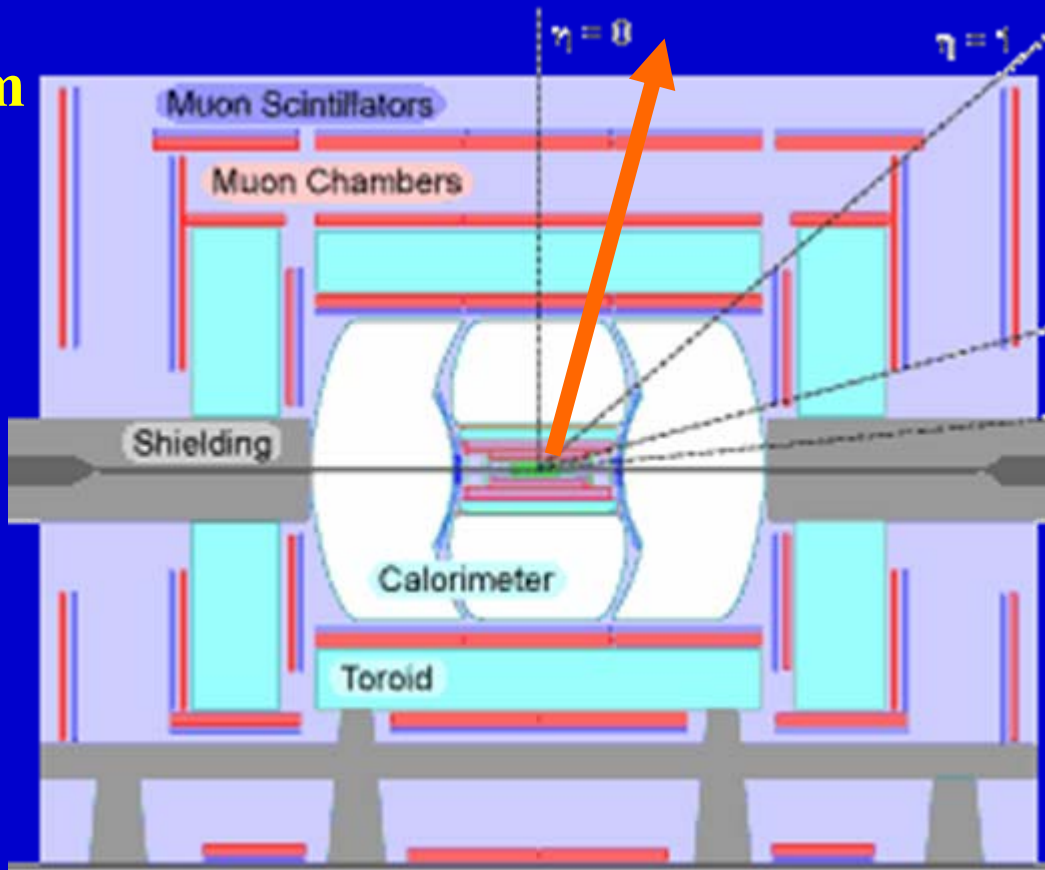
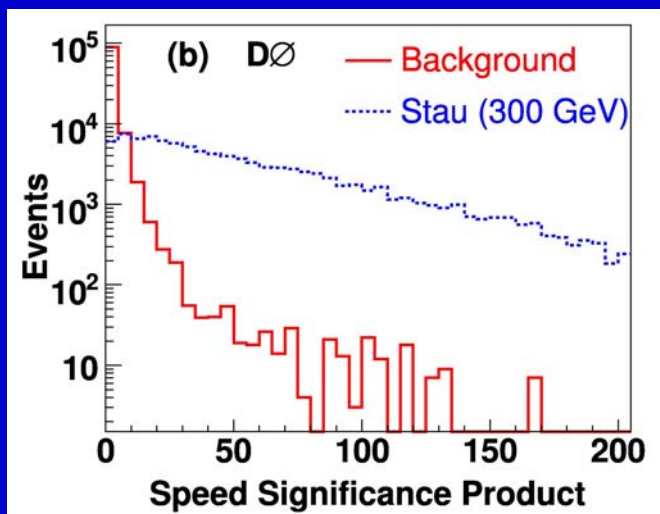


Charged, Massive Stable Particles

- Search for slow-moving, muon-like particles in DØ detector
- $\beta < 1$
- use timing in muon system

- large distance
- measure speed significance

$$\frac{1 - \beta}{\sigma_{\beta}}$$



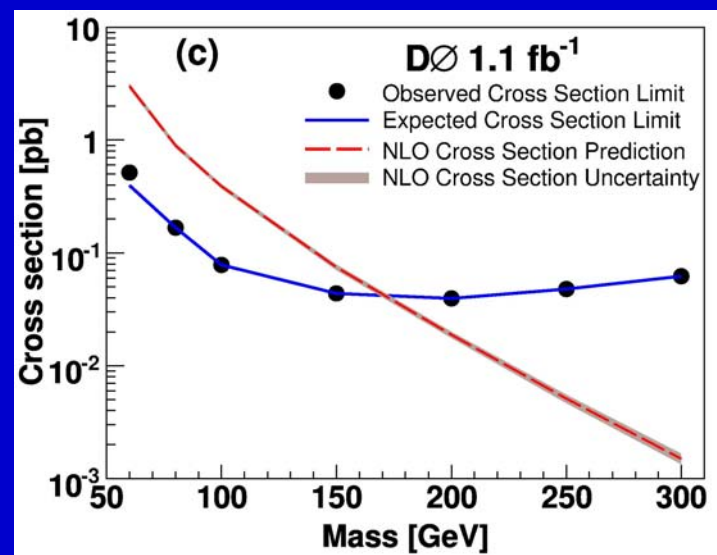
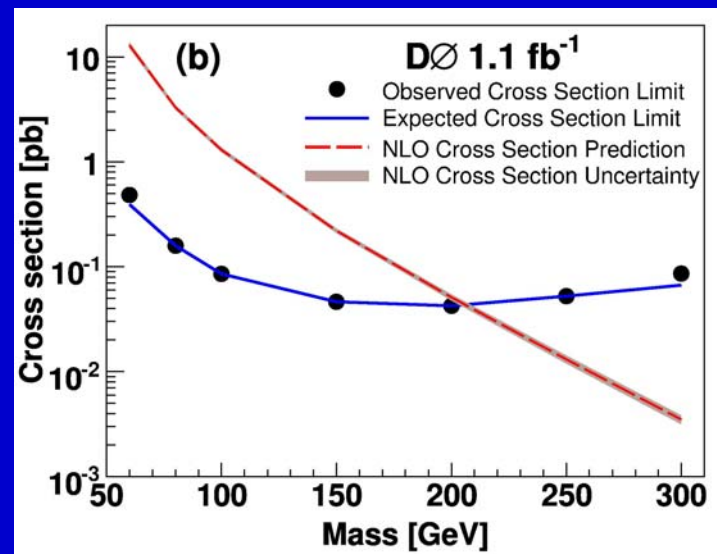
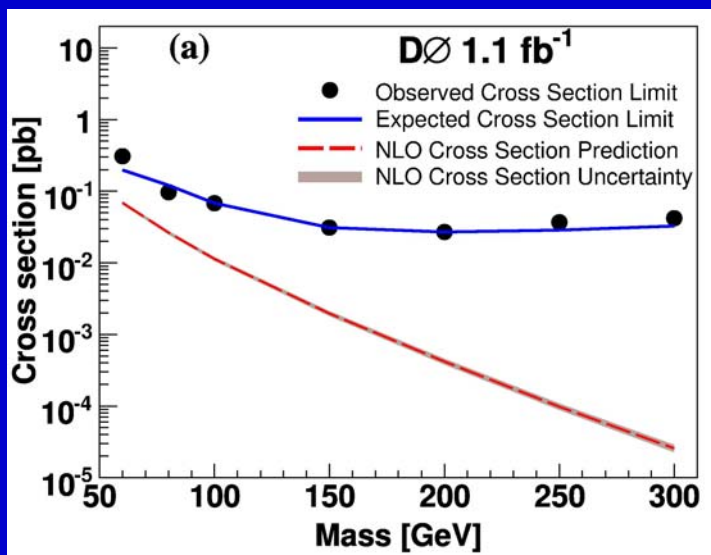
1.1 fb⁻¹



CMSP Limits

1.1 fb⁻¹

- Several models considered
 - GMSB stau (a)
 - AMSB-inspired
 - gaugino-like chargino (b)
 - higgsino-like chargino (c)



arXiv.org:0809.4472



General Searches



Model Independent Search

1 fb⁻¹

- “Global” search of D0 data with leptons

High-pT

Select events with one of more high-pT leptons



MIS

Determine scale factors
7 non-overlapping inclusive states



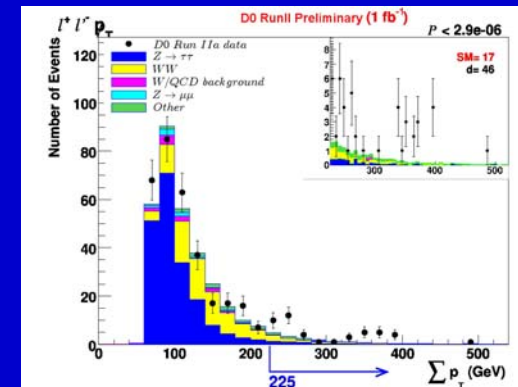
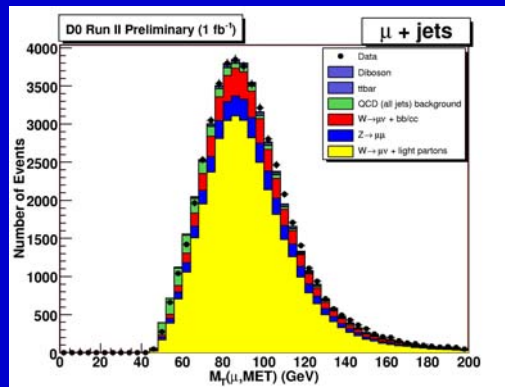
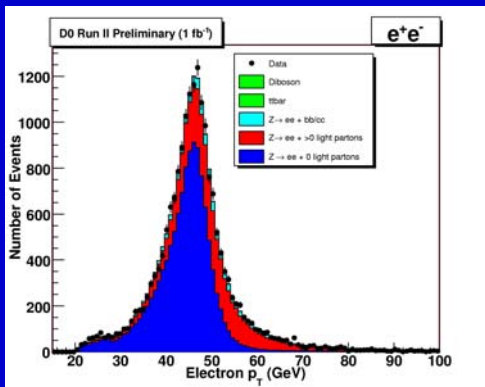
Vista

Compare ~10k histograms (normalization & shape)
180 exclusive final states



Sleuth

Investigate high-pT tails
MET+ Σp_T
Combine states (example:
 $e^+e^- + \mu^+\mu^- \rightarrow \ell^+\ell^-$)



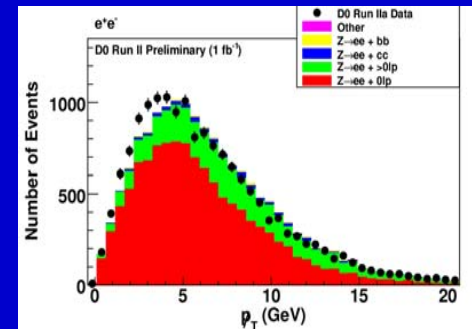
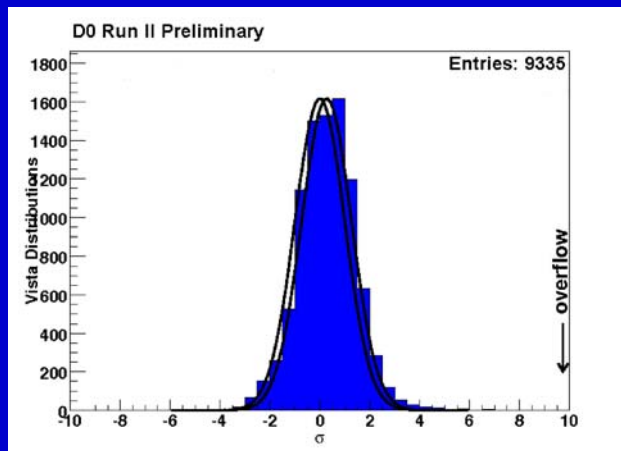


Model Independent Search

1 fb⁻¹

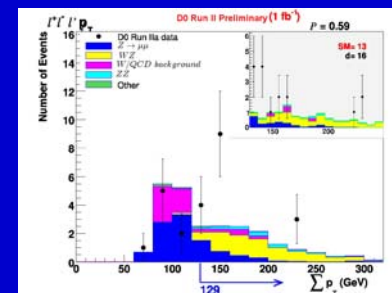
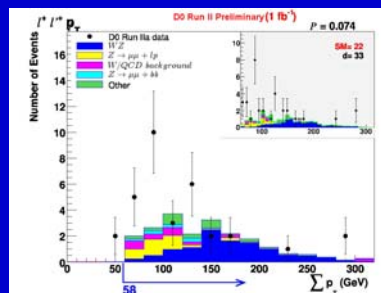
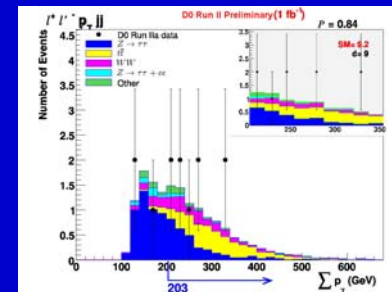
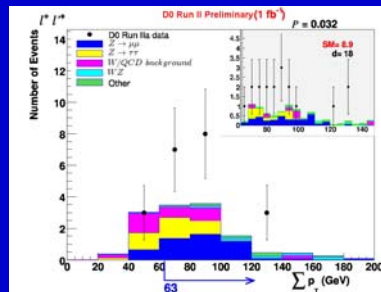
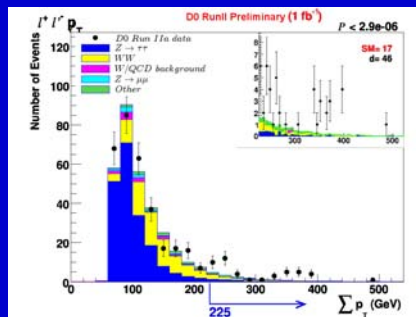
Vista Results

- $\mu+2j+MET$ 9.3 σ
- $\mu+\gamma+1j+MET$ 6.6 σ
- $\mu^++\mu^-+MET$ 4.4 σ
- $\mu^++\mu^-+\gamma$ 4.1 σ



Sleuth Results

- five most discrepant states
- $\ell^+\ell'^-+MET$
- $\ell + MET$
- $\ell^+\ell'^-$
- $\ell^+\tau^-+MET$
- $\ell^+\tau^+$





Comments on Simulation

- **DØ often uses data to model multijet background**
 - less faith in QCD Monte Carlo than CDF
 - multijet modeled from events with non- or nearly- isolated leptons
- **Some BSM signatures simulated with “fudged” Monte Carlo**
 - examples: long-lived particles
- **Other signals considered**
 - examples: hidden valleys, magnetic monopoles, quirks



Conclusions

- **DØ has a diverse physics program searching for new physics**
- **It will continue with more data arriving daily**
- **Still looking to explore new ideas**
 - **greatest discovery potential**



<http://www-d0.fnal.gov/Run2Physics/WWW/results.htm>



The Questions

What new BSM results does D0 have?

How are we using our Monte Carlo?

What SM Monte Carlo needs do we have?

What BSM Monte Carlo needs do we have?