Search for supersymmetry with the DØ detector: GMSB, AMSB, and Split SUSY

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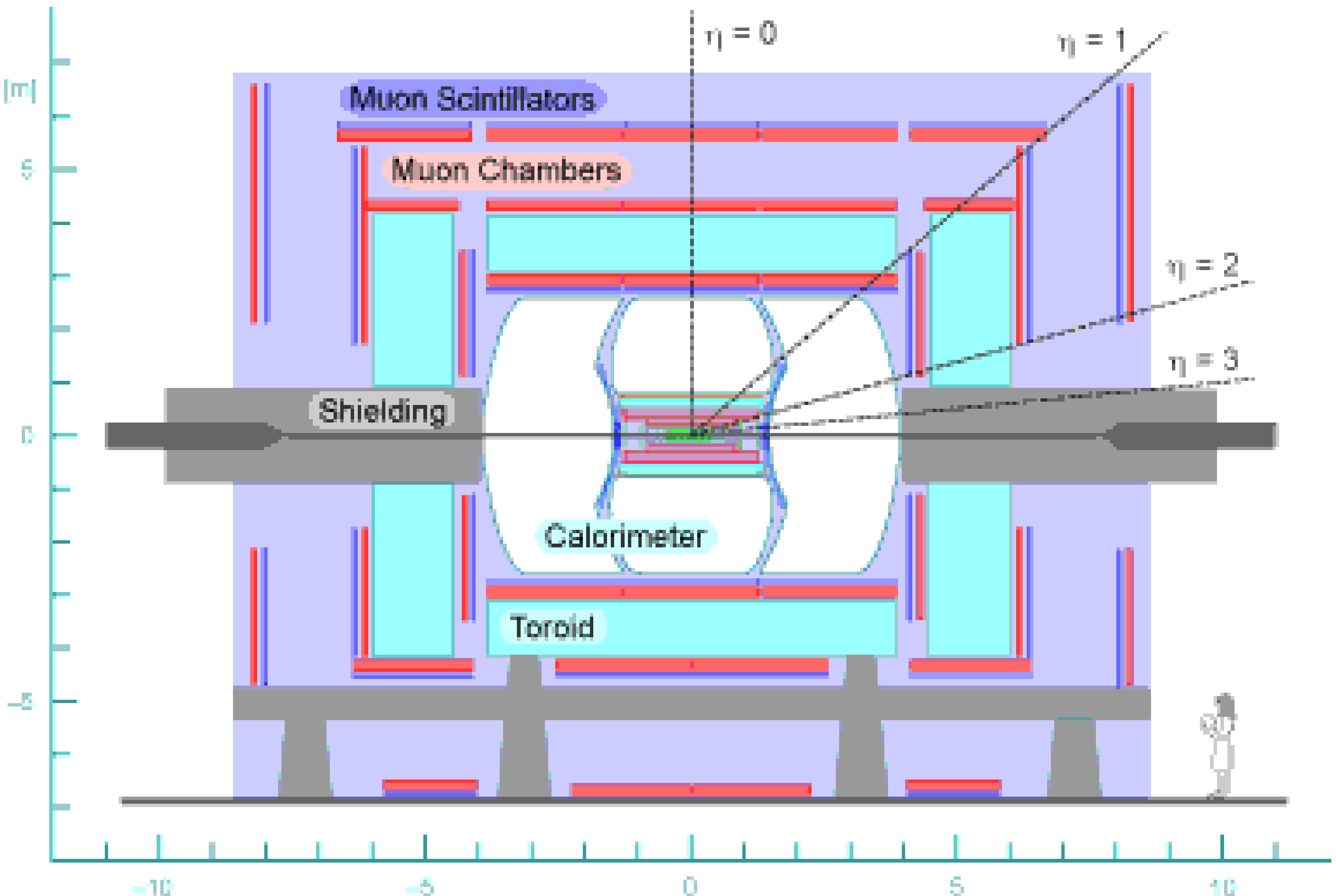
The DØ Detector

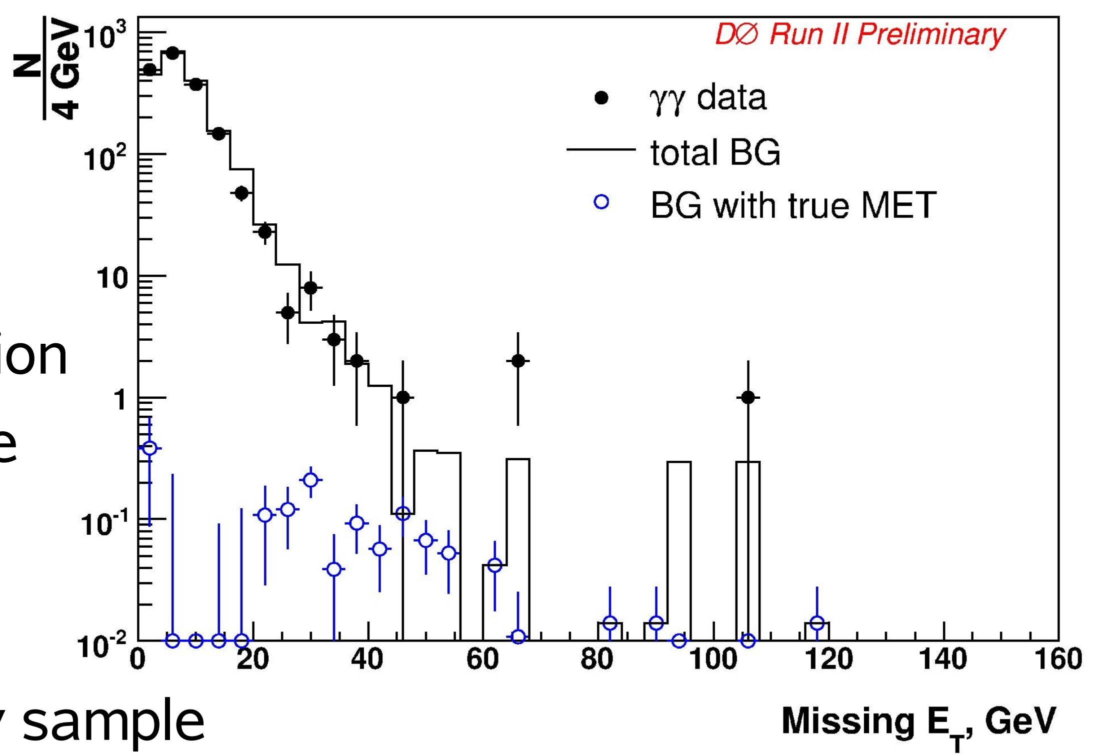


Supersymmetry Breaking

- SUSY is a broken symmetry
  - The phenomenology can be greatly affected by the SUSY breaking mechanism
- Gauge-mediated supersymmetry breaking (GMSB)
  - Gravitino is the lightest supersymmetric particle (LSP)
  - Phenomenology determined by next-to-lightest supersymmetric particle (NLSP)
  - If a neutralino is the NLSP, it will decay into a photon and a gravitino

The Diphoton + Missing E_T Analysis (I)

- The channel is $p\,\bar{p} \rightarrow gauginos \rightarrow \chi_1^0 \chi_1^0 + X \rightarrow \gamma\,\gamma + \tilde{G}\,\tilde{G} + X$
- The detector signature is two photons plus missing transverse energy (MET)
- Small backgrounds
  - Negligible physics bgds
  - Bgd with real MET
    - From e/γ mis-identification
    - Estimate with eγ sample
  - Bgd with fake MET
    - From QCD
    - Estimate with “loose” γγ sample



The Diphoton + Missing E_T Analysis (II)

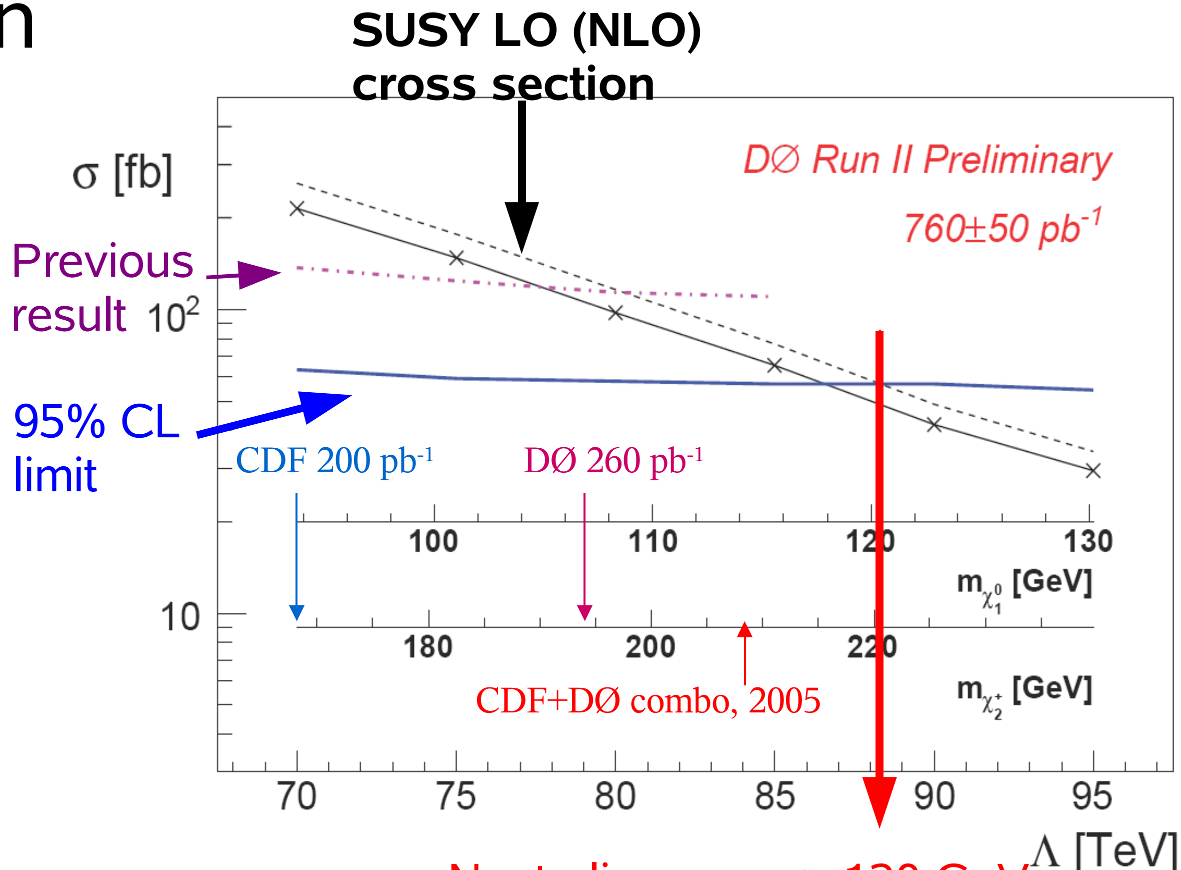
- No excess is observed, so limits are set on GMSB production

Bgd Samples

Signal Region

	Total events	$\not{E}_T$ < 12 GeV	$\not{E}_T$ > 45 GeV
$\gamma\gamma$	1790	1549	4
$e\gamma$	1469	1189	22
hh	6114	5172	6
QCD BG to $\gamma\gamma$			1.8 ± 0.7
QCD BG to $e\gamma$			1.4 ± 0.6
$e\gamma$ total			20.6 ± 4.4
$e\gamma$ BG to $\gamma\gamma$			0.28 ± 0.06
Total BG to $\gamma\gamma$			2.1 ± 0.7

2.1 background events expected, 4 events observed in data



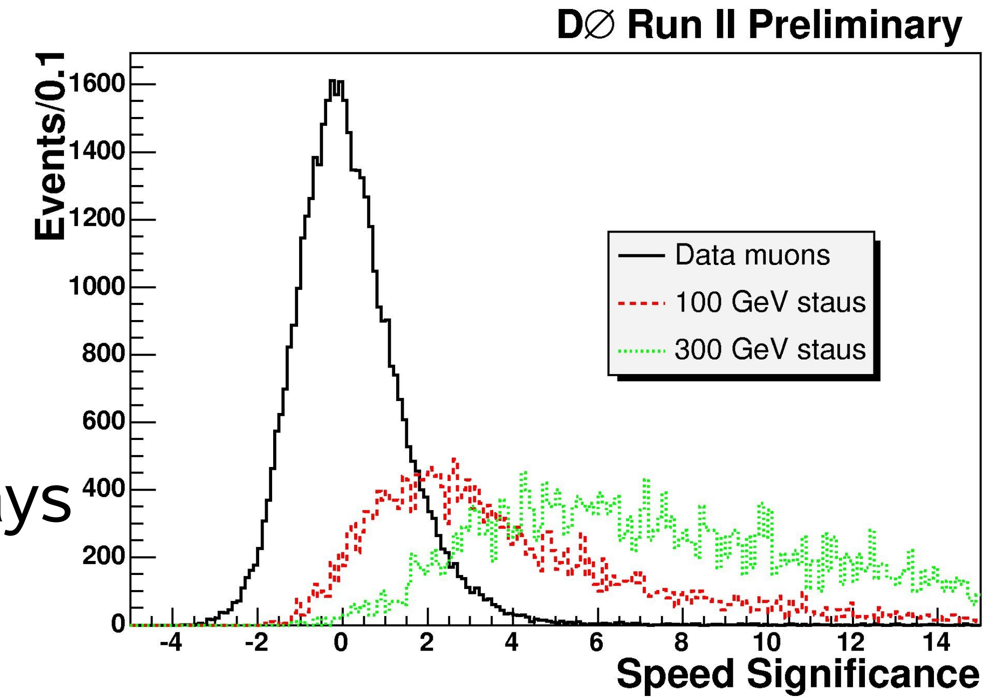
Neutralino mass > 120 GeV
Chargino mass > 220 GeV
Most stringent GMSB limits!

Charged Massive Stable Particles (CMSPs)

- In GMSB, a slepton (usually the lightest stau) can also be the NLSP
  - If the decays of the stau NLSP to the gravitino/goldstino LSP are suppressed, it can have a lifetime long enough to appear stable in the detector
- Charginos can also acquire long lifetimes in models without gaugino mass unification
  - This requires a small mass difference between the lightest chargino and the lightest neutralino (~<150 MeV)
  - This can happen in anomaly-mediated SUSY breaking (AMSB) models

The CMSP Analysis (I)

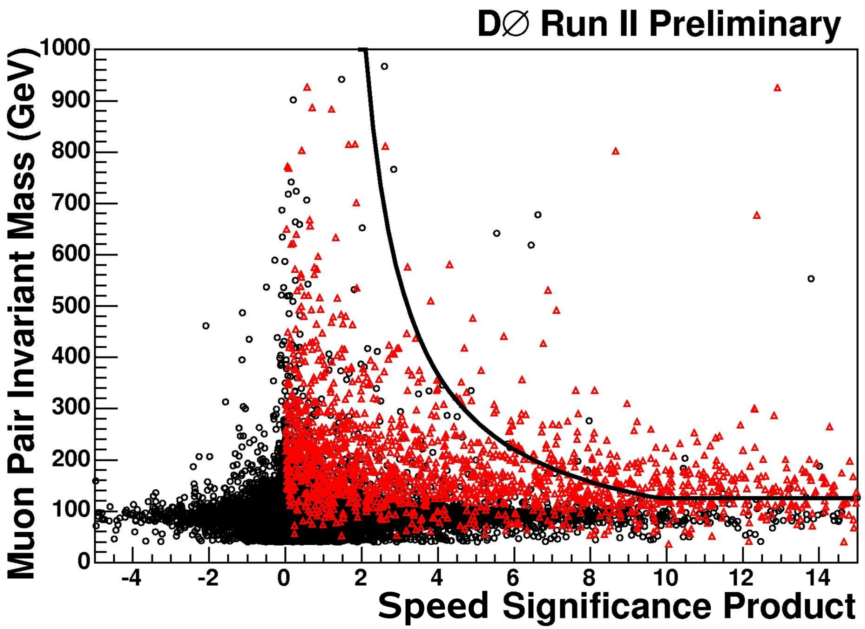
- Appears as a slow-moving, out of time muon
  - Assuming pair-production, each event will contain two “slow muons”
- Speed is measured with muon trigger scintillators
- Backgrounds are cosmic rays and real muons with mismeasured times
  - Estimated from data Z→μμ events and in-time muons



Speed significance is number of σ from speed of light (positive for slow particles)

The CMSP Analysis (II)

- Three models are considered
  - GMSB with stau NLSP
  - Higgsino-like and gaugino-like stable chargino
  - Masses from 60 GeV to 300 GeV considered
- Signal events have both high speed significance and high invariant mass



Black circles are muons in data
Red triangles are 60 GeV stable staus

Black line shows 2D cut (optimized separately for each mass point)

Significance product is product of speed significance for the two particles in the event

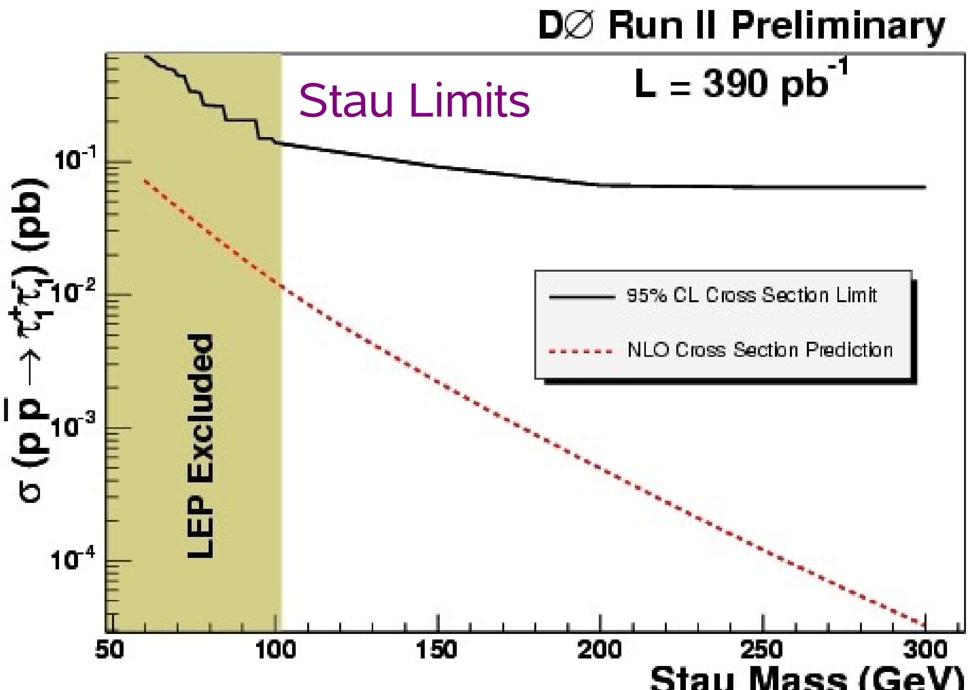
The CMSP Analysis (III)

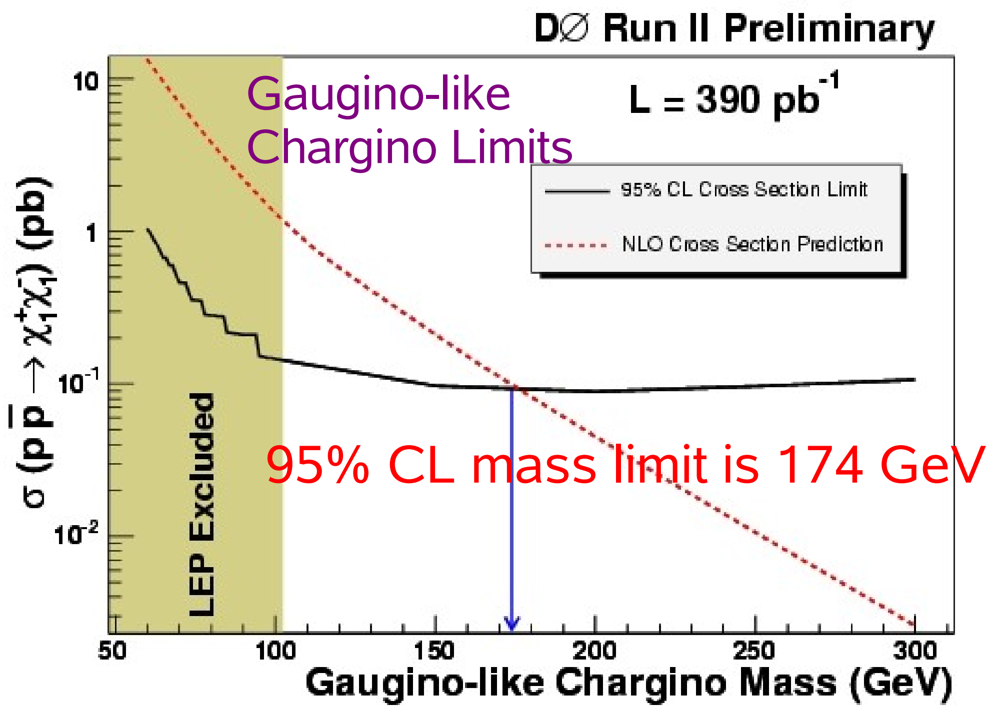
- No excess of events is observed
- Limits are set on the stau cross section and the chargino mass

Stau Results

TABLE IV: Analysis results for all six stau mass points.

Stau Mass (GeV)	Data Events	Background Prediction	Signal Acceptance
60	13	13.6 ± 0.7 (stat) ± 0.5 (syst)	0.0381 ± 0.0007 (stat) ± 0.0010 (syst)
100	0	0.66 ± 0.06 ± 0.02	0.0559 ± 0.0009 ± 0.0015
150	0	0.69 ± 0.05 ± 0.02	0.0968 ± 0.0014 ± 0.0026
200	0	0.60 ± 0.04 ± 0.02	0.1180 ± 0.0016 ± 0.0032
250	0	0.47 ± 0.03 ± 0.02	0.1222 ± 0.0017 ± 0.0033
300	0	0.61 ± 0.05 ± 0.02	0.1226 ± 0.0017 ± 0.0033





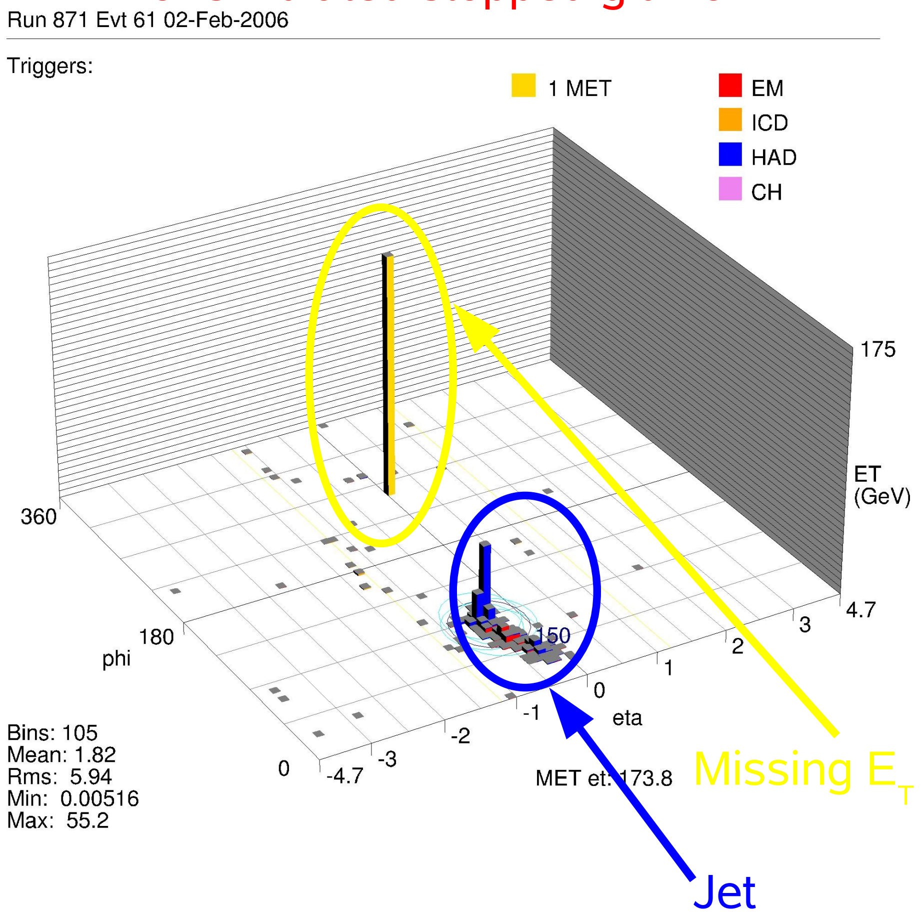
Split-SUSY

- Another type of SUSY model is known as split-SUSY
- In split-SUSY, all scalar supersymmetric particles are heavy (> 1 TeV)
- The gluino is the only weak-scale colored supersymmetric particle.
  - Its decays to a gluon and a neutralino are suppressed, resulting in a long gluino lifetime (from nanoseconds to hours)

The Stopped Gluino Analysis (I)

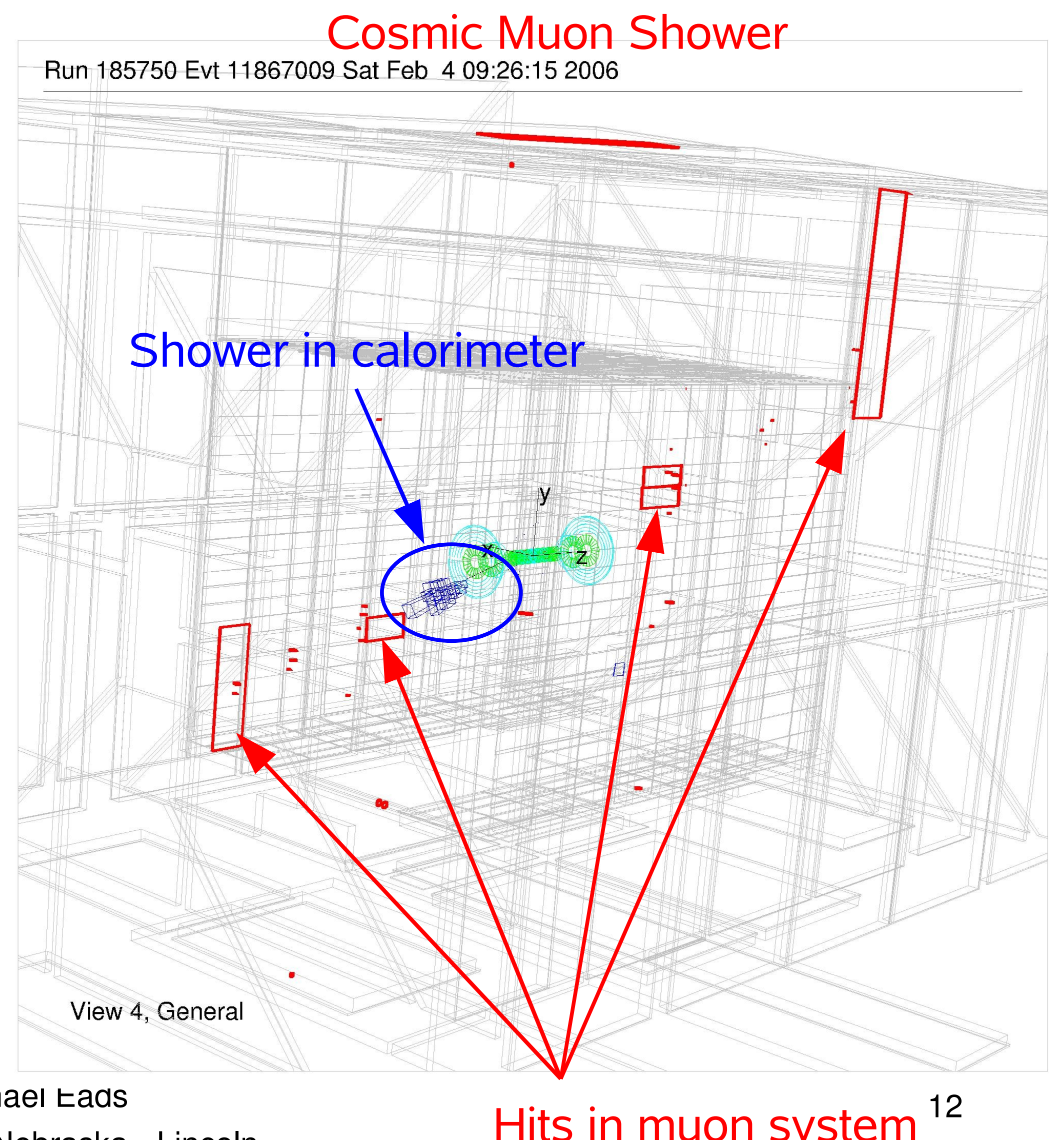
- A gluino is produced and hadronizes, coming to rest in the calorimeter
- Some time later (in another bunch crossing), it decays to a gluon jet (and a neutralino)

Calorimeter Energy Lego Plot for simulated stopped gluino



The Stopped Gluino Analysis (II)

- Main backgrounds
  - Cosmic muons inducing a shower
    - Look for muon entering/exiting detector
    - Estimate from cosmic muons in data
  - Beam-halo muons
    - Look for hits in muon system or energy parallel to beam
    - Negligible at high jet energies



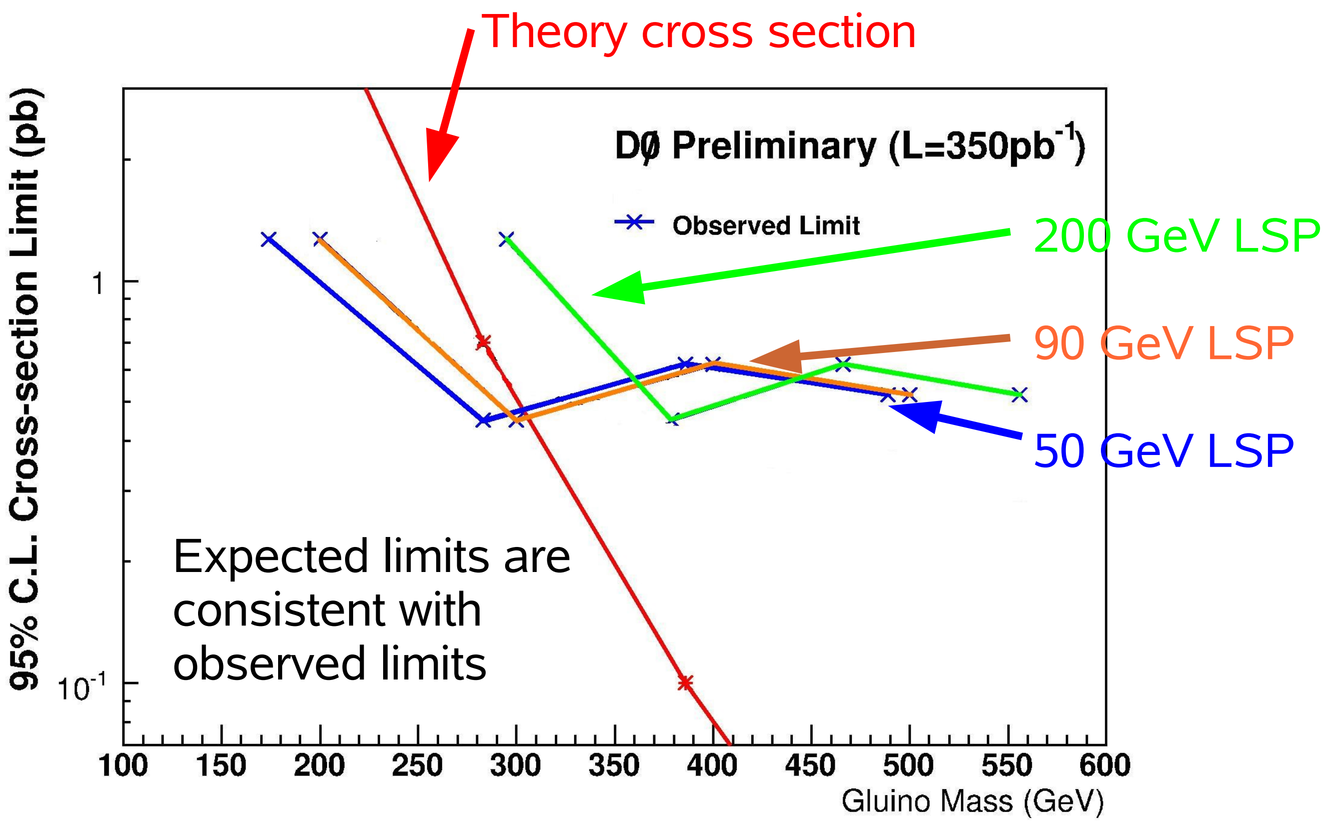
The Stopped Gluino Analysis (III)

- No excess of events is observed
- Limits are set on the gluino production cross section

Jet E Range (GeV)	Data	Bgnd.	Signal Efficiency
94.6-111.6	46	48.18	0.05
126.8-171.8	32	37.84	0.10
169.3-233.8	27	21.56	0.11
214.2-286.6	14	9.57	0.10

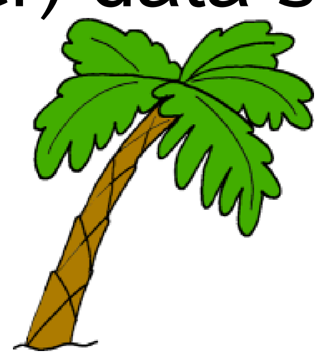
Gluinos with mass below 270 GeV excluded for light neutralinos.

First analysis of this kind at a hadron collider!



Conclusion

- DØ is actively investigating “alternate” SUSY scenarios
  - We have some of the world's best limits for these models
- These results (and many more) available at
  - http://www-d0.fnal.gov/Run2Physics/WWW/results.htm
- Many results will be updated with the full ~$1 fb^{-1}$ (or larger) data sample, so stay tuned



Aloha!