A Search for Charged Massive Stable Particles at DØ

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Massive Stable Particles

- *Stable* refers to lifetimes long enough to escape the detector (~10^{-6} s)
- In general, a massive stable particle could interact via electromagnetic, weak, or strong forces
  - This analysis searches for the pair-production of electrically charged particles (with unit charge), which will appear as slow-moving muons
- There are several reasons why their lifetime could be long:
  - A conserved quantum-number (such as *R*-parity)
  - Couplings (the coupling is very weak in the only allowed decay mode)
  - Kinematics (very little phase space in the allowed decay modes)

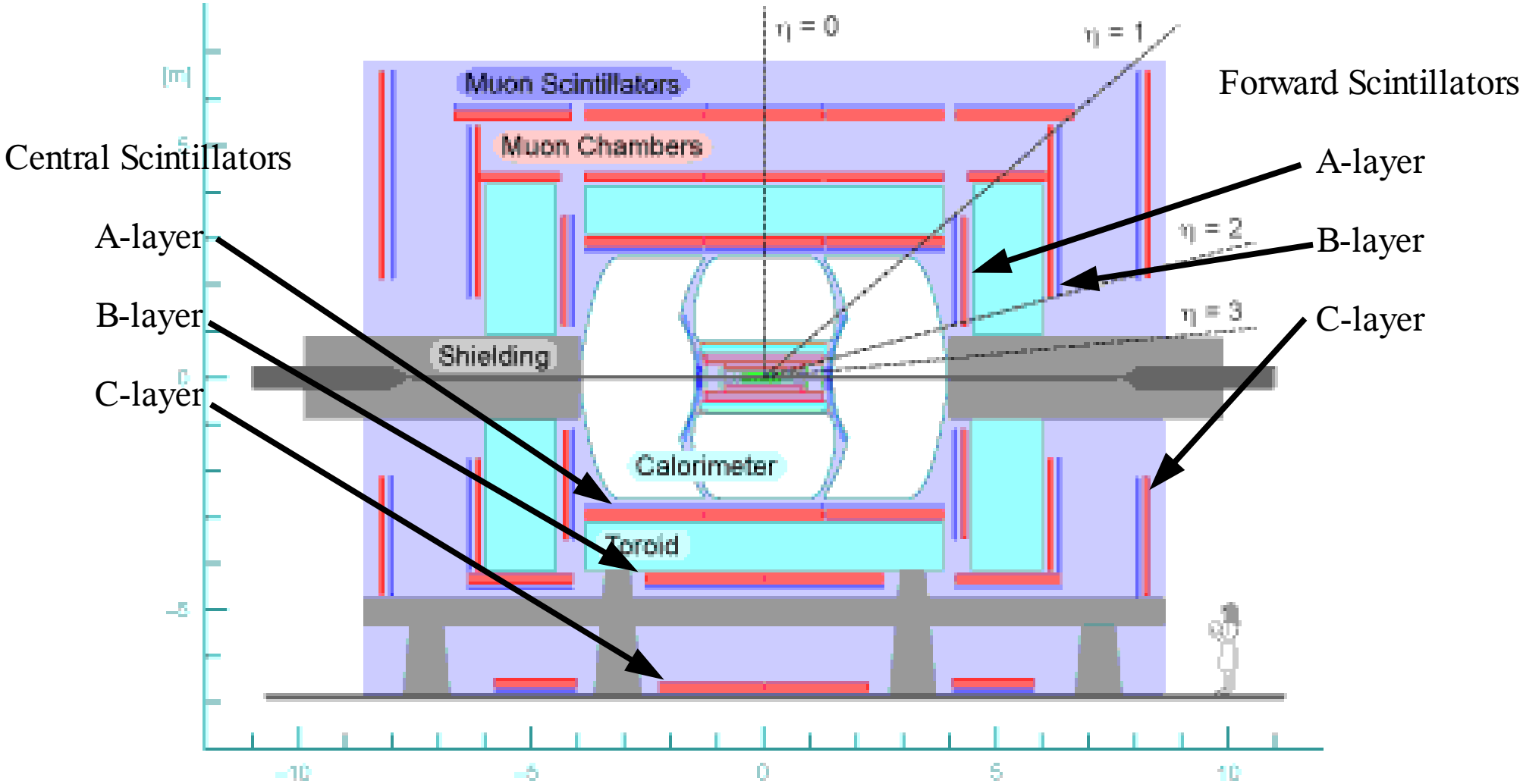
CMSP's in GMSB

- In gauge-mediated supersymmetry breaking (GMSB), SUSY is broken through gauge interactions
- The LSP is always the gravitino/goldstino
- The NLSP can be either the lightest scalar tau mass eignstate (stau) or the lightest neutral gaugino mass eigenstate (neutralino)
- If the stau is the NLSP it can obtain a long lifetime, depending on the coupling to the gravitino/goldstino
- A similar situation can also occur in supergravity, where the gravitino is the LSP and a stable stau is the NLSP

Stable Charginos

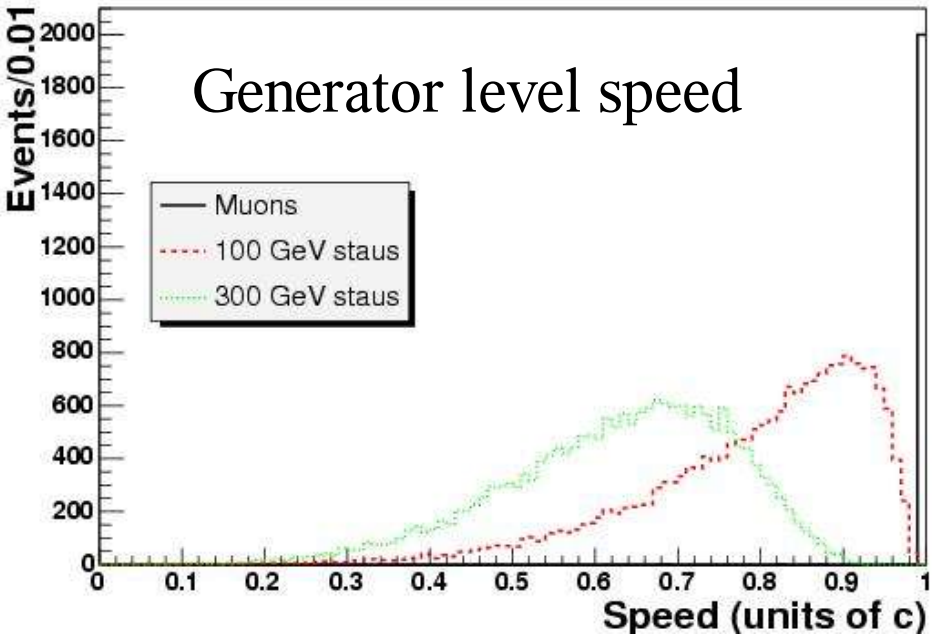
- The lightest chargino could appear stable if it is nearly mass degenerate with the Neutralino LSP
- The chargino is mostly higgsino
  - The higgsino mass parameter $|\mu|$ is small, while the gaugino mass parameters M_1 and M_2 are large
- The chargino is mostly gaugino
  - $|\mu|$ is large while M_2 is small (and $M_1 > M_2$)
  - This happens in Anomaly-Mediated SUSY breaking, although a stable chargino seems unlikely after loop corrections to masses
  - It may still be possible in SUSY models with other relations between M_1 and M_2

The DØ Detector



Simulating the Signal

- A parameterized Monte Carlo simulation (PMCS) is used to simulate the signal
  - Includes detector resolution smearing, trigger, and muon identification efficiencies tuned on Z→μμ events
  - Modifications were made to handle stable particles
  - A simulation of the muon scintillators was implemented



The Data Sample

- The data sample used consists of events with two reconstructed muons
  - This consists of data from the beginning of Run 2 through the August 2004 shutdown
- A dimuon trigger is required to fire, resulting in an integrated luminosity of 390 pb^{-1}
  - Requires 2 muons with scintillator hits in two layers
- Additionally, the two muons are required to have p_T > 15 GeV, isolated, track-matched, scintillator hits in at least two layers, and consistent layer speeds
- Cosmic cuts are also performed

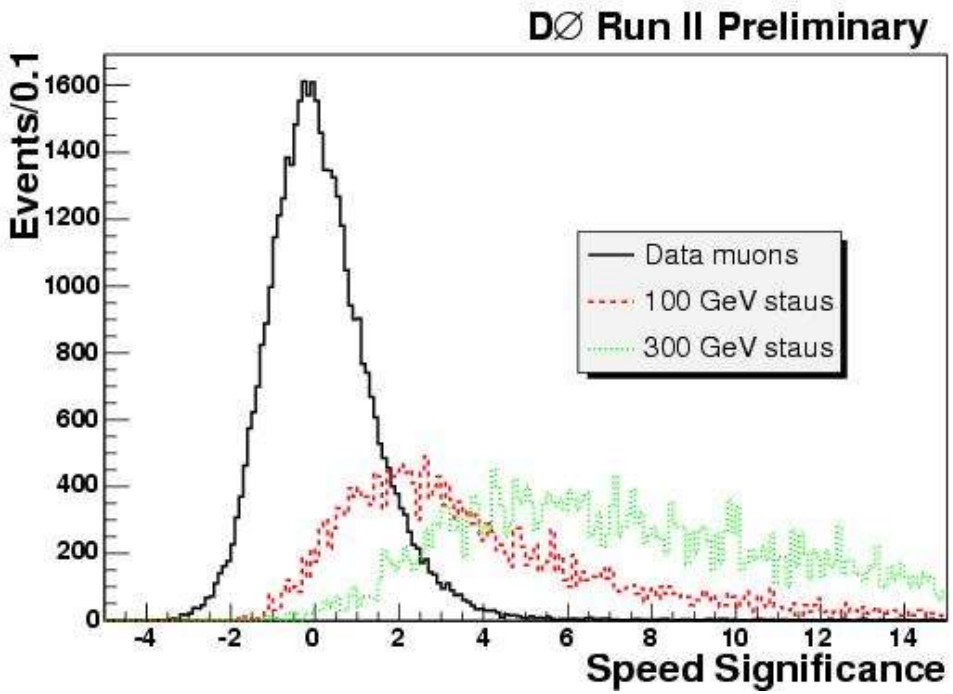
Calculating the Speed

- The speed is simply the distance traveled by the muon divided by the time measured in the muon scintillators
- The speed for a particle is calculated for each layer containing a scintillator hit
- The weighted average of the layer speeds gives the speed of the particle
- The χ^2 of the average is also calculated
  - A large χ^2 means the individual layer speeds are inconsistent with each other
  - A cut on χ^2 is made at preselection

Speed Significance

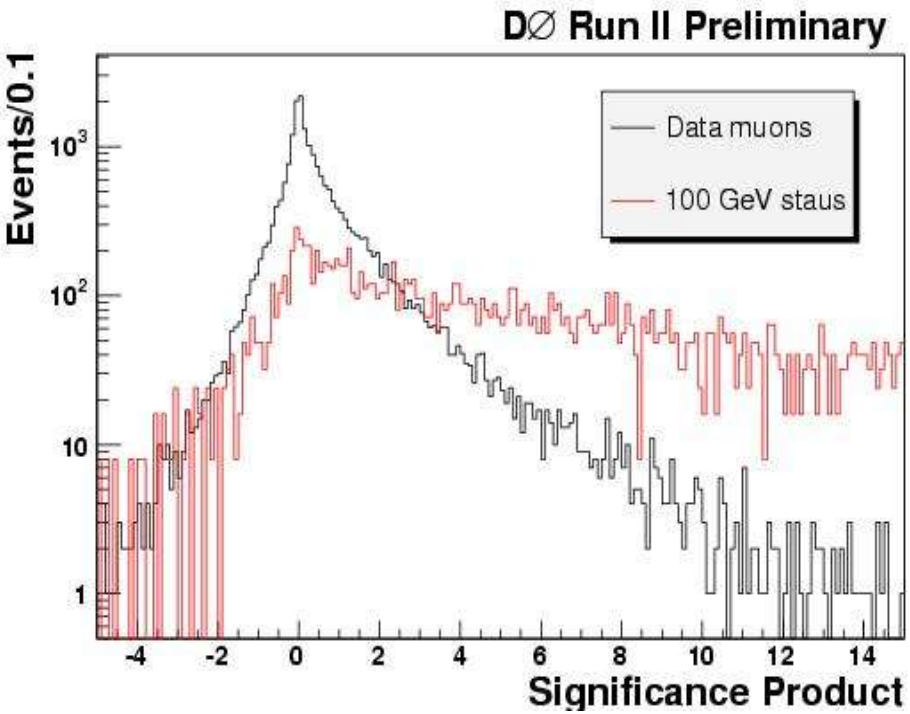
- The uncertainty on the calculated average speed is also useful
  - Events with a low average speed which is still consistent with the speed of light within its uncertainty should be rejected
- The *speed significance* is defined as:
  - $$speed\ significance = \frac{(c - speed)}{(speed\ error)}$$
  - In units of c = 1
  - This gives the number of standard deviations away from the speed of light
  - Signal events should be positive, background muons should be near zero

Speed Significance and Significance Product



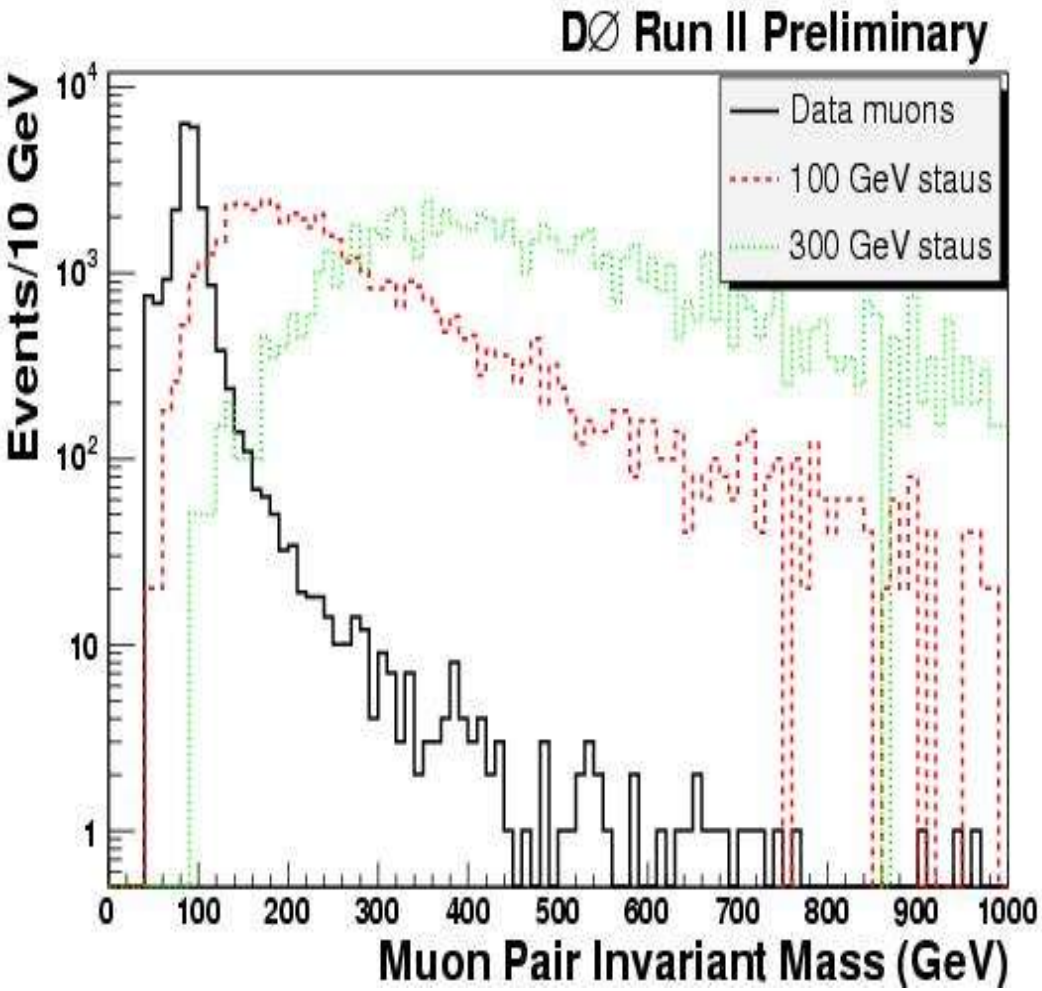
Significance Product is the product of the speed significance of the two particles in the event

→ The speed significance of both particles is required to be positive

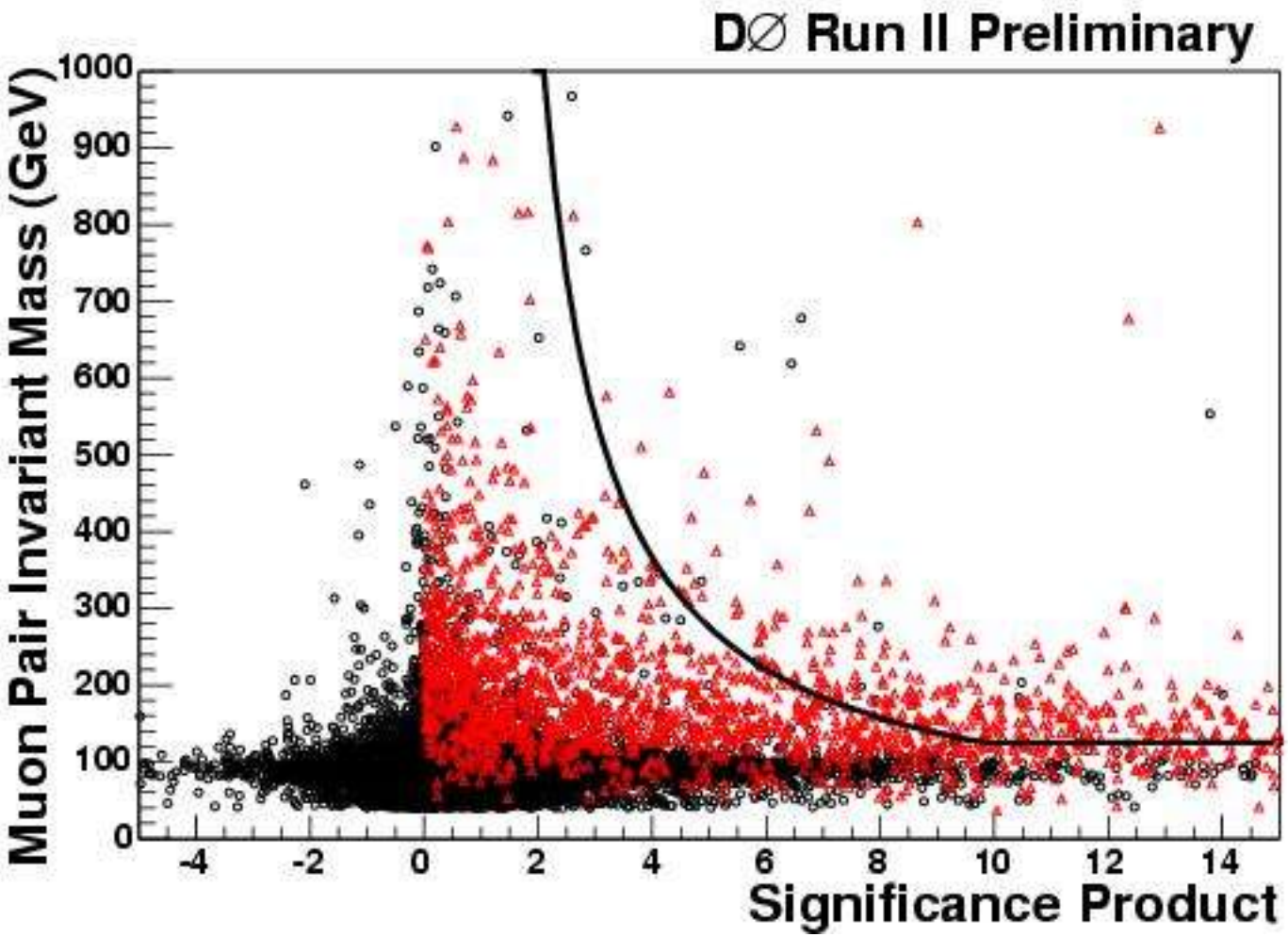


Invariant Mass

- The background has a peak in invariant mass at the Z mass, then falls sharply
- The signal is primarily at much larger invariant masses



Invariant Mass vs Significance Product Cut



Black circles are data muons

Red triangles are 60 GeV/c^2 staus

Solid line is optimized cut

Results

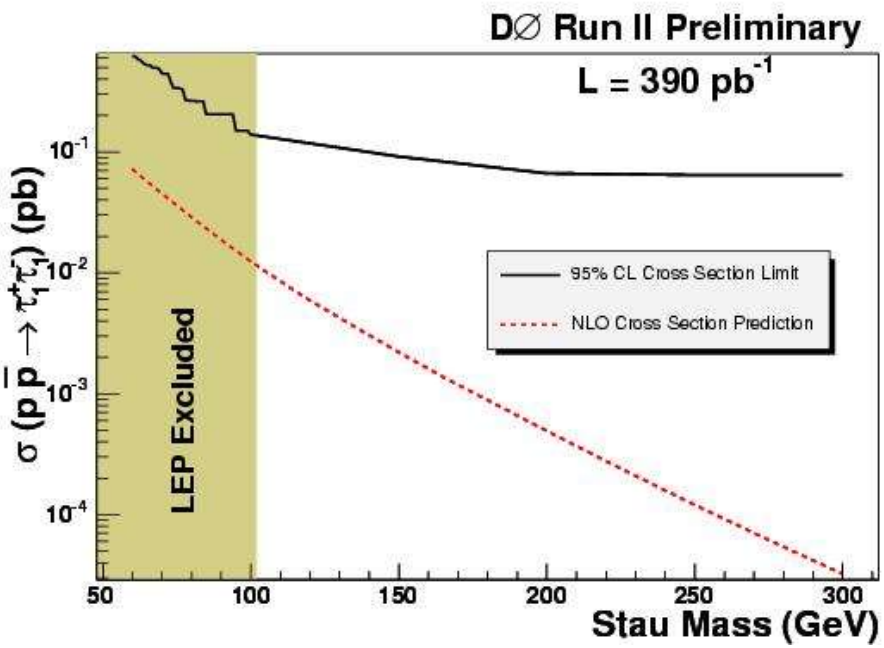
Cut Flow, 100 GeV/c^2 Staus

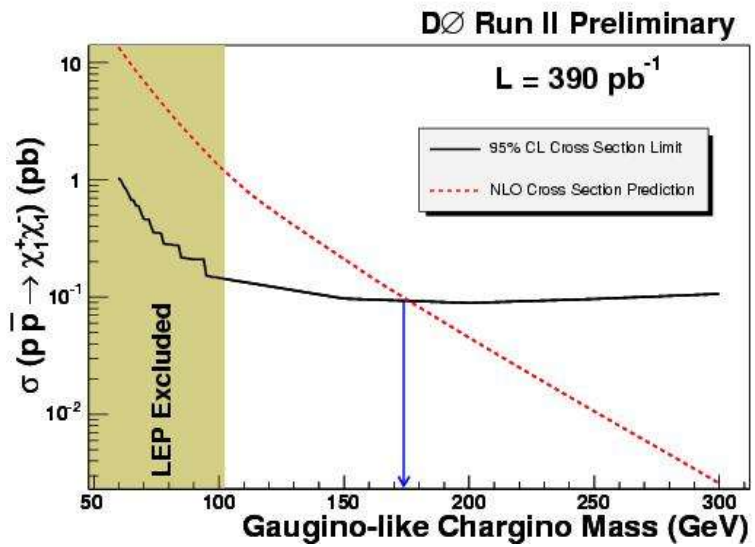
Cut	*Data Events*	*Predicted Background*	*Signal Acceptance*
Preselection	18985		0.19
Significance > 0	6410	6279±127±44	0.17
2D cut	0	0.66±0.06±0.02	0.06

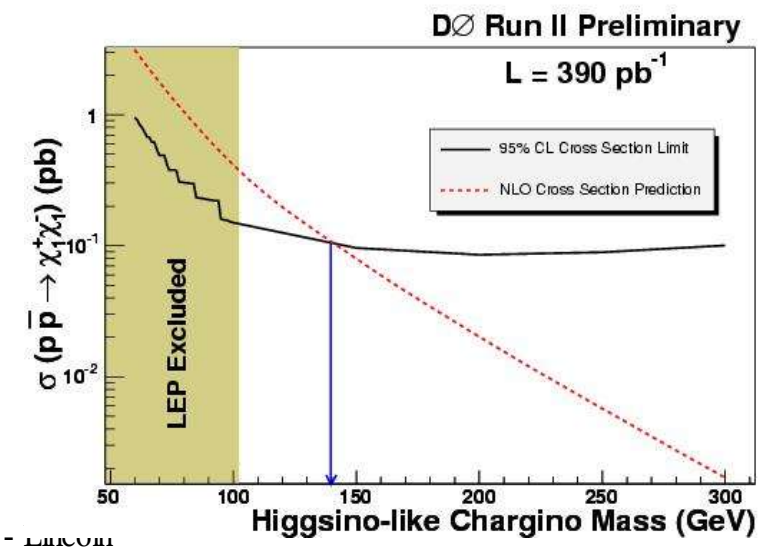
Results after all cuts

Mass (GeV/c^2)	*Data Events*	*Background Prediction*	*Stau Acceptance*	*Higgsino-like Chargino Acceptance*	*Gaugino-like Chargino Acceptance*
60	13	13.6±0.7±0.5	0.0381±0.0007±0.0010	0.0249±0.0006±0.0007	0.0227±0.005±0.0006
100	0	0.66±0.06±0.02	0.0559±0.0009±0.0015	0.0519±0.0009±0.0014	0.0536±0.0009±0.0015
150	0	0.69±0.05±0.02	0.0968±0.0014±0.0026	0.0815±0.0012±0.0022	0.0805±0.0012±0.0022
200	0	0.60±0.04±0.02	0.1180±0.0016±0.0032	0.0921±0.0013±0.0025	0.0880±0.0013±0.0024
250	0	0.47±0.03±0.02	0.1222±0.0017±0.0033	0.0872±0.0013±0.0024	0.0814±0.0012±0.0022
300	0	0.61±0.05±0.02	0.1226±0.0017±0.0033	0.0783±0.0012±0.0021	0.0733±0.0011±0.0020

Limits







A cross section limit is set for stable staus and a mass limit of 174 GeV (140 GeV) is set for gaugino-like (higgsino-like) stable charginos

Summary

- A search for stable staus and charginos has been performed using 390 pb^{-1} of data
- Cross section limits are set for pair production of stable staus from 0.62 pb to 0.06 pb
  - These are the most stringent limits to date from the Tevatron
- Mass limit of 140 GeV/c^2 set for higgsino-like charginos
- Mass limit of 174 GeV/c^2 set for gaugino-like charginos
  - These are currently the best limits to date for stable charginos