Searches for long lived particles at the Tevatron (including monopoles)

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DIS 2008

Long-lived Particles

Exotic long lived particles are predicted by many extensions of the Standard Model

- Many of these models provide good dark matter candidates

- Supersymmetry:
  - Gauge-mediated SUSY breaking (GMSB)
  - Light (MeV) Gravitino LSP; all supersymmetric particles decay via cascades to the NLSP
  - Coupling to gravity determines how quickly the NLSP decays
    - small symmetry breaking scale (large coupling)=> short lifetime
    - large symmetry breaking scale (small coupling)=> NLSP is long-lived
  - NLSP candidates: neutralino, stau lepton

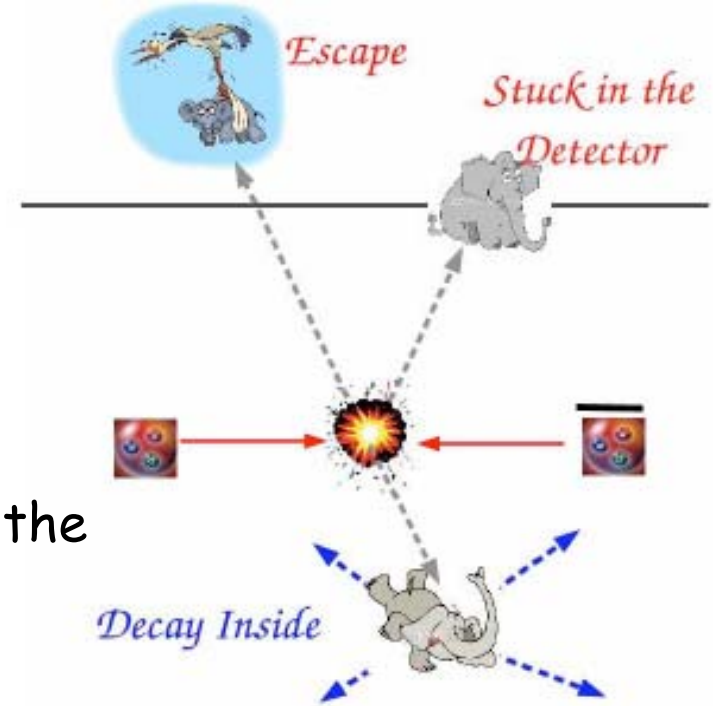
Long-lived Particles

- Supersymmetry:
  - Anamoly mediated supersymmetry breaking (AMSB)
    - Long lifetimes arise from small mass splittings between the LSP and the NLSP
    - If mass difference is small enough, phase space suppression impedes the decay of the NLSP
    - NLSP candidate: chargino
- Split supersymmetry
  - Decay rate of gluinos may be suppressed leading to long lifetimes
- Universal Extra Dimensions
  - Kaluza-Klein modes of SM particles
- Long-lived 4th generation quarks
- Models with R-parity violation

Experimental Signature

Different experimental signatures:

- Escape the detector (non-interacting)
  - Large MET
- Interact with the detector or decay
  - Delayed hits



Characteristics:

- "stable" ⇒ usually doesn't decay within the detector
- massive (>50 GeV) ⇒ small β (v/c)
- charged particles ⇒large energy dep.

Example : stop, stau

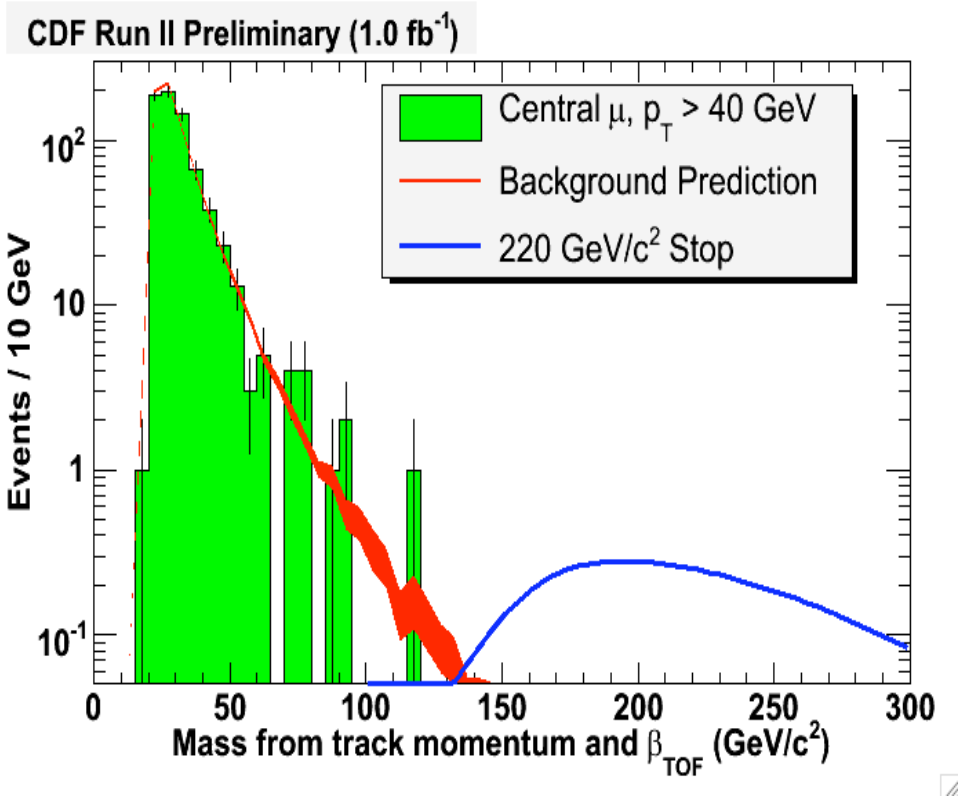
- Interacts in the detector like a heavy muon - no strong interactions or EM showers

CHAMPS @ CDF

CHArged Massive Stable ParticleS

- Register as delayed hits in Time of Flight (TOF) detector and Central Tracker (COT)
- Reconstruct β using origin vertex t_0 information
- Use muon chamber information for trigger
- Reconstruct mass from β and momentum

$$m_{\mathrm{TOF}} = p\sqrt{\frac{1}{\beta^2} - 1}$$

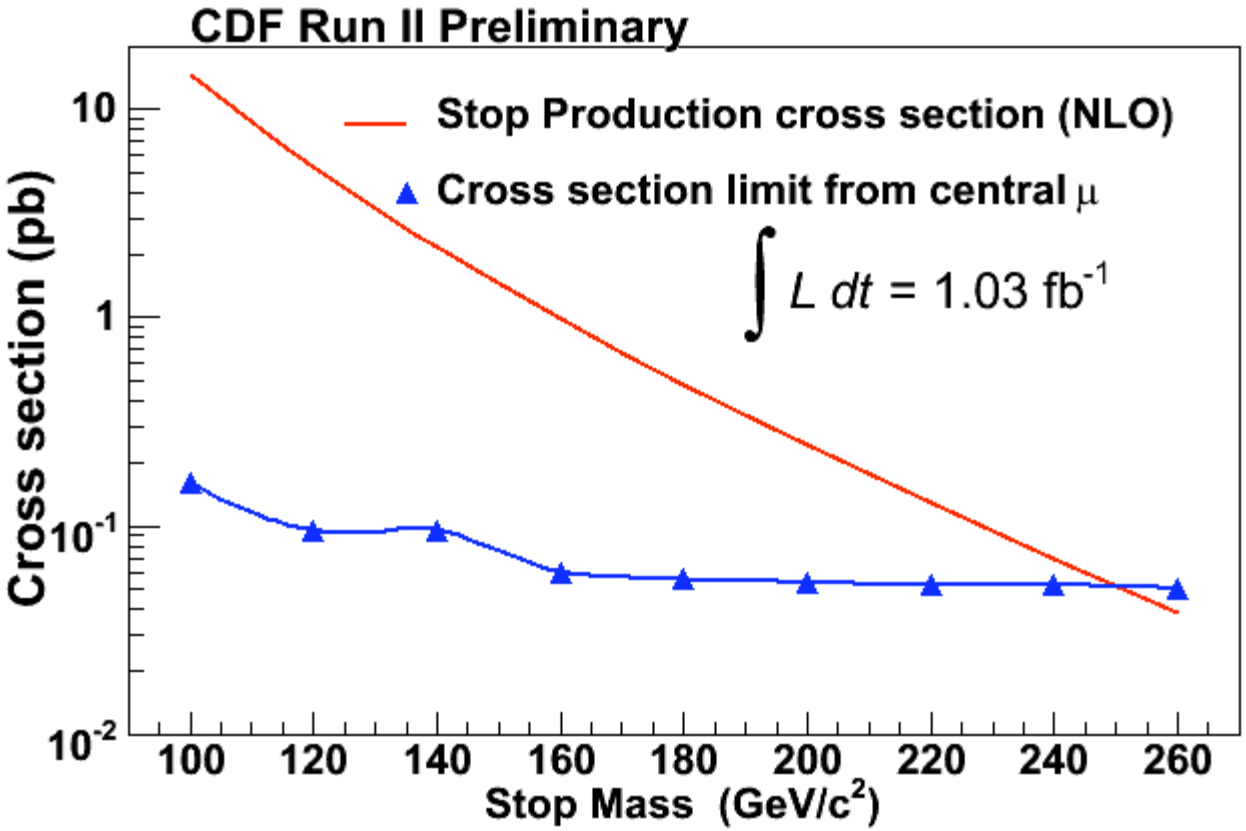


No excess observed in the data

CHAMPS @ CDF

Signal region events consistent with background predictions

Obtain cross section limits for strongly and weakly interacting stable stop



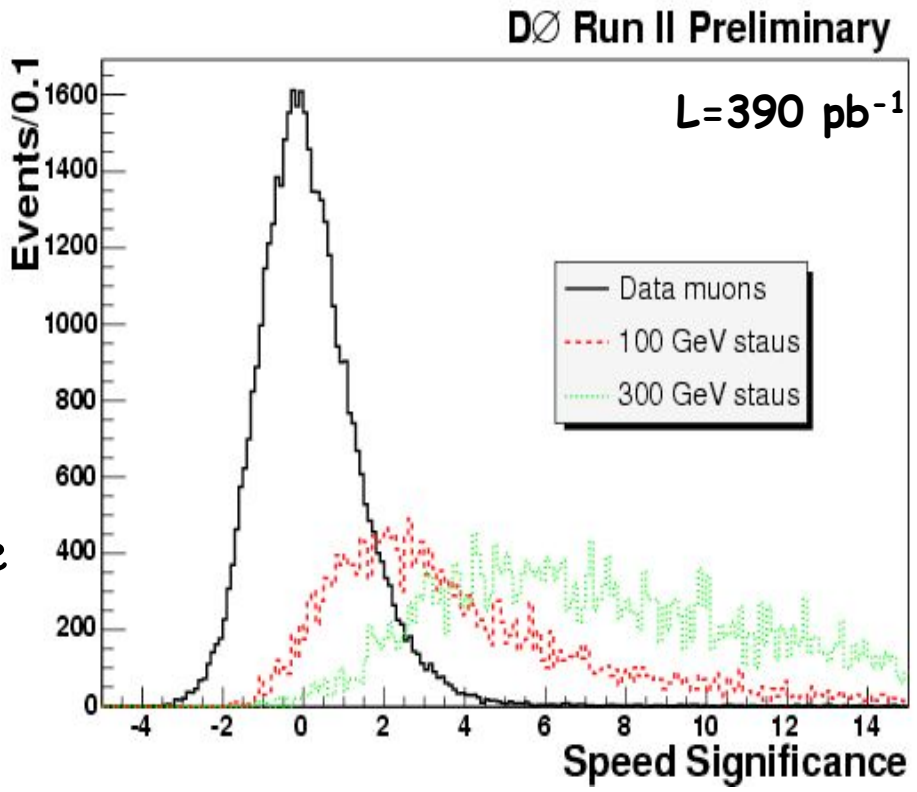
Exclude stable stop with mass below 250 GeV @ 95% C.L.

CMSPs @ DØ

Charged Massive Stable Particles

Study exclusive pair production of staus:

- Require two muons in the event
- Measure muon speed with scintillation counters
  - Resolution: 2-4 ns
- Speed resolution depends on the detector type and number of reconstructed muon hits
- Construct speed significance
  - Speed measured in units of c

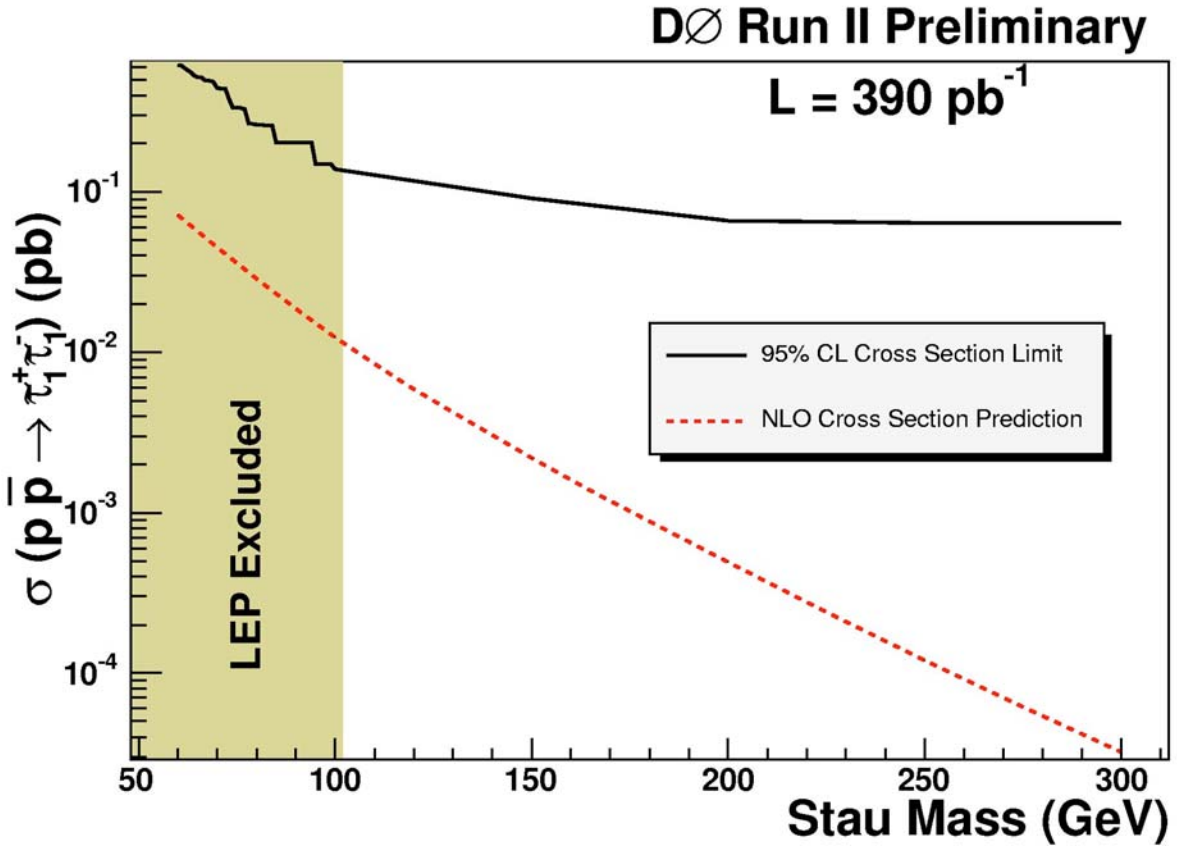


$$\text{Speed Significance} = \frac{1 - \text{speed}}{\sigma_{\text{speed}}}$$

CMSPs @ DØ

- Data agrees with SM expectation
- No excess => set limits

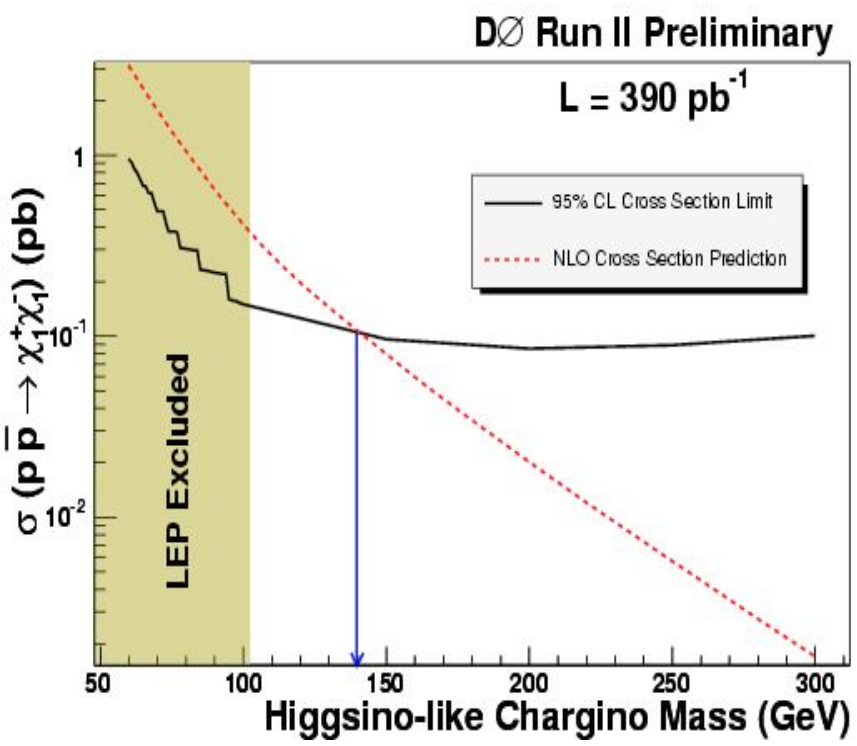
Updated version of analysis with more data coming out soon



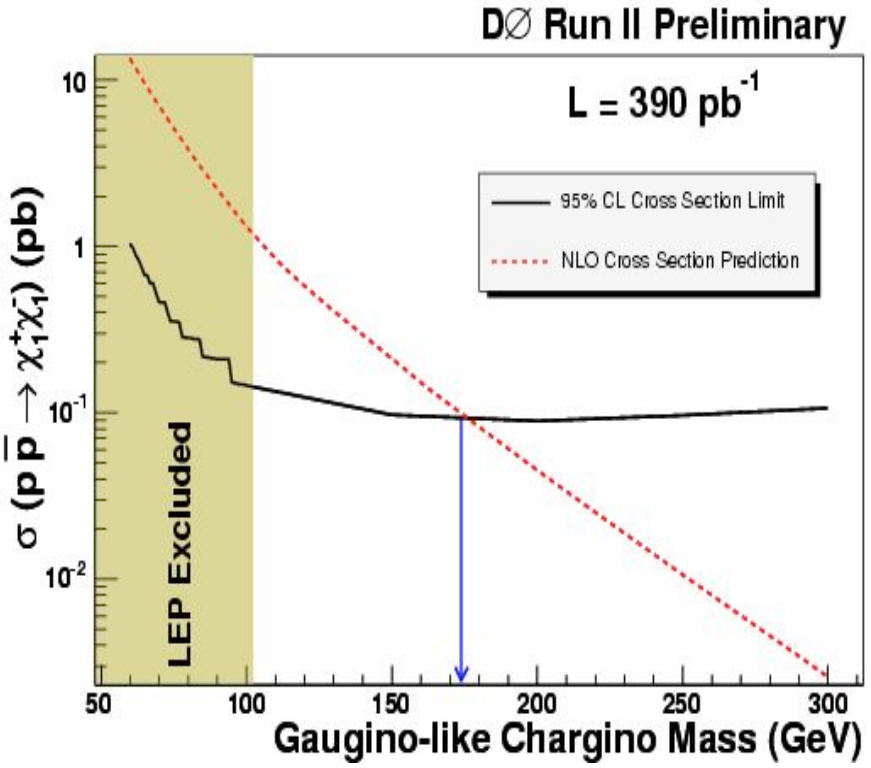
CMSPs @ DØ

Charginos look like staus…

Updated version of analysis with more data coming out soon



M > 140 GeV



M > 174 GeV

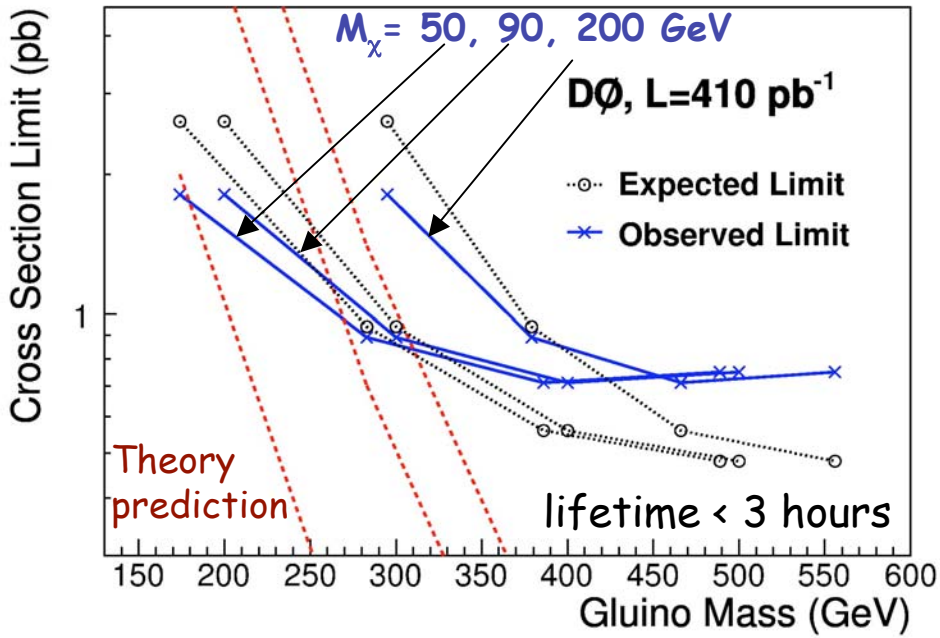
PRL 99, 131801 (2007)

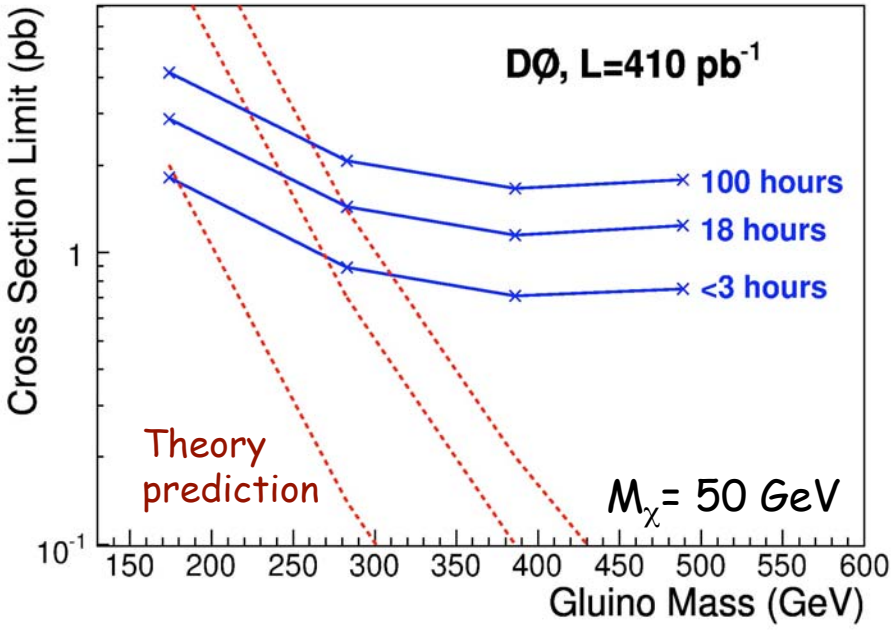
Stopped Gluinos @ DØ

Assume M_{SUSY}(scalars) >> M_{SUSY}(fermions)
⇒ gluino can have long lifetime and hadronize ("R-hadrons")

If lifetime > 10 μs:

- fraction of $\tilde{g}$'s stopped in calorimeters
- stopped gluino → $g + \tilde{\chi}^0_1$
- single high E_T shower and high MET; arrives at later times



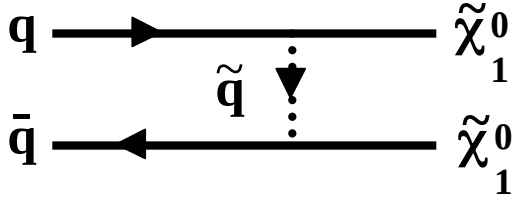


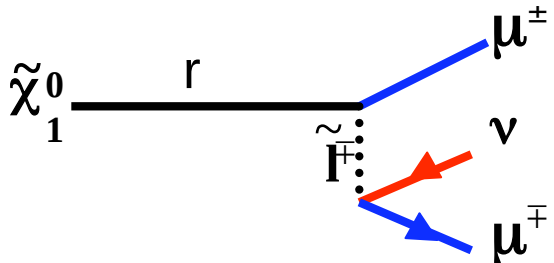
PRL 97, 161802 (2006)

Neutral long lived particles @ DØ

Inspired by NuTeV dimuon excess: 3 unexpected events in (2.2-15 GeV)

Low mass LSP decays to 2μ+ν, r = [5-20]cm, other χ escapes

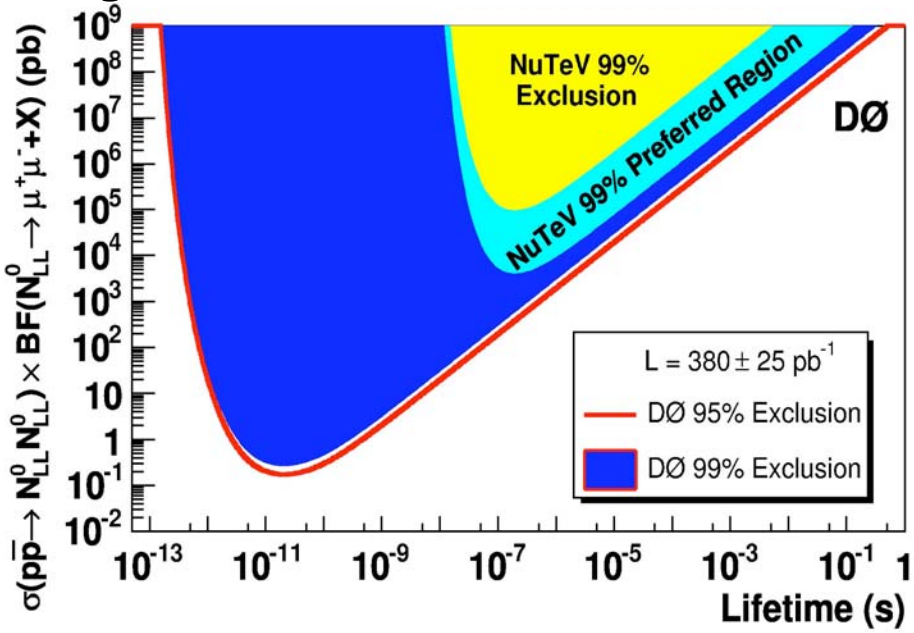


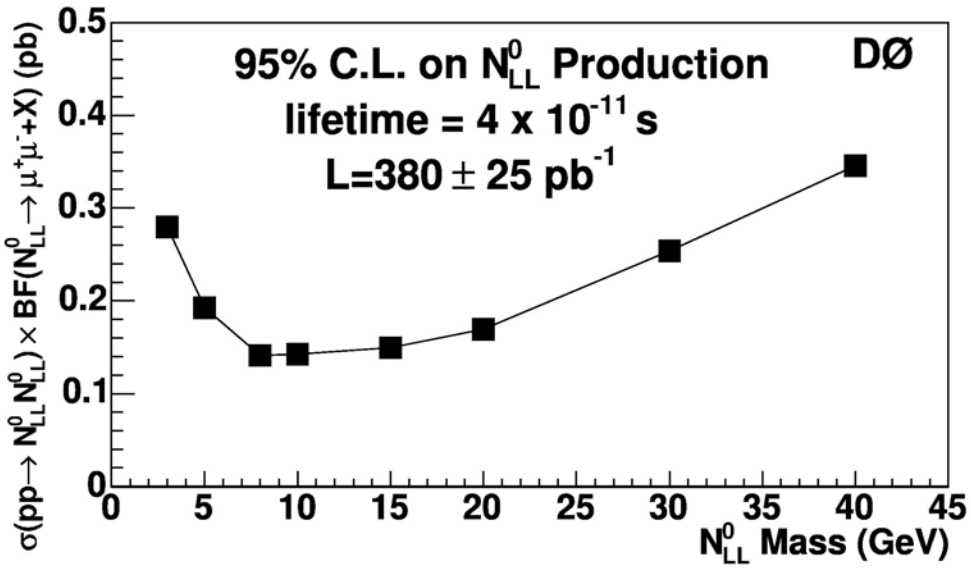


Bkg: 0. 75±1.1(stat)+ 75±1.1(sys)

Signal: 0 events

Excludes an interpretation of the NuTeV excess in many models



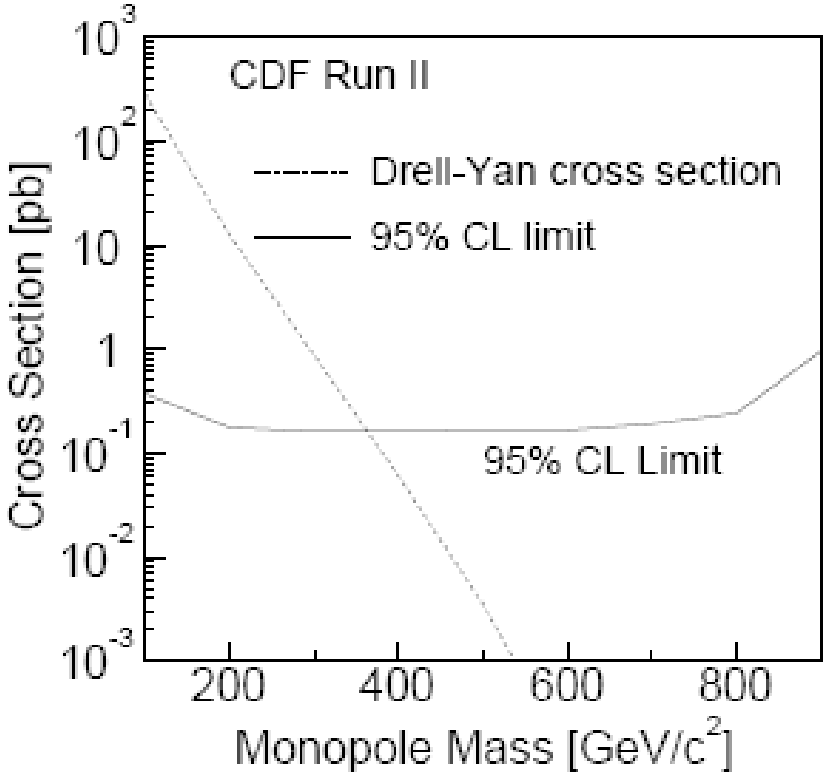


PRL 96, 201801 (2006)

Magnetic Monopoles @ CDF

- First hypothesized by Dirac in 1931…
  - Magnetic monopoles would be accelerated by a magnetic field like electrons in an electric field.
  - Monopoles would be heavy and highly ionizing
    - CDF triggers on large light pulses in Time-of-Flight scintillator bars
  - In the tracking detector, monopoles would cause highly ionizing hits in a pattern resembling a high p_T track.
  - No monopole candidates found, limits set.

Assuming a Drell-Yan like pair production:
Mass limit: 360 GeV



Summary

- There is an exciting hunt ongoing at the Tevatron for long-lived particles
  - These searches are complementary to underground dark matter searches and other cosmological studies
  - The searches involve a rich variety of exotic particles ranging from stops, staus, and charginos to monopoles
  - (Searches involving long-lived neutralinos decaying to photons covered in Y. Maravin's talk)

- There are more than 3 fb^{-1} of data ready to be analyzed

- Many new exciting results are expected over the summer