Search for Long-Lived Particles at DØ

SUSY05

IPPP Durham

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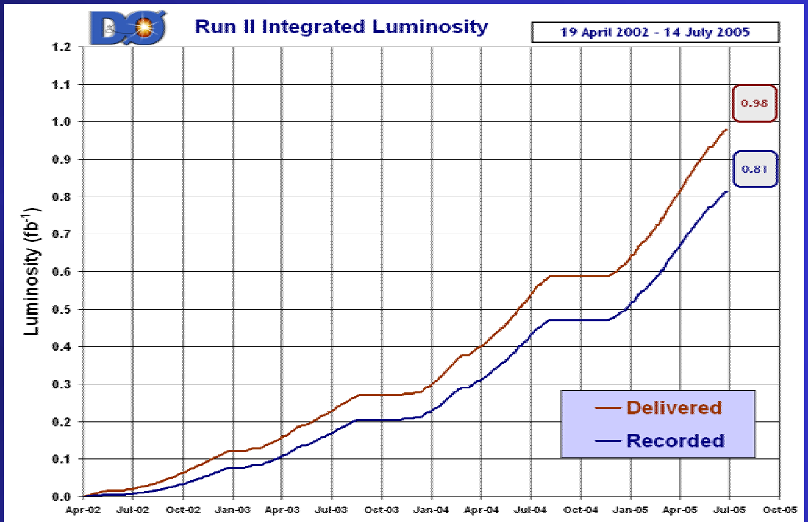
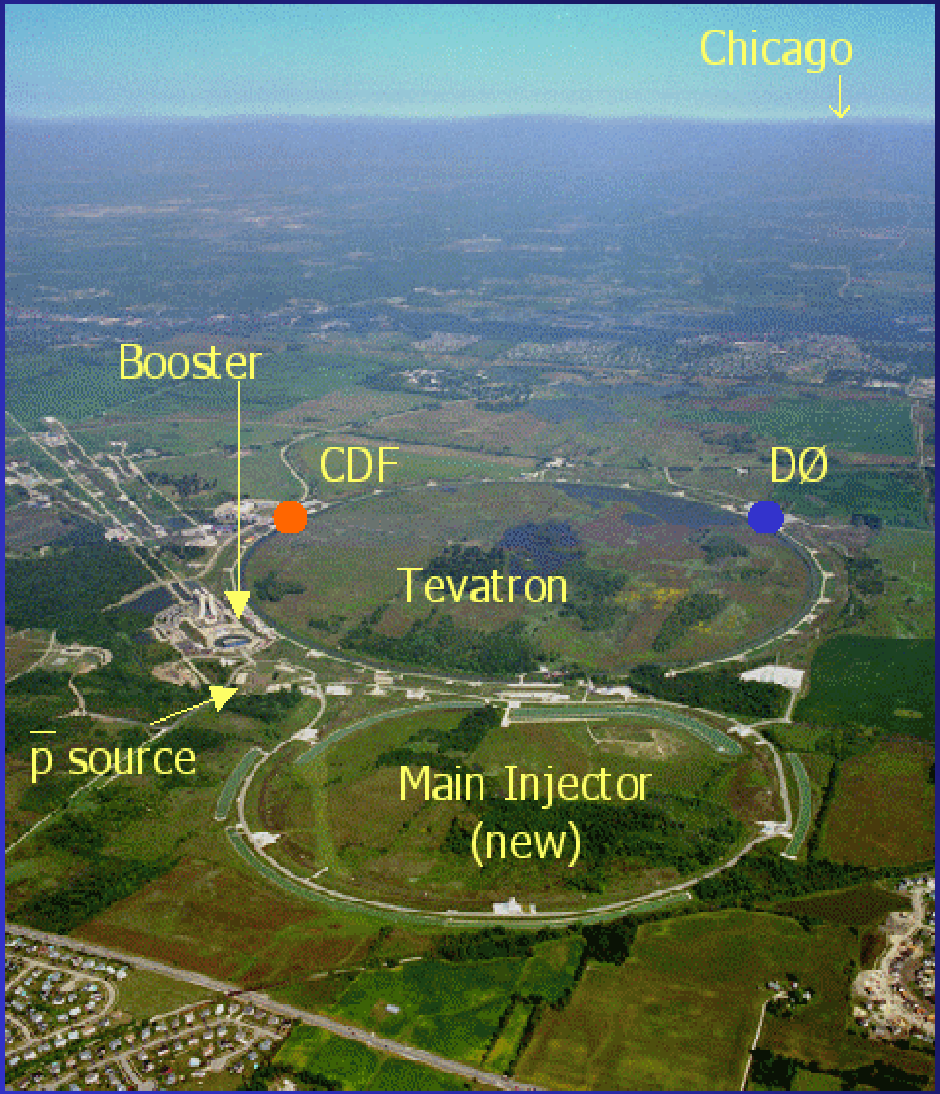
Tevatron

- $p\bar{p}$ collisions at 1960 GeV
- detectors:
  - DØ and CDF





recorded luminosity ~8 times Run I

Introduction

- Search for long-lived particles
  - "stable" = doesn't decay within the collider detector
    - can still decay
  - massive (>50 GeV)
  - charged particles = unique signature
- SUSY models
  - GMSB: stau
  - chargino
  - optimize for pair production

GMSB Model

- stable stau: NLSP (LSP is gravitino/goldstino)
- large value of C_{grav}
- Snowmass 2001 Model Line D

Λ_m	scale of SUSY breaking	19 to 100 TeV
M_m	messenger mass scale	$2\Lambda_m$
N5	number of messenger fields	3
$\tan\beta$	ratio of Higgs VEVs	15
sign μ	sign of higgsino mass term	+1
C_{grav}	factor for effective mass of gravitino	>>1

Chargino Model

- small (<150 MeV) mass difference between lightest chargino and lightest neutralino

- stable chargino
  - higgsino-like

    or
  - gaugino-like

	higgsino-like	gaugino-like
μ (GeV)	60-300	10,000
M_1 (GeV)	100,000	$3M_2$
M_2 (GeV)	100,000	60-300
M_3 (GeV)	500	500
$\tan\beta$	15	15
squark mass (GeV)	800	800

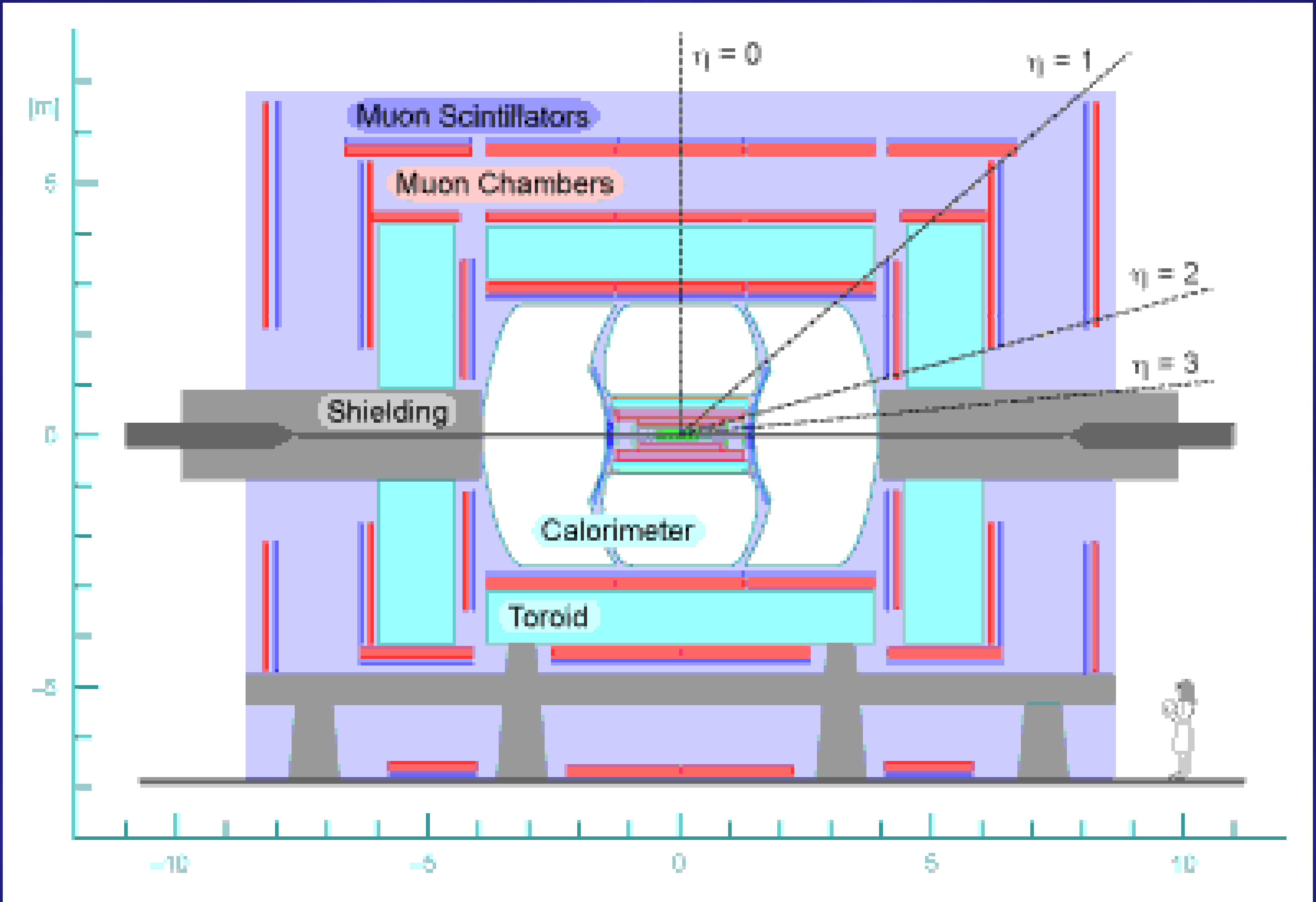
Charged Massive Stable Particles (CMSPs)

- Massive: >50 GeV
- Slow-moving: $\beta < 1$
- Charged: large energy deposition
  - Bethe-Block formula

$$\frac{dE}{dx} = \frac{4\pi N_0 z^2 e^4}{mv^2}\frac{Z}{A}\left[\ln\left(\frac{2mv^2}{I\left(1-\beta^2\right)}\right) - \beta^2\right]$$

- Long-lived: decays outside of muon detector
- Will look like slow moving muon

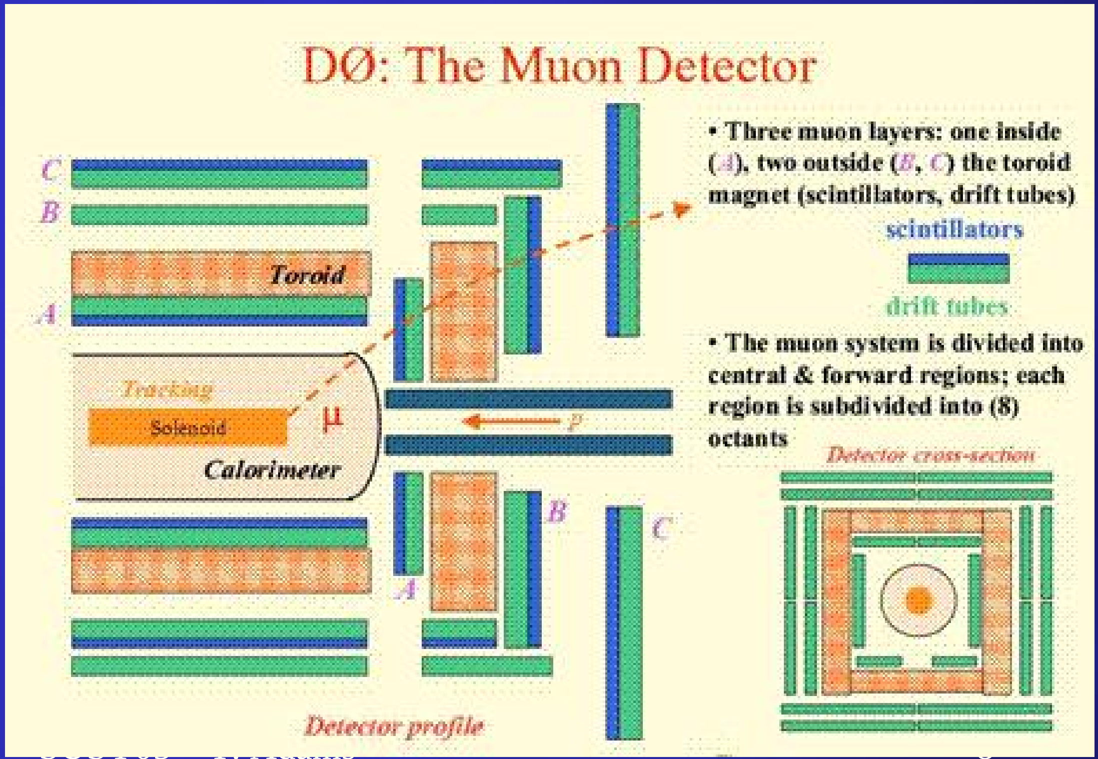
DØ Detector



η = 0
η = 1
η = 2
η = 3
[m]
5
0
−5
Muon Scintillators
Muon Chambers
Shielding
Calorimeter
Toroid
−10
−5
0
5
10

Muon System

- Detects minimum-ionizing particles
- Timing: speed of light particle will register at t=0 in all three layers
  - resolution is 2-3 ns
- Three layers
- Toroid between 1^{st} and 2^{nd} layers
- CMSP's will be out-of-time



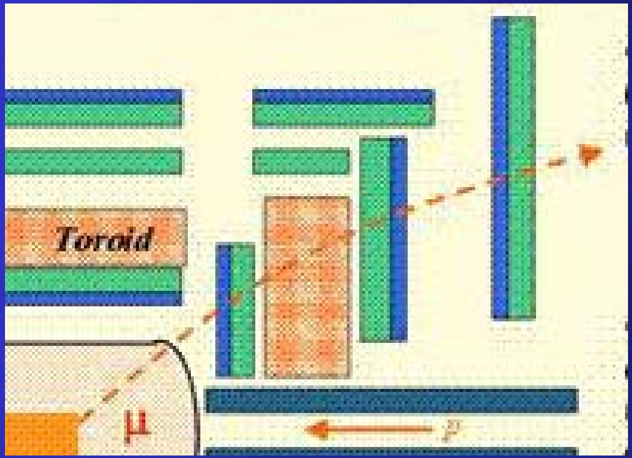
Trigger

- Trigger requires two tracks in muon system
- Timing issues:
  - trigger gate is asymmetric
    - allows later particles
  - trigger gate ranges from 20-85 ns for different layers
  - causes inefficiency for slower moving particles
  - efficiency drops as mass increases
  - sufficient for our mass range (60-300 GeV)

Preliminary Dimuon Selection

Luminosity = 390 pb^{-1}

- muon $p_T > 15$ GeV
- matched to track in central tracker
- scintillator hits in 2 of 3 layers of muon system
- at least one isolated muon
- $\Delta\varphi > 1.0$ radians
- cosmic ray muon rejection



Muon Speed

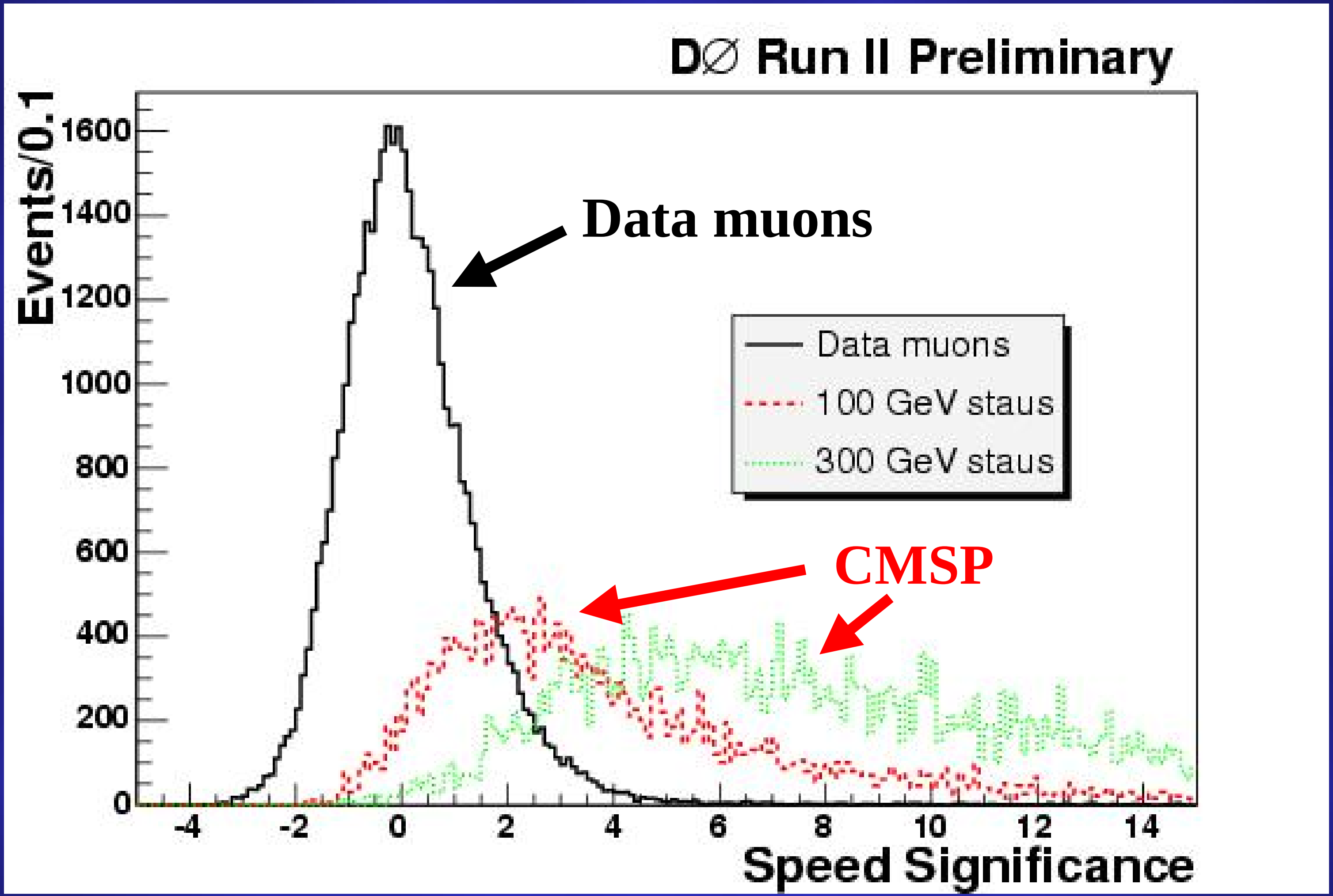
- Calculate speed of muon at each layer
  - $v = d/t$ (v in units of c)
  - σ_v from timing error
- Calculate average velocity for each muon
- Calculate speed χ^2

$$\chi^2 = \sum_{layer} \frac{(v_{avg} - v_{layer})^2}{\sigma^2}$$

- Require $\chi^2 < 4$

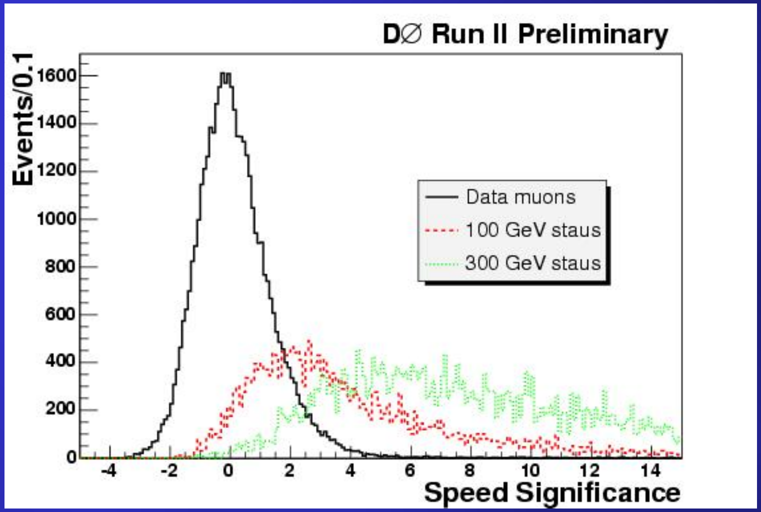
Speed Significance

$$\text{significance} = \frac{1 - \text{speed}}{\sigma_{\text{speed}}}$$

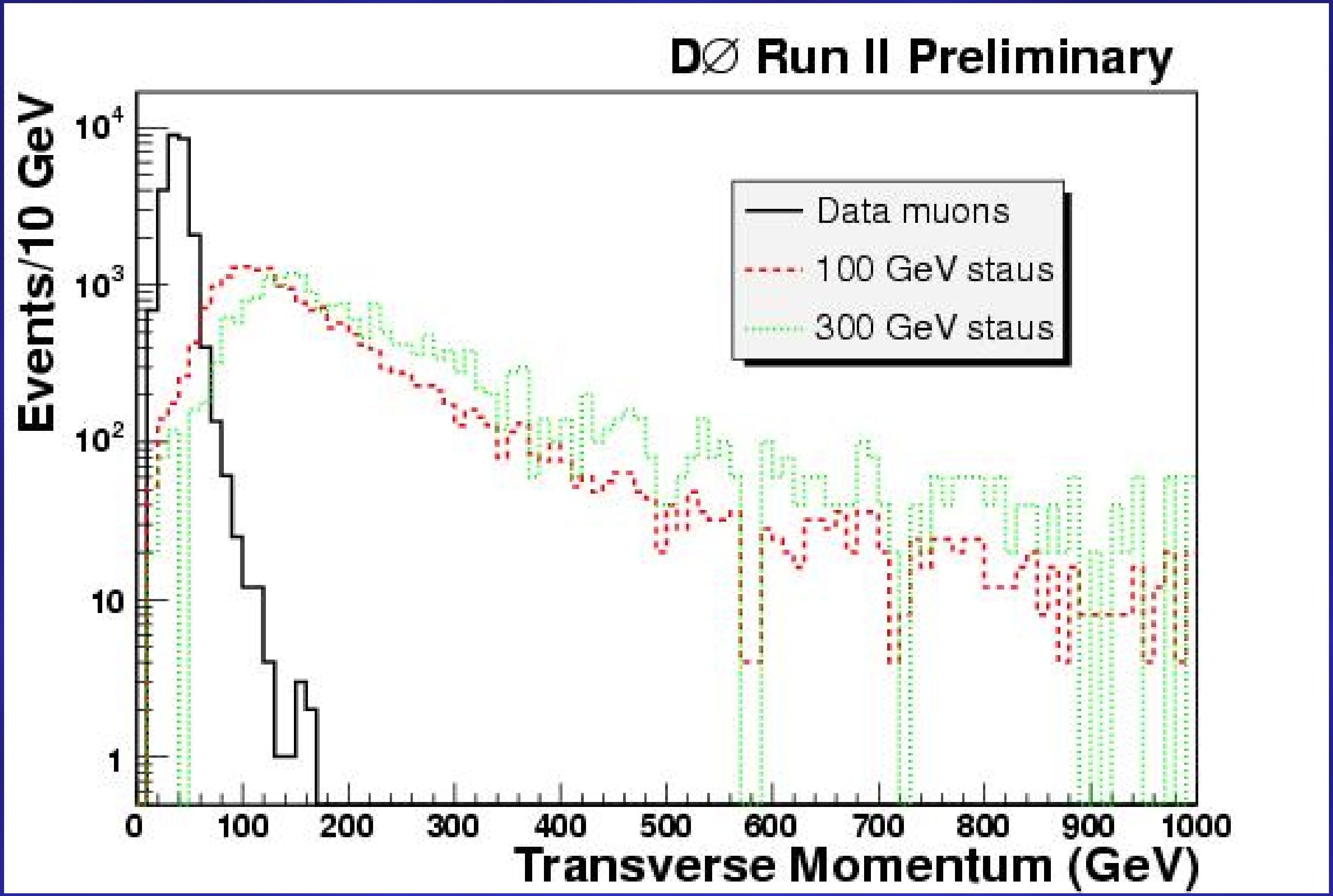


Backgrounds

- Z/Drell-Yan is major background
  - no natural source of slow-moving high-p_T particles
- Use data to estimate background
  - use Z-peak events for timing distribution
  - use negative time events for invariant mass distribution



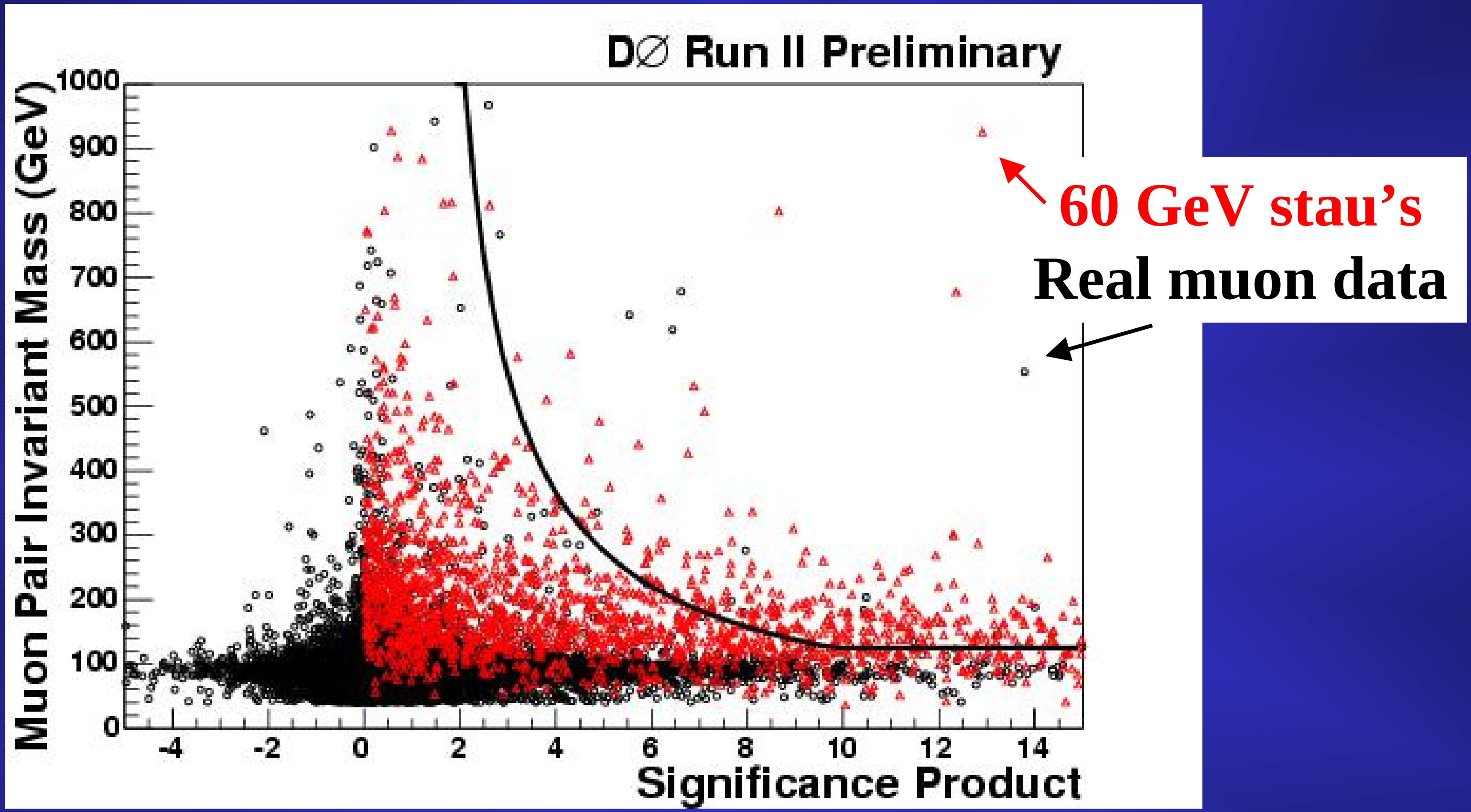
Transverse Momentum



Signal has larger p_T

Dimuon p_T vs Significance Product

- Significance product: Sig(μ_1) x Sig(μ_2)

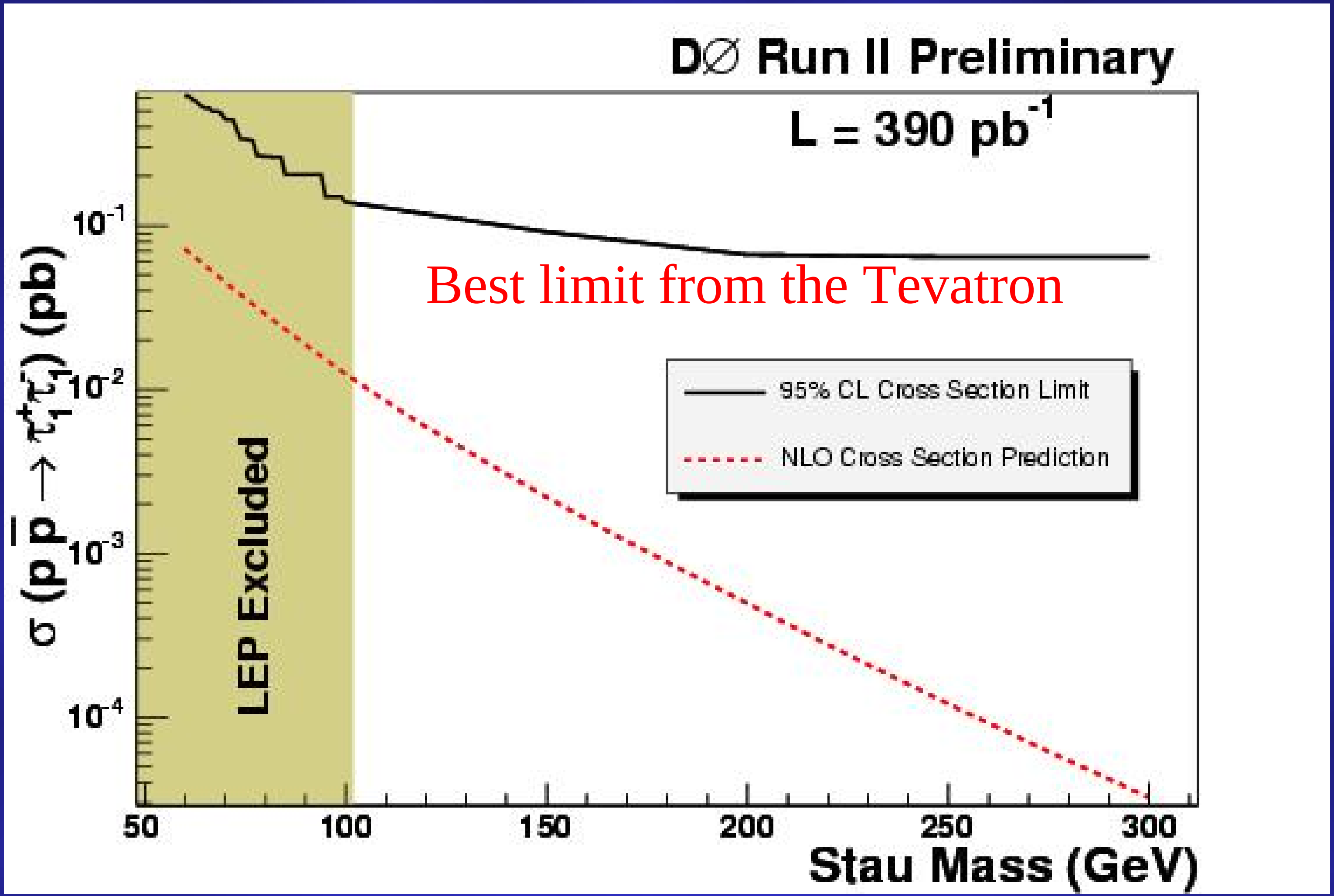


Analysis Results

Stau Mass (GeV)	Background Estimate	Data Events
60	13.6 ± 0.7 ± 0.5	13
100	0.66 ± 0.06 ± 0.02	0
150	0.69 ± 0.05 ± 0.02	0
200	0.60 ± 0.04 ± 0.02	0
250	0.47 ± 0.03 ± 0.02	0
300	0.61 ± 0.05 ± 0.02	0

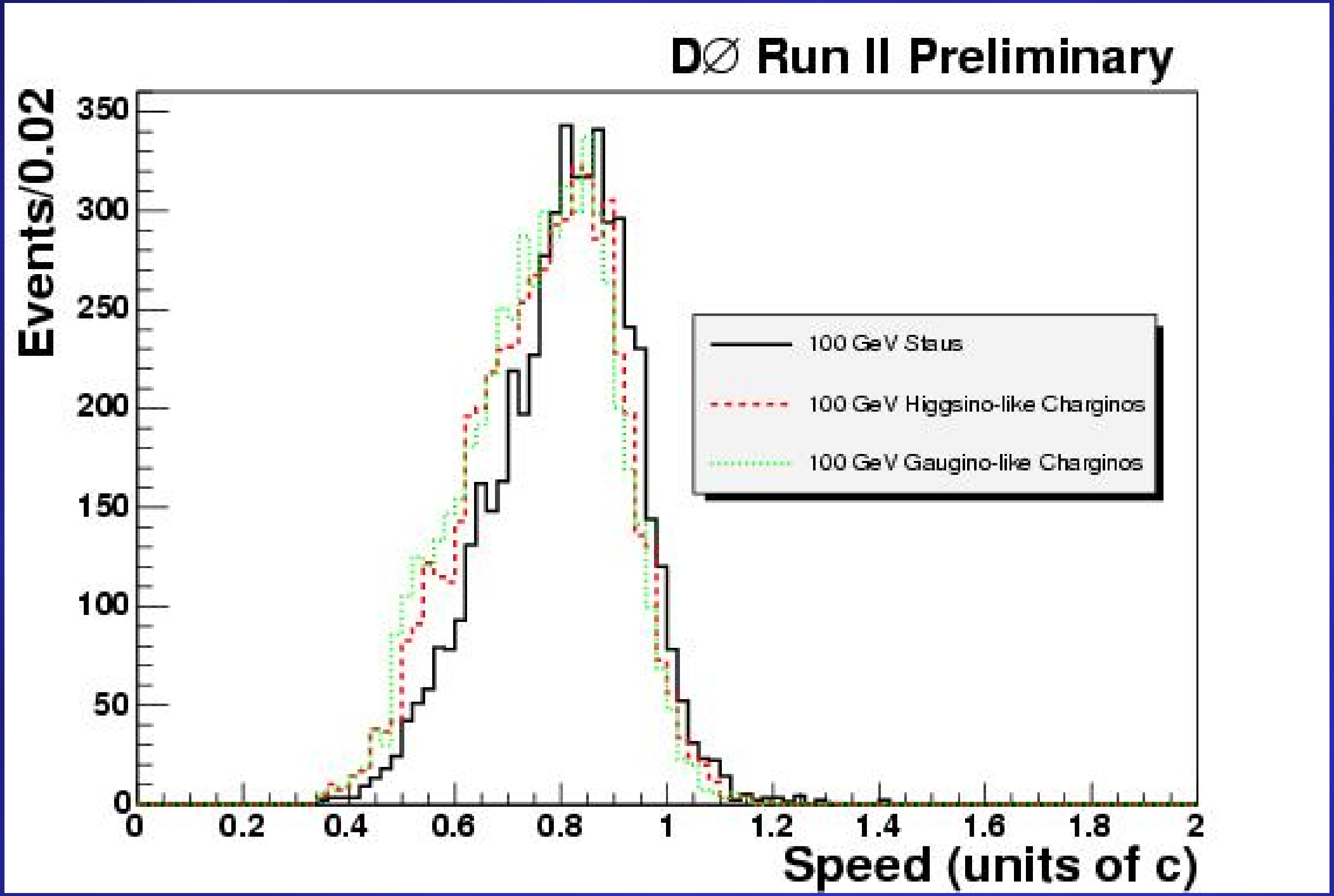
- Background estimated using data

stau Cross-section Limit



Charginos

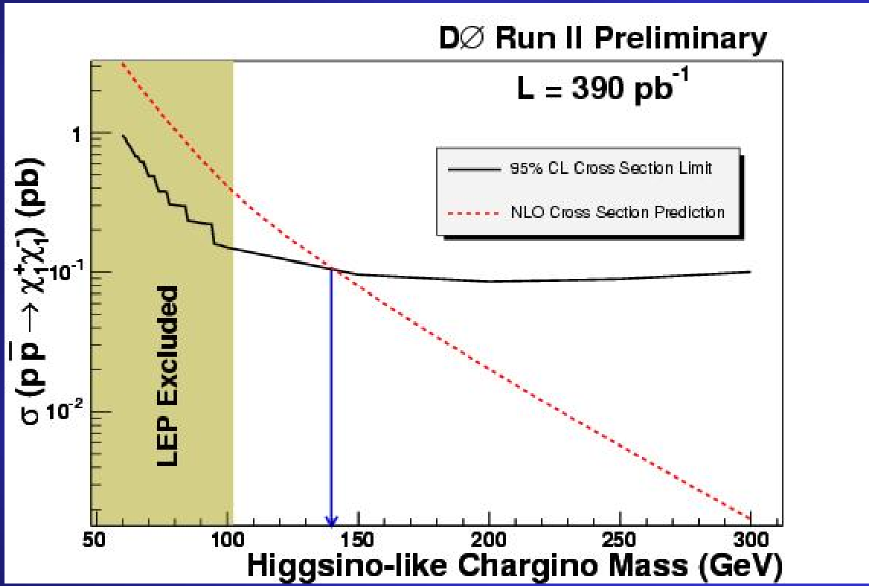
Charginos look like stau's



Use same analysis

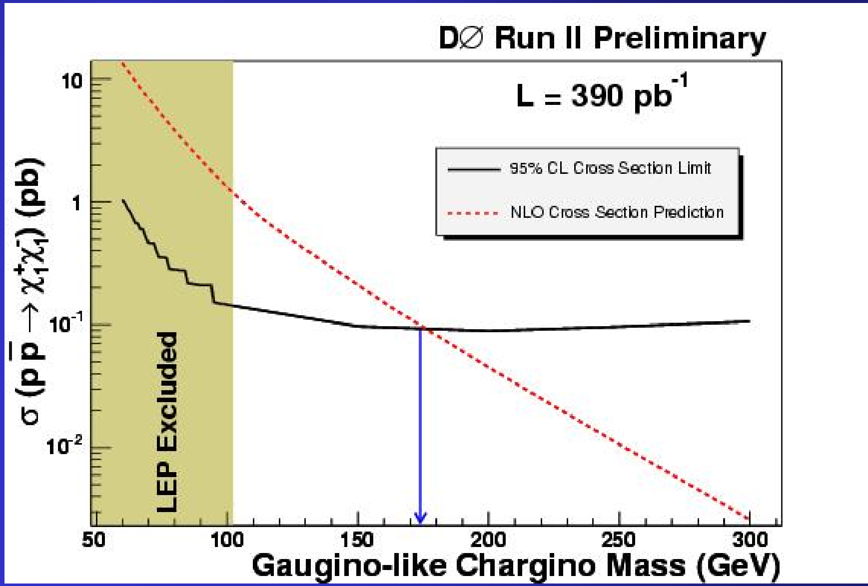
Chargino Limits

Higgsino-like



M > 140 GeV

Gaugino-like

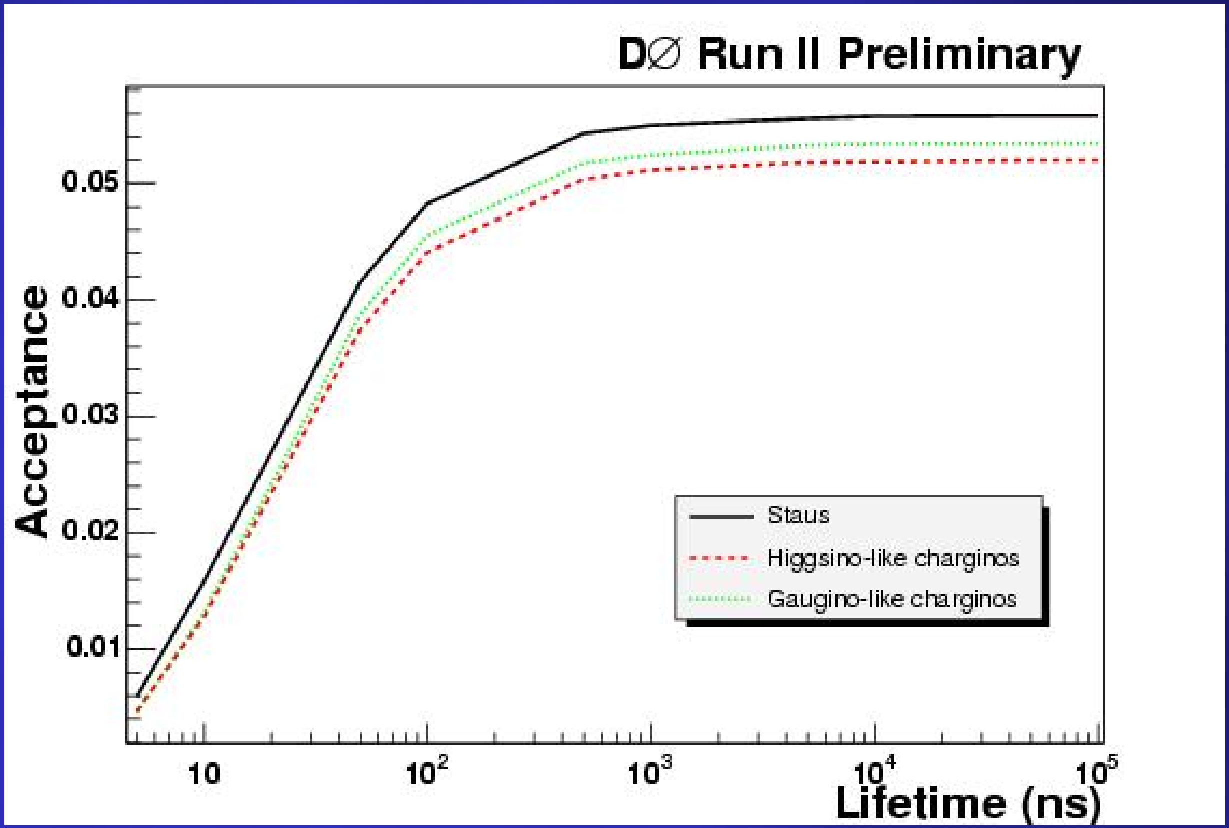


M > 174 GeV

DØ RunII Preliminary

Effect of Lifetime

- "Short" lifetime → decay within detector
- loss of acceptance



Conclusions

- DØ has performed a search for charged, massive stable particles
  - look for slow moving particles
- Set limits on stau and chargino production
  - best limits on chargino mass