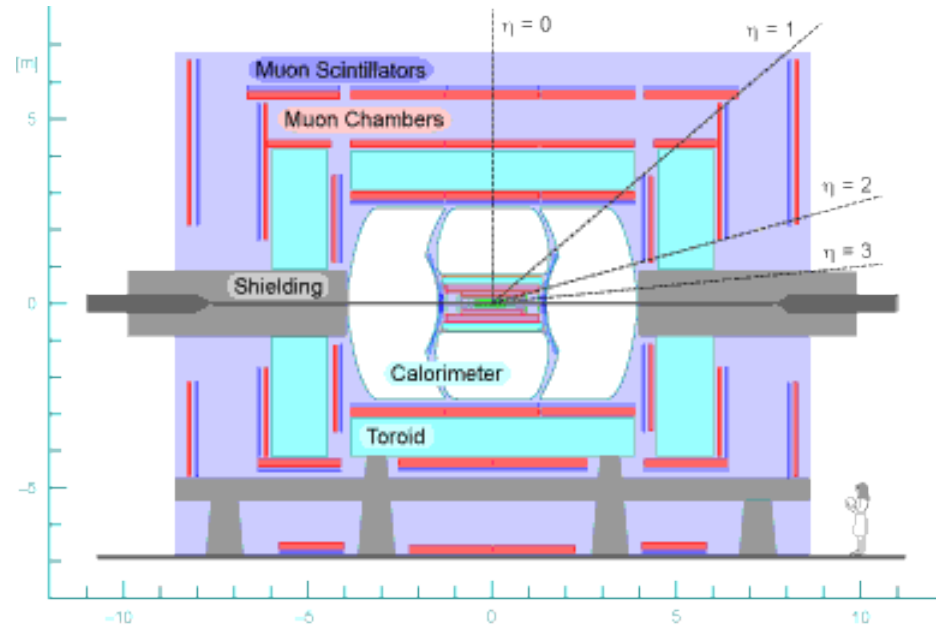
New D0 Results on QCD, New Phenomena, and B Physics

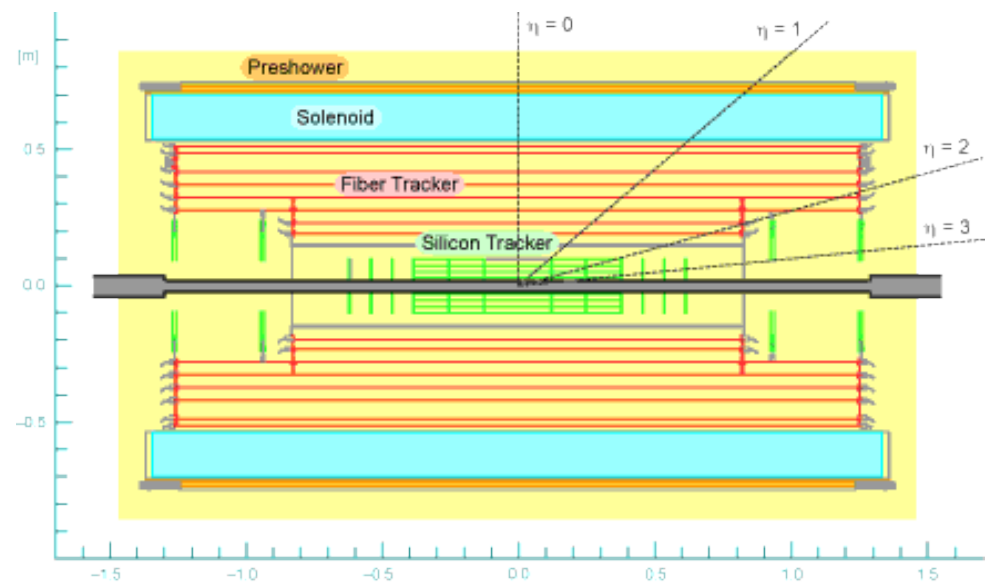
Bill Lee
Florida State University

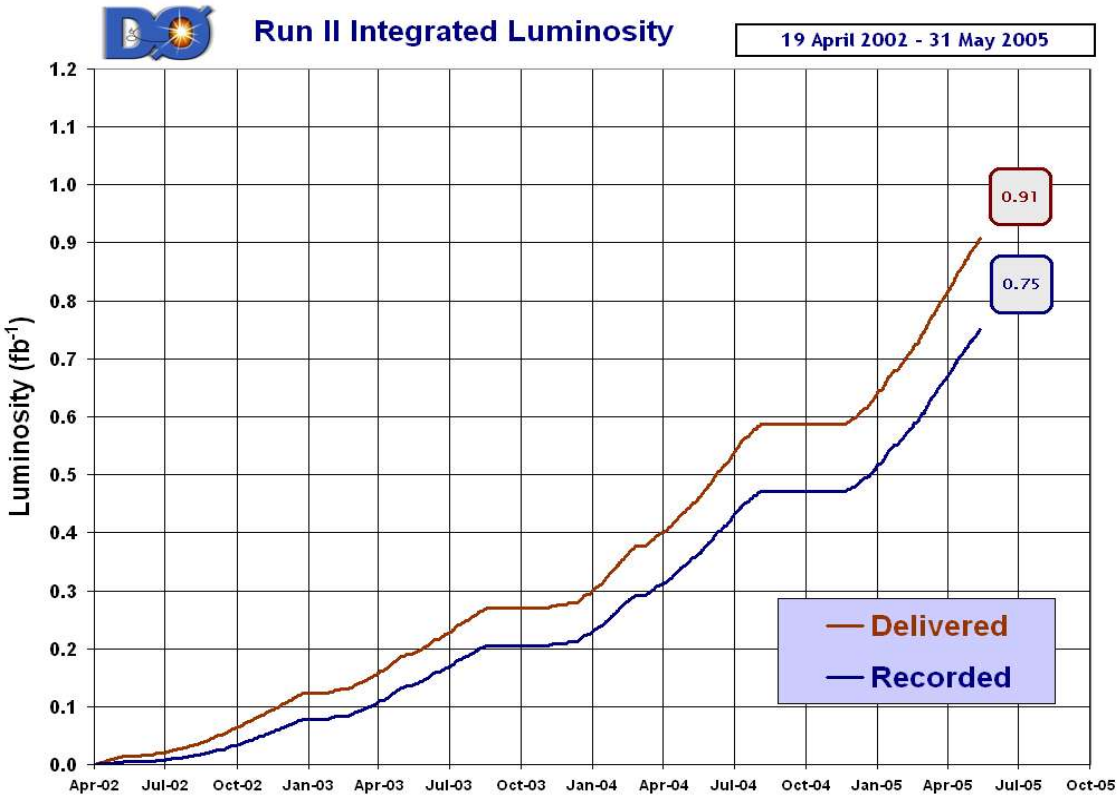
FermiLab Users Meeting
8 June 2005

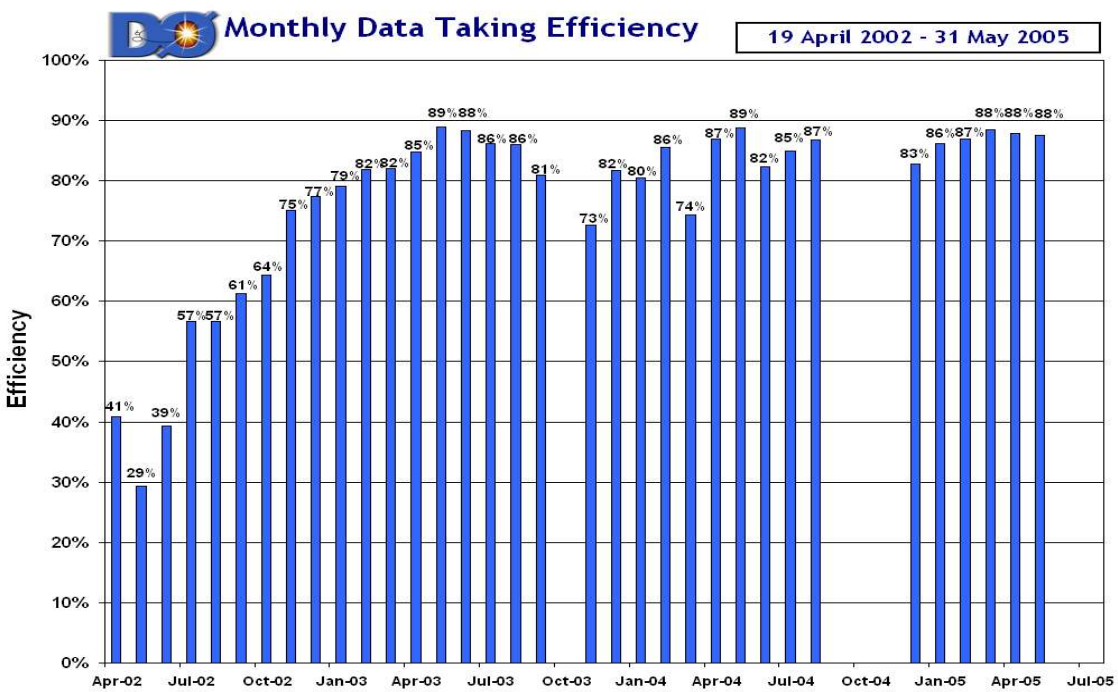
The D0 Run II Detector

- Built on the strength of Run I
  - State of the art hermetic calorimeter
- Superconducting 2T solenoid
- Inner tracker (silicon and fiber trackers)
- Preshower detectors
- Improved shielding, upgraded muon system
- Faster readout electronics
- New trigger system









Operations

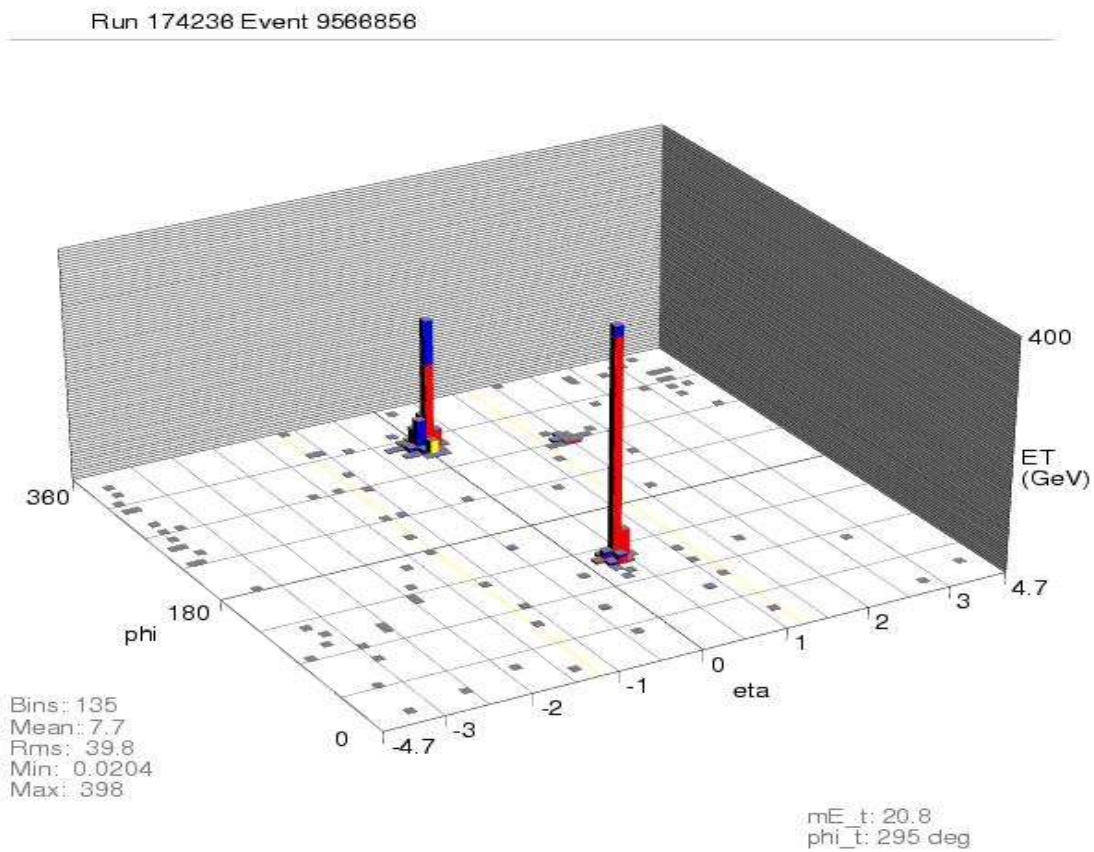
- So far D0 has recorded on tape over ¾ fb^{-1} of physics quality data with the full detector. Our data set has more than doubled in the last year. We record:
  - 2-2.5 pb^{-1} in a good day (3.7 pb^{-1} record)
  - 14 pb^{-1} in a good week (17 pb^{-1} record)
  - 55 pb^{-1} in a good month (59 pb^{-1} record)
- All of these records have happened in the last few months.
  - Our thanks go out to the Accelerator Division for the luminosity!
- All sub-detectors are operating well and the entire system is recording data at close to 90% efficiency.

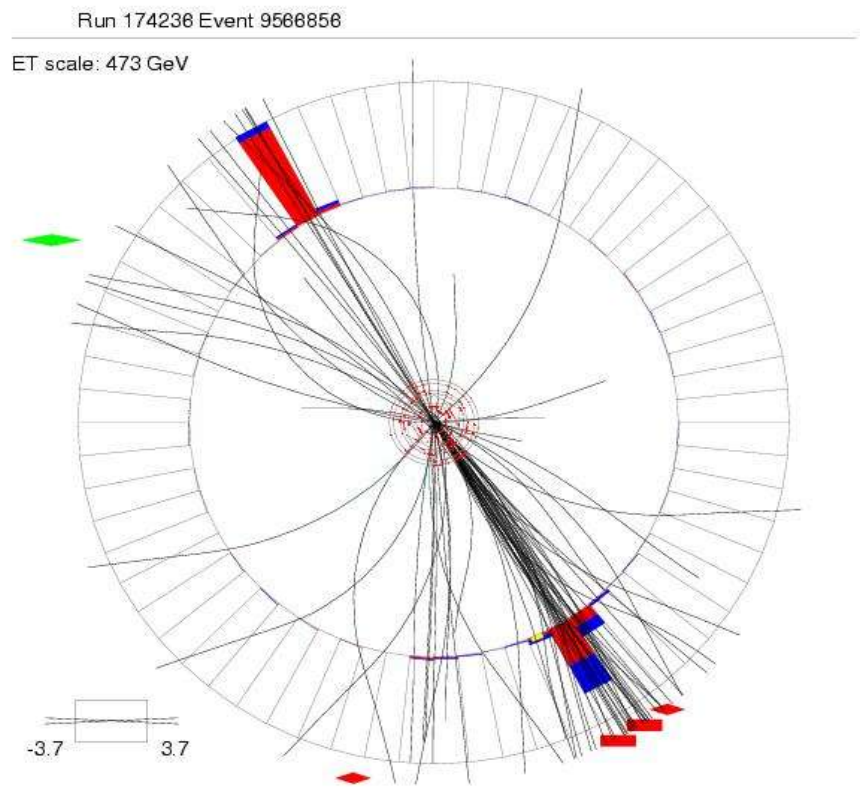
Physics Results - QCD

- QCD
  - High p_T cross sections
  - Heavy Flavor Jets
  - Dijet azimuthal correlations
- New Phenomena
- B Physics

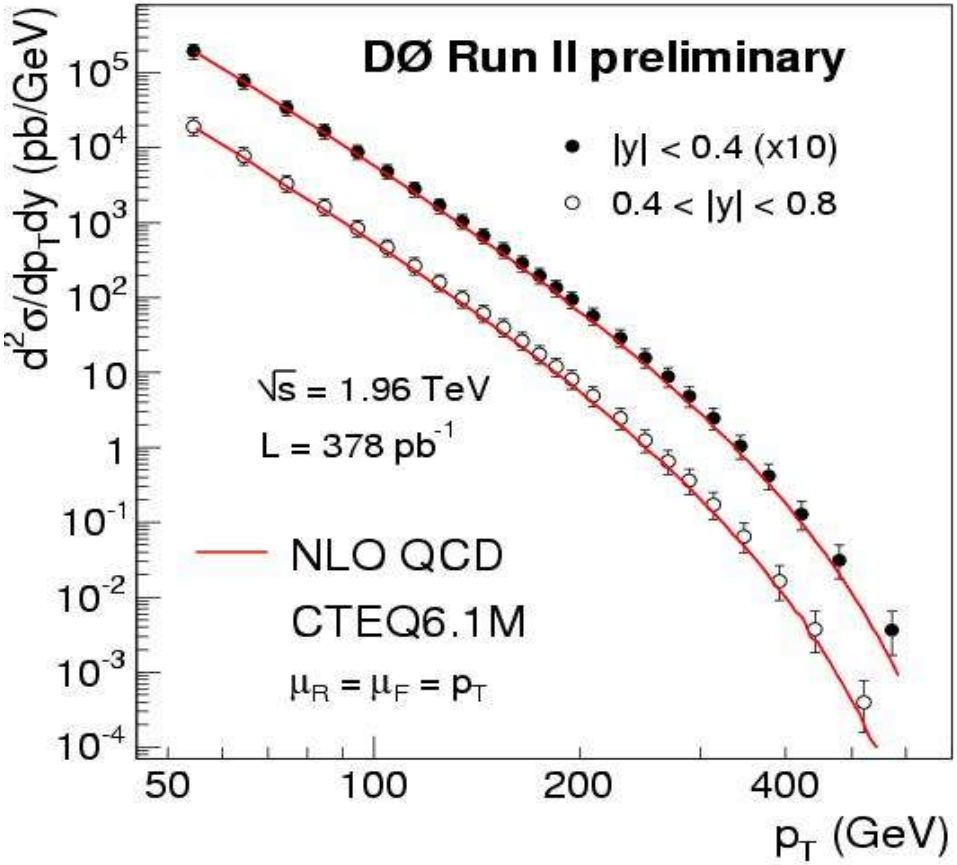
Highest p_T Jet Event

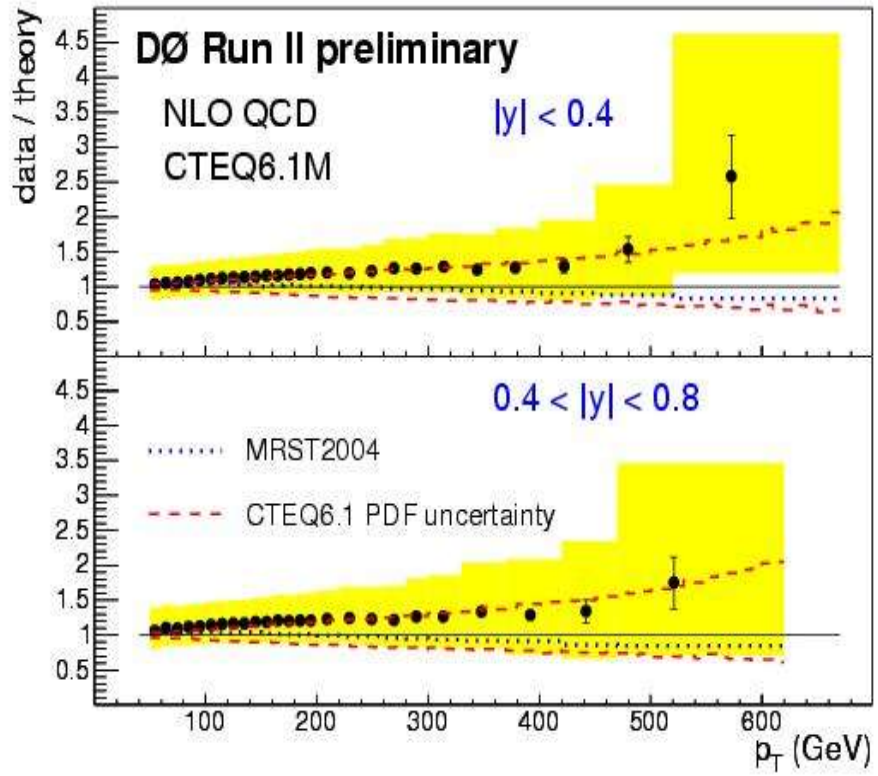
- The leading jet has p_T = 631 GeV balanced by a second jet of 560 GeV. The mass of the dijet system is 1208 GeV.
  - This corresponds to 60% of the available energy.





Inclusive Jet cross Section



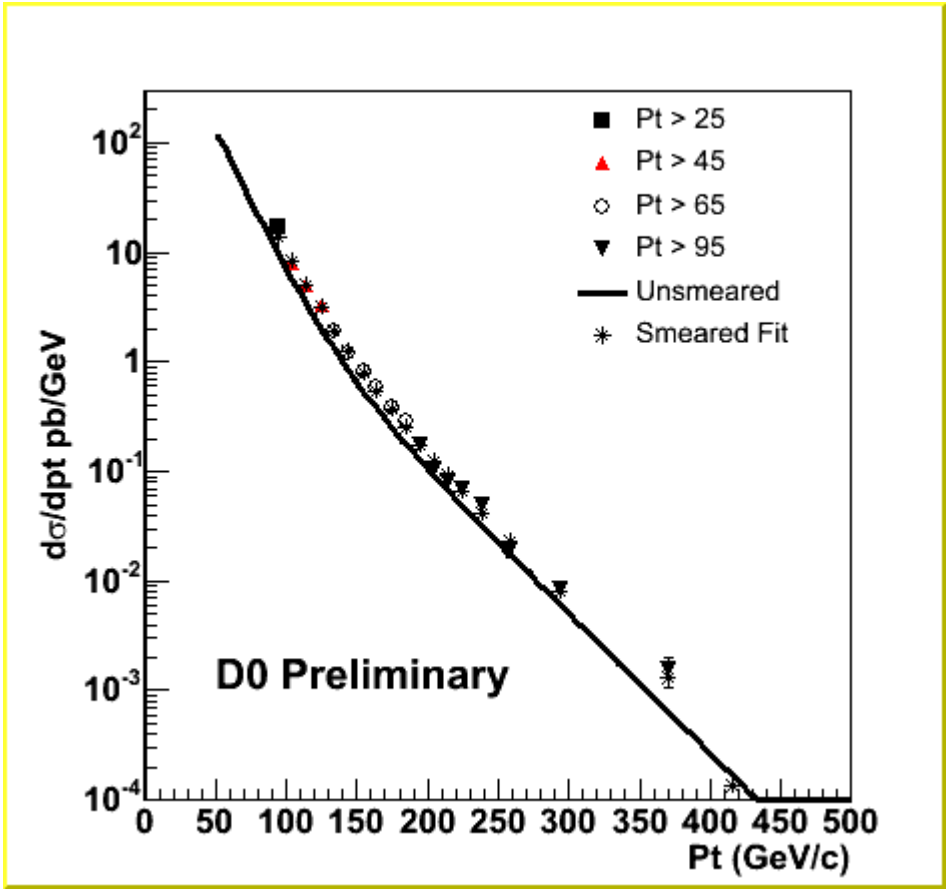


- Cross section given for two rapidities.
  - Data follows the theory over many orders of magnitude.
- Cross section divided by theory
  - Total experimental error is dominated by jet energy calibration uncertainty, ~5%.

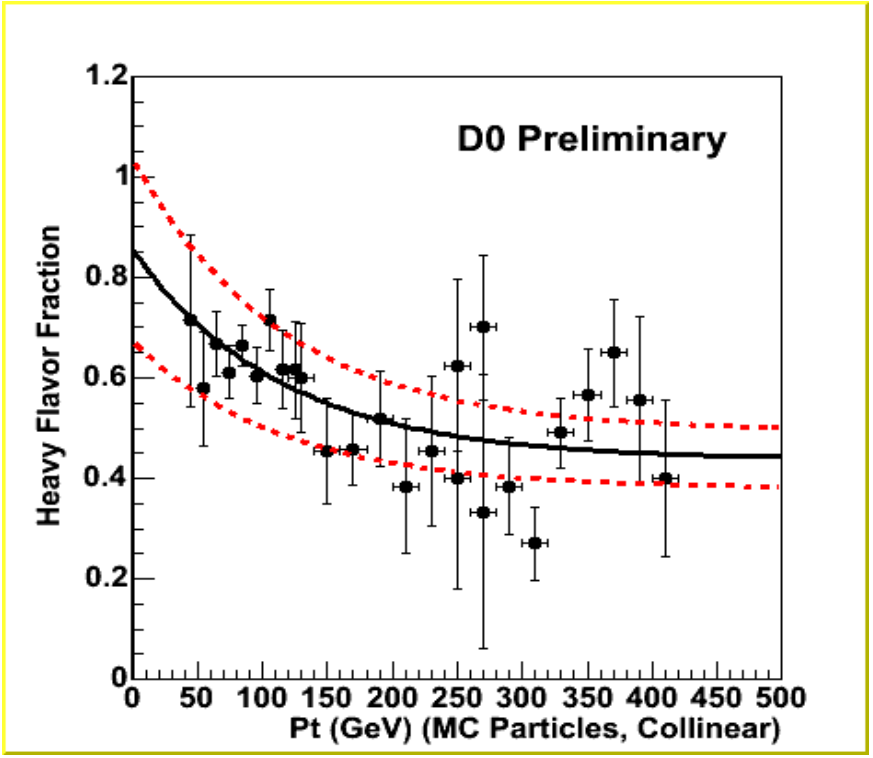
μ-tagged Jet Cross Section

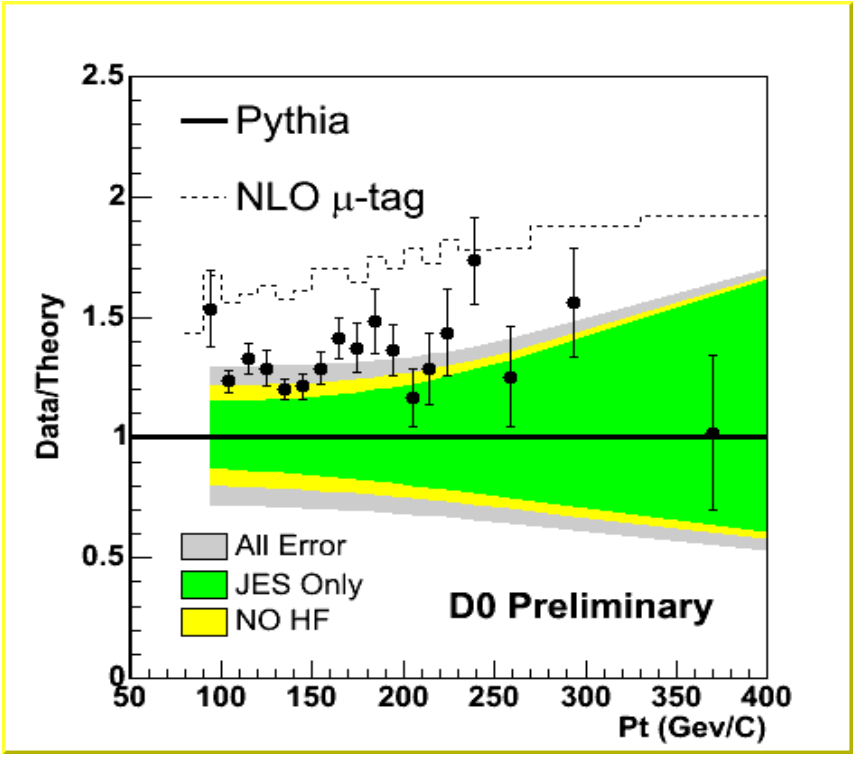
- If quarks and leptons were composed of smaller particles, then 2nd and 3rd generations might be excited states of 1st.
  - Then 3rd generation would show largest deviation from point like behavior.
  - So we want to look at heavy flavor production at high p_T.
- Simply require a tagged muon within the jet.
  - Central Jets ($|y| < 0.5$)
  - Cone size, R = 0.5
- Have a significantly enhanced heavy flavor sample.
  - model predicts 60% from b-Hadron (rest c)

$L = 294\ pb^{-1}$



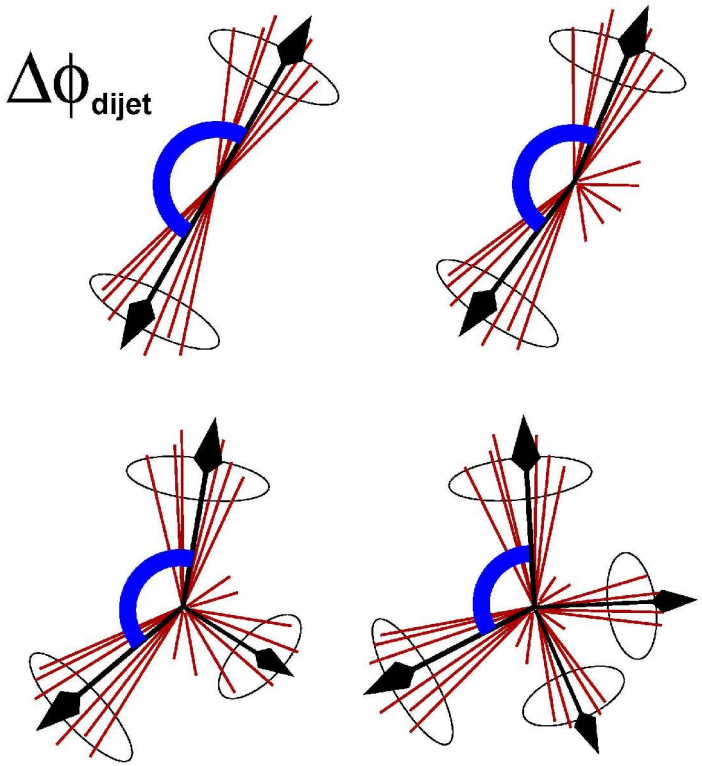
μ-tagged Jets

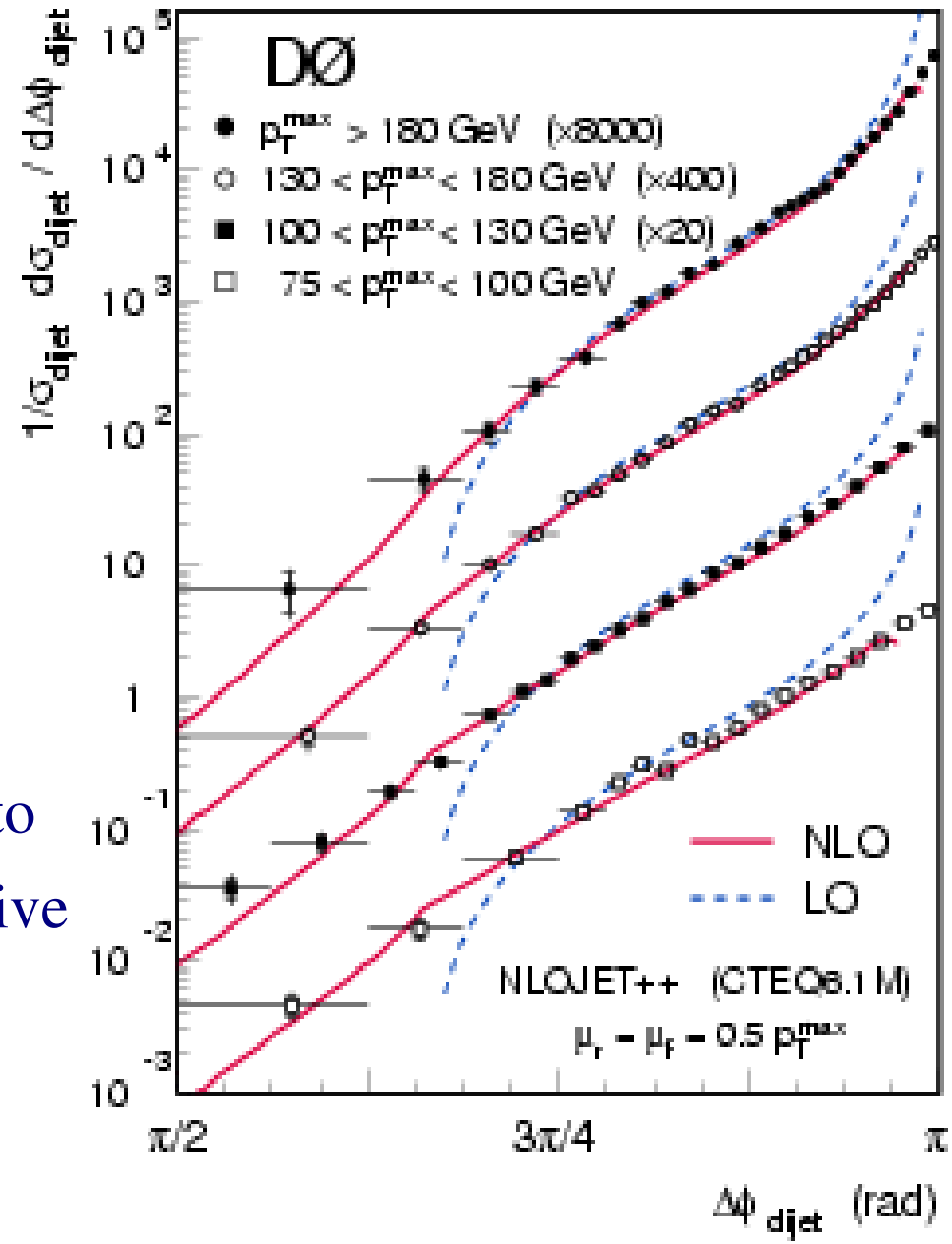




- Determine fraction which contains b or c Hadrons to correct data.
  - muons from pion/kaon decays
  - use PYTHIA with full simulation of D0 detector
- Compare to theory
  - PYTHIA slightly low
  - NLO prediction for inclusive jets * muon-jet fraction is slightly high
  - need true NLO calculation

Dijet Azimuthal Correlations





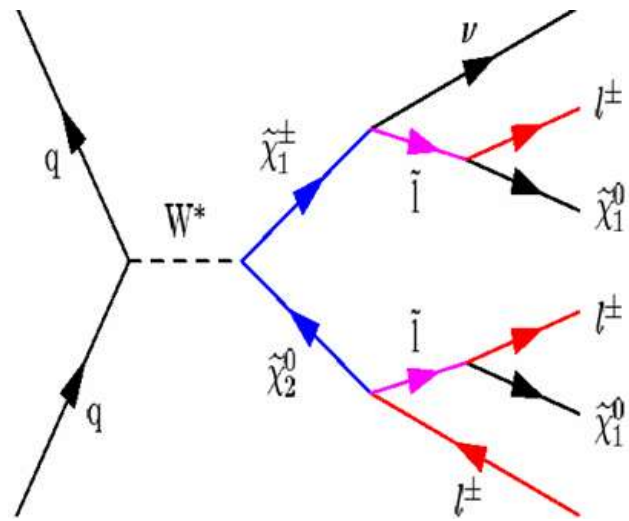
- Different regions in $\Delta\phi_{dijet}$ are sensitive to different jet production and QCD radiative processes
- Good agreement observed at NLO

Physics Results – New Phenomena

- QCD
- New Phenomena
  - Charginos and Neutralinos in tri-leptons
  - Charged Massive Stable Particles
  - Squarks and Gluinos
- B Physics

Tri-lepton Search

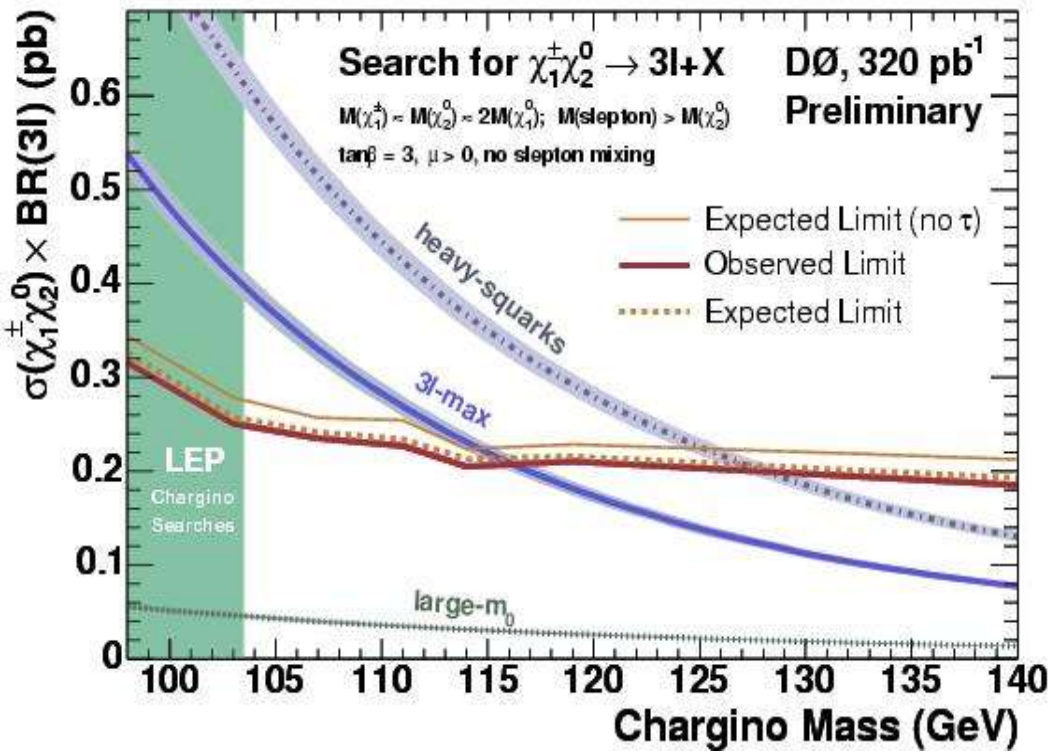
- Tri-lepton is one of the cleanest SUSY signatures.
  - Chargino-neutralino production decaying into WZ or sleptons + 2 LSP
  - Strategy:
    - combine eel, μμl, eμl, $\mu^{\pm}\mu^{\pm}$(l), eτl, μτl
  - Selection:
    - 2 well identified leptons, p_T > ~10, ~5 GeV
    - 3rd lepton = isolated track, p_T > ~5 GeV
    - missing E_T > ~20 GeV



SUSY Tri-leptons Combined Result

- Four candidates is within expected background.
  - Limits compared to three models (Beenakker et al., PRL 83 (1999) 3780)
    - heavy squarks and light sleptons
    - low slepton masses in mSUGRA
    - large m_0, with chargino/neutralino decaying to virtual guage bosons
- Run I limit ~1.5 pb
- Sensitivity for larger slepton masses will be increased with more data.

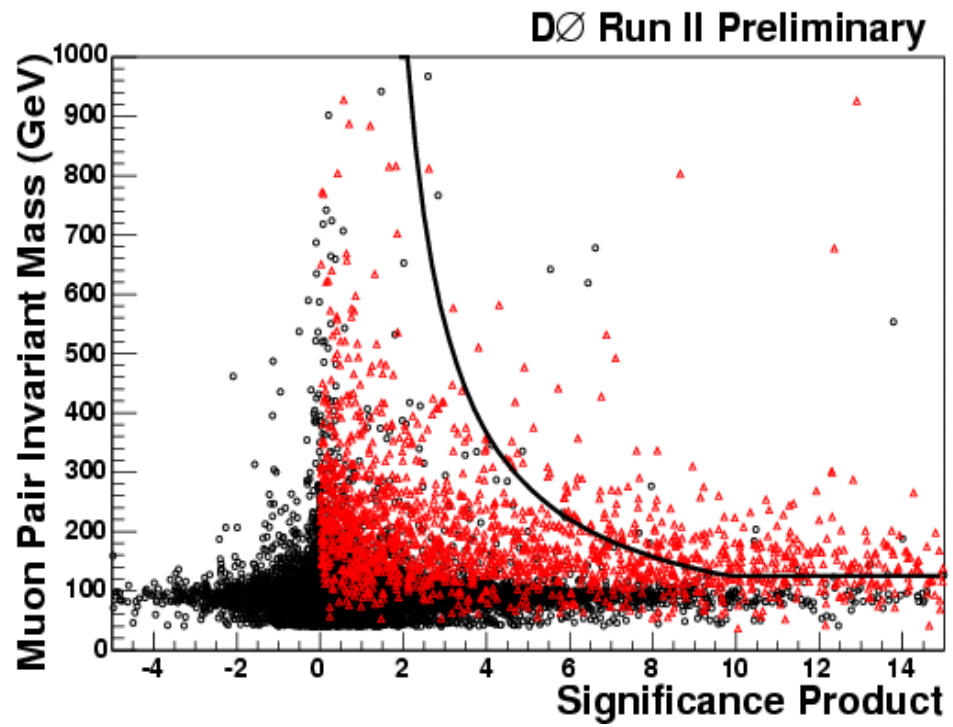
	data	bkg
eel	0	0.21 ± 0.11 ± 0.05
eμl	0	0.31 ± 0.13 ± 0.03
μμl	2	1.75 ± 0.37 ± 0.44
$\mu^{\pm}\mu^{\pm}$l	1	0.64 ± 0.36 ± 0.13
eτl	0	0.58 ± 0.11 ± 0.09
μτl	1	0.36 ± 0.12 ± 0.06
total	4	3.85 ± 0.57 ± 0.49



Charged Massive Stable Particles

- A search for new charged particles with a lifetime long enough to escape detector.
  - Model using a scaler tau NLSP
  - would look like a muon, but with inconsistent speed and mass.
  - use timing measured in muon system to look for pair produced staus.

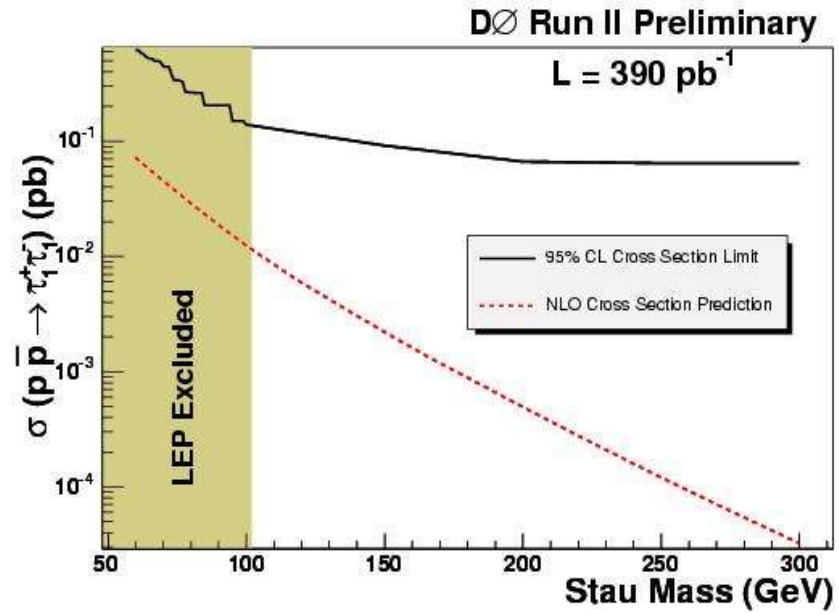
black - real muons
red - 60 GeV staus

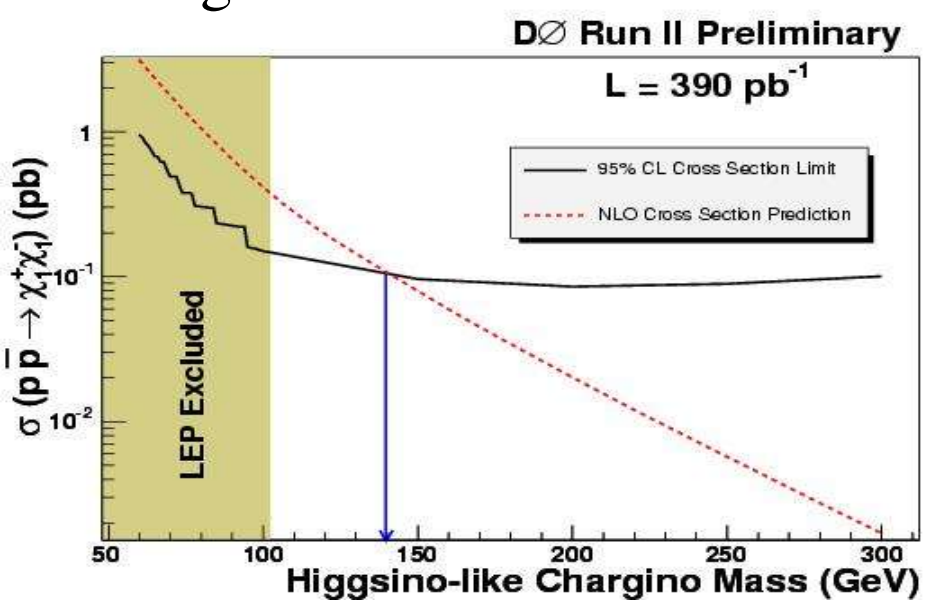


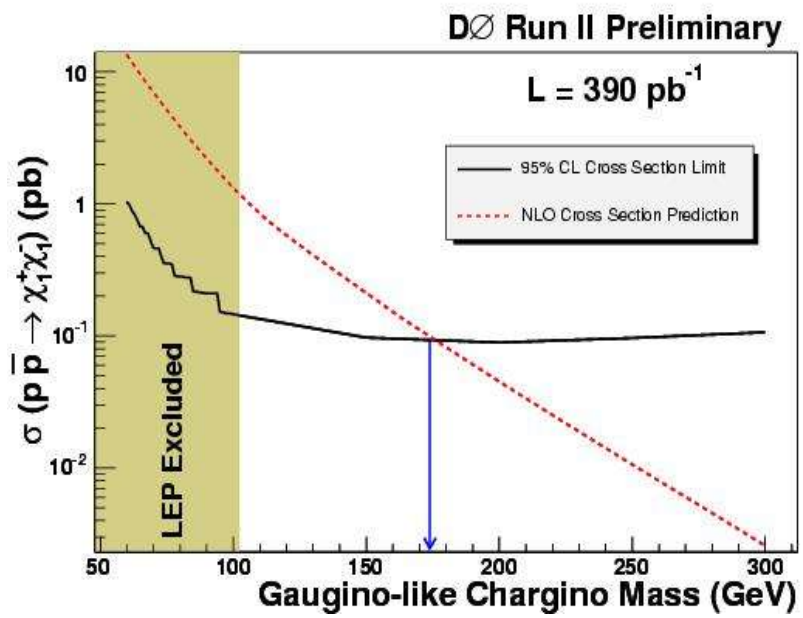
$$\text{speed significance} = \frac{1 - \text{speed}}{\sigma_{\text{speed}}}$$

Charged Massive Stable Particles

- stau – can not set limit on mass
- can be extrapolated to stable charginos
  - Gaugino-like chargino mass > 174 GeV
  - Higgsino-like chargino mass > 140 Gev
- best limits to date on stable charginos







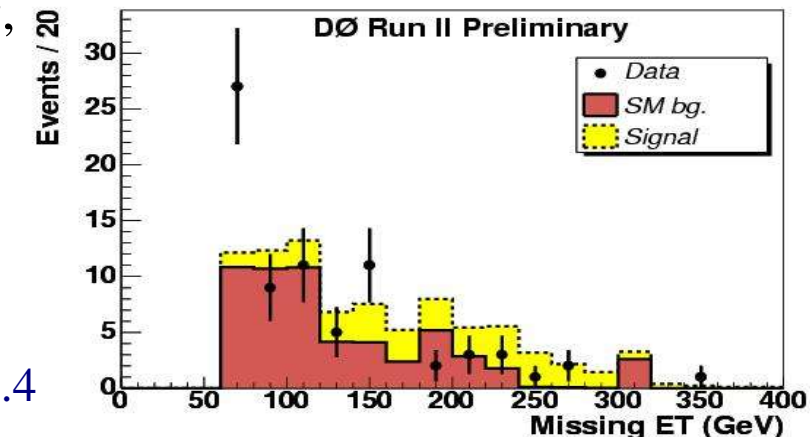
Squark Gluino Search

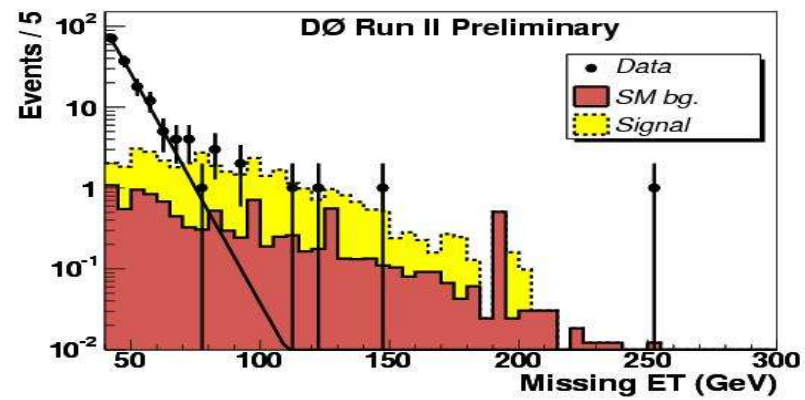
- In SUSY, scalar quarks, $\tilde{q}$, and fermionic gluinos, $\tilde{g}$, arise as partners to quarks and gluons.
  - Signal is jets + missing E_T
  - 3 mass topologies considered
    - $\tilde{g}$ heavier than $\tilde{q}$
      - $\tilde{q}\tilde{q}$ production dominates
      - look for acoplaner dijets
      - missing $E_T > 175$ GeV, $\Sigma E_T > 250$ GeV
    - $\tilde{q}$ heavier than $\tilde{g}$
      - $\tilde{g}\tilde{g}$ production dominates
      - look for multi (>4) jets
      - missing $E_T > 75$ GeV, $\Sigma E_T > 250$ GeV
    - $\tilde{g}$ and $\tilde{q}$ similar mass
      - $\tilde{g}\tilde{q}$ production dominates
      - look for three jets
      - missing $E_T > 100$ GeV, $\Sigma E_T > 325$ GeV

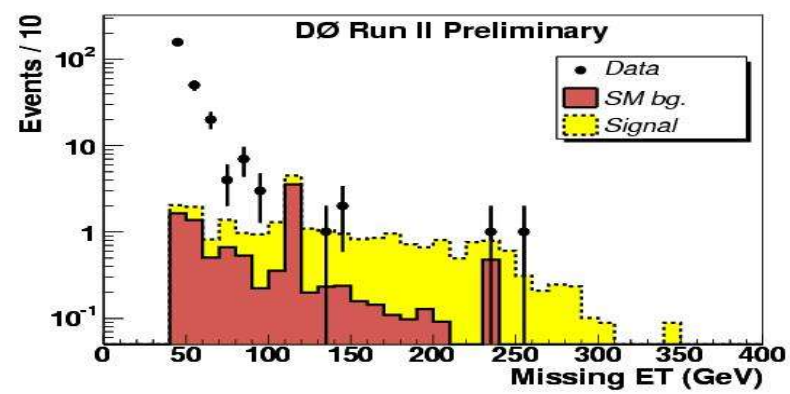
expected 12.8+-5.4
observed 12

expected 7.1+-0.9
observed 10

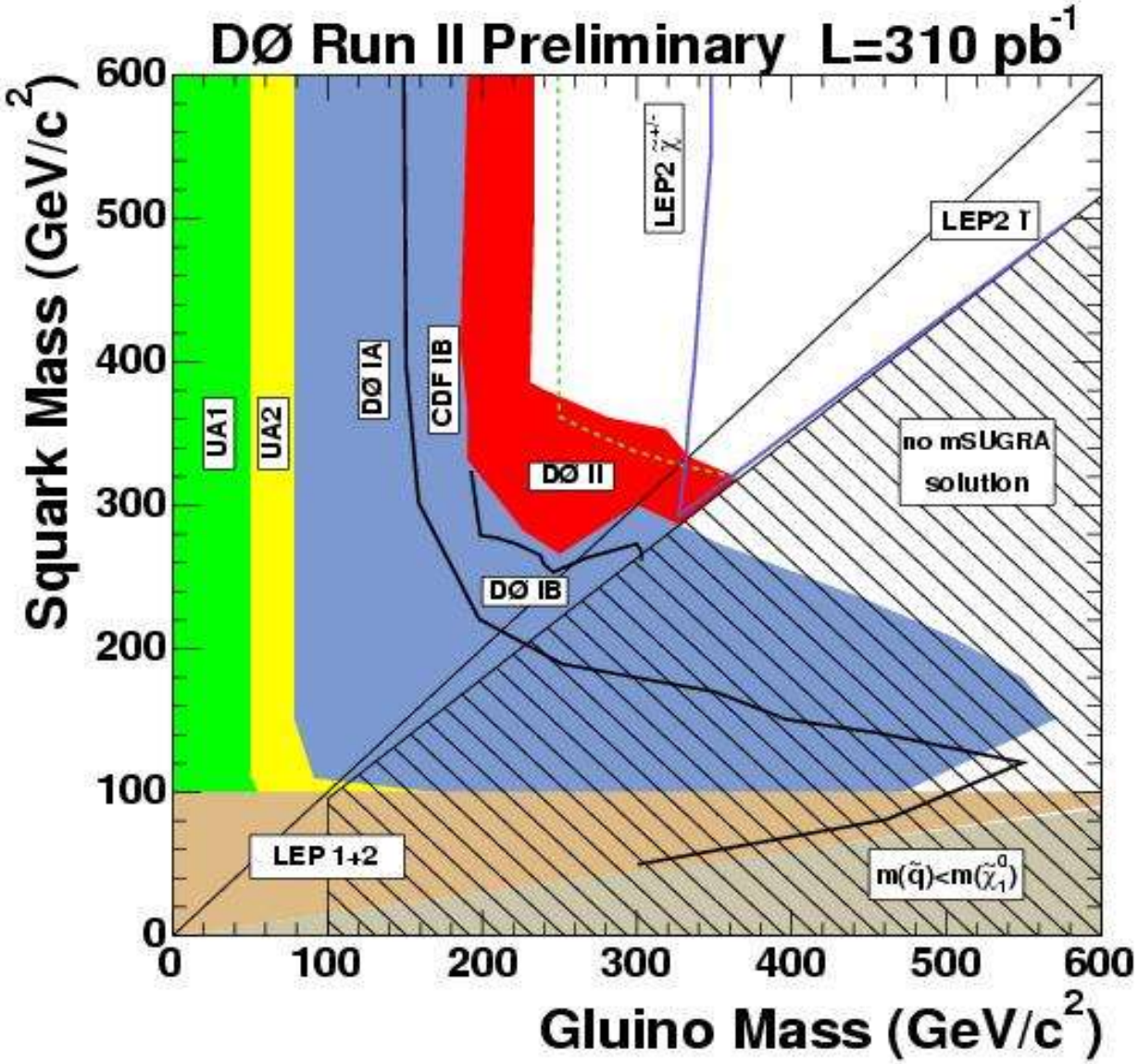
expected 6.1+-3.1
observed 5







Squark Gluino Results



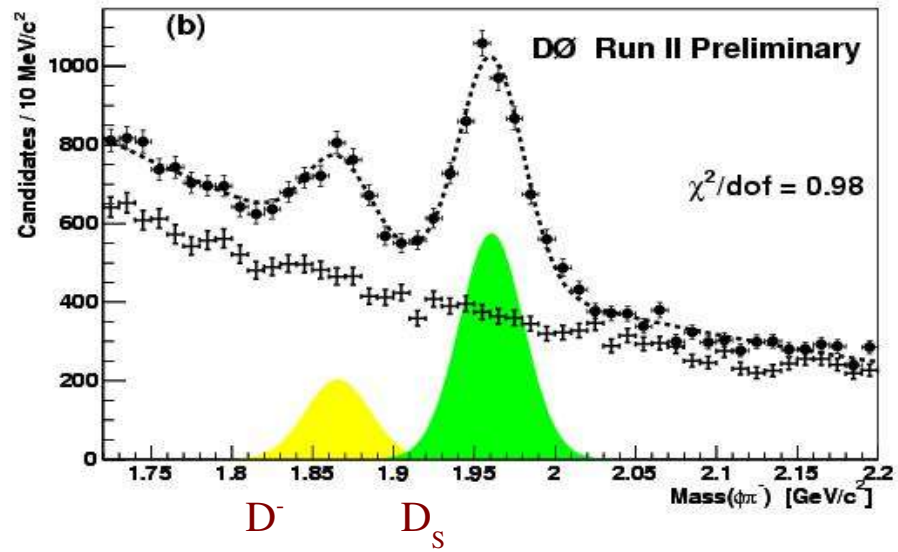
Physics Results – B Physics

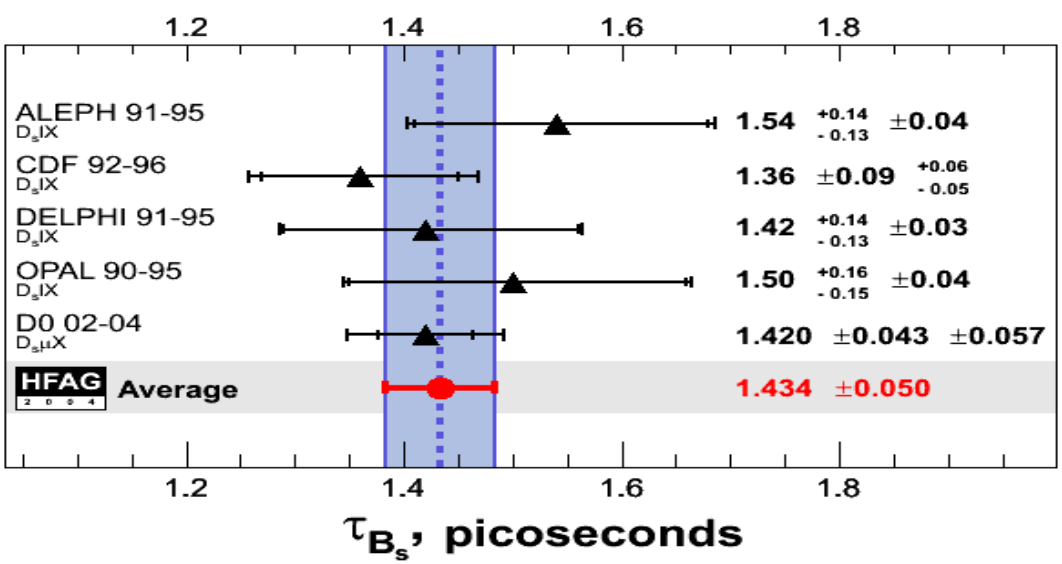
- QCD
- New Phenomena
- B Physics
  - Semileptonic B_s lifetime
  - B_s Mixing
  - Some Rare decays

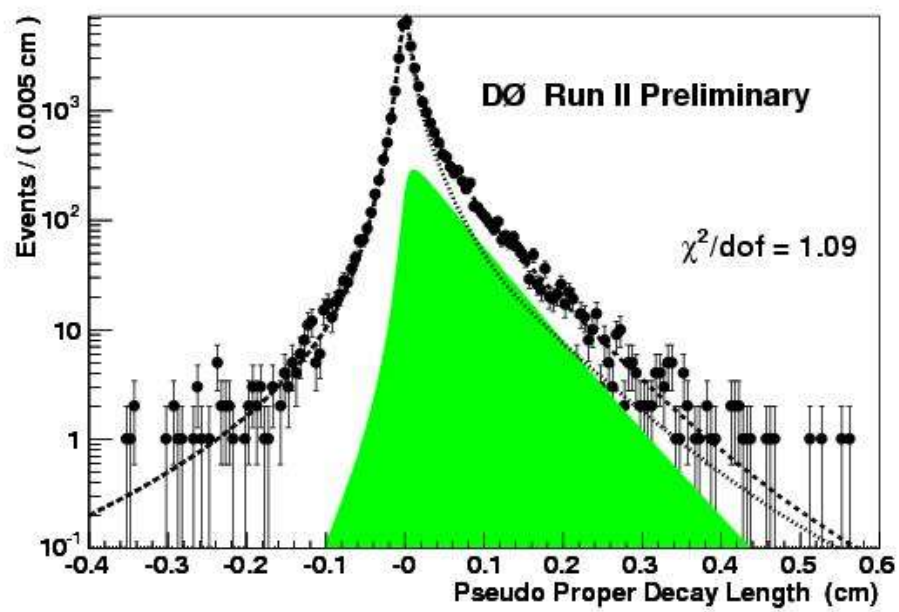
Semileptonic B_s Lifetime

- Semileptonic 'flavor-specific' mode is 50/50 CP-even/CP-odd at time=0.
- Large semileptonic yields and good proper time resolution
  - $B_s \rightarrow D_s \mu \nu X$; $D_s \rightarrow \phi \pi^-$
  - 5153 ± 265 (stat) ± 450 (sys) events
  - $\tau(B_s) = 1.420 \pm 0.043$ (stat) ± 0.057 (sys)
  - World's single most precise measurement.

L = 400 pb^{-1}

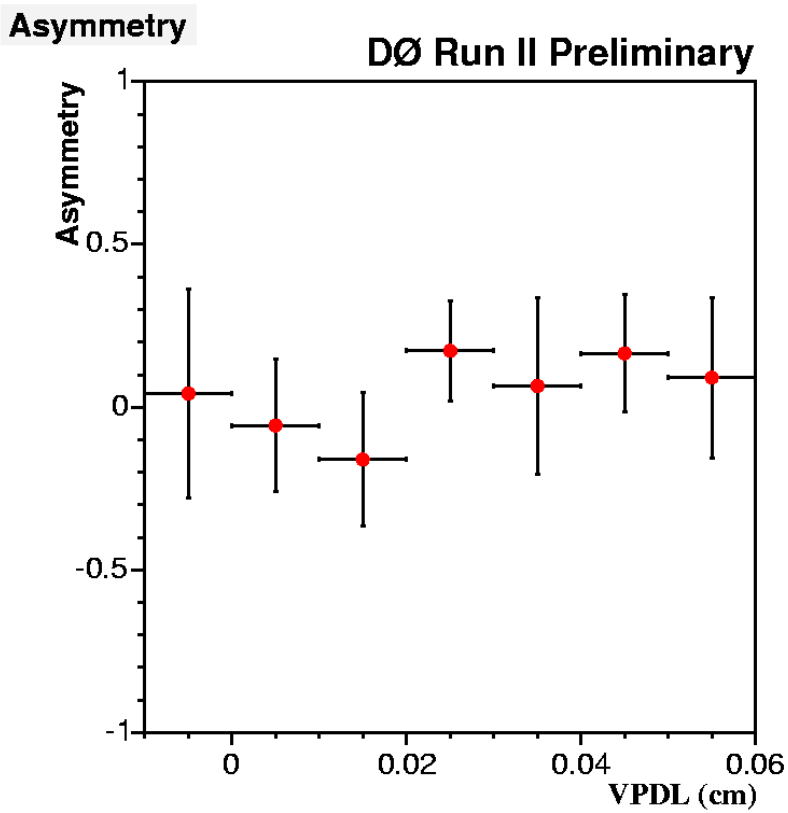


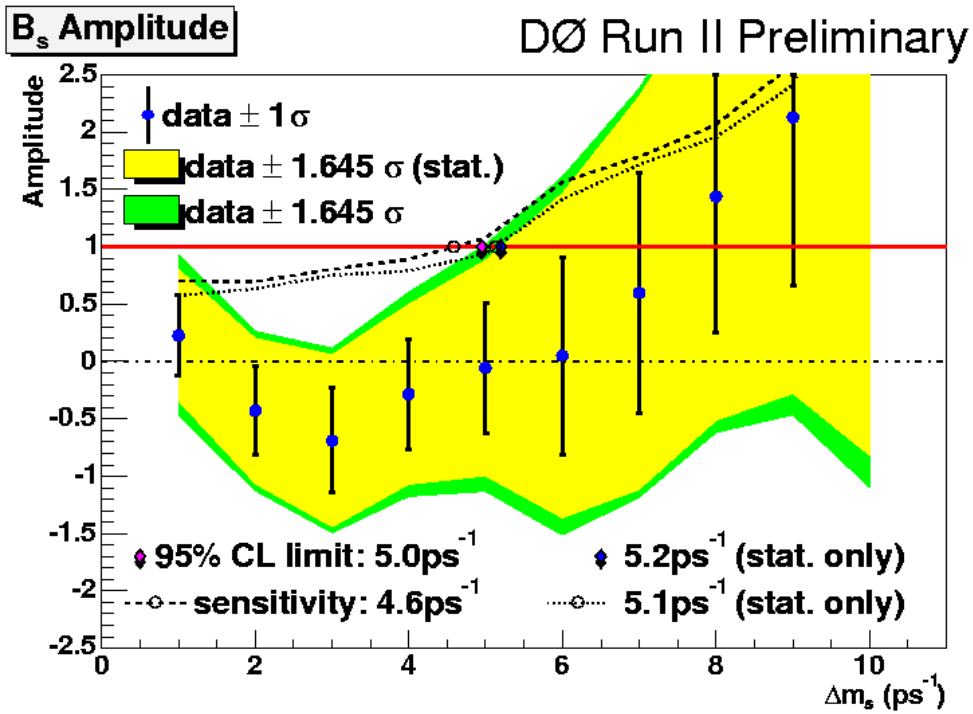




B_s Mixing

- With 450 pb^{-1}, we have 680 opposite muon + SV tagged $B_s \rightarrow D_s \mu X$

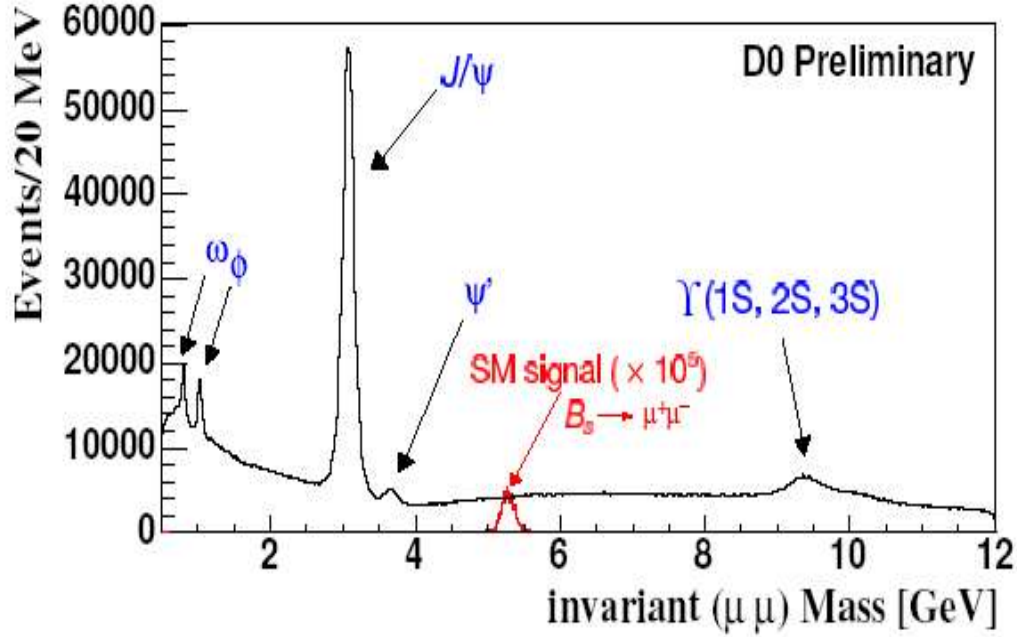


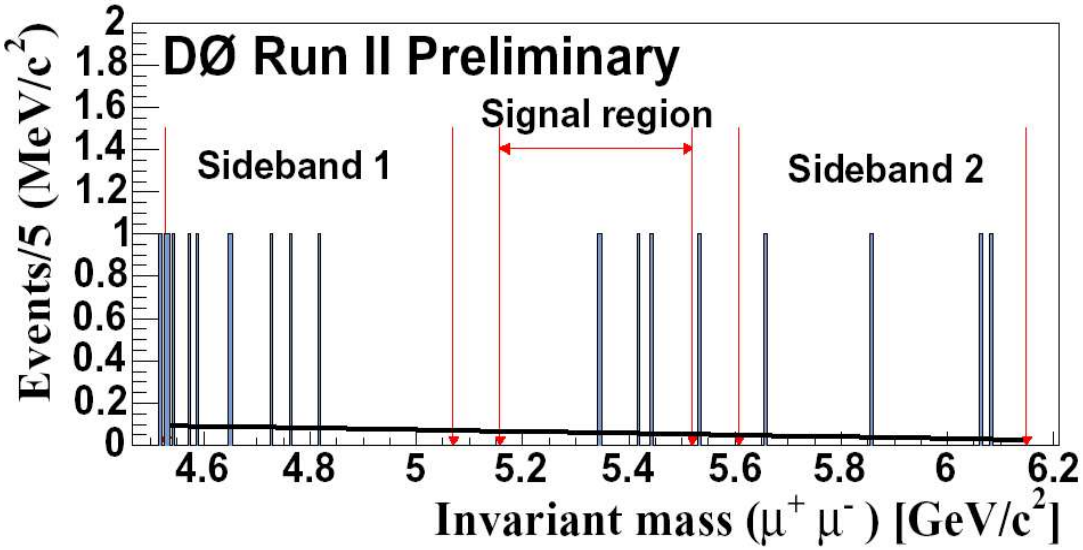


- Asymmetry vs visible proper decay length
- No oscillation observed. $\Delta m_s > 5.0$ ps^{-1} (95% CL)

Rare Decays

- $B_s \rightarrow \mu\mu$ update
- In the SM we do not expect to see a signal since FCNC decays are forbidden, but some theories predict an enhancement of the signal.
  - with 300 pb^{-1}, we observe 4 events and expect 4.3 ± 1.2
  - Br < 3.7 x 10^{-7} (95% CL)
    - Previous value was Br < 5.0 x 10^{-7} (95% CL)
- Coming soon: $B_s \rightarrow \mu\mu\phi$
  - The box was just opened this week





FCNC and $D_s^+ \to \phi\pi^+ \to \pi^+\mu^+\mu^-$

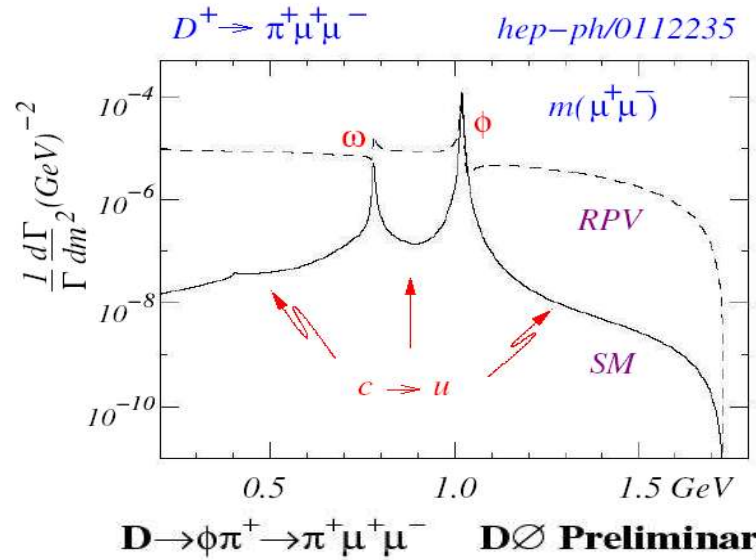
- SUSY R parity violation could enhance $D^\pm \to \phi\,\pi^\pm \to \mu^+\mu^-\,\pi^\pm$ signal. D0 Strategy: establish first resonant $D_s^\pm \to \phi\,\pi^\pm \to \mu^+\mu^-\,\pi^\pm$ then search in continuum for non-resonant decay.

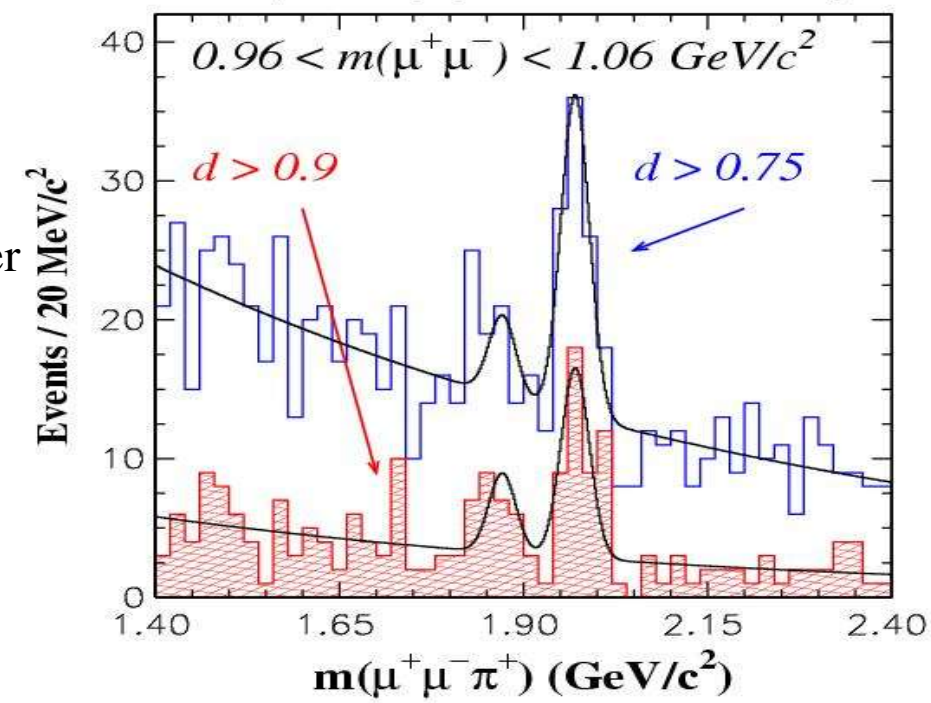
- 56 $D_s \to \phi\pi^+$ observed with a background of 18, a 7σ significance. With 508 pb^{-1}
  - BR < 3.1 x 10^{-6} (90% CL)

- first observation of resonant decay $D^+ \to \phi\,\pi^+ \to \mu^+\mu^-\,\pi+$ as benchmark
  - fit yields 13 ± 5 D events (2.7σ)

- SM limit on $D^\pm \to \phi\,\pi^\pm \to \mu^+\mu^-\pi^\pm$ almost factor 3 better than previous experiments

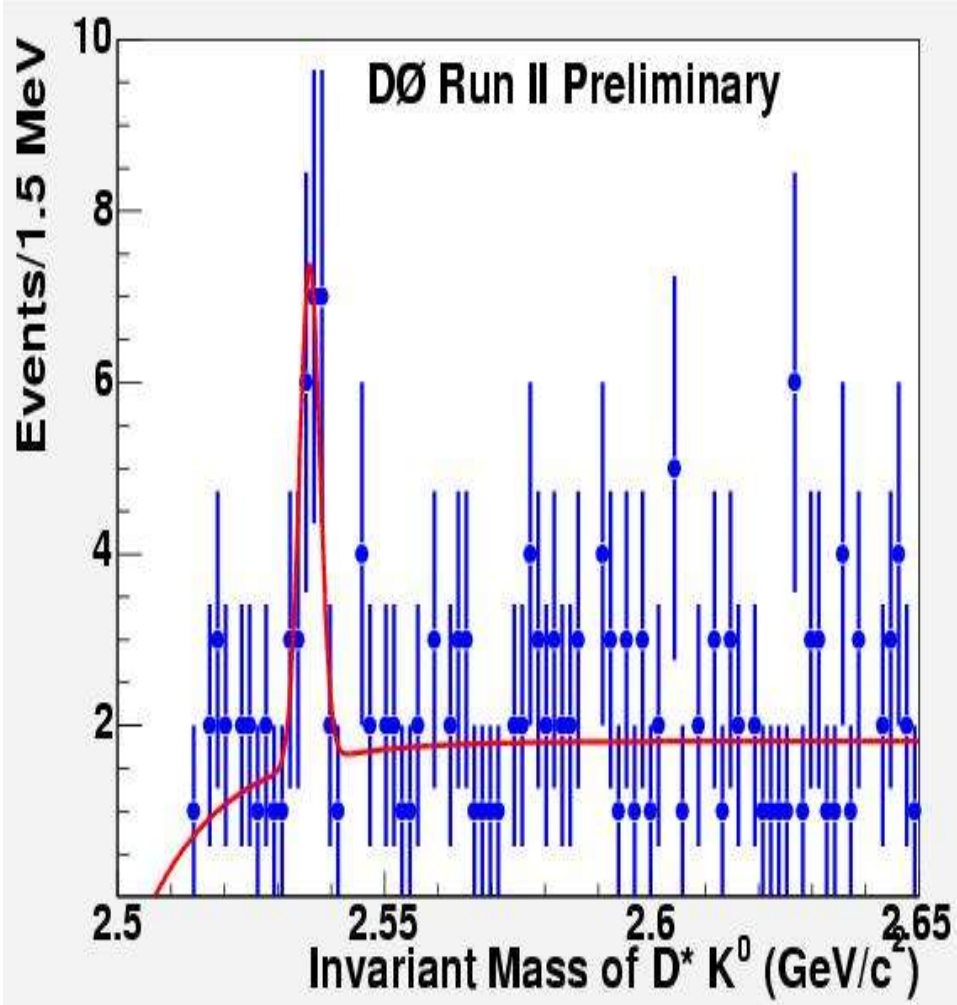
- accomplished first major step in FCNC three-body charm decay program
- Future: search for excess in non-resonant continuum region





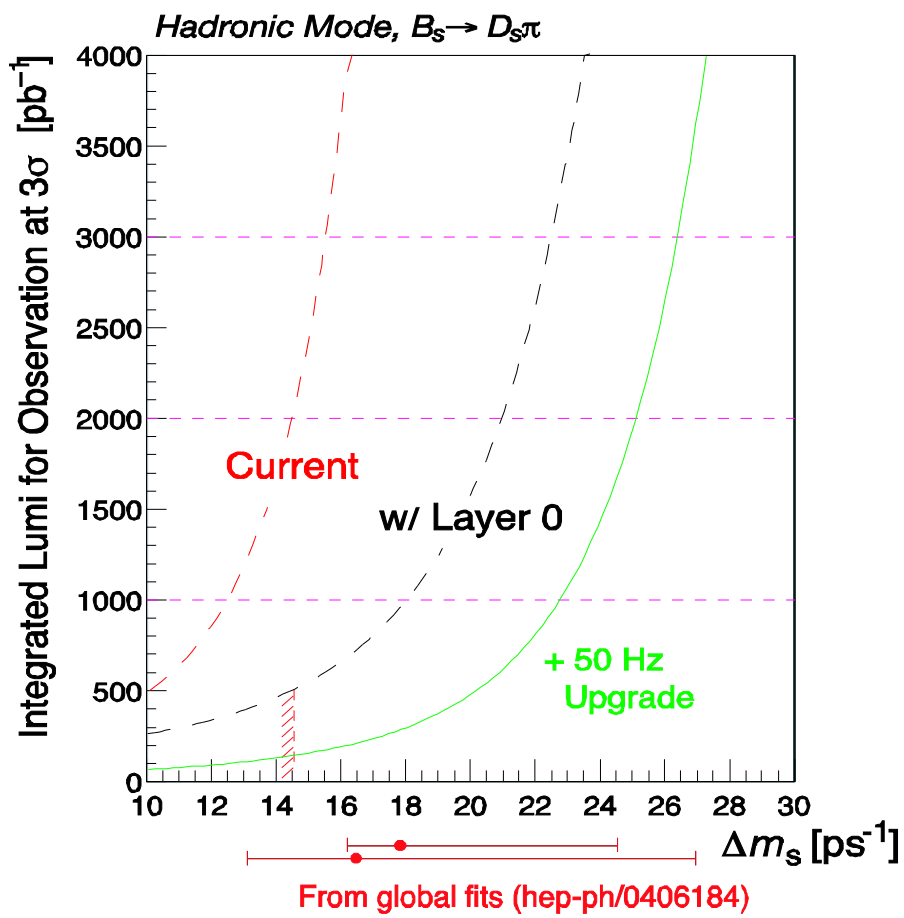
$B_s \rightarrow D_{s1}(2536)\ \mu\ \nu\ X$

- Evidence of the decay $B_s \rightarrow D_{s1}(2536)\ \mu\ \nu\ X$
  - where $D_{s1}(2536) \rightarrow D^* K^0$
    - $D^* \rightarrow D^0 \pi^+$; $D^0 \rightarrow K^- \pi^+$
  - with 485 pb-1 we see 18 ± 5 events for a significance of 3σ
- D0 would now like to measure the properties of this signal.



B_s and detector upgrades

- During the fall shutdown, D0 will be adding a "layer 0" silicon detector.
  - This will improve our tracking resolution.
- There is a proposal to add an additional 50 Hz rate to tape dedicated for B physics.
  - This will increase our statistics by a factor of 3.
- D0 will also have substantial calorimeter and track trigger upgrades.



Summary

- New discoveries, Better Limits: There is a lot of good physics at D0 with new analysis results coming out all of the time.
  - In just QCD, New Phenomena, and B Physics D0 has
    - published 8 results with 2 more accepted and 2 submitted
    - approved over 40 additional results for presentation.
- I could only cover a fraction of the physics going on.
  - See http://www-d0.fnal.gov/Run2Physics/WWW/results.htm for more results.
- The Run IIb upgrade will improve all aspects of our analysis for many years to come.
- More to come (today)
  - At 3:45 Ia Iashvili will be giving more D0 Physics results on Electroweak, Top and Higgs Physics.