Searches for New Phenomena at the Tevatron

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(for the CDF and DØ Collaborations)

A·S·P·E·N
Center for Physics

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Searching for New Phenomena

New Phenomena at the Tevatron can take many forms:

- Observation of unseen particles predicted by SM (Higgs)
- Discovery of particles not in the SM (SUSY, leptoquarks)
- Identification of new gauge interactions (W'/Z', technicolor)
- Unexpected complexities beyond the SM (compositeness)
- Fundamental changes to modern physics (extra dimensions)

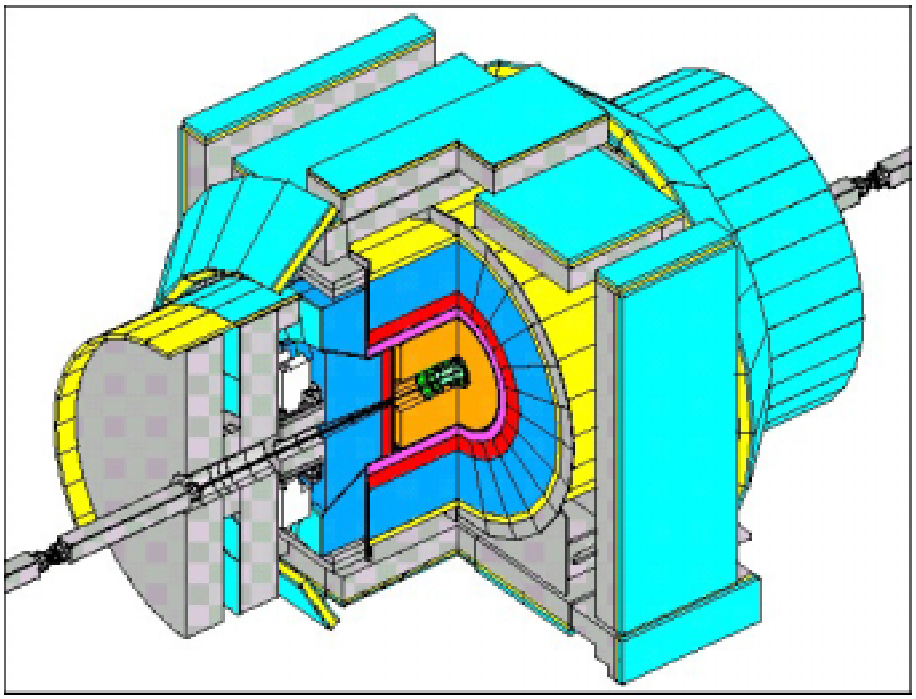
A thorough discussion of the possibilities for discovering new phenomena at the Tevatron is a logical impossibility

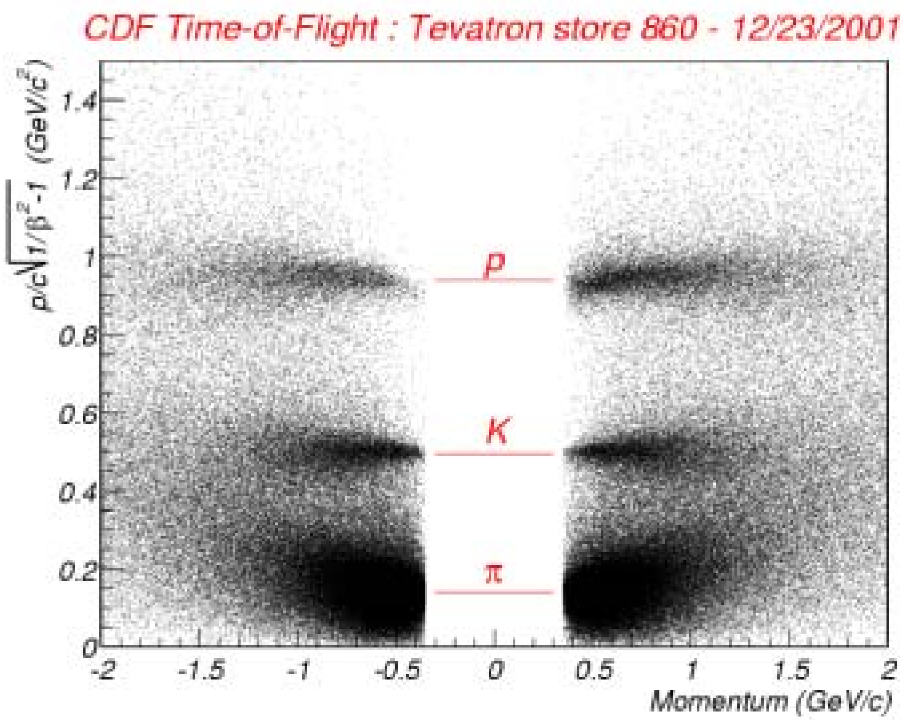
A thorough discussion of the CDF and DØ searches for new phenomena in 25' is merely a human impossibility

This talk will utilize CDF and DØ Run II results to illustrate the progress and prospects in searches for new phenomena

The Upgraded CDF Detector

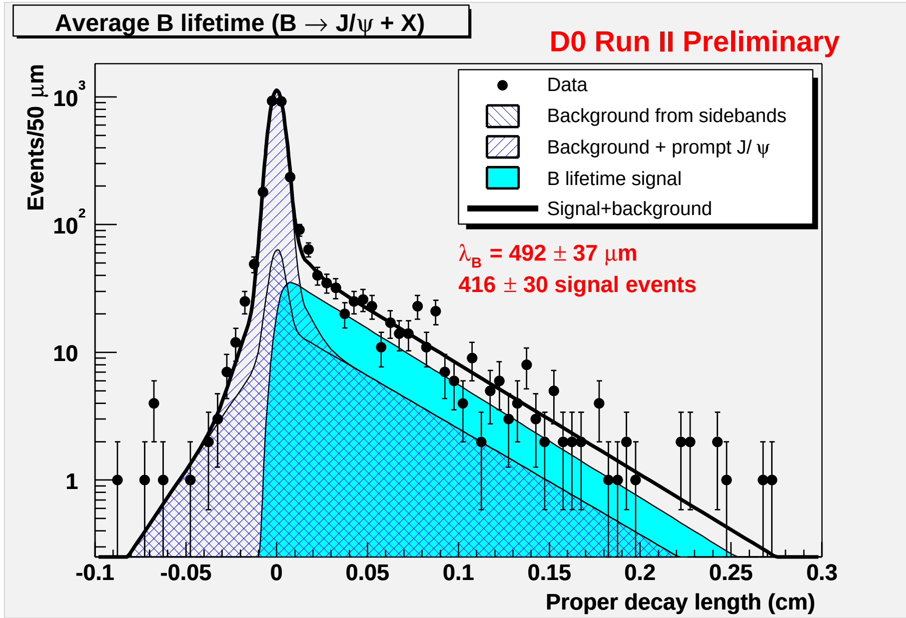
- New central drift chamber and silicon tracker
- New forward calorimeters ("plug") $(1<|\eta|<3)$
- New TOF, extended muon coverage, improved triggers, ...

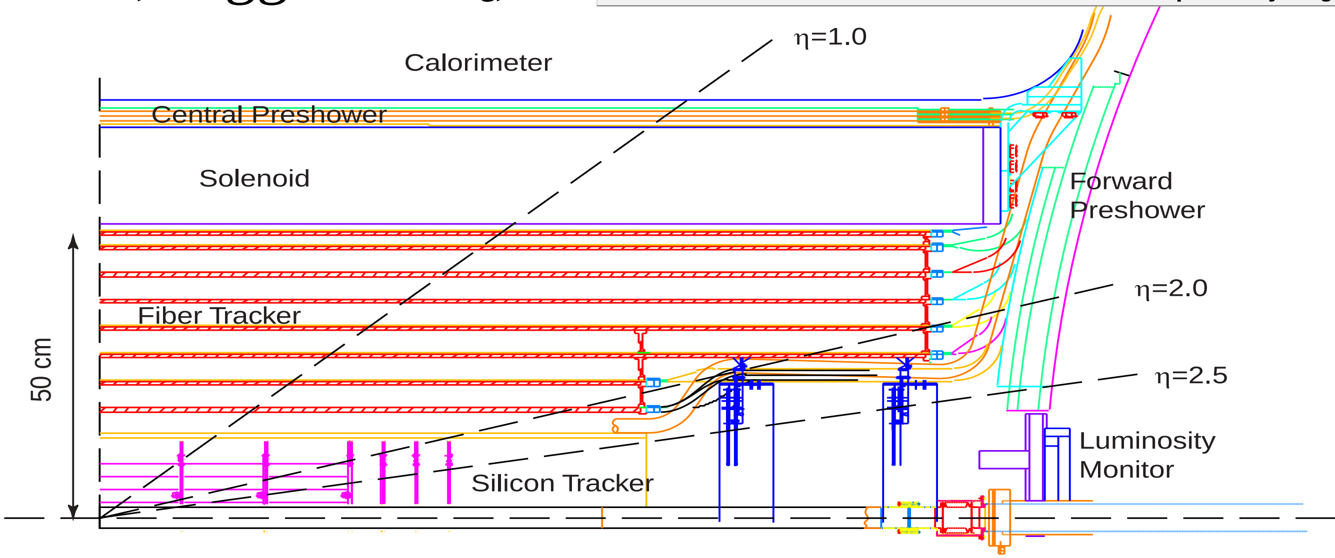




The Upgraded DØ Detector

- First time charged particle tracking added to a major "non-magnetic" detector!
  - 2T solenoid
  - >100K scintillating fibers
  - >700K silicon strips
- Major improvements to muon spectrometer, trigger/DAQ, ...





Searching for SUSY at the Tevatron

- One of the major features of SUSY it "protects" the SM against large radiative corrections from a high mass scale
  - » Fermion/Boson symmetry cancels loop divergences
- "The Case for a 500 GeV e^+e^- Linear Collider* " argues that the lightest chargino is likely to have a mass below 250 GeV
- Basic idea: if SUSY particles are heavy, radiative corrections again become large and require fine-tuning of parameters
- Chargino limits at right from ALCWG report*

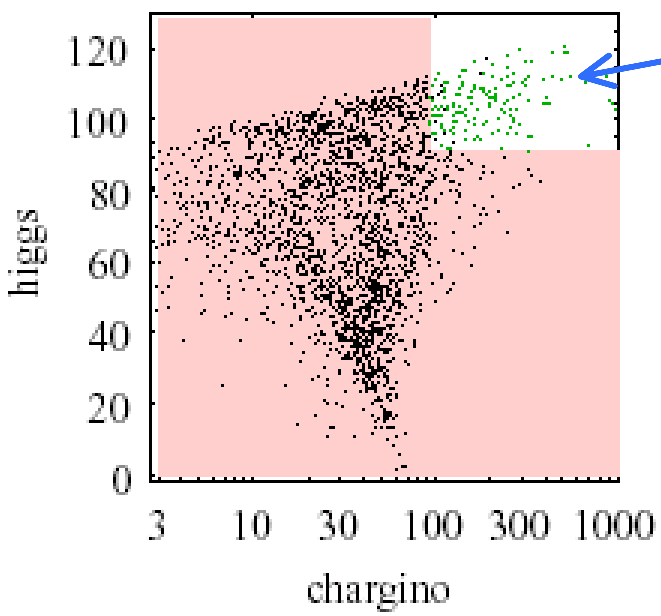
Authors	**m($\tilde{\chi}_1^+$)**
Barbieri-Giudice	<110
Ross-Roberts	<110
de Carlos-Casas	<250
Anderson-Castano	<270
Chan-Chattopadhyay-Nath	<250
Giusti-Romanino-Strumia	<500
Feng-Matchev-Moroi	<240/340

*American Linear Collider Working Group, prepared for Snowmass 2001.

Searching for SUSY at the Tevatron

Some Caveats:

- "Naturalness" approach to estimating SUSY mass scales is neither rigorous nor unique in its predictions
- Even if the lightest chargino mass is below 250 GeV, there is no guarantee that it will be visible at the Tevatron



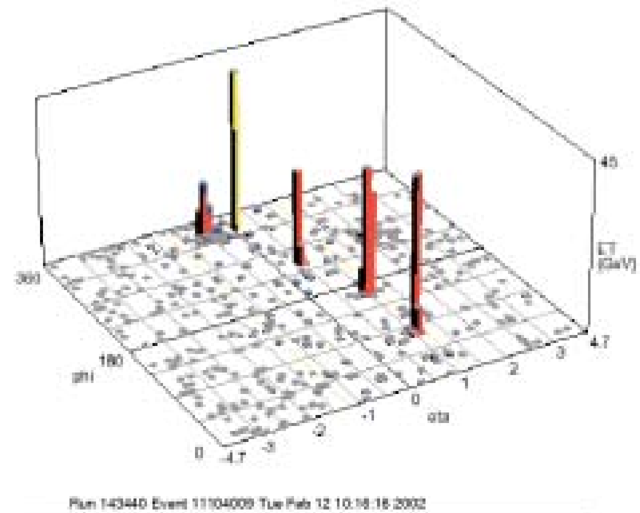
Allowed Region

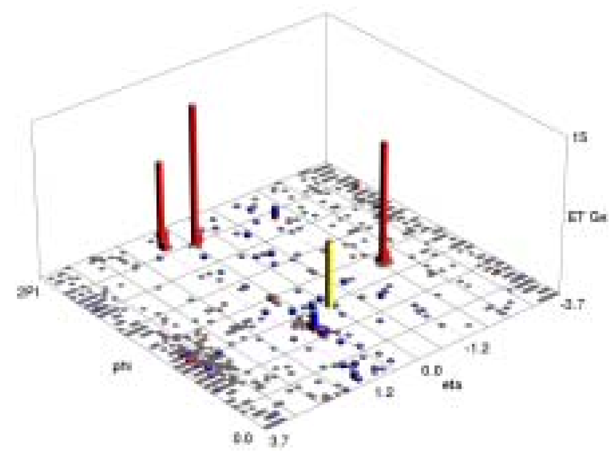
- LEP constraints already exclude SUGRA at the "95% CL"
  - » *e.g.* Strumia, Hep/PH9904247.
- Tevatron can also search for squark, gluino, and slepton production

DØ Tri-lepton Search in eee, eeμ

- Sensitive to chargino+neutralino production
- SM backgrounds are small, one of the cleanest SUSY signatures

eee Events



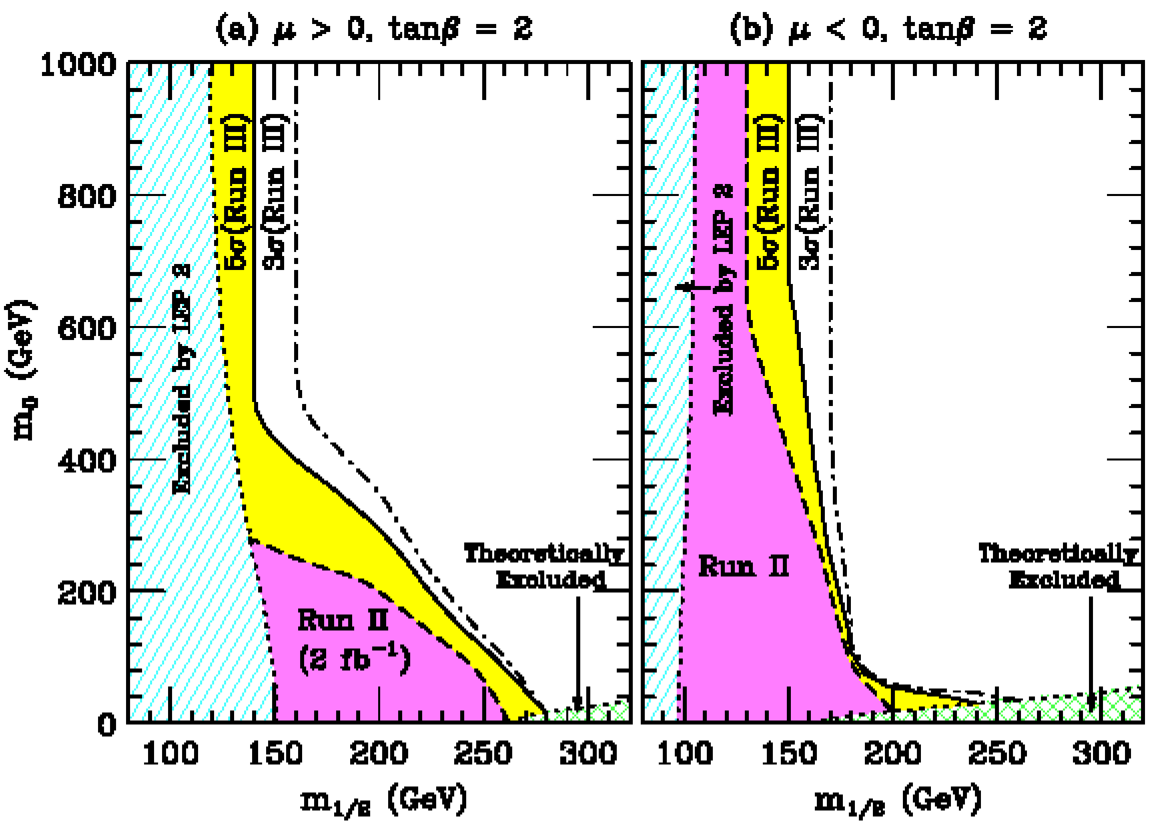


DØ Run II Preliminary (5.2 pb^{-1})

	eee	*eeμ*
SM Background	0.9 +- 0.2	0.13 +- 0.08
EM Fakes	1.0 +- 0.3	0.6 +- 0.2
Cosmics	---	0.145 +- 0.014
Total	1.9 +- 0.4	0.9 +- 0.2
Data	2	1

Prospects for SUSY Tri-lepton Search

- Run II will allow exploration of new regions in SUSY parameter space



purple: 5σ significance w/ 2 fb^{-1} (Run2a)

yellow: 5σ significance w/ 25 fb^{-1} (Run2b)

dashed: 3σ significance w/ 25 fb^{-1}

SUGRA Report, SUSY/Higgs Working Group, hep/ph0003154

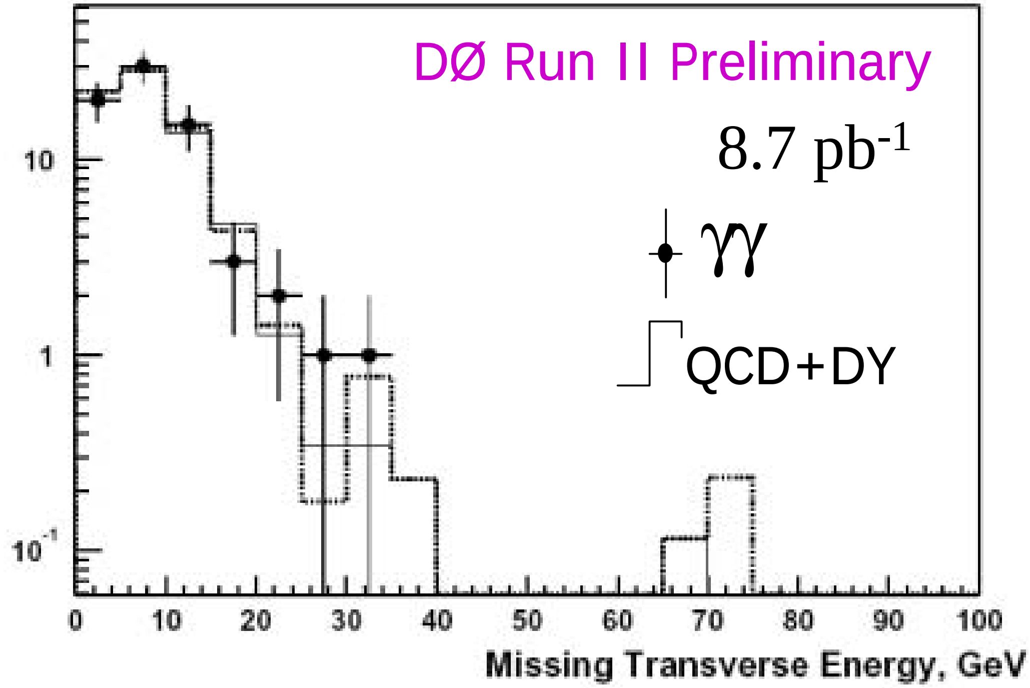
DØ Search for GM SUSY in $\gamma\gamma$ + MET

GM SUSY

- Light Gravitino (<<eV) is LSP, NLSP can be neutralino or slepton
- If neutralino NLSP:

$$\tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$$

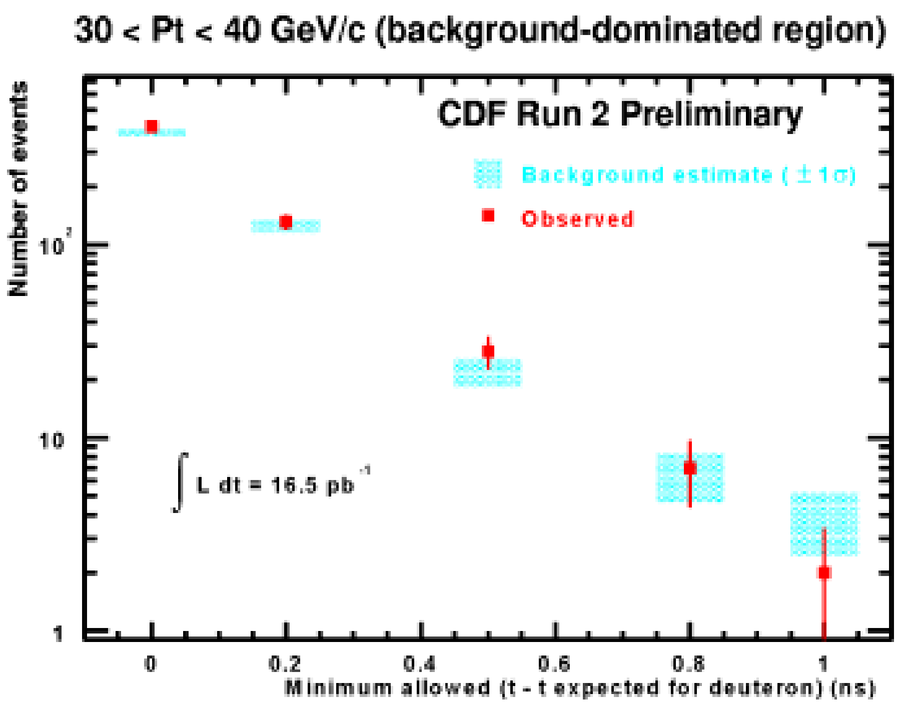
$\Rightarrow$ Search for $\gamma\gamma \not{E}_T$ + X



	$MET > 25\ GeV$	$MET > 30\ GeV$	$MET > 35\ GeV$
Data	2	1	0
Expected background	1.0 ± 0.3	0.7 ± 0.2	0.34 ± 0.20
95 % CL limit, pb	1.6	1.3	0.9

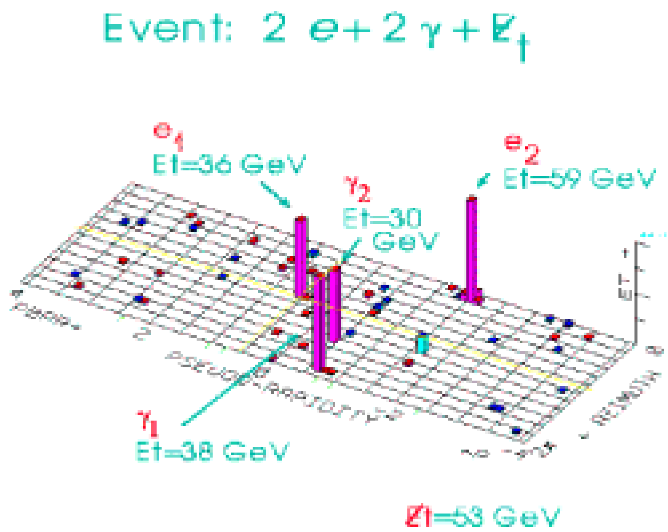
CDF Search for "CHAMPS"

- CHArged Massive Particles that are sufficiently long-lived to leave the detector (*e.g.* sleptons)
- Makes use of new CDF TOF detectors to identify slow particles at high p_T
- Low p_T samples used to estimate BG for high p_T signal region
- Test method: 20 $<p_T<$30 sample used to predict BG for 30 $< p_T <$ 40 sample



Did CDF Catch a Slepton Decay?

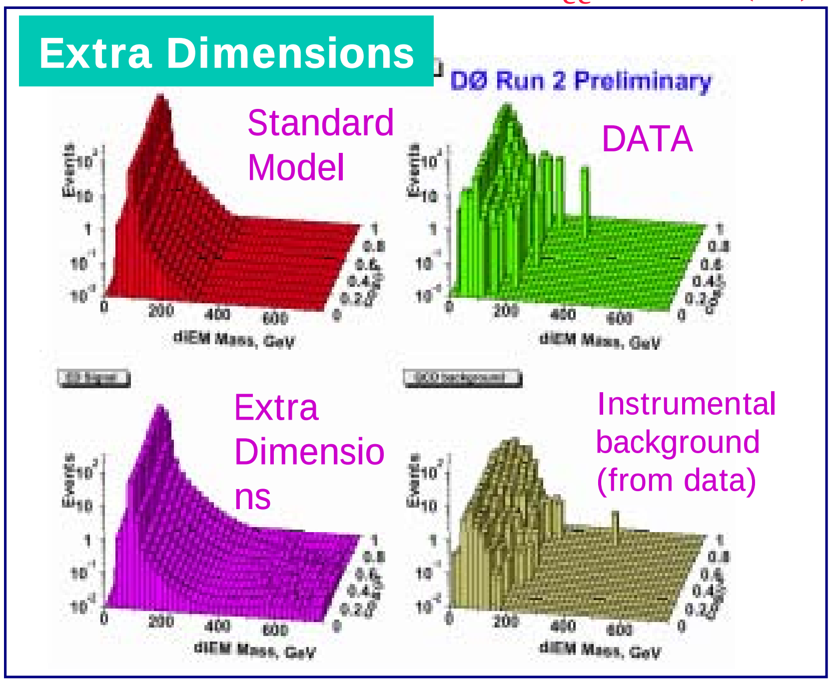
- CDF recorded one event in Run I in the "e"e+γγ+MET channel
- All we can say with certainty is that searches for related signatures have all been negative
  - » CDF and DØ γγ + missing E_T
  - » DØ γ + jets + missing E_T
  - » LEP



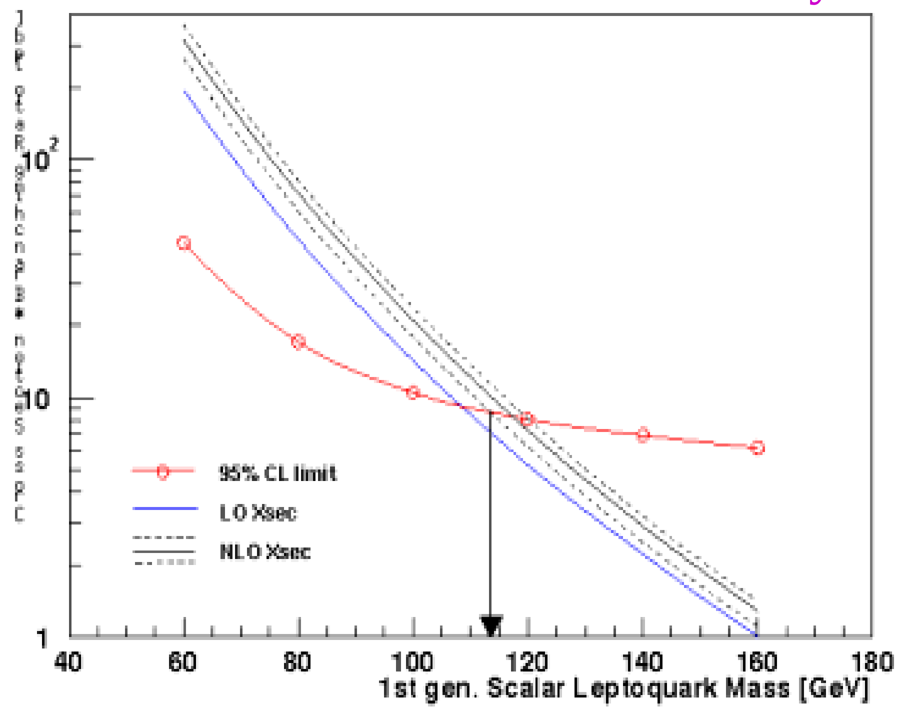
- Feynman: "On the way over here, I saw a car with license plate 7203234! What's the probability of that?"
  - » Random coincidence, unlikely to happen again?
  - » Someone was following Feynman, likely to be seen repeatedly?
  - » Feynman wrote down the wrong number, license plate doesn't exist ?

DØ Extra Dimensions, Leptoquark Hunts

Plot M_{ee} vs cos(θ^*)



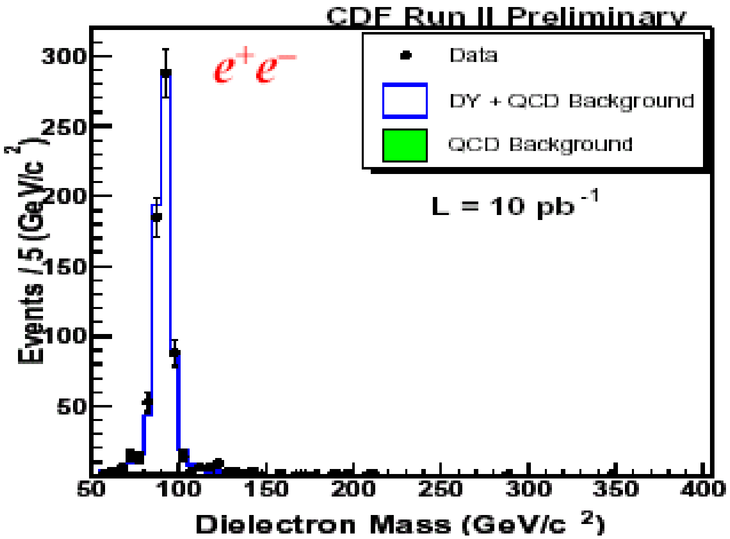
DØ Run II Preliminary

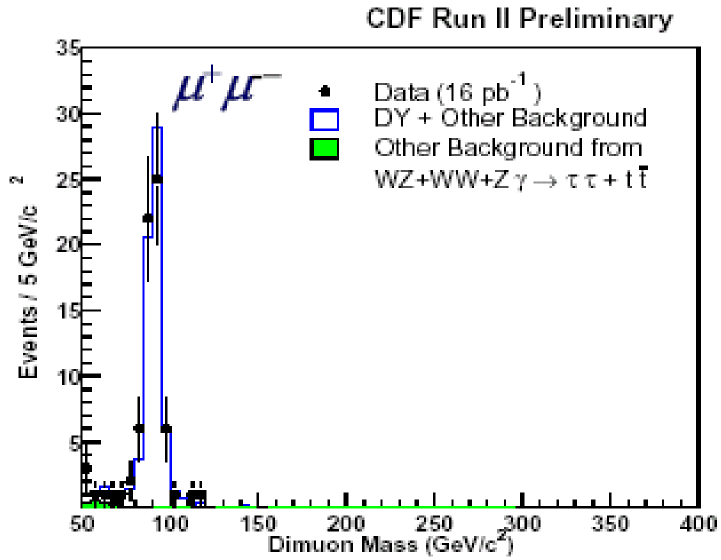


- Limits on ED in $p\bar{p} \rightarrow ee,\gamma\gamma,\mu\mu$
  - » M_s(GRW) > 0.92 TeV(ee, $\gamma\gamma$, 10 pb^{-1})
    - – Run 1: 1.2 TeV (ee, $\gamma\gamma$)
  - » M_s(GRW)>0.50 TeV($\mu\mu$, 4.5 pb^{-1})
- Limits on 1st generation LQ from $p\bar{p} \rightarrow eejj$ (8.0 pb^{-1})
  - » M_{LQ} > 113 GeV for B(LQ→ej)=1
    - – Run 1: 225 GeV

CDF Z' Search

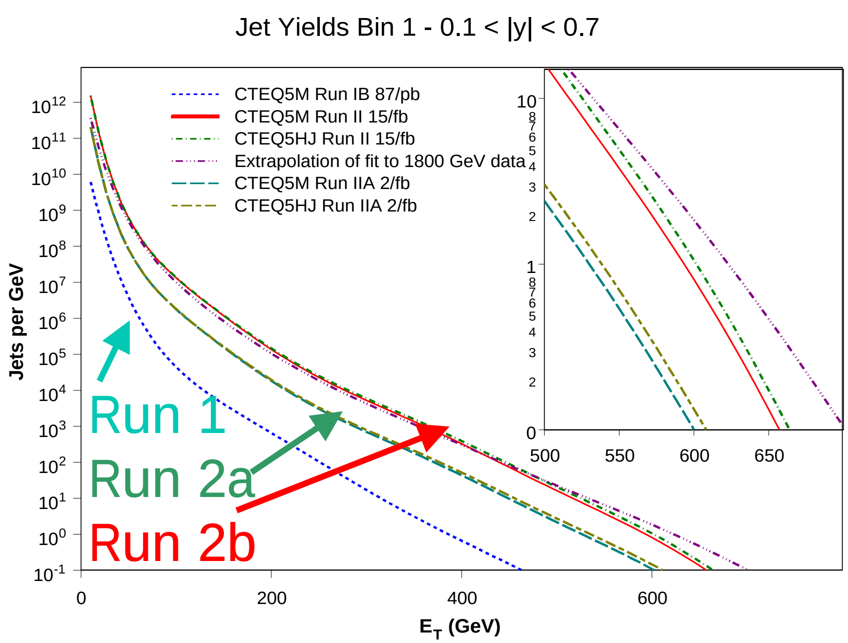
- CDF has studied Drell-Yan events to look for new gauge bosons or evidence of extra dimensions
- Limits on Z'
  - » $M_{Z'} > 450$ GeV (ee)
  - » $M_{Z'} > 270$ GeV ($\mu\mu$)
  - » Run 1: $M_{Z'} > 690$ GeV (ee + $\mu\mu$)
  - » Run 2 Expectation: $M_{Z'} > 1$ TeV
- Limits on mass scale for extra dimensions (Randall-Sundrum, $k/M_{Pl} > 0.1$)
  - » $M_G > 340$ GeV (ee)
  - » $M_G > 255$ GeV ($\mu\mu$)

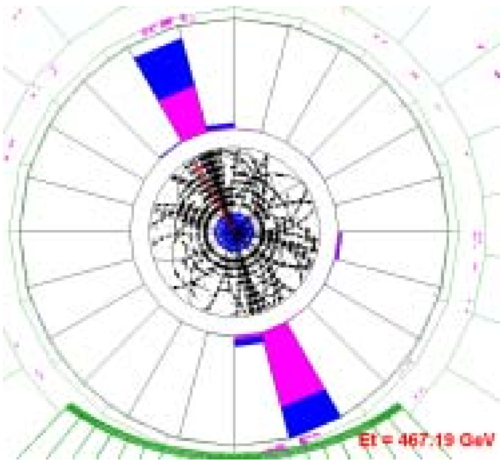




High E_T Jet Production

- Deviations from QCD predictions are potential signal for new physics (*e.g.* quark compositeness)
- Run II's increased energy, luminosity will increase sensitivity to new physics
- CDF Run II event has the largest jet E_T recorded!

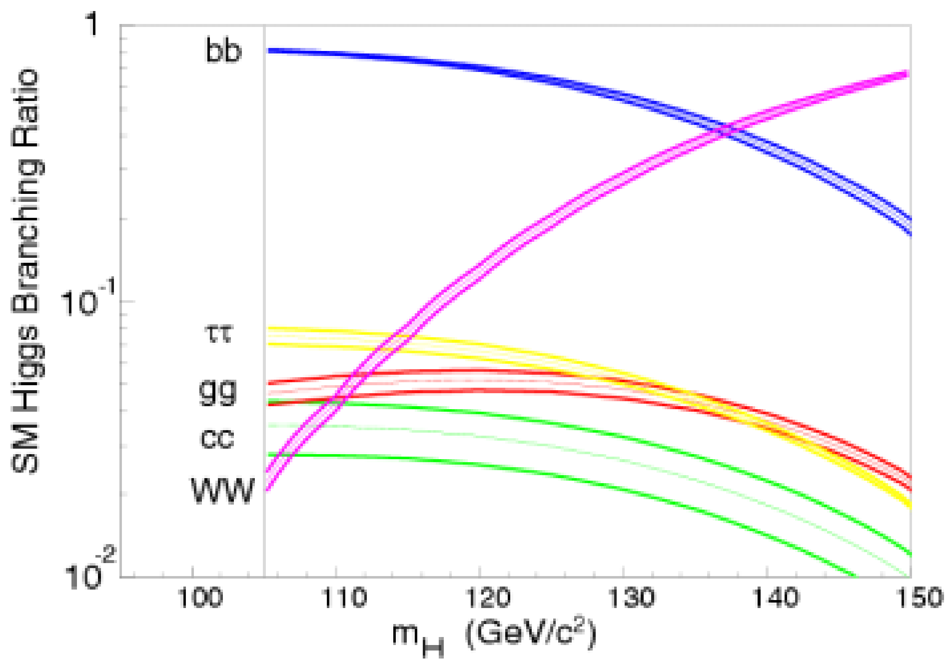


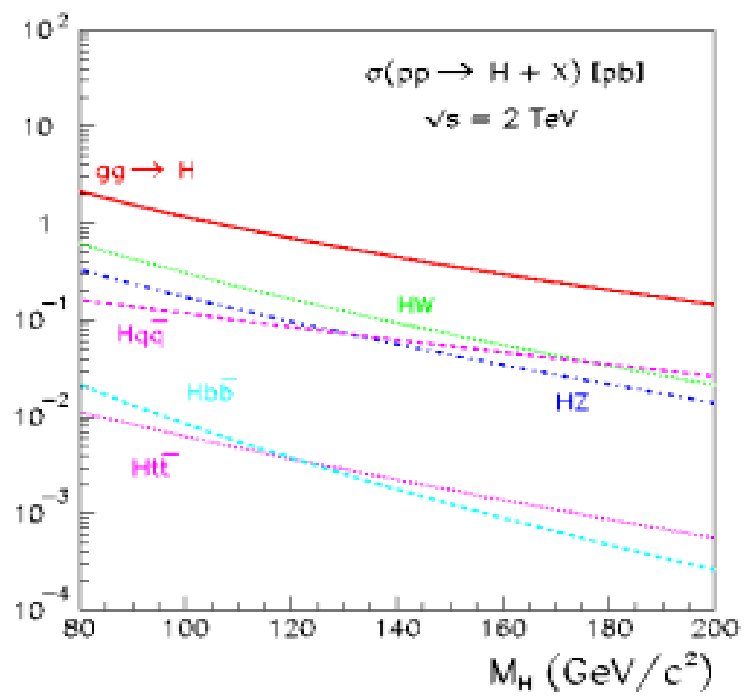


Dijet Mass = 1146 GeV (corr)

Standard Model Higgs

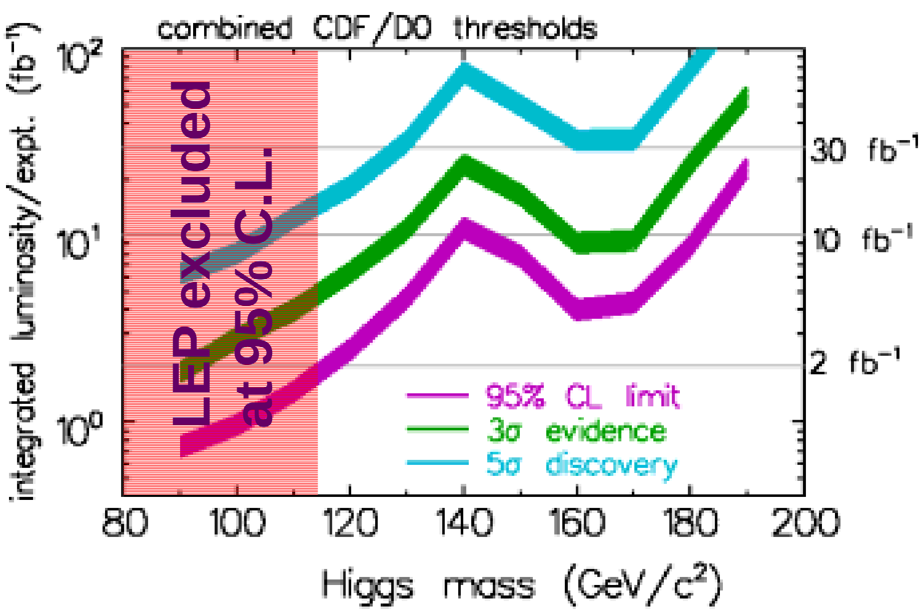
- Higgs mass constrained by direct and indirect measurements
  - » $M_H > 114.4$ GeV @ 95% CL (LEP direct search)
  - » $M_H < 193$ GeV @ 95% CL (Electroweak fits)
- Primary Tevatron channels: $WH \to b\bar{b}$, $ZH \to b\bar{b}$, $H \to WW^{(*)}$



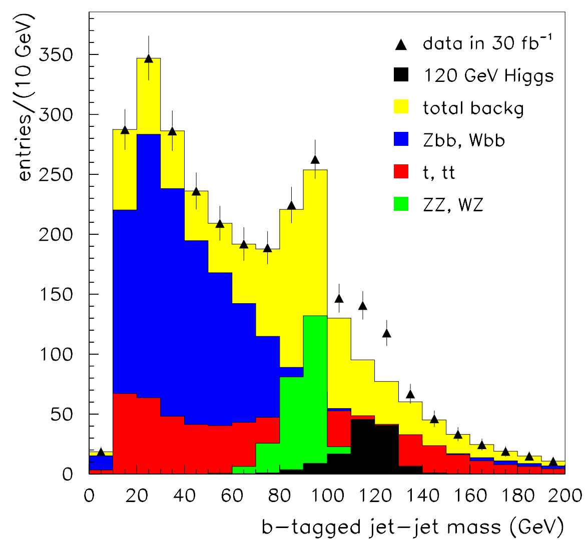


SM Higgs Prospects

- SUSY/Higgs WG demonstrated Tevatron Higgs sensitivity
- Current focus is on putting together the essential ingredients
  - » Good jet energy resolution
  - » Efficient b tagging, lepton identification, and triggering
  - » Optimization of S/B



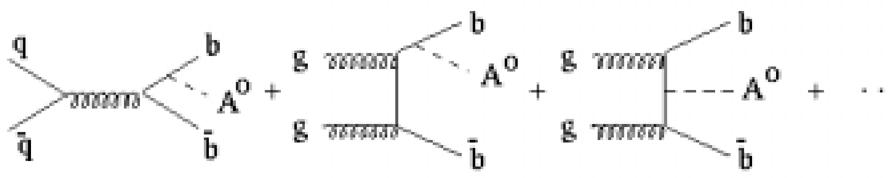
m_H = 120 GeV



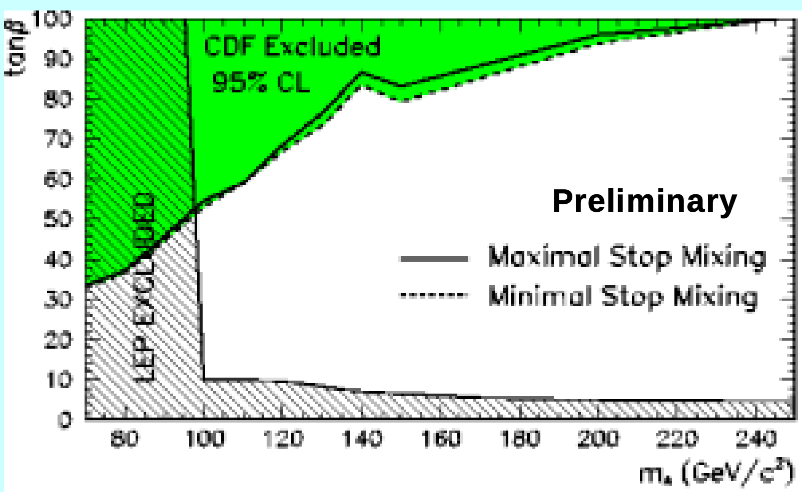
2 × 15fb^{-1} (2 experiments)

SUSY Higgs Production at the Tevatron

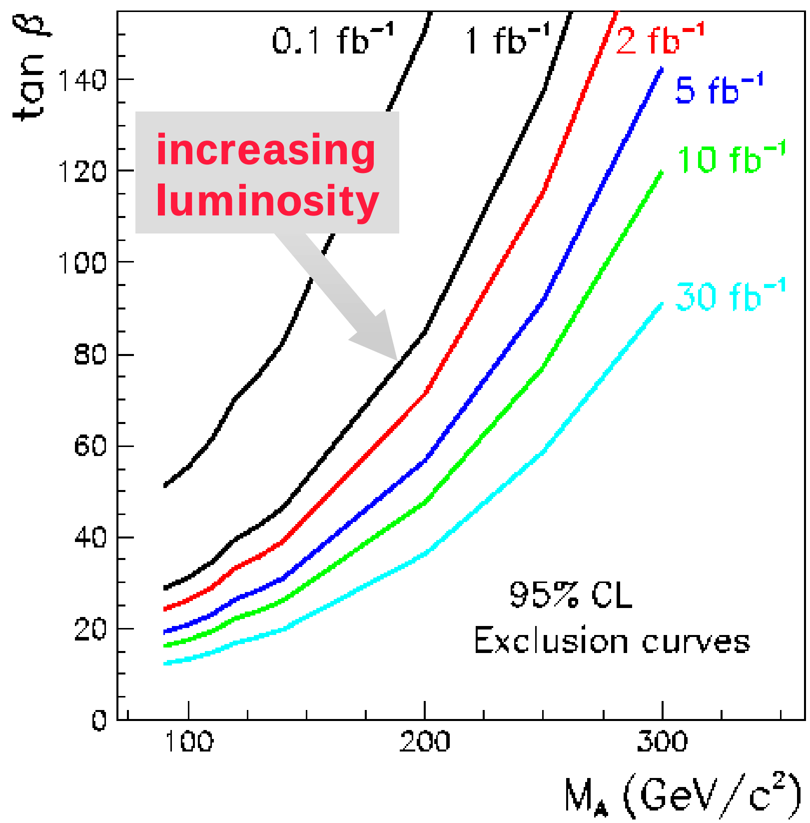
- bb(h/H/A) couplings are enhanced at large tan β
  - » σ ~ 1 pb for tan β = 30 and m_h = 130 GeV



CDF Run 1 analysis (4 jets, 3 b tags) sensitive to tan β > 60

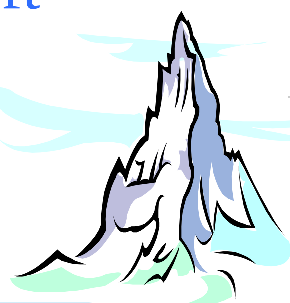


bb(h/A) → 4b



The "Luminosity Lift"

New physics panoramas open up each time we take the "Luminosity Lift"



Run II Physics Program

15 fb^{-1}
- 5σ Higgs signal @ m_H = 115 GeV
- 3σ Higgs signal @ m_H = 115-135, 150-175 GeV
- Reach ultimate precision for top, W, B physics

10 fb^{-1}
- 3σ Higgs signal @ m_H = 115-125, 155-170 GeV
- Exclude Higgs over whole range of 115-180 GeV
- Possible discovery of supersymmetry in a larger fraction of parameter space

5 fb^{-1}
- 3σ Higgs signal @ m_H = 115 GeV
- Exclude SM Higgs 115-130, 155-170 GeV
- Exclude much of SUSY Higgs parameter space
- Possible discovery of supersymmetry in a significant fraction of minimal SUSY parameter space (the source of cosmic dark matter?)

2 fb^{-1}
- Measure top mass ± 3 GeV and W mass ± 25 MeV
- Directly exclude m_H = 115 GeV
- Significant SUSY and SUSY Higgs searches
- Probe extra dimensions at the 2 TeV (10^{-19} m) scale
- B physics: constrain the CKM matrix

300 pb^{-1}
- Improved top mass measurement
- High p_T jets constrain proton structure
- Start to explore B_s mixing and B physics
- SUSY Higgs search @ large tan β
- Searches beyond Run I sensitivity

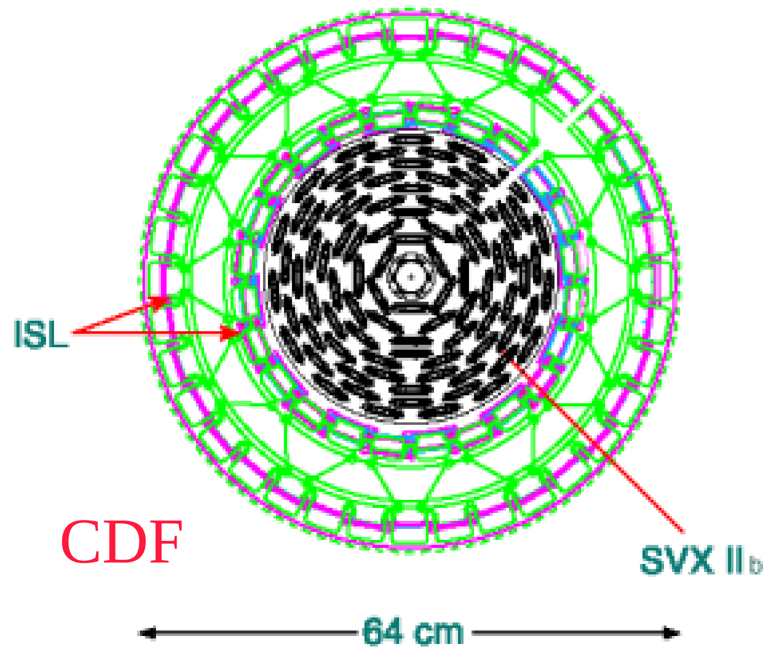
Each gain in luminosity yields a significant increase in reach and lays the foundation for the next steps

CDF and DØ Run IIb Projects

- CDF and DØ detectors were designed to withstand ~2-4 fb^{-1} with an average of ~2-3 interactions per crossing
  - » Integrated luminosity limited by radiation damage to silicon tracker
  - » Instantaneous luminosity limited by trigger rejection
- Tevatron goals for Run II are to accumulate 10-15 fb^{-1} with an average of ~5 interactions per crossing
- CDF and DØ have developed further detector upgrades needed to meet these goals
  - » Both experiments will replace silicon trackers, upgrade parts of the trigger
  - » CDF will replace central preshower detector, add EM calorimeter timing
- Projects have received DOE CD-3(a) approval, major procurements will begin in early 2003
- Run IIb to begin in 2006 following ~7 month shutdown

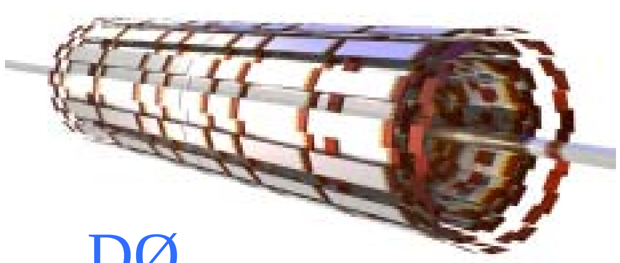
Run IIb Silicon Tracker Upgrade

- Overall geometry/capabilities similar for CDF and DØ designs
- 6 layers, good coverage for $|\eta| < 2$
- Rad-hard sensors and readout will survive > 15 fb^{-1}
- All critical elements have been prototyped, sensor procurement will begin in early 2003



CDF

DØ simulation studies show ~67% increase in double b-tag efficiency for Run IIb silicon tracker



DØ

Conclusions

- Run II at the Tevatron has outstanding opportunities to discover new phenomena
- CDF and DØ detectors have undergone significant upgrades that enhance their ability to make sensitive searches for new phenomena
- The detectors are working well and are beginning to produce physics results
- For many analyses, Run I results are currently the "competition" we are trying to beat – that will change soon!
- Recorded data samples are much larger than the 5-10 pb^{-1} presented here, expect many new results in the near future
- Run IIb upgrades needed to achieve full potential of the Tevatron collider are well underway