What's New at DØ

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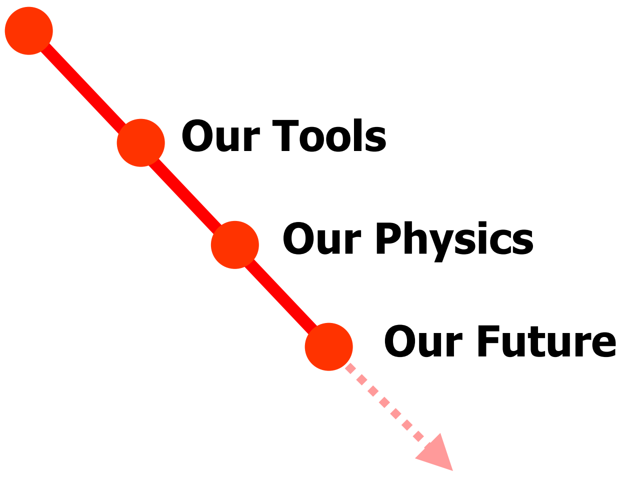
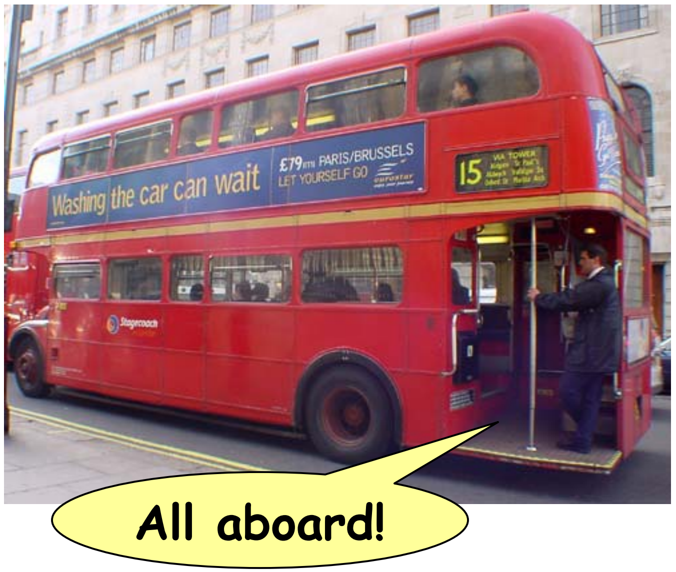
Outline

- **Route of this talk:**





DØ

- **DØ is an international collaboration of ~ 600 physicists from 18 nations who have designed, built and operate a collider detector at the Tevatron**

Institutions: 35 US, 41 non-US

Collaborators:

334 from US
312 from non-US institutions
(note strong European involvement)

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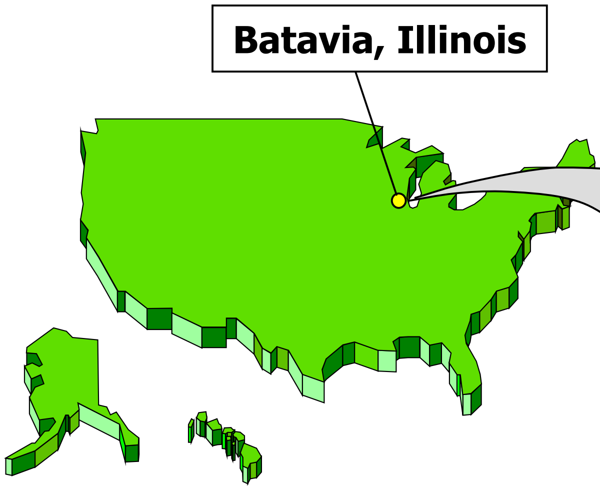
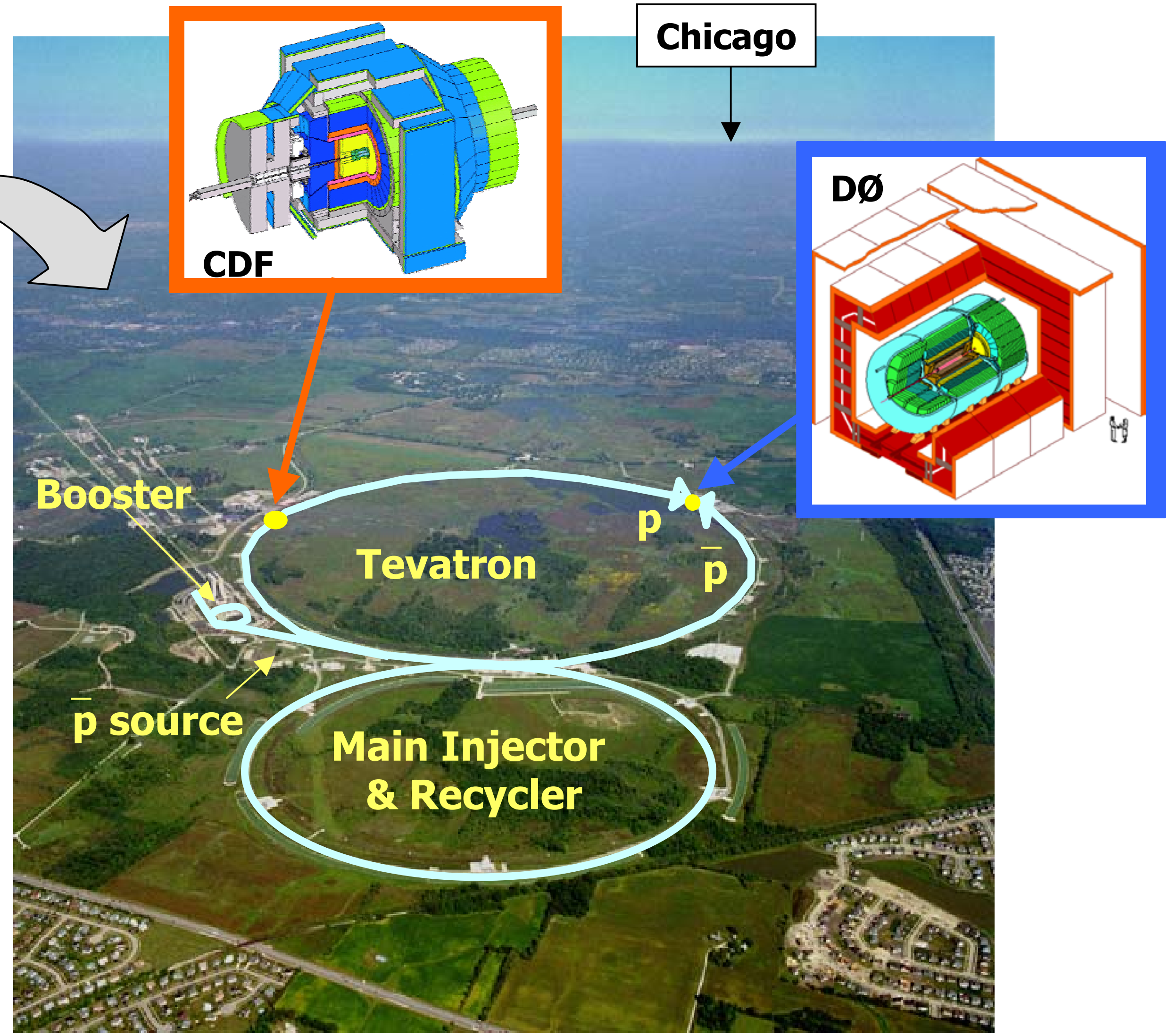
Fermilab





p → ← p̄

$\sqrt{s}$ = 1.96 TeV

Δt = 396 ns

Luminosity goals

4×10^{31} cm^{-2}s^{-1} (FY02)

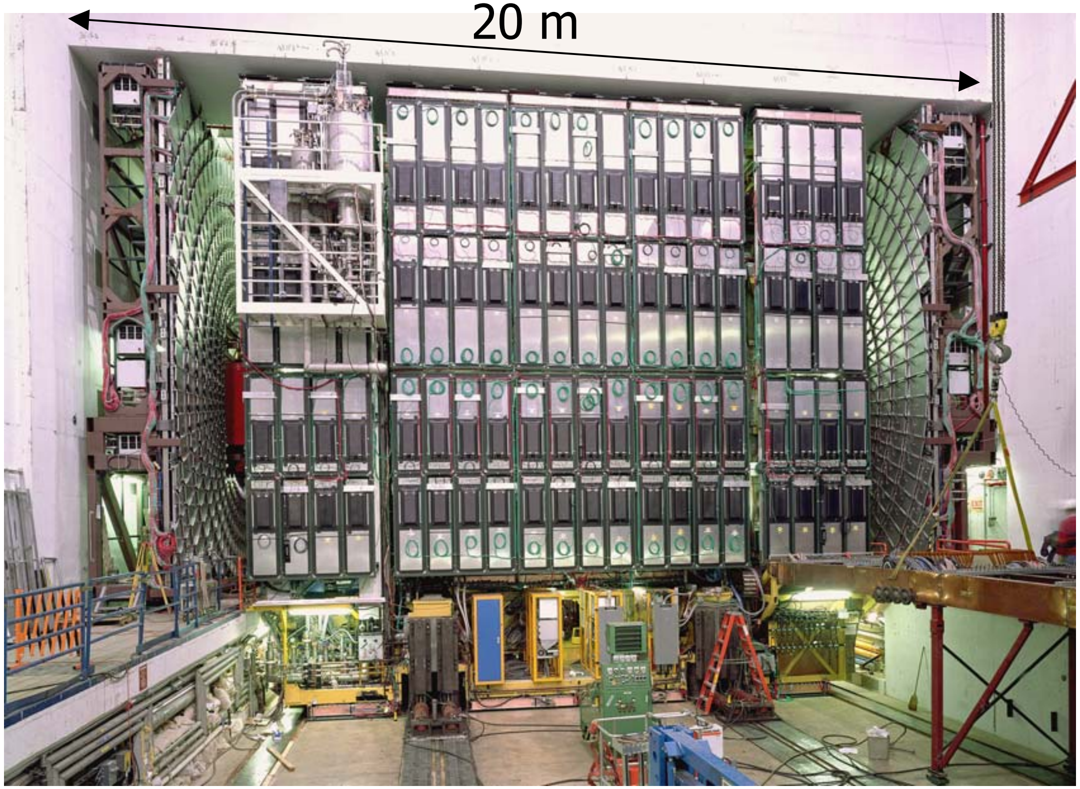
8×10^{31} cm^{-2}s^{-1} (Run IIa)

Physics goals

1. **Precise study of the known quanta of the Standard Model**
   – **Weak bosons, top quark, QCD, B-physics**
2. **Search for particles and forces beyond those known**
   – **Higgs, supersymmetry, extra dimensions, other new phenomena**

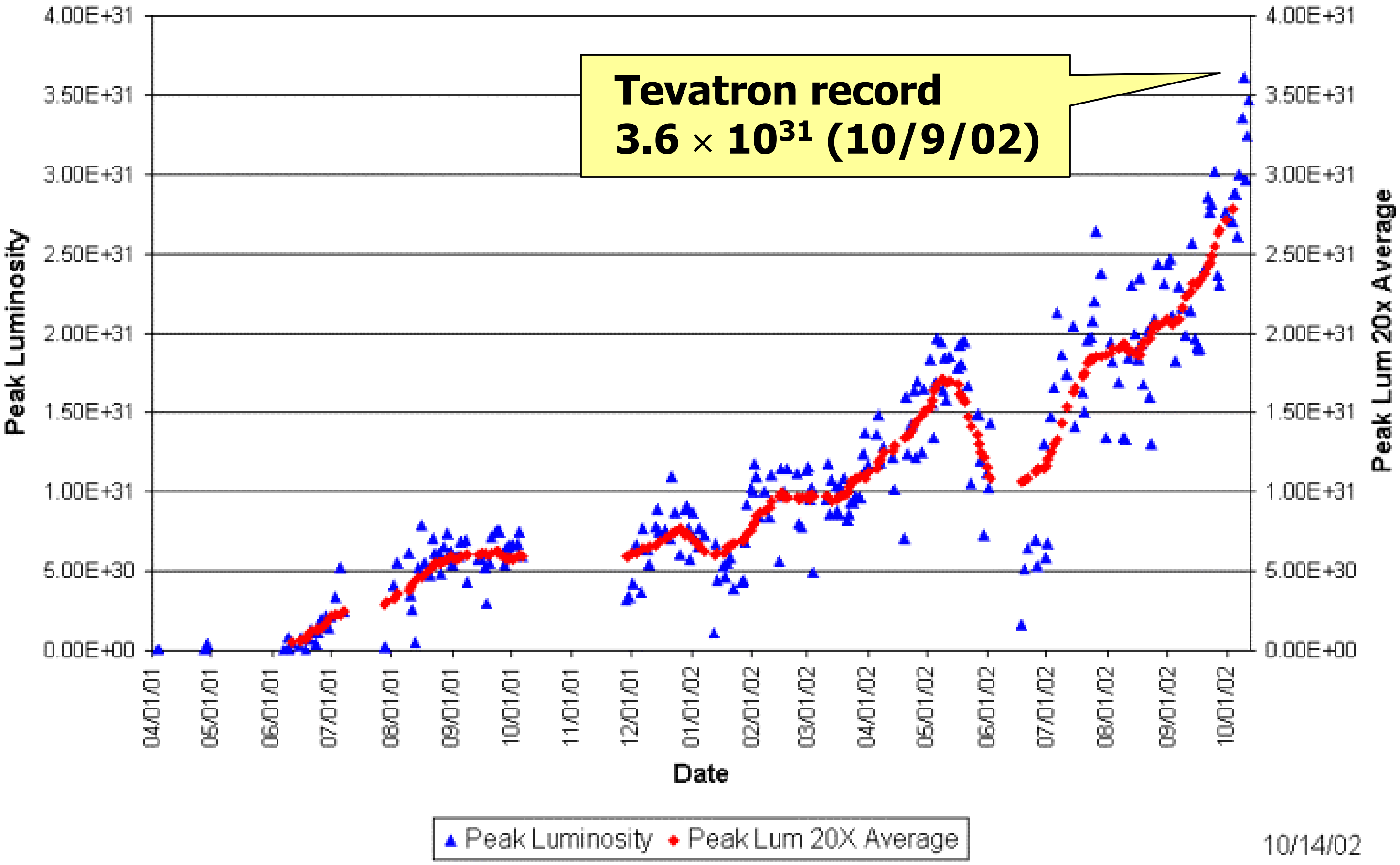
Driven by these goals, the detector emphasises

– **Electron, muon** and **tau** identification
– **Jets** and **missing transverse energy**
– **Flavor tagging** through **displaced vertices** and **leptons**



Tevatron Performance

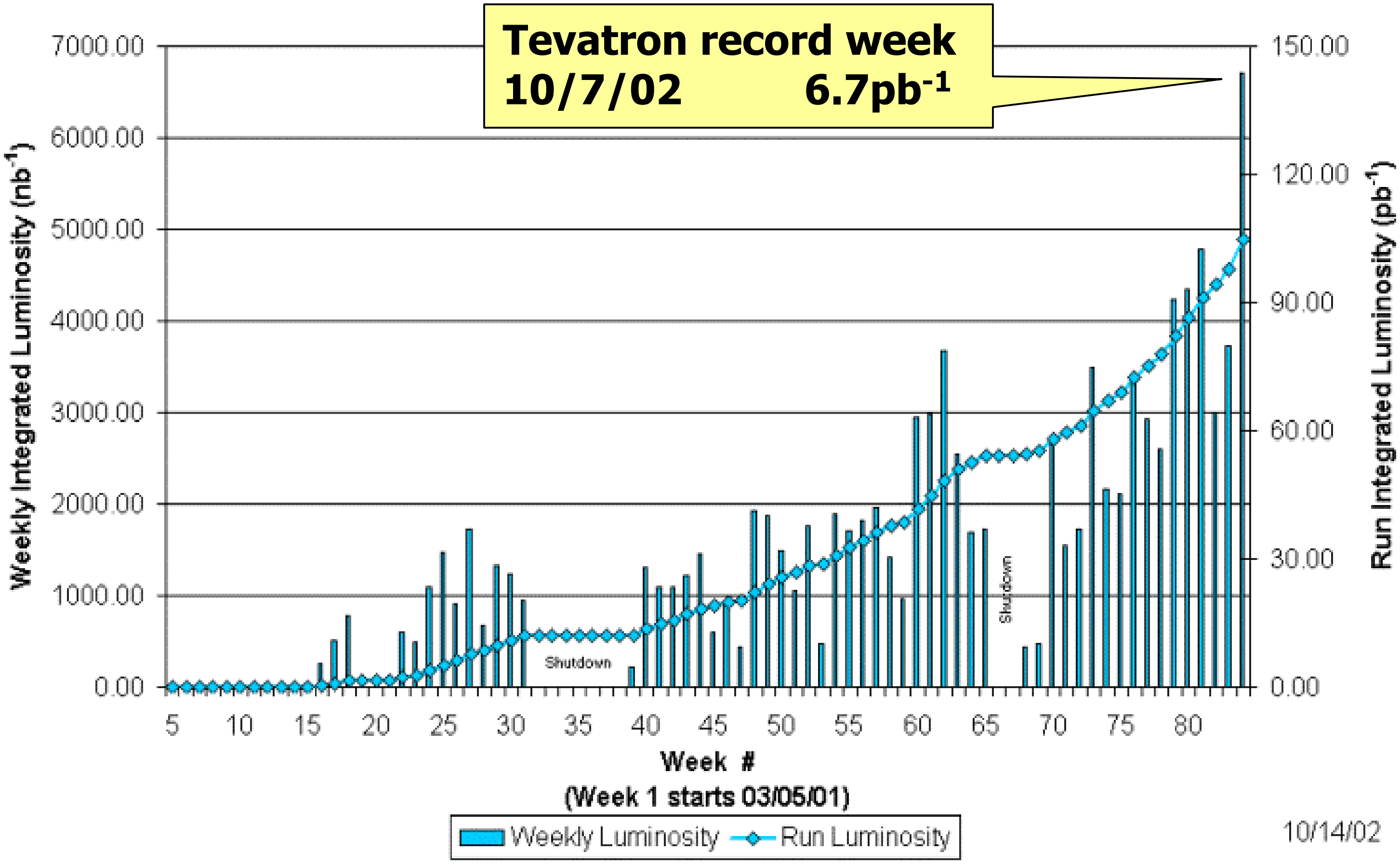
- Not out of the woods yet, but gratifying progress recently
- Tevatron peak luminosity:



10/14/02

Average CDF + DØ luminosity

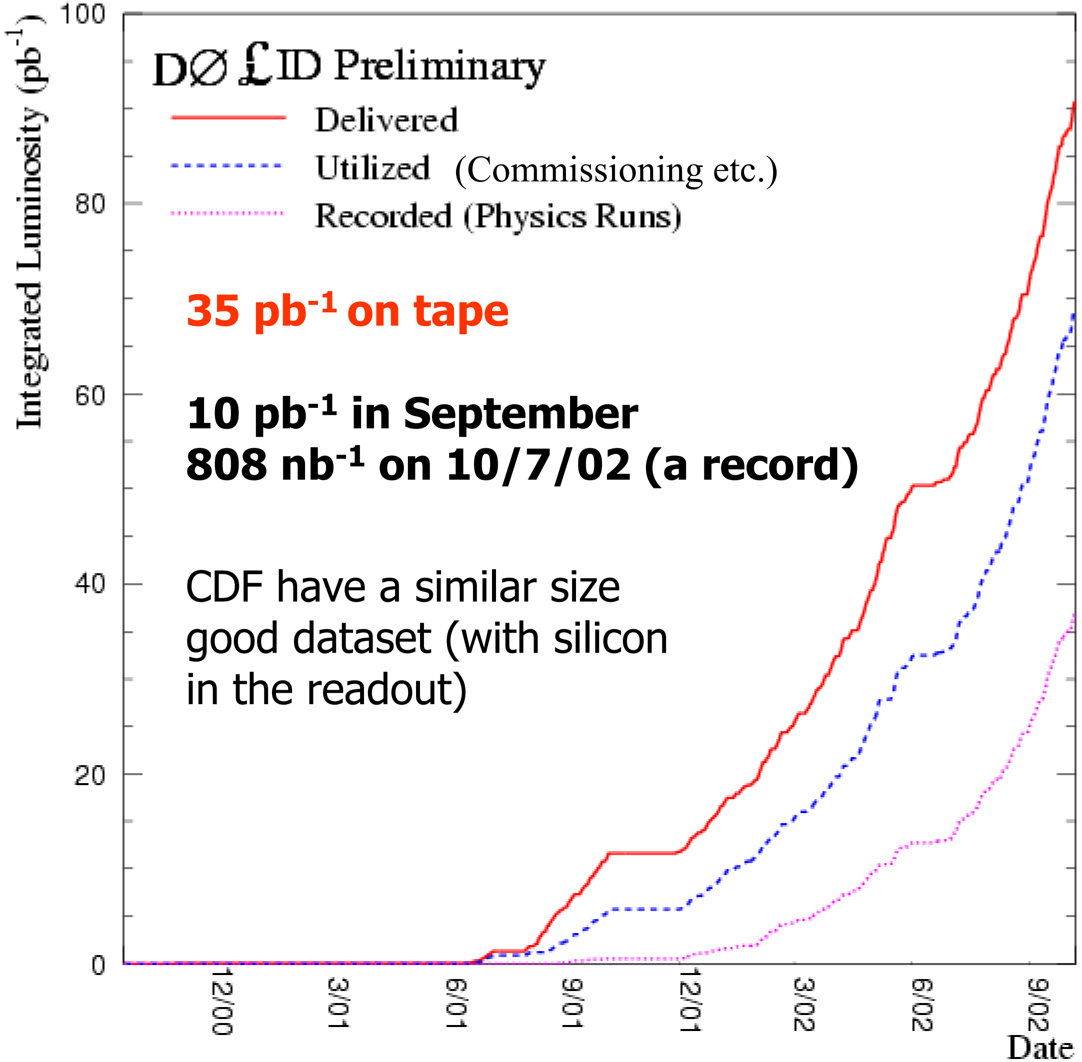
- **Luminosity per week and total Run II integrated luminosity**



Tevatron prospects

- Now exceeding Run I performance
- Improvements have come from specific modifications to the complex
- Injectors are providing the necessary beams for $L_0 = 6 \times 10^{31}$ cm^{-2}s^{-1}
- Fully resource loaded schedule and plan in place for FY03
- Major issues are:
  - Tevatron transfer and acceleration efficiencies
  - Emittance dilution
  - Beam lifetime at 150 GeV
  - Role of long range beam-beam effects
- No silver bullets
    - $(1.15)^{10} = 4.0$

Data on Tape



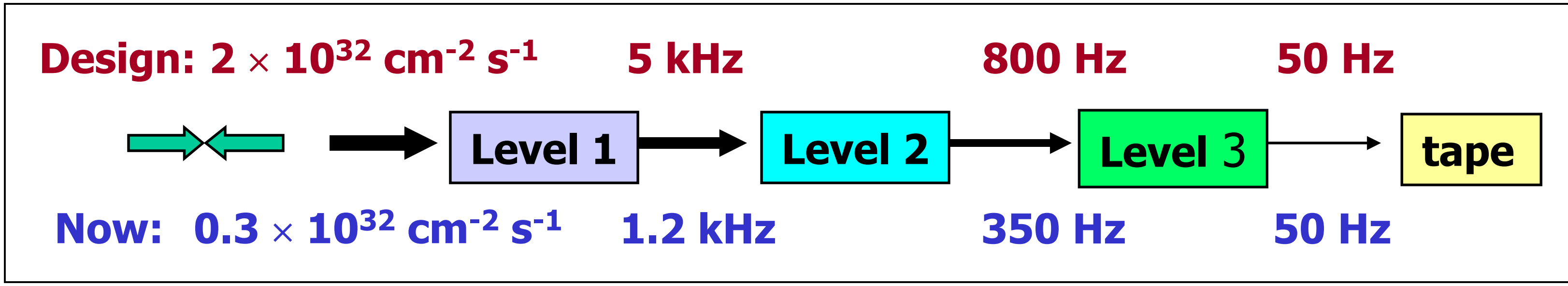
35 pb^{-1} on tape

10 pb^{-1} in September
808 nb^{-1} on 10/7/02 (a record)

CDF have a similar size good dataset (with silicon in the readout)

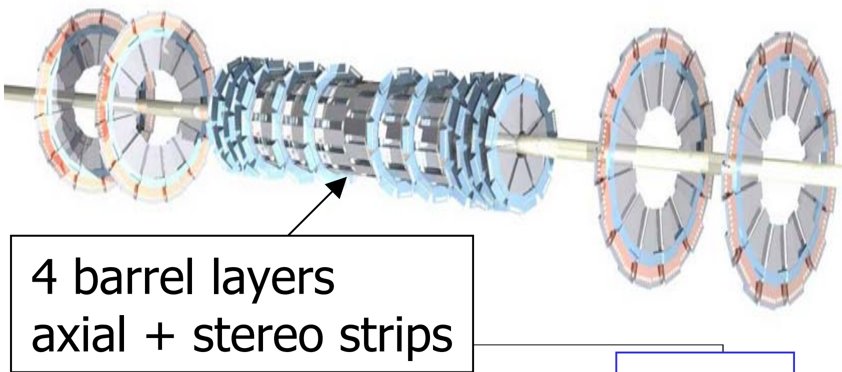
Status of DØ

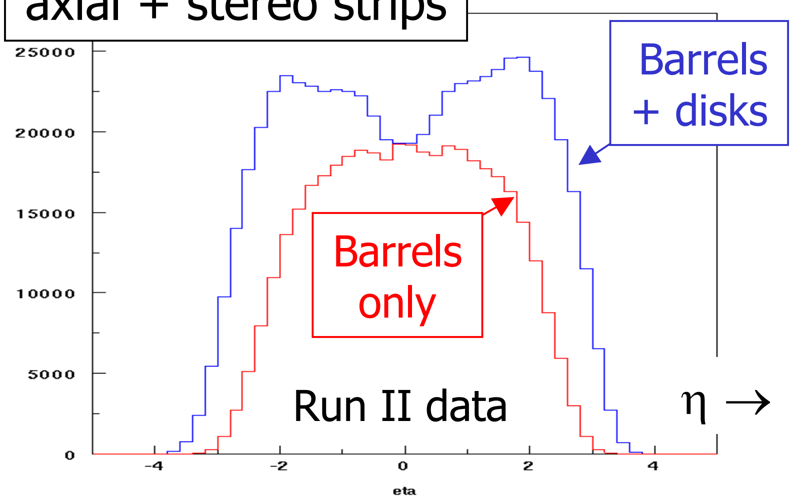
- The detector is working well and we are recording physics data
  - Changed to new, ethernet-based DAQ system this year; a major effort that went very well



- Currently emphasizing operational efficiency
- Improvements still in store will help us handle higher luminosities
  - L1 trigger capabilities
    - Fiber tracker trigger is being commissioned: muon system is now receiving track candidates
  - L2 trigger
    - We will replace the troublesome alpha processors
  - Silicon vertex trigger (NSF funded) is under construction
- Intense work on offline reconstruction, tracking efficiency, etc.

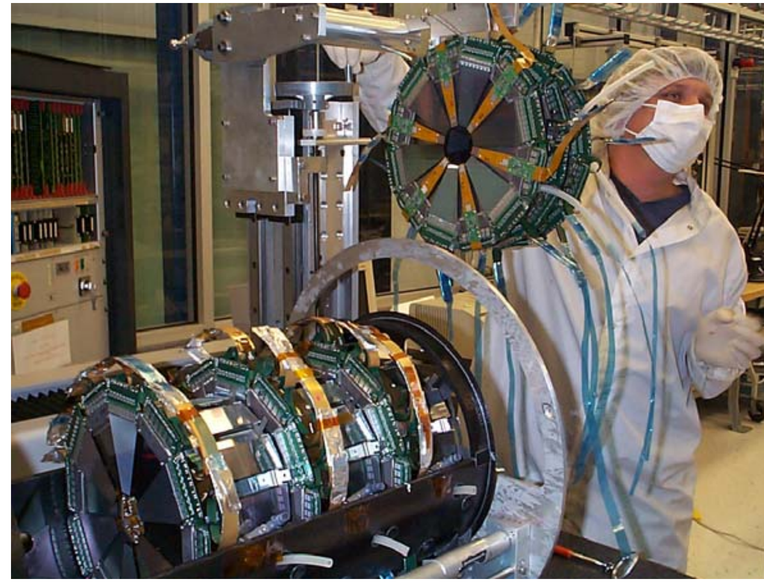
Silicon Microstrip Tracker Status

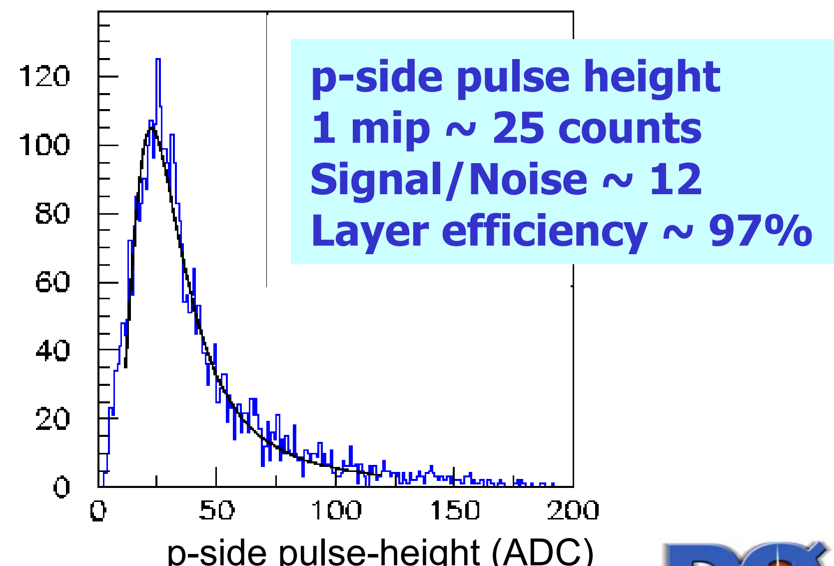




Track finding in barrels and disks

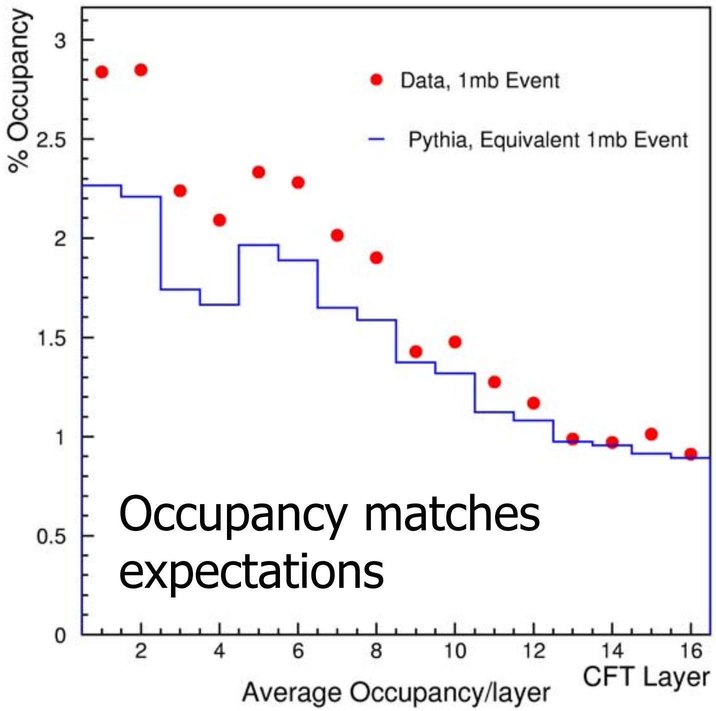
Barrels: 93% operational
F-disks: 96% operational
H-disks: 89% operational

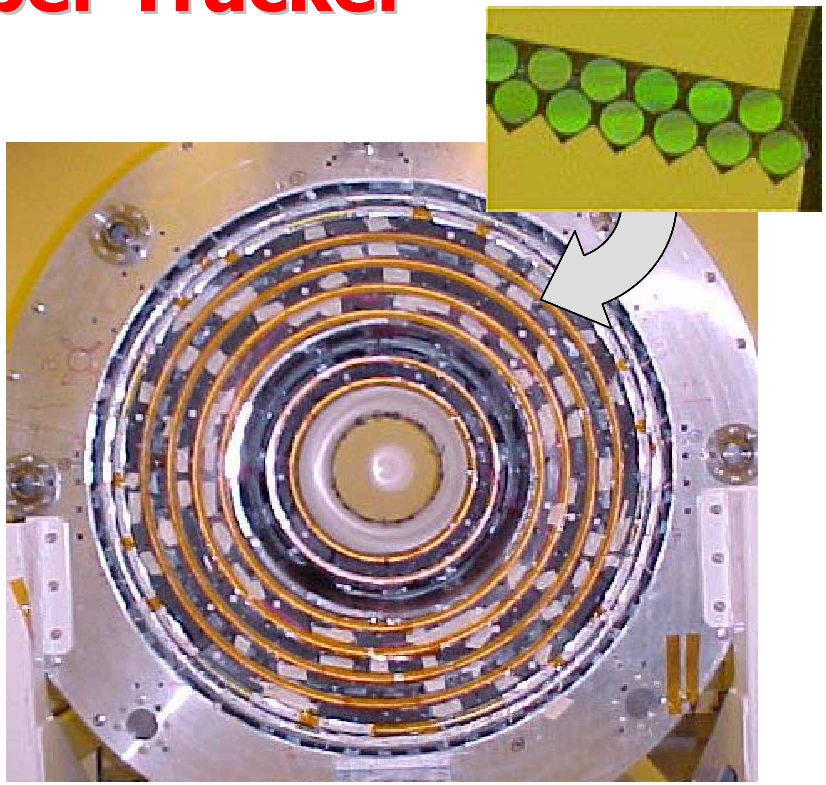


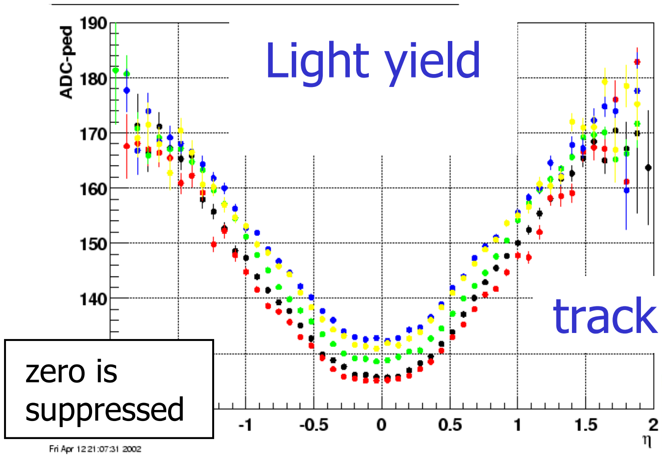


Scintillating Fiber Tracker

- **8 axial, 8 stereo layers**
- **VLPC readout**
- **Performing well**
  - **good light yield**
  - **layer ε > 98%**
    (including dead channels)







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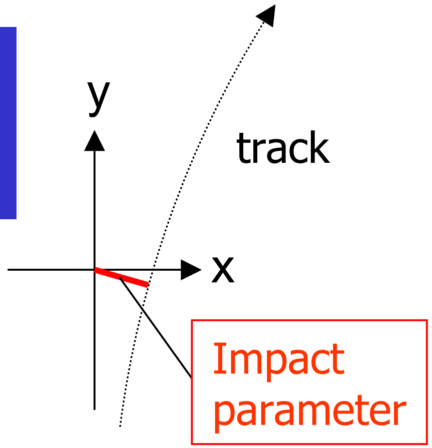
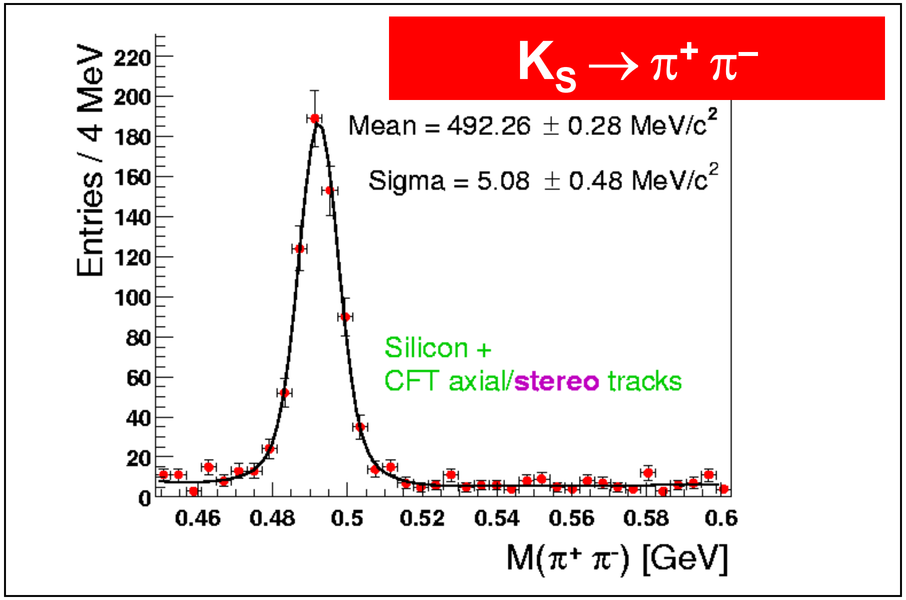
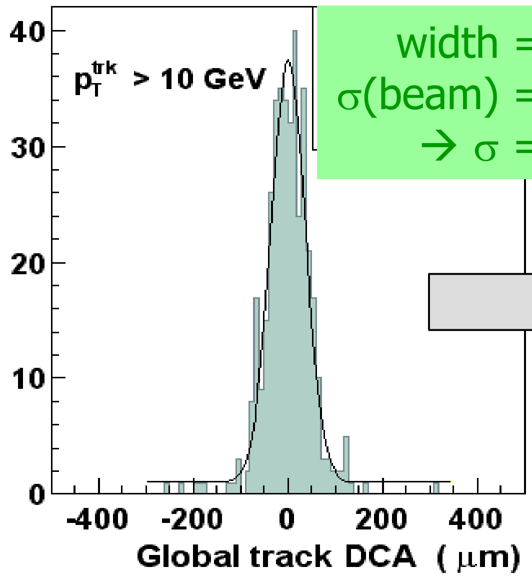
Tracking Performance

Impact Parameter Resolution

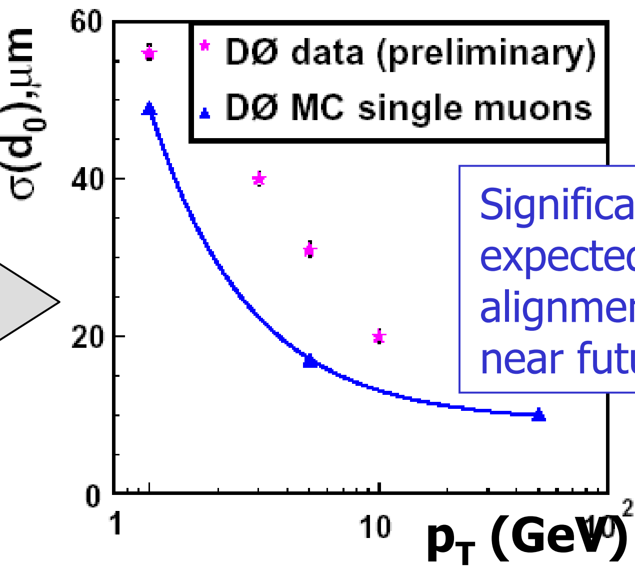




Survey-only alignment constants



width = 36 μm
σ(beam) = 30 μm
→ σ = 20 μm



Significant improvement expected from alignment with data in near future

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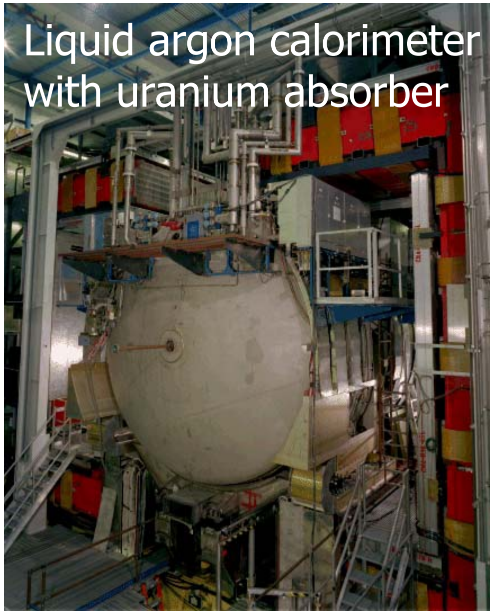
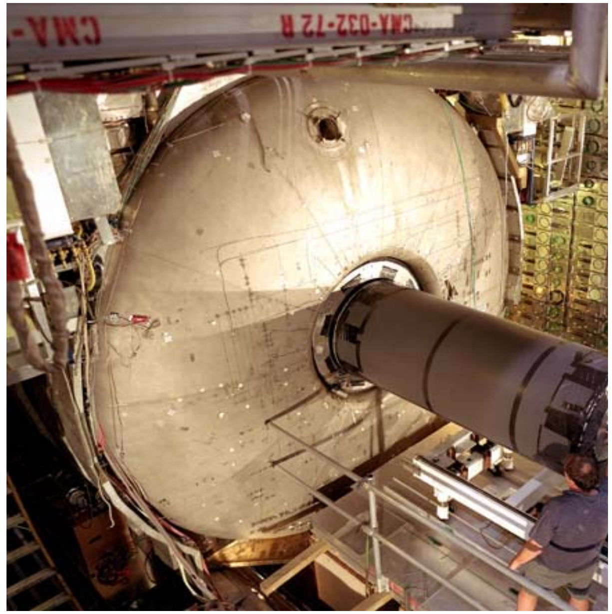
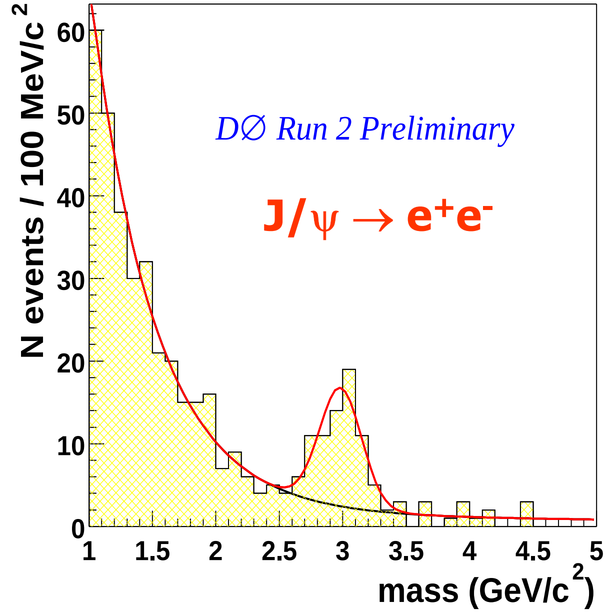
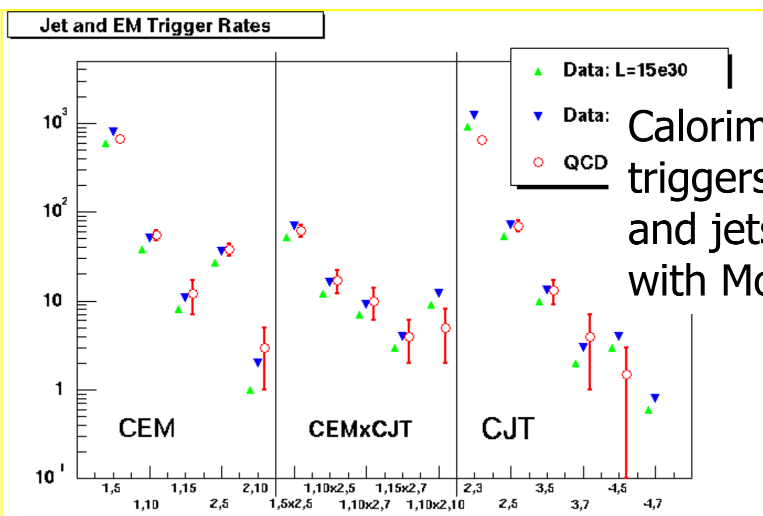
Calorimeter





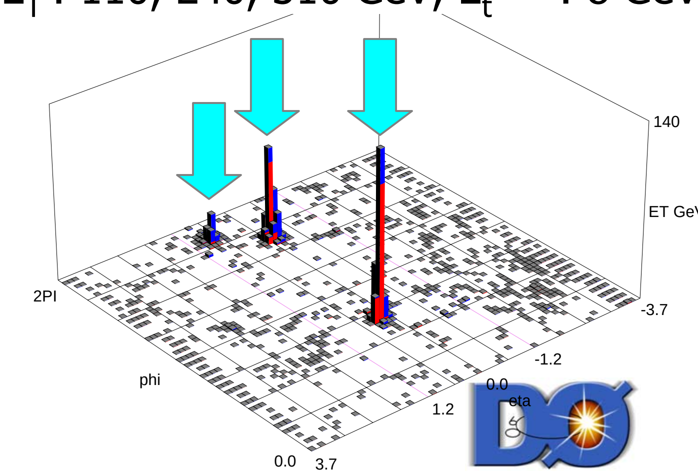




Calorimeter Level 1 triggers for electrons and jets: rates agree with Monte Carlo

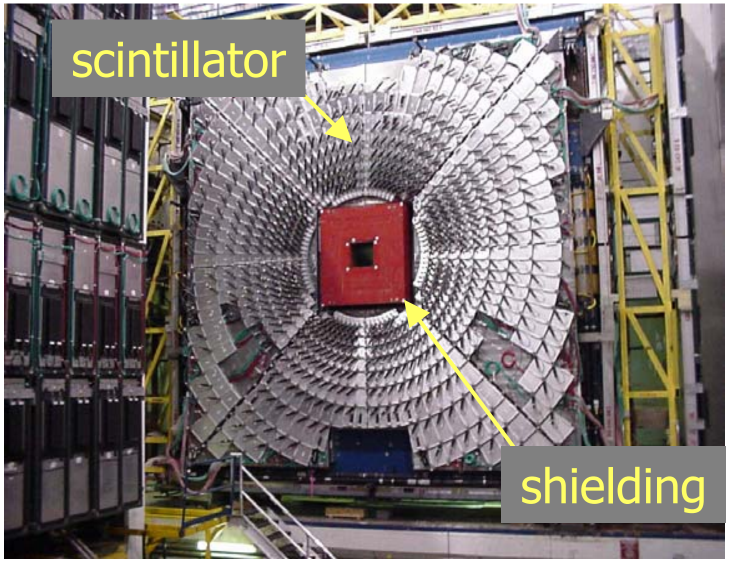
Highest E_T 3-jet event in Run II

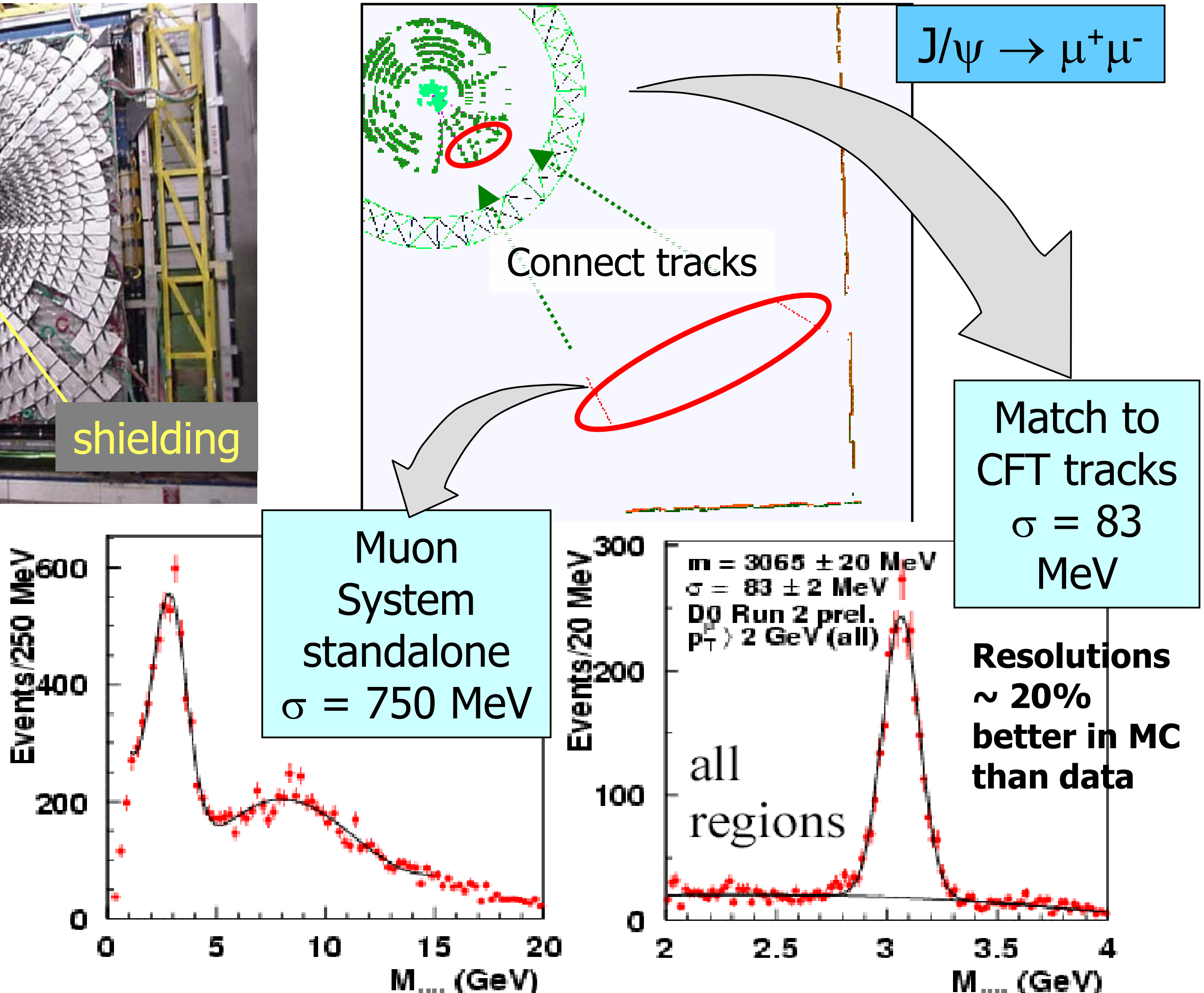
E_T : 110, 240, 310 GeV, E_t^{miss} : 8 GeV

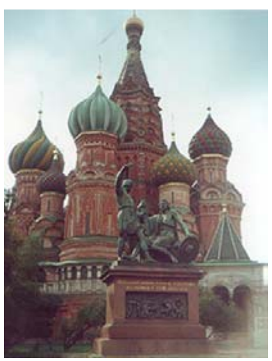


Muon System

- **Three layers of scintillator planes for triggering**
- **Three layers of drift tubes for precise track measurement**







Russian contribution

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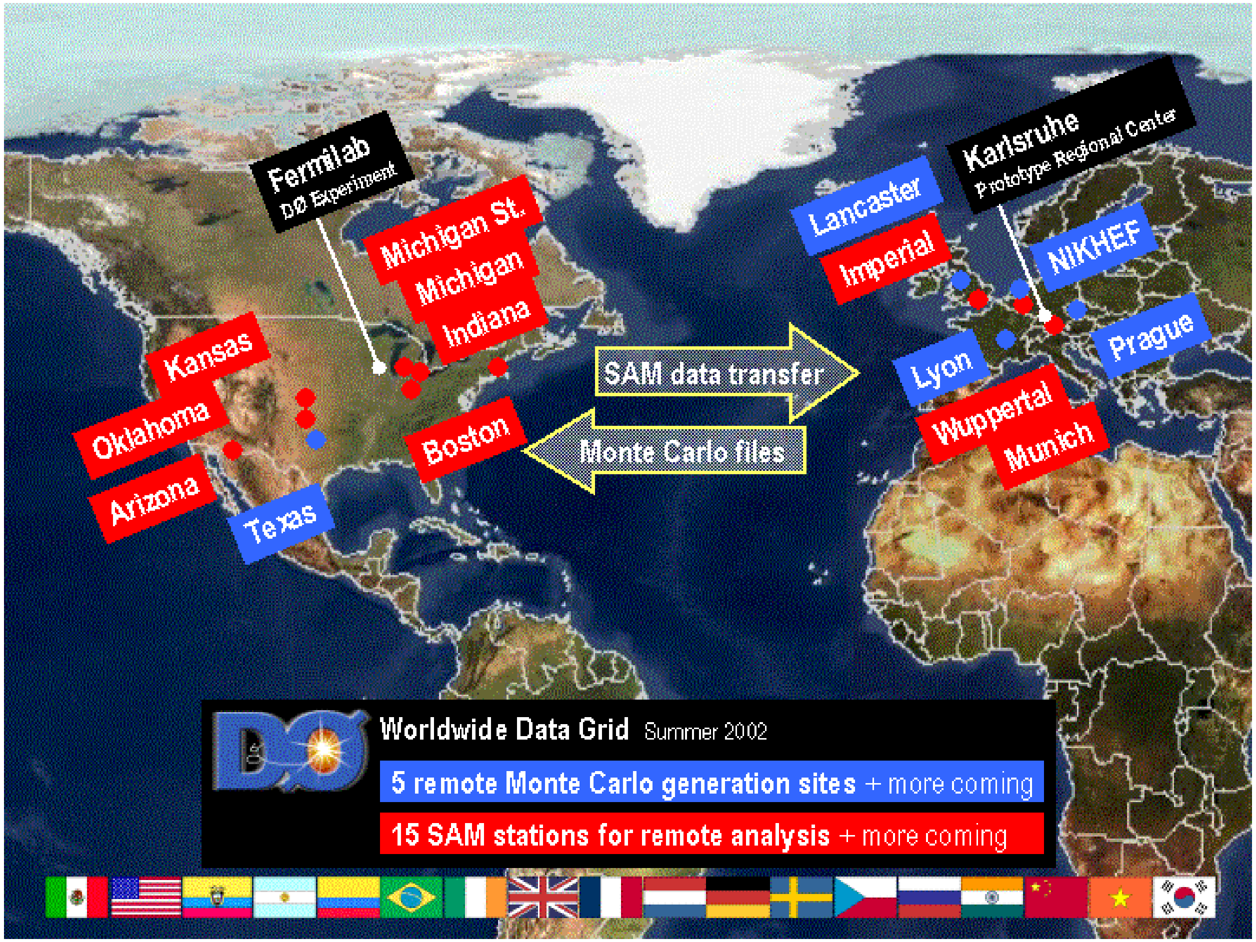
Computing Infrastructure

- "Something like" the Grid is becoming real:
  - SAM data access and distribution now being used by CDF and DØ
  - push towards offsite analysis of Run II data



Our Physics Goals

- **Confront the Standard Model through**
  - **1. The strong interaction**
  - **2. The CKM matrix**
  - **3. Precision electroweak tests**
  - **4. The top quark**
  - **5. The Higgs boson**

- **And directly search for new phenomena not part of the SM**

QCD

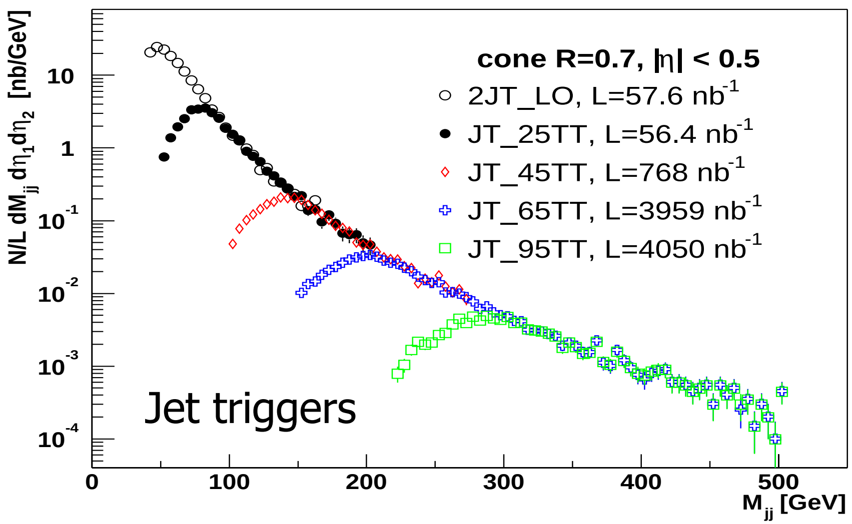
We need to: resolve some outstanding puzzles
understand the backgrounds to new physics

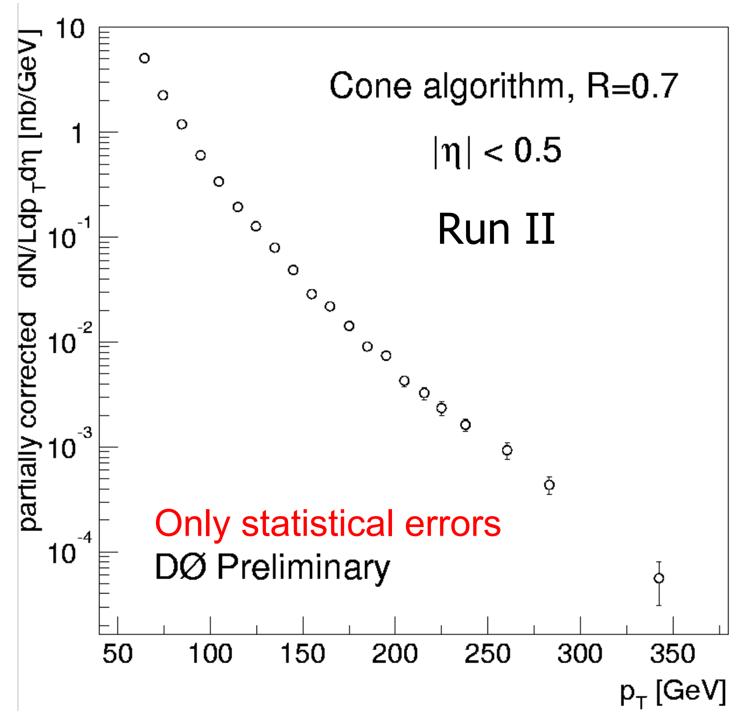
Jets in Run II

Inclusive Run II jet p_T spectrum

Central jets

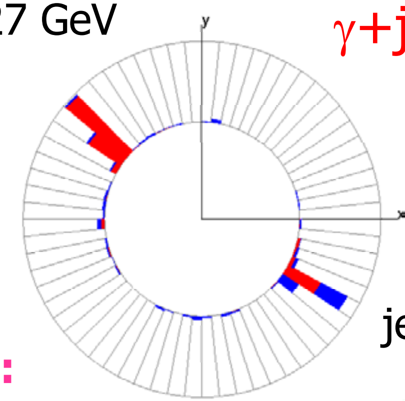
$\sim$ 1.9± 0.2 pb^{-1} at $\sqrt{s}$ = 1.96 TeV





γ E_T=27 GeV

γ+jet Event



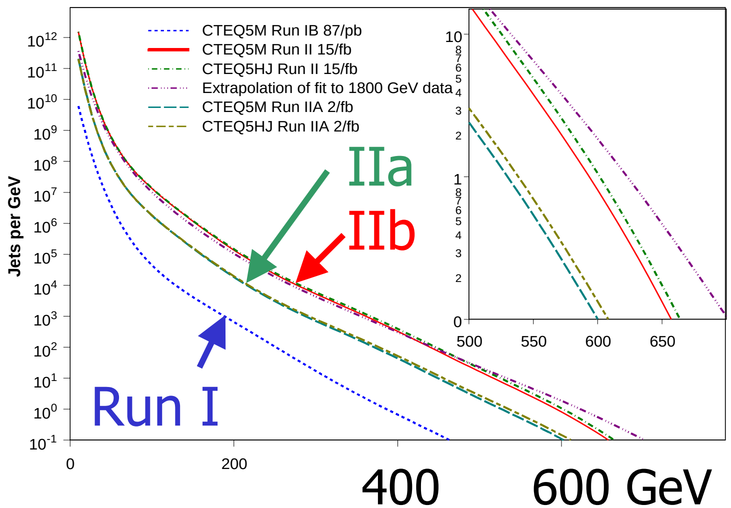
jet E_T=24 GeV

- **Not yet fully corrected**
  - **no resolution or trigger effects**
  - **30-50% systematic error in cross-section**
- **Preliminary correction for jet energy scale is derived from p_T balance in photon + jet events**

EM scale set by Z $\rightarrow$ ee events:

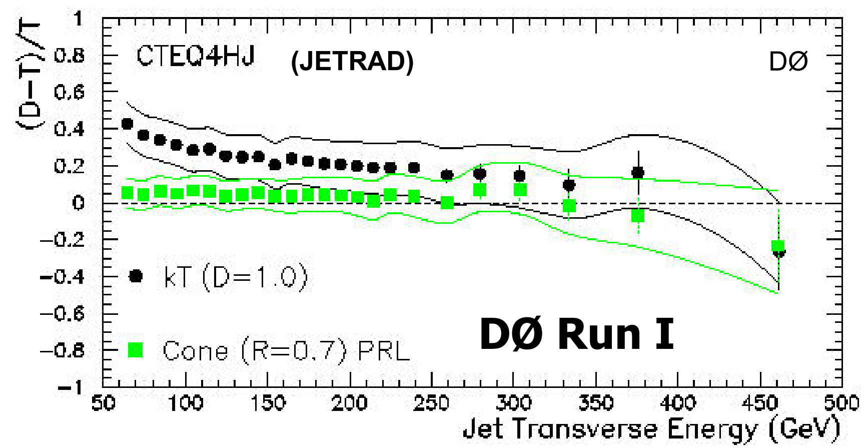
Physics goals for jets

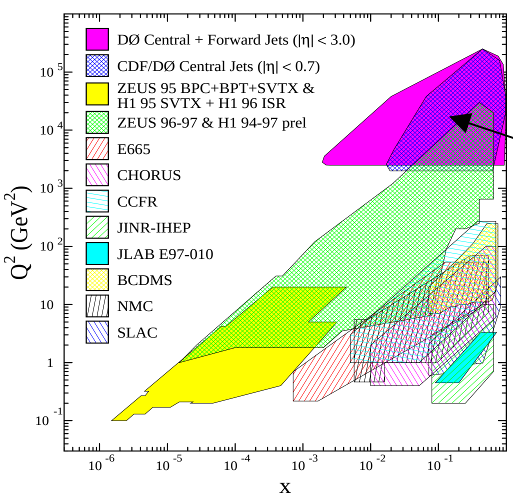
High p_T jets constrain the gluon content of the proton



Much theoretical discussion:

choice of Jet Algorithm for Run II and why $k_T \neq$ cone





DØ Run I jet data already used in CTEQ6 and MRST2001 parton distribution fits
Complement HERA's kinematic range

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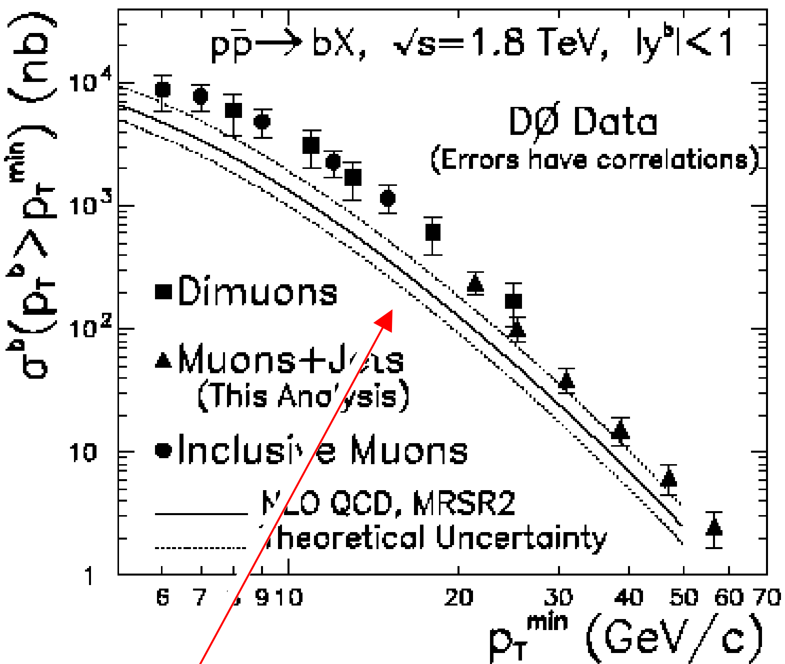
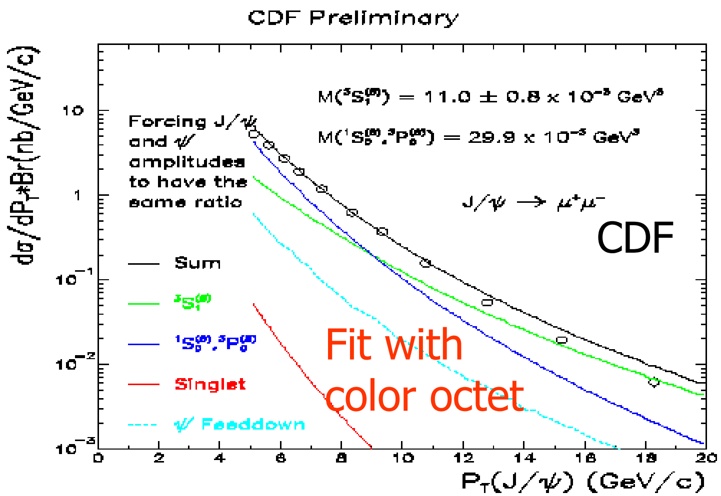
Heavy flavour production

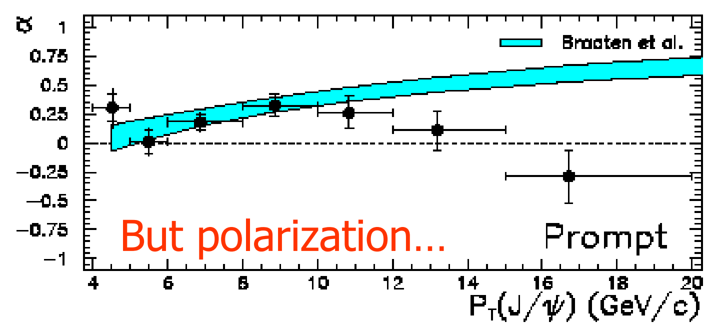
- **Lots of unanswered questions from Run I**
  - **B production cross section**

Charmonium cross section



Can be made to fit better using resummation and retuned fragmentation





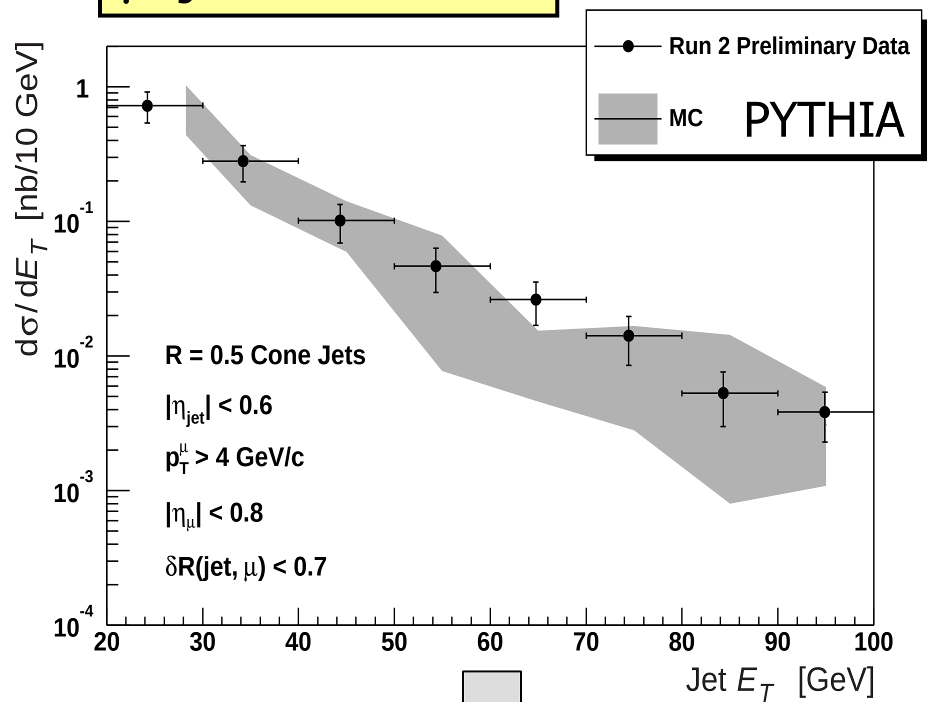
Polarization is determined from angle of μ^+ emitted in J/ψ rest frame

Heavy Flavour Production in Run II

results from ~ 5 pb^{-1}

J/ψ cross section as a function of η

μ+jet cross-section

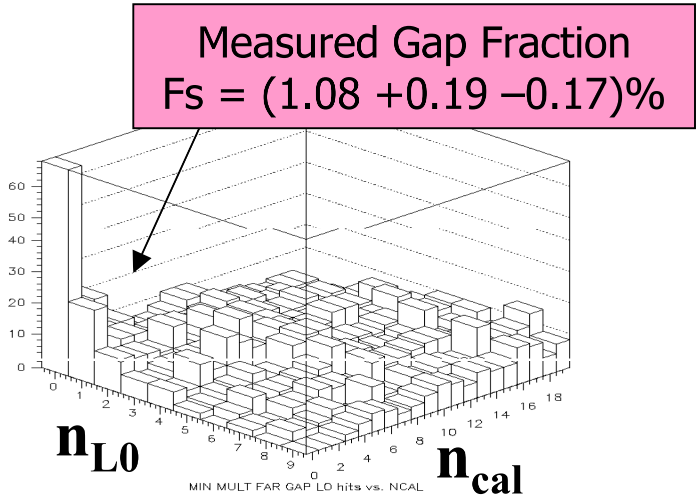


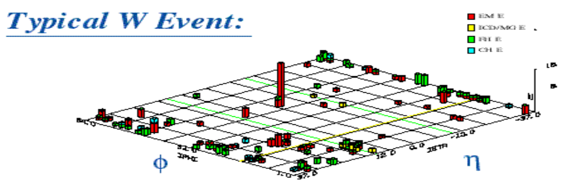
measure polarization
test production mechanism

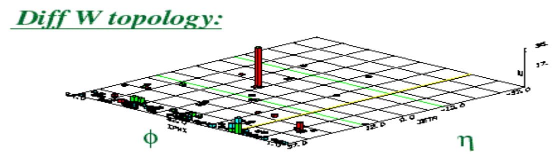
Determine b-jet cross-section
including high p_T behavior

Diffractive W production

- **New (Run I) diffractive W signal:**





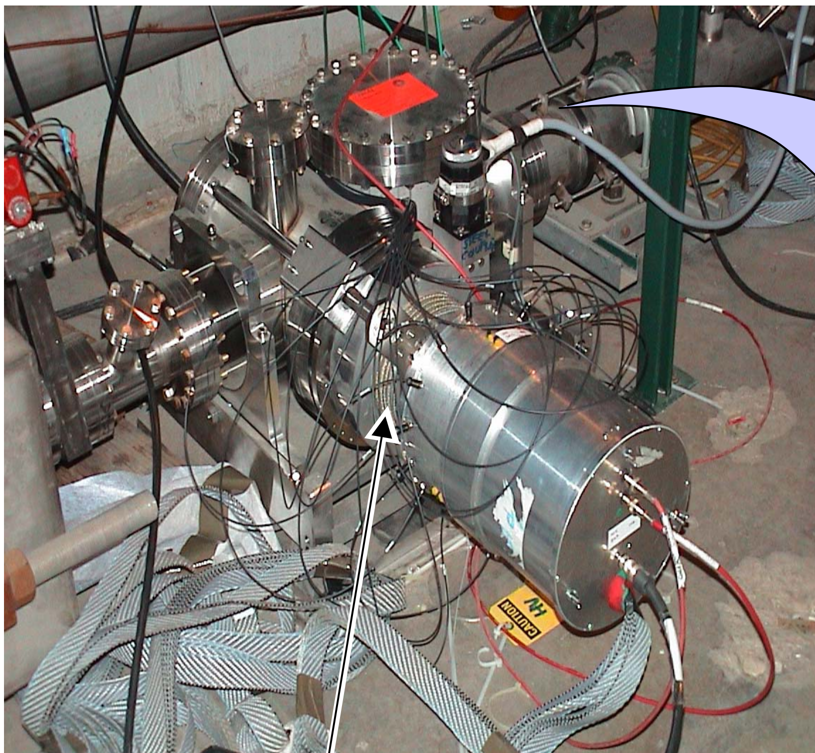


- **If a rapidity gap really implies diffraction, how can it be that we can kick a parton out of a proton with $Q^2 = m_W^2$ and not destroy the proton in the process?**
  - **And do this 10% of the time?** *(1% rate, 10% survival probability)*
  - **What does this tell us about the colour content of the proton?**
- **How do we relate gaps to the "normal" underlying event?**
  - **Is a rapidity gap an underlying event as particle/energy flow → 0?**
  - **Or one possible colour configuration? (or is that the same thing?)**

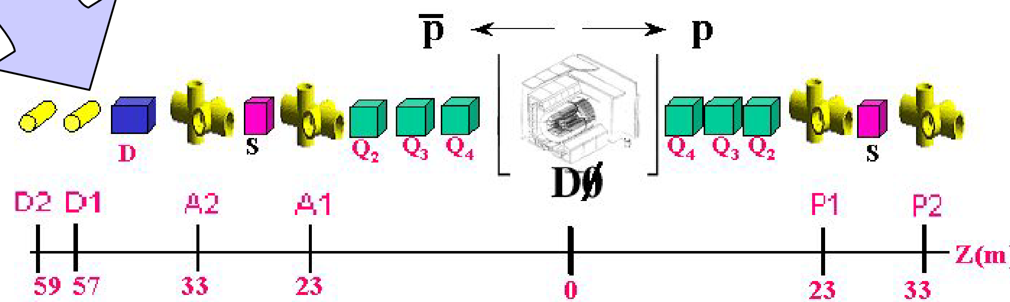
Forward Proton Detector

- **New instrumentation for Run II:**
  - **Roman pots at z = ± 23, 33, 57, 59m, plus veto counters to cover 2.5 < |η| < 6**

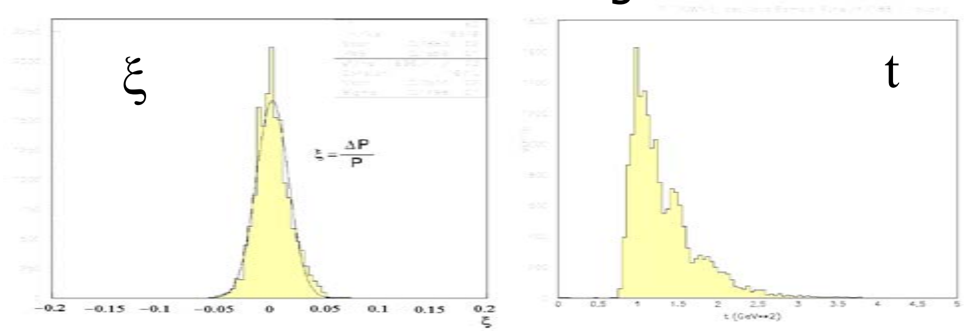
Brazilian contribution



Scintillating fiber detector inside



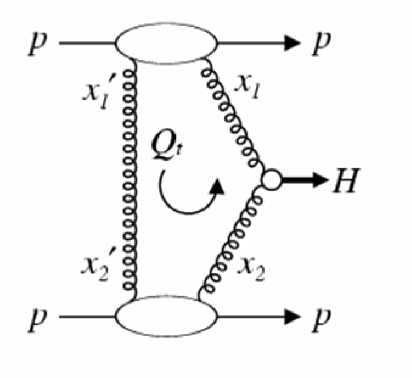
Elastic scattering data



Diffraction in Run II

Some physics goals *for the "Pomeron skeptical"*

- **Measure the gap survival probability: relate rapidity gaps to diffractive (anti-)protons seen in Roman Pots**
- **Measure $\bar{p}p \rightarrow \bar{p}$ (gap) jj (gap) p**
  - **Will provide a sanity check for "loose talk of Higgs production" at the LHC**



Khoze, Martin & Ryskin predict S/B > 1 for m_H = 115 GeV includes gap survival factor 1/50

BUT other authors say it's impossible (e.g. Schlein)

Published cross section estimates cover 3 orders of magnitude

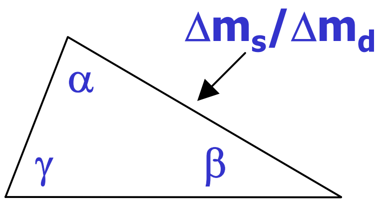
CKM Physics

Confront the unitarity triangle in ways that complement measurements at the e^+e^- B-factories

e.g. through the B^0_s system . . .

B-physics at Hadron Colliders

- CP violation established in the B system through $B_d \to J/\psi\ K_S$
  - $\sin\phi_d = 0.734 \pm 0.054$
    - Either $\phi_d = 47°$ (2β in SM) or 133° (new physics)
- BaBar and BELLE will do much more with their data e.g.
  - Is $B \to \pi K$ consistent with SM $\gamma < 90°$?
  - Same mixing asymmetry in $B_d \to J/\psi\ K_S$ and $B_d \to \phi\ K_S$?
  - $B_d \to \pi\ \pi$ will be an important piece of the puzzle
- For hadron colliders (first CDF and DØ, then BTeV and LHCb) the B_S system is the "El Dorado"
  - Mixing parameters Δm_s, $\Delta\Gamma_s$
    - $x_s = \Delta m_s / \Gamma_s > 20$ (LEP)
  - Sizeable CP violation in $B_S \to J/\psi\ \phi$?
  - $B_S \to KK$ complements $B_d \to \pi\ \pi$; $\to$ extract γ
  - $B_S \to D_S K$: extract $\phi_S + \gamma \to \gamma$

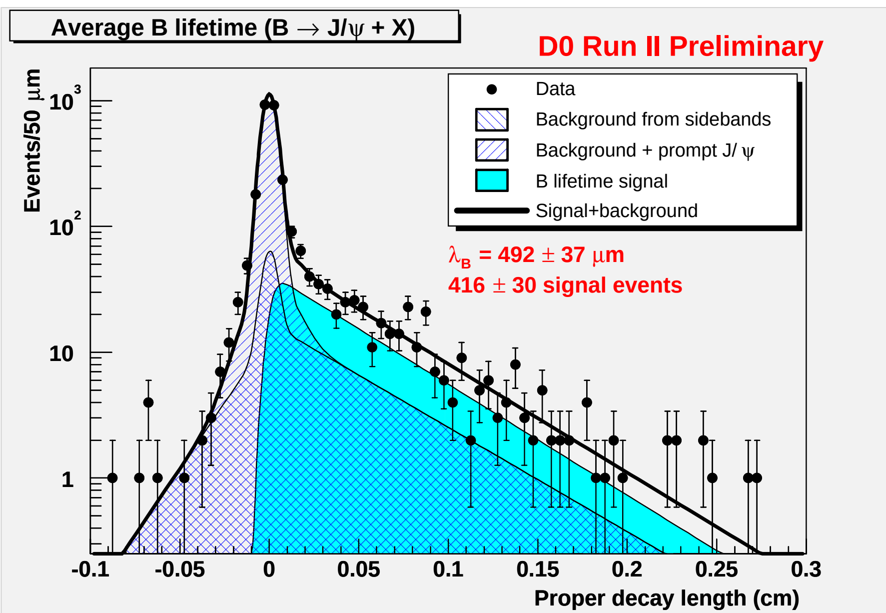


- Many other interesting topics e.g.
  - Rare decays e.g. $B \to K^*\mu^+\mu^-$, $B_{s,d} \to \mu^+\mu^-$

B Physics at DØ in Run II

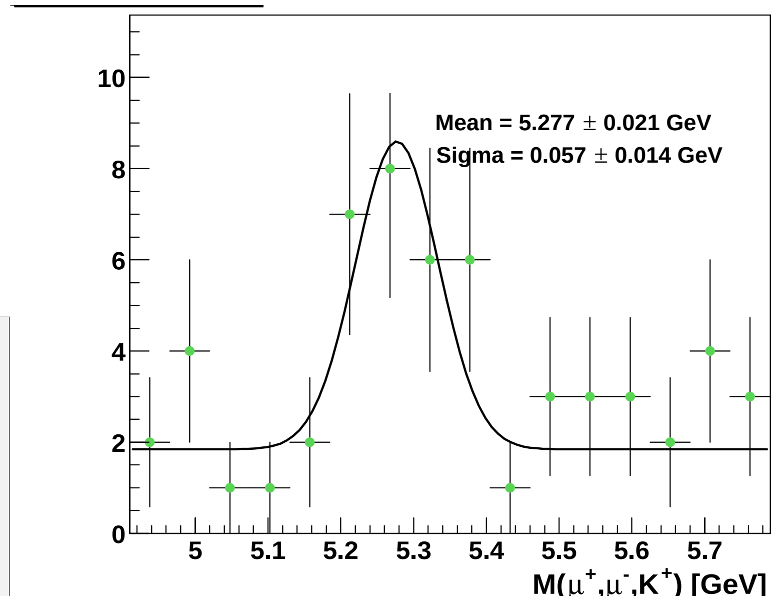
Putting the tools in place:

- $J/\psi \rightarrow \mu^+\mu^-$
- $J/\psi \rightarrow e^+e^-$
- $K_S \rightarrow \pi^+\pi^-$
- B tagging
  - muons
  - electrons (working on it!)
  - displaced vertices



$\tau(B) = 492 \pm 37\ \mu m$

DØ's First B mesons: $B \rightarrow J/\psi K^\pm$



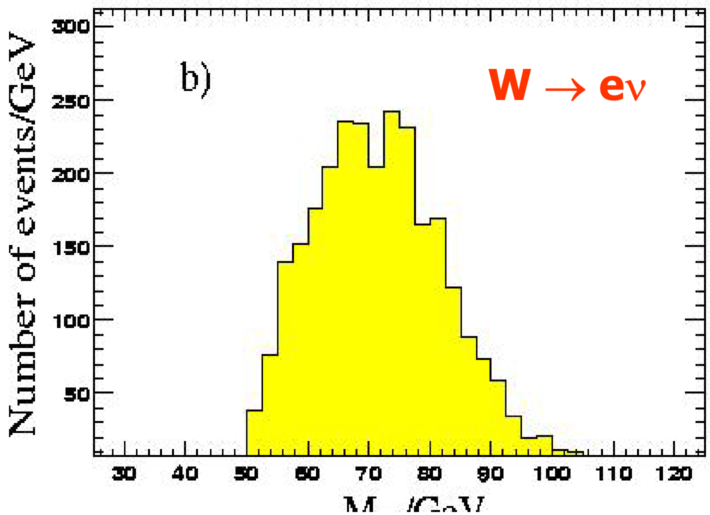
DØ cannot exploit purely hadronic triggers, but benefits from large muon acceptance, forward tracking coverage, and ability to make use of $J/\psi \rightarrow e^+e^-$

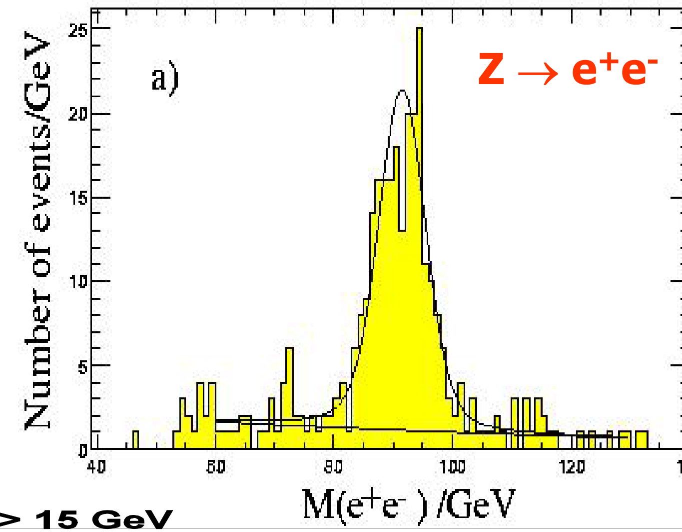
Electroweak Physics

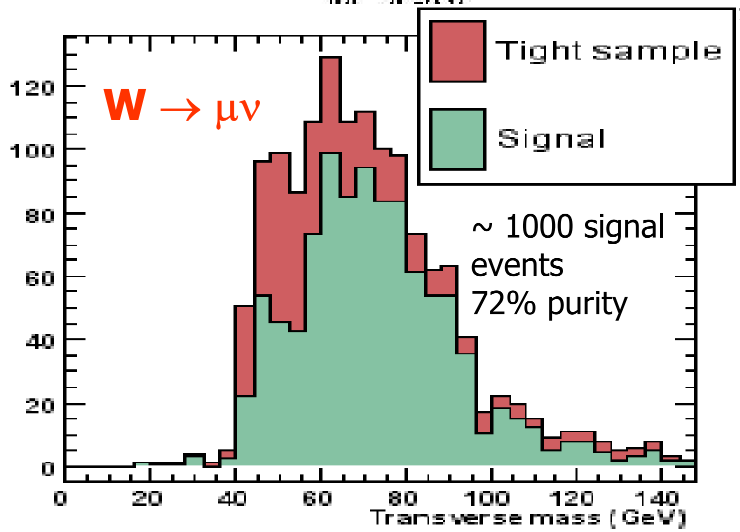
Indirectly constrain new physics through precision measurements of electroweak parameters

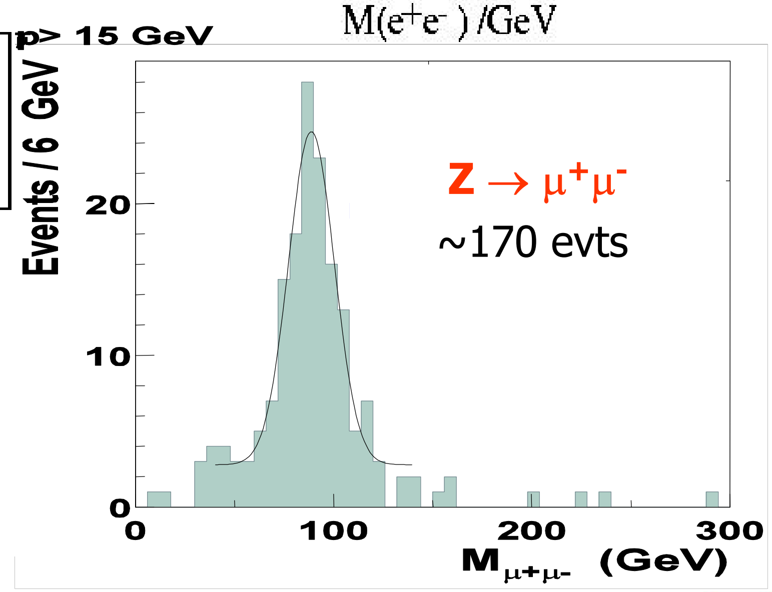
Especially m_W

W and Z bosons at DØ



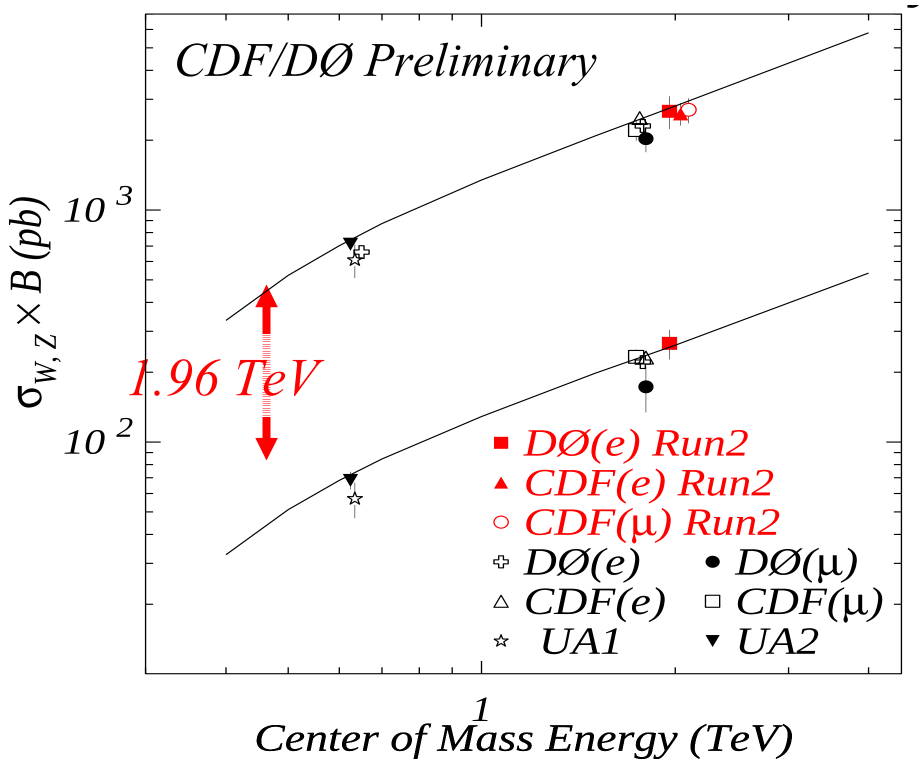






John Womersley

W and Z cross sections at new √s

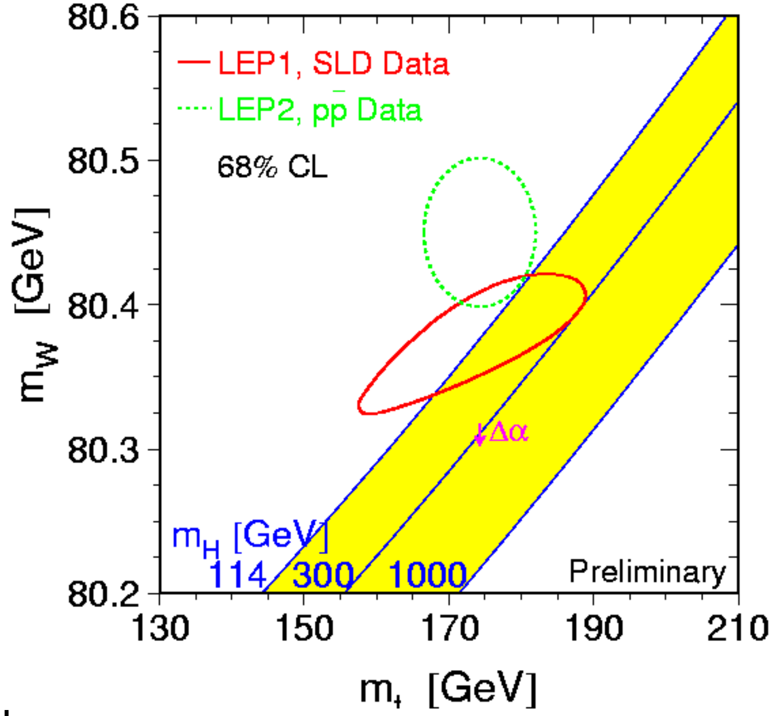


- $\sigma \cdot B\ (W \rightarrow e\nu) = 2.67 \pm 0.06\ (stat) \pm 0.33\ (sys) \pm 0.27\ (lum)$ nb
- $\sigma \cdot B\ (Z \rightarrow ee) = 266 \pm 20\ (stat) \pm 20\ (sys) \pm 27\ (lum)$ pb
- $R_e = 10.0 \pm 0.8\ (stat) \pm 1.3\ (sys)$
- $\Gamma_W = 2.26 \pm 0.18\ (stat) \pm 0.29\ (sys) \pm 0.04\ (theory)$ GeV

Prospects for electroweak measurements

Current knowledge of m_W

- **DØ:**
  - **80 483 ± 84 MeV**
- **hadron colliders:**
  - **80 454 ± 59 MeV**
- **world:**
  - **80 451 ± 33 MeV**



Run II prospects (per experiment)

	Δm_W
2 fb^{-1}	**±27 MeV**
15 fb^{-1}	**±15 MeV**

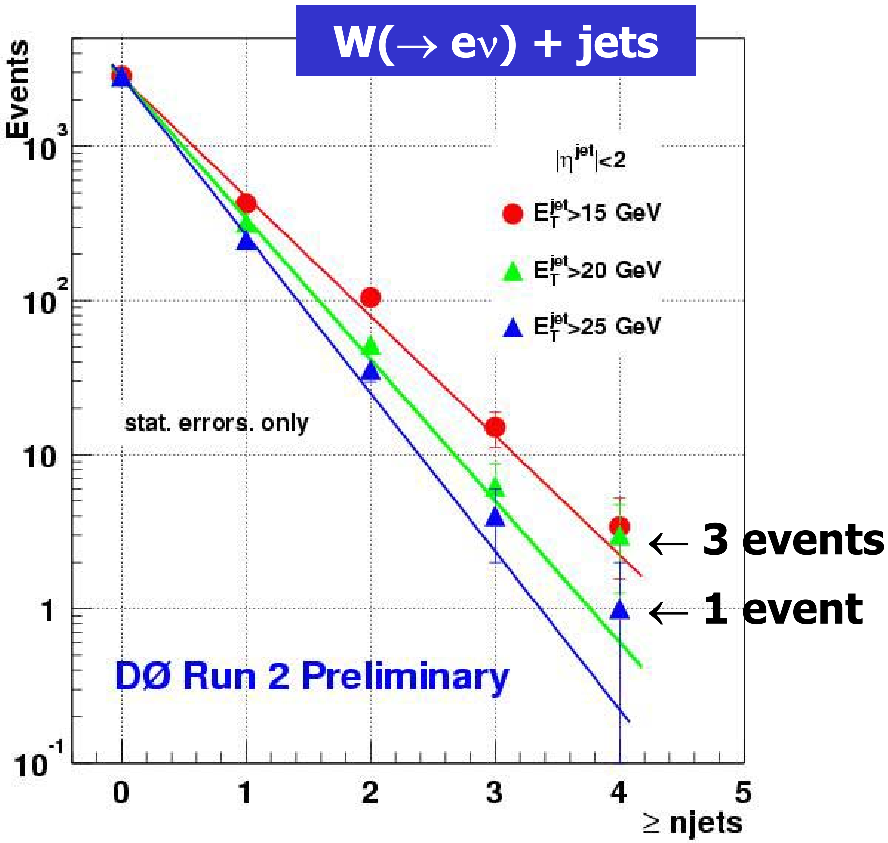
To improve on LEP wil require ~ fb^{-1} datasets
Clearly not a short term goal

- **We will also measure forward-backward asymmetry in Z production, multiboson production, boson + jets, …**

The Top Quark

Measure its properties with greatly increased statistics

The Top Quark at DØ



- **W→ eν + jets scaling in Run IIa data: a school figure on the way to re-discovering top**

Improved top mass measurements will help to constrain the Higgs mass:

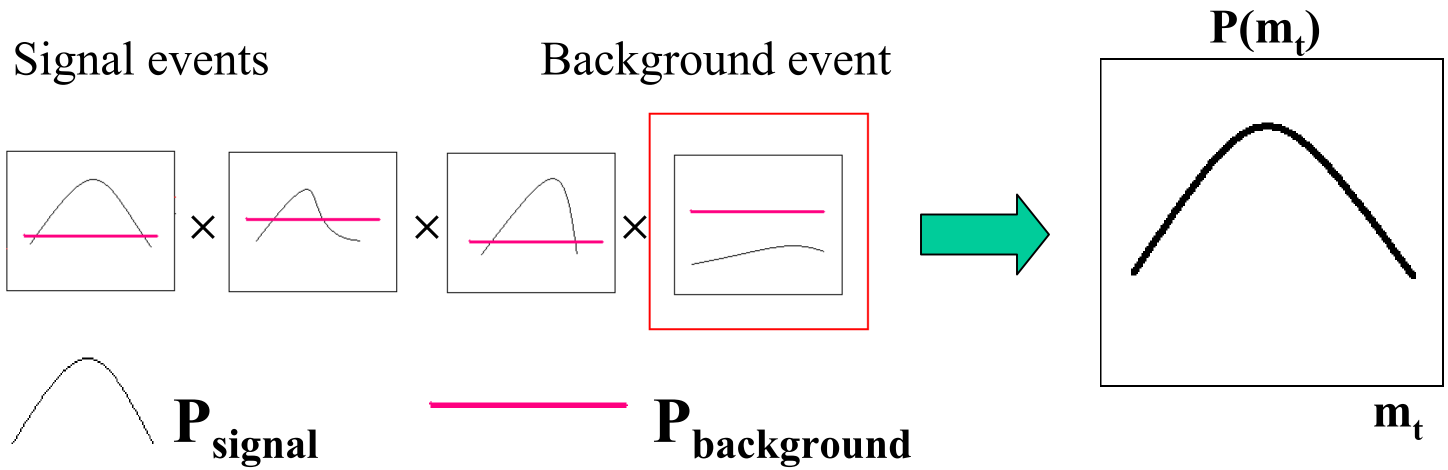
	Δm_t
2 fb^{-1}	± 2.7 GeV
15 fb^{-1}	± 1.3 GeV

In contrast to the W, we can look forward to improved precision on m_t in the near future

- More data (few hundred pb^{-1})

- Improved techniques

A new measurement of the top mass



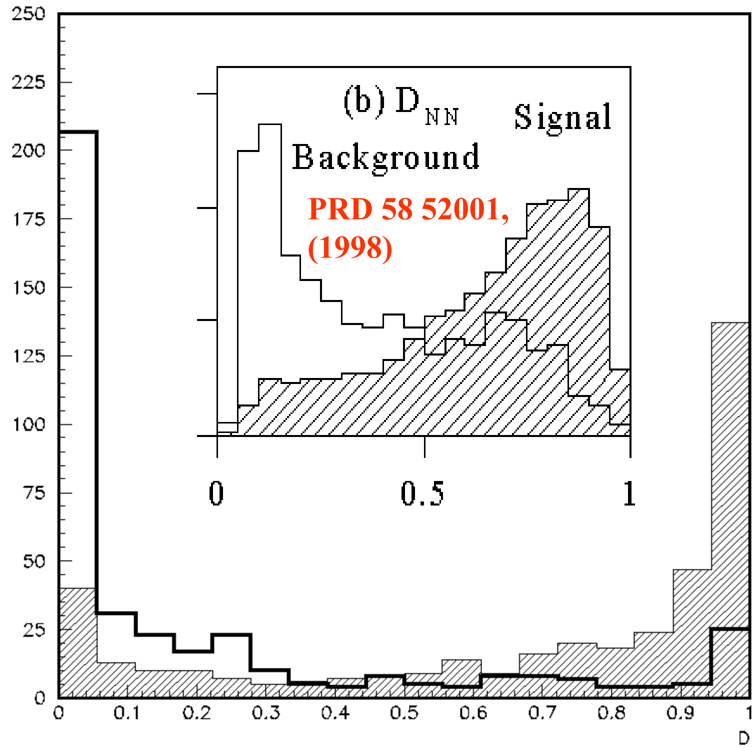
For each event, signal and background probabilities are added. The probabilities for individual events are then multiplied together.

- **Uses all measured quantities per event and their errors**
  - **consider all 12 jet combinations, all neutrino momenta**
    - **Analogous to Kondo, Dalitz, Goldstein technique as used for the top dilepton sample**
- **Run I dataset**

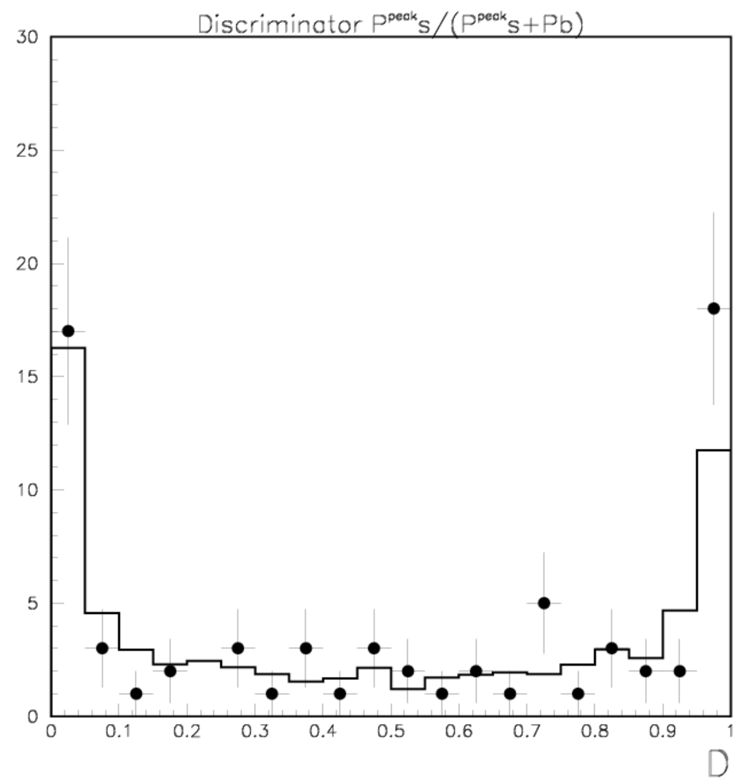
For more details: see J. Estrada, in Proceedings of HCP 2002 (in preparation)

Signal/background discrimination

- **Define D = $P_S/(P_S+P_B)$**
  - **No cut on this variable, but demonstrates improved discrimination compared to our 1998 analysis**

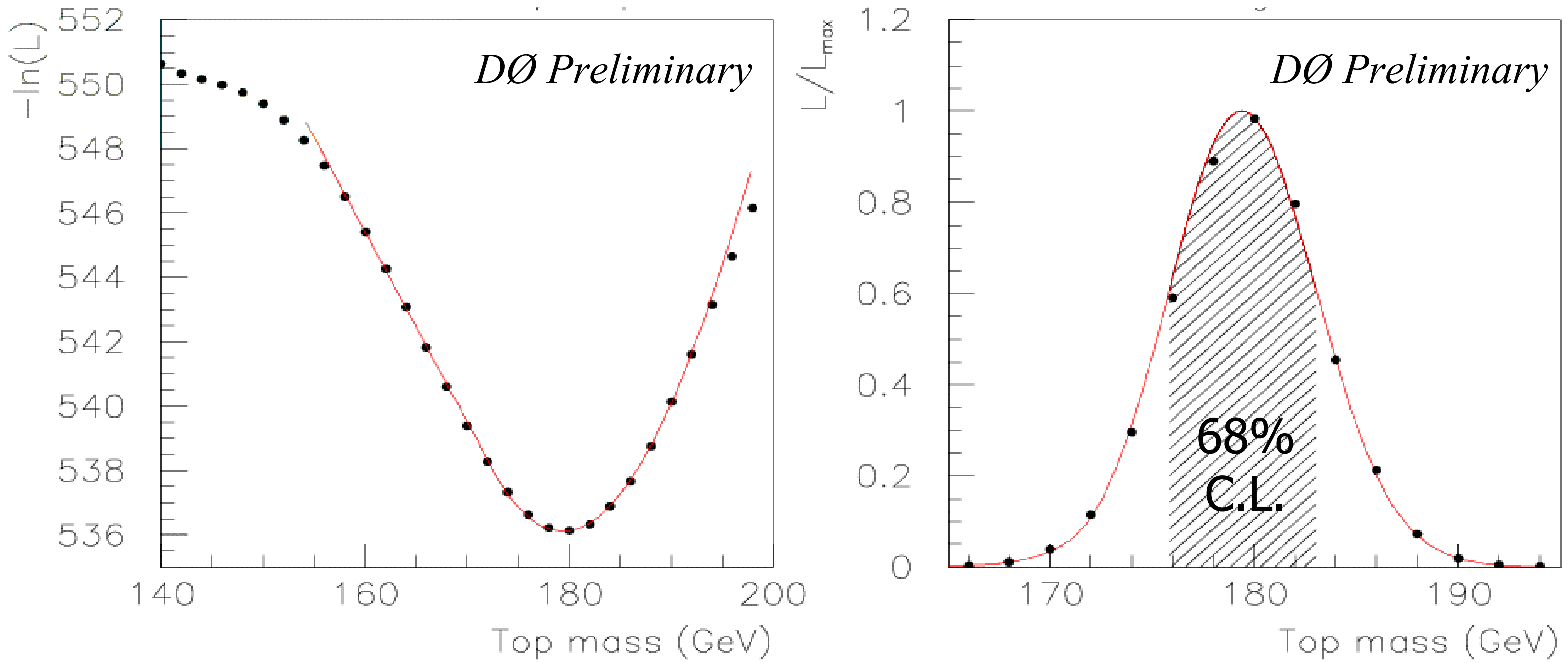


Signal and background MC



Data and expected sum of signal and background

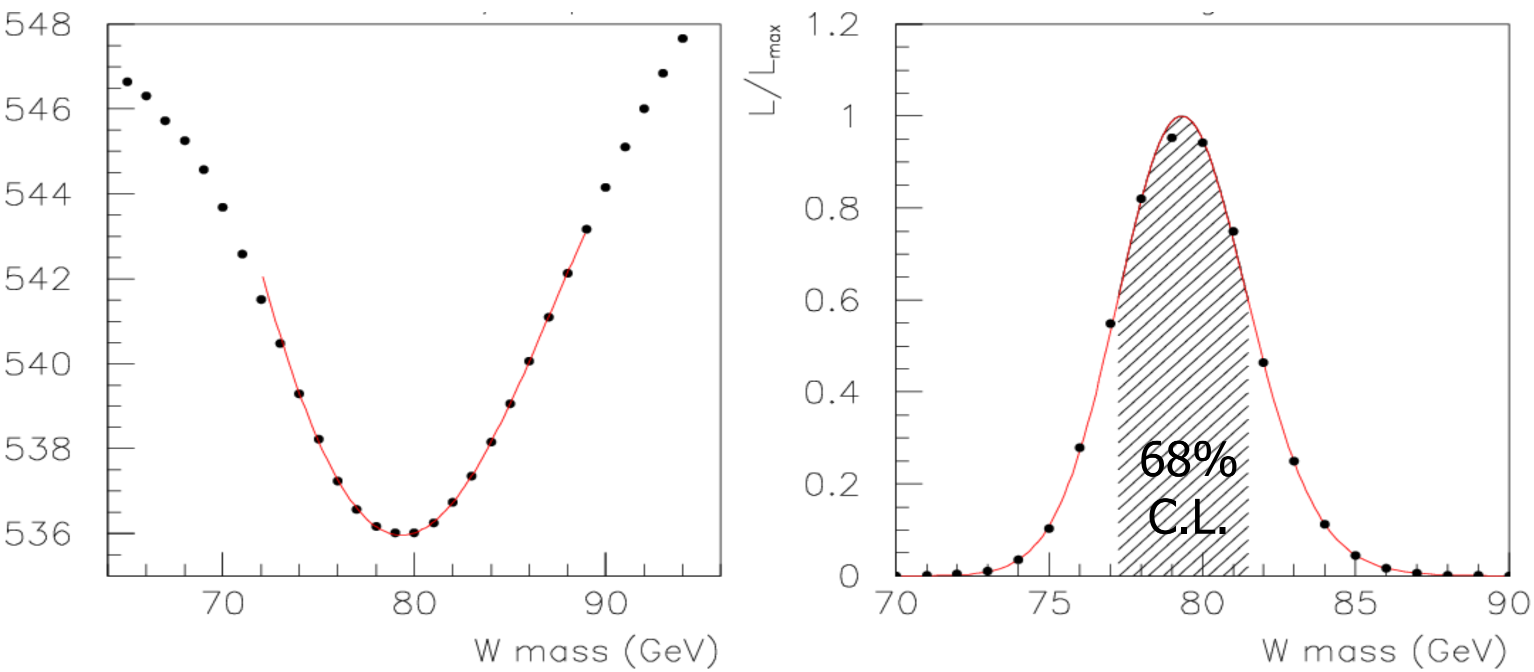
New Preliminary Top Mass



m_t= 179.9 ± 3.6 (stat) ± 6.0 (sys) GeV *preliminary*

- **Improves statistical error from 5.6 GeV [PRD 58 52001, (1998)] to 3.6 GeV: equivalent to a factor of 2.4 in the number of events**
- **22 events pass final cuts (from fit: 12 S + 10 B)**

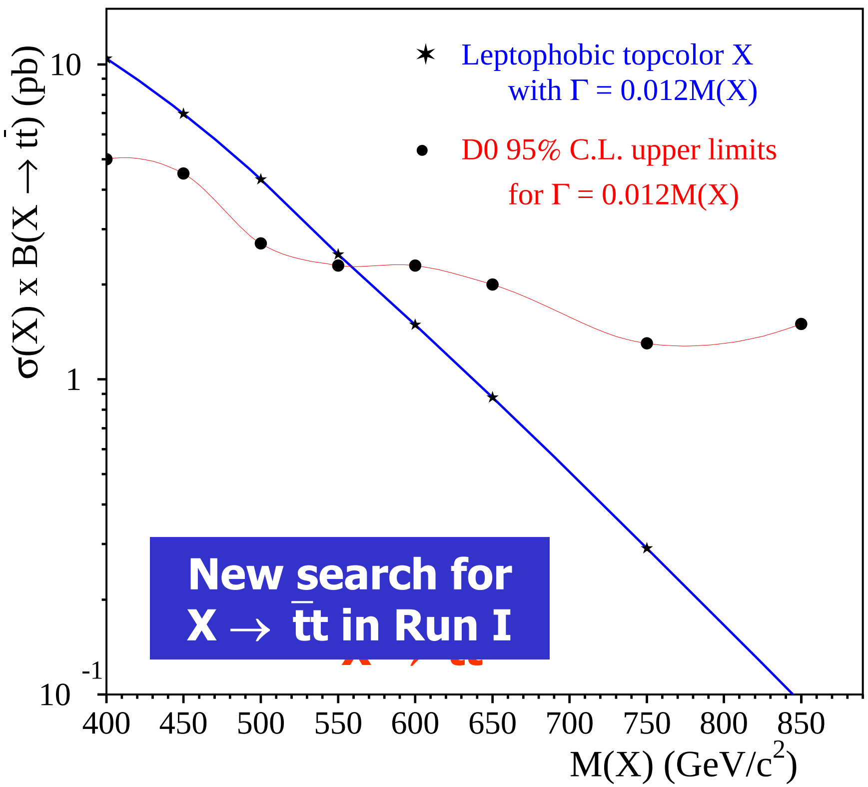
Systematic error



- **Dominant systematic uncertainty on m_t derives from the jet energy scale**
  - **5.6 GeV (out of a total systematic error of 6.0 GeV)**
  - **Will try to reduce this by using the reconstructed W mass in the same sample as a calibration**

Top as a window on new physics

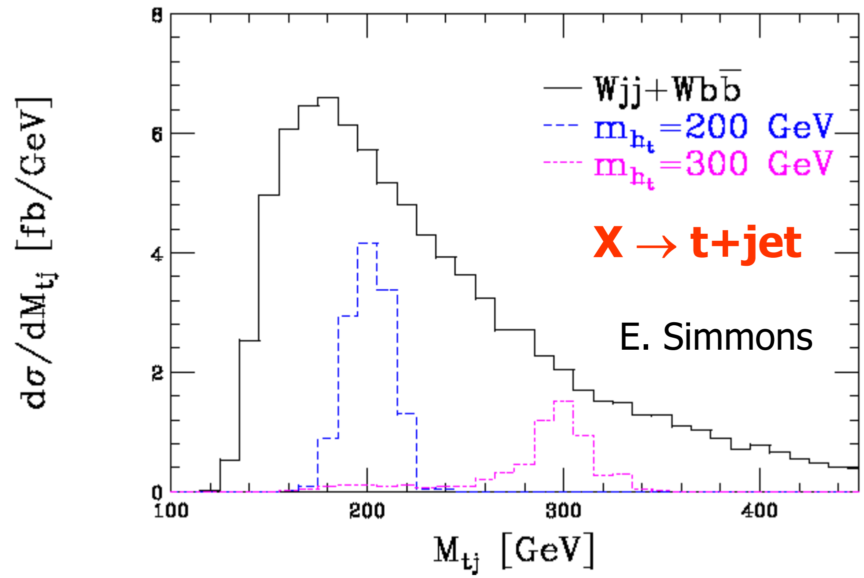
Can top provide insight into electroweak symmetry breaking?



- **Exclude a narrow, leptophobic X boson with m_X < 560 GeV/c^2**

BSM theories predict unusual top properties and states visible in Run II

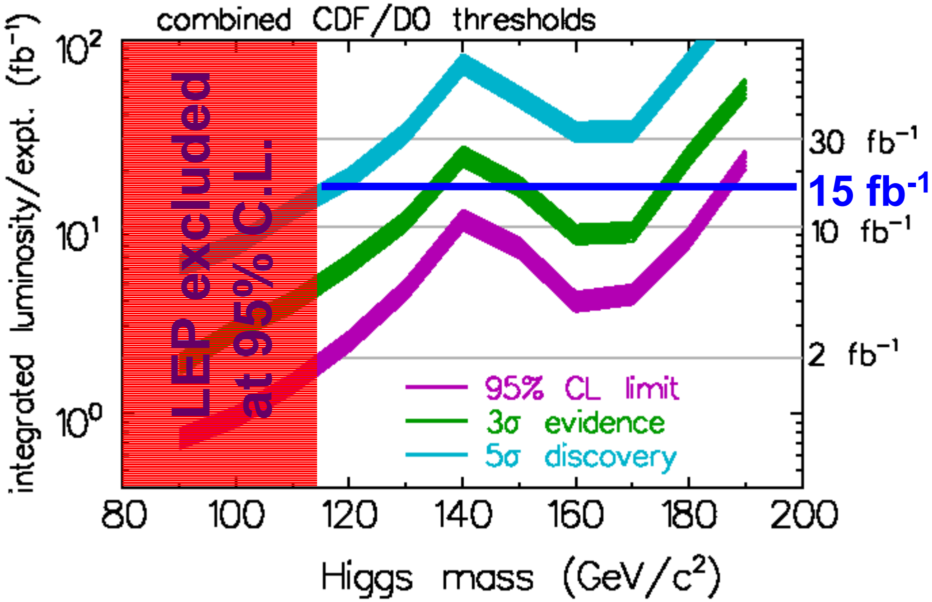
- **Z′ (analysis of Run I data at left)**
- **top-higgs with FC decays (simulation below)**



The Higgs Boson

Discover (or exclude)
Constrain its properties

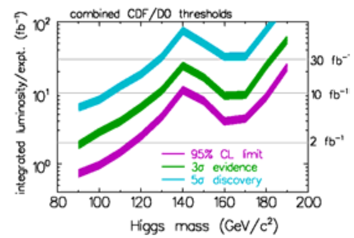
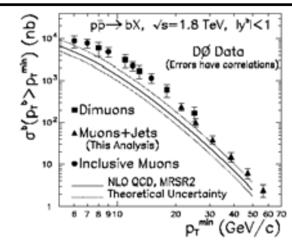
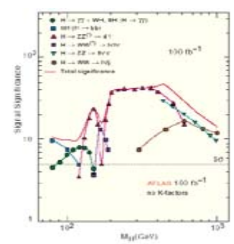
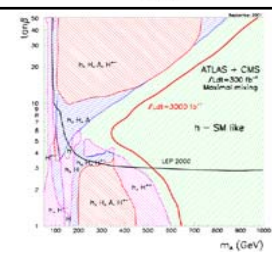
The Higgs boson at the Tevatron



- **Remember, this assumes**
  - **Two experiments (OK)**
  - **Resolutions at least as good as Run 1**
  - **Good b-jet and lepton identification**
  - **Trigger efficient at high luminosities**
  - **Good understanding of all the backgrounds**

What the experiments are working on

Just for fun: plots shown at HCP 2002

	Plot	Number of showings
Tevatron Higgs reach		**8**
Tevatron B cross section		**6**
LHC Higgs sensitivity		**5**
LHC SUSY Higgs m_A, tan β		**3**

Searches

Find evidence for phenomena outside the SM
Improve constraints on such theories

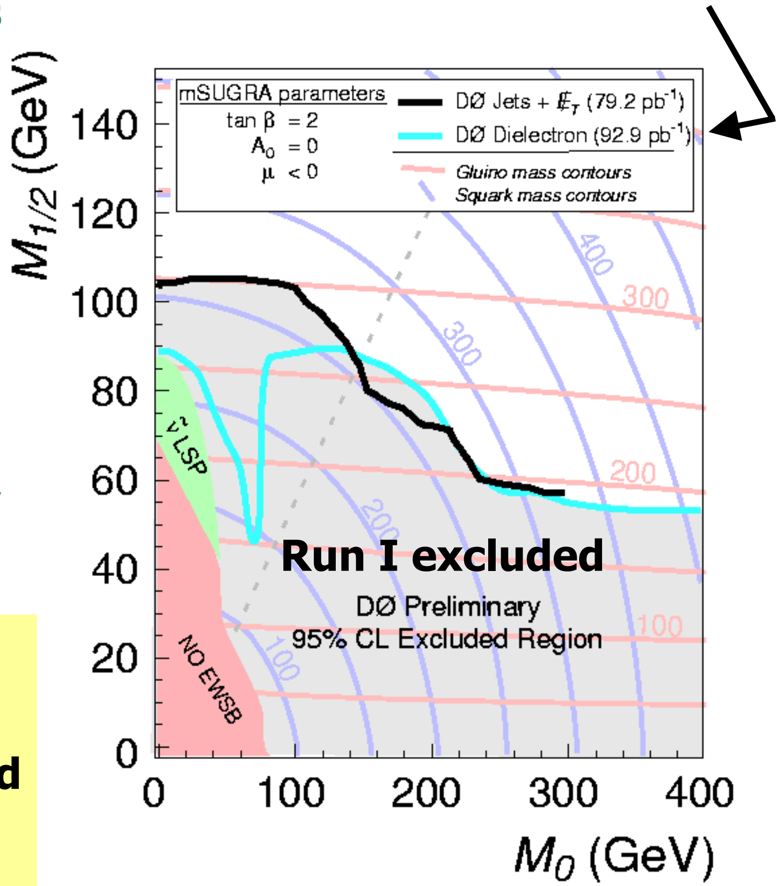
Searches at the Tevatron

- **In Run I, CDF and DØ carried out extensive searches for SUSY**
  - **Squarks/gluinos → Missing E_T + jets (+ lepton(s))**
  - **Charginos/neutralinos → multileptons**
  - **GMSB → Missing E_T + photon(s)**
  - **Stop, sbottom**
  - **RPV signatures**
- **Searches for other new phenomena**
  - **leptoquarks, dijet resonances, W′,Z′, massive stable particles, extra dimensions . . .**

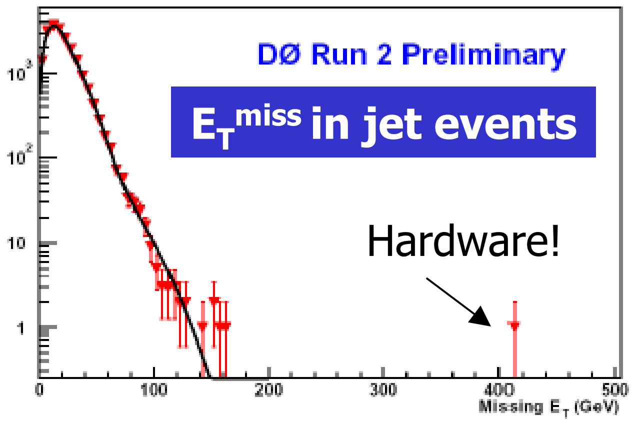
No sign of new physics

DØ analysed 32 final states containing electrons, muons, photons, jets, W's, Z's and missing E_T
Find an 89% CL for agreement with the Standard Model *(PRD 64 012004)*

Run II prospect: gluino mass ~ 400 GeV

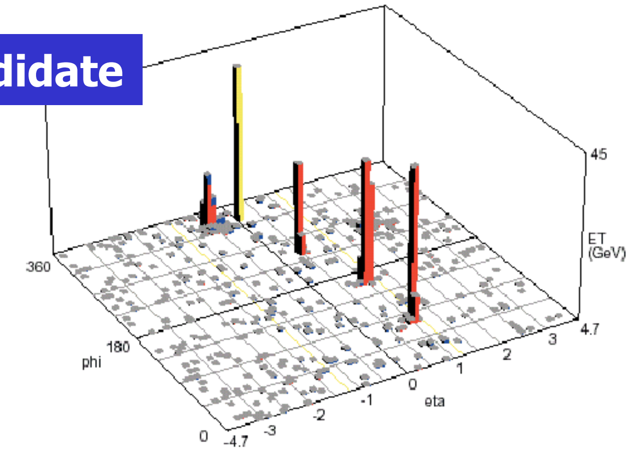


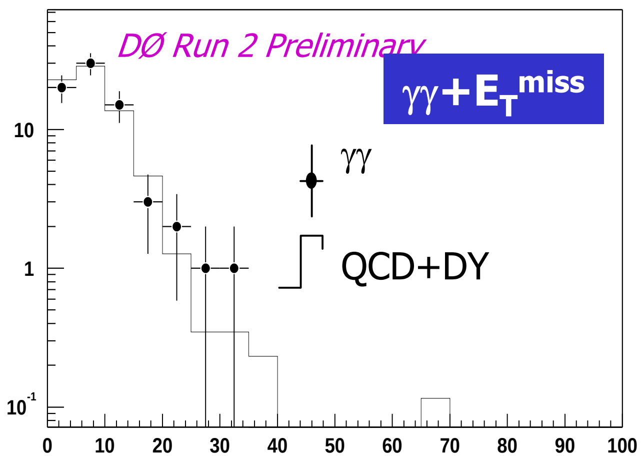
SUSY searches in Run II



Missing Transverse Energy

Trilepton candidate





Missing Transverse Energy

First Run II SUSY limit

Gauge mediated SUSY $p\bar{p} \rightarrow \gamma\gamma+E_T^{miss}$

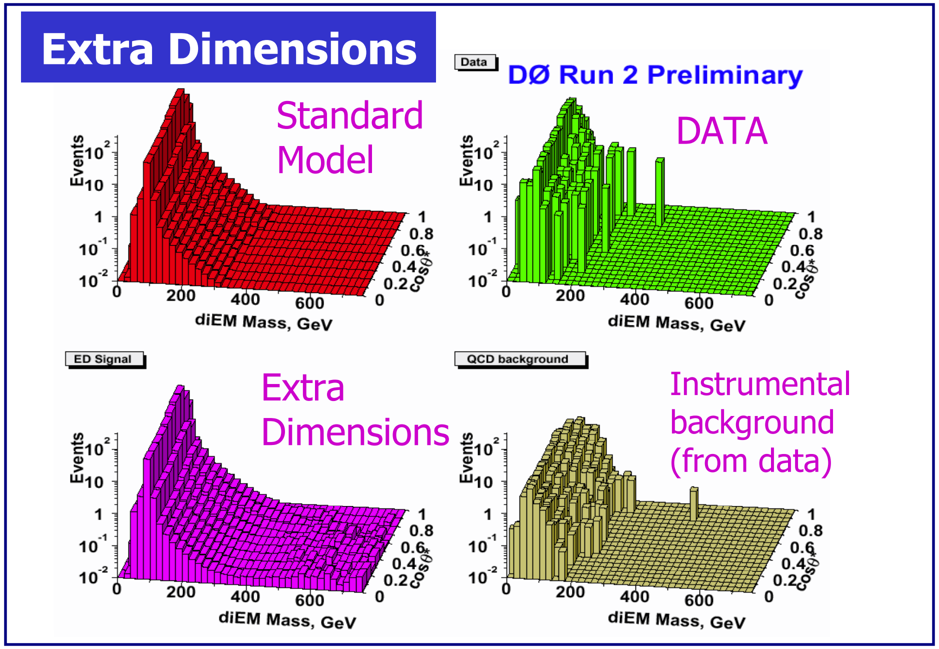
Cross section for $\gamma\gamma+E_T^{miss}$ > 0.9pb

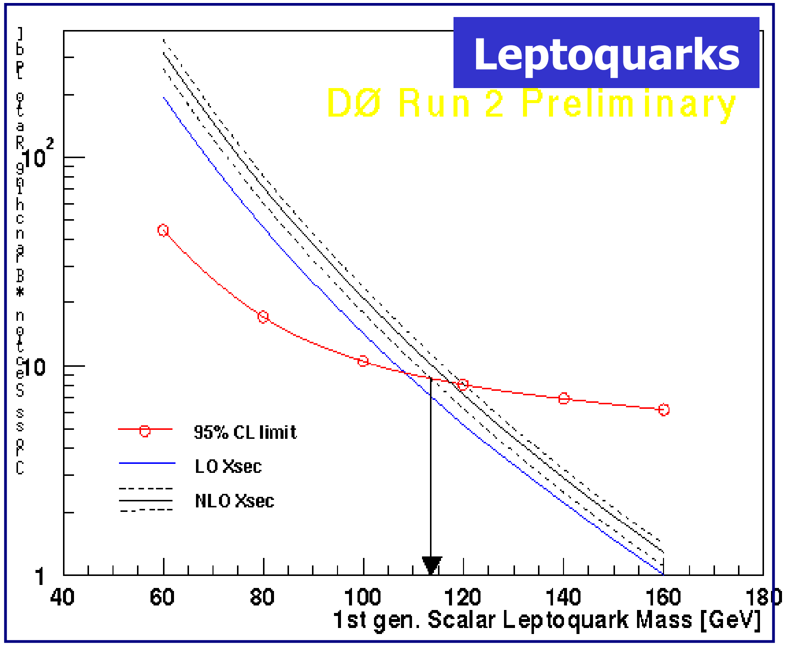
Run II limits are not yet competitive, but show we are ready for this physics

Run II students are graduating

John Womersley

Other new phenomena in Run II





Run II limits from $\bar{p}p \to ee, \mu\mu, \gamma\gamma$

M_S(GRW) > 0.92 TeV (ee/$\gamma\gamma$)

M_S(GRW) > 0.50 TeV ($\mu\mu$)

(first limit from a hadron collider in this channel)

First generation leptoquark Run II mass limit

M_{LQ} > 113 GeV for B(LQ $\to$ ej) = 1

John Womersley

Our future

Short term prospects

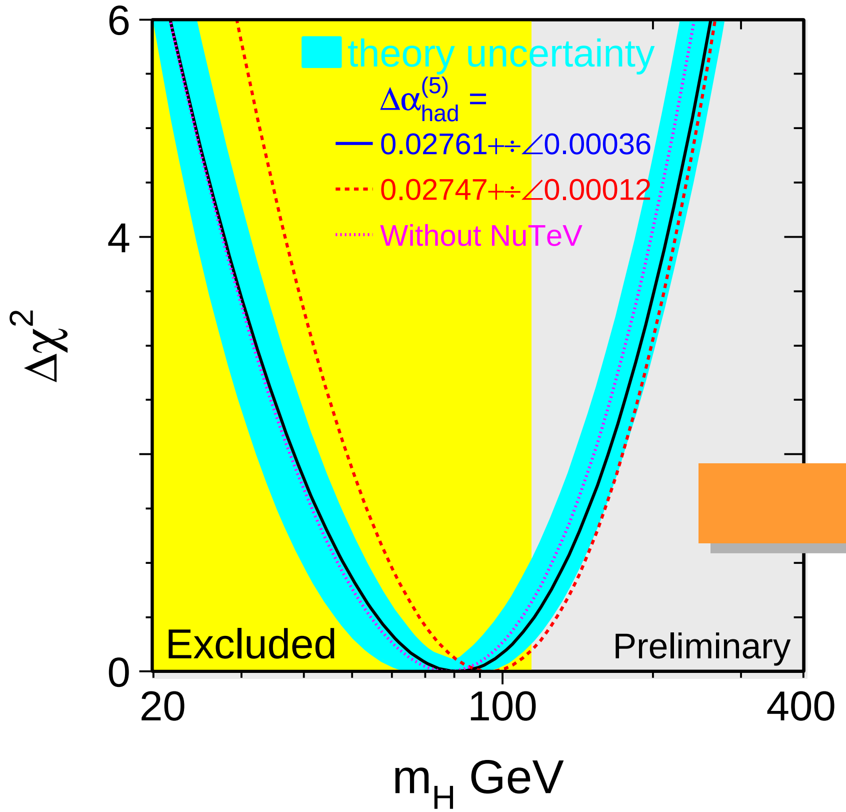
- **For the spring conferences, we plan to "rediscover" the top quark, and present other improved results with ~ $50pb^{-1}$**
- **By next summer (LP2003 at Fermilab), we expect physics results from Run II with a few hundred pb^{-1}**
  - **significantly increased sample over Run I with improved detectors and a higher center of mass energy**
    - **B_s mixing (CDF?)**
    - **Top quark measurements with increased statistics and purity**
    - **Jet cross section at high E_T (constrain gluon PDF)**
    - **New limits on physics beyond the SM**
      - e.g. MSSM A/H at large tan β
    - **. . .**

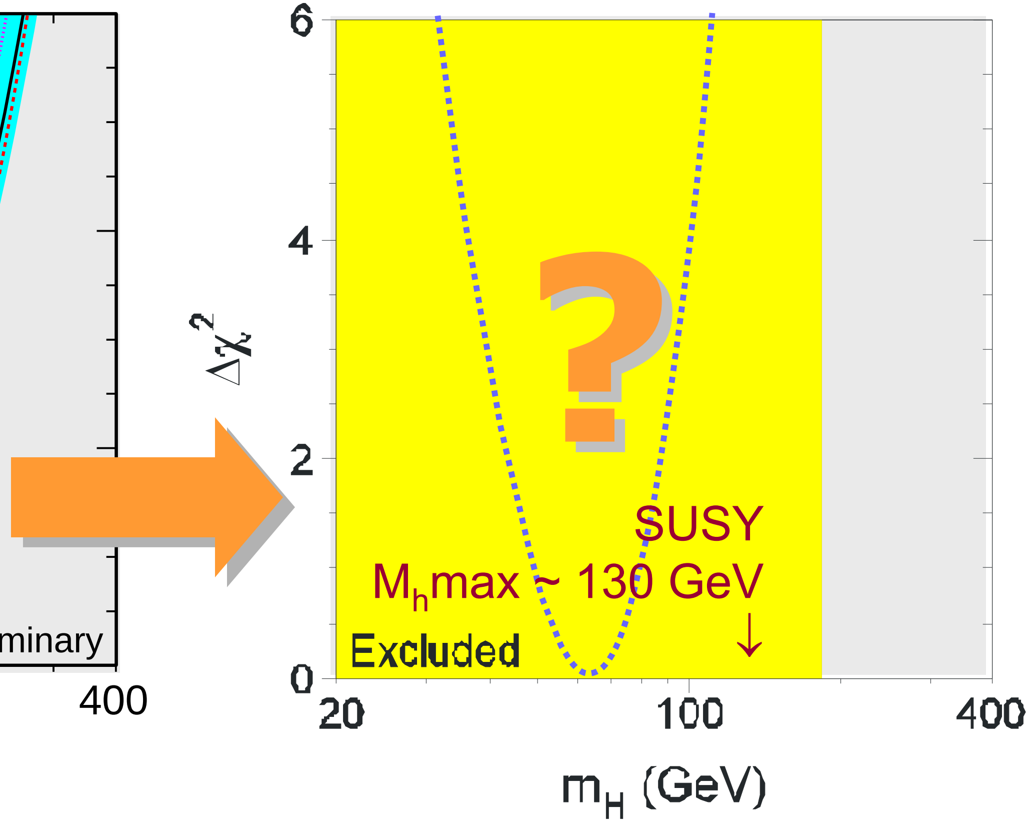
Can we address the really big questions?

- Seven anomalies that point to physics beyond the SM
  - Massive ν
    - new scale » 246 GeV
  - gravity
  - astrophysics/cosmology
    - dark matter, dark E, baryon asymmetry, inflation
  - precision EW fits poor
  - Why mass spectrum? Why mixing angles small (q)/large(ν)
  - Unification
    - Why is charge of electron = charge of proton?
  - Hierarchy problems
    - why 246 GeV?

- The Higgs is central to all of these
  - the key question for the SM
  - Window to beyond-the-SM physics

Prospects for the full Run II





2

Grünewald, Heintz, Narain, Schmitt, hep-ph/0111217
Assumes current central values
$\delta\Delta\alpha^{(5)}_{had}(M_Z^2) = 10^{-4}$, δM_W = 20 MeV, δm_t = 1 GeV

Run IIb Upgrades

- **The present detector was designed for ~ 2fb^{-1} and 2 $\times$ 10^{32} cm^{-2} s^{-1}**
- **The Director has set the goal of accumulating ~15 fb^{-1} before LHC physics**
  - **Exceeds radiation tolerance of existing silicon detector**
  - **Requires higher luminosities, ~ 5 $\times$ 10^{32} cm^{-2} s^{-1}, trigger upgrades**

Replace Silicon Detector with a more radiation-hard version

Improve impact-parameter resolution (b-tagging) through additional layers and smaller beampipe

Maintain good pattern recognition over $|\eta| < 2$

Upgrade Trigger

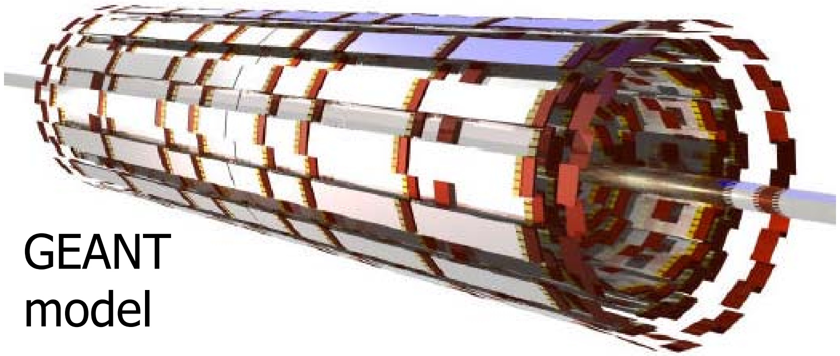
Shift functionality upstream and increase overall Level 1 trigger capability – contain rates, dead time

- Calorimeter clustering & digital filtering
- Enhance track trigger to respond to increased occupancies
- Calorimeter cluster match with track

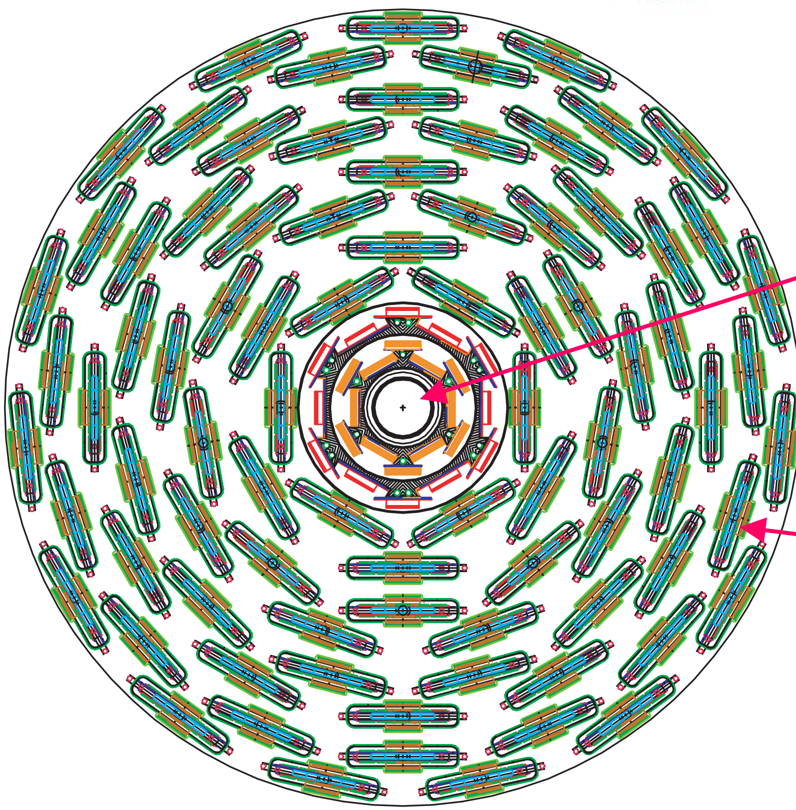
Incremental Upgrades to Level 2, Level 3 Triggers and online system

Lehman review in September 2002 recommended the CDF and DØ Run IIb upgrades for baselining

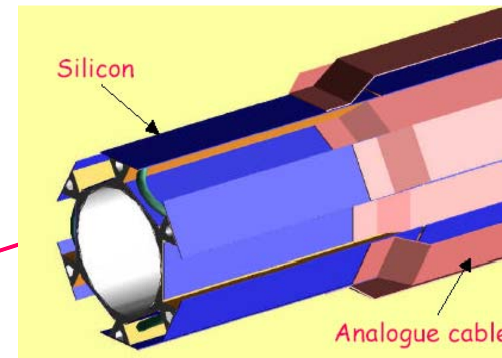
Run IIb Silicon Detector



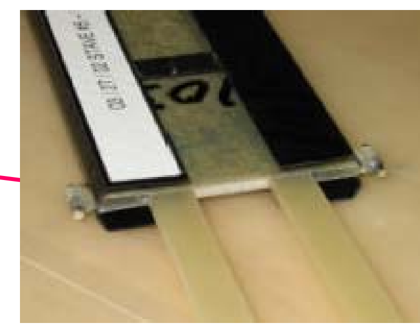
GEANT model



- **Single sided silicon, barrels only**
- **Detector installed in two halves inside collision hall in ~7 month shutdown**
- **Inner (vertexing) layers 0, 1**
  - **Axial only**
  - **mounted on carbon support**

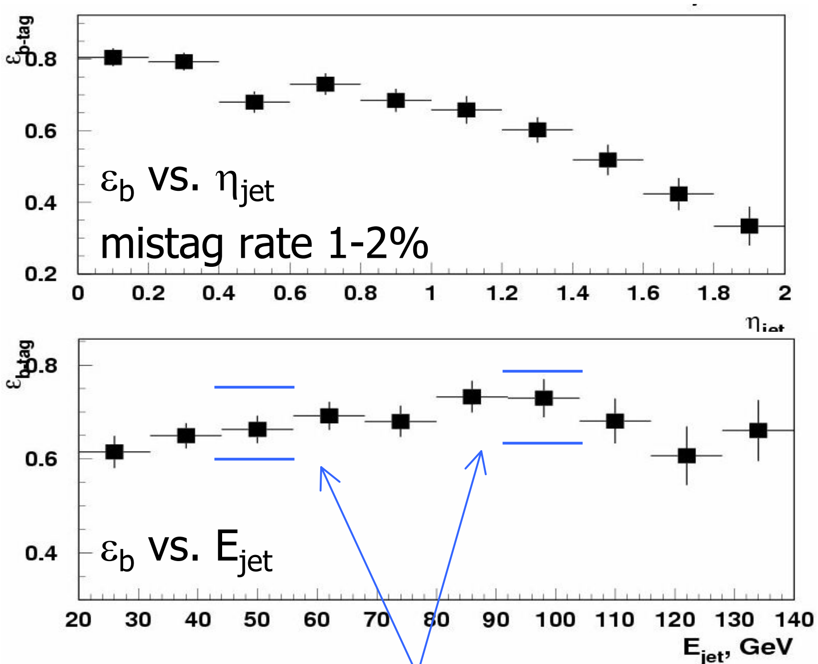


- **Outer (tracking) layers 2-5**
  - **Axial and stereo (tilted sensors)**
  - **Stave structures**

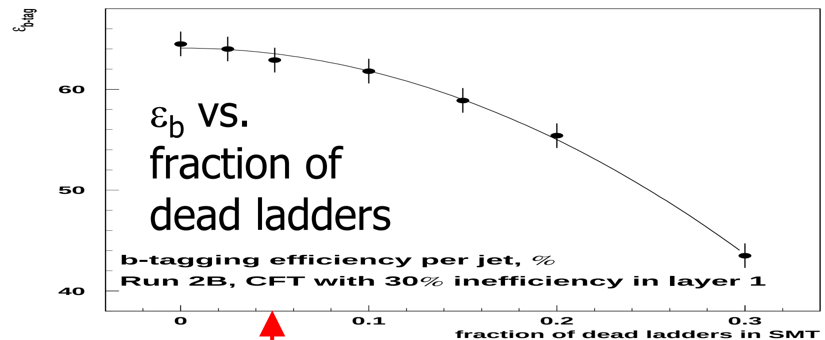


Run IIb Silicon Performance

- **b-tagging performance studied with full GEANT simulation and pattern recognition**



Run II workshop assumptions for tight and loose tags



Now

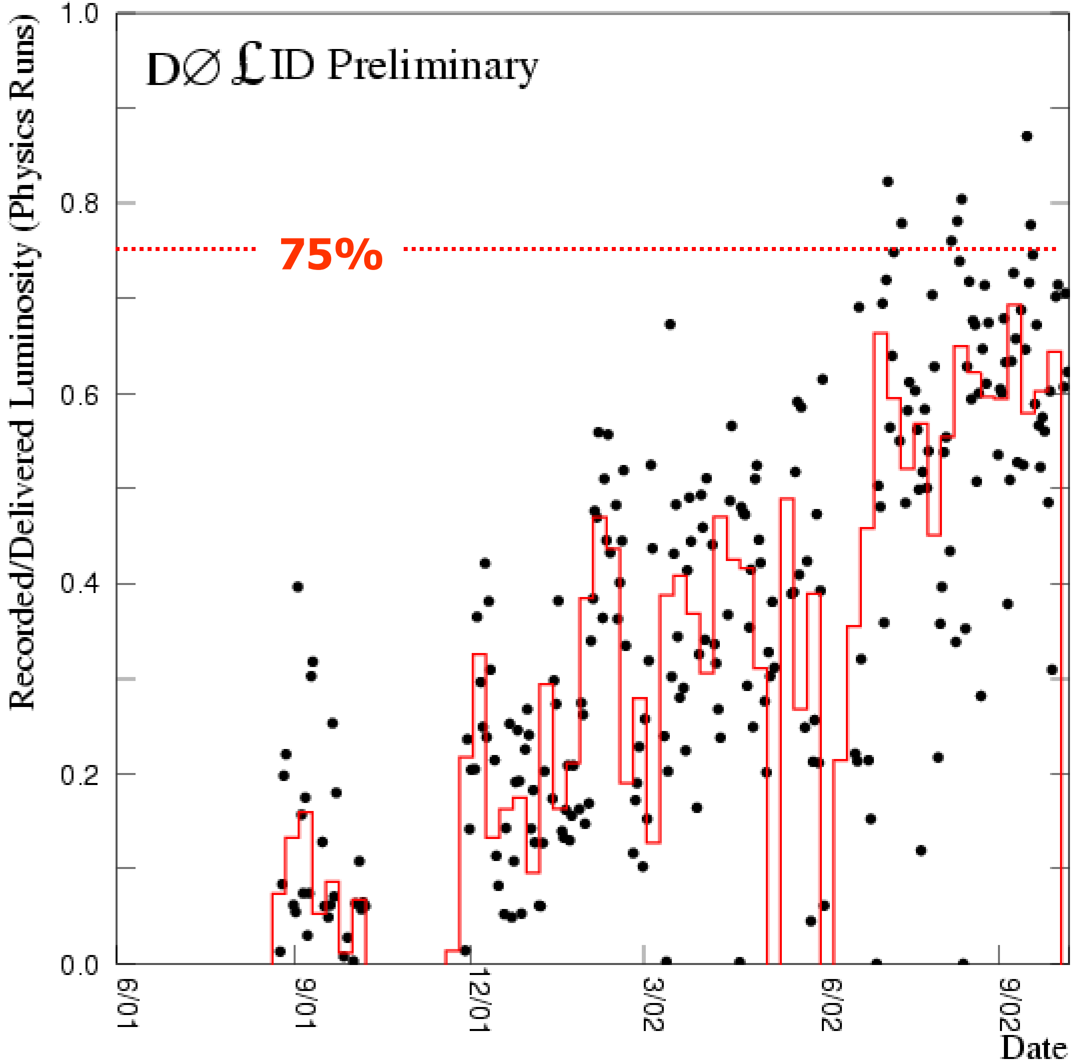
Performance meets the physics requirements
(based on the Run II Higgs/SUSY workshop)

Conclusions

- Whichever side of the Atlantic we were on, hadron collider physics seemed to be beset by problems over the last year
  - technical, financial, management, schedule, politics . . .
  - casts a cloud over the whole field
- This cloud appears (fingers crossed!) to be lifting
  - Gratifying progress at the Tevatron
  - Detectors are working
- I believe that the physics remains the best in the world
- We have a vibrant, enthusiastic community of young physicists
- Ensuring the success of Run II this decade is the foundation for the success of the whole field in the following decades

We are looking forward to the next 14.95 fb^{-1}!

Overall DØ efficiency = $\frac{\text{Recorded luminosity}|_{\text{physics runs}}}{\text{Delivered luminosity}}$



Major effort to improve our performance

Averaged ~ 60% in September

Averaging ~66% in October so far

The trend is good

Immediate goal: 75%