Brief Report from the TEVATRON

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- Introduction: Current Result on CP Violation
- Status of the CDF and DØ Upgrade
- B Physics Prospects at the Tevatron

Disclaimer:

There are dedicated B physics experiments being proposed for the Tevatron such as the BTeV experiment. But of immediate interest is what is being done and will be done in the very near future by the Tevatron experiments CDF and D0. This talk discusses the B physics goals of CDF and D0 using their upgraded detectors, where I will mainly focus on the CDF experiment.

The Tevatron as a B Factory

- Advantages of B Physics at the Tevatron:
  - All B hadrons are produced: B^0, B^+, B_S^0, B_c^+, Λ_b^0
  - Enormous cross section
    - at $\Upsilon(4S)$: $\sigma(B\bar{B}) \approx 1\ nb$
    - at Tevatron: $\sigma(p\bar{p} \to b\bar{b}) \approx 50\ \mu b$
  - $\approx 5 \cdot 10^9\ b\bar{b}$ pairs produced in Run I during 1992-96
- Compare yield of B mesons:

CLEO: $\mathcal{L} = 3100\ \text{pb}^{-1}$

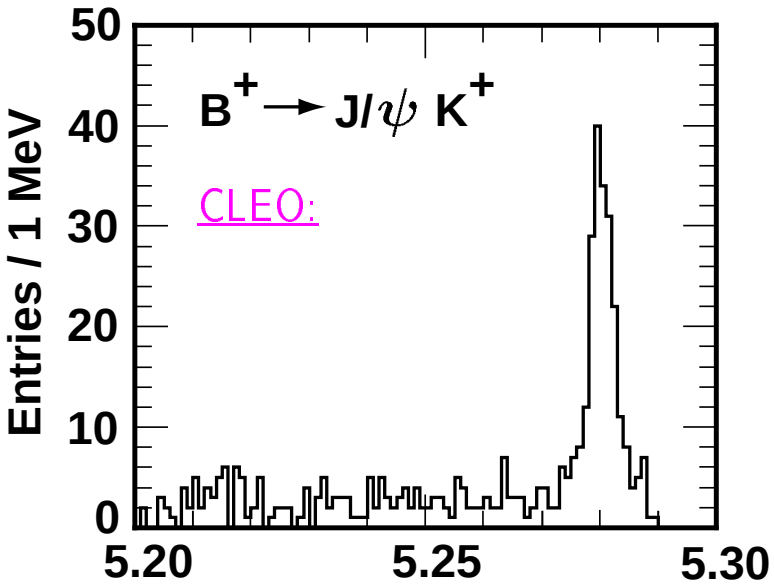
$N(B^+ \to J/\psi K^+) =$

198 ± 15

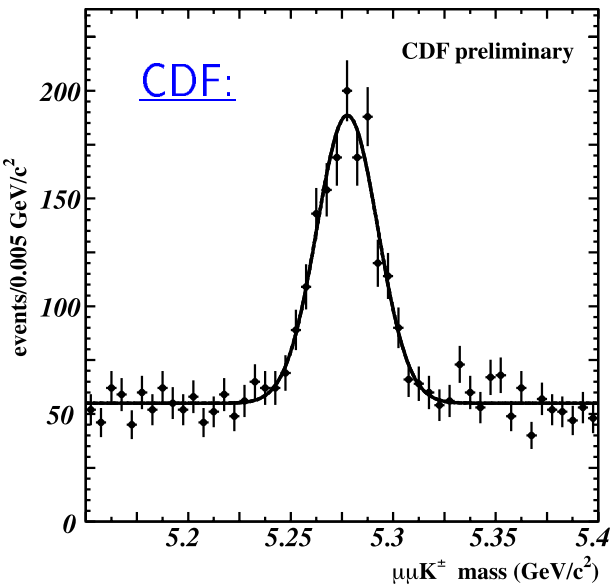
CDF: $\mathcal{L} = 110\ \text{pb}^{-1}$

$N(B^+ \to J/\psi K^+) =$

998 ± 51



PRL 79, 4533 (1997)



Measurement of $\sin 2\beta$ at CDF

★ Goal of B factories:

★ Discover CP violation in $B^0 \to J/\psi K^0_S$:

Measure CP asymmetry

$$\mathcal{A}_{CP}(t) = \frac{N(\bar{B}^0(t)) - N(B^0(t))}{N(\bar{B}^0(t)) + N(B^0(t))} = \sin 2\beta \, \sin \Delta m_d \, t$$

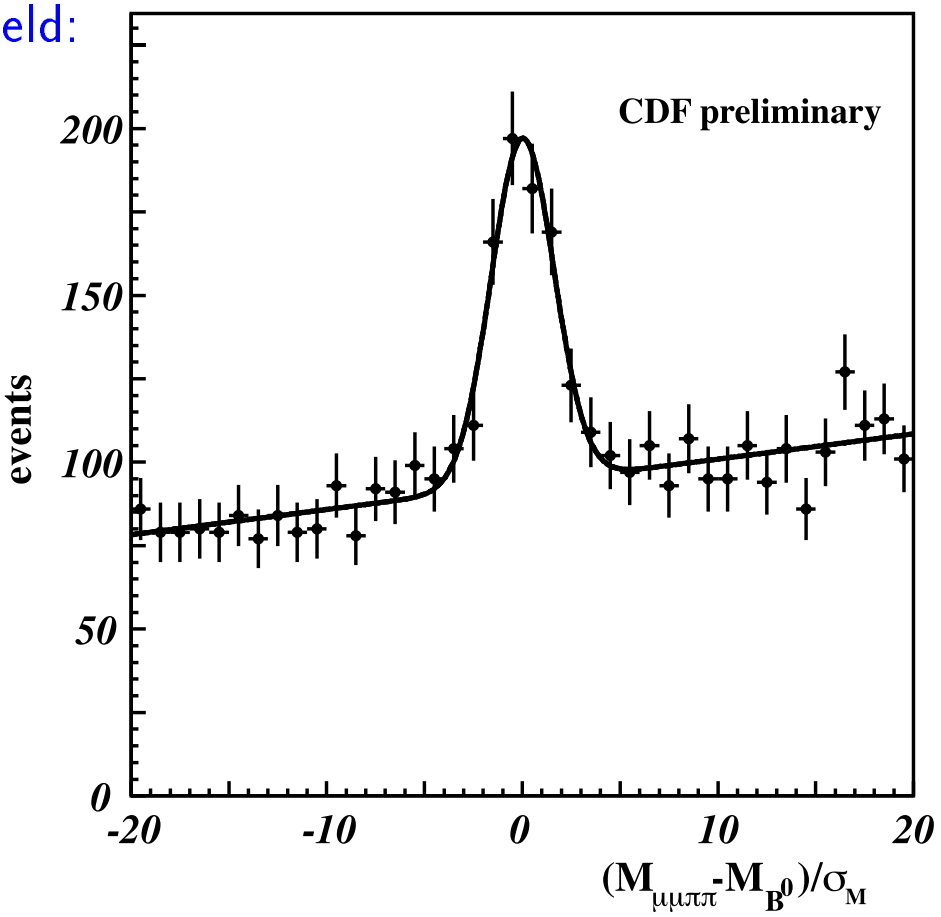
★ CDF: Initial measurement of $\sin 2\beta$:

$B^0 \to J/\psi K^0_S$ yield:

395 ± 31 events

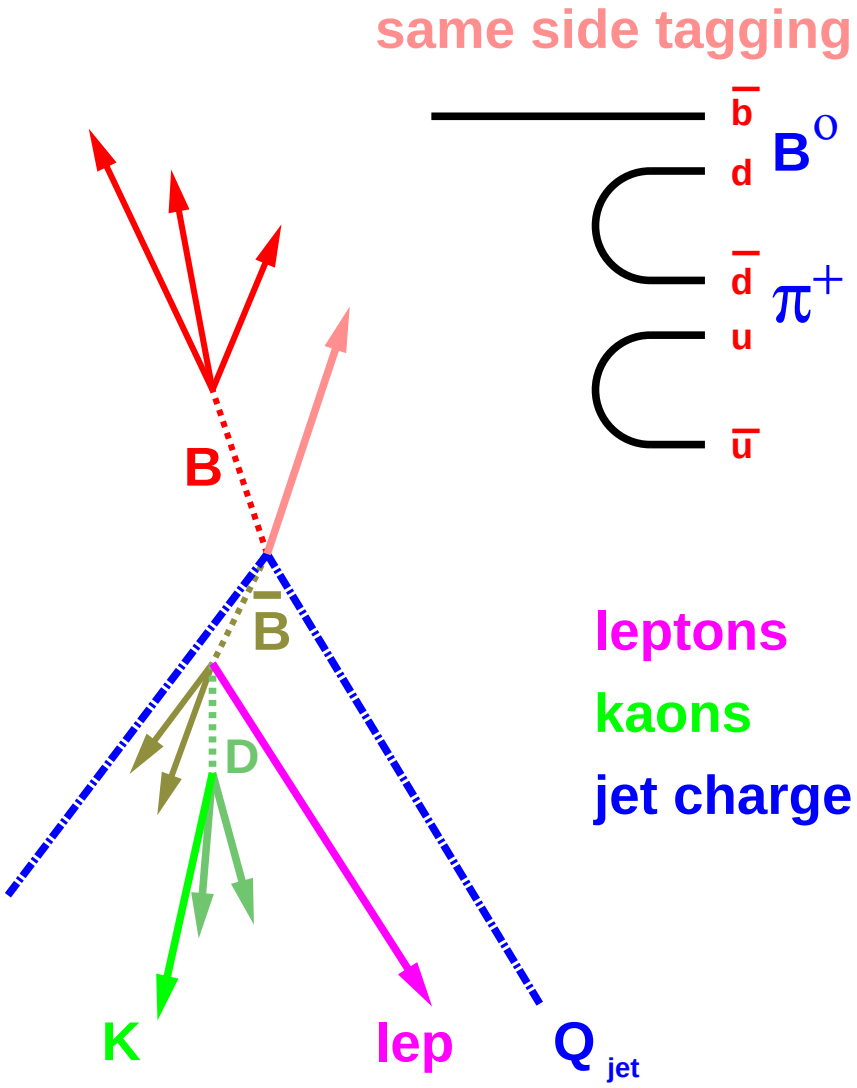
$S/B = 0.7$

Currently world's largest sample of $J/\psi K^0_S$



B Flavour Tagging

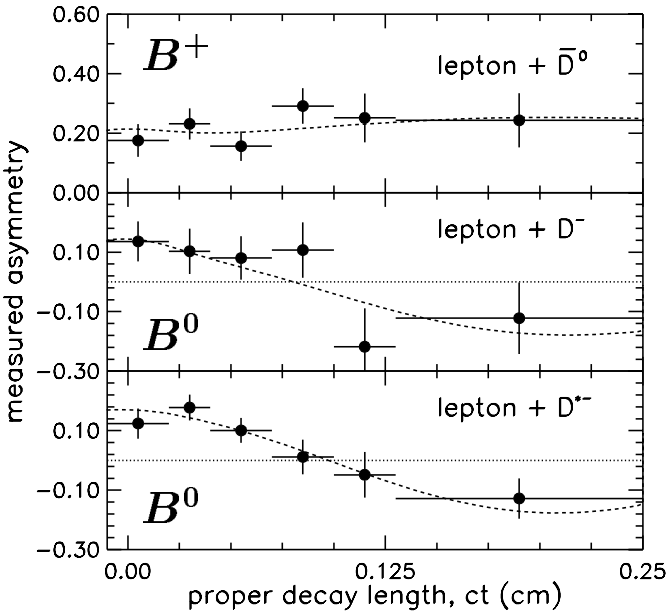
Determine whether B^0 or $\bar{B}^0$ are produced



* Several B flavour tagging methods exist:
  - opposite side lepton tagging
  - jet charge tagging
  - same side tagging

B Flavour Tagging

- Crucial for CP violation measurement at Tevatron
- Figure of merit to quantify flavour tagging:
  - Effective tagging efficiency: $\varepsilon \mathcal{D}^2$
    - $\varepsilon :=$ efficiency
    - $\mathcal{D} = (N_R - N_W)/(N_R + N_W) :=$ dilution
- Tagging power determined with data from measurement of $B^0 \bar{B}^0$ oscillations



Same side tag:

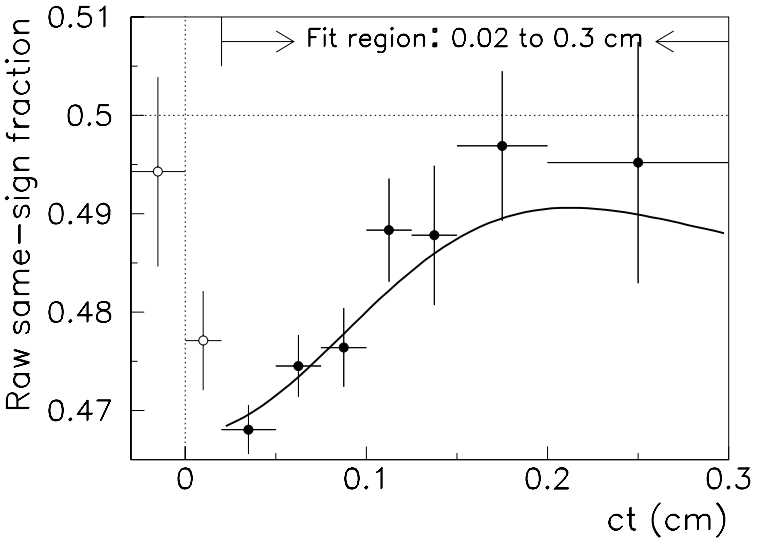
$\Delta m_d = (0.471^{+0.078}_{-0.068} \pm 0.034)\ \mathrm{ps}^{-1}$

$\varepsilon \mathcal{D}^2 = (1.8 \pm 0.4 \pm 0.3)\%$

Lepton & jet charge tags:

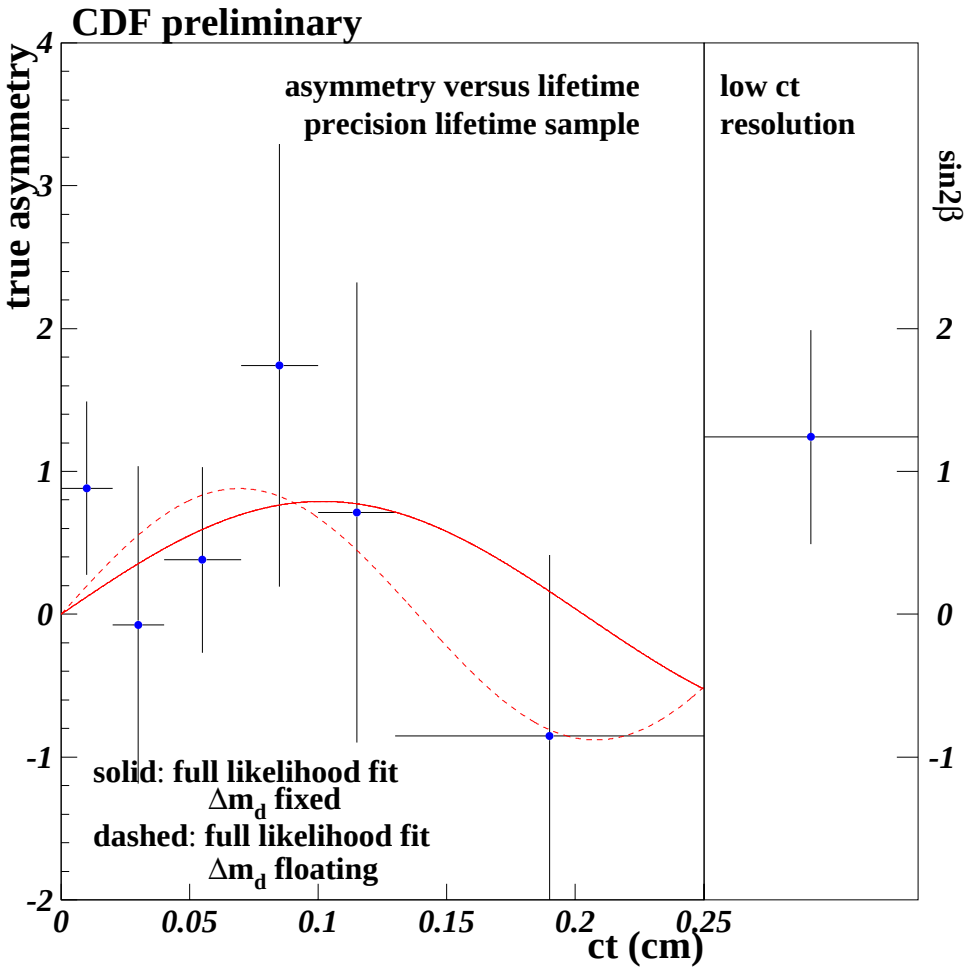
$\Delta m_d =$
$(0.500 \pm 0.052 \pm 0.043)\ \mathrm{ps}^{-1}$

$\varepsilon \mathcal{D}^2 =$
$(0.91 \pm 0.10 \pm 0.11)\%$ (lep)
$(0.78 \pm 0.12 \pm 0.08)\%$ (Q_{jet})



CP Asymmetry from $J/\psi K^0_S$

Best direct measurement of CP violation in B system



- Unbinned max. likelihood fit

$$\sin 2\beta = 0.79 \pm 0.39 \pm 0.16$$

- Limit: $0 < \sin 2\beta < 1$ at 93% C.L.
- CDF demonstrated that CP violation measurement is feasible at Tevatron in Run II !

The Tevatron in Run II

- Tevatron upgrade:
  - Main injector: New 150 GeV accelerator
    $\Rightarrow$ 20 times higher luminosities in Tevatron
  - Finished 1 June 1999; first circulating beam
- Run II:
  - Originally: 2 fb^{-1} in 2 years starting in 2000
  - Run II continues until 2006 with no major shutdown

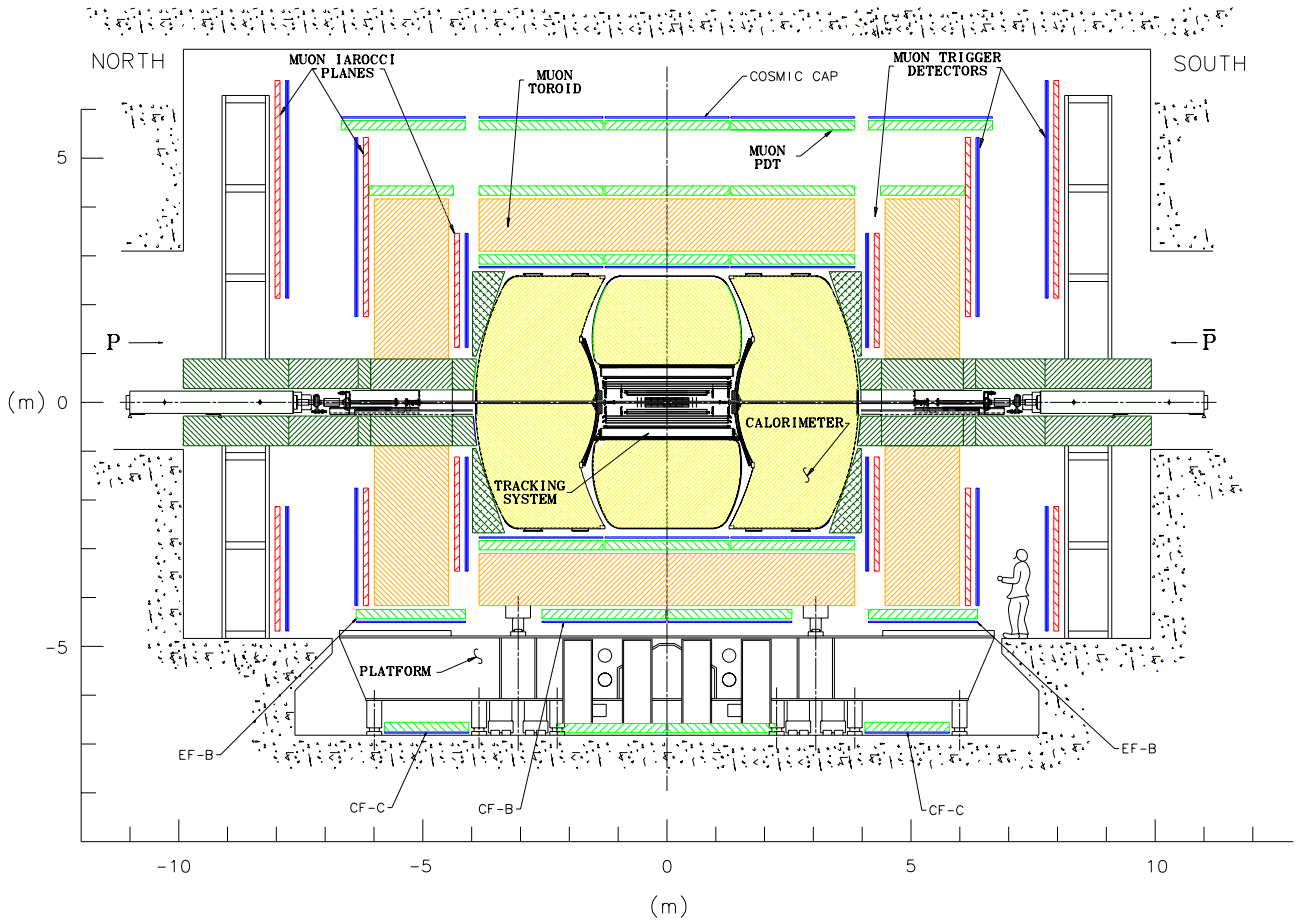
DØ Detector Upgrade

- Superconducting Solenoid (B = 2 Tesla)
- Central Fiber Tracker

  $\Rightarrow$ Measurement of charged particle momentum

- Silicon Microstrip Tracker
- Improvements to μ system, trigger and calorimeter

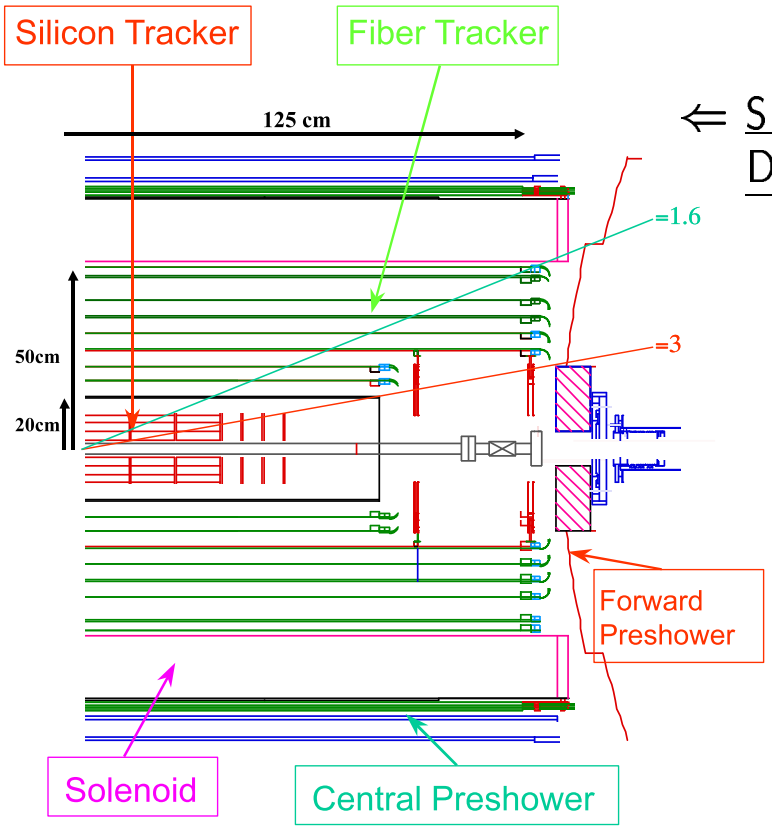
$\Rightarrow$ DØ with highly improved B physics capabilities



DØ Tracking System

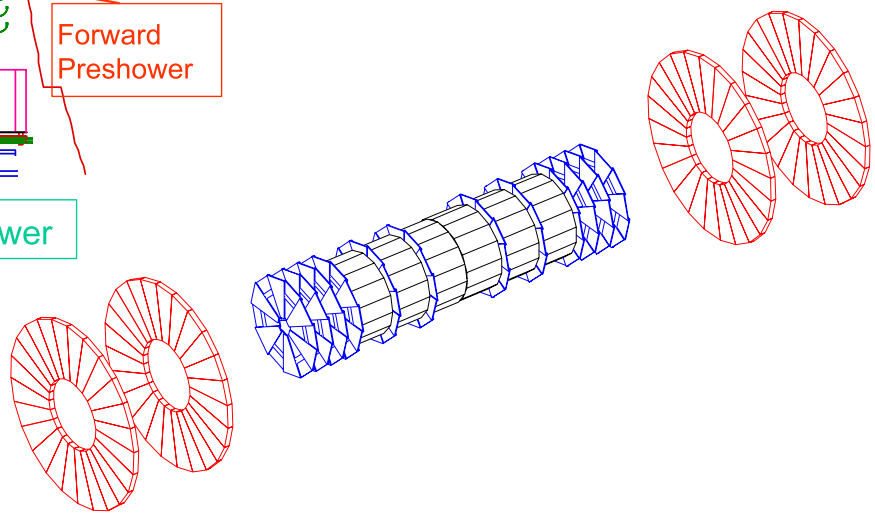
- Central Fiber Tracker
  - 8 superlayers of scintillating fibers

  $\Rightarrow$ Measurement of charged particle momentum
- Silicon Microstrip Tracker
  - 6 barrels with 4 layers each ($r\phi$ and rz readout)
  - 12+4 forward disks out to 1.25 m in z



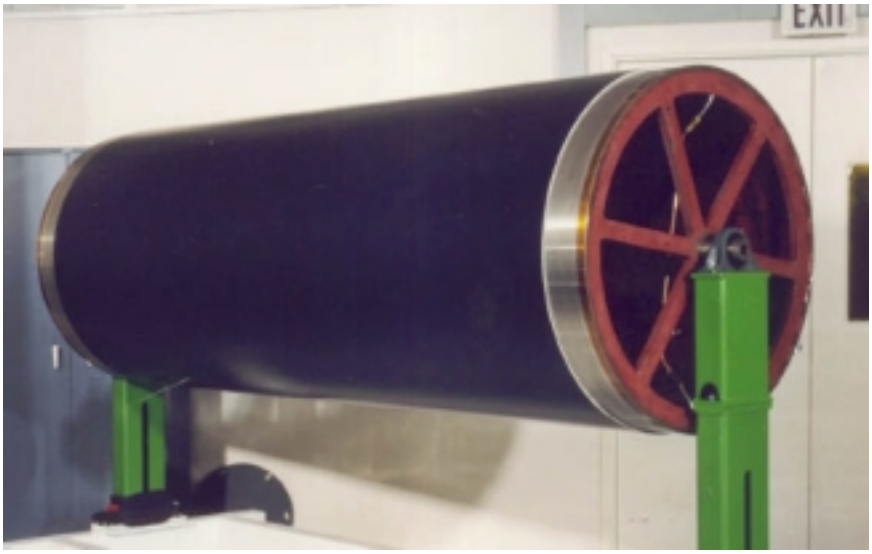
⇐ Side-view of DØ tracking system

DØ silicon system ⇓

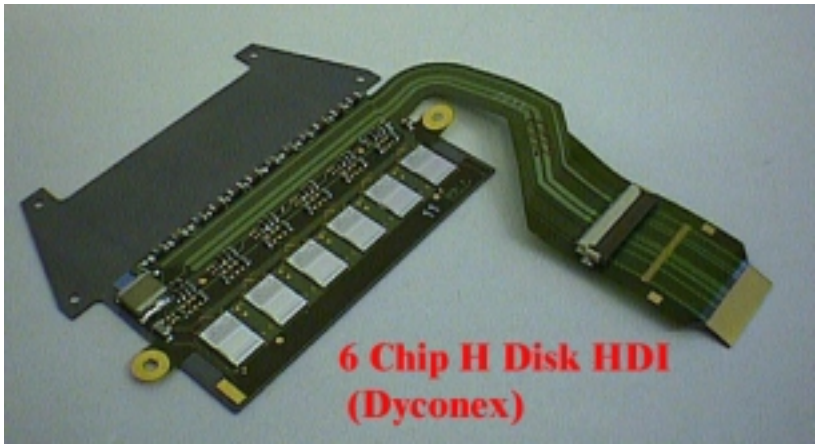


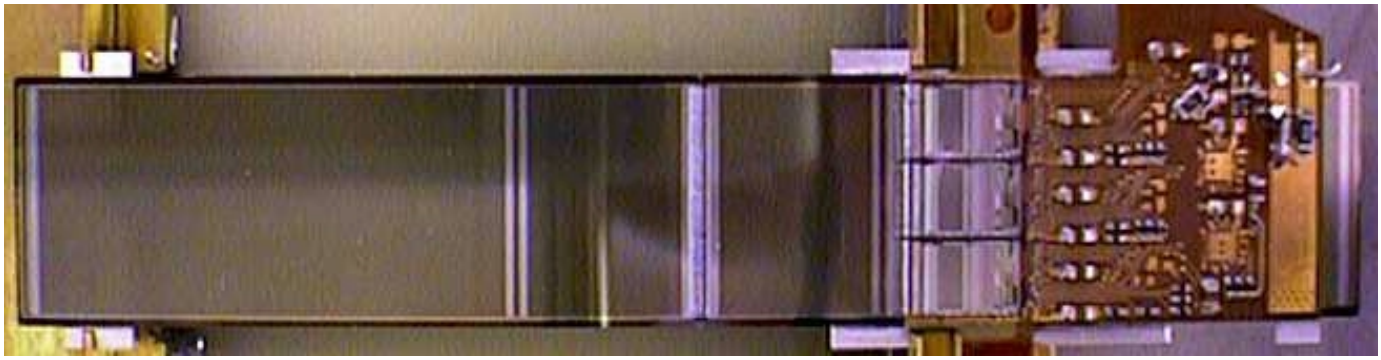
Status of DØ Upgrade

- Central Fiber Tracker assembled in Jan 2000



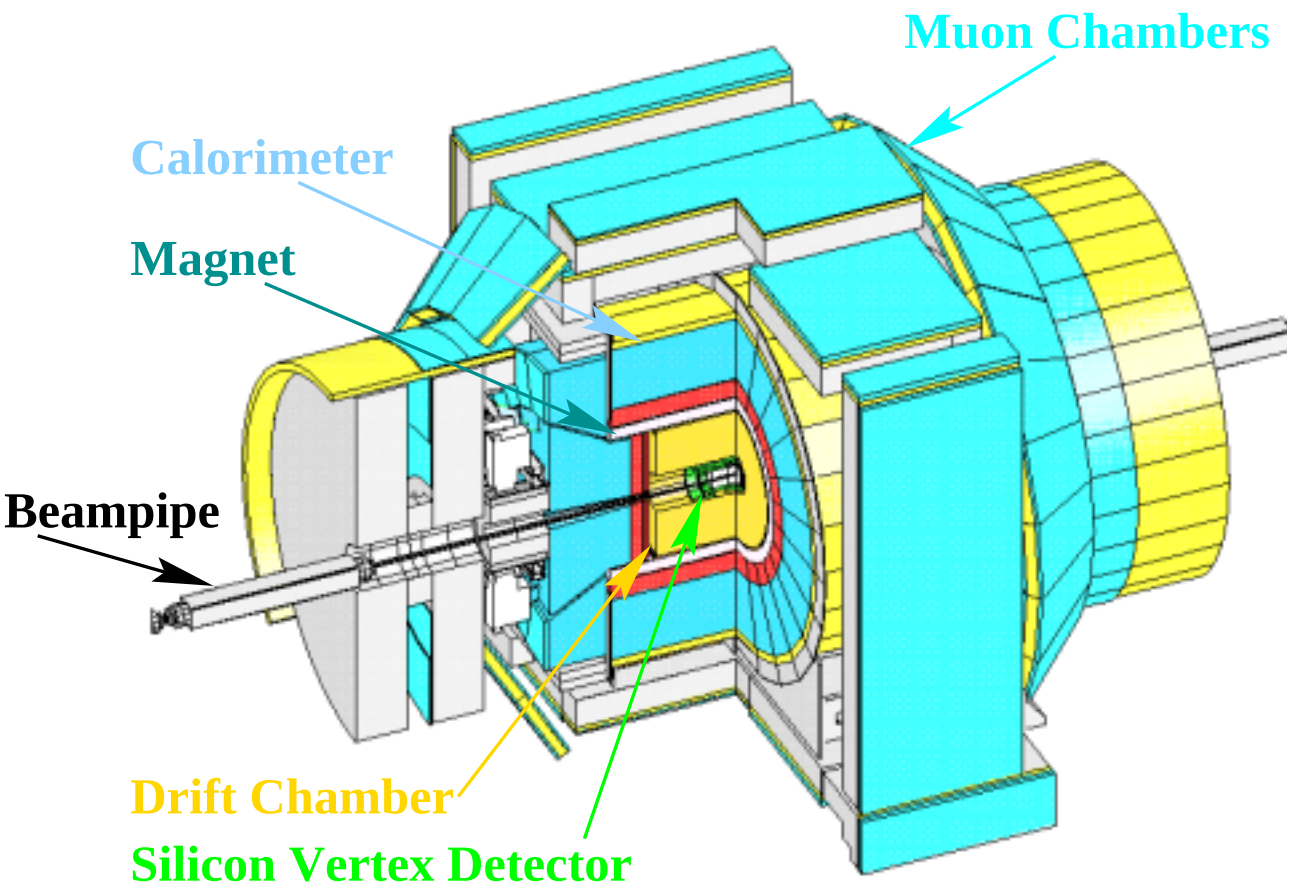
- Silicon assembly complete Feb 2000





CDF in Run II

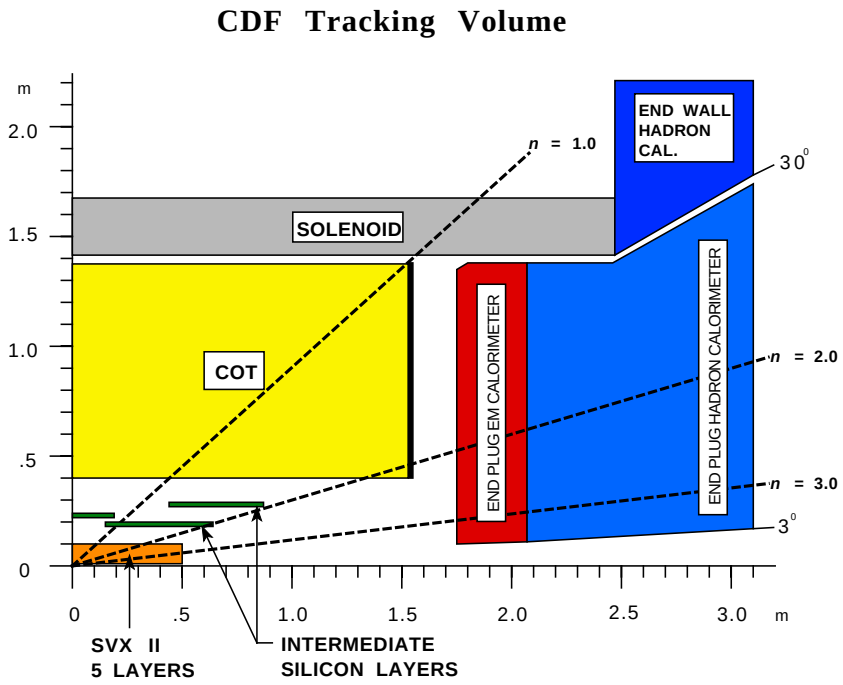
- Cross section of CDF II detector:

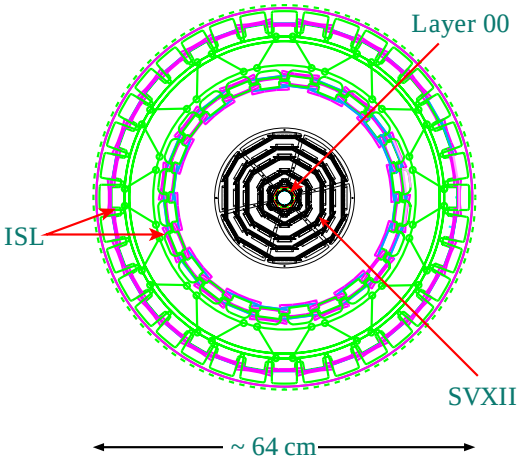


- Major upgrade of tracking system
- New endplug calorimeter
- Improved muon coverage
- Trigger/DAQ upgrade (pipelined)
- New front end electronics
- Time of flight system

CDF Tracking Upgrade

- Optimized integrated tracking system:





- New silicon tracking system:
  - SVX II: 5 layers (2.5<R<10.6 cm), double sided Si ⇒ 3-d tracking ($r\phi$ and rz), 96 cm long (double Run I acceptance)
  - ISL: 2 additional Si layers (R<28 cm); cover $|\eta| < 2$
  - L00: inner layer of Si at beam pipe (R=1.5 cm)

  ⇒ Standalone silicon tracking up to $|\eta| = 2$

- New central outer tracker (COT):
  - open cell drift chamber (30,240 sense wires)
  - maintain Run I tracking efficiencies and resolutions
  - dE/dx capability

CDF Central Outer Tracker

Status of CDF Central Outer Tracker:

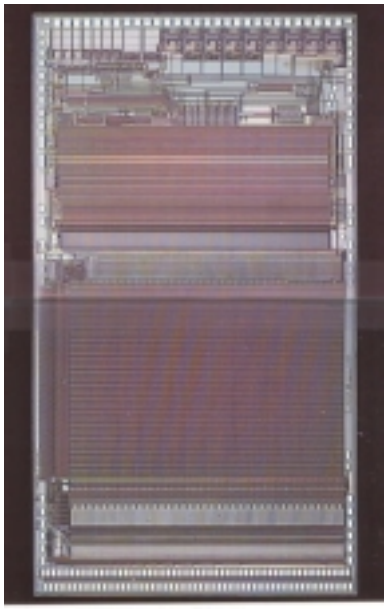
- Stringing completed May 1999
- Currently: quality control, gas seal work
- HV tests and electronics installation in progress
- COT ready to install in CDF by Jan 2000!

CDF Silicon Upgrade

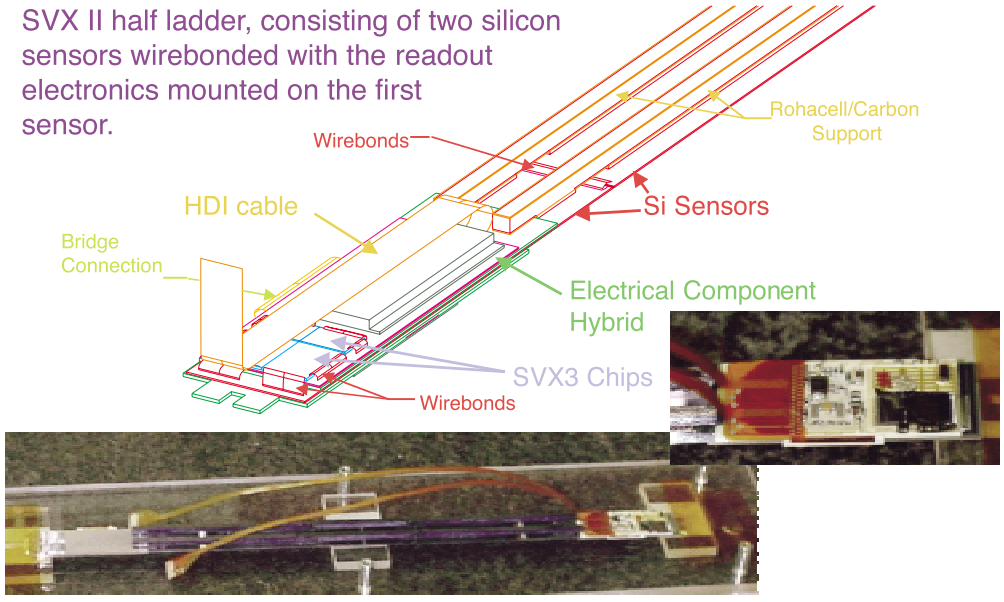
Status of CDF Silicon Upgrade:

- 45% of readout chips in hand (performance excellent, yield good). Expect rest by Oct 1999.
- Hybrid production finished; assembly ongoing.
- Building first production ladders.
- Delivery of silicon sensors determines critical path for completion of CDF II detector.
- **Silicon ready to install in COT by June 2000!**

SVX3d Chip:



SVX Ladder Production:



Time Schedules

- Current Schedule for CDF Upgrade Project:
  - Cosmic ray run: Nov 1999 - Mar 2000
  - COT installed in CDF: Feb 2000
  - Engineering Run: Mar - Jul 2000
  - Install silicon: Jul - Nov 2000
  - Full detector ready for collisions: Nov 2000
- Current Schedule DØ Upgrade Project:
  - Fiber tracker assembled: Jan 2000
  - Silicon assembly complete: Feb 2000
  - Calorimeter electronics recabled: Mar 2000
  - Muon detectors fully assembled: Jul 2000
  - Full detector rolled in: Jul 2000
- Fermilab Schedule:
  - Expect to review CDF, DØ and accelerator schedule in Oct 1999
  - Final schedule and run plan attempt to optimize physics potential for Run II

CP Violation with 2 fb^{-1}

Prospects for CDF: similar expectations for DØ

* Measurement of $\sin 2\beta$ with 2 fb^{-1}:

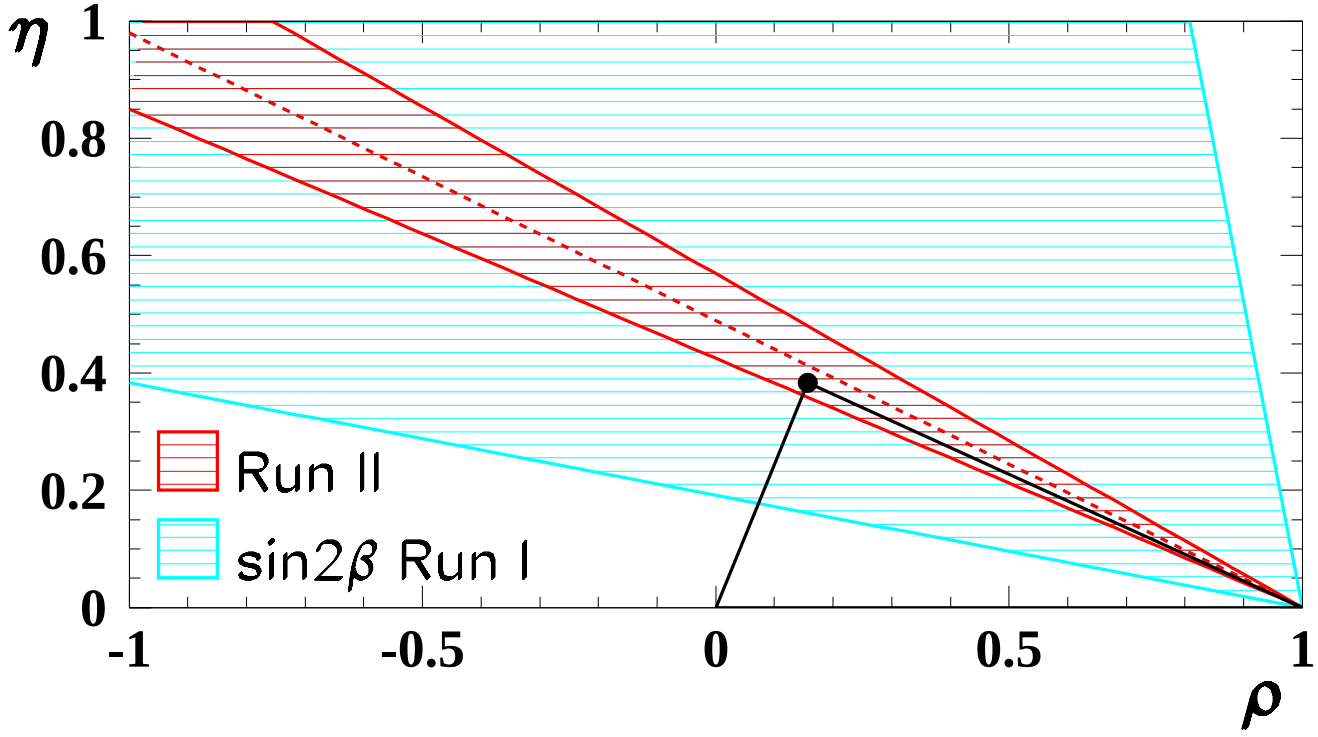
  $\sim 10\,000$ $J/\psi K^0_S$ events with $J/\psi \to \mu^+\mu^-$

* Improved B flavour tagging:

Flavour tag	$\varepsilon\mathcal{D}^2$ Run I	$\varepsilon\mathcal{D}^2$ Run II
Same side tag	$(1.8 \pm 0.4 \pm 0.3)\%$	2.0%
Jet charge tag	$(0.78 \pm 0.12 \pm 0.08)\%$	3.0%
Lepton tag	$(0.91 \pm 0.10 \pm 0.11)\%$	1.7%
Kaon tag	–	2.4%

- Total $\varepsilon\mathcal{D}^2 \approx 9.1\%$

* Expect $\Delta \sin 2\beta \sim 0.07$ (2 fb^{-1})



Other CP Modes with 2 fb^{-1}

* CP Asymmetry in $B \to \pi\pi$: $\sin 2\alpha$

  Use displaced two-track trigger:

  Level 1: Fast track trigger finds track pairs in COT with $p_T > 2\ \mathrm{GeV}/c\ (\sigma(p_t)/p_t^2 < 0.01(\mathrm{GeV}/c)^{-1})$ (22 kHz)

  Level 2: Link tracks into Silicon and require track impact parameter $d > 100\ \mu m\ (\sigma(d) \approx 25\ \mu m)$ (25 Hz)

  Level 3: Use full event information. (1 Hz)

* Expected signal in 2 fb^{-1}:

  $\sim$ 4000 - 7000 $B^0 \to \pi^+\pi^-$ (BR=0.47·10^{-5})

  $\sim$ 16,000 - 28,000 $B^0 \to K^+\pi^-$ (BR=1.88·10^{-5})

* Implications for $\sin 2\alpha$ under study

* Measurement of $\sin\gamma$ using B_S^0:

- Signal: $\sim 700\ B_S^0/\bar{B}_S^0 \to D_S^{\pm}K^{\mp}$
- Initial measurement of $\sin\gamma$ possible?

$B_S^0 \bar{B}_S^0$ Mixing with 2 fb^{-1}

* Prospects for $B_S^0 \bar{B}_S^0$ flavour oscillations:

  Measure $|V_{td}|/|V_{ts}|$

  Additional inner layer of Si improves σ_t:

  – $\sigma_t = 0.060$ ps $\rightarrow 0.045$ ps

  $\Rightarrow$ σ_t important if Δm_S unexpectedly large

  ToF enhances effectiveness of flavour tagging

  – $\varepsilon \mathcal{D}^2 = 11.3\%$ (same side tag on kaons)

  Signal: 15,000 - 23,000 $B_S^0 \rightarrow D_S^- \pi^+$, $D_S^- 3\pi$ events from two-track hadronic trigger in 2 fb^{-1}

* For 20k events: 5σ measurement for $\Delta m_S < 40$ ps^{-1}

  (current limit $\Delta m_S < 14.3$ ps^{-1} at 95% C.L.)

* Physics with B_S^0 mesons unique to Tevatron

Conclusion

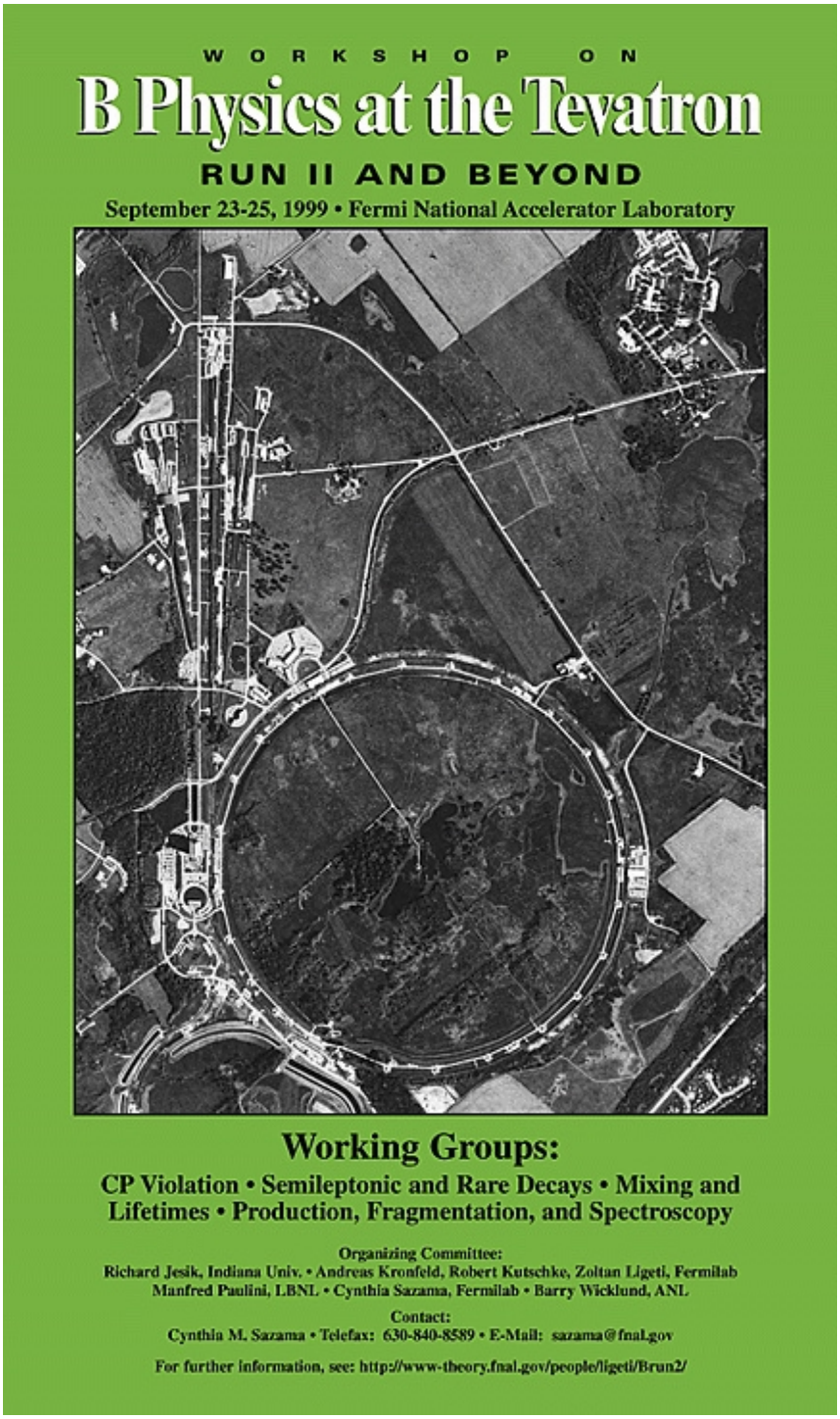
- CDF & DØ upgrades well underway
  - Data taking will start in fall of 2000
- Excellent prospects for B physics in Run II
  - CP violation: $\Delta \sin 2\beta \sim 0.07$
  - B_S^0 mixing: Δm_S reach up to 40 ps^{-1}
- Extension of Run II until 2006 will increase sensitivity
- CDF and DØ looking forward to join the party

"Anyone who keeps the ability
to see beauty never grows old."

(Franz Kafka)

Workshop on "B Physics at the Tevatron"

Fermilab, 23–25 September 1999



"Do you find the b?"