Prospects for Run II Beauty Physics at DØ

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1. Introduction
2. Run II DØ Detector
3. CP Violation
4. B_s Mixing
5. Λ_b Lifetime

DPF 2000
Columbus, OH

Introduction

- **Why study B physics at DØ?**
  - **Large rate:** $\sigma(p\bar{p} \rightarrow b\bar{b}) \approx 150\ \mu b$
  - **All species, including B_s, B_c, Λ_b, produced**
- **Topics include**
  - **Cross sections**
  - **B_s mixing**
  - **CP violation and CKM angles**
  - **Spectroscopy and lifetimes**
  - **Rare and radiative decays**
  - **Charmonium polarization**

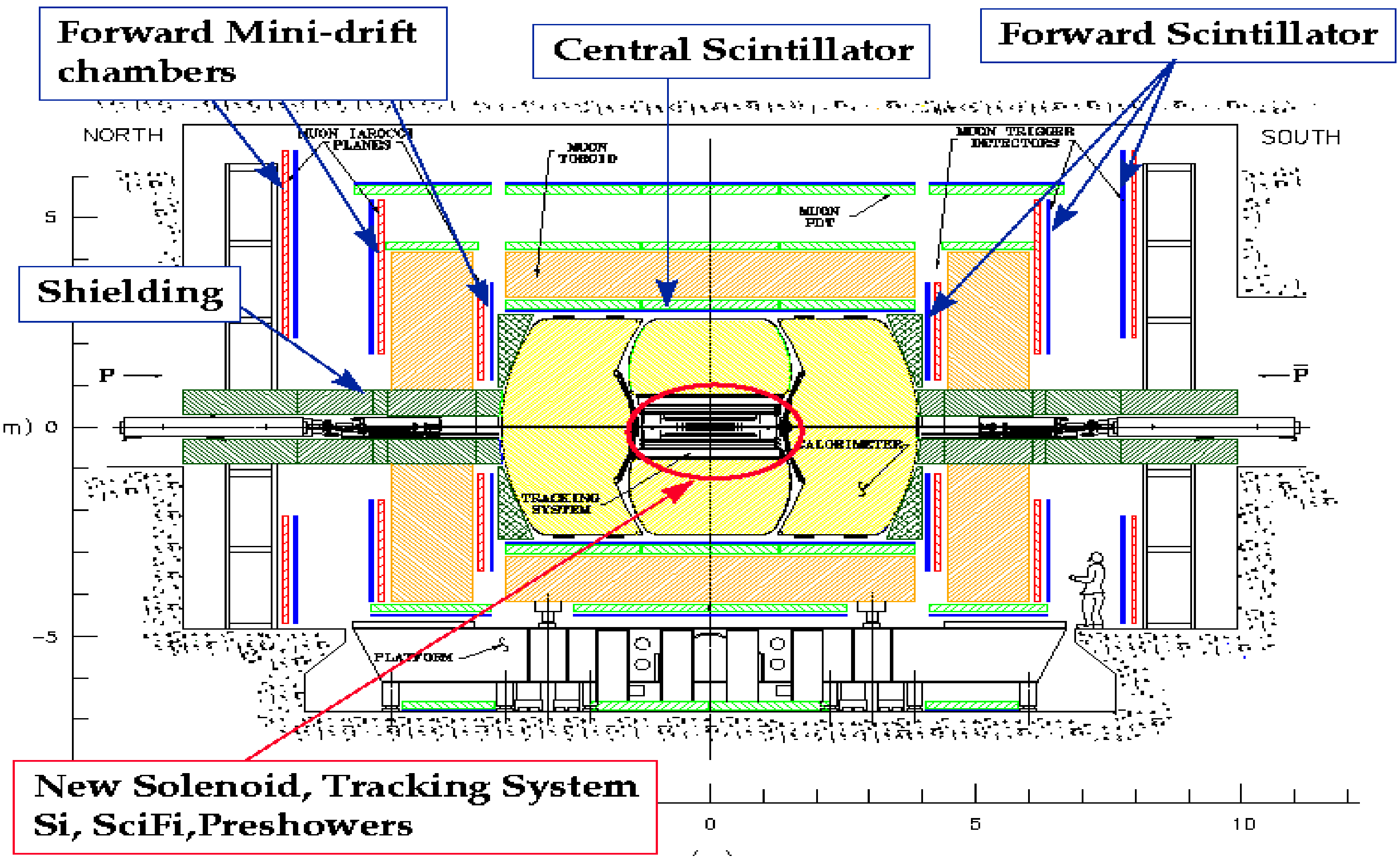
Upgrade for Run II

- Excellent Run I calorimeter ⇒ EM & HAD Energy

- 2 Tesla Magnetic Field ⇒ Momentum
- Scintillating Fiber Tracker ⇒ Improved Tracking
- Silicon Microstrip Tracker ⇒ Secondary Vertexing
- Preshower Detectors ⇒ Enhanced EM Identification
- Muon System Upgrades ⇒ Enhanced Muon Trigger

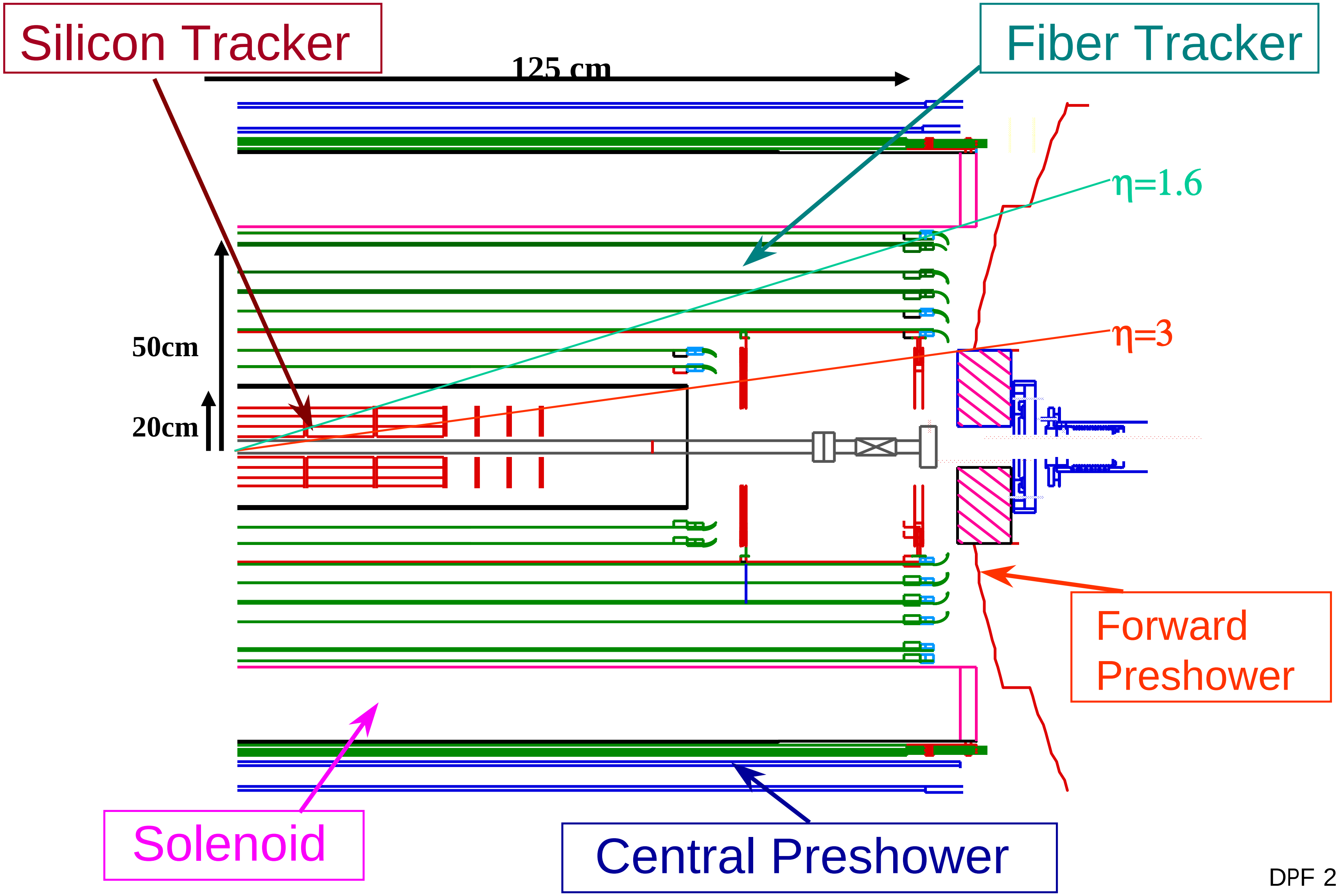
- L1 Central Track Trigger ⇒ Selection of Stiff Tracks
- L2 Impact Parameter Trigger (1 year into Run II) ⇒ Identification of Long-Lived Particles

Run II Detector



+ New Electronics, Trig, DAQ

Inner Tracking System



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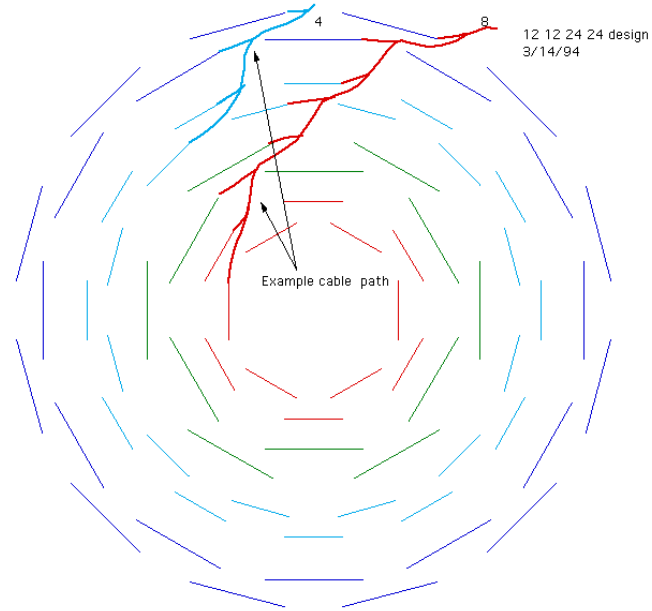
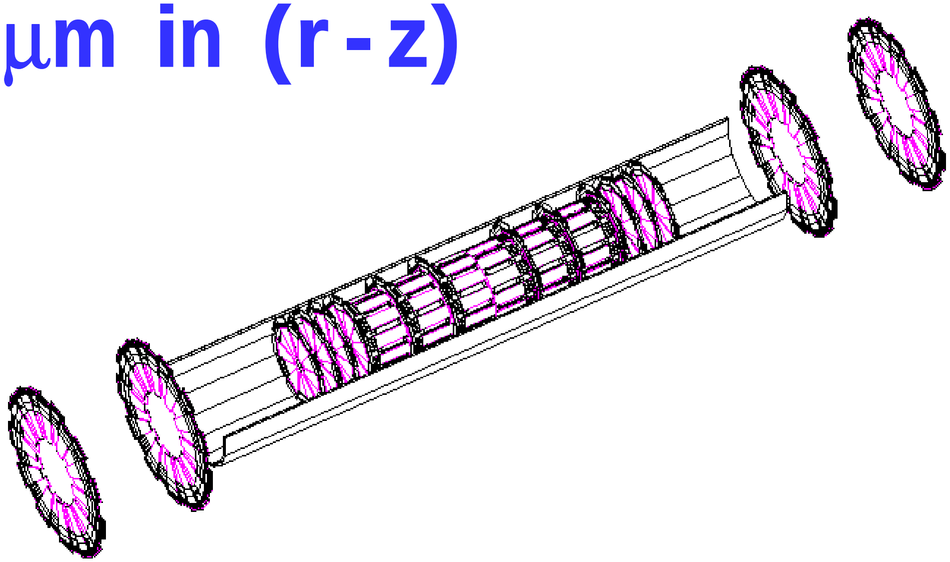
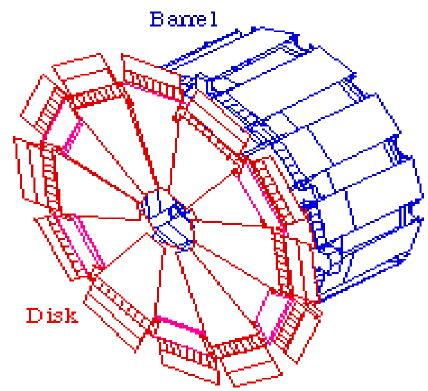
Silicon Microstrip Tracker

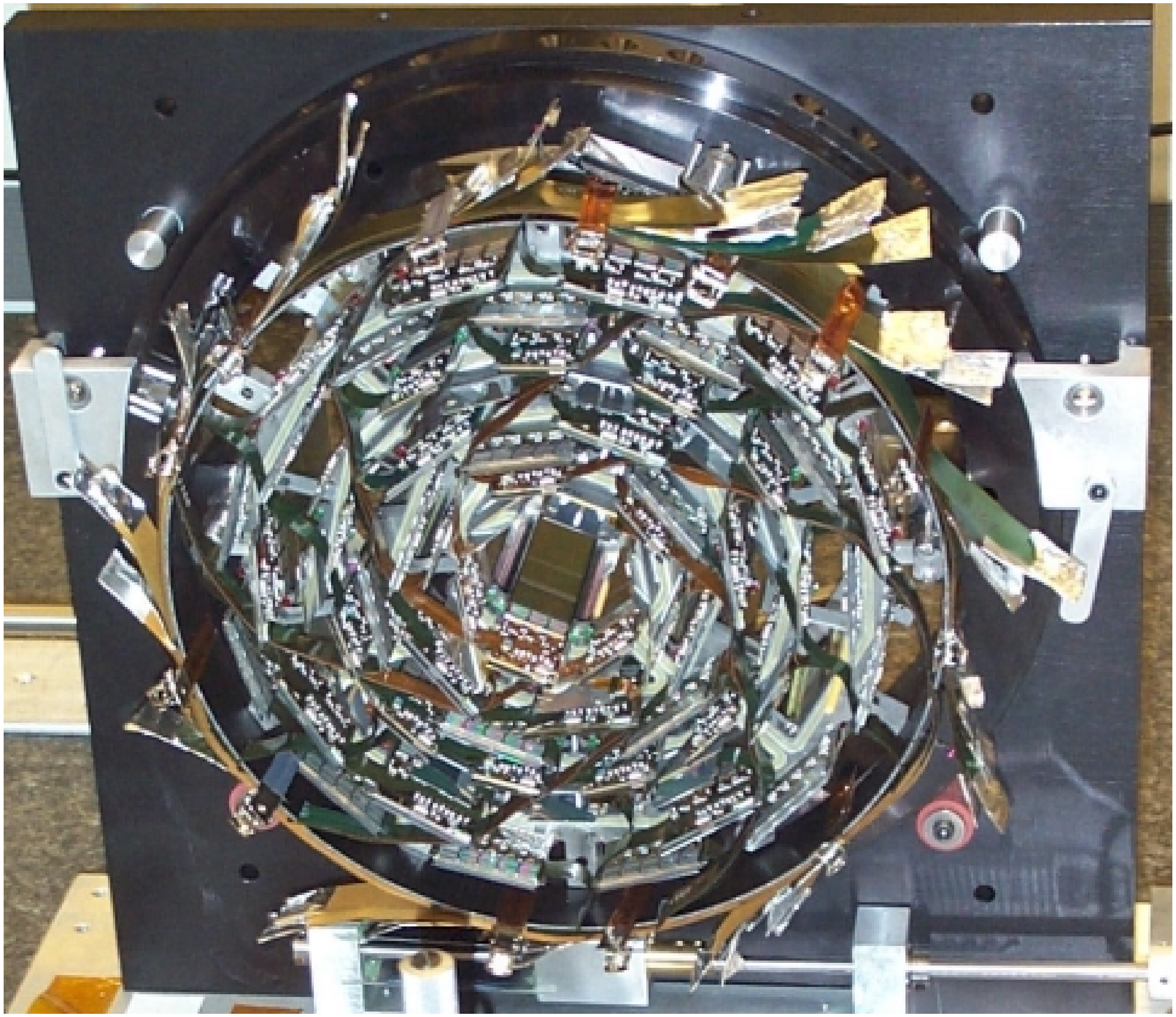
- 6 4-layer barrels
- 16 disks
- Hit resolution 10μm
- Secondary vertex resolution 40μm (r-ϕ), 80μm in (r-z)





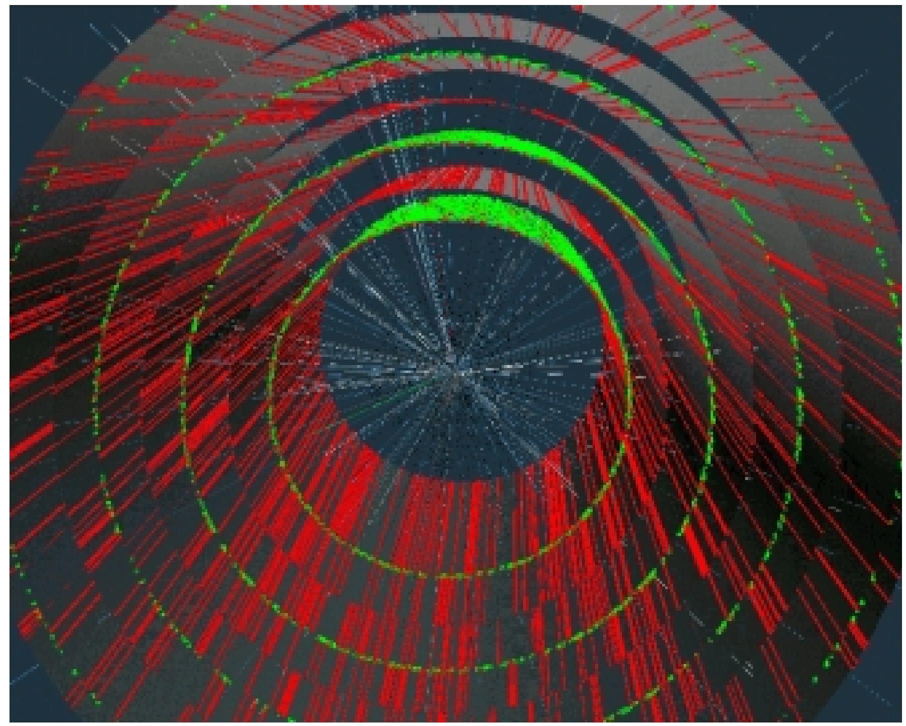


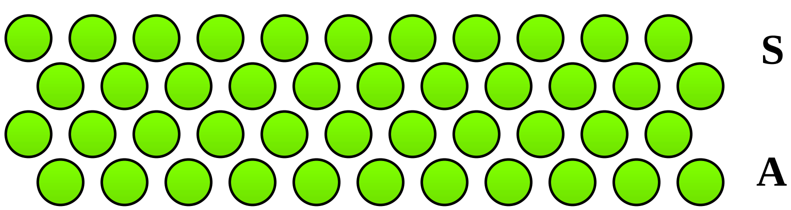
SMT Barrel



Central Fiber Tracker

- **835μm scintillator fibers**
- **Mounted on 8 cylinders**
- **Alternating axial and ±3° stereo doublets**

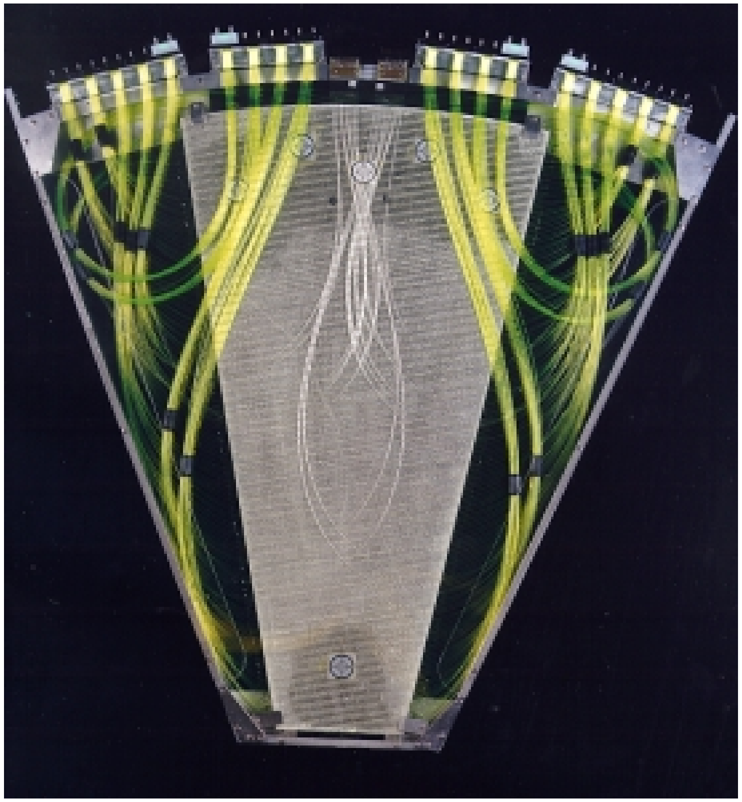


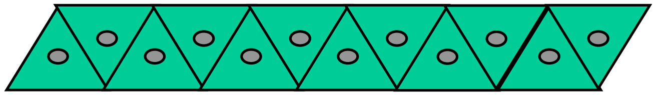


- **Fast enough for L1**
- **Good resolution**

Preshower Detectors

- Refines position and energy measurements of EM showers
- Central and forward
- Extruded triangular scintillator strips with embedded WLS fibers
- Axial and ±20° stereo layers





Muon System Upgrades

- **Central**
  - 630 $\Delta\eta \times \Delta\phi = 0.2 \times 4.5^\circ$ scintillation counters
  - allow triggers down to p_T=1.5 GeV/c
- **Forward**
  - 3 layers of mini drift tubes, spatial resolution ~350μm
  - 3 layers of $\Delta\eta \times \Delta\phi = 0.1 \times 4.5^o$ scintillator pixels

Muon System

Central

Forward

Detector Performance

- **Momentum resolution**
  - dp_T/p_T^2=0.002
- **Tracking efficiency**
  - 95% for $|\eta|<3$
- **Vertex reconstruction**
  - primary: σ=15-30μm (r-ϕ)
  - secondary: σ=40μm (r-ϕ), 80μm (r-z)
- **Lepton trigger and ID acceptance**
  - muons: p_T>1.5 GeV/c, $|\eta|<2$
  - electrons: p_T>1 GeV/c, $|\eta|<2.5$

CP Violation in B° Decays

- **Direct and mixed decays yield the same CP eigenstates at different rates**

$$A(B_d \to \overline{B}_d) \propto m_t^2 V_{td}^2 \approx |A| e^{i2\beta}$$

$$A(\overline{B}_d \to B_d) \propto m_t^2 V_{td}^{*2} \approx |A| e^{-i2\beta}$$

- **Reconstruct B°→J/ψ K$_s$ decays to measure sin(2β)**

$$A_{CP}(t) = \frac{\Gamma\left(\overline{B^0} \to J/\psi K_S^0\right) - \Gamma\left(B^0 \to J/\psi K_S^0\right)}{\Gamma\left(\overline{B^0} \to J/\psi K_S^0\right) + \Gamma\left(B^0 \to J/\psi K_S^0\right)}$$

$$= \sin(2\beta)\sin(\Delta m_d t)$$

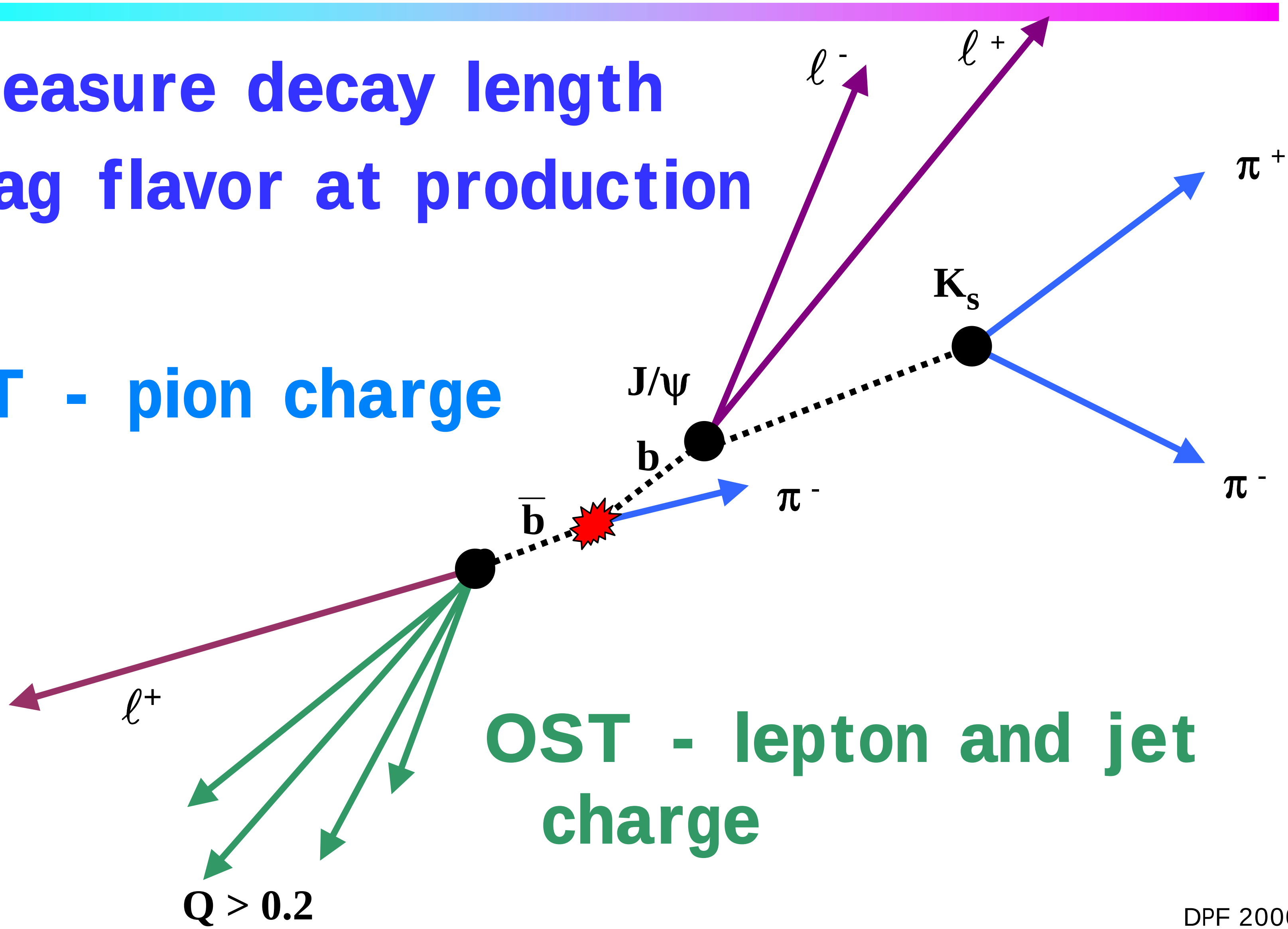
Flavor Tagging

- Opposite-side tags (other b)
  - charge of lepton from semileptonic decay
  - charge sum of particles in jet
- Same-side tags
  - charge of pion produced in decay or fragmentation
- Dilution $D=2P-1$, where P=correct tag probability
- Tag quality=εD^2, where ε=efficiency

$B^\circ \rightarrow J/\psi\ K_s$ Reconstruction

- Measure decay length
- Tag flavor at production

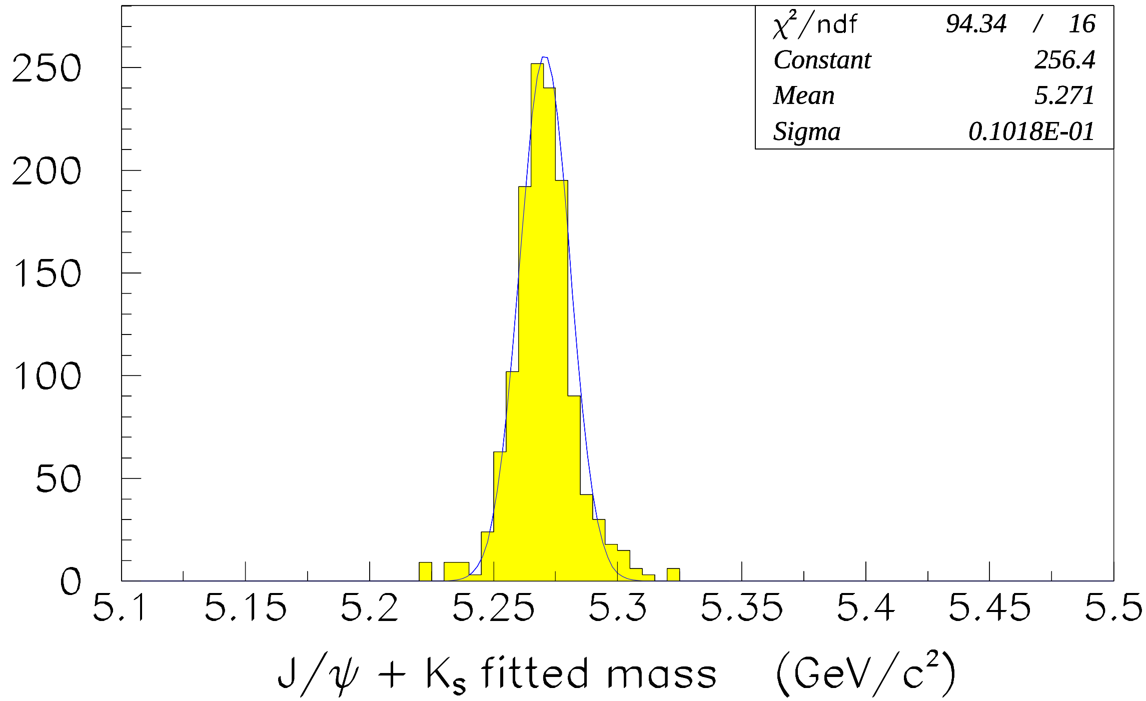
SST - pion charge



OST - lepton and jet charge

$B^\circ \to J/\psi\ K_s$ Fitted Mass

- **4-track fit**
- **$m(\pi\pi)=m(K_s)$**
- **$m(\mu\mu)=m(J/\psi)$**
- **K_s momentum points back to B vertex**

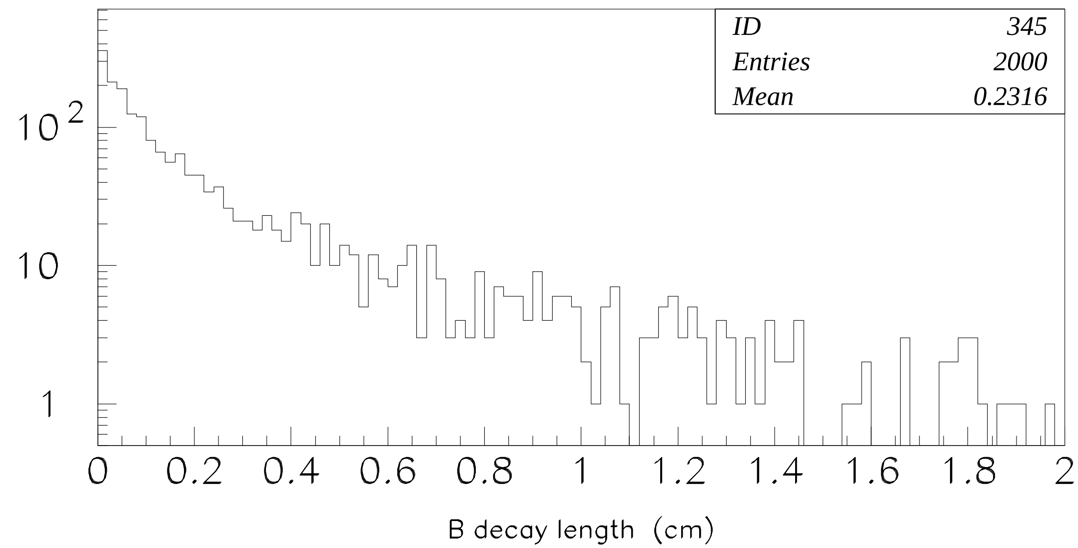


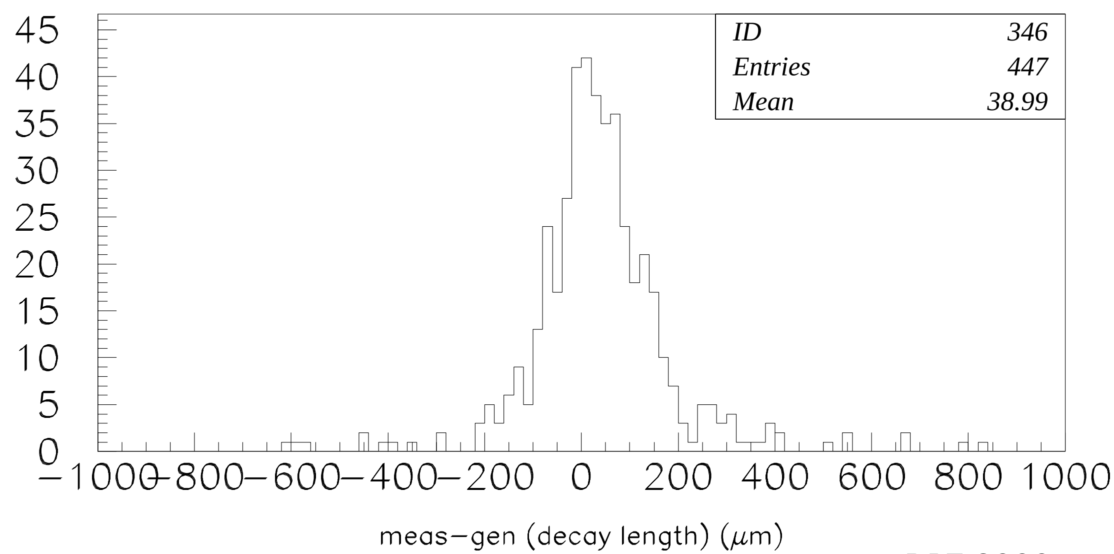
- **B momentum points back to primary vertex**

$B^\circ \rightarrow J/\psi\ K_s$ Decay Length

- **Average B decay length 2.3mm**

- **Expected decay length resolution 100μm**





Sin(2β) Expectations

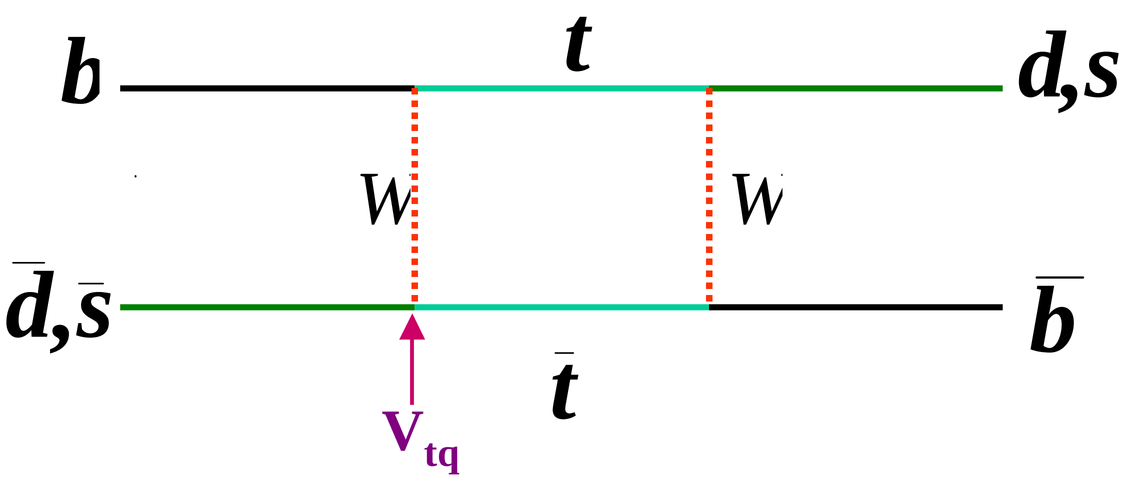
$$\sigma(\sin 2\beta) \approx e^{x_d^2 \Gamma^2 \sigma_\tau^2} \sqrt{\frac{1+4x_d^2}{2x_d}} \frac{1}{\sqrt{\varepsilon D^2 N}} \sqrt{1+\frac{B}{S}}$$

For 2 fb^{-1}

- $\varepsilon D^2 \sim 9.8\%$
- $S/B \sim 0.75$
- $\sigma_\tau \sim 90$ fs

mode	$J/\psi \to \mu^+\mu^-$	$J/\psi \to e^+e^-$
trigger eff. (%)	27	20
reco'd events	40,000	30,000
$\sigma(\sin 2\beta)$	0.04	0.05
	0.03	

B_s Mixing



- Weak eigenstates ≠ mass eigenstates
- Mixing due to higher order corrections
- $\Delta m_q = m(B^o_{heavy}) - m(B^o_{light})$
- $Þ_{mixed}(t) = !(1 - \cos\Delta m_q t)$, $\Delta m_q \propto |V_{tb} \bullet V_{tq}|^2$
- Mixing parameters $x_q = \Delta m_q / \Gamma_q$ and $\Delta\Gamma_q$

B_s Mixing Event Yields

$$B_s^0 \rightarrow D_s^- \ell^+ \nu X$$

$$D_s^- \rightarrow \phi \; X$$

$$\phi \rightarrow K^+ K^-$$

- limited reach in x_s but lots of events
- trigger on dilepton events
- initial flavor tagged by opposite side lepton
- final flavor tagged by same side lepton

$$B_s^0 \rightarrow D_s^- \pi^+ (\pi^- \pi^+)$$

$$D_s^- \rightarrow \phi \pi^-$$

$$\phi \rightarrow K^+ K^-$$

- 400-1200 events
- opposite side triggered by lepton
- lepton charge tags initial flavor
- final flavor tagged by charge of D_s

Expected x_s reach is ~30 in 2 fb^{-1}

Λ_b Lifetime

- Naïve spectator model predicts $\tau(\Lambda_b^0)/\tau(B^0) = 1$
- Current data suggests $\tau(\Lambda_b^0)/\tau(B^0) = 0.79 \pm 0.05$

- Non-spectator processes (final state quark interference and W boson exchange) too small in SM (10%) to account for deviation

- Previous measurements used semileptonic modes to achieve statistical precision
- Disadvantage is that neutrino is lost, carrying with it momentum information

Λ_b Lifetime Measurement

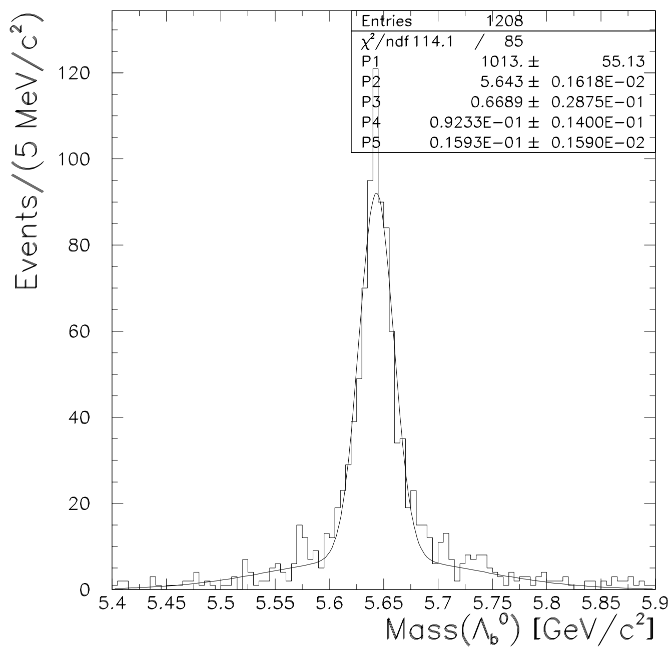
- 20 times the statistics during Run II

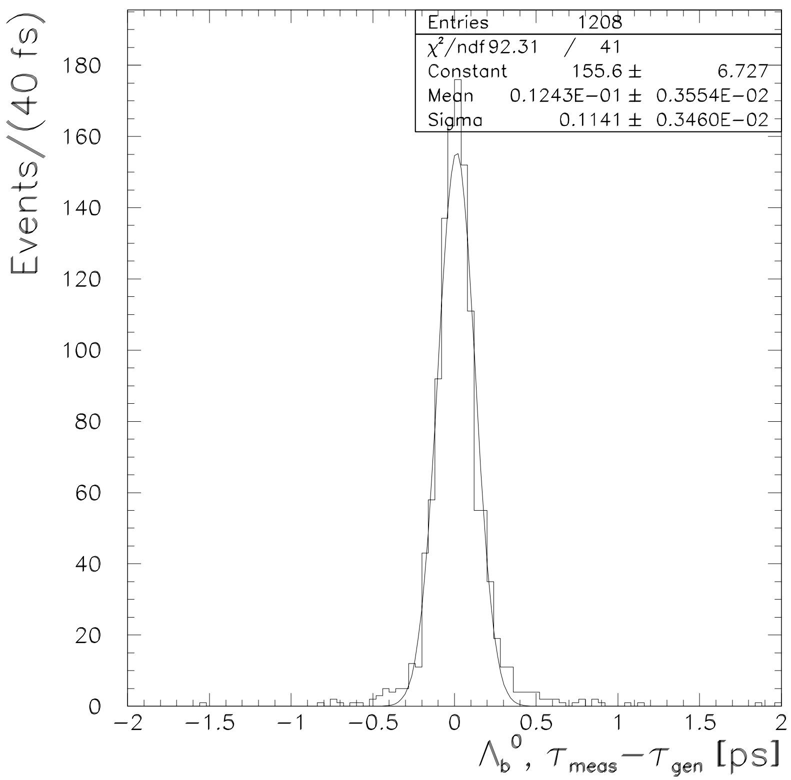
- Fully hadronic mode $\Lambda_b \rightarrow J/\psi\ \Lambda^0$
  - BR($\Lambda_b \rightarrow J/\psi\ \Lambda^0$)=5x10^{-4}
  - Trigger on $J/\psi \rightarrow \ell^+\ell^-$ dilepton
  - Reconstruct $\Lambda^0 \rightarrow p\pi$ in J/ψ events
  - expect 15 000 events

- No need to rely on Monte Carlo for momentum correction

Λ_b Lifetime Projections

- $\Lambda_b \rightarrow J/\psi\Lambda$
  - p(Λ) points to $\mu^+\mu^-$ vertex
  - mass/vertex constraints





- Λ_b mass resolution 16 MeV/c^2
- Λ_b lifetime resolution 0.11 ps

Conclusions

- Run II starts March 2001
- After 2 years/2 fb^{-1} of data we will
  - measure $\sin(2\beta)$ to an accuracy of 0.03
  - probe B_s mixing to $x_s \approx 30$
  - measure Λ_b lifetime in exclusive decays
  - study several rare decays
  - measure cross sections
- DØ looks forward to contributing to the Beauty physics program

Flavor Tagging

Tag	εD^2 (%) measured CDF Run I	εD^2 (%) expected CDF Run II	Relevant DØ difference	DØ capabilities
Same side	$1.8 \pm 0.4 \pm 0.3$	2.0	same	2.0
Soft lepton	$0.9 \pm 0.1 \pm 0.1$	1.7	μ, e ID coverage	3.1
Jet charge	$0.8 \pm 0.1 \pm 0.1$	3.0	forward tracking	4.7
Opp. side K		2.4	no K ID	none
Combined		9.1		9.8

$B^0 \rightarrow \pi^+ \pi^-$

- Trigger on lepton from other b: $p_T(\ell)>3$ GeV/c
- 2 tracks with $p_T>1.5$ GeV/c
- Efficiency ~0.5%

- Expected tagged events:

$B_d \rightarrow \pi^+\pi^-$ 300 - 600

$B_s \rightarrow K^+ K^-$ 650 - 1300

$B_d \rightarrow K^+ \pi^-$ 1300 - 2600

$B_s \rightarrow K^+ \pi^-$ 150 - 300