B Physics in Run II from CDF

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Workshop on
B Physics at the Tevatron
Run II and Beyond

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Contents

B Physics in Run II at CDF

Assumptions:

- Run II: int. $\mathcal{L} = 2\ \text{fb}^{-1}$ in 1st 2 years
- $i.e.$, 10^{11} $b\bar{b}$ per year
- Projections based on CDF Run I data whenever possible

Emphasis on:

- New capabilities

  hadronic trigger, PID, 3-D vertexing

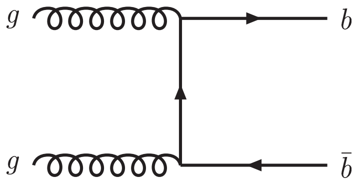
- Complementary measurements to B factories

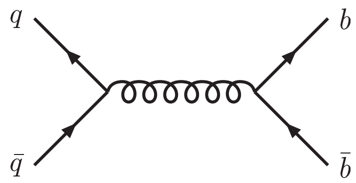
I do not discuss beyond Run II when FNAL may have a dedicated B physics detector

B Physics at Hadron Colliders

Strong interaction produces b quarks

Examples of lowest order (α_s^2) production:





produces $b\bar{b}$ pairs close in y

Quarks fragment into hadrons

$\bar{B}^0$ $(b\bar{d})$, $\bar{B}_s^0$ $(b\bar{s})$, $\bar{B}^-$ $(b\bar{u})$, Λ_b (bdu), B_c^- $(b\bar{c})$

also B^*, B^{**} etc.

Lowest lying states decay via weak interaction

Studies of these decays leads to information on
$V_{\rm cb}$, $V_{\rm ub}$, $V_{\rm tb}$, $V_{\rm ts}$, $V_{\rm td}$
$\Longrightarrow$ tests the EW Theory

B Physics is Three Subjects

1. The Study of Weak Decays

Test of CKM Mechanism

$\bar{B}_s^0$, Λ_b, B_c^- *unique* to had. machines

2. New Physics from Rare Decays

e.g. $B^0, B_s^0 \to \mu^+\mu^-$ or $e^\pm\mu^\mp$

3. Quantitative Study of QCD

- $m_b \gg \Lambda_{\mathrm{QCD}} \Longrightarrow$ inclusive production calculable with Perturbation Theory.
- Probe gluon structure func: $gg \to b\bar{b}$.
- At Tevatron NLO (α_s^3) corrections as large as L0 (α_s^2)
- *unique* to hadron colliders (like $\Gamma_{b\bar{b}}$ on Z^0)
- Also nonperturbative measurements: ratios of lifetimes and BFs, production fractions

B Trigger Required

Enormous cross-section:

$$\begin{aligned} \Upsilon(4S) &: \sigma(B\bar{B}) \sim 1 \text{ nb } (\bar{B}^0 \text{ and } B^- \text{ only}) \\ Z^0 &: \sigma(b\bar{b}) \sim 7 \text{ nb} \\ p\bar{p} &: \sigma(p\bar{p} \to b\bar{b}X) \sim 100\ \mu\text{b } (\text{at } \sqrt{s} = 1.8\,\text{TeV}) \end{aligned}$$

BUT: $\sigma(\text{inel}) \sim 10^3 \cdot \sigma(b\bar{b})$
$\Longrightarrow$ specialized B triggers required

Run I triggers:

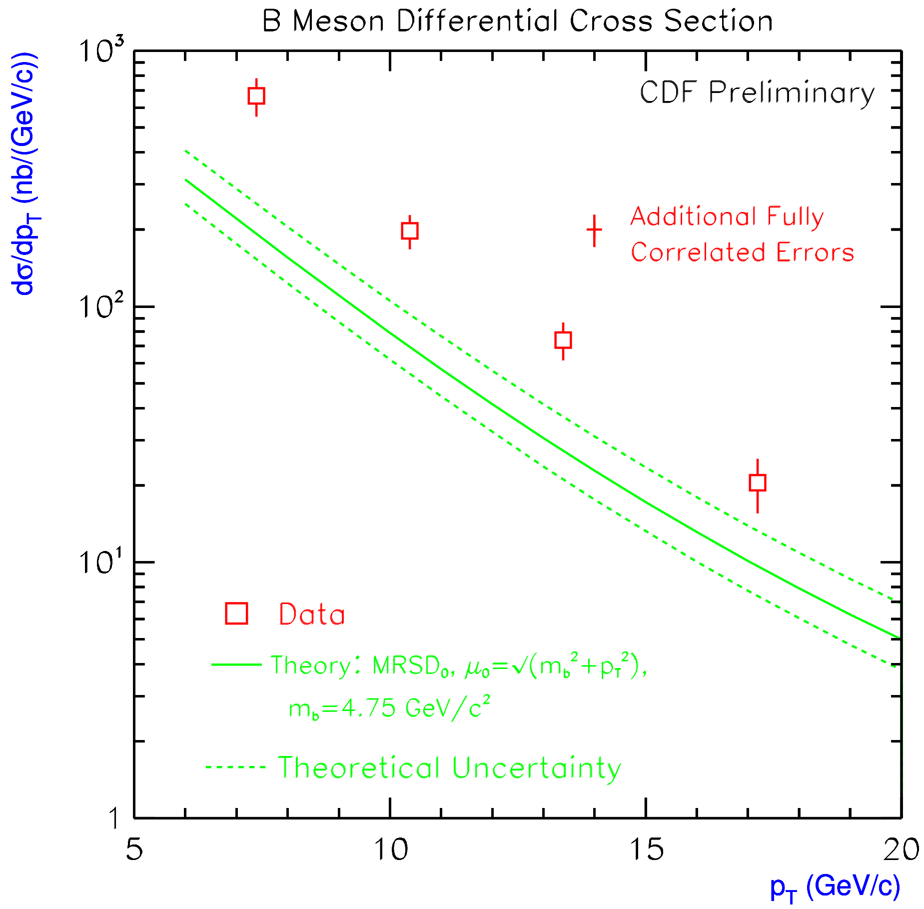
- Inclusive lepton: *e.g.* $b \to e, \mu$
  $\langle p_T(B) \rangle \approx 20\,\text{GeV}/c$
- Dilepton: *e.g.* $b \to J/\psi X, \psi \to \mu^+\mu^-$
  $\langle p_T(B) \rangle \approx 10\,\text{GeV}/c$

Run II trigger additions:

Exploit B lifetime
$\Longrightarrow$ trigger on displaced tracks
All hadronic B trigger possible
e.g., $B^0/\bar{B}^0 \to \pi^+\pi^-$, $B_s^0 \to D_s^-\pi^+$
Discuss this in detail

B Meson Cross Section

"Useful" B meson cross section



$$\sigma(\bar{B}^0, p_T(\bar{B}) > 6\,\mathrm{GeV}/c, |y(\bar{B})| < 1)$$
$$= 2.91 \pm 0.21\,(\mathrm{stat}) \pm 0.41\,(\mathrm{syst})\,\mu\mathrm{b}$$

Run I B Physics Results: Highlights

- Precise mass measurements of $\bar{B}_s^0$ and Λ_b
- Precise inclusive and species specific B lifetime measurements
- Neutral B meson flavor oscillations

  Precise measurement of Δm_d

  lower limit on Δm_s

  developed b flavor tags
- Search for rare/forbidden B decays

  FCNC: *e.g.*,$\bar{B}^0, \bar{B}_s^0 \to \mu^+\mu^-, B^- \to \mu^+\mu^- K^-$

  Lepton number violation: $\bar{B}^0, \bar{B}_s^0 \to \mu^\pm e^\mp$
- Polarization in $\bar{B}^0 \to J/\psi \bar{K}^{*0}$ $B_s^0/\bar{B}_s^0 \to J/\psi\, \phi$
- Discovery of B_c^- from $B_c^- \to J/\psi \ell X, \ell = e, \mu$
- First measurement of $\sin(2\beta)$ from $B^0/\bar{B}^0 \to J/\psi K_{\mathrm{S}}^0$

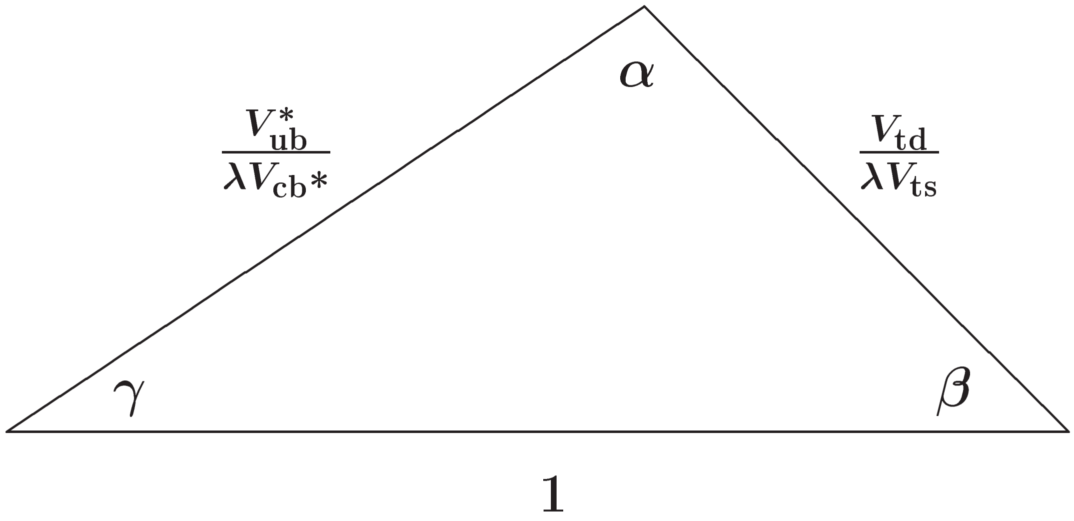
Run I B Physics Results (cont.)

- inclusive differential cross sections (b and B) at $\sqrt{s} = 630\&1800\,\mathrm{GeV}$
- correlated $b\bar{b}$ production (φ and y)
- Relative production rates (f_u, f_d, f_s, f_{baryon})
- Precise relative branching fractions
- Studies of prompt and non-prompt $J/\psi, \psi(2S)$ production including polarization
- $\Upsilon(1S), \Upsilon(2S), \Upsilon(3S)$ production
- $\chi_c(1P), \chi_c(2P), \chi_b$ production

In total: over 40 publications submitted or published

Future Analysis in B Physics

Goal of B physics in next decade:



Next test of Unitarity may be a combination of:

1. $\sin(2\beta)$ from $B^0/\bar{B}^0 \to J/\psi K^0_S$
2. $|V_{td}/\lambda V_{ts}|$ from $B^0 - \bar{B}^0$ and $B^0_s - \bar{B}^0_s$ flavor oscillations

Unique capability to do both at Had. Coll.

CDF Upgrade for Run II

New silicon tracking system

- SVX II: 5 Layer, 96 cm, $r-\phi$ and $r-z$
- ISL: 2 additional layers, covers $|\eta| < 2$

3D Vertex, $\sim$ 2 more acceptance

New central drift chamber (B=1.4 T, R=1.4 m)

Maintain Run I track eff. and resol.

New deadtimeless trigger

- Track trigger moved to Level 1
- Use silicon information at Level 2

Purely hadronic B trigger possible

Recently approved additions

- New inner layer of Si at $r = 1.4\,\mathrm{cm}$
- Time-of-Flight:

  2σ K/π sep. for $p < 1.6\,\mathrm{GeV}/c$

Tevatron Run II B Physics

- Precise Measurement of $|V_{\rm td}/V_{\rm ts}|$
  - (†) $B_s^0 - \bar{B}_s^0$ flavor oscillations (also $\Delta\Gamma_s/\Gamma_s$)
  - Radiative decays:
    e. g. $B_s^0 \to K^{*0}\gamma$ vs. $B_s^0 \to \phi\gamma$ (†)
- Observe CP Viol. in $B^0/\bar{B}^0 \to J/\psi K_S^0$
  Precise measurement of $\sin(2\beta)$
- Observe CP Viol. in $B^0/\bar{B}^0 \to \pi^+\pi^-$
  Precise measurement of asymmetry ($\sin(2\alpha)$)
- (†) Measure CP asym. in $B_s^0/\bar{B}_s^0 \to J/\psi\,\phi$
  Large asymmetry is physics beyond SM
- Observe decay modes related to angle γ
  $B_s^0 \to D_s^\pm K^\mp$(†) and $B^+ \to \bar{D}^0 K^+$
- Rare Decays
  Observe $B^+ \to \mu^+\mu^- K^+$, $B^0 \to \mu^+\mu^- K^{*0}$,
  $B_s^0 \to \mu^+\mu^-\phi$ (†)
- (†) Study B_c^+ meson and b baryons

(†) Unique to Hadron Machines

Measuring $B_s^0 - \bar{B}_s^0$ Oscillations

Measure oscillation frequency $\Delta m_s = x_s/\tau(B_s^0)$
Requires:

- Proper decay time t
- Flavor at production: B_s^0 $(\bar{b}s)$ or $\bar{B}_s^0$ $(b\bar{s})$
- Flavor at Decay
  (unambiguous for decay modes here)

Also: B_s^0 signal with adequate signal-to-noise

$$\frac{N_{\text{unmixed}}(t) - N_{\text{mix}}(t)}{N_{\text{unmixed}}(t) + N_{\text{mix}}(t)} = D \cdot \cos\left(\frac{x_s}{\tau(B_s^0)} t\right)$$

Flavor tag Dilution: $D = 2 \cdot \mathcal{P} - 1$

Proper time reconstruction:

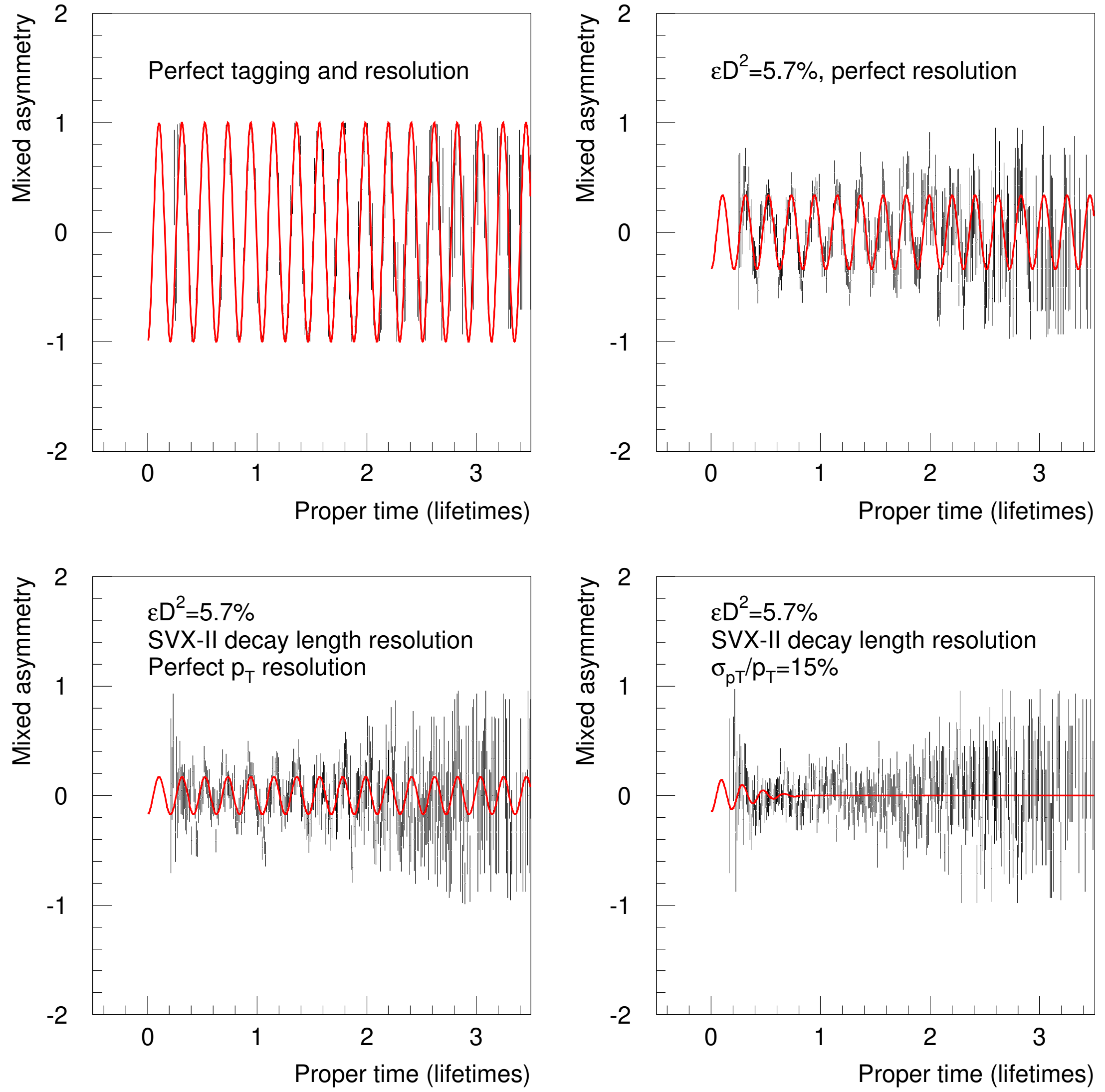
$$t = m(B) \cdot \frac{L}{p}$$

Uncertainty δt on t:

$$(\delta t)^2 = \left(\frac{m(B)}{p}\delta L\right)^2 \oplus \left(t \cdot \frac{\delta p}{p}\right)^2$$

Illustration of $B_s^0 - \bar{B}_s^0$ Oscillations

Example: $x_s = 30$



Conclusion:

To go beyond current limit
need **fully** reconstructed B_s^0

B_s^0 Hadronic Modes

We study the following modes:

- $B_s^0 \to D_s^- \pi^+$ (BF=$0.30 \pm 0.04\%$ from B^0 mode)
- $B_s^0 \to D_s^- \pi^+ \pi^- \pi^+$ (BF=$0.80 \pm 0.25\%$ from B^0 mode)

For the D_s^- we use

- $D_s^- \to \phi \pi^-$ (BF=$3.6 \pm 0.9\%$), $\phi \to K^+ K^-$
- $D_s^- \to K^{*0}(892) K^-$ (BF=$3.3 \pm 0.9\%$), $K^{*0} \to K^+ \pi^-$

For comparison, we also include

- $B_s^0 \to D_s^{*-} \pi^+$ (BF=$0.28 \pm 0.02\%$ from B^0 mode)
- $B^0 \to \pi^+ \pi^-$ BF=10^{-5} (assumption)

Acceptance normalized to CDF measurement:
$\sigma(p\bar{p} \to B^0 X, p_T > 6 \text{ GeV}/c, |y| < 1) = 2.39 \pm 0.54\ \mu\text{b}$

$$f_s = \frac{\sigma(p\bar{p} \to B_s^0 X)}{\sigma(p\bar{p} \to B^0 X)} = 0.26 \pm 0.05 \text{ (LEP)}$$

Acceptance modeled with single b Monte Carlo based on NDE next-to-leading order calculation.

Assume 2 fb^{-1} integrated luminosity

CDF Run II Trigger

Three Level Architecture (like Run I)
"Deadtimeless" (pipelined)

Level 1

- Simple objects (same as Run I)
  $e.g.$, EM cal. cluster
  track stub in μ chamber
- New: tracks (XFT) for $p_T > 1.5$ GeV/c
  $\delta p_T / p_T^2 = 0.015\ (\mathrm{GeV}/c)^{-1}$
  $\delta \phi_6 = 0.0015$ rad
- Output: 50 KHz

Level 2

- Limited Event reconstruction with Alpha (like Run I)
- New: Silicon information available (SVT)
  trigger on impact parameter and displaced vertex
- Output: 300 Hz

Level 3

- Full event reconstruction on PC farm (LINUX)
- Output: 75 Hz

All-Hadronic B Decay Trigger

Level 1:

Inclusive p_T spectrum in $p\bar{p} \to h^{\pm}X \propto p_t^{-8}$

p_T spectrum from $p\bar{p} \to b\bar{b}X$ harder

- Require two stiff tracks ($i.e.$, $p_T > p_{T,\min}$)
- remove back-to-back combinations ($\Delta\phi < \Delta\phi_{\max}$)
- require opposite charge

Level 2:

B hadrons have relatively long lifetime ($\tau \sim 1.5$ps)

SVT provides impact parameter information
(and improved helix parameters)

Alpha can combine tracks to form vertices
($i.e.$, limited event reconstruction)

- Require two tracks with large impact parameter d_0
- Vertex tracks - require positive decay length
- tighten azimuthal requirements ($\Delta\phi$)

Hadronic B Trigger (continued)

Consider 3 operating scenarios

Scenario	T_{bunch} (ns)	$\mathcal{L}$ $\times 10^{32}$ cm^{-2}s^{-1}	$\langle N_{p\bar{p}} \rangle$
A	396	0.7	2
B	132	2.0	2
C	396	1.7	5

and 2 trigger selections

1. **two-body decays**
   optimized on $B^0 \to \pi^+\pi^-$
2. **multi-body decays**
   optimized on $B_s^0 \to D_s^- \pi^+$, $D_s^- \pi^+\pi^-\pi^+$

The hadronic B trigger is the "or" of these two selections

Level 1 Selection and Rates

Level 1 selection

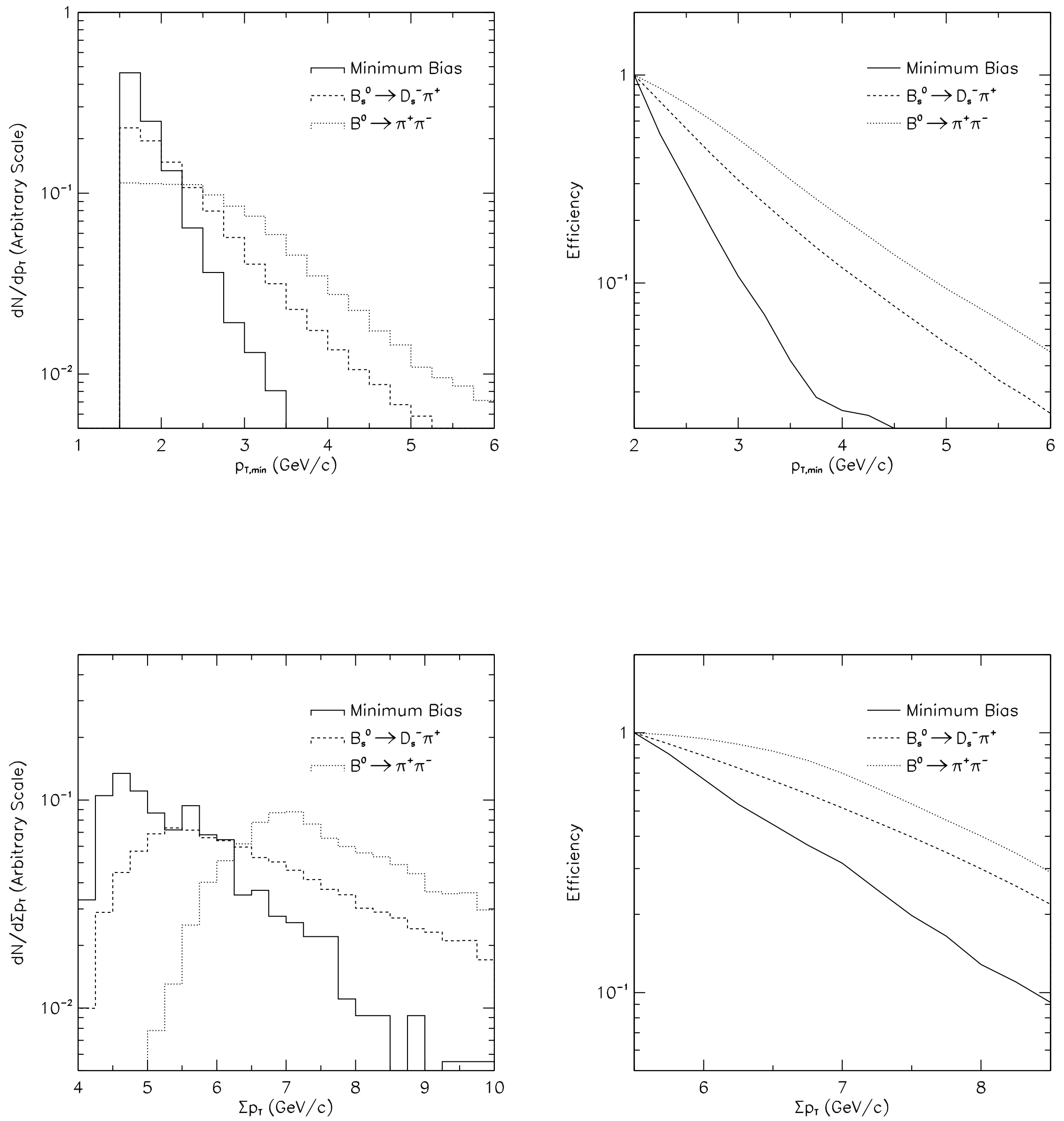
Scenario	$p_{T,\mathrm{min}}$ GeV/c	$(\Sigma p_T)_{\mathrm{min}}$ GeV/c	$\Delta\phi_{6,\mathrm{max}}$
A	2.00	5.5	135°
B	2.25	6.0	135°
C	2.50	6.5	135°

Predicted Level 1 rates

Scenario	Two-track cross section (μb)	Two-track rate (kHz)
A	252 ± 18	18
B	152 ± 14	30
C	163 ± 16	28

- **Uses Run I minimum bias data**
  provides realistic hit distributions
  used as input to COT and XFT simulations
- **Within Level 1 bandwidth (50 kHz)**

Level 1 Selection Criteria



Level 2 Selection and Rates

Level 2 selections

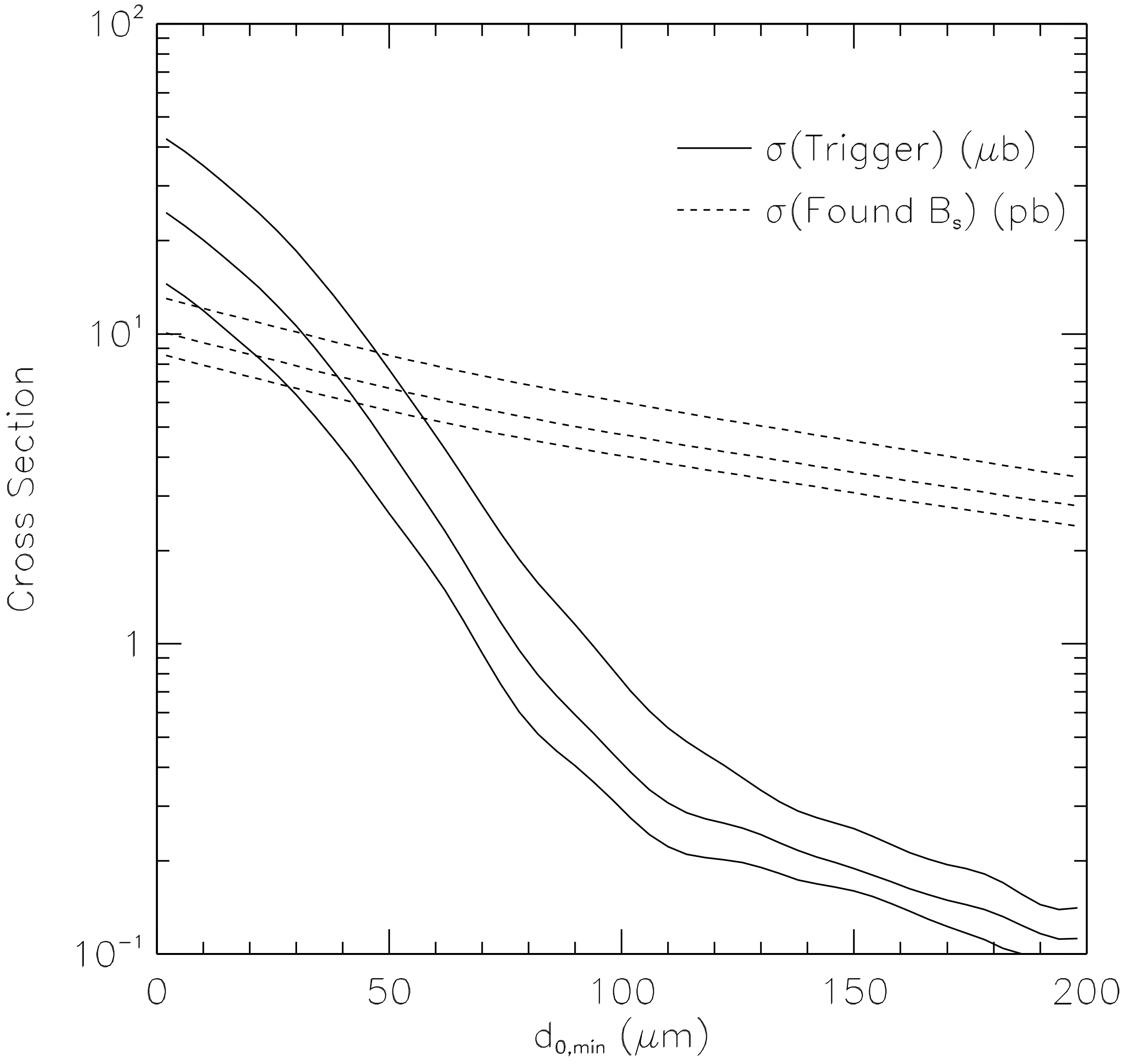
Multi-body ($B_s^0 \to D_s^- \pi^+$)	Two-body ($B^0 \to \pi^+\pi^-$)
$120\ \mu\text{m} < \lvert d_0 \rvert < 1$ mm	$100\ \mu\text{m} < \lvert d_0 \rvert < 1$ mm
$2^\circ < \Delta\phi_0 < 90^\circ$	$20^\circ < \Delta\phi_0 < 135^\circ$
$p_T \cdot X_v > 0$	$P_T \cdot X_v > 0$
—	$d_B < 140\ \mu$m

Predicted Level 2 rates (nb)

Scenario	Multi-body selection	Two-body selection	Combined selections	Level 2 Rate (Hz)
A	394 ±105	360 ±100	560 ±125	39
B	280 ±89	196 ±74	336 ±97	67
C	196 ±74	84 ±48	224 ±79	38

- **Can predict using Run I data**
  (special two CFT track trigger)
  use hits from Run I Si det. SVX′
  SVX II and SVX′ have similar geometry
  SVT uses $r\phi$ information only
- **Within Level 2 bandwidth (300 Hz)**

Level 2 Selection Criteria



Predicted Signal Rates (2 fb^{-1})

Signal Cross-sections (pb)

Mode	A	B	C
$B_s^0 \to D_s^- \pi^+$	5.3	4.2	3.6
$B_s^0 \to D_s^- \pi^+ \pi^- \pi^+$	6.4	5.2	4.1
$B_s^0 \to D_s^{*-} \pi^+$	4.7	3.7	2.9
$B^0 \to \pi^+ \pi^-$	7.6	5.9	4.2

Signal Sizes

Mode	A	B	C
$B_s^0 \to D_s^- \pi^+$	10600	8400	7200
$B_s^0 \to D_s^- \pi^+ \pi^- \pi^+$	12800	10400	8100
$B_s^0 \to D_s^{*-} \pi^+$	9400	7400	5800
$B^0 \to \pi^+ \pi^-$	15200	11800	8400

- Correlated uncertainty on B_s^0 rates = 40% (due to cross-section, BF's, and f_s)
- Use $D_s^- \pi^+$, $D_s^- \pi^+ \pi^- \pi^+$ only for x_s reach
- Use 20000 as central value (5000 to 30000)

Signal to Background: Introduction

Large sample of all-hadronic B decays

Question: Can we extract them from the enormous combinatorial background?

We use Run I data to study these backgrounds

- No all-hadronic B trigger $\Longrightarrow$ use inclusive e & μ
- Inclusive leptons $\sim 40\%$ $b\bar{b}$ from $b \to \ell$
  remainder is $c\bar{c}$ and fake ℓ ($e.g.$, $\gamma \to e^+e^-$)

Two sources of combinatoric background

1. Heavy flavor ($b\bar{b}$ and $c\bar{c}$)
   have true lifetime and displaced tracks.

   Can predict with Monte Carlo, but use data

   Opposite ℓ is unbiased B decay

   Look for signal, study background from $b\bar{b}$

2. Light quark and gluon production (generic QCD)
   Mismeasured tracks or K, Λ or $\gamma \to e^+e^-$.

   Cannot predict with Monte Carlo, must use data

   Opposite identified $\gamma \to e^+e^-$

   study background from generic QCD

Generic QCD versus $b\bar{b}$

What fraction of triggered events are $b\bar{b}$?

Predict rate with Monte Carlo normalized to CDF measured B cross-section

Compare to rate in Run I data (scenario A)

	data rate	$b\bar{b}$ MC	$b\bar{b}$ fraction
Level 1	$(252 \pm 18)\mu$b	(720 ± 20)nb	0.3%
Level 2	(394 ± 105)nb	(81 ± 4)nb	24%

After Level 2 Multi-body B trigger is $\sim \frac{1}{4}$ $b\bar{b}$

Similar purity in inclusive ℓ and J/Ψ samples
Found clean $B \rightarrow D\ell\nu$ and $B \rightarrow J/\psi K$

Conclusion:

Background from Generic QCD manageable

Generic Jets and Top b Tag

Top quark discovery:

b identification using lifetime drastically reduces generic QCD jet background

Applied to jet-triggered data $\Longrightarrow$
80% of jets with positive lifetime ($c\tau$) are $b\bar{b}$ and $c\bar{c}$

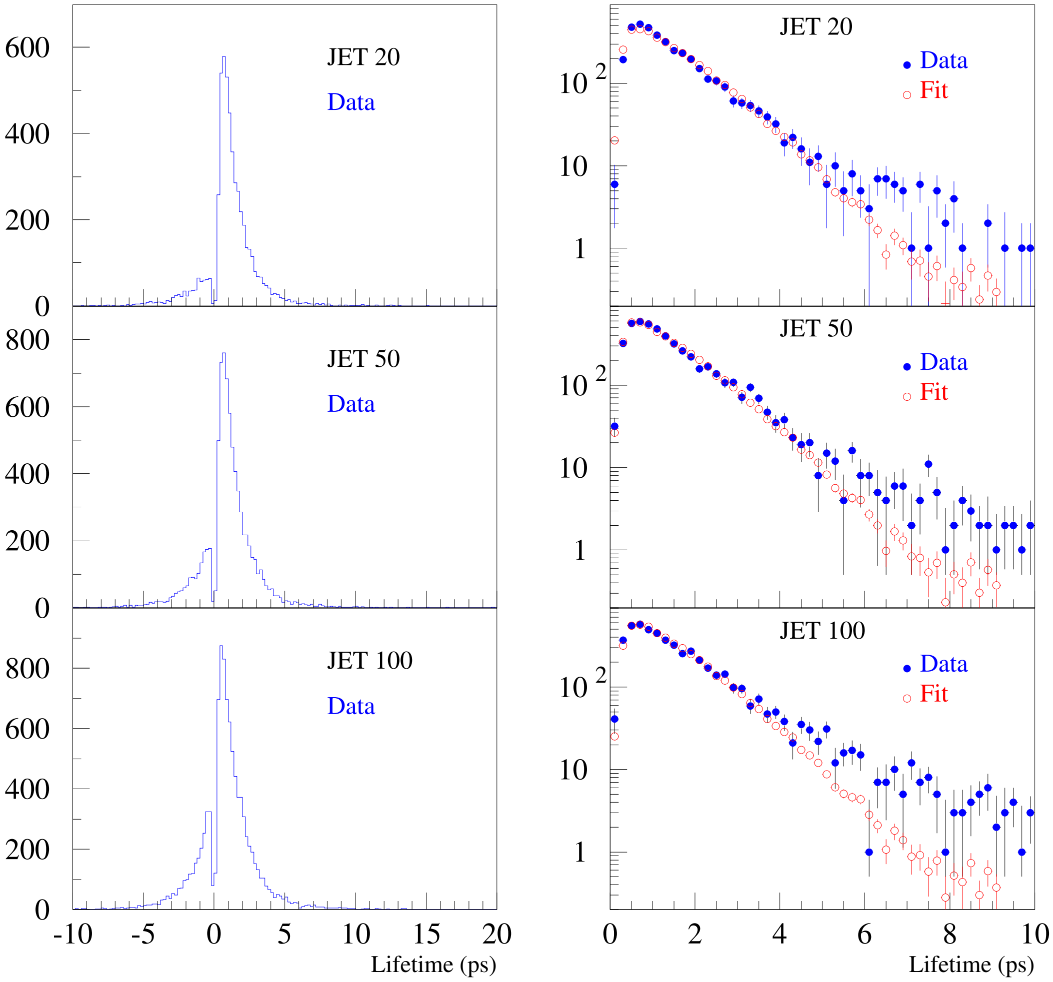


Figure 9: $c\tau$ distributions of SECVTX tags before and after mistag subtraction in all QCD data.

Background from $b\bar{b}$

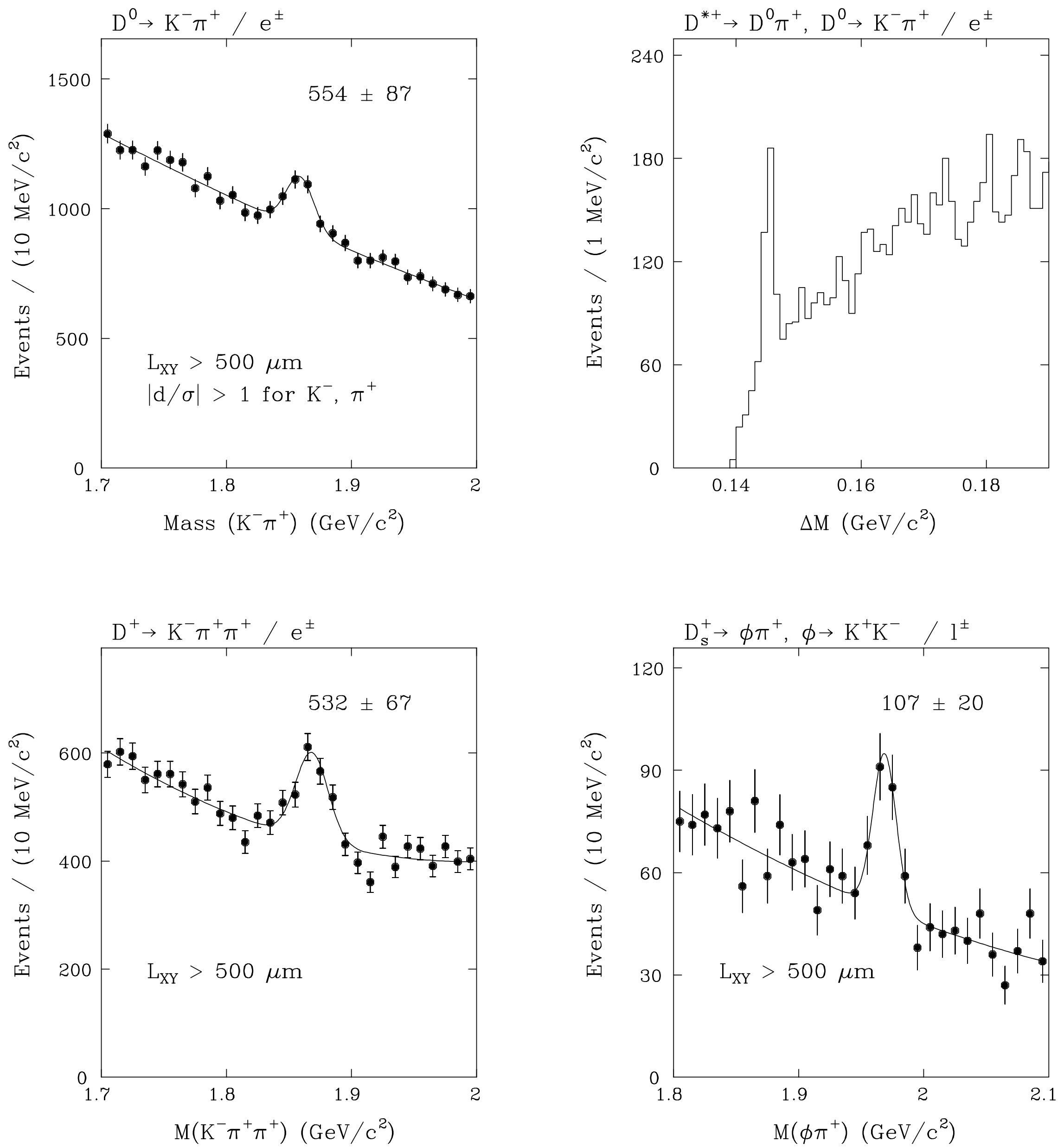
Search for the following decay modes:

- $B \to D\pi, D\pi\pi\pi$;
- where $D = D^0, D^{*+}, D^+, D_s^+$

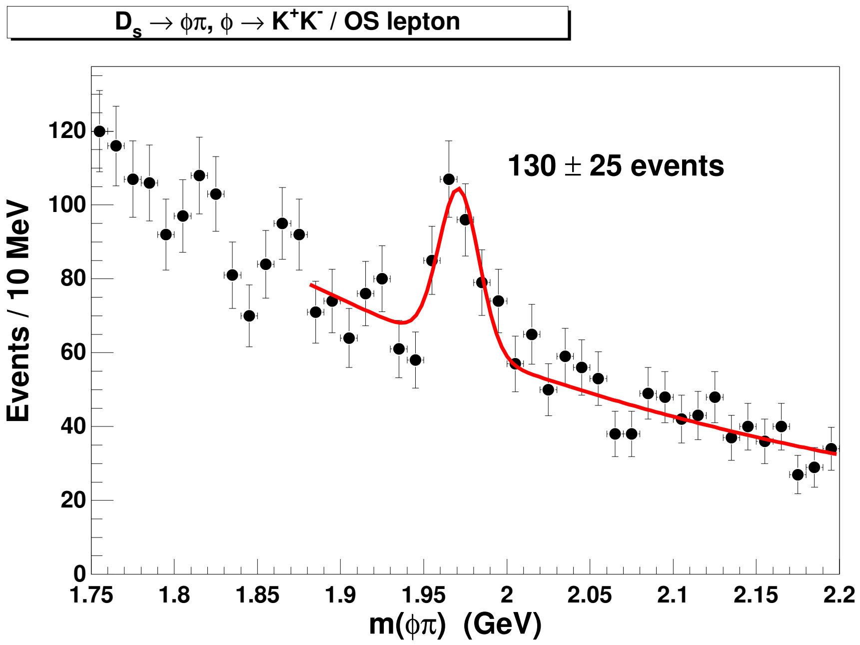
Start by looking for D opposite ℓ

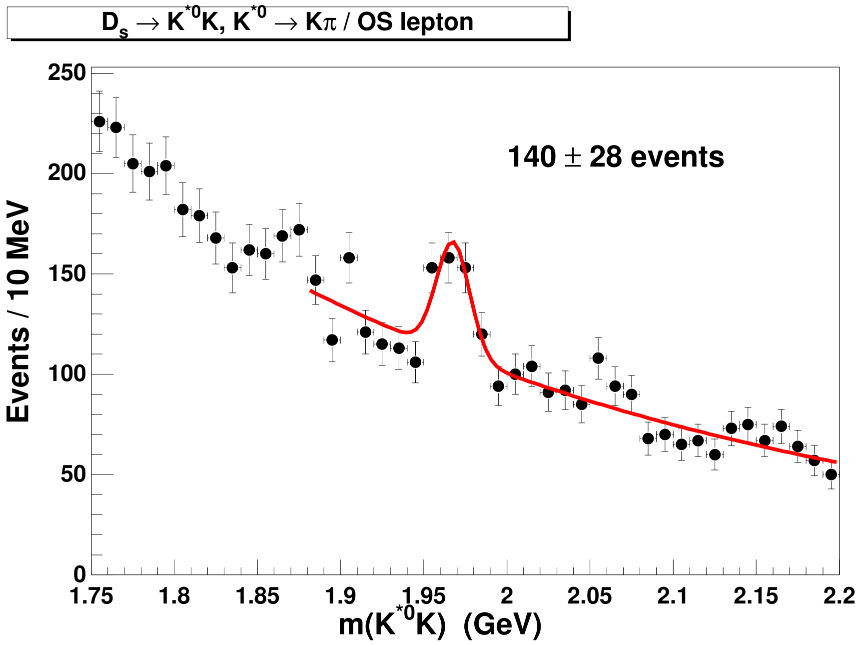
- $D^0 \to K^-\pi^+$;
- $D^{*+} \to D^0\pi^+$, D^0 reconstructed as above;
- $D^+ \to K^-\pi^+\pi^+$;
- $D_s^+ \to \phi\pi^+$, with $\phi \to K^+K^-$;

D Signals Opposite Leptons



See $D_s^- \to \phi\pi^-$, and $K^{*0}K^-$

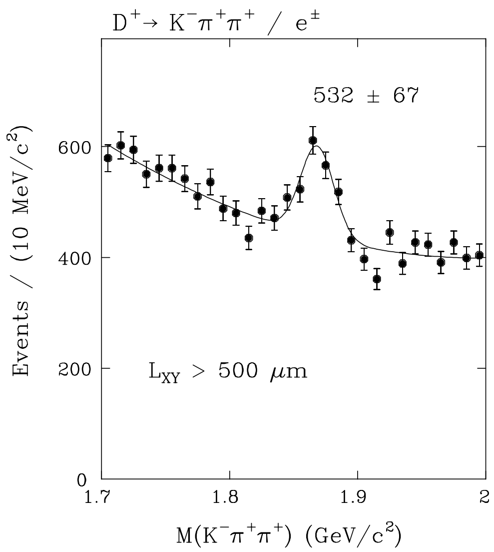




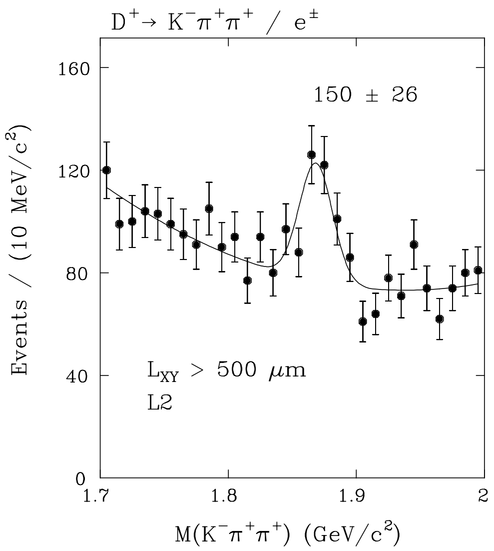
Focus on D^+

$D^+ \to K^-\pi^+\pi^+$ like $D_s^+ \to \phi\pi^+, \phi \to K^+K^-$
(Three-prong vertex)

No Run II trigger



Run II Level 1 & Level 2

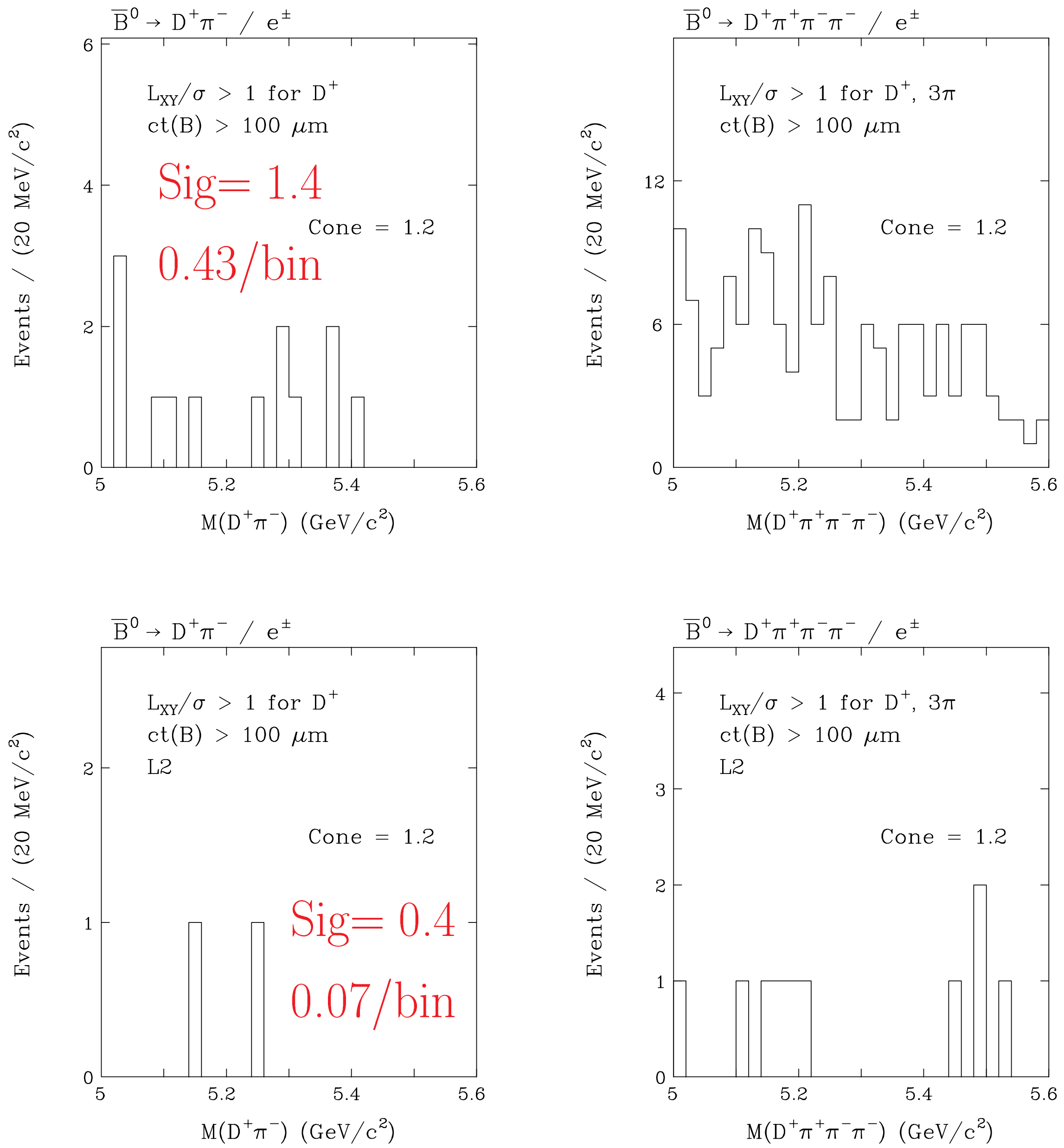


Run II trigger requirements
improve D^+ signal to noise

Combine D^+ signals with π^- or $\pi^-\pi^+\pi^-$

$\Longrightarrow$

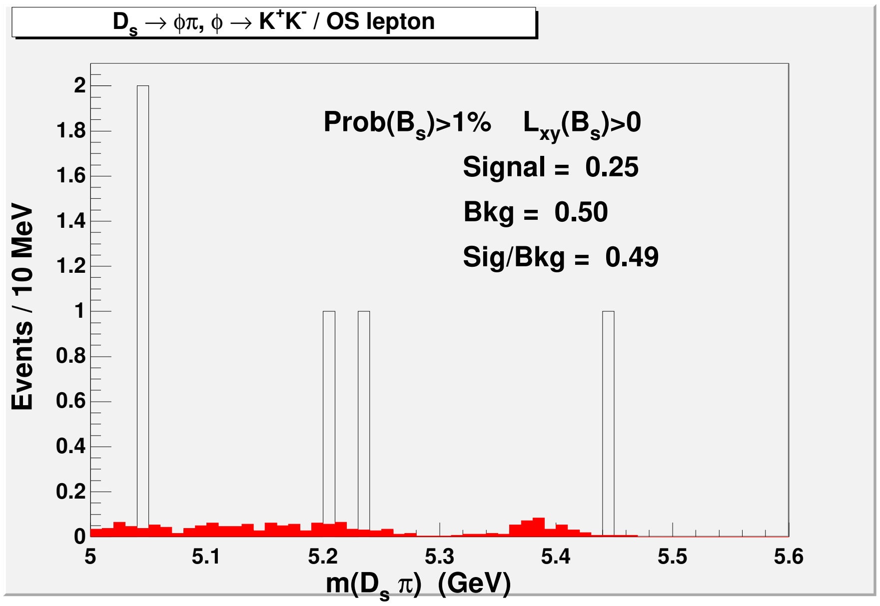
$\bar{B}^0 \to D^+\pi^-, D^+\pi^-\pi^+\pi^-$



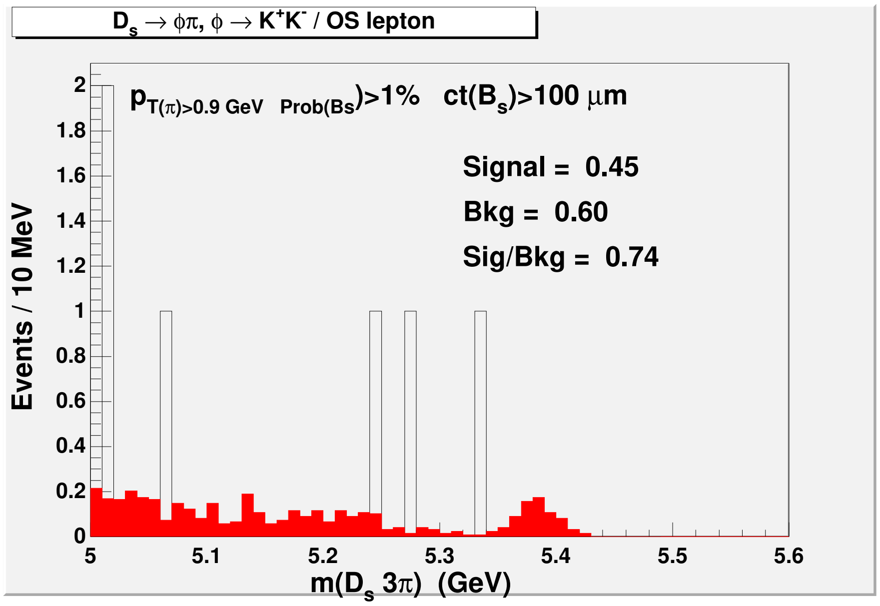
$\bar{B}^0 \to D^+\pi^-$	Expected Signal	Background/20 MeV/c^2	S:N
no trigger selection	1.4	0.43	**3:1**
Run II trigger	0.4	0.07	**6:1**

Background in $B_s^0 \to D_s^- \pi^+, D_s^- \pi^+ \pi^- \pi^+$

$B_s^0 \to D_s^- \pi^+$



$B_s^0 \to D_s^- \pi^+ \pi^- \pi^+$



Conclusions: Signal to Noise

Combinatoric background expected from

1. Heavy Flavor
2. Generic QCD

Heavy Flavor: D signals found opposite ℓ

- Combined with π^+ and $\pi^+\pi^-\pi^+$
- No B signal seen (not expected)
- observed background $\Longrightarrow$ S:N better than 1:1 especially after Run II trigger

Generic QCD:

- Monte Carlo: $b\bar{b}$ fraction significant after Level 2
- No D signals opposite $\gamma \to e^+e^-$
- Combinatorics in $\gamma \to e^+e^- \Longrightarrow$ Generic QCD similar to Heavy Flavor
- Should be better in Run II, SVX II is 3-D

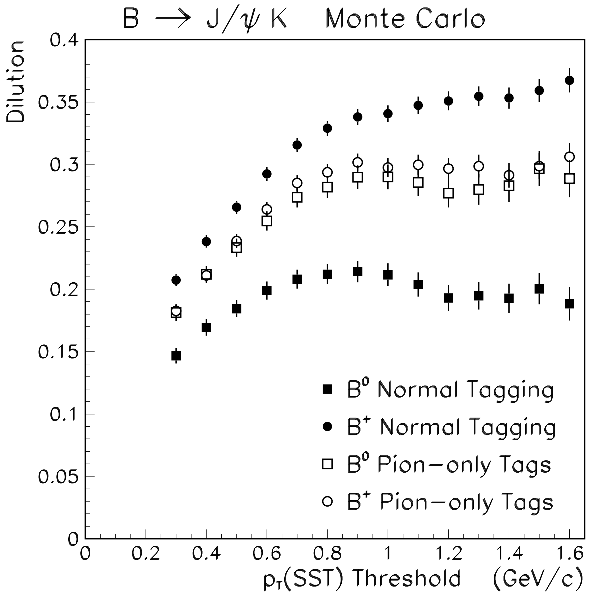
Conclusion:

Varying S:N from 1:2 $\rightarrow$ 2:1 reasonable
(Worse S:N does not compromise x_s reach)

Expected Flavor Tagging in Run II B_d^0

TOF provides opposite-side K tag

TOF improves same-side π tag (K veto)



$B^0/\bar{B}^0 \to J/\psi K_S^0$		
	without TOF	with TOF
Same-Side (pion)	1.4	1.9
Soft Lepton (μ)	1.0	1.0
Soft Lepton (e)	0.7	0.7
Jet Charge	3.0	3.0
Opp.-Side Kaon	—	2.4
Total	6.1%	9.0%

Expected Flavor Tagging in Run II B_s^0

$B_s^0 \rightarrow D_s^- \pi^+$		
	without TOF	with TOF
Same-Side (Kaon)	1.0	4.2
Soft Lepton (μ)	1.0	1.0
Soft Lepton (e)	0.7	0.7
Jet Charge	3.0	3.0
Opp.-Side Kaon	—	2.4
Total	5.7%	11.3%

$B_s^0/\bar{B}_s^0 \rightarrow J/\psi\phi$		
	without TOF	with TOF
Same-Side (Kaon)	0.2	2.6
Soft Lepton (μ)	1.0	1.0
Soft Lepton (e)	0.7	0.7
Jet Charge	3.0	3.0
Opp.-Side Kaon	—	2.4
Total	4.9%	9.7%

B_s^0 Flavor Oscillations in Run II

- Expected signal: 20000 $B_s^0 \to D_s^-\pi^+, D_s^-\pi^+\pi^-\pi^+$; $D_s^- \to \phi\pi^-, K^{*0}(892)K^-$ after trigger and selection
- Proper time resolution:

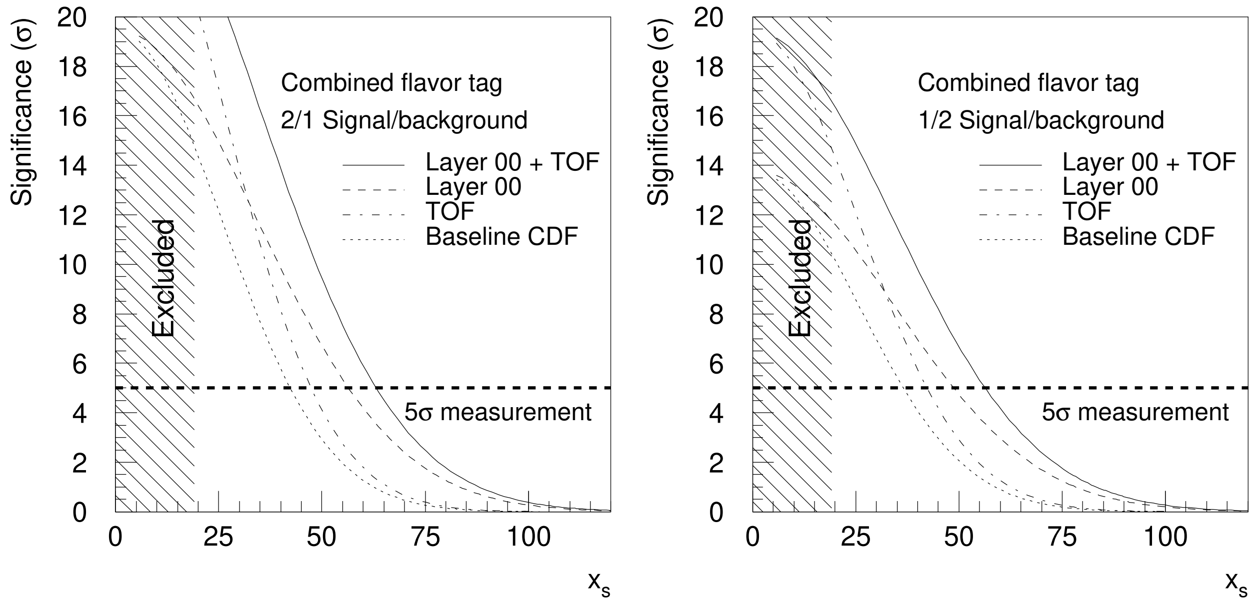
$$\sigma_t = 0.060 \text{ ps} \oplus t \cdot \sigma_{p_T}/p_T \text{ (SVXII only)}$$
$$\sigma_t = 0.045 \text{ ps} \oplus t \cdot \sigma_{p_T}/p_T \text{ (SVXII with L00)}$$

- Flavor tag effectiveness:

$$\epsilon D^2 = 5.7\% \text{ (CDF Baseline detector)}$$
$$\epsilon D^2 = 11.3\% \text{ (with addition of TOF)}$$

- Signal to Noise: 2:1→1:2 (used Run I data)

$$\text{Sig}(x_s) = \sqrt{\frac{N\epsilon D^2}{2}} e^{-(x_s\sigma_{ct}/\tau)^2/2} \sqrt{\frac{S}{1+S}}$$



Sensitive to $x_s < 63$

Expectations for CP Modes

$\sin 2\beta$ from $B^0/\bar{B}^0 \to J/\psi K^0_S$

- For 10K $B^0/\bar{B}^0 \to J/\psi K^0_S$
- Calibrate tags with 40K $B^\pm \to J/\psi K^\pm$ and 20K $B^0 \to J/\psi K^{*0}$
- $\epsilon D^2 = 6.7\%$ (add 2.4% more with TOF)

$$\delta(\sin 2\beta) \approx 0.084$$

Asymmetry in $B^0/\bar{B}^0 \to \pi^+\pi^-$ ($\sin(2\alpha)$)

- Signal: 8 400 to 15 200 (if BR$= 1.0 \times 10^{-5}$)
- If signal of 10K and $\epsilon D^2 = 9.1\%$

$$\delta\mathcal{A}(\pi^+\pi^-) \sim 0.09$$

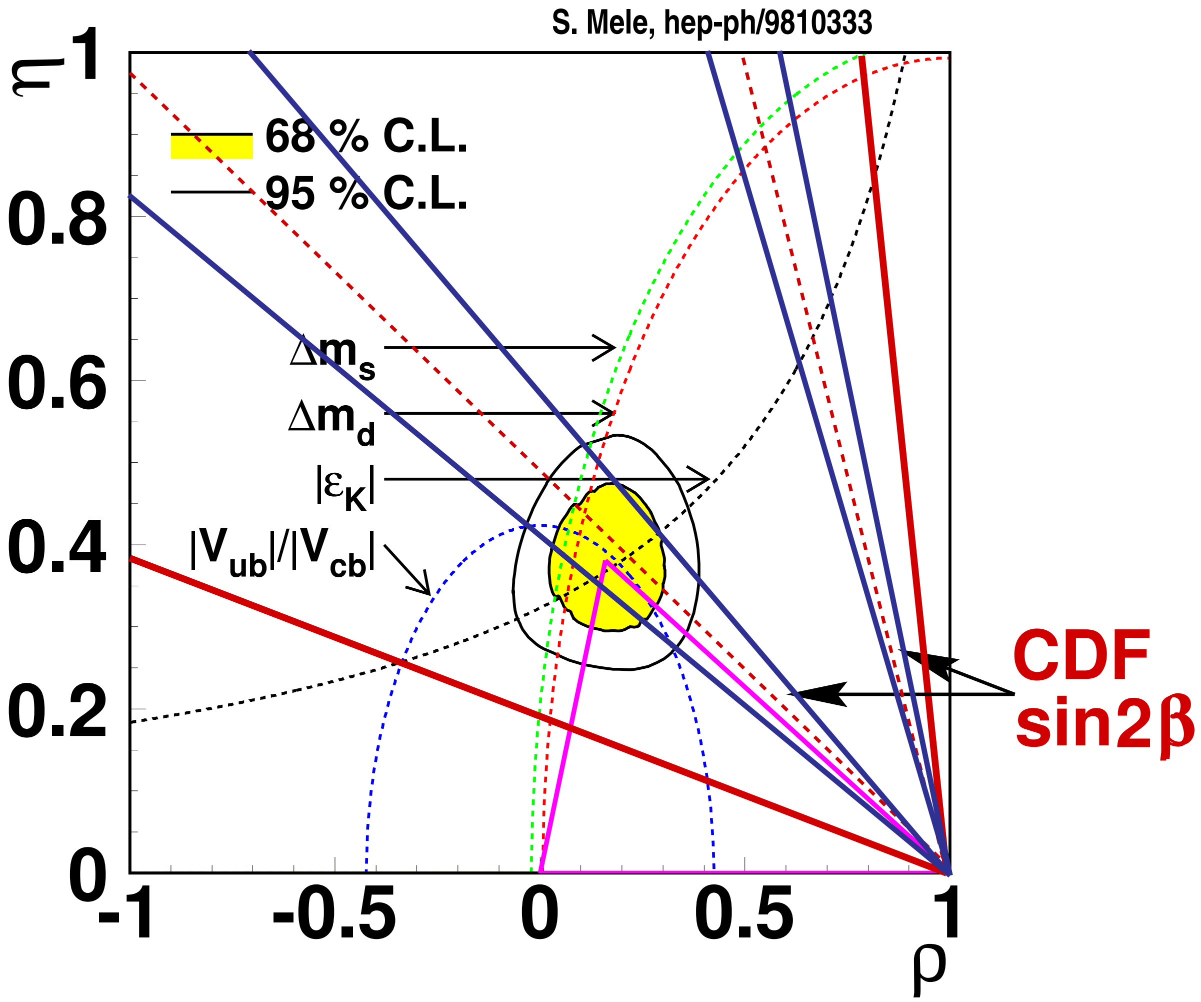
Modes related to $\sin(\gamma)$

- $B^0_s/\bar{B}^0_s \to D^\pm_s K^\mp$ Signal: ~ 700
- $B^\pm \to K^\pm D^0_{CP}$ (direct CP)
- $B^- \to K^- D^0, D^0 \to K^+\pi^-$ and $B^- \to K^- \bar{D}^0, \bar{D}^0 \to K^+\pi^-$

Run II: Expected Limit in $\rho - \eta$ Plane

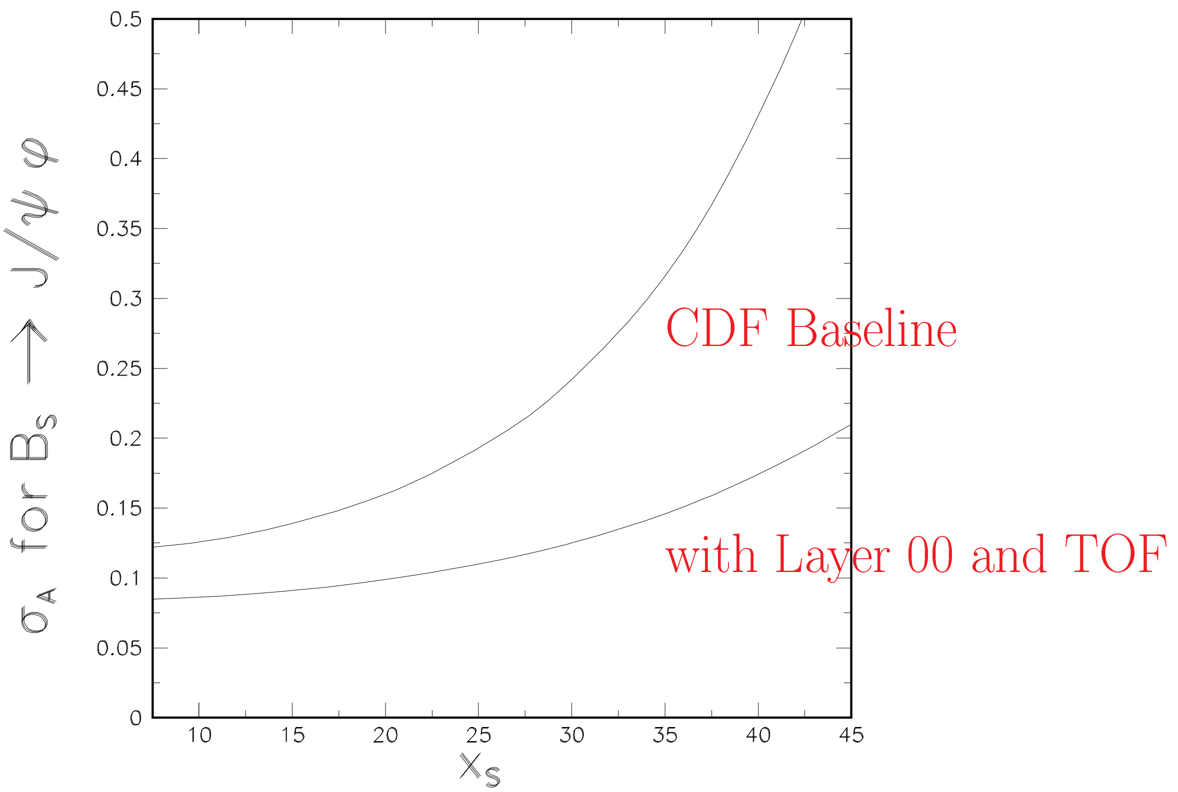
Run I value with proj. Run II error:

$$\sin(2\beta) = 0.79 \pm 0.084$$



CP Violation in $B_s^0/\bar{B}_s^0 \rightarrow J/\psi\phi$

- Small in the Standard Model
  Significant asymmetry unambiguous sign of new physics
- Expected signal: 6000 $B_s^0/\bar{B}_s^0 \rightarrow J/\psi\phi$
- Requires measurement of x_s
- Expected combined ϵD^2 for this sample: $\epsilon D^2 = 9.7\%$



Rare B Decays

Limits on $B^0/B_s^0 \to \mu^+\mu^-$ (F. Abe et al., PRD **57**, R3811 (1998))

- Allowed in SM, but 3 orders of magnitude below our current sensitivity
- Some SUSY models predict substantial enhancement

$$\mathrm{BR}(B^0 \to \mu^+\mu^-) < 8.6 \times 10^{-7} \text{ (95\%CL)}$$
$$\mathrm{BR}(B_s^0 \to \mu^+\mu^-) < 2.6 \times 10^{-6} \text{ (95\%CL)}$$

Limits on $B^0/B_s^0 \to e^\pm\mu^\mp$ (F. Abe et al., PRL **81**, 5742 (1998))

- Forbidden in SM
- Sensitive to new particles: Pati-Salam Leptoquarks

$$\mathrm{BR}(B^0 \to e^\pm\mu^\mp) < 4.5 \times 10^{-6} \text{ (95\%CL)}$$
$$\mathrm{BR}(B_s^0 \to e^\pm\mu^\mp) < 8.2 \times 10^{-6} \text{ (95\%CL)}$$

Corresponding to

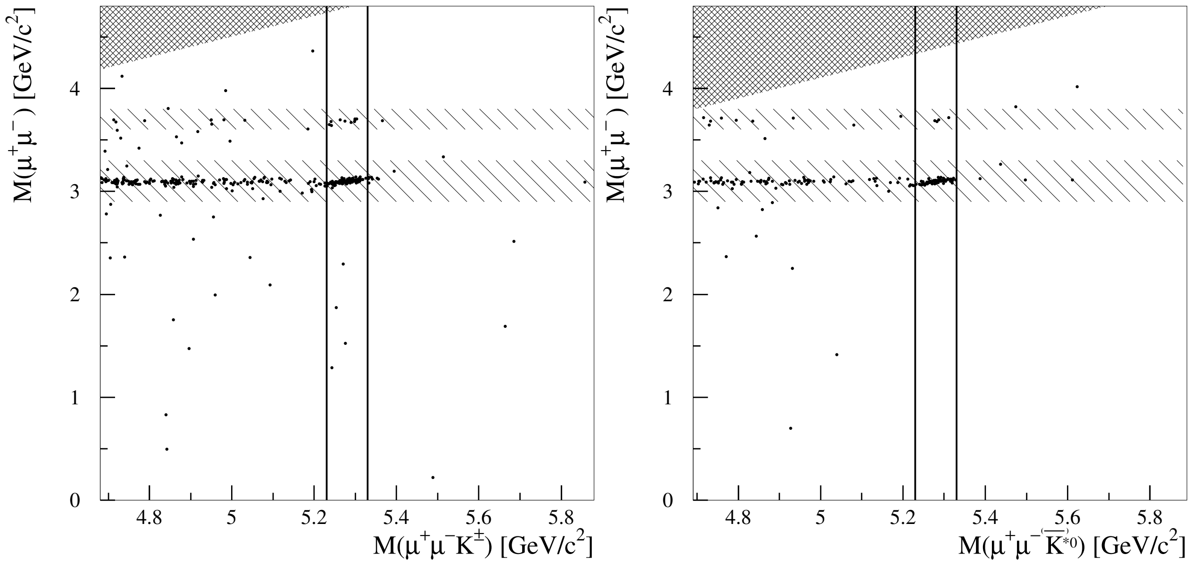
$$M_{\mathrm{LQ}}(B^0) > 20.4\,\mathrm{TeV}/c^2 \text{ (95\%CL)}$$
$$M_{\mathrm{LQ}}(B_s^0) > 19.3\,\mathrm{TeV}/c^2 \text{ (95\%CL)}$$

Run II:

- **Current limits not limited by background**
  Limits should scale with luminosity
- **Sensitive to $M_{\mathrm{LQ}} > 30\,\mathrm{TeV}/c^2$**

Nonresonant $B \to \mu\mu K$

Run I:



- Expect 0.5 Events in each channel from SM
- Comparable level of background

$$\mathrm{BR}(B^+ \to \mu^+\mu^-K^+) < 5.2 \times 10^{-6}\ (90\%\mathrm{CL})$$
$$\mathrm{BR}(B^0 \to \mu^+\mu^-K^{*0}) < 4.0 \times 10^{-6}\ (90\%\mathrm{CL})$$

Run II:

- Should see signal in Run II
- But statistics too low for new physics studies

Summary

Run I:

Important measurements of B hadron decay properties despite trigger restrictions.

Competitive with e^+e^- colliders.

Gained experience ($\sin 2\beta$, B^0 Flavor oscillations, rare decays) and developed tools (*e.g.*, flavor tags and trigger strategies) for Run II.

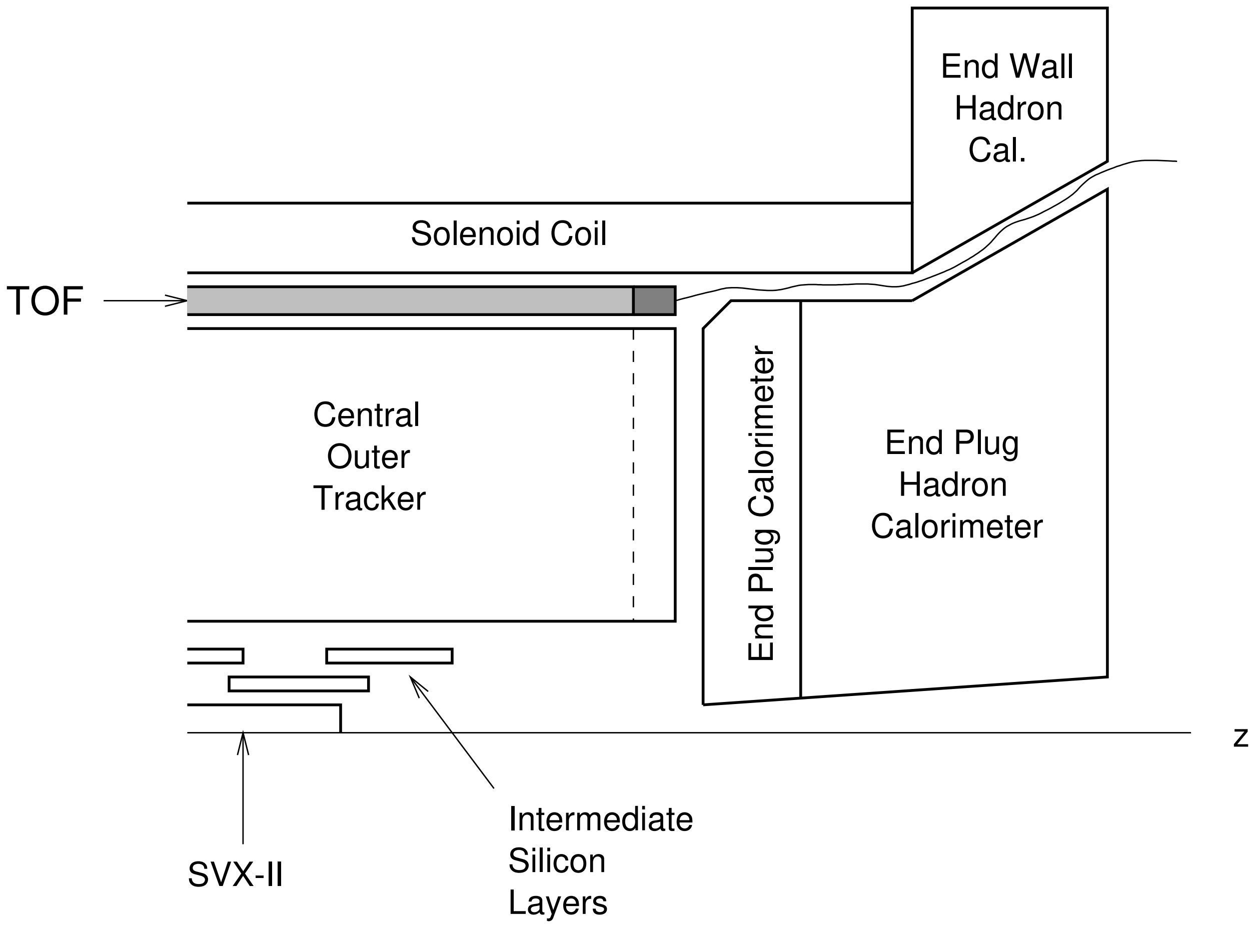
Run II:

Improved detectors increase scope of B Physics: *e.g.*, hadronic B triggers and TOF for PID.

Precision on $\sin 2\beta$ competitive with B factories (and is complementary). CP asymmetries in B_s^0 decays and Δm_s unique to Tevatron.

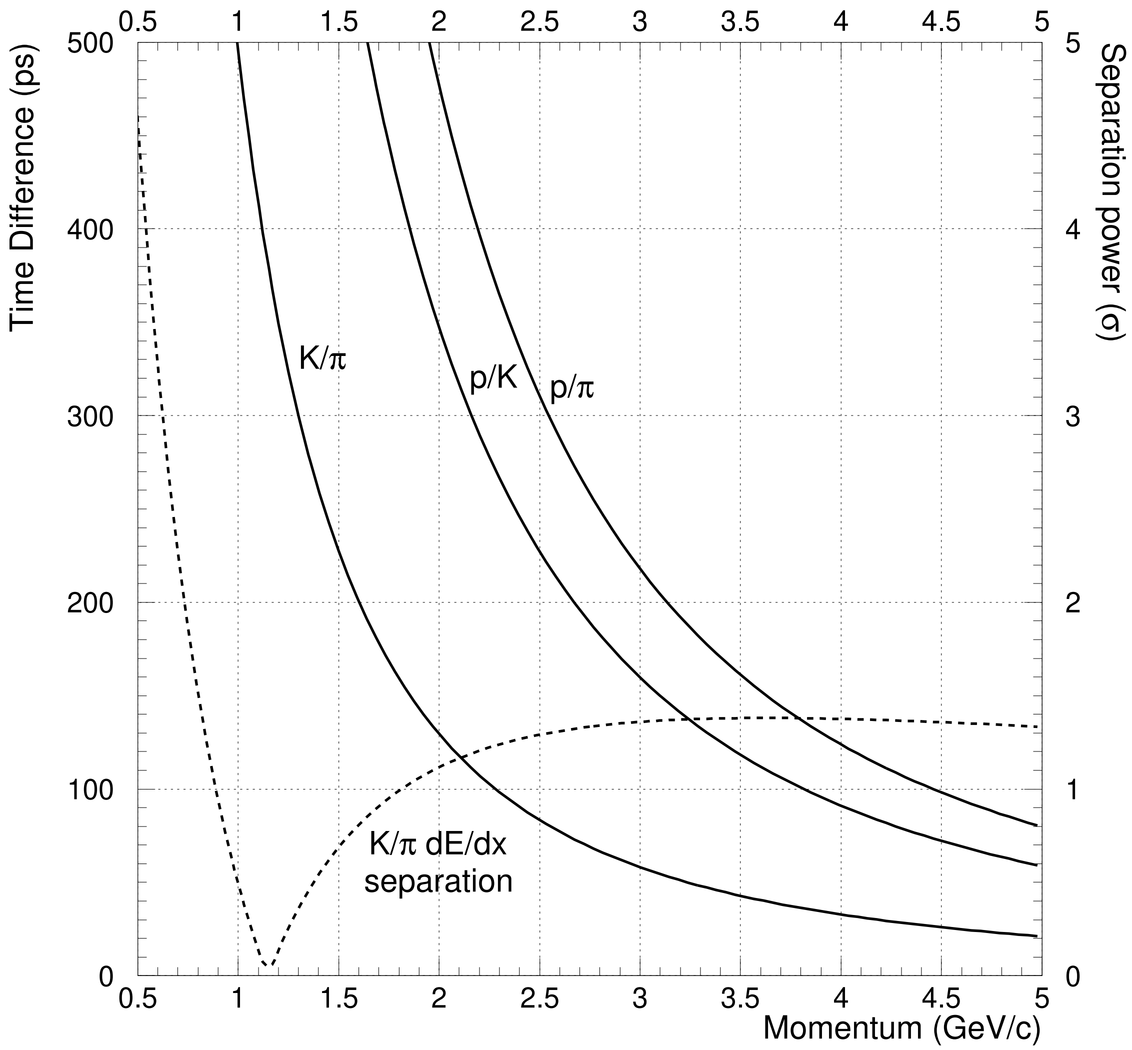
The Tevatron will play a crucial, unique role in our test of the CKM Matrix.

A Time-of-Flight Detector for CDF



- 216 scintillator bars located just outside COT
  - 3m long
  - cross-section $\approx 4 \times 4\mathrm{cm}^2$
  - read out on both ends with fine-mesh PMTs
- Expected time-of-flight resolution: 100ps
- Primary purpose: kaon identification for B hadron flavor determination

Particle Identification with TOF



With 100ps resolution: 2σ separation of

- K and π for $p < 1.6$ GeV$/c$
- p and K for $p < 2.7$ GeV$/c$
- p and π for $p < 3.2$ GeV$/c$

TOF and dE/dx are complementary