Lifetimes and Mixing at DØ

Brendan Casey, Brown University

- Motivation
- Flavor Physics at DØ
- Lifetimes and Mixing with:
  - $B \to J/\psi X$
  - $B_{uds} \to D_{uds} X \mu \nu_\mu$

ITS A GIRL!

8lb. 15oz. June 27, 2AM.

Why Study Mixing?

What we've learned from mixing:

$K^0 - \bar{K}^0$ mixing $\Rightarrow$	CPV!
	existence of a third generation!
$B_d - \bar{B}_d$ mixing $\Rightarrow$	Top is heavy!
	$m_t > m_W$
	Top has CPV couplings!
	$Arg(V_{td}) = -24°$
$\nu - \bar{\nu}$ mixing $\Rightarrow$	neutrinos have mass!

Every flavor mixing measurement has lead to a major discovery. Usually involving the nature of particles inaccessible at the energy frontier!

B_s mixing $\Rightarrow |V_{td}/V_{ts}| + ???$

Why Study Lifetimes?

$\tau(B_{q'})/\tau(B_q) \Rightarrow$ $= 1+$ higher order corrections to OPE

quark-hadron duality, spectator models,

non perturbative QCD...

Key link between experiment

and underlying physics.

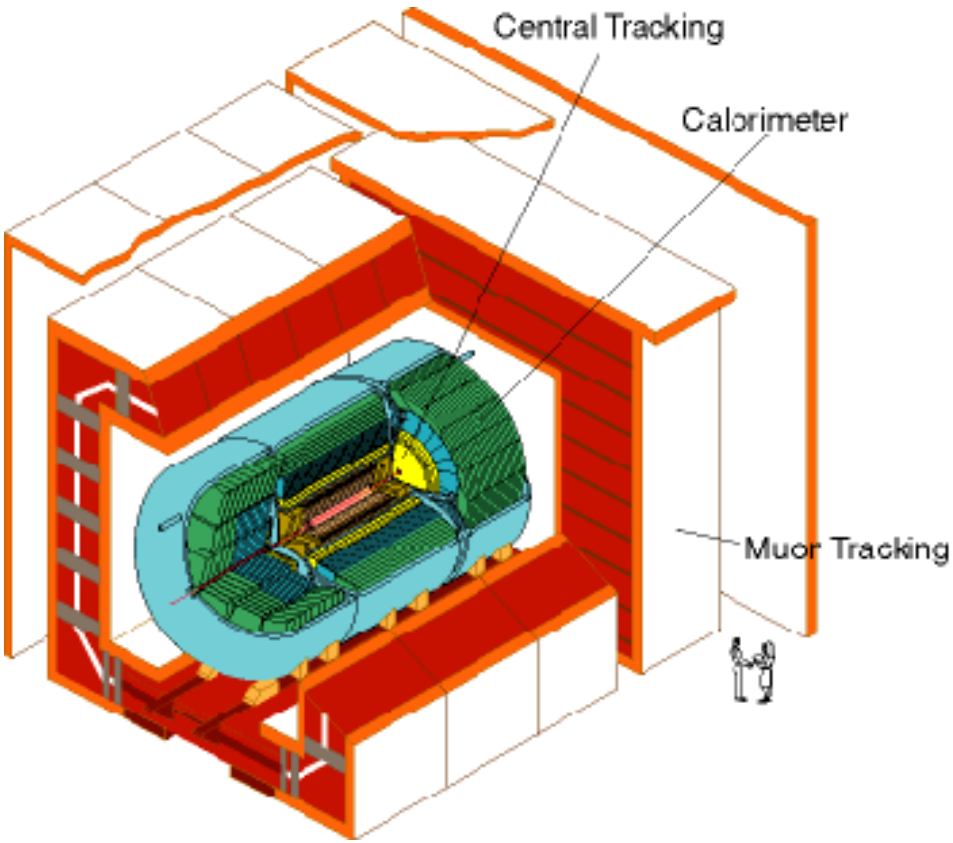
$\tau(B_s \to f_{CP}) \Rightarrow$ look for $\tau(\text{even}) \neq \tau(\text{odd})$

$\Delta\Gamma =$ mixing $\Rightarrow$ discovery

DØ Flavor Physics Program

Focus on the strengths of the DØ detector:

- muon spectrometer
- tracking and vertexing
- single and dimuon triggers



$\Rightarrow$ Semi-leptonic decays and $b, c \to \mu^+\mu^- X$

Ideal samples for mixing and lifetime studies

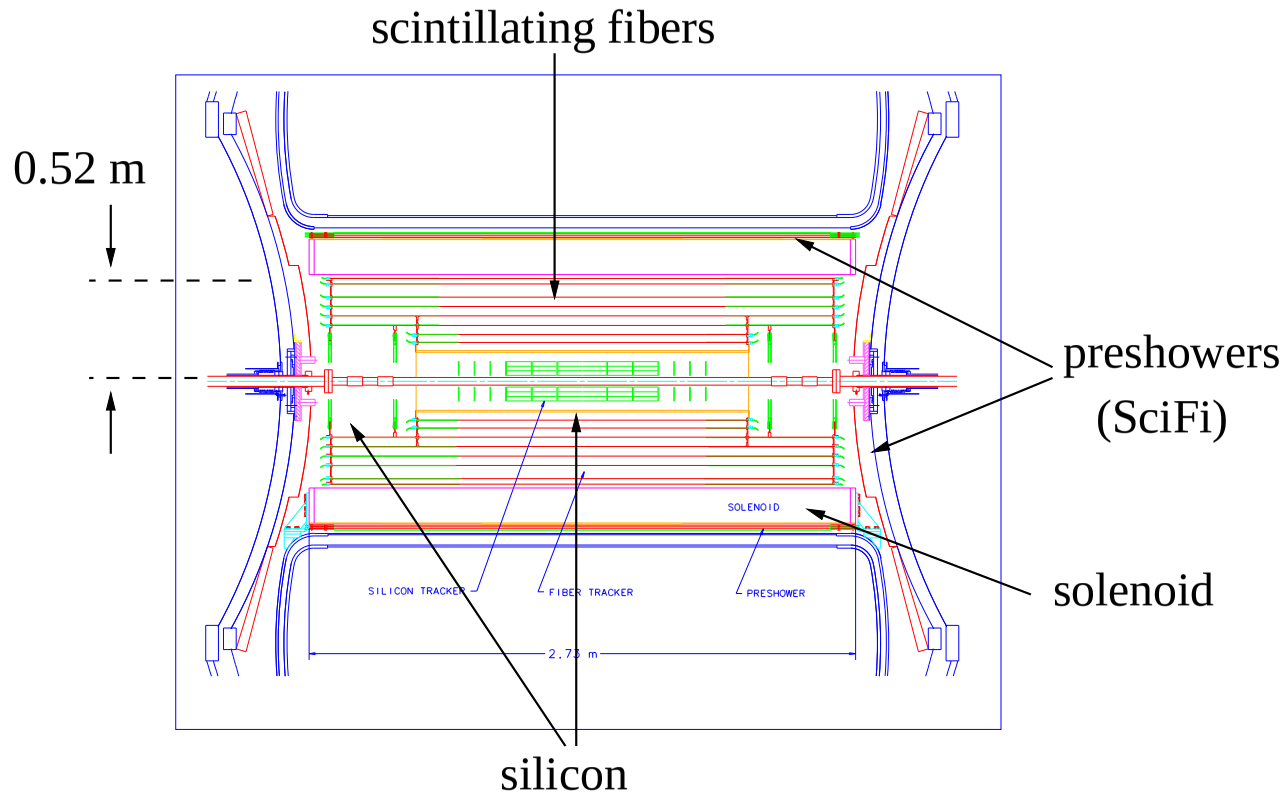
DØ Tracking

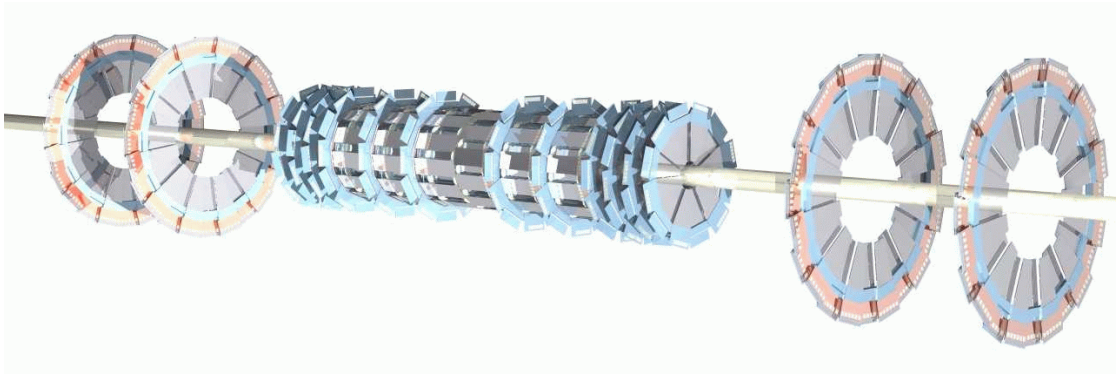
8 doublet layers
scintillating fibers

4 silicon barrels
plus 16 disks

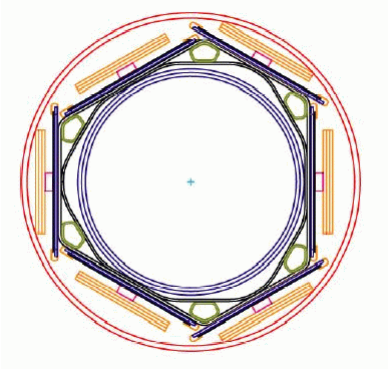
2T B field

adding new
layer zero barrel
$r = 16.4$ mm
in summer 2005!





Layer Ø



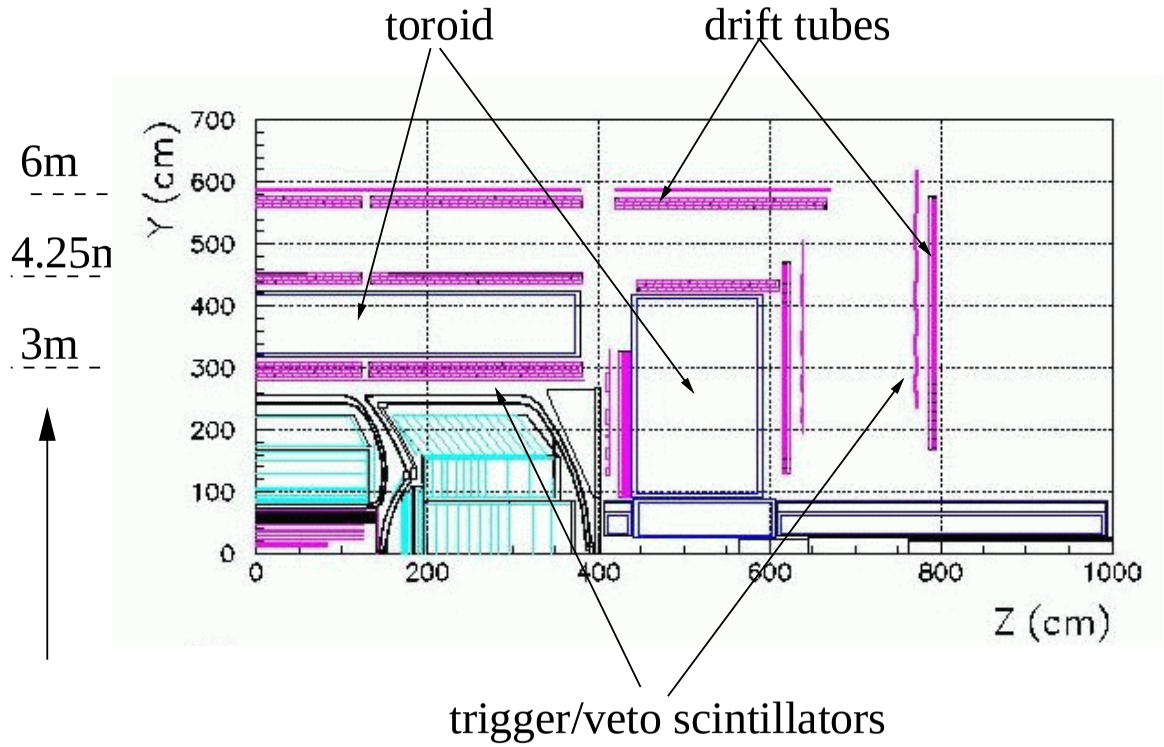
DØ Muon Spectrometer

Three layers of proportional tubes + toroid: stand alone muon tracking

coverage to $|\eta| = 2$

Polarity options:

solenoid	toroid
+	+
+	−
−	+
−	−



Scintillators for trigger; scintillator timing: cosmic/beam veto

Muon Triggering and Readout

Level 1,2 dominated by muon info

Level 3 flexible software based trigger

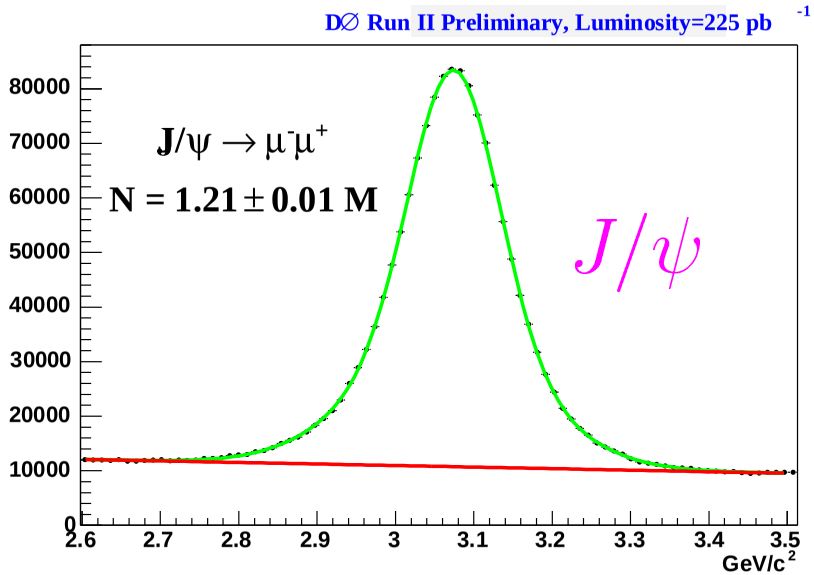
Level 1	Level 2	Level 3
muon scintillators	muon tracking	fast tracking
muon wire hits	impact parameter	track matching
central track finding		primary vertex z
primary vertex z		impact parameter
		invariant mass

(red means not used yet)

As $\mathcal{L}$ increases:

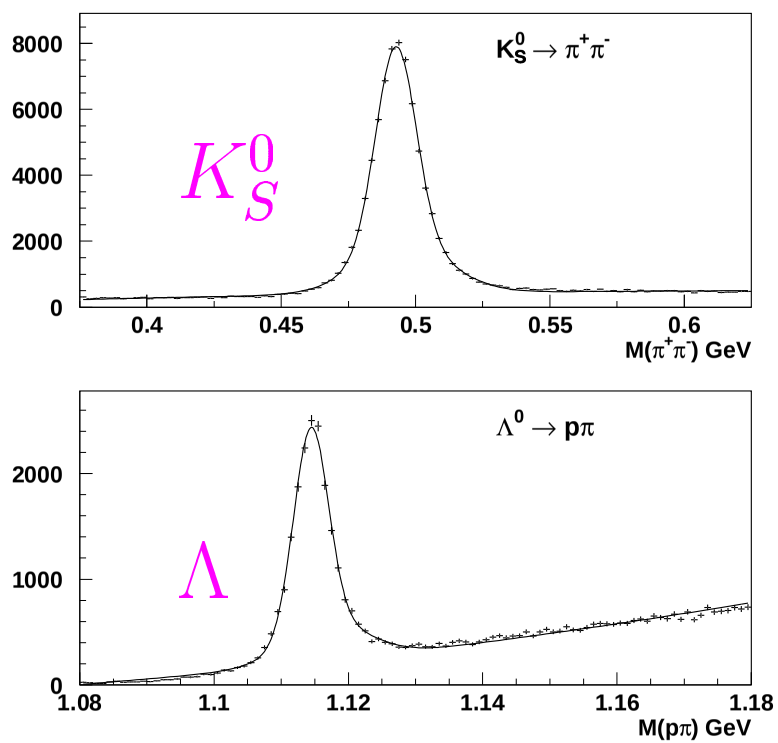
hardware upgrades at L1, L2
partially move offline reconstruction $\Rightarrow$ L3
add processors and increase rate to tape

$B \to J/\psi X$

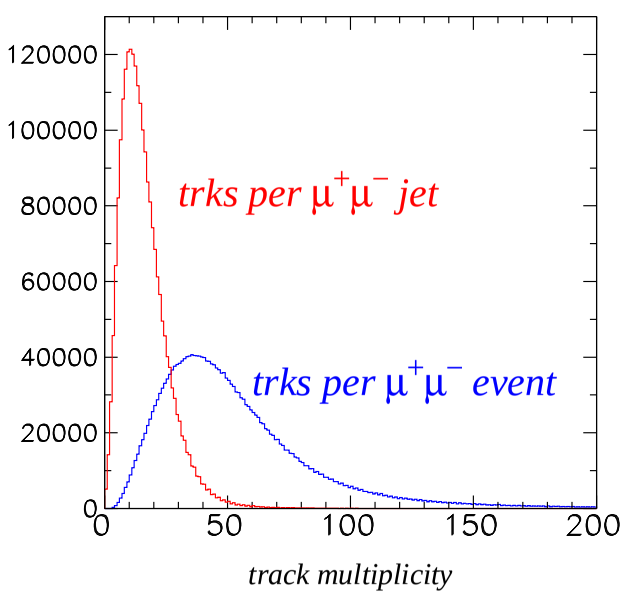


At least one μ in μ spect.
Other can be a calorimeter MIP

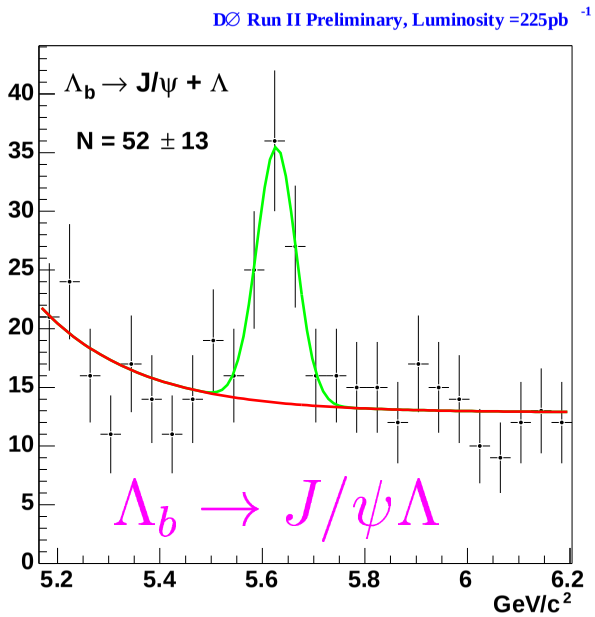
reco. in pairs: $(\Lambda/K_S^0,\ \phi/K^{*0})$

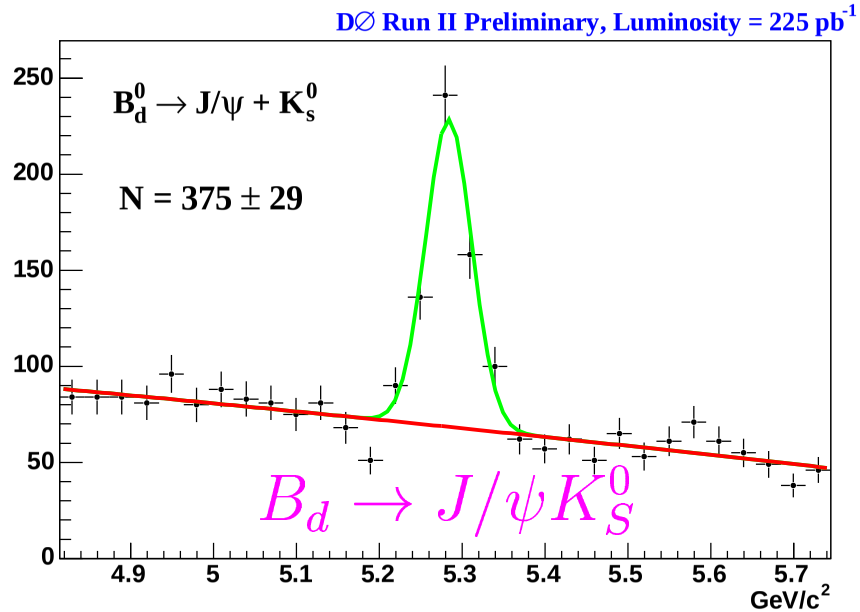


All tracks in the same jet.



$J/\psi + \Lambda/K_S^0$ Yields at 225 pb^{-1}

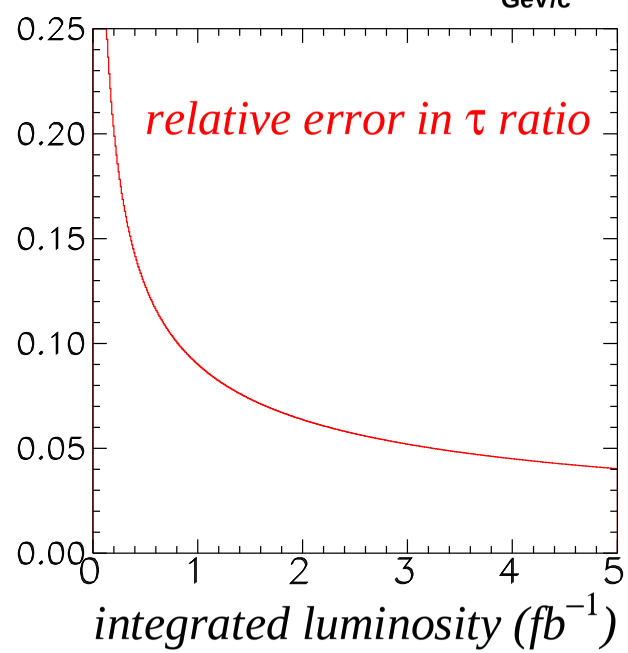




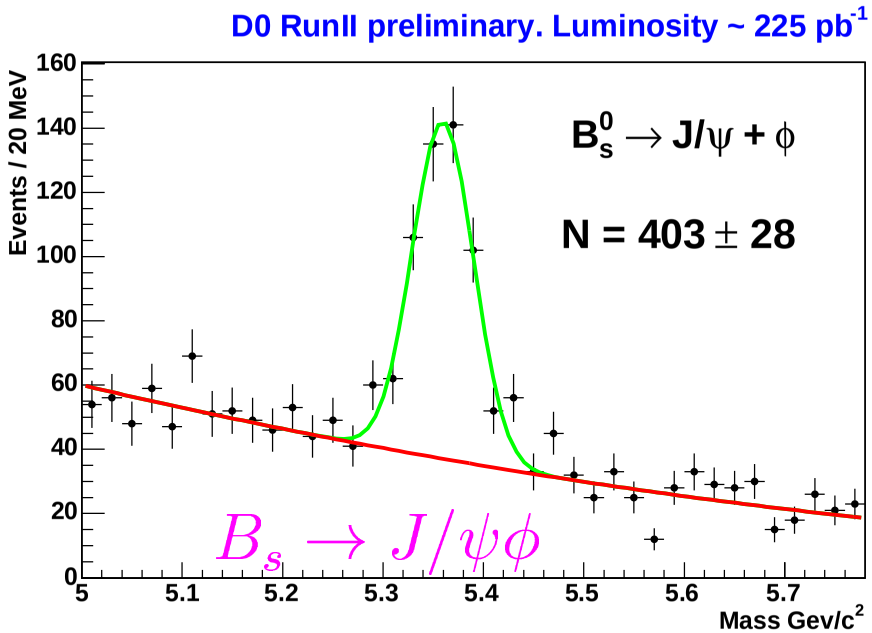
$52 \pm 13\ \Lambda_b$
$375 \pm 29\ B_d$

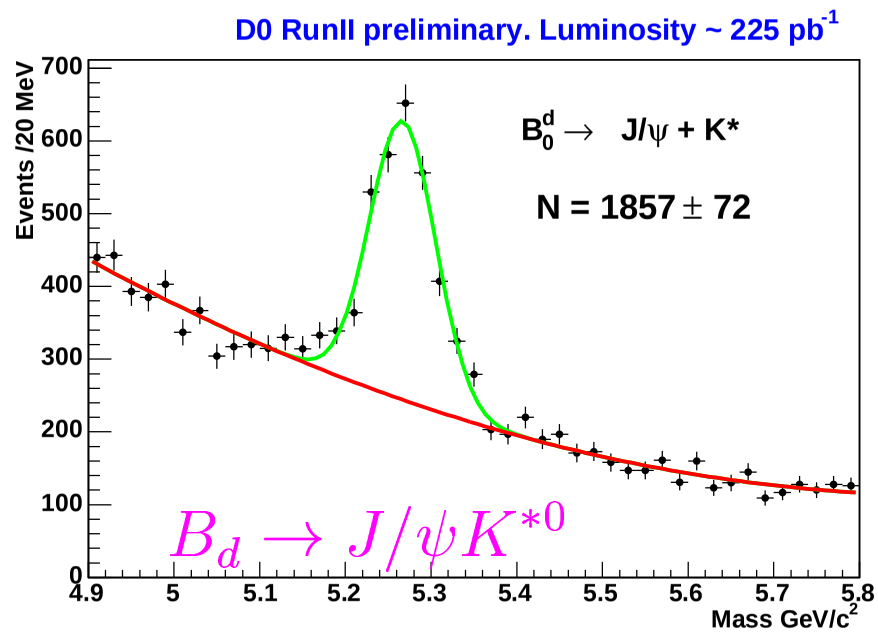
Expect $\sim 20\%$ error on $\tau(\Lambda_b)/\tau(B_d)$ with present statistics

Need to add semi-leptonic to make an $\mathcal{O}(1\%)$ measurement



$J/\psi + KK/K\pi$ Yields



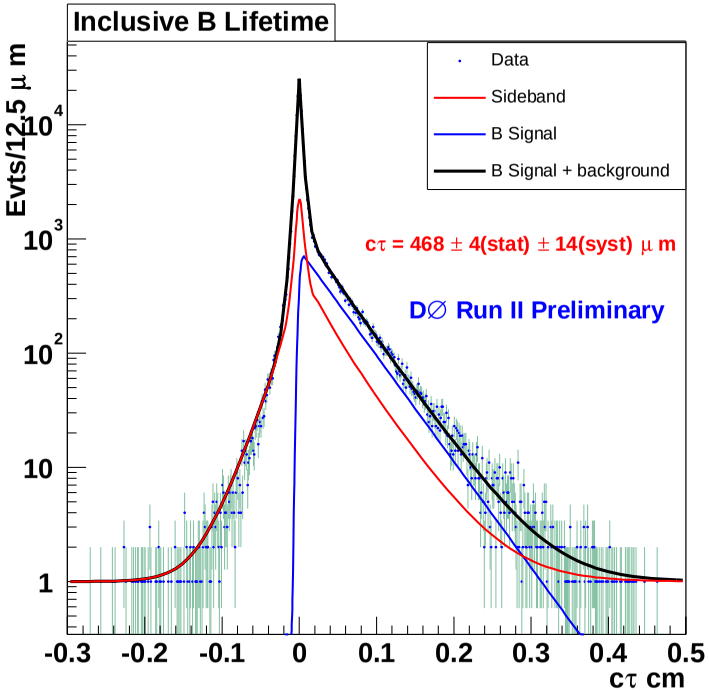


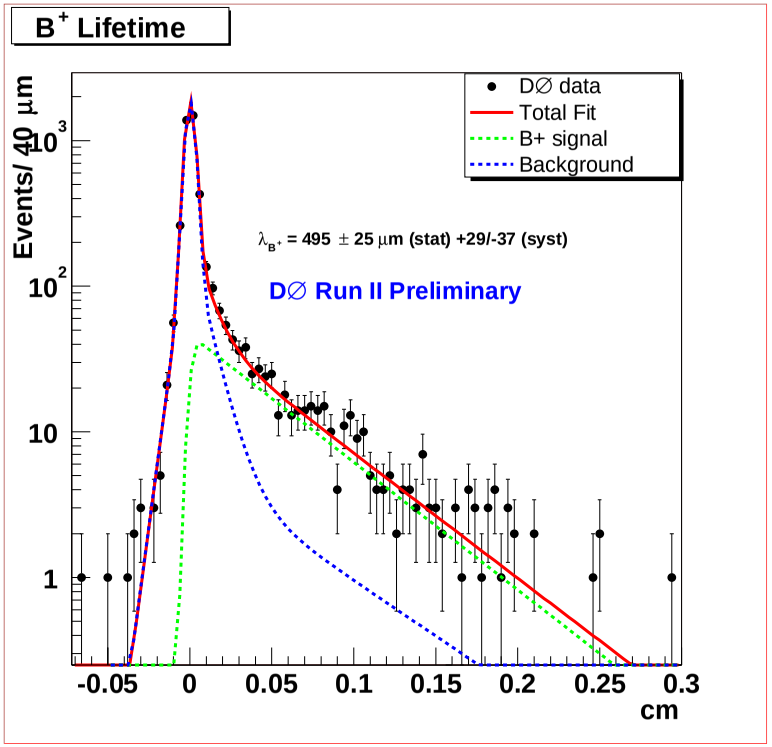
$403 \pm 28\ B_s$ $\qquad$ $1857 \pm 72\ B_d$

Limits on $\Delta\Gamma/\Gamma$ coming soon

interesting numbers with 2 to 3× more data

$B \to J/\psi X$ Lifetimes





lifetime analysis performed with ~ 120 pb^{-1}

update coming soon based on ~ 250 pb^{-1}

inc. J/ψ	$1.562 \pm 0.013 \pm 0.045$ ps
$J/\psi K^+$	$1.650 \pm 0.083^{+0.096}_{-0.123}$ ps
$J/\psi K^{*0}$	$1.51^{+0.19}_{-0.17} \pm 0.20$ ps
$J/\psi K_S^O$	$1.56^{+0.32}_{-0.25} \pm 0.13$ ps
$J\psi\phi$	$1.19^{+0.19}_{-0.16} \pm 0.14$ ps

$B \to D^0 X \mu\nu$ Reconstruction

$p_T(\mu) > 2$ GeV, $p(\mu) > 3$ GeV

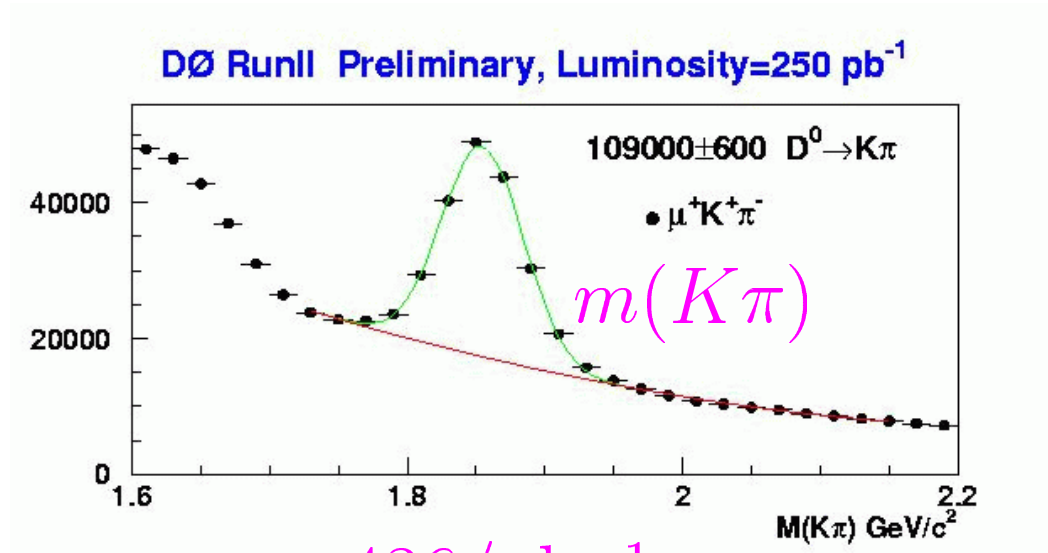
Search for $D^0 \to K^+\pi^-$ in the μ jet

muon charge provides kaon ID

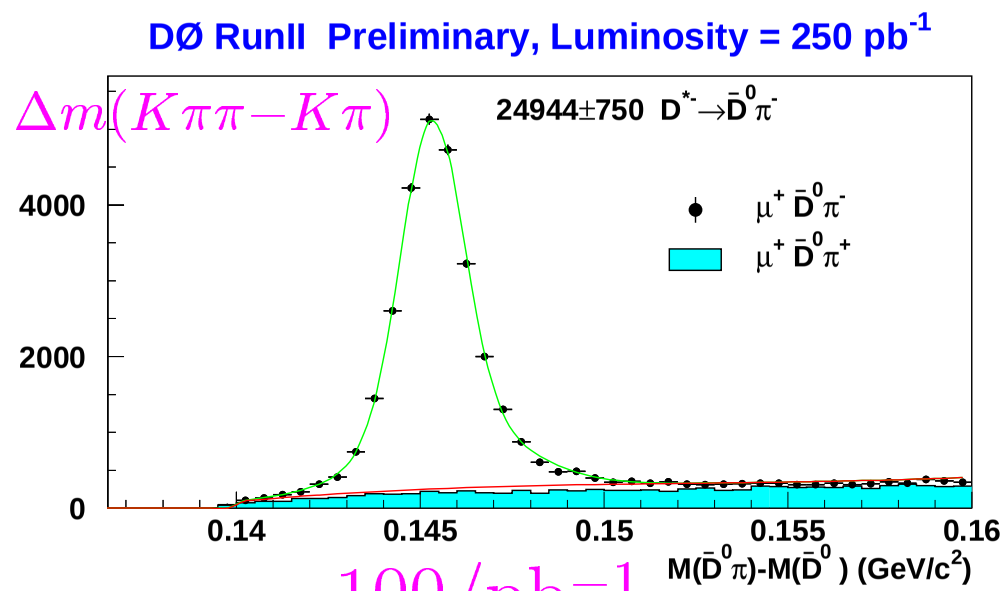
impact parameter cuts on tracks and vertex significance cuts on the D^0

$\to$ biases the lifetime but no bias to the lifetime ratio

D^* sample extracted by combining D^0 with a slow π



$\sim 436/\text{pb}^{-1}$



$\sim 100/\text{pb}^{-1}$

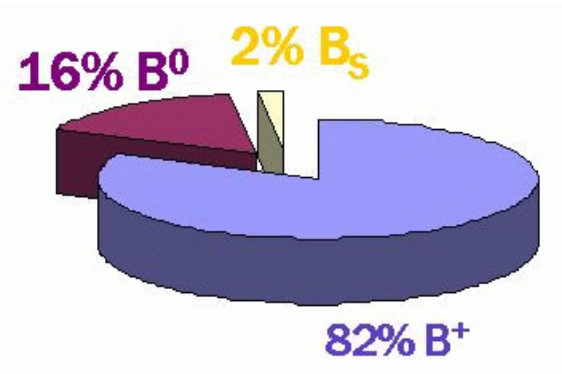
Sample Composition

using PDG BFs

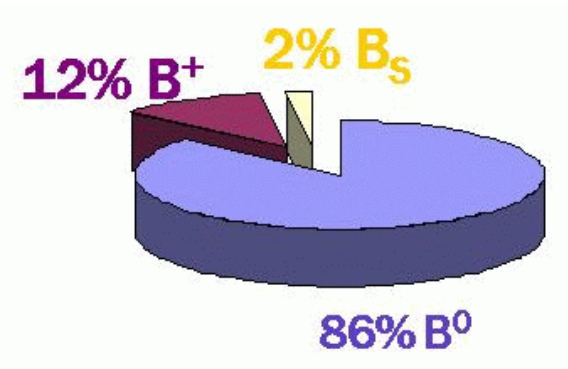
plus isospin

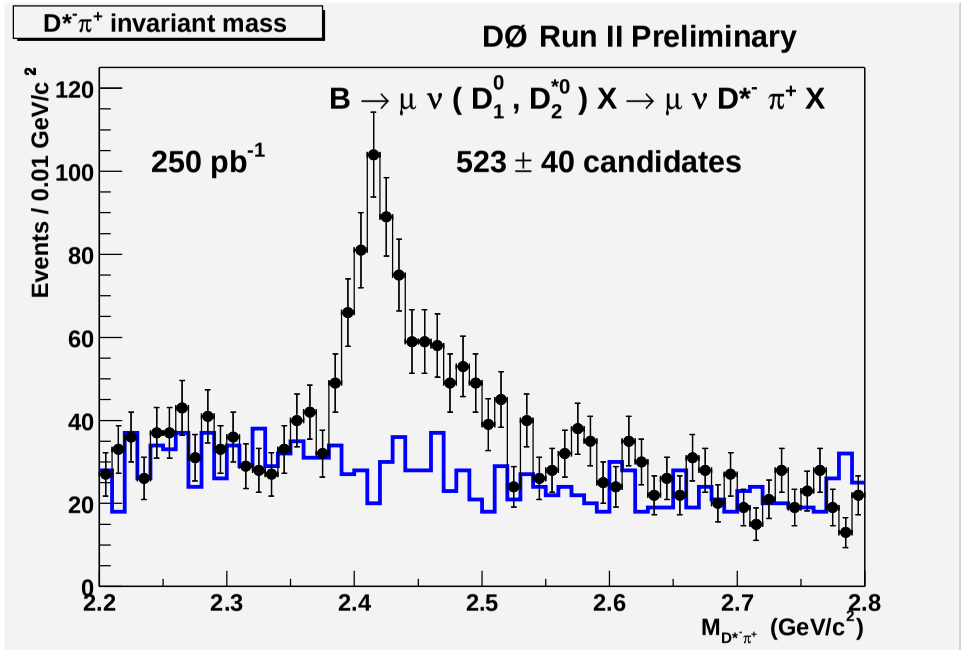
Can eventually improve on all numbers using our data sample.

D^0 sample:



D^* sample:

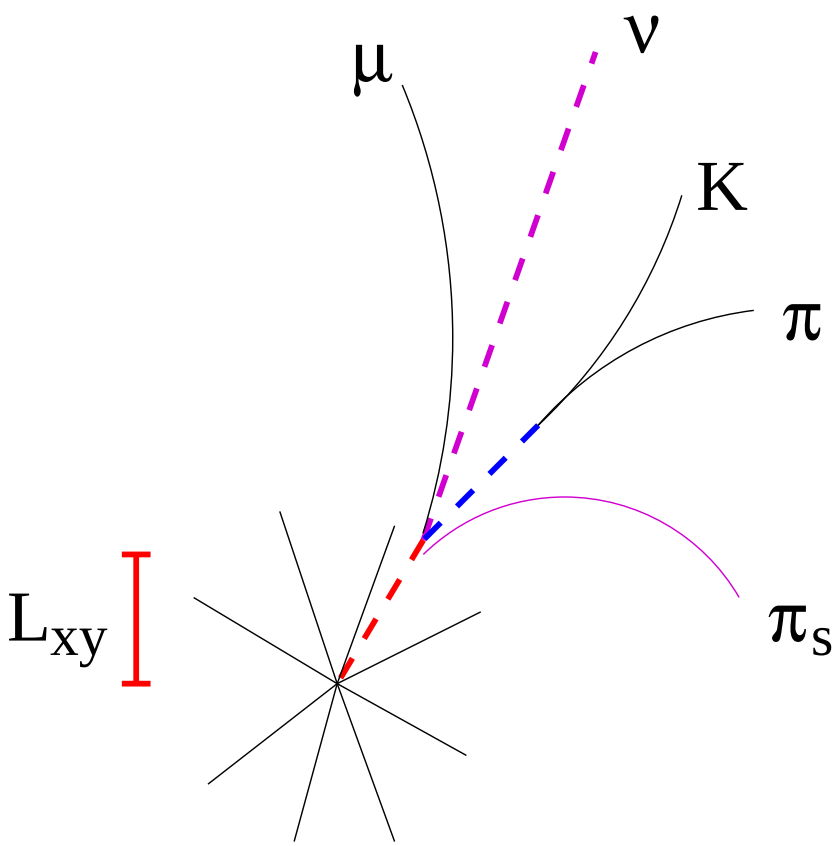




$m(D^*\pi)$

(see talk by B. Abbott on Friday)

Proper Time Reconstruction

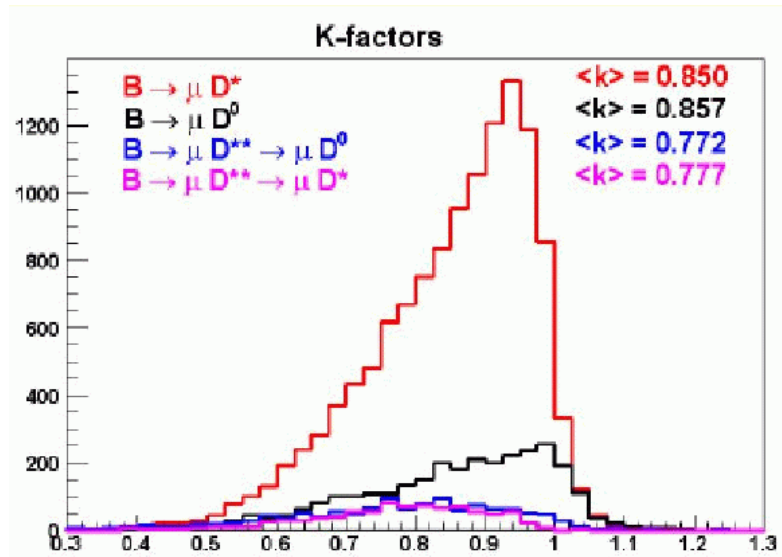


reconstruct $K\pi$ vertex and $D^0\mu$ vertex in transverse plane L_{xy}

boost back using $D^0\mu$:

$$c\tau_{vis} = L_{xy} \times m_B / p_T(D^0\mu)$$

use MC for boost correction function $Z(K)$



$Z(K)$

Lifetime Ratio Extraction

instead of simultaneous fit to two samples

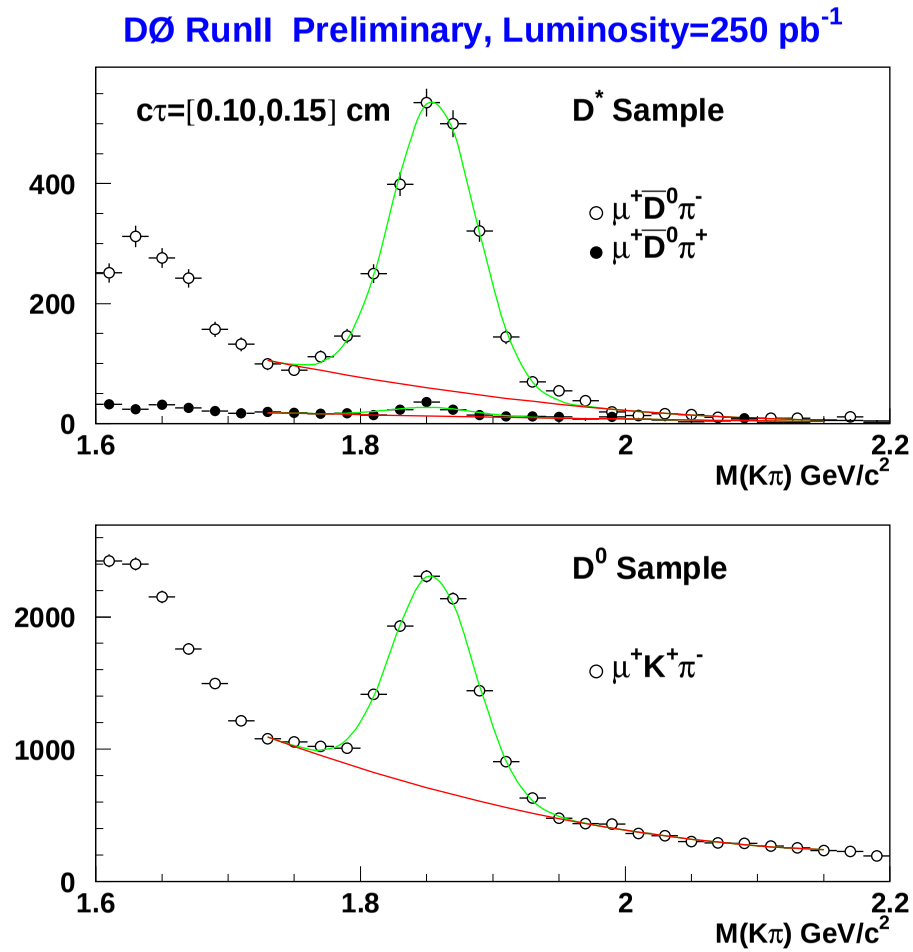
group data in $c\tau_{vis}$ bins

extract yield from $m(K\pi)$ spectra

perform χ^2 fit to ratio of yields

Expected value based on:

- sample composition
- boost correction (p_{miss})
- resolution
- $\tau(B_d)$, $\tau(B^+)/\tau(B_d)$

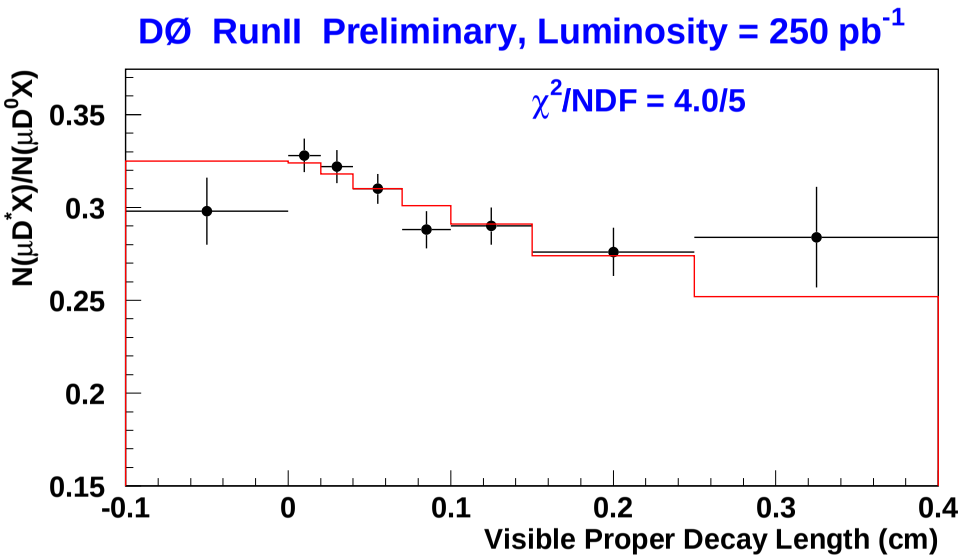


slow π only used to define D^* sample

not used in yield extraction, vertex, or boost correction

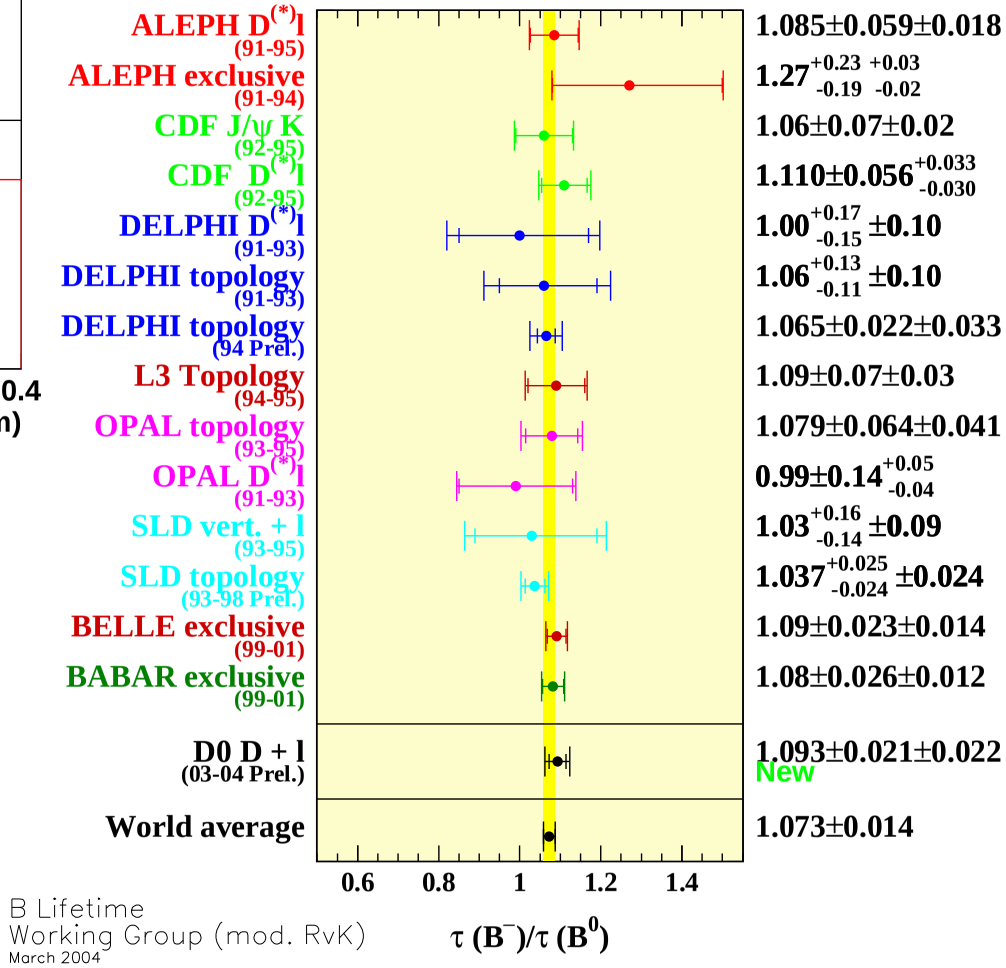
$$\epsilon(D^*) = C \times \epsilon(D^0),\ C \neq C(c\tau_{vis})$$

Lifetime Ratio



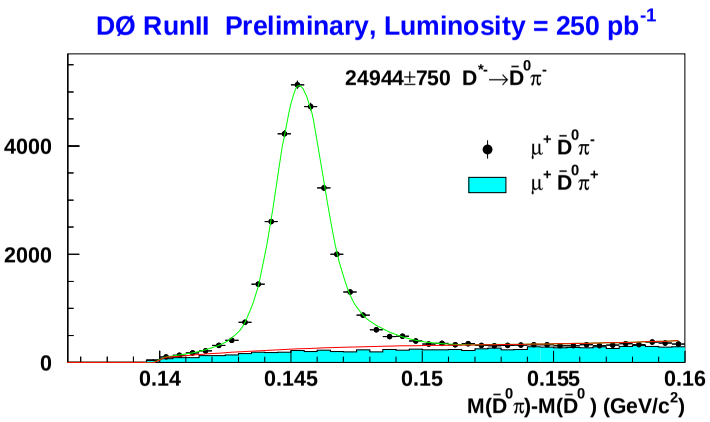
$$\tau(B^+)/\tau(B_d) = 1.093 \pm 0.021 \pm 0.022$$

using $\tau(B_d) = 1.674 \pm 0.018$ ps (PDG)



(DØ not included in W.A.)

Mixing Program



reconstruction

B_d B_s

↓

Time dependence

B_d B_s

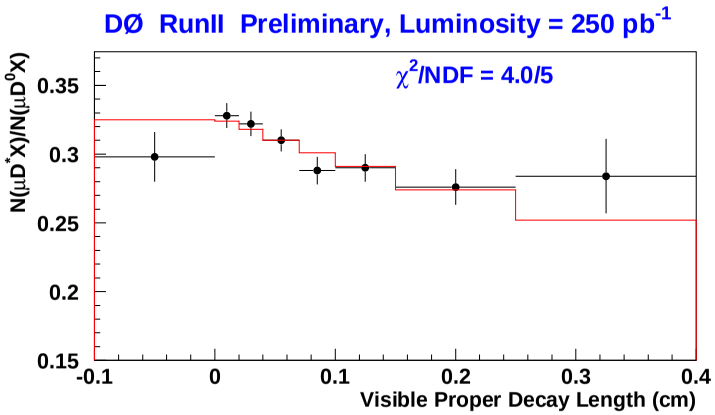
↓

Flavor tagging

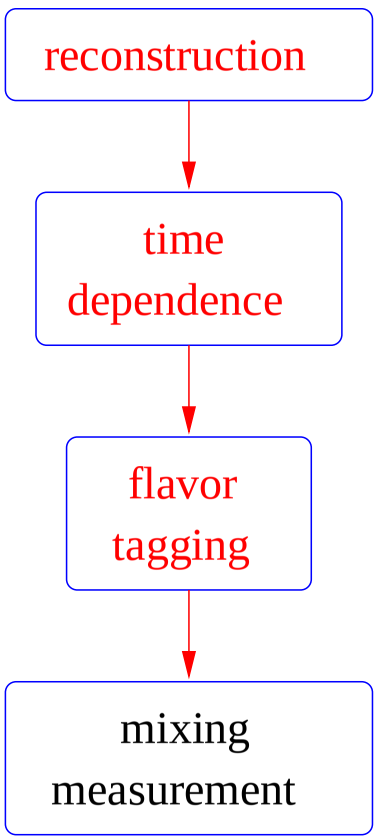
↓

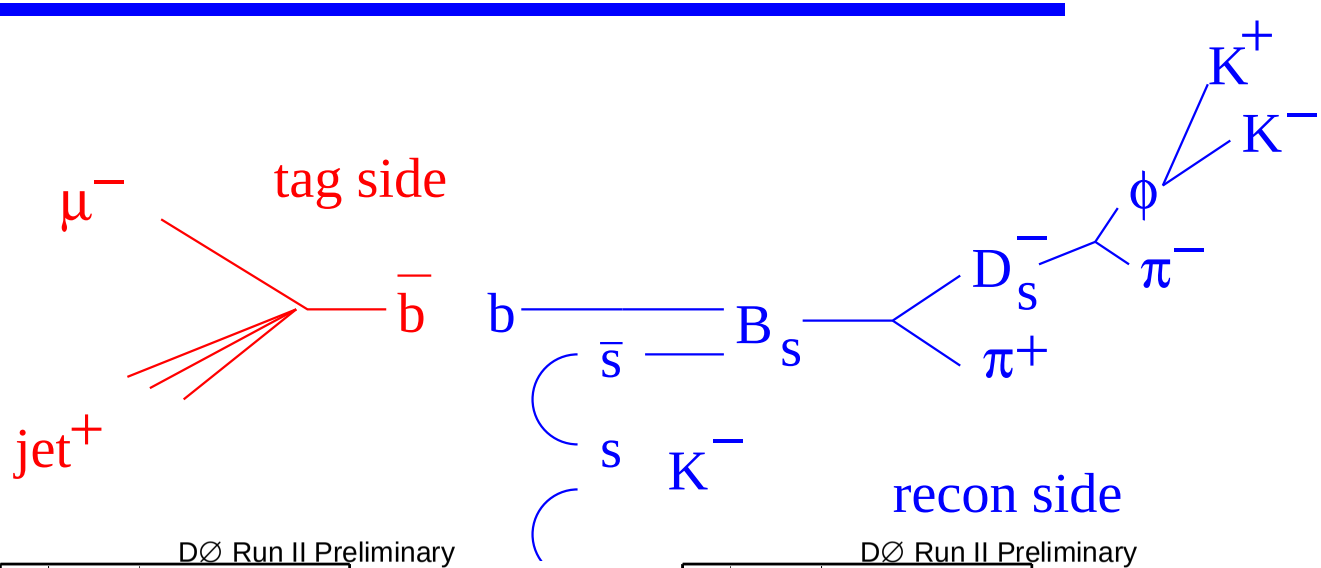
mixing measurement

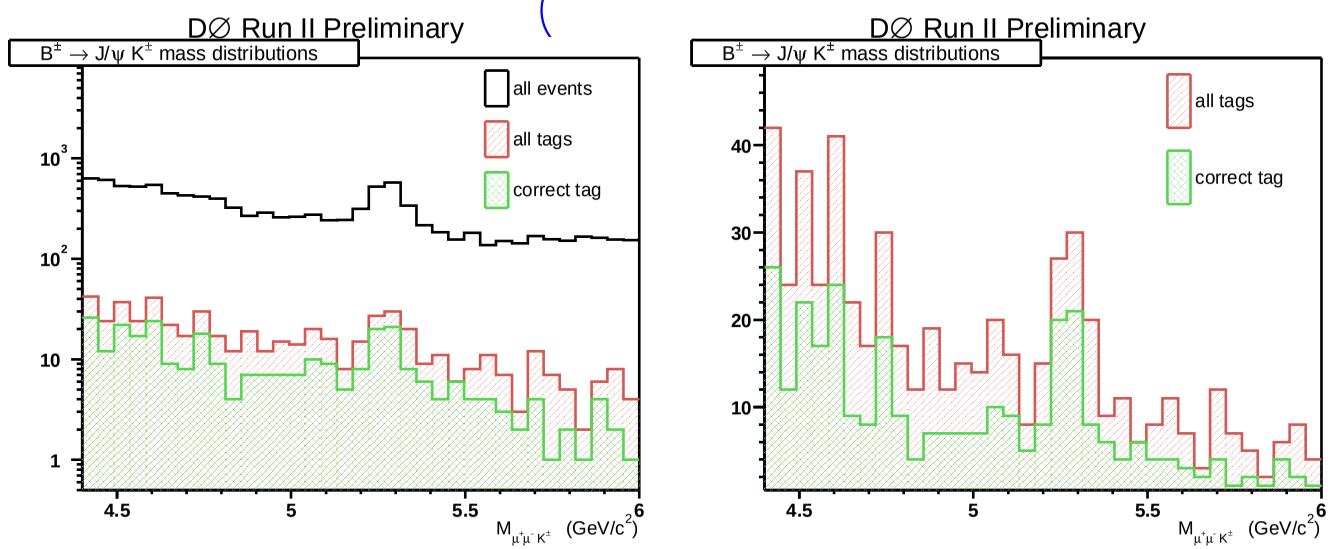
B_d B_s



Flavor Tagging





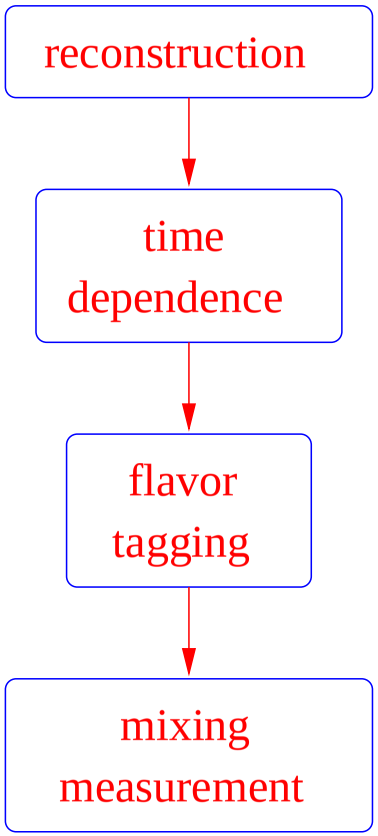


$B^+ \to J/\psi K^+$ with muon tags

$\epsilon \times D^2$ muons: $\sim 1\%$, jet charge: $\sim 1\%$, same side: $\sim 1\%$

Lots of room for improvements, more taggers, smart comb.

Mixing Measurement



B_d: build on success of τ ratio measurement

$\Rightarrow$ bin data and fit asymmetry

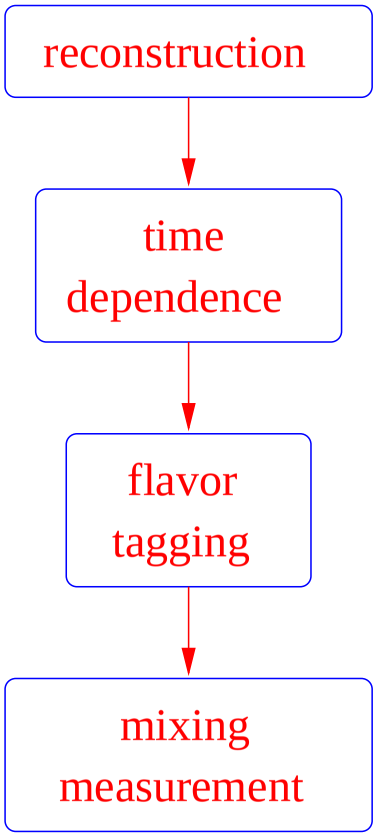
$$\frac{\mathrm{N(mixed)-N(unmixed)}}{\mathrm{N(mixed)+N(unmixed)}}$$

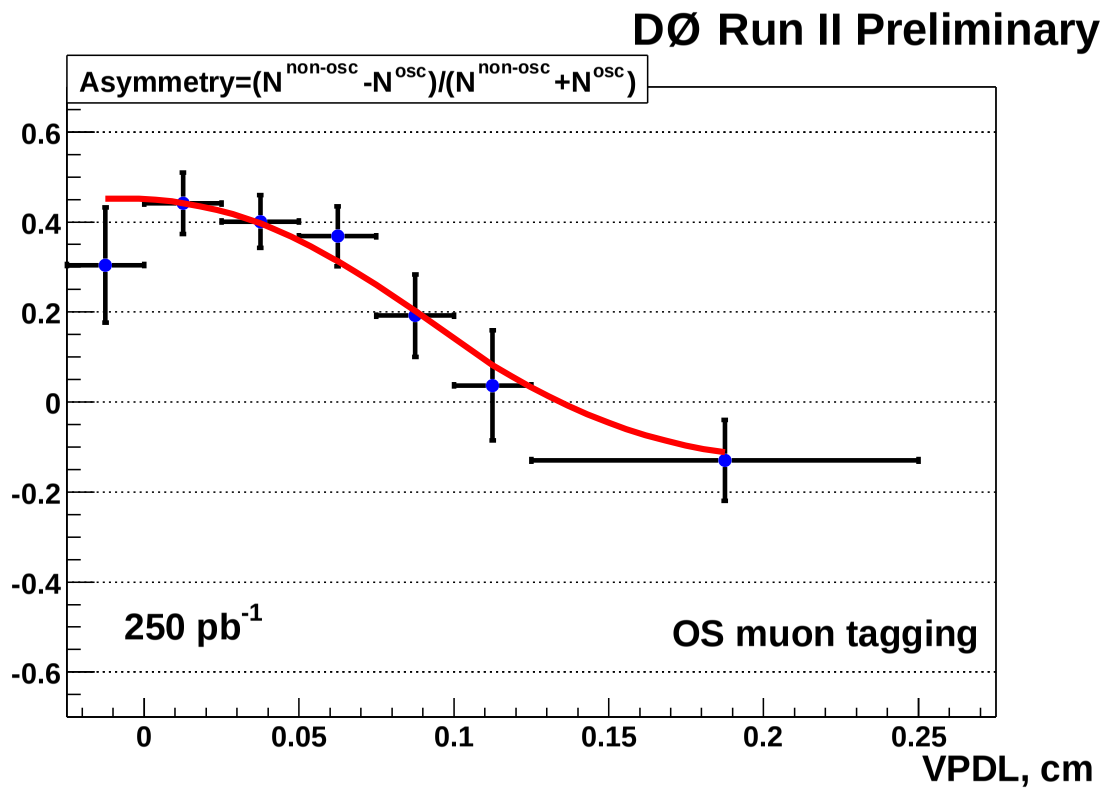
B_s: can not bin for final measurement,

still good for systematic studies.

B_d Mixing

Muon tagged D^* sample:





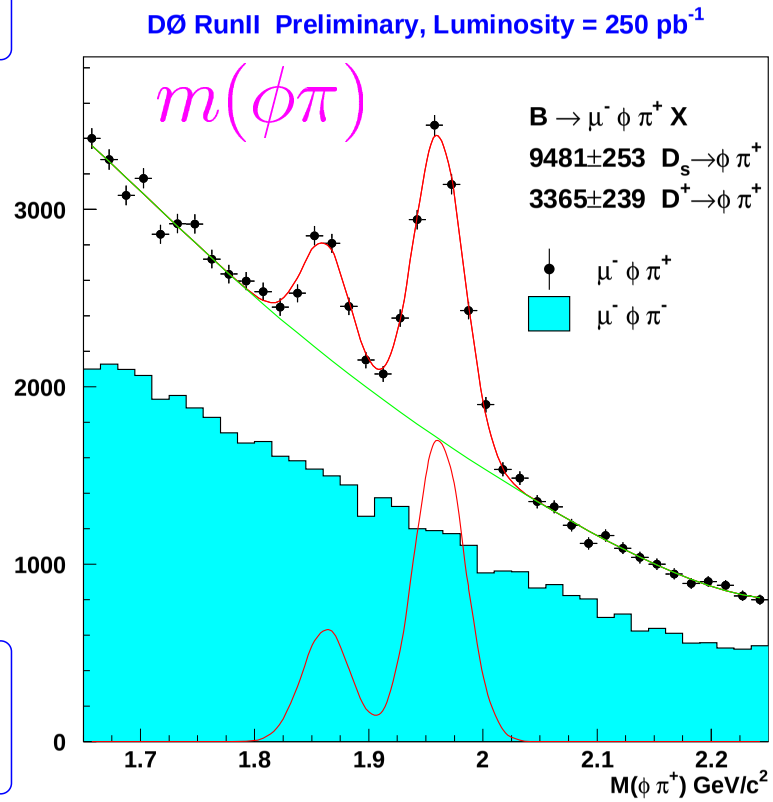
$$\Delta m_d = 0.506 \pm 0.055 \pm 0.049 \text{ ps}^{-1}$$

dilution for μ: 0.46 ± 0.04

working on systematics for jet charge and same side tagging

B_s Mixing

reconstruction
↓
time dependence
↓
flavor tagging
↓
mixing measurement



9481 ± 253 D_s

in $\phi\pi$ channel alone

Adding:

K^*K, K_SK...

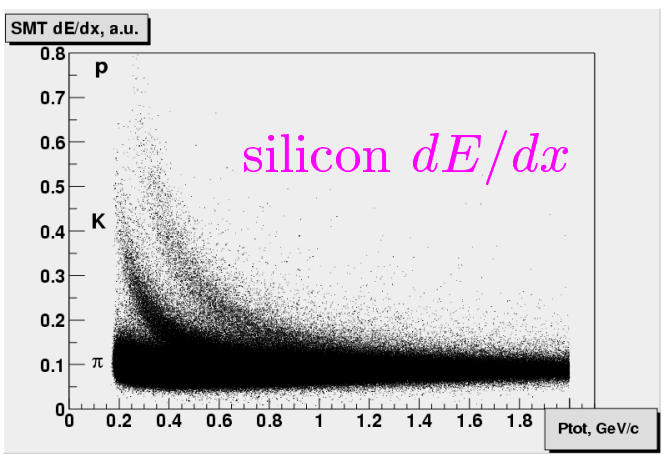
Plus:

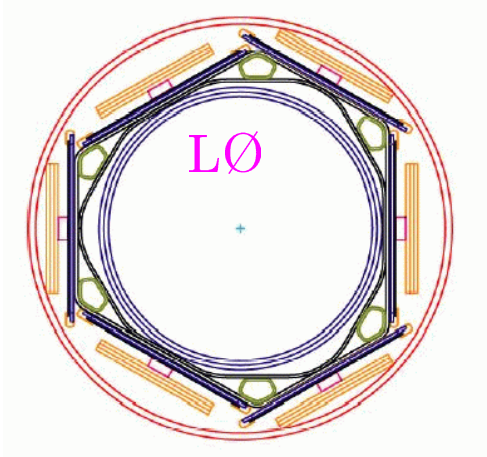
better tagging

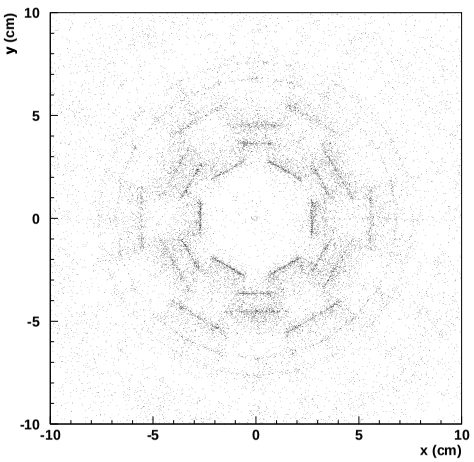
better resolution

better simulation

. . .







Conclusions

Tevatron is taking off

- new records ∼weekly
- on track to double data set every year

DØ B physics program competitive and only getting better

- more semi-leptonic channels, hadronic channels, neutrals...

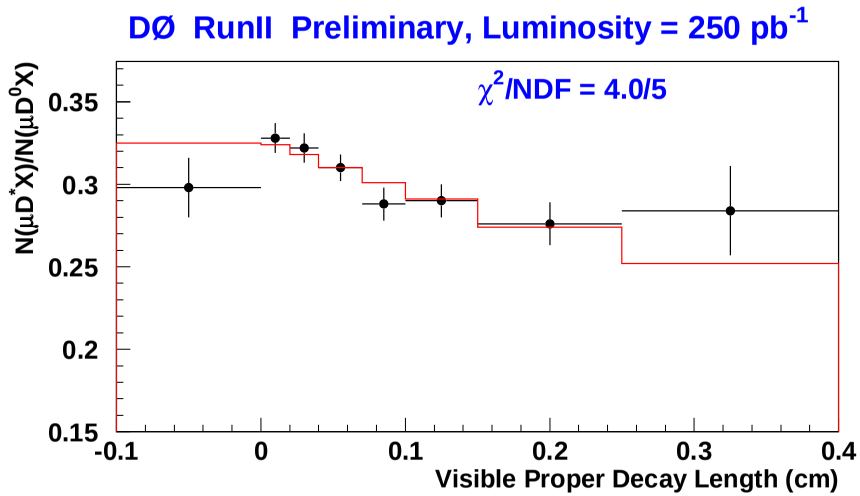
This data is all on tape!

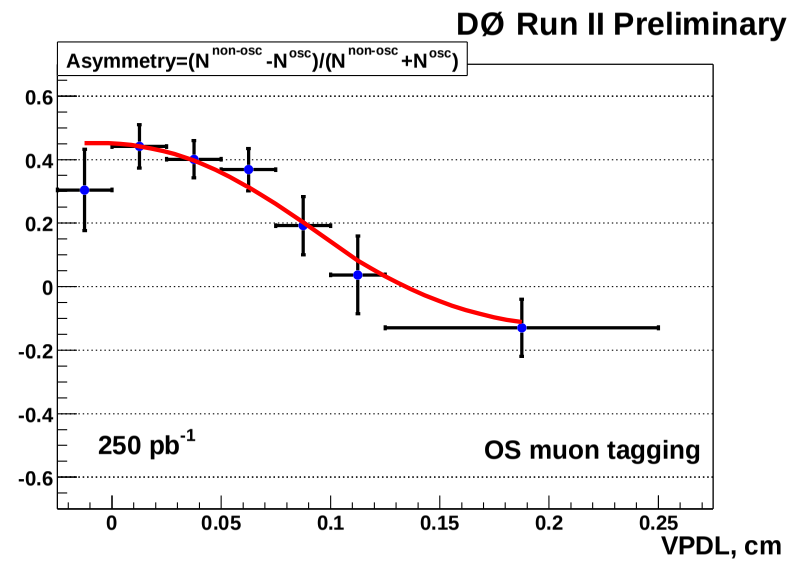
Benchmark measurements performed and competitive

- $\tau(B^+)/\tau(B_d)$, Δm_d

Key Run II measurements on track

- $\tau(\Lambda_b)/\tau(B_d)$, $\Delta\Gamma_s/\Gamma_s$, Δm_s





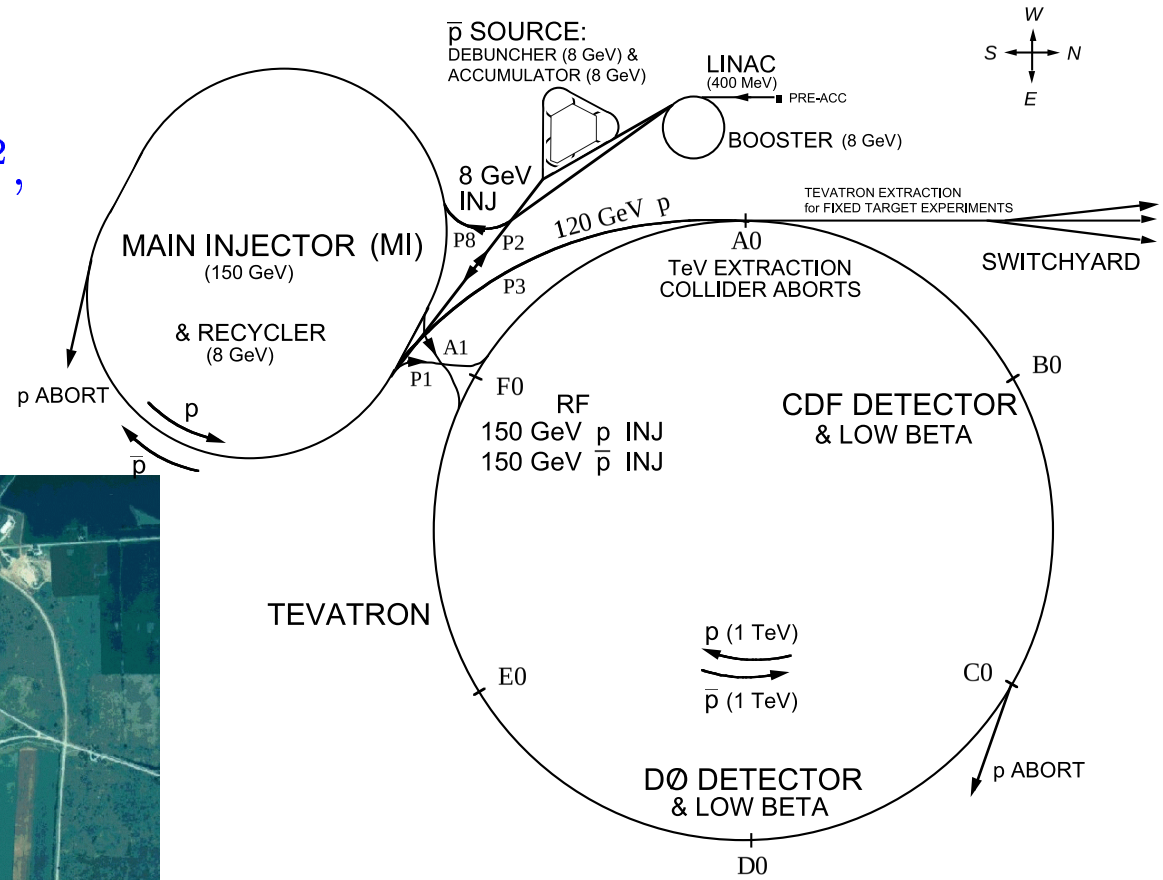
Backup Slides

Tevatron

Achieved:

8.48×10^{31} cm/s^2,

490 pb^{-1}



expected $\mathcal{L}$: $1.5 - 3 \times 10^{32}$ cm/s^2

$\Rightarrow$ 4-8 fb^{-1} before LHC

Sample Composition

D^* sample

- $B_d \to \mu^+ \nu D^{*-}$
- $B_d \to \mu^+ \nu D^{**-}$
  $\to \mu^+ \nu D^{*-} X$
- $B^+ \to \mu^+ \nu \bar{D}^{**0}$
  $\to \mu^+ \nu D^{*-} X$
- $B_s \to \mu^+ \nu D_s^{**-} X$
  $\to \mu^+ \nu D^{*-} X$

D^0 sample

- $B^+ \to \mu^+ \nu \bar{D}^0$
- $B^+ \to \mu^+ \nu \bar{D}^{*0}$
- $B^+ \to \mu^+ \nu \bar{D}^{**0} \to \mu^+ \nu \bar{D}^0 X$
- $B^+ \to \mu^+ \nu \bar{D}^{**0} \to \mu^+ \nu \bar{D}^{*0} X$
- $B_d \to \mu^+ \nu D^{**-} \to \mu^+ \nu \bar{D}^0 X$
- $B_d \to \mu^+ \nu D^{**-} \to \mu^+ \nu \bar{D}^{*0} X$
- $B_s \to \mu^+ \nu \bar{D}_s^{**0} X \to \mu^+ \nu \bar{D}^0 X$
- $B_s \to \mu^+ \nu \bar{D}_s^{**0} X \to \mu^+ \nu \bar{D}^{*0} X$