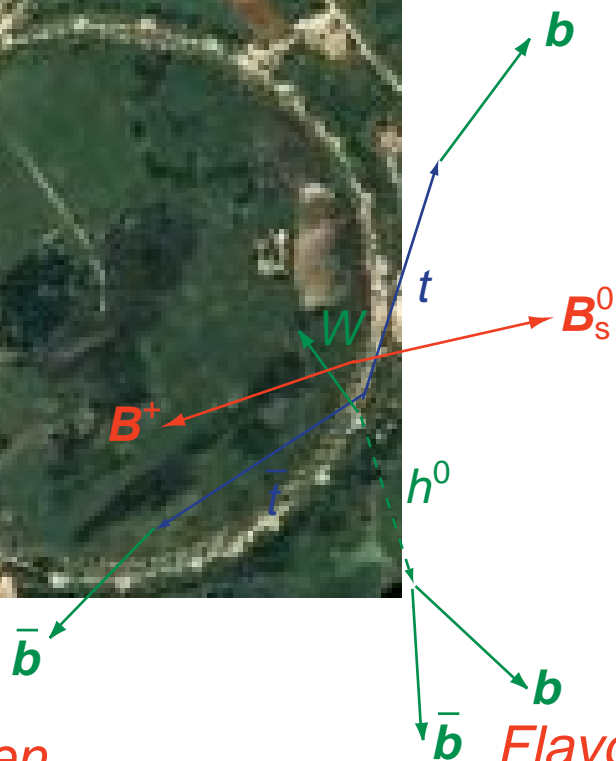


# Status of DØ for *B* Physics



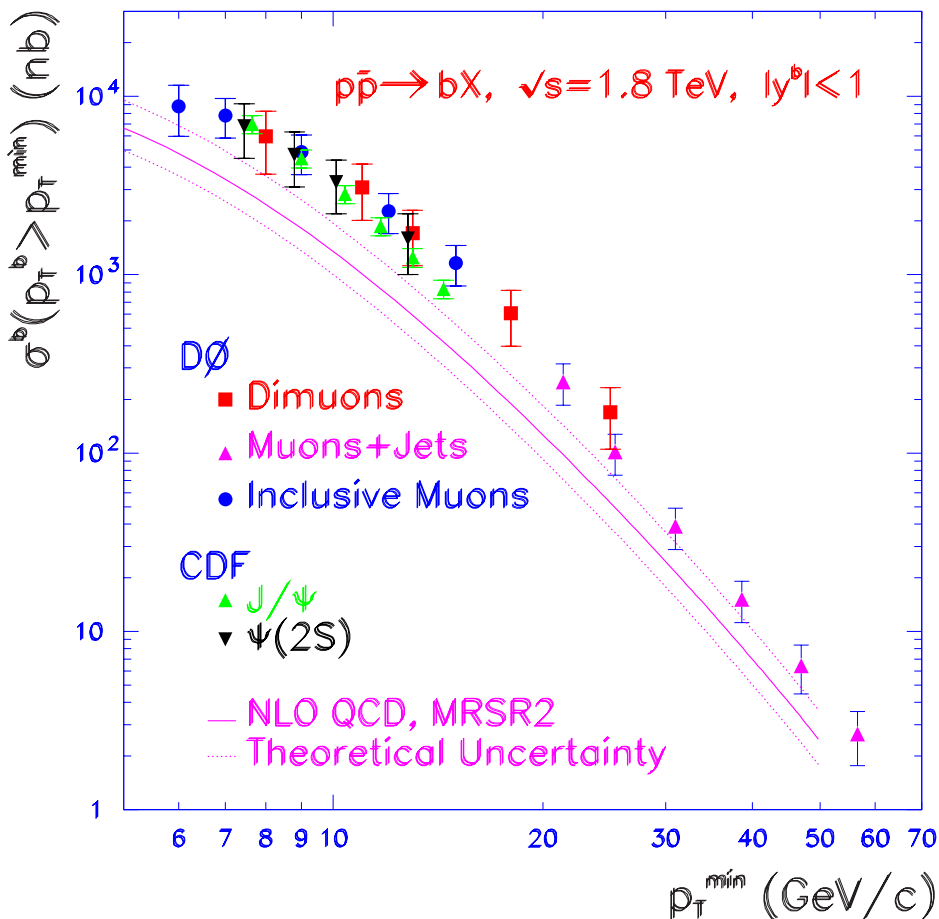
*Rick Van Kooten  
Indiana University  
Representing the  
DØ Collaboration*

*Flavor Physics  
& CP Violation (FPCP)  
16–18 May 2002  
Univ. of Pennsylvania  
Philadelphia*

# Motivation

## Why study $B$ physics at the Tevatron?

- Large rate:  $\sigma(p\bar{p} \rightarrow b\bar{b}) \approx 150 \mu\text{b}$  at 2 TeV  
 $\sigma(e^+e^- \rightarrow b\bar{b}) \approx 7 \text{ nb}$  at  $Z^0$   
 $\sigma(e^+e^- \rightarrow B\bar{B}) \approx 1 \text{ nb}$  at  $Y(4S)$



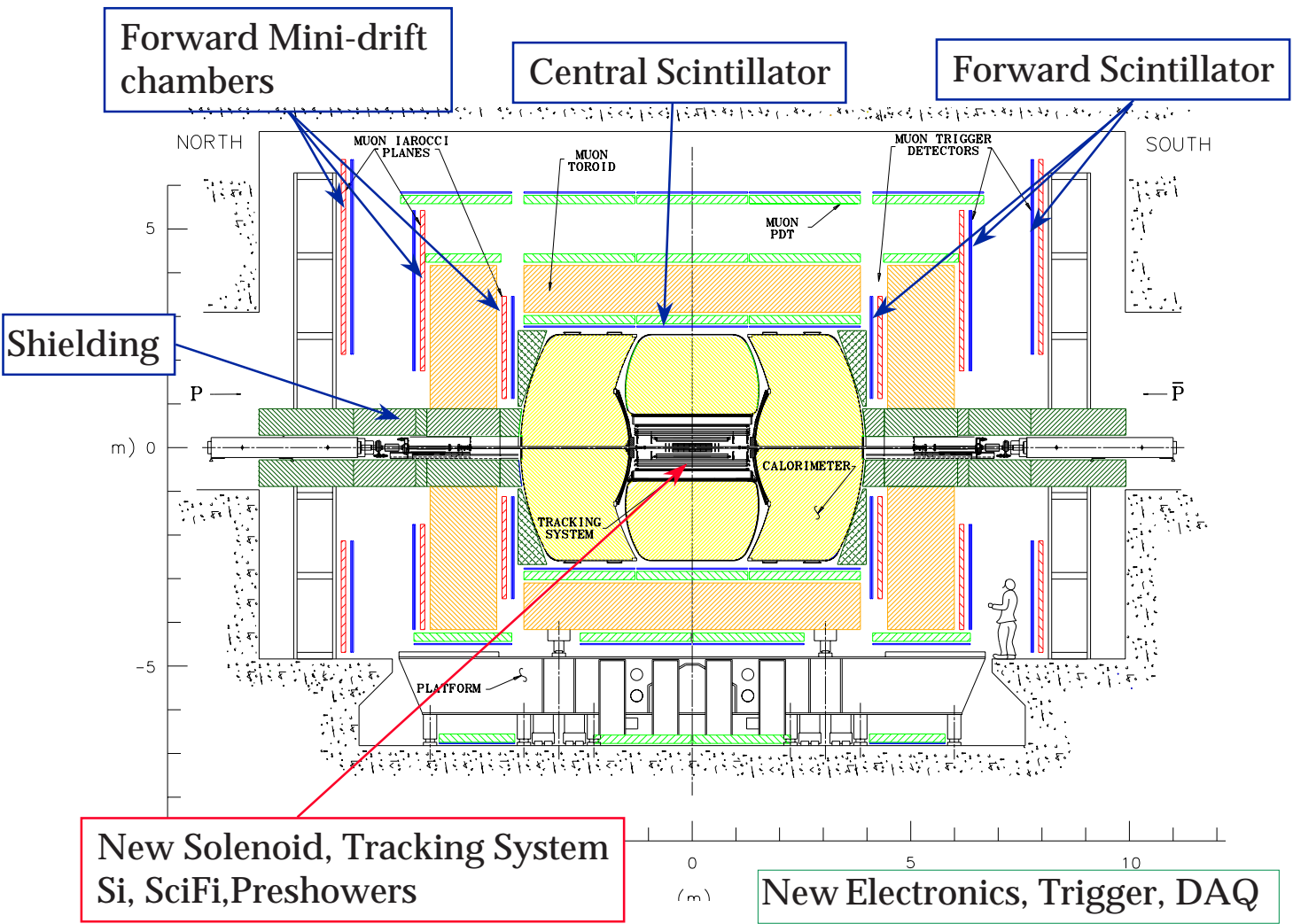
- All species, including  $B_s$ ,  $B_c$ ,  $\Lambda_b$  produced

# DØ Run 2 *B* Physics Program

- QCD tests
  - cross sections
  - correlations
  - charmonium polarization
- CP Violation  
CKM angles
  - $\sin(2\beta)$ ,  $B \rightarrow J/\psi K_s$
  - $\alpha, \gamma$   $B \rightarrow \pi^+\pi^-$  ?  $B_s \rightarrow K^+K^-$  ?
- Non SM CP  
Violation
  - $B_s \rightarrow J/\psi \phi$
- $B_s$  Mixing
  - $B_s \rightarrow D_s n\pi$
  - $B_s \rightarrow D_s \ell \nu$
- Spectroscopy  
& Lifetimes
  - $B^0, B^+, B_s, B_c, \Lambda_b,$   
*double heavy baryons*
- Rare decays
  - $B \rightarrow \ell^+ \ell^- X_s$
  - $B \rightarrow \ell^+ \ell^-$

# DØ Upgrade Detector

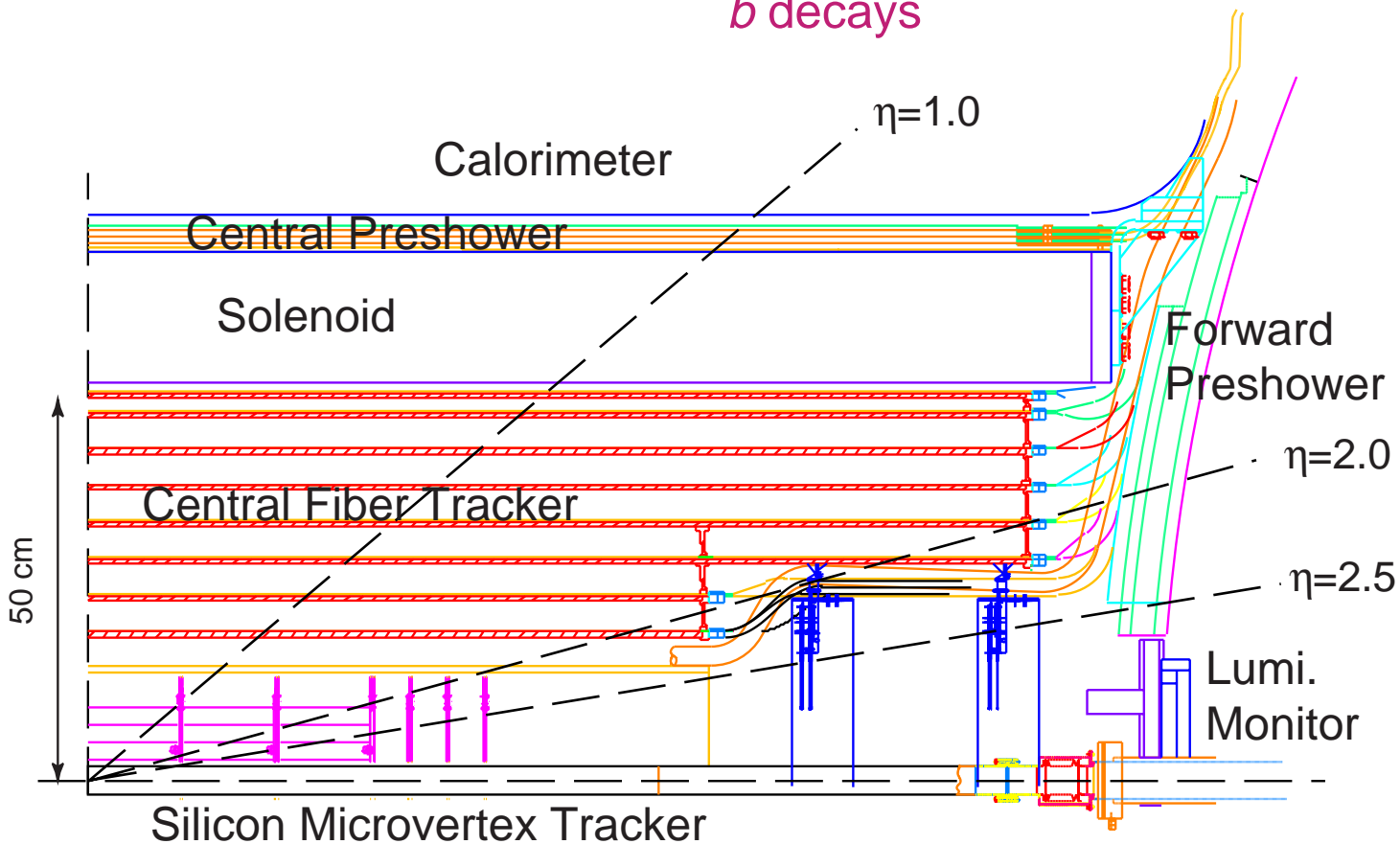
- Retain excellent calorimetry, increase speed of readout
- Upgraded muon system for better muon identification and triggering (tagging *b*'s)



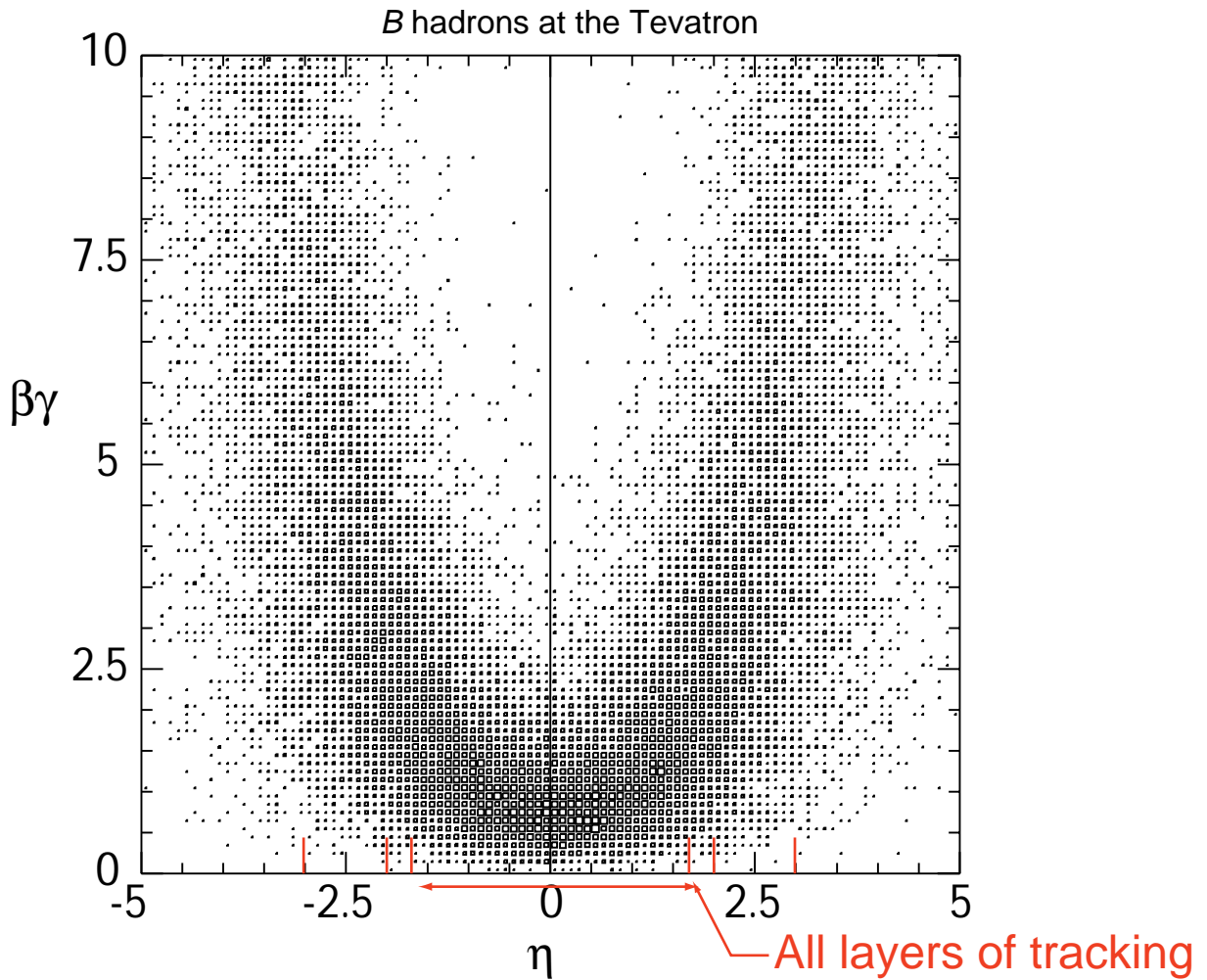
- Zooming in...

# New tracker, preshower detectors

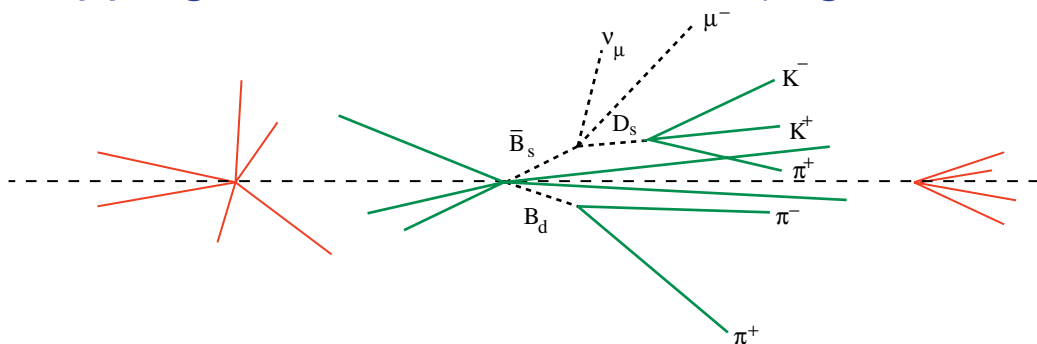
- Silicon Microvertex Tracker: 6 barrels (4 layers), single and double-sided interspersed double-sided disks  
800k channels → impact parameter resolution
- Central Fiber Tracker: 8 barrels of scintillating fiber doublets (half stereo), visible light photon detector readout, fast pick-off for track trigger  
77k channels → momentum resolution
- Solenoid: 2 T superconducting
- Central, Forward Preshower Detectors: scintillator strips, stereo, WLS fiber readout  
→ non-isolated electron id for  $b$  decays



# What's different?



- Signal/background:  $\sigma_{\text{had}}^{\text{tot}} \sim 75 \text{ mb}$      $\sigma_{bb} \sim 0.1 \text{ mb}$   
 $\Rightarrow$  triggering challenge: pipelined Level-3 trigger  
 trigger on displaced tracks at Level 2 (STT)  
 trigger on tracks at Level 1 (CTT)
- Overlapping minimum bias events (e.g. <2.0> Run 2a)



# Projected Performance

- Good Momentum resolution:

$$dp_T/p_T^2 = 0.002 \quad (\text{Silicon + Fiber tracker})$$

- Tracking out to forward regions

$$|\eta| < 3 \quad (\text{Silicon disks})$$

- Vertex Reconstruction:

$$\text{primary vertex: } \sigma^{\text{vertex}} = 15\text{-}30 \mu\text{m (r-}\phi\text{)}$$

$$\text{secondary vertex: } \sigma^{\text{vertex}} = 40 \mu\text{m (r-}\phi\text{)}, 80 \mu\text{m (r-z)}$$

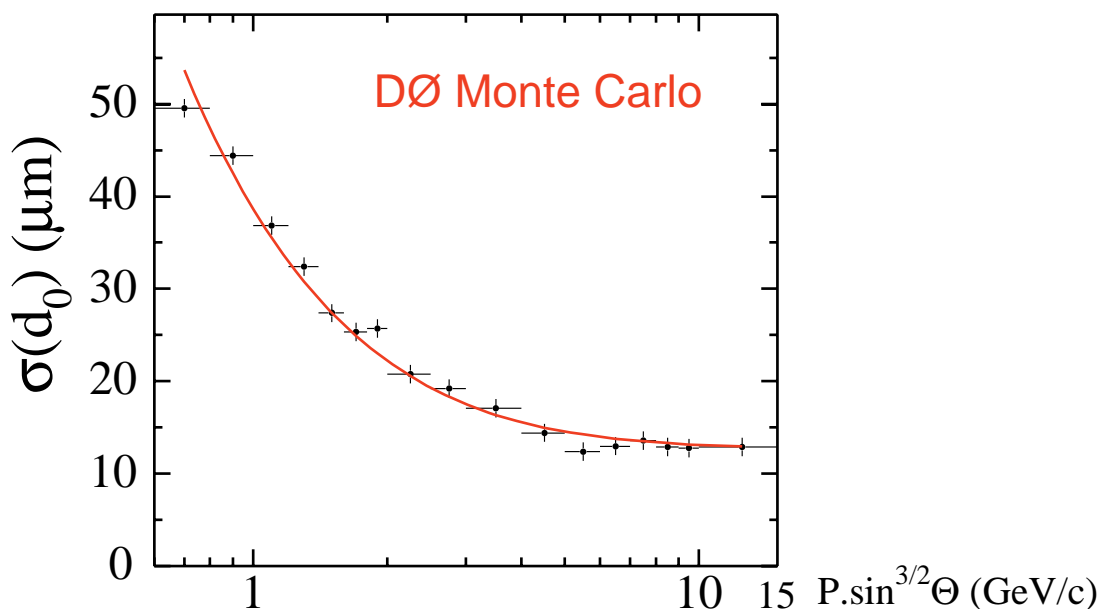
- Excellent lepton coverage trigger and ID efficiency:

$$\text{muons: } p_T > 1.5 \text{ GeV}, |\eta| < 2$$

$$\text{electrons: } p_T > 2.0 \text{ GeV}, |\eta| < 2.5$$

- Impact parameter trigger

Silicon track trigger at Level 2 starting end Summer 2002

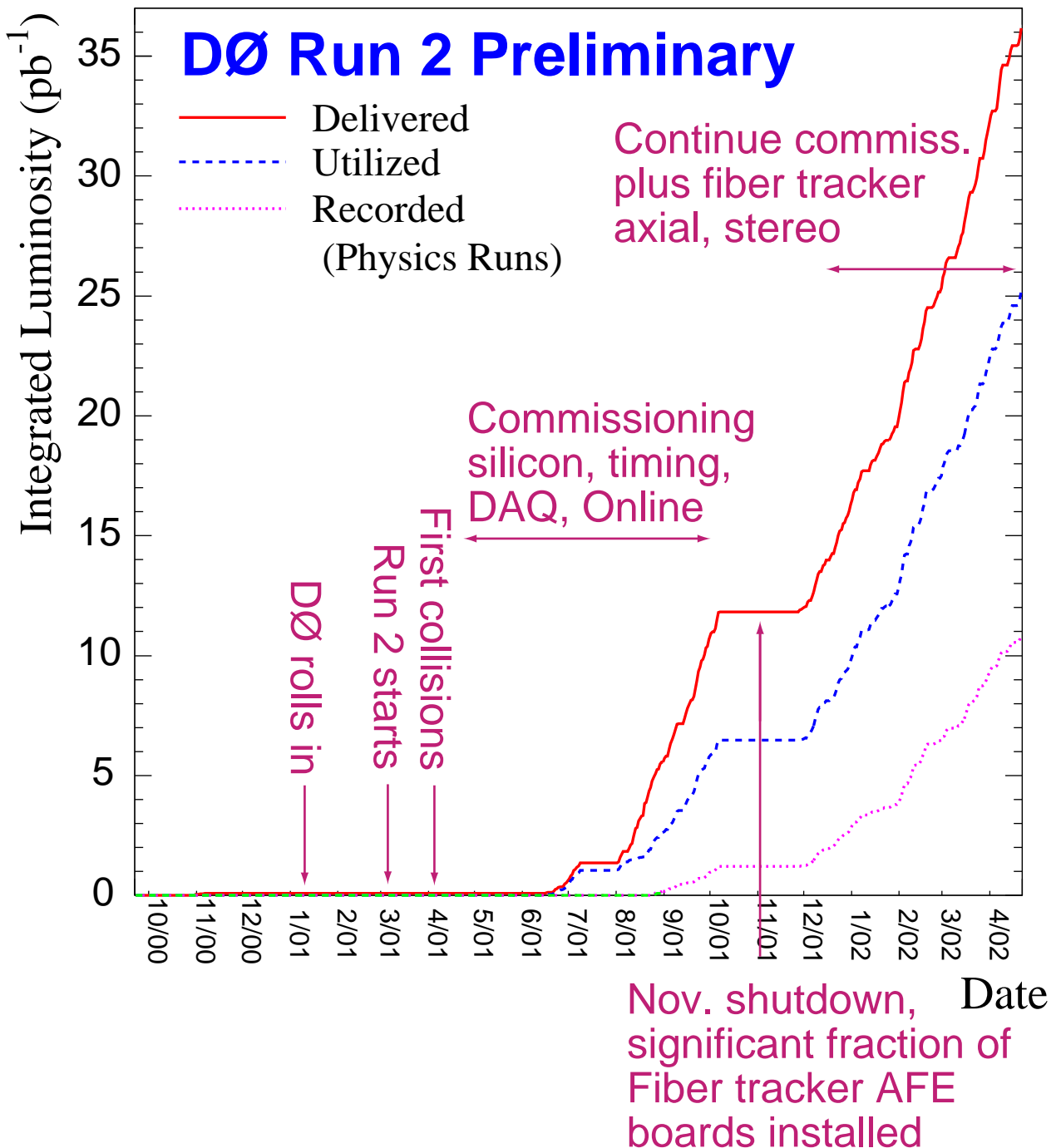


*Status: What about now?*

# Run 2

- Increases energy from 1.8 TeV to 1.96 TeV ( $b\bar{b}$  cross section up by ~30%)
- Increases luminosity: 

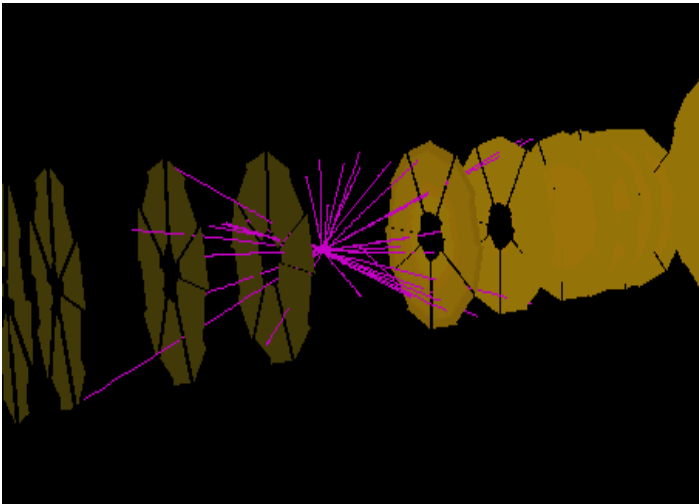
Run 1	Run 2a	Run 2b
0.1 fb <sup>-1</sup>	2 fb <sup>-1</sup>	15 fb <sup>-1</sup>





Importance of tracking in  $B$  physics – critical path item was late Analog Front End (AFE) boards essential for reading out central fiber tracker (CFT) and preshower detectors.

- Summer 2001: very restrictive slice in  $\phi$  instrumented with CFT axial
- Nov. 2001 shutdown: large fraction of CFT axial AFE boards installed, commissioned over winter
- Many commissioning studies with silicon-only tracking!

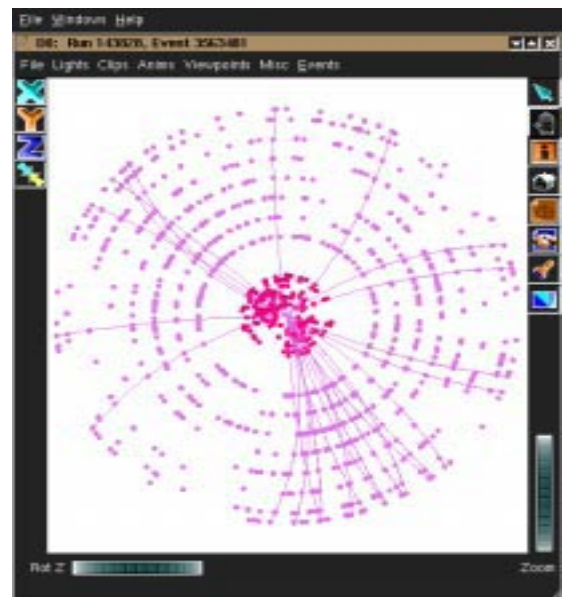


Primary vertex  
with silicon-only  
tracking

Operational

Barrel	95%
F-disks	96%
H-disks	87%

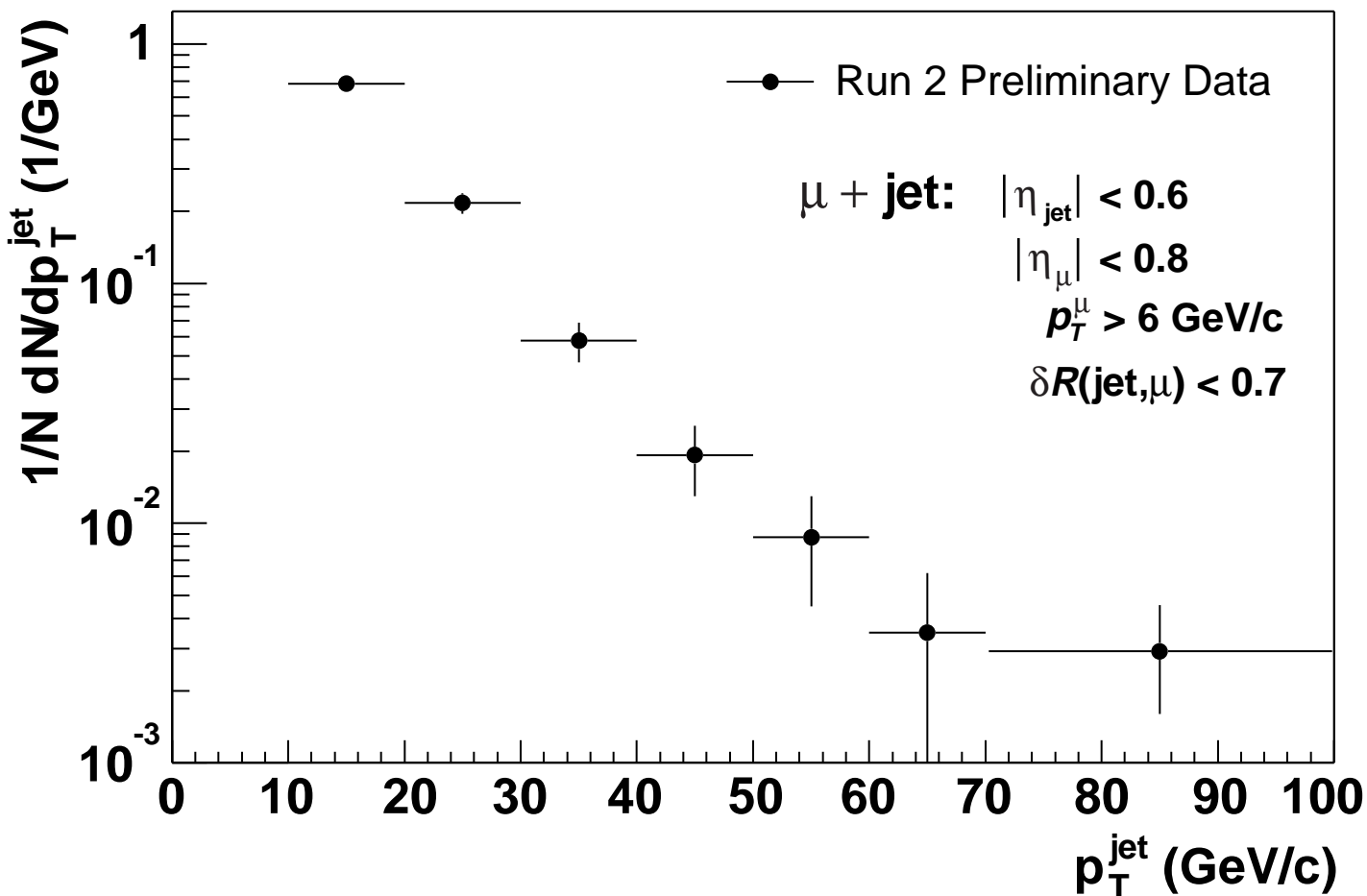
- Now CFT axial completely instrumented, and *as of ~3 weeks ago, CFT stereo fully instrumented (i.e., full tracking only very recent...)*



# *b*'s from Muons

- Muons associated with jets

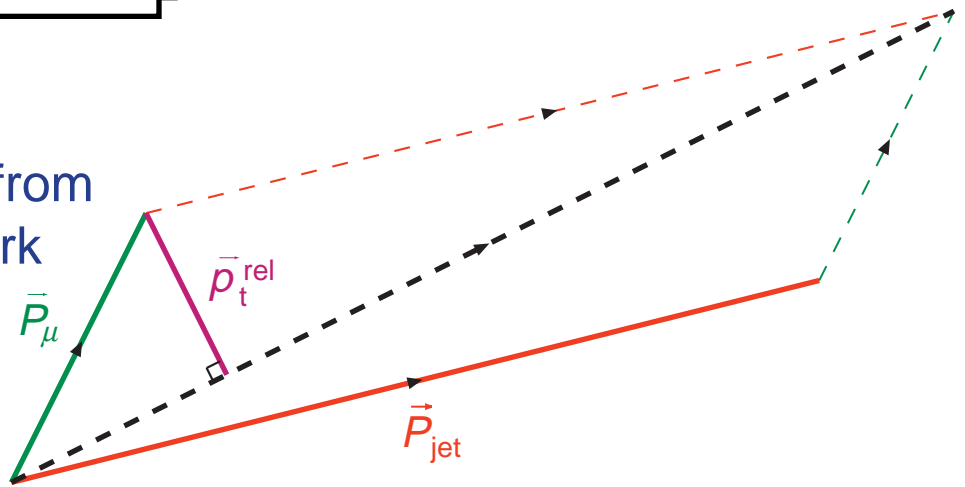
## DØ Run 2 Preliminary



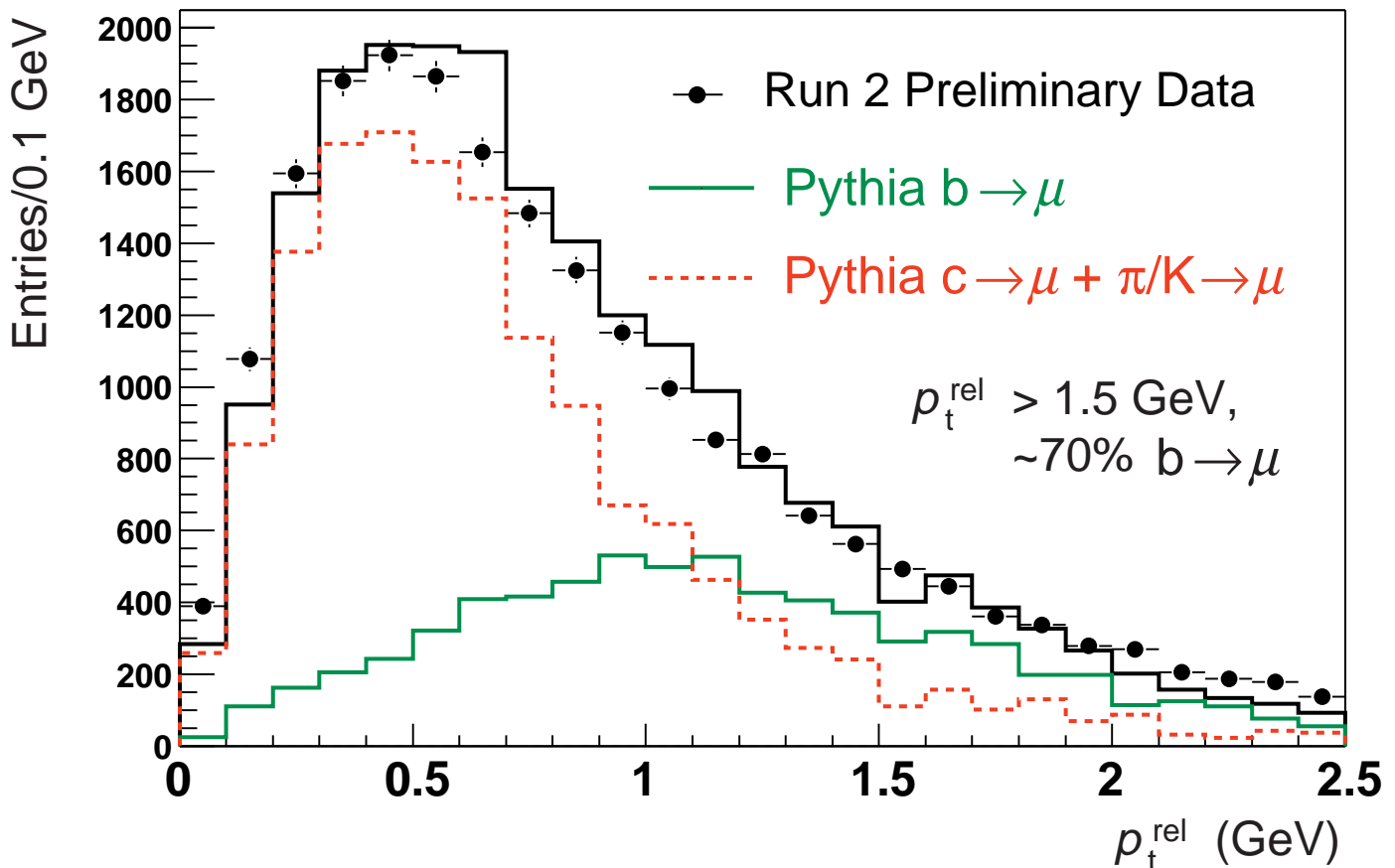
- Consistent in shape with DØ Run 1 results in same kinematic region

# ***b*'s from Muons**

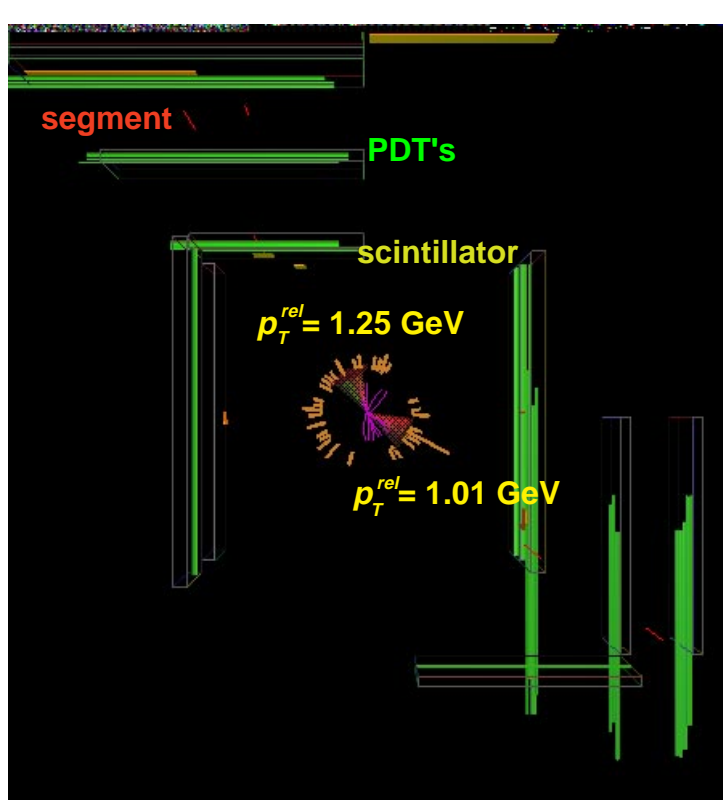
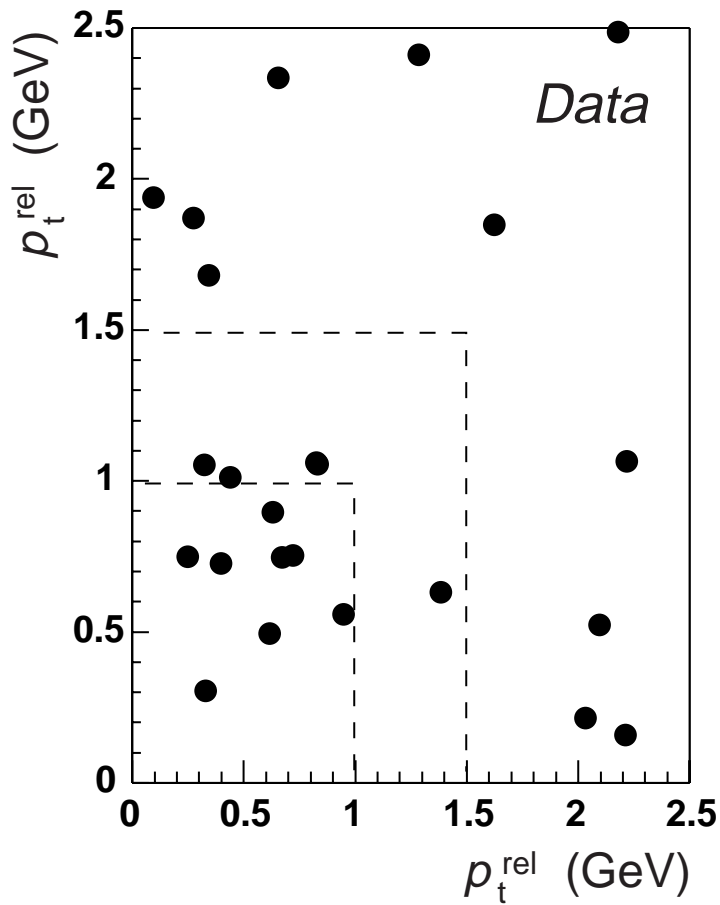
- Decay muon from heavier *b* quark gets transverse kick



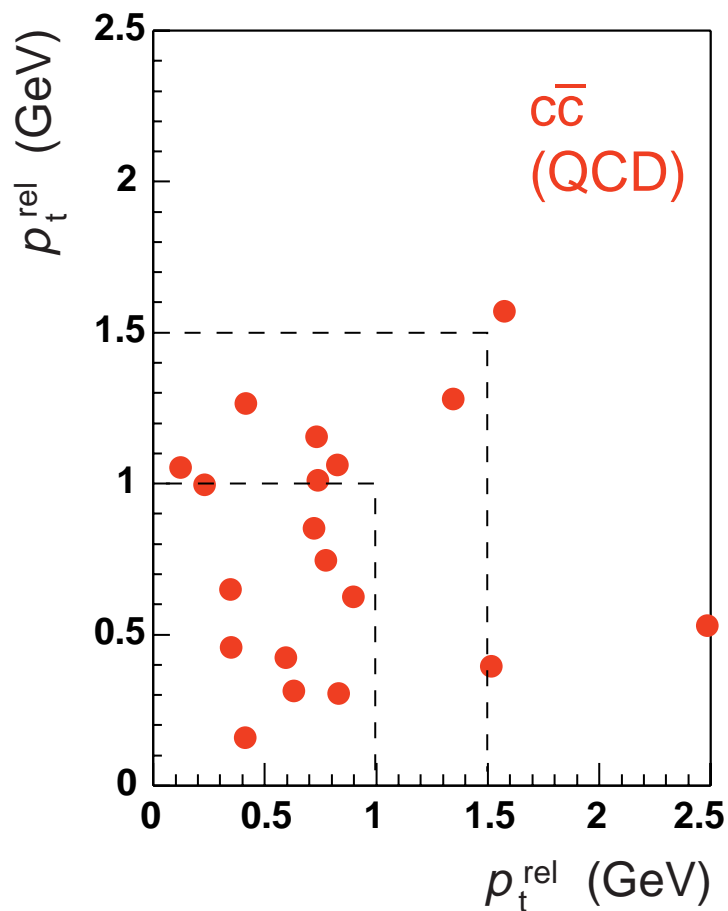
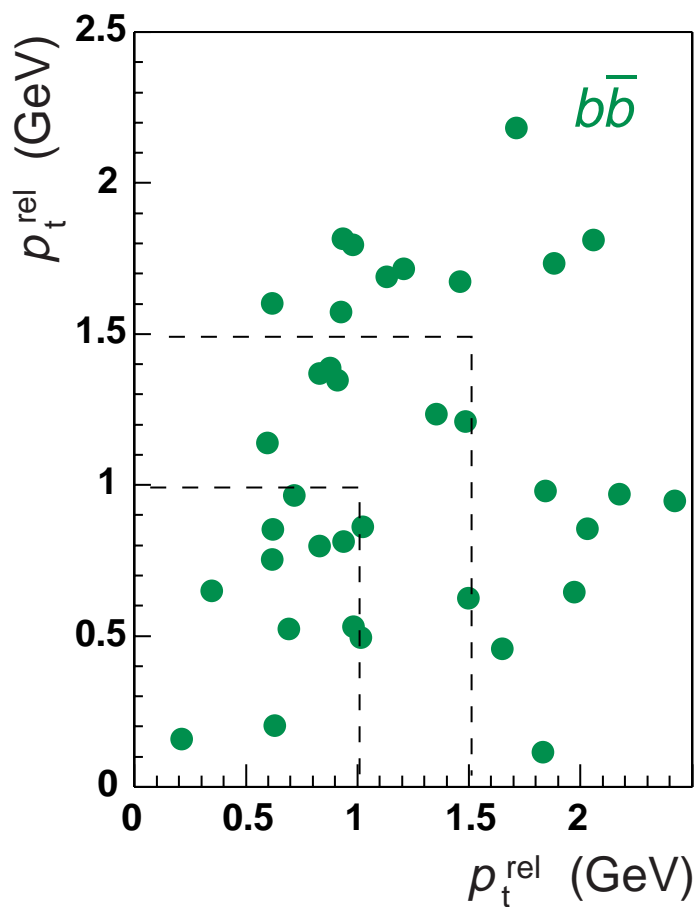
## **DØ Run 2 Preliminary**



- Muons without charged particle match, current work with matched muons shows substantial improvement in separation



## DØ Run 2 Preliminary

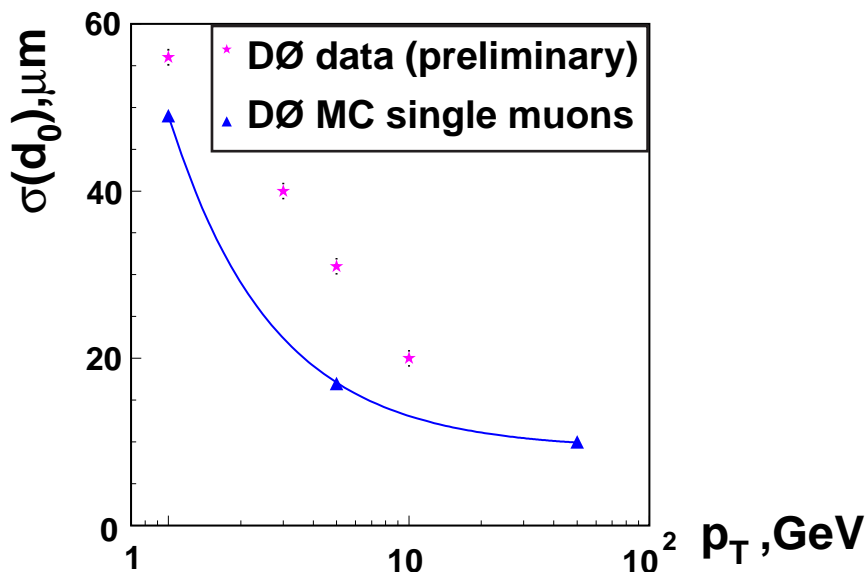
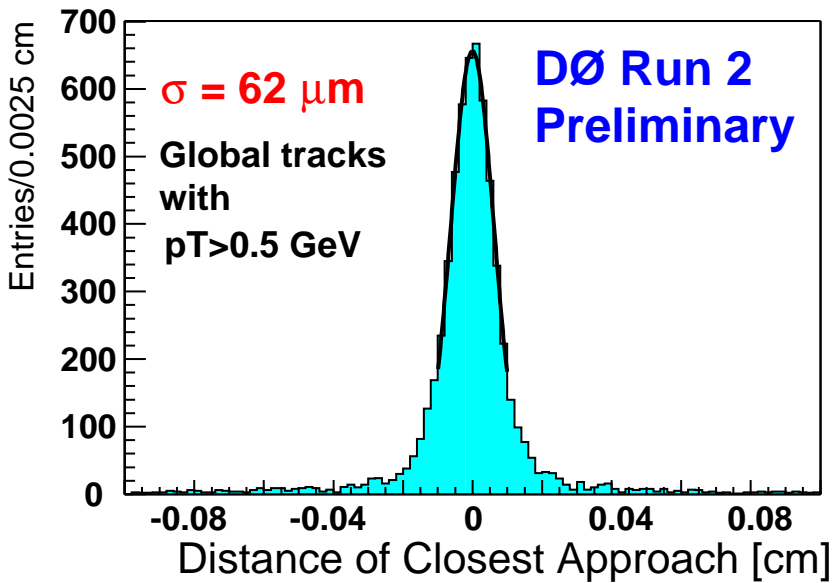
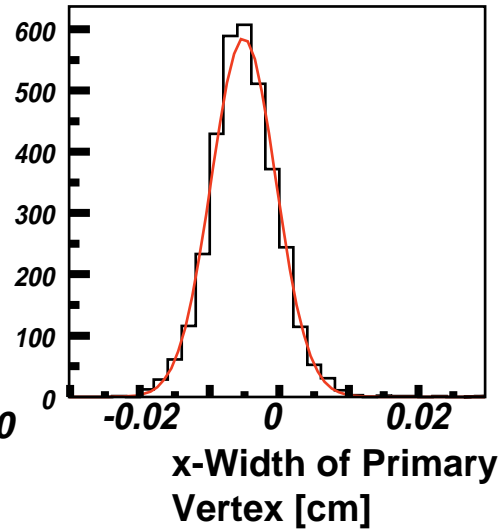
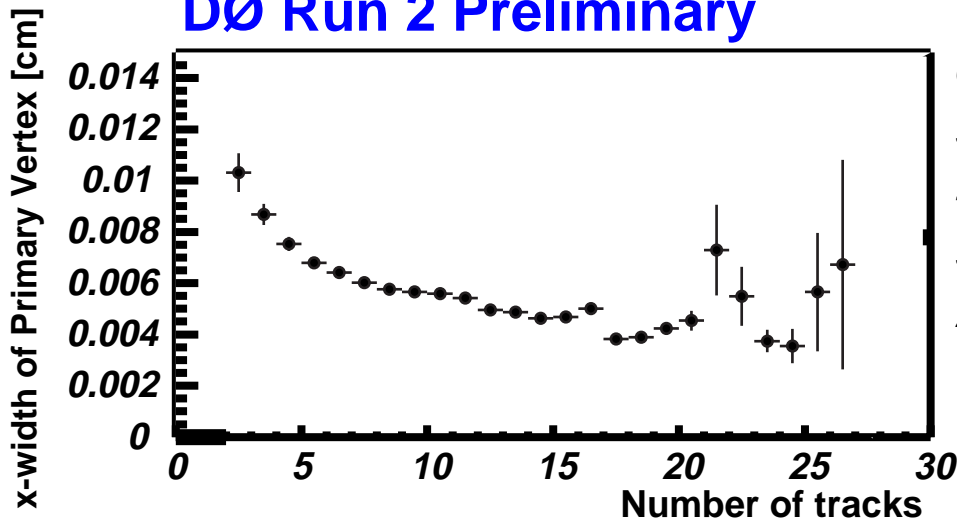


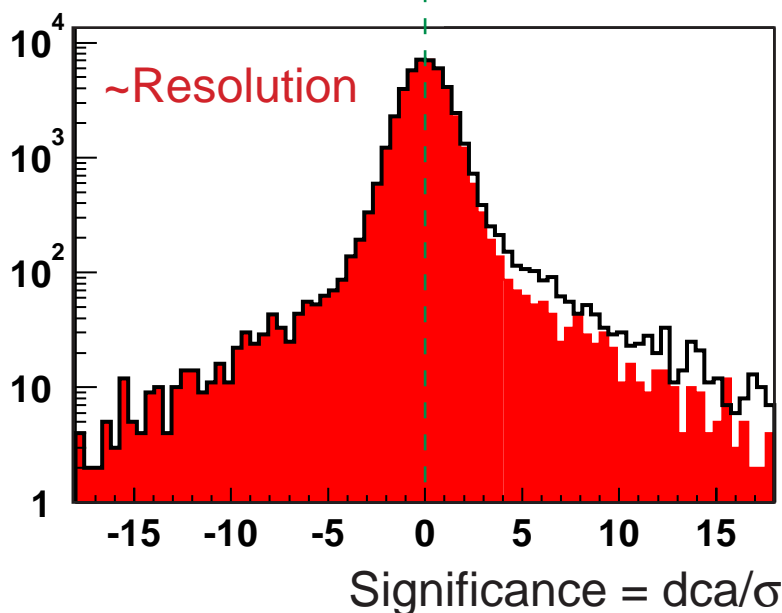
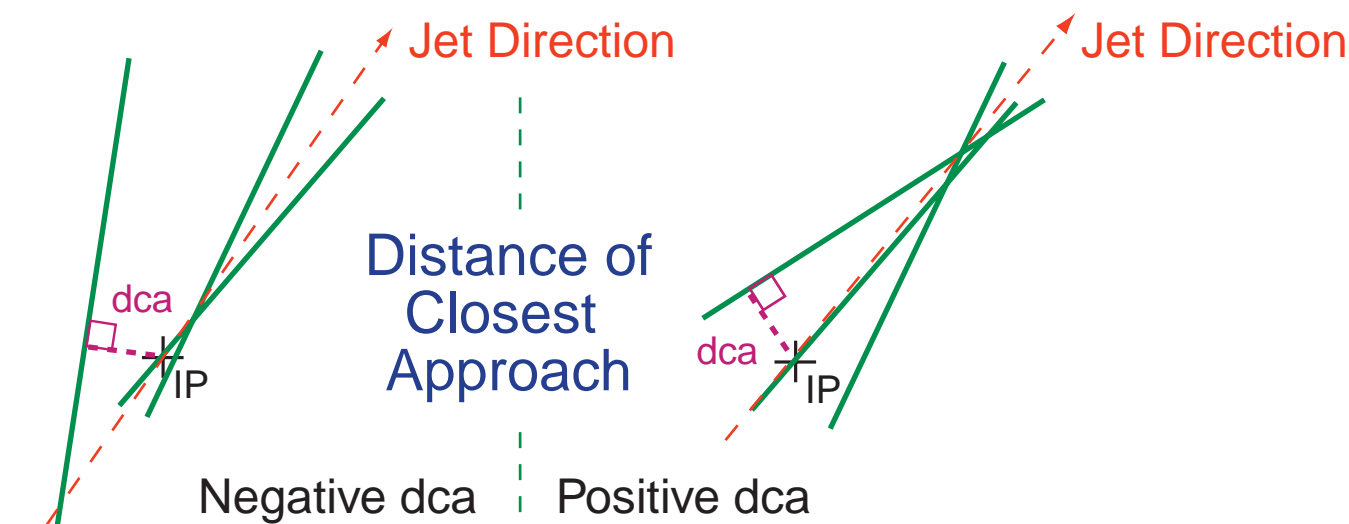
# Lifetime signals from $B$ 's

$N_{\text{tracks}} > 13$ ,  
 $|z_{\text{vtx}}| < 20$  cm

$$\sigma_x = 46 \mu\text{m}$$

**DØ Run 2 Preliminary**

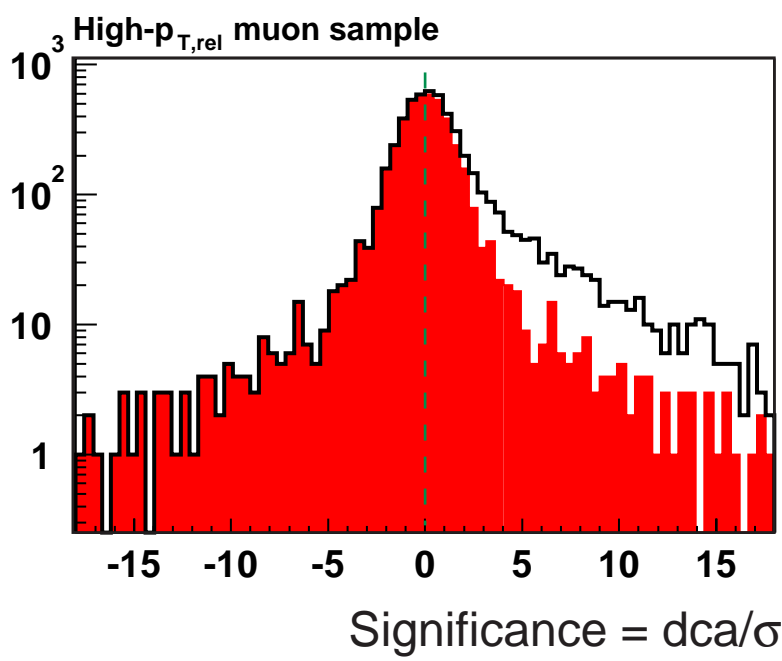




di-jet sample

- Track  $p_T > 1.5$  GeV
- $> 10$  total hits (SMT+CFT)
- $|dca| < 1.0$  mm (reduces  $K_S^0, \Lambda$ )

## DØ Run 2 Preliminary



$\mu$  associated w/ jet ( $dR < 0.7$ )

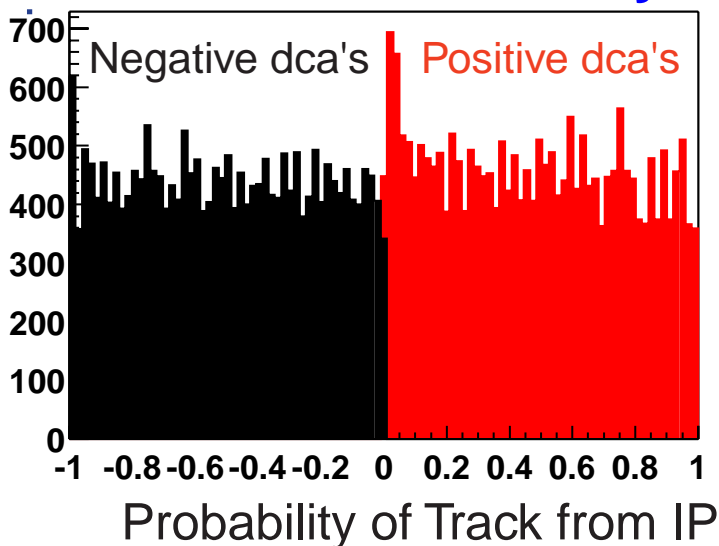
$p_T^{rel} > 1.5$  GeV

- Same cuts

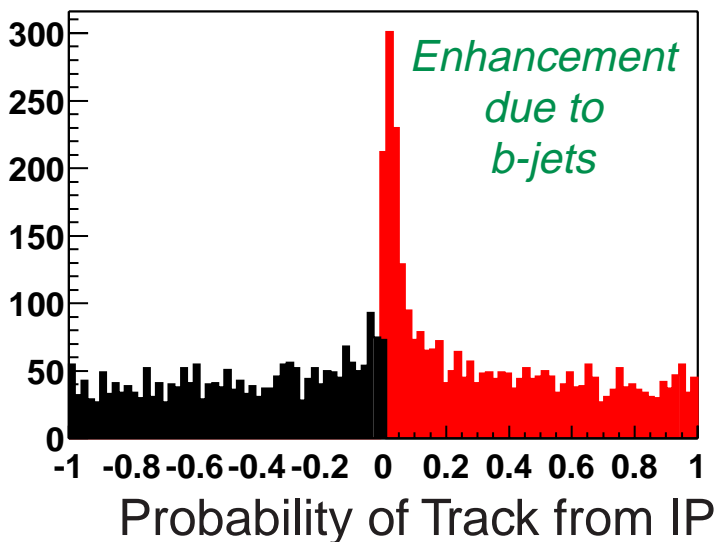
*Enhanced in b-jet Content*

Convert to probability (negative dca distribution of di-jets used, applied to all):

## DØ Run 2 Preliminary



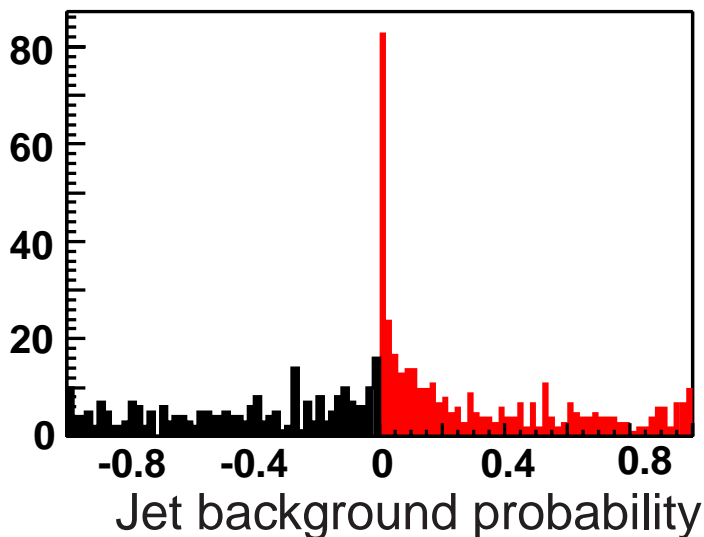
di-jet sample



$\mu$  associated w/ jet  
( $dR < 0.7$ )

$p_t^{\text{rel}} > 1.5 \text{ GeV}$

*Enhanced in  
b-jet Content*



Combine track probabilities  
of tracks in same jet  
into a jet probability

# Vertexing and the "Benchmark"

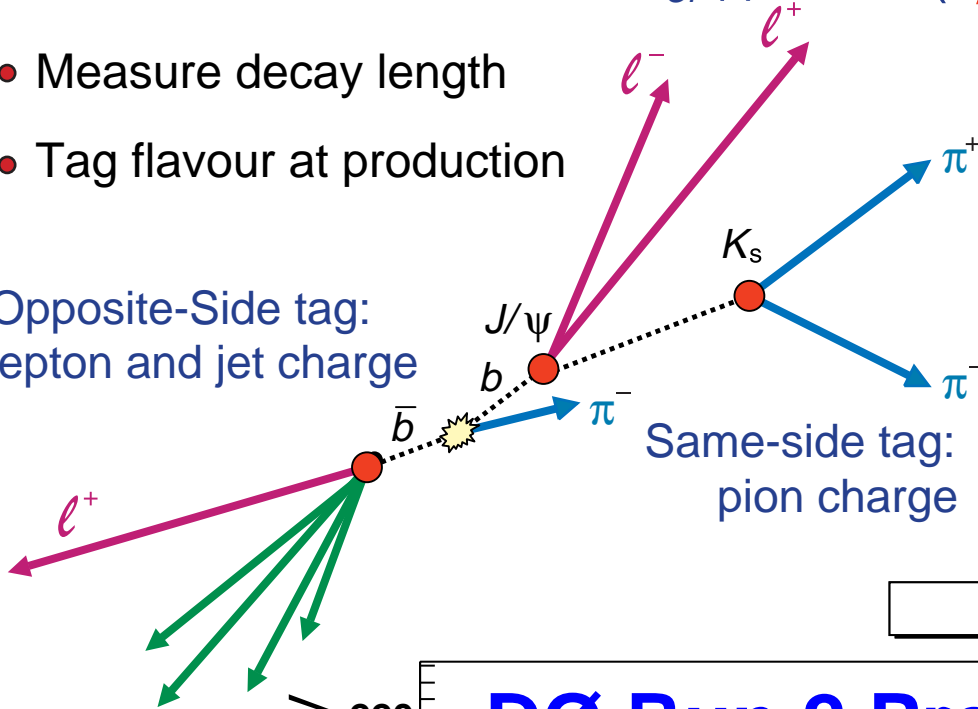
$J/\psi K_S$  Reconstruction:

$$A_{CP}(t) = \sin(2\beta) \sin(\Delta m_d t)$$

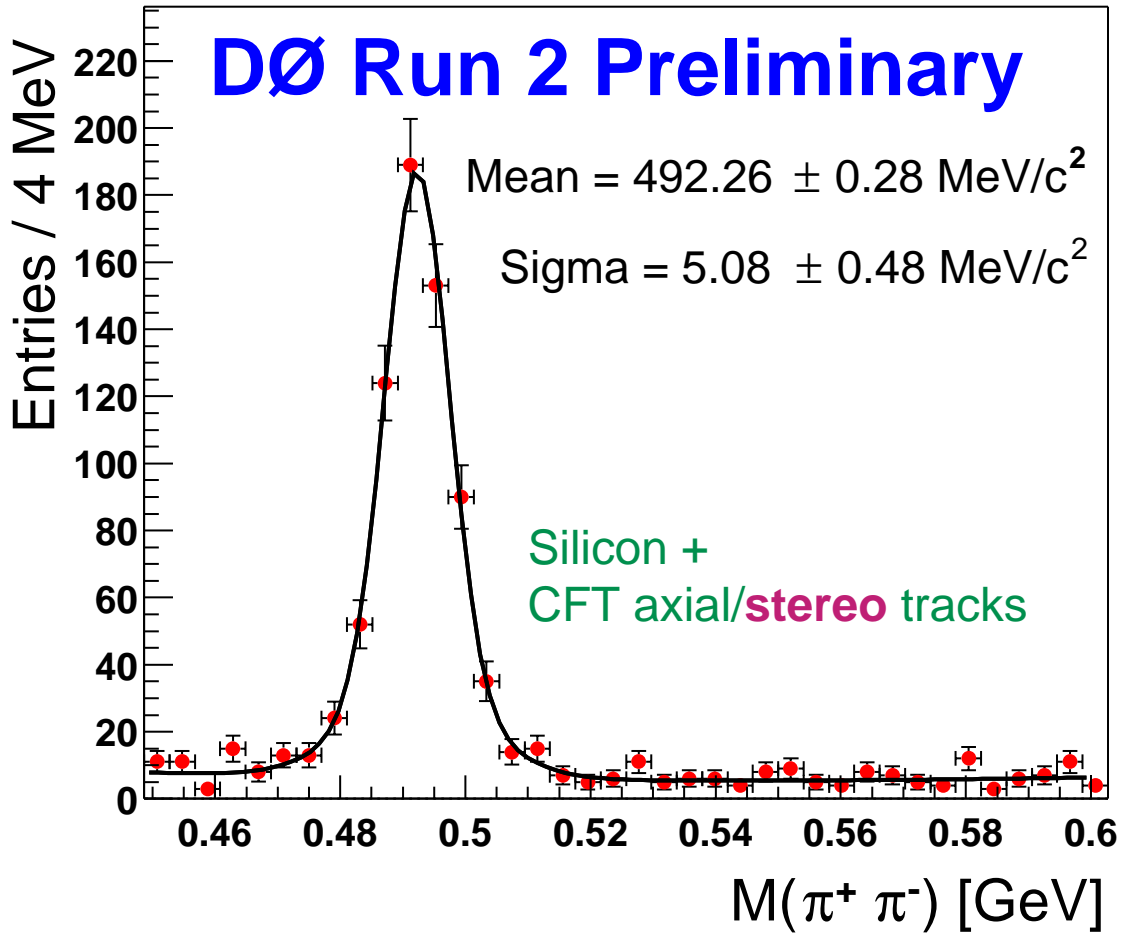
- Measure decay length
- Tag flavour at production

Opposite-Side tag:  
lepton and jet charge

Same-side tag:  
pion charge



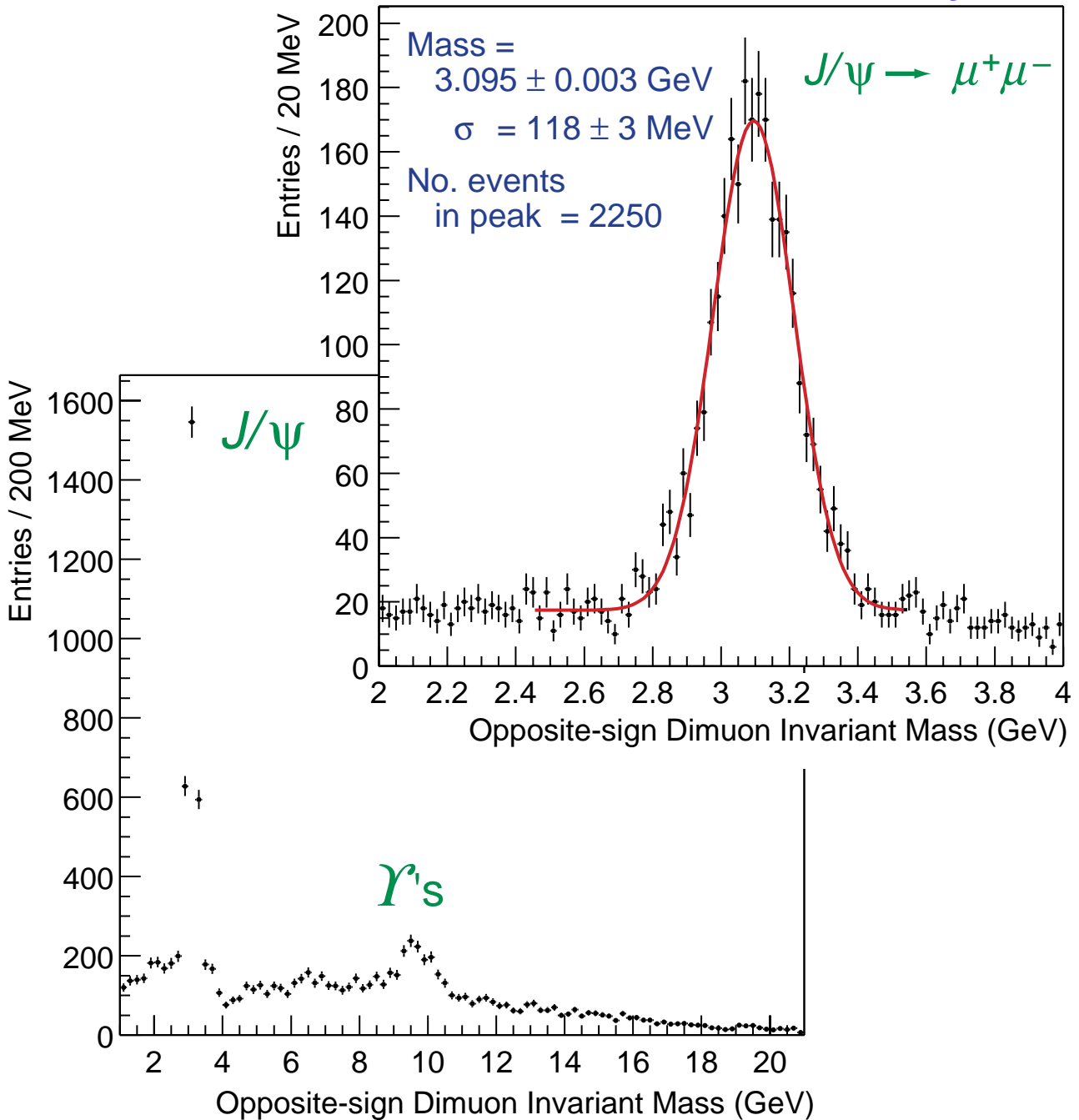
$K_S^0$  Invariant Mass





- Muons with central track match (no match, factor 3–4 more)

## DØ Run 2 Preliminary



- For  $J/\psi$  , if only take tracks with both silicon and CFT hits, mass resolution  $\sim 70$  MeV, c.f. 50–60 MeV expected from Monte Carlo

Tagging Efficiency,  $\epsilon = \frac{N_{\text{tag}}}{N_{\text{tot}}}$

Dilution,  $D = \frac{N_R - N_W}{N_R + N_W}$

Flavour Tag Quality =  $\epsilon D^2$

Tag	DØ Strength	DØ $\epsilon D^2$
Same side	–	2.0
Soft lepton	$\mu, e$ ID coverage	3.1
Jet charge	forward tracking	4.7
Opp. side $K$	no $K$ ID	none
Combine		9.8

(+trigger on  $J/\psi \rightarrow e^+e^-$ )

After Run 2a ( $2 \text{ fb}^{-1}$ ),  
Expect 30-40k  
reconstructed events

$\Rightarrow \delta \sin 2\beta \sim 0.04$

# $B_s^0$ Mixing

## Hadronic

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

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

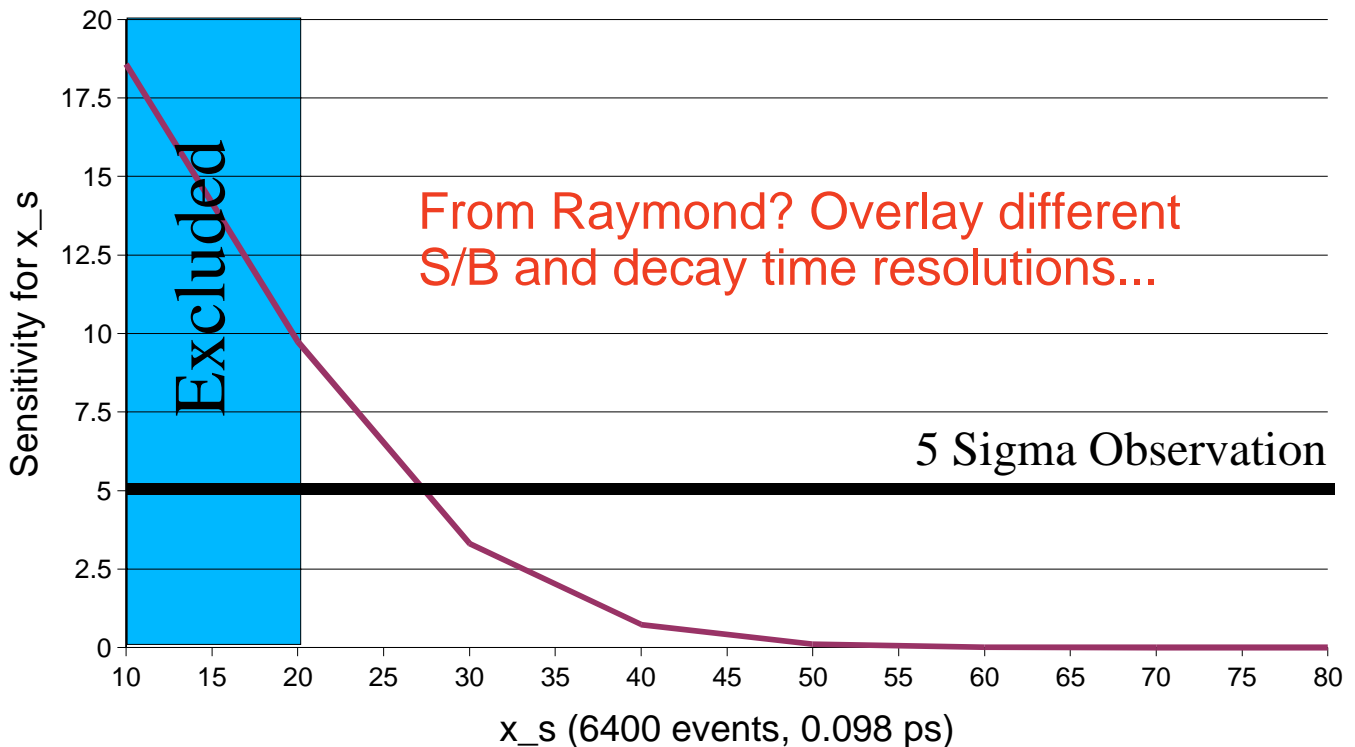
$$\phi \rightarrow K^+ K^-$$

No missing  $\nu$  !

- trigger on opposite-side lepton
- lepton charge tags initial flavour
- final flavour tagged by charge of charge of  $D_s$
- expect 6400 events in  $2 \text{ fb}^{-1}$
- reach estimates on  $x_s$

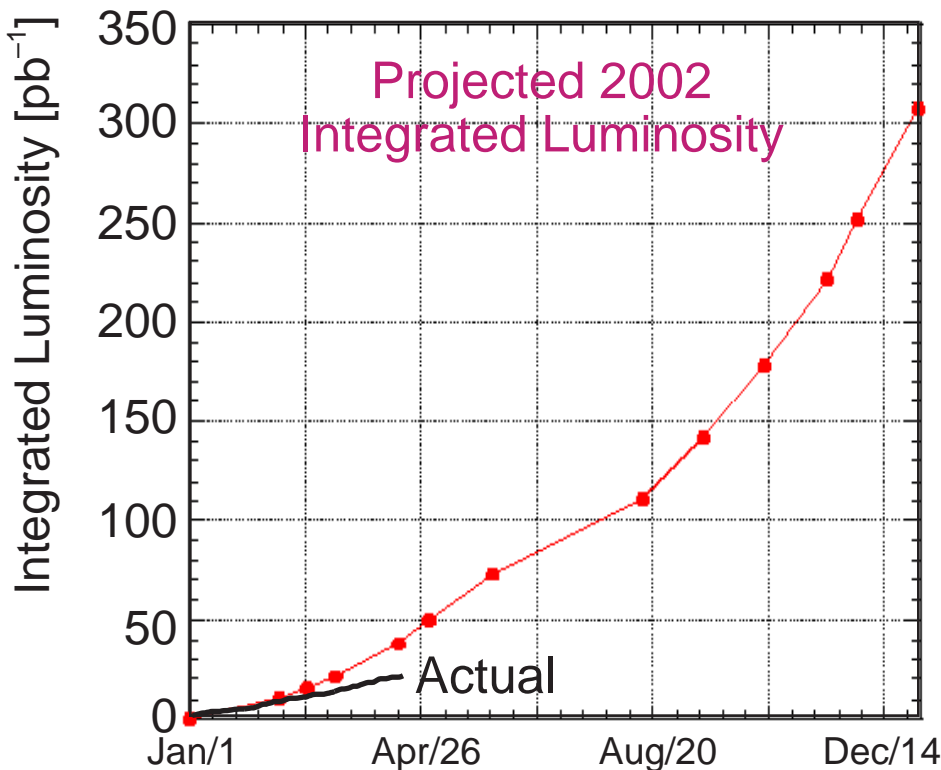
## Average Significance Estimates

Average Significance (S/B = 1/2)



# Future

- Finish detector commissioning
- Debugging, calibration, alignment
- Continue refining reconstruction algorithms
- Full tracking → secondary vertexing, electron id (and  $J/\psi \rightarrow ee$ ) with road method and preshowerers
- Complete triggers and improve DAQ
  - Level 2 trigger coming online
  - extend jet trigger beyond  $|\eta| = 0.8$  → weeks
  - Level 1 central track trigger → Summer 2002
  - Level 2 silicon track trigger → End summer 2002
- Luminosity!!



- ...but doesn't show last 3 weeks where turning up and record peak luminosity achieved!