Heavy Flavor Physics at DØ

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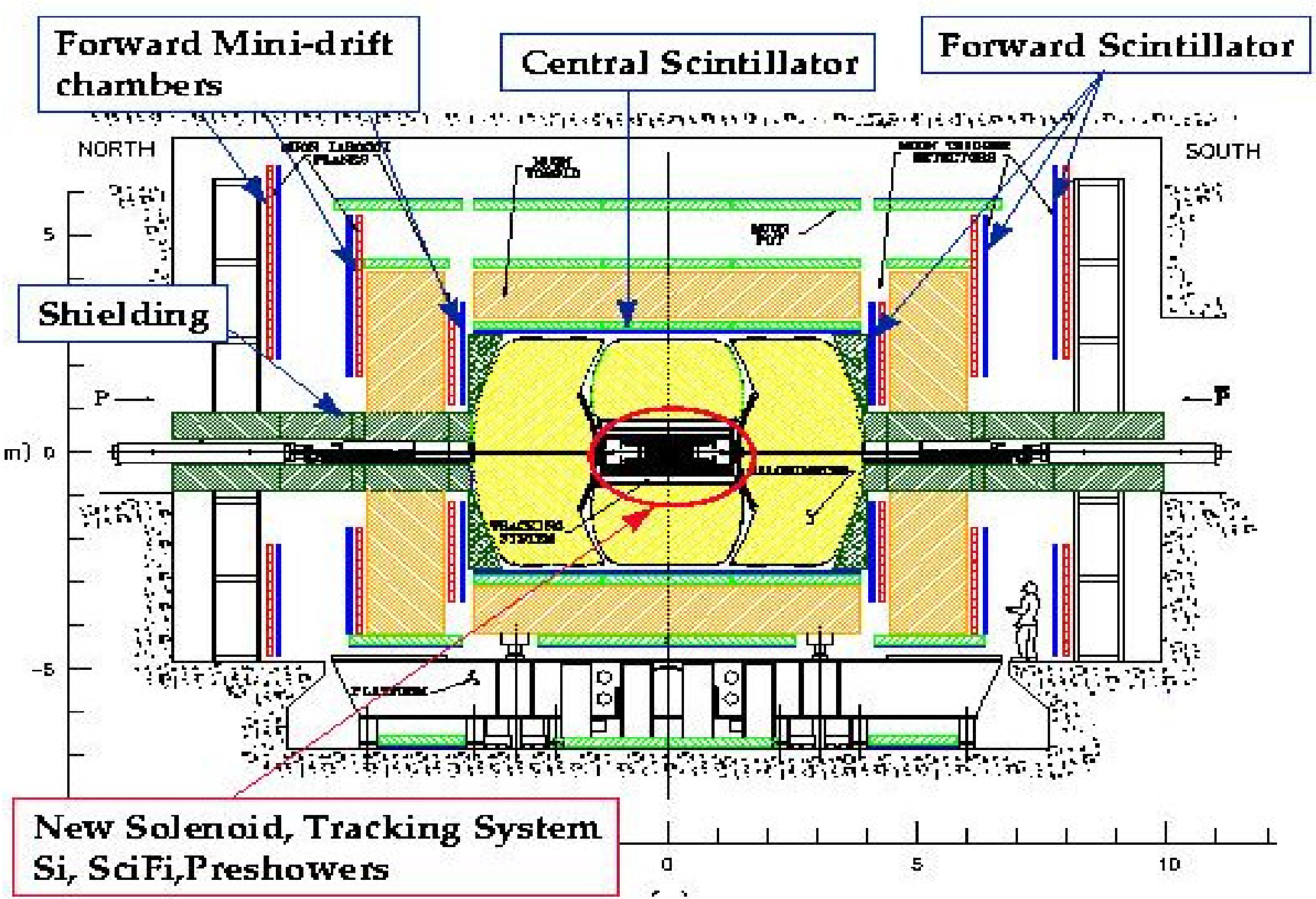
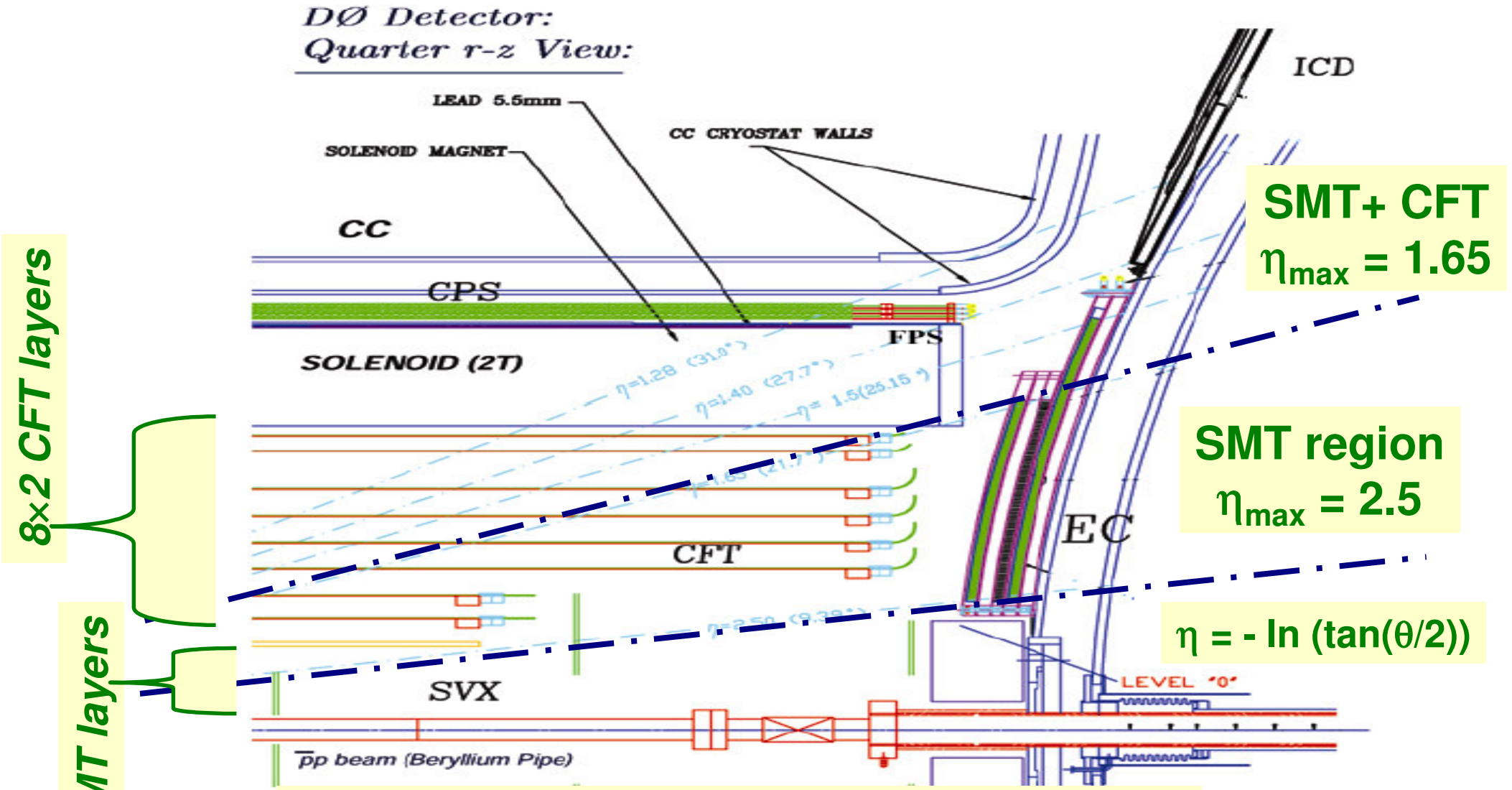
DØ Collaboration

DØ Detector

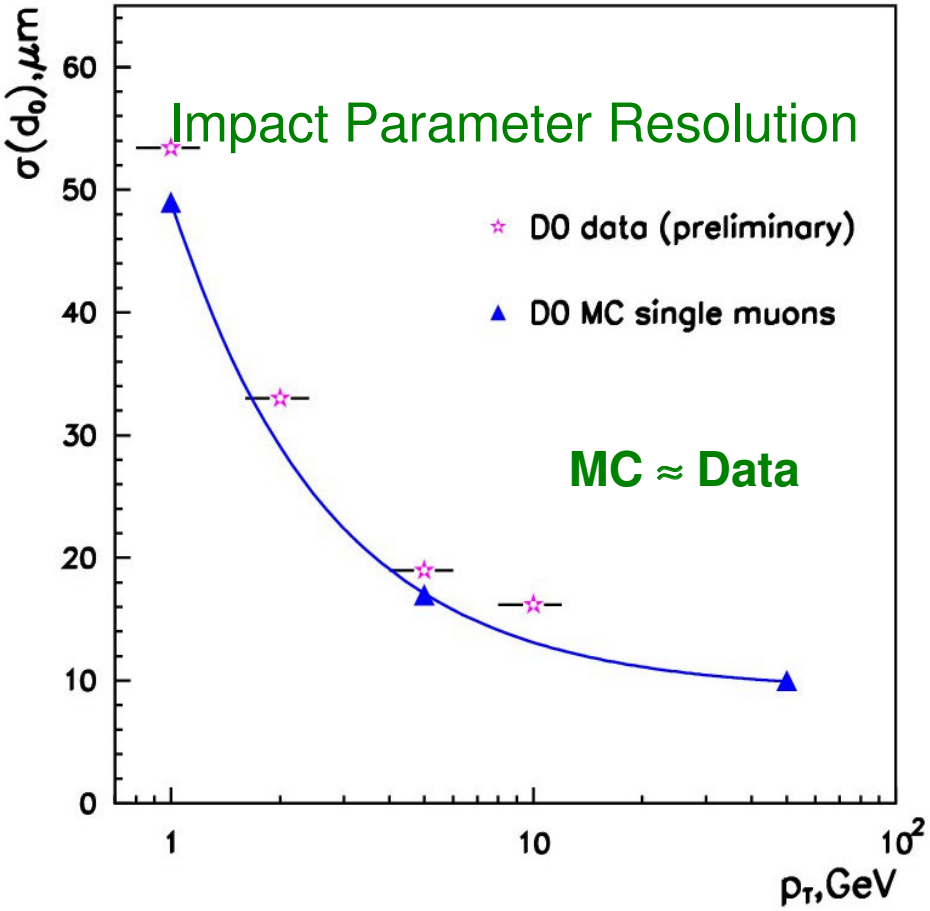

Forward Mini-drift chambers
Central Scintillator
Forward Scintillator
NORTH
SOUTH
Shielding
New Solenoid, Tracking System
Si, SciFi,Preshowers
5
0
-5
0
5
10

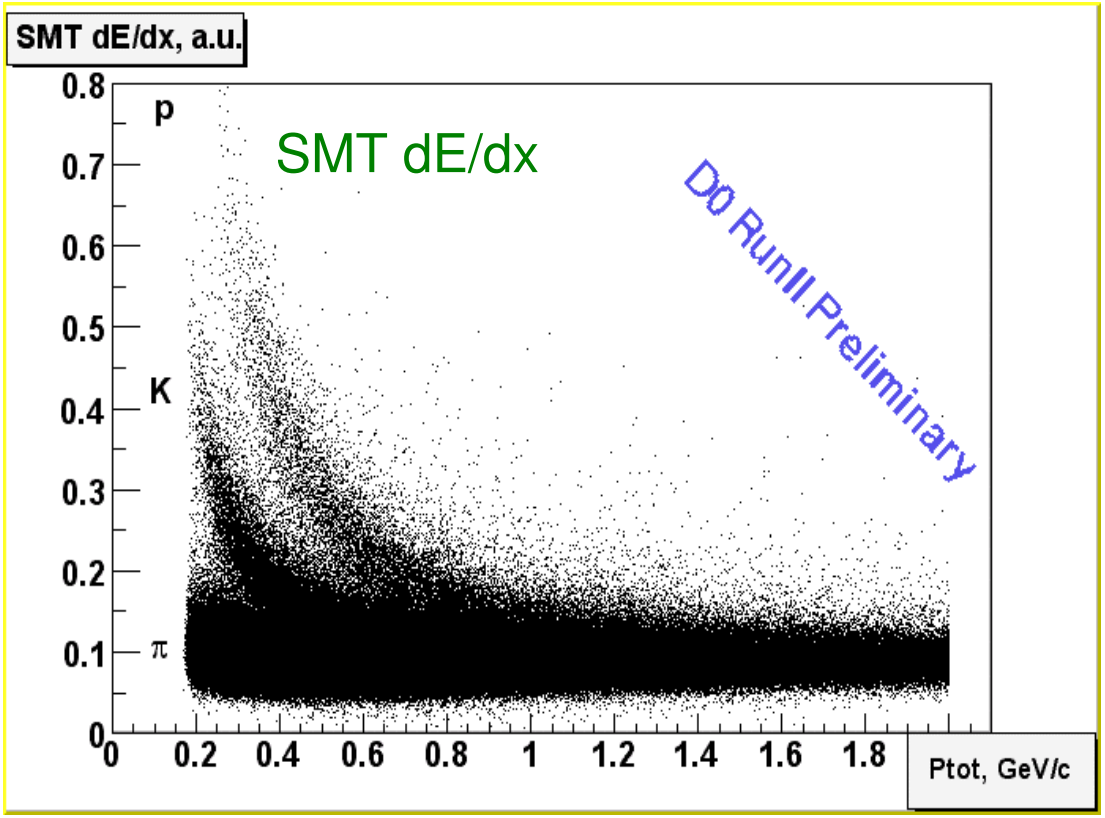
Tracker



Trigger: muon+track covers $|\eta|<2.2$

Tracking Performance





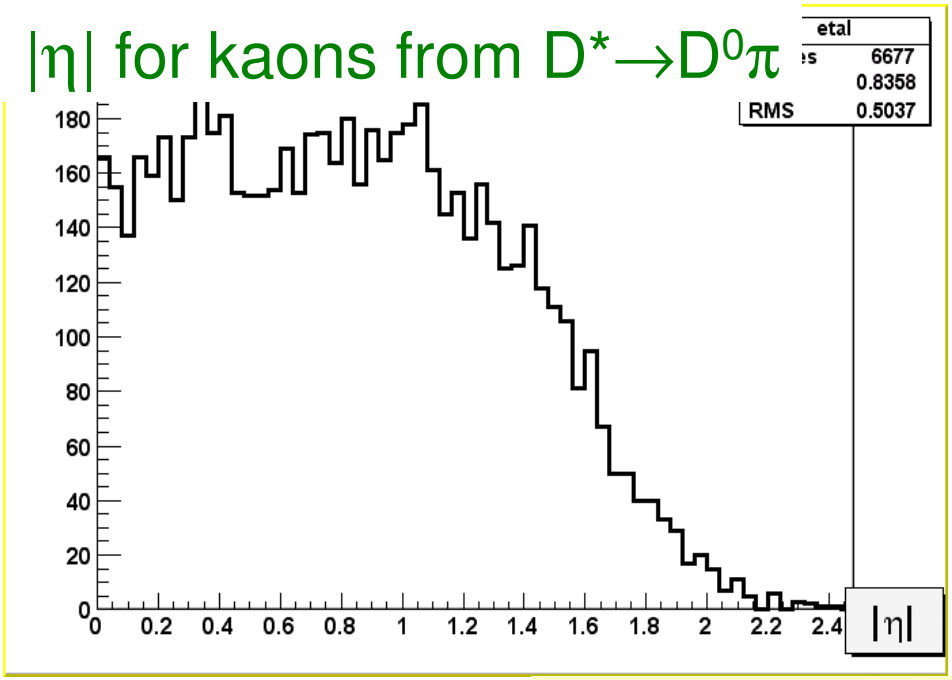
σ(DCA)≈53μm @ P_t=1GeV
and ≈15 μm @ higher P_t

Can provide
K/π separation for P_{tot}<400 MeV
p/π separation for P_{tot}<700 MeV
NOT yet used for PID

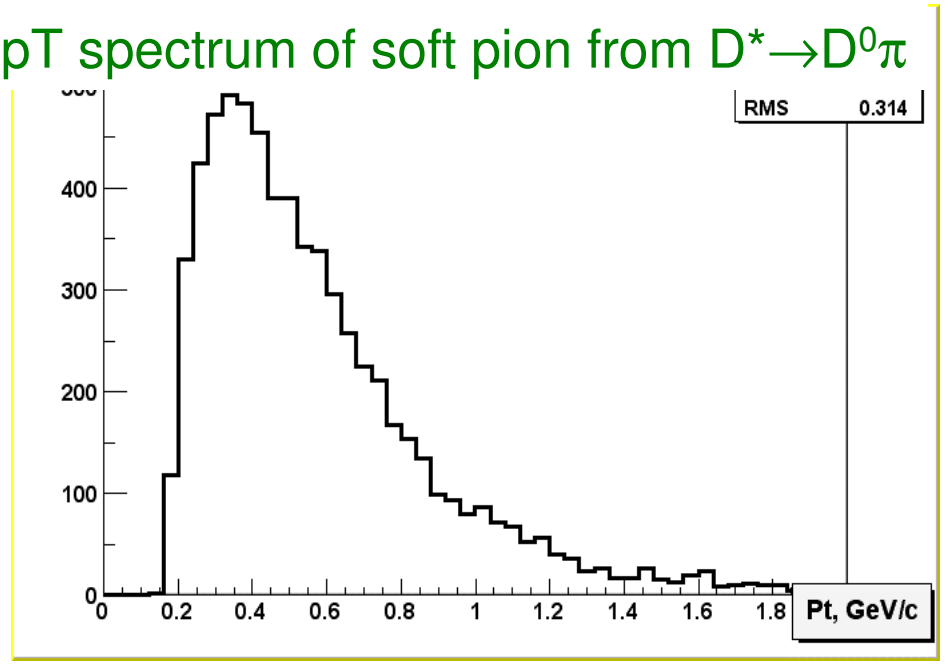
Tracking Performance

Data from semileptonic decays (B → μ D X)

|η| for kaons from D*→D^{0}π



pT spectrum of soft pion from D*→D^{0}π

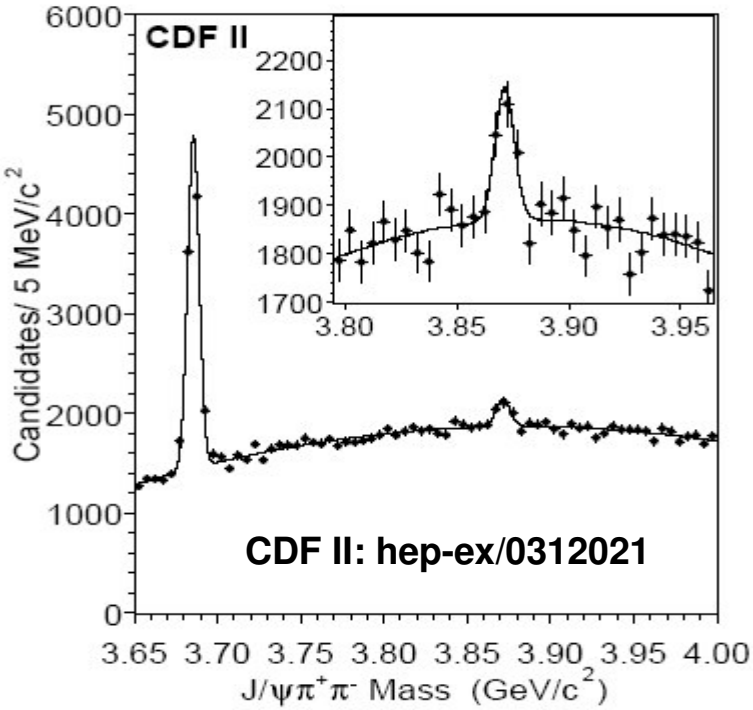


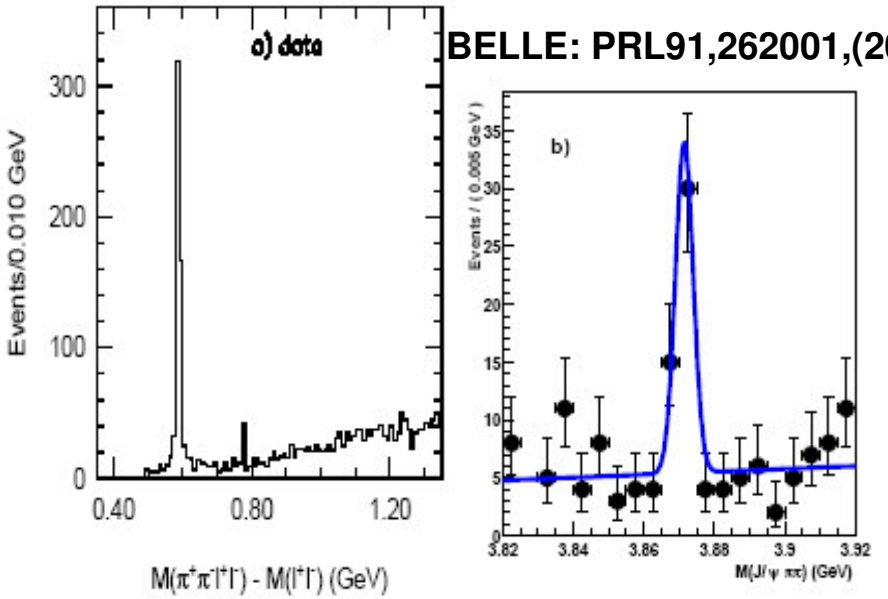
Tracks are reconstructed
- **over a wide η range**
- **starting from p_T = 180 MeV**

Efficient muon and tracking system give us a large sample of semileptonic B decays

A New Particle: X(3872)

- Last Summer BELLE announced a NEW particle around 3872 MeV/c^2 when looking at $B \rightarrow K^+X$ ($X \rightarrow J/\psi\ \pi^+\pi^-$)
- possible charmonium state or an exotic meson molecule (?)
- BELLE didn't find evidence for $\gamma\chi_{c1}$





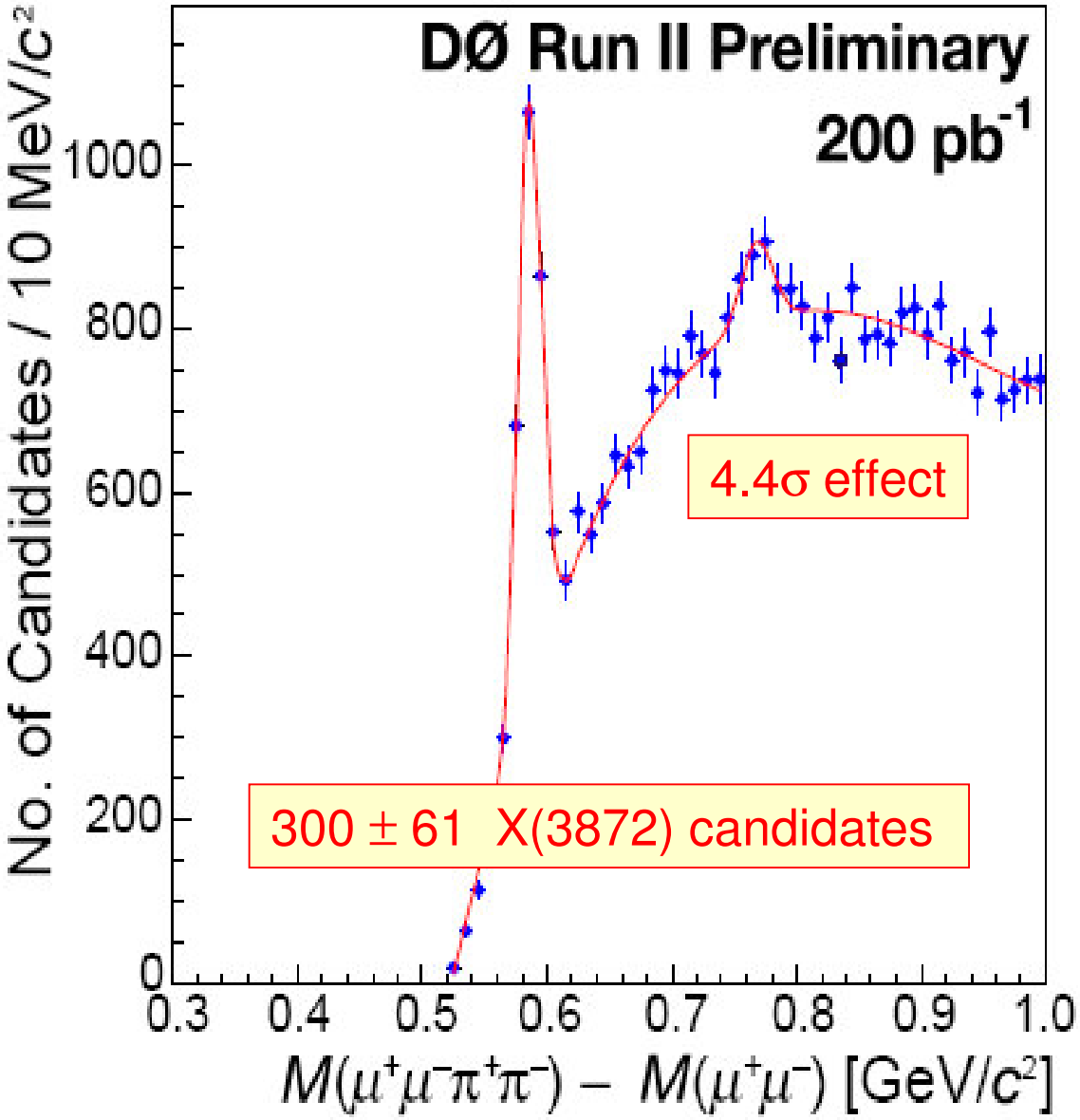
BELLE: PRL91,262001,(2003)

- $X(3872) \rightarrow J/\psi\ \pi^+\pi^-$ production in ppbar collisions has been confirmed by CDF

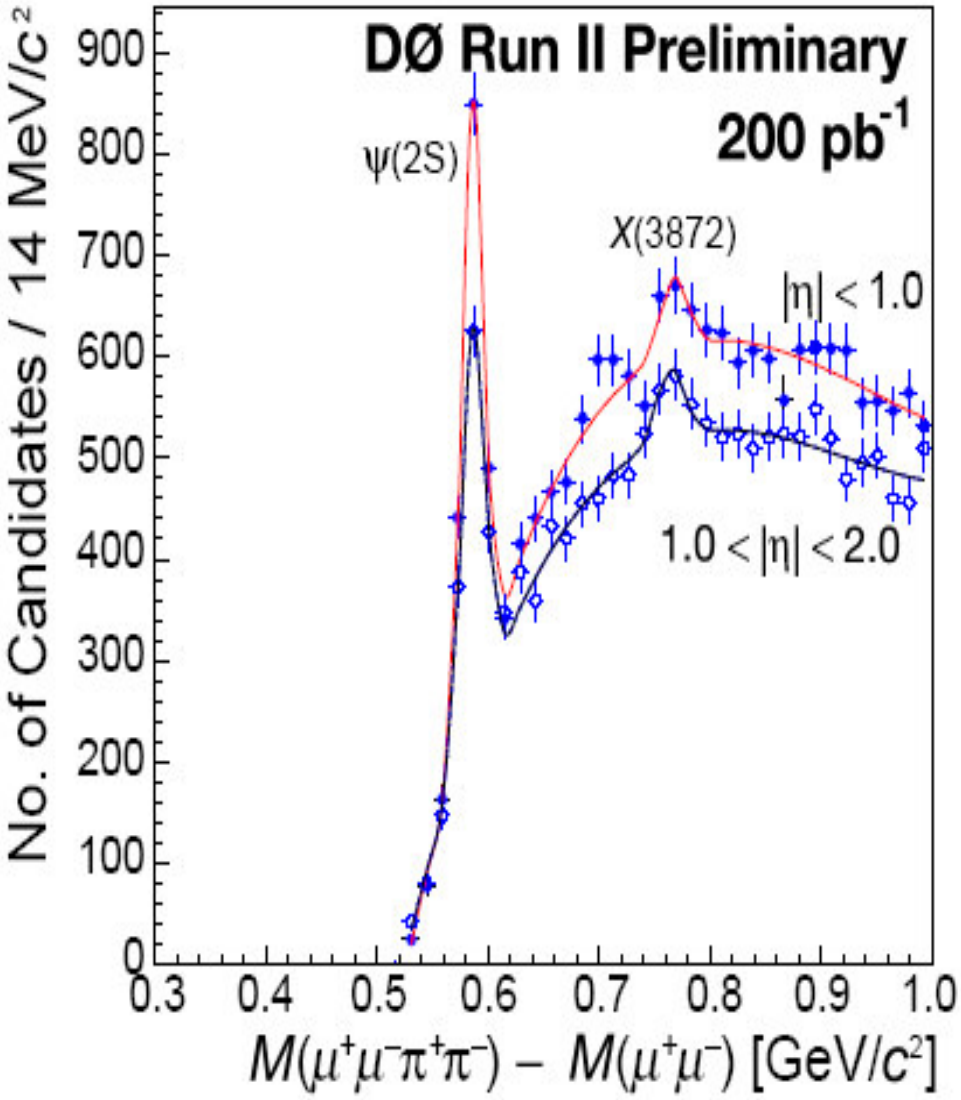
What can we say about the X(3872)?

- Using 200 pb^{-1} of DATA collected April 2002 – September 2003, we look for X(3872) $\rightarrow J/\psi\,\pi^+\pi^-$
  - SMT hit > 1
  - num tracks < 100
  - pT(J/ψ) > 4 GeV/c
  - 2.8 < $M(\mu^+\mu^-)$ < 3.4 GeV/c^2
  - pT(π) > 0.4 GeV/c
  - π's within same cone as J/ψ
  - $M(\pi^+\pi^-)$ > 0.52 GeV/c^2
  - $M(\mu^+\mu^-\pi^+\pi^-) - M(\mu^+\mu^-)$ < 1.0 GeV/c^2
  - χ^2 ($\mu^+\mu^-\pi^+\pi^-$ - vertex) < 16
  - $|z_{vertex}|$ < 35 cm

$\Delta M = 0.7684 \pm 0.0035$ (stat) $\pm$ 0.0039 (sys) GeV/ c^2

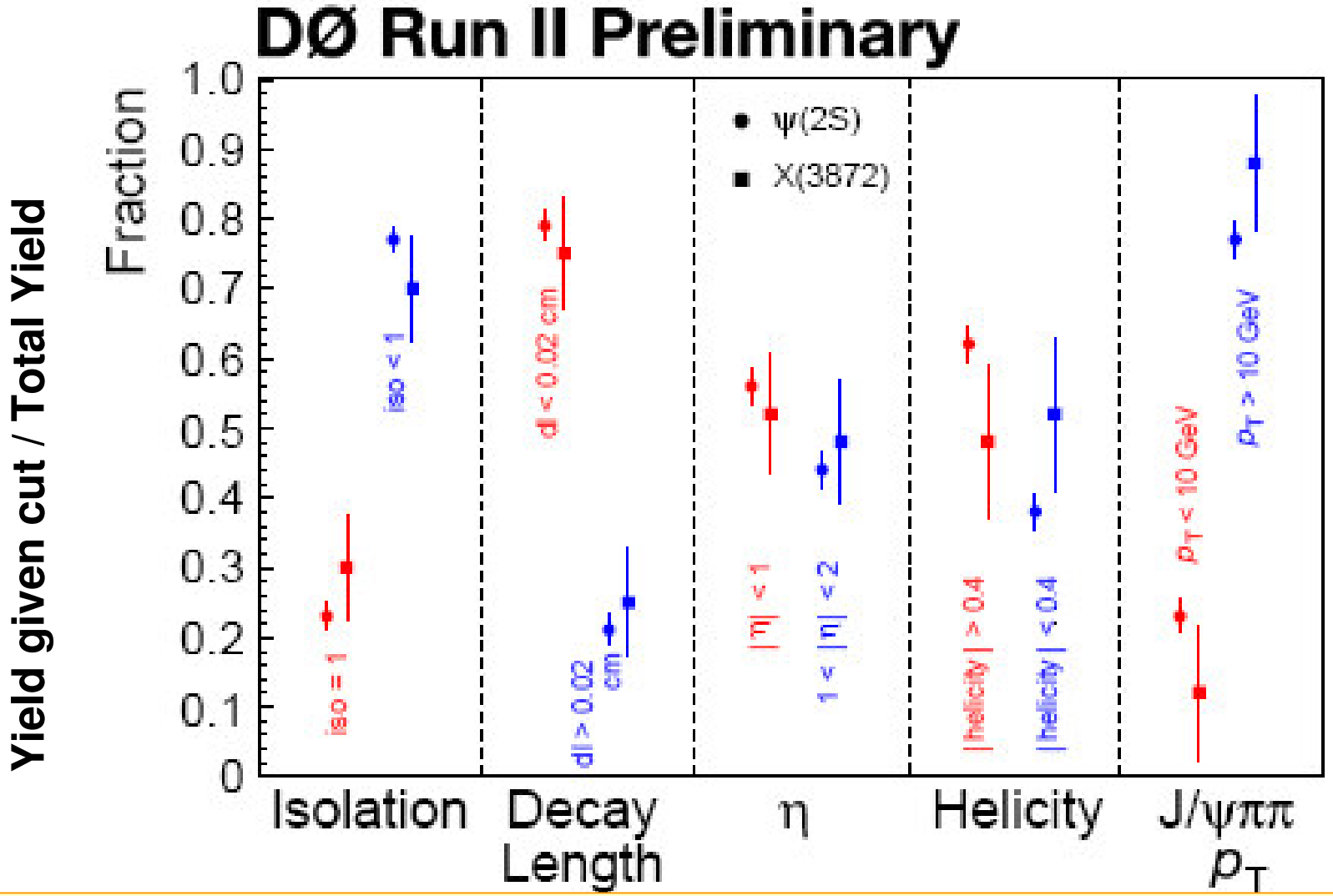


Properties of X(3872)



- Look if production characteristics are similar to ψ(2S).
- Data was binned for different variables: decay-length, isolation, η (pseudo-rapidity) pT, and helicity of ($\pi^+\pi^-$)

X(3872) - ψ(2S) comparison



Within the current statistical uncertainties, the production of X(3872) has similar behavior as the cc(bar) state ψ(2S)

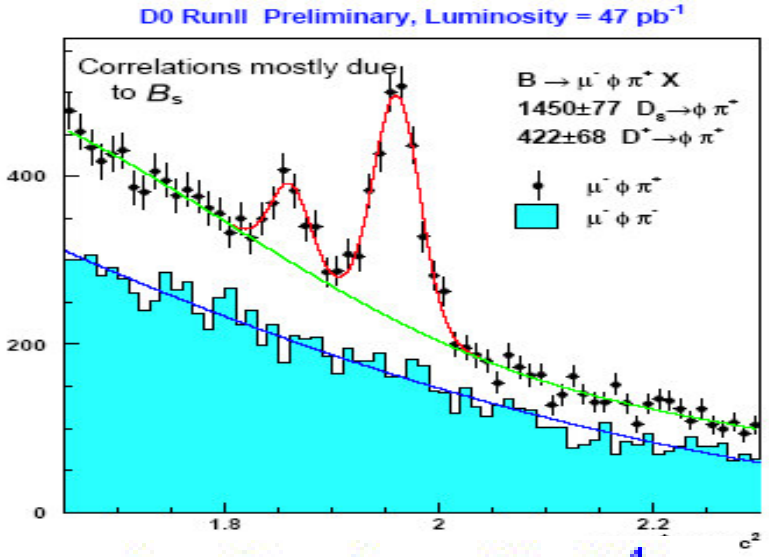
What is X(3872)?

- If the charged analog $X^+ \to J/\psi\pi^+\pi^0$ was observed, then cc(bar) hypothesis could be ruled out
- While observing radiative decays $X \to \gamma\chi_{c1}$ would favor cc(bar) hypothesis
- Both of these would require DØ to identify low energy π^0 and γ (work in progress)
- Our tests show: production characteristics of X(3872) (in the used variables) seems similar to those from $\psi(2S)$ (within the statistical uncertainties), this would tend to favor a cc(bar) hypothesis, but we do not know (yet) how these characteristics look for an exotic meson-molecule (theoretical input needed).

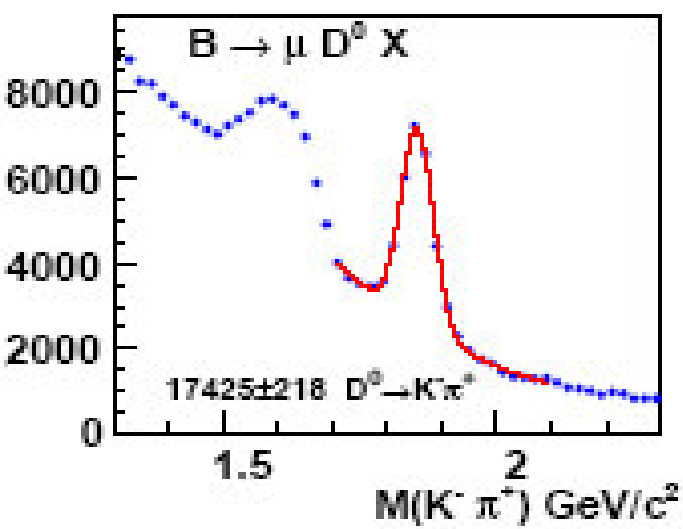
B Semileptonic Samples

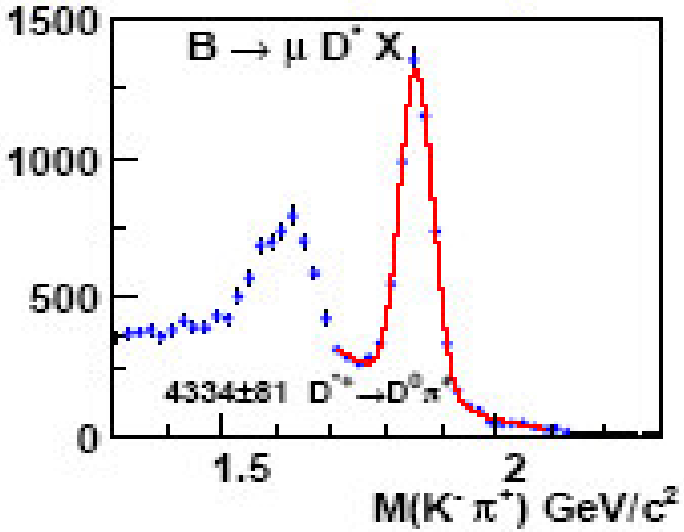
- **Muon:**
  - Pt > 2 GeV/c
  - nSMT > 1
  - nCFT > 1
- **Charged tracks:**
  - pT > 0.7-1 GeV/c
- **Secondary Vertex**
  - $L_{xy} / \sigma_L > 4$
  - $\cos(\theta(L,P_D))>0.95$

For Mixing and Lifetime studies

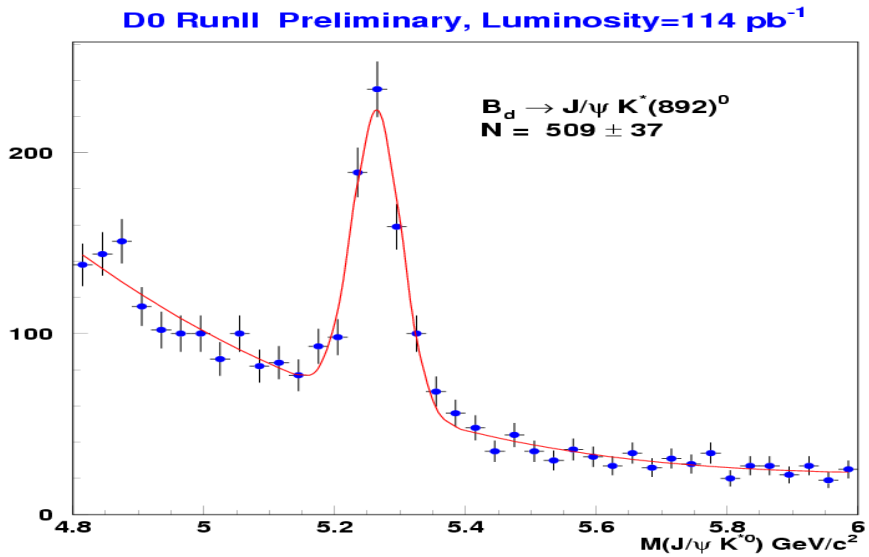


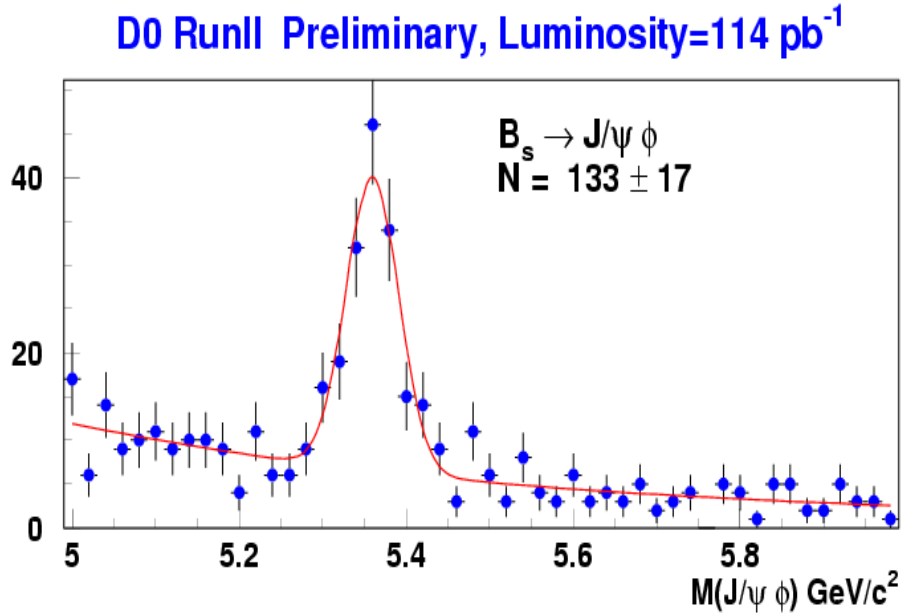
D0 Run II Preliminary, Luminosity = 43 pb^{-1}

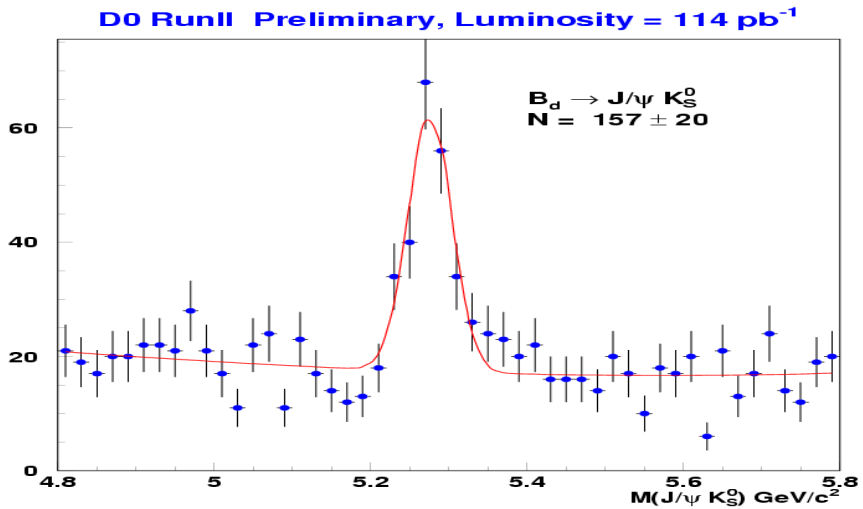


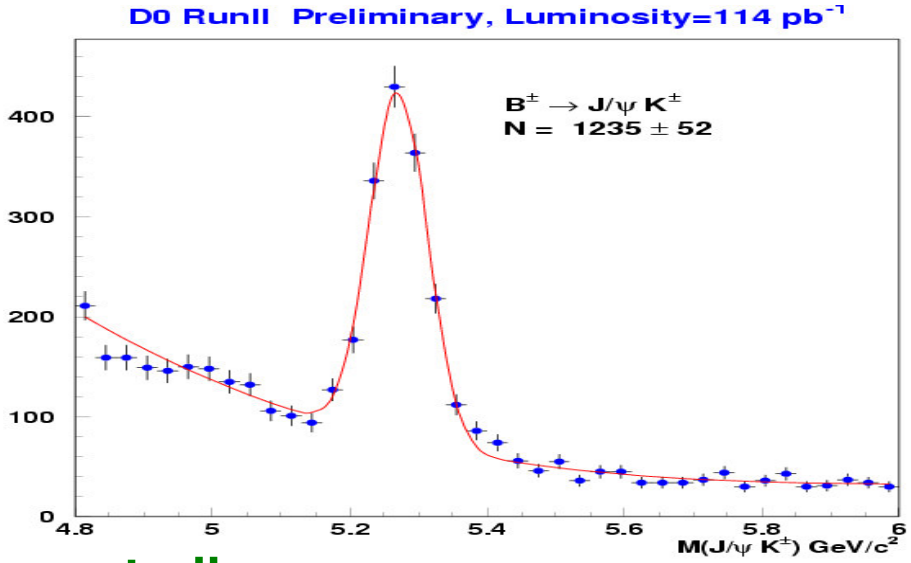


$B_{d,s}$ Masses (J/ψ + K^{0*},ϕ,K^0_s)









For CP and Lifetime studies

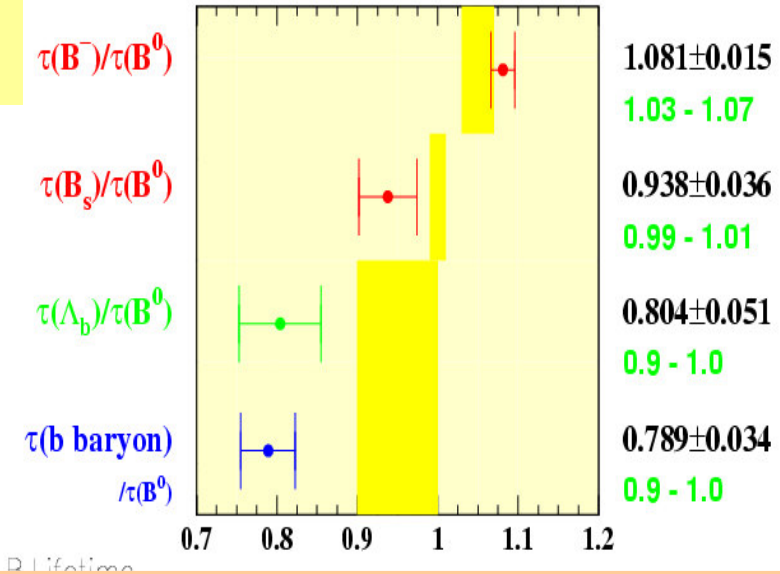
B Lifetime Measurements

Predictions

Report of the B Physics at the Tevatron Workshop (12/2001)

- $\tau(B_d)/\tau(B_s) = 1 \pm 0.01$
- $\tau(\Xi^0_b) \approx \tau(\Lambda_b) < \tau(B_d) < \tau(\Xi^-_b) < \tau(\Omega_b)$
- $\Gamma(\Lambda_b) - \Gamma(\Xi^-_b) \approx 0.11 \pm 0.03 \ ps^{-1}$
- $0.9 < \tau(\Lambda_b)/\tau(B_d) < 1$

Comparisons



Experimental Results

- $\tau(B) = 1.573 \pm 0.008$ ps
- $\tau(B^0) = 1.534 \pm 0.013$ ps
- $\tau(B^+) = 1.652 \pm 0.014$ ps
- $\tau(B^+)/\tau(B^0) = 1.081 \pm 0.015$
- $\tau(B_S) = 1.439 \pm 0.053$ ps
- $\tau(b_{baryon}) = 1.210 \pm 0.051$ ps
- $\tau(\Lambda_b) = 1.233^{+0.078}_{-0.076}$ ps

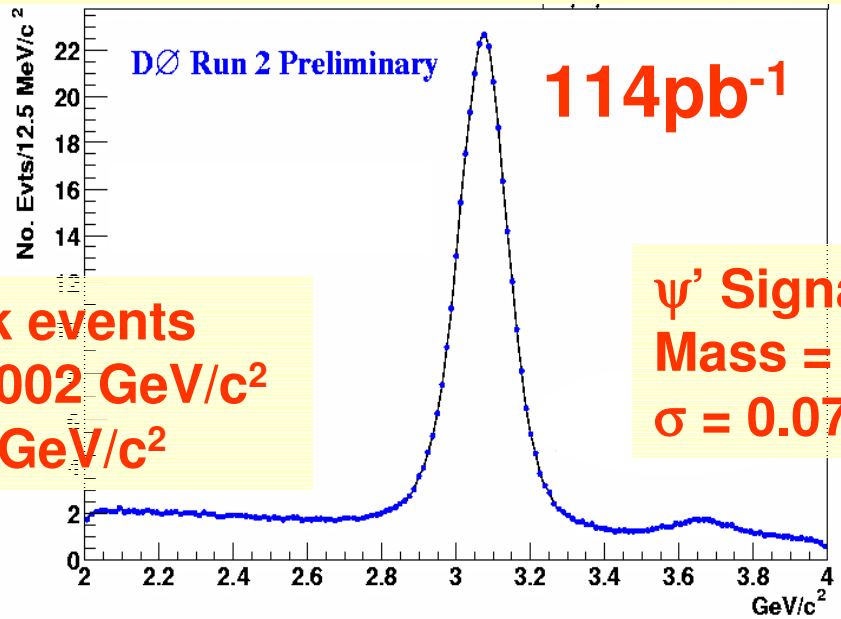
B Lifetime Group (Summer 2003)

Measuring Lifetime using B→ J/ψ X, J/ψ →μ⁺μ⁻

Use J/ψ→μ⁺μ⁻ for tagging, vertex constraint, p_T determination:

- √ Clean signal
- √ Large statistics
- √ Good vertex resolution
- √ Good momenta resolution

- × Large prompt J/ψ contamination
- × Need Pt correction factor from MC

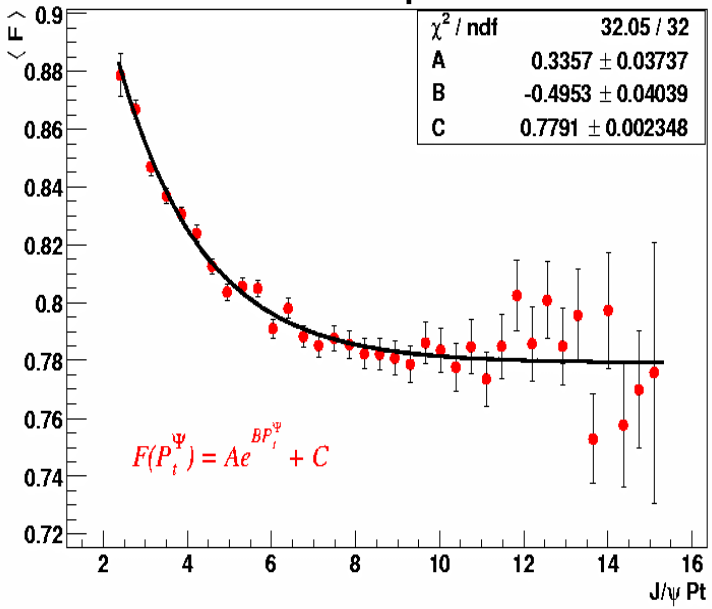


J/ψ Signal = 290.3k events
Mass = 3.0718±0.0002 GeV/c²
σ = 0.0741±0.0002 GeV/c²

ψ' Signal = 8.22K events
Mass = 3.668 ± 0.002 GeV/c²
σ = 0.071 ± 0.002 GeV/c²

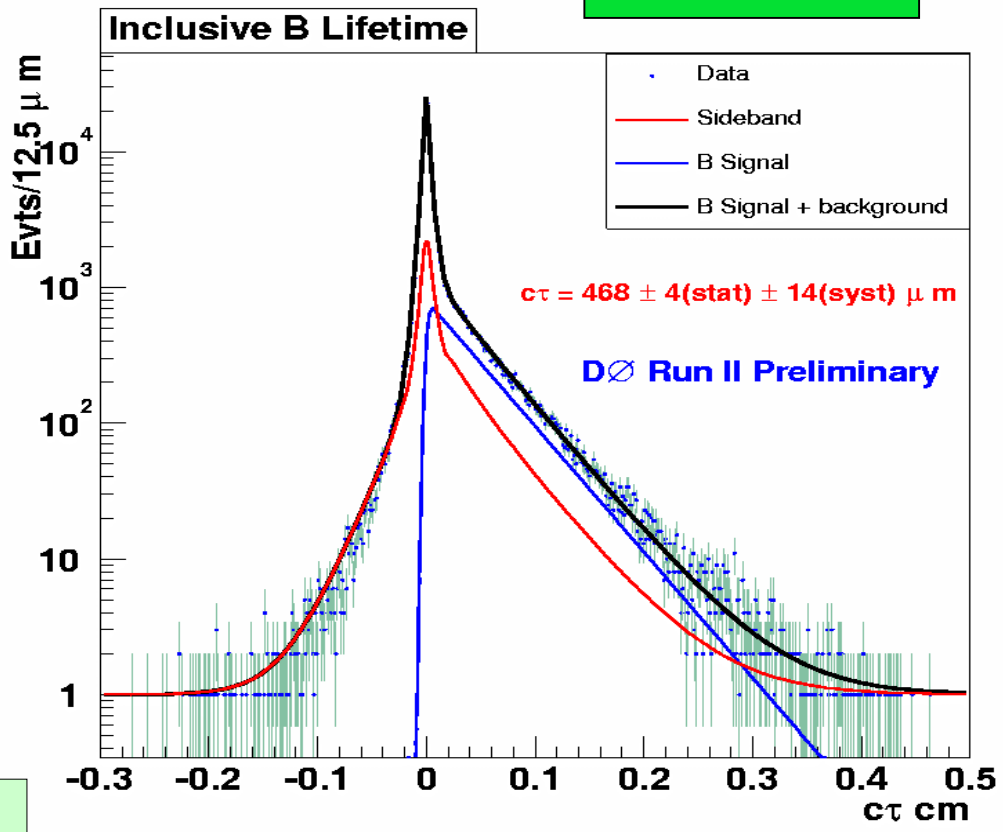
B Lifetime from Inclusive B→J/ψ+X

b→ J/ψ X



∫£dt≈114 pb^{-1}

$$\lambda = \frac{L_{xy} M_{\Psi}}{P_{T\Psi} F(P_T)}$$



F: correction factor to use the pT(J/ ψ) to estimate the momentum of the B to find proper time. Obtained from Monte Carlo

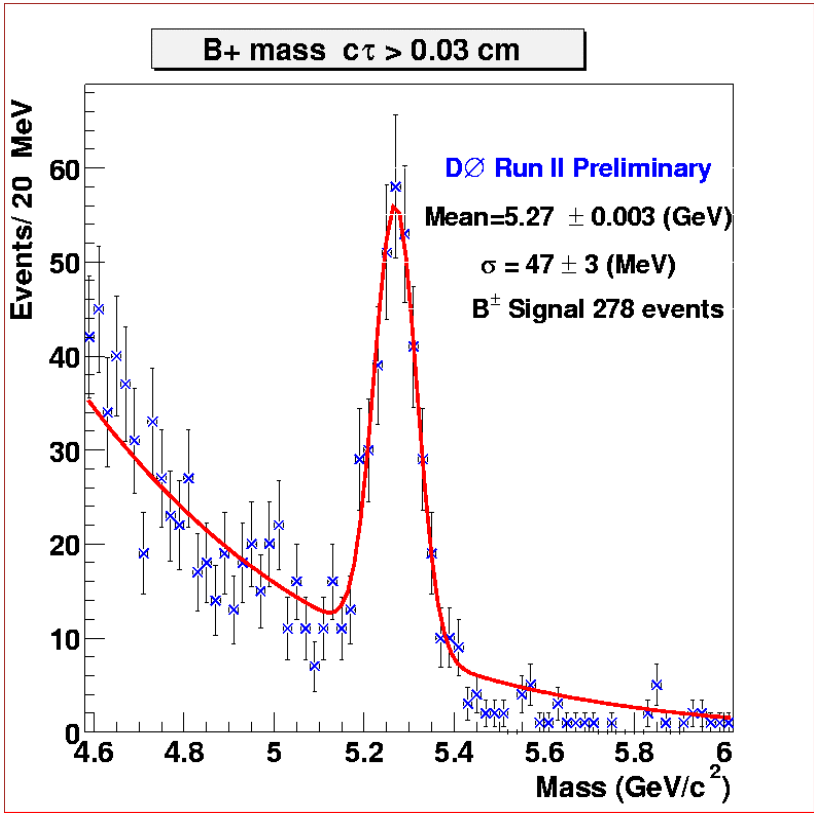
$\langle\tau\rangle = 1.564 \pm 0.014$ ps (PDG)

$\langle\tau\rangle = 1.562 \pm 0.013 \pm 0.045$ ps

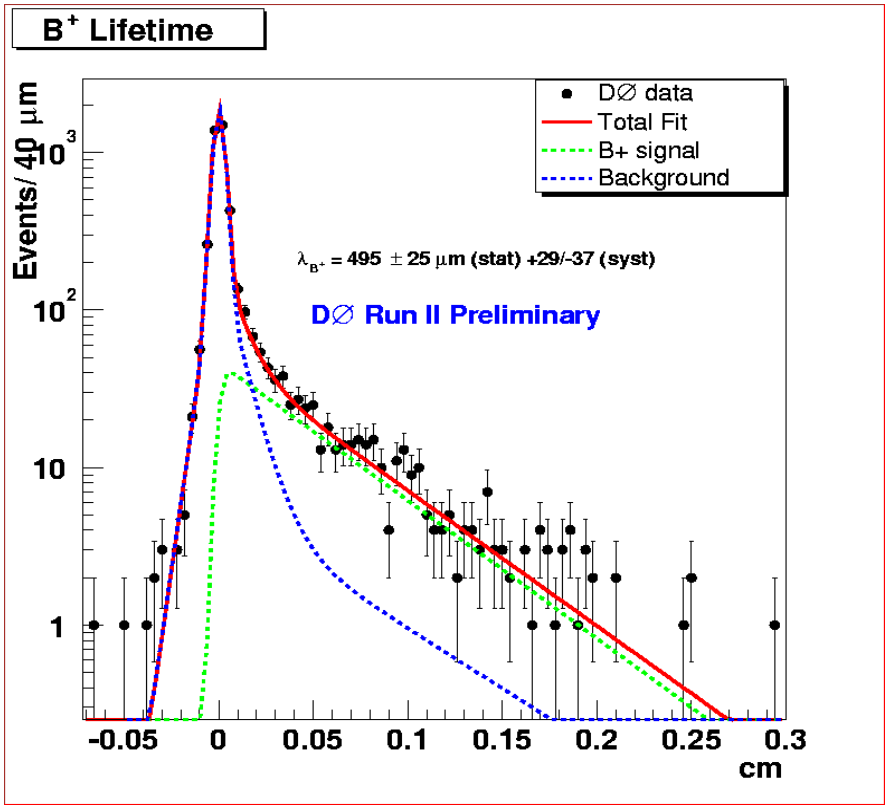
J/ψ from B's = 18%

Correction factor leads to the major systematic error

$B^{\pm}$ Lifetime from $B^{\pm} \rightarrow J/\psi K^{\pm}$



$\int \pounds dt \approx 114\ pb^{-1}$

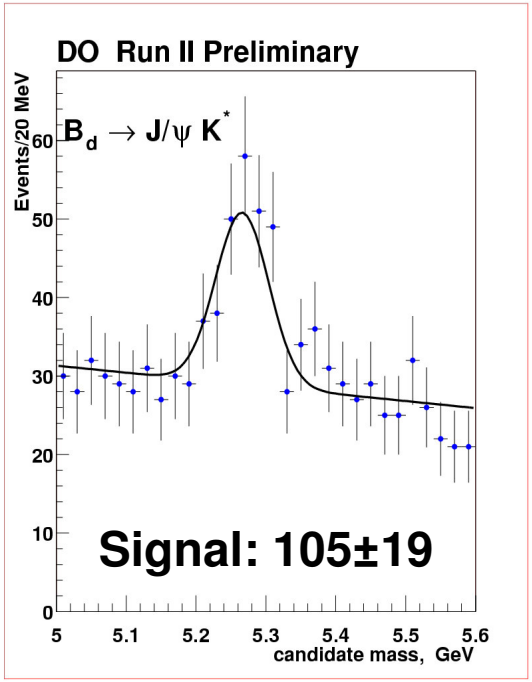


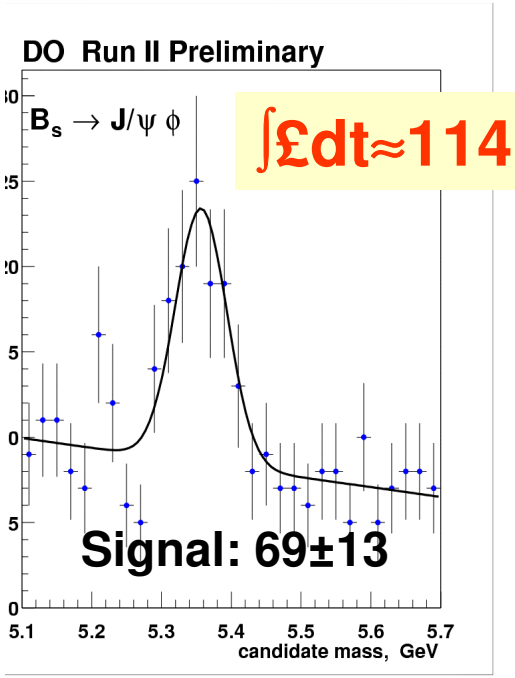
Fully reconstructed→No Correction Factor!

$\langle \tau_{B^{\pm}} \rangle = 1.65 \pm 0.083(stat) \pm 0.123(syst)$ ps

$\langle \tau_{B^{\pm}} \rangle = 1.671 \pm 0.018$ ps (PDG)

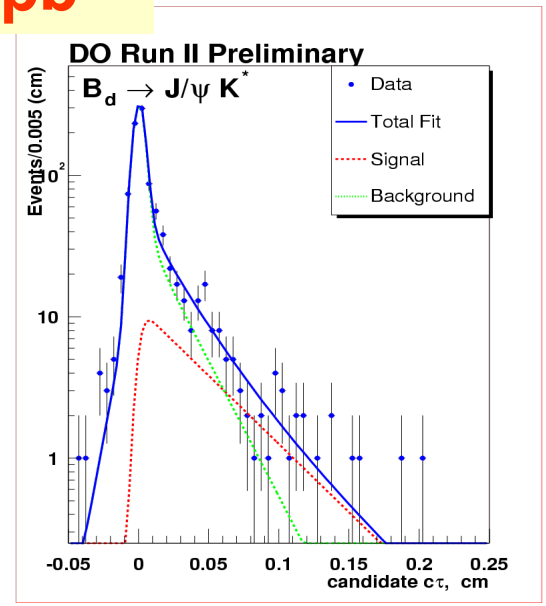
$B_{d,s}$ Lifetimes from $B \rightarrow J/\psi + K^{0*}, \phi$

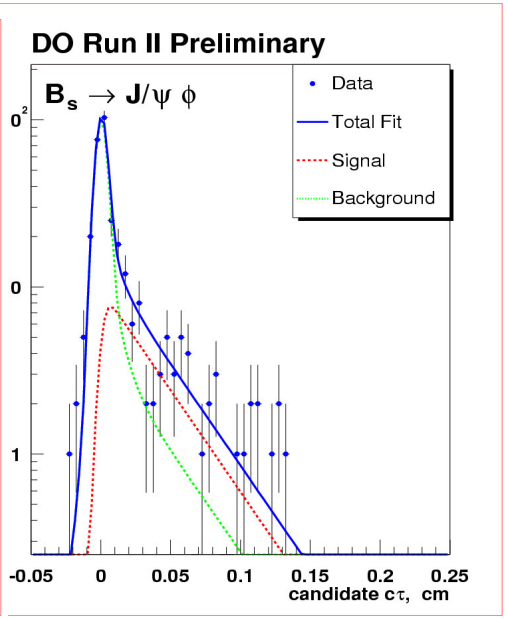




$\int £dt \approx 114\ pb^{-1}$

Similar kinematics→Some systematic errors can be cancelled in ratio!





$\tau_{Bd} = 1.51^{+0.19}_{-0.17}$ (stat) ± 0.20(syst) ps

$\tau_{Bs} = 1.19^{+0.19}_{-0.16}$ (stat) ± 0.14(syst) ps

$\tau_{Bs}/\tau_{Bd} = 0.79 \pm 0.14$

PDG: $\tau_{Bd} = 1.537 \pm 0.015$ ps

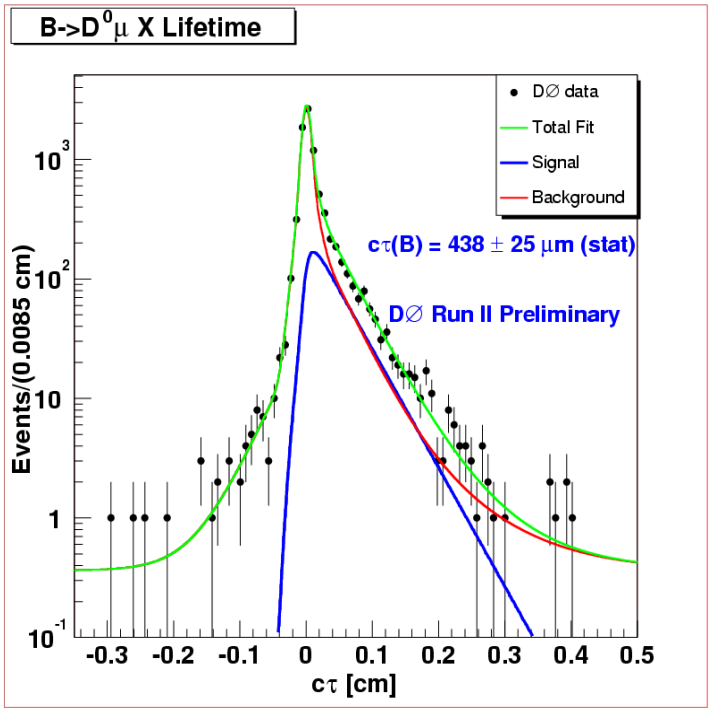
PDG: $\tau_{Bs} = 1.461 \pm 0.057$ ps

PDG: $\tau_{Bs}/\tau_{Bd} = 0.95 \pm 0.038$

B Lifetime from Semileptonic Decays $B \rightarrow D^0 \mu X$

$\int Ldt \approx 12\ pb^{-1}$

We are able to measure Lifetime



$$c\tau = L_{xy} M_b K / Pt_{(D+\mu)}$$

$$K = Pt_{(D+\mu)} / Pt_B \quad \text{(from MC)}$$

$$\tau_B = 1.460 \pm 0.083\ (\text{stat})\ \text{ps}$$

We will use this for mixing studies

Mixing: Flavour tagging

- Use **flavour-specific decays** to get flavour of B at decay. To get **flavour of B at production** use

  - Soft-lepton tags - High dilution power, low efficiency (SL decay of other B)

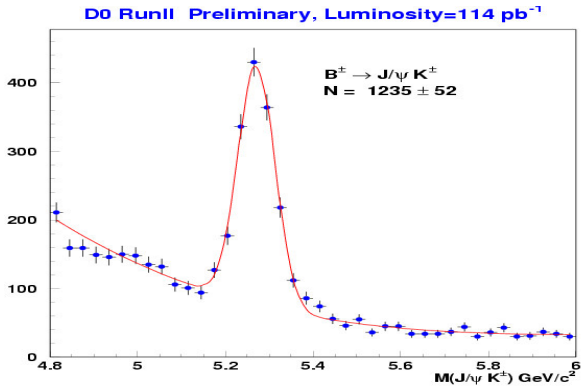
$$D = \frac{N_R - N_W}{N_R + N_W} \qquad \varepsilon = \frac{N_R + N_W}{N_R + N_W + N_{notag}}$$

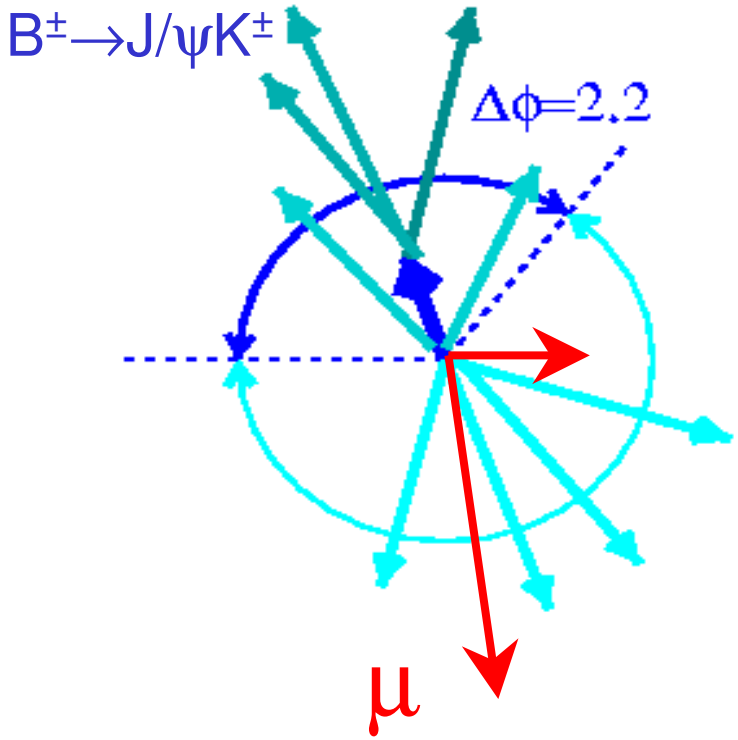
  - Jet Charge tag - Poorer dilution power, high efficiency (track-jet from other b quark)

  - Same Side tagging - Poorer dilution power, high efficiency (fragmentation, B**)

- We test this tools using B^+ data sample

Opposite Side Muon Tagging



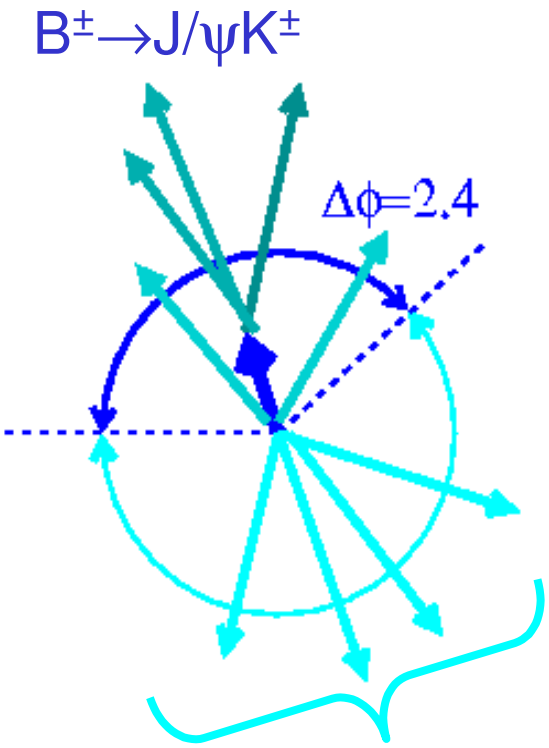


- P^T_μ > 1.9 GeV
- Q_μ – charge of muon with the highest P_T
- Classification:
  - Q_μ != Q_K : correct tag
  - Q_μ == Q_K : wrong tag
  - No muon : No tag

DØ RunII preliminary

- D = (57.0 ± 19.3)%
- ε = (5.0 ± 0.7)%
- εD^2 = (1.6 ± 1.1)%

Opposite Side Jet Charge Tagging



$$Q = \Sigma P_t q / \Sigma P_t$$

- $P_T > 0.5$ GeV
- $\Delta Z_{PV} < 2$ cm
- Classifications:
  - $|Q|>0.2$ && sign(Q) != Q_K : correct tag
  - $|Q|>0.2$ && sign(Q) == Q_K : wrong tag
  - $|Q|<0.2$: no tag

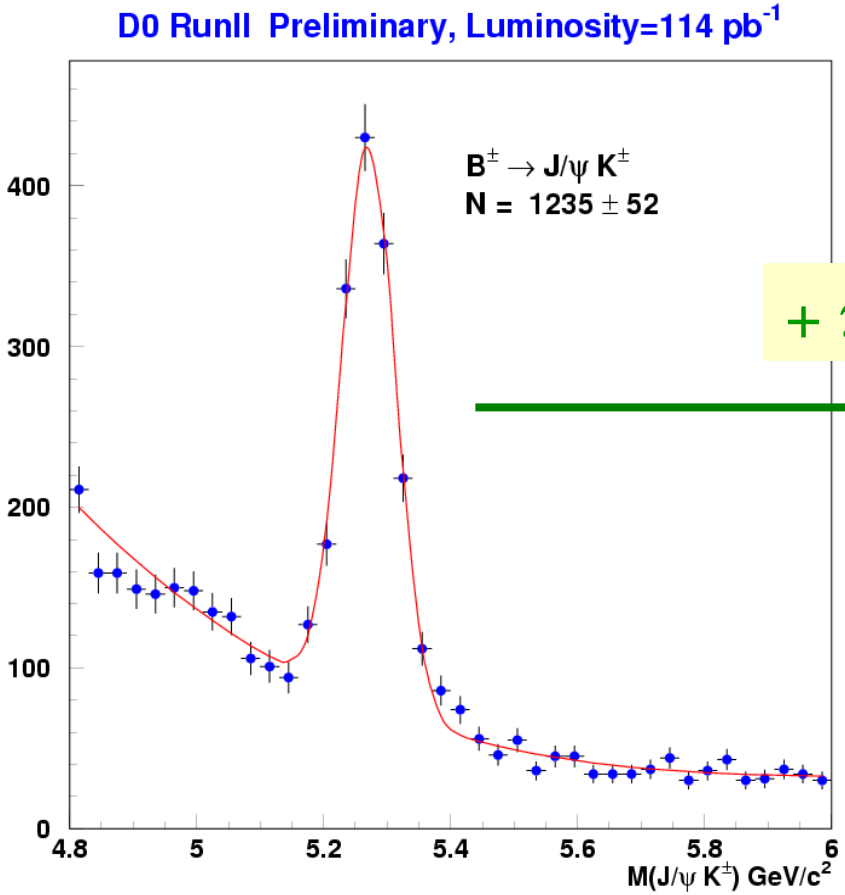
DØ RunII preliminary

- **D = (26.7 ± 6.8)%**
- **ε = (46.7 ± 2.7)%**
- **εD^2 = (3.3 ± 1.7)%**

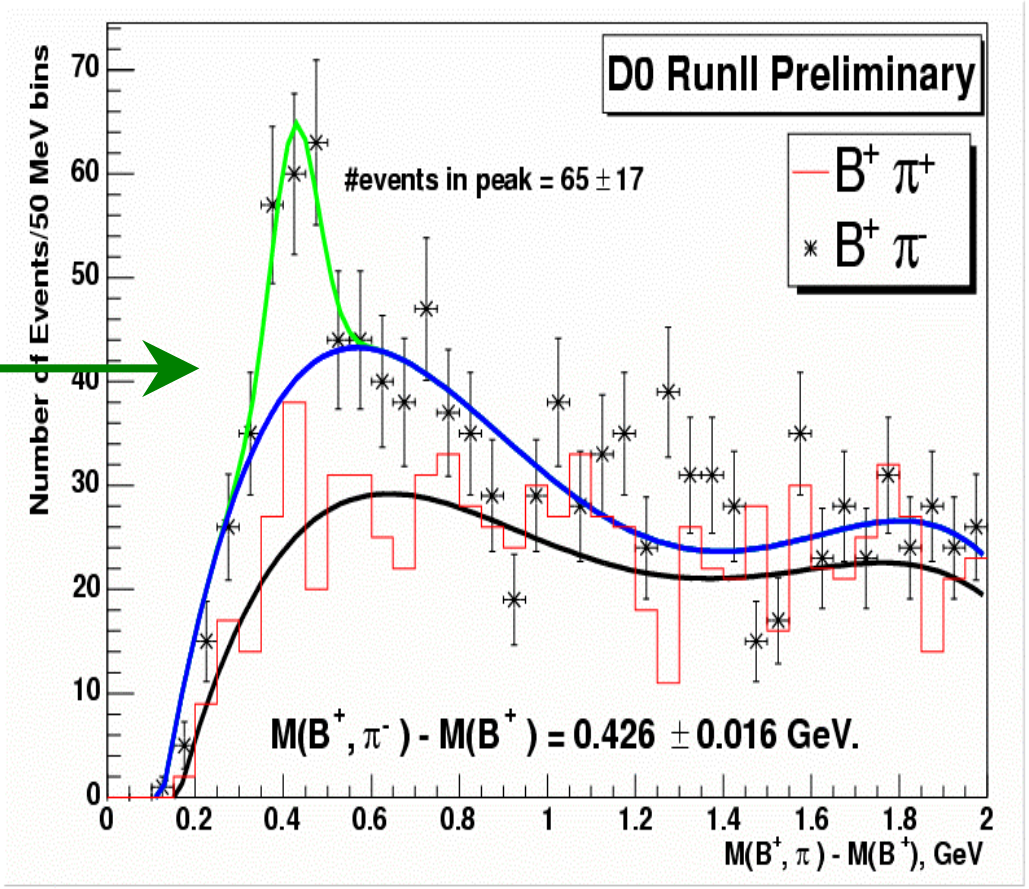
Same Side Tagging

Excited B** decays into B and pion/kaon that carries the initial state flavor information

Example: $B^{**}_d \rightarrow B^+\pi^-$



+ $\pi^{\pm}$



Flavour Tagging results

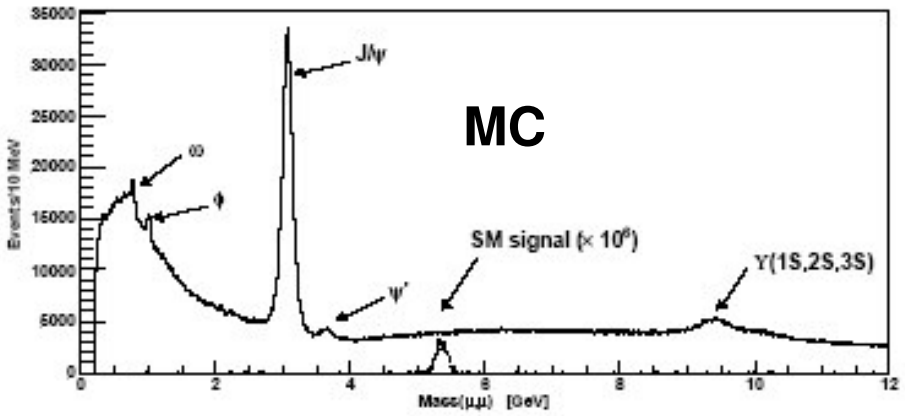
DØ RunII Preliminary

Method **Based on B+ Signal**	Efficiency ε	Dilution D	Tagging Power $\varepsilon D^2(\%)$
Soft Muon	**5%**	**57%**	1.6 ± 1.1
Jet Charge	**47%**	**27%**	3.3 ± 1.7
Same Side	**79%**	**26%**	5.5 ± 2.0

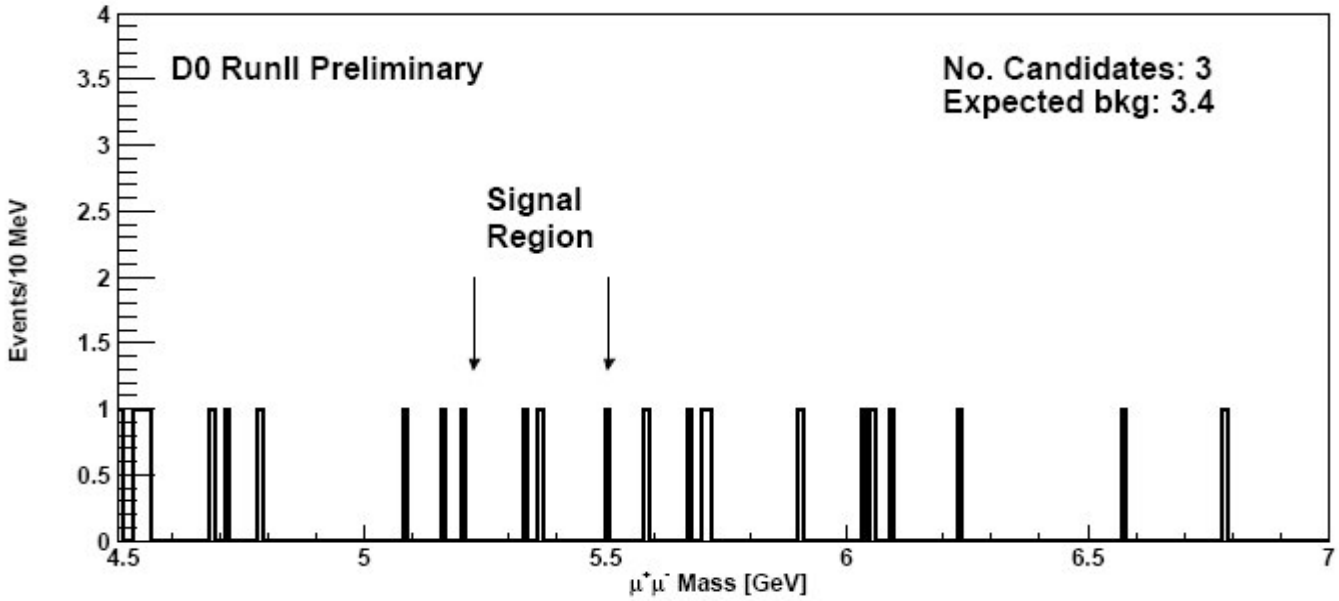
Muon DATA, will also use electrons

Performance with B^0/B_s is under study

Search for $B_s \rightarrow \mu^+\mu^-$



$\int Ldt \approx 100\ pb^{-1}$

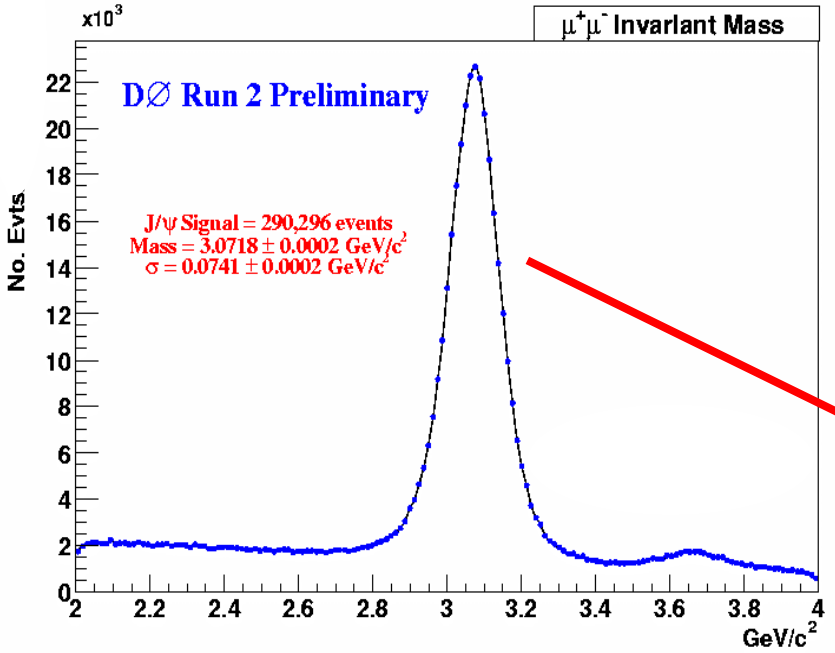


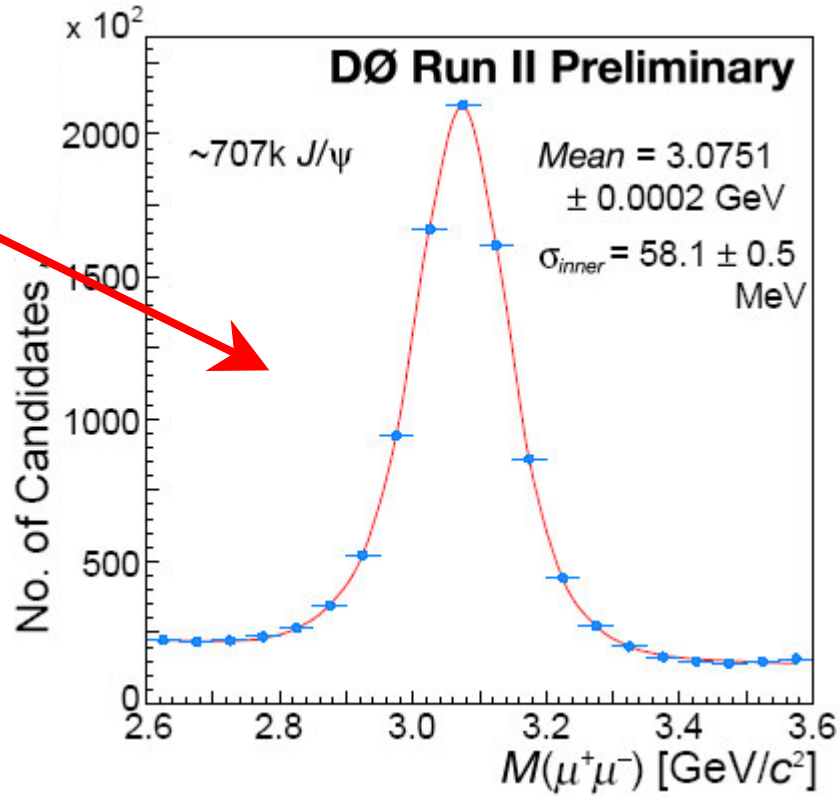
$Br(B_s \rightarrow \mu^+\mu^-) < 1.6 \times 10^{-6}$ at 90% CL

Summary

- DØ has observed the X(3872) particle in 200 pb^{-1} data
  - Statistical significance of 4.4σ
  - $\Delta M = 0.7684 \pm 0.0035$ (stat) ± 0.0039 (sys)
  - Data separated into various regions, we found similar behaviour as $\psi(2S)$, within statistical uncertainties
- Many other results as B physics program under way
- We have reprocessed $\approx$ 200 pb^{-1} of data to better improve our analyses
- A lot more interesting results very soon!

More Data



∫Ldt ≈114 pb^{-1}

Reprocessed ∫Ldt≈200 pb^{-1}