B Physics Review: Part II

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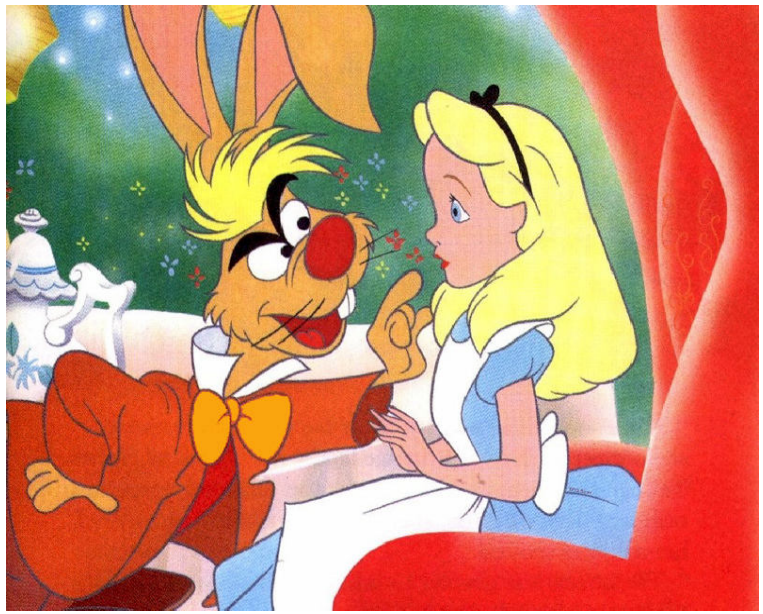
RTN Workshop
The 3rd generation as a probe for new physics
Bratislava, 4 – 6 July, 2003

Review of Tevatron measurements:

- B and Λ_b lifetimes and masses
- B_s Mixing

New CDF results:

- B_s and Λ_b yields
- J/ψ cross section
- D^0 branching ratio and CP asymmetries



How do we collect b?

Old style:

o Di-muon trigger:

- 2 muons P_t > 1.5 GeV
  (RunI Pt > 2 GeV)
- charmonium physics
- B lifetime, B mass, rare decays $B_s \rightarrow \mu\mu$

New era:

Multi-bodies Hadronic trigger (SVT):

- 2 tracks P_t>2 GeV, |d|>120 μm, ΣP_t>5.5 GeV, L_{xy}>200 μm
- All you can imagine with $B \rightarrow X$ where X>2

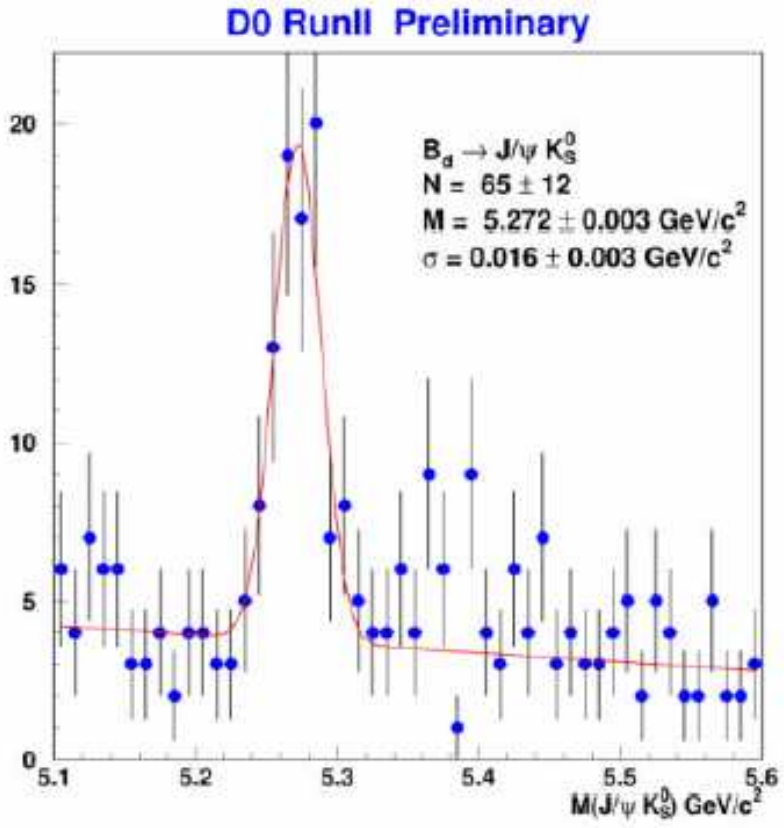
A combination of Old and New

§ Lepton P_t>4 GeV (Run I P_t>8 GeV)+ track P_t>2 GeV |d|>120 μm

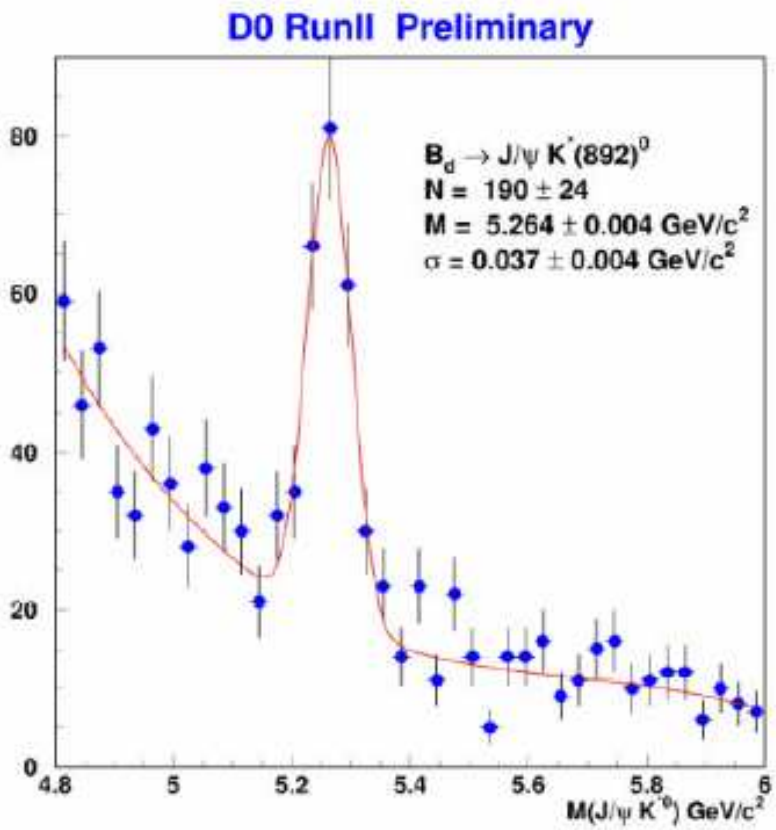
- $B \rightarrow$ lDX decays, flavor tagging optimization

D0: Results from J/ψ trigger

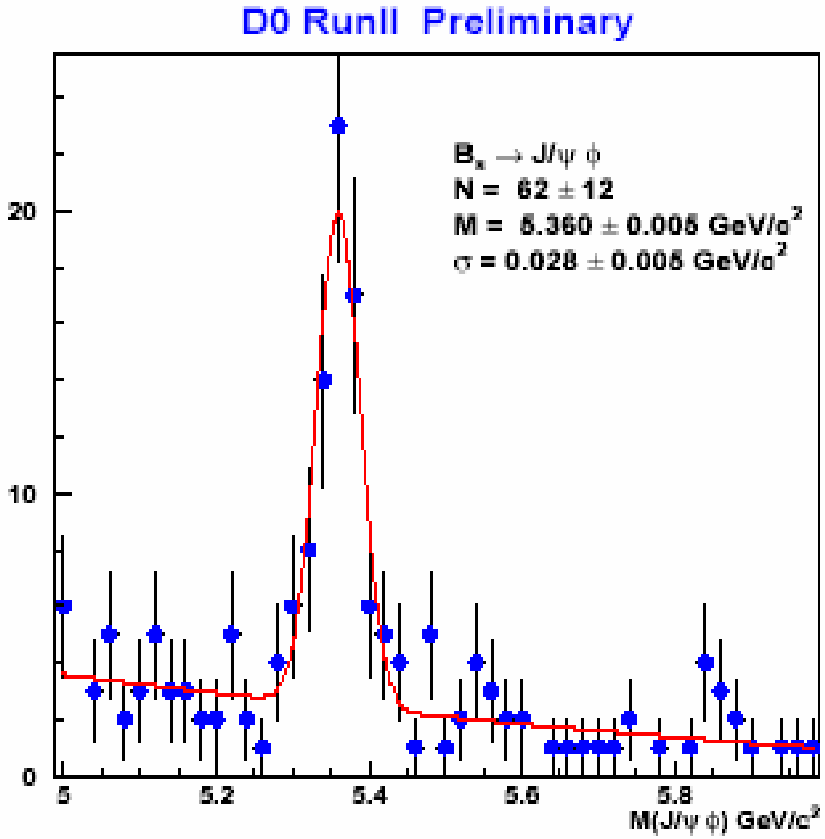
$B_d \rightarrow J\psi / K_s$

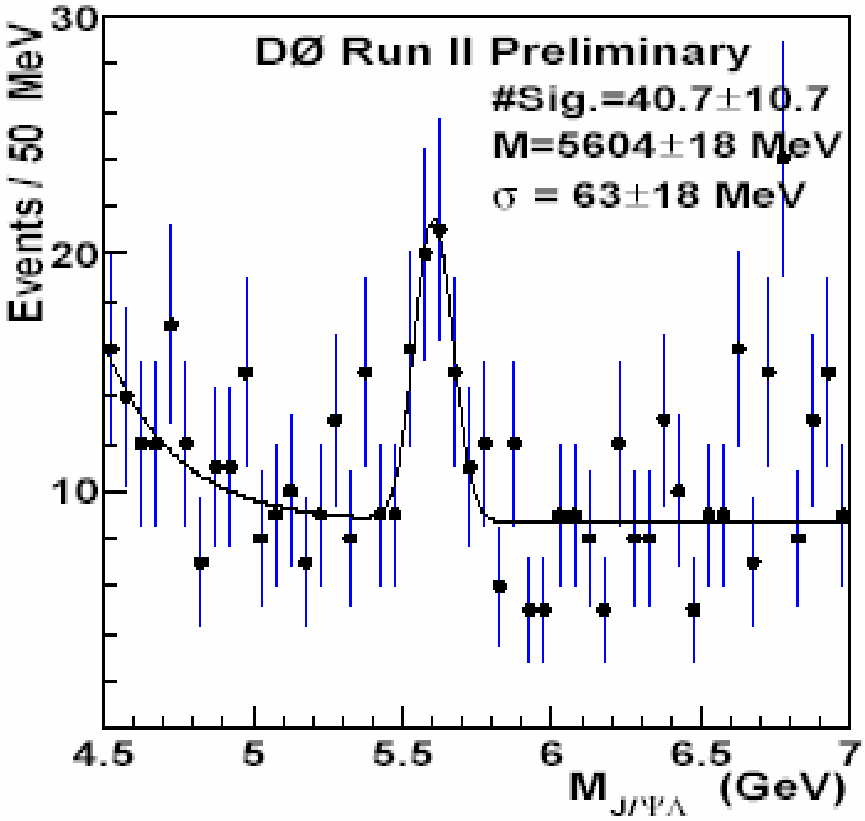


$B_d \rightarrow J\psi / K^{*0}$



D0: Results from J/ψ trigger





B Mesons Mass Measurements

Decay modes:

$B^+ \rightarrow J/\psi K^+$

$B^0 \rightarrow J/\psi K^{*0}$

$B_s^0 \rightarrow J/\psi \phi$

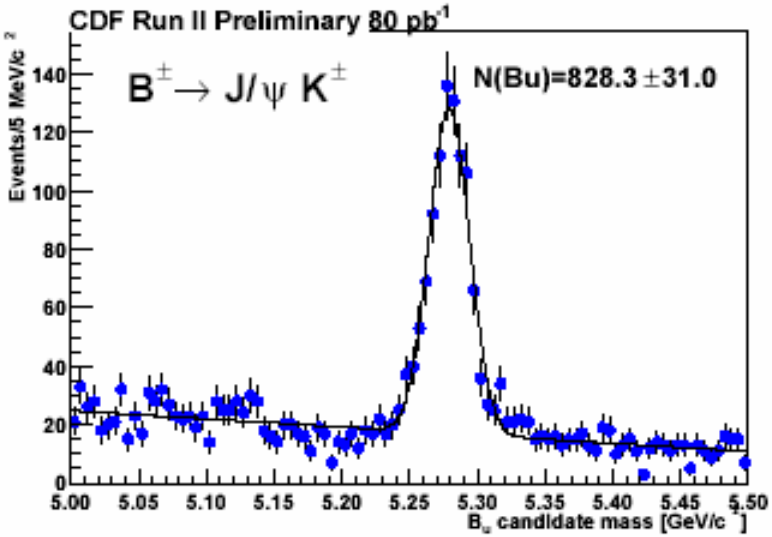
The current results:

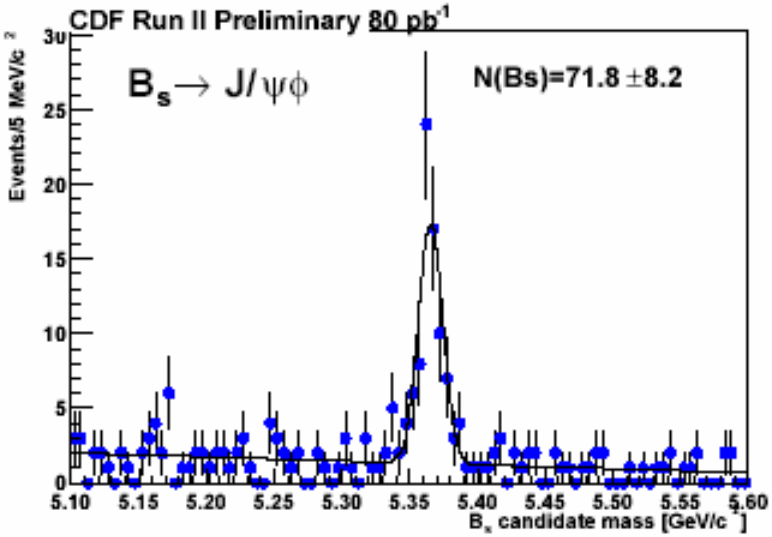
$B^+ : 5279.32 \pm 0.68\ (\text{stat}) \pm 0.94,\ (\text{sys})$

$B^0 : 5280.30 \pm 0.92\ (\text{stat}) \pm 0.92\ (\text{sys})$

$B_S : 5365.5 \pm 1.3\ (\text{stat}) \pm 0.94\ (\text{sys})$

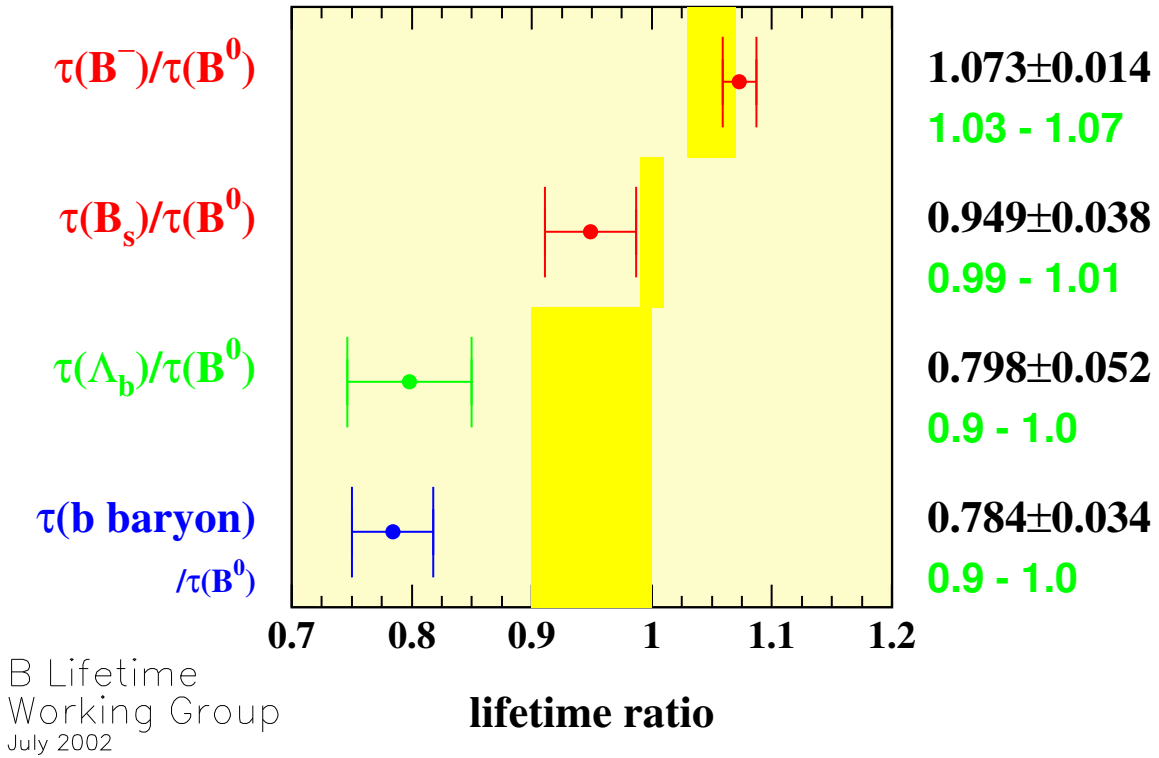
Best in the world





b Hadrons Lifetime Measurements

Is it still interesting?



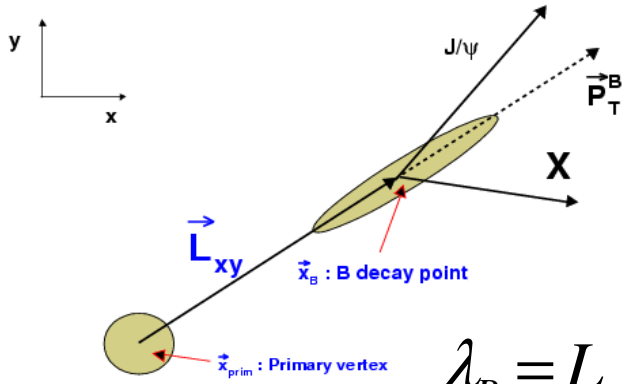
Several decays channels are available at Tevatron
good test of the theory

b Hadrons Lifetime Measurement

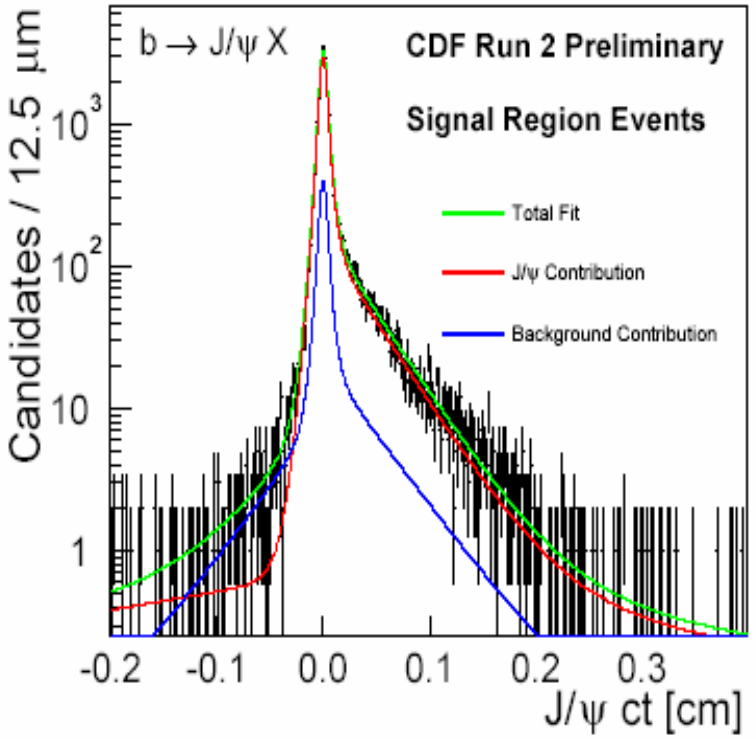
Experimental needs:

- § calibrate resolution
- § understand the alignments
- § βγ correction if not fully reconstructed decays

Inclusive b lifetime: b→ J/ψ X



$$\lambda_B = L_{xy}\frac{M^{\Psi}}{P_T^{\Psi}\left\langle F(P_T^{\Psi})\right\rangle}$$



CDF result:

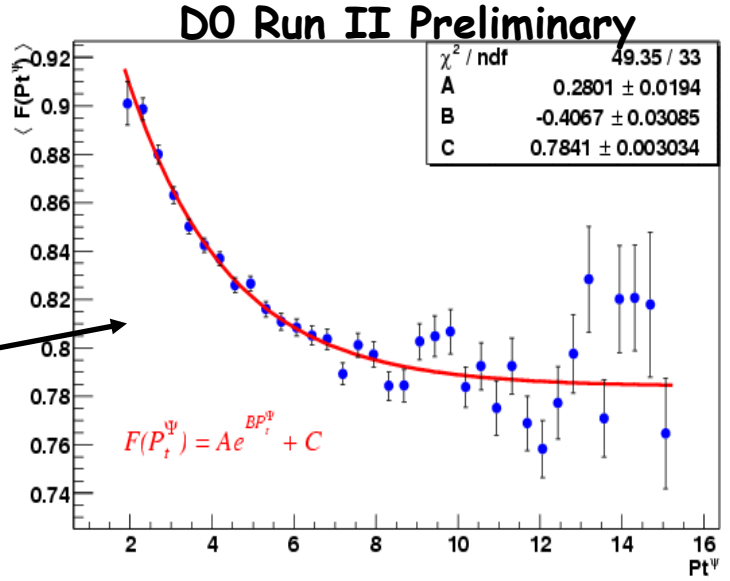
$c\tau_{incl} = 458 \pm 10\ (\text{stat}) \pm 11\ (\text{sys})\ \mu\text{m}$

$\tau = 1.527 \pm 0.033 \pm 0.033$ ps

Inclusive B → J/ψ X Lifetime at DO

First time at DO
Use the same technique of CDF

$$\lambda_B = L_{xy} \frac{M^{\Psi}}{P_T^{\Psi} \left\langle F(P_T^{\Psi}) \right\rangle}$$

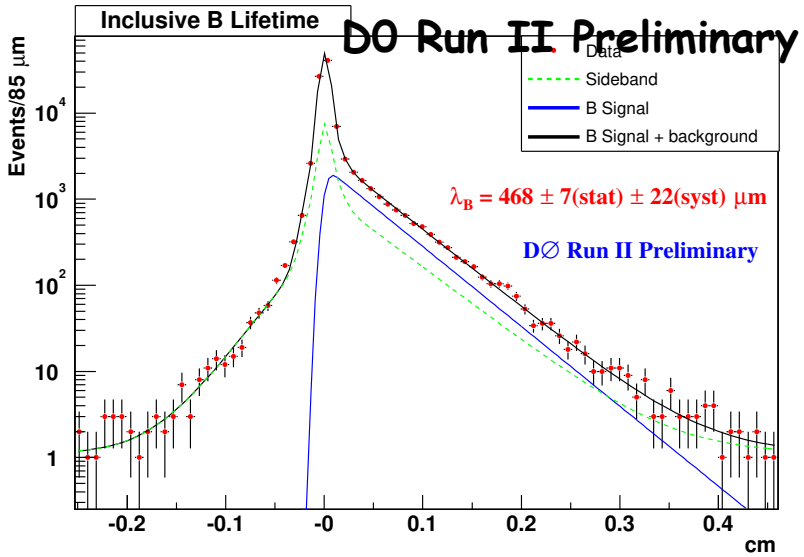


DO Result:

τ = 1.561±0.024±0.074 ps

PDG 2003

τ = 1.564±0.014 ps



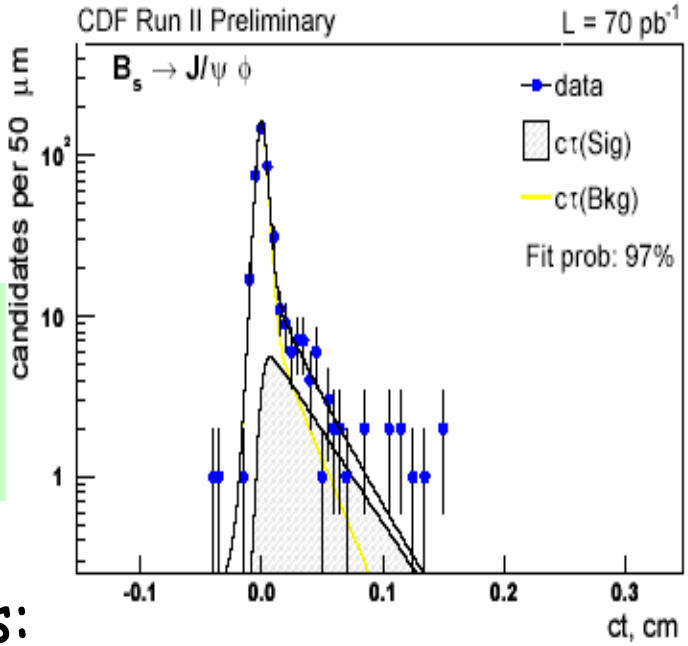
b Hadrons Lifetime Measurement

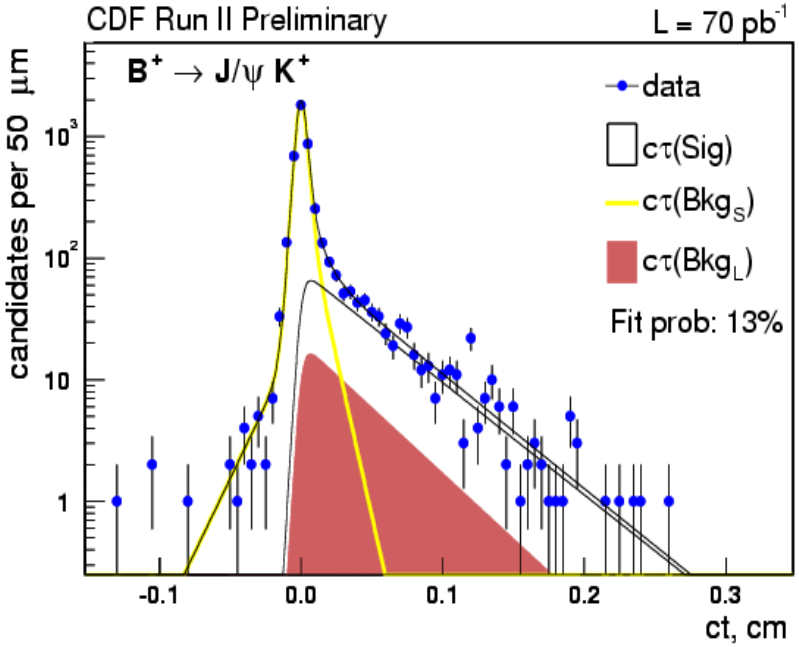
Exclusive lifetime with J/ψ:

$B^+ \to J/\psi K^+$
$B^0 \to J/\psi K^{*0}$
$B_s^0 \to J/\psi \phi$

$\beta\gamma$ well measured

Simultaneous fitting of
M_B: Extract signal fraction
ct: Extract the lifetime





CDF Results:

B^+	$1.57 \pm 0.07 \pm 0.02$ (ps)
B_d	$1.42 \pm 0.09 \pm 0.02$ (ps)
B_s	$1.26 \pm 0.2 \pm 0.02$ (ps)

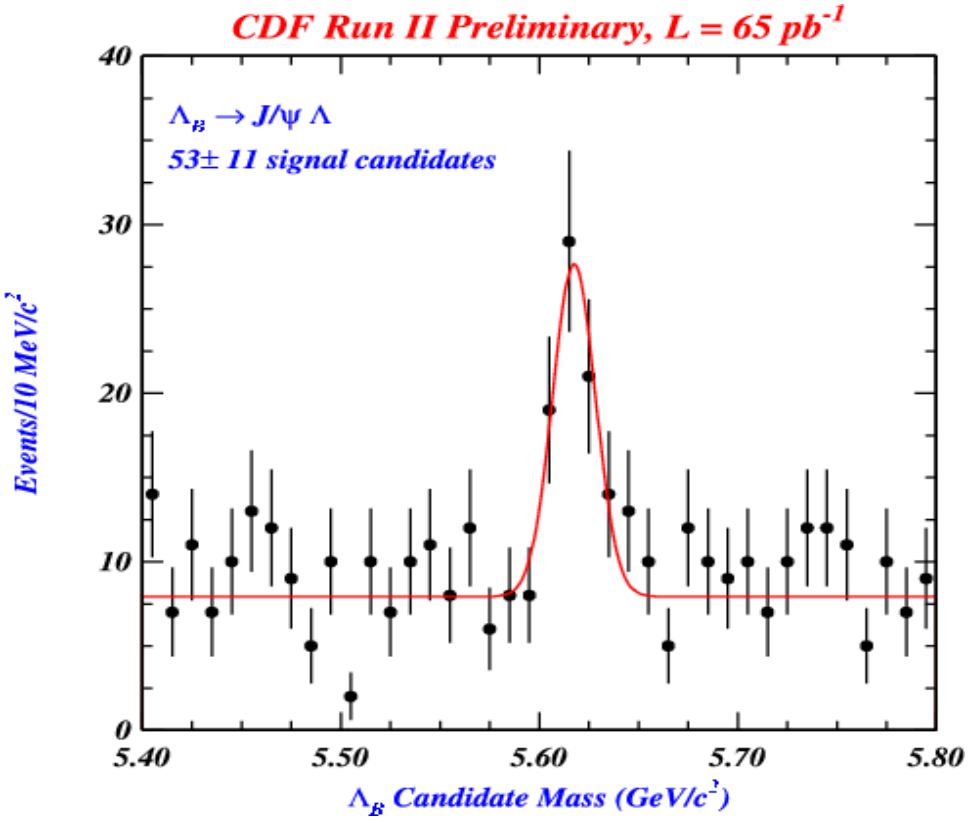
$$\frac{\tau(B_s)}{\tau(B_d)} = 0.89 \pm 0.15$$

$$\frac{\tau(B^+)}{\tau(B_d)} = 1.11 \pm 0.09$$

News about Λ_b

$\Lambda_b \rightarrow J/\psi\ \Lambda$

Exclusive Λ_b lifetime (pre-blessed)
Mass measurement (pre-blessed)

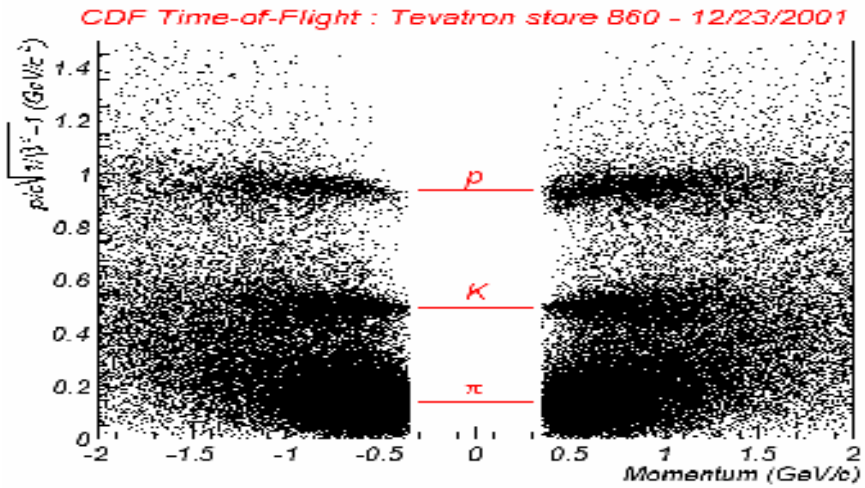


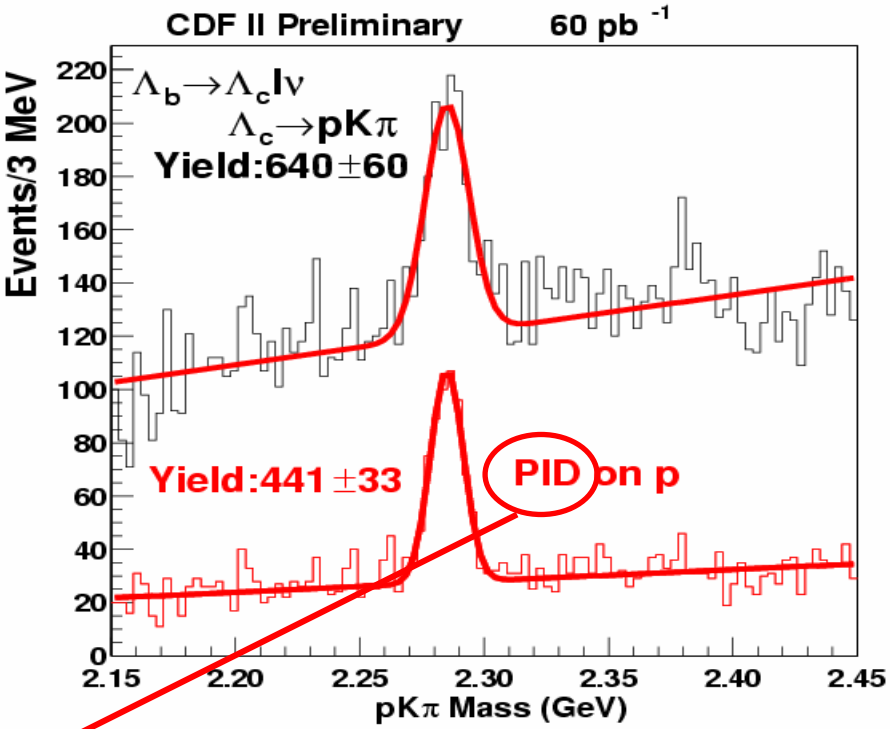
News about Λ_b cont'd

Λ_b $\Lambda_c l\nu$ $[pK\pi]\, l\nu$

Semi-exclusive lifetime
Branching ratio

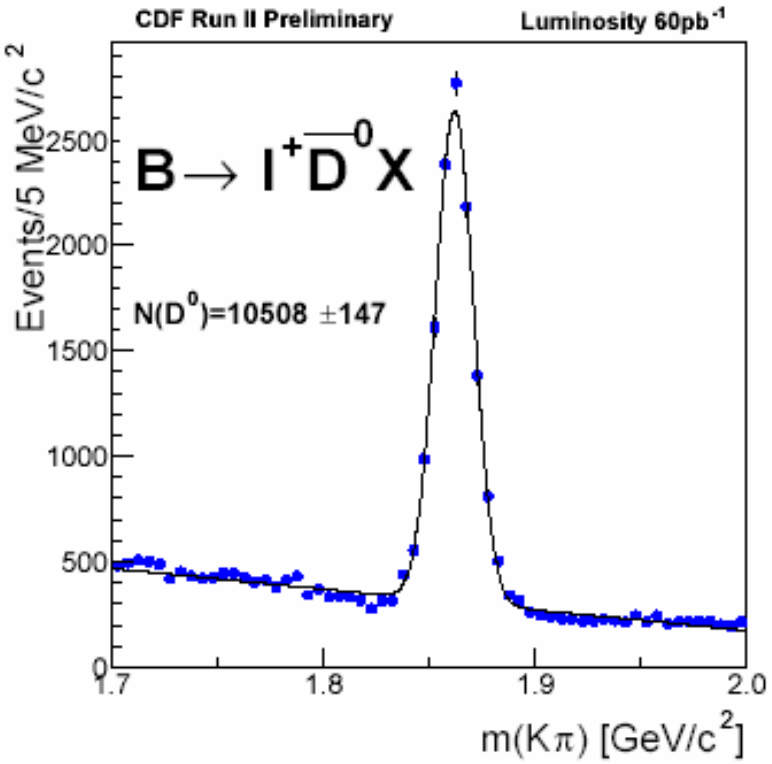
Difficult to disentangle from decays through excited baryons

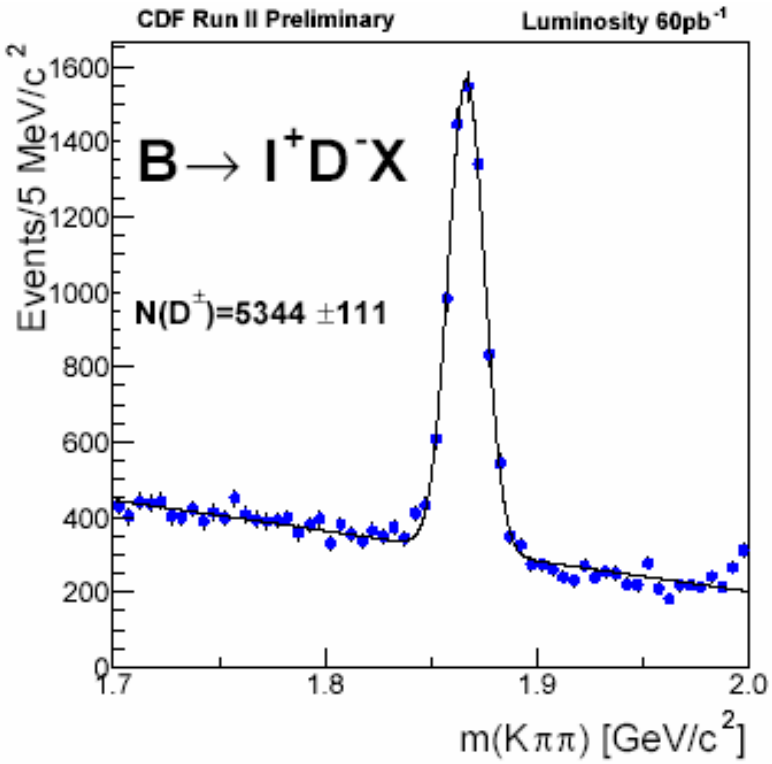




And dE/dX

B Lifetime measurement: semi-leptonic decays

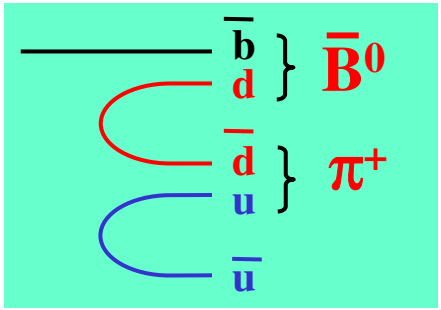




Useful to optimize B mixing and flavor tagging

Flavor tagging

- Lepton (muon and electron) tagging: under optimization in the huge sample of $B \rightarrow lDX$
- Same Side Tagging (SST): B^0 ($\overline{B^0}$) accompanied by π^- (π^+)

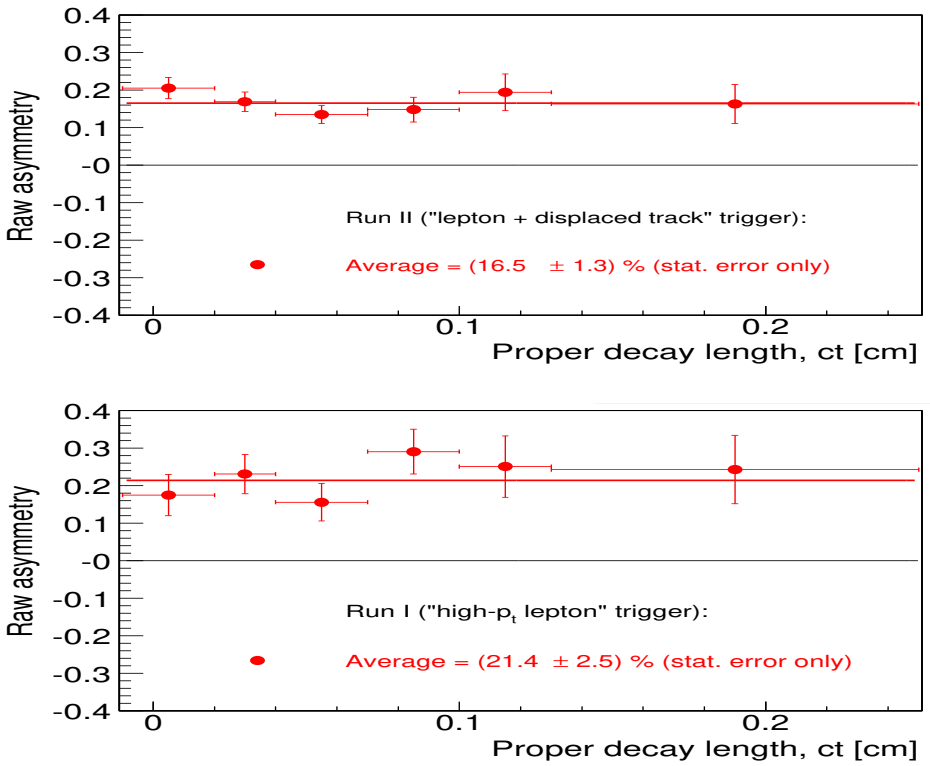


$$A(t) = \frac{N^{RS}(t) - N^{WS}(t)}{N^{RS}(t) + N^{WS}(t)}$$

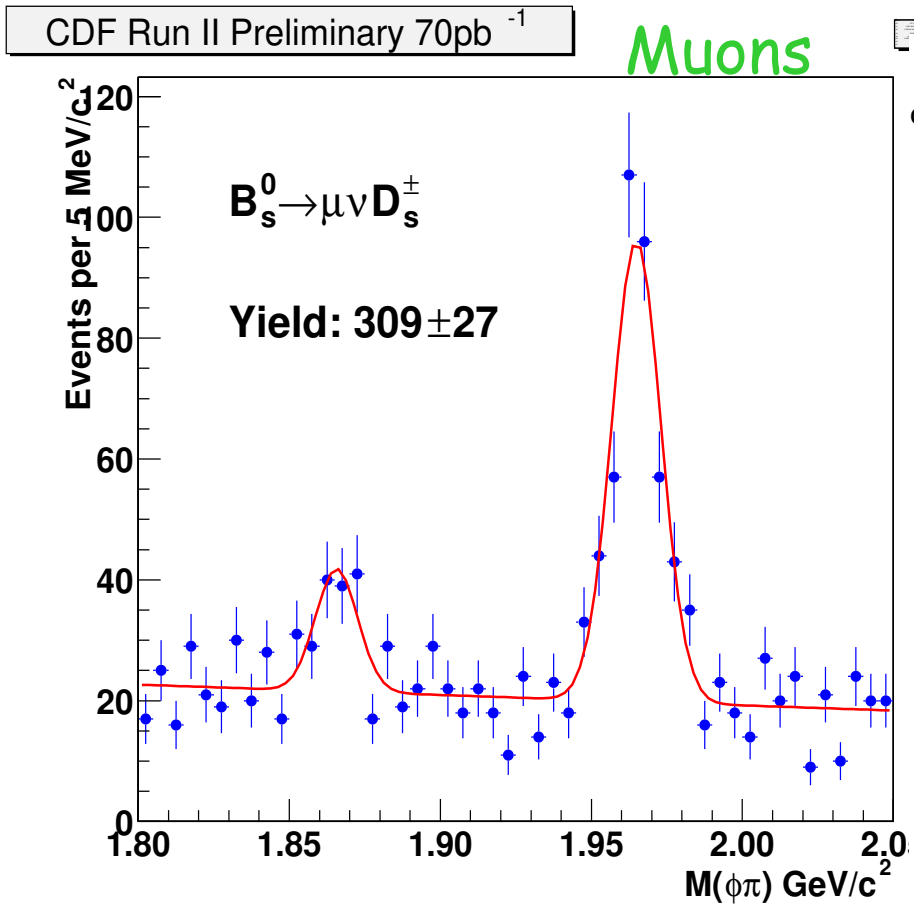
B^0: $A(t) = D\cos(\Delta m \cdot t)$

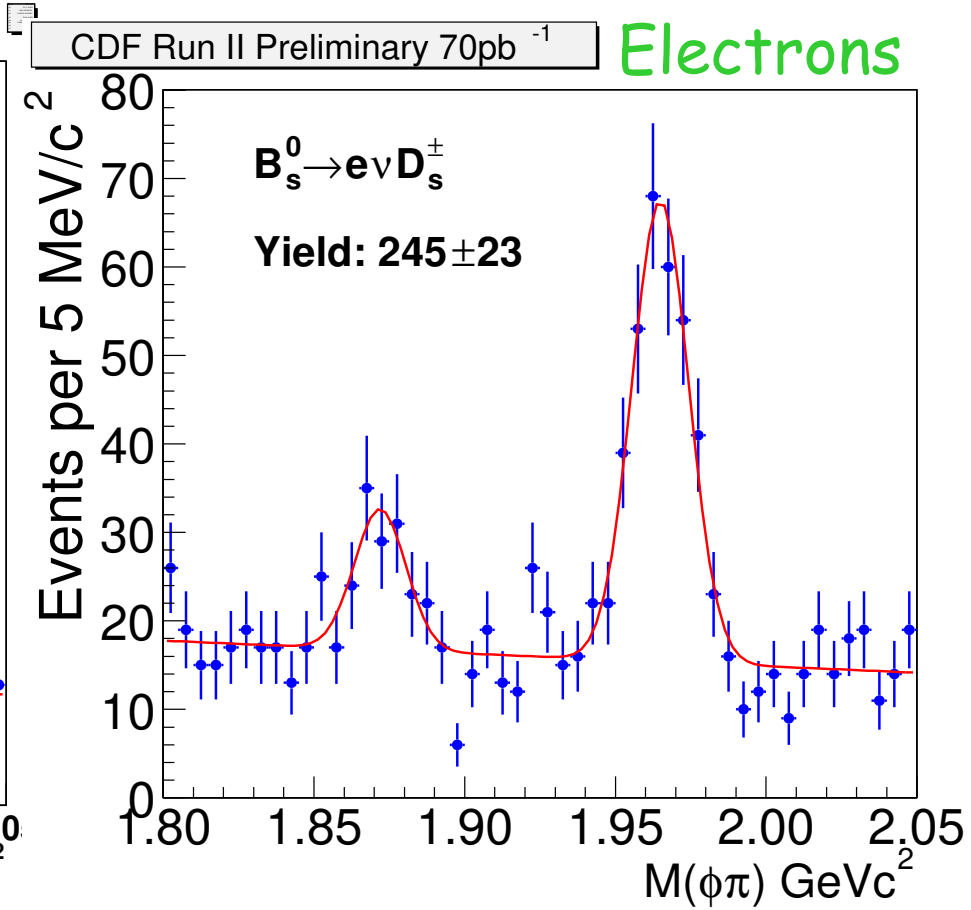
$B^{\pm}$: $A(t) = \cos t$

Raw asymmetry plots



B_s Lifetime measurement: semi-leptonic decays





Signal to noise ratio better than expected !

Observed yield: RunI×5

Lifetime and $\Delta\Gamma$ Perspectives

CDF lifetime expectation in 2 fb^{-1} are:

	Semi-leptonic decays	Fully reconstr. decays
$\sigma(c\tau)/c\tau$	2%	0.5%

$B_s \rightarrow J/\psi\varphi$ and $B_s \rightarrow lD_s X$ combined $\Rightarrow$ $\sigma(\Delta\Gamma/\Gamma)$~few %
for both CDF and D0

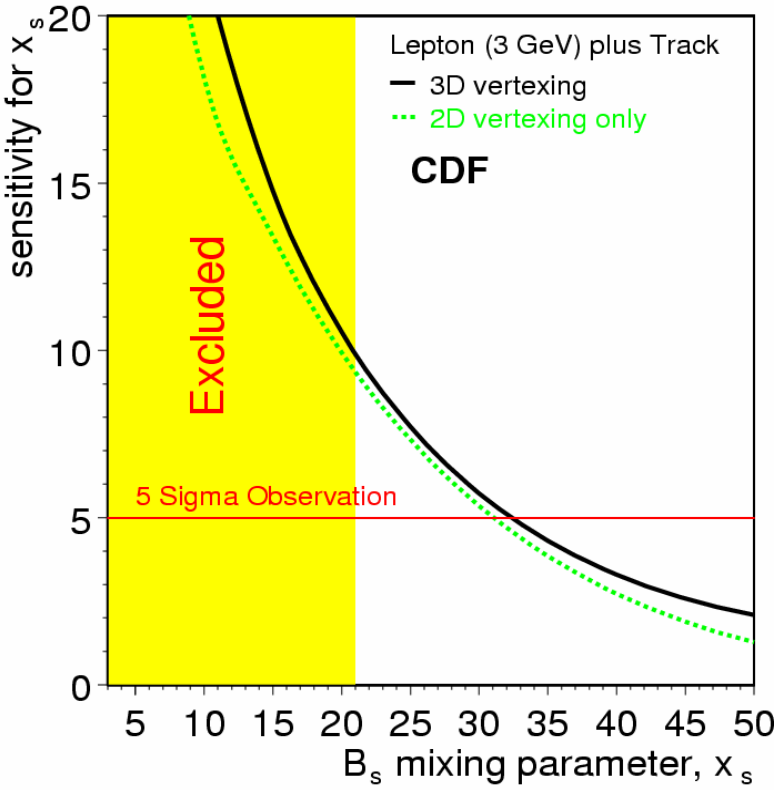
CP asymmetry in $B_s \rightarrow J/\psi\varphi$ expected small in S. M.
If bigger $\Rightarrow$ new physics

If Δm_s larger:

- difficult to measure also with high statistics sample
- $\Delta\Gamma/\Gamma$ sizeable $\Rightarrow$ easy to measure
- $\Delta m_s = \Delta\Gamma \cdot C$ where C can be calculated inside the S. M.

$X_s=\Delta m_s \times \tau_{B_s}$ measurement: semi-leptonic decays

Current limit $X_s > 20.6$



Sensitive up to $x_s \approx 30$

CDF

Decays included:

$B_s \rightarrow D_s^{\mp} l$, $D_s^{*\mp} l$

($D_s^{\mp} \rightarrow \phi\pi^{\mp}$, $K^{*0}K^{\mp}$, $\pi^-\pi^+\pi^{\mp}$)

~40K events in 2 fb^{-1}

Proper time resolution:

$$ct = \frac{L_{xy}(B_s)M(B_s)}{P_t(B_s)} = \frac{L_{xy}(B_s)M(B_s)}{P_t(l+D_s)} \times K$$

$$K = \frac{P_t(l+D_s)}{P_t(B_s)} \leftarrow \text{from Monte Carlo}$$

σ_t = 60 fs $\oplus$ t $\cdot$ $\sigma K/K$

$\sigma K/K$ ~ 14%

Tagging:

εD^2 = 11.3 % (all taggers)

D^0 :B_s mixing in fully hadronic decays

Fully reconstructed decays

Decays included:

$B_s \rightarrow D_s^{\mp}\pi^{\pm}$, $D_s^{\mp}\pi^+\pi^-\pi^{\pm}$

($D_s^{\mp} \rightarrow \phi\pi^{\mp}$, $K^{*0}K^{\mp}$, $K^{*\mp}K^0$)

$B_s \rightarrow J/\psi K^{*0}$

Proper time resolution:

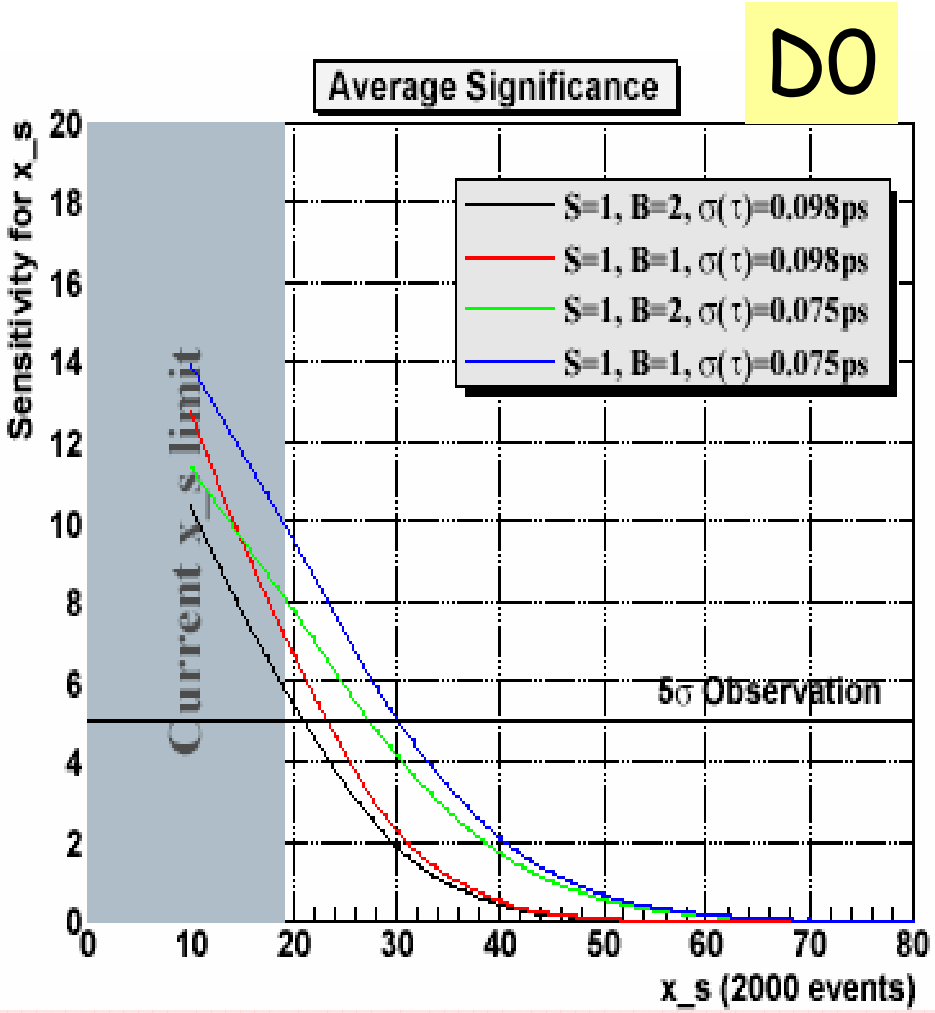
0.40 ps

Tagging:

εD^2 = 3.1 % Jet Charge

εD^2 = 4.7 % Lepton

S/B: 1:2

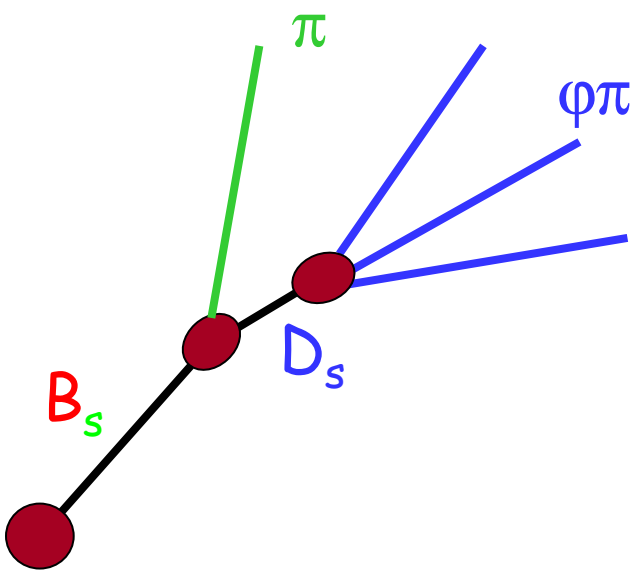


CDF sensitive up to $x_s \approx 60$

old (Y.B.) prediction

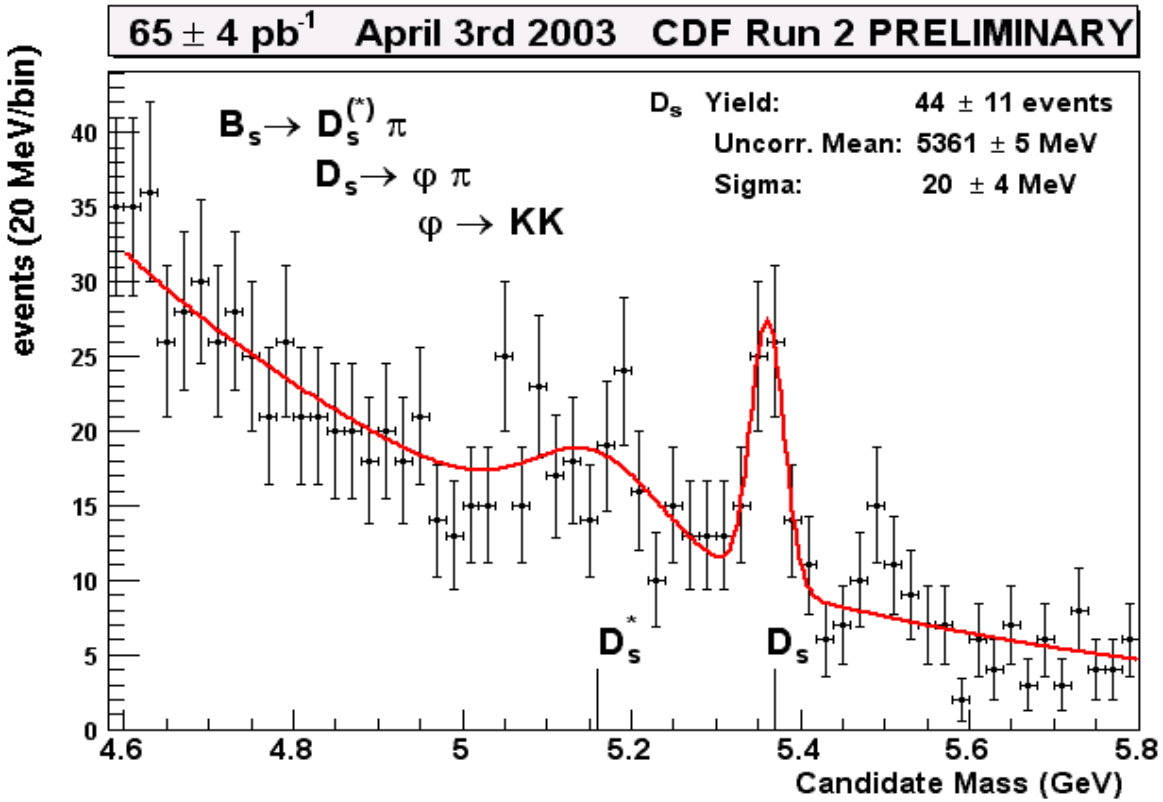
B_s Yield Study: the cuts applied

- Offline Trigger confirmation
- 3D Vertex for D and B vertices
- $1.013 < m(KK) < 1.028$ GeV
- D_s Mass constraint
- $\Delta R(D_s - \pi) < 1.5$
- $\chi_{xy}^{B} < 15$ and $\chi_{xy}^{D} < 10$
- $P^{Ds} > 4$ GeV and $P_t^{B} > 6$ GeV
- $L_{xy}^{D} > 400$ μm
- $L_{xy}^{B} > 100$ μm
- $|d^{B}| < 100$ μm



B_s Yield Study: the signal

First observation !



Can we measure the yield?

- fs/fd: discrepancy LEP - CDF
- Branching Fraction: unknown
- Cross section: big uncertainty

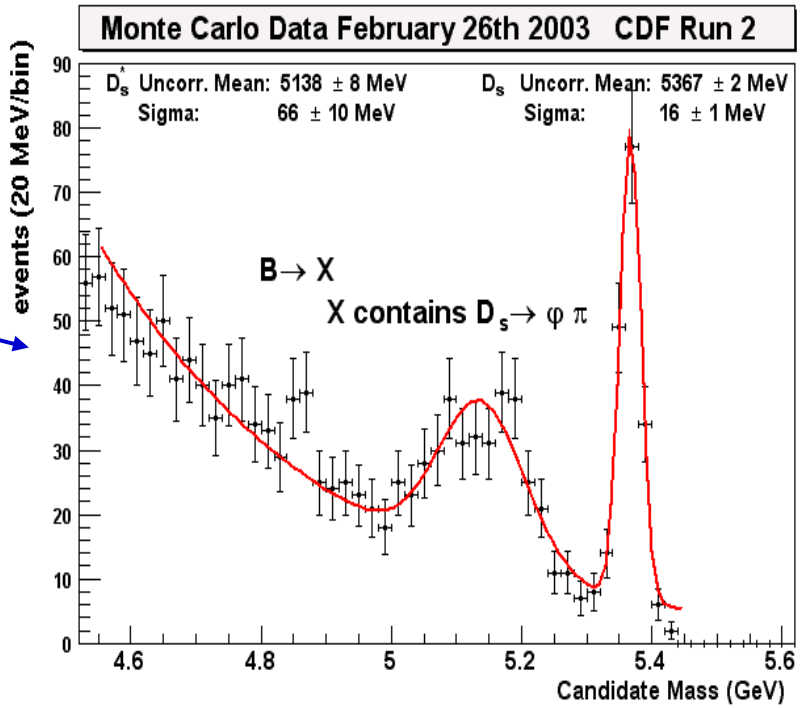
B_s Yield Study: the technique

$$\frac{N(B_s)}{N(B_d)} = \frac{f_s}{f_d}\,\frac{\varepsilon_s}{\varepsilon_d}\,\frac{Br(B_s\to D_s^-\pi^+)\,Br(D_s^-\to\varphi\pi^-)\,Br(\varphi\to k^+k^-)}{Br(B_d\to D^-\pi^+)\,Br(D^-\to k^+\pi^-\pi^-)}$$

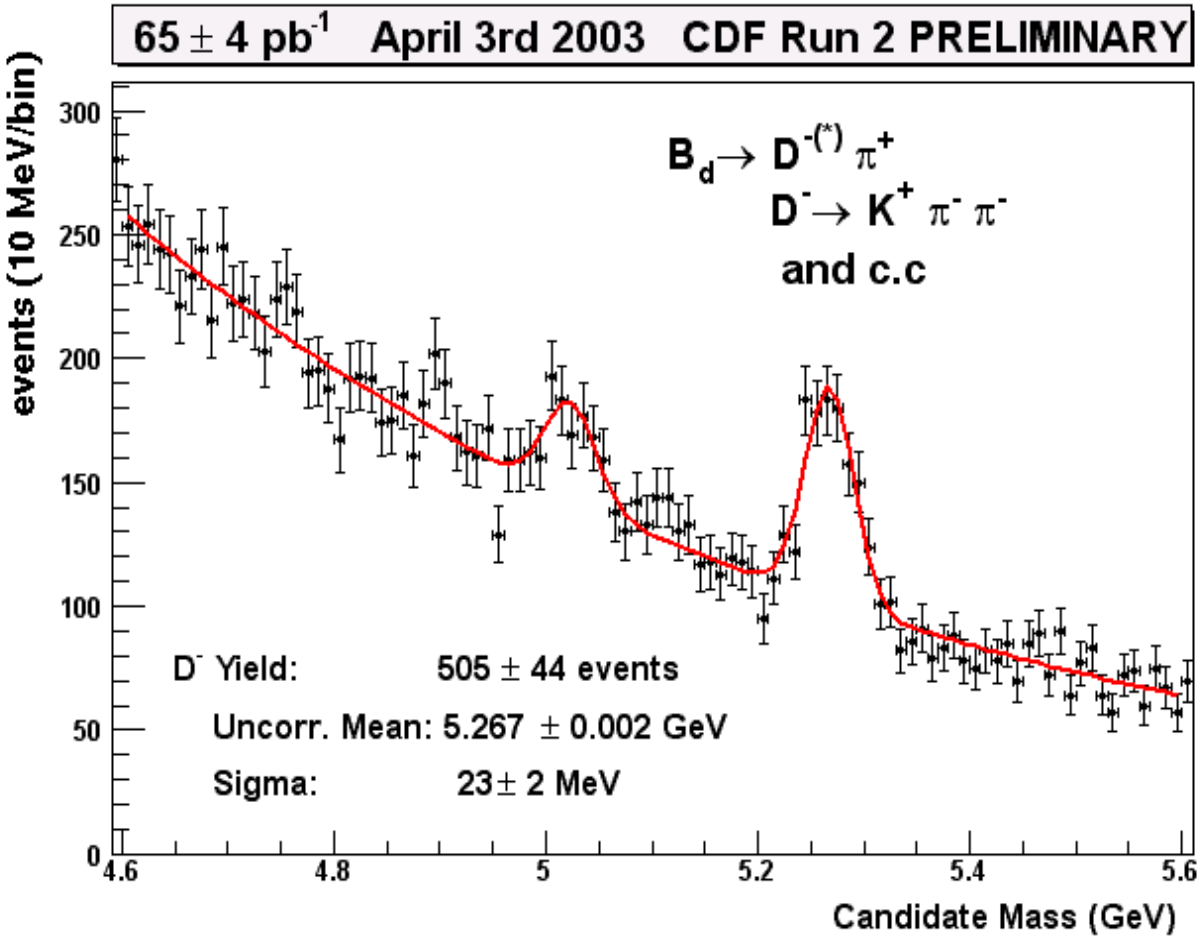
Monte Carlo

PDG

Big effort in a full detector and trigger simulation optimization "a la LEP" to measure the efficiencies



B_s Yield Study: Normalization mode



- Same mode for:
  - $B^0_S \rightarrow D^{\mp}_S \pi^{\pm}$
  - $\Lambda^0_b \rightarrow \Lambda^+_c \pi^-$
- Similar cuts to signal
- D^* also visible.

B_s Yield Study: Systematic

Particle	$\sigma\left(\frac{N_{B_s}}{N_{B_d}}\right)$
B_s	± 0.008
B_d	± 0.008

← Uncertainty in $\frac{N_{B_s}}{N_{B_d}}$ due to fit.

Source	$\sigma\left(\varepsilon_{B_s}/\varepsilon_{B_d}\right)$
XFT 1-miss	$+0.001$
Min b quark p_t	-0.08 $---$
B lifetimes	-0.02 $+0.04$
D lifetimes	0.00 $+0.04$
Total	-0.08 $+0.06$

← Uncertainty in $\frac{\varepsilon_{B_s}}{\varepsilon_{B_d}}$ (Due to MC)

BR Total Syst: ± 0.07

B_s Yield Study: Result

$$\frac{f_s \times BR(B_s \to D_s \pi)}{f_d \times BR(B_d \to D\,\pi)} = 0.44 \pm 0.11(stat) \pm 0.11(BR) \pm 0.07(syst)$$

From PDG: $\frac{f_s}{f_d} = 0.273 \pm 0.034$:

$$\frac{BR(B_s \to D_s \pi)}{BR(B_d \to D\,\pi)} = 1.61 \pm 0.40(stat) \pm 0.40(BR) \pm 0.26(syst) \pm 0.20\left(PDG\,\frac{f_s}{f_d}\right)$$

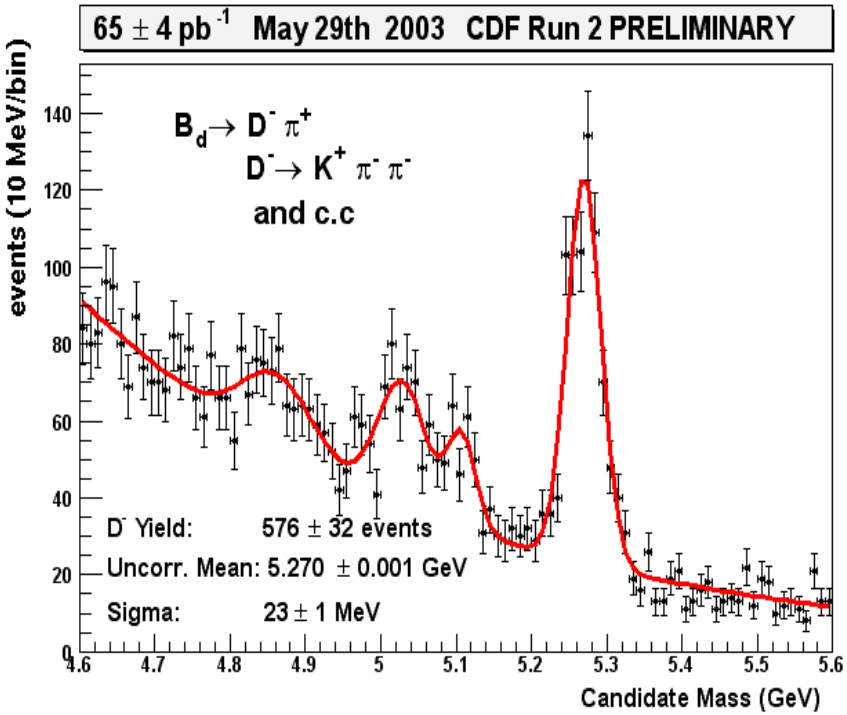
B_s Yield Measurement: where we are

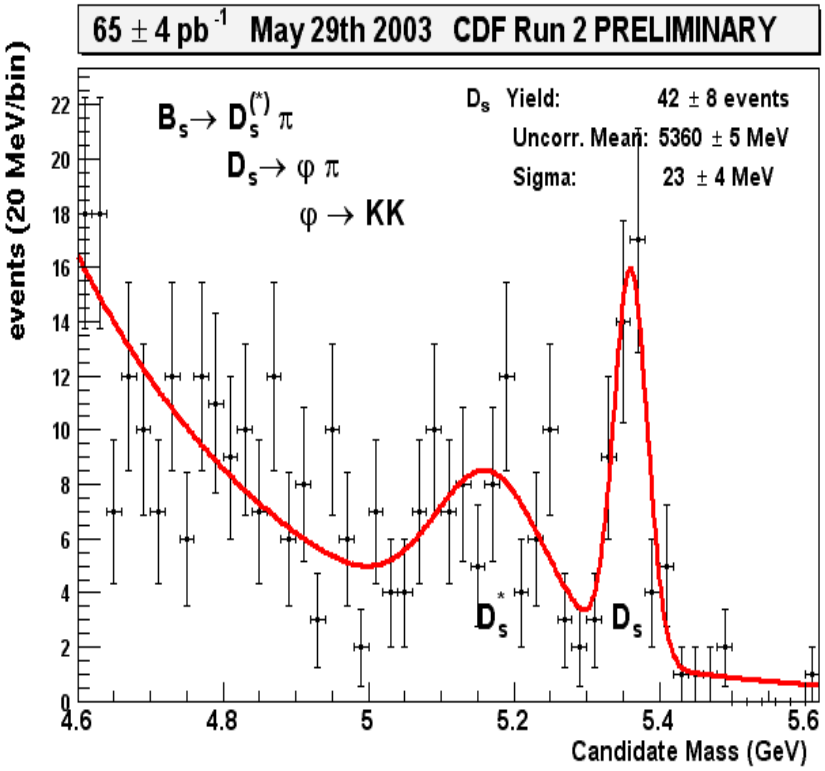
Signal to noise optimization: $S/\sqrt{B}$ is optimized with ε>60%

- Offline Trigger confirmation
- 3D Vertex for D and B vertices
- 1.010<m(KK)<1.028 GeV (only for B_s)
- D Mass constraint
- $\Delta R(D-\pi)<1.5$
- $\chi_{xy}^{B} < 15$ and $\chi_{xy}^{D} < 10$
- P^{D}> 3 GeV (3.5 for B_s) and P_t^{B}>6 GeV (5.5 for B_s)
- $L_{xy}^{D}>-150$ μm
- L_{xy}^{B}>250 μm (400 for B_s)
- $|d^{B}|<80$ μm
- $Pt(\pi_B)>1.6$ (1.9 for B_s)

Bs Yield Measurement: where we are

Signal to noise optimization



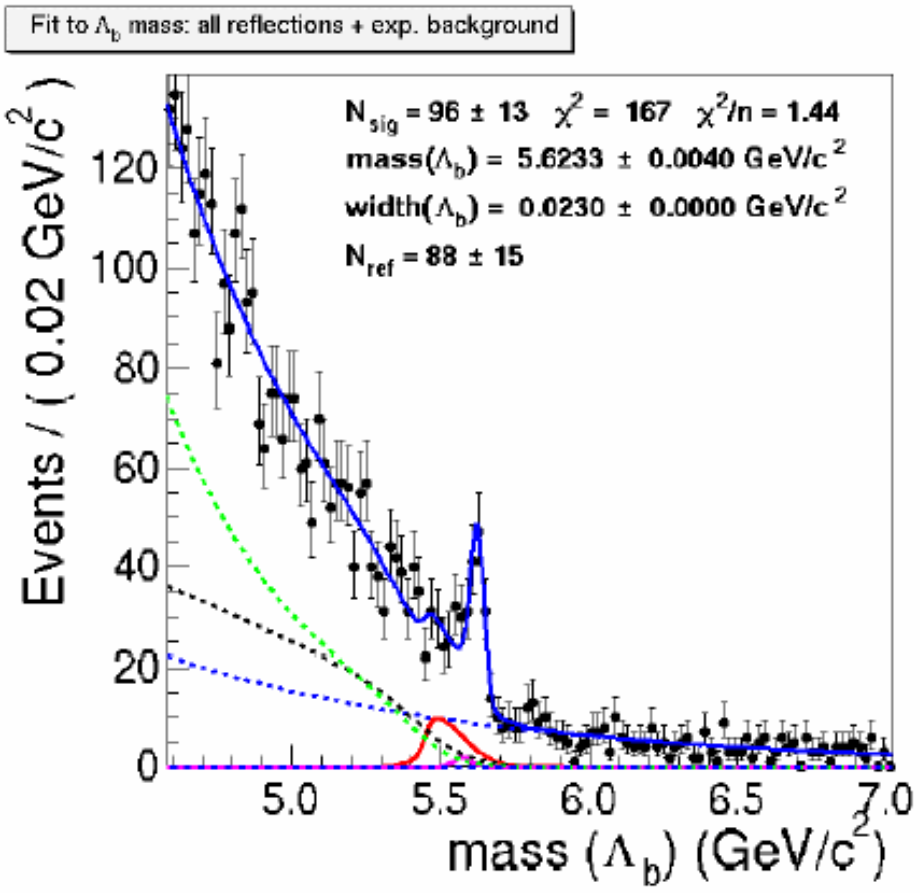


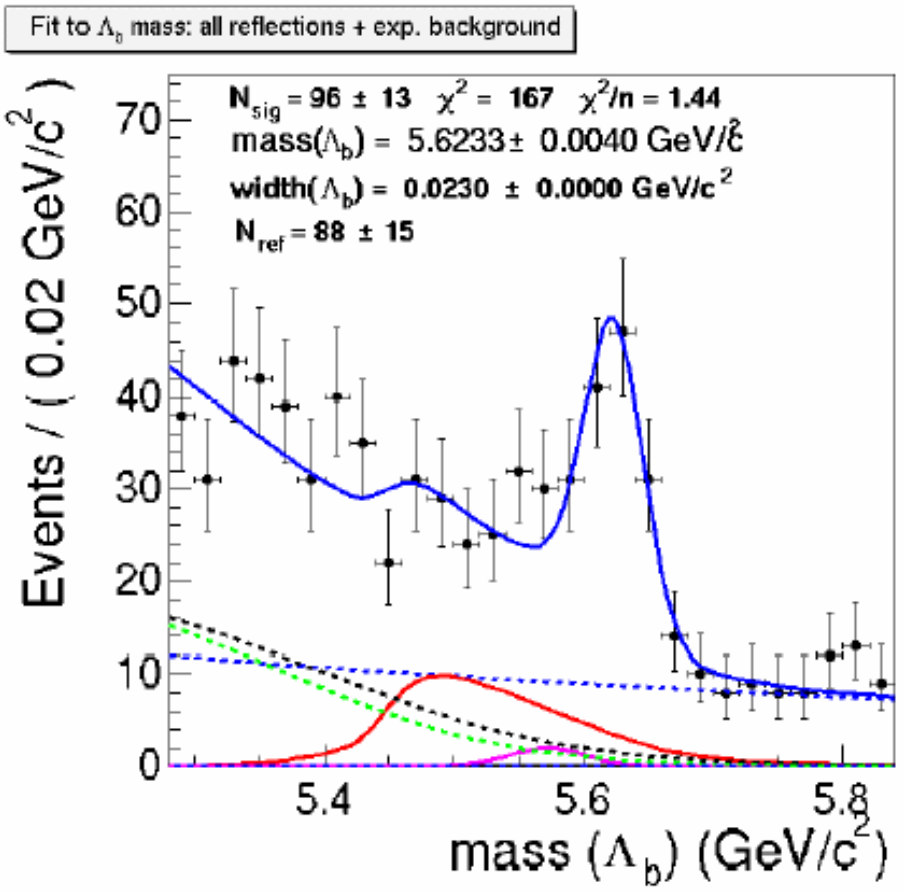
$\Lambda_b \rightarrow \Lambda_c \pi$ Relative Yield Measurement

Same technique used for B_s

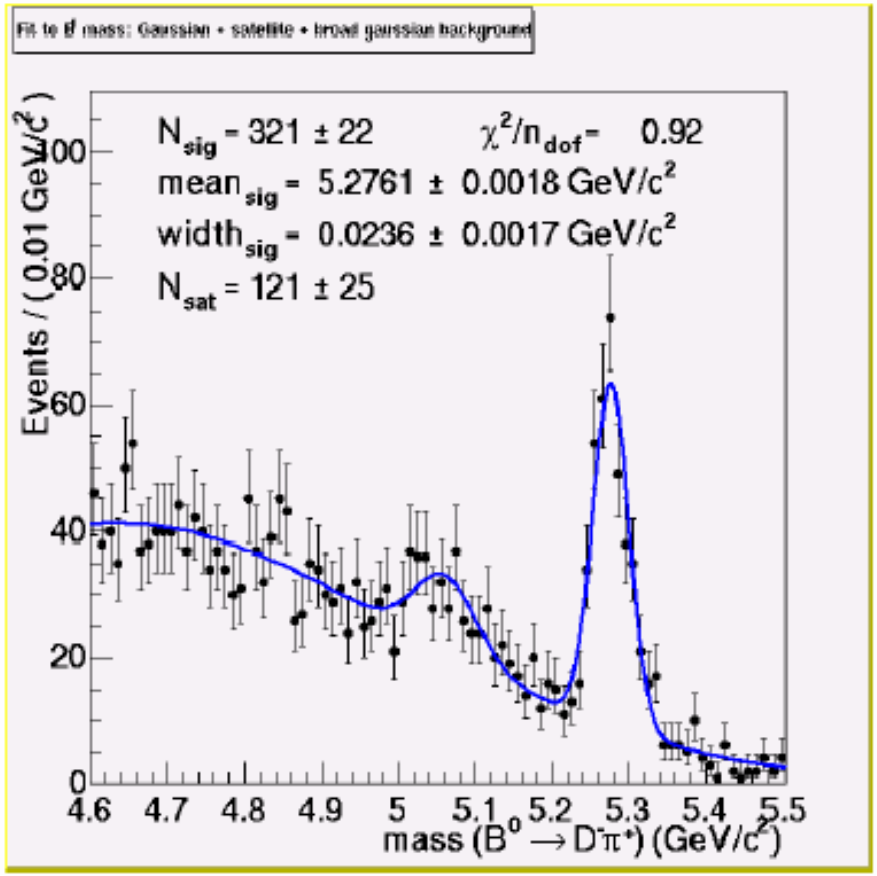
- Confirm trigger cuts
- Pt(proton)>2 GeV
- Pt(π from Λ_b)>2 GeV
- Pt(Λ_c)>4.5 GeV
- Pt(Λ_b)>7.5 GeV
- $c\tau(\Lambda_b)$> 225 μm
- $c\tau(\Lambda_c$from $\Lambda_b)$> -65 μm
- d0(Λ_b)<85 μm
- Pt(proton)>Pt(π from Λ_c)
- 2.269<m(Λ_c)<2.302 GeV
- $\chi_{xy}(\Lambda_b)$<30
- $\chi_{xy}(\Lambda_c)$<20

$\Lambda_b \rightarrow \Lambda_c \pi$ Relative Yield Measurement





The Normalization Channel



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

same cuts optimized for Λ_b are applied

$\Lambda_b \rightarrow \Lambda_c \pi$ Relative Yield Measurement

	$\varepsilon_B / \varepsilon_\Lambda$
$\varepsilon^{Trigger}$	1.30+/-0.01
ε^{Recon}	0.96+/-0.01
ε^{Ana}	0.96+/-0.01
ε^{tot}	1.20+/-0.02

	Central value	Variation range	Change (%)
B lifetime	462	457-467	negligible
Λ_b lifetime	369	345-393	+4 -5
Λ_c Dalitz structure			+/-1
Pt spectrum			+1
Λ_b , Λ_c polarization	0	+/-1	+/-7
XFT 1 miss	2miss	1miss	+3
Phi efficiency			+3
Total			+/-9

$\Lambda_b \to \Lambda_c \pi$ Relative Yield Measurement

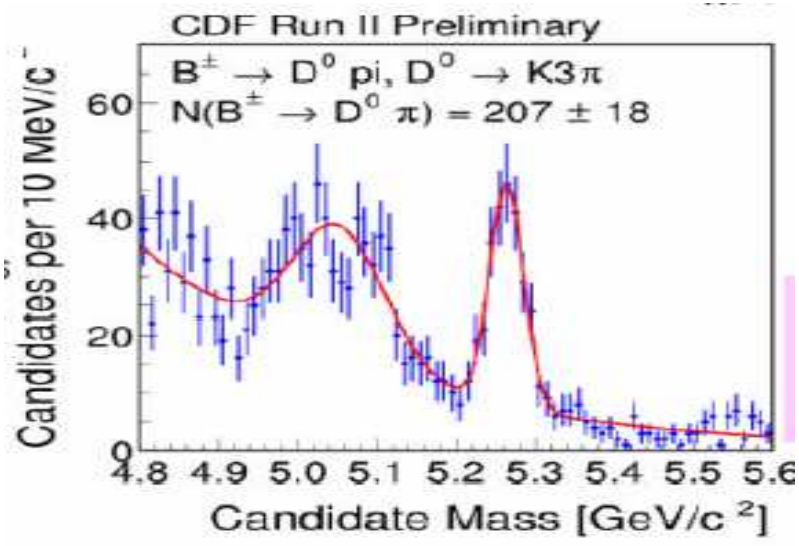
$$\frac{Br(D^- \to k\pi\pi)}{Br(\Lambda_c^+ \to pK\pi)} = 1.82 \pm 0.49 \; ----(FromPDG)$$

$$\frac{\varepsilon_B}{\varepsilon_{\Lambda_b}} = 1.20 \pm 0.02(stat.) \pm 0.11(syst.)$$

$$\frac{N_{\Lambda_b}}{N_{B^0}} = 0.30 \pm 0.05(stat.) \pm 0.03(syst.)$$

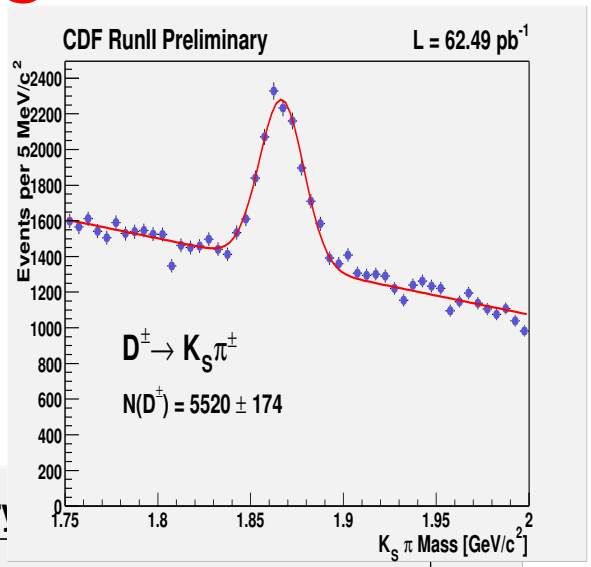
$$\frac{f_{\Lambda_b} \bullet Br(\Lambda_b \to \Lambda_c^+ \pi)}{f_d \bullet Br(B^0 \to D^+ \pi)} = 0.66 \pm 0.11(stat.) \pm 0.09(sys.) \pm 0.18(BR)$$

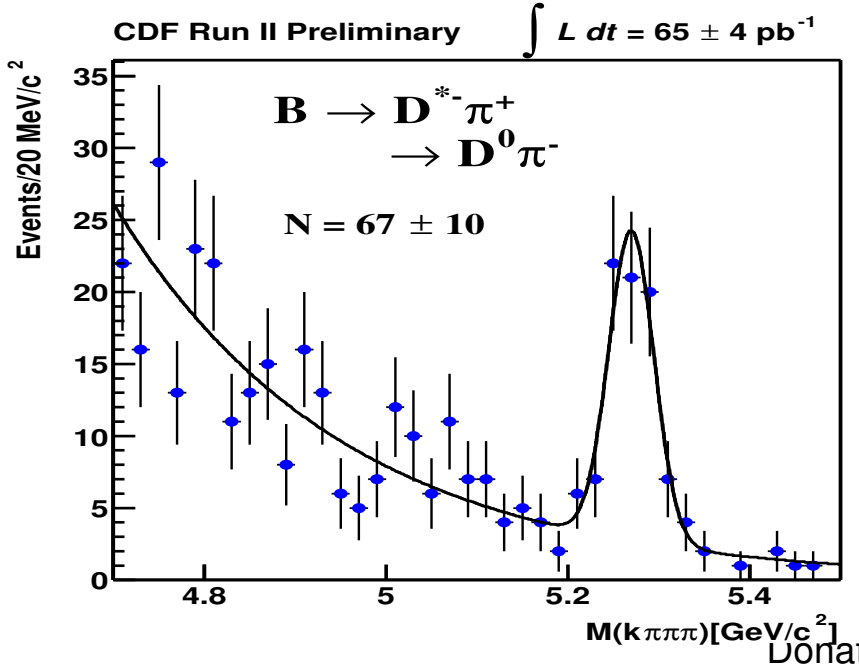
Many other B decays

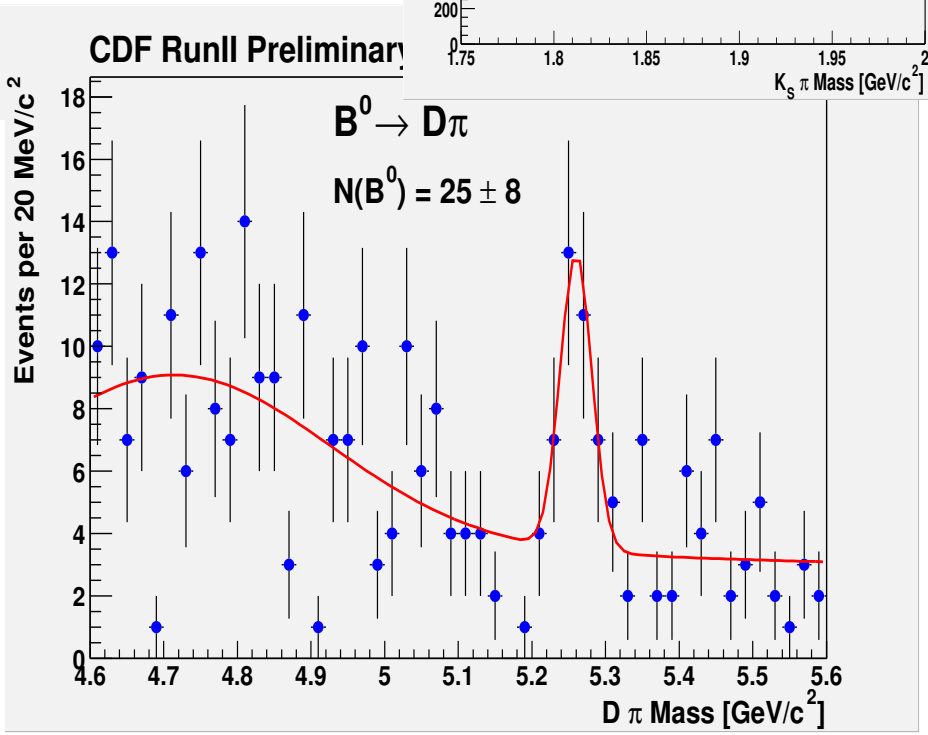


$B \to D^+\pi^-$

$D^{\pm} \to K_s \pi^{\pm}$







CP violation in Standard Model: γ at CDF

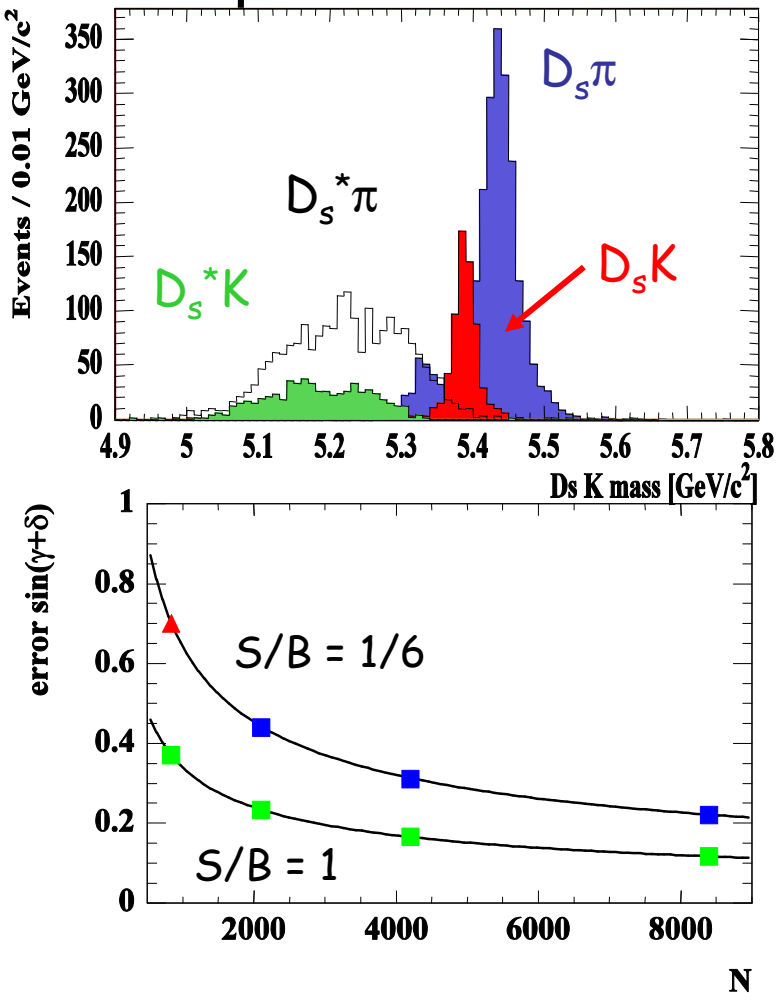
R. Aleksan et al. Z Phys. C54 653 (1992) proposal:

B_s $D_s^{\mp}K^{\pm}$ time dependent decay rate depends on:

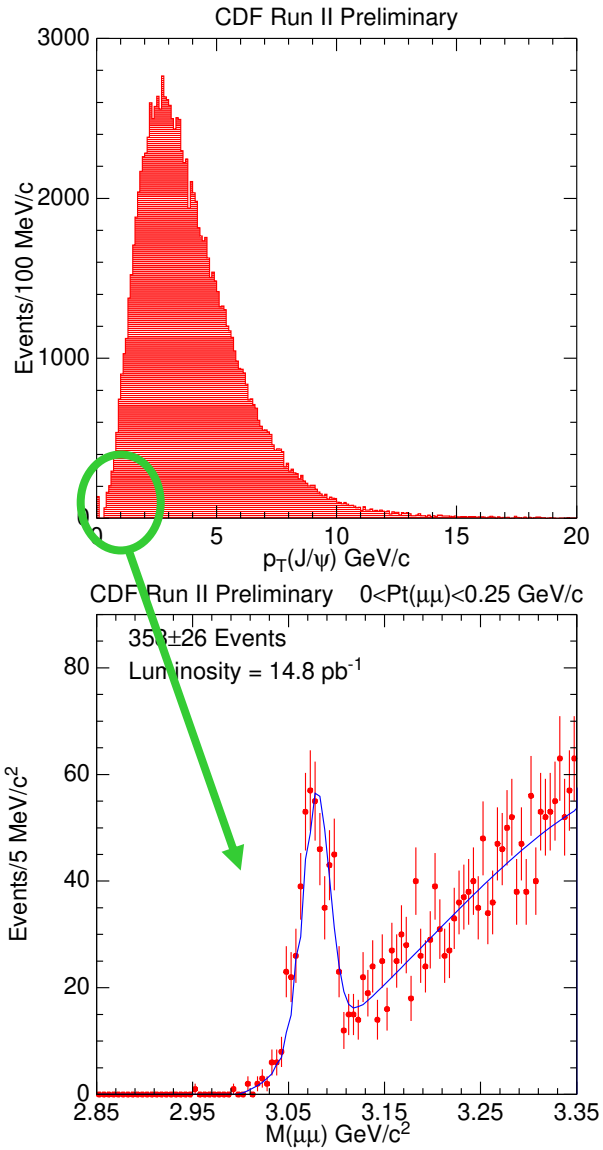
$\sin(\delta\pm\gamma)$ and $\cos(\delta\pm\gamma)$

a) Theoretically clean
b) Reasonable Branching ratio
c) Background B_s $D_s\pi$
d) Need tagging
e) Need time dependent analys

~ 1000 events in RunIIa
~ 3500 events in RunIIb

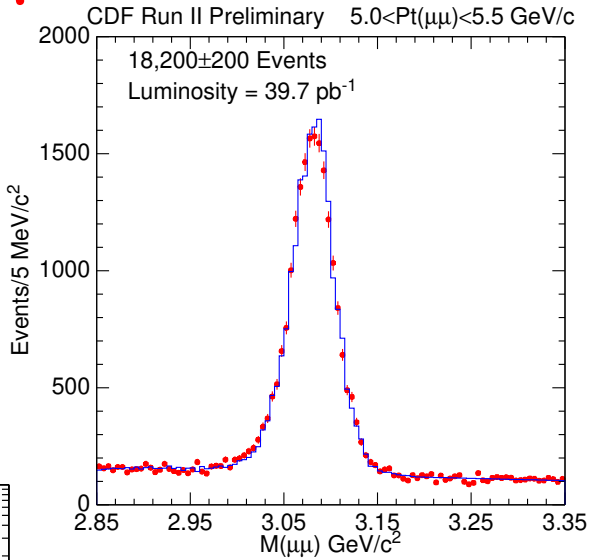


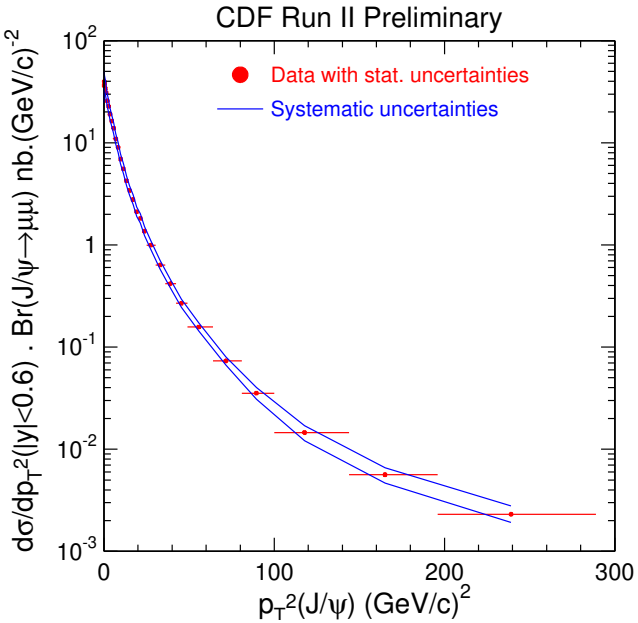
J/ψ cross section



$P_t^{\mu}>1.5 \rightarrow Pt(J/\psi)\geq 0$

First time at Tevatron

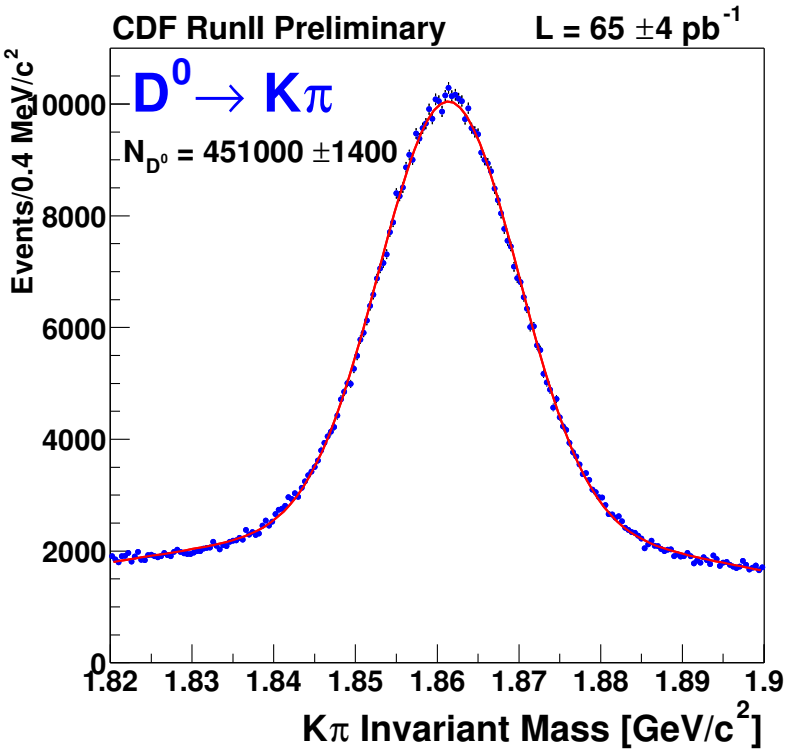


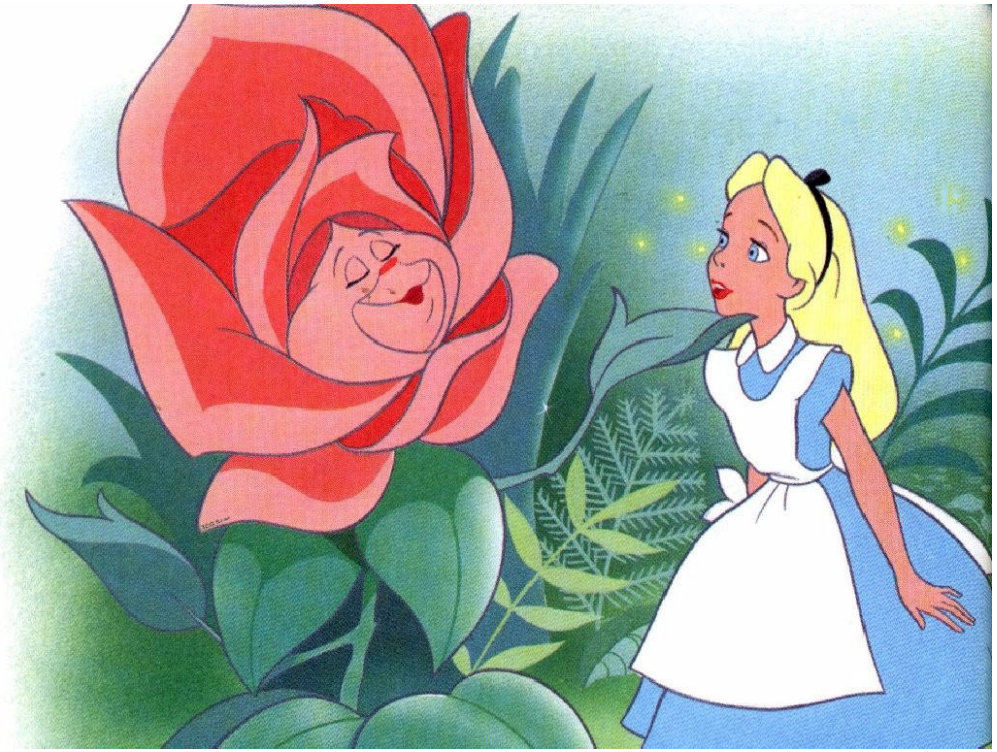


$\sigma(P_t>0,\ |y|<0.6)=240\pm1(stat)^{+35}_{-28}(syst)$ nb

CP Asymmetries and Decays Ratios of $D^0 \to h^+h^-$

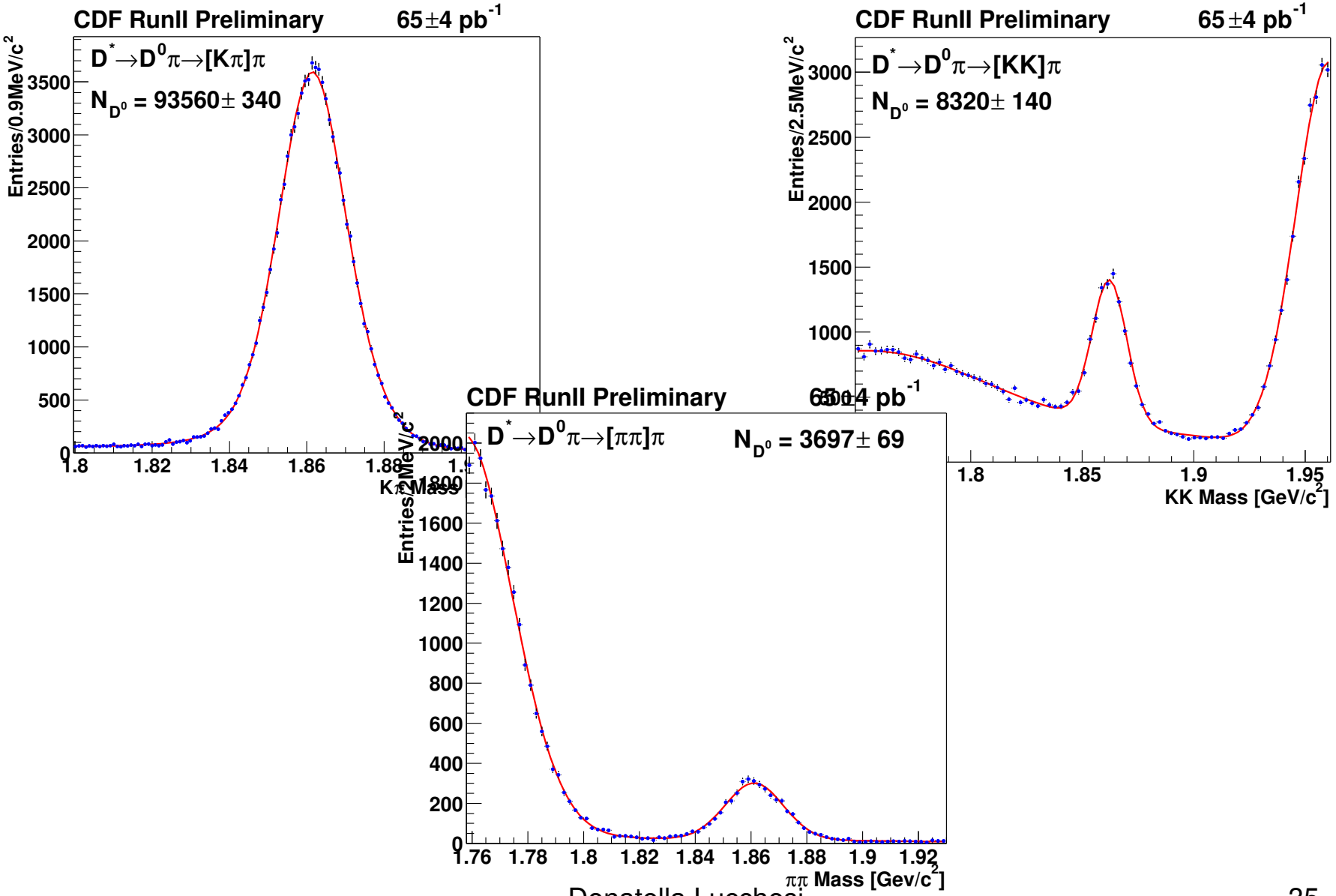
Two Tracks Trigger open CDF to a new field, charm physics





Pure D^0 samples are required $\Rightarrow$ D^* tag used
The charge of the slow pion gives the D^0 flavor

CP Asymmetries and Decays Ratios of $D^0 \to h^+h^-$



CP Asymmetries and Decays Ratios of $D^0 \to h^+h^-$

$$\frac{\Gamma(D^0 \to KK)}{\Gamma(D^0 \to K\pi)} = 9.38 \pm 0.18 \text{ (stat)} \pm 0.10 \text{ (syst)} \%$$

$$\frac{\Gamma(D^0 \to \pi\pi)}{\Gamma(D^0 \to K\pi)} = 3.686 \pm 0.076 \text{ (stat)} \pm 0.036 \text{ (syst)} \%$$

Results competitive with dedicated experiments and e^+e^- machines i.e. CLEO FOCUS

$$A_{CP} = \frac{\Gamma(D^0 \to f) - \Gamma(\overline{D}^0 \to f)}{\Gamma(D^0 \to f) + \Gamma(\overline{D}^0 \to f)}$$

$A_{CP}(\pi\pi) = 2.0 \pm 1.7 \text{ (stat)} \pm 0.6 \text{ (syst)} \%$

$A_{CP}(KK) = 3.0 \pm 1.9 \text{ (stat)} \pm 0.6 \text{ (syst)} \%$

Summary

CDF is starting doing competitive B physics measurements

D0 need more time since the new detector

In Italy many activities:

- B_s branching ratio analysis
- D^0 branching ratio & CP measurements
- No contribution on J/ψ analysis
- Many opportunities for students !