B_s Physics and Prospects at the Tevatron

Donatella Lucchesi
for the CDF and D0 Collaborations

CKM Workshop Durham April 5-9 2003

The status of B_s physics at the Tevatron

- Lifetimes
- Mixing

Other related talks :

J. Rademacker talk for lifetimes and lifetime differences

R. Oldeman presentation about detector performances

I. Villa talk about SVT trigger

How do we collect B_s

Old style:

- Di-muon trigger: low P_t respect to Run I $\Rightarrow$ much more J/ψ

  $B_s \rightarrow J/\psi\varphi$ "$B_s \rightarrow J/\psi\eta$"

New era:

Hadronic trigger (SVT): displaced tracks

all hadronic decays

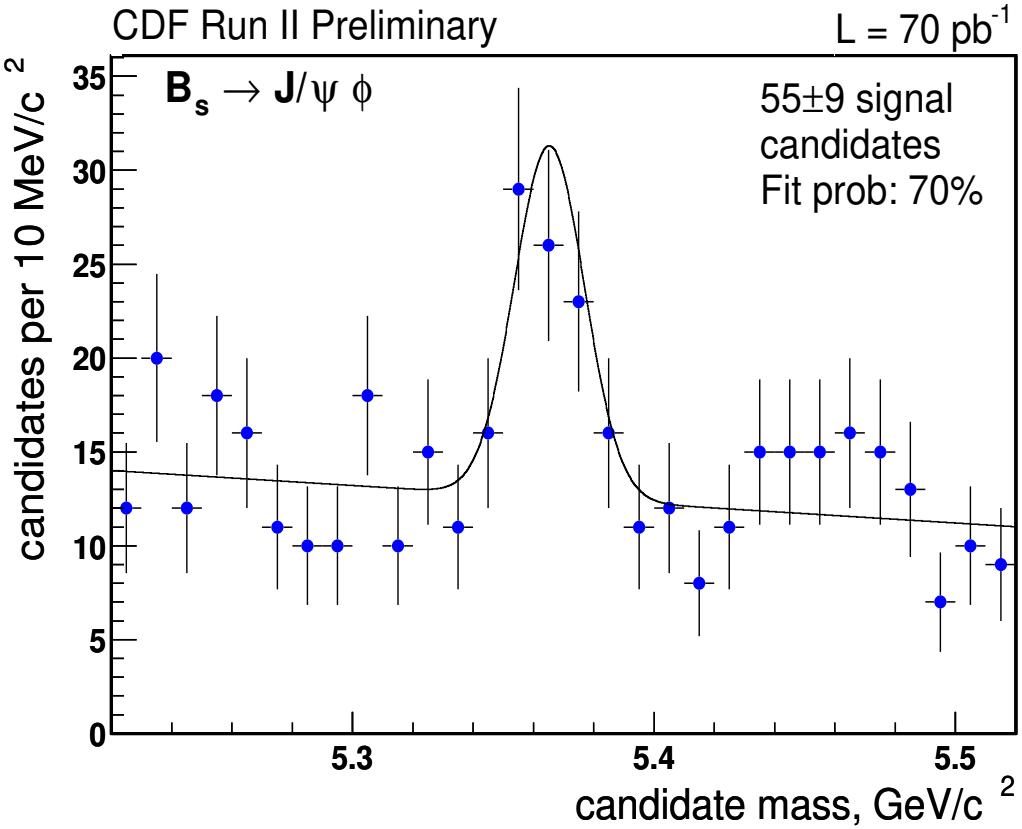
A combination of Old and New

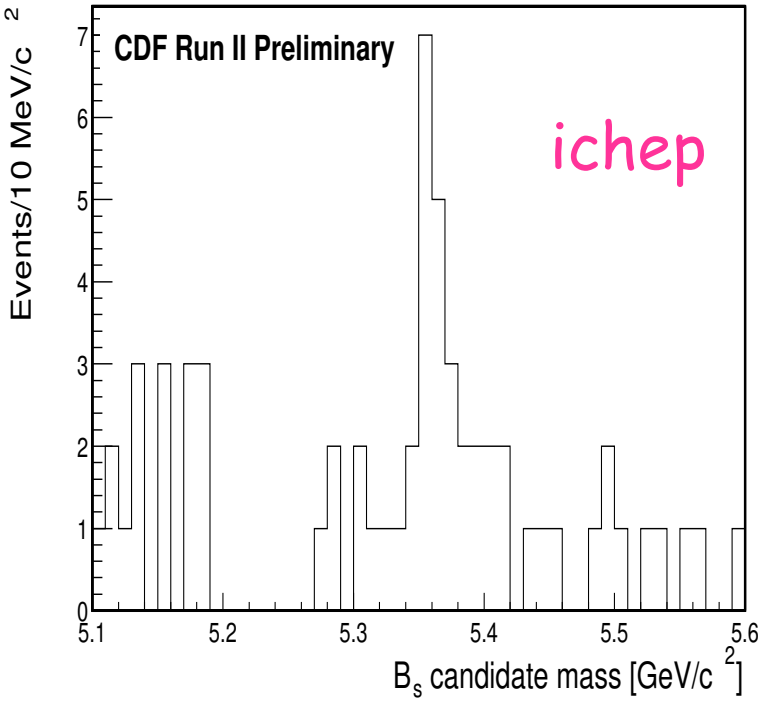
- Lepton + displaced track trigger

  $B_s \rightarrow l D_s X$

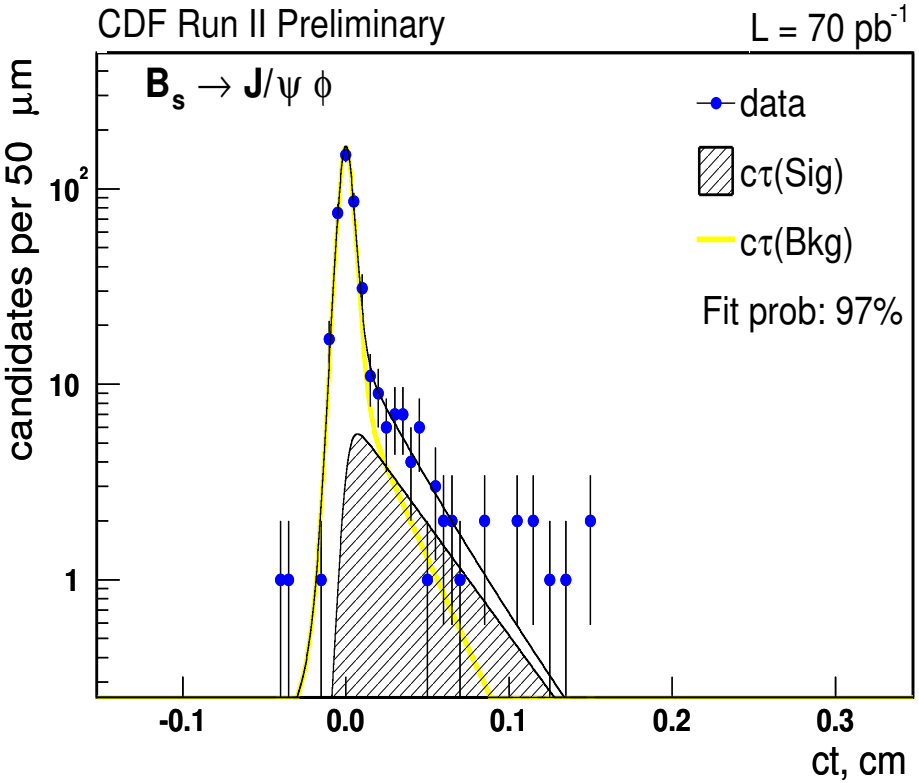
Exploiting the J/ψ: Mass Measurement

$m(B_s)=5360.3\pm3.8(stat)^{+2.1}_{-2.9}(sys)$ MeV/c² ichep result



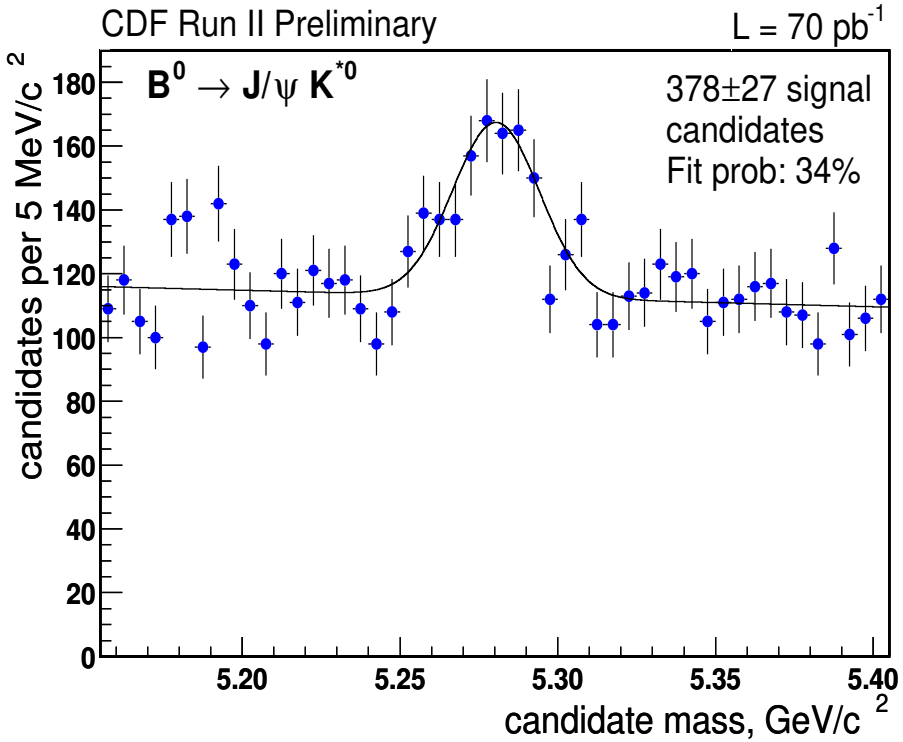


$B_s \rightarrow J/\psi\varphi$: Lifetime Measurement



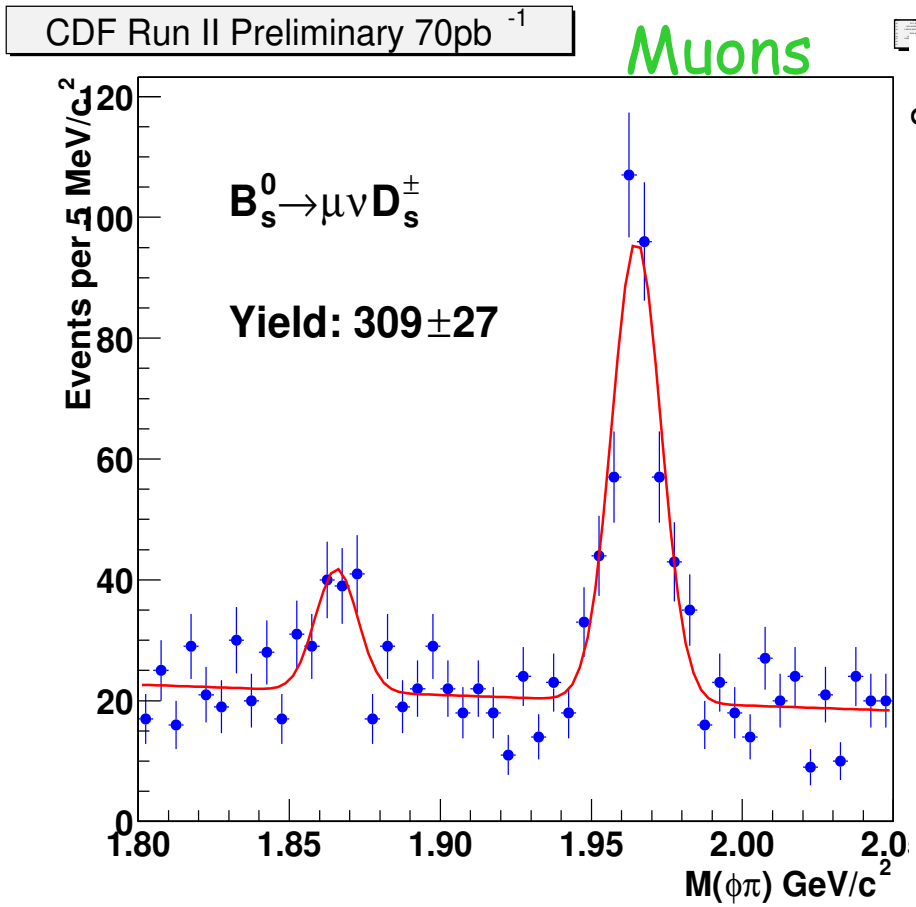
$\tau_{B^0} = 1.42 \pm 0.09(\text{stat}) \pm 0.02(\text{sys})$

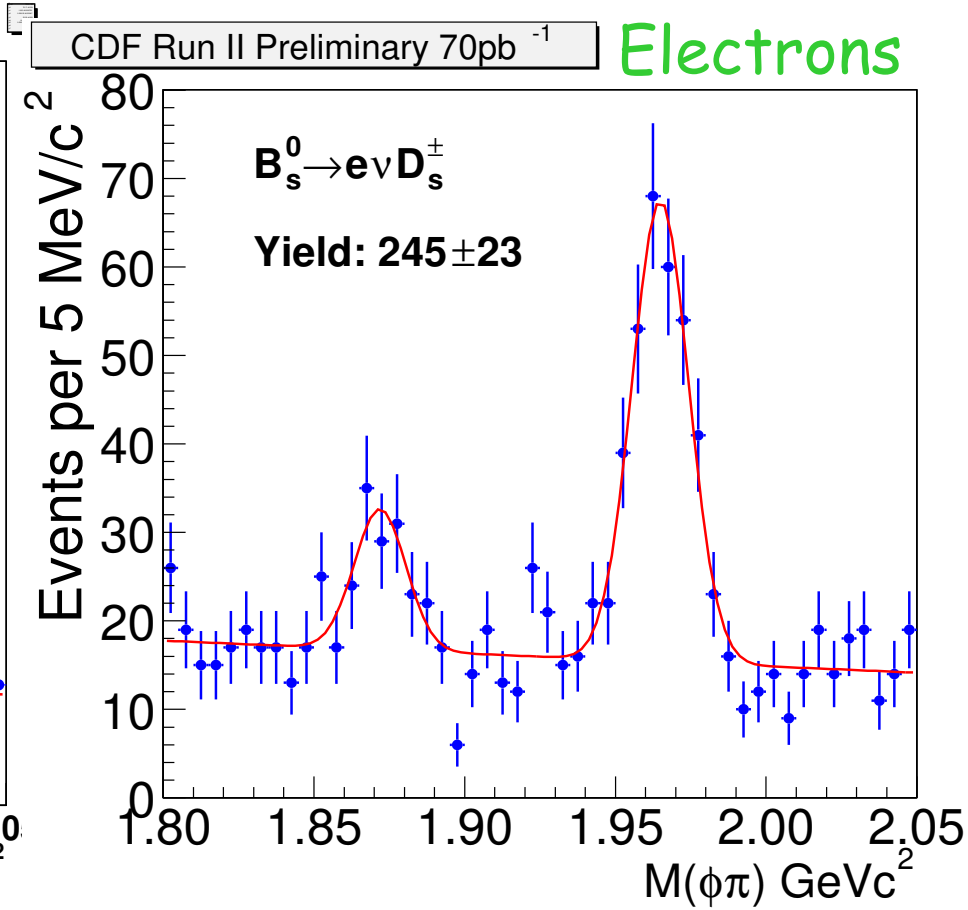
$\tau_{B_s} = 1.26 \pm 0.20(\text{stat}) \pm 0.02(\text{sys})$



$\tau_{B_s}/\tau_{B^0} = 0.89 \pm 0.15(\text{tot.})$

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 (see Jonas talk for details)

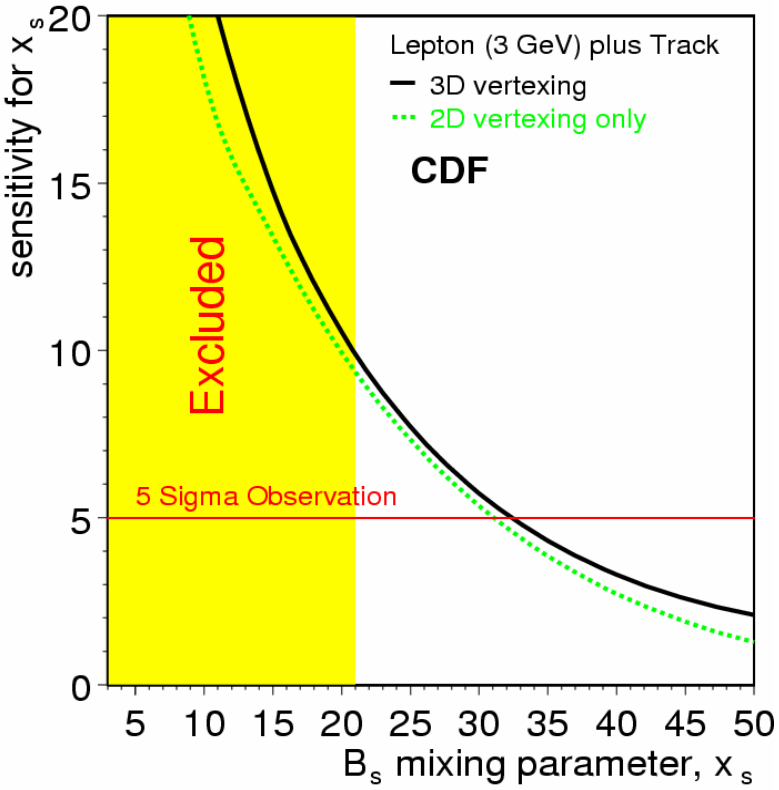
CP asymmetry in $B_s \rightarrow J/\psi\varphi$ expected small in S. M.
If bigger $\Rightarrow$ new physics

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 · $\sigma K/K$

$\sigma K/K$ ~ 14%

Tagging:

εD^2 = 11.3 % (all taggers)

B_s mixing in fully hadronic decays

Fully reconstructed decays

D0

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:

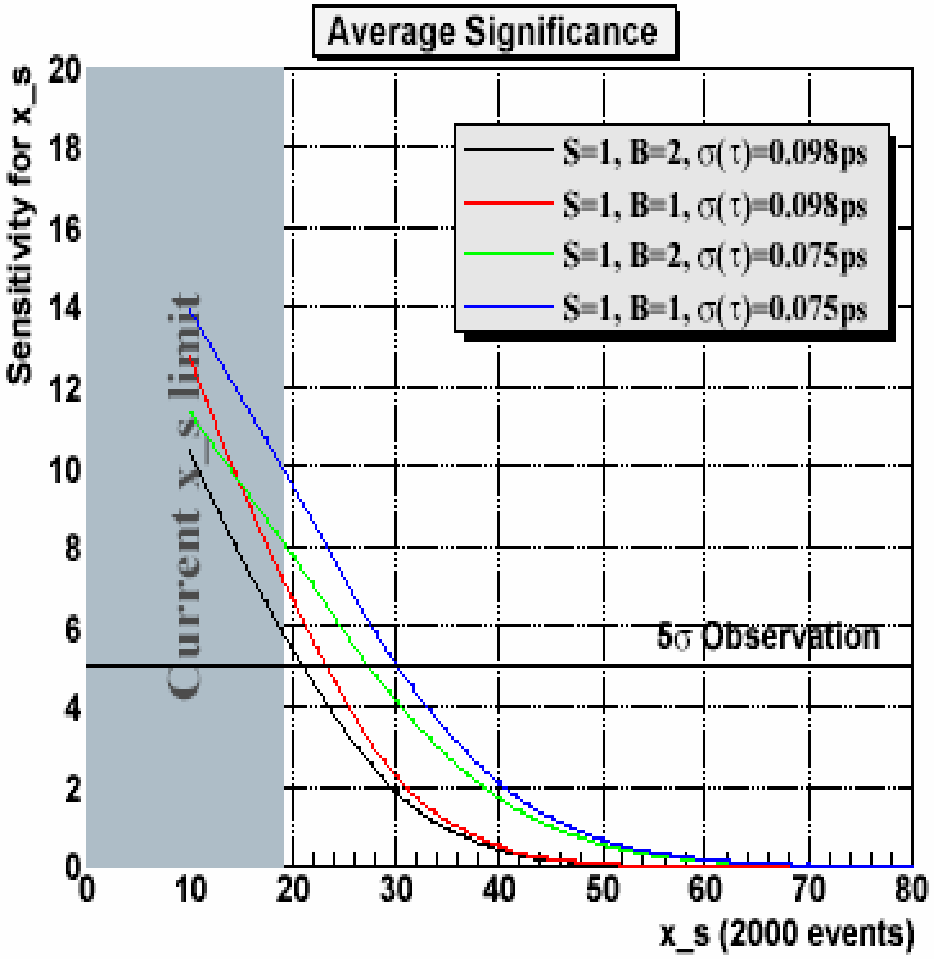
0.40 ps

Tagging:

εD^2 = 3.1 % Jet Charge

εD^2 = 4.7 % Lepton

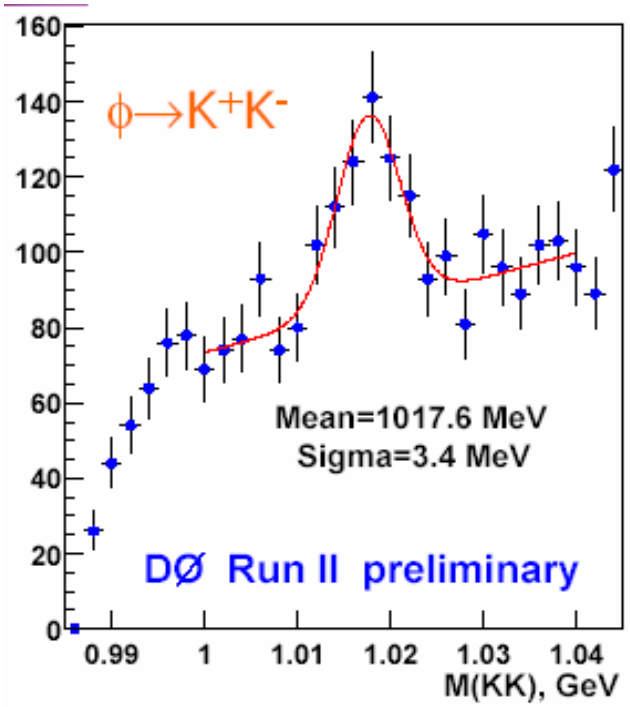
S/B: 1:2



Current status of D0

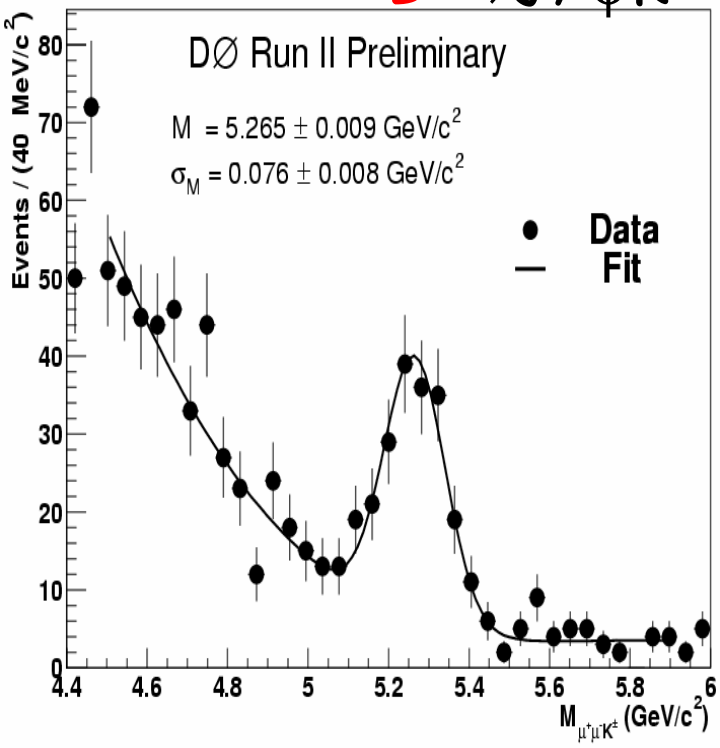
Total Luminosity: ~40 pb^{-1}

Many B reconstructed see Jonas talk.



Optimize tracking and flavor tagging

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



P_t>2 GeV all tracks

2.8 < $m_{\mu\mu}$ < 3.3 GeV

B decay length >0.3 mm

B_s mixing at D0: Flavor tagging

$$\text{Efficiency } \varepsilon = \frac{N_{\text{correct}} + N_{\text{wrong}}}{N_{\text{correct}} + N_{\text{wrong}} + N_{\text{no tag}}}$$

$$\text{Dilution } D = \frac{N_{\text{correct}} - N_{\text{wrong}}}{N_{\text{correct}} + N_{\text{wrong}}}$$

$$\text{Tagging power} : \varepsilon \times D^2$$

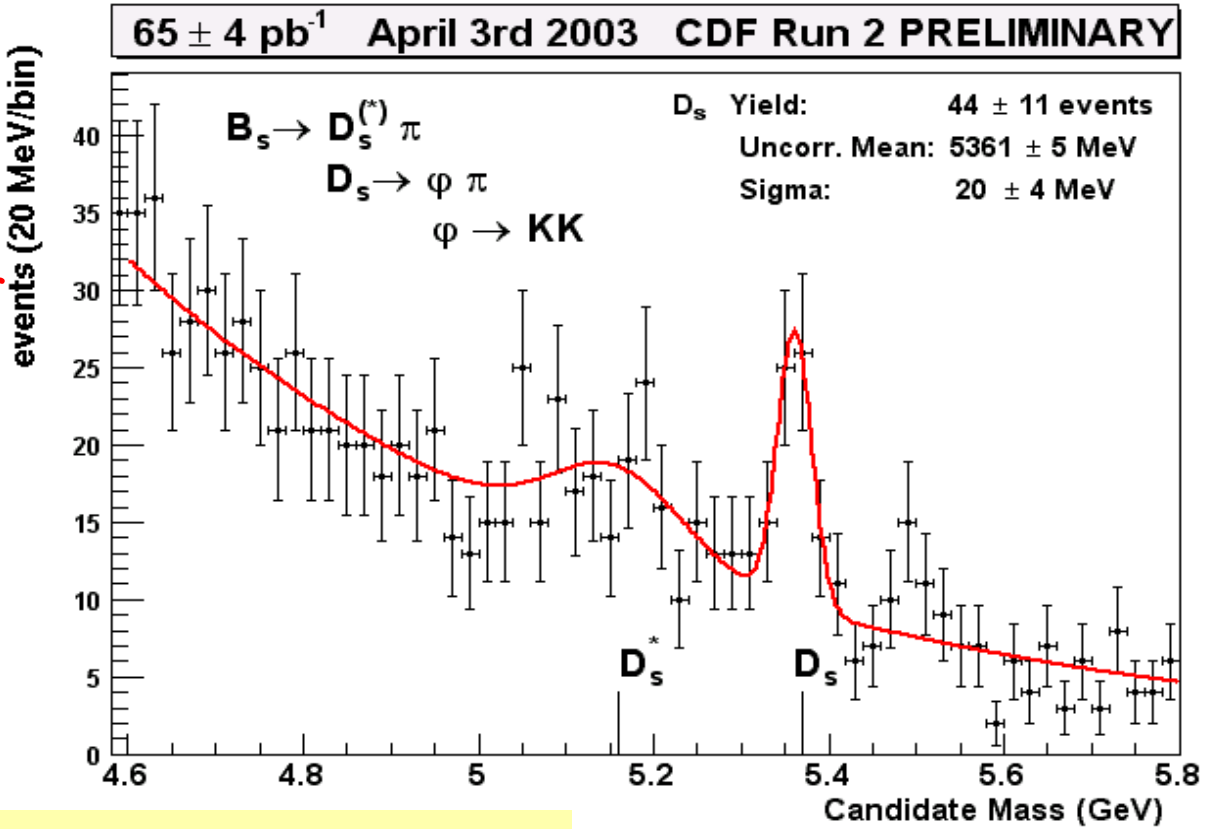
DØ Run-II Preliminary

	Muon	Jet Charge
ε(%)	8.2±2.2	55.1±4.1
D(%)	63.9±30.1	21.1±10.6
εD^2 (%)	3.3±1.8 (3.1 pred.)	2.4±1.7 (4.7 pred.)

Current status of CDF: Yield Study

Hadronic trigger

First observation !



Can we measure the yield?

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

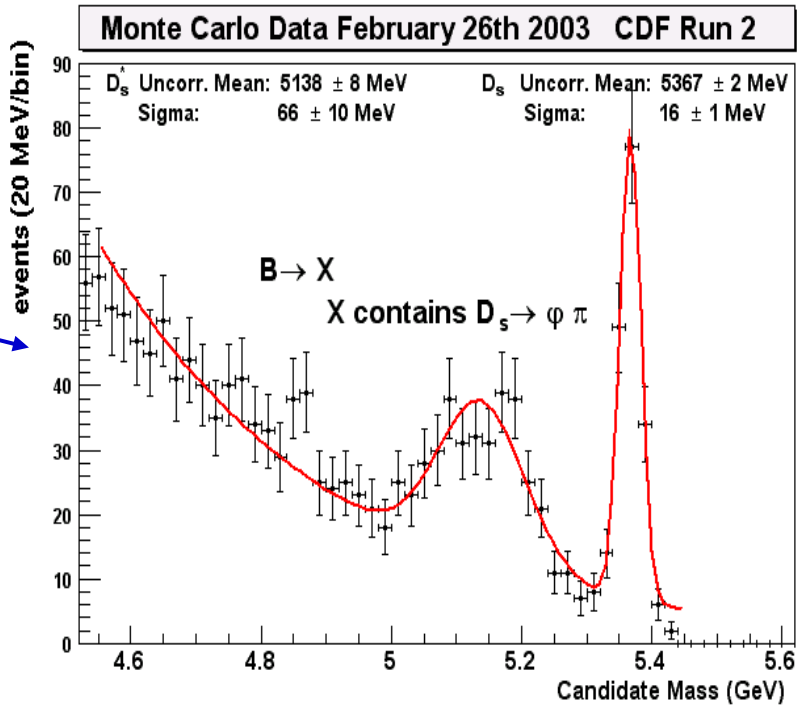
Current status of CDF: Yield Study

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

Monte Carlo

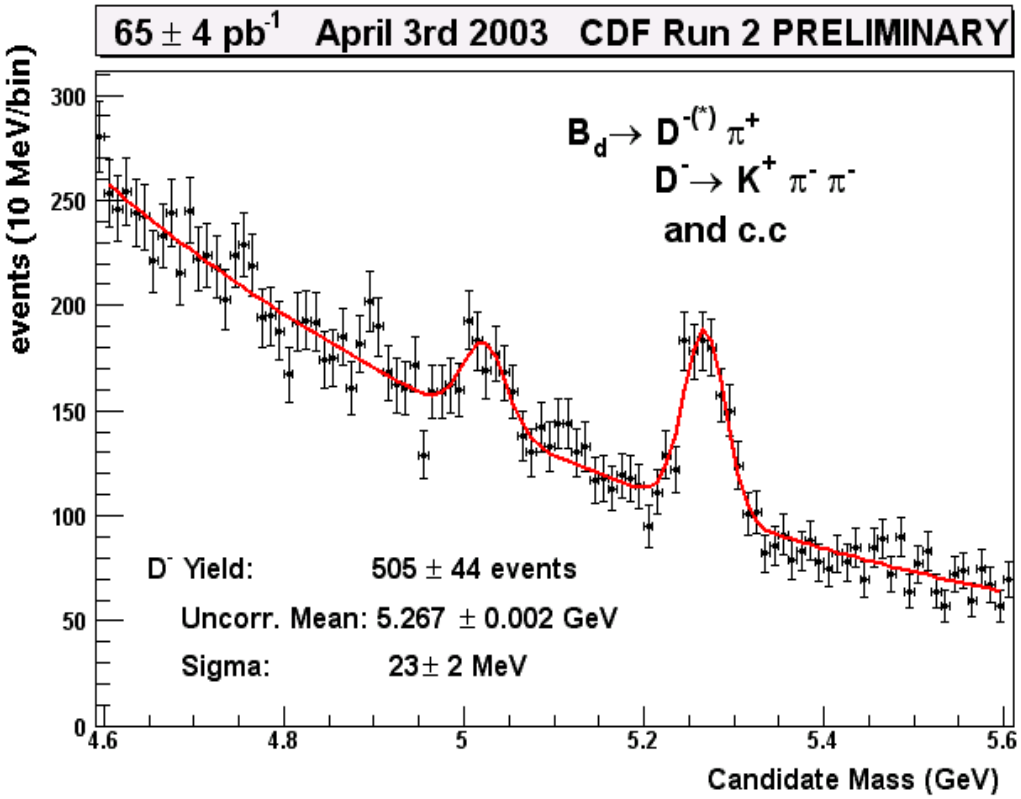
PDG

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



Current status of CDF: Yield Study

$B_d \to D^- \pi^+$, $D^- \to k^+ \pi^- \pi^-$) reconstructed



New !

$$\frac{f_s}{f_d}\frac{Br(B_s \to D_s^- \pi^+)}{Br(B_d \to D^- \pi^+)} = 0.42 \pm 0.11(stat.) \pm 0.11(Br.) \pm 0.07(syst.)$$

Conclusions

CDF starts doing measurements with:

- B_s semileptonic decays
- $B_s \rightarrow J/\psi\varphi$ and fully reconstructed hadronic decays

D0 has less integrated luminosity $\Rightarrow$ tools optimization

Several improvements underway:

- removing trigger rate limit
- SVT increase efficiency

(see Rolf presentation for details)

- flavor tagging optimization B_d mixing measurements for the summer
- add all the other D_s decay channels

Backup slides

CP violation in Standard Model: γ at CDF

1) R. Fleischer proposal:

Fit the asymmetries in the B^0 $\pi^+\pi^-$/B_s K^+K^-

$A_{CP}=A_{CP}(dir)\cos(\Delta m\times t) + A_{CP}(mix)\sin(\Delta m\times t)$

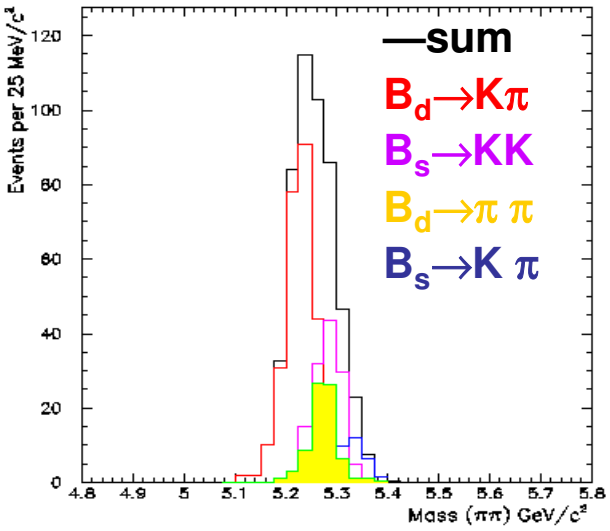
How do we separate $\pi\pi$/$K\pi$/KK/πK:

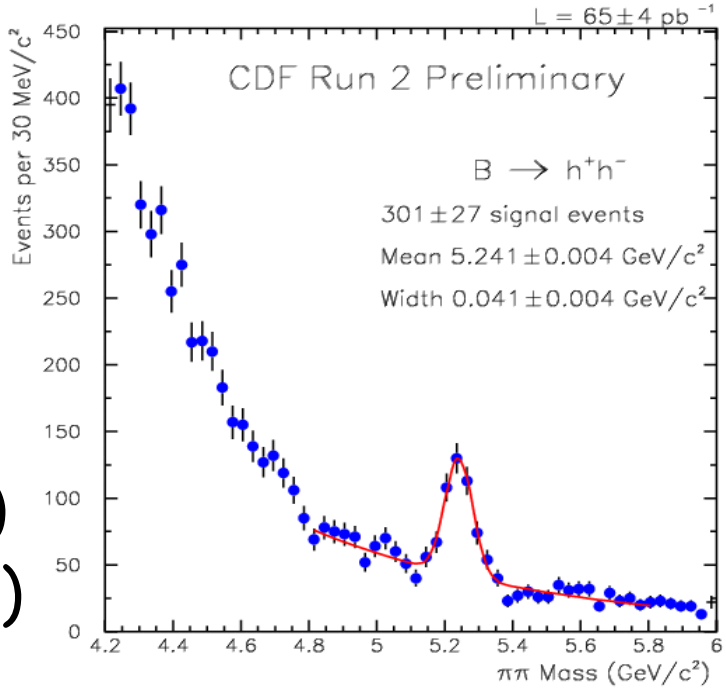
Inv. mass ~ 20 MeV/c2

Kinematical variables

dE/dX

$\Delta Md \ll \Delta Ms$





RunIIa: $\sigma ACP(dir, mix)\sim 0.2$ (B_d $\pi\pi$)

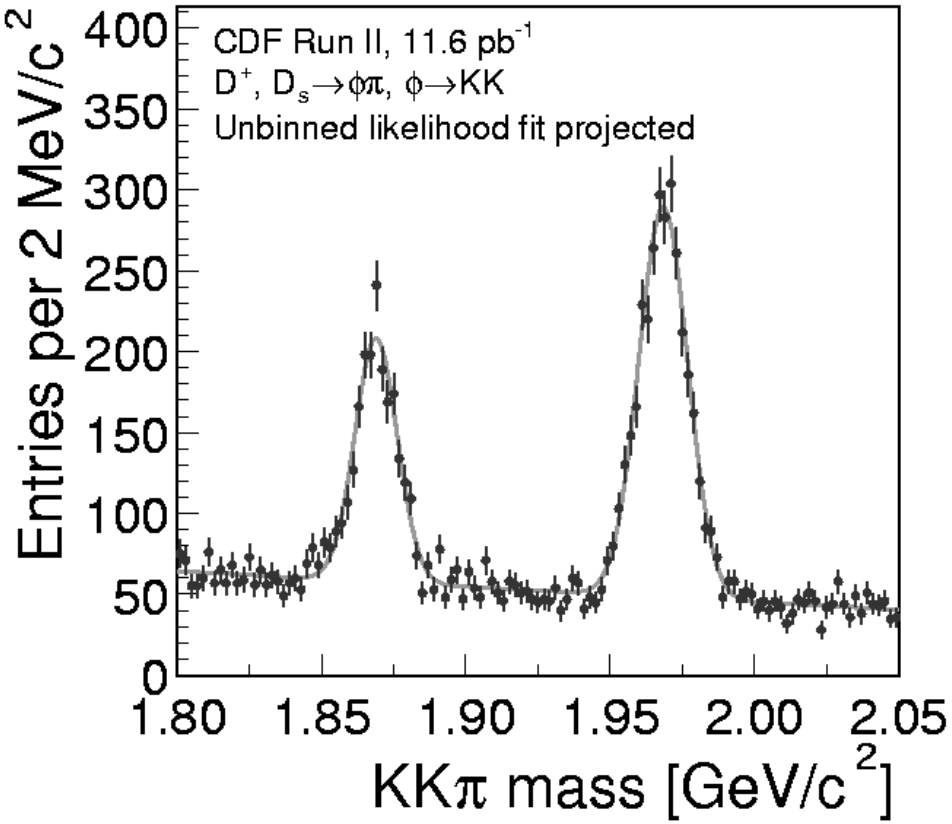
~ 0.1 (B_s KK)

$\sigma(\gamma) = \pm 10^\circ(stat) \pm 3^\circ(theory)$

B_s mixing in fully hadronic decays

Trigger on displaced tracks
Many D_s reconstructed

CDF

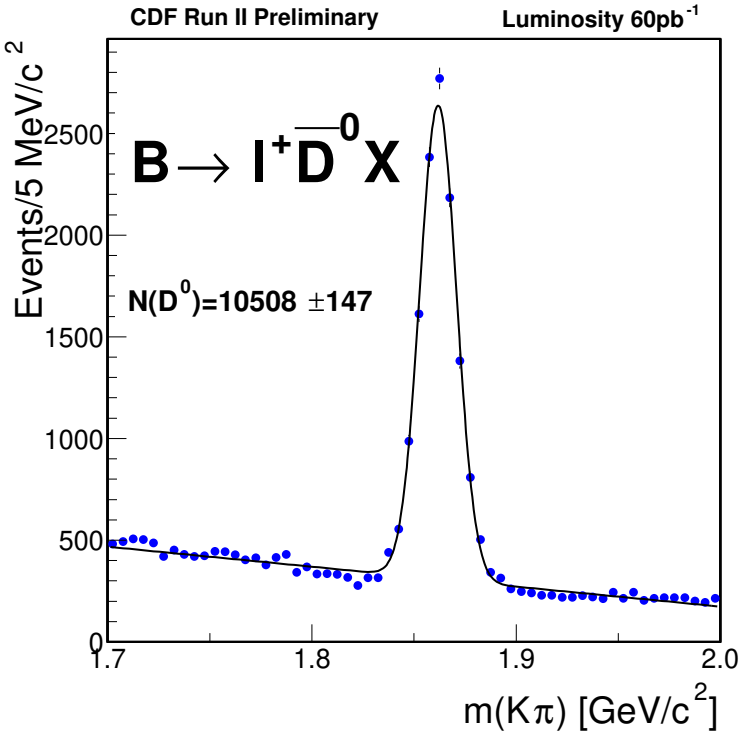


+ $Ds \to \pi\pi\pi$
+ $Ds \to Ks\pi$
+ $Ds \to K^{*0}K^{\mp}$

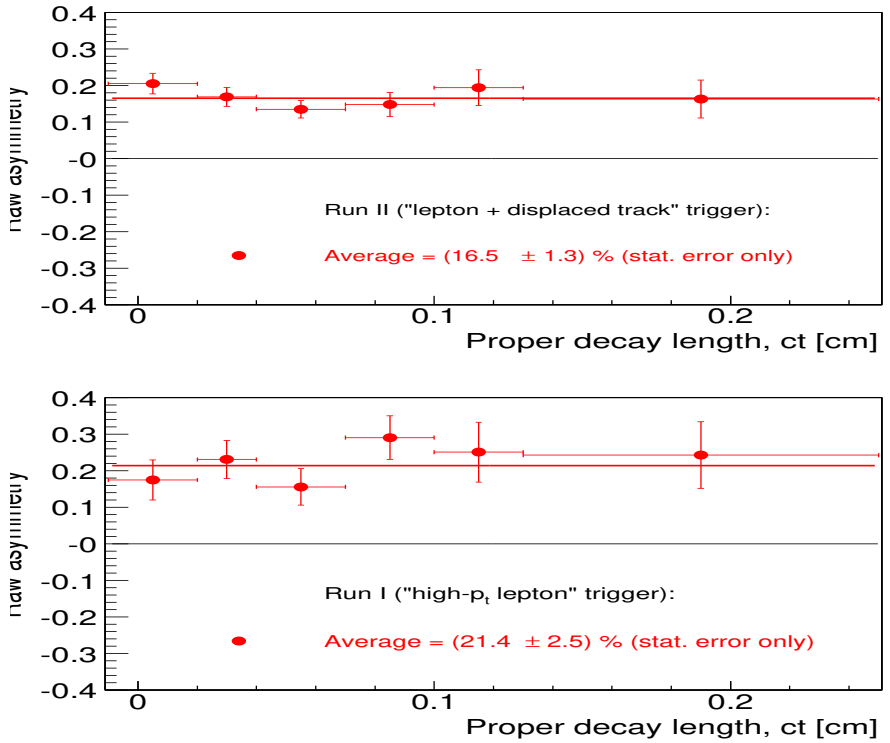
...and the B_s?

B_s mixing at CDF: Flavor tagging

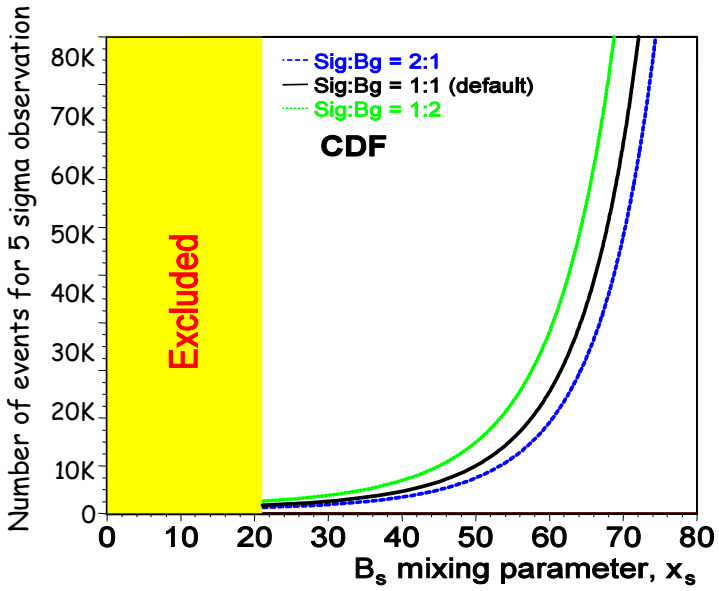
- Lepton (muon and electron) tagging: under optimization in a huge sample of B from the lepton+displaced track trigger
- Same Side Tagging

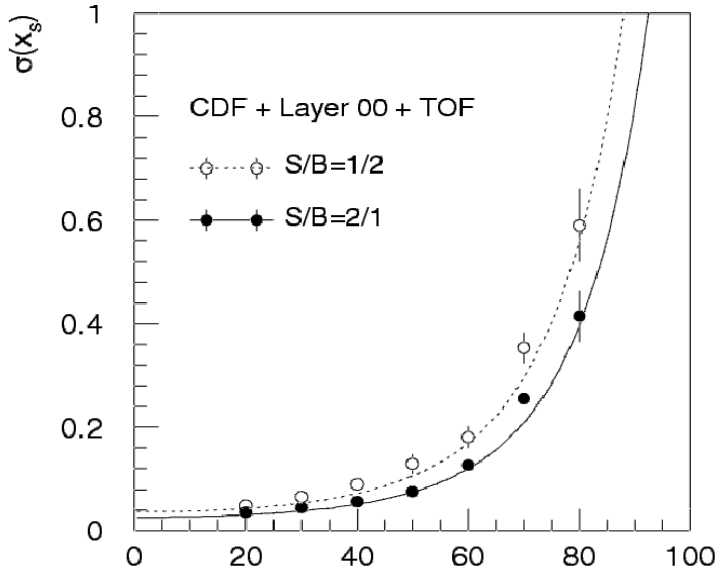


Raw asymmetry plots



$X_s = \Delta m_s \times \tau_{B_s}$ measurement: CDF expectations





Fully reconstructed decays

Decays included

$B^0_s \rightarrow D_s^{\mp}\pi^{\pm}$, $D_s^{\mp}\pi^+\pi^-\pi^{\pm}$

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

Proper time resolution:

σ_t = 45 fs $\oplus$ t · σ_{Pt}/P_t

(L00+SVX)

Tagging:

εD^2 = 11.3 % (all taggers)

S/B:

2:1, 1:1, 1:2

CP violation in Standard Model: γ at CDF

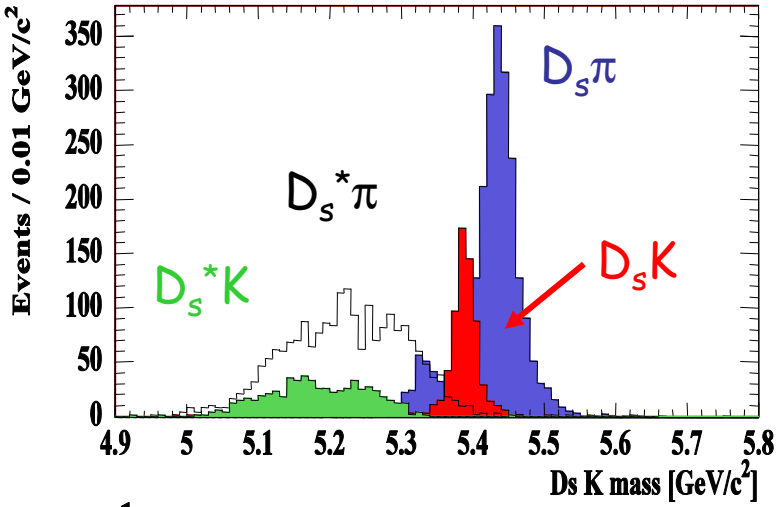
2) R. Aleksan et al. Z Phys. C54 653 (1992) proposal:

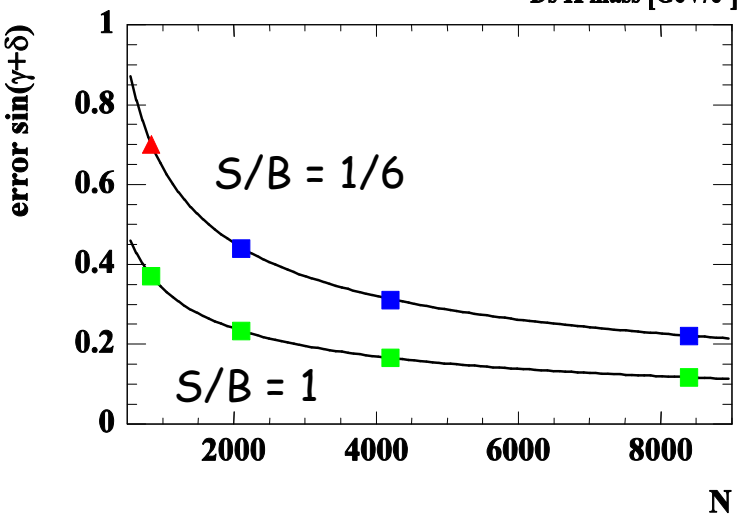
B_s $D_s^{\mp}K^{\pm}$ time dependent decay rate depends on:

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

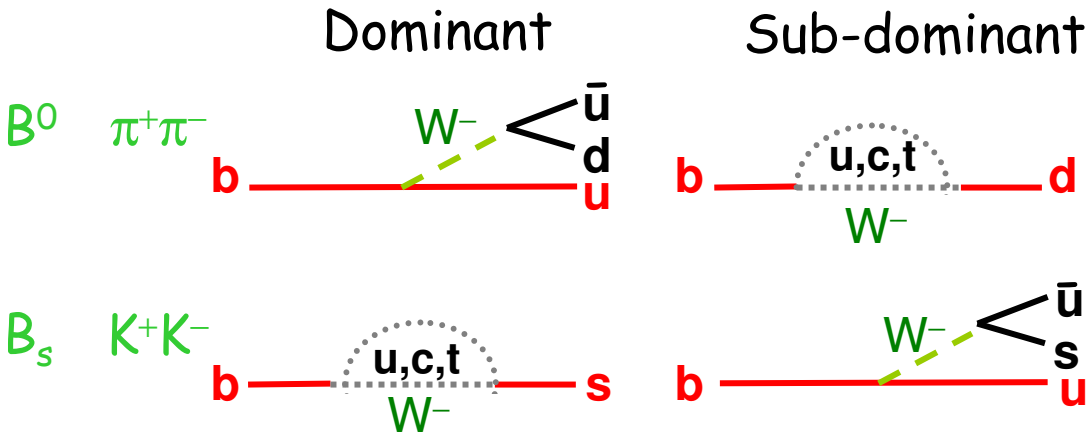
~ 1000 events in RunIIa
~ 3500 events in RunIIb





γ via B0 π+π− / Bs K+K−

- R. Fleischer:
  - B0 π+π− measure sin2(β+γ) (~30% penguins contamination)
  - P/T ratio measurement with a simultaneous fit of Bs K+K− asymmetry



$$A_{CP}(t) = A_{CP}^{dir} \times \cos \Delta M t + A_{CP}^{mix} \times \sin \Delta M t$$

$$A_{CP}^{dir}(\pi\pi) = -2d \sin\theta \sin\gamma + O(d^2)$$

$$A_{CP}^{dir}(KK) = \frac{2\lambda^2}{d(1-\lambda^2)} \sin\theta \sin\gamma + O((\lambda^2/d)^2)$$

$$A_{CP}^{mix}(KK) = \frac{2\lambda^2}{d(1-\lambda^2)} \cos\theta \sin\gamma + O((\lambda^2/d)^2)$$

$$A_{CP}^{mix}(\pi\pi) = \sin 2(\beta+\gamma) + 2d \cos\theta \times [\cos\gamma \sin 2(\beta+\gamma) - \sin(2\beta+\gamma)] + O(d^2)$$

Measurement of 4 asymmetries time dependent

Fit of d=P/T ~ 0.3, θ=strong phase of P/T, γ, β constrained from sin(2β)