# Relative BR of $B_s \rightarrow J/\Psi\ f_0(980)$ to $B_s \rightarrow J/\Psi\ \phi$

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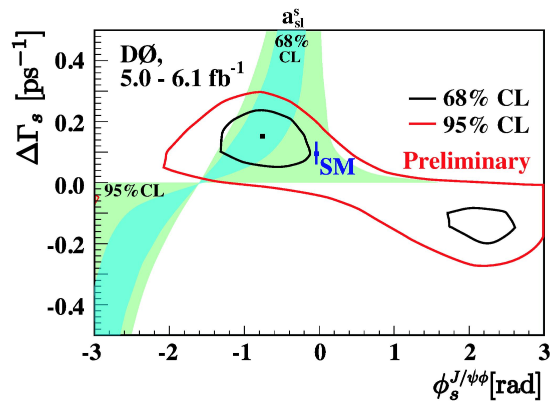
# Introduction

- $B_s \rightarrow J/\psi\ \phi$
  - Golden mode to measure weak CP violating phase $\phi_s$
  - Very sensitive to new physics since $\phi_s \sim 0$ in SM
  - Current measurements have values larger than the SM, but the errors are such that the result is not yet statistically significant.
- Would like to add in other decay modes to measure $\phi_s$
  - Decays based on same tree diagram
  - $B_s \longrightarrow$ VP, PP decays
    (V: Vector, P:Pseudoscalar)




Possible modes (VP,PP)

$$B_s \rightarrow J/\psi f_0(\pi^+\pi^-)$$

$$B_s \rightarrow J/\psi\eta(\gamma\gamma,\pi^+\pi^-\pi^0)$$

$$B_s \rightarrow J/\psi\eta'(\rho\gamma,\pi^+\pi^-\eta)$$

$$B_s \rightarrow J/\psi(e^+e^-)\phi$$

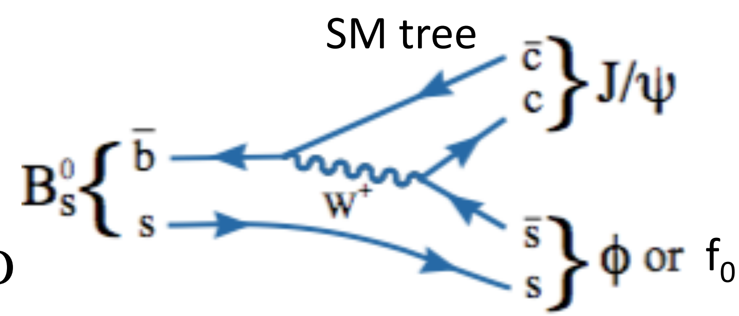
$$B_s \rightarrow \psi(2S)\phi$$

$$B_s \rightarrow \eta_c(4\pi,2\pi 2K,4K(\phi\phi))\phi$$

$$B_s \rightarrow D_s^+D_s^-,D_s^{*+}D_s^{*-}$$

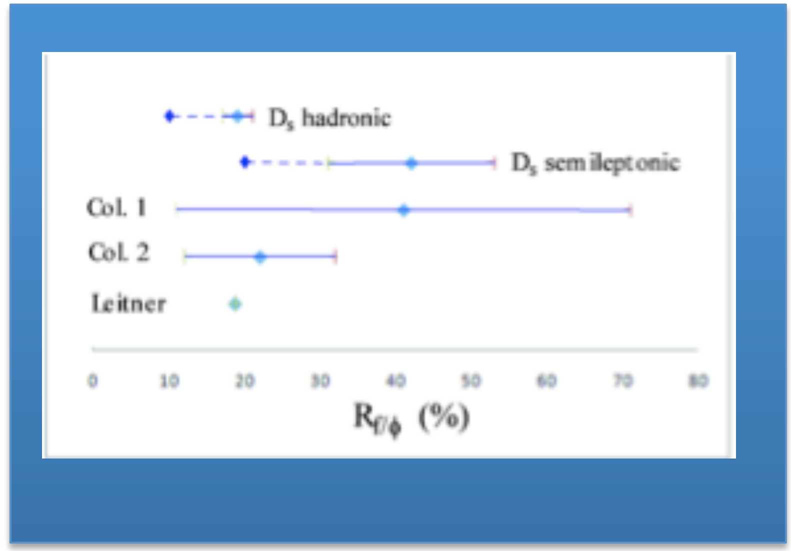
# $J/\psi\ f_0(980)$

- $B_s \to J/\psi\ f_0\ (f_0 \to K^+K^-)$
  - Same final state as $J/\psi\ \phi$
  - Can introduce s-wave $K^+K^-$ component under $\phi$ mass peak
  - Background to $J/\psi\ \phi$
- $B_s \to J/\psi\ f_0\ (f_0 \to \pi^+\pi^-)$
  - Same tree diagram as $B_s \to J/\psi\ \phi$
  - CP odd eigenstate (if $\phi_s \sim 0$)
  - Sensitive to $\Delta\Gamma_s$ and $\phi_s$
- $B_s \to VP$ mode
  - No angular measurement required for measuring $\phi_s$



# Predictions for Relative BR

$$R_{f/\phi} = \frac{\Gamma(B_s \to J/\Psi f_0, f_0 \to \pi^+\pi^-)}{\Gamma(B_s \to J/\Psi\phi, \phi \to K^+K^-)}$$




S. Stone and L. Zhang, PRD 79,074024
P. Colangelo, F. de Fazio and W. Wang, arXiv:1002.2880[hep-ph] and arXiv:1009.4612[hep-ph]
O. Leitner, et al., [arXiv:1003.5980]

Stone and Zhang use $D_s^+ \to K^+K^-\pi^+$
And $D_s^+ \to \phi e^+\nu$ vs $D_s^+ \to f_0 e^+\nu$
Colangelo, de Fazio and Wang use Light Cone Sum Rules
Leitner et al., use QCD factorization

All predict sizeable event rates ~20-40%

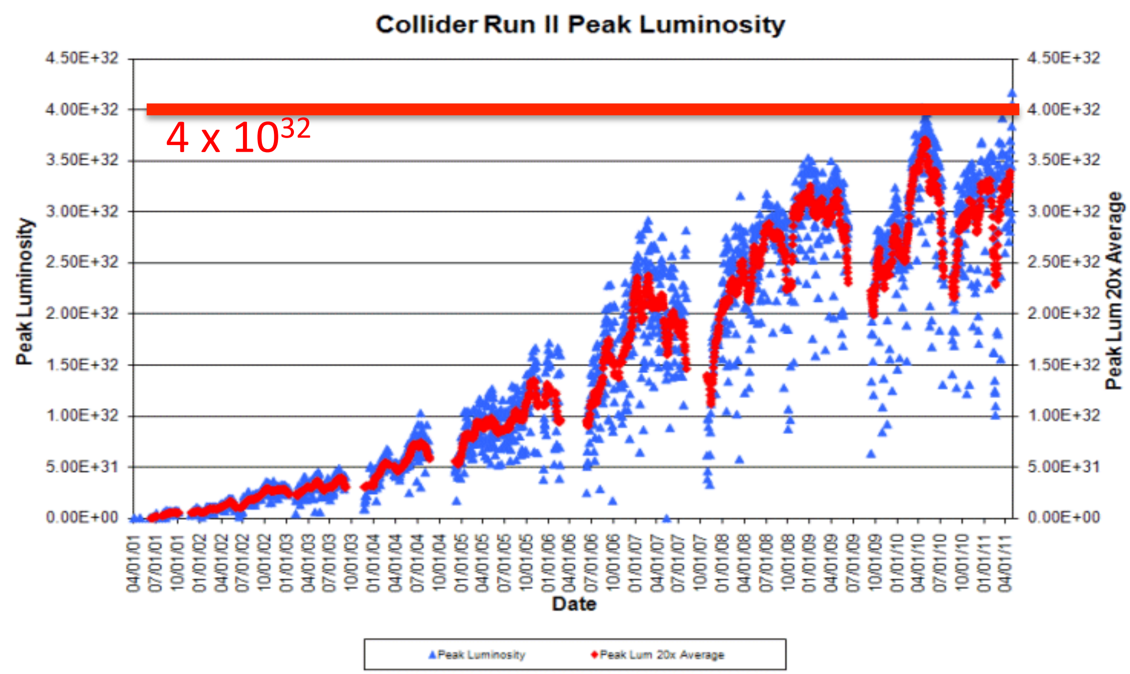
# Relative BR

- Relative BR = $\dfrac{N_{J/\Psi f_0} \bullet \varepsilon(J/\Psi\phi)}{N_{J/\Psi\phi} \bullet \varepsilon(J/\Psi f_0)}$

- All is needed are relative yields and relative reconstruction efficiencies to measure relative BR.

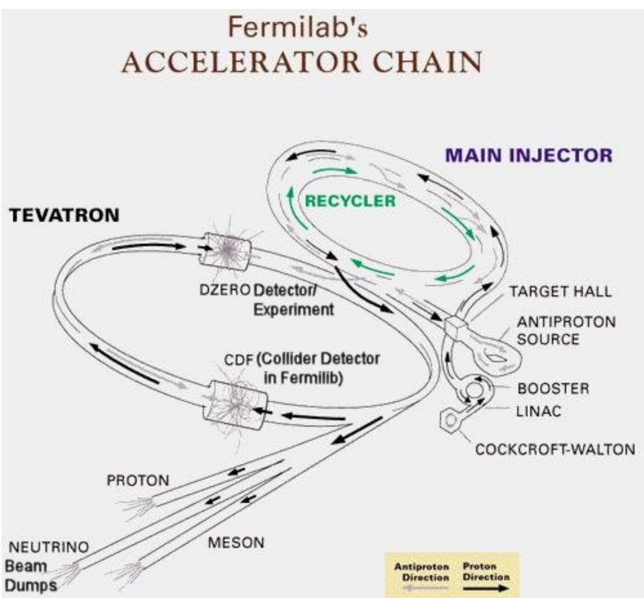
# Environment

Data from $p\bar{p}$ collisions at Tevatron $\sqrt{s}$ = 1.96 TeV
Instantaneous Luminosity ~ 3.5 x $10^{32}$ $cm^{-2}s^{-1}$



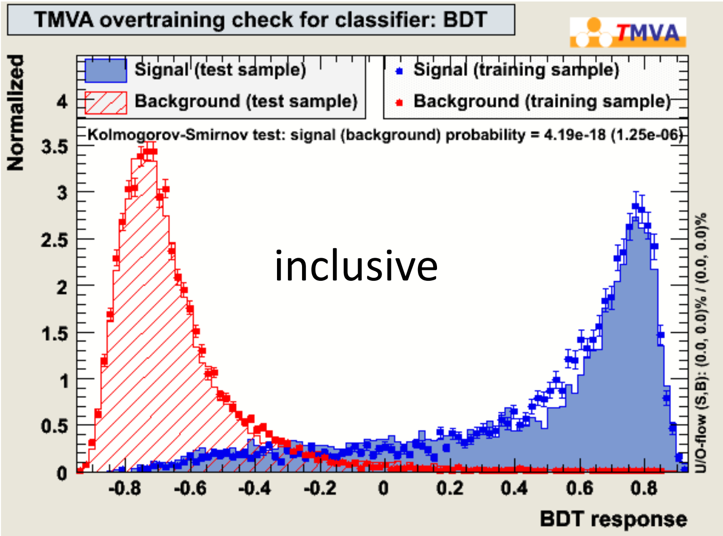

Large $b\bar{b}$ production cross section
~ 40 x $10^6$ $b\bar{b}$ pairs/hour

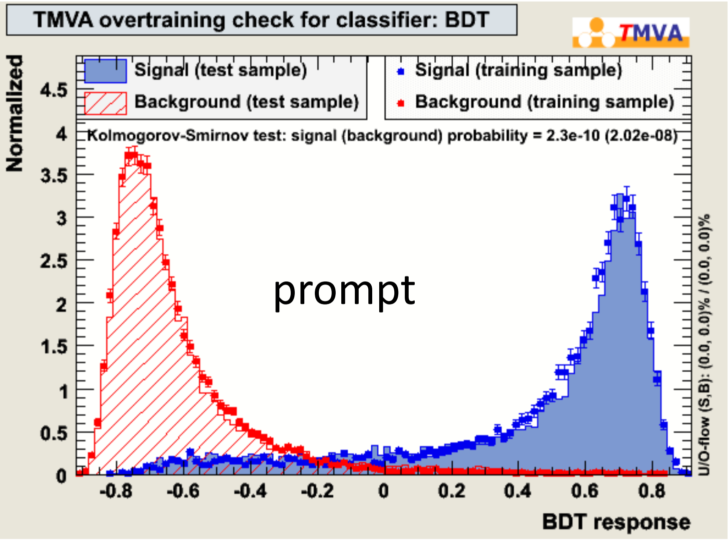
But with large backgrounds



# Boosted Decision Tree

- 2 MC background samples: inclusive($B_s \rightarrow J/\psi$ X) and prompt (directly produced $J/\psi$)
- Signal sample $B_s \rightarrow J/\psi\ f_0(980)$
- 36 variables used to train BDT
- $f_0$ mass not a variable



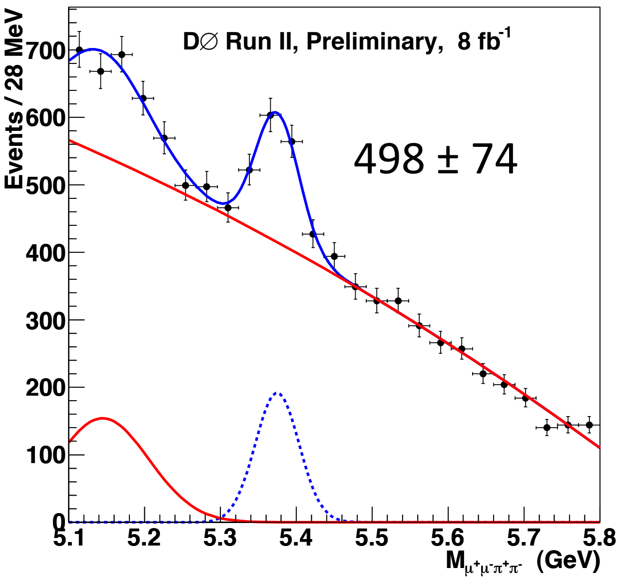



# Analysis cuts

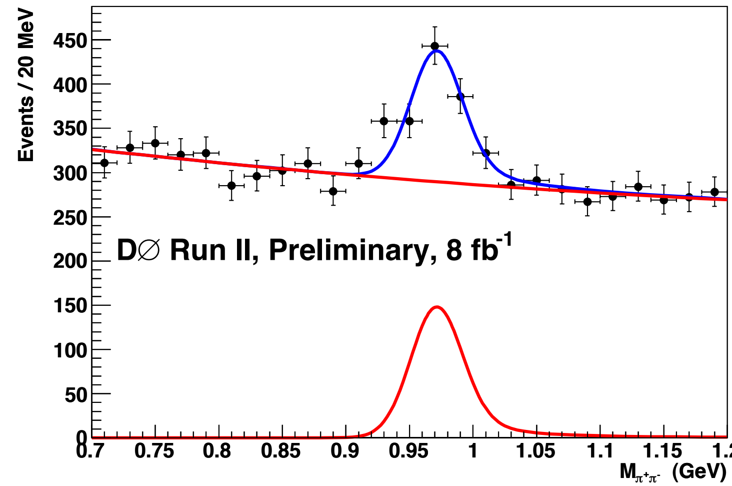
- $J/\Psi \rightarrow \mu^+\mu^-$
  - Good quality muons
  - # hits in silicon tracker>0
  - # hits in fiber tracker>0
  - Good vertex
  - Invariant mass 2.9-3.2 GeV
- $f_0 \longrightarrow \pi^+\pi^-$
  - # hits in silicon tracker>1,
  - # hits in fiber tracker >1
  - # hits in silicon and fiber tracker>7
  - Good vertex
  - mass .91-1.05 ($\phi$ mass : 1.01-1.03 GeV)
- Pion leading $p_t$>1.4 GeV, $B_s$ $p_t$>5 GeV, $f_0$ $p_t$>1.6 GeV, BDT_inclusive>0.35, BDT_prompt>0.35
- All bad runs removed, events that only fired an IP trigger removed.

# Data yields (8 $fb^{-1}$)

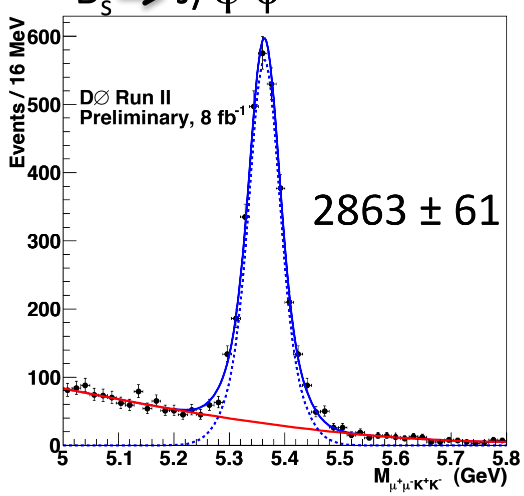
$B_s \rightarrow J/\psi\ f_0$



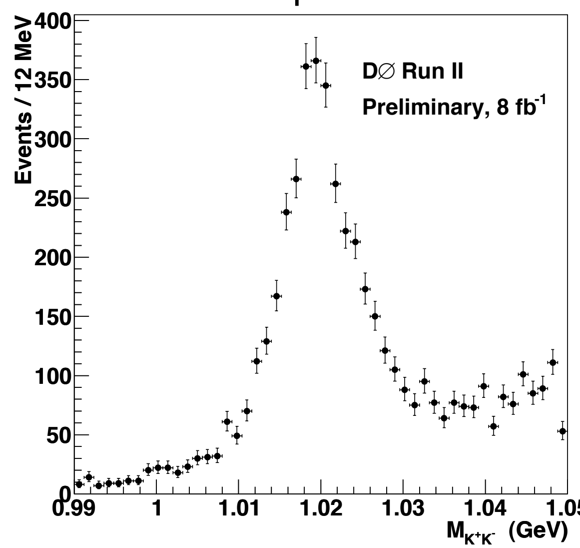

$f_0$



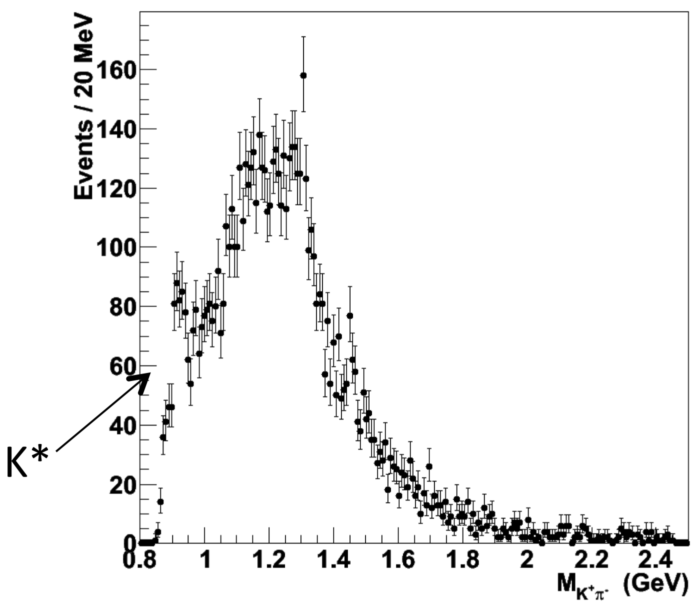

$B_s \rightarrow J/\psi\ \phi$




$\phi$



# Potential Physics Background



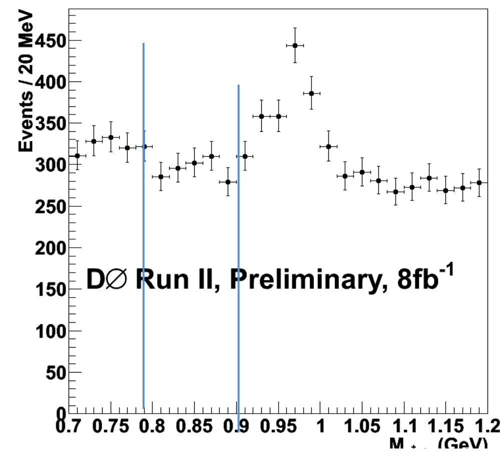

Kπ masses for those events within $B_s \rightarrow J/\psi\ f_0$ mass window

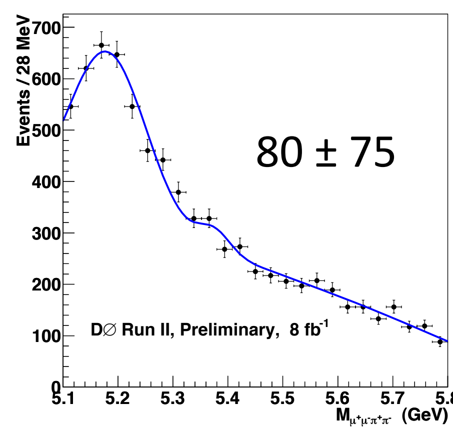
Want to avoid known resonances

B->J/ψ K*(K* → Kπ)

B->ρ X (ρ → ππ)

So choose 0.8-0.9 GeV




No evidence of any ππ non-resonant bkg

# Efficiencies

- Generated MC samples for both $J/\psi\ \phi$ and $J/\psi\ f_0$
- Ran analysis code over samples to determine reconstruction efficiencies.
- Samples have a 0.4 GeV pion/kaon preselection cut during generation so also need to determine efficiency of preselection cut on both samples
- Preselection cut efficiencies
  - $J/\psi\ \phi$ : 0.795 ± 0.011
  - $J/\psi\ f_0$ : 0.594 ± 0.010
- Relative efficiencies
  - RunIIa: 1.21 ± 0.03
  - RunIIb1: 1.31 ± 0.04
  - RunIIb2: 1.20 ± 0.05

Data collected in 4 periods with different average instantaneous luminosities
RunIIa (1.4 $fb^{-1}$)
RunIIb1(1.4 $fb^{-1}$)
RunIIb2(3.3 $fb^{-1}$)
RunIIb3(2.1 $fb^{-1}$)

# 8 $fb^{-1}$ Systematics

- Vary cuts around nominal to see effects

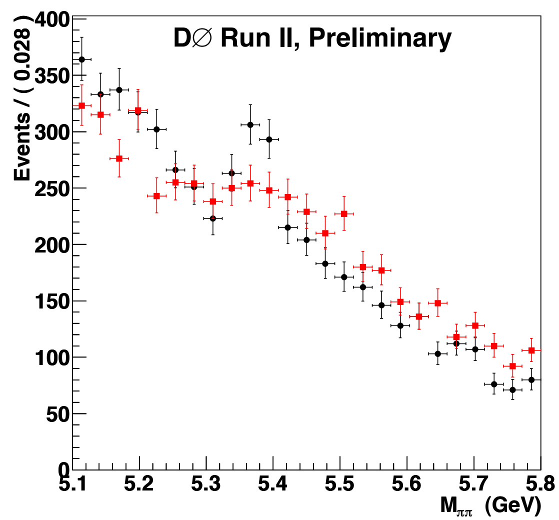
| cut | Affect on R |
|---|---|
| **Bdt inclusive > 0.3** | **.958** |
| Bdt prompt >0.3 | .1.007 |
| Bdt inclusive > 0.4 | .982 |
| Bdt prompt > 0.4 | .99 |
| B pt >5.5 | .95 |
| B pt >4.5 | .9939 |
| f0 pt > 1 | 1 |
| f0 pt > 2 | .993 |
| K leading pt > 1.0 | 1.059 |
| K leading pt > 1.8 | .88 |
| Decay length sig >4 | 1.008 |
| Decay length sig >5 | 1.02 |

# Systematics: fitting choices

| Nominal Fit | 498 ± 74 |
|---|---|
| 3rd degree bkg function | 446 ± 72 |
| Exponential bkg function | 423 ± 67 |
| Fit range 5.1-5.6 | 437 ± 78 |
| Fit range 5.15-5.8 | 427 ± 63 |
| Fit range 5.05-5.8 | 449 ± 71 |

Fairly large variation with fitting choices

Biggest Systematic

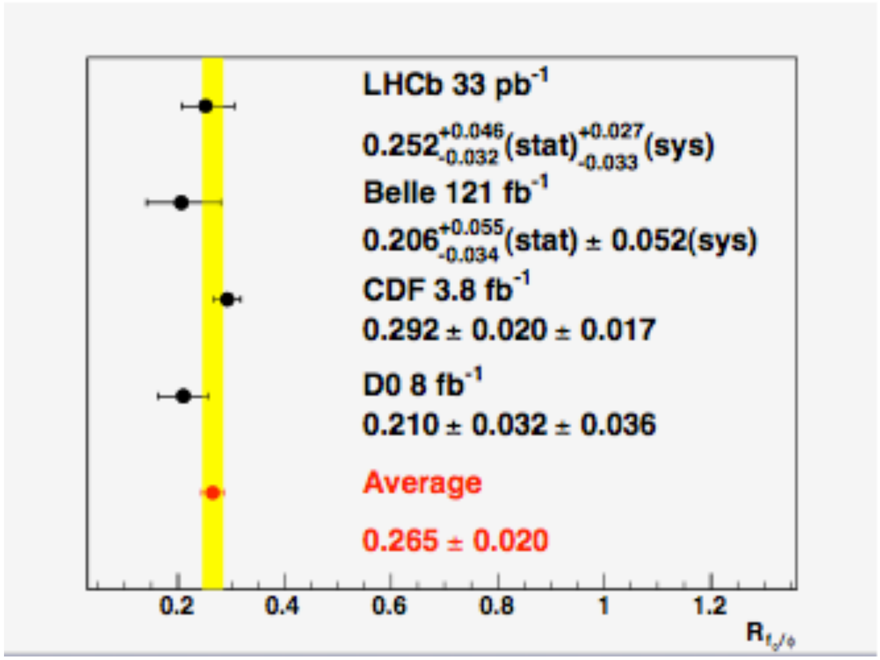



Black: opp sign pions

Red: same sign pions

# Preliminary Result

$$R_{f/\phi} = \frac{\Gamma(B_s \to J/\Psi f_0, f_0 \to \pi^+\pi^-)}{\Gamma(B_s \to J/\Psi \phi, \phi \to K^+K^-)} = 0.210 \pm 0.032(\text{stat}) \pm 0.036(\text{syst.})$$

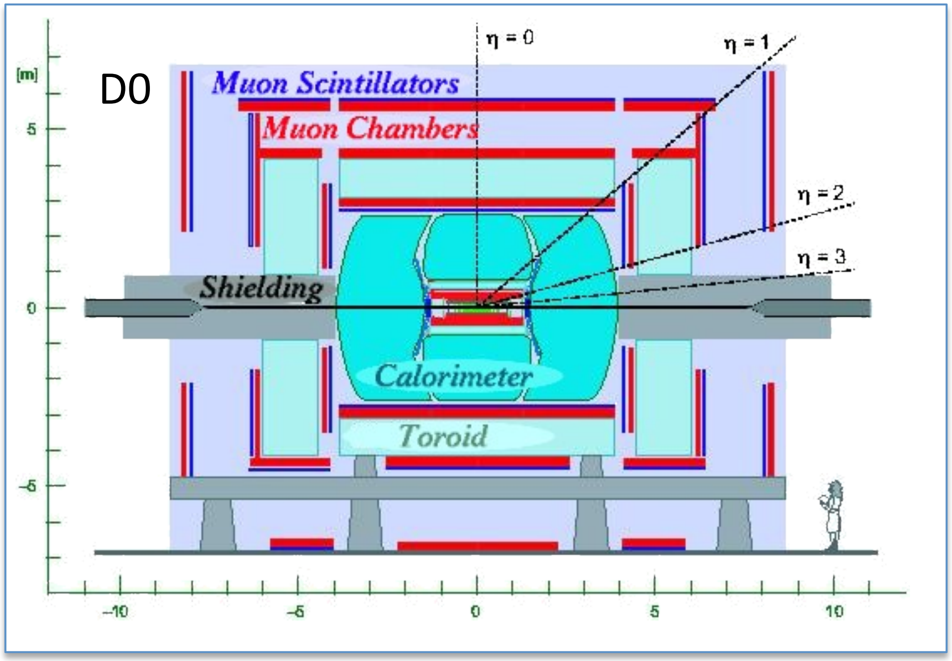


# Conclusions

- Results consistent with previous measurements and theoretical predictions.
- Large relative branching ratio make this mode promising for measuring $\Delta\Gamma_S$ and $\phi_s$
- Currently working on extracting $\Delta\Gamma_S$ and $\phi_s$ from data.

# BACKUP

# Detector




Good muon ID with wide acceptance $|\eta|<2$

Improved vertex detector with Layer 0 inserted in 2006

Very good data taking efficiency
Selective triggers to deal with high instantaneous luminosity

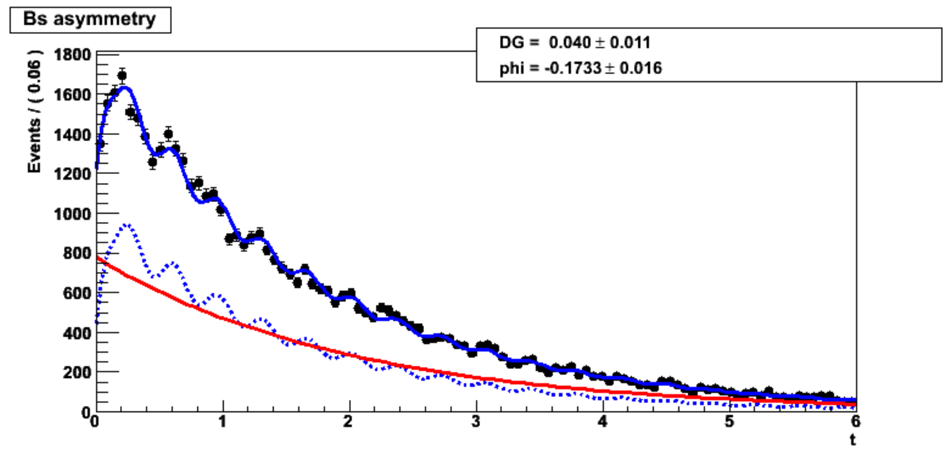
# Measuring $\phi_s$ (eventually)

Lifetime ~ $e^{-\Gamma t}\{\cosh \Delta\Gamma t/2 + \cos(\phi_s)\sinh\Delta\Gamma t/2 \pm \sin(\phi_s)\sin(\Delta m_s t)\}$

+ sign $\overline{B}_s$
- sign $B_s$

Toy MC

Red- background
Blue dotted -signal
Blue solid - signal+bkg




Flavor tagging required