DØ Results on
$B_d \to J/\psi + K^*$ and $B_s \to J/\psi + \phi$
Decay Parameters

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Outline

- Overview.
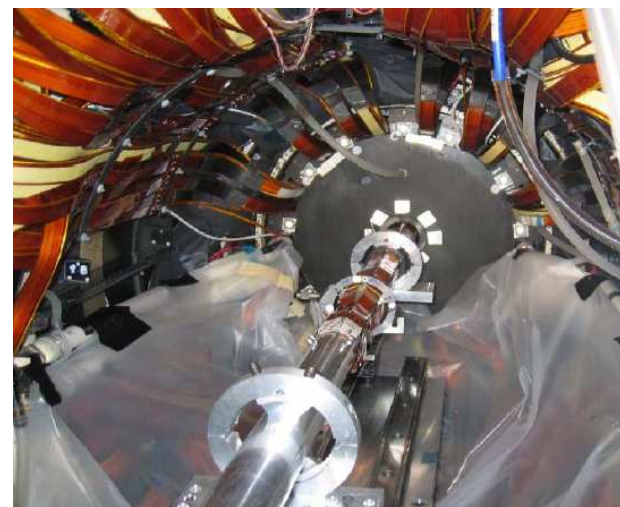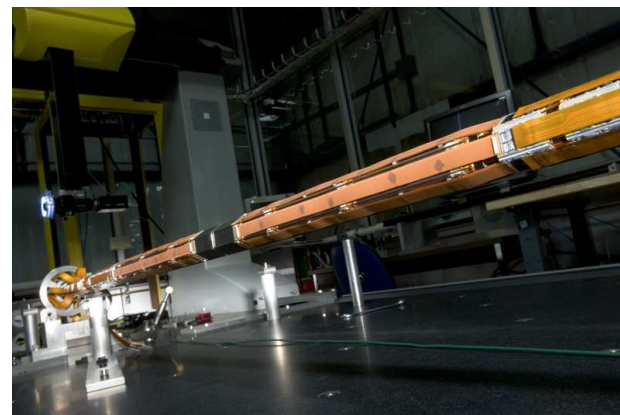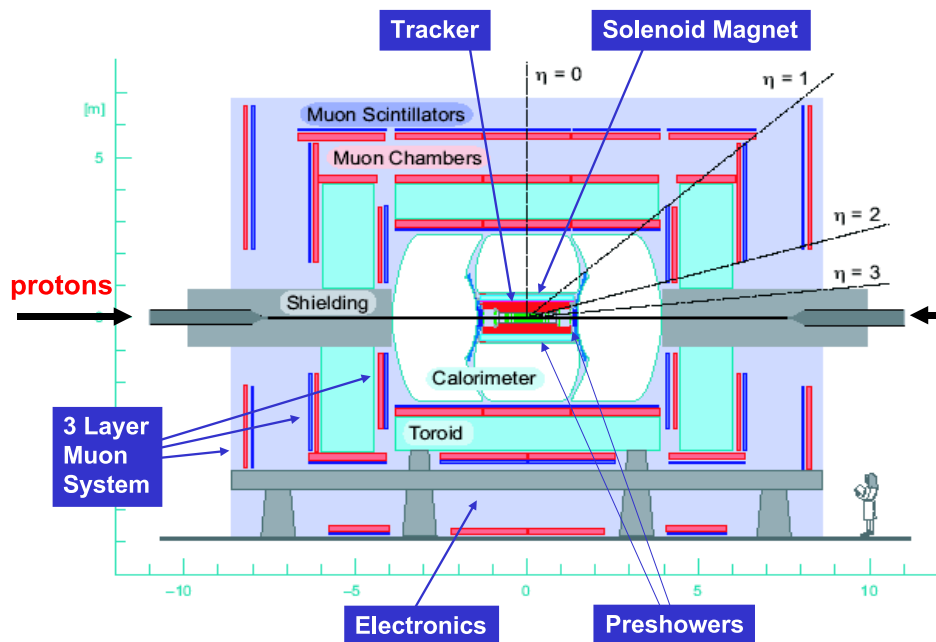
- DØ Detector.

- $B_q \to J/\psi + V$ Color suppressed decays.

- Untagged measurements of $B_d \to J/\psi + K^*$ & $B_s \to J/\psi + \phi$ decays [1]:

  ❖ Angular and lifetime decay parameters.

- Tagged measurements of $B_s \to J/\psi + \phi$ [2]:

  ❖ Lifetime difference & CP-violating phase.

- Summary.

DØ Detector

- $\int \mathcal{L}\, dt = 2.8$ fb^{-1} & $> 90\%$ data taking eff.

- Large muon acceptance

- Excellent muon trigger

- Silicon vertex detector—*recently added additional inner layer (L0) w/25% improvement in proper time resolution.*
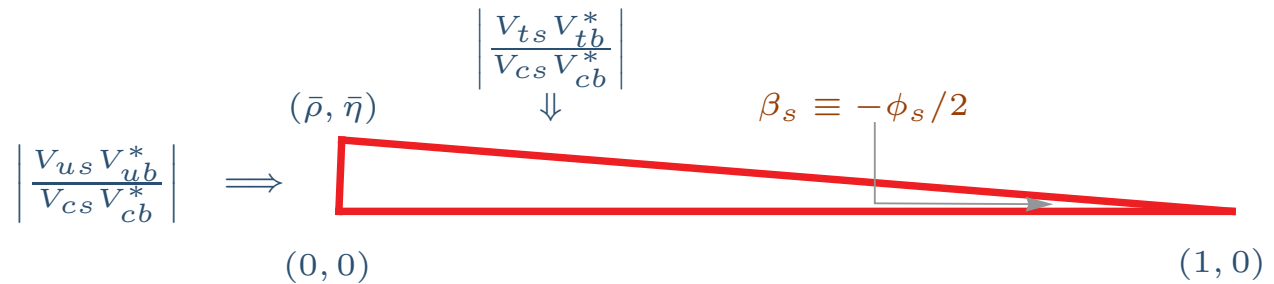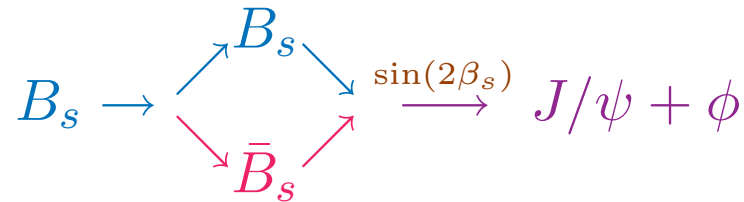
CP-Violation

- B mesons fertile ground for CP-violation studies;

  ❖ $B_s \to J/\psi + \phi$ CP-violation through mixing;

$$B_s \to \quad \nearrow B_s \searrow \quad \xrightarrow{\sin(2\beta_s)} \quad J/\psi + \phi$$
$$\searrow \bar{B}_s \nearrow$$

$$\left| \frac{V_{us} V_{ub}^*}{V_{cs} V_{cb}^*} \right| \Longrightarrow \qquad (\bar{\rho}, \bar{\eta}) \qquad \left| \frac{V_{ts} V_{tb}^*}{V_{cs} V_{cb}^*} \right| \Downarrow \qquad \beta_s \equiv -\phi_s/2$$

$$(0,0) \qquad\qquad\qquad\qquad\qquad\qquad (1,0)$$

Area $\propto$ level of CPV   Interference $\propto \sin(2\beta_s)$

- $B_d \to J/\psi + K^{*0}$ no CP-violation expected.

Angular Analysis

● Extraction of CP eigenstates through angular analysis

$$\frac{d^4 \mathcal{P}}{d\vec{\omega}dt} = \sum_{i=1}^{6} g_i(A, \Gamma, \Delta M; t) f_i(\vec{\omega})$$
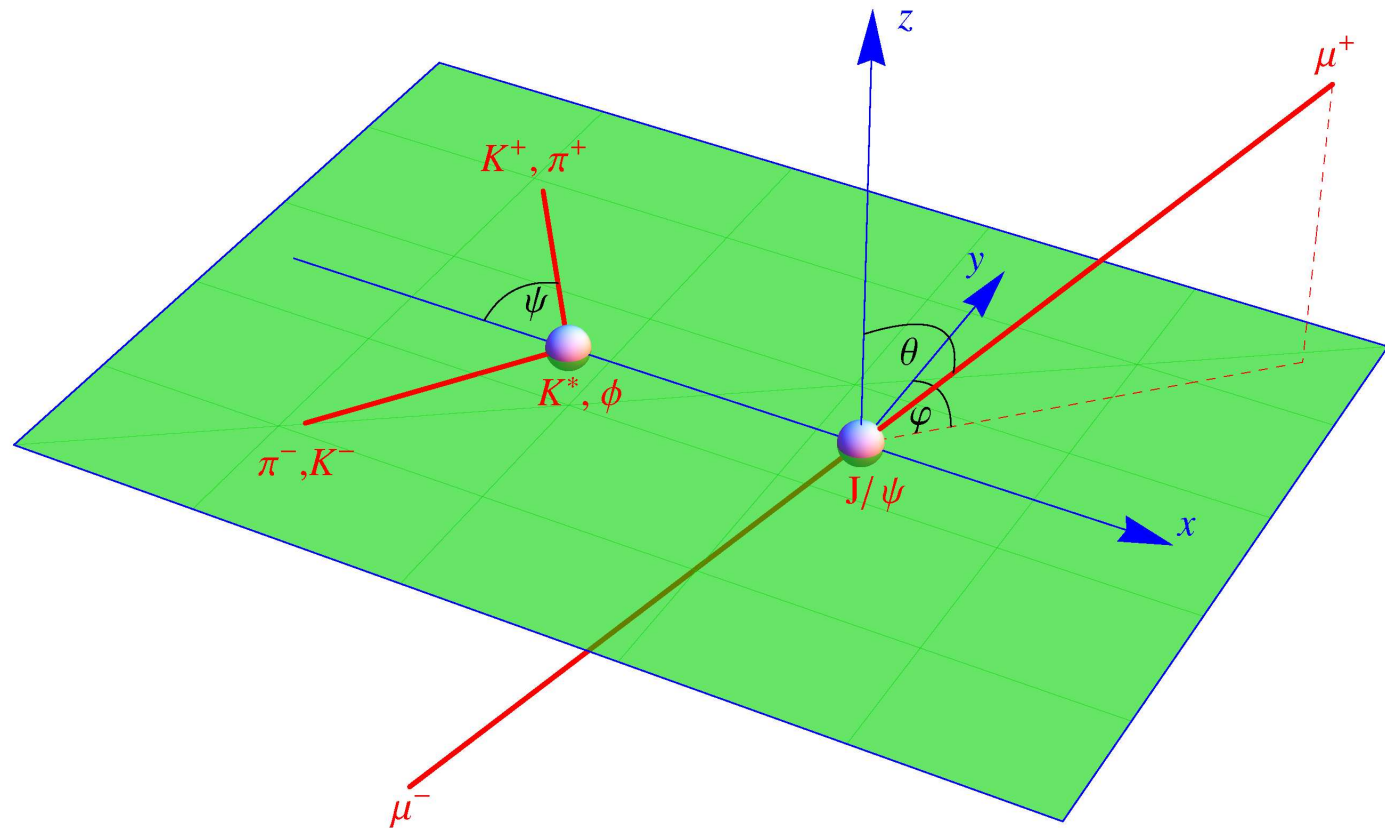
● $B_q \to J/\psi + V \quad \Rightarrow \quad$ Spin $0 \to 1 + 1 \quad \Rightarrow \quad L = 0, 1, 2$

  ❖ A_0: Both longitudinal polarization ($L = 0, 2$ CP-even)

  ❖ $A_{||}$: transverse polarization both same ($L = 0, 2$ CP-even)

  ❖ $A_\perp$: transverse polarization the 2 $\perp$ ($L = 1$ CP-odd)

● ΔM: mass difference of mass eigenstates.

● $\Gamma_{L,H}$: lifetime of two mass eigenstates.

  ❖ Since CP phase expected to be small, CP and mass eigenstates approximately the same $\Delta\Gamma_s = \Delta\Gamma_{CP} \cos\phi_s \approx \Delta\Gamma_{CP}$
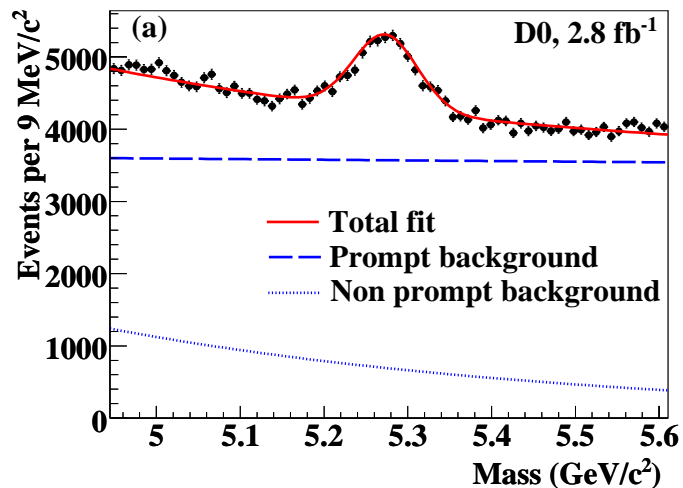
J/ψ Rest Frame

Angles in respective particle's rest frames

Untagged Analysis
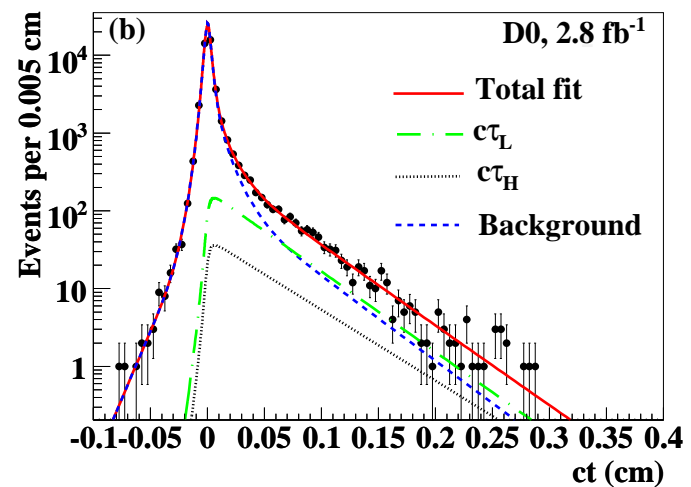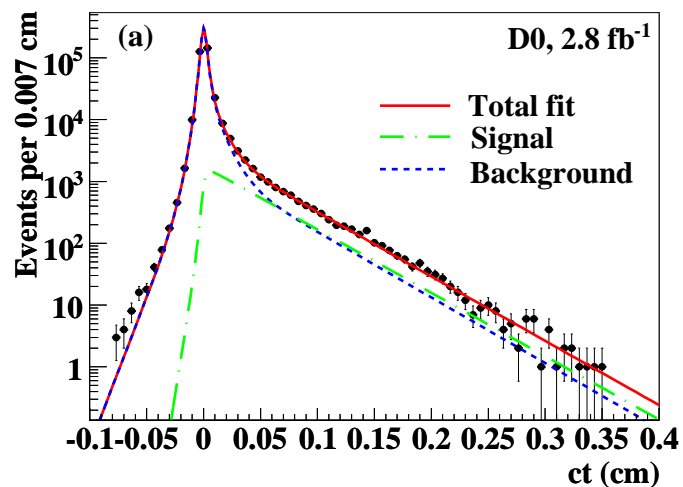
Results Untagged
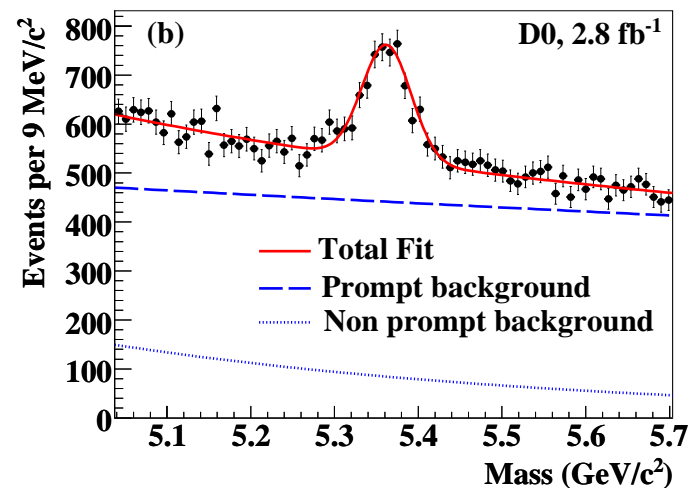
Untagged analysis independent of ΔM,   Assumed $\phi_s = 0$

Parameter	B_d^0	B_s^0	Units
$|A_0|^2$	$0.587 \pm 0.011 \pm 0.013$	$0.555 \pm 0.027 \pm 0.006$	$-$
$|A_\parallel|^2$	$0.230 \pm 0.013 \pm 0.025$	$0.244 \pm 0.032 \pm 0.014$	$-$
δ_1	$-0.38 \pm 0.06 \pm 0.090$	$-$	rad
δ_2	$3.21 \pm 0.06 \pm 0.06$	$-$	rad
$\delta_\parallel$	$-$	$2.72^{+1.12}_{-0.27} \pm 0.26$	rad
τ	$1.414 \pm 0.018 \pm 0.034$	$1.487 \pm 0.060 \pm 0.028$	ps
$\bar{\tau}_s/\tau_d$	$1.053 \pm 0.061 \pm 0.015$		
$\Delta\Gamma_s$	$-$	$0.085^{+0.072}_{-0.078} \pm 0.001$	ps^{-1}
N_{sig}	11195 ± 167	1926 ± 62	$-$

Relative Strong Phases $= \left\{ \begin{array}{l} \delta_1 = \delta_\perp - \delta_\parallel \\ \delta_2 = \delta_\perp \end{array} \right\}$ with $\delta_0 = 0$

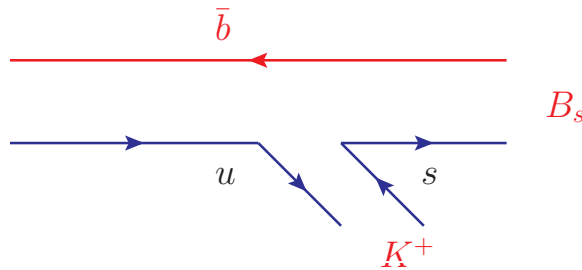$\delta_i = 0 \mod (\pi) \quad \Rightarrow \quad$ Factorization

DØ result $\delta_1 = -0.38 \pm 0.06 \pm 0.09$ 3.5σ from 0 ie nonzero Final State Strong Interactions
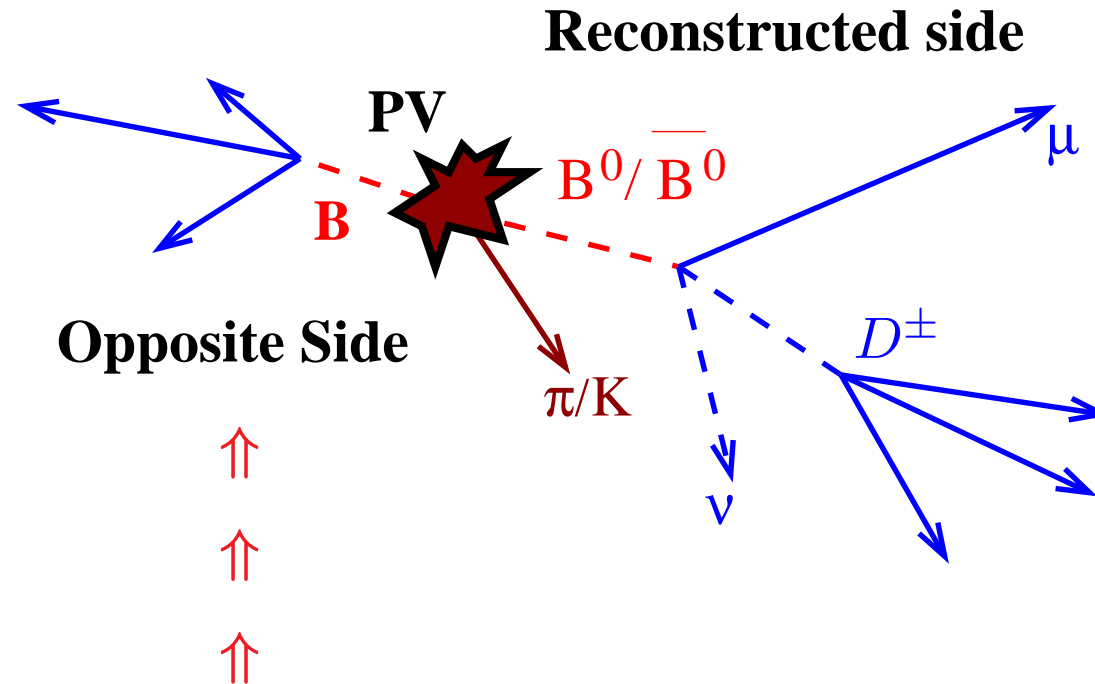
SU(3) Symmetry holds

$B_s \to J/\psi + \phi$ *Tagged Analysis*

$$\bar{b} \to B_s(\bar{b}s) + K^+(\bar{s}u) + \cdots$$

Select $p_t > 500$ MeV, $\Delta R_{\min}$

$\Downarrow$

Exploit fact b's produced in pairs ($b\bar{b}$)

Discriminating Variables

- **Same side tagging**

  - ❖ K^+ tagging $Q_{\Delta R} = q \cdot \Delta R$

  - ❖ Jet charge $Q_{\text{jet}} = \sum_i q^i (p_T^i)^{0.6} / \sum_i (p_T^i)^{0.6}$

- **Opposite side tagging** $\cos \phi(\vec{\mathbf{p}}_i, \vec{\mathbf{p}}_B) < 0.8$

  - ❖ Lepton jet charge $Q_\ell = \sum_i q^i (p_T^i) / \sum_i (p_T^i)$

  - ❖ Secondary vertex charge $Q_{\text{SV}} = \sum_i q^i (p_T^i)^{0.6} / \sum_i (p_T^i)^{0.6}$

  - ❖ Event charge $Q_{\text{EV}} = \sum_i q^i (p_T^i) / \sum_i (p_T^i)$

- Discriminating variables combined using likelihood ratio.

  - ❖ Tagging power $\mathcal{P} = \epsilon \mathcal{D}^2 = (4.68 \pm 0.54)\%$
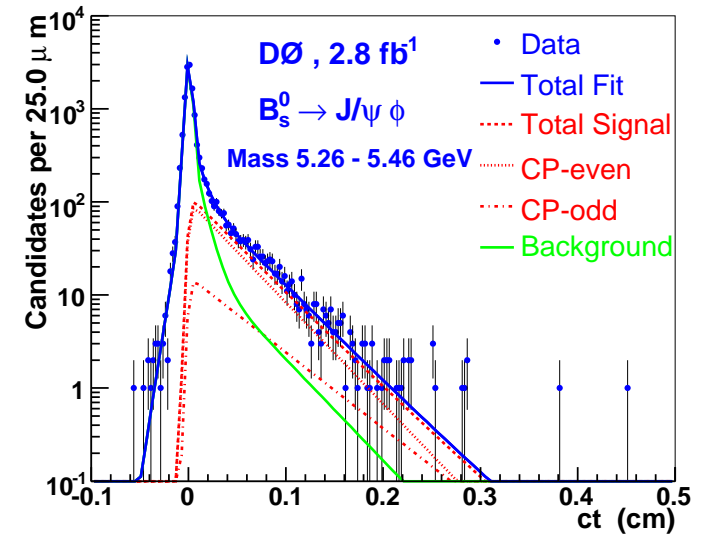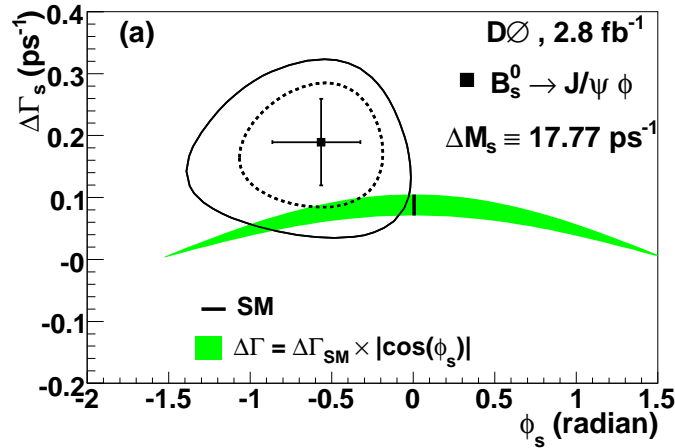
Angular Distributions
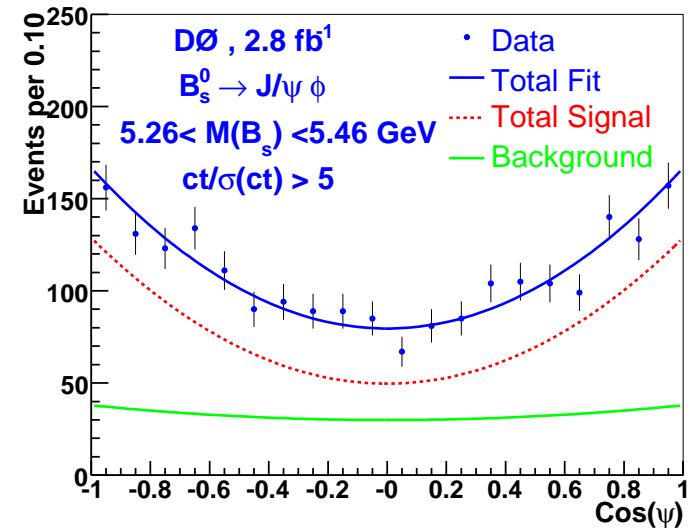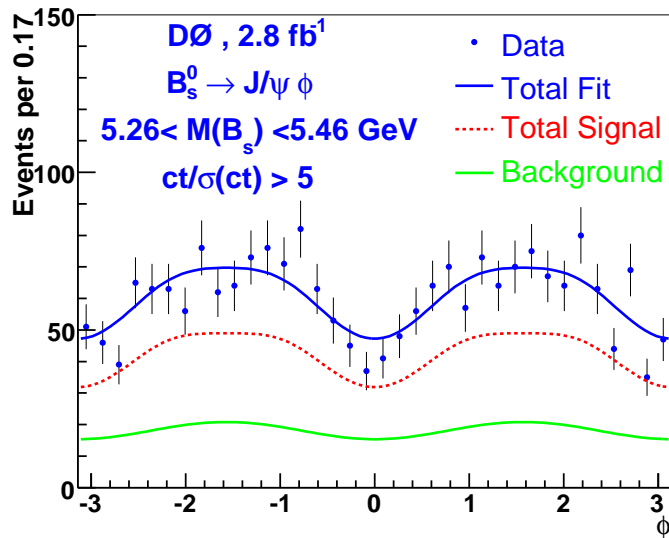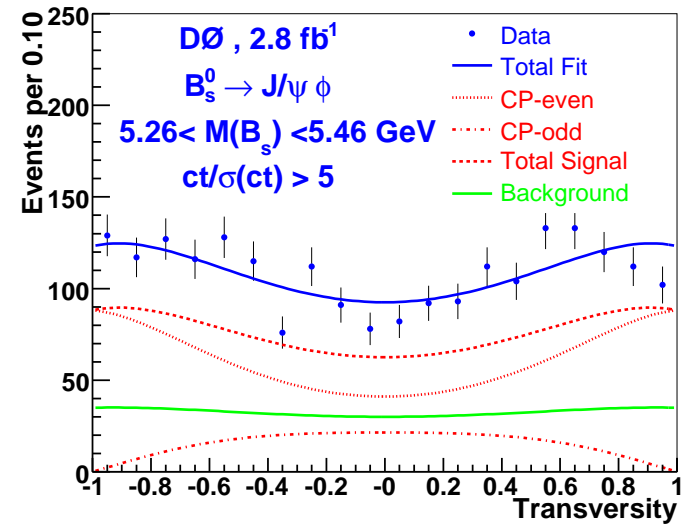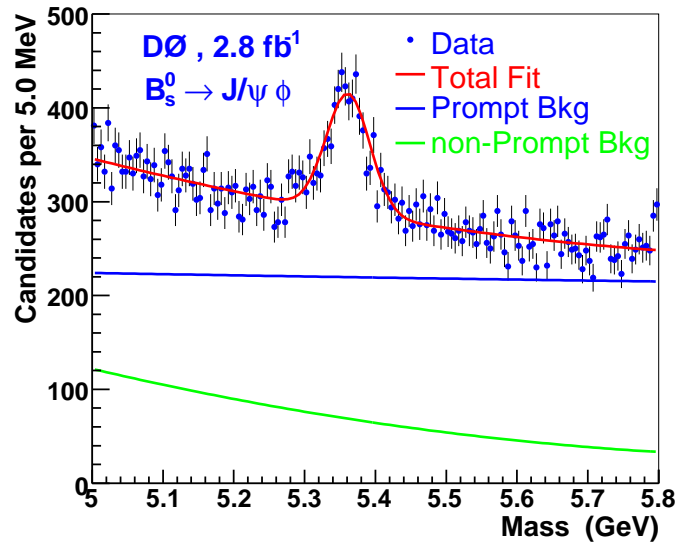
Results Tagged

	δ_i Constrained	δ_i Free ($\Delta\Gamma_s > 0$)
$\overline{\tau}_s$ (ps)	$1.52 \pm 0.06 \pm 0.01$	1.52 ± 0.06
$\Delta\Gamma_s$ (ps^{-1})	$0.19 \pm 0.07^{+0.02}_{-0.01}$	0.20 ± 0.07
$A_\perp(0)$	$0.41 \pm 0.04^{+0.01}_{-0.02}$	0.41 ± 0.04
$|A_0(0)|^2 - |A_{||}(0)|^2$	$0.34 \pm 0.05 \pm 0.03$	0.34 ± 0.05
δ_1	-0.52 ± 0.42	$-0.18 \pm 0.90,\ 1.05 \pm 0.59$
$\delta_1 - \delta_2$	2.59 ± 0.29	$2.61 \pm 0.28,\ -2.61 \pm 0.29$
ϕ_s	$-0.57^{+0.24+0.08}_{-0.30-0.02}$	$-0.59^{+0.31}_{-0.28}$
ΔM_s (ps^{-1}) [3]	$\equiv 17.77$	$\equiv 17.77$

Summary

● Have made measurements of decay parameters of color suppressed $B_q \to J/\psi + V$ decays with 2.8 fb^{-1};

● Found SU(3) symmetry holds;

● δ_1 3.5σ from zero, therefore final state strong interactions must be considered;

● $\phi_s \equiv -2\beta_s = -0.57^{+0.24}_{-0.30}$ and $\Delta\Gamma_s = 0.19 \pm 0.16$ measured;

● Improvements expected with $\gtrsim 6$ fb^{-1} DØ has collected.

References

[1] V.M. Abazov *et al.* (DØ Collaboration), Phys. Rev. Lett. **102**, 032001 (2009).

[2] V.M. Abazov *et al.* (DØ Collaboration), Phys. Rev. Lett. **101**, 241801 (2009).

[3] A. Abulencia *et al.* (CDF Collaboration), Phys. Rev. Lett. **97**, 242003 (2006).