Recent results on CP violation from DØ experiment

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The DØ Collaboration

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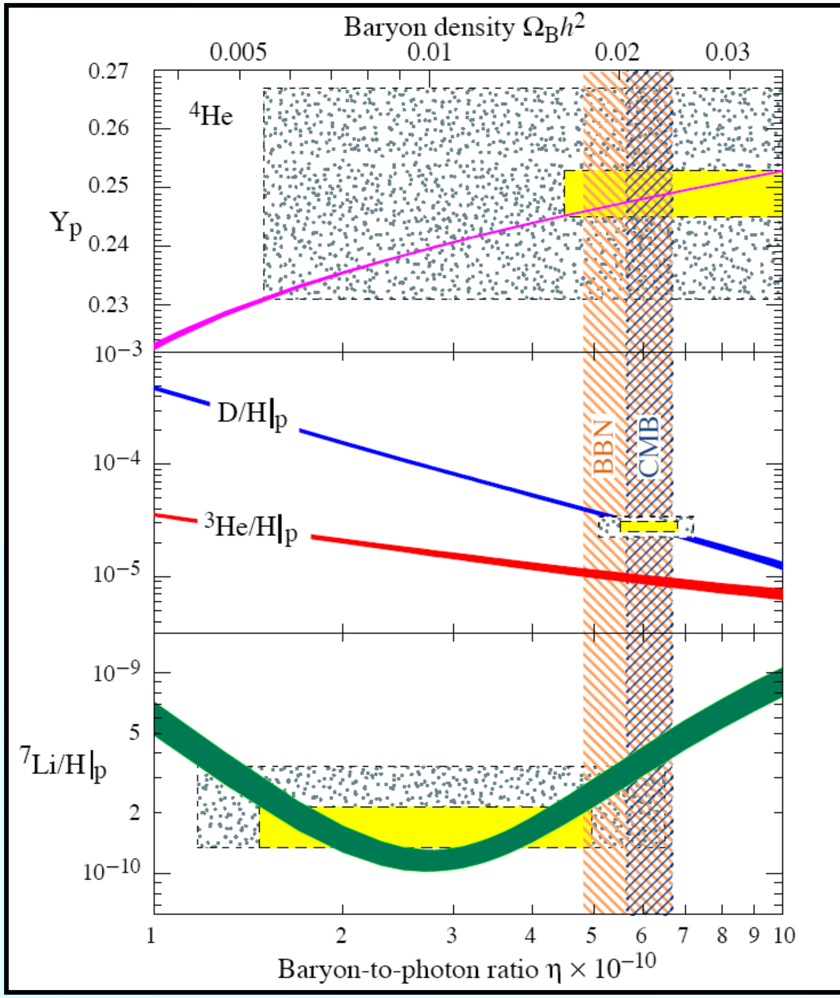
Ann Heinson, UC Riverside

CP Violation and creation of Universe

- **Big Bang Nucleosynthesis (BBN) - great success of modern physics;**
- **Combination of results from many branches of science:**
  - **Astrophysics;**
  - **Particle physics;**
  - **Nuclear physics;**
- **Based on the Standard Model;**
- **Predicts the abundance of light elements:**
  - **Abundance of different elements varies by many orders of magnitude, but still in a striking agreement with theory;**



Matter - antimatter asymmetry and CPV

- Excess of baryons over anti-baryons is the initial condition of BBN;
- No explanation of the evolution of anti-elements;
- One of the biggest puzzles in explaining the birth of our Universe;
- CP violation, resulting in different properties of matter and antimatter - necessary ingredient for explaining our existence;
- It provides a mechanism to generate a net baryon number through decay of heavy to light particles;

CPV in Standard Model

- **The only source of CPV in the Standard Model - complex quark-mixing matrix (CKM matrix):**

$$\boxed{\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}}$$

$$\boxed{V_{ub} \neq V_{ub}^{*}; V_{td} \neq V_{td}^{*} \Rightarrow \text{CPV}}$$

CPV in Standard Model

- **Condition of unitarity ($V^\dagger V=1$), and the freedom to redefine phases of quark eigenstates results in three real mixing angles and a single complex phase of the CKM matrix:**

$$V_{\mathrm{CKM}} = \begin{pmatrix} 1-\frac{1}{2}\lambda^2-\frac{1}{8}\lambda^4 & \lambda & A\lambda^3(\rho-i\eta) \\ -\lambda+\frac{1}{2}A^2\lambda^5[1-2(\rho+i\eta)] & 1-\frac{1}{2}\lambda^2-\frac{1}{8}\lambda^4(1+4A^2) & A\lambda^2 \\ A\lambda^3[1-(1-\frac{1}{2}\lambda^2)(\rho+i\eta)] & -A\lambda^2+\frac{1}{2}A\lambda^4[1-2(\rho+i\eta)] & 1-\frac{1}{2}A^2\lambda^4 \end{pmatrix}$$

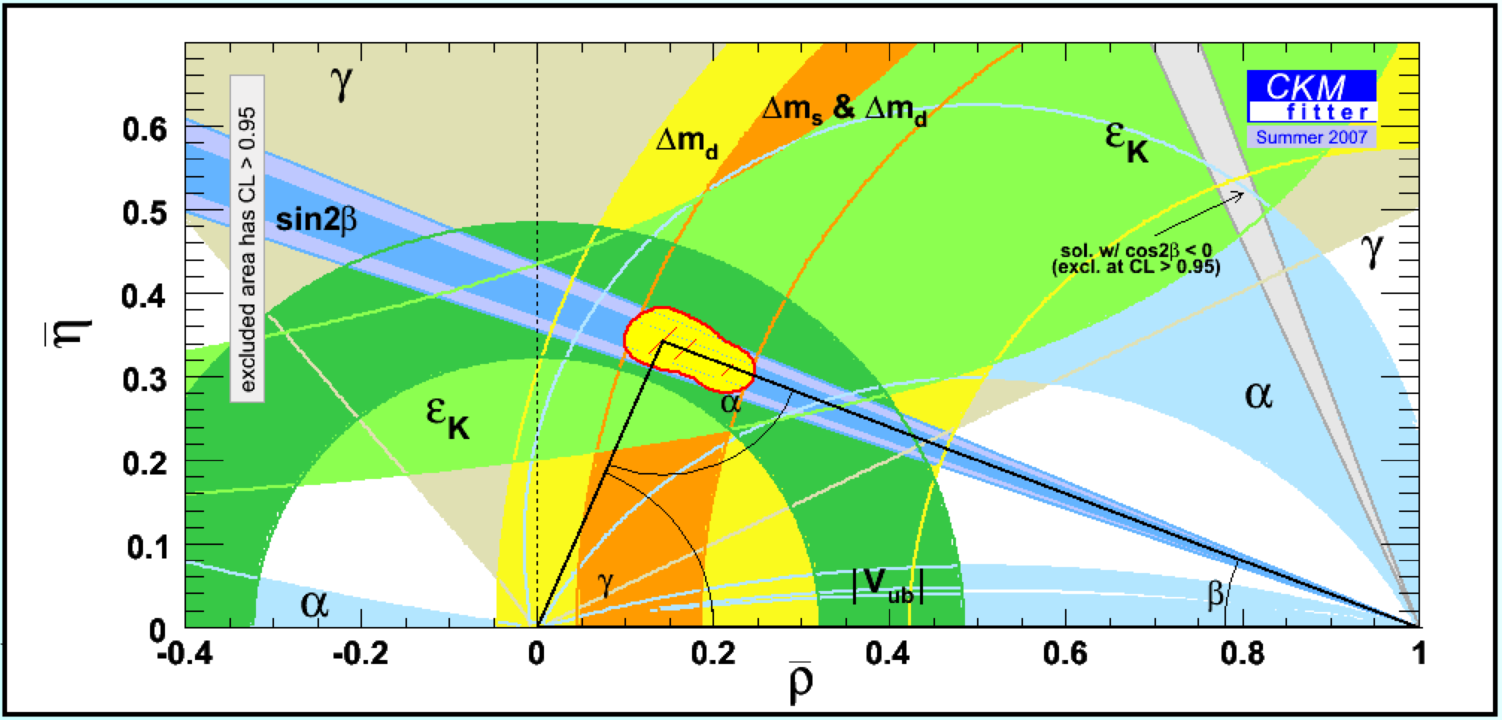
- **This single phase is sufficient to describe all CPV phenomena observed so far;**

Unitarity Triangle

- **The most recent success of the Standard Model – test of one of unitarity relations ("The Unitarity Triangle"):**

$$\boxed{V_{ud}V_{ub}^{*} + V_{cd}V_{cb}^{*} + V_{td}V_{tb}^{*} = 0}$$

- **All CP-conserving and CP-violating measurements so far confirm this relation;**



Call for New Physics

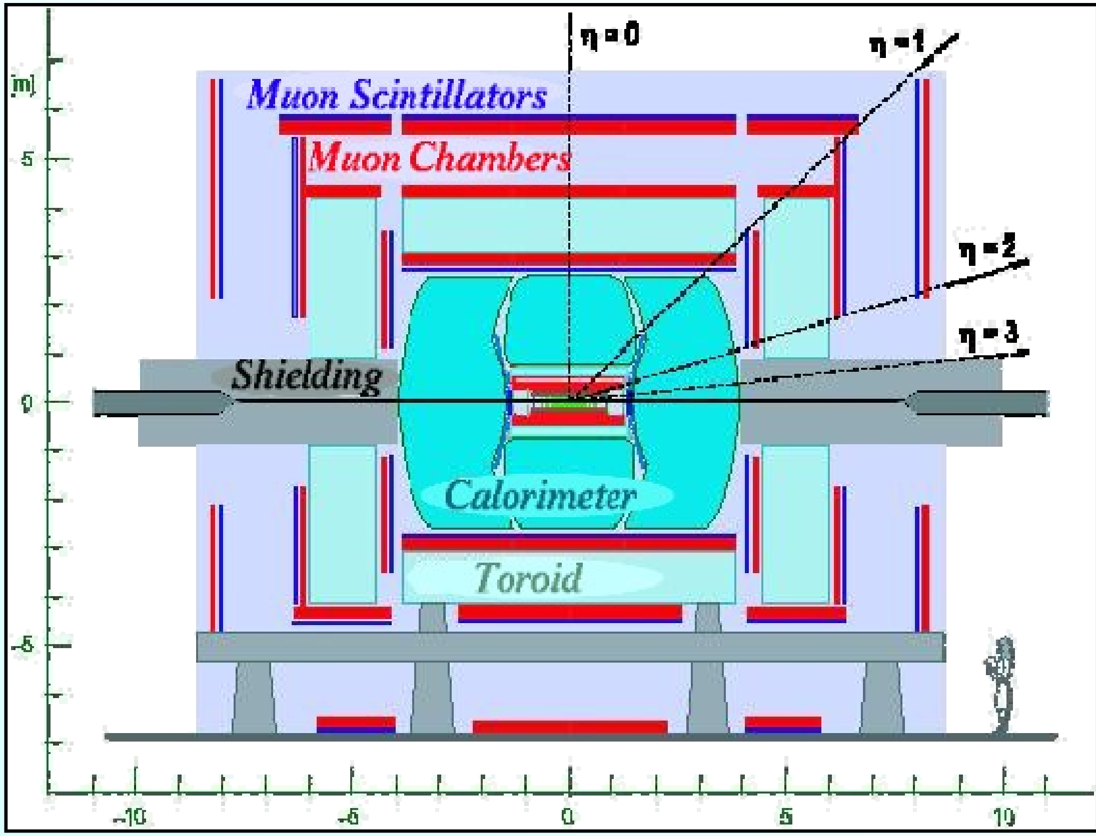
- Regardless all success of the SM in describing the CPV phenomena, the magnitude of the CPV in the SM is too small (~15 orders of magnitude) to explain the observed asymmetry between matter and antimatter;
- The mere fact of our existence demands the new sources of the CPV beyond the standard model;
- The search of these sources is one of the main goals of current and future experiments;
- A promising strategy of this search is to study the processes where the Standard Model predicts a small CPV, and extensions of the Standard Model predict large CPV effects;

This strategy is adopted in DØ experiment

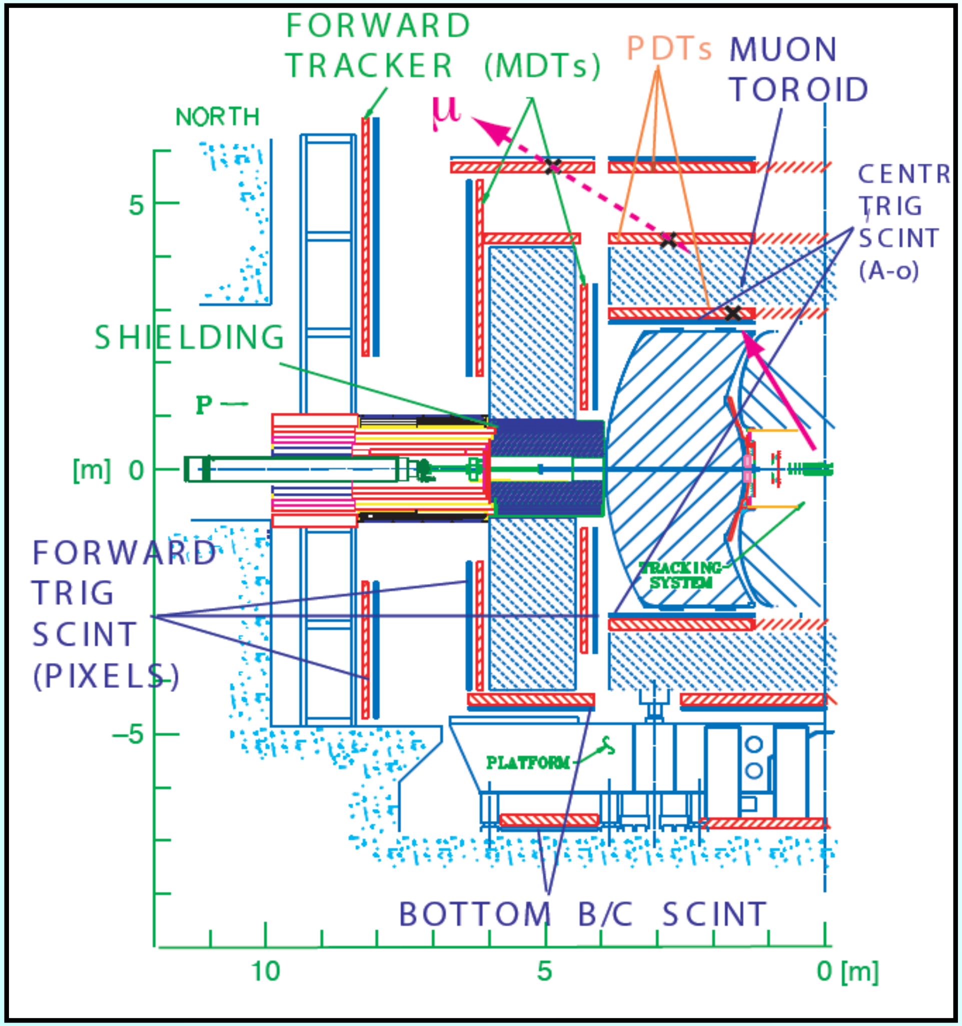
DØ Detector

Key elements for B-physics:

- Muon system;
- Muon trigger;
- Solenoid + Toroid;
- Polarities of magnets are regularly reversed;
- Tracking with precise vertex detector;
- Wide acceptance up to $|\eta|\sim2$;

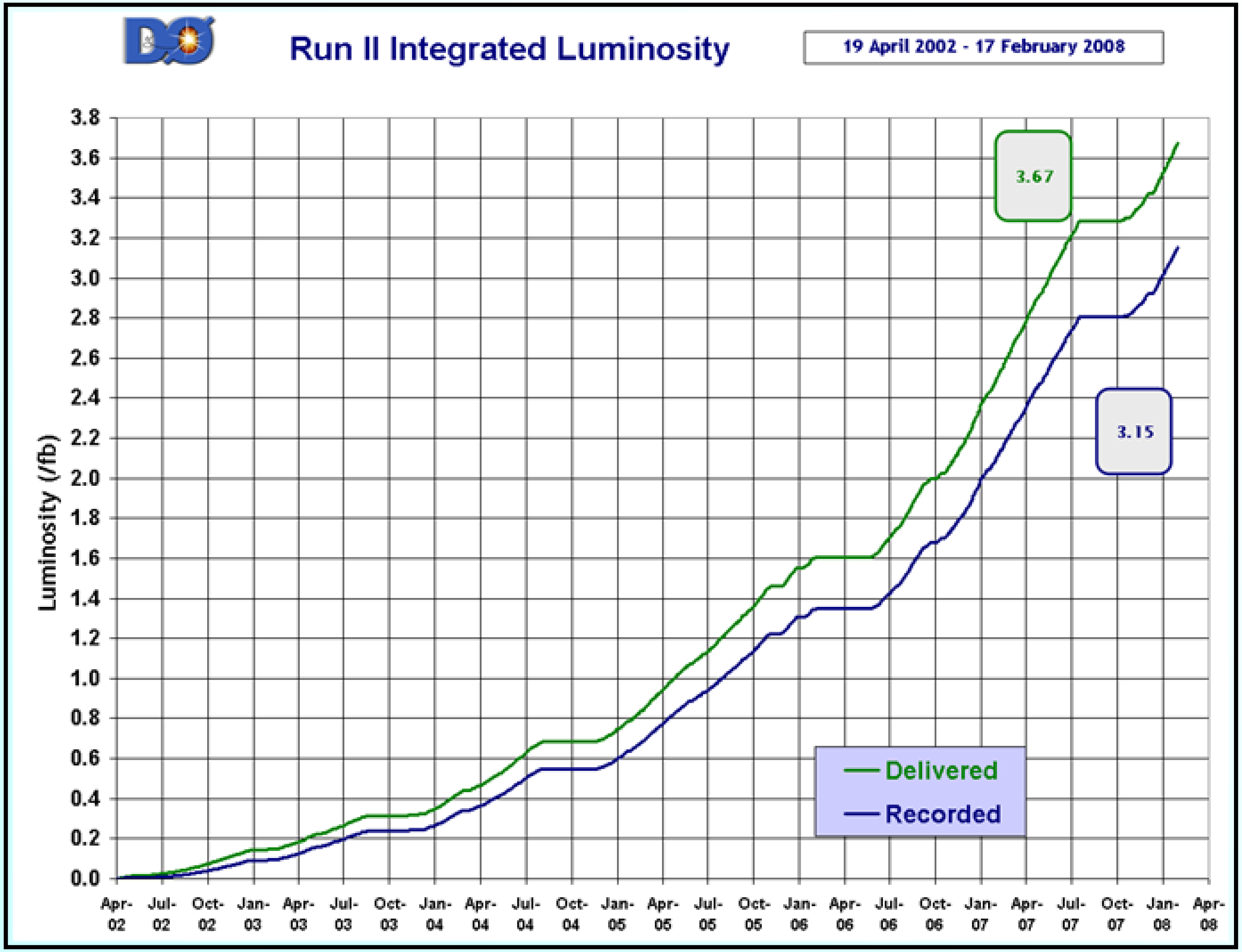


DØ Muon System



- **Large acceptance |η|< 2.2;**
- **Excellent triggering;**
- **Cosmic ray rejection;**
- **Low punch-through;**
- **Local measurement of muon charge and momentum;**
- **High purity of muon ID;**

Delivered Luminosity



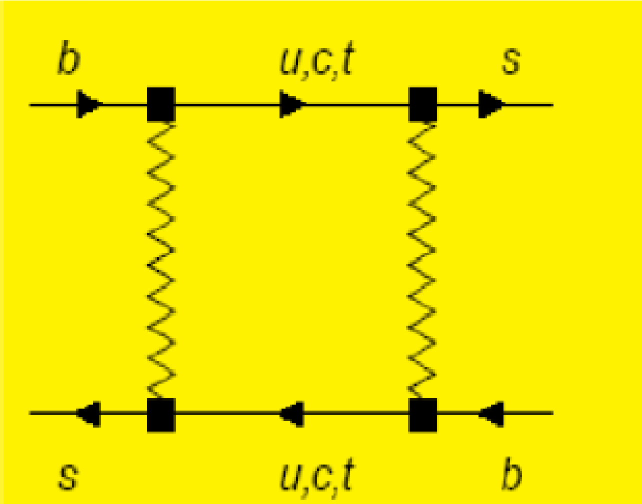
These results correspond to the recorded luminosity 2.8 fb^{-1}

Time dependent analysis of $B_s \to J/\psi\ \varphi$ decay

Disclaimer: too many letters "φ","ϕ" are used in a different context

B_s system

- **Contrary to any other system, B_s is strongly mixed;**
- **Two physical states B_s^H (heavy) and B_s^L (light) have distinct masses and lifetimes:**



$$\Delta M_s = M_H - M_L \approx 2|M_{12}|$$

$$\Delta\Gamma_s = \Gamma_L - \Gamma_H \approx 2|\Gamma_{12}|\cos\phi_s$$

$$\phi_s = \arg\left(-\frac{M_{12}}{\Gamma_{12}}\right)$$

$$\overline{\Gamma}_s = \frac{1}{2}(\Gamma_L + \Gamma_H)$$

M_{12} and Γ_{12} are elements of complex mass matrix $(M-i\,\Gamma/2)$ of B_s system;

ϕ_s- CP violating phase;

Γ_s, $\Delta\Gamma_s$, ΔM_s and ϕ_s are 4 parameters describing B_s system

Decay $B_s \to J/\psi\ \varphi$

- The final state is a mixture of CP-even and CP-odd state;
- The decay is described by 3 complex amplitudes: A_0, $A_\parallel$, $A_\perp$;
- CP-even B_s state decays through A_0, $A_\parallel$ amplitudes; CP-odd state decays through $A_\perp$;
- The time evolution of these amplitudes is different if the B_s^L and B_s^H have different width;
- In presence of CP violation, the time evolution of amplitudes for $B_s(0)$ and $\overline{B}_s(0)$ is different;
- We can obtain the width of B_s^L and B_s^H and the CP violating phase by studying the evolution in time of the angular distributions of $B_s \to J/\psi\ \varphi$ decay products;

CP violating phase ϕ_s

- CP violation is predicted to be very small for $B_s \to J/\psi\ \varphi$:

$$\boxed{\phi_s^{SM} = -2\beta_s = 2\arg\left(-\frac{V_{tb}V_{ts}^*}{V_{cb}V_{cs}^*}\right) = -0.04 \pm 0.01}$$

- Contribution of the new physics can modify this prediction. In general form:

$$\boxed{\phi_s = \phi_s^{SM} + \phi_s^{\Delta}}$$

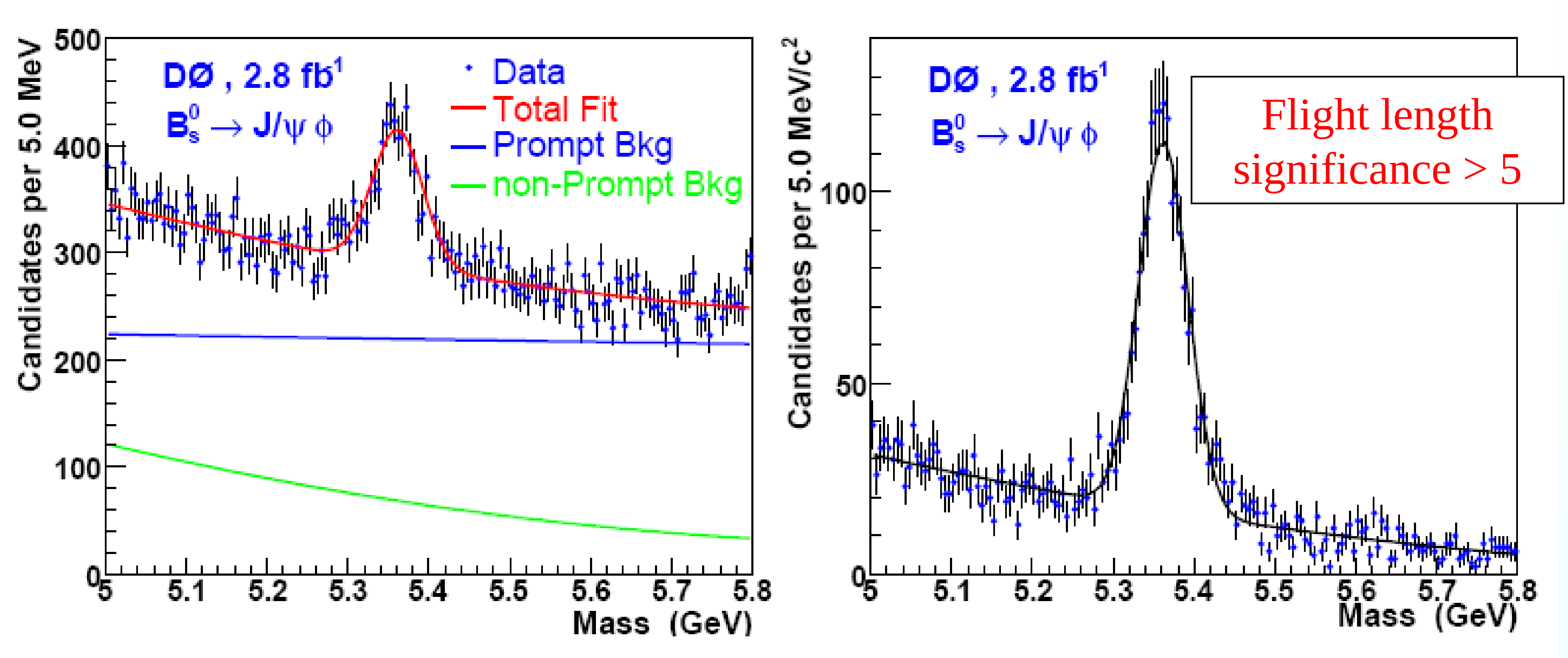
- Any large non-zero value of the phase ϕ_s will be a clear and unambiguous indication of the new physics contribution;

Ingredients of analysis

- **Exclusive selection of the decay $B_s \to J/\psi\ \varphi$;**
- **Precise measurement of B_s lifetime;**
- **Angular distributions;**
- **Tagging of the initial B_s flavour;**
- **Likelihood fit including angular variables, B_s mass and lifetime;**

$B_s \to J/\psi\ \varphi$ Selection

- Select $J/\psi \to \mu^+\mu^-$ and $\varphi \to K^+K^-$;

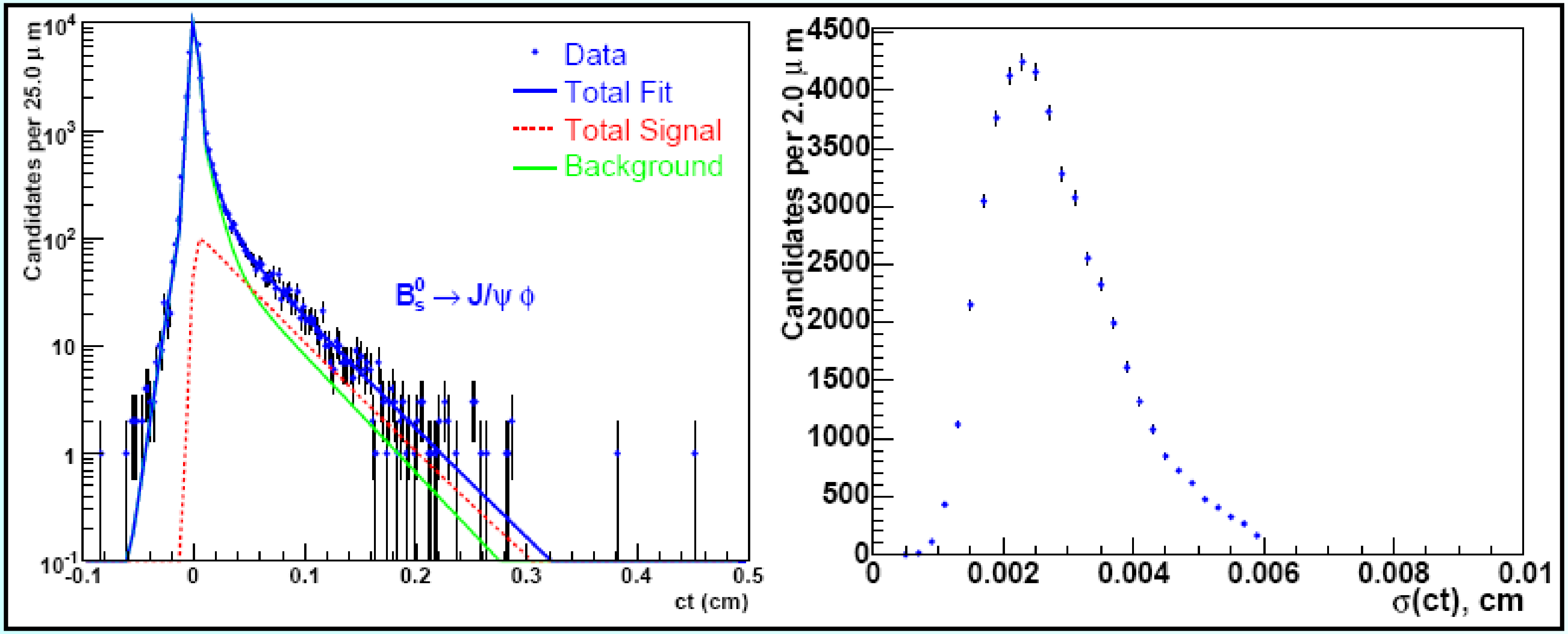


Flight length significance > 5

1967±65 B_s Candidates

Measurement of B_s lifetime

- **Since we use the exclusive decay, the lifetime resolution is very good: $\sigma(c\tau) \approx 25$ µm;**



Angular distributions

- For an initial $B_s(0)$ state, the angular distributions can be presented as:

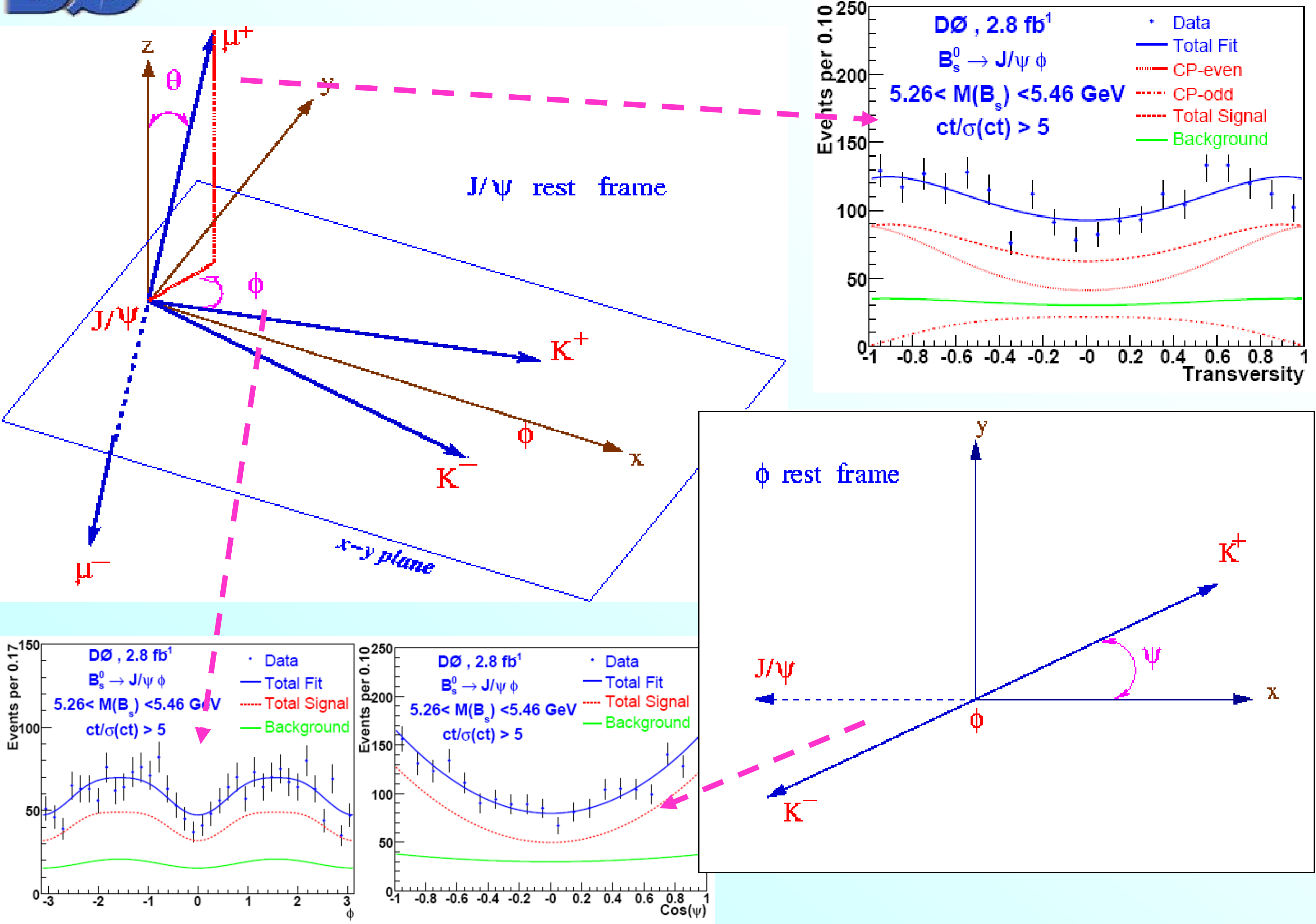
$$\boxed{\frac{d^4\Gamma(B_s(t)\rightarrow J/\psi(\rightarrow \mu^+\mu^-)\phi(\rightarrow K^+K^-))}{dt\cdot d\cos\theta\cdot d\cos\psi\cdot d\varphi}\propto\sum_k O^{(k)}(t)g^{(k)}(\theta,\psi,\varphi)}$$

- For an initial $\overline{B}_s(0)$ state, the angular distributions are:

$$\boxed{\frac{d^4\Gamma(\overline{B}_s(t)\rightarrow J/\psi(\rightarrow \mu^+\mu^-)\phi(\rightarrow K^+K^-))}{dt\cdot d\cos\theta\cdot d\cos\psi\cdot d\varphi}\propto\sum_k \overline{O}^{(k)}(t)g^{(k)}(\theta,\psi,\varphi)}$$

- Angular functions $g^{(k)}(\theta,\psi,\varphi)$ are the same for $B_s(0)$ and $\overline{B}_s(0)$

3 angles


z
μ+
θ
ψ
J/ψ rest frame
J/ψ
φ
K+
K−
φ
x
μ−
x−y plane
DØ , 2.8 fb-1
B0s → J/ψ φ
5.26< M(Bs) <5.46 GeV
ct/σ(ct) > 5
Data
Total Fit
CP-even
CP-odd
Total Signal
Background
Events per 0.10
0
50
100
150
200
250
-1
-0.8
-0.6
-0.4
-0.2
-0
0.2
0.4
0.6
0.8
1
Transversity
φ rest frame
y
K+
J/ψ
ψ
x
φ
K−
DØ , 2.8 fb-1
B0s → J/ψ φ
5.26< M(Bs) <5.46 GeV
ct/σ(ct) > 5
Data
Total Fit
Total Signal
Background
Events per 0.17
0
50
100
150
-3
-2
-1
0
1
2
3
φ
DØ , 2.8 fb-1
B0s → J/ψ φ
5.26< M(Bs) <5.46 GeV
ct/σ(ct) > 5
Data
Total Fit
Total Signal
Background
Events per 0.10
0
50
100
150
200
250
-1
-0.8
-0.6
-0.4
-0.2
-0
0.2
0.4
0.6
0.8
1
Cos(ψ)

Angular Distributions

$$\begin{aligned}
\frac{d^4\Gamma(B_s(t)\to J/\psi(\to\mu^+\mu^-)\phi(\to K^+K^-))}{dt\cdot d\cos\theta\cdot d\cos\psi\cdot d\varphi} \propto \\
2\cos^2\psi(1-\sin^2\theta\cos^2\varphi)\cdot|A_0(t)|^2 \\
+\sin^2\psi(1-\sin^2\theta\sin^2\varphi)\cdot|A_\parallel(t)|^2 \\
+\sin^2\psi\sin^2\theta\cdot|A_\perp(t)|^2 \\
+(1/\sqrt{2})\sin 2\psi\sin^2\theta\sin 2\varphi\cdot\Re(A_0^*(t)A_\parallel(t)) \\
+(1/\sqrt{2})\sin 2\psi\sin 2\theta\cos\varphi\cdot\Im(A_0^*(t)A_\perp(t)) \\
-\sin^2\psi\sin 2\theta\sin\varphi\cdot\Im(A_\parallel^*(t)A_\perp(t)).
\end{aligned}$$

- **Evolution of amplitudes in time for $B_s(0)$ (upper sign) and for $\overline{B}_s(0)$ (lower sign):**

$$
\begin{aligned}
|A_0(t)|^2 &= |A_0(0)|^2 \left[\mathcal{T}_+ \pm e^{-\overline{\Gamma} t} \sin\phi_s \, \sin(\Delta M_s t)\right], \\
|A_\parallel(t)|^2 &= |A_\parallel(0)|^2 \left[\mathcal{T}_+ \pm e^{-\overline{\Gamma} t} \sin\phi_s \, \sin(\Delta M_s t)\right], \\
|A_\perp(t)|^2 &= |A_\perp(0)|^2 \left[\mathcal{T}_- \mp e^{-\overline{\Gamma} t} \sin\phi_s \, \sin(\Delta M_s t)\right],
\end{aligned}
$$

where

$$\mathcal{T}_\pm = (1/2)\left[(1 \pm \cos\phi_s) e^{-\Gamma_L t} + (1 \mp \cos\phi_s) e^{-\Gamma_H t}\right].$$

- **Here the CP violating phase $\phi_s = -2\beta_s + \phi_s^\Delta$; ϕ_s^Δ is the possible contribution of new physics;**

Evolution of amplitudes in time (continued)

$$\begin{aligned}\Re(A_0^*(t)A_\parallel(t)) &= |A_0(0)||A_\parallel(0)|\cos(\delta_2-\delta_1)[\mathcal{T}_+ \\ &\pm\ e^{-\overline{\Gamma}t}\sin\phi_s\ \sin(\Delta M_s t)],\end{aligned}$$

$$\begin{aligned}\Im(A_0^*(t)A_\perp(t)) &= |A_0(0)||A_\perp(0)|[\ e^{-\overline{\Gamma}t}(\ \pm\sin\delta_2\cos(\Delta M_s t)\ \mp \\ &\cos\delta_2\sin(\Delta M_s t)\cos\phi_s) - (1/2)\left(e^{-\Gamma_H t}-e^{-\Gamma_L t}\right)\sin\phi_s\ \cos\delta_2],\end{aligned}$$

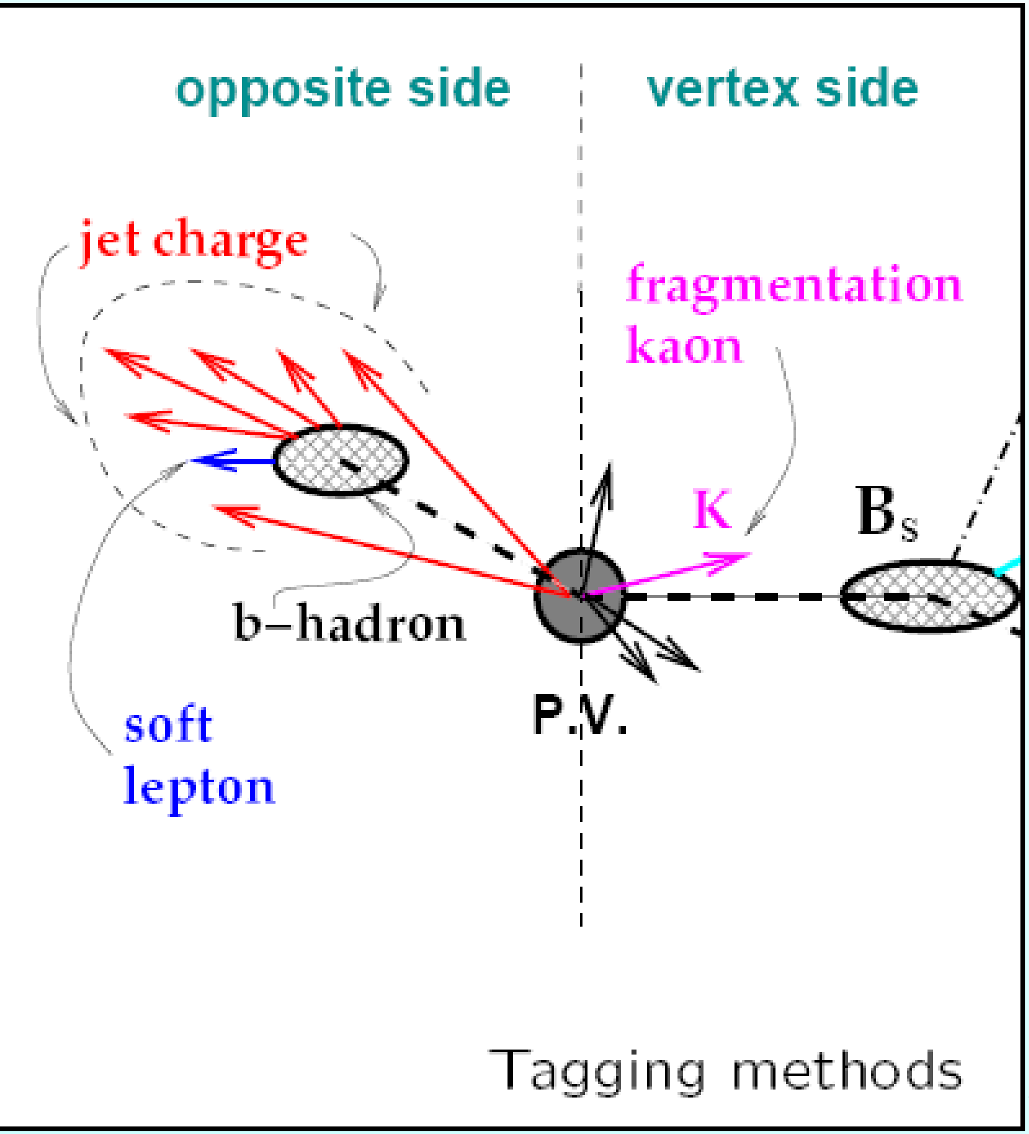
$$\begin{aligned}\Im(A_\parallel^*(t)A_\perp(t)) &= |A_\parallel(0)||A_\perp(0)|[\ e^{-\overline{\Gamma}t}(\ \pm\sin\delta_1\cos(\Delta M_s t)\ \mp \\ &\cos\delta_1\sin(\Delta M_s t)\cos\phi_s) - (1/2)\left(e^{-\Gamma_H t}-e^{-\Gamma_L t}\right)\sin\phi_s\ \cos\delta_1],\end{aligned}$$

- **Here:** $\delta_1 \equiv \arg\left\{A_\parallel^*(0)A_\perp(0)\right\}; \quad \delta_2 \equiv \arg\left\{A_0^*(0)A_\perp(0)\right\}$
- **Normalization at t=0:** $|A_0(0)|^2+|A_\parallel(0)|^2+|A_\perp(0)|^2=1$

Flavor tagging of initial state

- **Amplitudes are different for $B_s(0)$ and for $\overline{B}_s(0)$**
- **The initial state of the B_s meson is determined by the flavor tagging;**
- **To do this, we identify the set of properties of the B hadron opposite to the reconstructed B_s meson (opposite-side tagging), or the properties of particles accompanying the reconstructed B_s meson (same-side tagging);**
- **These properties should have different distribution for $B_s(0)$ and $\overline{B}_s(0)$.**

Different properties for flavor tagging



Tagging methods

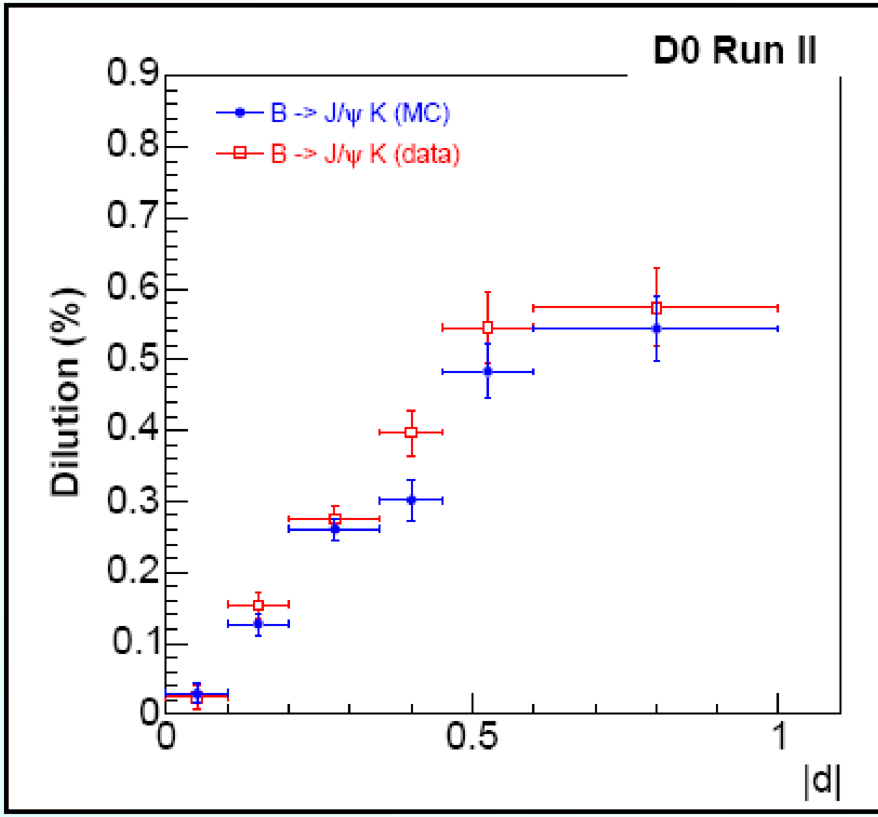
- **From the opposite side:**
  - **Charge of secondary lepton (muon or electron);**
  - **Jet charge of secondary vertex;**
  - **P_t- Weighted charge of all tracks from the opposite side;**
- **From the same side:**
  - **charge of track closest to B_s direction;**
  - **Jet charge of tracks from primary vertex;**
- **All properties are combined into a single variable "d";**

Performance of tagging

- Performance of flavor tagging is described in terms of "dilution":

$$D = \frac{N_{cor} - N_{wr}}{N_{cor} + N_{wr}}$$

  - N_{cor} – Number of correct tags;
  - N_{wr} – Number of wrong tags;
- Calibration of D(d) is performed using the MC events;
- Agreement between data and MC is verified using $B^{\pm} \rightarrow J/\psi\ K^{\pm}$ events, where the initial flavor is known;
- Equivalent tagging power of flavor tagging: $P = \varepsilon \cdot D^2 = (4.68 \pm 0.54)\%$



Dilution versus tagging variable d in B±→J/ψ K± events for data and MC

Likelihood fit

- We perform unbinned likelihood fit to the proper time, mass of (J/ψ φ), and 3 decay angles;
- There are 32 parameters in the fit describing the background, the mass and lifetime resolution:

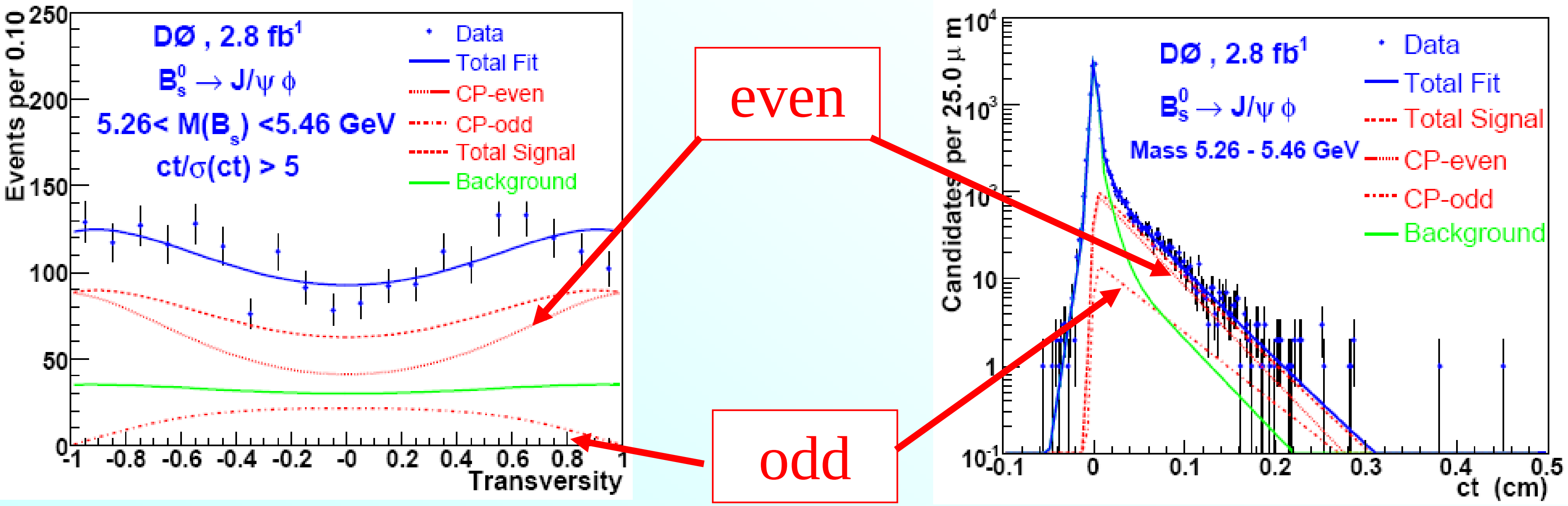
$$\boxed{L = \prod_{i=1}^{N}\left[f_{sig}\cdot F_{sig}^{i} + (1 - f_{sig})\cdot F_{bck}^{i}\right]}$$

  - f_{sig} – fraction of the signal in the sample;
  - F_{sig} (F_{bck}) – distribution of signal (background) in mass proper decay time and 3 decay angles;

Constraints of the fit

- **We constraint $\Delta M_s = 17.77 \pm 0.12$ ps^{-1} (from CDF)**
- **The fit still has two-fold ambiguity:**
  - **$\Delta\Gamma > 0$, $\cos(\phi_s) > 0$, $\cos(\delta_1) > 0$, $\cos(\delta_2) < 0$;**
  - **$\Delta\Gamma < 0$, $\cos(\phi_s) < 0$, $\cos(\delta_1) < 0$, $\cos(\delta_2) > 0$;**
- **These phases were measured by Babar in a similar decay $B_d \rightarrow J/\psi K^*$ (hep-ex/0704.0522). The solution with $\delta_1 < 0$, $\delta_2 > 0$ is preferred both experimentally and theoretically;**
- **Following the approximate SU(2) flavor symmetry, we constraint δ_1, δ_2 to the world average values: $\delta_1 = -0.46$; $\delta_2 = 2.92$ measured in $B_d \rightarrow J/\psi K^*$, with the Gaussian of width $\pi/5$ to allow the SU(2) symmetry breaking;**

Results of the fit

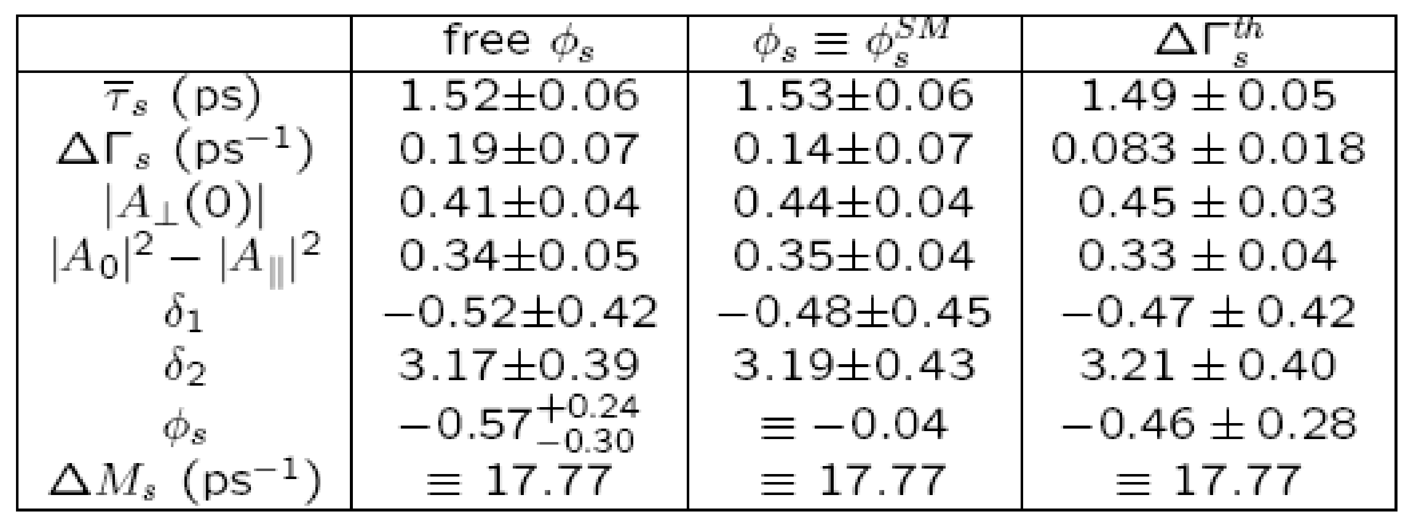


even

odd

Results of the fit

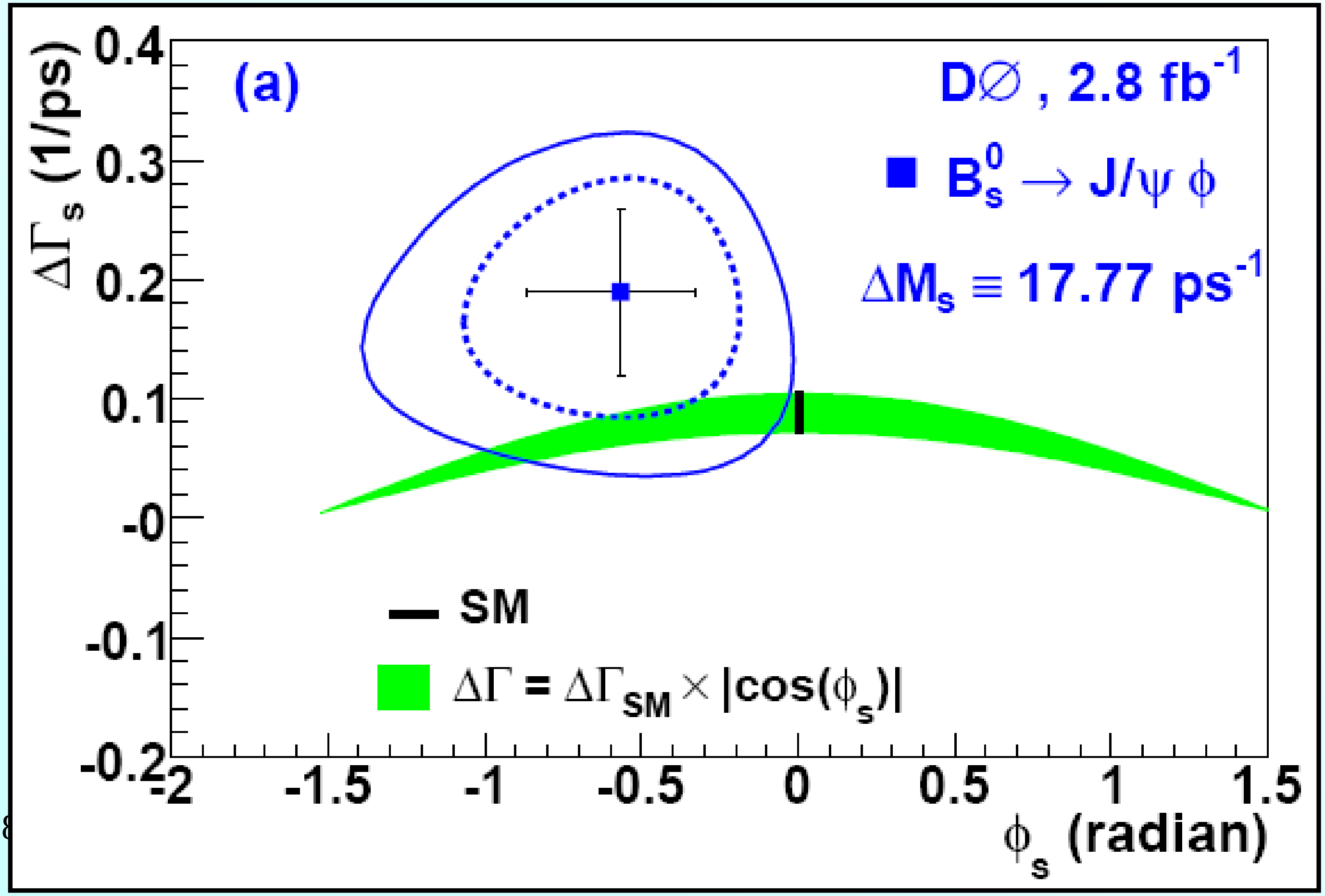
- **Three scenarios:**
  - **Free CP violating phase ϕ_s;**
  - **$\phi_s \equiv -0.04$ (SM prediction);**
  - **$\Delta\Gamma_s = \Delta\Gamma_s^{SM} |\cos \phi_s|$;**



	free ϕ_s	$\phi_s \equiv \phi_s^{SM}$	$\Delta\Gamma_s^{th}$
$\overline{\tau}_s$ (ps)	1.52 ± 0.06	1.53 ± 0.06	1.49 ± 0.05
$\Delta\Gamma_s$ (ps^{-1})	0.19 ± 0.07	0.14 ± 0.07	0.083 ± 0.018
$\|A_\perp(0)\|$	0.41 ± 0.04	0.44 ± 0.04	0.45 ± 0.03
$\|A_0\|^2 - \|A_\parallel\|^2$	0.34 ± 0.05	0.35 ± 0.04	0.33 ± 0.04
δ_1	-0.52 ± 0.42	-0.48 ± 0.45	-0.47 ± 0.42
δ_2	3.17 ± 0.39	3.19 ± 0.43	3.21 ± 0.40
ϕ_s	$-0.57^{+0.24}_{-0.30}$	$\equiv -0.04$	-0.46 ± 0.28
ΔM_s (ps^{-1})	$\equiv 17.77$	$\equiv 17.77$	$\equiv 17.77$

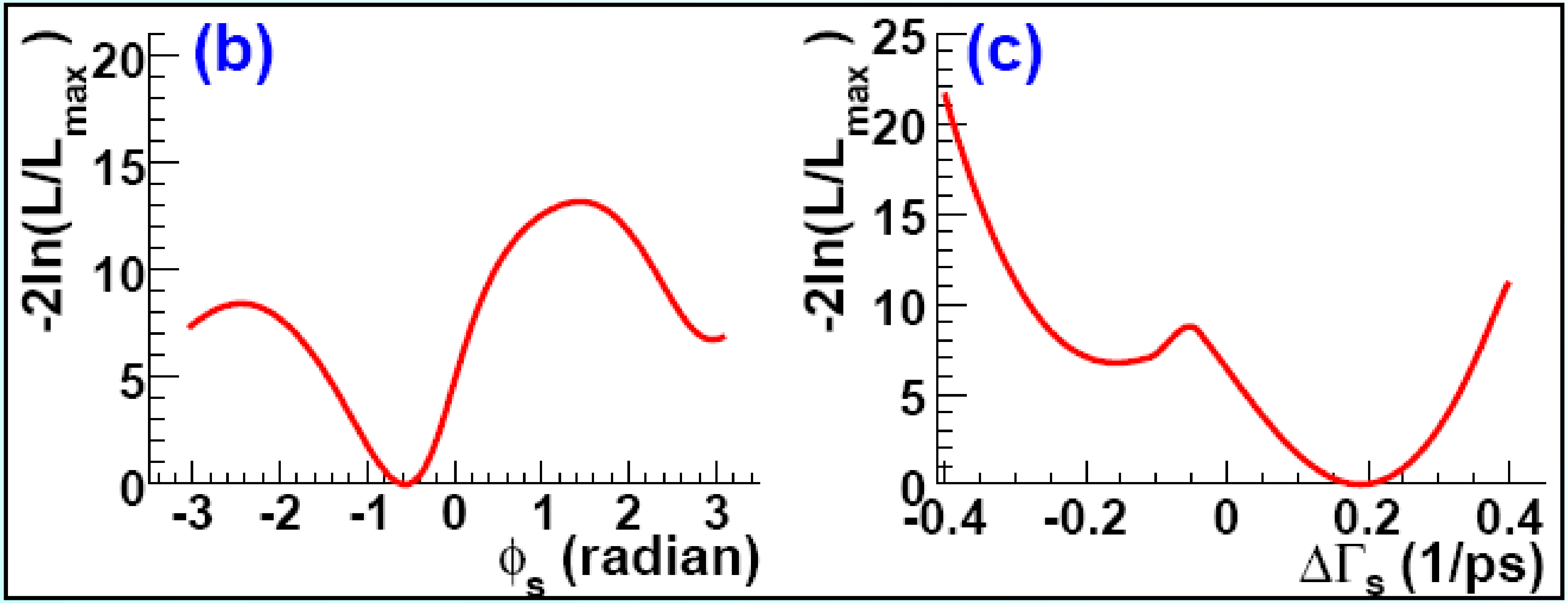
Contour plot

- Contours are at δ(-2 ln L) = 2.30 (CL = 0.683) and 4.61 (CL = 0.90);
- The cross has δ(-2 ln L) =1.



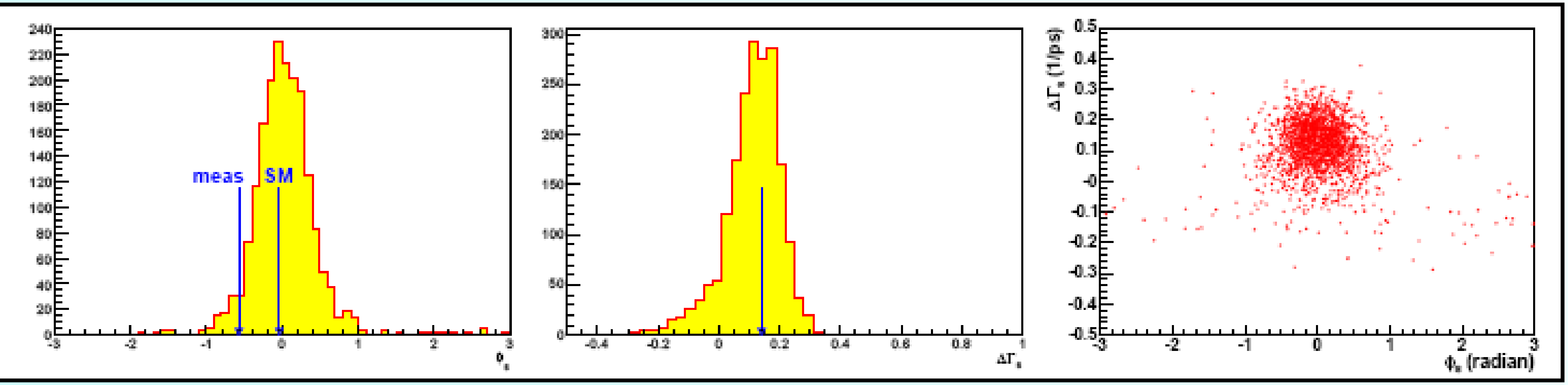
Likelihood scan

- Likelihood scan shows a clear minimums with significance > 2.5σ both for ϕ_s and for $\Delta\Gamma_s$:

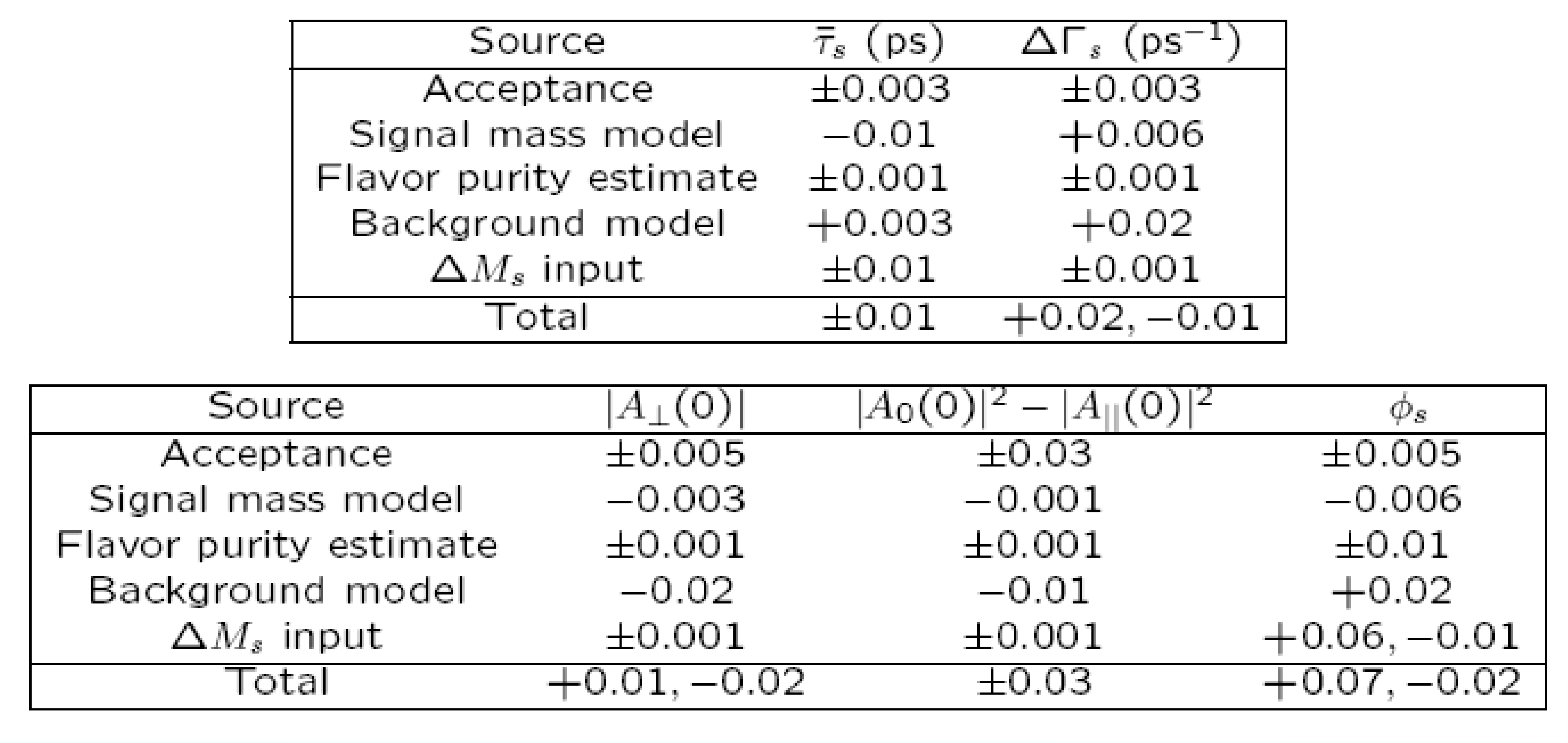


Consistency with the SM

- **To test the consistency of our results with the standard model we performed 2000 MC pseudo-experiments with the true value of ϕ_s set to the SM prediction (-0.04);**
- **With the measured value ϕ_s = -0.57, the P-value for the SM hypothesis is 6.6%**



Systematic uncertainty



Source	$\bar{\tau}_s$ (ps)	$\Delta\Gamma_s$ (ps^{-1})
Acceptance	±0.003	±0.003
Signal mass model	-0.01	$+0.006$
Flavor purity estimate	±0.001	±0.001
Background model	$+0.003$	$+0.02$
ΔM_s input	±0.01	±0.001
Total	±0.01	$+0.02, -0.01$

Source	$\|A_\perp(0)\|$	$\|A_0(0)\|^2 - \|A_\parallel(0)\|^2$	ϕ_s
Acceptance	±0.005	±0.03	±0.005
Signal mass model	-0.003	-0.001	-0.006
Flavor purity estimate	±0.001	±0.001	±0.01
Background model	-0.02	-0.01	$+0.02$
ΔM_s input	±0.001	±0.001	$+0.06, -0.01$
Total	$+0.01, -0.02$	±0.03	$+0.07, -0.02$

Results

- We obtain:

$$\phi_s = -0.57^{+0.24}_{-0.30}\,(\text{stat})^{+0.07}_{-0.02}\,(\text{syst})$$

$$\Delta\Gamma_s = 0.19 \pm 0.07\,(\text{stat})\,{}^{+0.02}_{-0.01}\,(\text{syst})\,\text{ps}^{-1}$$

$$\bar{\tau}(B_s^0) = 1.52 \pm 0.05 \pm 0.01\,\text{ps}$$

$$-1.20 < \phi_s < 0.06, \quad 0.06 < \Delta\Gamma_s < 0.30\,\text{ps}^{-1}\text{ at 90\% C.L.}$$

- The SM hypothesis for ϕ_s has P-value 6.6%;
- For the SM case $\phi_s \equiv -2\beta_s = -0.04$ we obtain:

$$\Delta\Gamma_s = 0.14 \pm 0.07\,(\text{stat})\,{}^{+0.02}_{-0.01}\,(\text{syst})\,\text{ps}^{-1}$$

$$\bar{\tau}(B_s^0) = 1.53 \pm 0.06 \pm 0.01\,\text{ps}$$

Results (continued)

- **For the case $\Delta\Gamma_s^{th} = \Delta\Gamma_s^{SM}\cdot|\cos\phi_s|$:**

$$\boxed{\begin{aligned} \phi_s &= -0.46 \pm 0.28\,(\text{stat})^{+0.07}_{-0.02}\,(\text{syst}) \\ \bar{\tau}(B_s^0) &= 1.53 \pm 0.06 \pm 0.01\,\text{ps} \end{aligned}}$$

Comparison with other measurements

- Previous DØ result, which included the combination of different measurements gives:

$$\boxed{\phi_s = -0.70^{+0.47}_{-0.39}}$$

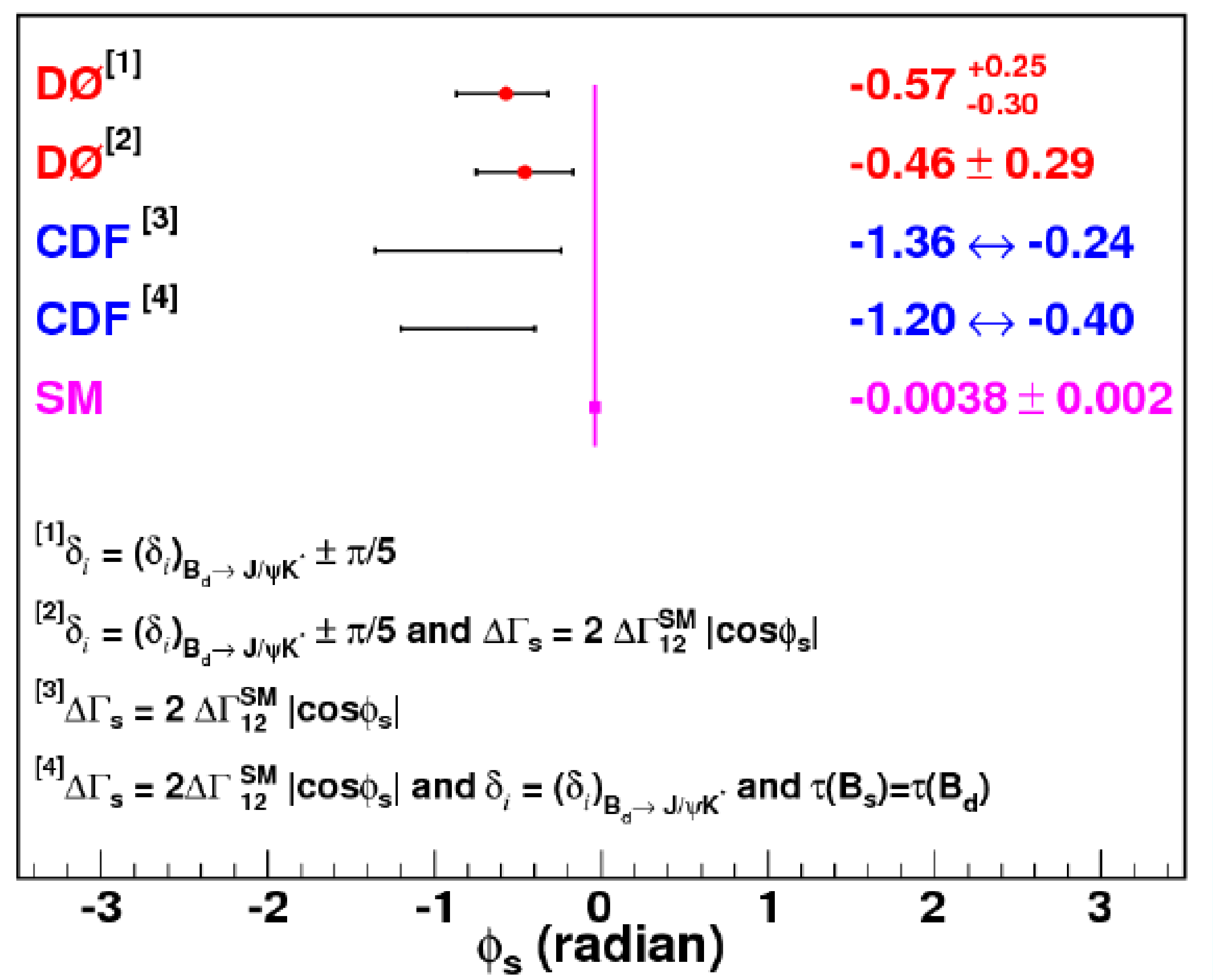
(with 4-fold ambiguity);

  - Phys. Rev. D76, 057101 (2007)

- Recent CDF analysis of the same decay $B_s \to J/\psi\ \varphi$ gives:

$$\boxed{-1.20 < \phi_s < -0.40 \text{ at } 68\% \text{ CL}}$$

  - the DØ sign convention, which is opposite to CDF;
  - arXiv: hep-ex/0712.2397;



[1] $\delta_i = (\delta_i)_{B_d \to J/\psi K^*} \pm \pi/5$

[2] $\delta_i = (\delta_i)_{B_d \to J/\psi K^*} \pm \pi/5$ and $\Delta\Gamma_s = 2\,\Delta\Gamma_{12}^{SM}\,|\cos\phi_s|$

[3] $\Delta\Gamma_s = 2\,\Delta\Gamma_{12}^{SM}\,|\cos\phi_s|$

[4] $\Delta\Gamma_s = 2\Delta\Gamma_{12}^{SM}\,|\cos\phi_s|$ and $\delta_i = (\delta_i)_{B_d \to J/\psi K^*}$ and $\tau(B_s)=\tau(B_d)$

Conclusions

- **Tevatron starts to deliver interesting results in the CP asymmetry measurements;**
- **They are complementary to the B-factories and exploit the B_s sector, not accessible there;**
- **We still expect to increase the statistics significantly by the end of RunII;**
- **CP violation measurements have an exciting future at the Tevatron;**

BACKUP SLIDES

CPV and B Mesons

- **B mesons - ideal place to study CPV:**
  - **Direct access to small elements of mixing matrix;**
  - **Can be sensitive to the new physics;**
  - **Neutral B mesons continuously transforming between matter and antimatter state (oscillate);**
- **B mesons with *u* and *d* quark are extensively studied at b-factories (BaBar and Belle experiments);**
- **B_s meson (bound state of *b* and *s* quarks) can currently be studied only at Tevatron;**

Experimental Observables

Standard Model predicts the following values of experimental observables for B_s system (A. Lenz, U. Nierste, hep-ph/0612167):

- Mass difference: $\Delta M_s^{SM} = (19.30 \pm 6.74)\,\mathrm{ps}^{-1}$
- Lifetime difference: $\Delta\Gamma_s^{SM} = (0.096 \pm 0.039)\,\mathrm{ps}^{-1}$
- Ratio: $\Delta\Gamma_s^{SM} / \Delta M_s^{SM} = (49.7 \pm 9.4) \times 10^{-4}$
- CP violating phase: $\phi_s^{SM} = (4.2 \pm 1.4) \times 10^{-3}$
- CP violating phase in $B_s \to J/\psi\ \varphi$ decay: $-2\beta_s = -0.04 \pm 0.01$

Notice that the CP violating phases for Bs system is predicted to be very small in the Standard Model

New Physics Contribution

- The SM prediction can be significantly modified in the presence of new physics;
- It changes the M_{12} element of mass matrix:

$$M_{12} = M_{12}^{SM} \cdot \Delta_s; \quad \Delta_s = |\Delta_s| e^{i\phi_s^{\Delta}}$$

- The Γ_{12} element is determined by the tree diagrams and is not modified by the new physics;

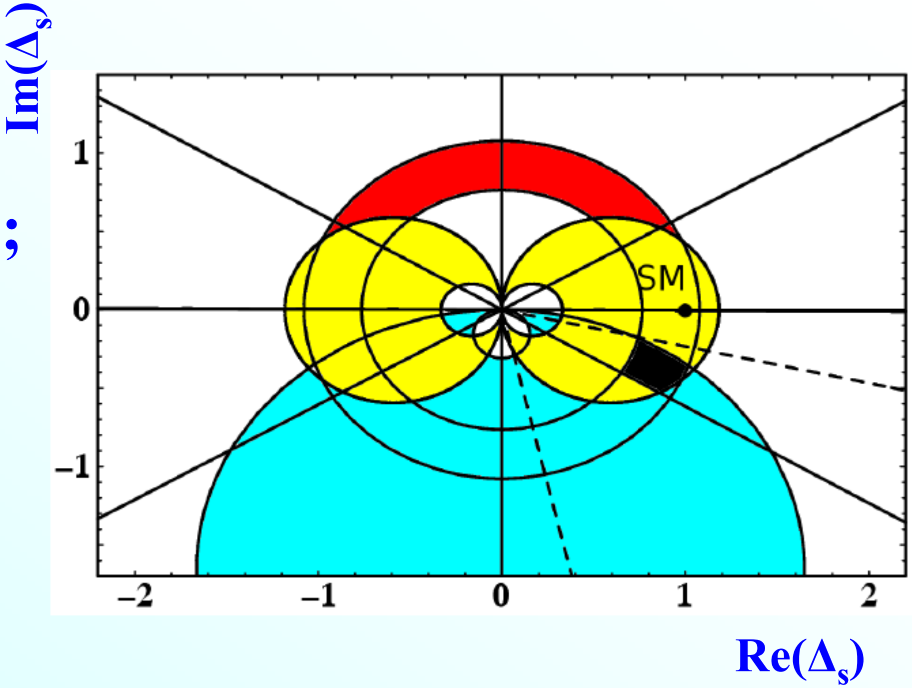
New Physics Contribution

- In the presence of new physics, the experimental observables are modified as:
- Mass difference: $\Delta M_s = \Delta M_s^{SM} |\Delta_s|$
- Lifetime difference: $\Delta\Gamma_s = (0.096 \pm 0.039)\,\mathrm{ps}^{-1} \cdot \cos\phi_s$
- Ratio: $\Delta\Gamma_s / \Delta M_s = (49.7 \pm 9.4) \times 10^{-4} \cdot \cos\phi_s / |\Delta_s|$
- CP violating phase: $\phi_s = \phi_s^{SM} + \phi_s^{\Delta}$
- CP violating phase in $B_s \to J/\psi\ \varphi$ decay: $-2\beta_s + \phi_s^{\Delta}$

The CP violating phases for B_s system can be significantly modified by the contribution of the new physics, since the SM prediction is expected to be small

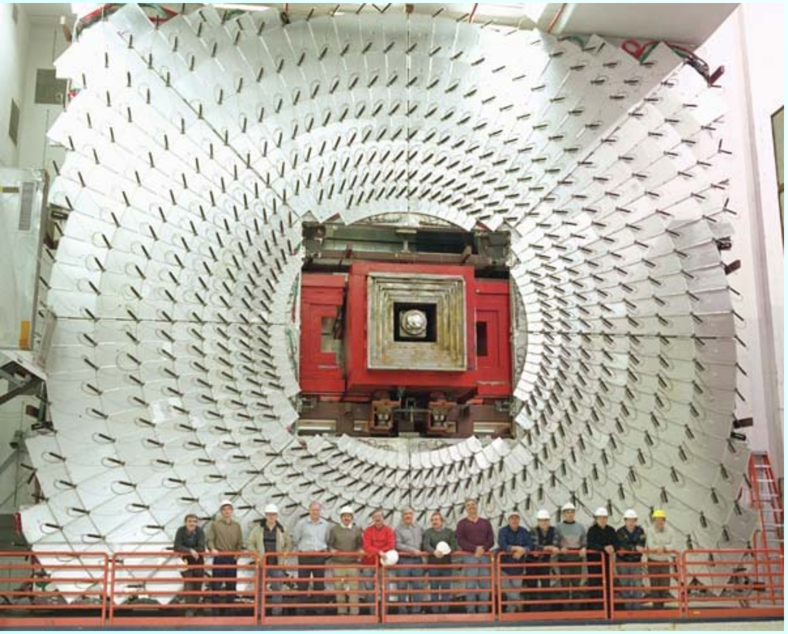
Experimental constraints

- $\Delta_s = 1$ – Standard Model;
- Red: $\Delta M_s = 17.77 \pm 0.12$ ps^{-1} (CDF);
- Yellow: $\Delta\Gamma_s = 0.17 \pm 0.1$ ps^{-1} (DØ);
- Blue: $A_{SL}^{\,s} = (-8.8 \pm 7.3) \times 10^{-3}$ (combination of DØ results with $A_{SL}^{\,d}$ = SM value);
- Forward and backward solid wedges – constraint on φ_s from $\Delta\Gamma_s$ measurement;



A. Lenz, U. Nierste, hep-ph/0612167

Muon Triggers



- **Single inclusive muons**
  - **$|\eta|<2.0$, $p_T > 3,4,5$ GeV**
  - **Muon + track match at Level 1**
  - **No direct lifetime bias**
    - Still could give a bias to measured lifetime if cuts on decay length are imposed offline
  - **Prescaled or turned off depending on inst. lumi.**
  - **B physics triggers at all lumi's**
    - Extra tracks at medium lumi's
    - Impact parameter requirements
    - Associated invariant mass
    - Track selections at Level 3
- **Dimuons: other muon for flavor tagging**
- **e.g. at $50 \cdot 10^{-30}$ cm^{-2}s^{-1}**
  - **20 Hz of unbiased single μ**
  - **1.5 Hz of IP+μ**
  - **2 Hz of dimuons**
- **No rate problem at L1/L2**