Mixing and CP violation in the B_s system with ATLAS

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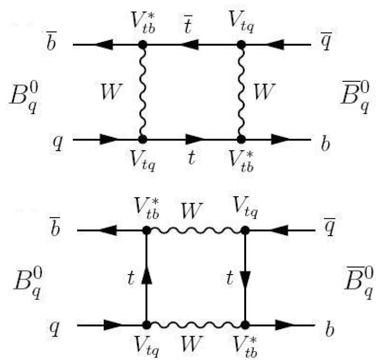
Outline

Paper preprint: http://arxiv.org/abs/1407.1796 (accepted by PRD)

- Motivation
- Description of the angular analysis
- Experimental setup
- Data, Monte Carlo simulation and trigger selection
- Decay reconstruction and selection
- Flavor tagging
- Maximum likelihood fit
- Systematic uncertainties
- Results

Mixing in B_s system

- **Mixing** between B_s^0 and $\bar{B}_s^0$ gives rise to **heavy** and **light** mass eigenstates, B_L and B_H, with different lifetimes
- **Mass difference** [PDG] $\Delta m_s = m_s^H - m_s^L = 17.69 \pm 0.08\ \mathrm{ps}^{-1}$
- **Decay width difference** [PRL 108 (2012) 241801] $\Delta\Gamma_s = \Gamma_s^L - \Gamma_s^H = 0.087 \pm 0.021\ \mathrm{ps}^{-1}$



Box diagrams of $B^0 - \bar{B}^0$ mixing

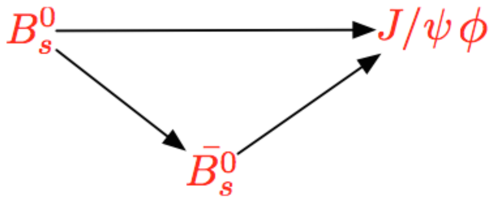
$$i\frac{\mathrm{d}}{\mathrm{d}t}\begin{pmatrix} |B^0(t)\rangle \\ |\bar{B}^0(t)\rangle \end{pmatrix} = \left[\begin{pmatrix} M_{11} & M_{12} \\ M_{12}^* & M_{22} \end{pmatrix} - \frac{i}{2}\begin{pmatrix} \Gamma_{11} & \Gamma_{12} \\ \Gamma_{12}^* & \Gamma_{22} \end{pmatrix}\right]\begin{pmatrix} |B^0(t)\rangle \\ |\bar{B}^0(t)\rangle \end{pmatrix}$$

B^0 system time evolution

Motivation

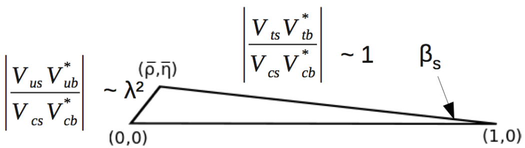
CP violation in $B_s \to J/\psi\phi$ decay

- **Interference** between **mixing** and **direct** decay
- Decay width depends on the **CP-violating** weak phase: ϕ_s



CP violation in the Standard Model

- **CP violation** described by a **complex phase** in the CKM matrix



$$\beta_s = \arg\left(-\frac{V_{ts}V_{tb}^*}{V_{cs}V_{cb}^*}\right)$$

- In the **SM**: $\phi_s^{SM} \approx -2\beta_s = -0.0368 \pm 0.0018$

Motivation

New Physics

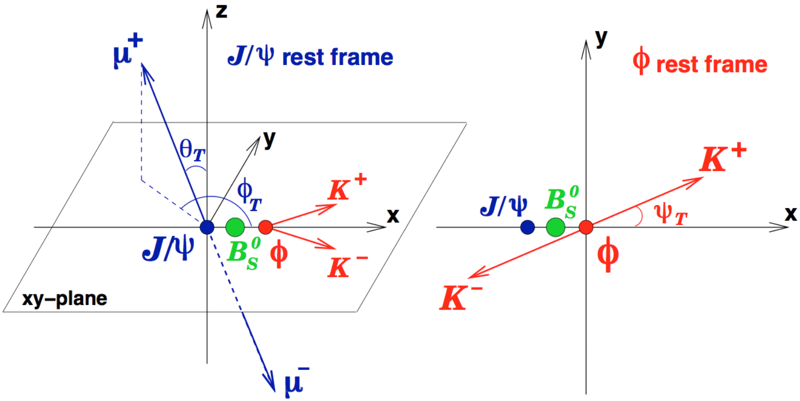
- In the **SM** $\boldsymbol{\phi_s}$ is **small** $\Rightarrow \phi_s = \phi_s^{SM} + \phi_s^{NP} \approx \phi_s^{NP}$
- **Non-zero value** of ϕ_s indicates **new physics**
- $\boldsymbol{\Delta\Gamma_s}$ is not sensitive to NP, but can be used to **test theoretical predictions**

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

- **Clear experimental signature** $B_s \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$
- Pseudo-**scalar** to **vector-vector** meson decay:
  - **CP-even** states: $L = 0, 2$
  - **CP-odd** state: $L = 1$
- Statistically **distinguishable** through **time-dependent angular** analysis

Angular analysis

Transversity base decay angles



- In the B_s **rest frame**: x-axis aligned with the ϕ momentum and xy plane aligned with the ϕ decay plane
- $\boldsymbol{\theta_T}$ and $\boldsymbol{\phi_T}$ are the **polar and azimuthal** angles of the $\boldsymbol{\mu}^+$ momentum in the J/ψ rest frame
- $\boldsymbol{\psi_T}$ is the angle between the $\boldsymbol{K}^+$ momentum and $\hat{\boldsymbol{x}}$ in the ϕ rest frame

Angular analysis

Decay amplitudes and phases

- **Differential decay rate** of $B_s \to J/\psi\phi$ depends on the following **parameters**:

Amplitudes:

- $|\boldsymbol{A_0(0)}|$: longitudinal CP-even state
- $|\boldsymbol{A_{||}(0)}|$: transverse CP-even
- $|\boldsymbol{A_{\perp}(0)}|$: transverse CP-even odd

Strong phases:

- $\boldsymbol{\delta_0} = 0$ (fixed by convention)
- $\boldsymbol{\delta_{||}} = \arg[A_{||}(0)A_0^*(0)]$
- $\boldsymbol{\delta_{\perp}} = \arg[A_{\perp}(0)A_0^*(0)]$

- **Weak phase** ϕ_s
- **Decay rates** Γ_s^L and Γ_s^H
- Mass difference Δm_s (cannot be extracted due to limited time resolution)

Angular analysis

Decays $B_s \to J/\psi K^+K^-$ and $B_s \to J/\psi f_0(K^+K^-)$

- Non-resonant S-wave decay $\boldsymbol{B_s \to J/\psi K^+K^-}$ and $\boldsymbol{B_s \to J/\psi f_0}$ contribute to the final state
- Included in the differential decay rate due to interference with the $B_s \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$ decay
- **Additional two parameters:**
  - Amplitude $|A_S(0)|$
  - Phase δ_S

Differential decay rate

$$\frac{d\Gamma}{dt\, d\Omega} = \sum_{k=1}^{10} \mathcal{O}^{(k)}(t)\; g^{(k)}(\theta_T, \phi_T, \psi_T)$$

- $\boldsymbol{\mathcal{O}^{(k)}(t)}$: time-dependent terms; $\boldsymbol{g^{(k)}(\theta_T, \phi_T, \psi_T)}$: angular terms

Angular analysis

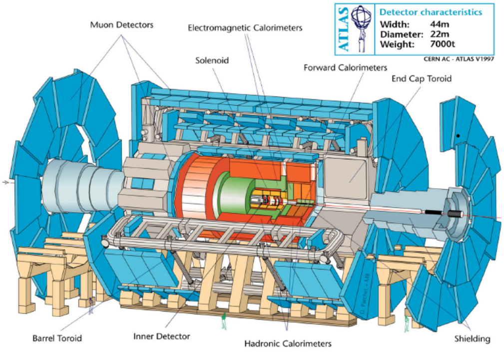
Differential decay rate

- If initial flavor not known $\to$ terms starting with $\pm$ and $\mp$ disappear
- Initial **flavor tagging** $\to$ measurement of ϕ_s **gains sensitivity**

$\pm$ "+" for B_s^0 and "−" for $\bar{B}_s^0$ $\quad$ $\mp$ "−" for B_s^0 and "+" for $\bar{B}_s^0$

k	$\mathcal{O}^{(k)}(t)$	$g^{(k)}(\theta_T,\psi_T,\phi_T)$
1	$\frac{1}{2}\lvert A_0(0)\rvert^2\left[(1+\cos\phi_s)\,e^{-\Gamma_{\mathrm{L}}^{(s)}t}+(1-\cos\phi_s)\,e^{-\Gamma_{\mathrm{H}}^{(s)}t}\pm 2e^{-\Gamma_s t}\sin(\Delta m_s t)\sin\phi_s\right]$	$2\cos^2\psi_T(1-\sin^2\theta_T\cos^2\phi_T)$
2	$\frac{1}{2}\lvert A_\parallel(0)\rvert^2\left[(1+\cos\phi_s)\,e^{-\Gamma_{\mathrm{L}}^{(s)}t}+(1-\cos\phi_s)\,e^{-\Gamma_{\mathrm{H}}^{(s)}t}\pm 2e^{-\Gamma_s t}\sin(\Delta m_s t)\sin\phi_s\right]$	$\sin^2\psi_T(1-\sin^2\theta_T\sin^2\phi_T)$
3	$\frac{1}{2}\lvert A_\perp(0)\rvert^2\left[(1-\cos\phi_s)\,e^{-\Gamma_{\mathrm{L}}^{(s)}t}+(1+\cos\phi_s)\,e^{-\Gamma_{\mathrm{H}}^{(s)}t}\mp 2e^{-\Gamma_s t}\sin(\Delta m_s t)\sin\phi_s\right]$	$\sin^2\psi_T\sin^2\theta_T$
4	$\frac{1}{2}\lvert A_0(0)\rvert\lvert A_\parallel(0)\rvert\cos\delta_\parallel$ $\left[(1+\cos\phi_s)\,e^{-\Gamma_{\mathrm{L}}^{(s)}t}+(1-\cos\phi_s)\,e^{-\Gamma_{\mathrm{H}}^{(s)}t}\pm 2e^{-\Gamma_s t}\sin(\Delta m_s t)\sin\phi_s\right]$	$-\frac{1}{\sqrt{2}}\sin 2\psi_T\sin^2\theta_T\sin 2\phi_T$
5	$\lvert A_\parallel(0)\rvert\lvert A_\perp(0)\rvert[\frac{1}{2}(e^{-\Gamma_{\mathrm{L}}^{(s)}t}-e^{-\Gamma_{\mathrm{H}}^{(s)}t})\cos(\delta_\perp-\delta_\parallel)\sin\phi_s$ $\pm e^{-\Gamma_s t}(\sin(\delta_\perp-\delta_\parallel)\cos(\Delta m_s t)-\cos(\delta_\perp-\delta_\parallel)\cos\phi_s\sin(\Delta m_s t))]$	$\sin^2\psi_T\sin 2\theta_T\sin\phi_T$
6	$\lvert A_0(0)\rvert\lvert A_\perp(0)\rvert[\frac{1}{2}(e^{-\Gamma_{\mathrm{L}}^{(s)}t}-e^{-\Gamma_{\mathrm{H}}^{(s)}t})\cos\delta_\perp\sin\phi_s$ $\pm e^{-\Gamma_s t}(\sin\delta_\perp\cos(\Delta m_s t)-\cos\delta_\perp\cos\phi_s\sin(\Delta m_s t))]$	$\frac{1}{\sqrt{2}}\sin 2\psi_T\sin 2\theta_T\cos\phi_T$
7	$\frac{1}{2}\lvert A_S(0)\rvert^2\left[(1-\cos\phi_s)\,e^{-\Gamma_{\mathrm{L}}^{(s)}t}+(1+\cos\phi_s)\,e^{-\Gamma_{\mathrm{H}}^{(s)}t}\mp 2e^{-\Gamma_s t}\sin(\Delta m_s t)\sin\phi_s\right]$	$\frac{2}{3}\left(1-\sin^2\theta_T\cos^2\phi_T\right)$
8	$\lvert A_S(0)\rvert\lvert A_\parallel(0)\rvert[\frac{1}{2}(e^{-\Gamma_{\mathrm{L}}^{(s)}t}-e^{-\Gamma_{\mathrm{H}}^{(s)}t})\sin(\delta_\parallel-\delta_S)\sin\phi_s$ $\pm e^{-\Gamma_s t}(\cos(\delta_\parallel-\delta_S)\cos(\Delta m_s t)-\sin(\delta_\parallel-\delta_S)\cos\phi_s\sin(\Delta m_s t))]$	$\frac{1}{3}\sqrt{6}\sin\psi_T\sin^2\theta_T\sin 2\phi_T$
9	$\frac{1}{2}\lvert A_S(0)\rvert\lvert A_\perp(0)\rvert\sin(\delta_\perp-\delta_S)$ $\left[(1-\cos\phi_s)\,e^{-\Gamma_{\mathrm{L}}^{(s)}t}+(1+\cos\phi_s)\,e^{-\Gamma_{\mathrm{H}}^{(s)}t}\mp 2e^{-\Gamma_s t}\sin(\Delta m_s t)\sin\phi_s\right]$	$\frac{1}{3}\sqrt{6}\sin\psi_T\sin 2\theta_T\cos\phi_T$
10	$\lvert A_0(0)\rvert\lvert A_S(0)\rvert[\frac{1}{2}(e^{-\Gamma_{\mathrm{H}}^{(s)}t}-e^{-\Gamma_{\mathrm{L}}^{(s)}t})\sin\delta_S\sin\phi_s$ $\pm e^{-\Gamma_s t}(\cos\delta_S\cos(\Delta m_s t)+\sin\delta_S\cos\phi_s\sin(\Delta m_s t))]$	$\frac{4}{3}\sqrt{3}\cos\psi_T\left(1-\sin^2\theta_T\cos^2\phi_T\right)$

The ATLAS Experiment



The ATLAS experiment

- **Inner detector:** tracks $p_T > 500$ MeV and $|\eta| < 2.5$
- **Muon spectrometer:** $p_T \gtrsim 2500$ MeV and $|\eta| < 2.7$
  - **Combined muons:** ID+MS combined track
  - **Tagged muons:** ID track + matched MS segments
  - **Extrapolated muons:** MS track extrapolated to ID

This analysis

- Using only **combined** and segment **tagged** muons
- Track parameters from the **ID measurement** only (precision dominated by the ID)

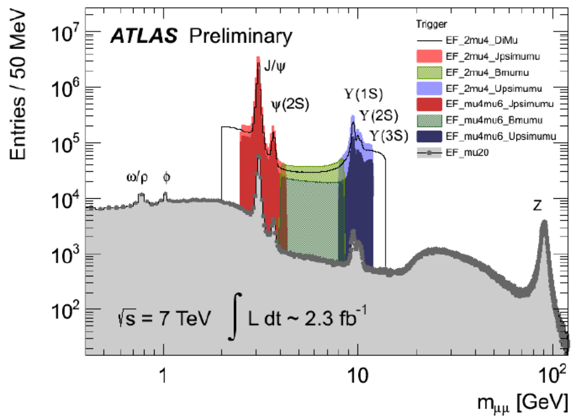
Data, Monte Carlo, and Trigger

Data and Monte Carlo

- **7 TeV data** collected in **2011**, integrated luminosity of 4.9 fb^{-1}
- **Monte Carlo**
  - **Signal**: $B_s^0 \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$ (12 M, Pythia 6)
  - **Background**: $B^0 \to J/\psi K^{*0}$, $b\bar{b} \to J/\psi X$, and $pp \to J/\psi X$

Trigger selection

- **Combination** of **single** and **di-muon** triggers
  - J/ψ trigger with p_T requirement of **4 GeV** on **both** muons (almost unprescaled)
  - J/ψ trigger with p_T requirement of **4 GeV and 2.5 GeV** (prescale)
  - Other prescaled muon triggers
- MC events **weighted** to **emulate** trigger **prescales**



Decay reconstruction

1. $J/\psi \to \mu^+\mu^-$: oppositely charged muons fit to a common vertex
2. $\phi \to K^+K^-$: oppositely charged tracks, $p_T > 0.5$ GeV, $|m_{KK} - m_\phi| < 11$ MeV
3. $B_s \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$: $\mu^+\mu^-K^+K^-$ vertex fit
   - J/ψ mass constrained in the fit
   - Vertex $\chi^2/N_{dof} < 3$
   - Invariant mass range $5.15 < m_{\mu\mu KK} < 5.65$ GeV

- Selected **132k** *Bs* candidates
- **No** explicit **requirement** made on **proper decay time!**

Primary vertex

- In each bunch-crossing on average $\langle\mu\rangle \sim 5.6$ collisions
- Primary vertex: **closest** to the $\boldsymbol{B_s}$ **momentum** in 3D

Flavor tagging

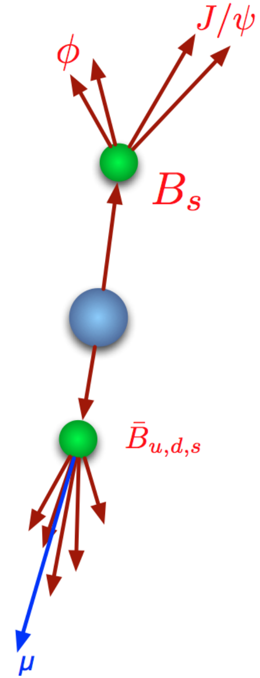
- Knowledge of **initial** *B* **flavor** improves **precision** of ϕ_s measurement
- **Opposite-side** tagging:
  - *b* quarks created in **pairs** $b\bar{b}$
  - **Flavor** of B_s is **correlated** with the flavor of **other** *B* meson in the event

Muon tagging

- $b \to \mu$ transition: *b* **flavor** given by $\boldsymbol{\mu}$ **charge**
- **Diluted** by $b \to c \to \mu$ cascade decays and neutral *B* meson oscillations

Jet charge tagging

- Search for **jet** opposite to B_s meson
- Momentum-weighted **track charge** sum as discriminating variable

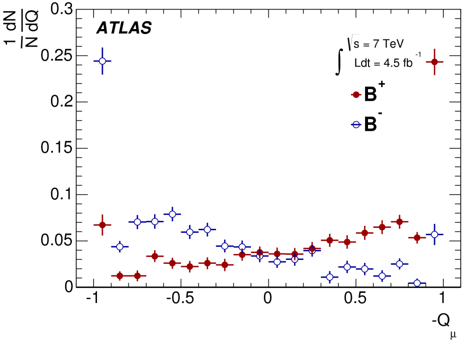


Flavor tagging

Muon tagging

- Additional **muon** in the event
- Muon and tracks in the cone $\Delta R < 0.5$ around the muon:

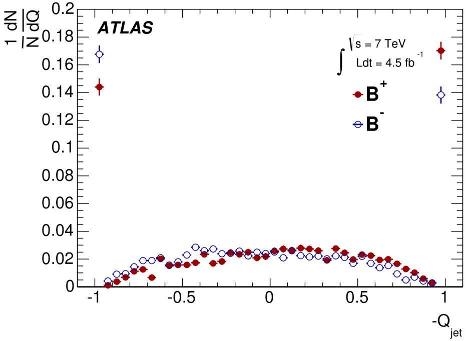
$$Q_\mu = \frac{\sum_{tracks} q^i (p_T^i)^\kappa}{\sum_{tracks} (p_T^i)^\kappa}$$



Jet charge tagging

- In absence of μ use b-tagged **jet**
- Tracks in the cone $\Delta R < 1.0$ around the jet axis:

$$Q_{jet} = \frac{\sum_{tracks} q^i (p_T^i)^\kappa}{\sum_{tracks} (p_T^i)^\kappa}$$

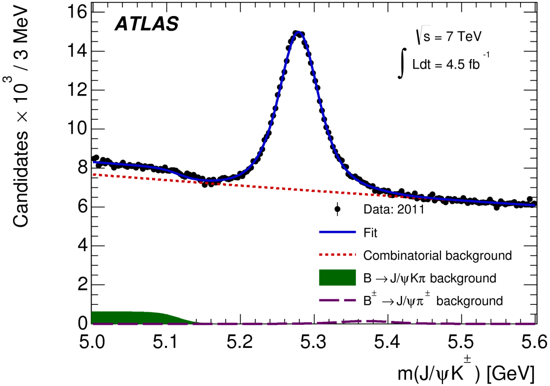


- Taggers **calibrated** with $B^\pm \to J/\psi K^\pm$ decays with **known flavor**

Flavor tagging

Tagging calibration

- **Probability distributions** for Q_μ and Q_{jet} created using events with $B^\pm \to J/\psi K^\pm$
- **Background subtracted** using distributions of Q_μ and Q_{jet} for events in **sidebands**



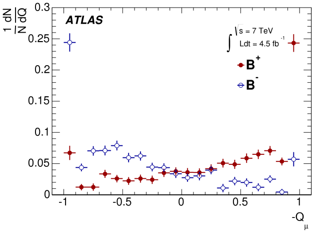
- **Calibration** → probability distributions $P(Q|B^+)$ and $P(Q|B^-)$
- **Tagging probability:** (Bayes' theorem)

$$P(B|Q) = \frac{P(Q|B^+)}{P(Q|B^+) + P(Q|B^-)} \qquad P(\bar{B}|Q) = \frac{P(Q|B^-)}{P(Q|B^+) + P(Q|B^-)}$$

Flavor tagging

Tagging performance

- Tagging efficiency $\epsilon = 32.1 \pm 0.1$ %
- Effective dilution $\mathcal{D} = 21.3 \pm 0.08$ %
- Tagging power $TP = 1.45 \pm 0.05$ %



$$P_i = \frac{P(Q_i|B^+)}{P(Q_i|B^+)+P(Q_i|B^-)}$$

$$\epsilon = \frac{1}{N}\sum_{i=1}^{n_{bins}} n_i \qquad \mathcal{D} = \sqrt{\frac{TP}{\epsilon}} \qquad TP = \frac{1}{N}\sum_{i=1}^{n_{bins}} n_i[2P_i - 1]^2$$

Tagger	Efficiency [%]	Dilution [%]	Tagging Power [%]
Combined μ	3.37 ± 0.04	50.6 ± 0.5	0.86 ± 0.04
Segment Tagged μ	1.08 ± 0.02	36.7 ± 0.7	0.15 ± 0.02
Jet charge	27.7 ± 0.1	12.68 ± 0.06	0.45 ± 0.03
Total	32.1 ± 0.1	21.3 ± 0.08	1.45 ± 0.05

Maximum likelihood fit

Observables

- Invariant mass $\boldsymbol{m_{J/\psi KK}}$
- Proper decay time: $\boldsymbol{t}$ $= L_{xy} m_B / p_T$
- Uncertainties $\boldsymbol{\sigma_m}$ and $\boldsymbol{\sigma_t}$
- Three transversity angles $\boldsymbol{\Omega}$ $\equiv (\theta_T, \phi_T, \psi_T)$
- Tagging probability: $\boldsymbol{P(B|Q)}$
- Transverse momentum: $\boldsymbol{p_T}$

Likelihood function

$$\ln \mathcal{L} = \sum_{i=1}^{N} \{ w_i \cdot \ln(f_s \cdot \mathcal{F}_s(m_i, t_i, \Omega_i, P(B|Q)) + f_s \cdot f_{B^0} \cdot \mathcal{F}_{B^0}(m_i, t_i, \Omega_i, P(B|Q)) + (1 - f_s \cdot (1 + f_{B^0})) \cdot \mathcal{F}_{\text{bkg}}(m_i, t_i, \Omega_i, P(B|Q))) \}$$

- Time-dependent muon trigger **efficiency correction**
- **Signal** probability density function (**PDF**)
- **Background** from $B^0 \to J/\psi K^{*0}$ and $B^0 \to J/\psi K\pi$
- Prompt and non-prompt **combinatorial background**

In total **25 free parameters**

Maximum likelihood fit

Signal PDF

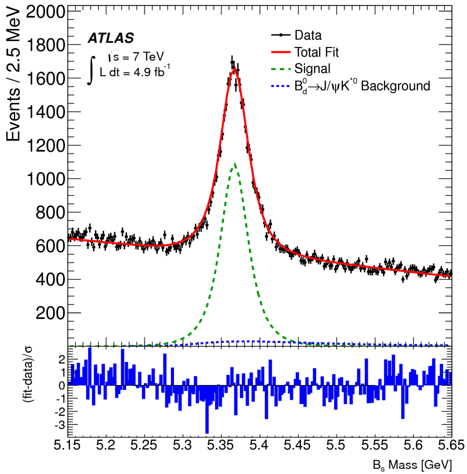
$$\mathcal{F}_\mathrm{s}(m_i, t_i, \Omega_i, P(B|Q)) = P_\mathrm{s}(m_i, \sigma_{m_i}) \cdot P_\mathrm{s}(\sigma_{m_i}) \cdot P_\mathrm{s}(\Omega_i, t_i, P(B|Q), \sigma_{t_i}) \cdot P_\mathrm{s}(\sigma_{t_i}) \cdot P_\mathrm{s}(P(B|Q)) \cdot A(\Omega_i, p_{\mathrm{T}i}) \cdot P_\mathrm{s}(p_{\mathrm{T}i})$$

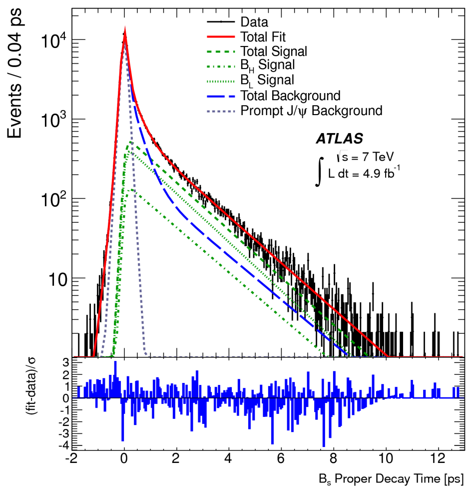
- **Mass PDF**: **gaussian** with width σ_{m_i}
- **Time-angular** PDF convolved with time resolution function $\mathcal{G}(t, \sigma_{t_i})$. Flavor-dependent terms weighted by the corresponding tagging probability
- Angular **acceptance** (from MC, in bins of p_T)
- **Punzi terms** [empirical distributions of σ_{m_i}, σ_{t_i}, and $P(B|Q)$].

Maximum likelihood fit

Results of the fit (Δm_s fixed, $|A_\perp|$ from the constraint, $\delta_0 \equiv 0$)

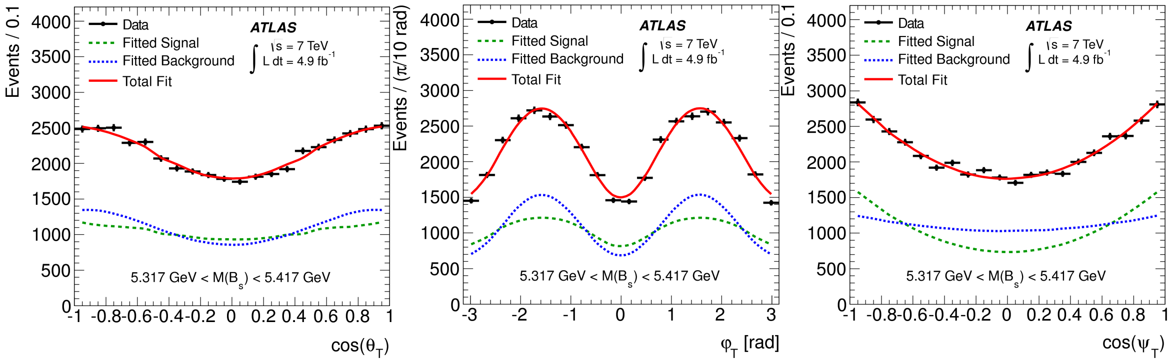
- $\phi_s = 0.12 \pm 0.25$ rad
- $\Delta\Gamma_s$: $0.053 \pm 0.021 \text{ps}^{-1}$
- $\Gamma_s = 0.677 \pm 0.007 \text{ ps}^{-1}$
- $|A_\parallel(0)|^2 = 0.220 \pm 0.008$
- $|A_0(0)|^2 = 0.529 \pm 0.006$
- $|A_S(0)|^2 = 0.024 \pm 0.014$
- $\delta_\perp = 3.89 \pm 0.47$ rad
- $\delta_\parallel \in [3.14, 3.23]$ rad
- $\delta_\perp - \delta_S$: $[3.02, 3.25]$ rad





Results of the fit

Projections of the fitted PDF onto angular axes for events in the mass range [5.317, 5.417] GeV



Systematic uncertainties

	ϕ_s [rad]	$\Delta\Gamma_s$ [ps^{-1}]	Γ_s [ps^{-1}]	$\|A_{\parallel}(0)\|^2$	$\|A_0(0)\|^2$	$\|A_S(0)\|^2$	$\delta_\perp$ [rad]	$\delta_\parallel$ [rad]	$\delta_\perp - \delta_S$ [rad]
ID alignment	$<10^{-2}$	$<10^{-3}$	$<10^{-3}$	$<10^{-3}$	$<10^{-3}$	-	$<10^{-2}$	$<10^{-2}$	-
Trigger efficiency	$<10^{-2}$	$<10^{-3}$	0.002	$<10^{-3}$	$<10^{-3}$	$< 10^{-3}$	$<10^{-2}$	$<10^{-2}$	$<10^{-2}$
B^0 contribution	0.03	0.001	$<10^{-3}$	$<10^{-3}$	0.005	0.001	0.02	$<10^{-2}$	$<10^{-2}$
Tagging	0.03	$<10^{-3}$	$<10^{-3}$	$<10^{-3}$	$<10^{-3}$	$<10^{-3}$	0.04	$<10^{-2}$	$<10^{-2}$
Acceptance	0.02	0.004	0.002	0.002	0.004	-	-	$<10^{-2}$	-
Models:									
Default fit	$<10^{-2}$	0.003	$<10^{-3}$	0.001	0.001	0.006	0.07	0.01	0.01
Signal mass	$<10^{-2}$	0.001	$<10^{-3}$	$<10^{-3}$	0.001	$<10^{-3}$	0.03	0.04	0.01
Background mass	$<10^{-2}$	0.001	0.001	$<10^{-3}$	$<10^{-3}$	0.002	0.06	0.02	0.02
Resolution	0.02	$<10^{-3}$	0.001	0.001	$<10^{-3}$	0.002	0.04	0.02	0.01
Background time	0.01	0.001	$<10^{-3}$	0.001	$<10^{-3}$	0.002	0.01	0.02	0.02
Background angles	0.02	0.008	0.002	0.008	0.009	0.027	0.06	0.07	0.03
Total	0.05	0.010	0.004	0.009	0.012	0.028	0.11	0.09	0.04

- Uncertainty of **trigger efficiency** correction
- Variation of physics **background fractions**
- Variation of **tagging calibration** parametrization
- Uncertainty estimated form **MC tests** of acceptance fitting method
- Pseudo-experiments with **variations of parameterizations**

Results

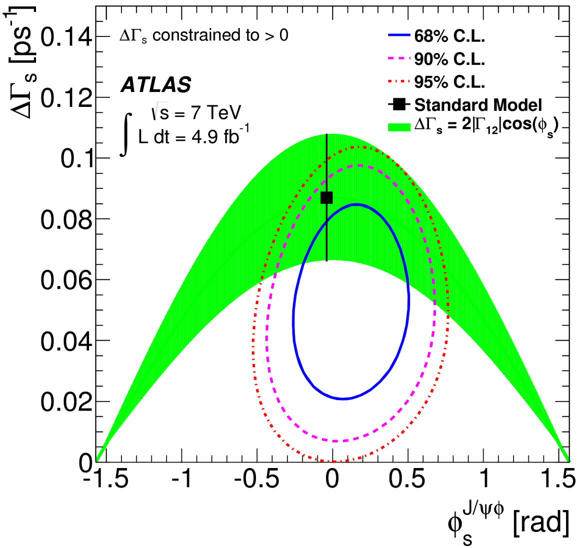
- Ambiguity in sign of $\Delta\Gamma_s$: $\{\phi_s, \Delta\Gamma_s, \delta_\perp, \delta_\parallel\} \rightarrow \{\pi - \phi_s, -\Delta\Gamma_s, \pi - \delta_\perp, 2\pi - \delta_\parallel\}$
- $\boldsymbol{\Delta\Gamma_s > 0}$ constrained by LHCb (PRL 108 (2012) 241801)

Summary of the fit extracted parameters

Parameter	Value	Statistical uncertainty	Systematic uncertainty
ϕ_s[rad]	0.12	0.25	0.05
$\Delta\Gamma_s$[ps^{-1}]	0.053	0.021	0.010
Γ_s[ps^{-1}]	0.677	0.007	0.004
$\lvert A_\parallel(0)\rvert^2$	0.220	0.008	0.009
$\lvert A_0(0)\rvert^2$	0.529	0.006	0.012
$\lvert A_S(0)\rvert^2$	0.024	0.014	0.028
$\delta_\perp$	3.89	0.47	0.11
$\delta_\parallel$	[3.04, 3.23]		0.09
$\delta_\perp - \delta_S$	[3.02, 3.25]		0.04

$$\phi_s^{SM} = -0.0368 \pm 0.0018$$

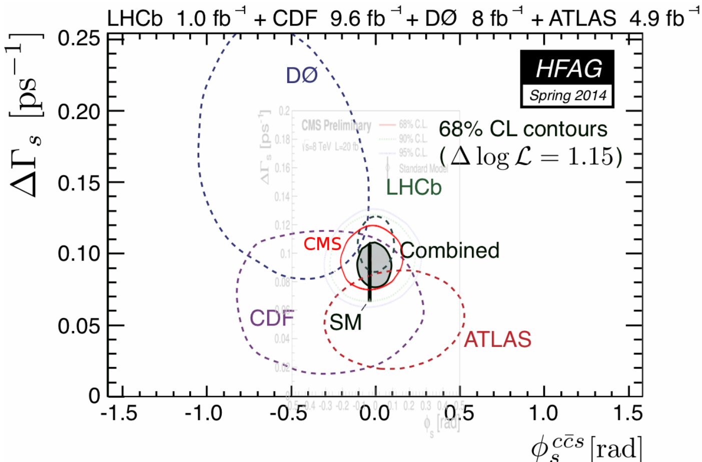
log L contours in $\phi_s \times \Delta\Gamma_s$ space



Results

Comparison with other measurements

- HFAG combination shows an **agreement with the SM**
- HFAG combination **does not include** the **CMS** result
- CMS result **superimposed**



CMS-PAS-BPH-11-006: (20 fb^{-1})	**ATLAS**:	LHCb: (PRD 87 112010)
ϕ_s [rad]: $0.03 \pm 0.11 \pm 0.03$	$0.12 \pm 0.25 \pm 0.05$	$0.07 \pm 0.09 \pm 0.01$
$\Delta\Gamma_s$ [ps]: $0.096 \pm 0.014 \pm 0.007$	$0.053 \pm 0.021 \pm 0.010$	$0.100 \pm 0.016 \pm 0.003$

[$\phi_s = 0.070 \pm 0.068 \pm 0.008$ with $J/\psi\pi\pi$ (arXiv:1405.4140)]

Conclusions

- Flavor-tagged time-angular analysis of $B_s \to J/\psi\phi$ decay with ATLAS 7 TeV data (2011) was performed
- The weak phase ϕ_s and the B_s^L and B_s^H decay rate difference was measured to be

$$\phi_s = 0.12 \pm 0.25(stat) \pm 0.05(syst)\ \text{rad}$$
$$\Delta\Gamma_s = 0.053 \pm 0.021(stat) \pm 0.010(syst)\ \text{ps}^{-1}$$

- The results is in agreement with measurements by D0, CDF, LHCb, and CMS
- The results is in agreement with the SM expectations
- Analysis of 8 TeV data (2012) is under way
- Exciting prospects of precision measurement with run-2 data (ATL-PHYS-PUB-2013-010)

Backup slides

Maximum likelihood fit

Tagging probability distributions (Punzi terms)

- Parametrized from **fits** to B_s **data** using Chebychev polynomials
- **Background** distributions fixed in **sidebands**
- Probabilities for events with $Q = \pm 1$ treated separately
- P = 0.5 in absence of tagging information