Mixing and CP-violation in the B_s^0 system with ATLAS

Les Rencontres de Physique de la Valle d'Aoste - 2015

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On behalf of the
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Introduction

Why $B_s^0 \rightarrow J/\psi\phi$?

- Why, what, and how to measure

ATLAS 2011 Results

- ATLAS and other RUN 1 results

Upcoming ATLAS 2012 Analysis

- Improvements made between 2011 and 2012

ATLAS in RUN 2 and Beyond

- Expectations for the future

CPV Measurements in B_s^0 Systems

CP-Violation Phases

- $B_s^0 \to J/\psi\phi$ expected to be extremely sensitive to BSM physics
- CP-violation phase: ϕ_s, predicted by SM to high precision
  - $\phi_{s\mathrm{SM}} = (-0.0364 \pm 0.0016)$
- Pseudo-scalar $\to$ vector vector
  - 3 P-wave CP eigenstates
  - 2 S-wave contributions
    - Non-resonant $B_s^0 \to J/\psi(\mu^+\mu^-)K^+K^-$
    - Resonant $B_s^0 \to J/\psi(\mu^+\mu^-)f_0(K^+K^-)$
- Requires time-dependent angular analysis to resolve CP eigenstates

ATLAS Results

- Two publications on CPV in $B_s^0 \to J/\psi\phi$ using 2011 data
  - Untagged, JHEP 12 (2012) 072 [1]
  - Tagged, Phys. Rev. D 90 (2014) 052007 [2]

ATLAS 2011 Measurement

Method

- Measure:
  - Mass and lifetime
  - Transversity angles
  - Initial flavour ($\approx$ 30% of events)
- Unbinned maximal likelihood fit
  - $B_s^0 \to J/\psi\phi$ signal PDF
  - Two dedicated S-wave signal channels
  - Two B_d^0 background channels
  - Combinatorial background

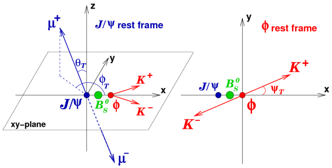
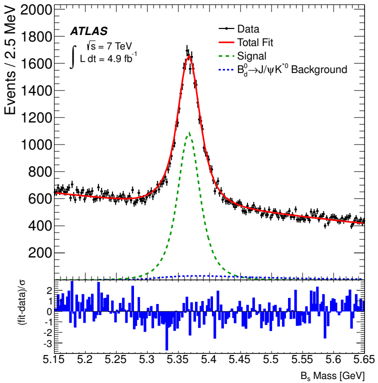


Figure: Transversity angles [3]

B_d^0 Background

- Due to misidentified $\pi^\pm$
  - $B_d^0 \to J/\psi(\mu^+\mu^-)K^+\pi^-$
  - $B_d^0 \to J/\psi(\mu^+\mu^-)K^*(K^+\pi^-)$

ATLAS 2011 Mass and Lifetime Fits



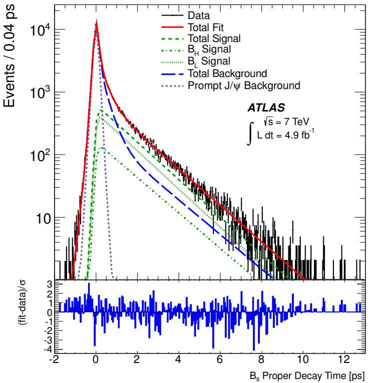


Figure: ATLAS 2011 candidate event mass (left), and lifetime fit (right) [2]

Event Selection

p_T Cuts

- $p_T(\mu^\pm) > \sim$4.0 GeV (trigger thresholds)
- $p_T(K^\pm) > 0.5$ GeV

Track/Vertex Quality Cuts

- 1 Pixel hit, 4 SCT hits track quality cut
- Vertex quality of:
  - χ^2/d.o.f < 10 for J/ψ candidate
  - χ^2/d.o.f < 3 for B_s^0 candidate

Mass Cuts

- $2.852 < m(\mu^+\mu^-) < 3.332$ GeV
- 1.0085 GeV $< m(K^+K^-) <$ 1.0305 GeV
- $5.15 < m(\mu^+\mu^-K^+K^-) < 5.65$ GeV

ATLAS Tagged 2011 Results

Measured Parameters

- Events:
  - Total, $\approx 131\,000$
  - Signal, $\approx 22\,000$
- Weak phase parameters:
  - ϕ_s
  - Γ_s and $\Delta\Gamma_s$
- Transversity amplitudes:
  - $|A_0(0)|^2$ and $|A_{||}(0)|^2$
  - $|A_\perp(0)|^2$
  - $|A_S|^2$
- Relative strong phases:
  - $\delta_{||}$ and $\delta_\perp$
  - $\delta_\perp - \delta_S$

Par	Atlas 2011 [2]		
	Val	Stat	Syst
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
$\|A_{\|\|}(0)\|^2$	0.220	0.008	0.009
$\|A_0(0)\|^2$	0.529	0.006	0.012
$\|A_S\|^2$	0.024	0.014	0.028
$\delta_\perp$	3.89	0.47	0.11
$\delta_{\|\|}$	[3.04, 3.23]		0.09
$\delta_\perp - \delta_S$	[3.02, 3.25]		0.04

$\Delta\Gamma_s > 0$, Δm_S set to PDG value

Table: ATLAS tagged 2011 results

ATLAS 2011 Results, 2D Contours

Standard Model

- Results are consistent with theoretical expectations

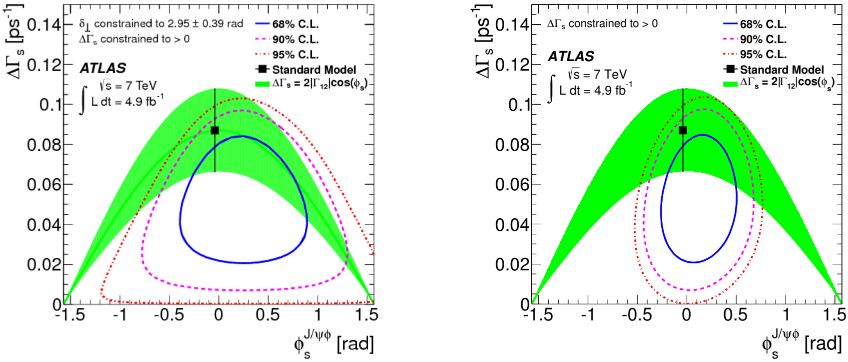


Figure: ATLAS 2011 2D likelihood scans in the ϕ_s- $\Delta\Gamma_s$plane for the untagged analysis (left) [1] and tagged analysis (right) [2]

Current LHC Results

Current LHC Results

- Current LHC results show no significant deviation from SM predictions
- LHCb include additional channels in the measurement of ϕ_s
  - Improvement in statistical errors
  - Remove measurement of S-wave contributions

	Atlas 2011 [2]			CMS 2012 [4]			LHCb 2011 [5]			LHCb RUN1 [6]		
$\int L\,\mathrm{d}t$ [fb^{-1}]	4.9			20			1.0			3.0		
Par	Val	Stat	Syst	Val	Stat	Syst	Val	Stat	Syst	Val	Stat	Syst
ϕ_s[rad]	0.12	0.25	0.05	- 0.03	0.11	0.032	0.07	0.09	0.01	-0.058	0.049	0.006
$\Delta\Gamma_s$[ps^{-1}]	0.053	0.021	0.010	0.096	0.014	0.0073	0.100	0.016	0.003	0.0805	0.0091	0.0032
Γ_s[ps^{-1}]	0.677	0.007	0.004	0.670 *	-	-	0.663	0.005	0.006	0.6603	0.0027	0.0015

*, CMS report $c\tau = 447.3 \pm 3.0 \pm 3.5$ [μm]

Table: Selected LHC RUN 1 results

LHC RUN 1 Results, 2D Contours

Standard Model

- No significant deviations from SM predictions

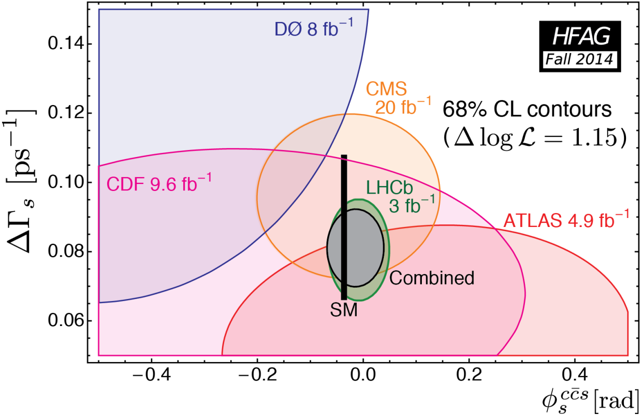


Figure: LHC RUN 1 2D likelihood scans in the ϕ_s- $\Delta\Gamma_s$plane [7]

ATLAS 2012 and RUN 1

ATLAS 2012 Results

- Expected soon
- Will include a full RUN 1 result
  - BLUE combination
  - $\int L\,\mathrm{d}t = 19.2\ \mathrm{fb}^{-1}$

Background Model

- New background model for:
  - Mass, lifetime, p_T
  - Angular distribution

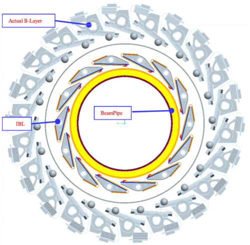
Flavour Tagging

- New tagging method

CPV Measurements in RUN 2 and Beyond

Hardware and Pile-Up

- Study for $B_s^0 \to J/\psi\phi$ complete, see ATL-PHYS-PUB-2013-010 [8]
- Full detector simulation of IBL (RUN 2/3) $\to$ Baseline ITK (HL-LHC)
- ϕ_s sensitivity to:
  - Detector hardware
  - Run environment



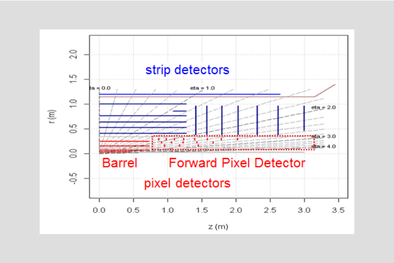


Figure: IBL (left) [9] and baseline ITK (right) [10] geometries

Expected σ_τ Distributions

Per-candidate Lifetime Uncertainties

- ATLAS + IBL improves time resolution by 30% for fixed p_T
- ATLAS RUN 2 resolution competitive with LHCb expectations

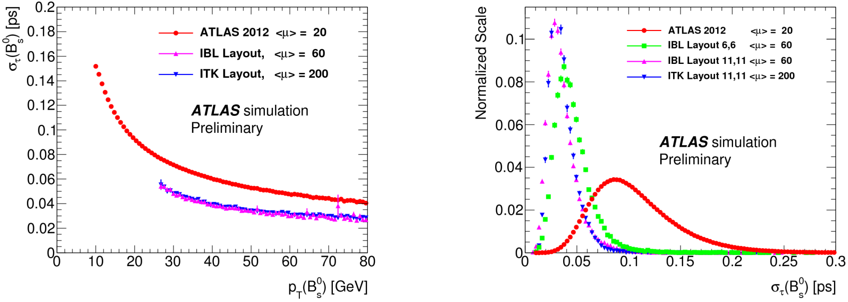
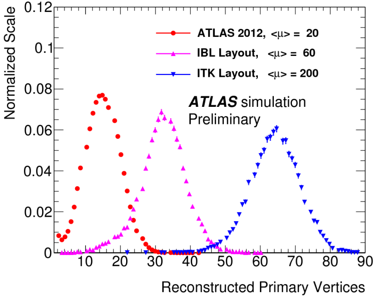


Figure: Per-candidate lifetime uncertainties as a function of p_T (left), and expected lifetime uncertainty distribution (right) [8]

Increased Luminosity

Primary Vertex Reconstruction

- Increased luminosity brings additional challenges:
  - Quality of reconstructed vertices
  - B_s^0 to vertex association



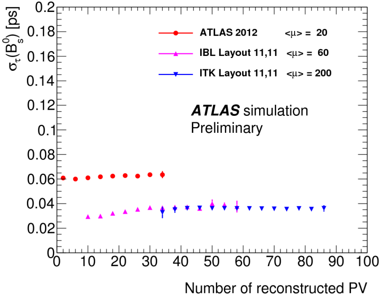


Figure: Expected number of reconstructed primary vertices (left), and per-candidate lifetime uncertainties (right) [8]

Expected Statistical Errors on ϕ_s

Estimation of ϕ_s Precision

- Pseudo-experiments used to estimate future statistical errors
- Model (based on ATLAS 2011 analysis) assumes:
  - $b\bar{b} \rightarrow J/\psi X$ cross-section doubles at 14 TeV
  - Conservative assumptions for triggers, vertexing, and flavour tagging

	2011	2012	RUN 2		RUN 3	HL-LHC
Detector	current	current	IBL		IBL	ITK
Average interactions per BX $<\mu>$	6-12	21	60		60	200
Luminosity, fb^{-1}	4.9	20	100		250	3 000
Di-μ trigger p_T thresholds, GeV	4 - 4(6)	4 - 6	6 - 6	11 - 11	11 - 11	11 - 11
Signal events per fb^{-1}	4 400	4 320	3 280	460	460	330
Signal events	22 000	86 400	327 900	45 500	114 000	810 000
Total events in analysis	130 000	550 000	1 874 000	284 000	758 000	6 461 000
MC $\sigma(\phi_s)$ (stat.), rad	0.25	0.12	0.054	0.10	0.064	0.022

Table: Expected statistical errors in future $B_s^0 \rightarrow J/\psi \phi$ analyses [8], highlighted are RUN 2, RUN 3, and HL-LHC predictions

Conclusions

$B_s^0 \to J/\psi\phi$ Remains an Important Channel

- For B-physics in general
- As a BSM search tool

ATLAS Results

- 2011 Tagged analysis available [2]
- 2012 + RUN 1 results - soon

RUN 2 Expectations

- Exciting times in 2015–17!

[1] "Time-dependent angular analysis of the decay $B_s^0 \to J/\psi\phi$ and extraction of $\Delta\Gamma_s$ and the CP-violating weak phase ϕ_s by ATLAS". In: *J. High Energy Phys.* 12.arXiv:1208.0572. CERN-PH-EP-2012-182 (Aug. 2012), 072. 40 p.

[2] *Flavour tagged time dependent angular analysis of the $B_s \to J/\psi\phi$ decay and extraction of $\Delta\Gamma$ and the weak phase ϕ_s in ATLAS*. Tech. rep. ATLAS-CONF-2013-039. Geneva: CERN, Apr. 2013.

[3] T. Aaltonen et al. "Measurement of the CP-Violating Phase $\beta_s^{J/\Psi\phi}$ in $B_s^0 \to J/\Psi\phi$ Decays with the CDF II Detector". In: *Phys.Rev.* D85 (2012), p. 072002. DOI: 10.1103/PhysRevD.85.072002. arXiv: 1112.1726 [hep-ex].

[4] *Measurement of the CP-violating weak phase phi-s and the decay width difference DeltaGamma-s using the Bs to J/psiPhi(1020) decay channel*. Tech. rep. CMS-PAS-BPH-13-012. Geneva: CERN, 2014.

[5] R Aaij et al. "Measurement of *CP* violation and the B_s^0 meson decay width difference with $B_s^0 \to J/\psi K^+K^-$ and $B_s^0 \to J/\psi\pi^+\pi^-$ decays". In: *Phys. Rev. D 87,* 112010 (2013). DOI: 10.1103/PhysRevD.87.112010. arXiv: 1304.2600 [hep-ex].

[6] Roel Aaij et al. "Precision measurement of *CP* violation in $B_s^0 \to J/\psi K^+K^-$ decays". In: *Phys.Rev.Lett.* 114 (2015), p. 041801. DOI: 10.1103/PhysRevLett.114.041801. arXiv: 1411.3104 [hep-ex].

[7] Y. Amhis et al. "Averages of *b*-hadron, *c*-hadron, and τ-lepton properties as of summer 2014". In: (2014). arXiv: 1412.7515 [hep-ex].

[8] *ATLAS B-physics studies at increased LHC luminosity, potential for CP-violation measurement in the $B_s^0 \to J/\psi\phi$ decay*. Tech. rep. ATL-PHYS-PUB-2013-010. Geneva: CERN, Sept. 2013.

[9] M Capeans et al. *ATLAS Insertable B-Layer Technical Design Report*. Tech. rep. CERN-LHCC-2010-013. ATLAS-TDR-19. Geneva: CERN, Sept. 2010.

[10] A Clark et al. *Final Report: ATLAS Phase-2 Tracker Upgrade Layout Task Force*. Tech. rep. ATL-UPGRADE-PUB-2012-004. Geneva: CERN, Oct. 2012.

Backup

Backup Slides

Signal PDF

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

Table: Signal PDF for the $B_s^0 \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$ analysis, showing kinematic, tagging, and helicity components [2]

Likelihood Formula, 1

$$\ln\ \mathcal{L} = \sum_{i=1}^{N} \{w_i \cdot \ln(f_s \cdot \mathcal{F}_s(m_i, t_i, \Omega_i, P(B|Q)) + f_s \cdot f_{B^0} \cdot \mathcal{F}_{B^0}(m_i, t_i, \Omega_i, P(B|Q)) + (1 - f_s \cdot (1 + f_{B^0}))\mathcal{F}_{\text{bkg}}(m_i, t_i, \Omega_i, P(B|Q)))\} \quad (5.1)$$

Likelihood Function

As shown in [2]. The terms in the log represent the signal, dedicated B^0_d, and combinatorial background PDFs while w_i is a trigger efficiency weighting.

Likelihood Formula, 2

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

Likelihood Function

As shown in [2], the terms are (in order) mass Punzi, mass uncertainty Punzi, helicity PDF, lifetime uncertainty Punzi, tagging Punzi, detector angular sculpting PDF, and the p_T Punzi.

ATLAS 2011 Tagged Correlation Table

	ϕ_s	$\Delta\Gamma$	Γ_s	$\lvert A_{\parallel}(0)\rvert^2$	$\lvert A_0(0)\rvert^2$	$\lvert A_S(0)\rvert^2$	$\delta_{\parallel}$	$\delta_{\perp}$	$\delta_{\perp} - \delta_S$
ϕ_s	1.000	0.107	0.026	0.010	0.002	0.029	0.021	-0.043	-0.003
$\Delta\Gamma$		1.000	-0.617	0.105	0.103	0.069	0.006	-0.017	0.001
Γ_s			1.000	-0.093	-0.063	0.034	-0.003	0.001	-0.009
$\lvert A_{\parallel}(0)\rvert^2$				1.000	-0.316	0.077	0.008	0.005	-0.010
$\lvert A_0(0)\rvert^2$					1.000	0.283	- 0.003	-0.016	-0.025
$\lvert A_S(0)\rvert^2$						1.000	-0.011	-0.054	-0.098
$\delta_{\parallel}$							1.000	0.038	0.007
$\delta_{\perp}$								1.000	0.081
$\delta_{\perp} - \delta_S$									1.000

Figure: Fitted parameter correlations, as shown in [2]

ATLAS 2011 Tagged Systematic Errors

	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

Figure: Systematic errors, as shown in [2]

Current LHC Results

	Atlas 2011 [2]			CMS 2012 [4]			LHCb 2011 [5]			LHCb RUN1 [6]		
$\int L\,\mathrm{d}t$ [fb^{-1}]	4.9			20			1.0			3.0		
Par	Val	Stat	Syst	Val	Stat	Syst	Val	Stat	Syst	Val	Stat	Syst
ϕ_s[rad]	0.12	0.25	0.05	- 0.03	0.11	0.032	0.07	0.09	0.01	-0.058	0.049	0.006
$\Delta\Gamma_s$[ps^{-1}]	0.053	0.021	0.010	0.096	0.014	0.0073	0.100	0.016	0.003	0.0805	0.0091	0.0032
Γ_s[ps^{-1}]	0.677	0.007	0.004	0.670 *	-	-	0.663	0.005	0.006	0.6603	0.0027	0.0015
$\|A_0(0)\|^2$	0.529	0.006	0.012	0.511	0.006	0.0116	0.521	0.006	0.010	0.5241	0.0034	0.0067
$\|A_\perp(0)\|^2$	0.227 **	-	-	0.242	0.008	0.0117	0.249	0.009	0.006	0.2504	0.0049	0.0036
$\|A_S\|^2$	0.024	0.014	0.028	0.015	0.016	0.022	-	-	-	-	-	-
$\delta_\perp$	3.89	0.47	0.11	2.73	0.36	0.66	3.07	0.22	0.08	3.08	$^{+0.14}_{-0.15}$	0.06
$\delta_\parallel$	[3.04, 3.23]		0.09	3.48	0.36	0.685	3.30	$^{+0.13}_{-0.21}$	0.08	3.26	$^{+0.10}_{-0.17}$	$^{+0.06}_{-0.07}$
$\delta_\perp - \delta_S$	[3.02, 3.25]		0.04	0.34	0.24	1.12	-	-	-	-	-	-

*, CMS report $c\tau = 447.3 \pm 3.0 \pm 3.5$ [μm]

**, ATLAS report $|A_\parallel(0)|^2 = 0.220 \pm 0.008 \pm 0.009$

Table: Selected LHC RUN 1 results

CPV Measurements in RUN 2 and Beyond

Process	Trigger	Geometry	μ	MC Events
$B_s^0 \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$	$p_T(\mu^\pm) > 3.5$ GeV	2012	20	$40 \cdot 10^6$
$B_s^0 \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$	$p_T(\mu^\pm) > 6$ GeV	IBL	60	$50 \cdot 10^3$
$B_s^0 \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$	$p_T(\mu^\pm) > 11$ GeV	IBL	60	$50 \cdot 10^3$
$B_s^0 \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$	$p_T(\mu^\pm) > 11$ GeV	ITK	200	$50 \cdot 10^3$

Table: Selected future CPV studies for $B_s^0 \to J/\psi\phi$ [8]