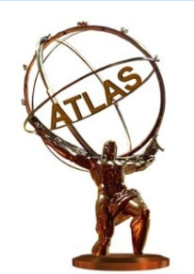


Properties of b-hadrons with ATLAS: B_s^0 rare decays and Λ_b^0 decay properties

John Baines

for the ATLAS Collaboration

Overview

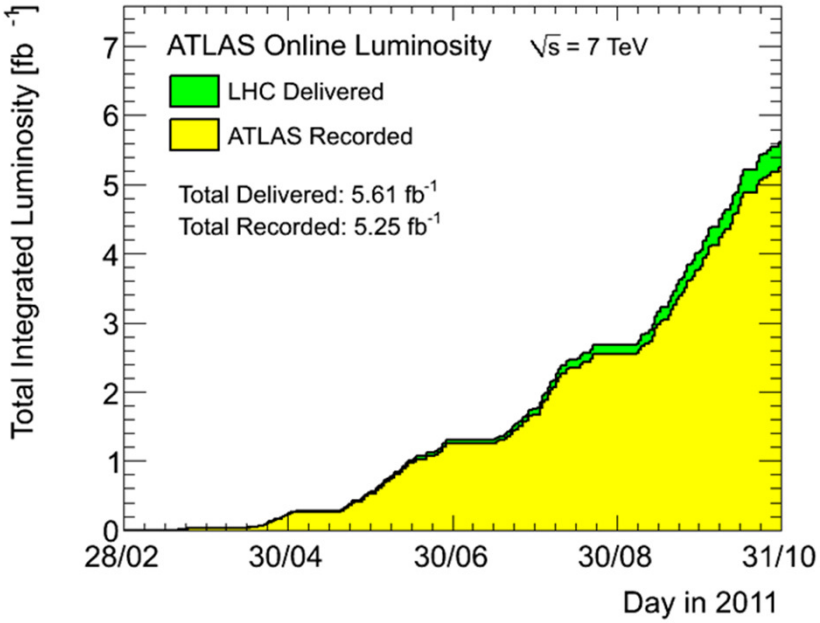
Measurements based on 2011 Dataset

- $B_s^0 \to \mu^+\mu^-$ Branching Ratio
  - Update with full 2011 dataset

NEW

- Λ_b^o mass and lifetime
- Parity violation asymmetry parameter α_b and helicity amplitudes in $\Lambda_b^o \to \Lambda^0 J/\psi$

NEW



See also other B-physics talks in this conference:

- **QCD session:** ***Review of ATLAS Heavy-Quark and Quarkonium results:*** Miriam Watson
- **This session:** ***Studies of rare and suppressed processes in B mesons decays and of mixing/CP violation in the Bs system with the ATLAS detector:*** Jochen Schieck

ATLAS Detector & B-Physics Triggers

Precision Muon Detectors: $|\eta|<2.7$:

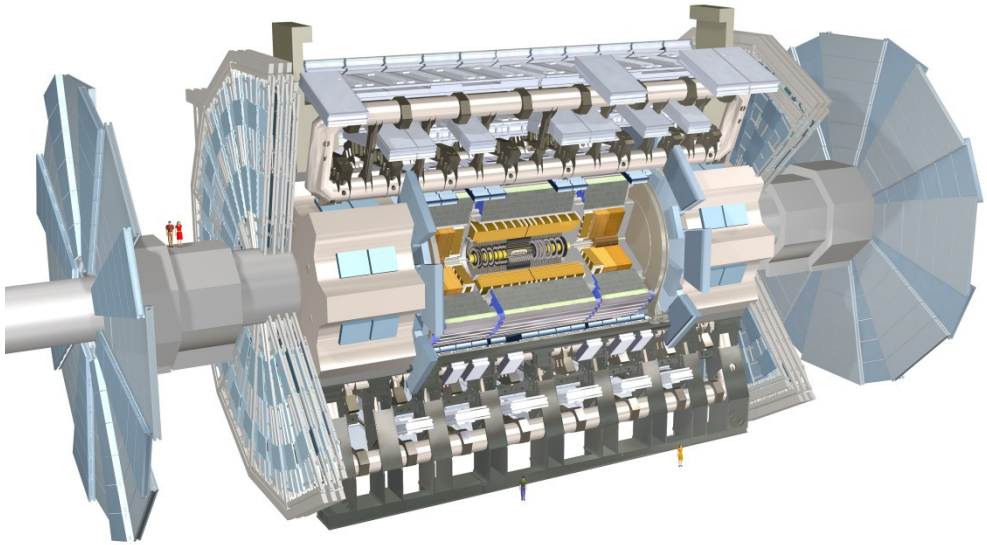
- Resolution ~40 μm

Inner Detector: $|\eta|<2.5$

- d_0 resolution ~10 μm

Combined tracks (ID+Muon):

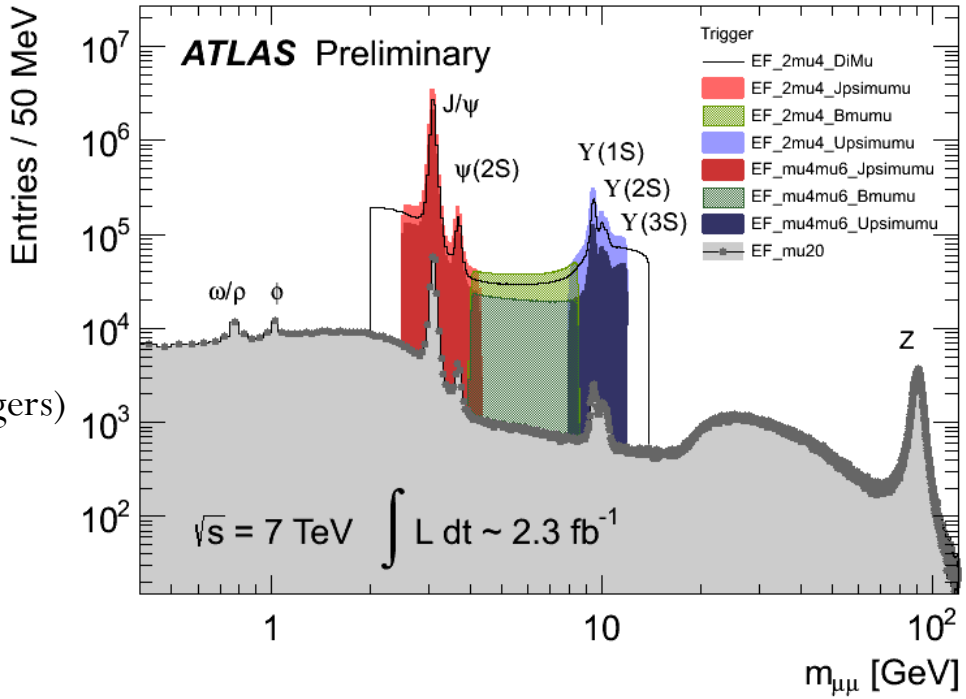
- $\sigma(m_{J/\psi}) = 60$ MeV



B-Physics Triggers:

- First Level Trigger (L1):
  - Single muon & Dimuon Triggers
  - Thresholds 4 – 40 GeV p_T
- High Level Trigger (L2&L3):
  - Single muon & dimuon triggers
  - B-physics triggers:
    - Muons from common vertex
    - Opposite charge (except some control triggers)
    - **Loose mass cuts:**

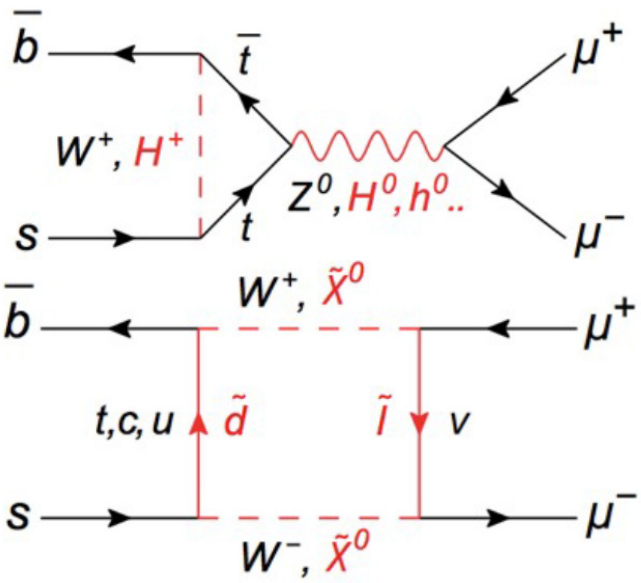
J/ψ: 2.5 < M(μμ) < 4.3 GeV
B: 4.0 < M(μμ) < 8.5 GeV



$B_s^0 \to \mu^+\mu^-$ Branching Ratio

NEW

ATLAS-CONF-2013-076



- Flavour Changing Neutral Current processes:
  - Strongly suppressed in SM[1]: BR=$(3.23\pm0.27)\times10^{-9}$
  - Can be enhanced by new physics
  - First measurement made by LHCb[2]: BR=$(3.2^{+1.5}_{-1.2})\times10^{-9}$
- Previous ATLAS[3] limit used half 2011 data (2.4 fb^{-1}).
- Now updated with full 2011 dataset: 4.9 fb^{-1}
  - Including improved event reconstruction & analysis improvements

- Blind analysis - Blinded Region: 5066–5666 MeV
- BR measured w.r.t. reference channel:

$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = \underbrace{\mathcal{B}(B^\pm \to J/\psi K^\pm \to \mu^+\mu^- K^\pm)}_{\text{PDG value}} \times \underbrace{\frac{f_u}{f_s}}_{\text{LHCb}^4\text{ measurement}} \times \frac{N_{\mu^+\mu^-}}{N_{J/\psi K^\pm}} \times R_{A\epsilon}$$

$B_s^0 \to \mu^+\mu^-$ observed in data after S.B. subtraction

Reference Channel Yield from Data

$$R_{A\epsilon} = \frac{A_{J/\psi K^\pm}}{A_{\mu^+\mu^-}} \frac{\epsilon_{J/\psi K^\pm}}{\epsilon_{\mu^+\mu^-}}$$

Acceptance × Efficiency Ratio from MC

1: Buras et. al. Eur. Phys. J **C72** (2012) 2172 2: Phys. Rev. Lett. **110** (2013) 021810
3: Phys. Lett. **B713** (2012) 387 4:JHEP **1304** (2013) 001

$B_s^0 \to \mu^+\mu^-$ Branching Ratio Measurement

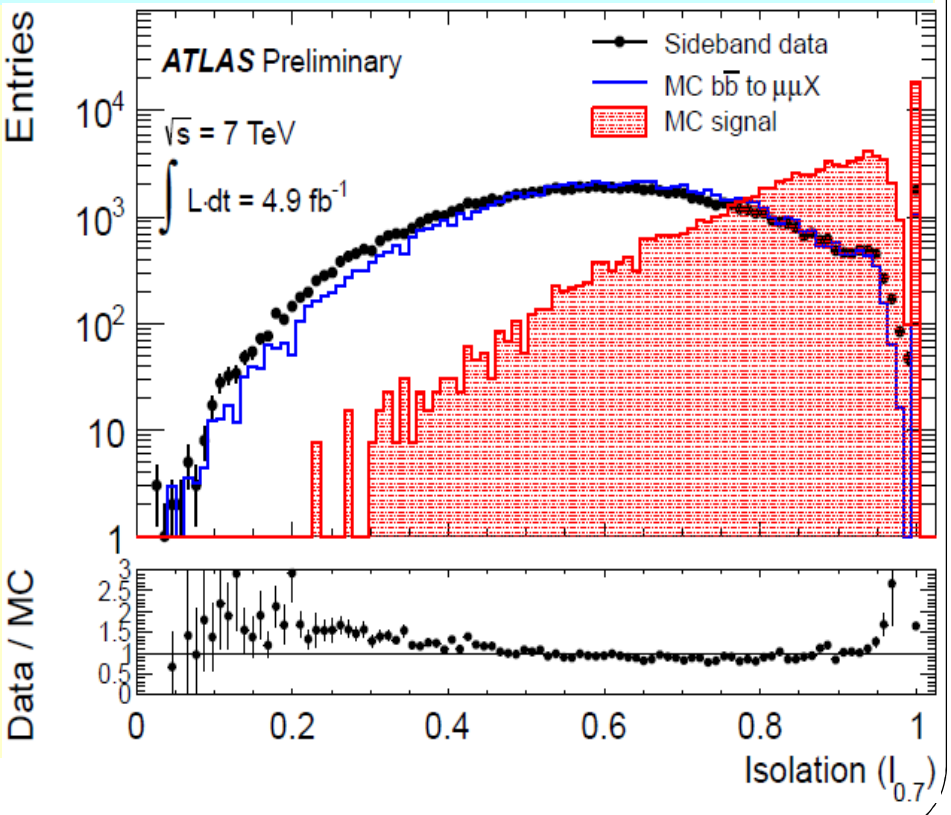
Data Selection:

- Trigger: L1: dimuon $p_T > 4$ GeV; HLT: dimuon, Loose B & J/ψ mass cuts
- Pre-selection to select good quality reconstructed tracks & vertices
- Reference Channel Data divided into two parts to avoid bias of yield extraction:
  - Odd-#: odd event numbers used for data-driven reweighting of MC
  - Even-#: even event numbers used to extract reference channel yield and background estimate

Monte-Carlo tuning:

- J/ψ polarization correction
  - MC generated without decay polarization
- Binned (p_T^B, η^B) re-weighting of MC:
  - Generator Level (GL) re-weighting:
    - Applied to signal & reference MC
    - Corrects for GL filter biases
    - Derived from MC samples generated with a loose GL filter
  - Data Driven re-weighting :
    - Applied to signal, reference & $b\bar{b} \to \mu\mu X$
    - Derived from differences between MC and odd-# reference channel data
- Small residual diff.s $\Rightarrow$ Syst. error on $R_{A\epsilon}$

Side-band data c.f. MC for Isolation parameter $I_{0.7}$



Background Modelling & Selection Optimization

Combinatorial Background:

- Suppressed by BDT Discriminant
  - 13 discriminating variables inputs
  - Training using MC datasets
  - Selection Optimization using MC & data:
    - 2D optimization (Δm, BDT output)
    - Signal MC & odd-# sideband data

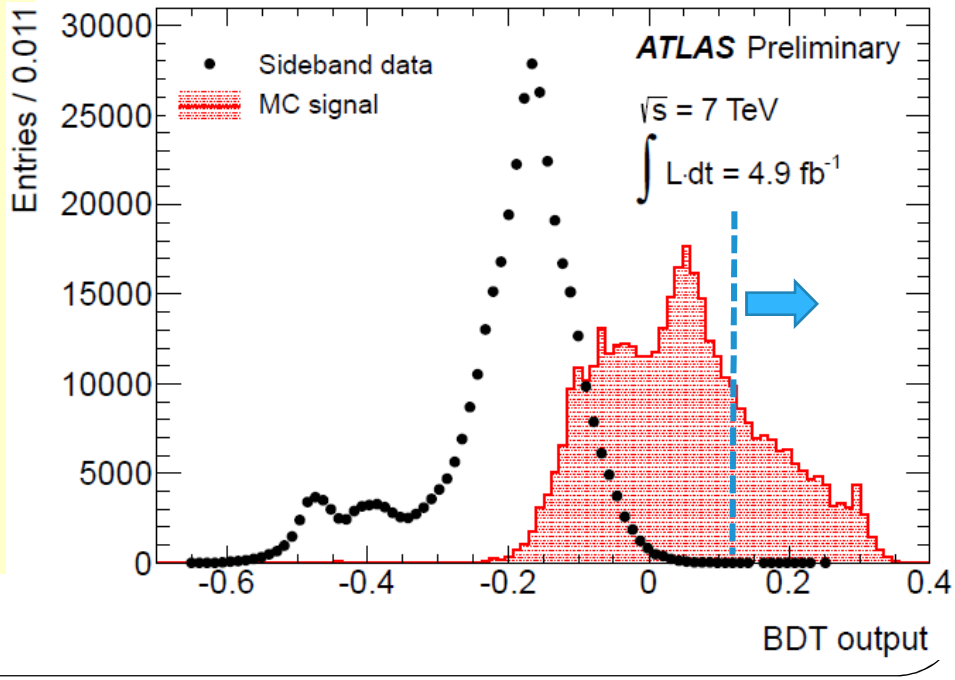
    Maximize : $\mathcal{P} = \frac{\epsilon}{1+\sqrt{B}}$

  $\Rightarrow$ **Δm < 121 GeV; BDT output > 0.118**
- Residual background, after Δm & BDT cuts, determined by interpolation:
  - using even even-# side-band data

Peaking background:

- B candidates with 1 or 2 misidentified μ
- Misidentification prob. from MC:

  $\pi^{\pm}$: 2.1‰; K^{+}: 4.1‰; K^{-}: 3.3‰
- Estimate yield for B→hh' from luminosity, measured branching fractions, acceptance & effic.



Single Event Sensitivity

$B(B^{\pm} \to J/\psi K^{\pm})$:	$1.016 \pm 0.033 \times 10^{-3}$	(PDG)[a]
$B(B^{\pm} \to \mu^{+}\mu^{-})$:	$5.93 \pm 0.06 \times 10^{-2}$	(PDG)[a]
f_u/f_s :	0.256 ± 0.020	(LHCb)[b]

SES: BR corresponding a single observed signal event:

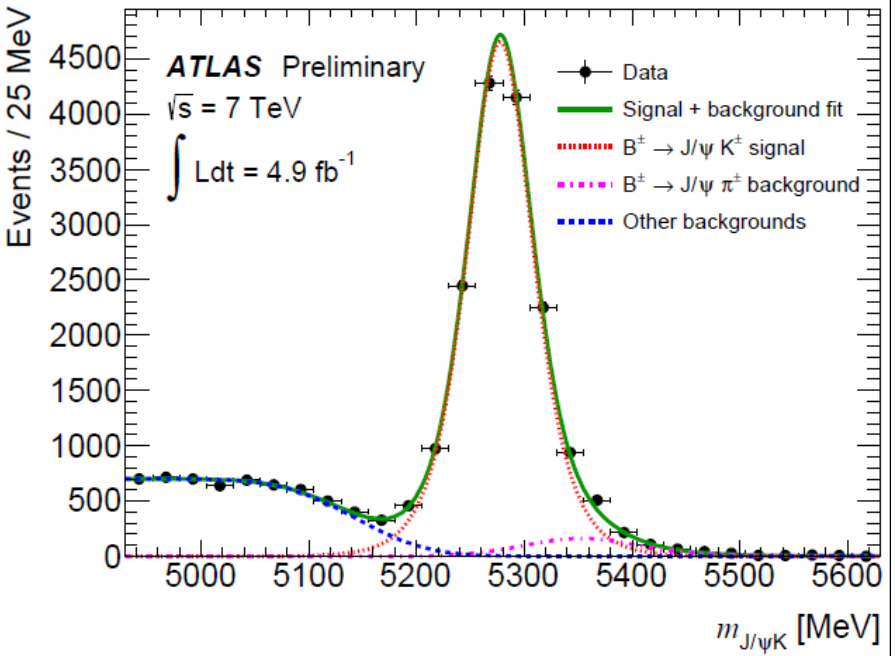
$$B(B_s^0 \to \mu^+\mu^-) = \mathrm{SES} \times N_{\mu^+\mu^-}$$

$$SES = B(B^{\pm} \to J/\psi K^{\pm} \to \mu^-\mu^+K^{\pm}) \times \frac{f_u}{f_s} \times \frac{R_{A\epsilon}}{N_{J/\psi K^{\pm}}}$$

- Acceptance × Efficiency Ratio, $R_{A\epsilon}$:
  - Evaluated from MC sample:

$A \times \epsilon$ for B^+:	$1.317 \pm 0.008\%$(stat.)
$A \times \epsilon$ for B_s^0:	$4.929 \pm 0.084\%$(stat.)

$R_{A\epsilon} = 0.267 \pm 1.8\%$(stat.)$\pm 6.9\%$(syst.)



- Yield for Reference Channel, $N_{J/\psi K^{\pm}}$:
  - Unbinned extended max. likelihood fits to mass & mass uncertainty (m, δm)
  - Using even-# data in mass range: 4930-5630 MeV

$N_{J/\psi K^{\pm}} = 15\,214$ even-no. events $\pm 1.1\%$(stat.) $\pm 2.4\%$(syst.)

Stat. error (2.1%) plus syst. error (12.5%) in quadrature.

- Single Event Sensitivity: **$SES = (2.065 \pm 0.262) \times 10^{-9}$**
  - Dominant Syst. : Ref. Chan. BR & f_u/f_s : 8.5%; $R_{A\epsilon}$: 6.9%

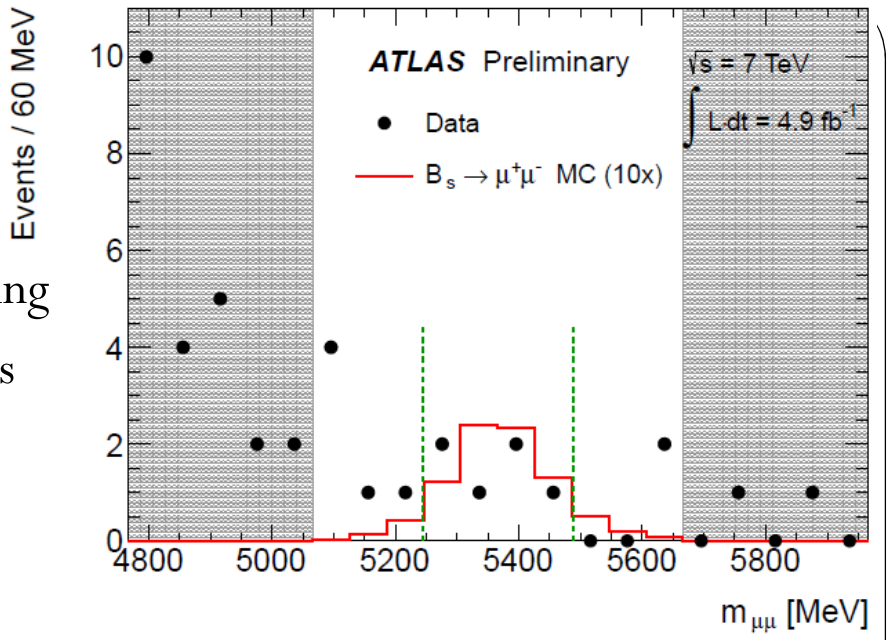
a: Phys Rev D86 (2012) 010001
b: JHEP **1304** (2013) 001

$B_s^0 \to \mu^+\mu^-$ BR Limit

$$B(B_s^0 \to \mu^+\mu^-) = \text{SES} \times N_{\mu^+\mu^-}$$

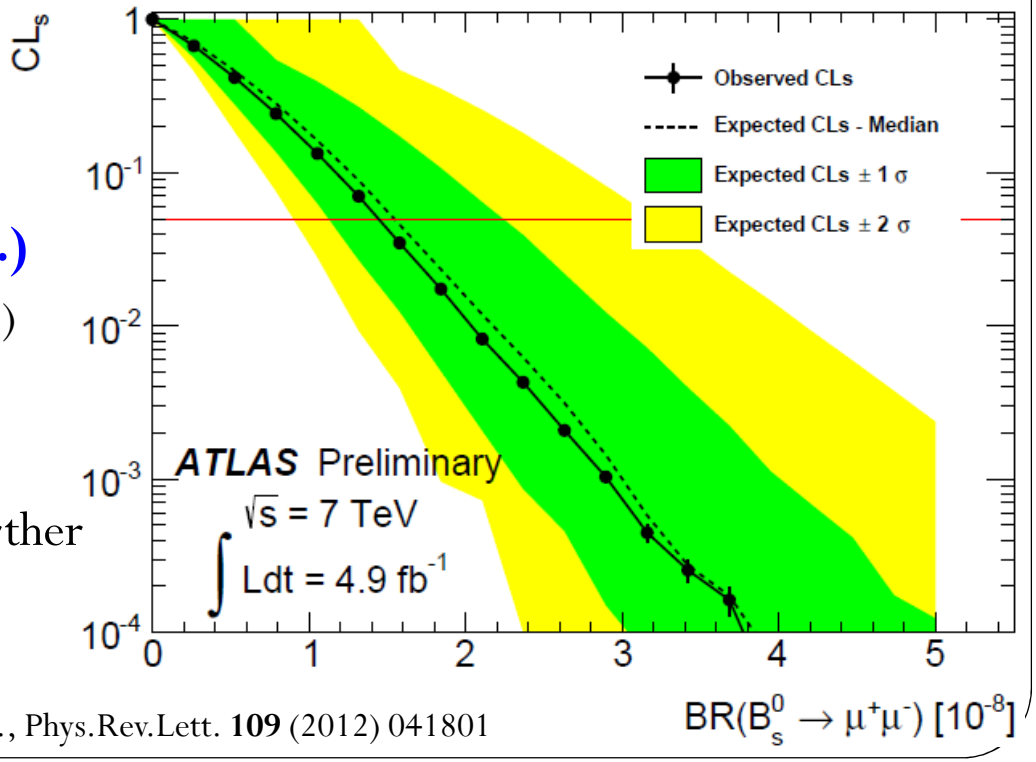
- 6 events observed in mass region after un-blinding
- Estimated background contribution: 6.75 events
  - From SB interpolation using even-# events
  - Includes estimated 0.295 B→hh' events

SM prediction: 1.7 ± 0.2 signal events in mass window



- Upper limit from CLs method:

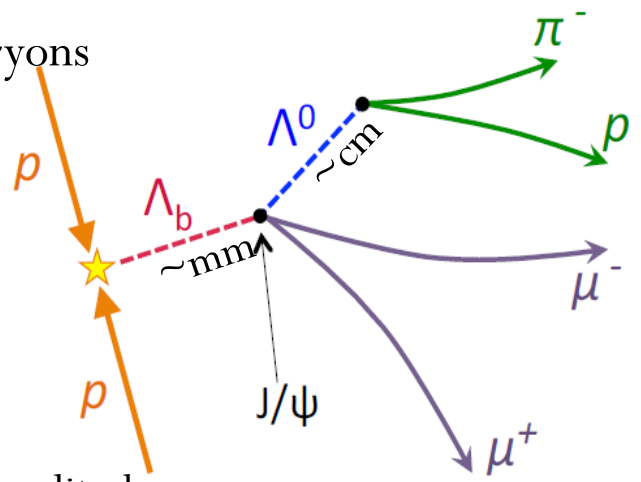
  $B(B_s^0 \to \mu^+\mu^-) < 1.5 \times 10^{-8}$ (95% C.L.)
  - Expected limit: $1.6^{+0.7}_{-0.4} \times 10^{-8}$ (95% C.L.)
  - Time integrated SM[1] prediction:
    - BR=(3.54±0.30)×10⁻⁹
- Will update with 2012 data including further analysis improvements



1:K.De Bruyn et al., Phys.Rev.Lett. **109** (2012) 041801

Λ_b Properties

- Hadron colliders are currently the only place to study b baryons
- Provides means to test theory:
  - How heavy quarks are produced; how they hadronize
  - Whether polarization is preserved in the process
- Use decay: $\Lambda_b^o \rightarrow J/\psi(\mu^+\mu^-)\Lambda^0(p^+\pi^-)$ to measure:
  - Λ_b^o mass & lifetime
  - Parity violating decay assymmetry parameter, α_b, & helicity amplitudes
  - Compare Lifetime Ratio $\tau(\Lambda_b)/\tau(B_d)$ and α_b with theory predictions



- Data Pre-selection:
  - J/ψ & Λ^o pre-selection:
    - J/ψ: 2.8 GeV<M(μμ)<3.4GeV
    - Λ^o : 1.08 < M(hh)<1.15 GeV
  - $\Lambda_b^o \rightarrow J/\psi(\mu^+\mu^-)\Lambda^0(p^+p^-)$ pre-selection:
    - Cascade topology fit – constrain:
      - J/ψ & Λ^o masses
      - $\vec{p}_{V^0}$ points to μμ vertex

Cascade topology fit requirements:

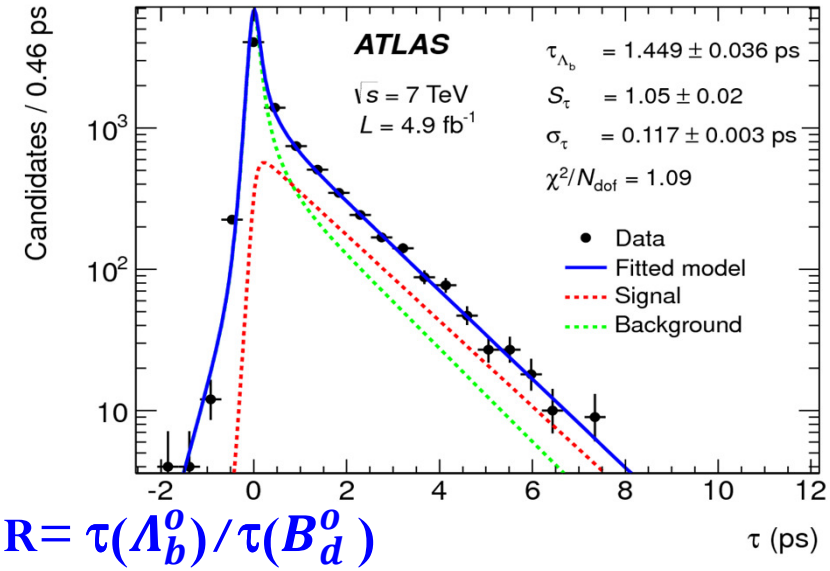
- Fit $\chi^2/N_{dof}<3$ ($N_{dof}=6$)
- V^o : $p_T > 3.5$ GeV; $L_{xy} > 10$ mm
- $5.38 < M(J/\psi\,\Lambda^0) < 5.90$ GeV
- If also B_d^o: $\mathcal{P}(\Lambda_b^o) - \mathcal{P}(B_d^o) > 0.05$

Λ_b mass & lifetime

Phys. Rev. D87 (2013) 032002

- Unbinned maximum likelihood fit:

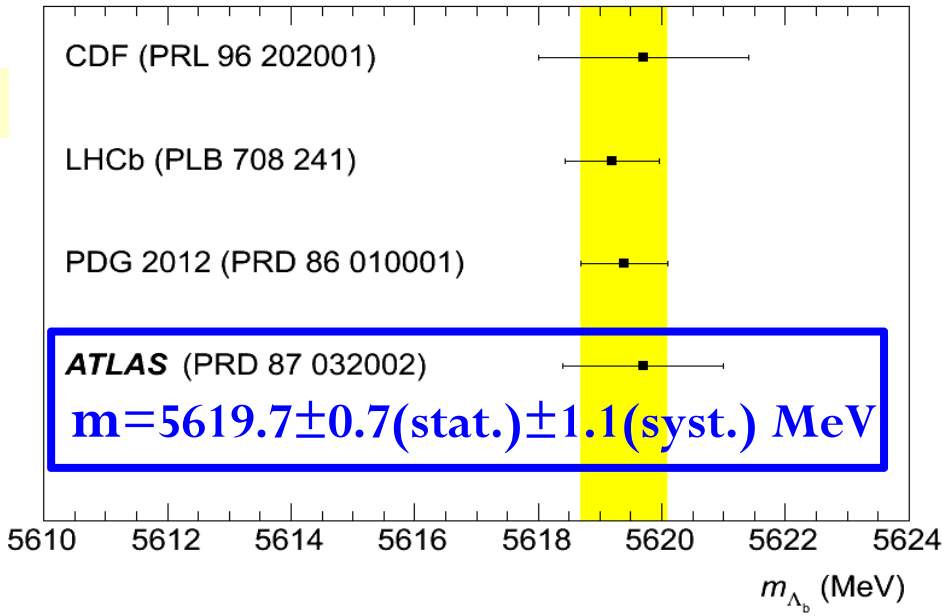
$$L = \prod_{i=1}^{N} \Big[f_{\rm sig}\mathcal{M}_{\rm s}(m_i|\delta_{m_i})\mathcal{T}_{\rm s}(\tau_i|\delta_{\tau_i})w_{\rm s}(\delta_{m_i},\delta_{\tau_i}) + (1-f_{\rm sig})\mathcal{M}_{\rm b}(m_i|\delta_{m_i})\mathcal{T}_{\rm b}(\tau_i|\delta_{\tau_i})w_{\rm b}(\delta_{m_i},\delta_{\tau_i}) \Big]$$

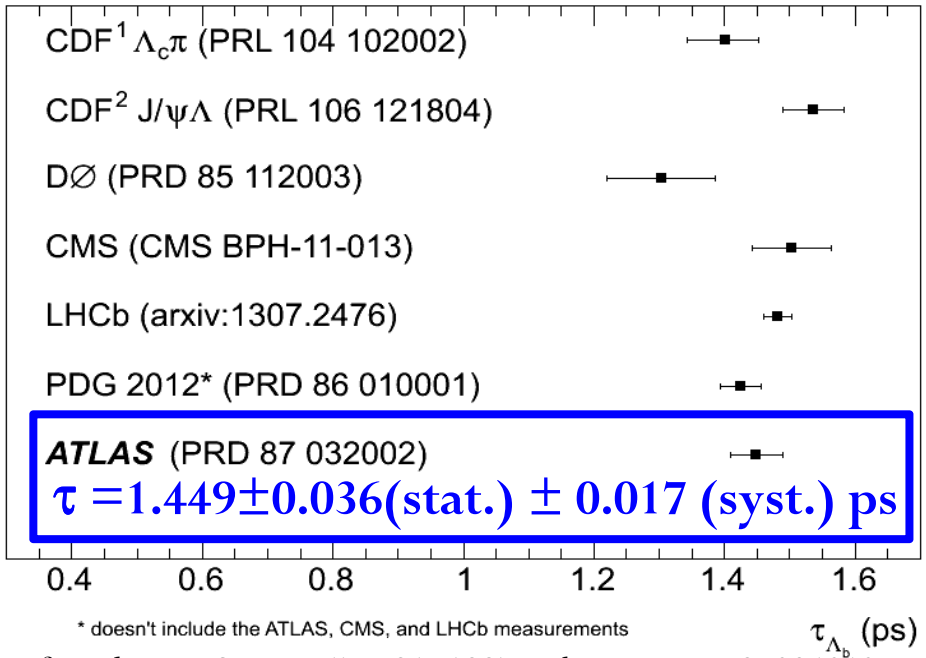


R= $\tau(\Lambda_b^0)/\tau(B_d^0)$
= 0.960±0.025(stat.)±0.016(syst.)

c.f. 0.976±0.013 (LHCb); 0.864±0.052 (D0);
1.020±0.030 (CDF[2])

0.88–0.97 (HQE[a]); 0.86[b]–0.88[c](±0.05) (NLO pQCD[b])





[a] Phys. Lett. B 376 (1996) 303; Ann. Rev. of Nucl. Part. Science 47, 591 (1997); Phys. Rev. D 59, 034012 (1999); Phys. Rev. D 61, 074026 (2000); [b] Phys. Rev D70 (2004) 094031; [c] Eur. Phys. J C33 (2004) S895

α_b Measurement

NEW

ATLAS-CONF-2013-071

Amplitude	λ_Λ	$\lambda_{J/\psi}$
a_+	$+1/2$	0
a_-	$-1/2$	0
b_+	$-1/2$	-1
b_-	$+1/2$	$+1$

$|a_+|^2+|a_-|^2+|b_+|^2+|b_-|^2=1$

- $\Lambda_b^o \to J/\psi(\mu^+\mu^-)\Lambda^0(p^+\pi^-)$ decay described by:
  - 4 helicity amplitudes $\Rightarrow$
  - Dynamics described by 5 angles - sensitive to squared amplitudes
  - Parity violating decay asymmetry parameter:

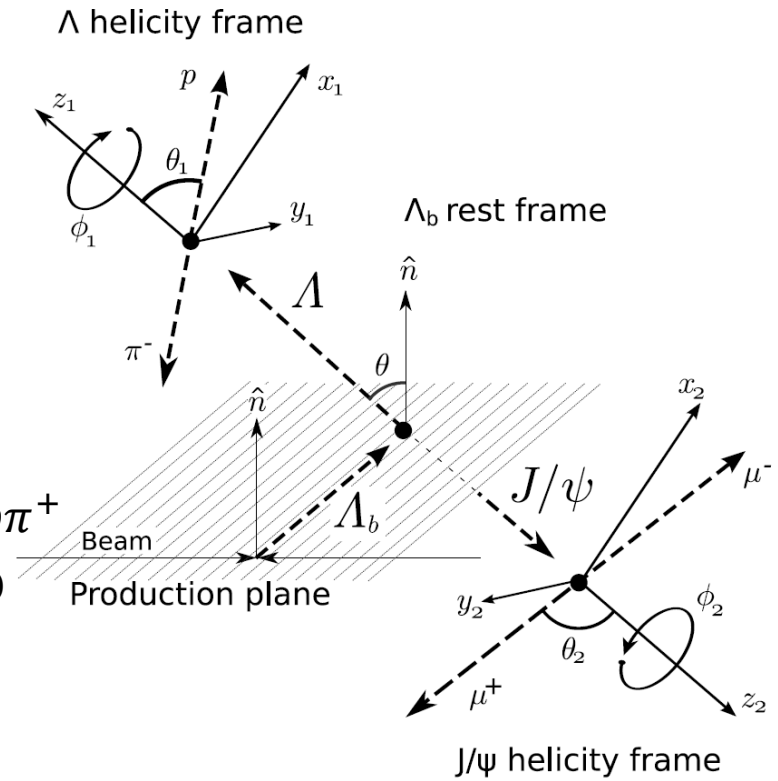
    $\alpha_b = |a_+|^2 - |a_-|^2 + |b_+|^2 - |b_-|^2$
- Full angular PDF:

$$W(\vec{\Omega},\vec{A},P) = \frac{1}{(4\pi)^3}\sum_{i=0}^{19} f_{1i}(\vec{A}) f_{2i}(P\alpha_\Lambda) F_i(\vec{\Omega})$$

  - $f_{1i}(\vec{A})$: bilinear combination of helicity amplitudes

$$\vec{A} \equiv (a_+, a_-, b_+, b_-) \qquad \begin{aligned} a_+ &= |a_+| e^{i\rho_+},\ a_- = |a_-| e^{i\rho_-}, \\ b_+ &= |b_+| e^{i\omega_+},\ b_- = |b_-| e^{i\omega_-} \end{aligned}$$

  - $f_{2i}(P\alpha_\Lambda)$: has a values of $P\alpha_\Lambda$, P, α_Λ or 1
    - Assym. param. $\alpha_\Lambda = -0.642 \pm 0.013$[1] for $\Lambda^0 \to p\pi^+$
    - Exploit ATLAS symmetry in $\eta \Rightarrow$ Polarization $= 0$
  - $F_i(\vec{\Omega})$: orthogonal functions of decay angles
- Analysis uses method of moments:
  - Extract α_b and helicity amplitudes from measured averages of each F_i (moments).

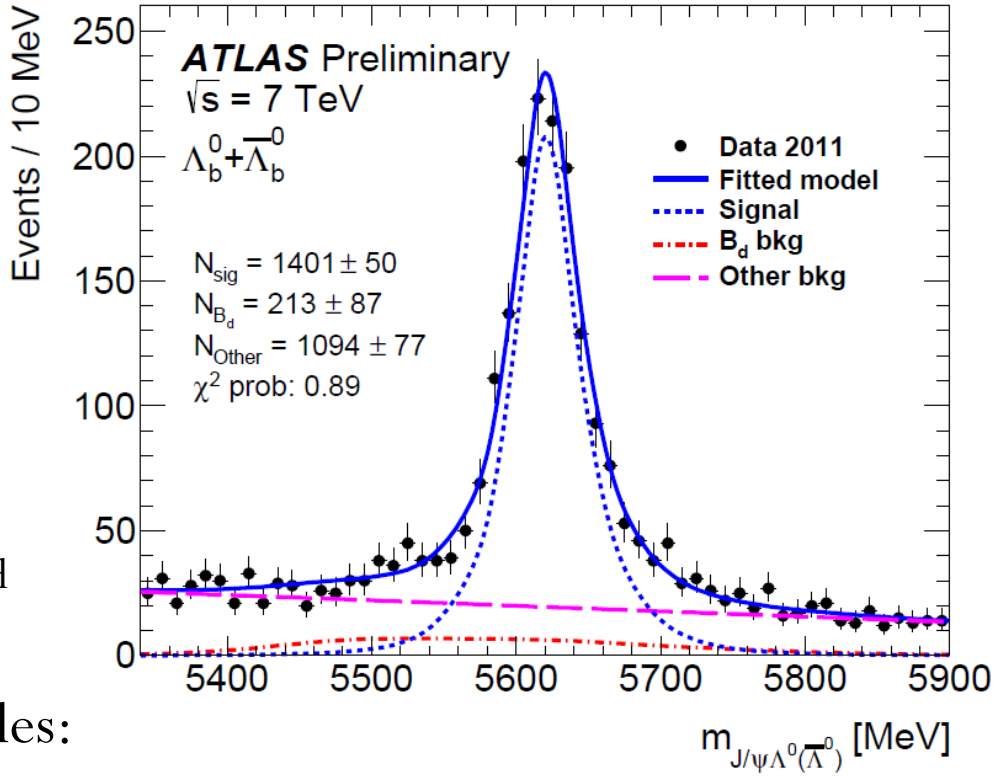


[1]: PDG J. Phys. G **37** (2010)

α_b Measurement

Selection of Λ_b^0 dataset:

- As for the mass & lifetime analysis plus specific requirements for this analysis:
  - B_d^0 veto: $\mathcal{P}(\Lambda_b^0) > \mathcal{P}(B_d^0)$ if both
  - Λ_b proper decay time $\tau > 0.35$ ps
  - Sig. Reg.: $5560 < M(J/\psi\,\Lambda^0) < 5680$ MeV
- $N_{sig}, N_{B_d}, N_{other}$ determined from extended binned maximum likelihood fit



Extraction of α_b and helicity amplitudes:

- Perform χ^2 fit to measured moments $\langle F_i \rangle$:

$$\chi^2 = \sum_{i=1}^{5}\sum_{j=1}^{5}(\langle F_i\rangle^{\text{expected}} - \langle F_i\rangle)V_{ij}^{-1}(\langle F_j\rangle^{\text{expected}} - \langle F_j\rangle)$$

V_{ij}: Covariance matrix of measured $< F_i >$

$$\langle F_i\rangle^{\text{expected}} = \sum f_j(\vec{A})C_{ij}$$

Model

Detector Effects

- Model defined in terms of 5 free parameters:

$$\alpha_b,\ k_0 = \frac{|a_+|}{\sqrt{|a_-|^2+|b_+|^2}},\ k_1 = \frac{|b_-|}{\sqrt{|a_-|^2+|b_-|^2}},$$

$$\Delta_+ = \rho_+ - \omega_+$$
$$\Delta_- = \rho_- - \omega_-$$

- Detector accept. and effic. encoded by C_{ij}:
  - No dependence on helicity parameters
  - Determined from MC samples generated with flat angular distributions

Fit Result

- Fit Result:

  $\alpha_b = 0.28 \pm 0.16 \pm 0.06$

  $|a_+| = 0.17^{+0.12}_{-0.17}$ (stat.) $\pm$ 0.06 (syst.)

  $|a_-| = 0.59^{+0.06}_{-0.07}$ (stat.) $\pm$ 0.04(syst.)

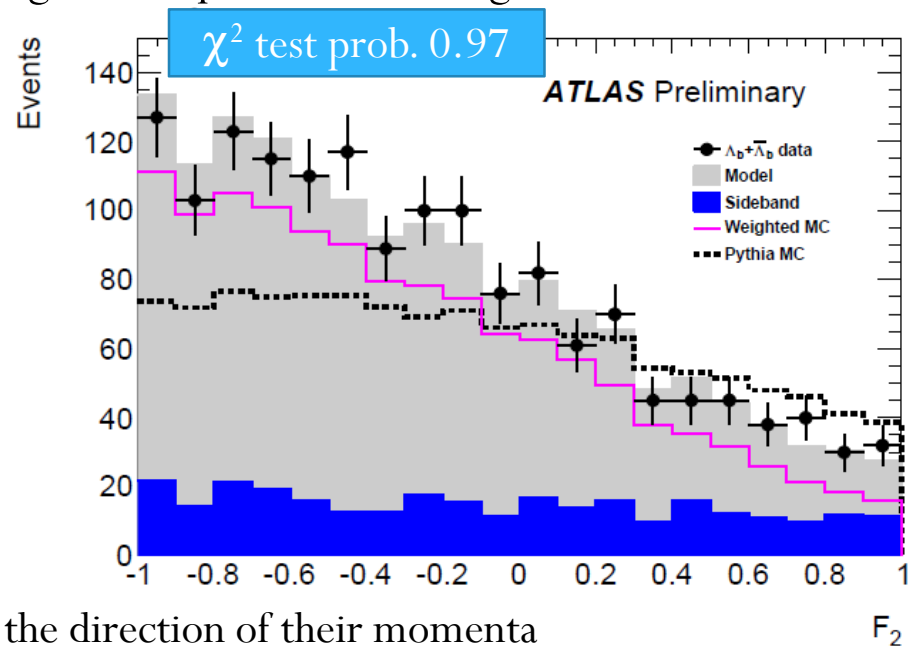
  $|b_+| = 0.78^{+0.04}_{-0.05}$ (stat.) $\pm$ 0.02 (syst),

  $|b_-| = 0.08^{+0.13}_{-0.08}$ (stat.) $\pm$ 0.05 (syst.)

- Systematics mainly from:
  - Uncertainties in background contrib. to measured $\langle F_i \rangle$
  - Calculation of correction matrix

Check of fit results:

- MC events weighted with signal PDF and parameters resulting from fit
- Compare F_i distribution for data with weighted signal MC plus sideband b.g.



- Λ^0 and J/ψ from Λ_b^0 decay are highly polarized in the direction of their momenta
- Large $|a_-|$ and $|b_+| \Rightarrow$ negative-helicity states for Λ^0 preferred
- α_b value:
  - consistent with LHCb measurement: $0.05 \pm 0.17(\text{stat.}) \pm 0.07(\text{syst.})$ Physics Letters **B 724** (2013) 27
  - Intermediate between pQCD and HQET predictions:

    $\sim 2.5\sigma$ c.f. pQCD expectation $\sim(-0.14 \rightarrow -0.18)$ Chou et. al. Phys. Rev. D65 (2002) 074030

    $\sim 2.9\sigma$ c.f. HQET expectation (0.78) Leitner et al. Nucl. Phys. A755 (2005) 435, Ajaltouni et al. Phys. Let. B614 (2005) 165

Summary

NEW

- **$B(B_s^0 \to \mu^+\mu^-)$ measurement updated with full 2011 dataset (4.9 fb^{-1}):**
  - $B(B_s^0 \to \mu^+\mu^-) < 1.5$ (95% C.L.)
  - Consistent with SM expectation, LHCb measurement and other experimental limits

ATLAS-CONF-2013-076

- **Λ_b^0 mass & lifetime have been measured:**

$\tau = 1.449 \pm 0.036(\text{stat.}) \pm 0.017$ (syst.) (ps)

$m = 5619.7 \pm 0.7(\text{stat.}) \pm 1.1(\text{syst.})$ MeV

$R = \tau(\Lambda_b^0)/\tau(B_d^0) = 0.960 \pm 0.025(\text{stat.}) \pm 0.016(\text{syst.})$

Phys. Rev. D87 (2013) 032002

  - Consistent with both pQCD and HQET predictions and other experimental measurements

NEW

- **Λ_b^0 partity violating parameter, α_b, and helicity amplitudes have been measured:**

$\alpha_b = 0.28 \pm 0.16 \pm 0.06$

$|a_+| = 0.17^{+0.12}_{-0.17}$ (stat.) $\pm$ 0.06 (syst.); $|a_-| = 0.59^{+0.06}_{-0.07}$ (stat.) $\pm$ 0.04(syst.)

$|b_+| = 0.78^{+0.04}_{-0.05}$ (stat.) $\pm$ 0.02 (syst); $|b_-| = 0.08^{+0.13}_{-0.08}$ (stat.) $\pm$ 0.05 (syst.)

ATLAS-CONF-2013-071

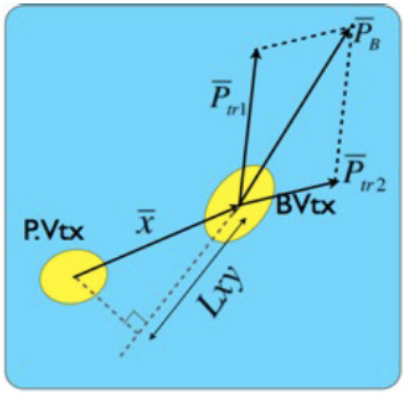
  - α_b differs from pQCD expectation –(0.14~0.18) by ~2.5σ and HQET expectation (0.78) by 2.9σ

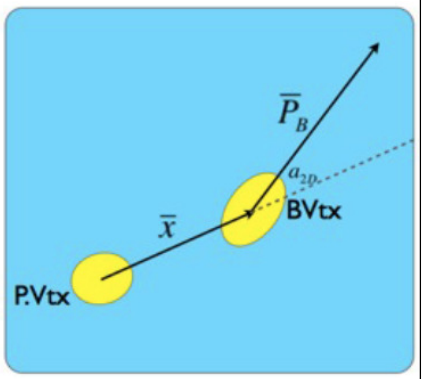
- **More accurate measurements will be made with 2012 data (21.7 fb^{-1} rec.)**

Backup

Discriminating Variables for $B_s^0 \to \mu^+\mu^-$

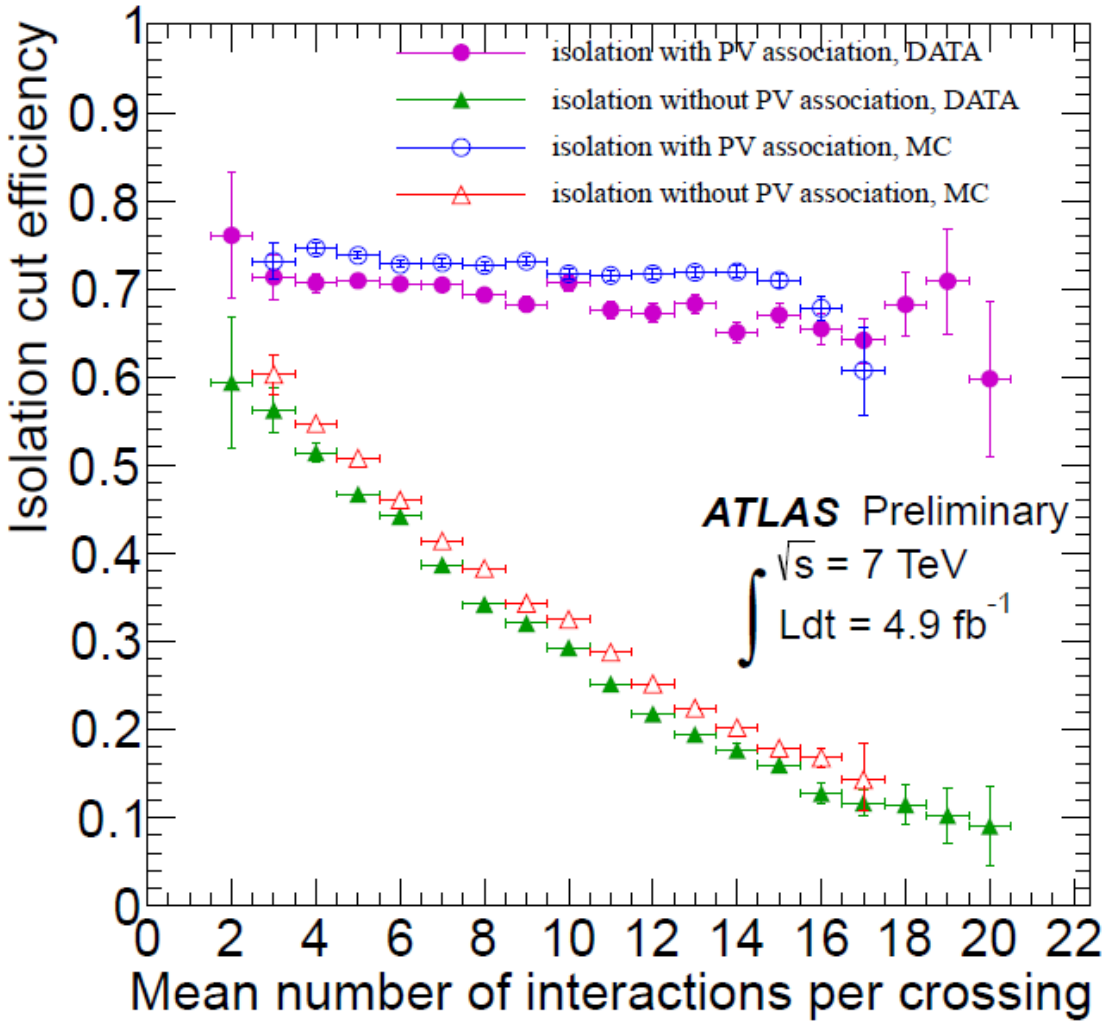
Variable	Description	Ranking
L_{xy}	Scalar product in the transverse plane of $(\Delta\vec{x} \cdot \vec{p}^B)/\lvert\vec{p}_T^B\rvert$	1
$I_{0.7}$ isolation	Ratio of $\lvert\vec{p}_T^B\rvert$ to the sum of $\lvert\vec{p}_T^B\rvert$ and the transverse momenta of all tracks with $p_T > 0.5$ GeV within a cone $\Delta R < 0.7$ from the B direction, excluding B decay products	2
$\lvert\alpha_{2D}\rvert$	Absolute value of the angle in the transverse plane between $\Delta\vec{x}$ and $\vec{p}^B$	3
p_L^{min}	Minimum momentum of the two muon candidates along the B direction	4
p_T^B	B transverse momentum	5
ct significance	Proper decay length $ct = L_{xy} \times m_B/p_T^B$ divided by its uncertainty	6
χ^2_z, χ^2_{xy}	Significance of the separation between production (PV) and decay vertex (SV) $\Delta\vec{x}^T \cdot \left(\sigma^2_{\Delta\vec{x}}\right)^{-1} \cdot \Delta\vec{x}$, in z and (x, y), respectively	7, 13
$\lvert D_{xy}\rvert^{min}$, $\lvert D_z\rvert^{min}$	Absolute values of the minimum distance of closest approach in the xy plane or along z of tracks in the event to the B vertex	8, 11
ΔR	Angle $\sqrt{(\Delta\phi)^2 + (\Delta\eta)^2}$ between $\Delta\vec{x}$ and $\vec{p}^B$	9
$\lvert d_0\rvert^{max}$, $\lvert d_0\rvert^{min}$	Absolute values of the maximum and minimum impact parameter in the transverse plane of the B decay products relative to the primary vertex	10, 12





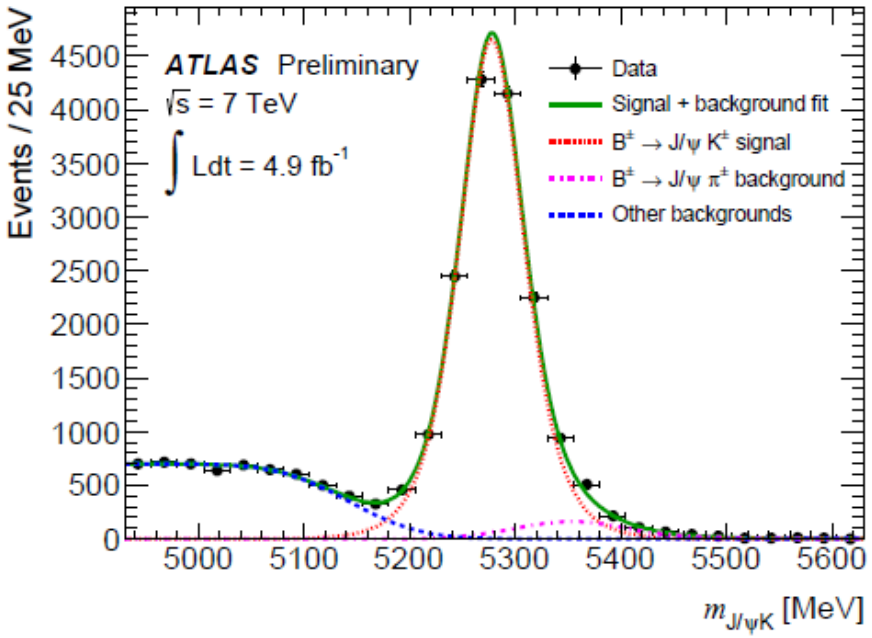
BDT input variables for $B(B_s^0 \to \mu^+\mu^-)$ measurement

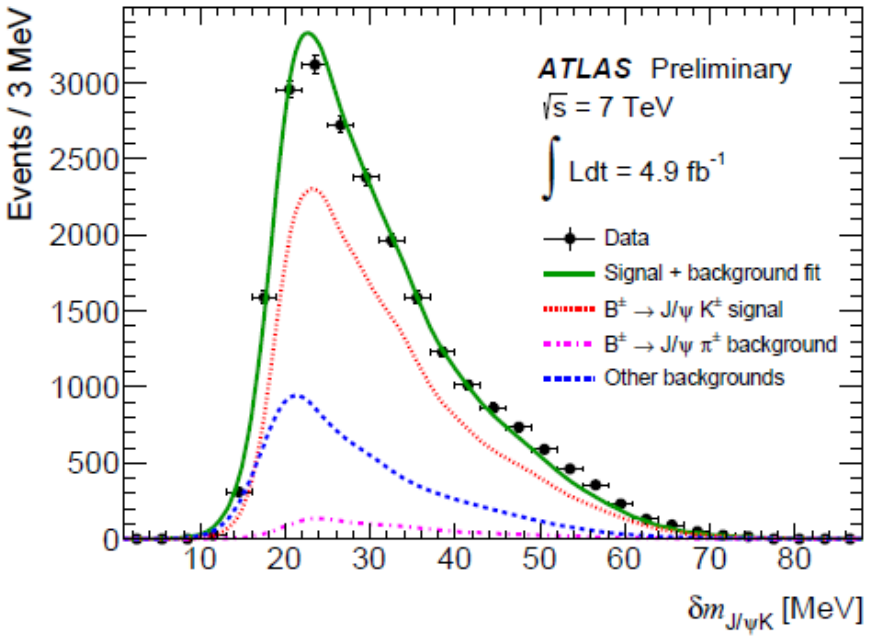
- Stability of Isolation parameter w.r.t. pile-up



B->J/ψK yield

Fit results





CLs limit extraction

$$\mathcal{L} = \text{Poisson}(N_{SR}^{obs}|\epsilon\,\mathcal{B} + N_{bkg} + N_{B\to hh})\,\text{Poisson}(N_{bkg,SB}^{obs}|R_{bkg}\,N_{bkg}) \times$$
$$\text{Gauss}(\epsilon^{obs}|\epsilon,\sigma_\epsilon)\,\text{Gauss}(R_{bkg}^{obs}|R_{bkg},\sigma_{R_{bkg}})$$

$\mathcal{B}$ Branching fraction to be measured

ϵ Inverse of the SES constrained to ϵ^{obs}

N_{bkg} No. Continuum background events in signal region

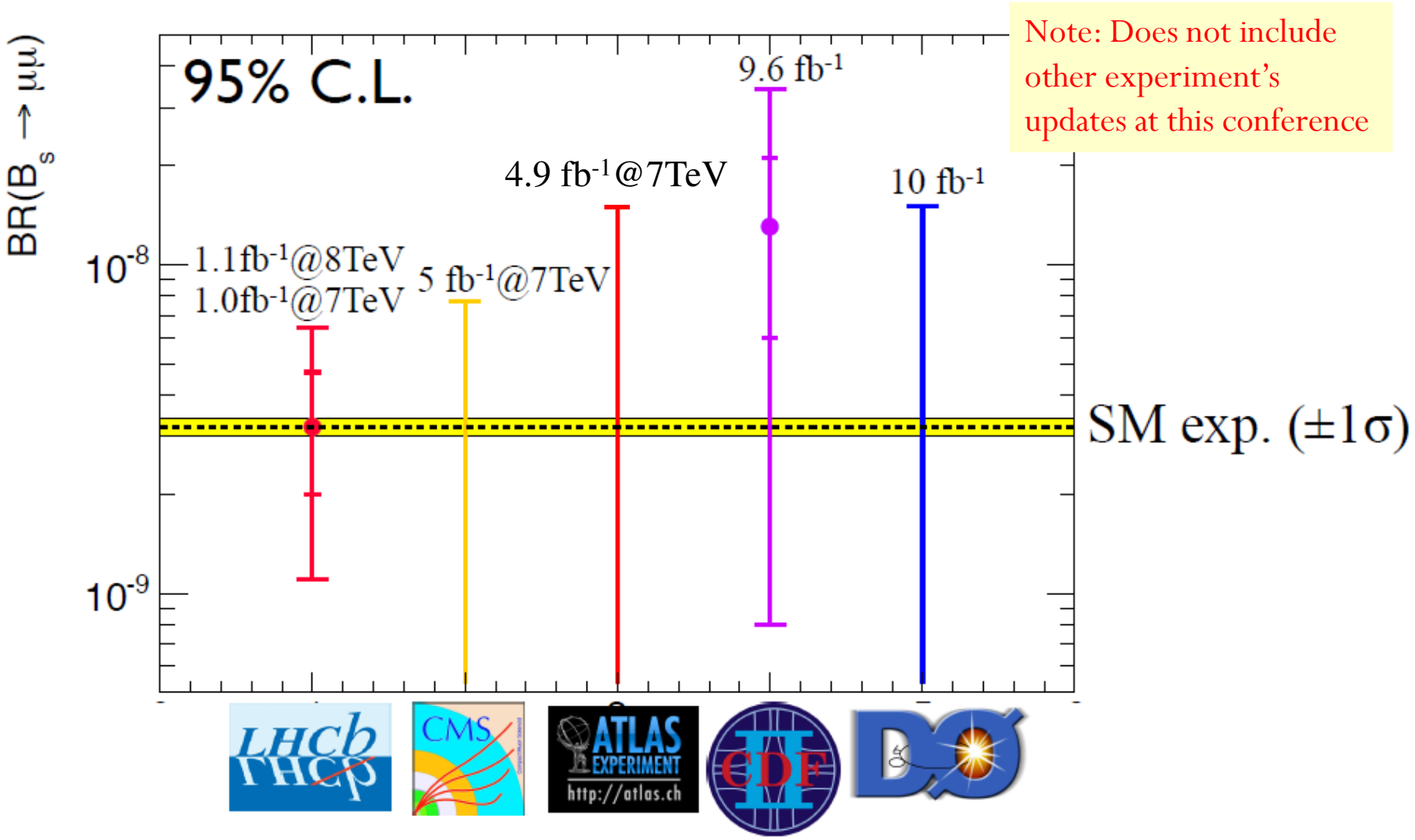
N_{SR}^{obs} No. even and odd numbered events observed in the signal region

$N_{bkg,SB}^{obs}$ No. even no. events observed in sidebands

$N_{B\to hh'}$ Contribution from irreducible resonant B→hh' background

R_{bkg} Expected ration of background events in the SB to those in the SR - constrained to R_{bkg}^{obs} the ratio of widths of the two regions

Comparison with other measurements

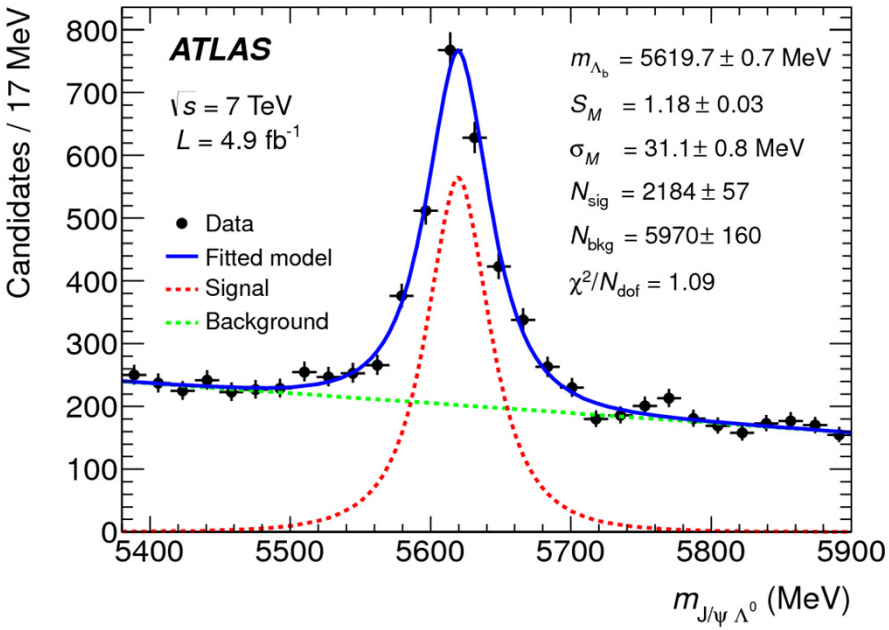


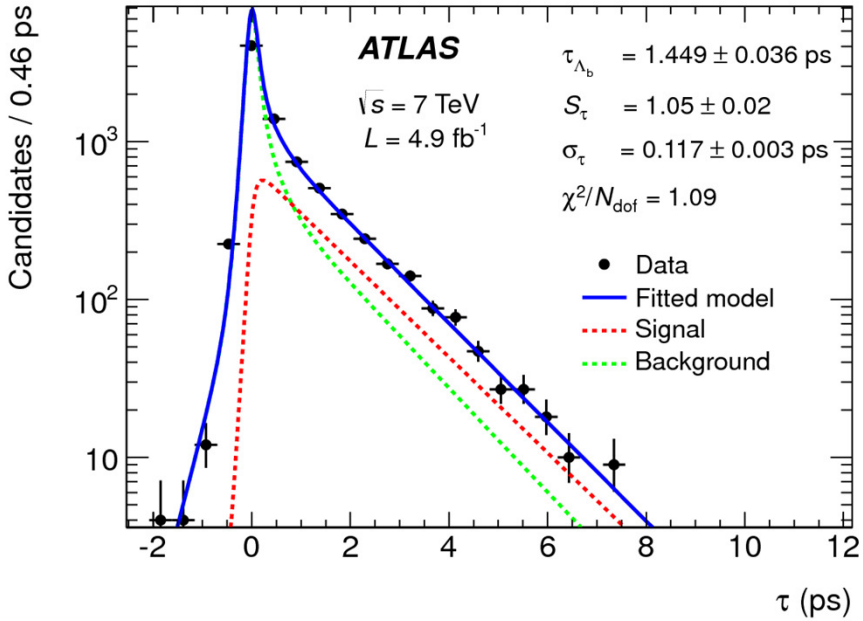
Note: Does not include other experiment's updates at this conference

$$\textbf{\textit{ATLAS}}: \; B(B_s^0 \to \mu^+\mu^-) < 1.5 \text{ (95\% C.L.)}$$

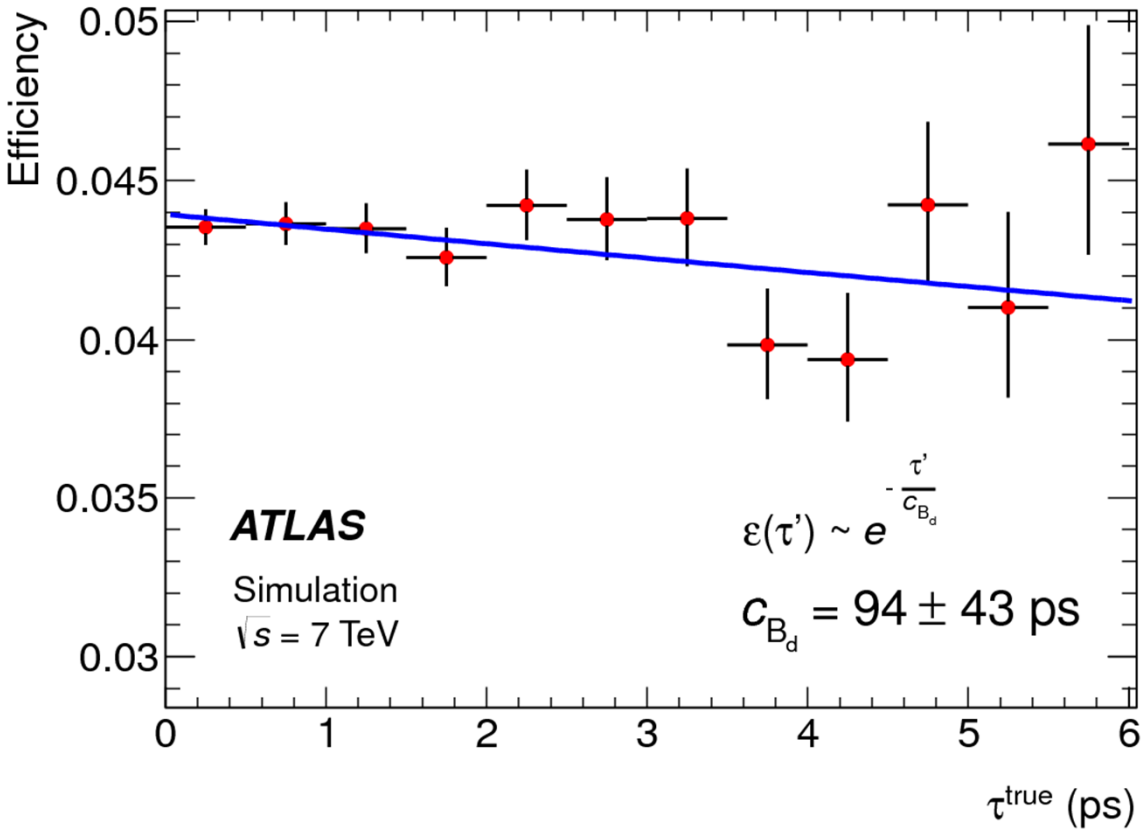
		$BR\left(B^0 \to \mu^+\mu^-\right)$	$BR\left(B_s^0 \to \mu^+\mu^-\right)$
LHCb	1.1 fb^{-1}(8TeV) 1.0 fb^{-1}(7TeV)	$<9.4\times10^{-10}$	$[1.1, 6.4]\times10^{-9}$ $(3.2^{+1.5}_{-1.2})\times10^{-9}$
CMS	5 fb^{-1}(7TeV)	$<1.8\times10^{-9}$	$<7.7\times10^{-9}$
ATLAS	**4.9 fb-1 (7TeV)**	-	$<1.5\times10^{-8}$
CDF	9.6 fb^{-1}	$<4.6\times10^{-9}$	$[0.8, 34]\times10^{-9}$ $(1.3^{+0.9}_{-0.7})\times10^{-8}$
DØ	10 fb^{-1}	-	$<1.5\times10^{-8}$
BELLE	78fb^{-1}	$<1.6\times10^{-8}$	-
BABAR	347fb^{-1}	$<8.3\times10^{-9}$	-

Mass & Lifetime Fit





Λ_b Liftetime measurement



Efficiency correction as a function of decay length

Λ_b assymetry measurement

Full Angular PDF

$$w(\vec{\Omega},\vec{A},P)=\frac{1}{(4\pi)^3}\sum_{i=0}^{19} f_{1i}(\vec{A})f_{2i}(P,\alpha_\Lambda)F_i(\vec{\Omega})$$

i	f_{1i}	f_{2i}	F_i
0	$a_+a_+^*+a_-a_-^*+b_+b_+^*+b_-b_-^*$	1	1
1	$a_+a_+^*-a_-a_-^*+b_+b_+^*-b_-b_-^*$	P	$\cos\theta$
2	$a_+a_+^*-a_-a_-^*-b_+b_+^*+b_-b_-^*$	α_Λ	$\cos\theta_1$
3	$a_+a_+^*+a_-a_-^*-b_+b_+^*-b_-b_-^*$	$P\,\alpha_\Lambda$	$\cos\theta\,\cos\theta_1$
4	$-a_+a_+^*-a_-a_-^*+\frac{1}{2}b_+b_+^*+\frac{1}{2}b_-b_-^*$	1	$\frac{1}{2}(3\cos^2\theta_2-1)$
5	$-a_+a_+^*+a_-a_-^*+\frac{1}{2}b_+b_+^*-\frac{1}{2}b_-b_-^*$	P	$\frac{1}{2}(3\cos^2\theta_2-1)\cos\theta$
6	$-a_+a_+^*+a_-a_-^*-\frac{1}{2}b_+b_+^*+\frac{1}{2}b_-b_-^*$	α_Λ	$\frac{1}{2}(3\cos^2\theta_2-1)\cos\theta_1$
7	$-a_+a_+^*-a_-a_-^*-\frac{1}{2}b_+b_+^*-\frac{1}{2}b_-b_-^*$	$P\,\alpha_\Lambda$	$\frac{1}{2}(3\cos^2\theta_2-1)\cos\theta\cos\theta_1$
8	$-3Re(a_+a_-^*)$	$P\,\alpha_\Lambda$	$\sin\theta\,\sin\theta_1\,\sin^2\theta_2\,\cos\varphi_1$
9	$3Im(a_+a_-^*)$	$P\,\alpha_\Lambda$	$\sin\theta\,\sin\theta_1\,\sin^2\theta_2\,\sin\varphi_1$
10	$-\frac{3}{2}Re(b_-b_+^*)$	$P\,\alpha_\Lambda$	$\sin\theta\,\sin\theta_1\,\sin^2\theta_2\,\cos(\varphi_1+2\varphi_2)$
11	$\frac{3}{2}Im(b_-b_+^*)$	$P\,\alpha_\Lambda$	$\sin\theta\,\sin\theta_1\,\sin^2\theta_2\,\sin(\varphi_1+2\varphi_2)$
12	$-\frac{3}{\sqrt{2}}Re(b_-a_+^*+a_-b_+^*)$	$P\,\alpha_\Lambda$	$\sin\theta\,\cos\theta_1\,\sin\theta_2\,\cos\theta_2\,\cos\varphi_2$
13	$\frac{3}{\sqrt{2}}Im(b_-a_+^*+a_-b_+^*)$	$P\,\alpha_\Lambda$	$\sin\theta\,\cos\theta_1\,\sin\theta_2\,\cos\theta_2\,\sin\varphi_2$
14	$-\frac{3}{\sqrt{2}}Re(b_-a_-^*+a_+b_+^*)$	$P\,\alpha_\Lambda$	$\cos\theta\,\sin\theta_1\,\sin\theta_2\,\cos\theta_2\,\cos(\varphi_1+\varphi_2)$
15	$\frac{3}{\sqrt{2}}Im(b_-a_-^*+a_+b_+^*)$	$P\,\alpha_\Lambda$	$\cos\theta\,\sin\theta_1\,\sin\theta_2\,\cos\theta_2\,\sin(\varphi_1+\varphi_2)$
16	$\frac{3}{\sqrt{2}}Re(a_-b_+^*-b_-a_+^*)$	P	$\sin\theta\,\sin\theta_2\,\cos\theta_2\,\cos\varphi_2$
17	$-\frac{3}{\sqrt{2}}Im(a_-b_+^*-b_-a_+^*)$	P	$\sin\theta\,\sin\theta_2\,\cos\theta_2\,\sin\varphi_2$
18	$\frac{3}{\sqrt{2}}Re(b_-a_-^*-a_+b_+^*)$	α_Λ	$\sin\theta_1\,\sin\theta_2\,\cos\theta_2\,\cos(\varphi_1+\varphi_2)$
19	$-\frac{3}{\sqrt{2}}Im(b_-a_-^*-a_+b_+^*)$	α_Λ	$\sin\theta_1\,\sin\theta_2\,\cos\theta_2\,\sin(\varphi_1+\varphi_2)$

α_b Measurement

- Polarization P=0: due to symmetry of initial state & ATLAS symmetry in pseudo-rapidity
  - f_{1i}, f_{2i}, F_i reduced to 6 coefficients (from 20):

i	f_{1i}	f_{2i}	F_i
0	1	1	1
2	$(k_0^2 + k_1^2 - 1) + \alpha_b(k_0^2 - k_1^2)$	α_Λ	$\cos\theta_1$
4	$\frac{1}{4}[(3k_1^2 - 3k_0^2 - 1) + 3\alpha_b(1 - k_1^2 - k_0^2)]$	1	$\frac{1}{2}(3\cos^2\theta_2 - 1)$
6	$-\frac{1}{4}[(k_0^2 + k_1^2 - 1) + \alpha_b(3 + k_0^2 - k_1^2)]$	α_Λ	$\frac{1}{2}(3\cos^2\theta_2 - 1)\cos\theta_1$
18	$\frac{3}{\sqrt{2}}[\frac{1-\alpha_b}{2}\sqrt{k_1^2(1-k_1^2)}\cos(-\Delta_-) - \frac{1+\alpha_b}{2}\sqrt{k_0^2(1-k_0^2)}\cos(\Delta_+)]$	α_Λ	$\sin\theta_1 \sin\theta_2 \cos\theta_2 \cos(\varphi_1 + \varphi_2)$
19	$-\frac{3}{\sqrt{2}}[\frac{1-\alpha_b}{2}\sqrt{k_1^2(1-k_1^2)}\sin(-\Delta_-) - \frac{1+\alpha_b}{2}\sqrt{k_0^2(1-k_0^2)}\sin(\Delta_+)]$	α_Λ	$\sin\theta_1 \sin\theta_2 \cos\theta_2 \sin(\varphi_1 + \varphi_2)$

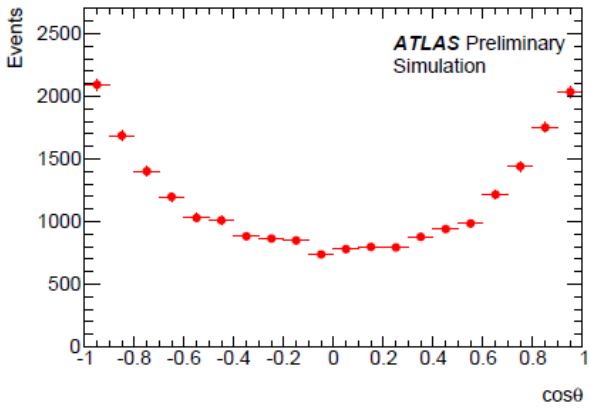
- Use following 5 parameters to define model:

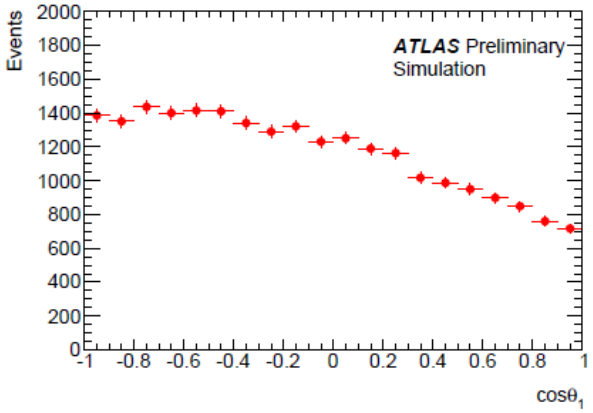
$$\alpha_b = |a_+|^2 - |a_-|^2 + |b_+|^2 - |b_-|^2$$

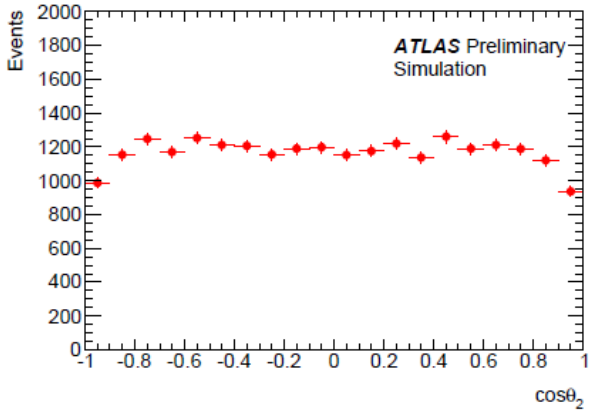
$$k_0 = \frac{|a_+|}{\sqrt{|a_-|2+|b_+|^2}}, \quad k_1 = \frac{|b_-|}{\sqrt{|a_-|^2+|b_-|^2}}$$

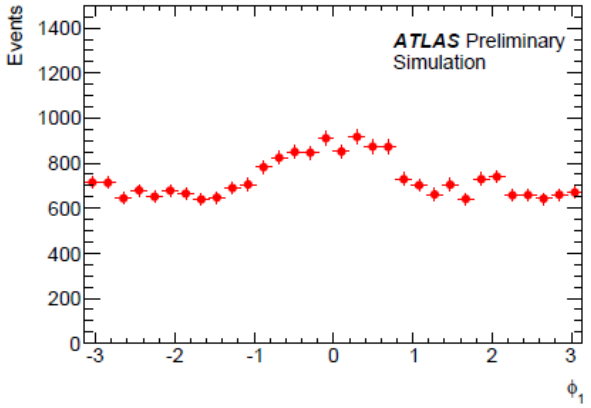
$$\Delta_+ = \rho_+ - \omega_+, \qquad \Delta_- = \rho_- - \omega_-$$

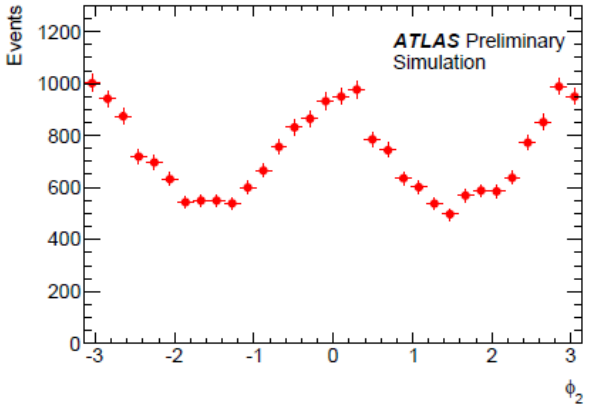
Efficiency Correction

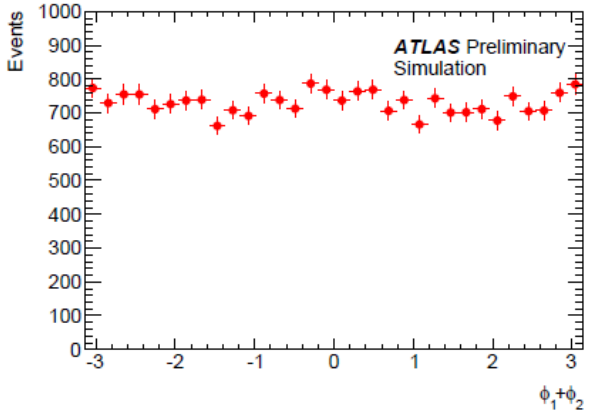












$$\mathbf{C} = \begin{pmatrix} 1 & -0.114 & -0.030 & 0.0069 & 0.0220 & -0.0028 \\ -0.113 & 0.3093 & 0.0066 & -0.0125 & 0.0029 & -0.0009 \\ -0.030 & 0.0070 & 0.1782 & -0.0188 & 0.0040 & -0.0001 \\ 0.0066 & -0.0124 & -0.0188 & 0.0547 & 0.00012 & 0.00032 \\ 0.0219 & 0.0028 & 0.0039 & 0.00016 & 0.0465 & 0.0005 \\ -0.0032 & -0.0007 & -0.0003 & 0.00035 & 0.0005 & 0.0450 \end{pmatrix}$$

Ideal case, no detector effects:

$$\mathbf{D} = diag\{1, \tfrac{1}{3}, \tfrac{1}{5}, \tfrac{1}{15}, \tfrac{2}{45}, \tfrac{2}{45}\}$$

Fit Results

- Measured <F_i> values:
  - <F_2>=-0.282±0.021
  - <F_4>=-0.044±0.017
  - <F_6>=0.001±0.010
  - <F_{18}>=0.019±0.009
  - <F_{19}>=-0.002±0.009

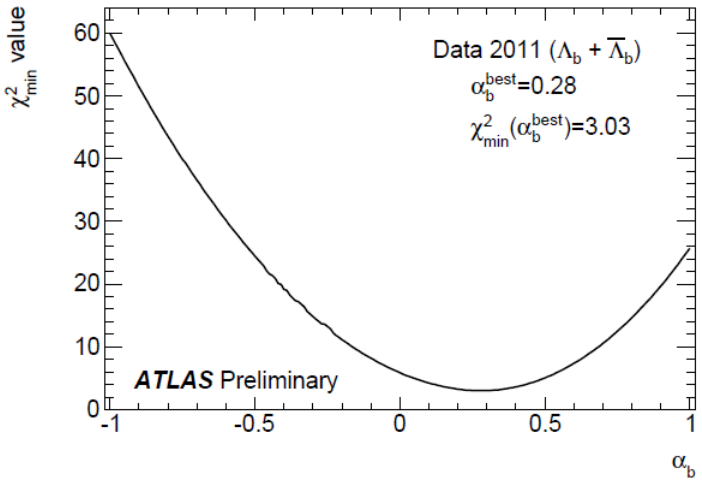
$\langle F_i \rangle$	$\langle F_2 \rangle$	$\langle F_4 \rangle$	$\langle F_6 \rangle$	$\langle F_{18} \rangle$	$\langle F_{19} \rangle$
$\langle F_2 \rangle$	1	−0.066	−0.121	0.028	0.003
$\langle F_4 \rangle$		1	−0.503	0.088	0.000
$\langle F_6 \rangle$			1	−0.025	−0.008
$\langle F_{18} \rangle$				1	0.048
$\langle F_{19} \rangle$					1

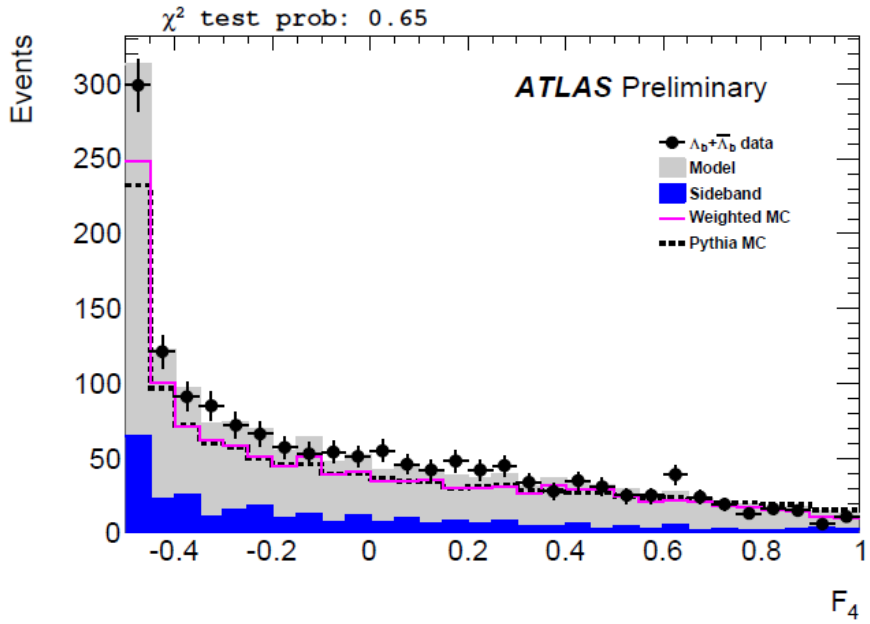
Correlation matrix of <F_i> Measurements

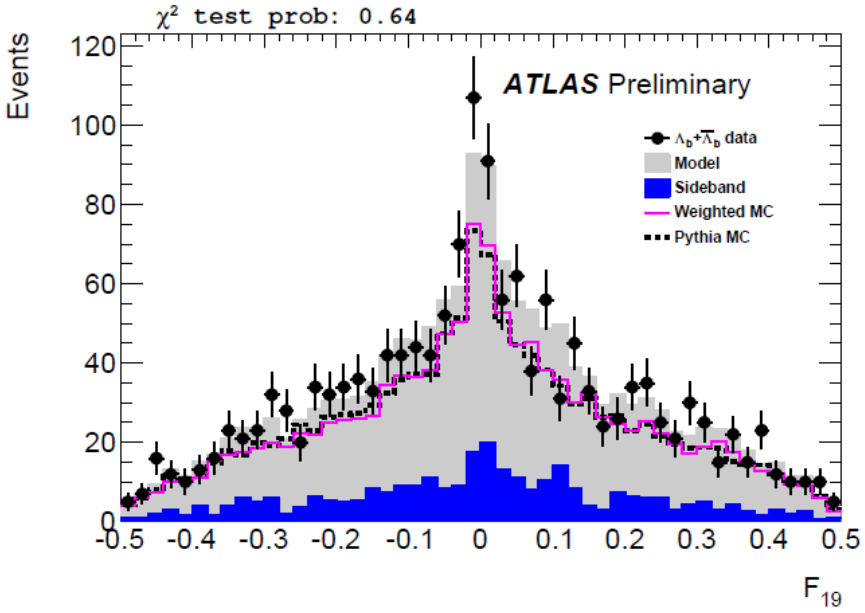
- Values obtained from fit:
  - α_b=0.28±0.16, $k_0=0.22^{+0.14}_{-0.57}$, $k_1=0.13^{+0.20}_{-0.47}$

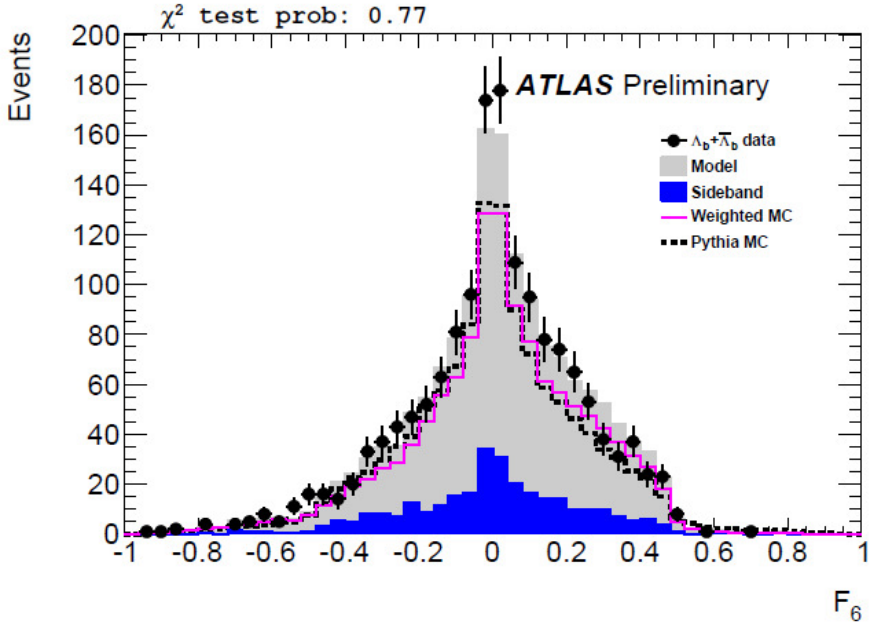
Correlation matrix of the fitted parameters.

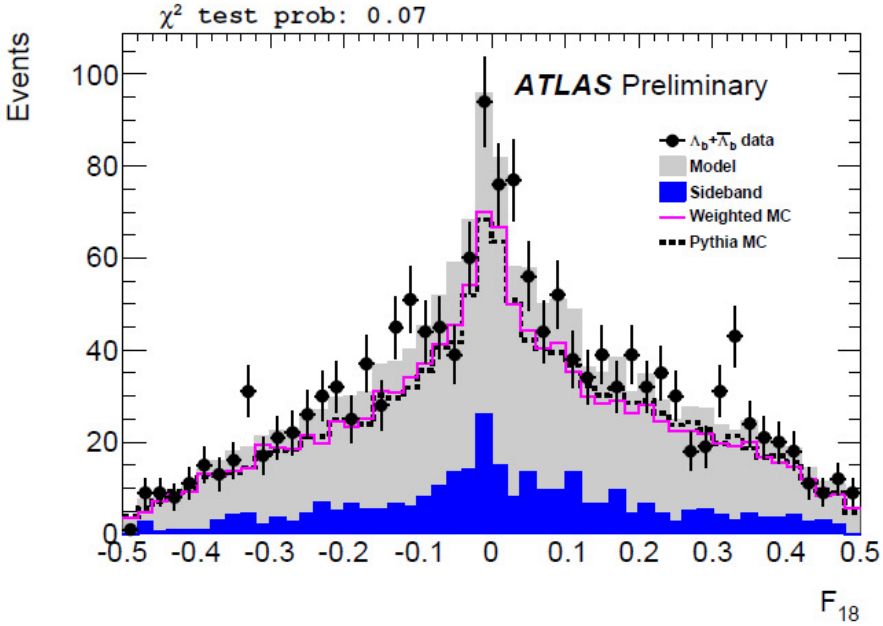
Parameter	α_b	k_0	k_1
α_b	1	0.41	−0.20
k_0		1	0.19
k_1			1




χ² test prob: 0.65
ATLAS Preliminary
Λb+Λ̄b data
Model
Sideband
Weighted MC
Pythia MC
Events
F4


χ² test prob: 0.64
ATLAS Preliminary
Λb+Λ̄b data
Model
Sideband
Weighted MC
Pythia MC
Events
F19


χ² test prob: 0.77
ATLAS Preliminary
Λb+Λ̄b data
Model
Sideband
Weighted MC
Pythia MC
Events
F6


χ² test prob: 0.07
ATLAS Preliminary
Λb+Λ̄b data
Model
Sideband
Weighted MC
Pythia MC
Events
F18