Studies of suppressed processes in B-meson decays and of mixing/CP violation in the B_s system with the ATLAS detector

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Overview

- Flavour tagged time dependent angular analysis of the decay $B_s \rightarrow J/\Psi\Phi$ and extraction of $\Delta\Gamma_s$ and the weak phase Φ_S

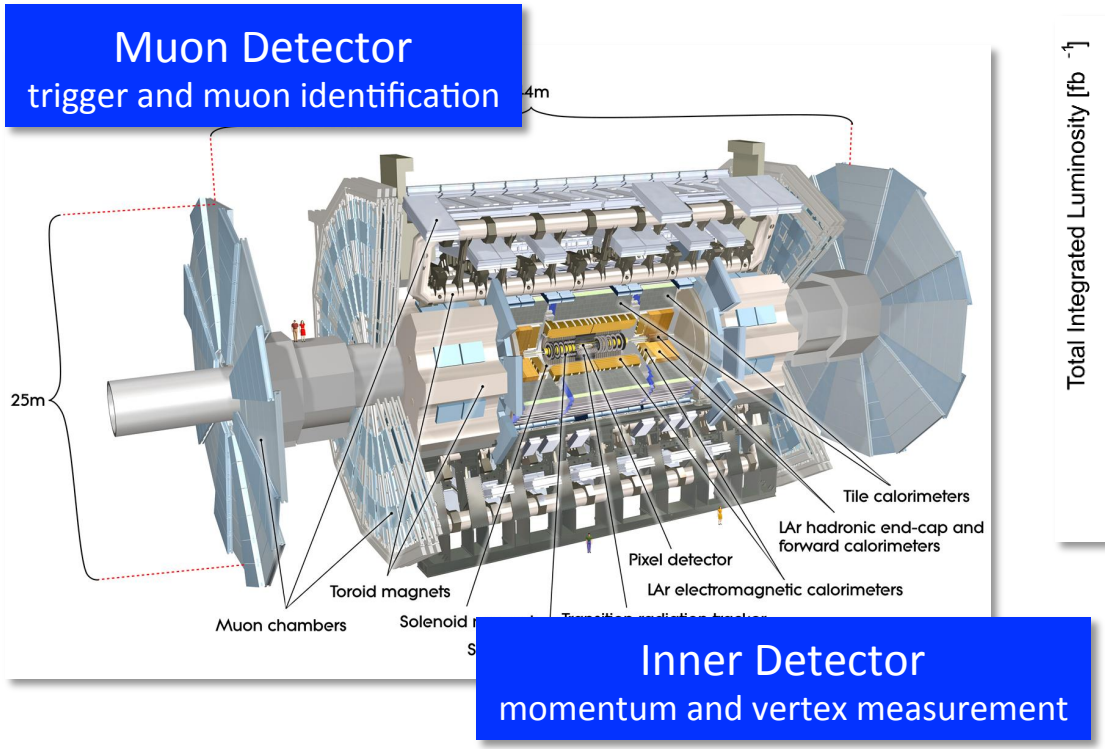
ATLAS-CONF-2013-039

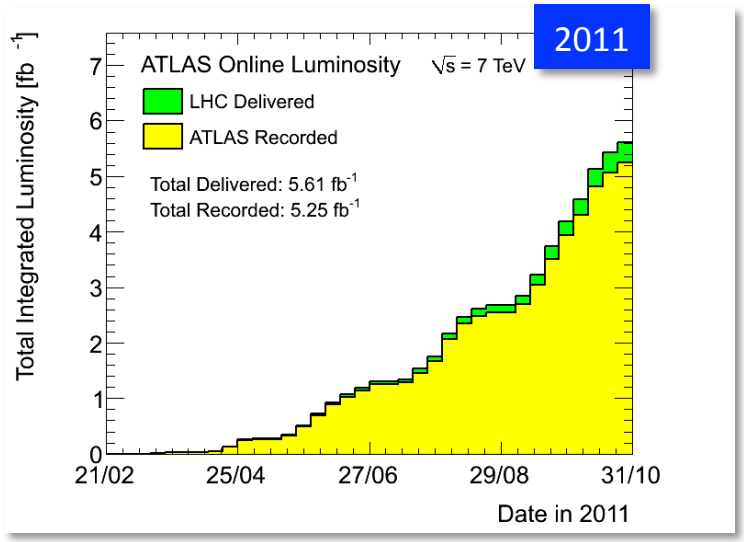
- Angular Analysis of the decay $B^0 \rightarrow K^{0*}\mu^+\mu^-$

ATLAS-CONF-2013-038

EXPERIMENTAL SETUP

The ATLAS Experiment and Data Sample

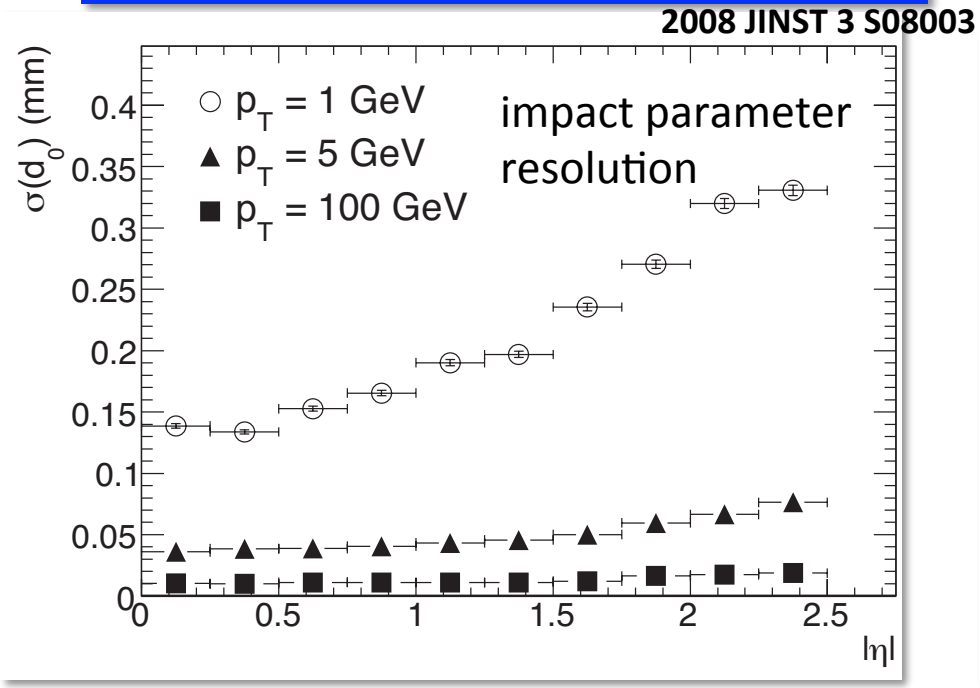




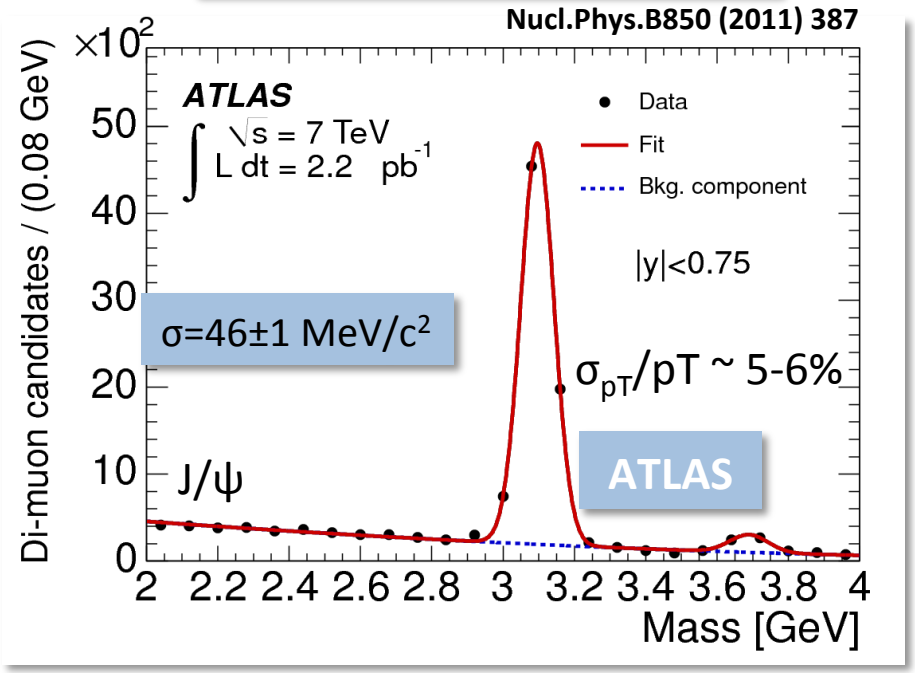
- Analyses based on 4.9 fb^{-1} collected in 2011
- Max inst. luminosity ~3.5 x 10^{33} cm^{-2} s^{-1}
  - up to 12 collisions / event on average
- Expect about ~ 0.5x10^9 B^0–pairs and ~10^7 $B_S \rightarrow J/\psi\phi$ events and ~ 10^5 $B \rightarrow K^* \mu^+ \mu^-$ events for 5 fb^{-1}

Detector Performance

Impact Parameter Resolution



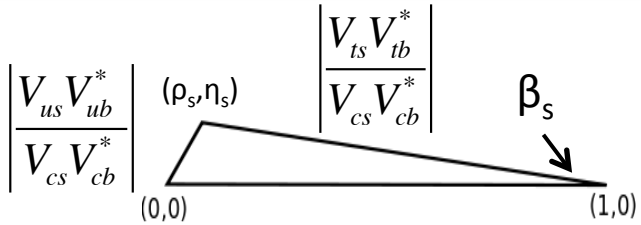
Mass Resolution



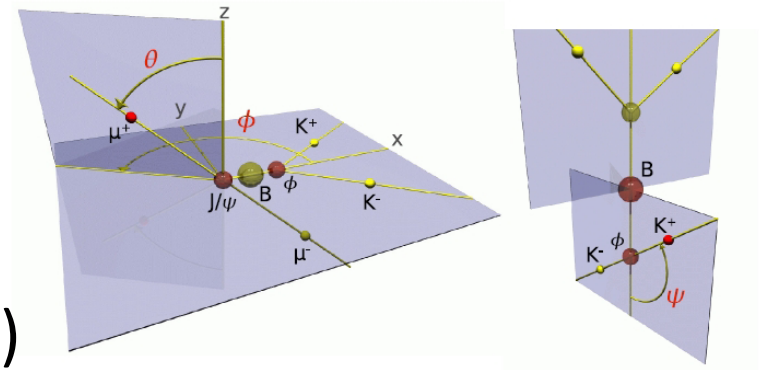
- Good impact parameter resolution required for lifetime based measurements
- Excellent mass resolution required for good S/B performance
- Limited particle ID (only for $p_T < 1$ GeV K/π – separation possible)

MEASUREMENT OF $\Delta\Gamma_S$ AND Φ_S IN THE DECAY $B_S \rightarrow J/\Psi\Phi$

Introduction

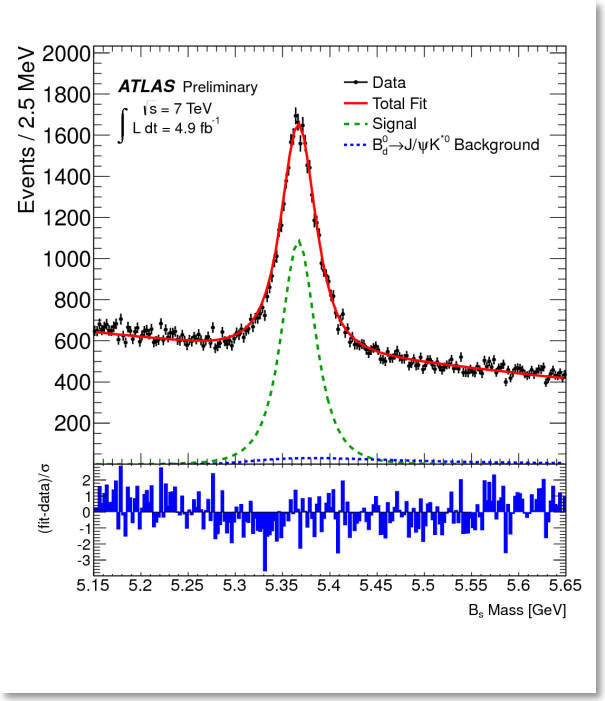


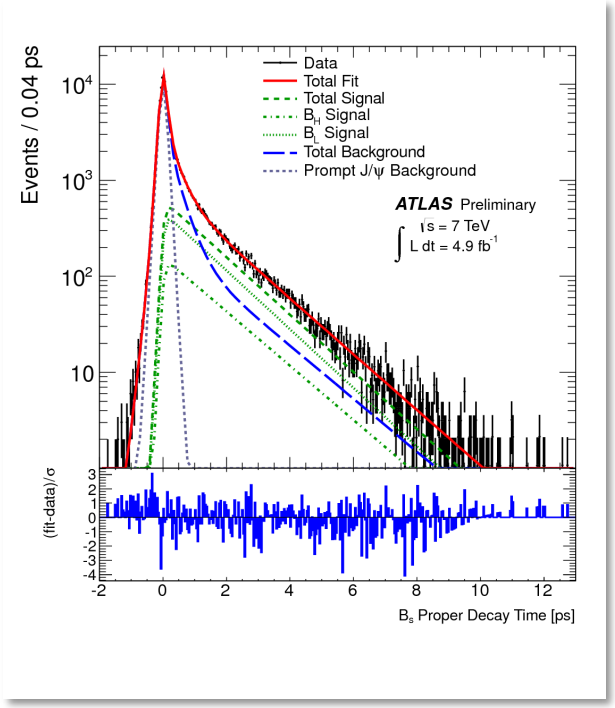
- Motivation:
  - Standard Model predicts very small value for B_s mixing phase $\Phi_s = \arg(-M_{12}/\Gamma_{12}) \approx -0.04 \pm 0.002 \approx 2\beta_s$
  - Any significant deviation would be a signal for physics beyond the Standard Model
- Experimental Challenge:
  - Good vertex resolution for time information
  - Significant background (no PID)
  - J/ψΦ not a pure CP eigenstate
    → statistical decomposition of CP-states



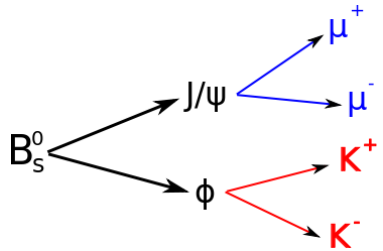
transversity basis

Measurement of $\Delta\Gamma$ and Φ_S in the decay $B_s \rightarrow J/\Psi\Phi$





Event Selection



- J/ψ trigger
- Reconstruction of $B_s \rightarrow \mu^+\mu^-K^+K^-$ candidate

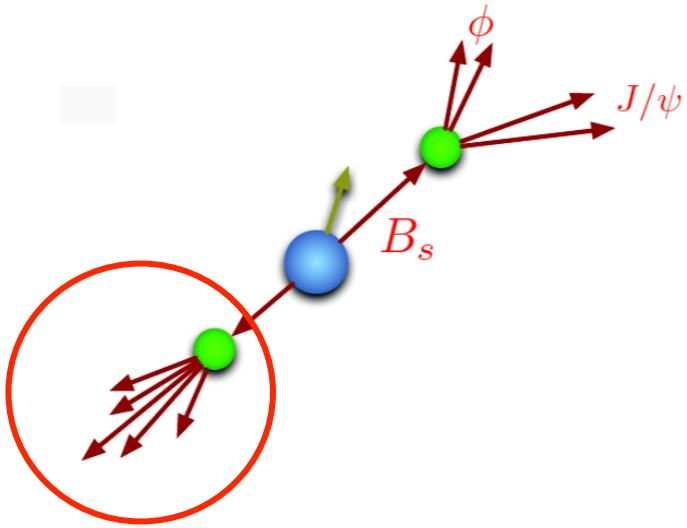
- Determine mass and proper decay time

$$\tau = \frac{L_{xy}\, M_{B_s}}{p_{t_B}}$$

- Measure transversity angles of the event
  → transv. angles: θ_T, ψ_T and ϕ_T

Charge Flavour Tagging

Task: determine flavour eigenstate of B_s-meson at production time



- Opposite side flavour tagging used
- Two different methods applied in hierarchy of performance

Muon Tagger

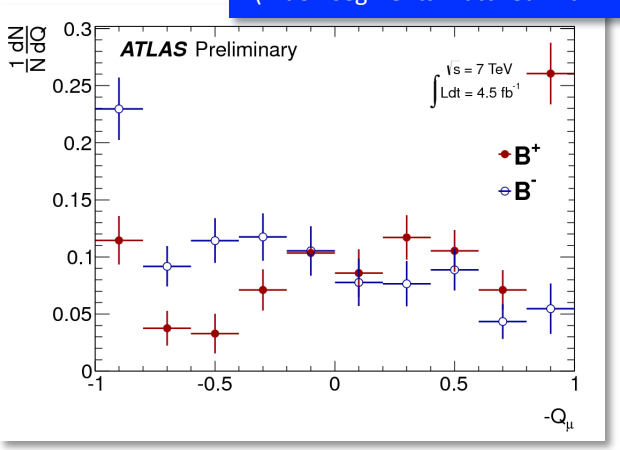
- Identify the muon from semileptonic decay
- Calculate muon cone charge Q_μ

Jet Charge Tagger

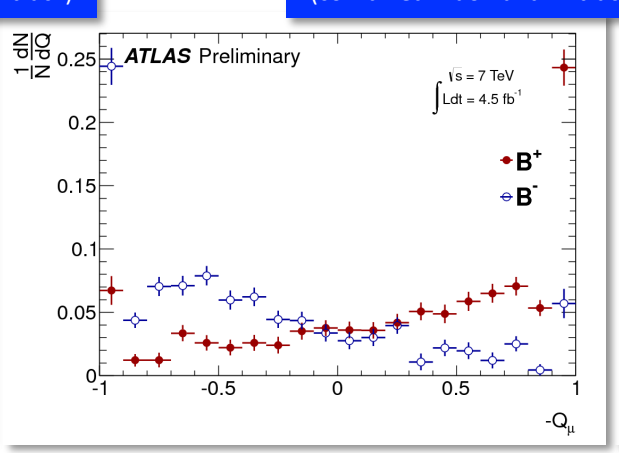
- Identify jet originating from same primary vertex
- Calculate jet charge Q_{jet}

Charge Flavour Tagging

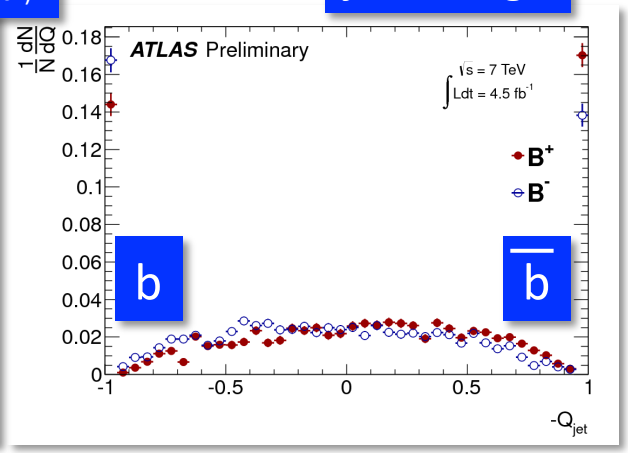
segmented muons
(muon segments matched with ID track)



combined muons
(combined muon and ID track)



jet charge



- Determine probability that signal decay contains $\bar{b}$ as function of Q_μ and Q_{jet} using calibration sample $B^+ \rightarrow J/\psi K^+$

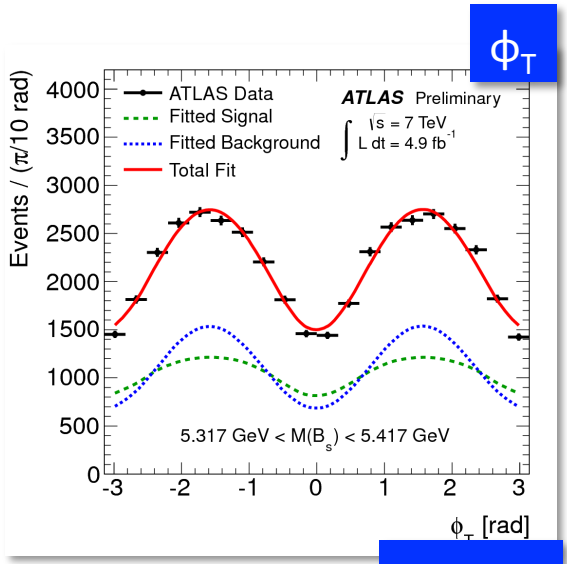
Tagger	Efficiency [%]	Dilution [%]	Tagging Power [%]
Segment Tagged muon	1.08 ± 0.02	36.7 ± 0.7	0.15 ± 0.02
Combined muon	3.37 ± 0.04	50.6 ± 0.5	0.86 ± 0.04
Jet charge	27.7 ± 0.1	12.68 ± 0.06	0.45 ± 0.03
Total	32.1 ± 0.1	21.3 ± 0.08	1.45 ± 0.05

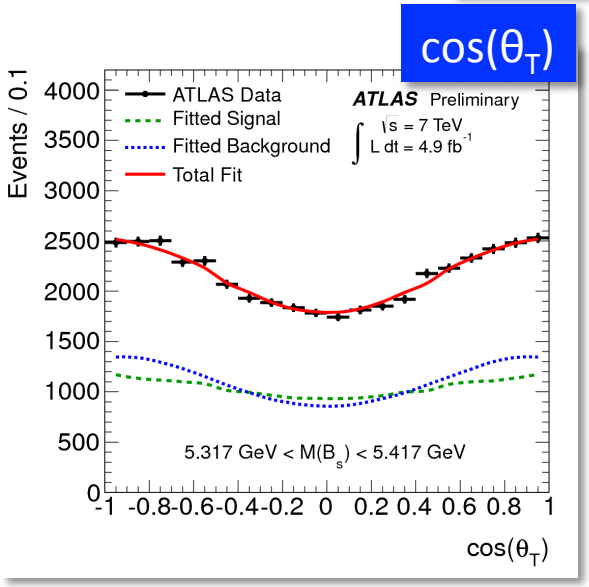
Summary of Tagging Performance

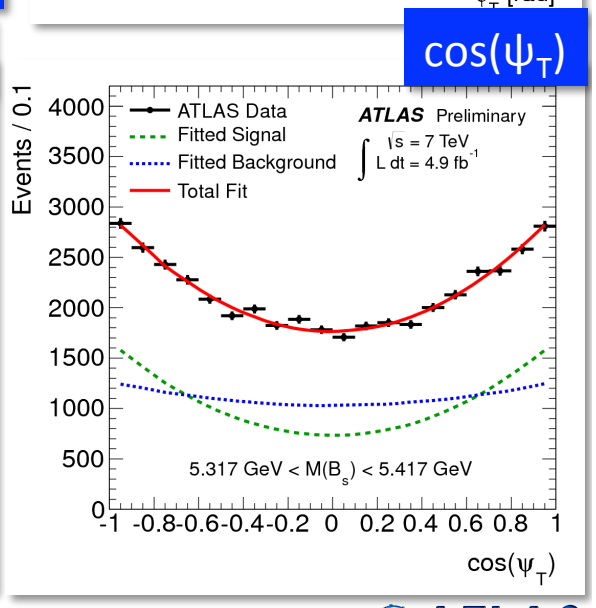
Measurement of $\Delta\Gamma_s$ and ϕ_s

- Unbinned maximum likelihood fit taking event-by-event errors into account
- non resonant $B_s \rightarrow J/\psi K^+K^-$ decays included by additional amplitude A_s
- dedicated function to describe background from $B \rightarrow J/\psi K^*$ and $B \rightarrow J/\psi K\pi$ decays (6.5% and 4.5%)

transversity angles in signal region



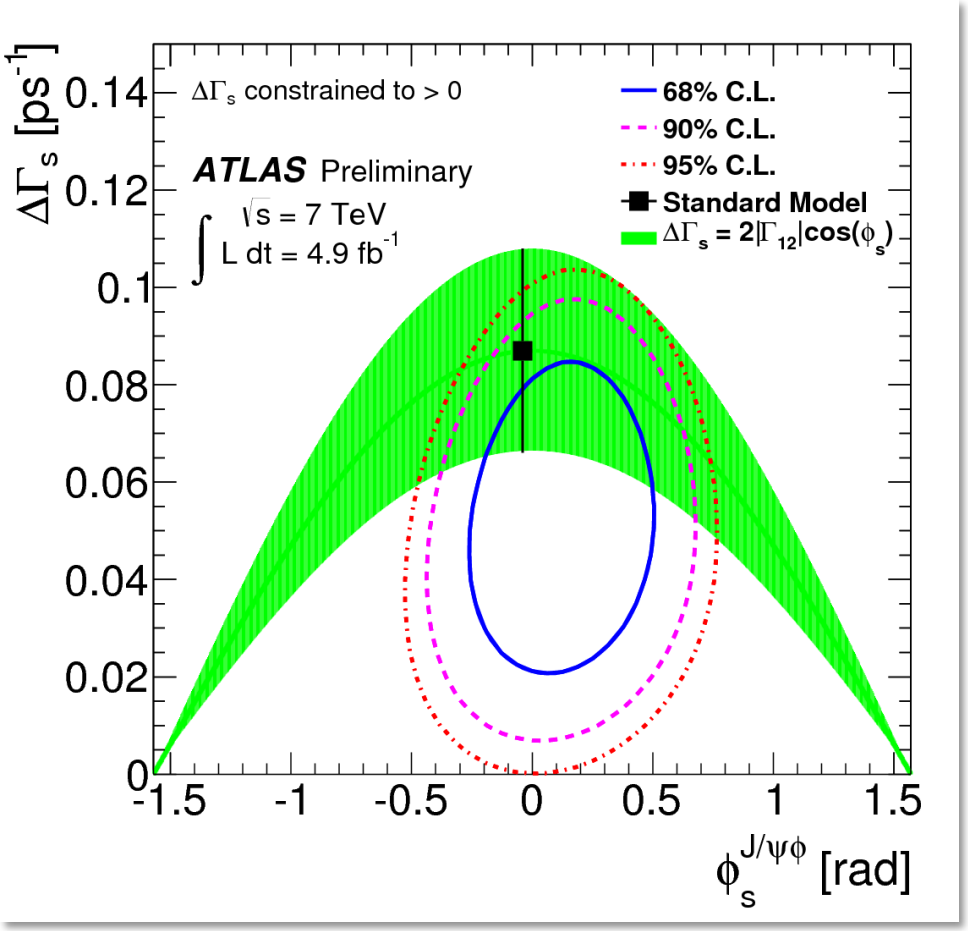




Measurement of $\Delta\Gamma$ and Φ_s in the decay $B_s \rightarrow J/\Psi\Phi$

$$\phi_s = 0.12 \pm 0.25\ (\text{stat.}) \pm 0.11\ (\text{syst.})\ \text{rad}$$
$$\Delta\Gamma_s = 0.053 \pm 0.021\ (\text{stat.}) \pm 0.009\ (\text{syst.})\ \text{ps}^{-1}$$
$$\Gamma_s = 0.677 \pm 0.007\ (\text{stat.}) \pm 0.003\ (\text{syst.})\ \text{ps}^{-1}$$
$$|A_0(0)|^2 = 0.529 \pm 0.006(\text{stat.}) \pm 0.011\ (\text{syst.})$$
$$|A_{\|}(0)|^2 = 0.220 \pm 0.008(\text{stat.}) \pm 0.009\ (\text{syst.})$$
$$\delta_{\perp} = 3.89 \pm 0.46\ (\text{stat.}) \pm\ 0.13\ (\text{syst.})\ \text{rad}$$

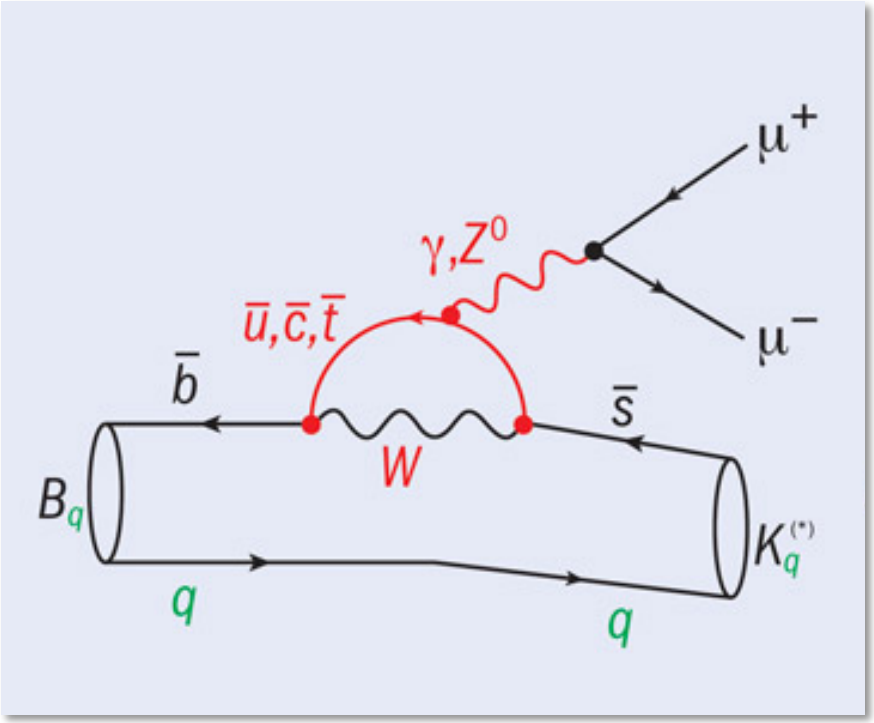
- Uncertainty on Φ_s improved by 40% compared to untagged analysis
- Uncertainty statistically dominated
  - 2012 data currently analysed
- Uncorrelated description of background angle dominant systematic uncertainty



ANGULAR ANALYSIS OF $B \rightarrow K^{*}\mu^{+}\mu^{-}$

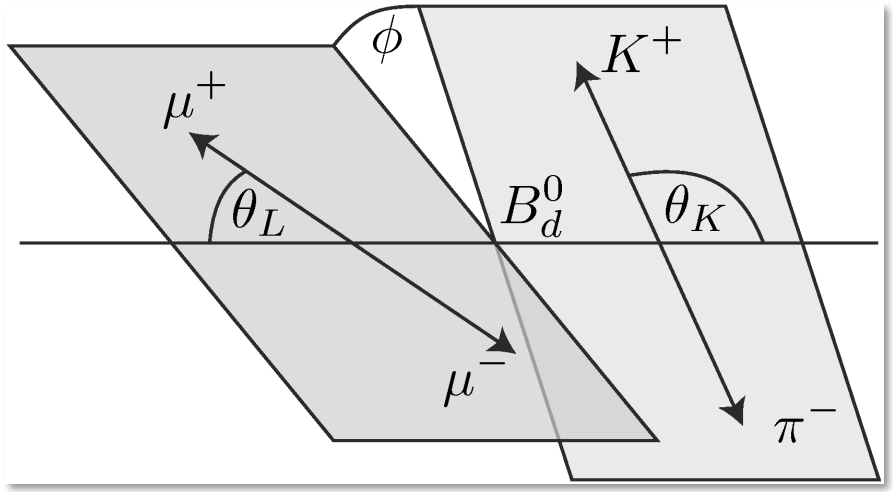
Introduction

- FCNC transitions only allowed at loop level and GIM suppressed
- Significant contribution from physics beyond SM possible
- b→s transitions offers such possibility with $B \to K^* \mu^+ \mu^-$ being one exclusive decay mode



Event Reconstruction

- Events triggered on single and di-muon trigger
- Cut based selection optimized for whole q^2 region
  (q^2: invariant mass of μ-pair)
- Measure forward-backward asymmetry A_{FB} and longitudinal polarization fraction F_L with unbinned maximum likelihood fit

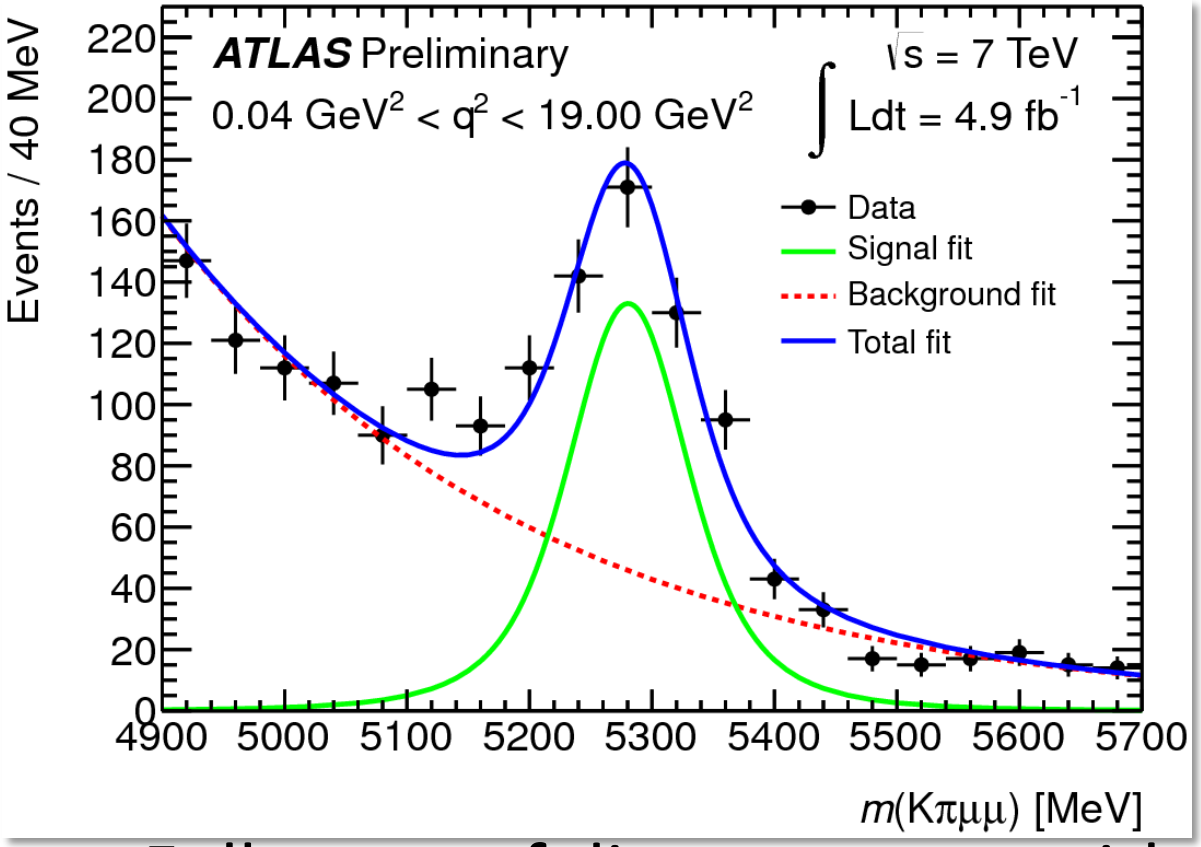


$$\frac{1}{\Gamma}\frac{d^2\Gamma}{dq^2 d\cos\theta_L} = \frac{3}{4}F_L(q^2)\left(1-\cos^2\theta_L\right) + \frac{3}{8}\left(1-F_L(q^2)\right)\left(1+\cos^2\theta_L\right) + A_{FB}(q^2)\cos\theta_L$$

relation between angles and A_{FB} and F_L

Signal Observation

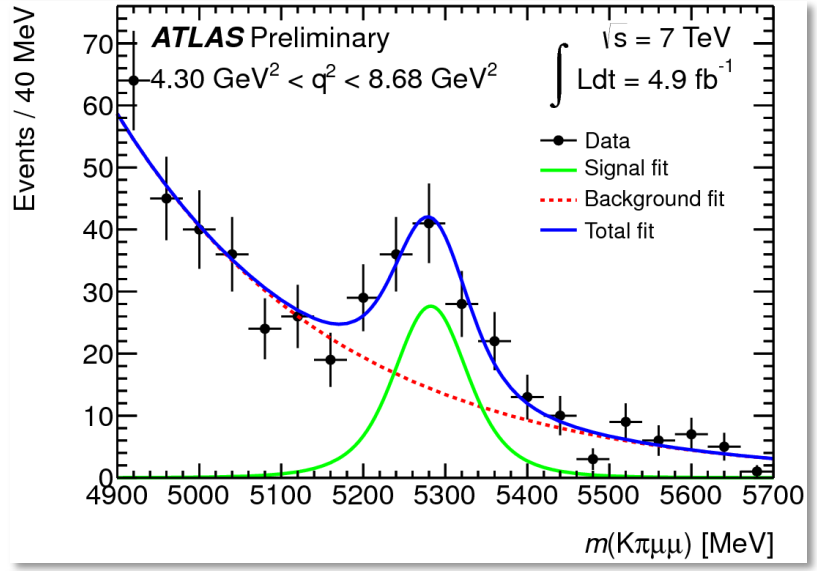
- Mass-fit with Gauss function using per-candidate error and exponential background
- $B \rightarrow K^* \mu^+ \mu^-$ signal decay clearly visible
- reconstruct 446±34 signal and 1132±43 background events

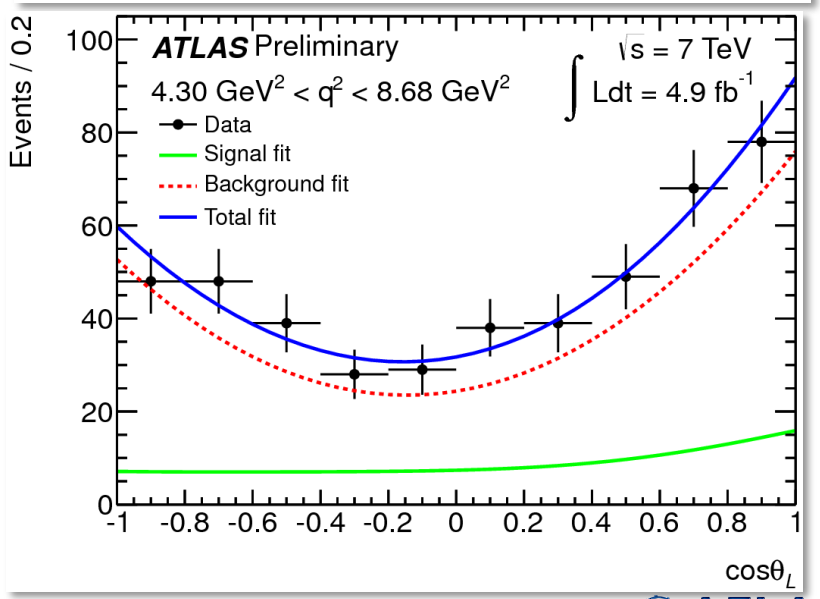


Full range of di-muon mass with J/ψ and ψ(2s) region excluded

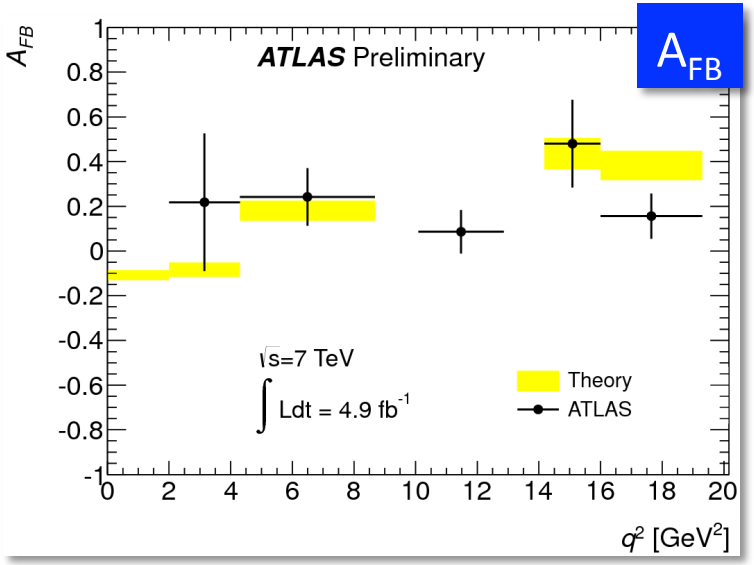
Measurement of A_{FB} and F_L

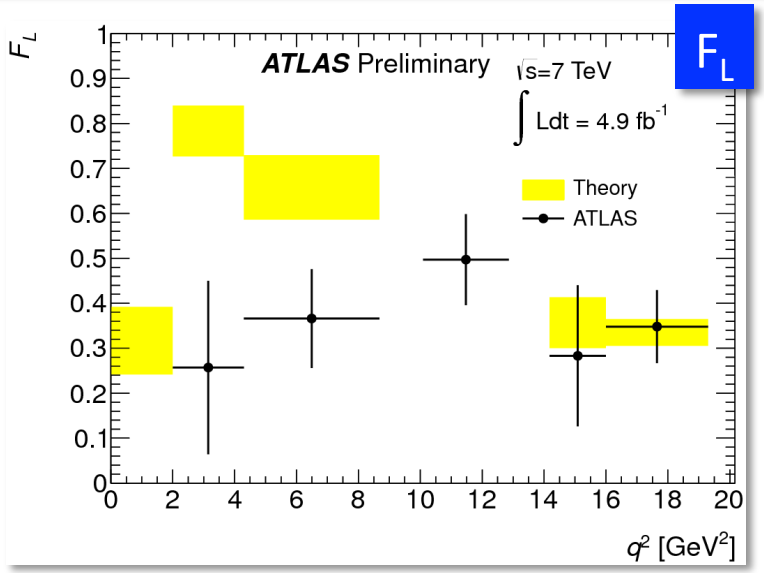
- Measure A_{FB} and F_L in different regions of q^2
- Use unbinned maximum likelihood fit
- Sequential fit approach applied
  - Use mass to separate signal and background contribution
  - Angular fit with result from fit to mass fixed





Result

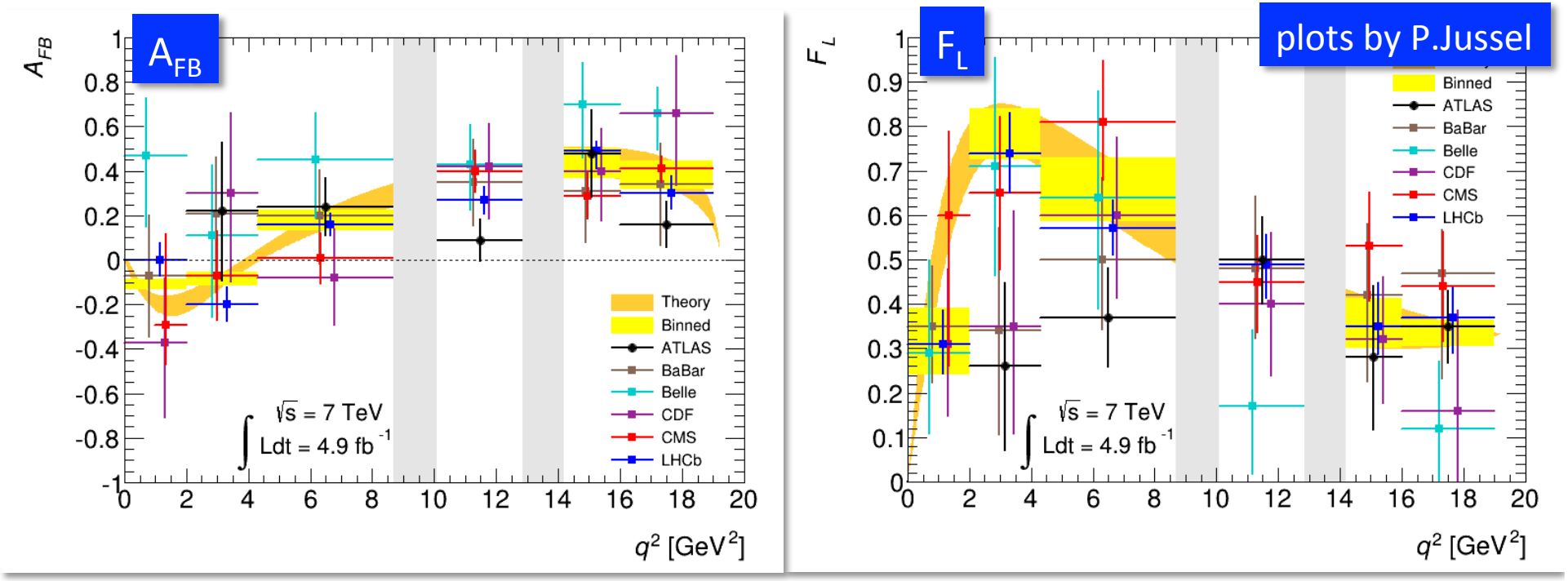




- Uncertainty statistically limited
- Measurement consistent with SM prediction

q^2 range (GeV^2)	N_{sig}	A_{FB}	F_L
$2.00 < q^2 < 4.30$	19 ± 8	$0.22 \pm 0.28 \pm 0.14$	$0.26 \pm 0.18 \pm 0.06$
$4.30 < q^2 < 8.68$	88 ± 17	$0.24 \pm 0.13 \pm 0.01$	$0.37 \pm 0.11 \pm 0.02$
$10.09 < q^2 < 12.86$	138 ± 31	$0.09 \pm 0.09 \pm 0.03$	$0.50 \pm 0.09 \pm 0.04$
$14.18 < q^2 < 16.00$	32 ± 14	$0.48 \pm 0.19 \pm 0.05$	$0.28 \pm 0.16 \pm 0.03$
$16.00 < q^2 < 19.00$	149 ± 24	$0.16 \pm 0.10 \pm 0.03$	$0.35 \pm 0.08 \pm 0.02$
$1.00 < q^2 < 6.00$	42 ± 11	$0.07 \pm 0.20 \pm 0.07$	$0.18 \pm 0.15 \pm 0.03$

Measurement of A_{FB} and F_L



Very competitive measurement in low recoil region

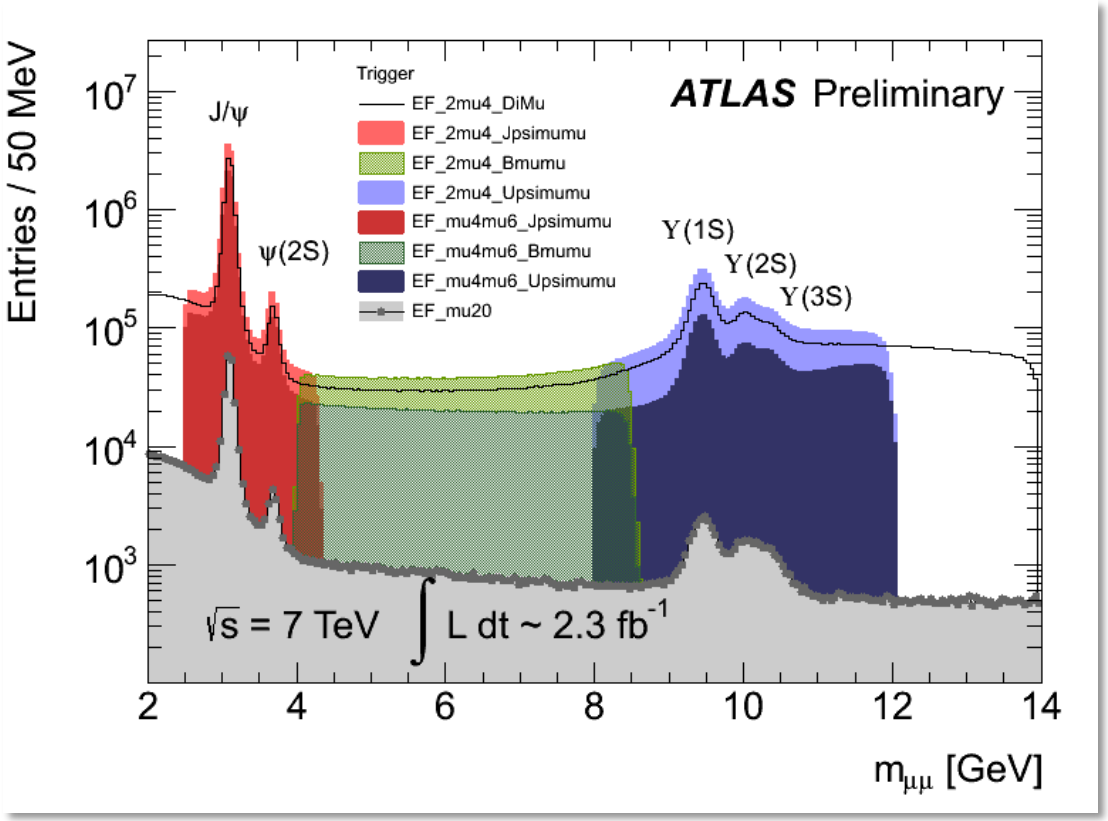
SUMMARY

Summary

- ATLAS able to provide high quality B-physics measurements:
  - measurement of CP violating phase Φ_S and the decay width difference $\Delta\Gamma_s$ in the decay $B_s \rightarrow J/\Psi\Phi$
  - angular analysis of the decay $B^0 \rightarrow K^{0*}\mu^+\mu^-$
- Both measurements are consistent with prediction from the Standard Model
  - no sign for physics beyond the Standard Model
- Both measurements are statistically limited
  - analysis including 2012 data (~ 20 fb^{-1}) ongoing

BONUS MATERIAL

Low p_T $\mu^+\mu^-$-Events



Selection of events with b hadron using two muons in the final state

- $\mu^+\mu^-$: ~1.5-14 GeV
- $J/\psi \rightarrow \mu^+\mu^+$: ~2.5-4.3 GeV
- intermediate $m_{\mu\mu}$ ~4.0-8.5 GeV
- $\Upsilon \rightarrow \mu^+\mu^-$: ~8-12 GeV

Adjust trigger rates by increasing thresholds or prescaling