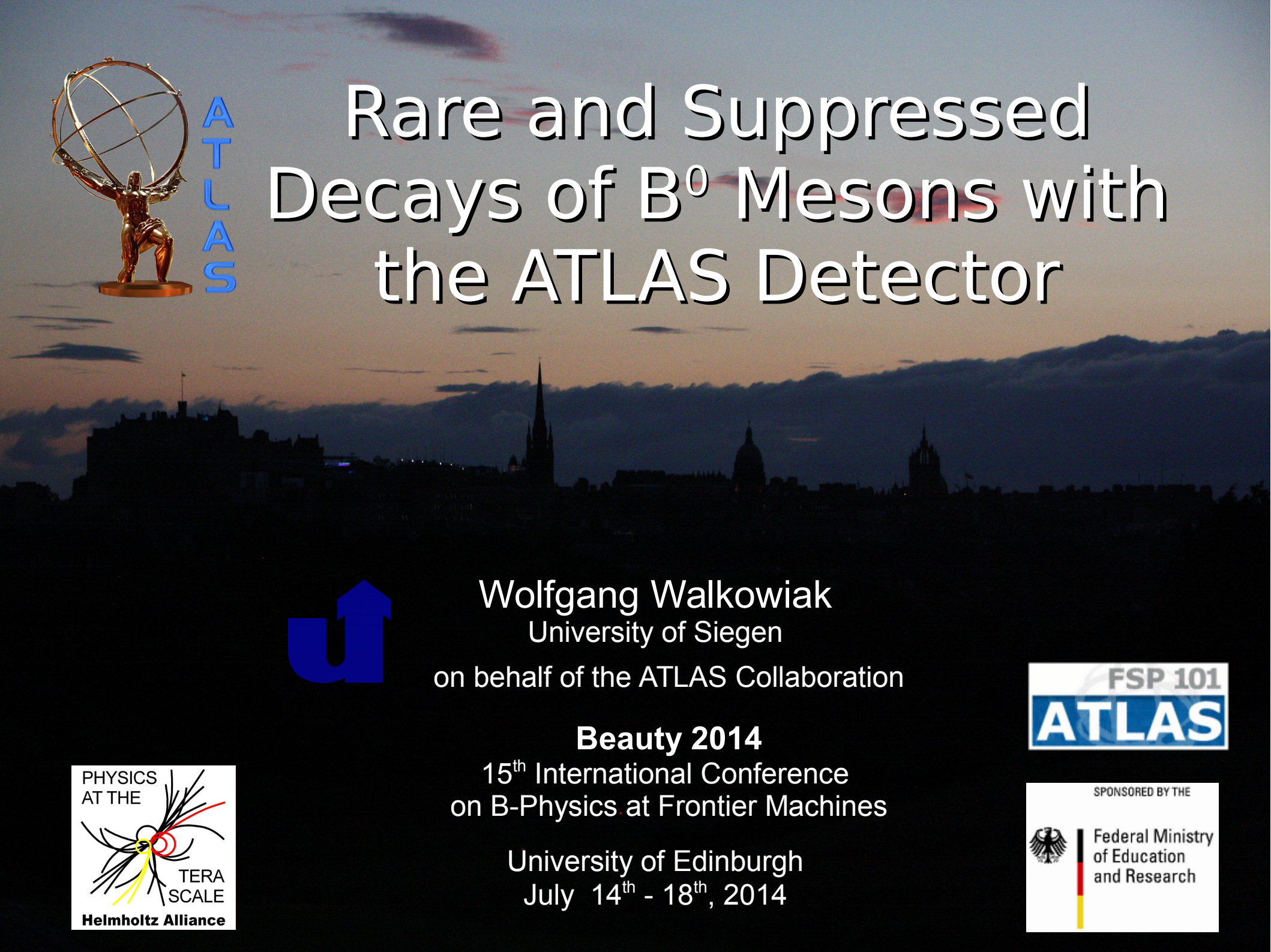

Rare and Suppressed Decays of B^0 Mesons with the ATLAS Detector

Wolfgang Walkowiak
University of Siegen
on behalf of the ATLAS Collaboration

Beauty 2014
15th International Conference
on B-Physics at Frontier Machines

University of Edinburgh
July 14th - 18th, 2014

FSP 101 ATLAS

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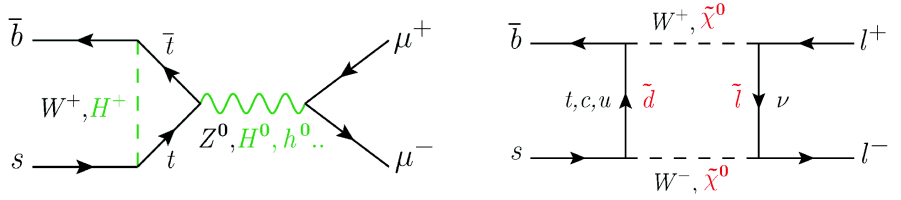
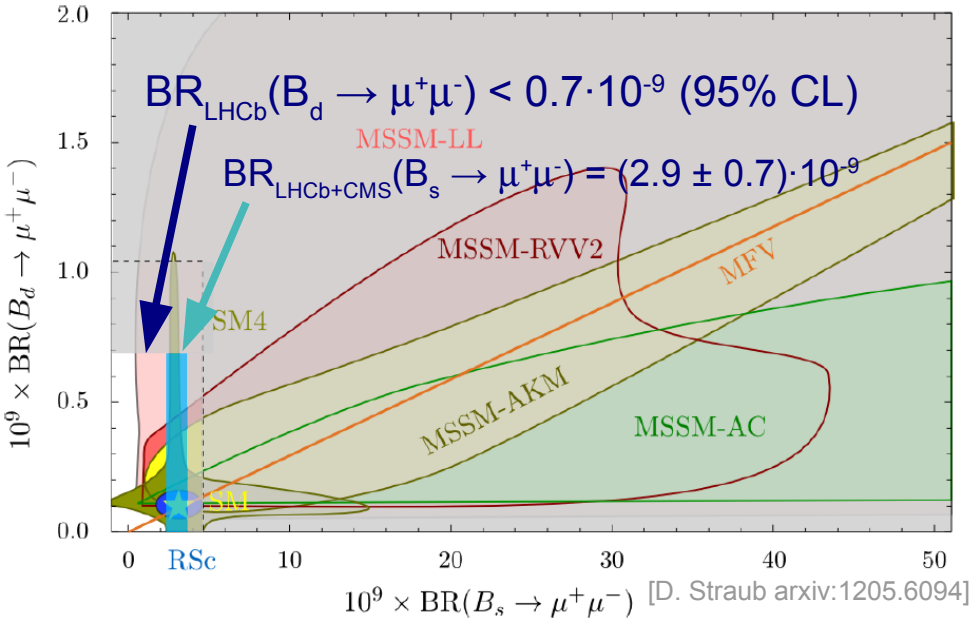
PHYSICS AT THE TERA SCALE
Helmholtz Alliance

New Physics in Rare B Decays

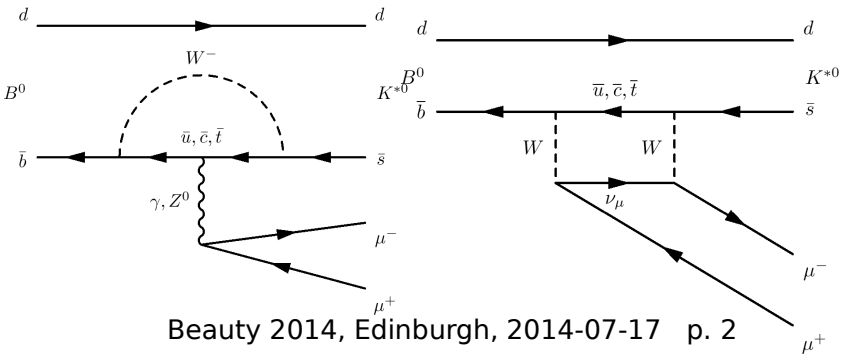
Study Flavor Changing Neutral Currents (FCNC)

- Rare decay $B^0_s \rightarrow \mu^+\mu^-$
  - Highly suppressed in SM
  - Non-SM particles → modify BR
  - Powerful indirect search for NP
  - BR expectation: $(3.27 \pm 0.27)\cdot 10^{-9}$
    [Buras et al., Eur.Phys.J. C72 (2012) 2172]
  - Time-integrated: $(3.54 \pm 0.30)\cdot 10^{-9}$
    [K. De Bruyn et al., Phys.Rev.Lett 109 (2012) 041801]
  - CMS and LHCb: $(2.9 \pm 0.7)\cdot 10^{-9}$
    [LHCb: arXiv:1307.5024, CMS: arXiv:1307.5025]
- Angular analysis of $B^0 \rightarrow K^{*0}\mu^+\mu^-$
  - Exclusive final state for $b \rightarrow s\, l^+l^-$
    BR = $(1.06 \pm 0.10)\cdot 10^{-6}$ [PDG 2013]
  - Angular distribution of 4 final state particles and decay amplitude sensitive to NP (interference with SM diagrams)
    [C. Bobeth et al, Phys. Rev. D 87 (2013) 034016]





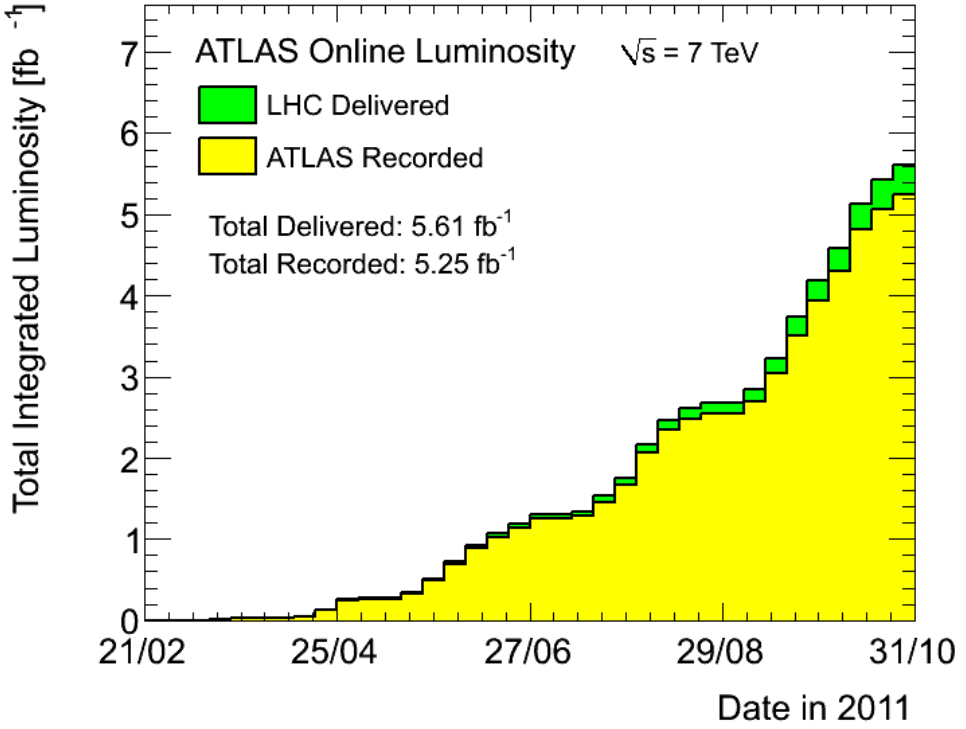
[D. Straub arxiv:1205.6094]

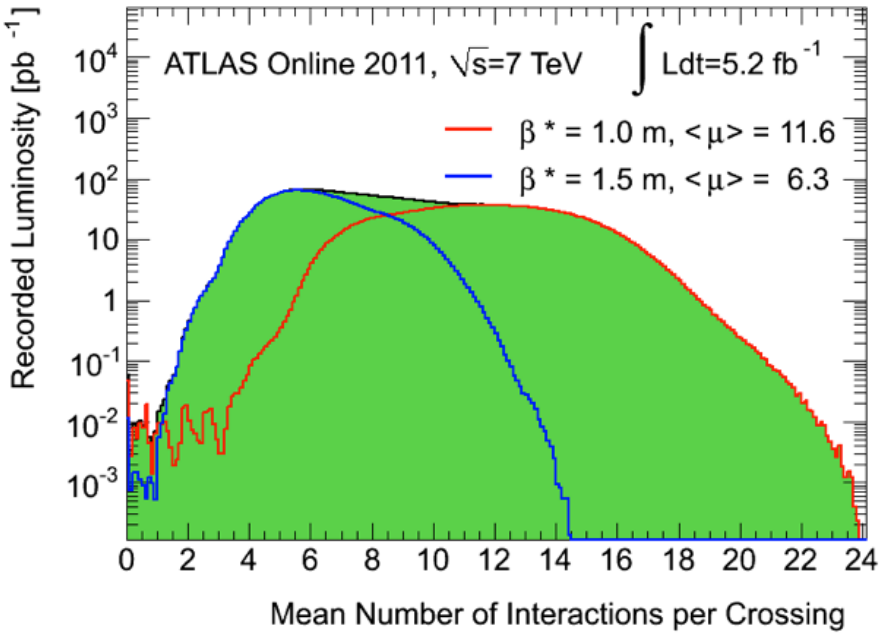


ATLAS Data 2011 for B-Physics

Data-taken in 2011:

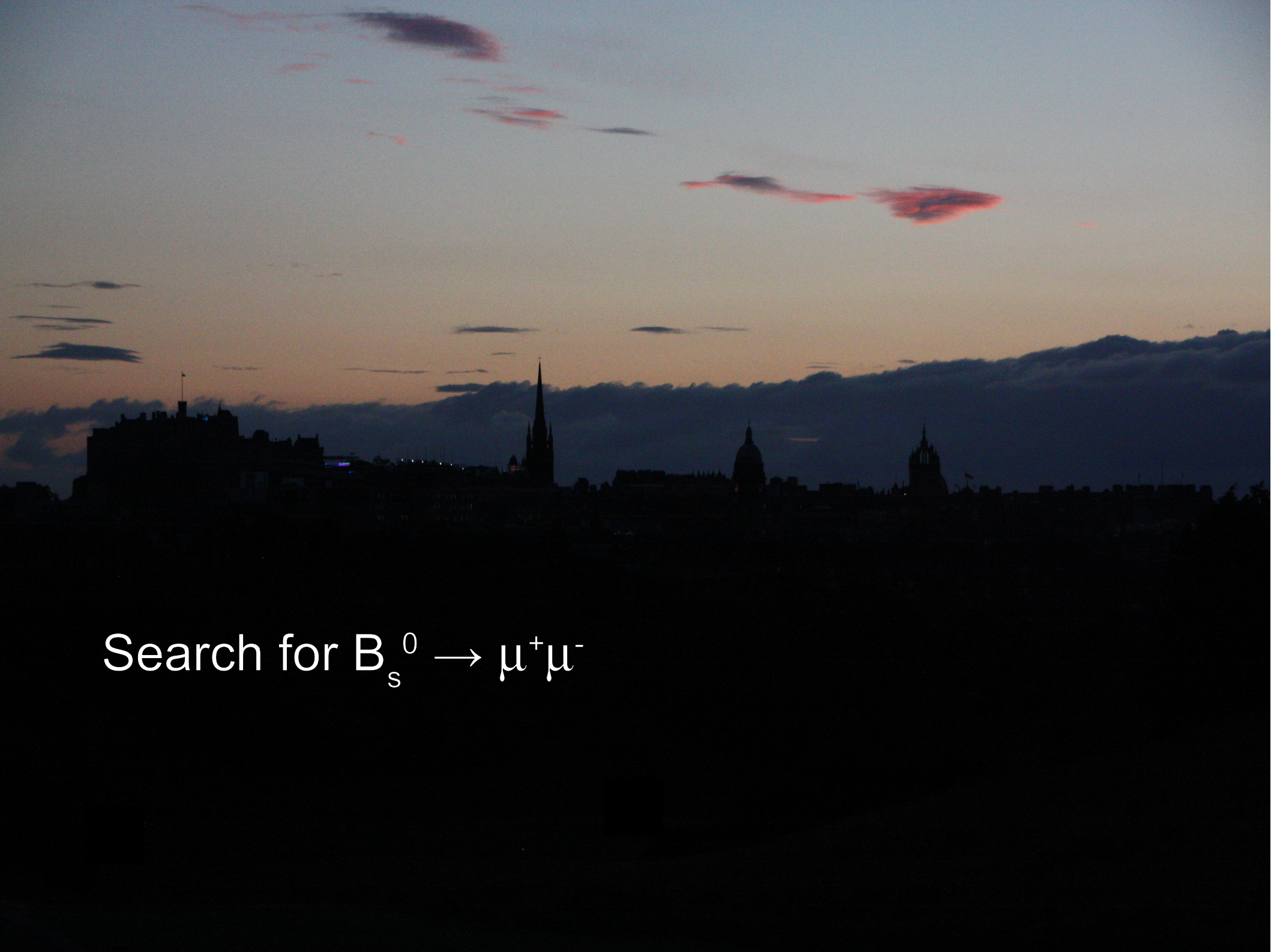
- E_{CM} = 7 TeV
- up to 1380 bunches per beam
- 50 ns bunch spacing
- $L > 3.65 \times 10^{33}\ cm^{-2}s^{-1}$
- $\langle\mu\rangle = 9.1$
- $\int L\,dt > 5.25\ fb^{-1}$ recorded





B physics analyses shown here:

- $\int L\,dt > 4.9\ fb^{-1}$ used
- Di-μ trigger with $p_T(\mu) > 4$ GeV
- Multiple primary vertices per event
  → special discrimination applied



Search for $B_s^0 \rightarrow \mu^+\mu^-$

$B_s^0 \to \mu^+\mu^-$: Analysis Strategy

Relative BR measurement:

[LHCb: JHEP 1304 (2013) 001]]

$$BR(B_s^0 \to \mu^+\mu^-) = N_{\mu\mu} \cdot \frac{1}{N_{J/\psi K^+}} \cdot \frac{\epsilon_{J/\psi K^+} A_{J/\psi K^+}}{\epsilon_{\mu\mu} A_{\mu\mu}} \cdot \frac{f_u}{f_s} \cdot BR(B^+ \to J/\psi K^+ \to \mu^+\mu^- K^+)$$

[PDG 2012]

- Reference channel $B^\pm \to J/\psi K^\pm$
  - Partial cancelation of uncertainties (on luminosity, efficiencies, ...)
- Blind analysis $\to$ $m_{B_s^0}$ ± 300 MeV blinded
- Signal extraction:
  - Counting $N_{\mu\mu}$ in signal region
  - Background estimation:
    - Interpolation from sideband data (even #'d events): continuum & semi-leptonic B decays
    - Resonant B $\to$ hh' with hadrons misidentified as $\mu^\pm$ (MC: 0.3 events)
  - Limit by CLs method
- Boosted Decision Tree (BDT): suppress non-resonant background
- $\varepsilon \times A = N_{rec\&sel} / N_{gen}$ from MC ("calibrated" on data)
  - Systematics from data-MC discrepancies

[ATLAS-CONF-2013-076]

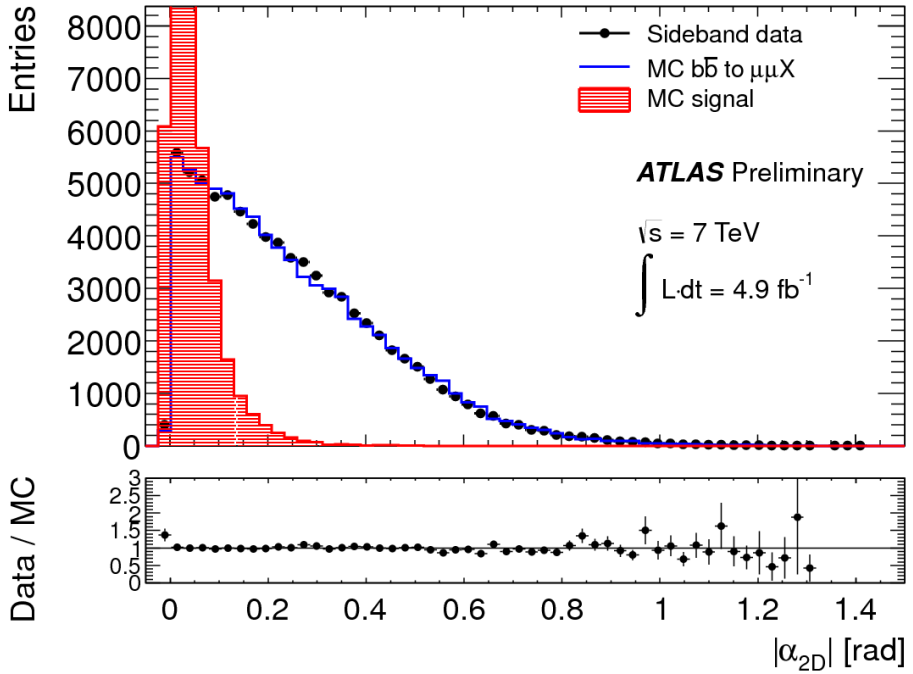
$B_s^0 \to \mu^+\mu^-$: Background Discrimination

Continuum background:

- Dominated by $b\bar{b} \to \mu\mu$ X
- BDT:
  - 13 discriminating variables
  - Trained on MC
  - optimized on sideband data (odd #'d events)

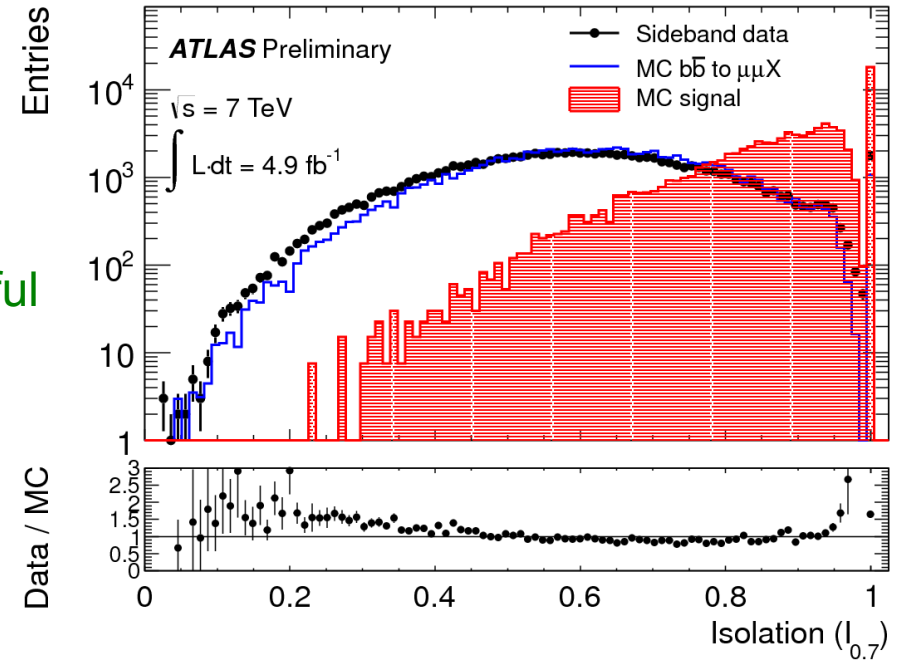
Two most powerful variables

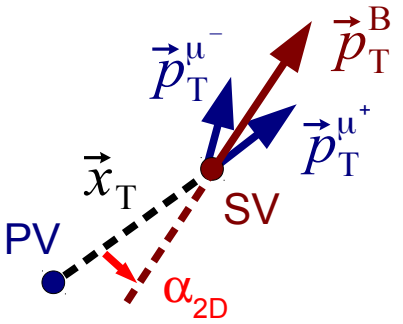
Pointing angle



$$I_{\Delta R} = \frac{p_T^B}{p_T^B + \sum_{i_{track} \in cone(\Delta R)} p_T^{i_{track}}}$$

Isolation





[ATLAS-CONF-2013-076]

$B_s^0 \to \mu^+\mu^-$: BDT Selection

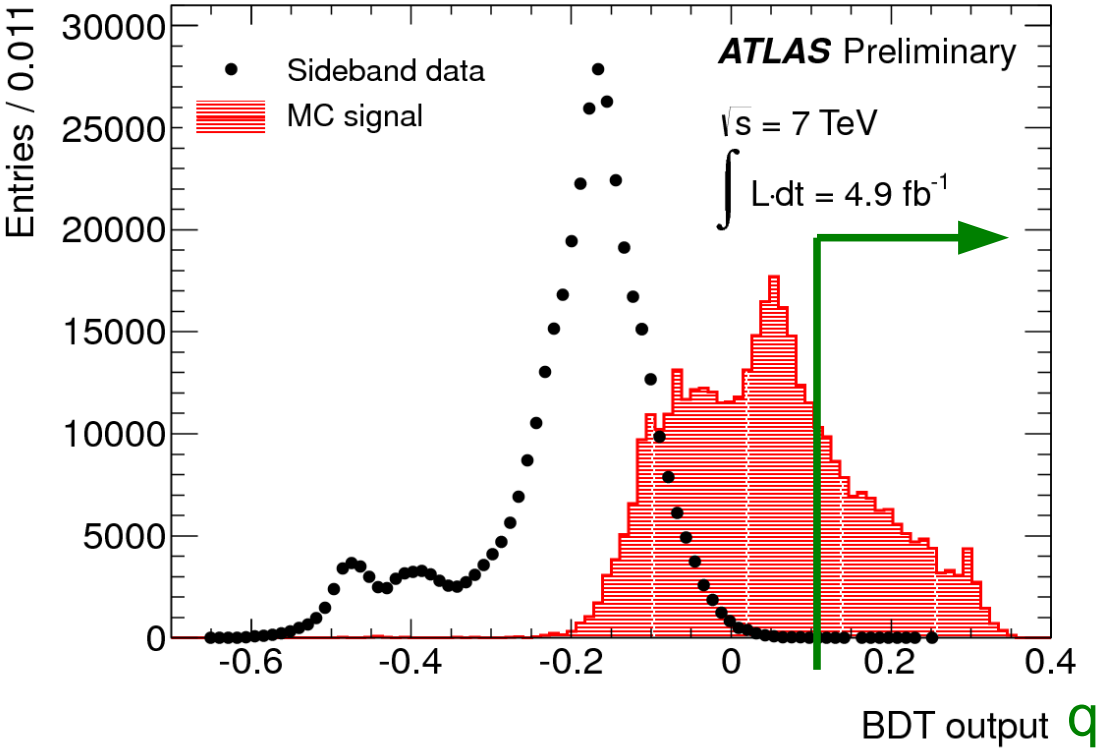
Selection optimization in 2D space:

- q : BDT event classifier
- Δm : signal mass window width
- Maximize

$$P(\Delta m, q) = \frac{\epsilon_{sig}}{1+\sqrt{N_{bkg}}}$$

  - ε_{sig} from signal MC
  - N_{bkg} in signal region from sideband data (odd #'d events)

- Working point:
  - q > 0.118
  - Δm = 121 MeV



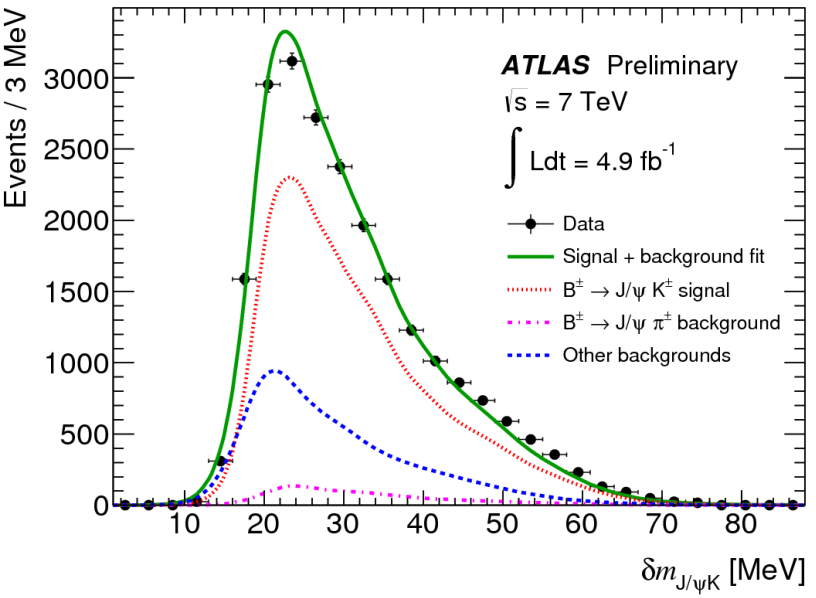
[ATLAS-CONF-2013-076]

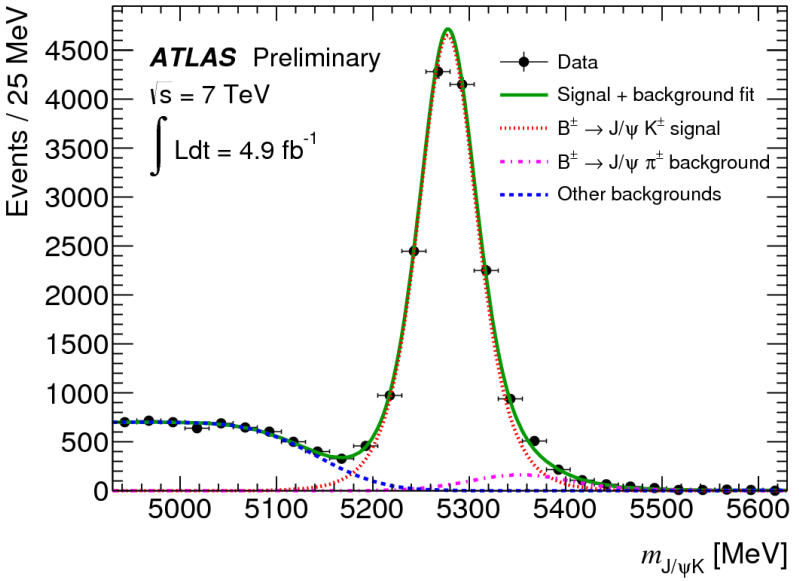
$B_s^0 \to \mu^+\mu^-$: Reference Channel Yield

$N_{J/\psi K^+}$ extraction:

- minimize overall systematics:
  - selection as similar as possible to B_s
  - same B_s-trained BDT
- unbinned max. likelihood fit
  - per-event mass resolution δm
- main systematics estimate:
  - vary continuum background models

- $N_{J/\psi K^+}$ =
  15 214 ± 1.1% (stat) ± 2.4% (syst)



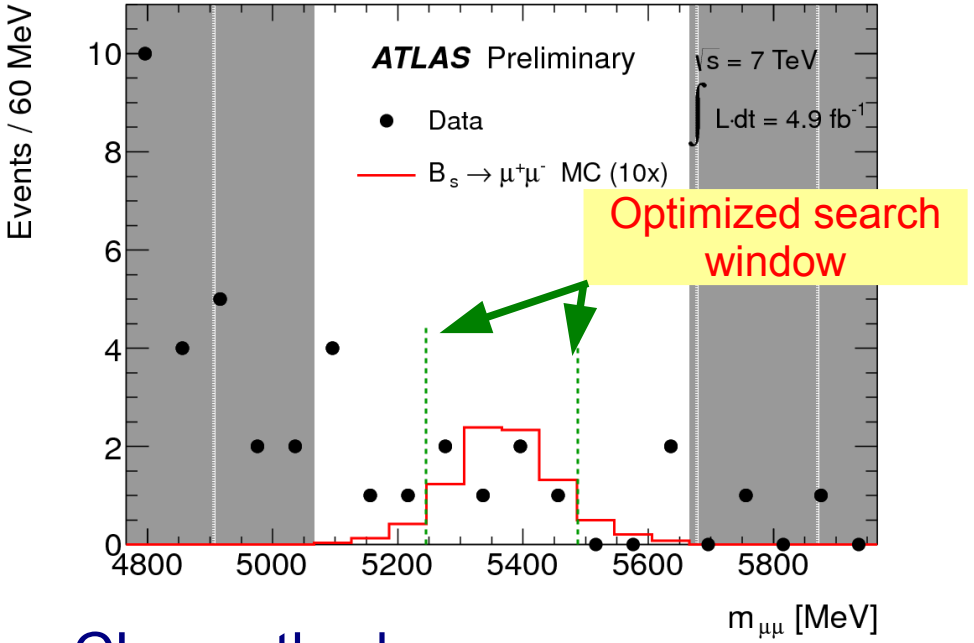


[ATLAS-CONF-2013-076]

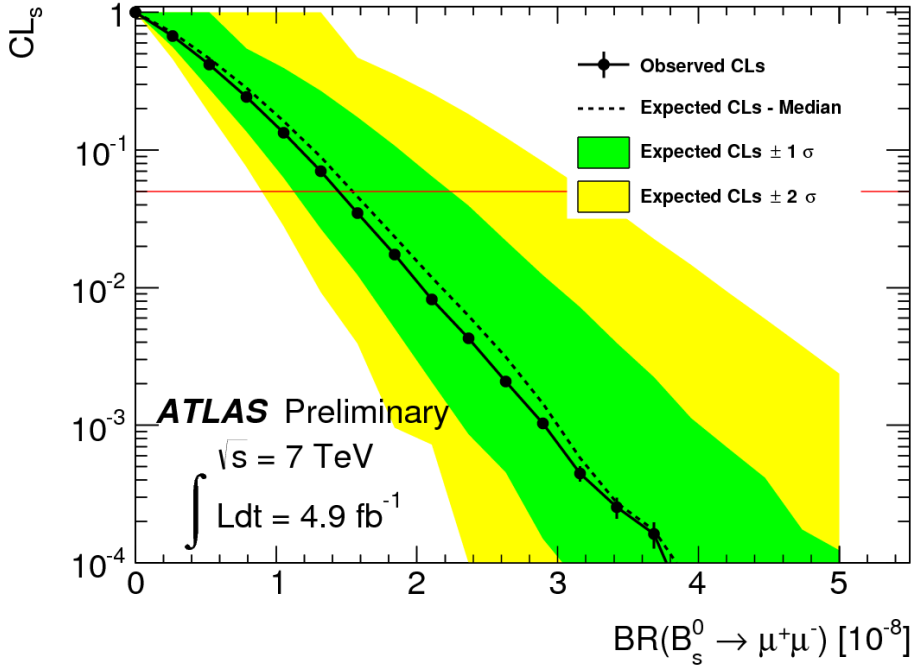
$B_s^0 \to \mu^+\mu^-$: Result on 4.9 fb^{-1} at 7 TeV

- Single-event-sensitivity:

$$SES = \frac{1}{N_{J/\psi K^+}} \cdot \frac{\epsilon_{J/\psi K^+} A_{J/\psi K^+}}{\epsilon_{\mu\mu} A_{\mu\mu}} \cdot \frac{f_u}{f_s} \cdot BR\left(B^+ \to J/\psi K^+ \to \mu^+\mu^- K^+\right) = \left(2.07 +/- 0.26\,(\text{stat})\right) \cdot 10^{-9}$$



- Main systematics (± 12.5%): BR(B^+), f_u/f_s and $\varepsilon \cdot A$ ratio



CLs method:

- N_{bkg} expected in signal window: 6.75 events
  - $BR(B_s^0 \to \mu^+\mu^-) < 1.6 \times 10^{-8}$
- $N_{\mu\mu}$ observed in signal window: 6 events
  - $BR(B_s^0 \to \mu^+\mu^-) < 1.5 \times 10^{-8}$ (@ 95% CL)

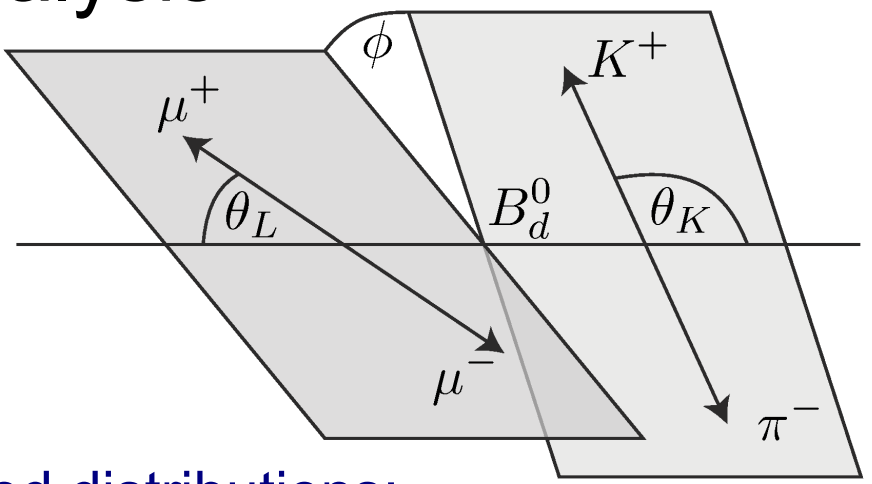
[ATLAS-CONF-2013-076]

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

$B^0 \to K^{*0} \mu^+\mu^-$ Angular Analysis

- 4 kinematic variables:
  - Di-muon mass q^2
  - Three angles: θ_L, θ_K, ϕ

$$\frac{d^4\Gamma}{dq^2\, d\cos\Theta_L\, d\cos\Theta_K\, d\Phi}$$



- Limited by statistics → two integrated distributions:

$$\frac{1}{\Gamma}\frac{d^2\Gamma}{dq^2\, d\cos\Theta_K} = \frac{3}{2}F_L(q^2)\cos^2\Theta_K + \frac{3}{4}\left(1-F_L(q^2)\right)\left(1-\cos^2\Theta_K\right)$$

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

- Extract by unbinned maximum likelihood fit in q^2 bins:
  - $A_{FB}(q^2)$: muon forward-backward asymmetry
  - $F_L(q^2)$: fraction of longitudinally polarized K^{*0} mesons

$B^0 \to K^{*0} \mu^+\mu^-$ Signal Selection

[ATLAS-CONF-2013-038]

Background contributions:

- $B^0 \to K^{*0}$ J/ψ and $B^0 \to K^{*0}$ ψ(2S)
  → veto mass regions in q^2
  & $|(m(B^0)_{rec} - m(B^0)_{PDG})-(m(\mu\mu)_{rec}-m(J/\psi)_{PDG})| < \Delta m$
- $b\bar{b} \to \mu\mu X$, $c\bar{c} \to \mu\mu X$ (small)
  → $\tau/\sigma_\tau > 12.75$
  & $\cos\theta_{pointing} > 0.999$

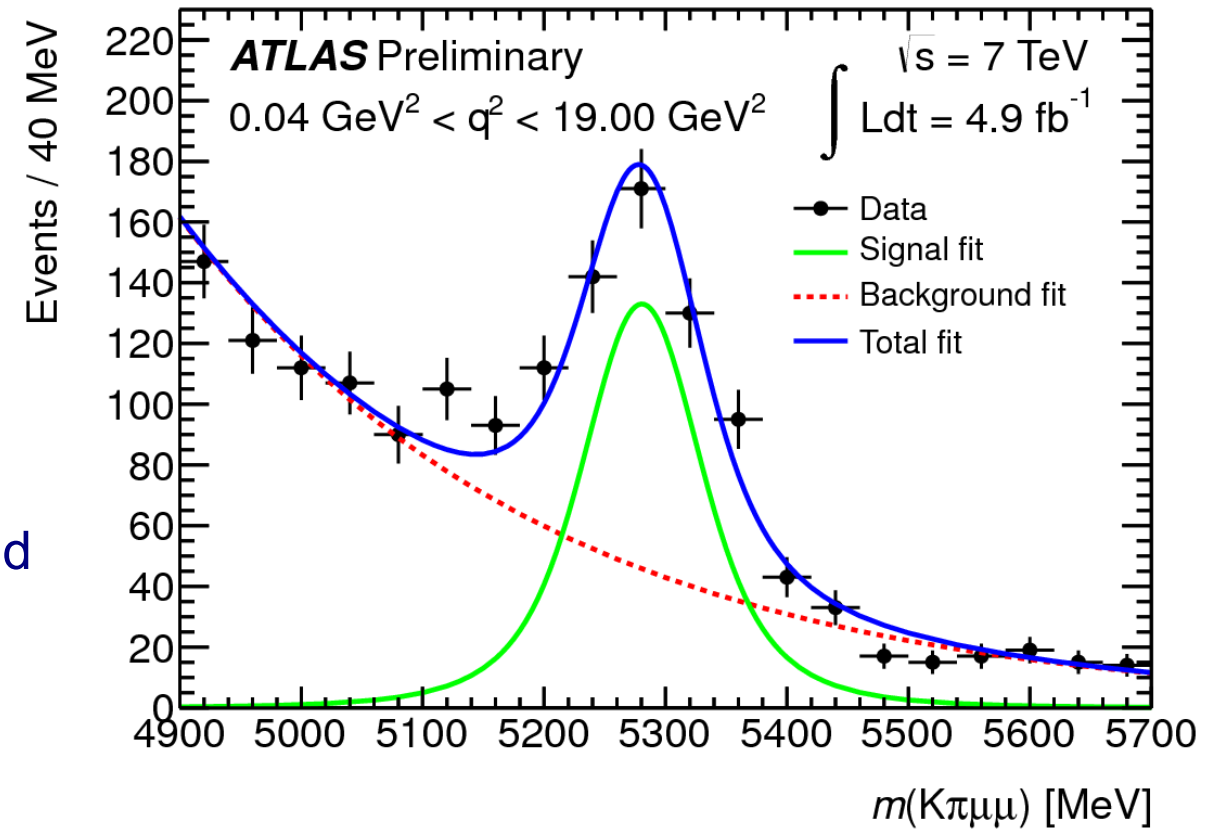
Cut based selection

- optimized on MC

B^0 mass fit

- Gaussian for signal (with per-event errors)
- Exponential for background

  - N_{sig} = 466 ± 34
  - N_{bkg} = 1 132 ± 43

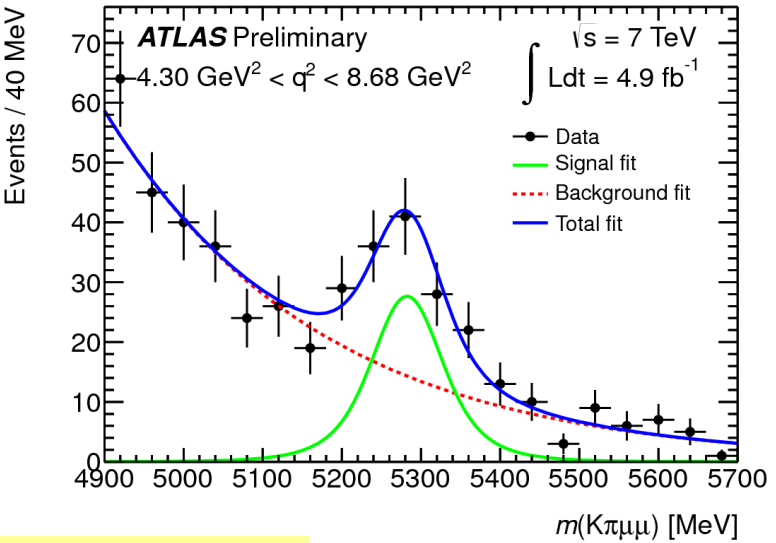


$B^0 \to K^{*0} \mu^+\mu^-$ A_{FB} and F_L Measurements

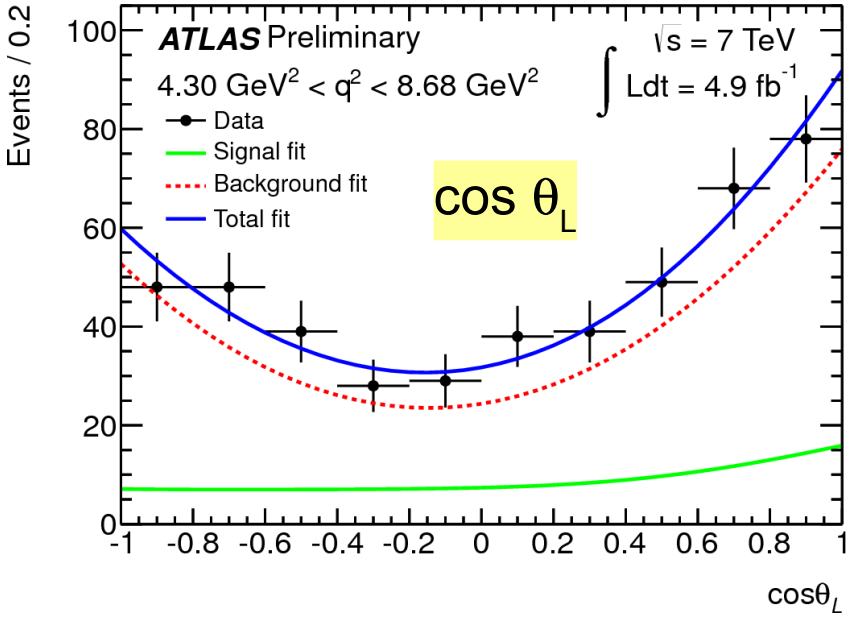
[ATLAS-CONF-2013-038]

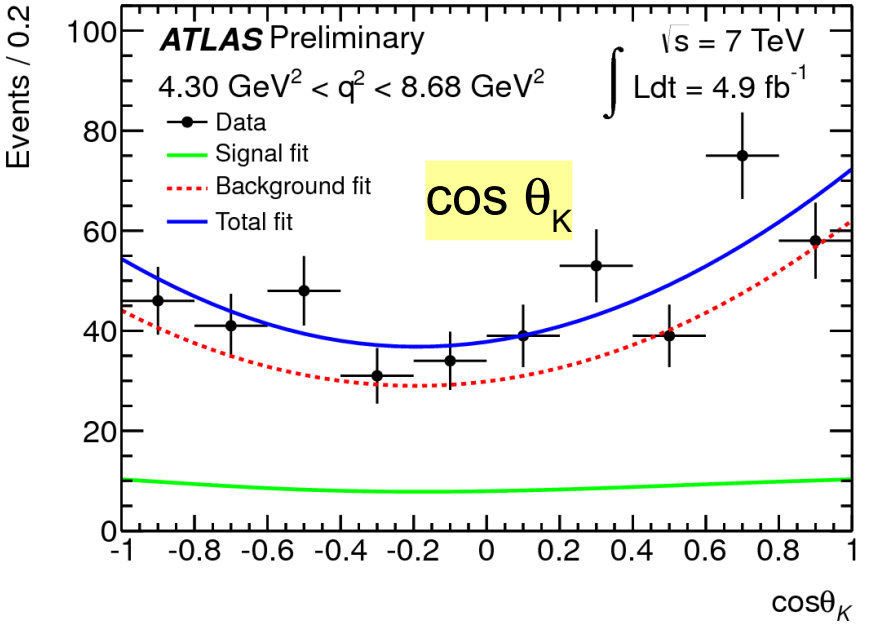
Un-binned max. likelihood fits:

- Sequential fit approach:
  - Fit mass distribution
    → Separate signal and background
  - Fit angular distributions
    → Extract A_{FB} and F_L
    (fixed mass PDF & signal fraction)
- Performed in 5+1 different q^2 regions (like Belle)



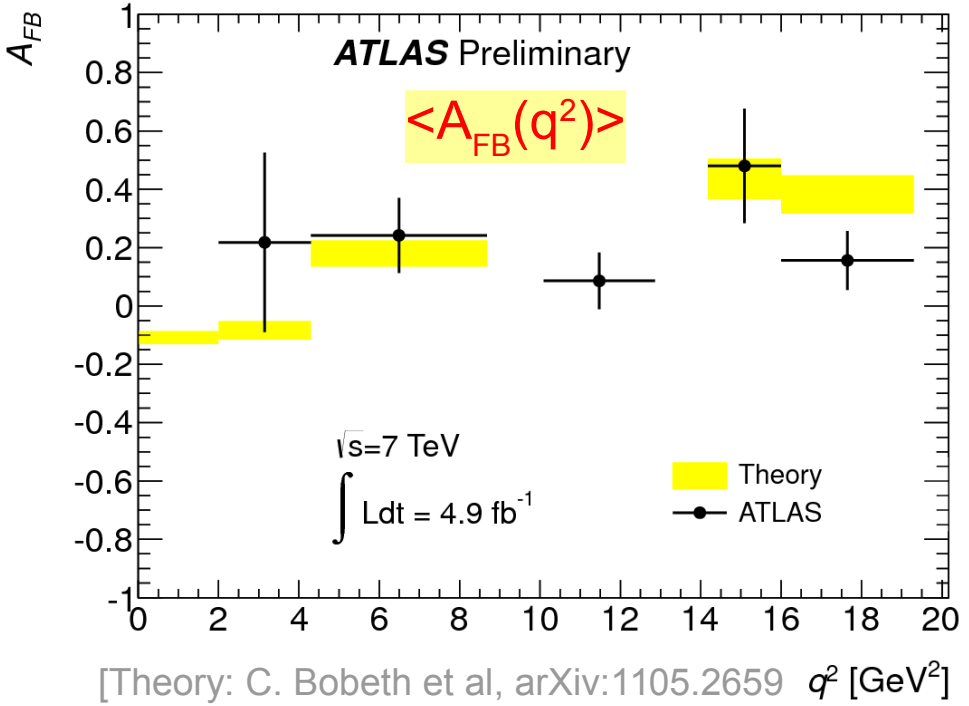
$4.30 < q^2 < 8.68\ \text{GeV}^2$

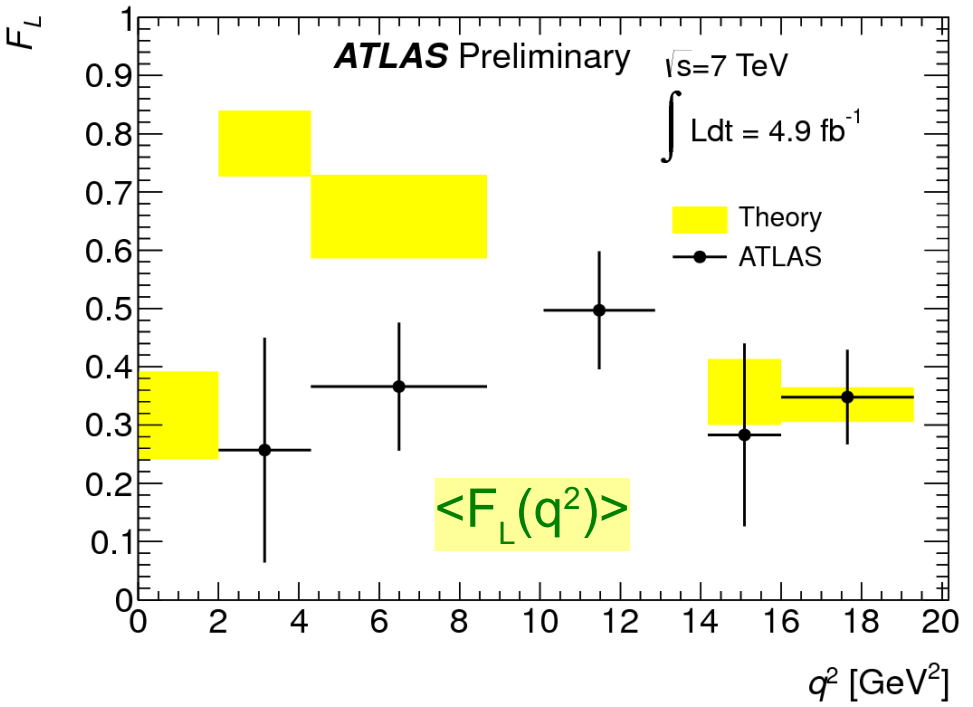




$B^0 \to K^{*0} \mu^+\mu^-$ Results on 4.9 fb^{-1} at 7 TeV

[ATLAS-CONF-2013-038]



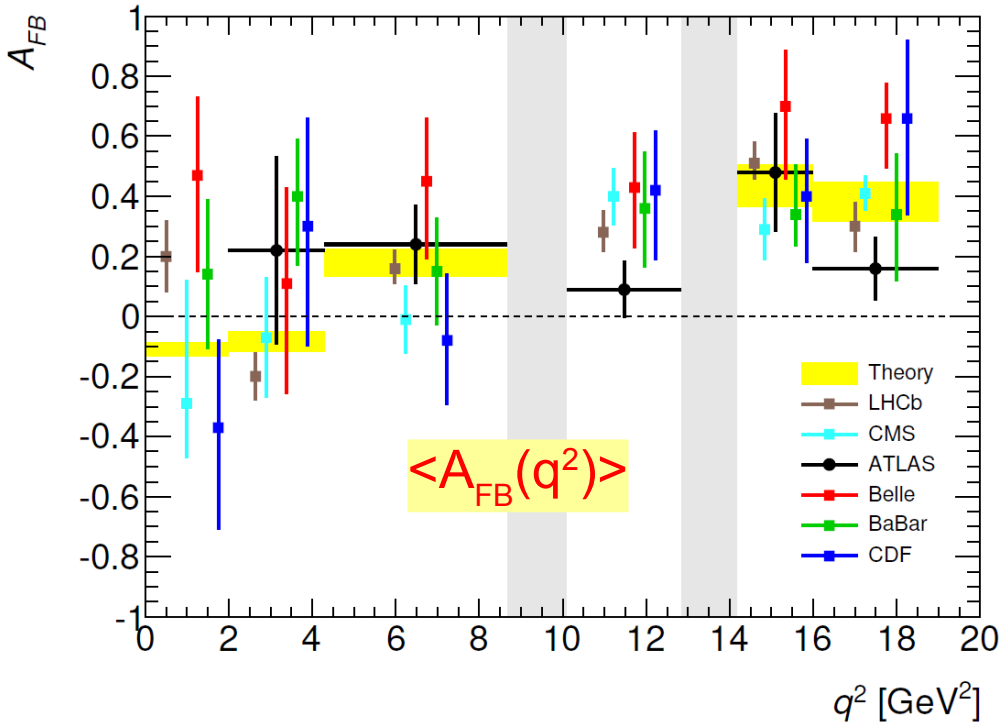


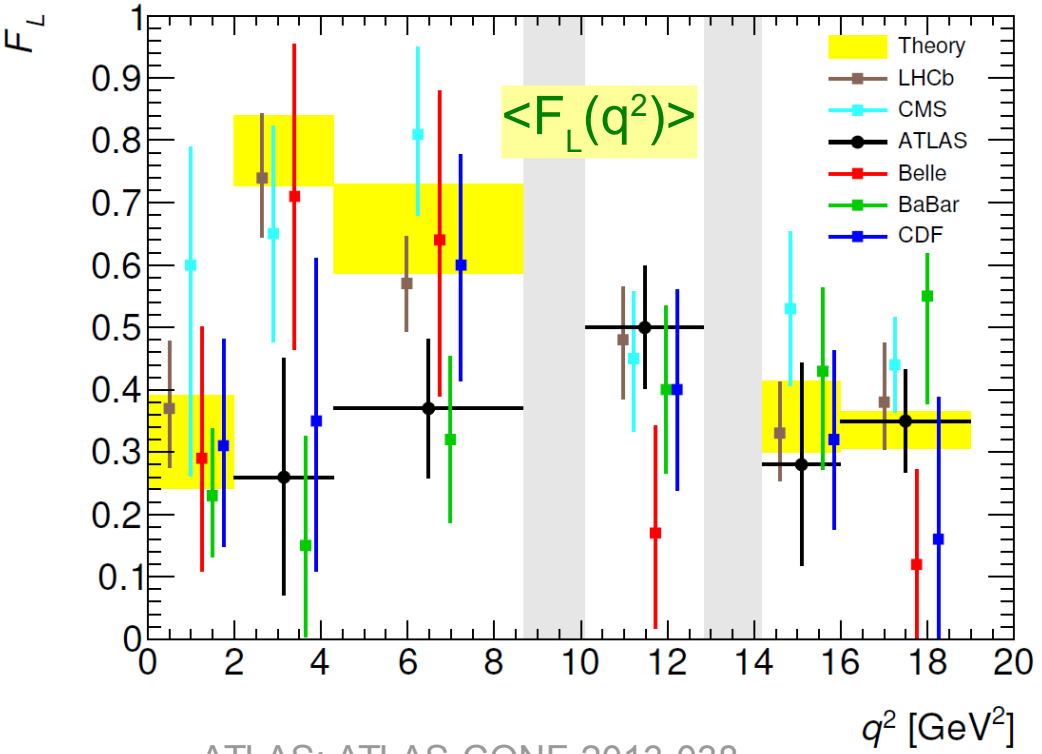
[Theory: C. Bobeth et al, arXiv:1105.2659 and Phys. Rev. D 87 (2013) 034016]

- Measurement consistent with SM predictions
- Uncertainties limited by statistics

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	$0.07 \pm 0.20 \pm 0.07$	$0.18 \pm 0.15 \pm 0.03$

$B^0 \to K^{*0} \mu^+\mu^-$ Comparison of Results





- ATLAS result is competitive in high q^2 region

ATLAS: ATLAS-CONF-2013-038
BaBar: arXiv:1301.1700v1
Belle: arXiv:0904.0770
CDF: arXiv:1108.0695
CMS: Phys. Lett. B, 727 (2013) 77-100
LHCb: JHEP 1308 (2013) 131

Theory: C. Bobeth et al, arXiv:1105.2659 and Phys. Rev. D 87 (2013) 034016

Conclusions

- ATLAS provides high-quality B-physics measurements
  - Rare decay $B^0_s \rightarrow \mu^+\mu^-$
    → ATLAS-CONF-2013-076
  - Angular analysis of $B^0 \rightarrow K^{*0}\,\mu^+\mu^-$
    → ATLAS-CONF-2013-038

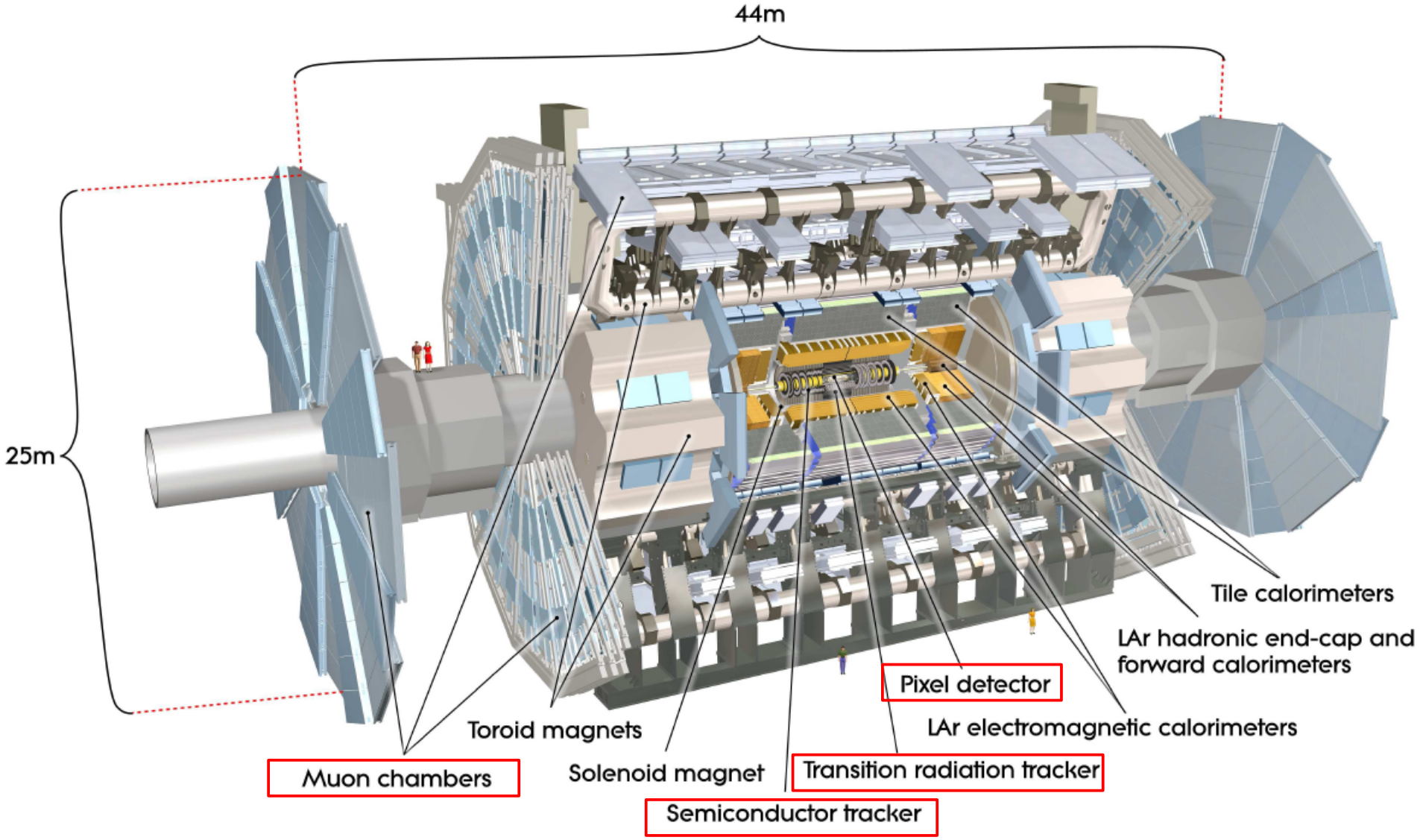
- Results from full 2011 dataset
  → no signs of New Physics or significant deviations from SM

- Measurements statistically limited
  - Ongoing analyses on full ATLAS 2012 dataset (~ 20 fb^{-1})

- Data from LHC Run II may give final answers

Supporting Slides

A Toroidal LHC ApparatuS (ATLAS)



Inner detector and muon chambers most important for analyses presented

Di-μ Triggers for Low p_T Di-μ Events

Full $m_{\mu\mu}$ range:

- Dimu 1.5 – 14.0 GeV

$J/\psi \rightarrow \mu^+\mu^-$:

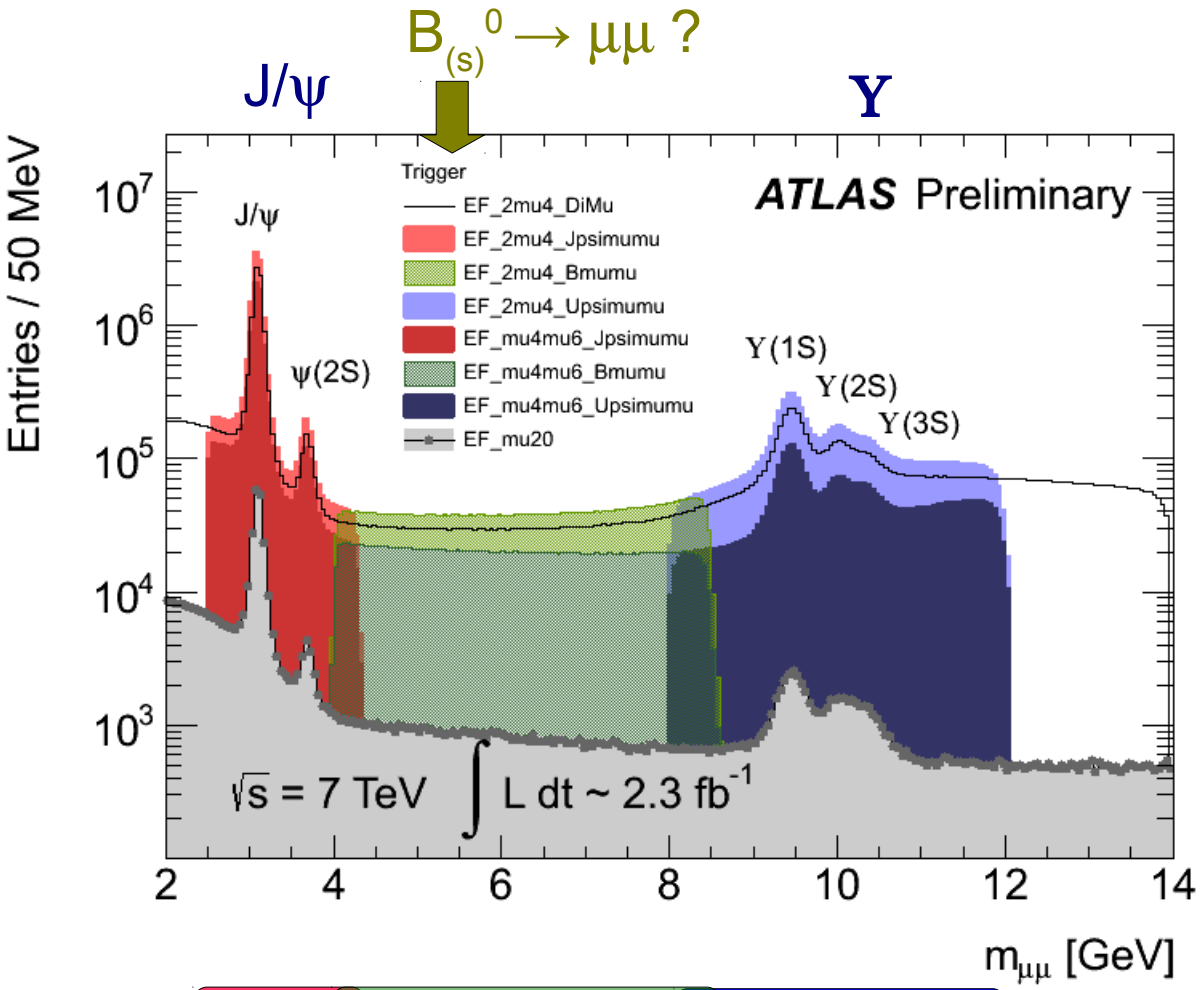
- Jpsimumu 2.5 – 4.3 GeV

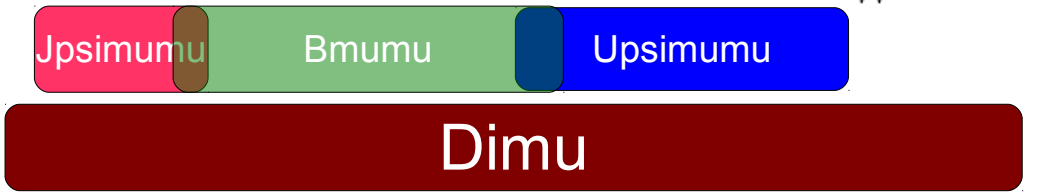
Intermediate $m_{\mu\mu}$ range:

- Bmumu 4.0 – 8.5 GeV

$\Upsilon \rightarrow \mu^+\mu^-$:

- Upsimumu 8.0 – 12.0 GeV





Adjust trigger rates by

- Increasing μ p_T trigger thresholds
- Adding prescale factors
- Lifetime cuts at HLT possible

$B_s^0 \to \mu^+\mu^-$: Preselection Cuts

General

- $p_{T,\mu} > 4$ GeV, $|\eta_\mu| < 2.5$ (both μ "combined")
- $p_{T,K} > 2.5$ GeV, $|\eta_K| < 2.5$ ($B^\pm$)
- Tracks: # pixel hits >0, # SCT hits > 5, # TRT hits > 8
  - μ tracks: good muon track quality requirements

J/ψ specific ($B^\pm$):

- $2.915 < m_{J/\psi} < 3.275$ GeV
- J/ψ vertex χ^2/ndf < 10

$K^\pm$ specific ($B^\pm$):

- $|d_0| < 1.5$ mm
- $|z_0 \sin\theta| < 1.5$ mm

B_s ($B^\pm$) specific:

- B_s ($B^\pm$) vertex χ^2/ndf < 2 (6)
- $p_T > 8$ GeV, $|\eta| < 2.5$
- PV closest in z to B vertex

Trigger selection:

- EF_2mu4(T)_Bmumu (B_s)
  56% efficiency (pres. level)
- EF_2mu4(T)_Jpsimumu ($B^\pm$)
  52% efficiency (pres. level)

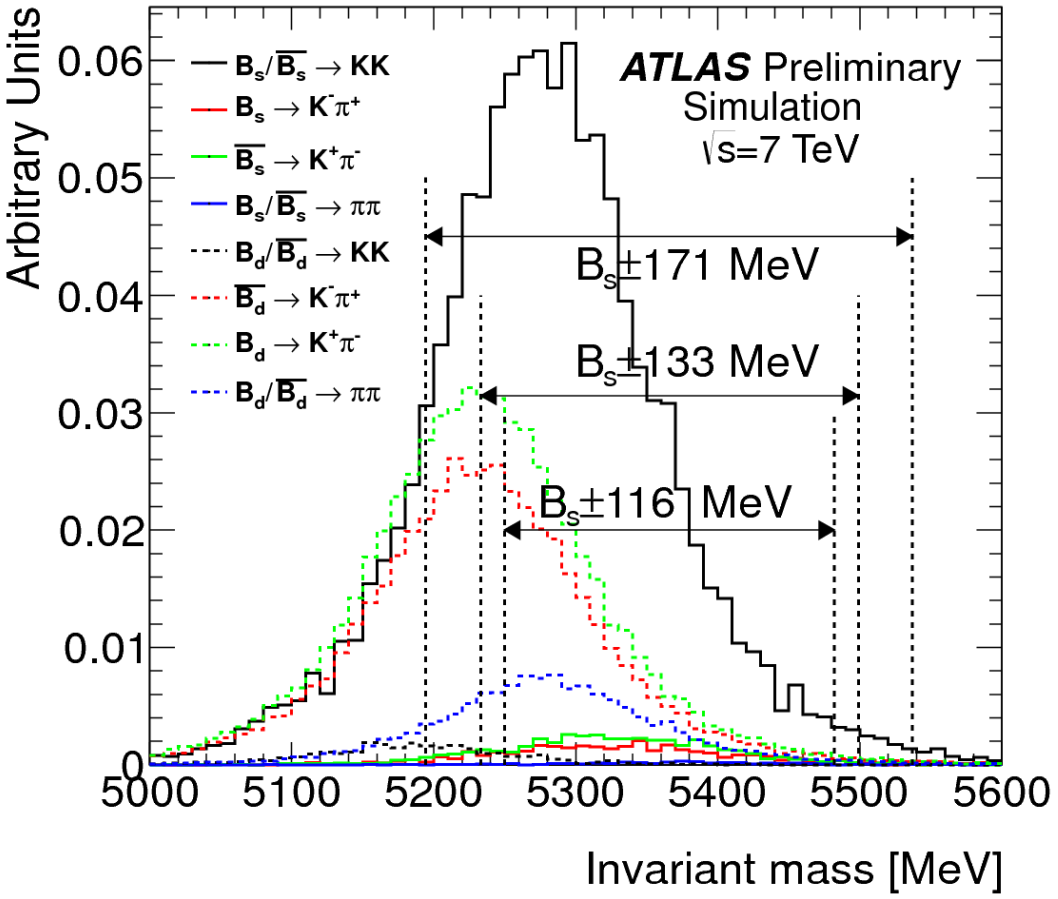
[ATLAS-CONF-2013-076]

$B_s^0 \to \mu^+\mu^-$: Background from "Fake" Muons

$B \to hh'$ (KK, Kπ, $\pi\pi$)

- Close topology
  → "quasi irreducible"
- BR x (fake rate) ~ 10^{-9}
  → close to SM BR($B_s^0 \to \mu^+\mu^-$)
- Estimated on MC
  → contribution almost negligible

$B \to hh'$ reconstructed as $\mu^+\mu^-$



[ATLAS-CONF-2012-010]

$B_s^0 \to \mu^+\mu^-$: Background Discrimination BDT

Variables to separate signal from background:

- 13 discriminating variables in Boosted Decision Tree (BDT):
  - Not correlated with invariant mass
  - Highest discriminating power
  - Excluded variables with high correlation

- Exploiting:
  - PV-SV separation → L_{xy}, proper time significance
  - Symmetry of final state → $|\alpha_{2D}|$, d_0, …
  - Full reconstruction → $|\alpha_{2D}|$, d_0, DCA, ZCA
  - B hadronisation features → $p_T(B)$, Isolation

[ATLAS-CONF-2013-076]

$B_s^0 \to \mu^+\mu^-$: Background Discrimination BDT

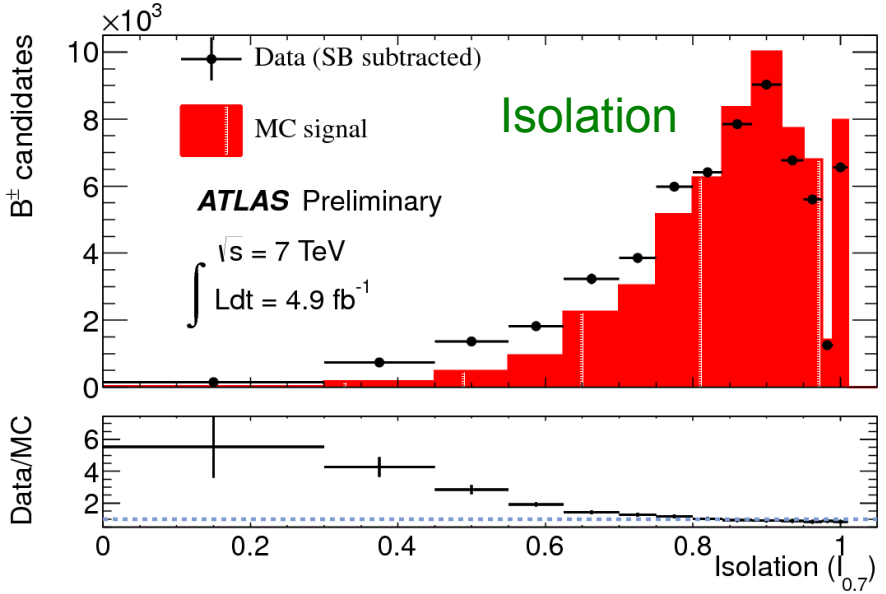
[ATLAS-CONF-2013-076]

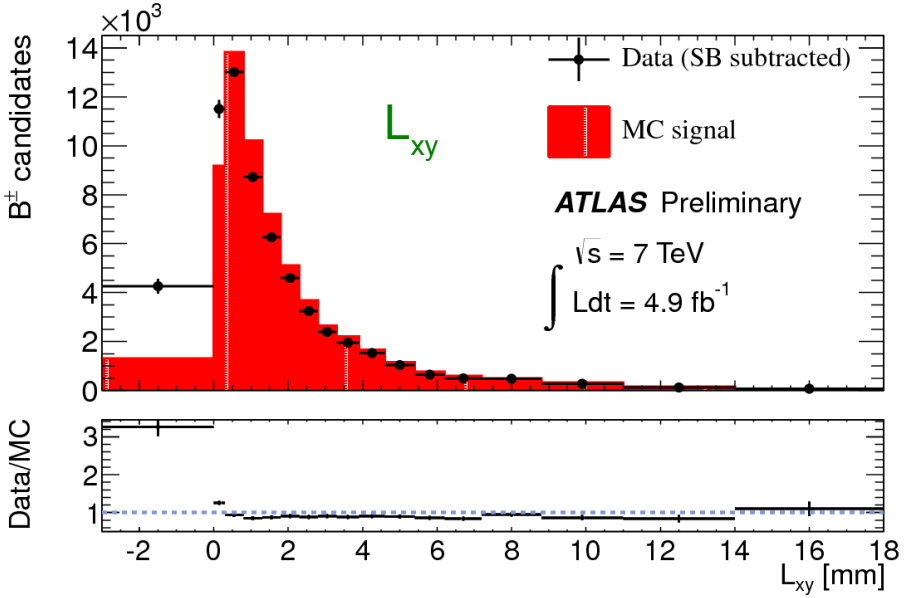
Variable	Description
L_{xy}	Scalar product in the transverse plane of $(\Delta\vec{x} \cdot \vec{p}^B)/\lvert\vec{p}_T^B\rvert$
$I_{0.7}$ isolation	Ratio of $\lvert\vec{p}_T^B\rvert$ to the sum of $\lvert\vec{p}_T^B\rvert$ and the transverse momenta of all tracks with $p_T > 0.5$ GeV within a cone $\Delta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

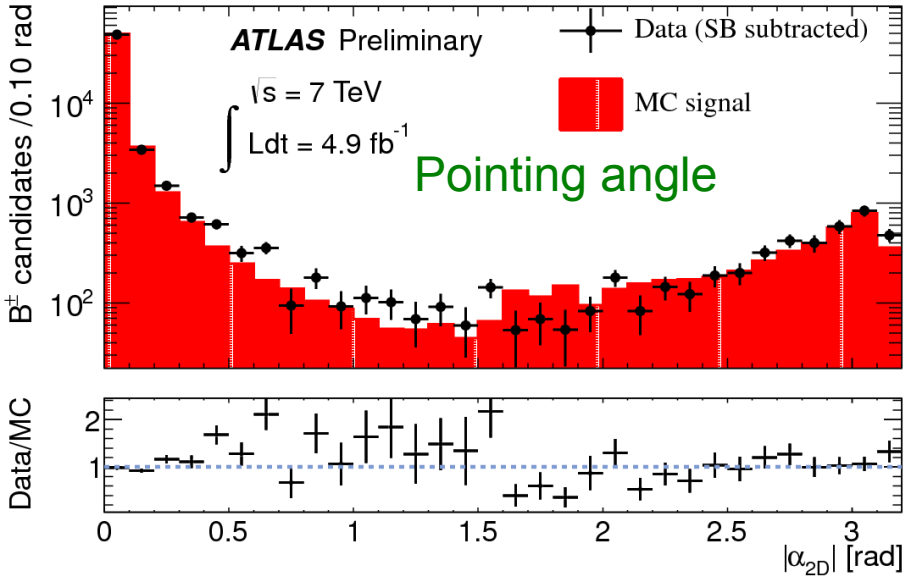
$B_s^0 \to \mu^+\mu^-$: Data-MC Comparison

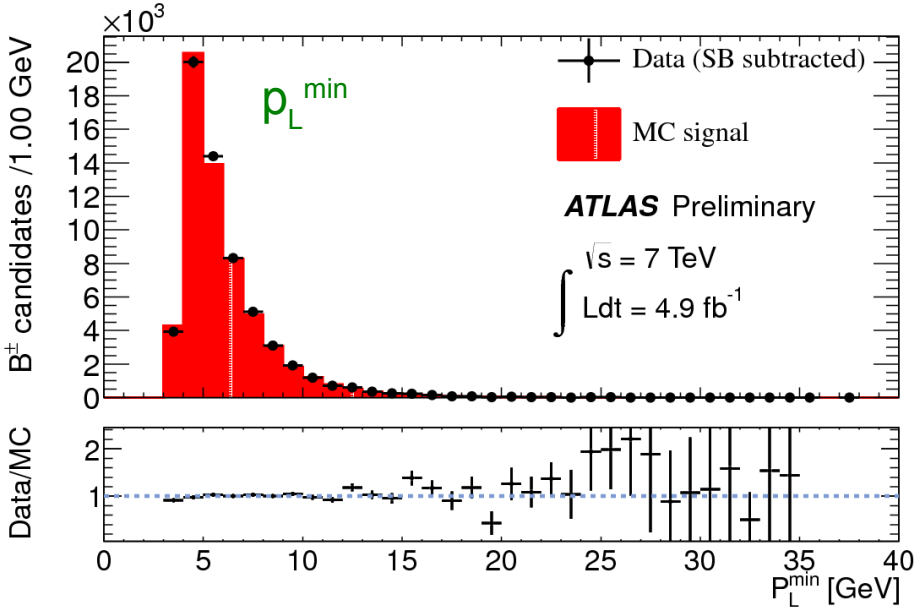
[ATLAS-CONF-2013-076]

- $B^+ \to J/\psi\, K^+$ MC (reweighted) vs sideband-subtracted data









$B_s^0 \to \mu^+\mu^-$: Isolation Variable

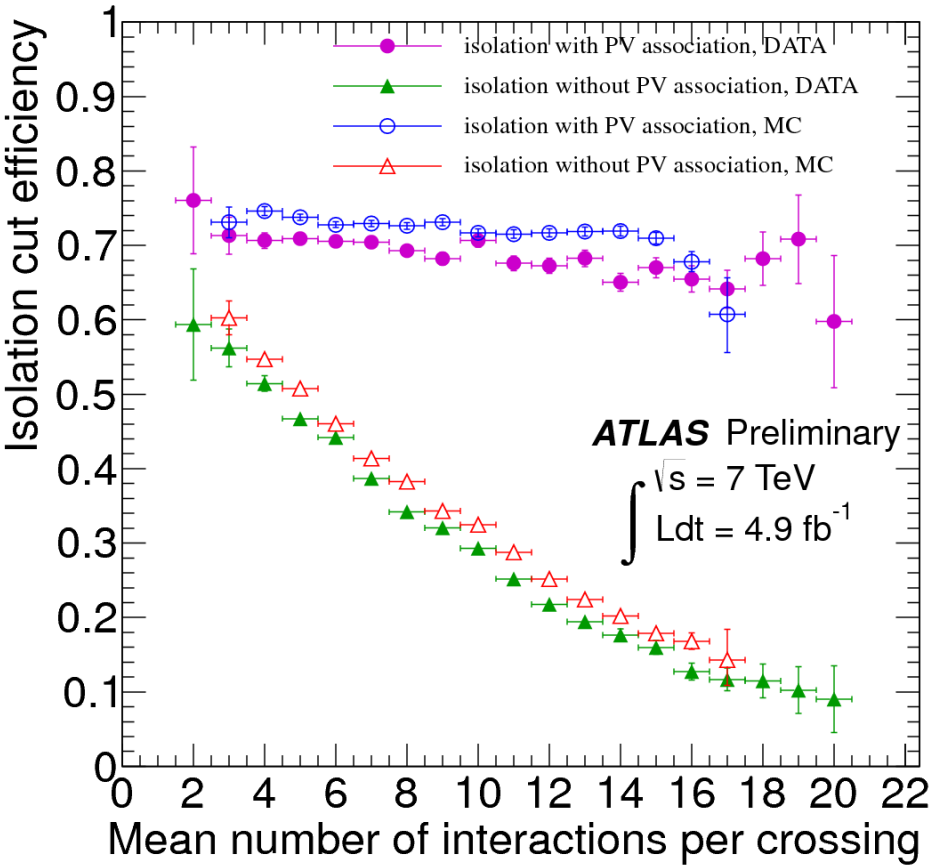
- Isolation variable:

$$I_{\Delta R} = \frac{p_T^B}{p_T^B + \sum_{i_{track} \in cone(\Delta R)} p_T^{i_{track}}}$$

  - Tracks with $p_T > 0.5$ GeV excluding B daughters in $\Delta R < 0.7$ with

$$\Delta R = \sqrt{\Delta\eta^2 + \Delta\varphi^2}$$

- PV association of tracks:
  - Removes interference from other interactions
  - Isolation cut efficiency is independent of pile-up



[ATLAS-CONF-2013-076]

$B_s^0 \to \mu^+\mu^-$: ε x A Ratio

- Efficiency x acceptance ratio:

$$\frac{\epsilon_{J/\psi K^+} A_{J/\psi K^+}}{\epsilon_{\mu\mu} A_{\mu\mu}}$$

  - Determined on reweighted B_s and B^+ MC samples (w.r.t. fiducial volume)

- Systematic uncertainties:
  - Data-MC discrepancies of separation variables
    → mainly Isolation and L_{xy}

Channel	$A \times \epsilon$	$R_{A\epsilon}$
B^+	$1.317 \pm 0.008\%\,(\text{stat})$	$0.267 \pm 1.8\%\,(\text{stat}) \pm 6.9\%\,(\text{syst})$
B_s^0	$4.929 \pm 0.084\%\,(\text{stat})$	

[ATLAS-CONF-2013-076]

$B_s^0 \to \mu^+\mu^-$: Limit Extraction

CLs method with profile likelihood ratio

- Likelihood for CLs:

signal region

sidebands

$$\mathscr{L} = G(\varepsilon_{obs}|\varepsilon,\sigma_\varepsilon)\, G(R^{bkg}_{obs}|R^{bkg},\sigma_{R^{bkg}})\, P(N^{sig}_{obs}|\varepsilon\, BR + N^{bkg} + N^{B\to hh})\, P(N^{bkg}_{obs}|R^{bkg}\, N^{bkg})$$

1/ses constraint

$R=\Delta_{sb}/\Delta_{sr}$ constraint

with $\varepsilon = ses^{-1}$

quantity	value
$N_{J/\psi K^\pm}$	$15\,214 \pm 1.10\% \pm 2.39\%$
$R_{A\epsilon}$	$0.267 \pm 1.8\% \pm 6.9\%$
SES	$(2.07 \pm 0.26) \cdot 10^{-9}$
R^{obs}_{bkg}	1.240 ± 0.050
N^{exp}_{SR} | N^{obs}_{SR}	6.75 | 6
$N^{obs}_{bkg,SB}$	8
$N_{B\to hh}$	0.30

[ATLAS-CONF-2013-076]

$B_s^0 \to \mu^+\mu^-$: SES Systematics

- Summary of ΔSES/SES
  - syst. uncertainties shown
  - stat. uncertainty of 2.1%

description	contribution
PDG branching fractions and f_s/f_d	8.5%
$K^\pm$ tracking efficiency	5%
vertexing efficiency	2%
$K^\pm$ charge asymmetry. in $B^\pm \to J/\psi K^\pm$	1%
$B^\pm \to J/\psi K^\pm$ yield	2.4%
$R_{A\epsilon}$	6.9%
total (comb. in quadrature)	12.5%

$BF(B^\pm \to J/\psi\, K^\pm) = (1.016 \pm 0.033)\cdot 10^{-3}$

$BF(J/\psi \to \mu^+\mu^-) = (5.93 \pm 0.06)\%$

[PDG 2012]

$f_s/f_d = 0.256 \pm 0.020$

[LHCb, JHEP 1304 (2013) 001]

using $f_d/f_u = 1$

- Background contributions:
  - Interpolation from sidebands → 4% on R_{bkg}
  - B → hh' negligible

[ATLAS-CONF-2013-076]

$B^0 \to K^{*0} \mu^+\mu^-$ q^2 Bins

Separation into 9 regions of di-μ squared mass q^2:

- $0.04 < q^2 < 2.00$ GeV^2 : Too little statistics due to trigger thresholds
- $2.00 < q^2 < 4.30$ GeV^2
- $4.30 < q^2 < 8.68$ GeV^2
- $8.68 < q^2 < 10.09$ GeV^2 : J/ψ veto
- $10.09 < q^2 < 12.86$ GeV^2
- $12.86 < q^2 < 14.18$ GeV^2 : ψ'(2S) veto
- $14.18 < q^2 < 16.00$ GeV^2
- $16.00 < q^2 < 19.00$ GeV^2

- $1.00 < q^2 < 6.00$ GeV^2

[binning identical to Belle's]

$B^0 \to K^{*0} \mu^+\mu^-$ Selection Cuts

[ATLAS-CONF-2013-038]

- Baseline cuts:
  - $p_T(\mu) > 3.5$ GeV
  - $|\eta| < 2.5$ for all tracks
  - $\chi^2/\text{n.d.f.}(\mu\mu) < 10$
  - $846 < M(K^{*0}) < 946$ MeV
  - $p_T(K) > 0.5$ GeV
  - $p_T(\pi) > 0.5$ GeV

- J/ψ, $\psi'(2S)$ regions are excluded

- Selection (cut values optimized):
  - $\tau/\Delta\tau(B^0) > 12.75$
  - $\cos(\theta) > 0.999$ – pointing angle
  - $\chi^2/\text{n.d.f.} < 2.0$
  - $p_T(K^{*0}) > 3$ GeV
  - $|(m(B^0)_{rec} - m(B^0)_{PDG}) - (m(\mu^+\mu^-)_{rec} - m(J/\psi)_{PDG})| > 130$ MeV

$B^0 \to K^{*0} \mu^+\mu^-$ Fit Strategy (1)

Extended unbinned maximum likelihood fit in each q^2 bin

- Sequential: first fit m(Kπμμ), then angular distributions
- Checked to give same results as single-step fit (except lowest q^2 bin → systematics)

Mass fit:

$$\mathcal{L} = \prod_{i=1}^{N} \left[N_{\text{sig}} \cdot \mathcal{M}_{\text{sig}}(m_i, \delta_{m_i}) + N_{\text{bckg}} \cdot \mathcal{M}_{\text{bckg}}(m_i) \right]$$

- Signal mass PDF: (Gaussian with per-candidate errors)

$$\mathcal{M}_{\text{sig}}(m_i, \delta_{m_i}) = \frac{1}{\sqrt{2\pi} s_m \delta_{m_i}} \exp\left(\frac{-(m_i - m_{B_d^0})^2}{2(s_m \delta_{m_i})^2} \right)$$

- Background mass PDF: (exponential)

$$\mathcal{M}_{\text{bckg}}(m_i) = e^{-\lambda \cdot m_i}$$

$B^0 \to K^{*0} \mu^+\mu^-$ Fit Strategy (2)

Angular fit (per q^2 bin):

$$\mathcal{L} = \prod_{i=1}^{N} [N_{\rm sig}^{\rm fix} \cdot \mathcal{M}_{\rm sig}(m_i, \delta_{m_i}|{\rm fixed}) \cdot \mathcal{A}_{L,{\rm sig}}(\cos\theta_{L,i}) \cdot \alpha_L(\cos\theta_{L,i}) \cdot$$
$$\mathcal{A}_{K,{\rm sig}}(\cos\theta_{K,i}) \cdot \alpha_K(\cos\theta_{K,i}) +$$
$$N_{\rm bckg}^{\rm fix} \cdot \mathcal{M}_{\rm bckg}(m_i|{\rm fixed}) \cdot \mathcal{A}_{L,{\rm bckg}}(\cos\theta_{L,i}) \cdot \mathcal{A}_{K,{\rm bckg}}(\cos\theta_{K,i})]$$

- Signal PDFs:

$$\mathcal{A}_{L,{\rm sig}}(\cos\theta_{L,i}) = \frac{3}{4} F_L(q^2) \left(1 - \cos^2\theta_{L,i}\right) +$$
$$\frac{3}{8} \left(1 - F_L(q^2)\right) \left(1 + \cos^2\theta_{L,i}\right) + A_{FB}(q^2) \cos\theta_{L,i}$$

$$\mathcal{A}_{K,{\rm sig}}(\cos\theta_{K,i}) = \frac{3}{2} F_L(q^2) \cos^2\theta_{K,i} + \frac{3}{4} \left(1 - F_L(q^2)\right) \left(1 - \cos^2\theta_{K,i}\right)$$

- Background PDF (Chebychef polynomials up to 2nd order):

$$\mathcal{A}_{L(K),{\rm bkg}} = 1 + p_{1L(K)} \cos\theta_{L(K),i} + p_{2L(K)} \left(2\cos^2\theta_{L(K),i} - 1\right)$$

- $\alpha_L(\cos\theta_{L,i})$, $\alpha_K(\cos\theta_{K,i})$ – acceptance functions (detector and selection effects)

$B^0 \to K^{*0} \mu^+\mu^-$ Systematic Uncertainties

[ATLAS-CONF-2013-038]

- Mass fit region
- Angular background shape
- Contribution of $B^\pm \to K^\pm \mu^+\mu^-$ events
- Acceptance effects
- Fit mode (sequential fit approach)

- Studied, but negligible sources:
  - S-wave contribution
  - $B_s^0 \to \phi\ \mu^+\mu^-$ contribution
  - Bias due to fit model (linearity, 1D-2D)

A_{FB}

q^2 range (GeV^2)	fit region	ang. fit	$B^\pm \to K^\pm\mu^+\mu^-$	acc. maps	fit	SUM
$2.00 < q^2 < 4.30$	0.02	0.01	0.08	0.01	0.10	0.136
$4.30 < q^2 < 8.68$	0.00	0.01	0.01	0.01		0.013
$10.09 < q^2 < 12.86$	0.03	0.01	0.02	0.00		0.031
$14.18 < q^2 < 16.00$	0.03	0.01	0.03	0.02		0.050
$16.00 < q^2 < 19.00$	0.02	0.01	0.02	0.01		0.026
$1.00 < q^2 < 6.00$	0.05	0.01	0.02	0.04		0.069

F_L

q^2 range (GeV^2)	fit region	ang. fit	$B^\pm \to K^\pm\mu^+\mu^-$	acc. maps	fit	SUM
$2.00 < q^2 < 4.30$	0.01	0.01	0.02	0.01	0.05	0.058
$4.30 < q^2 < 8.68$	0.01	0.01	0.00	0.02		0.021
$10.09 < q^2 < 12.86$	0.04	0.01	0.00	0.02		0.042
$14.18 < q^2 < 16.00$	0.01	0.01	0.02	0.01		0.025
$16.00 < q^2 < 19.00$	0.02	0.01	0.01	0.00		0.023
$1.00 < q^2 < 6.00$	0.02	0.01	0.00	0.03		0.034