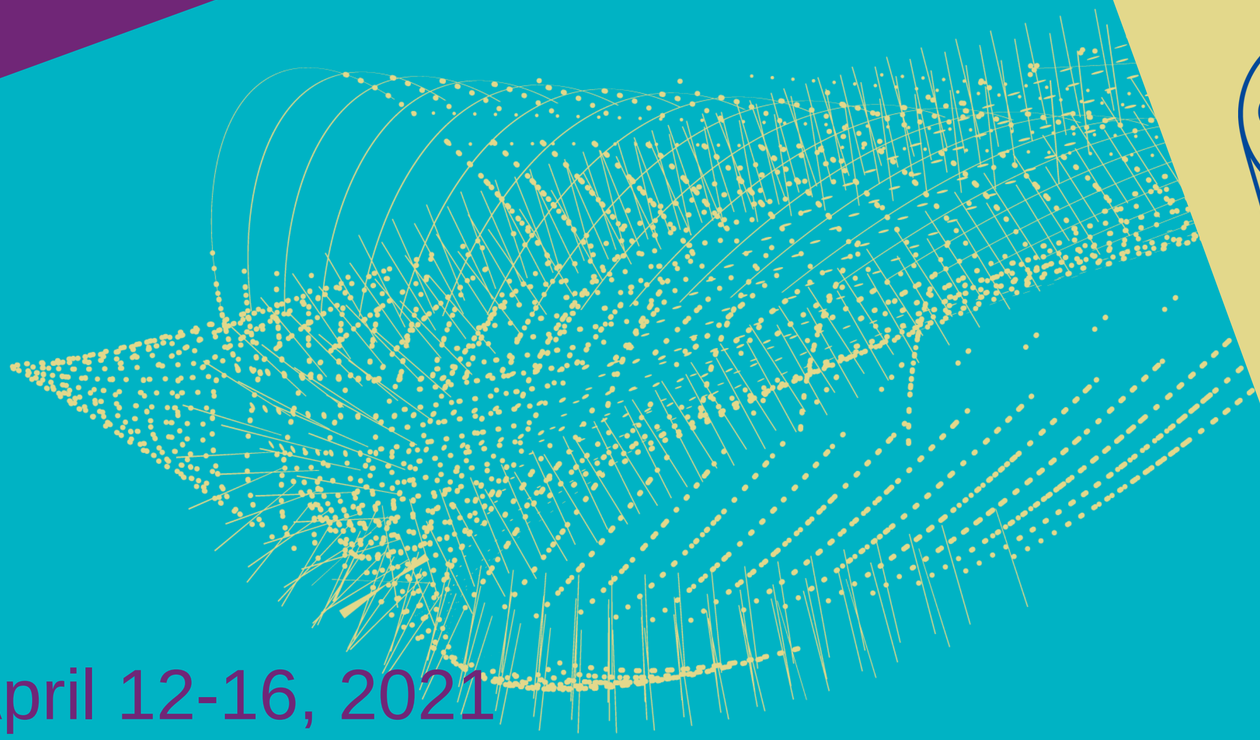


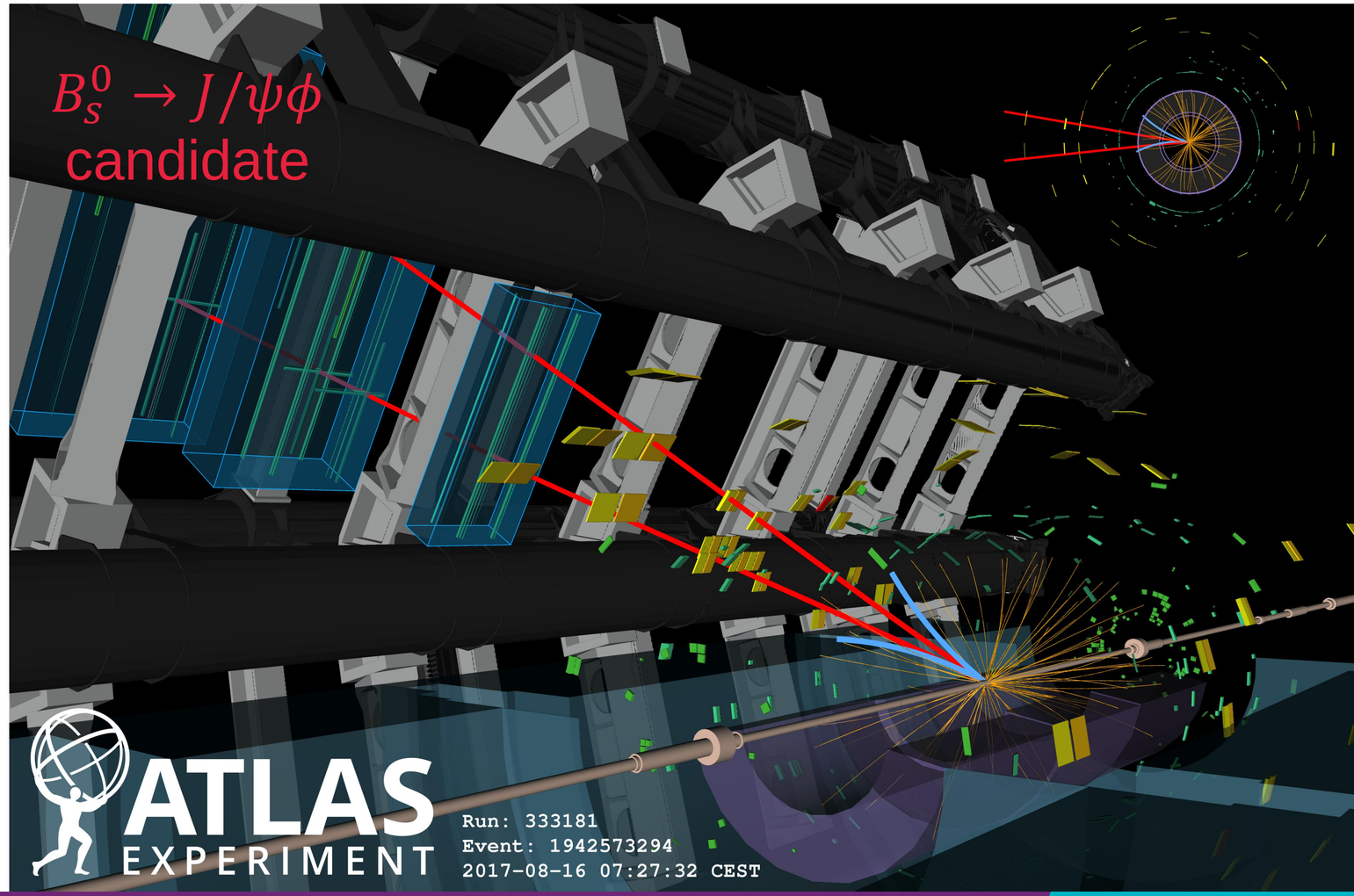
DIS2021, Stony Brook Univ., April 12-16, 2021

ATLAS RESULTS WITH BEAUTY MESONS

Ann-Kathrin Perrevoort
on behalf of ATLAS
(ann-kathrin.perrevoort@cern.ch)

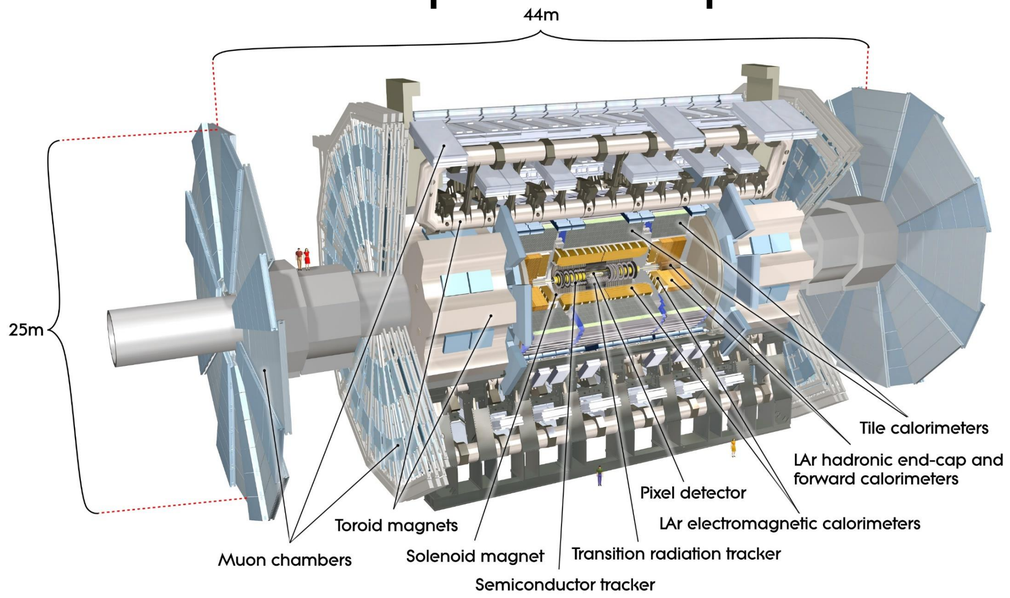
ATLAS RESULTS WITH BEAUTY MESONS

- B physics in ATLAS
- $B_c^{\pm}$ production and decays
- Relative $B_c^{\pm}/B^{\pm}$ production xsec
- Rare decays $B_{(s)}^0 \to \mu\mu$
- ATLAS early Run 2 results
- ATLAS, CMS, LHCb combination
- CP violation in $B_s^0 \to J/\psi\phi$
- CPV phase ϕ_s between $B_s^0 - \bar{B}_s^0$ mixing and decay

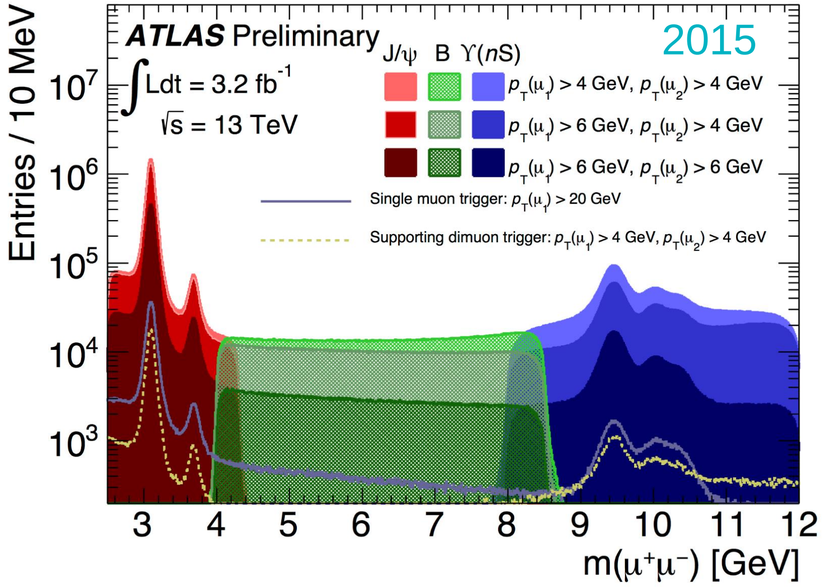


B -PHYSICS PROGRAM IN THE ATLAS EXPERIMENT

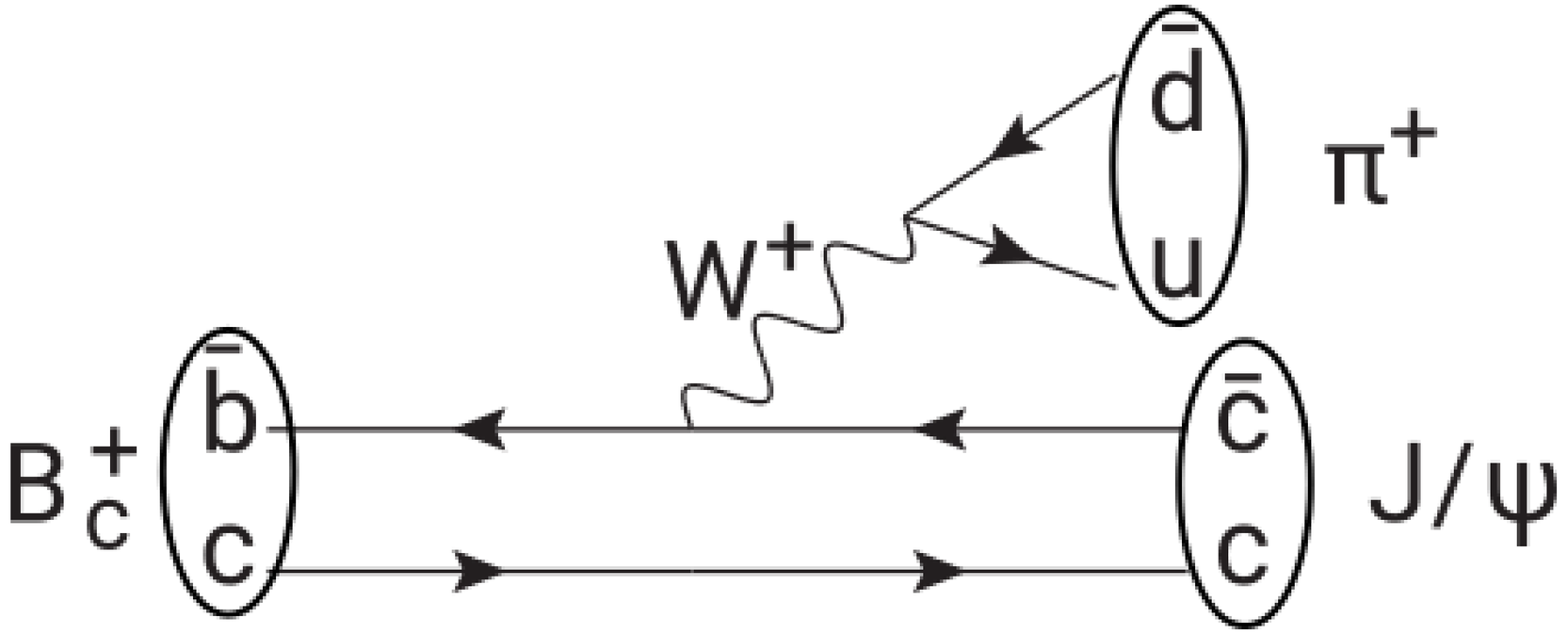
- ATLAS collected 139fb^{-1} of pp collisions at $\sqrt{s} = 13\text{TeV}$ in 2015-2018
- B_s, B_c etc. accessible at the LHC
- ~2.5 million $b\bar{b}$ pairs/sec produced



- Typical B physics trigger: low p_T, very low mass di-muon trigger using inner tracker and muon detectors
- ~150-200 events with $b\bar{b}$ pairs/sec recorded

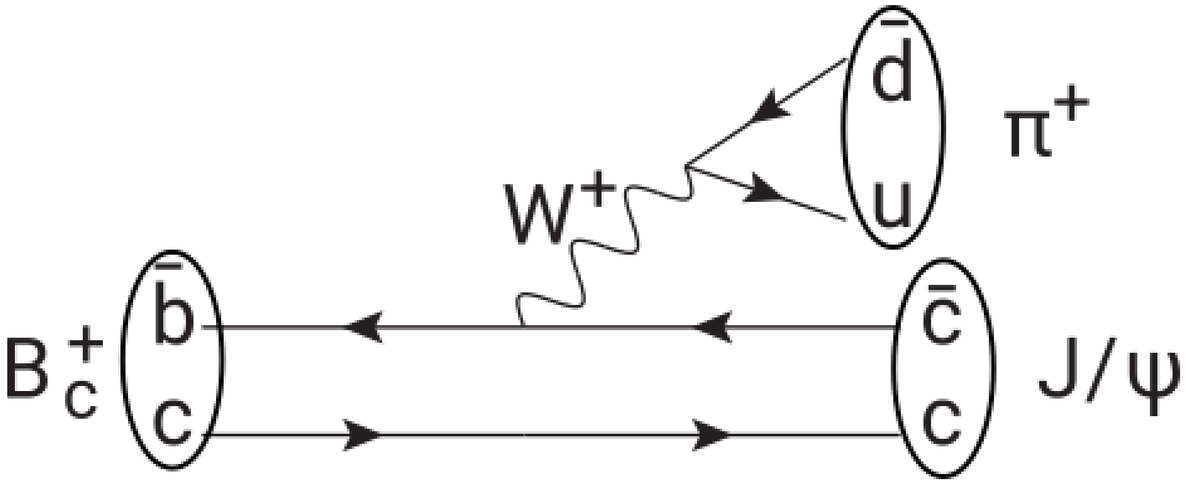


Relative $B_c^{\pm}/B^{\pm}$ production xsec



RELATIVE $B_c^{\pm}/B^{\pm}$ PRODUCTION XSEC

- B_c^+ is a ‘double-heavy’ meson
  $(c\bar{b})$
- Production gives insight on heavy-quark hadronisation
- Weak decays, here
  $B_c^{\pm} \to J/\psi\pi^{\pm}$ with $J/\psi \to \mu^+\mu^-$
- $B_c^{\pm} \to J/\psi D_s^{(*)+}$ also measured in ATLAS

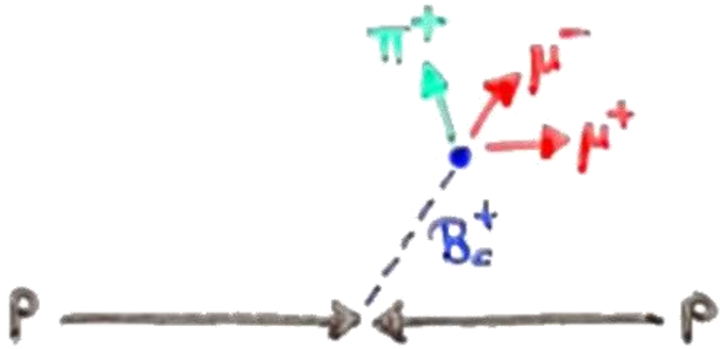


arXiv:1912.02672, sub. PRD

RELATIVE $B_c^{\pm}/B^{\pm}$ PRODUCTION XSEC

- Double differential measurement of relative production xsec $\times \mathcal{B}$ of $B_{(c)}^{\pm}$ in 2 bins of $p_{\mathrm{T}}\left(B_{(c)}^{\pm}\right)$ and $\left|y\left(B_{(c)}^{\pm}\right)\right|$
- Using similar decay modes

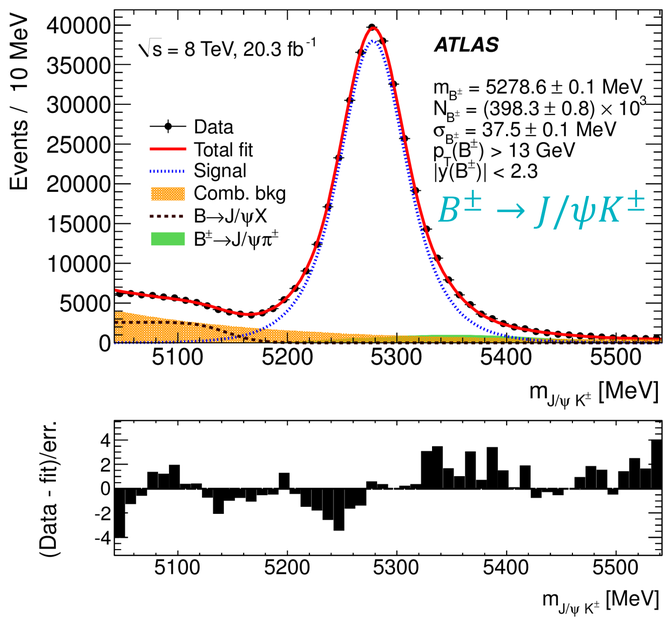
$$\frac{\sigma(B_c^{\pm}) \cdot \mathcal{B}(B_c^{\pm} \to J/\psi(\mu^+\mu^-)\pi^{\pm})}{\sigma(B^{\pm}) \cdot \mathcal{B}(B^{\pm} \to J/\psi(\mu^+\mu^-)K^{\pm})} = \frac{N^{\mathrm{reco}}(B_c^{\pm})}{N^{\mathrm{reco}}(B^{\pm})} \cdot \frac{\varepsilon(B^{\pm})}{\varepsilon(B_c^{\pm})}$$

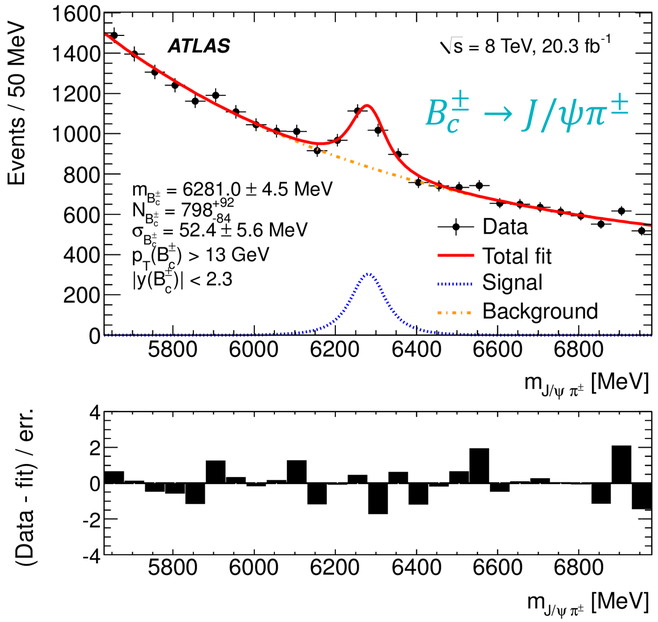


- ATLAS measurement of using $20.3\ \mathrm{fb}^{-1}$ of pp collision data at $\sqrt{s} = 8\mathrm{TeV}$ (2012)
- Di-muon trigger for $J/\psi \to \mu^+\mu^-$

arXiv:1912.02672, sub. PRD

RELATIVE $B_c^{\pm}/B^{\pm}$ PRODUCTION XSEC





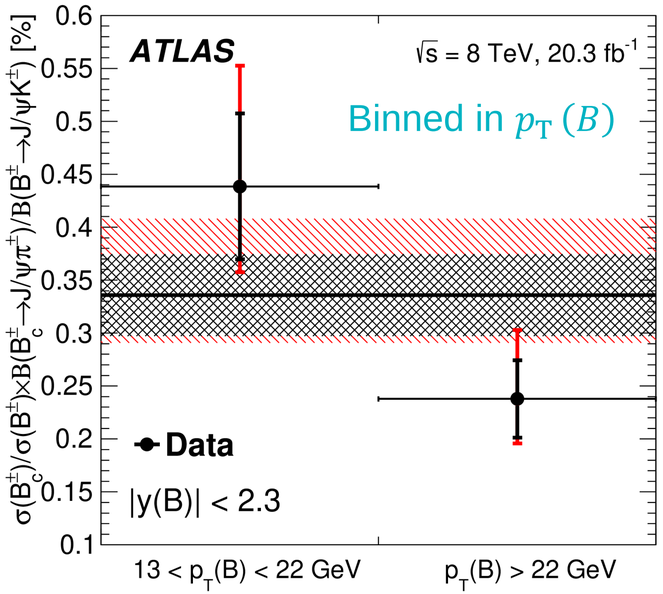
Complete dataset
$(p_{\mathrm{T}}(B) > 13\ \mathrm{GeV},\ |y(B)| < 2.3)$

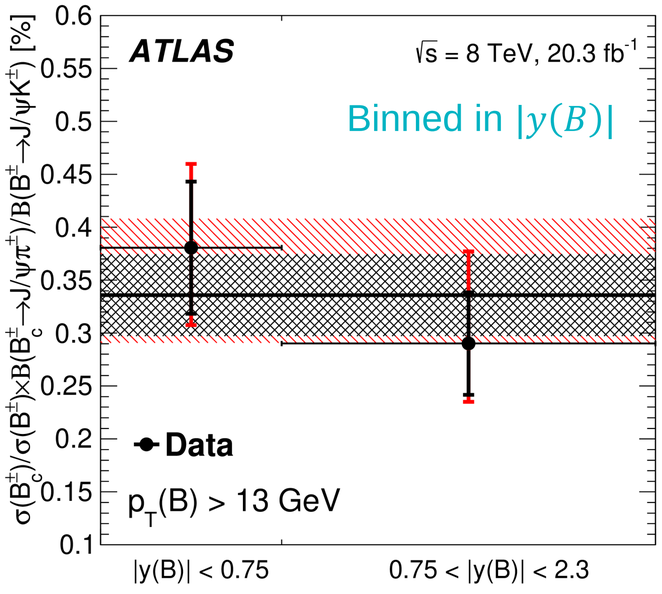
$N^{\mathrm{reco}}(B^{\pm}) \sim 400\mathrm{k}$
$N^{\mathrm{reco}}(B_c^{\pm}) \sim 800$

- $B^{\pm}_{(c)}$ candidates formed from vertex fit of $\mu^+\mu^-$+one track
- Background from partially reco. b-hadron decays, $B^{\pm} \to J/\psi\pi^{\pm}$, combinatorial
- Fiducial volume: $p_{\mathrm{T}}\left(B^{\pm}_{(c)}\right) > 13\ \mathrm{GeV}$ and $\left|y\left(B^{\pm}_{(c)}\right)\right| < 2.3$
- Extract $N^{\mathrm{reco}}(B^{\pm}_{(c)})$ in fit to $m(B^{\pm}_{(c)})$ in two bins of p_{T} and $|y|$

arXiv:1912.02672, sub. PRD

RELATIVE $B_c^{\pm}/B^{\pm}$ PRODUCTION XSEC





Analysis bin	$\sigma(B_c^{\pm})/\sigma(B^{\pm}) \times \mathcal{B}(B_c^{\pm} \to J/\psi\pi^{\pm})/\mathcal{B}(B^{\pm} \to J/\psi K^{\pm})$
$p_{\mathrm{T}}(B) > 13$ GeV, $\lvert y(B)\rvert < 2.3$	$(0.34 \pm 0.04_{\mathrm{stat}}\ ^{+0.06}_{-0.02\ \mathrm{syst}} \pm 0.01_{\mathrm{lifetime}})\%$
$13 < p_{\mathrm{T}}(B) < 22$ GeV, $\lvert y(B)\rvert < 2.3$	$(0.44 \pm 0.07_{\mathrm{stat}}\ ^{+0.09}_{-0.04\ \mathrm{syst}} \pm 0.01_{\mathrm{lifetime}})\%$
$p_{\mathrm{T}}(B) > 22$ GeV, $\lvert y(B)\rvert < 2.3$	$(0.24 \pm 0.04_{\mathrm{stat}}\ ^{+0.05}_{-0.01\ \mathrm{syst}} \pm 0.01_{\mathrm{lifetime}})\%$
$p_{\mathrm{T}}(B) > 13$ GeV, $\lvert y(B)\rvert < 0.75$	$(0.38 \pm 0.06_{\mathrm{stat}}\ ^{+0.05}_{-0.04\ \mathrm{syst}} \pm 0.01_{\mathrm{lifetime}})\%$
$p_{\mathrm{T}}(B) > 13$ GeV, $0.75 < \lvert y(B)\rvert < 2.3$	$(0.29 \pm 0.05_{\mathrm{stat}}\ ^{+0.07}_{-0.02\ \mathrm{syst}} \pm 0.01_{\mathrm{lifetime}})\%$

- No evident dependence on rapidity $|y(B)|$
- Results suggest that $\sigma(B_c^{\pm})$ decreases faster with p_{T} than $\sigma(B^{\pm})$

- Complementary/compatible to CMS results (overlap in fiducial volume) and LHCb results (different fiducial volume)

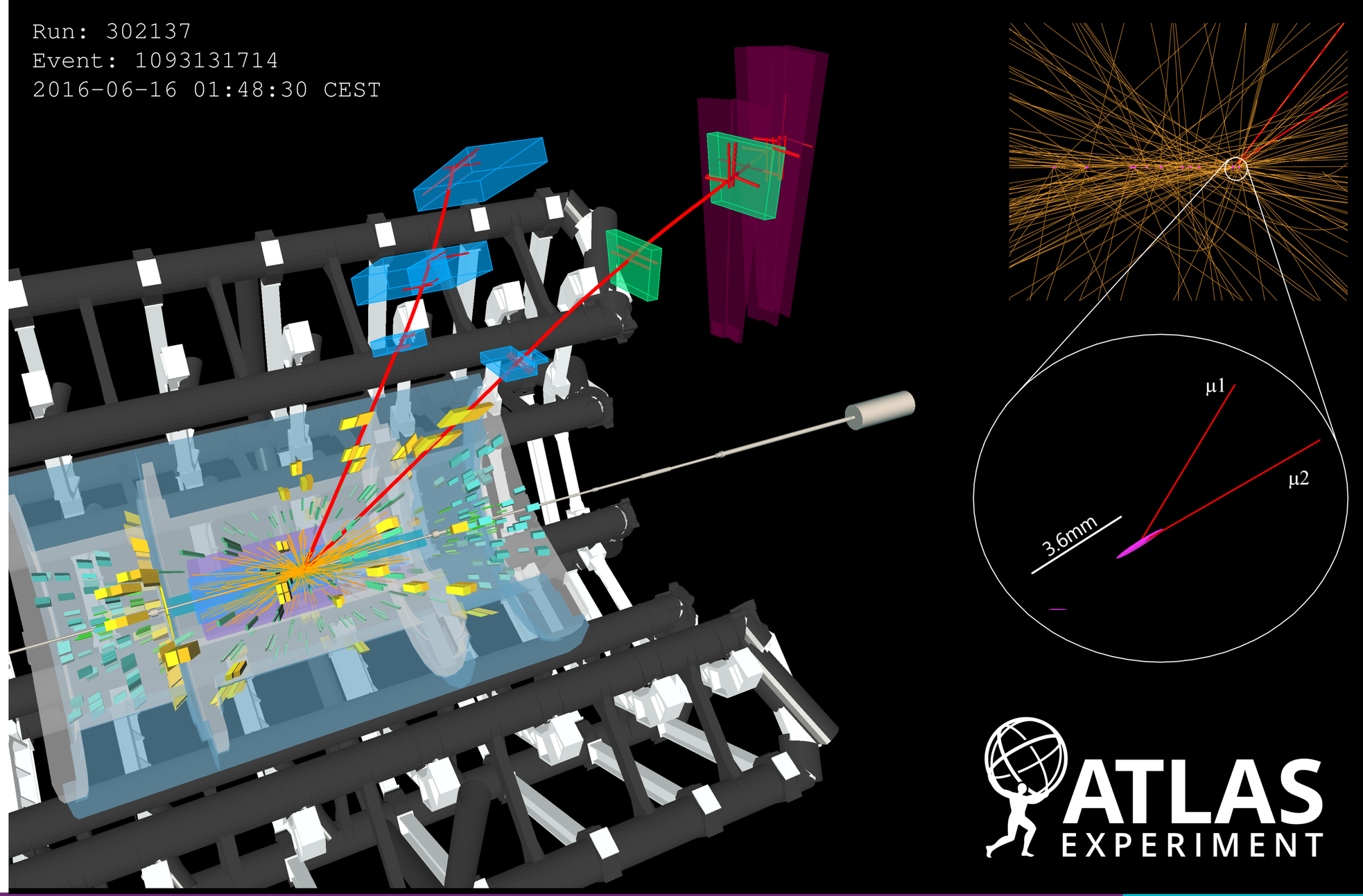
arXiv:1912.02672, sub. PRD

Rare Decays

$B^0 \to \mu^+\mu^-$

and

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



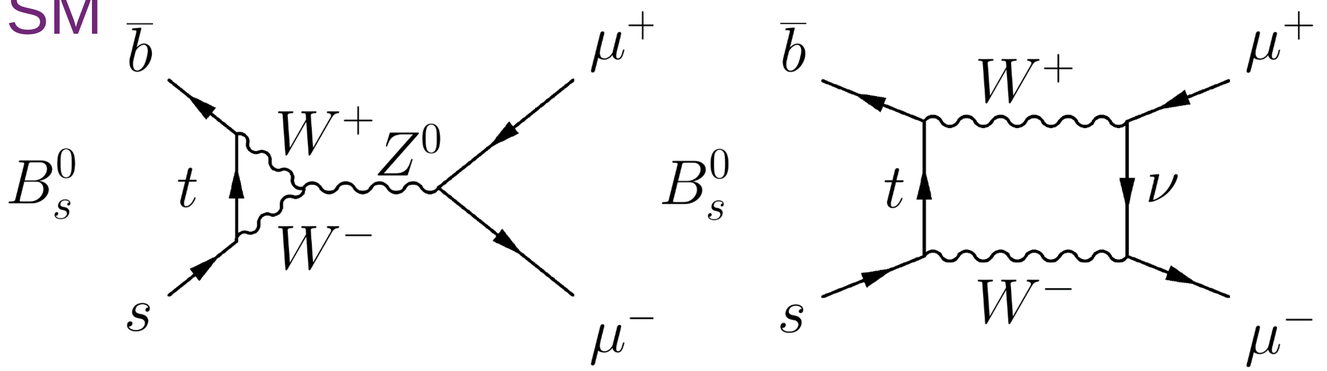
RARE DECAYS $B^0 \to \mu^+\mu^-$ AND $B_s^0 \to \mu^+\mu^-$

- FCNC in the SM via loop and box diagrams
- Helicity- and CKM-suppressed
- $B^0 \to \mu^+\mu^-$ at $\mathcal{B} \sim 10^{-10}$ (V_{td}, V_{tb})
- $B_s^0 \to \mu^+\mu^-$ at $\mathcal{B} \sim 10^{-9}$ (V_{ts}, V_{tb})

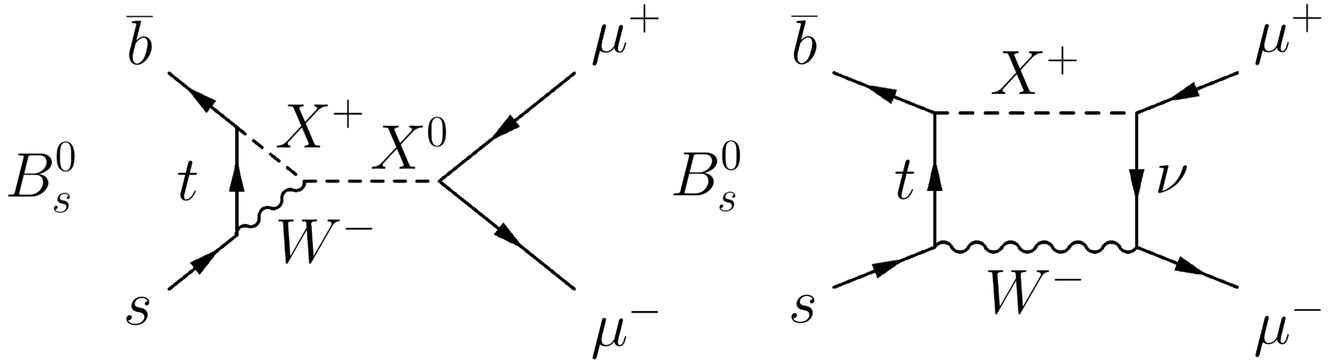
- Enhancements might arise from BSM contributions
- Deviations from predicted $\mathcal{B}$?

Example $B_s^0 \to \mu^+\mu^-$

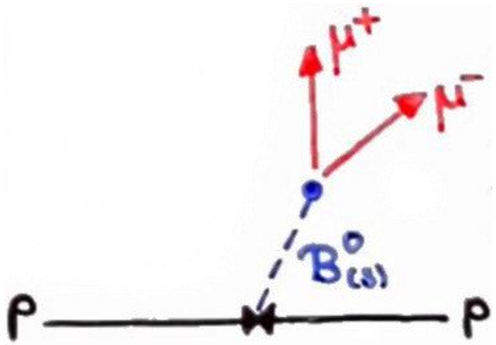
SM

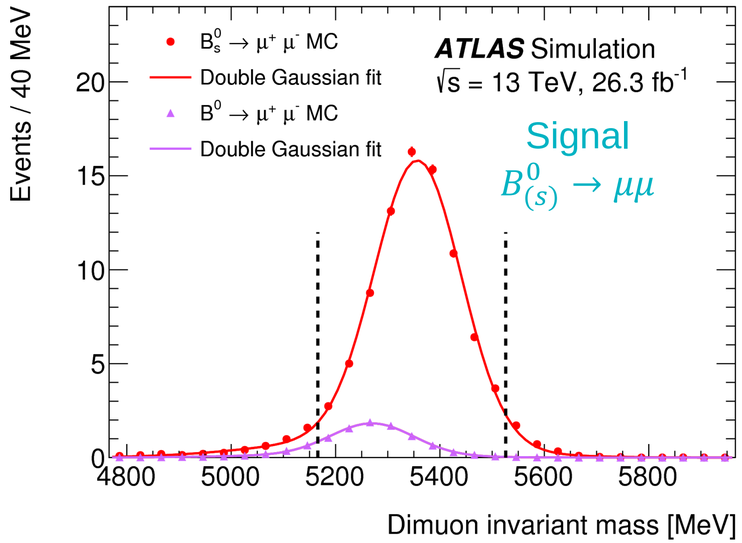


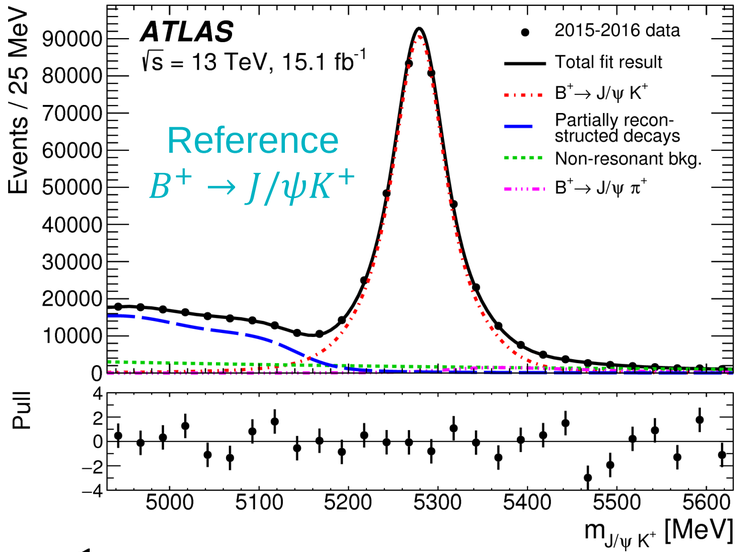
BSM



BRANCHING FRACTIONS OF $B^0_{(s)} \to \mu^+\mu^-$





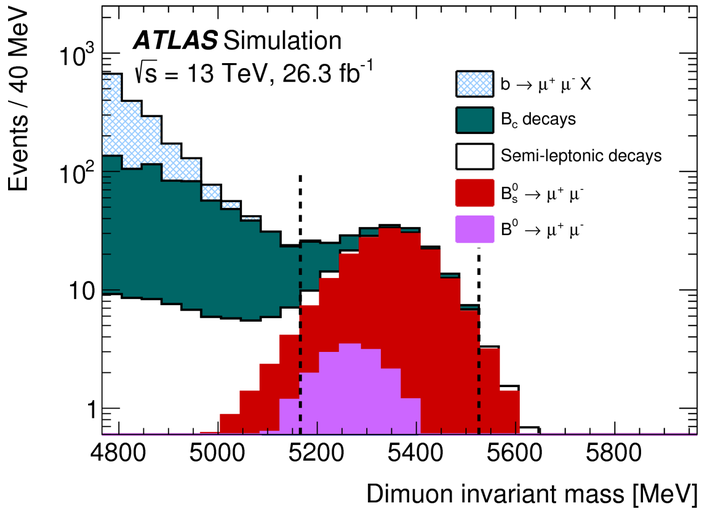


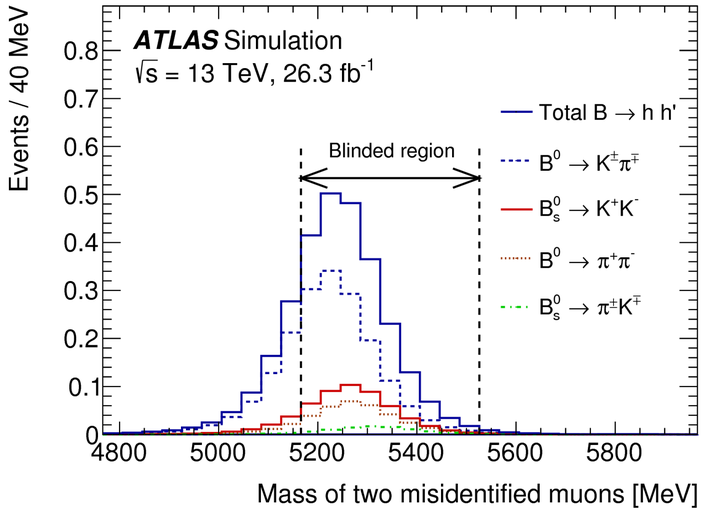
- ATLAS measurement of $\mathcal{B}(B^0_{(s)} \to \mu^+\mu^-)$ using 26.3 fb^{-1} of pp collision data at $\sqrt{s} = 13$ TeV (2015+2016)
- Using di-muon trigger
- Simultaneous fit of $\mathcal{B}(B^0 \to \mu^+\mu^-)$ and $\mathcal{B}(B^0_s \to \mu^+\mu^-)$
- Measurement relative to reference channel $B^+ \to J/\psi(\mu\mu)\, K^+$
- Separate signal from background using boosted decision tree (BDT) JHEP 04(2019) 098

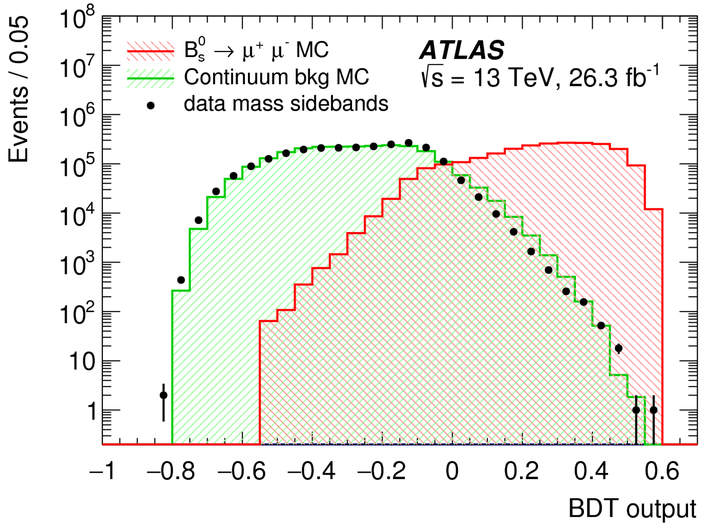
BRANCHING FRACTIONS OF $B^0_{(s)} \to \mu^+\mu^-$

JHEP 04(2019) 098

- Partially reconstructed b–hadron decays mostly at lower di-muon mass
- Peaking background: $B^0_{(s)}$ decays to π and K which are mis-identified as μ
- Continuum background: combinatorial background from μ of uncorrelated hadron decays; reduced with BDT

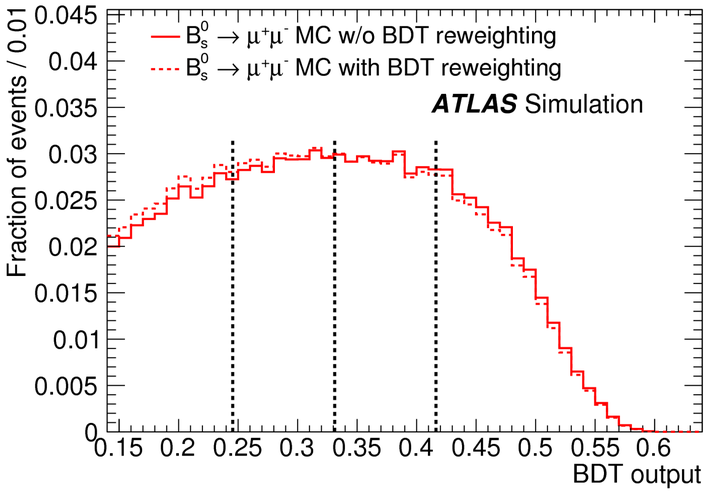




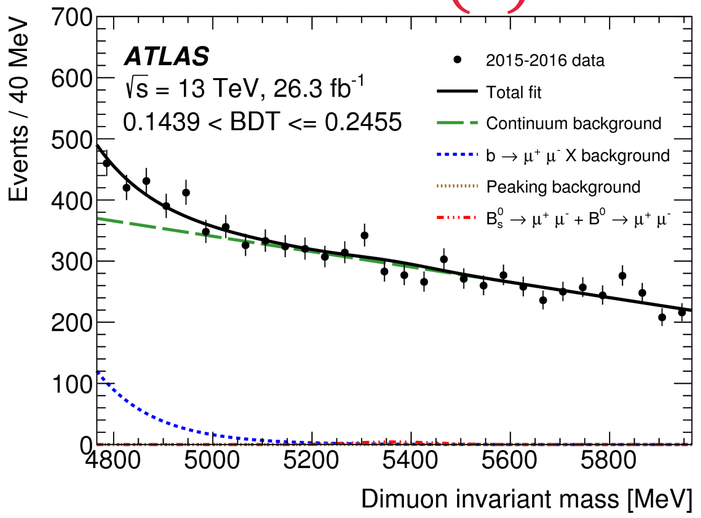


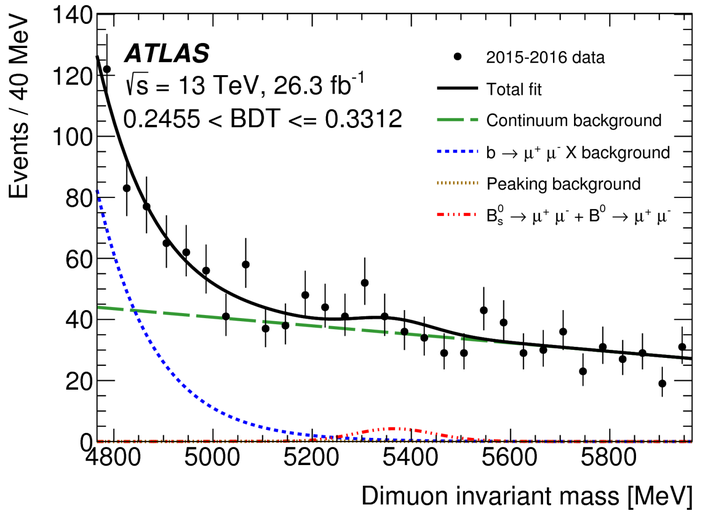
BRANCHING FRACTIONS OF $B^0_{(s)} \to \mu^+\mu^-$

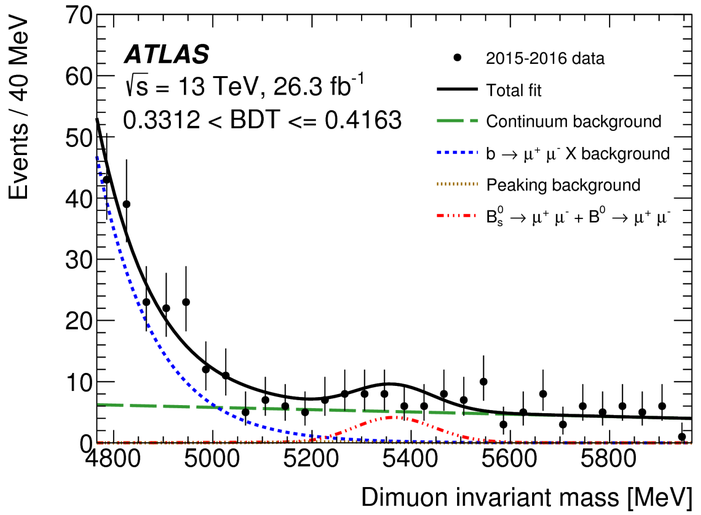
JHEP 04(2019) 098

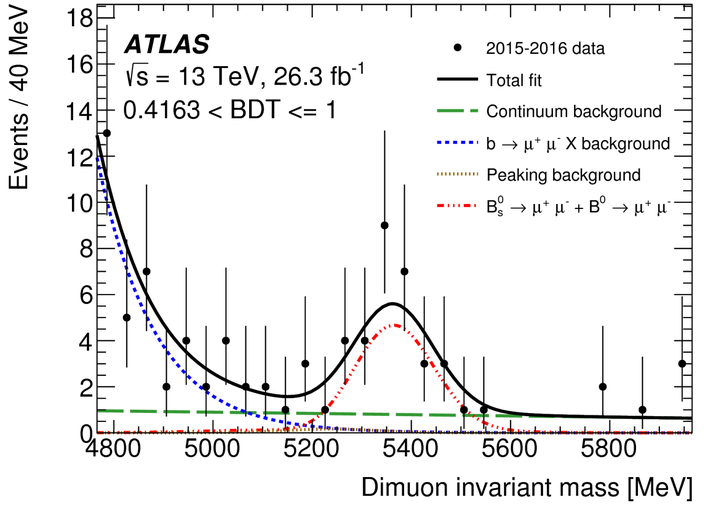


- Signal region divided in 4 BDT intervals with constant signal efficiency
- ➢ Fit extracts simultaneously the yields of $B_s^0 \to \mu\mu$ and $B^0 \to \mu\mu$

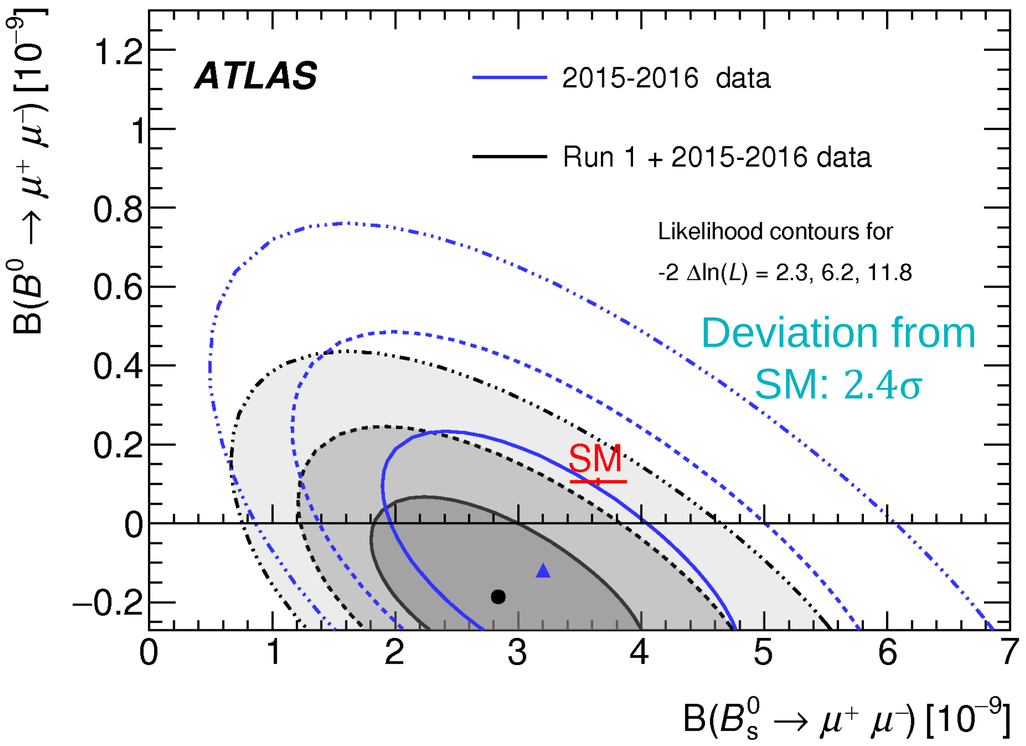








BRANCHING FRACTIONS OF $B^0_{(s)} \to \mu^+\mu^-$



Standard Model [JHEP 10(2019)232]

$\mathcal{B}(B_s^0 \to \mu\mu) = (3.66 \pm 0.14) \times 10^{-9}$

$\mathcal{B}(B^0 \to \mu\mu) = (1.03 \pm 0.05) \times 10^{-10}$

Run 2

$\mathcal{B}(B_s^0 \to \mu\mu) = (3.2^{+1.1}_{-1.0}) \times 10^{-9}$

$\mathcal{B}(B^0 \to \mu\mu) < 4.3 \times 10^{-10}$ at 95% CL

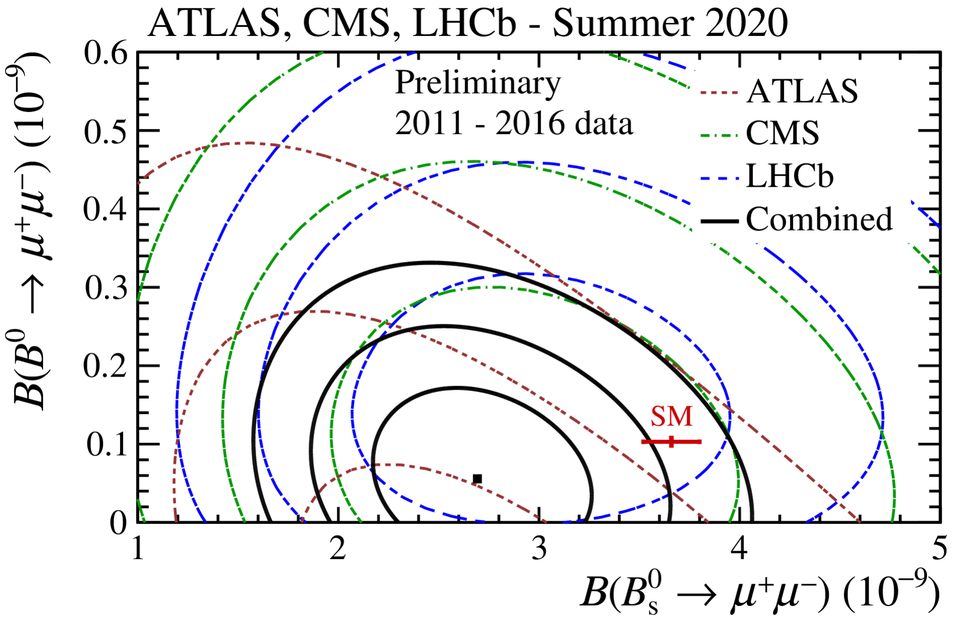
Run 1 + Run 2 (2015-2016)

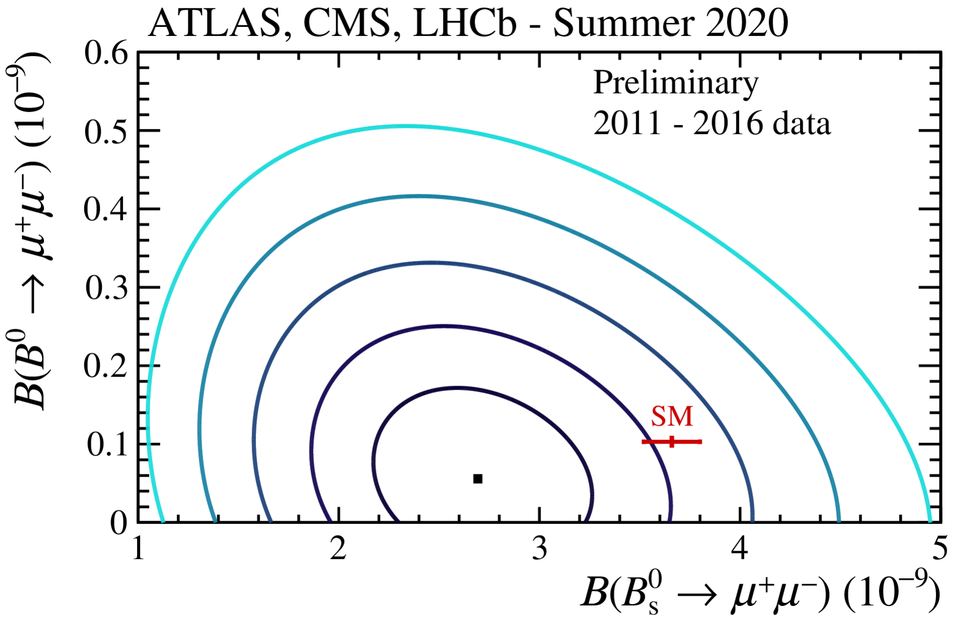
$\mathcal{B}(B_s^0 \to \mu\mu) = (2.8^{+0.8}_{-0.7}) \times 10^{-9}$ Significance: 4.6σ

$\mathcal{B}(B^0 \to \mu\mu) < 2.1 \times 10^{-10}$ at 95% CL

[JHEP 04(2019) 098]

BRANCHING FRACTIONS OF $B^0_{(s)} \to \mu^+\mu^-$





Deviation from SM: 2.1σ

Combination ATLAS, CMS, LHCb for Run 1 + Run 2 ((2015 +) 2016)

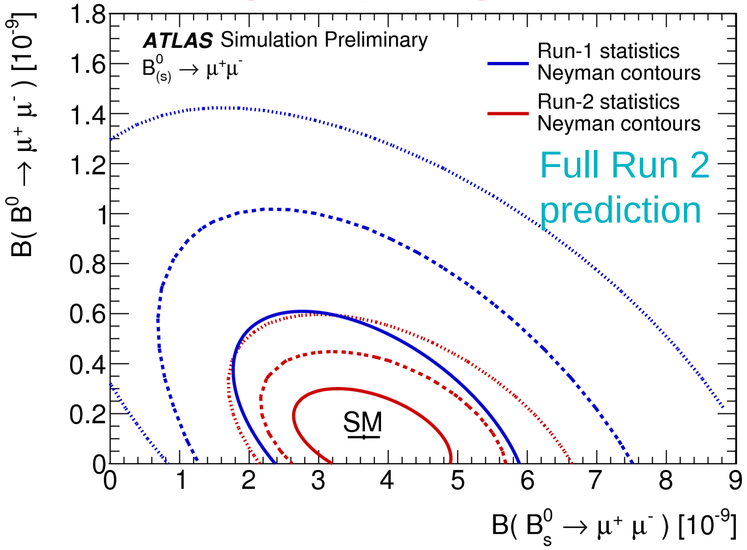
(latest LHCb results not included)

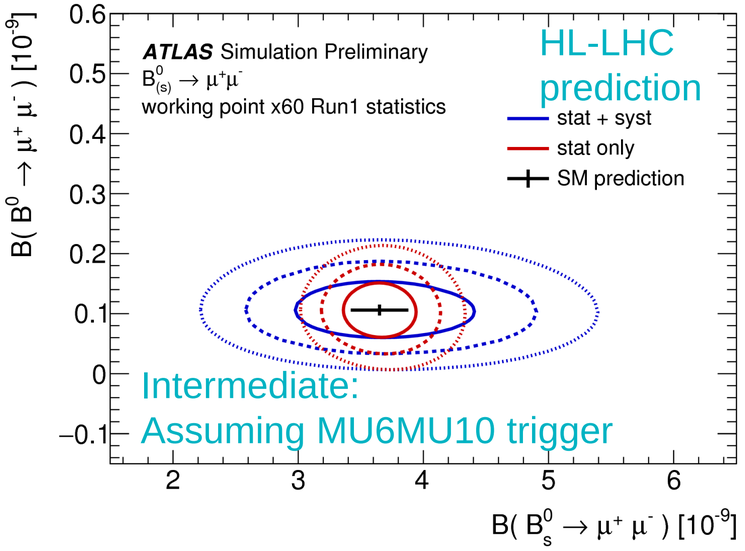
$\mathcal{B}(B^0_s \to \mu\mu) = (2.69^{+0.37}_{-0.35}) \times 10^{-9}$

$\mathcal{B}(B^0 \to \mu\mu) < 1.9 \times 10^{-10}$ at 95% CL

BPH 20 003

BRANCHING FRACTIONS OF $B^0_{(s)} \to \mu^+\mu^-$





Extrapolation of Run 1 results to full Run 2 and HL-LHC

- Increase in luminosity from 25 fb^{-1} to 130 fb^{-1}/3 ab^{-1}
- Increase in $\sqrt{s}$ from 7/8TeV to 13TeV
- Adaptions for detector performance and trigger efficiencies

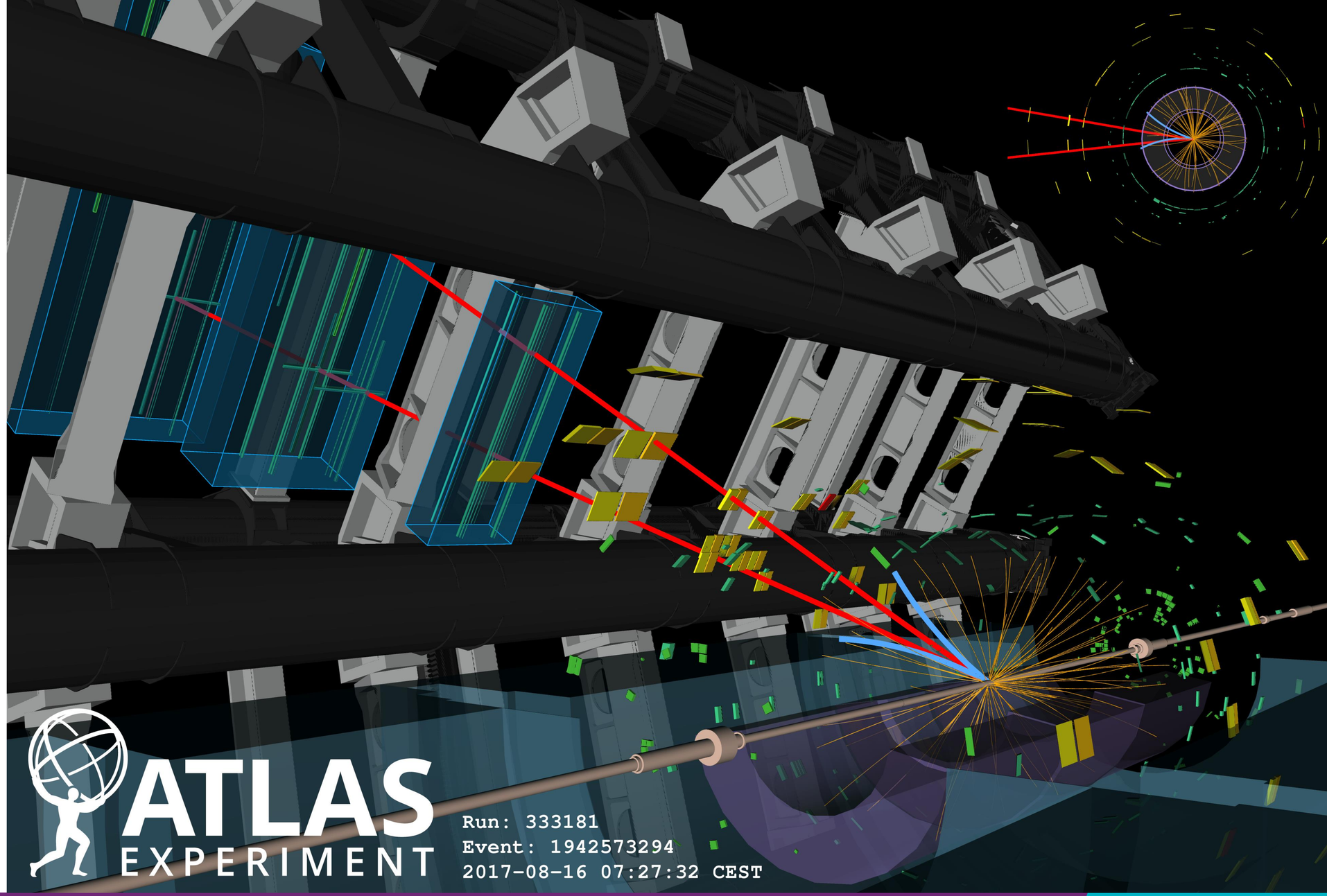
In HL-LHC:

- Conservative: 2MU10 trigger x15 Run 1 statistics
- Intermediate: MU6MU10 trigger x60 Run 1 statistics
- High yield: 2MU6 trigger x75 Run 1 statistics

Uncertainty on $\mathcal{B}$	$\mathcal{B}(B^0_s \to \mu^+\mu^-)$		$\mathcal{B}(B^0 \to \mu^+\mu^-)$	
	stat $[10^{-10}]$	stat + syst $[10^{-10}]$	stat $[10^{-10}]$	stat + syst $[10^{-10}]$
Run 2	7.0	8.3	1.42	1.43
HL-LHC: Conservative	3.2	5.5	0.53	0.54
HL-LHC: Intermediate	1.9	4.7	0.30	0.31
HL-LHC: High-yield	1.8	4.6	0.27	0.28

ATL PHYS PUB 2018-005

CP Violation in $B_s^0 \to J/\psi\phi$



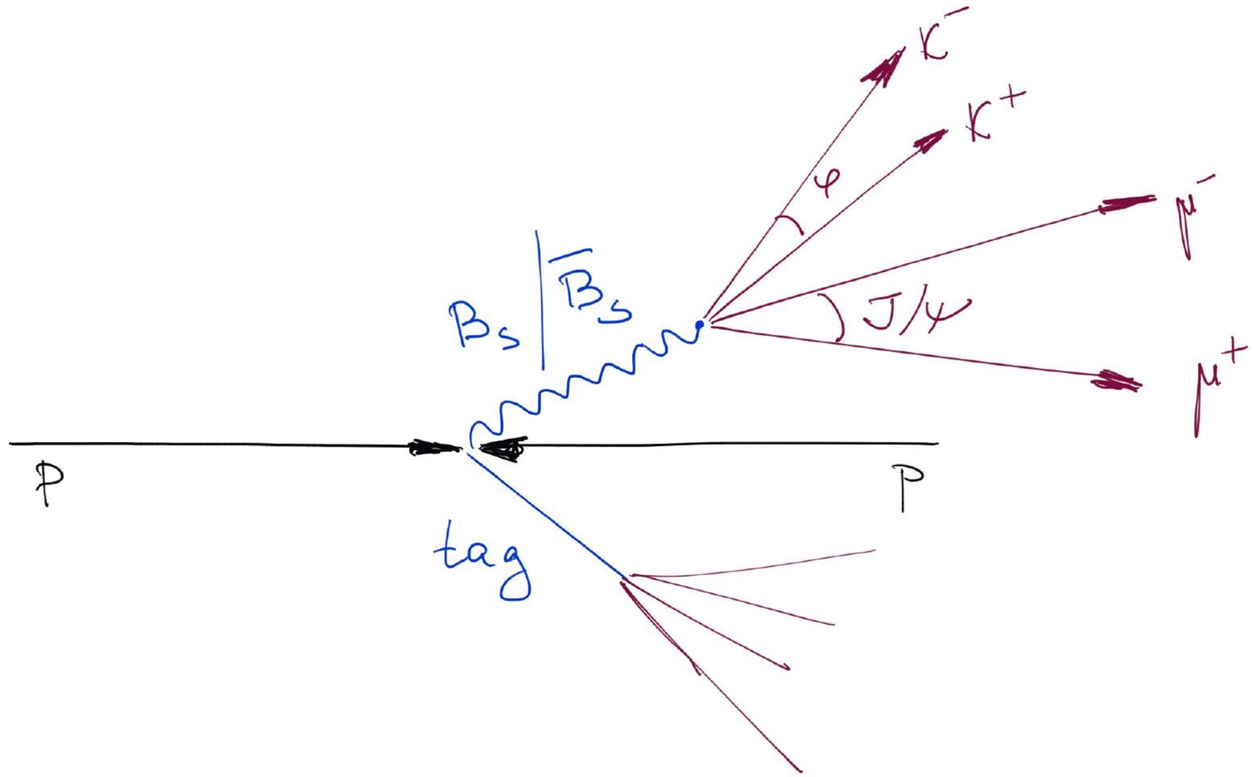
CP VIOLATION IN $B_s^0 \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$

- CP violating phase ϕ_s is weak phase difference between $B_s^0 - \bar{B}_s^0$ mixing amplitude and $b \to c\bar{c}s$ decay amplitude

$$\phi_s^{\mathrm{SM}} = -36.5^{+1.3}_{-1.2}\ \mathrm{mrad}$$

- ATLAS measurement of ϕ_s and $\Delta\Gamma_s$ in $B_s^0 \to J/\psi\phi$ using 80.5 fb^{-1} (2015-2017)

- Di-muon triggers for $J/\psi \to \mu^+\mu^-$
- Opposite side flavour tagging
- Time-dependent angular analysis



arXiv:2001.07115, acc. EPJC

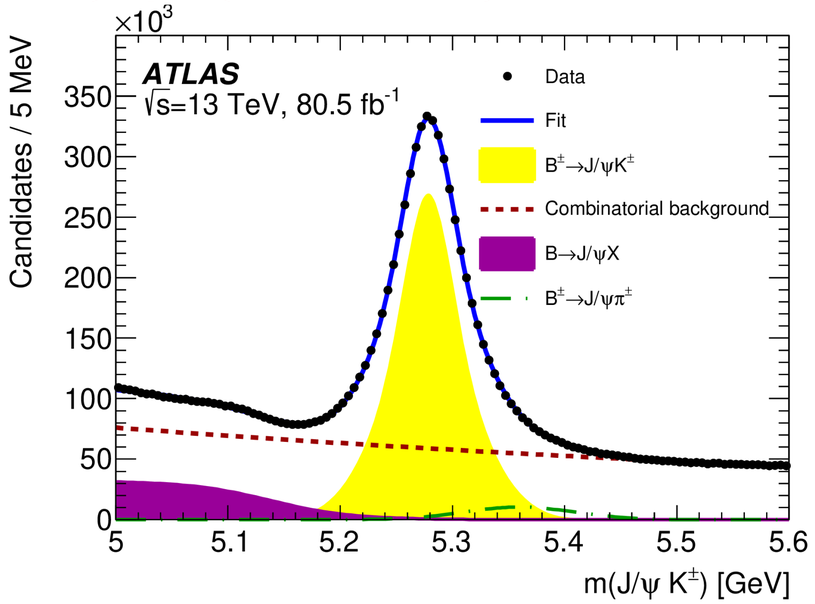
CP VIOLATION IN $B_s^0 \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$

Opposite-side tagging

- $b\bar{b}$ pair production:
  Identify flavour of signal B candidate from other b-hadron
- Tag charge from leptons/jets with tracks in cone of $\Delta R < 0.5$

$$Q = \frac{\Sigma_i^{N_{trk}} q^i (p_T^i)^\kappa}{\Sigma_i^{N_{trk}} (p_T^i)^\kappa}$$

- Calibration channel $B^\pm \to J/\psi\, K^\pm$



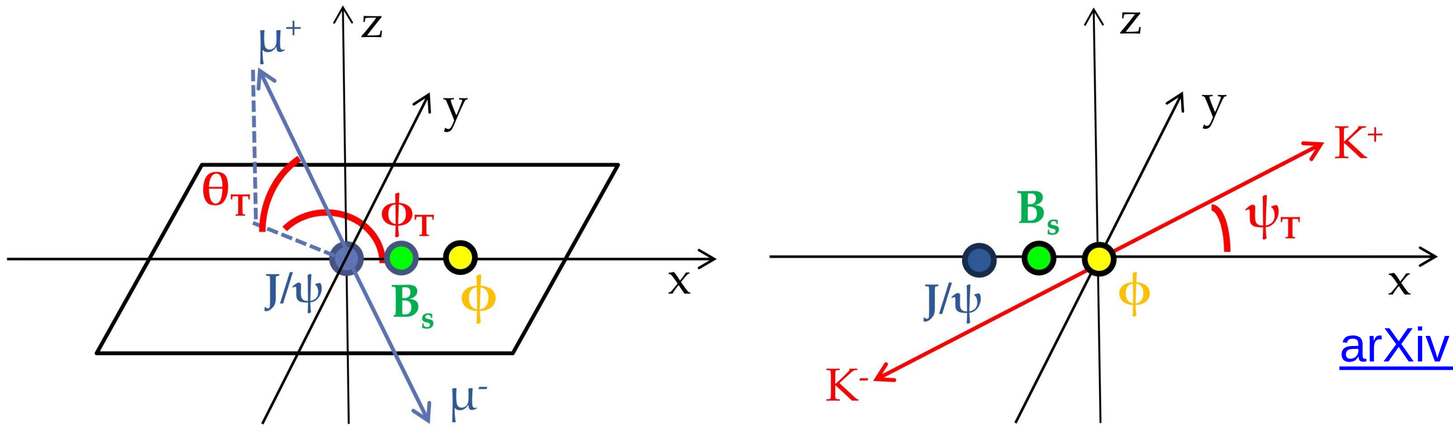
Tag method	ϵ_x [%]	D_x [%]	T_x [%]
Tight muon	4.50 ± 0.01	43.8 ± 0.2	0.862 ± 0.009
Electron	1.57 ± 0.01	41.8 ± 0.2	0.274 ± 0.004
Low-p_T muon	3.12 ± 0.01	29.9 ± 0.2	0.278 ± 0.006
Jet	12.04 ± 0.02	16.6 ± 0.1	0.334 ± 0.006
Total	21.23 ± 0.03	28.7 ± 0.1	1.75 ± 0.01

arXiv:2001.07115, acc. EPJC

CP VIOLATION IN $B_s^0 \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$

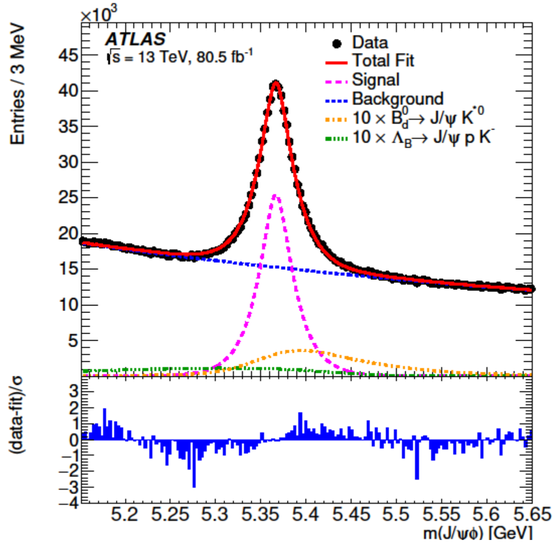
Time-dependent angular analysis

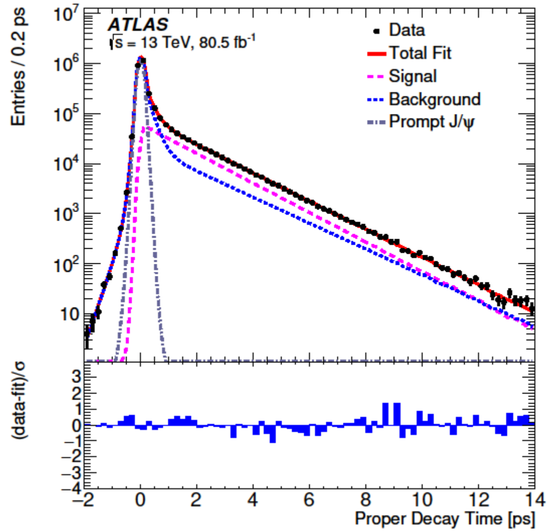
- $B_s^0 \to J/\psi\phi$: $J^P = 0^- \to 1^- + 1^-$
- CP-odd (L=1) and CP-even (L=0,2) states in final state can be distinguished in time-dependent angular analysis
- Interference from non-resonant $B_s^0 \to J/\psi\, K^+K^-$
- Unbinned maximum likelihood fit for B_s^0 mass, decay time and decay angles



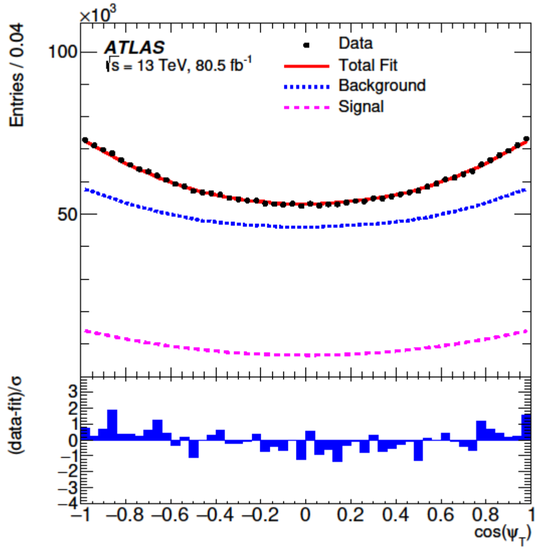
arXiv:2001.07115, acc. EPJC

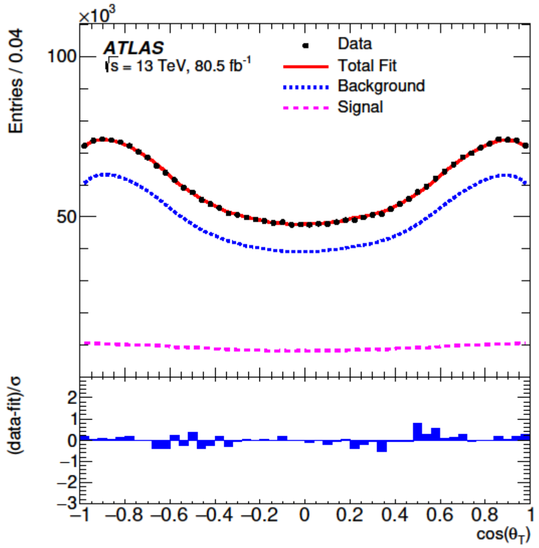
CP VIOLATION IN $B_s^0 \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$

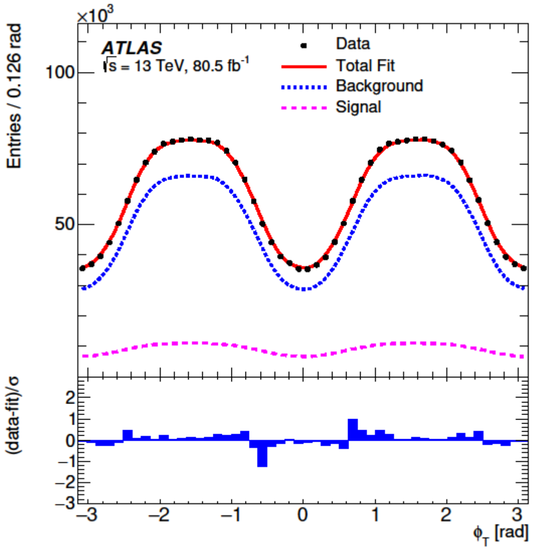




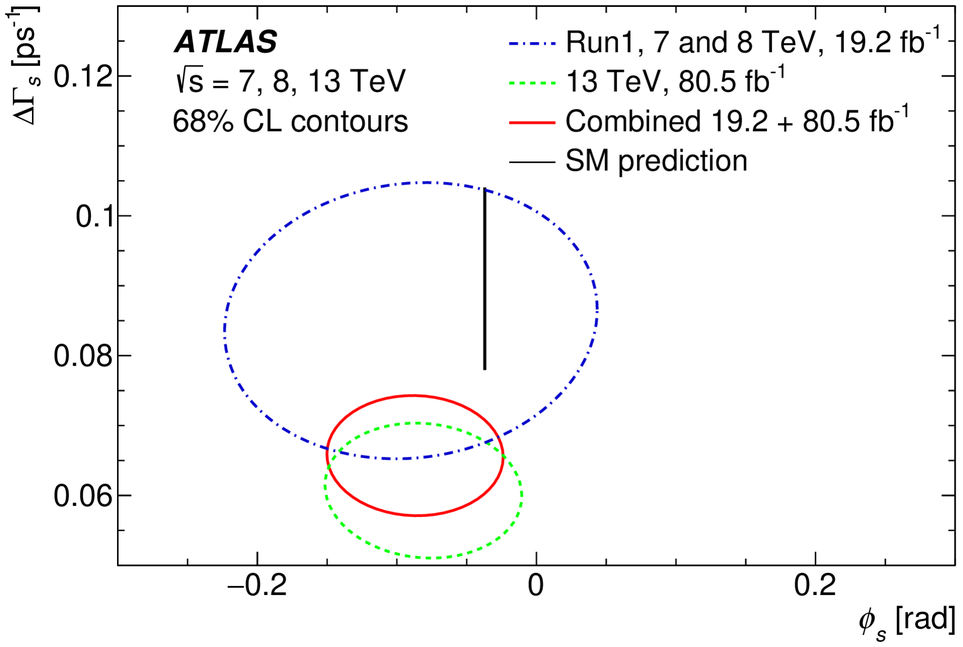
arXiv:2001.07115, acc. EPJC

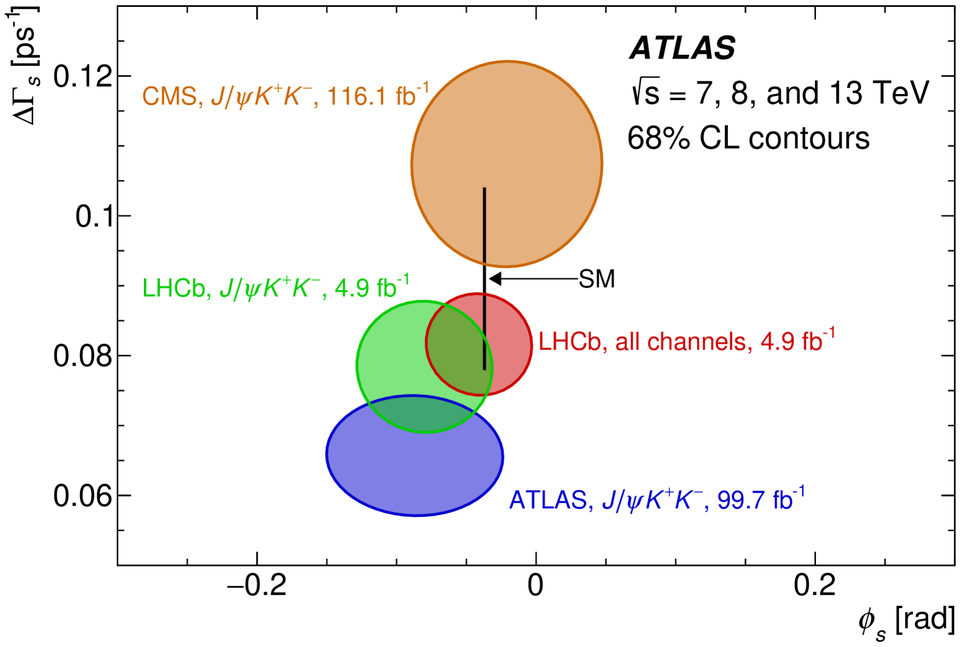






CP VIOLATION IN $B_s^0 \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$





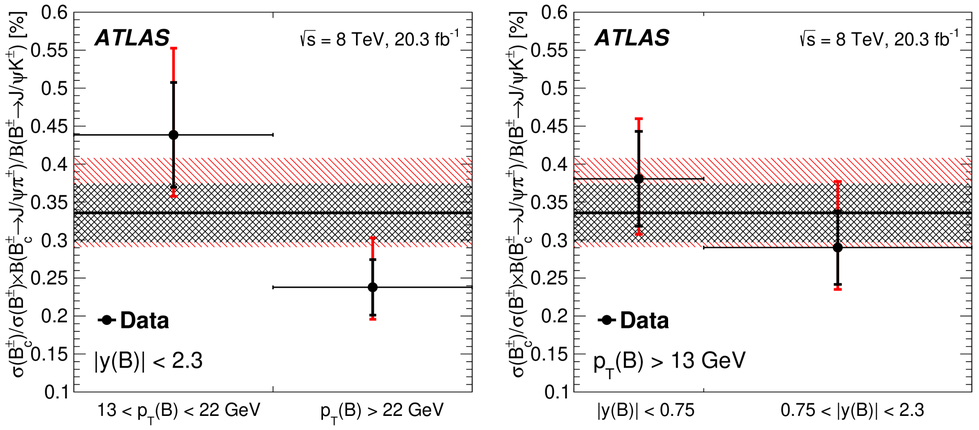
Results combined with Run 1 ($19.2 + 80.5\text{fb}^{-1}$)

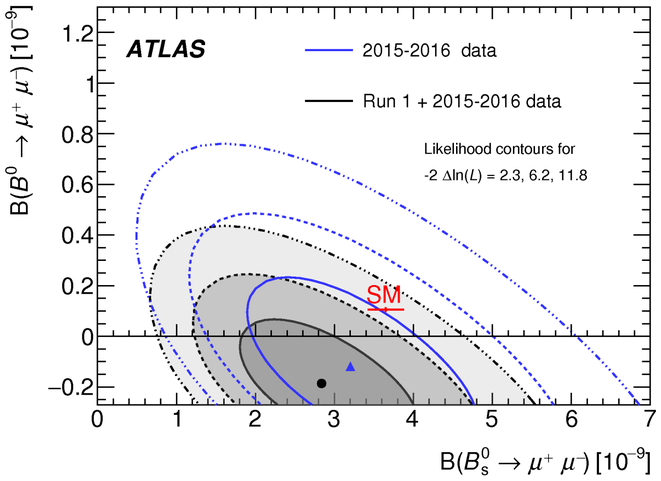
$$\begin{aligned} \phi_s &= -0.087 \pm 0.036\ (\text{stat.}) \pm 0.021\ (\text{syst.})\ \text{rad} \\ \Delta\Gamma_s &= 0.0657 \pm 0.0043\ (\text{stat.}) \pm 0.0037\ (\text{syst.})\ \text{ps}^{-1} \\ \Gamma_s &= 0.6703 \pm 0.0014\ (\text{stat.}) \pm 0.0018\ (\text{syst.})\ \text{ps}^{-1} \end{aligned}$$

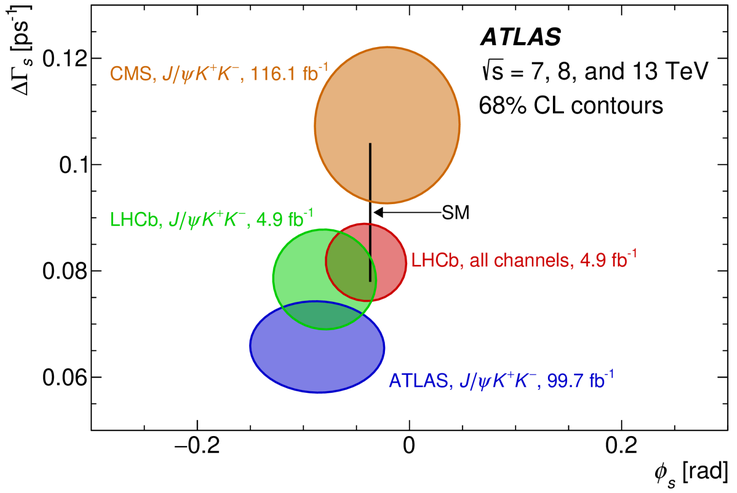
- Consistent with SM predictions
- Measurement of decay width Γ_s at 13TeV deviates by $\sim 3\sigma$

arXiv:2001.07115, acc. EPJC

SUMMARY





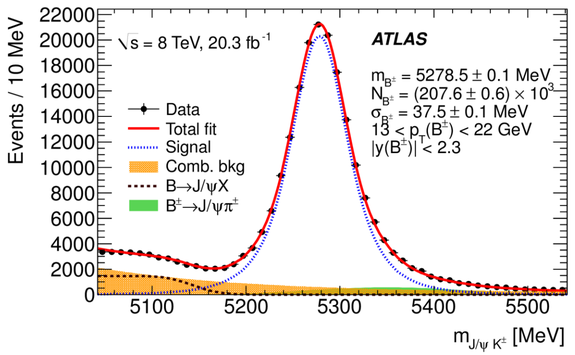


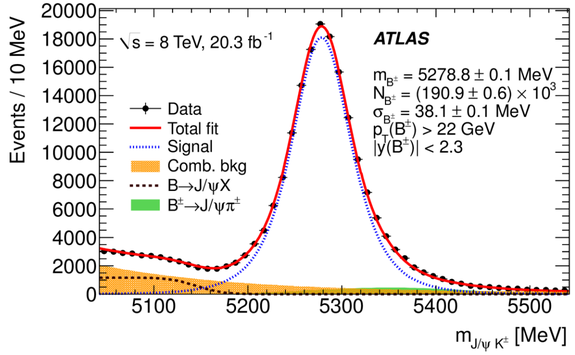
ATLAS has a rich B-physics program

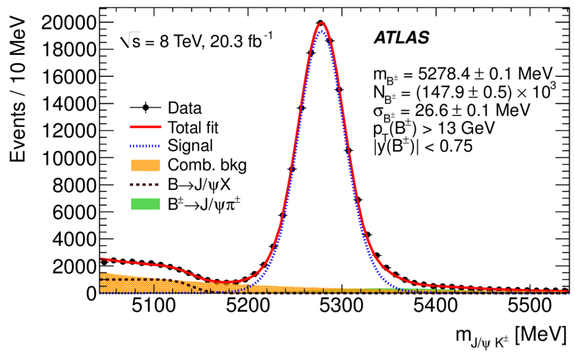
- Relative $B_c^{\pm}/B^{\pm}$ production xsec $\times \mathcal{B}$ (2012 data)
- Branching fractions of $B^0_{(s)} \to \mu^+\mu^-$ (2015-2016 data)
- CP violating phase ϕ_s in $B_s^0 \to J/\psi\phi$ (2015-2017)
- Results consistent with SM predictions
- Precision will improve with full Run 2 dataset and future data

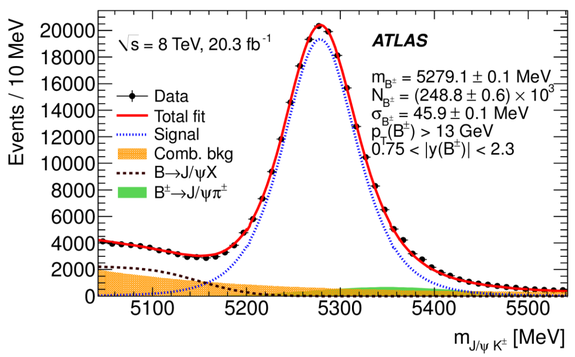
RELATIVE $B_c^{\pm}/B^{\pm}$ PRODUCTION XSEC

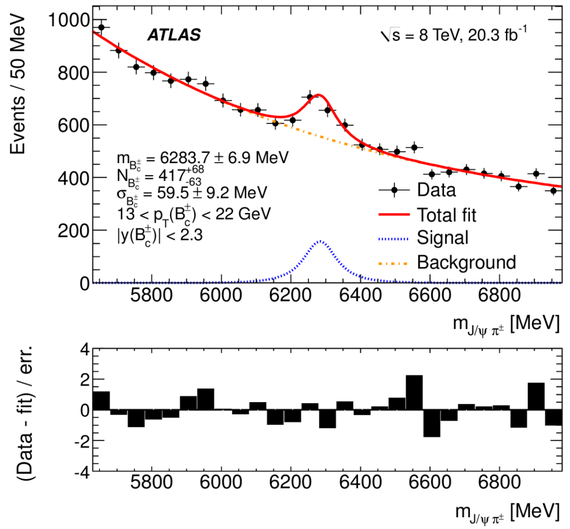
arXiv:1912.02672, sub. PRD

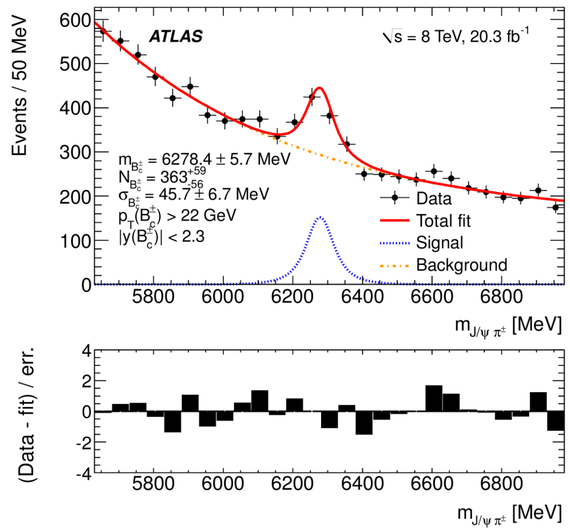


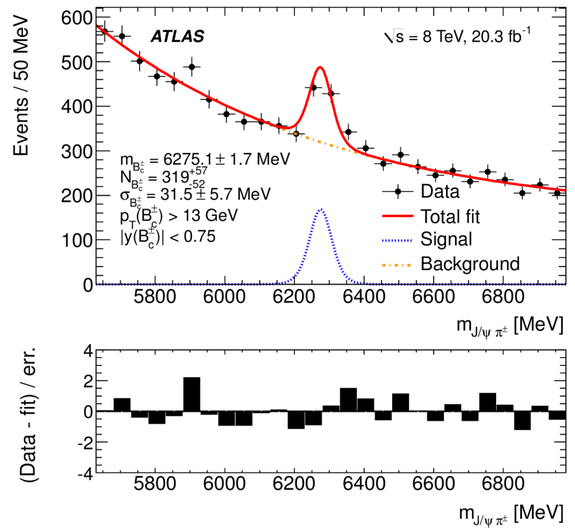


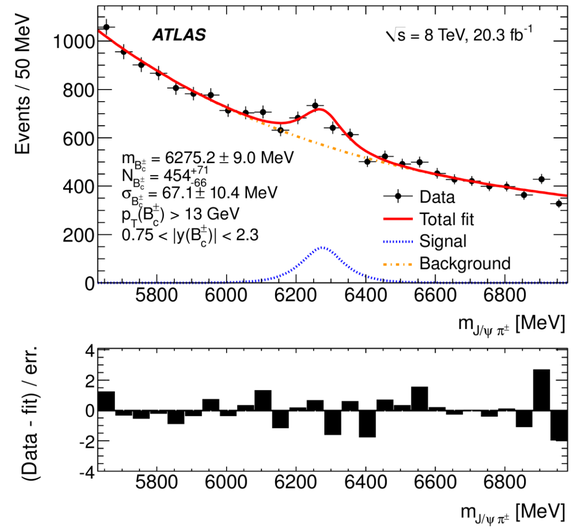












RELATIVE $B_c^{\pm}/B^{\pm}$ PRODUCTION XSEC

$N^{\mathrm{reco}}(B_{(c)}^{\pm})$ are corrected for trigger, reconstruction and selection efficiencies

$$\epsilon = \epsilon^{\mathrm{trigger}} \cdot \epsilon^{\mathrm{MS}}(\mu^+) \cdot \epsilon^{\mathrm{MS}}(\mu^-) \cdot \left(\epsilon^{\mathrm{ID}}(\mu^{\pm})\right)^2 \cdot \epsilon^{\mathrm{ID}}(X_h) \cdot \epsilon^{\mathrm{vertex}}(B) \cdot \epsilon^{\mathrm{selection}}(B)$$

Efficiency ratios excluding minimal selection criteria $\varepsilon^{\mathrm{selection}}$

Analysis bin	Efficiency ratio $\sigma(B_c^{\pm})/\sigma(B^{\pm})$
$p_{\mathrm{T}}(B) > 13$ GeV, $\lvert y(B)\rvert < 2.3$	1.75±0.03
$13 < p_{\mathrm{T}}(B) < 22$ GeV, $\lvert y(B)\rvert < 2.3$	2.19±0.05
$p_{\mathrm{T}}(B) > 22$ GeV, $\lvert y(B)\rvert < 2.3$	1.22±0.03
$p_{\mathrm{T}}(B) > 13$ GeV, $\lvert y(B)\rvert < 0.75$	1.74±0.05
$p_{\mathrm{T}}(B) > 13$ GeV, $0.75 < \lvert y(B)\rvert < 2.3$	1.76±0.04

Corrections due to minimal selection criteria

Analysis bin	Correction to the $B_c^{\pm}$	Correction to the $B^{\pm}$	Ratio of the corrections
$p_{\mathrm{T}}(B) > 13$ GeV, $\lvert y(B)\rvert < 2.3$	$0.0969 \pm 0.0004 \pm 0.0024$	$0.0929 \pm 0.0004 \pm 0.0022$	$0.959 \pm 0.006 \pm 0.024$
$13 < p_{\mathrm{T}}(B) < 22$ GeV, $\lvert y(B)\rvert < 2.3$	$0.0829 \pm 0.0004 \pm 0.0031$	$0.0826 \pm 0.0004 \pm 0.0029$	$0.996 \pm 0.007 \pm 0.039$
$p_{\mathrm{T}}(B) > 22$ GeV, $\lvert y(B)\rvert < 2.3$	$0.2164 \pm 0.0014 \pm 0.0018$	$0.2213 \pm 0.0013 \pm 0.0017$	$1.023 \pm 0.009 \pm 0.009$
$p_{\mathrm{T}}(B) > 13$ GeV, $\lvert y(B)\rvert < 0.75$	$0.0984 \pm 0.0007 \pm 0.0033$	$0.0996 \pm 0.0007 \pm 0.0035$	$1.012 \pm 0.010 \pm 0.035$
$p_{\mathrm{T}}(B) > 13$ GeV, $0.75 < \lvert y(B)\rvert < 2.3$	$0.0952 \pm 0.0005 \pm 0.0014$	$0.0859 \pm 0.0005 \pm 0.0016$	$0.902 \pm 0.007 \pm 0.014$

arXiv:1912.02672, sub. PRD

BRANCHING FRACTIONS OF $B^0_{(s)} \to \mu^+\mu^-$

- Measurement of $\mathcal{B}(B^0_{(s)} \to \mu^+\mu^-)$ relative to reference channel $B^+ \to J/\psi(\mu\mu)\, K^+$

$$\mathcal{B}\left(B^0_{(s)} \to \mu^+\mu^-\right) = \frac{N_{d(s)}}{\varepsilon_{\mu^+\mu^-}} \left[\mathcal{B}(B^+ \to J/\psi\, K^+) \cdot \mathcal{B}(J/\psi \to \mu^+\mu^-)\right] \frac{\varepsilon_{J/\psi K^+}}{N_{J/\psi K^+}} \frac{f_u}{f_{d(s)}}$$

- $\frac{f_u}{f_{d(s)}}$ is ratio of hadronisation probabilities of a b-quark into B^+ and $B^0_{(s)}$

JHEP 04(2019) 098

BRANCHING FRACTIONS OF $B^0_{(s)} \to \mu^+\mu^-$

Expected systematic uncertainties on $\mathcal{B}(B^0_{(s)} \to \mu\mu)$

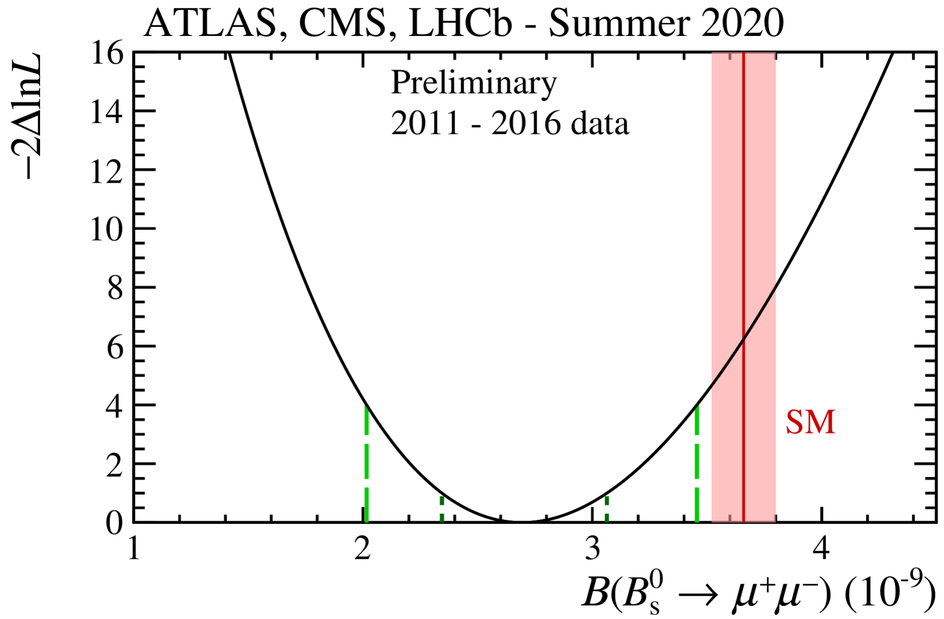
Source	B^0_s [%]	B^0 [%]
f_s/f_d	5.1	-
B^+ yield	4.8	4.8
R_ε	4.1	4.1
$\mathcal{B}(B^+ \to J/\psi\, K^+) \times \mathcal{B}(J/\psi \to \mu^+\mu^-)$	2.9	2.9
Fit systematic uncertainties	8.7	65
Stat. uncertainty (from likelihood est.)	27	150

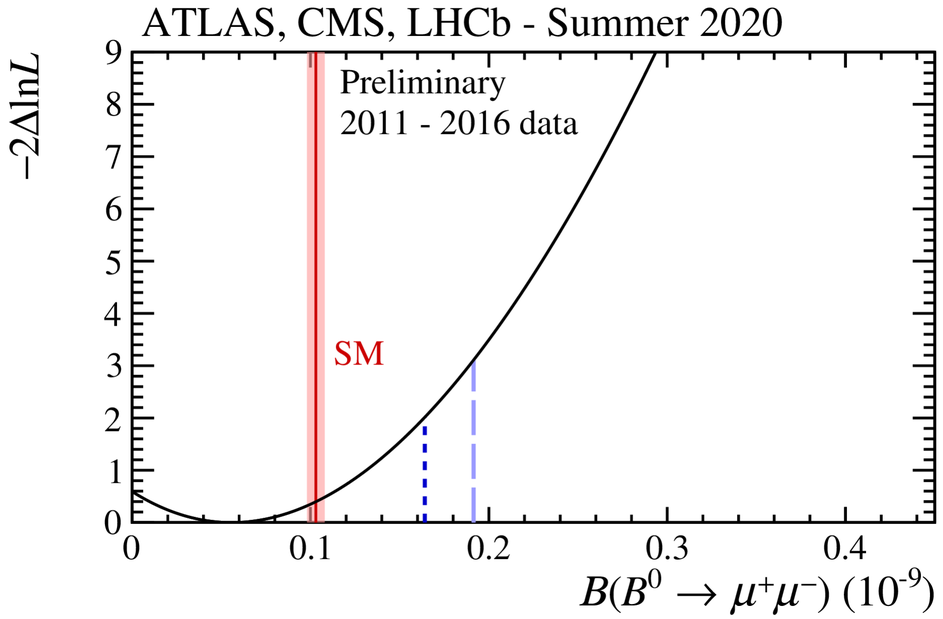
Uncertainties on R_ε

Source	Contribution [%]
Statistical	0.8
BDT input variables	3.2
Kaon tracking efficiency	1.5
Muon trigger and reconstruction	1.0
Kinematic reweighting (DDW)	0.8
Pile-up reweighting	0.6

JHEP 04(2019) 098

BRANCHING FRACTIONS OF $B^0_{(s)} \to \mu^+\mu^-$





Combination ATLAS, CMS, LHCb for Run 1 + Run 2 ((2015 +) 2016)

$\mathcal{B}(B^0_s \to \mu\mu) = (2.69^{+0.37}_{-0.35}) \times 10^{-9}$

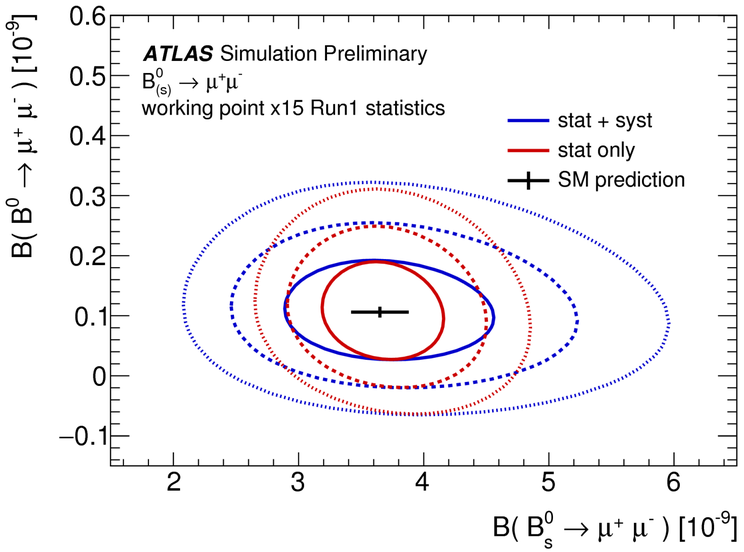
$\mathcal{B}(B^0 \to \mu\mu) < 1.9 \times 10^{-10}$ at 95% CL

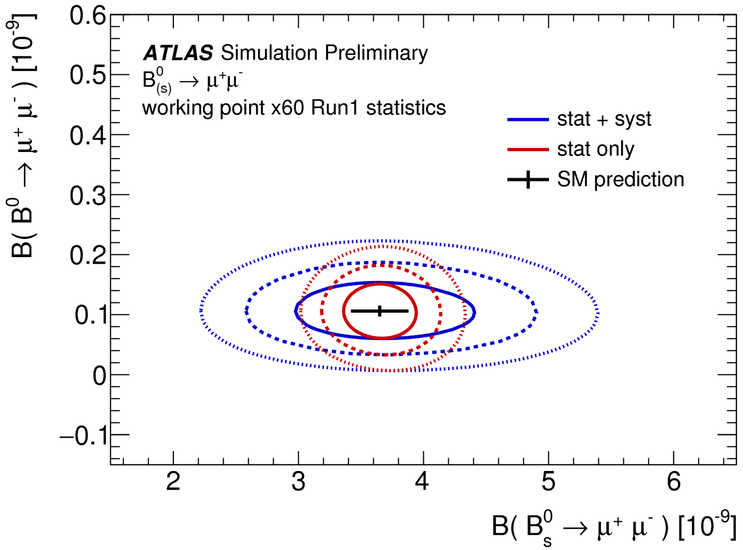
BPH 20 003

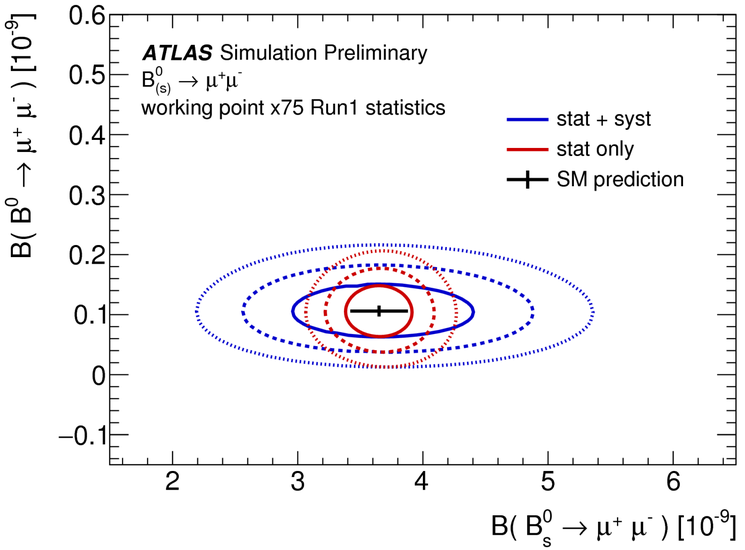
BRANCHING FRACTIONS OF $B^0_{(s)} \to \mu^+\mu^-$

Extrapolation of Run 1 results to HL-LHC

- Conservative: 2MU10 trigger x15 Run 1 statistics
- Intermediate: MU6MU10 trigger x60 Run 1 statistics
- High yield: 2MU6 trigger x75 Run 1 statistics







ATL PHYS PUB 2018-005

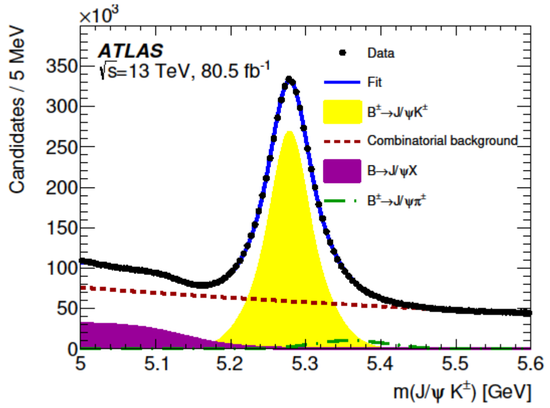
CP VIOLATION IN $B_s^0 \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$

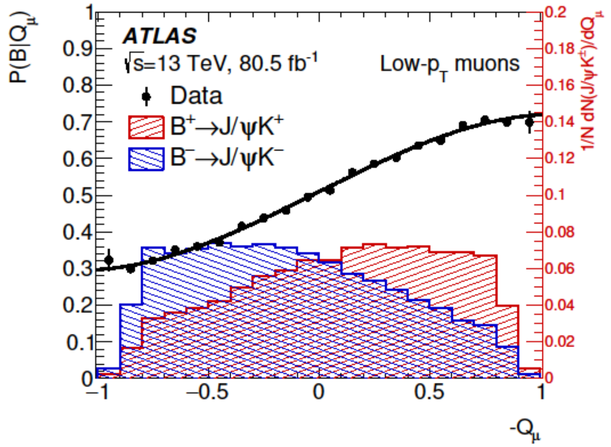
Opposite-side tagging

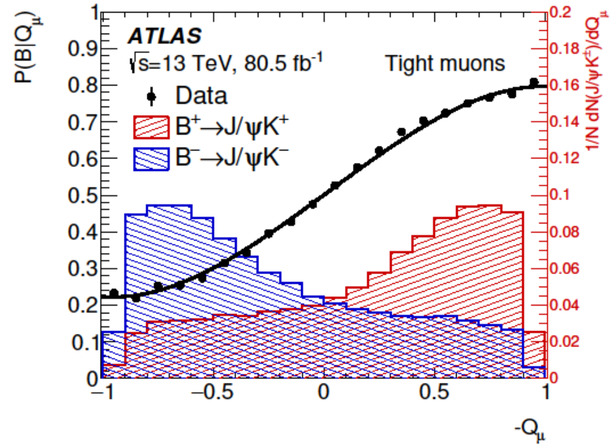
- Tag charge from leptons/jets with tracks in cone of $\Delta R < 0.5$

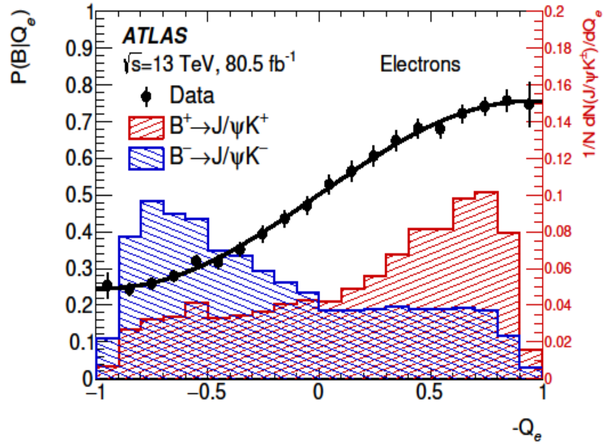
$$Q = \frac{\Sigma_i^{N_{trk}} q^i (p_T^i)^\kappa}{\Sigma_i^{N_{trk}} (p_T^i)^\kappa}$$

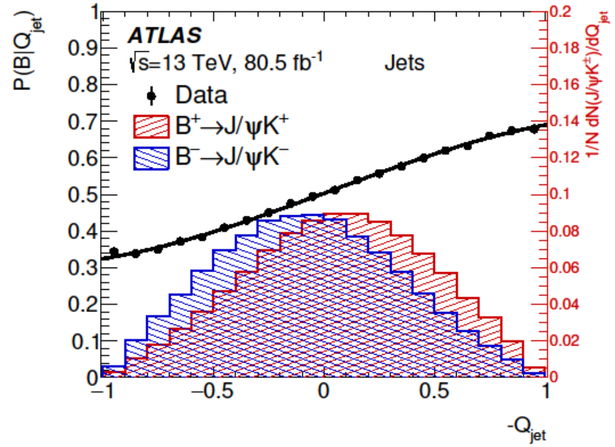
- Calibration channel $B^\pm \to J/\psi\, K^\pm$











[arXiv:2001.07115, acc. EPJC]

CP VIOLATION IN $B_s^0 \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$

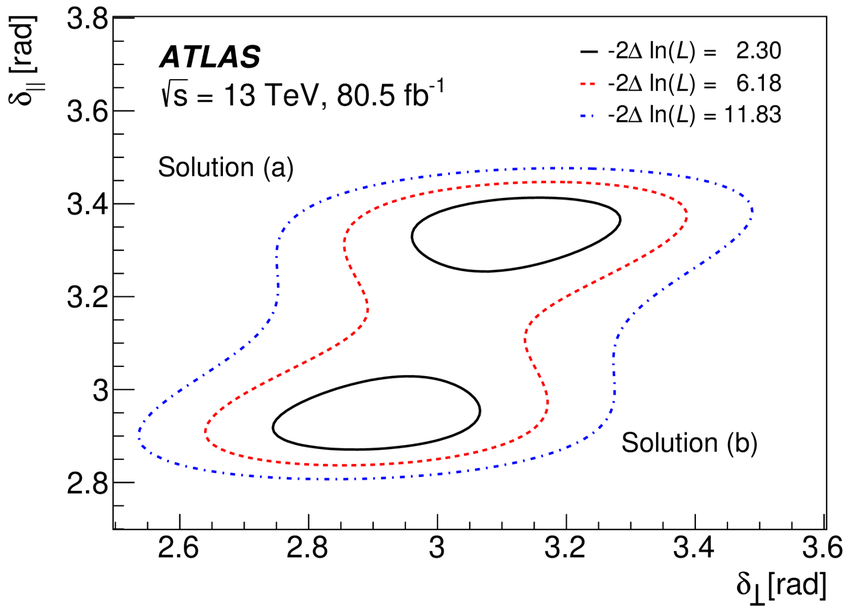
Summary of systematic uncertainties

	ϕ_s [10^{-3} rad]	$\Delta\Gamma_s$ [10^{-3} ps^{-1}]	Γ_s [10^{-3} ps^{-1}]	$\lvert A_\parallel(0)\rvert^2$ [10^{-3}]	$\lvert A_0(0)\rvert^2$ [10^{-3}]	$\lvert A_S(0)\rvert^2$ [10^{-3}]	$\delta_\perp$ [10^{-3} rad]	$\delta_\parallel$ [10^{-3} rad]	$\delta_\perp - \delta_S$ [10^{-3} rad]
Tagging	19	0.4	0.3	0.2	0.2	1.1	17	19	2.3
ID alignment	0.8	0.2	0.5	< 0.1	< 0.1	< 0.1	11	7.2	< 0.1
Acceptance	0.5	0.3	< 0.1	1.0	0.9	2.9	37	64	8.6
Time efficiency	0.2	0.2	0.5	< 0.1	< 0.1	0.1	3.0	5.7	0.5
Best candidate selection	0.4	1.6	1.3	0.1	1.0	0.5	2.3	7.0	7.4
Background angles model:									
Choice of fit function	2.5	< 0.1	0.3	1.1	< 0.1	0.6	12	0.9	1.1
Choice of p_T bins	1.3	0.5	< 0.1	0.4	0.5	1.2	1.5	7.2	1.0
Choice of mass window	9.3	3.3	< 0.1	0.4	0.8	0.4	17	8.6	1.8
Choice of sidebands intervals	0.4	0.1	0.1	0.3	0.3	1.3	4.4	7.4	2.3
Dedicated backgrounds:									
B_d^0	2.6	1.1	< 0.1	0.2	3.1	1.5	10	23	2.1
Λ_b	1.6	0.3	0.2	0.5	1.2	1.8	14	30	0.8
Alternate Δm_s	1.0	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	15	4.0	< 0.1
Fit model:									
Time res. sig frac	1.4	1.1	0.5	0.5	0.6	0.8	12	30	0.4
Time res. p_T bins	0.7	0.5	0.8	0.1	0.1	0.1	2.2	14	0.7
S-wave phase	0.3	< 0.1	< 0.1	< 0.1	< 0.1	0.2	8.0	15	37
Fit bias	5.7	1.3	1.2	1.3	0.4	1.1	3.3	19	0.3
Total	22	4.3	2.2	2.3	3.8	4.6	55	88	39

arXiv:2001.07115, acc. EPJC

CP VIOLATION IN $B_s^0 \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$

- Approximate symmetry in signal pdf gives 2 minima for the strong phases $(\delta_\parallel, \delta_\perp)$ in the fit
- No significant difference in ϕ_s and $\Delta\Gamma_s$ for the two solutions



Parameter	Solution (a) Value	Solution (a) Statistical uncertainty	Solution (a) Systematic uncertainty	Solution (b) Value	Solution (b) Statistical uncertainty	Solution (b) Systematic uncertainty
ϕ_s [rad]	−0.087	0.036	0.021	−0.087	0.036	0.021
$\Delta\Gamma_s$ [ps^{-1}]	0.0657	0.0043	0.0037	0.0657	0.0043	0.0037
Γ_s [ps^{-1}]	0.6703	0.0014	0.0018	0.6704	0.0014	0.0018
$\lvert A_\parallel(0)\rvert^2$	0.2220	0.0017	0.0021	0.2218	0.0017	0.0021
$\lvert A_0(0)\rvert^2$	0.5152	0.0012	0.0034	0.5152	0.0012	0.0034
$\lvert A_S\rvert^2$	0.0343	0.0031	0.0045	0.0348	0.0031	0.0045
$\delta_\perp$ [rad]	3.22	0.10	0.05	3.03	0.10	0.05
$\delta_\parallel$ [rad]	3.36	0.05	0.09	2.95	0.05	0.09
$\delta_\perp - \delta_S$ [rad]	−0.24	0.05	0.04	−0.24	0.05	0.04

arXiv:2001.07115, acc. EPJC