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ATLAS EXPERIMENT

CERN

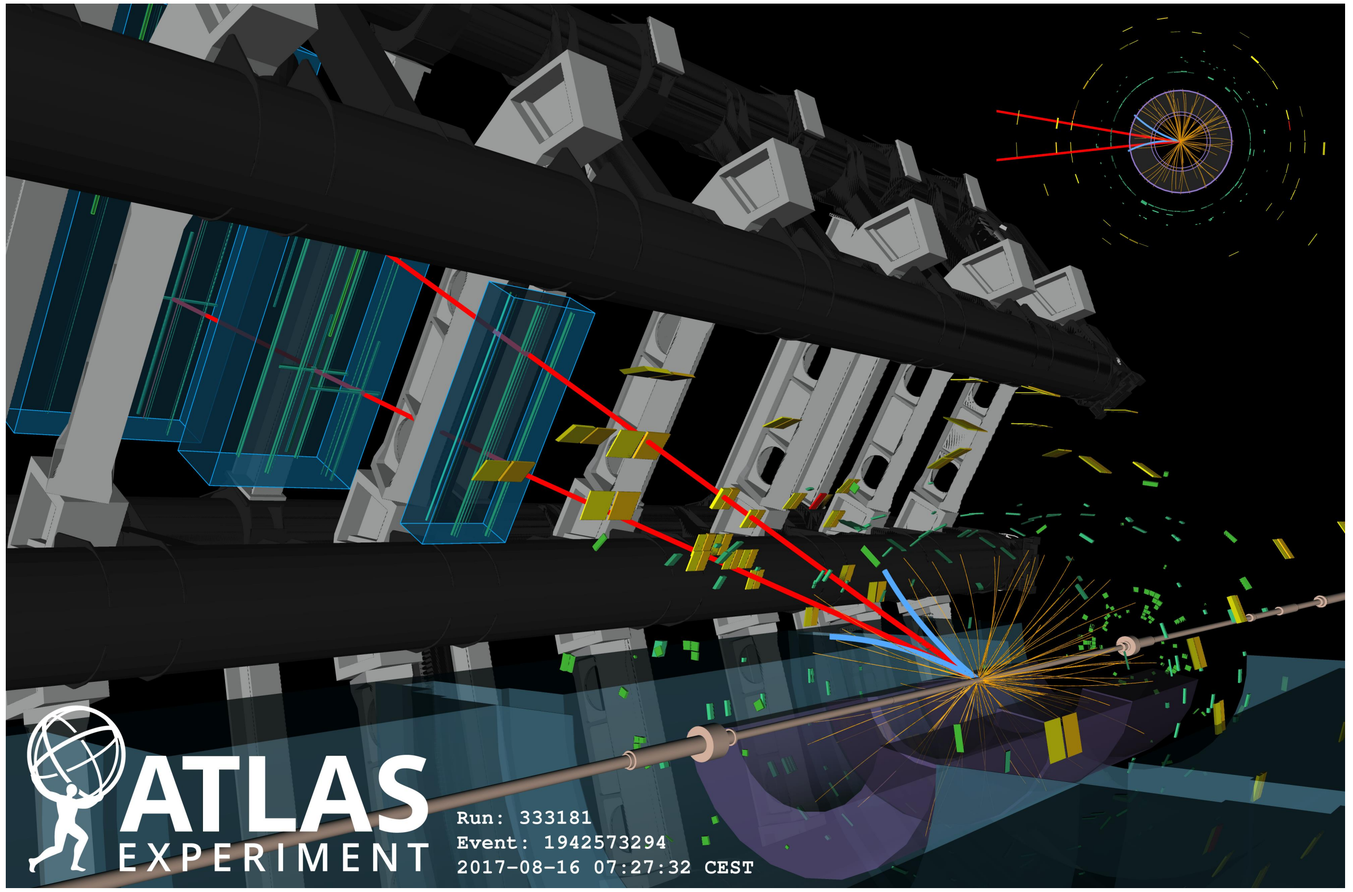
Pheno 2020, Pittsburgh, May 4-6, 2020

ATLAS MEASUREMENTS OF CP VIOLATION AND RARE DECAYS PROCESSES WITH BEAUTY MESONS

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

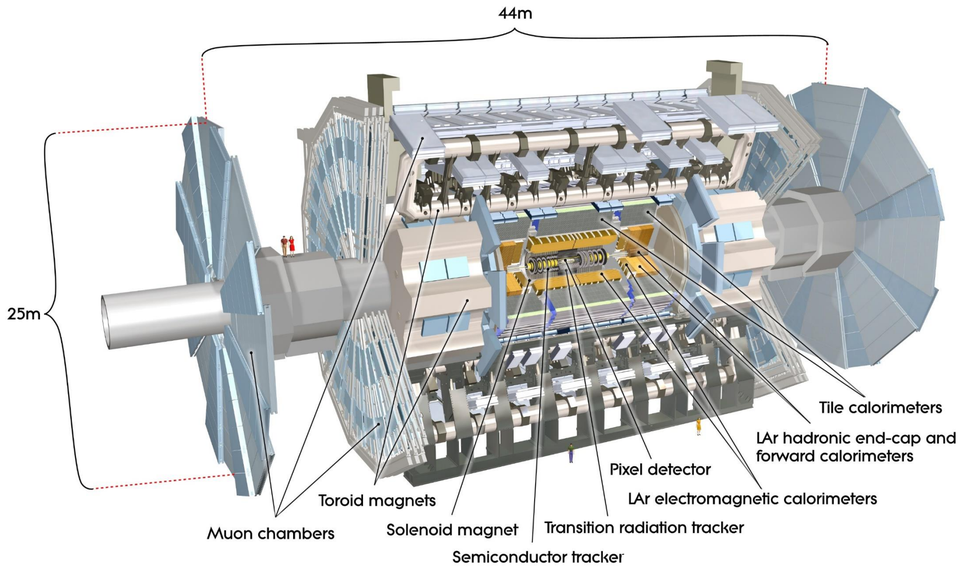
ATLAS MEASUREMENTS OF CP VIOLATION AND RARE DECAYS PROCESSES WITH BEAUTY MESONS

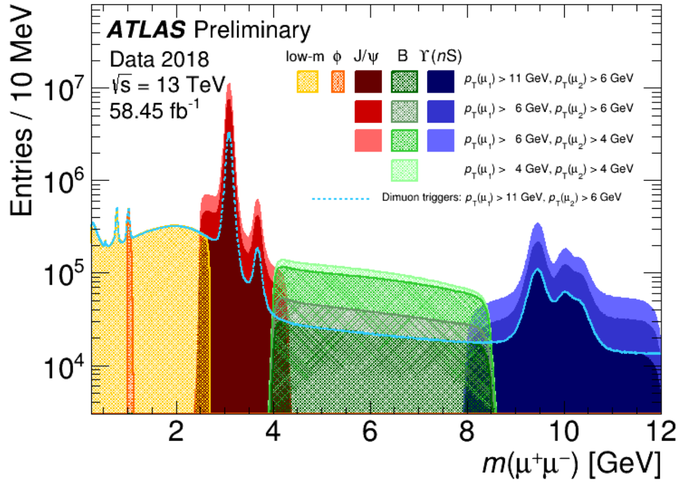
- B physics in ATLAS
- Rare decays $B^0_{(s)} \to \mu\mu$
- CP violation in $B^0_s \to J/\psi\phi$
- Conclusion



B-PHYSICS PROGRAM IN THE ATLAS EXPERIMENT

- ATLAS collected 139fb^{-1} of pp collisions at $\sqrt{s} = 13\text{TeV}$ in 2015-2018
- About 2.5 million $b\bar{b}$ pairs produced per second
- High $\sqrt{s}$ makes B_s, B_c etc. accessible
- Typical B physics trigger is low p_T, very low mass di-muon trigger using inner tracker and muon detectors
- About 150-200 events with $b\bar{b}$ pairs recorded per second





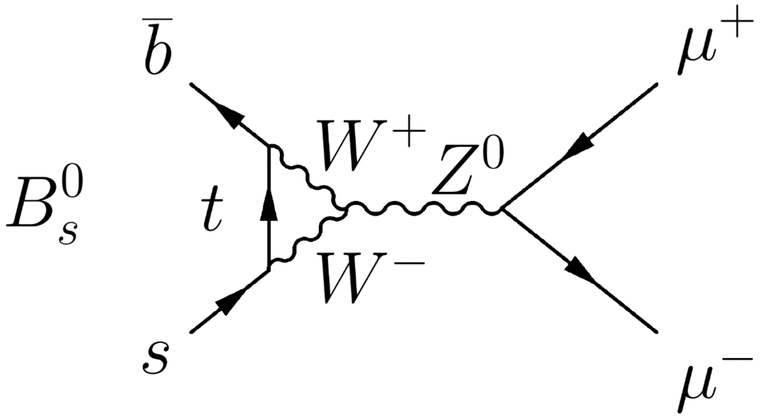
Rare Decays

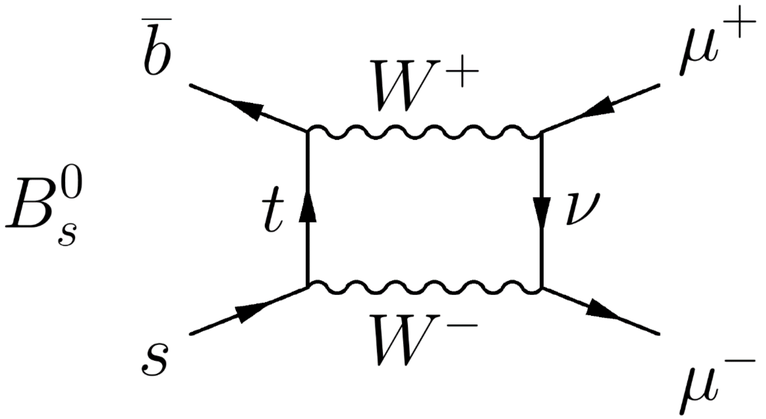
$B^0 \to \mu^+\mu^-$

and

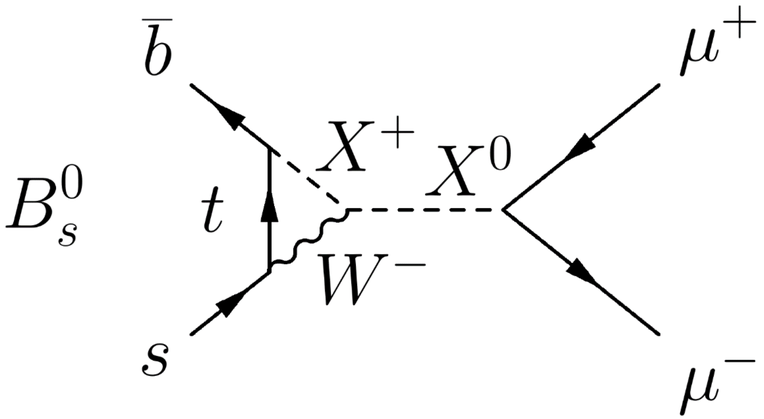
$B_s^0 \to \mu^+\mu^-$

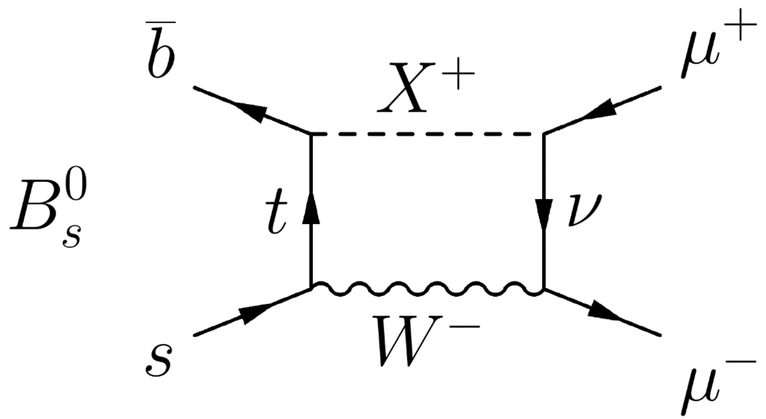
SM



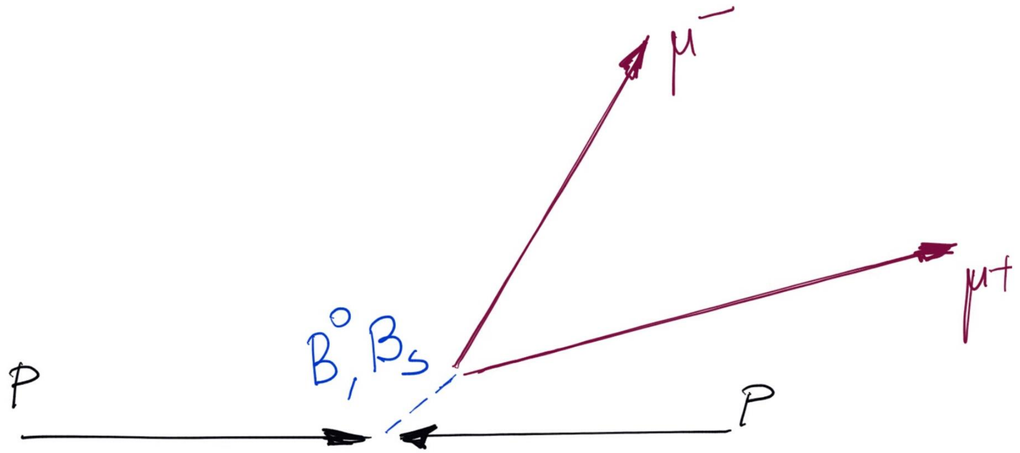


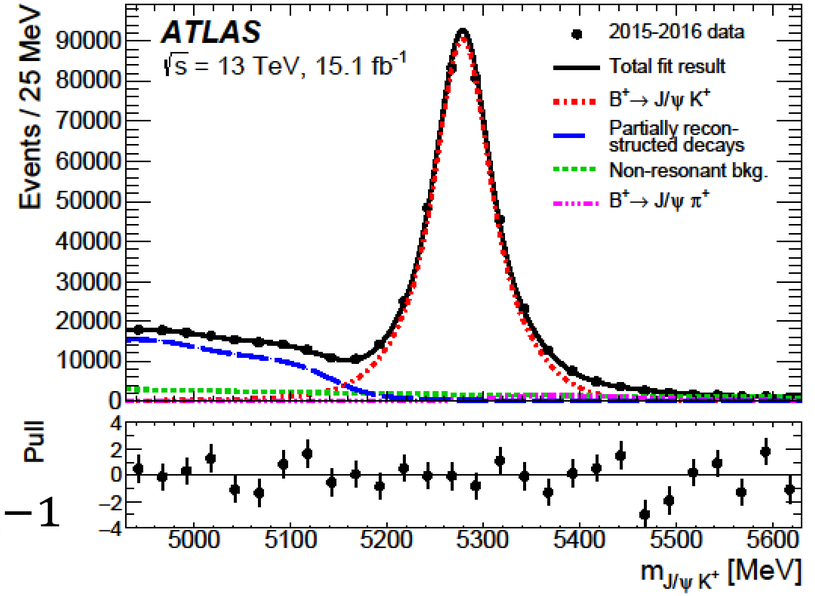
BSM?





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





- ATLAS measurement of $\mathcal{B}(B^0_{(s)} \to \mu^+\mu^-)$ using 26.3 fb^{-1}

- Using di-muon trigger
- Measurement relative to reference channel $B^+ \to J/\psi(\mu\mu)\, K^+$
- Separate signal from background using boosted decision tree (BDT)

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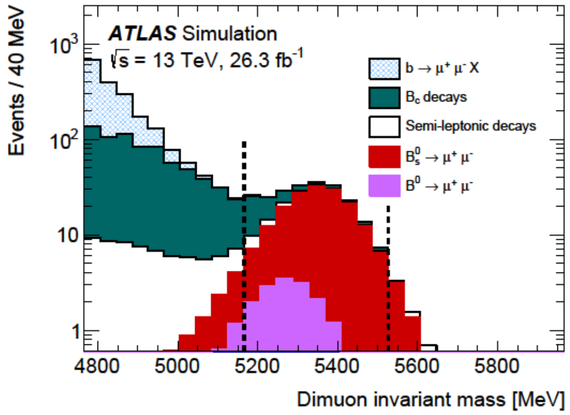
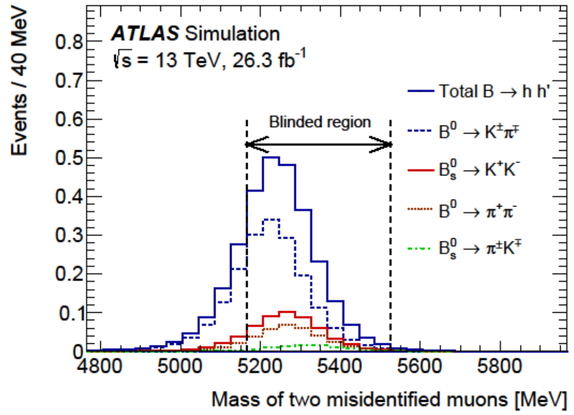
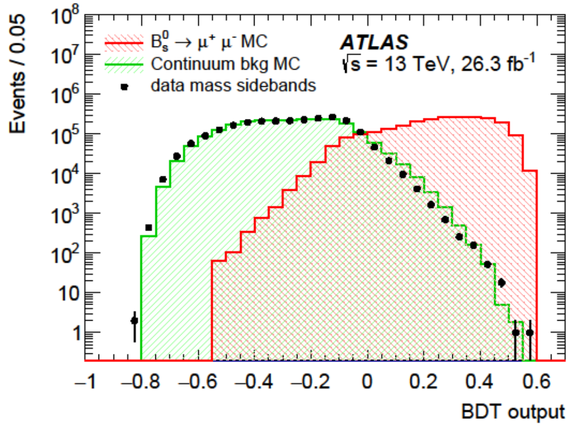
RARE DECAYS $B^0 \to \mu^+\mu^-$ AND $B_s^0 \to \mu^+\mu^-$

- Partially reconstructed b–hadron decays mostly at lower di-muon mass
- Peaking background: $B^0_{(s)} \to hh'$ with h/h' being mis-identified as μ
- Continuum background: combinatorial background from μ of uncorrelated h decays; reduced with BDT







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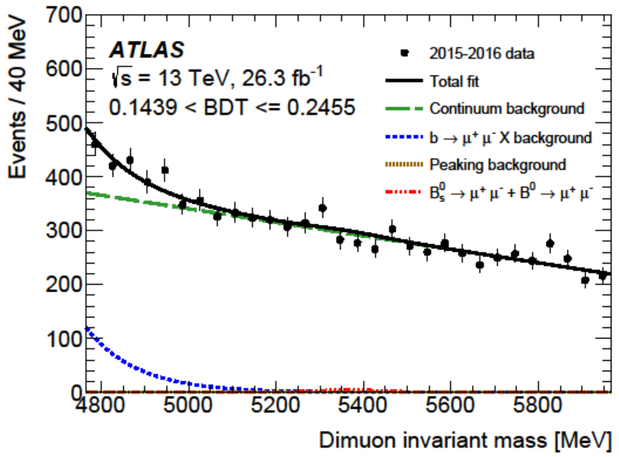
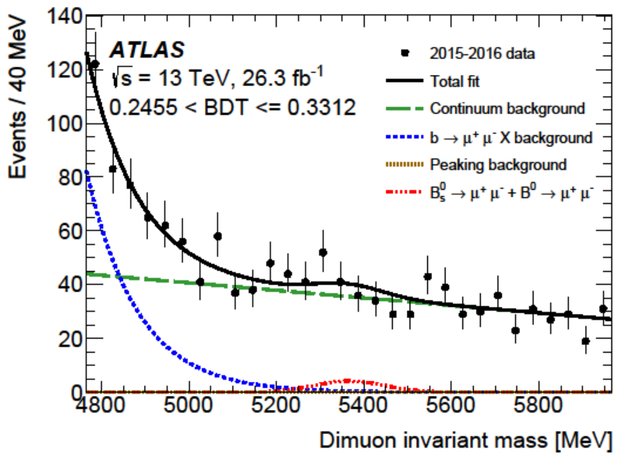
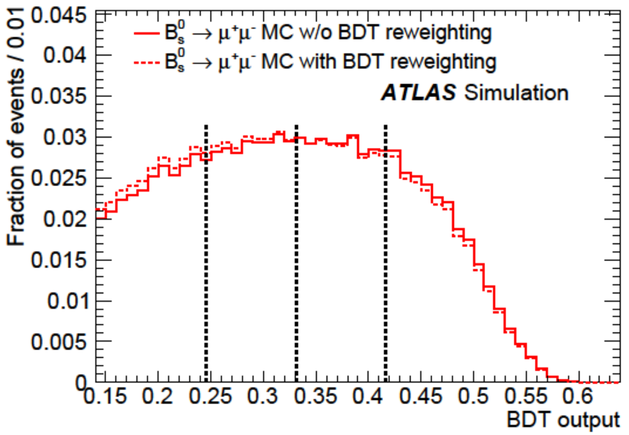
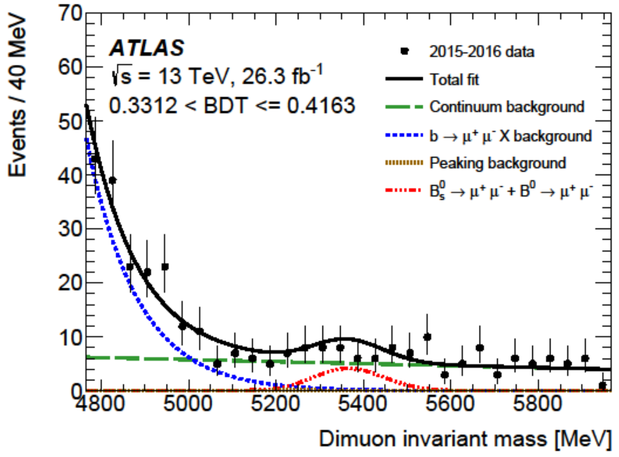
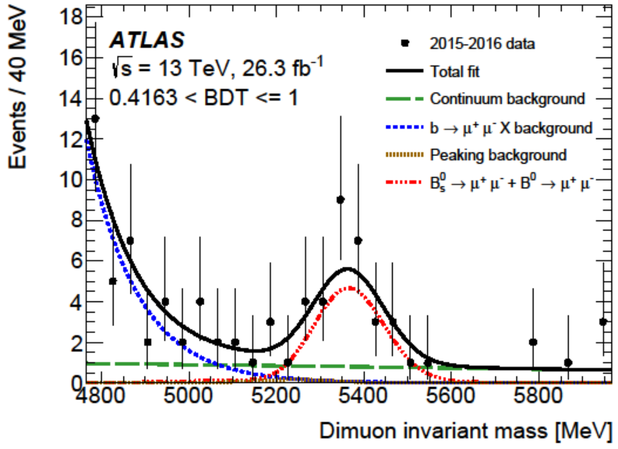
RARE DECAYS $B^0 \to \mu^+\mu^-$ AND $B_s^0 \to \mu^+\mu^-$











Simultaneous fit of $\mathcal{B}(B_s^0 \to \mu\mu)$ and $\mathcal{B}(B^0 \to \mu\mu)$ in 4 BDT intervals

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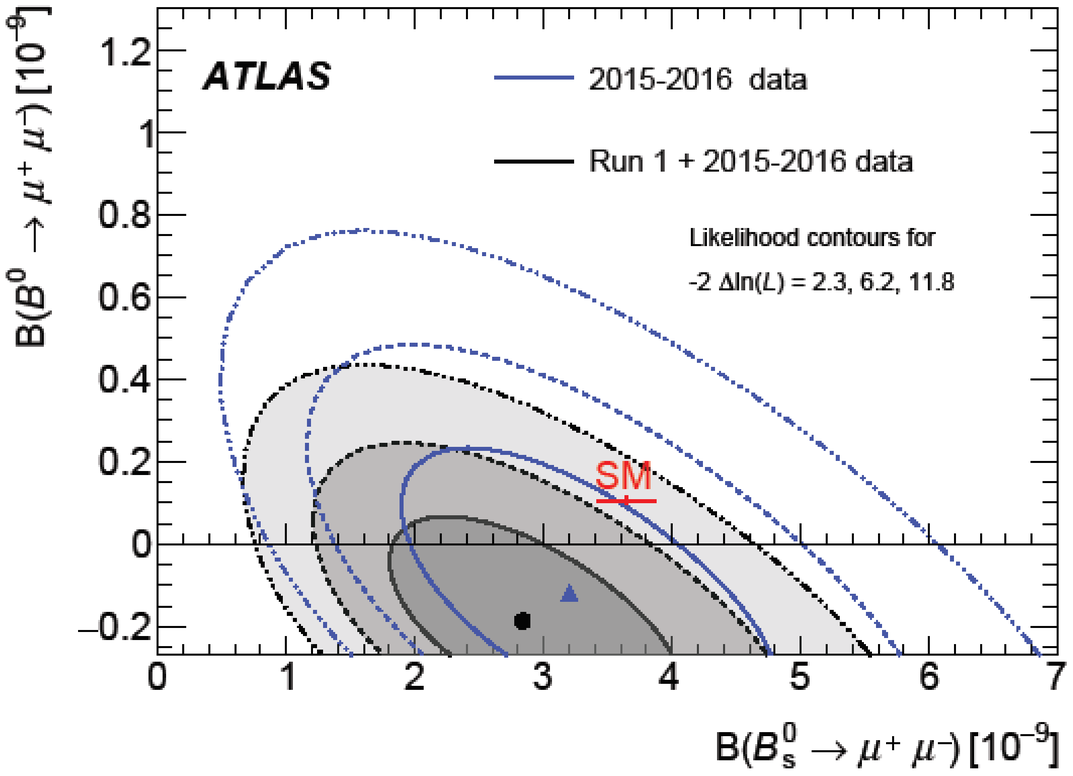
RARE DECAYS $B^0 \to \mu^+\mu^-$ AND $B_s^0 \to \mu^+\mu^-$



Standard Model

$\mathcal{B}(B_s^0 \to \mu\mu) = (3.65 \pm 0.23) \times 10^{-9}$

$\mathcal{B}(B^0 \to \mu\mu) = (1.06 \pm 0.09) \times 10^{-10}$

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)

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

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

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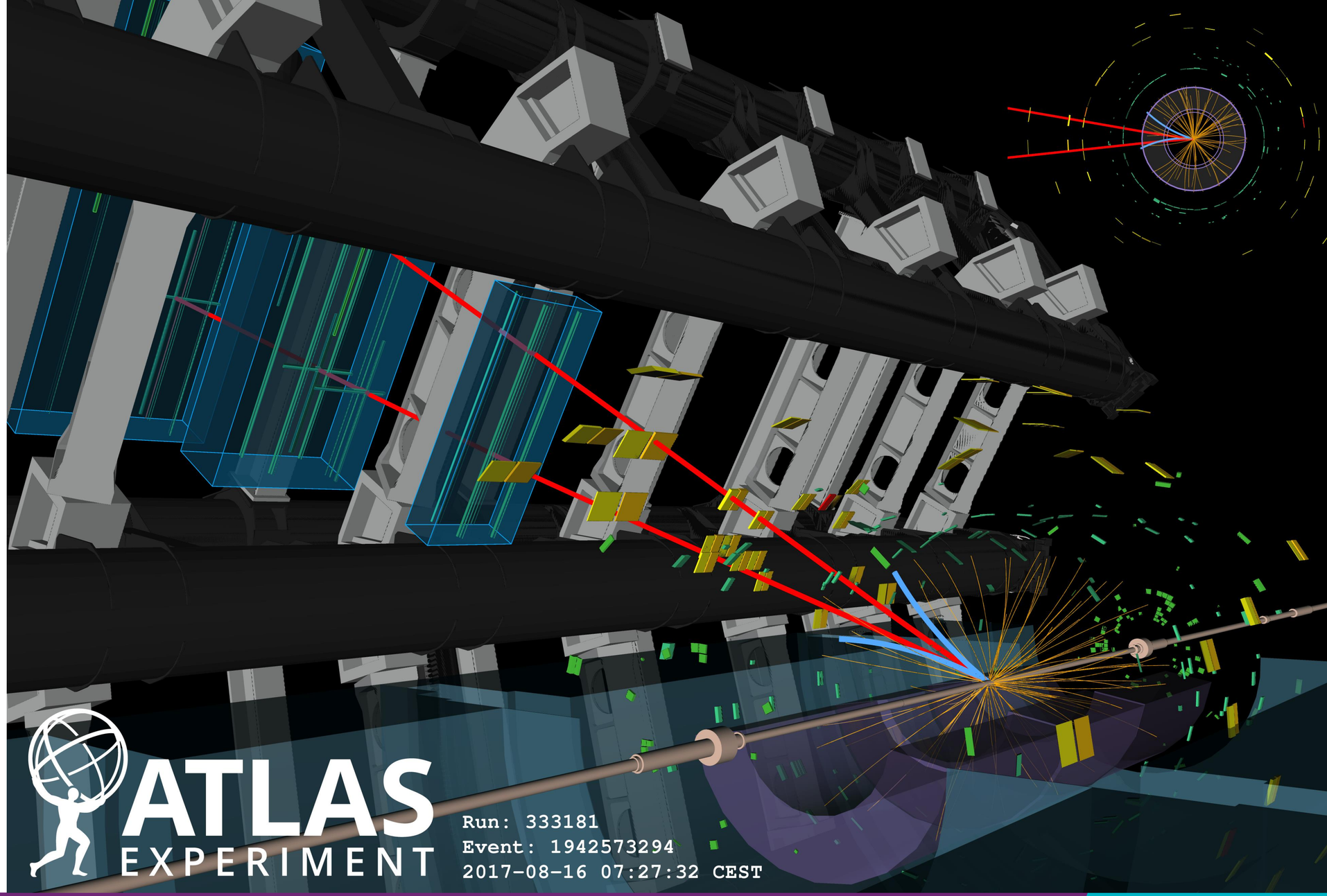
CP Violation in $B_s^0 \to J/\psi\phi$



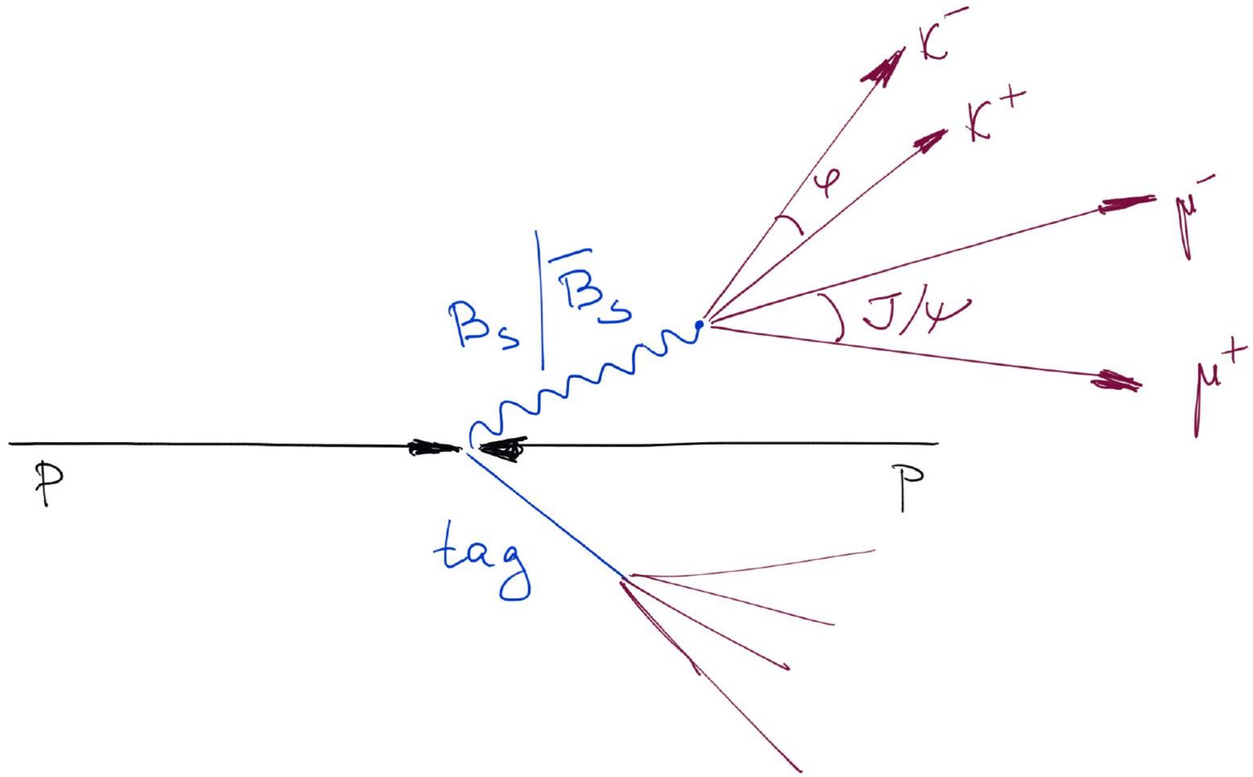
CP VIOLATION IN $B_s^0 \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$

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

$$\phi_s^{\mathrm{SM}} = -36.3^{+1.6}_{-1.5}\ \mathrm{mrad}$$

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

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



arXiv:2001.07115, sub. EPJC

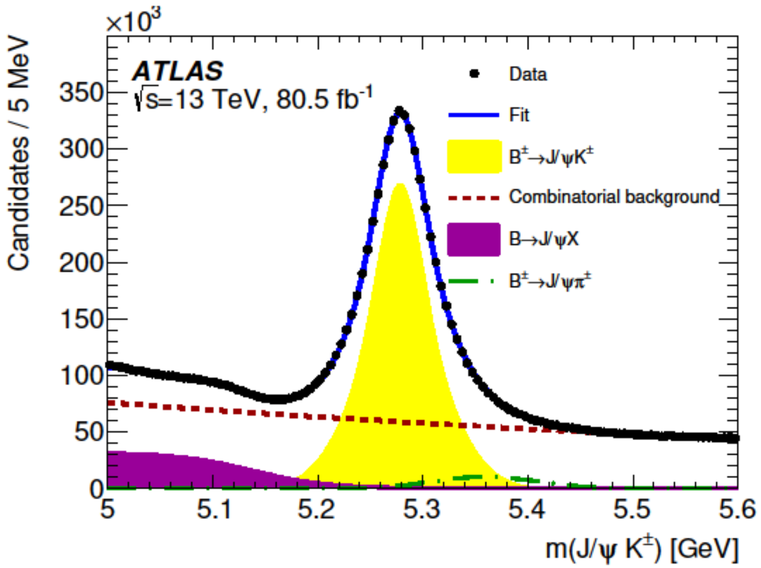
CP VIOLATION IN $B_s^0 \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$

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

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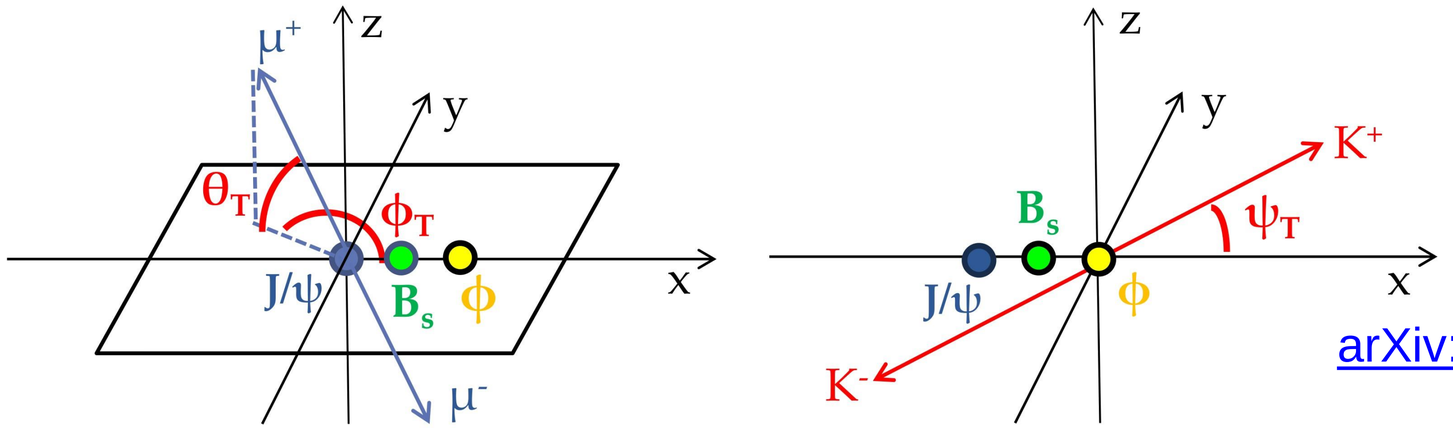
CP VIOLATION IN $B_s^0 \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$

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



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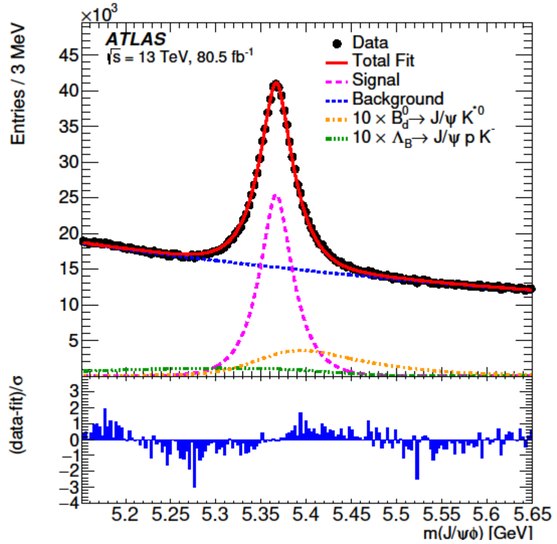

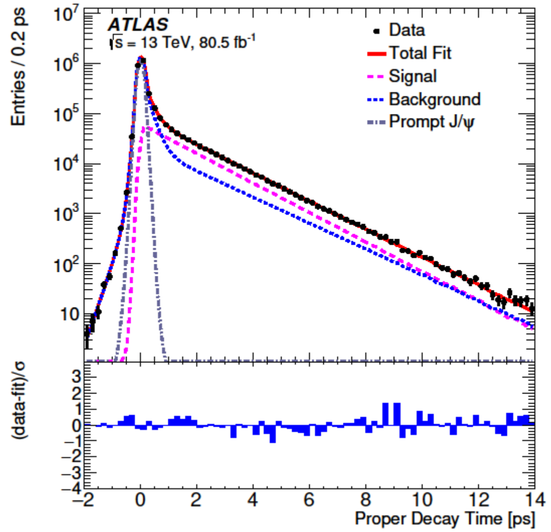

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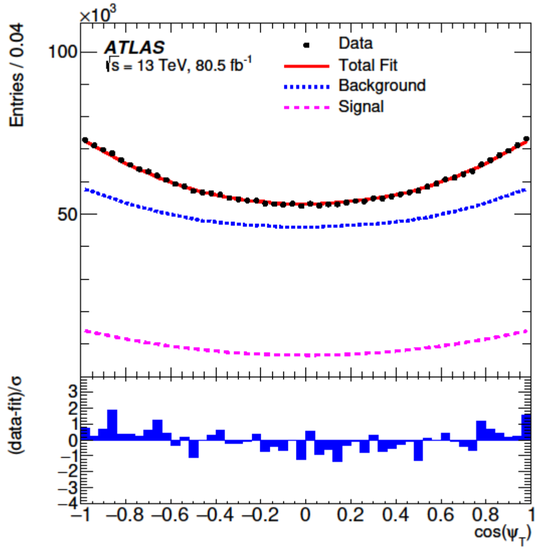
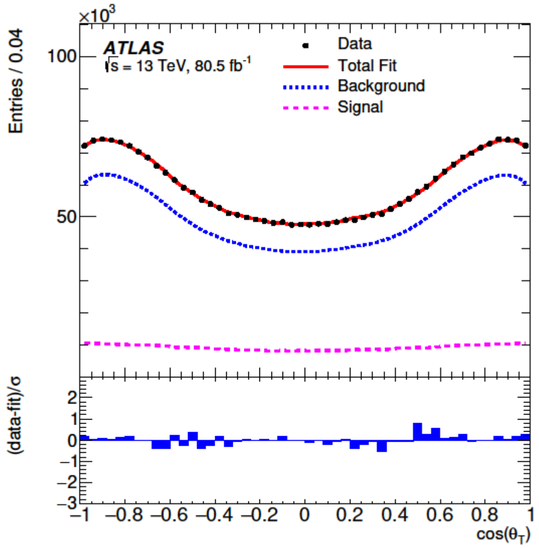
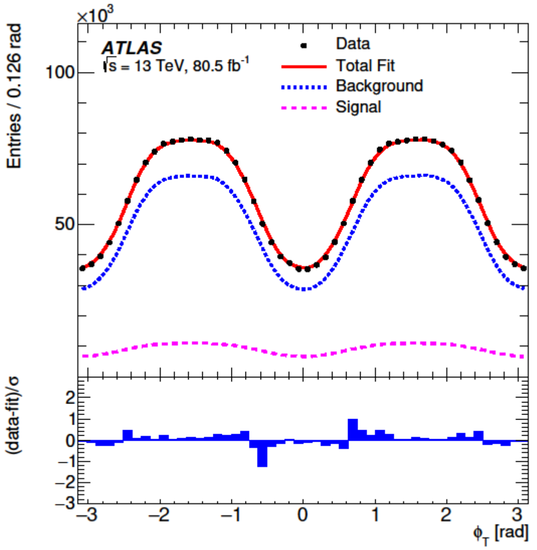




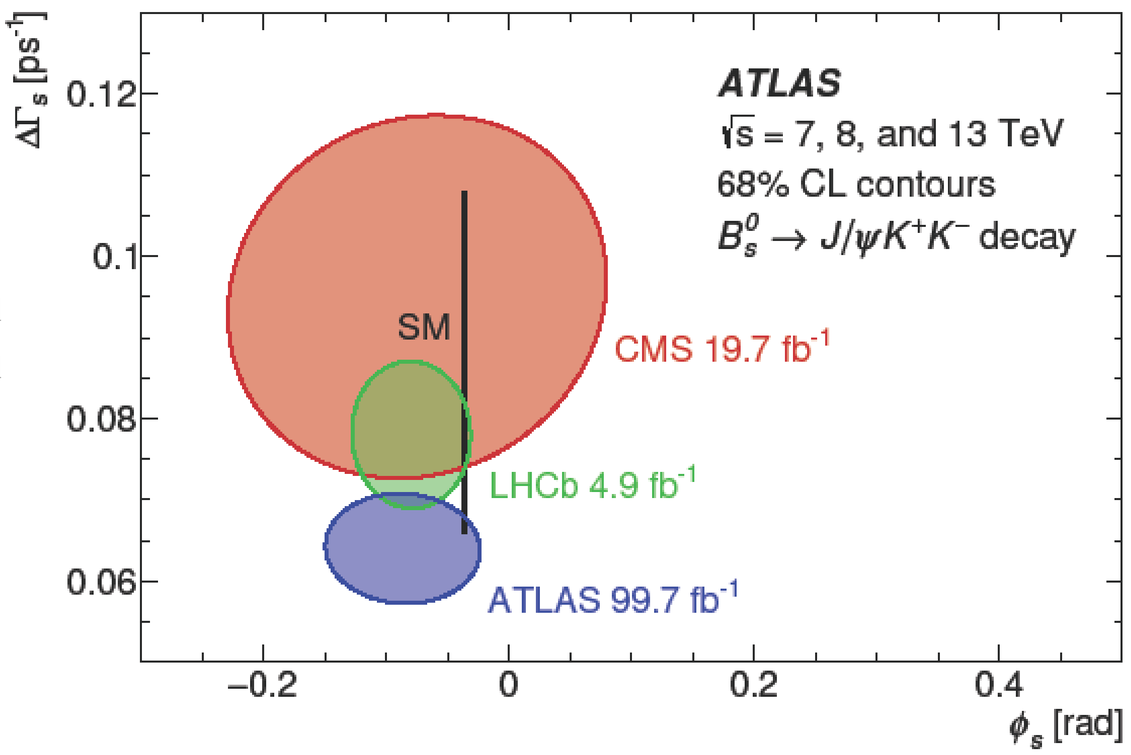


CP VIOLATION IN $B_s^0 \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$

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

Consistent with SM predictions

ϕ_s	=	-0.087	$\pm$	0.037	(stat.)	$\pm$	0.019	(syst.)	rad
$\Delta\Gamma_s$	=	0.0640	$\pm$	0.0042	(stat.)	$\pm$	0.0024	(syst.)	ps^{-1}
Γ_s	=	0.6698	$\pm$	0.0014	(stat.)	$\pm$	0.0015	(syst.)	ps^{-1}
$\lvert A_\parallel(0)\rvert^2$	=	0.2221	$\pm$	0.0018	(stat.)	$\pm$	0.0022	(syst.)	
$\lvert A_0(0)\rvert^2$	=	0.5149	$\pm$	0.0012	(stat.)	$\pm$	0.0031	(syst.)	
$\lvert A_S(0)\rvert^2$	=	0.0343	$\pm$	0.0032	(stat.)	$\pm$	0.0044	(syst.)	
$\delta_\perp$	=	3.21	$\pm$	0.10	(stat.)	$\pm$	0.05	(syst.)	rad
$\delta_\parallel$	=	3.36	$\pm$	0.05	(stat.)	$\pm$	0.08	(syst.)	rad
$\delta_\perp - \delta_S$	=	-0.24	$\pm$	0.05	(stat.)	$\pm$	0.02	(syst.)	rad



arXiv:2001.07115, sub. EPJC

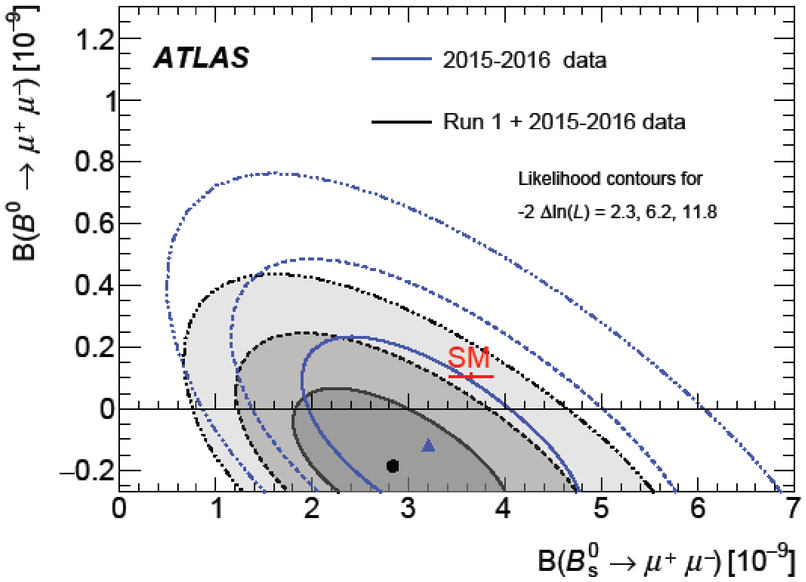
NB: Latest CMS results not included

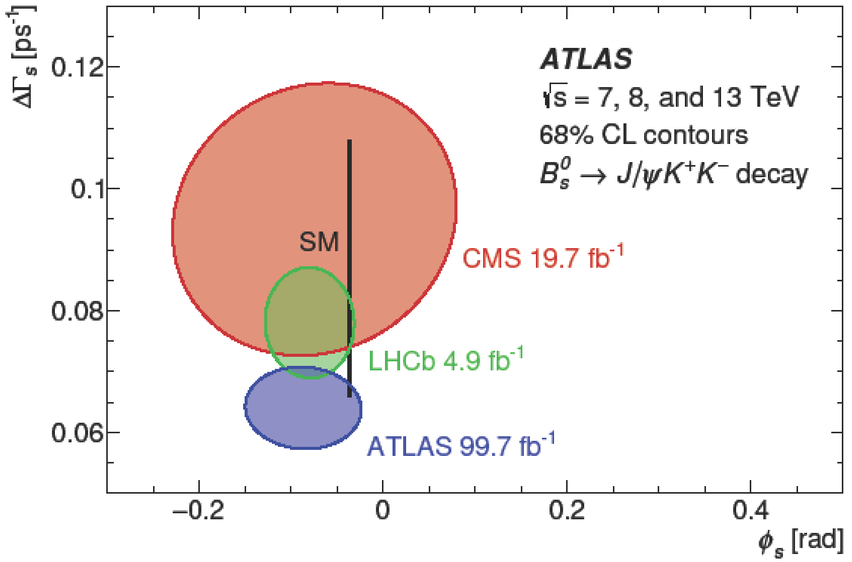
SUMMARY

ATLAS has performed studies of CP violation and rare decays in b mesons

- $B_s^0 \to \mu^+\mu^-$ with 2015-2016 data:
- Branching fraction consistent with SM expectations
- No sign of $B^0 \to \mu^+\mu^-$ observed

- Measurement of CP violating phase ϕ_s in $B_s^0 \to J/\psi\phi$ with 2015-2017 data set consistent with SM expectations





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

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

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

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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 $\Delta R < 0.5$

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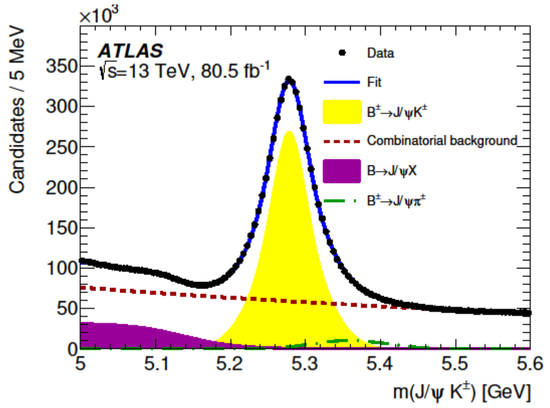

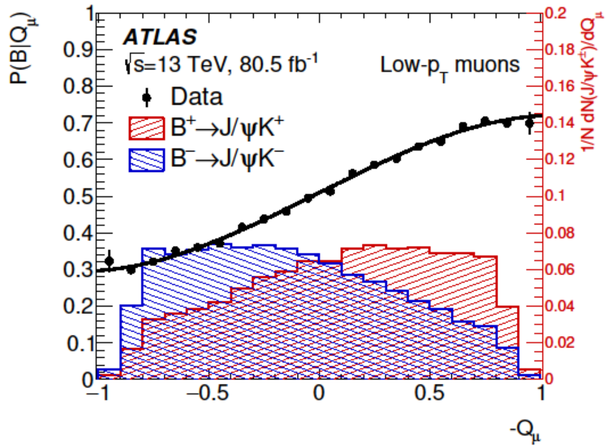

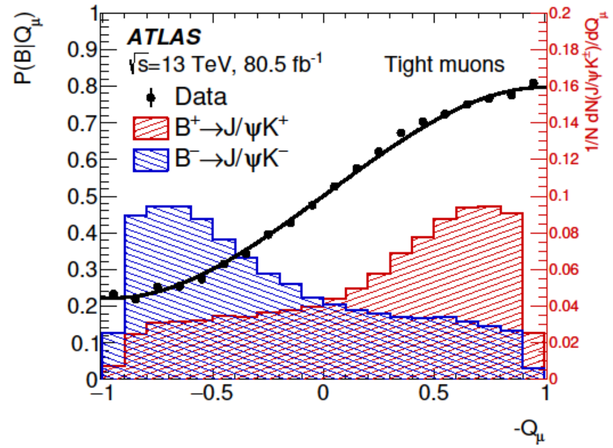

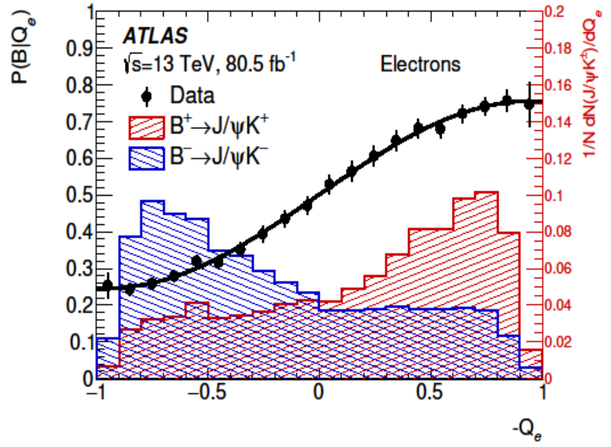

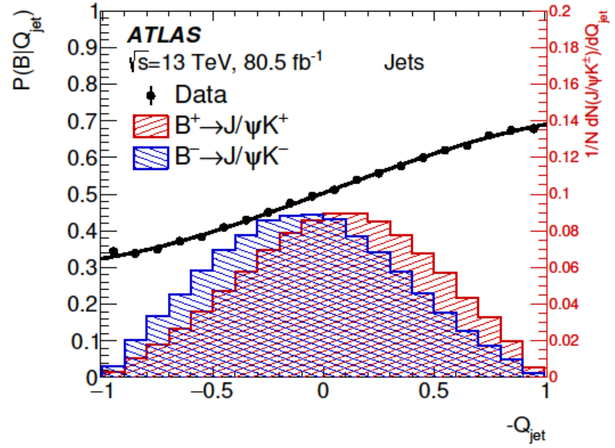

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