B-physics highlights from ATLAS and CMS

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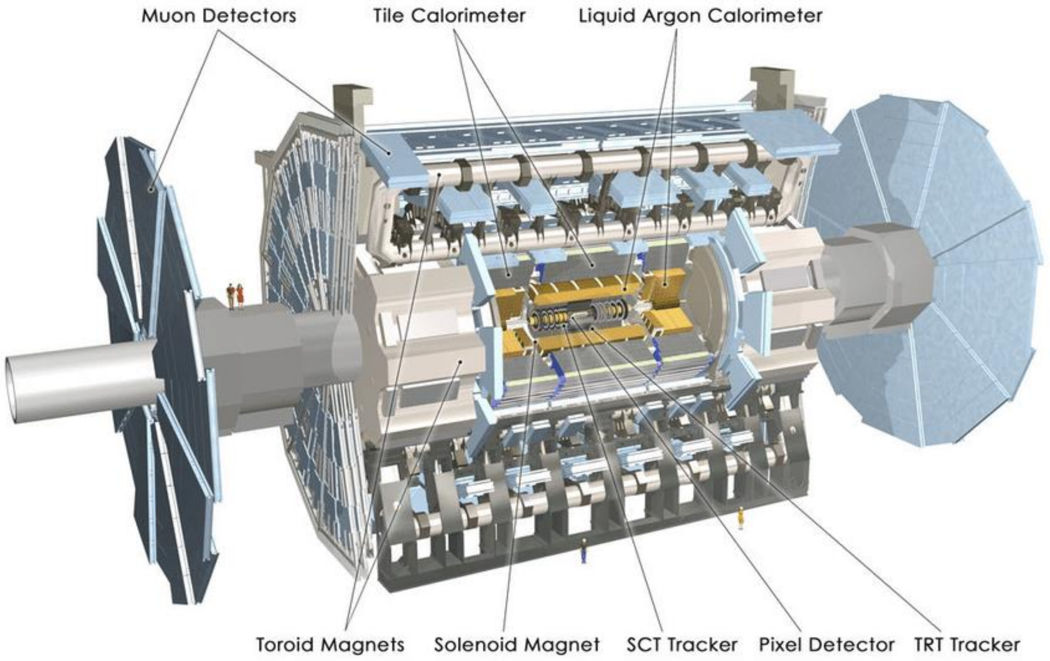
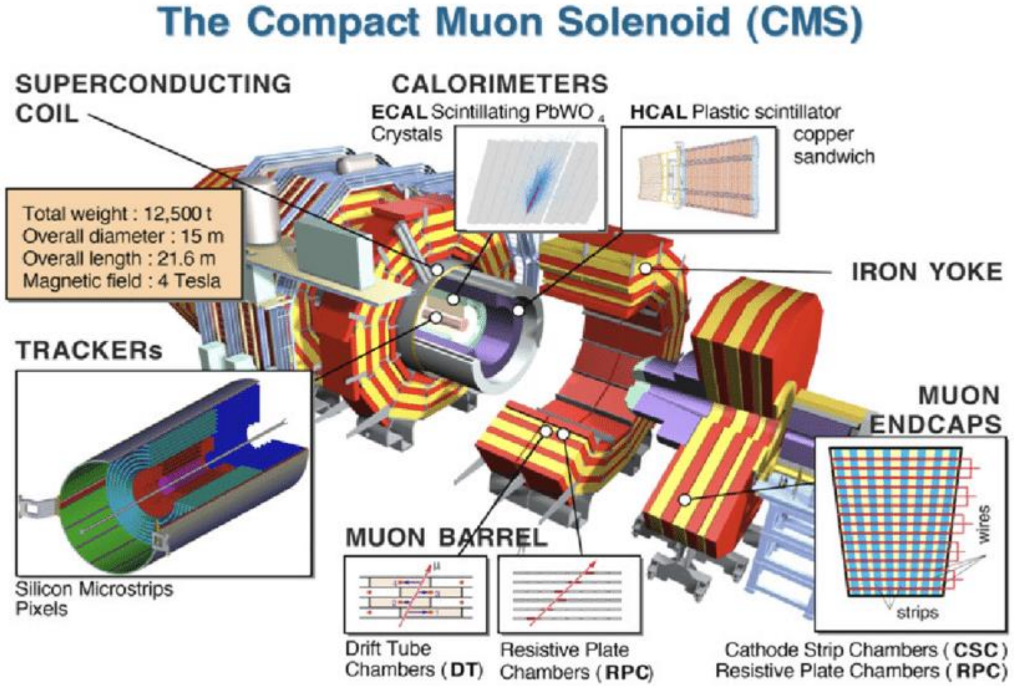
on **behalf on the ATLAS and CMS collaborations**

Moriond QCD 2023

Detectors



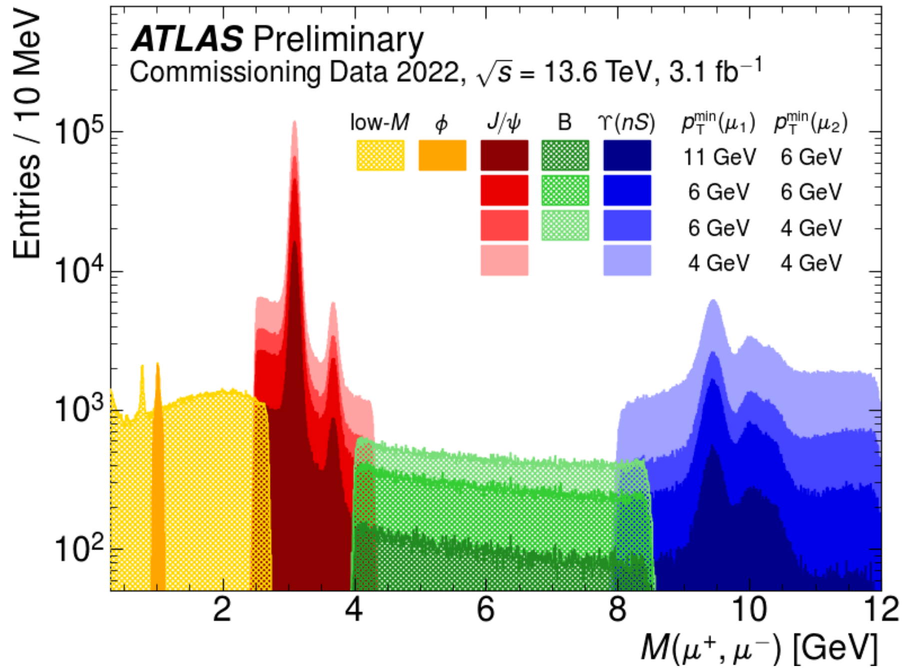


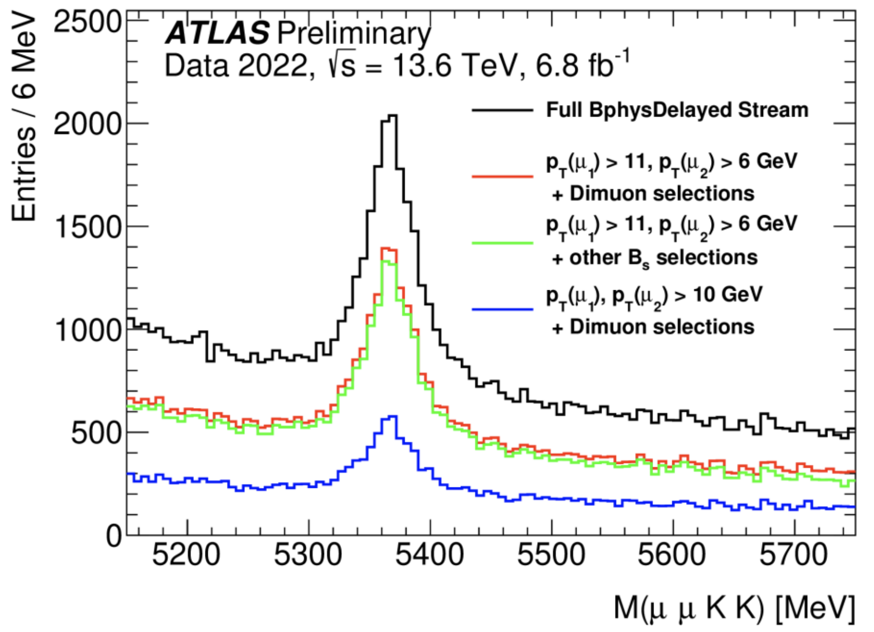
- Inner Detector: PIX, SCT and TRT, pT > 0.4 GeV, $|\eta| < 2.5$
- Run2: new IBL 25% improvement of time resolution with respect to Run1.
- Muon Spectrometer: triggering ($|\eta| < 2.4$), precision tracking ($|\eta| < 2.7$).
- B-physics: ~100 to 200 Hz trigger budget.

- CMS has a similar design with stronger magnetic field.
- Muon Spectrometer: triggering ($|\eta| < 2.1$), precision tracking ($|\eta| < 2.4$).
- B-physics: ~100Hz out of 1kHz total budget.

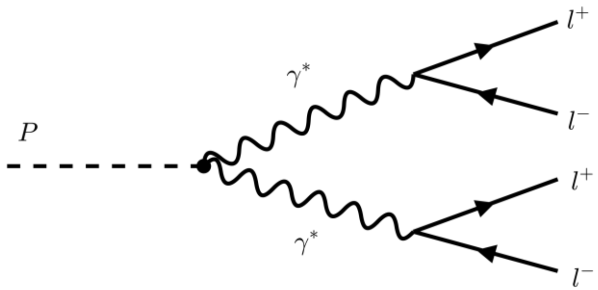
Data Collection

- Unlike LHCb, ATLAS and CMS operate our detector at high instantaneous luminosity without dilution and a lot of trigger bandwidths have been allocated to high-pT physics programs (e.g. Higgs, BSM searches).
- With higher luminosity we have increasing difficulties collecting low-pT events within the bandwidth budget.
- ATLAS introduced *topological* triggers to keep lower thresholds and stay within the bandwidth budget.





First observation of the rare 4μ decay of the η meson



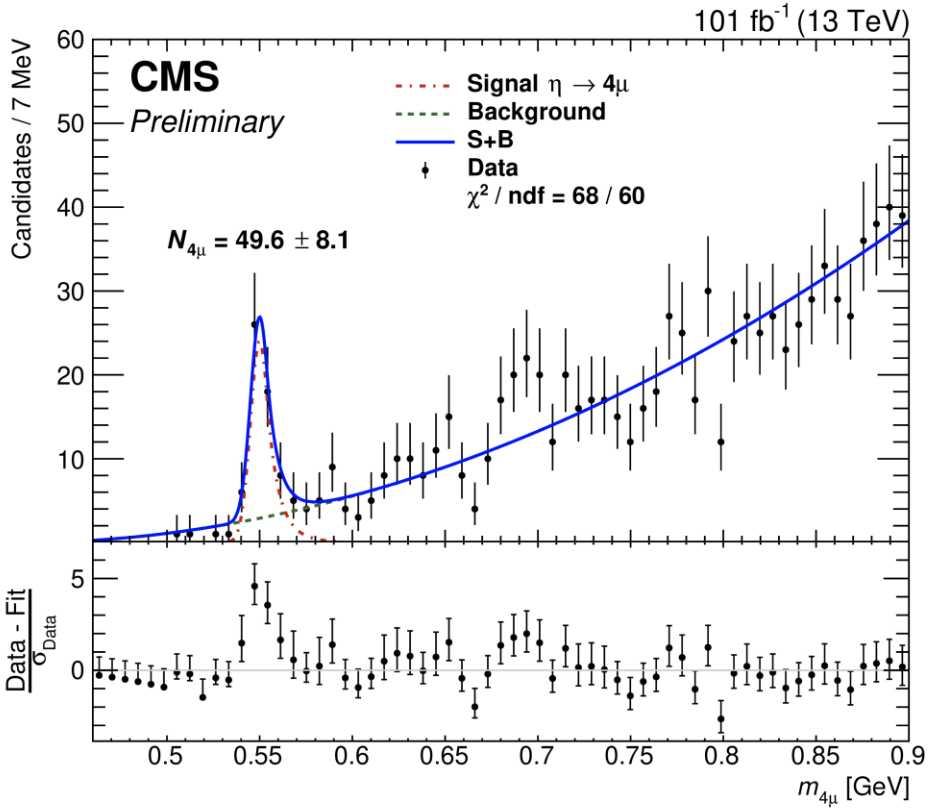
- 5 sigma+ observation of double-Dalitz decay $\eta \to \mu^+\mu^-\mu^+\mu^-$
- Data from high-rate low-pt muon triggers saving only HLT-level info, corresponding to 101 fb^{-1} (2017+2018).

$$\frac{\mathcal{B}_{4\mu}}{\mathcal{B}_{2\mu}} = (0.9 \pm 0.1\,(\text{stat}) \pm 0.1\,(\text{syst})) \times 10^{-3}$$

- Using world average:

$$\mathcal{B}(\eta \to 4\mu) = (5.0 \pm 0.8\,(\text{stat}) \pm 0.7\,(\text{syst}) \pm 0.7\,(\mathcal{B})) \times 10^{-9}$$

- Branching fraction is higher than predicted but within uncertainty.

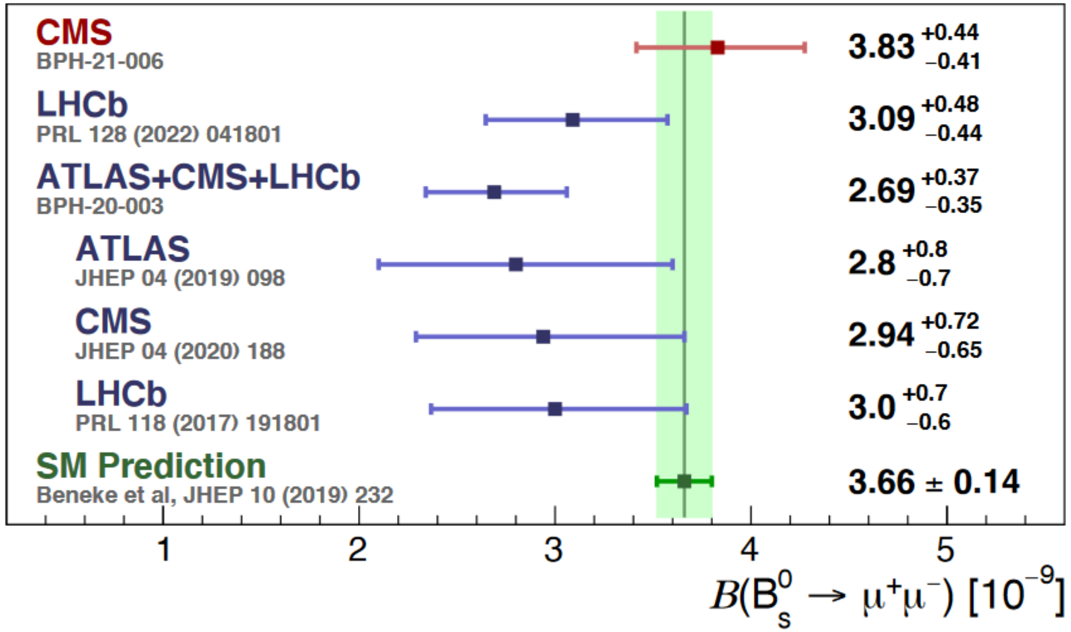


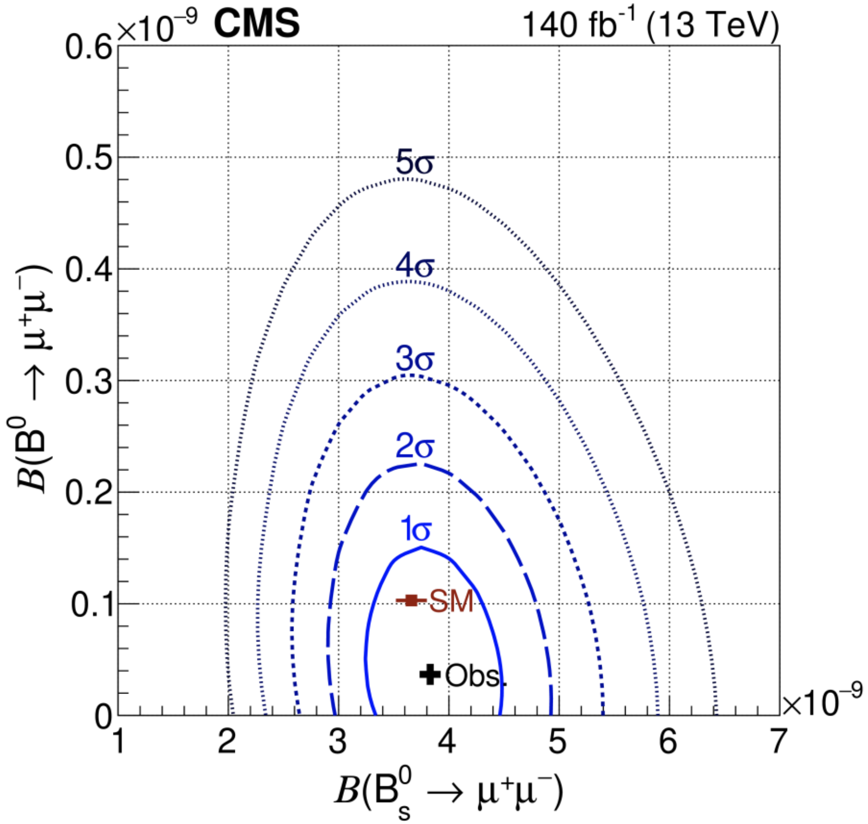
Measurement of the $B^0_s \to \mu^+\mu^-$ decay properties

- Integrated luminosity of 140fb^{-1}.
- The relative uncertainty is reduced from 23 to 11% compared with previous CMS measurement.

$$\mathcal{B}(B^0_s \to \mu^+\mu^-) = \left[3.83^{+0.38}_{-0.36}\,(\text{stat})\,^{+0.19}_{-0.16}\,(\text{syst})\,^{+0.14}_{-0.13}\,(f_s/f_u)\right] \times 10^{-9},$$

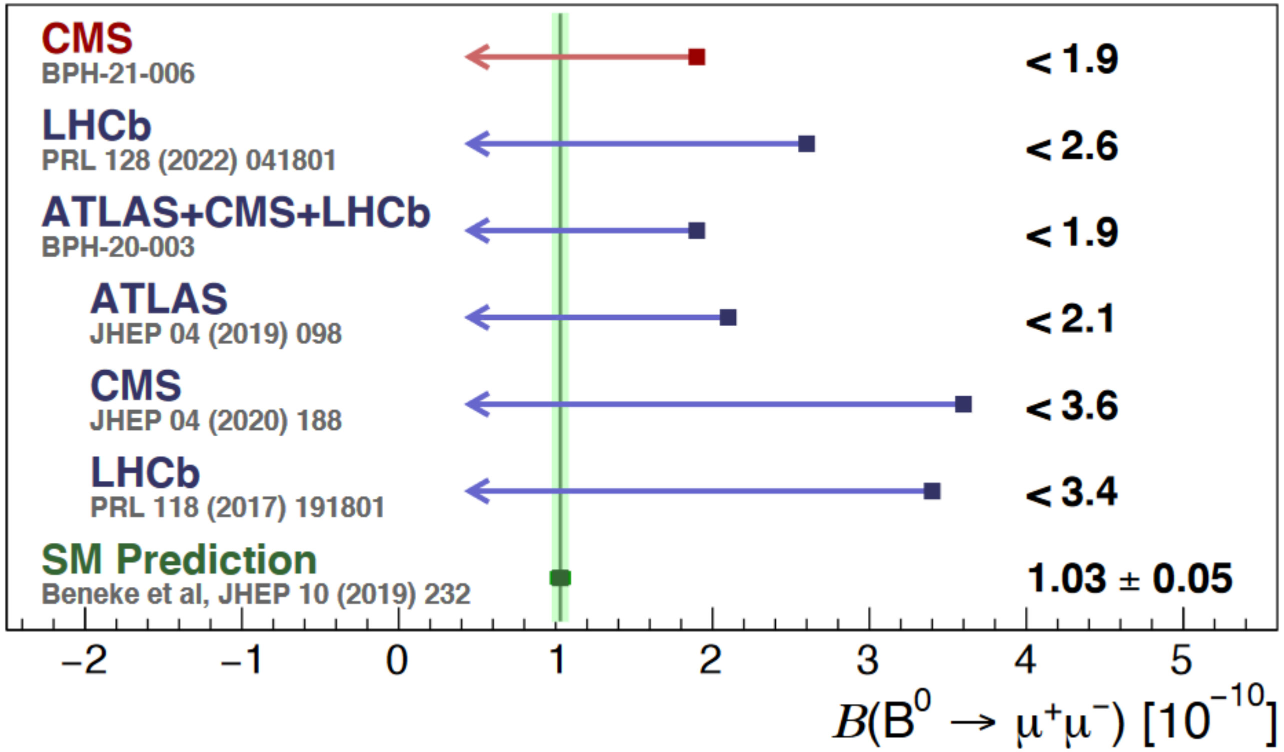
$$\tau = 1.83\,^{+0.23}_{-0.20}\,(\text{stat})\,^{+0.04}_{-0.04}\,(\text{syst})\,\text{ps}.$$

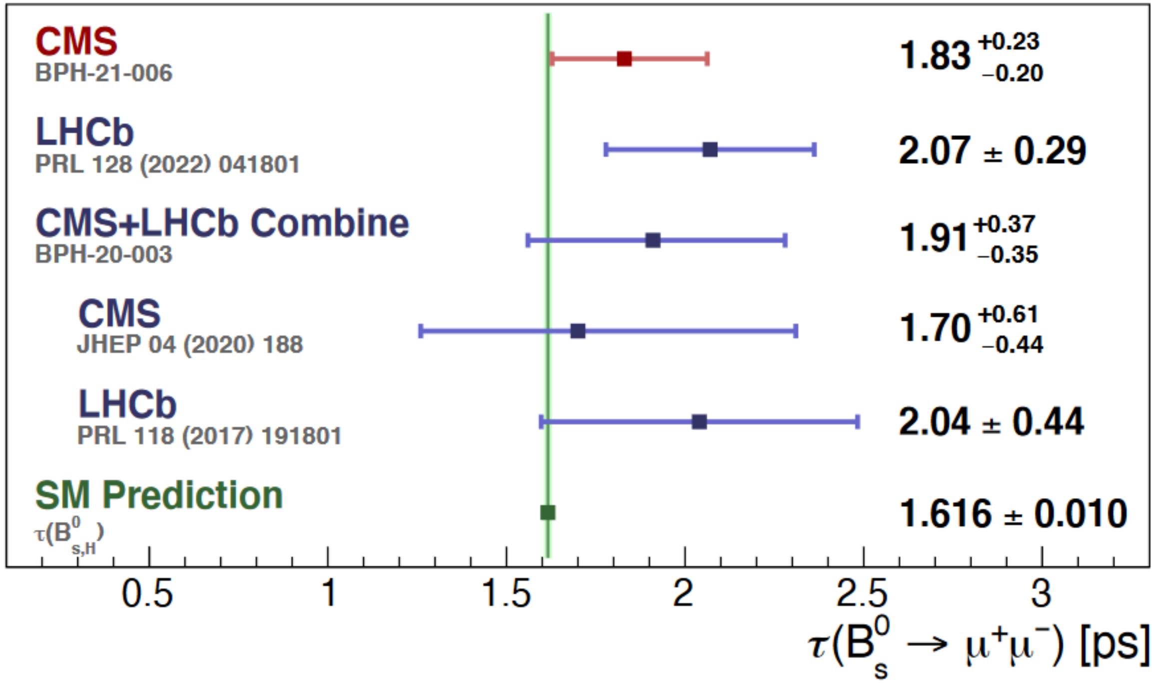




CMS is about 1.2 S.D. higher than LHCb
Some tension with previously combined result

Measurement of the $B^0_s \to \mu^+\mu^-$ decay properties

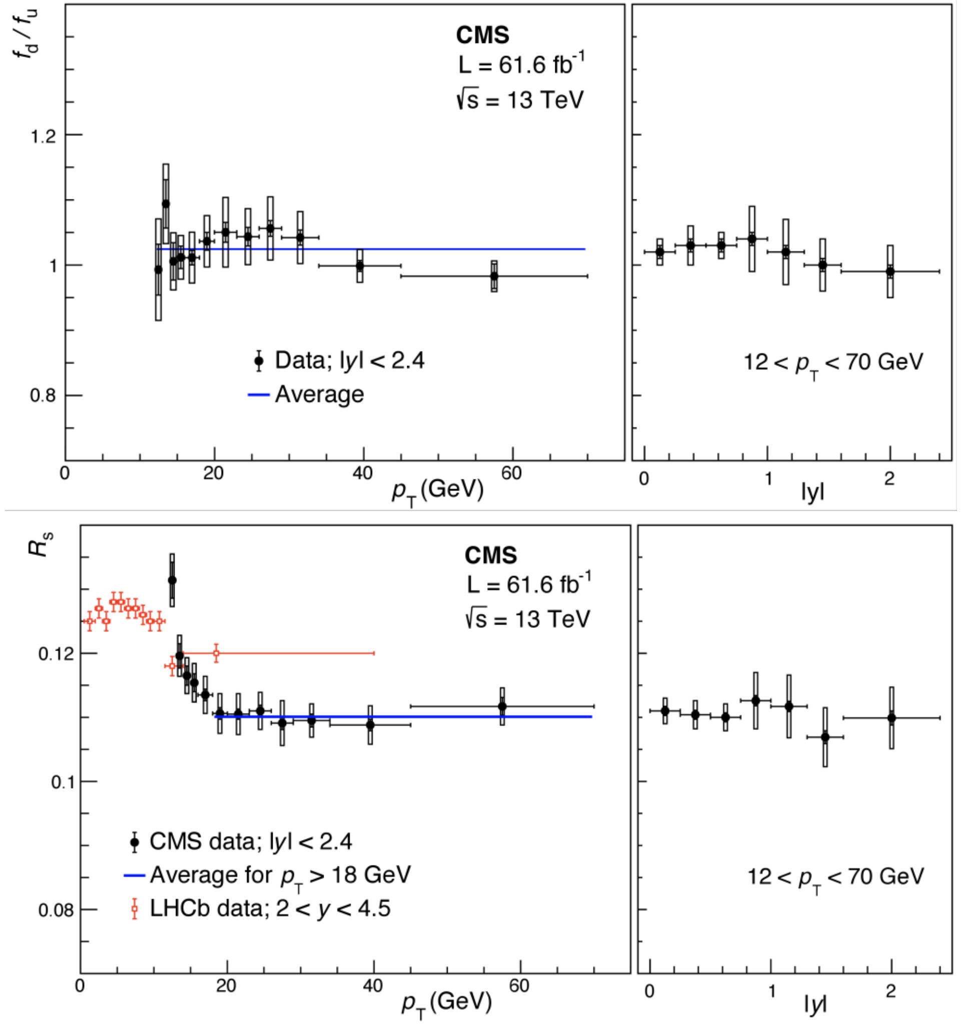




The main challenge with $B^0 \to \mu\mu$ is the combinatorial background.
It will require more data and analysis improvements to reach discovery level.

Measurement of the dependence of the hadron production fraction ratio f_s/f_u on B meson kinematic variables

- 2018 Data - an integrated luminosity of 61.6 fb^{-1}.
- The f_s/f_u ratio is observed to depend on the B p_T and to be consistent with becoming asymptotically constant at large p_T. Compatibly with unity.
- Efficiency-corrected yield ratio R, no significant rapidity dependence is observed but strong variation is observed in the 12 $<p_T<$ 18 GeV range, followed by a flat trend.



Observation of $B^0 \to \psi(2S)K^0_S\pi^+\pi^-$ and $B^0_s \to \psi(2S)K^0_S$ decays

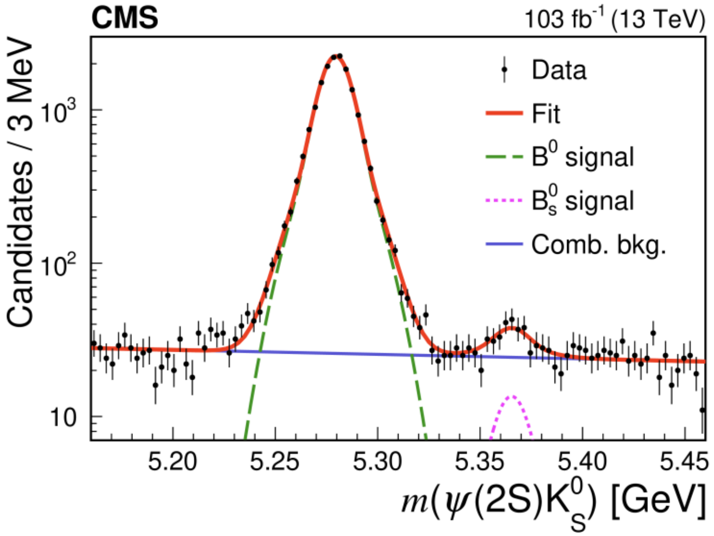
- Two decays are observed with > 5 S.D. with integrated luminosity of 103 fb^{-1}.
- Branching ratios measured for the first time:

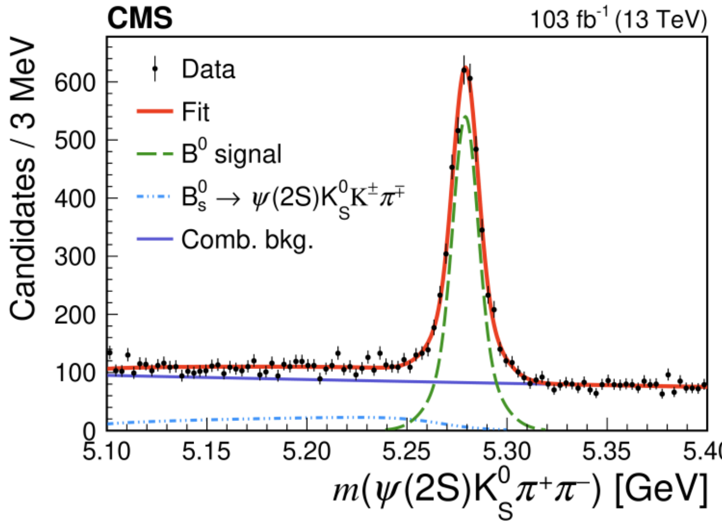
$$R_s = \frac{\mathcal{B}(B^0_s \to \psi(2S)K^0_S)}{\mathcal{B}(B^0 \to \psi(2S)K^0_S)} = (3.33 \pm 0.69\,(\text{stat}) \pm 0.11\,(\text{syst}) \pm 0.34\,(f_s/f_d)) \times 10^{-2}$$

$$R_s \frac{f_s}{f_d} = \frac{f_s}{f_d} \frac{\mathcal{B}(B^0_s \to \psi(2S)K^0_S)}{\mathcal{B}(B^0 \to \psi(2S)K^0_S)} = (0.69 \pm 0.14\,(\text{stat}) \pm 0.02\,(\text{syst})) \times 10^{-2}.$$

$$R_{\pi^+\pi^-} = \frac{\mathcal{B}(B^0 \to \psi(2S)K^0_S\pi^+\pi^-)}{\mathcal{B}(B^0 \to \psi(2S)K^0_S)} = 0.480 \pm 0.013\,(\text{stat}) \pm 0.032\,(\text{syst}).$$

- the observed decay can be used to study dynamics of the intermediate states of $B^0 \to \psi(2S)K^0_S\pi^+\pi^-$.





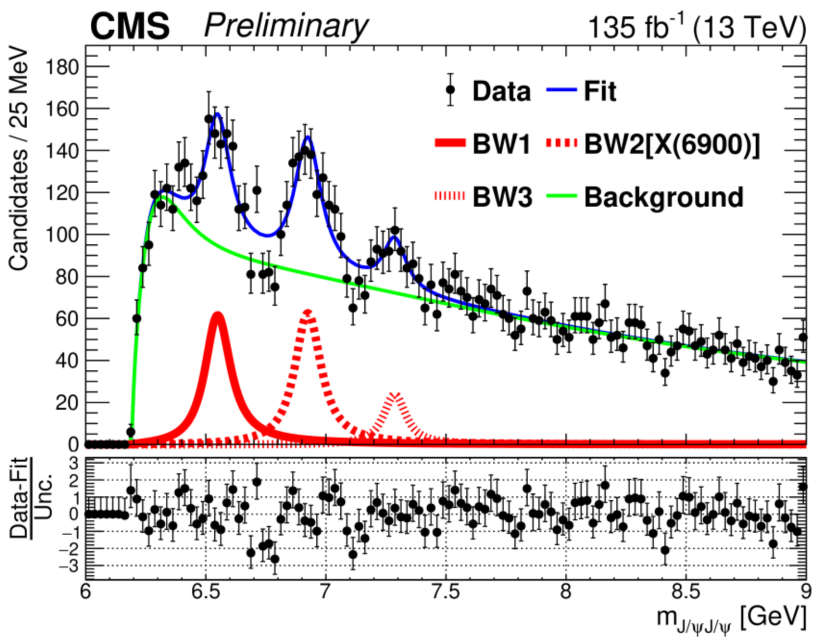
CMS-PAS-BPH-21-003

Coming Soon

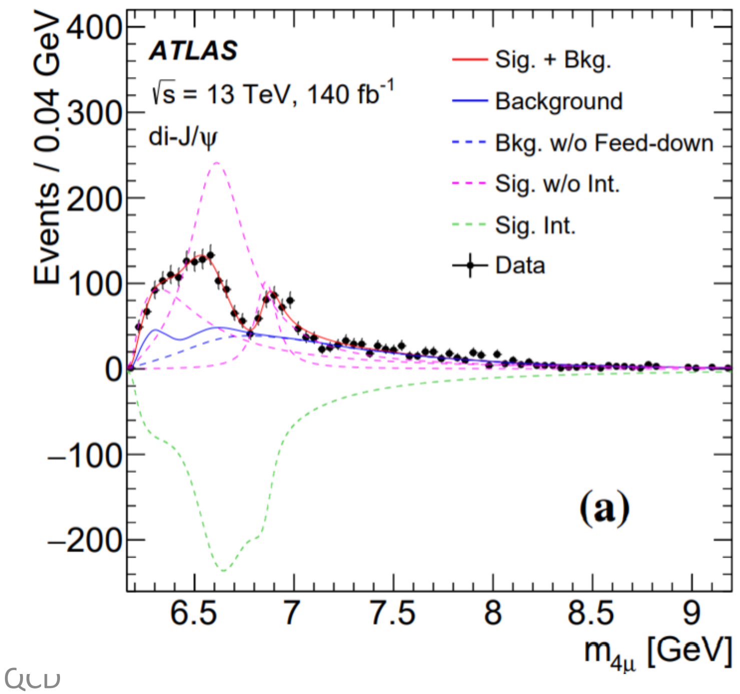
Observation of new structures in the J/ψ-J/ψ mass spectrum

- Studies were motivated by LHCb discovery of resonant-like signal X(6900) in di-J/ψ spectrum.
- Observation of the X (6900) structure is confirmed.

135 fb^{-1} recorded with the CMS



139 fb^{-1} recorded by ATLAS



CMS-PAS-BPH-21-003

Coming Soon

Observation of new structures in the J/ψ-J/ψ mass spectrum

CMS

	BW1	BW2	BW3
m	$6552 \pm 10 \pm 12$	$6927 \pm 9 \pm 5$	$7287 \pm 19 \pm 5$
Γ	$124 \pm 29 \pm 34$	$122 \pm 22 \pm 19$	$95 \pm 46 \pm 20$
N	474 ± 113	492 ± 75	156 ± 56

Exp.	Fit	m(BW1)	Γ(BW1)	m(6900)	Γ(6900)
LHCb [15]	Model I	unrep.	unrep.	$6905 \pm 11 \pm 7$	$80 \pm 19 \pm 33$
CMS	Model I	6550 ± 10	112 ± 27	6927 ± 10	117 ± 24
LHCb [15]	Model II	6741 ± 6	288 ± 16	$6886 \pm 11 \pm 11$	$168 \pm 33 \pm 69$
CMS	Model II	6736 ± 38	439 ± 65	6918 ± 10	187 ± 40

- Hint on the signal at 7.3GeV is more prominent in CMS data.
- Two LHCb models are fit and compared.
- Tension in amplitudes and widths of structures.
- Precise analysis of di-J/ψ spectrum (including angular information) is needed to shed light on structure of the threshold signals as well as exotic nature of X(6900) and X(7300) candidates.

ATLAS

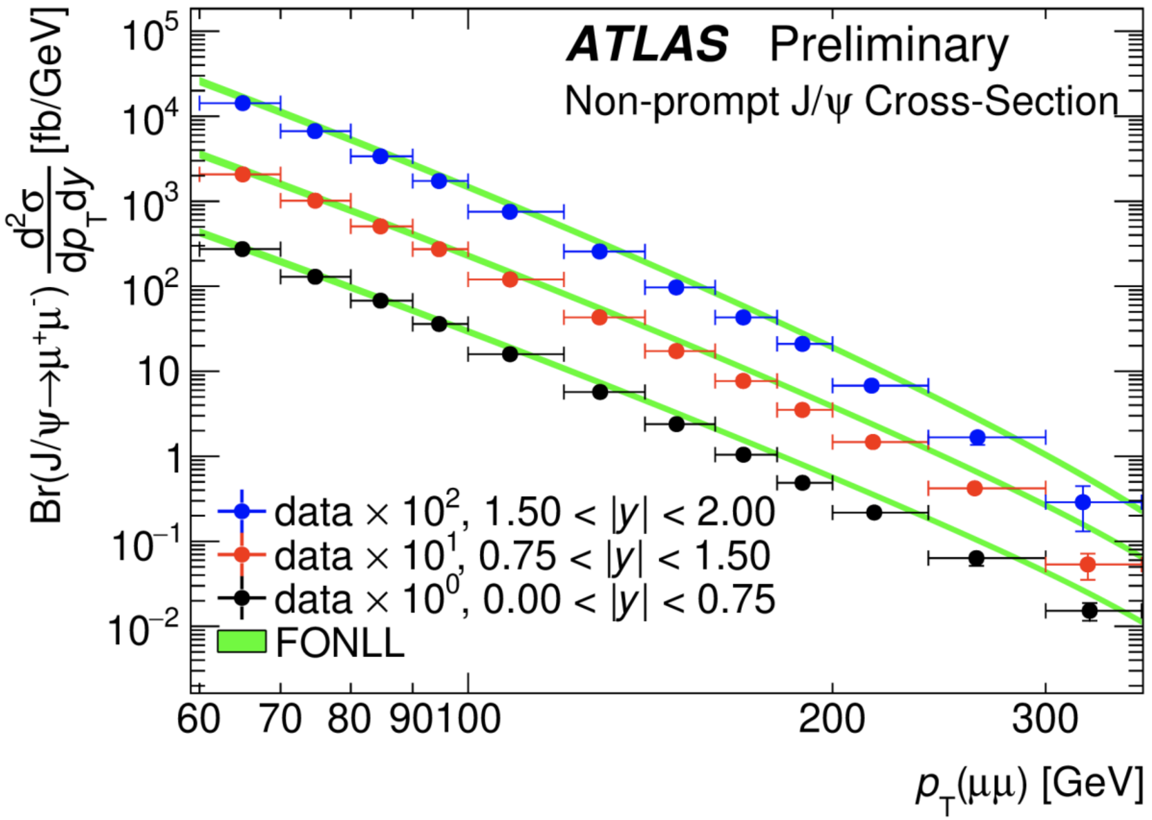
- Model A assumes that the same interfering resonances observed in the di-J/ψ channel also decay into J/ψ+ψ(2S).
- Model B assumes a single resonance in this channel.
- No interference between signal and the SPS di-charmonium background is assumed.
- In both channels, details of the lower-mass structure cannot be discerned directly from the data.
- More data are required to better characterize the excesses observed in both channels.

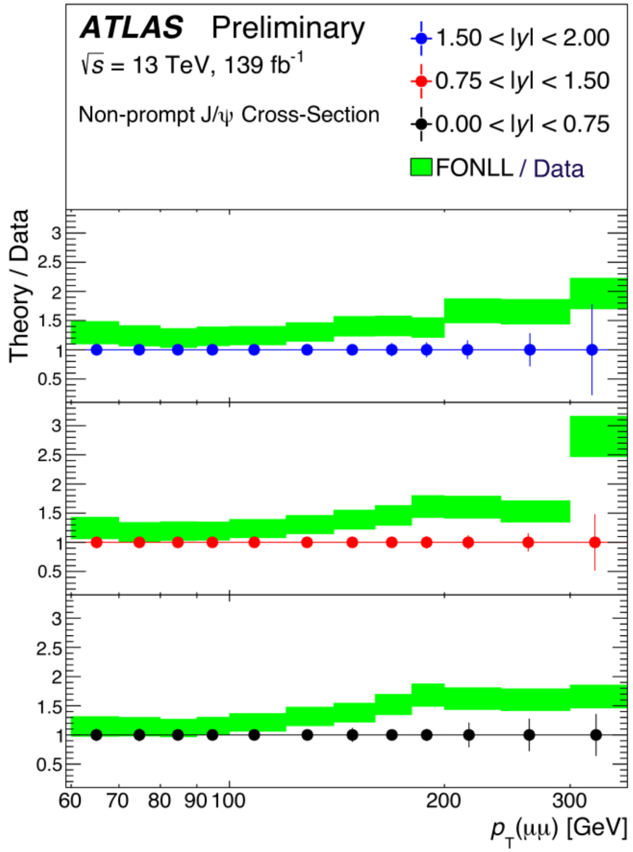
di-J/ψ	model A	model B
m_0	$6.41 \pm 0.08^{+0.08}_{-0.03}$	$6.65 \pm 0.02^{+0.03}_{-0.02}$
Γ_0	$0.59 \pm 0.35^{+0.12}_{-0.20}$	$0.44 \pm 0.05^{+0.06}_{-0.05}$
m_1	$6.63 \pm 0.05^{+0.08}_{-0.01}$	—
Γ_1	$0.35 \pm 0.11^{+0.11}_{-0.04}$	
m_2	$6.86 \pm 0.03^{+0.01}_{-0.02}$	$6.91 \pm 0.01 \pm 0.01$
Γ_2	$0.11 \pm 0.05^{+0.02}_{-0.01}$	$0.15 \pm 0.03 \pm 0.01$
$\Delta s/s$	$\pm 5.1\%^{+8.1\%}_{-8.9\%}$	—
$J/\psi+\psi(2S)$	model α	model β
m_3 or m	$7.22 \pm 0.03^{+0.01}_{-0.03}$	$6.96 \pm 0.05 \pm 0.03$
Γ_3 or Γ	$0.09 \pm 0.06^{+0.06}_{-0.03}$	$0.51 \pm 0.17^{+0.11}_{-0.10}$
$\Delta s/s$	$\pm 21\% \pm 14\%$	$\pm 20\% \pm 12\%$

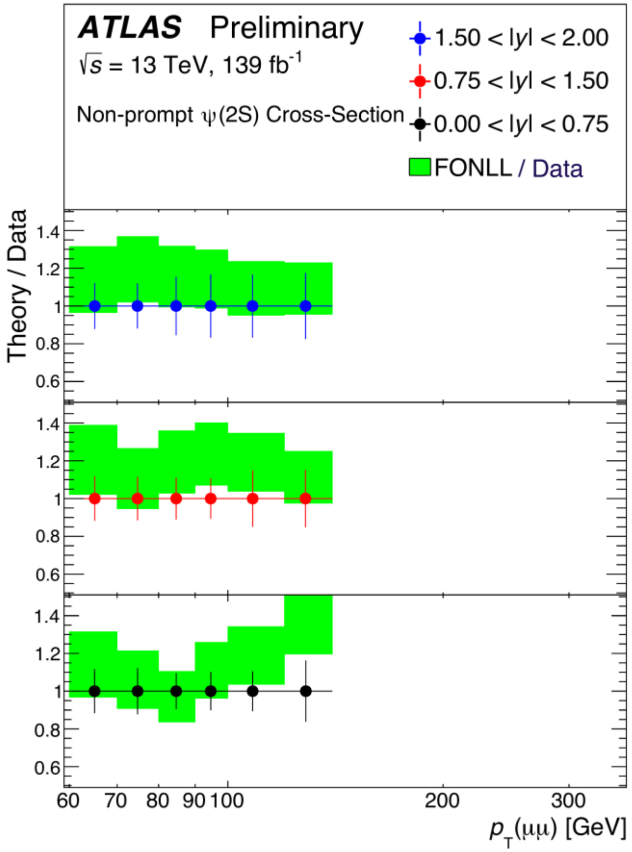
ATLAS-CONF-2019-047

Measurement of the production cross-section of J/ψ and $\psi(2S)$ mesons

Full Run 2 dataset at 13 TeV







overlaid with FONLL predictions.

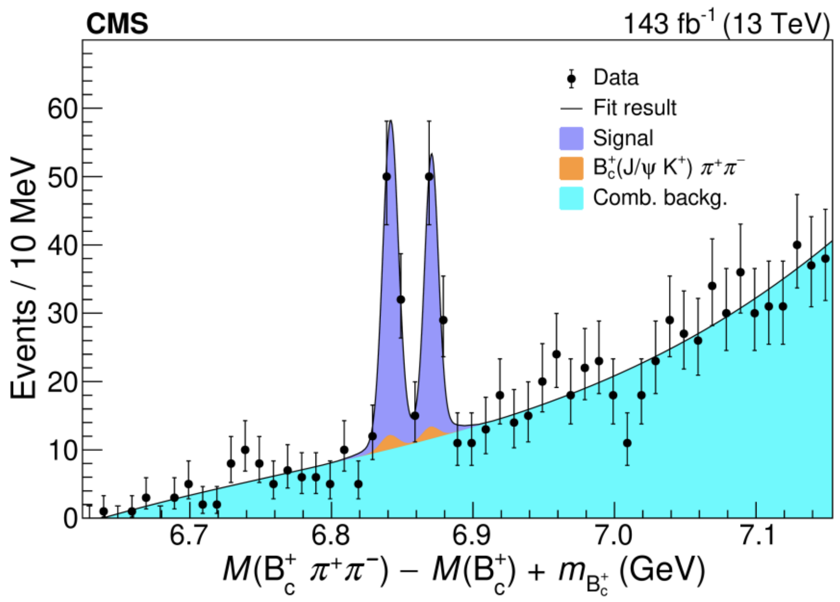
Comparison of various models with the data points

Non-prompt good agreement with Fixed-order-next-to-leading-log

[Phys. Rev. D 102 (2020) 092007]

[JHEP 08 (2022) 087]

B_c results from ATLAS and CMS



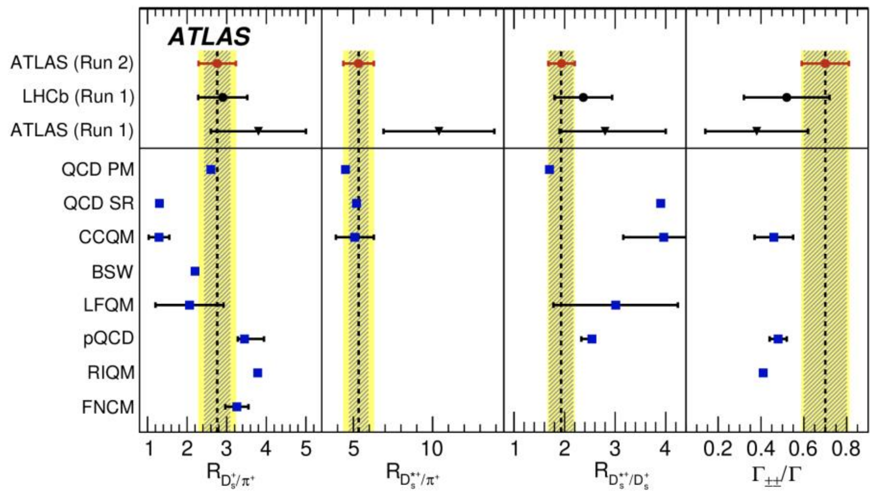
Measurement of $B_c(2S)^+$ and $B^*_c(2S)^+$ cross section ratios

$$R^+ = (3.47 \pm 0.63\,(\text{stat}) \pm 0.33\,(\text{syst}))\%,$$
$$R^{*+} = (4.69 \pm 0.71\,(\text{stat}) \pm 0.56\,(\text{syst}))\%,$$
$$R^{*+}/R^+ = 1.35 \pm 0.32\,(\text{stat}) \pm 0.09\,(\text{syst}).$$

No significant dependences on the transverse momentum pT or rapidity.

Bc pT > 15 GeV and |y| < 2.4 may provide new important input to improve the theoretical understanding of the nature of the b-bar$_c$ heavy quarkonium states and their production processes.

Study of $B^+_c \to J/\psi D^+_s$ and $B^+_c \to J/\psi D^{*+}_s$

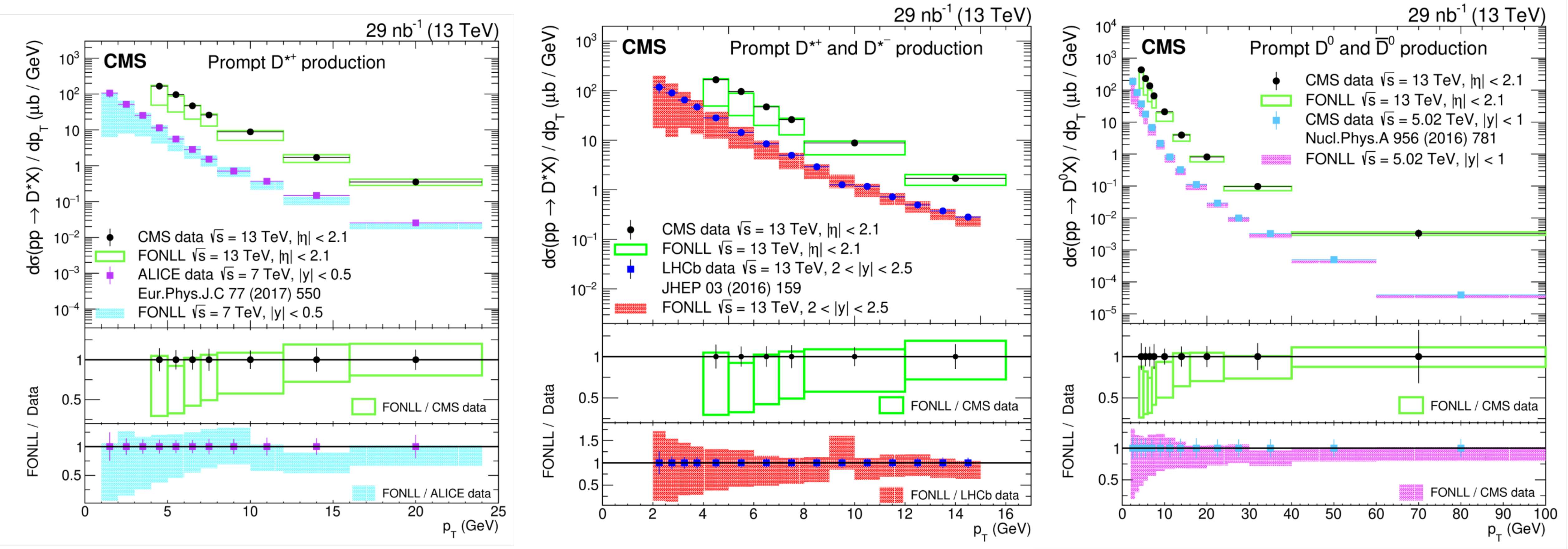


- New results consistent with earlier measurements.
- Using entire Run 2 dataset: aiming at more precise measurement of branching fractions and the final state polarization.
- QCD PM agrees very well while others deviate in some cases or lack precision.

JHEP 11 (2021) 225

Prompt open-charm production cross sections

Quick selection of plots - **see paper for more results**



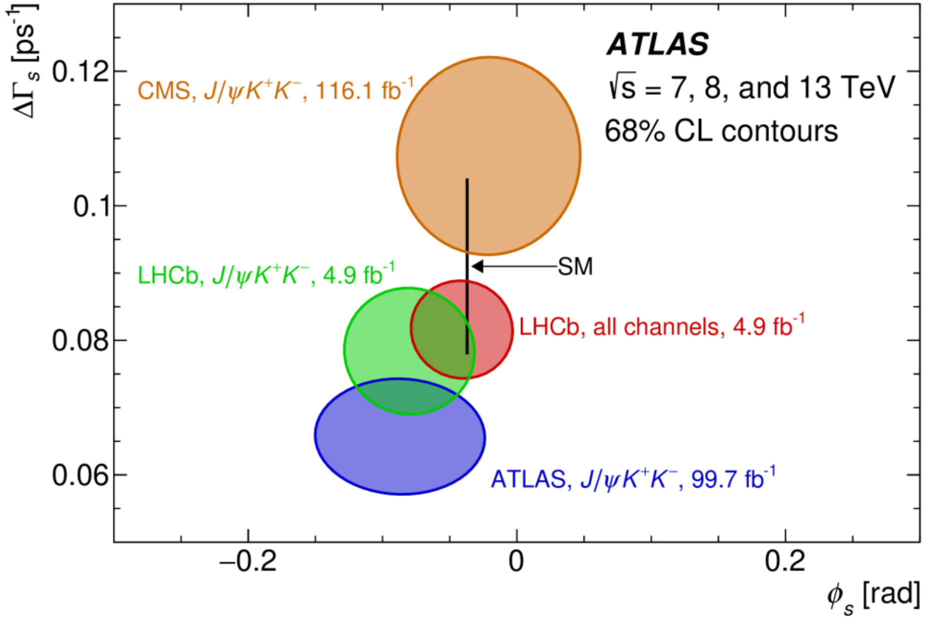
All models show good agreement – but no single model describes everything perfectly.

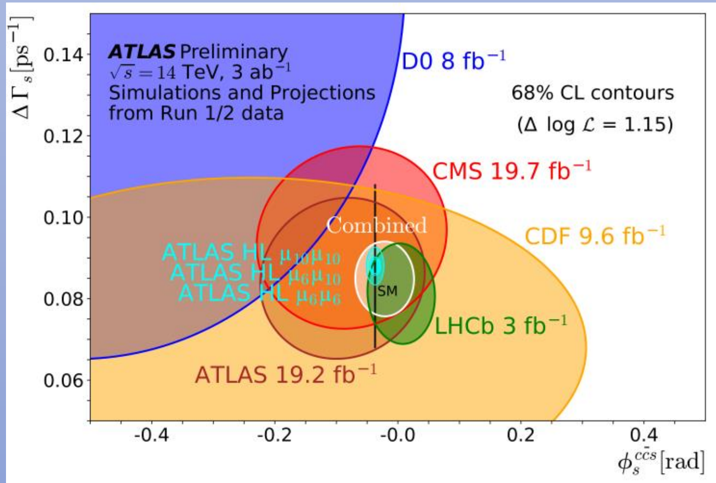
[Eur. Phys. J. C 81 (2021) 342]

$B_s \rightarrow J/\psi\phi$ Combination Run2 + 1

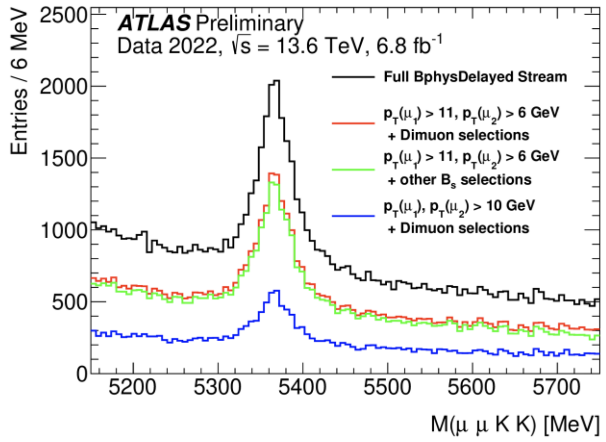
- Used to measure CP-violation phase potentially sensitive to New Physics.
- Time dependent angular maximum-likelihood fit.
- Published with Run1 to 2017 data. Ongoing Full Run 2 analysis.

Parameter	Value	Statistical uncertainty	Systematic uncertainty
ϕ_s [rad]	−0.081	0.041	0.022
$\Delta\Gamma_s$ [ps^{-1}]	0.0607	0.0047	0.0043
Γ_s [ps^{-1}]	0.6687	0.0015	0.0022
$\|A_\parallel(0)\|^2$	0.2213	0.0019	0.0023
$\|A_0(0)\|^2$	0.5131	0.0013	0.0038
$\|A_S(0)\|^2$	0.0321	0.0033	0.0046
$\delta_\perp - \delta_S$ [rad]	−0.25	0.05	0.04
Solution (a)			
$\delta_\perp$ [rad]	3.12	0.11	0.06
$\delta_\parallel$ [rad]	3.35	0.05	0.09
Solution (b)			
$\delta_\perp$ [rad]	2.91	0.11	0.06
$\delta_\parallel$ [rad]	2.94	0.05	0.09





Estimates for High Luminosity LHC



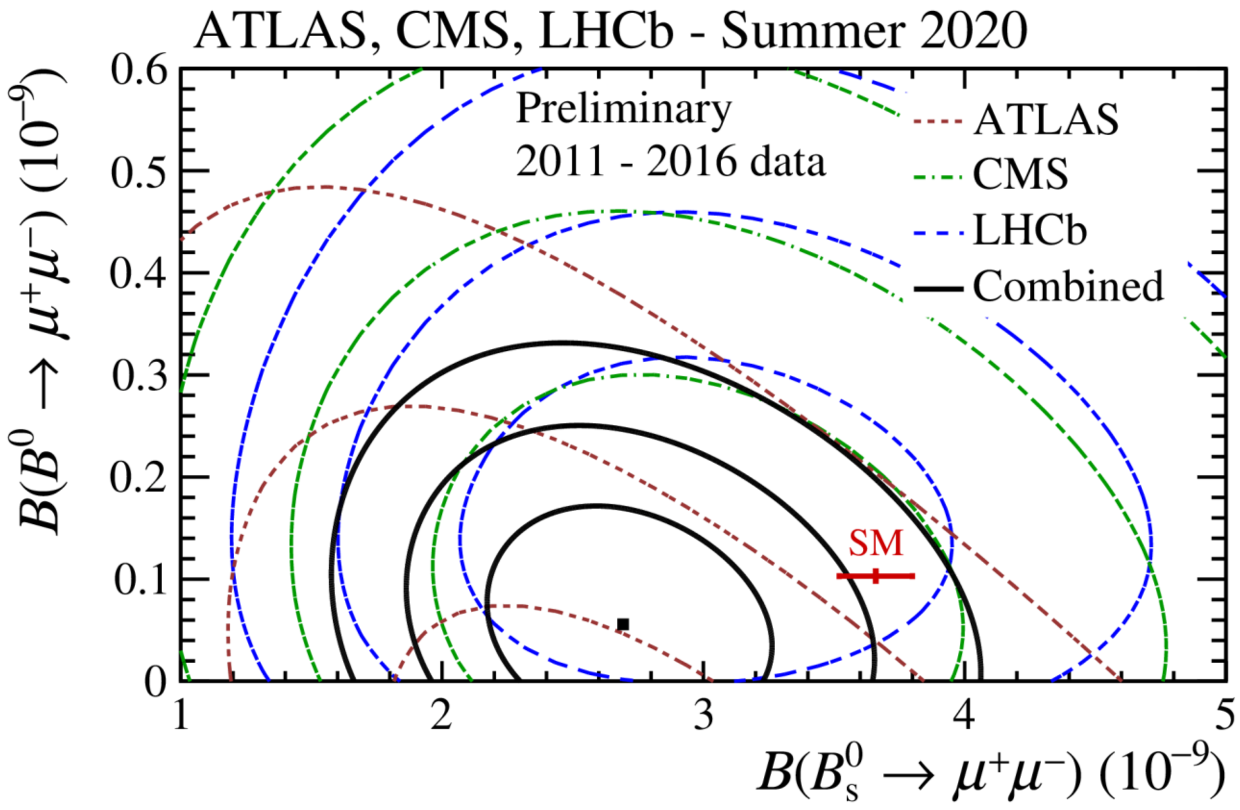
Early Run 3 Data

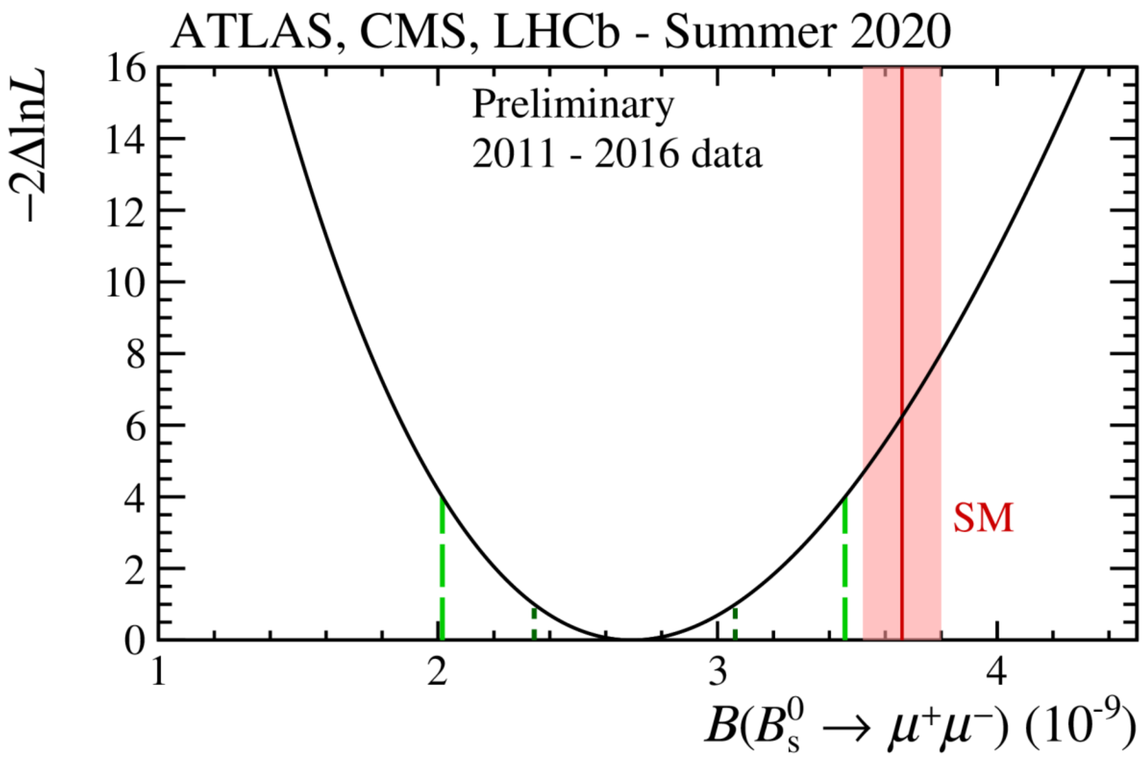
Conclusions

- Both ATLAS and CMS continues their B-Physics programs, publishing analyses from Run-2 and collecting new data in Run-3.
- I have presented the first observations of some resonances.
- I've presented a selection of results here, see published results pages for more ATLAS and CMS (preliminary).
- All measurements searching for new physics in B-flavour sector - confirmed no violation of SM - within a precision of data used since far.
- Measurements of Charmonia as well as the open-flavour hadron-productions, provide valuable tests to multiple QCD production models.

Backup

Combination of the ATLAS, CMS and LHCb results on the $B_s \to \mu^+\mu^-$ decays





Measurement of the production cross-section of J/ψ and $\psi(2S)$ mesons

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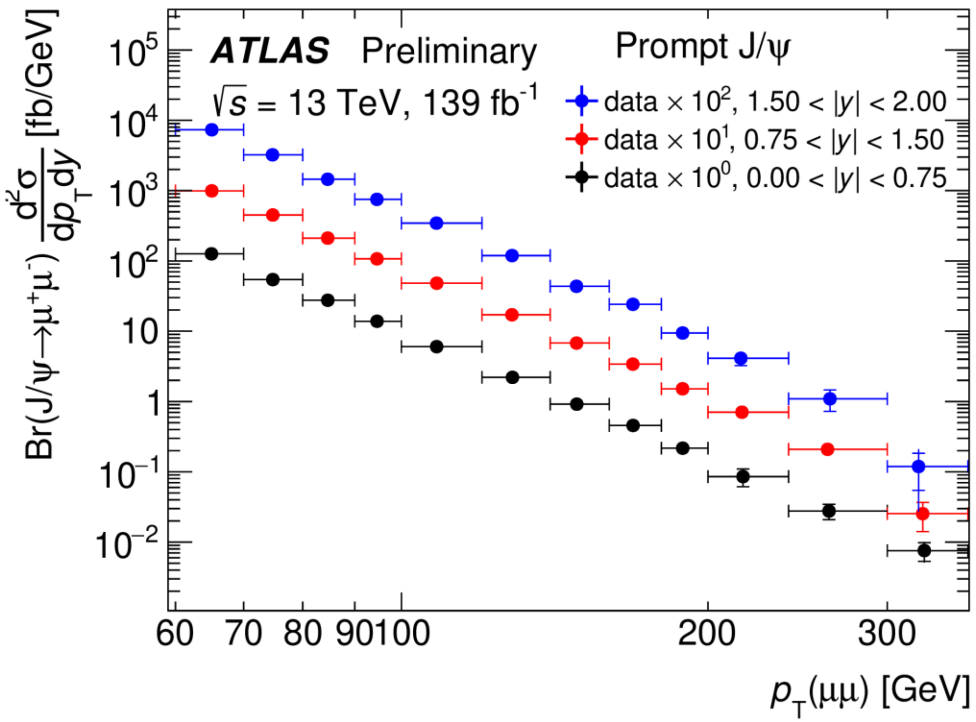

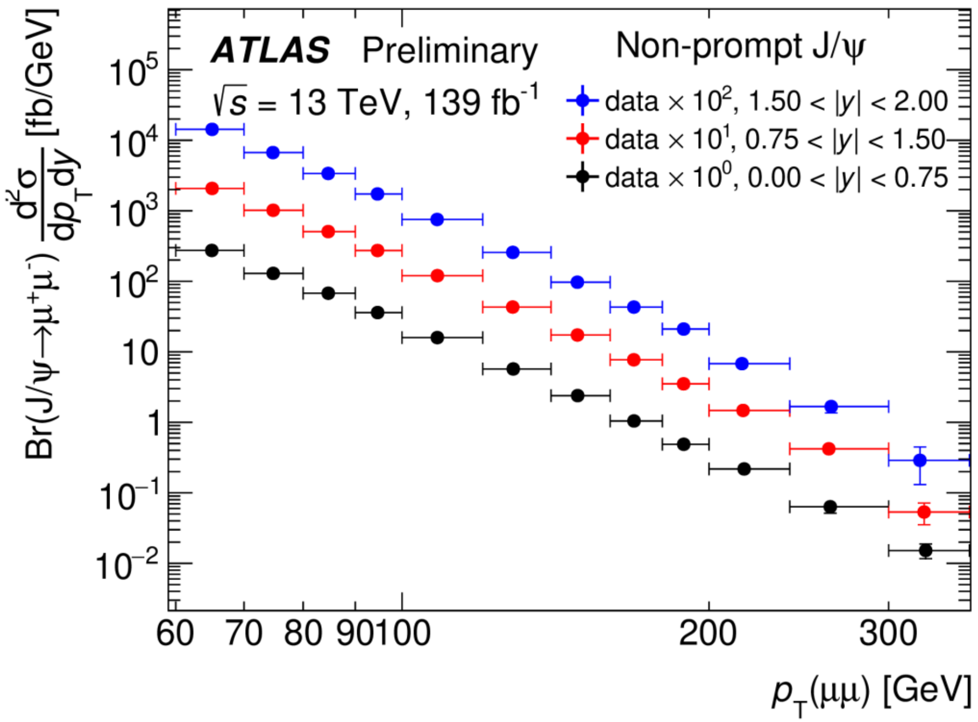

Good agreement with CMS and ALICE