

Recent Heavy-Flavor Spectroscopy and Rare Decay Results from ATLAS

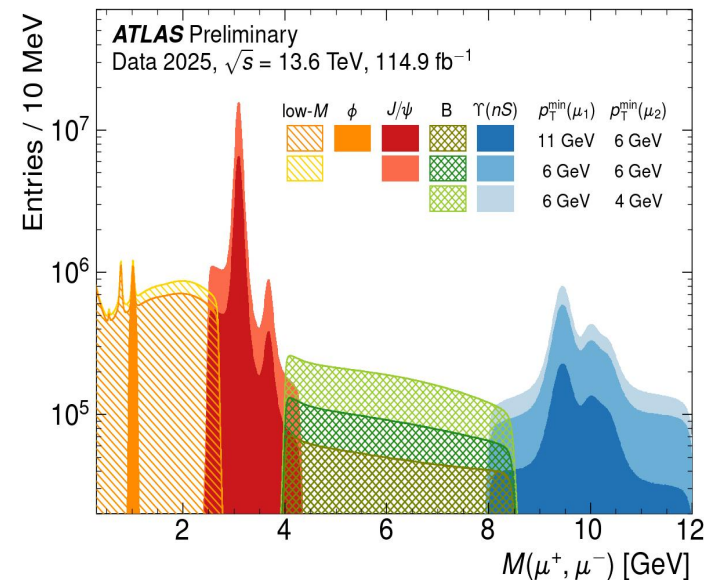
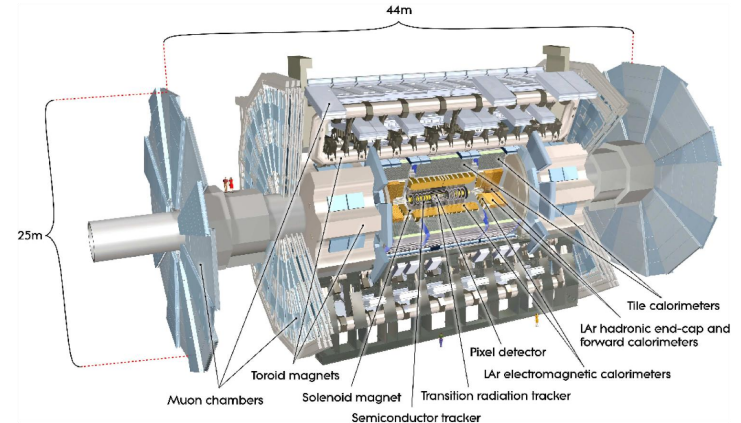
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On behalf of ATLAS collaboration

10/1/2026

QCD@LHC 2026, 28 Sep to 2 Oct 2026, University of Oxford, United Kingdom

Introduction

- Dedicated B-physics triggers; excellent tracking and muon identification enables
 - exotic hadrons
 - new meson states
 - rare decays
 in multi-muon final states
- In this talk:
 - Observation of resonance decay to $J/\psi + \psi(2s)$ by combining 4μ and $4\mu + 2\pi$ final states ([Phys.Rev.D 113,112015](#))
 - Observation of a B_c^{*+} meson via decay $B_c^{*+} \rightarrow B_c^+ + \gamma$ ([arXiv:2605.16228](#), accepted by PRL)
 - LFV search in rare decay $\tau \rightarrow 3\mu$ ([Phys.Lett.B 880 \(2026\) 140748](#))

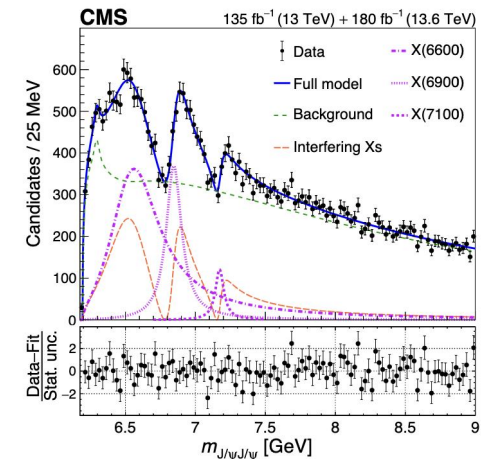
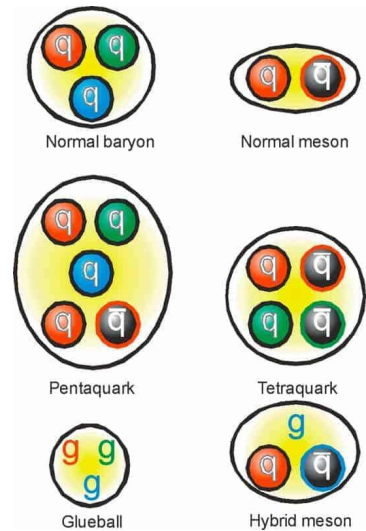


Observation of $J/\psi + \psi(2S)$ resonance by combining 4μ and $4\mu + 2\pi$ final state

[arXiv:2509.13101](https://arxiv.org/abs/2509.13101)
[Phys.Rev.D 113,112015](#)

Introduction and motivation

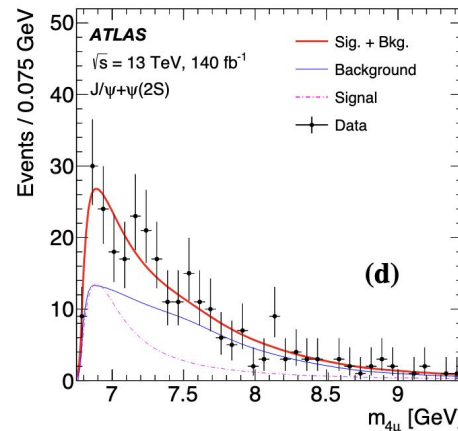
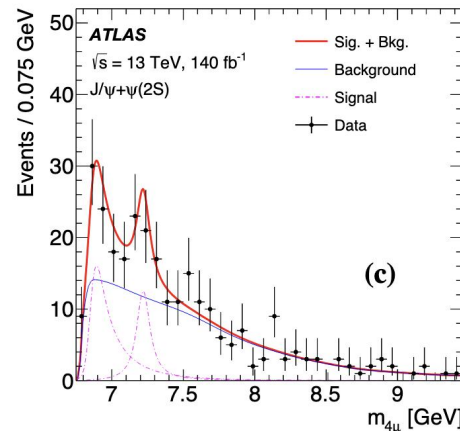
- The conventional quark model was proposed by Gell-Mann and Zweig in 1964, in which exotic hadrons were predicted at the same time as conventional hadrons
- In 2022, X(6900), a potential full-charm tetraquark($c\bar{c}c\bar{c}$), was observed in the di- $J/\psi \rightarrow 4\mu$ channel by LHCb ([Science Bulletin 65 \(2020\) 1983](#)), confirmed by ATLAS ([PhysRevLett.131.151902](#)) and CMS ([PhysRevLett.132.111901](#))
- In 2025, with Run 2 + partial Run 3 data, CMS observed X(7100) in the di- $J/\psi \rightarrow 4\mu$ channel with more statistics, and excess in the $J/\psi + \psi(2s) \rightarrow 4\mu$ channel is also confirmed, with X(7100)'s significance to be 4σ ([arXiv:2602.02252](#))



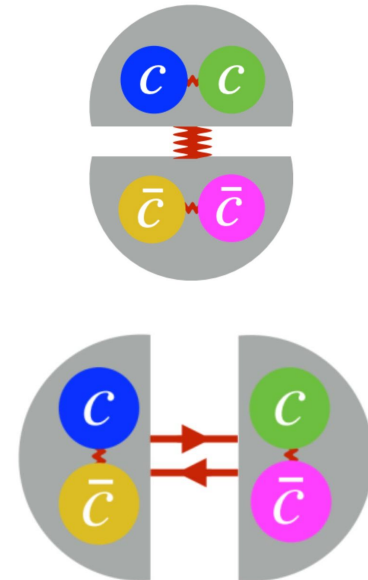
[arXiv:2602.02252](#)

Introduction and motivation

- Structures in $J/\psi + \psi(2s) \rightarrow 4\mu$ mass spectrum in ATLAS previous work ([PhysRevLett.131.151902](https://arxiv.org/abs/1311.1519)) still needs further support



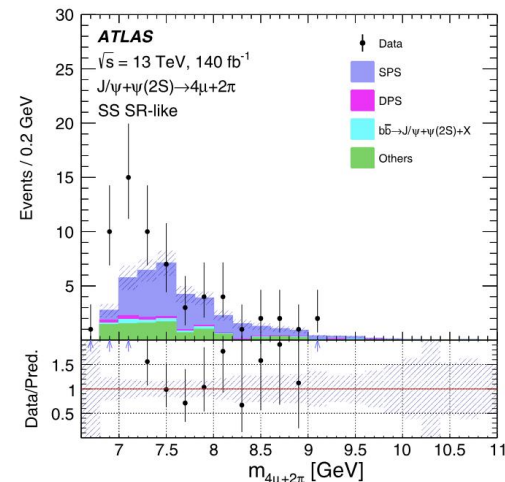
[PhysRevLett.131.151902](https://arxiv.org/abs/1311.1519)



- Another $\psi(2s)$ decay channel, $\psi(2s) \rightarrow J/\psi (\rightarrow 2\mu) + 2\pi$, is included in this work, which has ~ 3 larger decay BR
- Measurement of Relative partial decay widths
 - provide clues to its nature (compact tetraquark states; hadronic molecular states or threshold effects)

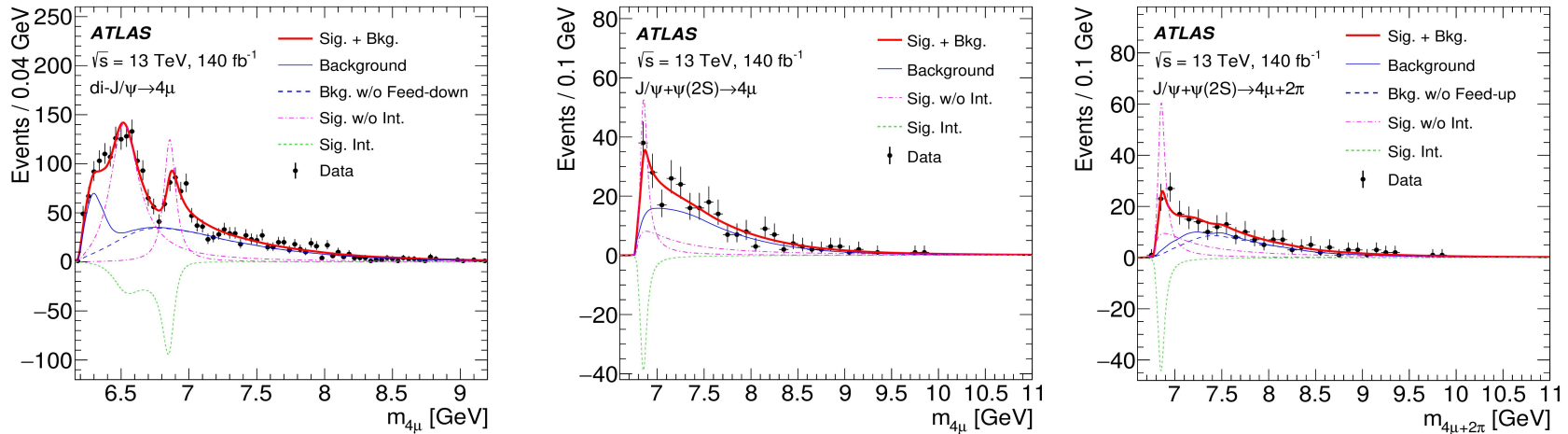
Background sources and estimation

- Double charmonia background:
 - Prompt backgrounds:
 - Single parton scattering (SPS): a pair of ψ mesons were produced in a single interaction, but were not from tetraquark
 - Double parton scattering (DPS): a pair of ψ mesons were produced in two separate interactions of gluons or quarks
 - Feed-up background (only in $4\mu + 2\pi$ channel) di- J/ψ signal + 2 random π
 - BDT trained for suppression
 - Constrained in the region with 2 same-sign (SS) charged π and shapes were taken from MC
 - Non-prompt backgrounds ($bb \rightarrow J/\psi + \psi(2s) + X$)
- Single ψ background and non-peaking background containing no real ψ candidate (Others)

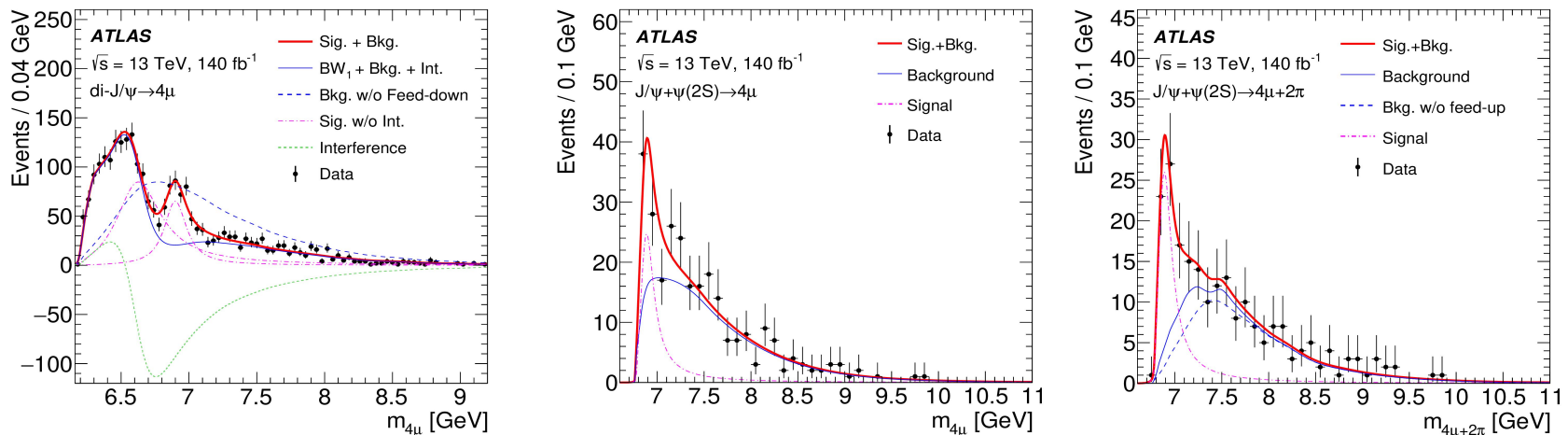


Fit models and results

- Model A: two interfering BW resonances the same as in the di- J/ψ channel

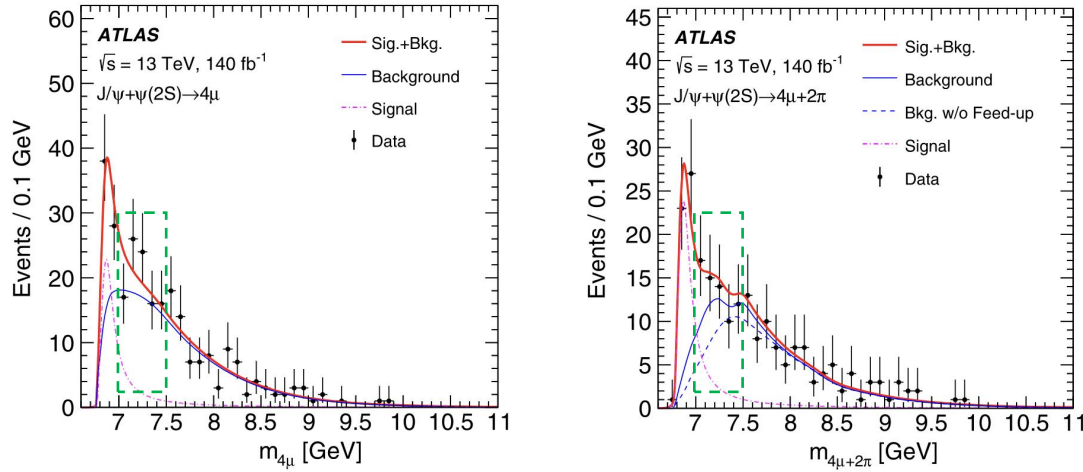


- Model B: two resonances the same as in di- J/ψ channel, one interfering with SPS, and the other standalone



Fit models and results results

- Model C: a standalone resonance in the $J/\psi + \psi(2s)$ channels



- The existence of another resonance with higher mass(X(7200)) in the $J/\psi + \psi(2s)$ channel is tested in each fit model
 - The yield of X(7200) relative to X(6900) in model C is 0.12 ± 0.11 , with an upper limit of 0.41 at 95% confidence level (CL)
- Related decay width is obtained via correlation of signal yields ratio, and is calculated in model A and B and shown here

	model A	model B	model C
m	$6.860 \pm 0.023 \pm 0.010$	$6.902 \pm 0.008 \pm 0.010$	$6.884 \pm 0.017^{+0.058}_{-0.005}$
Γ	$0.082 \pm 0.032 \pm 0.015$	$0.183 \pm 0.025 \pm 0.007$	$0.178 \pm 0.054^{+0.176}_{-0.024}$
R	$1.08 \pm 0.20^{+0.40}_{-0.09}$	$0.93 \pm 0.17 \pm 0.11$	—

$$R = \Gamma_{X(6900) \rightarrow J/\psi + \psi(2S)} / \Gamma_{X(6900) \rightarrow \text{di-}J/\psi}$$

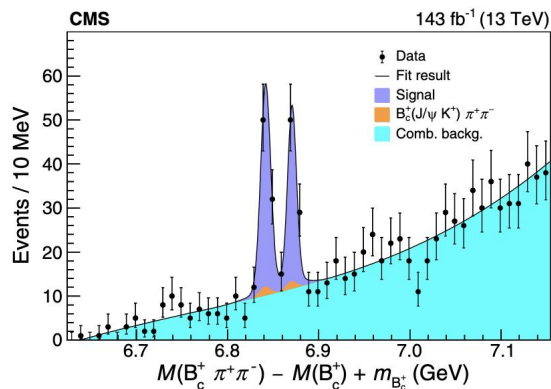
Observation of a B_c^{*+} meson via decay

$$B_c^{*+} \rightarrow B_c^+ + \gamma$$

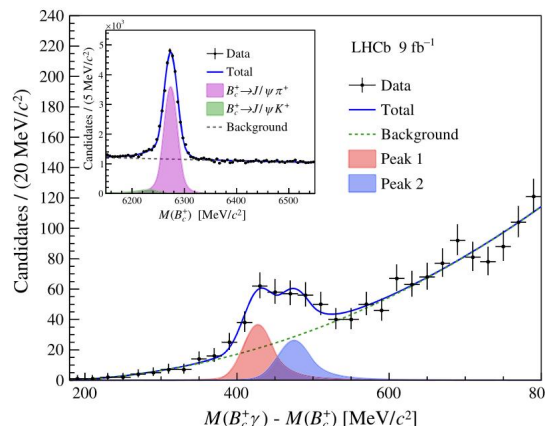
[arXiv:2605.16228](https://arxiv.org/abs/2605.16228)

Introduction and motivation

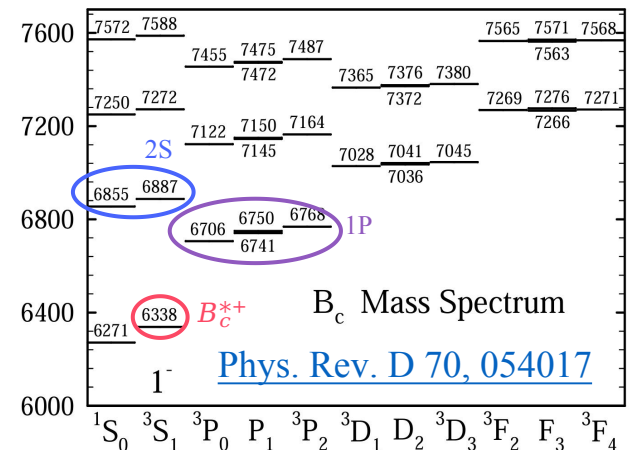
- Spectroscopy of $(\bar{b}c)$ system provides a unique heavy charmonium-like system of different heavy quarks
 - Besides the known excited B_c^+ states, like:
 - radial excitations of $B_c^+(2S)$ and $B_c^{*+}(2S)$, with $B_c^{(*)+}(2S) \rightarrow B_c^+ + \pi^+ \pi^-$
 - ATLAS: [PRL 113 \(2014\) 212004](#) (doublet not resolved)
 - CMS: [PRD 102 \(2020\) 092007](#)
 - LHCb: [PRL 122 \(2019\) 232001](#)
 - P-wave state $B_c^+(1P)$, with $B_c^+(1P) \rightarrow B_c^+ + \gamma$ ([PRL 135 \(2025\) 231902](#))
- the lightest excited state B_c^{*+} is predicted by QCD potential models, but has never been observed



[PRD102 \(2020\) 092007](#)

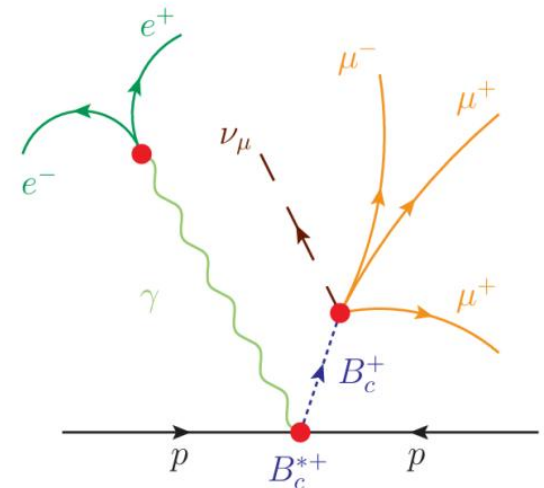


[PRL 135 \(2025\) 231902](#)



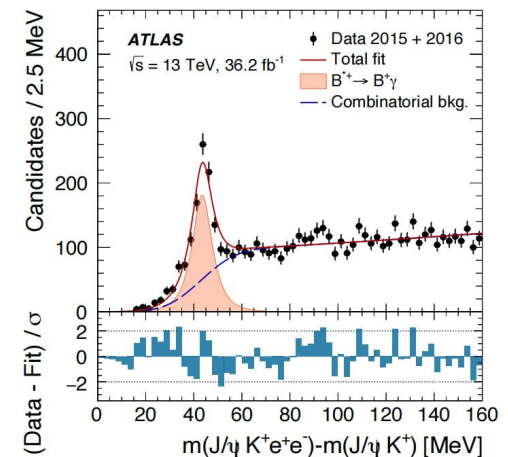
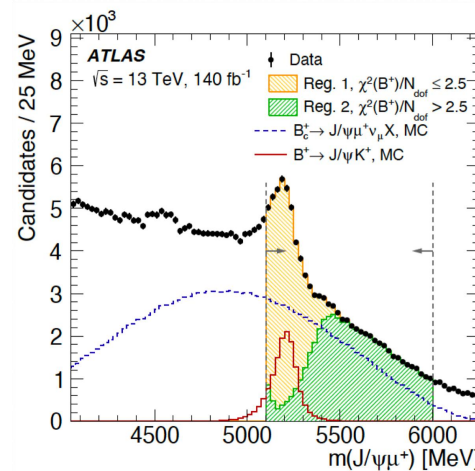
Introduction and motivation

- $B_c^{*+} \rightarrow B_c^+ + \gamma$ has a branching fraction close to 100%.
 - While $(M(B_c^{*+}) - M(B_c^+) \sim (50 - 70) \text{ MeV})$, making it experimentally challenging
- ATLAS searches for the lightest excitation (B_c^{*+}) with 140 fb^{-1} Run 2 data at 13 TeV with two main techniques
 - $B_c^+ \rightarrow J/\psi(\mu\mu) + \mu^+ + \nu_\mu + X$ - a decay mode for B_c^+ that has a relatively large BR(~ 20 times compared with $J/\psi + \pi^+$)
 - The soft photon turns into two soft electron tracks, special tracking is used down to 0.1 GeV to reconstruct the soft converted photon
- B_c^+ is only partially reconstructed due to neutrino and the $J/\psi(\mu\mu) + \mu$ mass is broad.
 - $\Delta m \equiv m(J/\psi + \mu + ee) - m(J/\psi + \mu)$ is used to get a narrower distribution
- Good tri- μ vertex quality, being displaced from PV. Several di- μ and tri- μ triggers are used to maximise the signal yield.



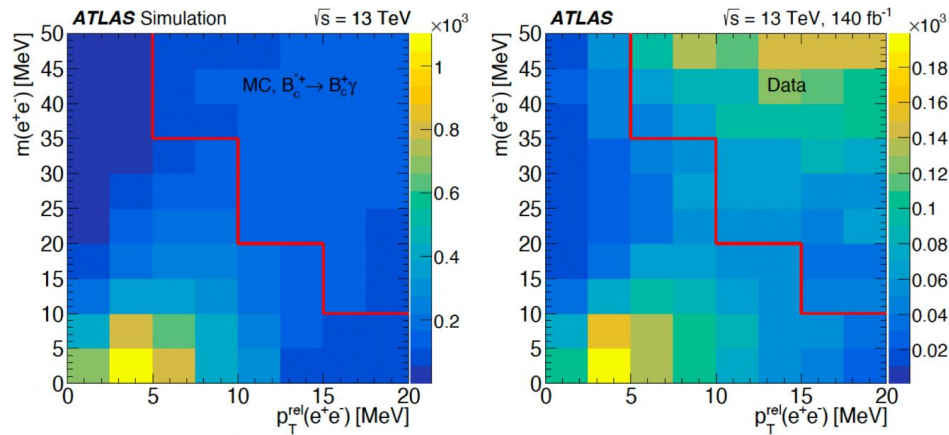
Signal analysis regions

- To suppress backgrounds with partially reconstructed b-hadron decays, only B_c^{*+} candidates with $m(J/\psi + \mu) \in [5.1, 6.0] \text{ GeV}$ is kept
- Besides signal decays, this region contains
 - Combinatorial background: meson combined with a true muon or a fake muon
 - $B^+ \rightarrow J/\psi K^+$ with K^+ mis-identified as a muon
- To suppress the peaking background of $B^+ \rightarrow J/\psi K^+$, the same events are also fitted with kaon mass hypothesis with B^+ mass constraint
 - $\chi^2(B^+)/N \leq 2.5$: $B^+ \rightarrow J/\psi K^+$ like events
 - $\chi^2(B^+)/N > 2.5$: free from B^+
- $B^{*+} \rightarrow B^+ + \gamma$ is used as an independent validation channel, to check photon momentum scale and resolution



Soft photon selection

- To further suppress the fake conversion candidates, a combined selection criterion based on the combination of $m(ee)$ and p_T^{rel*} is applied in the two-dimensional space of $m(ee)$ and p_T^{rel}
- Signal events tend to have lower values of these quantities while backgrounds have harder distributions

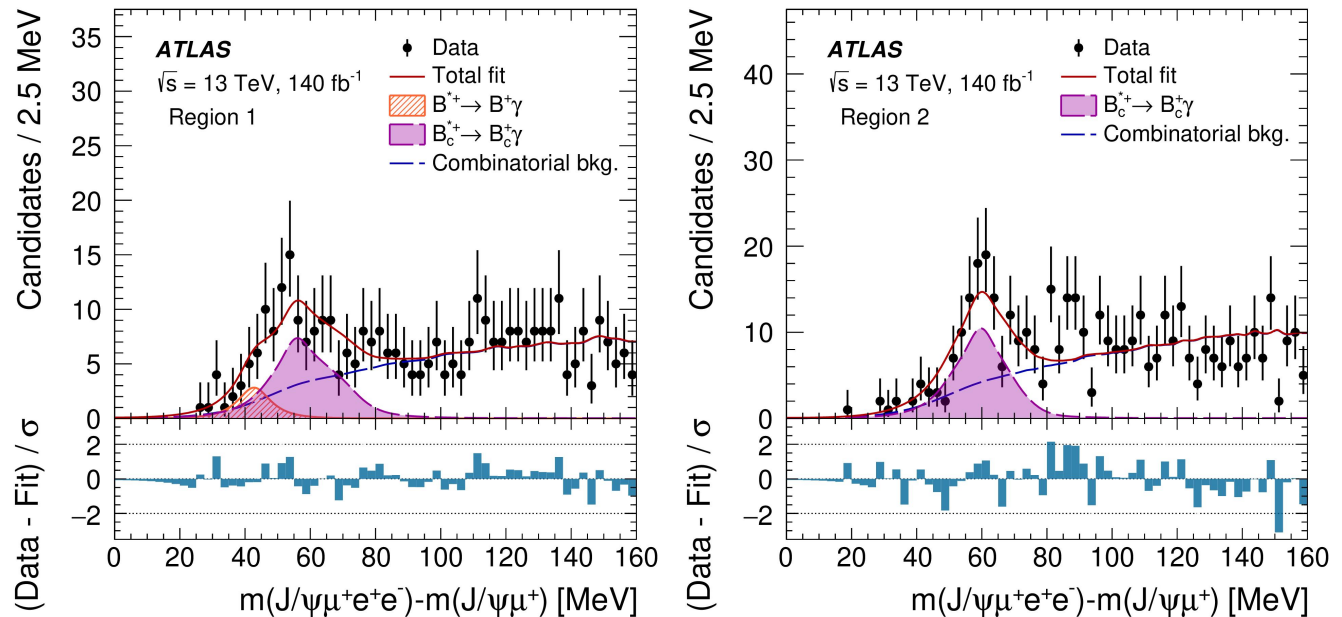


- The low- p_T tracking approach opens new opportunities for future hadron spectroscopy search involving soft photons

*the component of the photon candidate transverse momentum perpendicular to direction from PV to the photon vertex in the transverse plane

Excited B_c^{*+} states mass fit result

- Region 1 and 2 are fitted simultaneously to extract signal parameters
- The efficiency of converted photon is $\sim 0.4\%$, but with the large amount of B_c^{*+} candidates, we still get $N_{B_c^{*+}} = 163 \pm 19$ in region 1&2 together
 - $\Delta m(B_c^{*+}) = 64.5 \pm 1.4(stat.)_{-1.4}^{+1.0}(syst.) MeV$
 - $m(B_c^{*+}) = 6339.0 \pm 1.4(stat.)_{-1.4}^{+1.0}(syst.) \pm 0.3(m_{B_c^+}) MeV$
- The first observation of the lightest excitation $m(B_c^{*+})$ with a significance over 8σ



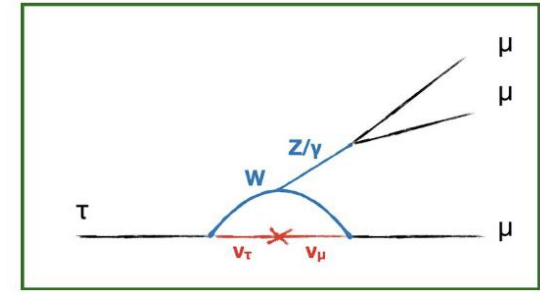
LFV search in rare decay $\tau \rightarrow 3\mu$

[Phys.Lett.B 880 \(2026\) 140748](#)

[arXiv:2603.18099](#)

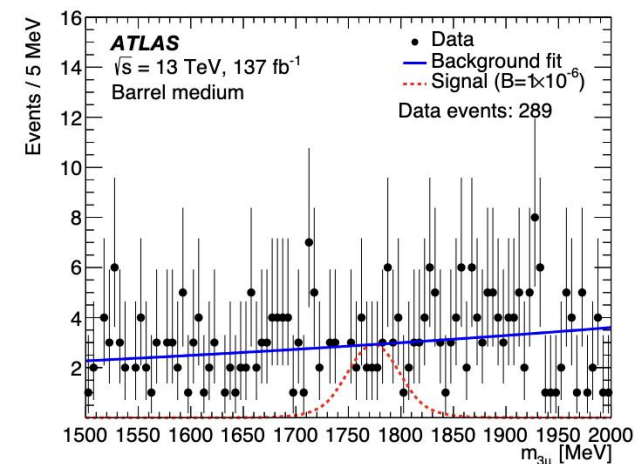
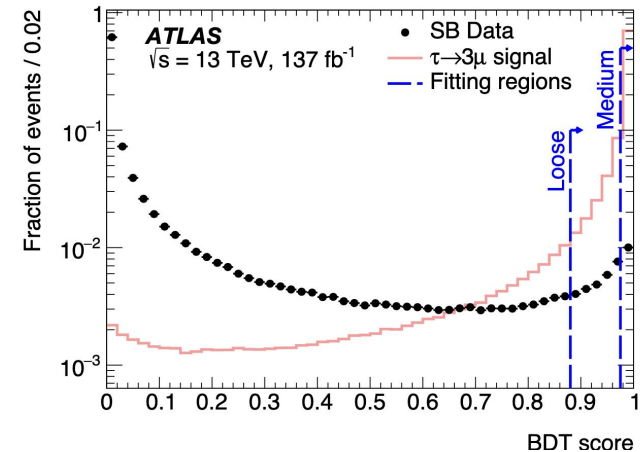
Introduction and Motivation

- Flavour is not a fundamental symmetry in the SM, flavour violation is observed in quarks and neutrinos but not in charged leptons
- Charged lepton-flavour violation (cLFV) is highly suppressed in the SM, from neutrino oscillation, the SM limit would be $Br(\tau \rightarrow 3\mu) \sim 10^{-55}$ ([Eur. Phys. J. C 79 \(2019\) 84](#)). Any observation would be evidence for new physics
- Utilizing the large τ -lepton production and dedicated multi- μ triggers, this work do the search for LFV in the $\tau \rightarrow 3\mu$ rare decay with ATLAS Run 2 dataset taken from 2016 to 2018 ($137 fb^{-1}$) at 13 TeV
- τ lepton production at LHC:
 - decays of heavy flavour hadrons, mainly $D_s \rightarrow \tau \nu_\tau$
 - decays of W and Z bosons, like $W^- \rightarrow \tau \nu_\tau$ and $Z \rightarrow \tau \bar{\tau}$
- The search is optimised for the electroweak $W^- \rightarrow \tau \nu_\tau$ production channel due to higher trigger efficiency, but also considers potential signal events from heavy-flavour production



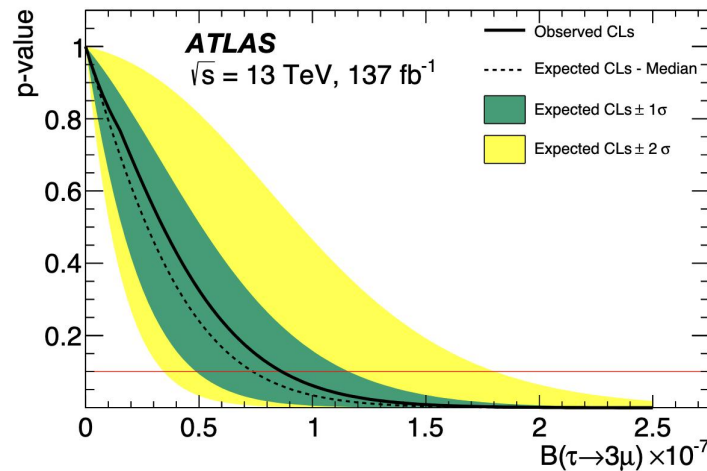
Event selection and fit

- 3 muon tracks form a secondary vertex (τ vertex)
- BDT is used to improve signal-to-background ratio
 - Vertex quality, tau displacement, triplet kinematics and muon isolation variables
- Events are split into different categories to optimise the sensitivity
 - 3 BDT regions (loose, medium and tight)
 - 2 detector regions (Barrel and Endcap)
- A simultaneous unbinned maximum-likelihood fit is performed on the $m(3\mu)$ distribution in all six fit categories
- The background-only fit and the expected signal, for $Br(\tau \rightarrow 3\mu) = 10^{-6}$, in the unblinded $m(3\mu)$ spectra.



Results

- The main resource of systematics comes from trigger efficiency and muon reconstruction efficiency



- No signal observed, observed (expected) upper limit set to
 - $Br(\tau \rightarrow 3\mu) < 8.7(7.5) \times 10^{-8}$ at 90% CL
 - $Br(\tau \rightarrow 3\mu) < 10.6(9.3) \times 10^{-8}$ at 95% CL
- Improved limit by a factor of 5 w.r.t previous ATLAS Run 1 results
 - a factor of 3 is expected solely from the larger production cross-sections at the increased centre-of-mass energy and larger dataset
 - rest from analysis/trigger improvements

Conclusion

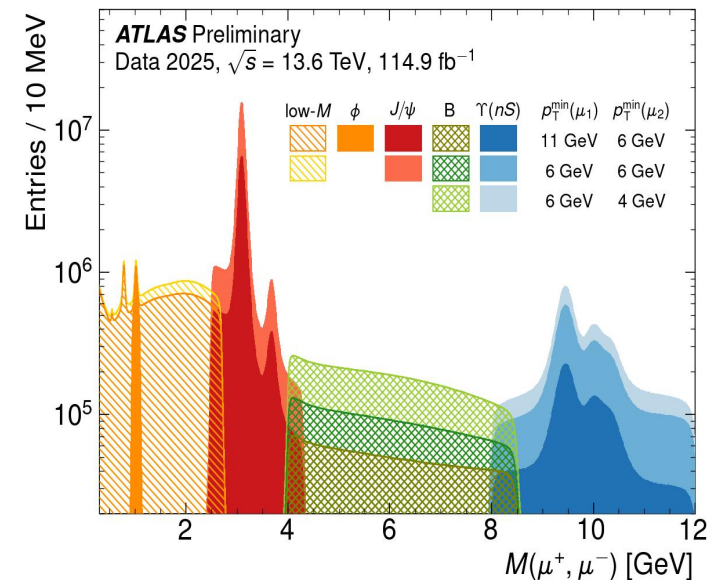
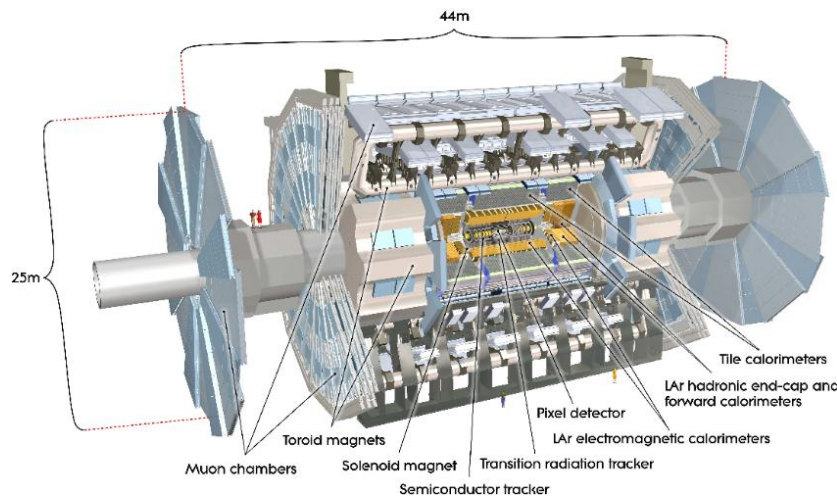
- ATLAS is competitive in many QCD related topics, due to dedicated triggers; muon ID and tracking performance
- This talk introduces 3 new ATLAS results on heavy flavour spectroscopy and rare decay:
 - Observation of resonant structure in the $J/\psi + \psi(2s)$ mass spectrum
 - Discovery of B_c^{*+} , the lowest excited states of $(\bar{b}c)$ system
 - LFV search through rare decays of $\tau \rightarrow 3\mu$
 - Limit improved by a factor of 5
- Please stay tuned for more results!

Thank You

Backup Slides

Introduction and Motivation

- The ATLAS Detector: Optimized for Heavy Flavour Physics
 - The Inner Detector (ID) - gives us precise vertex resolution required to cleanly isolate displaced b-hadron and D-meson decays
 - Muon Spectrometer (MS) - provides clean identification and sharp momentum resolution for final-state muons.
 - Trigger and Data Acquisition (TDAQ) system - Highly flexible muon trigger menu allowing seamless transitions from low- p_T dimuon thresholds to high- p_T single-muon triggers.

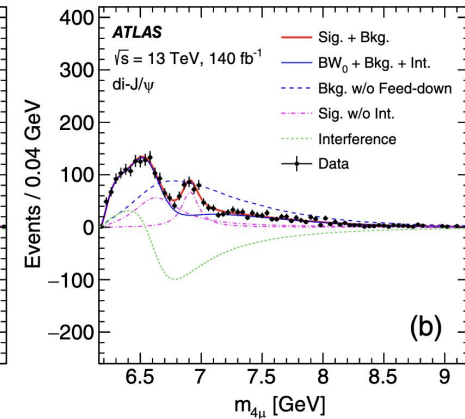
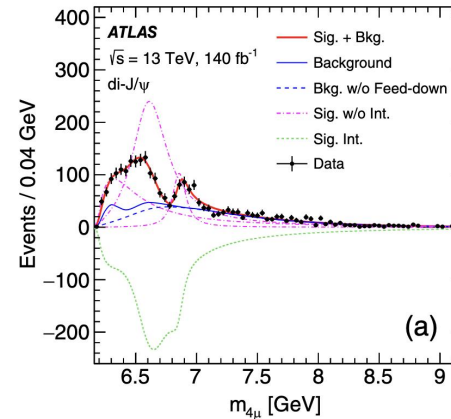
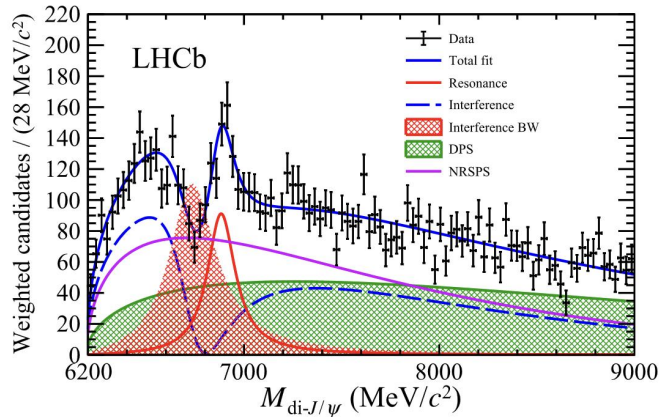


Observation of $J/\psi + \psi(2S)$ resonance by combining 4μ and $4\mu + 2\pi$ final state

arXiv:2509.13101

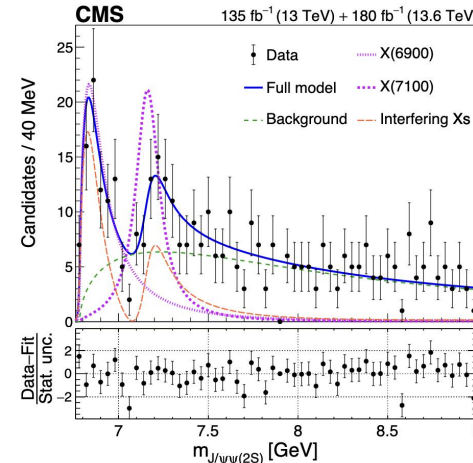
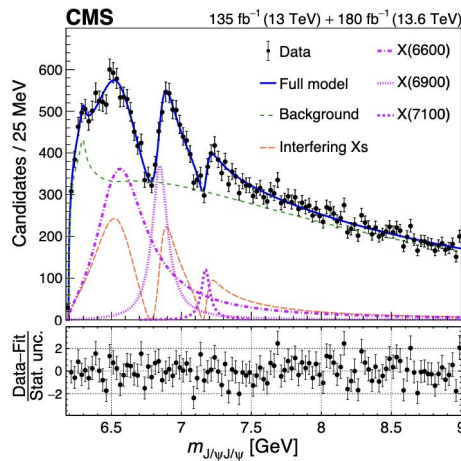
[Phys.Rev.D 113,112015](#)

Related work towards full-charm tetraquark



[Science Bulletin 65 \(2020\) 1983](#)

[PhysRevLett.131.151902](#)



[arXiv:2602.02252](#)

Event selections and analysis regions

- Di-muon and tri-muon triggers with ψ mass requirement are used
- Baseline selection:
 - Four muons with $p_T > 4, 4, 3, 3 \text{ GeV}$ and $|\eta| < 2.5$; two opposite-sign (OS) charged tracks with $p_T > 0.5 \text{ GeV}$
 - ψ mass requirement; Vertex fit quality(χ^2 / N_{dof}) and L_{xy} requirements
- Analysis regions

Signal region (CR)	Vertex cuts: $ L_{xy}^{charmoinum} < 0.3$ mm $L_{xy}^{4\mu(+2\pi)} < 0.2$ mm $\chi^2_{4\mu(+2\pi)}/N < 3$	$m_{4\mu(+2\pi)} < 8$ GeV	$\Delta R < 0.25$
Control region (CR)		BDT score > -0.3 ($4\mu + 2\pi$)	$\Delta R > 0.25$
SPS region		$8 \text{ GeV} < m_{4\mu(+2\pi)} < 12 \text{ GeV}$	
DPS region		$14 \text{ GeV} < m_{4\mu(+2\pi)} < 25 \text{ GeV}$	
Non-prompt region	Reverse vertex cuts		
Fake region	One J/ψ or $\psi(2S)$ candidate contains a track that fails the muon identification		

$$\Delta R: \sqrt{\Delta\phi^2 + \Delta\eta^2} \text{ between charmonia}$$

Trigger table for $J/\psi + \psi(2s)$ Analysis

year	run/period	trigger
2015	266904-284484 (A-H)	HLT_2mu4_bJpsimumu_noL2 HLT_mu6_mu4_bJpsimumu_noL2
	296939-302393 (A-C)	HLT_mu6_mu4_bJpsimumu HLT_2mu6_bJpsimumu HLT_mu10_mu6_bJpsimumu HLT_3mu4 HLT_mu6_2mu4_bJpsi HLT_3mu6_bJpsi
	302737-303560 (D)	HLT_mu6_mu4_bJpsimumu_Lxy0_delayed HLT_2mu6_bJpsimumu_delayed HLT_mu10_mu6_bJpsimumu_delayed HLT_3mu4 HLT_mu6_nomucomb_2mu4_nomucomb_delayed_L1MU6_3MU4 HLT_3mu6_bJpsi
2016	303638-311481 (E-L)	HLT_mu6_mu4_bJpsimumu_Lxy0_delayed HLT_2mu6_bJpsimumu_delayed HLT_3mu4_nomucomb_delayed HLT_mu6_nomucomb_2mu4_nomucomb_delayed_L1MU6_3MU4
	325713-328393 (A-B)	HLT_2mu6_bJpsimumu HLT_mu11_mu6_bDimu HLT_3mu4_bJpsi
2017	329385-340453 (C-K)	HLT_mu11_mu6_bDimu HLT_3mu4_bJpsi HLT_mu6_mu4_bJpsimumu_Lxy0_L1BPH-2M9-MU6MU4_BPH-0DR15-MU6MU4 HLT_2mu6_bJpsimumu_L1BPH-2M9-2MU6_BPH-2DR15-2MU6
	348197-364485 (A-R)	HLT_mu11_mu6_bDimu HLT_3mu4_bJpsi HLT_mu6_mu4_bJpsimumu_Lxy0_L1BPH-2M9-MU6MU4_BPH-0DR15-MU6MU4 HLT_2mu6_bJpsimumu_L1BPH-2M9-2MU6_BPH-2DR15-2MU6 HLT_2mu4_bJpsimumu_Lxy0_L1BPH-2M9-2MU4_BPH-0DR15-2MU4

Systematics for $J/\psi + \psi(2s)$ Analysis

Sources	Model A			Model B			Model C	
	m	Γ	R	m	Γ	R	m	Γ
Statistical uncertainties	± 23	± 32	± 0.20	± 8.1	± 25	± 0.17	± 17	± 54
Di- J/ψ bkg. modeling	± 5.4	± 7.7	± 0.041	± 1.4	—	—	—	—
$J/\psi + \psi(2S)$ bkg. modeling	± 4.1	± 6.7	± 0.038	—	—	—	± 2.6	± 8.6
Signal ratios	—	—	± 0.069	—	—	± 0.054	—	—
Mass resolution	± 6.8	± 8.6	± 0.033	± 1.3	± 2.2	± 0.002	± 0.3	± 4.4
Feed-up bkg.	—	—	± 0.002	—	—	± 0.002	± 0.3	± 0.6
P or D-wave BW	± 3.2	± 5.4	$+0.39$	± 9.9	± 2.9	± 0.094	$+58$	$+170$
Fit bias	± 0.2	± 2.1	± 0.007	± 0.2	± 4.7	± 0.010	± 0.4	± 11
Inclusion of $X(7200)$	± 1.0	± 1.2	—	± 0.1	± 3.8	± 0.001	± 4.2	± 19

Fitted results for different models

Table 11: The fitted masses, natural width (in GeV) of the resonances, as well as the ratio of $X(6900)$'s partial decay widths, with model *A*. The first uncertainty is statistical while the second one is systematic.

m_1	Γ_1	m_2
$6.531 \pm 0.011 \pm 0.002$	$0.244 \pm 0.021 \pm 0.021$	$6.860 \pm 0.023 \pm 0.010$
Γ_2	$\Gamma_{X(6900) \rightarrow J/\psi \psi(2S)} / \Gamma_{X(6900) \rightarrow 2J/\psi}$	
$0.082 \pm 0.032 \pm 0.015$	$1.08 \pm 0.20^{+0.40}_{-0.09}$	

Table 14: The fitted masses, natural width (in GeV) of the resonances with model *B*. The first uncertainty is statistical while the second one is systematic.

m_1	Γ_1	m_2
$6.646 \pm 0.018 \pm 0.021$	$0.390 \pm 0.045 \pm 0.037$	$6.902 \pm 0.008 \pm 0.010$
Γ_2	$\Gamma_{X(6900) \rightarrow J/\psi \psi(2S)} / \Gamma_{X(6900) \rightarrow 2J/\psi}$	
$0.183 \pm 0.025 \pm 0.007$	$0.93 \pm 0.17 \pm 0.11$	

Table 20: The fitted masses and natural widths (in GeV) of a single resonance (model *C*) in the $J/\psi + \psi(2S)$ mass spectrum. The first uncertainty is statistical while the second one is systematic.

m_2	Γ_2
$6.884 \pm 0.017^{+0.058}_{-0.005}$	$0.178 \pm 0.054^{+0.176}_{-0.024}$

Observation of a B_c^{*+} meson via decay

$$B_c^{*+} \rightarrow B_c + \gamma$$

arXiv:2605.16228

Systematics for B_c^{*+} analysis

Table 1: Systematic uncertainties associated with the measured value of $\Delta m_{B_c^{*+}}$.

Source	Uncertainty [MeV]
Material modelling and photon momentum scale & resolution	+0.44 -1.13
B_c^+ production modelling	± 0.19
$B_c^+ \rightarrow J/\psi \mu^+ \nu_\mu X$ decay modelling	± 0.05
$N_{B_c^{*+}}^{\text{R1}} / N_{B_c^{*+}}^{\text{R2}}$ ratio	± 0.12
Muon reconstruction and trigger	± 0.16
Background shape modelling	± 0.79
Total	+0.95 -1.41

$B_c^{*+} \rightarrow B_c^+ + \gamma$: MC shape

$B^{*+} \rightarrow B^+ + \gamma$: modified Gaussian function

Combinatorial background modelling: mixing B_c^+ and soft photon from different events

Fit model and signal extraction

The $B^{*+} \rightarrow B^+ \gamma$ decay is parameterized by a modified Gaussian function, G_{mod} [42, 43]:

$$G_{\text{mod}} \propto \exp \left(-0.5 \times t^2 + 1/(1 + t/2) \right), \quad (2)$$

where $t = |\Delta m - \Delta m_{B_{\text{reco}}}^{*+}|/\sigma_B^{*+}$ with the mean value $\Delta m_{B_{\text{reco}}}^{*+}$ and width σ_B^{*+} being fixed for the values, obtained from simulated samples ($\Delta m_{B_{\text{reco}}}^{*+} = 42.76$ MeV and $\sigma_B^{*+} = 4.80$ MeV), as described in Appendix G.3. This component only contributes to the Dataset 1 and is absent in the Dataset 2.

Parameter	Value
$\Delta m_{B_c^{*+}} [\text{MeV}]$	$64.49^{+1.39}_{-1.41}$
$N_{B_c^{*+}}$	163 ± 19
$N_{B^{*+}}$	17 ± 8

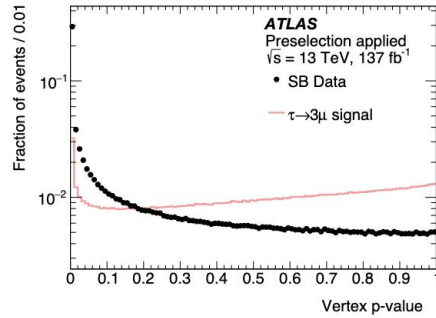
The total B_c^{*+} signal yield in Datasets 1 and 2, $N_{B_c^{*+}}$, and B^{*+} yield in Dataset 1, $N_{B^{*+}}$, are free parameters of the fit. The ratio of the B_c^{*+} yields in Datasets 1 and 2, $N_{B_c^{*+}}^{DS1}/N_{B_c^{*+}}^{DS2}$, is fixed for the value in the simulated sample, $N_{B_c^{*+}}^{DS1}/N_{B_c^{*+}}^{DS2} = 0.834 \pm 0.033$. Leaving it a free parameter yields a consistent value of $N_{B_c^{*+}}^{DS1}/N_{B_c^{*+}}^{DS2} = 0.76^{+0.22}_{-0.18}$, such unconstrained fit is used as a systematic variation.

LFV search in rare decay $\tau \rightarrow 3\mu$

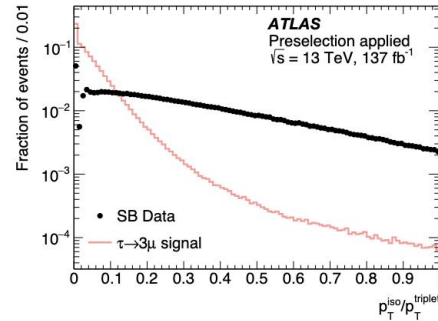
[Phys.Lett.B 880 \(2026\) 140748](#)

arXiv:2603.18099

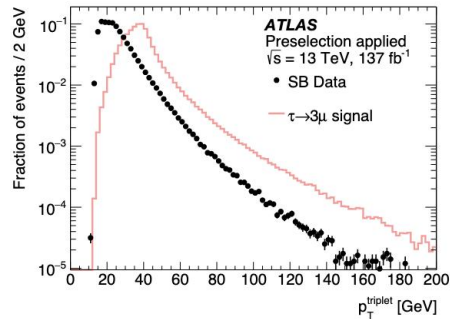
Distribution of main BDT input variables



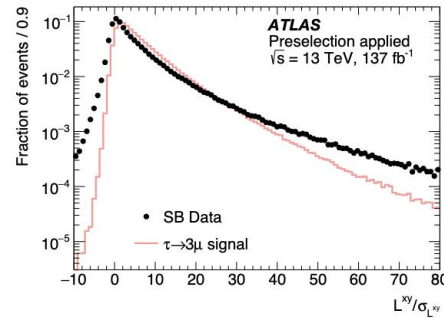
(a)



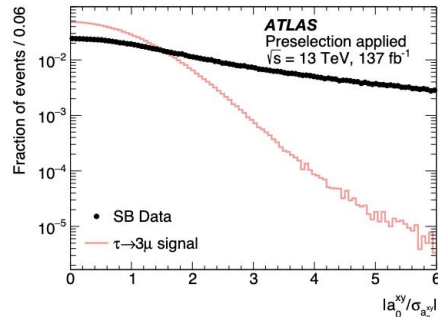
(b)



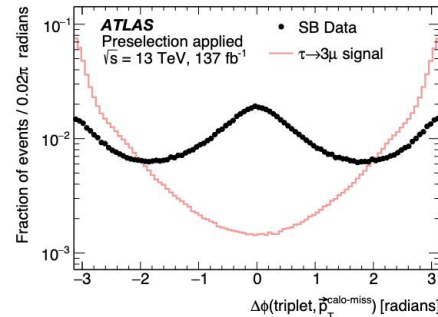
(c)



(d)



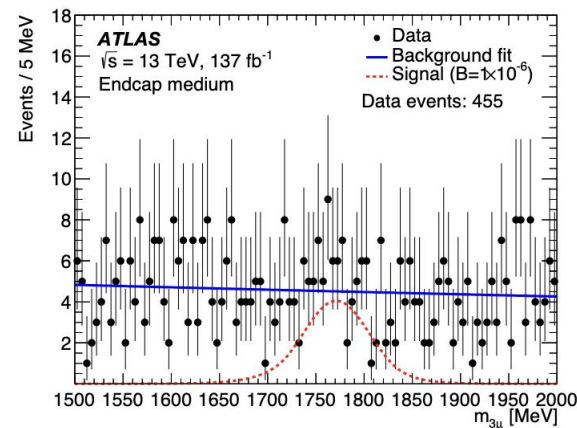
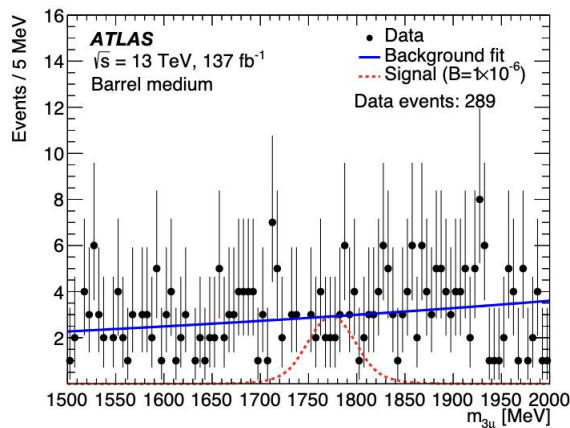
(e)



(f)

Fit results and systematics

- The simulated signals are parameterised separately in each category with a double sided Crystal Ball (DSCB) function
- The background $m(3\mu)$ shape is parameterised by exponential function, with the exponent allowed to be positive or negative.
- The background-only fit and the expected signal, for $Br(\tau \rightarrow 3\mu) = 10^{-6}$, in the unblinded $m(3\mu)$ spectra.



- The main resource of systematics comes from trigger efficiency and muon reconstruction efficiency

Systematics in categories

BDT category	Systematic signal uncertainty [%]					
	Loose		Medium		Tight	
	Barrel	Endcap	Barrel	Endcap	Barrel	Endcap
Trigger efficiency	± 26.7	± 10.1	± 20.9	± 9.1	± 16.2	± 11.4
Muon reconstruction efficiency	± 3.7	± 3.5	± 3.4	± 3.2	± 2.9	± 3.0
E_T^{miss} track resolution	± 1.9	± 1.1	± 0.8	± 1.2	∓ 2.4	∓ 2.3
Jet energy scale	± 5.0	± 3.3	± 0.9	± 0.4	∓ 5.1	∓ 3.2
Pile-up	± 1.5	± 1.5	< 0.1	< 0.1	∓ 1.8	∓ 1.4

Comparing with other results

