Recent spectroscopy results from ATLAS and CMS experiment

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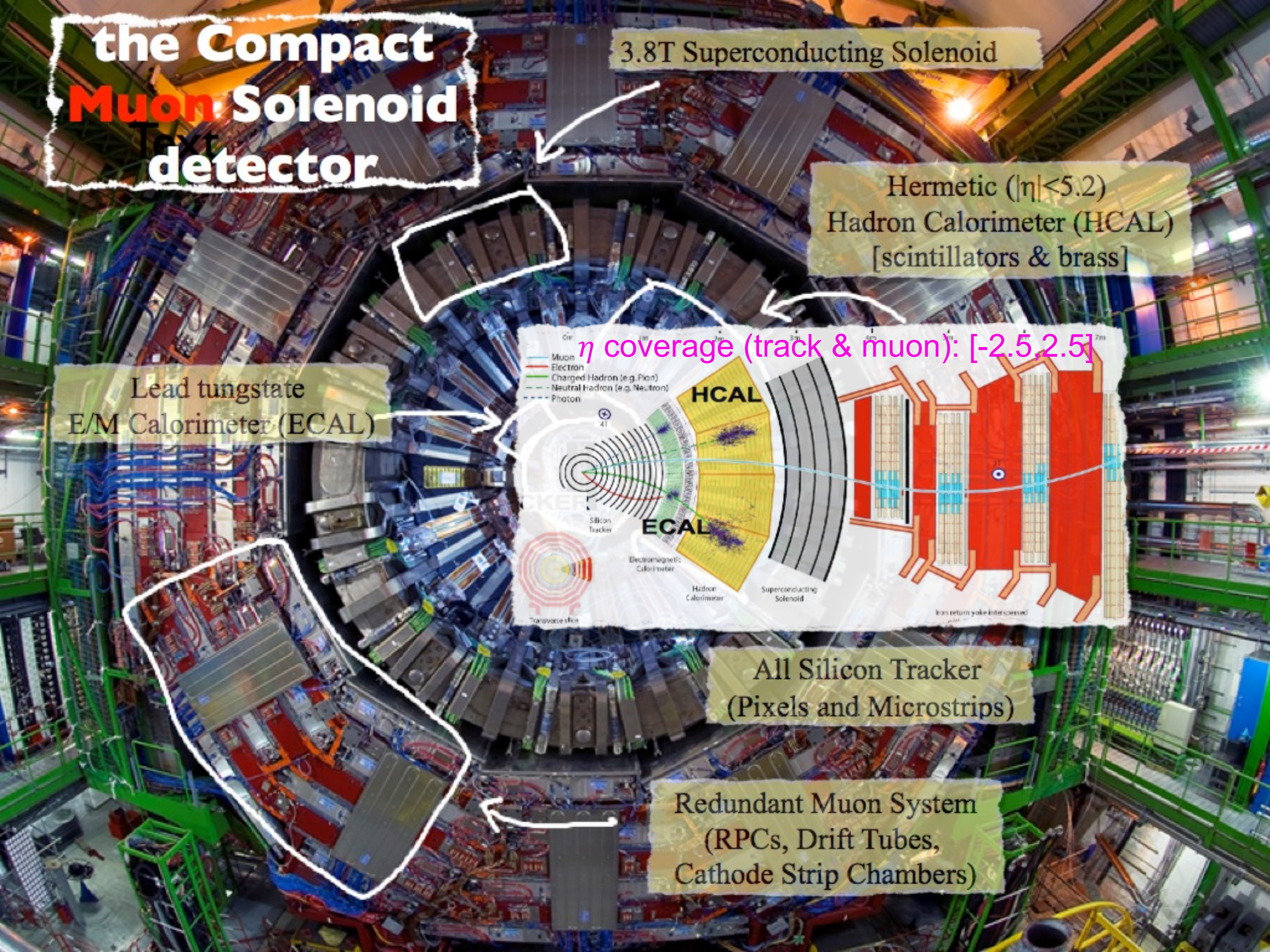
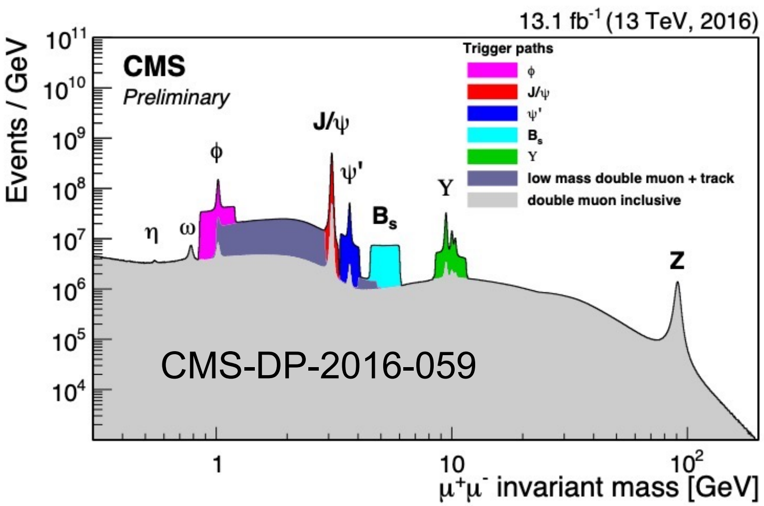
on behalf of the ATLAS & CMS collaborations

Sep 18, 2025

The **Large Hadron Collider** (**LHC**) at CERN is the world's largest particle collider. It lies in a tunnel 27 kilometres in circumference and as deep as 175 metres beneath the France–Switzerland border near Geneva.


the Compact Muon Solenoid detector
Text
3.8T Superconducting Solenoid
Hermetic (|η|<5.2)
Hadron Calorimeter (HCAL)
[scintillators & brass]
η coverage (track & muon): [-2.5,2.5]
Muon
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon
HCAL
ECAL
Silicon Tracker
Electromagnetic Calorimeter
Hadron Calorimeter
Superconducting Solenoid
Iron return yoke interspersed
Transverse slice
Lead tungstate
E/M Calorimeter (ECAL)
All Silicon Tracker
(Pixels and Microstrips)
Redundant Muon System
(RPCs, Drift Tubes,
Cathode Strip Chambers)

CMS trigger & dimuon spectrum

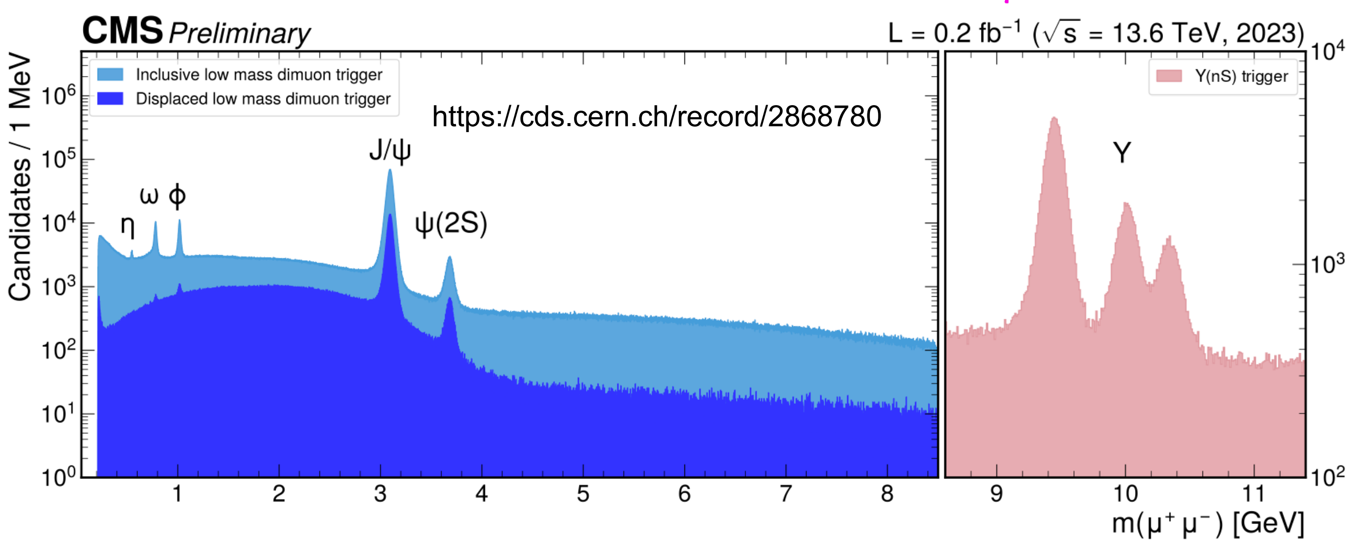


Excellent detector for studies with muons

- Muon system
  - High-purity muon ID, $\Delta m/m \sim 0.6\%$ for J/ψ
- Silicon Tracking detector, B=3.8T
  - $\Delta p_T/p_T \sim 1\%$ & excellent vertex resolution

Majority of analyses rely on dimuon triggers

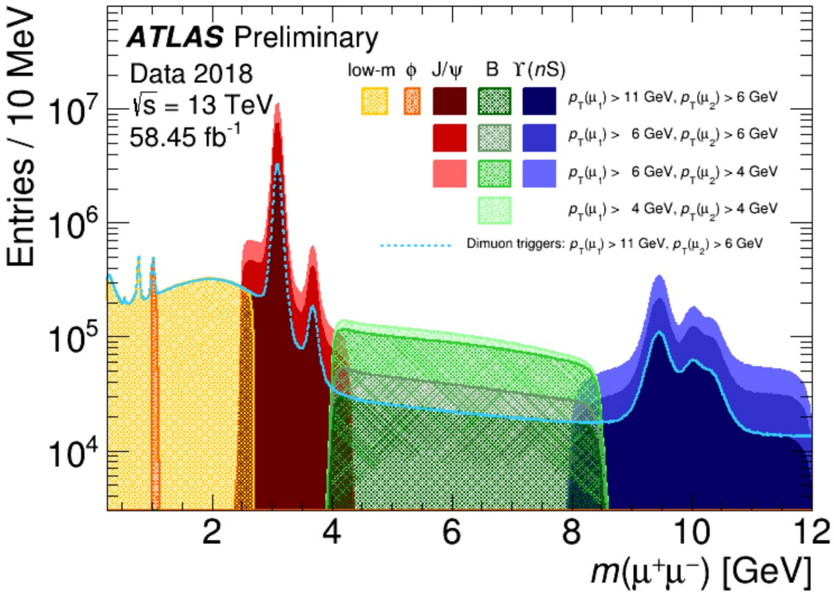
- Special triggers for different analyses
  - μ p_T, $(\mu\mu)$ p_T, $(\mu\mu)$ mass, $(\mu\mu)$ vertex, and additional μ

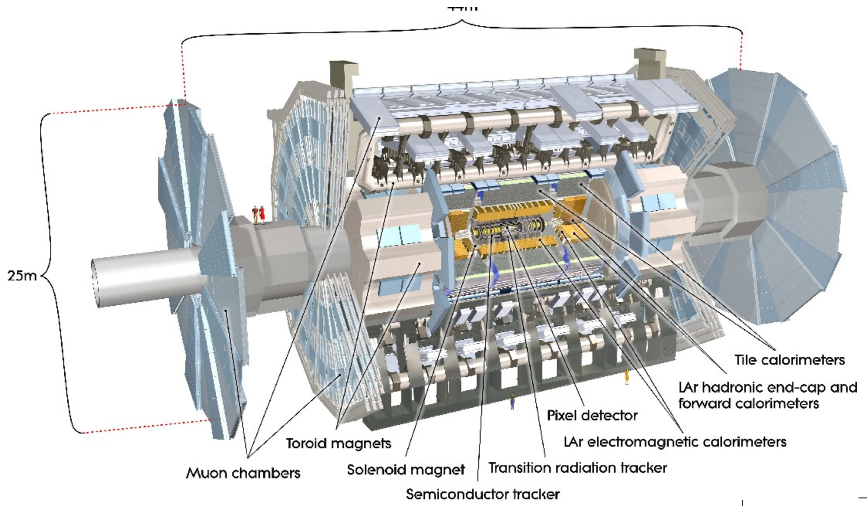


Significant acceptance improvement in Run-3!

Spectroscopy at ATLAS

- ATLAS also collected a large set of data
  - Run 1 (2010-2013): 4.9 fb^{-1} at 7 TeV and 20.3 fb^{-1} at 8 TeV
  - Run 2 (2015-2018): 139 fb^{-1} at 13 TeV
- Many analyses focus on final states with muons
- Dedicated B-physics triggers
- Excellent track and muon identification with the goodness of the inner detector and muon spectrometer





Recent spectroscopy results

- Spectroscopy of exotic hadrons
  - CMS: Observation of X(6600) and X(7100) in $\mathbf{J}/\psi\,\mathbf{J}/\psi$ (2023, 4/2025)
  - CMS: Observation of X(6900) in $\mathbf{J}/\psi\,\psi(\mathbf{2}S)$ (4/2025)
  - CMS: Spin-parity measurement of the tetraquark family X(6600),X(6900),X(7100) (4/2025)
  - ATLAS: Confirmation of X(6900) in $\mathbf{J}/\psi\,\mathbf{J}/\psi$ (2023)
  - ATLAS: Evidence of X(6900) in $\mathbf{J}/\psi\,\psi(\mathbf{2}S)$ (2023)

- Spectroscopy of conventional hadrons
  - CMS: First full reconstruction of B* mesons (2025)

New domain of exotics: all-heavy tetra-quarks

- First mention of 4c states at 6.2 GeV (1975)
  - Just one year after the discovery of J/ψ

We expect at least three exotic mesons with hidden charm, $c\bar{c}(p\bar{p}-n\bar{n})$ [between 3.7∼4.1 GeV], $c\bar{c}\lambda\bar{\lambda}$ [∼4.1 GeV] and $c\bar{c}c\bar{c}$ [∼6.2 GeV], to which we refer

Progress of Theoretical Physics, Vol. 54, No. 2, August 1975

A Possible Model for New Resonances

—Exotics and Hidden Charm—

Yoichi Iwasaki

Research Institute for Fundamental Physics
Kyoto University, Kyoto

(Received January 20, 1975)

- First calculation of 4c states (1981): Z. Phys. C 7 (1981) 317

L	S	J^{PC}	Mass (GeV)
1	0	1^{--}	6.55
	1	$0^{-+}, 1^{-+}, 2^{-+}$	
	2	$1^{--}, 2^{--}, 3^{--}$	
2	0	2^{++}	6.78
	1	$1^{+-}, 2^{+-}, 3^{+-}$	
	2	$0^{++}, 1^{++}, 2^{++}, 3^{++}, 4^{++}$	
3	0	3^{--}	6.98
	1	$2^{-+}, 3^{-+}, 4^{-+}$	
	2	$1^{--}, 2^{--}, 3^{--}, 4^{--}, 5^{--}$	

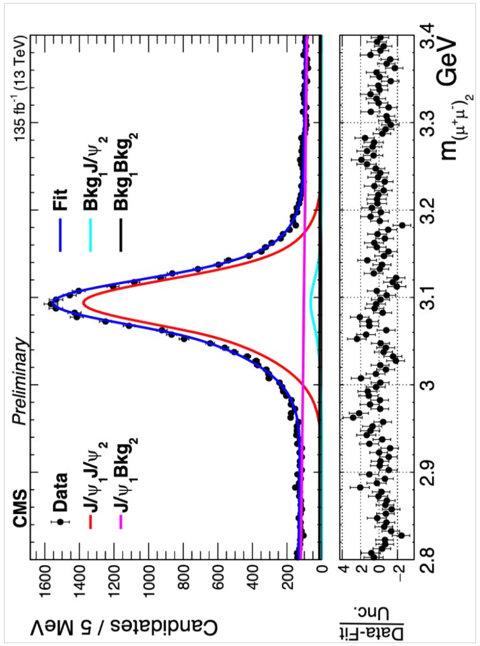
$\leftarrow (cc)_{\underline{3}^*} - (\overline{cc})_{\underline{3}}$

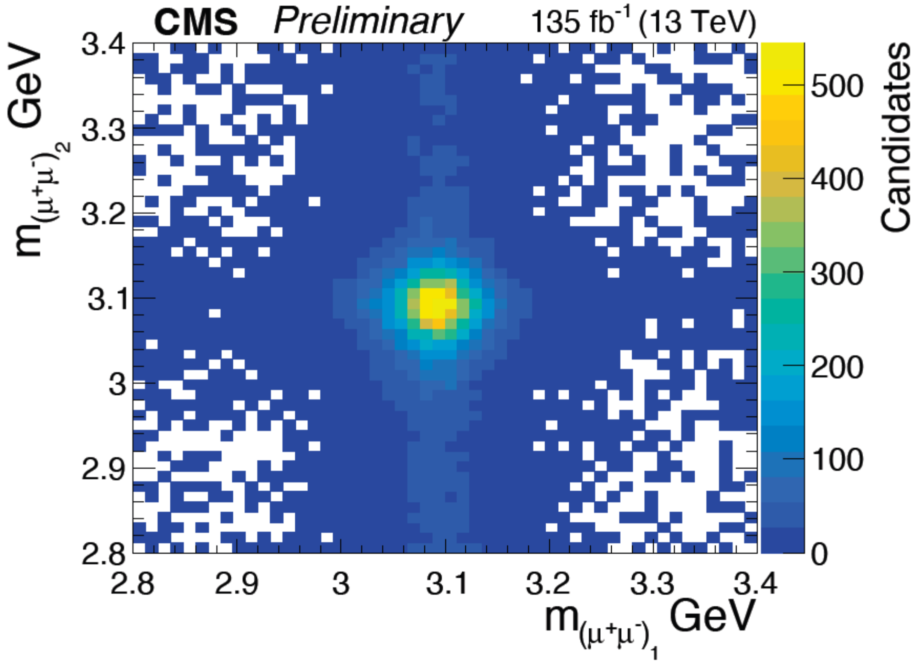
$(cc)_{\underline{6}} - (\overline{cc})_{\underline{6}^*} \rightarrow$

L	S	J^{PC}	Mass (GeV)
1	0	1^{--}	6.82
2	0	2^{++}	7.15
3	0	3^{--}	7.41

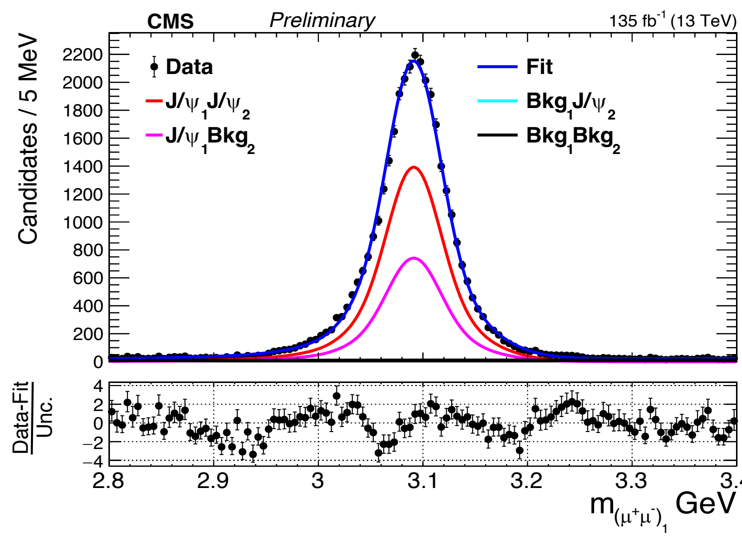
- A different system compared to exotics with light quarks

CMS J/ψJ/ψ candidates at 13 TeV



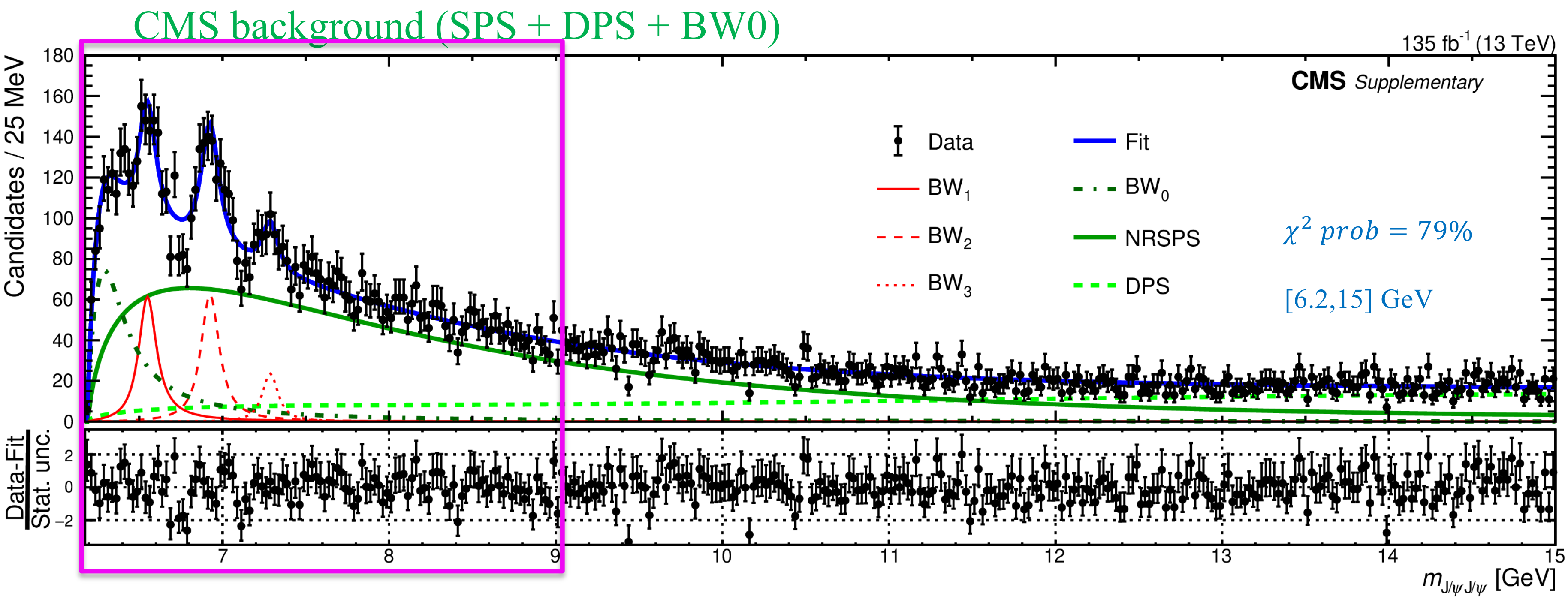


- J/ψJ/ψ from CMS:
  - 135 fb^{-1}, taken in 2016, 2017 and 2018 LHC runs
  - Clean J/ψJ/ψ signals are seen
  - J/ψ mass and vertex related cuts removed



CMS background (SPS + DPS + BW0)

PRL 132 (2024) 111901



- Most significant structure is a BW at threshold, BW0--what is its meaning?
- Treat BW0 as part of background due to:
  - BW0 parameters very sensitive to SPS and DPS model assumptions
  - A region populated by feed-down from possible higher mass states
  - Possible coupled-channel interactions, pomeron exchange processes…
- SPS+DPS+BW0 as our background

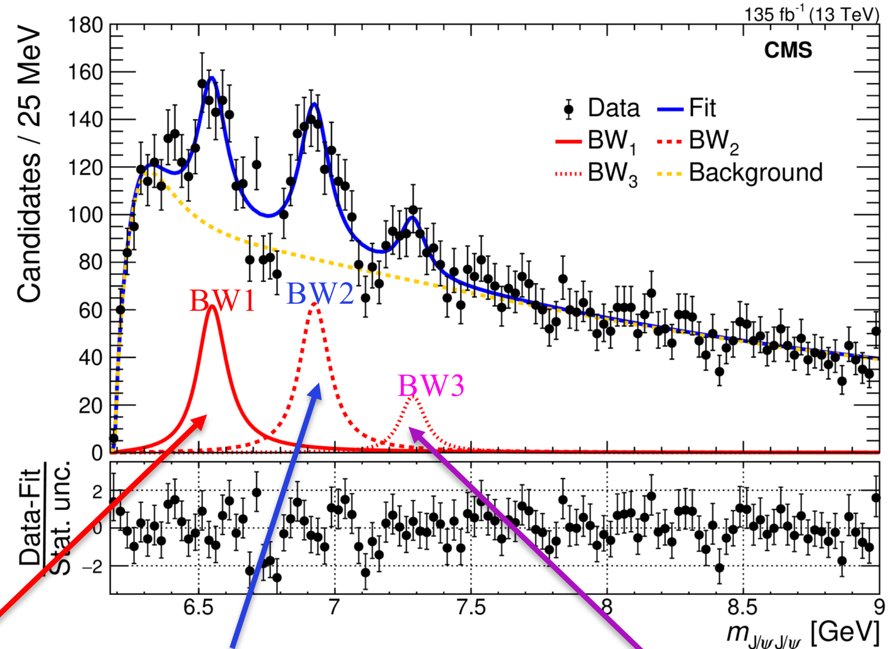
CMS J/ψJ/ψ fit: 3 BWs + Background

PRL 132 (2024) 111901

χ^2 Prob. = 1%

[6.2,7.8] GeV

Statistical significance based on: $2\ln(L_0/L_{max})$



	BW1 (MeV)	BW2 (MeV)	BW3 (MeV)
m	$6552 \pm 10 \pm 12$	$6927 \pm 9 \pm 4$	$7287^{+20}_{-18} \pm 5$
Γ	$124^{+32}_{-26} \pm 33$	$122^{+24}_{-21} \pm 18$	$95^{+59}_{-40} \pm 19$
N	470^{+120}_{-110}	492^{+78}_{-73}	156^{+64}_{-51}
σ(stat.)	6.5	9.4	4.1
σ(stat. + syst.)	5.7	9.4	4.1
	First Observation	Confirmation of X(6900) from LHCb	Evidence

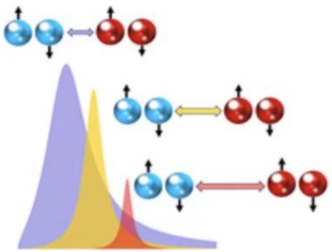
CMS J/ψJ/ψ interference fit

PRL 132 (2024) 111901

Editors' Suggestion

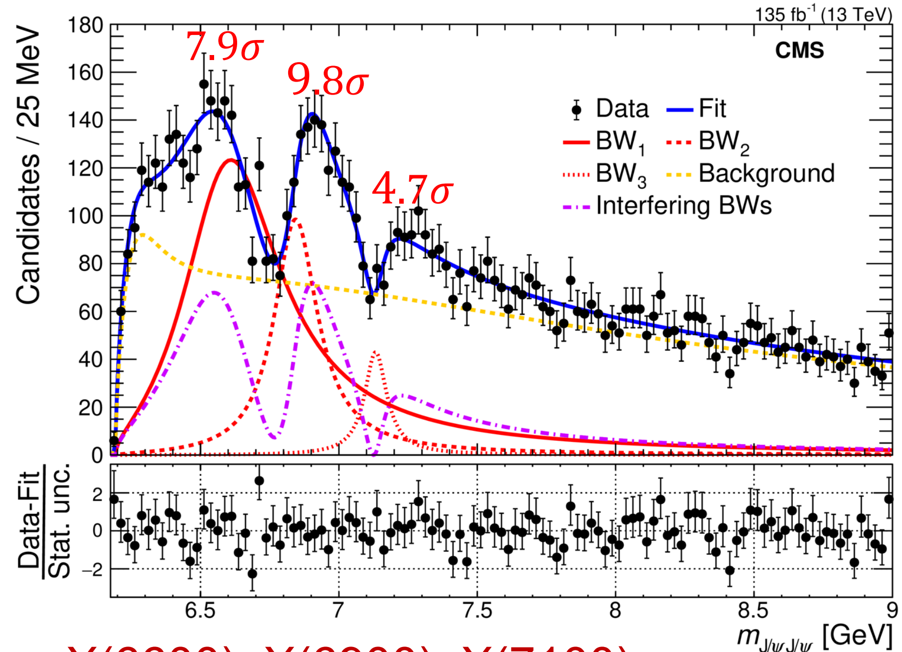
New Structures in the $J/\psi J/\psi$ Mass Spectrum in Proton-Proton Collisions at $\sqrt{s} = 13$ TeV

A. Hayrapetyan *et al.* (CMS Collaboration)
Phys. Rev. Lett. **132**, 111901 (2024) – Published 15 March 2024



Three structures, $X(6900)$ and two new ones around 6.64 and 7.13 GeV, are seen in the $J/\psi J/\psi$ mass spectrum that are consistent with being part of a family of radial excitations.

Show Abstract +



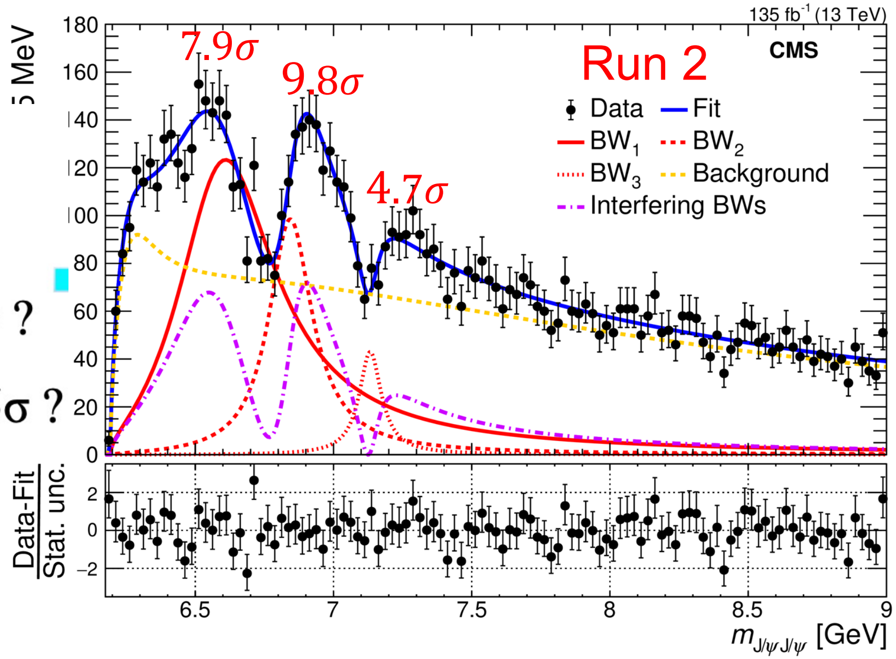
X(6600) X(6900) X(7100)

- Fit with interf. among BW1, BW2, and BW3 describes data well
- Measured mass and width in the interference fit

		BW_1	BW_2	BW_3
Interference	m [MeV]	6638^{+43+16}_{-38-31}	6847^{+44+48}_{-28-20}	7134^{+48+41}_{-25-15}
	Γ [MeV]	$440^{+230+110}_{-200-240}$	191^{+66+25}_{-49-17}	97^{+40+29}_{-29-26}

CMS J/ψJ/ψ Run 3 ?

- **X(7100)**: 4.7σ & Interference < 4σ
- Significance of **ALL** states over 5σ ?
- Significance of **interference** over 5σ ?

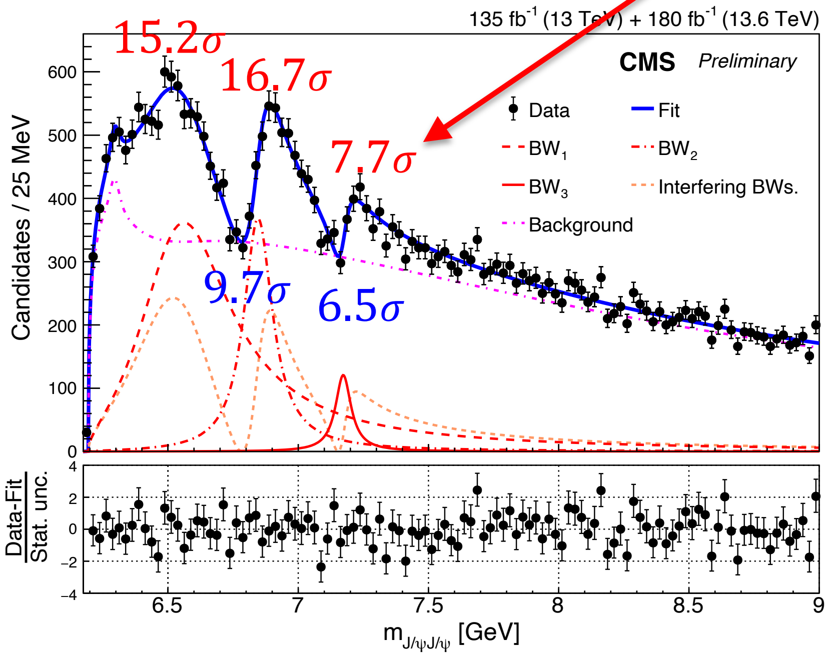


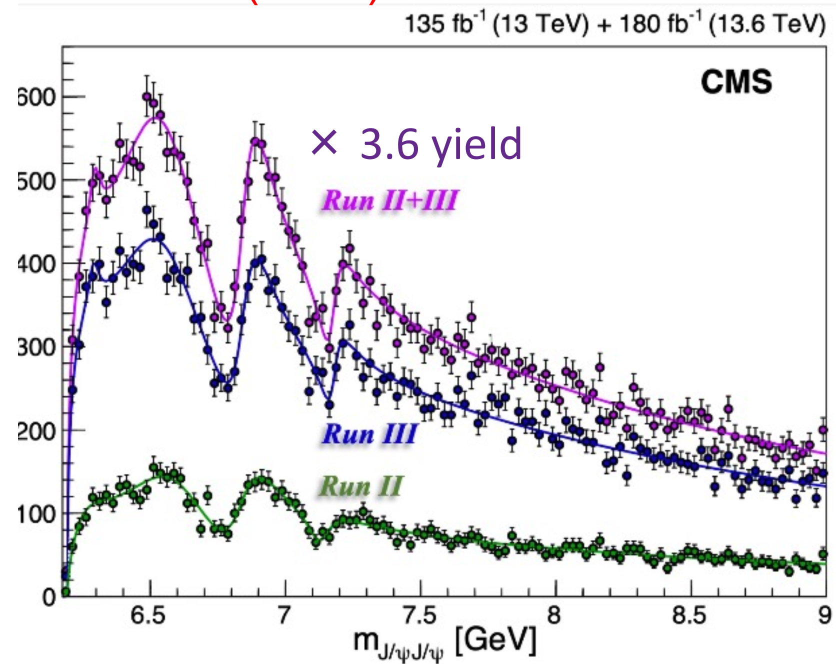
- Data samples [315 fb^{-1}]
  - Run II: 135 fb^{-1} data taken in 2016, 2017 and 2018
  - Run III: 180 fb^{-1} data taken in 2022, 2023 and 2024
  - J/ψJ/ψ events：3.6 * Run II

CMS J/ψJ/ψ fit – Run 2+3

First observation of X(7100)

CMS-PAS-BPH-24-003



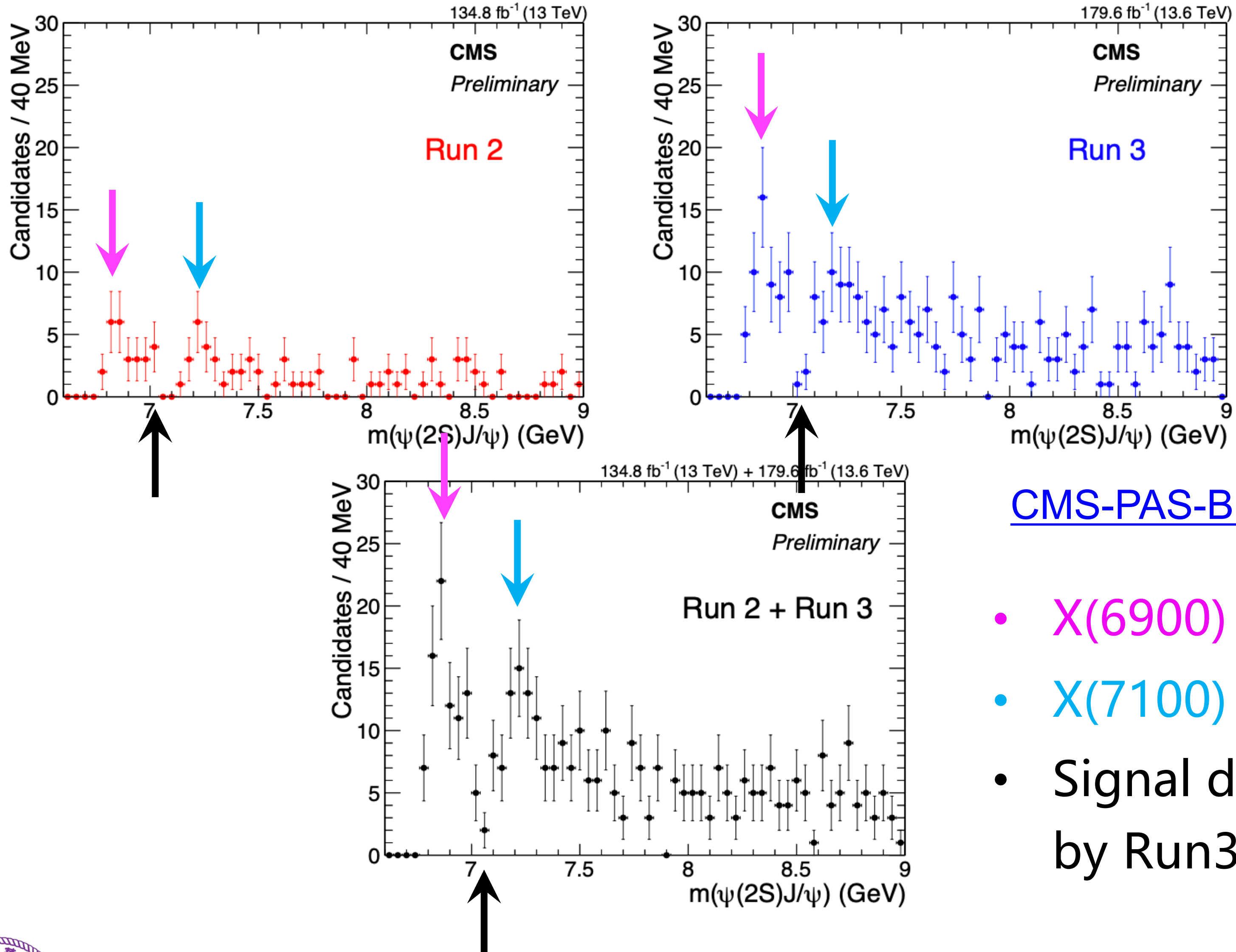


	BW1	BW2	BW3	Interf BW1-BW2	Interf BW2-BW3	Interf BW1-BW2-BW3
Significance (σ)	15.2	16.7	7.7	9.7	6.5	9.9

First observation of interferene

		BW_1	BW_2	BW_3
Interference	m (MeV)	$6593\,^{+15}_{-14} \pm 25$	$6847\,^{+10}_{-10} \pm 15$	$7173\,^{+9}_{-10} \pm 13$
(Run 2+Run 3)	Γ (MeV)	$446\,^{+66}_{-54} \pm 87$	$135\,^{+16}_{-14} \pm 14$	$73\,^{+18}_{-15} \pm 10$
Interference	m (MeV)	$6638\,^{+43+16}_{-38-31}$	$6847\,^{+44+48}_{-28-20}$	$7134\,^{+48+41}_{-25-15}$
(Run 2 [12])	Γ (MeV)	$440\,^{+230+110}_{-200-240}$	$191\,^{+66+25}_{-49-17}$	$97\,^{+40+29}_{-29-26}$

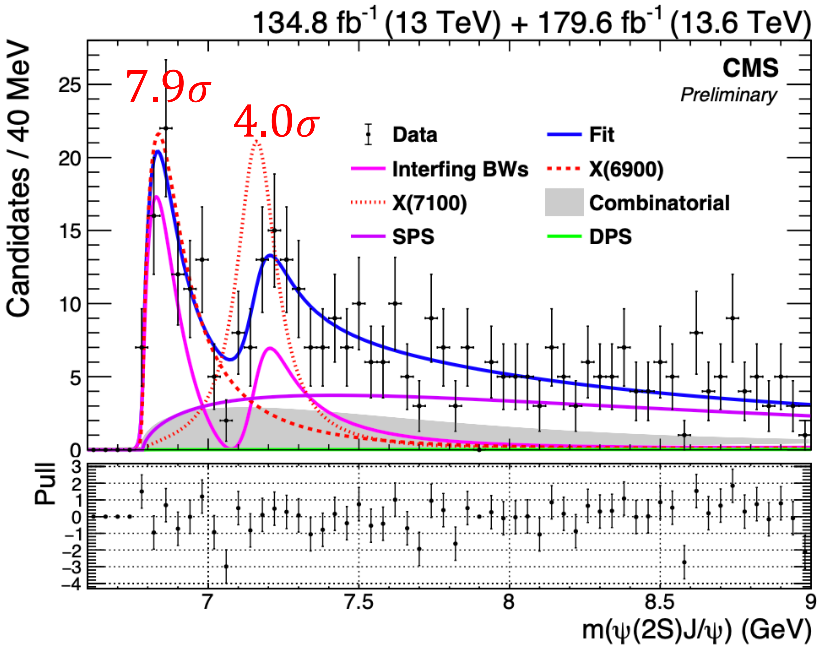
CMS ψ(2S)J/ψ mass Run 2+3



[CMS-PAS-BPH-22-004]

- X(6900) is obvious
- X(7100) is visible
- Signal dominated by Run3

CMS ψ(2S)J/ψ fit Run 2+3



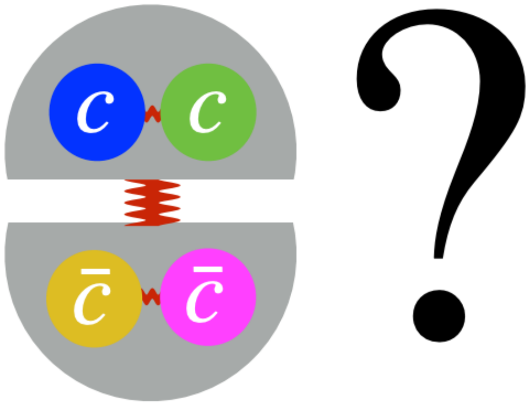
First observation of X(6900) → ψ(2S)J/ψ

Evidence of X(7100) → ψ(2S)J/ψ

CMS-PAS-BPH-22-004

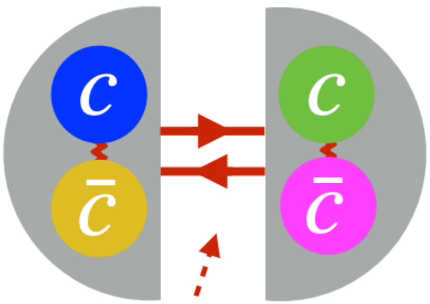
Fit	Sample	Interf.		X(6600)	X(6900)	X(7100)
f_{i23}	$J/\psi\psi(2S)$	BW_2, BW_3	m :	—	$6876^{+46+110}_{-29-110}$	7169^{+26+74}_{-52-70}
			Γ :	—	$253^{+290+120}_{-100-120}$	$154^{+110+140}_{-82-160}$
f_{JJ} [1]	$J/\psi J/\psi$	Interference	m (MeV)	$6593\ ^{+15}_{-14} \pm 25$	$6847\ ^{+10}_{-10} \pm 15$	$7173\ ^{+9}_{-10} \pm 13$
		(Run 2+Run 3)	Γ (MeV)	$446\ ^{+66}_{-54} \pm 87$	$135\ ^{+16}_{-14} \pm 14$	$73\ ^{+18}_{-15} \pm 10$
		Interference	m (MeV)	$6638\ ^{+43+16}_{-38-31}$	$6847\ ^{+44+48}_{-28-20}$	$7134\ ^{+48+41}_{-25-15}$
		(Run 2 [12])	Γ (MeV)	$440\ ^{+230+110}_{-200-240}$	$191\ ^{+66+25}_{-49-17}$	$97\ ^{+40+29}_{-29-26}$

4c States Spin Parity



"**True**" **tetraquark**
connects
two colored objects
(cc) and $(\bar{c}\bar{c})$
through direct strong interactions
like quarks in a proton or neutron

"**Molecule**"
a bound state of two mesons connected by residual nuclear force, like proton and neutron in a nucleus



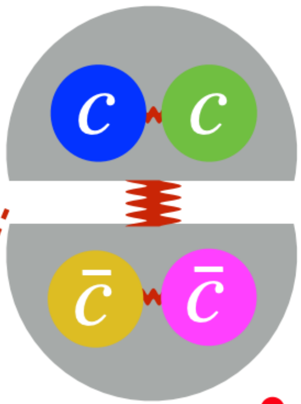
$$V(r) = g \cdot \frac{e^{-\frac{m_{\eta_c} c}{\hbar} r}}{r}$$

note $(c\bar{c})$ mass $\times$ 22 heavier than π

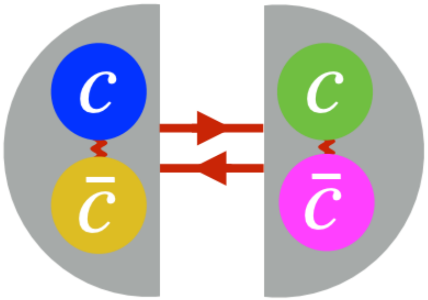
binding would be much weaker than in a nucleus or light "tetraquarks"

other empirical interactions?

4c States Spin Parity



- Fundamental study of matter at quark level…
  — unique all-heavy tetraquark states



- Quantum numbers $J^{PC} = ?$
  directly related to structure:

- Tightly-bound tetraquark:

(cc) or $(\bar{c}\bar{c})$ identical ⇒ color anti-triplet (bg-gb,..) $L = 0$, axial vector $S_{1,2} = 1$

$(cc) + (\bar{c}\bar{c})$ ⇒ $L = 0\ (\mathrm{n}S):\ S = 0, 2 \Rightarrow J^P = 0^+, 2^+$ most likely for a tetraquark

$L = 1\ (\mathrm{n}P):\ S = 1 \Rightarrow J^P = 0^-, 1^-, 2^-$ less likely

$n = 1,2,3,4,..$ $\quad L = 2\ (\mathrm{n}D):\ S = 0 \Rightarrow J^P = 2^+$

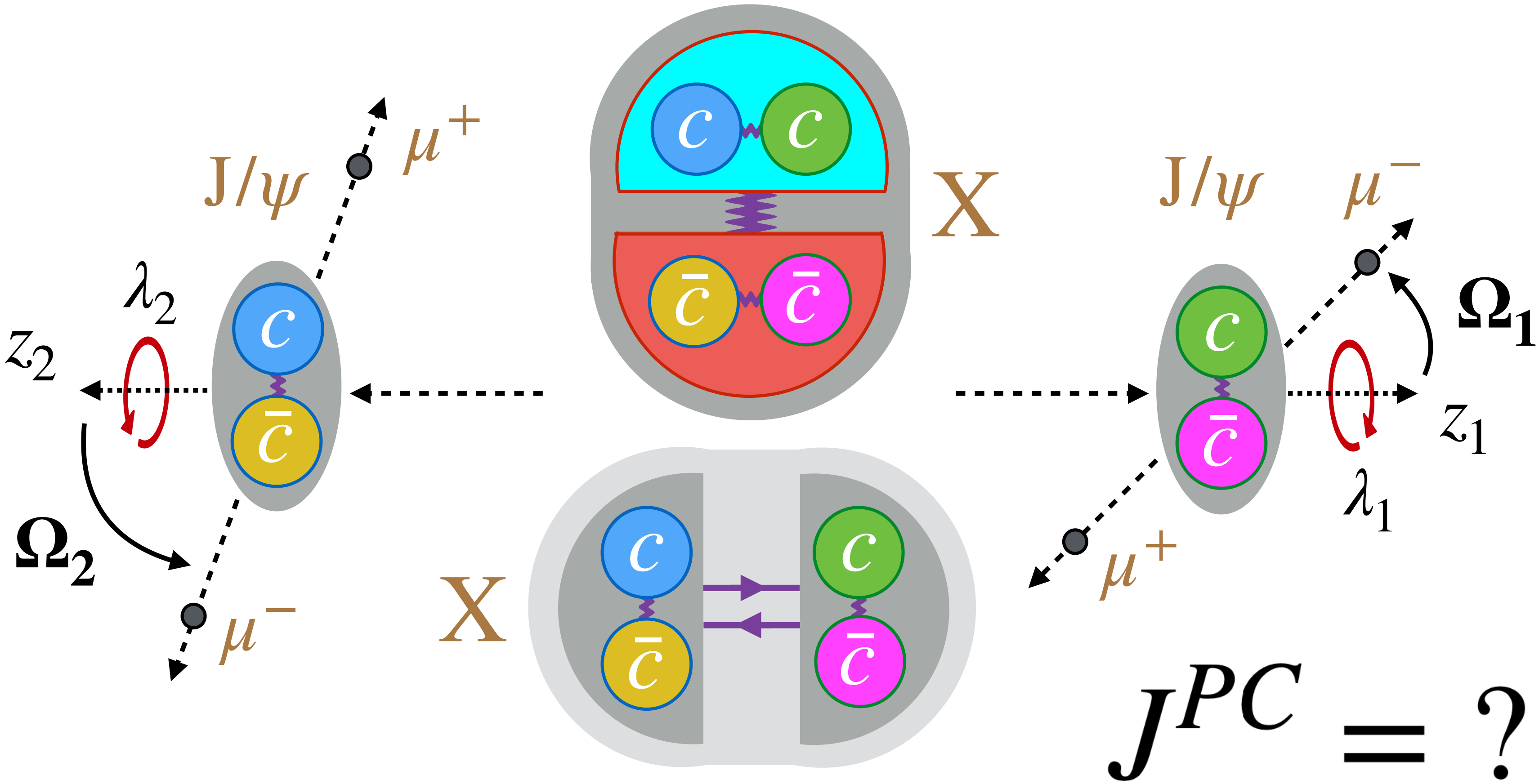
unlikely

$S = 2 \Rightarrow J^P = 0^+, 1^+, 2^+, 3^+, 4^+ \quad \ldots$

- Molecular: less restrictions (e.g. meson $S_{1,2} = 0,1$): recall $J^P = 1^+$

CMS Angular Analysis

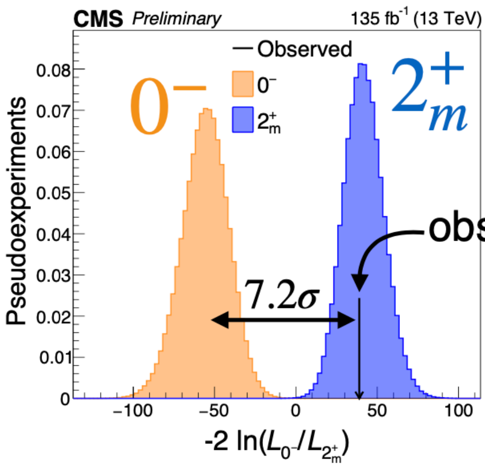
CMS-PAS-BPH-24-002, arXiv:2506.07944

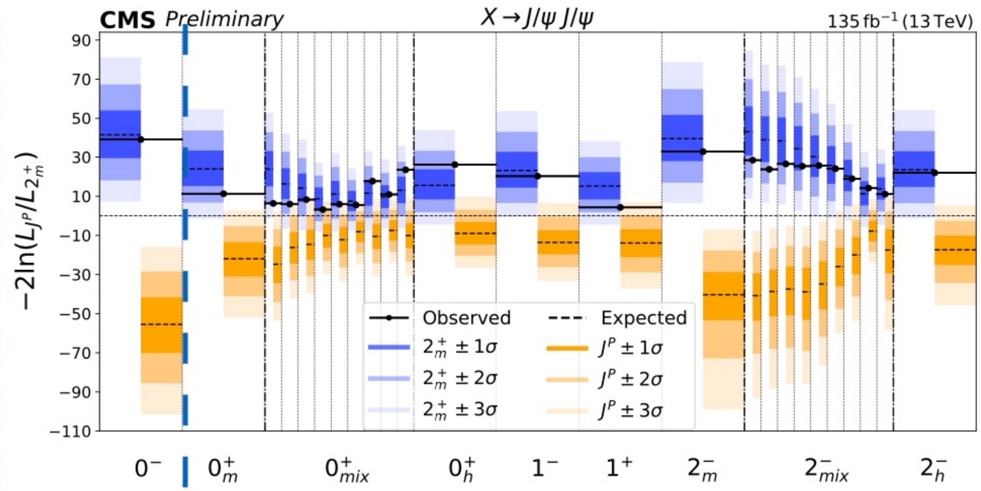


$$J^{PC} = ?$$

CMS Statistical Analysis of J^{PC}

[CMS-PAS-BPH-24-002](#), [arXiv:2506.07944](#)



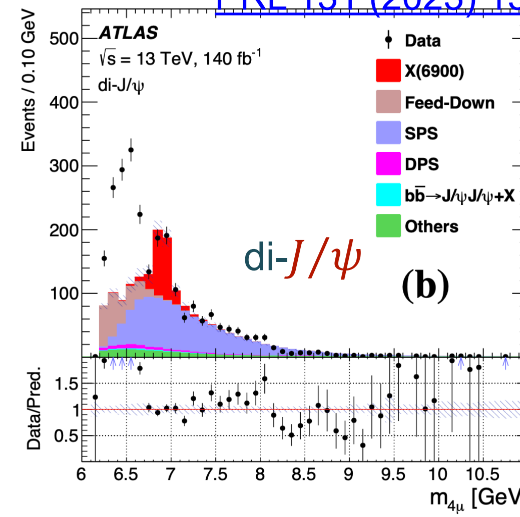


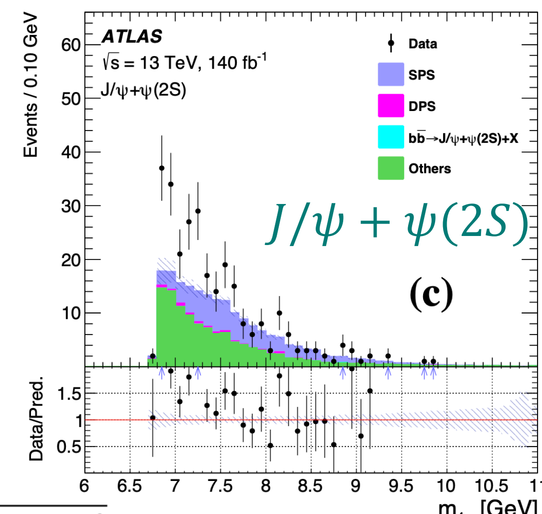
- Scan mixture of two 0^{++} amplitudes (11 steps)
  - — constructive interference most conservative
- Scan mixture of two 2^{-+} amplitudes (11 steps)
  - — no interference (different spin projections)
- Data are consistent with a 2^{++} model, inconsistent with others

Hunt for di-J/ψ resonances by ATLAS at 13 TeV

PRL 131 (2023) 151902

- Signal: $T_{cc\overline{cc}} \rightarrow J/\psi + J/\psi$ *or* $J/\psi + \psi(2S) \rightarrow 4\mu$
- Backgrounds:
  - Prompt: SPS and DPS
  - Non-prompt: $b\bar{b} \rightarrow J/\psi + J/\psi/\psi(2S) + X \rightarrow 4\mu$
  - Others: Single J/ψ background and non-peaking background containing no real J/ψ candidate
- **Excess in both channels**
- The unbinned maximum likelihood fits are performed in the 4μ mass spectrum.
  - The signal pdf: several interfering BW multiplied with a phase space factor and convolved with a mass resolution function





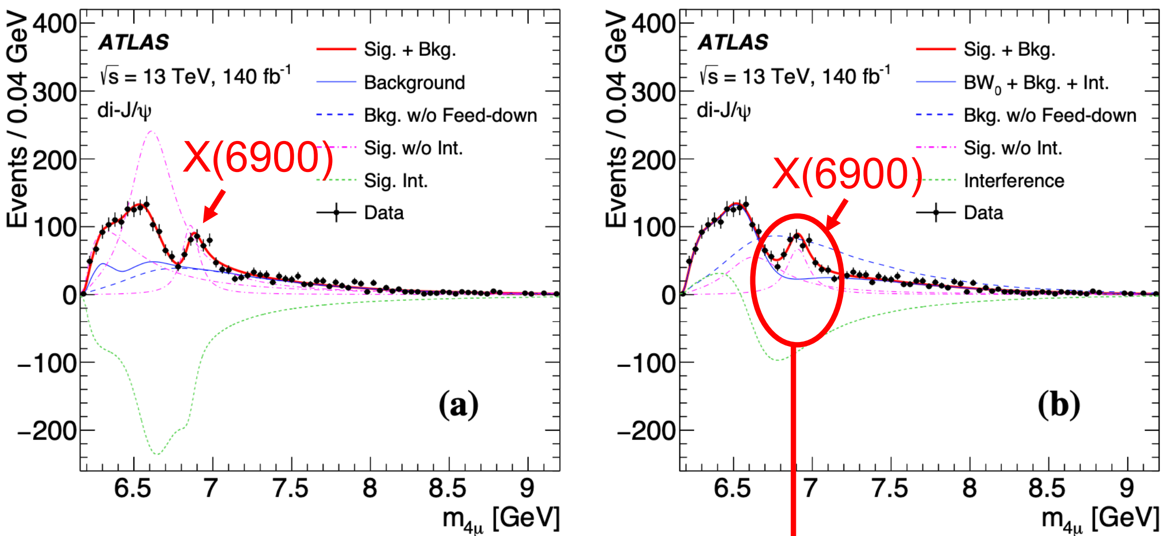
di-J/ψ : $f_s(x) = \left|\sum_{i=0}^{2} \frac{z_i}{x^2 - m_i^2 + i m_i \Gamma_i}\right|^2 \sqrt{1 - \frac{4m_{J/\psi}^2}{x^2}} \otimes R(\alpha)$

$J/\psi + \psi(2S)$: $f_s(x) = \left(\underbrace{\left|\sum_{i=0}^{2} \frac{z_i}{x^2 - m_i^2 + i m_i \Gamma_i}\right|^2} + \underbrace{\left|\frac{z_3}{x^2 - m_3^2 + i m_3 \Gamma_3}\right|^2}\right) \sqrt{1 - \left(\frac{m_{J/\psi} + m_{\psi(2S)}}{x}\right)^2} \otimes R(\alpha)$

ATLAS di-J/ψ channel

[PRL 131 (2023) 151902](PRL 131 (2023) 151902)

Model A   Model B



Extracted masses and widths (GeV)

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	$0.11 \pm 0.05^{+0.02}_{-0.01}$	$0.15 \pm 0.03 \pm 0.01$
$\Delta s/s$	$\pm 5.1\%^{+8.1\%}_{-8.9\%}$	—

X(6900) > 5σ

- Model A - similar to LHCb model I, but 2 auxiliary BWs interfere with X(6900)
- Model B - similar to LHCb model II: one auxiliary BW interferes with NRSPS
- Both models describe the data well
  - the broad structure at the lower mass could result from other physical effects, such as the feed-down
- The peak around 6.9 GeV is consistent with the LHCb observed X(6900), with significance > 5σ

ATLAS $J/\psi + \psi(2S)$ channel

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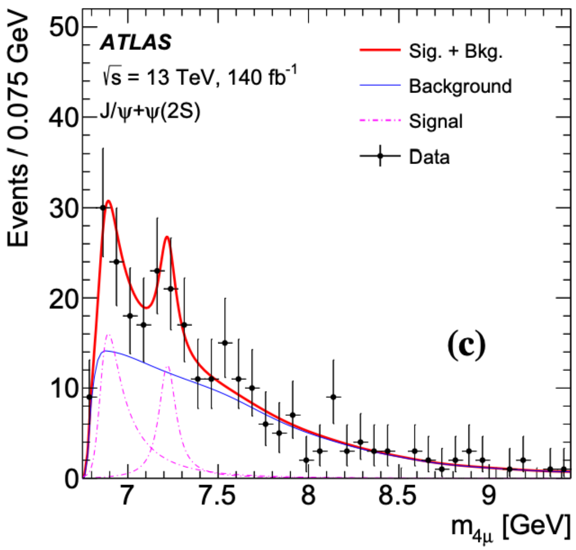
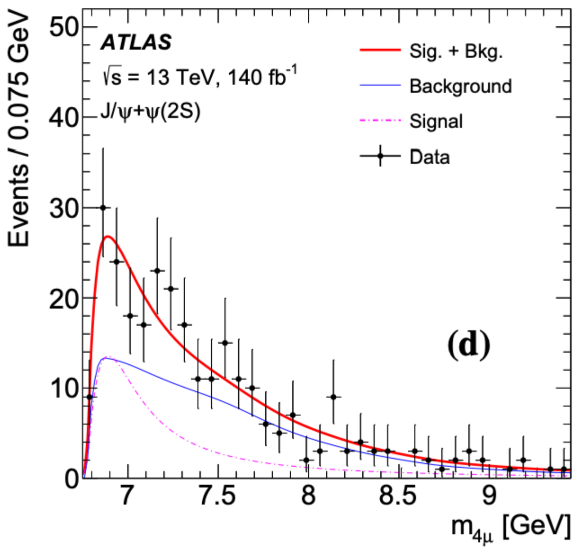
Model α



Model β

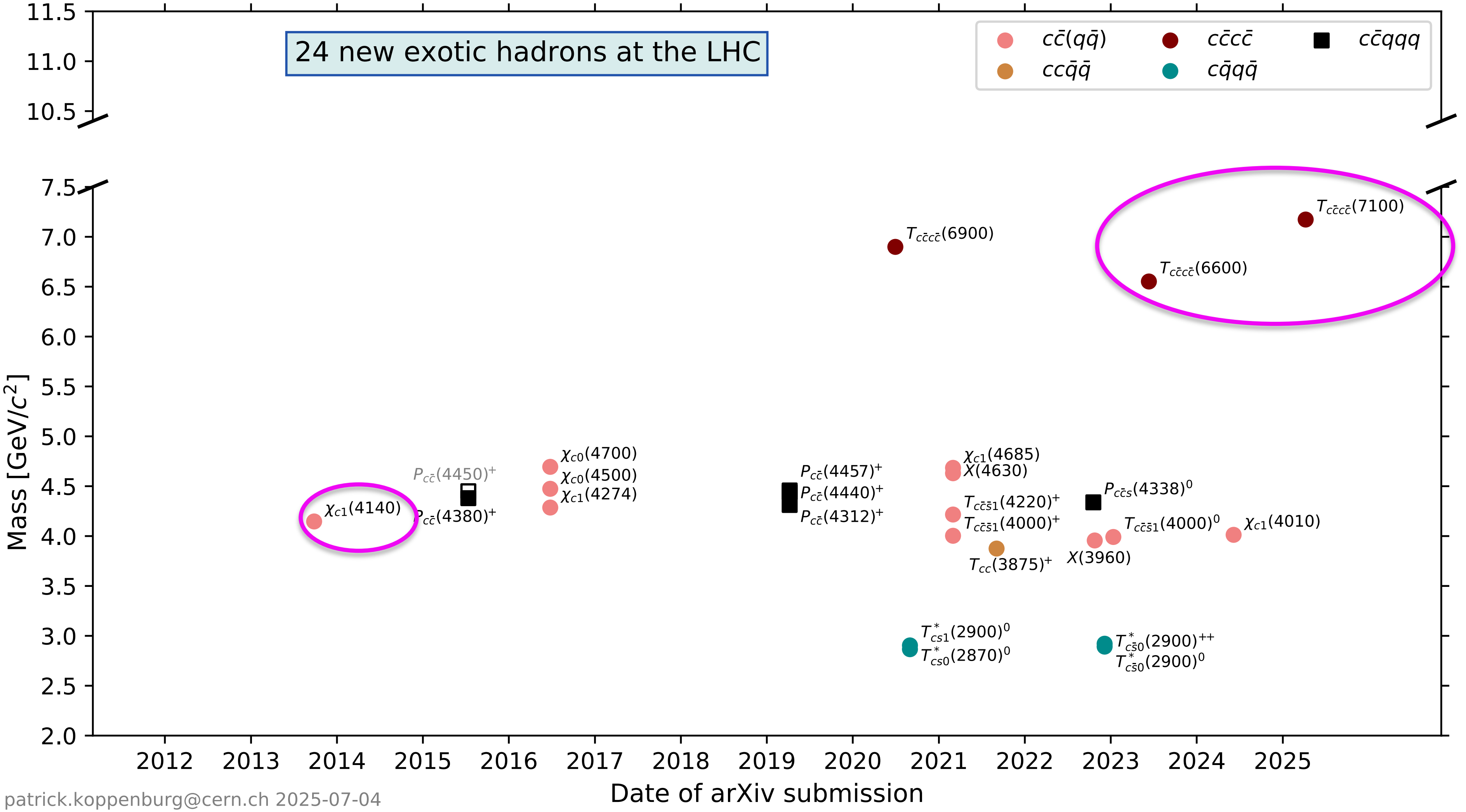


- Model α: X(6900)+2nd resonance
  - Two bumps together: 4.7 σ
  - 2nd bump alone: 3 σ
- Model β: a single resonance X(6900) in this channel
  - 4.3 σ

Extracted masses and widths (GeV)

$J/\psi+\psi(2S)$	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	$0.09 \pm 0.06^{+0.06}_{-0.03}$	$0.51 \pm 0.17^{+0.11}_{-0.10}$
$\Delta s/s$	$\pm 21\% \pm 14\%$	$\pm 20\% \pm 12\%$

Summary: new exotic hadrons at LHC



https://www.nikhef.nl/~pkoppenb/particles.html

Recent spectroscopy results

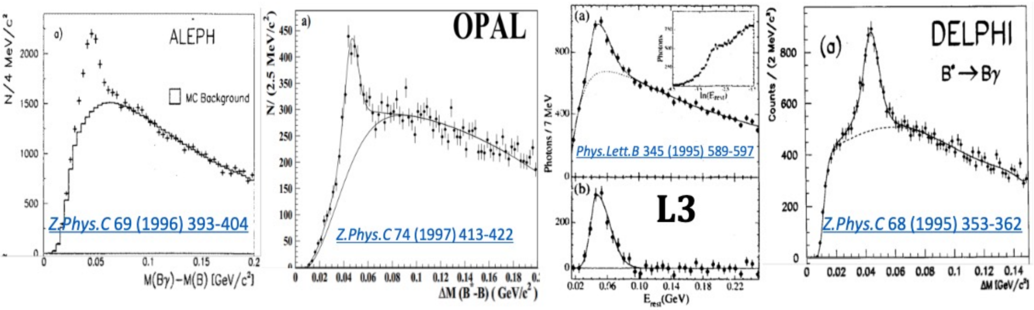
- Spectroscopy of exotic hadrons
  - CMS: Observation of X(6600) and X(7100) in $\mathrm{J}/\psi\,\mathrm{J}/\psi$ (2023, 2025)
  - CMS: Observation of X(6900) in $\mathrm{J}/\psi\,\psi(2S)$ (2025)
  - CMS: Spin-parity measurement of the tetraquark family X(6600),X(6900),X(7100) (2025)
  - ATLAS: Confirmation of X(6900) in.$\mathrm{J}/\psi\,\mathrm{J}/\psi$ (2023)
  - ATLAS: Evidence of X(6900) in $\mathrm{J}/\psi\,\psi(2S)$ (2023)

- Spectroscopy of conventional hadrons
  - CMS: First full reconstruction of B* mesons (2025)

History of B* meson studies

LEP experiments L3, DELPHI, OPAL, ALEPH
using $Z \to b\bar{b}$ process, inclusively reconstruct B meson as **b-jet**
combine **b-jet** with a converted photon (calibrated via π^0)

Measure **averaged between B^{*+}, B^{*0}, and B_s^{*0}** mass difference
***m*(B*)−*m*(B)**



Assumes $\Delta m = m(B^{*0})-m(B^0)=m(B^{*+})-m(B^+)$
for D mesons such Δm are different by 1.5 MeV!

$m_{B^*}-m_B$

VALUE (MeV)		EVTS	DOCUMENT ID		TECN
45.21 ± 0.21	OUR FIT				
45.42 ± 0.26	OUR AVERAGE includes data from $m_{B^*}-m_B$				
$46.2 \pm 0.3 \pm 0.8$			[1] ACKERSTAFF	1997M	OPAL
$45.3 \pm 0.35 \pm 0.87$		4227	[1] BUSKULIC	1996D	ALEP
$45.5 \pm 0.3 \pm 0.8$			[1] ABREU	1995R	DLPH
46.3 ± 1.9		1378	[1] ACCIARRI	1995B	L3

28+ year-old measurements!

Mass differences also measured via P-wave B_s^0 states

$m(B^{*+})-m(B^+)$ measured by LHCb using the difference between $B_{s2}^*(5840)^0 \to B^{*+}K^-$ and $B_{s2}^*(5840)^0 \to B^+K^-$ peak positions

$m(B^{*+})-m(B^{*0})$ was measured by CMS (BPH-16-003) via the difference between $B_{s1}(5830)^0 \to B^{*0}K_S^0$ and $B_{s1}(5830)^0 \to B^{*+}K^-$ peak positions

PDG still has a single "entry" for B^{*+} and B^{*0}!

$B^\pm$	$1/2(0^-)$
B^0	$1/2(0^-)$
$B^\pm/B^0$ ADMIXTURE	
$B^\pm/B^0/B_s^0/b$-baryon ADMIXTURE	
V_{cb} and V_{ub} CKM Matrix Elements	
B^*	$1/2(1^-)$
$B_1(5721)$	$1/2(1^+)$

B^* MASS	5324.71 ± 0.21 MeV
$m_{B^*}-m_B$	45.21 ± 0.21 MeV
$m_{B^{*+}}-m_{B^+}$	45.37 ± 0.21 MeV
$\lvert(m_{B^{*+}}-m_{B^+})-(m_{B^{*0}}-m_{B^0})\rvert$	< 6 MeV CL=95.0%
$m_{B^{*0}}-m_{B^{*+}}$	0.91 ± 0.26 MeV

Main challenge: very low-energy photons emitted in B*→Bγ

B_s^{*0} measurements at B-factories

B_s^{*0} mass difference w.r.t. B_s^0 was previously measured at B-factories via the energy spectrum of reconstructed B_s^0 mesons assumed to be produced in $\Upsilon(5S)$ decays:

- $\Upsilon(5S) \to B_s^0 \overline{B}_s^0$
- $\Upsilon(5S) \to B_s^{*0} \overline{B}_s^0$
- $\Upsilon(5S) \to B_s^0 \overline{B}_s^{*0}$
- $\Upsilon(5S) \to B_s^{*0} \overline{B}_s^{*0}$

However, the results were not in a good agreement with each other (PDG scale factor 2.9)

Central value of the mass difference is larger in comparison to B^+ & B^0

$m_{B_s^*} - m_{B_s}$

VALUE (MeV)		DOCUMENT ID		TECN	COMMENT
$48.5^{+1.8}_{-1.5}$	OUR FIT Error includes scale factor of 2.9.				
46.1 ± 1.5	OUR AVERAGE				
$45.7 \pm 1.7 \pm 0.7$		[1] AQUINES	2006	CLEO	$e^+ e^- \to \Upsilon(5S)$
47.0 ± 2.6		[2] LEE-FRANZINI	1990	CSB2	$e^+ e^- \to \Upsilon(5S)$

B_s^* MASS

From mass difference below and the B_s^0 mass.

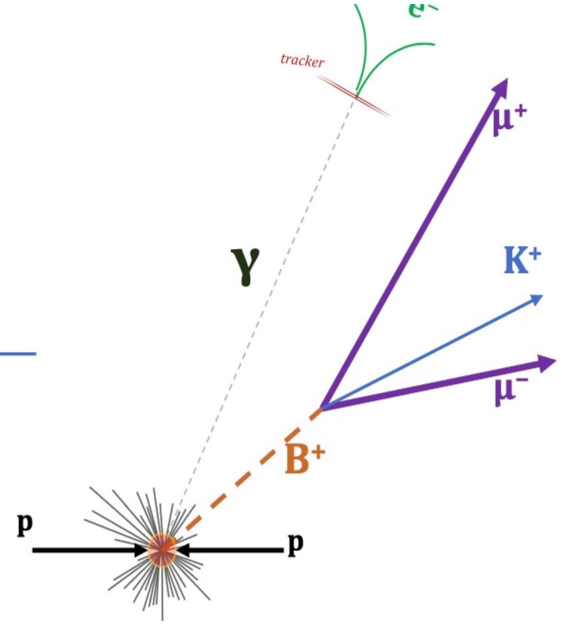
VALUE (MeV)		DOCUMENT ID		TECN
$5415.4^{+1.8}_{-1.5}$	OUR FIT Error includes scale factor of 2.9.			
5415.8 ± 1.5	OUR AVERAGE Error includes scale factor of 2.6.			
$5416.4 \pm 0.4 \pm 0.5$		LOUVOT	2009	BELL
$5411.7 \pm 1.6 \pm 0.6$		[1] AQUINES	2006	CLEO

Do we have enough data in CMS to exclusively reconstruct B^{*+}, B^{*0}, and B_s^{*0} mesons via J/ψ modes and provide separate measurements of the respective Δm?

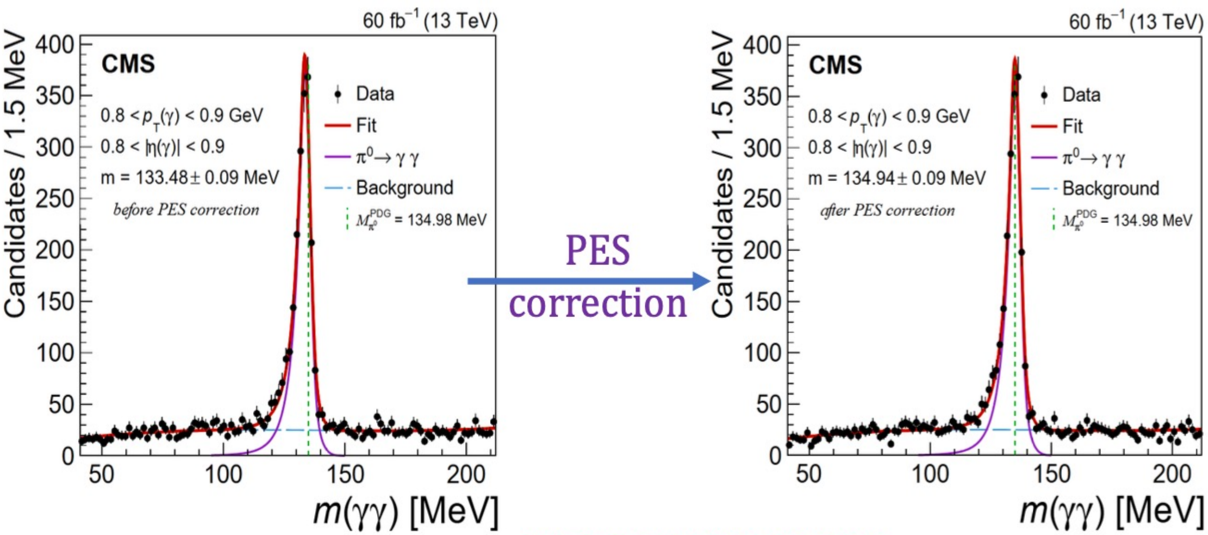
Reconstruction with CMS Run 2 data

CMS-BPH-24-011, arXiv:2508.05820

- No selection of a single trigger, use all
- Standard reconstruction of charmonium decays
  - $B^+ \to \psi K^+$, $B^0 \to \psi K^*(892)^0$ $[K^+\pi^-]$, $B_s^0 \to \psi \varphi$ $[K^+K^-]$, J/ψ or $\psi(2S)$ $\to \mu^+\mu^-$
- Add a **photon conversion**, refit e^+e^- tracks with m=0 constraint, Fit Bγ vertex
- Refit Bγ into PV to improve the mass resolution



Photon energy scale calibration with π^0



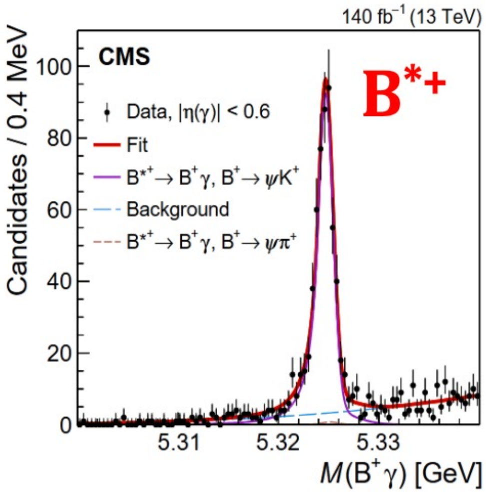
PDG π^0 mass: 134.9768 ± 0.0005 MeV

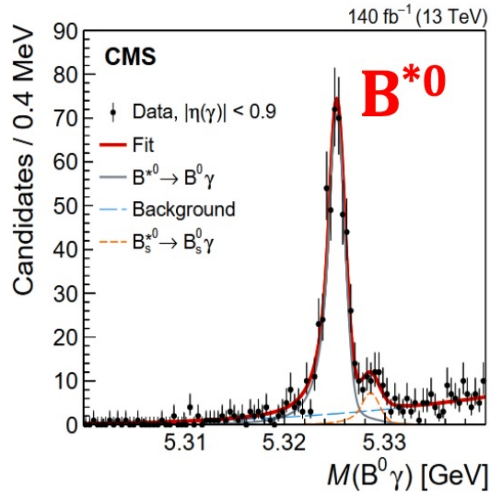
Photon energy from conversions is underestimated out of the box, developed a dedicated correction

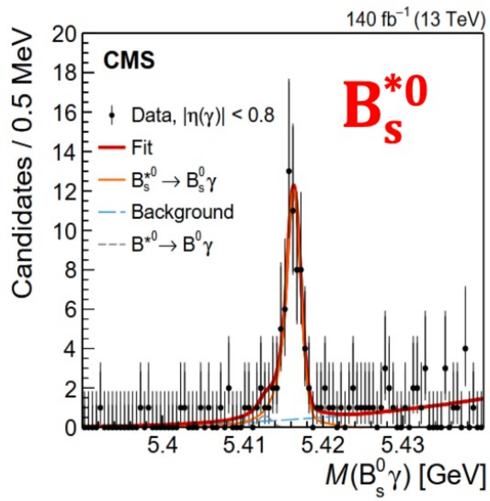
$\pi^0 \to \gamma\gamma$ signal from two conversions, in a number of p_T and η ranges,

B* signals in CMS Run 2 data

CMS-BPH-24-011, arXiv:2508.05820







Simultaneous fit in the 7 categories

Most sensitive 3 are shown here, the other 4 in backup

Signals are described by DCB shapes fixed to MC except a common (for all) resolution scaling factor

Mass differences are shared (within B flavour)

$B^+ \to J/\psi\pi^+$ fixed shape and relative normalization

$B^{*0} \Leftrightarrow B_s^{*0}$ cross-feed: shifted signal shapes, for B^{*0} fixed relative normalization

Bkg: $(m - m^0)^\beta$ with common β

3 states reconstructed fully exclusively for the 1st time

Precision order of magnitude better than PDG

Systematics much smaller than stat. uncertainty

$$M(X\gamma) = m(X\gamma) - m(X) + M^{PDG}(X)$$

CMS B* mass results

CMS-BPH-24-011, arXiv:2508.05820

	Parameter	Value
1	$\Delta m(\mathrm{B}^{*+}) \equiv m(\mathrm{B}^{*+}) - m(\mathrm{B}^{+})$	$45.277 \pm 0.039 \pm 0.027$ MeV
2	$\Delta m(\mathrm{B}^{*0}) \equiv m(\mathrm{B}^{*0}) - m(\mathrm{B}^{0})$	$45.471 \pm 0.056 \pm 0.028$ MeV
3	$\Delta m(\mathrm{B}_s^{*0}) \equiv m(\mathrm{B}_s^{*0}) - m(\mathrm{B}_s^{0})$	$49.407 \pm 0.132 \pm 0.041$ MeV
4	$m(\mathrm{B}^{*+})$	$5324.69 \pm 0.04 \pm 0.03 \pm 0.07$ MeV
5	$m(\mathrm{B}^{*0})$	$5325.19 \pm 0.06 \pm 0.03 \pm 0.08$ MeV
6	$m(\mathrm{B}_s^{*0})$	$5416.34 \pm 0.13 \pm 0.04 \pm 0.10$ MeV
7	$m(\mathrm{B}^{*0}) - m(\mathrm{B}^{*+})$	$0.50 \pm 0.07 \pm 0.01 \pm 0.05$ MeV
8	$m(\mathrm{B}_s^{*0}) - m(\mathrm{B}^{*+})$	$91.66 \pm 0.14 \pm 0.03 \pm 0.12$ MeV
9	$m(\mathrm{B}_s^{*0}) - m(\mathrm{B}^{*0})$	$91.15 \pm 0.14 \pm 0.03 \pm 0.12$ MeV
10	$m(\mathrm{B}_s^{*0}) - \frac{1}{2}\left[m(\mathrm{B}^{*0}) + m(\mathrm{B}^{*+})\right]$	$91.40 \pm 0.13 \pm 0.03 \pm 0.12$ MeV
11	$\Delta m(\mathrm{B}^{*0}) - \Delta m(\mathrm{B}^{*+})$	$0.19 \pm 0.07 \pm 0.01$ MeV
12	$\Delta m(\mathrm{B}_s^{*0}) - \Delta m(\mathrm{B}^{*+})$	$4.13 \pm 0.14 \pm 0.03$ MeV
13	$\Delta m(\mathrm{B}_s^{*0}) - \Delta m(\mathrm{B}^{*0})$	$3.94 \pm 0.14 \pm 0.03$ MeV
14	$\Delta m(\mathrm{B}_s^{*0}) - \frac{1}{2}\left[\Delta m(\mathrm{B}^{*0}) + \Delta m(\mathrm{B}^{*+})\right]$	$4.03 \pm 0.13 \pm 0.03$ MeV
15	$\Delta m(\mathrm{B}^{*0}) / \Delta m(\mathrm{B}^{*+})$	$1.0043 \pm 0.0015 \pm 0.0002$
16	$\Delta m(\mathrm{B}_s^{*0}) / \Delta m(\mathrm{B}^{*+})$	$1.0912 \pm 0.0031 \pm 0.0007$
17	$\Delta m(\mathrm{B}_s^{*0}) / \Delta m(\mathrm{B}^{*0})$	$1.0866 \pm 0.0031 \pm 0.0007$
18	$2\,\Delta m(\mathrm{B}_s^{*0}) / \left[\Delta m(\mathrm{B}^{*+}) + \Delta m(\mathrm{B}^{*0})\right]$	$1.0889 \pm 0.0030 \pm 0.0007$

PDG 2024 [MeV]

45.34 ± 0.20

45.34 ± 0.20

48.5 ± 1.4

Main result: hyperfine splittings in B system

Order of magnitude precision improvement!

Adding PDG B masses

"B* mass" 5324.75±0.20 MeV

B_s^{*0} mass 5415.4±1.4 MeV

Mass differences between vector states

CMS-BPH-16-003

In agreement, 3 times more precise

$M_{\mathrm{B}^{*0}} - M_{\mathrm{B}^{*+}} = 0.91 \pm 0.24 \pm 0.09 \pm 0.02$ MeV

first measurements

Differences between hyperfine splittings:
first measurements

Ratios between hyperfine splittings:
first measurements

Submitted to PRL

Summary

- ATLAS, CMS, LHCb paint a consistent picture of fully-charm tetraquarks:
  - Measured masses of 3 resonances with full Run2+3 data
  - Measurement of spin-parity reveal their $J^{PC} = 2^{++}$
- CMS fully exclusively reconstruct, for the first time, B^{*+}, B^{*0}, and B_s^{*0} signals
  - Order of magnitude precision improvement in the Δm values!
  - 18 various measurements, including differences and ratios, are provided for completeness
- Stay tuned for more results including those with much larger Run 3 dataset!

Thank you!