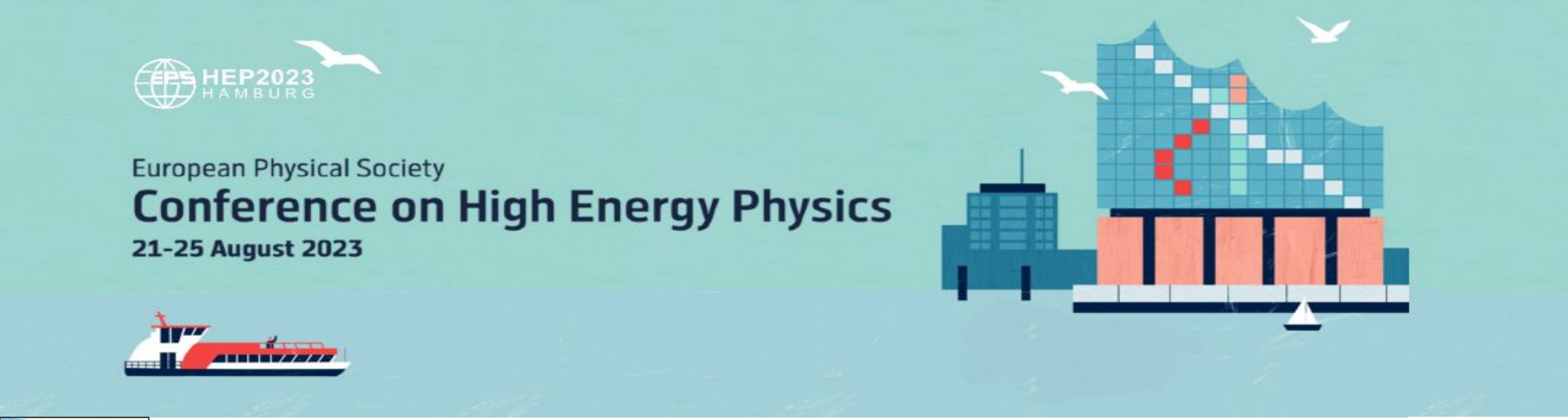

CMS results on flavor spectroscopy

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On behalf of the CMS collaboration

23/08/2023

Outline

Recent results in spectroscopy from the CMS collaboration.

- ➔ Observation of $\Xi_b(6100)^-$ baryon
- ➔ Observation of $\Lambda_b^0 \rightarrow J/\psi\, \Xi^-\, K^+$ decay
- ➔ Observation of $\eta \rightarrow 4\mu$ decay
- ➔ Observation of new structure in the $J/\psi\, J/\psi$ mass spectrum

Observation of $\Xi_b(6100)^-$ baryon

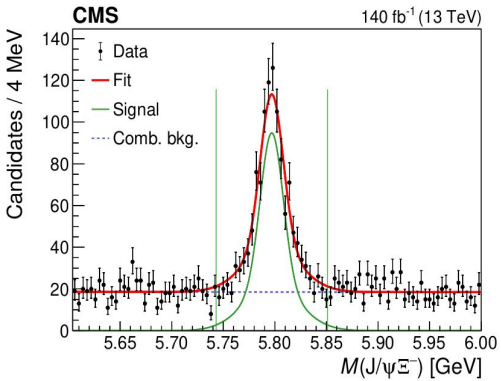
PhysRevLett.126.252003

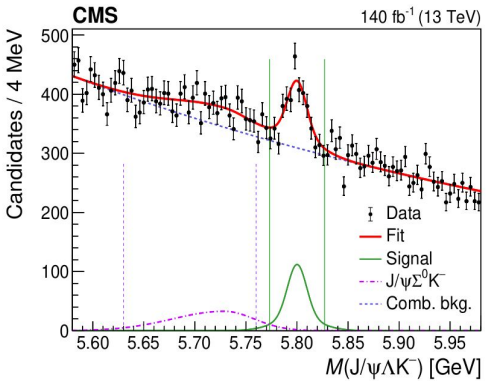
- The LHCb Collaboration reported the observation,

  $\Xi_b(6227)^- \rightarrow \Lambda_b^0 K^-$ and $\Xi_b^0 \pi^-$ [Phys. Rev. Lett. 121], $\Xi_b(6227)^0 \rightarrow \Xi_b^- \pi^+$ [Phys. Rev. D 103]

- CMS search for Ξ_b^- excited states with 2016+2017+2018 data (140 fb^{-1}) in the $\Xi_b^- \pi^+ \pi^-$ invariant mass spectrum.
- The ground state Ξ_b^- is reconstructed via $J/\psi\,\Xi^-$ and $J/\psi\,\Lambda\,K^-$, where, $J/\psi \rightarrow \mu^+\mu^-$, $\Xi^- \rightarrow \Lambda\pi^-$, and $\Lambda \rightarrow p\pi$.
- Invariant mass of $J/\psi\,\Xi^-$ (left) and $J/\psi\,\Lambda\,K^-$ (right). $J/\psi\,\Sigma^0\,K^-$ - partially reconstructed background.

Ξ_b^- PDG - 5797.0 ± 0.6 MeV





$J/\psi\,\Xi^-$	$J/\psi\,\Lambda\,K^-$
Model - Double Gaussians + 1st order polynomial	Model - Double Gaussians + Exponential
Yield - 859 ± 36	$J/\psi\,\Lambda\,K^-$ Yield - 815 ± 74
mass - 5797.0 ± 0.7 MeV (left)	$J/\psi\,\Sigma^0\,K^-$ Yield - 820 ± 158
	mass - 5800.1 ± 1.2 MeV (right)

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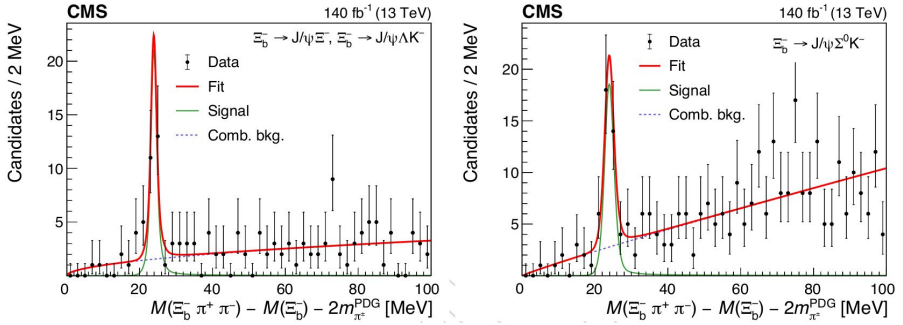
PhysRevLett.126.252003

Distributions of the invariant mass difference ΔM for the selected $\Xi_b^- \pi^+ \pi^-$ candidates, with the Ξ_b^- reconstructed in the $J/\psi\,\Xi^-$ and $J/\psi\,\Lambda\,K^-$ channels (left) or partially reconstructed in the $J/\psi\,\Sigma^0\,K^-$ channel (right).



Results :

The first observation of Ξ_b^{**-} beauty-strange baryon.

Natural width of this resonance is compatible with zero and a 95% confidence level upper limit of 1.9 MeV.

Fit is relativistic Breit-Wigner convoluted with resolution.

Fitted mass difference of the new $\Xi_b(6100)$ state –

$\Delta M_{\Xi b(6100)-}$: 24.14 ± 0.22 MeV.

Yield: 26 ± 7 (fully reconstructed) and 34 ± 9.

$$M(\Xi_b(6100)^-) - M(\Xi_b^-) - 2\,m_{\pi^\pm}^{PDG} = 24.14 \pm 0.22\,(\text{stat}) \pm 0.09\,(\text{syst})\,\text{MeV}$$

A 13 MeV mass increase places $\Xi_b(6100)^-$ above $\Lambda_b^0\,K^-$ threshold, could have been enabled the potential decay to $\Lambda_b^0\,K^-$ state.

Observation of $\Lambda_b^0 \rightarrow J/\psi\, \Xi^- K^+$ decay

CMS-PAS-BPH-22-002

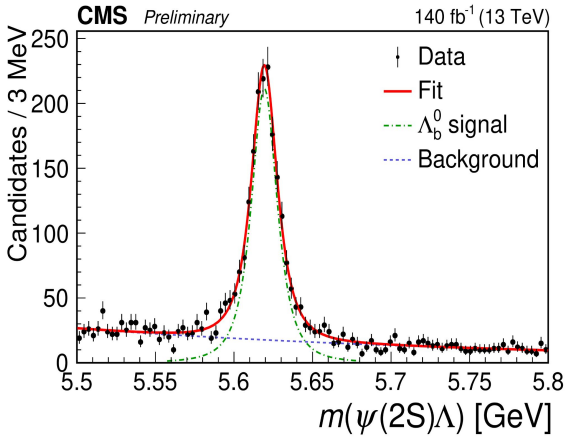
- LHCb Collaboration identified significant J/ψp structures in Λ_b^0 decaying to J/ψpK$^-$, marking exotic baryon spectroscopy breakthrough.
- Hidden-charm pentaquarks seen in J/ψp and J/ψΛ systems only.
- Exploring heavier baryon channels (e.g., Ξ^- and Ω^-) might unveil doubly or triply strange pentaquark states.
- CMS search for the $\Lambda_b^0 \rightarrow J/\psi \Xi^- K^+$ decay with 2016+2017+2018 data (140 fb^{-1}), where the $J/\psi \rightarrow \mu^+ \mu^-$, $\Xi^- \rightarrow \Lambda\pi^-$, and $\Lambda \rightarrow p\pi$ channels are used to reconstruct the intermediate decay products.

Normalization channel - $\Lambda_b^0 \rightarrow \psi(2S)\, \Lambda$

(similar decay topology and kinematics to the signal decay, can reduce systematic uncertainties)

Model - Student-T function for signal, Exponential for background

$m(\Lambda_b^0) = 5619.3 \pm 0.3$ MeV, Yield = 1744 ± 63



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CMS-PAS-BPH-22-002

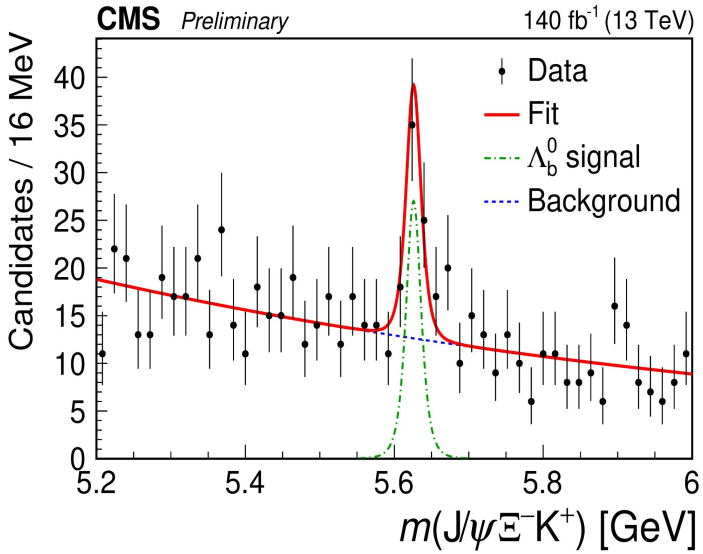
A narrow peak at the Λ_b^0 mass is observed with $J/\psi\Xi^-K^+(> 5\sigma)$. The 1st observed multibody decay containing the $J/\psi\Xi^-$ system.

Model - Student-T function for signal with mass and σ floating, but the n parameter fixed to the value found by fitting the simulation because of the limited signal yield, Exponential for background.

$m(\Lambda_b^0) = 5625.9 \pm 3.2$ MeV, agrees with the world-average value of

5619.60 ± 0.17 MeV, Yield = 46 ± 11.

Limited sensitivity to pentaquark due to low signal yields.



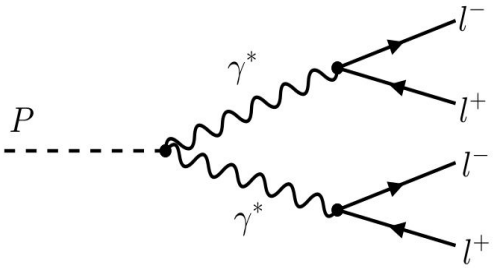
The Branching ratio is measured as :

$$\mathcal{R} \equiv \frac{\mathcal{B}(\Lambda_b^0 \to J/\psi\Xi^-K^+)}{\mathcal{B}(\Lambda_b^0 \to \psi(2S)\Lambda)} = [2.5 \pm 0.8\,(\text{stat}) \pm 0.9\,(\text{syst})]\%$$

Observation of $\eta \rightarrow 4\mu$ decay

https://arxiv.org/abs/2305.04904
Submitted to PRL

- η and $\eta`$ mesons with masses of 547.9 MeV and 957.8 MeV, composed of up, down, and strange quark admixtures.
- Several properties of the η and $\eta`$ are not measured. e.g. leptonic radiative decays, Dalitz decays.
- Dalitz decays involve electromagnetic coupling of pseudoscalar mesons to photons.
- Observed leptonic radiative decays : $\eta \rightarrow \mu^+ \mu^-$, $\eta \rightarrow e^+e^-e^+e^-$, $\eta` \rightarrow e^+e^-e^+e^-$.
- Remaining elusive : $\eta \rightarrow e^+e^-$, $\eta \rightarrow \mu^+ \mu^- \mu^+ \mu^-$, $\eta \rightarrow e^+e^-\mu^+ \mu^-$, most $\eta`$ decays.



- $\eta \rightarrow \mu^+ \mu^- \mu^+ \mu^-$
  - Rare decays offer precision tests of the standard model and sensitivity to new physics scenarios.
  - SM Predicted branching fraction: $(3.98 \pm 0.15) \times 10^{-9}$ Chinese Phys. C 42 (2018) 023109.
  - CMS reports first observation of $\eta \rightarrow \mu^+ \mu^- \mu^+ \mu^-$ decay.
    - High-rate triggers in CMS extend sensitivity to dimuon and four-muon resonances.
    - Improved precision by five orders of magnitude compared to previous methods.
    - Data - 2017 and 2018, corresponding to an integrated luminosity of 101 fb^{-1}.

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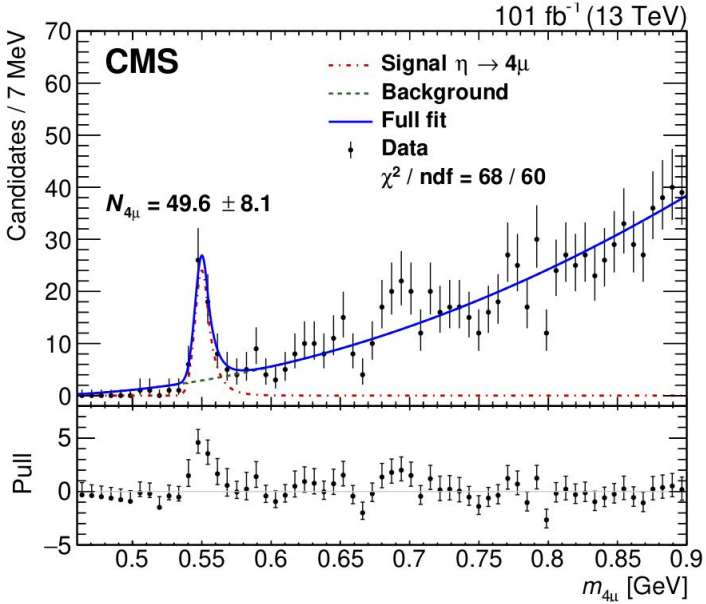
https://arxiv.org/abs/2305.04904
Submitted to PRL

- Clear peak with around 50 events (5σ significance) with data collected in 2017-2018 with 101 fb^{-1} integrated luminosity.
- First-ever observation of $\eta \rightarrow \mu^+ \mu^- \mu^+ \mu^-$ decay.
- Fit conducted with Model - Crystall-Ball + threshold model.
- Branching fraction measurement - Utilizing normalization from $\eta \rightarrow \mu^+ \mu^-$ decay, measured branching fraction $B(\eta \rightarrow \mu^+ \mu^- \mu^+ \mu^-)$.



$$\frac{\mathcal{B}_{4\mu}}{\mathcal{B}_{2\mu}} = (0.86 \pm 0.14\,(\text{stat}) \pm 0.12\,(\text{syst})) \times 10^{-3}$$

$$\mathcal{B}(\eta \rightarrow 4\mu) = (5.0 \pm 0.8\,(\text{stat}) \pm 0.7\,(\text{syst}) \pm 0.7\,(\mathcal{B}_{2\mu})) \times 10^{-9}$$

The measurement is in agreement with the theoretical prediction of $(3.98 \pm 0.15) \times 10^{-9}$, Chinese Phys. C 42 (2018) 023109

https://arxiv.org/abs/2306.07164
Submitted to PRL

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

In 2020, the LHCb Collaboration found a distinct structure in the J/ψJ/ψ channel – peak at X (6900). [LHCb], confirmed by the ATLAS experiment [ATLAS].

CMS report on the J/ψJ/ψ invariant mass spectrum, using a dataset representing 135 fb^{-1} of integrated luminosity at a center-of-mass energy of 13 TeV.

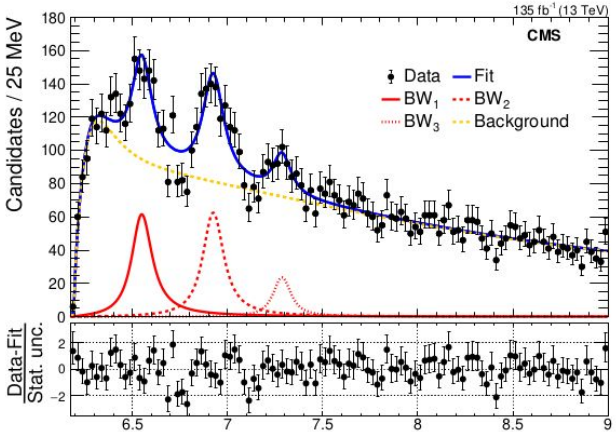
Major backgrounds - NRSPS and DPS components - shape from simulated events.

Signal - Relativistic Breit-Wigner functions convolved with resolution functions.

Three resonances structures observed to be statistically significant !

X(6550): 6.5σ (BW1), X(6900): 9.4σ (BW2), X(7300): 4.1σ (BW3)

X (6900) structure observed by LHCb is confirmed with a mass of 6927 ± 9 (stat) ± 4 (syst) MeV.



		BW_1	BW_2	BW_3
No-interference	m [MeV]	$6552 \pm 10 \pm 12$	$6927 \pm 9 \pm 4$	$7287^{+20}_{-18} \pm 5$
	Γ [MeV]	$124^{+32}_{-26} \pm 33$	$122^{+24}_{-21} \pm 18$	$95^{+59}_{-40} \pm 19$
	N	470^{+120}_{-110}	492^{+78}_{-73}	156^{+64}_{-51}

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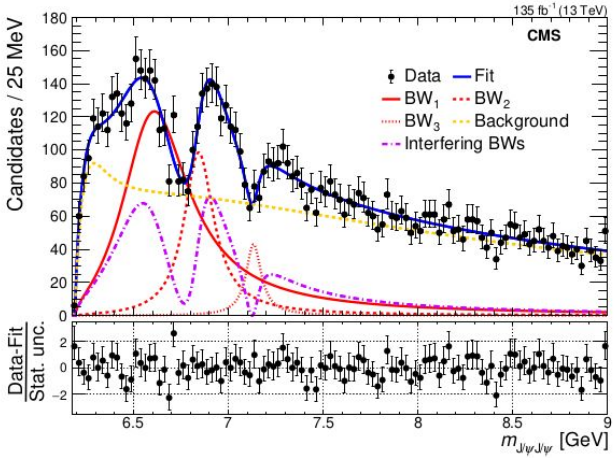
https://arxiv.org/abs/2306.07164
Submitted to PRL

- The dips around 6750 and 7150 MeV in the data lack accurate description.
- LHCb's interference model doesn't fit our data effectively.
- Including interference terms between the three resonances improved the fit, dips are well described and leads to resonance parameter shifts compared to no interference fit.



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}

Summary

- First observation of a new excited beauty strange baryon, $\Xi_b^-(6100)$.
- First observation of $\Lambda_b^0 \rightarrow J/\psi\, \Xi^-\, K^+$ decay.
- First observation of $\eta \rightarrow \mu^+\, \mu^-\, \mu^+\, \mu^-$ decay.
  - the measured Branching fraction is consistent with SM.
- With **J/ψJ/ψ study we confirm X(6900), and new structures** are found with mass 6552 ± 10 (stat) ± 12 (syst) MeV and mass 7287 ± 18 (stat) ± 5 (syst) MeV with 6.5σ, and 4.1σ respectively.

Stay tuned with CMS !