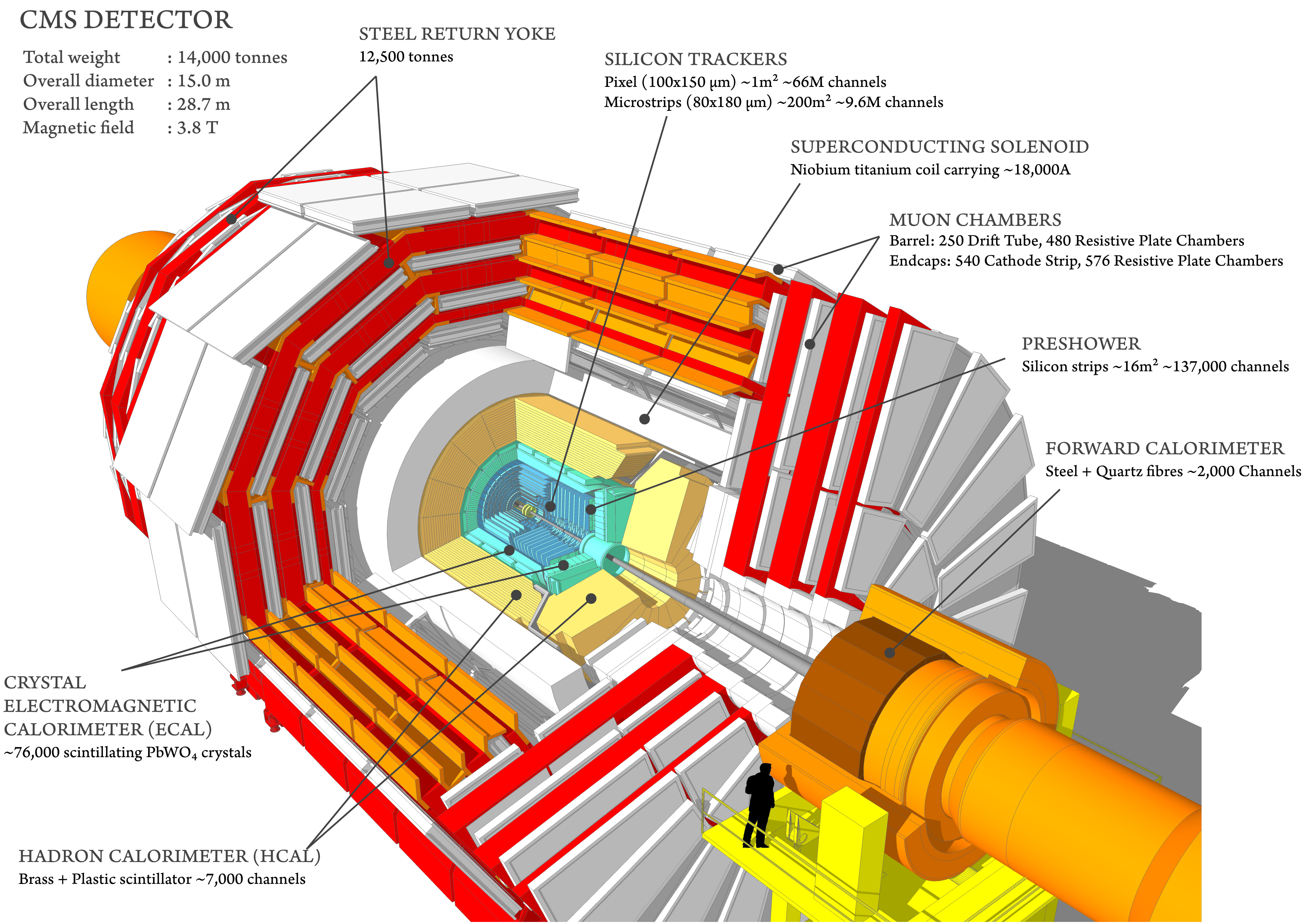
New results on conventional heavy baryons from CMS

A. Di Florio On Behalf of CMS Collaboration

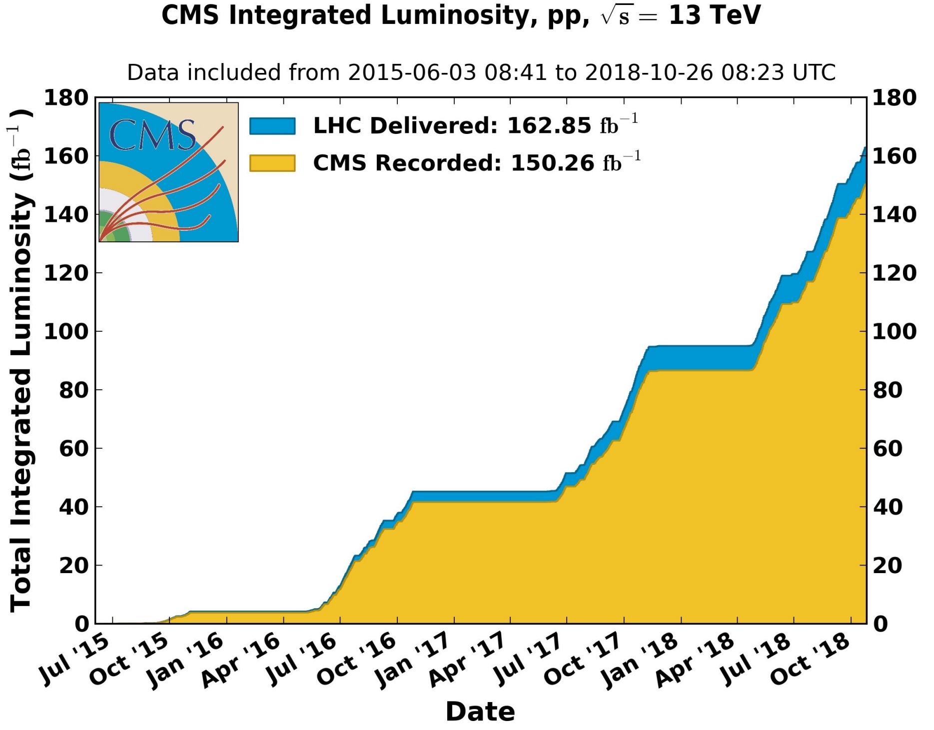
HADRON 2023 Genova 5-9 June 2023

Compact Muon Solenoid



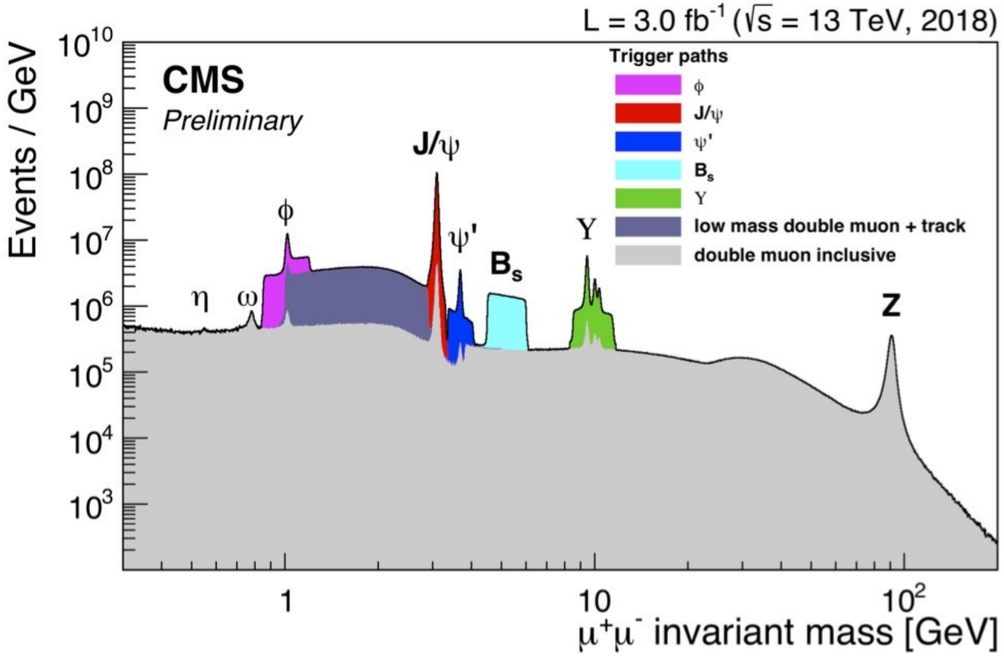
Compact Muon Solenoid

The CMS experiment has recorded 150 fb^{-1} at 13 TeV of data of which ~143 fb^{-1} have been certified for physics



Tracking system

- Good p_T resolution (down to $\Delta p_T/p_T \approx 0.01$ in barrel)
- Tracking efficiency >99% for central muons
- Good vertex reconstruction & impact parameter resolution O(μm)



Muon system

- Muon candidates reconstructed by matching muon segments and a silicon track in a large rapidity coverage ($|\eta|$<2.4)
- Good dimuon mass resolution ($|\eta|$ dependent):

$$\Delta M/M \sim 0.6 \div 1.5\% \longrightarrow \Delta M(J/\psi) \approx (20 \div 70) MeV$$

- Excellent muon-ID: $\varepsilon(\mu|\pi,K,p) \leq (0.1 \div 0.2)\%$

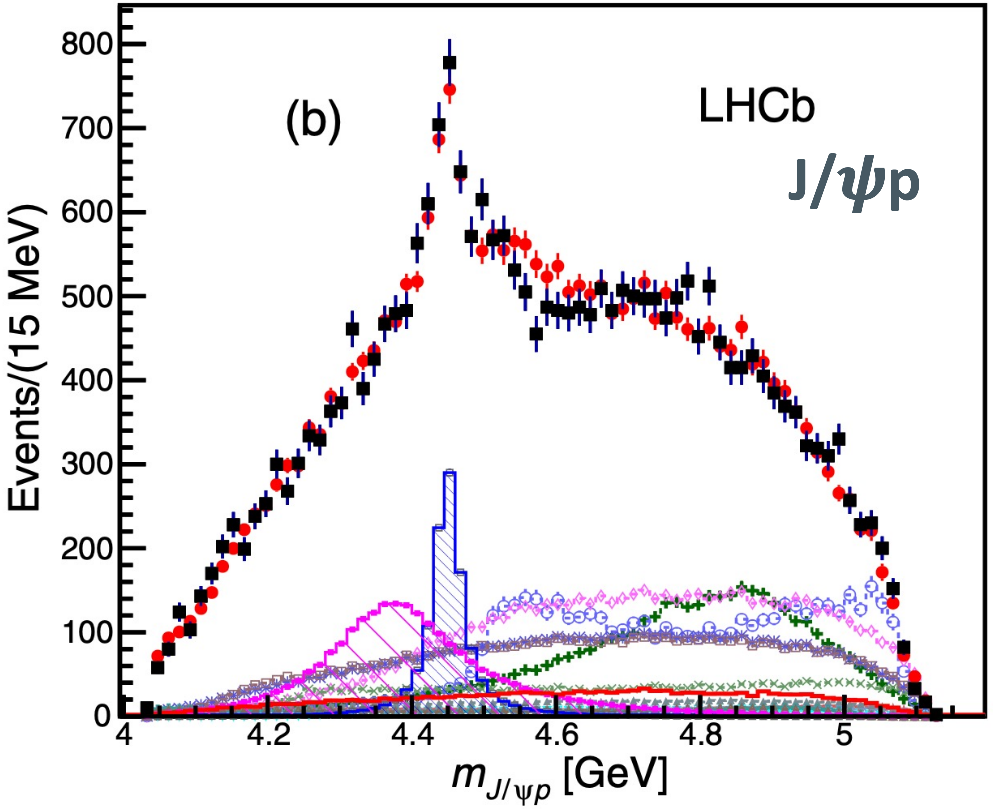
Outline

- Observation of the $\Lambda_b^0 \to J/\psi \Xi^- K^+$ decay — CMS PAS BPH-22-002
- Excited Λ_b^0 states — Phys. Lett. B 803 (2020) 135345
- Observation of a new excited Ξ_b^- baryon — Phys.Rev.Lett.126(2021)25,252003

(udb) spectroscopy: $\Lambda_b^0 \to J/\psi \Xi^- K^+$ observation

CMS PAS BPH-22-002

Motivation - I



- b hadron decays with charmonium and a baryon allow searching for pentaquarks in *ψ+baryon* system in the intermediate resonance structure

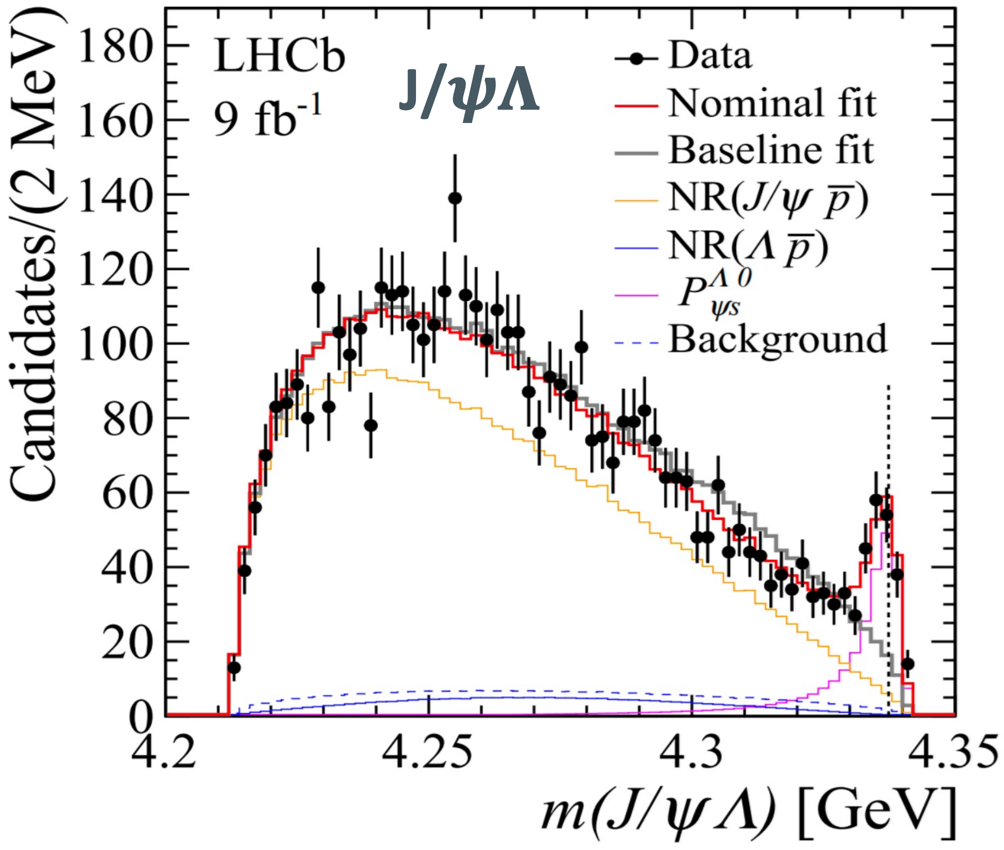
- 2015: The LHCb Collaboration reported the **observation** of statistically significant **J/ψp** pentaquark-like structures $P_c(4450)^+$ and $P_c(4380)^+$ in the decay of the lightest beauty baryon $\boldsymbol{\Lambda_b^0} \to J/\psi p K^-$.

- 2016: Confirmed later with a model-independent analysis and also seen in Cabibbo Suppressed $\boldsymbol{\Lambda_b^0} \to J/\psi p \pi^-$

- 2019: adding full Run-2 (9x $\boldsymbol{\Lambda_b^0}$ yield) with a 1D fit the $P_c(4450)^+$ is split in two peaks and a new $P_c(4312)^+$ is observed.

Motivation - II

In addition to J/ψp system, also the J/ψΛ system have been investigated.



- 2020: 6D full angular analysis by LHCb of $\Xi_b^- \rightarrow J/\psi\Lambda K^-$decay revealed evidence for **b** hidden-charm strange pentaquark $P_{cs}(4459)^0$.

- CMS in JHEP 12 (2019) 100, with Run-1 data, studied the $B^- \rightarrow J/\psi\Lambda^-\bar{p}$ decay: data consistent with no pentaquarks in $J/\psi\Lambda$ or $J/\psi p$.

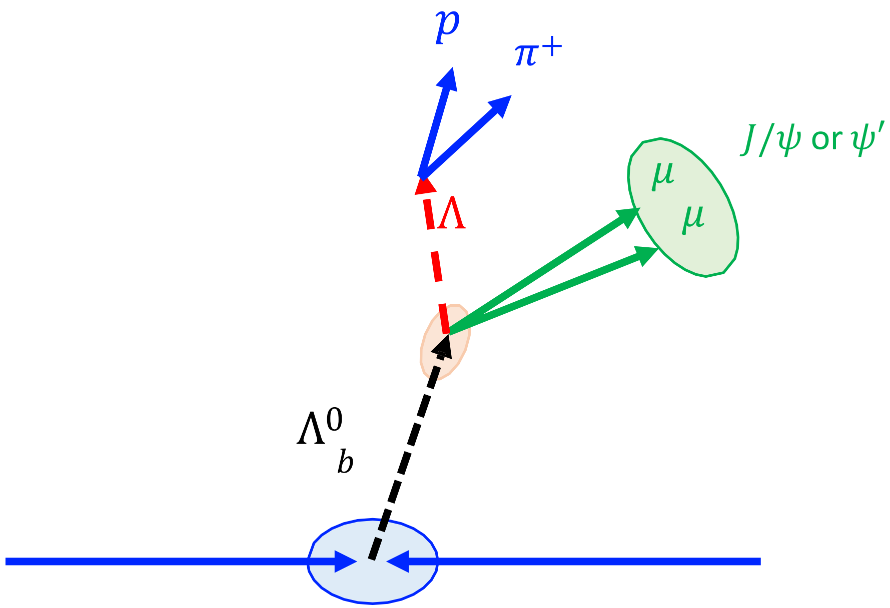
- 2022: with 6D amplitude analysis of $B^- \rightarrow J/\psi\Lambda p^-$ decay, observe new strange pentaquark $P_{cs}(4338)^0 \rightarrow J/\psi\Lambda$ with no significant contribution in the $J/\psi p$ spectrum.

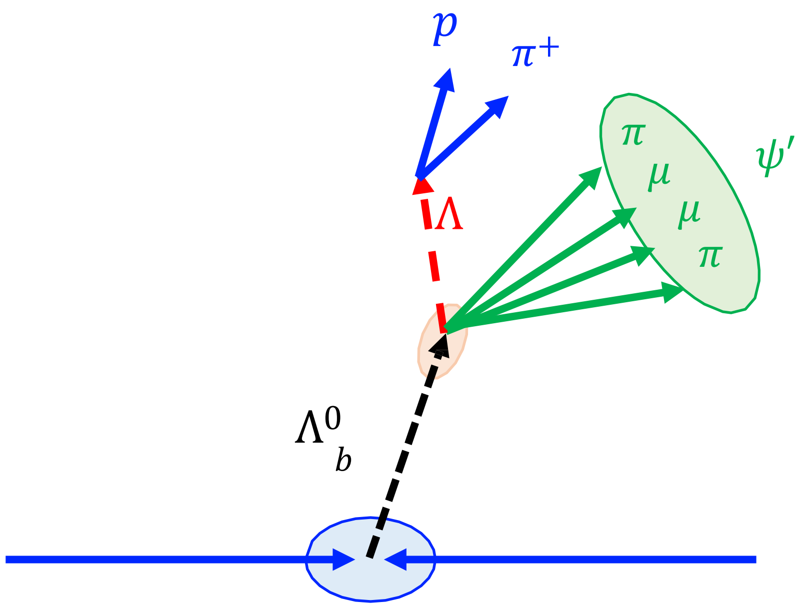
- $J/\psi\Lambda$ pentaquarks are found to be generally **narrower** than $J/\psi p$ states ($7-17$ vs $\sim 10-200$ MeV).

- Investigation of other channels with heavier baryons in the decay products, such as Ξ^- and Ω⁻, could unveil the existence of **doubly or triply** strange hidden-charm P_{css} decaying, e.g., in $J/\psi\Xi^-$. These are also expected to be even narrower.

An interlude: $\boldsymbol{\Lambda_b^0}$ reconstruction at CMS

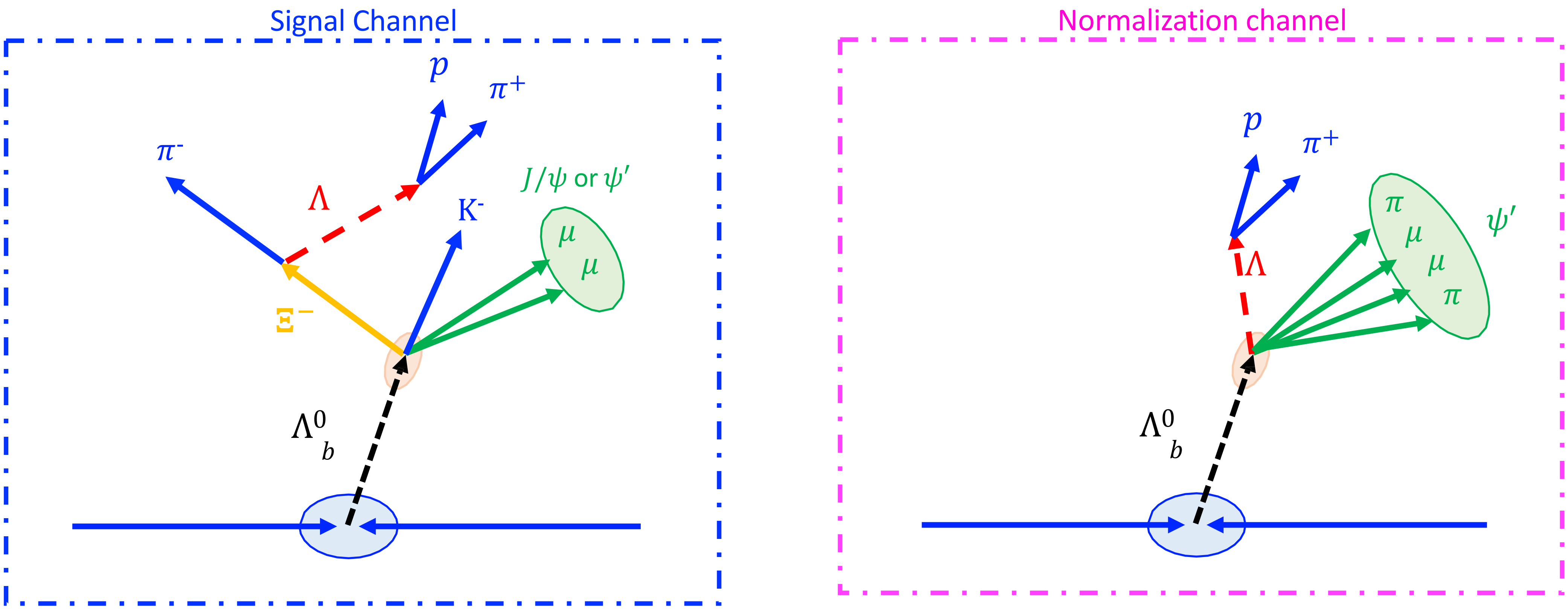
In CMS the most copious channels such as $\boldsymbol{\Lambda_b^0} \rightarrow \mathrm{J}/\psi p K^-$ and $\boldsymbol{\Lambda_b^0} \rightarrow \Lambda_c^+ \pi^-$cannot be used mainly because the backgrounds are too large due to the lack of hadronic PID. Good channels are $\boldsymbol{\Lambda_b}^{\mathbf{0}} \longrightarrow \boldsymbol{J/\psi\Lambda}$ and $\boldsymbol{\Lambda_b}^{\mathbf{0}} \longrightarrow \boldsymbol{\psi(2S)\Lambda}$ with $\boldsymbol{J/\psi}$ and $\boldsymbol{\psi(2S)}$ decaying both in dimuon ($\longrightarrow \mu\mu$) channel and hadronic ($\longrightarrow J/\psi\pi\pi$) using a combination of various $\boldsymbol{J/\psi} + \boldsymbol{X}$ and $\boldsymbol{\psi(2S)} + \boldsymbol{X}$ triggers.





$\Lambda_b^0 \to J/\psi\Xi^- K^+$ and $\Lambda_b^0 \to \Lambda\psi'$ reconstruction

- In CMS PAS BPH-22-002 CMS reported the search for $\Lambda_b^0 \to J/\psi\Xi^- K^+$ with $J/\psi \to \mu\mu$, $\Xi^- \to \Lambda\pi^-$ and $\Lambda \to p\pi^-$.
- The normalization channel is chosen to be $\Lambda_b^0 \to \Lambda\psi(2S)$with $\psi' \to J/\psi\ \pi\pi \to \mu\mu\pi\pi$ and again $\Lambda \to p\pi^-$.
- In both cases the final state is 2μ + 4Trk. The similar decay topology and kinematics lead to the reduction of many systematic uncertainties.



The analysis has used 2016-2018 Run II pp collision data ($\sim 140\text{fb}^{-1}$).

Reconstruction and selection

- Λ_b^0 **vertex fit from** $\mu\mu K\Xi$ for the signal channel and from $\mu\mu\pi\pi\,\Lambda$ for the normalization one
- The primary vertex (PV) is chosen as the one with the **smallest Λ_b^0 pointing angle**
- Mass constraints applied on $J/\psi \to \mu\mu$, $\Lambda \to p\pi^-$ and $\Xi^- \to \Lambda\pi^-$
- **Trigger** requiring a **trk** + μ+μ− pair

- For selection optimization the Punzi figure of merit is used:

$$f = \frac{S}{\frac{463}{13} + 4\sqrt{B} + 5\sqrt{25 + 8\sqrt{B} + 4B}}$$

- The background B yield is estimated by combining the data in the Λ_b^0 mass sideband, excluding the signal region, with the wrong-sign data combinations. The signal S is estimated from MC.

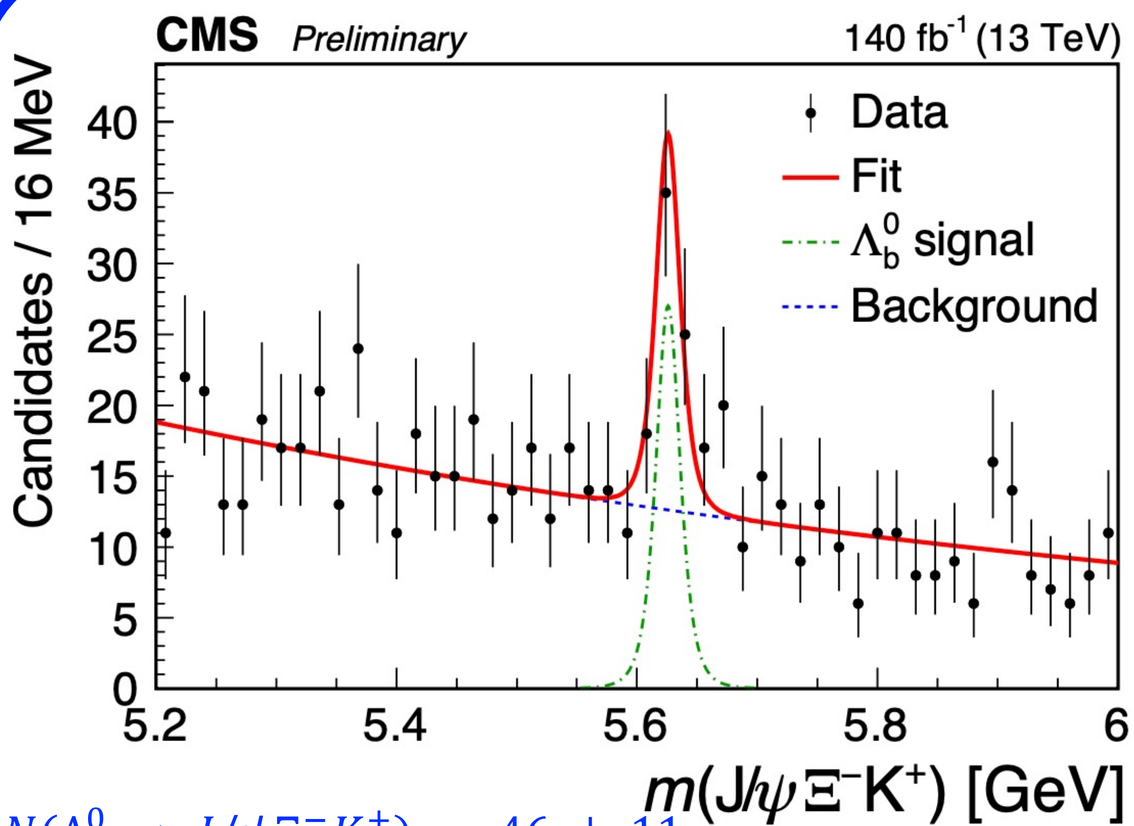
- The variables used in the optimization include:
  - p_T of all decay products;
  - the flight length significance of the Λ_b^0,Λ and Ξ baryons and the corresponding pointing angles;
  - the vertex fit probabilities;
  - the mass windows for Λ and Ξ.

- Background: reduction by x15. Signal efficiency: 70%. These criteria are kept as untouched as possible for the normalization channel $\Lambda_b^0 \to \Lambda\psi(2S)$ to reduce the systematic uncertainties.

$J/\psi\Xi^-K^+$ signal and $\psi(2S)\,\Lambda$ channel

- For both distributions: signal as a Student's t distribution(μ,σ,n), combinatorial background as an exponential function (α).

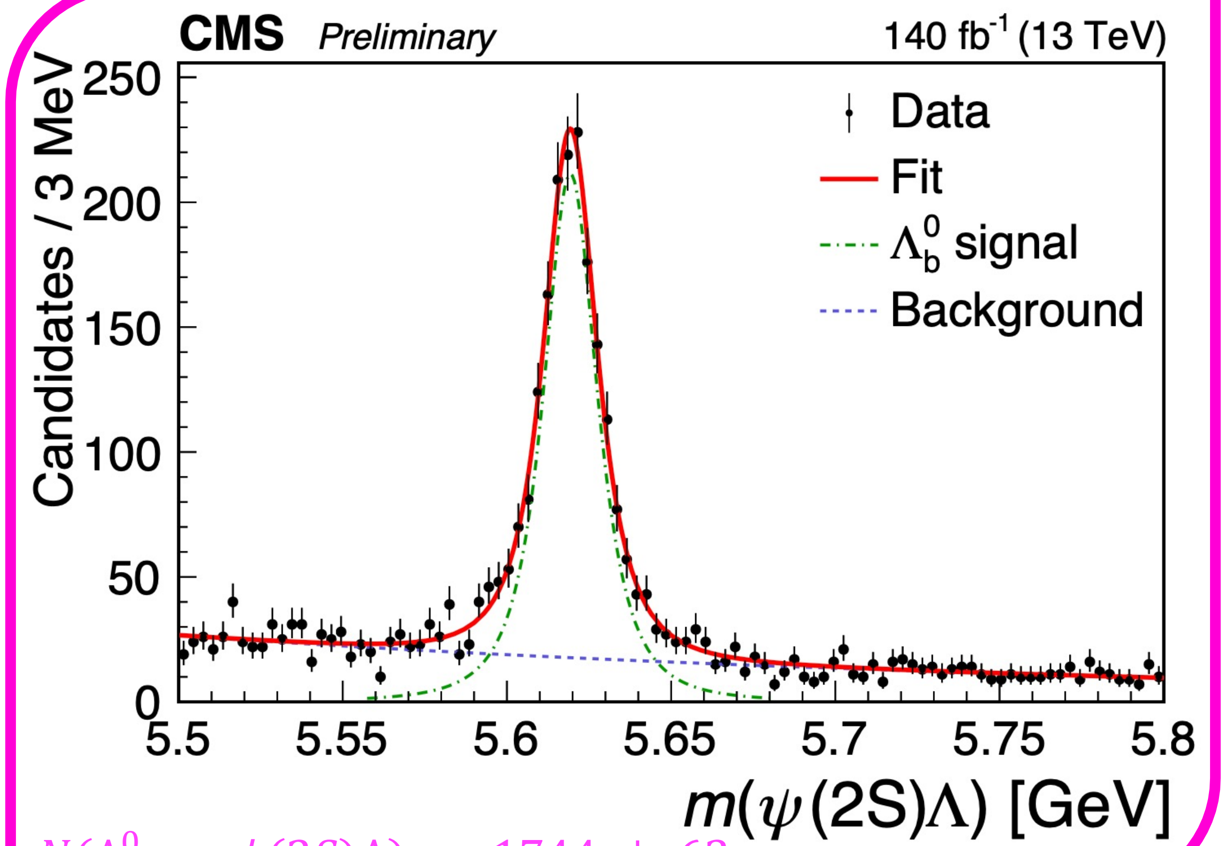
Signal Channel $\Lambda_b^0 \to J/\psi\Xi^-K^+$



$N(\Lambda_b^0 \to J/\psi\Xi^-K^+) = 46 \pm 11$

$\mu = 5625.9 \pm 3.2$ MeV $\quad \sigma = 10.4 \pm 3.3$ MeV

Normalization Channel $\Lambda_b^0 \to \Lambda\psi(2S)$



$N(\Lambda_b^0 \to \psi(2S)\Lambda) = 1744 \pm 63$

μ compatible with PDG $\quad \sigma = 8.90 \pm 0.40$ MeV

- First observation of with a statistical significance $> \mathbf{5\sigma}$. Ranging between 5.27 and 5.85 depending on the fit model.

Branching fraction ratio calculations

$$\mathcal{R} \equiv \frac{\mathcal{B}(\Lambda_b^0 \to J/\psi \Xi^- K^+)}{\mathcal{B}(\Lambda_b^0 \to \psi(2S)\Lambda)} =$$

$$= \frac{N(\Lambda_b^0 \to J/\psi \Xi^- K^+)}{N(\Lambda_b^0 \to \psi(2S)\Lambda)} \frac{\epsilon_{\psi(2S)\Lambda}}{\epsilon_{J/\psi \Xi^- K^+}} \times \frac{\mathcal{B}(\psi(2S) \to J/\psi \pi^+ \pi^-)}{\mathcal{B}(\Xi^- \to \Lambda \pi^-)}$$

Ratio of the signal yields in data

Ratio of total efficiencies from MC

Known branching fractions from PDG

$$\frac{\epsilon_{\psi(2S)\Lambda}}{\epsilon_{J/\psi \Xi^- K^+}} = 5.06 \pm 0.29$$

$$\mathcal{B}(\Xi \to \Lambda\pi) = (99.887 \pm 0.035\%)$$

$$\mathcal{B}(\psi(2S) \to J/\psi\pi\pi) = (34.68 \pm 0.30\%)$$

Systematic uncertainties

1. Signal model: several alternative models, take the largest variation in $\mathcal{R}$ as systematics (Double-gaussian or Johnson as alternatives).

2. Background model: several alternative models take the largest variation in $\mathcal{R}$ as systematics.

3. $non-\psi(2S)$ contribution of $\Lambda_b^0 \to J/\psi\pi^+\pi^-\Lambda$ taken into account via $sPlot$ technique.

4. Uncertainty on ϵ ratio due to limited MC statistics

5. Tracking efficiency: the p_T spectra of the harder of the two tracks are found to differ significantly between signal and normalization channels.

6. Testing different set of cuts: for each variation, the analysis is repeated, and the value of $\mathcal{R}$ is recalculated and compared to the baseline $\mathcal{R}$ value. The differences (d) between the two values and their uncertainties (δd). The largest value of $\sqrt{d^2-(\delta d)^2}$ is taken as $\mathcal{R}$ systematics. This is a very conservative estimate based on variation of cuts near trigger/reconstruction thresholds.

Source	Uncertainty (%)
Signal model	3.9
Background model	6.7
Non-$\psi(2S)$ contribution	2.5
Finite size of MC samples	5.6
Tracking efficiency	2.3
Alternative selection criteria	33.5
Total	35.0

Branching fraction and $\mathcal{R}$

- The branching fraction of the newly observed $\Lambda_b^0 \to J/\psi\Xi^- K^+$ decay, with respect to the $\Lambda_b^0 \to \psi(2S)\Lambda$ decay is measured as:

$$\frac{\mathcal{B}(\Lambda_b^0 \to J/\psi\Xi^- K^+)}{\mathcal{B}(\Lambda_b^0 \to \psi(2S)\Lambda) \times \mathcal{B}(\psi(2S) \to J/\psi\pi^+\pi^-)} = [7.3 \pm \underset{\text{(stat)}}{2.3} \pm \underset{\text{(sys)}}{2.6}]\%$$

- Using the known value of $\mathcal{B}(\psi(2S) \to J/\psi\pi^+\pi^-) = 34.68 \pm 0.30\%$ (PDG), the ratio $\mathcal{R}$ is measured as

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

where the uncertainty on $\mathcal{B}(\psi(2S) \to J/\psi\pi^+\pi^-)$ is negligible as compared to the total systematic uncertainty.

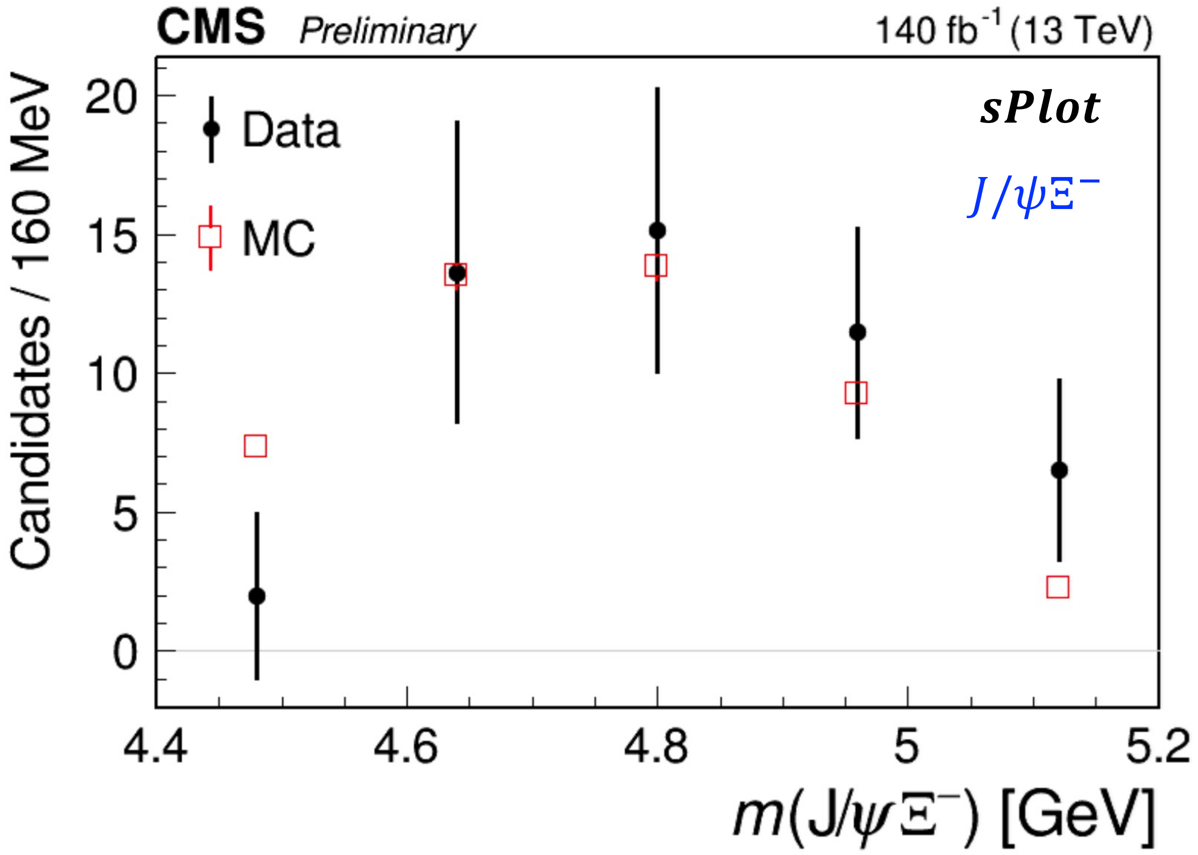
- Same order of magnitude as $\Lambda_b^0 \to J/\psi\Lambda\varphi$ decay that has similar Feynman diagram:

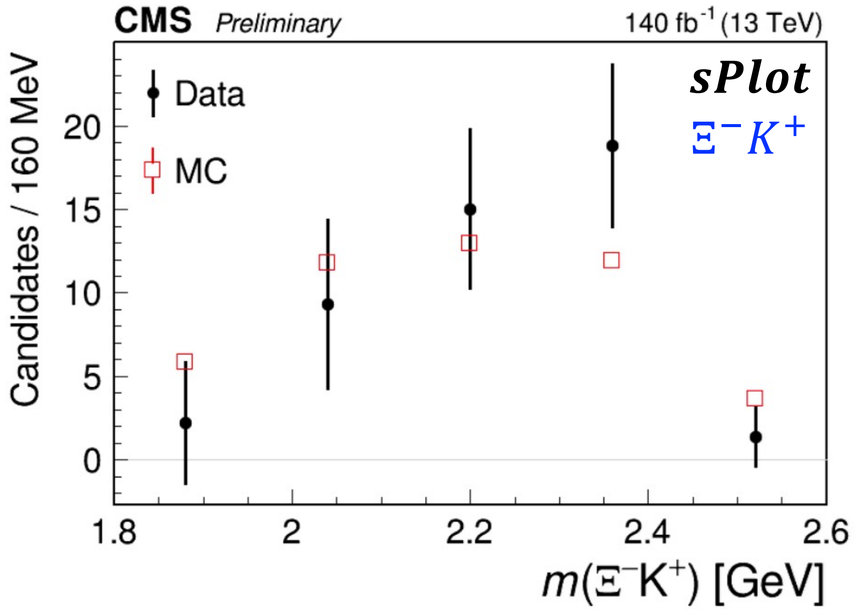
$$\mathcal{B}(\Lambda_b^0 \to J/\psi\Lambda\phi)/\mathcal{B}(\Lambda_b^0 \to \psi(2S)\Lambda) = 8.26 \pm 0.90\,(stat) \pm 0.68\,(syst) \pm 0.11(\mathcal{B})\%$$

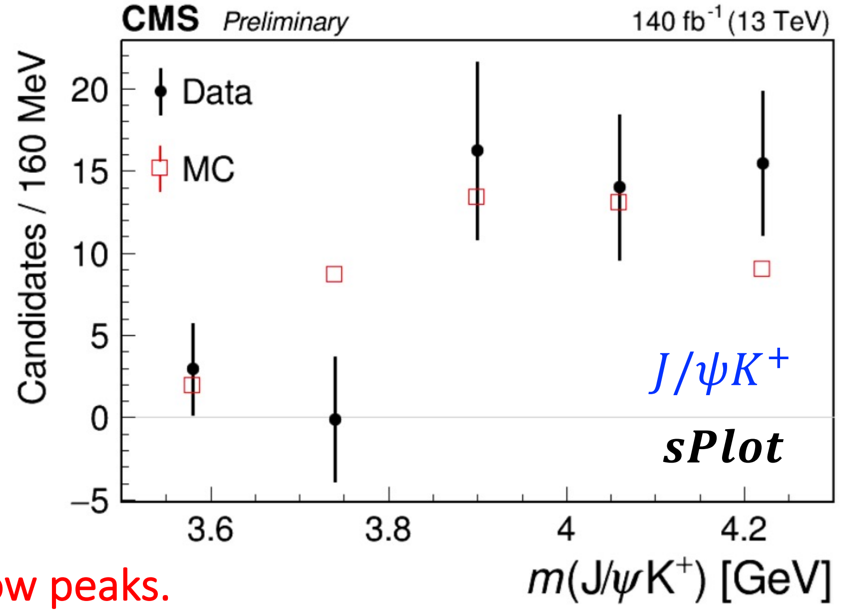
from Phys.Lett.B 802 (2020) 135203

Intermediate invariant masses

- The sensitivity of this analysis to potential pentaquark signals in the intermediate invariant mass distributions of the $\Lambda_b^0 \rightarrow J/\psi\Xi^- K^+$ decay is limited by the low signal yield.







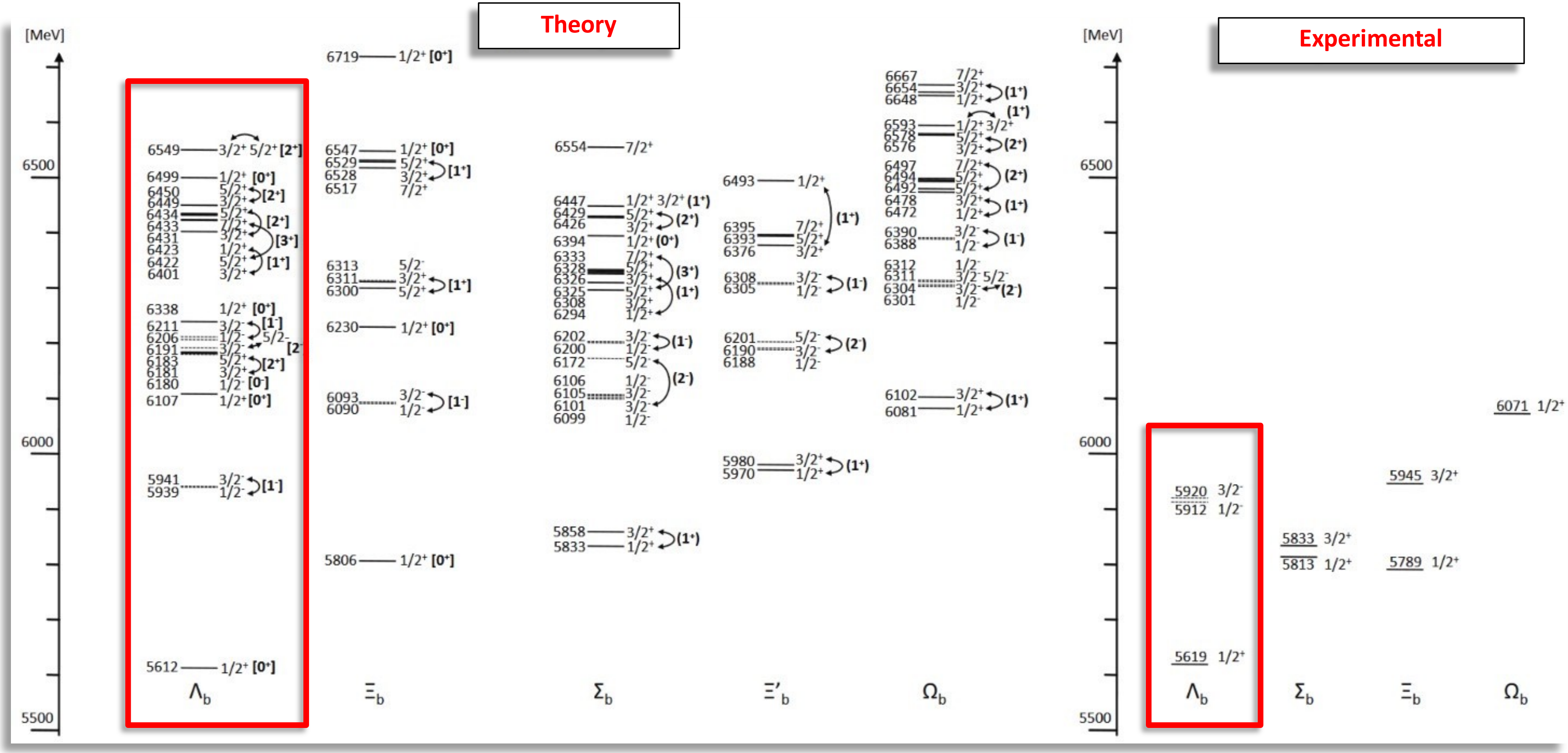
- Distributions consistent with the phase space simulation without any narrow peaks.

(udb) spectroscopy: excited Λ_b^0 states

Phys. Lett. B 803 (2020) 135345

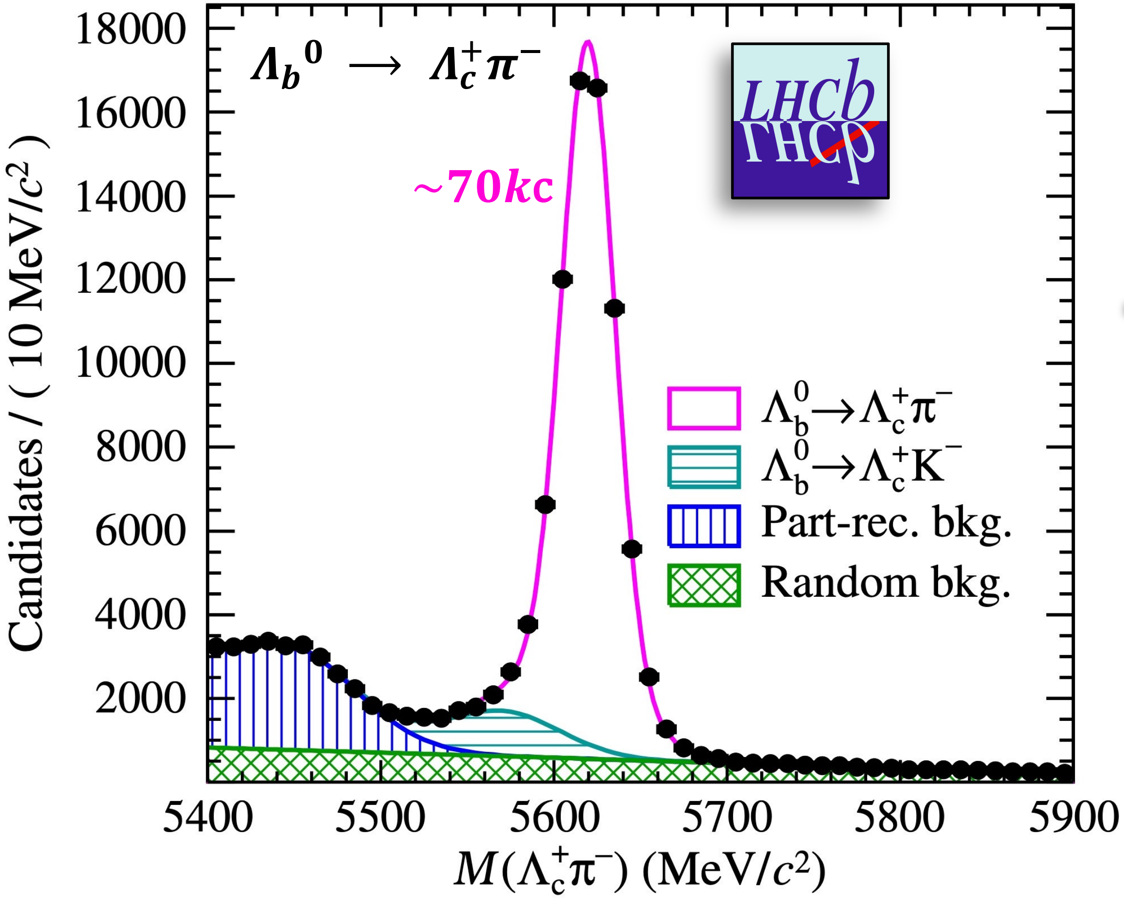
Λ_b^0 excited states

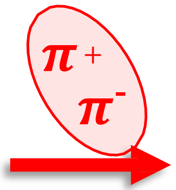
- Studies of excited heavy baryon spectrum are an important test of Heavy Quark Effective Theory. There are many theoretical predictions of excited Λ_b and Σ_b states, but the predicted masses are spread in rather wide regions and do not point to any narrow window to search for a signal.

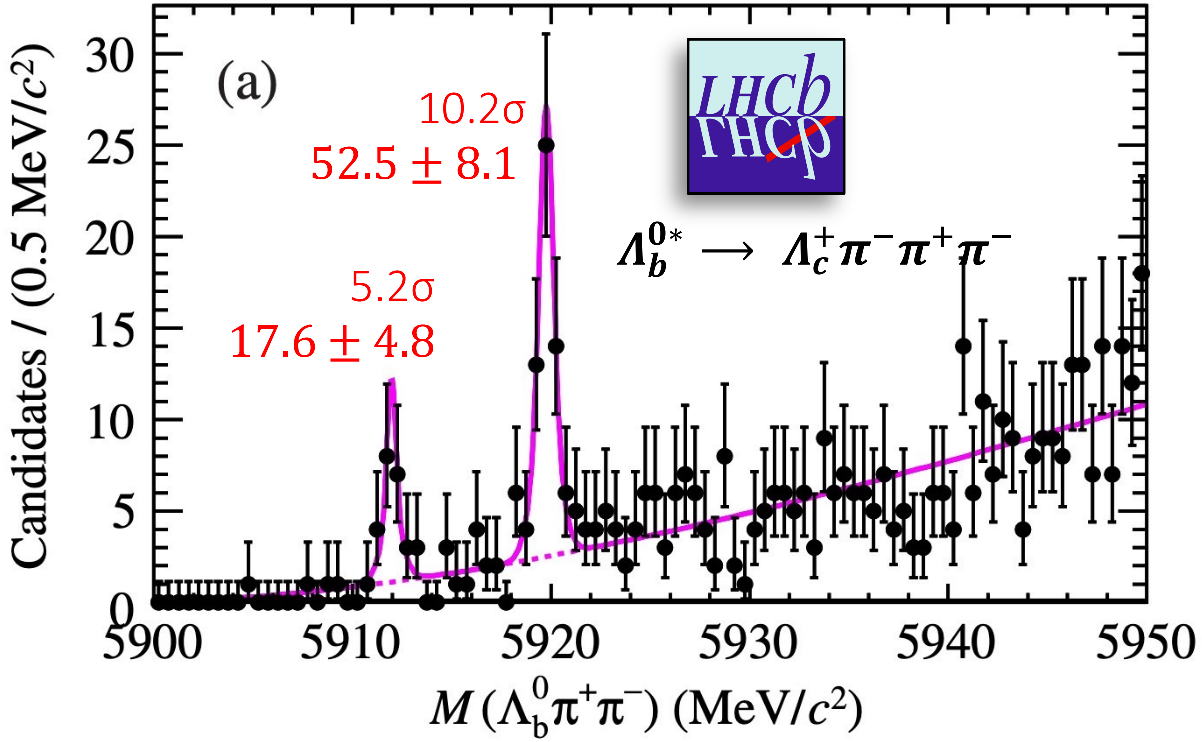


Λ_b^0 excited states –LHCb results

- In PhysRevLett.109.172003 LHCb (2012) using $1 fb^{-1}$ of 2011 data observed for the first time excited $\Lambda_b^{0*} \longrightarrow \Lambda_b^0 \pi^+ \pi^-$ using $\Lambda_b^{0*} \rightarrow \Lambda_c^+ \pi^-$ channel.





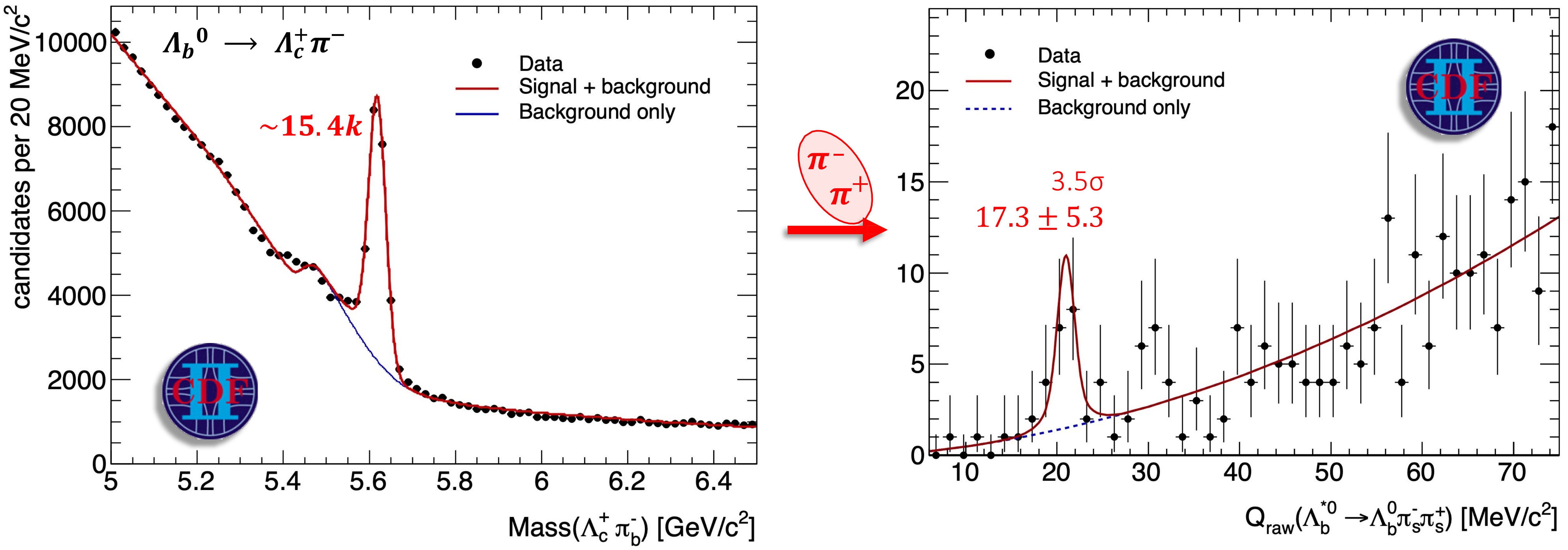


$$M_{\Lambda_b^{*0}(5912)} = 5911.97 \pm 0.12 \pm 0.02 \pm 0.66 \text{ MeV}/c^2$$

$$M_{\Lambda_b^{*0}(5920)} = 5919.77 \pm 0.08 \pm 0.02 \pm 0.66 \text{ MeV}/c^2$$

Λ_b^0 excited states – CDF Confirmations

- In PhysRevD.88.071101 CDF (2013): confirmed only the higher mass state $\boldsymbol{\Lambda_b(5920)^0 \longrightarrow \Lambda_b^0\pi^+\pi^-}$ with a significance of **3.5σ**

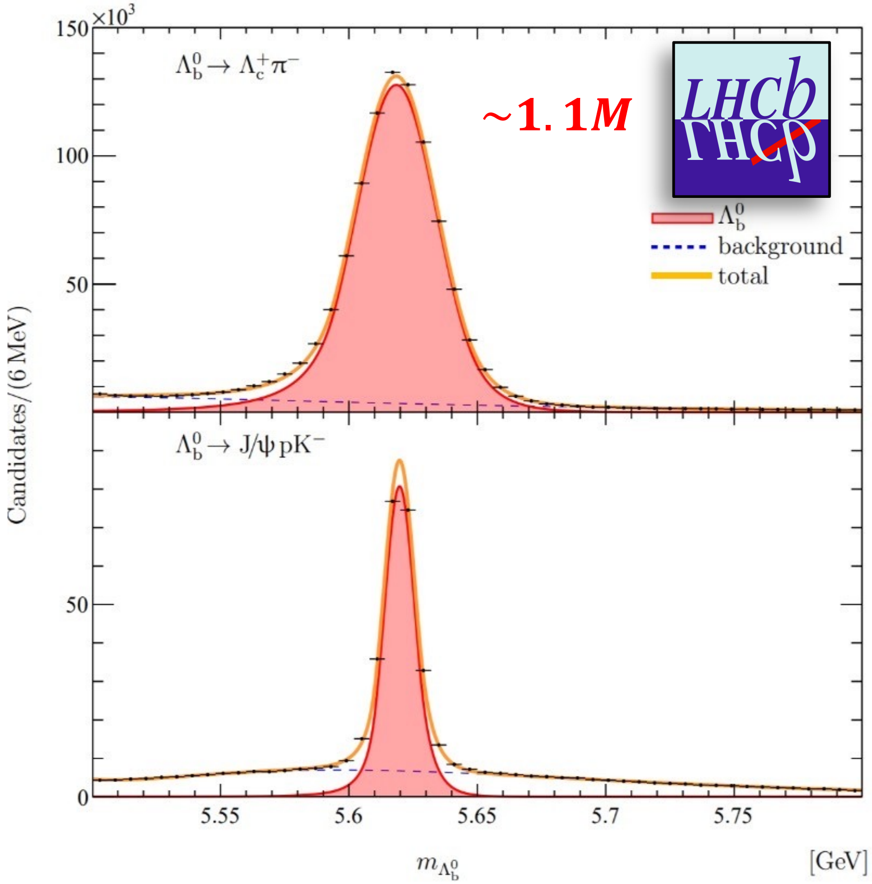


Λ_b^0 LHCb – 2019 more states!

- In 2019 in PRL 123 (2019) 152001 LHCb using full Run-I+II dataset observed two new excited states decaying to $\Lambda_b^0\pi^+\pi^-$ final state:

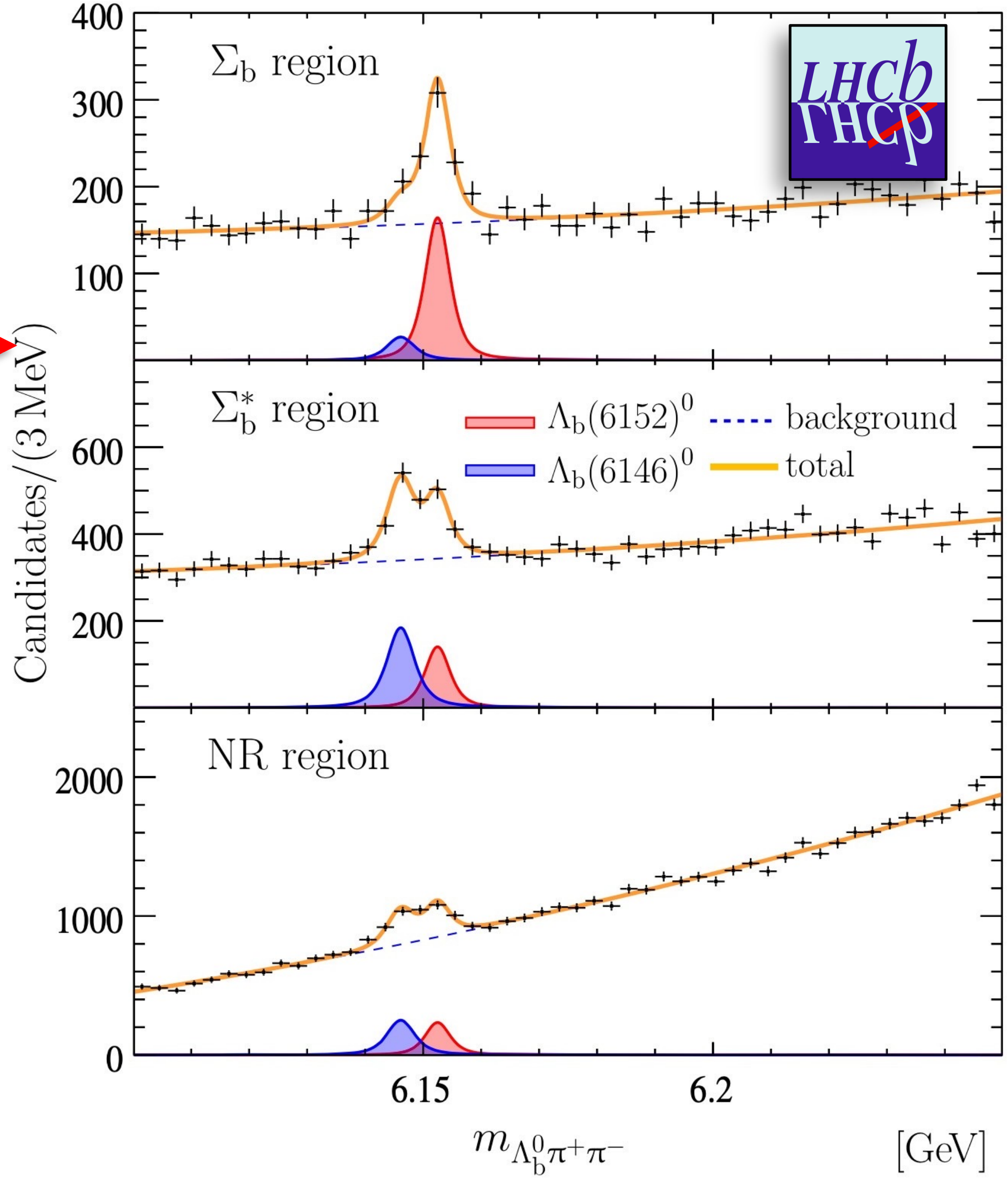
$\Lambda_b\,(6146)^0$ and $\Lambda_b\,(6152)^0$

using both channels $\Lambda_b^0 \to \Lambda_c^+\pi^-$ and $\Lambda_b^0 \to J/\psi p K^+$ with about $\mathbf{1.1M}$ $\boldsymbol{\Lambda^0}$ in total



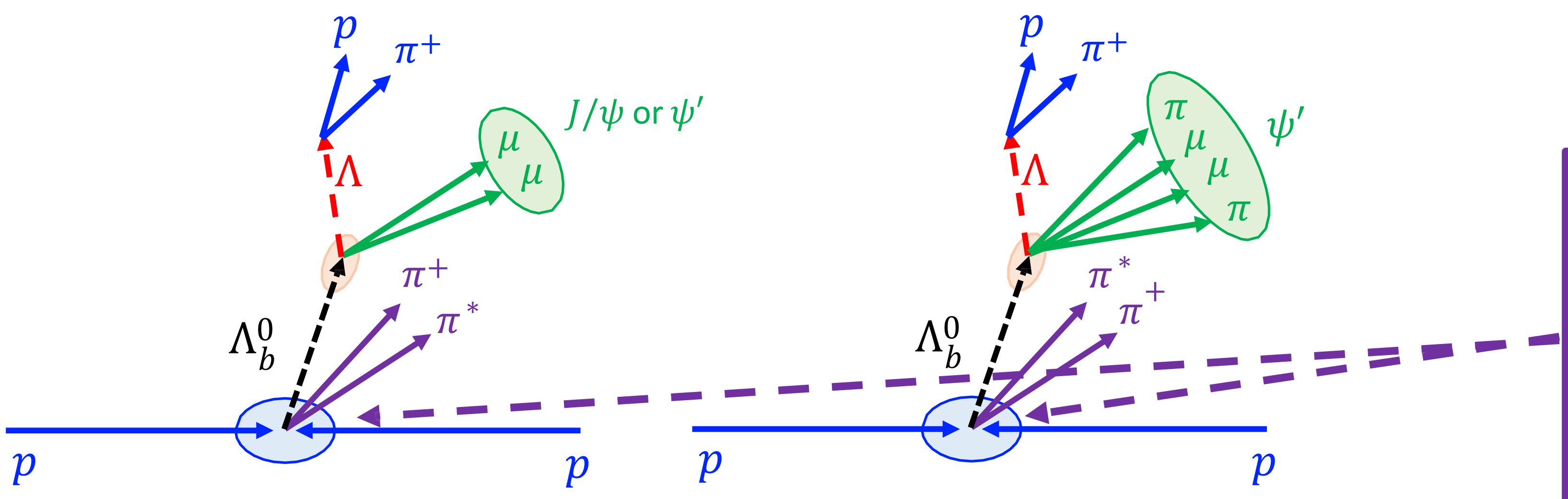
π^- π^+

In CMS we cannot use these most copious channels since no dedicated trigger (for $\Lambda_b^0 \to \Lambda_c^+\pi^-$) was configured and the backgrounds are large due to the lack of hadronic PID (for both)



Λ_b^0 reconstruction at CMS (again)

As already mentioned: good channels are $\Lambda_b{}^0 \longrightarrow J/\psi\Lambda$ and $\Lambda_b{}^0 \longrightarrow \psi(2S)\Lambda$ with $\psi(2S)$ decaying both in dimuon ($\longrightarrow \mu\mu$) channel and hadronic ($\longrightarrow J/\psi\pi\pi$) using a combination of various $J/\psi + X$ and $\psi(2S) + X$ triggers. For the excited states, prompt $\pi\,\pi$ are «added».



Two additional OS prompt tracks (with pion mass hypothesis) are selected from the tracks forming the PV, chosen as the one with the smallest 3D pointing angle of the Λ_b^0 candidate.

Combinations with SS prompt pions are used as a control channel

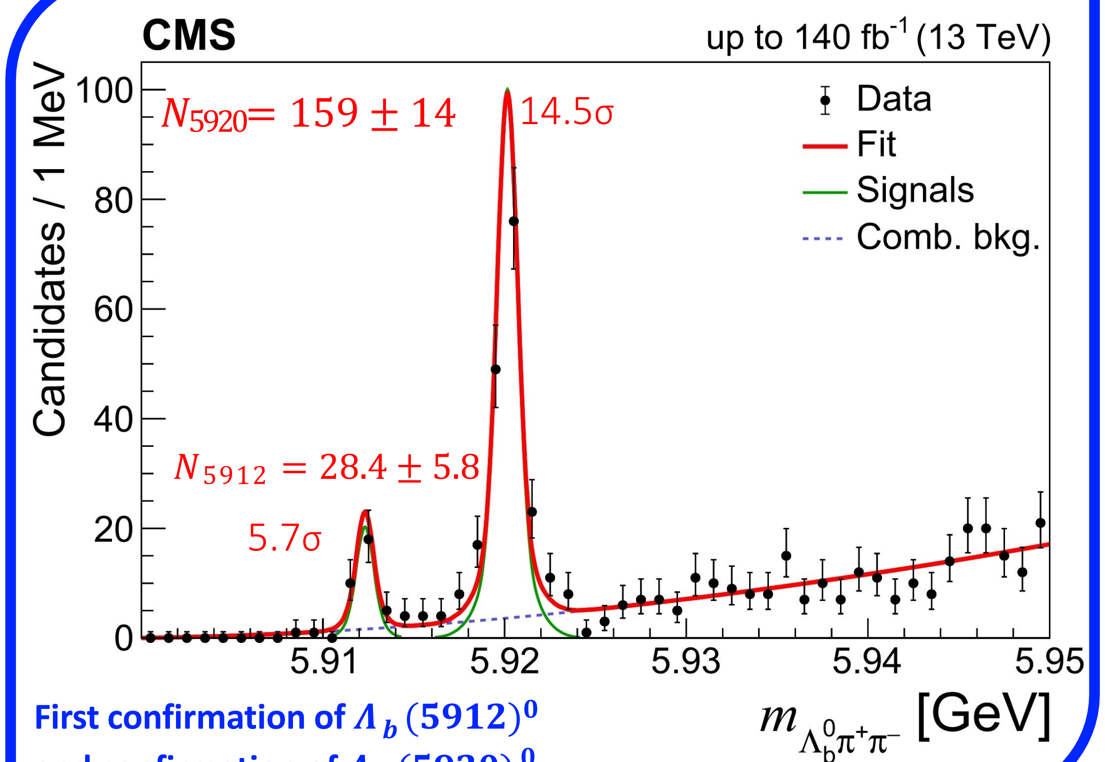
The analysis has used full Run II pp collision data and has been optimized differently.

- at low masses, near threshold where backgrounds level is low.
- at high masses where background is large.

Λ_b^0 excited states at CMS

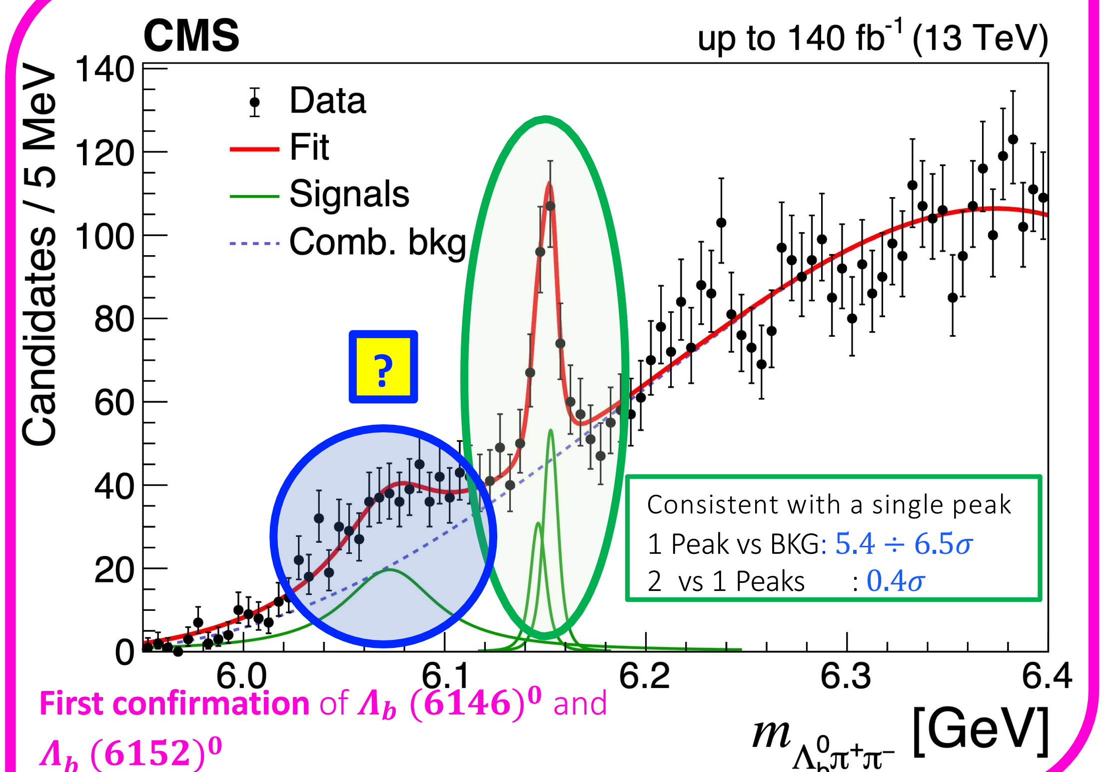
- To study the excited Λ_b states, CMS used $\Lambda^0_b \to J/\psi\Lambda$ and $\Lambda^0_b \to \psi(2S)\Lambda$ channels with $\psi(2S) \longrightarrow \mu\mu$ or $\psi(2S) \longrightarrow J/\psi\pi^-\pi^+$.
- $m_{\Lambda_b^0\pi^+\pi^-} = M(\Lambda_b^0\pi^+\pi^-) - M_{\Lambda_b^0} + M_{\Lambda_b^0}^{PDG}$ ⊕ a new PV refit technique, i.e. fitting all the tracks forming the **PV + *B candidate*** and use 4-momenta from this vertex fit; crucial to improve detector resolution.

at **low masses** (near threshold)



First confirmation of $\Lambda_b(5912)^0$ and confirmation of $\Lambda_b(5920)^0$

at **high masses** (higher background)



First confirmation of $\Lambda_b(6146)^0$ and $\Lambda_b(6152)^0$

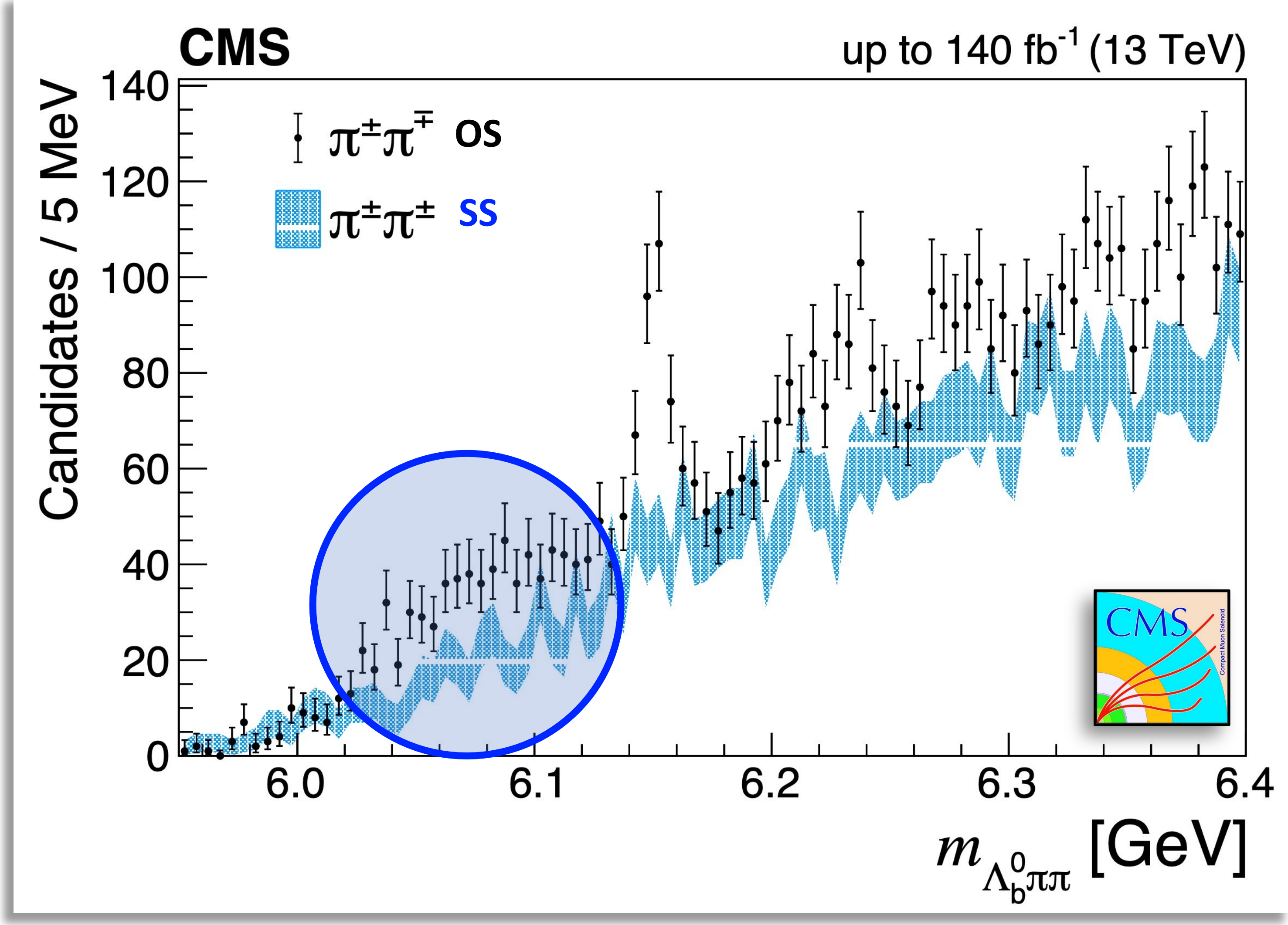
$$M(\Lambda_b(5912)^0) = [5912.32 \pm 0.12(stat) \pm 0.01(syst) \pm 0.17(m_{PDG}(\Lambda_b^0))]\text{MeV}$$

$$M(\Lambda_b(5920)^0) = [5920.16 \pm 0.07(stat) \pm 0.01(syst) \pm 0.17(m_{PDG}(\Lambda_b^0))]\text{MeV}$$

$$M(\Lambda_b(6146)^0) = [6146.5 \pm 1.9(stat) \pm 0.8(syst) \pm 0.2(m_{PDG}(\Lambda_b^0))]\text{MeV}$$

$$M(\Lambda_b(6152)^0) = [6152.7 \pm 1.1(stat) \pm 0.4(syst) \pm 0.2(m_{PDG}(\Lambda_b^0))]\text{MeV}$$

Same Sign $\pi^{\pm}\pi^{\pm}$ Distributions



The *bump* in the $\Lambda_b^0\pi^{\pm}\pi^{\mp}$ invariant mass spectrum is **not present in the same sign spectrum $\Lambda_b^0\pi^{\pm}\pi^{\pm}$.**

Assuming a single broad resonance X_b and using the same signal fit model as before:

$$M(X_b) = [6073 \pm 5(stat)]MeV$$

$$\Gamma(X_b) = [55 \pm 11(stat)]MeV$$

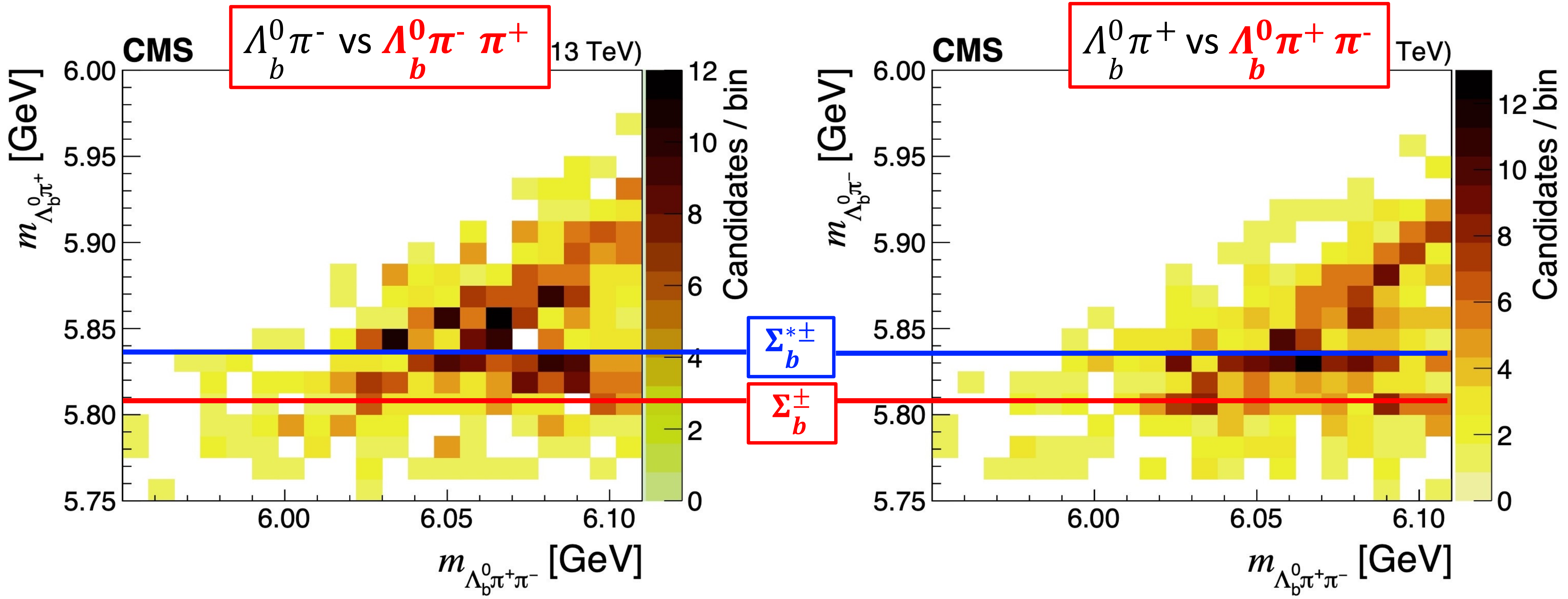
with **4σ** statistical significance.

Various reflections have been thoroughly studied and excluded as the origin/nature of the bump. However it may be created by partially reconstructed decays of higher-mass states.

The amount of data is too low to try a proper interpretation of the broad structure as it could not necessarily be a single state but - instead - a superposition or several nearby broad states.

$\Sigma^{(*)\pm}$ Contributions

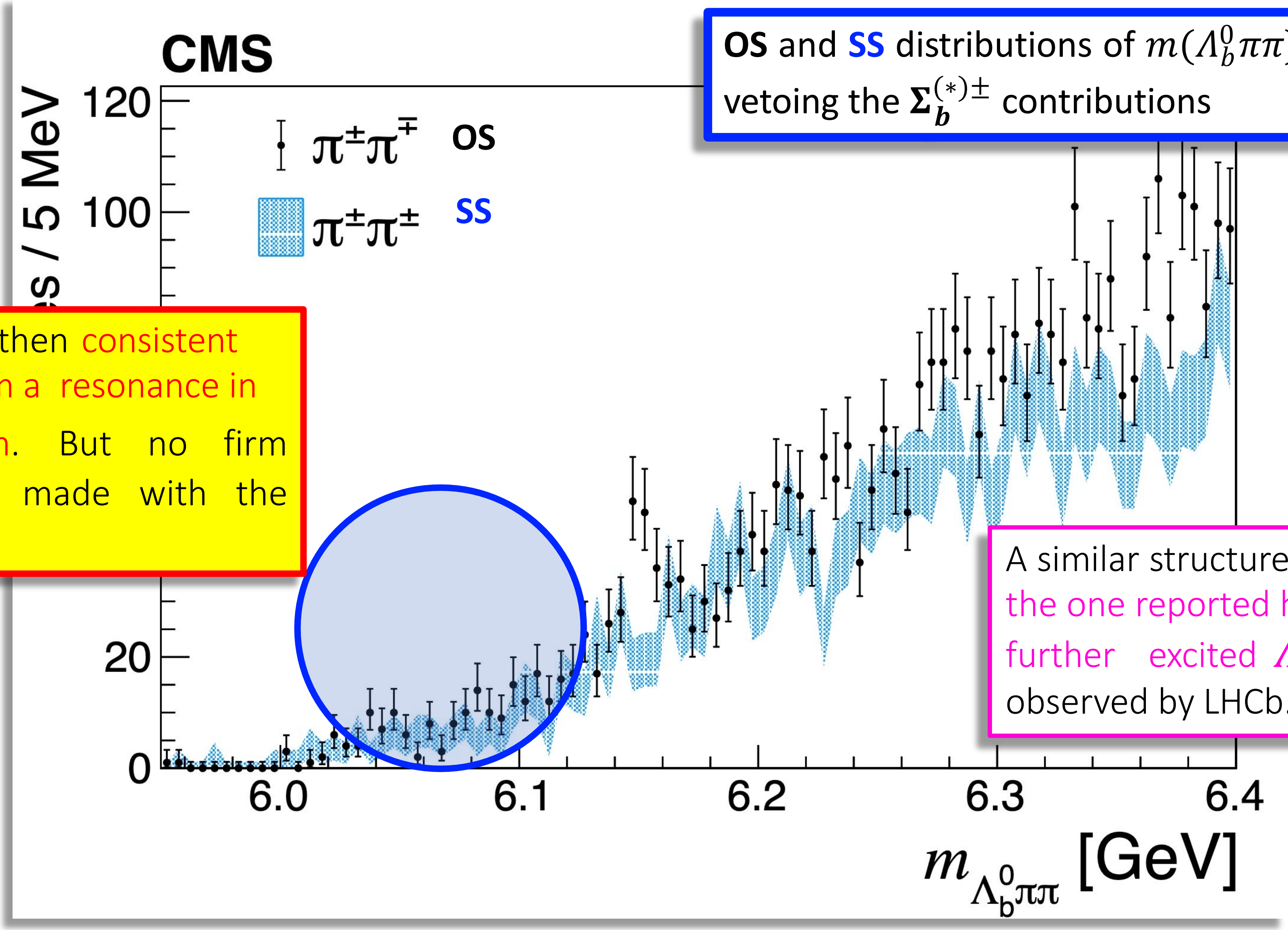
Inspecting the scatter plots $\Lambda_b^0\pi^\pm$ vs $\Lambda_b^0\pi^\pm\pi^\mp$ in the region of interest ($m_{\Lambda_b^0\pi^\pm\pi^\mp} < 6.11$ GeV).



Horizontal bands corresponding to the $\Sigma_b^{(*)\pm} \longrightarrow \Lambda_b^0\pi^\pm$ are visible and if we veto them ...

$\Sigma^{(*)\pm}$ Veto

… we see that the «bump» disappears:



OS and **SS** distributions of $m(\Lambda_b^0\pi\pi)$ vetoing the $\Sigma_b^{(*)\pm}$ contributions

The broad excess is then consistent with originating from a resonance in the $\Sigma_b^{(*)\pm}\pi^{\mp}$ system. But no firm conclusion can be made with the present data.

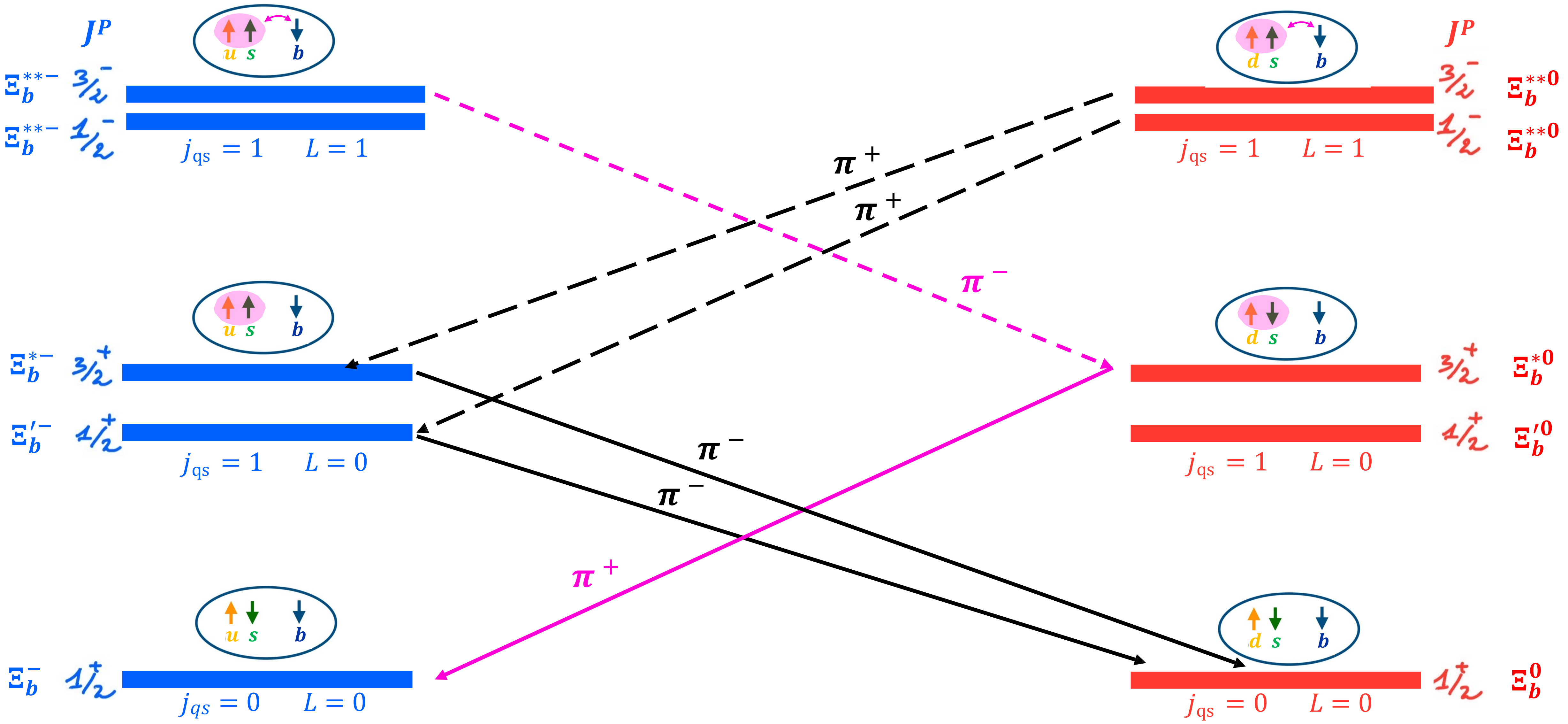
A similar structure, consistent with the one reported here and possibly a further excited Λ_b^0 state has been observed by LHCb.

Ovservation of a new excited Ξ_b^- baryon

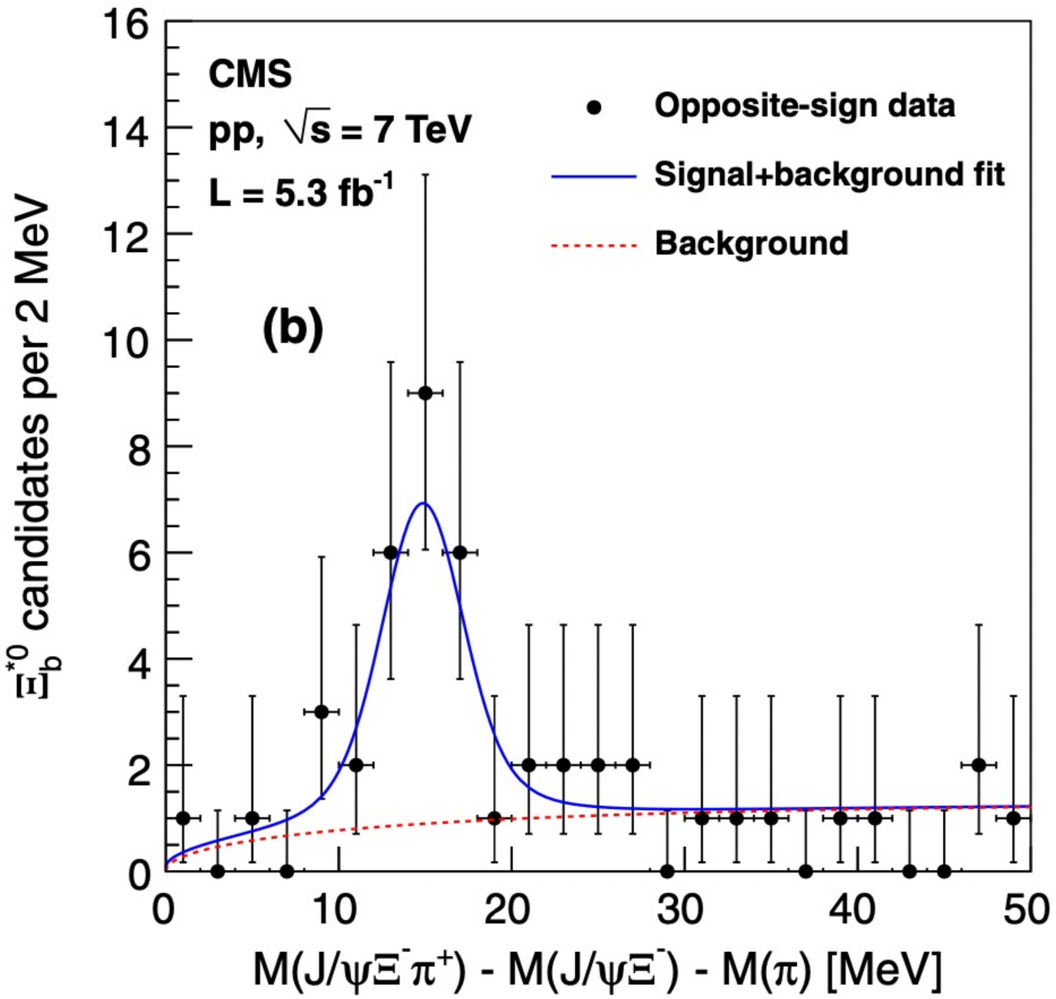
[Phys.Rev.Lett.126(2021)25,252003]

Ξ_b excited states

- Ξ_b^0 and Ξ_b^- forms isodoublet of (qsb) bound states with $q = u \vee d$.



Going back in (pre)history: Ξ_b^{0*}



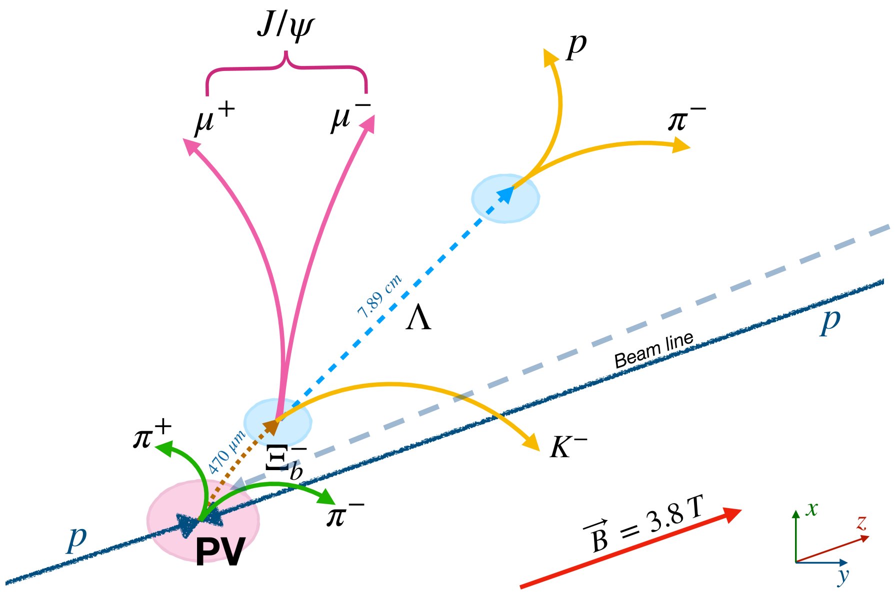
Phys. Rev. Lett. 108 (2012) 252002

- At the very beginning of Run1 (in 2012 with 2011 data).
- CMS observed for the first time Ξ_b^{0*} decaying in $\Xi_b^-\pi^+$ (and cc.).
- Ξ_b^- reconstructed via $\Xi_b^- \to \Xi^- J/\psi$ with $J/\psi \to \mu\mu$, $\Xi^- \to \Lambda\pi^-$, and $\Lambda \to p\pi^-$.

Search for $\Xi_b^{**-} \rightarrow \Xi_b^{*0}\pi^- \rightarrow \Xi_b^-\pi^-\pi^+$ excited states

- A new resonance is searched through $\Xi_b^{**-} \rightarrow \Xi_b^{*0}\pi^- \rightarrow \Xi_b^-\pi^-\pi^+$. (charge conjugate states are implied).

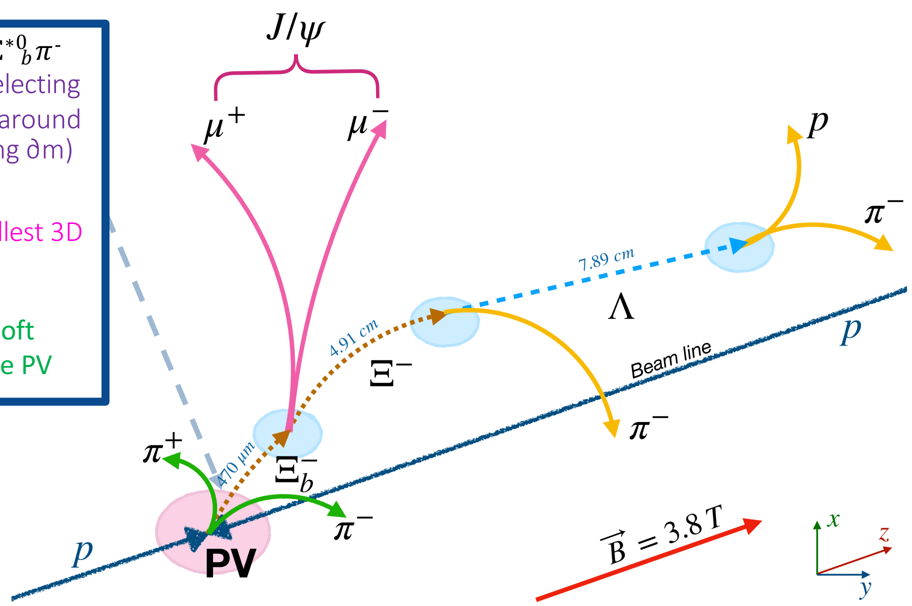
- Ξ_b^- is then reconstructed via its decays $\Xi_b^- \rightarrow J/\psi\Xi^-$ and $\Xi_b^- \rightarrow J/\psi\Lambda K^-$ (with a contribution from partially reconstructed $\Xi_b^- \rightarrow J/\psi\Sigma^0 K^-$ channel) with $J/\psi \rightarrow \mu\mu$, $\Xi^- \rightarrow \Lambda\pi^-$, and $\Lambda \rightarrow p\pi^-$.



The intermediate $\Xi_b^{**-} \rightarrow \Xi_b^{*0}\pi^-$ is taken into account by selecting a 5 MeV mass window around the Ξ_b^{*0} for the $\Xi_b^{*0}\pi^-$ (using ∂m)

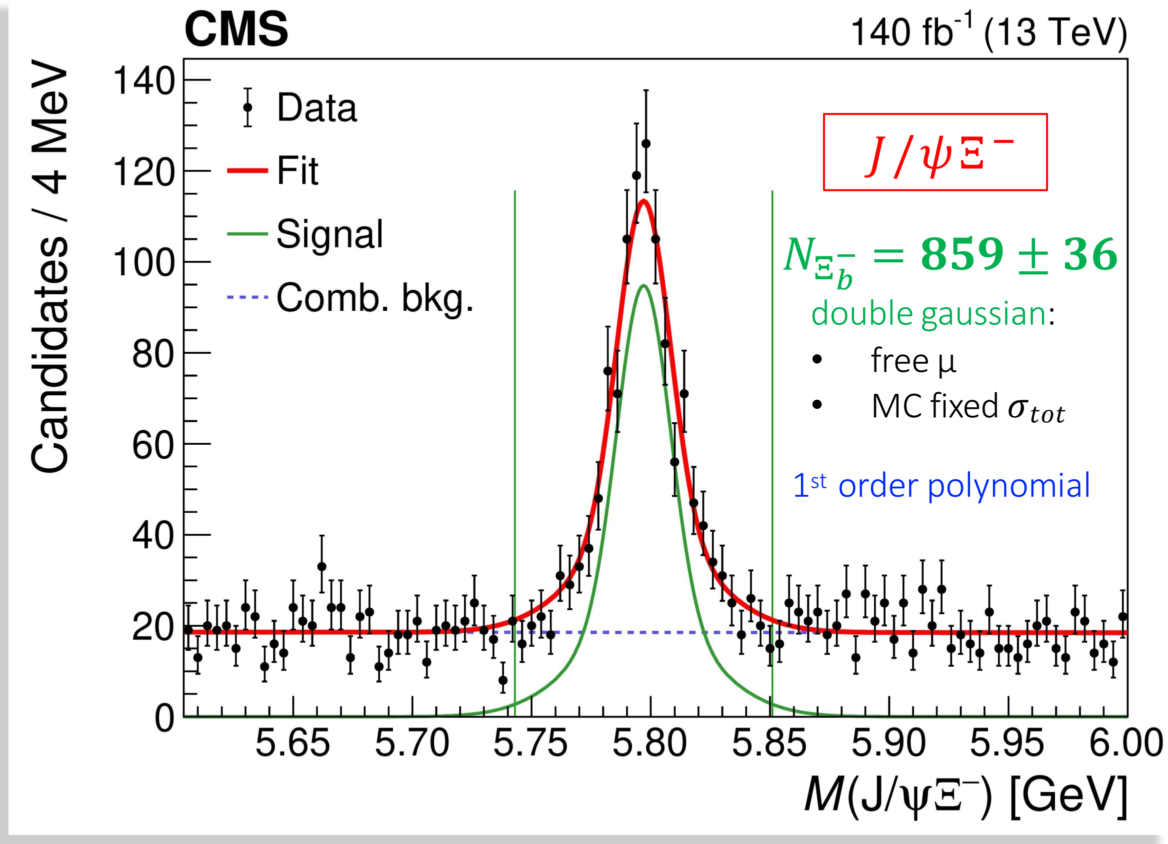
PV is the one with the smallest 3D pointing angle

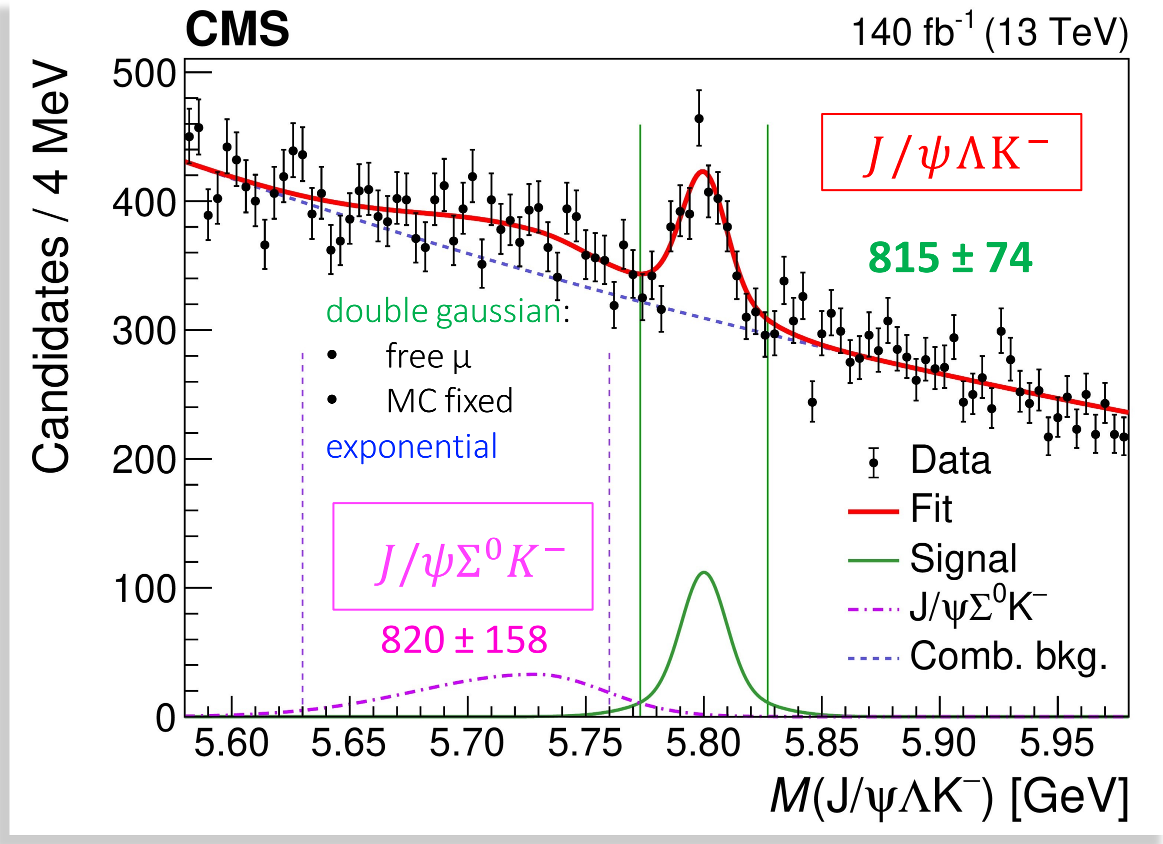
Ξ_b^- is combined with two soft pion tracks coming from the PV



- Selection criteria are optimised using Punzi Figure of Merit $f = S/(463/13 + 4\sqrt{B} + 5\sqrt{25 + 8\sqrt{B} + 4B})$.

Ξ_b^- signals

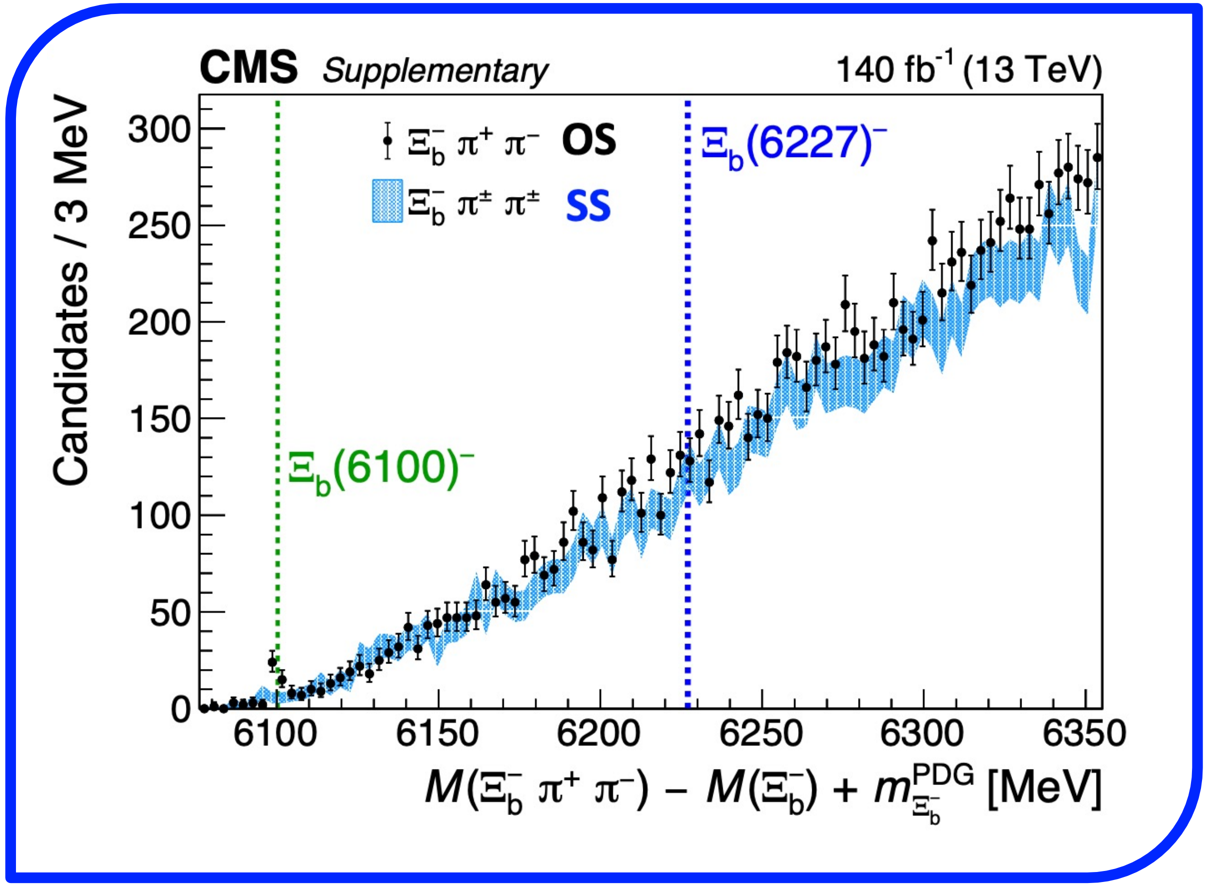




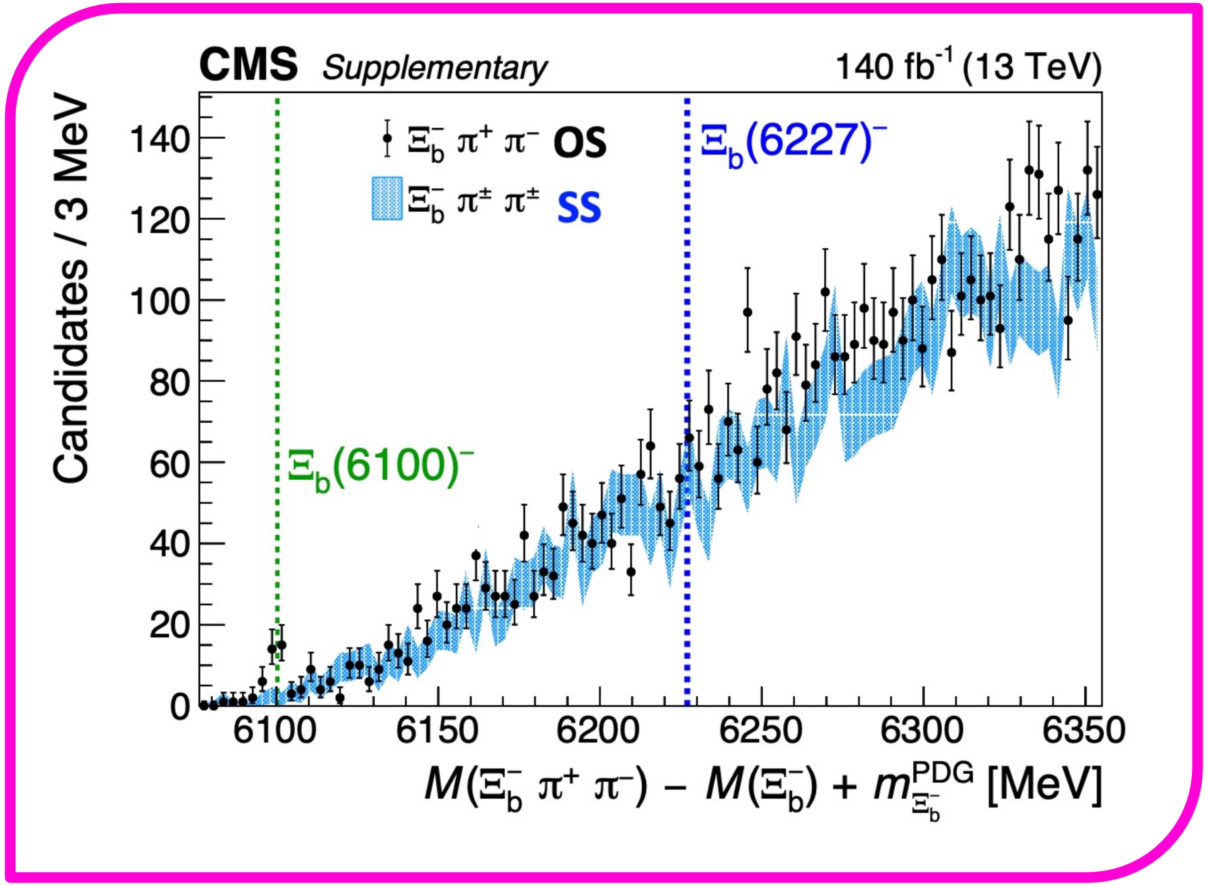
- The $\Xi_b^- \to J/\psi\Sigma^0 K^-$ is partially reconstructed due to the soft photon in $\Sigma^0 \to \Lambda\gamma$ and is modelled with an asymmetrical gaussian.
- Both the fully reconstructed and partially reconstructed decays are used to build the $\Xi_b^-\pi^-\pi^+$ candidates (see mass selection on the plots).

Same sign and opposite sign $\pi\pi$ distributions.

$\Xi_b^- \to J/\psi\Xi^-$ and $\Xi_b^- \to J/\psi\Lambda K^-$



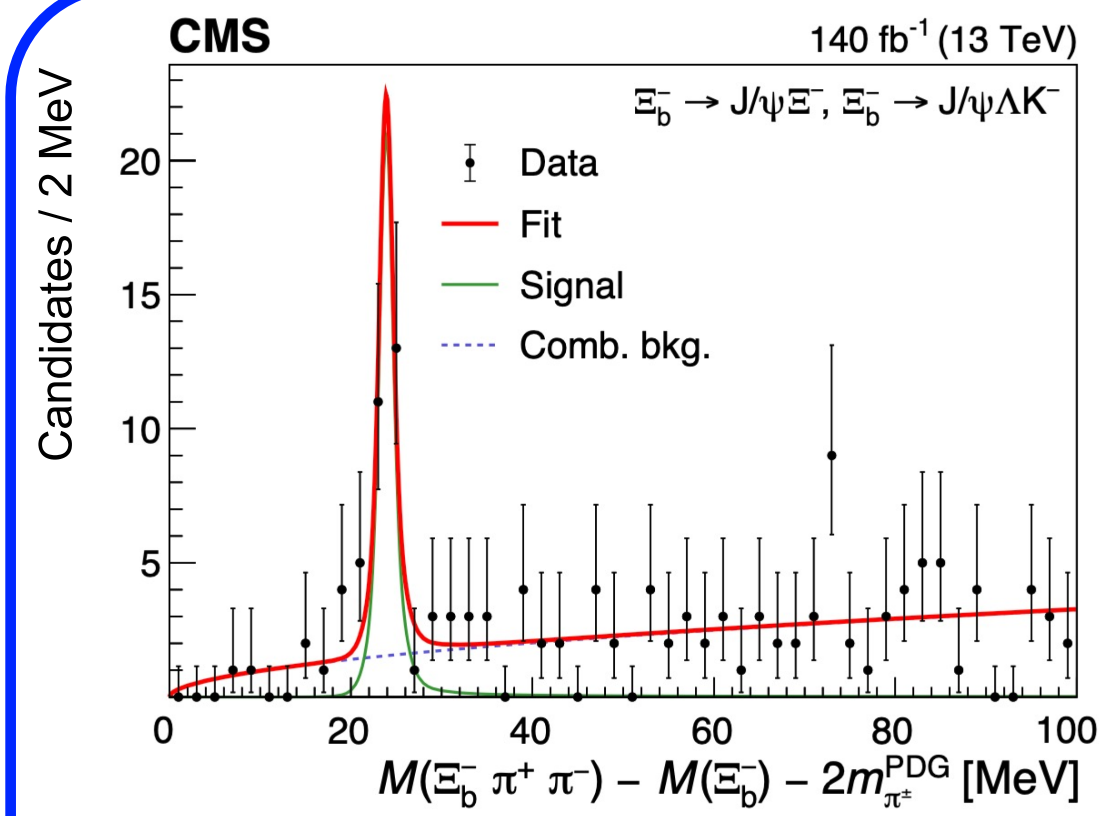
$\Xi_b^- \to J/\psi\Sigma^0 K^-$



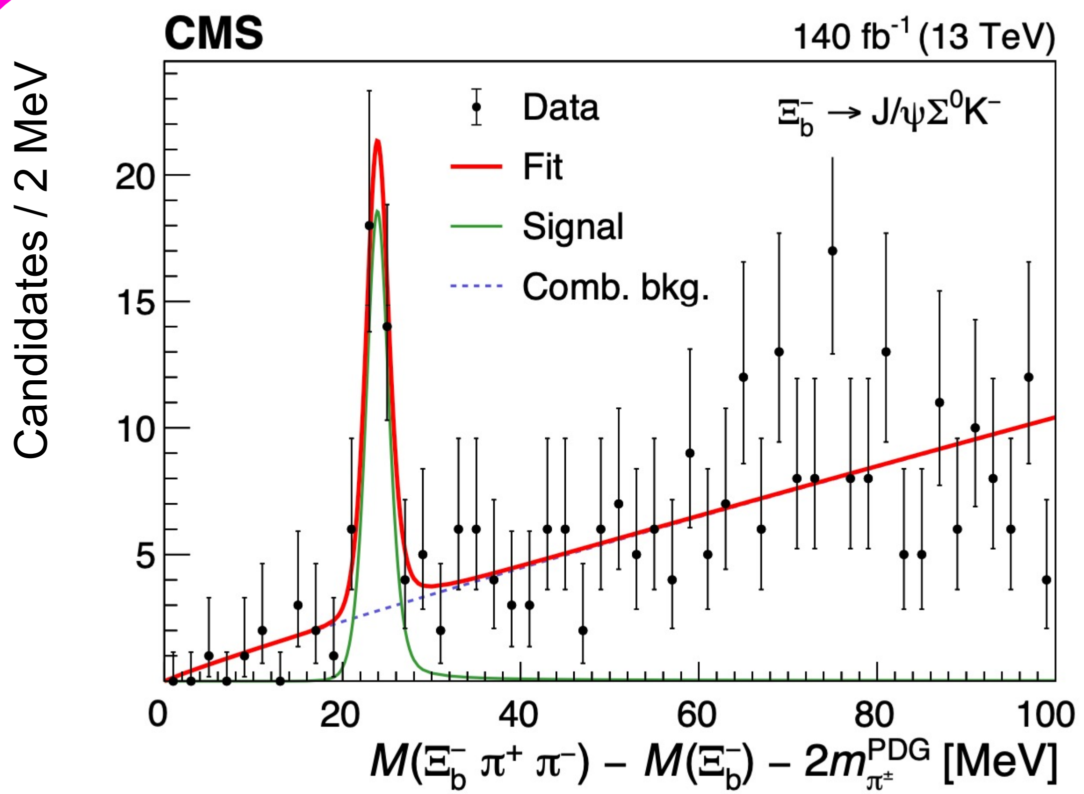
- No Ξ_b^{*0} mass cut on $\Xi_b^- \pi^+$.
- Only peaking structure at ~6100 MeV.
- No hint of $\Xi_b(6227)^-$ reported by LHCb in PhysRevD.103.012004.

$\Xi_b(6100)^-$

$\Xi_b^- \to J/\psi\Xi^-$and $\Xi_b^- \to J/\psi\Lambda K^-$



$\Xi_b^- \to J/\psi\Sigma^0 K^-$

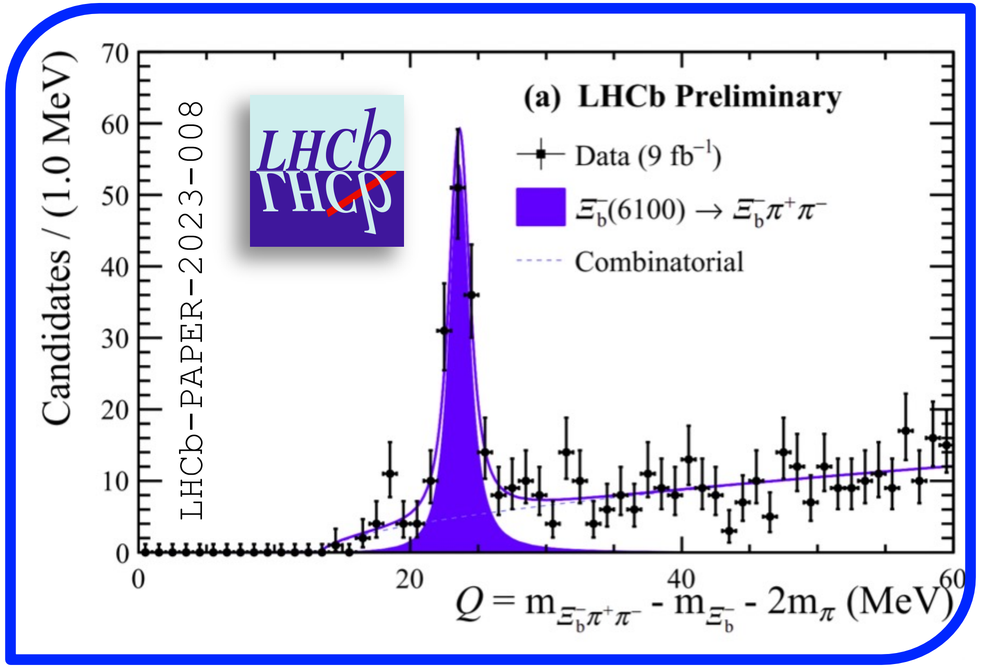


- Simultaneous fit to the two distribution: common mean and width

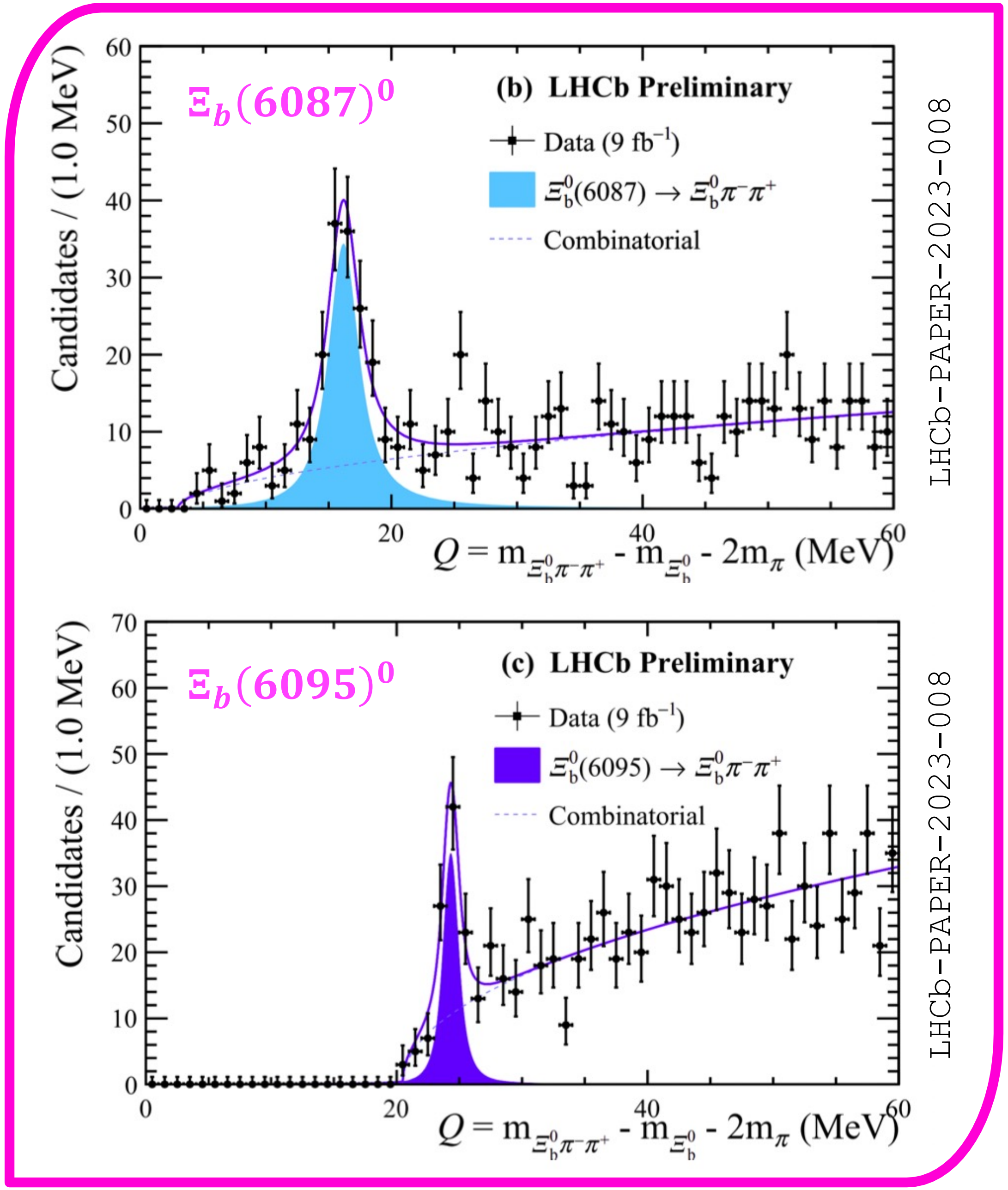
$$M(\Xi_b(6100)^-) = 6100.3 \pm 0.2 \pm 0.1 \pm 0.6\ MeV \qquad \Gamma(\Xi_b(6100^-) < 1.9\ MeV\ @95\%\ CL$$

- **Significance > 6σ : first observation of $\Xi_b(6100)^-$**compatible with the orbitally excited Ξ_b^- with $J^P = \frac{3^-}{2}$analogue of $\Xi_c(2815)$.
- $\Delta M = M(\Xi_b^+\pi^+\pi^*) - M(\Xi_b^+\pi^+) - 2m_{\pi\pm}^{PDG}$ $\oplus$ a new PV refit technique crucial to improve detector resolution.

LHCb confirmation and isospin partners



$\Xi_b(6100)$ **confirmation!**



- Very recently LHCb, with 9fb^{-1} has observed three new excited Ξ_b baryons in $\Xi_b^-\pi^+\pi^-$ and $\Xi_b^0\pi^+\pi^-$ final states.
- Confirmed $\Xi_b(6100)$ state and $\Xi_b(6087)^0$ and $\Xi_b(6095)^0$.
- Paper in preparation, find further details here.

Summary

- The $\Lambda_b^0 \to J/\psi \Xi^- K^+$ decay was observed by CMS for the first time:
  - Significance $> 5\sigma$.
  - Intermediate $J/\psi\Xi$, ΞK, $J/\psi K$ masses explored. No hint for narrow pentaquark-like peak. Consistent with phase-space. Statistics limited still.
- Excited Λ_b^0 baryons decaying into $\Lambda_b^0\pi\pi$ have been studied:
  - States $\Lambda_b\,(5912)^0$ and $\Lambda_b\,(5920)^0$, $\Lambda_b\,(6146)^0$ and $\Lambda_b\,(6152)^0$ are confirmed and their masses are measured.
  - Extra broad excess with $M \sim 6075\mathrm{MeV}$ and $\Gamma \sim 55\mathrm{MeV}$. Nature unclear due to low statistics.
- Observation of a new excited Ξ_b^- baryon:
  - **First observation of $\boldsymbol{\Xi_b(6100)^-}$** compatible with the orbitally excited $\boldsymbol{\Xi_b^-}$ with $\boldsymbol{J^P = \frac{3}{2}^-}$, analogue of $\boldsymbol{\Xi_c(2815)}$. Significance > $\boldsymbol{6\sigma}$.
  - Very recently [LHCb-PAPER-2023-008] **confirmed by LHCb** together with its isospin partners.

Thank you!

Questions?