



Recent LHCb results on pentaquark candidates

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Introduction

 Observed pentaquark-like structures at LHCb in 2019 indicate interesting physics related to thresholds of charmed mesons and baryons



 Narrow widths need excellent mass resolution

State	M [MeV]	Γ [MeV]
$P_c(4312)^+$	$4311.9\pm0.7^{+6.8}_{-0.6}$	$9.8 \pm 2.7^{+3.7}_{-4.5}$
$P_c(4440)^+$	$4440.3 \pm 1.3^{+4.1}_{-4.7} 2$	$20.6 \pm 4.9^{+8.7}_{-10.1}$
$P_c(4457)^+$	$4457.3 \pm 0.6^{+4.1}_{-1.7}$	$6.4\pm2.0^{+5.7}_{-1.9}$

More pentaquark states?

• Prediction from many theoretical papers:

i.e. Progr.Phys.41(2021)65-93, exist around threshold of any pair of heavy-baryon and antiheavy-meson with attractive interaction



 Recent searches with amplitude analysis at LHCb

> $B_s^0 \rightarrow J/\psi p \overline{p}$ LHCb-PAPER-2021-018 in preparation

 $\Xi_b^- \to J/\psi \Lambda K^-$ Sci.Bull.66(2021)1278-1287

Evidence for a new structure P_c in $B_s^0 \to J/\psi p \overline{p}$ decays

Invariant mass coverage

- Several thresholds covered in the $m(J/\psi p)$ distribution
- Check P_c^+ structures in 2019



 $B_s^0 \to J/\psi p \overline{p}$ reconstruction

- First observed by LHCb using 5.2fb⁻¹ data PRL122(2019)191804
- Full amplitude analysis using 9fb⁻¹ data LHCb-PAPER-2021-018 in preparation



Default amplitude model



- 4D amplitude using helicity formalism
 - Untagged B decay CP conservation: $\mathcal{M}(\bar{B}^0) = \mathcal{M}(B^0)$ Total amplitude: $|\bar{\mathcal{M}}|^2 = \frac{1}{2}(|\mathcal{M}(B^0)|^2 + |\mathcal{M}(\bar{B}^0)|^2)$
 - Default model can not describe data well

Amplitude model with P_c

• Add $P_c^+ \to J/\psi p, P_c^- \to J/\psi \overline{p}$

• The same mass, width and couplings for P_c^{\pm}

 Improvement in mass and helicity distributions



Evidence of a new structure

- LHCb-PAPER-2021-018 in preparation
- New pentaguark-like state with significance $3.1 \sim 3.7 \sigma$ for $J^{P}(1/2^{\pm}, 3/2^{\pm})$

 $M_{P_c} = 4337^{+7}_{-4}(\text{stat})^{+2}_{-2}(\text{syst}) \text{ MeV}$ $\Gamma_{P_c} = 29^{+26}_{-12}(\text{stat})^{+14}_{-14}(\text{syst}) \text{ MeV}$

can not distinguish JP due to limited sample size

Tested other contributions:

exclude $P_c^+(4312) \rightarrow J/\psi p$ and $f_I(2220) \rightarrow p\overline{p}$

No confirmation of 2019 structures

Evidence for a new structure P_{cs} in $\Xi_b^- \to J/\psi \Lambda K^-$ decays

$\Xi_b^- \to J/\psi \Lambda K^-$ reconstruction

- 1750 signal candidates using 9fb⁻¹ data, purity ~80%
- Clear structures of Ξ^{*-} , hint for P_{cs}^0 ?



Sci.Bull.66(2021)1278-1287

Amplitude analysis results

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First evidence for hidden-charm pentaquark with strangeness $P_{cs}(4459)^0$, with significance of 3.1σ



State	$M_0 \; [{ m MeV}]$	$\Gamma_0 \; [{ m MeV}]$	FF (%)
$P_{cs}(4459)^0$	$4458.8 \pm 2.9 {}^{+4.7}_{-1.1}$	$17.3 \pm 6.5 {}^{+ 8.0}_{- 5.7}$	$2.7^{+1.9+0.7}_{-0.6-1.3}$
$\Xi(1690)^{-}$	$1692.0 \pm 1.3 {}^{+1.2}_{-0.4}$	$25.9 \pm 9.5 {}^{+14.0}_{-13.5}$	$22.1^{+6.2}_{-2.6}{}^{+6.7}_{-8.9}$
$\Xi(1820)^{-}$	$1822.7 \pm 1.5 {}^{+1.0}_{-0.6}$	$36.0 \pm 4.4 {}^{+7.8}_{-8.2}$	$32.9^{+3.2+6.9}_{-6.2-4.1}$
$\Xi(1950)^-$	1910.6 ± 18.4	105.7 ± 23.2	$11.5^{+5.8+49.9}_{-3.5-9.4}$
$\Xi(2030)^-$	2022.8 ± 4.7	68.2 ± 8.5	$7.3^{+1.8+3.8}_{-1.8-4.1}$
NR	_	_	$35.8^{+4.6+10.3}_{-6.4-11.2}$

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Highlight of $P_{cs}^0(4459)$ contribution

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 $P_{cs}^{0}(4459)$ improves the description of mass and angular distribution



Summary

• Evidence for two new structures after discovery in 2019

	M[MeV]	Γ [MeV]	
$P_c(4337)^+$	$4337^{+7}_{-4} \pm 2$	$29^{+26}_{-12} \pm 14$	LHCb-PAPER-2021-018 in preparation
$P_{cs}(4459)^0$	$4458.8 \pm 2.9^{+4.7}_{-1.1}$	$17.3 \pm 6.5^{+8.0}_{-5.7}$	Sci.Bull.66(2021)1278-1287

- No confirmation of P_c^+ structures observed in 2019
- More data needed, and lots of interesting results are expected from LHCb Upgrade

