新强子态研究新进展

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兰州大学

第十六届粒子物理、核物理和宇宙学交叉学科前沿问题研讨会

2023年6月30日-7月4日

Outline

- Background
- Pentaquark is always a focused point
- Abundant phenomena around tetraquark candidates
- Pay more attention to the study of light hadron spectroscopy
- Summary-Never underestimate the ability of experiment

Many light hadrons

(1950's &1960's)

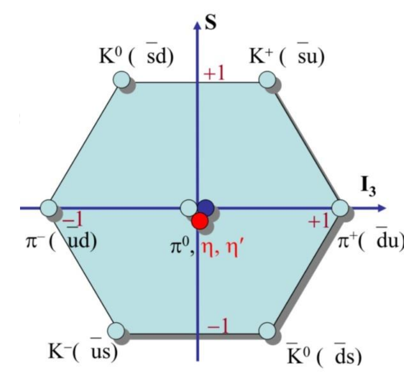
Volume 8, number 3 PHYSICS LETTERS 1 February 1964

Quark model

A SCHEMATIC MODEL OF BARYONS AND MESONS

M. GELL-MANN
California Institute of Technology, Pasadena, California

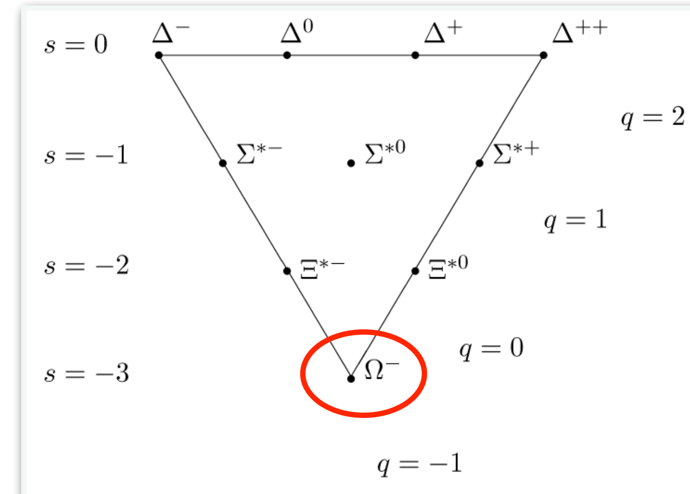
Received 4 January 1964

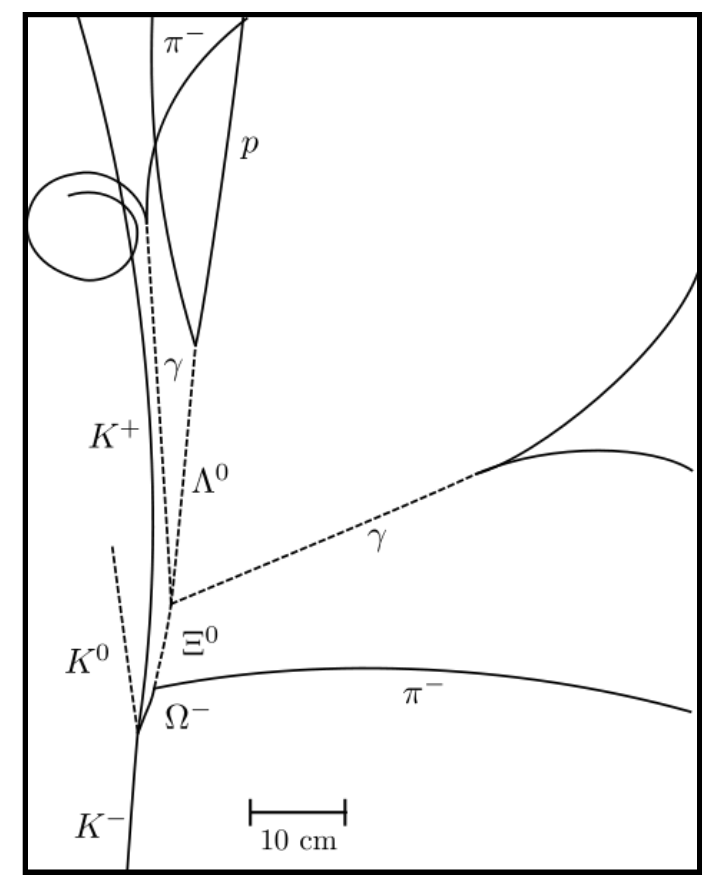


If we assume that the strong interactions of baryons and mesons are correctly described in terms of the broken "eightfold way"[1-3], we are tempted to look for some fundamental explanation of the situation. A highly promised approach is the purely dynamical "bootstrap" model for all the strongly interacting particles within which one may try to derive isotopic spin and strangeness conservation and broken eightfold symmetry from self-consistency alone[4]. Of course, with only strong interactions, the orientation of the asymmetry in the unitary space cannot be specified; one hopes that in some way the selection of specific components of the F-spin by electromagnetism and the weak interactions determines the choice of isotopic spin and hypercharge directions.

ber $n_t - n_{\bar{t}}$ would be zero for all known baryons and mesons. The most interesting example of such a model is one in which the triplet has spin $\frac{1}{2}$ and $z = -1$, so that the four particles d^-, s^-, u^0 and b^0 exhibit a parallel with the leptons.

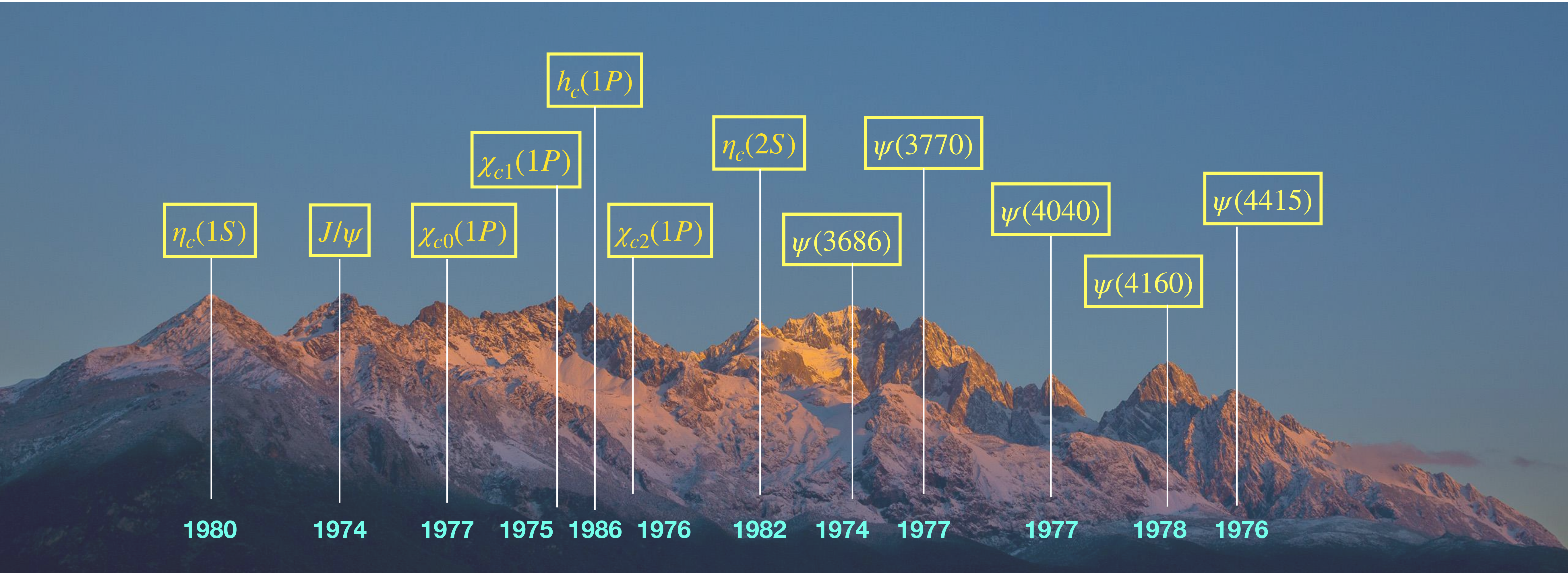
A simpler and more elegant scheme can be constructed if we allow non-integral values for the charges. We can dispense entirely with the basic baryon b if we assign to the triplet t the following properties: spin $\frac{1}{2}$, $z = -\frac{1}{3}$, and baryon number $\frac{1}{3}$. We then refer to the members $u^{\frac{2}{3}}$, $d^{-\frac{1}{3}}$, and $s^{-\frac{1}{3}}$ of the triplet as "quarks"[6] q and the members of the anti-triplet as anti-quarks $\bar{q}$. Baryons can now be constructed from quarks by using the combinations (qqq), $(qqqq\bar{q})$, etc., while mesons are made out of $(q\bar{q})$, $(qq\bar{q}\bar{q})$, etc. It is assuming that the lowest





Status of charmonium family

(1974-1982)



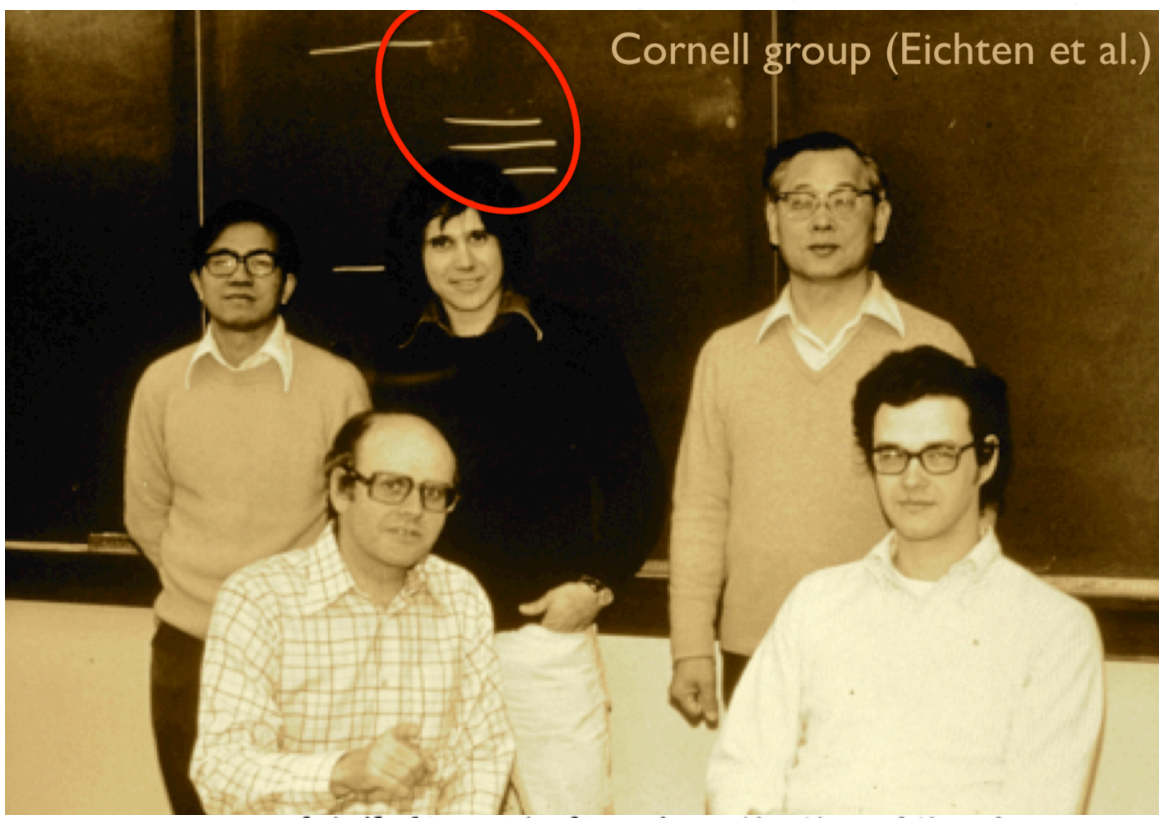
Most of charmonia listed in PDG were observed

PHYSICAL REVIEW D VOLUME 17, NUMBER 11 1 JUNE 1978

Charmonium: The model

E. Eichten,* K. Gottfried, T. Kinoshita, K. D. Lane,* and T.-M. Yan†
Laboratory of Nuclear Studies, Cornell University, Ithaca, New York 14853
(Received 9 February 1978)

A comprehensive treatment of the charmonium model of the ψ family is presented. The model's basic assumption is a flavor-symmetric instantaneous effective interaction between quark color densities. This interaction describes both quark-antiquark binding and pair creation, and thereby provides a unified approach for energies below and above the threshold for charmed-meson production. If coupling to decay channels is ignored, one obtains the "naive" model wherein the dynamics is completely described by a single charmed-quark pair. A detailed description of this "naive" model is presented for the case where the instantaneous potential is a superposition of a linear and Coulombic term. A far more realistic picture is attained by incorporating those terms in the interaction that couple charmed quarks to light quarks. The coupled-channel formalism needed for this purpose is fully described. Formulas are given for the inclusive e^+e^- cross section and for e^+e^- annihilation into specific charmed-meson pairs. The influence of closed decay channels on ψ states below charm threshold is investigated, with particular attention to leptonic and radiative widths.



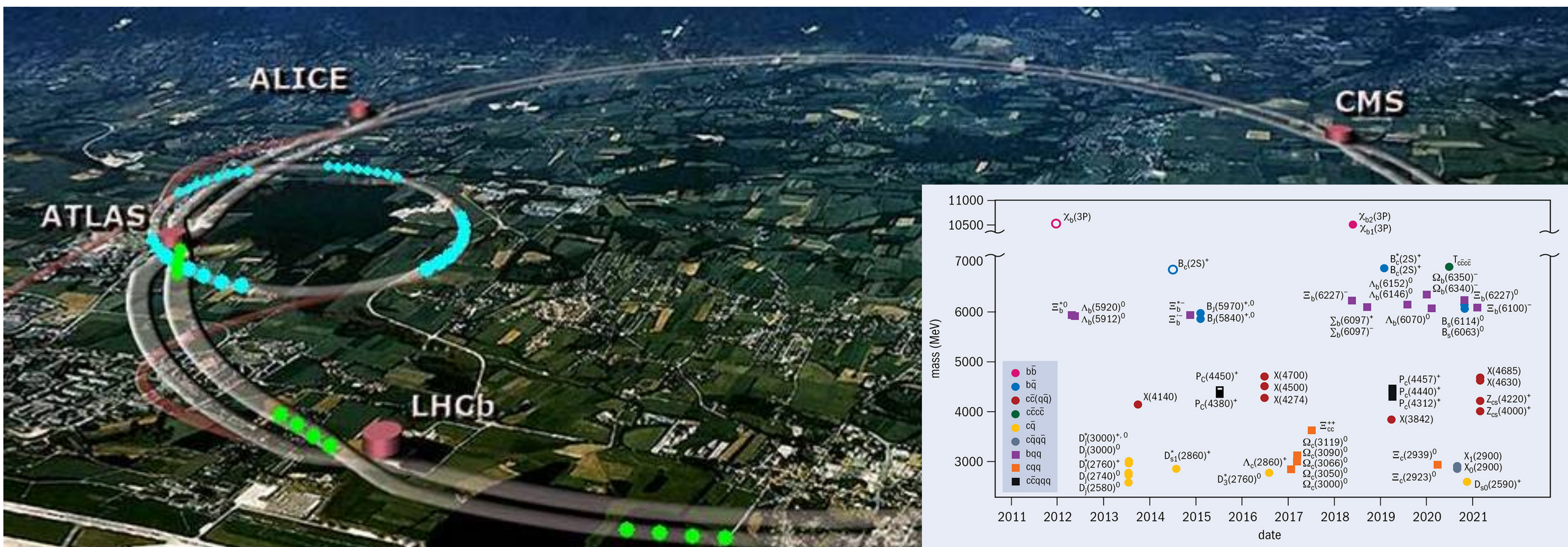
color gauge interaction leads to forces that are so strong at large distances that quarks are permanently confined in color-neutral bound states—the mesons and baryons. We also adopt this assumption.

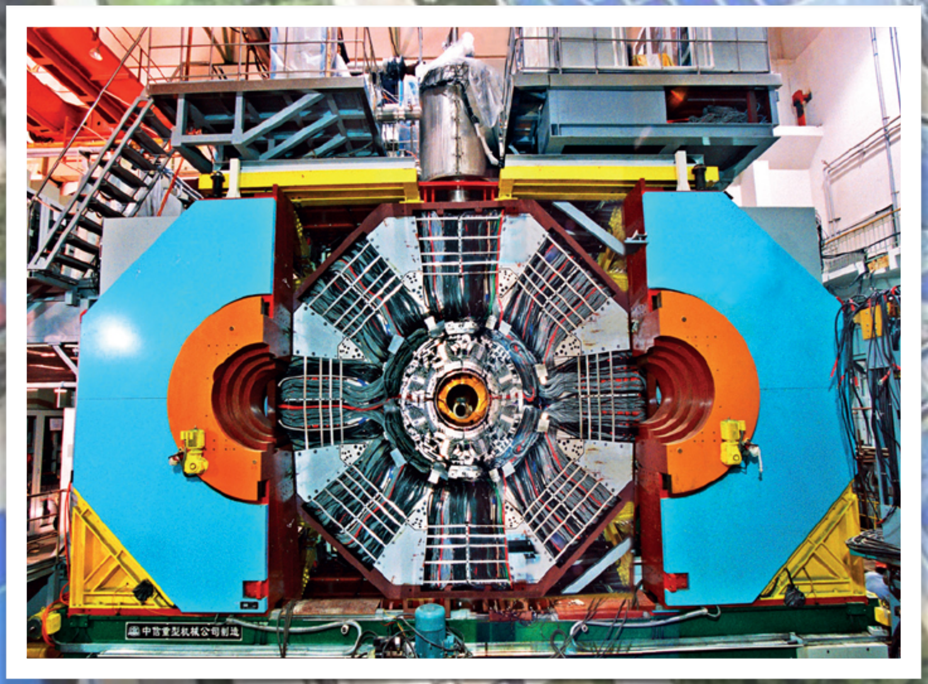
Secondly, the large masses of the ψ resonances and charmed mesons lead to the assumption that the charmed quarks are so heavy that they may be treated nonrelativistically.[4] No one has yet succeeded in calculating the effective form of the interquark forces from quantum chromodynamics,[16] even in the nonrelativistic limit. To fill this gap we postulate that in this limit many of the gross features of the potential between the charmed quarks can be simulated by the potential

$$V(r) = -\frac{\kappa}{r} + \frac{r}{a^2}\,. \qquad (1.1)$$

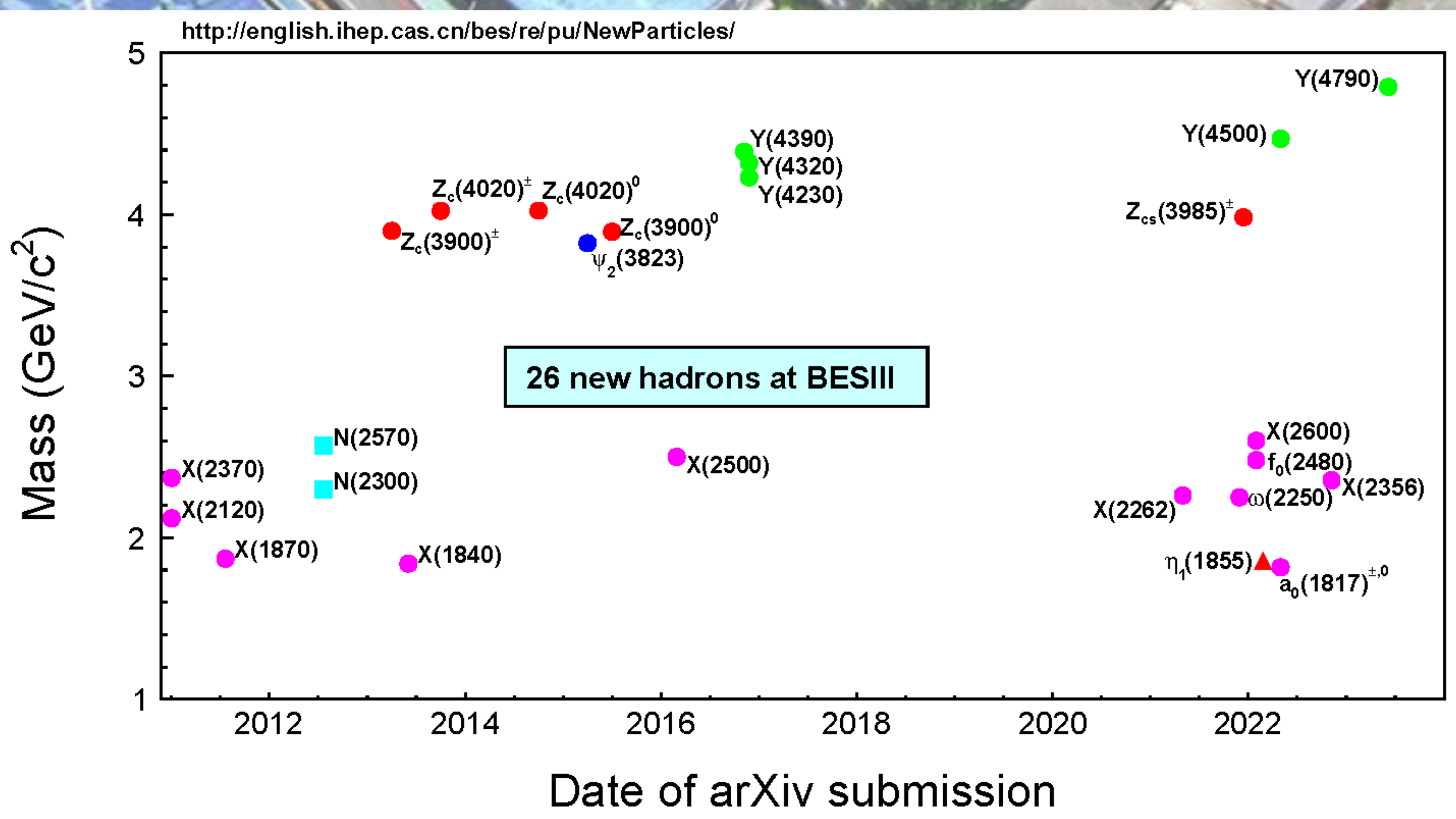
Cornell potential

Experimental statu of new hadronic states (2003-now)

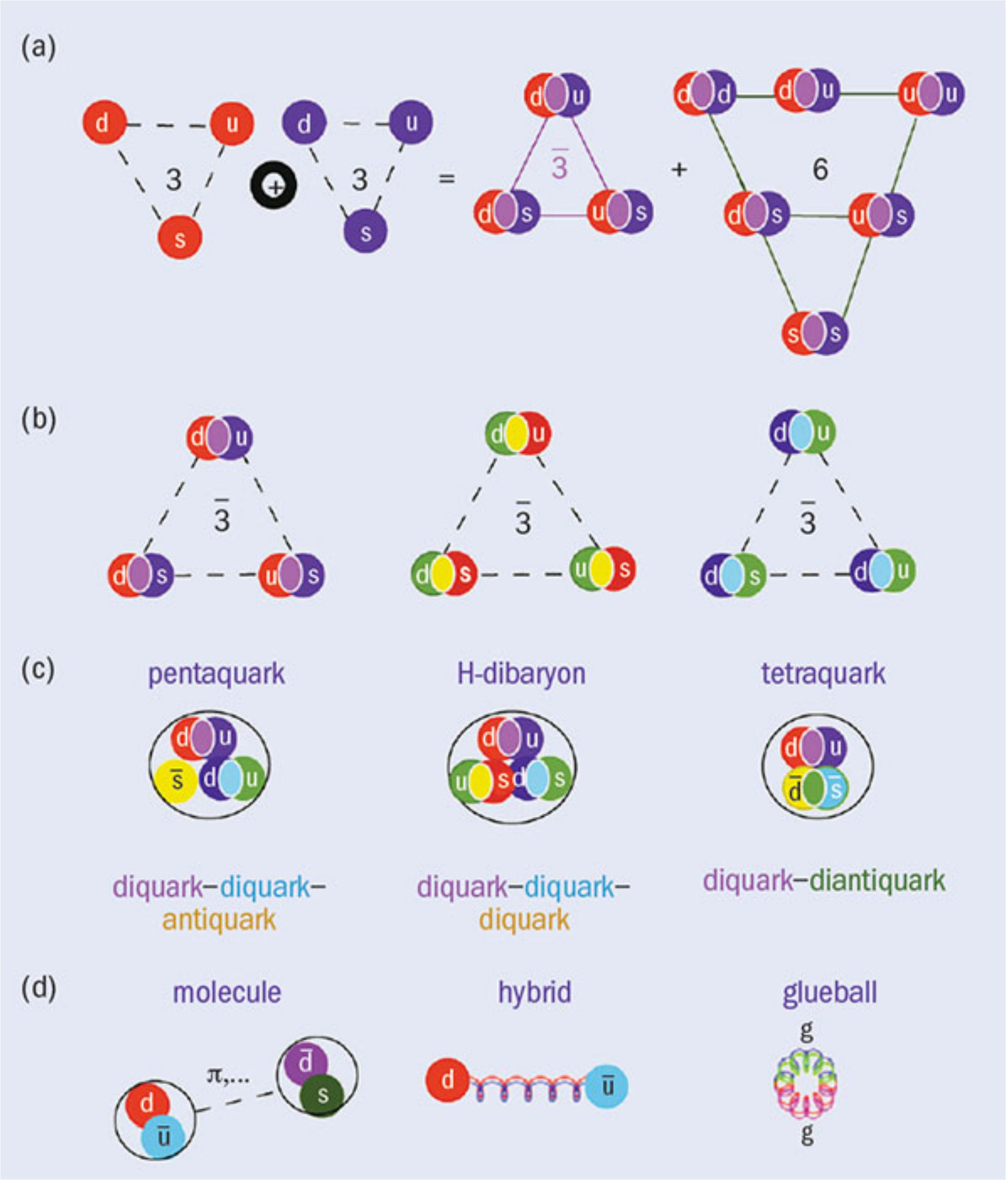




BESIII


http://english.ihep.cas.cn/bes/re/pu/NewParticles/
26 new hadrons at BESIII
Mass (GeV/c^2)
Date of arXiv submission
1
2
3
4
5
2012
2014
2016
2018
2020
2022
X(2370)
X(2120)
X(1870)
N(2570)
N(2300)
X(1840)
$Z_c(4020)^{\pm}$
$Z_c(4020)^0$
$Z_c(3900)^{\pm}$
$Z_c(3900)^0$
$\psi_2(3823)$
Y(4390)
Y(4320)
Y(4230)
X(2500)
Y(4790)
Y(4500)
$Z_{cs}(3985)^{\pm}$
X(2600)
$f_0(2480)$
X(2356)
X(2262)
ω(2250)
$\eta_1(1855)$
$a_0(1817)^{\pm,0}$

"Particle Zoo 2.0" — Exotic states



Long reviews

1. The hidden-charm pentaquark and tetraquark states **960 citations**
   H.X. Chen, W. Chen, X. Liu, S.L. Zhu
   Phys.Rept. 639 (2016) 1-121
2. Hadronic molecules **933 citations**
   F.K. Guo, C. Hanhart, U.G. Msissner, Q. Wang, Q. Zhao, B.S. Zou
   Rev.Mod.Phys. 90 (2018) 015004
3. Multiquark resonances **568 citations**
   A. Esposito, A. Pilloni, A.D. Polosa
   Phys.Rept. 668 (2017) 1-97
4. A review of the open charm and open bottom systems **317 citations**
   H.X. Chen, W. Chen, X. Liu, Y.R. Liu, S.L. Zhu
   Rept.Prog.Phys.80 (2017) 076201
5. Pentaquark and tetraquark states **472 citations**
   Y.R. Liu, H.X. Chen, W. Chen, X. Liu, S.L. Zhu
   Prog.Part.Nucl.Phys. 107 (2019) 237-320
6. The XYZ states: experimental and theoretical status and perspectives **527 citations**
   N. Brambilla. S. Eidelman, C. Hanhart, A. Nefediev, C.P. Shen, C.E. Thomas, A. Vairo, C.Z. Yuan
   Phys.Rept. 873 (2020) 1-154
7. An updated review of the new hadron states **164 citations**
   H.X. Chen, W. Chen, X. Liu, Y.R. Liu, S.L. Zhu
   Rept.Prog.Phys.86 (2023) 026201

……

1. Pentaquark is always a focused point

Summary of pentaquark observations

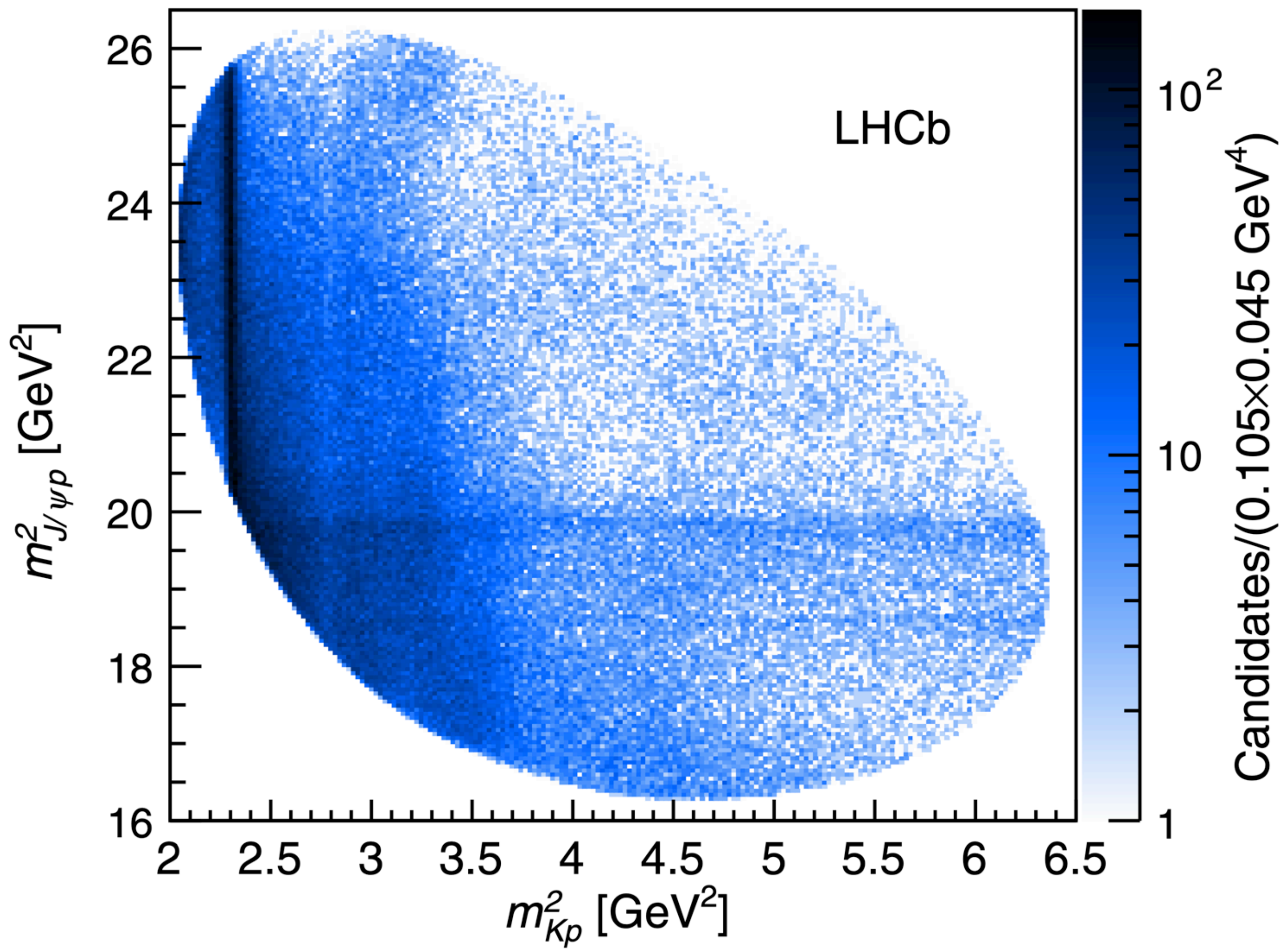
$\bullet\ X_b \to (J/\psi p)\ldots$	$\bullet\ X_b \to (J/\psi\Lambda)\ldots$
$\Lambda_b^0 \to (J/\psi p)K^-$	$\Xi_b^- \to (J/\psi\Lambda)K^-$
$\Lambda_b^0 \to (J/\psi p)\pi^-$	$B^- \to (J/\psi\Lambda)\bar{p}$
$B_s^0 \to (J/\psi p)\bar{p}$	
Threshold: $\Sigma_c^{(*)+}\bar{D}^{(*)0}/\Sigma_c^{(*)++}D^{(*)-}$	**Threshold:** $\Xi_c^{(*)0}\bar{D}^{(*)0}/\Xi_c^{(*)+}D^{(*)-}$
P_ψ^N	$P_{\psi s}^\Lambda$

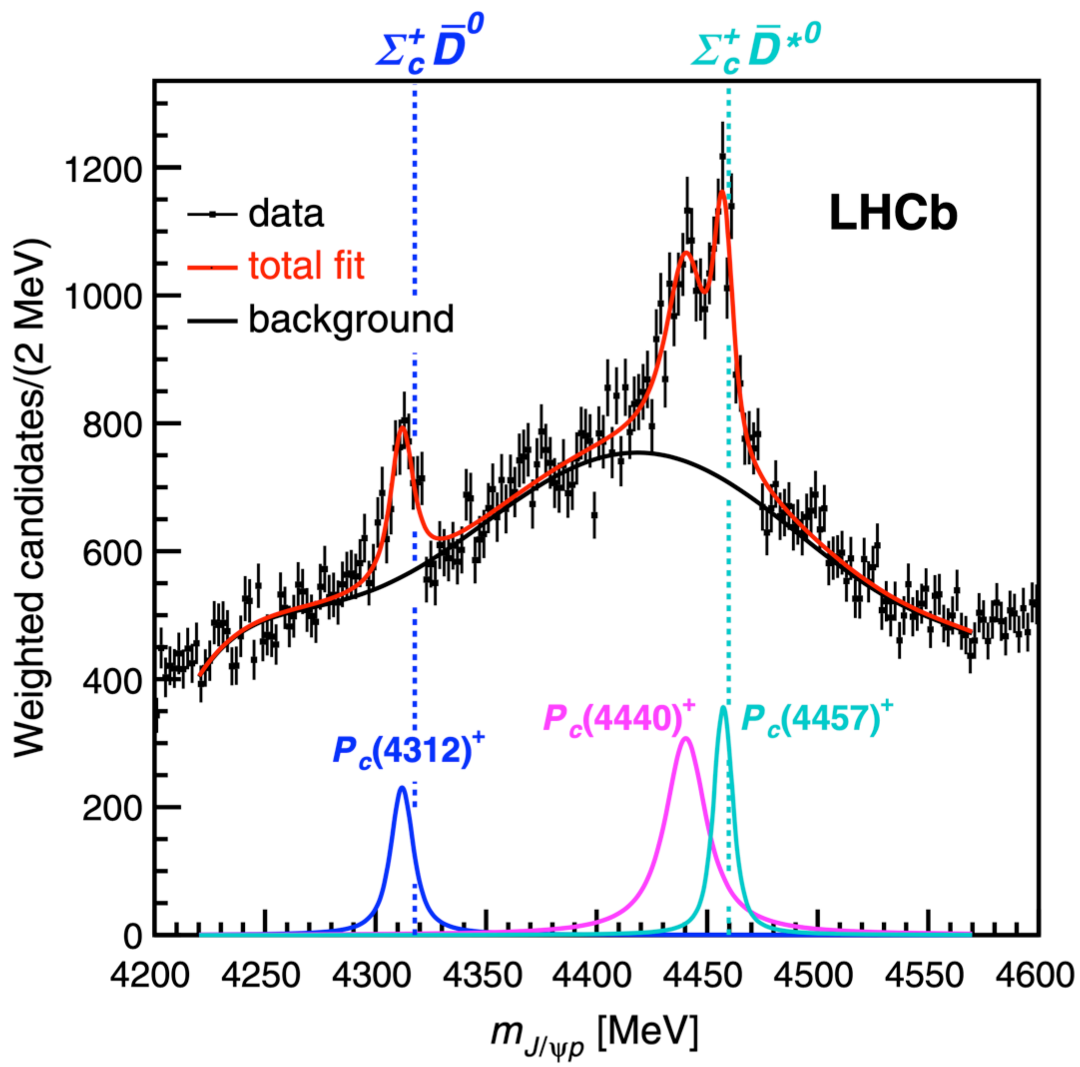
LHCb proposal for the new name convention of exotic hadrons [arXiv:2206.15233]

$P_\psi^N(4312)$ $P_\psi^N(4440)$ $P_\psi^N(4457)$

$$\Lambda_b^0 \to (J/\psi p)K^-$$

The first pentaquark



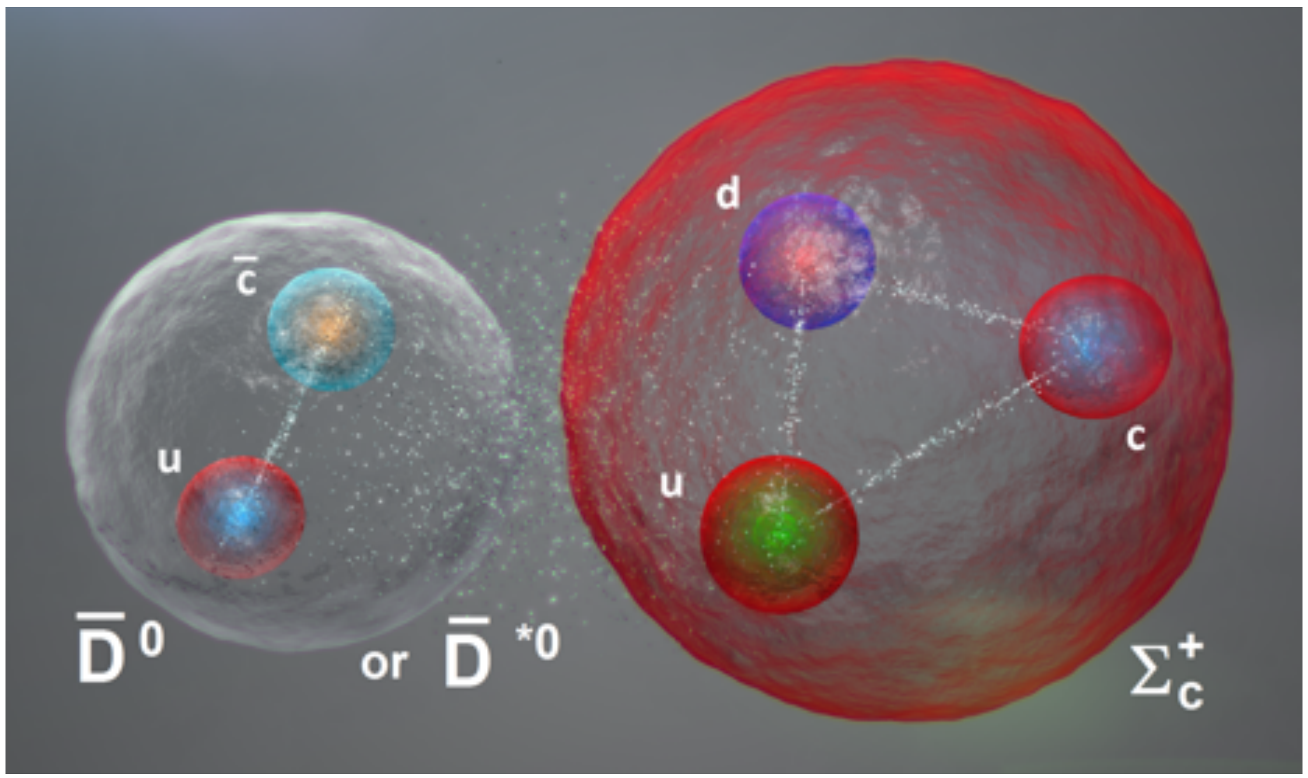


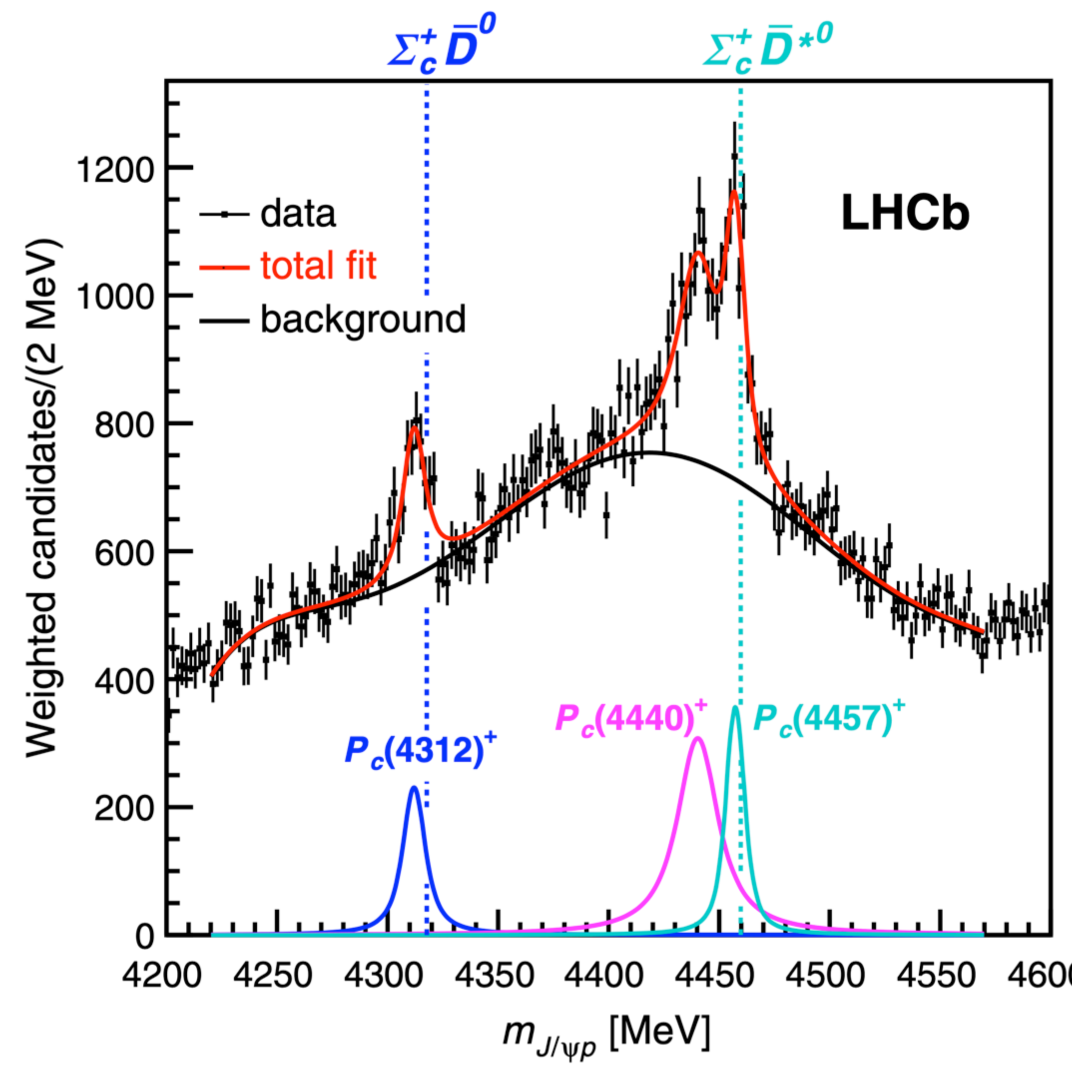
LHCb Collaboration: PRL 115 (2015) 072001; PRL 122 (2019) 222001

$P_\psi^N(4312)$ $P_\psi^N(4440)$ $P_\psi^N(4457)$

$$\Lambda_b^0 \to (J/\psi p)K^-$$

The first pentaquark





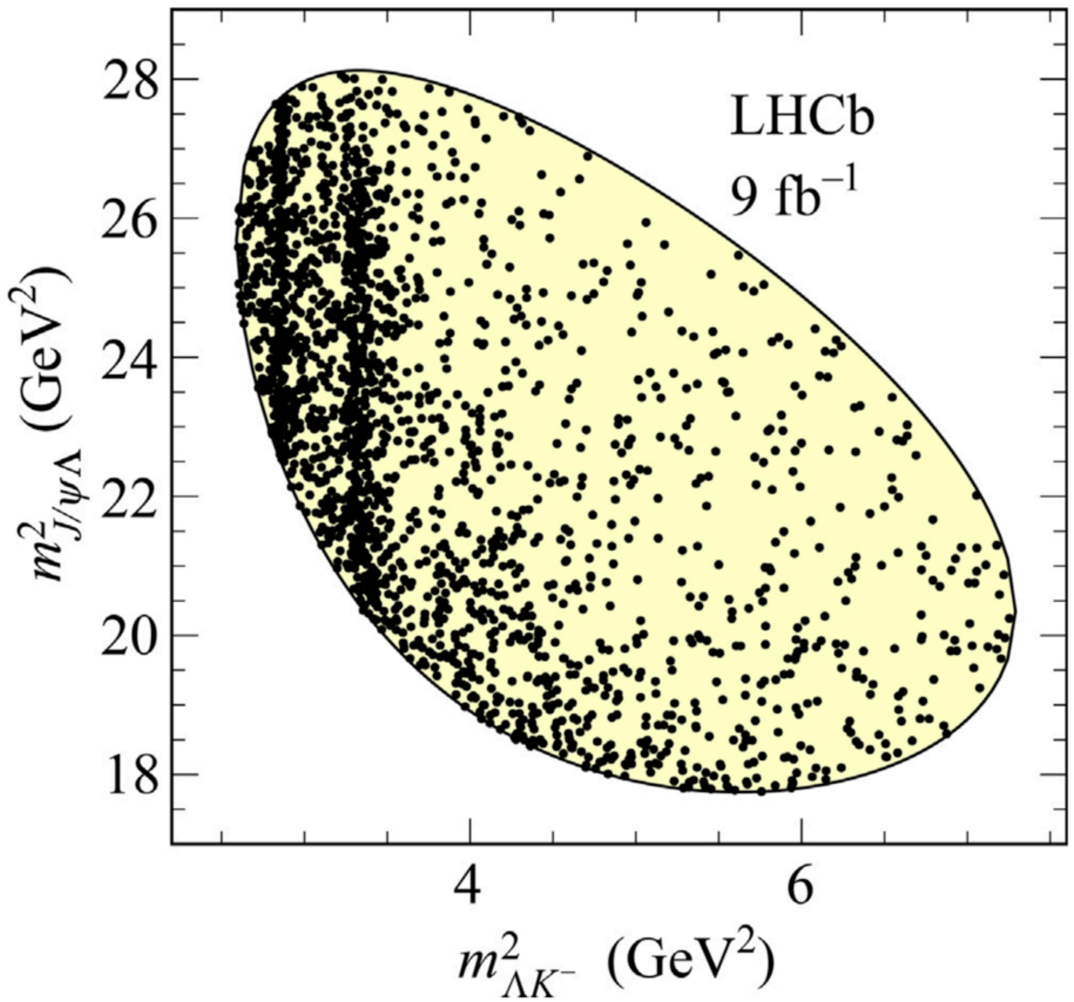
高精度的实验数据支持分子态构型

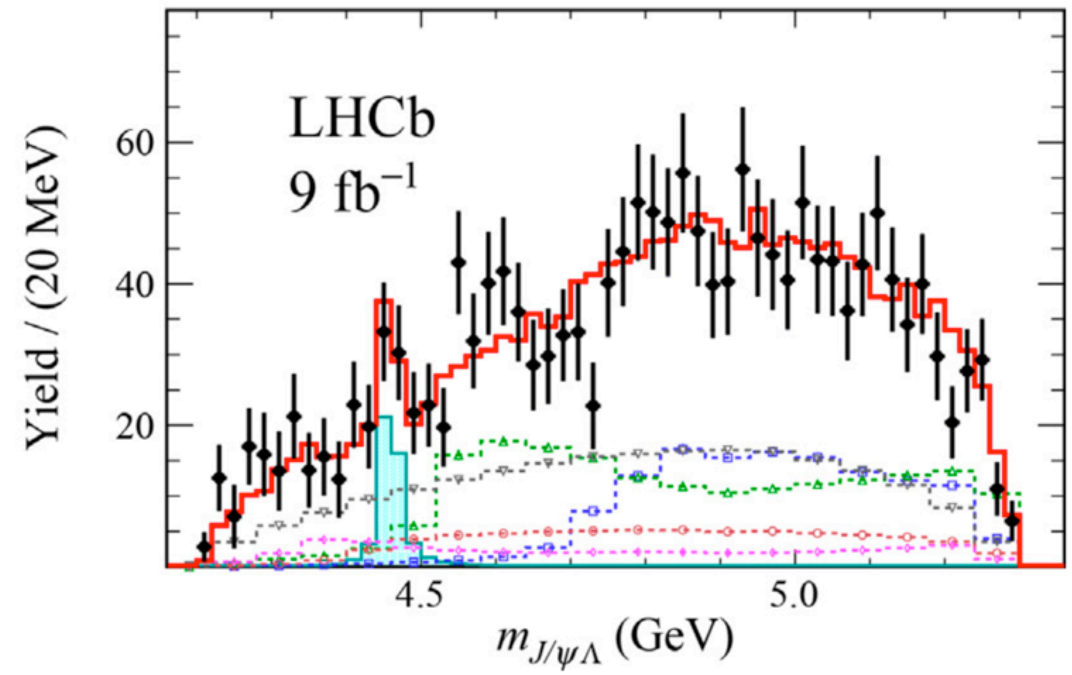
LHCb Collaboration: PRL 115 (2015) 072001; PRL 122 (2019) 222001

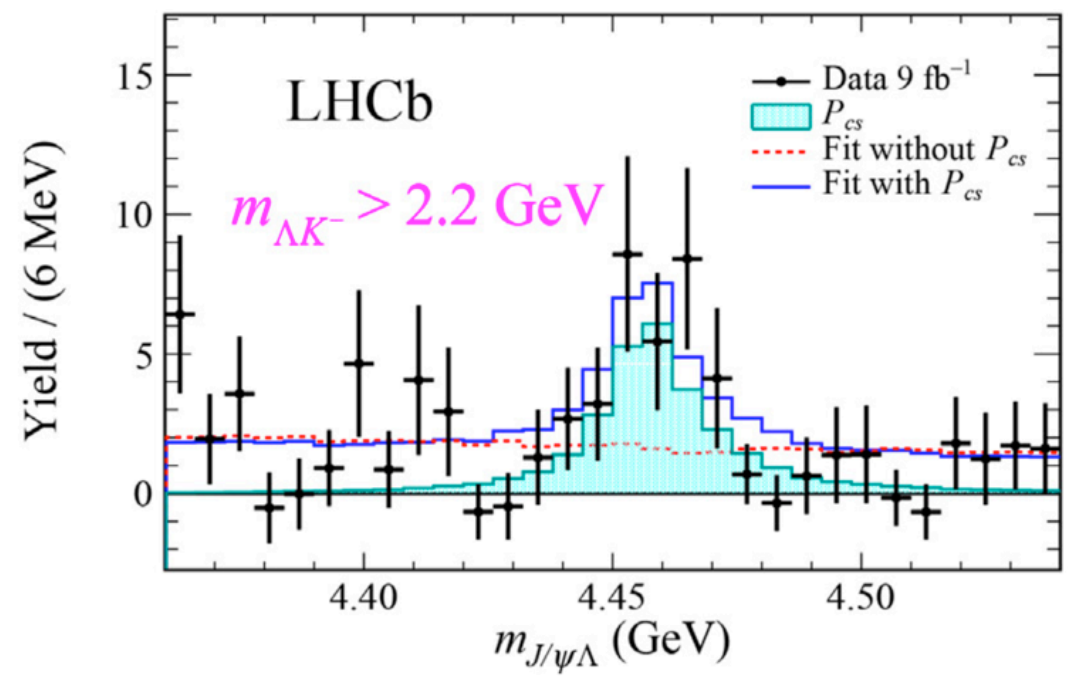
$P_{\psi s}^{\Lambda}(4459)$

Hint for the strange partners

$\Xi_b^- \to (J/\psi\Lambda)K^-$







$M = 4458 \pm 2.9^{+4.7}_{-1.1}$ MeV

$\Gamma = 17.3 \pm 6.5^{+8.0}_{-5.7}$ MeV

4.3σ significance

LHCb: Sci.Bull. 66 (2021) 1278-1287

$P_{\psi s}^{\Lambda}(4338)$ Another strange partner

$$B^- \to (J/\psi\Lambda)\bar{p}$$

Amplitude contributions:

- $NR(\bar{p}\Lambda)$
- $NR(\bar{p}J/\psi)$
- $P_{\psi s}^{\Lambda}(J/\psi\Lambda)$

Fit results:

$m = 4338.2 \pm 0.7$ MeV

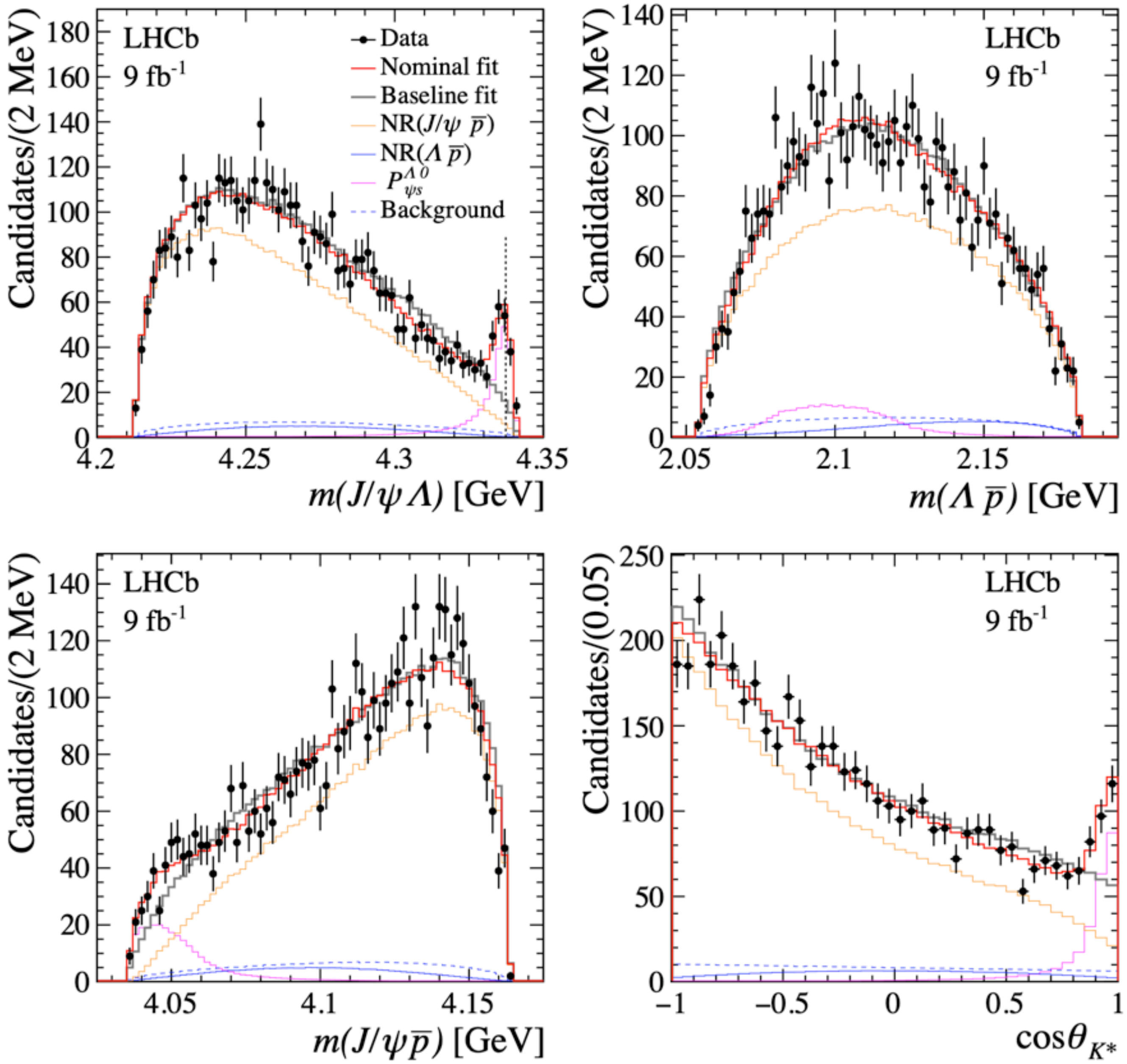
$\Gamma = 7.0 \pm 1.2$ MeV

Spin-parity:

$J^P = 1/2^-$ is preferred

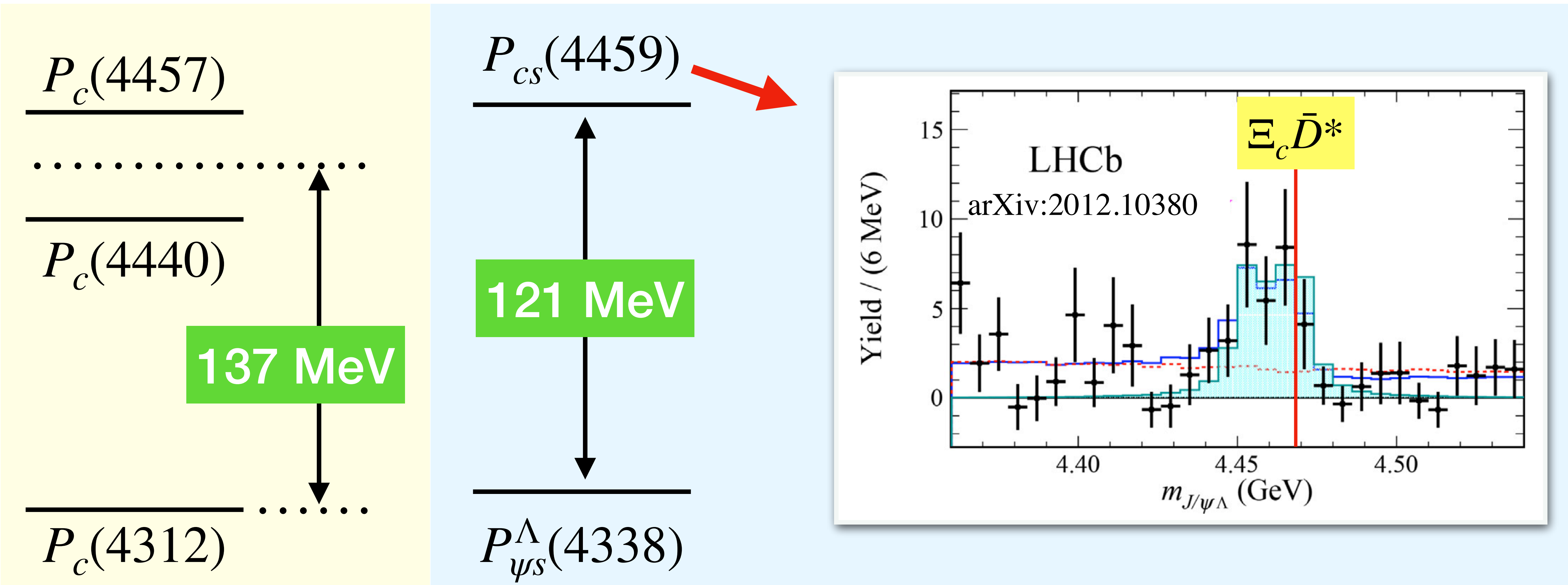
Significance:

$> 10\sigma$



LHCb: arXiv:2210.10346

Similarity between P_{ψ}^{N} and $P_{\psi s}^{\Lambda}$



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

F.L. Wang, Xiang Liu, Phys.Lett.B 835(2022)137583

Bound state properties for the S-wave isoscalar $\Xi_c\bar{D}^{(*)}$ systems by considering the S-D wave mixing effect. Here, the cutoff Λ, binding energy E, and root-mean-square radius $r_{\rm RMS}$ are in units of GeV, MeV, and fm, respectively.

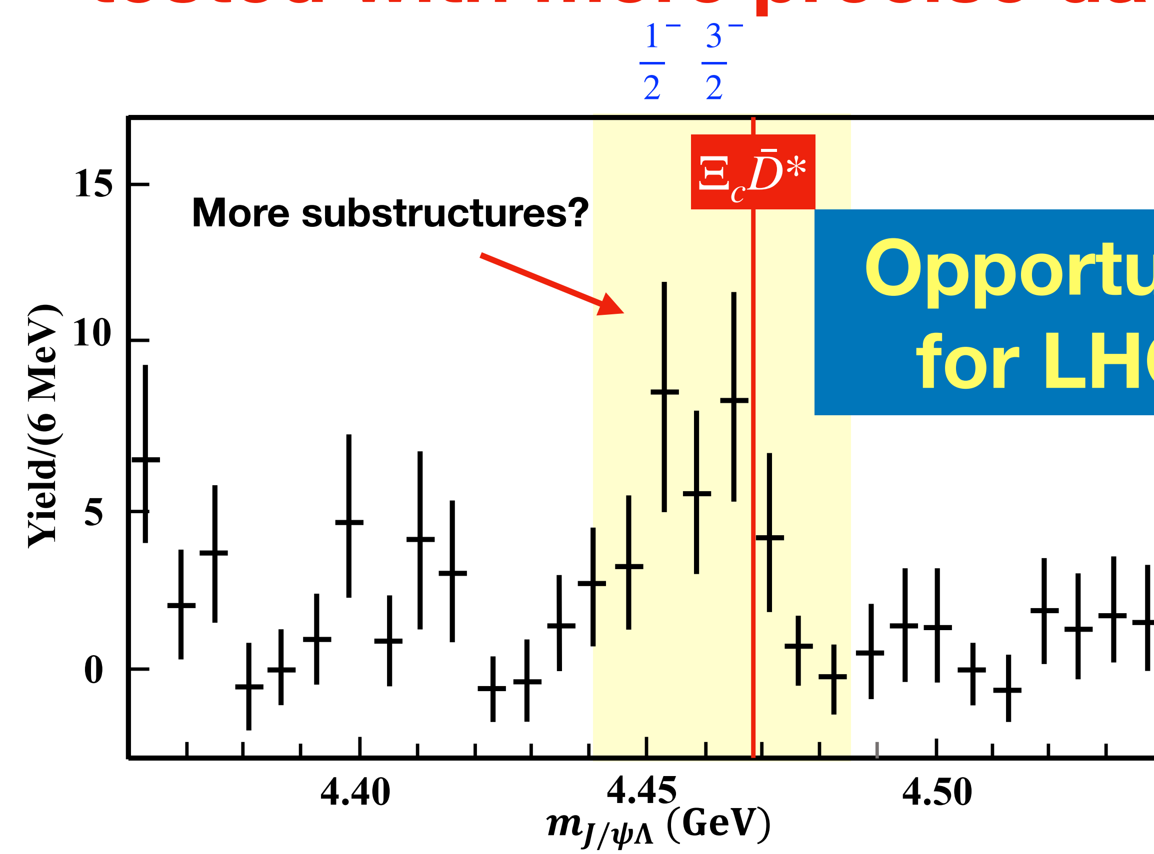
$\Xi_c\bar{D}(J^P=1/2^-)$			
Λ	E	$r_{\rm RMS}$	
1.41	−0.35	4.73	
1.61	−4.82	1.64	
1.79	−12.49	1.10	
$\Xi_c\bar{D}^*(J^P=1/2^-)$			
Λ	E	$r_{\rm RMS}$	$P(^2\mathbb{S}_{\frac{1}{2}}/^4\mathbb{D}_{\frac{1}{2}})$
1.39	−0.34	4.70	**100.00**/o(0)
1.57	−4.71	1.63	**100.00**/o(0)
1.74	−12.21	1.10	**100.00**/o(0)
$\Xi_c\bar{D}^*(J^P=3/2^-)$			
Λ	E	$r_{\rm RMS}$	$P(^4\mathbb{S}_{\frac{3}{2}}/^2\mathbb{D}_{\frac{3}{2}}/^4\mathbb{D}_{\frac{3}{2}})$
1.39	−0.34	4.70	**100.00**/o(0)/o(0)
1.57	−4.71	1.63	**100.00**/o(0)/o(0)
1.74	−12.21	1.10	**100.00**/o(0)/o(0)

Bound state properties for the S-wave isoscalar $\Xi_c\bar{D}^*$ system by performing the coupled channel analysis. Here, the cutoff Λ, binding energy E, and root-mean-square radius $r_{\rm RMS}$ are in units of GeV, MeV, and fm, respectively. Additionally, Λ and Λ' denote the cutoff parameters of the $\Xi_c\bar{D}^*$ and $\Xi_c'\bar{D}^*$ channels, respectively.

Λ	Λ'	E	$r_{\rm RMS}$	$P(\Xi_c\bar{D}^*/\Xi_c'\bar{D}^*)$
$\Xi_c\bar{D}^*(J^P=1/2^-)$				
1.12	0.92	−0.30	4.74	**97.75**/2.25
1.16	0.96	−4.33	1.58	**89.46**/10.54
1.20	1.00	−14.67	0.89	**77.76**/22.24
$\Xi_c\bar{D}^*(J^P=3/2^-)$				
1.31	1.11	−0.29	4.87	**99.73**/0.27
1.43	1.23	−4.52	1.64	**98.54**/1.46
1.56	1.36	−15.01	0.98	**96.48**/3.52

There exists mass degeneration for the S-wave isoscalar $\Xi_c\bar{D}^*$ states with $J^P=1/2^-$ and $J^P=1/2^-$ when adopting same cutoff value.
Coupled-channel may result in the violation of mass degeneration.

Double-peak structure can be tested with more precise data



Opportunity for LHCb

F.L. Wang, Xiang Liu, Phys.Lett.B 835(2022)137583

Similar behavior happen for the $\Xi_c'\bar{D}$ systems

$\Xi_c'\bar{D}$: $J^P = 1/2^-$

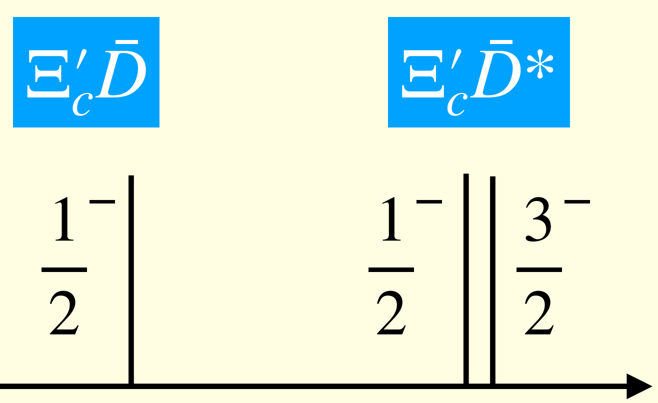
Λ	E	r_{RMS}
1.45	-0.29	4.92
1.65	-4.62	1.65
1.84	-12.14	1.10

$\Xi_c'\bar{D}^*$: $J^P = 1/2^-$

Λ	E	r_{RMS}	$P\left({}^2S_{\frac{1}{2}}/{}^4D_{\frac{1}{2}}\right)$
0.92	-0.50	4.02	99.63/0.37
0.97	-4.18	1.64	99.45/0.55
1.02	-11.90	1.06	99.45/0.55

$\Xi_c'\bar{D}^*$: $J^P = 3/2^-$

Λ	E	r_{RMS}	$P\left({}^4S_{\frac{3}{2}}/{}^2D_{\frac{3}{2}}/{}^4D_{\frac{3}{2}}\right)$
1.63	-0.33	4.87	98.49/0.17/1.18
2.09	-4.79	1.75	96.63/0.32/3.05
2.55	-12.42	1.21	95.65/0.35/4.00



Characterististic spectrum

F.L. Wang, Xiang Liu, Phys.Lett.B 835(2022)137583

2. Abundant phenomena around tetraqurk candidates

Tetraquark candidates

$J/\psi\pi^+$	$J/\psi K^+$	$J/\psi\phi$	$J/\psi J/\psi$
T_ψ^b (Z_c)	$T_{\psi s}^\theta$ (Z_{cs})	$T_{\psi\phi}$ (X)	$T_{\psi\psi}$ ($T_{cc\bar{c}\bar{c}}$)
3900, 4430,...	4000, 4220,...	4140, 4274, 4500...	6900,...

$D^0D^0\pi^+$	D^+K^-	$D_s^\pm\pi^+$
T_{cc}	T_{cs}	$T_{c\bar{s}}$
3874	2900	2900

LHCb proposal for the new name convention of exotic hadrons [arXiv:2206.15233]

$T_{cc}(3874)$

Nature Commun. 13 (2022) 1, 3351
Nature Phys. 18 (2022) 7, 751-754

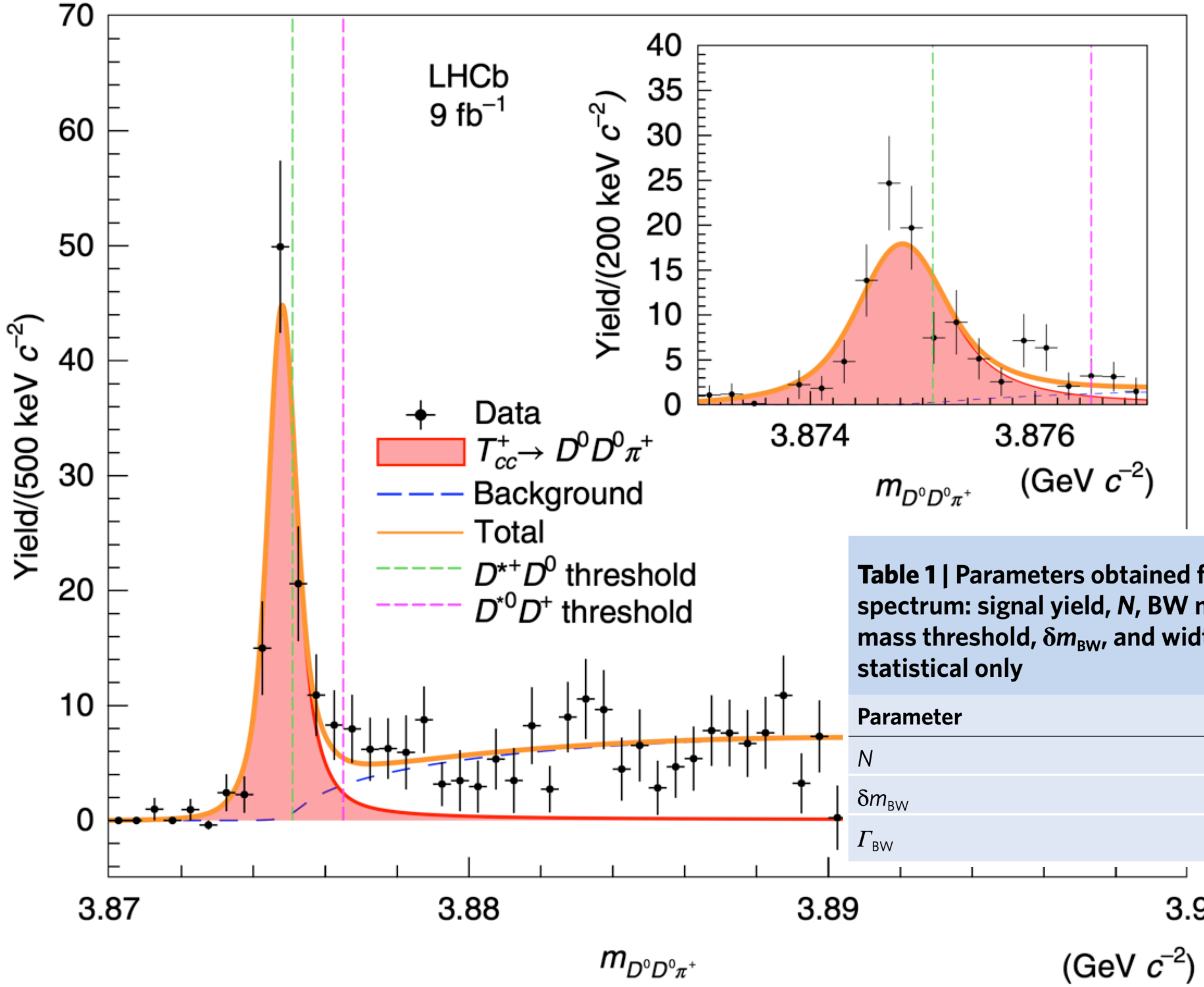


Table 1 | Parameters obtained from the fit to the $D^0D^0\pi^+$ mass spectrum: signal yield, N, BW mass relative to the $D^{*+}D^0$ mass threshold, δm_{BW}, and width, Γ_{BW}. The uncertainties are statistical only

Parameter	Value
N	117 ± 16
δm_{BW}	-273 ± 61 keV c^{-2}
Γ_{BW}	410 ± 165 keV

PHYSICAL REVIEW D **88,** 114008 (2013)

Coupled-channel analysis of the possible $D^{(*)}D^{(*)}$, $\bar{B}^{(*)}\bar{B}^{(*)}$ and $D^{(*)}\bar{B}^{(*)}$ molecular states

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[1]*Department of Physics and State Key Laboratory of Nuclear Physics and Technology, Peking University, Beijing 100871, China*
[2]*Institut für Kernphysik and Jülich Center for Hadron Physics, Forschungszentrum Jülich, D-52425 Jülich, Germany*
[3]*School of Physical Science and Technology, Lanzhou University, Lanzhou 730000, China*
[4]*Research Center for Hadron and CSR Physics, Lanzhou University and Institute of Modern Physics of CAS, Lanzhou 730000, China*
[5]*Center of High Energy Physics, Peking University, Beijing 100871, China*
[6]*Collaborative Innovation Center of Quantum Matter, Beijing 100871, China*

(Received 22 November 2012; revised manuscript received 17 September 2013; published 3 December 2013)

We perform a coupled-channel study of the possible deuteron-like molecules with two heavy flavor quarks, including the systems of $D^{(*)}D^{(*)}$ with double charm, $\bar{B}^{(*)}\bar{B}^{(*)}$ with double bottom, and $D^{(*)}\bar{B}^{(*)}$ with both charm and bottom, within the one-boson-exchange potential model. In our study, we take into account the *S*-*D* mixing which plays an important role in the formation of the loosely bound deuteron, and particularly, the coupled-channel effect in the flavor space. According to our results, the state $D^{(*)}D^{(*)}[I(J^P) = 0(1^+)]$ with double charm, the states $\bar{B}^{(*)}\bar{B}^{(*)}[I(J^P) = 0(1^+), 1(1^+)]$, $(\bar{B}^{(*)}\bar{B}^{(*)})_s[J^P = 1^+, 2^+]$ and $(\bar{B}^{(*)}\bar{B}^{(*)})_{ss}[J^P = 1^+, 2^+]$ with double bottom, and the states $D^{(*)}\bar{B}^{(*)}[I(J^P) = 0(1^+), 0(2^+)]$ with both charm and bottom might be good molecule candidates. However, the states $D^{(*)}D^{(*)}[I(J^P) = 0(2^+), 1(0^+), 1(1^+), 1(2^+)]$, $(D^{(*)}D^{(*)})_s[J^P = 0^+, 2^+]$ and $(D^{(*)}D^{(*)})_{ss}[J^P = 0^+, 1^+, 2^+]$ with double charm and the state $D^{(*)}\bar{B}^{(*)}[I(J^P) = 1(1^+)]$ with both charm and bottom are not supported to be

Binding energy

LHCb result of T_{cc}

-273 keV

Our prediction

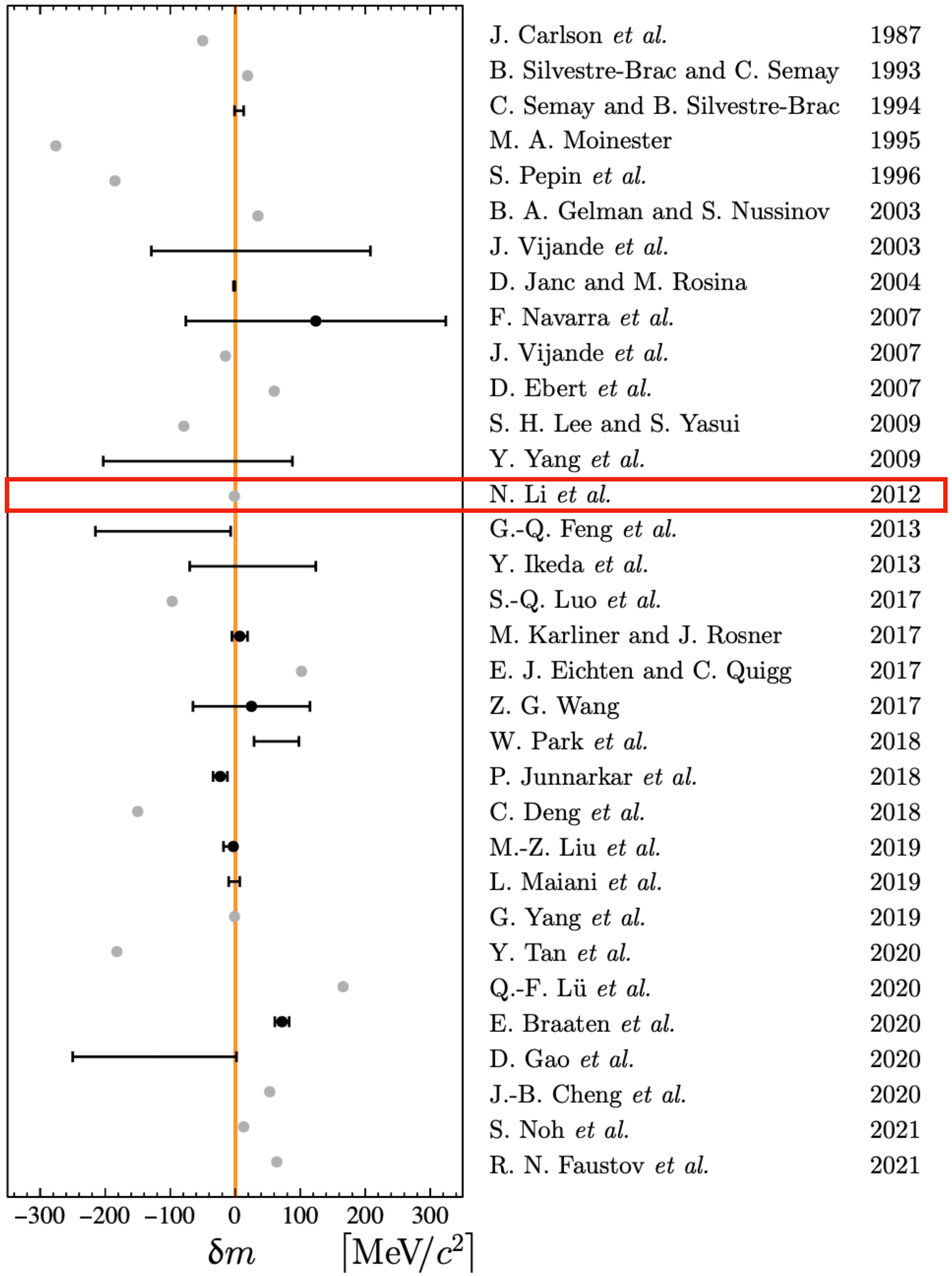
-470 keV

			$D^{(*)}D^{(*)}$							
I	J^P		OPE				OBE			
	0^+		* * *				* * *			
		Λ (GeV)	1.05	1.10	1.15	1.20	0.95	1.00	1.05	1.10
		B.E. (MeV)	1.24	4.63	11.02	20.98	0.47	5.44	18.72	42.82
		M (MeV)	3874.61	3871.22	3864.83	3854.87	3875.38	3870.41	3857.13	3833.03
		r_{rms} (fm)	3.11	1.68	1.12	0.84	4.46	1.58	0.91	0.64
0	1^+	P_1 (%)	96.39	92.71	88.22	83.34	97.97	92.94	85.64	77.88
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		P_4 (%)	0.08	0.13	0.14	0.13	0.04	0.09	0.08	0.05

Perfect $D\bar{D}^*$ molecular prediction matching the T_{cc} observation at LHCb

9年前给出精准预测

$\delta m_{\mathrm{BW}} = -273 \pm 61 \pm 5\ ^{+11}_{-14}\ \mathrm{keV}/c^2$



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EDITORS' SUGGESTION

Perfect *DD Molecular Prediction Matching the T_{cc} Observation at LHCb**

Ning Li, Zhi-Feng Sun, Xiang Liu, and Shi-Lin Zhu

Chin. Phys. Lett. 2021, 38 (9): 092001

亮点介绍

最近，欧洲核子中心的LHCb实验通过研究质子与质子对撞产生的$D^0D^0\pi^+$的不变质量谱，发现了名为T_{cc}^+的窄共振态结构，其共振态参数和衰变行为与2012年李宁、孙志峰、刘翔和朱世琳发表在Phys. Rev. D 88 (2013) 114008的关于双粲分子态类型的四夸克态的理论预言非常吻合。作者回顾并评述了给出这一理论预言的历程，指出了T_{cc}^+发现的重要物理意义，并对未来围绕T_{cc}^+展开的研究工作进行了展望。

原文链接 HTML PDF

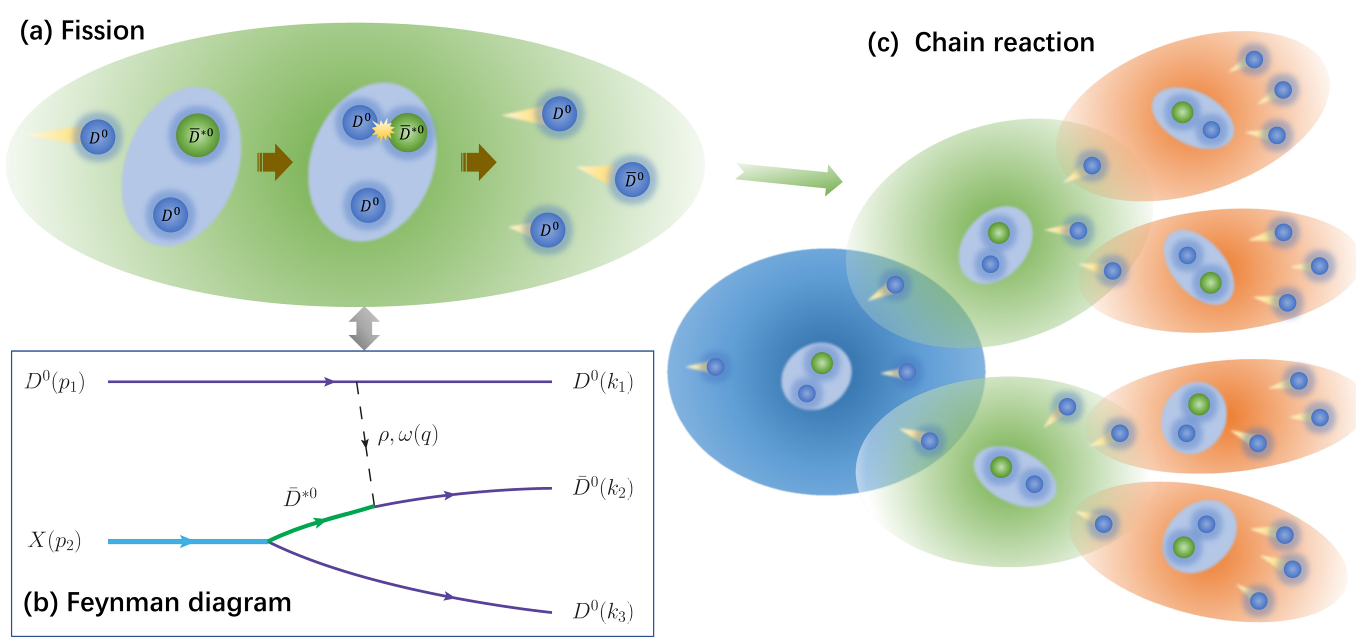
Chinese Physics Letters **39**, 091401 (2022)

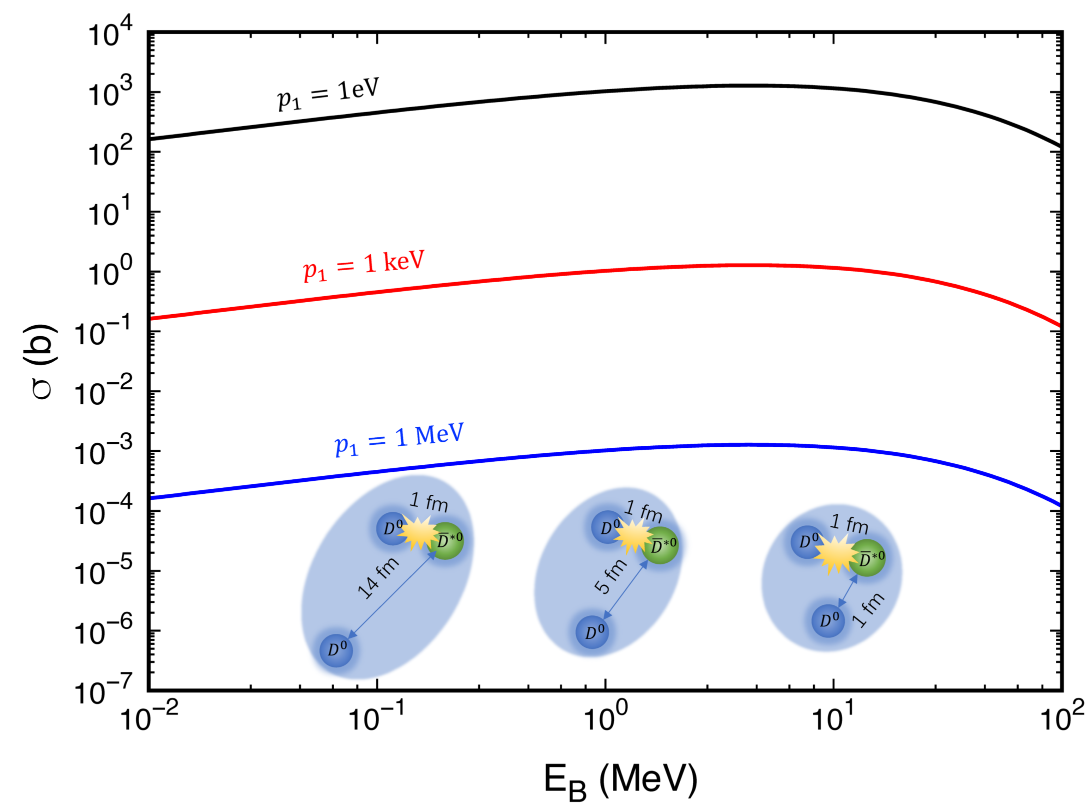
Induced Fission-Like Process of Hadronic Molecular States

Jun He(何军)[1,2], Dian-Yong Chen(陈殿勇)[2,3], Zhan-Wei Liu(刘占伟)[2,4], and Xiang Liu(刘翔)[2,4*]

We predict a new physical phenomenon, induced fission-like process and chain reaction of hadronic molecular states. As a molecular state, if induced by a D meson, the $X(3872)$ can split into $D\bar{D}$ final state which is forbidden due to the spin-parity conservation. The breeding of the D meson of the reaction, such as $D^0X(3872) \to D^0\bar{D}^0D^0$, makes the chain reaction of $X(3872)$ matter possible. We estimate the cross section of the D meson induced fission-like process of $X(3872)$ into two D mesons. With very small D^0 beam momentum of 1 eV, the total cross section reaches an order of 1000 b, and decreases rapidly with the increasing beam momentum. With the transition of D^* meson in molecular states to a D meson, the $X(3872)$ can release large energy, which is acquired by the final mesons. The momentum distributions of the final D mesons are analyzed. In the laboratory frame, the spectator D meson in molecular state concentrates in the low momentum area. The energy from the transition from D^* to D meson is mainly acquired by two scattered D mesons. The results suggest that the D meson environment will lead to the induced fission-like process and chain reaction of the $X(3827)$. Such a phenomenon can be extended to other hadronic molecular states.

$$K + f_1(1285) \to K\bar{K}^*K \to 2K + \bar{K},$$
$$D + T_{cc}(3875) \to DD^*D \to 3D,$$
$$B + Z_b(10610) \to B\bar{B}^*B \to 2B + \bar{B}.$$

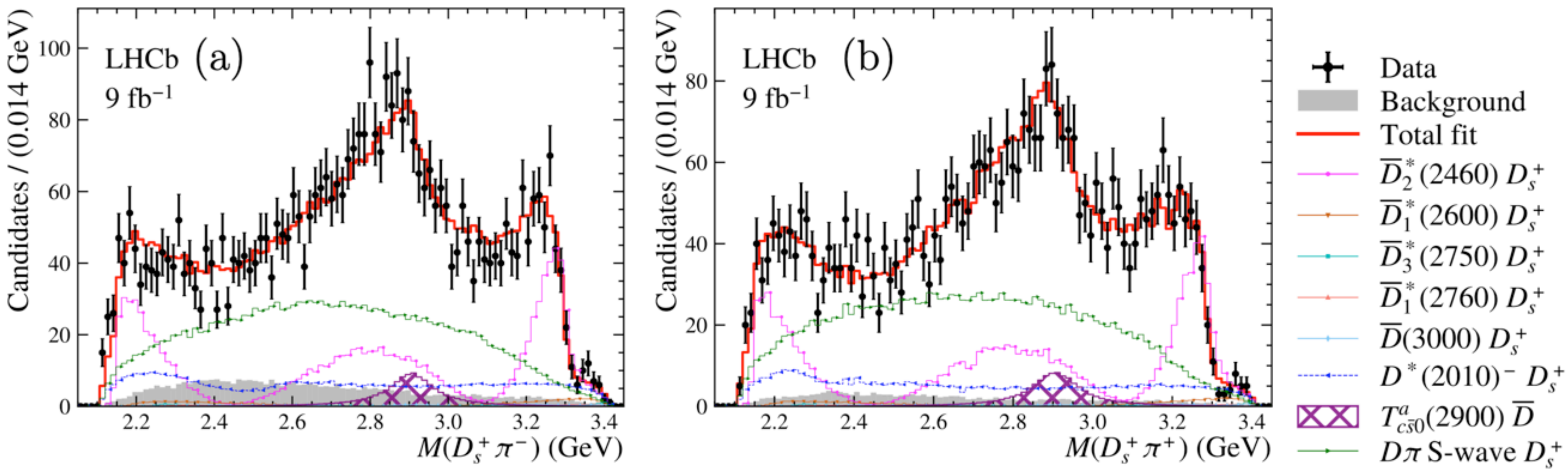


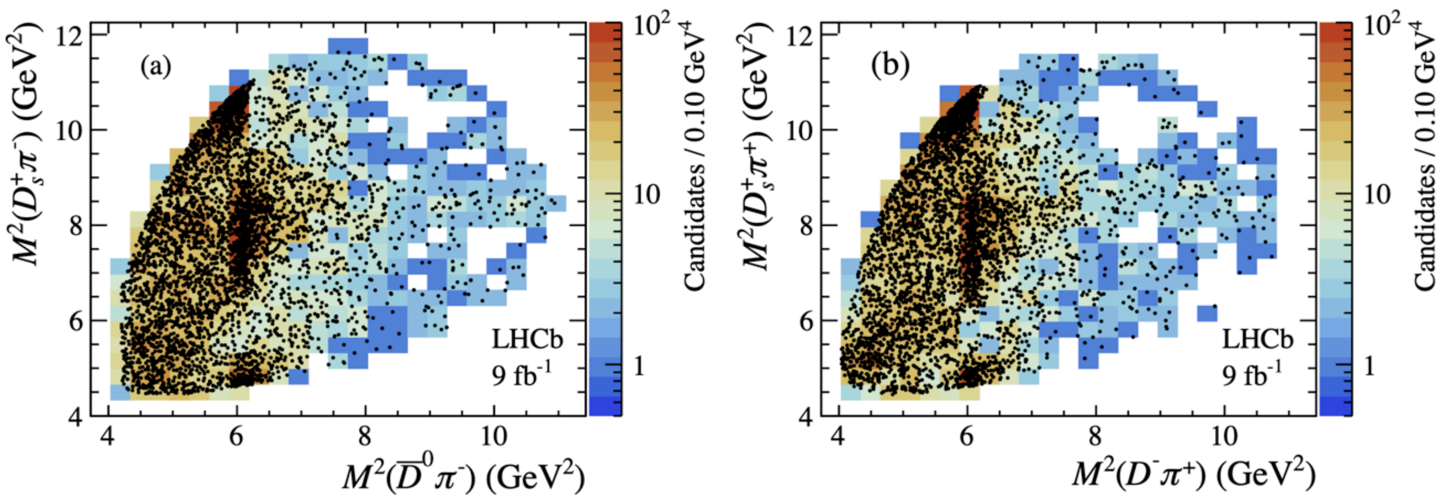


$$\bar{D}^0 + X(3872) \to \bar{D}^0\bar{D}^{*0}D^0 \to D^0 + 2\bar{D}^0$$

$T^a_{c\bar{s}0}(2900)$

$$B^0 \to \bar{D}^0 D_s^+ \pi^- \quad B^+ \to D^- D_s^+ \pi^+$$





$$T^a_{c\bar{s}0}(2900)^0 : M = 2.892 \pm 0.014 \pm 0.015\,\text{GeV},$$
$$\Gamma = 0.119 \pm 0.026 \pm 0.013\,\text{GeV},$$
$$T^a_{c\bar{s}0}(2900)^{++} : M = 2.921 \pm 0.017 \pm 0.020\,\text{GeV},$$
$$\Gamma = 0.137 \pm 0.032 \pm 0.017\,\text{GeV},$$

LHCb: arXiv:2212.02716; arXiv:2212.02717

PHYSICAL REVIEW D **106**, L111501 (2022)

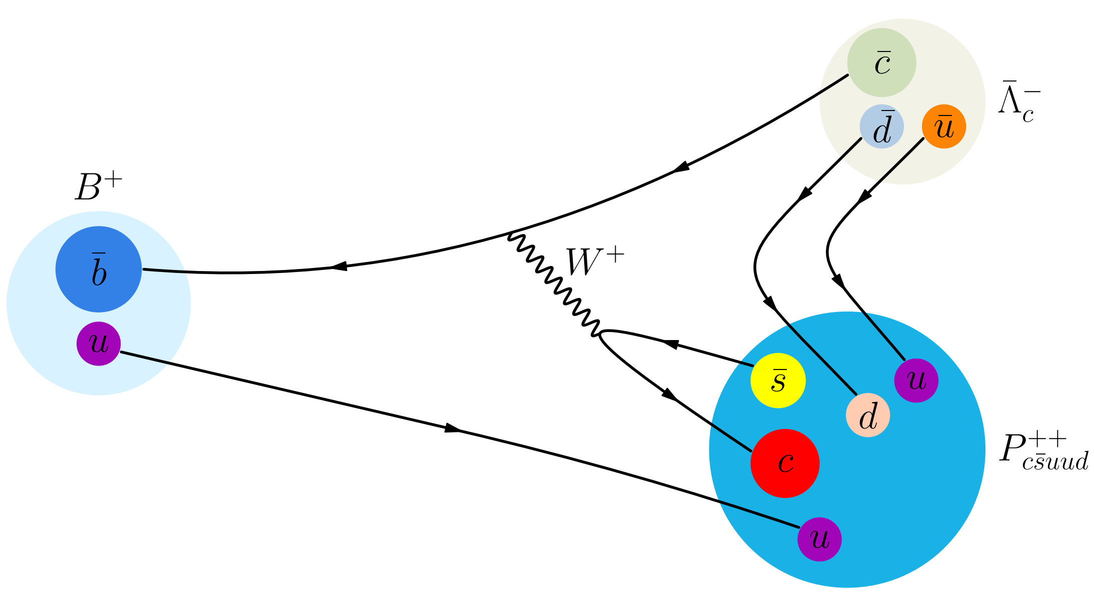
Letter

Discovery of $T^{a}_{c\bar{s}0}(2900)^{0,++}$ implies new charmed-strange pentaquark system

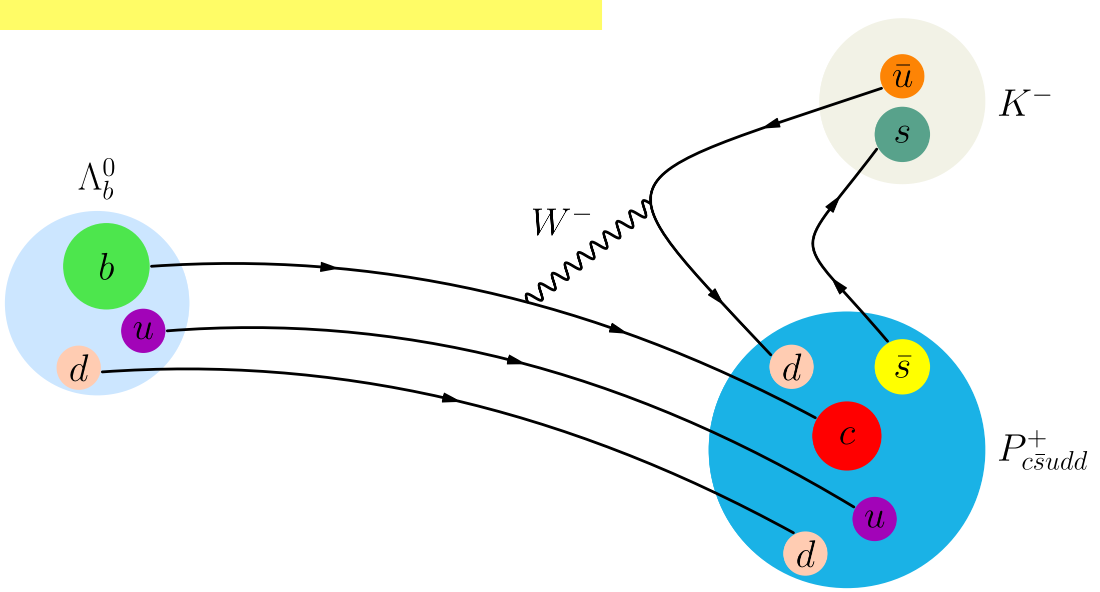
Hong-Tao An,[1,2,*] Zhan-Wei Liu,[1,2,3,†] Fu-Sheng Yu,[3,4,5,‡] and Xiang Liu[1,2,3,§]

Inspired by the very recently discovered tetraquark states $T^{a}_{c\bar{s}0}(2900)^{0,++}$ from the LHCb Collaboration, we predict the existence of a new charmed-strange pentaquark system, $c\bar{s}nnn$, which is closely connected to $c\bar{s}n\bar{n}$ by exchanging $\bar{n}$ into nn with $n = u, d$. Especially, it is suggested to experimentally search for the predicted new pentaquark system via the weak decays of B mesons or b baryons, with the support from the study of the mass spectrum and the decay properties. The predicted new pentaquark system must attract extensive attention from experimentalists and theorists when it constructs the "particle zoo 2.0" in the near future.

让我们拭目以待！

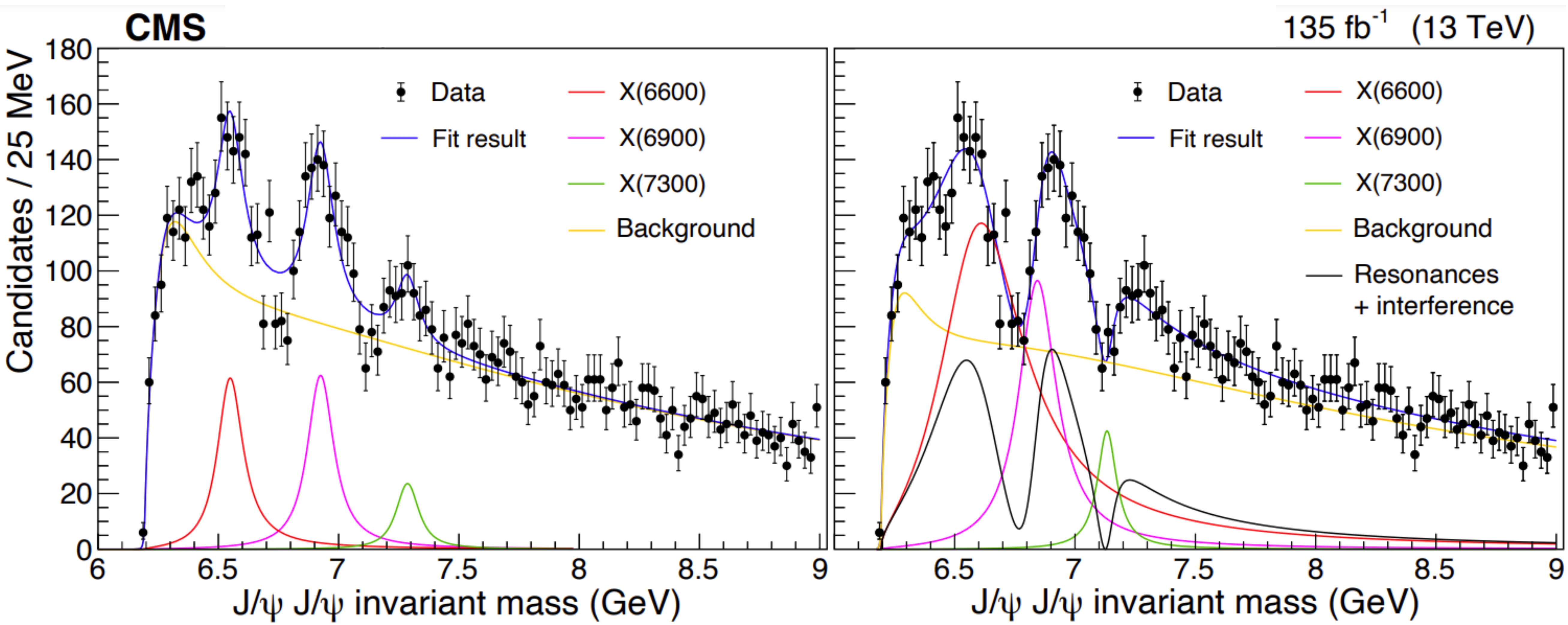


$B^+ \to P^{++}_{c\bar{s}uud}\,\bar{\Lambda}_c^-$



$\Lambda_b^0 \to P^{+}_{c\bar{s}udd}\,K^-$

More peaks in di-J/ψ invariant mass spectrum



CMS Collaboration: arXiv:2306.07164

ATLAS is joining this party

arXiv: 2304.08962

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	$0.11 \pm 0.05^{+0.02}_{-0.01}$	$0.15 \pm 0.03 \pm 0.01$
$\Delta s/s$	$\pm 5.1\%^{+8.1\%}_{-8.9\%}$	—
J/ψ+$\psi(2S)$	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	$0.09 \pm 0.06^{+0.06}_{-0.03}$	$0.51 \pm 0.17^{+0.11}_{-0.10}$
$\Delta s/s$	$\pm 21\% \pm 14\%$	$\pm 20\% \pm 12\%$

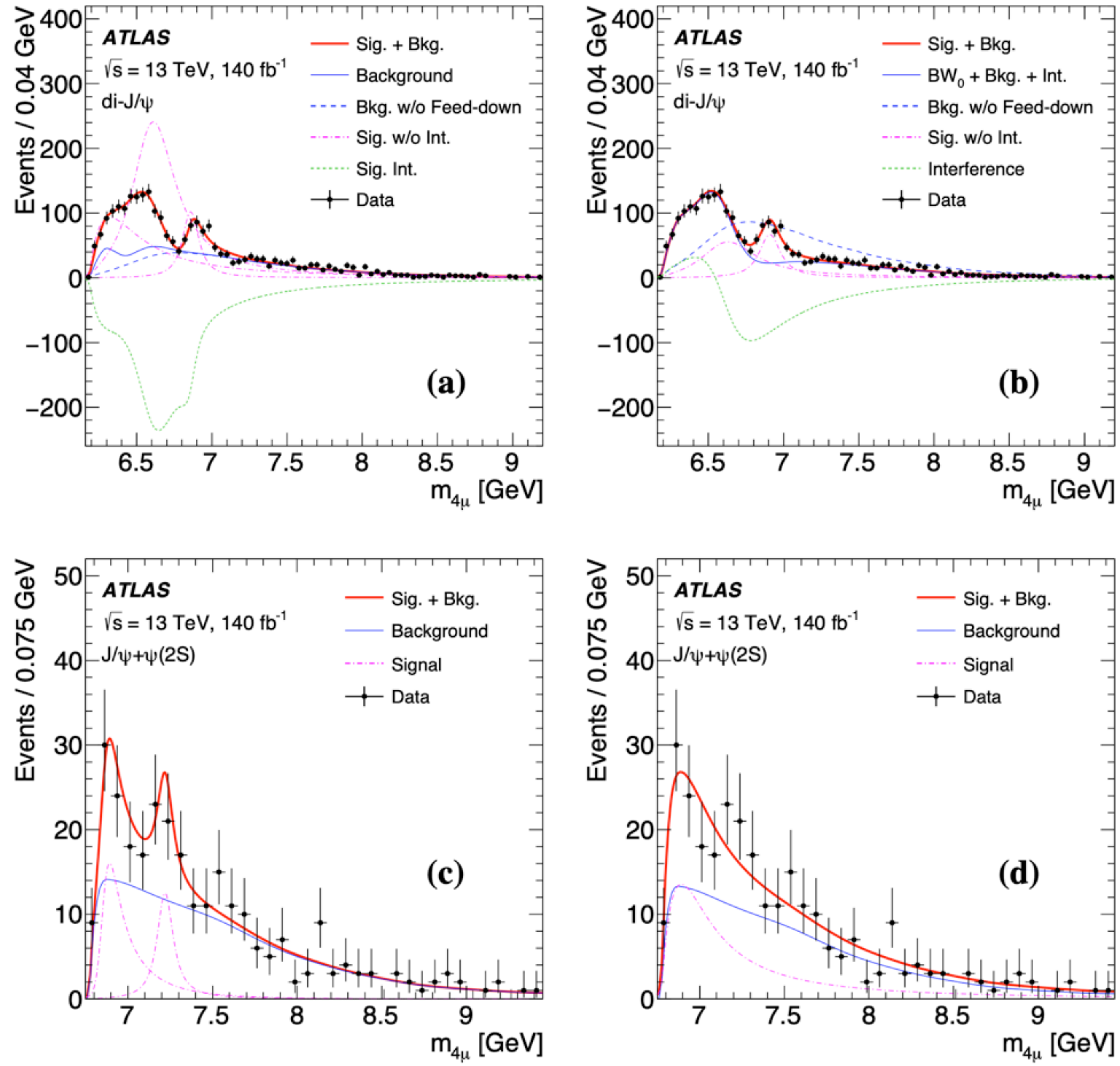
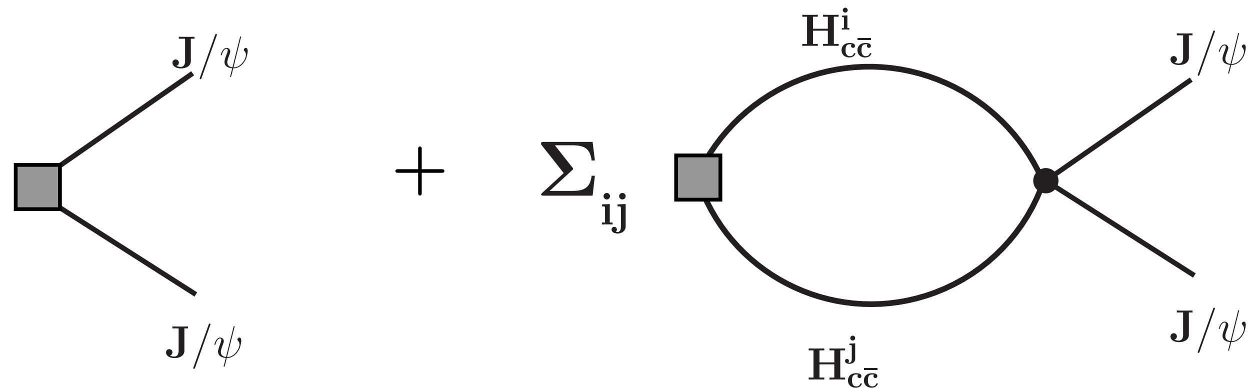


Figure 1: The fit to the mass spectra in the signal regions in the di-J/ψ (a,b) and J/ψ+$\psi(2S)$ (c,d) channels. Fit results for models A (a), B (b), α (c) and β (d) are shown. The purple dash-dotted lines represent the components of individual resonances, and the green short dashed ones represent the interferences among them.

Dynamical rescattering mechanism to product the fully charm peak structures



$$\mathscr{A}^2 = |\, \mathscr{A}_{direct}(m_{J/\psi J/\psi}) + \sum_{mn} e^{i\phi^{mn}} \mathscr{A}_{mn}(m_{J/\psi J/\psi})\, |^2 + |\, \mathscr{A}'_{direct}(m_{J/\psi J/\psi}) + \sum_{mn} e^{i\phi^{mn}} \mathscr{A}'_{mn}(m_{J/\psi J/\psi})\, |^2$$

$$\mathscr{A}^2_{direct} = g^2_{direct}\, e^{c_0 m_{ij}} \frac{1}{8\pi} \frac{\sqrt{\lambda(m_{ij}^2, m_i^2, m_j^2)}}{m_{ij}^2},$$

$$\mathscr{A}^2_{ij}(m_{J/\psi J/\psi}) = g^2_{ij} L^2_{ij}(m_{J/\psi J/\psi}) \frac{e^{c_0 m_{J/\psi J/\psi}} p_{J/\psi}}{m_{J/\psi J/\psi}},$$

$$L_{ij}(m_{J/\psi J/\psi}) = \int \frac{dq^4}{(2\pi)^4} \frac{e^{-(2\vec{q}\ )^2/\alpha^2}}{(q^2 - m_i^2 + i\epsilon)((P-q)^2 - m_j^2 + i\epsilon)}$$

$$= \frac{i}{4 m_i m_j} \left\{ \frac{-\mu\alpha}{\sqrt{2}(2\pi)^{3/2}} + \frac{\mu\sqrt{2\mu m_0}\left(\mathbf{erfi}\left[\frac{\sqrt{8\mu m_0}}{\alpha}\right] - i\right)}{2\pi / e^{-\frac{8\mu m_0}{\alpha^2}}} \right\}$$

J.Z. Wang, D.Y. Chen, Xiang Liu and T. Matsuki, PRD 103 (2021) L071503
J.Z. Wang, Xiang Liu, PRD 106 (2022) 054015

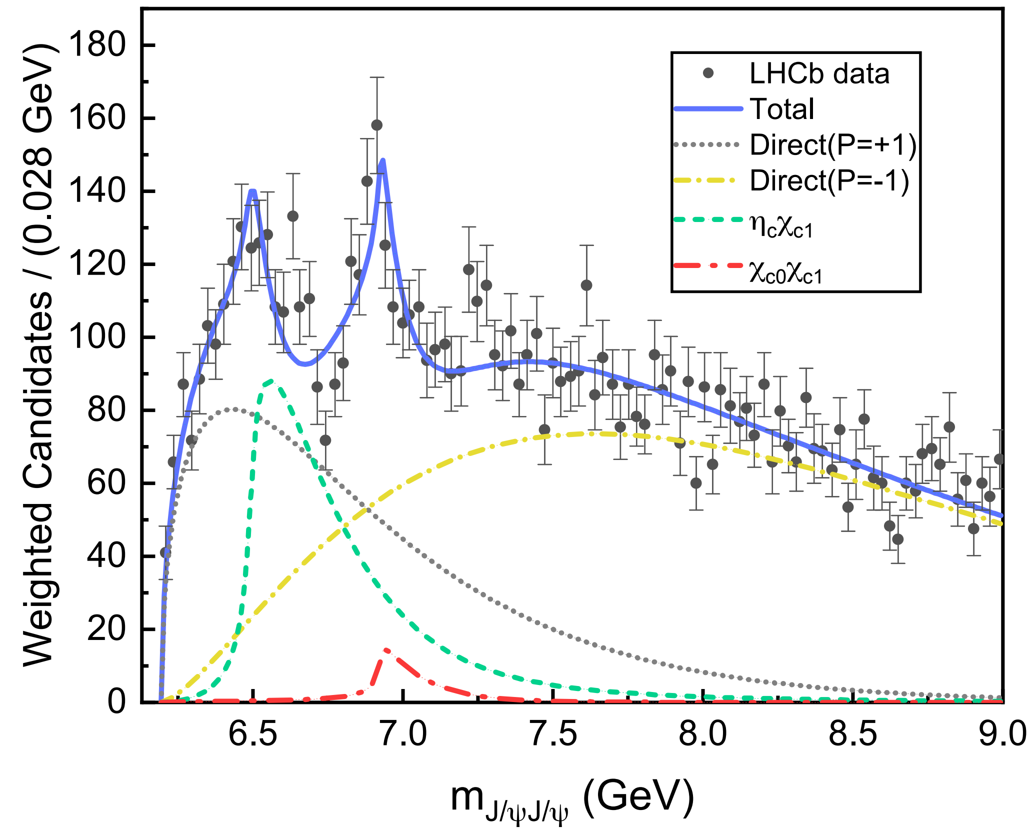
TABLE I. The parameters for reproducing the line shape of LHCb data with $\chi_{c1}\eta_c$ and $\chi_{c0}\chi_{c1}$ rescattering contributions. In this scenario, we set the parameter $\alpha_{\chi_{c1}\eta_c} = \alpha_{\chi_{c0}\chi_{c1}} = \alpha$.

Parameter	Value	Parameter	Value
c_0	-1.99 ± 0.01	c'_0	-1.02 ± 0.04
$\lvert g'_{\text{direct}}/g_{\text{direct}}\rvert$	0.0232 ± 0.0037	$\lvert g_{\eta_c\chi_{c1}}/g'_{\text{direct}}\rvert$	198 ± 46
$\lvert g_{\chi_{c0}\chi_{c1}}/g_{\text{direct}}\rvert$	55.9 ± 8.2	$\phi_{\eta_c\chi_{c1}}$	3.22 ± 0.07
$\phi_{\chi_{c0}\chi_{c1}}$	1.87 ± 0.16	α	1.40 ± 0.10

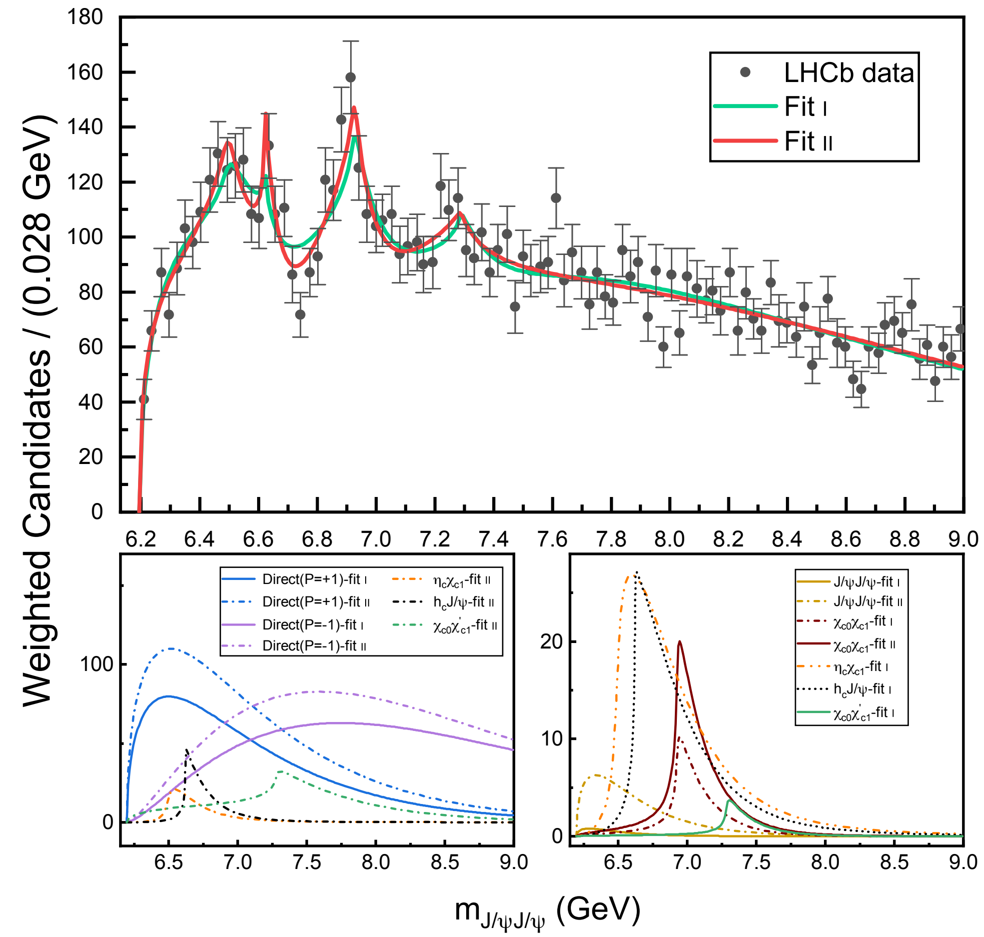
TABLE II. The parameters for reproducing the line shape of LHCb data in two fitting schemes of Fit I and Fit II.

Parameters	Fit I	Fit II
c_0 (GeV^{-1})	-1.52 ± 0.02	-1.45 ± 0.01
c'_0 (GeV^{-1})	-0.946 ± 0.058	-1.05 ± 0.01
$\lvert g'_{\text{direct}}/g_{\text{direct}}\rvert$	0.0767 ± 0.0204	0.137 ± 0.042
$\lvert g_{J/\psi J/\psi}/g_{\text{direct}}\rvert$	8.53 ± 3.64	14.0 ± 1.4
$\lvert g_{\eta_c\chi_{c1}}/g'_{\text{direct}}\rvert$	91.6 ± 75.4	112 ± 28
$\lvert g_{J/\psi h_c}/g'_{\text{direct}}\rvert$	69.7 ± 16.1	109 ± 8
$\lvert g_{\chi_{c0}\chi_{c1}}/g_{\text{direct}}\rvert$	33.3 ± 8.2	38.5 ± 7.6
$\lvert g_{\chi_{c0}\chi'_{c1}}/g_{\text{direct}}\rvert$	25.8 ± 10.6	19.0 ± 4.3
$\phi_{J/\psi J/\psi}$ (rad)	1.53 ± 0.51	3.16 ± 0.19
$\phi_{\eta_c\chi_{c1}}$ (rad)	2.69 ± 0.20	2.80 ± 0.15
$\phi_{J/\psi h_c}$ (rad)	4.40 ± 0.33	2.95 ± 0.24
$\phi_{\chi_{c0}\chi_{c1}}$ (rad)	2.14 ± 0.18	2.89 ± 0.20
$\phi_{\chi_{c0}\chi'_{c1}}$ (rad)	2.00 ± 0.33	3.23 ± 0.20
$\alpha_{J/\psi J/\psi}$ (GeV)	1.71 ± 0.01	2.30 ± 0.21
$\alpha_{\eta_c\chi_{c1}}$ (GeV)	1.71 ± 0.01	1.20 ± 0.21
$\alpha_{J/\psi h_c}$ (GeV)	1.71 ± 0.01	1.20 ± 0.03
$\alpha_{\chi_{c0}\chi_{c1}}$ (GeV)	1.71 ± 0.01	1.73 ± 0.26
$\alpha_{\chi_{c0}\chi'_{c1}}$ (GeV)	1.71 ± 0.01	5.20 ± 0.05
χ^2/d.o.f.	1.41	1.25

J.Z. Wang, D.Y. Chen, Xiang Liu and T. Matsuki, PRD 103 (2021) L071503



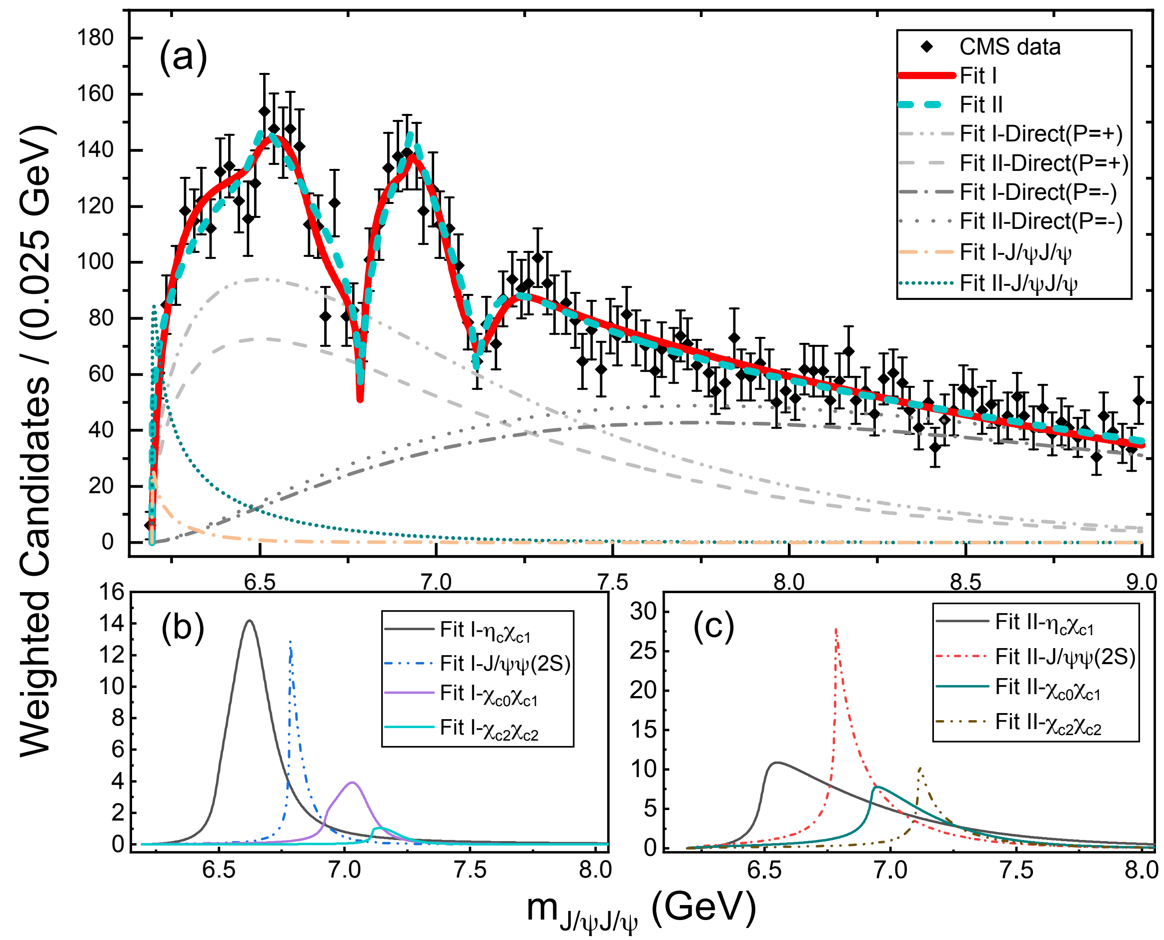
Reproduce the LHCb data well

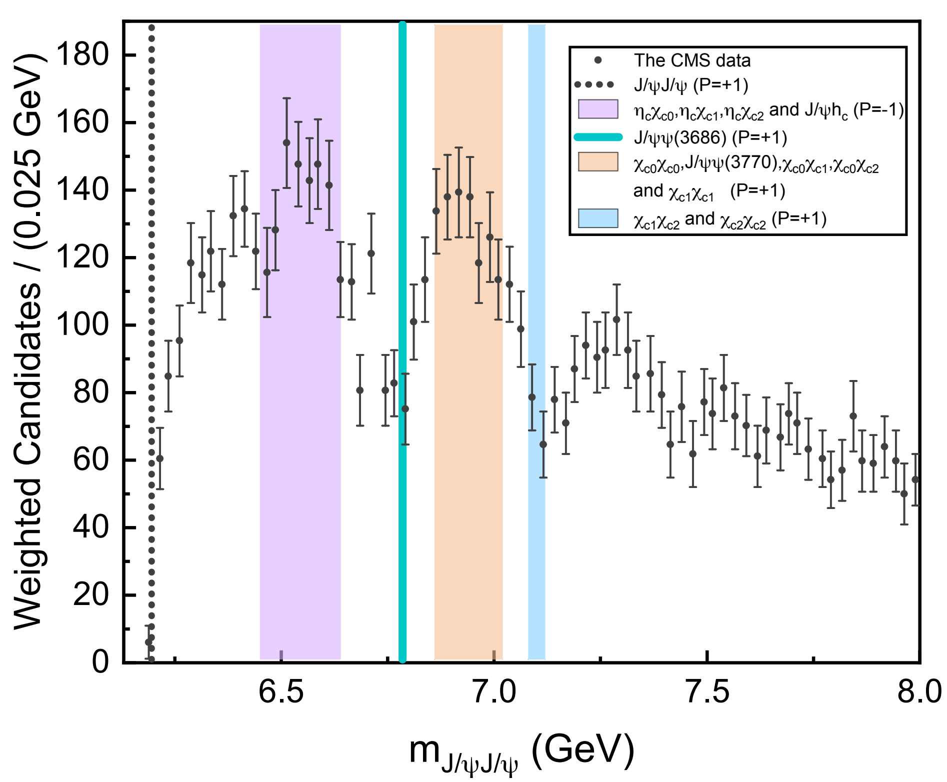


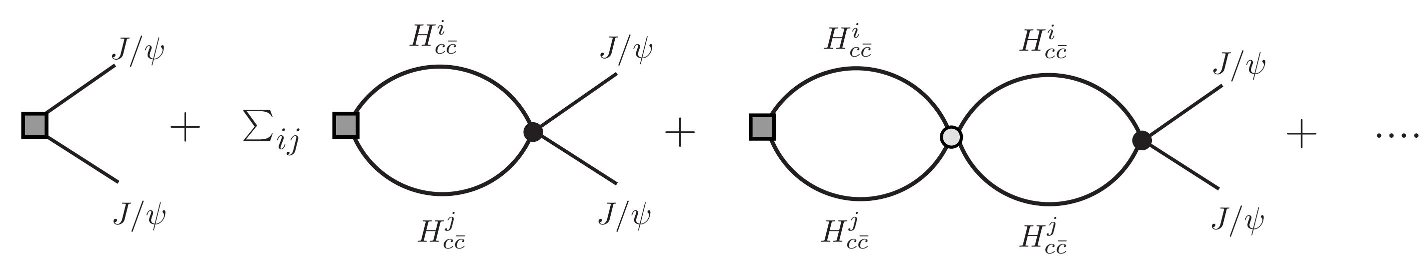
Reproduce the CMS data well!

TABLE I. The fitted parameters for reproducing the line shape of the CMS data within the fit-I and fit-II schemes.

Parameters	Fit I	Fit II
$\lvert g'_{\rm direct}/g_{\rm direct}\rvert$	0.0575 ± 0.0009	0.0699 ± 0.0010
$g_{\eta_c\chi_{c1}}/g'_{\rm direct}$	125 ± 26	28.2 ± 2.7
$g_{J/\psi\psi(3686)}/g_{\rm direct}$	-26.1 ± 4.7	-16.4 ± 1.7
$g_{\chi_{c0}\chi_{c1}}/g_{\rm direct}$	32.9 ± 5.8	16.2 ± 1.4
$g_{\chi_{c2}\chi_{c2}}/g_{\rm direct}$	-15.3 ± 6.1	-12.3 ± 1.4
$\mathcal{C}_{J/\psi J/\psi}$	-144 ± 14	-82.3 ± 1.8
$\mathcal{C}_{\eta_c\chi_{c1}}$	342 ± 107	-21.3 ± 18.7
$\mathcal{C}_{J/\psi\psi(3686)}$	-20 ± 40	-32.0 ± 5.5
$\mathcal{C}_{\chi_{c0}\chi_{c1}}$	380 ± 54	20.0 ± 50.6
$\mathcal{C}_{\chi_{c2}\chi_{c2}}$	145 ± 175	-41.4 ± 13.3
α (GeV)	0.871 ± 0.046	1.813 ± 0.030
χ^2/d.o.f.	0.657	0.699

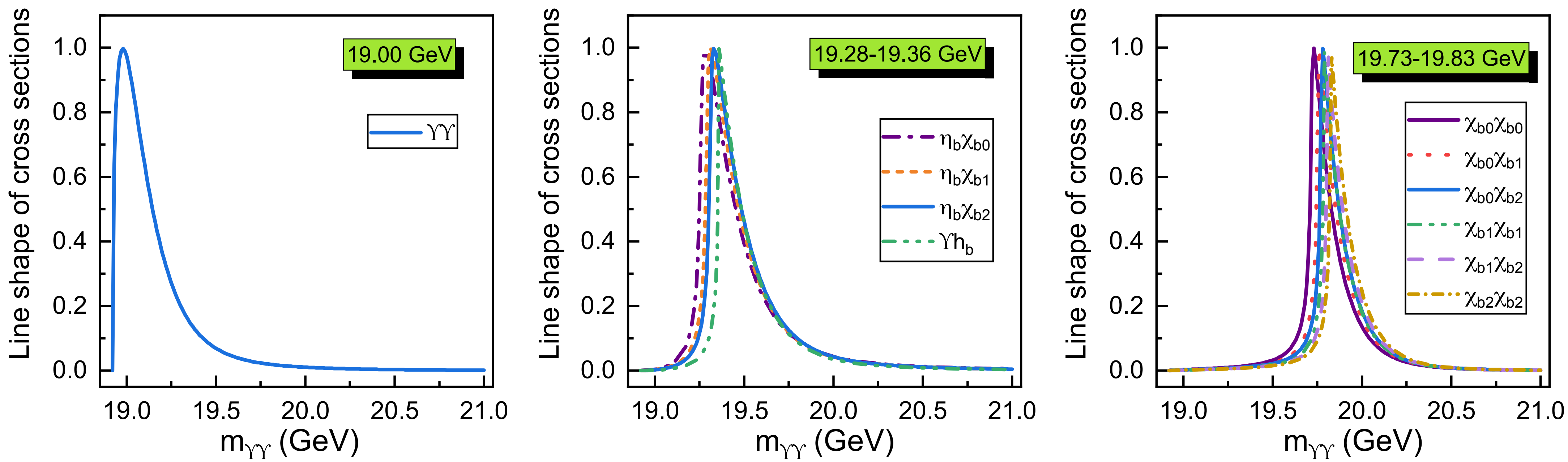




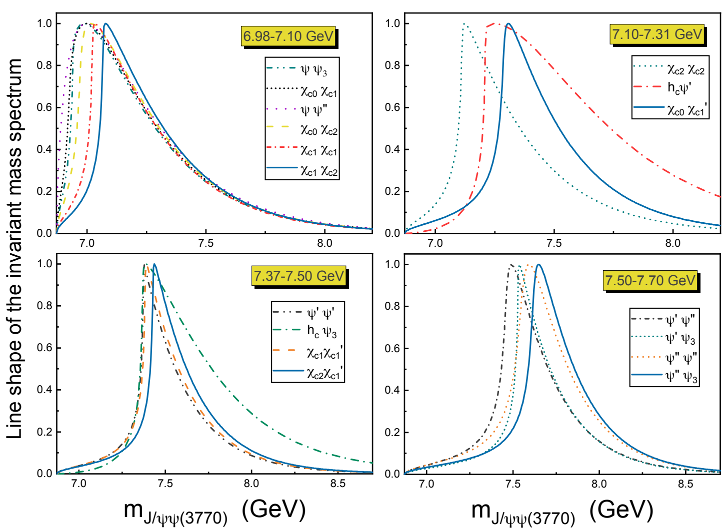


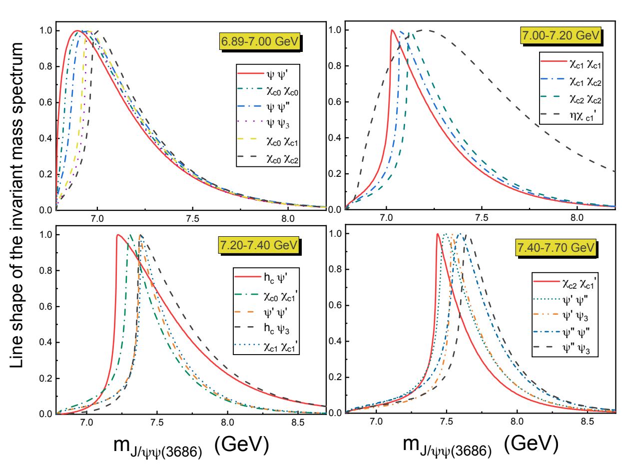
J.Z. Wang, Xiang Liu, PRD 106 (2022) 054015

Predictions for the peak line shape in di-Υ invariant mass spectrum

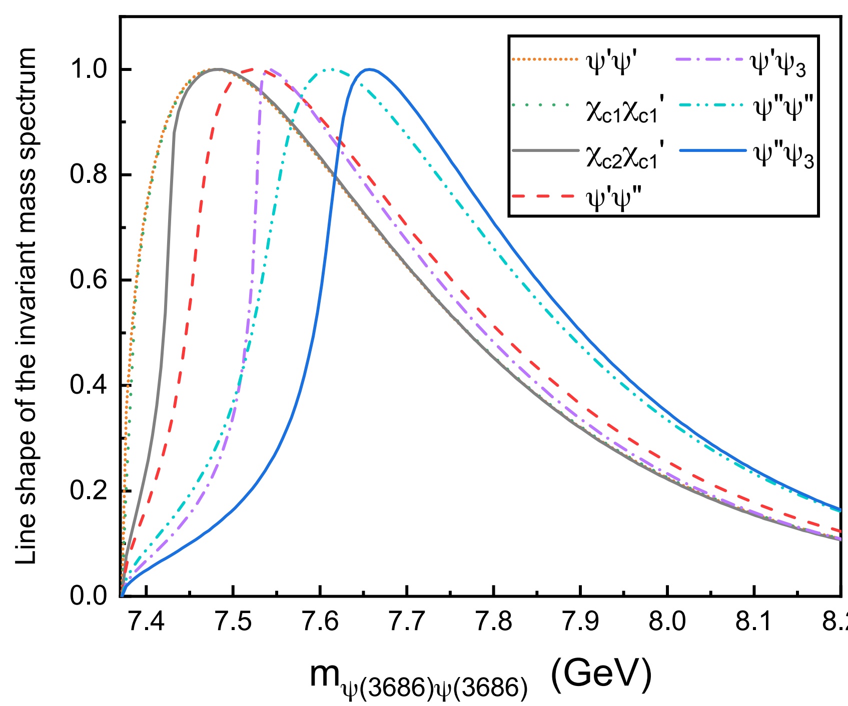


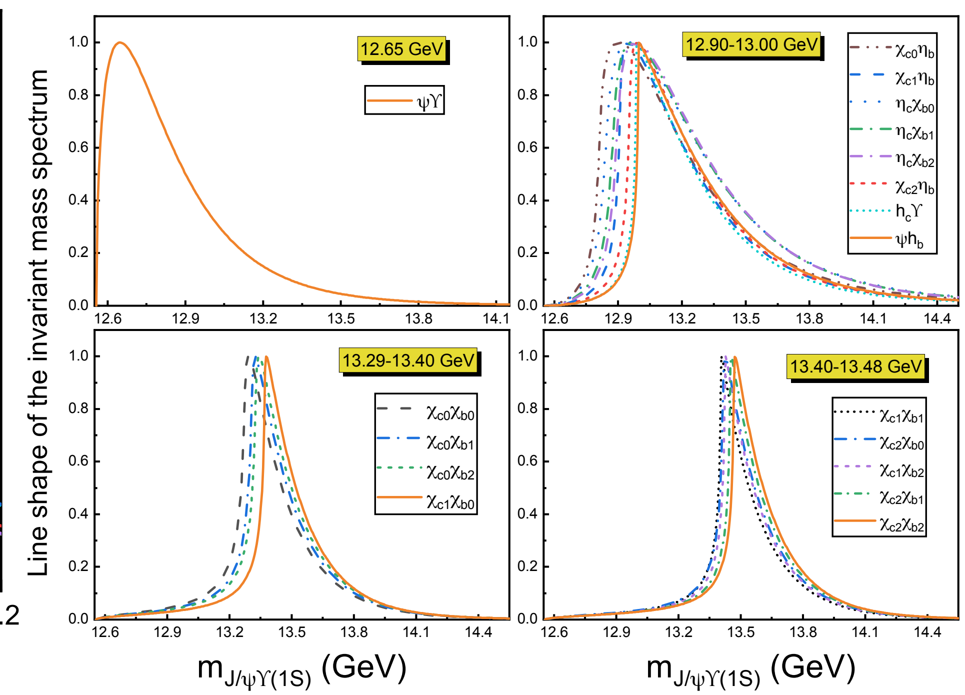
J.Z. Wang, D.Y. Chen, Xiang Liu and T. Matsuki, PRD 103 (2021) L071503





More predictions





J.Z. Wang, Xiang Liu and T. Matsuki, PLB 816 (2021) 136209

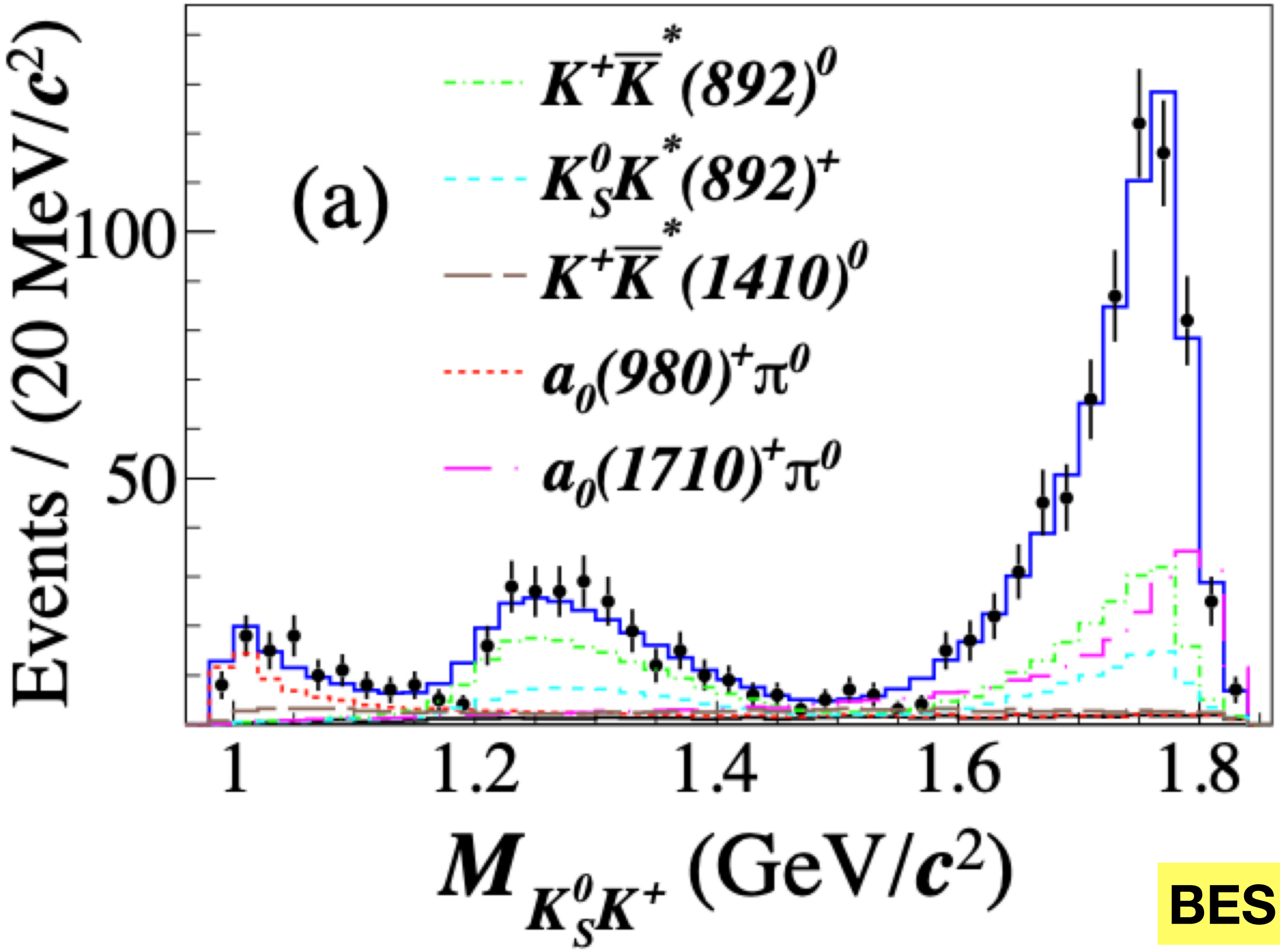
3. Pay more attentions to the study of light hadron spectroscopy

Observation of $a_0(1710)^+ \to K_S^0 K^+$ in study of the $D_s^+ \to K_S^0 K^+ \pi^0$ decay

Challenge for $f_0(1710)$ as glueball

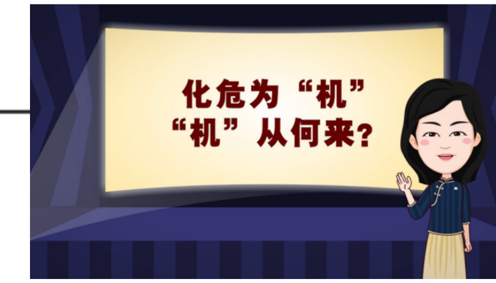
$$M = 1.817 \pm 0.008(\text{stat}) \pm 0.020(\text{syst})\ \text{GeV}$$

$$\Gamma = 0.097 \pm 0.022(\text{stat}) \pm 0.015(\text{syst})\ \text{GeV}$$



BESIII, arXiv:2204.09614

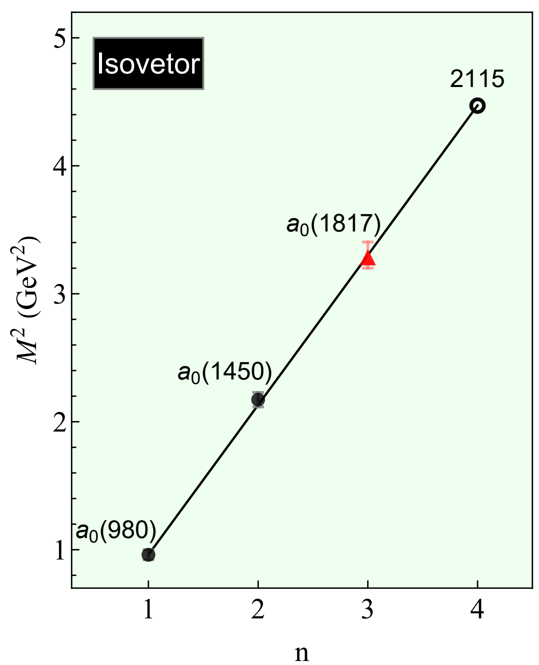
PHYSICAL REVIEW D **105,** 114014 (2022)

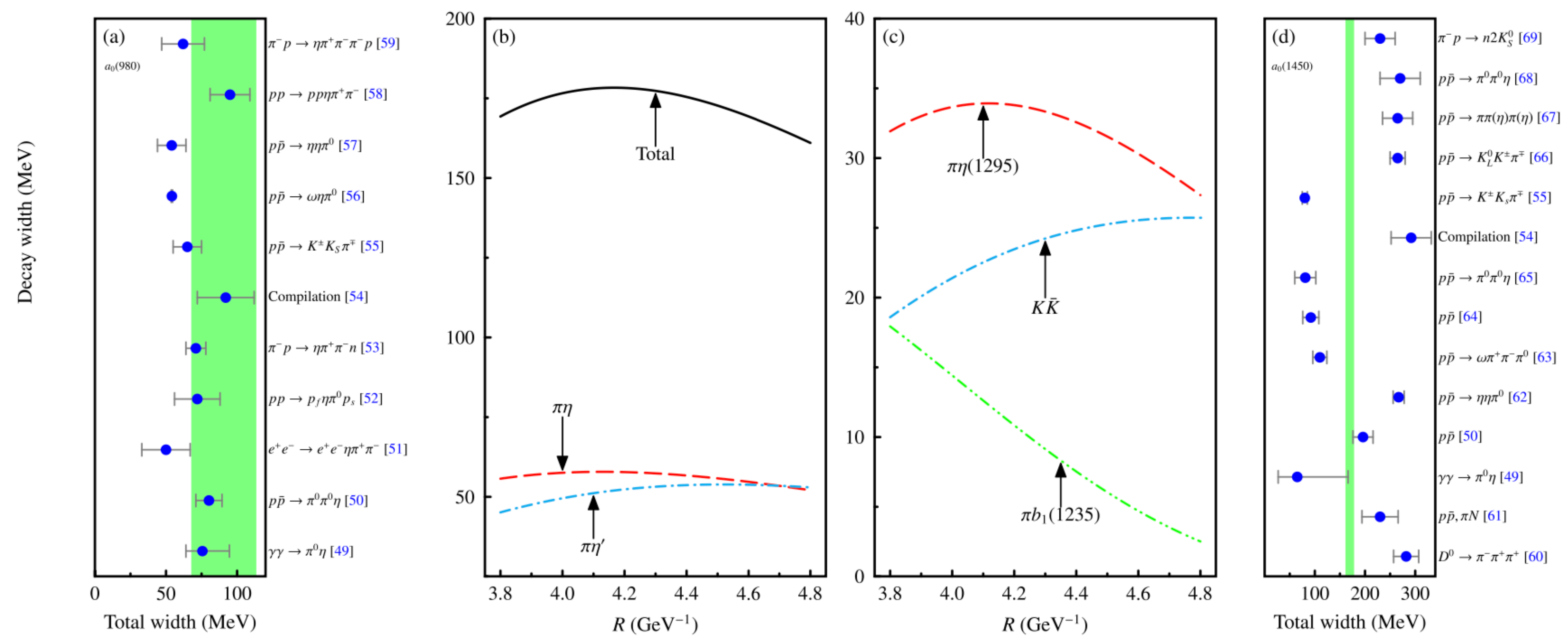


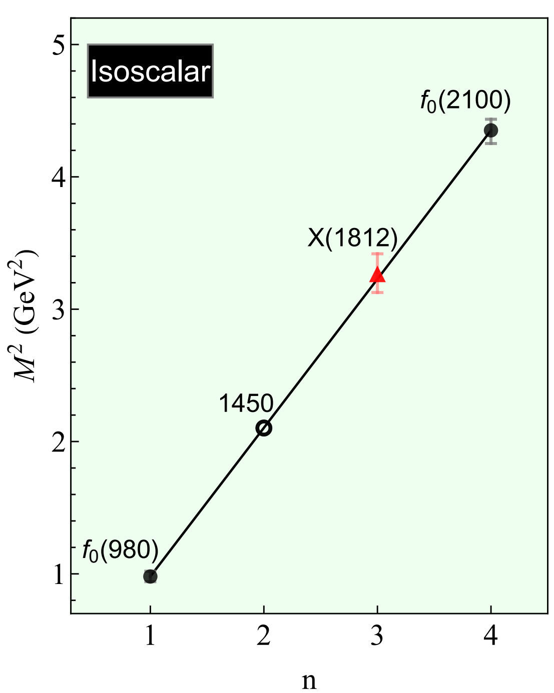
It is safe to assign $f_0(1710)$ as glueball

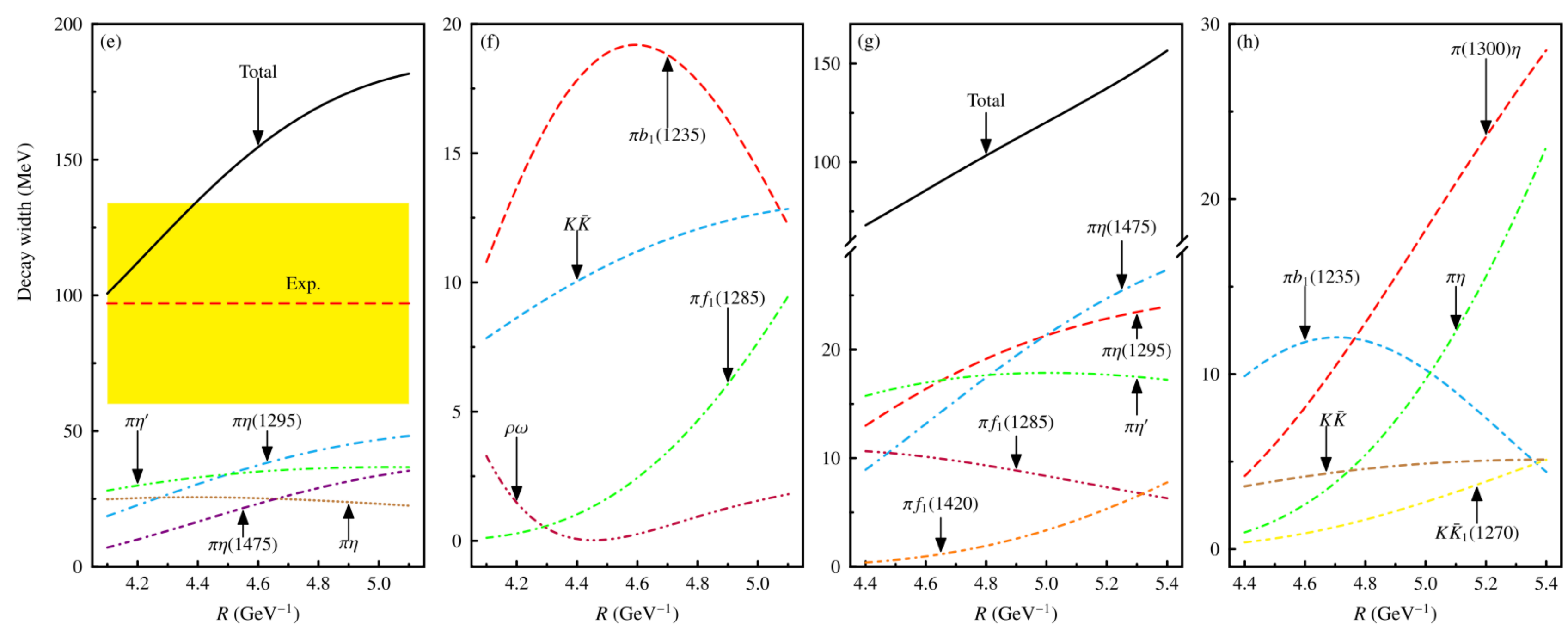
Newly observed $a_0(1817)$ as the scaling point of constructing the scalar meson spectroscopy

Dan Guo,[1,2,*] Wei Chen,[4,†] Hua-Xing Chen,[5,‡] Xiang Liu,[1,2,3,7,§] and Shi-Lin Zhu[6,‖]









实验与理论相辅相成

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Observation of an a_0-like State with Mass of 1.817 GeV in the Study of $D_s^+ \to K_S^0 K^+ \pi^0$ Decays

M. Ablikim *et al.* (BESIII Collaboration)

Phys. Rev. Lett. **129**, 182001 – Published 28 October 2022

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ABSTRACT

Using e^+e^- annihilation data corresponding to an integrated luminosity of $6.32\,\mathrm{fb}^{-1}$ collected at center-of-mass energies between 4.178 and 4.226 GeV with the BESIII detector, we perform the fi
amplitude analysis of the decay $D_s^+ \to K_S^0 K^+ \pi^0$ and determine the relative branching fractions ar
phases for intermediate processes. We observe an a_0-like state with mass of 1.817 GeV in its deca
$K_S^0 K^+$ for the first time. In addition, we measure the ratio
$\{\mathcal{B}[D_s^+ \to \bar{K}^*(892)^0 K^+]/\mathcal{B}[D_s^+ \to \bar{K}^0 K^*(892)^+]\}$ to be $2.35^{+0.42}_{-0.23\,\mathrm{stat}} \pm 0.10_{\mathrm{syst}}$. Finally, we provid
precision measurement of the absolute branching fraction
$\mathcal{B}(D_s^+ \to K_S^0 K^+ \pi^0) = (1.46 \pm 0.06_{\mathrm{stat}} \pm 0.05_{\mathrm{syst}})\%$.

实验在前 理论在后

BESIII正式发表在PRL论文中接受了我们的理论建议

Observation of $a_0(1710)^+ \to K_S^0 K^+$ in study of the $D_s^+ \to K_S^0 K^+ \pi^0$ decay

M. Ablikim[1], M. N. Achasov[10,b], P. Adlarson[69], M. Albrecht[4], R. Aliberti[29], A. Amoroso[68A,68C], M. R. An[33], Q. An[65,51], X. H. Bai[59], Y. Bai[50], O. Bakina[30], R. Baldini Ferroli[24A], I. Balossino[25A], Y. Ban[40,g], V. Batozskaya[1,38], D. Becker[29], K. Begzsuren[27], N. Berger[29], M. Bertani[24A], D. Bettoni[25A], F. Bianchi[68A,68C], J. Bloms[62], A. Bortone[68A,68C], I. Boyko[30], R. A. Briere[5], A. Brueggemann[62], H. Cai[70], X. Cai[1,51], A. Calcaterra[24A], G. F. Cao[1,56], N. Cao[1,56], S. A. Cetin[55A], J. F. Chang[1,51], W. L. Chang[1,56], G. Chelkov[30,a], C. Chen[37], G. Chen[1], H. S. Chen[1,56], M. L. Chen[1,51], S. J. Chen[36], T. Chen[1], X. R. Chen[26,56], X. T. Chen[1], Y. B. Chen[1,51], Z. J. Chen[21,h], W. S. Cheng[68C], G. Cibinetto[25A], F. Cossio[68C], J. J. Cui[43], H. L. Dai[1,51], J. P. Dai[72], A. Dbeyssi[15], R. E. de Boer[4], D. Dedovich[30], Z. Y. Deng[1], A. Denig[29], I. Denysenko[30], M. Destefanis[68A,68C], F. De Mori[68A,68C], Y. Ding[34], J. Dong[1,51], L. Y. Dong[1,56], M. Y. Dong[1,51,56], X. Dong[70], S. X. Du[74], P. Egorov[30,a], Y. L. Fan[70], J. Fang[1,51], S. S. Fang[1,56], Y. Fang[1], R. Farinelli[25A], L. Fava[68B,68C], F. Feldbauer[4], G. Felici[24A], C. Q. Feng[65,51], J. H. Feng[52], K Fischer[63], M. Fritsch[4], C. Fritzsch[62], C. D. Fu[1], H. Gao[56], Y. N. Gao[40,g], Yang Gao[65,51], S. Garbolino[68C], I. Garzia[25A,25B], P. T. Ge[70], Z. W. Ge[36], C. Geng[52], E. M. Gersabeck[60], A Gilman[63], L. Gong[34], W. X. Gong[1,51], W. Gradl[29], M. Greco[68A,68C], L. M. Gu[36], M. H. Gu[1,51], Y. T. Gu[13], C. Y Guan[1,56], A. Q. Guo[26,56], L. B. Guo[35], R. P. Guo[42], Y. P. Guo[9,f], A. Guskov[30,a], T. T. Han[43], W. Y. Han[33], X. Q. Hao[16], F. A. Harris[58], K. K. He[48], K. L. He[1,56], F. H. Heinsius[4], C. H. Heinz[29], Y. K. Heng[1,51,56], C. Herold[53], T. Holtmann[4], G. Y. Hou[1,56], Y. R. Hou[56], Z. L. Hou[1], H. M. Hu[1,56], J. F. Hu[49,i], T. Hu[1,51,56], Y. Hu[1], G. S. Huang[65,51], K. X. Huang[52], L. Q. Huang[66], L. Q. Huang[26,56], X. T. Huang[43], Y. P. Huang[1], Z. Huang[40,g], T. Hussain[67], N Hüsken[23,29], W. Imoehl[23], M. Irshad[65,51], J. Jackson[23], S. Jaeger[4], S. Janchiv[27], Q. Ji[1], Q. P. Ji[16], X. B. Ji[1,56], X. L. Ji[1,51], Y. Y. Ji[43], Z. K. Jia[65,51], H. B. Jiang[43], S. S. Jiang[33], X. S. Jiang[1,51,56], Y. Jiang[56], J. B. Jiao[43], Z. Jiao[19], S. Jin[36], Y. Jin[59], M. Q. Jing[1,56], T. Johansson[69], N. Kalantar-Nayestanaki[57], X. S. Kang[34], R. Kappert[57], M. Kavatsyuk[57], B. C. Ke[74], I. K. Keshk[4], A. Khoukaz[62], P. Kiese[29], R. Kiuchi[1], L. Koch[31], O. B. Kolcu[55A], B. Kopf[4], M. Kuemmel[4], M. Kuessner[4], A. Kupsc[38,69], W. Kühn[31], J. J. Lane[60], J. S. Lange[31], P. Larin[15], A. Lavania[22], L. Lavezzi[68A,68C], Z. H. Lei[65,51], H. Leithoff[29], M. Lellmann[29], T. Lenz[29], C. Li[37], C. Li[41], C. H. Li[33], Cheng Li[65,51], D. M. Li[74], F. Li[1,51], G. Li[1], H. 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Lu[52], H. J. Lu[19], J. G. Lu[1,51], X. L. Lu[1], Y. Lu[1], Y. P. Lu[1,51], Z. H. Lu[1], C. L. Luo[35], M. X. Luo[73], T. Luo[9,f], X. L. Luo[1,51], X. R. Lyu[56], Y. F. Lyu[37], F. C. Ma[34], H. L. Ma[1], L. L. Ma[43], M. M. Ma[1,56], Q. M. Ma[1], R. Q. Ma[1,56], R. T. Ma[56], X. Y. Ma[1,51], Y. Ma[40,g], F. E. Maas[15], M. Maggiora[68A,68C], S. Maldaner[4], S. Malde[63], Q. A. Malik[67], A. Mangoni[24B], Y. J. Mao[40,g], Z. P. Mao[1], S. Marcello[68A,68C], Z. X. Meng[59], J. G. Messchendorp[57,11], G. Mezzadri[25A], H. Miao[1], T. J. Min[36], R. E. Mitchell[23], X. H. Mo[1,51,56], N. Yu. Muchnoi[10,b], H. Muramatsu[61], Y. Nefedov[30], F. Nerling[11,d], I. B. Nikolaev[10,b], Z. Ning[1,51], S. Nisar[8,l], Y. Niu[43], S. L. Olsen[56], Q. Ouyang[1,51,56], S. Pacetti[24B,24C], X. Pan[9,f], Y. Pan[60], A. Pathak[1], A. Pathak[28], M. Pelizaeus[4], H. P. Peng[65,51], J. Pettersson[69], J. L. Ping[35], R. G. Ping[1,56], S. Plura[29], S. Pogodin[30], R. Poling[61], V. Prasad[65,51], H. 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Construct light hadron spectroscopy always on the road

PHYSICAL REVIEW D **107**, 072001 (2023)

Study of the reactions $e^+e^- \to K^+K^-\pi^0\pi^0\pi^0$, $e^+e^- \to K^0_S K^\pm \pi^\mp \pi^0\pi^0$, and $e^+e^- \to K^0_S K^\pm \pi^\mp \pi^+\pi^-$ at center-of-mass energies from threshold to 4.5 GeV using initial-state radiation

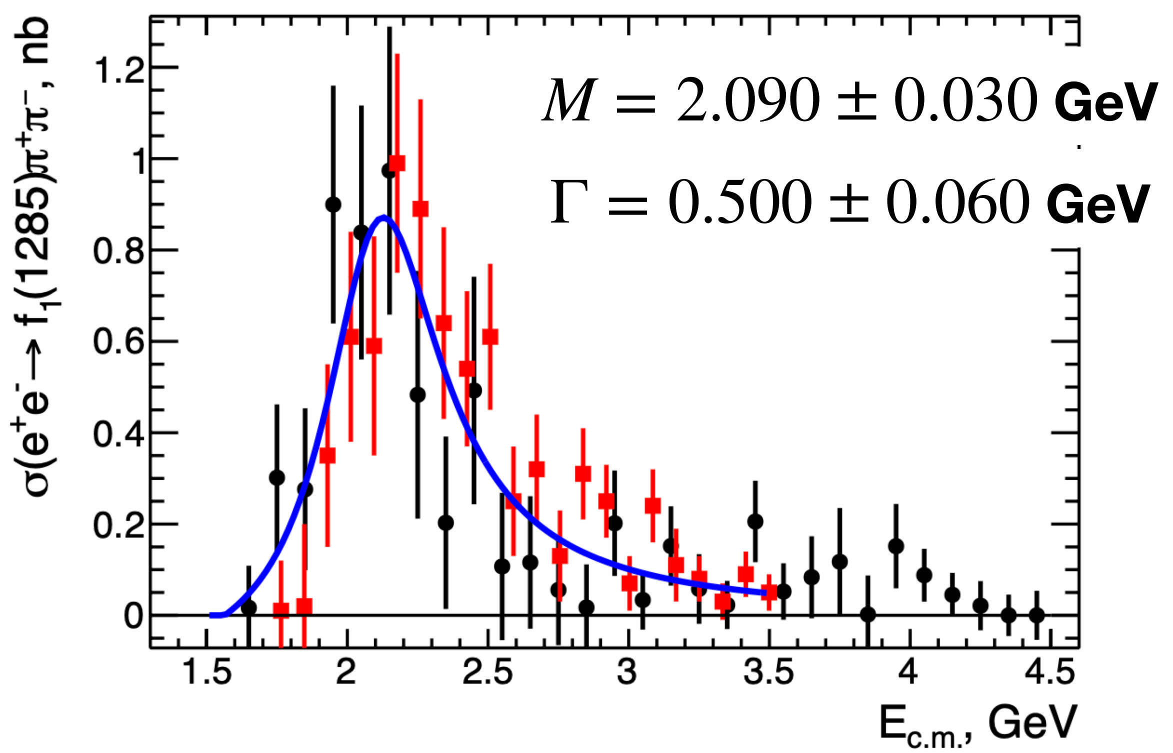
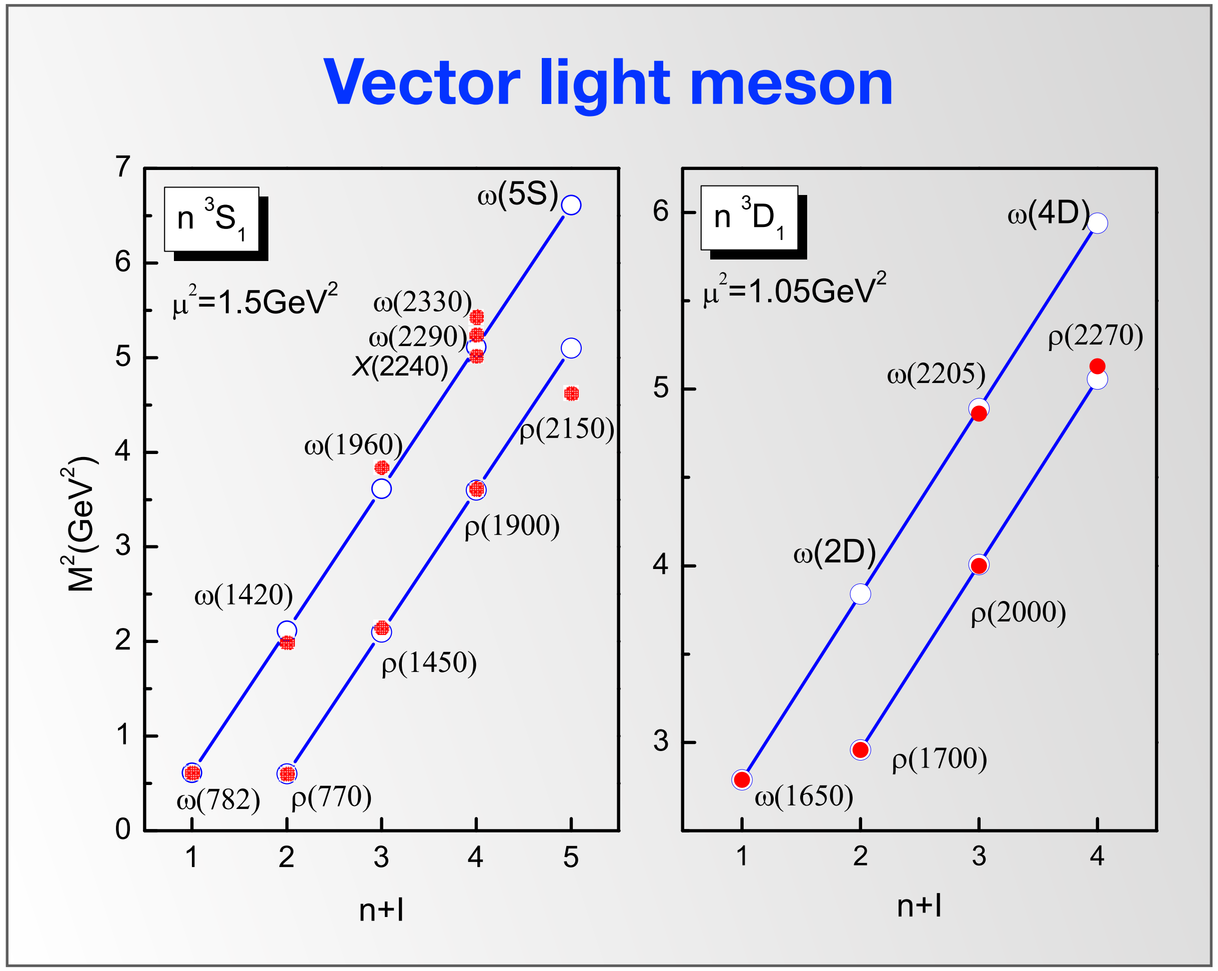


FIG. 13: The measured $e^+e^- \to f_1(1285)\pi^+\pi^-$ cross section from the present analysis (dots) in comparison with previous measurement (squares) [12]. The solid curve is fit explained in the text.



Our knowledge of light hadron spectroscopy is helpful to establish exotic states

Model with only K^*

$P_{\psi s}^{\Lambda}(4338)$

Amplitude contributions:

- NR($\bar{p}\Lambda$)
- $K^{*+}_{2,3,4}$ → peaks out of phsp, no obvious contribution in $\bar{p}\Lambda$ distribution

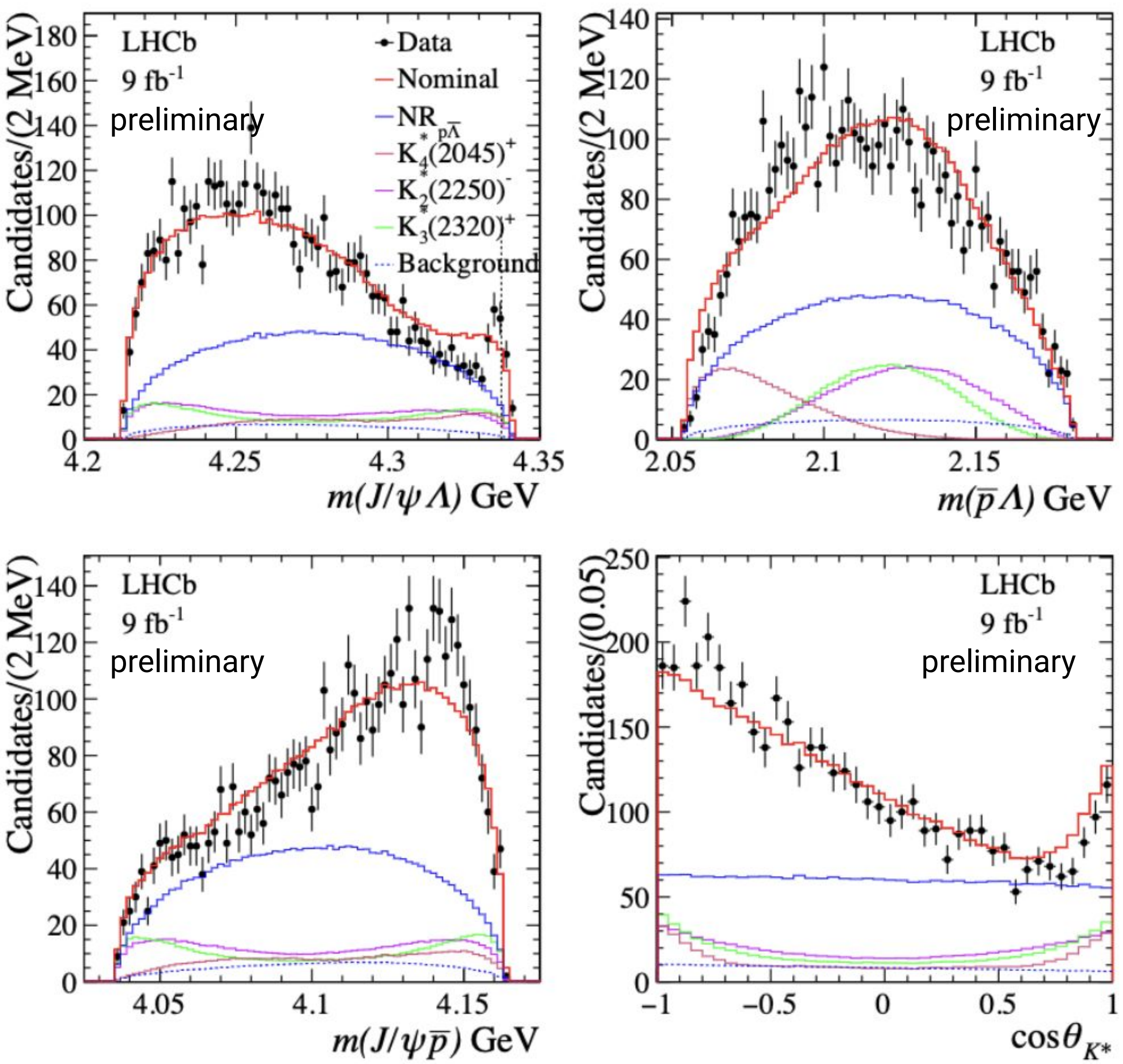
Resonance	Mass (MeV)	Natural width (MeV)	J^P
$K_4^*(2045)^+$	2045 ± 9	198 ± 30	4^+
$K_2^*(2250)^+$	2247 ± 17	180 ± 30	2^-
$K_3^*(2320)^+$	2324 ± 24	150 ± 30	3^+

PDG 2020

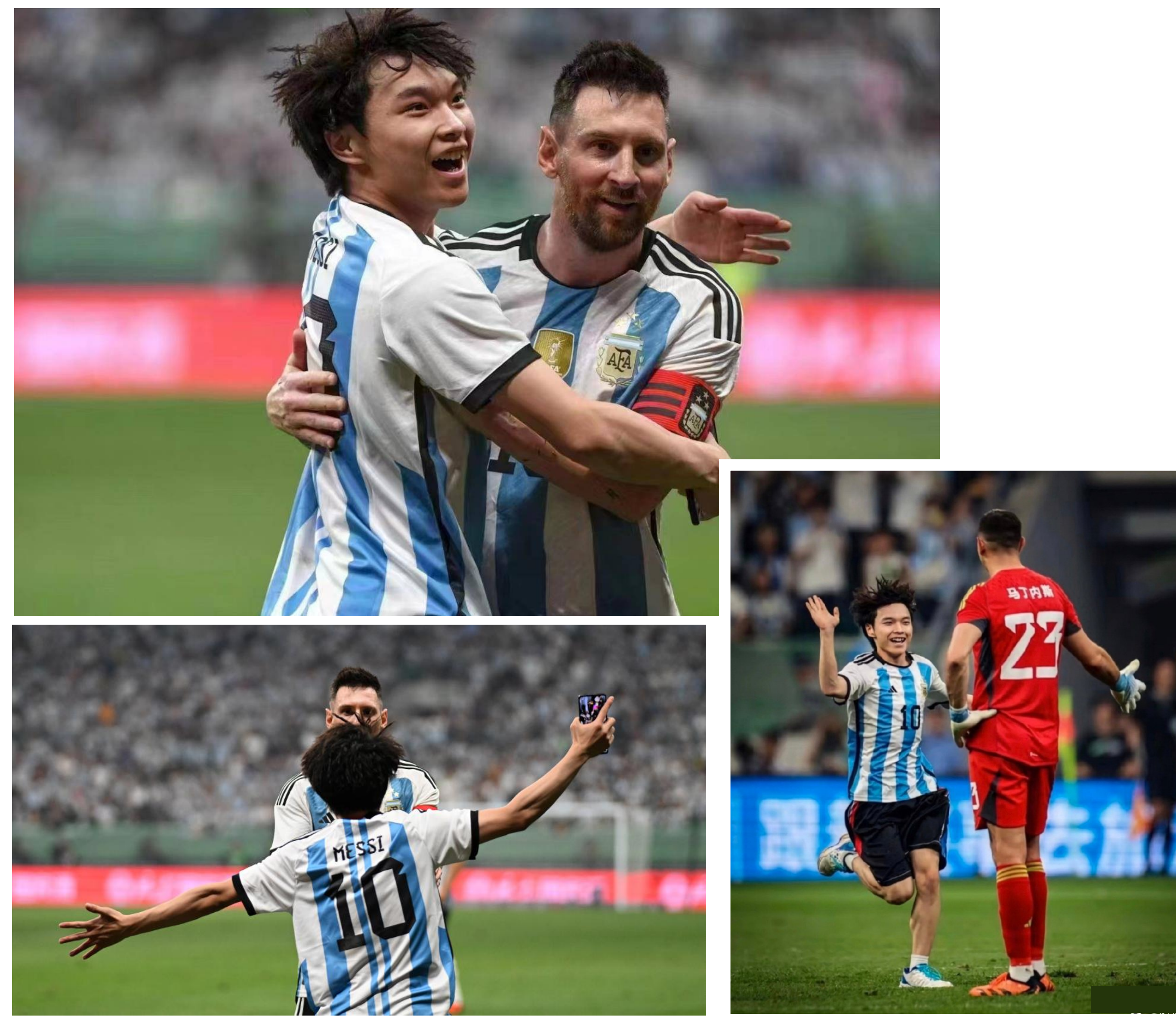
Model with K^* cannot describe data

Goodness-of-fit test

$$\chi^2/ndf = 123/33$$



4. Summary—Never underestimate the ability of experiment



PHYSICAL REVIEW D **104**, 034036 (2021)

EXAMPLE

Hidden-bottom hadronic decays of $\Upsilon(10753)$ with a $\eta^{(\prime)}$ or ω emission

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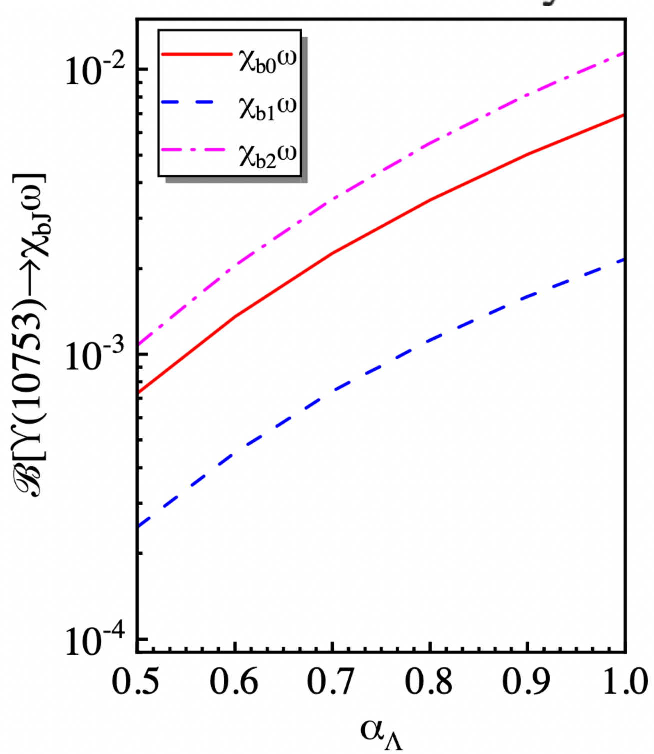
In this work, we propose the $4S$-$3D$ mixing scheme to assign the $\Upsilon(10753)$ into the conventional bottomonium family. Under this interpretation, we further study its hidden-bottom hadronic decays with a
... include $\Upsilon(10753) \to \Upsilon(1S)\eta^{(\prime)}$, $\Upsilon(10753) \to h_b(1P)\eta$, and $\Upsilon(10753) \to \chi_{bJ}\omega$
... ince the $\Upsilon(10753)$ is above the $B\bar{B}$ threshold, the coupled-channel effect cannot
... lculating partial decay widths of these $\Upsilon(10753)$ hidden-bottom decays, we apply
... nism. Our result shows that these discussed decay processes own considerable
... an order of magnitude of 10^{-4}–10^{-3}, which can be accessible at Belle II and other

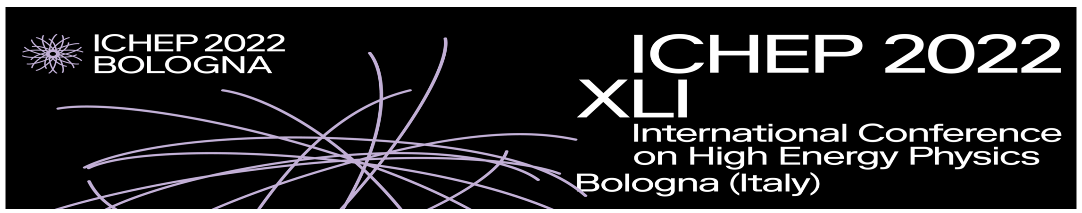


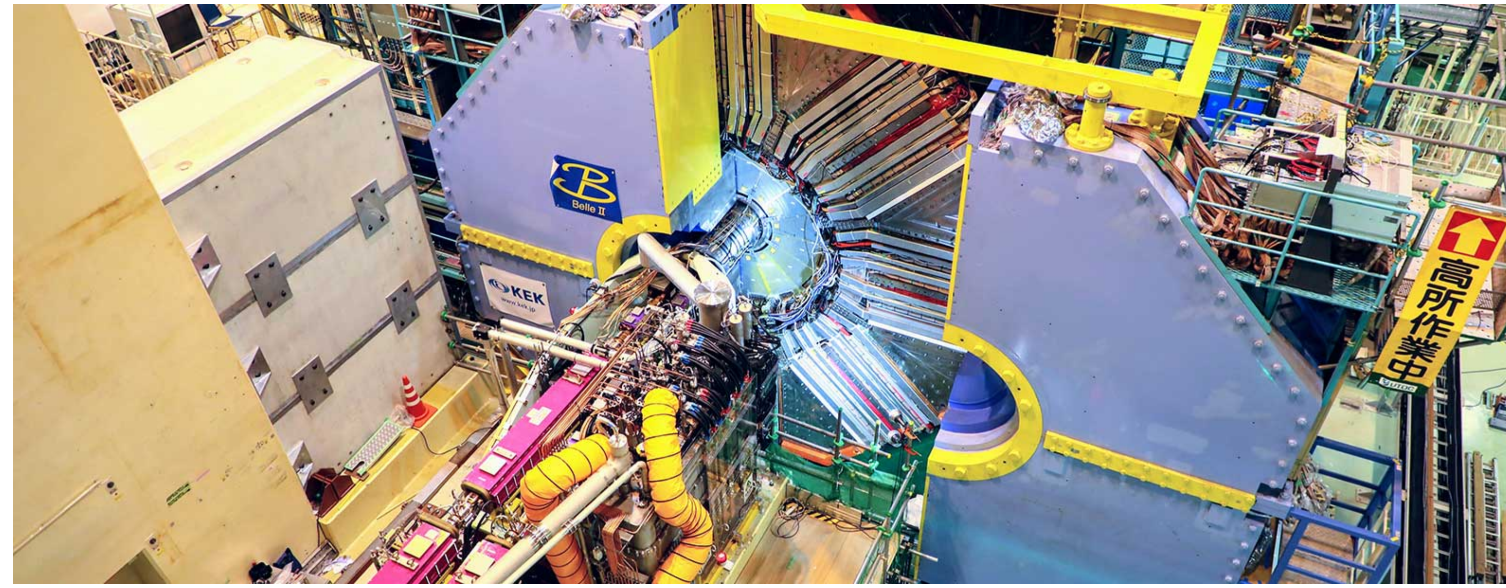
In 2021, we predicted $\Upsilon(10753) \to \chi_{bJ}\omega$ with sizable branching ratios

First analysis of Belle II energy scan data

Qingping Ji (Henan Normal University)

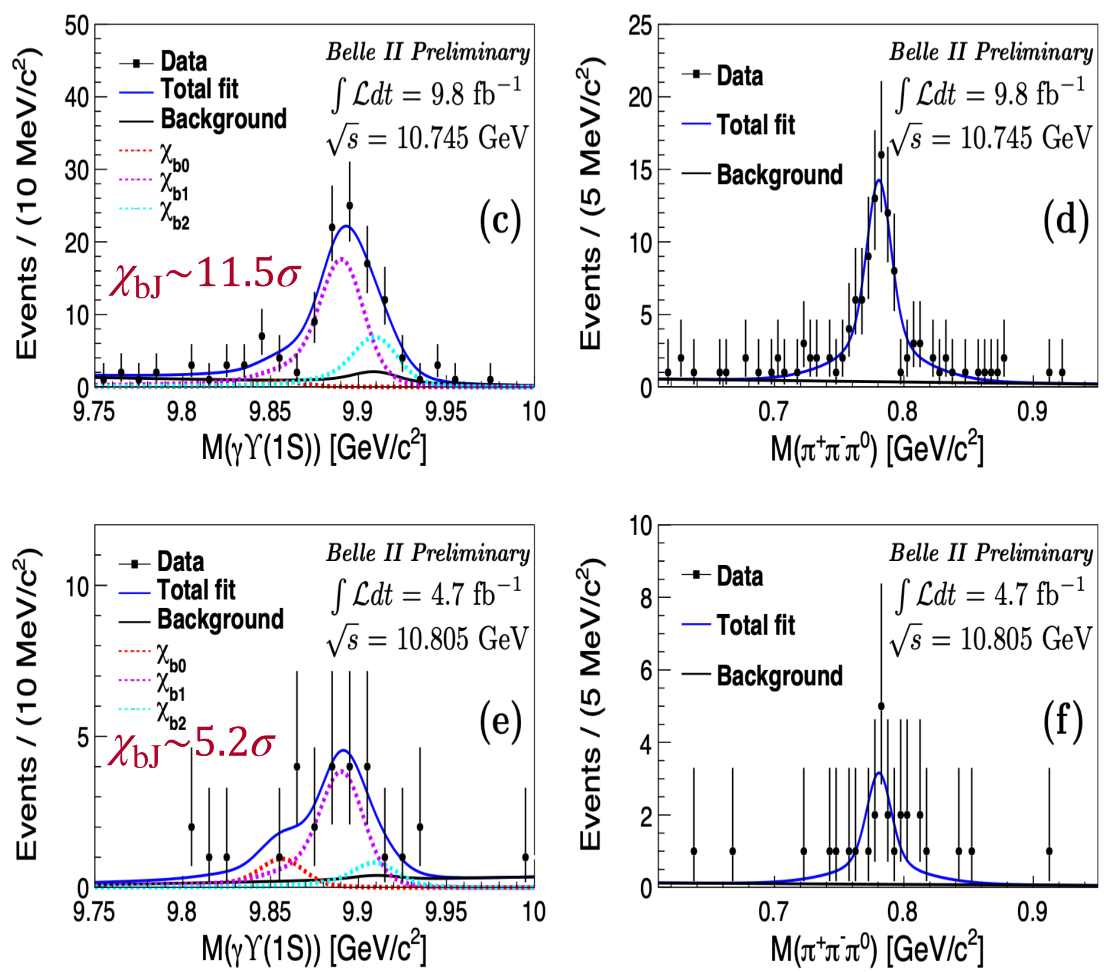
(On behalf of the Belle II Collaboration)





New for ICHEP !

Observation of $e^+e^- \to \omega\chi_{bJ}$



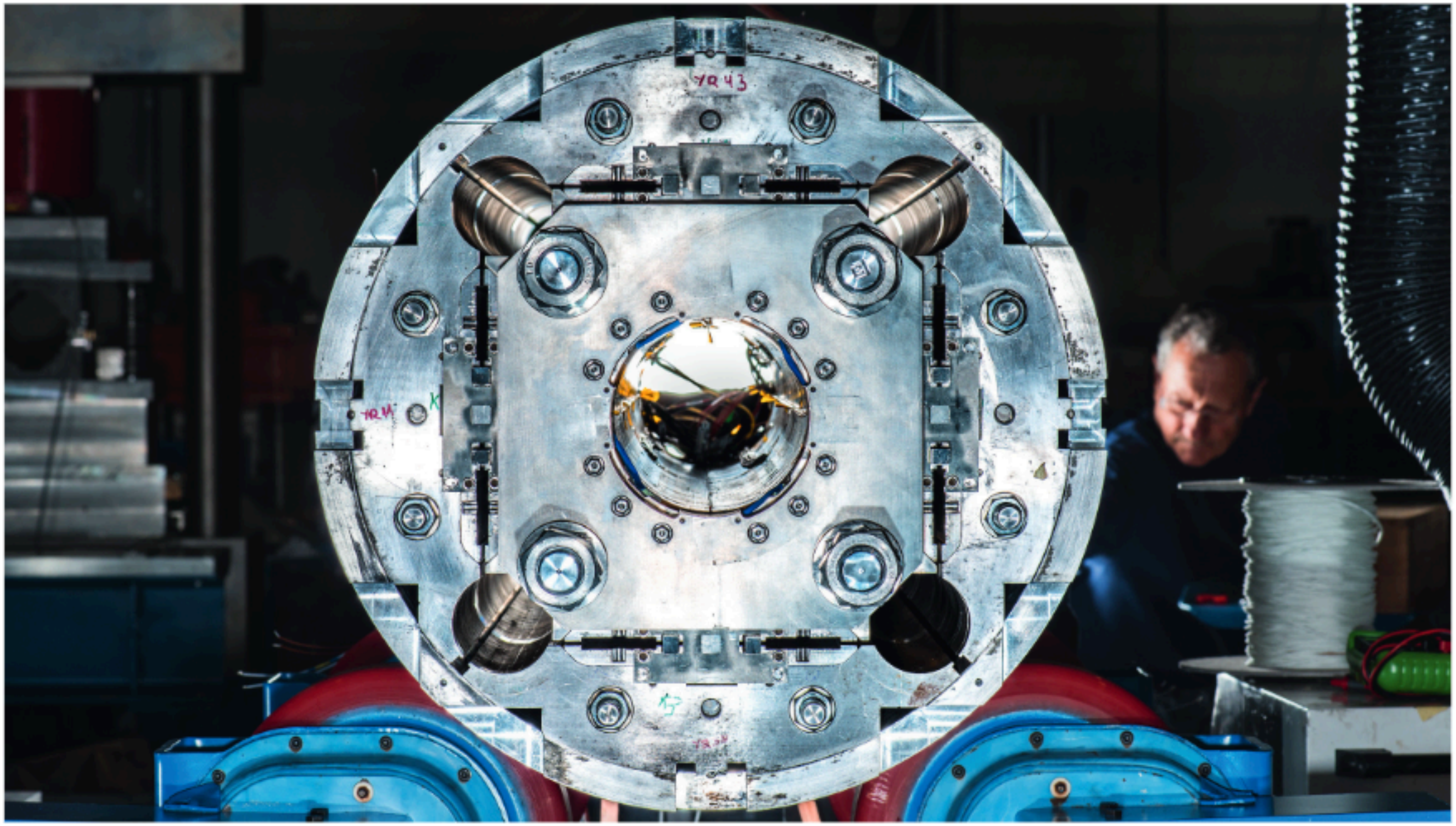
Two dimensional unbinned maximum likelihood fit to $M(\gamma\Upsilon(1S))$ and $M(\pi^+\pi^-\pi^0)$.

Channel	$\sqrt{s}$ (GeV)	$N^{\text{sig.}}$	$\sigma_B^{(\text{up})}$ (pb)
$e^+e^- \to \omega\chi_{b1}$	10.745	$68.9^{+13.7}_{-13.5}$	$3.6^{+0.7}_{-0.7}$ (stat.) $\pm$ 0.4 (syst.)
$e^+e^- \to \omega\chi_{b2}$		$27.6^{+11.6}_{-10.0}$	$2.8^{+1.2}_{-1.0}$ (stat.) $\pm$ 0.5 (syst.)
$e^+e^- \to \omega\chi_{b1}$	10.805	$15.0^{+6.8}_{-6.2}$	1.6 @ 90% C.L.
$e^+e^- \to \omega\chi_{b2}$		$3.3^{+5.3}_{-3.8}$	1.5 @ 90% C.L.

No evident signal are found at $\sqrt{s} = 10.710$ GeV.

The High-Luminosity LHC: a new horizon for science and technology

The High-Luminosity LHC (HL-LHC) is a major upgrade of the Large Hadron Collider (LHC). The LHC collides tiny particles of matter (protons) at an energy of 13 TeV in order to study the fundamental components of matter and the forces that bind them together. The High-Luminosity LHC will make it possible to study these in more detail by increasing the number of collisions by a factor of between five and ten.



Prototype of a quadrupole magnet for the High-Luminosity LHC. (Image: Robert Hradil, Monika Majer/ProStudio22.ch)

Thank you for your attention!