



Highlights of BESIII Results

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高能物理研究所

超级陶粲装置研讨会

2026年6月30日-7月4日，西安

Outline

- BEPCII/BESIII
- Physics accomplishments
- Future prospects

τ -charm physics for 40 years at BES: evergreen tree

BES

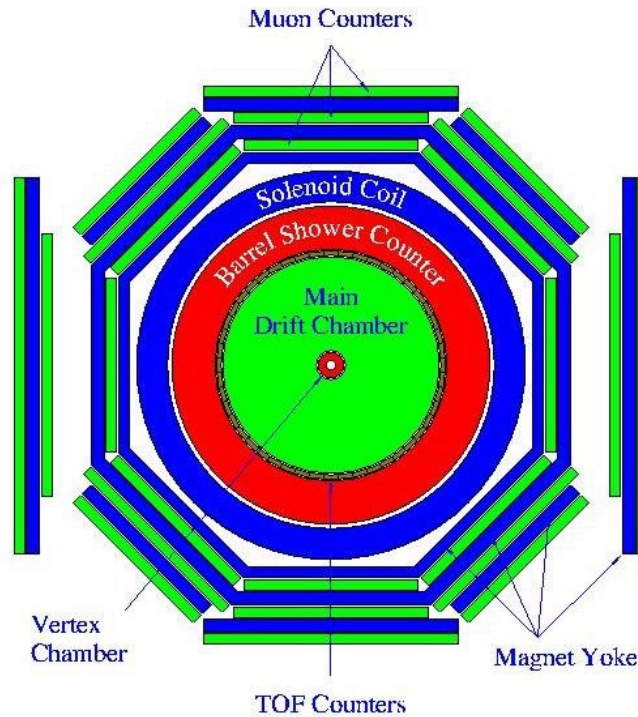
BESII

BESIII

BES		BESII		BESIII	
Construction	Data taking	Upgrade	Data taking	Construction	Data taking
1984	1988	1995	1998	2004	2008
					2009
					203X ?

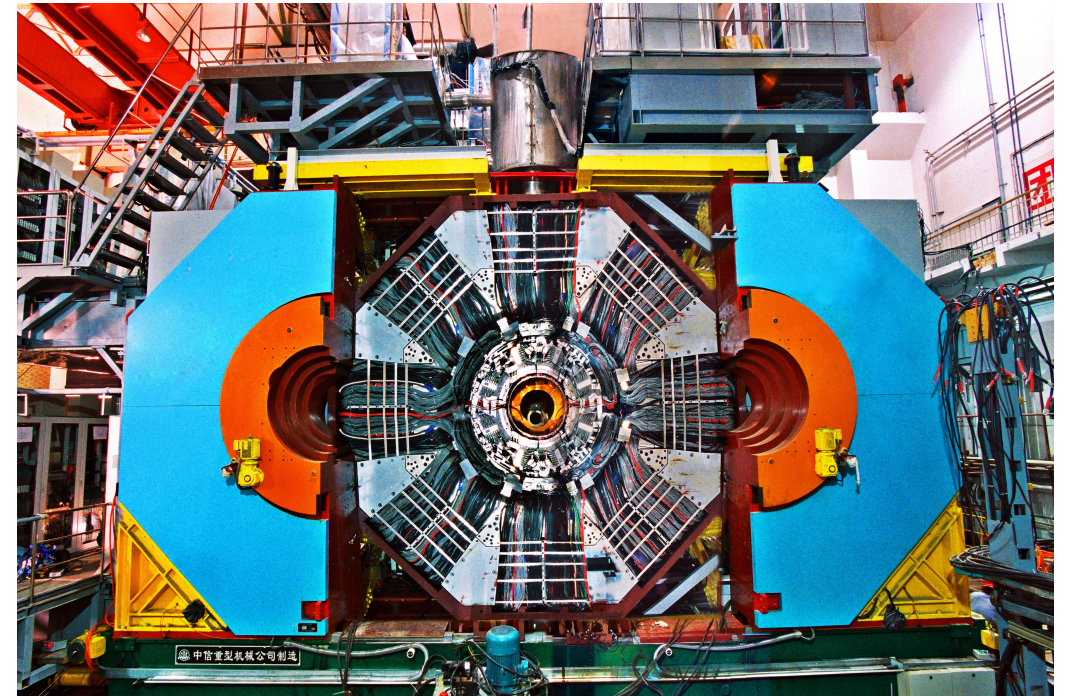


BES



End view of the BESII detector

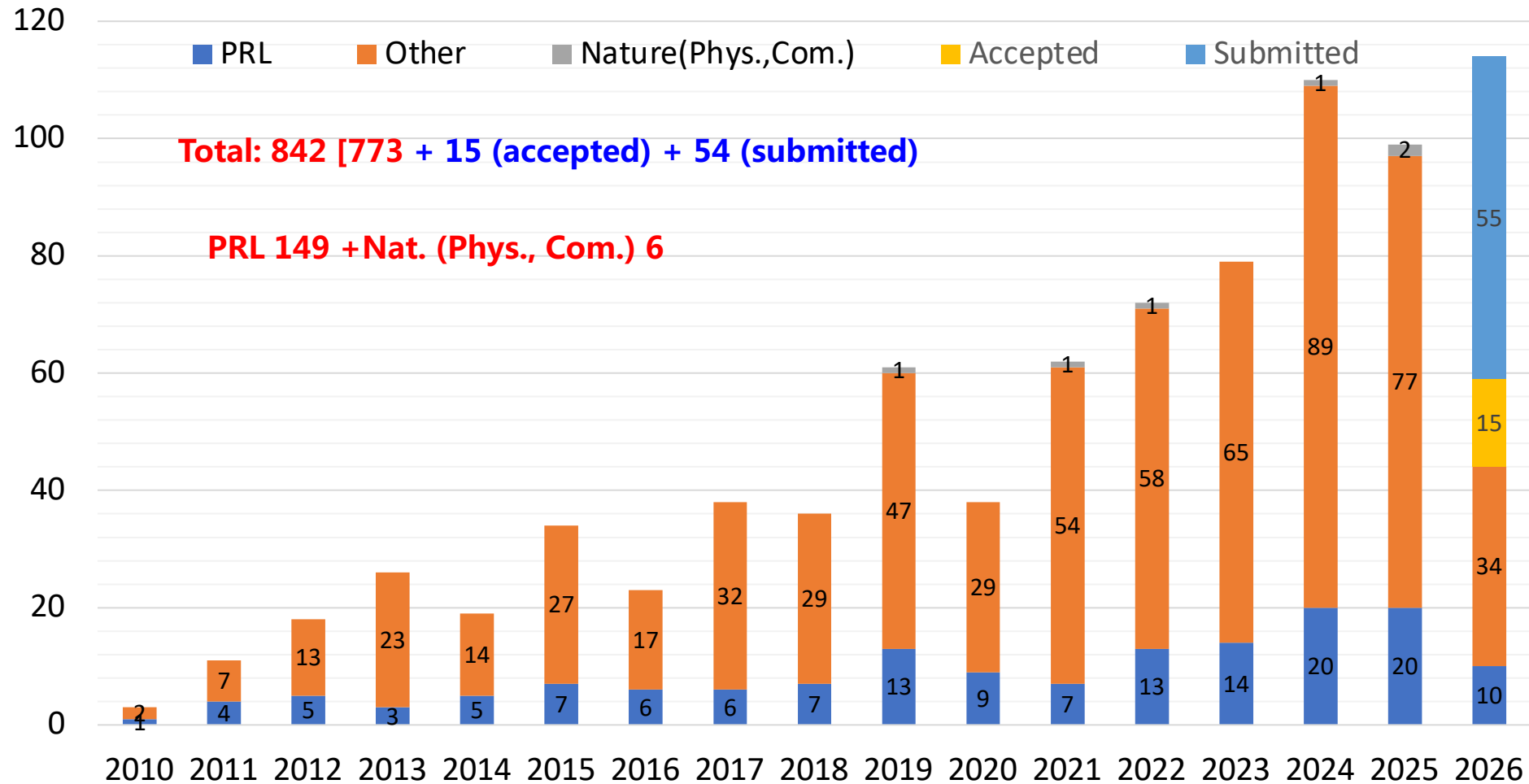
BESII



BESIII detector

$$R$$


Publications as of June 30 2026

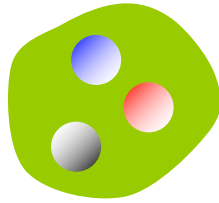


Physics accomplishments

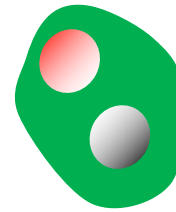
- Light exotics
- Charmonium-like states
- Charm physics
- New physics searches
-

Conventional & Exotic hadrons

- Quark Model

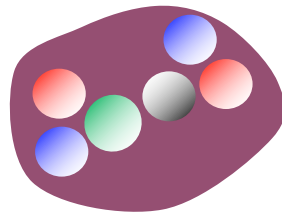


baryon

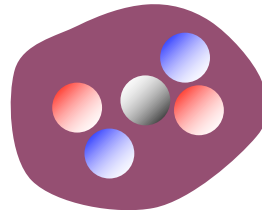


meson

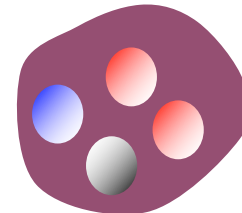
- QCD allows for hadrons beyond Quark Model



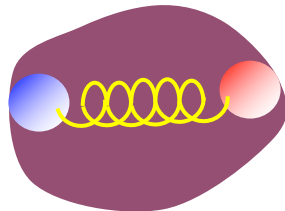
dibaryon



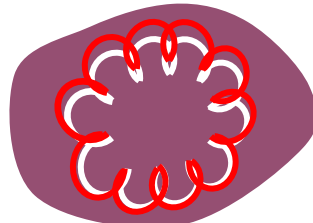
Pentaquark



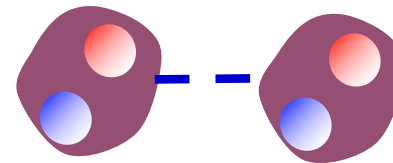
tetraquark



hybrid

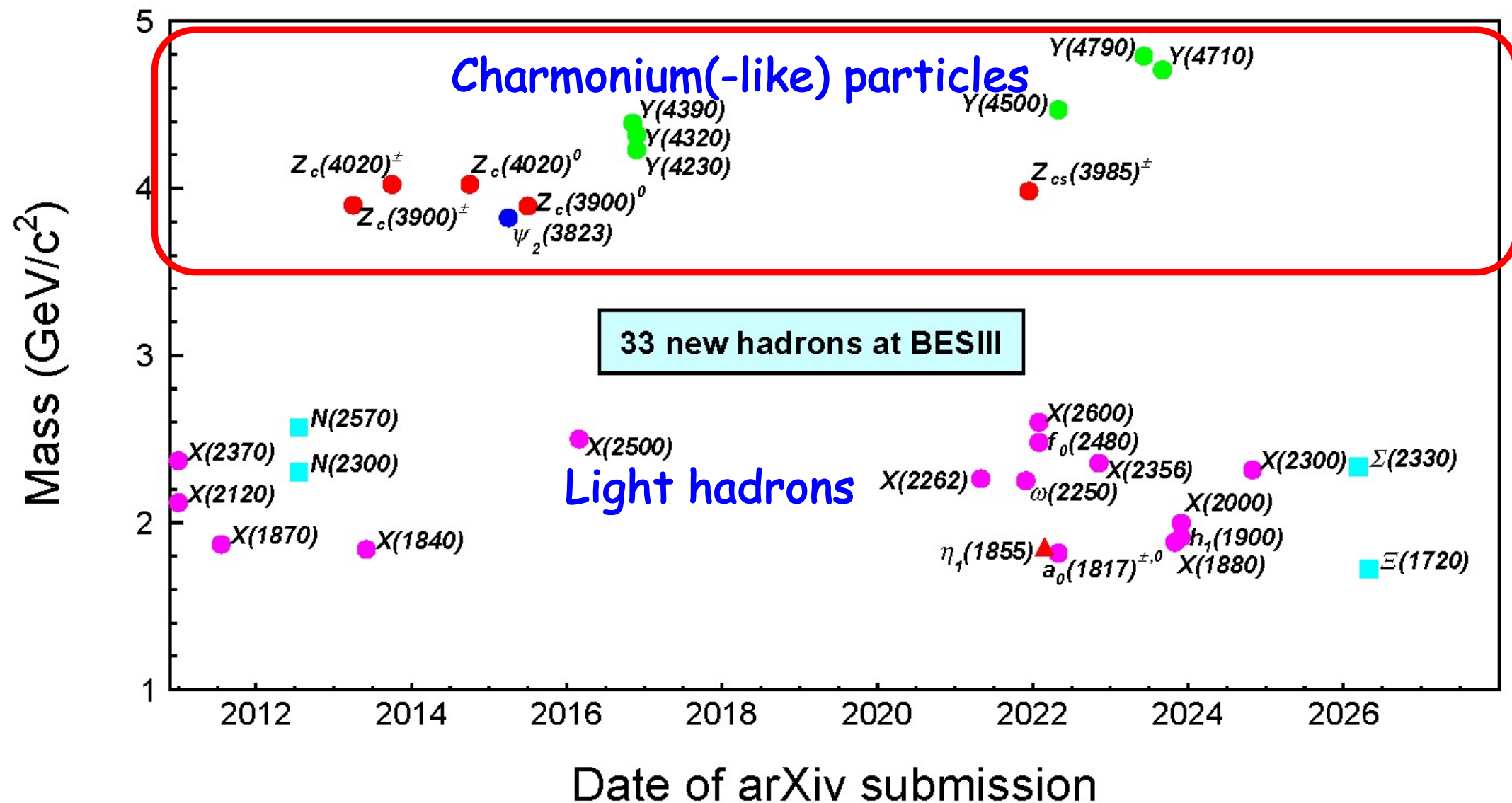


glueball



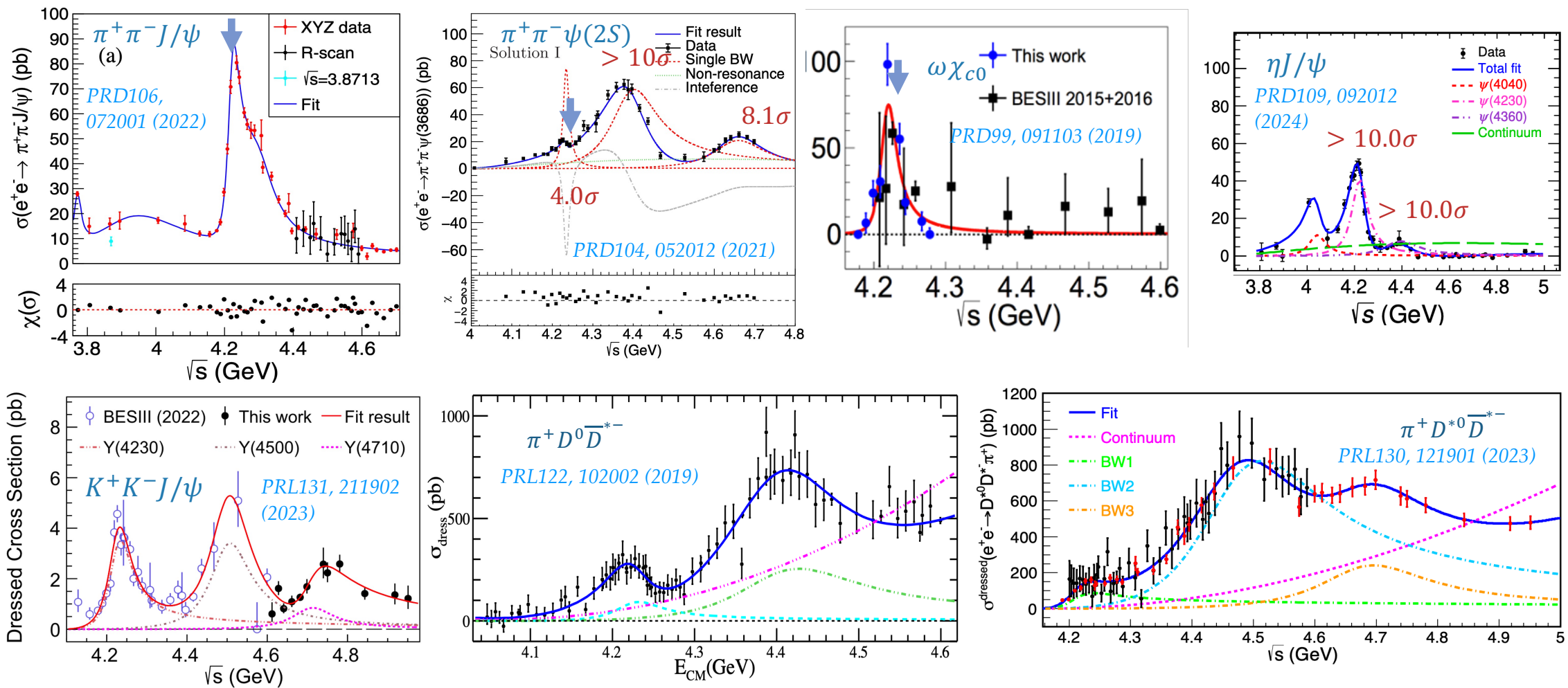
molecule

New resonant structures at BESIII



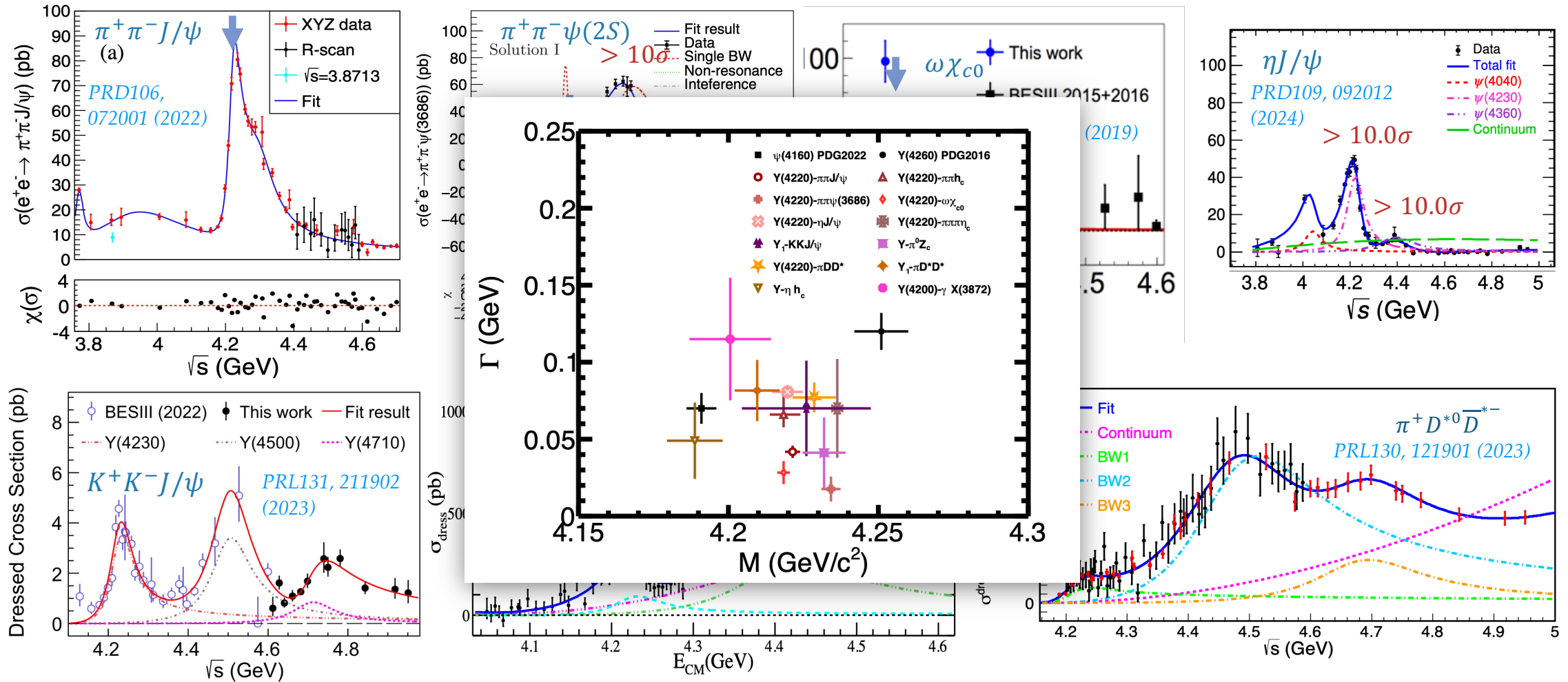
$\Upsilon(4260) \Rightarrow \Upsilon(4230)$

● Seen in more than 10 decay modes, including open charm final states



$Y(4260) \Rightarrow Y(4230)$

● Seen in more than 10 decay modes, including open charm final states

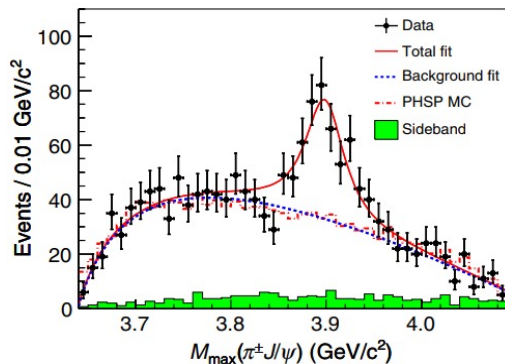


Z_c states $e^+e^- \rightarrow \pi^+\pi^- + c\bar{c}$

$$e^+e^- \rightarrow \pi^+\pi^- J/\psi$$

$Z_c(3900)^+$

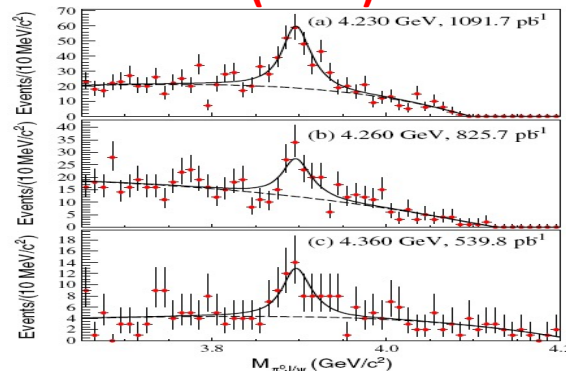
PRL110(2013)252001



$$e^+e^- \rightarrow \pi^0\pi^0 J/\psi$$

$Z_c(3900)^0$

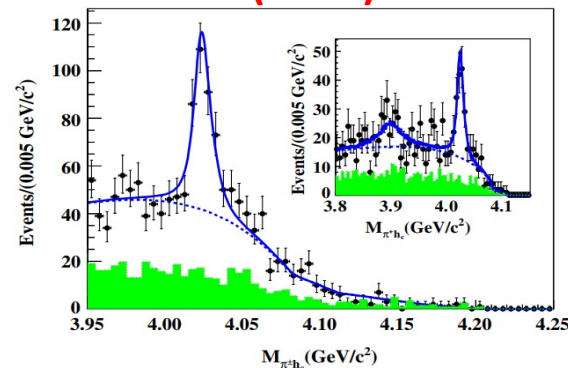
PRL115(2015)112003



$$e^+e^- \rightarrow \pi^+\pi^- h_c$$

$Z_c(4020)^+$

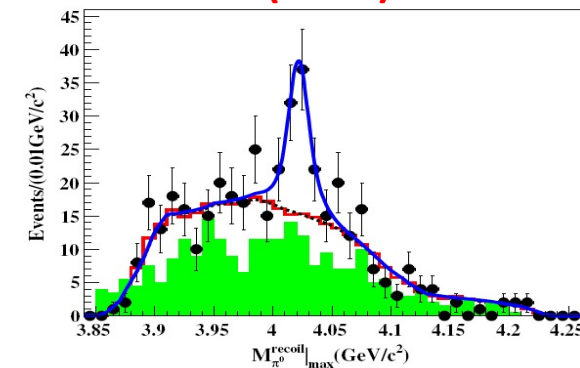
PRL111(2013)242001



$$e^+e^- \rightarrow \pi^0\pi^0 h_c$$

$Z_c(4020)^0$

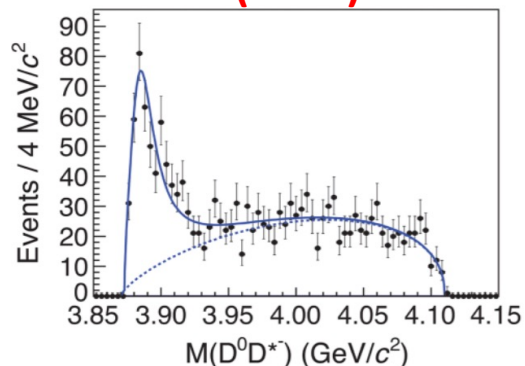
PRL113(2014)212002



$$e^+e^- \rightarrow \pi^-(D\bar{D}^*)^+$$

$Z_c(3885)^+$

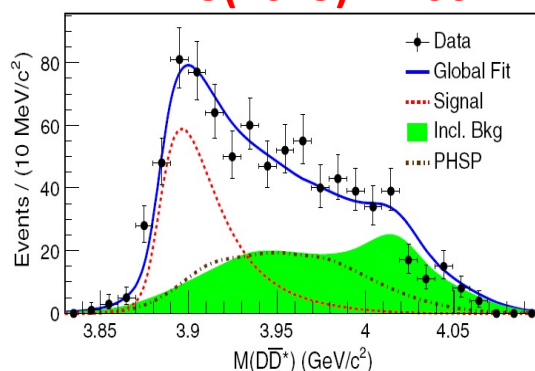
PRL112(2014)022001



$$e^+e^- \rightarrow \pi^0(D\bar{D}^*)^0$$

$Z_c(3885)^0$

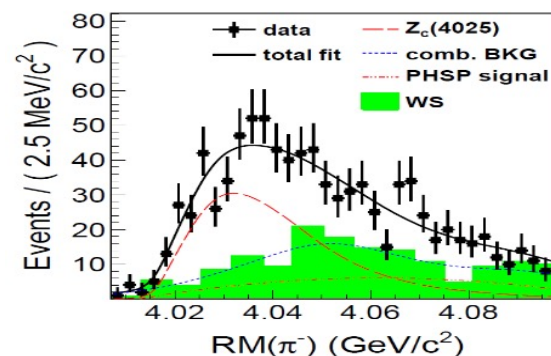
PRL115(2015)222002



$$e^+e^- \rightarrow \pi^-(D^*\bar{D}^*)^+$$

$Z_c(4025)^+$

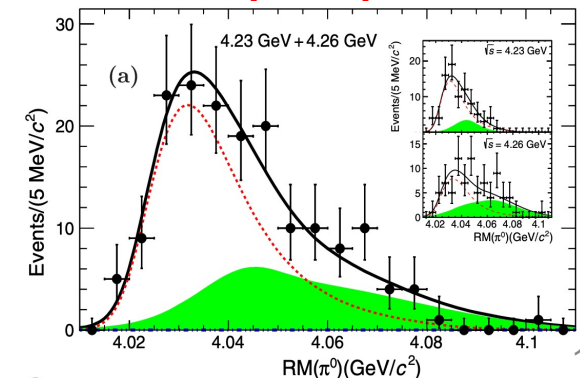
PRL112(2014)132001



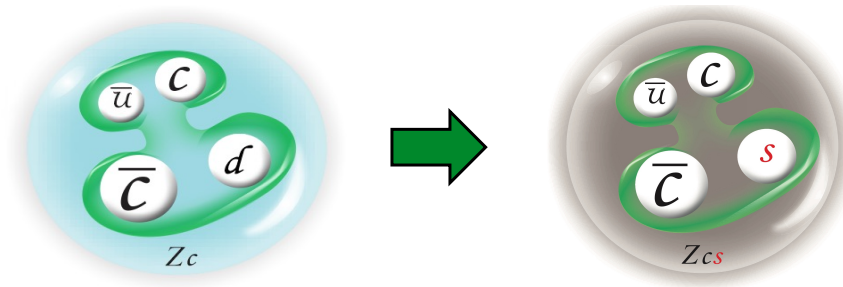
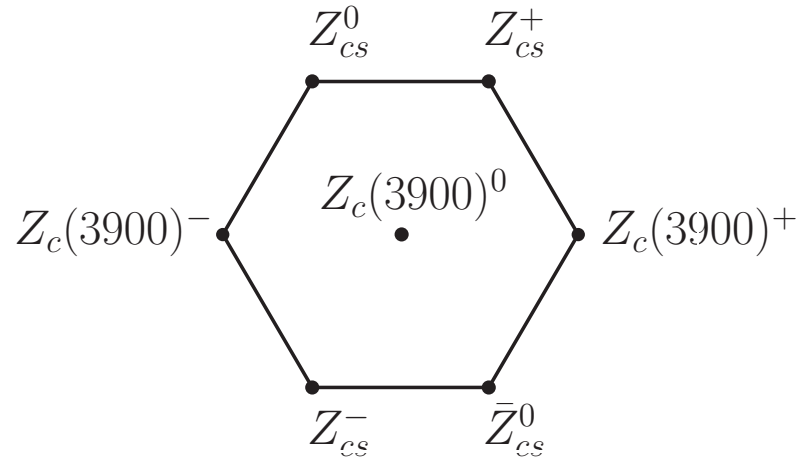
$$e^+e^- \rightarrow \pi^0(D^*\bar{D}^*)^0$$

$Z_c(4025)^0$

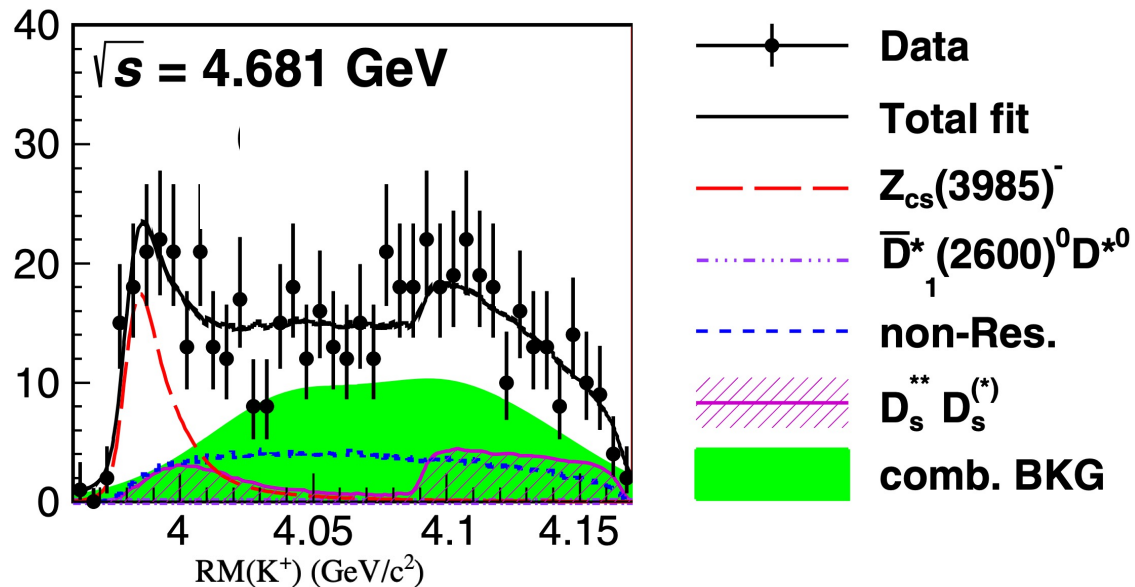
PRL115(2015)182002



Observation of $Z_{cs}(3985)$: SU(3) partner of Z_c

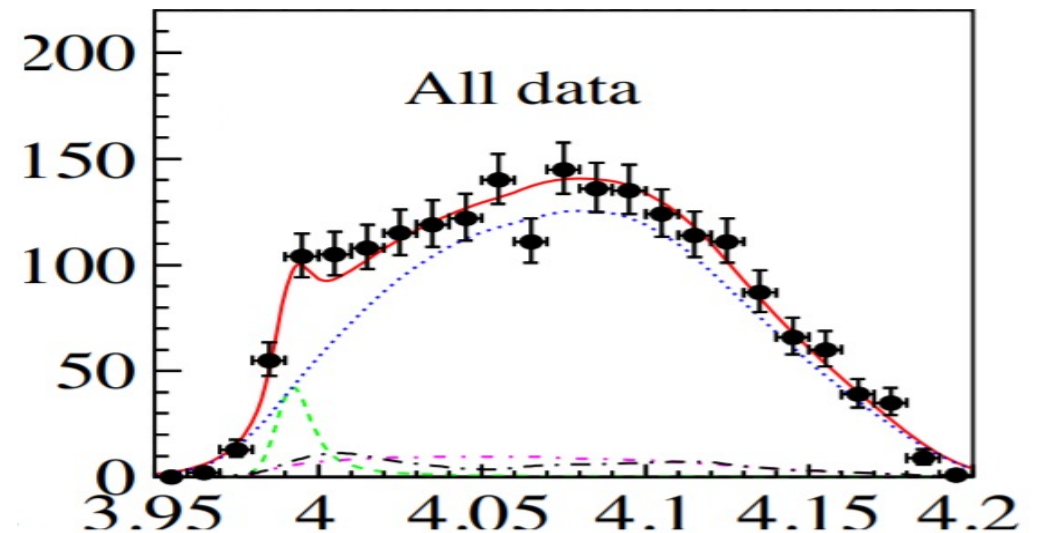


$$e^+e^- \rightarrow K^+ (D_s^- D^{*0} + D_s^{*-} D^0)$$



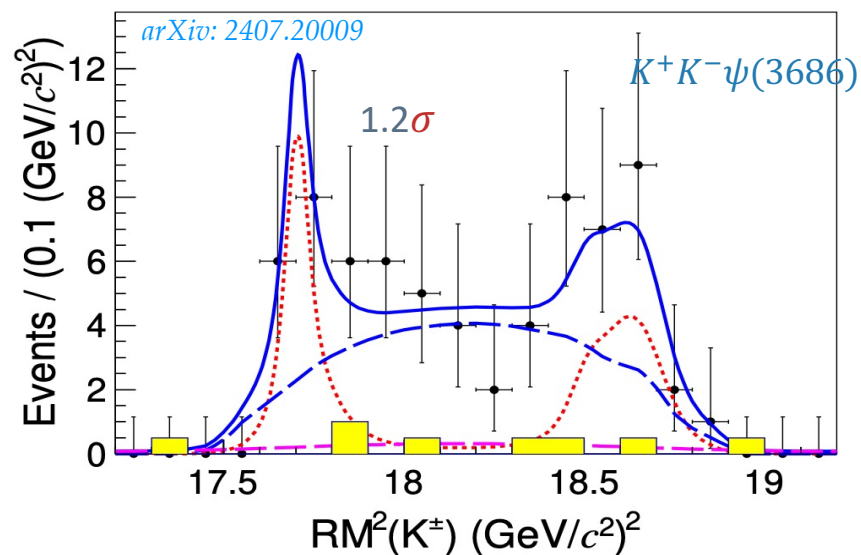
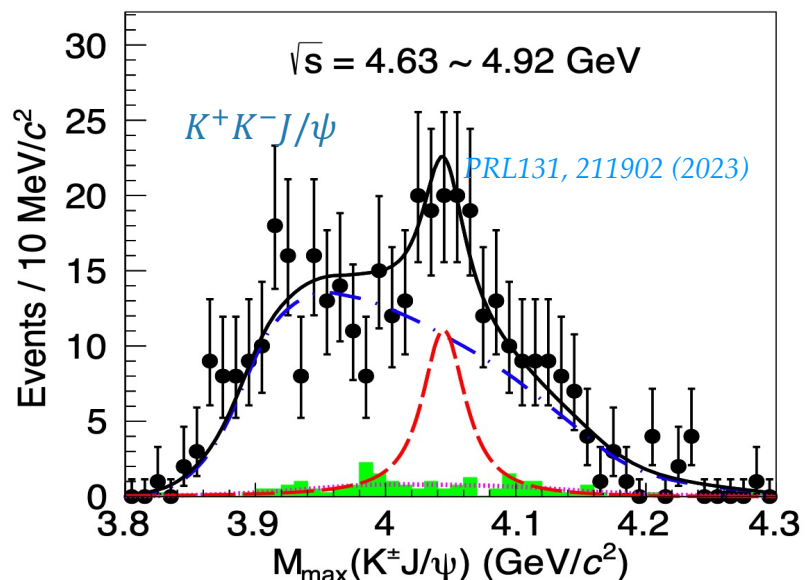
PRL126(2021)102001

$$e^+e^- \rightarrow K_s^0 (D_s^+ D^{*-} + D_s^{*+} D^-)$$



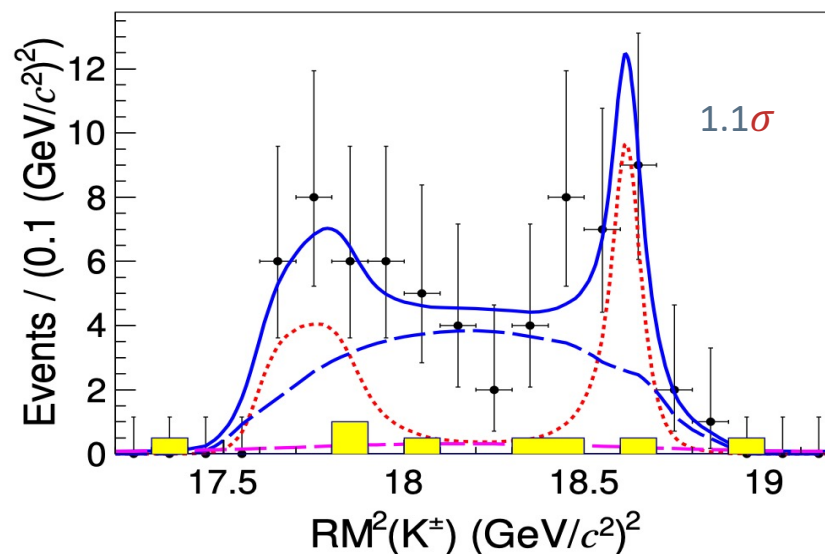
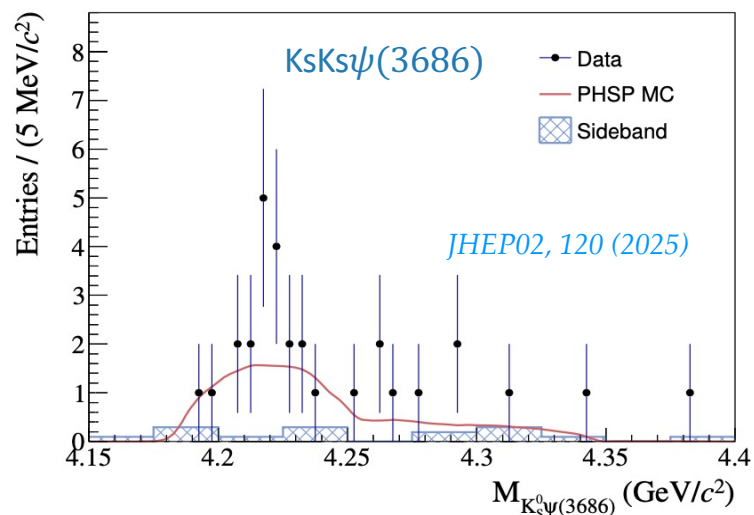
PRL129(2022)112003

Z_{cs} in $e^+e^- \rightarrow K\bar{K} + c\bar{c}$



$$M = 4208.4 \pm 3.1 \text{ MeV}/c^2$$

$$\Gamma = 6.1 \pm 5.7 \text{ MeV}$$



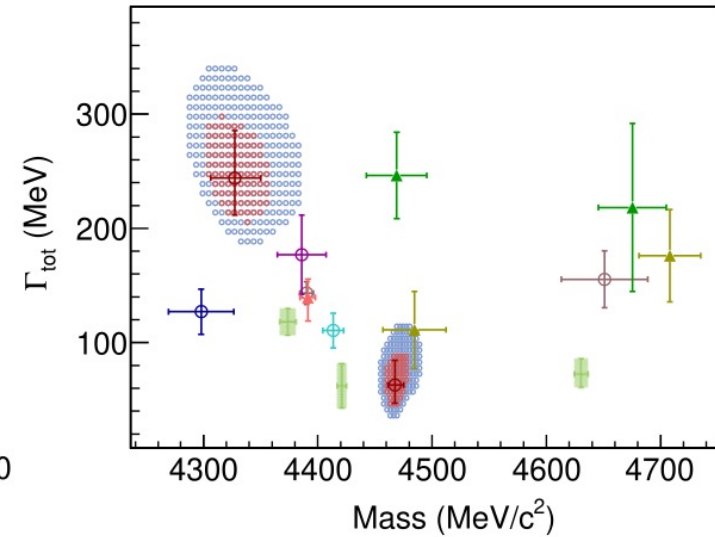
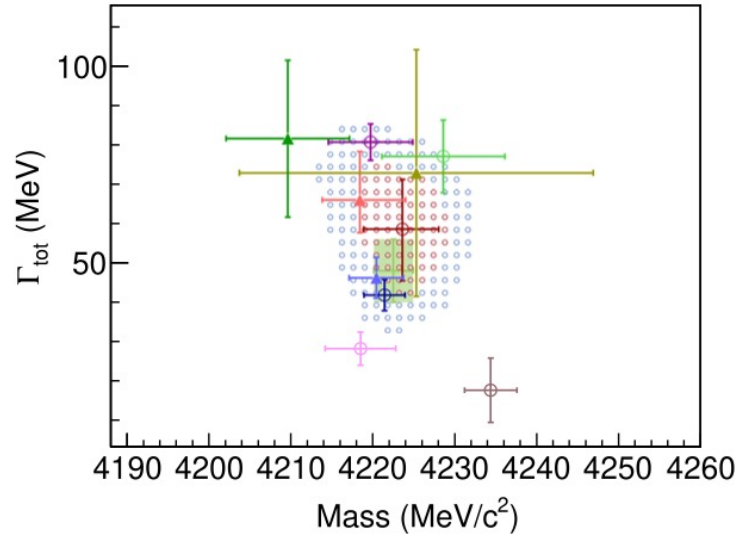
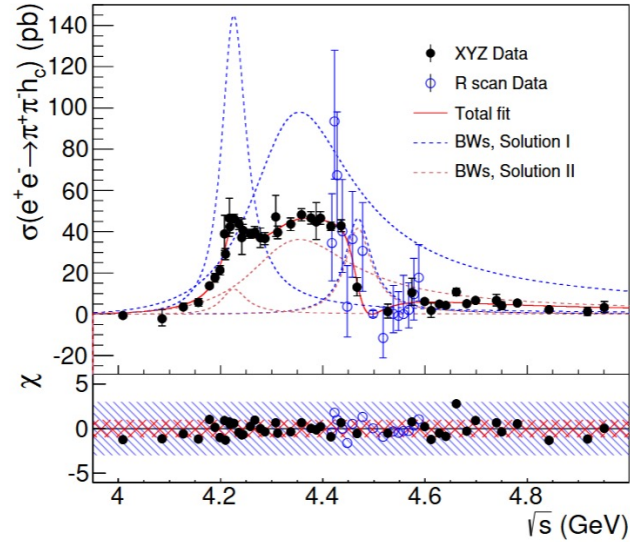
$$M = 4316.0 \pm 2.7 \text{ MeV}/c^2$$

$$\Gamma = 9.0 \pm 8.6 \text{ MeV}$$

High statistics needed !

Three Resonances in the Cross Section of $e^+ e^- \rightarrow \pi^+ \pi^- h_c$

[Phys. Rev. Lett. 135, 071901 \(2025\)](#)

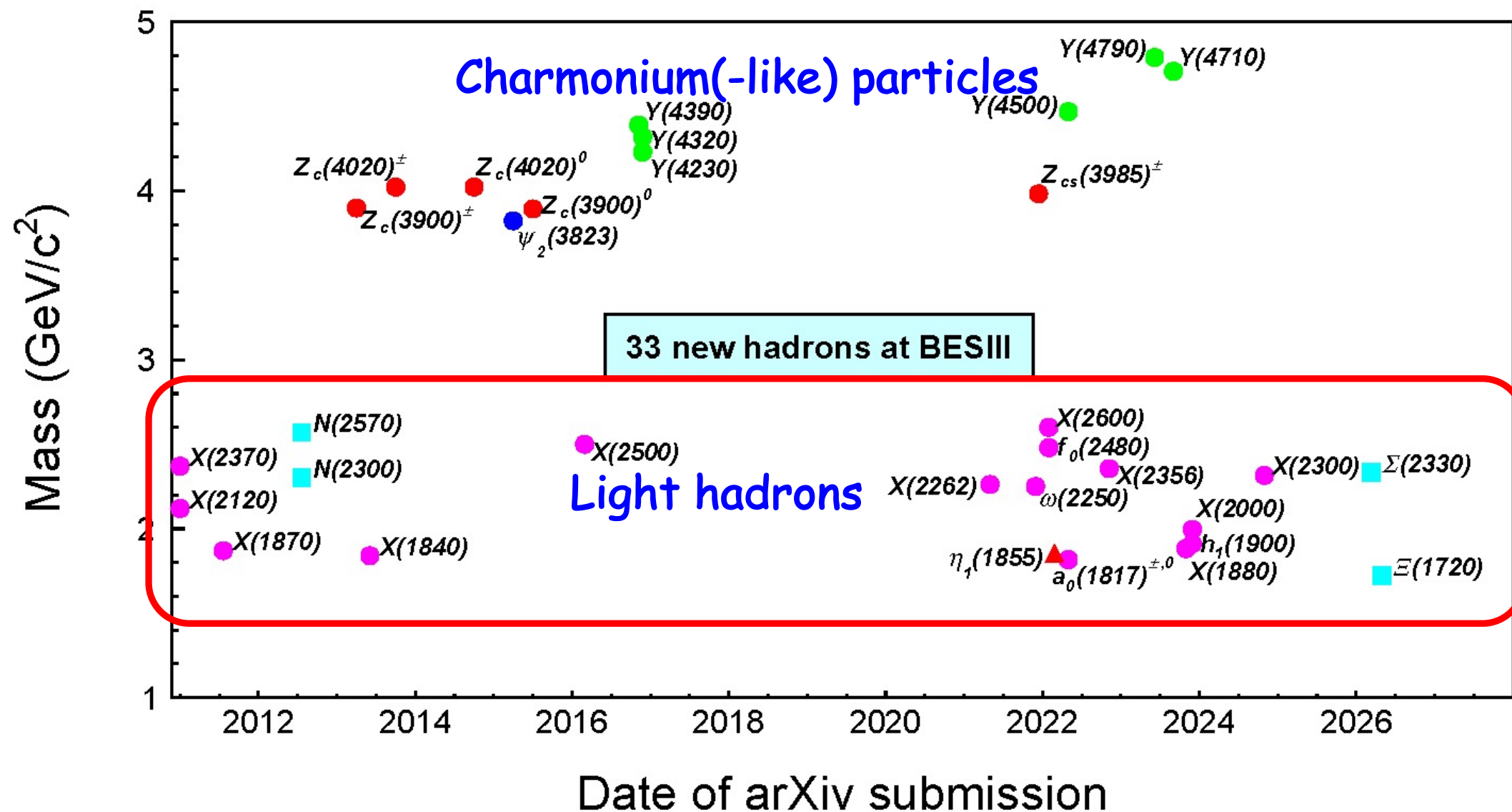


- ◆— $\pi^+\pi^-h_c$, this work
- 95.5% C.L., this work
- 68.3% C.L., this work
- ◆— $\pi^+\pi^-h_c$, Ref. [20]
- ◆— $\pi^+\pi^-J/\psi$
- ◆— $\pi^0Z_c^0$
- ◆— $\pi^+\pi^-\psi(3686)$
- ◆— $\omega\chi_{c0}$
- ◆— $\omega\chi_{c2}$
- ◆— $\pi^+D^0D^*$
- ◆— $\pi^+D^{*0}D^{*-}$
- ◆— $\eta J/\psi$
- ◆— K^+K^-J/ψ
- PDG

Parameter	R_1	R_2	R_3
M (MeV/ c^2)	$4223.6^{+3.6+2.6}_{-3.7-2.9}$	$4327.4^{+20.1+10.7}_{-18.8-9.3}$	$4467.4^{+7.2+3.2}_{-5.4-2.7}$
Γ (MeV)	$58.5^{+10.8+6.7}_{-11.4-6.5}$	$244.1^{+34.0+24.2}_{-27.1-18.3}$	$62.8^{+19.2+9.9}_{-14.4-7.0}$
$\Gamma_{ee} \cdot \mathcal{B}(R \rightarrow \pi^+\pi^-h_c)$ (eV)	$10.2^{+1.2+1.4}_{-1.5-1.4} (0.9^{+0.4+0.3}_{-0.4-0.2})$	$29.1^{+5.7+4.4}_{-3.9-3.4} (10.8^{+2.5+1.9}_{-1.8-1.5})$	$3.9^{+3.5+1.7}_{-1.7-0.5} (3.5^{+3.0+1.5}_{-1.6-0.7})$
ϕ (rad)	...	$3.6^{+0.1+0.1}_{-0.1-0.1} (0.7^{+0.3+0.2}_{-0.3-0.2})$	$0.7^{+0.3+0.1}_{-0.3-0.2} (-2.2^{+0.3+0.2}_{-0.3-0.1})$

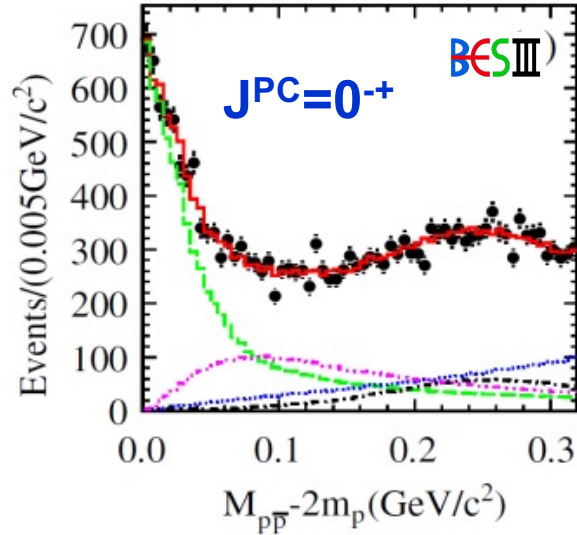
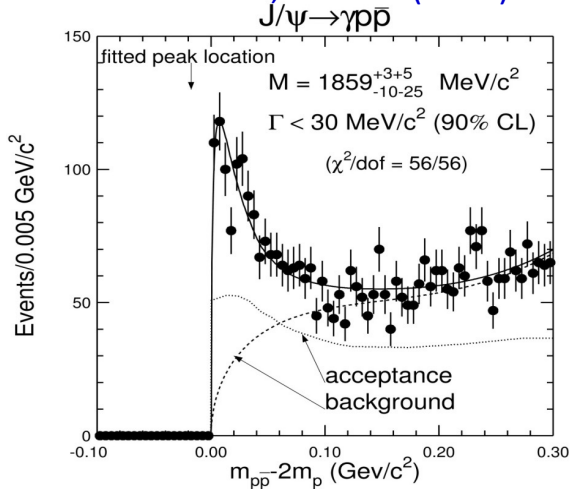
Cross section shapes, especially at higher energy region, continue to be quite difficult, and will require a coupled channel analysis

New resonant structures at BESIII

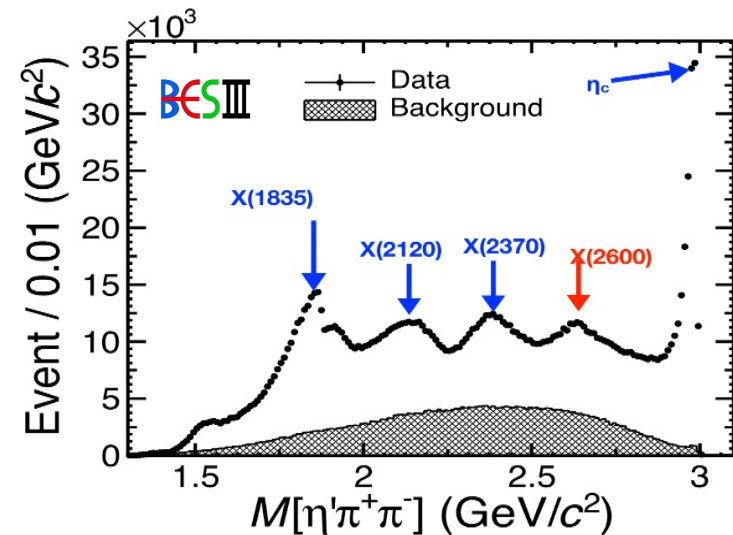
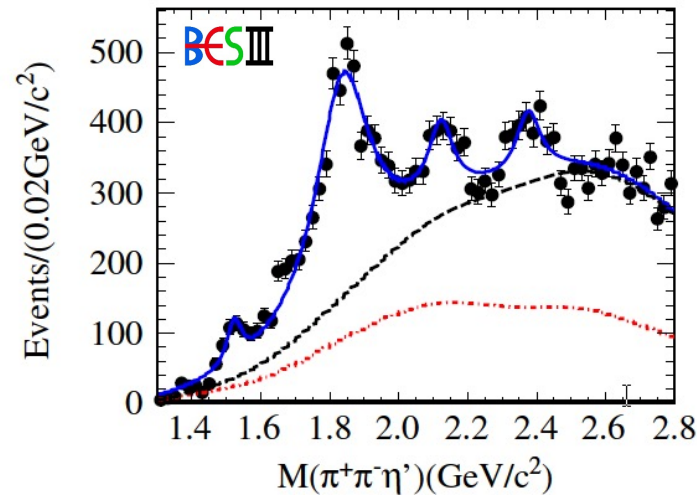
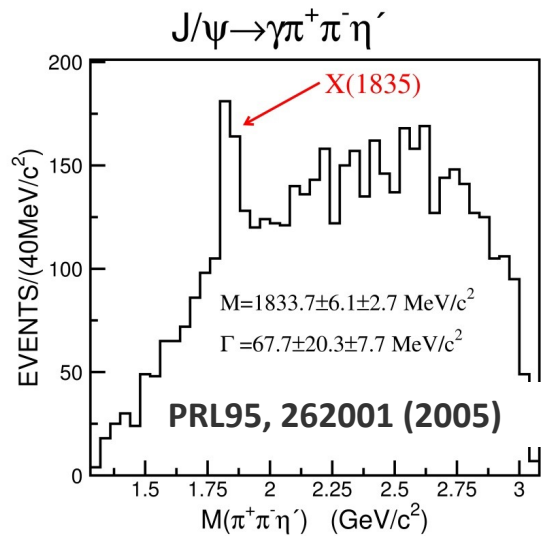


Observation of X(18??) at BESII-BESIII

PRL91, 022001 (2003)

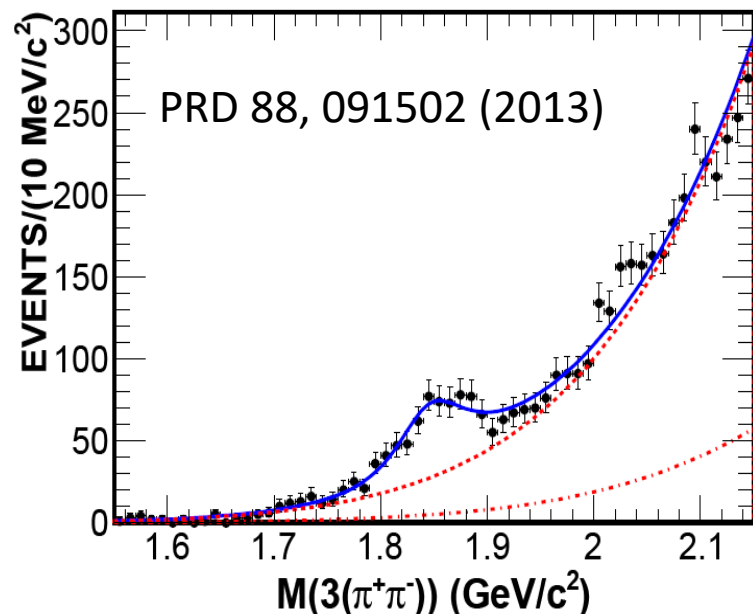


Are they the same state? Nature is still mysterious. It is crucial to understand their connections

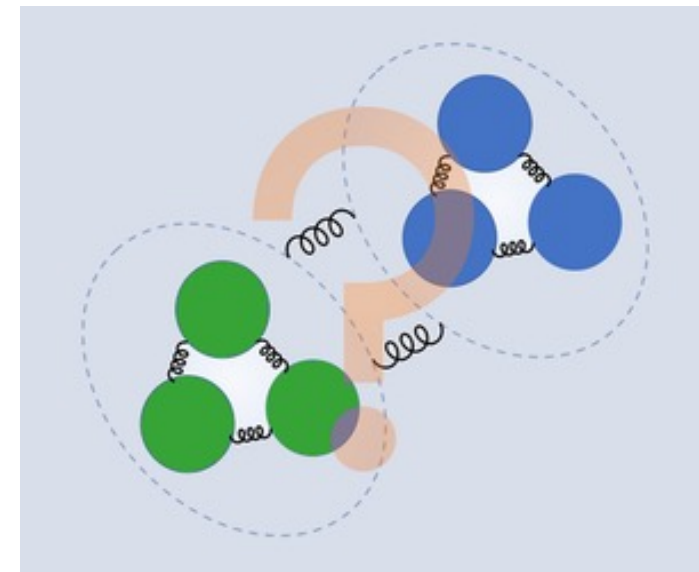
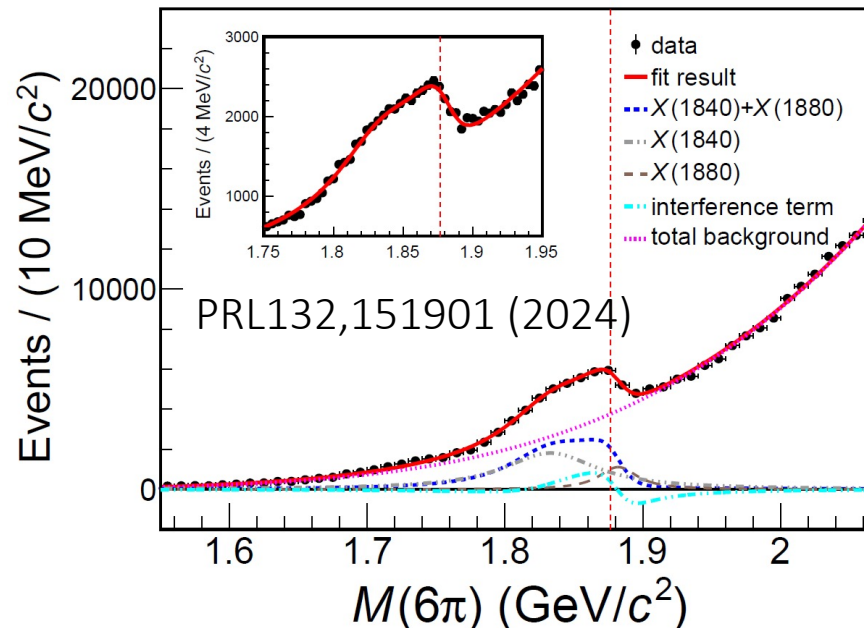


Observation of the anomalous structure around 1.84 GeV

$J/\psi \rightarrow \gamma 3(\pi^+\pi^-)$



$J/\psi \rightarrow \gamma 3(\pi^+\pi^-)$



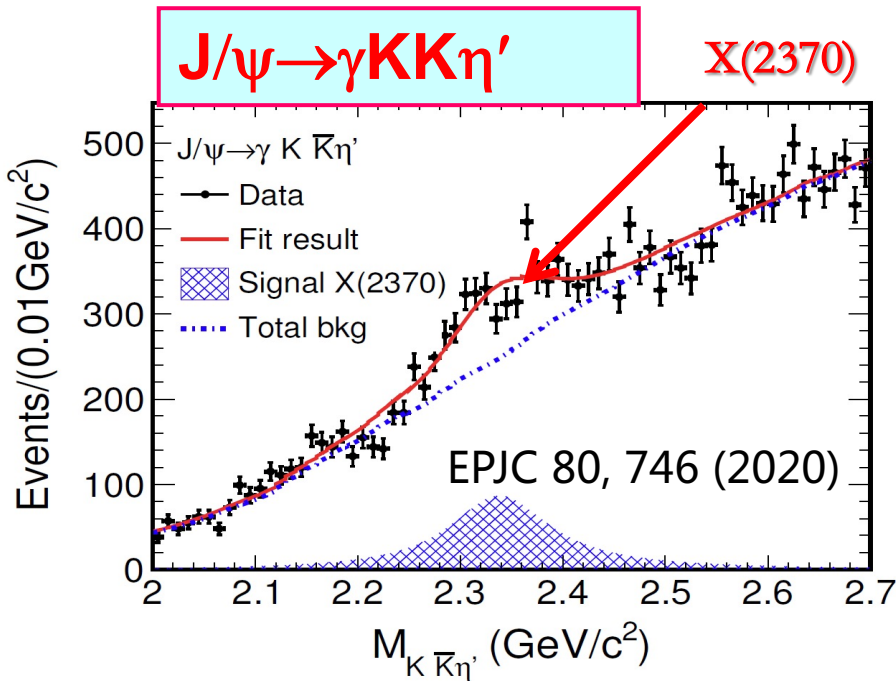
Resonance	M (MeV/c ²)	Γ (MeV/c ²)
X(1880)	$1882.1 \pm 1.7 \pm 0.7$	$30.7 \pm 5.5 \pm 2.4$
X(1830)	$1832.5 \pm 3.1 \pm 2.5$	$80.7 \pm 5.2 \pm 7.7$

Featured in Physics:
"Evidence of a new subatomic particle"

Narrow state around $N\bar{N}$ -bar threshold !

Pseudoscalars above 2 GeV: X(2370)

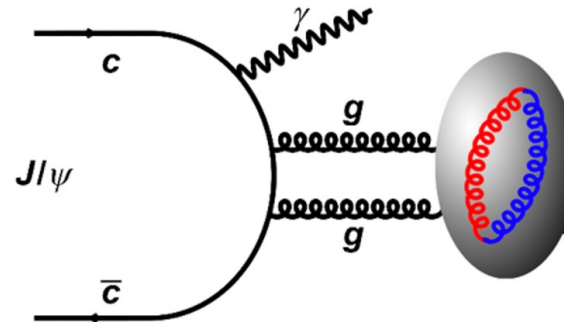
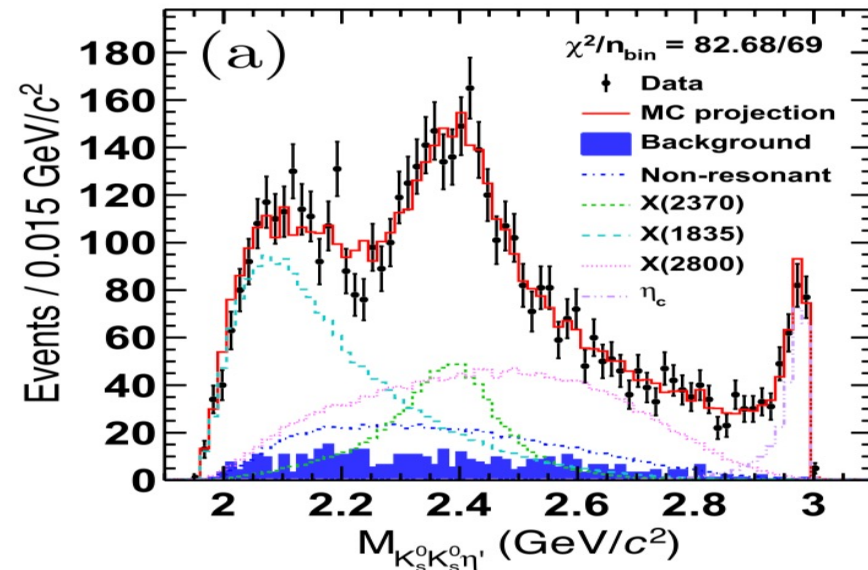
new glueball candidates ?



6 Glueballs and light hybrid mesons

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6.1.2 Scalar glueballs and the $f_0(1500)/f_0(1710)$	95
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6.1.4 Pseudoscalar glueballs and the X(2370).	101

Rept.Prog.Phys. 86 (2023) 2, 026201



BESIII实验发现胶球存在的迹象

Physics \ General Physics

Editors' notes

Physics \ Quantum Physics

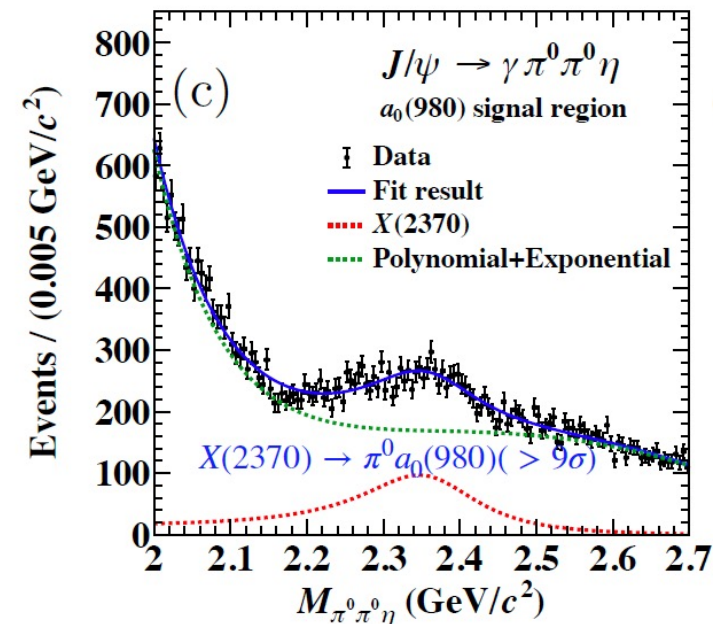
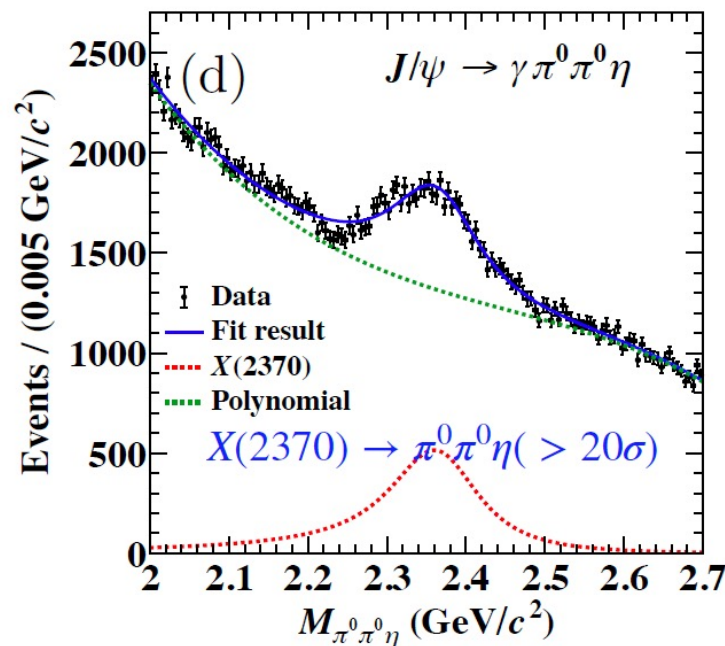
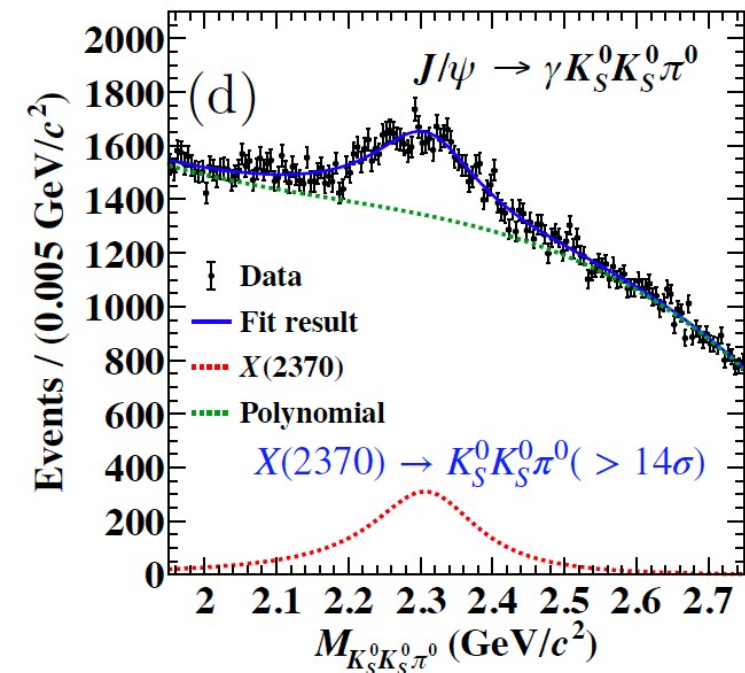
Possible evidence of glueballs found during Beijing Spectrometer III experiments

by Bob Yirka , Phys.org

REPORT

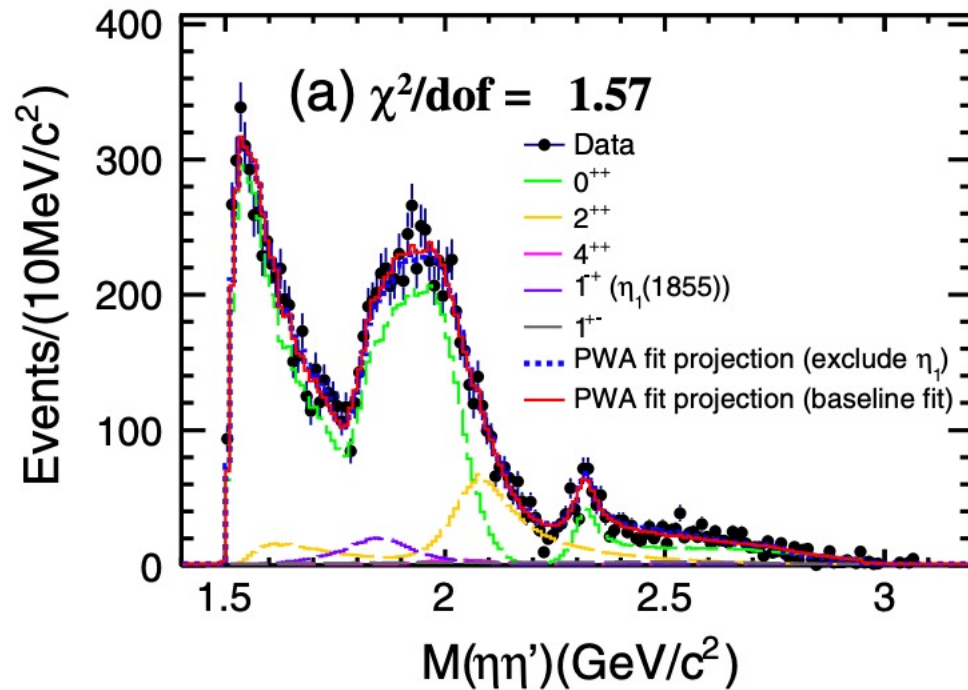
Observation of new decay modes of X(2370)

arXiv:2605.26495, submitted to CPC



New decay modes $X(2370) \rightarrow \eta' \pi \pi$, $\eta' K K$, $K_S K_S \eta$, $K_S K_S \pi^0$, $\eta \pi \pi$, $a_0(980) \pi^0$

Observation of $\eta_1(1855)$ in $J/\psi \rightarrow \gamma \eta \eta'$

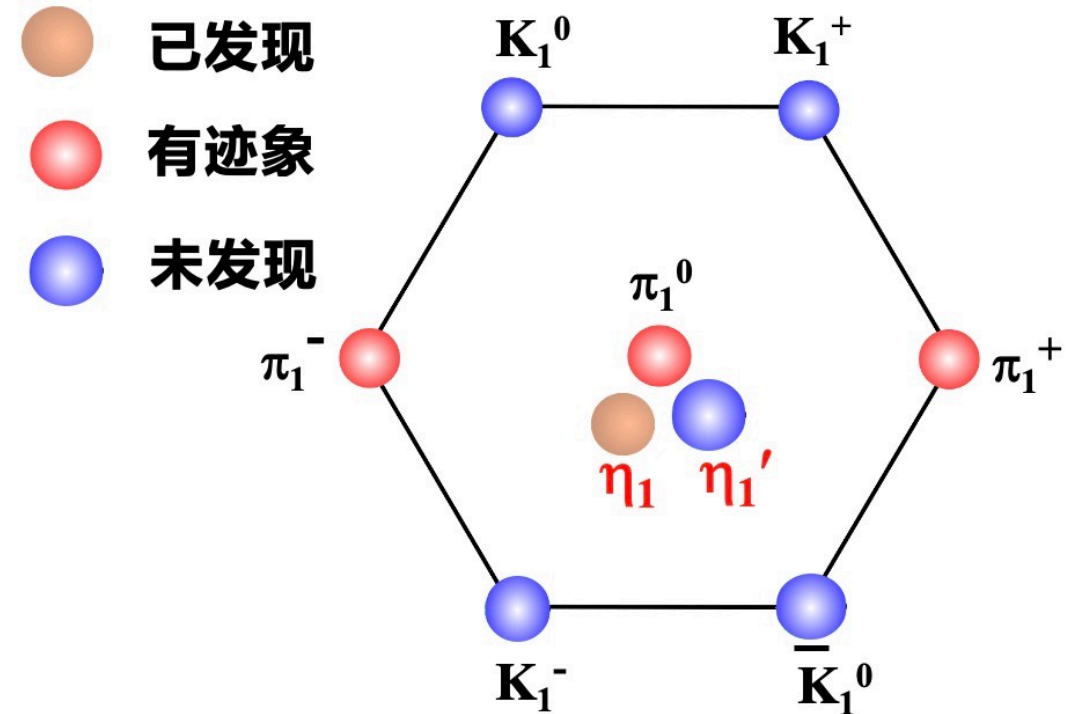


PRL129, 192002(2022)

Isoscalar state with $J^{PC}=1^{-+}$

$$M = 1855 \pm 9_{-1}^{+6} \text{ MeV}/c^2$$

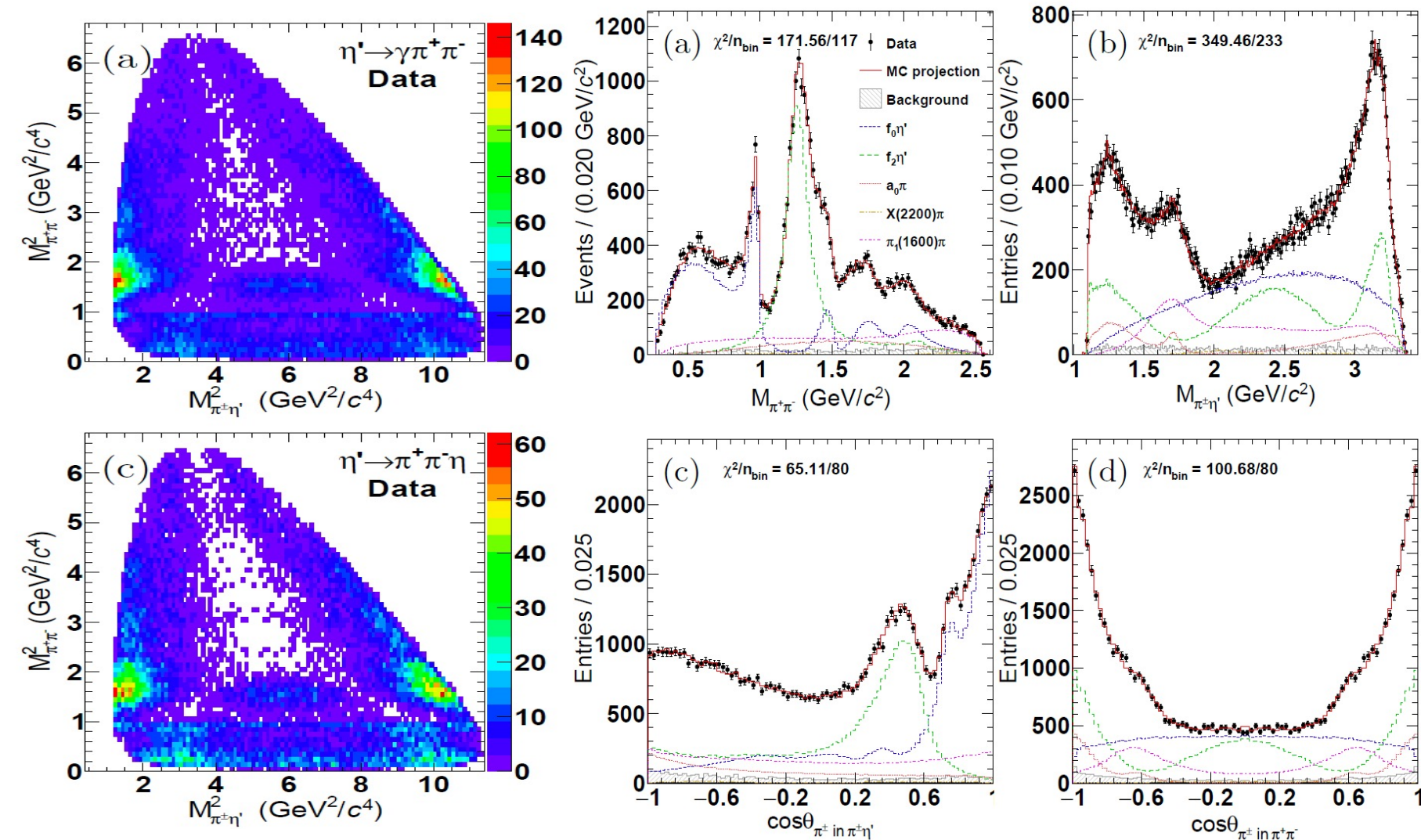
$$\Gamma = 188 \pm 18_{-8}^{+3} \text{ MeV}$$



Critical to establish the 1^{-+} hybrid nonet !

Observation of $\pi_1(1600)$ in $\chi_{c1} \rightarrow \pi^+\pi^-\eta'$

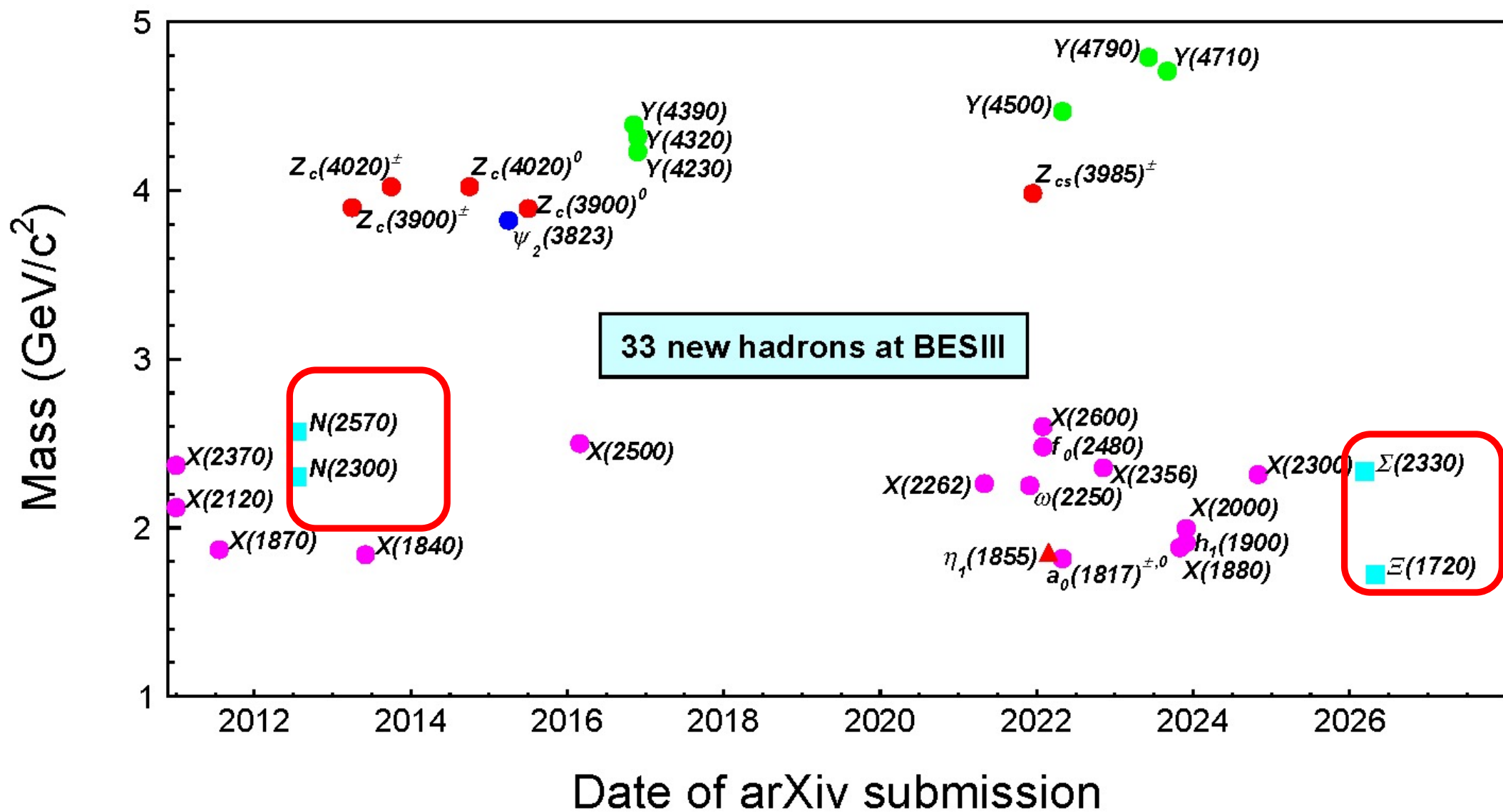
arXiv:2604.12524 submitted to PRL



- $\pi_1(1600)$ observed $>21\sigma$
- Isospin = 1

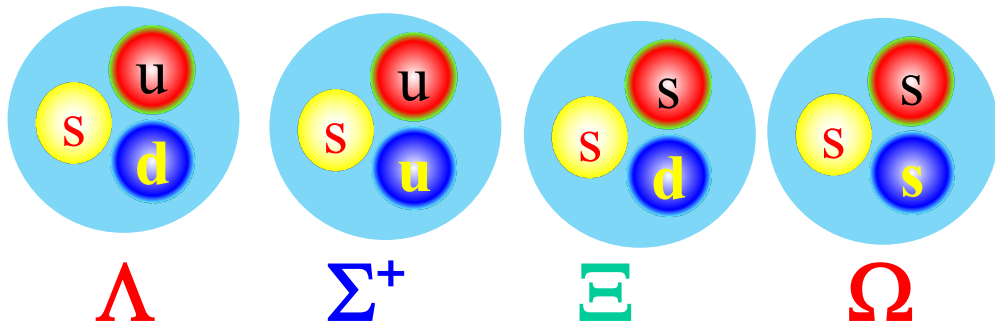
$$M = 1828 \pm 8^{+11}_{-33} \text{ MeV}/c^2,$$

$$\Gamma = 638 \pm 26^{+35}_{-86} \text{ MeV}$$



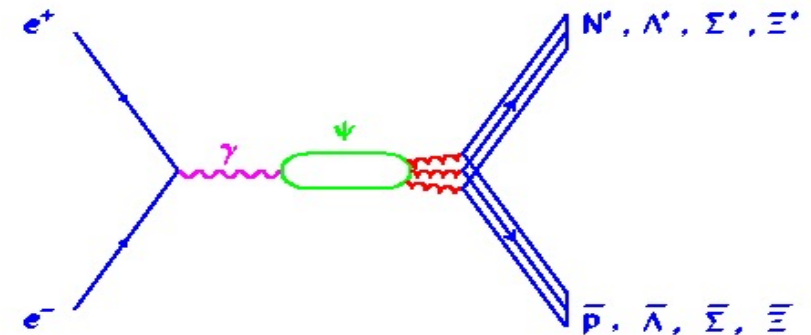
Hyperon status

J^P	(D, L_N^P)	S	Octet members				Singlets
$1/2^+$	$(56, 0_0^+)$	$1/2$	$N(939)$	$\Lambda(1116)$	$\Sigma(1193)$	$\Xi(1318)$	
$1/2^+$	$(56, 0_2^+)$	$1/2$	$N(1440)$	$\Lambda(1600)$	$\Sigma(1660)$		
$1/2^-$	$(70, 1_1^-)$	$1/2$	$N(1535)$	$\Lambda(1670)$	$\Sigma(1620)$	$\Xi(1620)$	$\Lambda(1405)$
					$\Sigma(1560)^\dagger$		
$3/2^-$	$(70, 1_1^-)$	$1/2$	$N(1520)$	$\Lambda(1690)$	$\Sigma(1670)$	$\Xi(1820)$	$\Lambda(1520)$
$1/2^-$	$(70, 1_1^-)$	$3/2$	$N(1650)$	$\Lambda(1800)$	$\Sigma(1750)$	$\Xi(1690)$	
					$\Sigma(1620)^\dagger$		
$3/2^-$	$(70, 1_1^-)$	$3/2$	$N(1700)$	$\Lambda(?)$	$\Sigma(1940)^\dagger$	$\Xi(?)$	
$5/2^-$	$(70, 1_1^-)$	$3/2$	$N(1675)$	$\Lambda(1830)$	$\Sigma(1775)$	$\Xi(1950)^\dagger$	
$1/2^+$	$(70, 0_2^+)$	$1/2$	$N(1710)$	$\Lambda(1810)$	$\Sigma(1880)$	$\Xi(?)$	$\Lambda(1810)^\dagger$
$3/2^+$	$(56, 2_2^+)$	$1/2$	$N(1720)$	$\Lambda(1890)$	$\Sigma(?)$	$\Xi(?)$	
$5/2^+$	$(56, 2_2^+)$	$1/2$	$N(1680)$	$\Lambda(1820)$	$\Sigma(1915)$	$\Xi(2030)$	
$7/2^-$	$(70, 3_3^-)$	$1/2$	$N(2190)$	$\Lambda(?)$	$\Sigma(?)$	$\Xi(?)$	$\Lambda(2100)$
$9/2^-$	$(70, 3_3^-)$	$3/2$	$N(2250)$	$\Lambda(?)$	$\Sigma(?)$	$\Xi(?)$	
$9/2^+$	$(56, 4_4^+)$	$1/2$	$N(2220)$	$\Lambda(2350)$	$\Sigma(?)$	$\Xi(?)$	



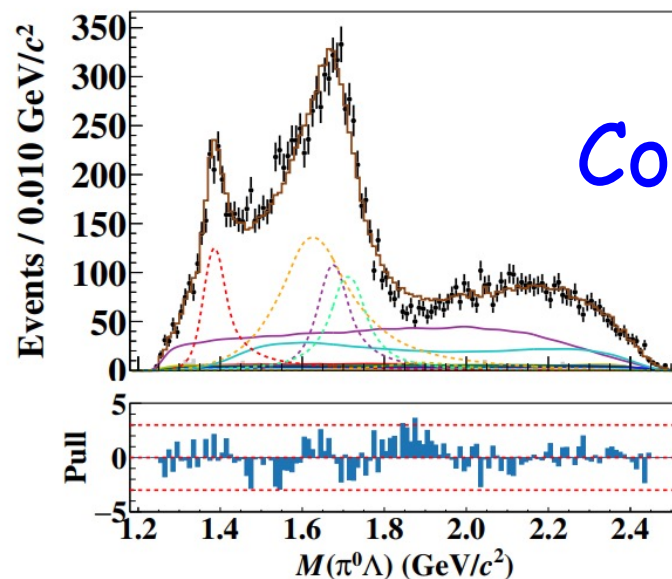
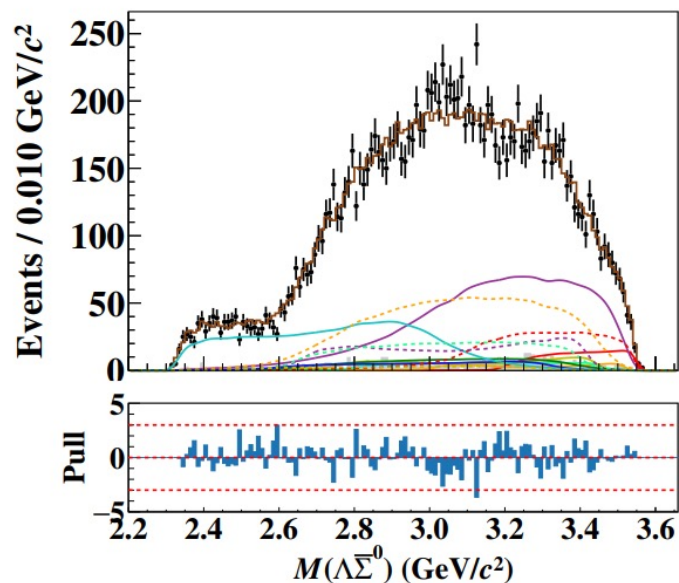
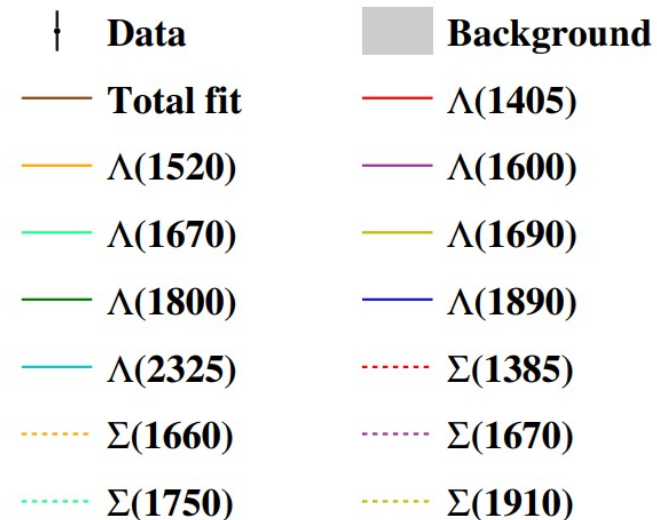
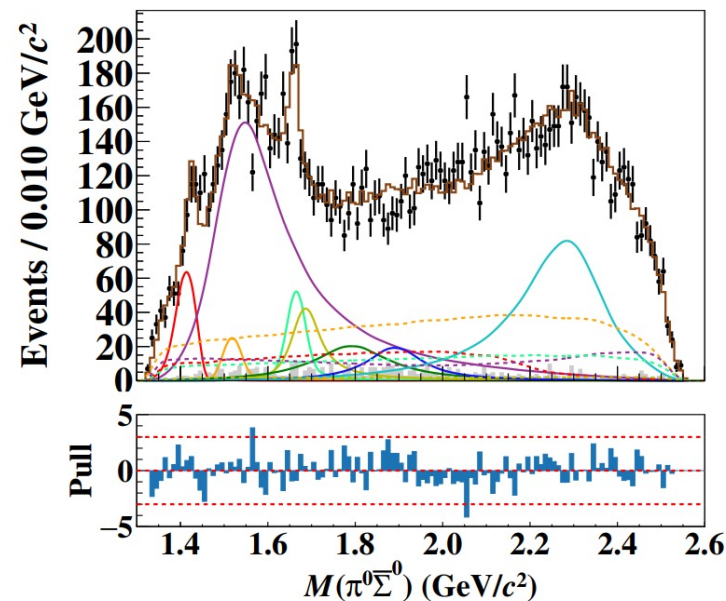
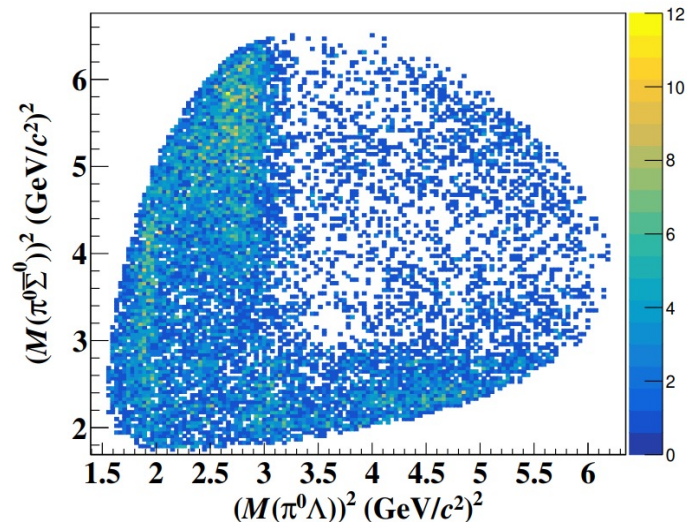
J^P	(D, L_N^P)	S	Decuplet members			
$3/2^+$	$(56, 0_0^+)$	$3/2$	$\Delta(1232)$	$\Sigma(1385)$	$\Xi(1530)$	$\Omega(1672)$
$3/2^+$	$(56, 0_2^+)$	$3/2$	$\Delta(1600)$	$\Sigma(1690)^\dagger$	$\Xi(?)$	$\Omega(?)$
$1/2^-$	$(70, 1_1^-)$	$1/2$	$\Delta(1620)$	$\Sigma(1750)^\dagger$	$\Xi(?)$	$\Omega(?)$
$3/2^-$	$(70, 1_1^-)$	$1/2$	$\Delta(1700)$	$\Sigma(?)$	$\Xi(?)$	$\Omega(2012)$
$5/2^+$	$(56, 2_2^+)$	$3/2$	$\Delta(1905)$	$\Sigma(?)$	$\Xi(?)$	$\Omega(?)$
$7/2^+$	$(56, 2_2^+)$	$3/2$	$\Delta(1950)$	$\Sigma(2030)$	$\Xi(?)$	$\Omega(?)$
$11/2^+$	$(56, 4_4^+)$	$3/2$	$\Delta(2420)$	$\Sigma(?)$	$\Xi(?)$	$\Omega(?)$

$$J/\Psi \rightarrow \bar{B} B M \Rightarrow N^*, \Lambda^*, \Sigma^*, \Xi^*$$



Λ^* and Σ^* in $\psi(2S) \rightarrow \pi^0 \Lambda \bar{\Sigma}$

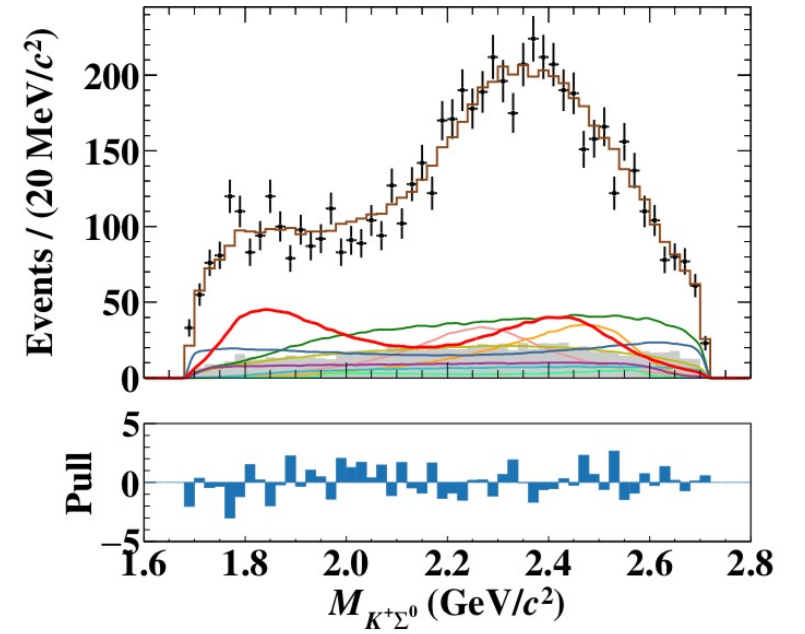
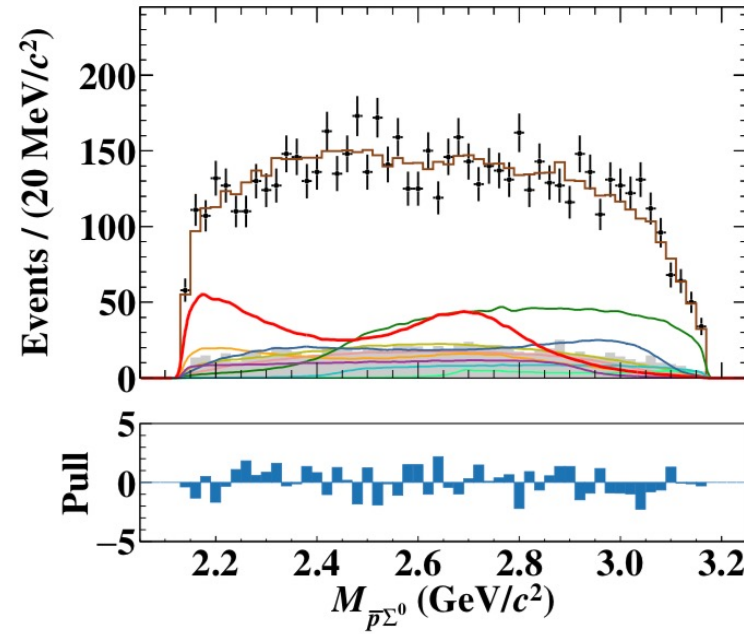
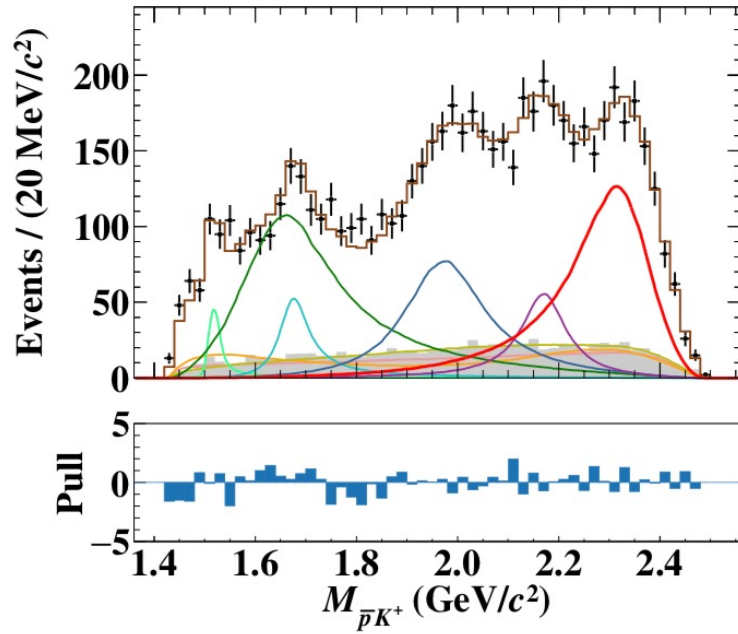
JHEP 02(2025), 212



Confirmation of the $\Lambda(2325)$!

Σ^* and Ξ^* in $\psi(2S) \rightarrow p K \bar{\Sigma}$

arXiv:2602.11501, submitted to PRL

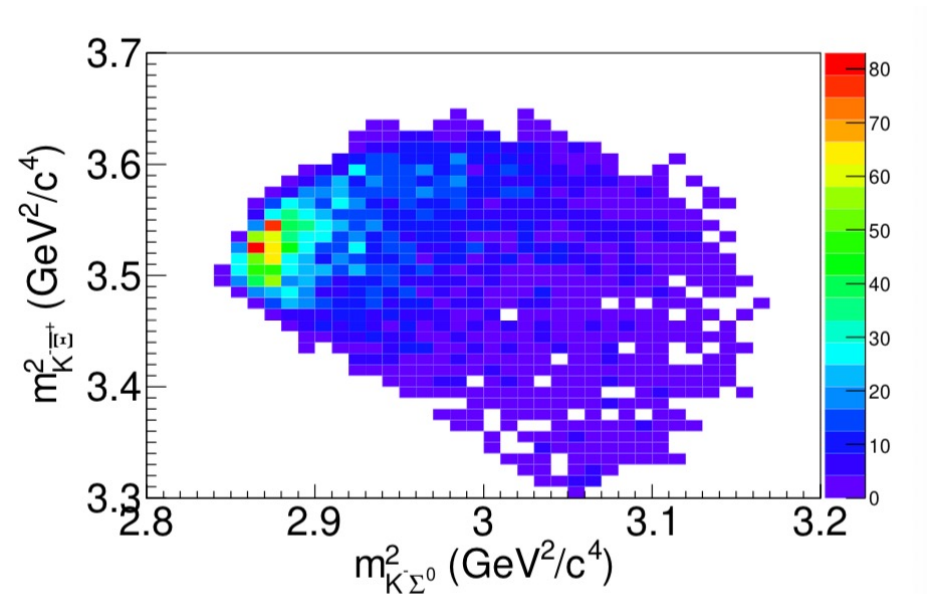
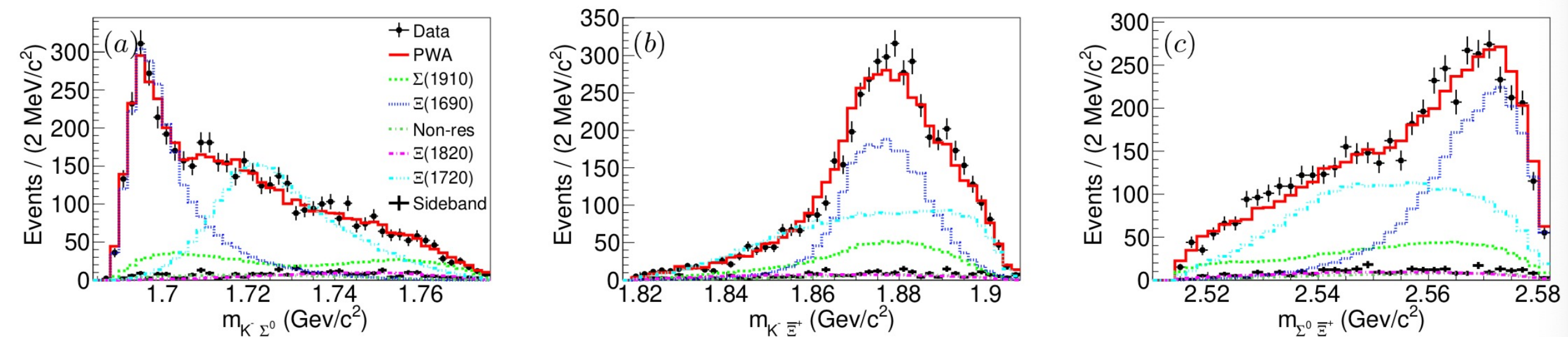


Observation of a new excited state $\Sigma(2330)$!

$M=2334.7 \pm 7.9 \pm 16.0$ MeV/c², $\Gamma= 206.3 \pm 9.5 \pm 18.4$ MeV

Σ^* and Ξ^* in $J/\psi \rightarrow K \Sigma \Xi$

arXiv:2604.27028, submitted to PRL

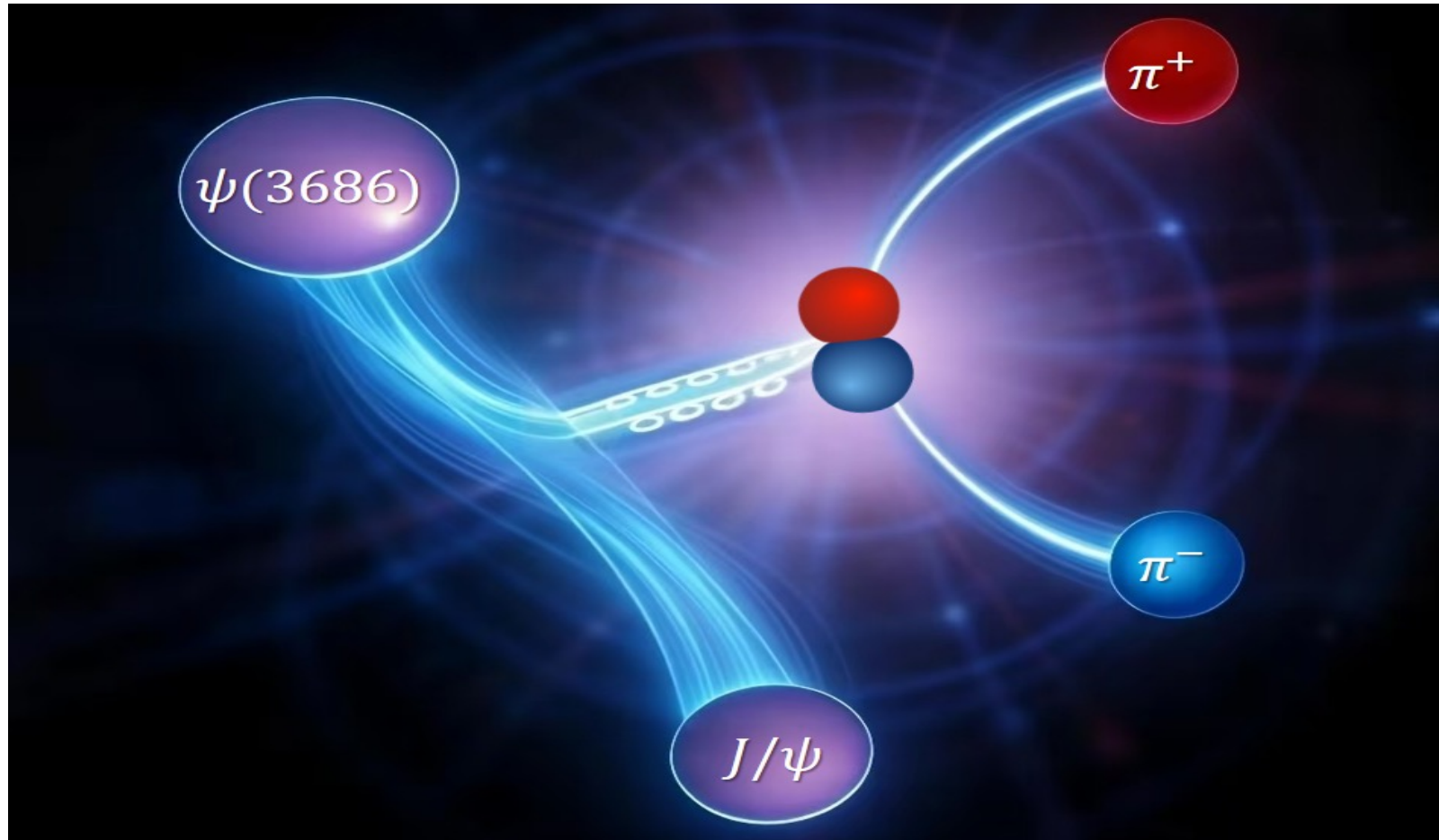


Observation of a new $\Xi(1720)$!

$$M = 1721.0 \pm 5.2 \pm 3.4 \text{ MeV}/c^2$$

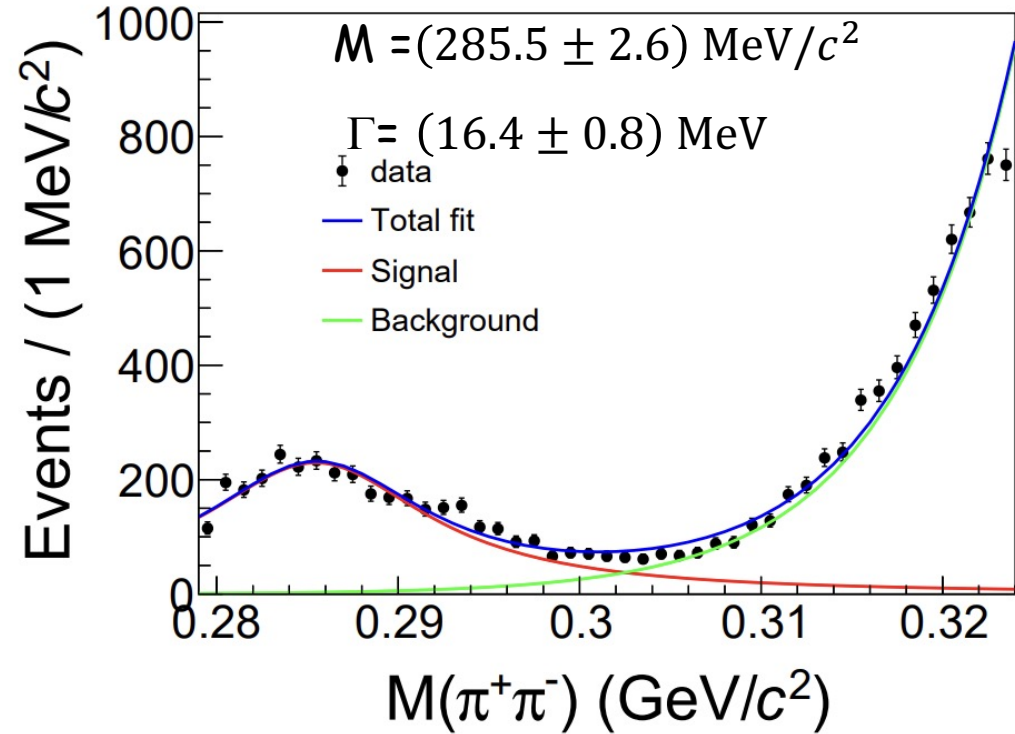
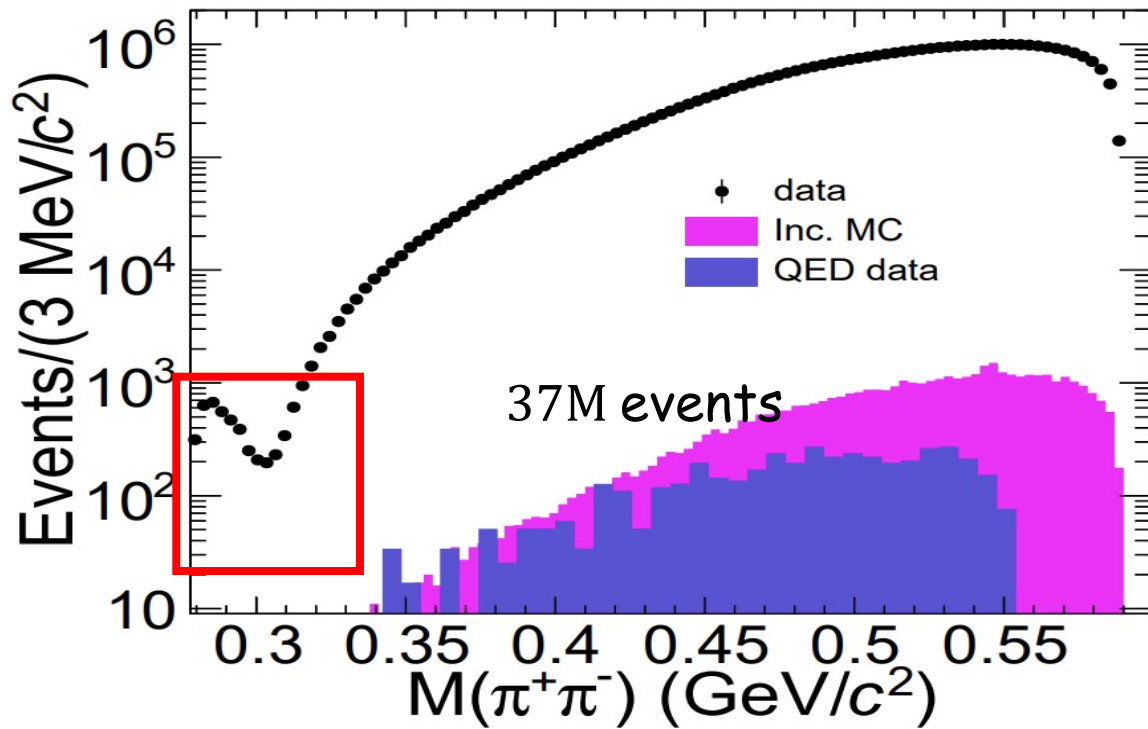
$$\Gamma = 31.3 \pm 18.3 \pm 15.4 \text{ MeV}$$

Precision Charmonium Decay Dynamics



Precision study of $\psi(3686) \rightarrow \pi^+ \pi^- J/\psi$ decay dynamics

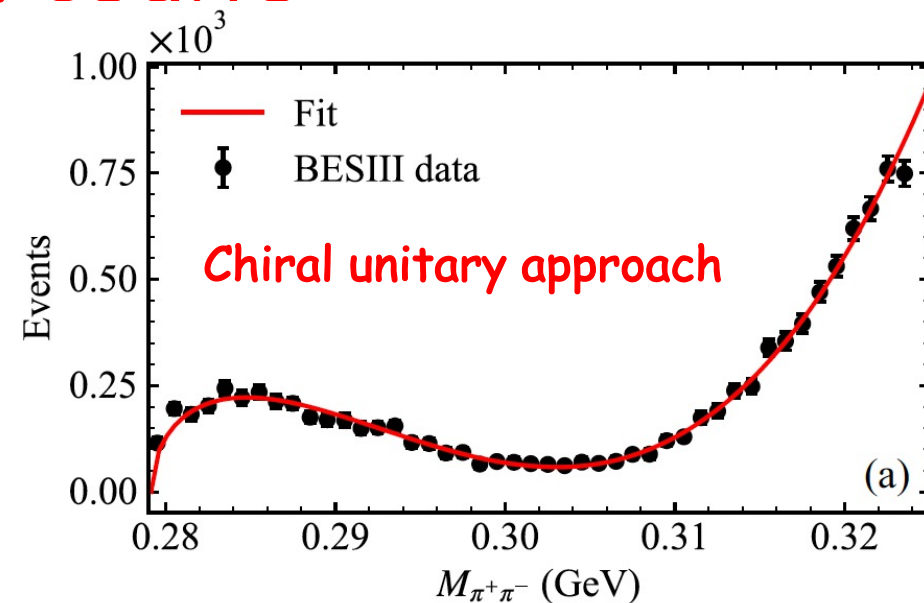
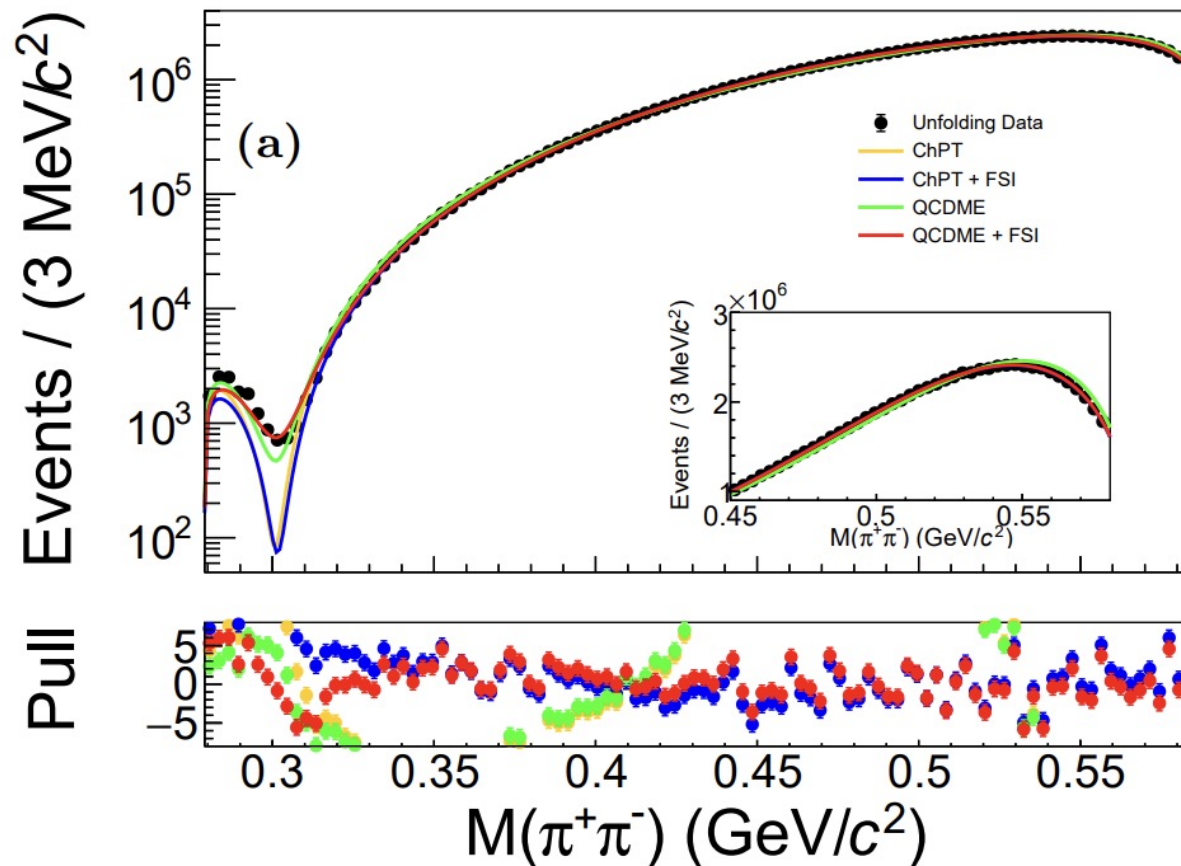
PRL136,141902(2026)



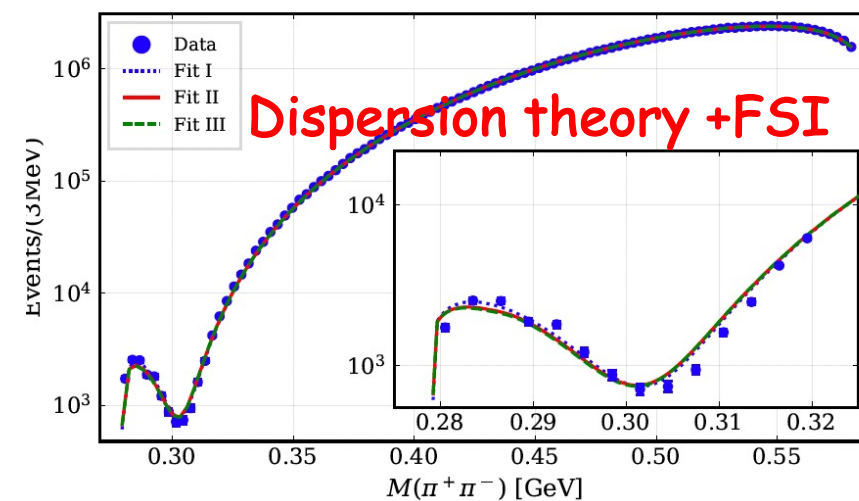
Clear $\pi^+ \pi^-$ threshold enhancement

Resonance-like hypothesis ($\pi^+ \pi^-$ atom ?)

QCDME (ChPT)+FSI: Fitting results



ZY Wang, Z Liu, X Liu PRD 113, L031502 (2026)



YH Chen, XK Dong, FK Guo .., PRD 113, 054018 (2026)

- FSI is necessary for high mass spectrum
- QCDME : $\psi(3686)$ is the mixture of S-D wave!
- Chiral symmetry provide a reasonable description

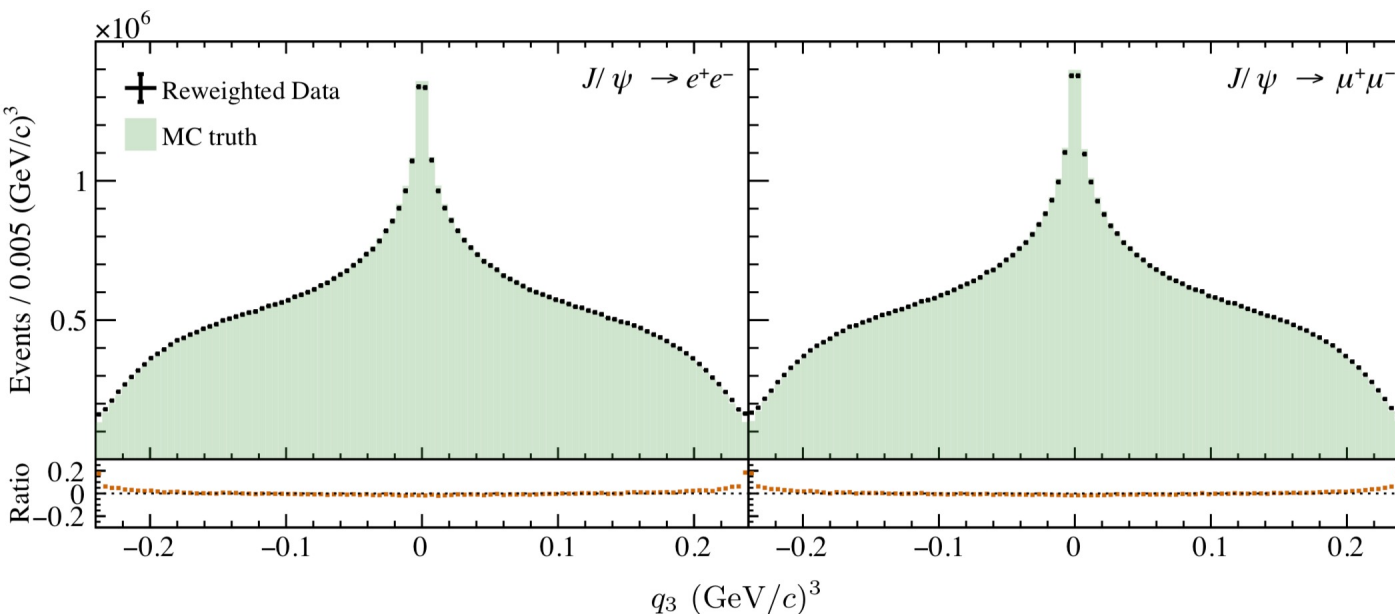
Test Chromo-EDM of charm quark $\psi(3686) \rightarrow \pi^+ \pi^- J/\psi$

PRL136,231903(2026)

CP observable:

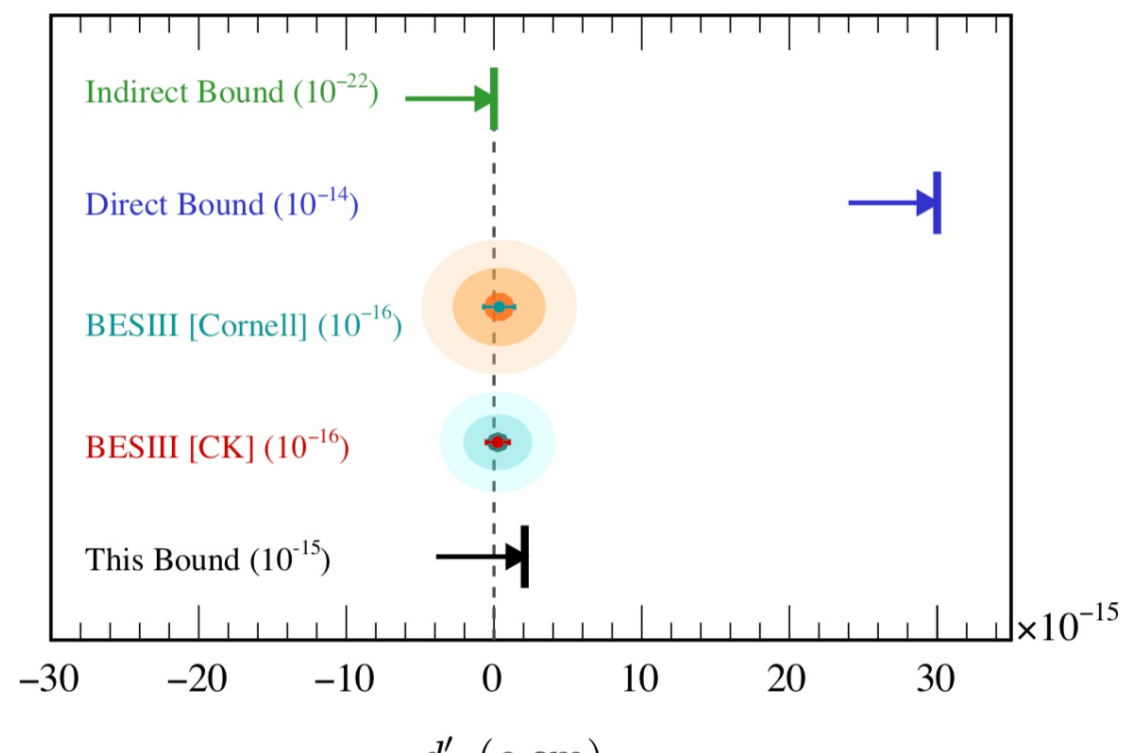
$$q_3 \equiv \vec{p}_{e^+} \cdot (\vec{p}_{\pi^+} - \vec{p}_{\pi^-}) \vec{p}_{e^+} \cdot \frac{\vec{p}_{\pi^+} \times \vec{p}_{\pi^-}}{|\vec{p}_{\pi^+} \times \vec{p}_{\pi^-}|}$$

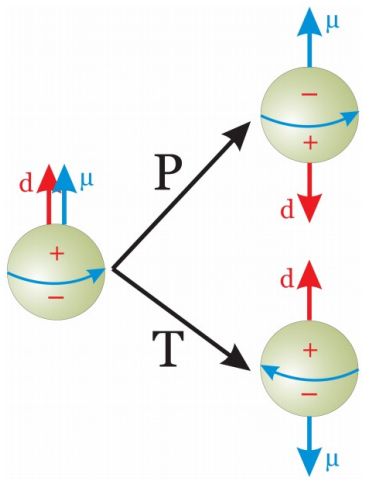
YP Kuang, JP Ma, et al Phys.Rev.D 85 (2012) 114010



Phys. Rev. Lett. 136, 231903 (2026)

Parameter	$J/\psi \rightarrow e^+ e^-$	$J/\psi \rightarrow \mu^+ \mu^-$
$A_{CP} (\times 10^{-4})$	$3.3 \pm 2.9 \pm 0.4$	$-1.2 \pm 2.4 \pm 0.1$
$\langle A_{CP} \rangle (\times 10^{-4})$	$0.6 \pm 1.8 \pm 0.1$	
$d'_c [\text{CK}] (e \cdot \text{cm})$	$(2.6 \pm 7.8 \pm 0.4 \pm 0.6) \times 10^{-16}$	
$d'_c [\text{Cornell}] (e \cdot \text{cm})$	$(3.5 \pm 10.5 \pm 0.6 \pm 0.5) \times 10^{-16}$	
$ d'_c (e \cdot \text{cm})$	$< 2.1 \times 10^{-15}$	





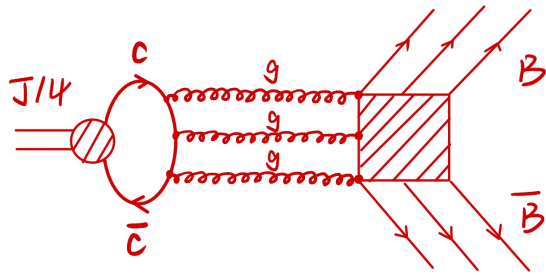
Searching for hyperon EDM at BESIII

X.G. He, J.P. Ma, Phys. Lett. B 839(2023)137834

X.G. He, J.P. Ma, B. McKellar, Phys. Rev. D 47 (1993) R1744-R1746

Detailed dynamics in J/ψ decay to hyperon pair, have been studied:

$$\mathcal{A} = \epsilon_\mu(\lambda) \bar{u}(\lambda_1) \left(\mathbf{F}_V \gamma^\mu + \frac{i}{2M_\Lambda} \sigma^{\mu\nu} q_\nu \mathbf{H}_\sigma + \gamma^\mu \gamma^5 \mathbf{F}_A + \sigma^{\mu\nu} \gamma^5 q_\nu \mathbf{H}_T \right) v(\lambda_2)$$

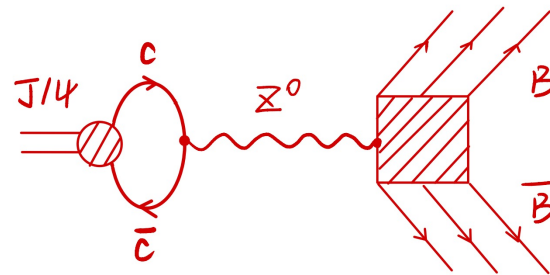


Dominant contribution

[arXiv:hep-ph/0412158](https://arxiv.org/abs/hep-ph/0412158)

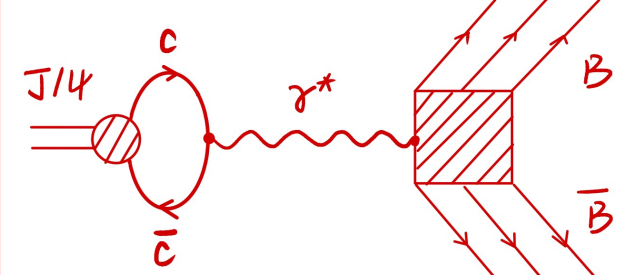
Psionic form factor

$\mathbf{F}_V$ and $\mathbf{H}_\sigma$
can also be represented as $\mathbf{G}_1$
and $\mathbf{G}_2$



P violation term

Complex form factor, $F_A \neq 0$
indicate P violation



$\mathbf{H}_T$ is included in this term

$$H_T(q^2) = \frac{2e}{3m_{J/\psi}^2} g_V d_B(q^2)$$

Assuming $d_B(q^2) \equiv d_B(0)$

$d_B(q^2)$: electric dipole form factor

$d_B(0)$: electric dipole moment

[Physics Letters B 551 \(2003\) 16–26](https://arxiv.org/abs/hep-ph/0305162)

Most precise Λ hyperon EDM measurement

BESIII: arXiv:2506.19180, accepted by Science

- EDM extracted via **full angular analysis**:

$$\text{Re}(d_\Lambda) = (-3.1 \pm 3.2 \pm 0.5) \times 10^{-19} e \cdot \text{cm}$$

$$\text{Im}(d_\Lambda) = (2.9 \pm 2.6 \pm 0.6) \times 10^{-19} e \cdot \text{cm}$$

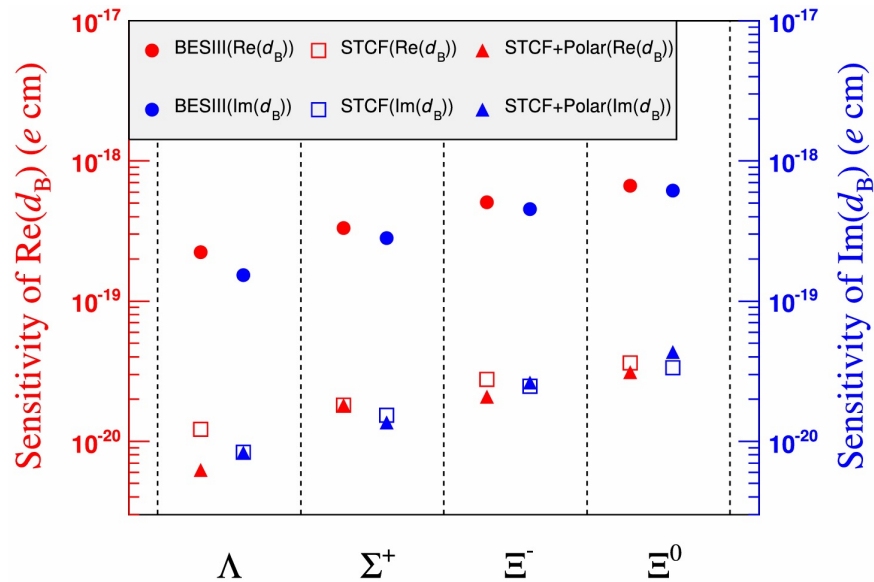
$$e^+ e^- \rightarrow J/\psi \rightarrow \Lambda \bar{\Lambda}, \Lambda \rightarrow p \pi^-, \bar{\Lambda} \rightarrow \bar{p} \pi^+$$

which corresponds to an upper bound of:

$$|d_\Lambda| < 6.5 \times 10^{-19} e \cdot \text{cm} \quad (95\% \text{ CL})$$

- Improves sensitivity by more than **2 orders of magnitude** over previous best.

Prior direct Λ EDM limit (Fermilab, 1981): $|d_\Lambda| < 1.5 \times 10^{-16} e \cdot \text{cm}$.



(a) Sensitivity for $\text{Re}(d_B)$ and $\text{Im}(d_B)$

SM: $\sim 10^{-26} e \text{ cm}$

BESIII: milestone for hyperon

EDM measurement

Λ $10^{-19} e \text{ cm}$ (FermiLab

$10^{-16} e \text{ cm}$)

first achievement for Σ^+, Ξ^-

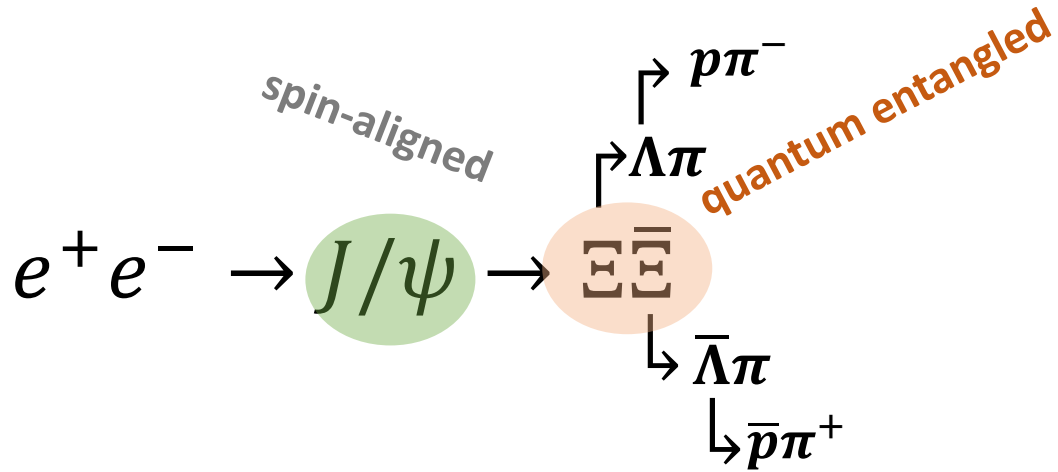
and Ξ^0 at level of $10^{-19} e \text{ cm}$

a litmus test for new physics

J. Fu, H.B. Li, J. Wang, F. Yu, and J. Zhang,
PhysRevD.108.L091301

STCF: improved by more than one order of magnitude

Search for CPV in Ξ decay



Through the **sequential decays of Ξ** , the B_{CP} (CPV phase) can be directly measured!

CPV tests in hyperon decays

$$\Xi^- \rightarrow \Lambda\pi^-$$

$$S = |S| \exp(i\xi_S + i\delta_S)$$

$$P = |P| \exp(i\xi_P + i\delta_P)$$

$$\bar{\Xi}^+ \rightarrow \bar{\Lambda}\pi^+$$

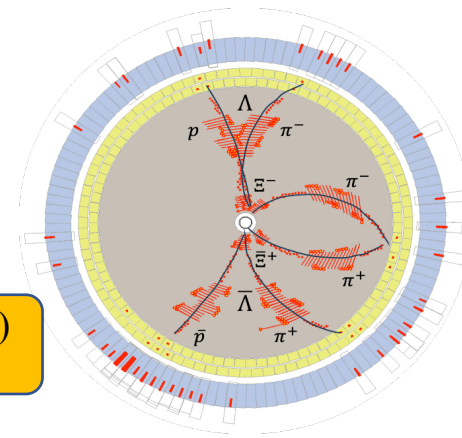
$$\bar{S} = |S| \exp(-i\xi_S + i\delta_S)$$

$$\bar{P} = -|P| \exp(-i\xi_P + i\delta_P)$$

CP-odd phases

$$A_{CP} := \frac{\alpha + \bar{\alpha}}{\alpha - \bar{\alpha}} \text{ and } B_{CP} := \frac{\beta + \bar{\beta}}{\alpha - \bar{\alpha}}$$

Phys. Rev. D 99, 056008 (2019)
 Phys. Lett. B 772, 16 (2017)



$$\omega = (\alpha_\psi, \Delta\Phi, \alpha_\Xi, \phi_\Xi, \alpha_{\bar{\Xi}}, \phi_{\bar{\Xi}}, \alpha_\Lambda, \alpha_{\bar{\Lambda}})$$

Hyperon Production

Hyperon decays

$$W(\xi; \omega) = \sum_{\mu, \bar{\nu}} C_{\mu\bar{\nu}} \sum_{\mu', \bar{\nu}'} a_{\mu, \mu'}^\Xi a_{\bar{\nu}, \bar{\nu}'}^{\bar{\Xi}} a_{\mu', 0}^\Lambda a_{\bar{\nu}', 0}^{\bar{\Lambda}}$$

$$\xi = (\theta_\Xi, \theta_\Lambda, \phi_\Lambda, \theta_{\bar{\Lambda}}, \phi_{\bar{\Lambda}}, \theta_p, \phi_p, \theta_{\bar{p}}, \phi_{\bar{p}})$$

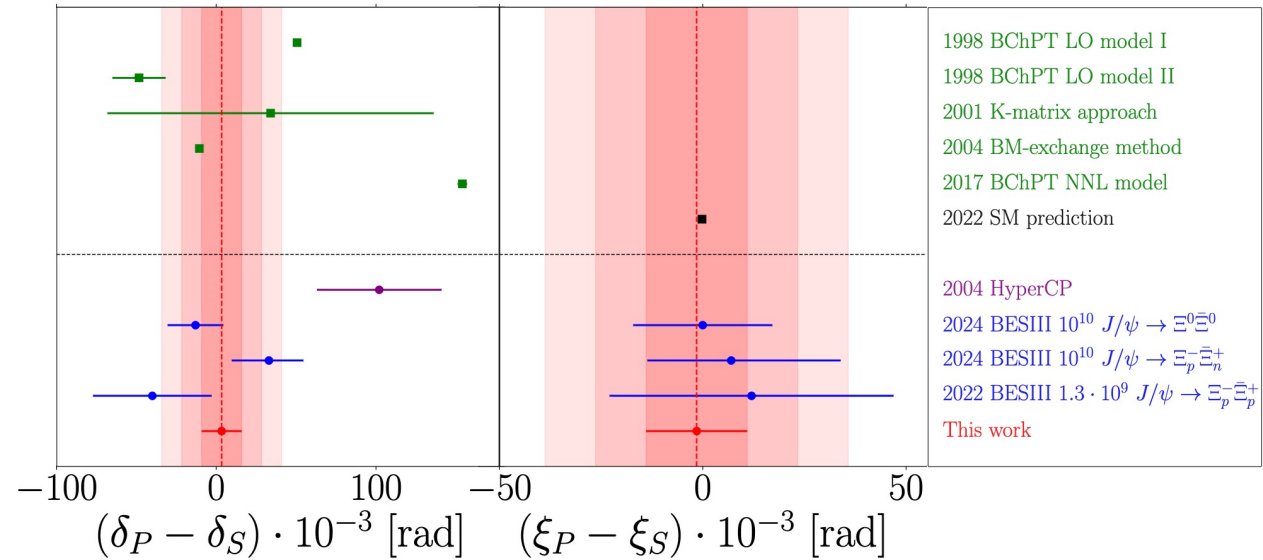
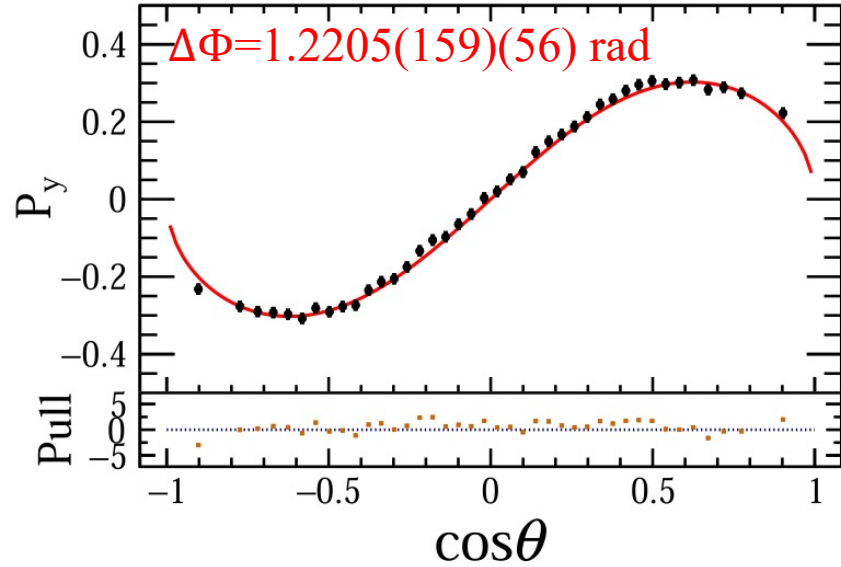
$$A_{CP} = -\tan(\delta_P - \delta_S) \tan(\xi_P - \xi_S)$$

$$B_{CP} = \tan(\xi_P - \xi_S),$$

The **perfect** reaction for hyperon **CPV** searches!

Search for CPV in $\Xi^- \rightarrow \Lambda \pi^-$ with $J/\psi \rightarrow \Xi^- \bar{\Xi}^+$

PRL 136, 201802 (2026) , 10^{10} J/ψ : 5.8×10^5 $\Xi^- \bar{\Xi}^+$ pairs (0.3% bkg)



The most precise decay parameters:

$$\alpha_{\Xi} = -0.3813(26)(5)$$

$$\bar{\alpha}_{\Xi} = 0.3873(26)(6)$$

$$\Phi_{\Xi} = -0.0008(72)(10) \text{ rad}$$

$$\bar{\Phi}_{\Xi} = 0.0020(72)(6) \text{ rad}$$

$$\alpha_{\Lambda} = 0.7434(39)(15)$$

$$\bar{\alpha}_{\Lambda} = -0.7478(38)(15)$$

Three CPV tests:

$$A_{CP}^{\Xi} := \frac{\alpha_{\Xi} + \bar{\alpha}_{\Xi}}{\alpha_{\Xi} - \bar{\alpha}_{\Xi}} = (-7.8 \pm 4.8 \pm 0.8) \times 10^{-3}$$

$$A_{CP}^{\Lambda} := \frac{\alpha_{\Lambda} + \bar{\alpha}_{\Lambda}}{\alpha_{\Lambda} - \bar{\alpha}_{\Lambda}} = (-2.9 \pm 4.3 \pm 0.7) \times 10^{-3}$$

$$\Delta\Phi_{CP}^{\Xi} := \frac{\Phi_{\Xi} + \bar{\Phi}_{\Xi}}{2} = (0.6 \pm 5.1 \pm 0.2) \times 10^{-3} \text{ rad}$$

The weak CP and strong phases are extracted :

$$(\xi_P - \xi_S) = (-0.2 \pm 1.2 \pm 0.1) \times 10^{-2} \text{ rad}$$

$$(\delta_P - \delta_S) = (0.3 \pm 1.2 \pm 0.2) \times 10^{-2} \text{ rad}$$

Charm physics

CKM Matrix

☞ CKM matrix elements are fundamental parameters of the Standard Model (SM):

$$V_{\text{CKM}} = \begin{pmatrix} V_{ud} & V_{us} & \overline{V_{ub}} \\ \boxed{V_{cd}} & \boxed{V_{cs}} & \overline{V_{cb}} \\ \overline{V_{td}} & \overline{V_{ts}} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1 - \lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1 - \lambda^2/2 & A\lambda^2 \\ A\lambda^3(1 - \rho - i\eta) & -A\lambda^2 & 1 \end{pmatrix} + \mathcal{O}(\lambda^4)$$

Charm decays + LQCD
 Expected precision < 1% at BESIII

B decays + LQCD

☞ Any deviation of V_{CKM} from unitarity indicates new physics

→ Measurements of CKM matrix elements [[from PDG2024](#)]

$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 0.9984 \pm 0.0009 = 1(\text{SM})$$

$$|V_{cd}|^2 + |V_{cs}|^2 + |V_{cb}|^2 = 1.001 \pm 0.007 = 1(\text{SM})$$

Precision: 0.7%

Precision: (0.6-1.8)%

$$|V_{cd}| = 0.221 \pm 0.004$$

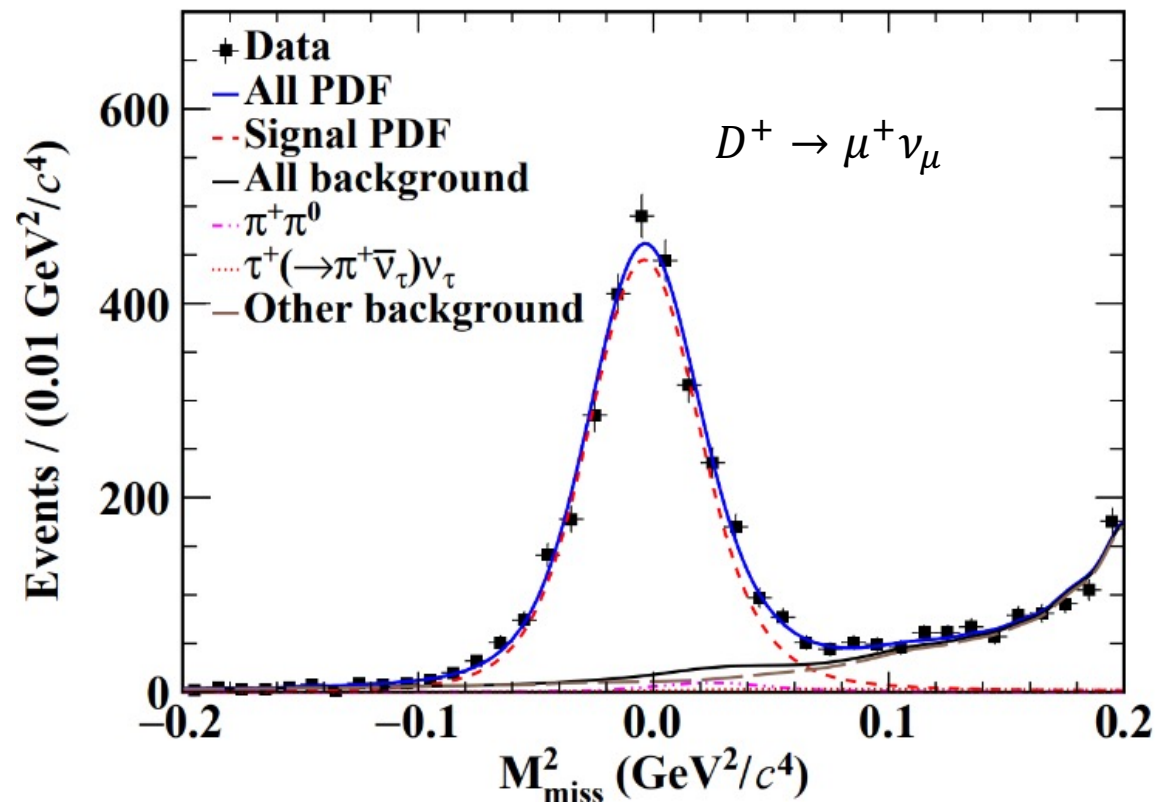
$$|V_{cs}| = 0.975 \pm 0.006$$

$$|V_{cb}| = 0.0410 \pm 0.0012$$

☞ D/D_s (Semi-)leptonic decays provide direct measurements of $|V_{cs}|$ and $|V_{cd}|$

$|V_{cd}|$ from $D^+ \rightarrow \mu^+ \nu_\mu$

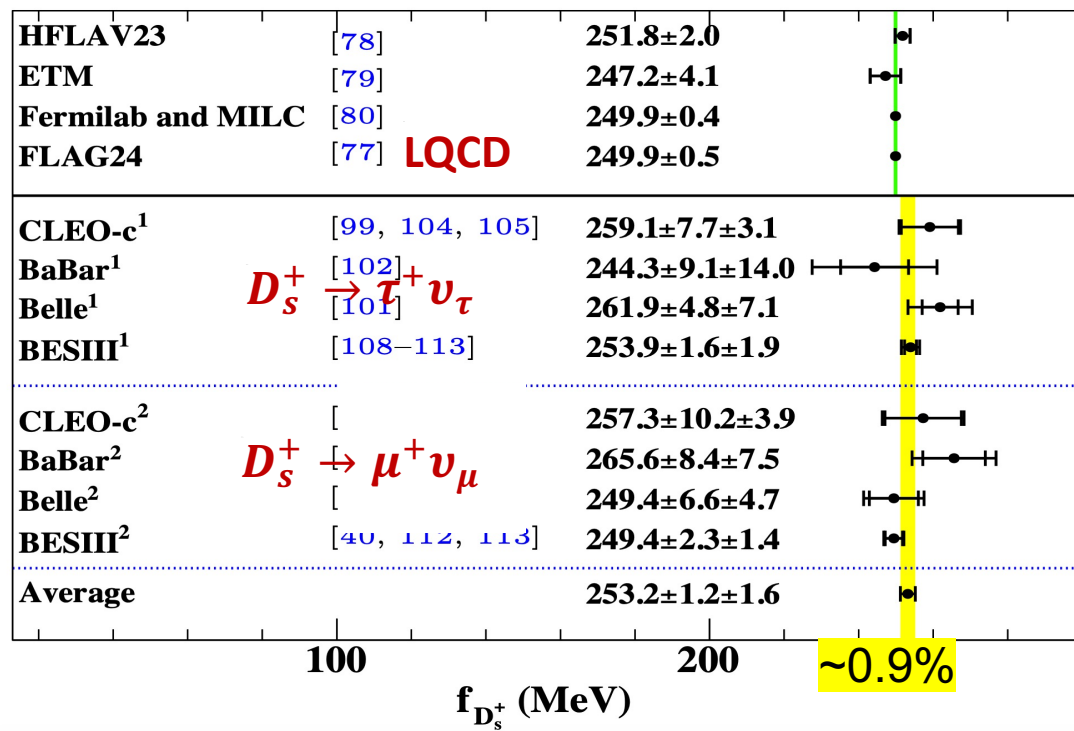
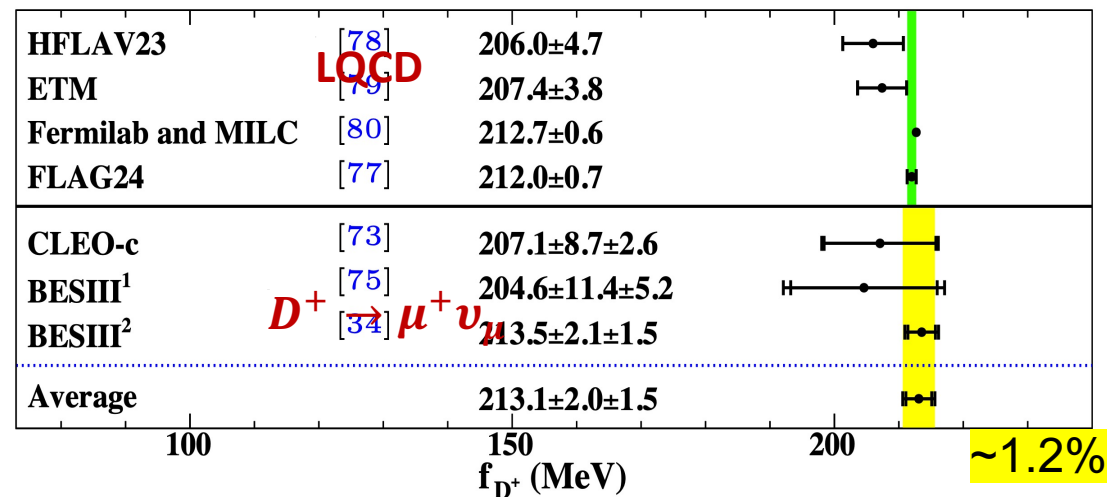
PRL 135, 061801 (2025)



$$f_{D^+}|V_{cd}| = (48.02 \pm 0.48 \pm 0.24 \pm 0.12_{\text{input}} \pm 0.15_{\text{EM}}) \text{ MeV}$$

$$|V_{cd}| = (0.2265 \pm 0.0023 \pm 0.0011 \pm 0.0009 \pm 0.0007)$$

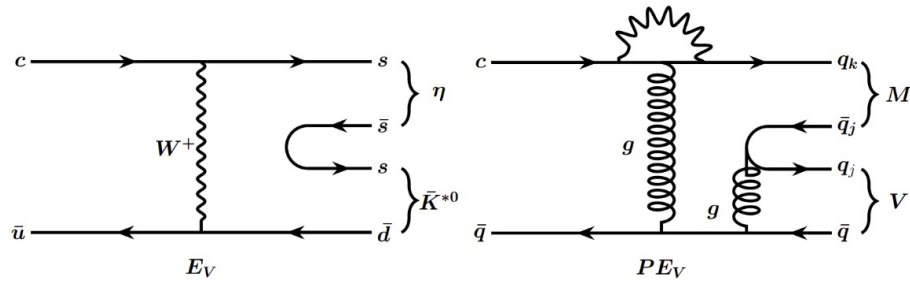
$$f_{D^+} = (213.5 \pm 2.1 \pm 1.1 \pm 0.8 \pm 0.7) \text{ MeV} (\sim 1.2\%)$$



Amplitude analysis of $D^0 \rightarrow K_S^0 \pi^0 \eta$

$\otimes D^0 \rightarrow \eta \bar{K}^*(892)^0$

Impacts predictions from the topological diagram approach,
affecting CP violation and DCS branching fraction estimates.



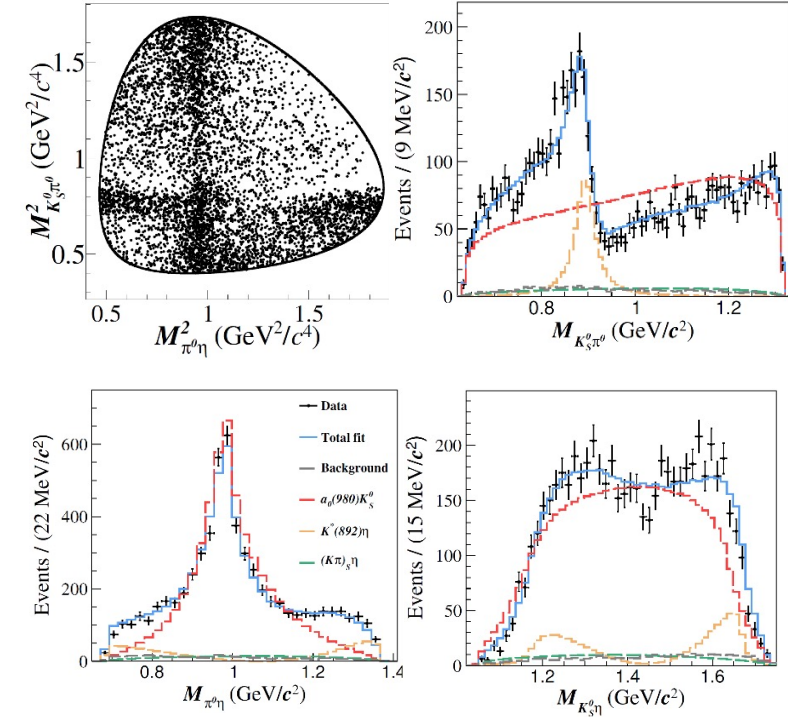
$\otimes D^0 \rightarrow K_S^0 a_0(980)^0$

Source	Branching Fraction ($\times 10^{-3}$)	
	D^0 channel	D^+ channel
BESIII	$9.88 \pm 0.37 \pm 0.42$	$13.3 \pm 0.5 \pm 0.4$ [35]
$q\bar{q}$ model	0.55 [2]	6.5 [2]
Tetraquark	9.5-15.0 [2]	13.5 [2]

Favor prediction under tetraquark model

Helps determine the $\bar{T}$ -diagram contribution

arXiv:2512.23389



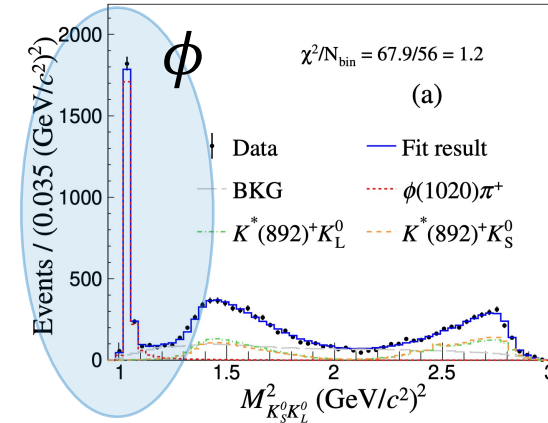
Amplitude	BF (10^{-3})
$D^0 \rightarrow K_S^0 a_0(980)^0, a_0(980)^0 \rightarrow \pi^0 \eta$	$9.88 \pm 0.37 \pm 0.42$
$D^0 \rightarrow K_S^0 a_2(1320)^0, a_2(1320)^0 \rightarrow \pi^0 \eta$	$0.08 \pm 0.11 \pm 0.11$
$D^0 \rightarrow \bar{K}^*(892)^0 \eta, \bar{K}^*(892)^0 \rightarrow K_S^0 \pi^0$	$1.22 \pm 0.09 \pm 0.11$
$D^0 \rightarrow \bar{K}^*(1410)^0 \eta, \bar{K}^*(1410)^0 \rightarrow K_S^0 \pi^0$	$0.56 \pm 0.14 \pm 0.16$
$D^0 \rightarrow (K_S^0 \pi^0)_{S\text{-wave}} \eta$	$0.64 \pm 0.10 \pm 0.10$
$D^0 \rightarrow \bar{K}^*(1680)^0 \pi^0, \bar{K}^*(1680)^0 \rightarrow K_S^0 \eta$	$0.19 \pm 0.07 \pm 0.05$
$D^0 \rightarrow \bar{K}_2^*(1980)^0 \pi^0, \bar{K}_2^*(1980)^0 \rightarrow K_S^0 \eta$	$0.45 \pm 0.15 \pm 0.16$

Amplitude analysis of $D^+ \rightarrow \phi(K_S^0 K_L^0)\pi^+$

$$D^+ \rightarrow K_S^0 K_L^0 \pi^+$$

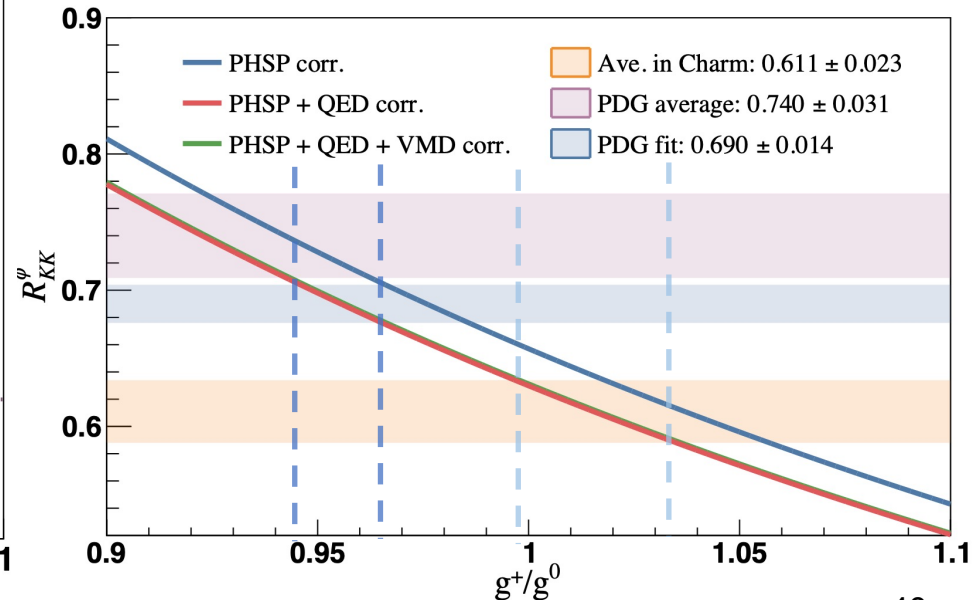
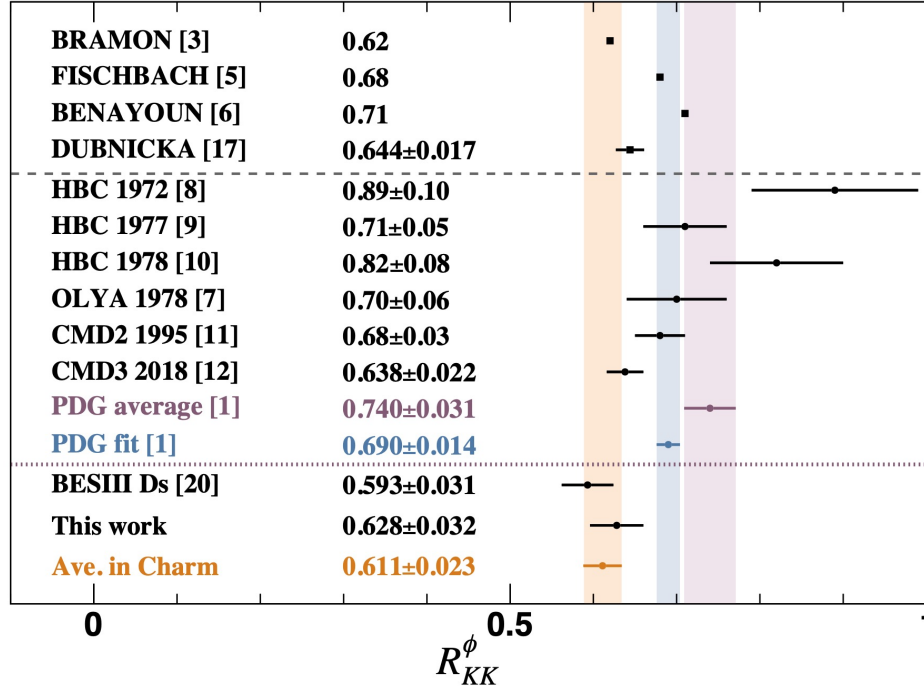
ArXiv: 2605.11464

Amplitude	Phase (rad)	FF (%)	BF (10^{-3})
$D^+ \rightarrow \phi\pi^+$	0.0(fixed)	$29.24 \pm 0.97 \pm 0.65$	$1.69 \pm 0.06 \pm 0.04$
$D^+ \rightarrow K_L^0 K^*(892)^+$	$2.34 \pm 0.09 \pm 0.09$	$40.21 \pm 0.83 \pm 0.26$	$2.33 \pm 0.06 \pm 0.03$
$D^+ \rightarrow K_S^0 K^*(892)^+$	$5.50 \pm 0.09 \pm 0.09$	$38.06 \pm 0.79 \pm 0.25$	$2.20 \pm 0.06 \pm 0.03$

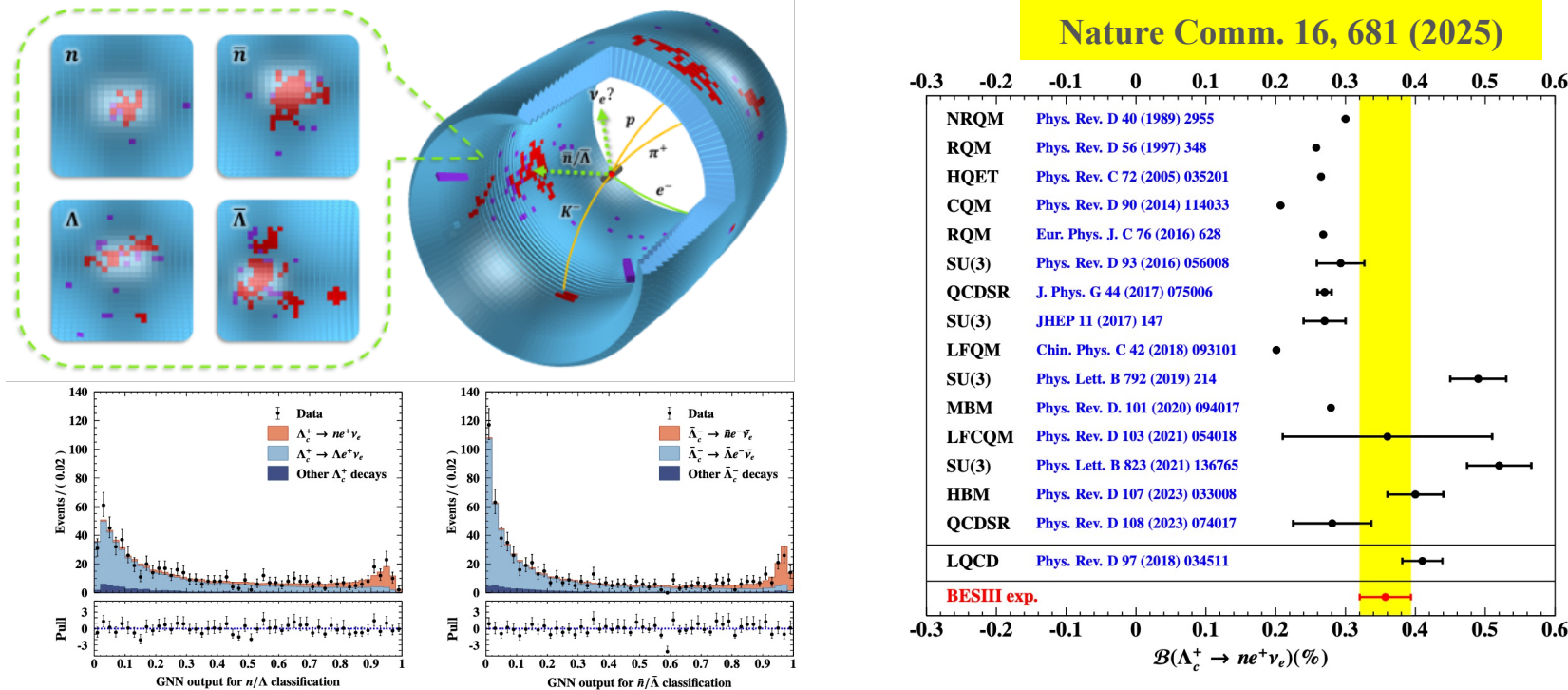


$$\frac{B(\phi \rightarrow K_S^0 K_L^0)}{B(\phi \rightarrow K^+ K^-)} = 0.611 \pm 0.023$$

Test isospin symmetry breaking with the $\phi \rightarrow K^+ K^-$ and $\phi \rightarrow K^0 \bar{K}^0$ couplings



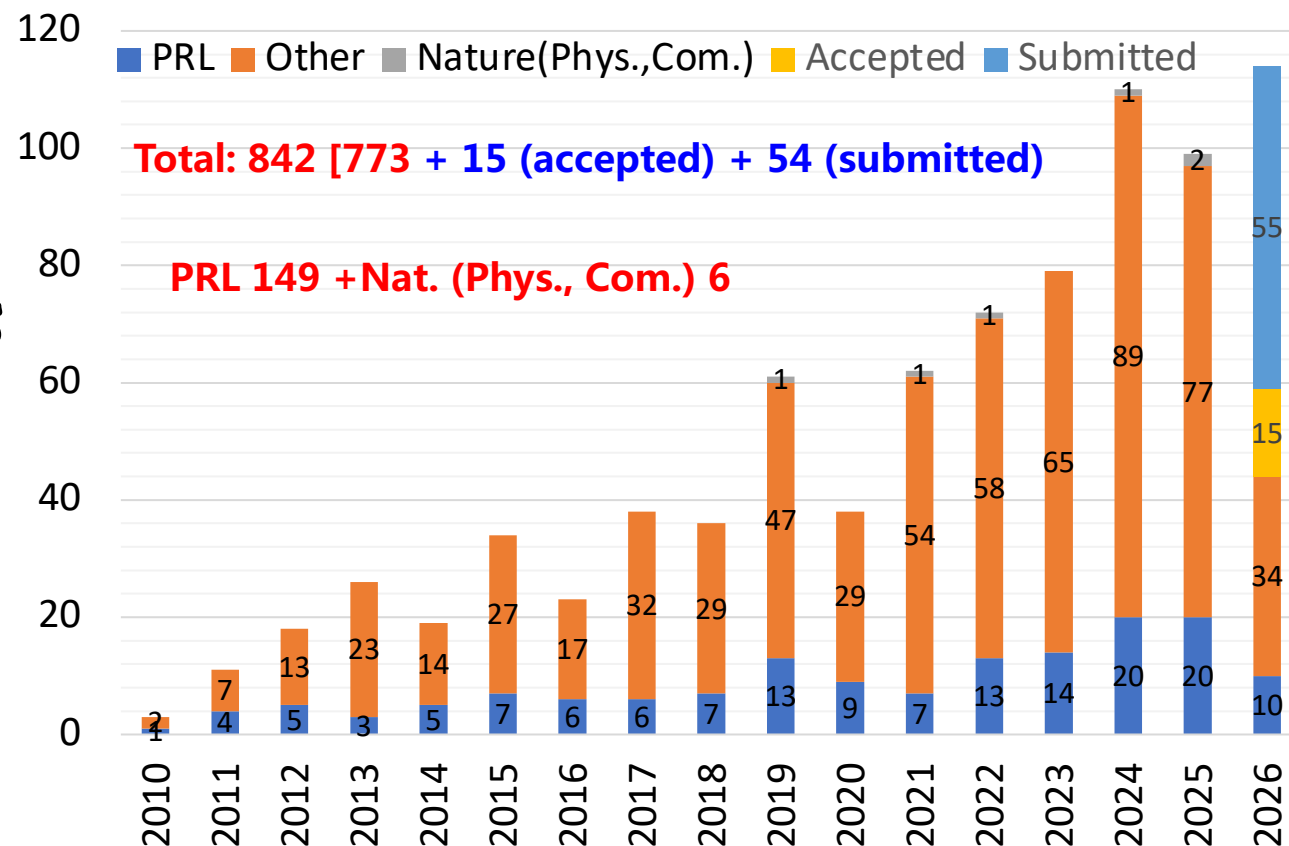
Observation of $\Lambda_c^+ \rightarrow ne^+\nu_e$ with Machine Learning



- A novel Deep Learning is utilized to separate signals from dominant background from $\Lambda_c^+ \rightarrow \Lambda(\rightarrow n\pi^0)e^+\nu$
- Train GNN with **ParticleNet** using control data based on 10B J/ψ decays
- First observation of $\Lambda_c^+ \rightarrow ne^+\nu_e$
 - $\mathcal{B}(\Lambda_c^+ \rightarrow ne^+\nu_e) = (0.357 \pm 0.034_{\text{stat}} \pm 0.014_{\text{syst}})\% (> 10\sigma)$
- Demonstrate a level of precision comparable to the LQCD prediction.

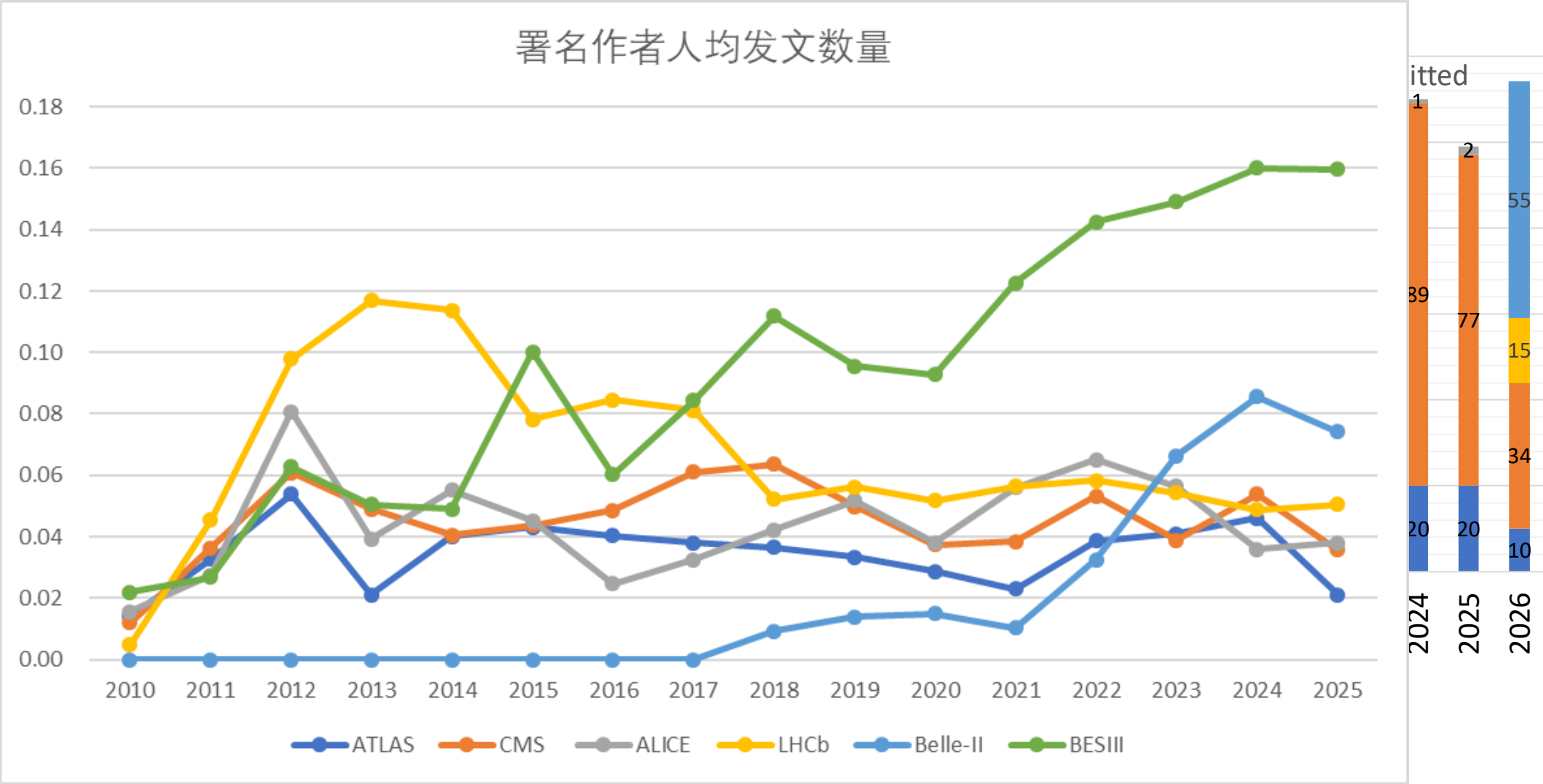
Not included in the talk, but more results on:

- π^0 space-like form factor
- Nucleon-hyperon interactions
- Inclusive hadron cross sections
- Light meson physics
- Hyperon radiative decays
- Meson spectroscopy
- Rare decays
-



Not included in the talk, but more results on:

- π^0 space
- Nucleon
- Inclusive
- Light m
- Hyperon
- Meson s
- Rare de
-

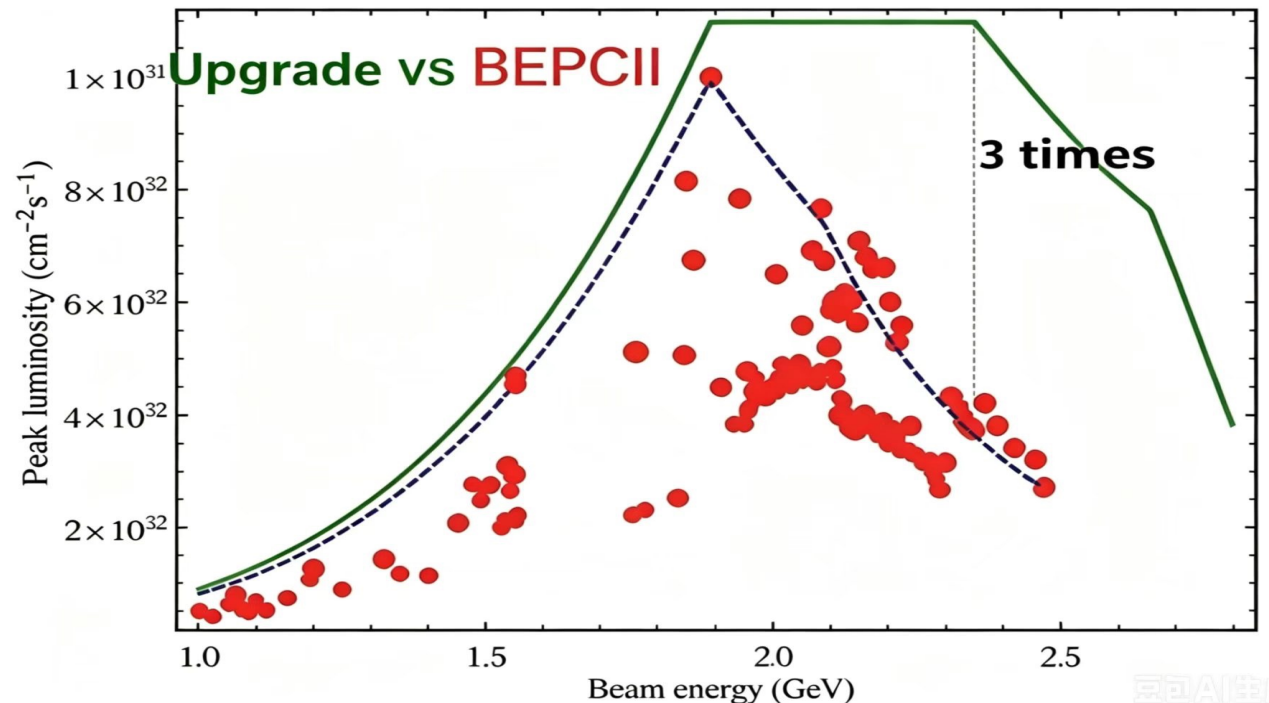


Future prospects

- BEPCII/BESIII upgraded in 2024
- Optimization E_{cm} at 4.7 GeV with luminosity 3 times higher than the current BEPCII → more effective data taking
- Extend E_{cm} up to 5.6 GeV → more physics opportunity

More exciting results are expected in the near future !

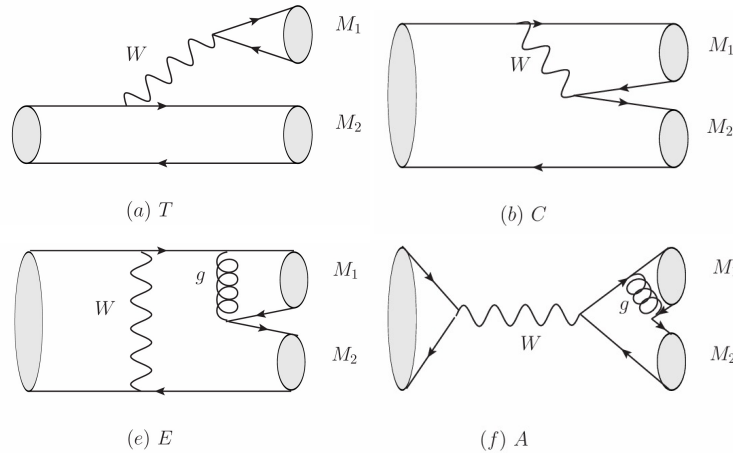
BEPCII-CW ?



非常感谢！

Why study hadronic decays of charmed mesons?

➤ Topological Diagram Approach



Mode	Amplitude
$D^0 \rightarrow K^+ \pi^-$	$\lambda_{ds}(1.23T + E)$
$D^0 \rightarrow K^0 \pi^0$	$\frac{1}{\sqrt{2}}\lambda_{ds}(C - E)$
$D^0 \rightarrow K^0 \eta$	$\lambda_{ds} \left[\frac{1}{\sqrt{2}}(C + E) \cos \phi - E \sin \phi \right]$
$D^0 \rightarrow K^0 \eta'$	$\lambda_{ds} \left[\frac{1}{\sqrt{2}}(C + E) \sin \phi + E \cos \phi \right]$
$D^+ \rightarrow K^0 \pi^+$	$\lambda_{ds}(C + 0.71A)$
$D^+ \rightarrow K^+ \pi^0$	$\frac{1}{\sqrt{2}}\lambda_{ds}(1.23T - 0.71A)$
$D^+ \rightarrow K^+ \eta$	$\lambda_{ds} \left[\frac{1}{\sqrt{2}}(1.05T + A) \cos \phi - 0.81A \sin \phi \right]$
$D^+ \rightarrow K^+ \eta'$	$\lambda_{ds} \left[\frac{1}{\sqrt{2}}(1.05T + A) \sin \phi + 0.81A \cos \phi \right]$
$D_s^+ \rightarrow K^0 K^+$	$\lambda_{ds}(1.27T + 1.03C)$

- $D \rightarrow PP$: high efficiency, low background, no interference, (usually) high precision. Good for A_{CP} , $\eta - \eta'$ mixing etc..
- $D \rightarrow SP$, $D \rightarrow SV$, ($D \rightarrow SS$): Understand the nature of light scalar mesons, $a_0(980)$, $f_0(980)$, $K(700)$, $f_0(500)$ etc..
- $D \rightarrow VP$: Clarifying the nonperturbative mechanism. Well defined quark content of V. Better than the PP and VV, due to the multiple-amplitude composition of P and the polarization in VV.
- $D \rightarrow VV$: Polarization in charmed decays.
- $D \rightarrow AP$: Study axial-vector mesons, $a_1(1260)$ $K_1(1400)$ etc..