The BESIII Experimental Program

Giulio Mezzadri (INFN Ferrara)
gmezzadr@fe.infn.it

On behalf of the BESIII collaboration

Jefferson Lab User Organization Annual Meeting – JLAB - 06/26/2023

INFN
FERRARA

BEPCII @ IHEP

中國科學院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

Largest particle accelerator in China

electron-positron collider

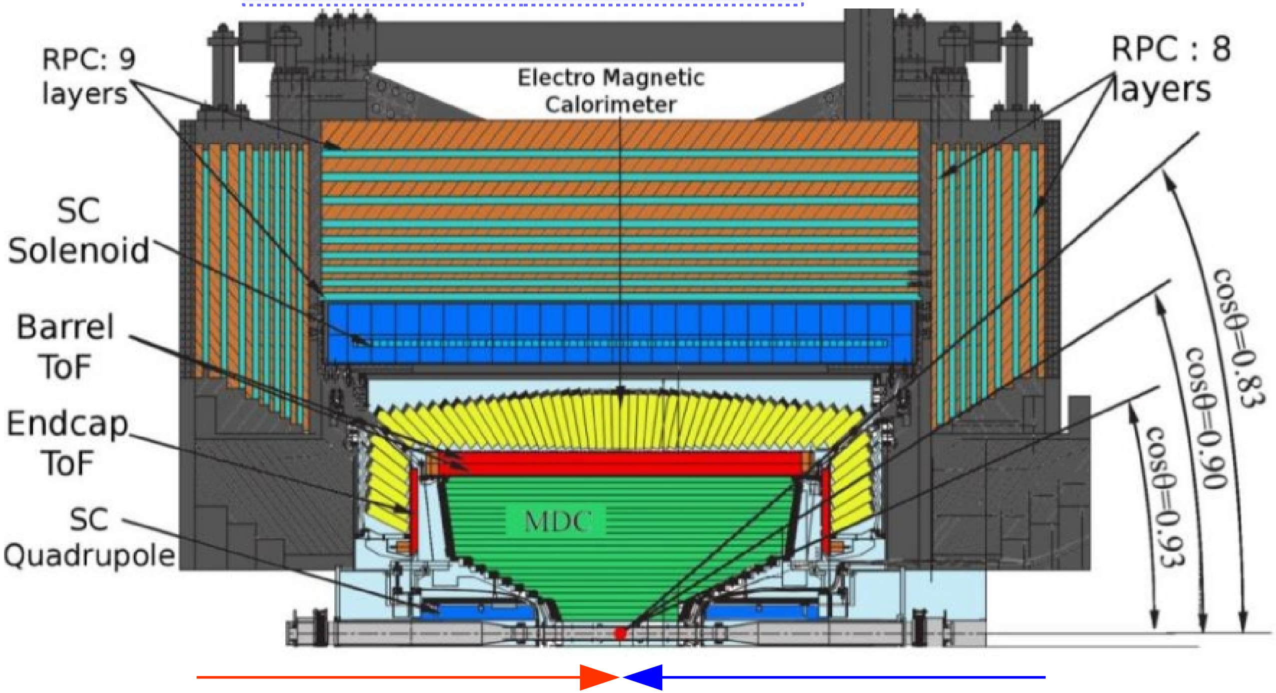
E_{cm} = 2 – 4.95 GeV

Luminosity = 10^{33} $cm^{-2}s^{-1}$

To be upgraded in 2024 to increase luminosity at high energy

BESIII @ BEPCII

1 Tesla Magnetic field



Muon counters:
$\delta_{r\varphi}$ = 1.4 cm – 1.7 cm

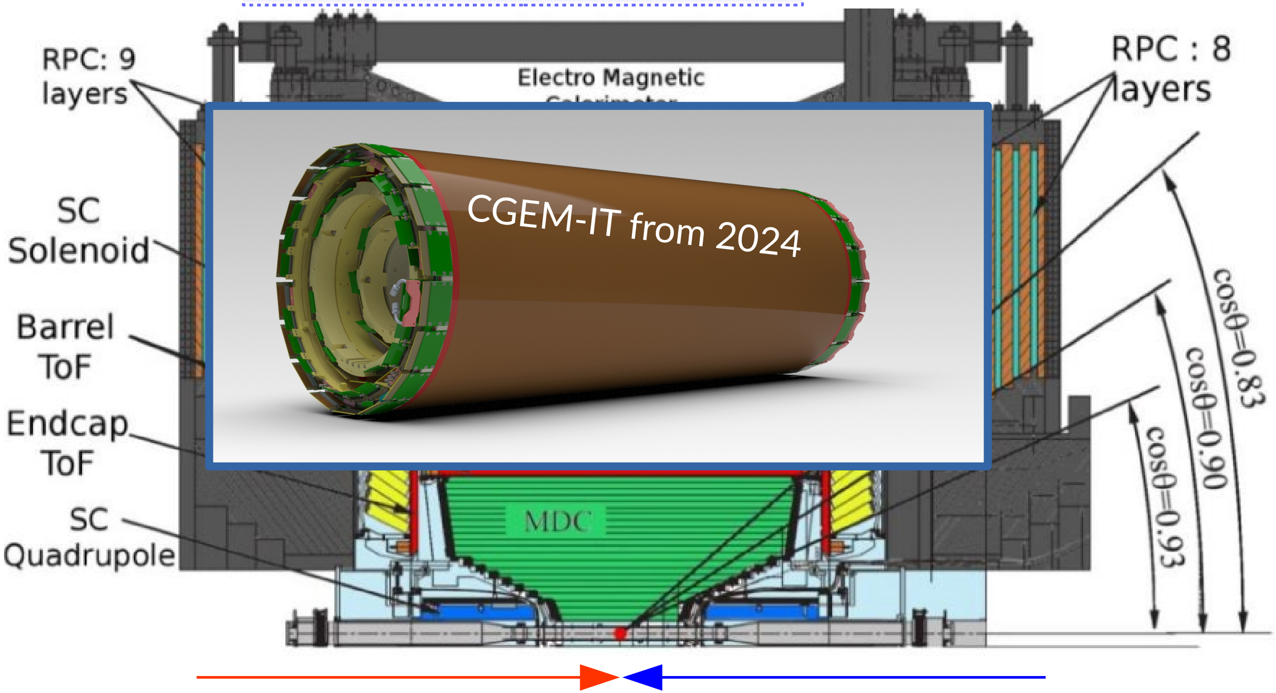
Electromagnetic Calorimeter:
dE/√E (1 GeV) = 2.5 %

Time Of Flight:
σ_t (barrel) = 70 ps
σ_t (endcap) = 60 ps

Main Drift Chamber:
σ_x (1 GeV/c) ~ 130 μm
dp/p (1 GeV/c) = 0.5 %

BESIII @ BEPCII

1 Tesla Magnetic field

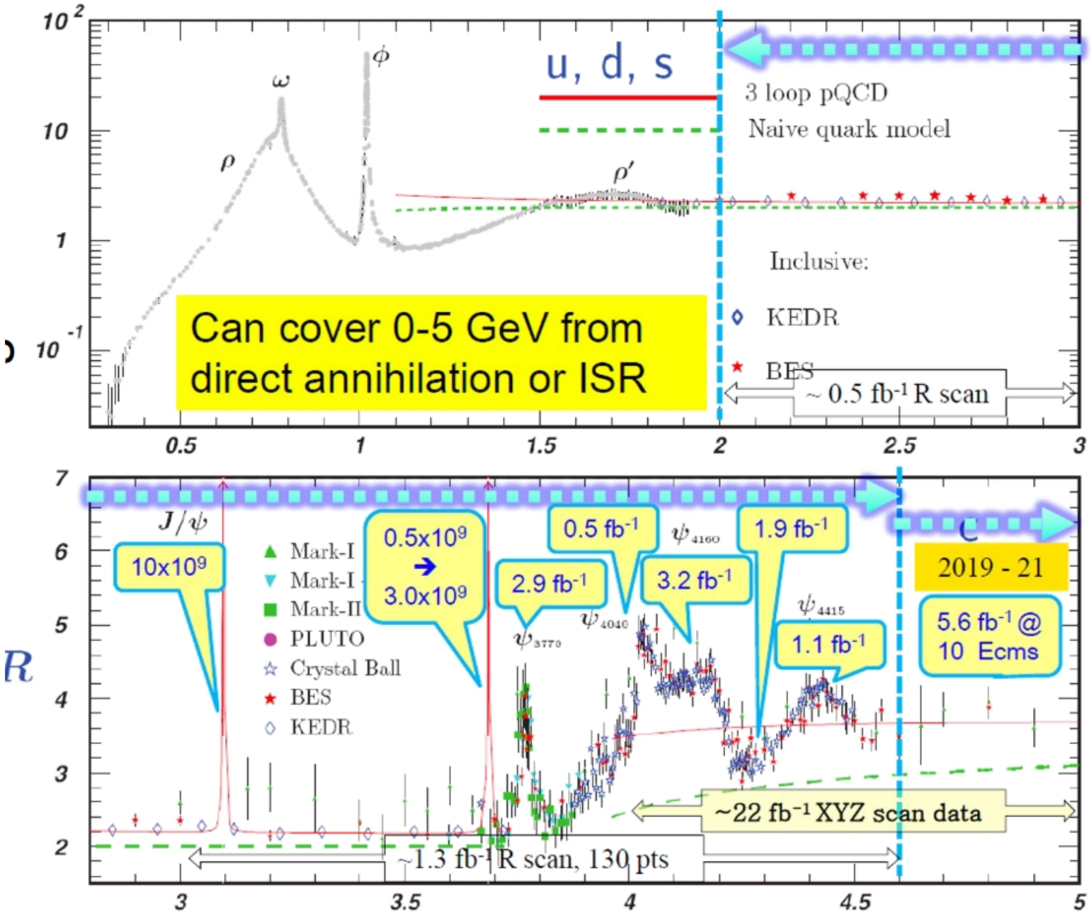


Muon counters:
$\delta_{r\varphi}$ = 1.4 cm – 1.7 cm

Electromagnetic Calorimeter:
dE/√E (1 GeV) = 2.5 %

Time Of Flight:
σ_t (barrel) = 70 ps
σ_t (endcap) = 60 ps

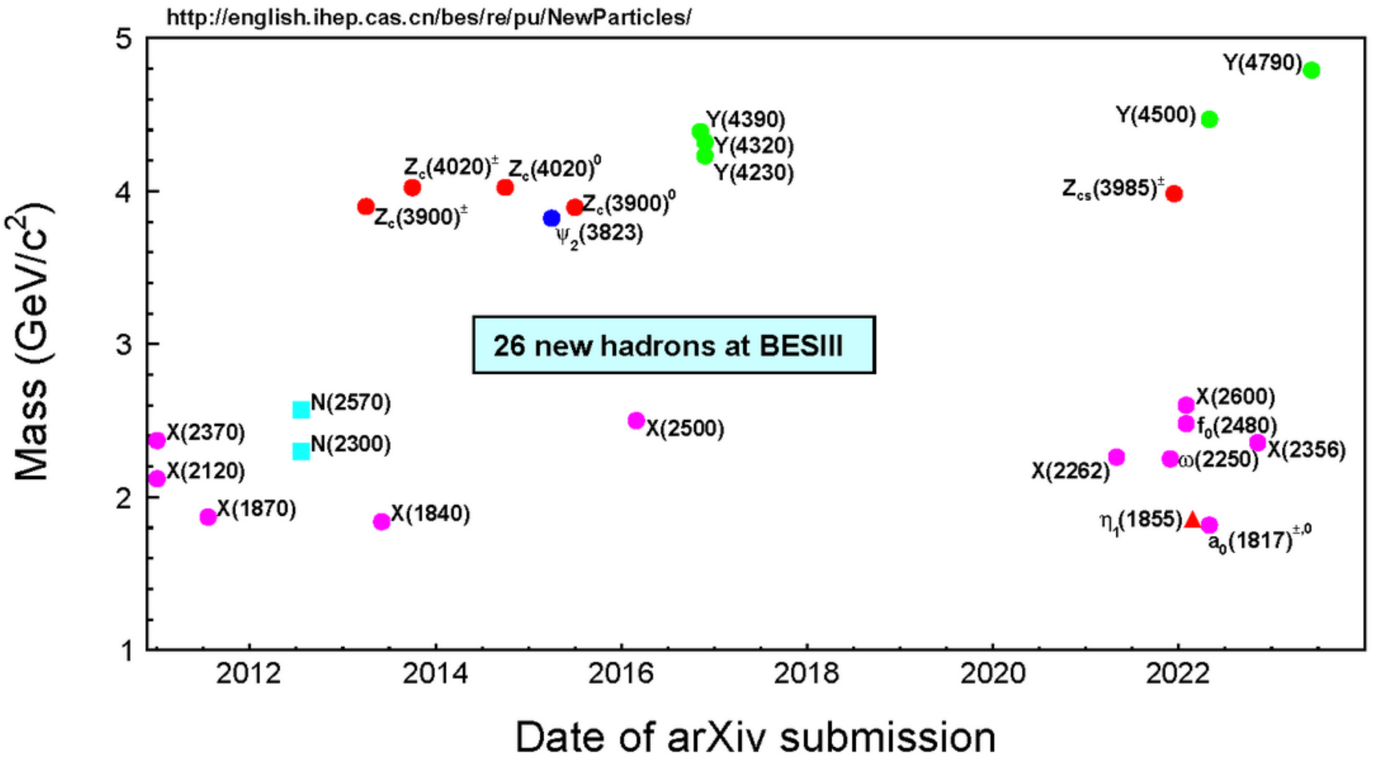
Main Drift Chamber:
σ_x (1 GeV/c) ~ 130 μm
dp/p (1 GeV/c) = 0.5 %



BESIII datasets guarantee rich physics program

- world's largest 10B J/ψ dataset for light hadron searches
- 2.7B ψ(2S) for conventional charmonia below threshold
- ~30/fb for XYZ measurements and above threshold searches
- fine scan at low mass for R and light hadron searches

Hadrons @ BESIII



Name	Mass(MeV/c^2)	Width(MeV)	Journal	arXiv
N(2570)	2570_{-10-10}^{+19+34}	250_{-24-21}^{+14+69}	PhysRevLett.110, 022001	1207.0223
N(2300)	$2300_{-30-0}^{+40+109}$	$340_{-30-58}^{+30+110}$	PhysRevLett.110, 022001	1207.0223
X(1870)	$1877.3\pm6.3_{-7.4}^{+3.4}$	$57\pm12_{-4}^{+19}$	PhysRevLett.107, 182001	1107.1806
X(1840)	$1842.2\pm4.1_{-2.6}^{+7.1}$	83±14±11	PhysRevD.88.091502	1305.5333
X(2500)	$2470_{-19-23}^{+15+101}$	230_{-35-33}^{+64+56}	PhysRevD.93.112011	1602.01523
X(2262)	2262±4±28	72±5±43	PhysRevD.104.052006	2104.08754
X(2120)	$2122.4\pm6.7_{-2.7}^{+4.7}$	$83\pm16_{-11}^{+31}$	PhysRevLett.106.072002	1012.3510
X(2370)	$2376.3\pm8.7_{-4.3}^{+3.2}$	$83\pm 17_{-6}^{+44}$	PhysRevLett.106.072002	1012.3510
X(2600)	$2617.8\pm2.1_{-1.9}^{+18.2}$	$200\pm 8_{-17}^{+20}$	PhysRevLett. 129, 042001	2201.10796
X(2356)	2356±7±17	304±28±54		2211.10755
f0(2480)	$2470\pm 4_{-6}^{+4}$	$75\pm9_{-8}^{+11}$	PhysRevD 105, 072002	2201.09710
omega(2250)	2223±16±11	51±29±21	PhysRevD.105.032005	2112.15076
a0(1817)+-0	1817±8 ±20	97 ±22±15	PhysRevLett.129.182001	2204.09614
eta1(1855)	$1855\pm9_{-1}^{+16}$	$188\pm18_{-8}^{+3}$	PhysRevLett. 129, 192002	2202.00621
Y(4390)	$4391.6_{-6.9}^{+6.3}\pm1.0$	$139.5_{-20.6}^{+16.2}\pm0.6$	PhysRevLett. 118, 092002	1610.07044
Y(4320)	4320.0±10.4±7.0	$1101.4-_{19.7}^{+25.3}\pm10.2$	PhysRevLett. 118, 092001	1611.01317
Y(4230)	4222.0±3.1±1.4	44.1±4.3±2.0	PhysRevLett. 118, 092001	1611.01317
Y(4790)	4793.3±7.5	27.1±7.0		2305.10789
psi2(3823)	3821.7 ± 1.3 ± 0.7	<16	PhysRevLett.115.011803	1503.08203
Y(4500)	4484.7±13.3±24.1	111.1±30.1±15.2	Chin.Phys.C,46,111002	2204.07800
Zc(3900)+-	3899.0±3.6±4.9	46±10±20	PhysRevLett.110.252001	1303.5949
Zc(3900)0	3894.8±2.3±3.2	29.6±8.2±8.2	PhysRevLett.115.112003	1506.06018
Zc(4020)+-	4022.9 ± 0.8 ± 2.7	7.9 ± 2.7 ± 2.6	PhysRevLett.111.242001/ PhysRevLett.112.132001	1309.1896/ 1308.2760
Zc(4020)0	4023.9±2.2±3.8	7.9(Fixed)	PhysRevLett.113.212002	1409.6577
Zcs(3985)+-	$3982_{-2.6}^{+1.8}\pm2.1$	$12.8_{-4.4}^{+5.3}\pm3.0$	PhysRevLett.126.102001	2011.07855

Today's outline

Light hadrons spectroscopy:

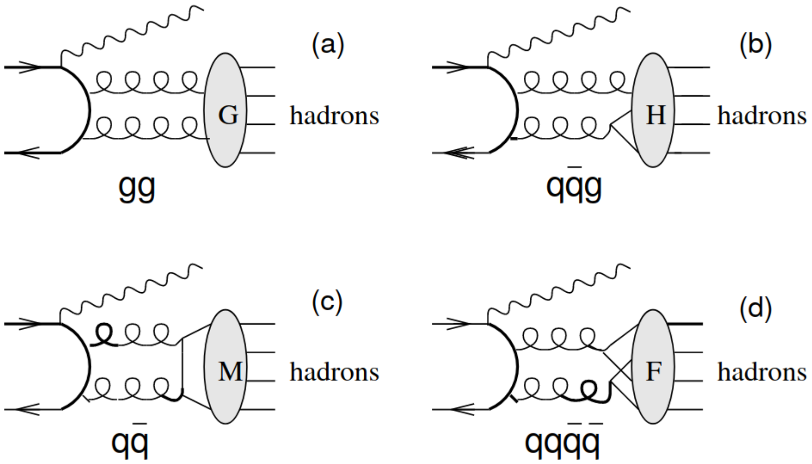
- $\eta_1(1855)$
- $\Phi(2170)$ searches
- $X(2600)$ in $J/\psi \to \gamma\eta'\pi\pi$
- cusp effect in $\eta' \to \pi^0\pi^0$
- $a_0(1817)^{0,\pm}$ in D_s decays

XYZ states:

- X(3872) production at BESIII
- Status of Y states
- $Z_{cs}(3985)$ isospin triplet

Other non-spectroscopy measurements:

- hyperon polarization
- hyperon scattering with beam pipe
- neutron form factor
- inclusive hadron production
- dark photon from charmed baryons



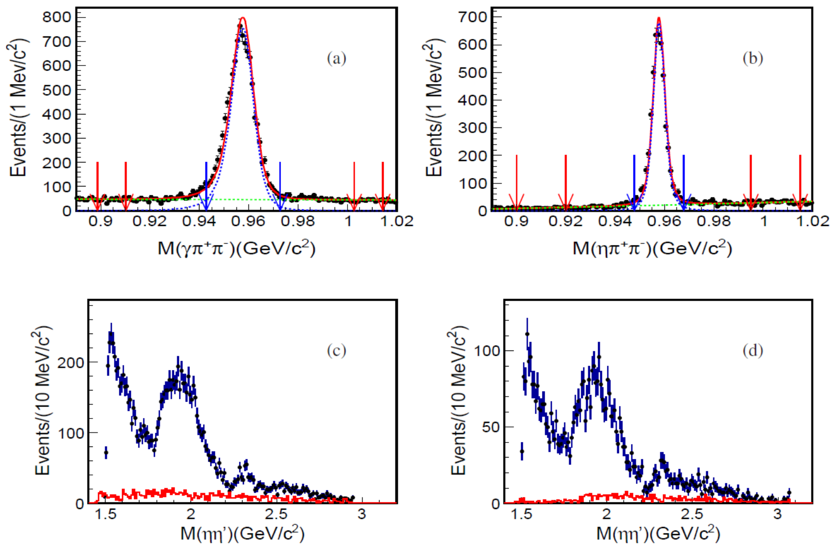
Light hadrons spectroscopy

PRD 106, 072012 (2022)
PRL 129, 192002 (2022)

Event selection

$J/\psi \to \gamma\eta\eta'$, $\eta \to \gamma\gamma$ $\eta' \to \eta\pi\pi/\gamma\pi\pi$

Backgrounds estimated from η’ sidebands in data
No significant peaking background



PWA

Covariant tensor amplitude (EPJ A 16, 537) and GPUPWA (J. Phys. Conf. Ser. 219, 042031)

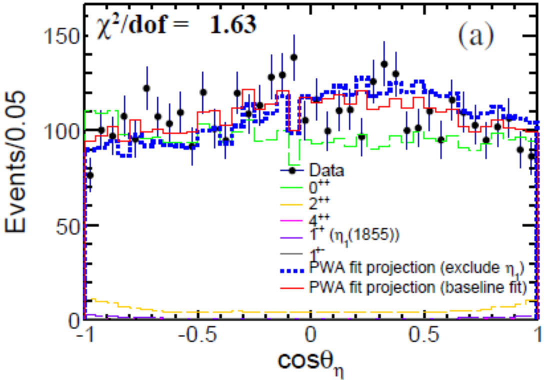
- Background subtracted
- Combined unbinned maximum likelihood fit for the two η’ decay

All kinematically allowed resonance with 0^{++}, 2^{++}, 4^{++} ($\eta\eta'$) and 1^{+-} and 1^{--} ($\gamma\eta^{(\prime)}$) considered

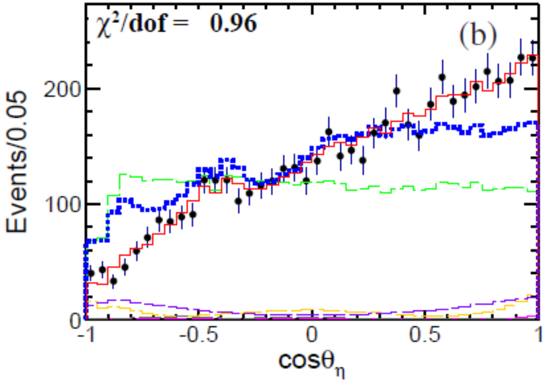
A significant 1^{-+} additional contribution is needed in the ηη’ system around 1.9 GeV

Further checks

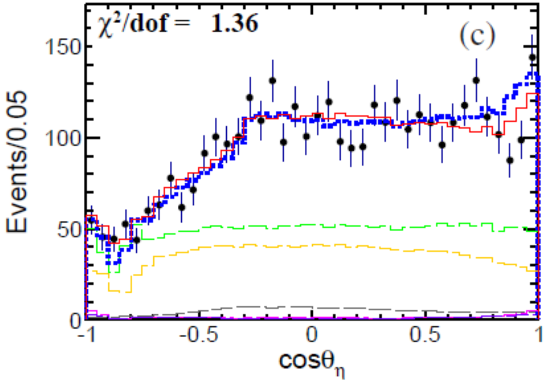
[1.5,1.7) GeV/c^2



[1.7,2.0) GeV/c^2

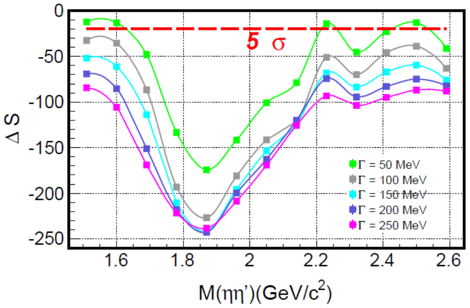


[2.0,2.3) GeV/c^2



Asymmetry largerly due to η_1(1855)

Other tests: change of BW phase motion; scan of different masses and widths assuming a resonance



Angular distribution as a function of M(ηη′) can be expressed model-independently in terms of Legendre polynomial moments

$$\langle Y_l^0\rangle \equiv \sum_{i=1}^{N_k} W_i Y_l^0(\cos\theta_\eta^i)$$

Data, W_i are background subtracted
MC, W_i are from the PWA events

The moments are related to the spin-0 (S), spin-1 (P) and spin-2 (D) amplitudes by

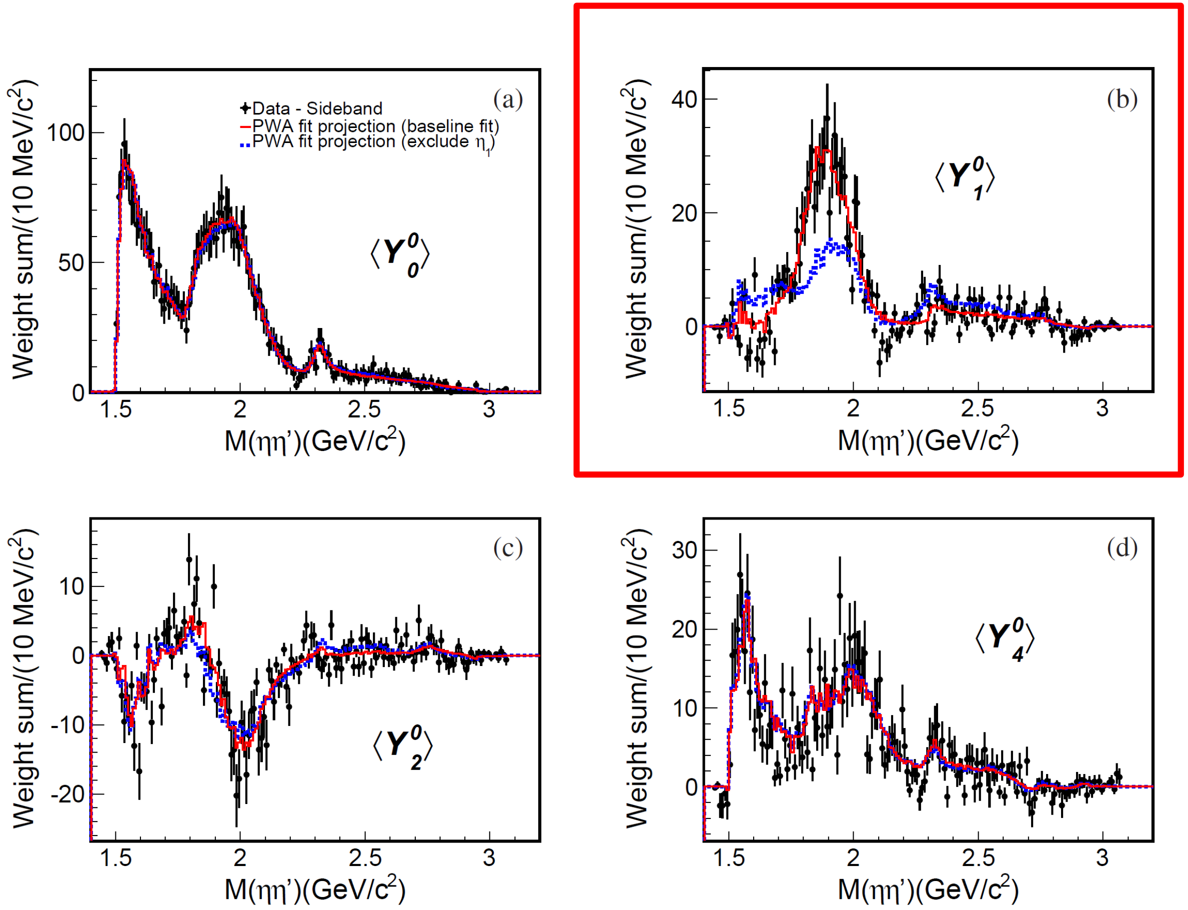
$$\sqrt{4\pi}\langle Y_0^0\rangle = S_0^2 + P_0^2 + P_1^2 + D_0^2 + D_1^2 + D_2^2,$$

$$\sqrt{4\pi}\langle Y_1^0\rangle = 2S_0P_0\cos\phi_{P_0} + \frac{2}{\sqrt{5}}(2P_0D_0\cos(\phi_{P_0}-\phi_{D_0}) + \sqrt{3}P_1D_1\cos(\phi_{P_1}-\phi_{D_1})),$$

$$\sqrt{4\pi}\langle Y_2^0\rangle = \frac{1}{7\sqrt{5}}(14P_0^2 - 7P_1^2 + 10D_0^2 + 5D_1^2 - 10D_2^2) + 2S_0D_0\cos\phi_{D_0},$$

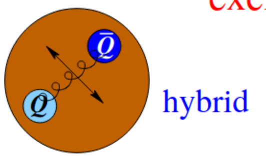
$$\sqrt{4\pi}\langle Y_3^0\rangle = \frac{6}{\sqrt{35}}(\sqrt{3}P_0D_0\cos(\phi_{P_0}-\phi_{D_0}) - P_1D_1\cos(\phi_{P_1}-\phi_{D_1})),$$

$$\sqrt{4\pi}\langle Y_4^0\rangle = \frac{1}{7}(6D_0^2 - 4D_1^2 + D_2^2).$$



The $\eta_1(1855)$: experimental vs LQCD

gluonic excitations



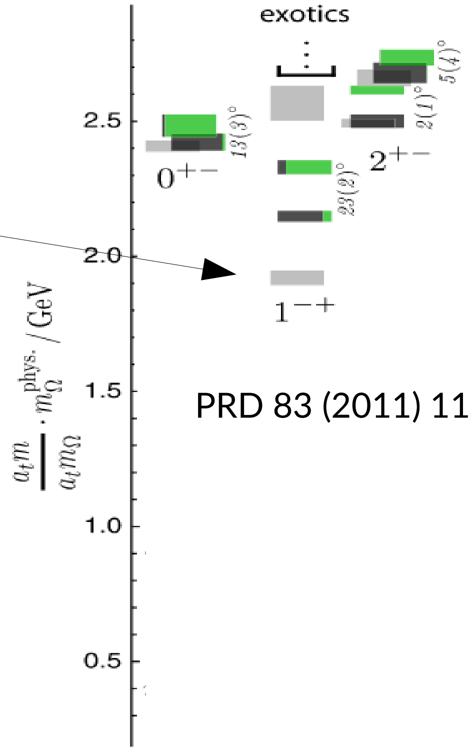
An isoscal 1^{-+}, $\eta_1(1855)$, has been observed in $J/\psi \to \gamma\eta\eta'$ (> 19σ)

$$M = (1855 \pm 9^{+6}_{-1})\,\mathrm{MeV}/c^2$$

$$\Gamma = (188 \pm 18^{+3}_{-8})\,\mathrm{MeV}$$

$$\mathcal{B}(J/\psi \to \gamma\eta_1(1855) \to \gamma\eta\eta') = (2.70 \pm 0.41^{+0.16}_{-0.34}) \times 10^{-6}$$

Good agreement



PRD 83 (2011) 111502

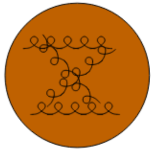
- Investigation on other production/decay mechanism
- Search for other partners in more reactions

Scalar glueball decay to ηη’ suppressed with respect to the ππ mode

$$\frac{B(G\to\eta\eta')}{B(G\to\pi\pi)} < 0.04$$

PRD 92, 121902 (2015)

$f_0(1710)$ and the glueball



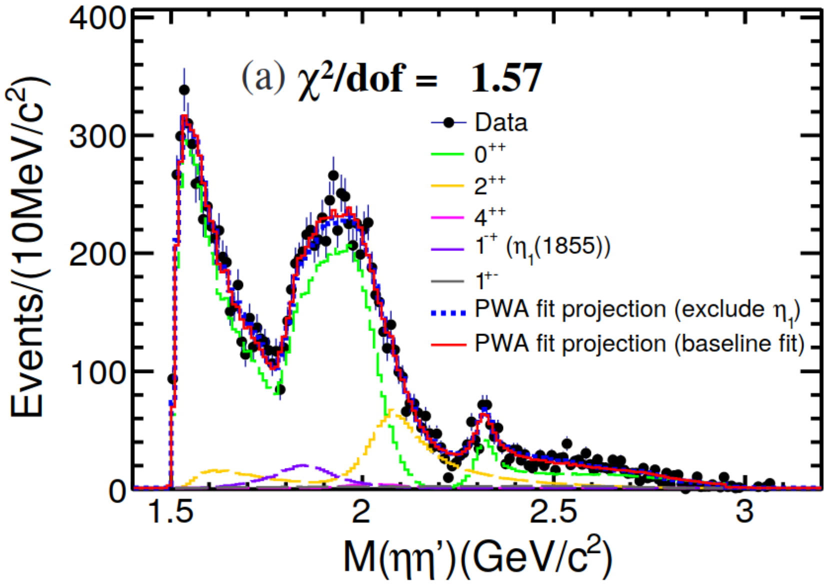
glue–ball

gluonic excitations

Significant $J/\psi \to \gamma f_0(1500) \to \gamma\eta\eta'$ has been observed, while $f_0(1710)$ is insignificant

$$\frac{B(f_0(1500)\to\eta\eta')}{B(f_0(1500)\to\pi\pi)} = (8.96^{+2.95}_{-2.87})\times10^{-2},$$

$$\frac{B(f_0(1710)\to\eta\eta')}{B(f_0(1710)\to\pi\pi)} < 1.61\times10^{-3} \text{ (90\% CL)}$$

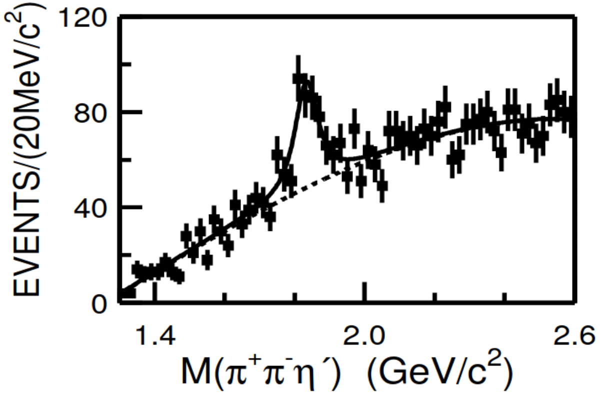


which supports the hypothesis of a large $f_0(1710)$/glueball overlap

History of a decay full of surprises

Radiative $J/\psi \to \gamma\eta'\pi^+\pi^-$

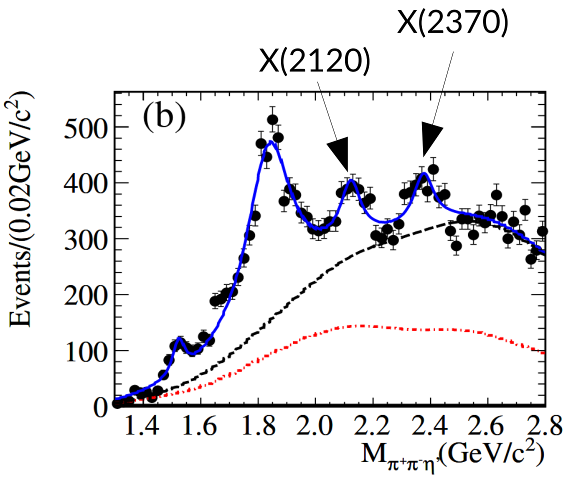
PRL 95 (2005) 262001



58 Million J/ψ

Clear signal of exotic X(1835)

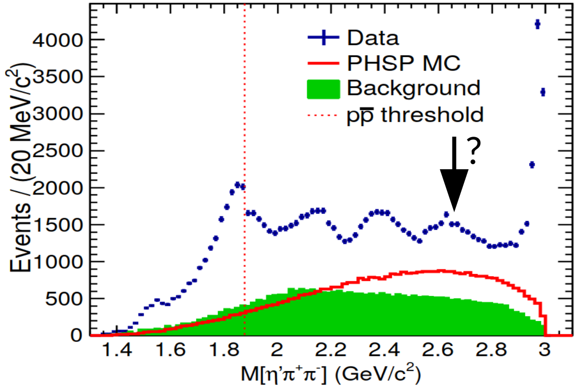
PRL 106 (2011) 072002



225 Million J/ψ

X(1835) confirmed
other two structures emerge

PRL 117 (2016) 042002



1.3 Billion J/ψ

@ 1835 MeV:
2 states or threshold effect?

10B J/ψ Era

Phys. Rev. Lett. 129 (2022) 042002

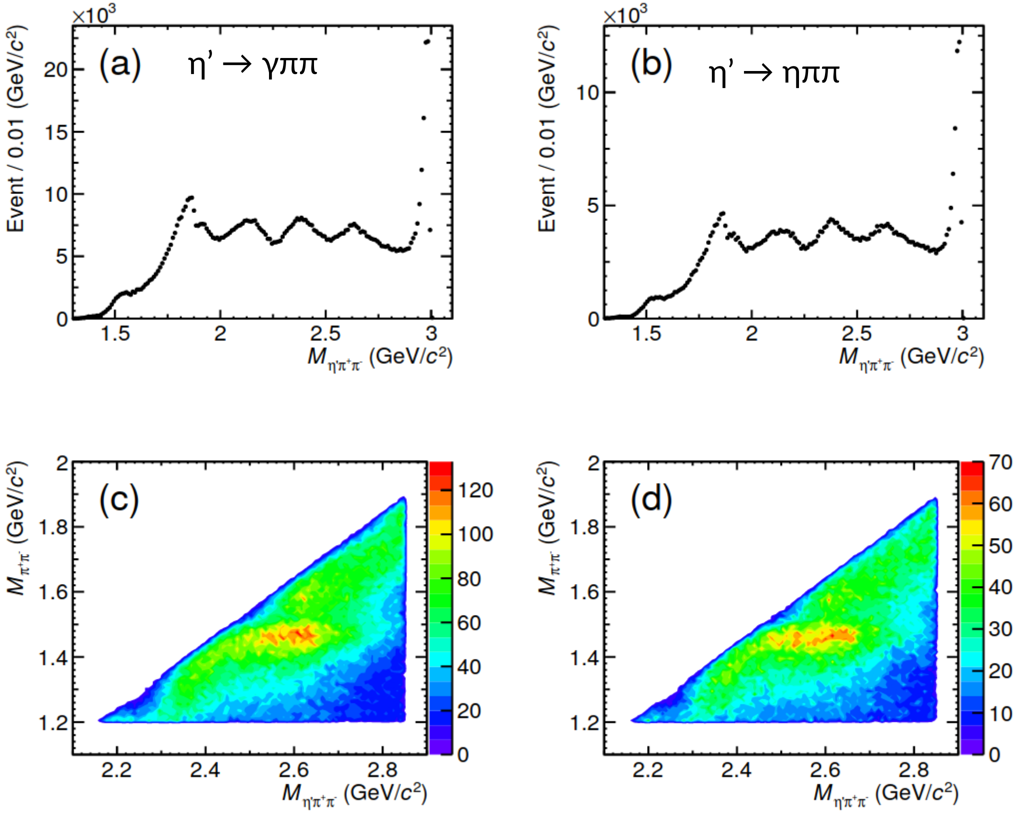
Most accurate measurements of this final state

η’ → γππ and η’ → ηππ

Confirmed known state:

- $f_0(1500)$
- X(1835)
- X(2120)
- X(2370)
- η_c

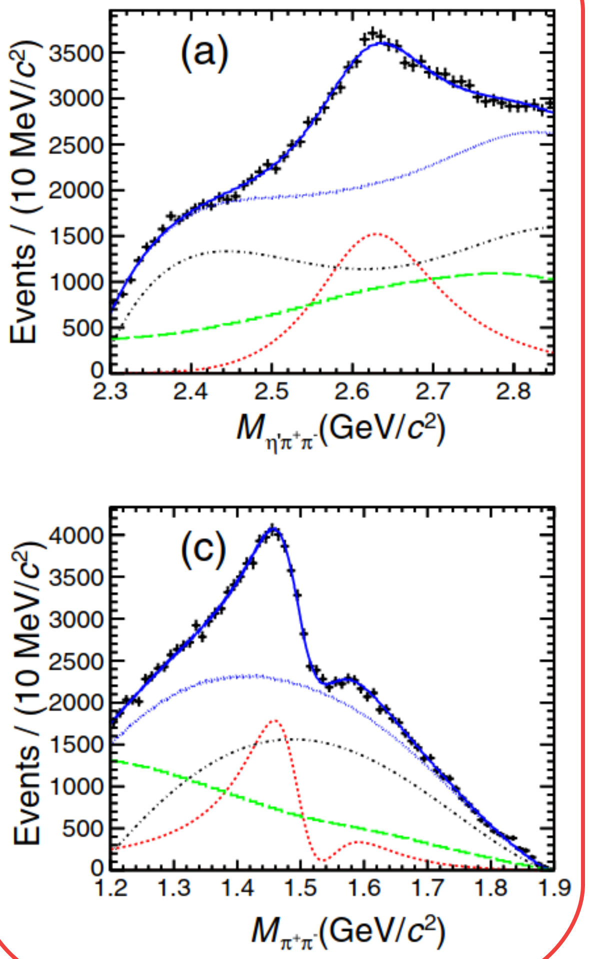
Observed a new state!



X(2600)

Phys. Rev. Lett. 129 (2022) 042002

η' → γππ



η' → ηππ

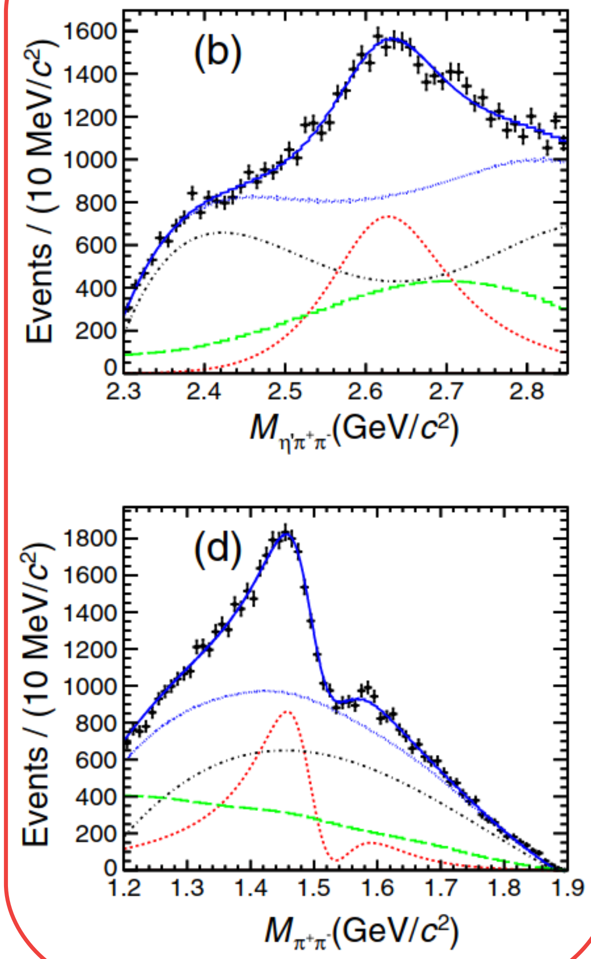


TABLE I. Masses and widths of the $f_0(1500)$, $X(1540)$, and $X(2600)$. The first uncertainties are statistical, and the second are systematic.

Resonance	Mass (MeV/c^2)	Width (MeV)
$f_0(1500)$	$1492.5 \pm 3.6^{+2.4}_{-20.5}$	$107 \pm 9^{+21}_{-7}$
$X(1540)$	$1540.2 \pm 7.0^{+36.3}_{-6.1}$	$157 \pm 19^{+11}_{-77}$
$X(2600)$	$2618.3 \pm 2.0^{+16.3}_{-1.4}$	$195 \pm 5^{+26}_{-17}$

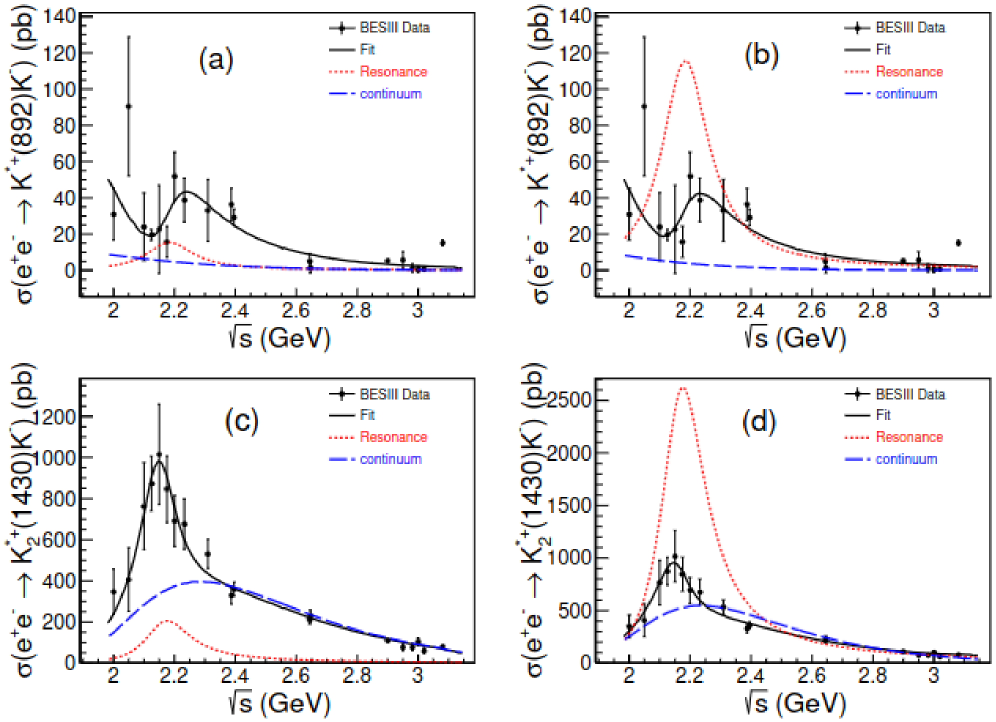
More than 20σ significance for the 3 resonances

Structure @ 1.5 GeV well described by interference between $f_0(1500)$ and X(1540)

JHEP07(2022)045

ϕ(2170) in K*K

Hints on the nature of ϕ(2170) may be found by searching for other final states, testing different models.



PWA of $e^+e^- \to KK\pi^0$ process

~600/pb dataset divided in two groups (2-2.230 GeV and 2.3 -3 GeV) to study intermediate resonances contribution.

Good agreement with BaBar and SND data in $KK\pi^0$ and $\phi\pi^0$ cross section.

Peak in K*(892)K and K*(1430)K!
Simultaneous fit to both cross section assuming same structure in both channels

$$M_R = (2190 \pm 19)\ \mathrm{MeV}/c^2 \text{ and } \Gamma_R = (191 \pm 28)\ \mathrm{MeV}$$

Moreover: BR in K*(1440)K is more than 10 times larger than BR(K*(892)K)

$\phi(2170)$ in $\phi\pi^+\pi^-$

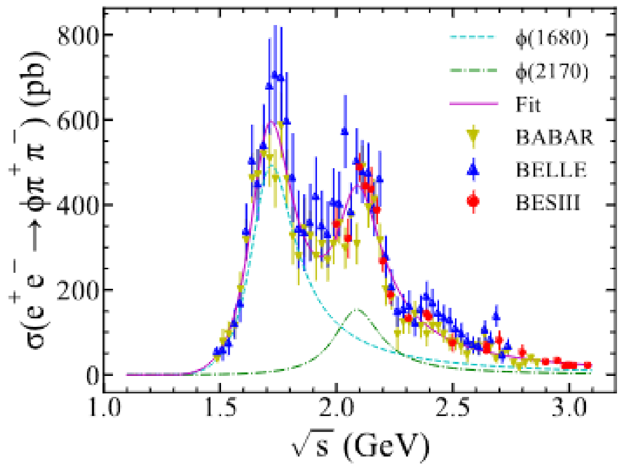
ArXiv: 2112.13219

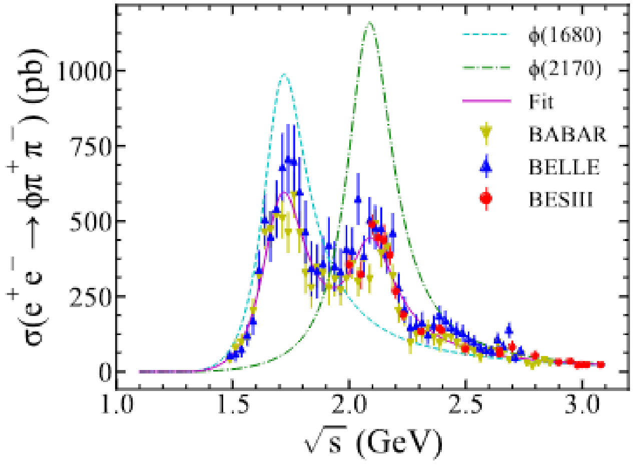
Additional final states can also pin-point BW parameters of ϕ(2170)

Additional resonance in the spectrum hinted by BaBar at 2.4 GeV

Using ~650/pb, study of the $\phi\pi^+\pi^-$ process

Parameters	Solution I	Solution II
$M_r(\phi(1680))$	1694 ± 8	
$\Gamma_r(\phi(1680))$	227 ± 32	
$Br\Gamma_{ee}(\phi(1680))$	21.8 ± 1.3	43.6 ± 1.5
$M_r(\phi(2170))$	2076 ± 10	
$\Gamma_r(\phi(2170))$	243 ± 21	
$Br\Gamma_{ee}(\phi(2170))$	10.8 ± 1.0	81.9 ± 5.5
$\phi_P(\phi(2170)/\phi(1680))$	0.75 ± 0.14	-2.07 ± 0.05





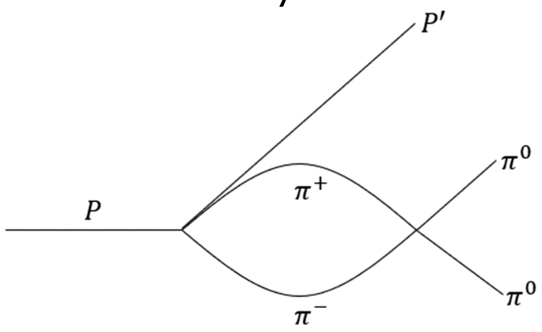
ϕ(2170) comparable with other observations

Not enough statistics to identify structure at 2.4 GeV

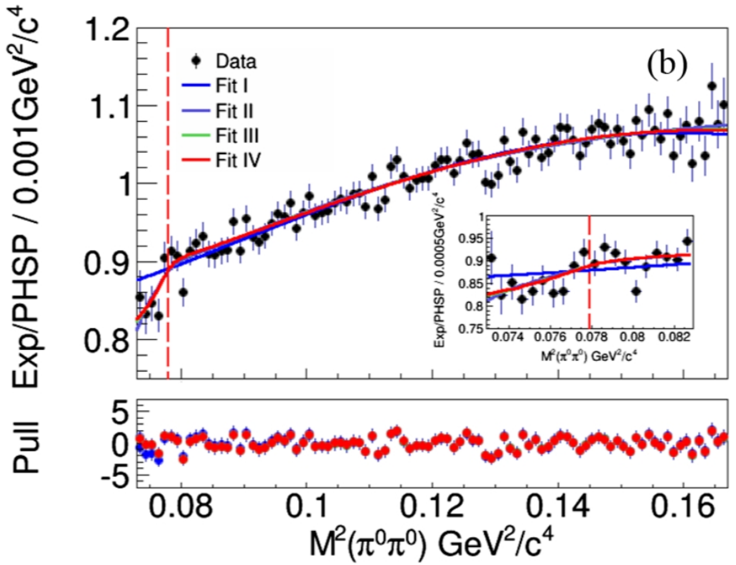
PRL130, 081901 (2023)

Cusp effect in η' → η $\pi^0\pi^0$ decay

- Study the fundamental properties of QCD at low energies
- Test effective ChPT
- Investigation on ππ and πη final interactions
- Sizeable cusp effect in this decay



The S-wave charge-exchange rescattering $\pi^+\pi^- \to \pi^0\pi^0$ causes a prominent cusp at the center of mass energy corresponding to the summed mass of two charged pions.

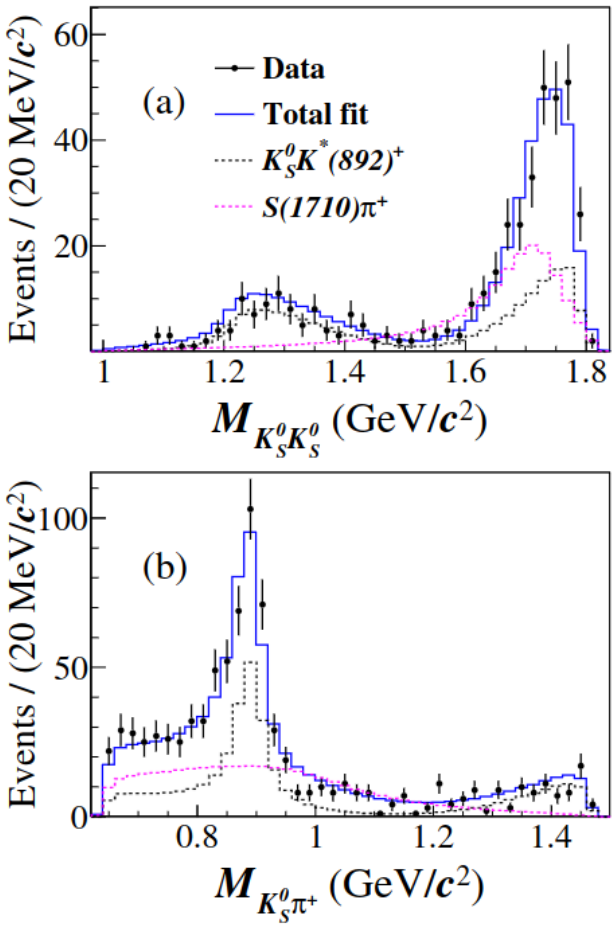


	FIT I	FIT II	FIT III	FIT IV
Statistical Significance	-	3.4σ	3.7σ	3.6σ

with CUSP effect

$D_s \to K_S K_S \pi^+$

PRD 105 (2022) L051103



D_s decay can be also used to shed new light on nature of light hadrons, like $f_0(1710)$

Due to high interference between f_0 and a_0, in the paper denoted generically as S-state.

Branching ratio of the full process is measured and it is compatible with PDG

Based on $f_0(1710)$ results, it is necessary that an $a_0(1710)^0$ state exists, as observed by BaBar (Phys. Rev. D 104, 072002 (2021))

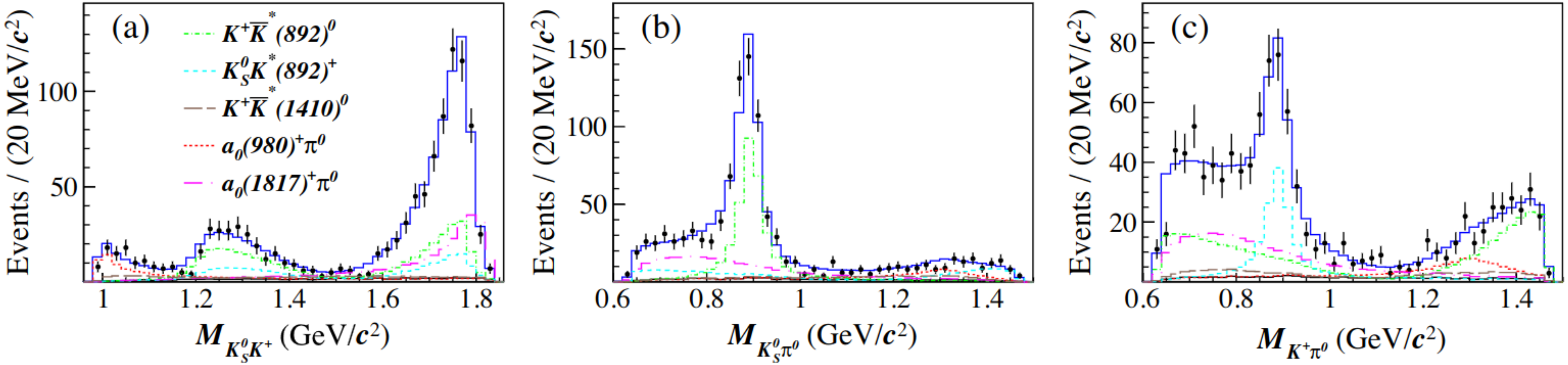
An $a_0(1710)^0$ charged partner is also expected in $K_S K$ mass to be searched in $D_s \to K_S K^+ \pi^0$

$D_s \to K_S K^+ \pi^0$

PRL 129 (2022) 182001

Using 6.28/fb D_s data, study the decay to search for possible $a_0(1710)$ charged partner

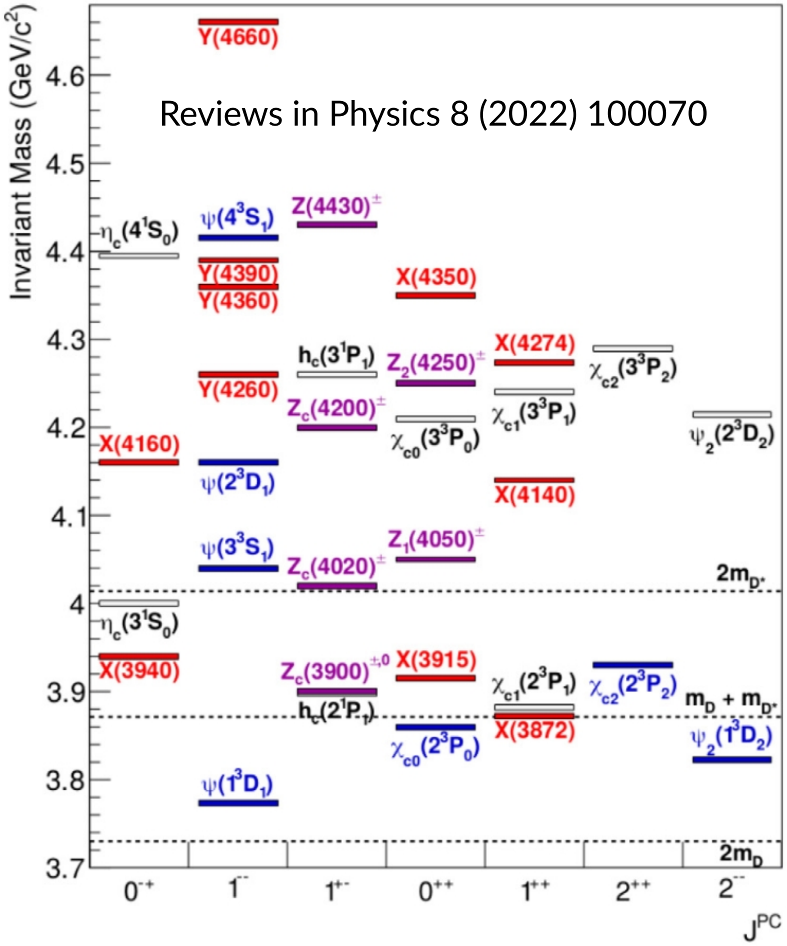
Total BR is found to be compatible with previous measurements



Observed a charged a_0-like structure in $K_s K^+$ mass with significance greater than 10σ. This results supports the existence of a new a_0 triplet, as predicted by Phys. Rev. D 79, 074009 (2009) and other works

Its mass is 100 MeV larger than expectation for $f_0(1710)$ isospin-1 partner. To extract further details on its nature, combined amplitude analysis of $D_s \to K_S K_S \pi^+$ and $D_s \to K_S K \pi^0$ is needed

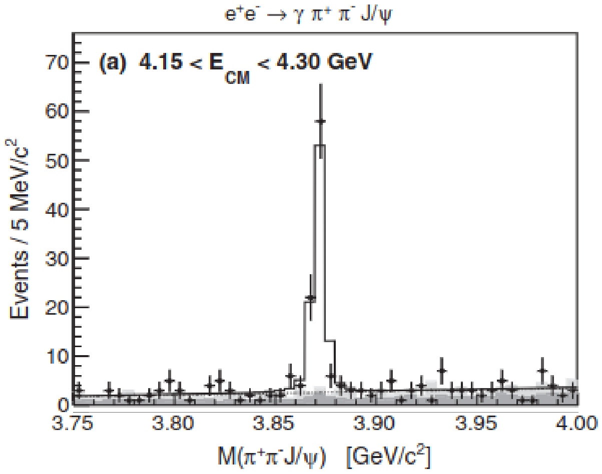
XYZ states


Invariant Mass (GeV/c2)
Y(4660)
Reviews in Physics 8 (2022) 100070
ηc(41S0)
ψ(43S1)
Z(4430)±
Y(4390)
Y(4360)
X(4350)
hc(31P1)
Z2(4250)±
X(4274)
χc2(33P2)
Y(4260)
Zc(4200)±
χc1(33P1)
X(4160)
χc0(33P0)
ψ2(23D2)
ψ(23D1)
X(4140)
ψ(33S1)
Z1(4050)±
Zc(4020)±
2mD*
ηc(31S0)
X(3940)
Zc(3900)±,0
X(3915)
χc1(23P1)
χc2(23P2)
mD + mD*
hc(21P1)
χc0(23P0)
X(3872)
ψ2(13D2)
ψ(13D1)
2mD
0-+
1--
1+-
0++
1++
2++
2--
JPC

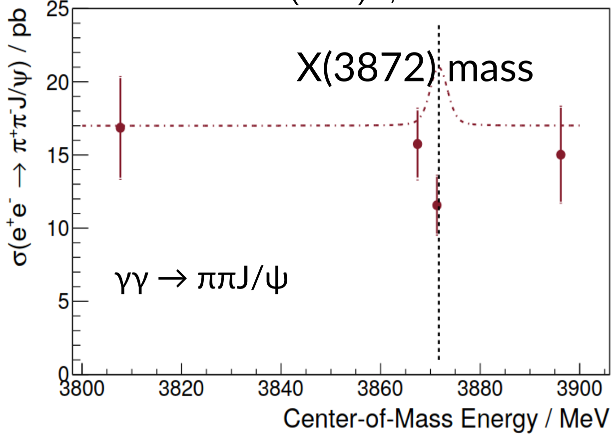
X(3872) production mode

20th anniversary of X(3872) discovery. Still, only clues on its nature.

PRL 122, 202001 (2019)

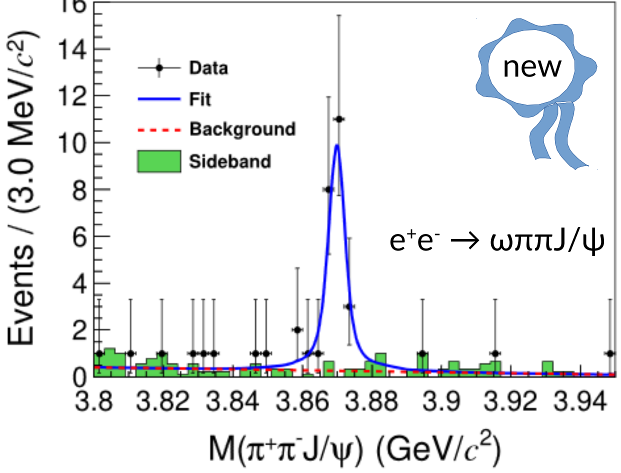


PRD 107 (2023) 3, 032007



$$\sigma(\sqrt{s}) = \sigma_{\text{cont}} + 12\pi \frac{\Gamma_{\text{tot}}\Gamma_{ee} \times \mathcal{B}(X(3872) \to \pi^+\pi^- J/\psi)}{(s - m_0^2)^2 + m_0^2\Gamma_{\text{tot}}^2}$$

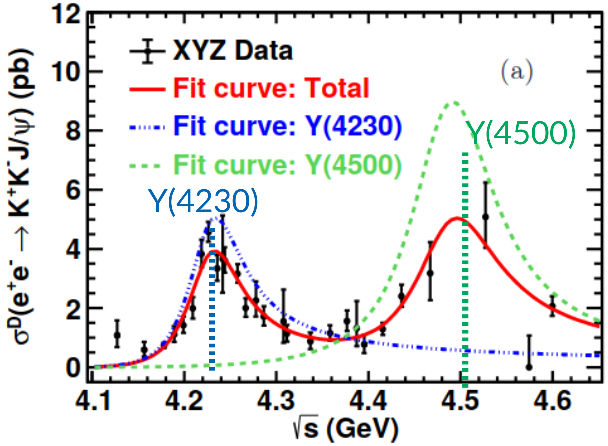
PRL 130, 151904 (2023)



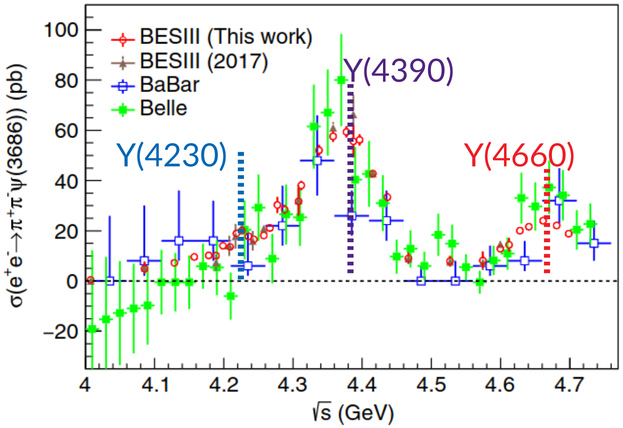
4.66 < Ecm < 4.95 GeV

Vector charmonium-like states

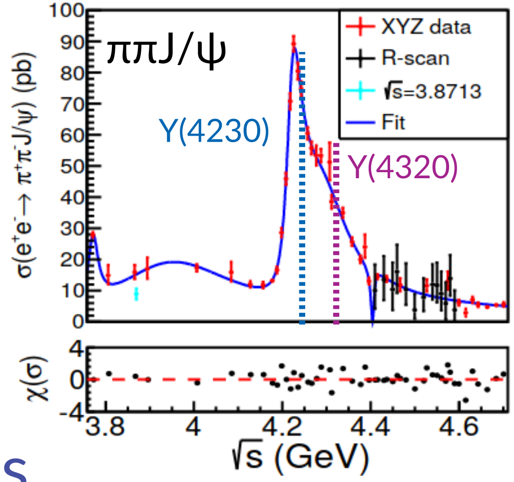
KKJ/ψ CPC 64 (2022) 111002



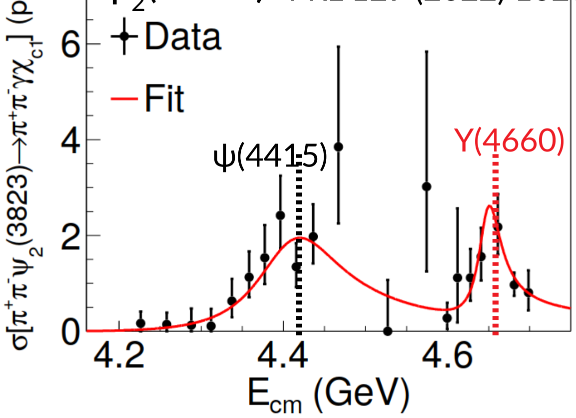
ππψ(2S) PRD 104 (2021) 052012



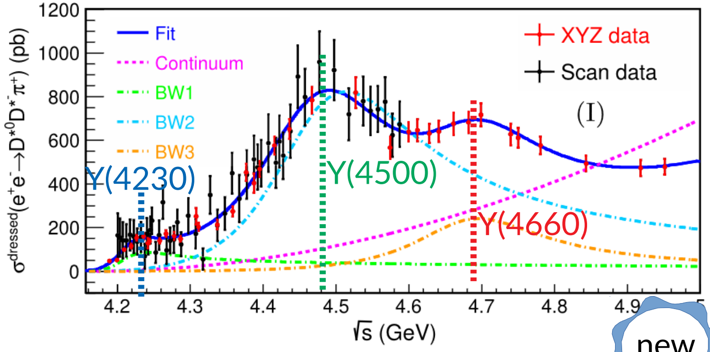
arXiv:2206.08554



$\pi\pi\psi_2(3823)$ PRL 129 (2022) 102003



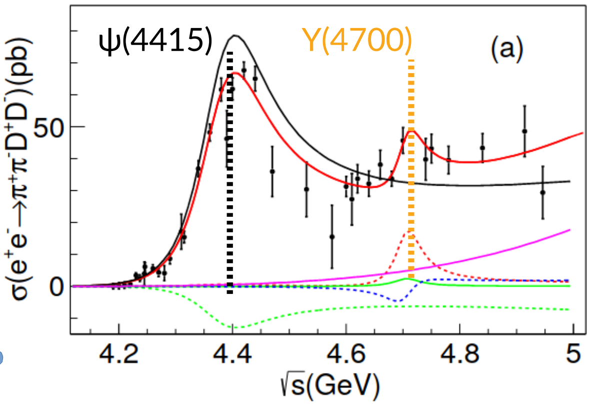
PRL 130, 121901 (2023)



$D^{*0}D^{*-}\pi^+$

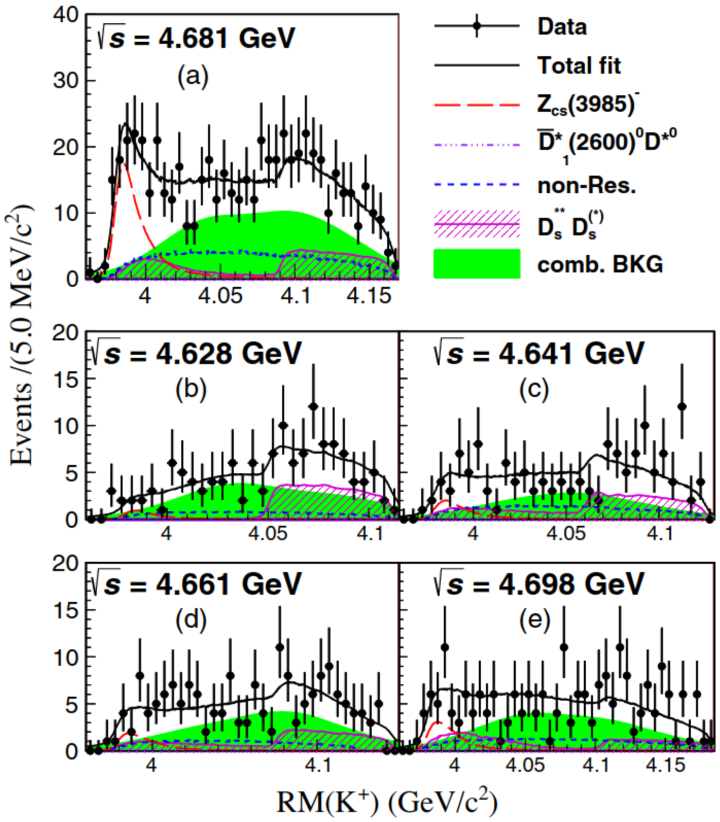
new

ππDD PRD 106 (2022) 052012



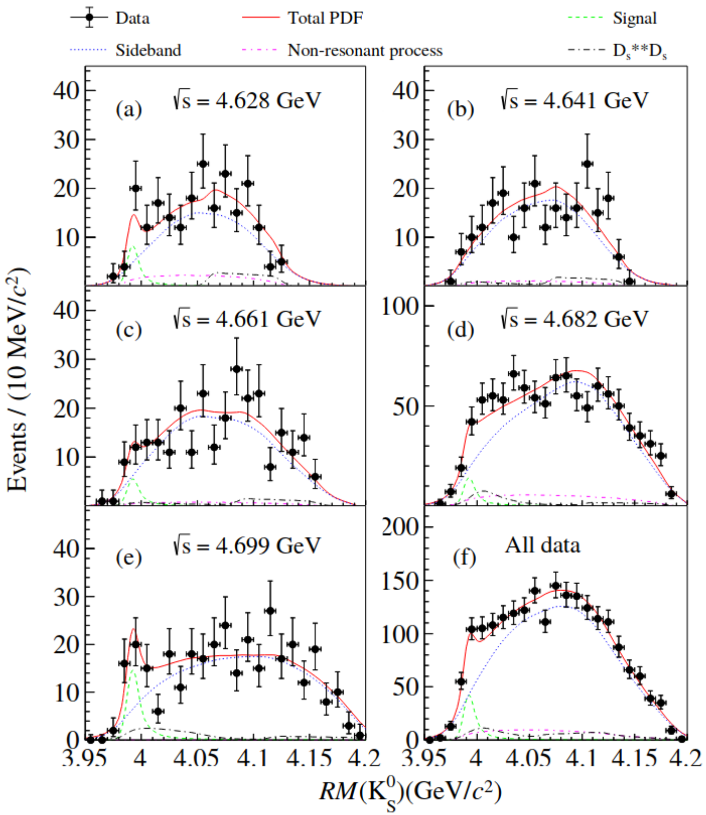
$Z_{cs}(3985)^{\pm,0}$

PRL 126 (2021) 102001



Observation in $(D_s^- D^{*0} + D_s^{*-} D^0)$

PRL 129 (2022) 112003



Evidence in $(D_s^+ D^{*-} + D_s^{*+} D^-)$

Iso-Vector open strangeness triplet

Bonus tracks from BESIII physics program

Ξ^0 hyperon polarization

Arxiv: 2305.09218

Hyperons have the most precise measurements of CP violation in the baryon sector

Doubly strange hyperons can be used as a probe for weak and strong phase differences by measuring the sequential decay chain

$$\tan(\xi_P - \xi_S) = \frac{\sqrt{1-\alpha_\Xi^2}\sin\phi_\Xi + \sqrt{1-\bar{\alpha}_\Xi^2}\sin\bar{\phi}_\Xi}{\alpha_\Xi - \bar{\alpha}_\Xi},$$

$$\tan(\delta_P - \delta_S) = \frac{\sqrt{1-\alpha_\Xi^2}\sin\phi_\Xi - \sqrt{1-\bar{\alpha}_\Xi^2}\sin\bar{\phi}_\Xi}{\alpha_\Xi - \bar{\alpha}_\Xi}.$$

Formalism exploits polarization, entanglement and sequential decays

PRD 99(1019) 056008
PRD 100(2019) 114005

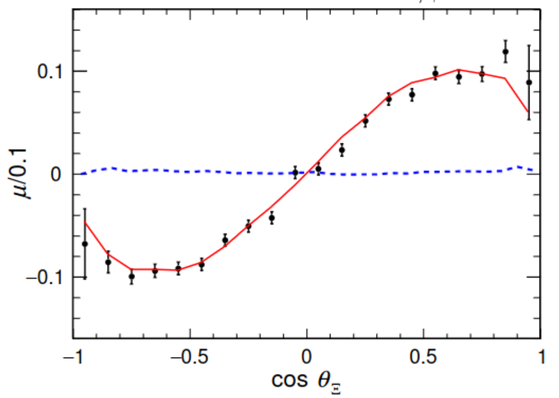
$$\mathcal{W}(\boldsymbol{\xi},\boldsymbol{\omega}) = \sum_{\mu,\bar{\nu}=0}^{3} C_{\mu\bar{\nu}} \sum_{\mu',\bar{\nu}'=0}^{3} a_{\mu\mu'}^{B_1} a_{\bar{\nu}\bar{\nu}'}^{\bar{B}_1} a_{\mu'0}^{B_2} a_{\bar{\nu}'0}^{\bar{B}_2}$$

9-dim phase space given by 9 helicity angles, 8 free parameters determined by unbinned MLL method

Ξ^0 hyperon polarization

Arxiv: 2305.09218

$$\mu(\cos\theta_\Xi) = \frac{\alpha_\Xi - \bar{\alpha}_\Xi}{2} \frac{1+\alpha_{J/\psi}\cos^2\theta_\Xi}{3+\alpha_{J/\psi}} P_y(\theta_\Xi)$$

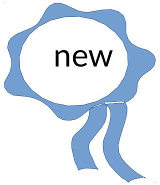


Clear polarization!

Parameter	This work	Previous result
$\alpha_{J/\psi}$	$0.514 \pm 0.006 \pm 0.015$	0.66 ± 0.06 [34]
$\Delta\Phi(\text{rad})$	$1.168 \pm 0.019 \pm 0.018$	-
α_Ξ	$-0.3750 \pm 0.0034 \pm 0.0016$	-0.358 ± 0.044 [18]
$\bar{\alpha}_\Xi$	$0.3790 \pm 0.0034 \pm 0.0021$	0.363 ± 0.043 [18]
$\phi_\Xi(\text{rad})$	$0.0051 \pm 0.0096 \pm 0.0018$	0.03 ± 0.12 [18]
$\bar{\phi}_\Xi(\text{rad})$	$-0.0053 \pm 0.0097 \pm 0.0019$	-0.19 ± 0.13 [18]
α_Λ	$0.7551 \pm 0.0052 \pm 0.0023$	0.7519 ± 0.0043 [13]
$\bar{\alpha}_\Lambda$	$-0.7448 \pm 0.0052 \pm 0.0017$	-0.7559 ± 0.0047 [13]
$\xi_P - \xi_S(\text{rad})$	$(0.0 \pm 1.7 \pm 0.2) \times 10^{-2}$	-
$\delta_P - \delta_S(\text{rad})$	$(-1.3 \pm 1.7 \pm 0.4) \times 10^{-2}$	-
A^Ξ_{CP}	$(-5.4 \pm 6.5 \pm 3.1) \times 10^{-3}$	$(-0.7 \pm 8.5) \times 10^{-2}$ [18]
$\Delta\phi^\Xi_{CP}(\text{rad})$	$(-0.1 \pm 6.9 \pm 0.9) \times 10^{-3}$	$(-7.9 \pm 8.3) \times 10^{-2}$ [18]
A^Λ_{CP}	$(6.9 \pm 5.8 \pm 1.8) \times 10^{-3}$	$(-2.5 \pm 4.8) \times 10^{-3}$ [13]
$\langle\alpha_\Xi\rangle$	$-0.3770 \pm 0.0024 \pm 0.0014$	-
$\langle\phi_\Xi\rangle(\text{rad})$	$0.0052 \pm 0.0069 \pm 0.0016$	-
$\langle\alpha_\Lambda\rangle$	$0.7499 \pm 0.0029 \pm 0.0013$	0.7542 ± 0.0026 [13]

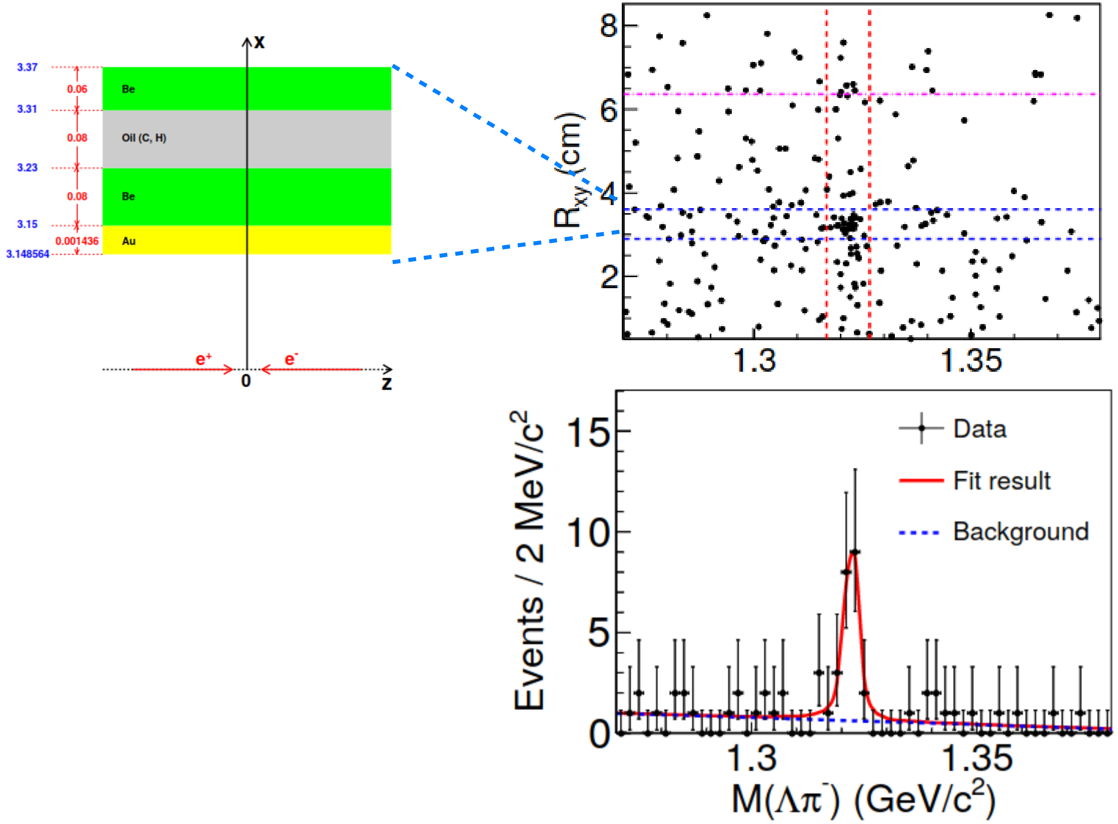
Results:

- First measurement of Ξ^0 polarization
- Improved $\Xi^0\Xi^0$ decay parameters
- Improved precision on Weak phase difference (compared to Ξ^- decay – Nature 606 (2022) 64)
- Independent CP tests



PRL130 (2023) 251902

$\Xi^0 n \rightarrow \Xi^- p$ scattering



Hyperon-nucleon scattering with a Ξ^0 beam with 818 MeV/c momentum

$$\sigma(\Xi^0 + {}^9\mathrm{Be} \to \Xi^- + p + {}^8\mathrm{Be}) = \frac{N^{\mathrm{sig}}}{\epsilon \mathcal{B} \mathcal{L}_{\mathrm{eff}}}$$

$$\mathcal{L}_{\mathrm{eff}} = \frac{N_{J/\psi}\mathcal{B}_{J/\psi}}{2+\frac{2}{3}\alpha} \int_a^b \int_0^\pi (1+\alpha\cos^2\theta) e^{-\frac{x}{\sin\theta\beta\gamma L}} N(x) C(x) \mathrm{d}\theta \mathrm{d}x.$$

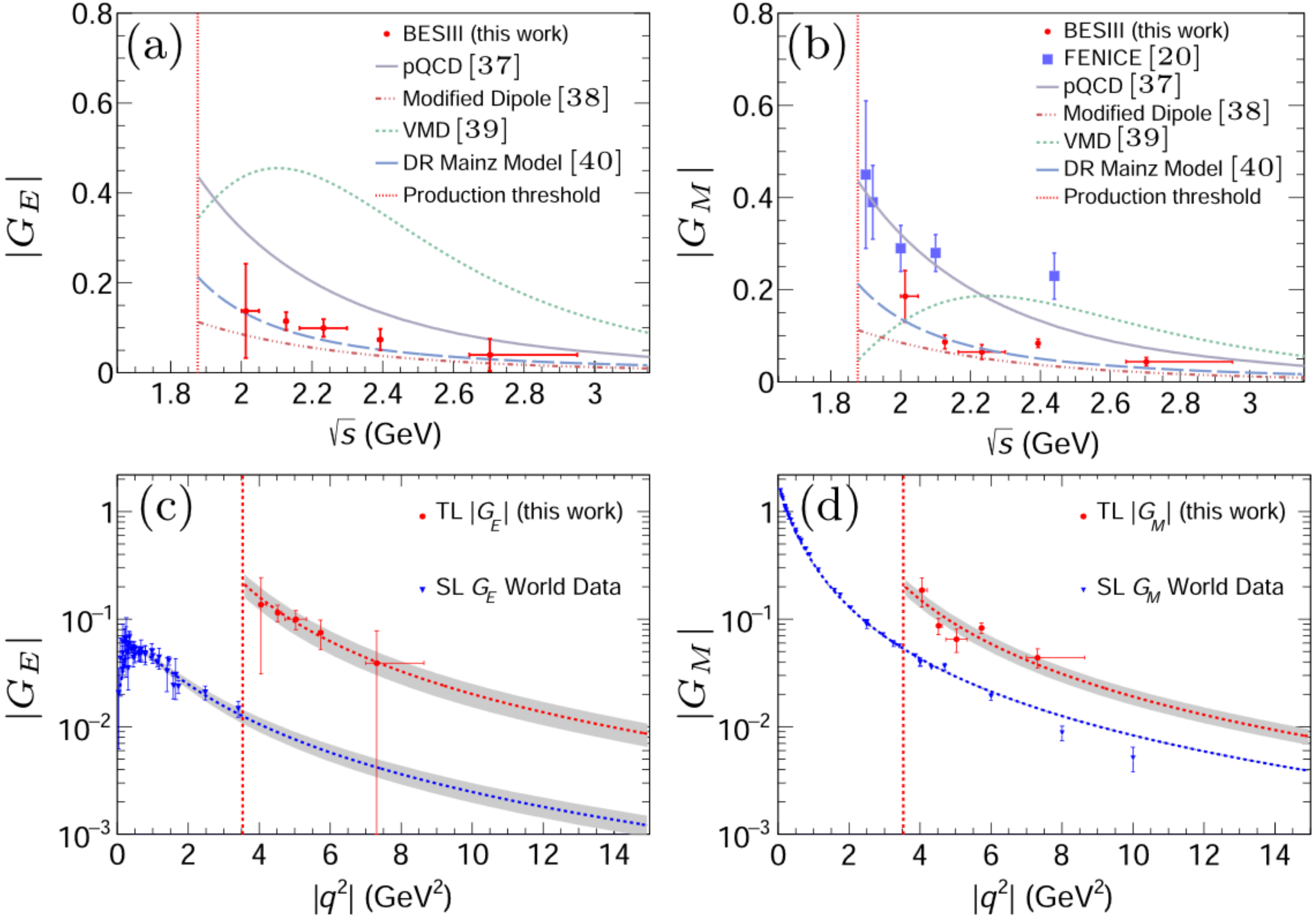
Clear signal found with 7.1σ significance
Cross section estimated to be

$$\sigma(\Xi^0 + {}^9\mathrm{Be} \to \Xi^- + p + {}^8\mathrm{Be}) = (22.1 \pm 5.3_{\mathrm{stat}} \pm 4.5_{\mathrm{sys}})\ \mathrm{mb}$$

Study other hyperons at BESIII ongoing

Neutron form factors

PRL 130, 151905 (2023)



Events classified with 3 categories:
1) n and $\bar{n}$ in TOF - $\bar{n}$ in EMC
2) $\bar{n}$ in TOF – n and $\bar{n}$ in EMC
3) no TOF – n and $\bar{n}$ in EMC

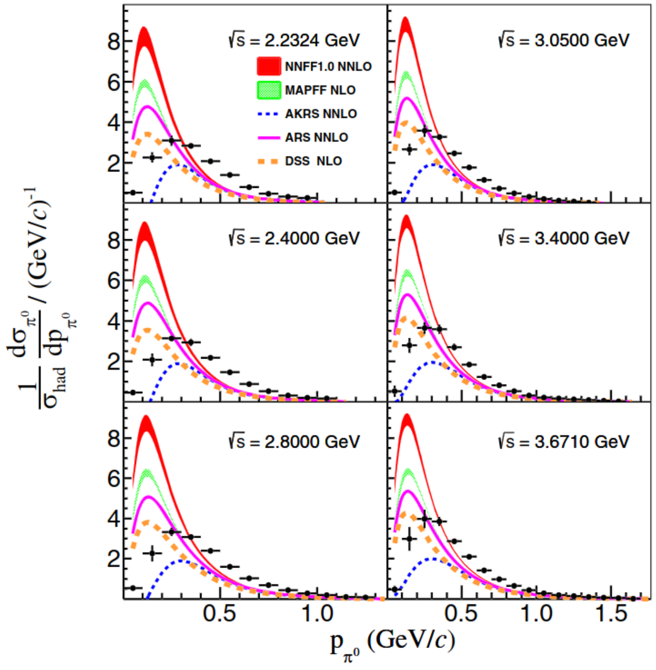
First direct measurement of G_M

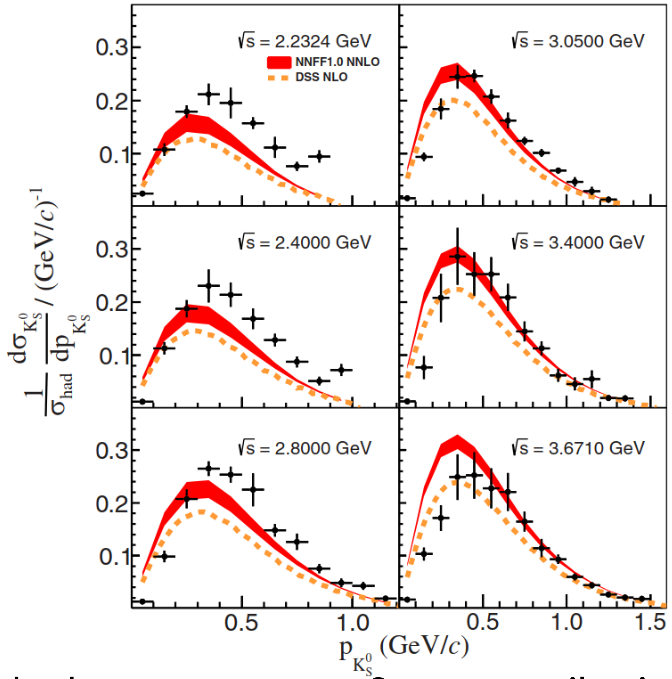
Comparable precision with SL data!

PRL 130 (2023) 231901

Inclusive hadron production

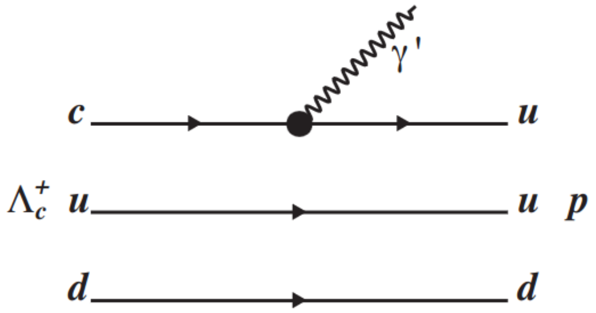
e^+e^- colliders can be used to study differential semi-inclusive $e^+e^- \to h + X$ cross section to compare with Fragmentation Function (FF) theoretical models extrapolated at low energy





Discrepancy observedat difference center of mass energy and hadron momentum. Some contribution from resonances to inclusive production Data can be used to tune FF models at low energy and test collinear QCD.

Dark photon in Charmed baryon decays

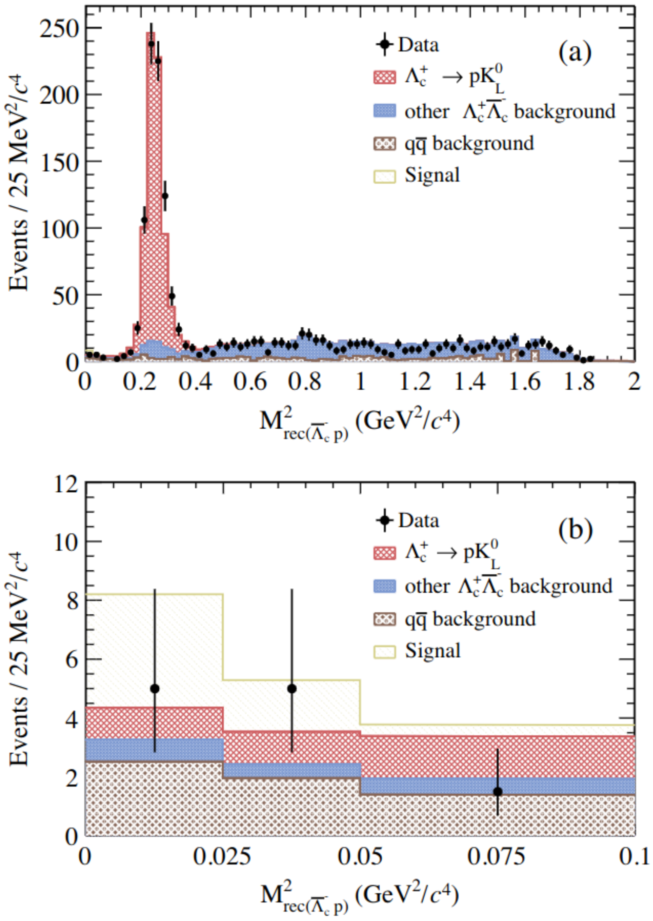


FCNC c → uγ' can be used to test BSM theories.

Double tag approach can be used to remove larger backgrounds and search for massless dark photon.

PRD 102 (2020) 115029 predicts BR to be ~ 10^{-5}

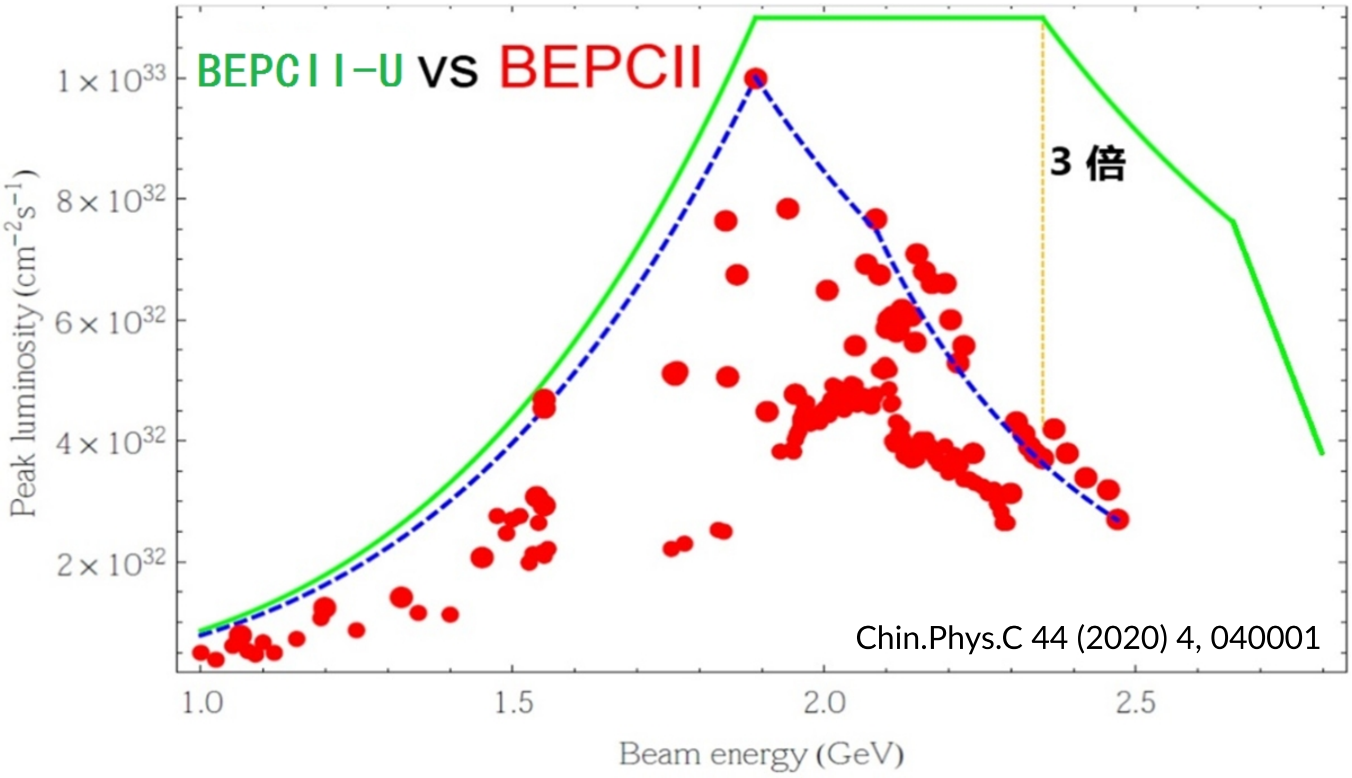
Found upper limit of UL($\Lambda_c \to p\gamma'$) < 8×10^{-5} @ 90% C.L.



BESIII Future program

Chin.Phys.C 44 (2020) 4, 040001

Pushing towards new limits

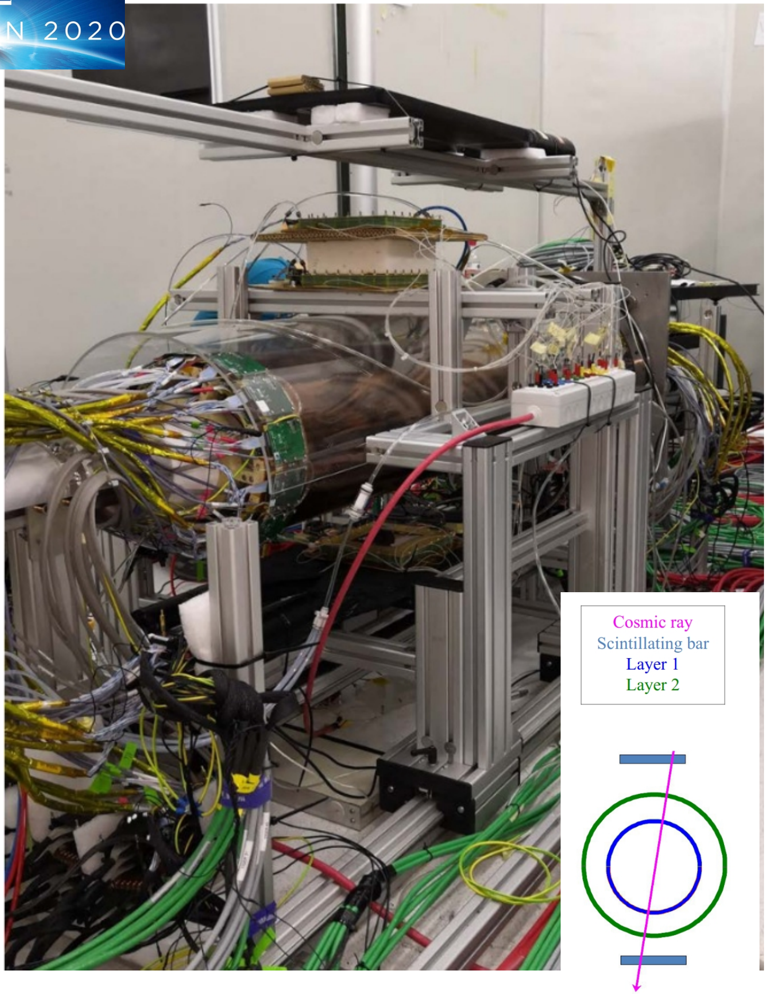


Accelerator upgrade:

- center of mass maximum energy up to 5.6 GeV
- 3 times the present luminosity in XYZ region

A new inner tracker

Symmetry 14 (2022) 5, 905
Chin.Phys.C 44 (2020) 4, 040001

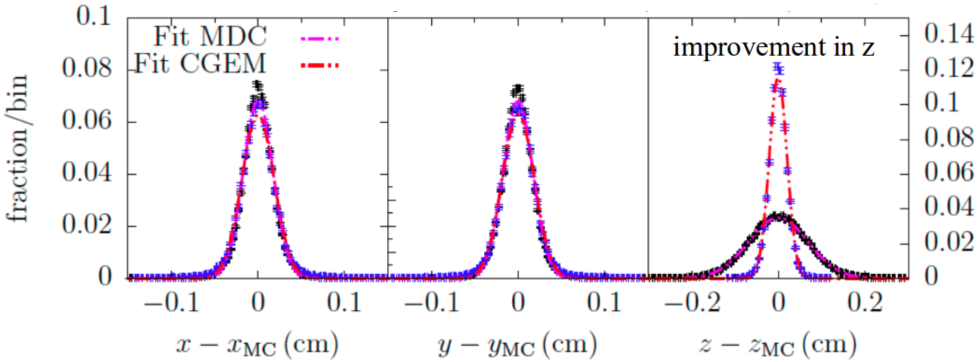


New inner tracker starting from an Italian proposal: the CGEM-IT

3 layers of Cylindrical triple-GEM to improve rate capability, radiation hardness and vertexes reconstruction

Status:

- First two layers in Beijing taking data (JINST 15 (2020) 08, C08004)
- Dedicated readout chain (JINST 16 (2021) 08, P08065)
- Hybrid costruction of the third layer in on-going



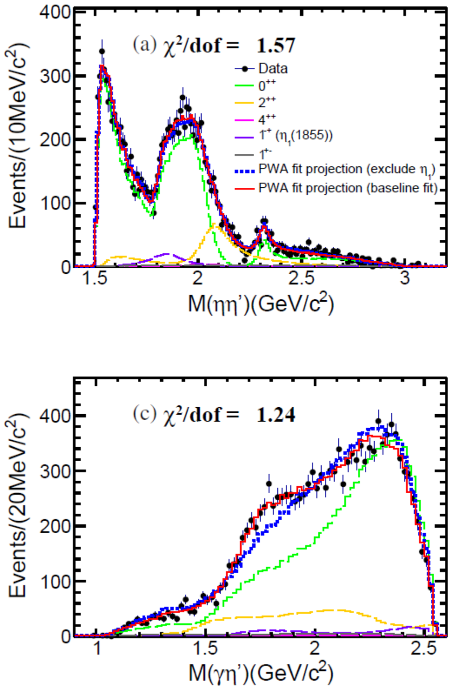
The CGEM-IT project is funded by the EU commission by the RISE-MSCA-H2020-2019 program within the FEST consortium

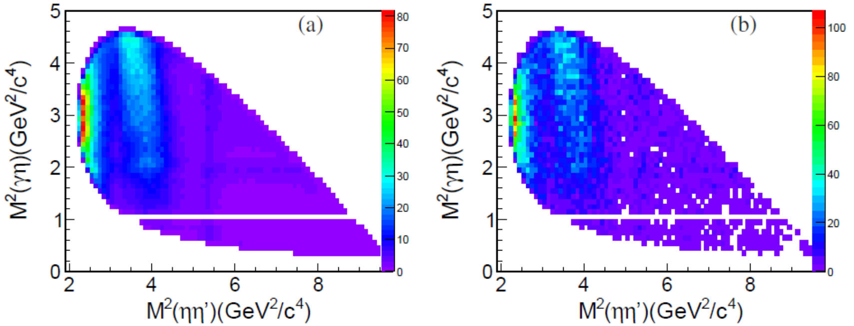
THANKS!

For many other details, please have a look to HADRON2023 BESIII contributions
https://agenda.infn.it/event/33110/contributions/

Additional materials

PWA fit projections

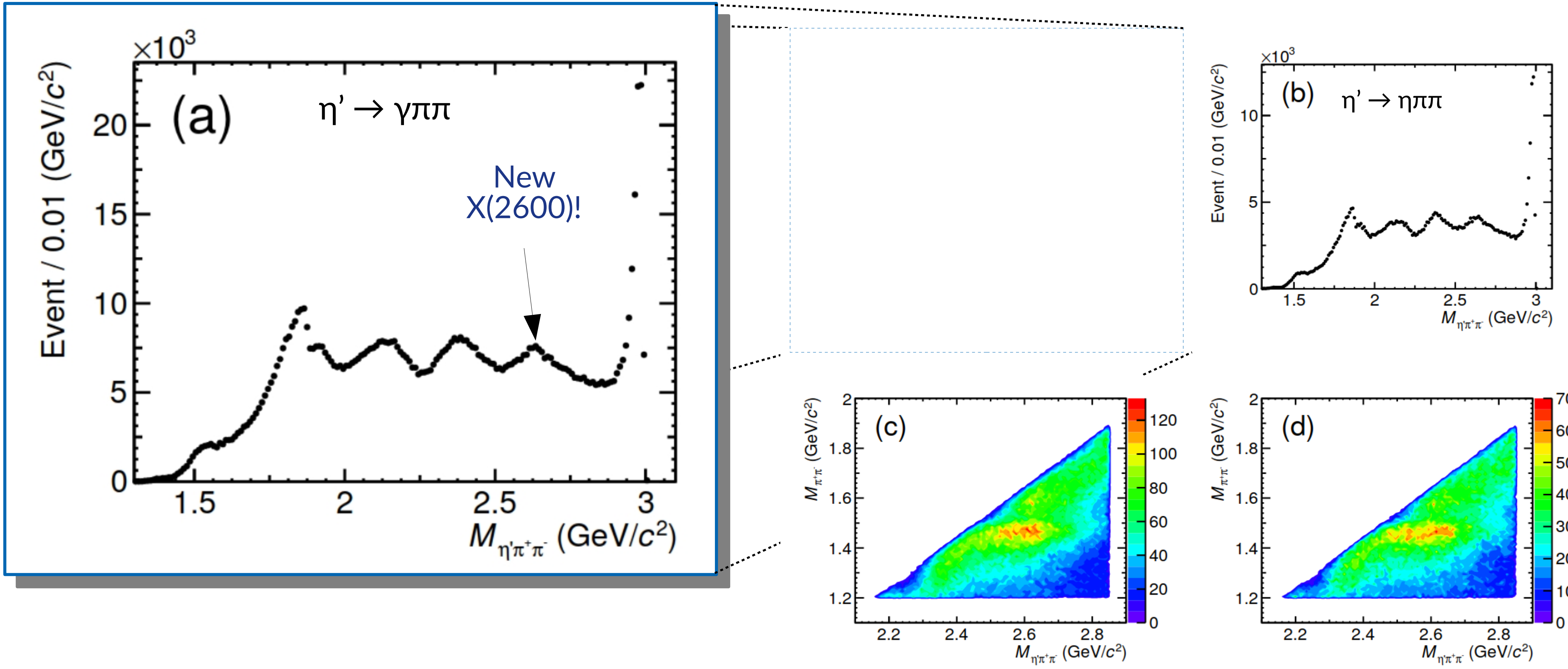




Decay mode	Resonance	M (MeV/c^2)	Γ (MeV)	$M_{\rm PDG}$ (MeV/c^2)	$\Gamma_{\rm PDG}$ (MeV)	B.F. ($\times 10^{-5}$)	Sig.
$J/\psi \to \gamma X \to \gamma\eta\eta'$	$f_0(1500)$	1506	112	1506	112	$1.81\pm0.11^{+0.19}_{-0.13}$	$\gg 30\sigma$
	$f_0(1810)$	1795	95	1795	95	$0.11\pm0.01^{+0.04}_{-0.03}$	11.1σ
	$f_0(2020)$	$2010\pm6^{+6}_{-4}$	$203\pm9^{+13}_{-11}$	1992	442	$2.28\pm0.12^{+0.29}_{-0.20}$	24.6σ
	$f_0(2330)$	$2312\pm7^{+7}_{-3}$	$65\pm10^{+3}_{-12}$	2314	144	$0.10\pm0.02^{+0.01}_{-0.02}$	13.2σ
	$\eta_1(1855)$	$1855\pm9^{+6}_{-1}$	$188\pm18^{+3}_{-8}$	-	-	$0.27\pm0.04^{+0.02}_{-0.04}$	21.4σ
	$f_2(1565)$	1542	122	1542	122	$0.32\pm0.05^{+0.12}_{-0.02}$	8.7σ
	$f_2(2010)$	$2062\pm6^{+10}_{-7}$	$165\pm17^{+10}_{-5}$	2011	202	$0.71\pm0.06^{+0.10}_{-0.06}$	13.4σ
	$f_4(2050)$	2018	237	2018	237	$0.06\pm0.01^{+0.03}_{-0.01}$	4.6σ
	0^{++} PHSP	-	-	-	-	$1.44\pm0.15^{+0.10}_{-0.20}$	15.7σ
$J/\psi \to \eta' X \to \gamma\eta\eta'$	$h_1(1415)$	1416	90	1416	90	$0.08\pm0.01^{+0.01}_{-0.02}$	10.2σ
	$h_1(1595)$	1584	384	1584	384	$0.16\pm0.02^{+0.03}_{-0.01}$	9.9σ

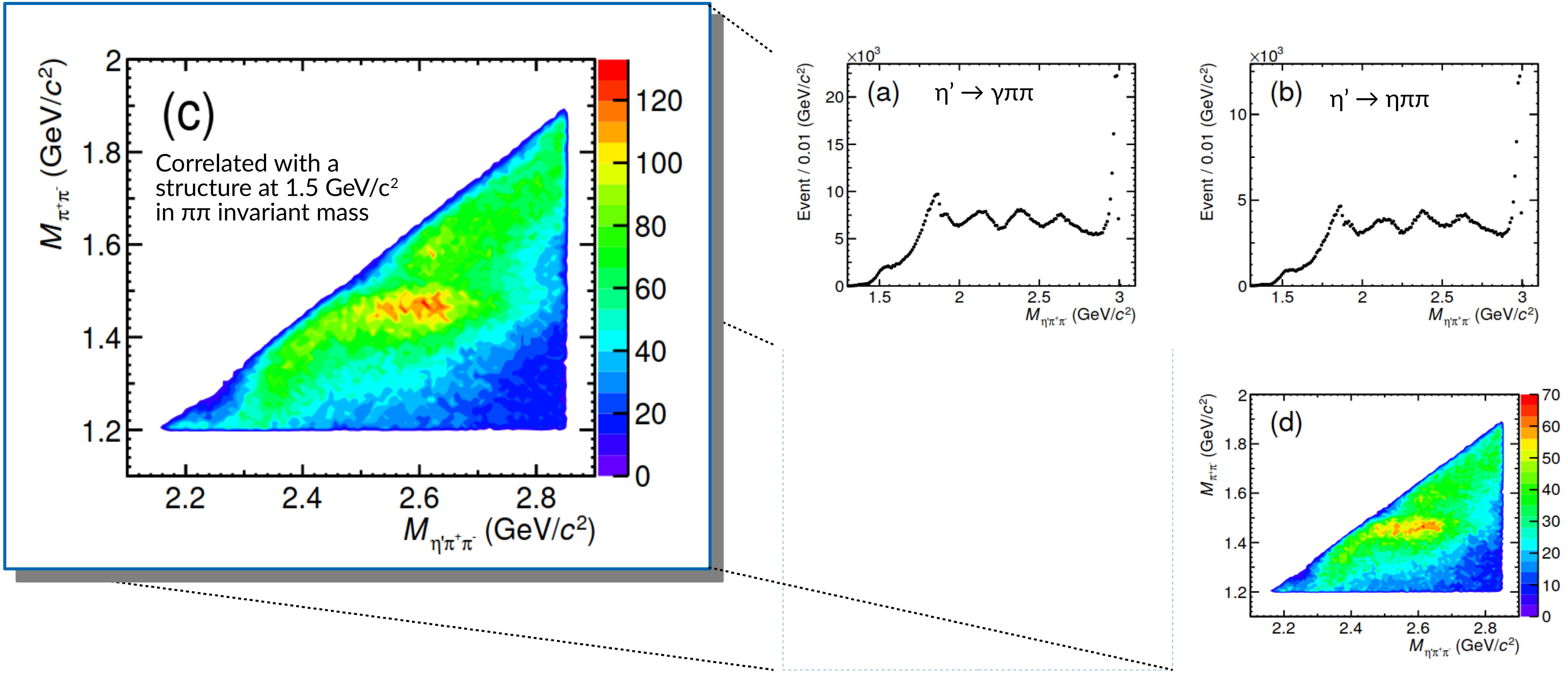
10B J/ψ Era

Phys. Rev. Lett. 129 (2022) 042002



10B J/ψ Era

Phys. Rev. Lett. 129 (2022) 042002



Φ(2170) in K*K

Process	Significance (2.125 GeV)	Significance (2.396 GeV)
$\phi\pi^0$	18.6σ	2.3σ
$\rho(1450)\pi^0$	7.8σ	2.4σ
$\phi(1680)\pi^0$	19.5σ	14.9σ
$\rho(1900)\pi^0$	7.2σ	7.4σ
$\rho_3(2250)$	5.5σ	5.0σ
$K^*(892)K$	15.9σ	15.6σ
$K^*(1410)K$	5.7σ	5.0σ
$K_2^*(1430)K$	35.4σ	25.3σ
$K_3^*(1780)K$	5.8σ	5.5σ

Table 2. Statistical significances of possible intermediate processes at $\sqrt{s} = 2.125$ and 2.396 GeV.

States	Mass (MeV/c^2)	Width (MeV)	PDG Mass (MeV/c^2)	PDG Width (MeV)
$K_2^*(1430)$	1428 ± 2	107 ± 4	1427.3 ± 1.5	100.0 ± 2.1
$\phi(1680)$	1673 ± 5	172 ± 8	1680 ± 20	150 ± 50
$\rho(1900)$	1880 ± 10	69 ± 15	1860–1910	10–160
ϕ	fixed	fixed	1019.5 ± 0.02	4.2 ± 0.01
$\rho(1450)$	fixed	fixed	1465 ± 25	400 ± 60
$\rho_3(2250)$	fixed	fixed	2248^{+17+59}_{-17-5} [44]	$185^{+31+17}_{-26-103}$ [44]
$K^*(892)$	fixed	fixed	891.7 ± 0.3	50.8 ± 0.9
$K^*(1410)$	fixed	fixed	1414 ± 15	232 ± 21
$K_3^*(1780)$	fixed	fixed	1776 ± 7	159 ± 21

Table 3. Masses and widths of the intermediate states at $\sqrt{s} = 2.125$ GeV. Due to the limited data sample size, only the statistical uncertainties are provided. The parameters of $\rho_3(2250)$ are cited from ref. [44], where the first uncertainty is statistical and the second one is systematic.

Process	Fraction (%) (2.125 GeV)	Fraction (%) (2.396 GeV)
$\phi\pi^0$	1.8 ± 0.4	0.7 ± 0.3
$\rho(1450)\pi^0$	3.8 ± 0.7	0.2 ± 0.2
$\phi(1680)\pi^0$	14.6 ± 2.3	13.6 ± 2.9
$\rho(1900)\pi^0$	2.1 ± 0.3	3.0 ± 1.0
$\rho_3(2250)$	0.9 ± 0.5	0.9 ± 0.6
$K^*(892)K$	2.8 ± 0.3	9.3 ± 1.2
$K^*(1410)K$	1.1 ± 0.8	3.6 ± 1.4
$K_2^*(1430)K$	73.0 ± 3.7	64.6 ± 3.2
$K_3^*(1780)K$	1.3 ± 0.5	2.1 ± 1.4

Table 4. Fit fractions of possible intermediate processes at $\sqrt{s} = 2.125$ and 2.396 GeV.

Φ(2170) in K*K – PWA projections

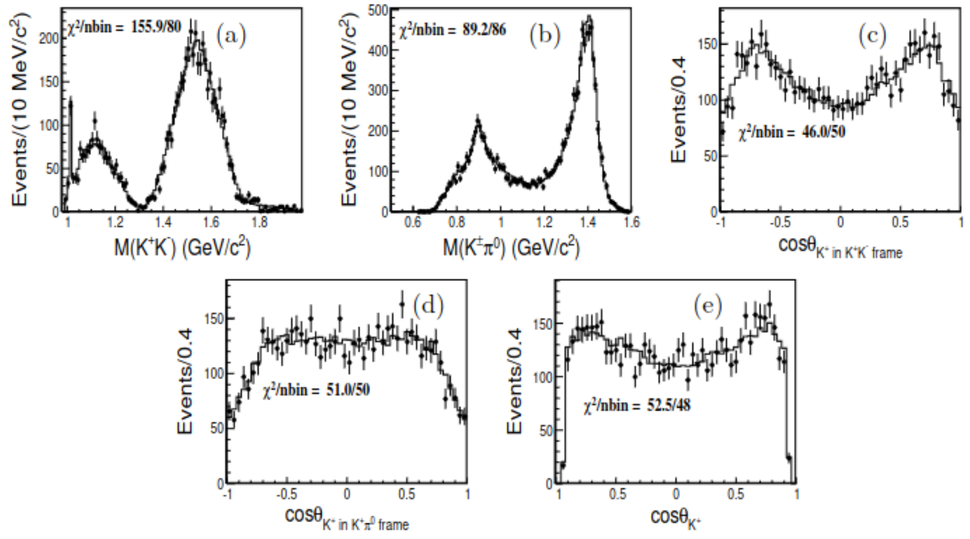


Figure 1. At $\sqrt{s} = 2.125\,\text{GeV}$, (a) invariant mass distribution of K^+K^-; (b) invariant mass distribution of $K^\pm\pi^0$; (c) cosθ distribution of K^+ in the K^+K^- rest frame; (d) cosθ distribution of K^+ in the $K^+\pi^0$ rest frame; (e) cosθ distribution of K^+ in the c.m. frame. θ is polar angle with respect to the z-axis. Dots with error bars are data, and the curves are the fit results.

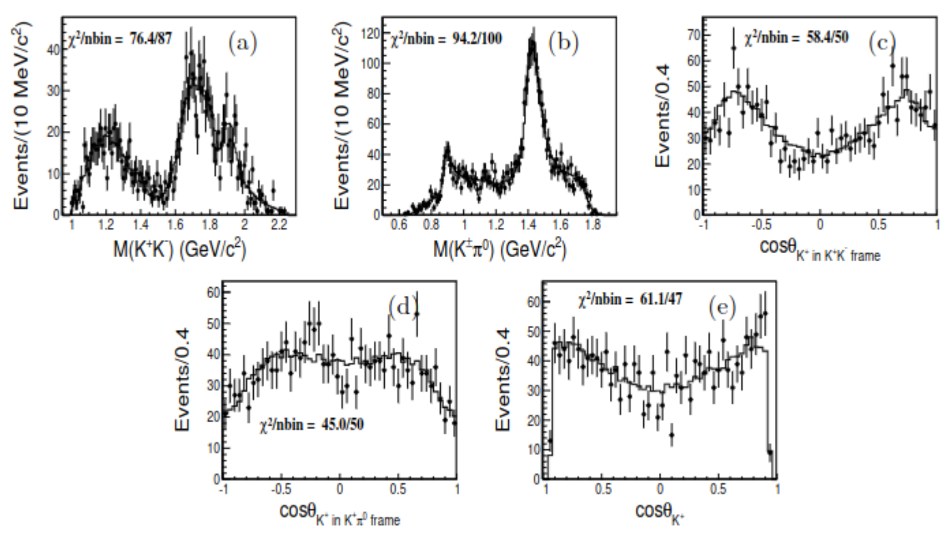
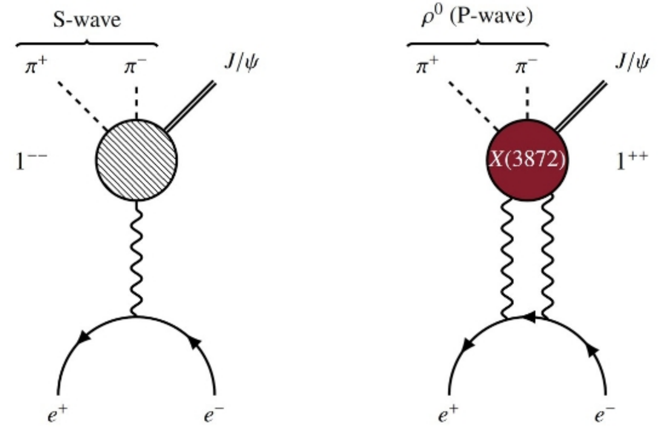


Figure 2. At $\sqrt{s} = 2.396\,\text{GeV}$, (a) invariant mass distribution of K^+K^-; (b) invariant mass distribution of $K^\pm\pi^0$; (c) cosθ distribution of K^+ in the K^+K^- rest frame; (d) cosθ distribution of K^+ in the $K^+\pi^0$ rest frame; (e) cosθ distribution of K^+ in the c.m. frame. θ is polar angle with

ArXiv: 2209.12007

X(3872) direct production

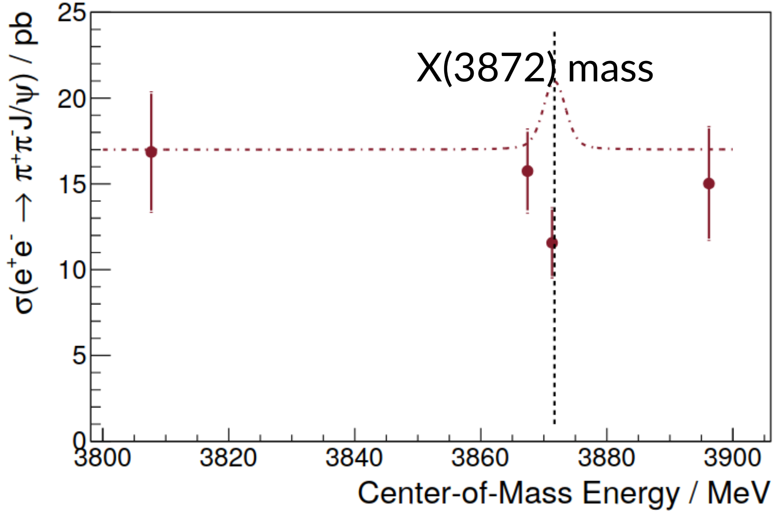


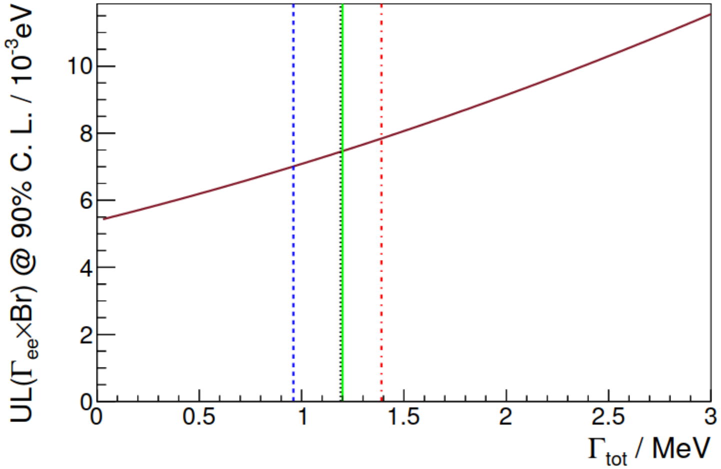
Following the experience of χ_{c1}(1P) production, we have searched also for X(3872) in $\pi\pi J/\psi$ final state

No observation, upper limit of Γ_{ee} x Br, with different Γ_{tot} hypotheses (U.L of 7.5 x 10^{-3} eV for Γ_{tot} = 1.19 ± 0.21 MeV)

No disagreement with theoretical prediction Γ_{ee} x Br ≥ 0.96 x 10^{-3} eV (PLB 736, (2014) 221)

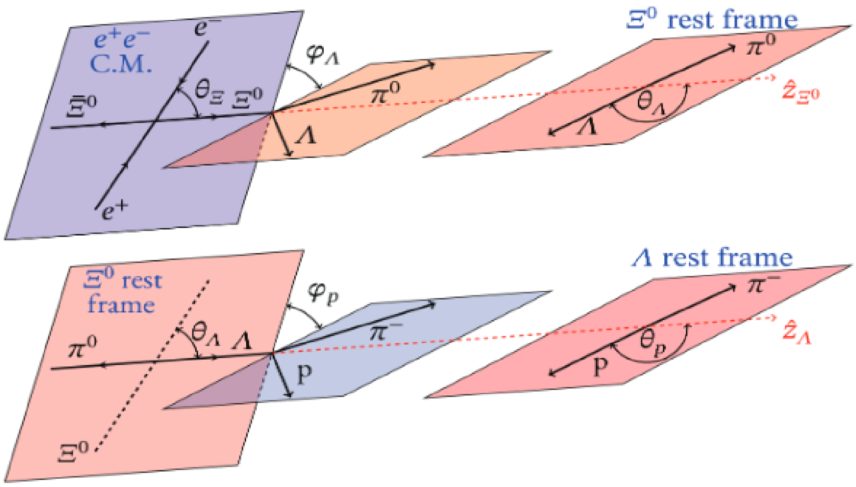
$$\sigma(\sqrt{s}) = \sigma_{\rm cont} + 12\pi \frac{\Gamma_{\rm tot}\Gamma_{ee} \times \mathcal{B}(X(3872) \to \pi^+\pi^- J/\psi)}{(s - m_0^2)^2 + m_0^2\Gamma_{\rm tot}^2}$$





Ξ^0 polarization

Helicity angles definition



CP variables

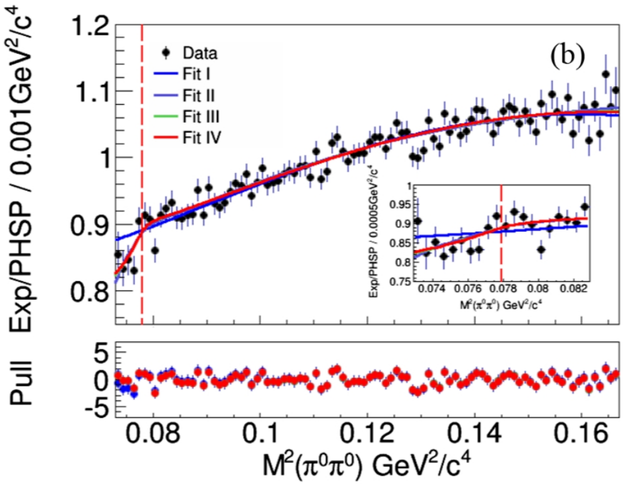
$$A^{\Xi}_{CP} = (\alpha_\Xi + \bar{\alpha}_\Xi)/(\alpha_\Xi - \bar{\alpha}_\Xi),$$
$$\Delta\phi^{\Xi}_{CP} = (\phi_\Xi + \bar{\phi}_\Xi)/2,$$
$$A^{\Lambda}_{CP} = (\alpha_\Lambda + \bar{\alpha}_\Lambda)/(\alpha_\Lambda - \bar{\alpha}_\Lambda),$$

A^{Ξ}_{CP} is sensitive to weak phase difference and it can be washed out if small phase

$\Delta\phi^{\Xi}_{CP}$ has no dependence so it more sensitive to CPV

Polarization term in moment distribution

$$P_y(\theta_\Xi) = \sqrt{1-\alpha^2_{J/\psi}}\sin(\Delta\Phi)\cos\theta_\Xi\sin\theta_\Xi/(1+\alpha_{J/\psi}\cos^2\theta_\Xi)$$



Cusp effect

Matching partial wave decomposition and NREFT

Non cusp pi0pi0 → pi0pi0

$$C_{00} = \frac{16\pi}{3}(a_0 + 2a_2)(1 - \xi),$$

Cusp term

$$C_x = \frac{16\pi}{3}(a_2 - a_0)\left(1 + \frac{\xi}{3}\right),$$

Non cusp pi+pi- → pi+pi-

$$C_{+-} = \frac{8\pi}{3}(2a_0 + a_2)(1 + \xi),$$

$$\xi = \frac{M_{\pi^\pm}^2 - M_{\pi^0}^2}{M_{\pi^\pm}^2},$$

TABLE I. Experimental values of the matrix element parameters for $\eta' \to \eta\pi^0\pi^0$.

Parameters	Fit I	Fit II	Fit III	Fit IV
a	$-0.075 \pm 0.003 \pm 0.001$	-0.207 ± 0.013	-0.143 ± 0.010	$-0.077 \pm 0.003 \pm 0.001$
b	$-0.073 \pm 0.005 \pm 0.001$	-0.051 ± 0.014	-0.038 ± 0.006	$-0.066 \pm 0.006 \pm 0.001$
d	$-0.066 \pm 0.003 \pm 0.001$	-0.068 ± 0.004	-0.067 ± 0.003	$-0.068 \pm 0.004 \pm 0.001$
$a_0 - a_2$	...	0.174 ± 0.066	0.225 ± 0.062	$0.226 \pm 0.060 \pm 0.013$
a_0	...	0.497 ± 0.094	...	...
a_2	...	0.322 ± 0.129	...	...
Statistical significance	...	3.4σ	3.7σ	3.6σ

Fixed a0 – 2a2 = 0.1312 in FIT III

Alternative fit (FIT IV) show little contribution of loop non cusp coefficient, while fitting increase parameter correlation