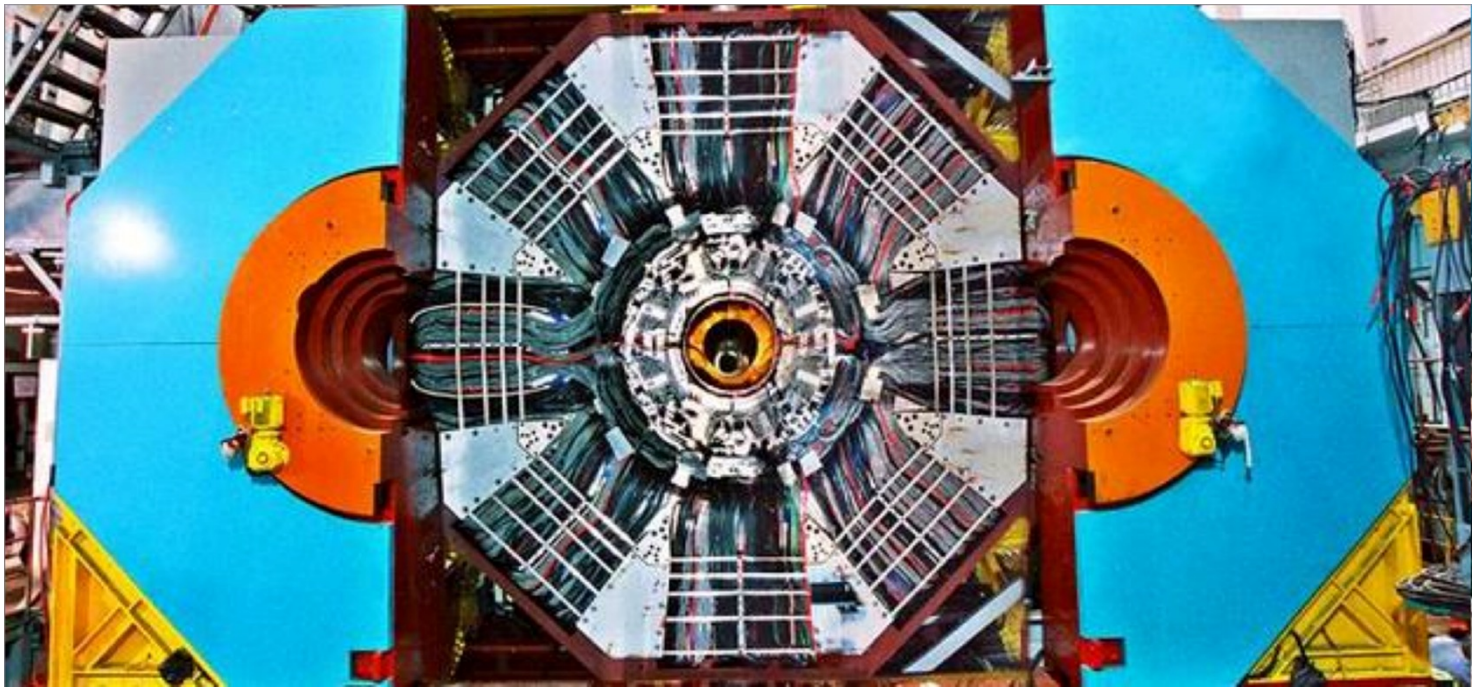


Recent XYZ results at BESIII

Xiao-Rui Lyu（吕晓睿）

University of Chinese Academy of Sciences (UCAS)

(On behalf of the BESIII collaboration)

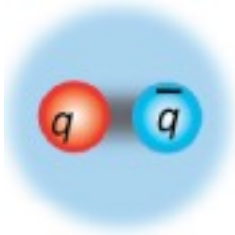
Outline

- **Introduction to BEPCII/BESIII**
- **Recent results on the XYZ states**
- **Prospects for the future**
- **Summary**

New forms of hadrons

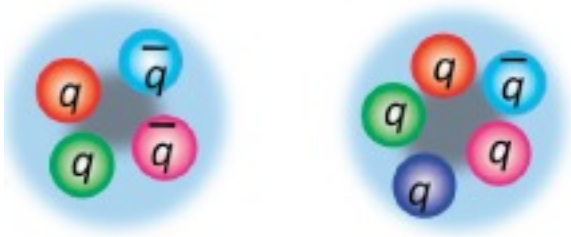
- **Conventional hadrons consist of 2 or 3 quarks:**

Naive Quark Model:

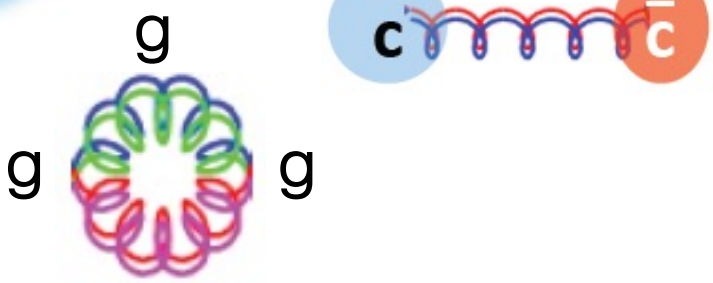
meson 

baryon

- **QCD predicts the new forms of hadrons:**
  - **Multi-quark states: Number of quarks >= 4**

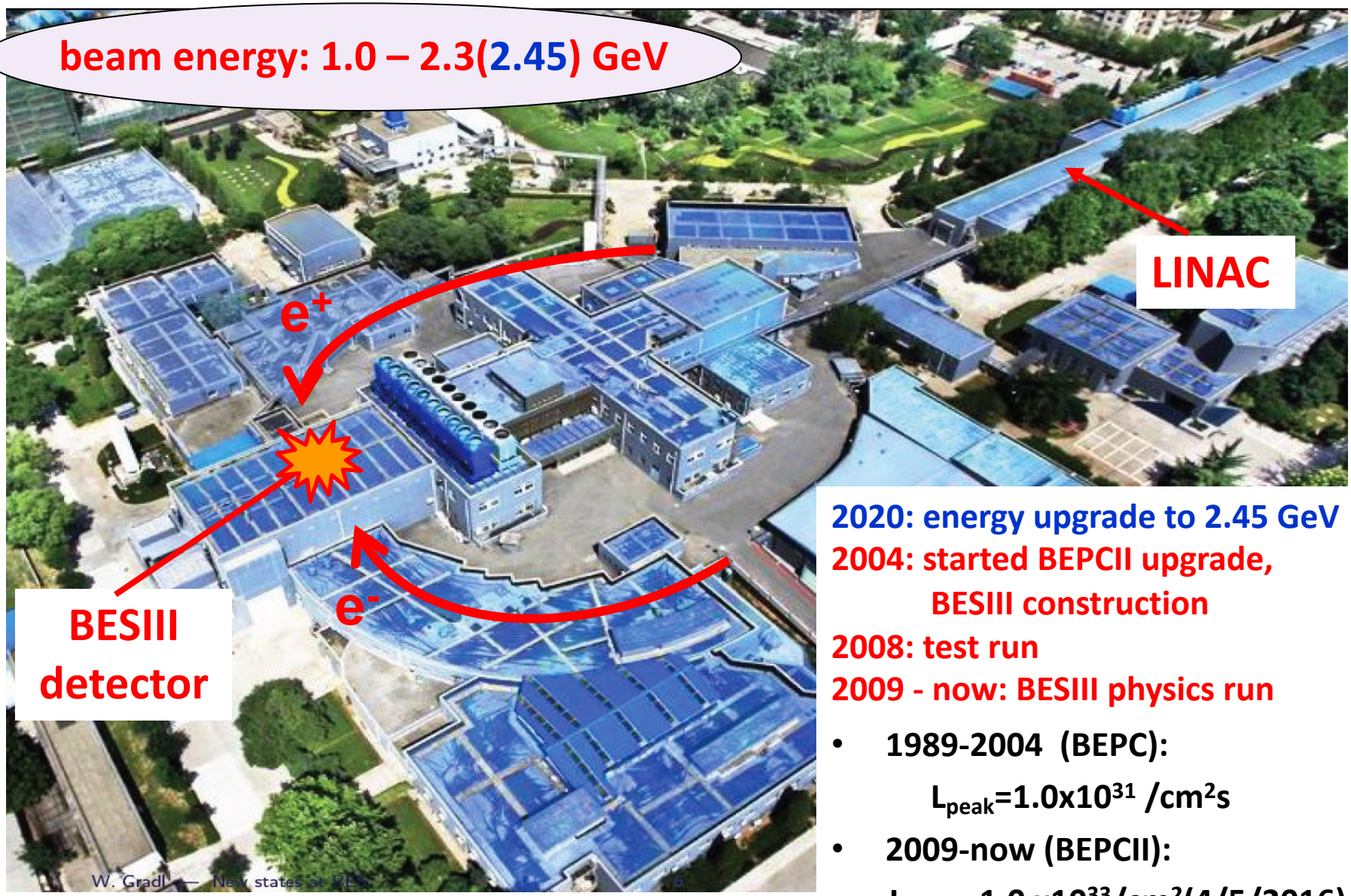


  - **Hybrids: $q\bar{q}g$, $qqqg$ ...**
  - **Glueballs: gg, ggg ...**



None of the new forms of hadrons is settled !

Beijing Electron Positron Collider (BEPCII)



2020: energy upgrade to 2.45 GeV

2004: started BEPCII upgrade,
BESIII construction

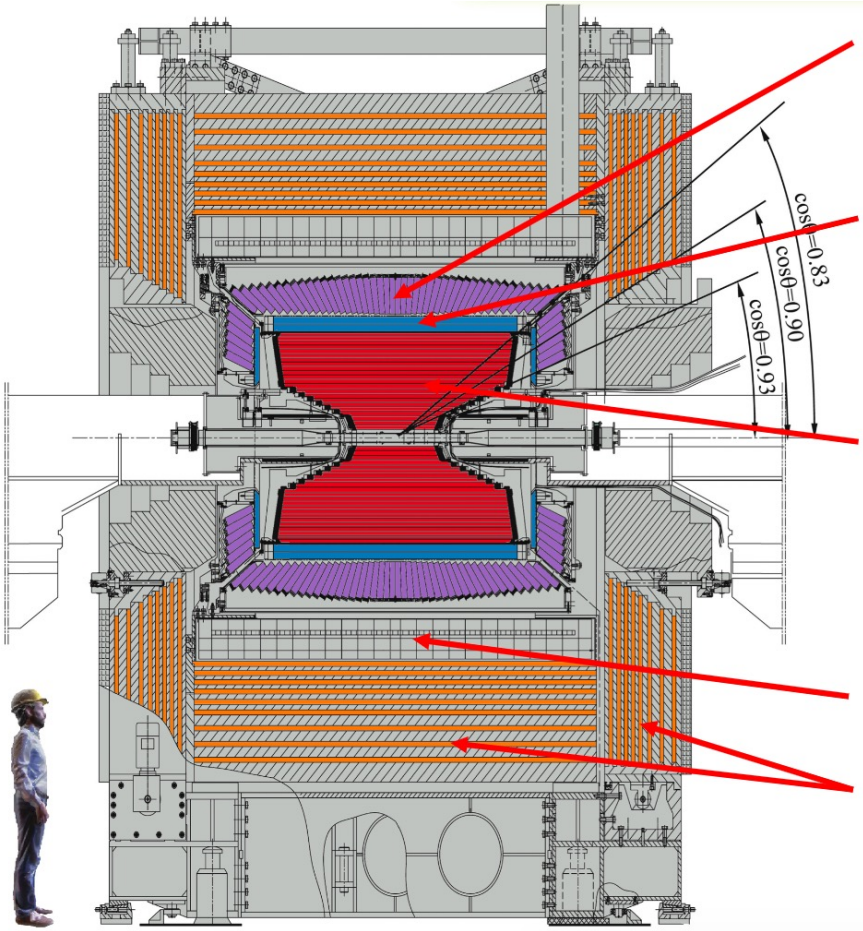
2008: test run

2009 - now: BESIII physics run

- 1989-2004 (BEPC):
  L_{peak}=1.0x10^{31} /cm^{2}s
- 2009-now (BEPCII):
  L_{peak}= 1.0 x10^{33}/cm^2(4/5/2016)

The BESIII detector

NIM A614, 345 (2010)



EMC: CsI crystals
ΔE/E = 2.5% @ 1 GeV - Barrel
ΔE/E = 5.0% @ 1 GeV - Endcaps

TOF:
σ_T = 80 ps Barrel
σ_T = 110 (60) ps Endcap

MDC: small cell & He gas
σ_{xy}= 130 μm
σ_p/p = 0.5% @1GeV
dE/dx = 6%

Magnet: 1T Super conducting

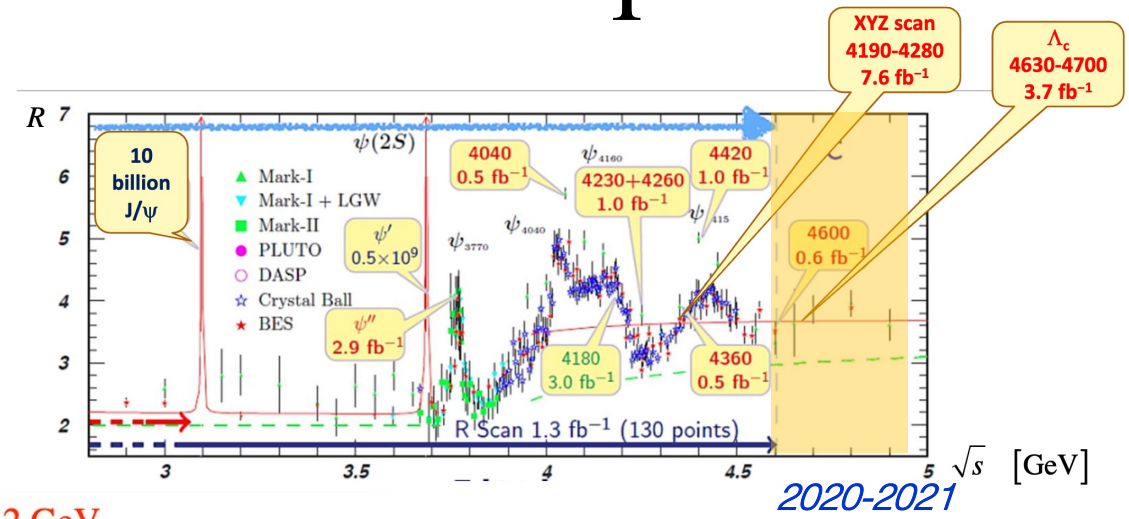
Muon ID: 9 layer RPC

Trigger: Tracks & Showers

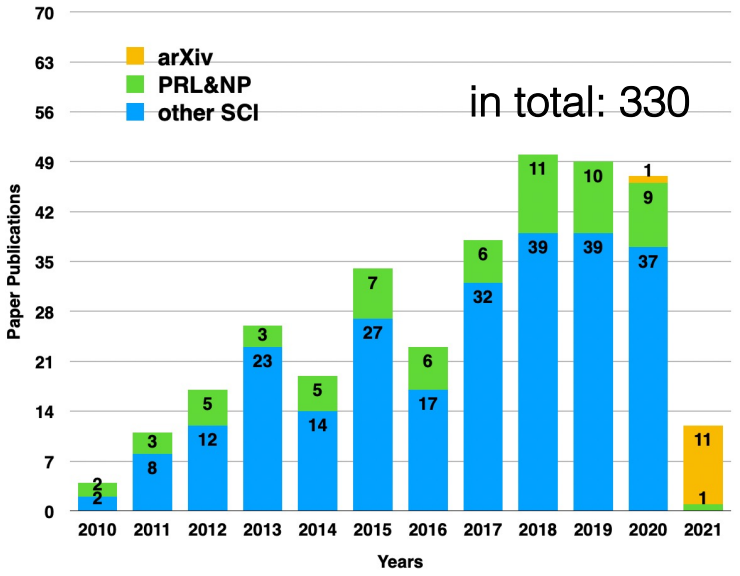
The new BESIII detector is hermetic for neutral and charged particle with excellent resolution, PID, and large coverage.

BESIII data sample

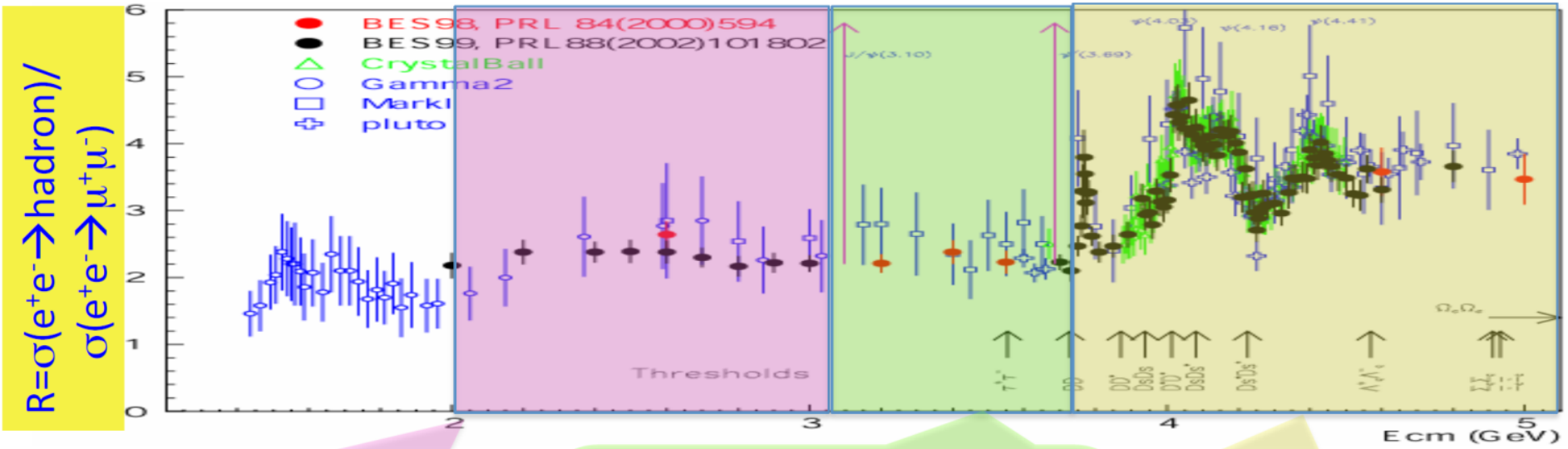
2009: 106M $\psi(2S)$
225M J/ψ
2010: 975 pb^{-1} at $\psi(3770)$
2011: 2.9 fb^{-1} *(total)* at $\psi(3770)$
482 pb^{-1} at 4.01 GeV
2012: 0.45B *(total)* $\psi(2S)$
1.3B *(total)* J/ψ
2013: 1092 pb^{-1} at 4.23 GeV
826 pb^{-1} at 4.26 GeV
540 pb^{-1} at 4.36 GeV
10 × 50 pb^{-1} scan 3.81 — 4.42 GeV
2014: 1029 pb^{-1} at 4.42 GeV
110 pb^{-1} at 4.47 GeV
110 pb^{-1} at 4.53 GeV
48 pb^{-1} at 4.575 GeV
567 pb^{-1} at 4.6 GeV
0.8 fb^{-1} R-scan 3.85 — 4.59 GeV
2015: R-scan 2 — 3 GeV + 2.175 GeV
2016: ~3fb^{-1} at 4.18 GeV (for D_s)
2017: 7 × 500 pb^{-1} scan 4.19 — 4.27 GeV
2018: more J/ψ *(and tuning new RF cavity)*
2019: 10B *(total)* J/ψ
8 × 500 pb^{-1} scan 4.13, 4.16, 4.29 — 4.44 GeV
2021 : 3.8 fb^{-1} scan 4.61-4.7 GeV
2021 : 2 fb^{-1} scan 4.74-4.946 GeV



2020-2021



Physics at tau-charm Energy Region

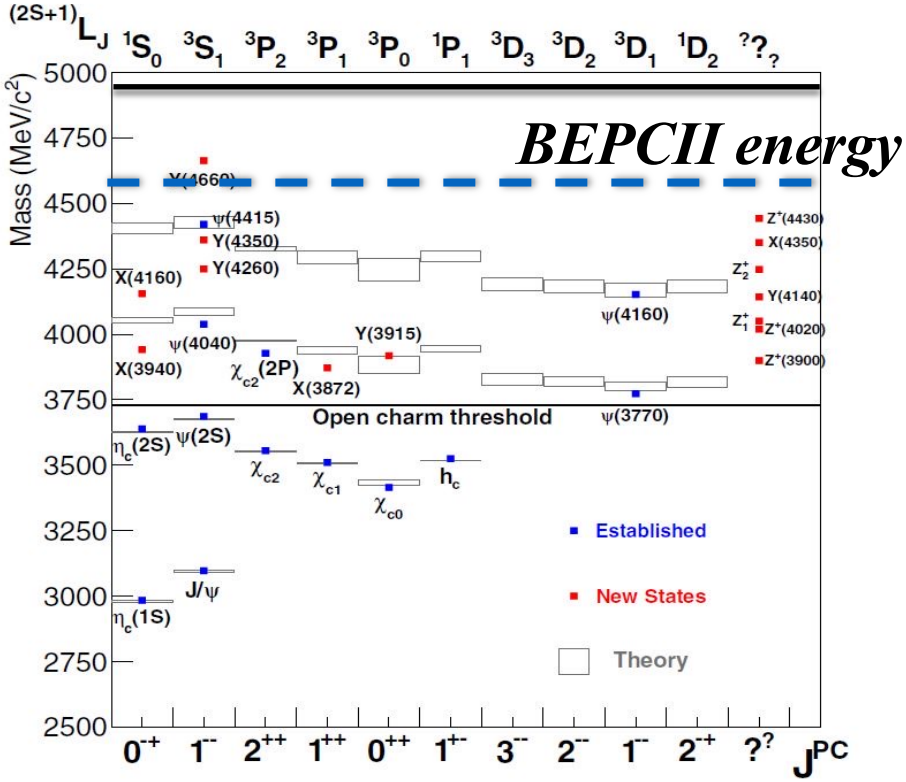


- Hadron form factors
- Y(2175) resonance
- Mutltiquark states with s quark, Zs
- MLLA/LPHD and QCD sum rule predictions

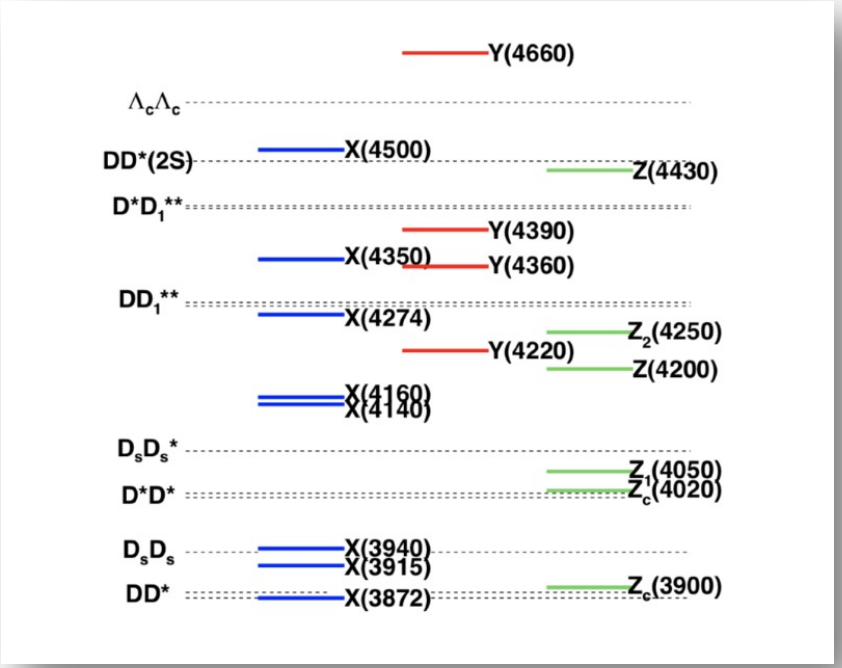
- Light hadron spectroscopy
- Gluonic and exotic states
- Process of LFV and CPV
- Rare and forbidden decays
- Physics with τ lepton

- XYZ particles
- D mesons
- f_D and f_{Ds}
- D_0-$\bar{D}_0$ mixing
- Charm baryons

Overpopulated charmonium spectrum



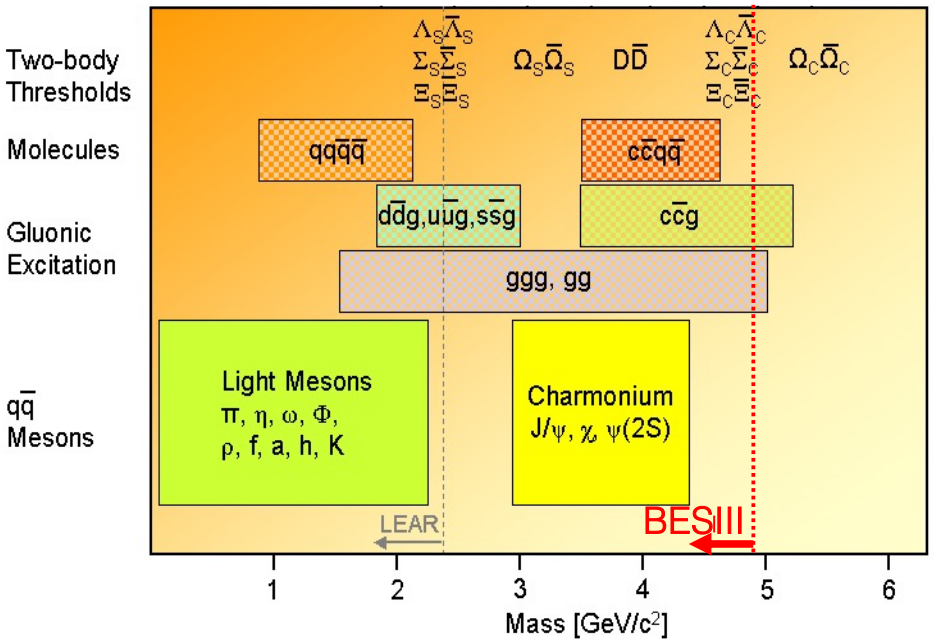
arXiv:1511.01589, arXiv:1812.10947



Overpopulated observed new charmonium-like states, i.e. "XYZ":

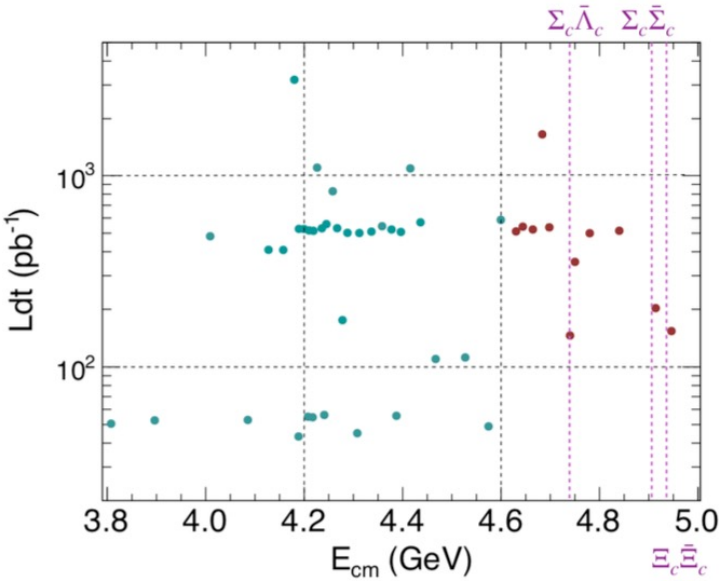
- Most of them are close to the mass thresholds of charmed meson pairs
- Some are not accommodated as conventional meson
  ==> candidate of exotic hadron states
- More efforts are needed to pin down their nature

Hadron Landscape



Hadron-physics challenges:

- Understanding of established states: precision spectroscopy
- Nature of exotic states: search and spectroscopy of unexpected states



XYZ studies: about 23 /fb data above 3.8 GeV

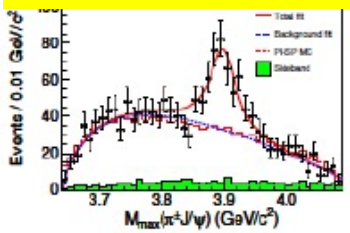
At BESIII, two golden measures to study hadron spectroscopy, *esp.*, to search for exotics

- Light hadrons: charmonium radiative decays (act as spin filter)
- Heavy hadrons: direct production, radiative and hadronic transitions

The Zc Family at BESIII

$Zc(3900)^+$

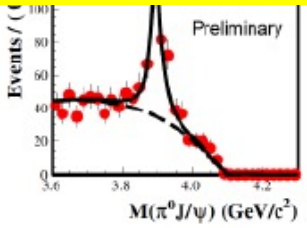
PRL 110, 252001 (2013)



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

$Zc(3900)^0$

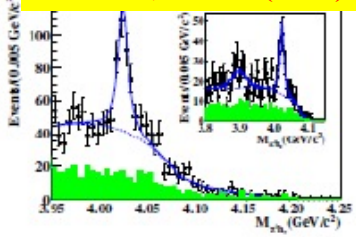
PRL 115, 112003 (2015)



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

$Zc(4020)^+$

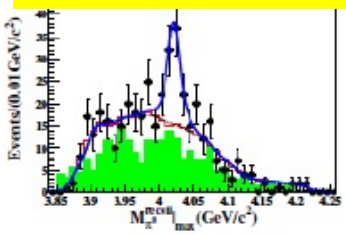
PRL 111, 242001(2013)



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

$Zc(4020)^0$

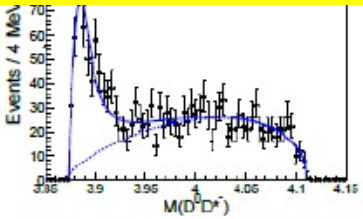
PRL113,212002 (2014)



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

$Zc(3885)^+$

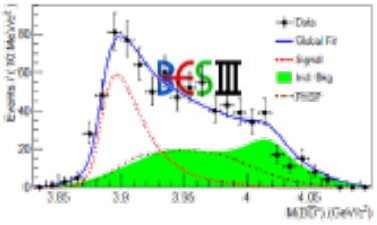
ST: PRL 112, 022001(2014)
DT: PRD92, 092006 (2015)



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

$Zc(3885)^0$

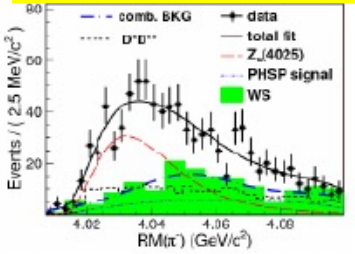
PRL 115, 222002 (2015)



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

$Zc(4025)^+$

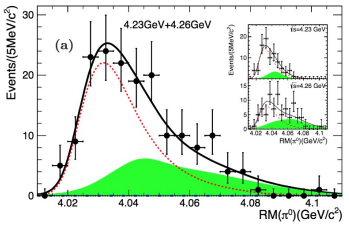
PRL 112, 132001 (2014)



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

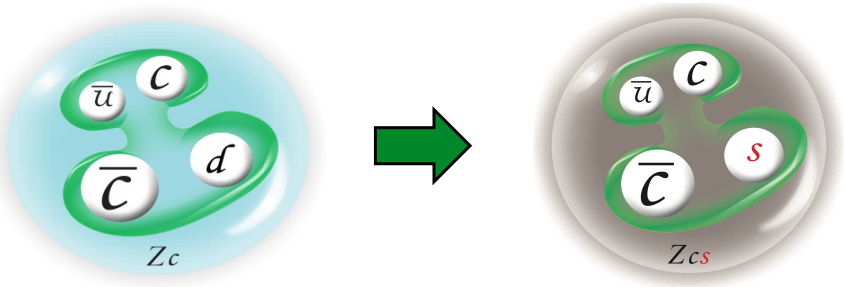
$Zc(4025)^0$

PRL115, 182002 (2015)



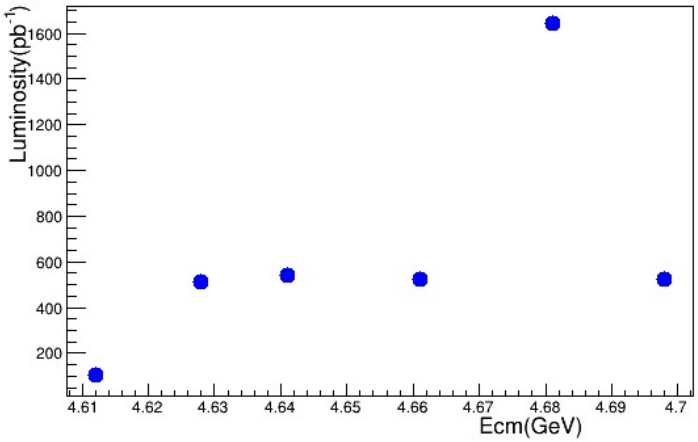
$e^+e^- \to \pi^0(D^*\bar{D}^*)^0$

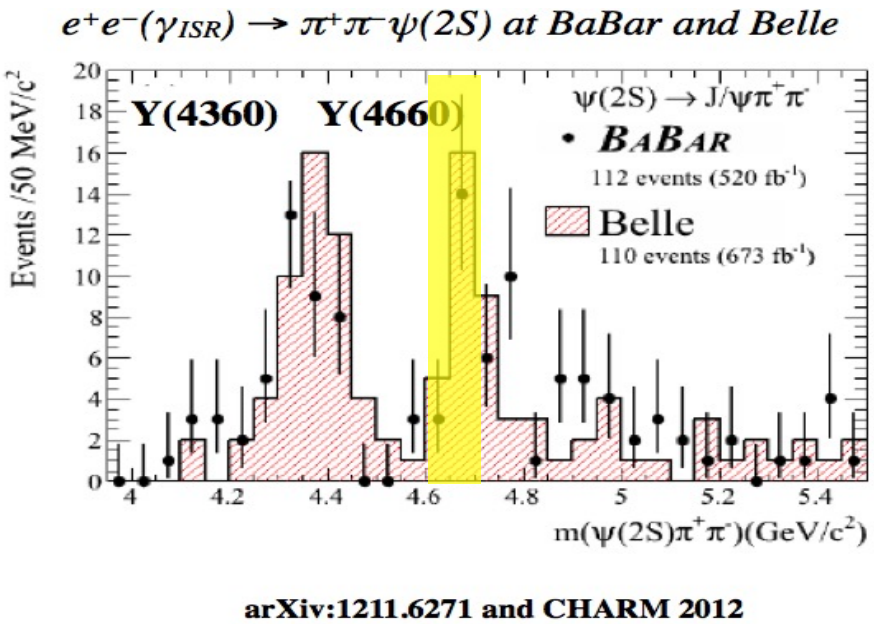
Which is the nature of these states?
If exists, there should be SU(3) counter-part Zcs state with strangeness



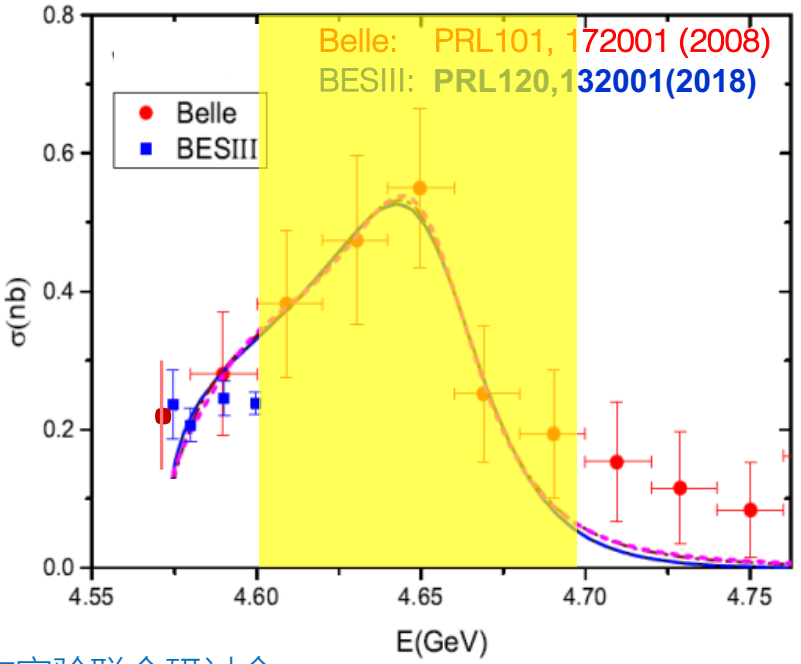
Data taking in 4.6-4.7 GeV in 2020

- 3.7 fb^{-1} data was accumulated at 4.628, 4.641, 4.661, 4.681 and 4.698GeV in 2020.
- Y(4630) & Y(4660)





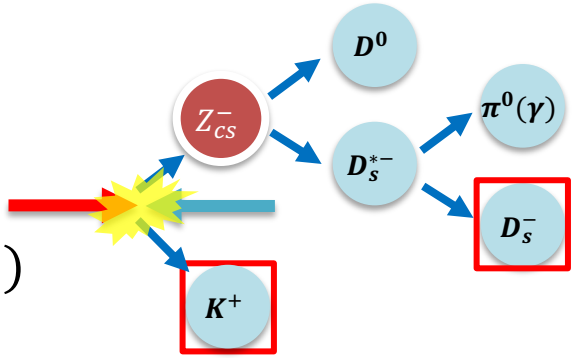
arXiv:1211.6271 and CHARM 2012



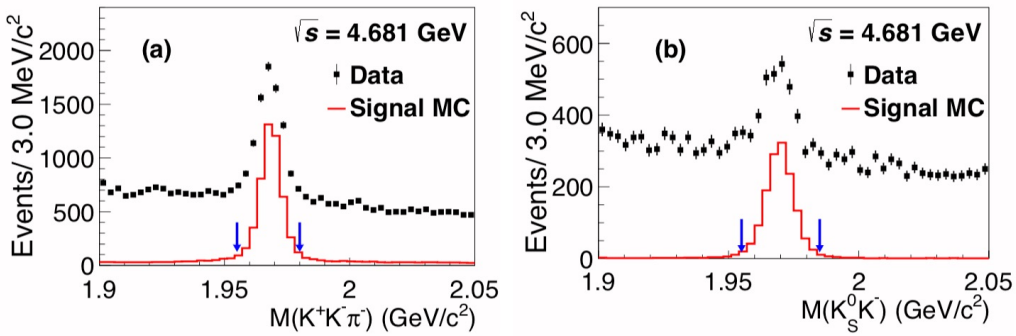
Observation of the $Z_{cs}(3985)^{\pm}$

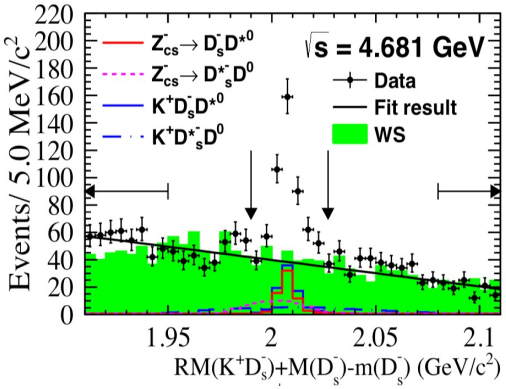
PRL126, 102001 (2021)

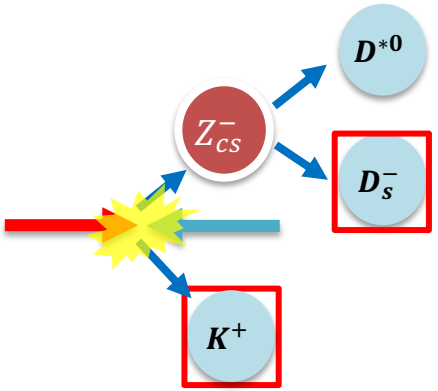
- We analyze 3.7fb^{-1} data accumulated at 4.628, 4.641, 4.661, 4.681 and 4.698GeV in 2020.
- **Partial reconstruction of K^+ and D_s^-**
- Signature in the **recoil mass spectrum of $K^+D_s^-$** to identify the process of $e^+e^- \to K^+(D_s^-D^{*0} + D_s^{*-}D^0)$



$e^+e^- \to K^+D_s^{*-}D^0$





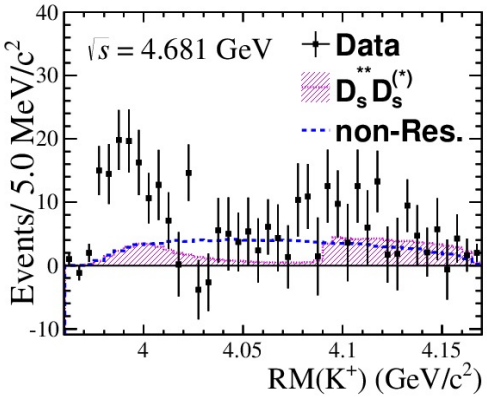


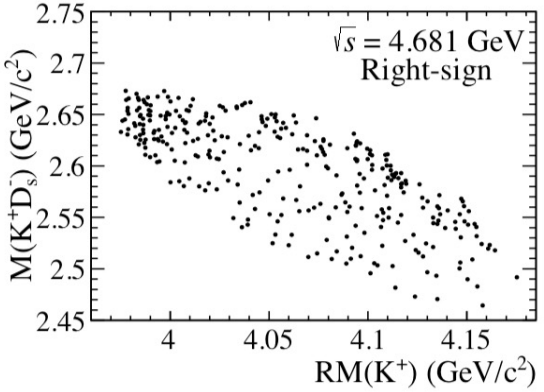
$e^+e^- \to K^+D_s^-D^{*0}$

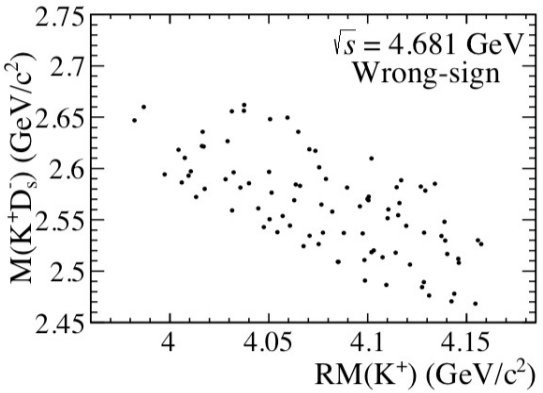
Observation of the $Z_{cs}(3985)^{\pm}$

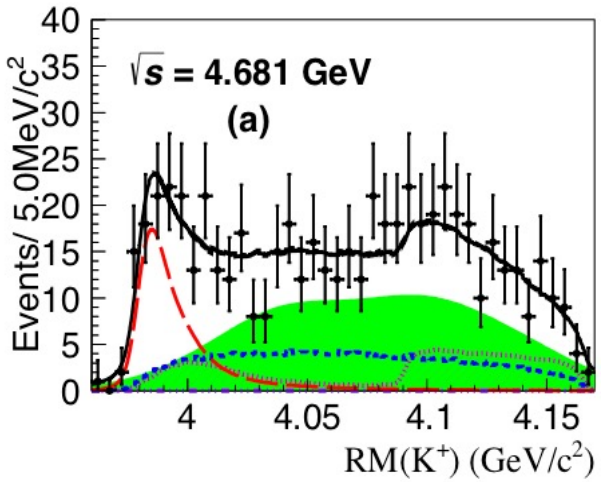
PRL126, 102001 (2021)

- Data driven background description: wrong Sign (WS) combination of D_s^- and K^-
- Conventional charmed mesons can not describe the enhancement below 4.0 GeV/c² at 4.681 GeV









- Assume the structure as a $D_s^- D^{*0}/D_s^{*-} D^0$ resonance, denoting it as the $Z_{cs}(3985)^-$.
- A fit of $J^P=1^+$ S-wave Breit-Wigner with mass dependent width returns:

$$\boldsymbol{m} = 3985.2^{+2.1}_{-2.0} \pm 1.7\ \mathrm{MeV/c^2}$$
$$\boldsymbol{\Gamma} = 13.8^{+8.1}_{-5.2} \pm 4.9\ \mathrm{MeV}$$

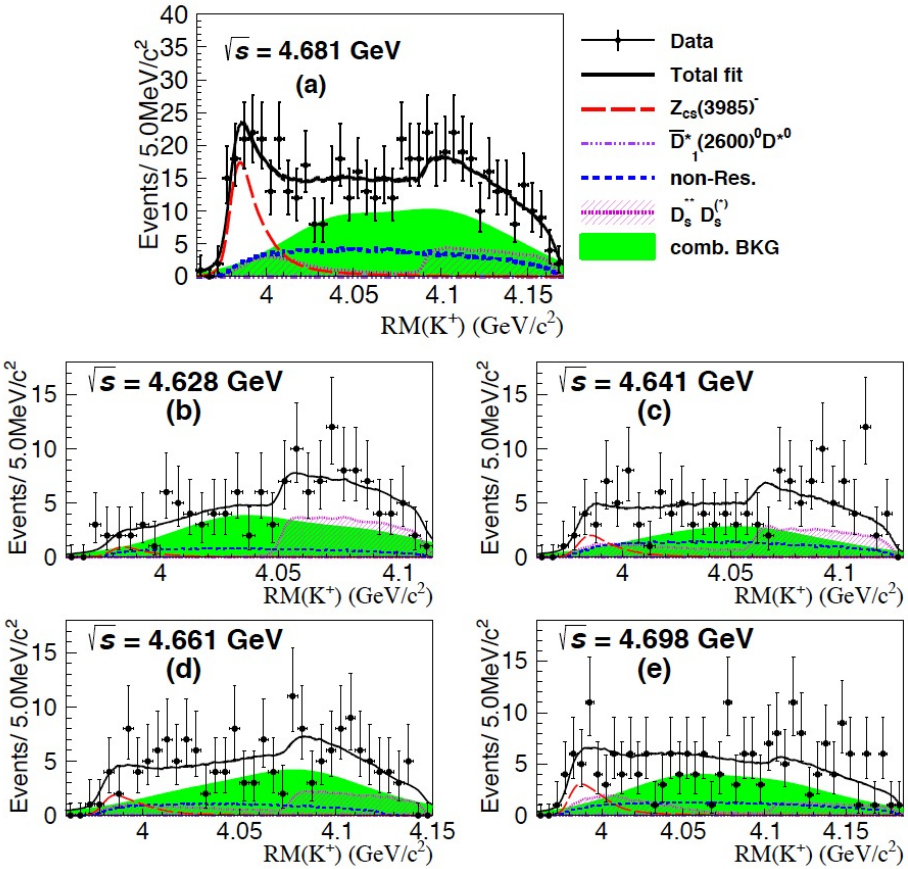
- Global significance: >5.3 $\boldsymbol{\sigma}$

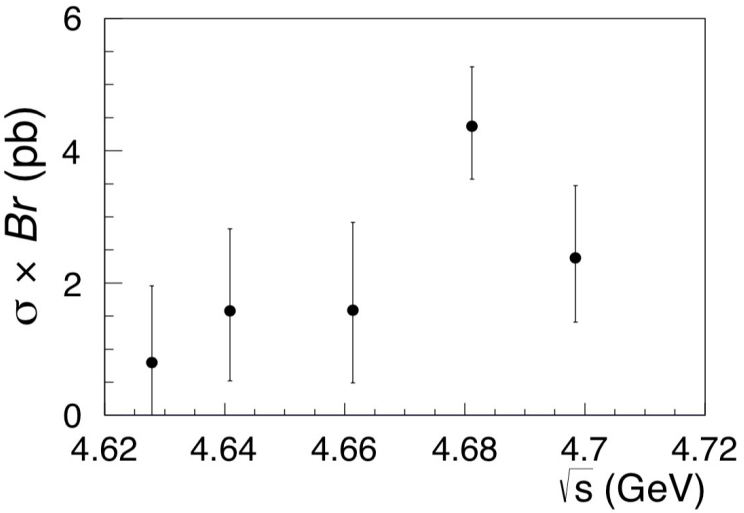
First candidate of the hidden-charm tetraquark with strangeness

Cross sections of the $Z_{cs}(3985)^{\pm}$ production

PRL126, 102001 (2021)

- Simultaneous fit to the five energy points





- Largest cross sections around 4.681 GeV

The Zcs (3985)$^{\pm}$ and Zc(3885)$^{\pm}$

	1643/pb data @4.681 GeV	525/pb data @4.26 GeV	
	$Z_{cs}(3985)^{\pm}$	$Z_c(3900)^{\pm}$	$Z_c(3885)^{\pm}$
Mass (MeV/c^2)	$3985.2^{+2.1}_{-2.0} \pm 1.7$	3899.0±3.6±4.9	3883.9±1.5±4.2
Width (MeV)	$13.8^{+8.1}_{-5.2} \pm 4.9$	46±10±26	24.8±3.3±11.0
$\sigma^{Born} \cdot \mathcal{B}$ (pb)	$4.4^{+0.9}_{-0.8} \pm 1.4$	13.5±2.1±4.8	83.5±6.6±22.0

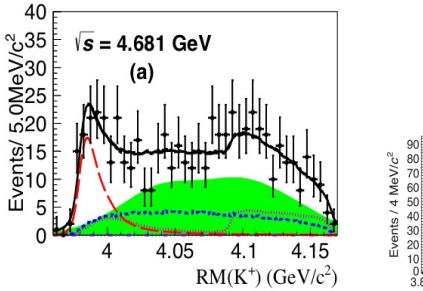
~10 MeV above D_sD^*/D_sD thresholds
similar to $Z_c(3900)$ & $Z_b(10,610)$
(DD*) (BB*)

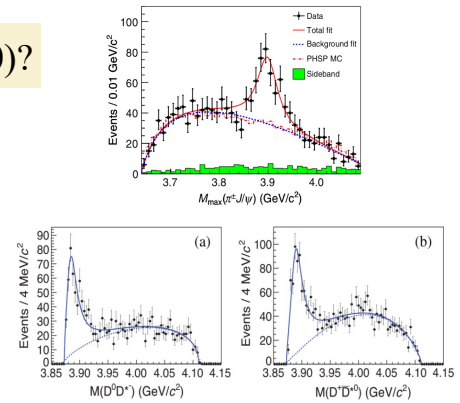
from Marek Karliner in Nov. 2020

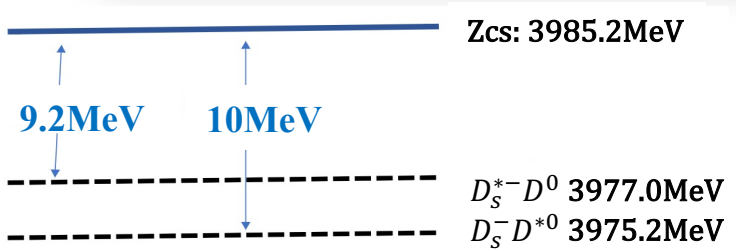
two general comments about
charm-tau factory program

- $J/\psi K^{\pm}$ resonances:
  $Z_c(3900)$ analogue?
  $Z_c(3900)^+ = (c\bar{c}u\bar{d})$; $d \to s$: $(c\bar{c}u\bar{s}) \sim D_s\bar{D}^*$
  no natural molecular binding,
  so if discovered, would indicate
  Tq or a novel mechanism

SU(3) partner of Zc(3900)?







$Z_{cs}(3985)$

$K^-Z_{cs}^+$	$\bar{K}^0Z_{cs}^0$	$K^0\bar{Z}_{cs}^0$	$K^+Z_{cs}^-$
1/4	1/4	1/4	1/4

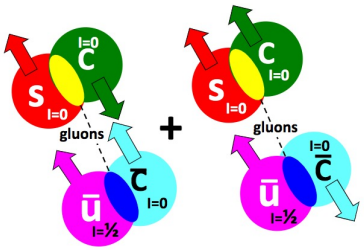
neutral/charged = 1

$Z_c(3900)$

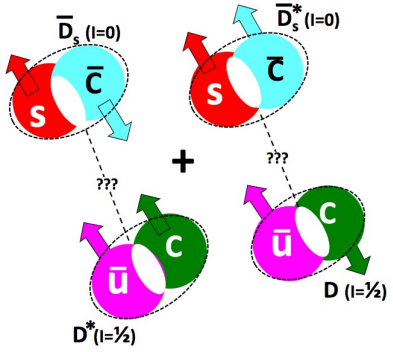
$\pi^-Z_c^+$	$\pi^0Z_c^0$	$\pi^+Z_c^-$
1/3	1/3	1/3

neutral/charged = 1/2

diquark-antidiquark?



D*$\bar{D}_s$ + cc molecule?

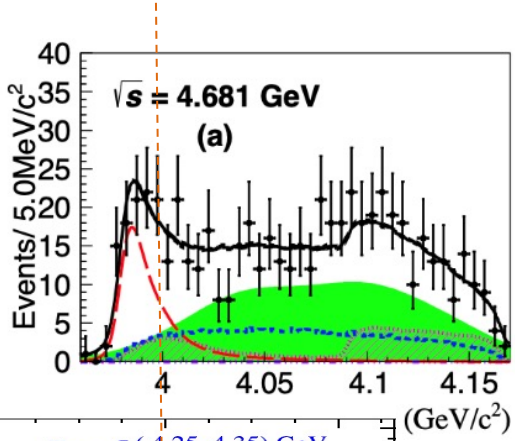


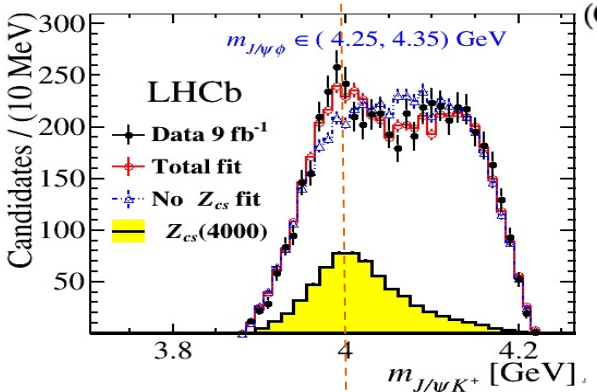
Discussions on the nature of $Z_{cs}(3985)^{\pm}$

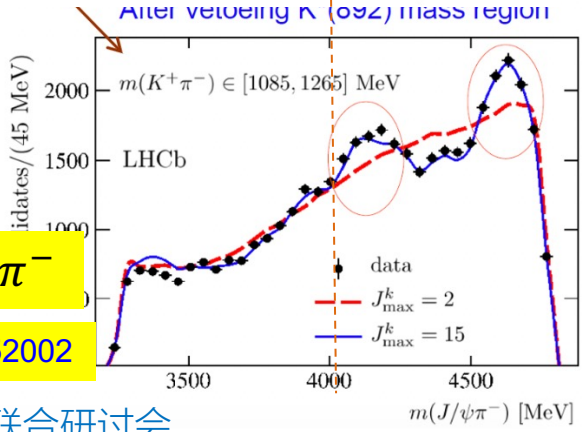
- Various interpretations are possible for the structure
  - Tetraquark state
  - Molecule
  - $D_{s2}^{*}(2573)^{+}D_{s}^{*-}$ threshold kinematic effects (Re-scattering , Reflection, Triangle singularity)
  - Mixture of molecular and tetraquark
  - …

$Z_{cs}(3985)$ from $e^{+}e^{-}$ annihilations and $Z_{cs}(4000)$ from B decays

- their masses are close, but widths are different
- If they are same, why width so different?
- If they are not same, is there the corresponding wide Zc(3900)?
- Looking for more channels will be useful





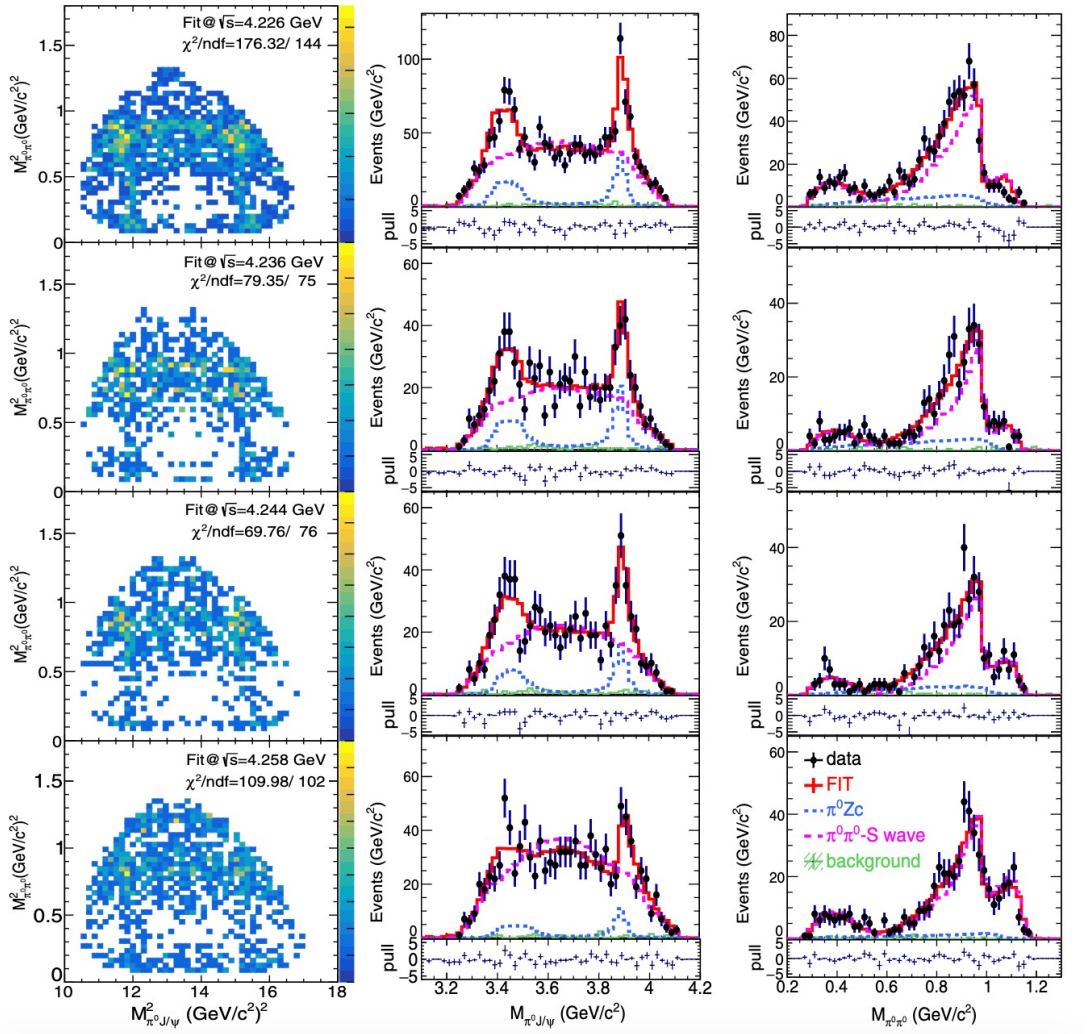


$B^0 \to J/\psi K^+\pi^-$

PRL 122 (2019) 152002

PWA of the $Z_c(3900)^0$

PRD 102, 012009 (2020)



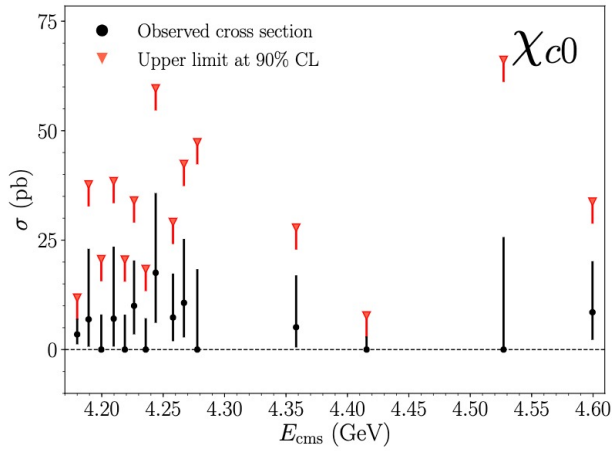
- Simultaneous PWA fit of $e^+e^-\to\pi^0\pi^0 J/\psi$ to the four energy points
- The spin-parity of $Z_c(3900)^0$ is determined to be 1^+
- The nominal fit includes the intermediate process $\sigma J/\psi$, $f(980)J/\psi$, $f(1370)J/\psi$ and π^0 $Z_c(3900)^0$.
- Mass and width of $Z_c(3900)^0$ is measured:
  - $M(Z_c(3900)^0) = (3893.0\pm2.3\pm3.2)$ MeV/c^2,
  - $\Gamma(Z_c(3900)^0) = (44.2\pm5.4\pm8.3)$ MeV.

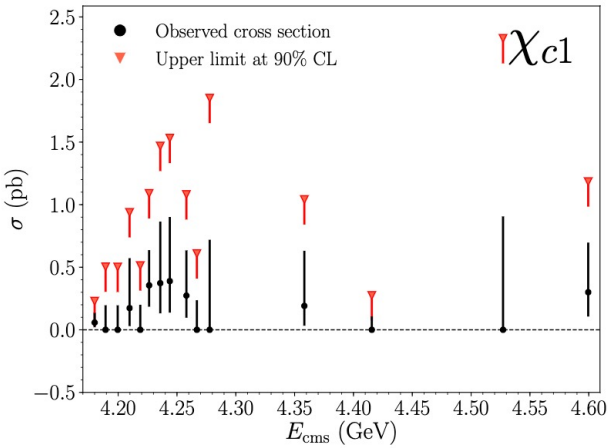
Search for $Z_c^+ \to \pi^+ \chi_{cJ}$

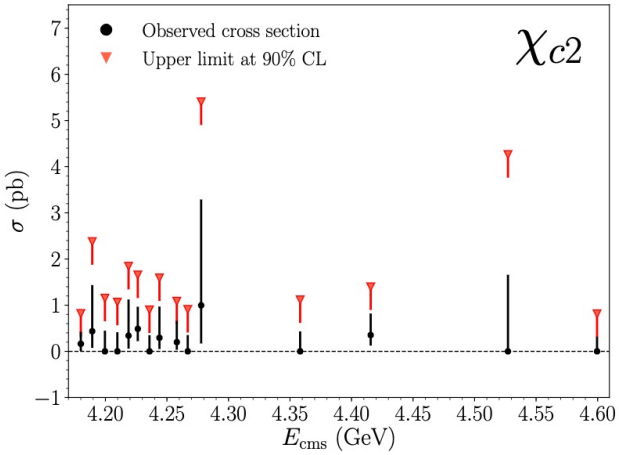
PRD 103, 052010 (2021)

- Belle reported the results of $Z_c\ (4050)^+$ and $Z_c\ (4250)^+$ in $\bar{B}^0 \to K^- Z_c^+, Z_c^+ \to \pi^+ \chi_{c1}$, while BaBar did not confirm them
- BESIII studies $e^+e^- \to \pi^+\pi^- \chi_{cJ}, \chi_{cJ} \to \gamma J/\psi$ from 4.178 GeV to 4.600 GeV
- None of the processes are observed and upper limits of the production cross sections are determined
- Hence, they can be the upper limits of the product cross sections of

$$e^+e^- \to \pi^- Z_c\ (4050)^+ + c.c., Z_c\ (4050)^+ \to \pi^+ \chi_{cJ}$$





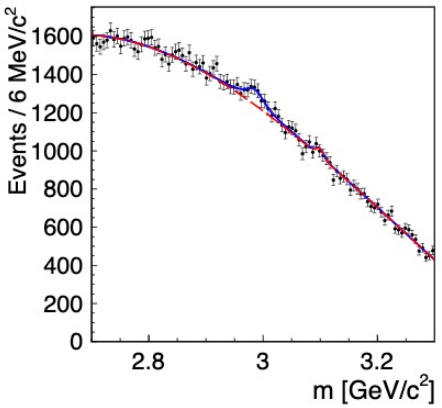


Search for $Z_c \to \pi\eta_c$

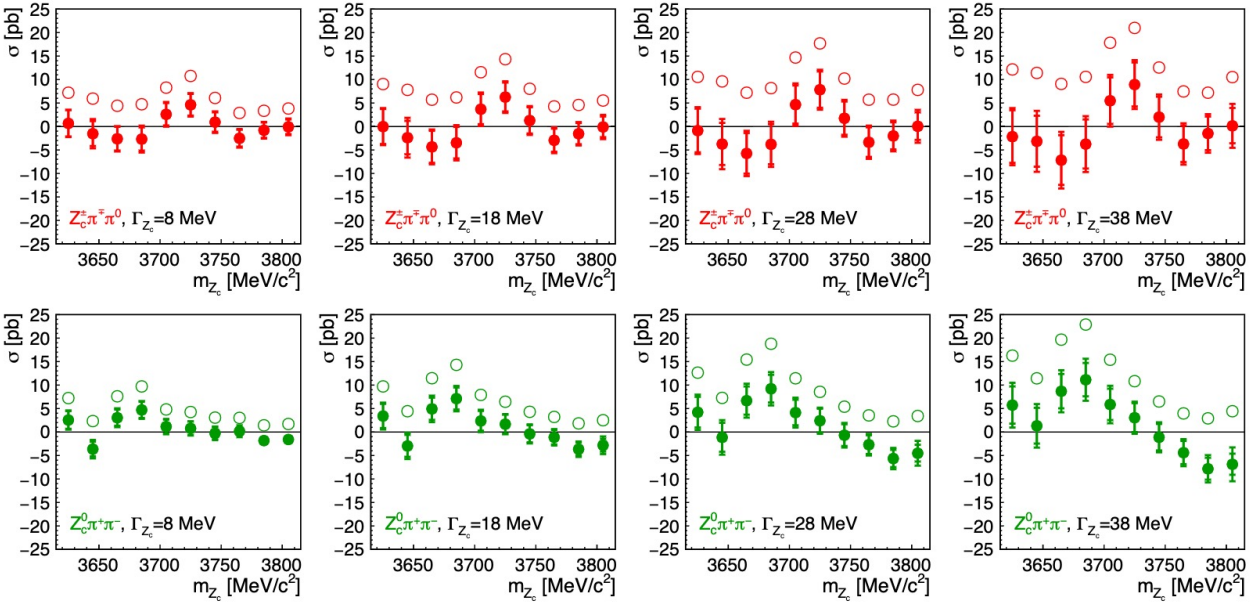
PRD 103, 032006 (2021)

- LHCb reported an evidence of $Z_c^+(4100) \to \pi^+\eta_c$ in $\bar{B}^0 \to K^- Z_c^+(4100)$ *LHCb, EPJ C78, 1019 (2018)*
- Studies of $e^+e^- \to \pi^+\pi^-\pi^0\eta_c, \pi^+\pi^-\eta_c, \gamma\pi^+\pi^-\eta_c$ at 6 energy points from 4.178 to 4.600 GeV
- 16 hadronic η_c channels are reconstructed
- Only evidence of $e^+e^- \to \pi^+\pi^-\pi^0\eta_c$ @ 4.226 GeV (4.1σ)
- Different mass and width assumptions in the vicinity of $D\bar{D}$ mass are tested for $Z_c^+ \to \pi^+\eta_c$ and $Z_c^0 \to \pi^0\eta_c$ in $e^+e^- \to \pi^+\pi^-\pi^0\eta_c$ at 4.226 GeV and found to be not significant

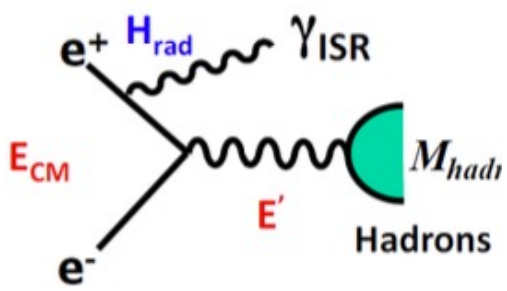
$$Z_c(4100)^-$$
$$M = 4096 \pm 20^{+18}_{-22}\ \text{MeV}$$
$$\Gamma = 152 \pm 58^{+60}_{-35}\ \text{MeV}$$
$$J^P = 0^+/1^-$$

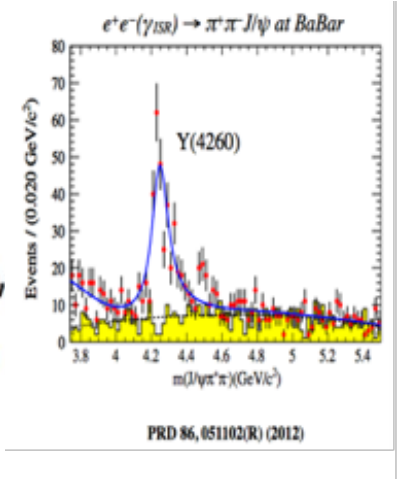


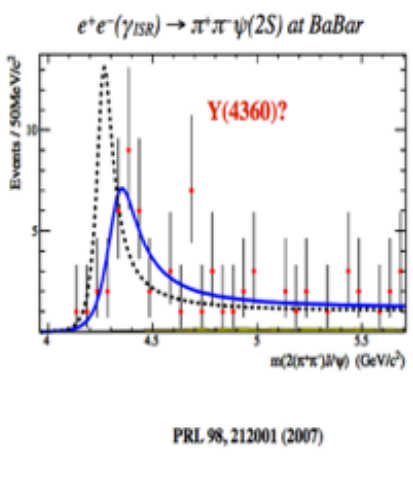
4.226 GeV

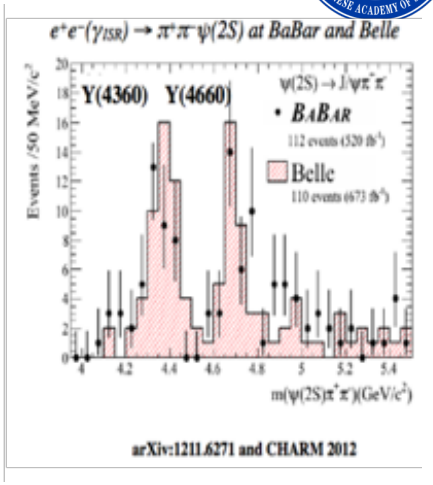


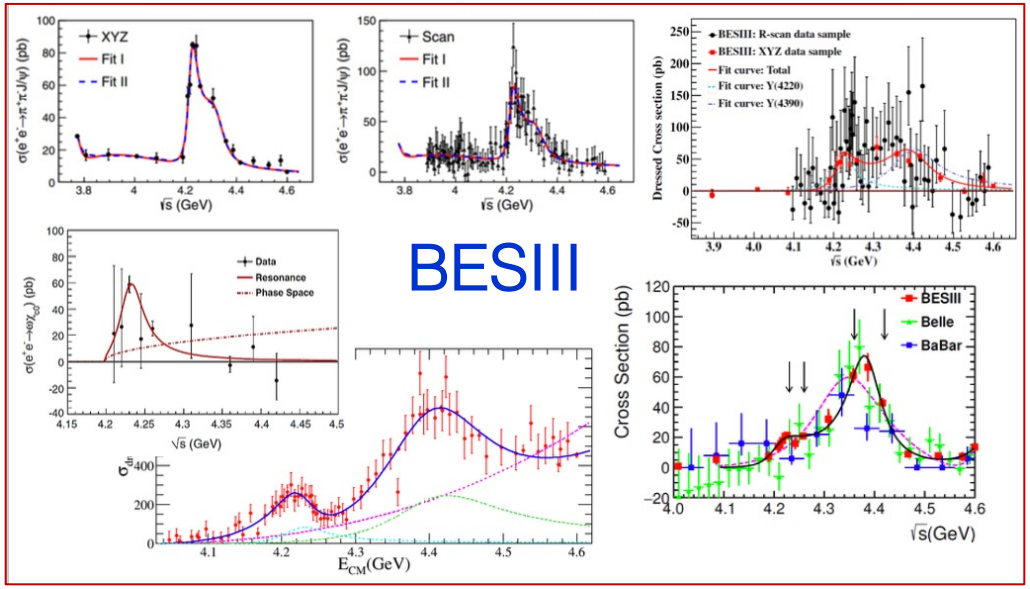
Y(4260) ➔ Y(4220) and new Y's

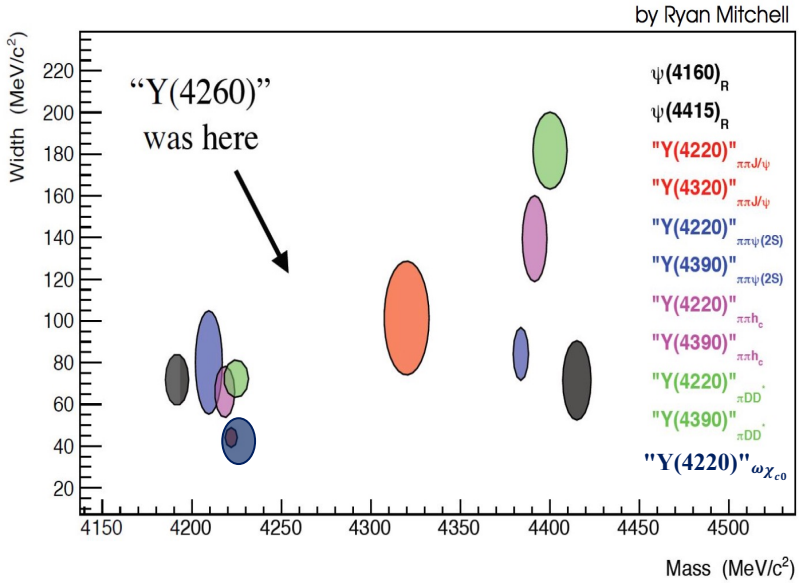








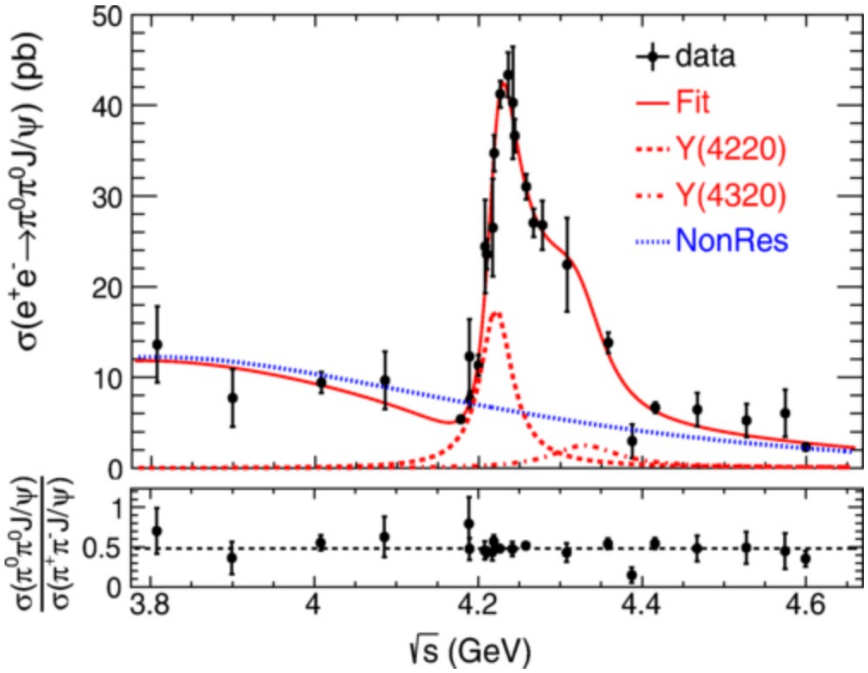




Cross section of $e^+e^- \to \pi^0\pi^0 J/\psi$

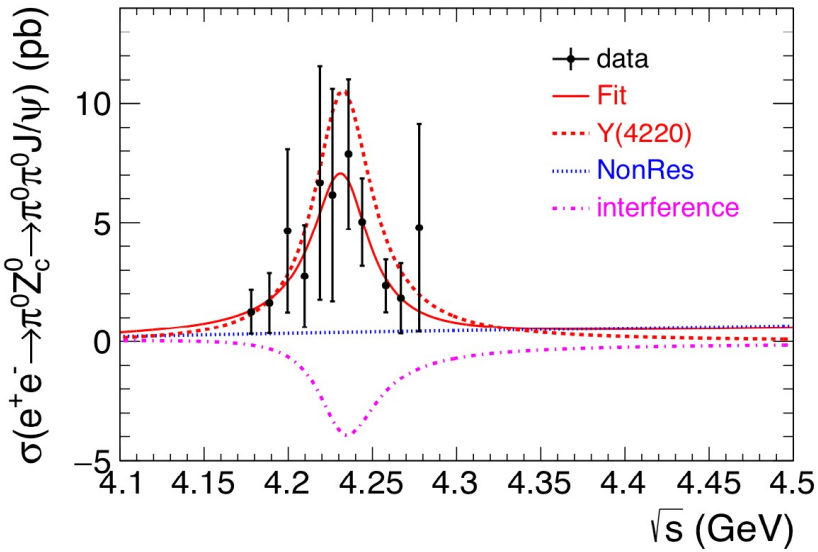
PRD 102, 012009 (2020)

- Cross sections relative to those of the charged channel $e^+e^- \to \pi^+\pi^- J/\psi$ follows isospin symmetry
- Fit to the $e^+e^- \to \pi^0\pi^0 J/\psi$ returns
  $M(\mathrm{Y4220}))=(4220.4\pm2.4\pm2.3)$ MeV/c^2 ; $\Gamma\big(\mathrm{Y}(4220)\big)=(46.2\pm4.7\pm2.1)$ MeV
- Stat. significance of the Y(4320) (fixed to the charged channel) is 4.2σ
- The mass and width are consistent with those measured in the charged process



Cross section of $e^+e^- \to \pi^0 Z_c(3900)^0$

PRD 102, 012009 (2020)



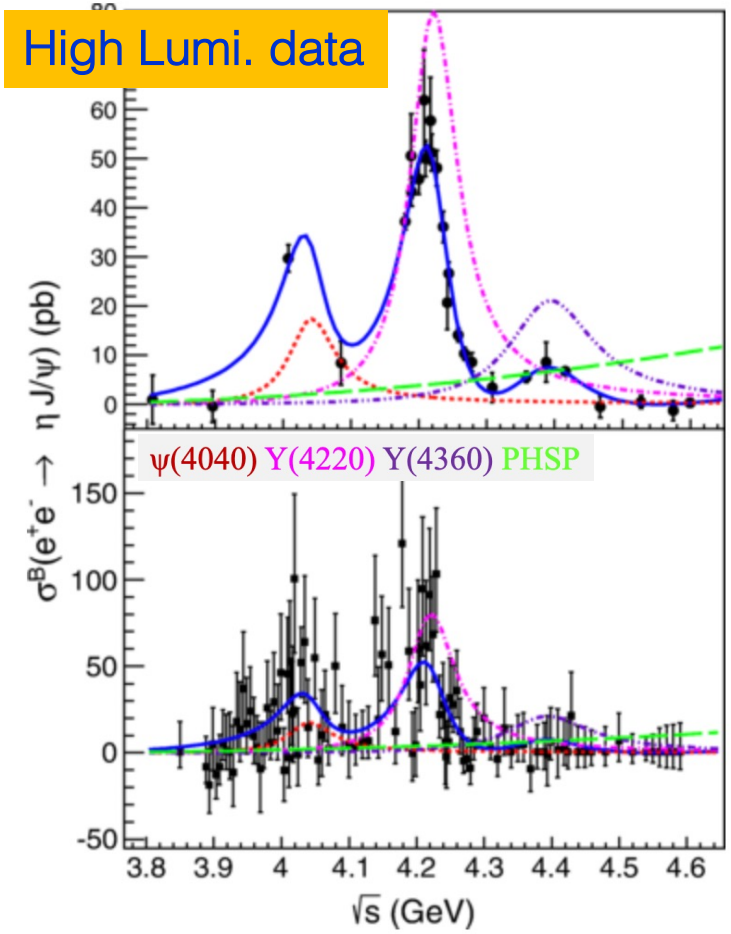
Parameters	Solution I	Solution II
$p_0(c^2/\mathrm{MeV})$	0.0 ± 11.3	
p_1	$(1.8 \pm 1.9) \times 10^{-2}$	
$M(R)$ (MeV/c^2)	4231.9 ± 5.3	
$\Gamma_{\mathrm{tot}}(R))$ (MeV)	41.2 ± 16.0	
$\Gamma_{ee}\mathcal{B}_{R\to\pi^0 Z_c(3900)^0}$ (eV)	0.53 ± 0.15	0.22 ± 0.25
$\phi(R)$	$(-103.9 \pm 33.9)°$	$(112.7 \pm 43.0)°$

- $Zc(3900)^0$ resonance parameters are fixed to the results of the previous four-energy-point fit
- The Born cross section of $e^+e^- \to \pi^0 Z_c(3900)^0 \to \pi^0\ \pi^0 J/\psi$ is extracted.
- Clear structure around 4.2 GeV is observed
  - $M = (4231.9 \pm 5.3 \pm 4.9)$ MeV/c^2,
  - $\Gamma = (41.2 \pm 16.0 \pm 16.4)$ MeV.
- Compatible with the Y(4220) line shape
- Indication of correlation between the production of the Y(4220) and $Z_c(3900)$.

Y(4220) and Y(4360) in $e^+e^- \to \eta J/\psi$

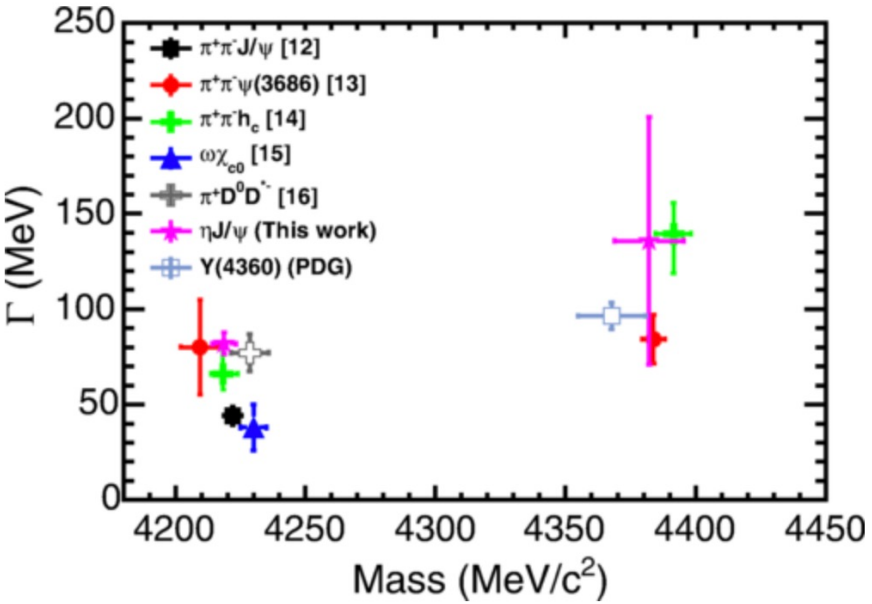
PRD 102, 031101(R) (2020)

- Assuming the lowest lying structure is the $\psi(4040)$
- Consistent with those of the Y(4220) and Y(4360) from previous measurements of different final states



two Y resonances:

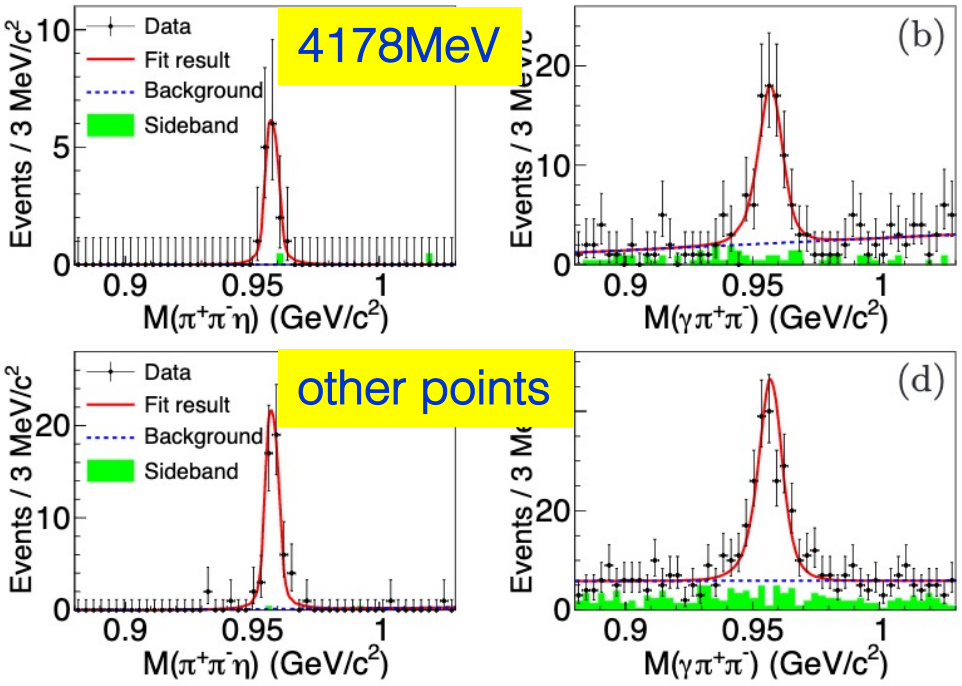
- mass (4218.6±3.8±2.5)MeV/c^2 , width (82.0±5.7±0.4) MeV
- mass (4382.0±13.3±1.7) MeV/c^2, width (135.8±60.8±22.5) MeV



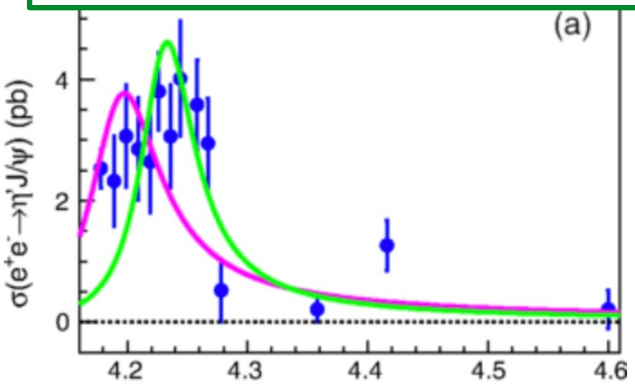
Cross section of $e^+e^- \to \eta' J/\psi$

PRD 101, 012008 (2020)

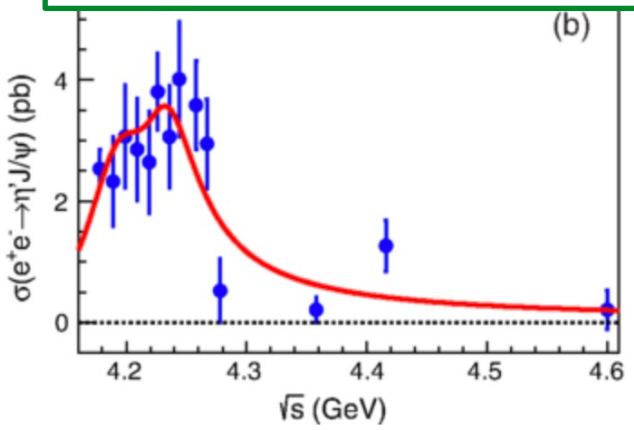
- Enhanced cross section around 4.2 GeV
- A coherent sum of the states of ψ(4160) and Y(4260) provide a reasonable description of the data
- Seems no enhancement around 4.36 GeV as that of $e^+e^- \to \eta J/\psi$



single fit of ψ(4160) or Y(4260)

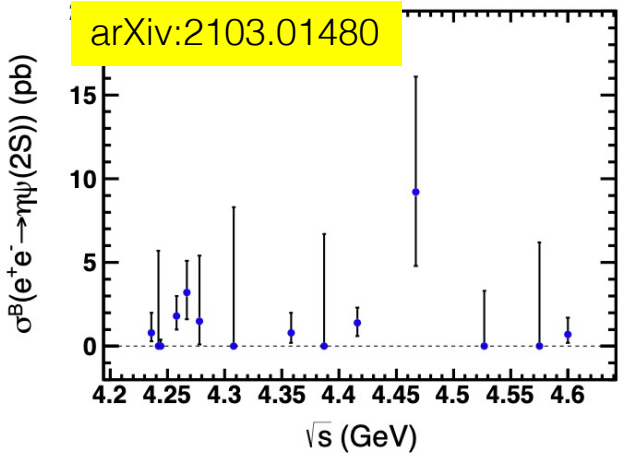


sum fit of ψ(4160) and Y(4260)



More charmonium channels

arXiv:2103.01480



Studies of $e^+e^- \to \eta_c\eta\pi^+\pi^-$: arXiv:2011.13850

$\sigma^{\rm up}_{4.23\ \rm GeV} = 6.2\,\rm pb$ $\quad \sigma^{\rm up}_{4.36\ \rm GeV} = 27.6\,\rm pb$

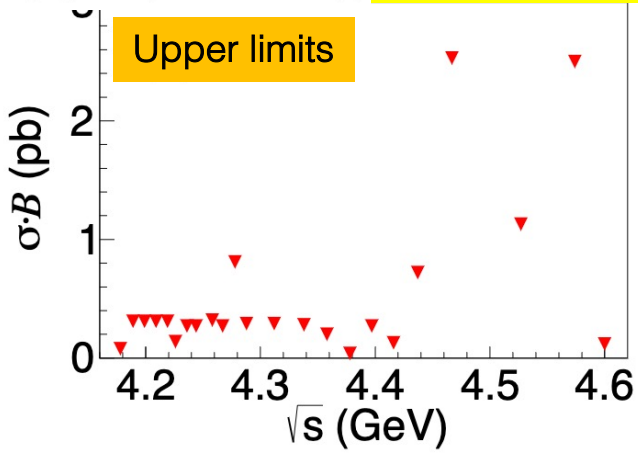
$\sigma^{\rm up}_{4.26\ \rm GeV} = 10.8\,\rm pb$ $\quad \sigma^{\rm up}_{4.42\ \rm GeV} = 22.6\,\rm pb$

$\sigma^{\rm up}_{4.60\ \rm GeV} = 23.7\,\rm pb$

PRD 103, 032006 (2021)

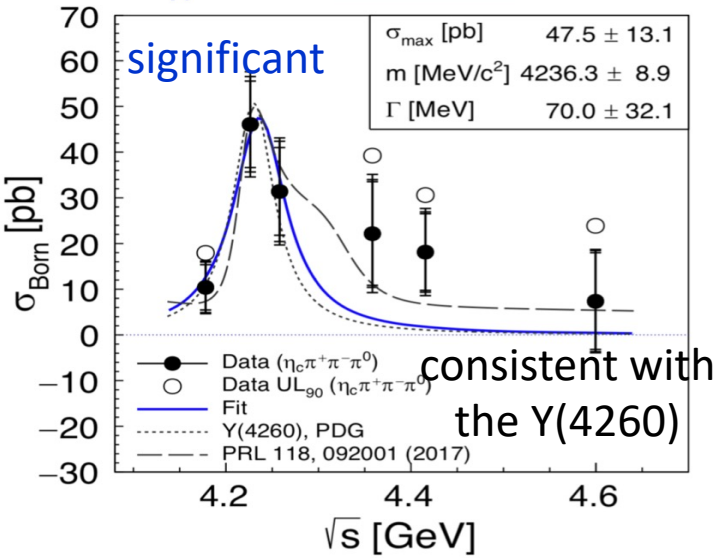
$\sigma(e^+e^- \to \pi^0 X(3872)\gamma) \cdot$
$\mathcal{B}(X(3872) \to \pi^+\pi^- J/\psi)$ arXiv: 2102.00644

Upper limits

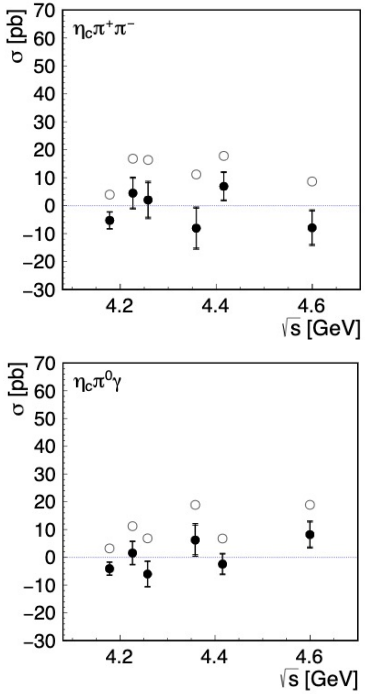


$e^+e^- \to \eta_c\pi^+\pi^-\pi^0$

significant



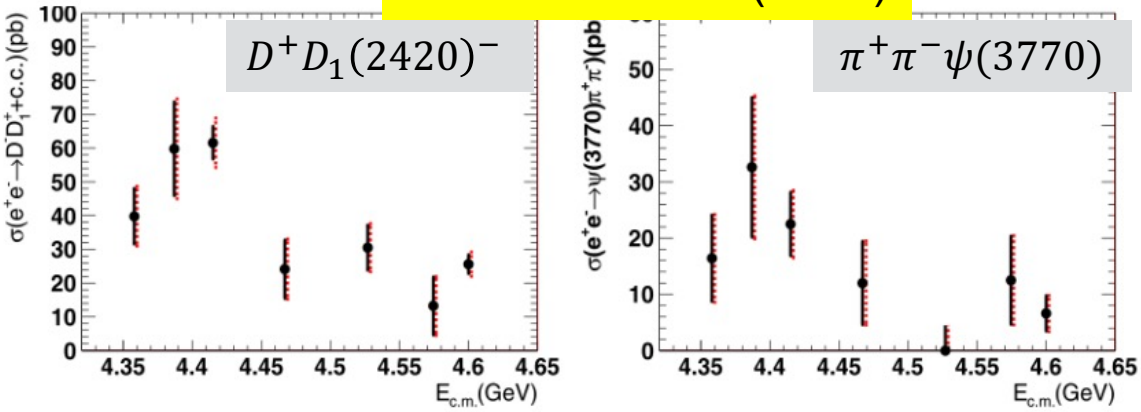
consistent with the Y(4260)



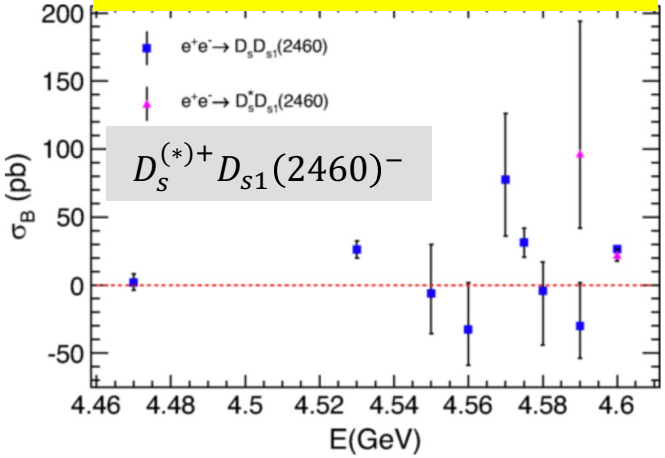
Cross sections of open charm final states

Partial reconstruction

PLB804.135395(2020)



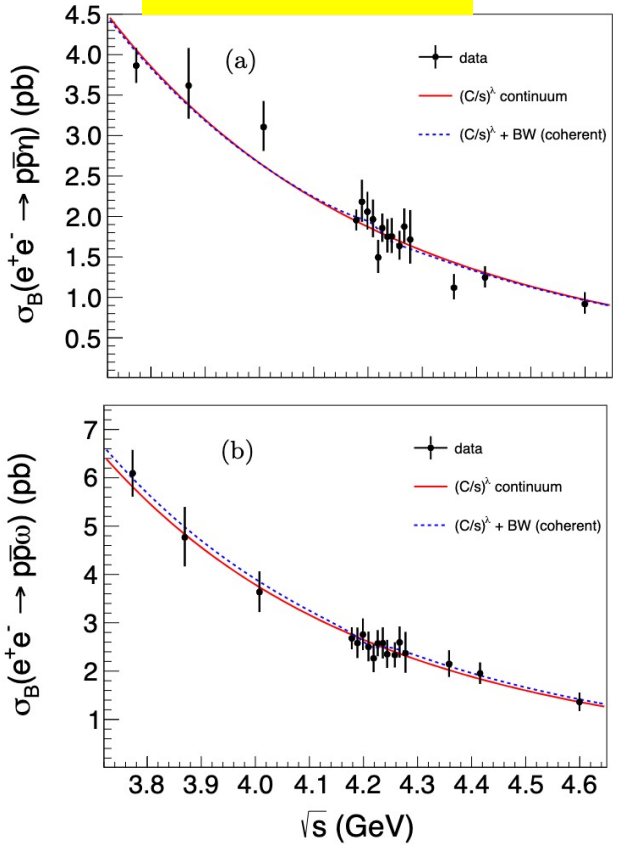
PRD101, 112008 (2020)



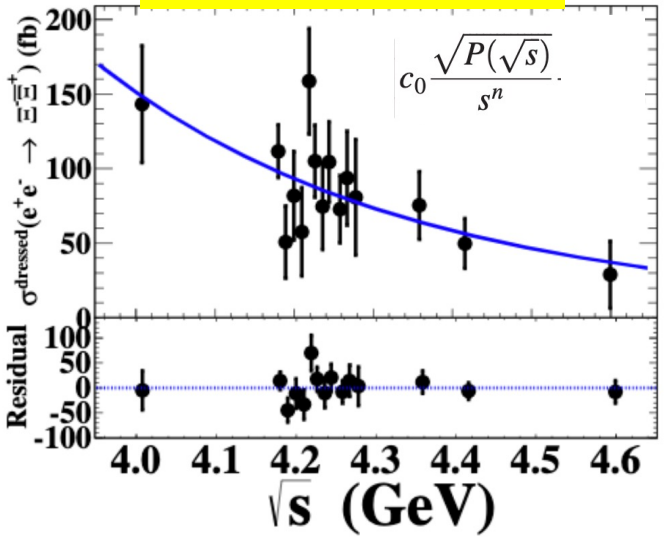
- Some indications of enhanced cross sections of $e^+e^- \to D^+D_1(2420)^-$ and $\pi^+\pi^-\psi(3770)$ between 4.36 and 4.42 GeV:
  ➔ potential contributions form the Y(4360) and $\psi(4415)$?
- No obvious structure in the cross sections of $e^+e^- \to D_s^{(*)+}D_{s1}(2460)^-$

Cross sections of baryonic final states

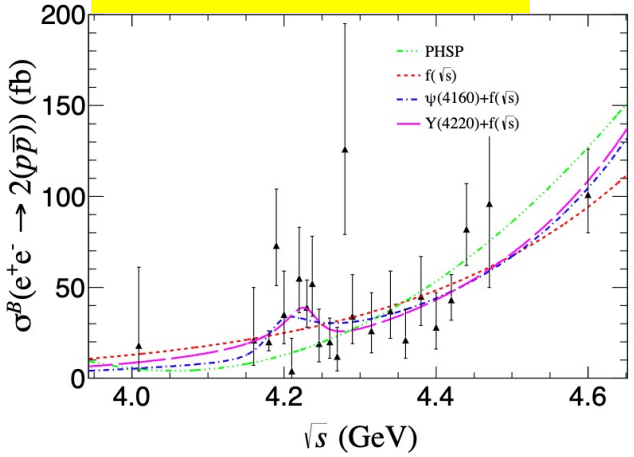
arXiv:2102.04268



PRL124, 032002(2020)



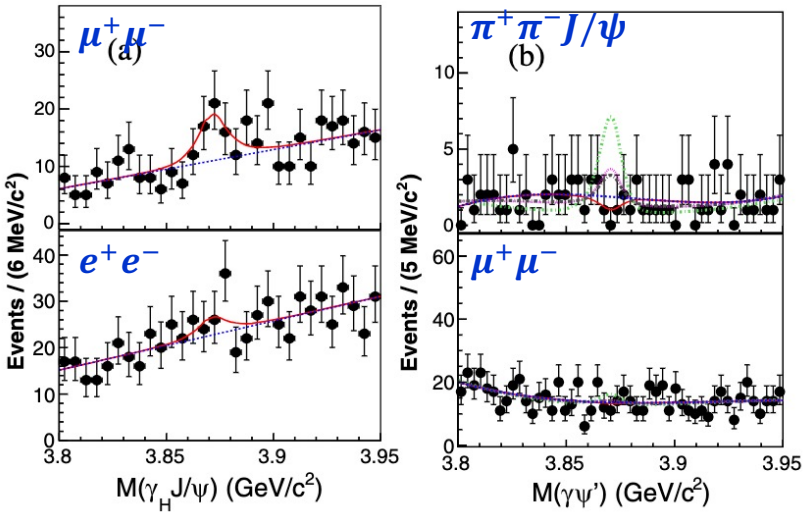
PRD103, 052003 (2021)

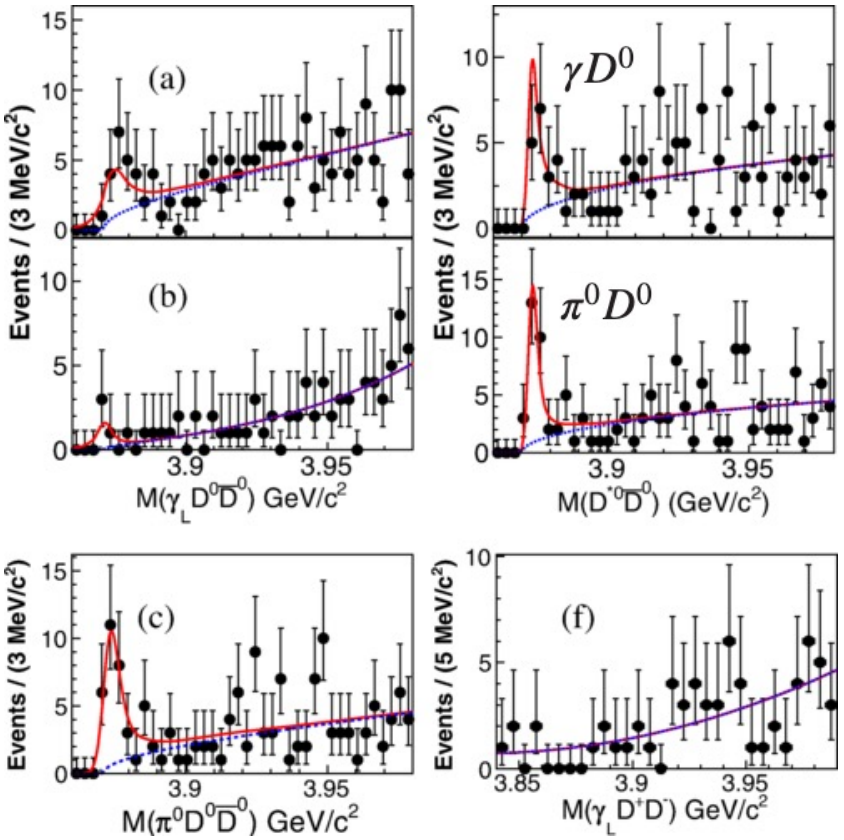


no evidence for a resonant structure

More decays of the X(3872)/χ_{c1}(3872)

PRL124, 242001(2020)





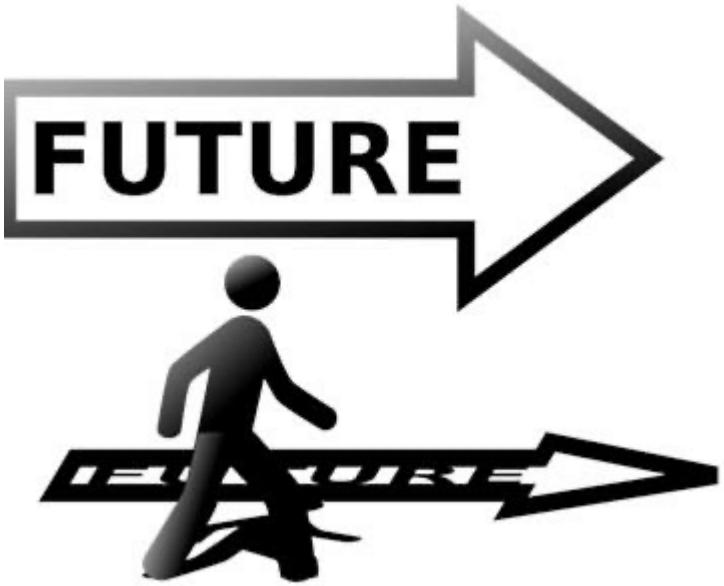
- No evidence of $X(3872) \to \gamma\psi'$

➔ $R_{\gamma\psi} = \frac{B(X(3872)\to\gamma\psi')}{B(X(3872)\to\gamma J/\psi)}$<0.59 (90% C.L.)

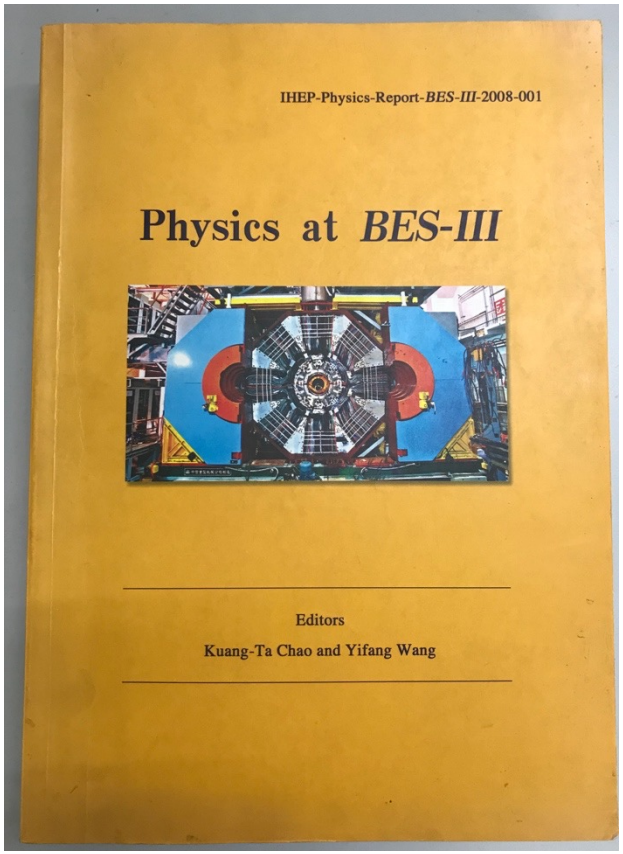
- Consistent with Belle, while disagree with LHCb and BaBar's results:
  LHCb: 2.46±0.64±0.29
  BaBar: 3.4±1.4

TABLE II. Relative branching ratios and UL on branching ratios compared with $X(3872) \to \pi^+\pi^- J/\psi$.

mode	$\gamma J/\psi$	$\gamma\psi'$	$\gamma D^0\bar{D}^0$	$\pi^0 D^0\bar{D}^0$	$D^{*0}\bar{D}^0 + c.c.$	γD^+D^-	$\omega J/\psi$	$\pi^0\chi_{c1}$
ratio	0.79 ± 0.28	-0.03 ± 0.22	0.54 ± 0.48	-0.13 ± 0.47	11.77 ± 3.09	$0.00^{+0.48}_{-0.00}$	$1.6^{+0.4}_{-0.3} \pm 0.2$ [18]	$0.88^{+0.33}_{-0.27} \pm 0.10$ [35]
UL	-	< 0.42	< 1.58	< 1.16	-	< 0.99	-	-


FUTURE

BESIII Physics



Int. J. Mod. Phys. A 24, S1-794 (2009)
[arXiv:0809.1869 [hep-ex]].

Chinese Physics C Vol. 44, No. 4 (2020)

Future Physics Programme of BESIII*

Abstract: There has recently been a dramatic renewal of interest in hadron spectroscopy and charm physics. This renaissance has been driven in part by the discovery of a plethora of charmonium-like *XYZ* states at BESIII and *B* factories, and the observation of an intriguing proton-antiproton threshold enhancement and the possibly related *X*(1835) meson state at BESIII, as well as the threshold measurements of charm mesons and charm baryons. We present a detailed survey of the important topics in tau-charm physics and hadron physics that can be further explored at BESIII during the remaining operation period of BEPCII. This survey will help in the optimization of the data-taking plan over the coming years, and provides physics motivation for the possible upgrade of BEPCII to higher luminosity.

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Chin. Phys. C 44, 040001 (2020)
doi:10.1088/1674-1137/44/4/040001
[arXiv:1912.05983 [hep-ex]].

Planned future data set

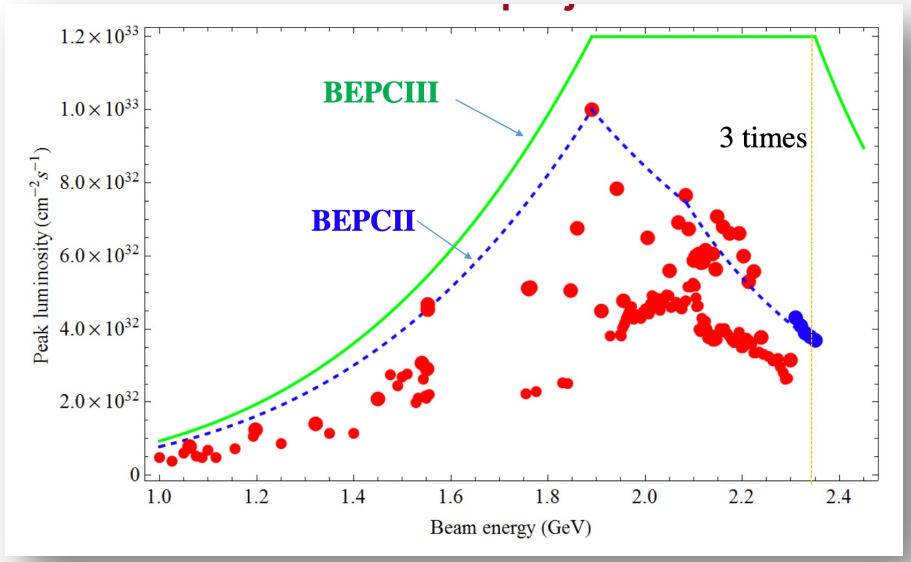
Table 7.1: List of data samples collected by BESIII/BEPCII up to 2019, and the proposed samples for the remainder of the physics program. The most right column shows the number of required data taking days in current (T_C) or upgraded (T_U) machine. The machine upgrades include top-up implementation and beam current increase.

Energy	Physics motivations	Current data	Expected final data	T_C / T_U
1.8 - 2.0 GeV	R values Nucleon cross-sections	N/A	0.1 fb^{-1} (fine scan)	60/50 days
2.0 - 3.1 GeV	R values Cross-sections	Fine scan (20 energy points)	Complete scan (additional points)	250/180 days
J/ψ peak	Light hadron & Glueball J/ψ decays	3.2 fb^{-1} (10 billion)	3.2 fb^{-1} (10 billion)	N/A
$\psi(3686)$ peak	Light hadron & Glueball Charmonium decays	0.67 fb^{-1} (0.45 billion)	4.5 fb^{-1} (3.0 billion)	150/90 days
$\psi(3770)$ peak	$D^0/D^{\pm}$ decays	2.9 fb^{-1}	20.0 fb^{-1}	610/360 days
3.8 - 4.6 GeV	R values XYZ/Open charm	Fine scan (105 energy points)	No requirement	N/A
4.180 GeV	D_s decay XYZ/Open charm	3.2 fb^{-1}	6 fb^{-1}	140/50 days
4.0 - 4.6 GeV	XYZ/Open charm Higher charmonia cross-sections	16.0 fb^{-1} at different $\sqrt{s}$	30 fb^{-1} at different $\sqrt{s}$	770/310 days
4.6 - 4.9 GeV	Charmed baryon/XYZ cross-sections	0.56 fb^{-1} at 4.6 GeV	15 fb^{-1} at different $\sqrt{s}$	1490/600 days
4.74 GeV	$\Sigma_c^+\bar{\Lambda}_c^-$ cross-section	N/A	1.0 fb^{-1}	100/40 days
4.91 GeV	$\Sigma_c\bar{\Sigma}_c$ cross-section	N/A	1.0 fb^{-1}	120/50 days
4.95 GeV	Ξ_c decays	N/A	1.0 fb^{-1}	130/50 days

Proposal of the BEPCIII

- Following up with the beam energy and top-up upgrade, we are planning the next generation of BEPCIII (200 million CNY), to be implemented around 2022: the optimized energy is 2.35 GeV with luminosity 3 times higher than BEPCII.

	BEPCII	BEPCIII
Lum. [10^{33}cm^{-2}s^{-1}] @2.35GeV	**0.35**	**1.2**
β_y^* [cm]	**1.5**	**1.35**
Bunch current	7.1 mA	7.5 mA
Bunch number	56	120
SR Power [kW]	**110**	**250**
$\xi_{y,\mathrm{lum}}$	**0.029**	**0.039**
Emittance [nmrad]	**138**	**120**
Coupling [%]	**0.53**	**0.40**
Bucket Height	0.0069	0.091
$\sigma_{z,0}$ [cm]	1.54	1.24
σ_z [cm]	**1.69**	**1.39**
RF voltage	**1.6MV**	**3.5MV**



Major modification
- RF region
- Vacuum chamber
- Beam parameters

Summary

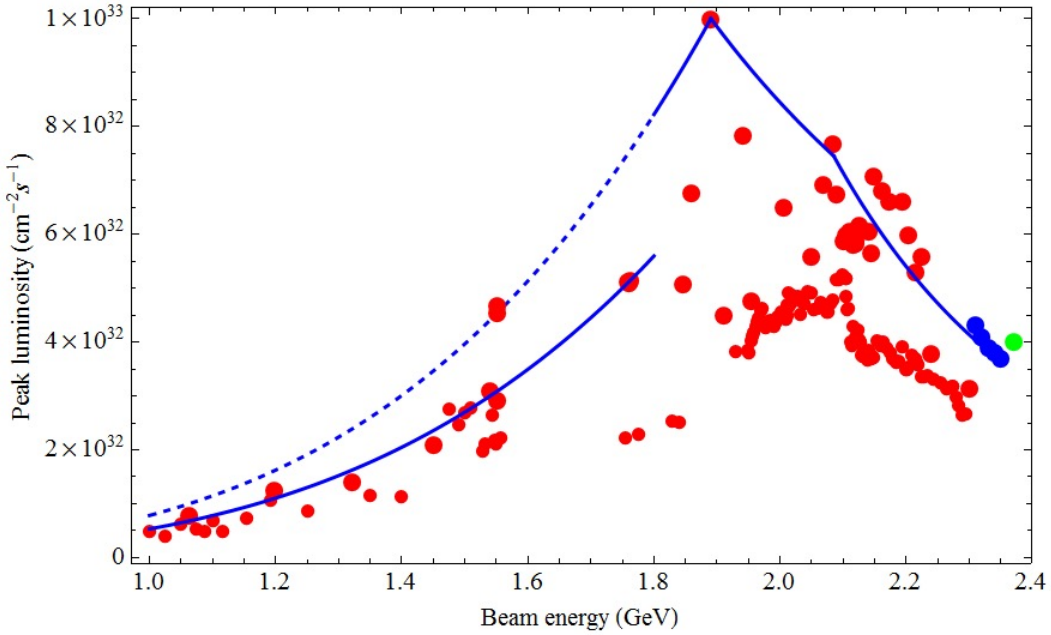
- BESIII is successfully operating since 2008, and will continue to run for 5–10 years
  – collected large data samples in the τ-charm mass region
- Many exciting results have been published covering many aspects on the XYZ states
  - ✓ Observation of the Zcs(3985)
  - ✓ PWA on Zc(3900)
  - ✓ Search for Y states in different final states
  - ✓ More decay patterns of X(3872)
- Future plan on XYZ physics
  high-lumi. fine scan between 3.8 GeV and 5.0 GeV
- BEPCIII: 3x upgrade on luminosity

Thank you!

谢谢!

BEPCII upgrade

- Increase of beam energy 2.30→2.35(2018)→2.45 GeV(2020')
  - ➔ 2.35 GeV in 2018 summer (done)
  - ➔ 2.45 GeV in 2020 summer (done),
    change ISPB (Interaction region SePtum Bending) magnet
- Top-up injection (done)
  - Data taking efficiency increases by 20~30%



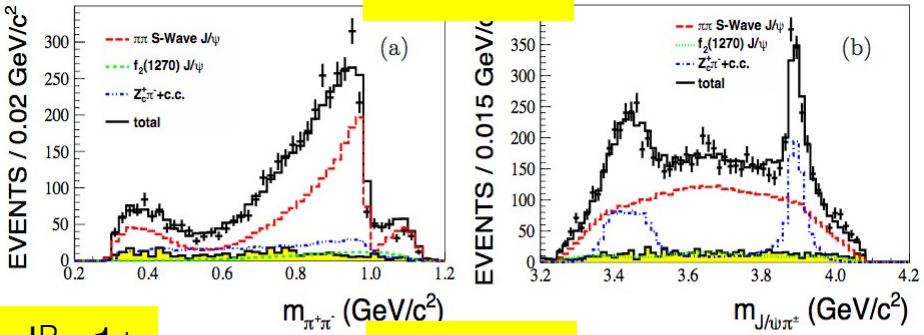
Spin-parity determination of the $Z_c^+(3900)$

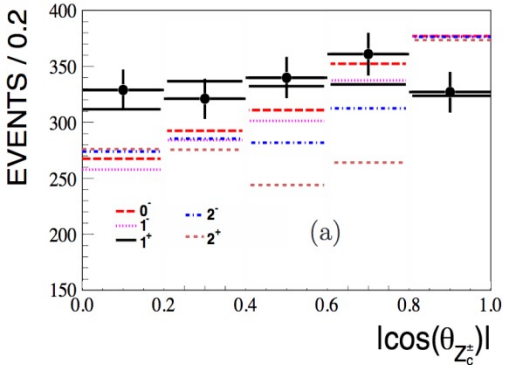
- Zc line shape parameterized with Flatte-like formula

PRL 119.072001 (2017)

$$BW(s) = \frac{1}{s - M^2 + i(g_1' \rho_{\pi J/\psi}(s) + g_2' \rho_{D^* D}(s))},$$

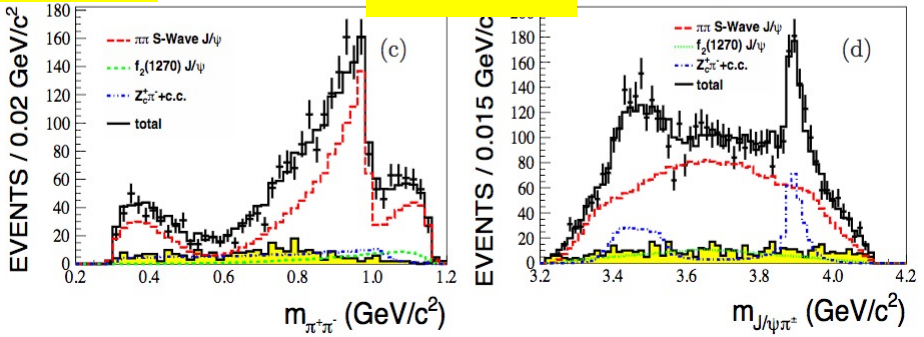
4.23GeV

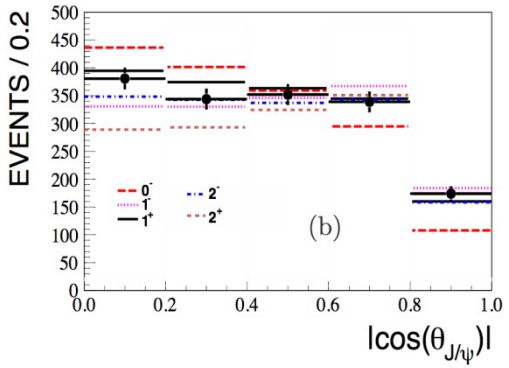




$J^P = 1^+$

4.26GeV





Hypothesis	$\Delta(-2\ln L)$	Δ(ndf)	Significance
1^+ over 0^-	94.0	13	7.6σ
1^+ over 1^-	158.3	13	10.8σ
1^+ over 2^-	151.9	13	10.5σ
1^+ over 2^+	96.0	13	7.7σ

J^P is measured to be 1^+ with significance larger than $7.6\boldsymbol{\sigma}$

Search for $Z_c^{(\prime)+} \to \rho^+ \eta_c$

PRD 100, 111102(R) (2019)

- Search for new decay mode of $Z_c(3900)$ and $Z_c(4020)$
- The ratios of $Z_c^{(\prime)} \to \rho\eta_c$ to $Z_c^{(\prime)} \to \pi J/\psi(\pi h_c)$ may discriminate **the tetra-quark** and **molecule** models.

$$R_z = \frac{B(Z_c \to \rho\eta_c)}{B(Z_c \to \pi J/\psi)}$$

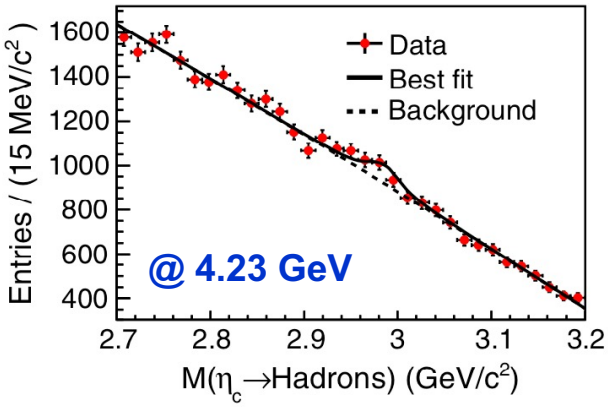
$$R_{z\prime} = \frac{B(Z_c' \to \rho\eta_c)}{B(Z_c' \to \pi h_c)}$$

Date sets:

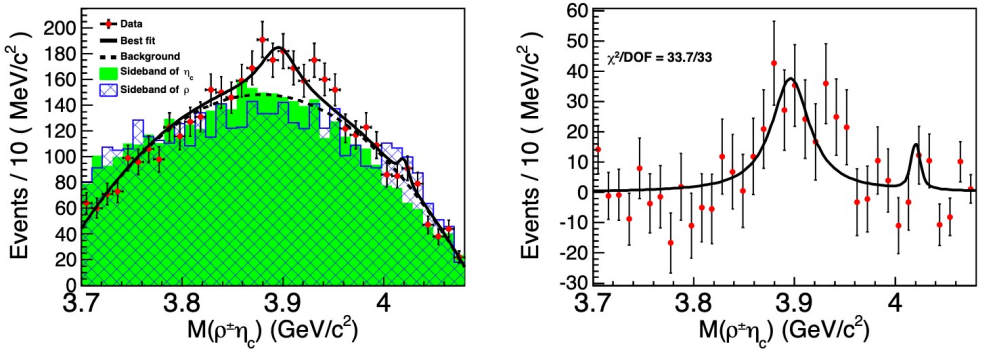
- ~4 fb^{-1} data set distributed at $\sqrt{s}$ = 4.23,4.26,4.36,4.40,4.60 GeV

Strategy of this analysis:

- Start with looking for $e^+e^- \to \pi^+\pi^-\pi^0\eta_c, \eta_c \to 9$ hadronic decays



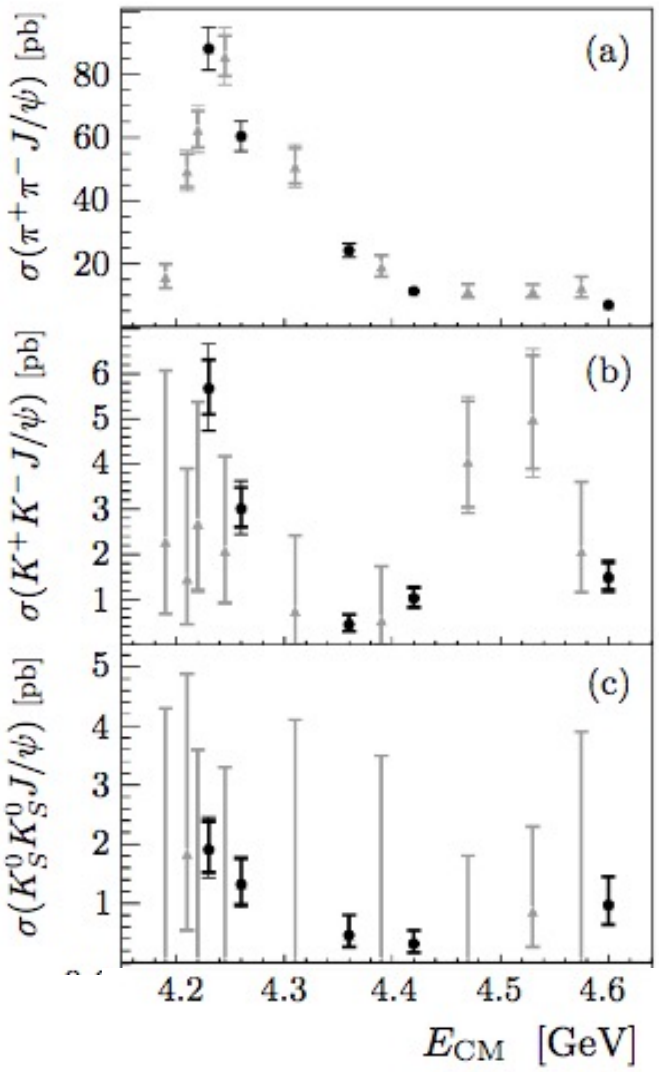
- Strong evidence of $e^+e^- \to \pi Z_c, Z_c \to \rho\eta_c$ is observed at $\sqrt{s} = 4.23$, statistical significance is 4.3σ. (3.9σ including systematics)
- $e^+e^- \to \pi Z_c', Z_c' \to \rho\eta_c$ is not seen in all data sets.



@ 4.23 GeV

$e^+e^- \to K\bar{K}J/\psi$

PRD 97, 071101 (2018)



- $\sigma\ (KKJ/\psi)$ lineshape is quite different from $\sigma\ (\pi^+\pi^- J/\psi)$ around Y(4220)/Y(4260)
- Higher bump around 4.5GeV is clear and need further investigation
- How about up to 4.9 GeV?