Hyperon pair production at BESIII

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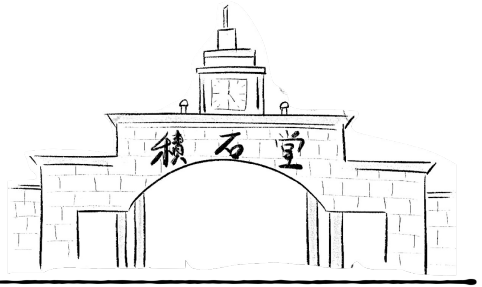
Lanzhou University

On behalf of the BESIII collaboration

– 12th International Workshop on Charm Physics –

Outline

- Introduction
- BEPCII and BESIII Detector
- Highlights
- Conclusion & Outlook



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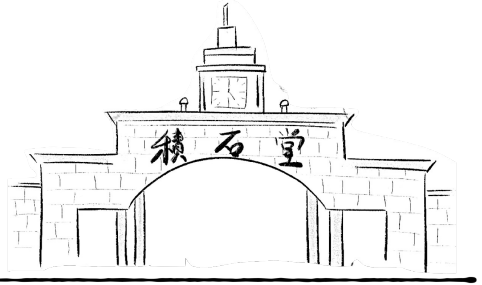
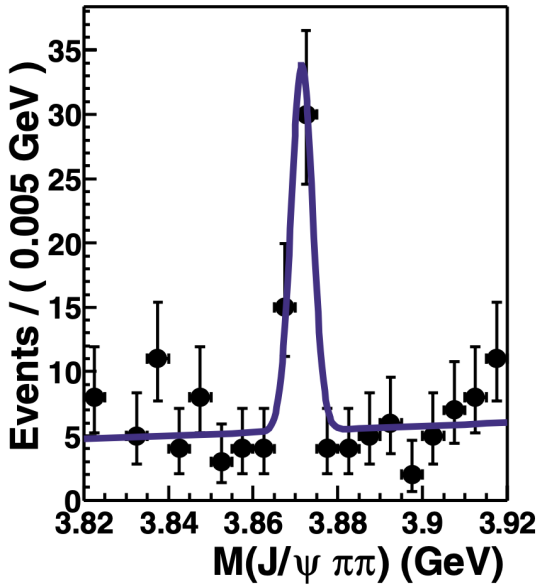


XYZ/Charmonium (-like) state

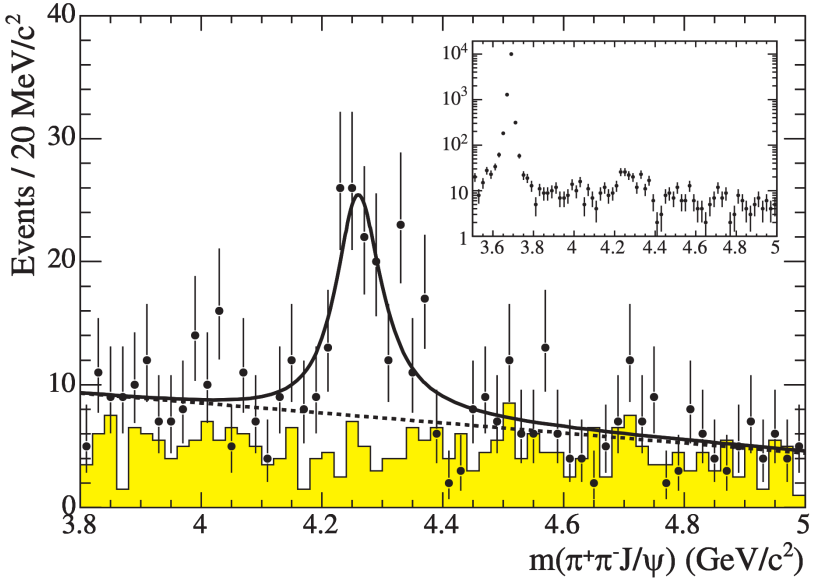
- A series of XYZ states have been observed in past decades.

$X(3872)$



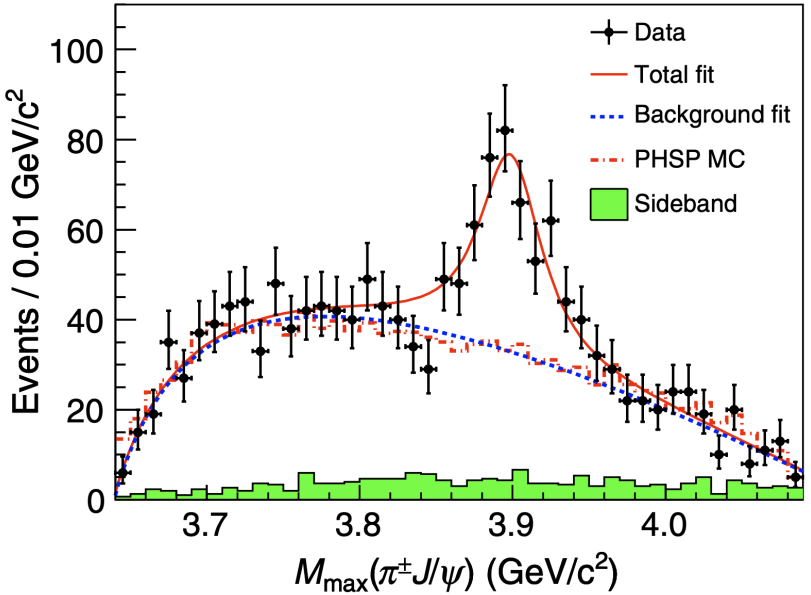
Phys. Rev. Lett. 91, 262001(2003)

$Y(4260)$



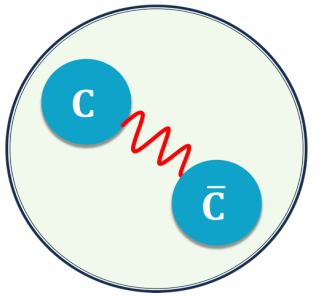
Phys. Rev. Lett. 95, 142001(2005)

$Z_c(3900)$

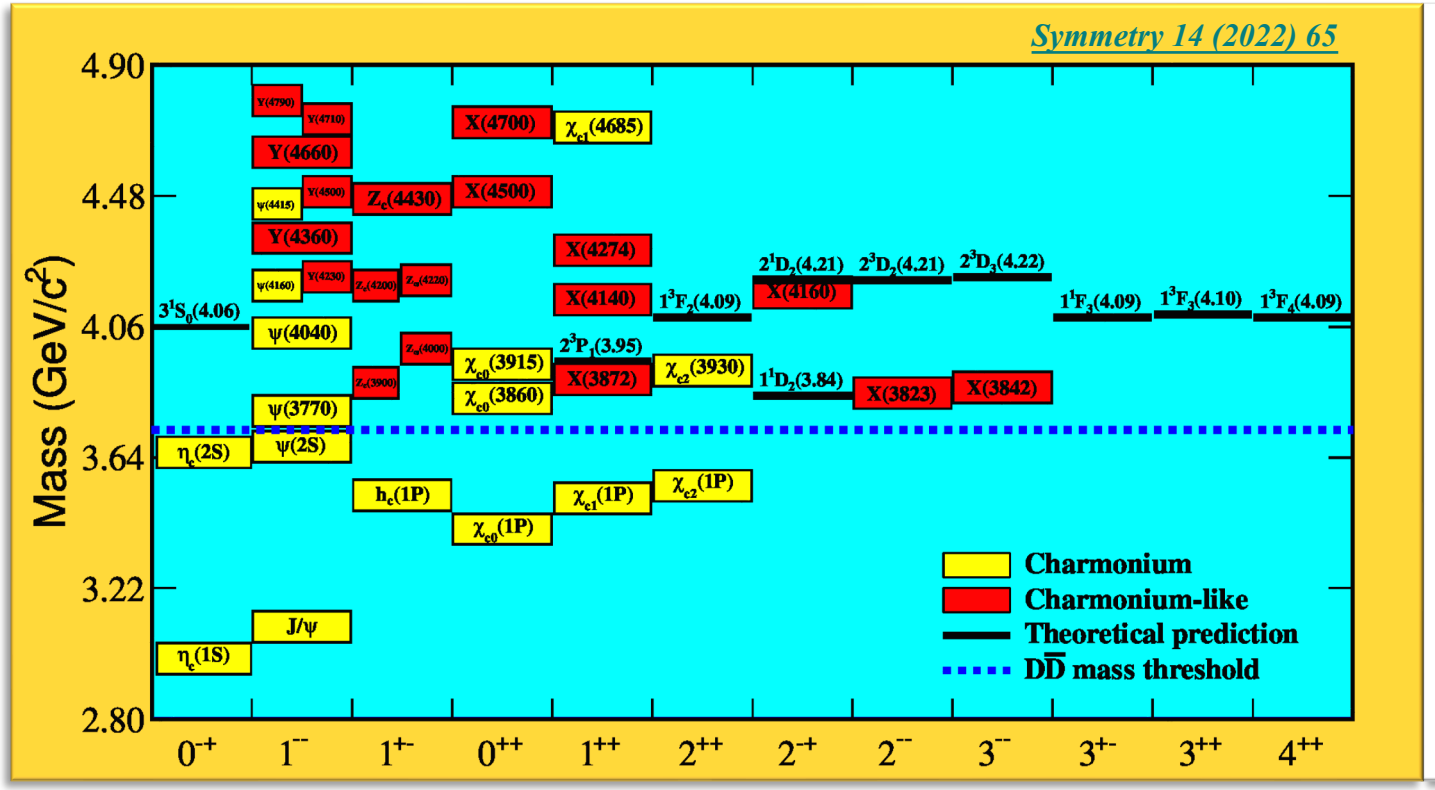


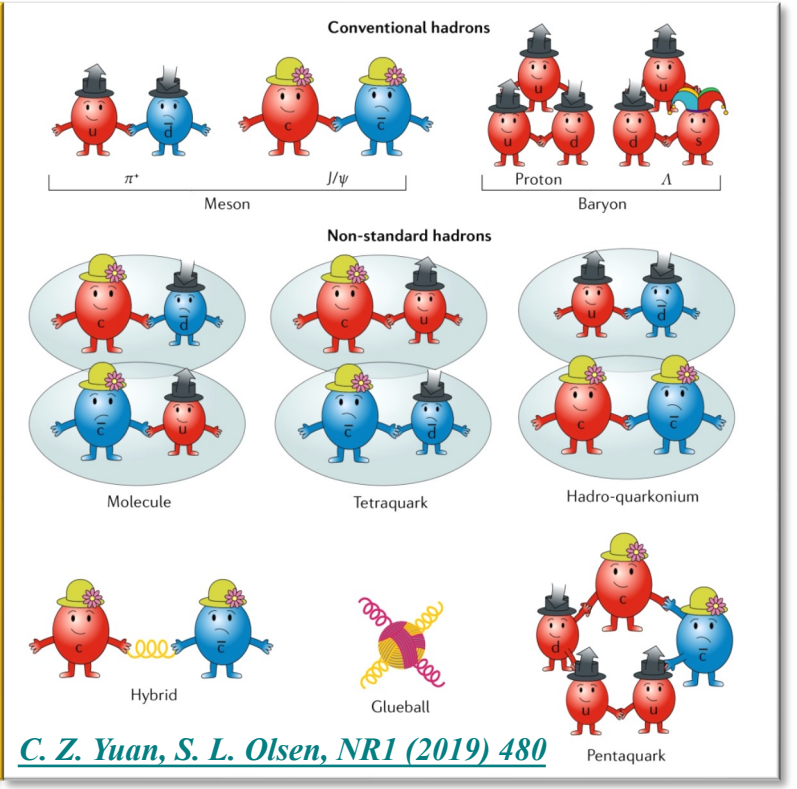
Phys. Rev. Lett. 110, 252001(2013)

XYZ/Charmonium (-like) state



- **Conventional Charmonium states**: Nonrelativistic $c\bar{c}$ bound state.
- **XYZ/Charmonium-like states**: Various scenarios have been proposed.

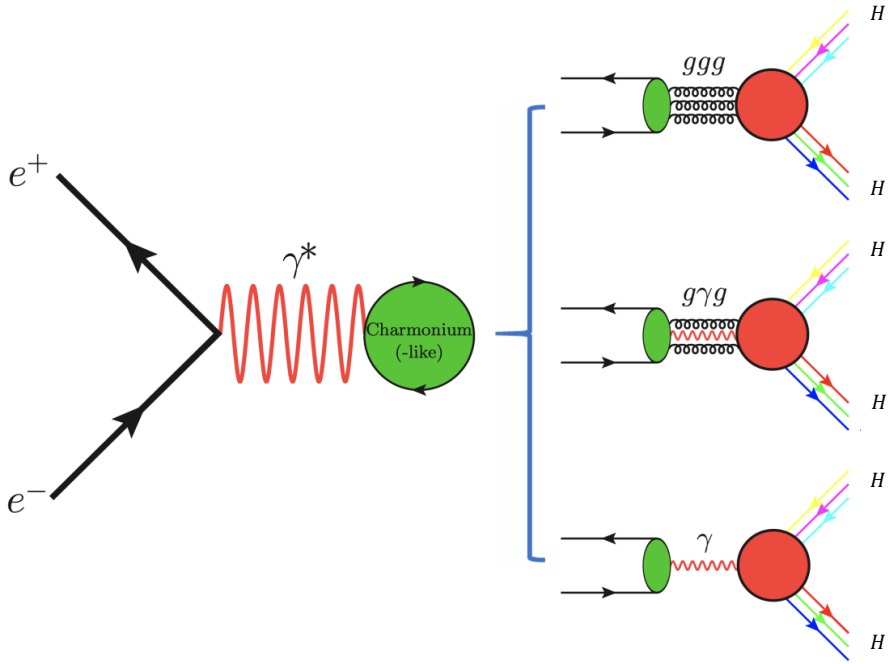




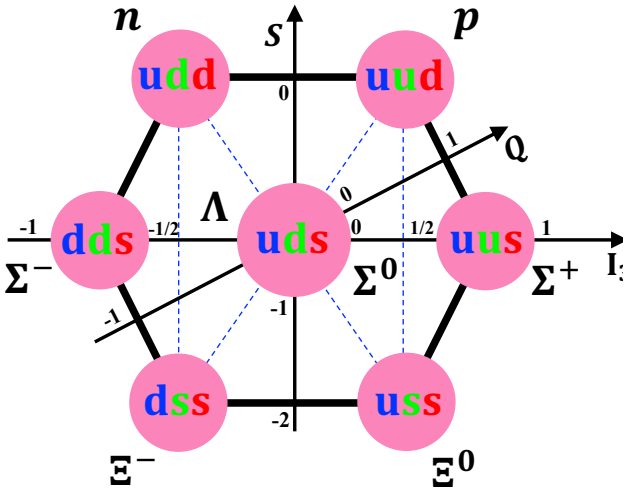
- **Nature still needs more effort in theory and experiment.**

A New Avenue

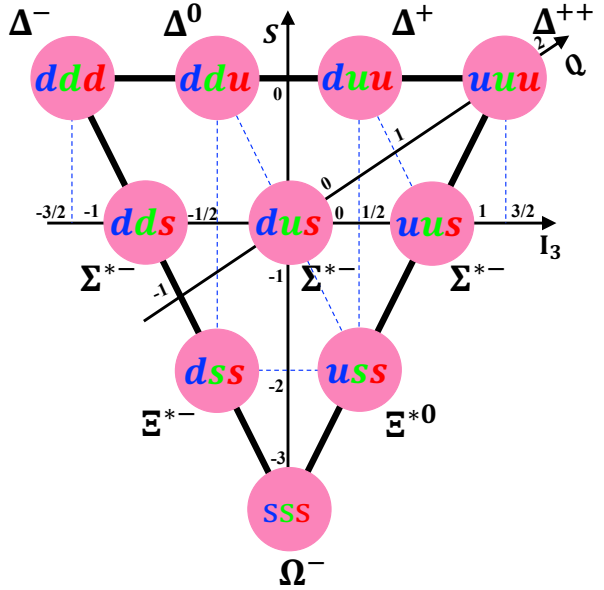
- There is a lack of research on the light hadronic decays of the XYZ states.



$H\bar{H}$ pair production



Baryon Octuplet



Baryon Decuplet

- A hyperon factory, provide a rich laboratory for probing non-pQCD, hyperon property/CPV, pQCD, etc.

PoS CHARM2020 (2021) 026

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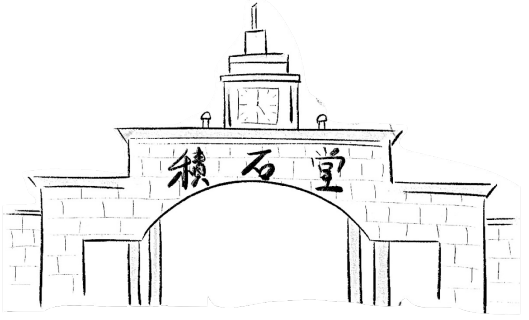
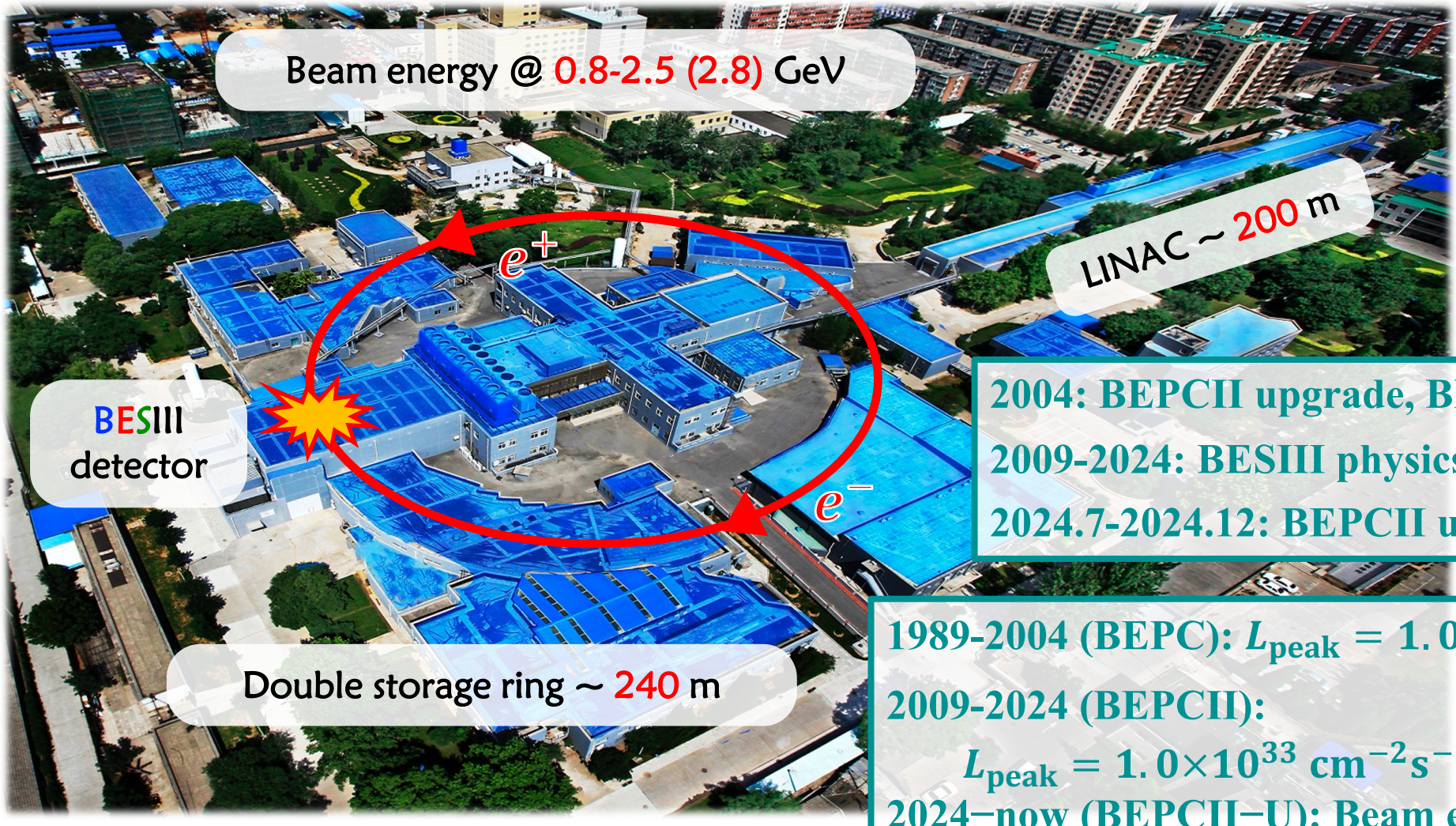


BEPCII and BESIII Detector



2004: BEPCII upgrade, BESIII construction

2009-2024: BESIII physics and SR run

2024.7-2024.12: BEPCII upgrade to BEPCII-U

1989-2004 (BEPC): $L_{peak} = 1.0\times10^{31}$ cm^{-2}s^{-1}

2009-2024 (BEPCII):

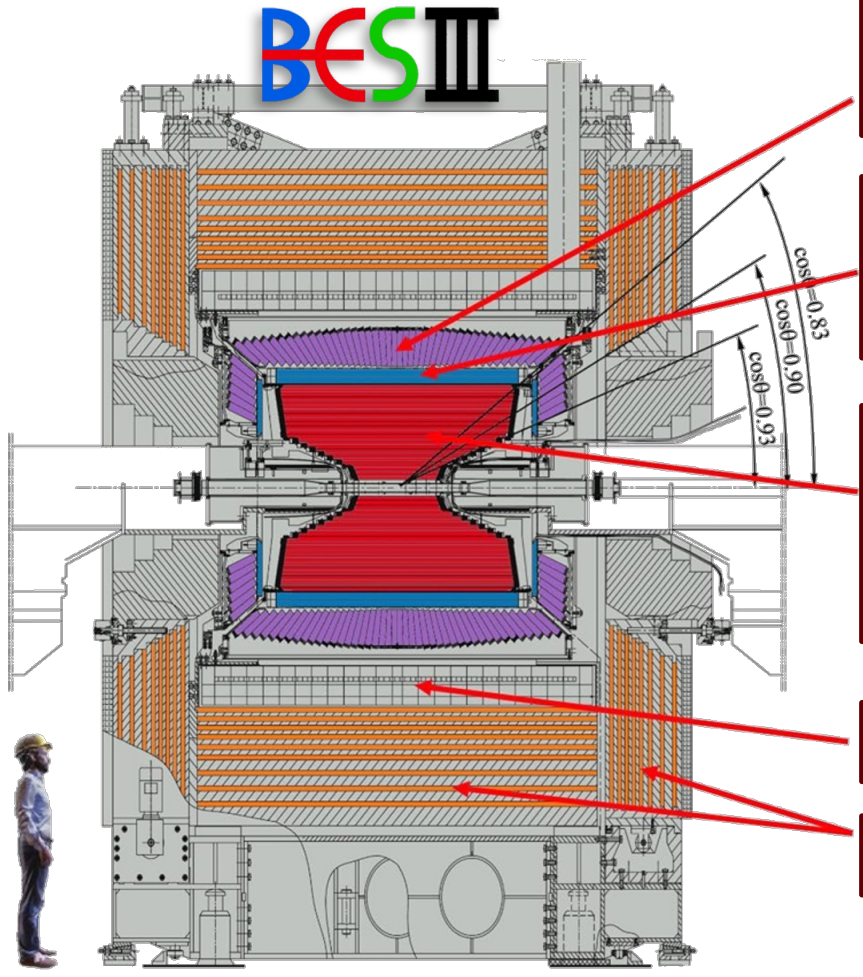
$L_{peak} = 1.0\times10^{33}$ cm^{-2}s^{-1} (beyond the design)

2024–now (BEPCII–U): Beam energy up to 2.8 GeV

BEPCII and BESIII Detector

- ✓ 10 billion J/ψ events
- ✓ 2.7 billion (more) $\psi(2S)$ events
- ✓ 20 fb^{-1} $\psi(3770)$ samples
- ✓ ~30 fb^{-1} R-scan & XYZ samples

- ✓ High statistic of data
- ✓ Clean background environment
- ✓ Angular coverage is almost 4π sr
- ✓ Wider energy range



EMC: CsI crystals
$\Delta E/E = 2.5\%$ @ 1 GeV (Barrel)
$\Delta E/E = 5.0\%$ @ 1 GeV (Endcap)

TOF:
$\sigma_T = 80$ ps (Barrel)
$\sigma_T = 110$ (60) ps (Endcap)

MDC: small cell & filled with helium
$\sigma_{xy} = 130$ μm
$\sigma_p/p = 0.5\%$ @ 1 GeV
$dE/dx = 6\%$

Super Conducting Magnet: 1 T

Muon ID: 9 layers RPC

Operating since 2008

Hadron structure & dynamics in the non-perturbative QCD regime.

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  - Hyperon pair production above open charm threshold
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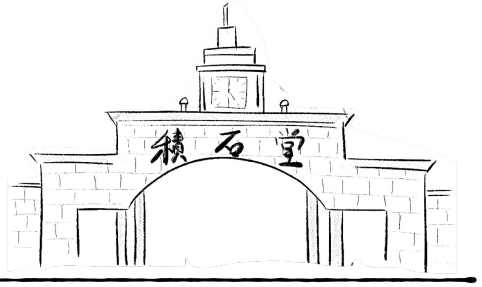
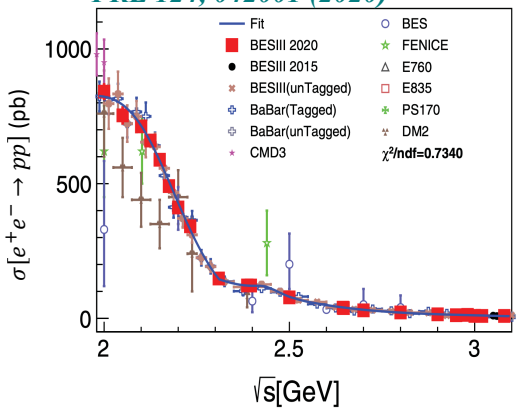


$e^+e^- \to H\bar{H}$ near threshold

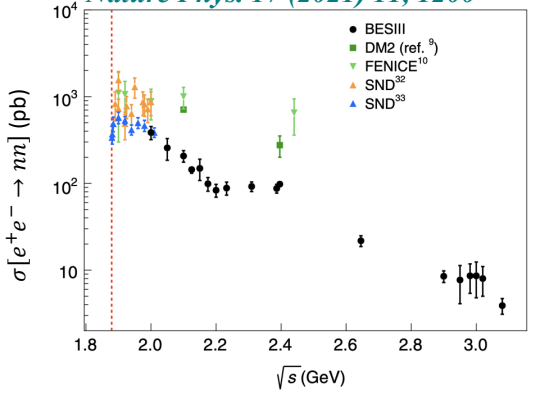
- **Threshold enhancement**

$e^+e^- \to p\bar{p}/n\bar{n}/\Lambda\bar{\Lambda}/\Lambda\bar{\Sigma}^0$

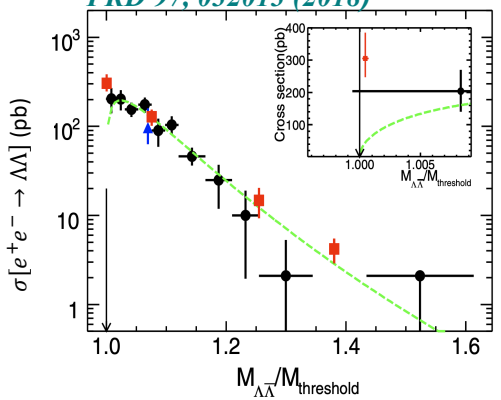
PRL 124, 042001 (2020)



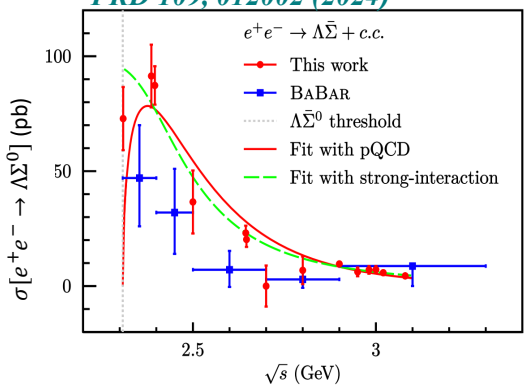
Nature Phys. 17 (2021) 11, 1200

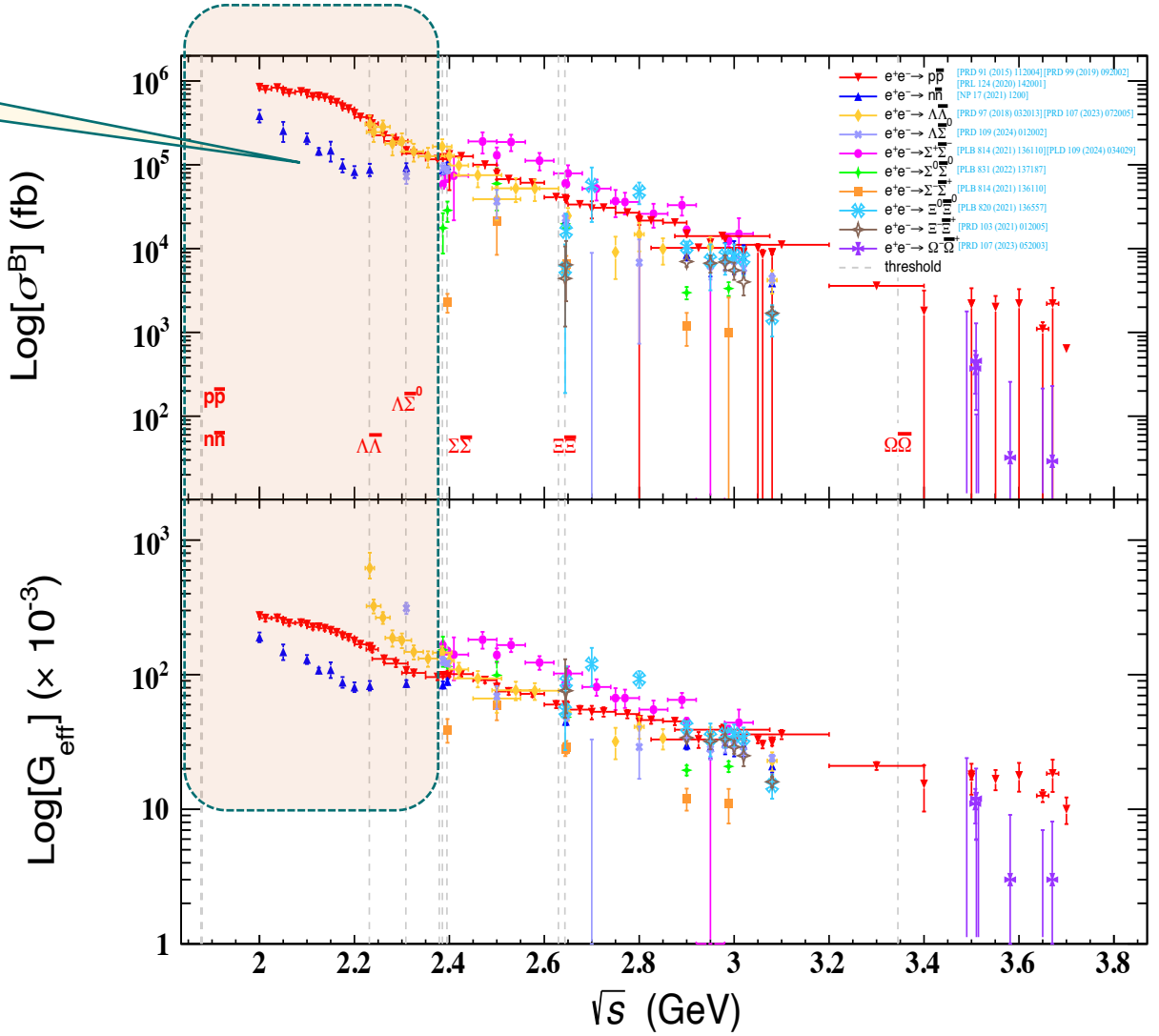


PRD 97, 032013 (2018)

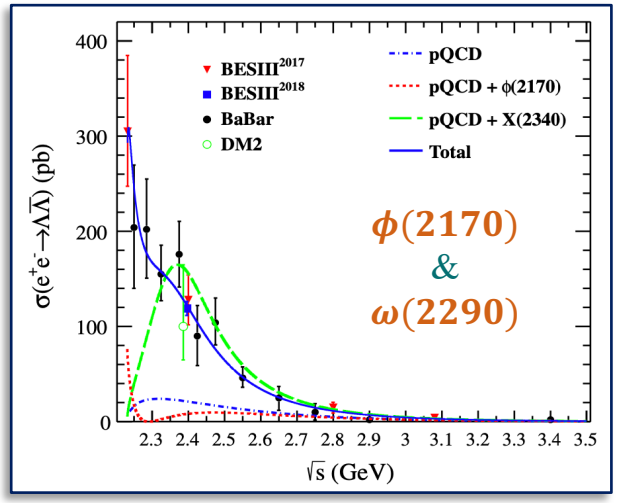


PRD 109, 012002 (2024)

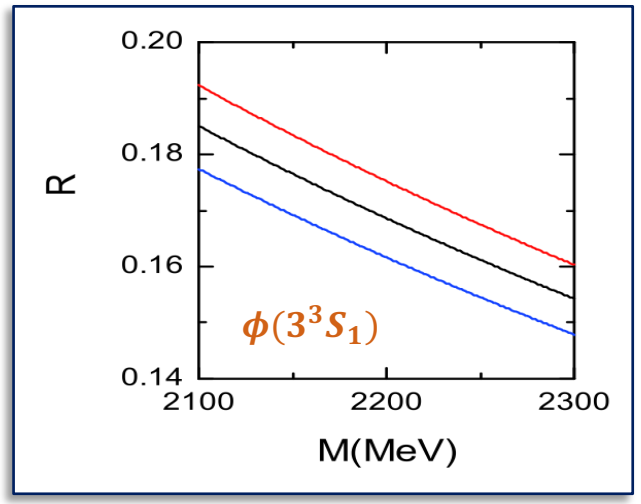




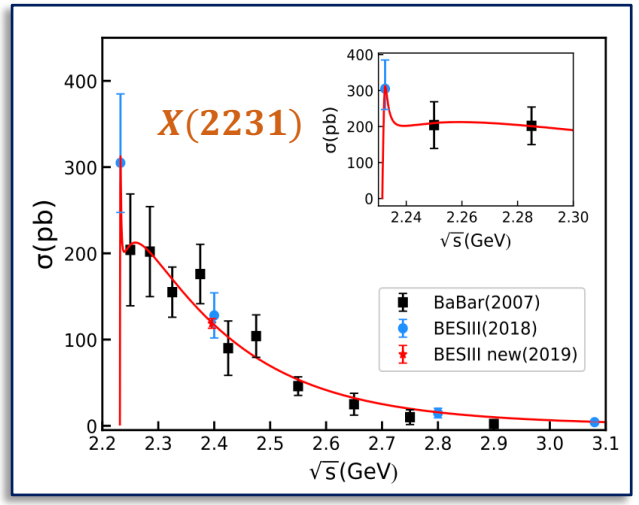
Diverse theoretical explanations



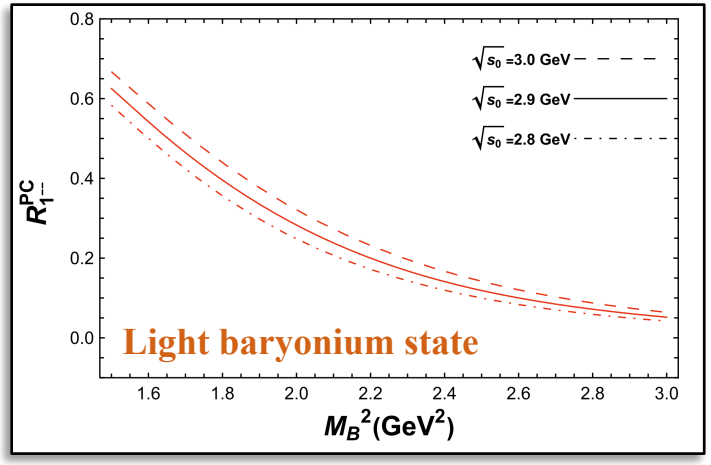
Cao et al, PRD 98, 094006 (2018)



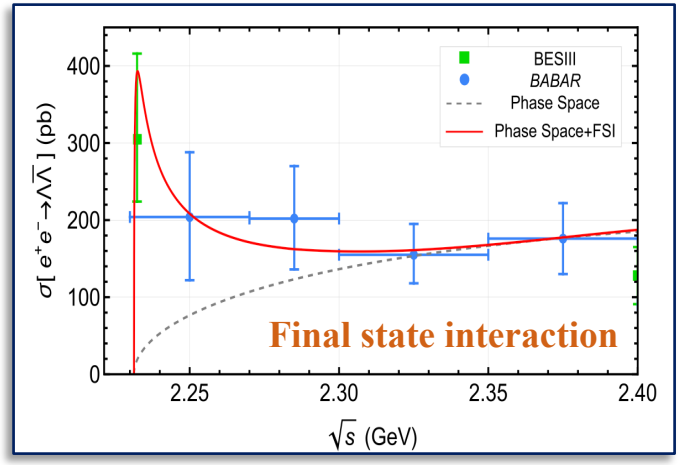
Xiao et al, CPC 43, 113105 (2019)



Xie et al, CPL 39, 011201 (2022)



Wan et al, PRD 105, 014016 (2022)



Qian et al, PRD 107, L091502 (2023)

Nature has still not been established well

Need more effort

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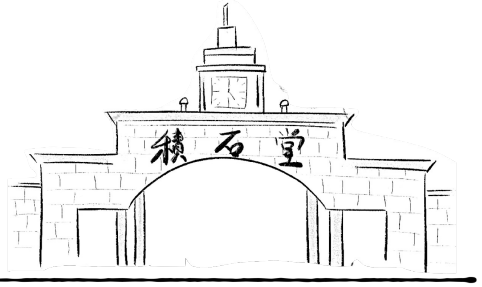
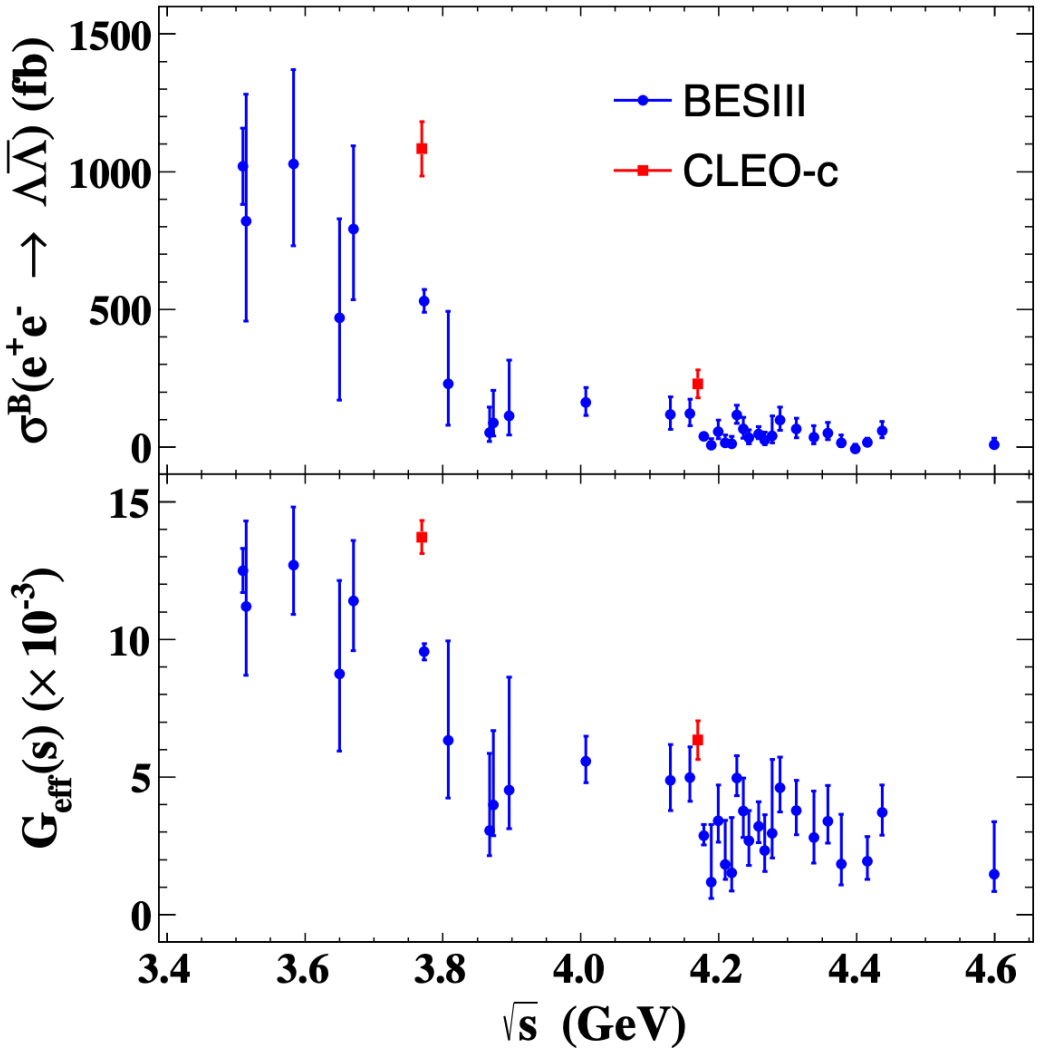
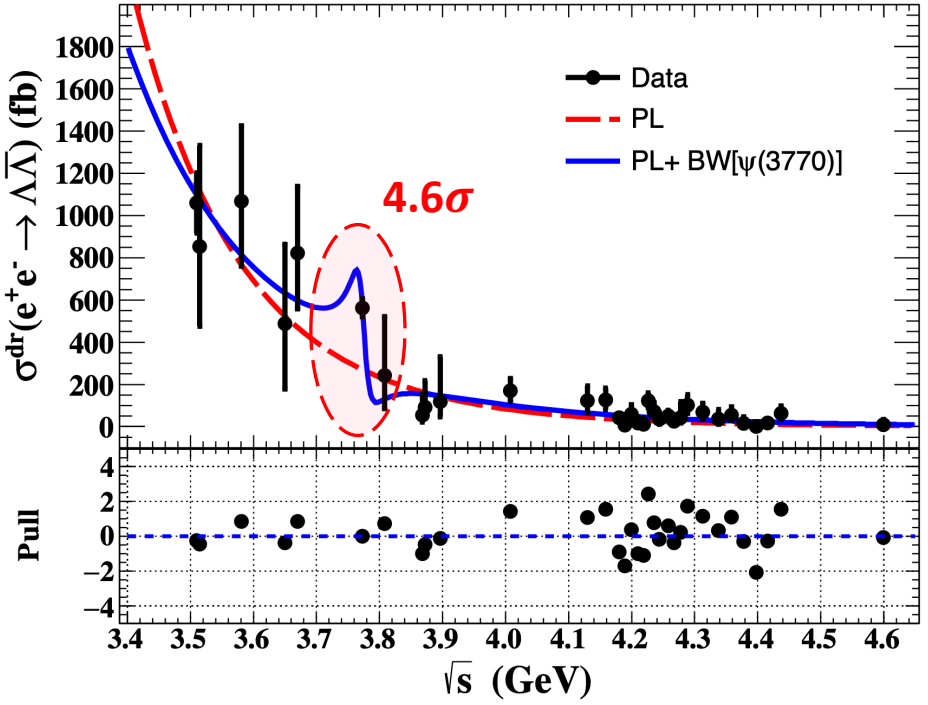


Study of $e^+e^- \to \Lambda\bar{\Lambda}$

PRD 104, L091104 (2021)



Data Sample: 20.0 fb^{-1} @ $\sqrt{s}$ = 3.5 – 4.6 GeV

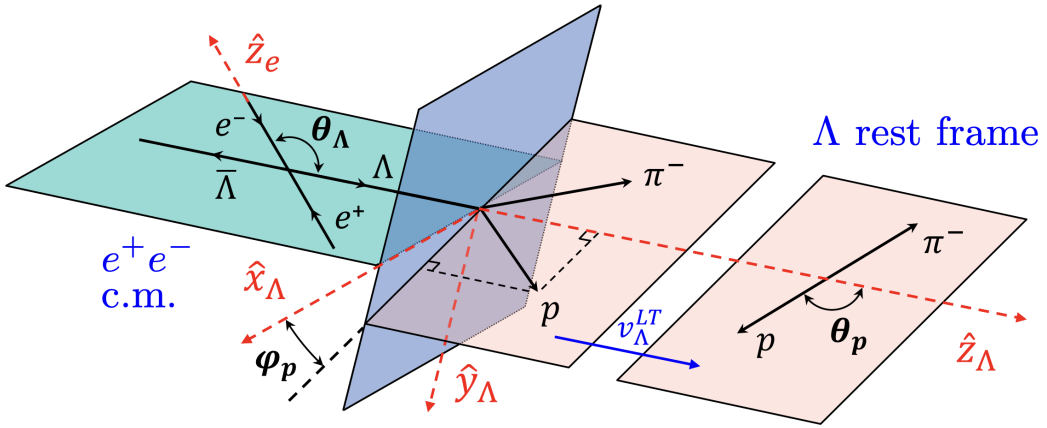


- First measurement of BCSs and EFFs above open charm threshold.
- Provide evidence of non-$D\bar{D}$ decays of $\psi(3770)$ and upper limits on $\Gamma_{ee}\mathcal{B}$ for other resonance assumptions.

$$\mathcal{B}[\psi(3770) \to \Lambda\bar{\Lambda}] = 2.4^{+15.0}_{-1.9}\times10^{-5} \ \& \ 14.4^{+2.7}_{-14.0}\times10^{-5}$$

Study of $e^+e^- \to \Lambda\bar{\Lambda}$

arXiv:2504.05584

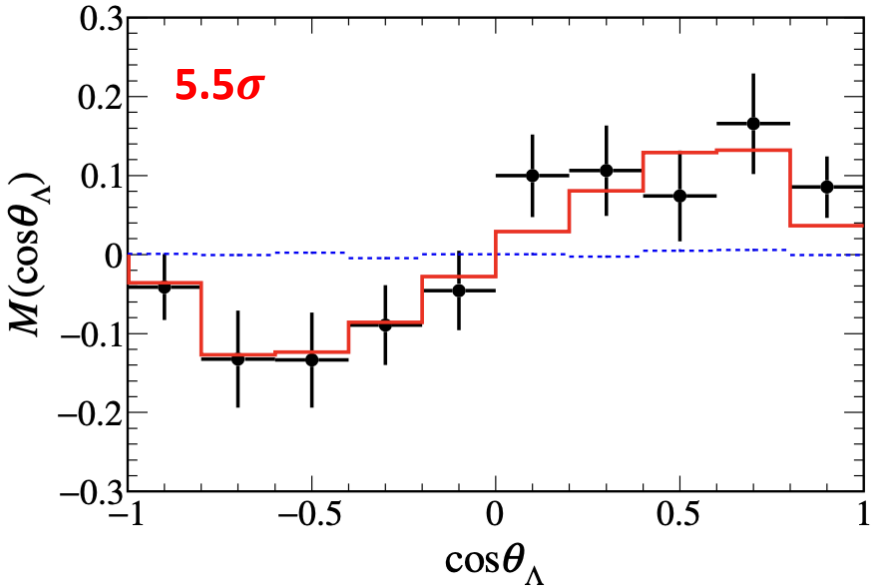


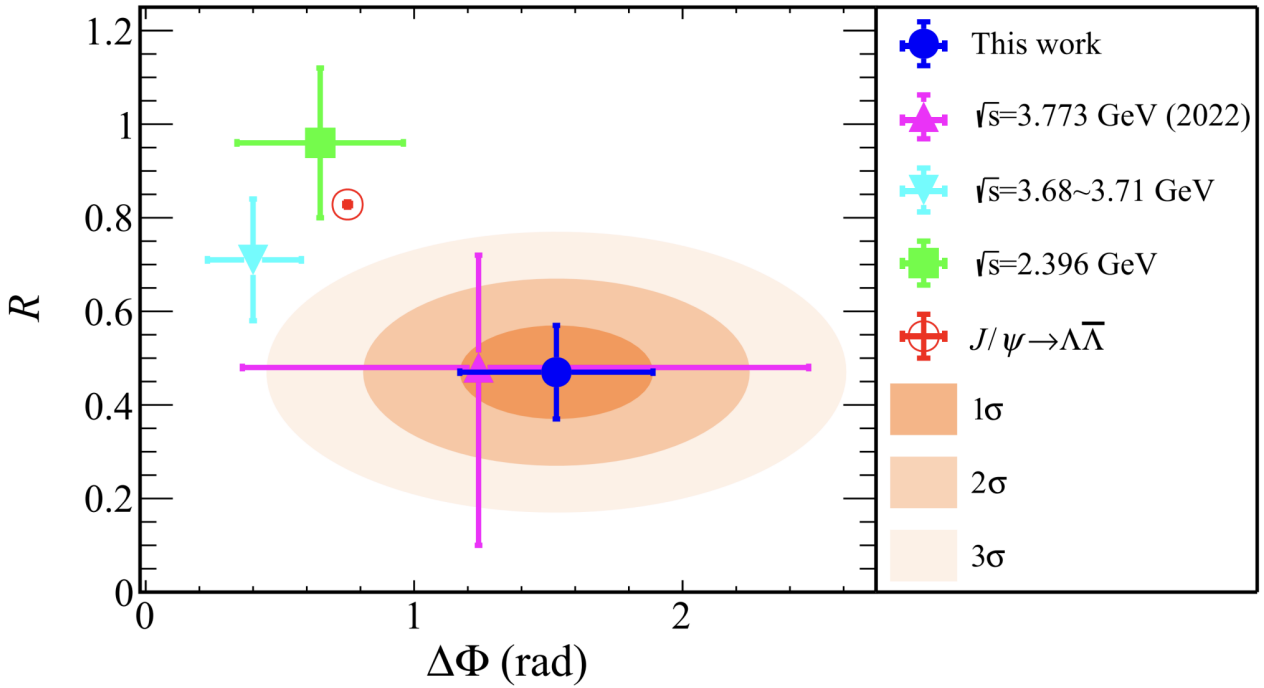
Λ rest frame

Data Sample: 20.3 fb^{-1} @ $\sqrt{s}$ = 3.773 GeV

- **A joint angular distribution is performed.**
- **The time-like EMFFs of Λ is determined completely.**

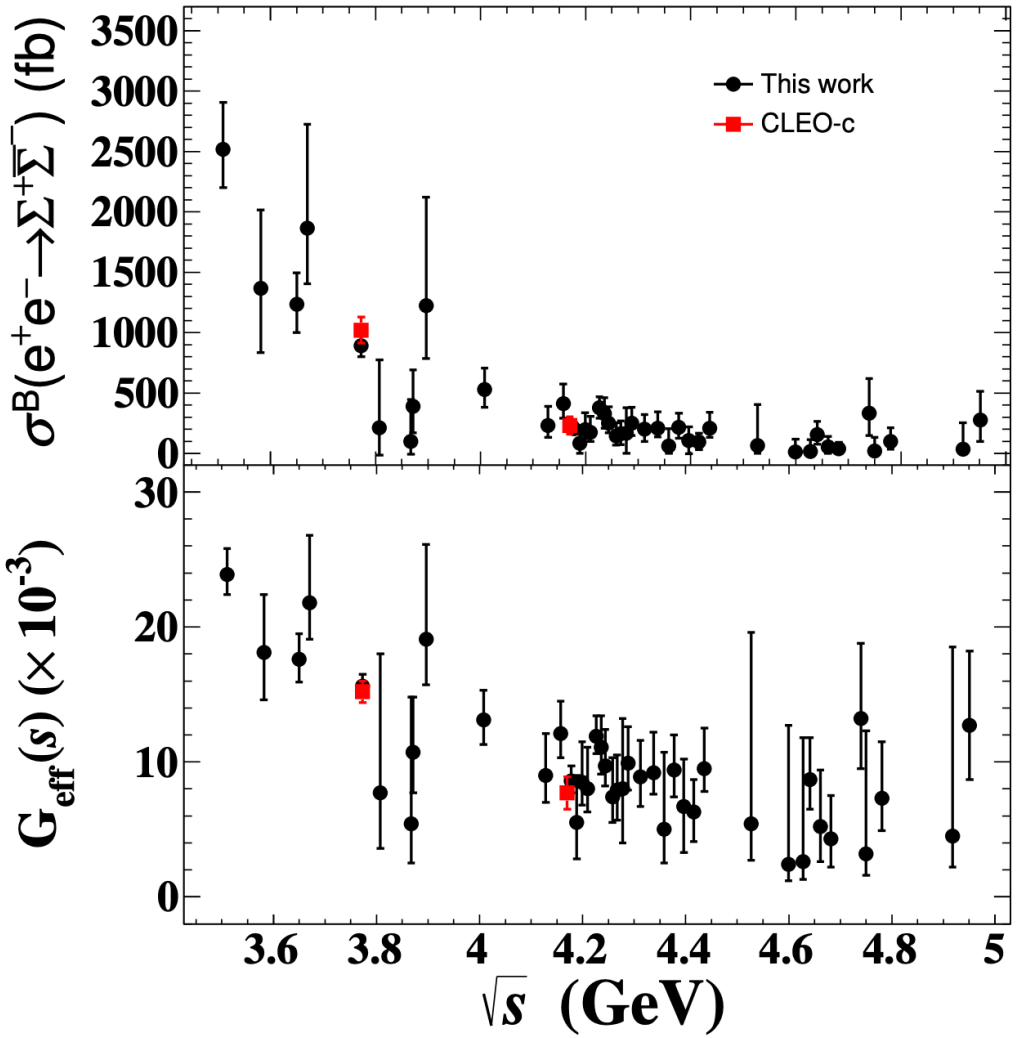
$$R = |G_E|/|G_M|$$



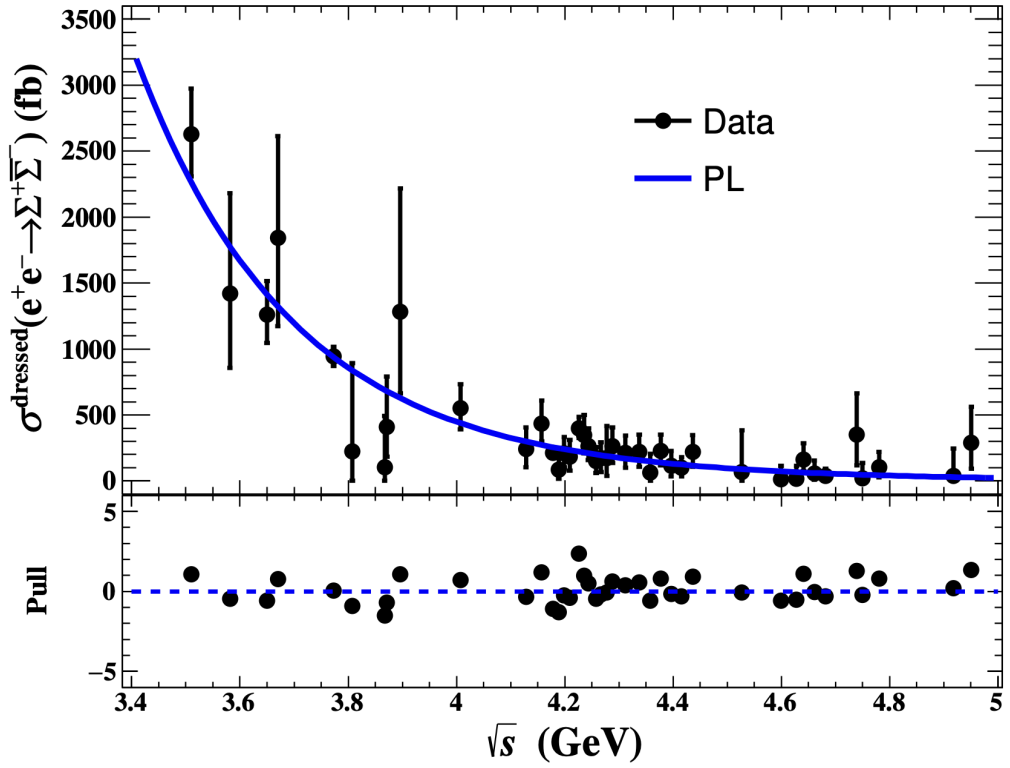


Study of $e^+e^- \to \Sigma^+\bar{\Sigma}^-$

JHEP 05 (2024) 022



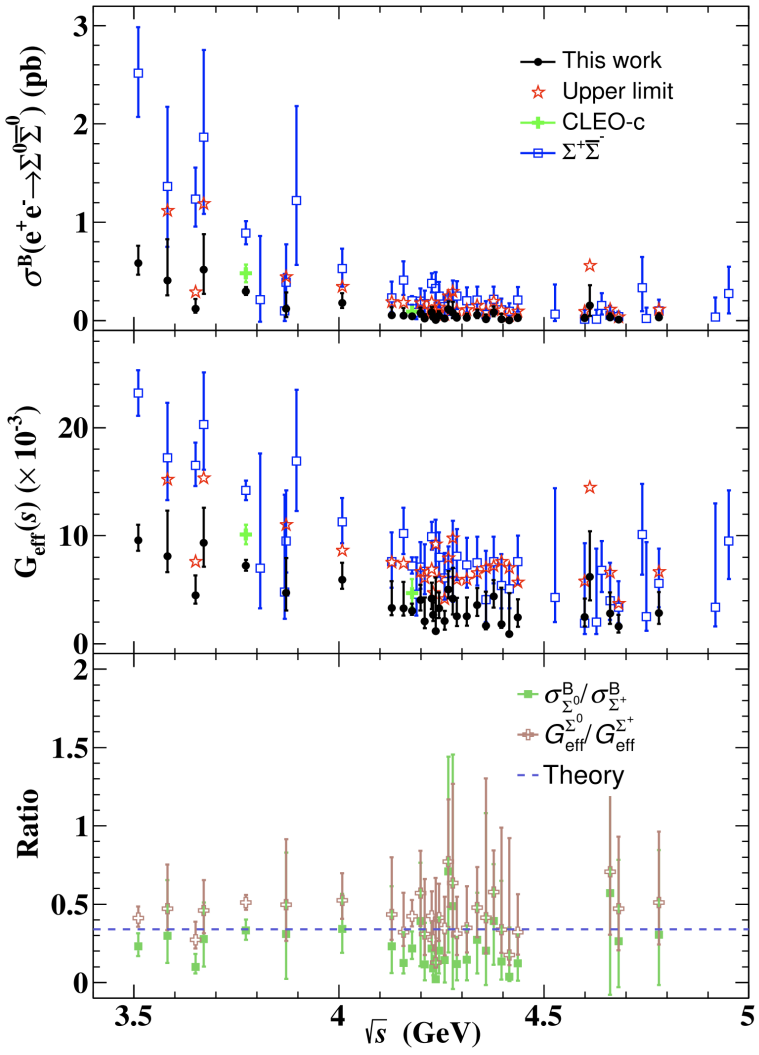
Data Sample: 24.1 fb^{-1} @ $\sqrt{s}$ = 3.5 – 4.9 GeV



- First measurement BCSs and EFFs above open charm threshold.
- No obvious signal is found, upper limits on $\Gamma_{ee}\mathcal{B}$ are provided for all resonance hypotheses.

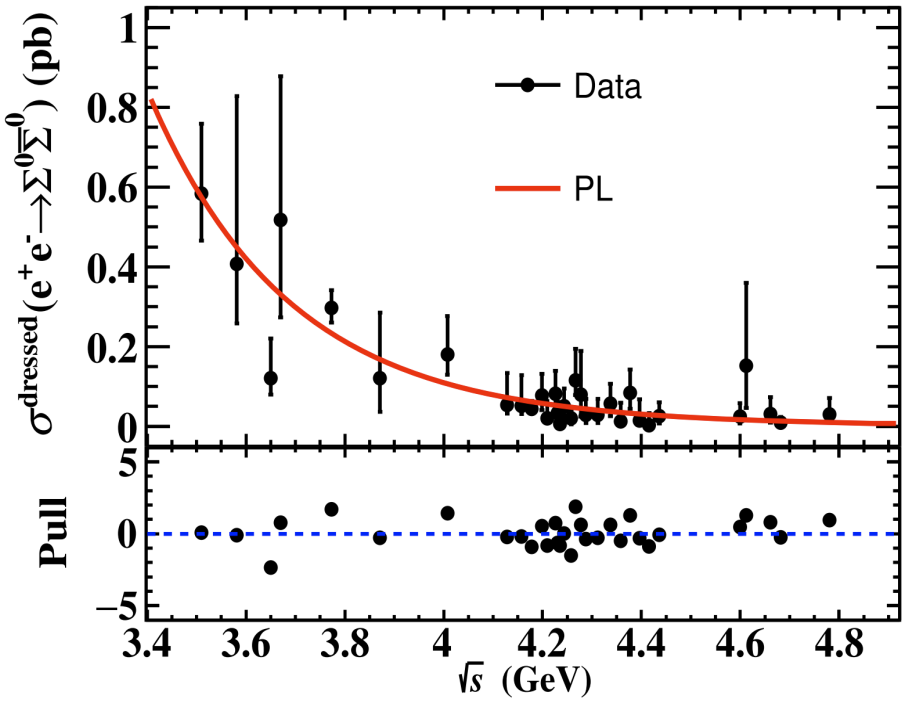
Study of $e^+e^- \to \Sigma^0\bar{\Sigma}^0$

PRD 111, L051502 (2025)



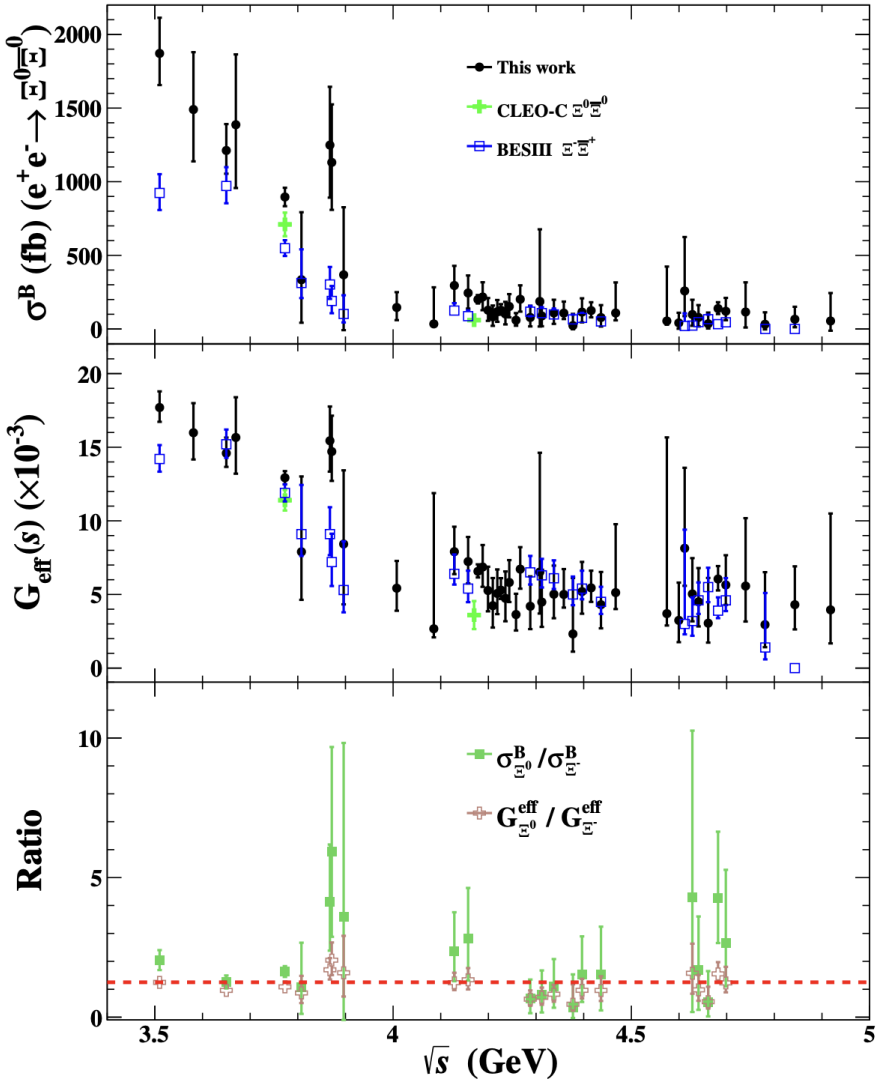
Data Sample: 25 fb^{-1} @ $\sqrt{s}$ = 3.5 – 4.9 GeV

- First measurement BCSs and EFFs above open charm threshold.
- No obvious signal is found, upper limits on $\Gamma_{ee}\mathcal{B}$ are provided for all resonance hypotheses.
- Measurements of Σ hyperons in different isospin states can validate the VMD model.

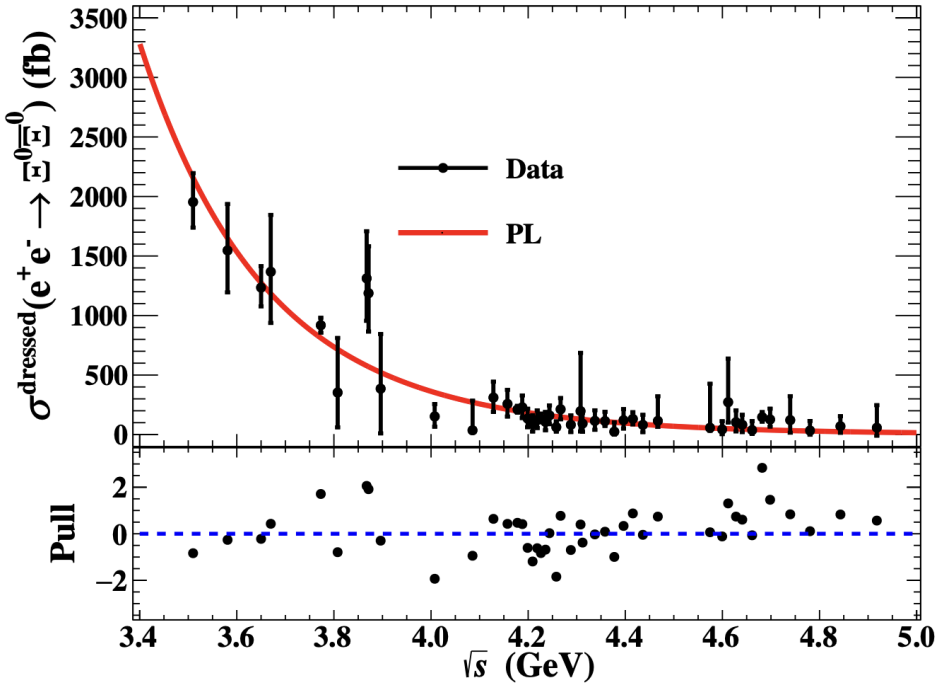


Study of $e^+e^- \to \Xi^0\bar{\Xi}^0$

JHEP 11 (2024) 062



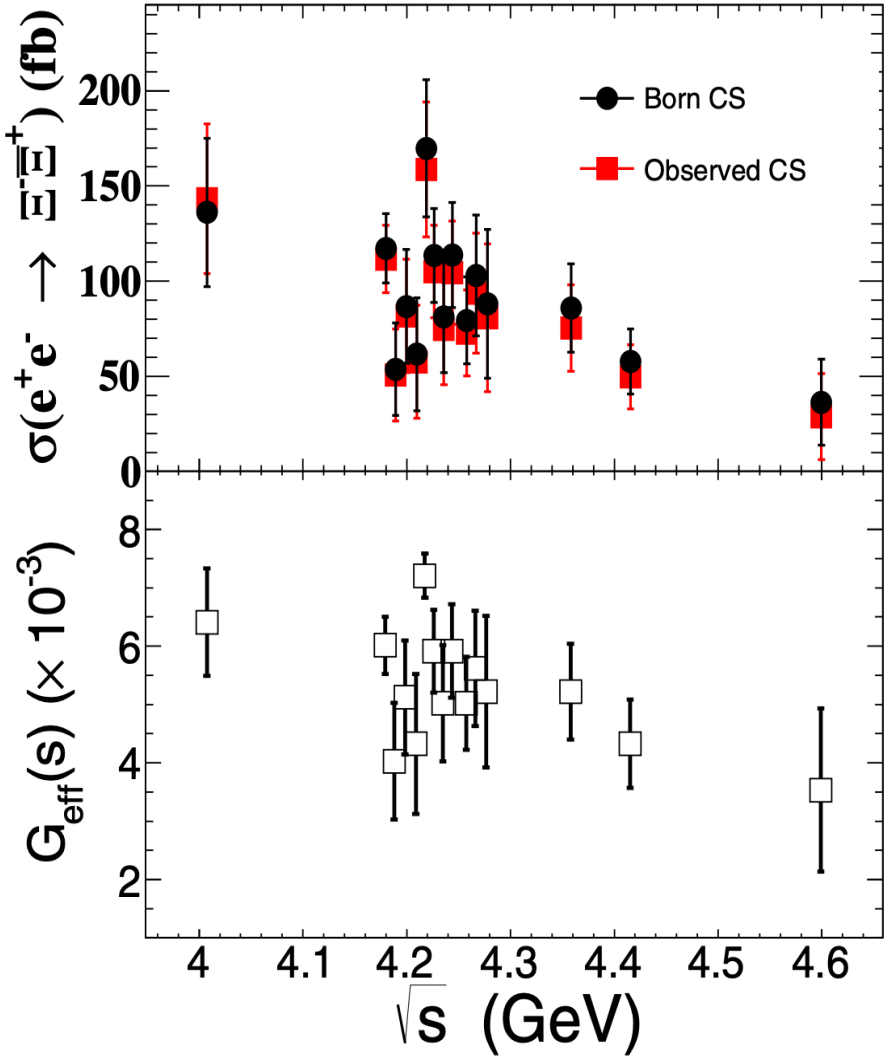
Data Sample: 30.0 fb^{-1} @ $\sqrt{s}$ = 3.5 – 4.9 GeV



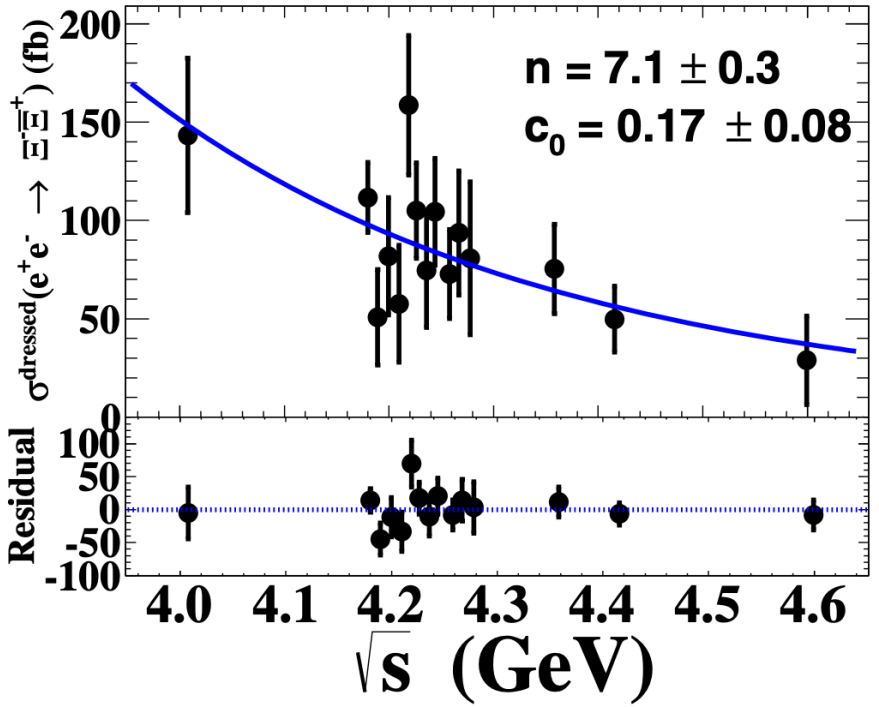
- First measurement BCSs and EFFs above open charm threshold.
- No obvious signal is found, upper limits on $\Gamma_{ee}\mathcal{B}$ are provided.
- Measurements in different isospin states can validate the VMD model.

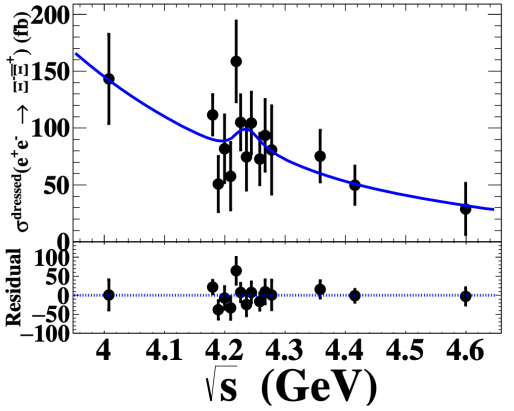
Study of $e^+e^- \to \Xi^-\bar{\Xi}^+$

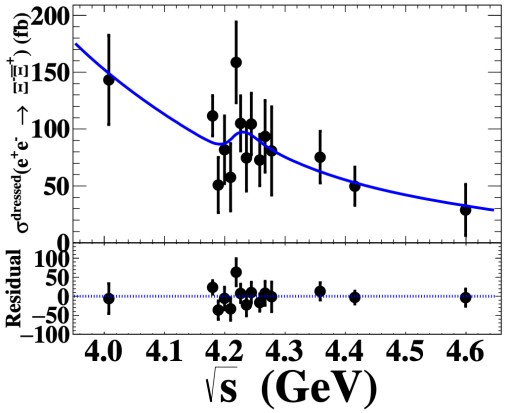
PRL 124, 032002, (2020)



Data Sample: 11.0 fb^{-1} @ $\sqrt{s}$ = 4.009 – 4.600 GeV





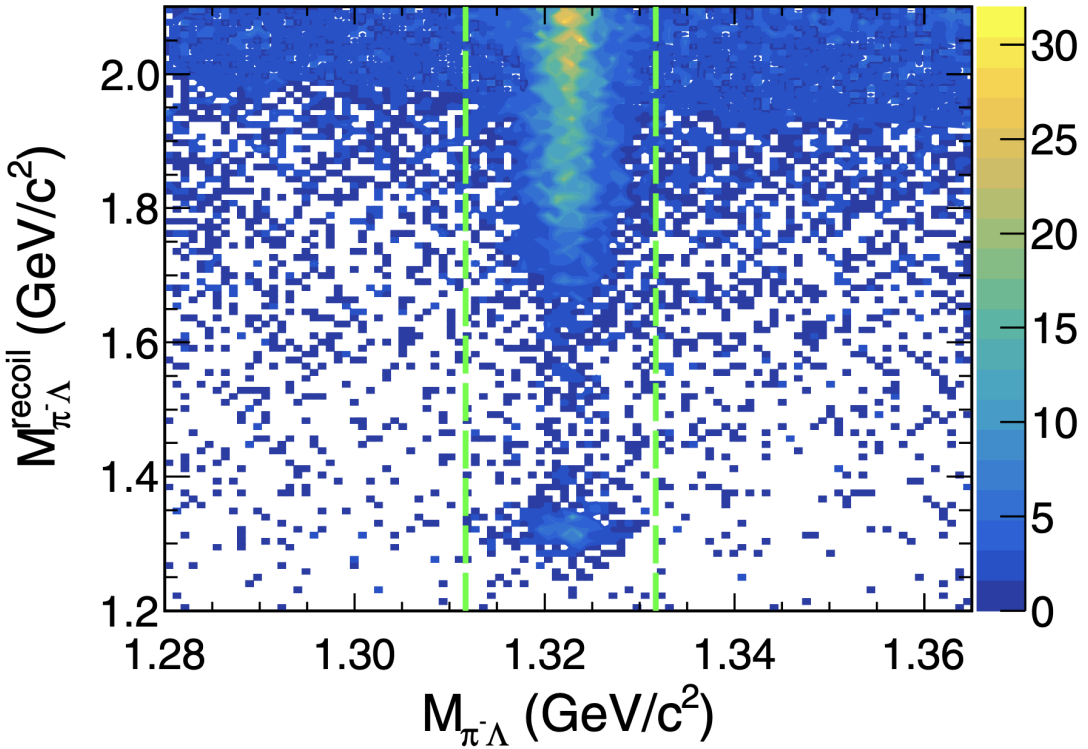


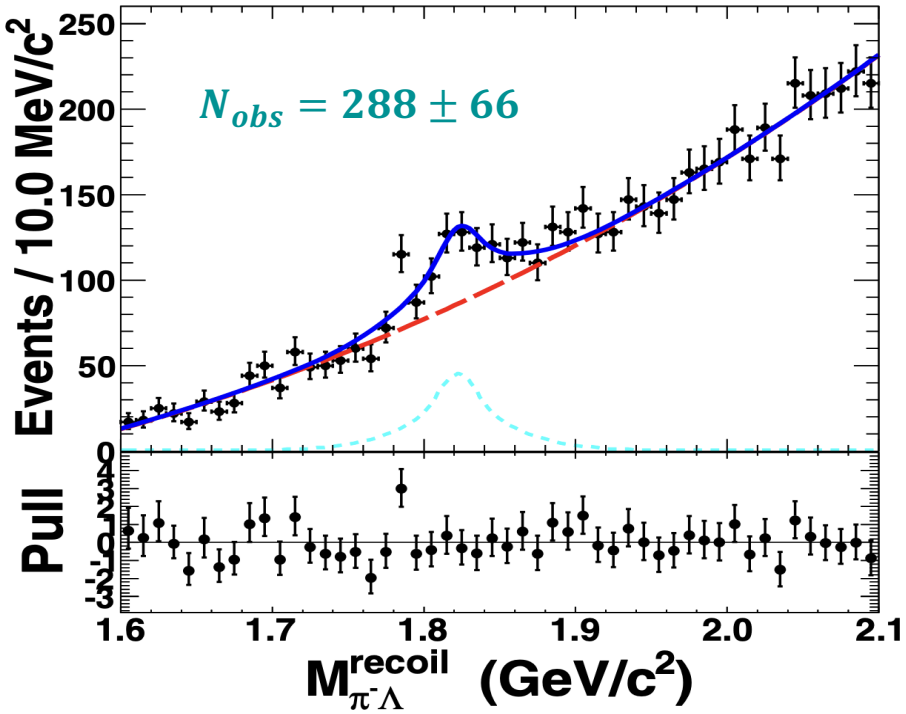
- First measurement BCSs and EFFs above open charm threshold.
- No obvious signal for $Y(4230/4260) \to \Xi^-\bar{\Xi}^+$ is found, upper limits on $\Gamma_{ee}\mathcal{B}$ are provided.

Study of $e^+e^- \to \Xi^-\bar{\Xi}^+$

PRL 124, 032002, (2020)

- Observed an excited Ξ state by combining all energy points.



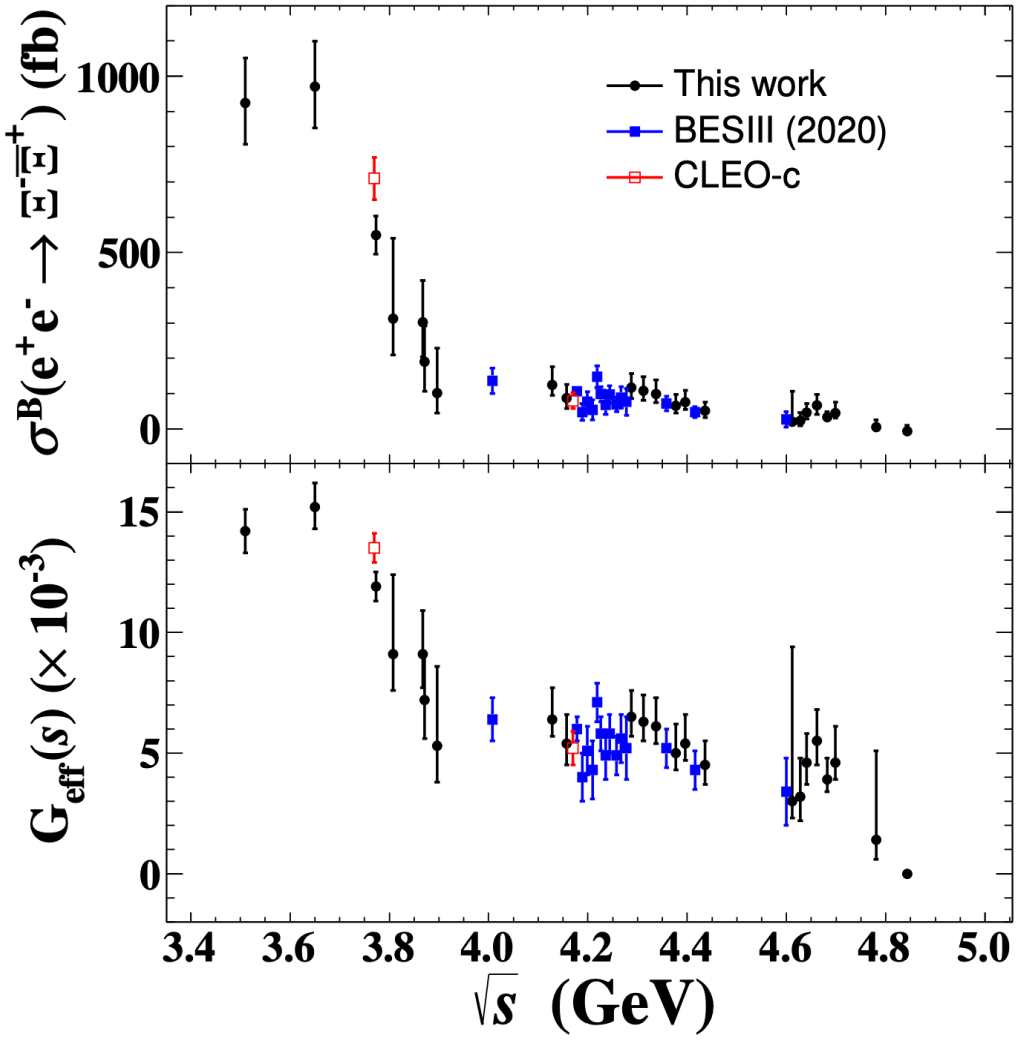


- Observed $e^+e^- \to \Xi^{\mp}X(1820)$ with 6.2σ significance.
- Consistent with the PDG values of $\Xi(1820)$.

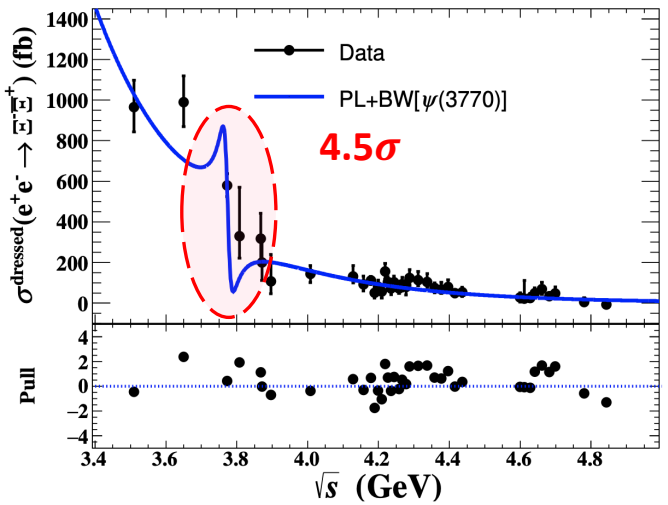
$$M = (1825.5 \pm 4.7 \pm 4.7)\ \mathrm{MeV}/c^2$$
$$\Gamma = (17.0 \pm 15.0 \pm 7.9)\ \mathrm{MeV}$$

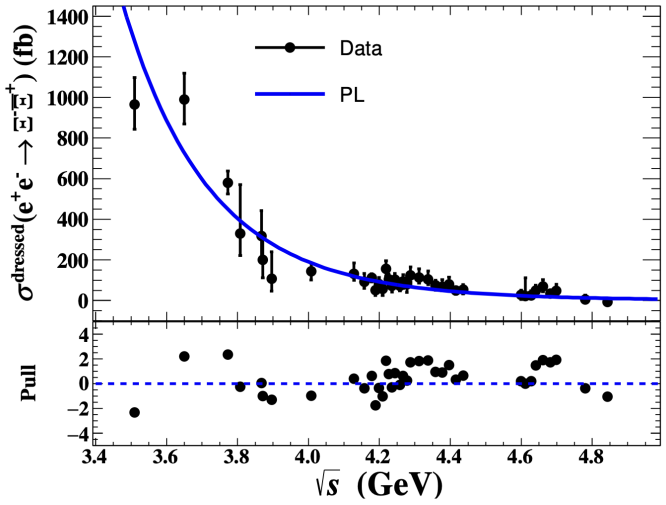
Study of $e^+e^- \to \Xi^-\overline{\Xi}^+$

JHEP 11 (2023) 228



Data Sample: 13.0 fb^{-1} @ $\sqrt{s}$ = 3.5 – 4.9 GeV





- **An updated measurement.**
- **Provide evidence of non-$D\bar{D}$ decays of $\psi(3770)$ and upper limits on $\Gamma_{ee}\mathcal{B}$ for other resonance assumptions.**

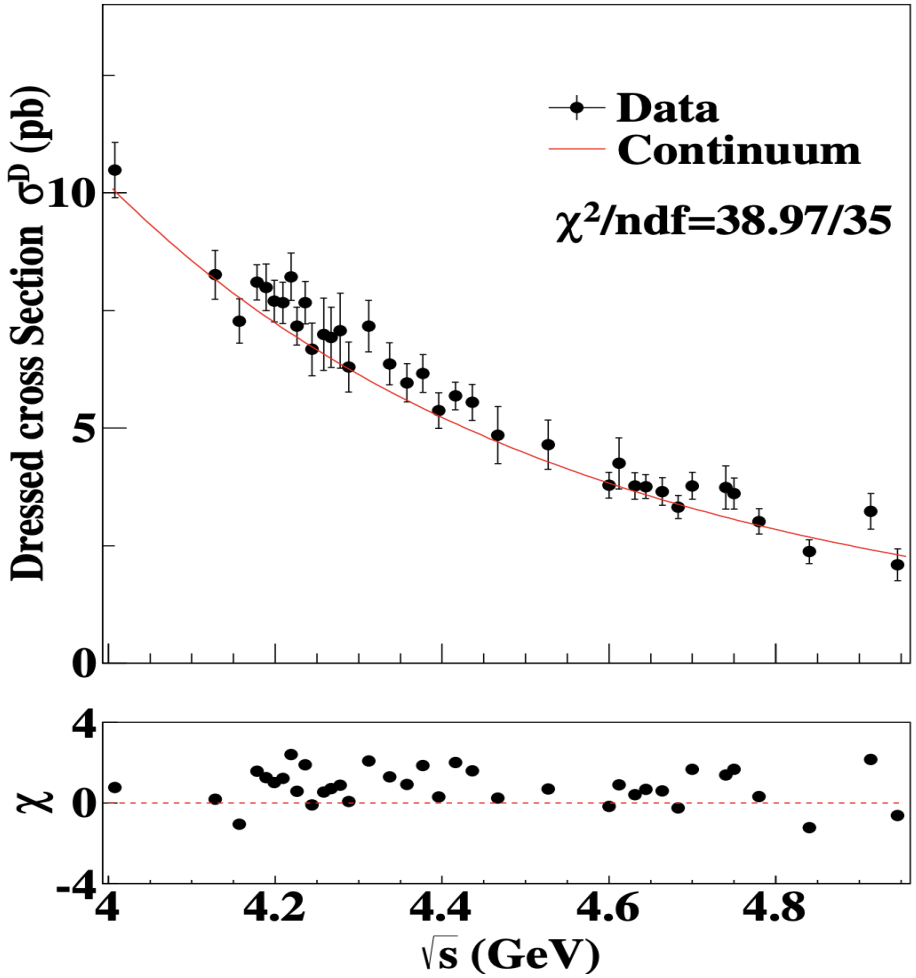
$$\mathcal{B}[\psi(3770) \to \Xi^-\overline{\Xi}^+] = (1.36 \pm 0.35) \times 10^{-4}$$

Study of $e^+e^- \to pK^-\bar{\Lambda} + c.c$

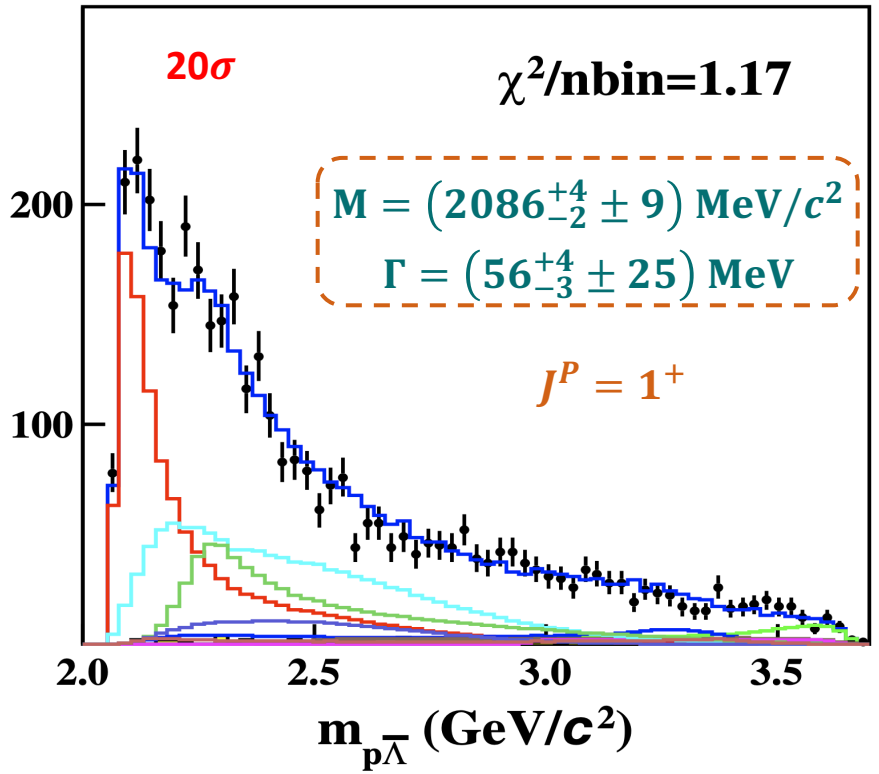
JHEP 12 (2023) 027

PRL 131, 151901 (2023)

Data Sample: 21.7 fb^{-1} @ $\sqrt{s}$ = 4.009 – 4.951 GeV



Data Sample: 8.4 fb^{-1} @ $\sqrt{s}$ = 4.009 – 4.682 GeV



- No obvious signal of charmonium (-like) states is found.
- A near threshold enhancement is observed on $p\bar{\Lambda}$ system.

Study of $e^+e^- \to K^-\bar{\Xi}^+\Lambda/\Sigma^0 + c.c$

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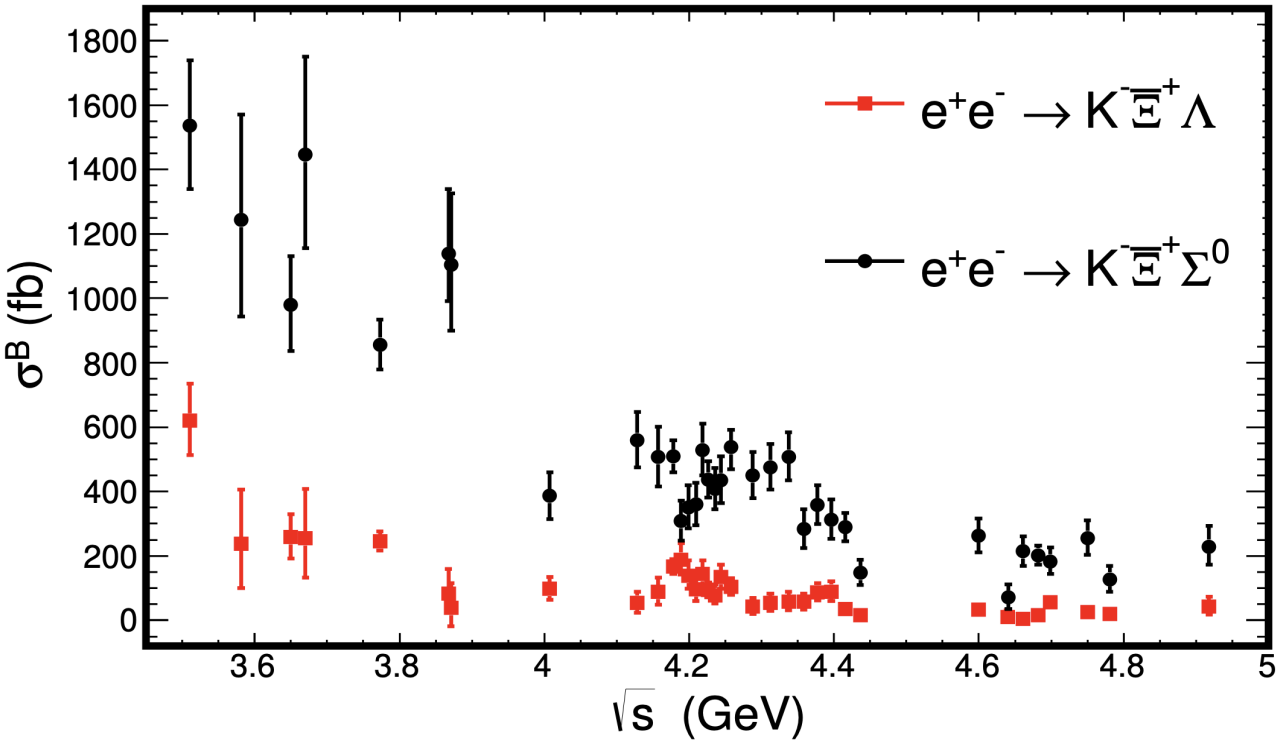
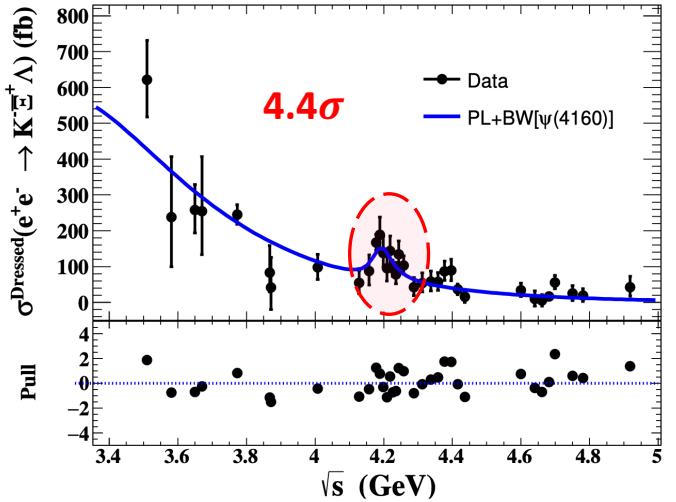
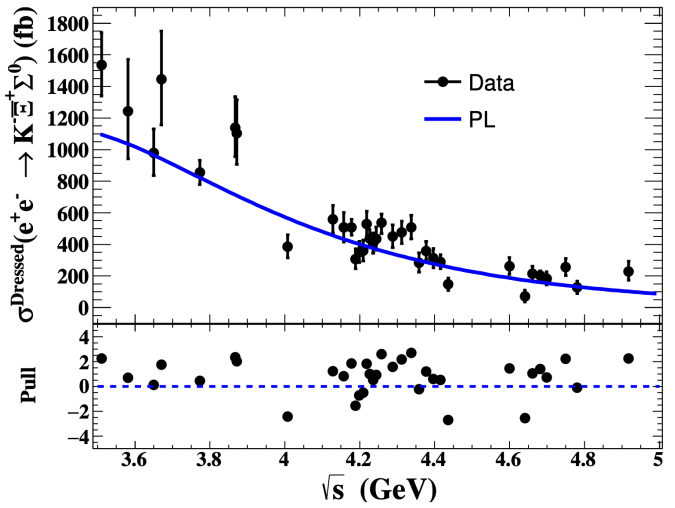
Data Sample: 25 fb^{-1} @ $\sqrt{s}$ = 3.510 – 4.914 GeV







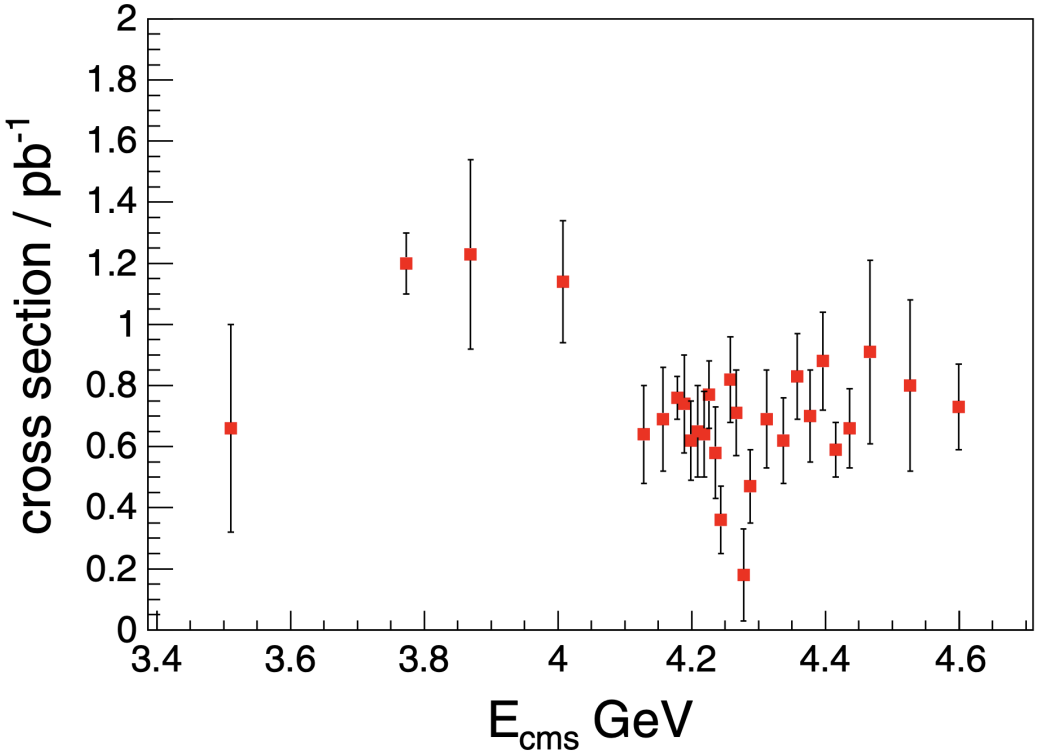
- An evidence is found for the decay of $\psi(4160) \to K^-\bar{\Xi}^+\Lambda$.

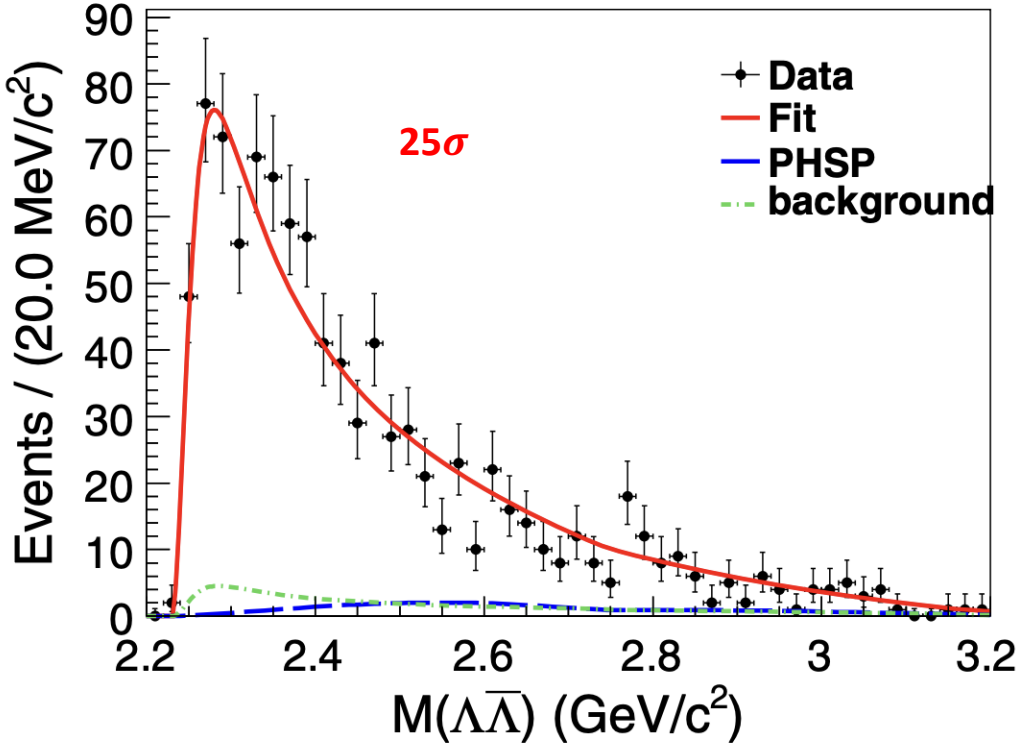
$$\mathcal{B}[\psi(4160) \to K^-\bar{\Xi}^+\Lambda] = (4.4 \pm 2.0)\times 10^{-6}$$

Study of $e^+e^- \to \phi\Lambda\bar{\Lambda}$

PRD 104, 052006 (2021)

Data Sample: 19.5 fb^{-1} @ $\sqrt{s}$ = 3.51 – 4.60 GeV





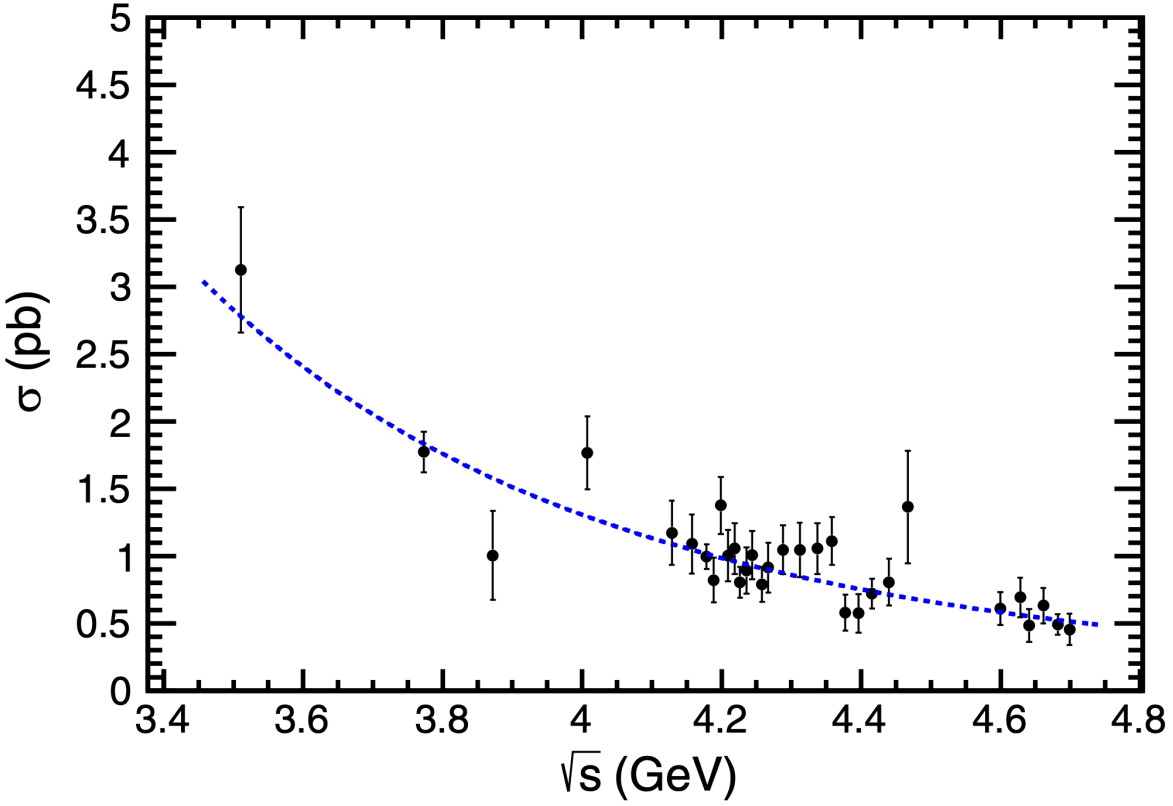
- A near threshold enhancement is observed on $\Lambda\bar{\Lambda}$ system.
- The J^{PC} quantum numbers could be 2^{++}, 2^{-+}, or 1^{++}.

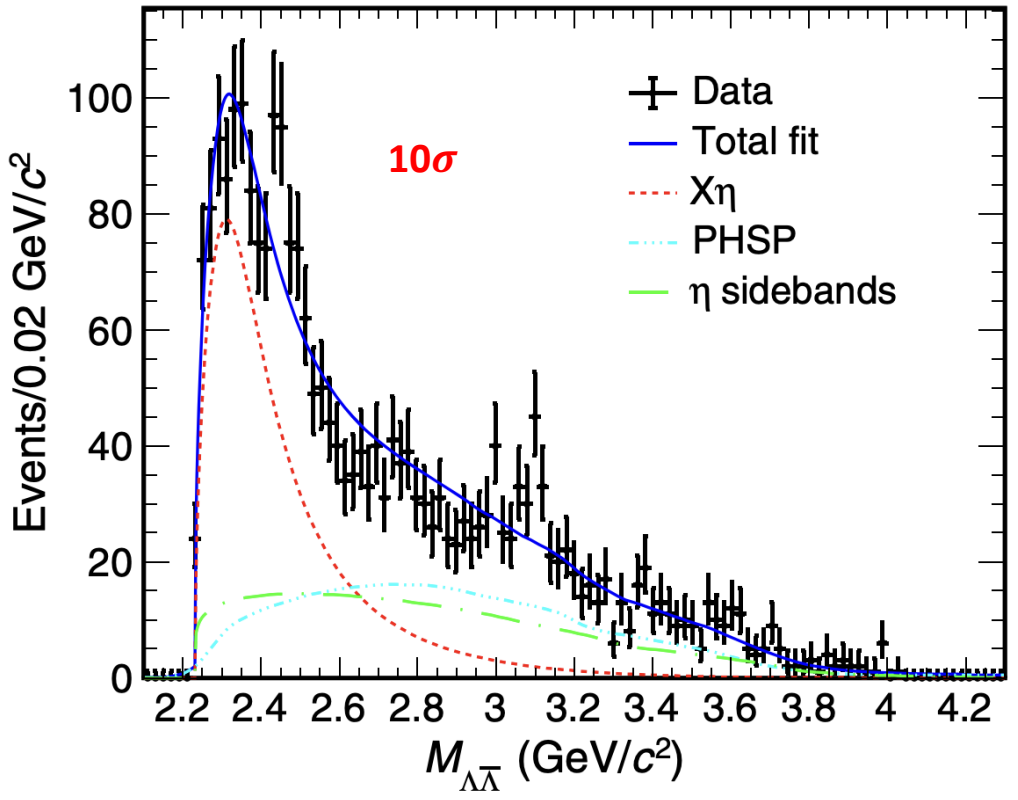
$M = (2262 \pm 4 \pm 28)$ MeV/c^2
$\Gamma = (72 \pm 5 \pm 43)$ MeV

Study of $e^+e^- \to \eta\Lambda\bar{\Lambda}$

PRD 107, 112001 (2023)

Data Sample: 18 fb^{-1} @ $\sqrt{s}$ = 3.51 – 4.70 GeV

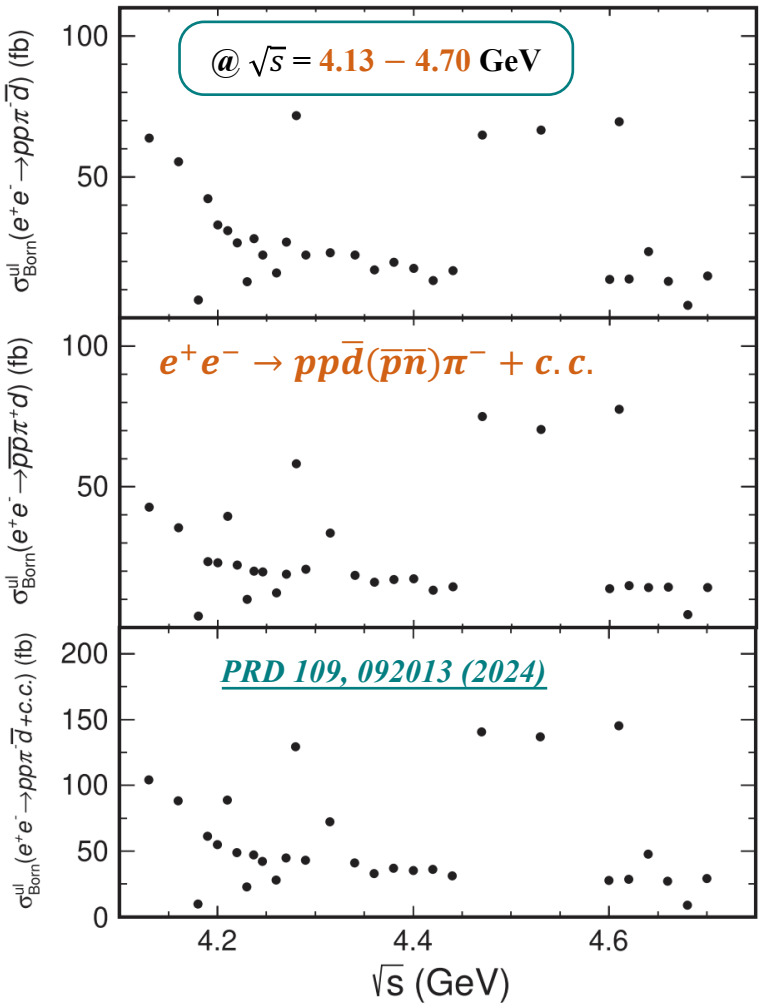




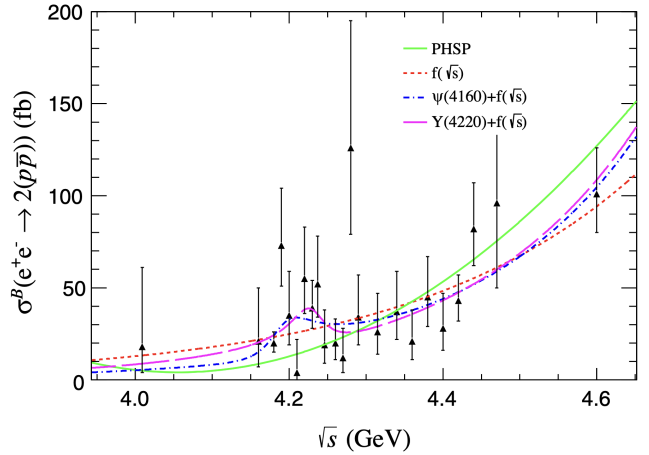
- **No significant structure** is observed in the line shape of Born cross section.
- A **near threshold enhancement** is observed on $\Lambda\bar{\Lambda}$ system.

$M = (2356 \pm 7 \pm 15)\ \mathrm{MeV}/c^2$
$\Gamma = (304 \pm 28 \pm 54)\ \mathrm{MeV}$

Other multi-body processes



- No significant (anti-)deuteron signal is observed.

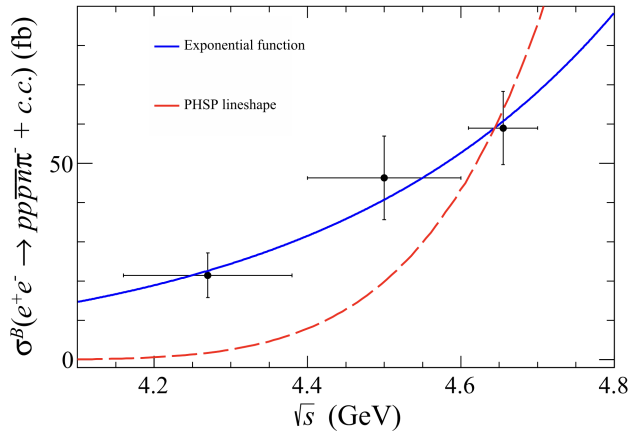


@ $\sqrt{s}$ = 4.0 – 4.6 GeV

$e^+e^- \to pp\bar{p}\bar{p}$

PRD 103, 052003 (2021)

- No significance for $Y(4220)/\psi(4160)$ assumption.
- Hexaquark/di-baryon state is searched.



@ $\sqrt{s}$ = 4.16 – 4.70 GeV

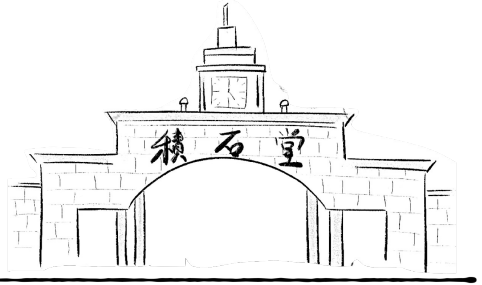
$e^+e^- \to pp\bar{p}\bar{n}\pi^- + c.c.$

CPC 47, 043001 (2023)

- $e^+e^- \to pp\bar{p}\bar{n}\pi^- + c.c.$ is observed for the first time (11σ).
- No significant deuteron, hexaquark, di-baryon, etc. are observed.

Outline

- Introduction
- BEPCII and BESIII Detector
- Highlights
- **Conclusion & Outlook**



Conclusion & Outlook

- **BESIII is successfully operating since 2008.**
  - ✓ **Collected large data samples in the τ-charm physics region**
  - ✓ **Continues to take data in coming years**
- **Many studies for $H\bar{H}$ production in Charmonium decay and in e^+e^- annihilation achieved:**
  - ✓ **More new/precise study for hyperon pair production**
  - ✓ **Evidence for the light hadronic decays of $\psi(3770)$ and $\psi(4160)$ has been found**
  - ✓ **Still need more experimental/theoretical efforts**
- **More new results are on the way!**

Thanks for your attention!