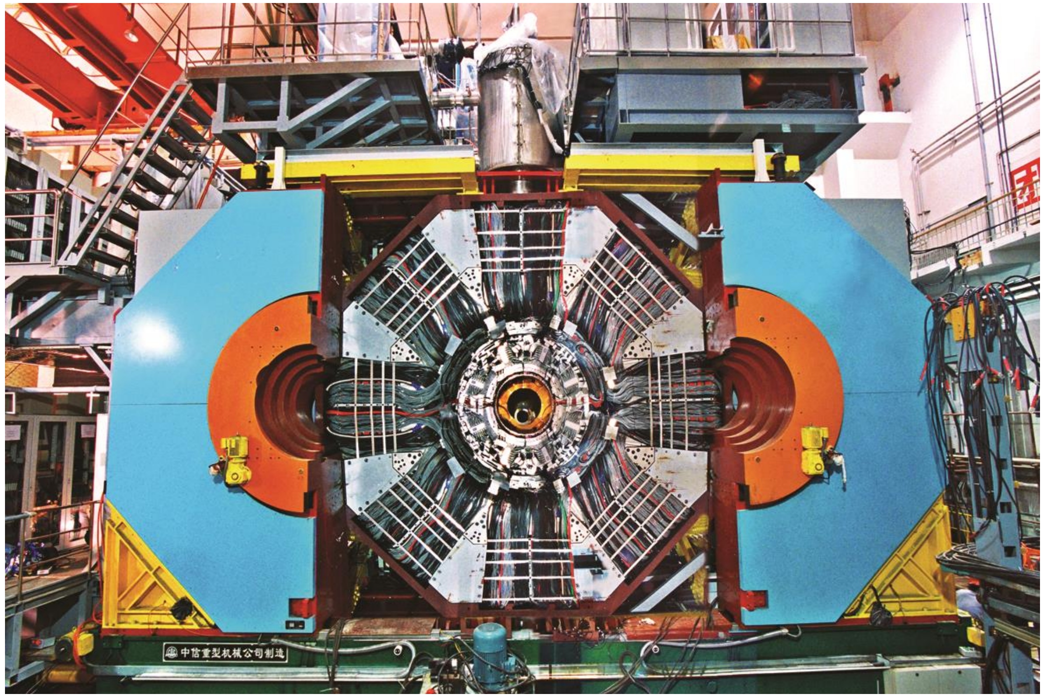
BESIII实验现状和展望



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University of Science and Technology of China

第三届BESIII-BelleII-LHCb粲强子物理联合研讨会

2025年6月30日，湖南长沙

Outline

- **Introduction**
- **Highlight on the recent results**
  - **No ~~charm~~ – see talks by Liaoyuan, Yu, Bo, Bai-Cian, Peirong, Liang, …**
  - **Hadron production and structure**
  - **Light hadron spectroscopy**
  - **CPV in hyperon decays**
  - **Charmonium(-like) states**
- **Prospects for the future**
- **Summary**

Disclaimer: selected topics only, not possible to cover all.

Beijing Electron-Positron Collider II (BEPCII)

Center of mass energy: 1.84~4.95 GeV

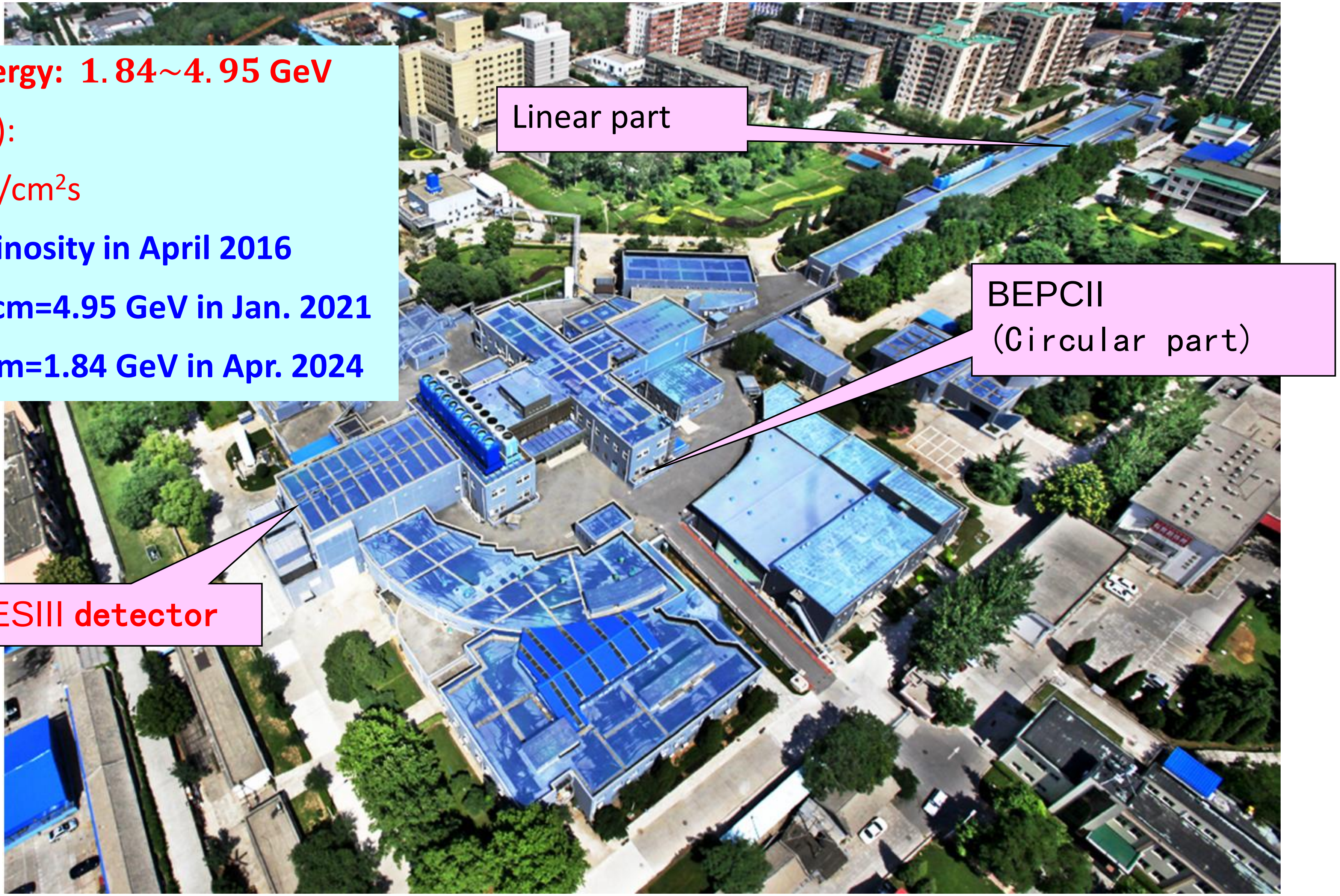
2008- **Now** (BEPCII):

$L_{peak}=1.0\times10^{33}/cm^2s$

Reached peak luminosity in April 2016

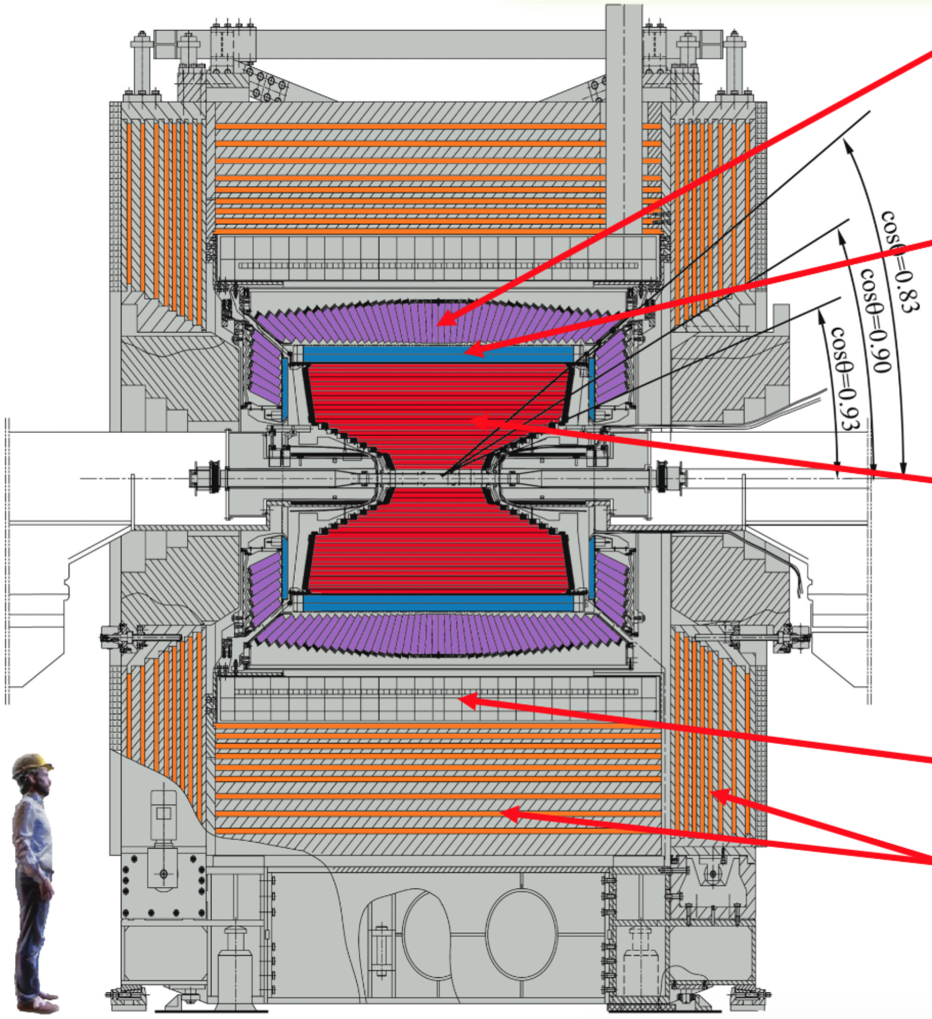
Reached highest Ecm=4.95 GeV in Jan. 2021

Reached lowest Ecm=1.84 GeV in Apr. 2024



BESIII detector

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



EMC: CsI crystals
$\Delta E/E$ = 2.5% @ 1 GeV - Barrel
$\Delta E/E$ = 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

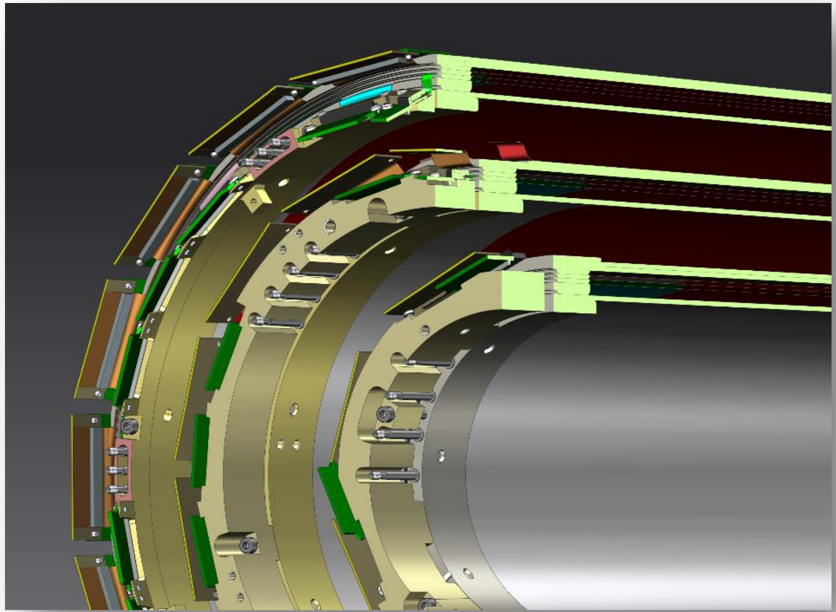
Muon ID: 9 layer RPC

Trigger: Tracks & Showers

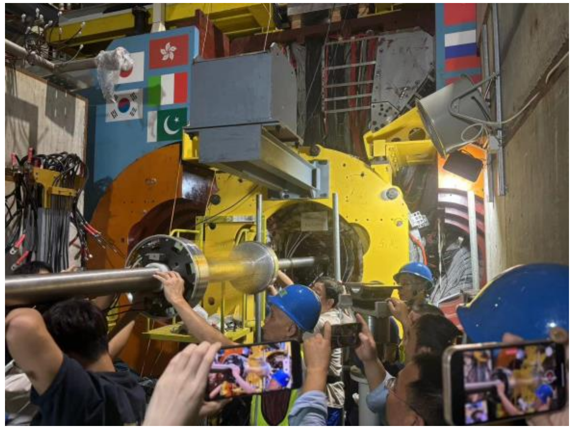
Total weight 730 ton, ~40,000 readout channels, Data rate: 5kHz, 50Mb/s

Has been in full operation since 2008, all subdetectors are in very good status!

Cylindrical Gas Electron Multiplier Inner Tracker (CGEM-IT)



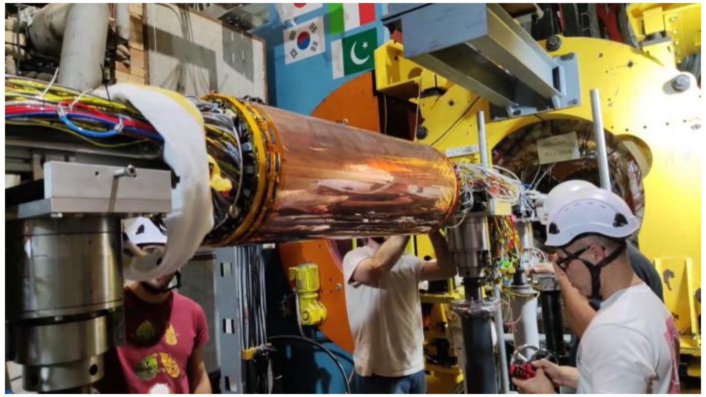
- Three layers of cylindrical triple GEM to replace the inner MDC
- Improve spatial resolution along the beam axis (< 300 μm), rate capability, and radiation hardness

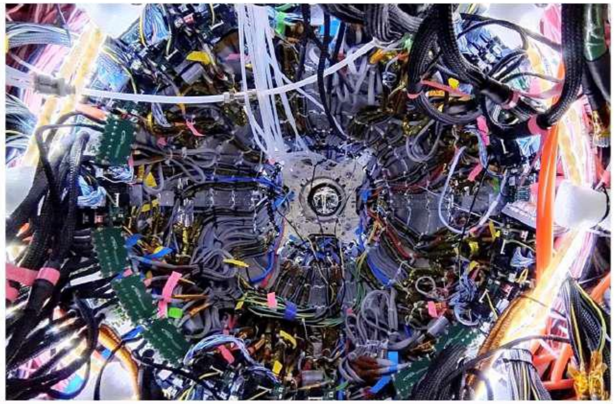
Extraction of inner draft chamber on Sep. 14th

Status and timeline

- Software review on Dec. 1st, 2023
- Performance review on Feb. 20th 2024
- Overall assessments of Installation (March, 2024)
- Installation in October 2024 during the BEPCII-upgrade

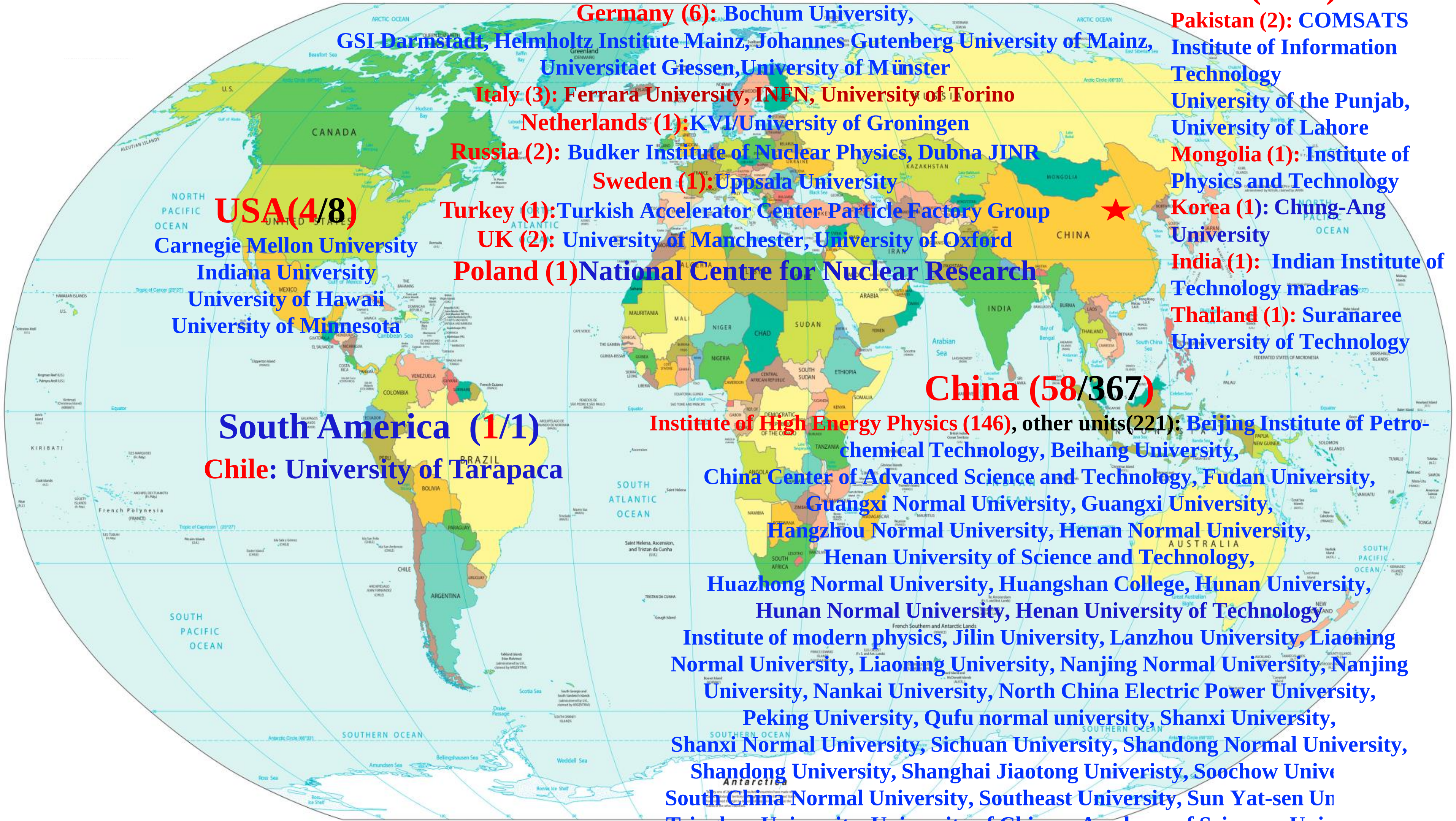


Ready for installation on Oct. 2nd



Completed on Oct 18th!

BESIII Collaboration



Europe (17/115)

Germany (6): Bochum University, GSI Darmstadt, Helmholtz Institute Mainz, Johannes Gutenberg University of Mainz, Universitaet Giessen, University of Münster

Italy (3): Ferrara University, INFN, University of Torino

Netherlands (1): KVI/University of Groningen

Russia (2): Budker Institute of Nuclear Physics, Dubna JINR

Sweden (1): Uppsala University

Turkey (1): Turkish Accelerator Center Particle Factory Group

UK (2): University of Manchester, University of Oxford

Poland (1) National Centre for Nuclear Research

Asia (6/10)

Pakistan (2): COMSATS Institute of Information Technology, University of the Punjab, University of Lahore

Mongolia (1): Institute of Physics and Technology

Korea (1): Chung-Ang University

India (1): Indian Institute of Technology madras

Thailand (1): Suranaree University of Technology

USA(4/8)

Carnegie Mellon University
Indiana University
University of Hawaii
University of Minnesota

South America (1/1)

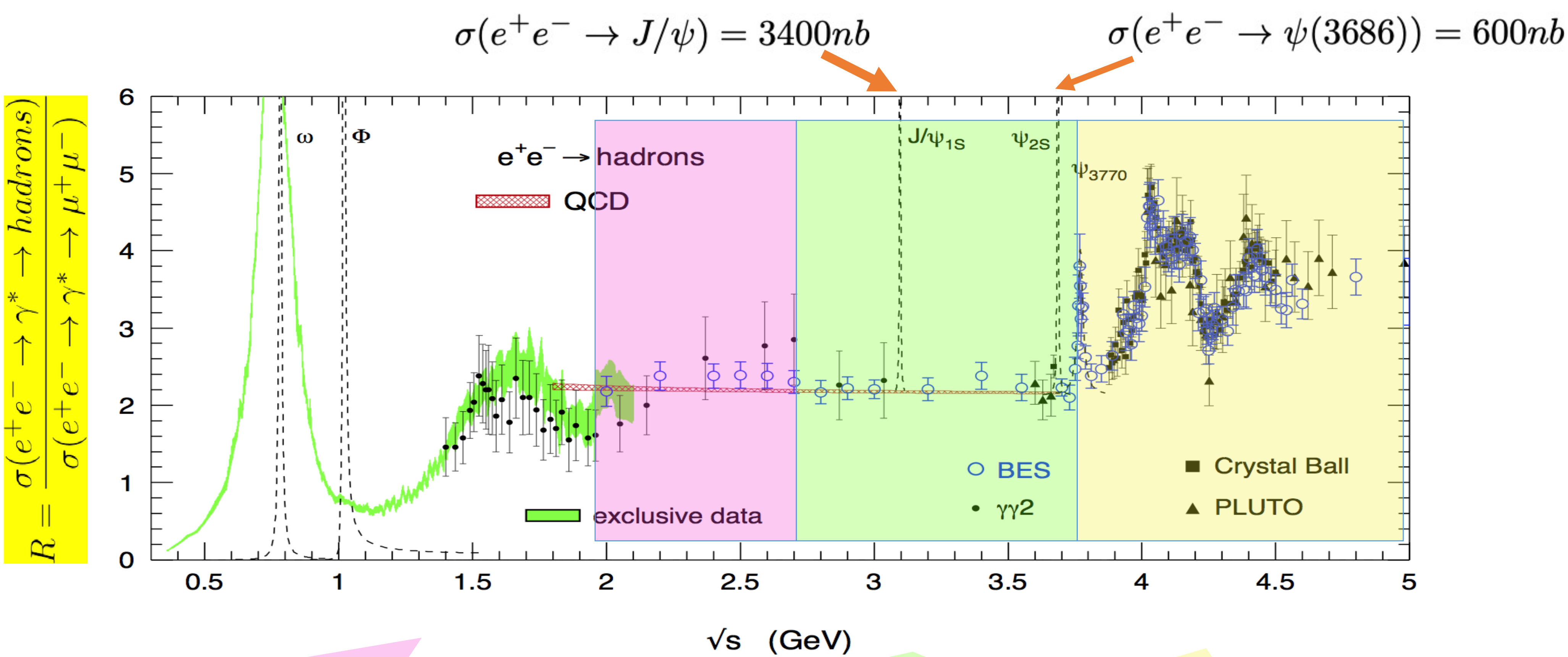
Chile: University of Tarapaca

China (58/367)

Institute of High Energy Physics (146), other units(221): Beijing Institute of Petro-chemical Technology, Beihang University, China Center of Advanced Science and Technology, Fudan University, Guangxi Normal University, Guangxi University, Hangzhou Normal University, Henan Normal University, Henan University of Science and Technology, Huazhong Normal University, Huangshan College, Hunan University, Hunan Normal University, Henan University of Technology, Institute of modern physics, Jilin University, Lanzhou University, Liaoning Normal University, Liaoning University, Nanjing Normal University, Nanjing University, Nankai University, North China Electric Power University, Peking University, Qufu normal university, Shanxi University, Shanxi Normal University, Sichuan University, Shandong Normal University, Shandong University, Shanghai Jiaotong Univeristy, Soochow Unive South China Normal University, Southeast University, Sun Yat-sen Un Tsinghua University, University of Chinese Academy of Sciences, Univ Jinan, University of Science and Technology of China, University of Science and Technology Liaoning, University of South China, Wuhan University, Xinyang Normal University, Zhejiang University, Zhengzhou University, YunNan University , China University of Geosciences

~700 members
From 86 institutions in 16 countries

Rich Physics at τ-charm Energy Region



- Hadron form factors
- R values and QCD

- Light hadron spectroscopy
- Gluonic and exotic states
- Physics with τ lepton

- XYZ particles
- Charm mesons
- Charm baryons

BESIII data samples: rich physics

Data sets collected so far include

- 10×10^9 J/ψ events
- 2.7×10^9 $\psi(2S)$ events
- 20 fb^{-1} ψ(3770)
- Scan data between

  1.84-1.97 GeV (13 points, 25 pb^{-1})

  2.0 - 3.08 GeV,

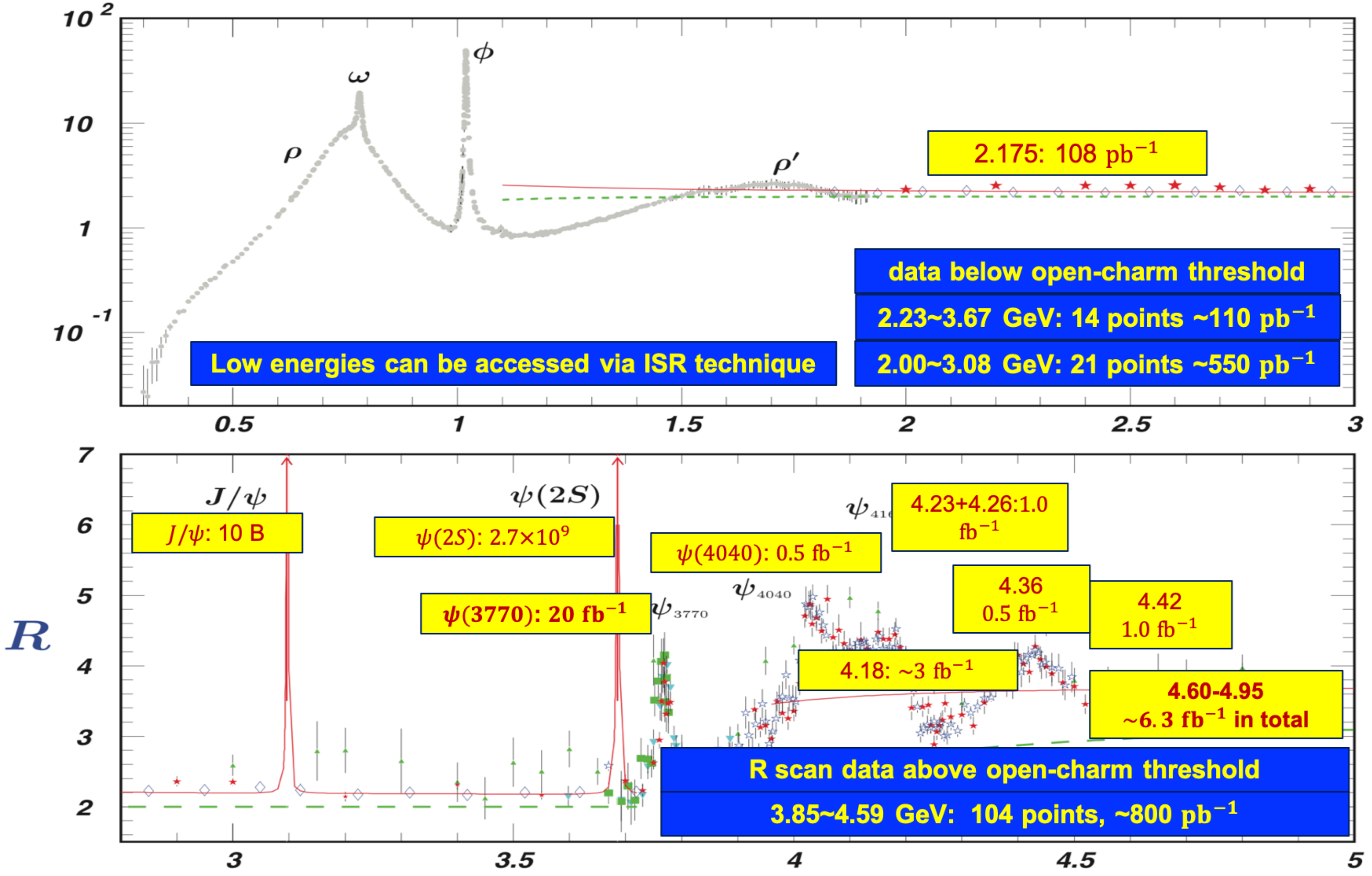
  and above 3.74 GeV
- Large datasets for XYZ studies:

  scan with >500 pb^{-1} per energy point

  space 10 – 20 MeV apart

- **Entangled hadron pair-productions near thresholds: form-factors, relative phase, polarization and CP violation.**

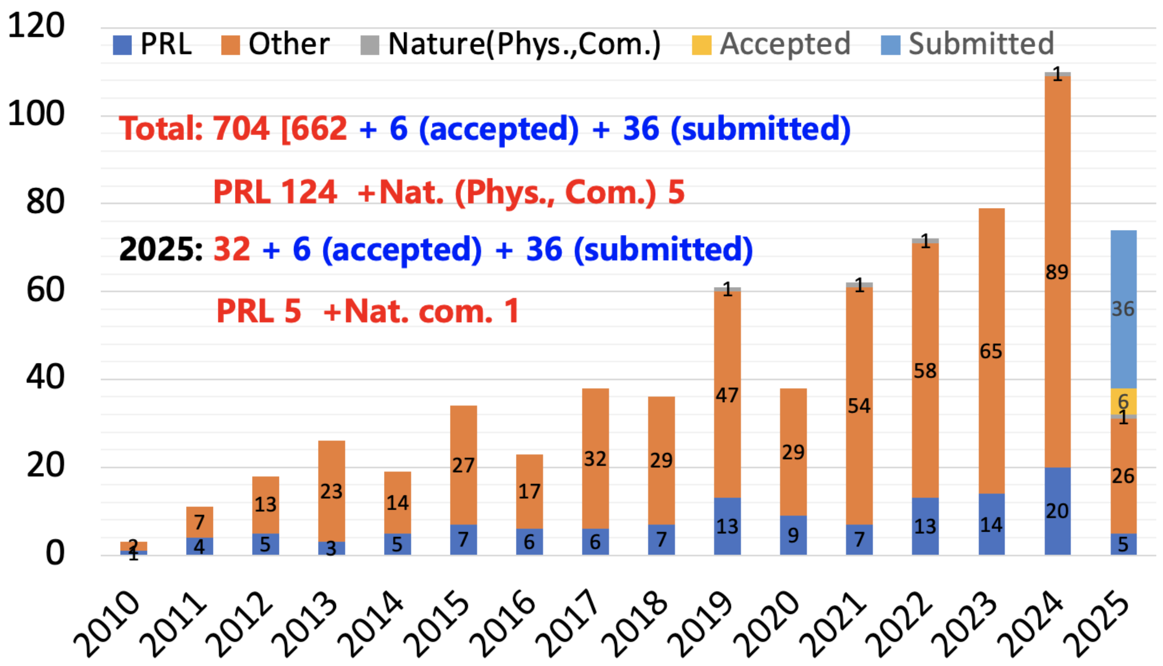
Totally about 50 fb^{-1} integrated luminosity from 1.84-4.95 GeV

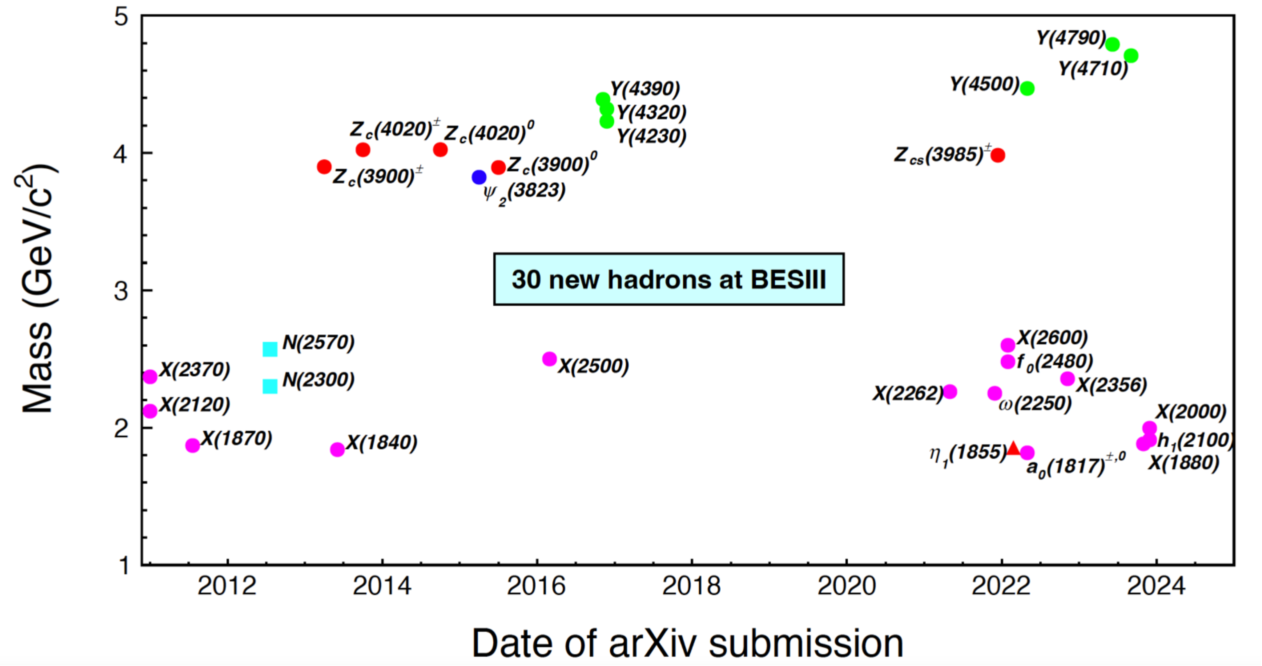


Hadron structure & dynamics in the non-perturbative QCD regime

Publications and achievements

- 110 papers published by BESIII in 2024
- 74 papers submitted by BESIII as of April 14, 2025





Advantage: unique data near to the thresholds

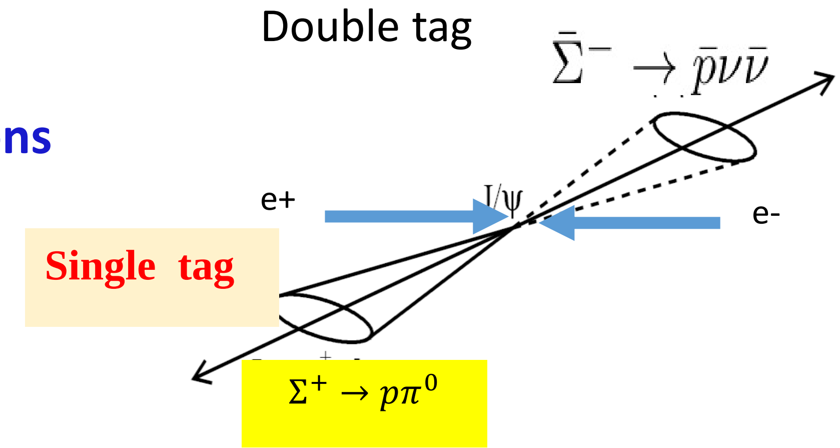
Known initial 4-momentum

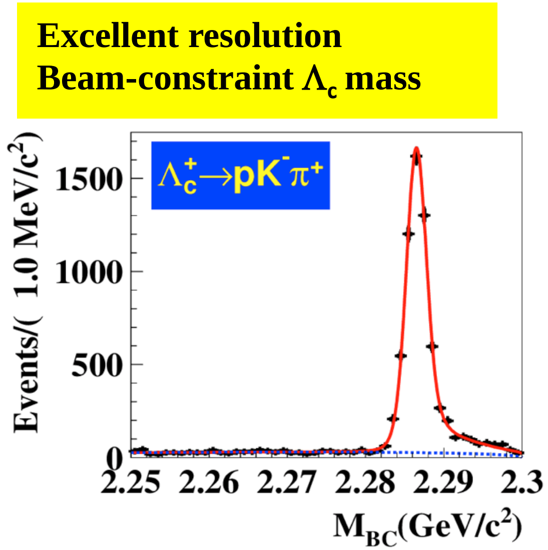
Known beam energy: pair productions

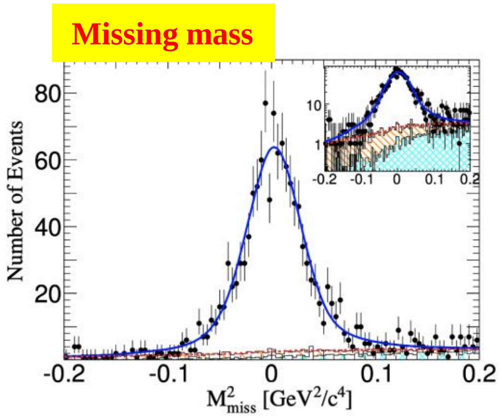
Decay with neutron & π^0

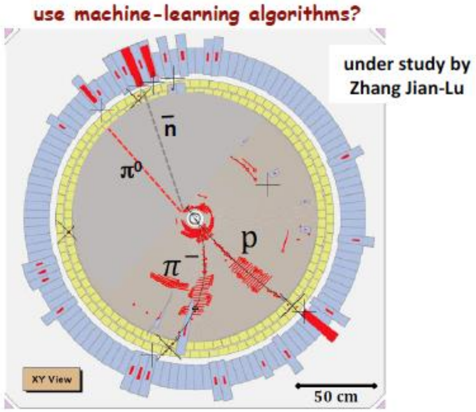
Decay with invisibles: neutrinos

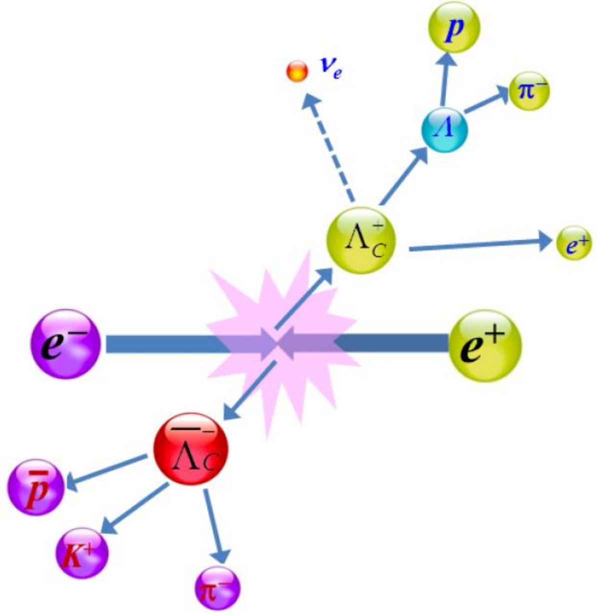
Missing mass or missing energy

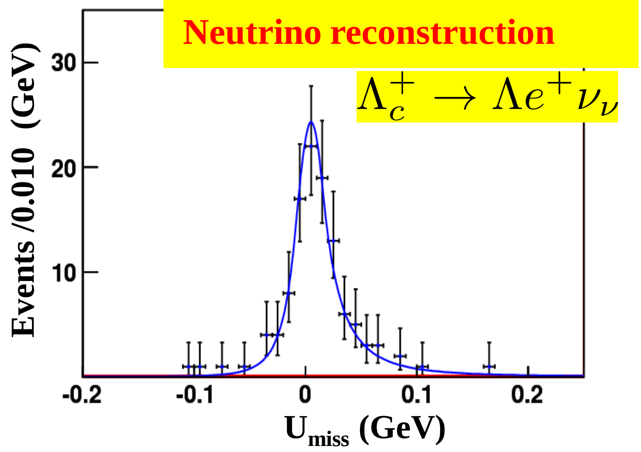








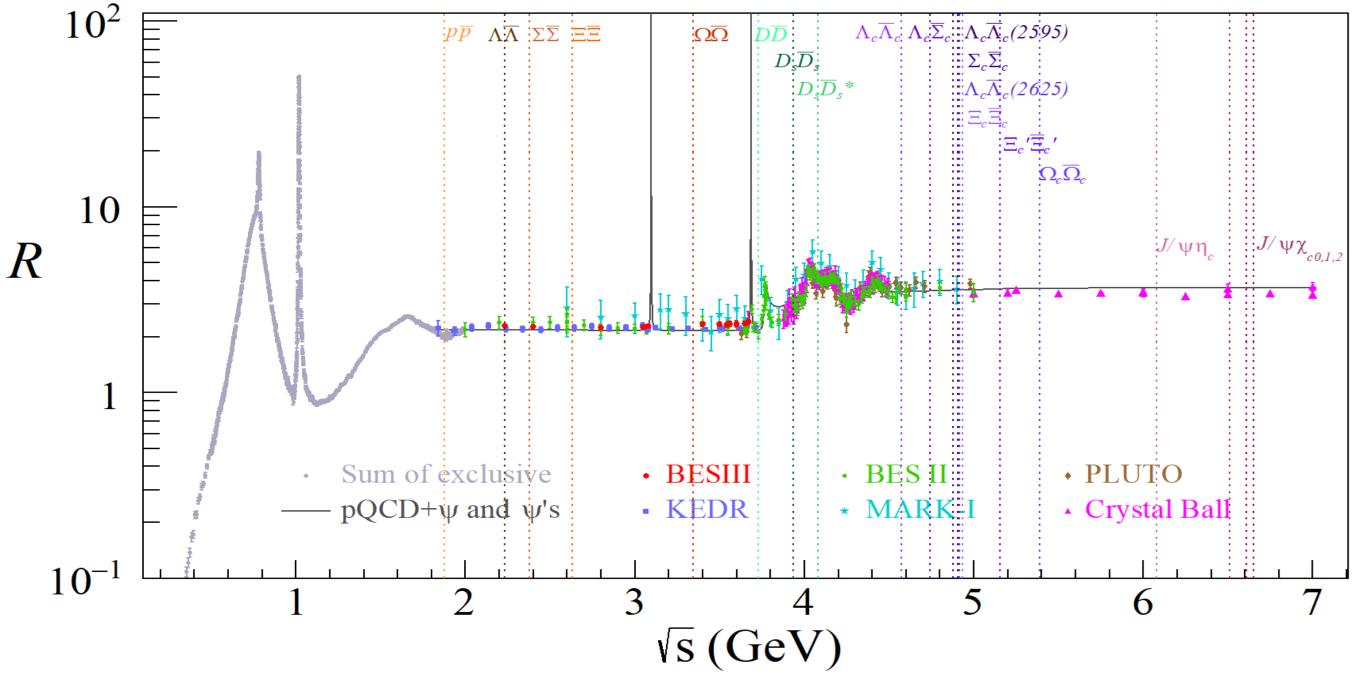


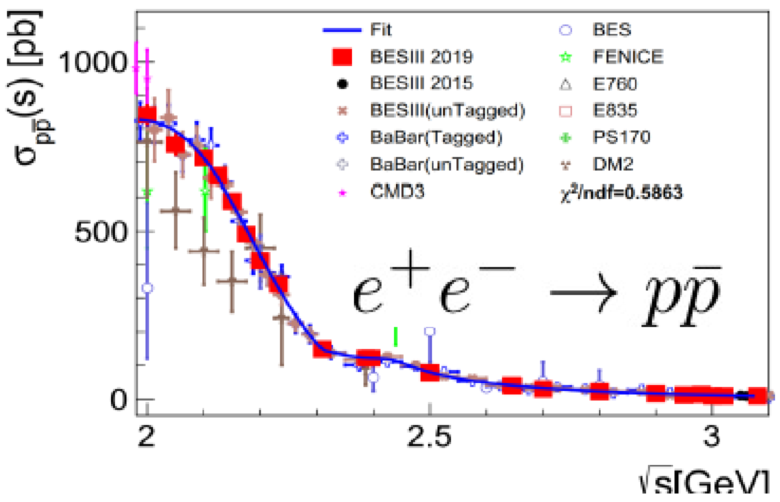


Advantage: data near to the thresholds

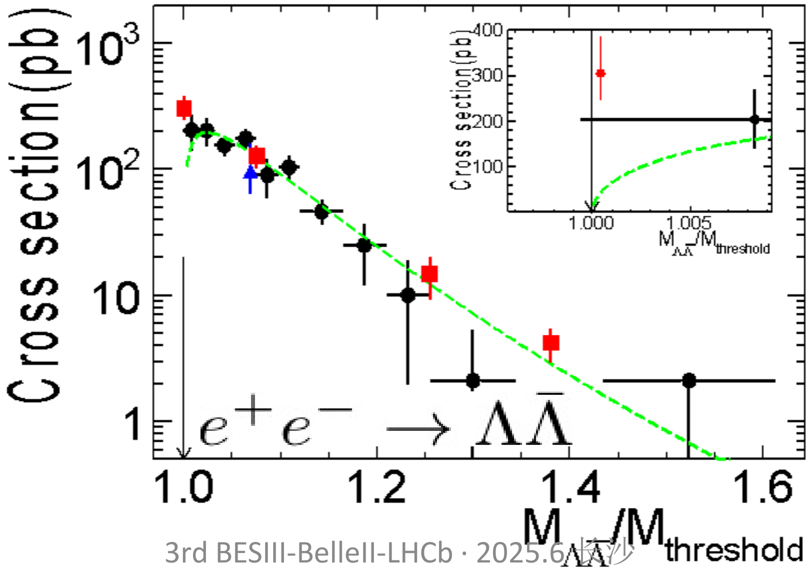
- **Meson and Baryon pairs productions near thresholds: form-factors, relative phase;**
- **Hyperon and charmed baryon entangled**

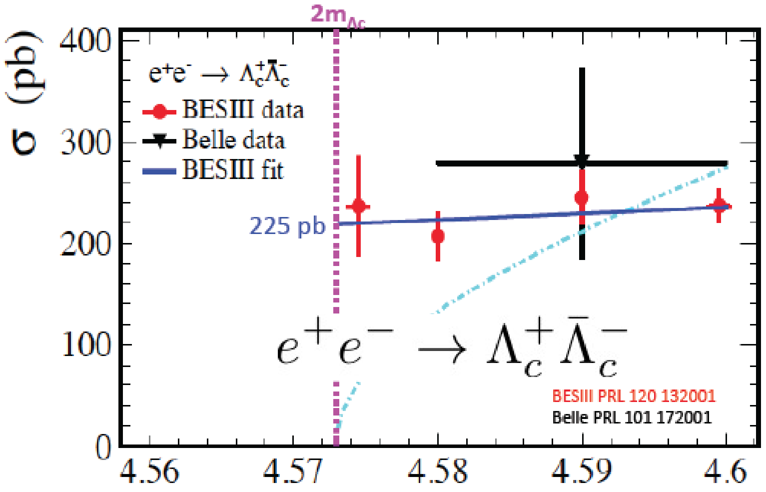
  Spin polarization;
- **CP violation with quantum-entangled hadron pairs.**



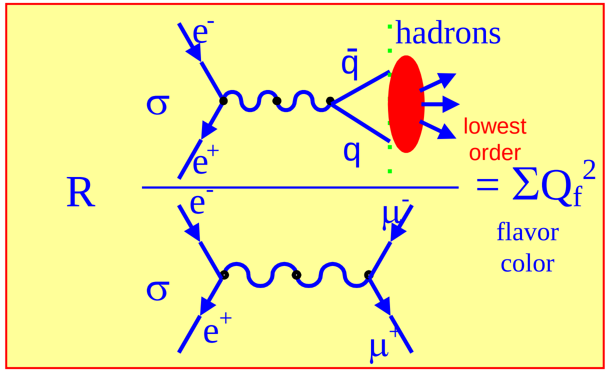


Best precision on σ: 3% (systematic dominant)



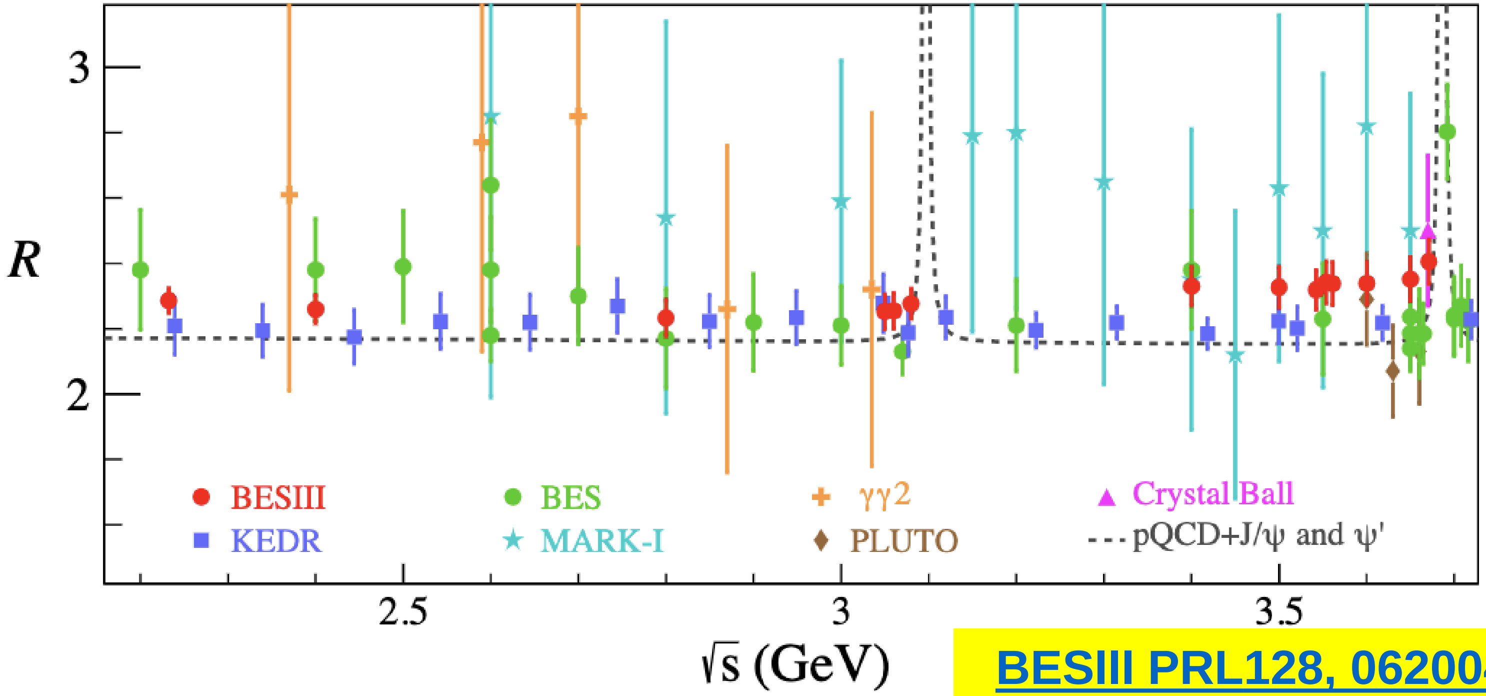


Updated R values at BESIII



- **14 fine-scan data points from 2.23-3.67 GeV**
- **Important inputs for SM-prediction of g-2**

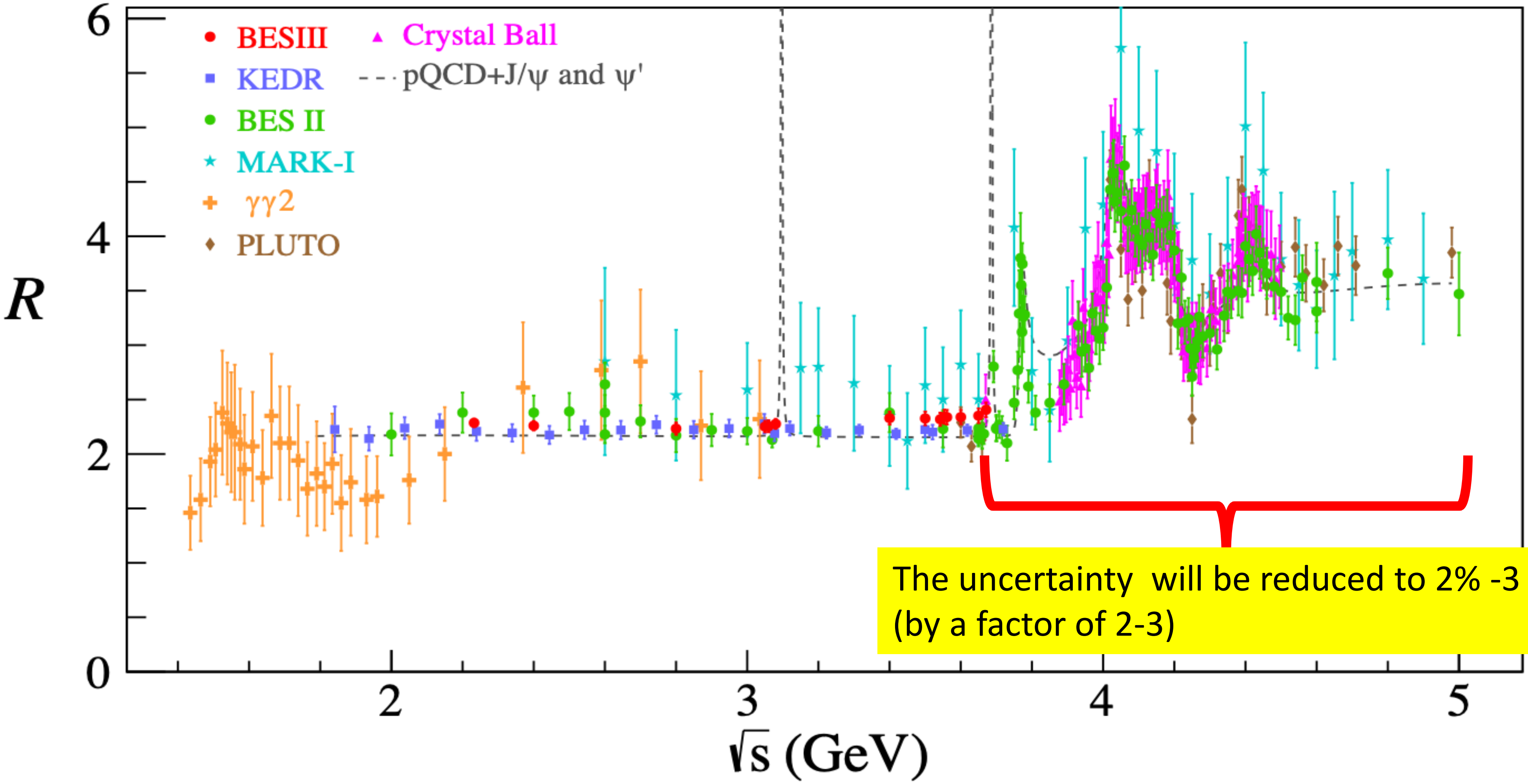
Comparing BESIII R values with previously published results:



BESIII PRL128, 062004 (2022)

- **The accuracy is better than 2.6% below 3.1 GeV and 3.0% above.**
- **Larger than the pQCD prediction by 2.7σ between 3.4 ~ 3.6 GeV.**

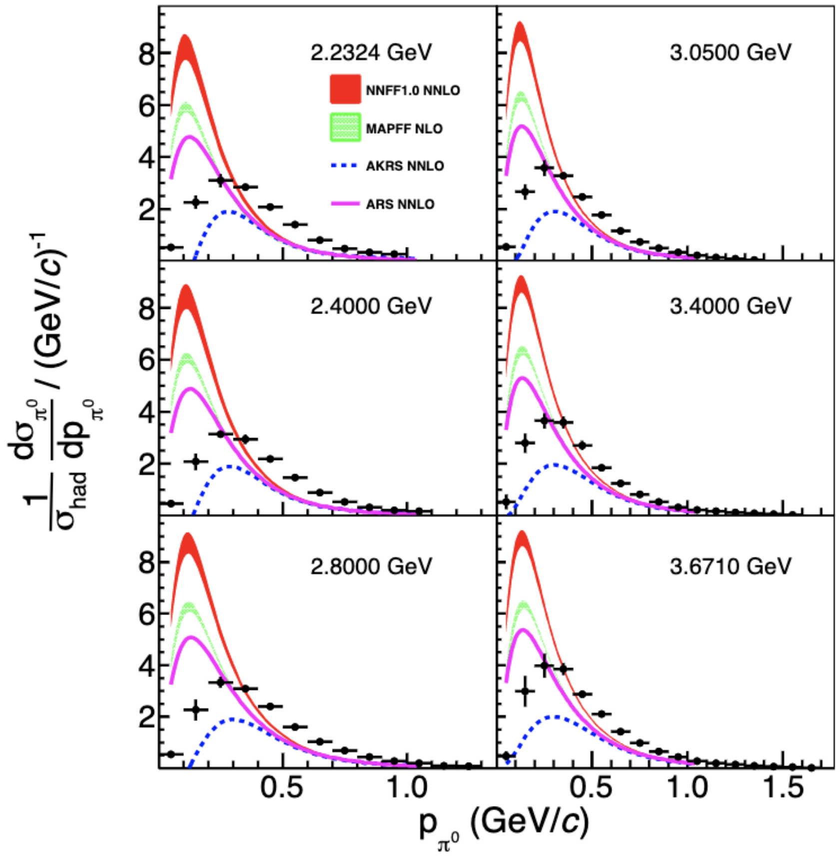
The *R* program at BESIII

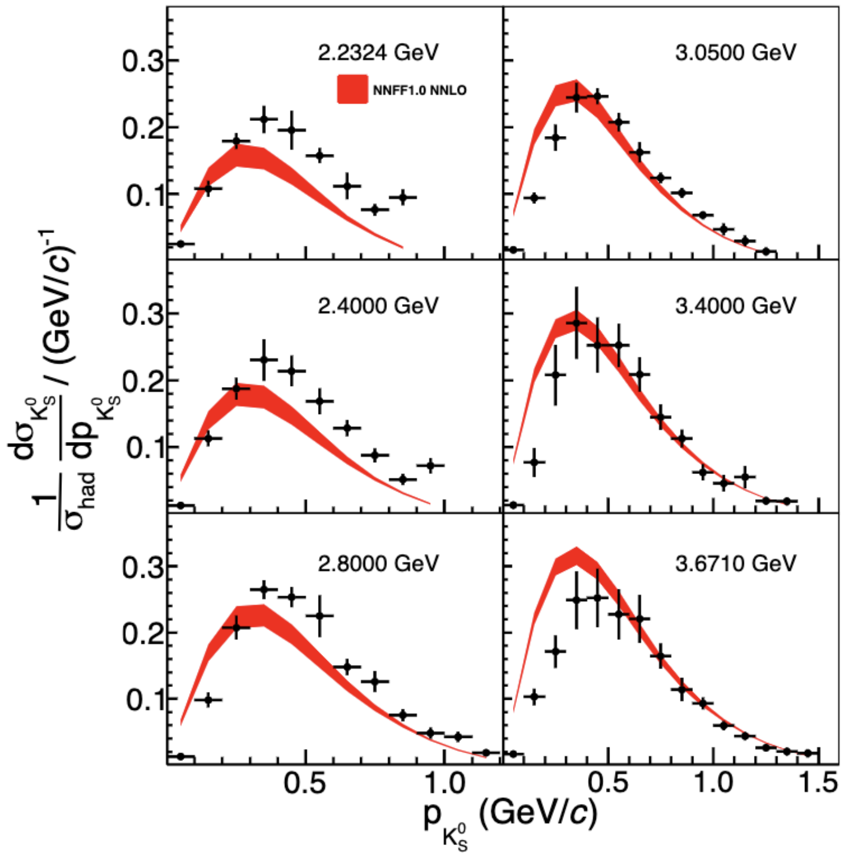


The uncertainty will be reduced to 2% -3 % (by a factor of 2-3)

- **R values in full range 1.84 - 4.95 GeV to come soon.**

Inclusive π^0 and K_S productions in e^+e^- annihilations

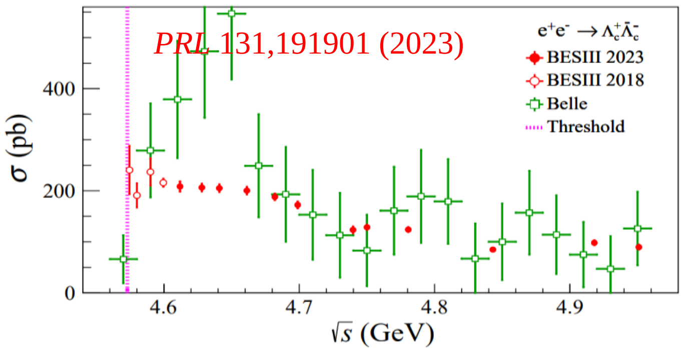




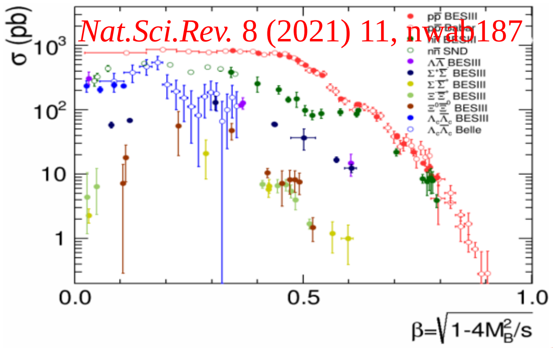
PRL 130 (2023) 231901

- Broad relative hadron energy range z_h from 0.1 to 0.9 with precision of around 3% at $z_h \sim 0.4$.
- Results significantly deviate from several theoretical calculations based on the existing FFs
- Provide brand new inputs in low-energy region to global fits of fragmentation function

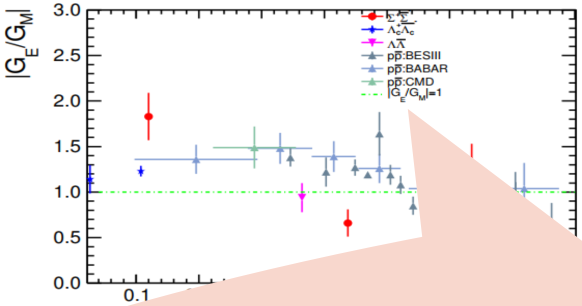
Baryon Electromagnetic form factors (EMFF)

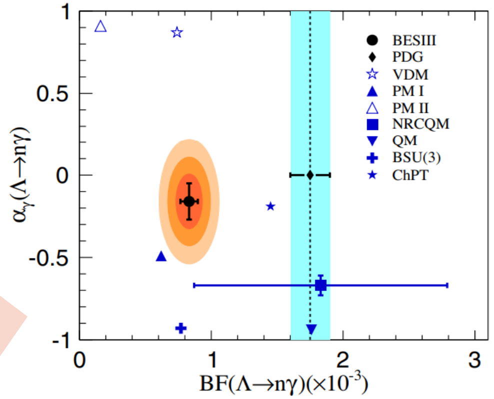


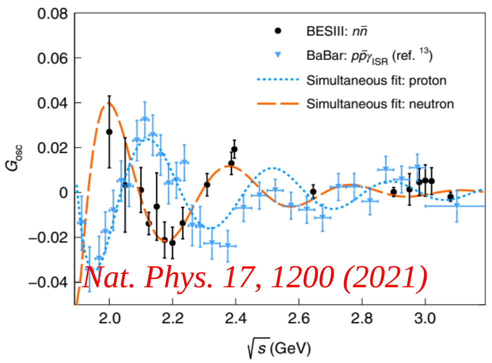
PRL 131,191901 (2023)



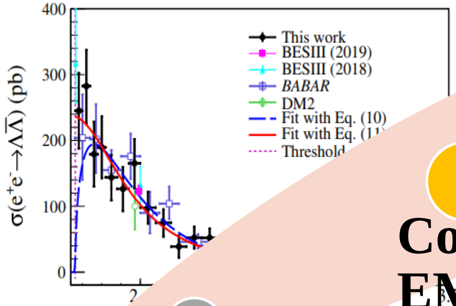
Nat.Sci.Rev. 8 (2021) 11, nwab187

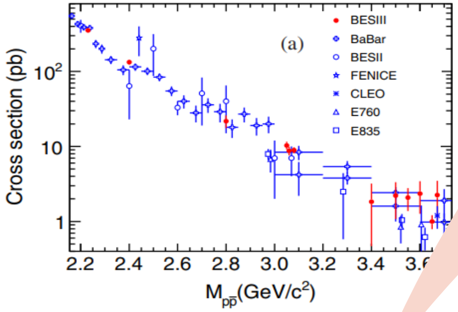




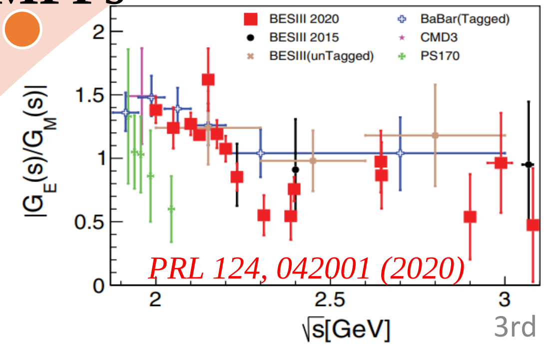


Nat. Phys. 17, 1200 (2021)





PRD 91, 112004 (2015)



PRL 124, 042001 (2020)

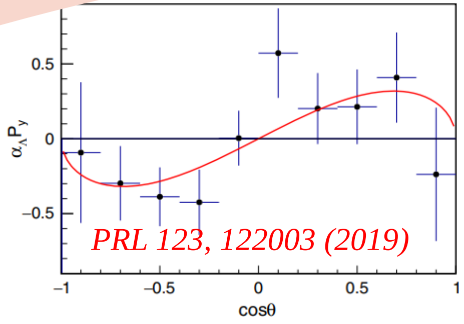
Baryon EMFFs

Threshold effect

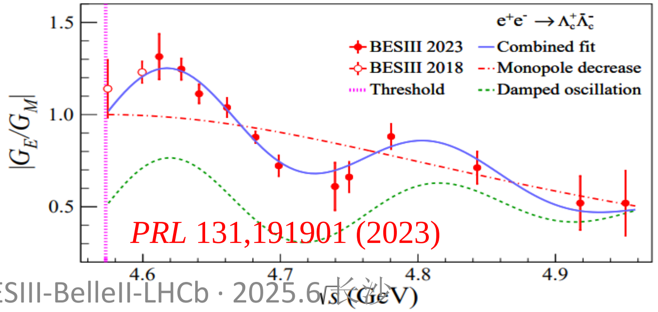
Complete EMFF

CP measurement

Weak radiative baryon decay



PRL 123, 122003 (2019)

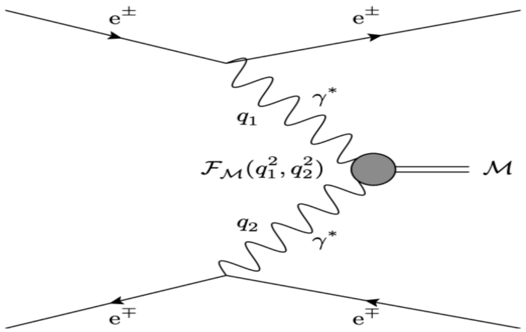


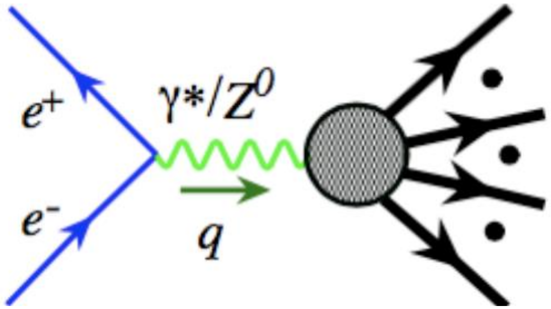
PRL 131,191901 (2023)

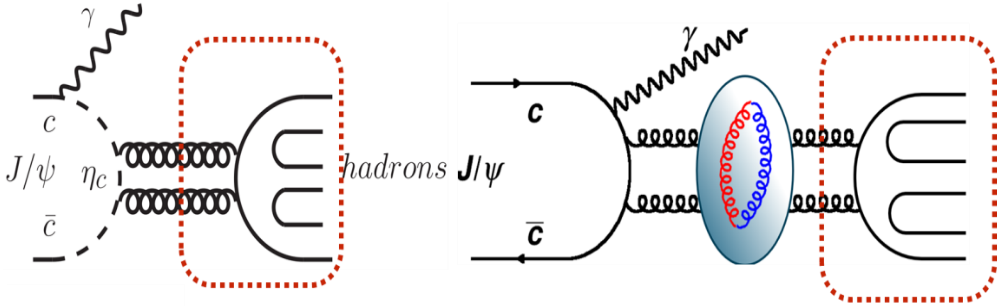
More precise results input to non-pQCD and SM!

Highlight: light spectroscopy

Light hadrons via Electron-positron annihilations, charmonium decays, charmed hadron decays, two-photon processes …
It is crucial to search for light exotic states: glueball, hybrid, multi-quark states …
Rich light scalars, missed excited baryons …



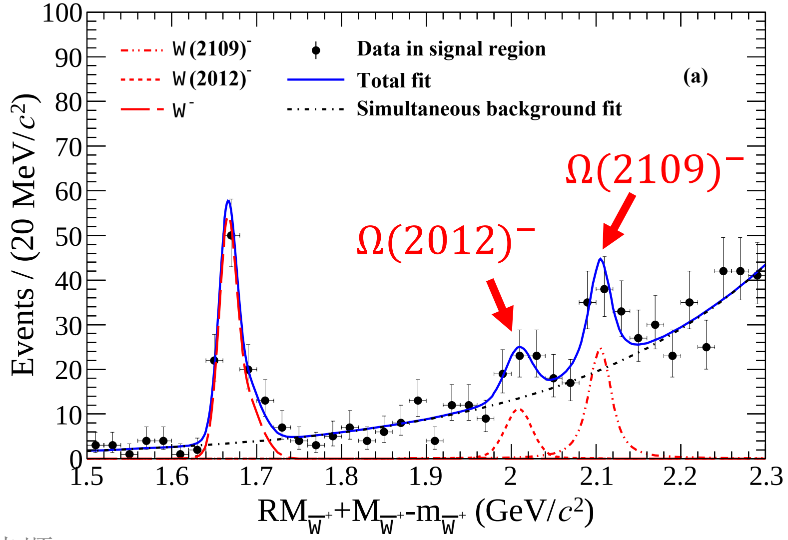


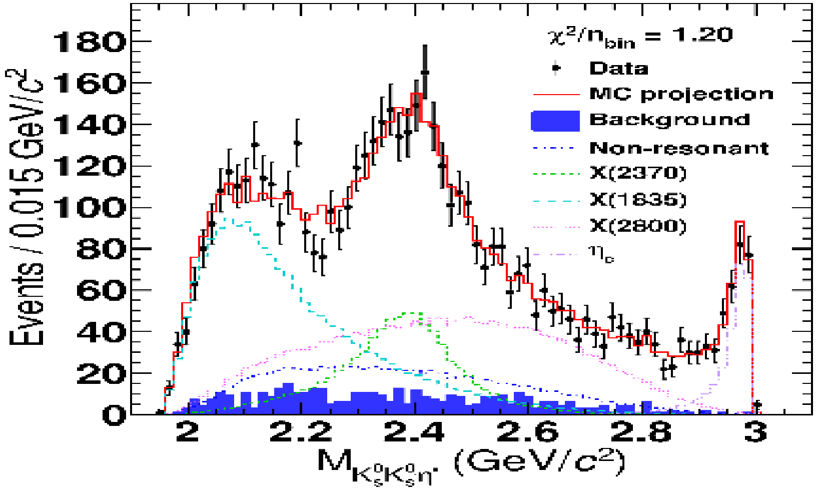


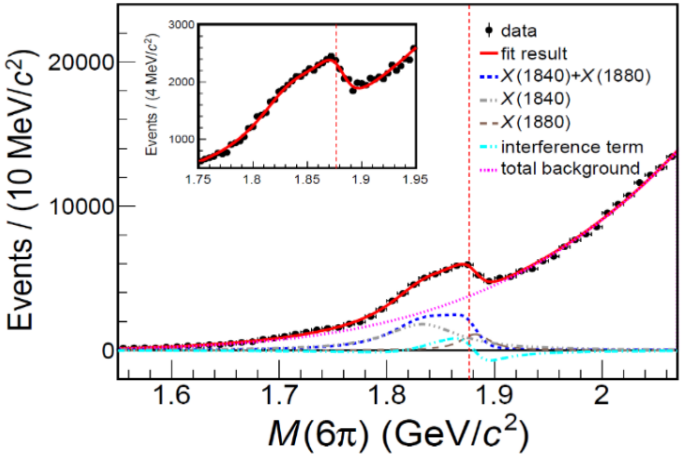
Evidence for Two Excited Ω^- Hyperons
BESIII, Phys. Rev. Lett. 134, 131903 (2025)

Discovered a Glueball-like Particle – X(2370)
BESIII, Phys. Rev. Lett. 132, 181901 (2024)

Discovery of fine structure near proton-anti-proton threshold:: X(1840) and X(1880), BESIII, PRL132 (2024) 151901







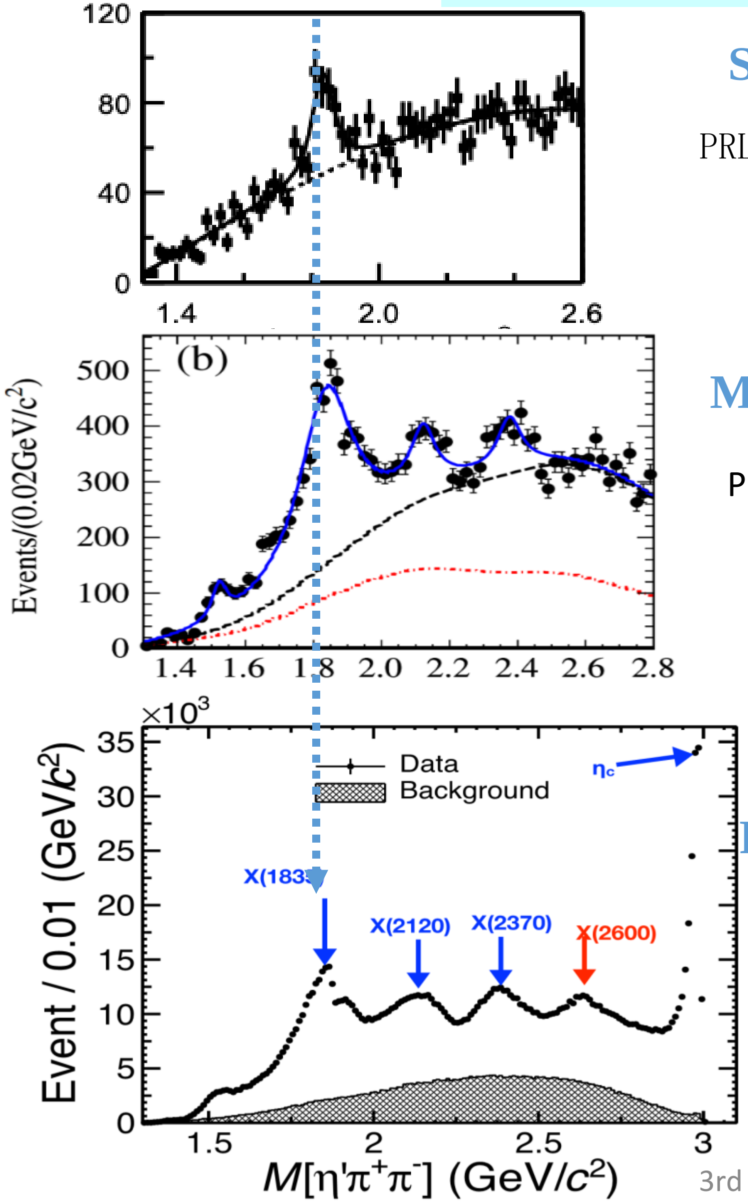
Hadron spectroscopy: high-statistics data

X(1835) $J/\psi \to \gamma \eta' \pi^+ \pi^-$

58 million

225 million

10 billion



Structure

PRL 95 (2005) 262001

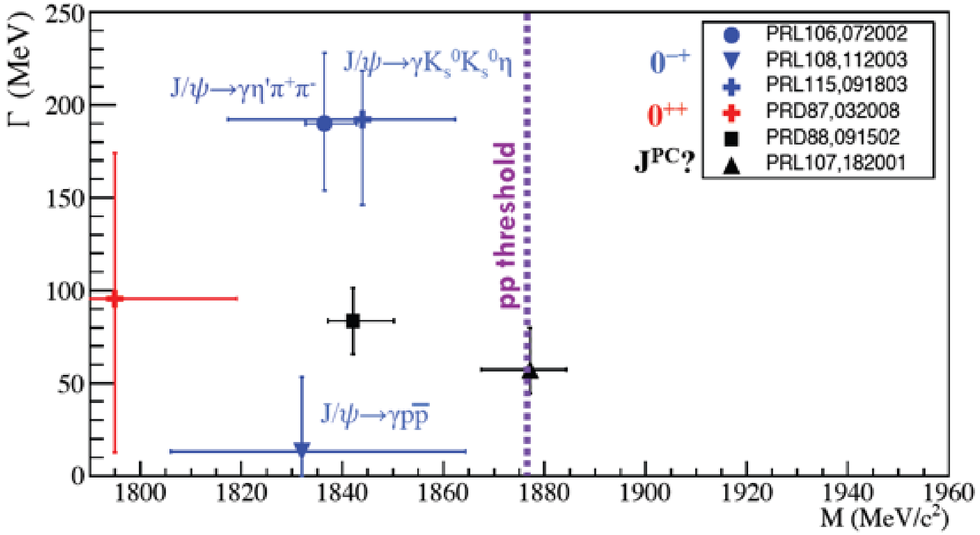
More structures

PRL106(2011)072002

Fine structures

PRL129 (2022) 042001

Rich spectra



You never have enough J/ψ events

–The case for a J/ψ factory–

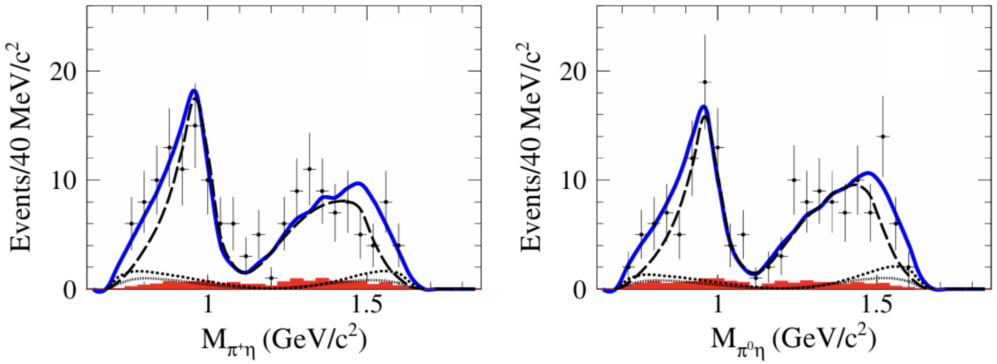
Stephen Lars Olsen

arXiv:2506.20975

Highlight: light hadron from charmed hadron decays

➢ $a_0(980)$ and $f_0(980)$: two-quark $q\bar{q}$ or tetraquark $q^2\bar{q}^2$?

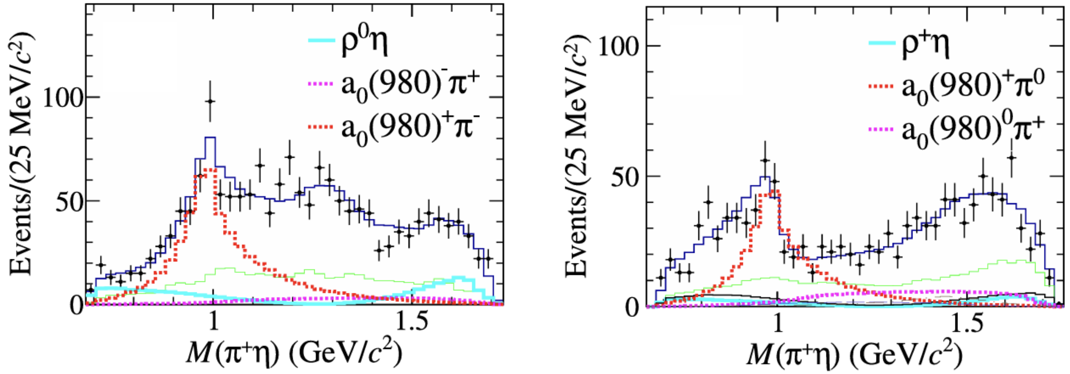
Phys. Rev. Lett. 123, 112001 (2019)



W-Annihilation

$$B(D_s^+ \to a_0\pi, a_0 \to \pi\eta) = (1.46 \pm 0.27)\%$$

Phys. Rev. D 110, L111102 (2024)

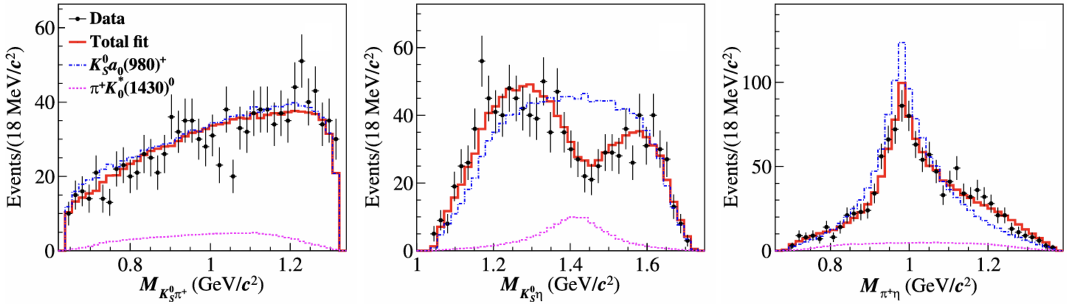


W-Emission & W-Exchange

$$B(D^+ \to a_0^0\pi^+) = (3.7 \pm 1.1); (a_0^+\pi^0) = (9.5 \pm 1.3) \times 10^{-4}$$

$$B(D^0 \to a_0^+\pi^-) = (5.5 \pm 0.9); (a_0^-\pi^+) = (0.7 \pm 0.2) \times 10^{-4}, a_0 \to \pi\eta$$

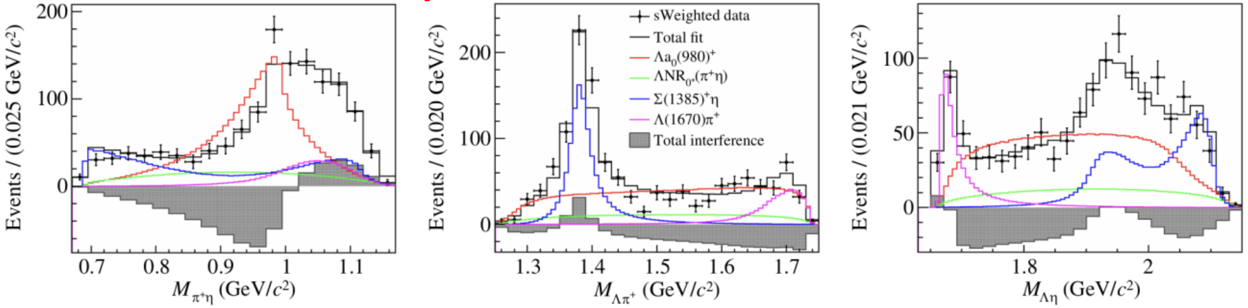
Phys. Rev. Lett. 132, 131903 (2024)



W-Emission

$$B(D^+ \to a_0^+K_S^0, a_0 \to \pi\eta) = (1.33 \pm 0.06)\%$$

Phys. Rev. Lett. 134, 021901 (2025)



W-Emission & W-Exchange

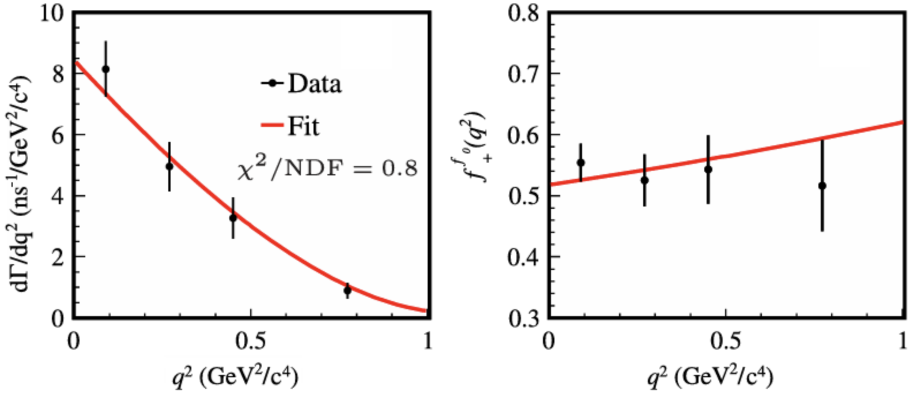
$$B(\Lambda_c^+ \to a_0^+\Lambda, a_0 \to \pi\eta) = (1.05 \pm 0.18)\%$$

All of the measured branching fractions deviate from the predictions made by $q\bar{q}$ model ⇒ $q^2\bar{q}^2$ and Final State Interaction?

Highlight: light hadron from charmed hadron decays

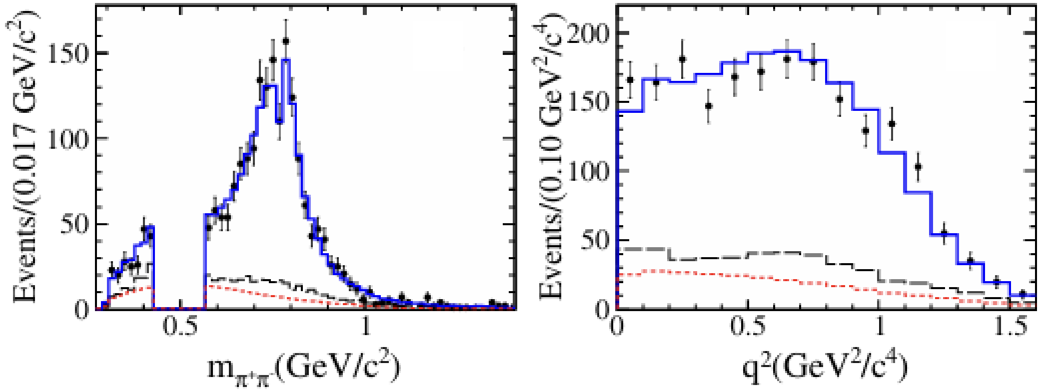
➤ $a_0(980)$ and $f_0(980)$: two-quark $q\bar{q}$ or tetraquark $q^2\bar{q}^2$?

Phys. Rev. Lett. 132, 141901 (2024)



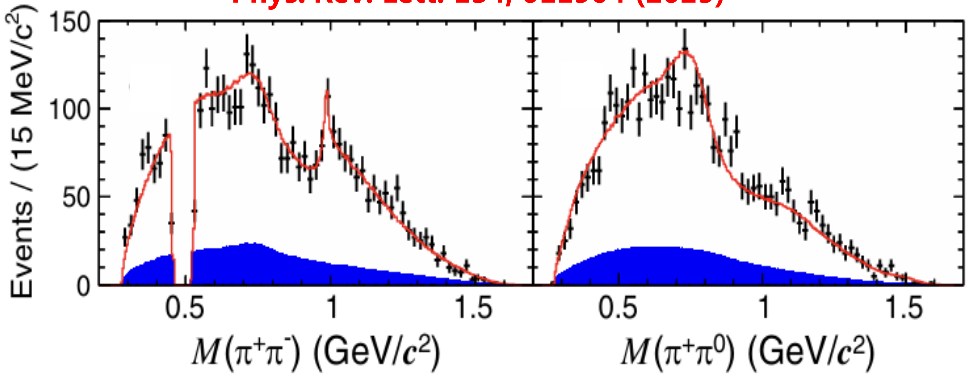
$$B(D_s^+ \to f_0 e^+ \nu_e, f_0 \to \pi^+\pi^-) = (1.72 \pm 0.16) \times 10^{-3}$$
$$f_+^{f_0}(0) = 0.52 \pm 0.04$$

Phys. Rev. Lett. 122, 062001 (2019)



$$B(D^+ \to f_0 e^+ \nu_e, f_0 \to \pi^+\pi^-) < 2.8 \times 10^{-5}$$

Phys. Rev. Lett. 134, 011904 (2025)



$$B(D_s^+ \to f_0(980)\rho^+, f_0 \to \pi^+\pi^-) = (2.57 \pm 0.48) \times 10^{-3}$$

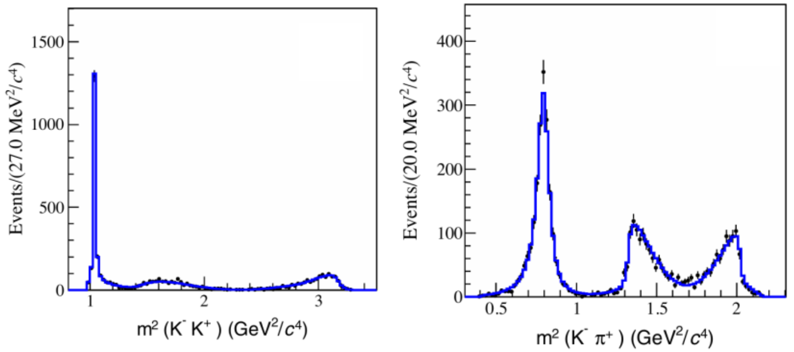
Theoretical predictions by JHEP12(2024)226	$q\bar{q}$	$q^2\bar{q}^2$
$f_+^{f_0}(0)$	0.52 ± 0.02	0.53 ± 0.02
$10^{-3}B(D_s^+ \to f_0 e^+ \nu_e)$	1.69 ± 1.39	1.72 ± 1.48
$10^{-5}B(D^+ \to f_0 e^+ \nu_e)$	1.3 ± 0.1	2.9 ± 0.7

Still being controversial!

Highlight: light hadron from charmed hadron decays

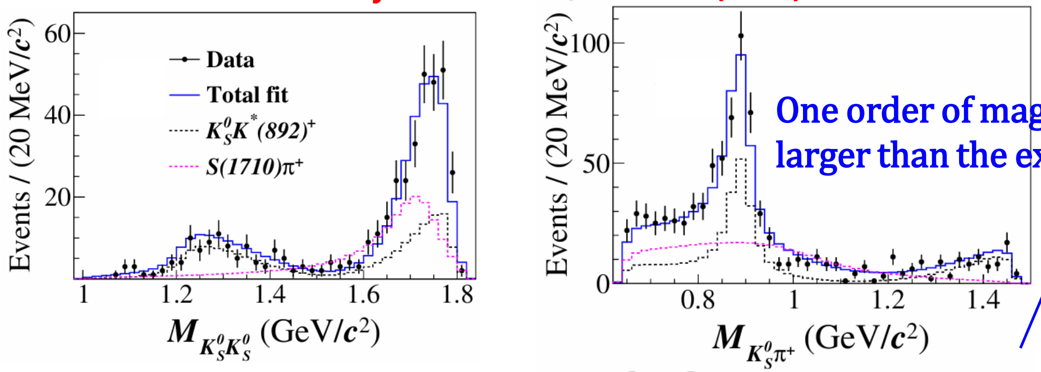
➤ $a_0(1817)$ and $f_0(1710)$

Phys. Rev. D 104, 012016 (2021)



$$B(D_s^+ \to f_0(1710)\pi^+, f_0 \to K^+K^-) = (0.10 \pm 0.04)\%$$

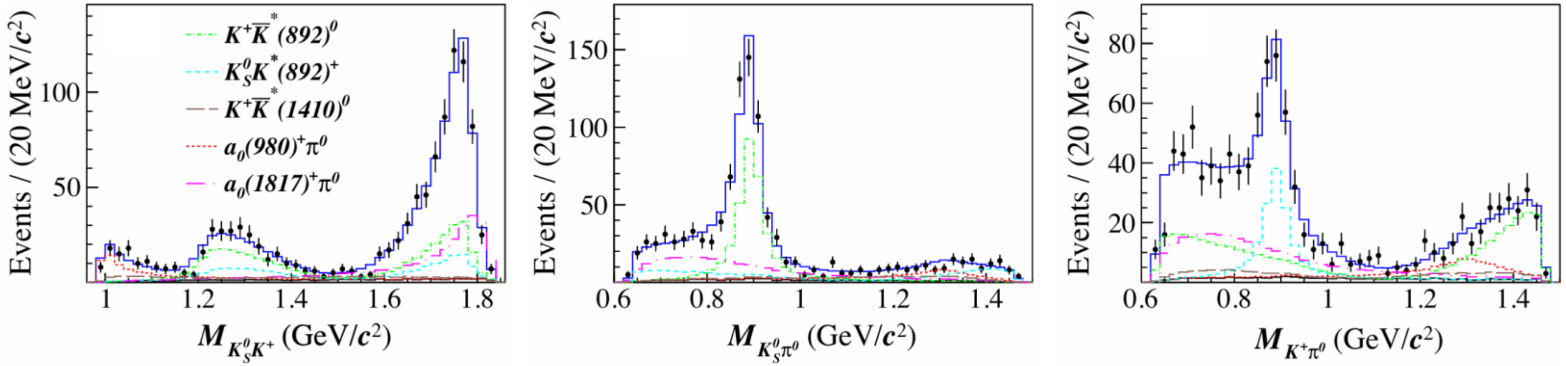
Phys. Rev. D 105, L051103 (2022)



One order of magnitude larger than the expectation!

$$B(D_s^+ \to f_0(1710)\pi^+, f_0 \to K_S^0 K_S^0) = (0.31 \pm 0.03)\%$$

Phys. Rev. Lett. 129, 182001 (2022)



Isospin-one partner of $f_0(1710)$ or $X(1812)$?

$$B(D_s^+ \to a_0(1817)^+\pi^0, a_0 \to K_S^0 K^+) = (3.44 \pm 0.61) \times 10^{-3}$$

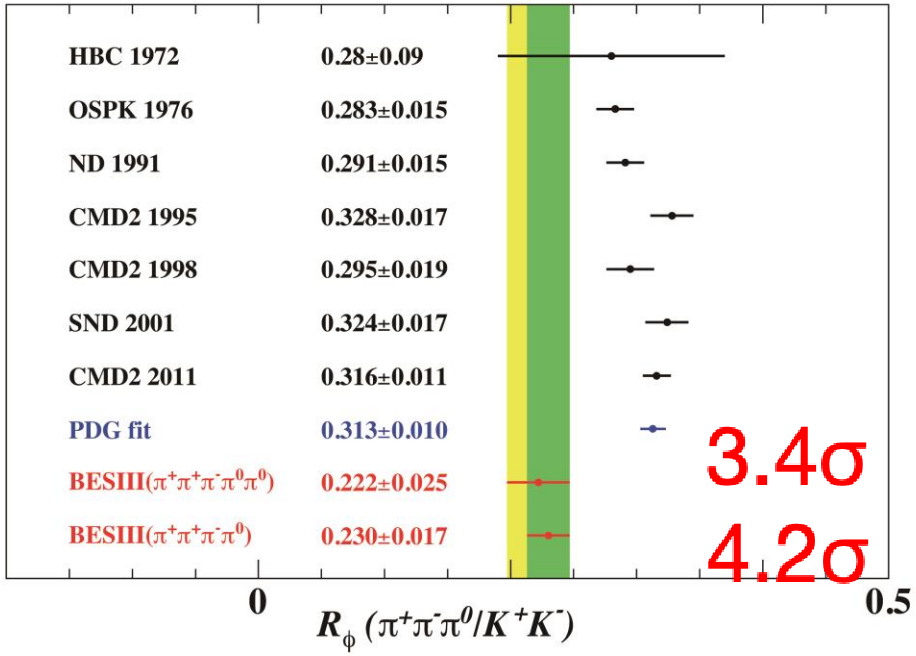
Mass: $(1.817 \pm 0.02)\mathrm{GeV}/c^2$ Width: $(0.097 \pm 0.027)\mathrm{GeV}/c^2$

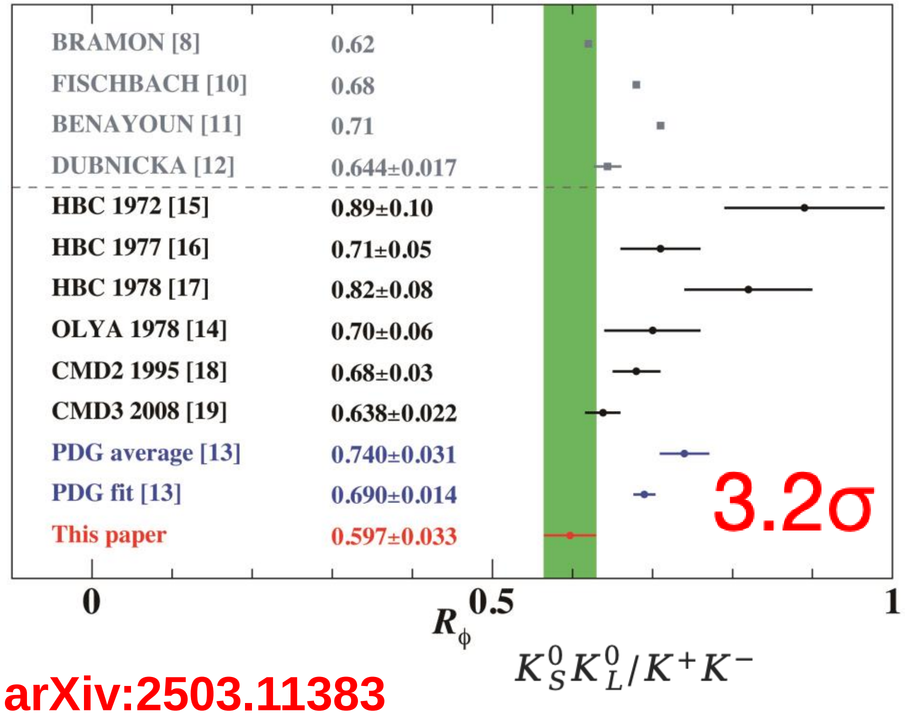
Highlight: Puzzle of ϕ decays in charm

- In $D_s^+ \to \pi^+\pi^+\pi^-\pi^0$, $D_s^+ \to \pi^+\pi^+\pi^-\pi^0\pi^0$ and $K_S^0 K_L^0 \pi^+$ decays, Relative Branching Fraction of ϕ meson deviate from PDG;
- More results are coming. New mechanism?

$$R_\phi = \frac{\mathcal{B}(\phi \to \pi^+\pi^-\pi^0)}{\mathcal{B}(\phi \to K^+K^-)}$$

$$R_\phi = \frac{\mathcal{B}(\phi \to K_S K_L)}{\mathcal{B}(\phi \to K^+K^-)}$$





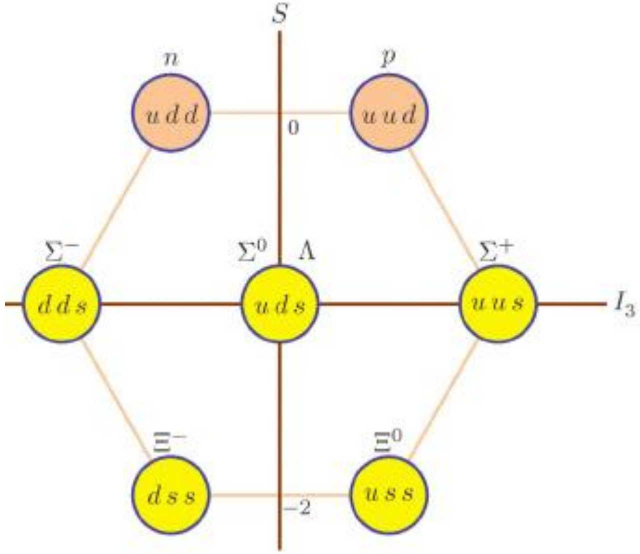
Phys. Rev. Lett. 134, 011904 (2025)
arXiv:2501.04451

arXiv:2503.11383

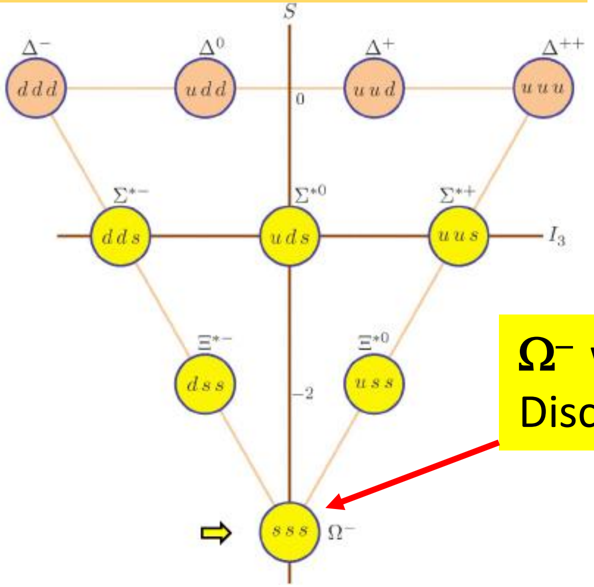
CPV in hyperon decays, # events we need?

CPV in SM is small：			# events	Experiments
B meson ：	O(1)	discovered (2001）	10^3	*B factory*
K meson ：	$O(10^{-3})$	discovered (1964）	10^6	*Fix targets*
D meson ：	$O(10^{-4})$	discovered(2019）	10^8	*LHCb*
Hyperon ：	$O(10^{-4})$	no evidence (10^{-2})	$O(10^8)$	*Fix targets*
				→ BESIII ?

Flavor-SU(3) Octet of spin ½



Flavor-SU(3) Decuplet of spin 3/2



Ω^- was predicted by quark model
Discovered in 1964 at BNL.

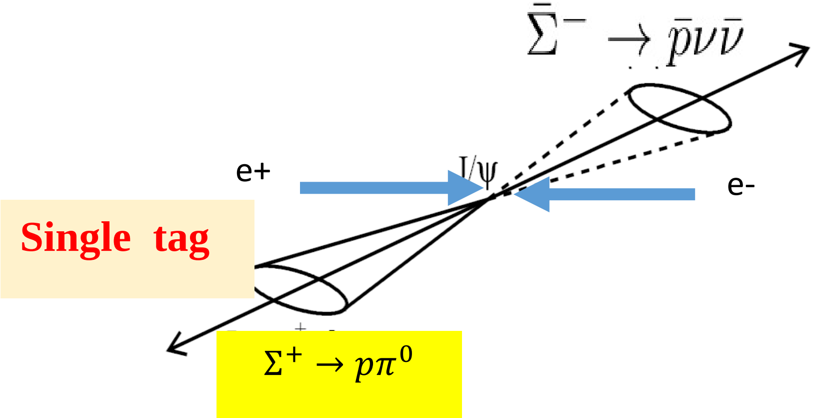
BESIII: A hyperon factory

10 billion J/ψ and 2.7 billion $\psi(2S)$ events collected

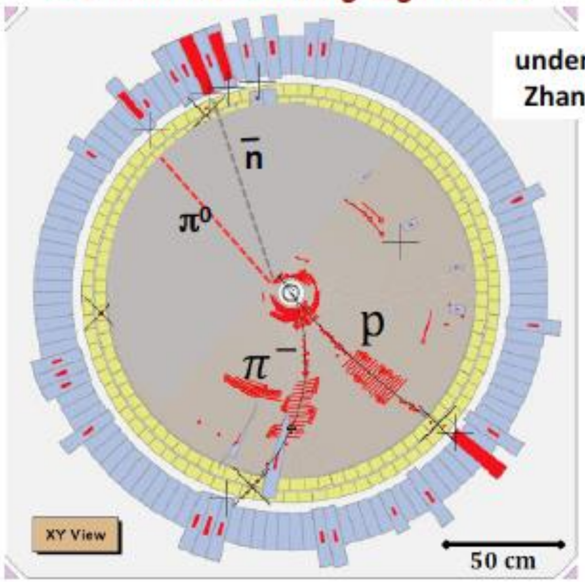
- Large BRs in J/ψ decays : 10^7 entangled hyperon pairs
- Quantum entangled pair productions
- Background free

Hai-Bo Li, arXiv:1612.01775

Decay mode	$\mathcal{B}(\times 10^{-3})$	N_B $(\times 10^6)$
$J/\psi \to \Lambda\bar{\Lambda}$	1.61 ± 0.15	16.1 ± 1.5
$J/\psi \to \Sigma^0\bar{\Sigma}^0$	1.29 ± 0.09	12.9 ± 0.9
$J/\psi \to \Sigma^+\bar{\Sigma}^-$	1.50 ± 0.24	15.0 ± 2.4
$J/\psi \to \Sigma(1385)^-\bar{\Sigma}^+$ (or c.c.)	0.31 ± 0.05	3.1 ± 0.5
$J/\psi \to \Sigma(1385)^-\bar{\Sigma}(1385)^+$ (or c.c.)	1.10 ± 0.12	11.0 ± 1.2
$J/\psi \to \Xi^0\bar{\Xi}^0$	1.20 ± 0.24	12.0 ± 2.4
$J/\psi \to \Xi^-\bar{\Xi}^+$	0.86 ± 0.11	8.6 ± 1.0
$J/\psi \to \Xi(1530)^0\bar{\Xi}^0$	0.32 ± 0.14	3.2 ± 1.4
$J/\psi \to \Xi(1530)^-\bar{\Xi}^+$	0.59 ± 0.15	5.9 ± 1.5
$\psi(2S) \to \Omega^-\bar{\Omega}^+$	0.05 ± 0.01	0.15 ± 0.03

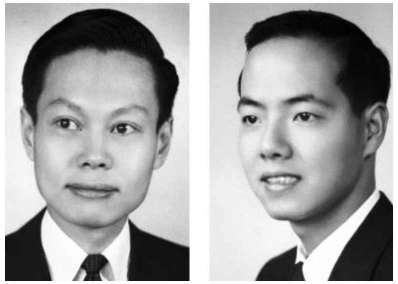


use machine-learning algorithms?



under study by Zhang Jian-Lu

CP observables in hyperon decays

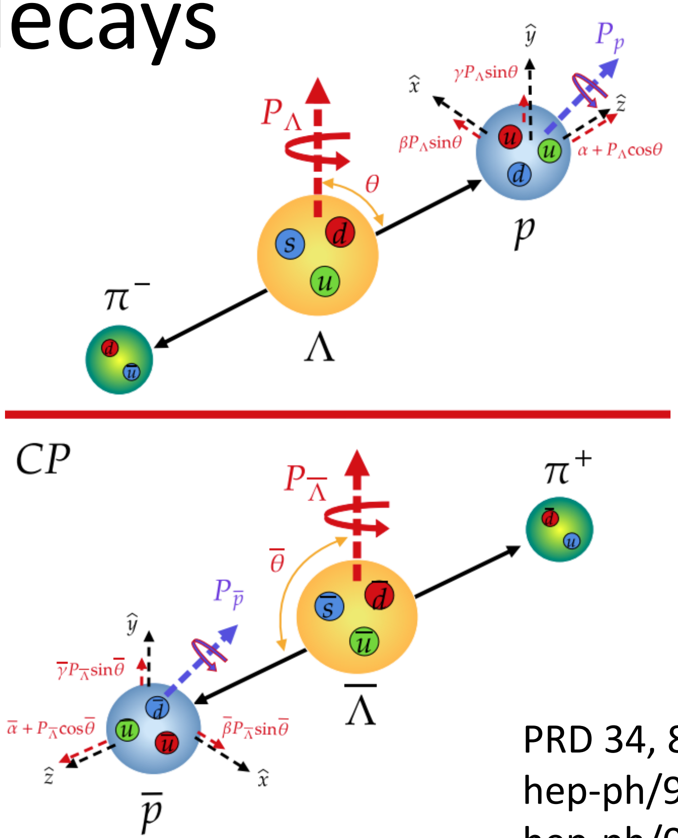


General Partial Wave Analysis of the Decay of a Hyperon of Spin ½

T. D. LEE* AND C. N. YANG
Institute for Advanced Study, Princeton, New Jersey

(Received October 22, 1957)

Phys. Rev. 108, 1645 (1957)



PRD 34, 833 1986
hep-ph/991023
hep-ph/0002210

The amplitude of spin ½ baryon B_i decay to a spin ½ baryon B_f and π:

$$\mathcal{A} \sim S\sigma_0 + P\boldsymbol{\sigma}\cdot\hat{\boldsymbol{n}}$$

The decay parameters are defined as:

$$\alpha_Y = \frac{2\,\mathrm{Re}\,(S^*P)}{|S|^2+|P|^2},\quad \beta_Y = \frac{2\,\mathrm{Im}\,(S^*P)}{|S|^2+|P|^2},\quad \gamma_Y = \frac{|S|^2-|P|^2}{|S|^2+|P|^2}$$

Two complex amplitudes: **ϕ weak phase, δ strong phase**

$$S = \Sigma^i S_i e^{i(\phi_i^S+\delta_i^S)},\qquad P = \Sigma^i P_i e^{i(\phi_i^P+\delta_i^P)}$$

Under CP transformation:

$$\bar{S} = -\Sigma^i S_i e^{i(-\phi_i^S+\delta_i^S)},\qquad \bar{P} = \Sigma^i P_i e^{i(-\phi_i^P+\delta_i^P)}$$

If CP conserved: $S \xrightarrow{CP} -S$, $P \xrightarrow{CP} P$ ⇒ $\alpha \xrightarrow{CP} \bar\alpha = -\alpha$, $\beta \xrightarrow{CP} \bar\beta = -\beta$

CPV observables

$$\Delta = \frac{\Gamma-\bar\Gamma}{\Gamma+\bar\Gamma}$$

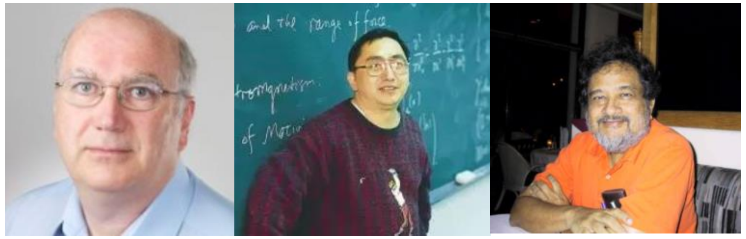
$$A = \frac{\Gamma\alpha+\bar\Gamma\bar\alpha}{\Gamma\alpha-\bar\Gamma\bar\alpha} \approx \frac{\alpha+\bar\alpha}{\alpha-\bar\alpha}+\Delta$$

$$B = \frac{\Gamma\beta+\bar\Gamma\bar\beta}{\Gamma\beta-\bar\Gamma\bar\beta} \approx \frac{\beta+\bar\beta}{\beta-\bar\beta}+\Delta$$

CP observables in hyperon decays

PRD 34,833 1986
hep-ph/991023
hep-ph/0002210

PHYSICAL REVIEW D VOLUME 34, NUMBER 3 1 AUGUST 1986



John F. Donoghue Xiao-Gang He Sandip Pakvasa

Hyperon decays and *CP* nonconservation

John F. Donoghue
Department of Physics and Astronomy, University of Massachusetts, Amherst, Massachusetts 01003

Xiao-Gang He and Sandip Pakvasa
Department of Physics and Astronomy, University of Hawaii at Manoa, Honolulu, Hawaii 96822

(Received 7 March 1986)

We study all modes of hyperon nonleptonic decay and consider the *CP*-odd observables which result. Explicit calculations are provided in the Kobayashi-Maskawa, Weinberg-Higgs, and left-right-symmetric models of *CP* nonconservation.

PRD 34,833 1986

SM Prediction of Λ decay

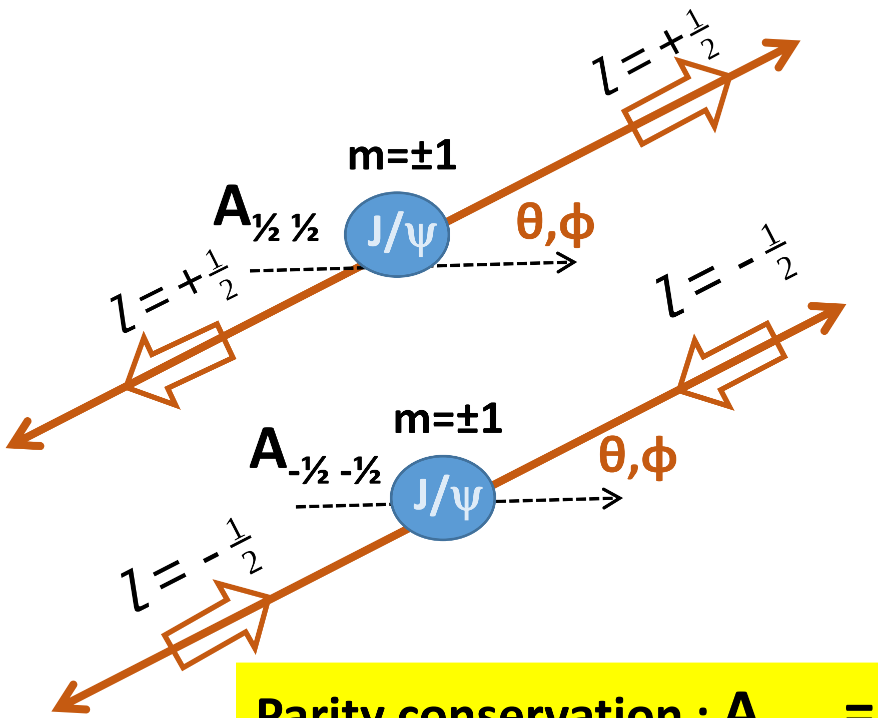
Not sensitive to *CPV* → **Decay width difference** $\Delta = \frac{\Gamma-\bar{\Gamma}}{\Gamma+\bar{\Gamma}} \approx \sqrt{2}\frac{T_{\frac{3}{2}}}{T_{\frac{1}{2}}}\sin\Delta_s \sin\phi_{CP}$ — -5.4×10^{-7}

Easiest to measure → **Decay parameter difference** $A = \frac{\Gamma\alpha+\bar{\Gamma}\bar{\alpha}}{\Gamma\alpha-\bar{\Gamma}\bar{\alpha}} \approx \tan\Delta_s \tan\phi_{CP}$ — -0.5×10^{-4}

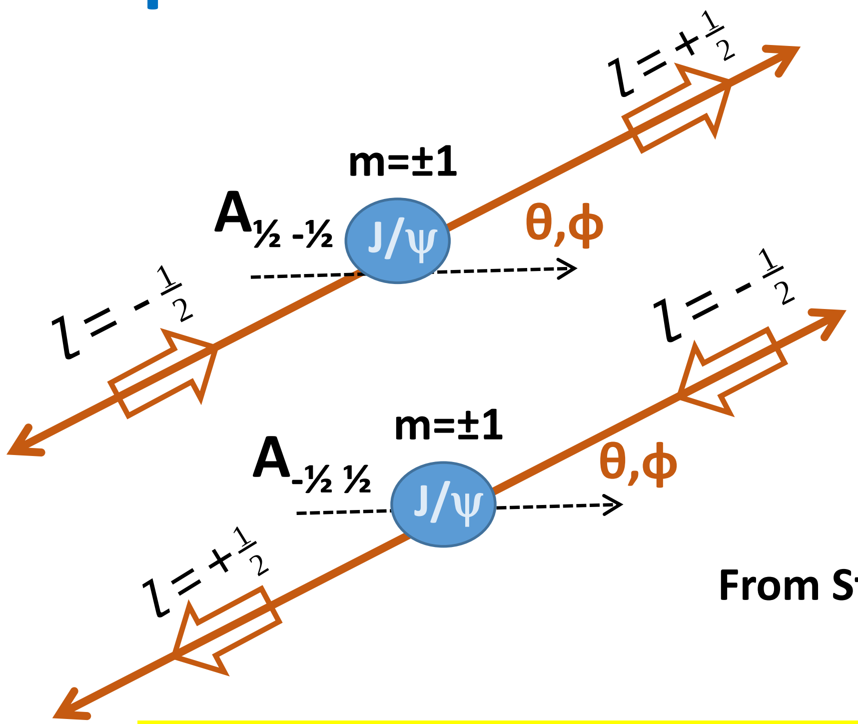
Polarization of decayed baryon needs to be measured → **Decay parameter difference** $B = \frac{\Gamma\beta+\bar{\Gamma}\bar{\beta}}{\Gamma\alpha-\bar{\Gamma}\bar{\alpha}} \approx \tan\phi_{CP}$ — 3.0×10^{-3}

Ξ^-, Ξ^0, Ω^- cascade decay

Entangled & Polarized hyperon pairs produced in e^+e^- collisions



Parity conservation : $A_{½ ½} = A_{-½ -½}$



From Steve Olsen

parity conservation : $A_{½ -½} = A_{-½ ½}$

$\Delta\Phi$= complex phase between $A_{½ ½}$ and $A_{½ -½}$

$$\frac{d|\mathcal{M}|^2}{d\cos\theta} \propto (1+\alpha_{J/\psi}\cos^2\theta), \quad \text{with} \quad \alpha_{J/\psi} = \frac{|A_{1/2,-1/2}|^2 - 2|A_{1/2,1/2}|^2}{|A_{1/2,-1/2}|^2 + 2|A_{1/2,1/2}|^2}$$

If $\Delta\Phi \neq 0$, Λ and $\bar{\Lambda}$ are transversely polarized

Correlated 5-dim. angular distribution $e^+e^- \to J/\psi \to \Lambda\bar{\Lambda}$

$$\mathcal{W}(\xi;\alpha_\psi,\Delta\Phi,\alpha_-,\alpha_+) = 1+\alpha_\psi\cos^2\theta_\Lambda$$

Unpolarized part

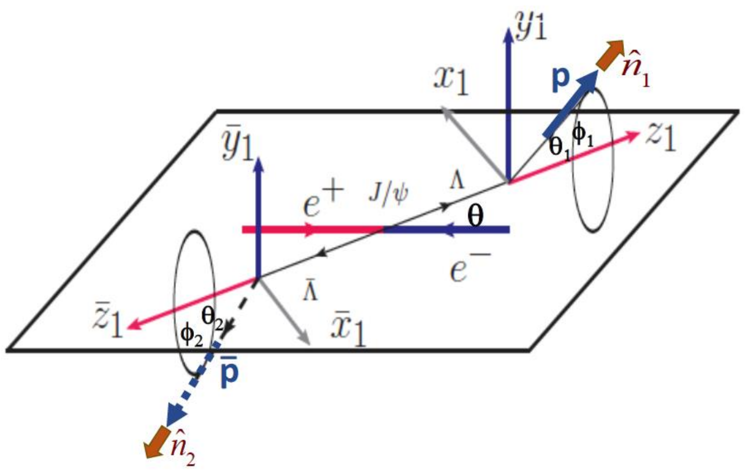
Entangled part

$$+\alpha_-\alpha_+\left[\sin^2\theta_\Lambda\left(n_{1,x}n_{2,x}-\alpha_\psi n_{1,y}n_{2,y}\right)+\left(\cos^2\theta_\Lambda+\alpha_\psi\right)n_{1,z}n_{2,z}\right]$$

$$+\alpha_-\alpha_+\sqrt{1-\alpha_\psi{}^2}\cos(\Delta\Phi)\sin\theta_\Lambda\cos\theta_\Lambda\left(n_{1,x}n_{2,z}+n_{1,z}n_{2,x}\right)$$

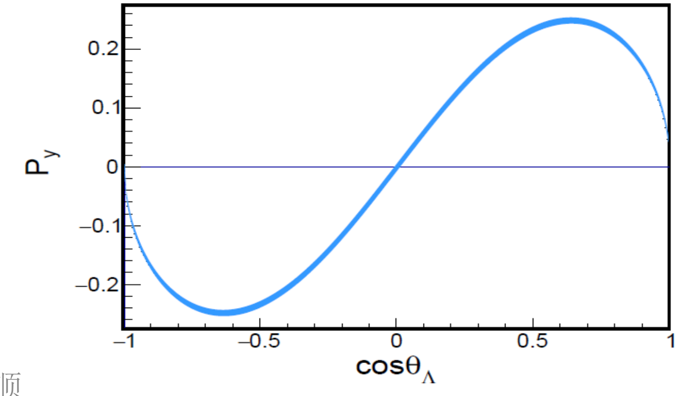
$$+\sqrt{1-\alpha_\psi{}^2}\sin(\Delta\Phi)\,\sin\theta_\Lambda\cos\theta_\Lambda\left(\alpha_- n_{1,y}+\alpha_+ n_{2,y}\right),$$

Polarized part



Polarization-term can be used to determine a_- and a_+ simultaneously

Λ

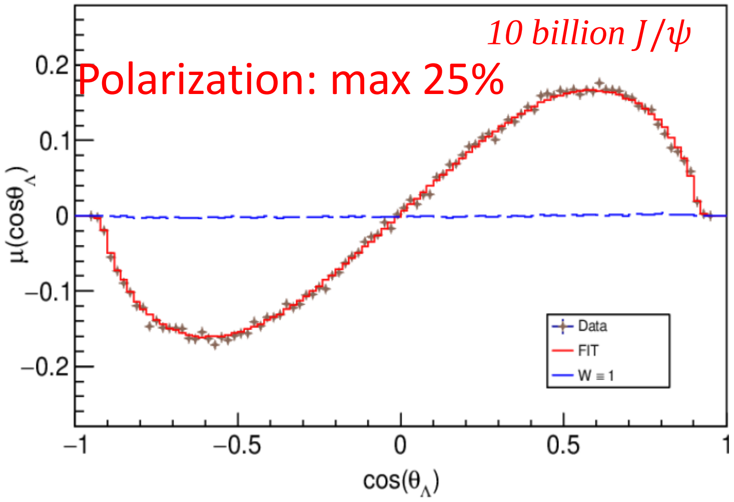


$$P_y(\cos\theta_\Lambda)=\frac{\sqrt{1-\alpha_\psi^2}\,\sin(\Delta\Phi)\cos\theta_\Lambda\sin\theta_\Lambda}{1+\alpha_\psi\cos^2\theta_\Lambda}$$

The most precise CP test in Λ and $\bar{\Lambda}$ decay

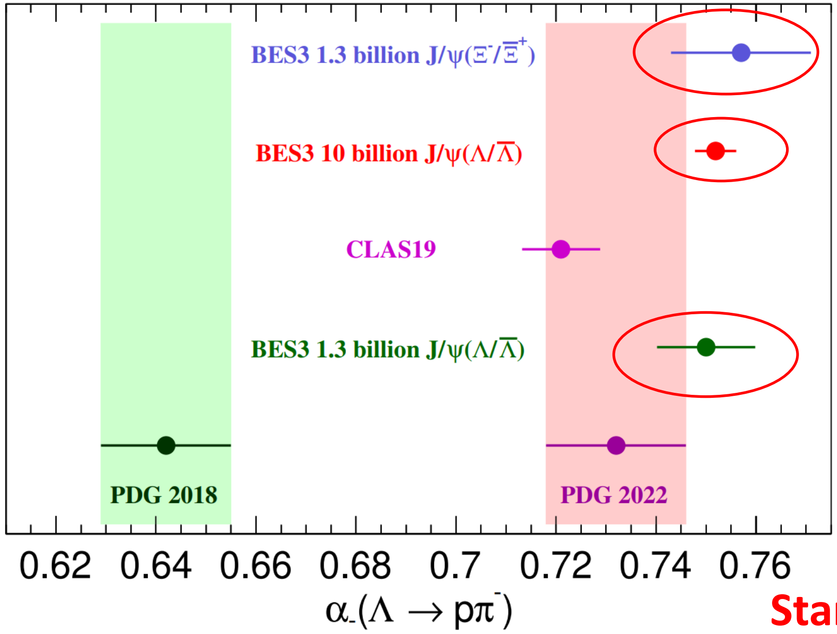
10 billion J/ψ, Phys. Rev. Lett. 129, 131801 (2022)

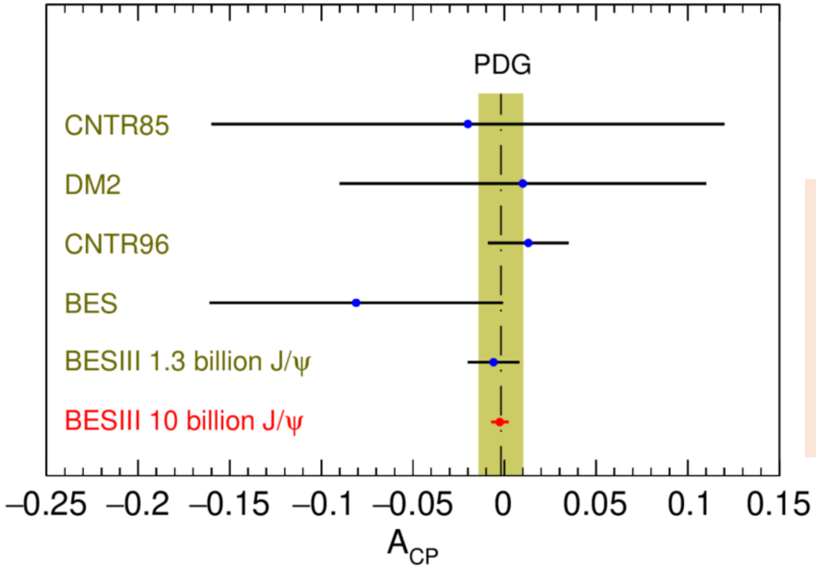
Nat. Phys. 15, 631 (2019)



Paras.	This Work (10 billion J/ψ)	Previous Results (1.3 billion J/ψ)
$\alpha_{J/\psi}$	$0.4748 \pm 0.0022 \pm 0.0024$	$0.461 \pm 0.006 \pm 0.007$
$\Delta\Phi$	$0.7521 \pm 0.0042 \pm 0.0080$	$0.740 \pm 0.010 \pm 0.009$
α_-	$0.7519 \pm 0.0036 \pm 0.0019$	$0.750 \pm 0.009 \pm 0.004$
α_+	$-0.7559 \pm 0.0036 \pm 0.0029$	$-0.758 \pm 0.010 \pm 0.007$
A_{CP}	$-0.0025 \pm 0.0046 \pm 0.0011$	$-0.006 \pm 0.012 \pm 0.007$
α_{avg}	$0.7542 \pm 0.0010 \pm 0.0020$	----

More than 10 standard deviation shift from all previous measurements





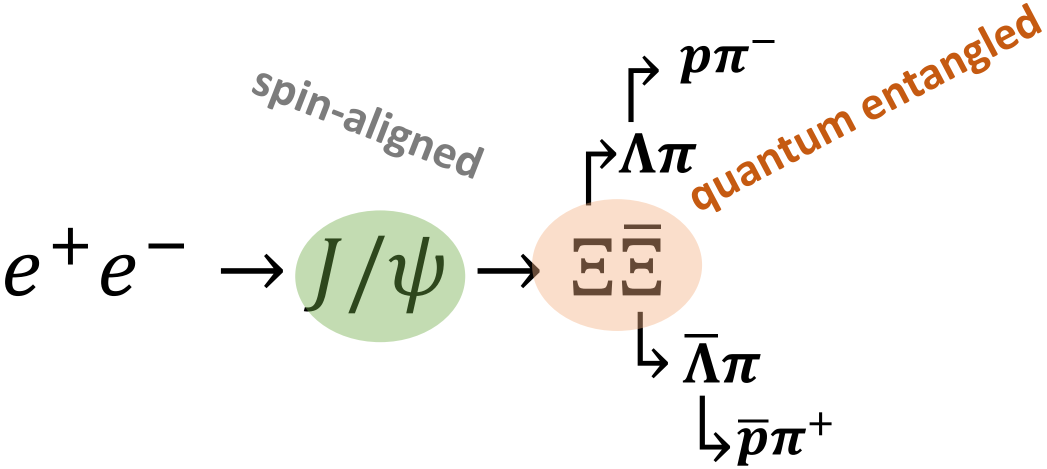
Sensitivity of A_{CP} : below 0.5% unprecedented precision

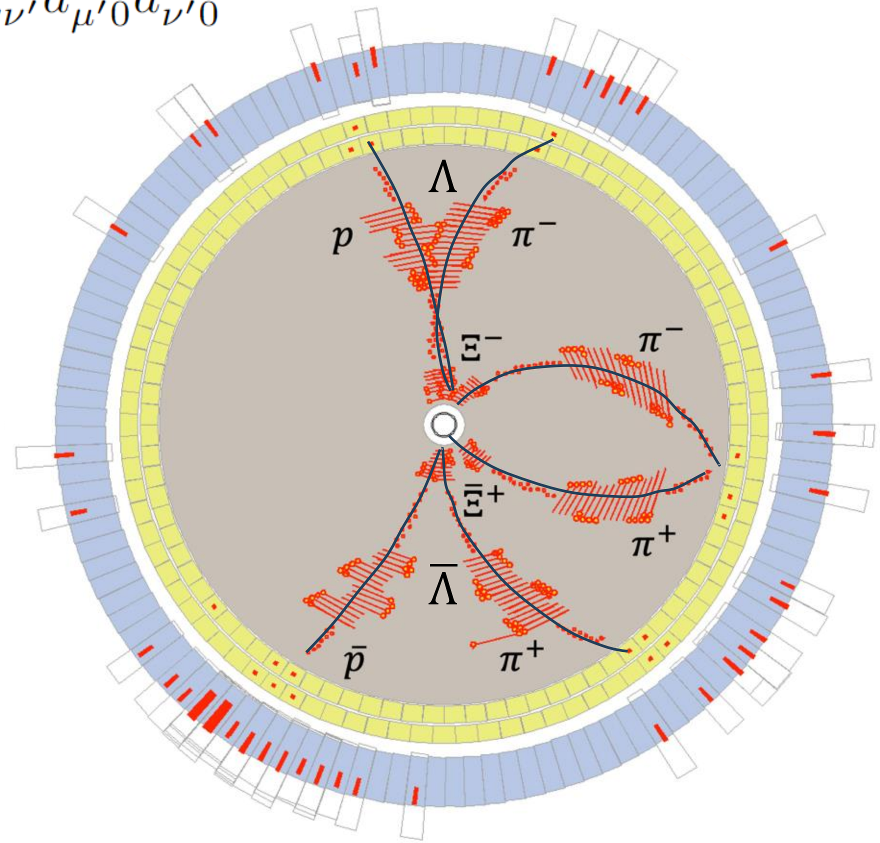
Standard model prediction : A_{CP}~ 10^{-4} (PRD 34, 833 (1986))

Search for CPV in Ξ decay

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

$$\mathcal{W}(\vec{\omega},\vec{\zeta}) = \sum_{\mu,\nu=0}^{3} C_{\mu\nu} \sum_{\mu'=0}^{3} \sum_{\nu'=0}^{3} a^{\Xi}_{\mu\mu'} a^{\bar{\Xi}}_{\nu\nu'} a^{\Lambda}_{\mu'0} a^{\bar{\Lambda}}_{\nu'0}$$





Through the sequential decays of Ξ, the CPV phase can be directly measured!

The *perfect* reaction for hyperon CPV searches!

BESIII

Search for CPV in Ξ decay

Ξ^- 1.3 billion J/ψ

The precision of our analysis (73K $\Xi^-\bar{\Xi}^+$) is comparable with the measurement from HyperCP (144M events), which means that the accuracy of a single event is more than 1000 times higher than HyperCP!

320K $\Xi^0\bar{\Xi}^0$ pairs

10 billion J/ψ Ξ^0

Parameter	Nature **606** (2022) 64-69	Previous result
α_ψ	0.586±0.012±0.010	0.58±0.04±0.08
$\Delta\Phi$	1.213±0.046±0.016 rad	–
α_Ξ	−0.376±0.007±0.003	−0.401±0.010
ϕ_Ξ	0.011±0.019±0.009 rad	−0.042 ± 0.011 ± 0.011
$\bar{\alpha}_\Xi$	0.371±0.007±0.002	HyperCP: PRL 93(2004) 011802
$\bar{\phi}_\Xi$	−0.021±0.019±0.007 rad	–
α_Λ	0.757±0.011±0.008	0.750±0.009±0.004
$\bar{\alpha}_\Lambda$	−0.763±0.011±0.007	−0.758±0.010±0.007
$\xi_P-\xi_S$	$(1.2\pm3.4\pm0.8)\times10^{-2}$ rad	–
$\delta_P-\delta_S$	$(-4.0\pm3.3\pm1.7)\times10^{-2}$ rad	$(10.2\pm3.9)\times10^{-2}$ rad
A^Ξ_{CP}	$(6\pm13\pm6)\times10^{-3}$	–
$\Delta\phi^\Xi_{CP}$	$(-5\pm14\pm3)\times10^{-3}$ rad	–
A^Λ_{CP}	$(-4\pm12\pm9)\times10^{-3}$	$(-6\pm12\pm7)\times10^{-3}$
$\langle\phi_\Xi\rangle$	0.016±0.014±0.007 rad	

Parameter	Phys. Rev. D 108, L031106 (2023)
$\alpha_{J/\psi}$	$0.514 \pm 0.006 \pm 0.015$
$\Delta\Phi$(rad)	$1.168 \pm 0.019 \pm 0.018$
α_Ξ	$-0.3750 \pm 0.0034 \pm 0.0016$
$\bar{\alpha}_\Xi$	$0.3790 \pm 0.0034 \pm 0.0021$
ϕ_Ξ(rad)	$0.0051 \pm 0.0096 \pm 0.0018$
$\bar{\phi}_\Xi$(rad)	$-0.0053 \pm 0.0097 \pm 0.0019$
α_Λ	$0.7551 \pm 0.0052 \pm 0.0023$
$\bar{\alpha}_\Lambda$	$-0.7448 \pm 0.0052 \pm 0.0017$
$\xi_P-\xi_S$(rad)	$(0.0 \pm 1.7 \pm 0.2) \times 10^{-2}$
$\delta_P-\delta_S$(rad)	$(-1.3 \pm 1.7 \pm 0.4) \times 10^{-2}$
A^Ξ_{CP}	$(-5.4 \pm 6.5 \pm 3.1) \times 10^{-3}$
$\Delta\phi^\Xi_{CP}$(rad)	$(-0.1 \pm 6.9 \pm 0.9) \times 10^{-3}$
A^Λ_{CP}	$(6.9 \pm 5.8 \pm 1.8) \times 10^{-3}$
$\langle\alpha_\Xi\rangle$	$-0.3770 \pm 0.0024 \pm 0.0014$
$\langle\phi_\Xi\rangle$(rad)	$0.0052 \pm 0.0069 \pm 0.0016$
$\langle\alpha_\Lambda\rangle$	$0.7499 \pm 0.0029 \pm 0.0013$

First measurements of the weak (CPV) phase difference in Ξ^-/Ξ^0 decays

Three CP tests in Ξ^-/Ξ^0 decays

The results of 10B J/ψ is on the way!

PRD(L) Editor's Suggestion

Polarization and CP test in $\Sigma^+\bar{\Sigma}^-$ J/ψ and $\psi(2S) \to \Sigma^+\bar{\Sigma}^-$

$$e^+e^- \to J/\psi, \psi(3686) \to \Sigma^+\bar{\Sigma}^-,\ \Sigma^+ \to p\pi^0,\ \bar{\Lambda} \to \bar{p}\pi^0$$

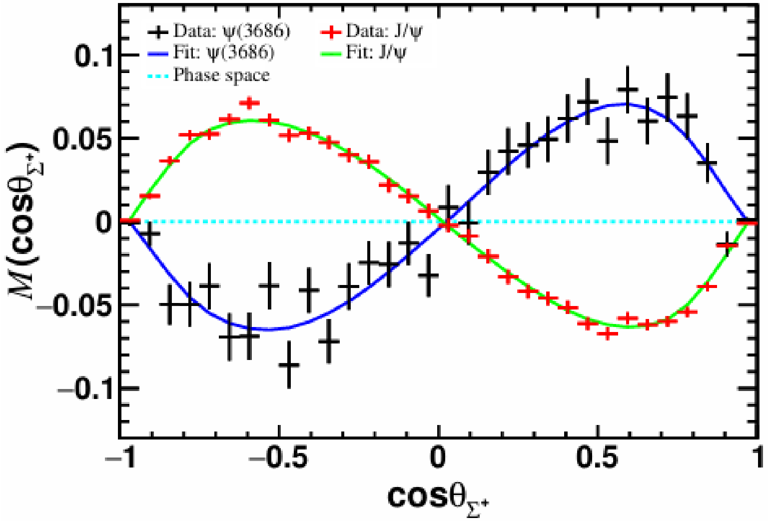
arXiv:2503.17165, submitted to PRL

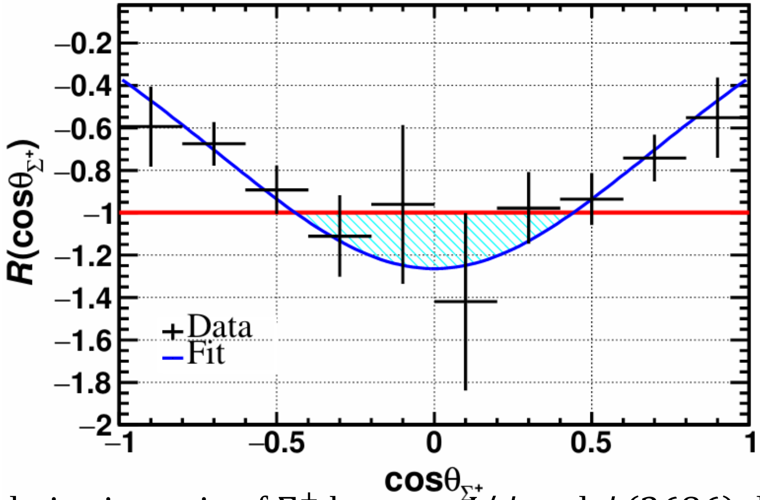
10B J/ψ and 2.7B $\psi(3686)$ 1.12 M $\Sigma^+\bar{\Sigma}^-$ pairs reconstructed

Parameter	This Letter	Phys. Rev. Lett. 131, 191802 (2023)
$\alpha_{J/\psi}$	$-0.5047 \pm 0.0018 \pm 0.0010$	$-0.508 \pm 0.006 \pm 0.004$
$\Delta\Phi_{J/\psi}$	$-0.2744 \pm 0.0033 \pm 0.0010$	$-0.270 \pm 0.012 \pm 0.009$
α_0	$-0.975 \pm 0.011 \pm 0.002$	$-0.998 \pm 0.037 \pm 0.009$
$\bar{\alpha}_0$	$0.999 \pm 0.011 \pm 0.004$	$0.990 \pm 0.037 \pm 0.011$
$\alpha_{\psi(3686)}$	$0.7133 \pm 0.0094 \pm 0.0065$	$0.682 \pm 0.030 \pm 0.011$
$\Delta\Phi_{\psi(3686)}$	$0.427 \pm 0.022 \pm 0.003$	$0.379 \pm 0.070 \pm 0.014$
$\langle\alpha_0\rangle$	$-0.9869 \pm 0.0011 \pm 0.0016$	$-0.994 \pm 0.004 \pm 0.002$
A_{CP}	$-0.0118 \pm 0.0083 \pm 0.0028$	$0.004 \pm 0.037 \pm 0.010$

- Opposite directions of the Σ^+ polarization in J/ψ and $\psi(3686)$ decays
- Most precise measurements of the Σ^+ decay parameters
- Most precise CP test in the decays of Σ^+

Polarizations of Σ^+





Polarization ratio of Σ^+ between J/ψ and $\psi(3686)$ decays

Search for Strong CPV in $\Sigma^0(\to\Lambda\gamma)$ decay

Phys. Rev. Lett. 133 (2024) 10, 101902

The CPV sources in SM:

- Weak interaction, CKM (observed, but too small)
- Strong interaction, θ-term (Not yet observed)

10 B J/ψ and 2.7 B $\psi(3686)$

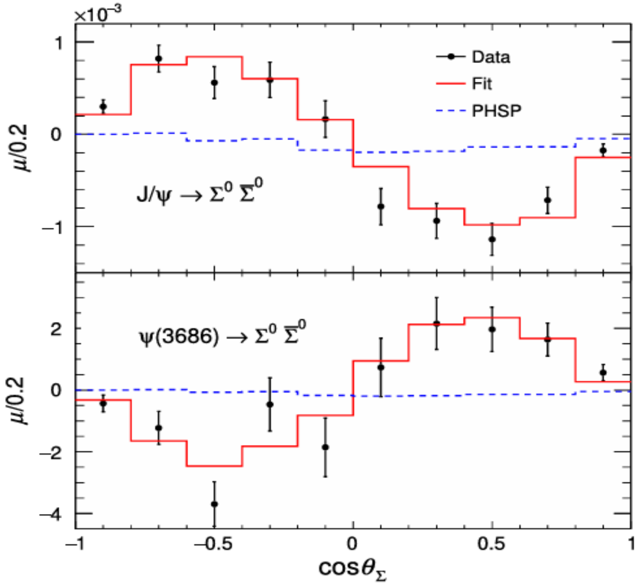
$e^+e^- \to J/\psi, \psi(3686) \to \Sigma^0(\to\Lambda\gamma)\bar{\Sigma}^0(\to\bar{\Lambda}\gamma), \Lambda\to p\pi^-, \bar{\Lambda}\to\bar{p}\pi^+$

Parameter	Phys. Rev. Lett. 133 (2024) 10, 101902
$\alpha_{J/\psi}$	$-0.4133 \pm 0.0035 \pm 0.0077$
$\Delta\Phi_{J/\psi}$ (rad)	$-0.0828 \pm 0.0068 \pm 0.0033$
$\alpha_{\psi(3686)}$	$0.814 \pm 0.028 \pm 0.028$
$\Delta\Phi_{\psi(3686)}$ (rad)	$0.512 \pm 0.085 \pm 0.034$
α_{Σ^0}	$-0.0017 \pm 0.0021 \pm 0.0018$
$\bar{\alpha}_{\Sigma^0}$	$0.0021 \pm 0.0020 \pm 0.0022$
α_{Λ}	$0.730 \pm 0.051 \pm 0.011$
$\bar{\alpha}_{\Lambda}$	$-0.776 \pm 0.054 \pm 0.010$
A_{CP}^{Σ}	$(0.4 \pm 2.9 \pm 1.3) \times 10^{-3}$
A_{CP}^{Λ}	$(-3.0 \pm 6.9 \pm 1.5) \times 10^{-2}$

Phys. Lett. B **788**, 535 (2019)

The Transition EDM of $\Sigma^0(\to\Lambda\gamma)$ —SU(3) symmetry→ Neutron EDM

$$\frac{d_{\Sigma\Lambda}}{d_n} = \frac{d_{\Sigma\Lambda}^{\text{tree}} + d_{\Sigma\Lambda}^{\text{loop}}}{d_n^{\text{tree}} + d_n^{\text{loop}}} \approx -0.88$$



Polarizations of Σ^0

Similar behavior is observed in Σ^+, but not in Λ or Ξ!

Opposite directions of the Σ^0 polarization

The first attempt to measure the P-violating decay parameter of $\Sigma\to\Lambda\gamma$.

The first strong-CP test in hyperon decays.

More and more J/ψ needed

BESIII collected
10 billion J/ψ
(4 million hyperons)

Current technology “Topup” × 2 +
improved technology “monochromatic collision” × 10 +
Someday with new facility (J/ψ factory) × 100

10^{13} J/ψ per year

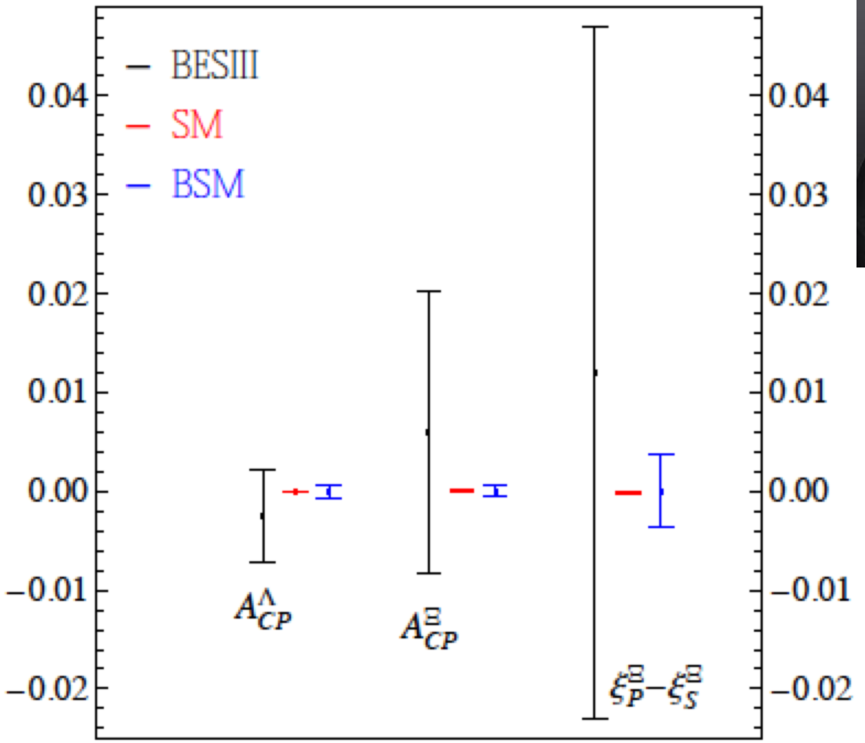
10 Billions of hyperon pairs produced

Billion of hyperon pairs reconstructed

CPV: $10^{-4} - 10^{-5}$

Challenge the Standard Model

X.G. He et al. Sci.Bull. 67 (2022) 1840-1843:



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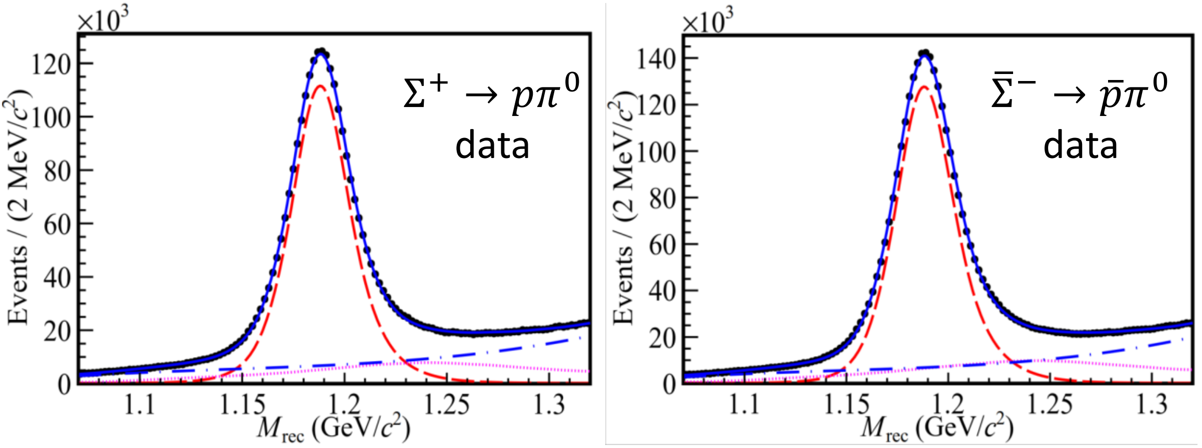
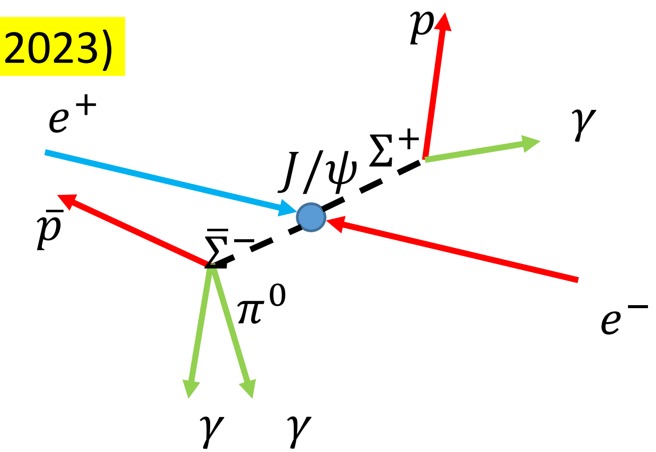
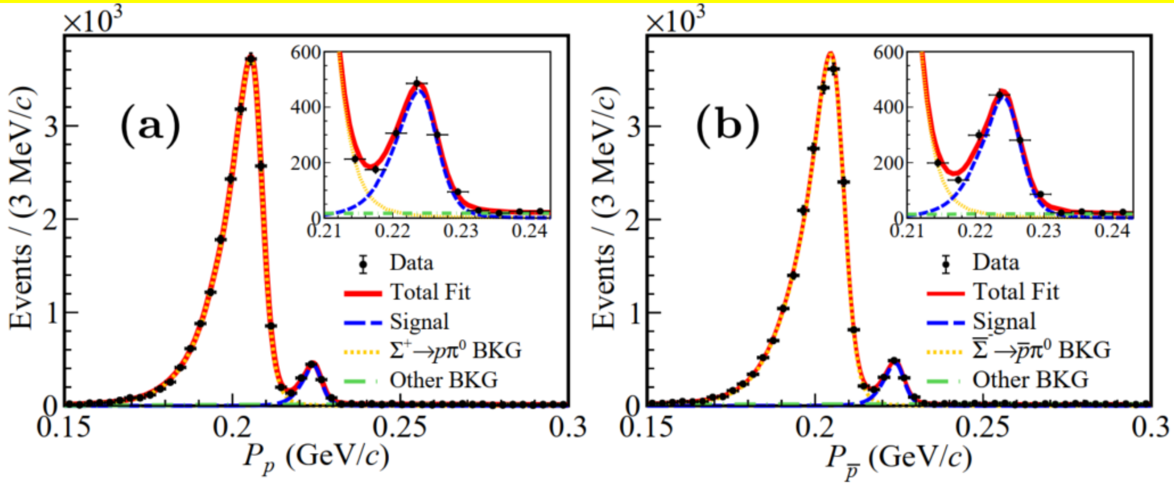
Radiative decay: $\Sigma^+ \to p\gamma$ in $J/\psi \to \Sigma^+\bar{\Sigma}^-$



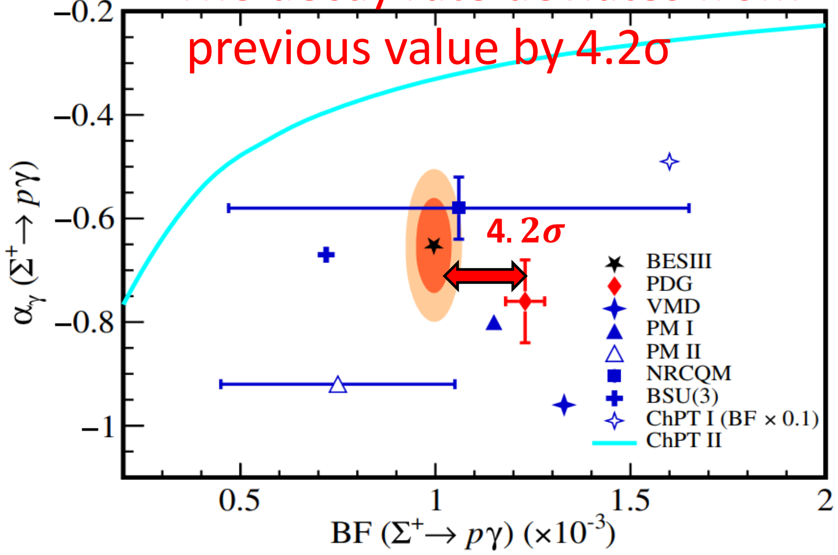
BESIII: PRL130, 211901(2023)



Signal side: momentum distributions of proton in the rest frame of Σ :



The decay rate deviates from previous value by 4.2σ



The CP asymmetry is calculated to be

$$A_{CP} = (\alpha_- + \alpha_+)/(\alpha_- - \alpha_+) = 0.095 \pm 0.087 \pm 0.022$$

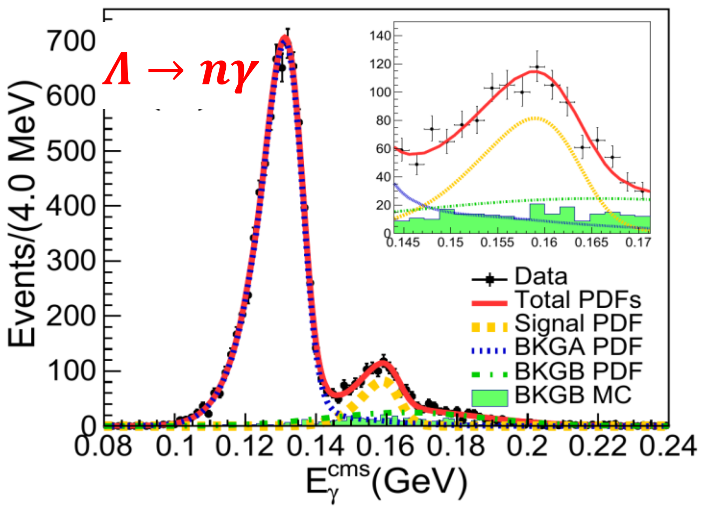
$$\Delta_{CP} = (\mathcal{B}_+ - \mathcal{B}_-)/(\mathcal{B}_+ + \mathcal{B}_-) = 0.006 \pm 0.011 \pm 0.006$$

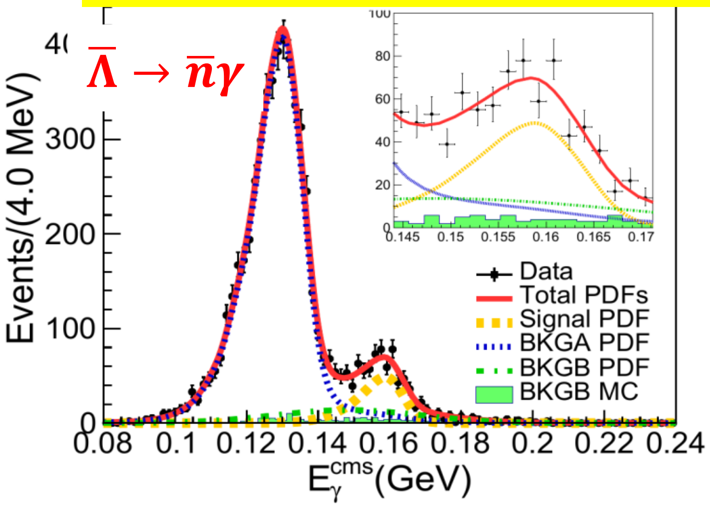
The decay rate $(0.996 \pm 0.022_{stat} \pm 0.017_{syst}) \times 10^{-3}$

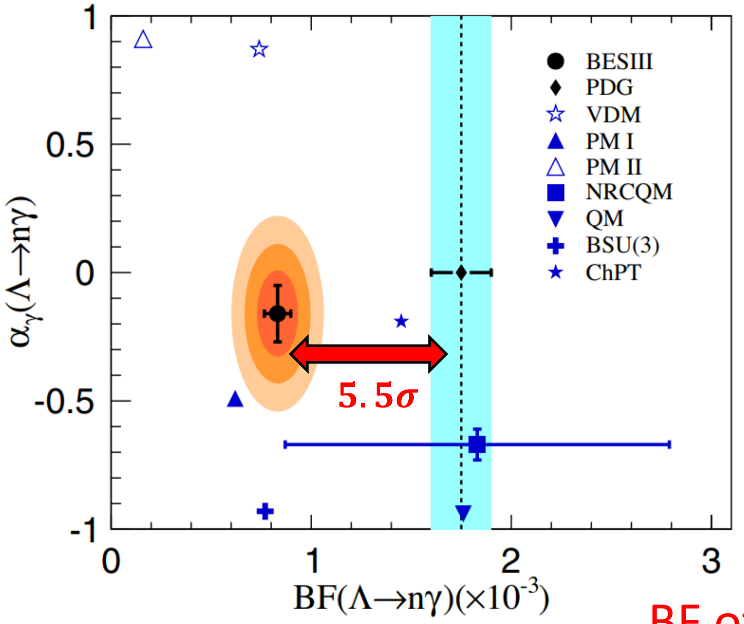
The decay parameter: $-0.651 \pm 0.056_{stat} \pm 0.020_{syst}$

Radiative decay: $\Lambda \to n\gamma$ in $J/\psi \to \Lambda\bar{\Lambda}$

BESIII: PRL 129, 212002 (2022)







Variables	$\Lambda \to \gamma n$	$\bar{\Lambda} \to \gamma\bar{n}$
BF ($\times 10^3$)	$0.834 \pm 0.046 \pm 0.064$	$0.876 \pm 0.071 \pm 0.082$
α_γ	$-0.13 \pm 0.13 \pm 0.02$	$0.21 \pm 0.15 \pm 0.06$
Δ_{CP}	$-0.025 \pm 0.049 \pm 0.060$	
A_{CP}	$-0.25 \pm 0.61 \pm 0.15$	

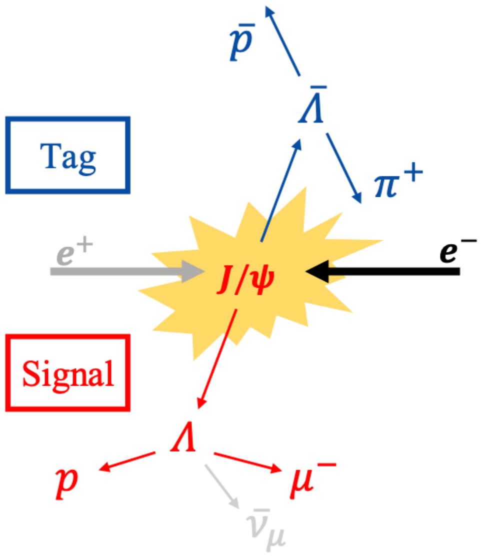
Theoretical attentions: L.S. Geng, Q. Zhao, R.M. Wang et al.

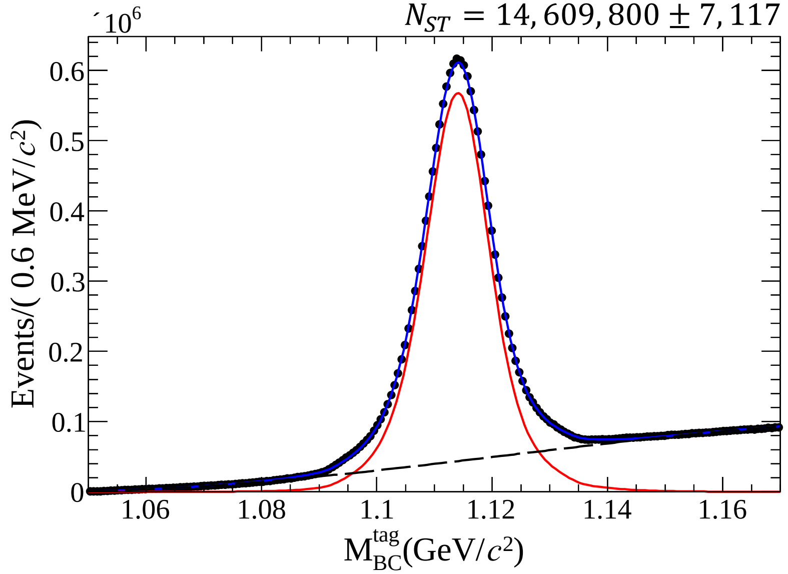
BF of $\Lambda \to n\gamma$, with improved precision, smaller than PDG value by 5.5σ

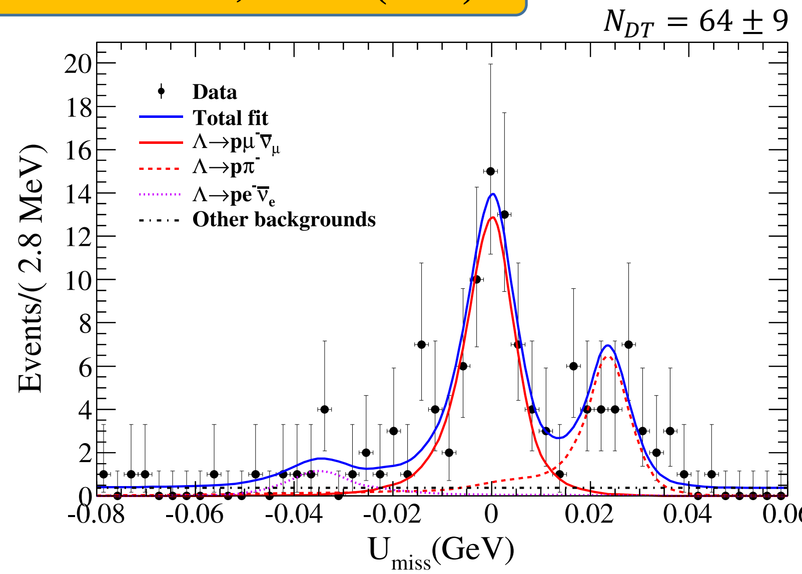
Absolute BF measurement of $\Lambda \to p\mu^-\bar{\nu}_\mu$

The results for $\Lambda \to pe^-\nu e$ will come soon.

Phys. Rev. Lett. 127, 121802 (2021)







First absolute BF measurement

$$\mathcal{B}(\Lambda \to p\mu^-\bar{\nu}_\mu) = (1.48 \pm 0.21 \pm 0.08) \times 10^{-4}$$

- ✓ Update measurement after a 50-year hiatus
- ✓ The first study of its absolute BF
- ✓ The most precise result to date

Test lepton flavor universality

$$R^{\mu e} = \frac{\mathcal{B}(\Lambda \to p\mu^-\bar{\nu}_\mu)}{\mathcal{B}(\Lambda \to pe^-\bar{\nu}_e)_{PDG}} = 0.178 \pm 0.028$$

Consistent with LFU

0.153 ± 0.008

Search for CP violation

$$\Delta_{CP} = \frac{\mathcal{B}_{\Lambda \to p\mu^-\bar{\nu}_\mu} - \mathcal{B}_{\bar{\Lambda} \to \bar{p}\mu^+\nu_\mu}}{\mathcal{B}_{\Lambda \to p\mu^-\bar{\nu}_\mu} + \mathcal{B}_{\bar{\Lambda} \to \bar{p}\mu^+\nu_\mu}} = 0.02 \pm 0.14 \pm 0.02$$

Consistent with CP symmetry

Searching for hyperon EDM at BESIII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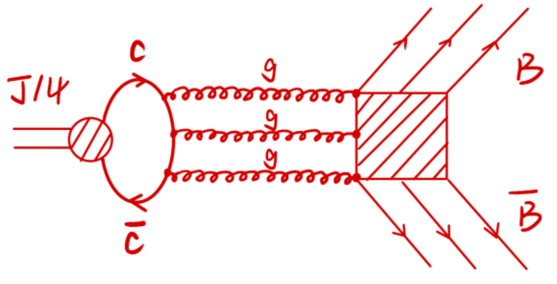
马建平

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

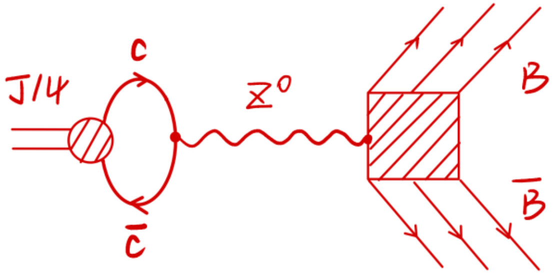
X.G.He, J.P. Ma, Phys.Lett.B 839(2023)137834

$$\mathcal{A} = \epsilon_\mu(\lambda)\bar{u}(\lambda_1)\left(F_V\gamma^\mu + \frac{i}{2M_\Lambda}\sigma^{\mu\nu}q_\nu H_\sigma + \gamma^\mu\gamma^5 F_A + \sigma^{\mu\nu}\gamma^5 q_\nu H_T\right)v(\lambda_2)$$



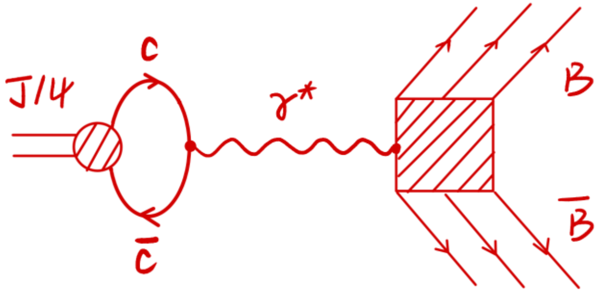
Dominant contribution
arXiv:hep-ph/0412158

Psionic form factor
F_V and H_σ
can also be represented as G_1 and G_2



P violation term

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



H_T is included in this term

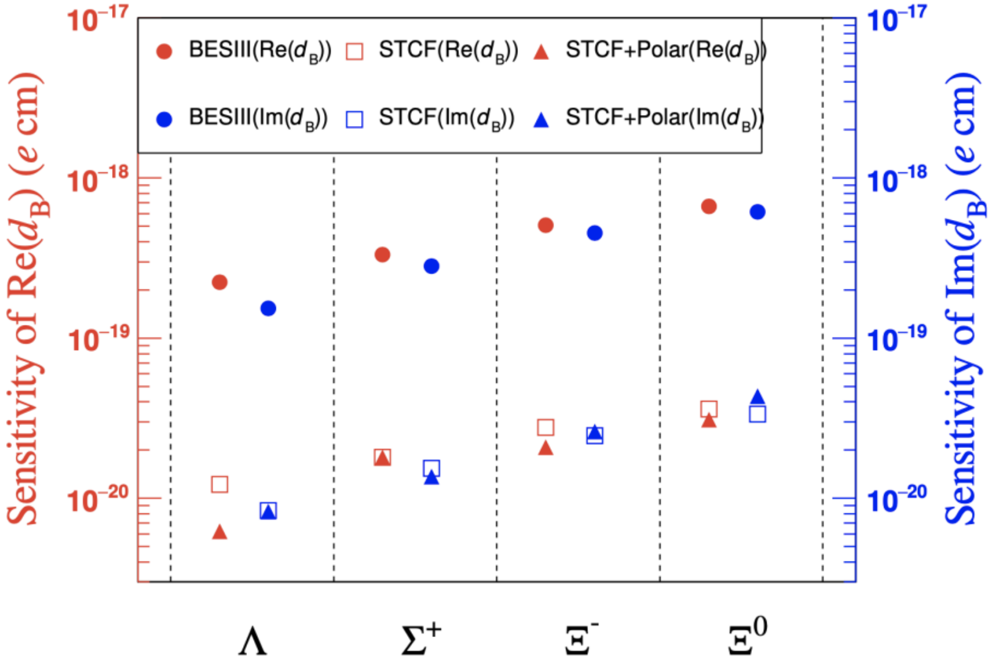
$$H_T(q^2) = \frac{2e}{3m_{J\psi}^2} g_V d_B(q^2)$$

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

$d_B(q^2)$: electric dipole form factor
$d_B(0)$: electric dipole moment
Physics Letters B 551 (2003) 16–26

Sensitivities of hyperon EDM at BESIII

reminder: $H_T = \frac{2e}{3M^2_{J/\psi}} g_V d_B$



(a)Sensitivity of $Re(d_B)$ and $Im(d_B)$

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

BESIII: milestone for hyperon EDM measurement

Λ 10^{-19}e cm (FermiLab 10^{-16} e cm)

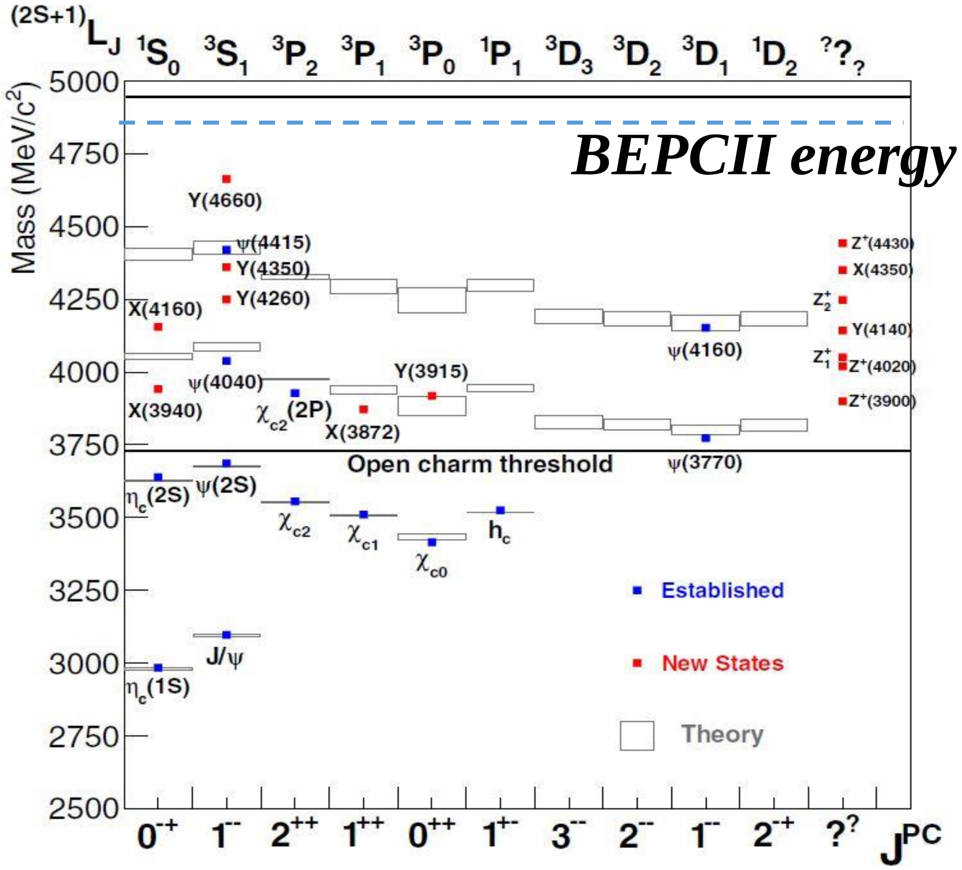
first achievement for Σ^+,Ξ^- and Ξ^0 at level of 10^{-19}e cm

a litmus test for new physics

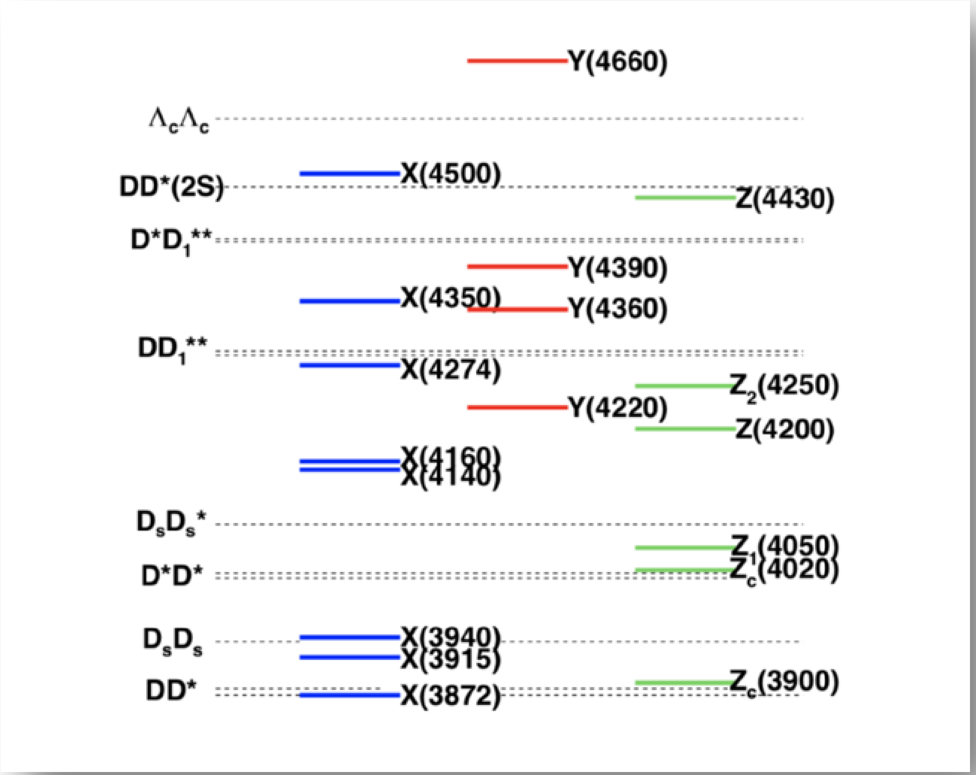
STCF: improved by 2 order of magnitude

Jinlin Fu, Hai-Bo Li, Jianpeng Wang, Fusheng Yu, and Jianyu Zhang, arxiv: 2307.04364

Overpopulated charmonium spectrum



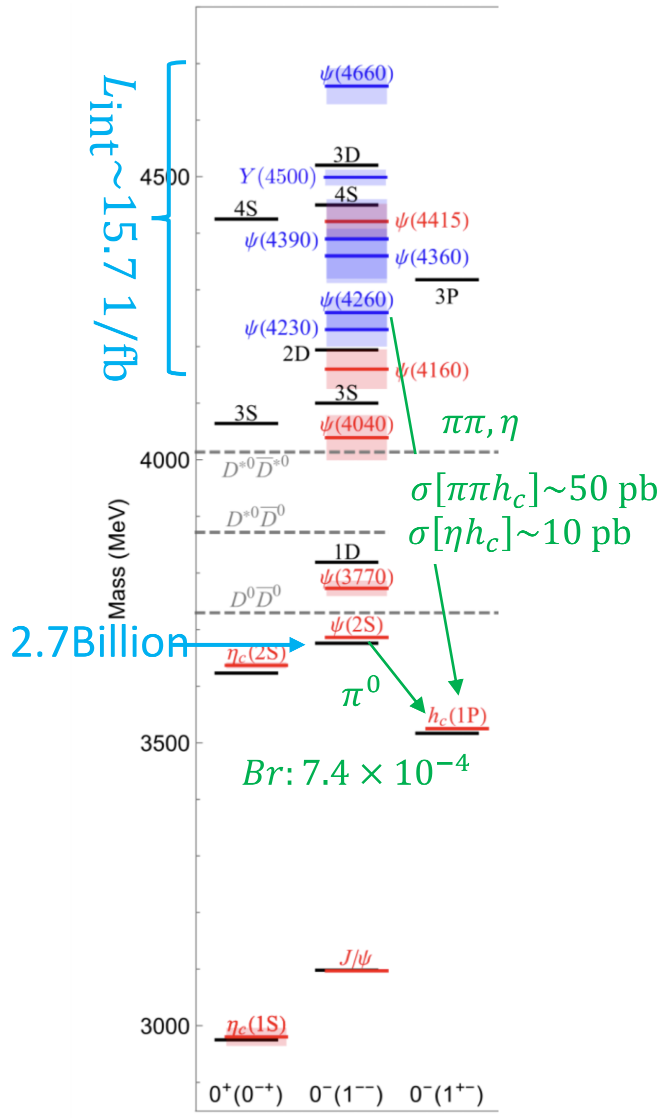
arXiv:1511.01589, arXiv:1812.10947



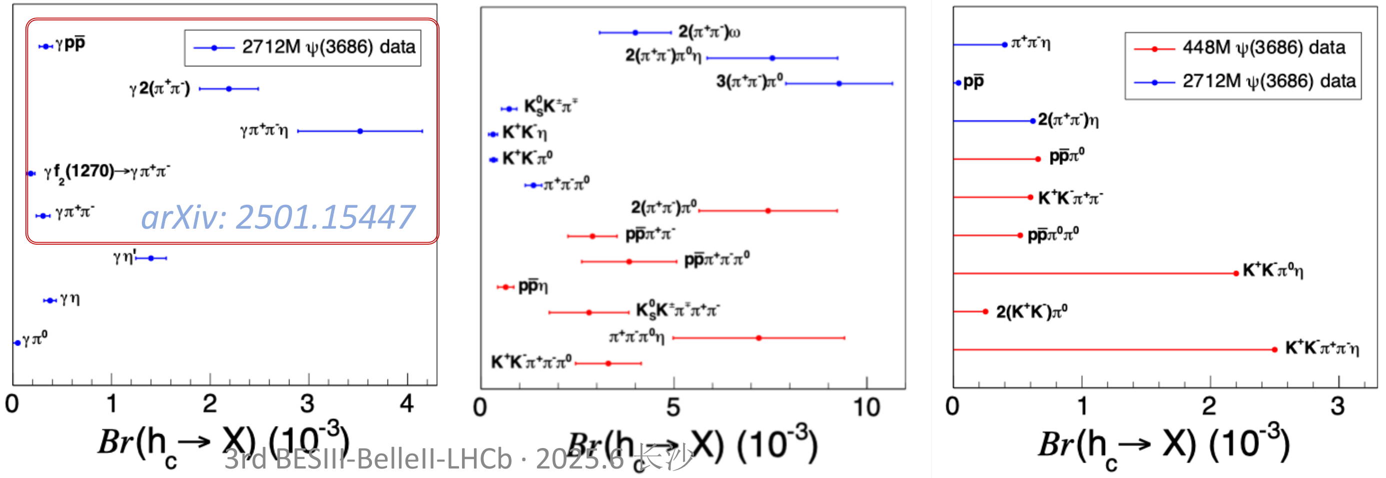
Overpopulated observed charmonium-like states, i.e. “XYZ”:

- 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

BESIII Highlight: Production and decay properties of h_c



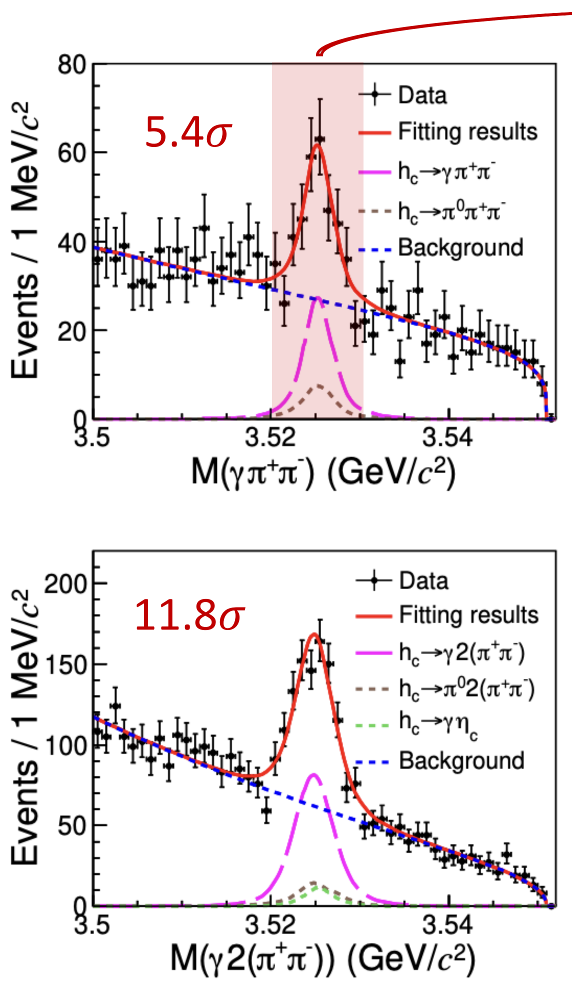
- ***P*-wave singlet charmonium state, first observed by CLEO**
- **First measurement of $B[\psi' \to \pi^0 h_c]$ by BESIII** *PRL95, 102003 (2005)* *PRL104, 132002 (2010)*
- **2M h_c particle in 2.7B ψ' events, possible to explore h_c decay mode with Br~10^{-4}; 0.7M h_c particle from XYZ scan sample**
- **Decay of h_c:**
  - pQCD prediction: $h_c \to \gamma gg$~5.5% *PRD 66, 014012 (2002)*
  - pQCD and NRQCD predictions of h_c →light hadrons: 48% and 8% *PRD 65, 094024 (2002)*

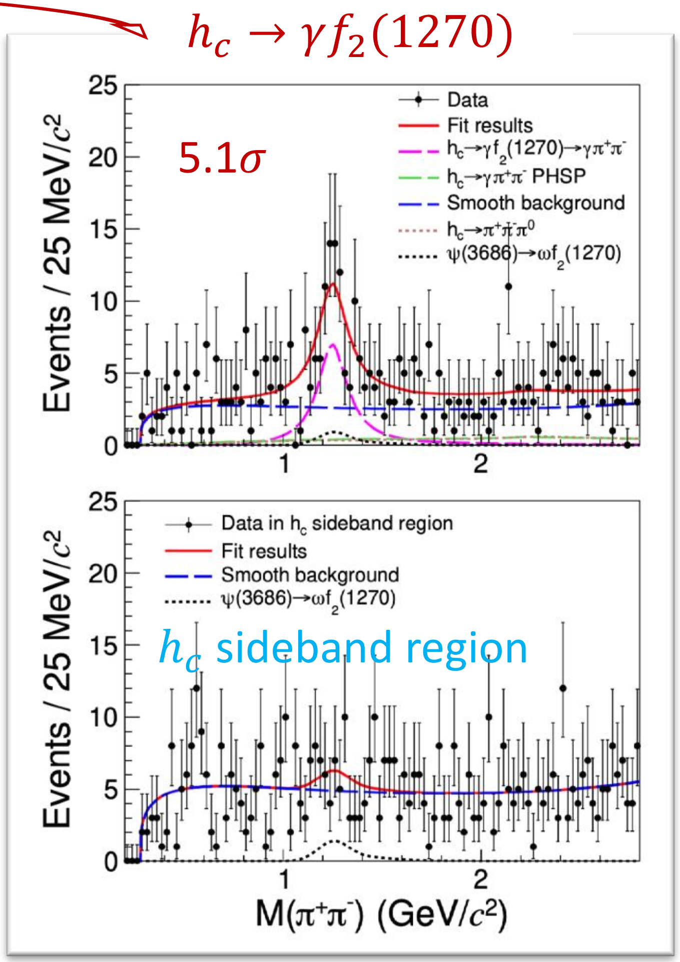


Highlight: Production and decay properties of h_c

Observation of h_c radiative decays and $h_c \to \gamma f_2(1270)$

arXiv: 2501.15447

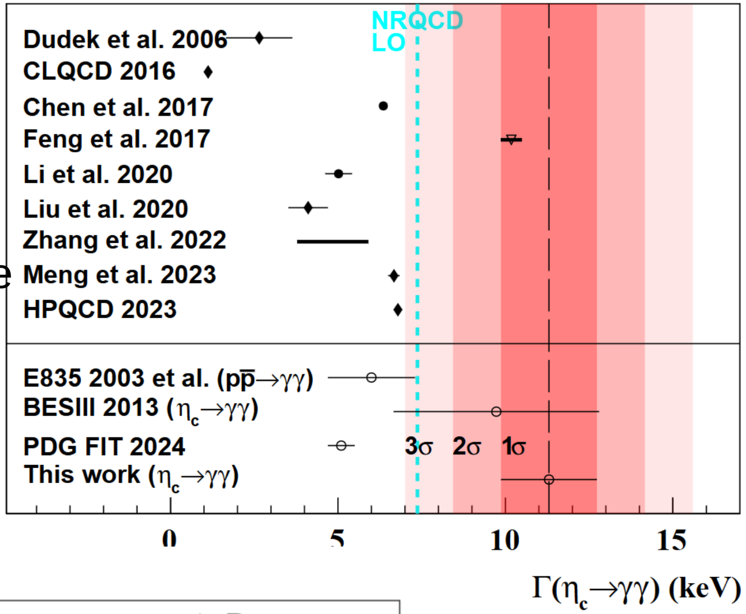




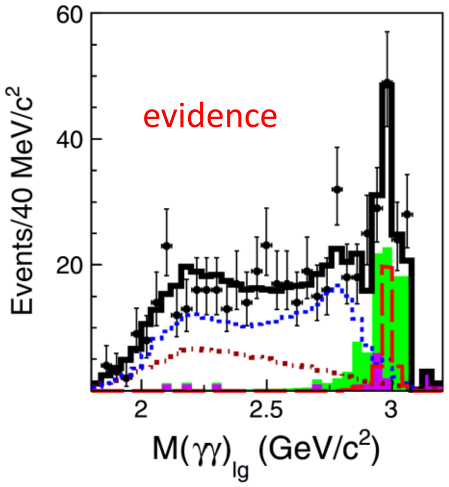
Highlight: measurements of $\eta_c \to \gamma\gamma$

arXiv: 2412.12998
PRL134, 181901 (2025)

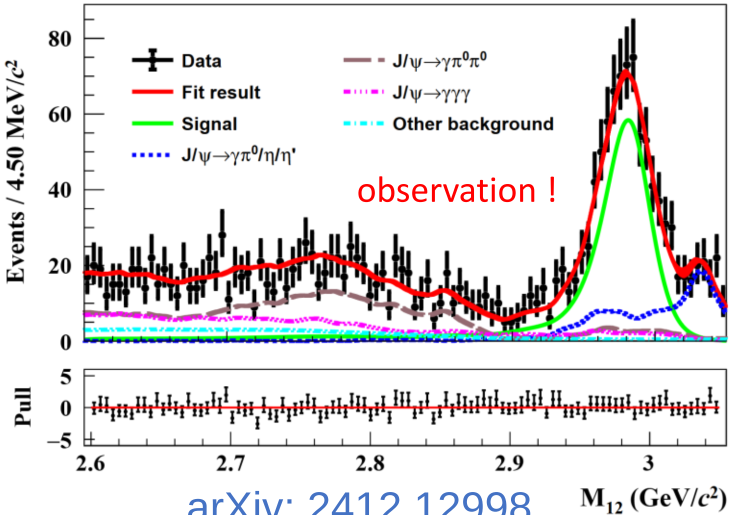
- As the simplest decay of η_c , $\eta_c \to \gamma\gamma$ serves as a benchmark for QCD calculation.
- Most measurements come from the time reversal process $\gamma\gamma^{(*)} \to \eta_c$
- BESIII has the unique opportunity to directly measure $\eta_c \to \gamma\gamma$ via $J/\psi \to \gamma\eta_c$ (first observation) or $h_c \to \gamma\eta_c$ (absolute branching fraction, most precise).
- Measured $B(J/\psi \to \gamma\eta_c) \times B(\eta_c \to \gamma\gamma)$ is consistent with theoretical predictions, while the individual $\Gamma(\eta_c \to \gamma\gamma)$ deviates from the most recent LQCD prediction by more than 3σ.



$$\Gamma(\eta_c \to \gamma\gamma) = (11.30 \pm 0.56_{\text{stat.}} \pm 0.66_{\text{syst.}} \pm 1.14_{\text{ref.}})\ \text{keV}$$

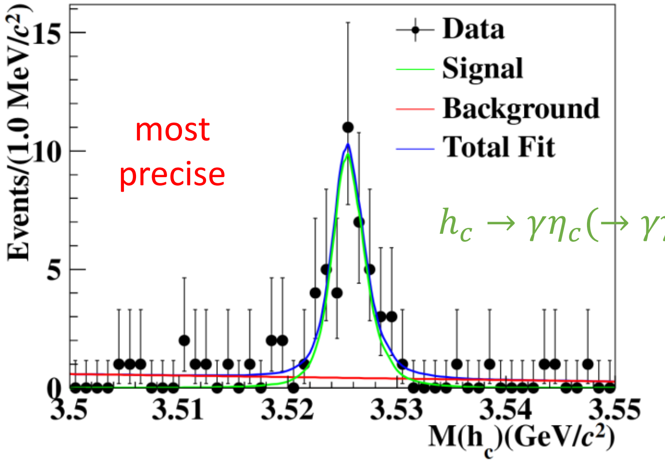


Phys. Rev. D 87 (2013) 3, 032003



arXiv: 2412.12998

$J/\psi \to \gamma\eta_c(\to \gamma\gamma)$



The first measurement of absolute branching fraction via $h_c \to \gamma\eta_c$ will provide a brand new reference

in preparation

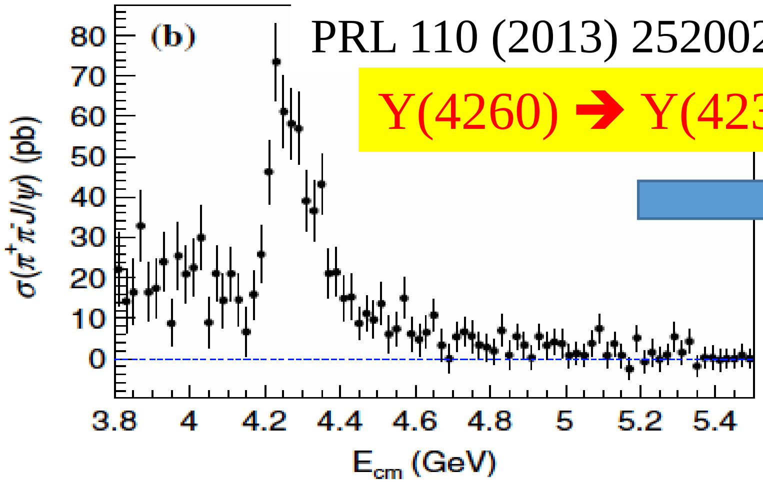
Precise test of LQCD: hyperfine mass splitting

The vector Y states from scan data near open-charm thresholds

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

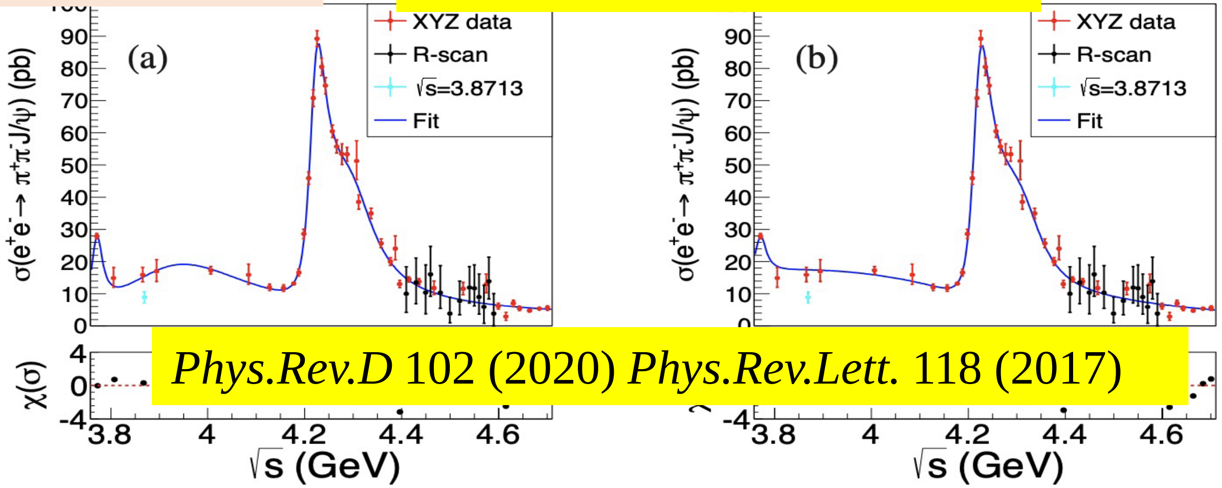
Belle Resolution: about 5-10 MeV

BESIII Resolution: 1 - 2 MeV



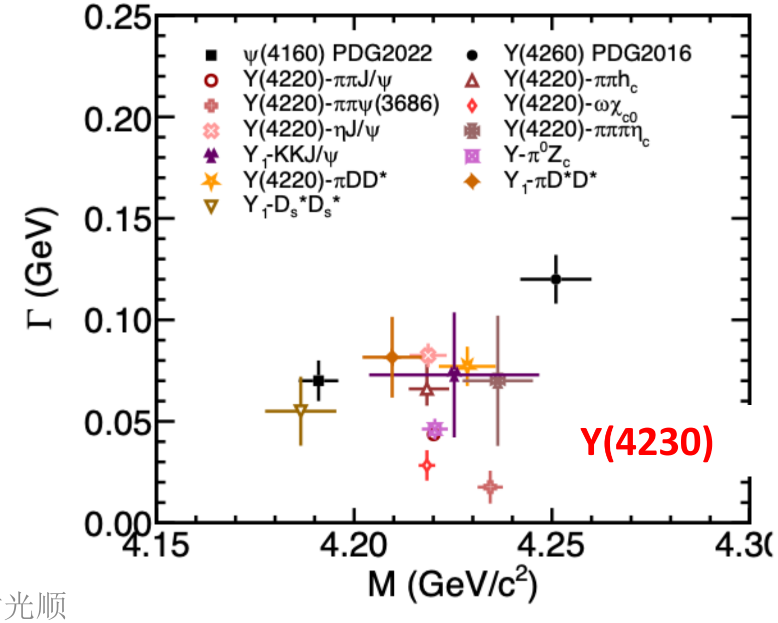
PRL 110 (2013) 252002

Y(4260) ➔ Y(4230)

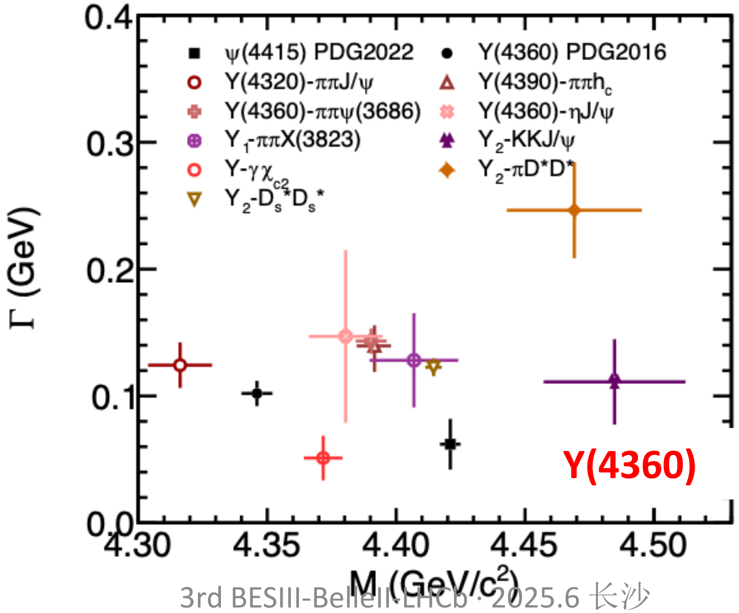


Phys.Rev.D 102 (2020) *Phys.Rev.Lett.* 118 (2017)

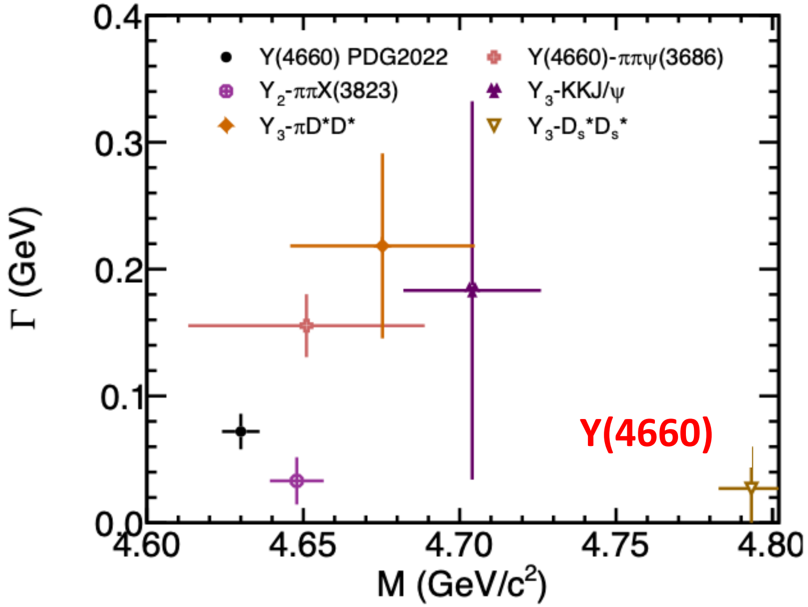
Fine structures of Charmonium-like states are seen at BESIII with scan data!



Y(4230)



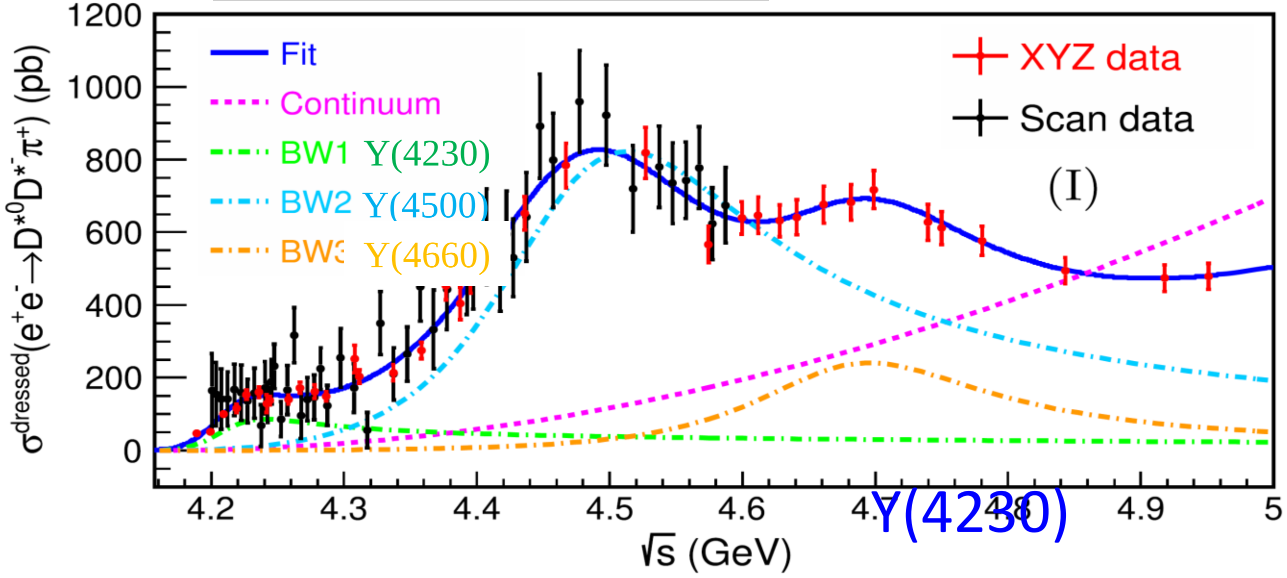
Y(4360)



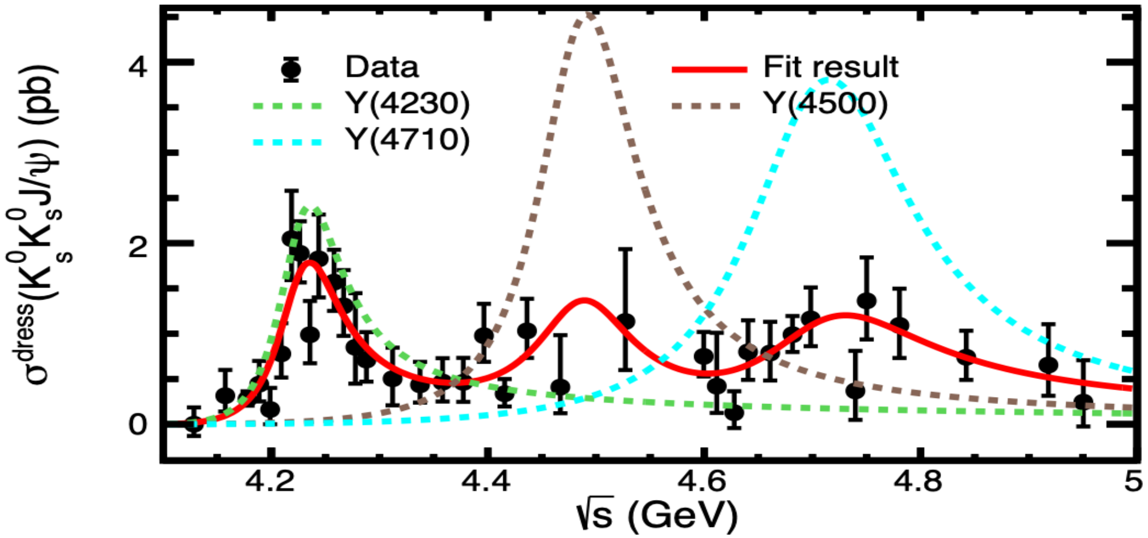
Y(4660)

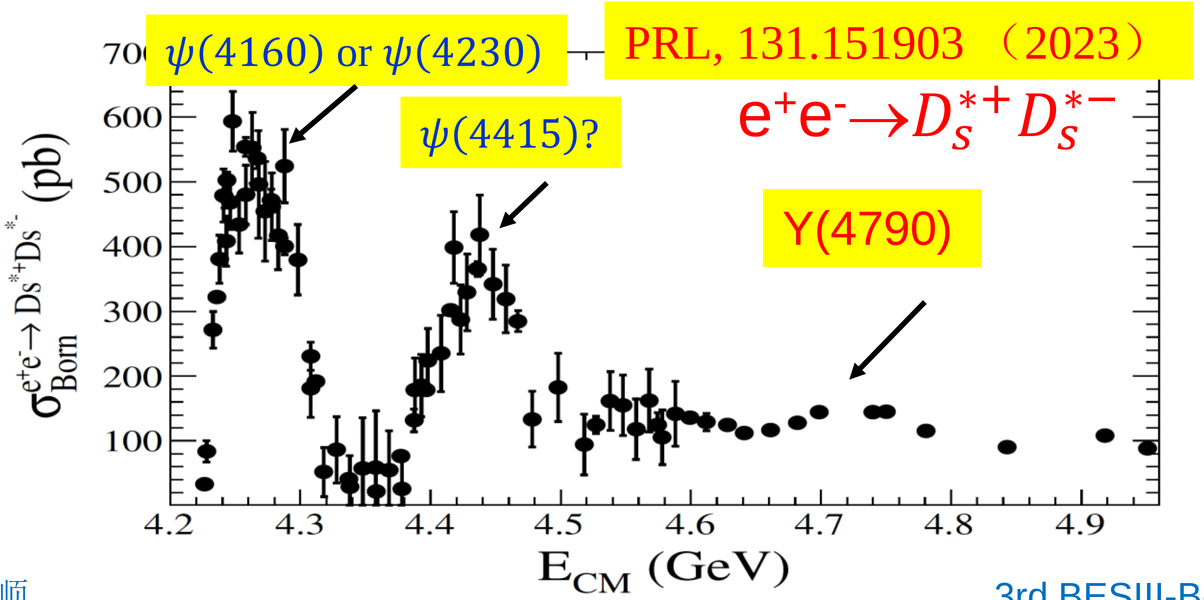
More Y states: Y(4500) ,Y(4710) and Y(4790)

PRL130, 121901 (2023) $e^+e^- \to D^{*0}D^{*-}\pi^+$

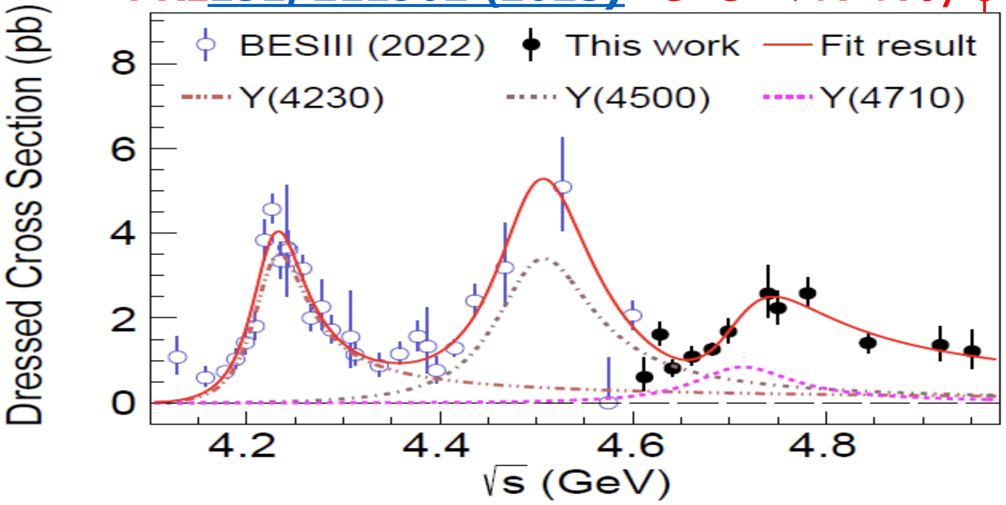


PRD107, 092005 (2023) $e^+e^- \to K_SK_SJ/\psi$

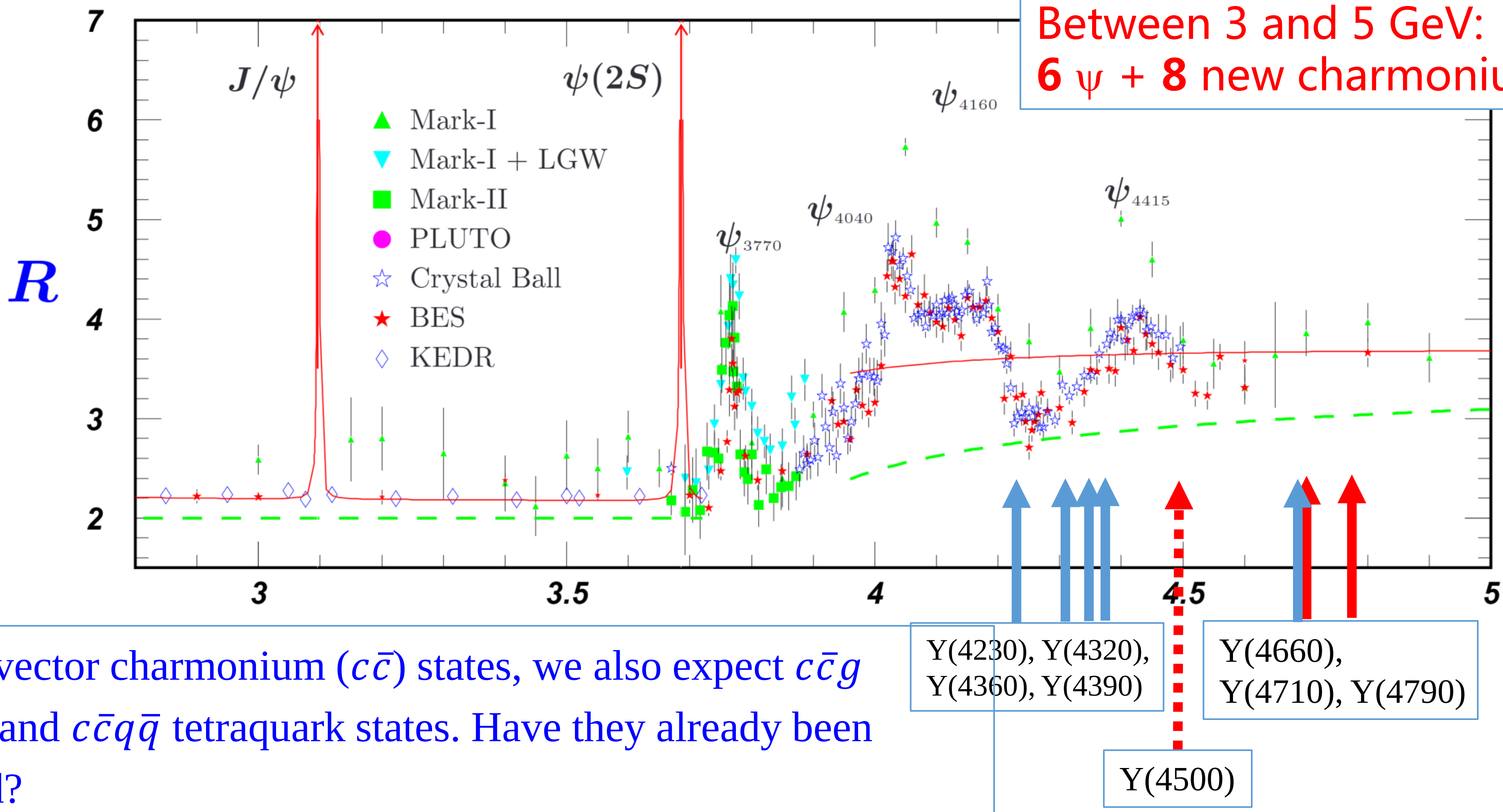




PRL131, 211902 (2023) $e^+e^- \to K^+K^-J/\psi$



How many vectors in charmonium energy region?

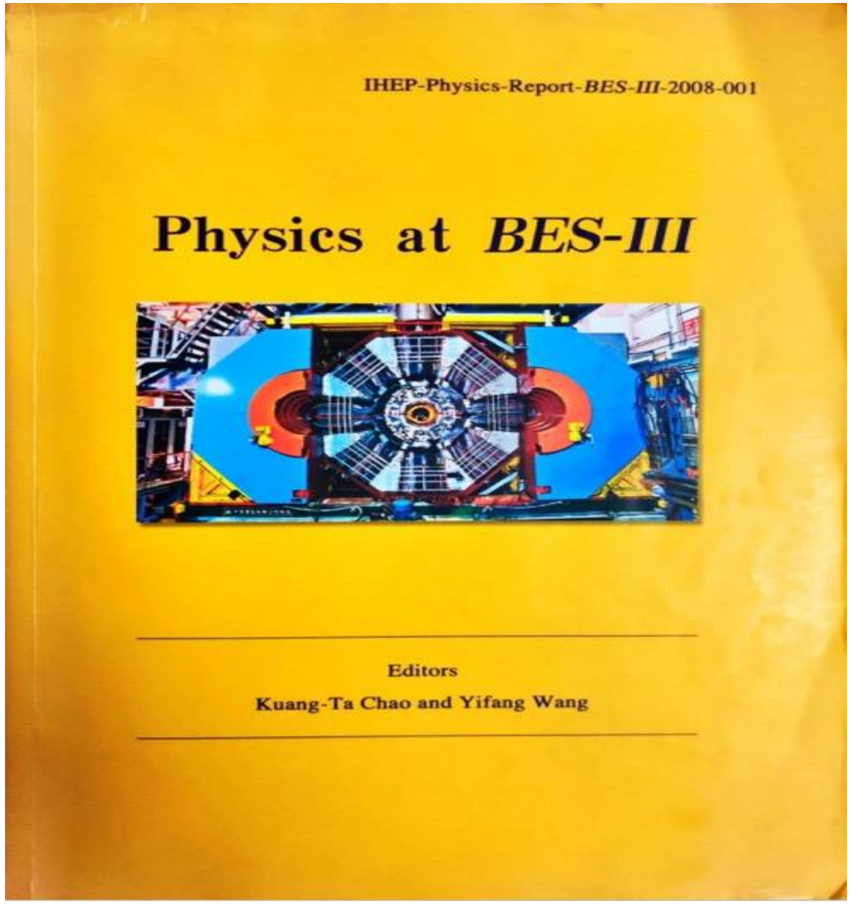


Between 3 and 5 GeV:
6 ψ + **8** new charmonium-like states

Besides vector charmonium ($c\bar{c}$) states, we also expect $c\bar{c}g$ hybrids, and $c\bar{c}q\bar{q}$ tetraquark states. Have they already been observed?

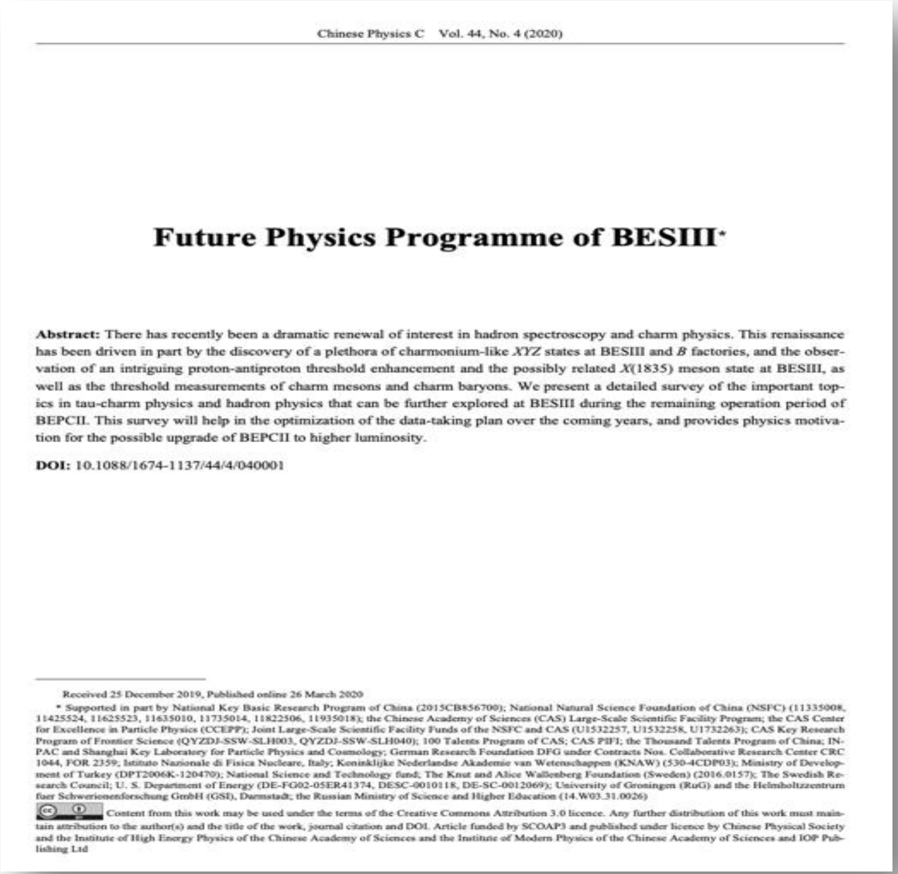
➔ More theoretical/experimental efforts necessary!

BESIII Prospects



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

yellow book


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.

DOI: 10.1088/1674-1137/44/4/040001

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Chin. Phys. C 44, 040001 (2020)
[arXiv:1912.05983 [hep-ex]].

white book

White book: planned future data

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

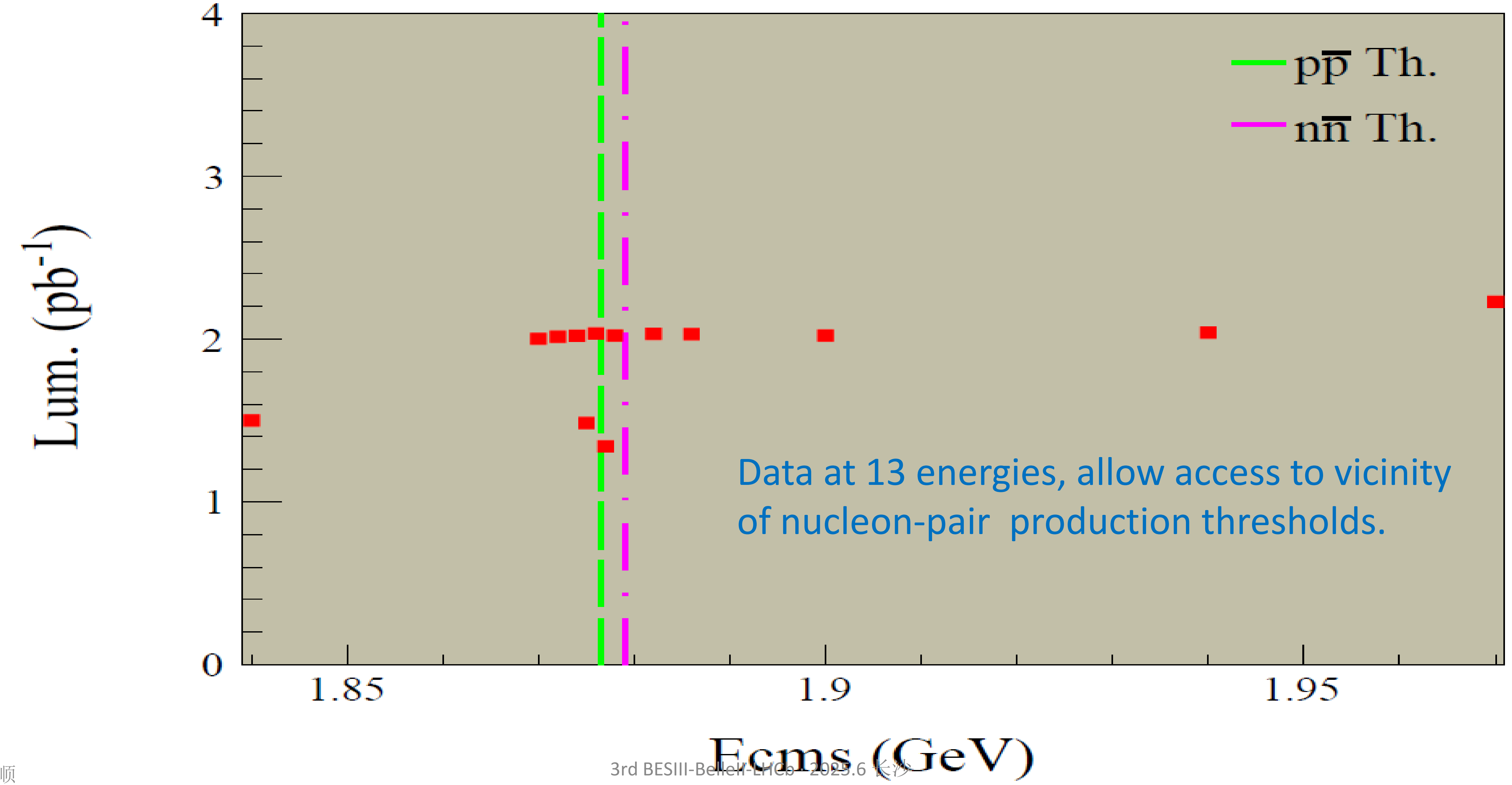
Only part 2024

Completed 2024

BEPCII-U

Another 6 years running to collect >60 fb^{-1} data at different energies .

1.84-1.97 GeV: low extremes of BEPCII



BEPCII upgrades in 2024

BEPCII upgrade (installation: 2024. 7- 2024. 12)

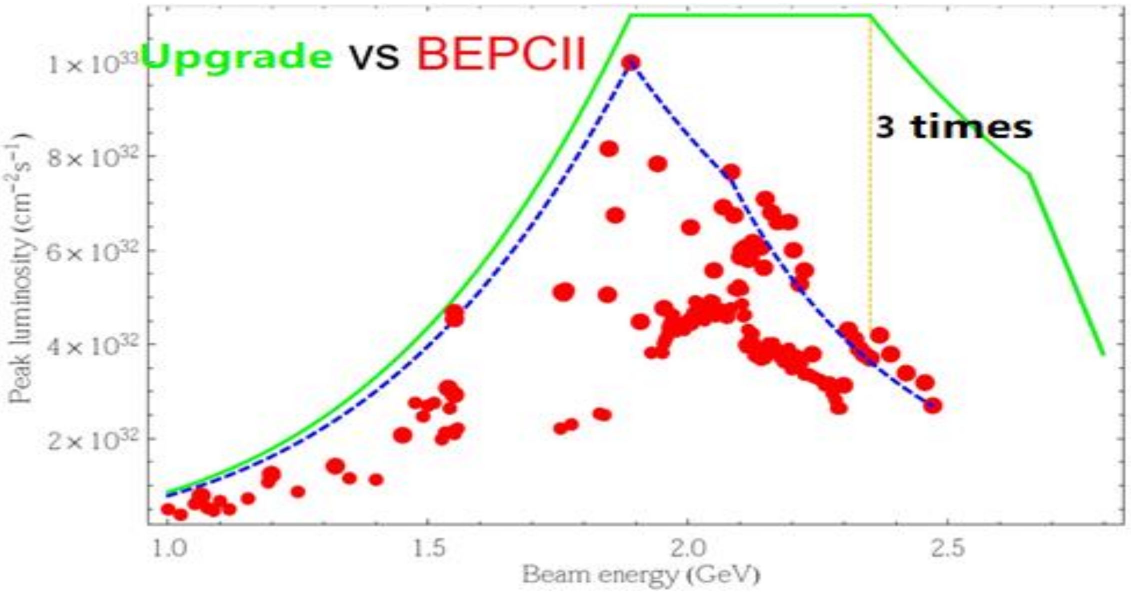
Highest beam energy: 2.8 GeV

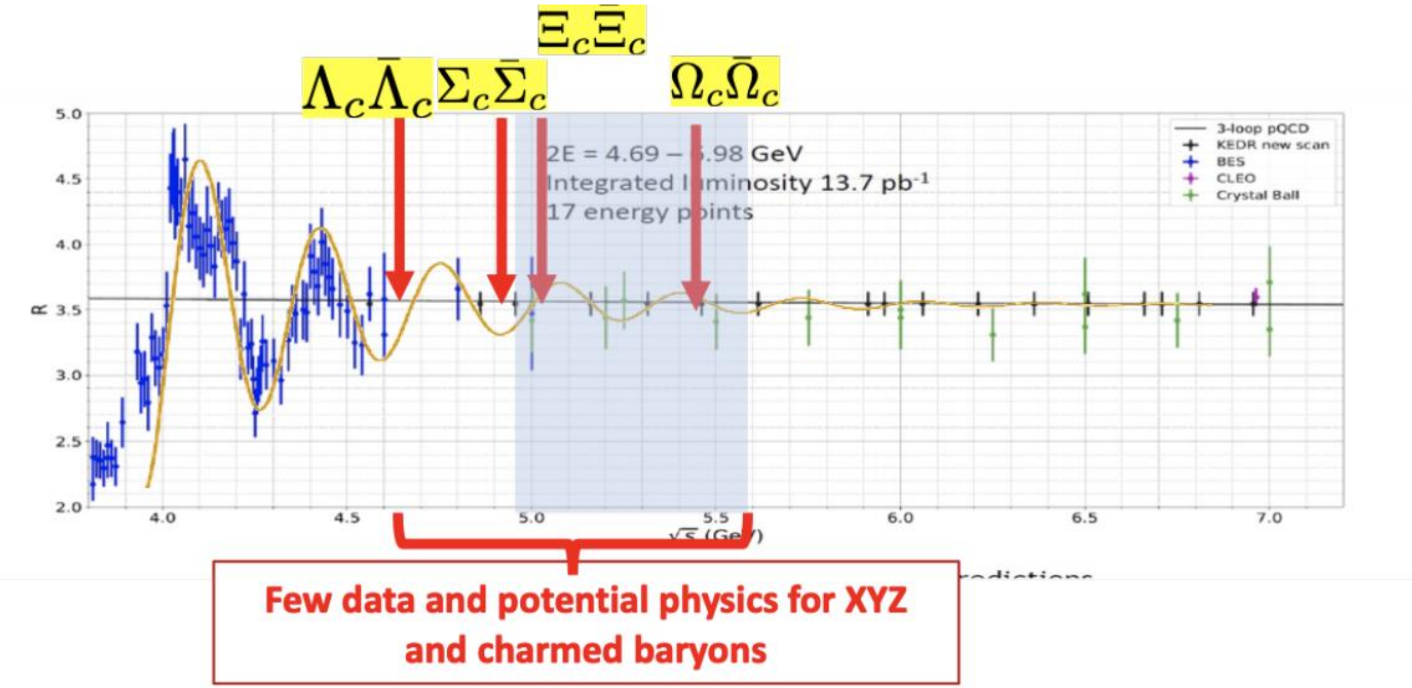
Luminosity: 1.2×10^{33} $cm^{-2}s^{-1}$ （ 4.0 ~ 5.0 GeV）

$(0.4\text{-}0.7) \times 10^{33}$ $cm^{-2}s^{-1}$ （ 5.0 ~ 5.6 GeV）

BESIII will collect about **60 fb^{-1}** between 4.0 – 5.6 GeV, and to study potential physics:

- ✓ Cover energy up to 5.6 GeV
- ✓ Deeper studies of the XYZ states
- ✓ Study the ground-state charmed baryons
- ✓ Provide information on charm-quark fragmentation function



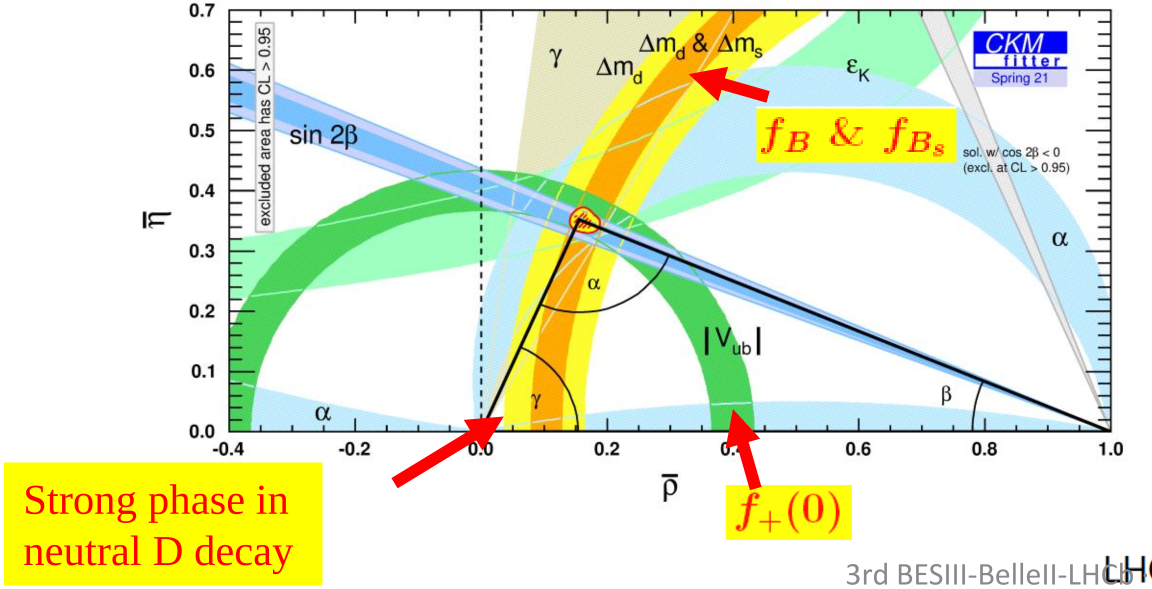


Summary

- BESIII is running smoothly, and very productive now;
- BEPCII upgrades have been finished in 2024, more data taking above 4.0 GeV, up to 5.6 GeV to study: excited charmonium, charmonium-like states, XYZ particles, charmed baryon …
- Advantages at BECPII/BESIII: scan data near thresholds, quantum-entangled meson and baryon pairs
- BESIII plays leading role in hadron physics, flavor physics (charmed hadron and strange hadron).

Charm is still needed for precise test of the SM!

2021



2035