Recent highlights at BESIII and future prospects

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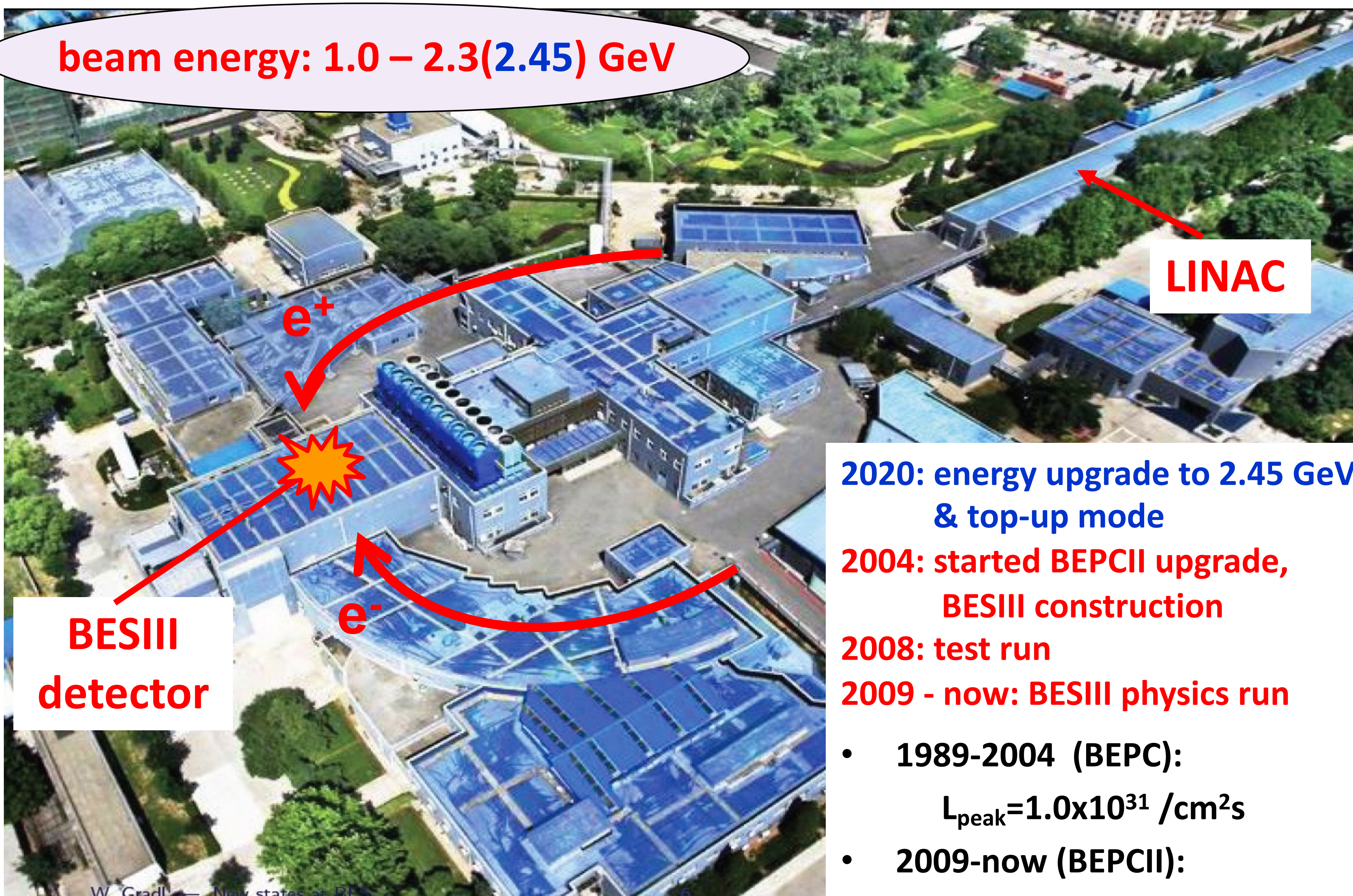
Outline

- BEPCII and BESIII
- Selected recent results
- Future prospects
- Summary

Beijing Electron Positron Collider (BEPCII)

beam energy: 1.0 – 2.3(2.45) GeV



2020: energy upgrade to 2.45 GeV & top-up mode

2004: started BEPCII upgrade, BESIII construction

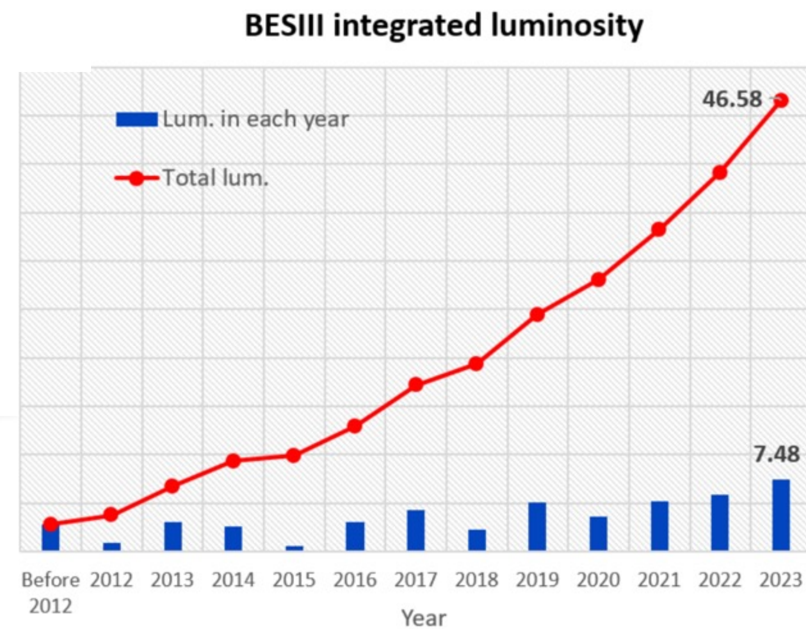
2008: test run

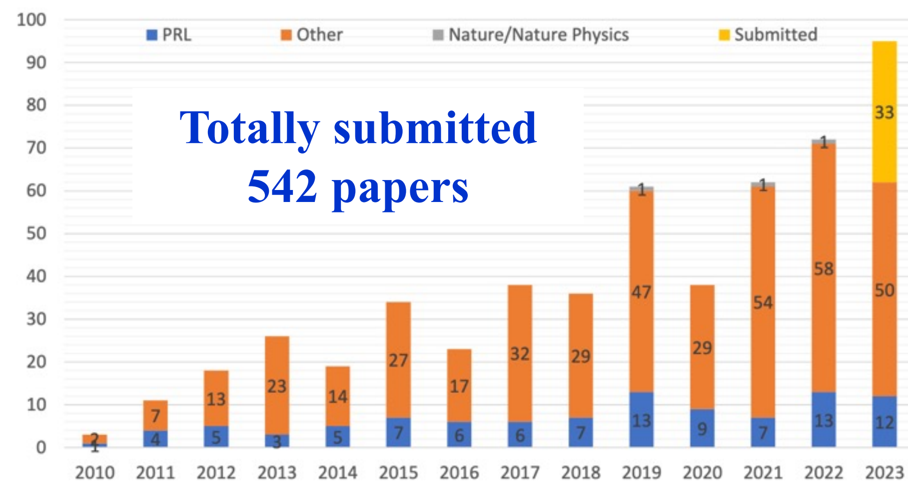
2009 - now: BESIII physics run

- 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)

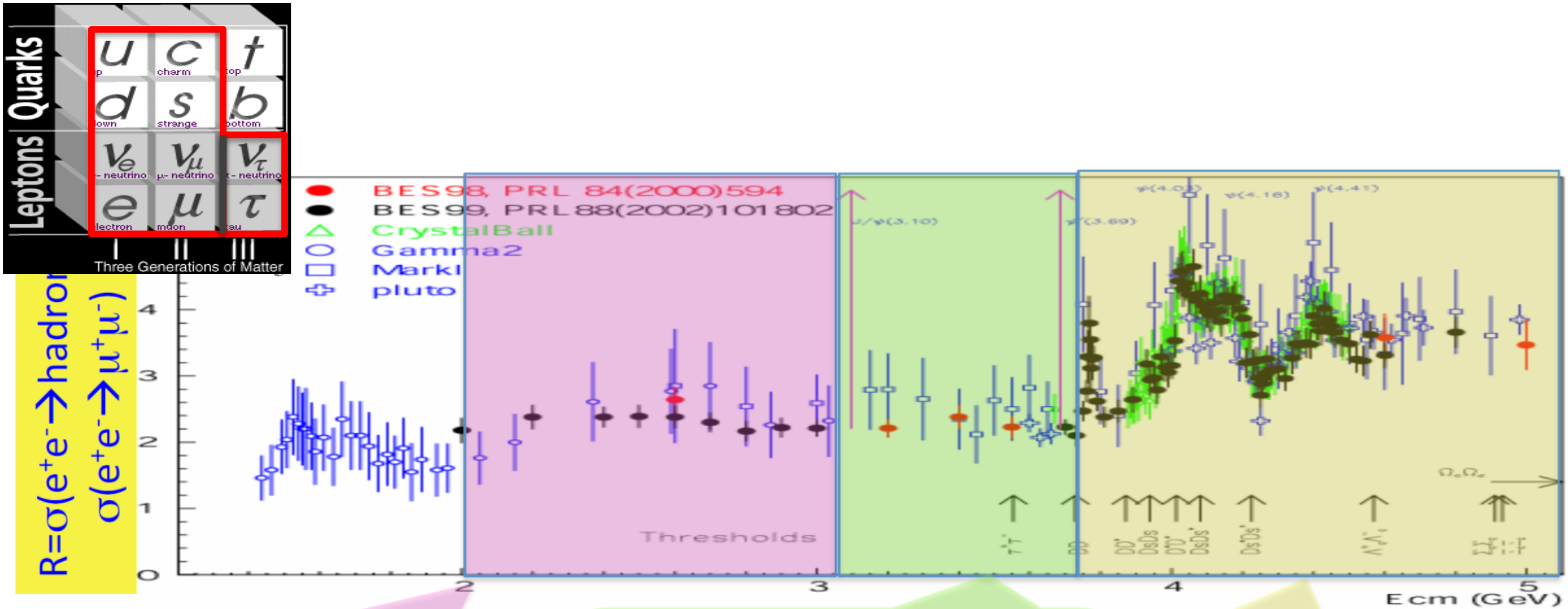
BESIII data sample

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
2020: 3.8 fb^{-1} scan **4.61-4.7 GeV**
2021: 2 fb^{-1} scan **4.74-4.95 GeV**; 2.55B $\psi(2S)$
2022: 5.1 fb^{-1} at $\psi(3770)$
2023: ~8.1 fb^{-1} will be taken at $\psi(3770)$





Physics at tau-charm Energy Region

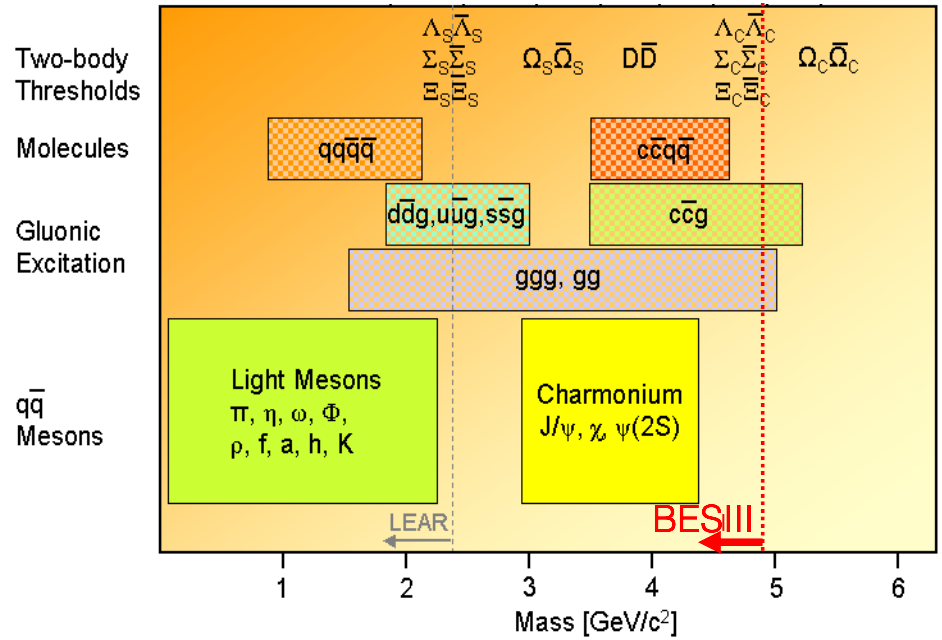


- Hadron form factors
- Y(2175) resonance
- Mutltiquark states with s quark, Zs
- MLLA/LPHD and QCD sum rule predictions

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

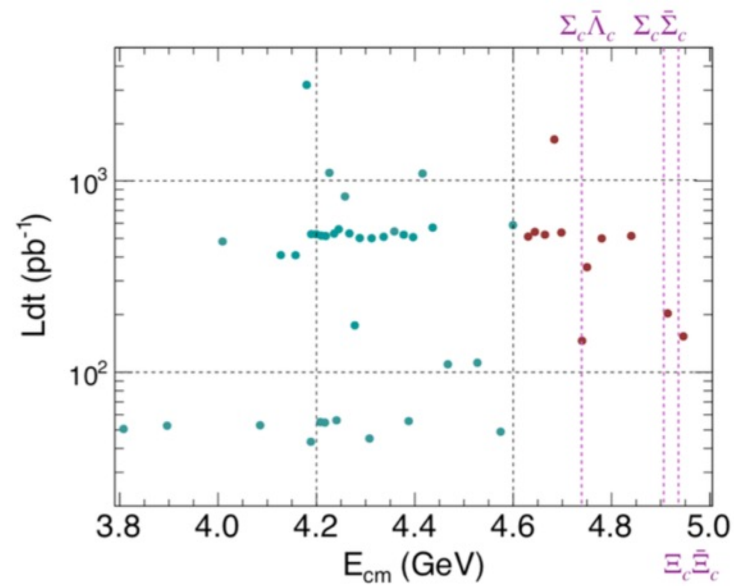
- XYZ particles
- D mesons
- f_D and f_{Ds}
- D_0-D_0 mixing
- Charm baryons

Hadron Landscape



Hadron-physics challenges:

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

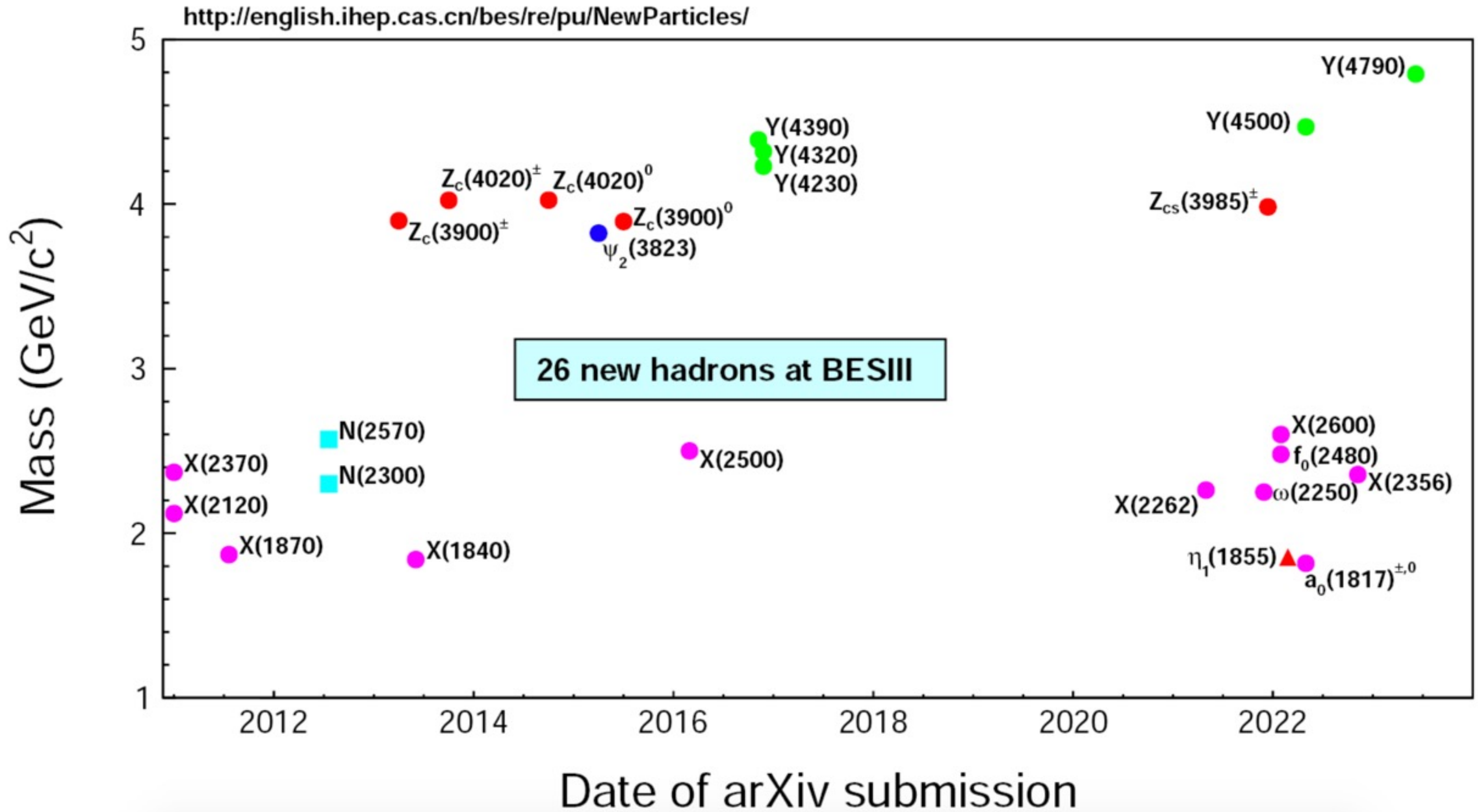


XYZ studies: about 23 /fb data above 3.8 GeV

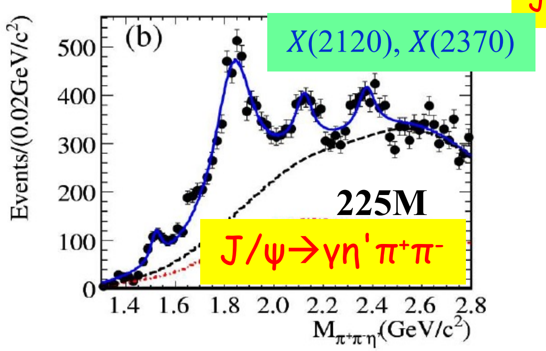
At BESIII, two golden measures to study hadron spectroscopy, *esp*., to search for exotics

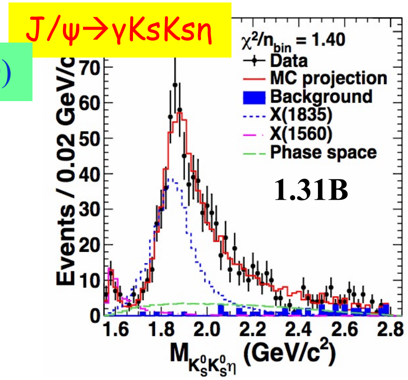
- Light hadrons: charmonium radiative decays (act as spin filter) (**10 B J/ψ and 3 B $\psi(2S)$**)
- Heavy hadrons: direct production, radiative and hadronic transitions (**data above 3.8 GeV**)

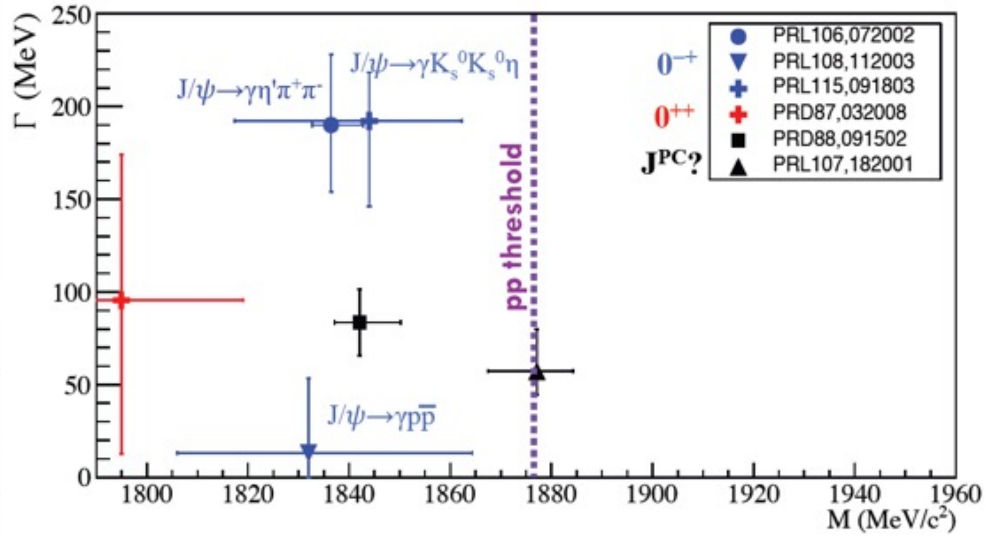
26 New Hadrons Discovered at BESIII

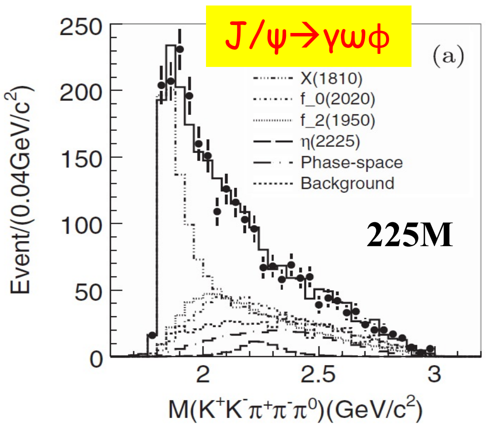


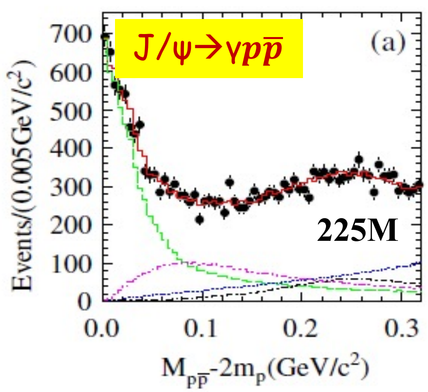
X($p\bar{p}$)/X(18??) from J/ψ radiative decays

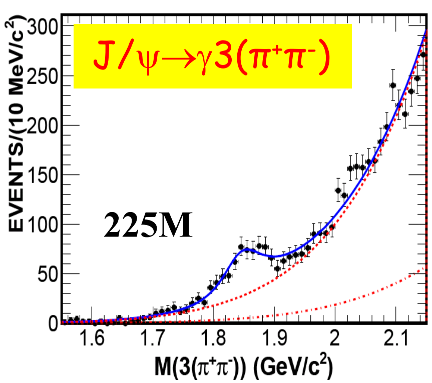


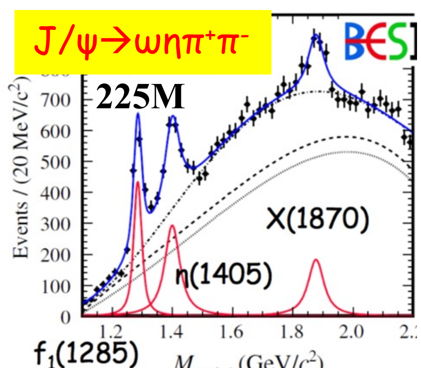






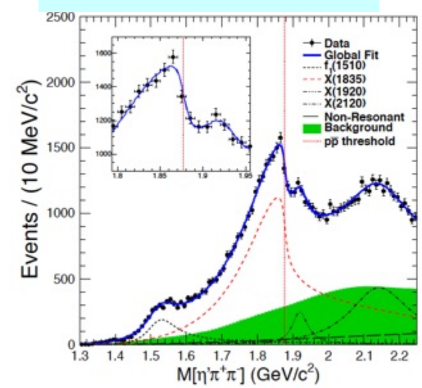






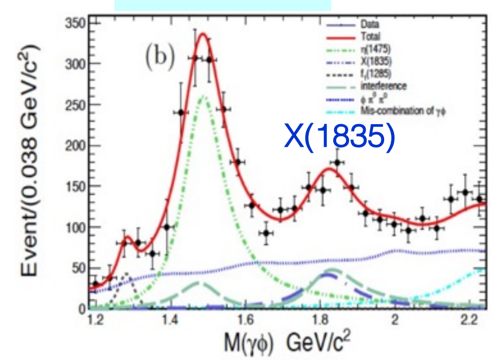
PRL117, 042002 (2016)

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



PRD97, 051101(R)(2018)

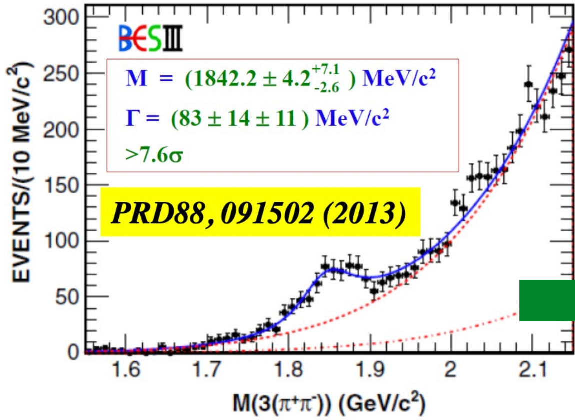
$J/\psi\to\gamma\gamma\phi$



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

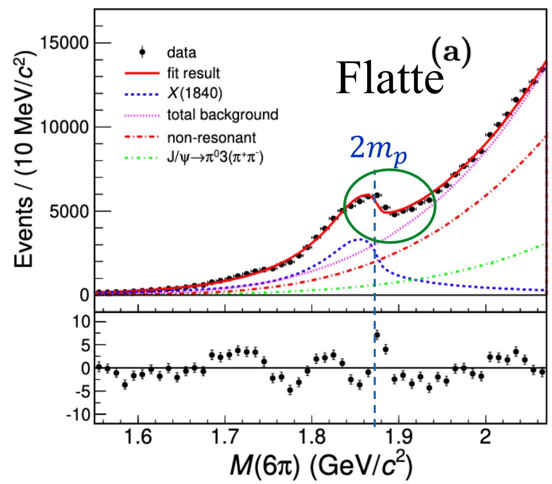
Anomolous lineshape of X(1840) in $J/\psi \to \gamma 3(\pi^+\pi^-)$

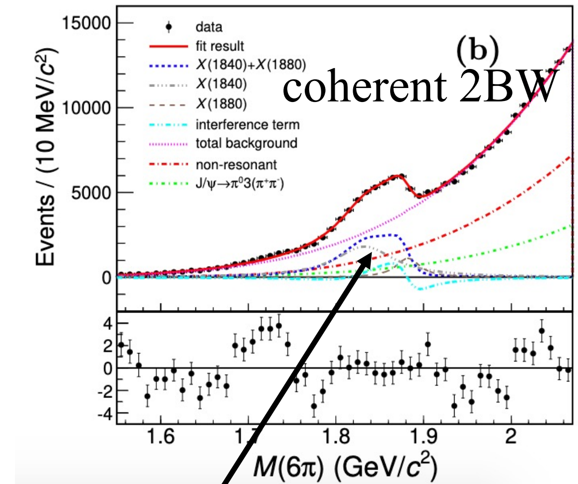
arXiv:2310.xxxx

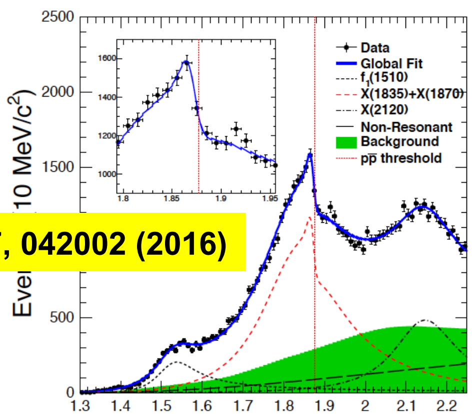


10B J/ψ events are analyzed:

50x more than the previous BESIII work



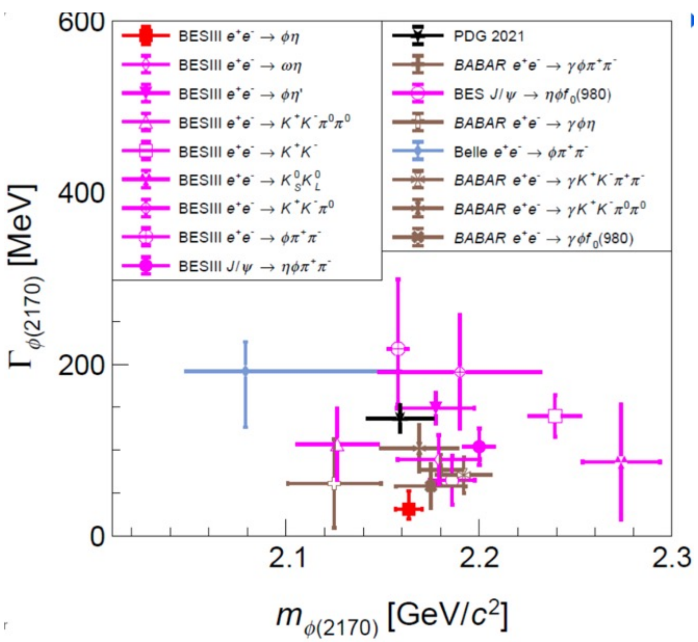




Parameters	Solution I	Solution II
$M_{X(1840)}$ (MeV/c^2)	$1832.5 \pm 3.1 \pm 2.5$	
$\Gamma_{X(1840)}$(MeV)	$80.7 \pm 5.2 \pm 7.7$	
$\mathcal{B}_{X(1840)}(\times 10^{-5})$	$1.19 \pm 0.30 \pm 0.15$	$2.07 \pm 0.50 \pm 0.36$
$M_{X(1880)}$ (MeV/c^2)	$1882.1 \pm 1.7 \pm 0.7$	
$\Gamma_{X(1880)}$(MeV)	$30.7 \pm 5.5 \pm 2.4$	
$\mathcal{B}_{X(1880)}(\times 10^{-5})$	$0.29 \pm 0.20 \pm 0.09$	$1.19 \pm 0.31 \pm 0.18$

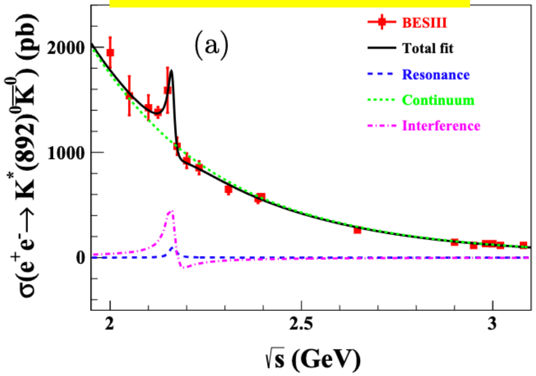
$X(1835)$	
Mass (MeV/c^2)	$1825.3 \pm 2.4^{+17.3}_{-2.4}$
Width (MeV/c^2)	$245.2 \pm 13.1^{+4.6}_{-9.6}$
$X(1870)$	
Mass (MeV/c^2)	$1870.2 \pm 2.2^{+2.3}_{-0.7}$
Width (MeV/c^2)	$13.0 \pm 6.1^{+2.1}_{-3.8}$

Rediscovery of Y(2175)/ϕ(2170)

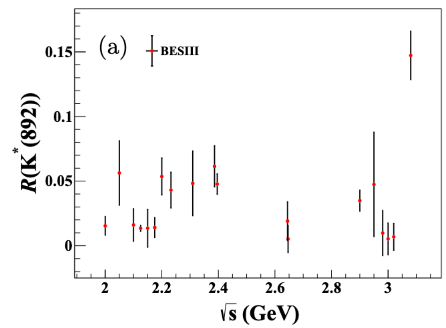


$e^+e^- \to K^*(892)^0\bar{K}^0$

arXiv:2309.13883



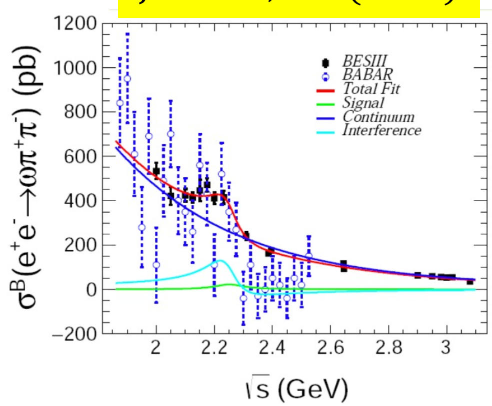
$$R(K^*(892)) = \frac{\sigma(e^+e^- \to K^*(892)^+K^-)}{\sigma(e^+e^- \to K^*(892)^0\bar{K}^0)}$$



R<0.2: much less than 1?

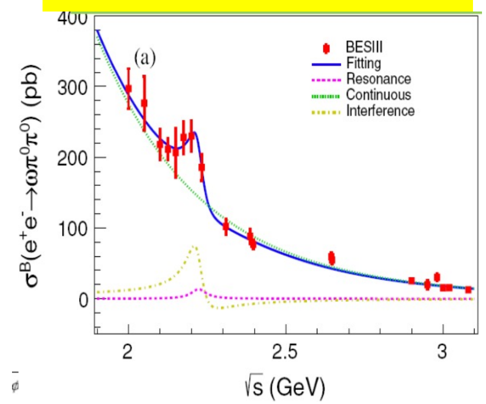
$e^+e^- \to \omega\pi^+\pi^-$

JHEP 01, 111(2023)



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

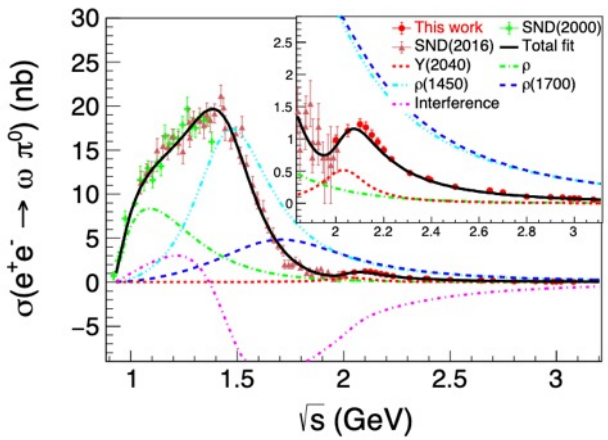
PRD105, 032005 (2022)



The isovector states

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

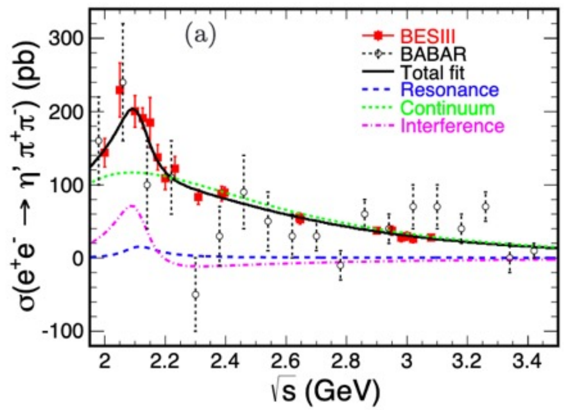
PLB 813, 136059 (2021)



- a structure Y(2040) with stat. significance $>10\sigma$
  $M = 2034 \pm 14 \pm 9\ \mathrm{MeV}/c^2$
  $\Gamma = 234 \pm 30 \pm 25\ \mathrm{MeV}$
- close to the isovector state $\rho(2000)$ or $\rho(2150)$

$e^+e^- \to \eta'\pi^+\pi^-$

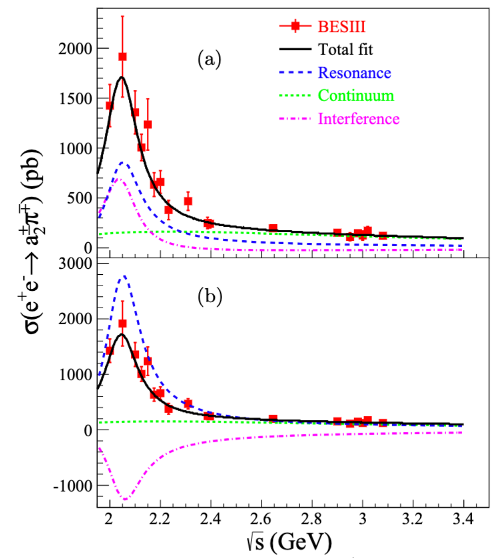
PRD 103, 072007 (2021)



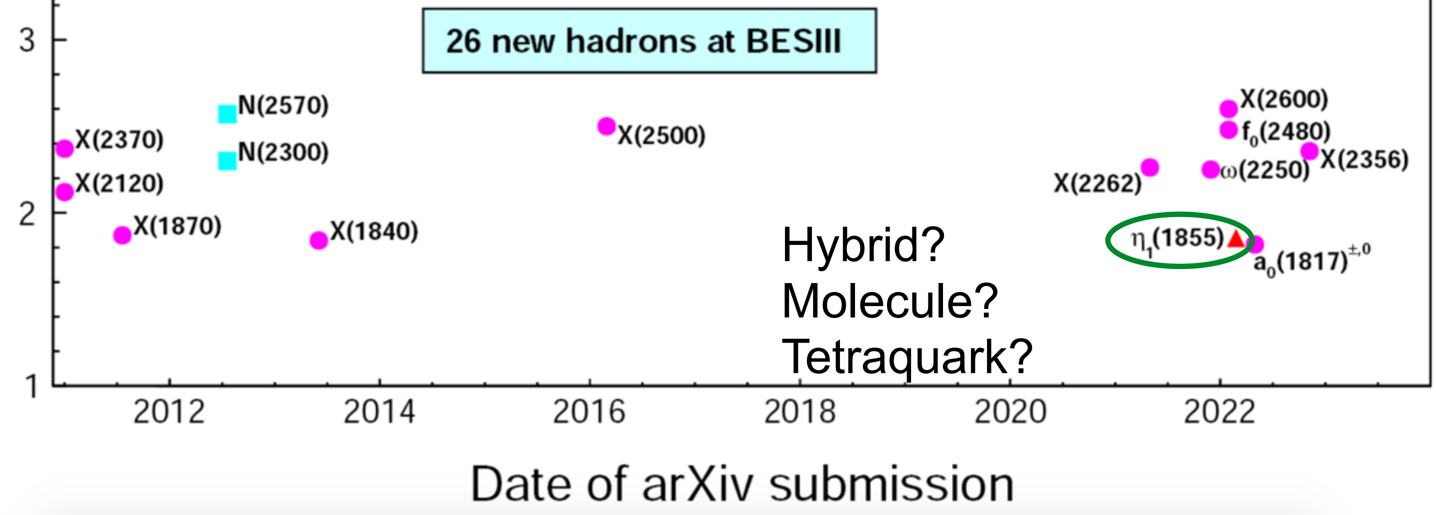
- a structure around 2.1 GeV: stat. significance $>6.3\sigma$
  $M = 2111 \pm 43 \pm 25\ \mathrm{MeV}/c^2$
  $\Gamma = 135 \pm 34 \pm 30\ \mathrm{MeV}$
- consistent with the Y(2040) in $e^+e^- \to \omega\pi^0$

$e^+e^- \to a_2^\pm\pi^\mp \to \eta\pi^+\pi^-$

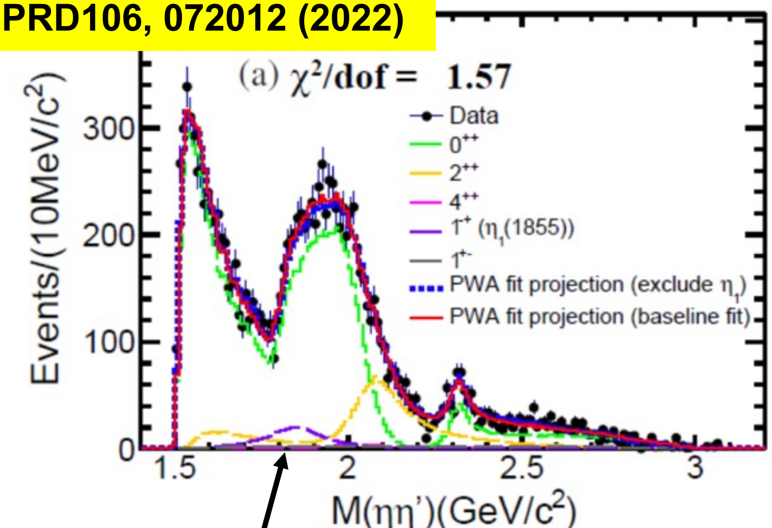
arXiv:2310.10452



- a structure around 2.1 GeV: stat. significance $>5.7\ \sigma$
  $M = 2040 \pm 28 \pm 2\ \mathrm{MeV}/c^2$
  $\Gamma = 160 \pm 67 \pm 3\ \mathrm{MeV}$
- consistent with the Y(2040) in $e^+e^- \to \omega\pi^0$

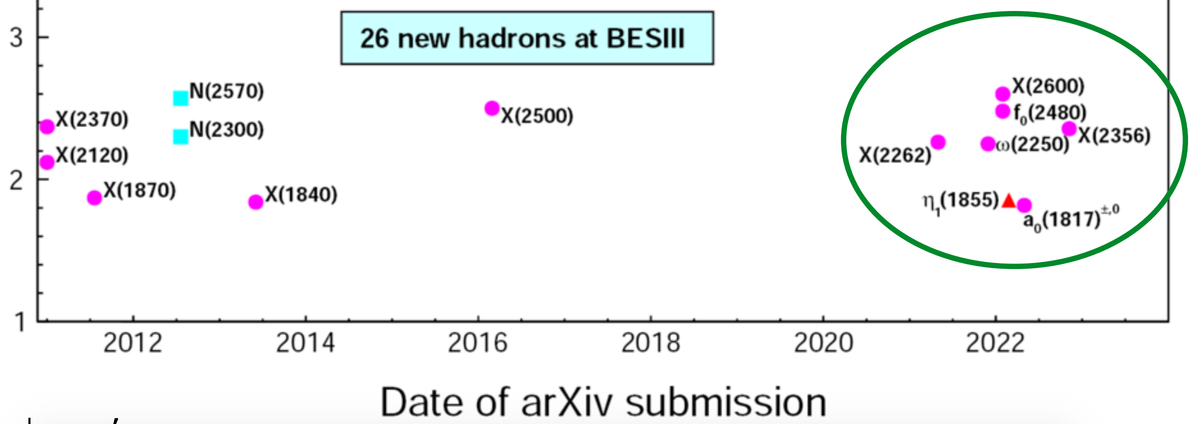


PRL129, 192002 (2022)
PRD106, 072012 (2022)



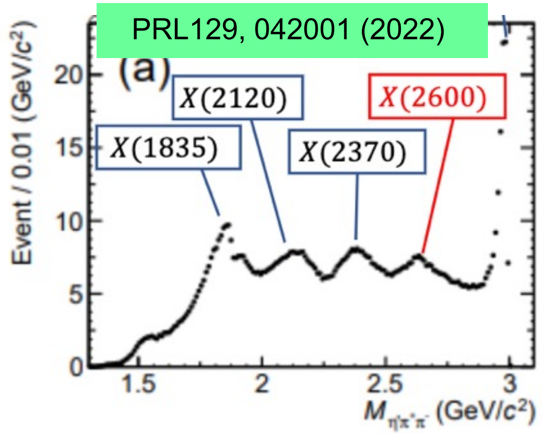
$\boldsymbol{\eta_1(1855)(1^{-+})}$

Decay mode	Resonance	M (MeV/c^2)	Γ (MeV)	$M_{\rm PDG}$ (MeV/c^2)	$\Gamma_{\rm PDG}$ (MeV)	B.F. ($\times10^{-5}$)	Sig.
$J/\psi\to\gamma X\to\gamma\eta\eta'$	$f_0(1500)$	1506	112	1506	112	$1.81\pm0.11^{+0.19}_{-0.13}$	$\gg30\sigma$
	$f_0(1810)$	1795	95	1795	95	$0.11\pm0.01^{+0.04}_{-0.03}$	11.1σ
	$f_0(2020)$	$2010\pm6^{+6}_{-4}$	$203\pm9^{+13}_{-11}$	1992	442	$2.28\pm0.12^{+0.29}_{-0.20}$	24.6σ
	$f_0(2330)$	$2312\pm7^{+7}_{-3}$	$65\pm10^{+3}_{-12}$	2314	144	$0.10\pm0.02^{+0.01}_{-0.02}$	13.2σ
	$\eta_1(1855)$	$1855\pm9^{+6}_{-1}$	$188\pm18^{+3}_{-8}$	-	-	$0.27\pm0.04^{+0.02}_{-0.04}$	21.4σ
	$f_2(1565)$	1542	122	1542	122	$0.32\pm0.05^{+0.12}_{-0.02}$	8.7σ
	$f_2(2010)$	$2062\pm6^{+10}_{-7}$	$165\pm17^{+10}_{-5}$	2011	202	$0.71\pm0.06^{+0.10}_{-0.06}$	13.4σ
	$f_4(2050)$	2018	237	2018	237	$0.06\pm0.01^{+0.03}_{-0.01}$	4.6σ
	0^{++} PHSP	-	-	-	-	$1.44\pm0.15^{+0.10}_{-0.20}$	15.7σ
$J/\psi\to\eta' X\to\gamma\eta\eta'$	$h_1(1415)$	1416	90	1416	90	$0.08\pm0.01^{+0.01}_{-0.02}$	10.2σ
	$h_1(1595)$	1584	384	1584	384	$0.16\pm0.02^{+0.03}_{-0.01}$	9.9σ



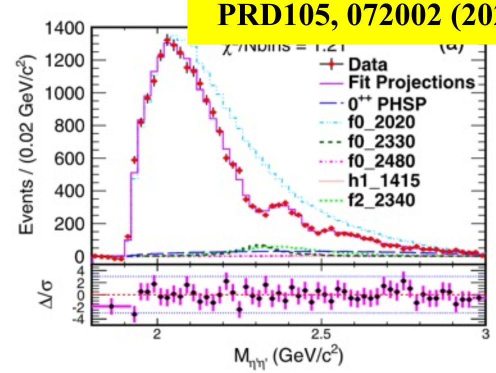
$X(2600)$ in $J/\psi \to \gamma\pi^+\pi^-\eta'$

PRL129, 042001 (2022)



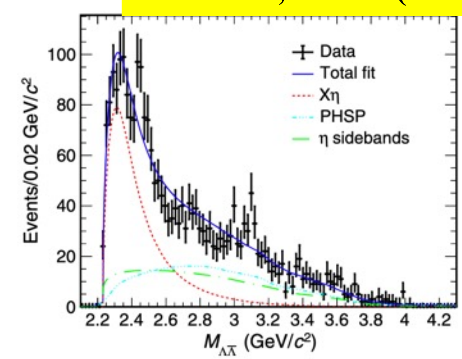
$f_0(2480)$ in $J/\psi \to \gamma\eta'\eta'$

PRD105, 072002 (2022)



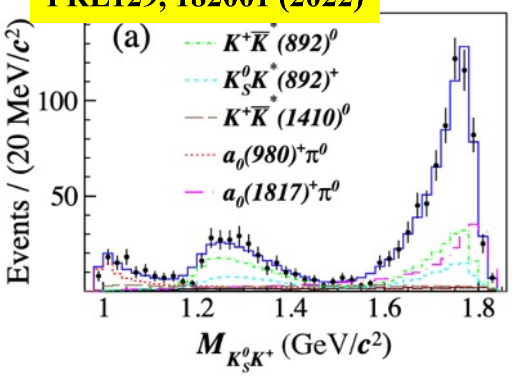
$X(2356) \to \Lambda\bar{\Lambda}$ in $e^+e^- \to \eta\Lambda\bar{\Lambda}$

PRD 107, 112001 (2023)



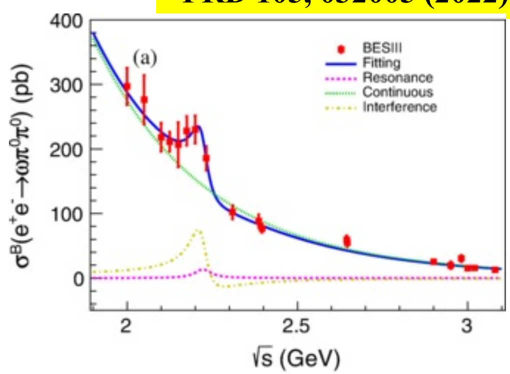
$a_0(1817)$ in $D_s^+ \to K_S K^+\pi^0$

PRL129, 182001 (2022)



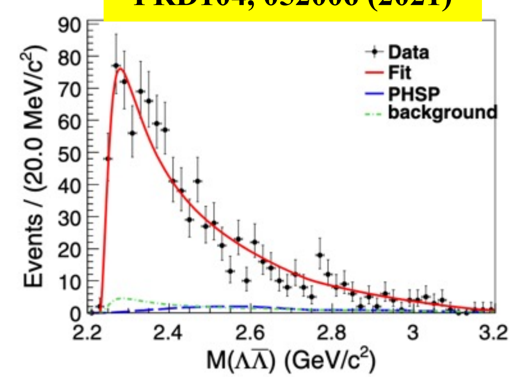
$\omega(2250)$ in $e^+e^- \to \omega\pi^0\pi^0$

PRD 105, 032005 (2022)



$X(2262) \to \Lambda\bar{\Lambda}$ in $e^+e^- \to \phi\Lambda\bar{\Lambda}$

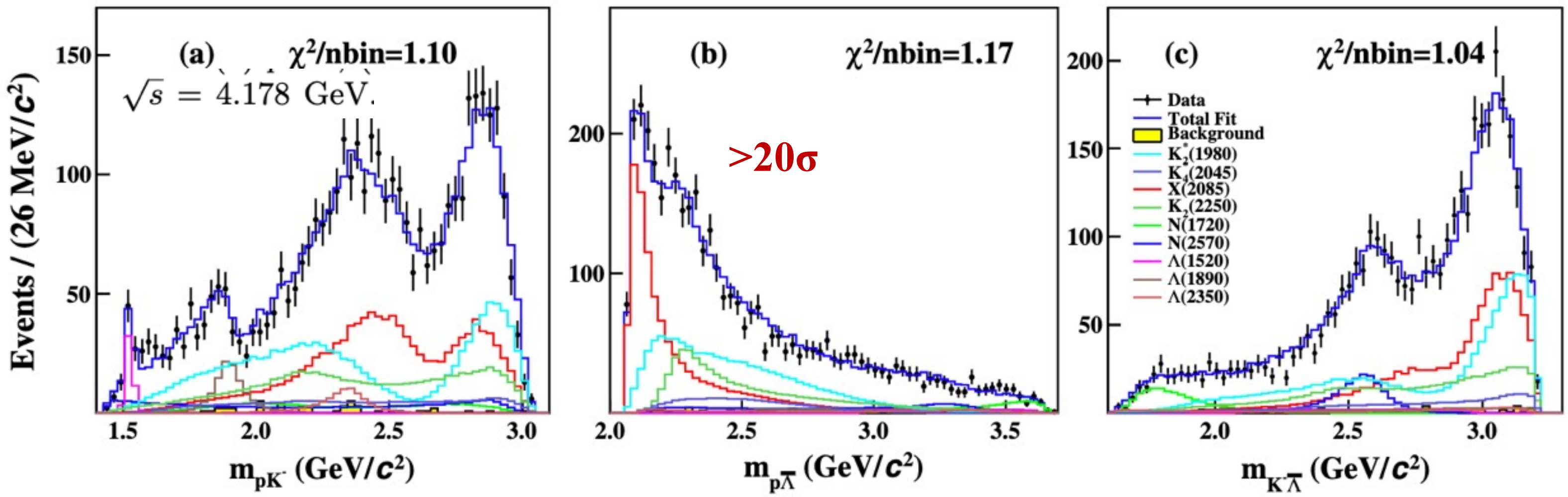
PRD104, 052006 (2021)



Amplitude analysis of X(2085) in $e^+e^- \to pK^-\bar{\Lambda}$

arXiv:2303.01989

$8.35\ \mathrm{fb}^{-1}$ data at 4.008, 4.178, 4.226, 4.258, 4.416, and 4.682 GeV



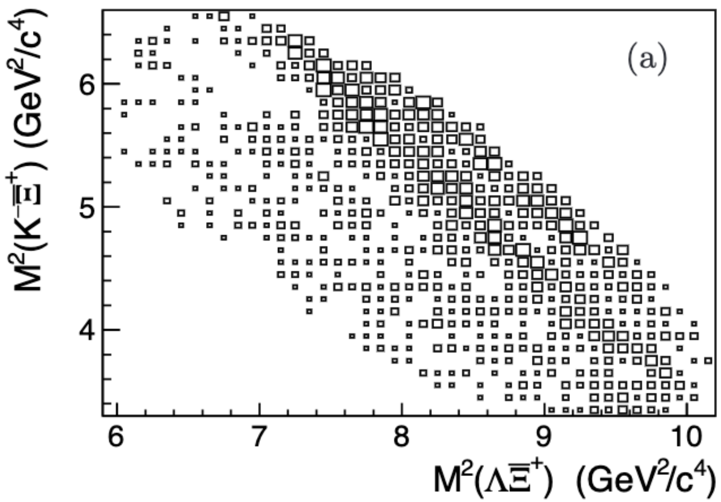
$\sqrt{s}$	$\mathcal{L}_{\mathrm{int}}$	Year	M_{pole}	Γ_{pole}
4.008	482.0 ± 4.7	2011	2085 ± 14	50 ± 16
4.178	3189.0 ± 31.9	2016	2085 ± 6	62 ± 10
4.226	1100.9 ± 7.0	2013	2088 ± 10	68 ± 12
4.258	828.4 ± 5.5	2013	2083 ± 11	48 ± 10
4.416	1090.7 ± 7.2	2014	2088 ± 13	56 ± 12
4.682	1669.3 ± 9.0	2020	2092 ± 10	54 ± 10
Average	—	—	2086 ± 4	56 ± 5

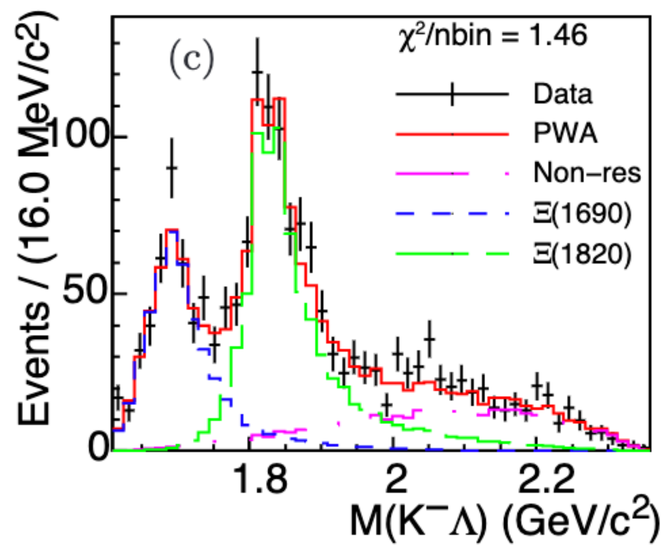
- $p\bar{\Lambda}$ resonance parameters and spin-parity:
  - ➢ pole mass: (2086±4±6) MeV/c^2
  - ➢ pole width: (56±5±16) MeV
  - ➢ favor 1^+
- no corresponding excited kaon candidates in experiment or in quark model prediction
- could be an exotic state

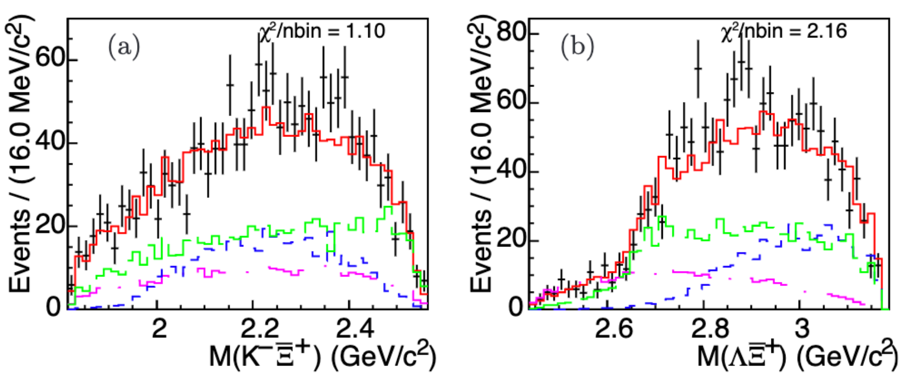
PWA on $\psi(3686) \to K^- \Lambda \bar{\Xi}^+$

arXiv:2308.15206

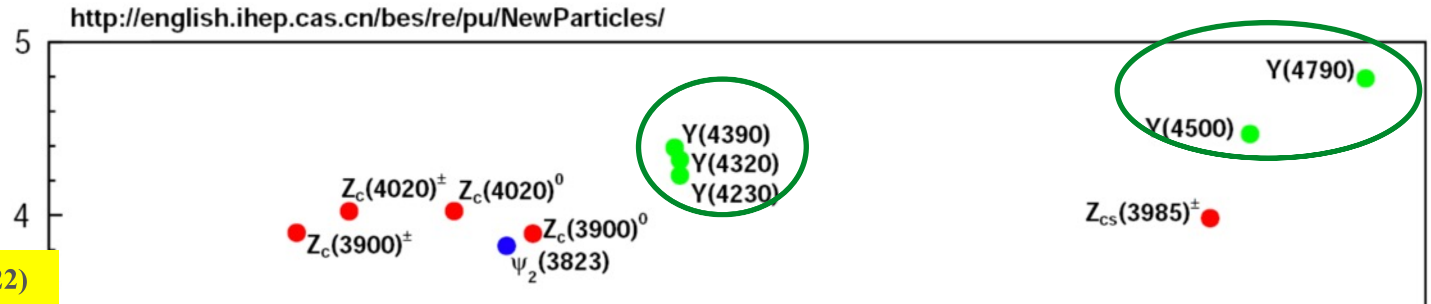
Based on 4.48 M $\psi(3686)$ events



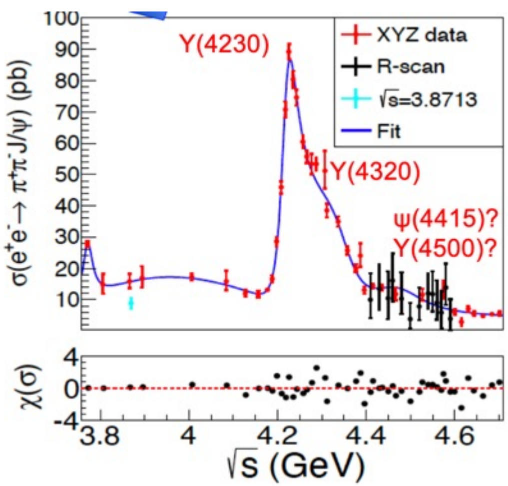




Resonance	$I(J^P)$	M (MeV/c^2)	Γ (MeV)
$\Xi(1690)^-$	$1/2(1/2^-)$	$1685^{+3}_{-2} \pm 12$	$81^{+10}_{-9} \pm 20$
$\Xi(1820)^-$	$1/2(3/2^-)$	$1821^{+2}_{-3} \pm 3$	$73^{+6}_{-5} \pm 9$



PRD106, 072001 (2022)

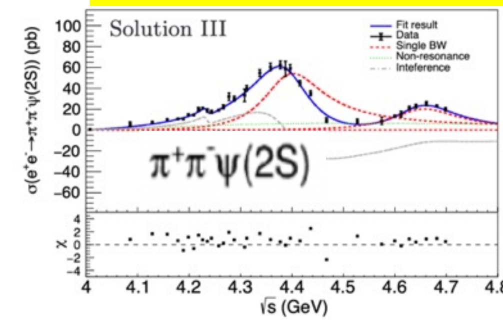


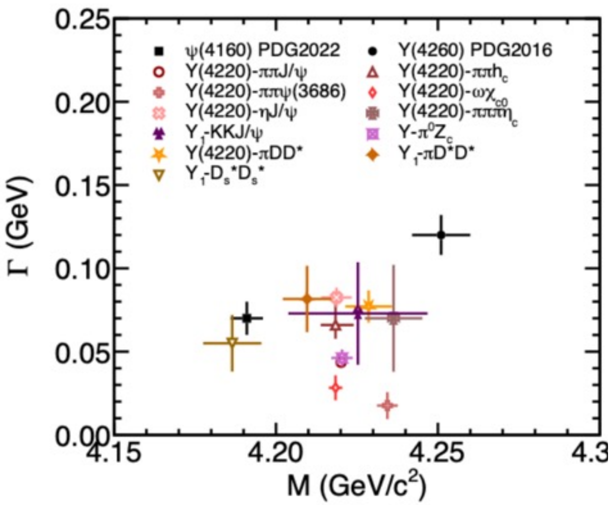
$Y(4260) \rightarrow Y(4230)$ & $Y(4320)$

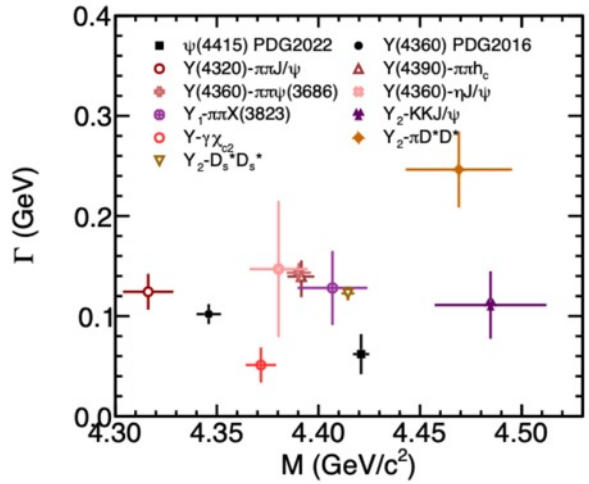
$M_{Y(4230)} = 4221.4 \pm 1.5 \pm 2.0\ \mathrm{MeV}/c^2$
$\Gamma_{Y(4230)} = 41.8 \pm 2.9 \pm 2.7\mathrm{MeV}$

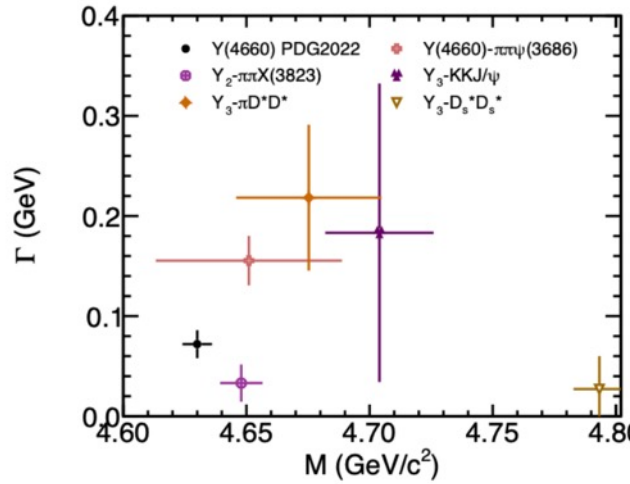
$M_{Y(4320)} = 4298 \pm 12 \pm 26\ \mathrm{MeV}/c^2$
$\Gamma_{Y(4320)} = 127 \pm 17 \pm 10\ \mathrm{MeV}$

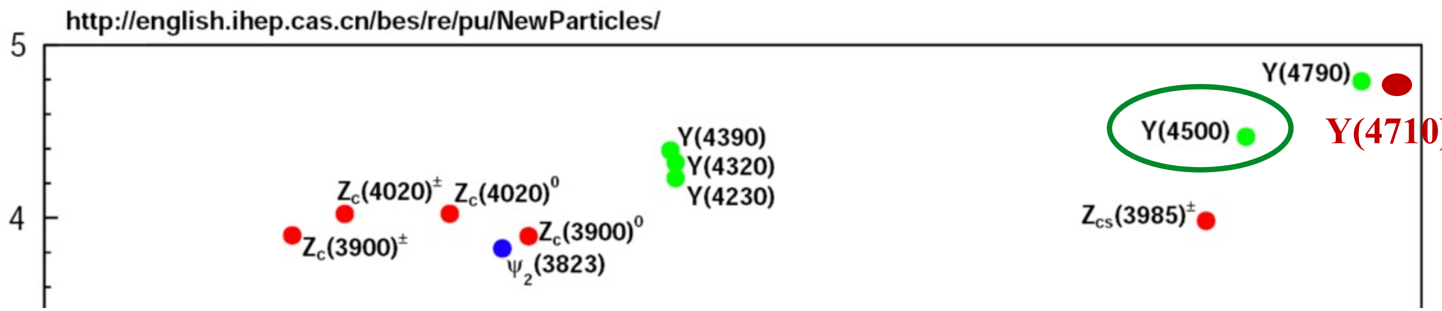
PRD 104, 052012 (2021)







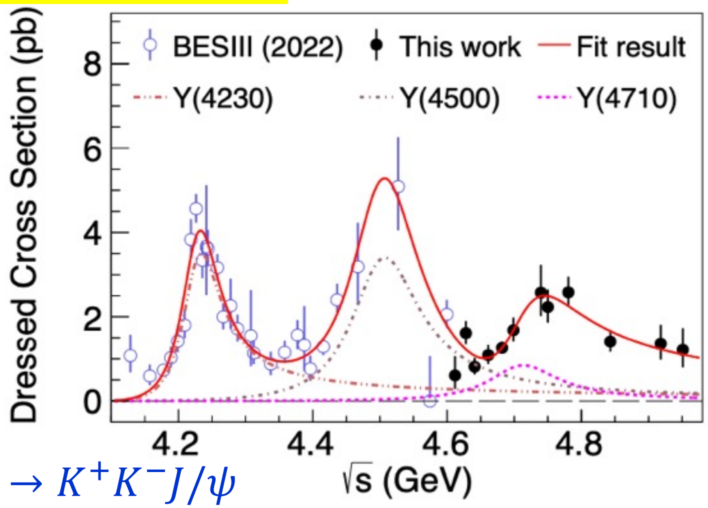




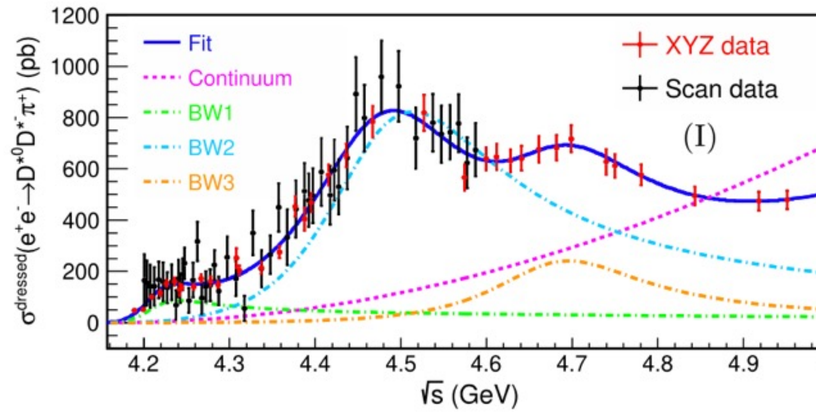
CPC 46, 111002 (2022)
arXiv:2308.15362

observation of the Y(4710)

PRL130, 121901 (2023)



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



	Parameters	Solution I	Solution II
$Y(4230)$	M(MeV)	$4225.3 \pm 2.3 \pm 21.5$	
	Γ_{tot}(MeV)	$72.9 \pm 6.1 \pm 30.8$	
	$\Gamma_{ee}\mathcal{B}$(eV)	$0.42 \pm 0.04 \pm 0.15$	$0.29 \pm 0.02 \pm 0.10$
$Y(4500)$	M(MeV)	$4484.7 \pm 13.3 \pm 24.1$	
	Γ_{tot}(MeV)	$111.1 \pm 30.1 \pm 15.2$	
	$\Gamma_{ee}\mathcal{B}$(eV)	$1.35 \pm 0.14 \pm 0.06$	$0.41 \pm 0.08 \pm 0.13$
[illegible]	[illegible]	[illegible]	[illegible]

$m_1 = 4209.6 \pm 4.7 \pm 5.9$ MeV/c^2,
$\Gamma_1 = 81.6 \pm 17.8 \pm 9.0$ MeV; ➔ Y(4230)

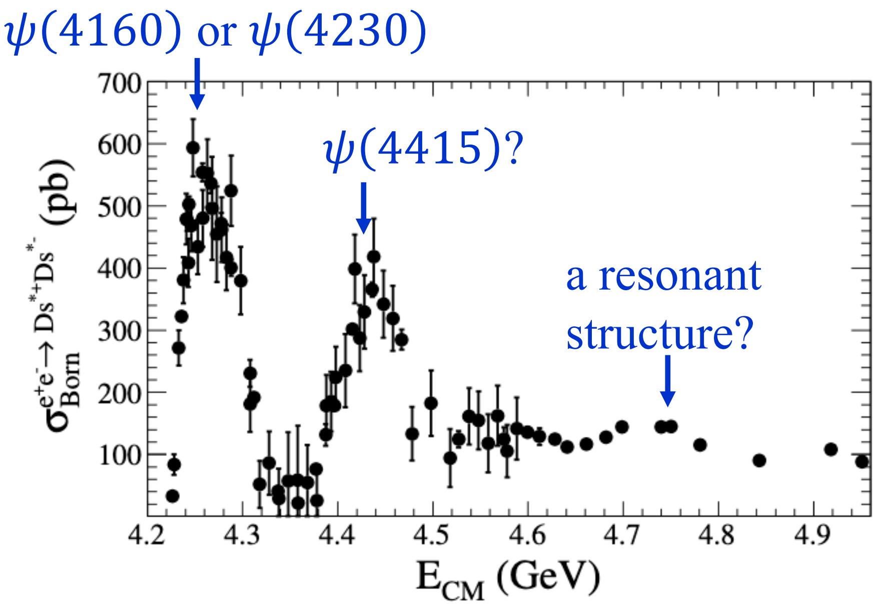
$m_2 = 4469.1 \pm 26.2 \pm 3.6$ MeV/c^2,
$\Gamma_2 = 246.3 \pm 36.7 \pm 9.4$ MeV; ➔ Y(4500)

$m_3 = 4675.3 \pm 29.5 \pm 3.5$ MeV/c^2,
$\Gamma_3 = 218.3 \pm 72.9 \pm 9.3$ MeV. ➔ Y(4660)

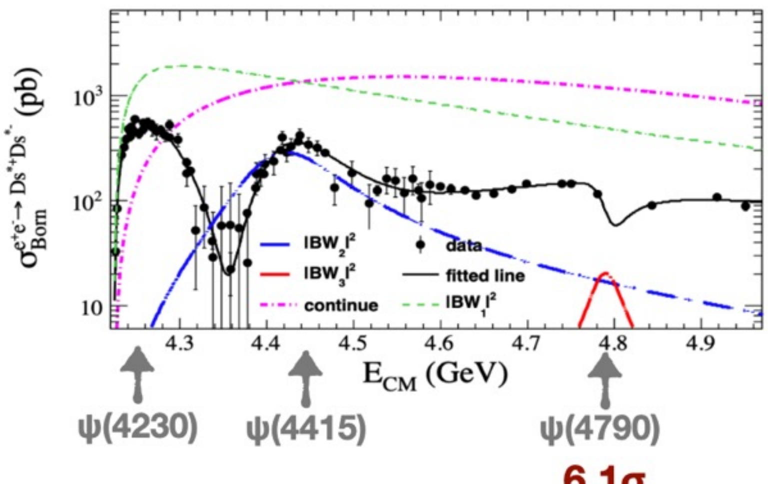
Y(4710) mass: $4708^{+17}_{-15} \pm 21$ MeV/c^2
Y(4710) width: $126^{+27}_{-23} \pm 30$ MeV

Cross sections of $e^+e^- \rightarrow D_s^{*+}D_s^{*-}$

arXiv:2305.10789



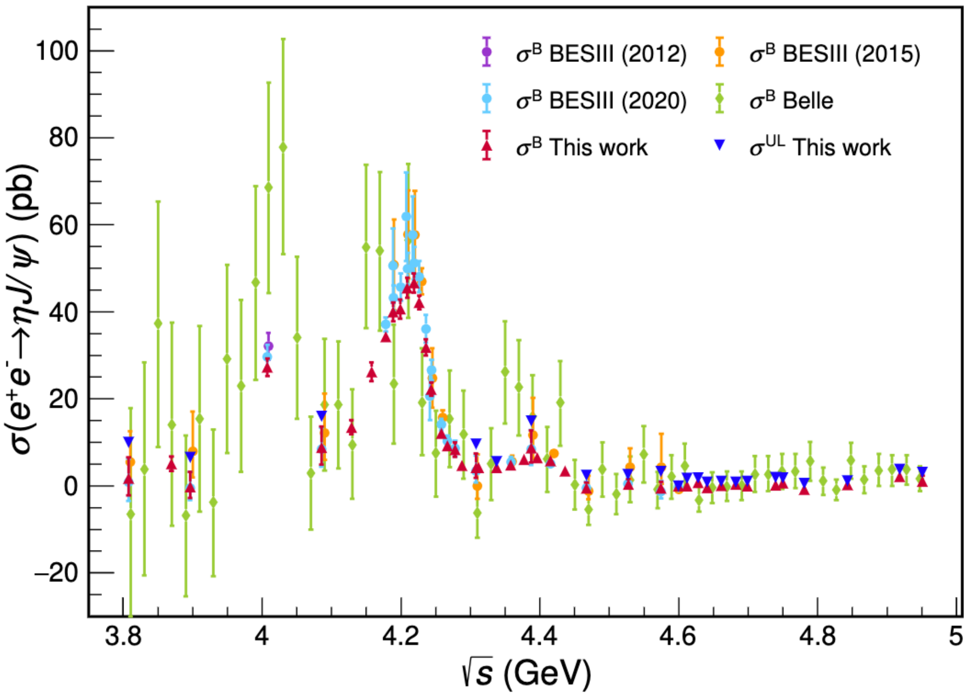
	Result 1	Result 2	Result 3
M_1 (MeV/c^2)	4186.5±9.0	4193.8±7.5	4195.3±7.5
Γ_1 (MeV)	55±17	61.2±9.0	61.8±9.0
M_2 (MeV/c^2)	4414.5±3.2	4412.8±3.2	4411.0±3.2
Γ_2 (MeV)	122.6±7.0	120.3±7.0	120.0±7.0
M_3 (MeV/c^2)	4793.3±7.5	4789.8±9.0	4786±10
Γ_3 (MeV)	27.1±7.0	41±39	60±35

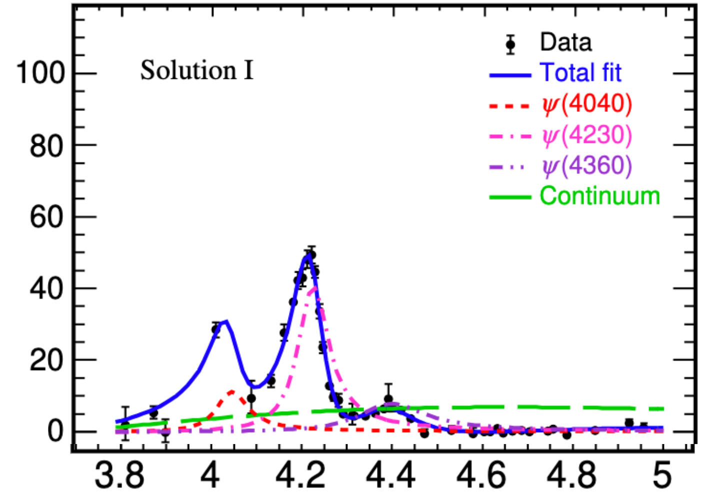


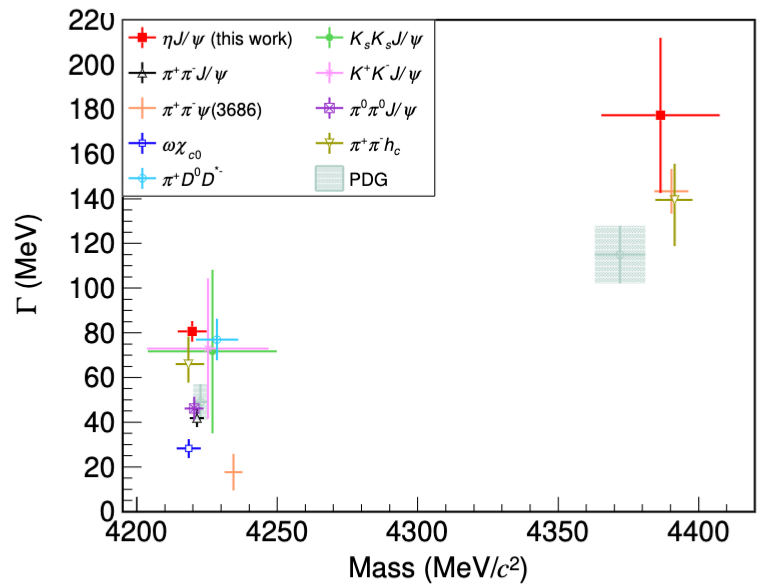
Y(4790): the heaviest charmoniumlike state!

Updated cross sections of $e^+e^- \to \eta J/\psi$

arXiv:2310.03361



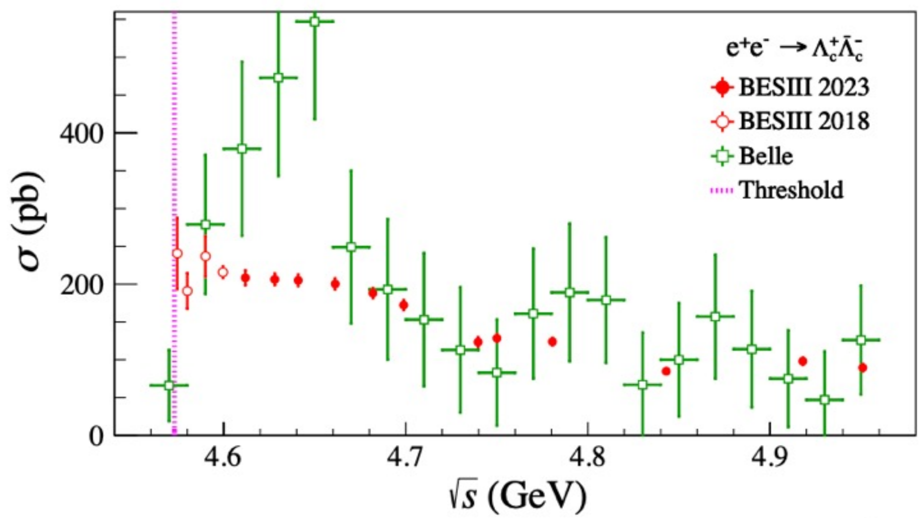


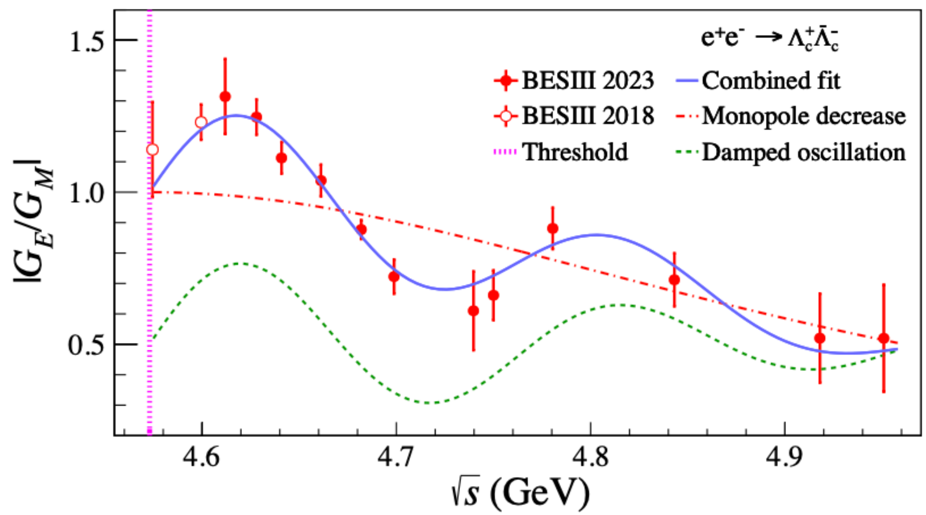


- **Y(4040), Y(4230) and Y(4360) are observed**
- **Large drop of cross sections above 4.5 GeV**

Cross sections of $e^+e^- \to \Lambda_c^+\Lambda_c^-$

arXiv:2307.07316





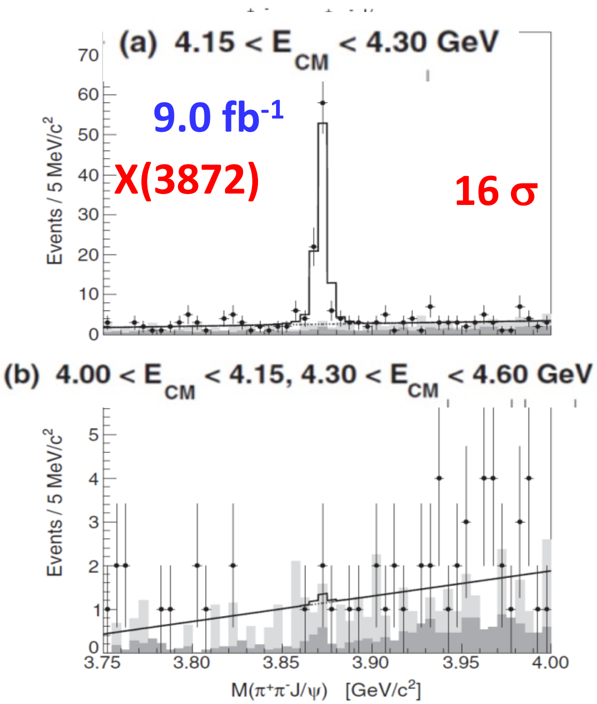
- Negate the $Y(4630)$ in decaying into $\Lambda_c^+\Lambda_c^-$ reported by BELLE
- Energy-dependence of $|G_E/G_M|$ reveals an oscillation feature, which may imply a non-trivial structure of the lightest charmed baryon.

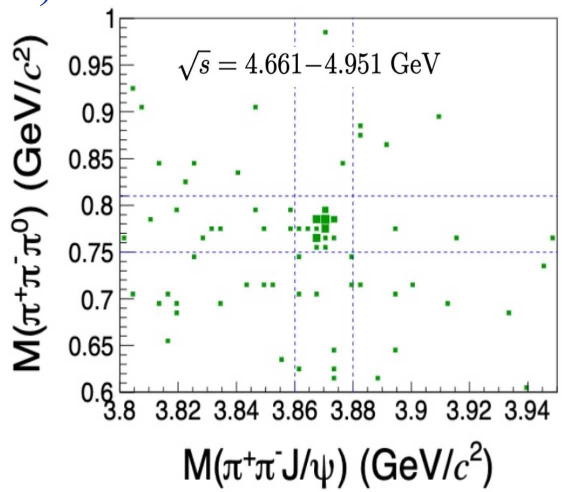
A new X(3872) production process $e^+e^- \to \omega X(3872)$

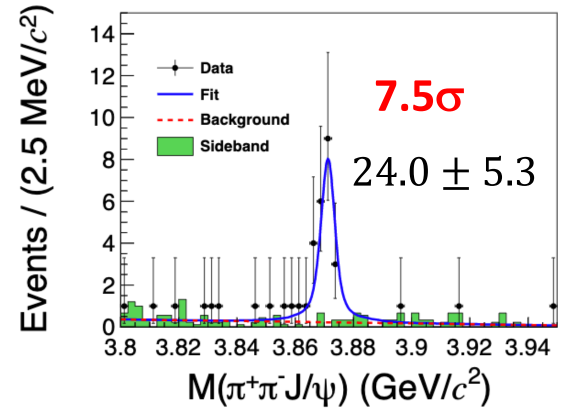
PRL130, 151904 (2023)

Radiative production in $e^+e^- \to \gamma X(3872)$

BESIII, PRL122, 202001 (2019)







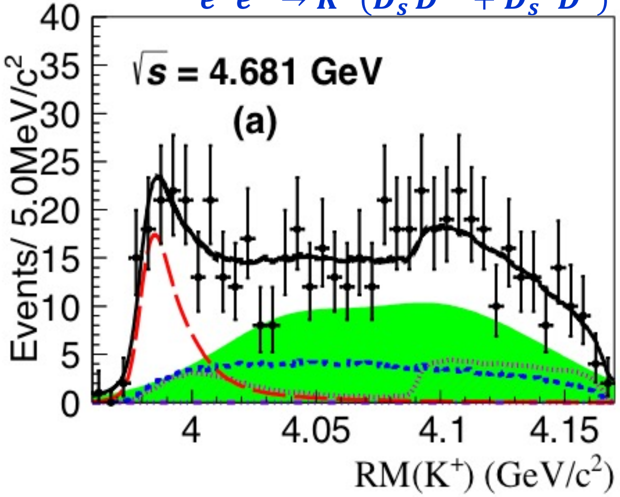
$\sqrt{s}$ (GeV)	$\mathcal{L}_{\rm int}({\rm pb}^{-1})$	$N_{\rm sig}$	$\epsilon(1+\delta)$ (%)	$\sigma^{\rm B}$(pb)	$\sigma^{\rm B}_{\rm up}$(pb)	Significance
4.661	529.63	$0.33^{+1.36}_{-0.33}$	28.25	$0.523^{+2.128}_{-0.523} \pm 0.051 \pm 0.165$	5.64	-
4.682	1669.31	$8.00^{+3.34}_{-2.68}$	24.62	$4.567^{+1.908}_{-1.528} \pm 0.393 \pm 1.442$	11.49	3.4σ
4.699	536.45	$0.00^{+0.95}_{-0.00}$	26.96	$0.000^{+1.541}_{-0.000} \pm 0.000 \pm 0.000$	3.32	-
4.740	164.27	$1.67^{+1.77}_{-1.10}$	21.83	$10.906^{+11.551}_{-7.213} \pm 1.025 \pm 3.444$	40.58	1.0σ
4.750	367.21	$5.00^{+2.58}_{-1.92}$	22.43	$14.239^{+7.349}_{-5.455} \pm 1.424 \pm 4.497$	38.17	3.1σ
4.781	512.78	$1.00^{+1.36}_{-0.70}$	31.60	$1.448^{+1.965}_{-1.011} \pm 0.216 \pm 0.457$	6.51	0.7σ
4.843	527.29	$4.67^{+2.58}_{-1.92}$	26.73	$7.768^{+4.295}_{-3.189} \pm 0.668 \pm 2.453$	21.14	2.6σ
4.918	208.11	$1.00^{+1.36}_{-0.70}$	22.64	$4.980^{+6.760}_{-3.477} \pm 0.433 \pm 1.573$	21.69	0.7σ
4.951	160.37	$0.00^{+0.95}_{-0.00}$	20.42	$0.000^{+6.802}_{-0.000} \pm 0.000 \pm 0.000$	14.67	-

a new X(3872) production process $e^+e^- \to \omega X(3872)$ is observed for the first time

Studies on the Z_{cs} states

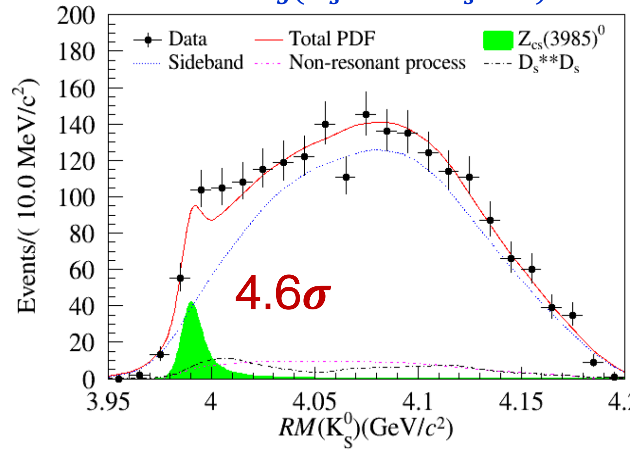
$Z_{cs}(3985)^+$ PRL126, 102001 (2021)

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



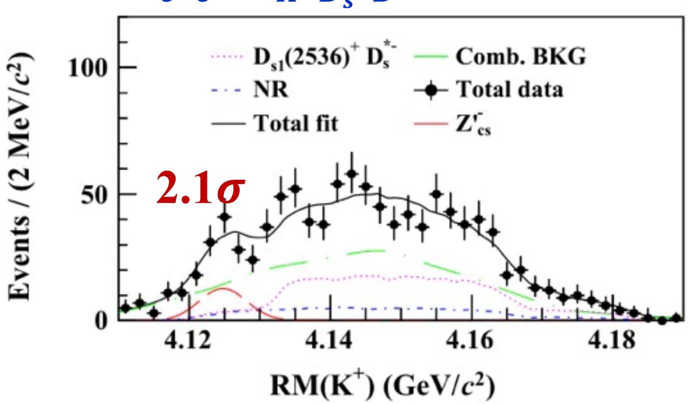
$Z_{cs}(3985)^0$ PRL129, 112003 (2022)

$e^+e^- \to K_S(D_s^- D^{*+} + D_s^{*-} D^+)$



Search for Z'_{cs} CPC47, 033001 (2023)

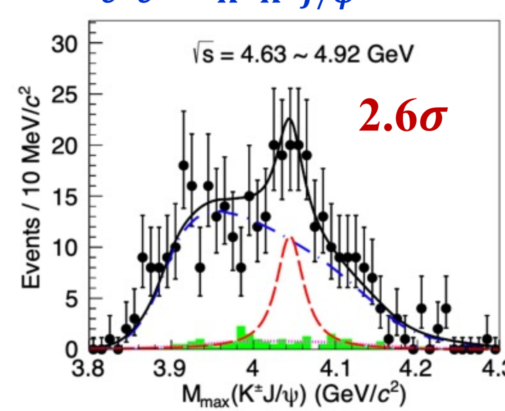
$e^+e^- \to K^+ D_s^{*-} D^{*0}$



$(4123.5 \pm 0.7_{stat.} \pm 4.7_{syst.})\,\mathrm{MeV}/c^2$

Search for $Z_{cs}^+ \to K^+ J/\psi$ arXiv:2308.15362

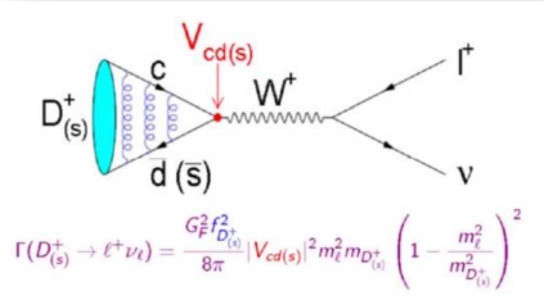
$e^+e^- \to K^+K^-J/\psi$

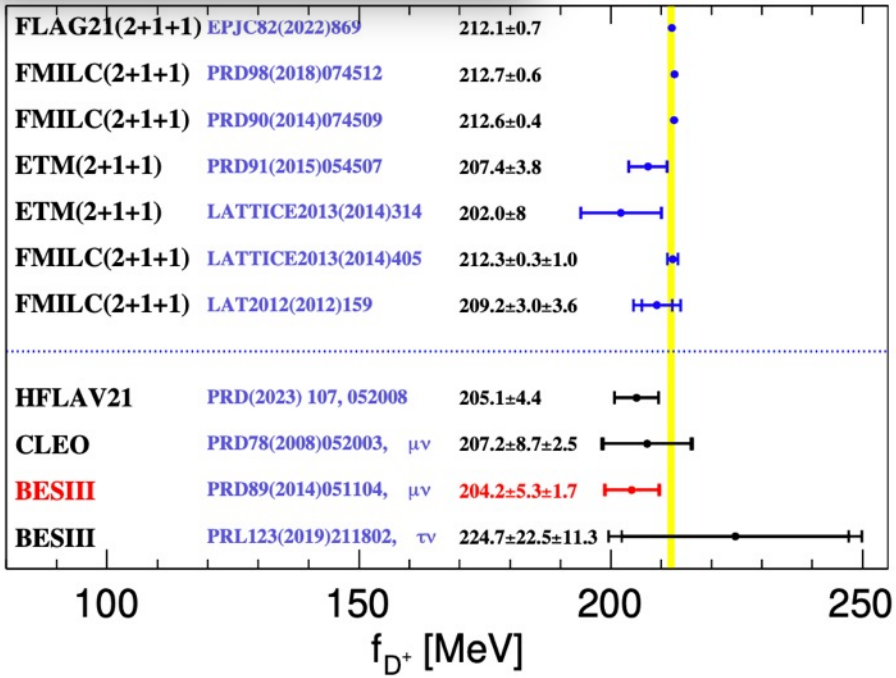


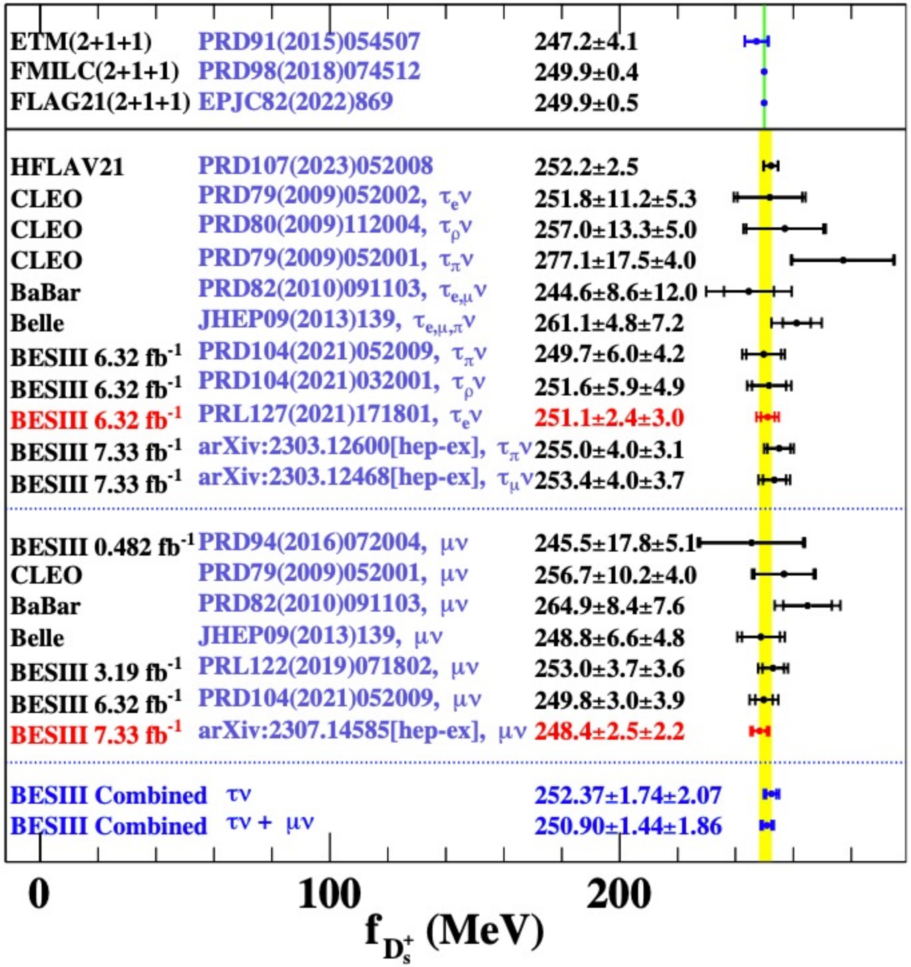
mass: 4044 ± 6 MeV/c^2

width: 36 ± 16 MeV

$D^+_{(s)}$ decay constant

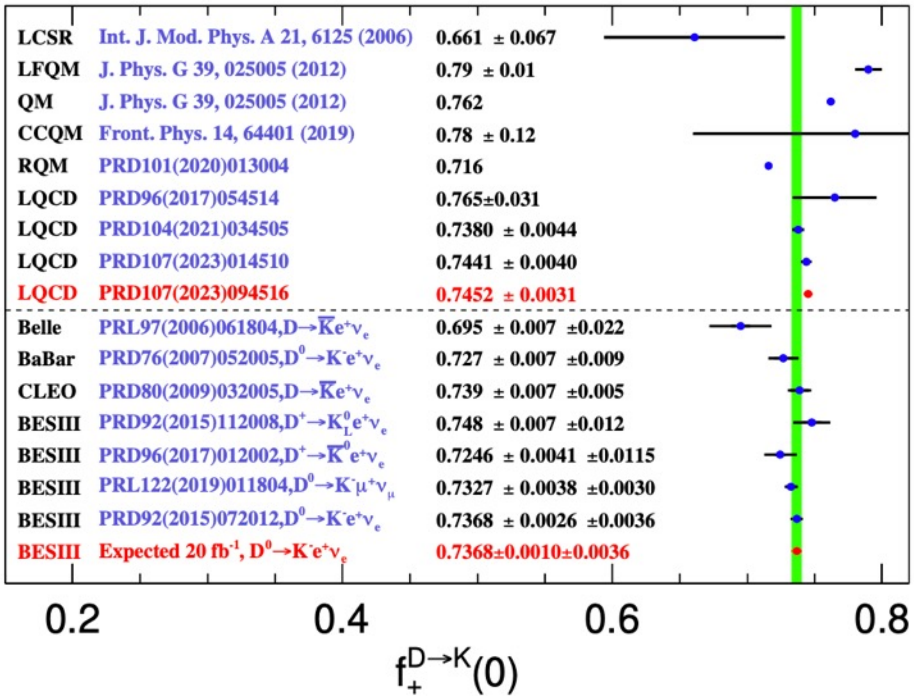


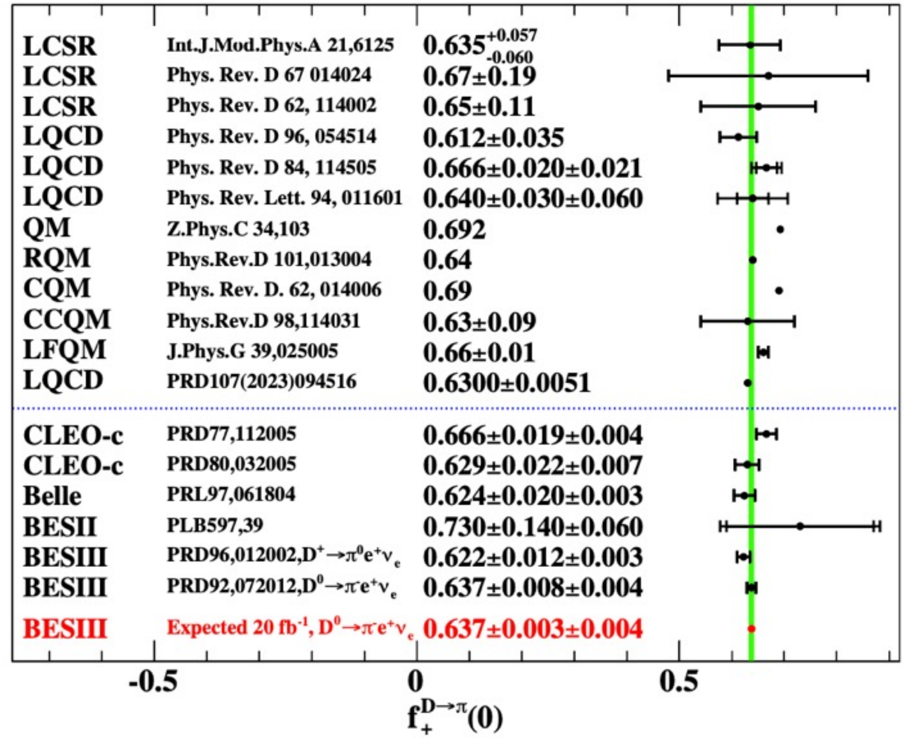


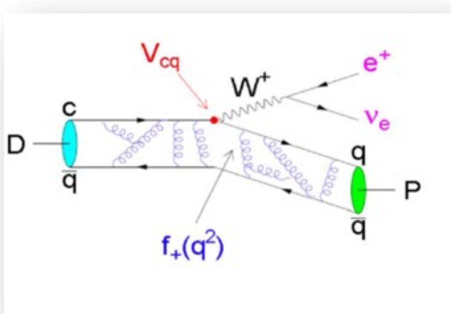


- Highest precision for f_{D^+} in single decay mode: $D^+ \to \mu^+\nu_\mu$: 2.7% (2.93 fb^{-1})→1.8% (7.9 fb^{-1})→1.3% (20 fb^{-1})
- Highest precision for $f_{D_s^+}$: 1.3% (7.33 fb^{-1} $D_s^+ \to \mu^+\nu_\mu$)→ 0.9% (Combine all $D_s^+ \to \ell^+\nu_\ell$)

Form factors $f_+^{D\to h}$

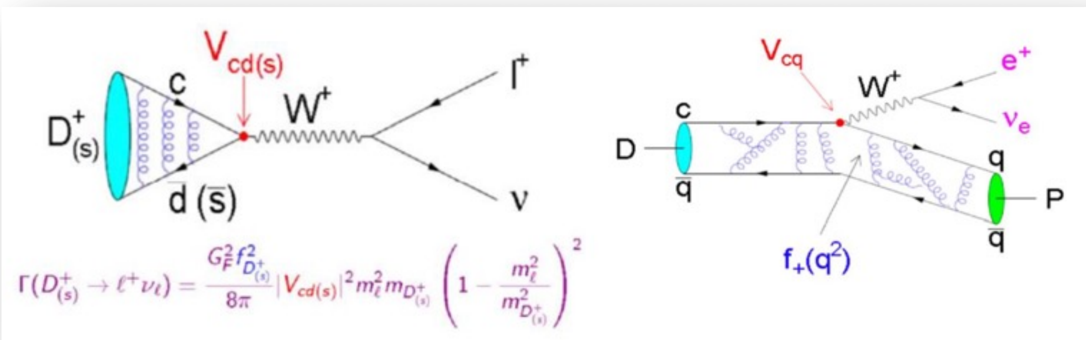


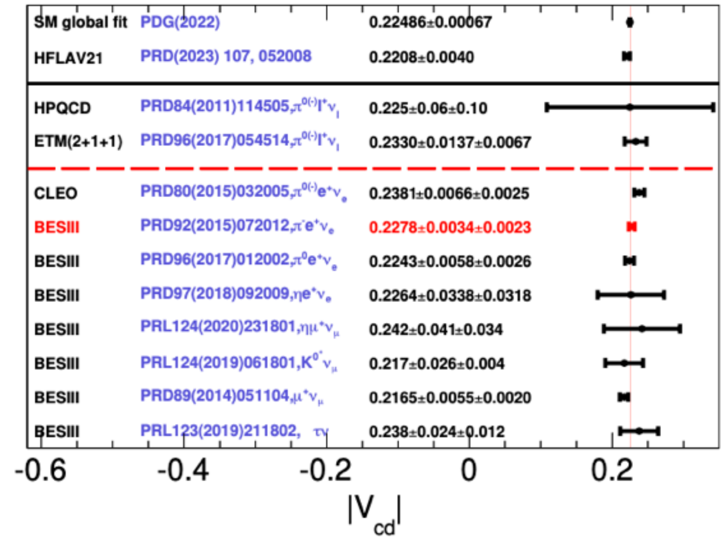




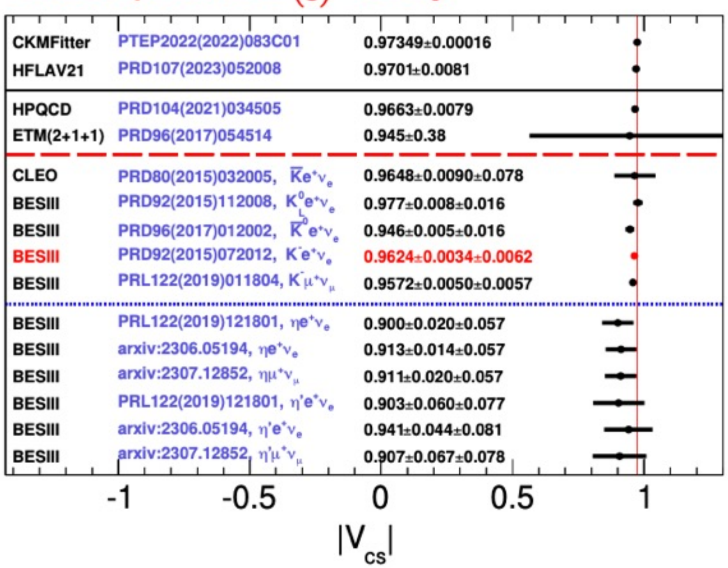
- LQCD has repaid improvement on precisions
- Systematics on from factors at BESIII will be dominant and crucial for further 20/fb charm data

Measurement of |Vcs| and |Vcd|

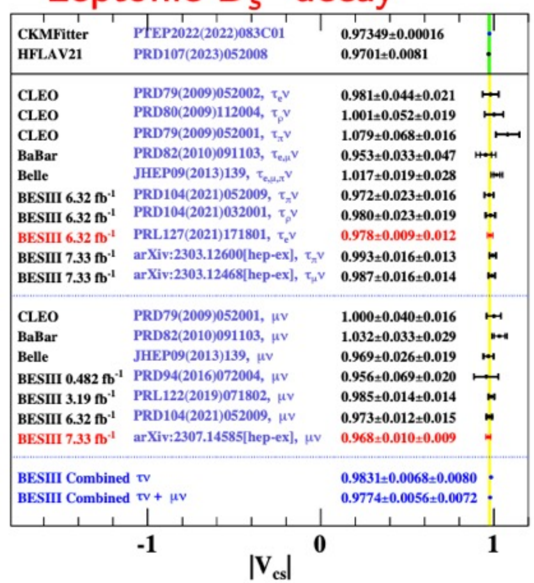




Semileptonic $D_{(s)}$ decay



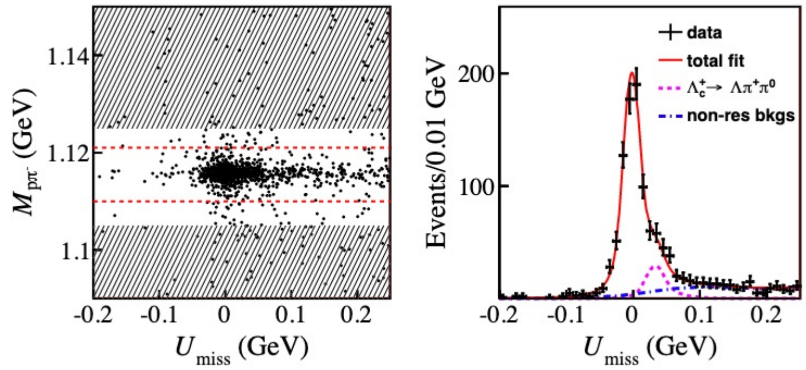
Leptonic D_s^+ decay

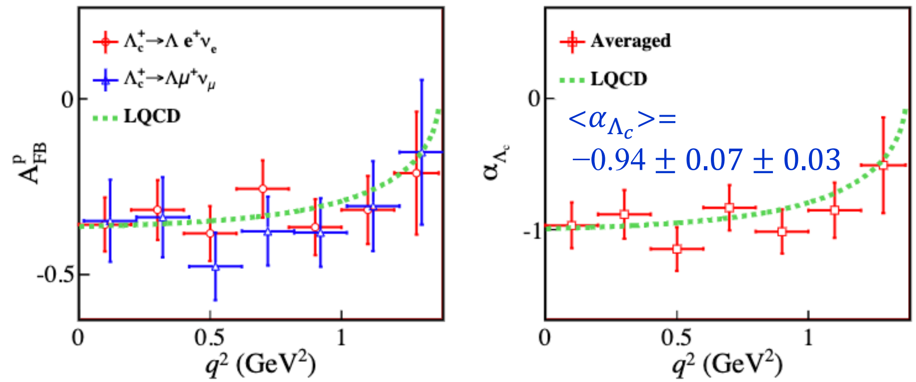


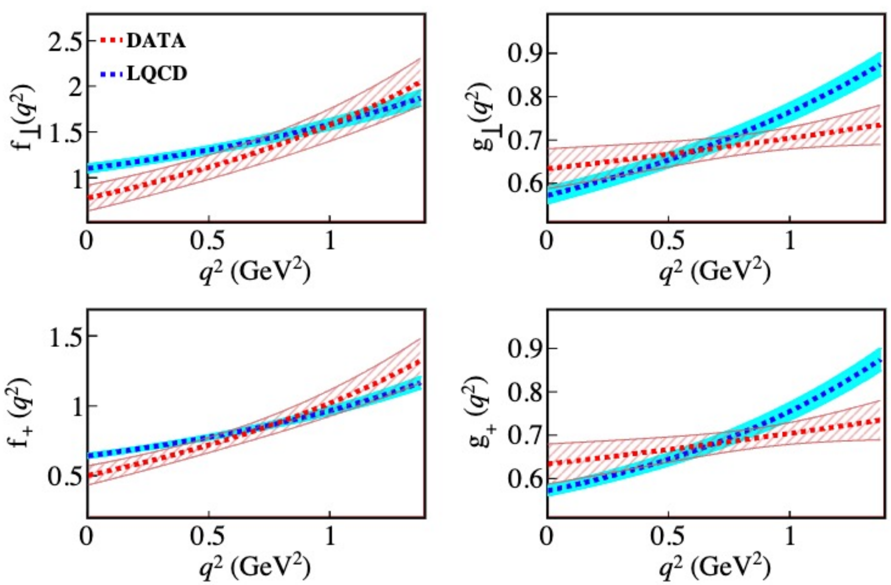
- Great precision improvement due to LQCD form factors
- No sign of conflicts between direct measurement and indirect fit

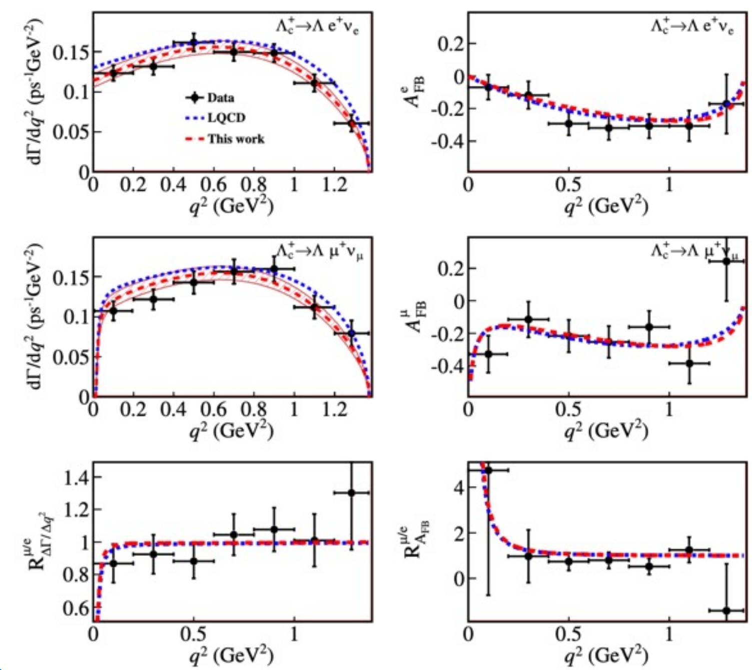
Combined form factor fits to $\Lambda_c^+ \to \Lambda\mu^+\nu_\mu$ and $\Lambda e^+\nu_e$

PRD108, L031105 (2023)







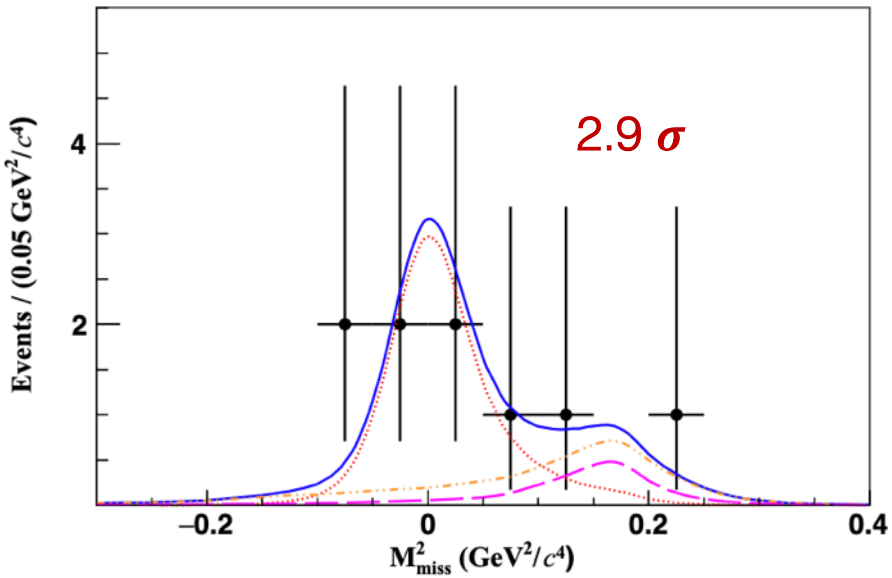


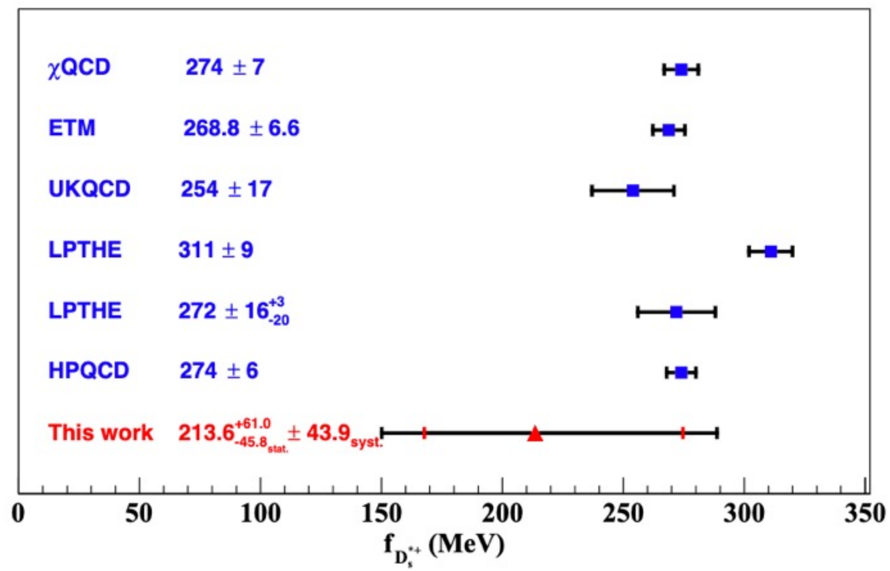
LQCD results from
S. Meinel, PRL118, 082001 (2017)

Study on $D_s^{*+} \to e^+\nu$

PRL131, 141802 (2023)

7.33 fb^{-1} of e^+e^- collision data between 4.128 and 4.226 GeV

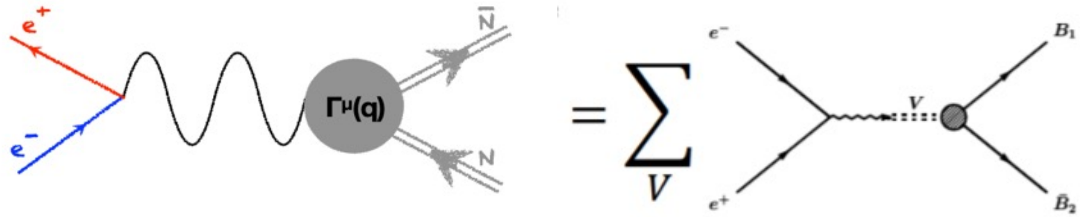


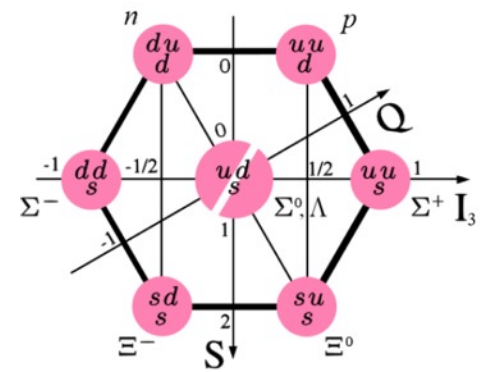


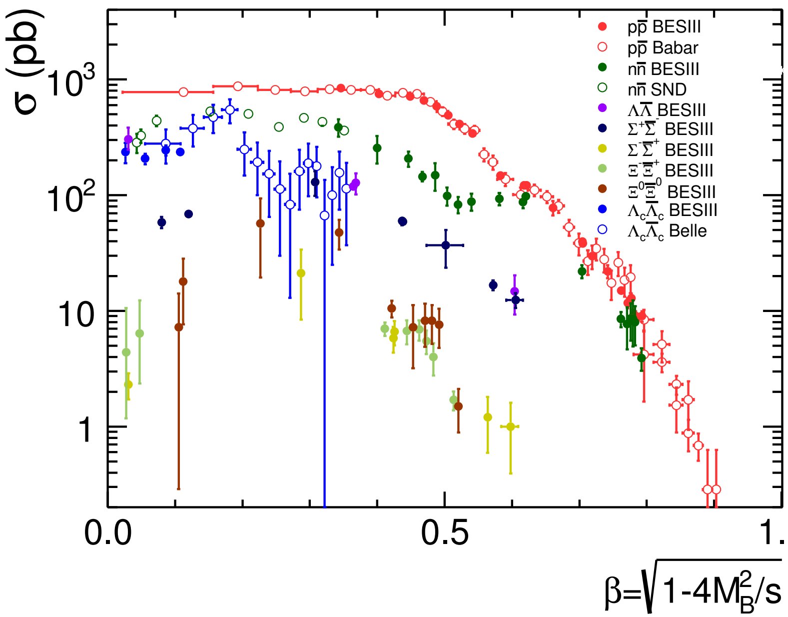
- Branching fraction is determined to be $(2.1^{+1.2}_{-0.9\,\text{stat.}} \pm 0.2_{\text{syst.}}) \times 10^{-5}$

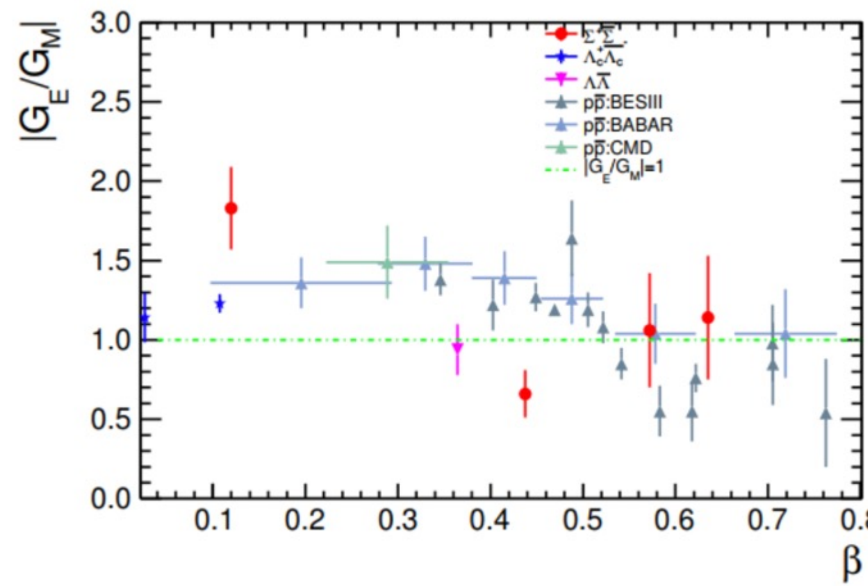
an avenue to study the weak decays of vector charmed mesons in experiment

Baryon pair production







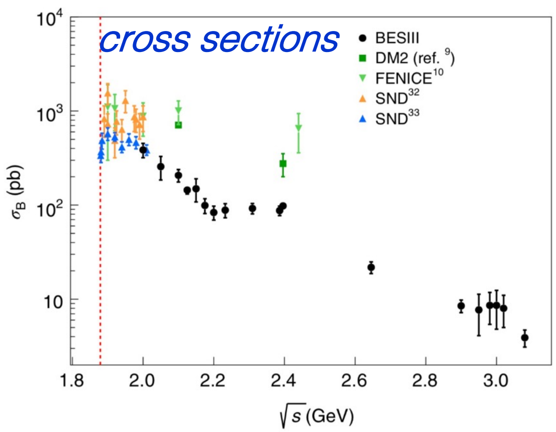


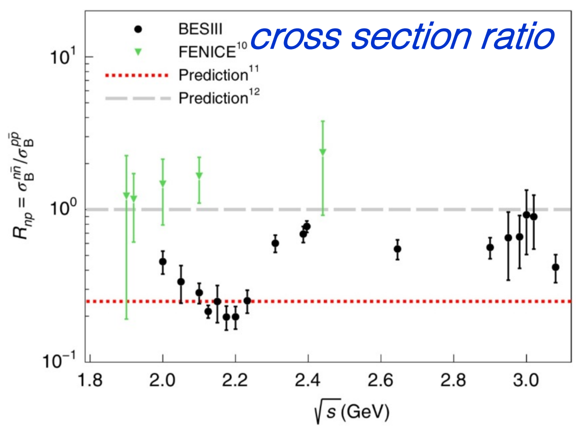
- Abnormal threshold effects observed in various baryon pair production: $p\bar{p},\ \Lambda\bar{\Lambda},\ \Lambda_c^+\bar{\Lambda}_c^-\ \ldots$
- $|G_E/G_M|$ ratio significantly larger than 1 at low beta for p, Λ_c^+, Σ^+, indicating large D-wave near threshold.

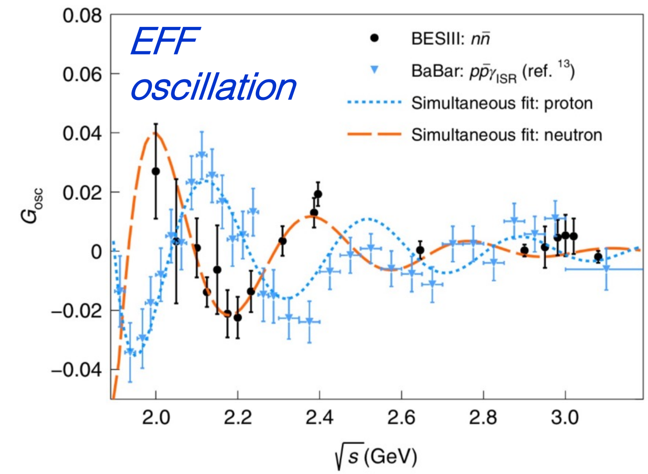
Threshold production of $e^+e^- \to n\bar{n}$

- Very challenging measurement due to pure neutron final states
- BESIII takes three approaches and provide validations among each other

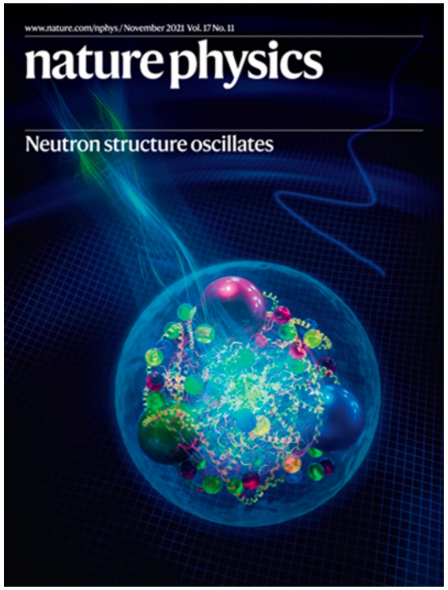
Nature Physics 17, 1200 (2021)







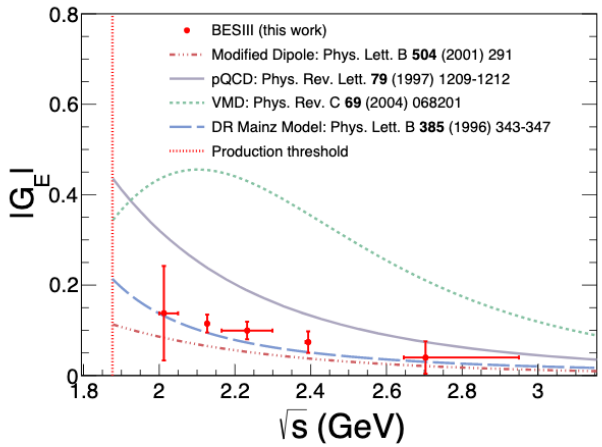
- XS measured in a wide range with unprecedented precision (~10%): confirming threshold enhancement
- XS ratio between proton and neutron: do not support the FENICE conjecture, but are within the theoretical predictions
- Oscillation of EFF observed in neutron data: simultaneous fit of proton and neutron data gives shared frequency (5.55±0.28) GeV^{-1} with almost orthogonal phase difference of (125±12)^{O}

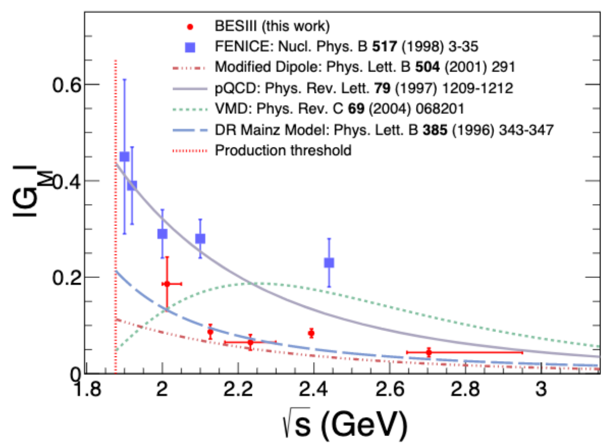


Separated electric and magnetic form factors of the neutron in time-like region

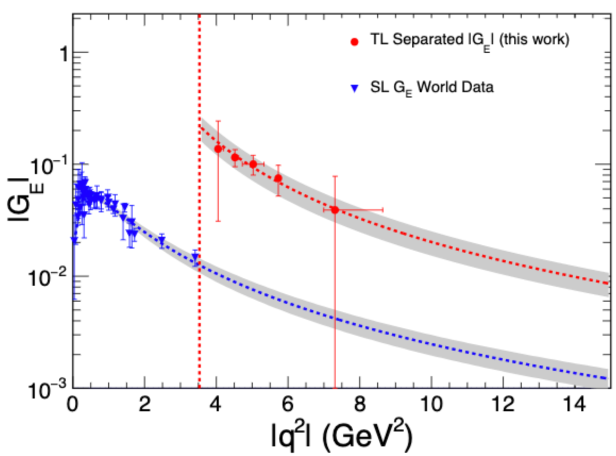
PRL130, 151905 (2023)

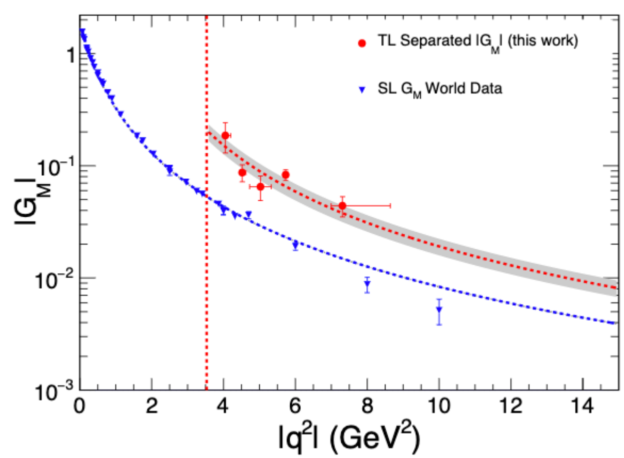
A spin-half particle, such as the nucleon, described by two EMFFs: $G_E(q^2)$ and $G_M(q^2)$, which are Fourier-transforms of the intrinsic electric and magnetic distributions of the nucleon in the Breit frame





- G_M: lower than FENICE results
- G_E and G_M: agree more with Dispersion Relations (DR)





Time-like (TL) vs Space-like (SL)

not sign of following the tendency of

$$\mathcal{R}^{E,M} \equiv \left|\frac{G^{TL}_{E,M}(q^2)}{G^{SL}_{E,M}(-q^2)}\right| \xrightarrow{|q^2|\to\infty} 1$$

Hyperon physics at BESIII

10 billion J/psi events collected

- Large rates in J/ψ decays
- Quantum entangled pair productions
- Background free, high efficiency

Hai-Bo Li, arXiv:1612.01775
A. Adlarson, A. Kupsc, arXiv:1908.03102

a hyperon factory!

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

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 ?

1980

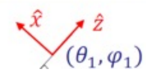
2008

Relative phase of Form Factors(FFs)

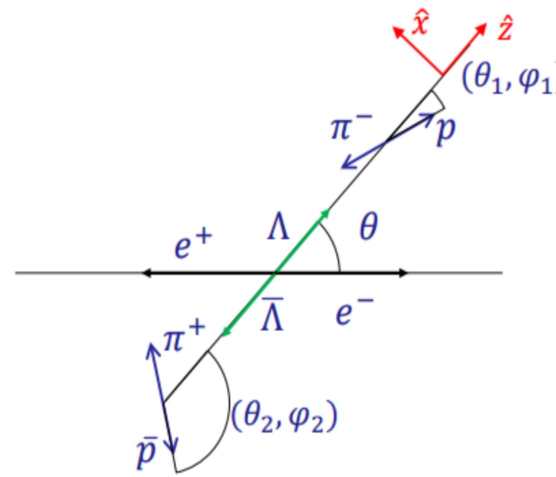
- Through the weak decay of hyperons, we could probe its polarization. Hence more information of the EFF can be studied
- $\Delta\phi$ is the phase angle difference of G_E and G_M: can be explored via angular analysis of the spin-coherent hyperon-pair weak decays

Unpolarized part   Polarized part   Spin correlated part

$$W(\xi) = F_0(\xi) + \eta F_5(\xi) + \alpha\bar{\alpha}\left(F_1(\xi) + \sqrt{1-\eta^2}\cos(\Delta\Phi)\,F_2(\xi) + \eta F_6(\xi)\right)$$
$$+\sqrt{1-\eta^2}\sin(\Delta\Phi)(\alpha F_3(\xi) + \bar{\alpha}F_4(\xi))$$



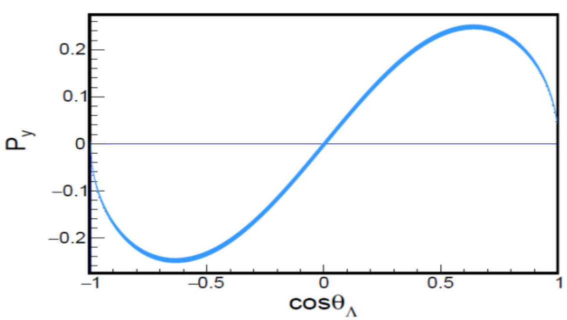
$$R = |G_E/G_M|,\ \Delta\Phi = \Phi_E - \Phi_M,\ \eta = \frac{\tau - R^2}{\tau + R^2}$$



polarization-term

independent α_- and α_+ dependence

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



$$\alpha = \frac{2\,\mathrm{Re}(S^*P)}{|S|^2+|P|^2}$$
$$\beta = \frac{2\,\mathrm{Im}(S^*P)}{|S|^2+|P|^2}$$
$$\gamma = \frac{|S|^2-|P|^2}{|S|^2+|P|^2}$$
$$\alpha^2+\beta^2+\gamma^2 = 1$$

CP asymmetry:

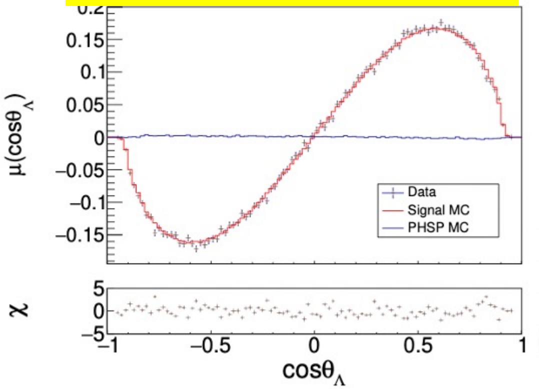
$$A = \frac{\alpha+\overline{\alpha}}{\alpha-\overline{\alpha}}, \quad B = \frac{\beta+\overline{\beta}}{\beta-\overline{\beta}}.$$

Polarization behavior in different hyperon pair productions

BESIII

$J/\psi \to \Lambda\bar{\Lambda}$

PRL129, 131801(2022)

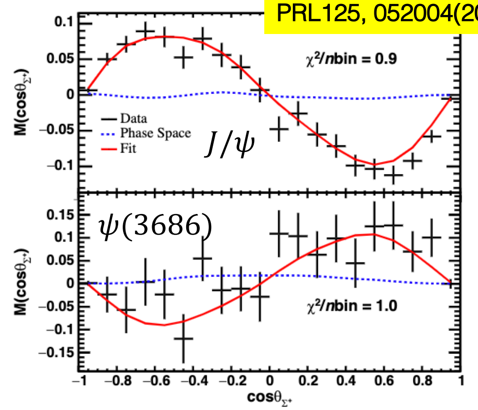


$\Delta\Phi = (0.7521 \pm 0.0042 \pm 0.0066) rad$

A_{CP}=$(-0.25 \pm 0.46 \pm 0.12)$%

$e^+e^- \to \psi \to \Sigma^+\bar{\Sigma}^- \to p\bar{p}\pi^0\pi^0$

PRL125, 052004(2020)

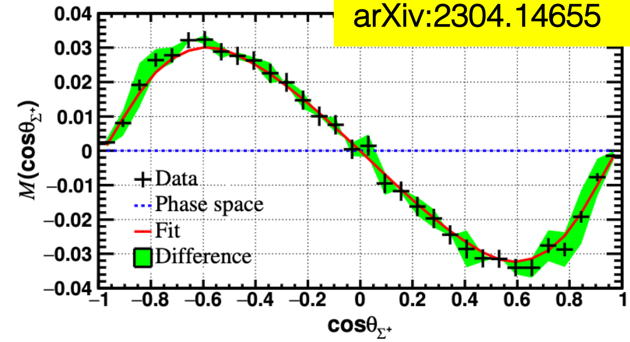


$\Delta\Phi[J/\psi] = 15.5° \pm 0.7° \pm 0.5°$ $\Delta\Phi[\psi'] = 21.7° \pm 4.0° \pm 0.8°$

A_{CP}=$(-0.4 \pm 3.7 \pm 1.0)$%

$e^+e^- \to J/\psi \to \Sigma^+\bar{\Sigma}^- \to n\pi^+\bar{p}\pi^0$

arXiv:2304.14655

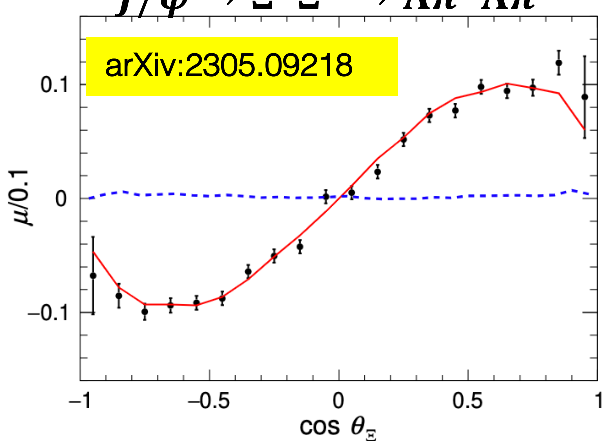


$\Delta\Phi = (-277.2 \pm 4.4 \pm 4.1)\times 10^{-3}$ rad

$A_{CP} = (-8.0 \pm 5.2 \pm 2.8)$%

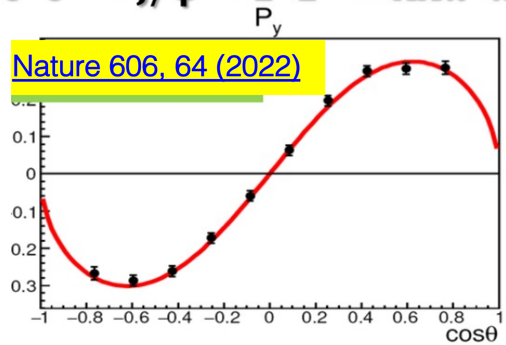
$J/\psi \to \Xi^0\bar{\Xi}^0 \to \Lambda\pi^0\bar{\Lambda}\pi^0$

arXiv:2305.09218



$e^+e^- \to J/\psi \to \Xi^-\bar{\Xi}^+ \to \Lambda\bar{\Lambda}\pi^+\pi^-$

Nature 606, 64 (2022)

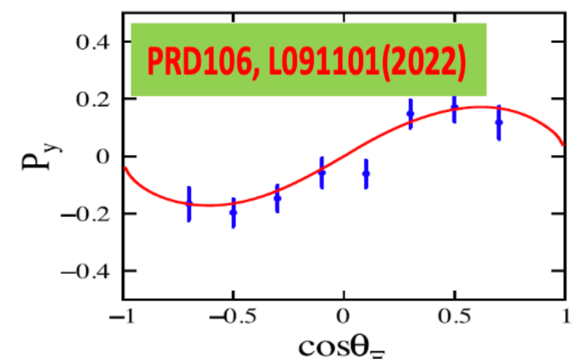


$\Delta\Phi = (1.213 \pm 0.046 \pm 0.016) rad$

A_{CP}=$(0.60 \pm 1.34 \pm 0.56)$%

$e^+e^- \to \psi' \to \Xi^-\bar{\Xi}^+ \to \Lambda\bar{\Lambda}\pi^+\pi^-$

PRD106, L091101(2022)

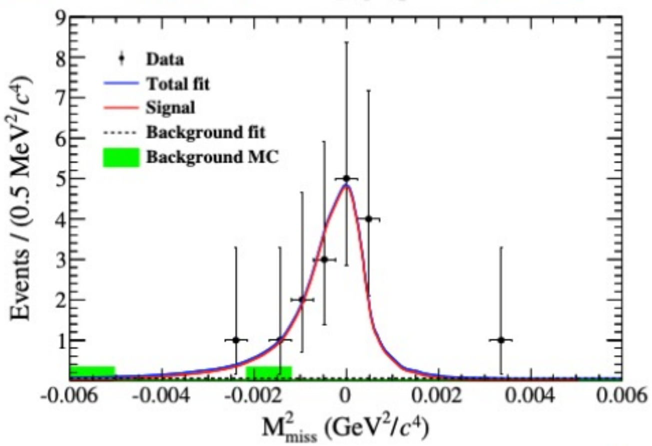


$\Delta\Phi = (0.667 \pm 0.111 \pm 0.058)$ rad.

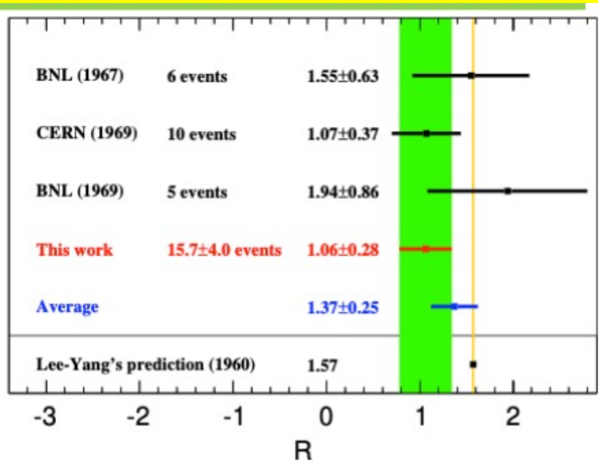
$A_{CP} = (-1.5 \pm 5.1 \pm 1.0)$%

Study on hyperon rare decays

$\Sigma^+ \to \Lambda e^- \nu$ via $J/\psi \to \Sigma^+ \bar{\Sigma}^-$

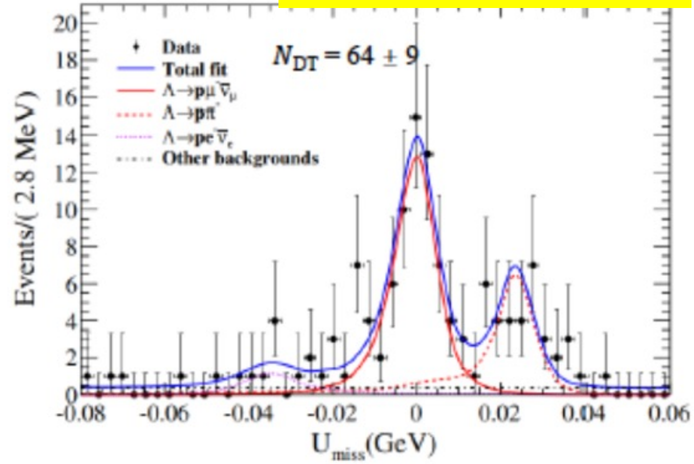


PRD 107, 072010 (2023)

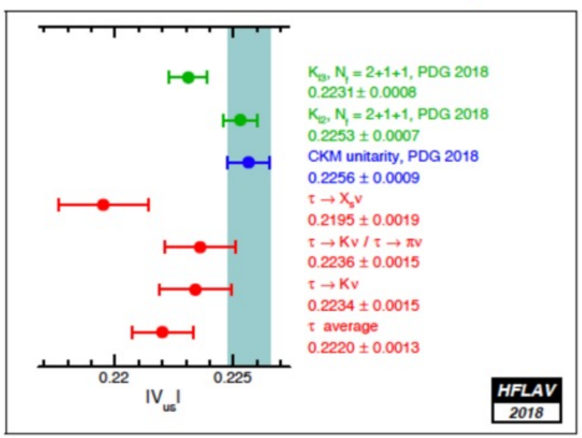


$\Lambda \to p\mu^- \nu$ in $J/\psi \to \Lambda\bar{\Lambda}$

PRL 127, 121802 (2023)



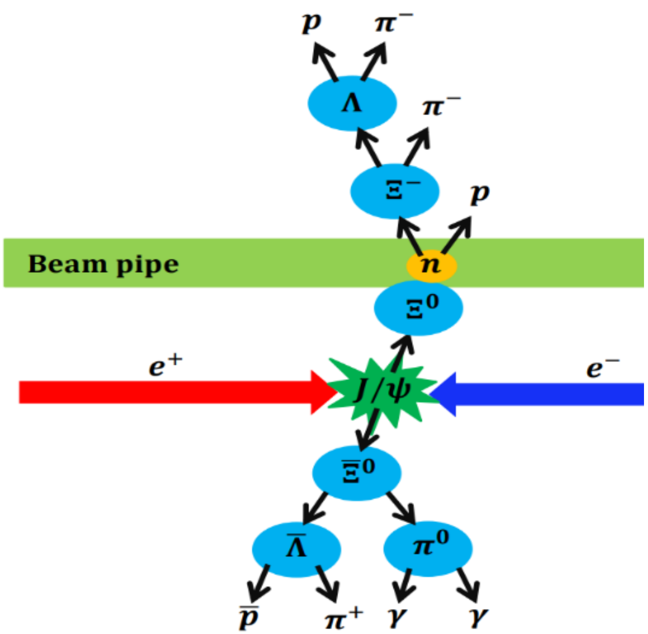
inconsistent |Vus| measurement



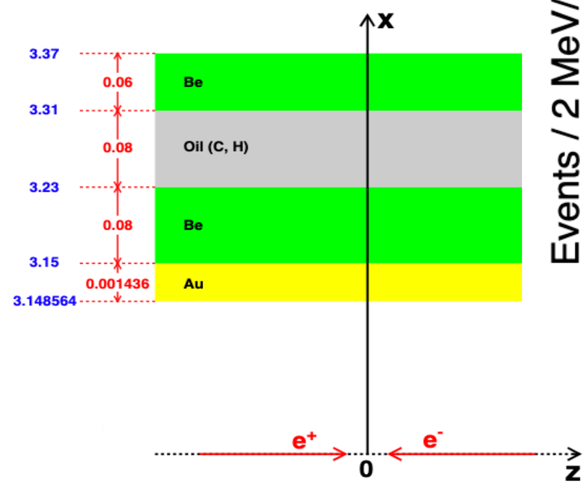
A hyperon beam bombarding beam-pipe target

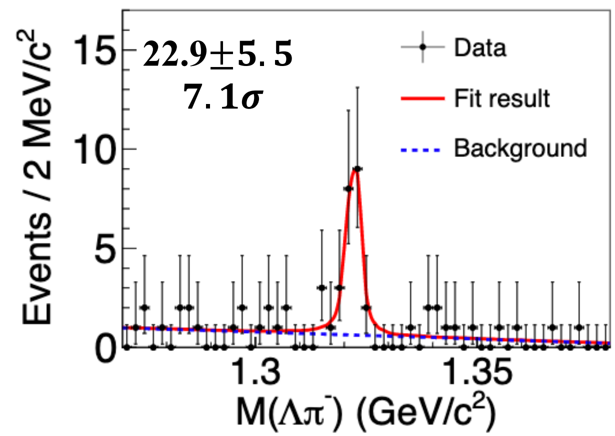
PRL130, 251902 (2023)

- Stable hyperon beam with well-known kinematics is challenging
- Hyperon-nucleon interactions have been studied both theoretically and experimentally. Among them, the knowledge about the Ξ-nucleon are very limited.
- Useful input to study *H*-dibaryon ($uuddss$) with S=-2



intense monoenergetic Ξ^0 baryon





$\Xi^0 n \to \Xi^- p$ is observed for the first time

For Ξ^0 momentum is 0.818 GeV/c

$$\sigma(\Xi^0 n \to \Xi^- p) = (7.4 \pm 1.8_{\rm stat} \pm 1.5_{\rm sys})\ {\rm mb}$$

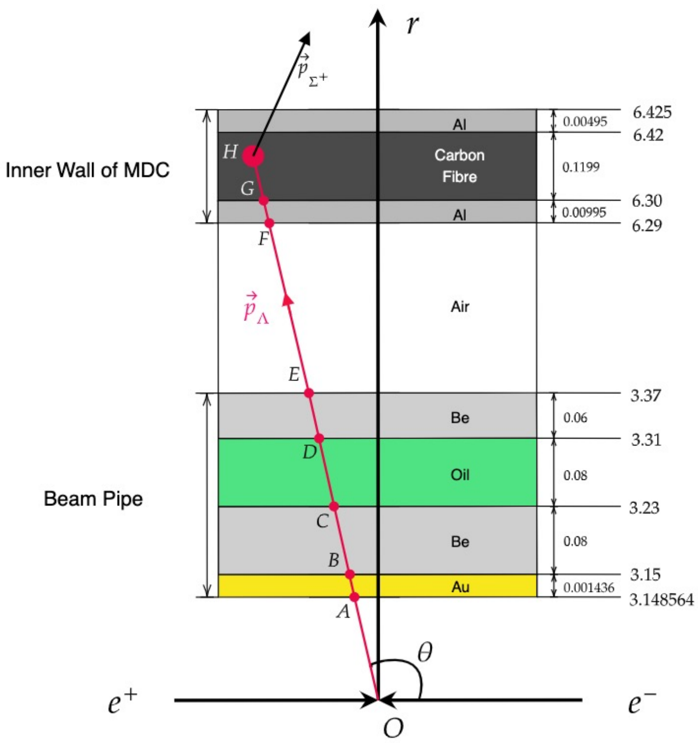
(assuming effective number of reaction neutrons in ^{9}Be is 3)

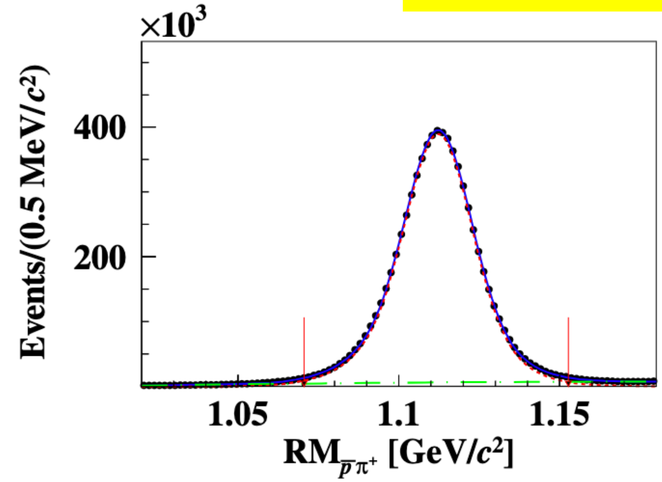
$$\sigma(\Xi^0 + {}^9{\rm Be} \to \Xi^- + p + {}^8{\rm Be}) = (22.1 \pm 5.3_{\rm stat} \pm 4.5_{\rm sys})\ {\rm mb}$$

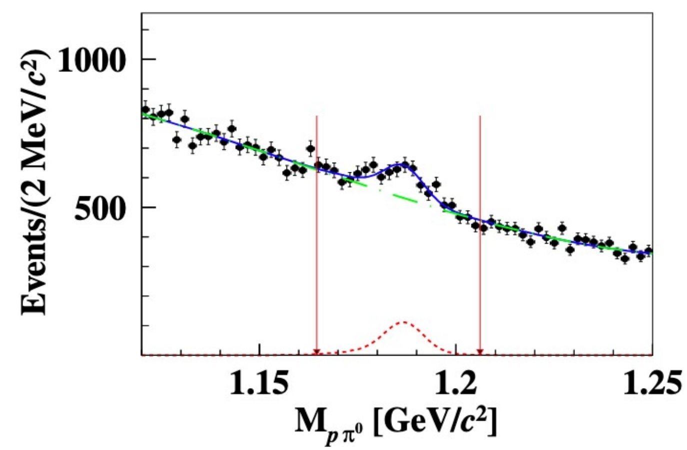
The first study of hyperon–nucleon interaction in electron–positron collisions!

Observation of $\Lambda N \to \Sigma^+ X$

arXiv:2310.00720







$$\sigma(\Lambda^9\mathrm{B_e} \to \Sigma^+ X) = (37.3 \pm 4.7 \pm 3.5)\ \mathrm{mb}$$
$$p_\Lambda \in [1.057, 1.091]\ \mathrm{GeV/c},$$

Planned future data set

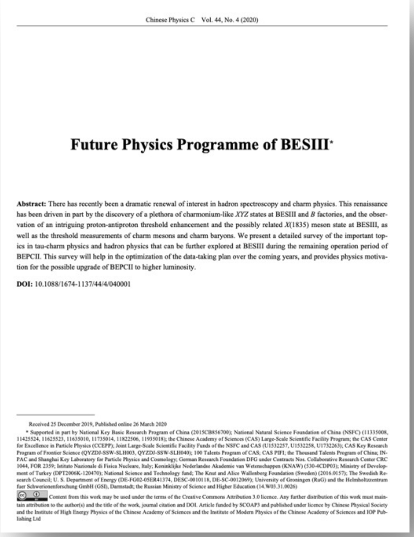
Chin. Phys. C 44, 040001 (2020)
[arXiv:1912.05983 [hep-ex]].

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

to be complete in 2022-24

~55 fb^{-1}


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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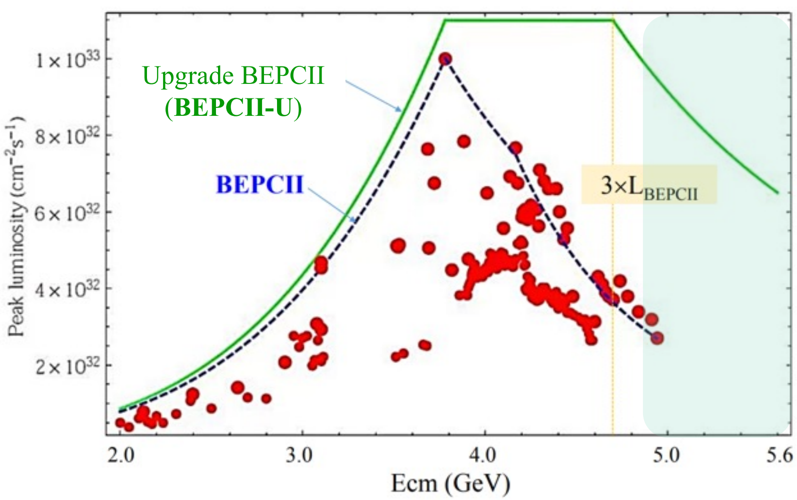
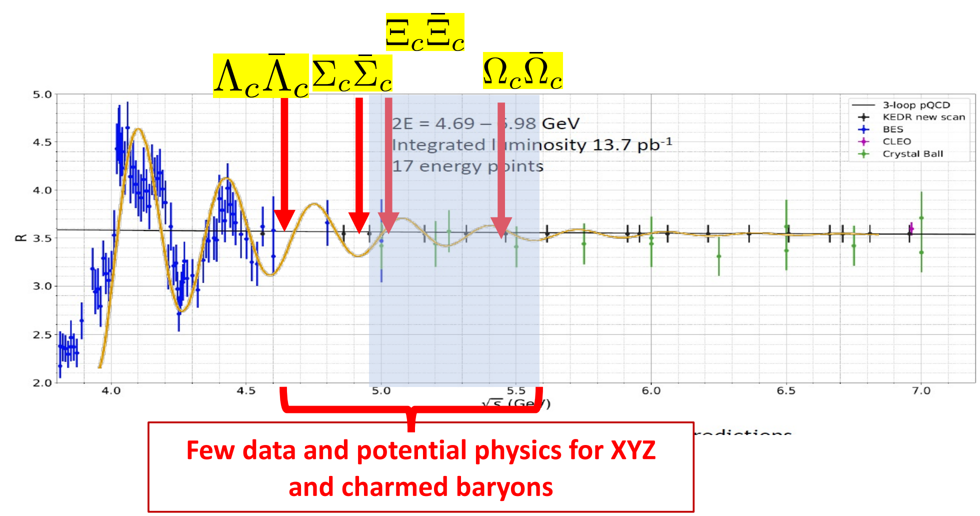
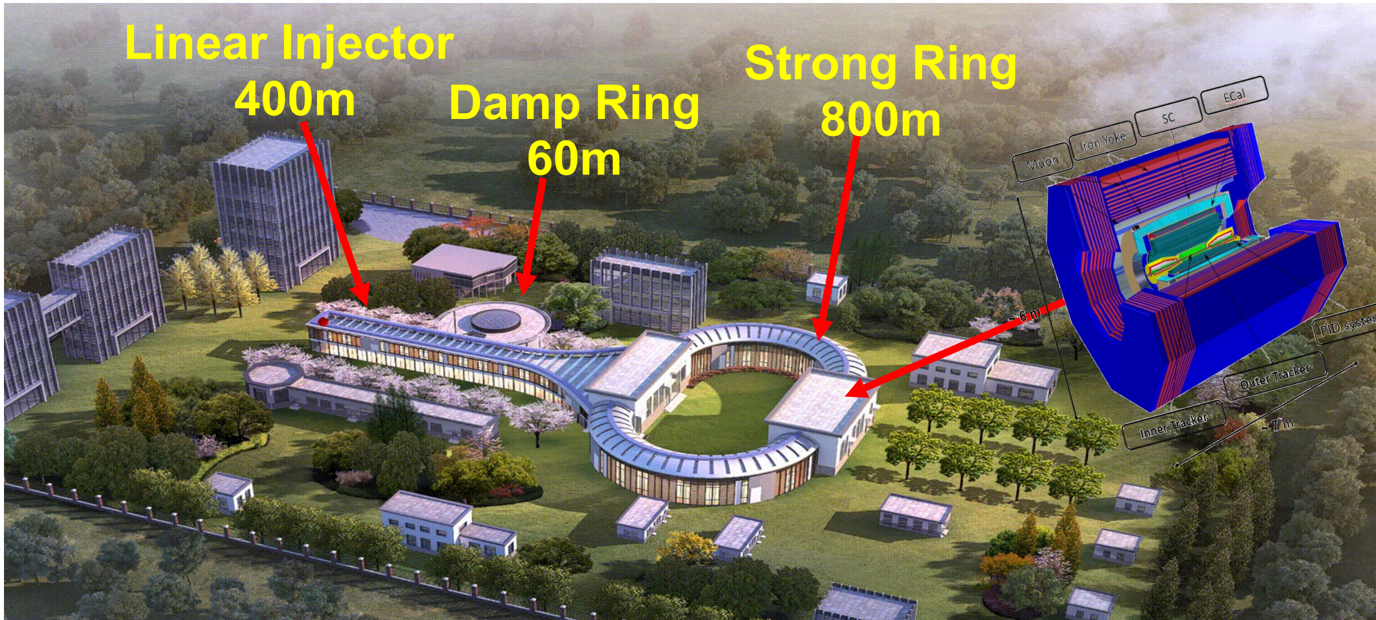
BEPCII-U in 2024

- ✓ Detailed studies of the known X/Y/$Z_{c(s)}$ states and search for `black swans` in the higher energy region within a considerable amount of data sets.
- ✓ Cover all the ground-state charmed baryons: production & decays, CPV search

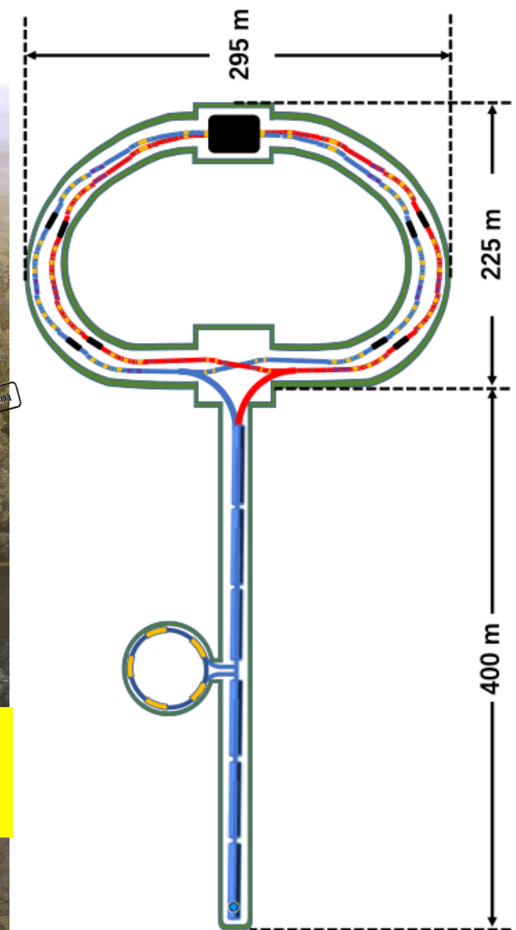




Super τ-Charm Facility



- E_{cm}=2-7GeV， peak Lumi.=5×10^{34} cm^{-2} s^{-1} @ 4GeV (100xBESIII)
- Potential for upgrade to increase L and realize polarized beam



- 14^{th} 5-year plan (2021-2025): Key technology R&D, 0.42 B CNY.
- 15^{th} 5-year plan (2026-2030): Construction, 6 years, 4.5 B CNY.
- Operating for 10 years, upgrade for 3 years, operating for another 7 years.

High Statistical Data : > 1 ab^{-1}/year

Table 1: The expected numbers of events per year at different STCF energy points.

CME (GeV)	Lumi (ab^{-1})		nb)	No. of Events	remark
3.097	1		00	3.4×10^{12}	
3.670	1		4	2.4×10^{9}	
3.686	1	$\psi(3686)$	640	6.4×10^{11}	
		$\tau^+\tau^-$	2.5	2.5×10^{9}	
		$\psi(3686) \to \tau^+\tau^-$		2.0×10^{9}	
3.770	1		6	3.6×10^{9}	
			8	2.8×10^{9}	
				7.9×10^{8}	Single Tag
		$D^+\bar{D}^-$		5.5×10^{8}	Single Tag
		$\tau^+\tau^-$	2.9	2.9×10^{9}	
4.009	1	$D^{*0}\bar{D}^0 + c.c$	4.0	1.4×10^{9}	$CP_{D^0\bar{D}^0} = +$
		$D^{*0}\bar{D}^0$	4.0	2.6×10^{9}	$CP_{D^0\bar{D}^0} = -$
			0.20	2.0×10^{8}	
			3.5	3.5×10^{9}	
4.180	1	$D_s^{+*}D_s^-$+c.c.	0.90	9.0×10^{8}	
		$D_s^{+*}D_s^-$+c.c.		1.3×10^{8}	Single Tag
		$\tau^+\tau^-$	3.6	3.6×10^{9}	
4.230	1	$J/\psi\pi^+\pi^-$	0.085	8.5×10^{7}	
		$\tau^+\tau^-$	3.6	3.6×10^{9}	
		$\gamma X(3872)$			
4.360	1	$\psi(3686)\pi^+\pi^-$	0.058	5.8×10^{7}	
		$\tau^+\tau^-$	3.5	3.5×10^{9}	
4.420	1	$\psi(3686)\pi^+\pi^-$	0.040	4.0×10^{7}	
		$\tau^+\tau^-$	3.5	3.5×10^{9}	
4.630	1	$\psi(3686)\pi^+\pi^-$	0.033	3.3×10^{7}	
		$\Lambda_c\bar{\Lambda}_c$	0.56	5.6×10^{8}	
		$\Lambda_c\bar{\Lambda}_c$		6.4×10^{7}	Single Tag
		$\tau^+\tau^-$	3.4	3.4×10^{9}	
4.0-7.0	3	300 points scan with 10 MeV step, 1 fb^{-1}/point			
> 5	2-7	several ab^{-1} high energy data, details dependent on scan results			

J/ψ 10^{12}

D pair 10^9

$\tau^+\tau^-$ 10^9

Millions to billions of Hyperons, light hadrons from J/ψ decays and XYZ's

Hyperon factory (10^{8-9})

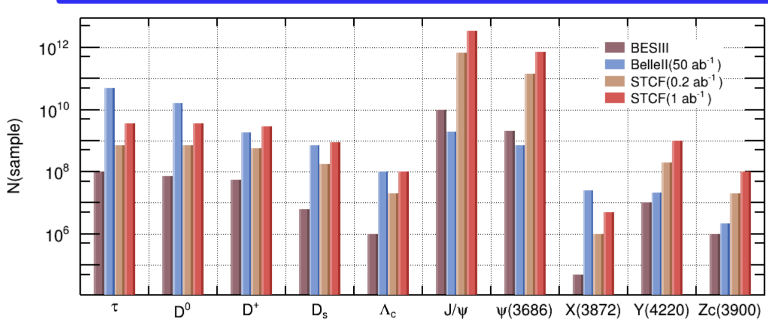
Decay mode	$\mathcal{B}$(units 10^{-4})	Angular distribution parameter α_ψ	Detection efficiency	No. events expected at STCF
$J/\psi \to \Lambda\bar{\Lambda}$	$19.43 \pm 0.03 \pm 0.33$	0.469 ± 0.026	40%	1100×10^6
$\psi(2S) \to \Lambda\bar{\Lambda}$	$3.97 \pm 0.02 \pm 0.12$	0.824 ± 0.074	40%	130×10^6
$J/\psi \to \Xi^0\bar{\Xi}^0$	11.65 ± 0.04	0.66 ± 0.03	14%	230×10^6
$\psi(2S) \to \Xi^0\bar{\Xi}^0$	2.73 ± 0.03	0.65 ± 0.09	14%	32×10^6
$J/\psi \to \Xi^-\bar{\Xi}^+$	10.40 ± 0.06	0.58 ± 0.04	19%	270×10^6
$\psi(2S) \to \Xi^-\bar{\Xi}^+$	2.78 ± 0.05	0.91 ± 0.13	19%	42×10^6

Light hadron (η/η') factory(10^{9-10})

Decay Mode	$\mathcal{B}$ ($\times 10^{-4}$) [2]	η/η' events
$J/\psi \to \gamma\eta'$	52.1 ± 1.7	1.8×10^{10}
$J/\psi \to \gamma\eta$	11.08 ± 0.27	3.7×10^{9}
$J/\psi \to \phi\eta'$	7.4 ± 0.8	2.5×10^{9}
$J/\psi \to \phi\eta$	4.6 ± 0.5	1.6×10^{9}

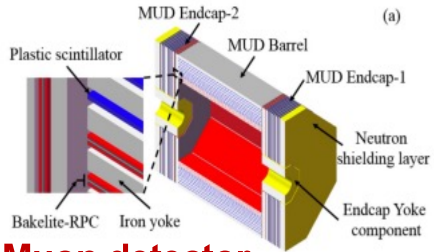
XYZ factory (10^{6-10})

XYZ	Y(4260)	$Z_c(3900)$	$Z_c(4020)$	X(3872)
No. of events	10^{10}	10^9	10^9	5×10^6



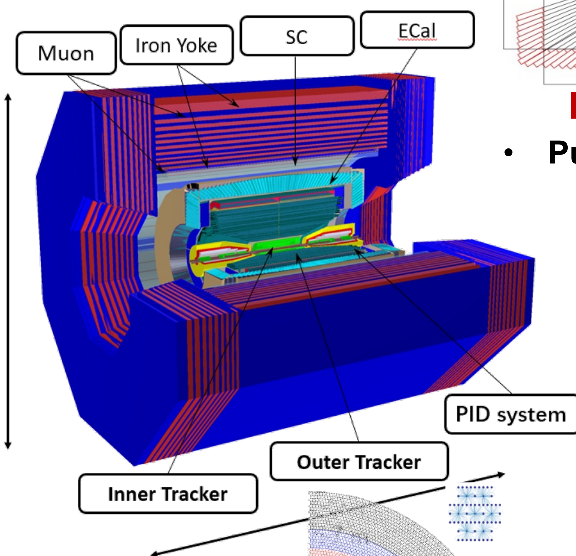
- QCD and Hadron Physics
- Flavor Physics and CPV
- Search for New Physics Beyond SM

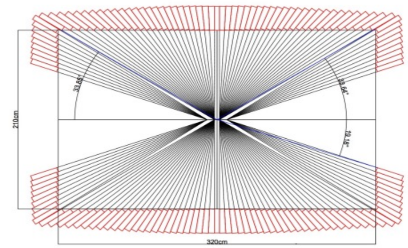
Detector options



Muon detector

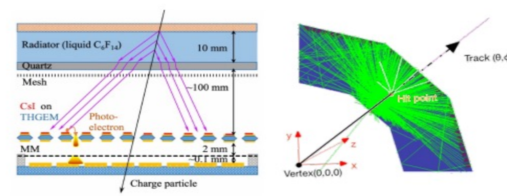
- Bakelite RPC + Scintillator strips





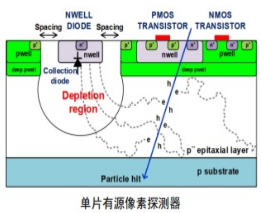
EM calorimeter

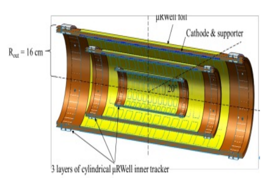
- Pure CsI crystal + APD



Particle Identification

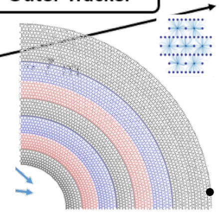
- Barrel : RICH
- EndCap : DIRC-Like TOF





Inner Tracker

- MPGD: Cylindrical μRWELL
- Silicon : CMOS MAPS



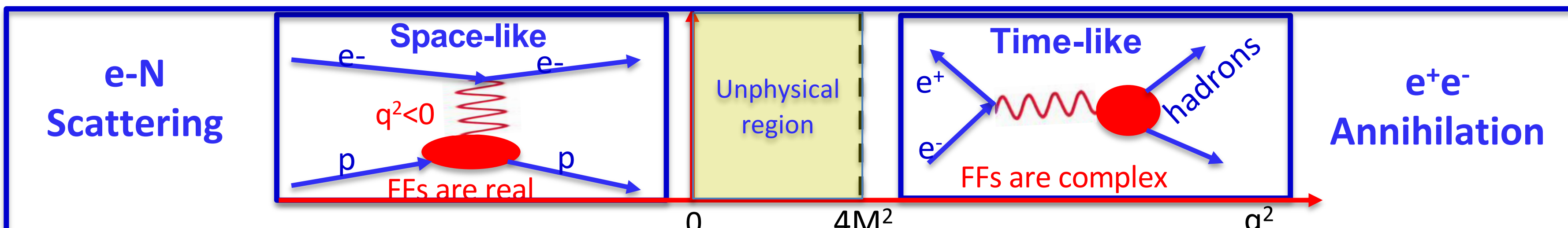
Central Tracker

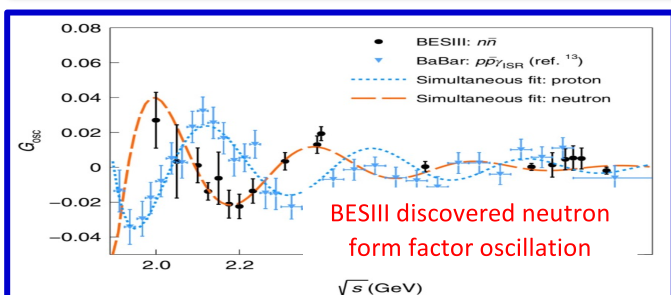
- Drift Chamber with extreme-low mass and small cell

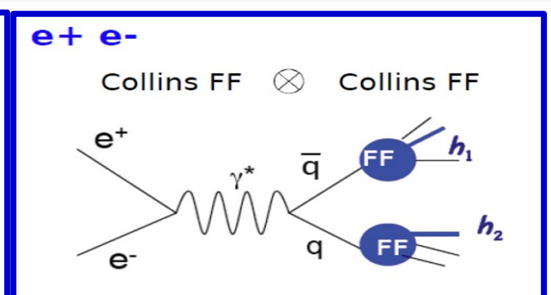
The R&D of each sub-system are ongoing, include both detector and electronics

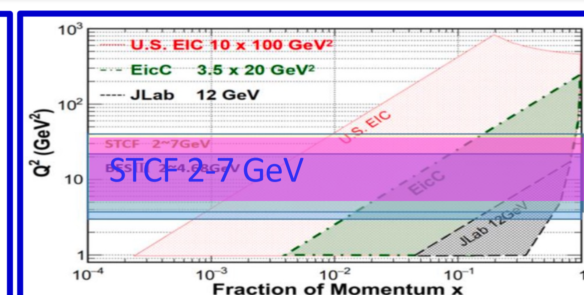
Hadron Production and Hadron Structure

- **Hadron production:**
  - ✓ from 0.6 to 7 GeV exclusively and inclusively (+ making use of ISR)
- **Nucleon electromagnetic form factors:**
  - ✓ fundamental observables reflect the inner structure of nucleon
  - ✓ complementary to e-N elastic scattering experiments in similar q^2 region.
- **Fragmentation function (FF):**
  - ✓ understanding QCD dynamics, hadron structure and production mechanism
  - ✓ new data from e^+e^- to compare with ep data and to verify its universality

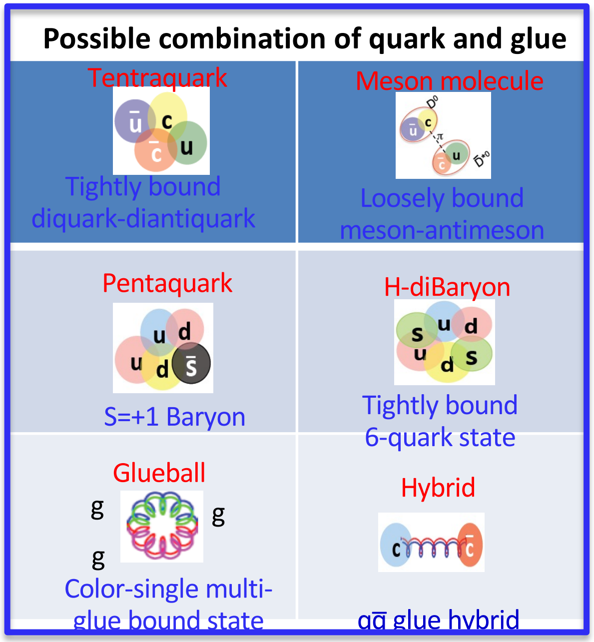


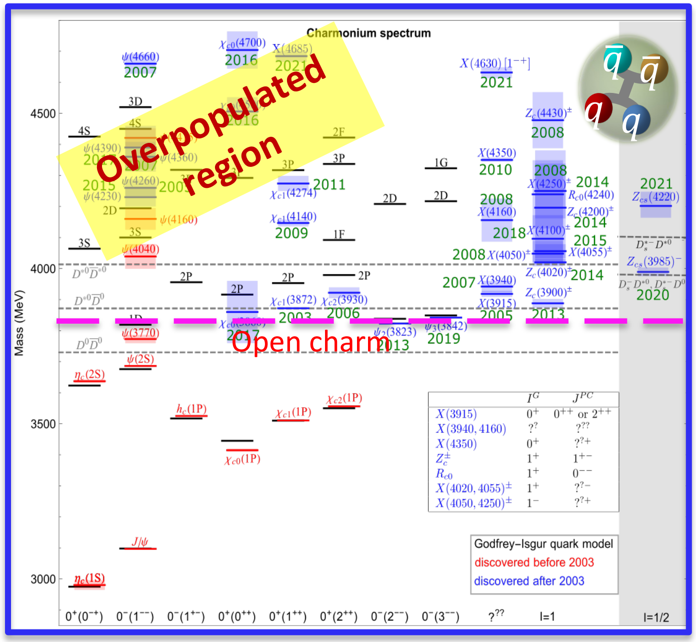


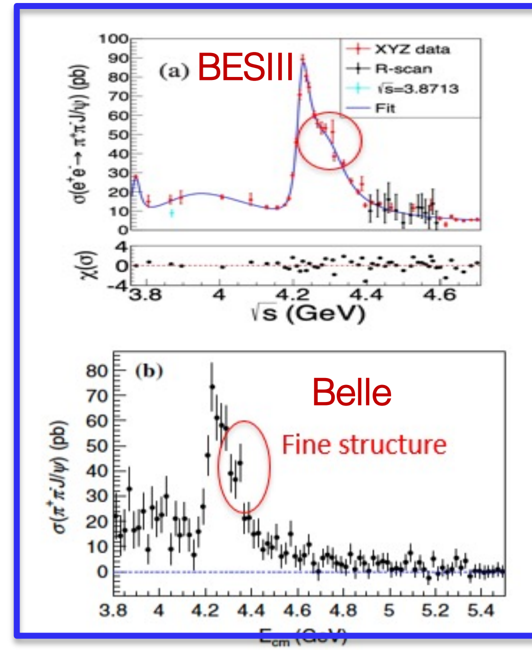




Hadron Spectroscopy and Exotic Hadrons







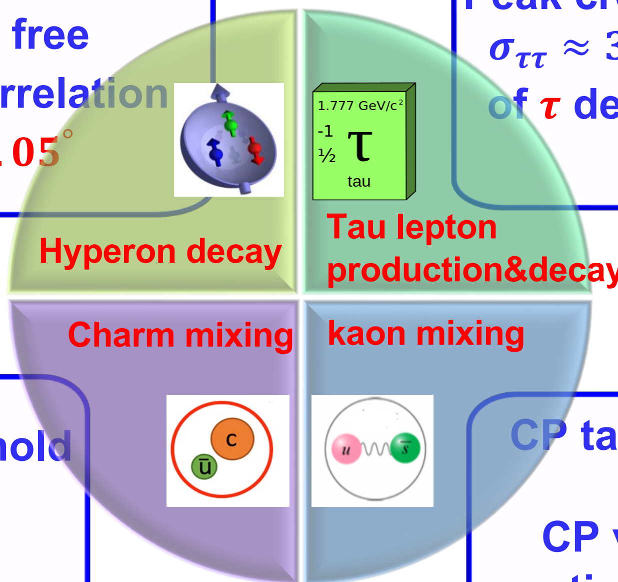
- Hadron **spectroscopy** is a crucial way to explore the QCD and its properties.
- QCD allows combinations of **multi-quarks and gluons**.
- Spectrum above open charm is much **overpopulated** → many exotic states?
- STCF has unique **advantages** for searching exotic hadrons (large effective luminosity, efficiency)

Flavor Physics and CP Violation

- **Large statistical** data samples from STCF offer the great opportunity to study **CP violation** in the Hyperon, Tau lepton, Charmed meson and Kaon
- **Polarized beam** is expected to improve the prob sensitivity.

Hyperon pairs from J/ψ decay,
clean topology, background free
Transversely polarized, spin correlation
Sensitivity: $A_{CP}\sim10^{-4}$, $\xi\sim0.05^{\circ}$

Peak cross section in $\sqrt{s}$ =4-5 GeV,
$\sigma_{\tau\tau}\approx3.5$ nb, 10 ab^{-1} data in total
of τ decay with 1ab^{-1} @ 4.26 GeV
Sensitivity $\sim10^{-3}$



$D^0\bar{D}^0$pairs produced at threshold
quantum coherence with
$(D^0\bar{D}^0)_{CP=-}$ or $(D^0\bar{D}^0)_{CP=+}$
Sensitivity: $x\sim0.035\%$,
$y\sim0.023\%$, $r_{CP}\sim0.017$, $\alpha_{CP}\sim1.3^{\circ}$

CP tagging and flavor tagging of
$K^0/\bar{K}^0$from J/ψ decay
CP variables determined with
time-dependent decay rate
CP, CPT sensitivity:
$\eta_{\pm}\sim10^{-3}$, $\Delta\phi_{\pm}\sim0.05^{\circ}$

Conceptual Design Report

arXiv > hep-ex > arXiv:2303.15790

Search...

Help | Advanced

High Energy Physics - Experiment

[Submitted on 28 Mar 2023]

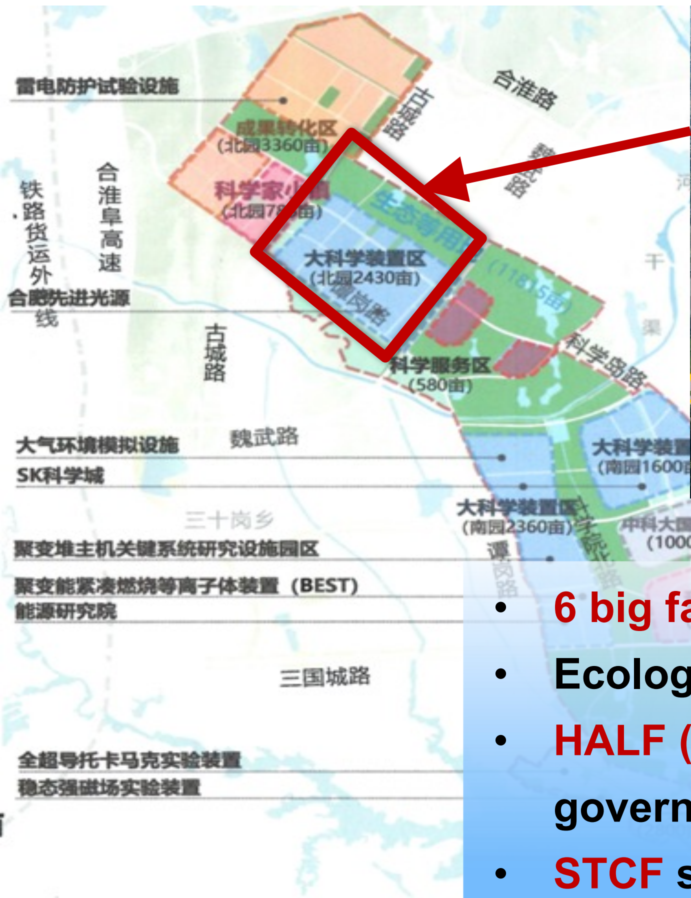
STCF Conceptual Design Report: Volume 1 -- Physics & Detector

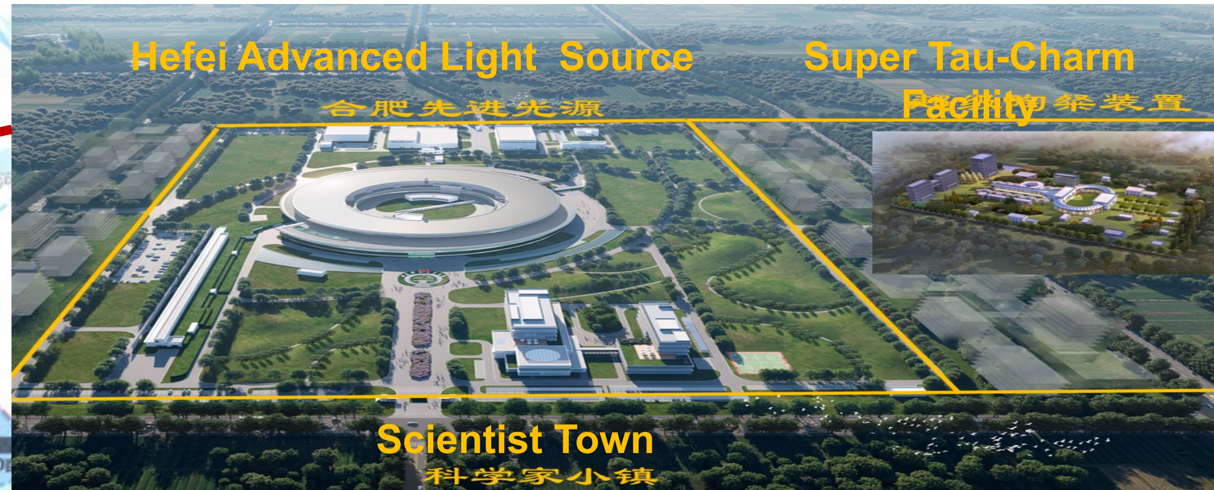
M. Achasov, X. C. Ai, R. Aliberti, Q. An, X. Z. Bai, Y. Bai, O. Bak
Bodrov, A. Bogomyagkov, A. Bondar, I. Boyko, Z. H. Bu, F. M.
Chang, K. T. Chao, D. Y. Chen, H. Chen, H. X. Chen, J. F. Che
Chen, S. Chen, S. P. Chen, W. Chen, X. F. Chen, X. Chen, Y. C
Cheng, J. P. Dai, L. Y. Dai, X. C. Dai, D. Dedovich, A. Denig, I.
Druzhinin, D. S. Du, Y. J. Du, Z. G. Du, L. M. Duan, D. Epifano
C. Q. Feng, X. Feng, Y. T. Feng, J. L. Fu, J. Gao, P. S. Ge, C. C
W. Gradl, J. L. Gu, A. G. Escalante, L. C. Gui, F. K. Guo, J. C.
L. Han, L. Han, M. Han, X. Q. Hao, J. B. He, S. Q. He, X. G. He
Hou, Y. R. Hou, C. Y. Hu, H. M. Hu, K. Hu, R. J. Hu, X. H. Hu, Y

The Super τ-Charm facility (STCF) is an electron-positron collider prop
is designed to operate in a center-of-mass energy range from 2 to 7 G
or higher. The STCF will produce a data sample about a factor of 100

Construction Site: Hefei, Anhui

Heifei Science City: one of three comprehensive national science centers for 'Mega-science' facilities in China





- **6 big facilities for science and technologies (17155 acres).**
- **Ecological green space and modern agricultural (11815 acres)**
- **HALF (4th generation light source) was approved by central government，and just began construction**
- **STCF site is preliminarily decided by local government in Apr. 2023, geological exploration and engineering design is ongoing**

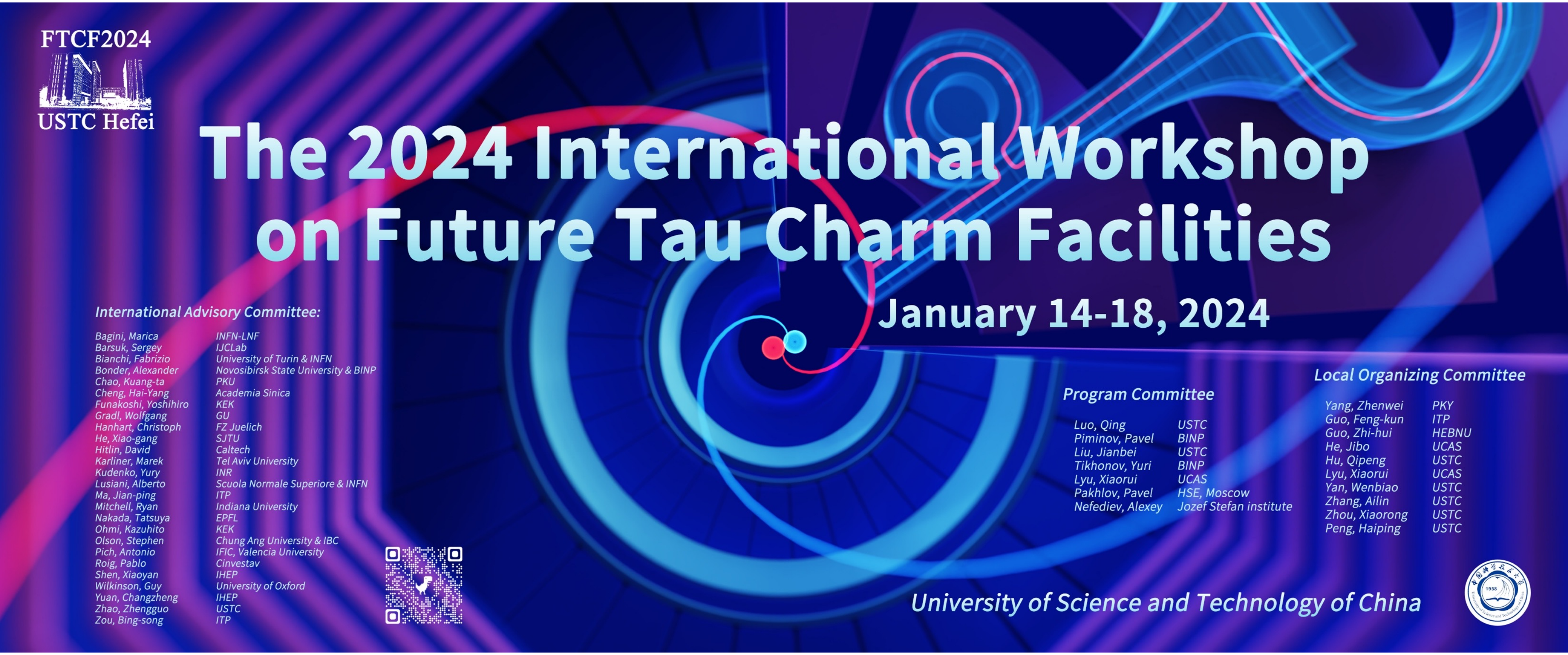
Tentative Plan of STCF

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032-2046	2046
Form collaboration																
Conception design CDR																
R&D (TDR)																
Construction																
Operation																

Summary

- BESIII is successfully operating since 2008, and will continue to run for 5–10 years
- Accomplish many precision measurements and new observations
  - ✓ Charmed mesons and baryons
  - ✓ XYZ states and light hadron spectroscopy
  - ✓ Form factors of the nucleon and hyperons
  - ✓ Low-Q^2 QCD studies
  - ✓ CPV search, rare decays and new physics search
  - ✓ …
- BEPCII-U: 3x upgrade on luminosity
- Future data set:50M D0, 50M D+, 15M Ds, 2M Λc , high-lumi. fine scan between 3.8 GeV and 5.6 GeV
- STCF will be an important next-generation project in the precision frontier

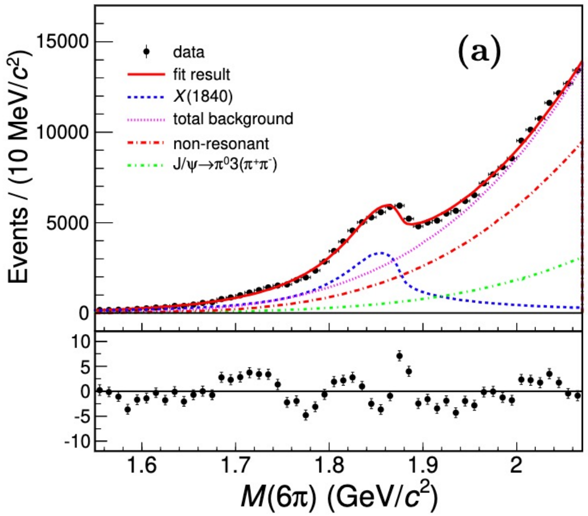
https://indico.pnp.ustc.edu.cn/event/91/



sincerely welcome your attendance!

Thank you!

谢谢！



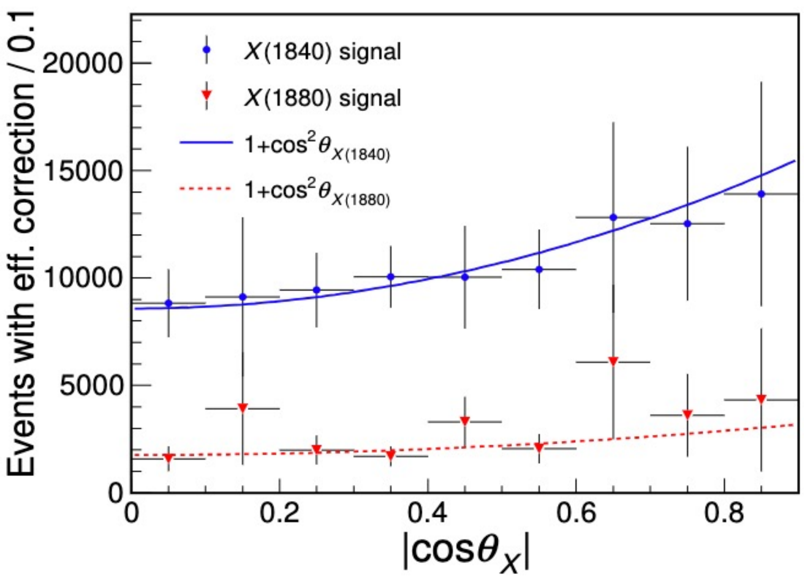
$$A = \left| \frac{1}{M^2 - s - i\sum_j g_j^2 \rho_j} \right|^2,$$

$$\sum_j g_j^2 \rho_j \approx g_0^2 (\rho_0 + \frac{g_{p\bar{p}}^2}{g_0^2} \rho_{p\bar{p}})$$

$M = 1.818 \pm 0.009\ \mathrm{GeV}/c^2,$

$g_{p\bar{p}}^2 = 51.4 \pm 14.8\ \mathrm{GeV}^2/c^4$

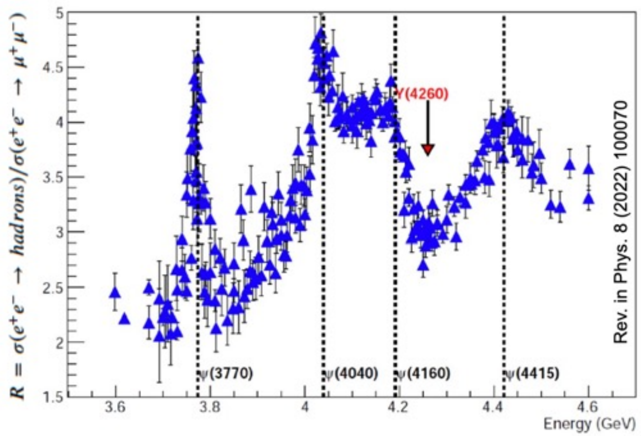
$g_0^2 = 18.0 \pm 2.8\ \mathrm{GeV}^2/c^4$



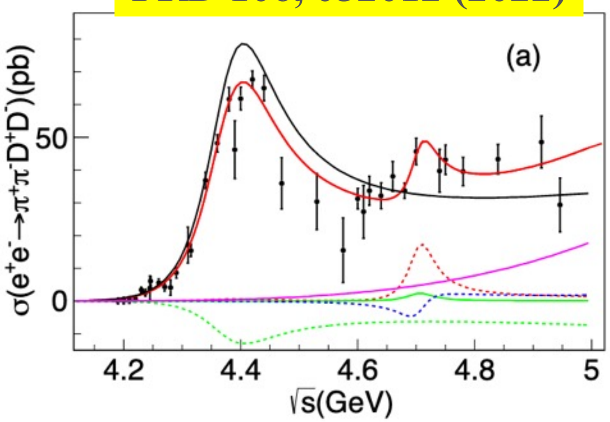
Name	Mass(MeV/c^2)	Width(MeV)	Journal	arXiv
N(2570)	2570_{-10-10}^{+19+34}	250_{-24-21}^{+14+69}	PhysRevLett.110, 022001	1207.0223
N(2300)	$2300_{-30-0}^{+40+109}$	$340_{-30-58}^{+30+110}$	PhysRevLett.110, 022001	1207.0223
X(1870)	$1877.3\pm6.3_{-7.4}^{+3.4}$	$57\pm12_{-4}^{+19}$	PhysRevLett.107, 182001	1107.1806
X(1840)	$1842.2\pm4.1_{-2.6}^{+7.1}$	$83\pm14\pm11$	PhysRevD.88.091502	1305.5333
X(2500)	$2470_{-19-23}^{+15+101}$	230_{-35-33}^{+64+56}	PhysRevD.93.112011	1602.01523
X(2262)	$2262\pm4\pm28$	$72\pm5\pm43$	PhysRevD.104.052006	2104.08754
X(2120)	$2122.4\pm6.7_{-2.7}^{+4.7}$	$83\pm16_{-11}^{+31}$	PhysRevLett.106.072002	1012.3510
X(2370)	$2376.3\pm8.7_{-4.3}^{+3.2}$	$83\pm17_{-6}^{+44}$	PhysRevLett.106.072002	1012.3510
X(2600)	$2617.8\pm2.1_{-1.9}^{+18.2}$	$200\pm8_{-17}^{+20}$	PhysRevLett. 129, 042001	2201.10796
X(2356)	$2356\pm7\pm17$	$304\pm28\pm54$		2211.10755
f0(2480)	$2470\pm4_{-6}^{+4}$	$75\pm9_{-8}^{+11}$	PhysRevD 105, 072002	2201.09710
omega(2250)	$2223\pm16\pm11$	$51\pm29\pm21$	PhysRevD.105.032005	2112.15076
a0(1817)+-0	$1817\pm8\pm20$	$97\pm22\pm15$	PhysRevLett.129.182001	2204.09614
eta1(1855)	$1855\pm9_{-1}^{+16}$	$188\pm18_{-8}^{+3}$	PhysRevLett. 129, 192002	2202.00621
Y(4390)	$4391.6_{-6.9}^{+6.3}\pm1.0$	$139.5_{-20.6}^{+16.2}\pm0.6$	PhysRevLett. 118, 092002	1610.07044
Y(4320)	$4320.0\pm10.4\pm7.0$	$1101.4_{-19.7}^{+25.3}\pm10.2$	PhysRevLett. 118, 092001	1611.01317
Y(4230)	$4222.0\pm3.1\pm1.4$	$44.1\pm4.3\pm2.0$	PhysRevLett. 118, 092001	1611.01317
Y(4790)	4793.3 ± 7.5	27.1 ± 7.0		2305.10789
psi2(3823)	$3821.7\pm1.3\pm0.7$	<16	PhysRevLett.115.011803	1503.08203
Y(4500)	$4484.7\pm13.3\pm24.1$	$111.1\pm30.1\pm15.2$	Chin.Phys.C,46,111002	2204.07800
Zc(3900)+-	$3899.0\pm3.6\pm4.9$	$46\pm10\pm20$	PhysRevLett.110.252001	1303.5949
Zc(3900)0	$3894.8\pm2.3\pm3.2$	$29.6\pm8.2\pm8.2$	PhysRevLett.115.112003	1506.06018
Zc(4020)+-	$4022.9\pm0.8\pm2.7$	$7.9\pm2.7\pm2.6$	PhysRevLett.111.242001/ PhysRevLett.112.132001	1309.1896/ 1308.2760
Zc(4020)0	$4023.9\pm2.2\pm3.8$	7.9(Fixed)	PhysRevLett.113.212002	1409.6577
Zcs(3985)+-	$3982_{-2.6}^{+1.8}\pm2.1$	$12.8_{-4.4}^{+5.3}\pm3.0$	PhysRevLett.126.102001	2011.07855

Open charm cross sections

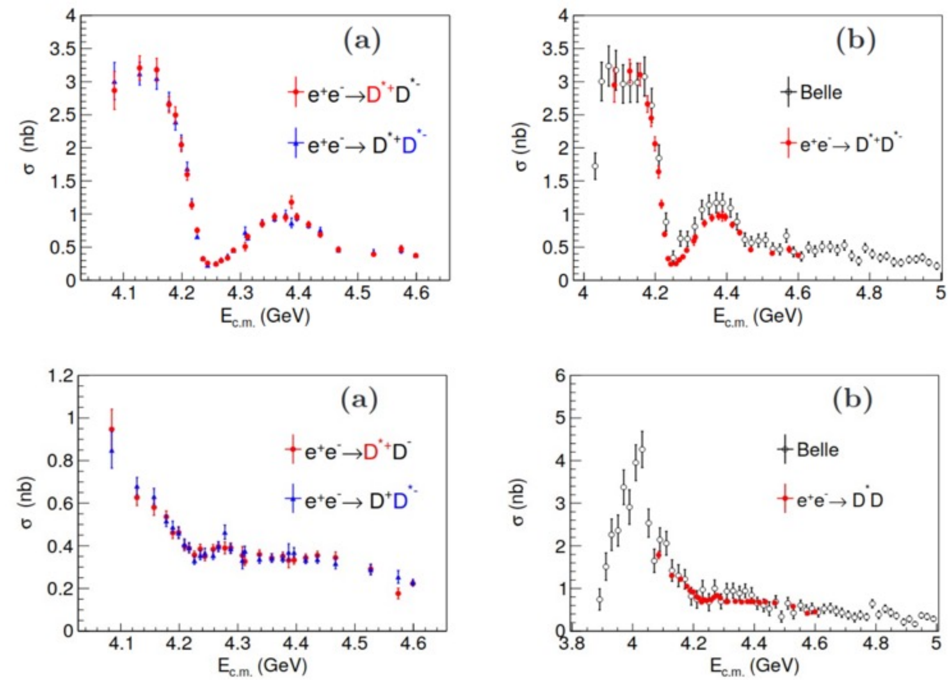
- essential to fully understand the XYZ states
- Important input for coupled-channel analysis



PRD 106, 052012 (2022)



JHEP2022, 55 (2022)

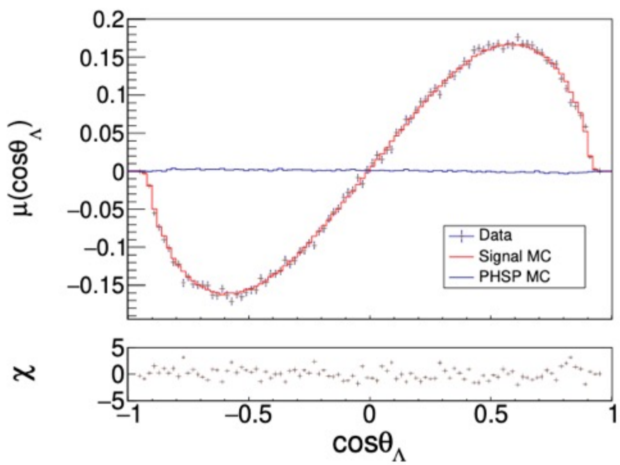


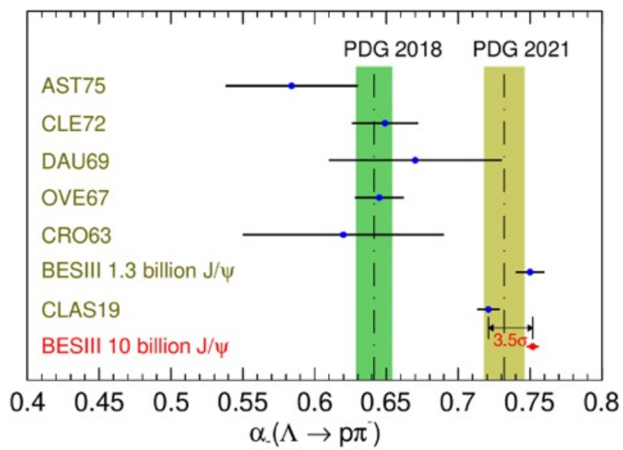
- Good agreement with existing measurements, with best precisions
- Structure at 4.39 GeV in D^*D^*?

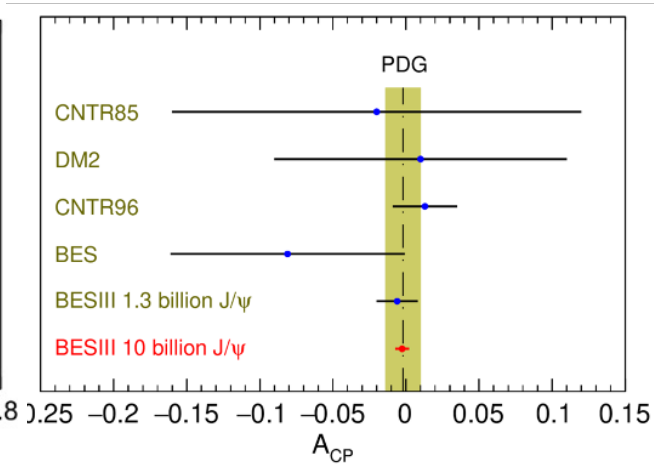
Updated Λ decay asymmetry in $J/\psi \to \Lambda\bar{\Lambda}$

PRL129, 131801(2022)

- Updated results based on 10B J/ψ events: ~0.42M signals
- Perfect fit to data
- Decay asymmetries with improved precisions are consistent with previous BESIII results
- Sensitivity of A_{CP} is improved to the level of below 0.5%







Par.	This Work*	Previous results **	PDG 2018 ***
$\alpha_{J/\psi}$	$0.4748 \pm 0.0022 \pm 0.0024$	$0.461 \pm 0.006 \pm 0.007$	0.469 ± 0.027
$\Delta\Phi$	$0.7521 \pm 0.0042 \pm 0.0080$	$0.740 \pm 0.010 \pm 0.009$	-
α_-	$0.7519 \pm 0.0036 \pm 0.0019$	$0.750 \pm 0.009 \pm 0.004$	0.642 ± 0.013
α_+	$-0.7559 \pm 0.0036 \pm 0.0029$	$-0.758 \pm 0.010 \pm 0.007$	-0.71 ± 0.08
A_{CP}	$-0.0025 \pm 0.0046 \pm 0.0011$	$0.006 \pm 0.012 \pm 0.007$	-
$\alpha_{\pm,avg.}$	$0.7542 \pm 0.0010 \pm 0.0020$	$0.754 \pm 0.003 \pm 0.002$	-

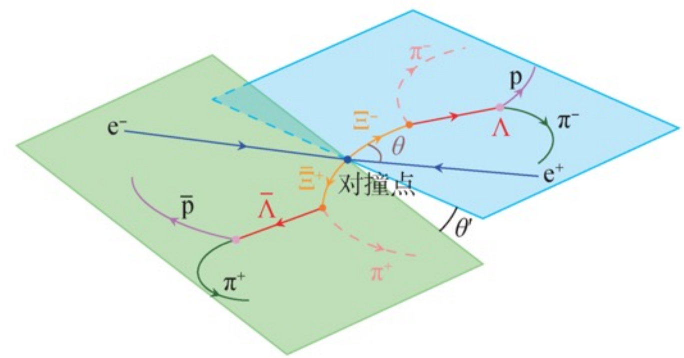
CPV in $\Xi^- \to \Lambda\pi^-$ decay

Nature 606, 64 (2022)

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

Parameter	This work	Previous result	
α_ψ	$0.586 \pm 0.012 \pm 0.010$	$0.58 \pm 0.04 \pm 0.08$	38
$\Delta\Phi$	$1.213 \pm 0.046 \pm 0.016$ rad.	–	
α_Ξ	$-0.376 \pm 0.007 \pm 0.003$	-0.401 ± 0.010	22
ϕ_Ξ	$0.011 \pm 0.019 \pm 0.009$ rad.	-0.037 ± 0.014 rad.	22
$\alpha_{\bar{\Xi}}$	$0.371 \pm 0.007 \pm 0.002$	–	
$\phi_{\bar{\Xi}}$	$-0.021 \pm 0.019 \pm 0.007$ rad.	–	
α_Λ	$0.757 \pm 0.011 \pm 0.008$	$0.750 \pm 0.009 \pm 0.004$	3
$\alpha_{\bar{\Lambda}}$	$-0.763 \pm 0.011 \pm 0.007$	$-0.758 \pm 0.010 \pm 0.007$	3
$\xi_p - \xi_s$	$(1.2 \pm 3.4 \pm 0.8) \times 10^{-2}$ rad.	–	
$\delta_p - \delta_s$	$(-4.4 \pm 3.6 \pm 1.8) \times 10^{-2}$ rad.	$(8.7 \pm 3.3) \times 10^{-2}$ rad.	2
A_{CP}^{Ξ}	$(6.0 \pm 13.4 \pm 5.6) \times 10^{-3}$	–	
$\Delta\phi_{CP}^{\Xi}$	$(-4.8 \pm 13.7 \pm 2.9) \times 10^{-3}$ rad.	–	
A_{CP}^{Λ}	$(-3.7 \pm 11.7 \pm 9.0) \times 10^{-3}$	$(-6 \pm 12 \pm 7) \times 10^{-3}$	3
$< \phi_\Xi >$	$0.016 \pm 0.014 \pm 0.007$ rad.		

Based on 1.3 B J/ψ events
(13% of total J/ψ events)
9-dimentional fit: ~73K signals



First measurement of baryon weak phase difference

We obtain the same precision for ϕ as HyperCP with ***three orders of magnitude*** smaller data sample!

HyperCP: $\phi_{\Xi,HyperCP} = -0.042 \pm 0.011 \pm 0.011$
BESIII: $<\phi_\Xi> = 0.016 \pm 0.014 \pm 0.007$

HyperCP: PRL 93(2004) 011802