Status and (mid-long term) Prospects of BESIII Experiment

BESIII 실험의 현황 및 중장기 전망

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BESIII Experiment : Present and Future

- Current Status
  - Started taking data in 2009.
  - The Original Plan was for a 10 years running program. (2008:0809.1869)

  XYZ physics showed up as main physics topics which weren't covered at the Physics book (2008) → Approved to extend 10 more years.
  - Both BEPC and BESIII will be upgraded, accordingly.
  - Publication: more than 307 papers (by 2020. Nov. 20).
  - >500 members from 74 institutions in 15 countries.
- Mid-term Prospect :
  - Approved CM energy upgrade 4.6→ 4.9GeV for XYZ, Lambda_c & Sigma_c physics
  - Approved luminosity upgrade by a factor of 2-3.
  - Similar modest upgrades will be continued.
  - Annual running time will be increased from 6 months/ys to 9 months/yr.
- Long-term Proposal :

  a huge e+e- collider(CEPC), Super tau-charm factory

  at Hefei in Central China being proposed by university groups

History of Korean-BESIII group

In 2010: a Korean BESIII team was established at Seoul National University

Leader: S. Olsen
Postdocs: Xiurong Li & Xinping Xu
Masters Students: Jeongwon Park & Jeong Hoon Kim

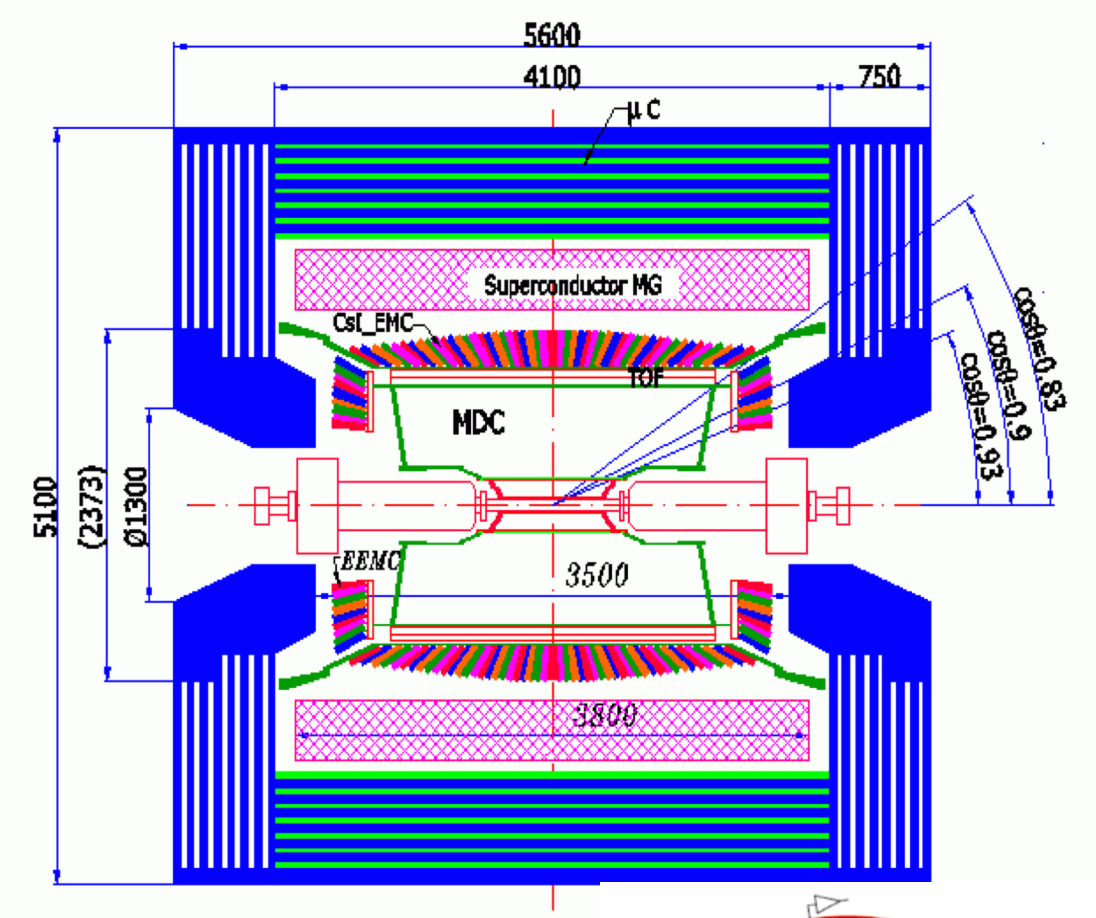
Papers: PRD 85, 092012 (2012) search for $J/\psi \rightarrow \gamma A^0$; $A^0 \rightarrow \mu^+\mu^-$ (38 cites)
PRL 112, 022001 (2014) 1st observation of $Z_c(3900) \rightarrow D^*D_{bar}$ (289 cites)
MS Theses: J.W. Park Study of $J/\psi \rightarrow \Lambda_{bar}\Sigma^+\pi^-$ + c.c.
J.H. Kim Validity check of BESIII tracking

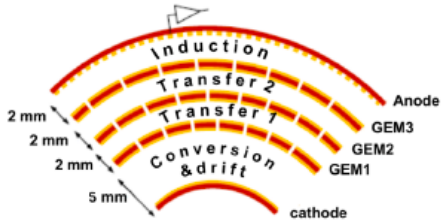
In 2013: GNU applied for membership in 2013

In 2014: Korean BESIII Funding expired & Olsen left SNU
attempts to recover BESIII funds failed & the
Korean BESIII team was terminated

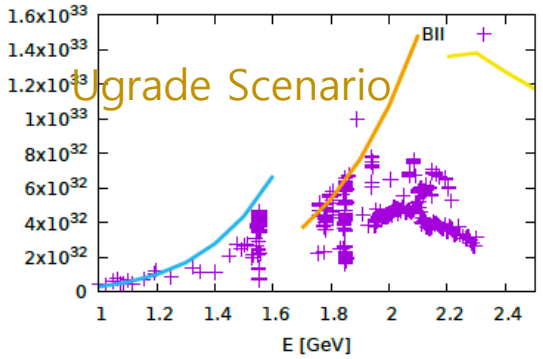
In 2020. 11, BESIII team (GNU) was re-established (unanimously approved)

BEPCII & BESIII Detector



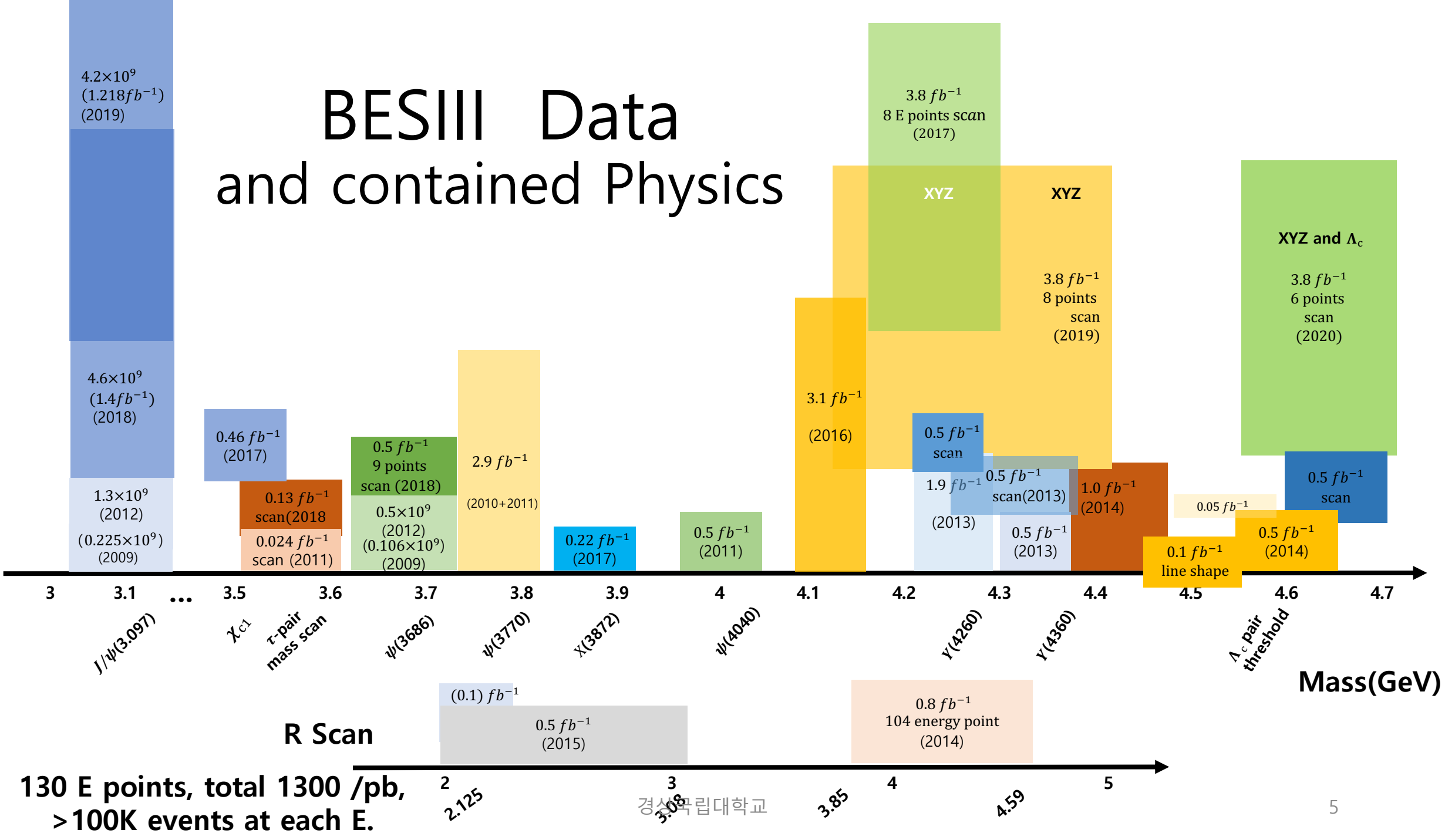


- 30 /fb : Total integrated luminosity
at different energy points from 2.0 to 4.6GeV
- Two major upgrade approved: to increase
  - Maximum beam energy up to 2.45GeV
  - from 2020, top-up injection give almost constant current (continuous injection) which increase Lum. ~20-30%
  - future plan: 0.9 – 2.5 GeV
- Further machine upgrade on luminosity needs one yr. break for installatic crab-waist collision scheme or with higher beam current ?



- Upgrade of ETOF
- Upgrade of inner MDC
(For the first MDC layer cells: 2kHz/cm^2, ~39% drop in '17)
=> Chosen option : CGEM-IT inner tracker
(Cylindrical Gas Electron Multiplier Inner Tracker)
- cZDD (crystal Zero Degree Detector) → reduce g-2 error !

BESIII Data and contained Physics



130 E points, total 1300 /pb, >100K events at each E.

Physics contained in BESIII Data

- Hadron (XYZ+light) spectroscopy
- Charm physics
- Charmonium physics
- R and tau-physics and g-2
- Precision test of SM
- Probe of new physics beyond SM
- Hyperon decays in J/psi →hyperons
- New Physics & exotics
- -----

In this talk

1. XYZ spectroscopy
   - $Z_{c(s)}$ states
   - Y(4260) ?
   - X(3872), X(3915)
2. Hyperon decays in J/psi events
3. R (or TFF) measurement
4. Other threshold effects

BESIII Data Set for XYZ spectroscopy

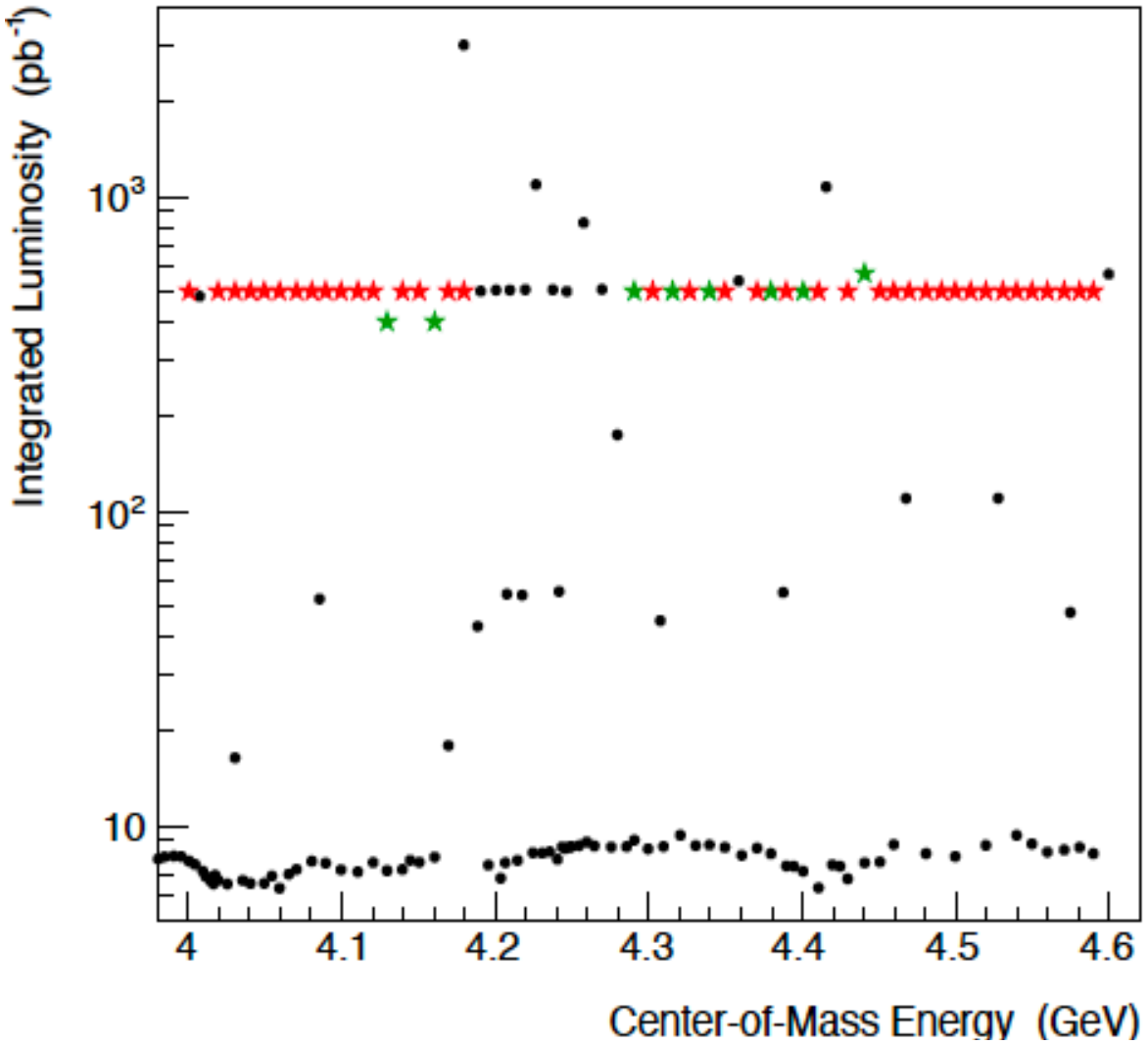
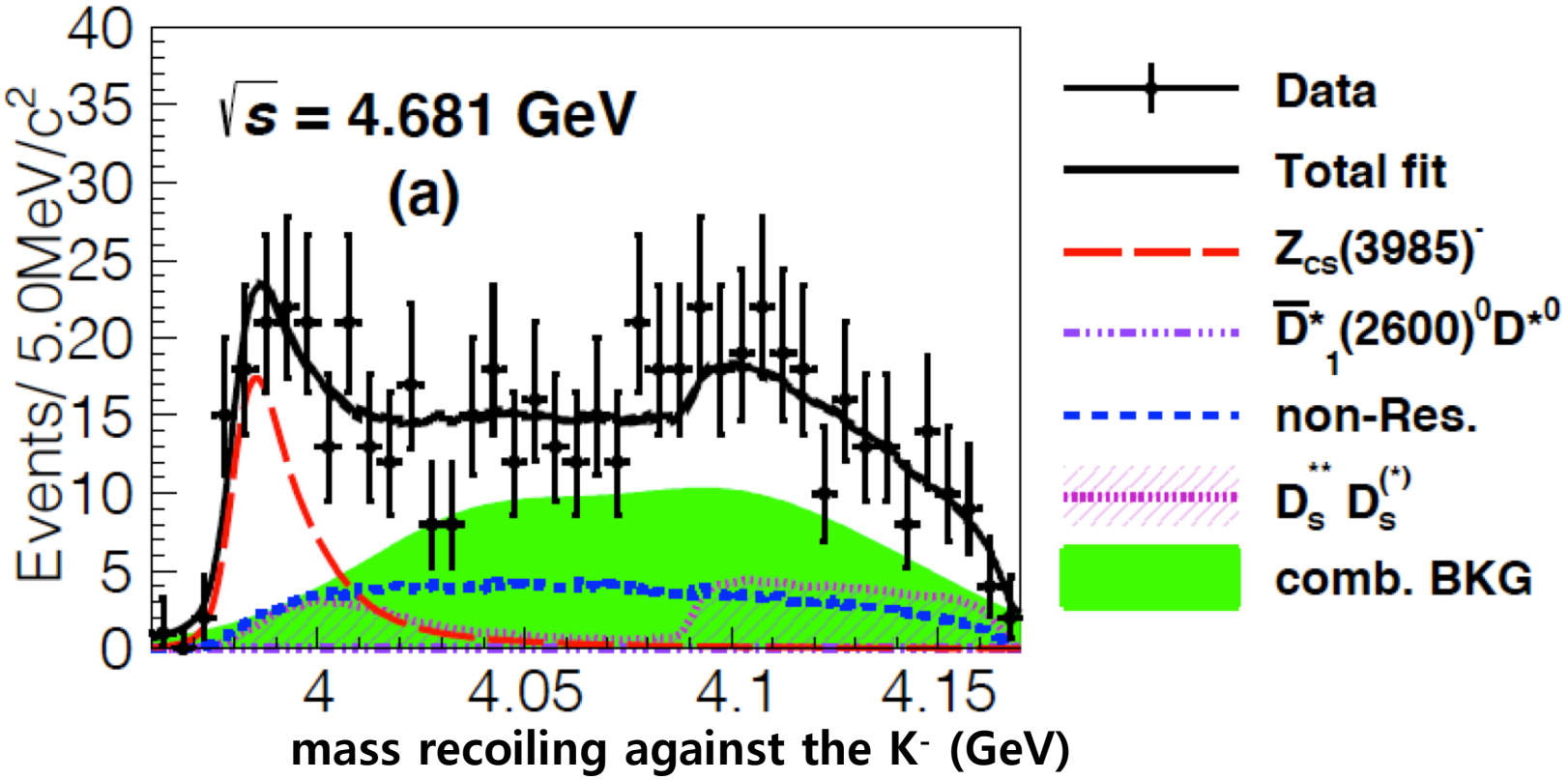


Figure 3.9: BESIII data sets that are relevant for XYZ physics. The data sets collected prior to 2019 are shown in black; those collected in 2019 are in green; and those considered for potential future measurements are shown in red.

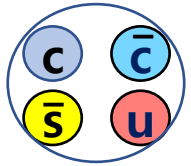
New: Discovery of $Z_{cs}(3985)^+ \to D_s^+ \bar{D}^{*0}$ or $D_s^{*+} \bar{D}^0$

arXiv:2011.07855 ← last month

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



the first 4-quark state that contains an s-quark



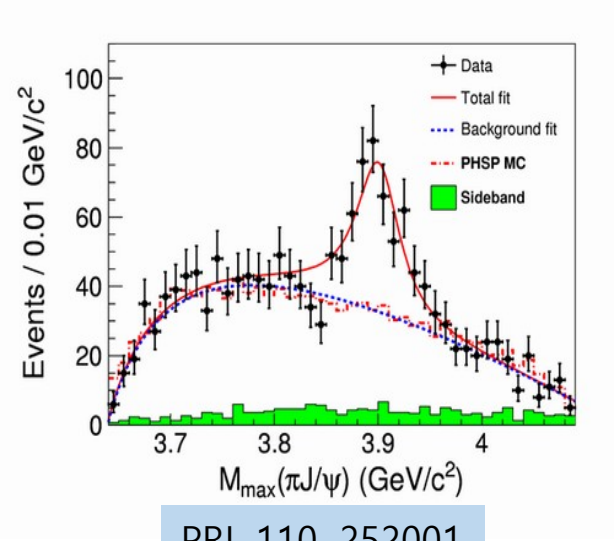
$$m_0(Z_{cs}(3985)^-) = 3985.2^{+2.1}_{-2.0}\,\mathrm{MeV}/c^2,$$
$$\Gamma_0(Z_{cs}(3985)^-) = 13.8^{+8.1}_{-5.2}\,\mathrm{MeV}.$$

significance $\gtrsim 5.3\sigma$

XYZ and Charmonium

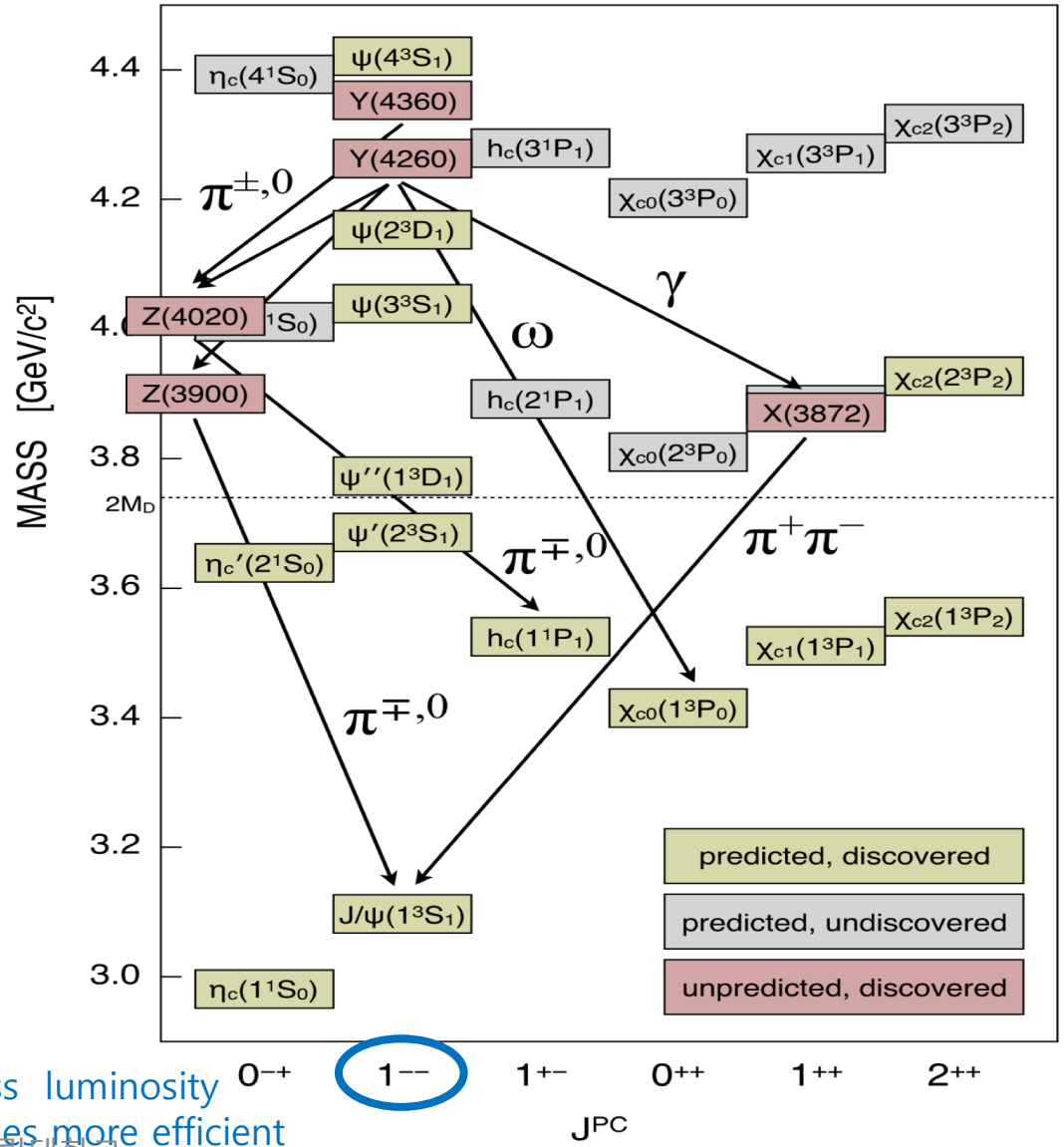
Charged charmoniumlike structure at BESIII

The representative state of the BESIII



PRL 110, 252001

$Z_c(3900)$

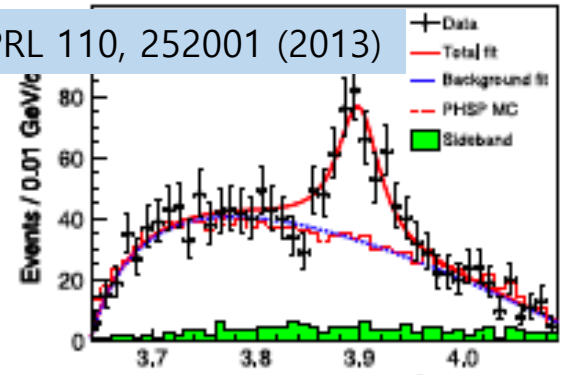


BESIII has 50 ~ 100 times less luminosity than Belle(II), but ~ 4000 times more efficient at producing 1^{--} states

Z_c states discovered by BESIII
4 most cited papers

$Z_c(3900)$ in $Y(4260)\rightarrow J/\psi\,\pi^+\pi^-$

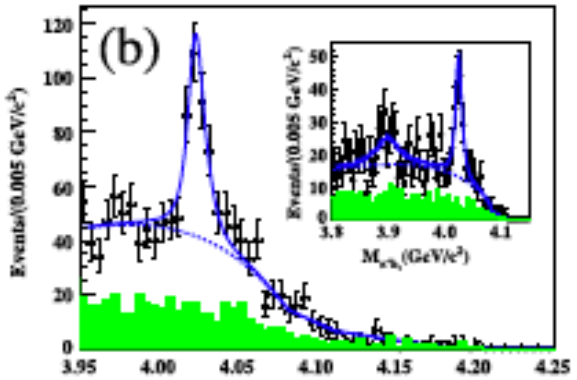
PRL 110, 252001 (2013)



$M_{max}(\pi^{\pm} J/\psi)$ GeV/c^2

12±3 MeV above D^0D^{*-} threshold

$Z_c(4020)$ in $Y(4260)\rightarrow h_c\pi^+\pi^-$



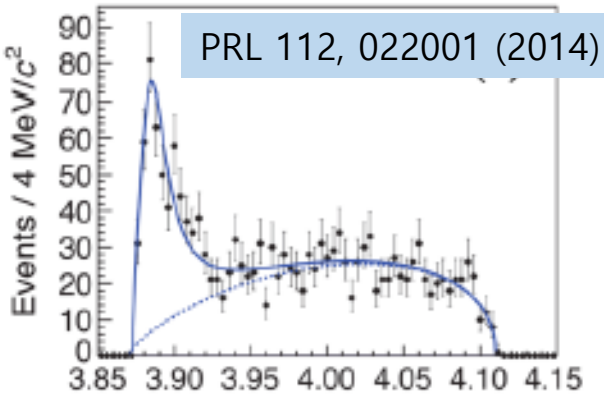
$M(\pi^{\pm} h_c)$ GeV/c^2

PRL 111, 242001 (2013)

5.6±2.8 MeV above $D^{*0}D^{*-}$ threshold

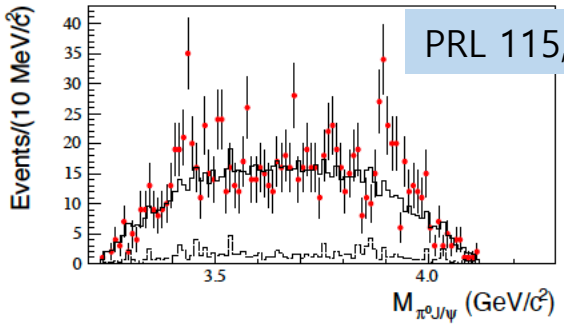
$Z_c(3900)$ in $Y(4260)\rightarrow (D^0D^*)^-\pi^+$

PRL 112, 022001 (2014)



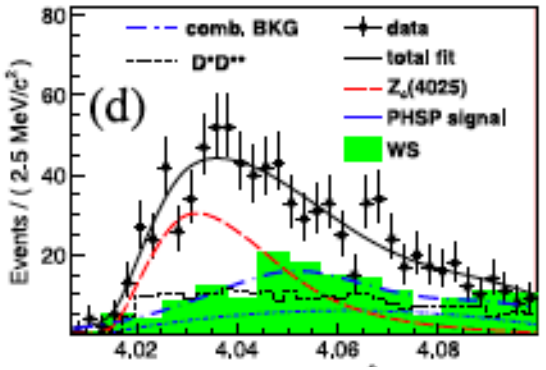
$M(D^0 D^{*-})$ GeV/c^2

in $Y(4260)\rightarrow J/\psi\,\pi^0\pi^0$



PRL 115, 112003 (2015)

$Z_c(4020)$ in $Y(4260)\rightarrow (D^{0*}D^*)^-\pi^+$



$M(D^{*0} D^{*-})$ GeV/c^2

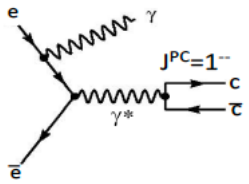
PRL 112, 132001(2014)

PRL 110, 252002 (2013) ←From Belle

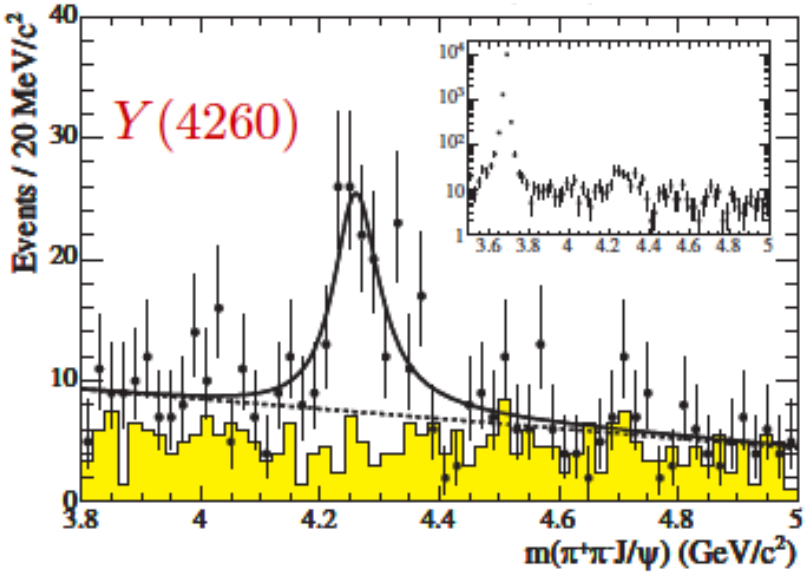
But not seen in B decays

Therefore,
→ Z_c is I=1 treplet

Y(4260)→$\pi^+\pi^-$J/ψ is actually 2 peaks

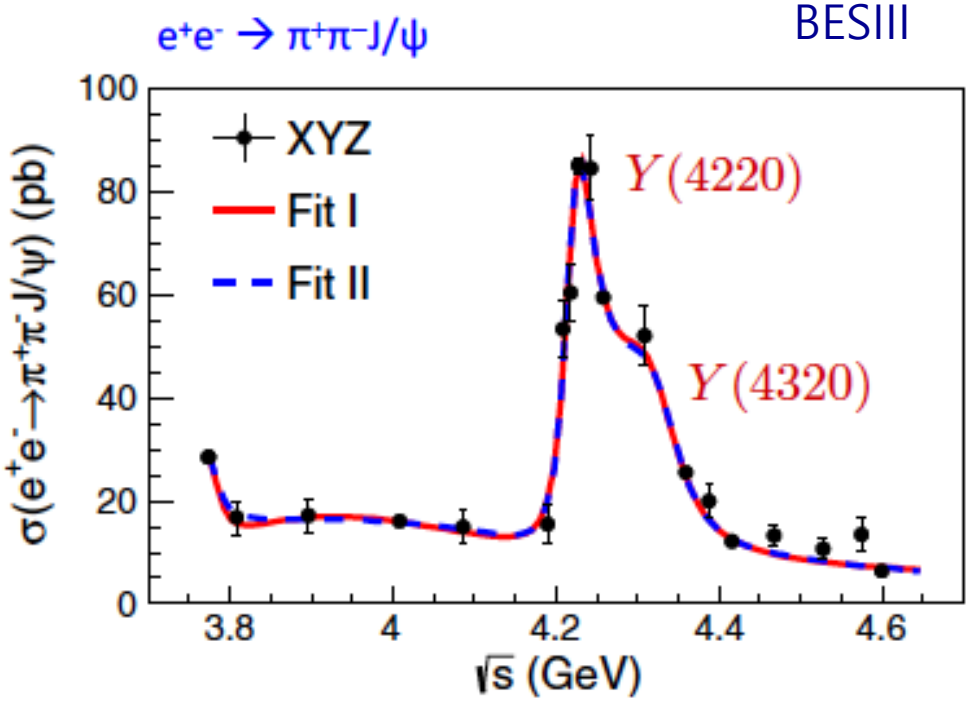


Babar



PRL118, 092001(2017)

BESIII



$M_1 = 4220 \pm 4$ MeV/c^2 $M_2 = 4320 \pm 13$ MeV/c^2

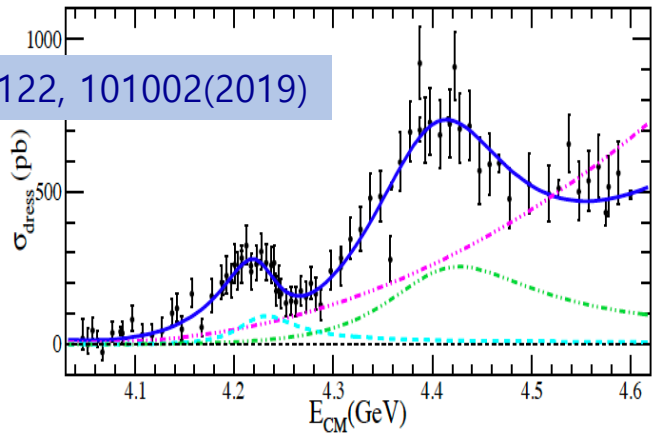
$\Gamma_1 = 44 \pm 5$ MeV $\Gamma_2 = 101^{+27}_{-22}$ MeV

Favorable models:
- Molecule candidate $DD_1(2460)$, but BE~65MeV
- QCD tetraquark, but no partner states have been identified
- QCD hybrid only 65MeV below LQCD's lightest 1^{--} hybrid

Y(4220)+Y(4320) at other modes

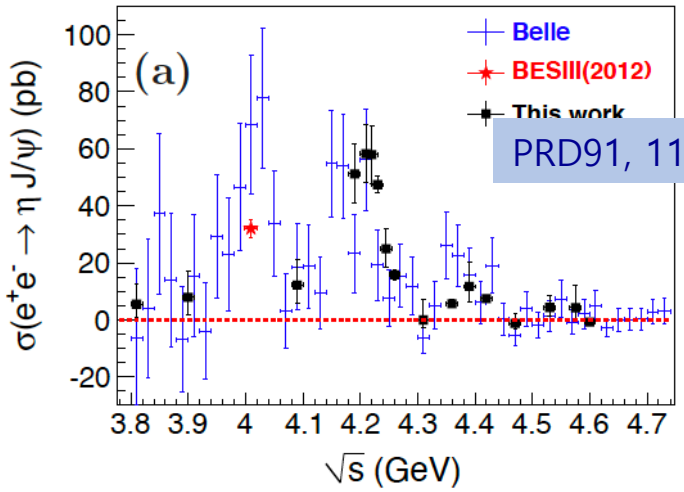
e+e- → $\pi^+ D^0 D^{*-}$

PRL122, 101002(2019)



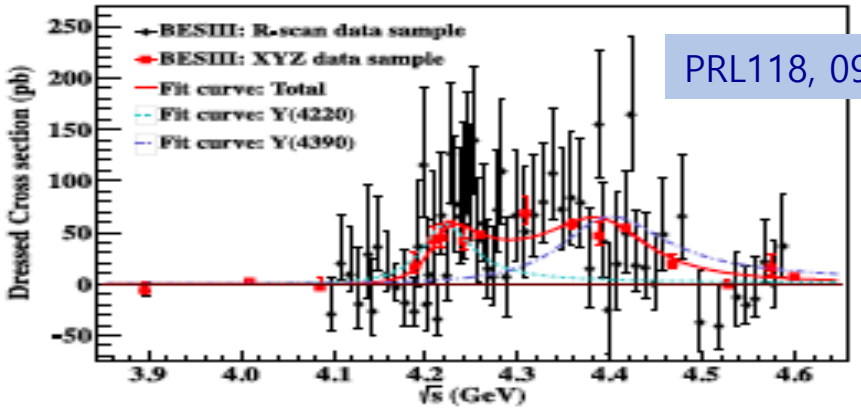
e+e- → $\eta J/\psi$

PRD91, 112005(2015)



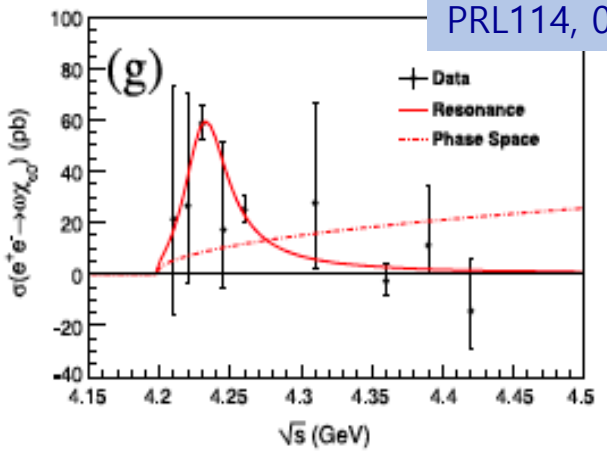
e+e- → $\pi^+\pi^- h_c$

PRL118, 092002(2017)



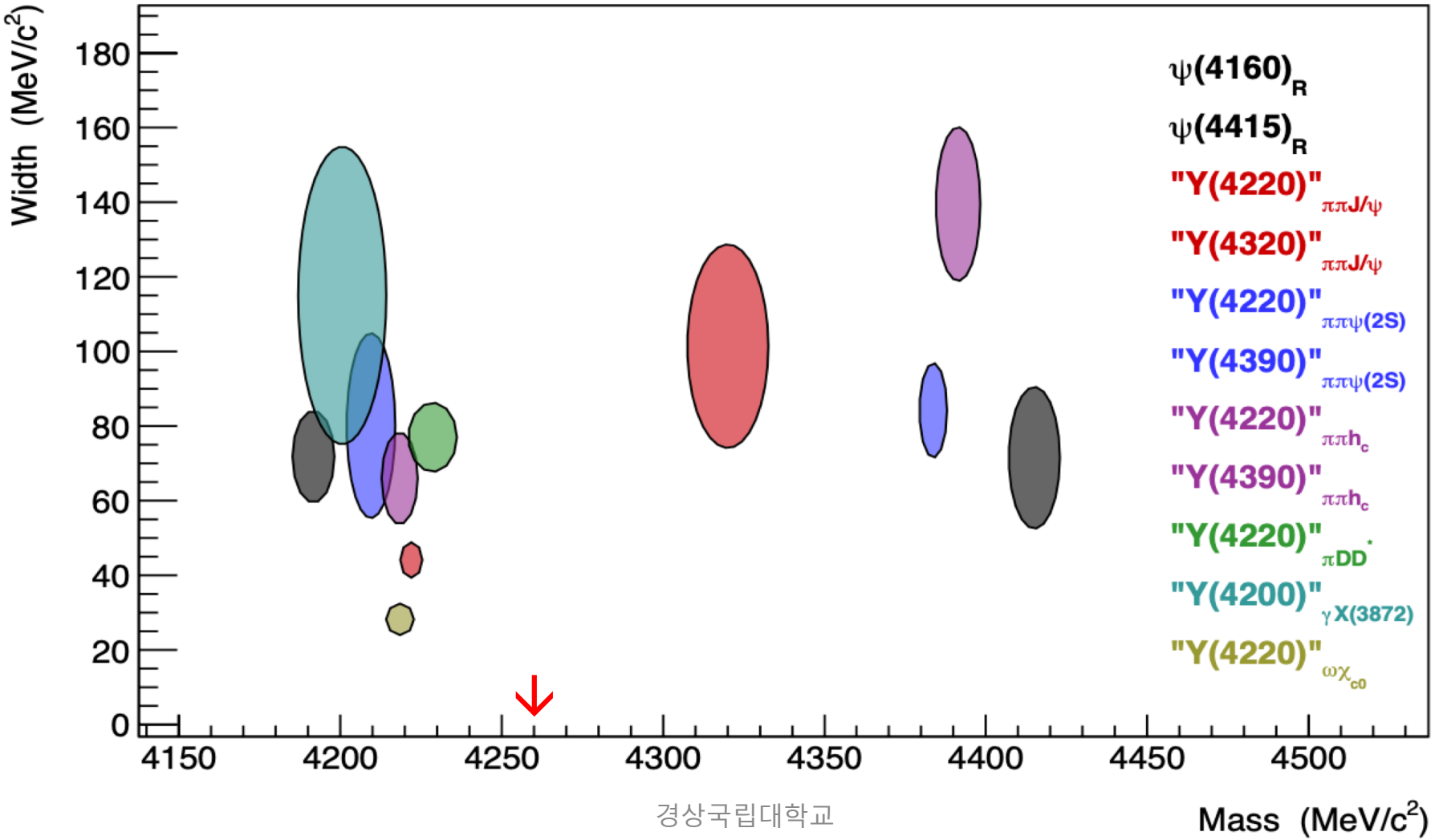
e+e- → $\omega\chi_{c0}$

PRL114, 092003(2015)



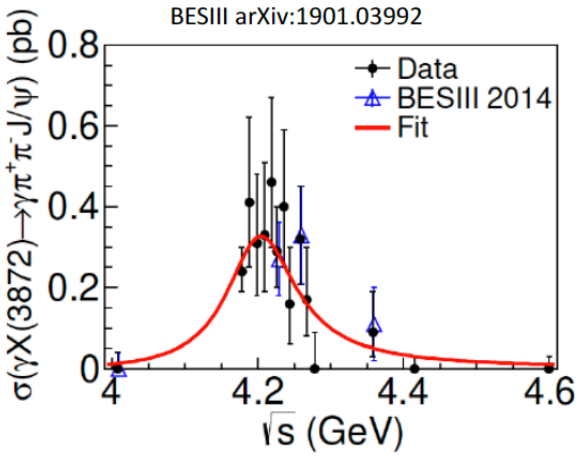
Masses and Widths of the Peaks in e^+e^- Cross Section

Masses and widths (and numbers of peaks) depend on parametrization!!

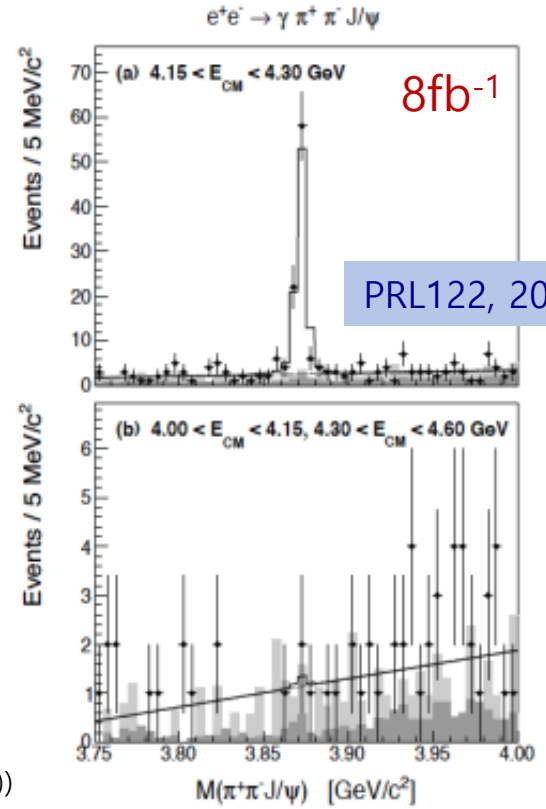


Served as production channels of X(3872) or X(3915)

e+e- →γX(3872); X→ππJ/ψ



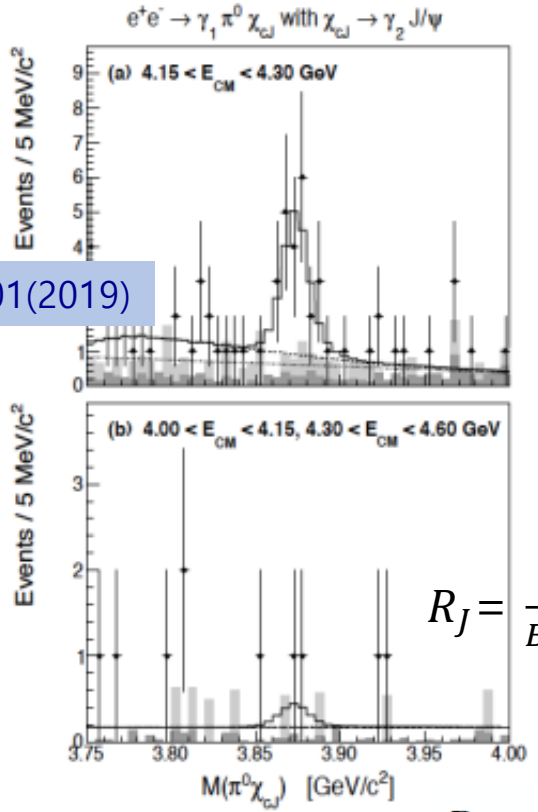
Y(4220)→γ[π⁺π⁻J/ψ]



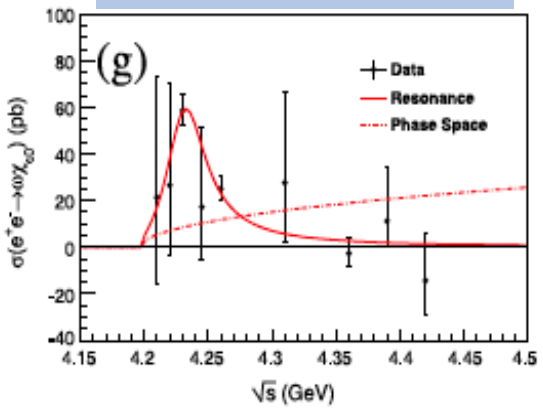
PRL122, 202001(2019)

e+e- →γX(3872); X→π⁰χcJ

Y(4220) →γ[χcJ π⁰]



PRL114, 092003(2015)



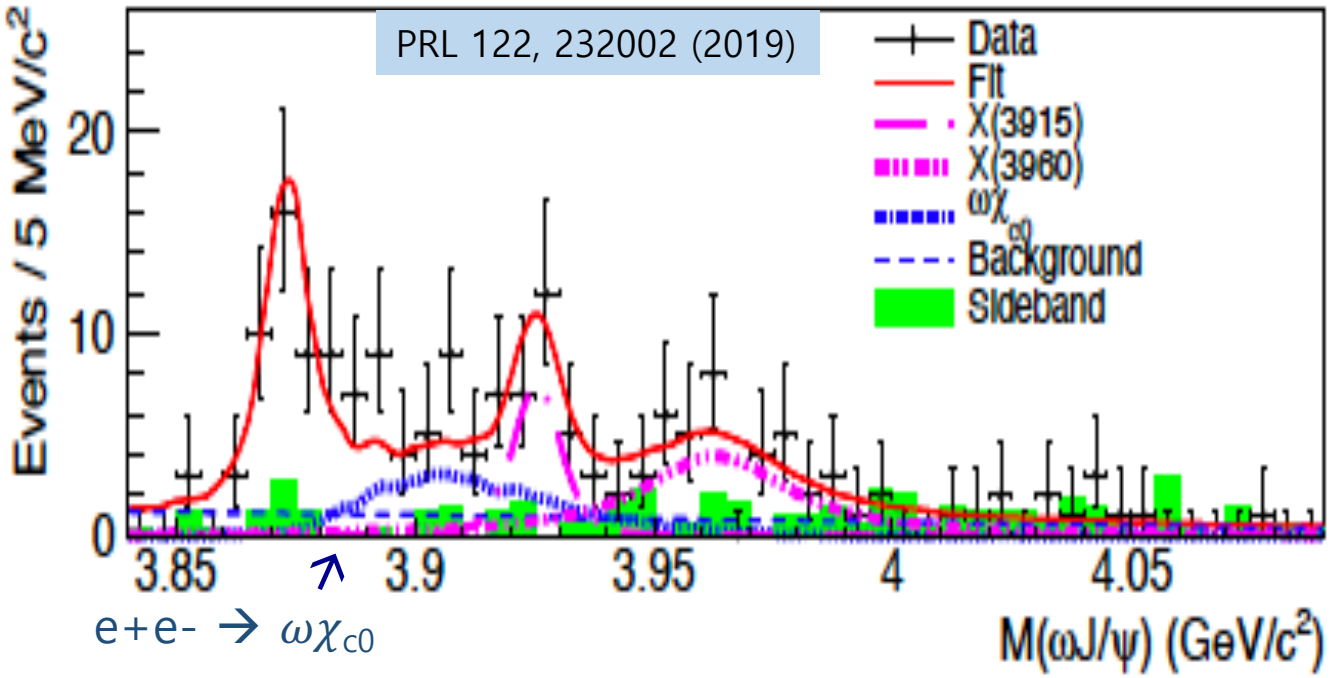
$$R_J = \frac{B(X(3872)\to\pi^0\chi_{cJ})}{B(X(3872)\to\pi^+\pi^- J/\psi)}$$

- $Br(X(3872)\to\pi^0\chi_{cJ}) \sim 3-6\%$
- If X(3872) is charmonium χ_{c1}',
  $\Gamma(X(3872)\to\pi^0\chi_{cJ}) \sim 0.06KeV$
  by Voloshin et.al.(PRD77,014013(2008))
- then, $\Gamma_{TOT}(X(3872)) \sim 0.5-1KeV$ is too small
- Therefore, charmonium (χ_{c1}') interpretation for the X(3872) is disfavored.

$R_0 < 19$ (90% U.L.)
$R_1 = 0.88^{+0.31}_{-0.26} \pm 0.14$
$R_2 < 1.0$ (90% U.L.)

Served as production channels of X(3872) or X(3915) (cont'd)

Y(4220)→γ {X(3872),X(3915)→ωJ/ψ}



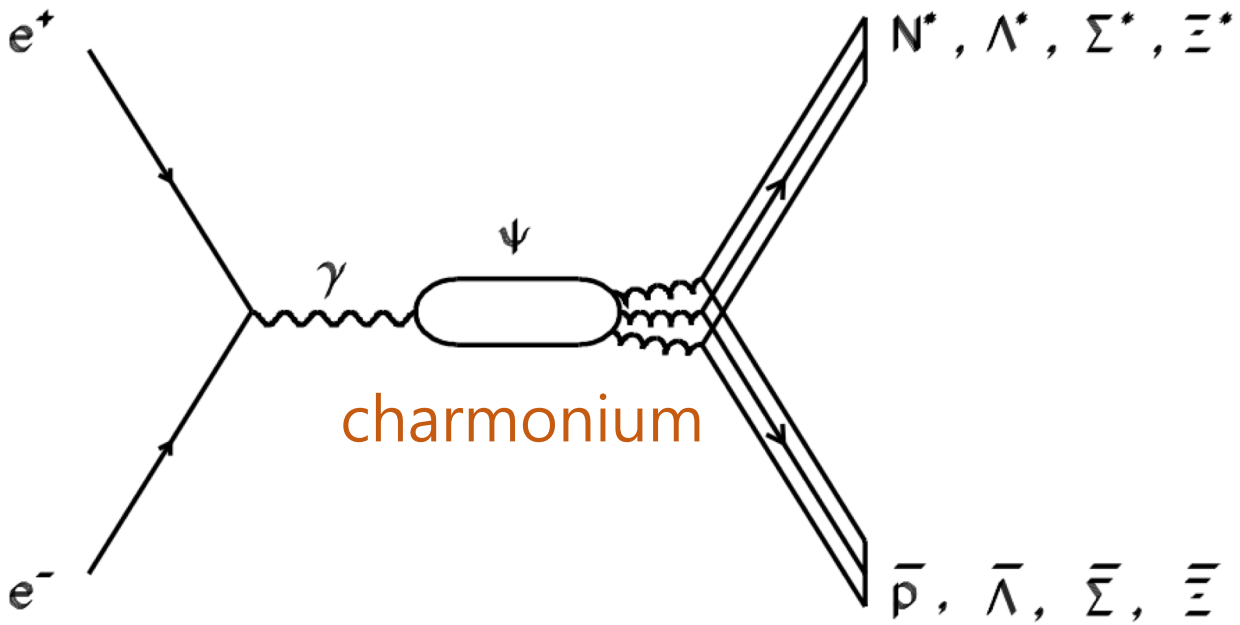
	Mass	Width
$X(3872)$	3873.3 ± 1.1 (3872.8 ± 1.2)	1.2 (1.2)
$X(3915)$	3926.4 ± 2.2 (3932.6 ± 8.7)	3.8 ± 7.5 (59.7 ± 15.5)
$X(3960)$	3963.7 ± 5.5	33.3 ± 34.2

경상 (Fit without the X(3960))

$$\frac{B(X(3872)\to \omega\, J/\psi\,)}{B(X(3872)\to \pi^+\pi^- J/\psi\,)} = 1.6^{+0.4}_{-0.3}$$

Baryon/Hyperon production in J/psi events

1. Search for Excited nucleons and hyperons or new types:



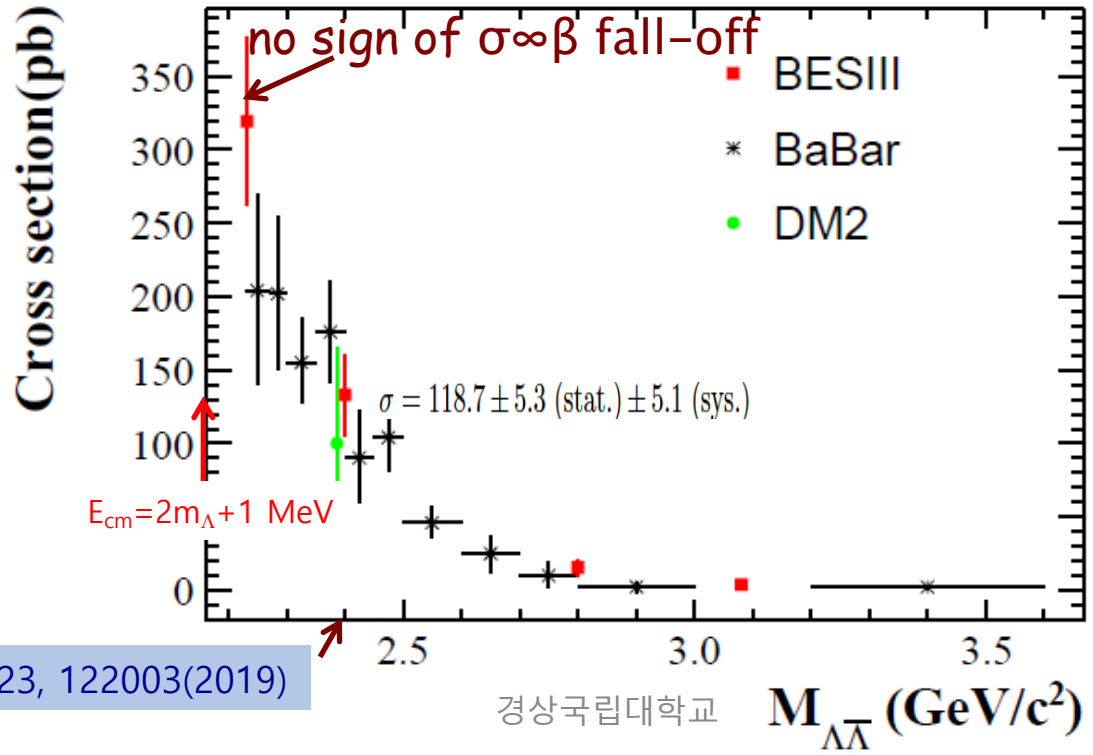
- The lowest excited states are not established yet.
- $\bar{p}N^*$, $\bar{\Lambda}\Lambda^*$, $\bar{\Sigma}\Sigma^*$ and $\bar{\Xi}\Xi^*$ production from e^+e^- collision through ψ meson.
- Production through three or more gluons provide favorable place for producing hybrid (qqqg) baryons and missing N*

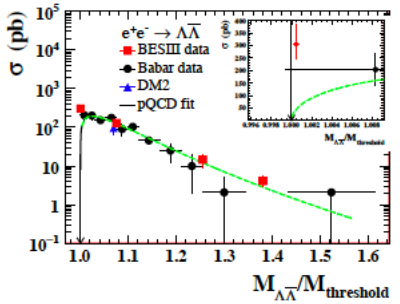
2. Baryon (hyperon) Form Factors

cross section: $e^+e^- \rightarrow \gamma^* \rightarrow \Lambda\bar{\Lambda}$

$$\sigma_{\Lambda\bar{\Lambda}}(m) = \frac{4\pi\alpha^2\beta}{3m^2}\left[|G_M(m)|^2 + \frac{1}{2\tau}|G_E(m)|^2\right] = \frac{4\pi\alpha^2\beta}{3m^2}|G_{eff}(m)|^2(1+1/2\tau)$$

If G_{eff}(m) is analytic, $\sigma \rightarrow 0$ as $E_{cm} \rightarrow$ threshold ($\beta \rightarrow 0$)



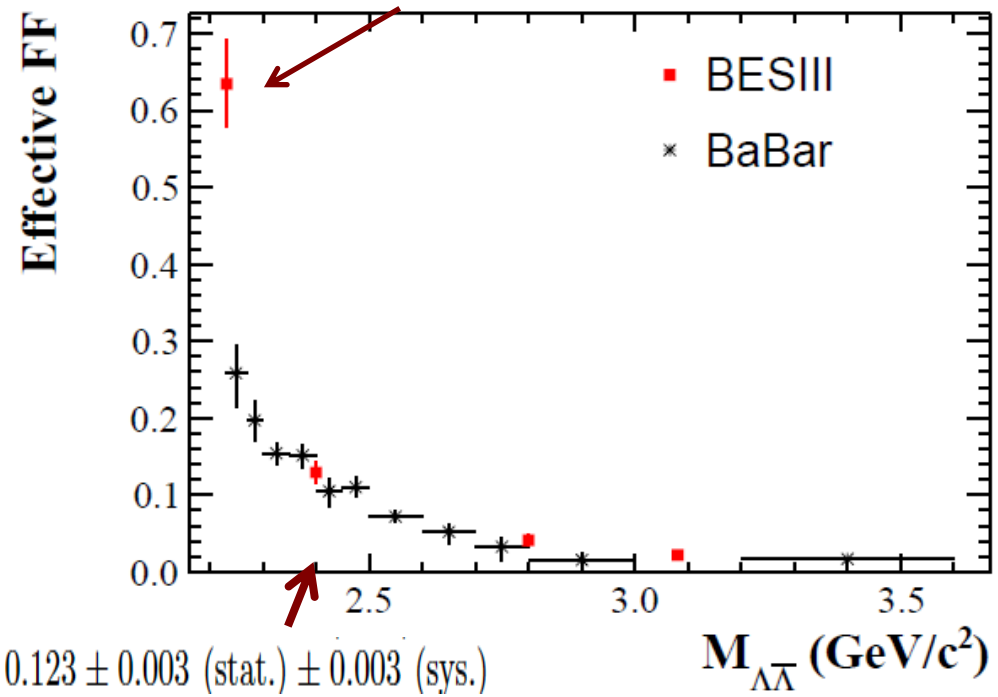


PRL123, 122003(2019)

Effective time-like form-factor of the Λ

$$\left|G_{eff}(m)\right| = \sqrt{\frac{3m^2\sigma_{\Lambda\bar{\Lambda}}}{4\pi\alpha^2\beta(1+1/2\tau)}}$$

diverging like 1/β?... faster?

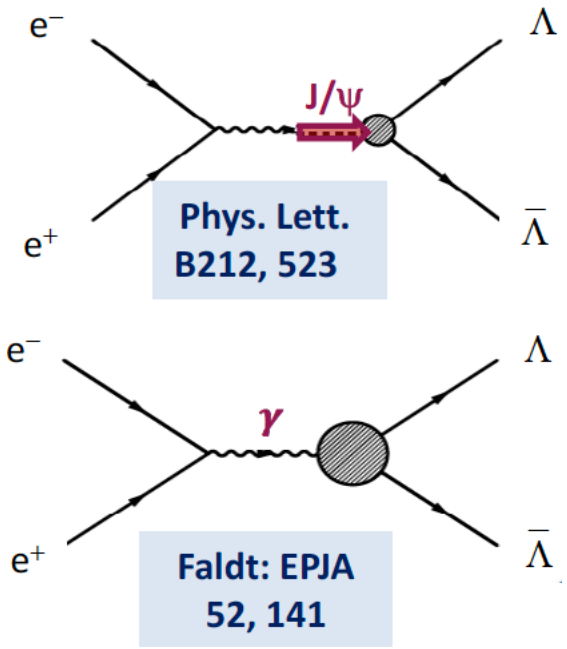


$|G| = 0.123 \pm 0.003\ (\text{stat.}) \pm 0.003\ (\text{sys.})$

$R = |G_E/G_M| = 0.96 \pm 0.14\ (\text{stat.}) \pm 0.02\ (\text{sys.})$

$\Delta\Phi = 37^\circ \pm 12^\circ\ (\text{stat.}) \pm 6^\circ\ (\text{sys.})$

ΔΦ ≠ 0

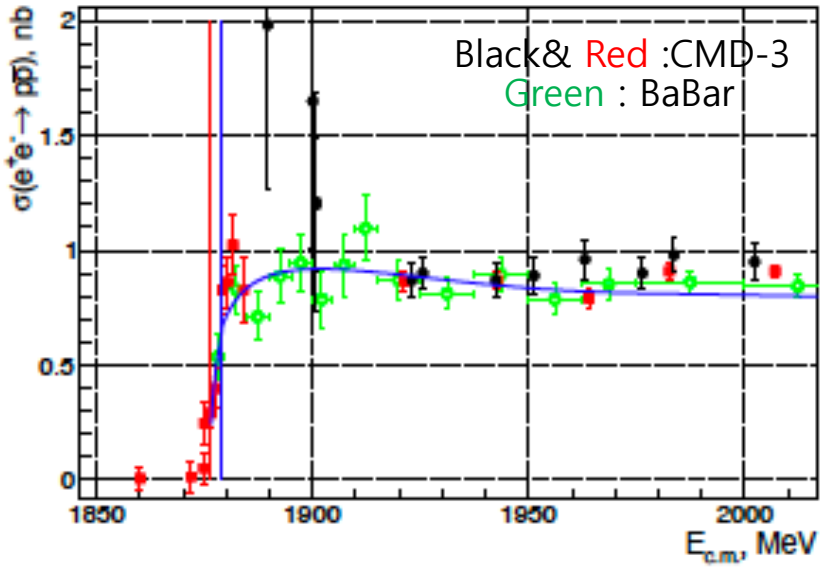


→ FSI introduced

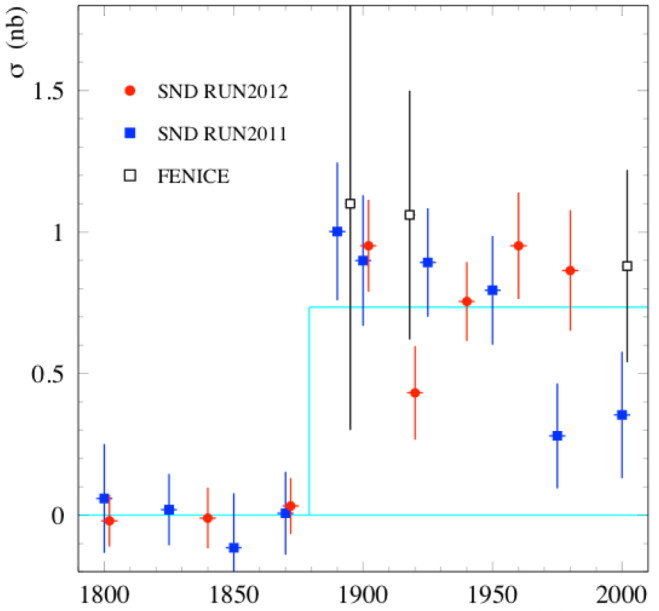
from fits to data from the $\bar{p}p \to \Lambda\bar{\Lambda}$ PS185 experiment at LEAR

similar behavior for $e^+e^- \rightarrow p\bar{p}$ ($n\bar{n}$)?

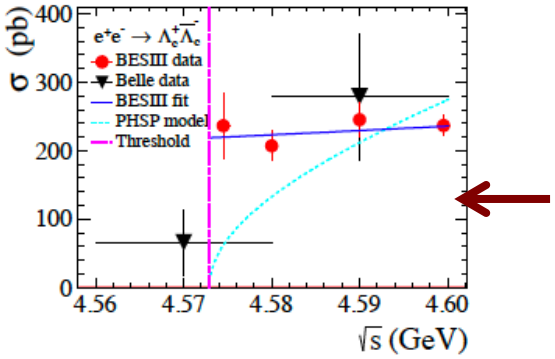
$e^+e^- \rightarrow p\bar{p}$



$e^+e^- \rightarrow n\bar{n}$



M.N. Achasov et al. (SND), PRD90, 112 007



a universal behavior?

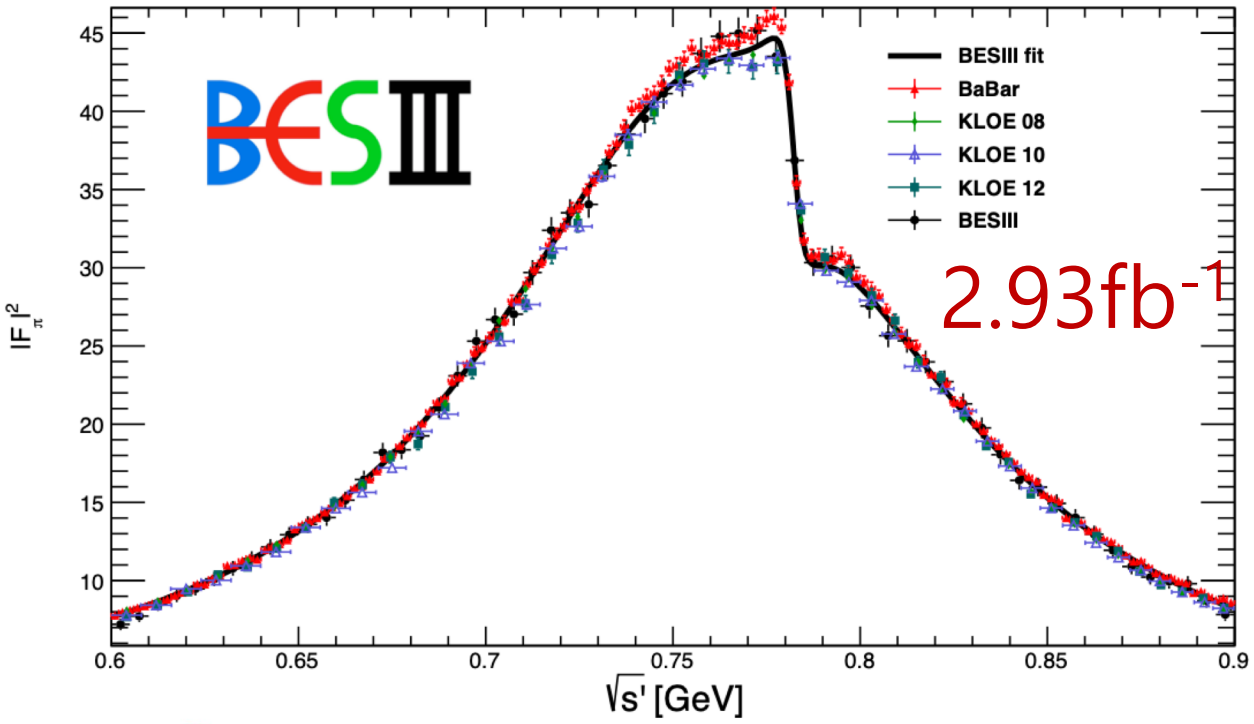
BESIII will have data for other threshold regions: $\Sigma\bar{\Sigma}$, $\Lambda\bar{\Sigma}$, $\Xi\bar{\Xi}$, $\Lambda_c\bar{\Lambda}_c$,...

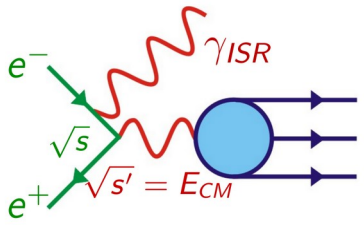
Data at the $\Lambda_c\bar{\Lambda}_c$ threshold data analysis is also done.

If it is universal, is it restricted to $J^{PC} = 1^{--}$ systems?

3. TFF (Transition Form Factor) : Time-like Pion form factor $|F\pi|^2$ in $e^+e^- \rightarrow \pi^+\pi^-$ via ISR

PLB 753, 629 (2016)



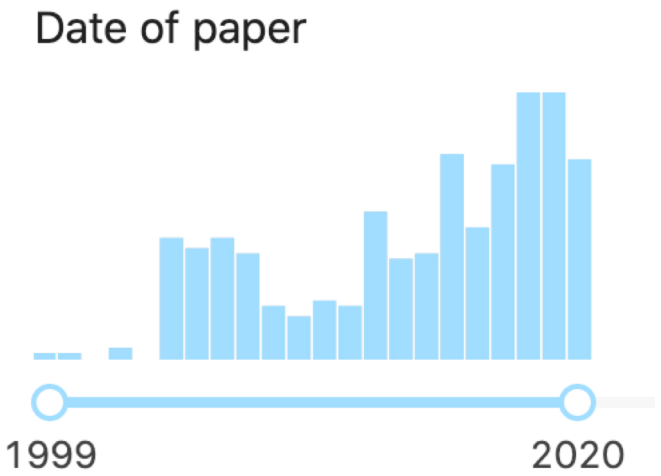


(Tagged Only)

With Leading-order Hadronic Vacuum polarization Contribution to (g-2)μ/2

$$a_\mu^{\pi\pi,\mathrm{LO}}(600-900\ \mathrm{MeV}) = (368.2 \pm 2.5_{\mathrm{stat}} \pm 3.3_{\mathrm{sys}}) \cdot 10^{-10}$$

Summary



- Very productive in publication :
  ~50papers/yr(recent) !!!
  (Especially in XYZ Study)
- Huge data set including 10B J/psi events
  is still remained with undiscovered physics.

- BESIII is Extended for 10 more years
- Modest upgrades on both BEPCII and BESIII are on-going.

- Long-term Proposal : a huge e+e- collider(CEPC), Super tau-charm factory
  at Hefei in Central China being proposed by university groups

Thanks