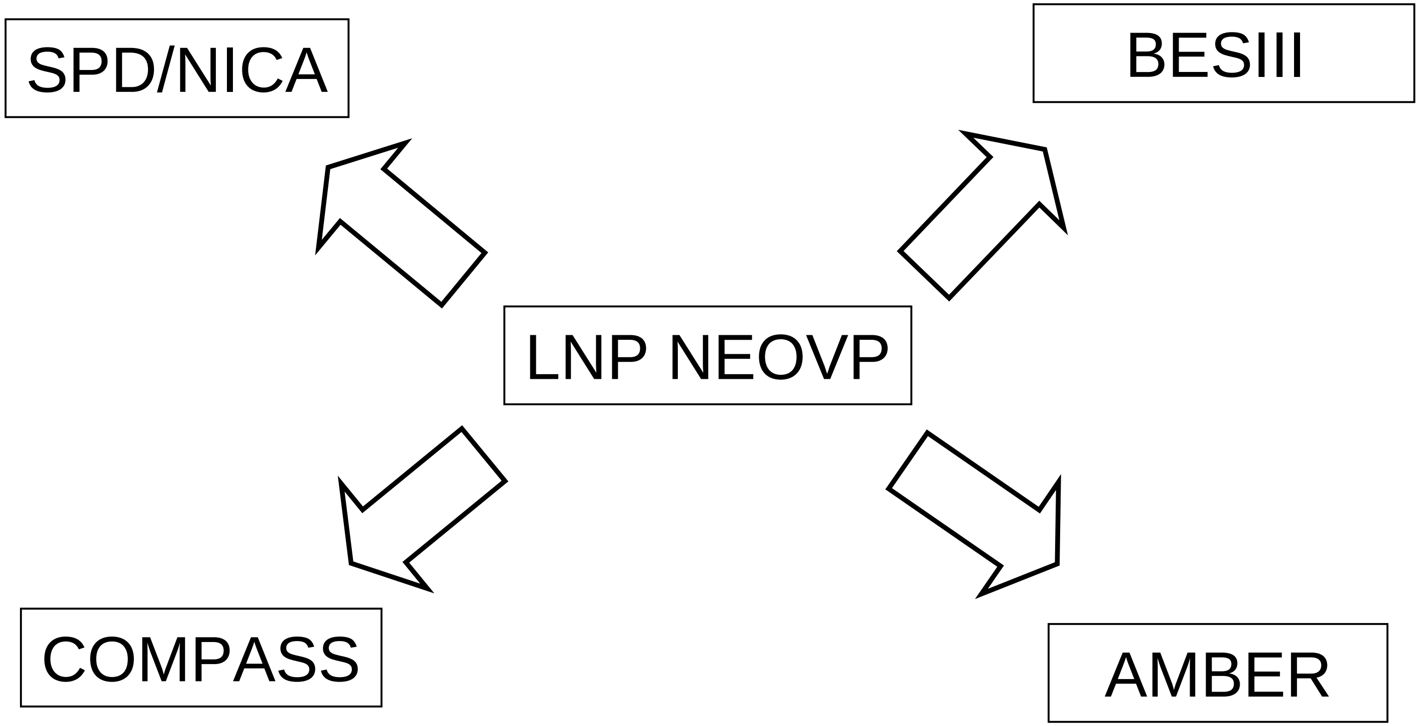
Physics in BESIII experiment: New results and prospectives

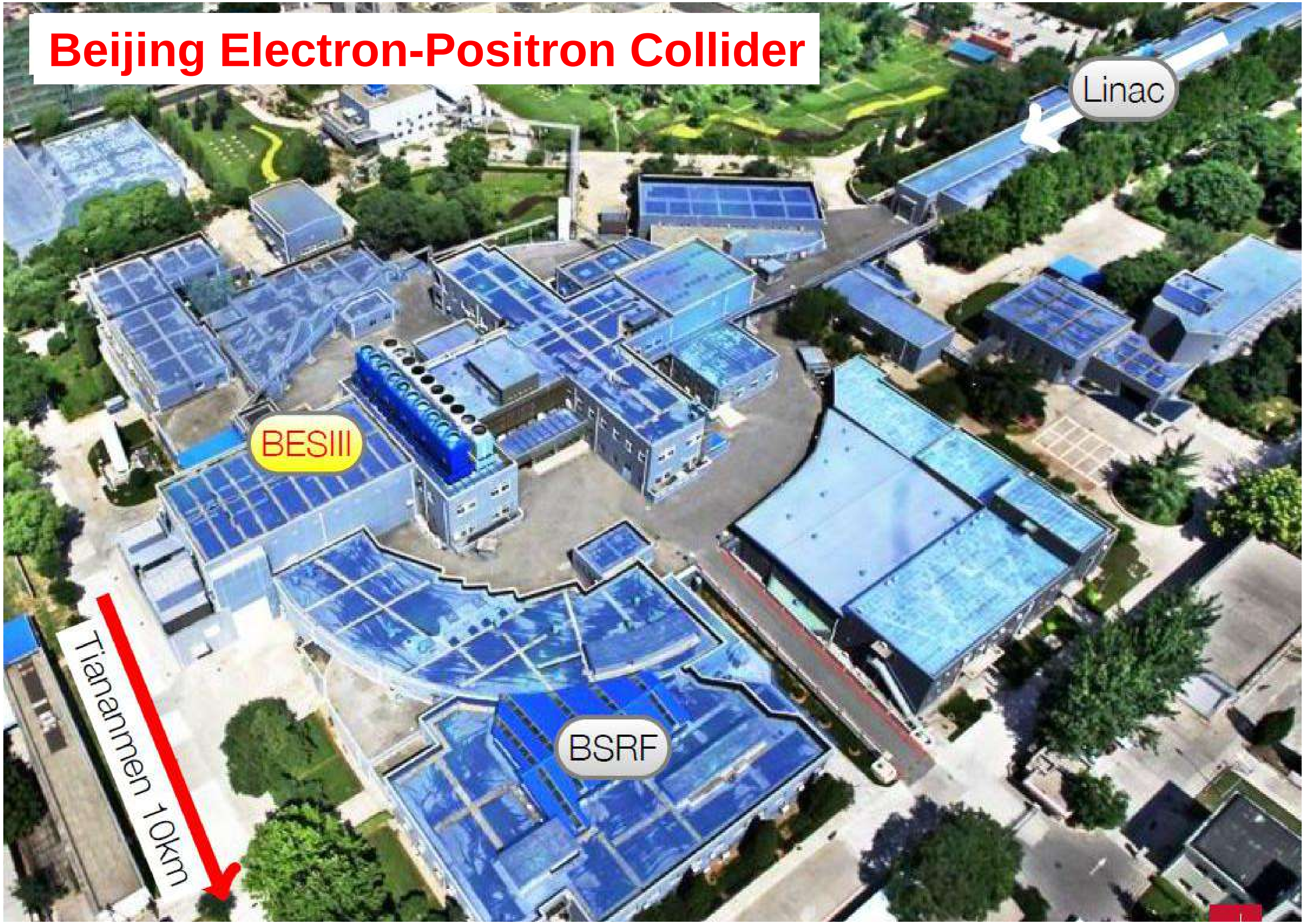
I.Boyko

LNP seminar
6 Apr 2022

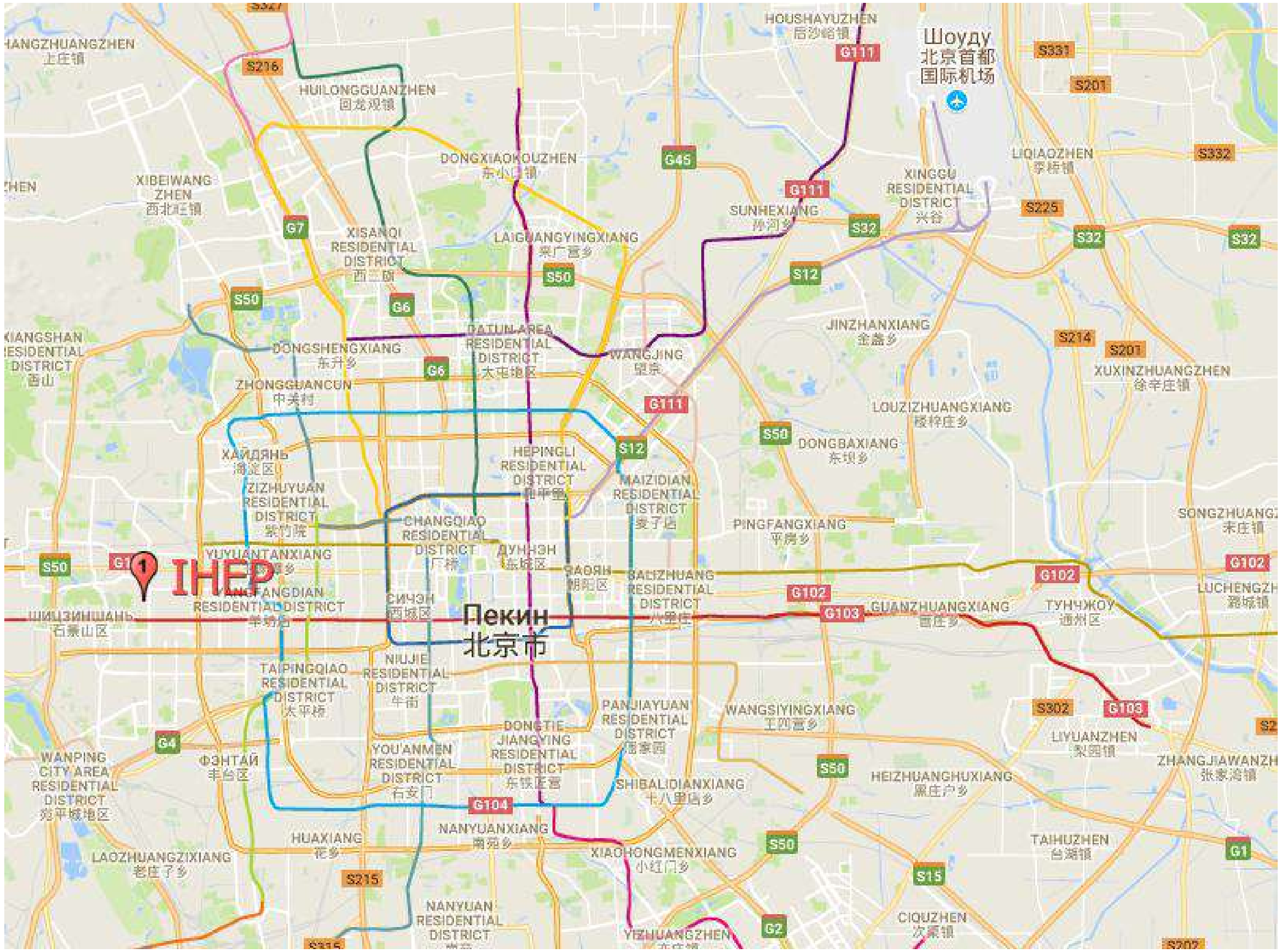
QCD experiments in LNP



Beijing Electron-Positron Collider



Location of IHEP in Beijing



History

- BES: 1989-1993 (BEPC)
- BESII: 1998-2004 (BEPC)
- BESIII: 2008-… (BEPCII)

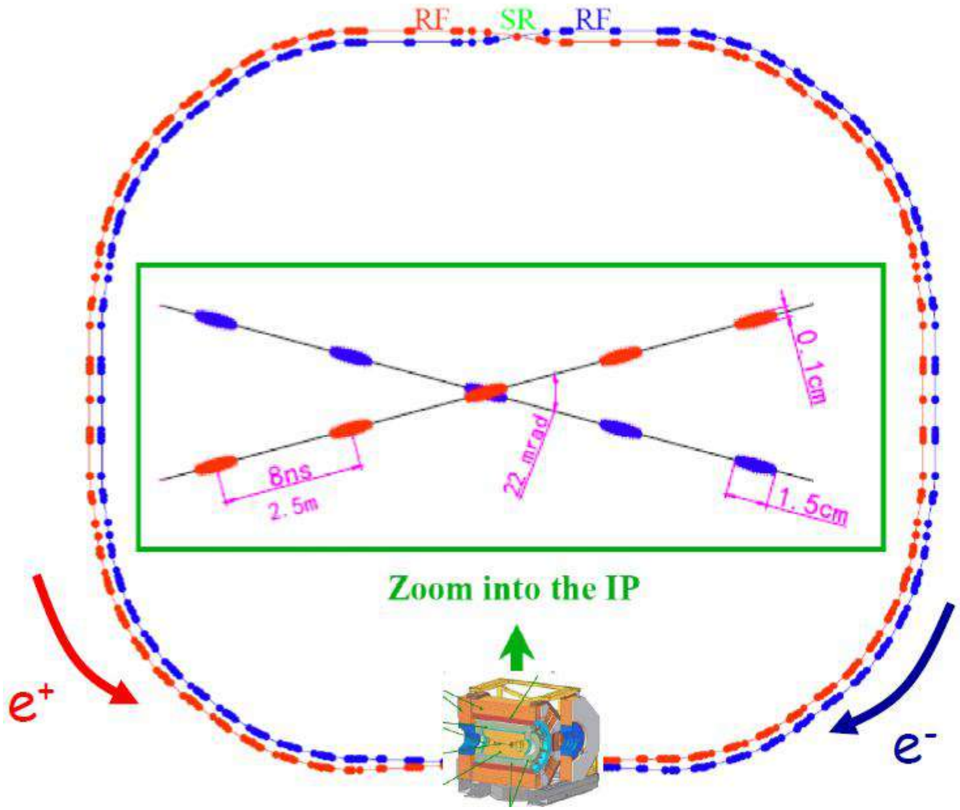
BES = BEijing Spectrometer

BEPC = Beijing Electron-Positron Collider

BESIII collaboration

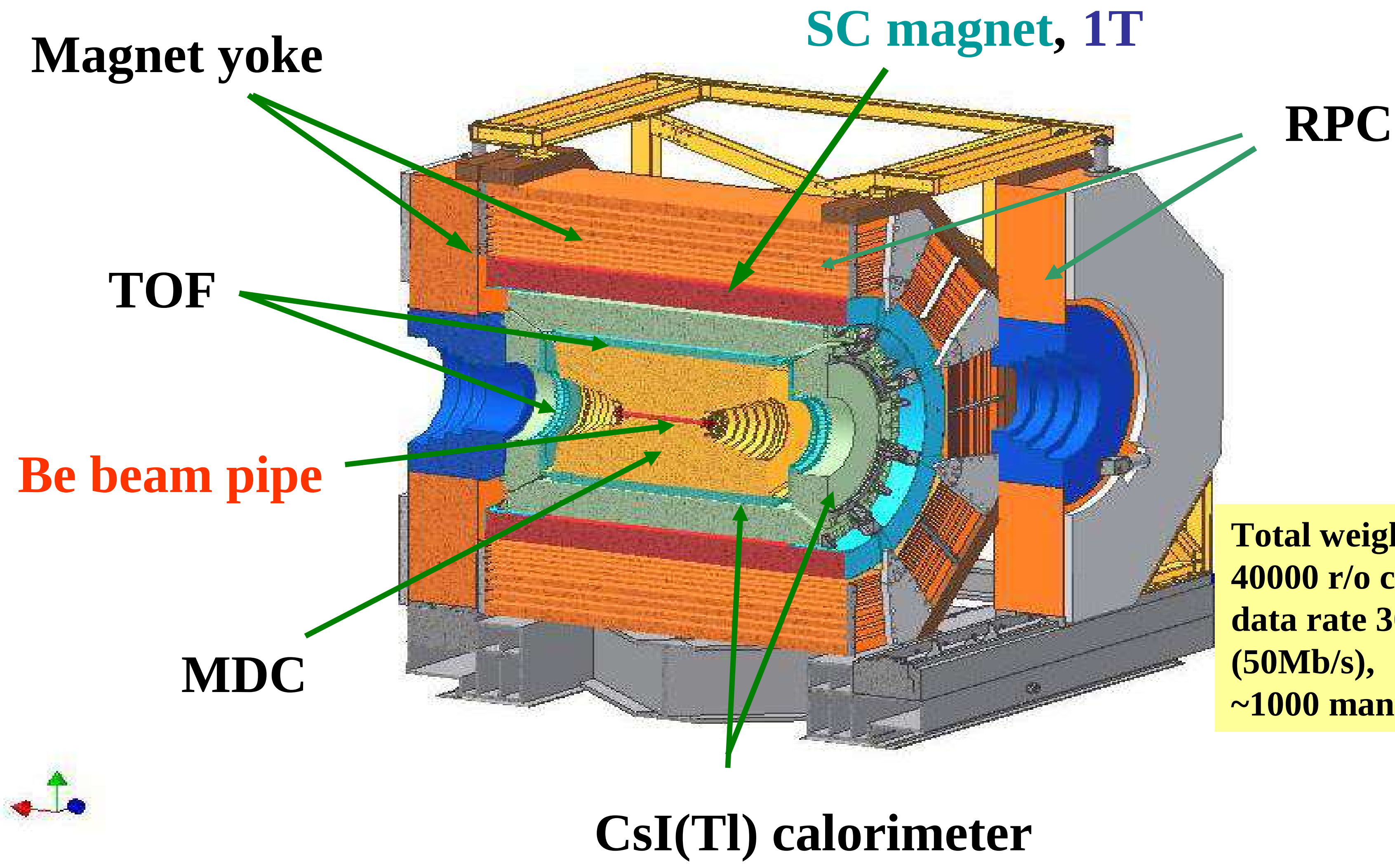
- About 500 members, 82 institutions, 17 countries
- 50 institutions from China, 9 rest of Asia,
  17 Europe (incl. Dubna and Novosibirsk),
  5 USA, 1 S.America

BEPCII storage rings



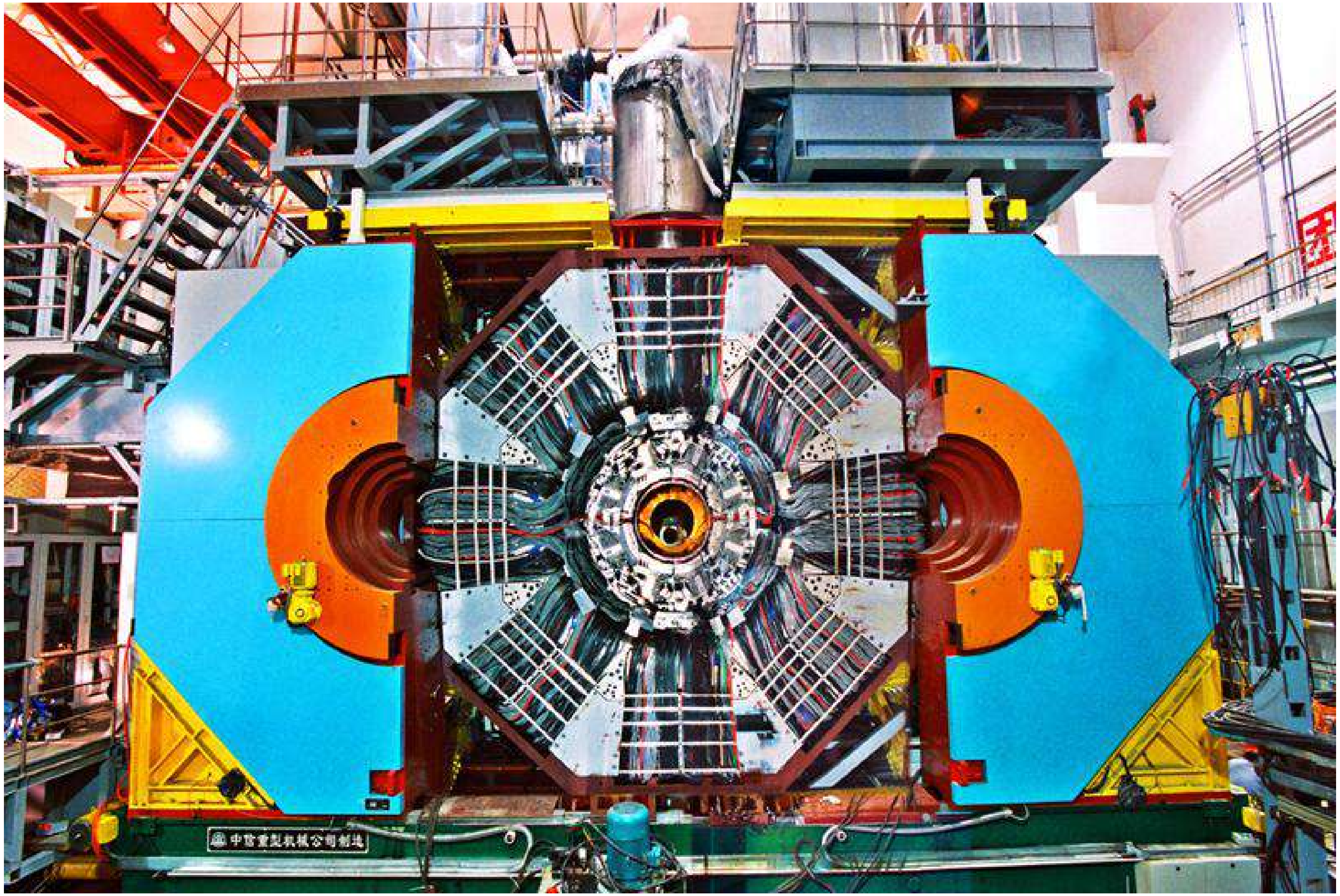
- Collision energy
  2.0 – 4.95 GeV
  (design: 2.0-4.6)
- Achieved luminosity
  1.0×10^{33} cm^{-2} s^{-1}
  (design: 1.0×10^{33})
- Energy spread
  5×10^{-4}
- No. of bunches
  93
- Total current
  0.91A
- Circumference
  237m

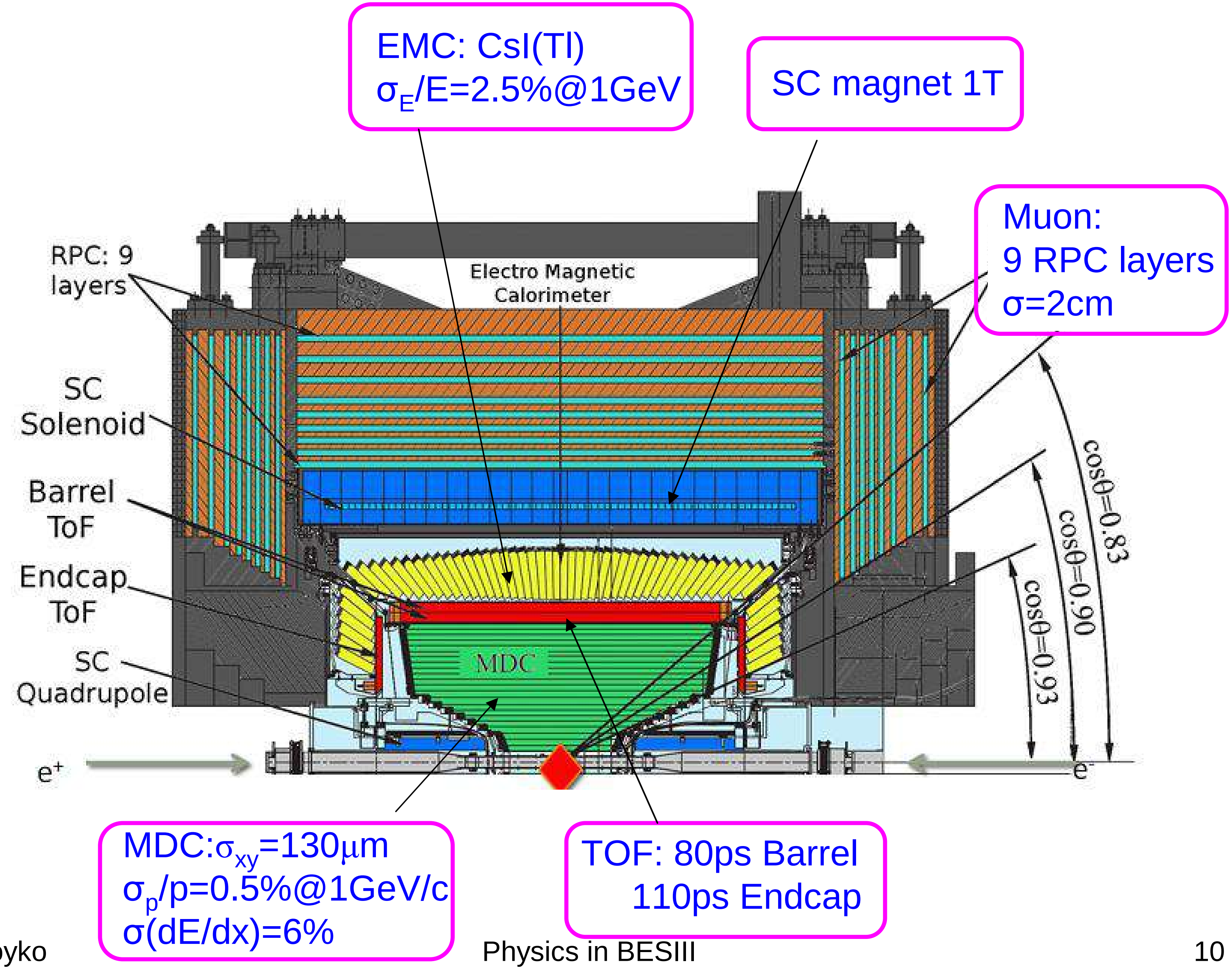
BESIII detector



Total weight 730t,
40000 r/o channels,
data rate 3000Hz
(50Mb/s),
~1000 man*year

BESIII general view

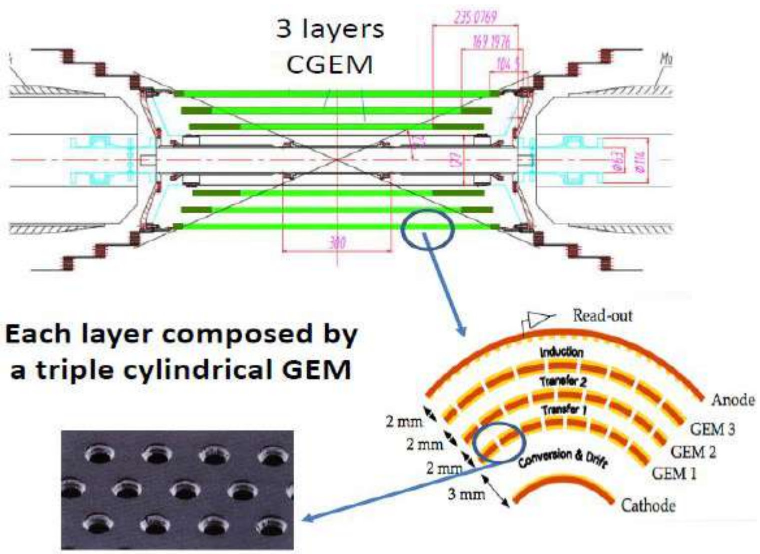


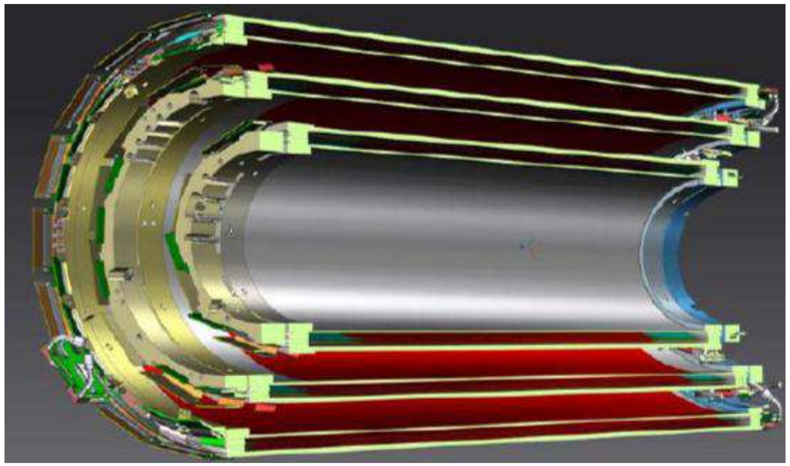

EMC: CsI(Tl)
σE/E=2.5%@1GeV
SC magnet 1T
Muon:
9 RPC layers
σ=2cm
RPC: 9 layers
Electro Magnetic Calorimeter
SC Solenoid
Barrel ToF
Endcap ToF
SC Quadrupole
MDC
e+
e-
cosθ=0.83
cosθ=0.90
cosθ=0.93
MDC:σxy=130μm
σp/p=0.5%@1GeV/c
σ(dE/dx)=6%
TOF: 80ps Barrel
110ps Endcap

Inner tracker upgrade

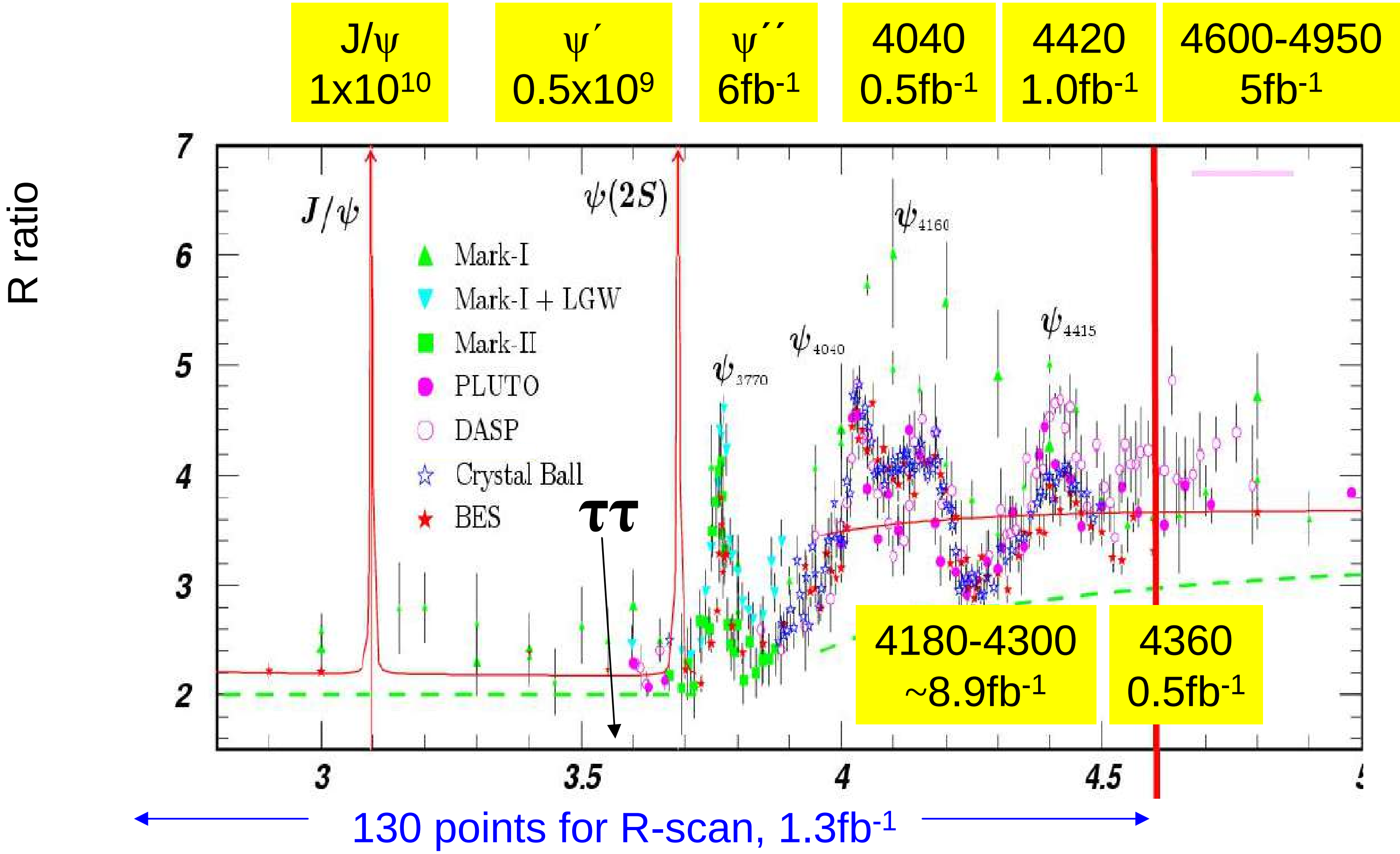
- Inner part of the Main Drift Chamber suffers from aging
- Since 2015, a Cylindrical GEM chamber is under construction
- Similar to KLOE-2 CGEM

- Material <1.5%X_0
- Rate 10^4 Hz/cm^2
- $\sigma_{r\varphi}$ ~130 μm
- σ_p/p=0.5%@1GeV/c





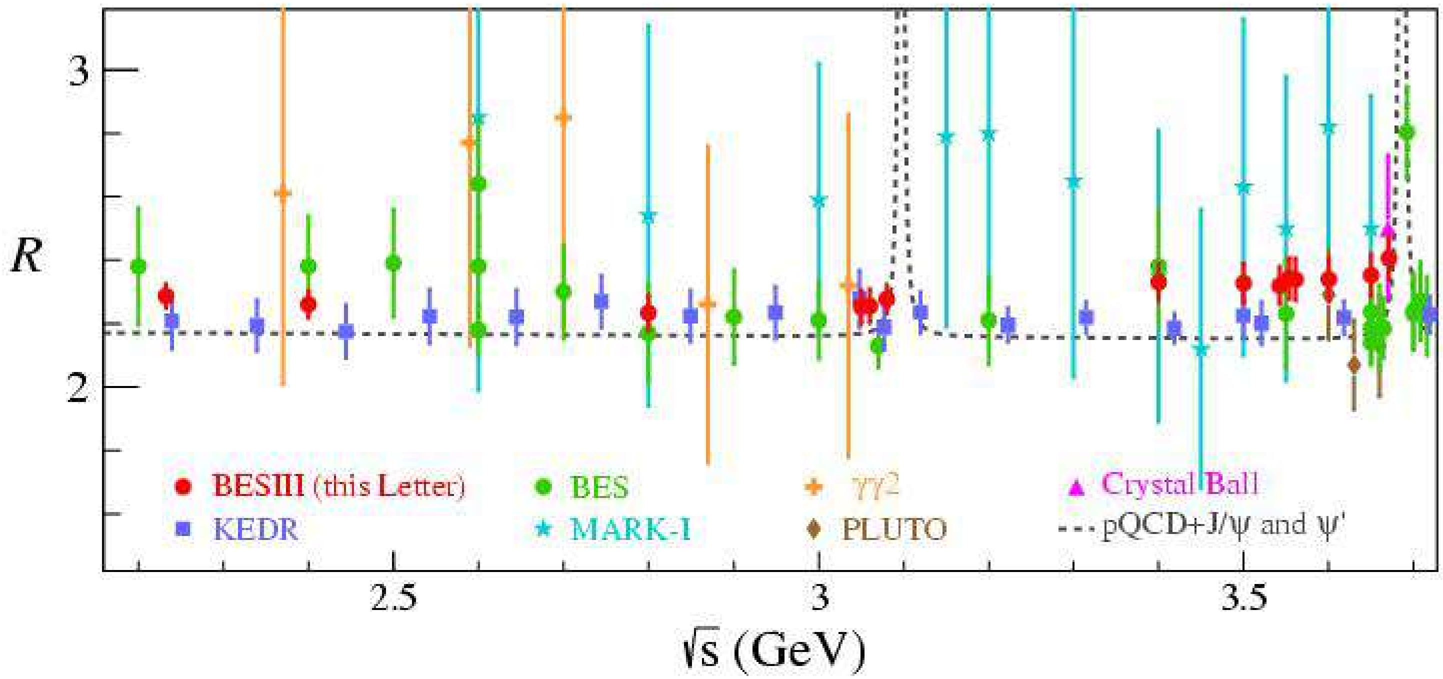
BESIII data



World largest samples of J/ψ, ψ(2S), ψ(3770), ψ(4040), ψ(4180), Y(4260), …

R-ratio for g-2 precision calculations

- $R = \sigma(ee \rightarrow \text{hadrons}) / \sigma(ee \rightarrow \mu\mu)$
- Sensitive to quark loop corrections to g-2



BESIII physics program

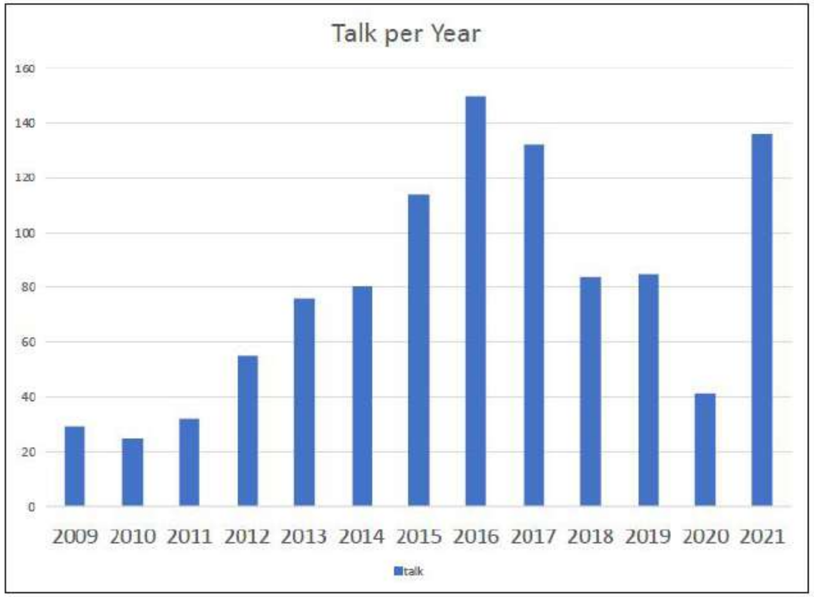
- Charmonium physics ($J/\psi, \psi', \psi'', \eta_c, \chi_{cJ}$)
- Charmed hadrons (D, Λ_c)
- Exotic states (X,Y,Z)
- Light hadron spectroscopy
- Tau lepton physics
- R-scan (inclusive hadron yield)
- Baryon form-factors
- Searches for new physics

Statistics of scientific results

Papers

YEAR	CWR	EDITING	DONE	TOTAL
2022 (3/12 Mo.)	13	8	3	24
2021	1	3	74	78
2020	1	0	51	52
2019	0	0	45	45

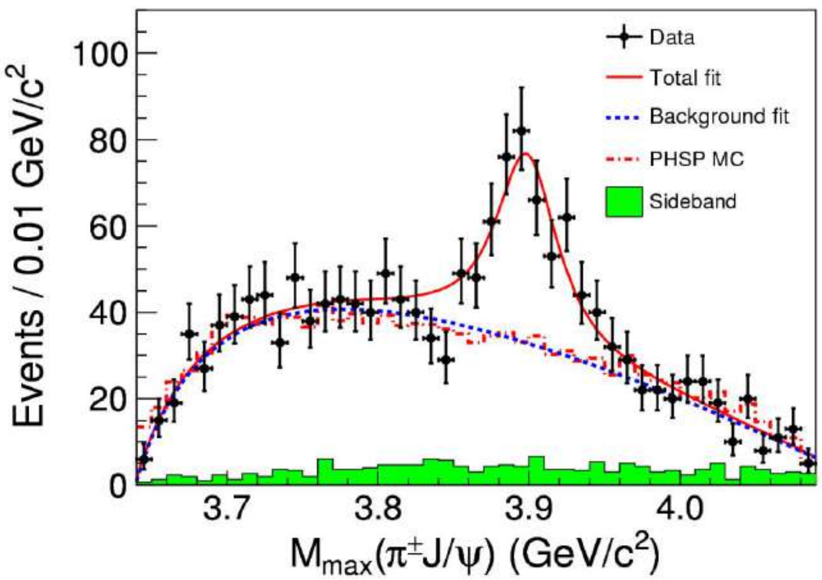
Talks



Zc states

First observation of a charged charmonium-like state

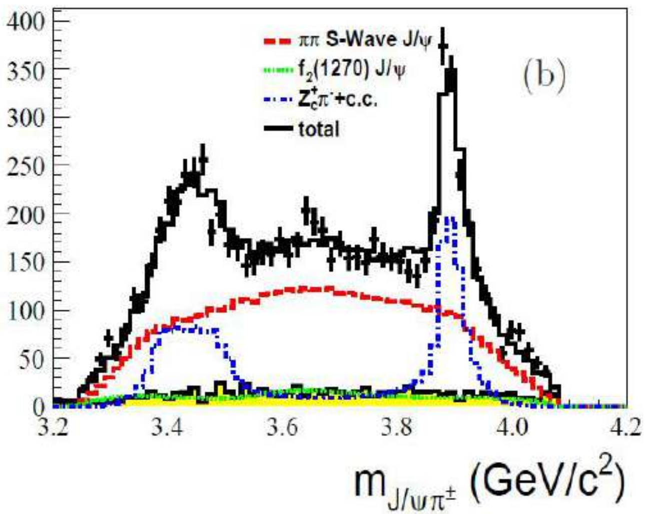
$Z_c(3900)^+$



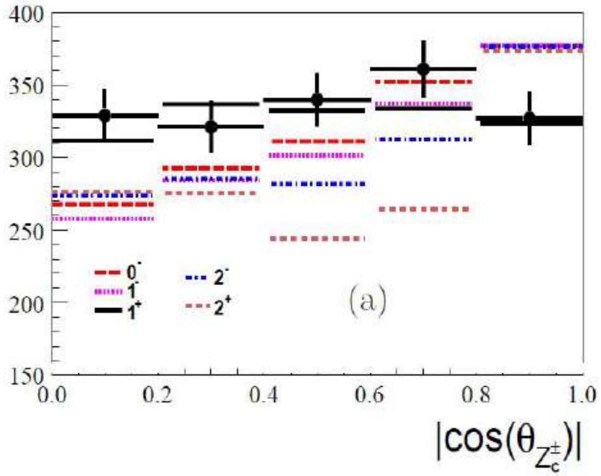
PRL 110, 252001

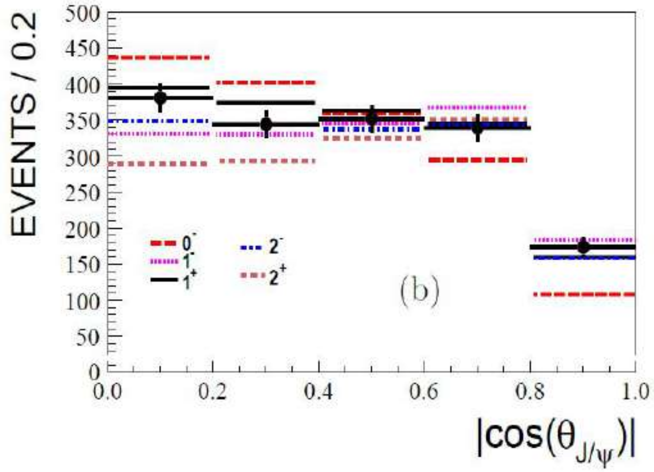
- An unambiguous peak of ($\pi^{\pm}J/\psi$) mass observed in $ee \rightarrow \pi^{+}\pi^{-}J/\psi$ data
- $M = 3899.0 \pm 3.6 \pm 4.9$ MeV
- $\Gamma = 46 \pm 10 \pm 20$ MeV
- Most natural interpretation is a 4-quark state ccqq (tetraquark); other interpretations also possible

PWA of Zc(3900)



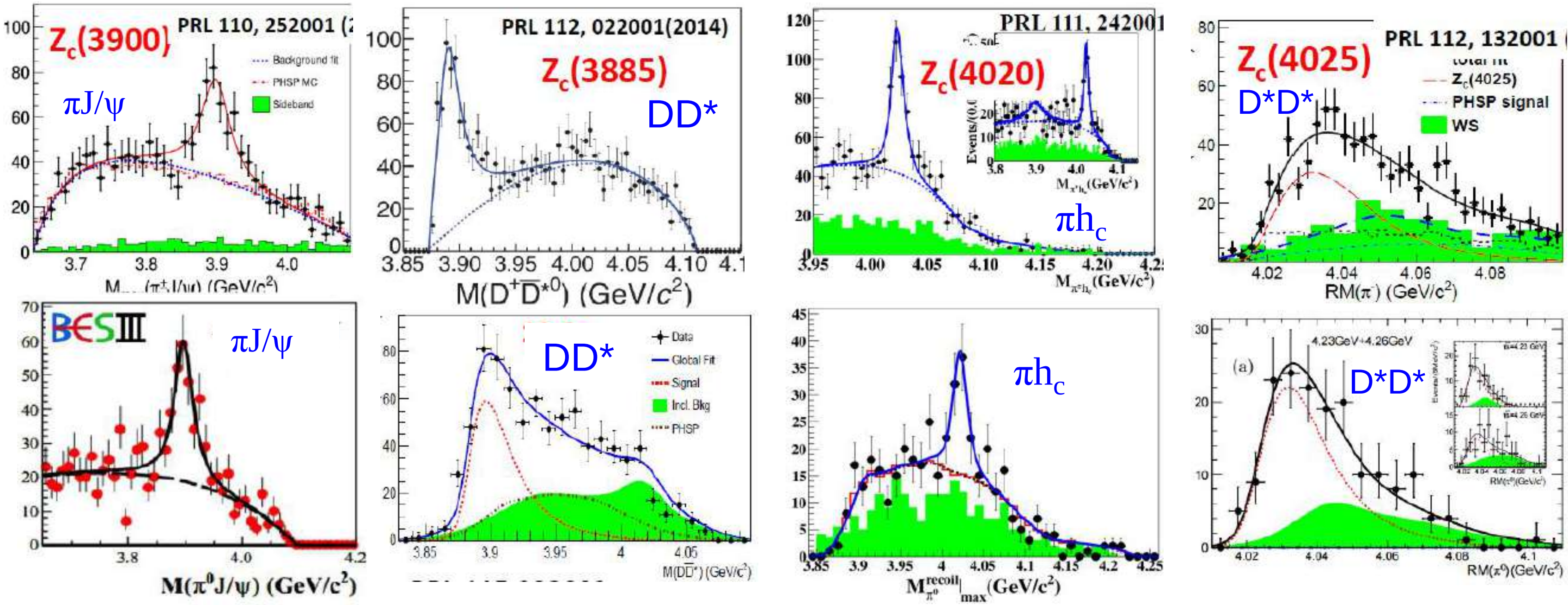
- Contributions from σ, $f_0(980)$, $f_2(1270)$ and $f_0(1370)$ have been considered
- Spin-parity established to be 1^+ at more than 7σ level





PRL 119, 072001

Other Zc states



- In total, 4 charged and 4 neutral states have been observed at ~3900 and ~ 4020 MeV in decay modes $\pi\pi J/\psi$, πh_c, D*D and D*D*
- A natural hypothesis: we observe 2 doublets of charged and neutral partners

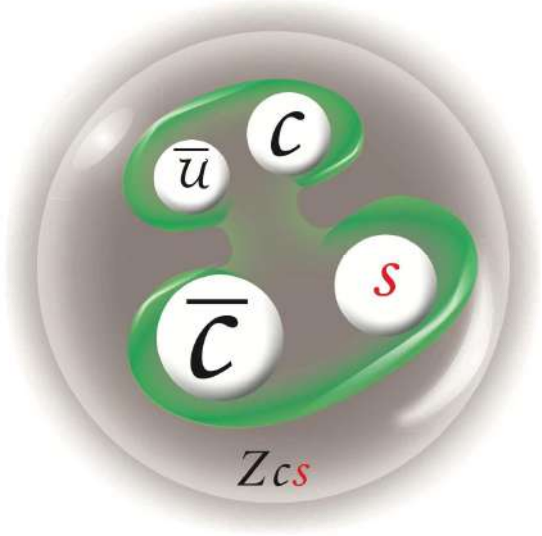
Summary on Zc decay modes

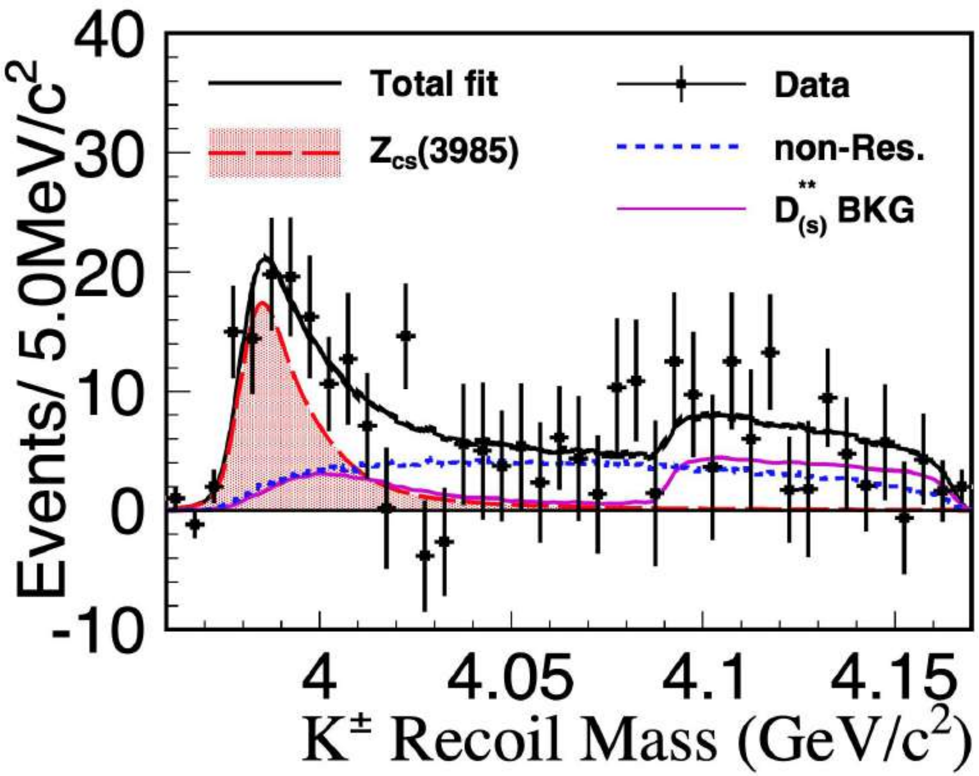
3900 MeV		4020 MeV	
charged	neutral	charged	neutral
$\pi^{\pm}J/\psi$ M = 3899.0 ± 6.1 Γ = 46 ± 22	$\pi^{0}J/\psi$ M = 3894.8 ± 2.3 Γ = 29.6 ± 8.2	$\pi^{\pm}h_c$ M = 4022.9 ± 2.8 Γ = 7.9 ± 3.7	$\pi^{0}h_c$ M = 4023.9 ± 4.4 Γ = 7.9 (fixed)
$(D^*D)^{\pm}$ M = 3882.0 ± 1.9 Γ = 26.5 ± 2.7	$(D^*D)^{0}$ M=3885.7 ± 10.2 Γ = 35 ± 19	$(D^*D^*)^{\pm}$ M = 4026.3 ± 4.5 Γ = 24.8 ± 9.5	$(D^*D^*)^{0}$ M = 4025.5 ± 5.6 Γ = 23.0 ± 6.1

Discovery of strange charmonium

- $ee \to K^+(D_sD^*)$
- M=3983 ± 3 GeV
- Γ = 13 ± 5

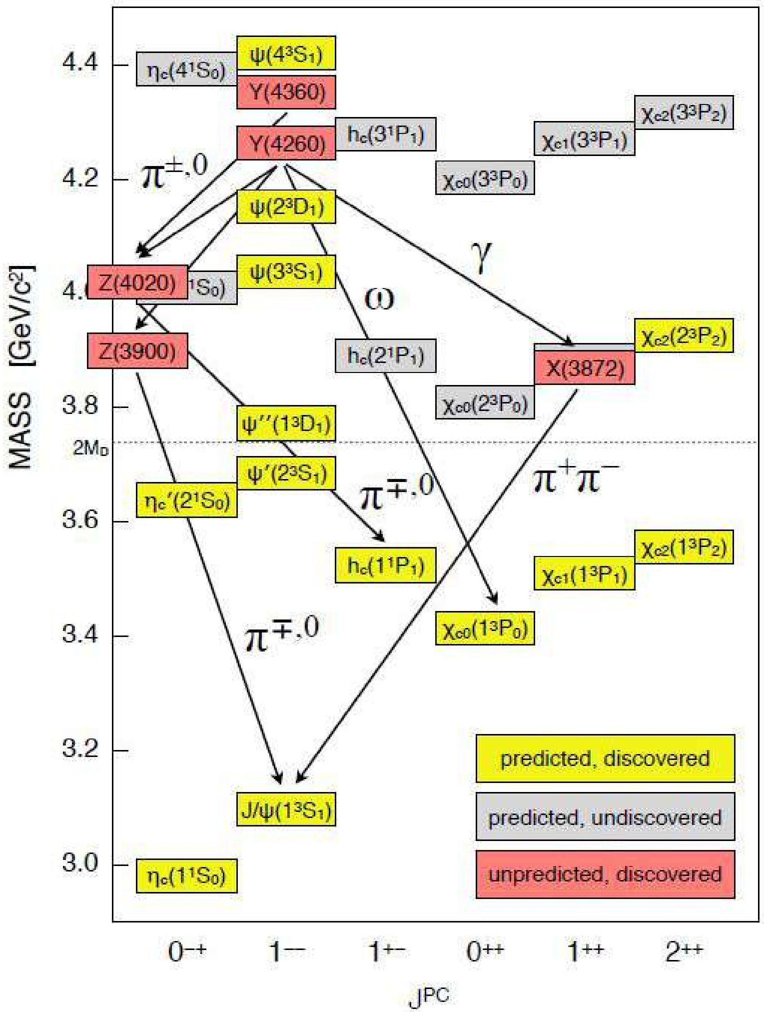
PRL **126**, 102001 (2021)



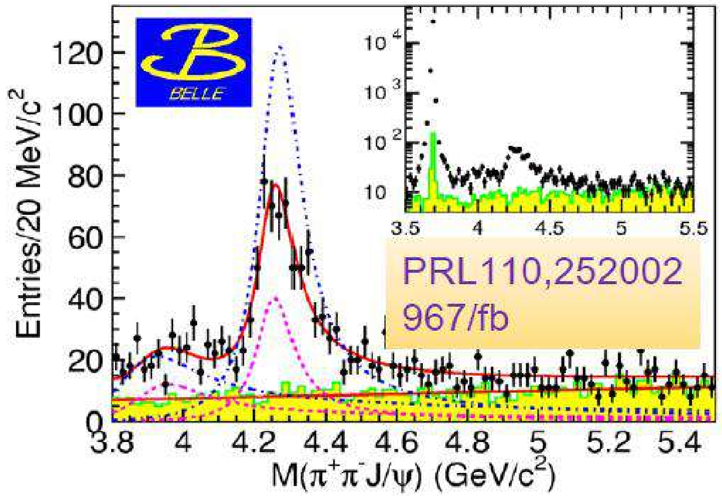


XYZ states

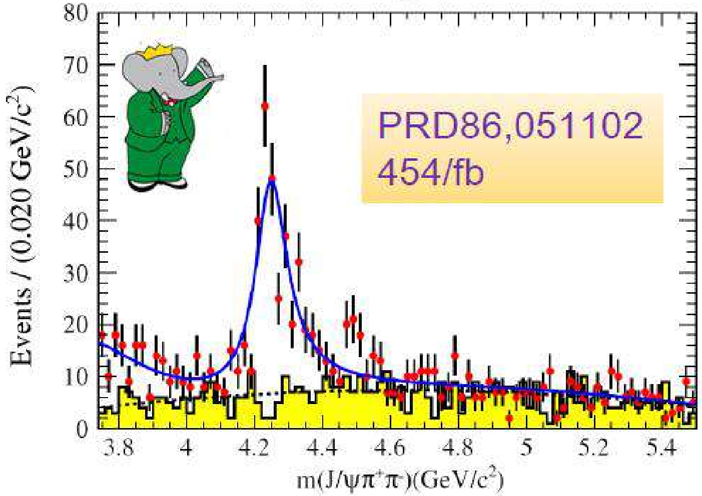
XYZ states



MASS [GeV/c²]
J^{PC}
predicted, discovered
predicted, undiscovered
unpredicted, discovered
Y(4360)
Y(4260)
Z(4020)
Z(3900)
X(3872)
J/ψ(1³S₁)

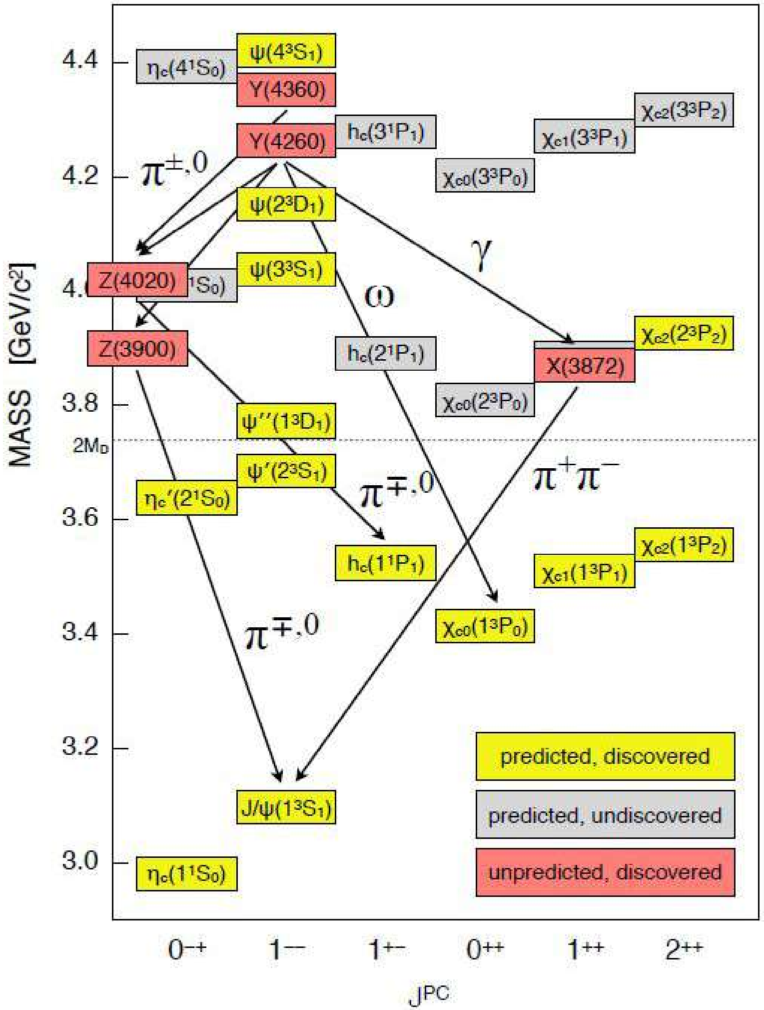


BELLE
PRL110,252002
967/fb
Entries/20 MeV/c²
M(π⁺π⁻J/ψ) (GeV/c²)



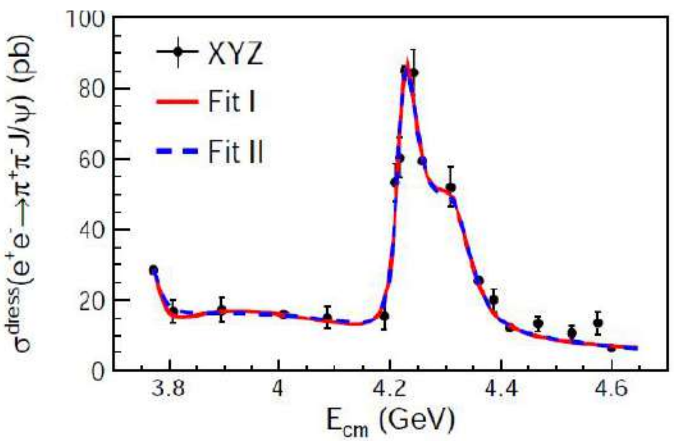
PRD86,051102
454/fb
Events / (0.020 GeV/c²)
m(J/ψπ⁺π⁻)(GeV/c²)

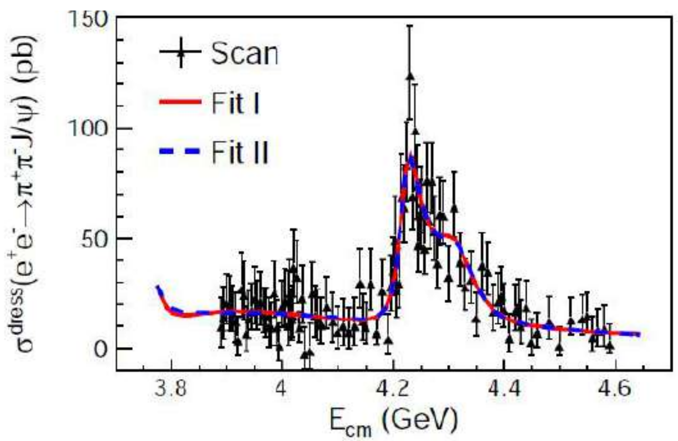
XYZ states

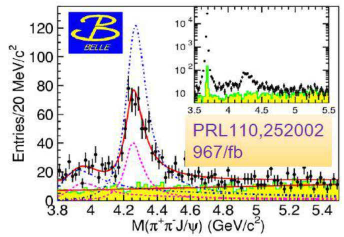


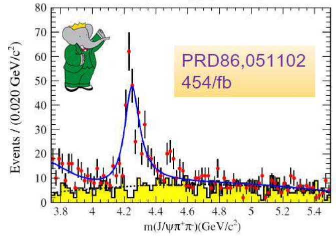
- An energy scan was performed in the energy domain of XYZ states
- Total 9.0 fb^{-1} data have been collected
  - Of them, 8.2 fb^{-1} from a dedicated XYZ-scan
  - Additional 0.8 fb^{-1} from earlier scans
- Collision energy between 3.77 and 4.60 GeV

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



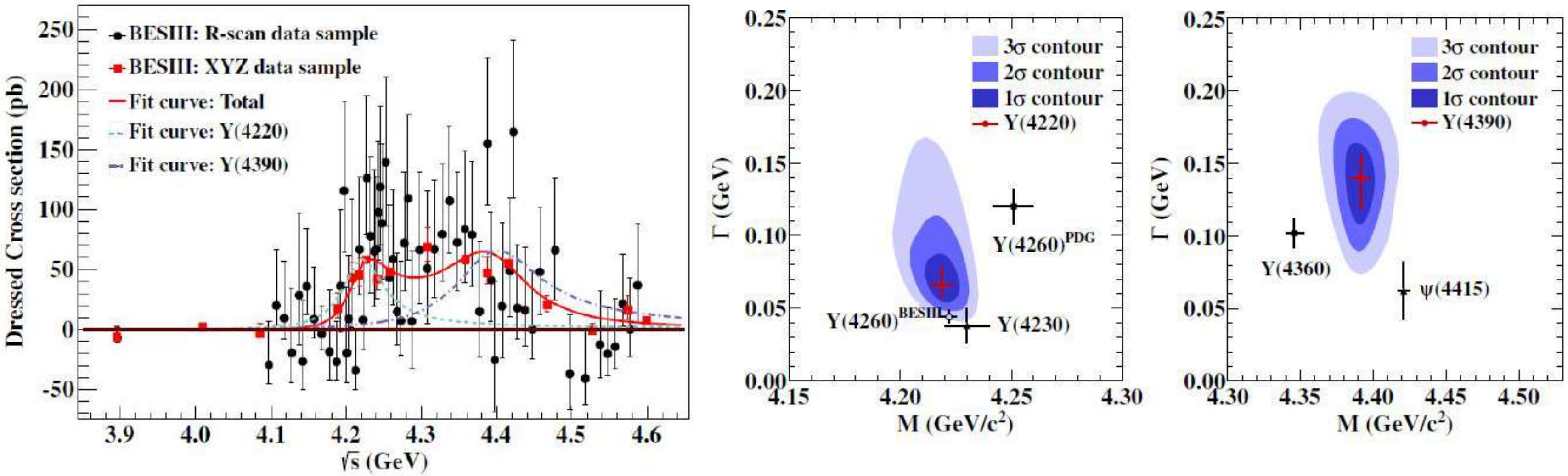






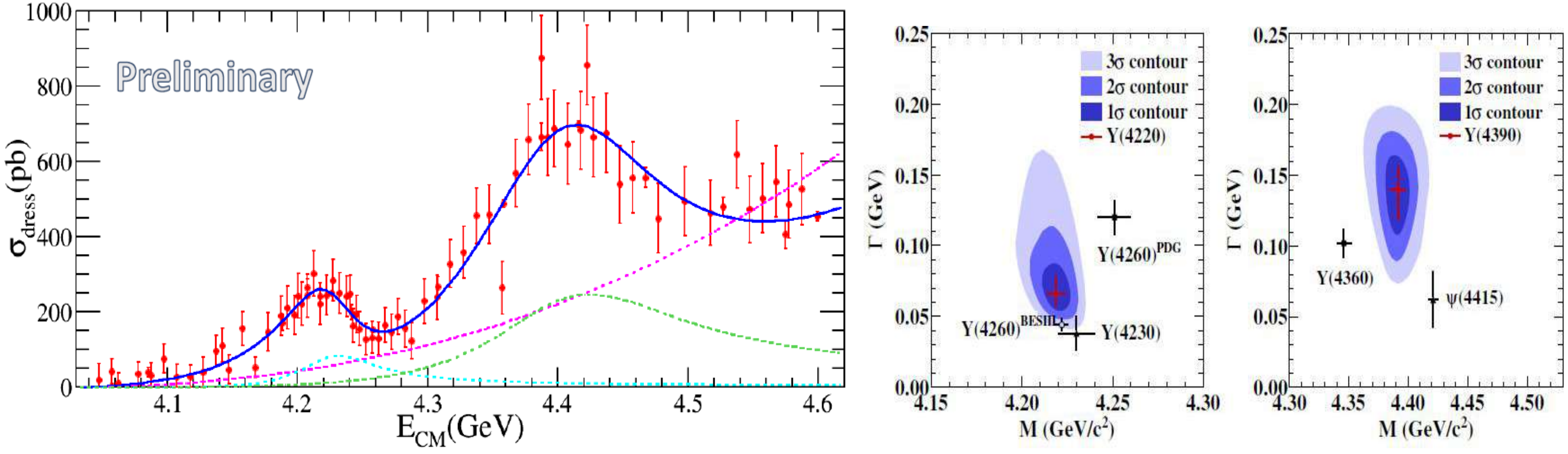
- Two resonant structures are observed:
  - Y(4260)? M = 4222.0 ± 3.1 ± 1.4, Γ = 44.1 ± 4.3 ± 2.0 MeV
  - Y(4360)? M = 4320.0 ± 10.4 ± 7, Γ = 101.4 ± 25 ± 10 MeV
- Precision on Y(4260) improved
- Y(4360): first observation in $ee \to \pi^+\pi^- J/\psi$
  - Seen in $ee \to \pi^+\pi^- \psi'$ by Belle and BaBar

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



- Two resonances observed:
  - Y(4220): M = 4218.0 ± 5 ± 0.9, Γ = 66 ± 12 ± 0.4 MeV
  - Y(4390): M = 4391.5 ± 6.8 ± 1.0, Γ = 139.5 ± 20 ± 0.6 MeV
- Inconsistent with $Y(4260)^{PDG}$, Y(4360), $\psi(4415)$
- Y(4220) consistent with the structure observed in $ee \to \omega\chi_{c0}$

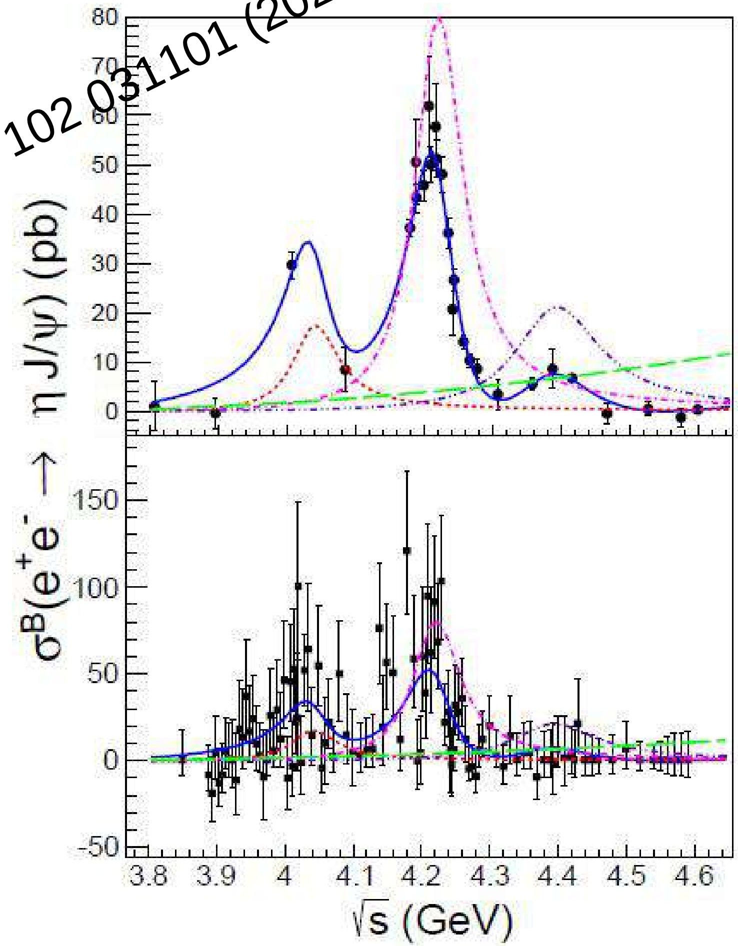
$ee \to \pi^- D^0 D^{*+}$

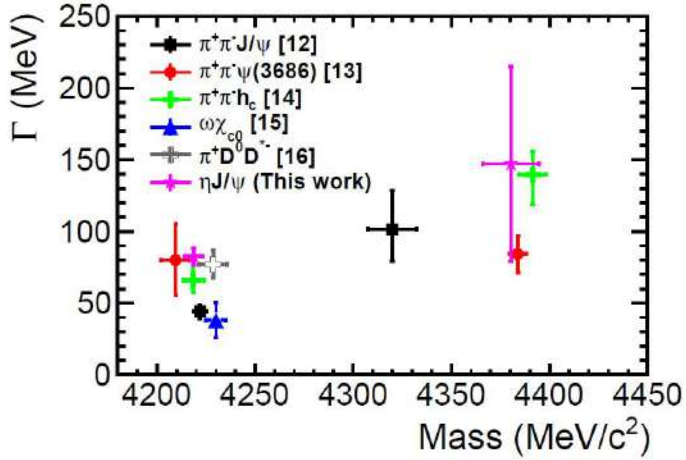


- Again, 2 resonances observed:
  - Y(4220): M = 4224.8 ± 5.6 ± 4, Γ = 72.3 ± 9.1 ± 0.9 MeV
  - Y(4390): M = 4400.1 ± 9.3 ± 2.1, Γ = 181.7 ± 16.9 ± 7.4 MeV
- Y(4220) consistent with $\pi^+\pi^- h_c$, $\pi^+\pi^- J/\psi$, $ee \to \omega\chi_{c0}$
- Y(4390) consistent with $\pi^+\pi^- h_c$

ee → η J/ψ

PRD 102 031101 (2020)

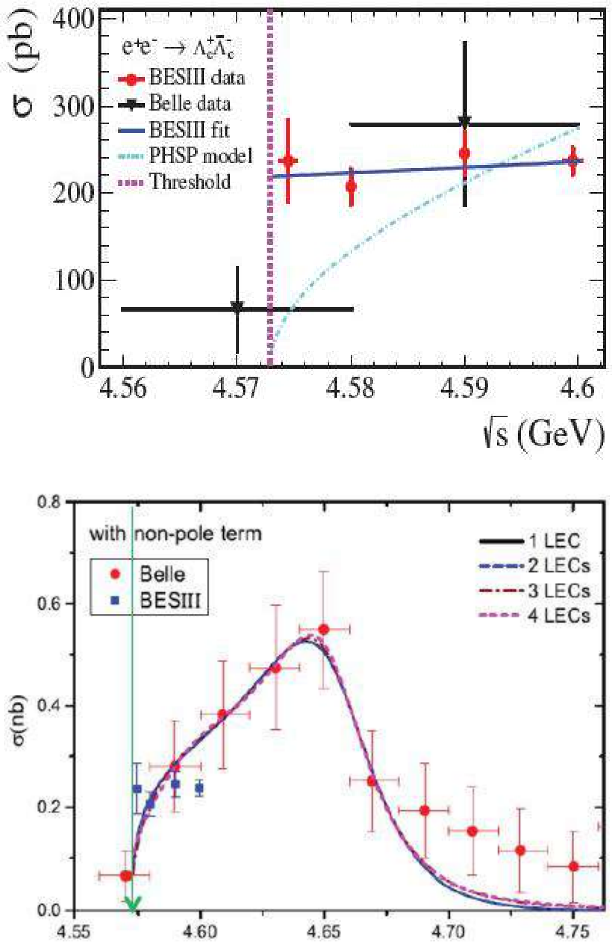




- BESIII results are consistent with 3 Y-states
- Masses: 4220, 4320, 4390
- Reported by other experiment 4260, 4360, 4415 were mis-interpretation

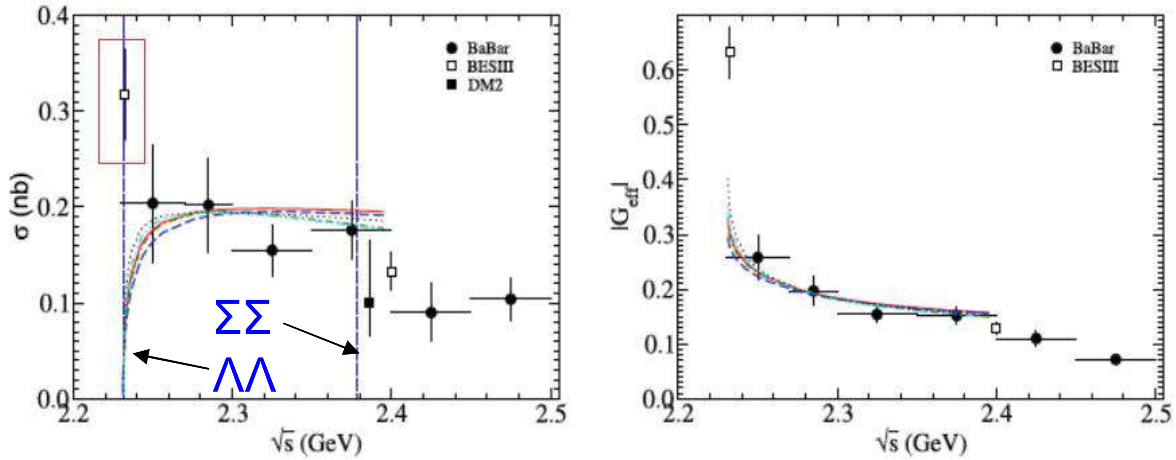
Baryonic form-factors

Λ_C: the lightest charmed baryon



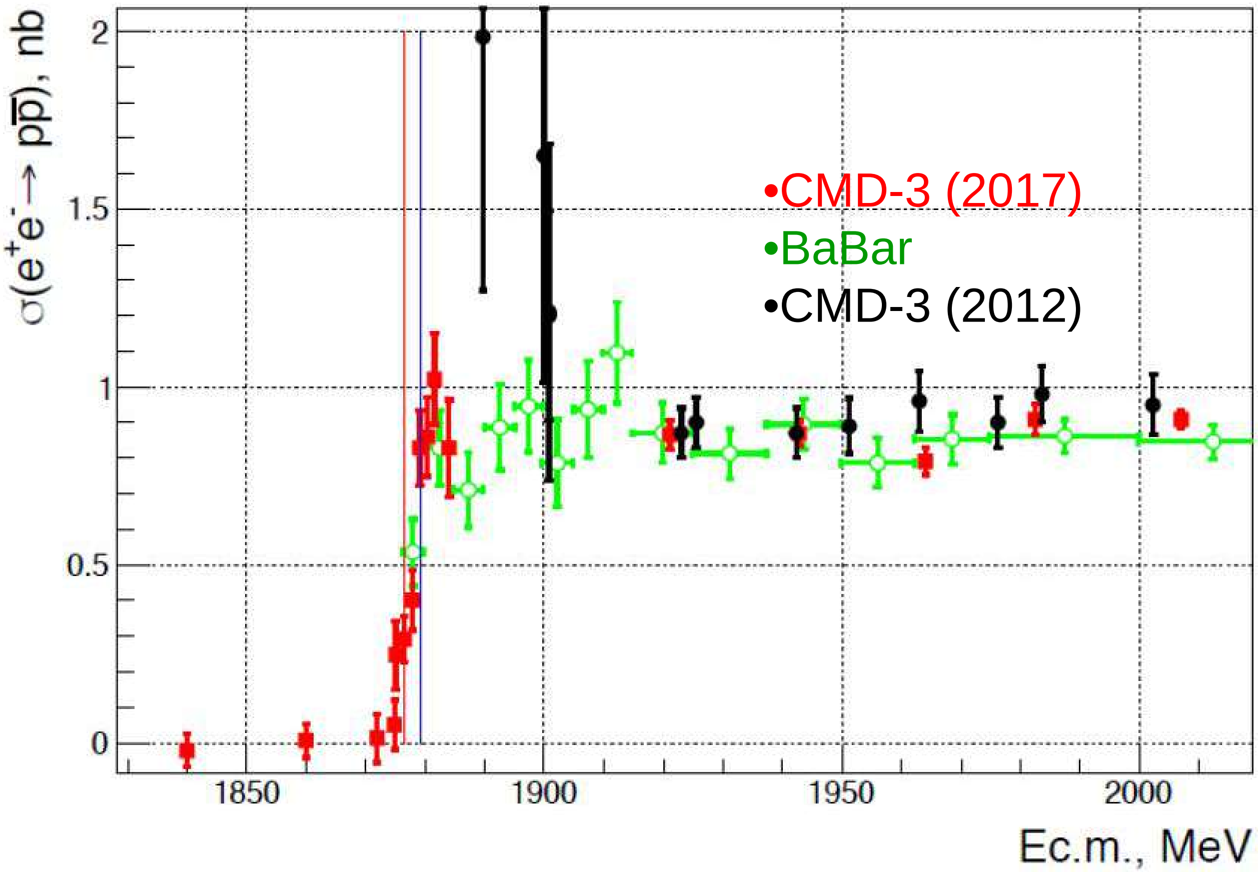
- Belle data can be described by a Y(4660) resonance
  - M = 4652.5 ± 3.4 MeV
- BESIII data show flat cross-section down to the threshold
- There is some tension between BESIII and Belle data

Lambda form-factor



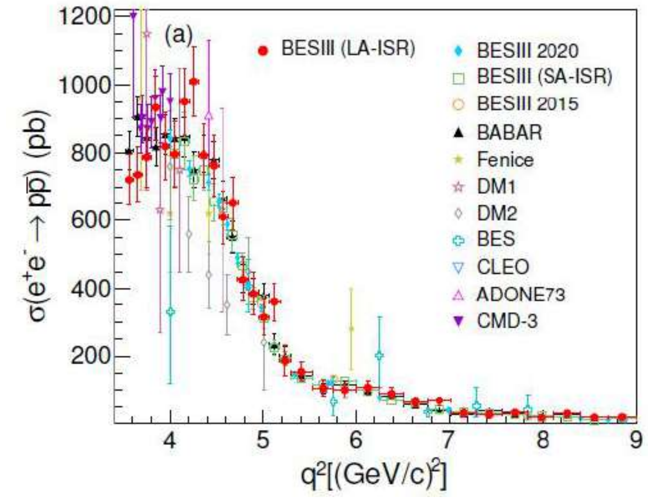
- At BESIII it is possible to measure cross-section down to the threshold energy (just 1 MeV above!)
- Like for Λ_C, BESIII observes a threshold enhancement
- BESIII results marginally consistent with BaBar, but not with the theoretical description

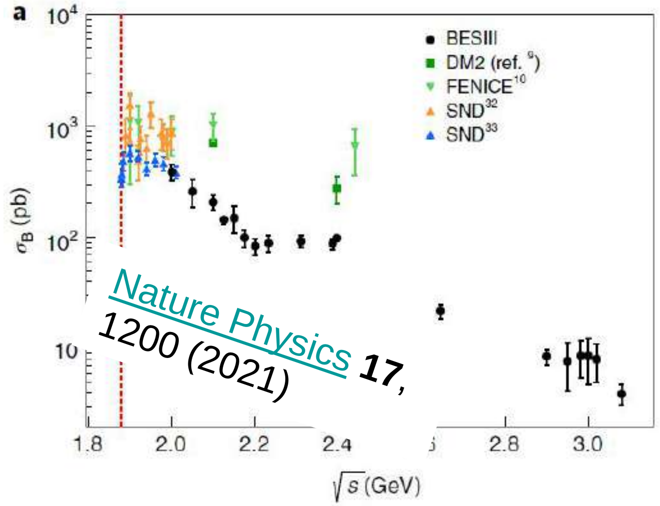
The ppbar threshold



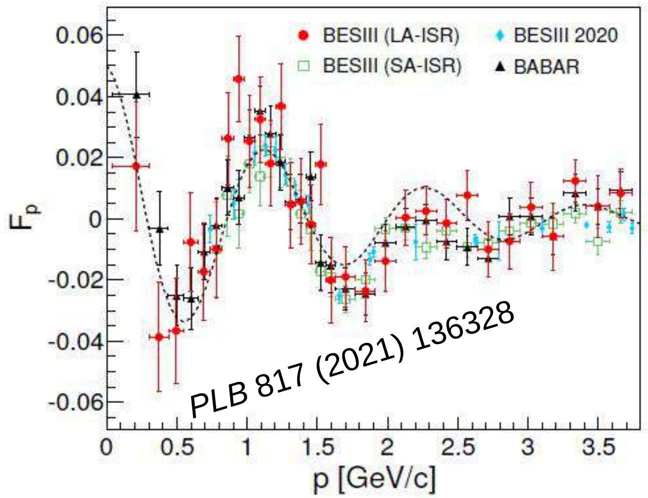
- Steep rise of ppbar cross-section is observed by CMD and BaBar
- BESIII scan down to 2000 MeV confirms the observations (see next slide)

Oscillations of ppbar and nnbar form-factor



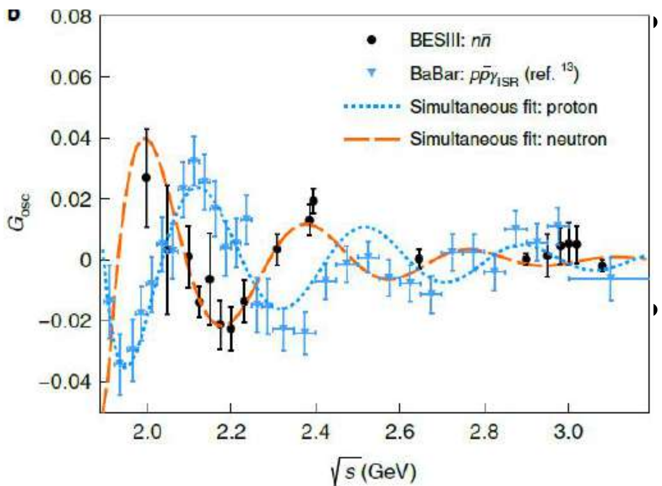


Nature Physics **17**, 1200 (2021)



PLB 817 (2021) 136328

ee→pp



ee→nn

- BESIII confirms the periodic oscillations of the effective form-factor as a function of ppbar relative momentum and discovers the same effect for nnbar
- Effect is observed on top of energy dependence predicted by dipole model
- An explanation is proton-antiproton rescattering at ~1 fm distances

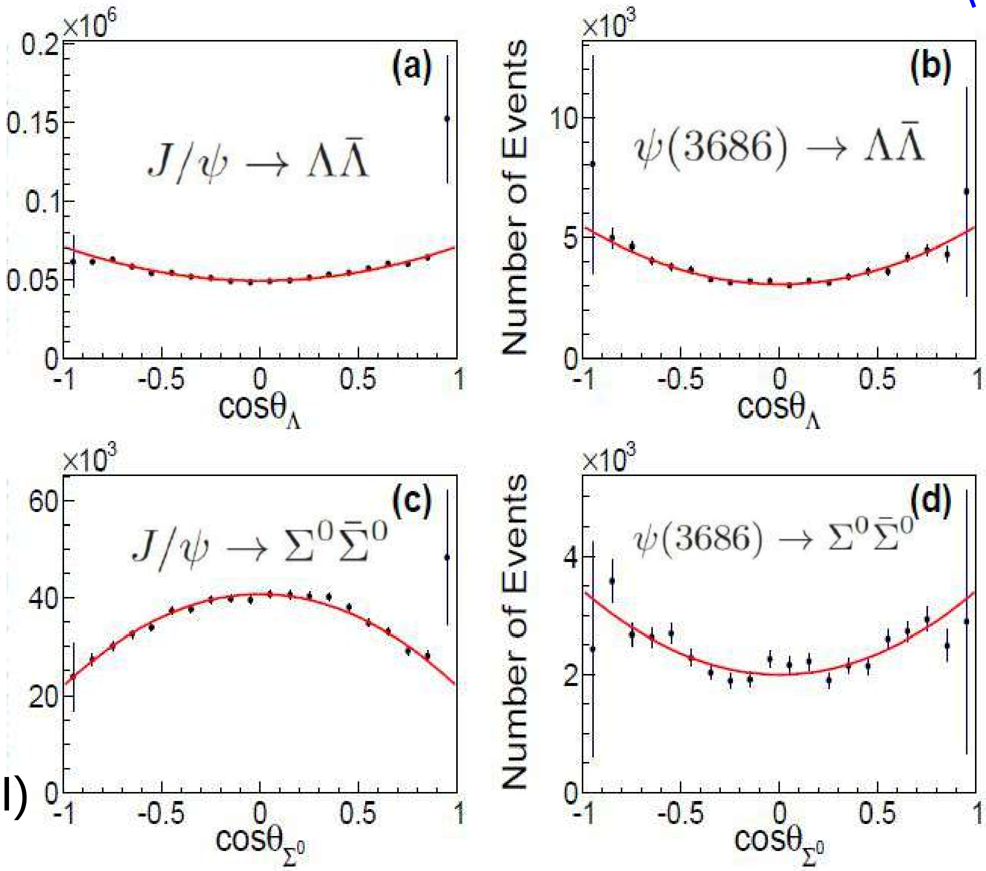
Charmonia baryonic decays (1)

PRD 95 (2017) 052003

$$\frac{dN}{d\cos\theta} \propto 1 + \alpha \cos^2\theta$$

BESIII:
0.469 ± 0.027
Theory:
0.32-0.51

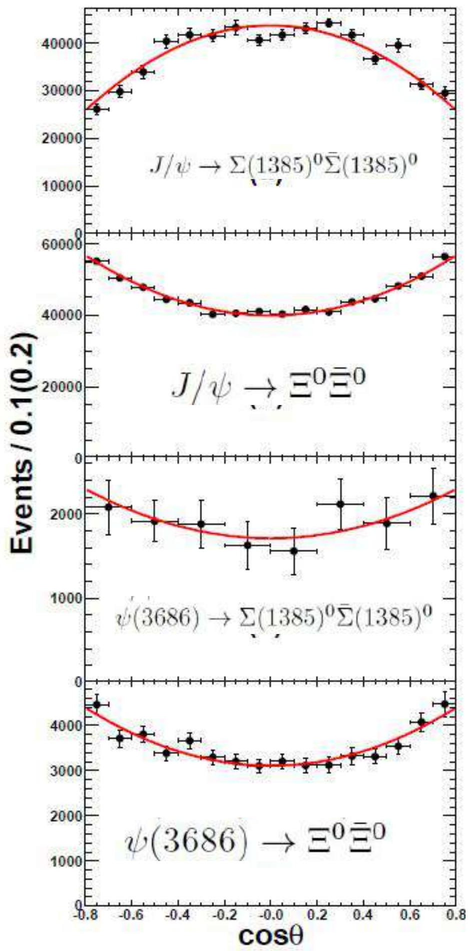
BESIII:
-0.449 ± 0.022
Theory:
0.31-0.43
Opposite sign!
(Confirm BESII)



BESIII:
0.82 ± 0.08
(first measurement)

BESIII:
0.71 ± 0.12
(first measurement)

Charmonia baryonic decays (2)



α = -0.64 ± 0.10

α = 0.66 ± 0.06

α = 0.59 ± 0.35

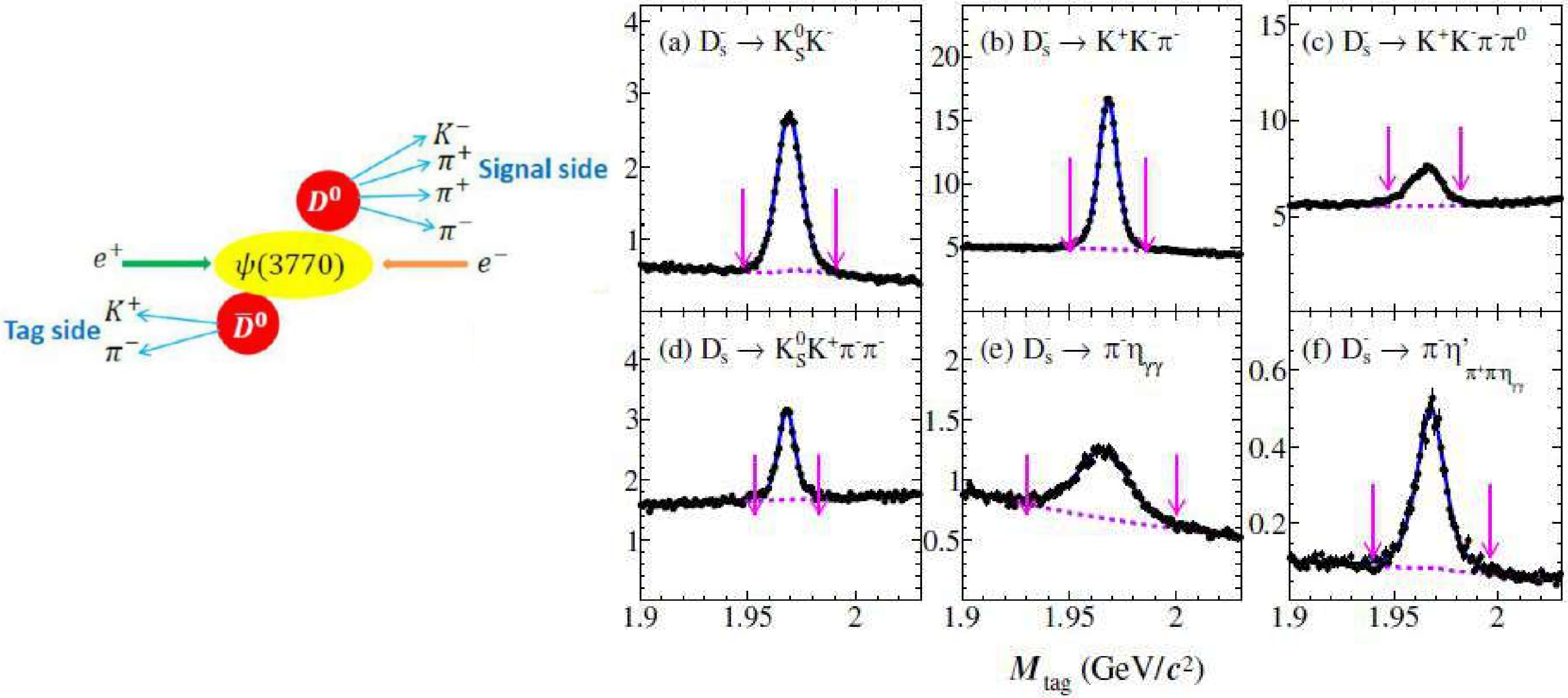
α = 0.65 ± 0.16

PLB 770 (2017) 217

- Again, negative angular parameter is observed in $J/\psi \to \Sigma\Sigma$
- Not the case for ψ' decays and for non-Σ final states
- LO QCD predicts positive α in all cases
- More sophisticated theoretical model are necessary to explain the observations

Charm decays

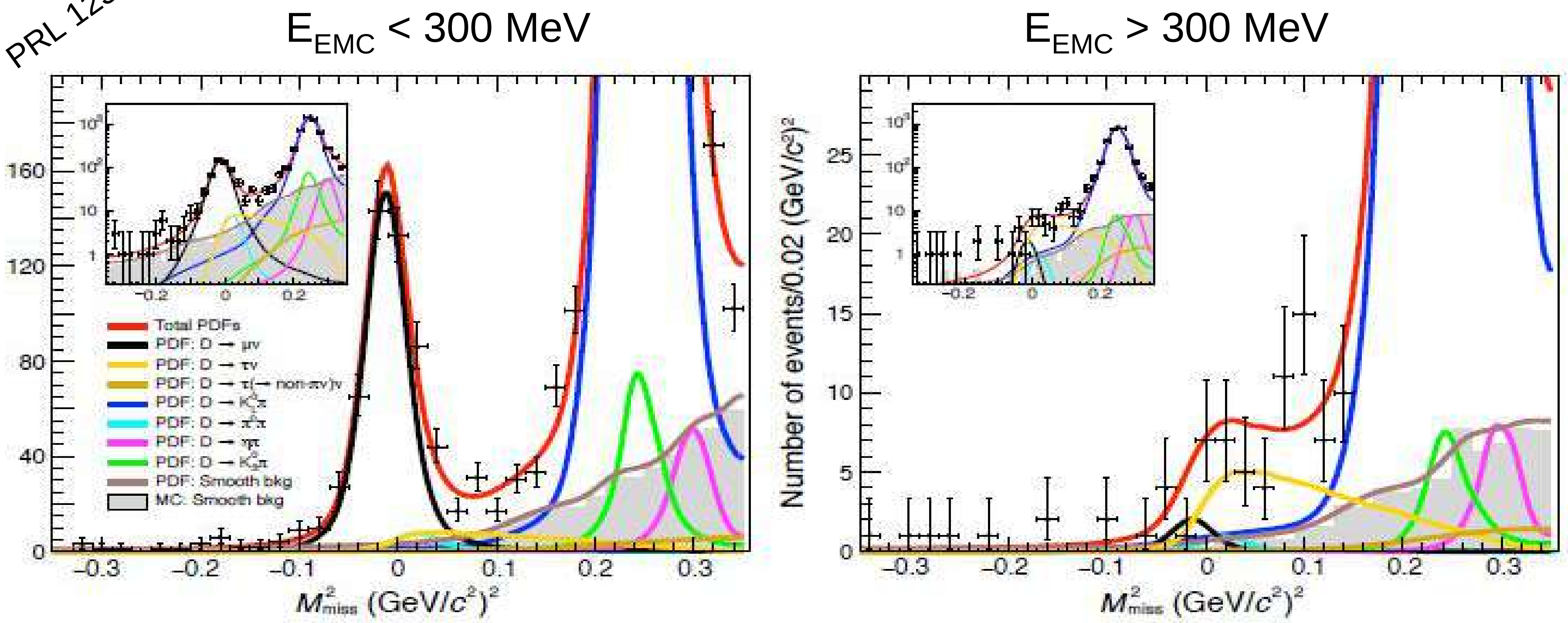
D meson measurements



- Clean decay modes (tag side) of $D^+/D^0/Ds$ are selected around D-meson invariant mass
- The second meson is reconstructed from the remaining particles (signal side)

$D^+ \to \tau^+\nu$

PRL 123, 211802 (2019)



- Nsig = 137 ± 27
- B[$D^+ \to \tau^+\nu$] = $(1.21 \pm 0.24_{stat})\text{x}10^{-3}$

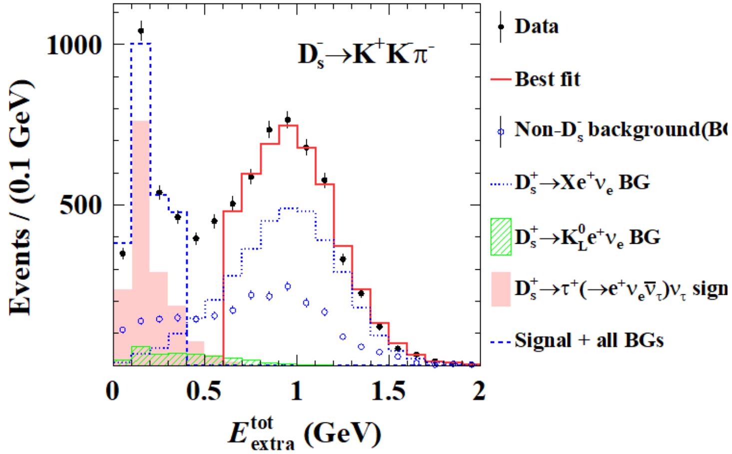
$$R \equiv \frac{\Gamma(D^+ \to \tau^+\nu)}{\Gamma(D^+ \to \mu^+\nu)}$$

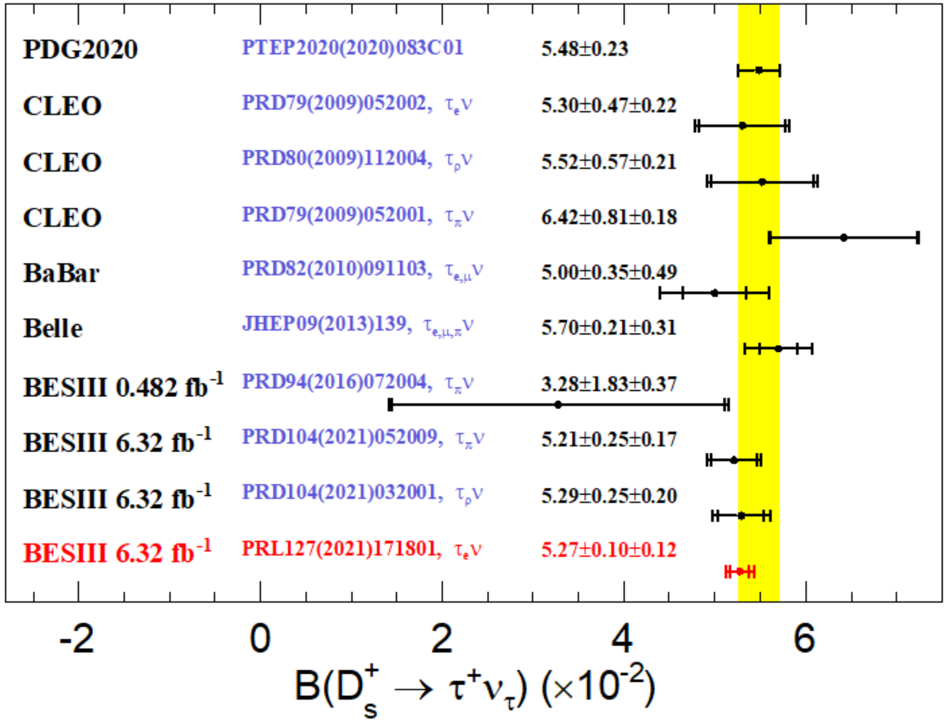
SM: R = 2.66 ± 0.01

BESIII: R = 3.21 ± 0.64

PRL 127, 171801 (2021)

$D_s^+ \to \tau^+\nu$





- Nsig = 4800 ± 120
- $B[D_s^+ \to \tau^+\nu] = (5.27 \pm 0.15)\%$

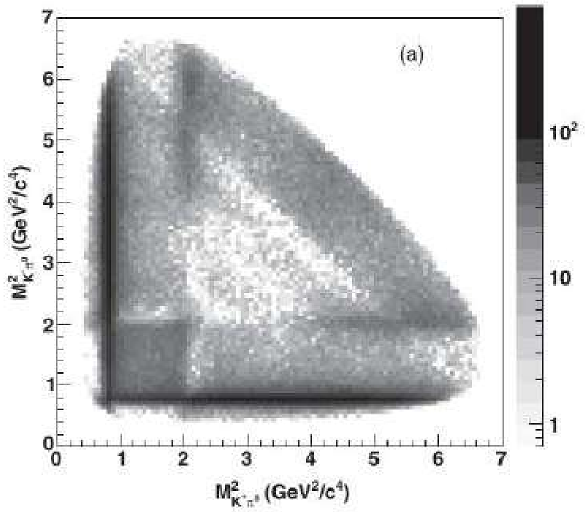
$$R \equiv \frac{\Gamma(D^+ \to \tau^+\nu)}{\Gamma(D^+ \to \mu^+\nu)}$$

SM: R = 9.75 ± 0.01

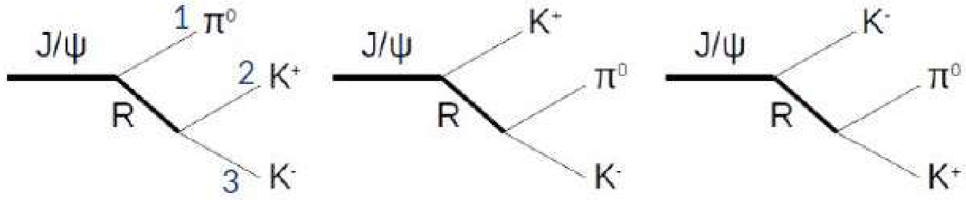
BESIII: R = 9.72 ± 0.37

Light hadron spectroscopy

Search for glueball
(Igor Denisenko Ph.D.)



- Отобрано 182972 события (см. доп. слайды)
- Фон от других распадов J/ψ оценивается с помощью инклюзивного набора МК-событий и составляет 0.3 %.



- Изобарная модель
- Резонансы параметризованы с помощью формулы Брейта-Вигнера
- В случае $K^*(892)^\pm$ и $K_2^*(1430)^\pm$

$$\Gamma(s_m, J_a) = \frac{\rho_J(s_m)}{\rho_J(M_a^2)}\Gamma_a,$$

$$\rho_J(s_m) = \frac{2q}{\sqrt{s_m}} \frac{q^{2J}}{F^2(q^2, r, J)}.$$

- Аппроксимация методом наибольшего правдоподобия
- Основной критерий включения или не включения резонанса в ПВА аппроксимацию – теорема Вилка

$$\mathrm{NLL} = -\sum_i \ln \frac{\omega_i \epsilon_i}{\int \epsilon \omega d\Phi} = -\sum_i \ln \frac{\omega_i}{\int \epsilon \omega d\Phi} + const$$

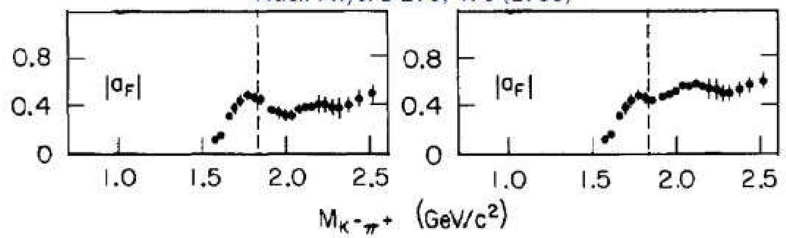
Search for glueball (Igor Denisenko Ph.D.)

$J/\psi \to K^+K^-\pi^0$ @ BESIII: ПВА аппроксимация II

- Широкий вклад в 3^- $K^\mp\pi^0$ парциальных волнах
- В решение включены состояния уменьшающие NLL более чем на 40
- Систематические ошибки включают неопределенности, связанные с построением ПВА аппроксимации и с качеством МК-моделирования работы детектора
- Нет указаний на существование X(1575)
- Для дальнейшего это решение считается основным

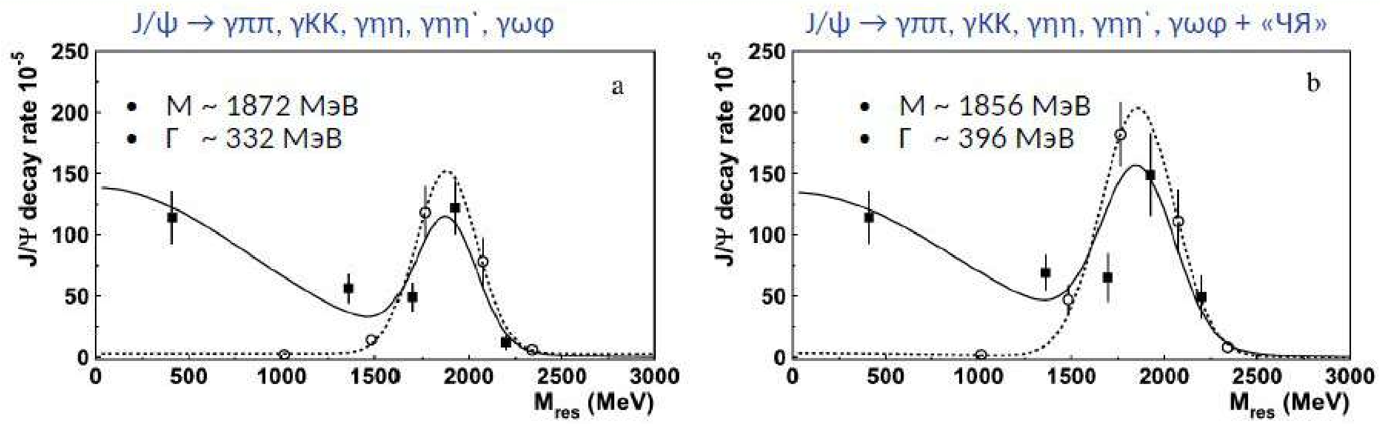
$K^\pm\pi^0$ channels						
J^{PC}	PDG	M(MeV/c^2)	Γ(MeV/c^2)	b(%)	$b^{+(-)}$(%)	ΔNLL
1^-	$K^*(892)^\pm$	$893.6\pm0.1^{+0.2}_{-0.3}$	$46.7\pm0.2^{+0.1}_{-0.2}$	$93.4\pm0.4^{+1.8}_{-5.8}$	$42.5\pm0.1^{+0.5}_{-1.7}$	–
1^-	$K^*(1410)^\pm$	1380^*	176^*	0.26 ± 0.04	0.11 ± 0.02	80
1^-	$K^*(1680)^\pm$	1677^*	205^*	0.20 ± 0.03	0.08 ± 0.01	56
2^+	$K_2^*(1430)^\pm$	$1432.7\pm0.7^{+2.2}_{-2.3}$	$102.5\pm1.6^{+3.1}_{-2.8}$	$9.4\pm0.1^{+0.8}_{-0.5}$	$4.2\pm0.1^{+0.3}_{-0.2}$	–
2^+	$K_2^*(1980)^\pm$	$1868\pm8^{+40}_{-57}$	$272\pm24^{+50}_{-15}$	$0.38\pm0.04^{+0.22}_{-0.05}$	$0.15\pm0.02^{+0.08}_{-0.02}$	192
3^-	$K_3^*(1780)^\pm$	1781^*	203^*	0.16 ± 0.02	0.07 ± 0.01	105
4^+	$K_4^*(2045)^\pm$	$2090\pm9^{+11}_{-29}$	$201\pm19^{+57}_{-17}$	$0.21\pm0.02^{+0.10}_{-0.05}$	$0.09\pm0.01^{+0.04}_{-0.02}$	212
3^-	non-resonant	– –	– –	$\sim 1.5\%$	$\sim 0.6\%$	629
K^+K^- channel						
J^{PC}	PDG	M(MeV/c^2)	Γ(MeV/c^2)	b(%)		$\Delta \ln L$
1^{--}		$1651\pm3^{+16}_{-6}$	$194\pm8^{+15}_{-7}$	$1.83\pm0.11^{+0.19}_{-0.17}$		796
1^{--}		$2039\pm8^{+36}_{-18}$	$193\pm23^{+25}_{-27}$	$0.23\pm0.04^{+0.07}_{-0.06}$		102

Nucl. Phys. B 296, 493 (1988)



Search for glueball
(Igor Denisenko Ph.D.)

J/ψ → γPP. Парциальные ширины рождения резонансов



Наилучшая оценка $M_G = (1865 \pm 25^{+10}_{-30})$ MeV $\Gamma_G = (370 \pm 50^{+30}_{-20})$ MeV

Непертурбативный подход	Работа	Предсказания массы глюбола (МэВ)
Unquenched LQCD	JHE1210, 170(2012)	1795±60
Инстантонные вычисления	PLB577,61(2003)	~1980
Уравнение Дайсона-Швингера и Бете-Солпетера	EPJC80,1077(2020)	1850±130
Дуальные модели	PRD104,034016(2021)	~1920

Парциальная ширина рождения

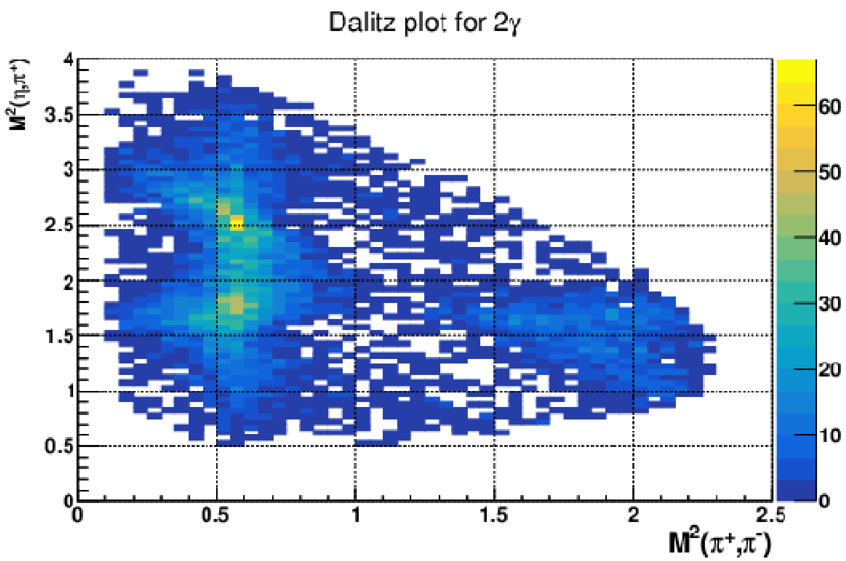
$B_{J/\psi \to \gamma G} = (5{,}8 \pm 1{,}0) \times 10^{-3}$

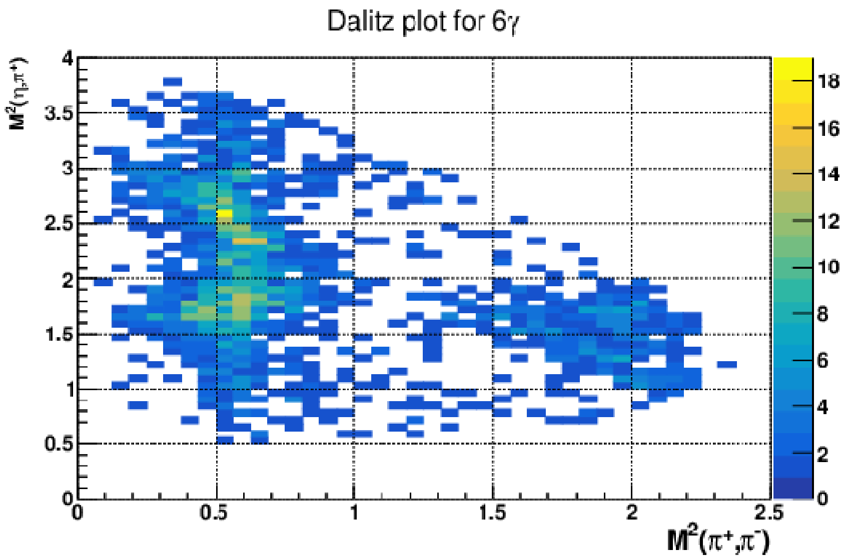
Решеточные вычисления (PRL110, 021601 (2013))

$B_{J/\psi \to \gamma G} = (3{,}8 \pm 0.9) \times 10^{-3}$

Cross-section of e+e− $\rightarrow \eta\pi^+\pi^-$

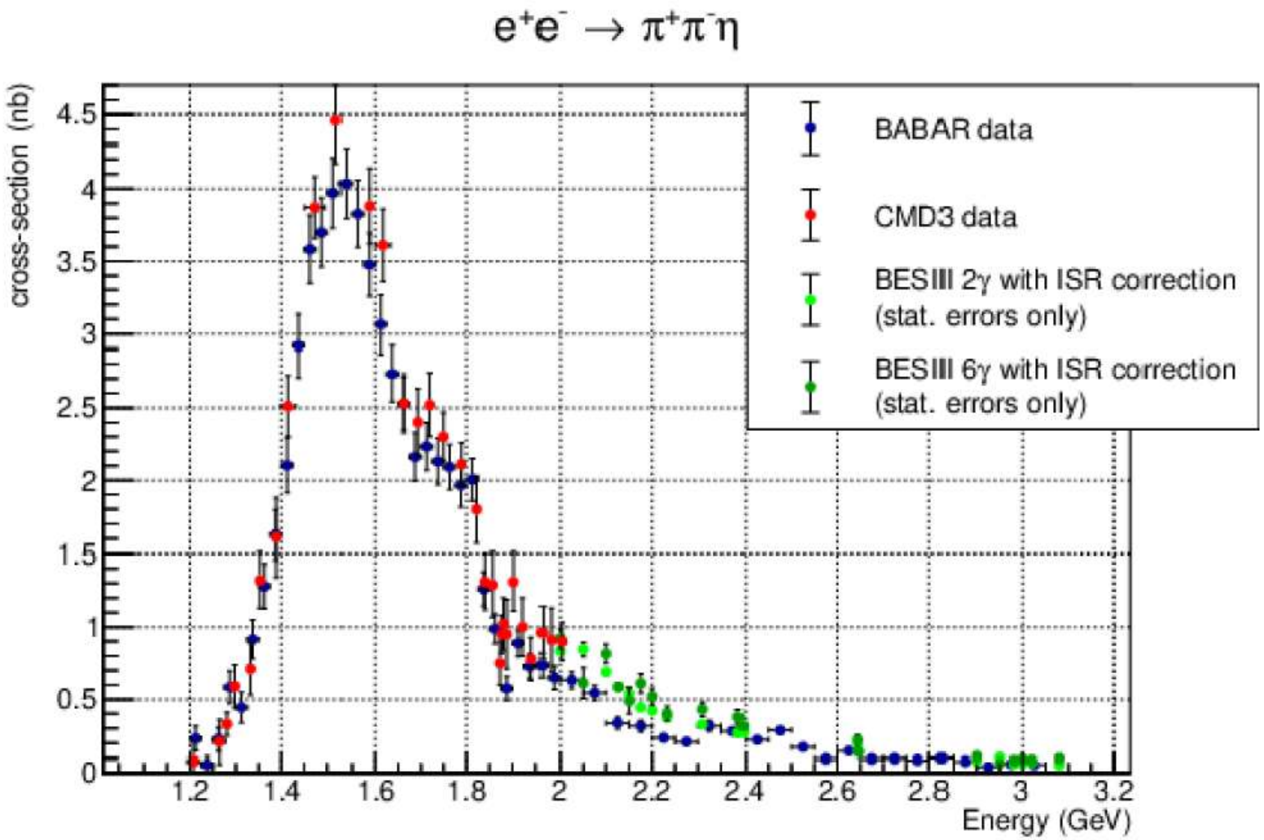
Two η decay channels are used: $\eta \rightarrow 2\gamma$ and $\eta \rightarrow 3\pi^0 \rightarrow 6\gamma$
Dalitz plots for $\sqrt{s}$ = 2126.55 MeV





The dominant components: e+e- $\rightarrow \rho\eta$ and e+e- $\rightarrow a_2^{\pm}\pi^{\mp}$

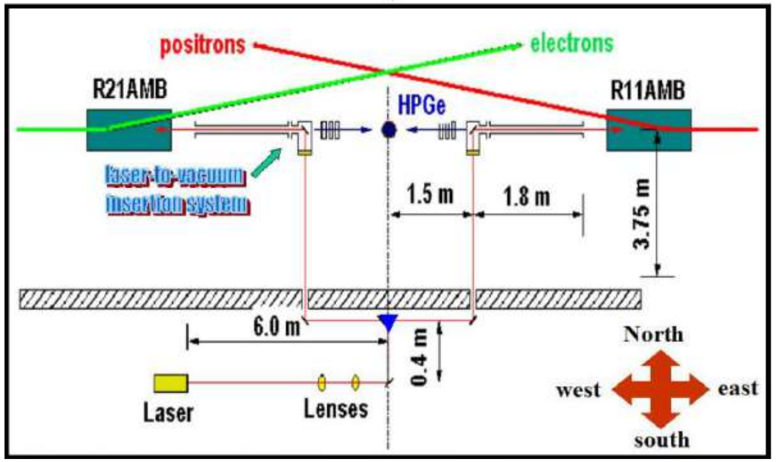
Cross-section of e+e− → $\eta\pi^+\pi^-$

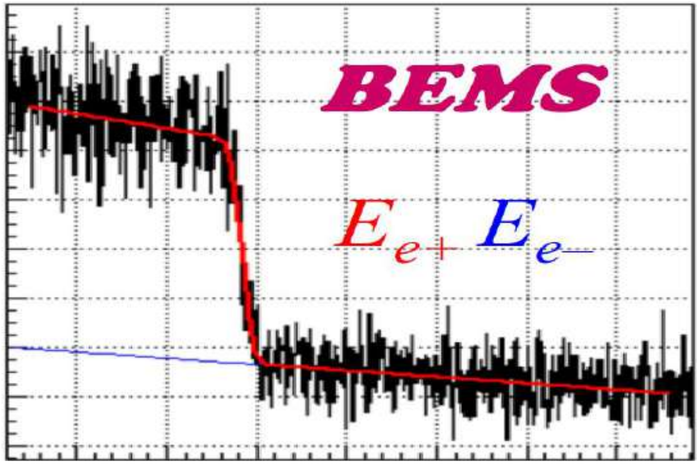


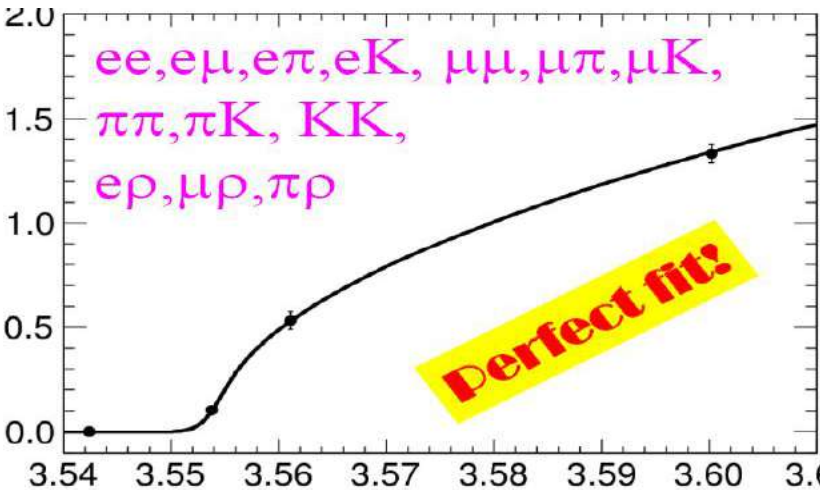
Data show resonance-like behavior near the our energy threshold of 2 GeV
We plan to extend our measurement using ISR method with higher energy data

Physics of τ-leptons

Precision measurement of $M\tau$







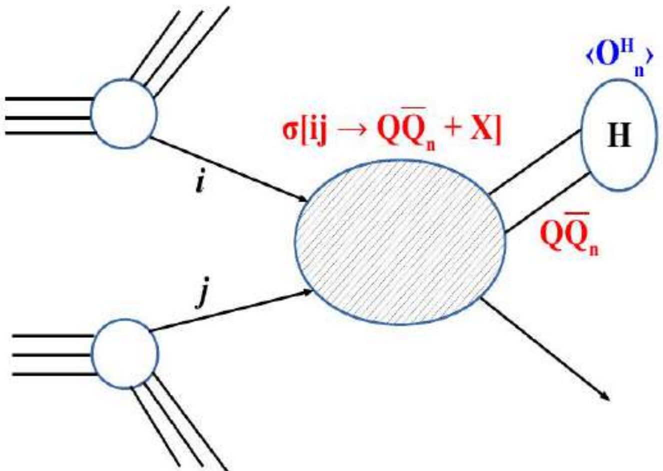
- $M\tau$ = **1776.91±0.12±0.12**
  - As good as the rest of the world
- PDG: 1776.86±0.12
- BESIII systematics: mostly the statistics of energy calibration runs

Physics of charmonium

Inclusive J/ψ production

- **Goals:**
- **Test the NRQCD factorization hypothesis:** the independence of Long Distance Matrix Elements (LDME) that describe the hadronization of the cc pair from the process (hadron-hadron collisions, electroproduction, or e+e- annihilation);
- **Clarify the contribution of the color octet channel** in the range of $\sqrt{s}$ below the J/ψcc threshold (~6 GeV): the color-octet LDMEs are non-zero if σ>10 pb at $\sqrt{s}$ = 4.6 ~ 5.6 GeV (Eur. Phys. J. C (2017) 77: 597);
- **Test if unknown channels/states exist**.

- **So far, measurements only done at $\sqrt{s}$ = 10.6 GeV:**
- **2.5 ± 0.3 pb** (BaBar)
- **1.5 ± 0.2 pb** (Belle)
- **1.9 ± 0.2 pb** (CLEO)



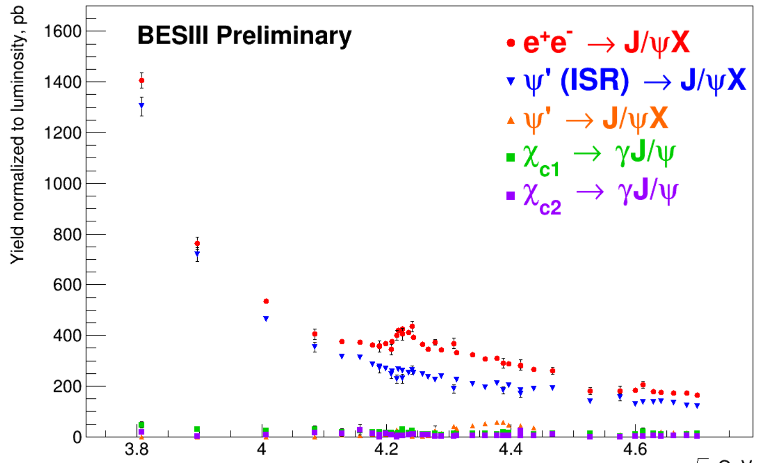
LDMEs $\langle O^H_n \rangle$ determined from experimental data.

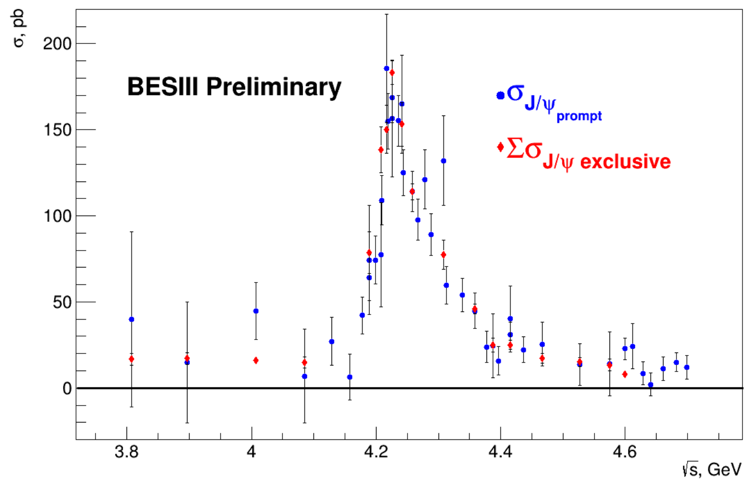
Inclusive J/ψ production

- **Data:** $\mathcal{L}$ = 20 fb^{-1}, $\sqrt{s}$ = 3.8 – 4.7 GeV
- **Signal:** ee → J/ψ+X, J/ψ → μ+μ-,
- Prompt J/ψ originates from sources other than known decays or initial-state radiation (ISR).
- Major background sources:
  - inclusive decays of ψ(3686) and χ_{cJ}, (J = 1, 2) to J/ψ + X
  - ISR return to the J/ψ and ψ(3686) resonances.
- The preliminary result for the prompt inclusive J/ψ production in the range 4.5 - 4.7 GeV is:

$\sigma = 13.2 \pm 2.1_{stat} \pm 3.4_{syst}$ pb

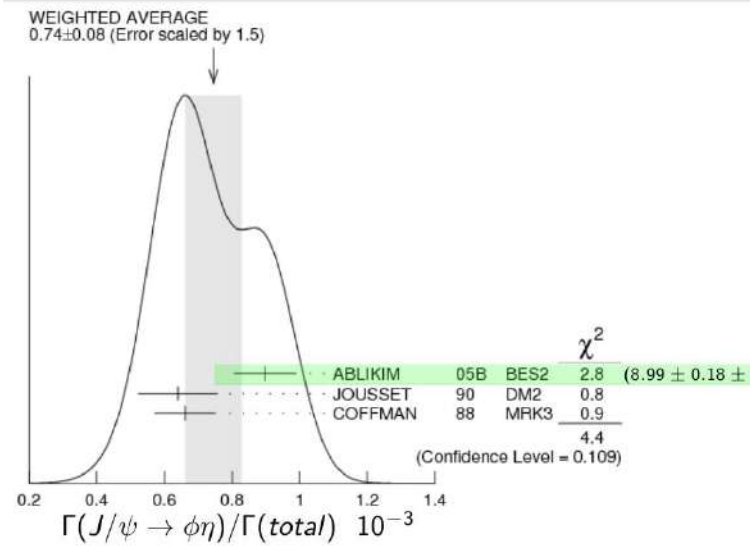
- **Analysis status:** internal review of the BESIII collaboration to obtain permission to publish the results.





Branching fraction of J/ψ →ϕη

- **The existing measurements** of B(J/ψ → ϕη) are **ambiguous** (PDG-2021);
- We plan to **use the precise measurements** of the B(J/ψ → ϕη) to **improve the estimation of the mixing angle between the strong and electromagnetic amplitudes** in the analysis of the energy dependence of e+e- → ϕη cross-section in the scan data around the J/ψ peak.



Formulas of cross section for lineshape fit of $e^+e^- \to \phi\eta$

$$\sigma_{\mathrm{born}}(s) = |\mathcal{A}_{cont.} + \mathcal{A}_{\gamma} + \mathcal{A}_{3g}|^2 = \frac{\sigma_0}{s^2}\left|1 + \frac{3/\alpha\,\sqrt{s\Gamma_e\Gamma_\mu}}{(s - M^2) + i\sqrt{s}\,\Gamma}\cdot(1 + Ae^{i\varphi})\right|^2 \times \left[\frac{|P|}{\sqrt{s}}\right]^3$$

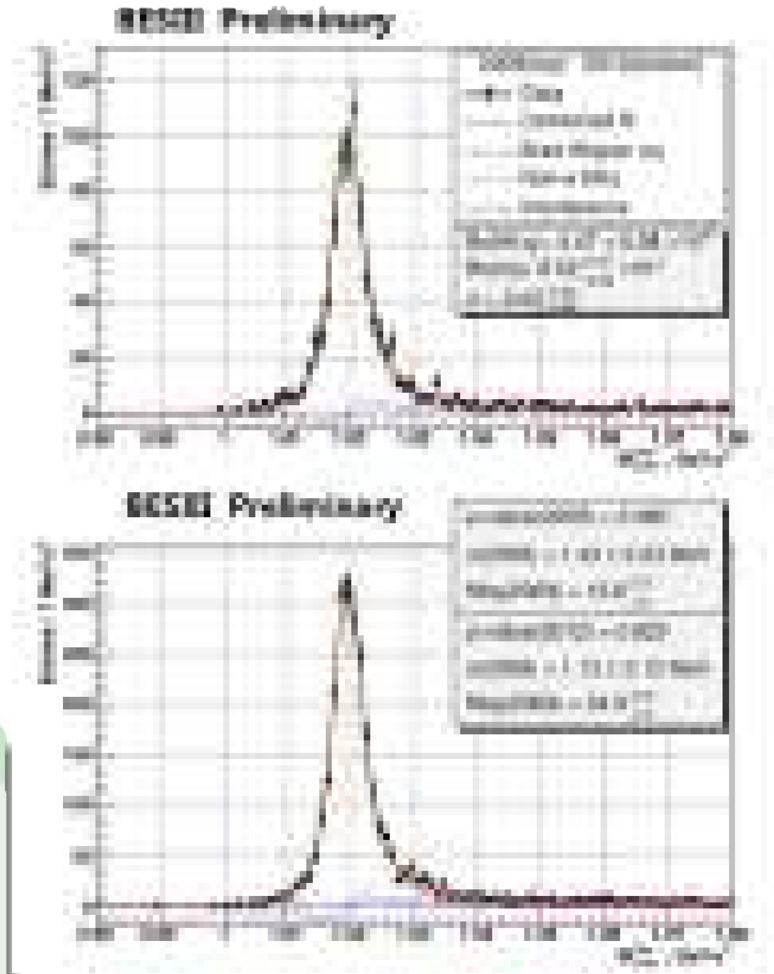
$$\text{where}\quad \sigma_0 = \frac{4\pi\alpha^2 s}{3}\cdot\frac{Br(J/\psi \to \phi\eta)}{Br(J/\psi \to \mu\mu)}\cdot\frac{1}{|1 + Ae^{i\varphi}|^2}\left[\frac{\sqrt{s}}{|P|}\right]^3$$

Branching fraction of $J/\psi \to \phi\eta$

- **Data:** 448M $\psi(3686)$ 2009 and 2012
- **Channel:** $\psi(3686) \to \pi^+\pi^- J/\psi$, $J/\psi \to \phi\eta$, $\phi \to K^+K^-$, $\eta \to \gamma\gamma$
- We need to use data in which there is no mixing of $J/\psi \to \phi\eta$ and $e^+e^- \to \phi\eta$.
- A good description of the invariant mass of K+K- is obtained only under the assumption of interference $J/\psi \to \phi\eta$ with other processes decaying to the same final state.
- The preliminary result for M(K+K-) < 1.08 GeV/c2 is:

$B(J/\psi \to \phi\eta) = (8.52 + 0.37/- 0.43_{stat} \pm 0.14_{syst}) \cdot 10^{-4}$

- **Analysis status:** internal review of the BESIII collaboration to obtain permission to publish the results.



Comparison with previous measurements

BES2	$(8.99 \pm 0.18 \pm 0.89) \times 10^{-4}$
DM2	$(6.4 \pm 0.4 \pm 1.1) \times 10^{-4}$
MARK-III	$(6.61 \pm 0.45 \pm 0.78) \times 10^{-4}$
PDG2020	$(7.4 \pm 0.8) \times 10^{-4}$

Future plans?

Future Physics Programme of BESIII

IHEP-Physics-Report-BESIII-2020-4-7

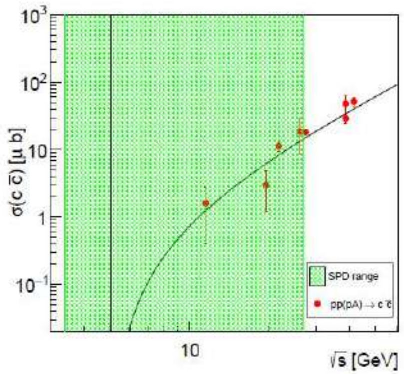
Published in Chinese Physics C 44, 040001 (2020)

Contents

Nearest plans

- Currently we are collecting data at 3770 MeV (D^+D^- and D^0D^0 production).
- The plan is to run for 1 year from now. The DD statistics will be (at least) tripled.
- For 2024, a collider upgrade is proposed to reach 5.6 GeV in 2025.

Plan to measure the charm fragmentation function



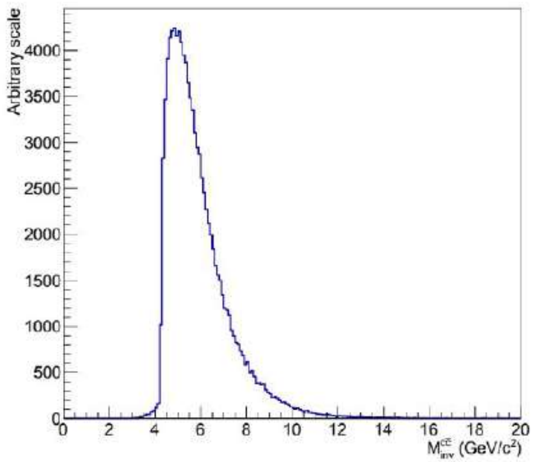


Fig. 1: Invariant mass of $c\bar{c}$ pair in proton-proton collisions at 27 GeV at SPD simulated with Pythia8.

- Measurement of open charm production is an important part of the NICA/SPD physics program.
- At NICA ccbar will be produced with 4-8 GeV invariant mass. Charm fragmentation function is essentially unknown in this energy domain.
- We plan to use 5fb^{-1} of BESIII data at 4.0-4.95 GeV to measure the low-energy the fragmentation function in the inclusive reaction ee → c+cbar+X
- Both transverse and longitudinal FF are accessible

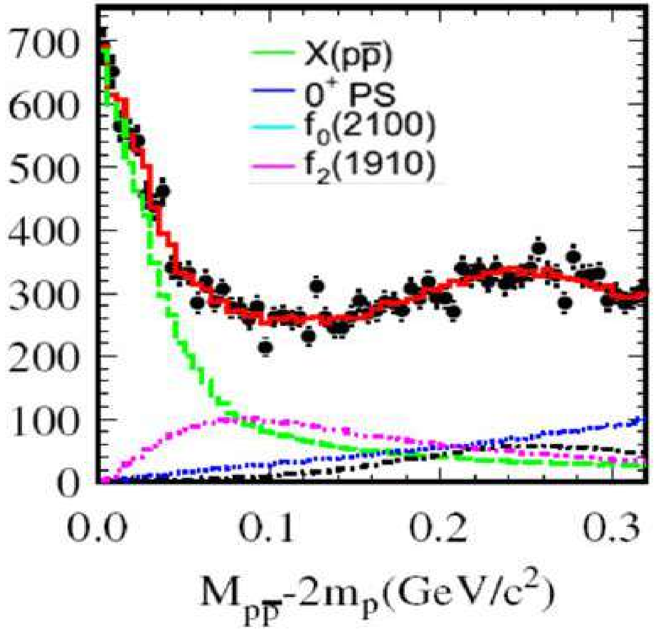
Summary

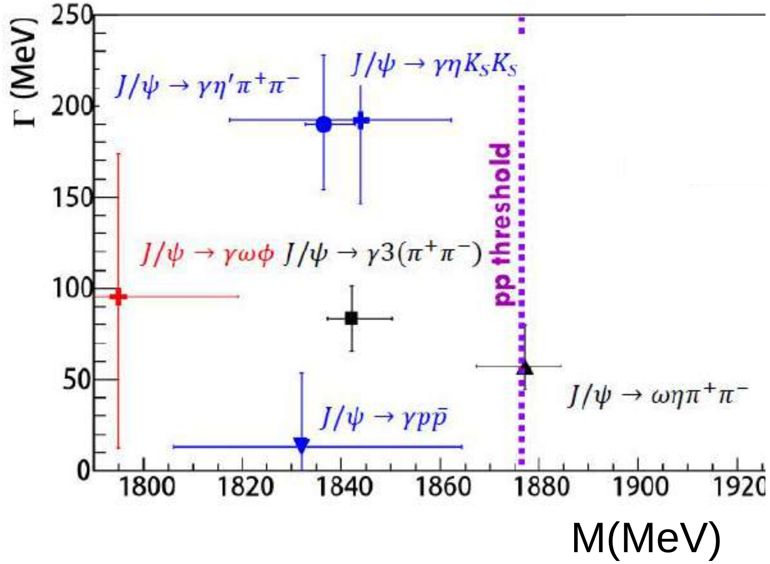
- With its excellent detector and huge statistics, BESIII is now the world leader in the energy domain of charm and charmonium
- Hundreds of “routine” measurements have been performed improving the world average precision by factors 3-10
- A number of ground breaking discoveries have been made which change completely our understanding of the matter structure
- JINR team contribution is very much visible in the collaboration (see also tomorrow NTS)
- Collider upgrade is planned and many new results are expected

Spare slides

Structures at the pp threshold

$J/\psi \rightarrow \gamma pp$



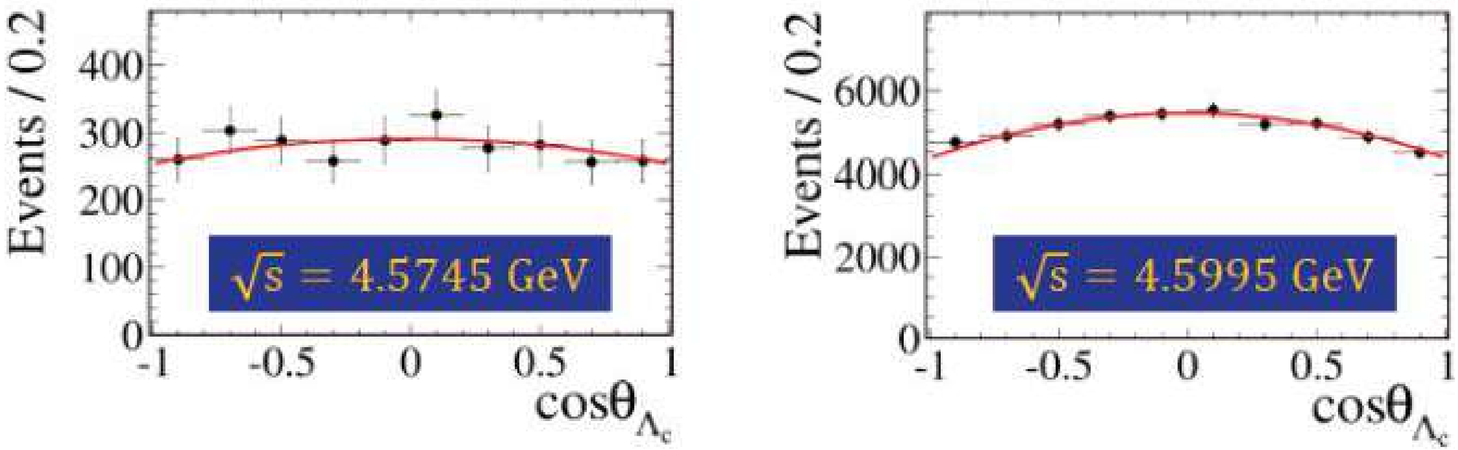


- $M(X) = 1832 \pm 32$ MeV
- $\Gamma(X) = 13 \pm 40$ MeV
- $J^{PC} = 0^{-+}$
- $B(J/\psi \rightarrow \gamma X) = (9.0 \pm 1.5) \times 10^{-5}$

- BESIII observed quite a number of structures right below the pp threshold
- Recent increase of J/ψ statistics (1.3B → 10B) will be extremely useful to clarify the situation

Λ_C polar angle distribution

- Can be parameterized by $1+\alpha_{\Lambda c}\cos^2\theta$
- Form-factor ratio given by: $|G_E/G_M|^2(1-\beta^2) = (1 - \alpha_{\Lambda c})/(1 + \alpha_{\Lambda c})$



|GE/GM| **1.14 ± 0.14 ± 0.07** **1.23 ± 0.05 ± 0.03**