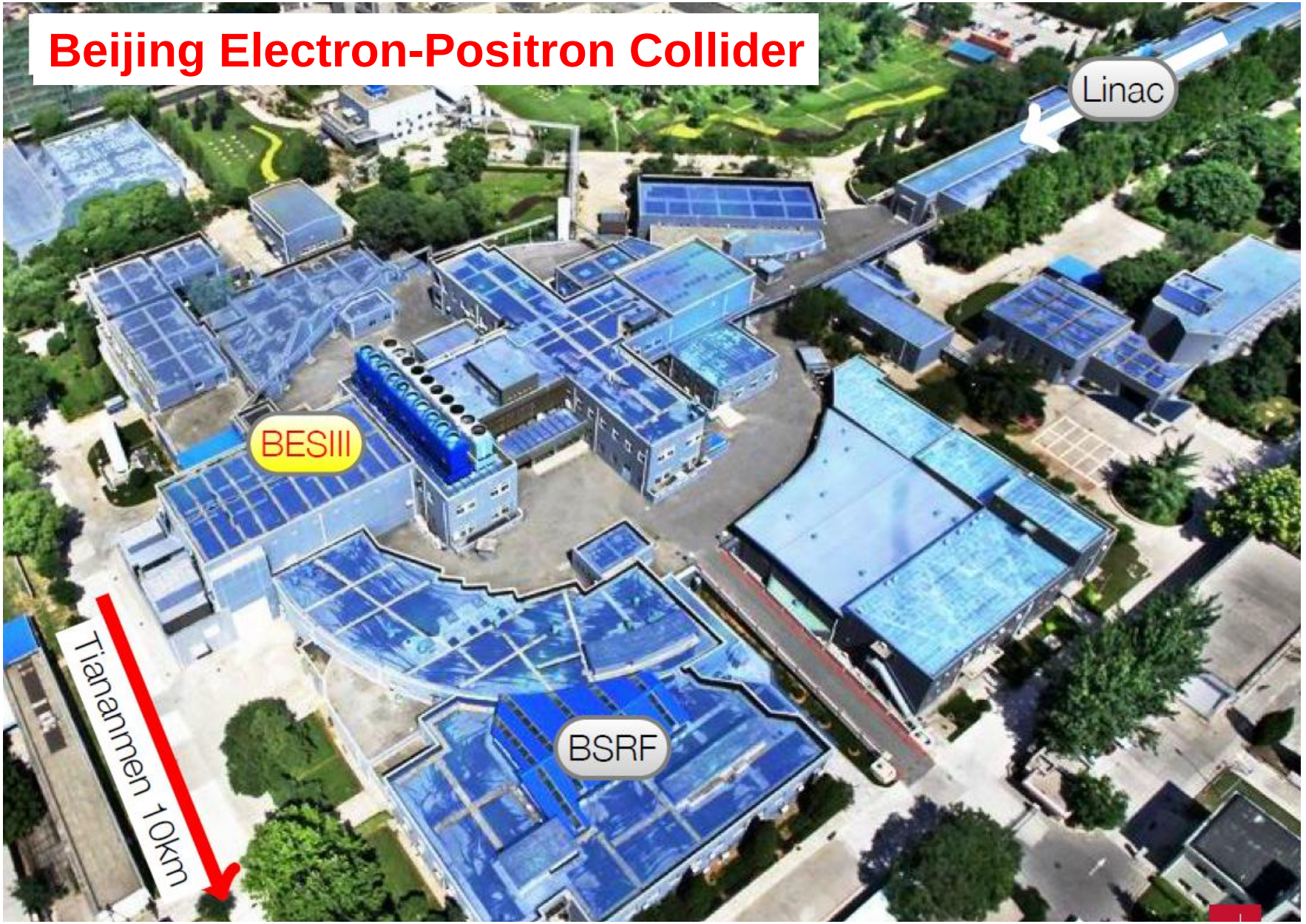
BESIII experiment: status and prospects

I.Boyko

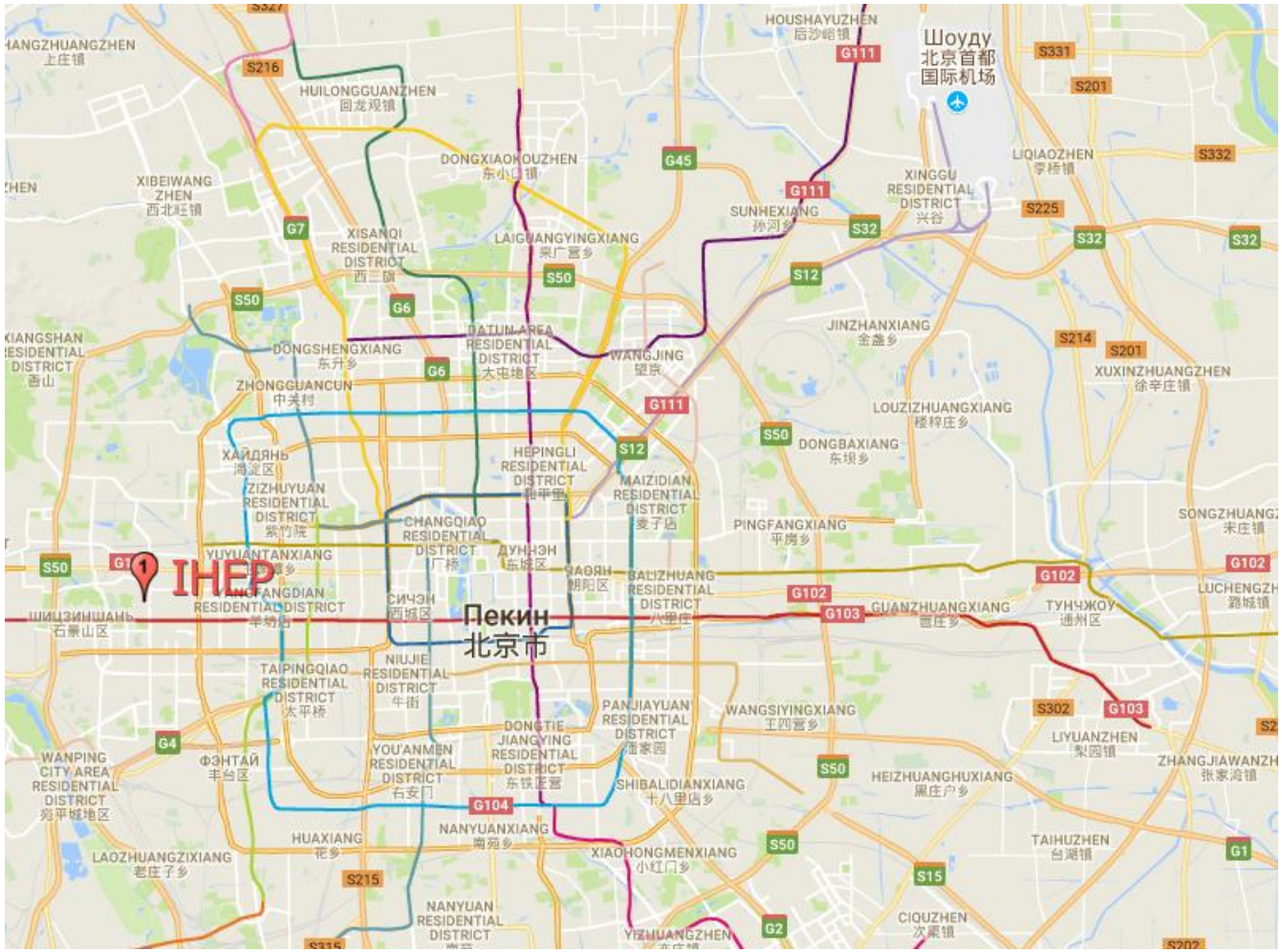
LNP seminar

21 November 2018

Beijing Electron-Positron Collider



Location of IHEP in Beijing



History

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

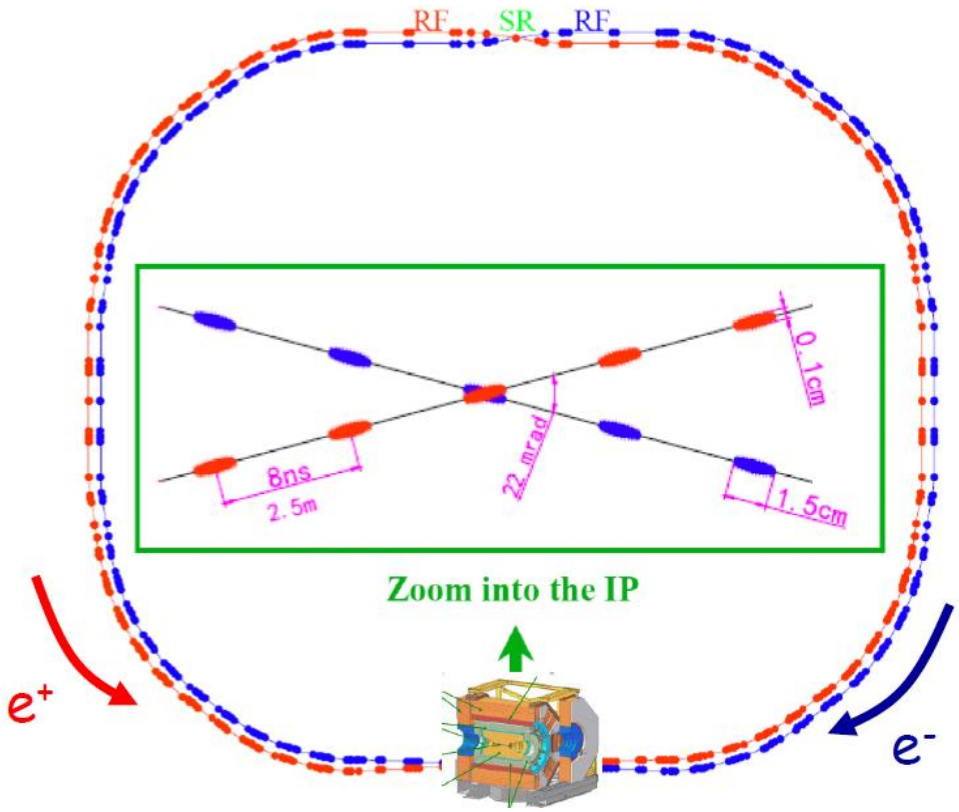
BES = BEijing Spectrometer

BEPC = Beijing Electron-Positron Collider

BESIII collaboration

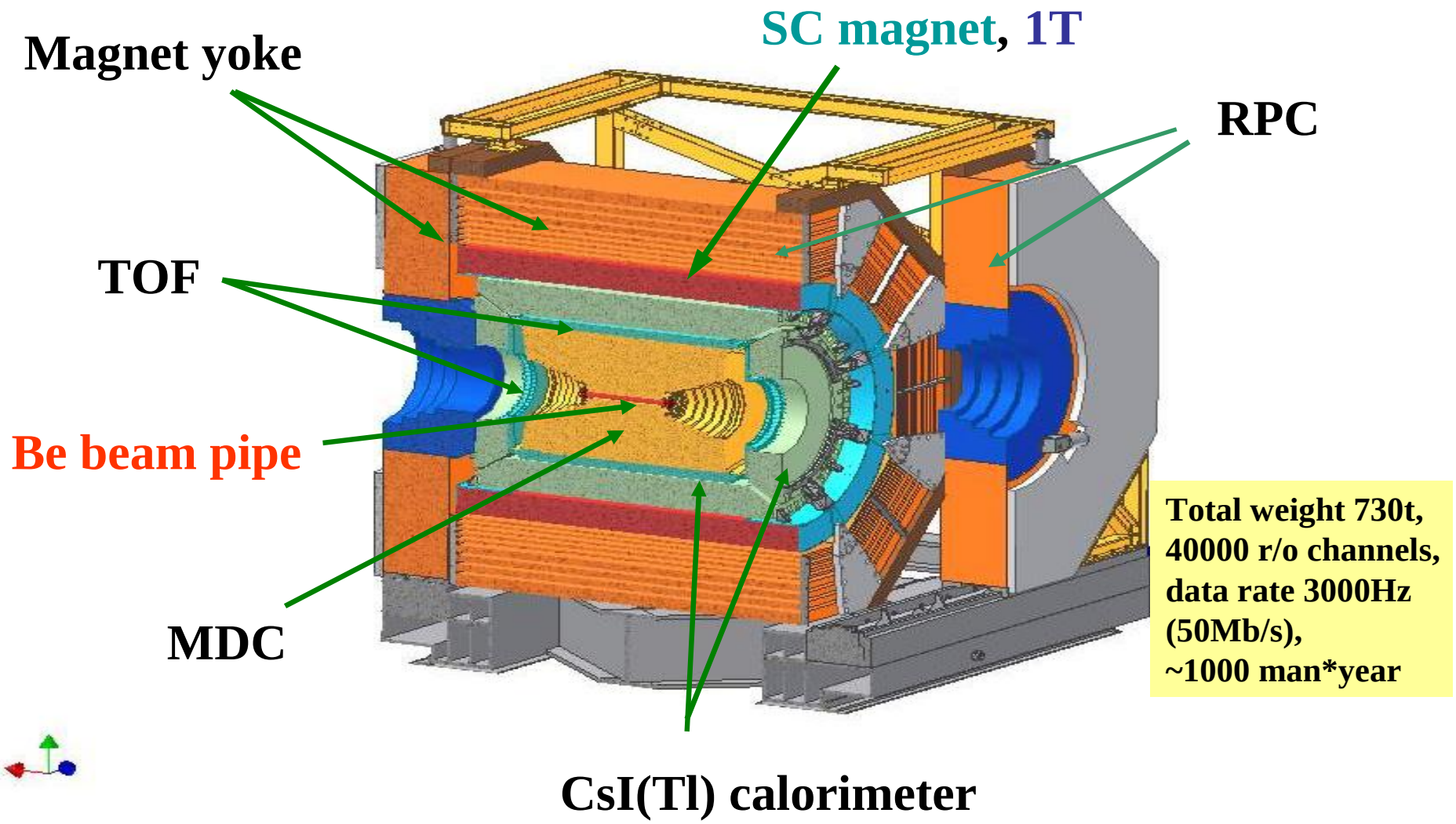
- Almost 500 members, 66 institutions, 14 countries
- 38 institutions from China, 7 rest of Asia,
  16 Europe (incl. Dubna and Novosibirsk), 5 USA

BEPCII storage rings

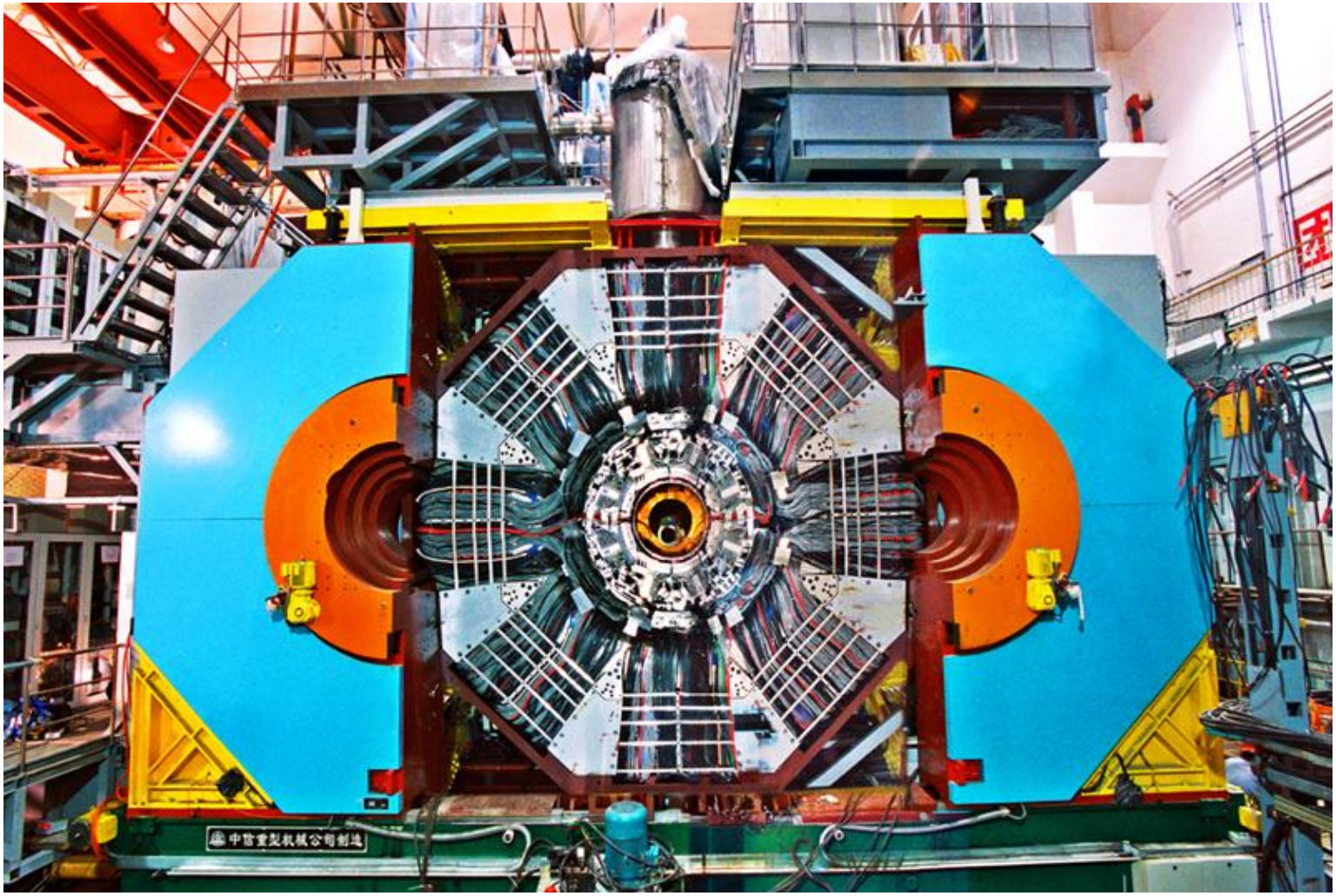


- Collision energy
  2.0 – 4.6 GeV
  → 4.9 GeV
- Design luminosity
  1.0×10^{33} cm^{-2} s^{-1}
- Achieved luminosity
  1.0×10^{33} cm^{-2} s^{-1}
  → +20-30%
- Energy spread
  5×10^{-4}
- No. of bunches
  93
- Total current
  0.91A
- Circumference
  237m

BESIII detector



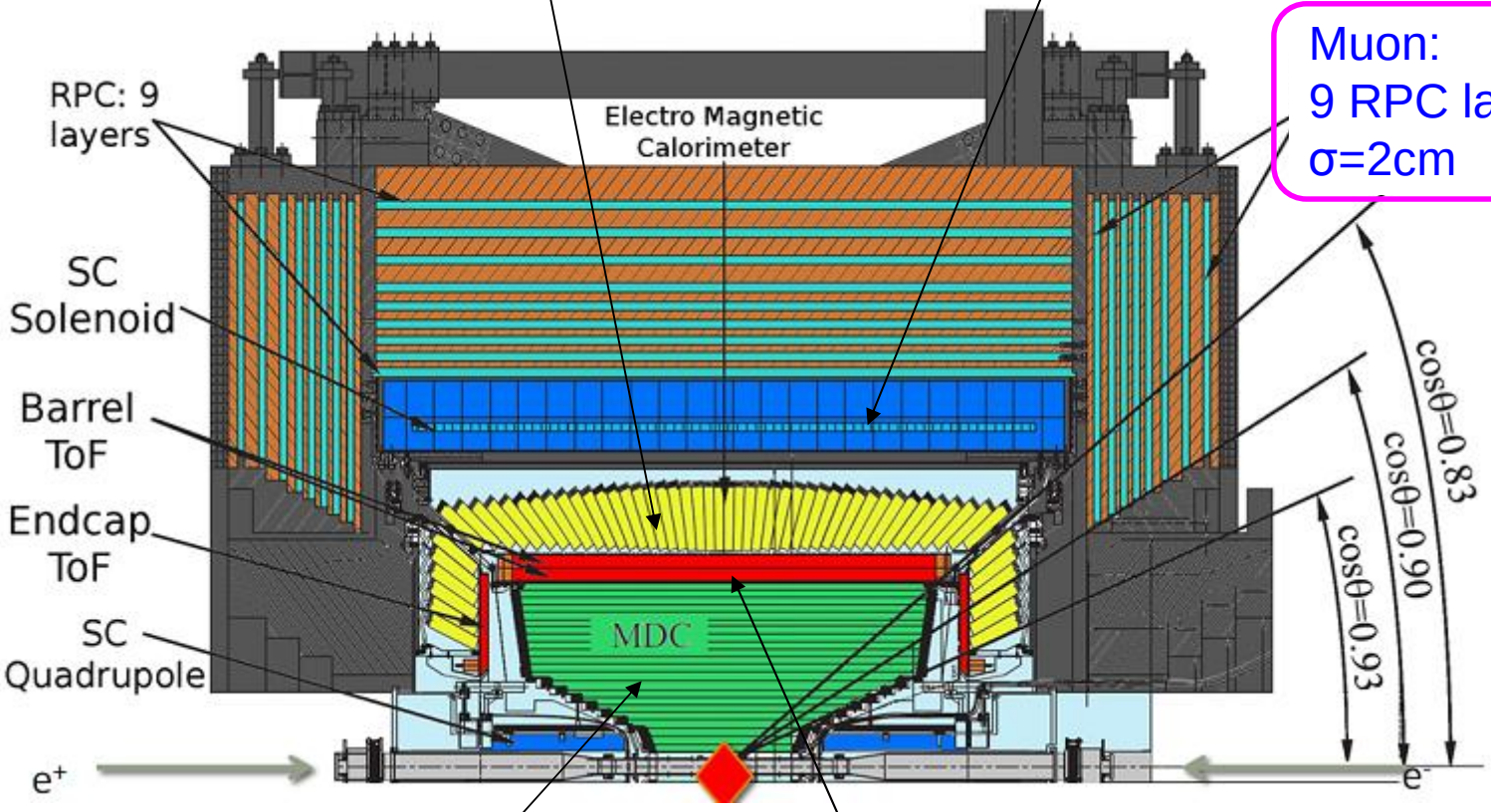
BESIII general view



EMC: CsI(Tl)
σ_E/E=2.5%@1GeV

SC magnet 1T

Muon:
9 RPC layers
σ=2cm



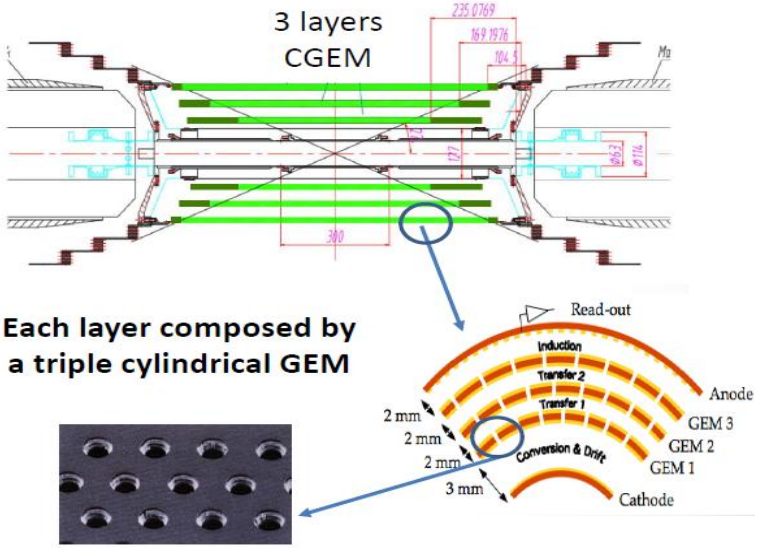
MDC:σ_{xy}=130μm
σ_p/p=0.5%@1GeV/c
σ(dE/dx)=6%

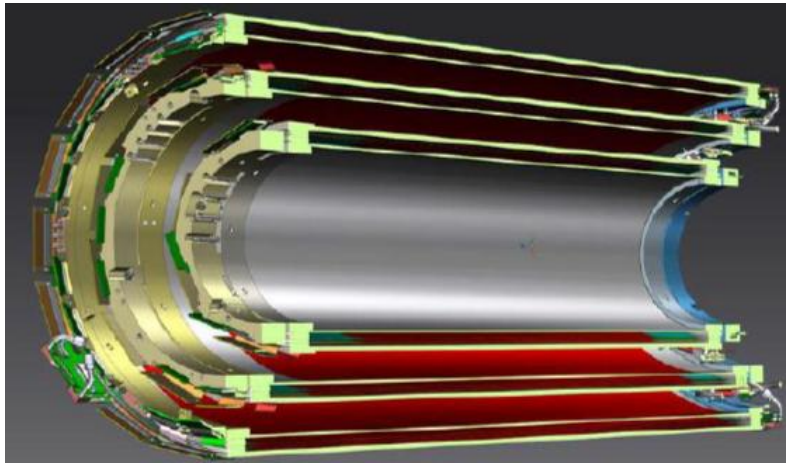
TOF: 80ps Barrel
110ps Endcap

Inner tracker upgrade

- Inner part of the Main Drift Chamber suffers from aging
- In summer 2019 it will be replaced by a Cylindrical GEM
- Similar to KLOE-2 CGEM

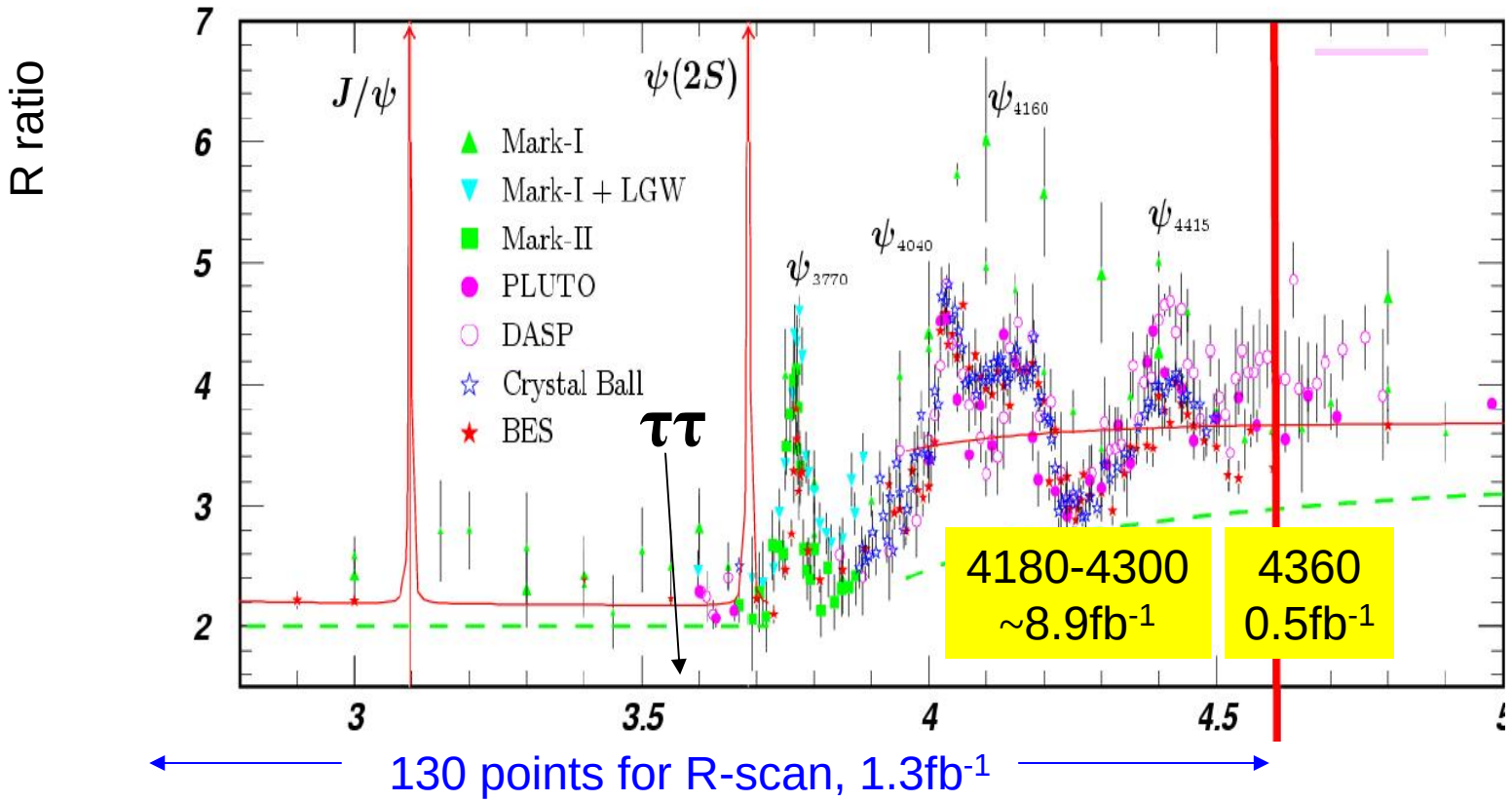
- Material <1.5%X_0
- Rate 10^4 Hz/cm^2
- $\sigma_{r\varphi}$ ~130 μm
- σ_p/p=0.5%@1GeV/c





BESIII data

J/ψ	ψ′	ψ′′	4040	4420	4600
1.3×10^9	0.5×10^9	$2.9\,fb^{-1}$	$0.5\,fb^{-1}$	$1.0\,fb^{-1}$	$0.6\,fb^{-1}$



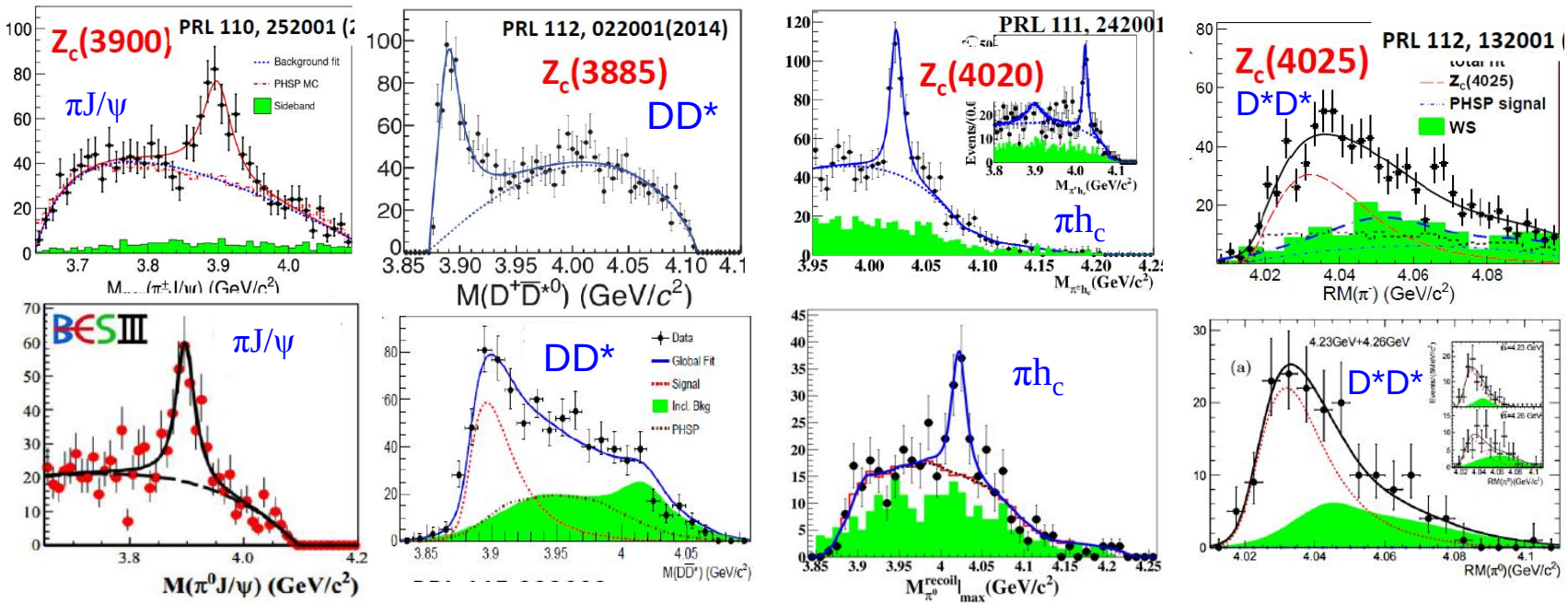
World largest samples of J/ψ, ψ(2S), ψ(3770), ψ(4040), ψ(4180), Y(4260), …

BESIII physics program

- Charmonium physics
- Charmed hadrons
- Exotic states
- Light hadron spectroscopy
- Tau lepton physics
- R-scan (inclusive hadron yield)
- Baryon form-factors
- Searches for new physics

Zc states
(tetraquark candidates)

Zc states



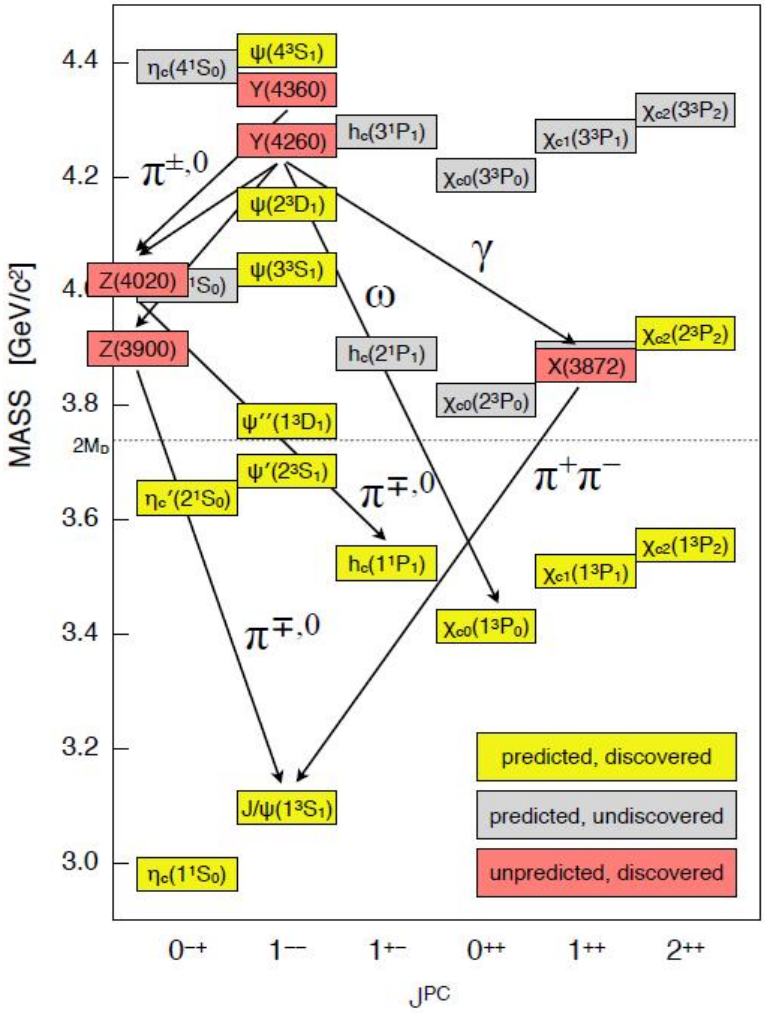
- In total, 4 charged and 4 neutral states have been observed at ~3900 and ~ 4020 MeV in decay modes $\pi\pi J/\psi$, πh_c, D*D and D*D*
- A natural hypothesis: we observe 2 doublets of charged and neutral partners

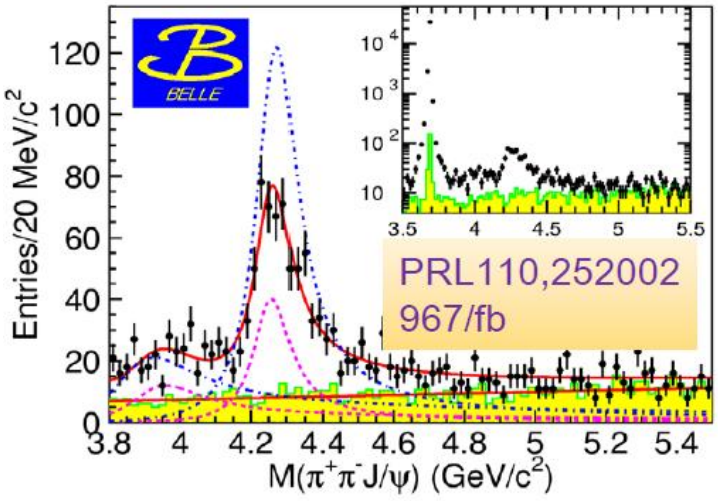
Summary on Zc decay modes

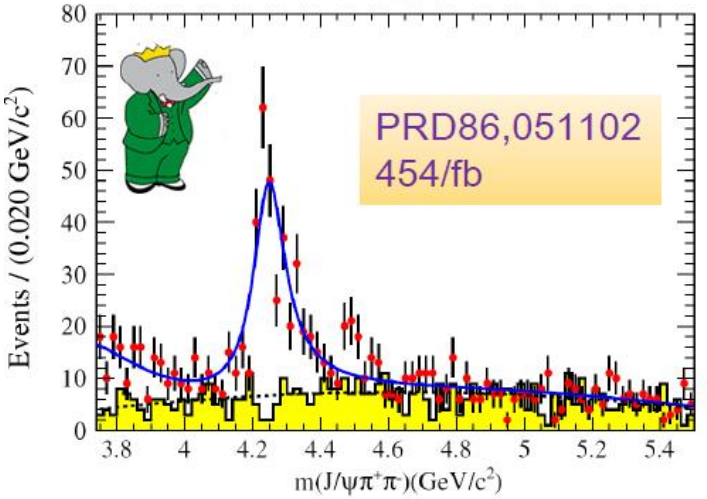
3900 MeV		4020 MeV	
charged	neutral	charged	neutral
$\pi^{\pm}J/\psi$ M = 3899.0 ± 6.1 Γ = 46 ± 22	$\pi^{0}J/\psi$ M = 3894.8 ± 2.3 Γ = 29.6 ± 8.2	$\pi^{\pm}h_c$ M = 4022.9 ± 2.8 Γ = 7.9 ± 3.7	$\pi^{0}h_c$ M = 4023.9 ± 4.4 Γ = 7.9 (fixed)
$(D^*D)^{\pm}$ M = 3882.0 ± 1.9 Γ = 26.5 ± 2.7	$(D^*D)^{0}$ M=3885.7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

XYZ states

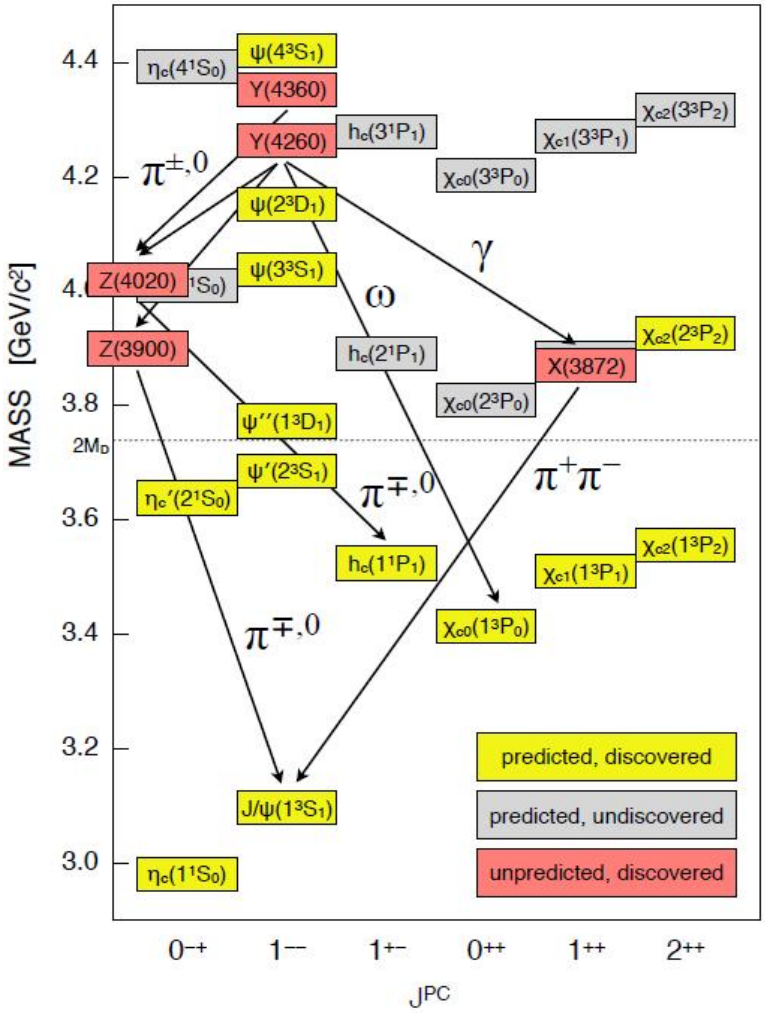
XYZ states


MASS [GeV/c²]
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
2M_D
ηc(4¹S0)
ψ(4³S1)
Y(4360)
Y(4260)
hc(3¹P1)
χc2(3³P2)
χc1(3³P1)
χc0(3³P0)
ψ(2³D1)
ψ(3³S1)
Z(4020)
Z(3900)
X(3872)
χc2(2³P2)
χc0(2³P0)
hc(2¹P1)
ψ''(1³D1)
ψ'(2³S1)
ηc'(2¹S0)
hc(1¹P1)
χc2(1³P2)
χc1(1³P1)
χc0(1³P0)
J/ψ(1³S1)
ηc(1¹S0)
π±,0
γ
ω
π∓,0
π+π−
π∓,0
predicted, discovered
predicted, undiscovered
unpredicted, discovered
0⁻⁺
1⁻⁻
1⁺⁻
0⁺⁺
1⁺⁺
2⁺⁺
JPC


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

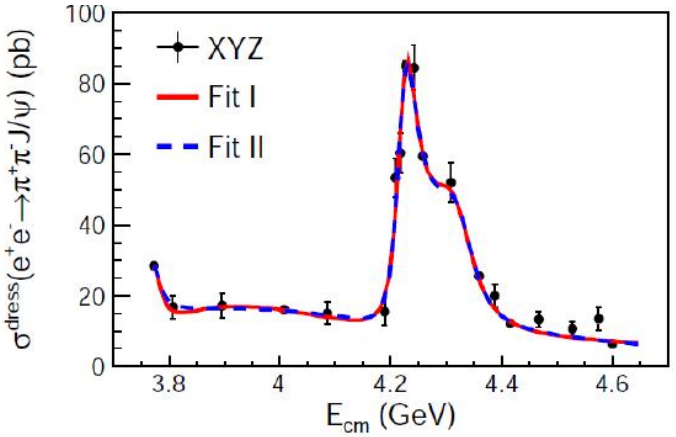

Events / (0.020 GeV/c²)
m(J/ψπ⁺π⁻)(GeV/c²)
PRD86,051102
454/fb

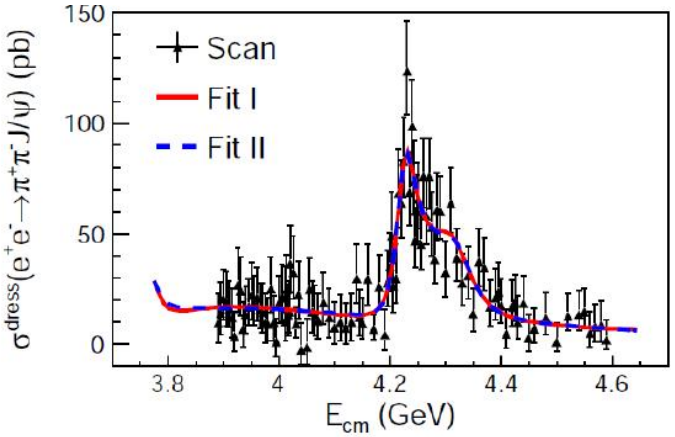
XYZ states

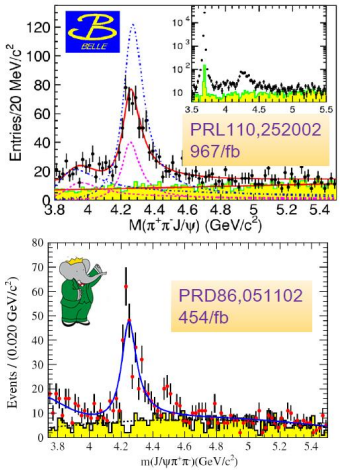


- An energy scan was performed in the energy domain of XYZ states
- Total 9.0 fb^{-1} data have been collected
  - Of them, 8.2 fb^{-1} from a dedicated XYZ-scan
  - Additional 0.8 fb^{-1} from earlier scans
- Collision energy between 3.77 and 4.60 GeV

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

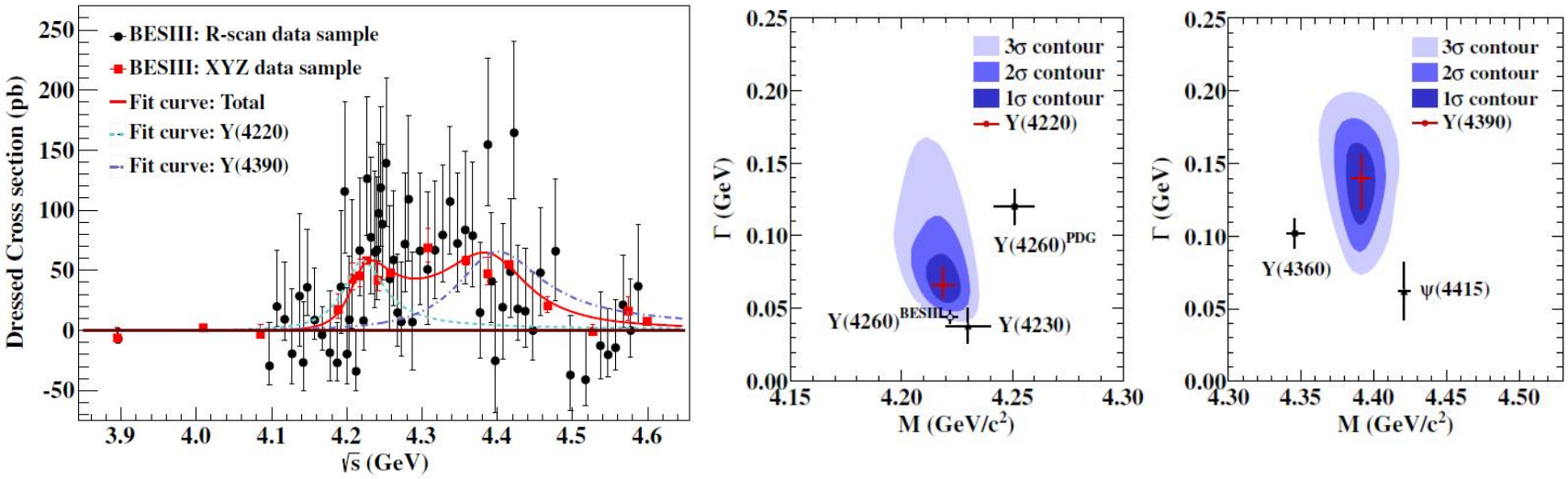






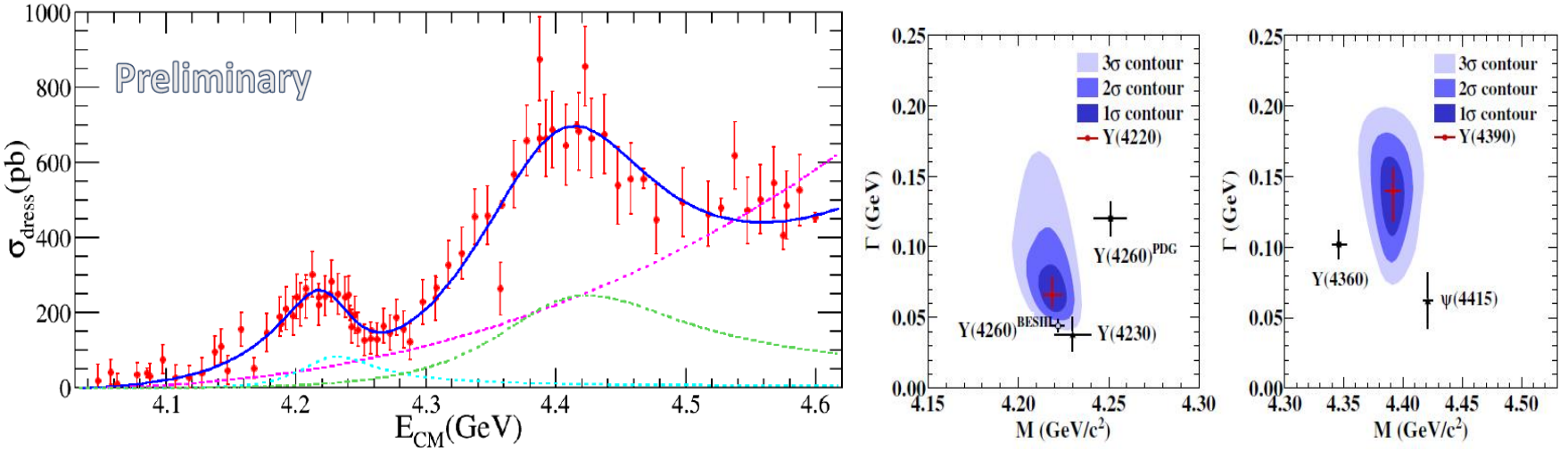
- Two resonant structures are observed:
  - Y(4260)? M = 4222.0 ± 3.1 ± 1.4, Γ = 44.1 ± 4.3 ± 2.0 MeV
  - Y(4360)? M = 4320.0 ± 10.4 ± 7, Γ = 101.4 ± 25 ± 10 MeV
- Precision on Y(4260) improved
- Y(4360): first observation in $ee \to \pi^+\pi^- J/\psi$
  - Seen in $ee \to \pi^+\pi^- \psi'$ by Belle and 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), ψ(4415)
- Y(4220) consistent with the structure observed in $ee \to \omega\chi_{c0}$

ee→ $\pi^{-}D^{0}D^{*+}$



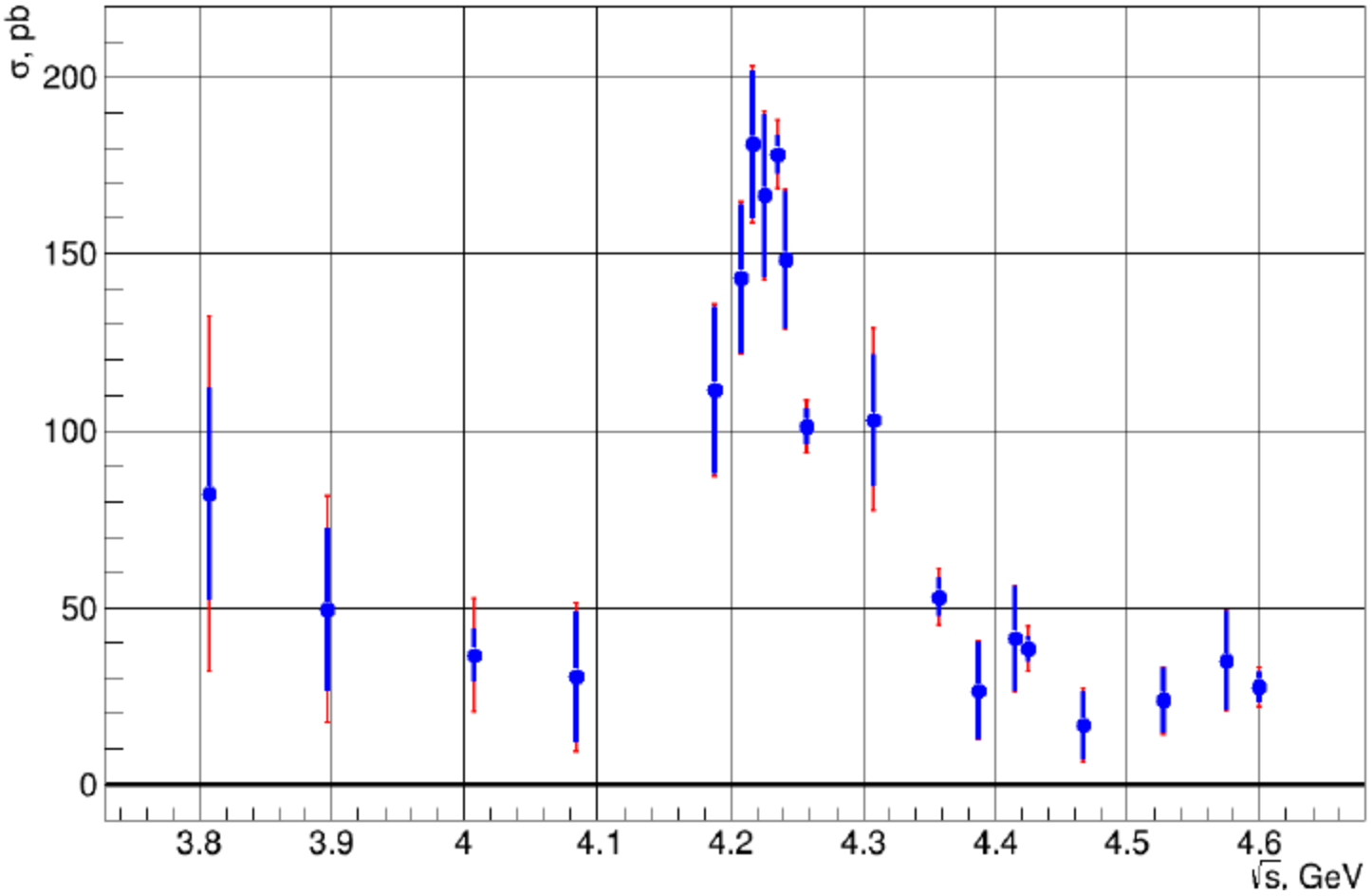
- Again, 2 resonances observed:
  - Y(4220): M = 4224.8 ± 5.6 ± 4, Γ = 72.3 ± 9.1 ± 0.9 MeV
  - Y(4390): M = 4400.1 ± 9.3 ± 2.1, Γ = 181.7 ± 16.9 ± 7.4 MeV
- Y(4220) consistent with $\pi^{+}\pi^{-}h_c$, $\pi^{+}\pi^{-}J/\psi$, ee→$\omega\chi_{c0}$
- Y(4390) consistent with $\pi^{+}\pi^{-}h_c$

XYZ states: JINR cotribution

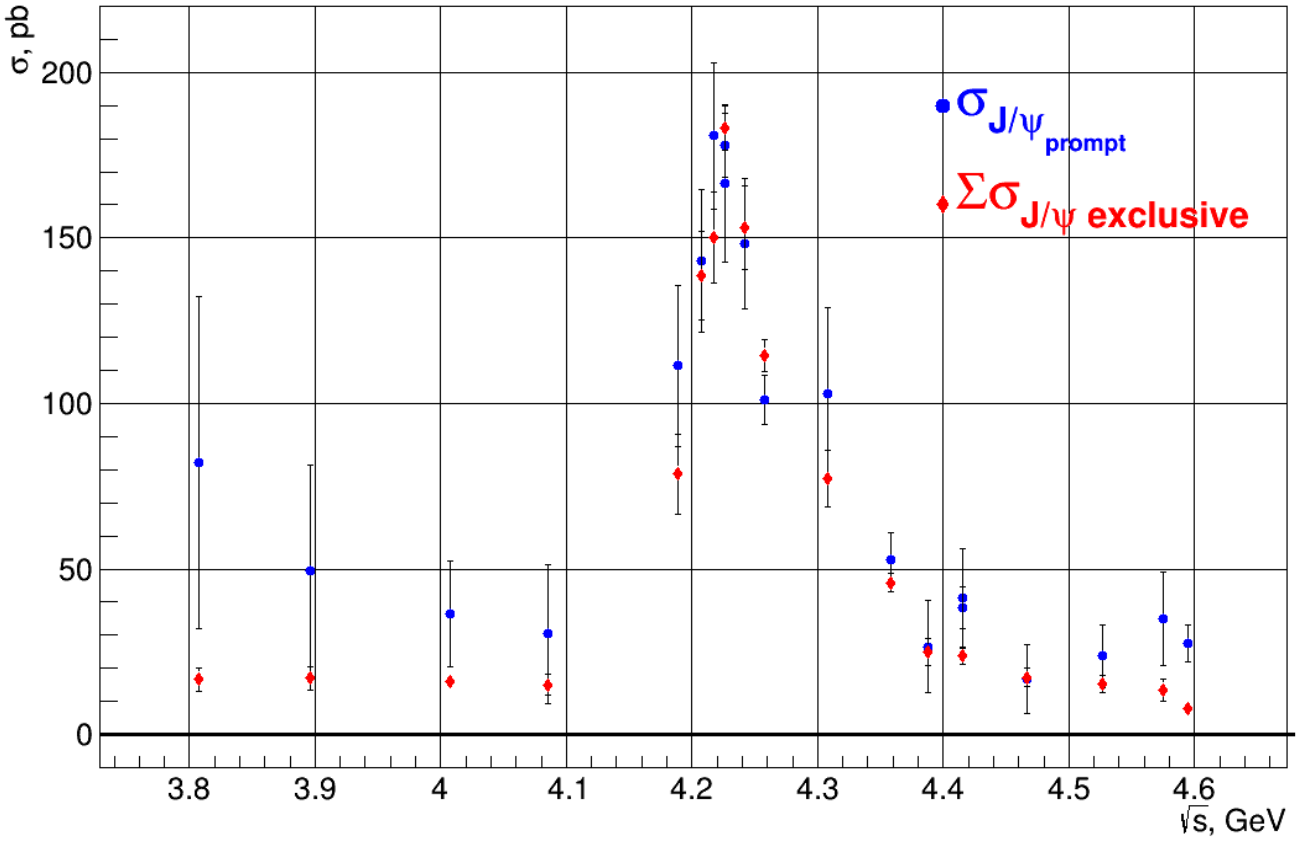
Inclusive prompt J/ψ production (ee→J/ψX)

- Prompt = Total – $(\psi' \to J/\psi)$ – $(\chi_c \to J/\psi)$ – $(ee \to \gamma J/\psi)$
- Goal:
  - Test NRQCD prediction
  - LDME non-zero if σ>10pb at 4.5-5.5 GeV
  - Test if unknown channels exist
- Data only available at 10.5 GeV:
  - 2.5 ± 0.3 pb (BaBar)
  - 1.5 ± 0.2 pb (Belle)
  - 1.9 ± 0.2 pb (CLEO)

Our result: σ(ee→J/ψX)



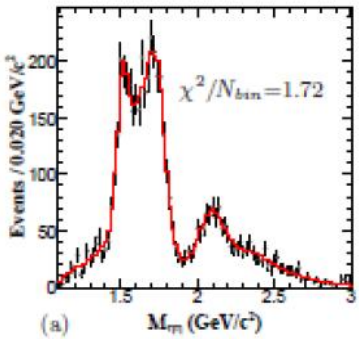
Comparison with exclusive channels



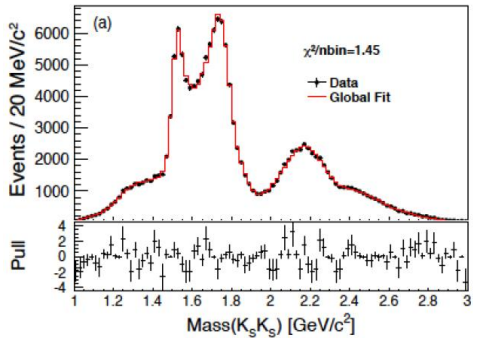
PWA and glueball searches

$f_0(1700)$: glueball candidate

$J/\psi \to \gamma\eta\eta$



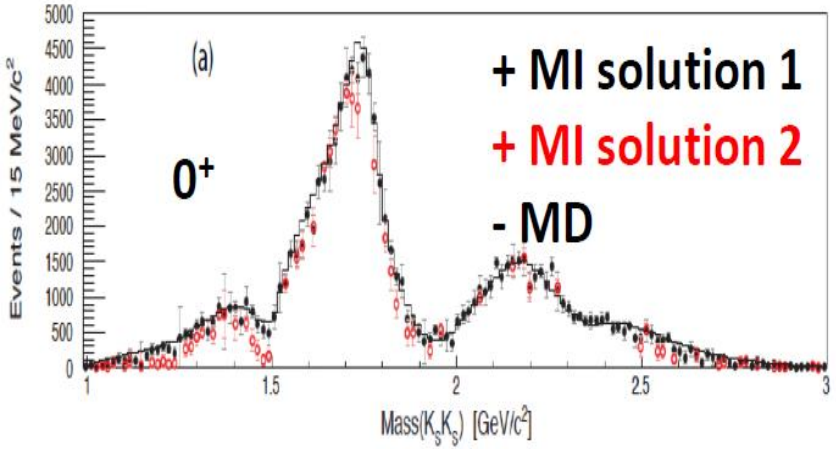
$J/\psi \to \gamma K_S K_S$



- Lattice prediction:
- M_G = 1710 ± 90 MeV

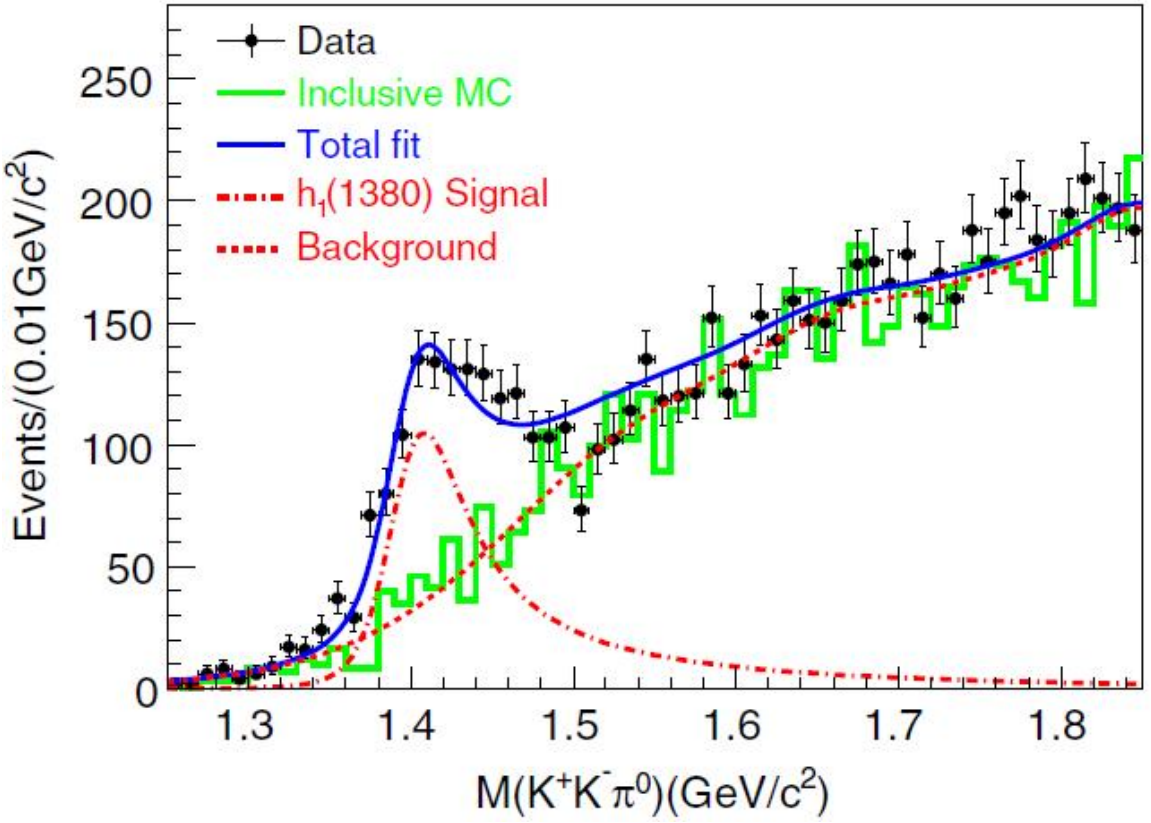
$$\Gamma(J/\psi \to \gamma G_{0^+}) = \frac{4}{27}\alpha\frac{|p|}{M^2_{J/\psi}}|E_1(0)|^2 = 0.35(8)keV$$

$$\Gamma/\Gamma\_tot = 0.33(7)/93.2 = 3.8(9)\times 10^{-3}$$



- BESIII $f_0(1700)$ result:
- M = 1759 ± 15 MeV
- $Br(J/\psi \to \gamma f_0) = (2.4\pm0.5)\times10^{-3}$

Observation of strangeonium 1^{+-} in $ee \rightarrow \eta' h_1(1380)$



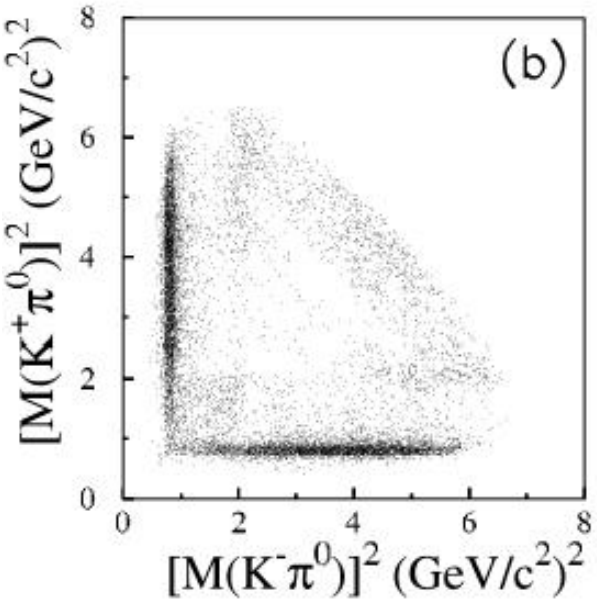
BESIII: M = 1423 ± 7 MeV

M.Chizhov(2004): M = 1415 ± 13 MeV

PWA: JINR contribution

$J/\psi \to K^+K^-\pi^0$ (prev. results)

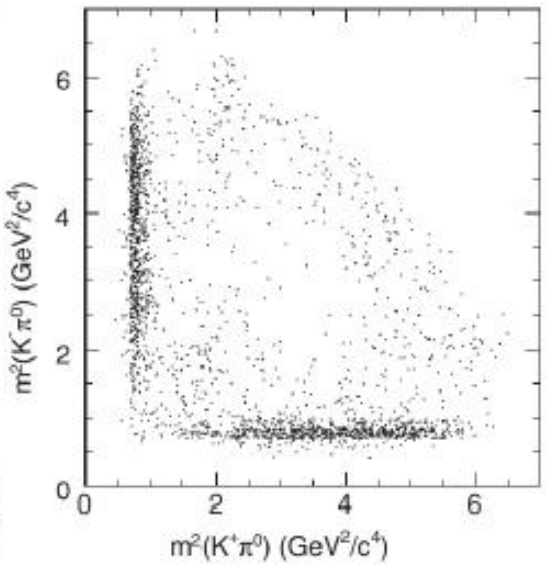
BESII, PRL97, 142002 (2006)



Exotic X(1575):
JPC = 1--

Pole position:
M ~ 1580 MeV
G ~ 800 MeV

BABAR, PRD95,072007 (2017)

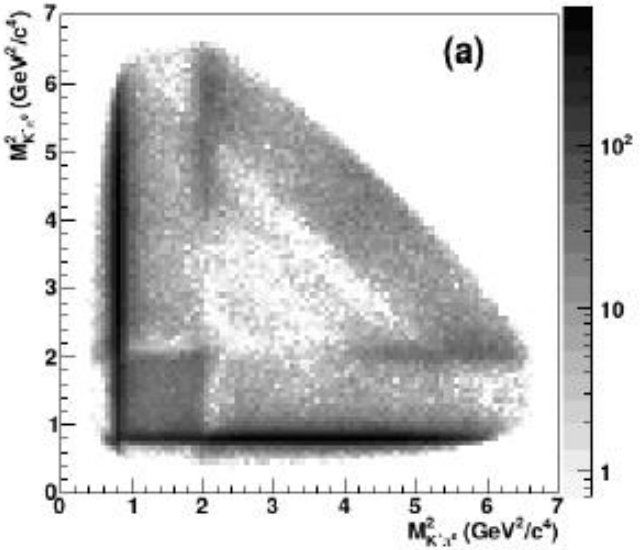


Observed ρ(1450) providing input for its puzzling [PDG review] structure:

$$\frac{\mathcal{B}(\rho(1450)^0 \to K^+K^-)}{\mathcal{B}(\rho(1450)^0 \to \pi^+\pi^-)} =$$

$$0.307 \pm 0.084(\text{stat}) \pm 0.082(\text{sys})$$

BESIII



?

$J/\psi \to K^+K^-\pi^0$ @BESIII

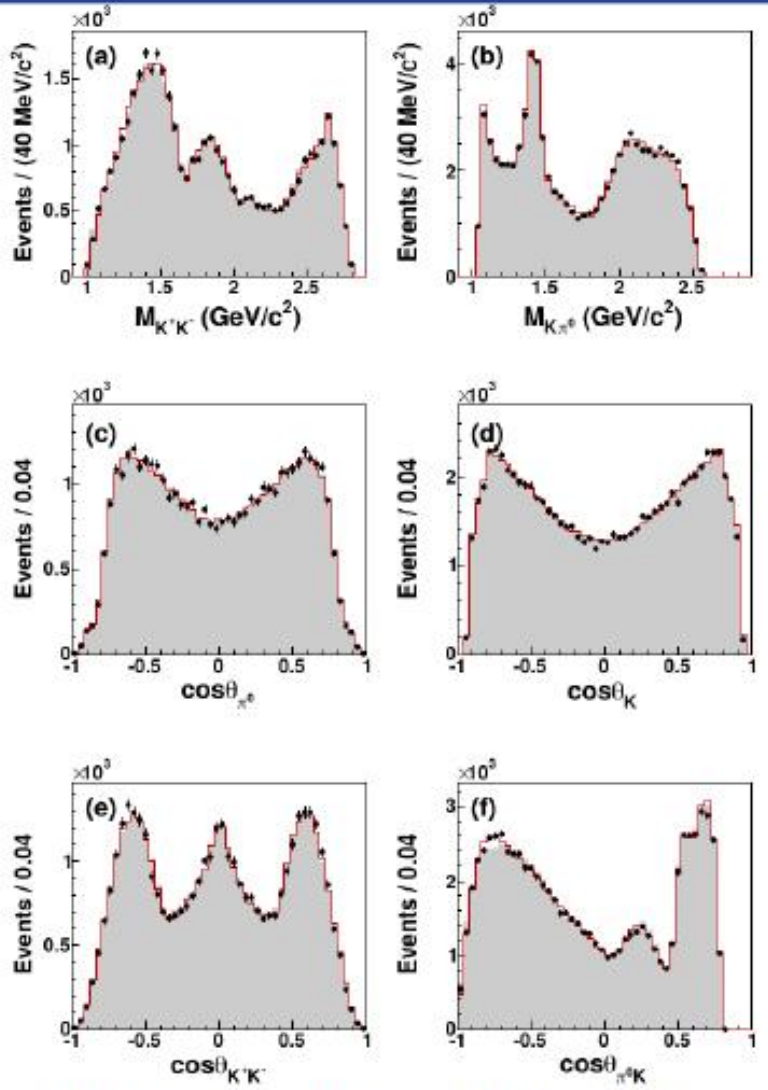
In the partial wave analysis two solution are obtained:

The first (solid histograms) is constructed only from known resonances and PHSP only.

In the second solution (red line) the most significant slowly changing background contribution in the JP=3- (Kπ) partial wave is also included. Possible effects due to previously not resolved contributions are not unexpected considering LASS results on Kπ elastic scattering amplitudes [PLB 180,308(1986)].

Common set of well-defined resonances:

- $K^*(892)$, $K_2^*(1430)$, $K_2^*(1980)$, $K_4^*(2045)$ (in Kπ);
- 1-- @1650 MeV and 1-- @2.050 MeV (in KK).



Mass and angular for projections in the M(Kπ)>1.05 GeV region

$J/\psi \to K^+K^-\pi^0$ @BESIII

Analysis results:

- The known decays through $K^*(892)$ and $K_2(1430)$ as well as parameters of these resonances are measured with high precision. Their parameters are are extracted with high precision:

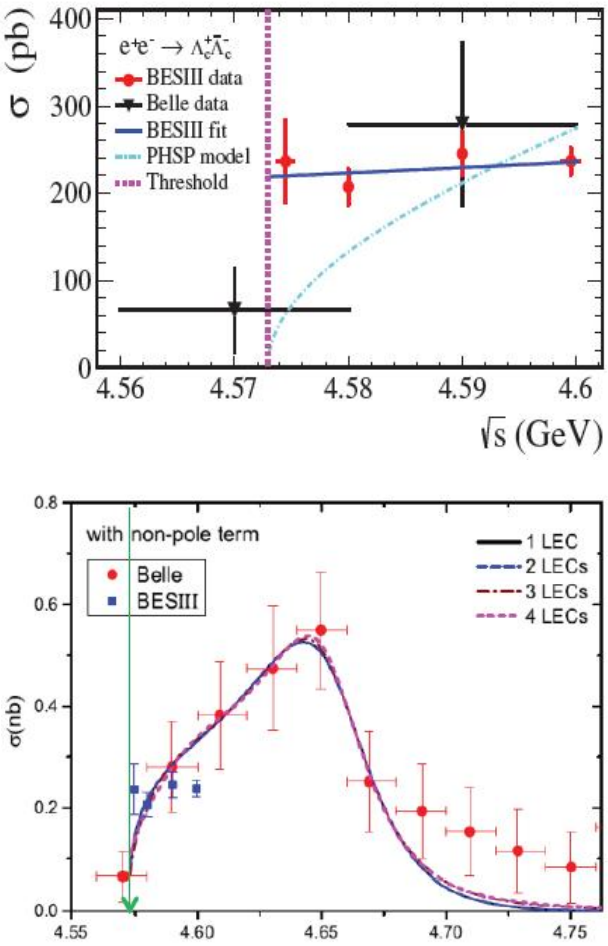
	This work**	PDG (hadroproduction)	PDG (leptoproduction)
$M(K^*(892)^\pm)$ / MeV	$893.6\pm0.1^{+0.2}_{-0.3}$	891.76±0.25	895.5±0.8
$\Gamma(K^*(892)^\pm)$ / MeV	$46.6\pm0.2^{+0.1}_{-0.3}$	50.3±0.8	46.2±1.3

**The width of $K^*(892)$ is extracted using method of JINST 10,P10028 (2015).

- The decays via $K_2^*(1980)$ and $K_4^*(2045)$ are observed and measured for the first time.
- In K^+K^- pair two resonance signals are observed ($^3D_1$ isovector, $\omega(1650)$?) Study of isospin related channel is required.
- The branching ratio of $J/\psi \to K^+K^-\pi^0$ is measured with high precision: $Br=(2.88\pm0.01\pm0.13)\times10^{-3}$ (PDG: $(2.14\pm0.24)\times10^{-3}$)
- We do not confirm BESII or BABAR conclusion on significant presence of X(1575) or ρ(1450)

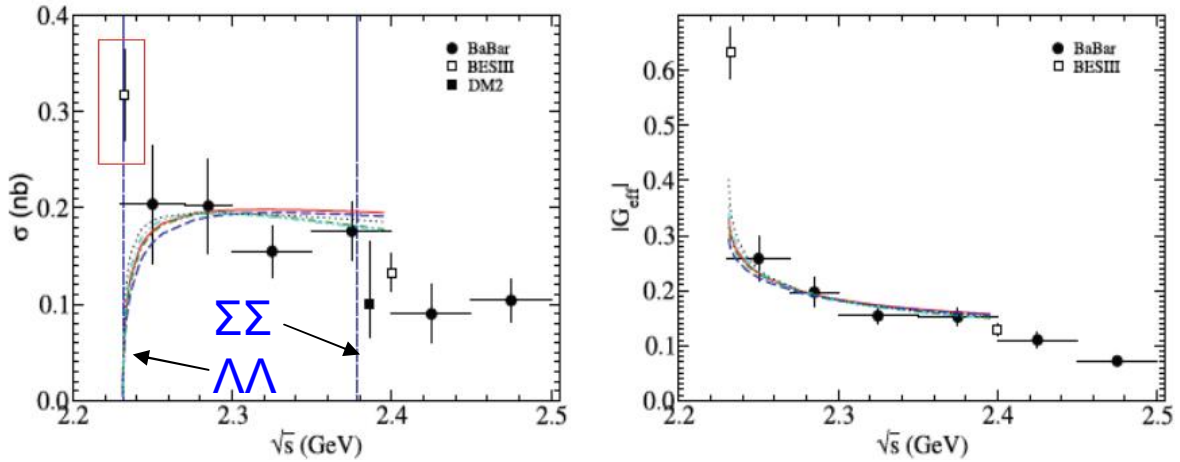
Baryonic form-factors

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

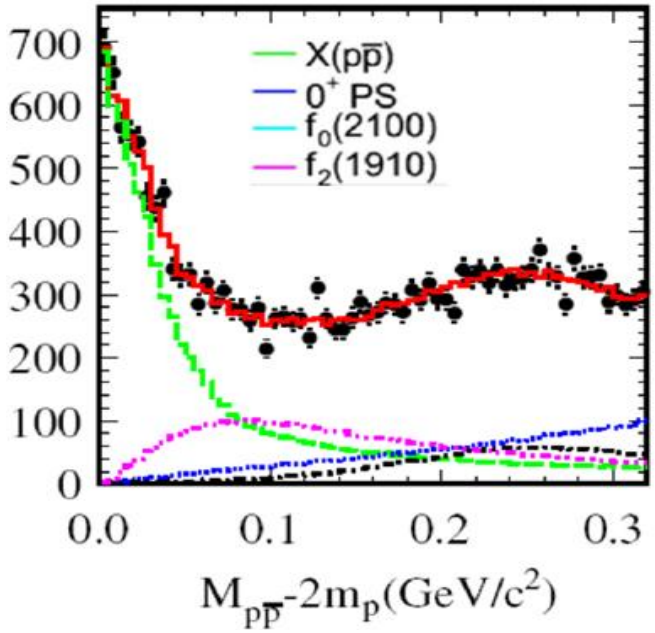
Lambda form-factor

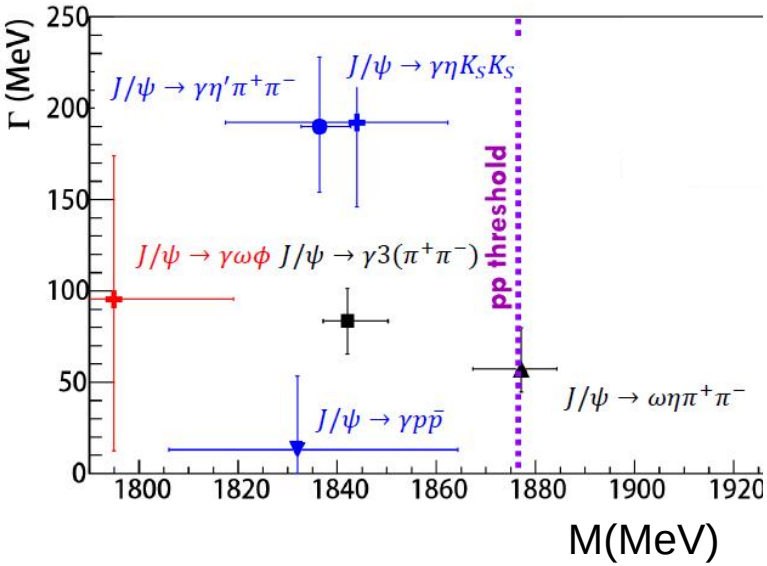


- At BESIII it is possible to measure cross-section down to the threshold energy (just 1 MeV above!)
- Like for Λ_C, BESIII observes a threshold enhancement
- BESIII results marginally consistent with BaBar, but not with the theoretical description

Structures at the pp threshold

$J/\psi \rightarrow \gamma pp$





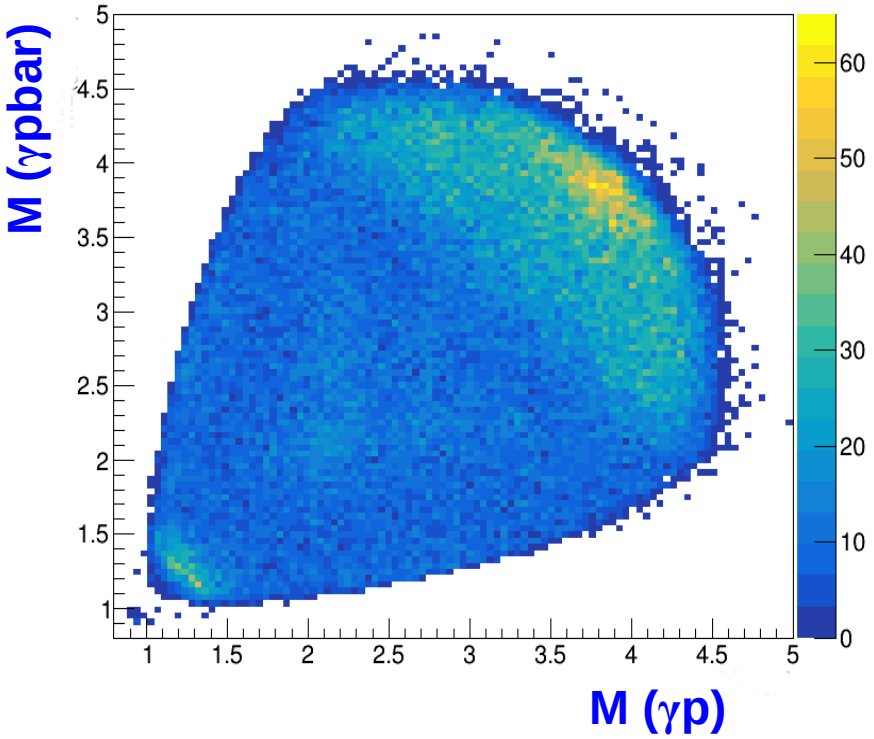
- M(X) = 1832 ± 32 MeV
- Γ(X) = 13 ± 40 MeV
- $J^{PC} = 0^{-+}$
- $B(J/\psi \rightarrow \gamma X) = (9.0 \pm 1.5) \times 10^{-5}$

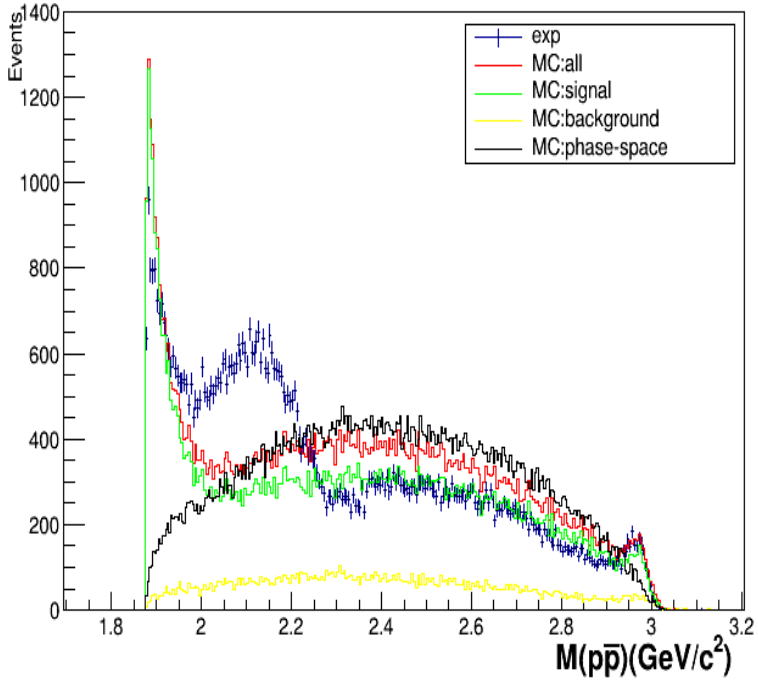
- BESIII observed quite a number of structures right below the pp threshold
- Recent increase of J/ψ statistics by factor of 4 (1.3B → 6B → 10B) will be extremely useful to clarify the situation

Baryonic form-factors: JINR contribution

Cross-check study of $J/\psi \rightarrow \gamma pp$

(Bachelor thesis by D.Seitova)





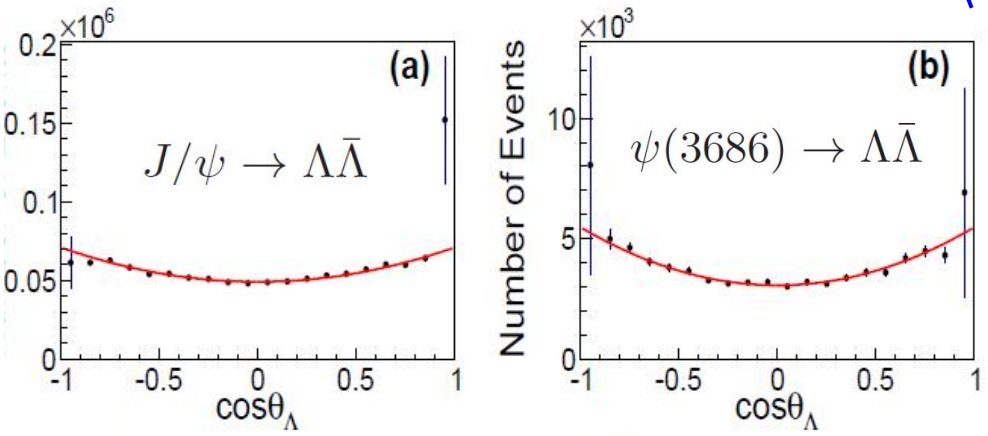
Study of charmonia decays

Charmonia baryonic decays (1)

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

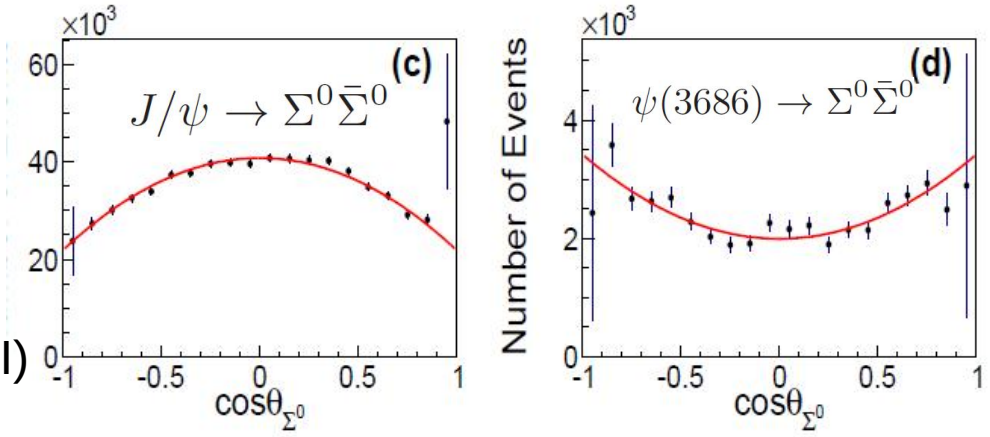
PRD 95 (2017) 052003

BESIII:
0.469 ± 0.027
Theory:
0.32-0.51



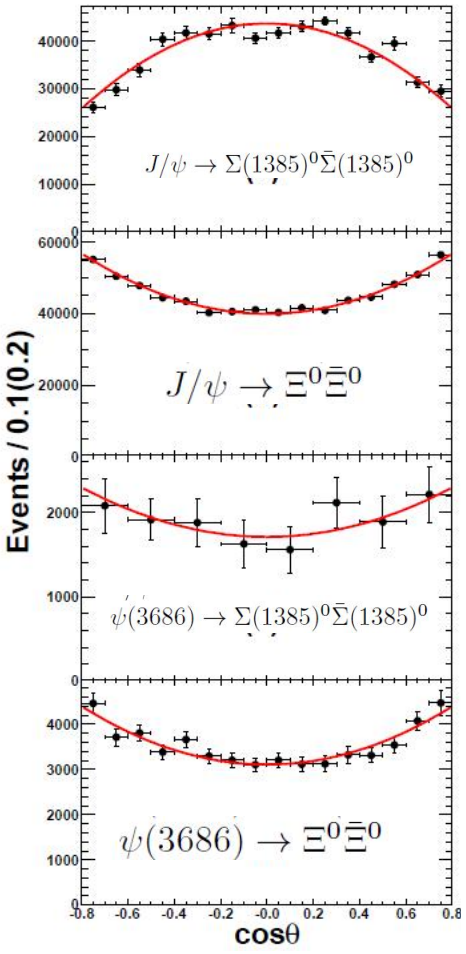
BESIII:
0.82 ± 0.08
(first measurement)

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



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

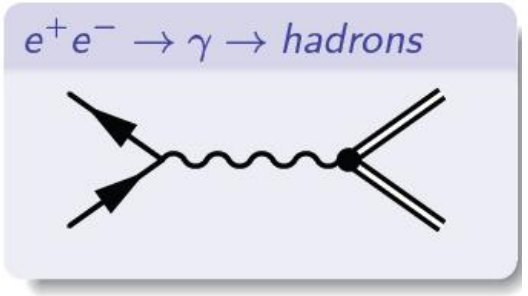
PLB 770 (2017) 217

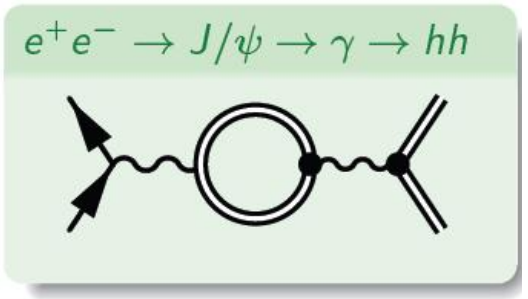
- Again, negative angular parameter is observed in $J/\psi \to \Sigma\Sigma$
- Not the case for ψ' decays and for non-Σ final states
- LO QCD predicts positive α in all cases
- More sophisticated theoretical model are necessary to explain the observations

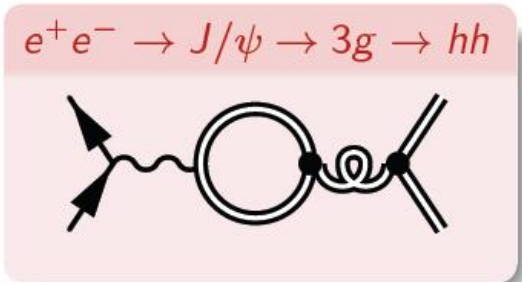
Charmonia decays:
JINR contribution

Strong/EM phase difference in J/ψ decays

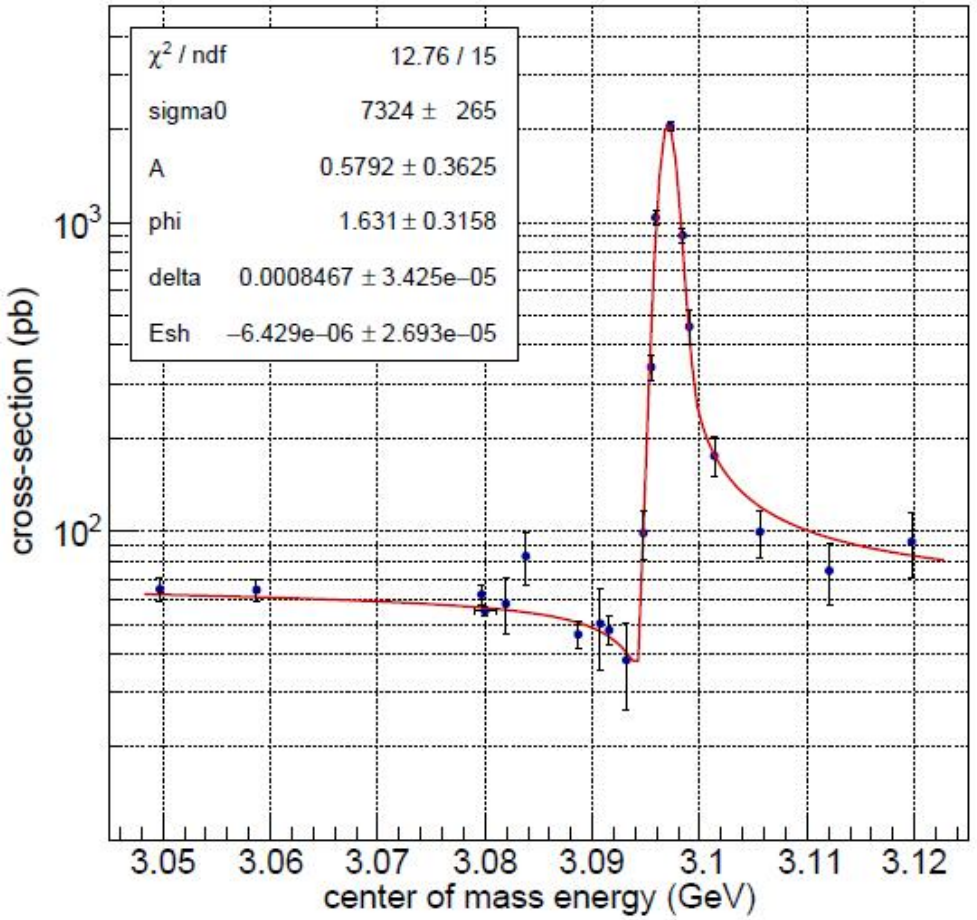
- In many J/ψ decay channels, there is 90º phase difference between strong and electromagnetic decay amplitudes
- There is a theoretical hypothesis that this 90º is a general law of nature
- We perform a scan of J/ψ peak to measure this phase
- As a spin-off, we provide systematic measurement of exclusive cross-sections, useful for generator tuning and theory constrains



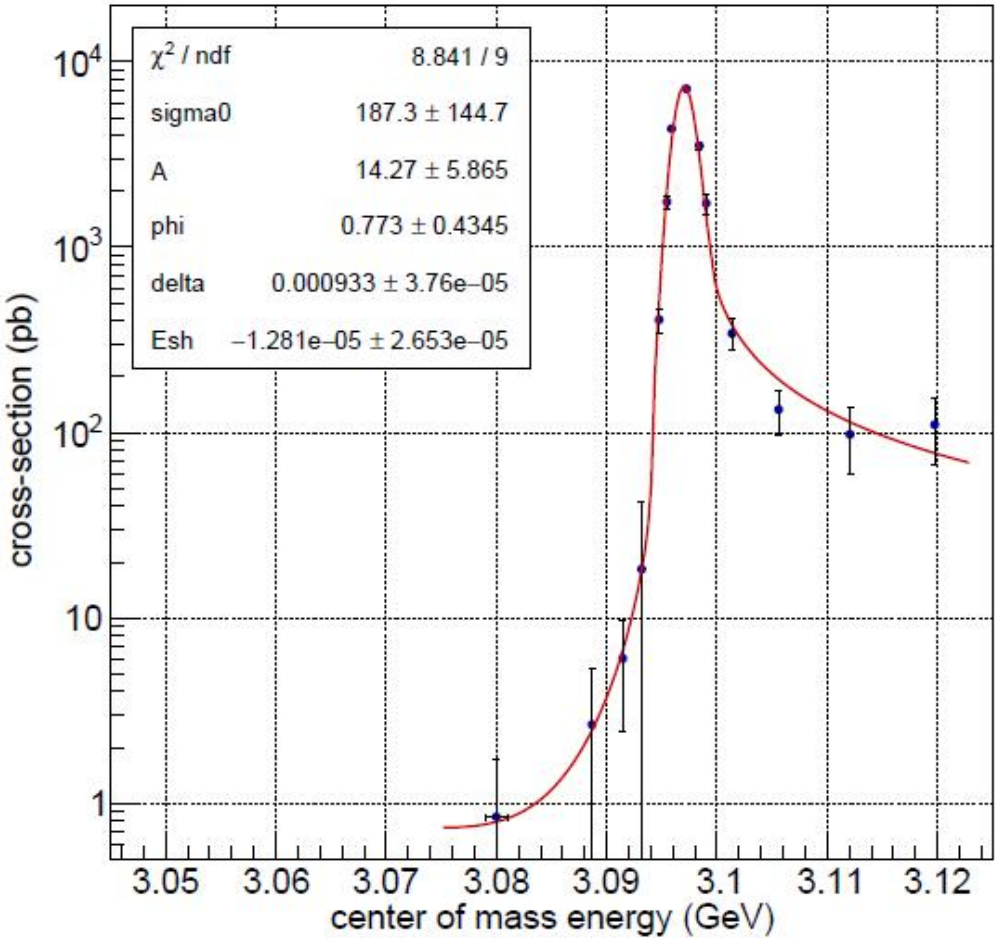




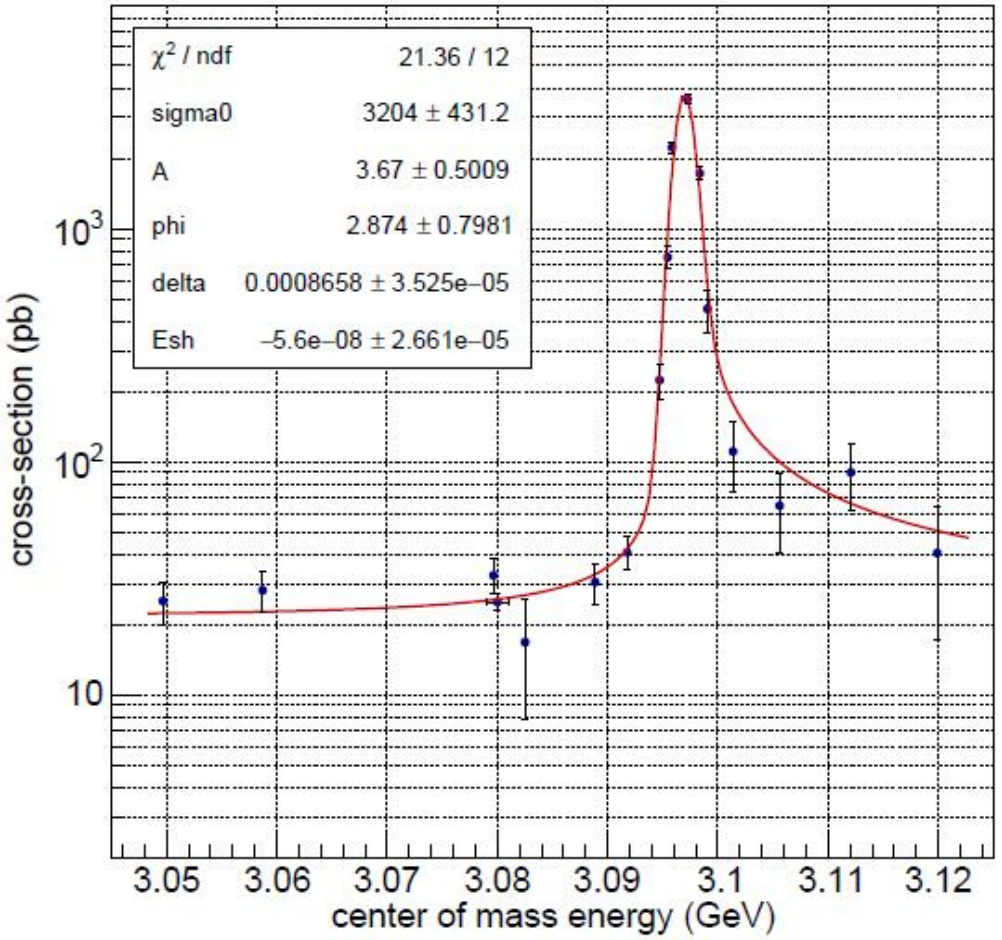
$ee \to \omega\pi^0$



ee→ωη

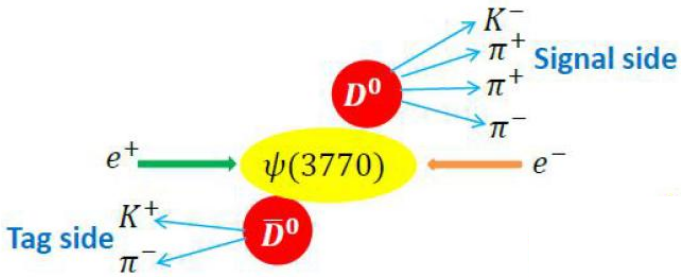

χ^2 / ndf 8.841 / 9
sigma0 187.3 ± 144.7
A 14.27 ± 5.865
phi 0.773 ± 0.4345
delta 0.000933 ± 3.76e−05
Esh −1.281e−05 ± 2.653e−05
cross-section (pb)
10^4
10^3
10^2
10
1
3.05
3.06
3.07
3.08
3.09
3.1
3.11
3.12
center of mass energy (GeV)

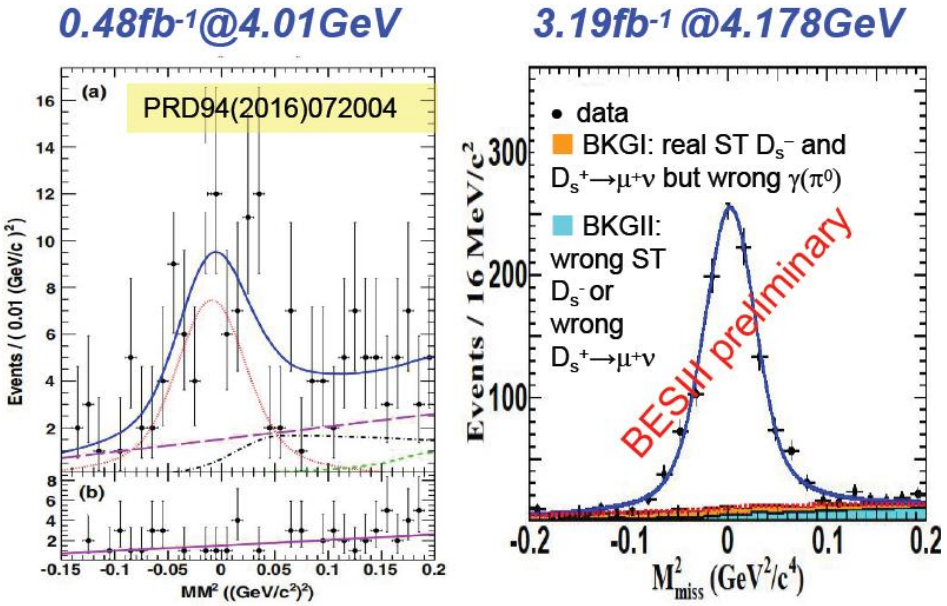
ee→φη


χ^2 / ndf 21.36 / 12
sigma0 3204 ± 431.2
A 3.67 ± 0.5009
phi 2.874 ± 0.7981
delta 0.0008658 ± 3.525e−05
Esh −5.6e−08 ± 2.661e−05
cross-section (pb)
10^3
10^2
10
3.05
3.06
3.07
3.08
3.09
3.1
3.11
3.12
center of mass energy (GeV)

Charm decays

$D_s^+ \to \mu^+ \nu$





- $B[D_s^+ \to \mu^+\nu] = 0.528 \pm 0.015 \pm 0.014\%$
- $f_{Ds}|Vcs| = 242.5 \pm 3.5 \pm 3.7$ MeV

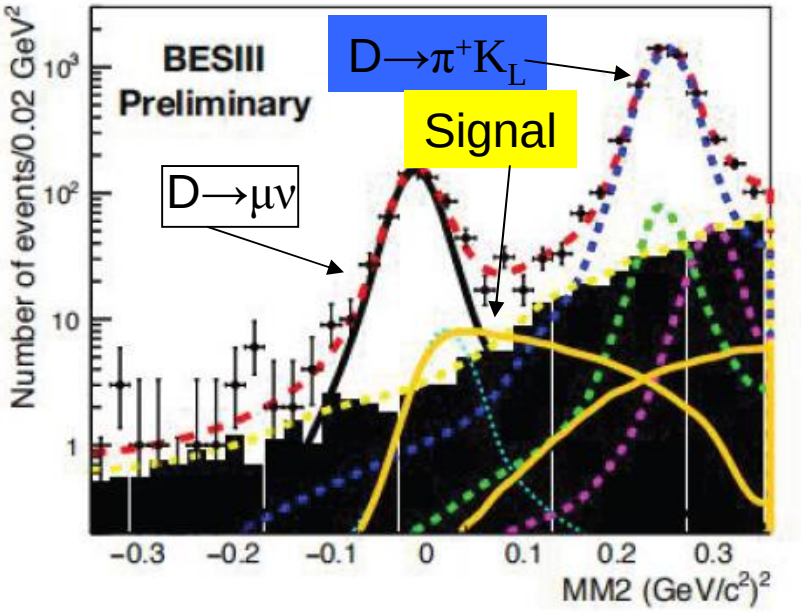
$$R \equiv \frac{\Gamma(D_s^+ \to \tau^+ \nu)}{\Gamma(D_s^+ \to \mu^+ \nu)}$$

SM: R = 9.74 ± 0.1

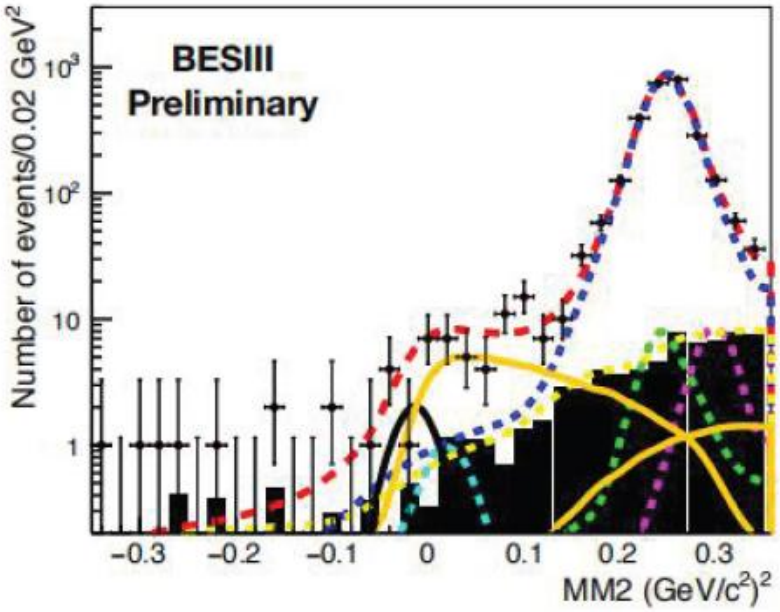
BESIII: R = 10.2 ± 0.5

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

E_{EMC} < 300 MeV



E_{EMC} > 300 MeV



- Nsig = 137 ± 27
- $B[D^+ \to \tau^+ \nu] = (1.20 \pm 0.24_{stat}) \times 10^{-3}$

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

SM: R = 2.66 ± 0.01

BESIII: R = 3.21 ± 0.64

Our plans

- We will continue our research program
- Charmonium production and XYZ exotic states:
  - Add new energy points (taken recently and future E>4.6 GeV running)
  - Add measurement of $ee \to \psi' X$
  - Measure charmonium polarization via muon angual distribution
- Scan of charmonium lineshape:
  - Analyze more channels
  - Add high-statistics points below J/ψ
  - Improve precision by factor ~2 by measuring J/ψ branchings using events $\psi' \to J/\psi$
- Search for processes $ee \to 2p2pbar$, $\rho ppbar$, $\rho pnbar$ and study the threshold effects in baryon pair systems

Spare slides

Kinematical acceptance of ee → 4p
(at least 3 protons have p_T>100 MeV/c)