

Participation of JINR in the BES-III physics research program (project BES-III/JINR)

Status report and prolongation proposal

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Beijing Electron-Positron Collider

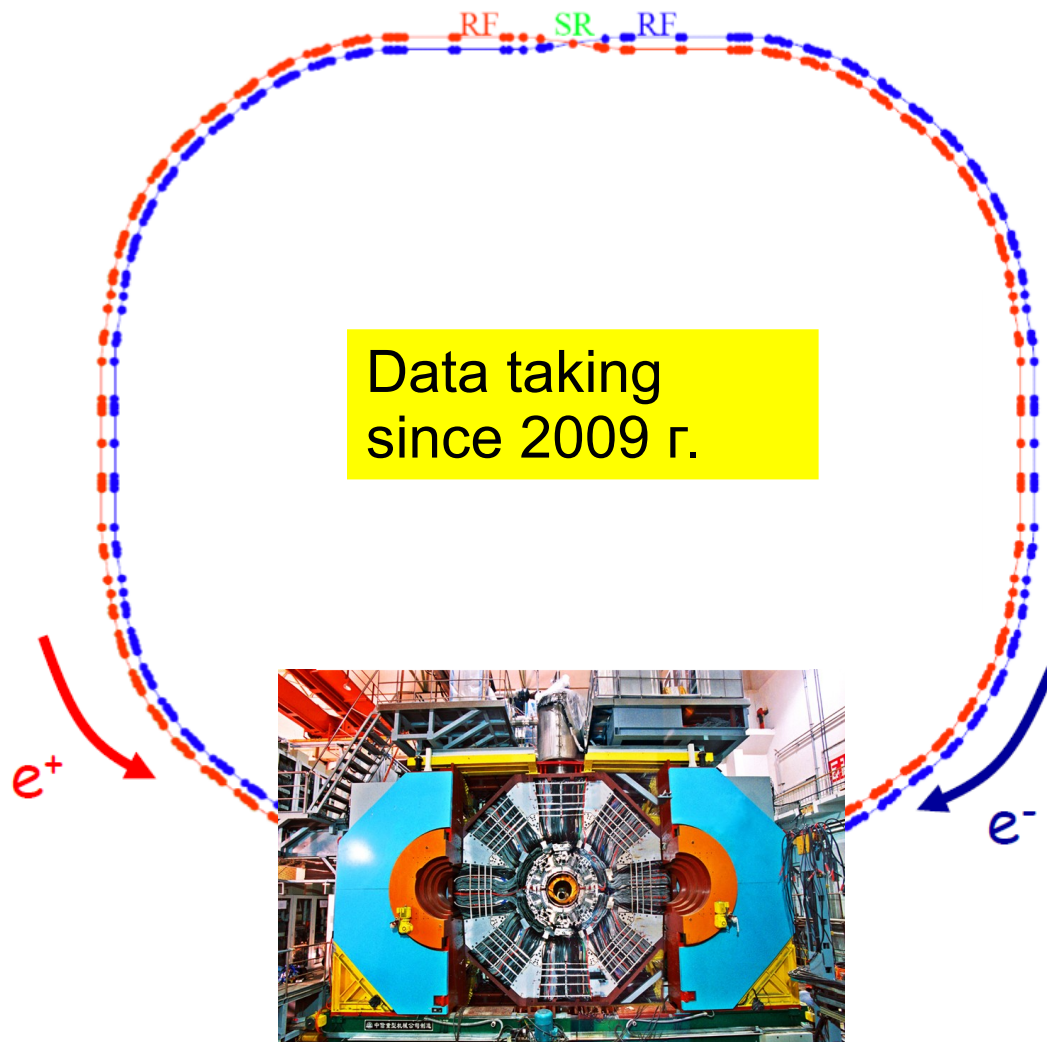


BESIII Collaboration

- About 500 members, 66 institutes, 14 countries
- 38 institutes from China, 7 - Asia, 16 - Europe (including JINR and Novosibirsk, Russia), 5 - USA

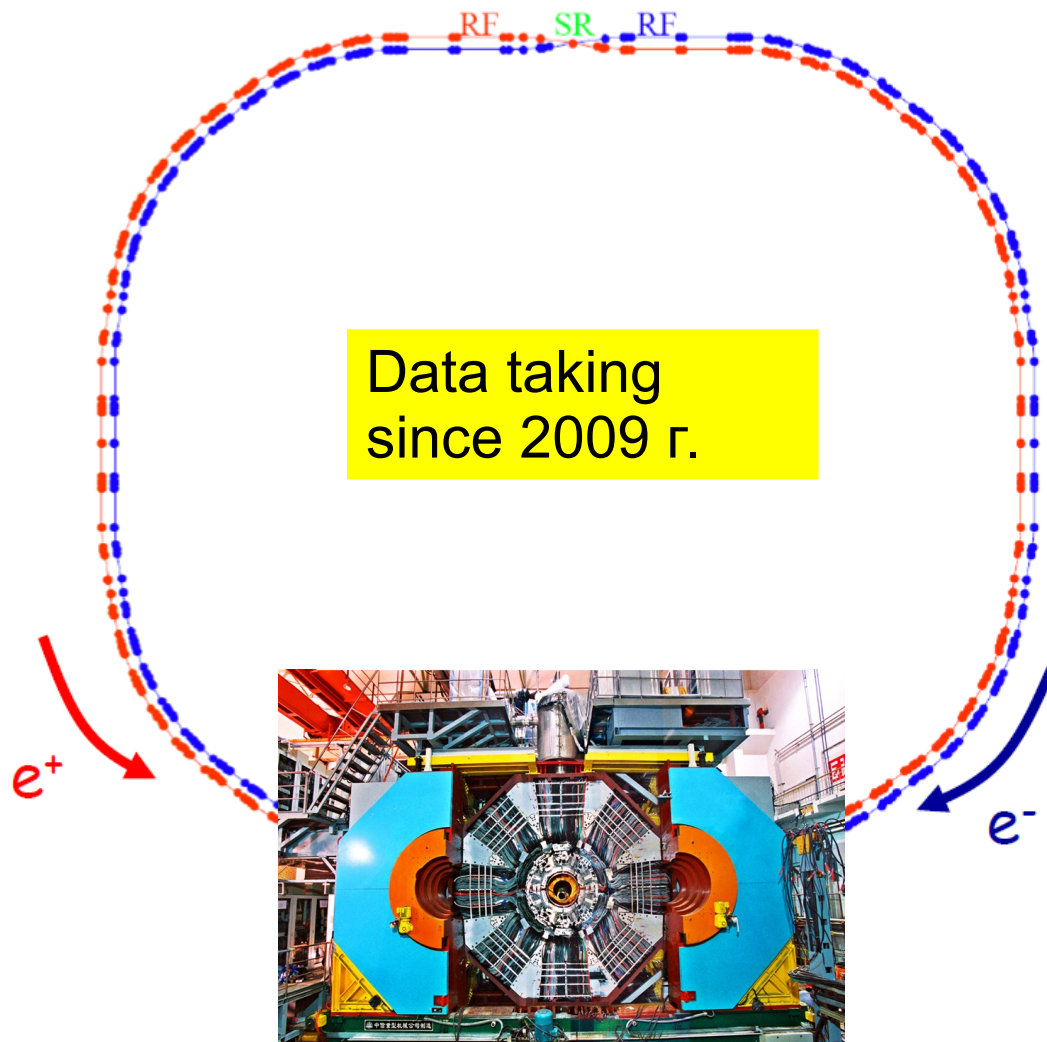


BEPCII Collider



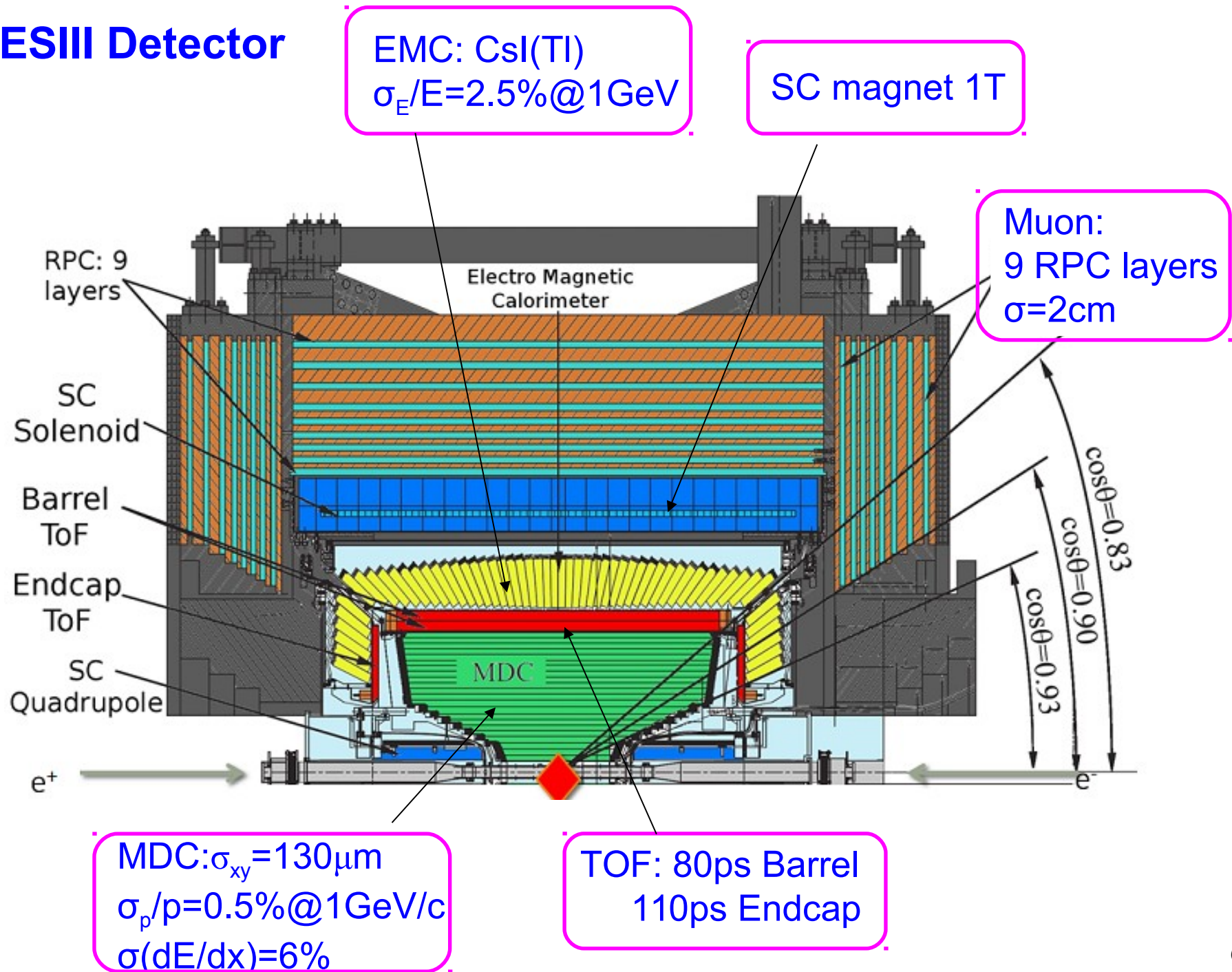
- Energy range
2.0 – 4.6 GeV
- Design luminosity
 $1.0 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$
- Achieved luminosity (2016)
 $1.0 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$
- Beam energy spread
 5×10^{-4}
- Bunch number
93
- Maximum beam current
0.91A
- Circumference
237m

BEPCII upgrade (2019)



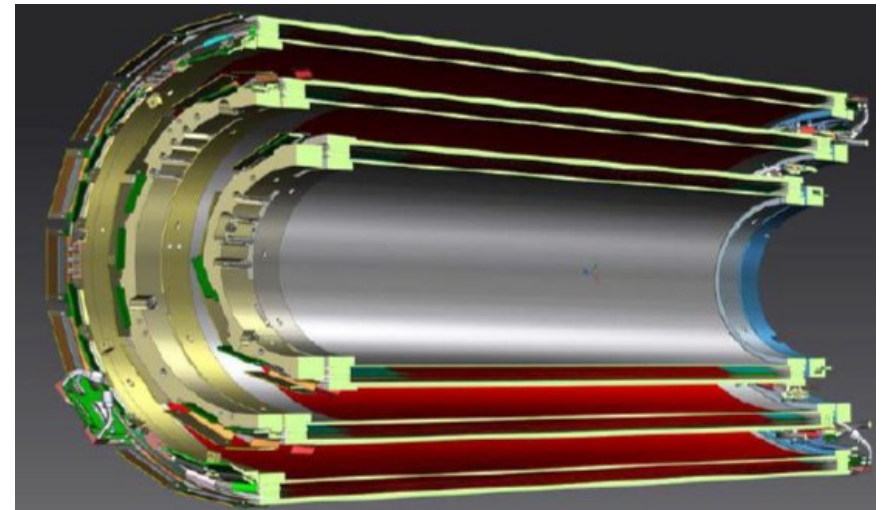
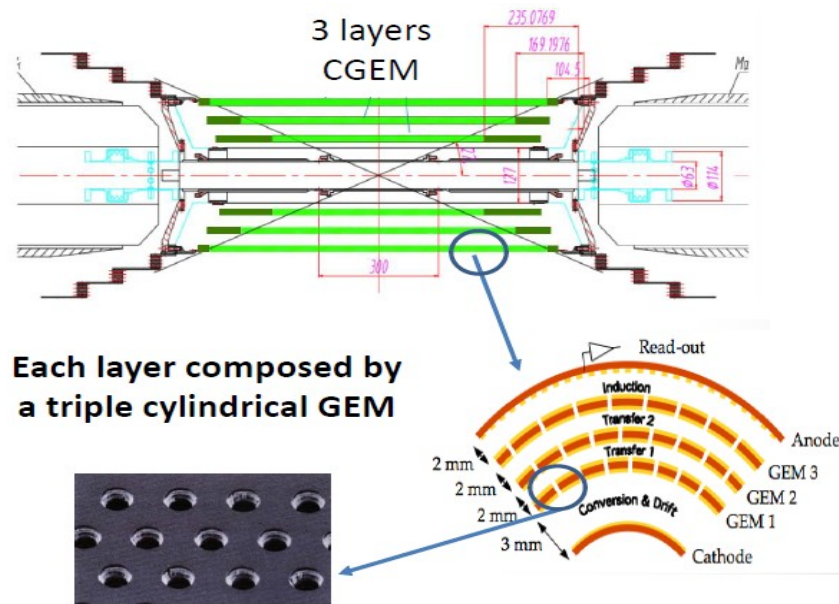
- Energy range
 $2.0 - 4.6 \text{ GeV}$
└─→ 4.9 GeV
- Design luminosity
 $1.0 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$
- Achieved luminosity (2016)
 $1.0 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$
└─→ top-up injection
+20-30% to the integrated
luminosity
- Beam energy spread
 5×10^{-4}
- Bunch number
93
- Maximum beam current
 0.91 A
- Circumference
237m

BESIII Detector

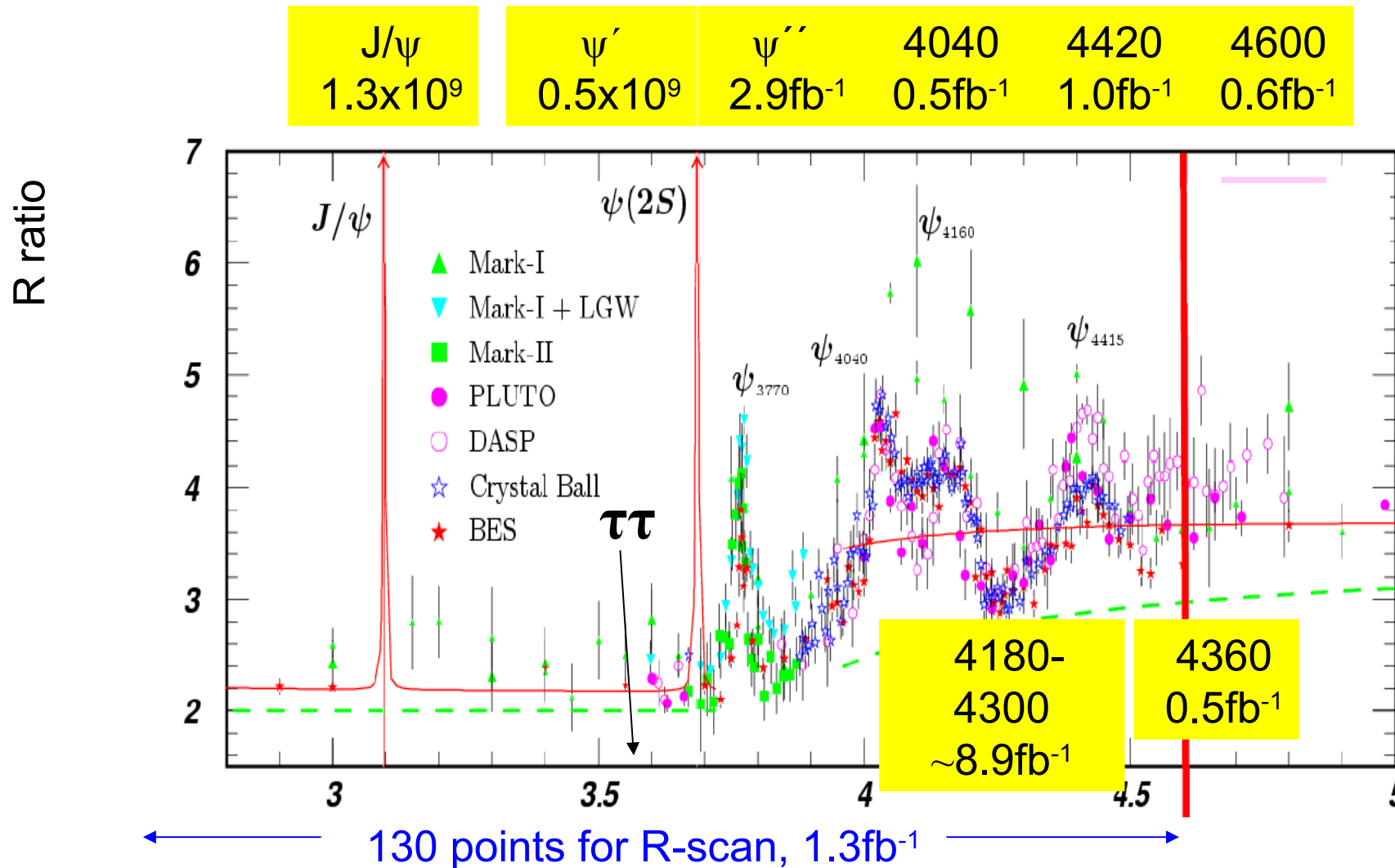


Upgrade plan (2019)

- 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
- $\sigma_{r\phi} \sim 130 \mu\text{m}$
- $\sigma_p/p = 0.5\% @ 1 \text{ GeV}/c$



BESIII Data Samples



World largest data samples J/ψ , $\psi(2S)$, $\psi(3770)$, $\psi(4040)$, $\psi(4180)$, $Y(4260)$, ...
More than 200 papers published using these data

BESIII Research Programme

- Charmonium physics
- Charm physics
- Exotic states (XYZ)
- Light hadron spectroscopy
- tau-lepton physics
- R-ratio scan
- Baryon form-factors
- Search for «new physics»

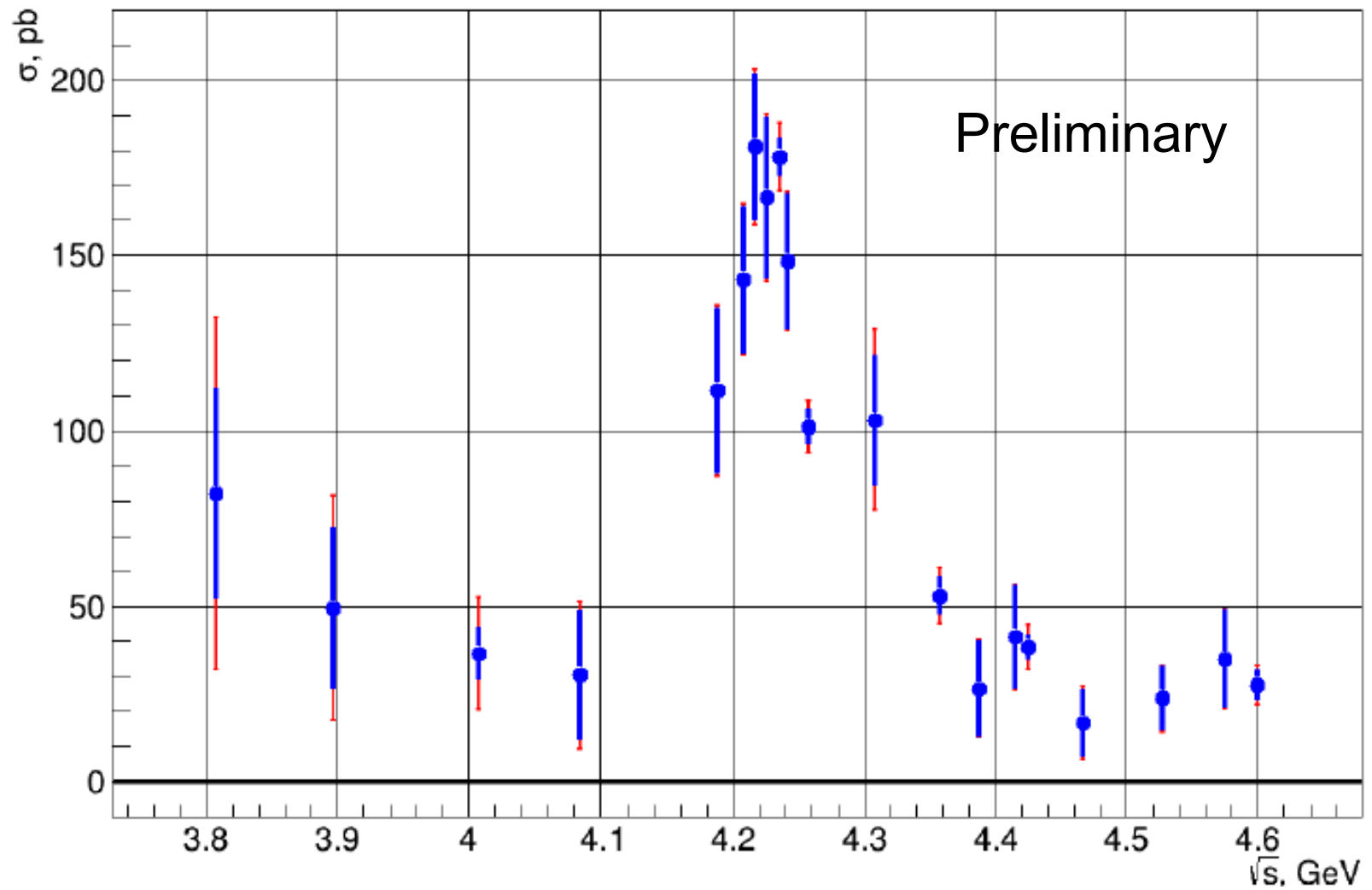
Results of JINR's group and plan for 2020-2022

- The inclusive prompt charmonium production
- Measurement of cross-sections in the region of J/ψ peak
- Search for bound $p\bar{p}$ states

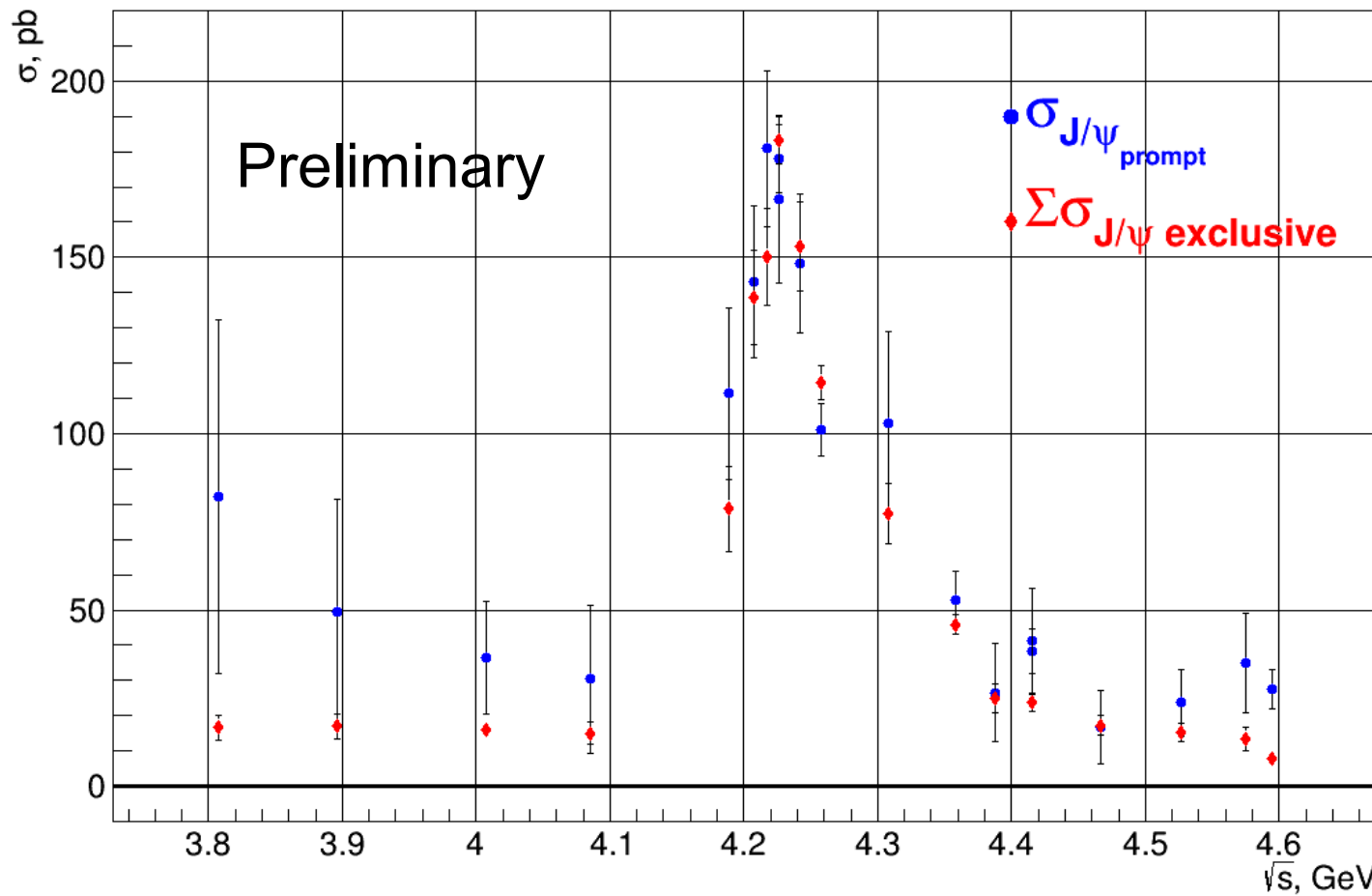
Inclusive prompt J/ψ production ($ee \rightarrow J/\psi X$)

- Prompt = Total – ($\psi' \rightarrow J/\psi$) – ($\chi_c \rightarrow J/\psi$) – ($ee \rightarrow \gamma J/\psi$)
- Goal:
 - Test NRQCD (in particular, the universality of the NRQCD LDMEs)
 - NRQCD prediction: set of color-octet LDMEs are non-zero if $\sigma > 10 \text{ pb}$ at 4.5-5.5 GeV [*Eur.Phys.J. C77 (2017) no.9, 597*]
 - Test if unknown channels/states exist
- Data only available at 10.5 GeV:
 - $2.5 \pm 0.3 \text{ pb}$ (BaBar)
 - $1.5 \pm 0.2 \text{ pb}$ (Belle)
 - $1.9 \pm 0.2 \text{ pb}$ (CLEO)

Our result: $\sigma(ee \rightarrow J/\psi X)$



Inclusive cross-section vs. sum of known cross-sections of exclusive channels



Research plan

- 2019 — to finalise the analysis and to publish the cross-section of the inclusive prompt J/ψ production in the energy range 3.8-4.6 GeV.
- 2020 – Measurement of the cross-section of the inclusive prompt $\psi(2S)$ production
- 2021 – Measurement of the cross-section of the inclusive J/ψ and $\psi(2S)$ production in the energy range 4.6-4.9 GeV.
- 2022 – Inclusive measurement of the J/ψ polarisation in the energy range above ~ 4 GeV

Strong/EM phase difference in J/ψ decays

- pQCD predicts that the phase difference between strong and electromagnetic decay amplitudes to be 0° or 180° at lowest order [*PRL* 59, 621 (1987), *Nucl. Phys. B* 246, 52 (1984)]
- Experimentally, in many J/ψ decay channels, there is $\sim 90^\circ$ phase difference
- There is a theoretical hypothesis that this 90° is a general law of nature [*PRD* 63, 054021 (2001)]
- A new method to measure the phase was proposed by BESII [*PLB* 593 (2004) 89–94]
- 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 constraints

$$e^+e^- \rightarrow \gamma \rightarrow \text{hadrons}$$



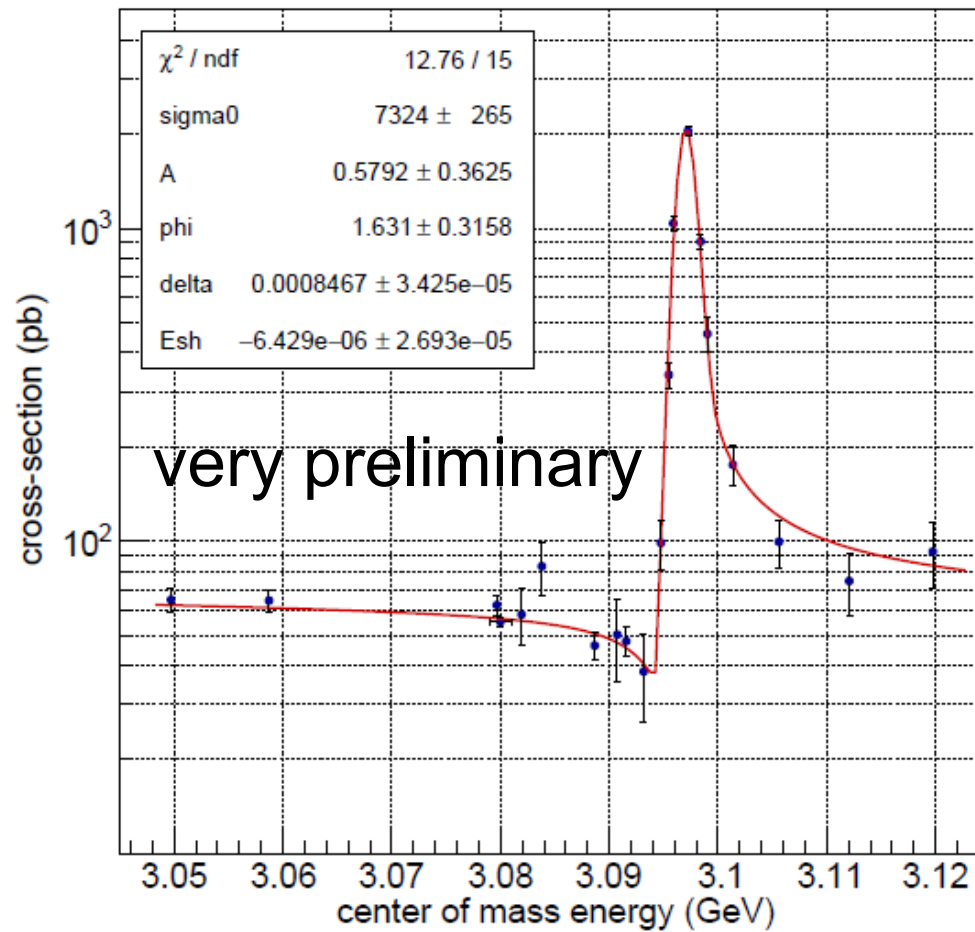
$$e^+e^- \rightarrow J/\psi \rightarrow \gamma \rightarrow hh$$



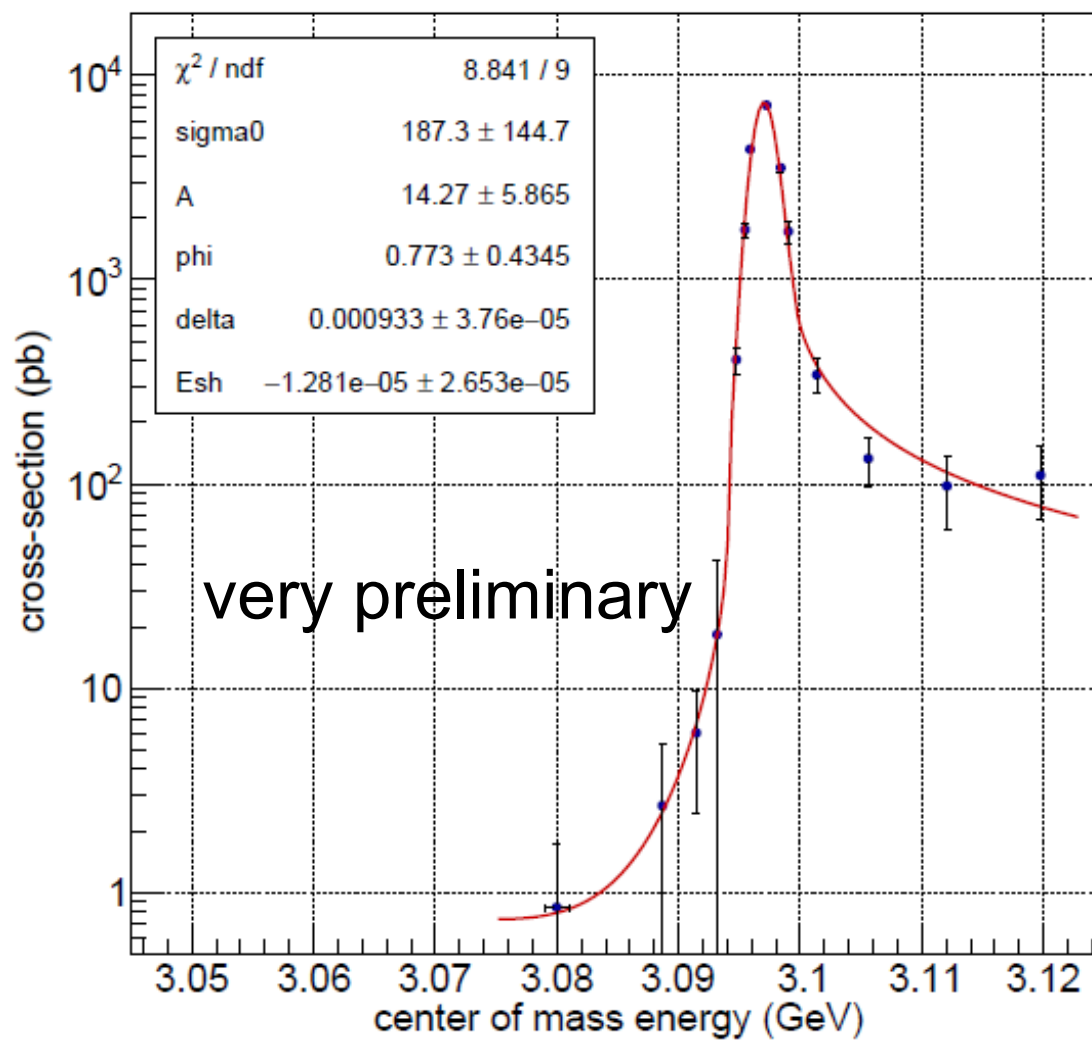
$$e^+e^- \rightarrow J/\psi \rightarrow 3g \rightarrow hh$$



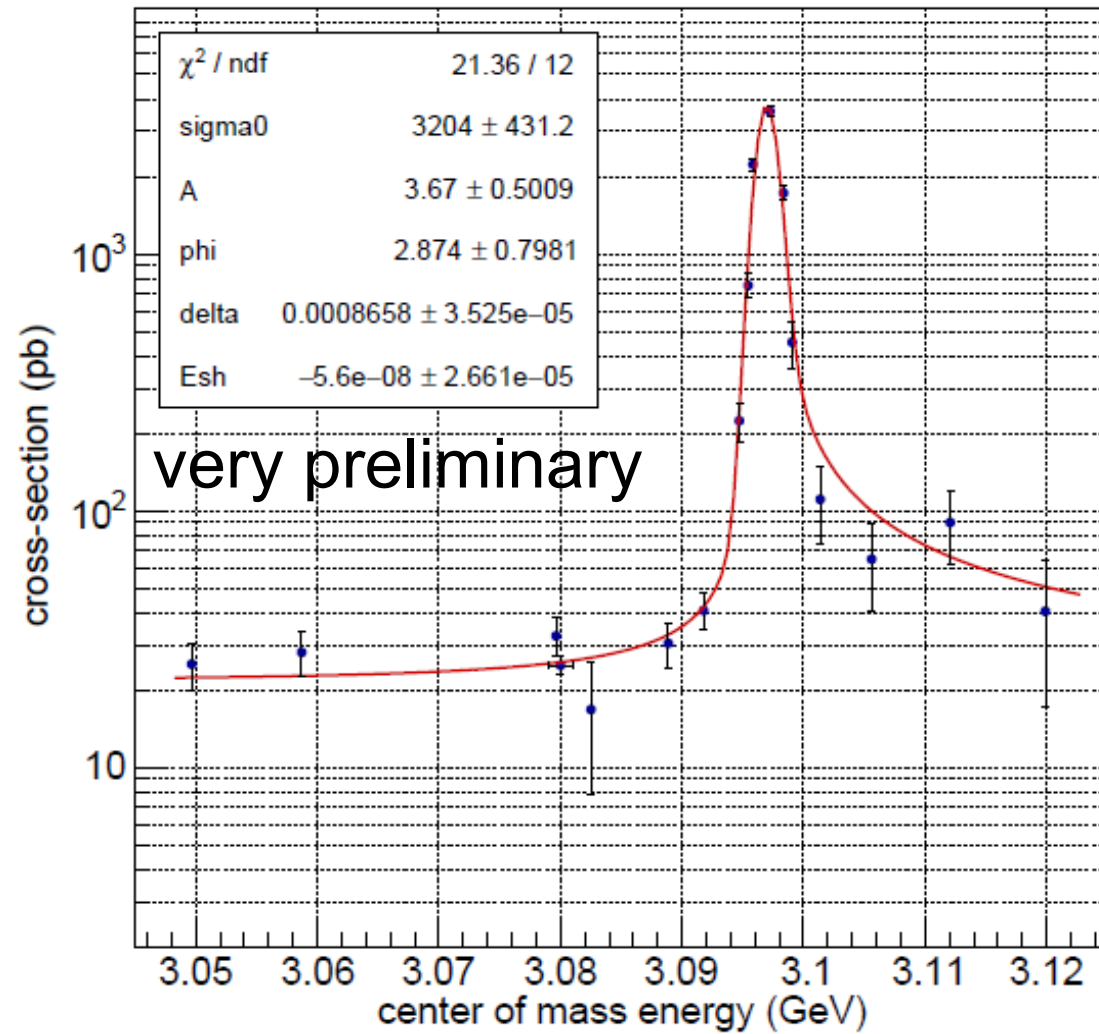
$$ee \rightarrow \omega \pi^0$$



$$ee \rightarrow \omega \eta$$



$ee \rightarrow \phi \eta$

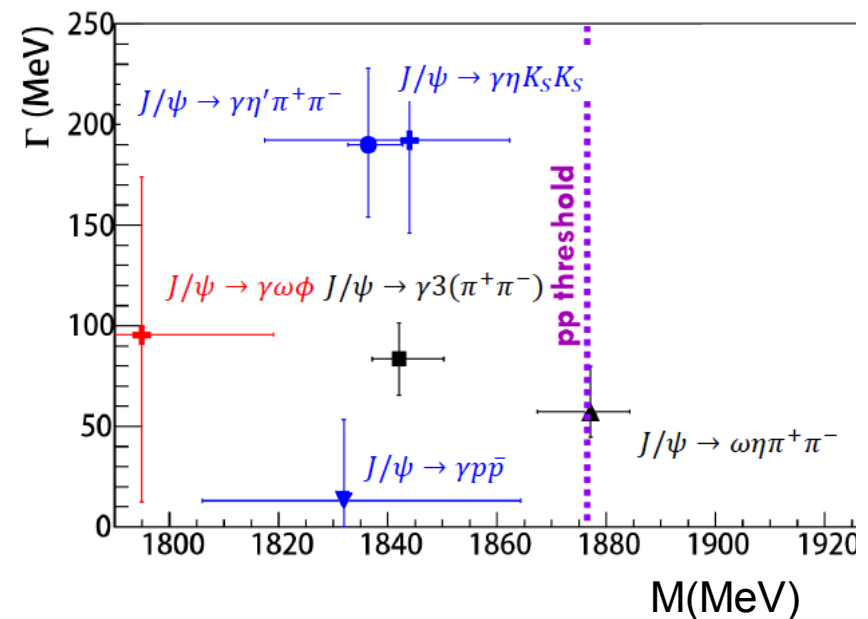
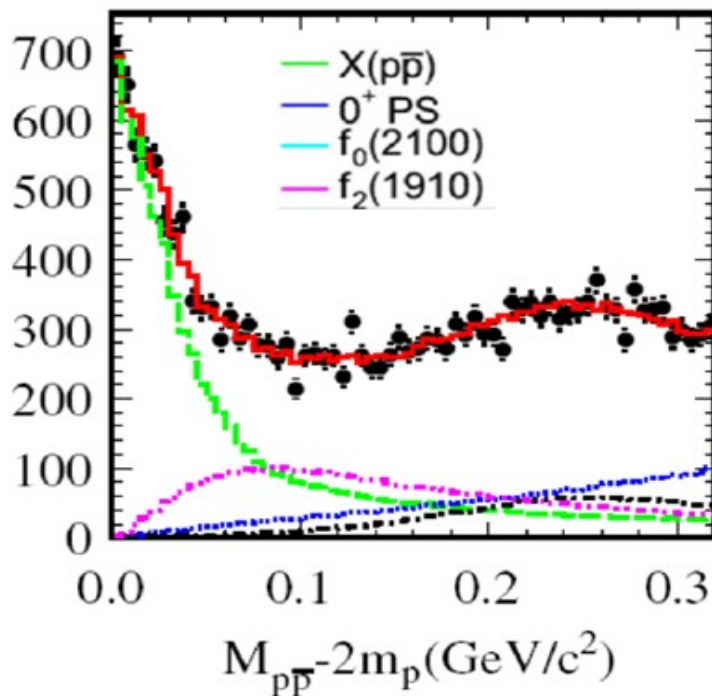


Research plan

- 2019 — to finalise the analysis and to prepare the BESIII analysis note on the method and the final results of $e^+e^- \rightarrow \omega\pi^0$
- 2020 – measurement of branching fraction of $J/\psi \rightarrow \phi\eta$. Final results on the phase difference in $e^+e^- \rightarrow \phi\eta$
- 2021 – Re-analysis of $e^+e^- \rightarrow \omega\eta$ taking into account new data set with the energy of 2.9 GeV. Final results on the phase difference in this reaction.
- 2022 – Study other reactions ($e^+e^- \rightarrow KK^*$, $e^+e^- \rightarrow \phi\eta'$) and possibly measure the phase difference

Structures at the $p\bar{p}$ threshold

$$J/\psi \rightarrow \gamma p\bar{p}$$



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

- BESIII observed quite a number of structures right below the $p\bar{p}$ threshold
- Recent increase of J/ψ statistics by factor of 4 (1.3B $\rightarrow$ 6B $\rightarrow$ 10B) will be extremely useful to clarify the situation

Research plan

2020 – Search for $e^+e^- \rightarrow 2(p\bar{p})$ above 4 GeV

2021 год – Search for bound baryon-antibaryon states (threshold enhancements) in $J/\psi \rightarrow \pi^- p \bar{n}$ and search for the decays $J/\psi \rightarrow \rho^0 p \bar{p}$, $J/\psi \rightarrow \rho^+ n \bar{p}$ and $J/\psi \rightarrow \rho^- n p$

Software development

- Technical contribution to the experiment
- Core framework development and maintenance (beam background simulation, database, software distribution etc.)
- Analysis tools (event generators, ROOT-based analysis framework, parallel PWA software etc.)
- Distributed computing (BES-III Grid & Cloud) — DLNP+LIT
- Development of machine learning algorithms for event reconstruction in CGEM/MDC — DLNP+LIT

Project authors

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Project funding in 2017-2019

Funding sources (kUSD)				
	Total	2017	2018	2019
JINR Budget (theme 1123)	75	25	25	25
External (RFBR-NSFC grant)	20	0	0	20

Main expenses are to cover travel costs to China:

- 1) Participation in the data taking shifts and technical works***
- 2) Data analysis and discussions, preparation of publications,***
to present results at international conferences
and to host our colleagues from BES-III at JINR

Funding request 2020-2022

Source	Total	2020	2021	2022
JINR Budget (theme 1123)	75	25	25	25
External	20	20	0	0

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Summary

- The BES-III experiment started operation in 2008, and continues to take data. It will remain the world leading project in the τ -charm domain until 2025.
- More than 200 papers are already published, and many more are coming.
- JINR group participates in BES-III since 2005, and made already a visible contribution to the experiment
- BES-III data analysis is ongoing in Dubna, aimed at the study of the charmonium production and decays and the search for the exotic charmonia and charmoniumlike structures
- We ask PAC to approve our proposal to prolong JINR's participation in the BES-III experiment until 2022