Участие ОИЯИ в программе физических исследований на установке BESIII

Отчет и предложение по продлению

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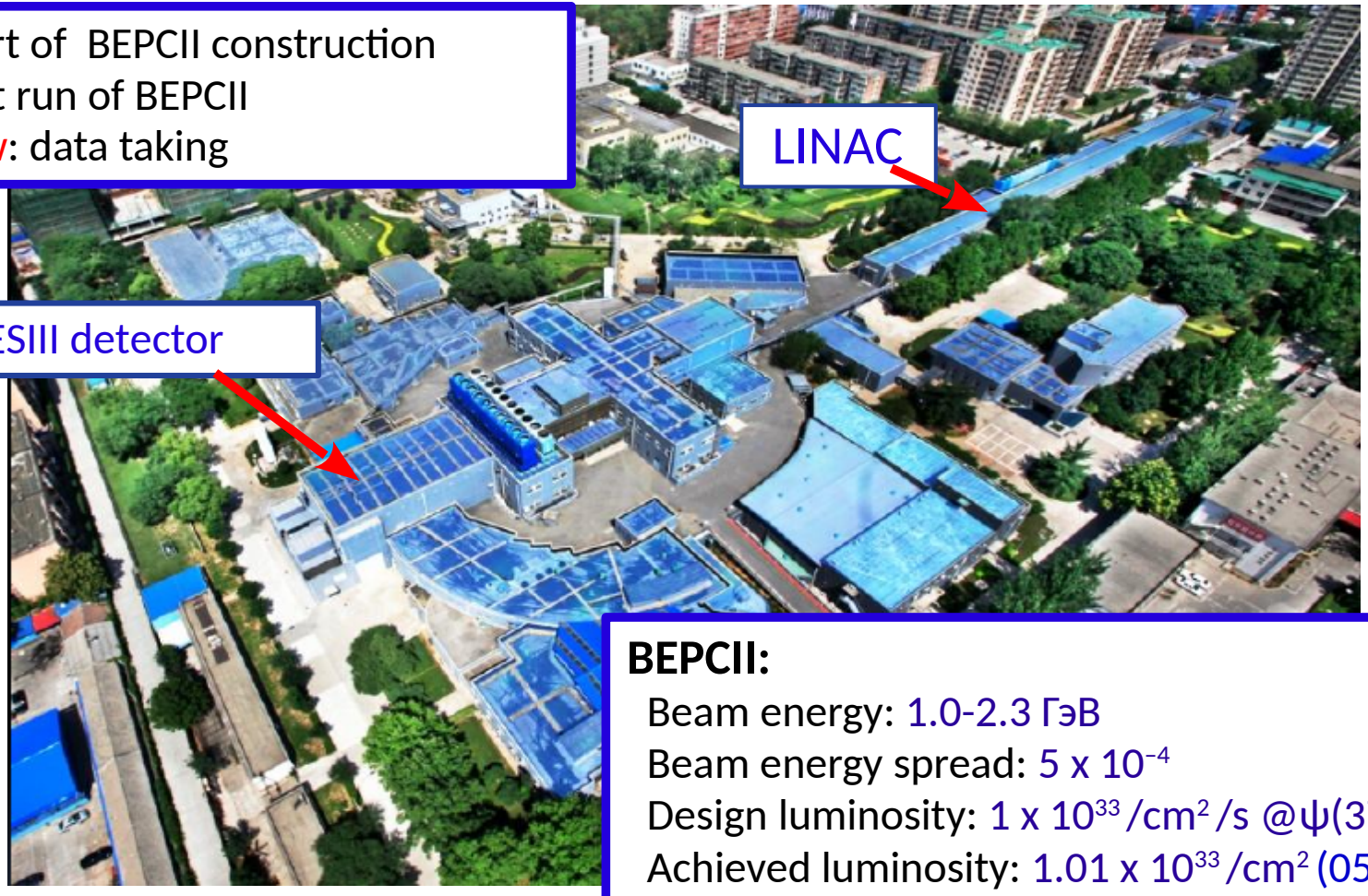
НТС ЛЯП
07.04.2021

BESIII and BEPCII (IHEP, Beijing, China)

2004: start of BEPCII construction
2008: test run of BEPCII
2009-now: data taking



BEPCII:

Beam energy: 1.0-2.3 ГэВ
Beam energy spread: 5×10^{-4}
Design luminosity: 1×10^{33} /cm^2/s @ψ(3770)
Achieved luminosity: 1.01×10^{33} /cm^2 (05.04.2016)

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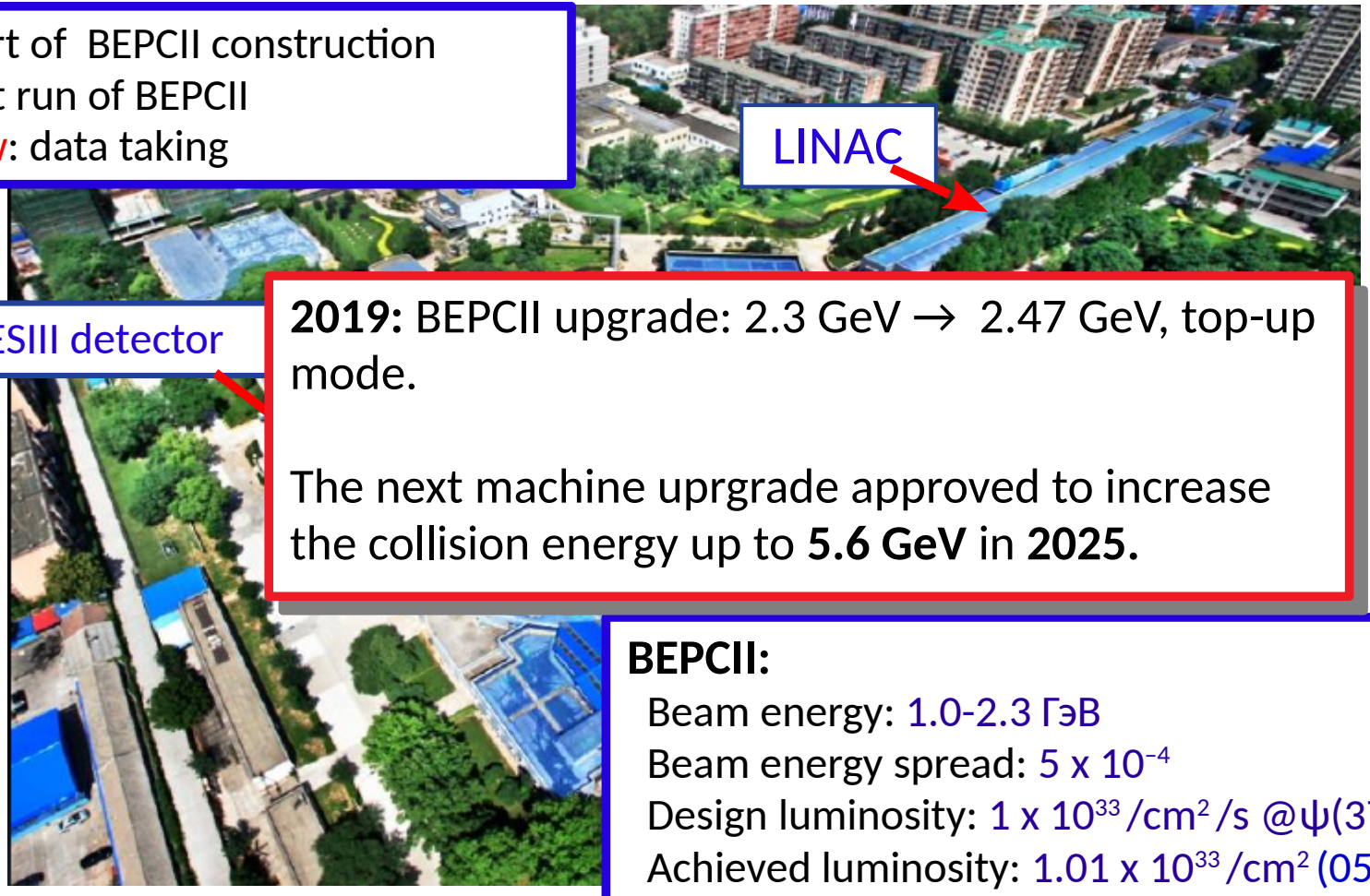

2019: BEPCII upgrade: 2.3 GeV → 2.47 GeV, top-up mode.

The next machine uprgrade approved to increase the collision energy up to **5.6 GeV** in **2025.**

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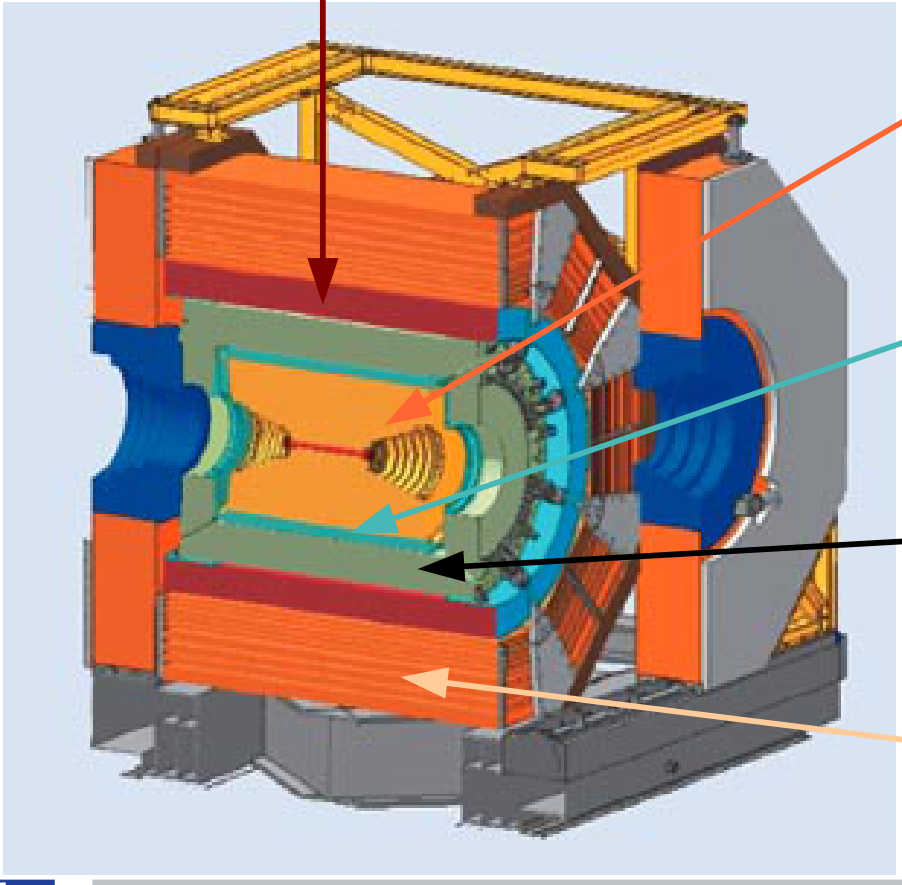
BESIII detector

Superconducting magnet: **1 T**

NIM A614, 345(2010)



MDC:
- Spatial resolution: σ_{xy} **= 120μm**
- Momentum resolution:**0.5% @ 1GeV**
- **dE/dx** resolution: 6%

TOF (double layer scintillator/MRPC):
Time resolution: **80ps** (barrel)
60ps (endcaps)

EMC: CsI cristal
- Energy resolution: **2.5% @1GeV**
- Spatial resolution: **6mm**

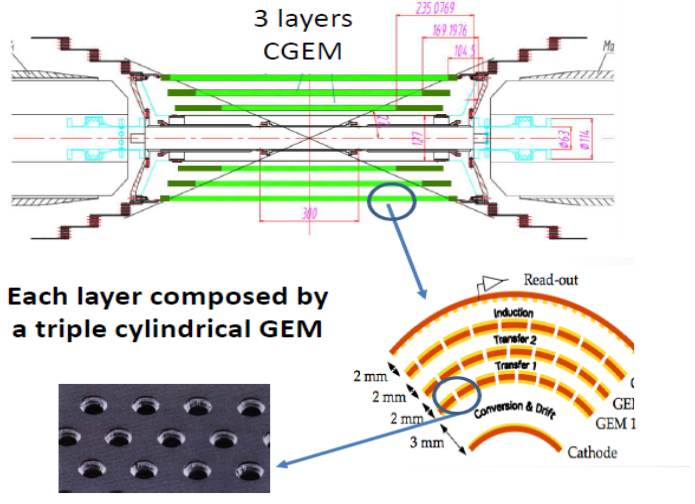
Muon ID:
9 layers RPC (8 for endcaps) in the flux-return yoke

BESIII upgrades (~~2019~~ 2023)

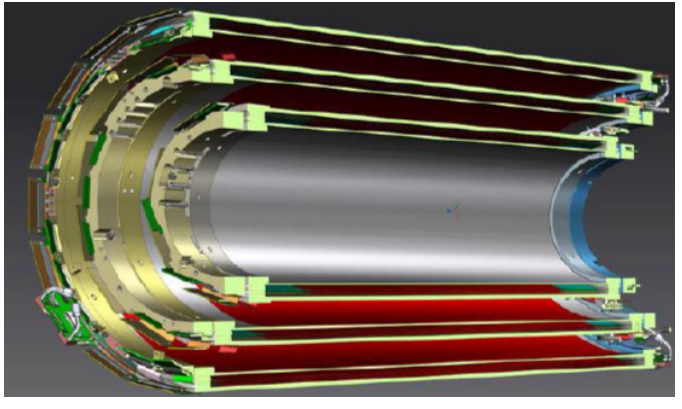
Inner part of the Main Drift Chamber suffers from aging

In summer ~~2019~~ 2023 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



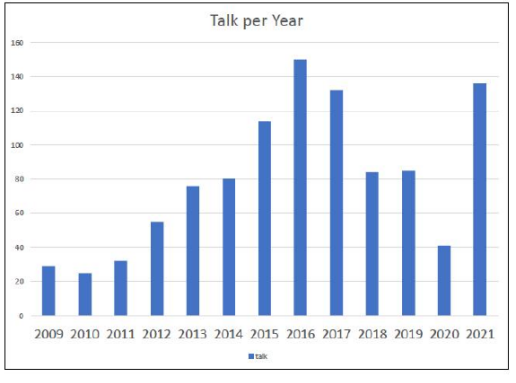
The BESIII Collaboration

The collaboration consists of more than 500 members from 17 countries.

Papers

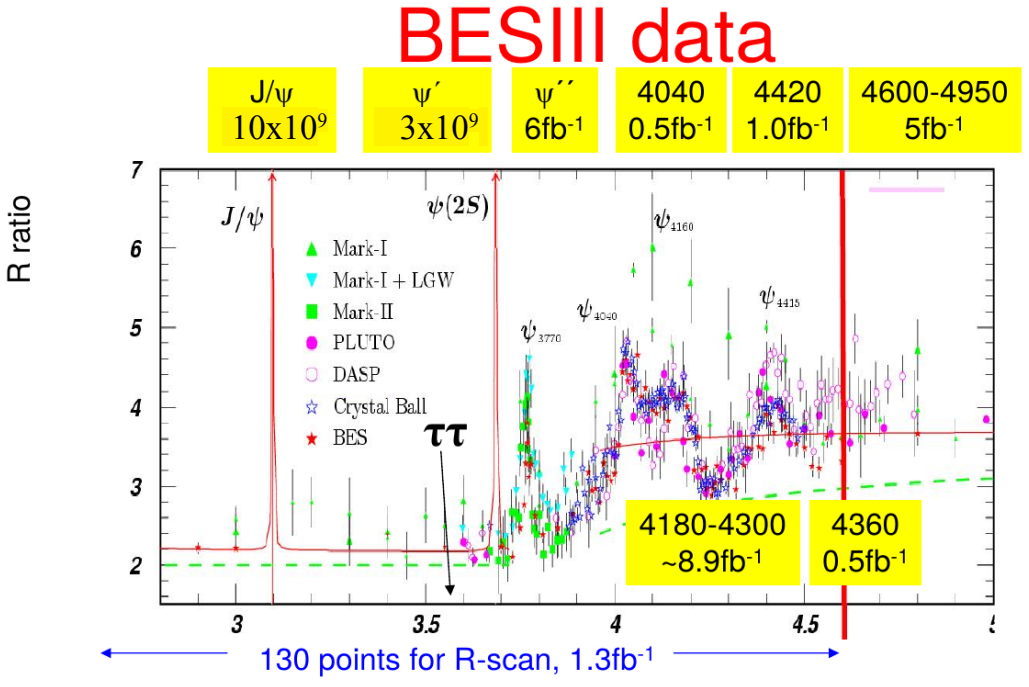
YEAR	CWR	EDITING	DONE	TOTAL
2022 (3/12 Mo.)	13	8	3	24
2021	1	3	74	78
2020	1	0	51	52
2019	0	0	45	45

Talks



Physics at BESIII

- Light hadron spectroscopy
- Charmonium physics and XYZ states
- Charm physics
- R values, QCD and τ physics
- Exotic decays and new physics



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

Physics at BESIII

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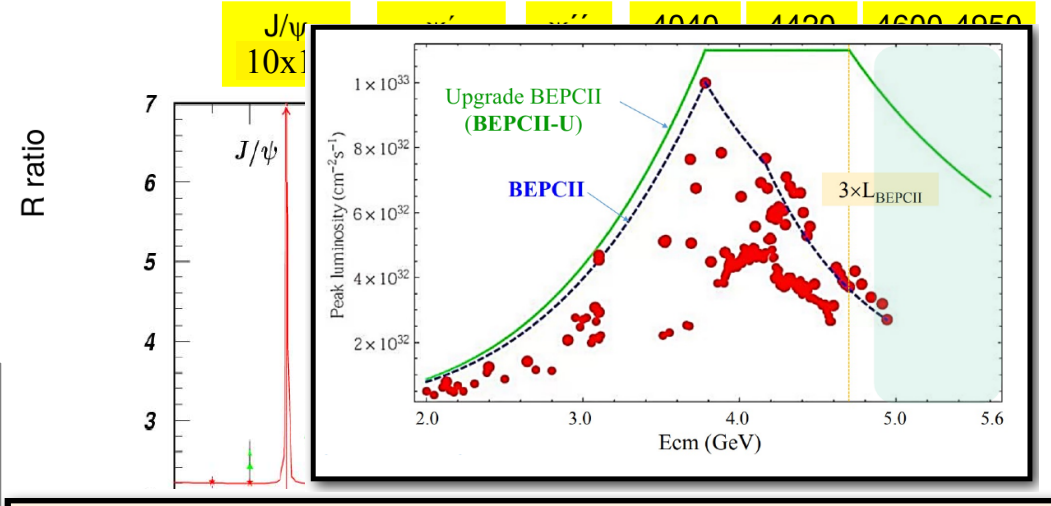
Future Physics Programme of BESIII

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

Published in Chinese Physics C **44**, 040001 (2020)

BESIII data



Physics Goals:

(1) Explore an unknown energy region.

(2) Access charm baryons at threshold.

$2 \times M(\Lambda_c^+) = 4572.9$ MeV

$2 \times M(\Sigma_c^{++,+,0}) = 4905.8 - 4907.9$ MeV

$2 \times M(\Xi_c^{+,0}) = 4935.4 - 4940.9$ MeV

$2 \times M(\Omega_c^0) = 5390.4$ MeV

JINR group at BESIII

- Light hadron spectroscopy
  - spectra of f_0 and f_2 mesons and search for scalar and tensor glueballs
  - properties of ρ-mesons in $e^+e^- \to \pi^+\pi^-\eta$
- Charmonium states
  - study of the production properties
- Phase difference between strong and EM phases in J/ψ decays
- Internal refereeing, RG
- Software and analysis tools development and maintenance
- Distributed computing
- Machine learning algorithms for track finding and vertex reconstruction

LNP: O. Bakina, I. Boyko, G. Chelkov, D. Dedovich, I. Denisenko, P. Egorov, A. Guskov, Yu. Nefedov, S. Pogodin, A. Zhemchugov

BLTP: V. Bytyev

LIT: V. Korenkov, G.A.Ososkov, I.Pelevanyuk

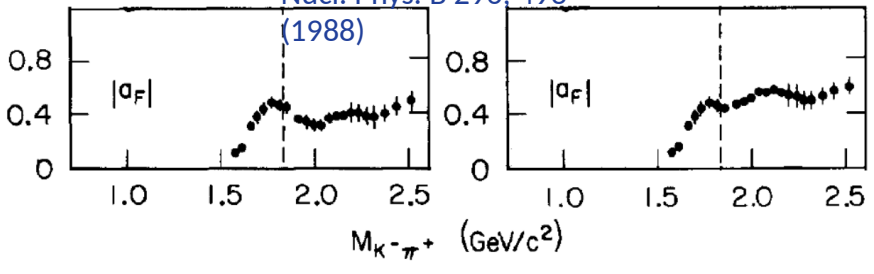
Partial wave analysis of $J/\psi \to K^+K^-\pi^0$ (PRD 100, 032004 (2019))

- Широкий вклад в $3^- K^\pm\pi^0$ 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

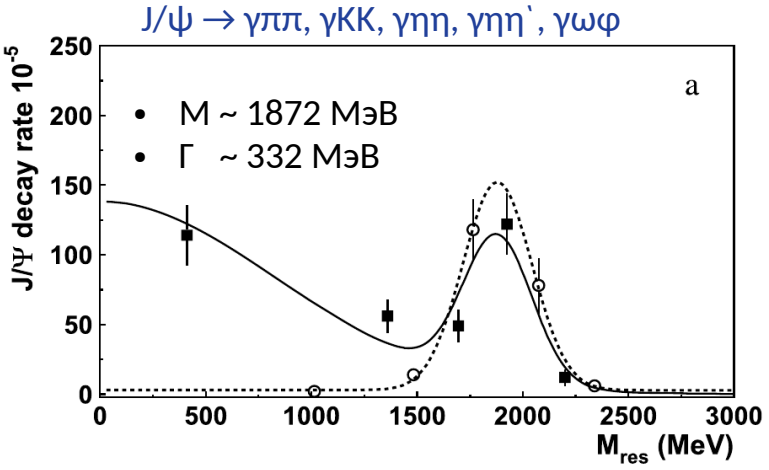
$K^\pm\pi^0$ channels						
J^{PC}	PDG	$M(\mathrm{MeV}/c^2)$	$\Gamma(\mathrm{MeV}/c^2)$	$b(\%)$	$b^{+(-)}(\%)$	ΔNLL
1^-	$K^*(892)^\pm$	$893.6\pm0.1^{+0.2}_{-0.3}$	$46.7\pm0.2^{+0.1}_{-0.2}$	$93.4\pm0.4^{+1.8}_{-5.8}$	$42.5\pm0.1^{+0.5}_{-1.7}$	–
1^-	$K^*(1410)^\pm$	1380*	176*	0.26 ± 0.04	0.11 ± 0.02	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

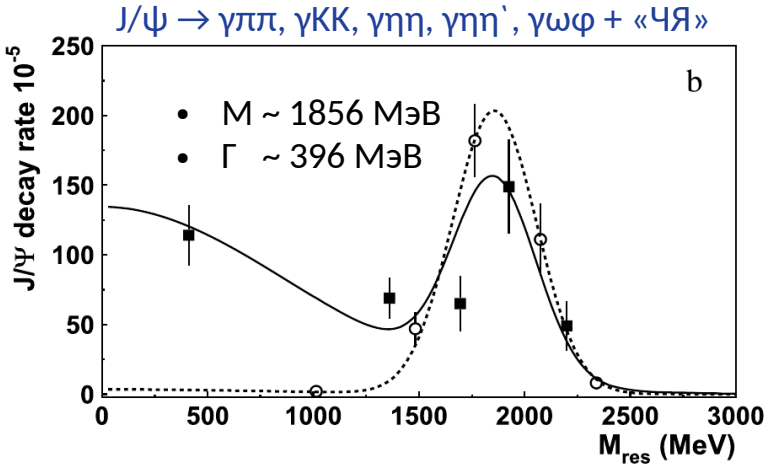
K^+K^- channel					
J^{PC}	PDG	$M(\mathrm{MeV}/c^2)$	$\Gamma(\mathrm{MeV}/c^2)$	b(%)	$\Delta \ln L$
1^{--}		$1651\pm3^{+16}_{-6}$	$194\pm8^{+15}_{-7}$	$1.83\pm0.11^{+0.19}_{-0.17}$	796
1^{--}		$2039\pm8^{+36}_{-18}$	$193\pm23^{+25}_{-27}$	$0.23\pm0.04^{+0.07}_{-0.06}$	102

Nucl. Phys. B 296, 493 (1988)



J/ψ → γPP: spectroscopy of f_0 mesons and scalar glueball (PLB 816, 136227 (2021))





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

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))

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

Ongoing work

- Cross-section measurement of the prompt inclusive $e^+e^- \to J/\psi X$ above 4.0 GeV
  - new recent data included, many analysis improvements, internal review stage
- Phase between strong and electromagnetic amplitudes in J/ψ decays
  - high precision results for $J/\psi \to \varphi\eta$ via $\psi(2S)$ decays, to be published separately
- Cross-section measurement of the light meson production in the energy range of 2-3 GeV and around the J/ψ peak
  - $e^+e^- \to \pi^+\pi^-\eta$ ($\eta \to \gamma\gamma$ and $\eta \to 3\pi^0$): BSc thesis, Dubna, 2020, MSc thesis expected this year
- Search for proton-antiproton bound state in the reaction $e^+e^- \to 2p2\bar{p}$
  - BSc thesis, Dubna

Conference talks

- I. Denisenko, “Light hadron spectroscopy at BESIII”, 19-th Lomonosov Conference on Elementary Particle Physics, Moscow, 22 - 28, August 2019.
- Ю. Нефедов, “Обзор эксперимента BESIII”, сессия-конференция СЯФ ОФН РАН, Новосибирск, март 2020.
- I. Denisenko, “Partial wave analysis of $J/\psi \to K^+K^-\pi^0$”, 9th International Conference on New Frontiers in Physics (ICNFP 2020), Crete, 4-12 October 2020.
- I. Denisenko, “Partial wave analysis of $J/\psi \to K^+K^-\pi^0$”, 5-th International Conference on Particle Physics and Astrophysics (ICPPA 2020), Moscow, 5-9 October 2020.
- I. Denisenko, “Partial wave analysis of $J/\psi \to K^+K^-\pi^0$”, XXIV International Scientific Conference of Young Scientists and Specialists (AYSS-2020), 9-13 November 2020.
- O. Bakina, poster “Proposal for the prompt inclusive J/ψ production measurement at future Super c-tau factories”, Workshop on future Super c-tau factories, 15-17 November 2021.
- O. Bakina, poster "Studies of charmonium decay from BESIII", 30th International Symposium on Lepton Photon Interactions at High Energies, 10-14 January 2022.

Qualification works

- S. Pogodin, “Search for proton-antiproton bound state in the reaction $e^+e^- \to 2p2\bar{p}$ in the BESIII experiment”, BSc thesis, Dubna, 2020.
- P. Egorov, “Measurement of the cross-section of $e^+e^- \to \eta\pi^+\pi^-$ in energy range 2.00 − 3.08 GeV”, BSc thesis, Dubna, 2020.
- I. Denisenko, “Light hadron spectroscopy and search for exotic states in the $J/\psi \to K^+K^-\pi^0$ decay and radiative J/ψ decays to two pseudoscalars”, PhD thesis, 2021.

Future plans (physics)

2023:

- Publication of the paper “Measurement of the branching fraction of J/ψ →φη”.
- Publication of the paper on the prompt J/ψ production in the collision energy range 3.81 – 4.70 GeV.
- Study of the $e^+e^- \rightarrow \pi^+\pi^-\eta$ reaction below J/ψ peak via ISR method.
- Preparation of the PhD thesis by O. Bakina.
- Feasibility study of probing fragmentation functions of c-quark from BESIII data.

2024:

- Final results on the phase shift measurement in $e^+e^- \rightarrow \varphi\eta$ and $e^+e^- \rightarrow \omega\eta$.
- Preliminary results from partial wave analysis of $J/\psi \rightarrow \gamma 4\pi^0$ decay.
- Studies of ψ(2S) radiative decays to two pseudoscalar mesons.
- Submission of the paper on $e^+e^- \rightarrow \pi^+\pi^-\eta$ reaction below J/ψ peak via ISR method.
- Measurement of inclusive J/ψ polarization in the energy range above 4 GeV.

2025:

- Incorporation of $J/\psi \rightarrow \gamma 4\pi^0$ decay and ψ(2S) decays to the global N/D fit. Publication of the results.
- Investigation of the inclusive η_c production.
- Publication on the results of c-quark fragmentation functions analysis from BESIII data (if feasible).

Software development

- Maintenance of the BESIII offline software and analysis tools.
- Distributed computing
- New R&D of algorithms for reconstruction of events using deep learning methods
  - Two new approaches to tracking using ML were developed in scope of the joint RFBR-NSFC project No. 19-57-53002
  - Existing well-established event reconstruction of the BESIII experiment based on classical algorithms allows to study the performance of ML algorithms, to investigate stability of these methods against noise and other data imperfections, and to elaborate methods for effective estimation of the systematic uncertainty connected with the use of the ML tools.
  - Will be useful not only for BESIII, but also for any other collider experiment including the ones of the NICA project.

Заявка на финансирование 2022-2025

Аналогично заявке на 2019-2021

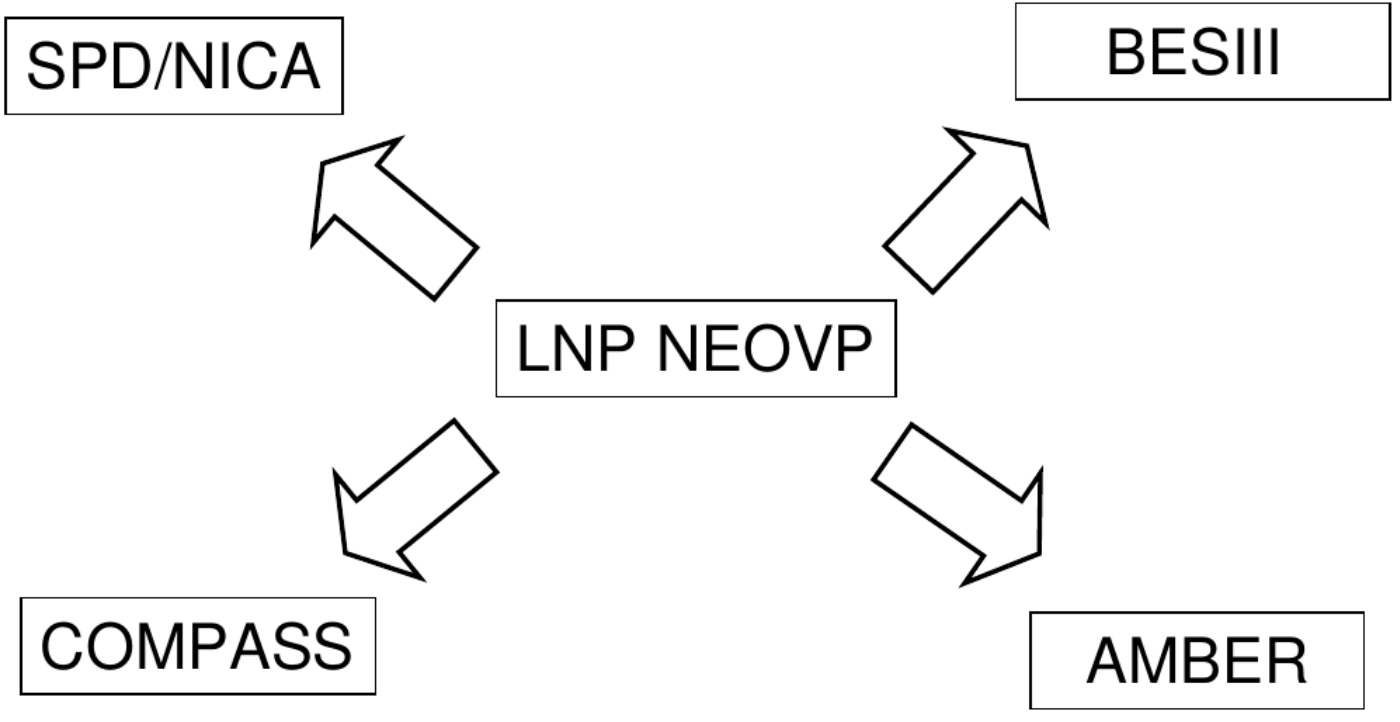
отличается от проекта

Источник	**Всего**	2023	2024	2025
Бюджет ОИЯИ (тема 1123)	**105**	25+10	25+10	25+10
Внебюджетные средства	**0**	0	0	0

Основные затраты – на командировочные расходы в КНР:

1) участие в сменах и обязательных технических работах
2) анализ данных, обсуждение и интерпретация результатов, подготовка публикаций
3) представление результатов на международных конференциях
4) аппаратное обеспечение для машинного обучения

QCD experiments in NEOVP



Спасибо!

Form #26

Form №26

Proposed Time-Schedule and Necessary Resources
for implementation of Project
Participation of JINR in the Physics Research Programme
at the BEPCII/BESIII

Parts and systems of set-up, resources and sources of financial support.	Cost of parts of set-up. Required financial support.	Profile proposed by Laboratory.		
Main parts and equipment (kUSD)				
		2023	**2024**	**2025**
Materials	–	–	–	–
Equipment	**30**	**10**	**10**	**10**
Travel costs	**75**	**25**	**25**	**25**
Necessary manpower support (man-hours)				
JINR Central workshop:	–	–	–	–
LNP: - workshop; - design bureau	–	–	–	–
Accelerator, Reactor	–	–	–	–
Computer	–	–	–	–
Maintenance & Operational	–	–	–	–
Sources of financial support (kUSD)				
JINR budget	105	35	35	35
Extra – budgetary (grants, agreements, sponsors etc.)	–	–	–	–

Form #29

Form №29

Financial Resources Needed for Project realization

Participation of JINR in the Physics Research Programme

at the BEPCII/BESIII

No	TASKS	Total value	2023	2024	2025
	Direct costs of the Project				
1	Accelerator, reactor	–	–	–	–
2	Computer	–	–	–	–
3	Materials	–	–	–	–
4	Equipment	30	10	10	10
5	R&D	–	–	–	–
7	Travel resources				
	a) in non-ruble area	66	22	22	22
	b) in ruble area	9	3	3	3
	Total direct cost:	**105**	**35**	**35**	**35**