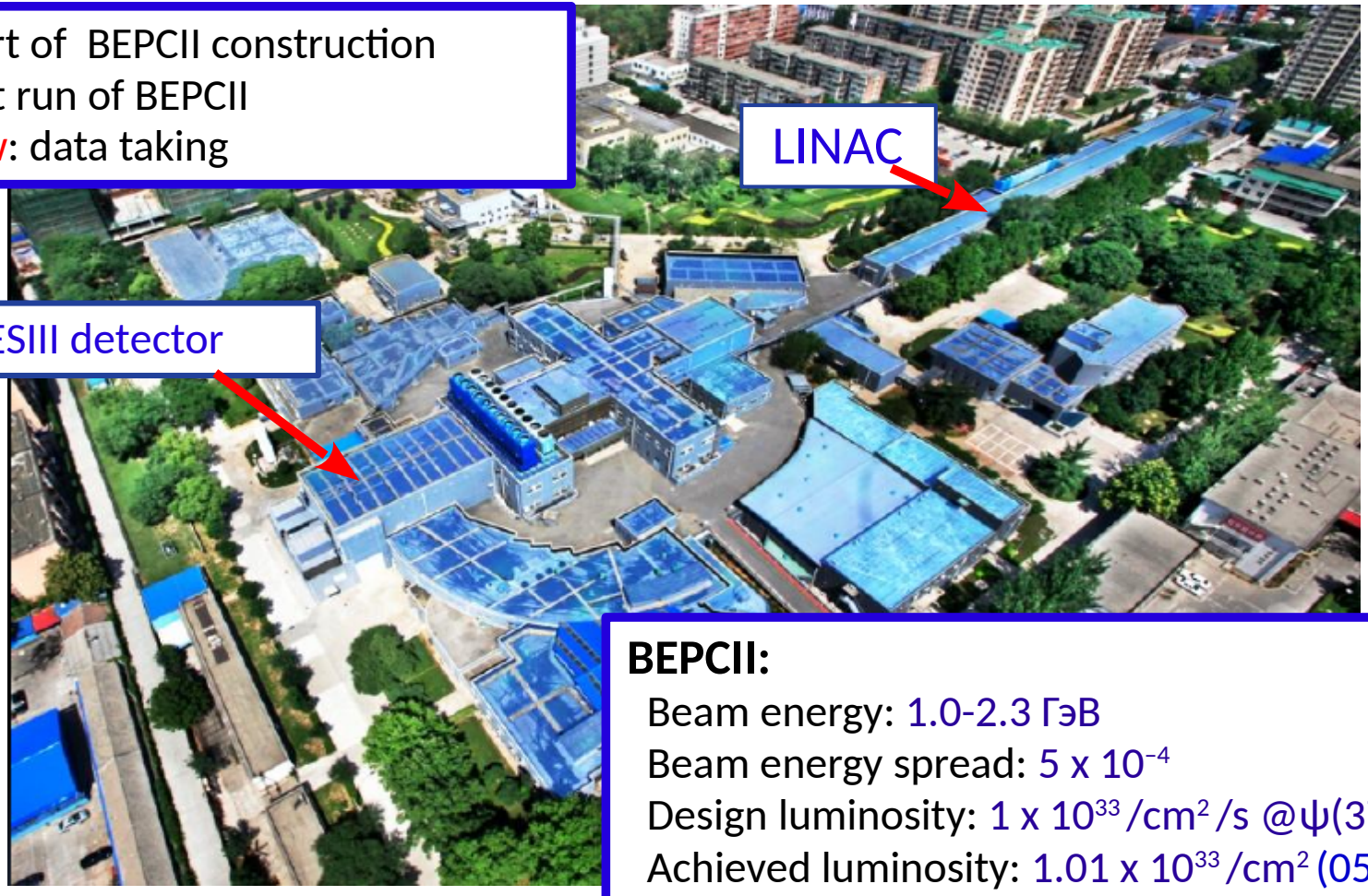
BESIII experiment and activities of the JINR BESIII group

Igor Denisenko

13.10.2022

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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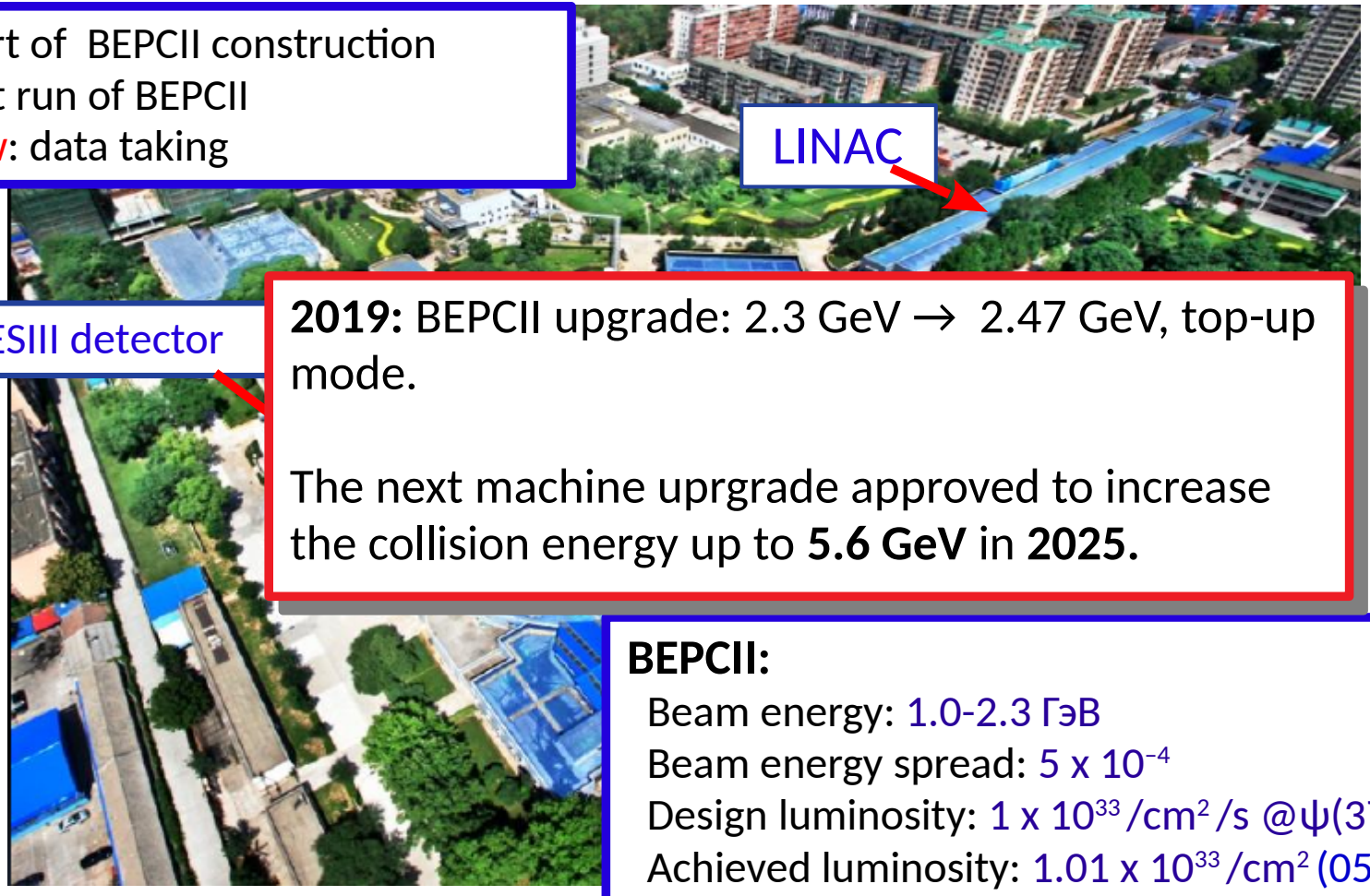

2019: BEPCII upgrade: 2.3 GeV → 2.47 GeV, top-up mode.

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

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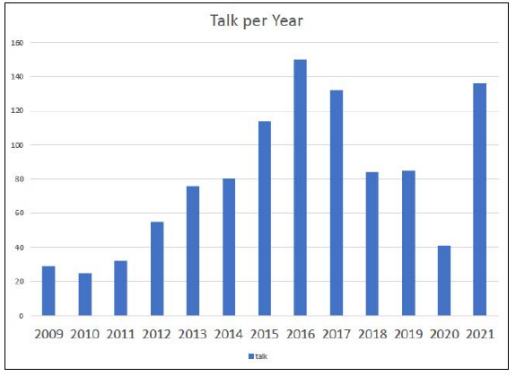
The BESIII Collaboration

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

Papers

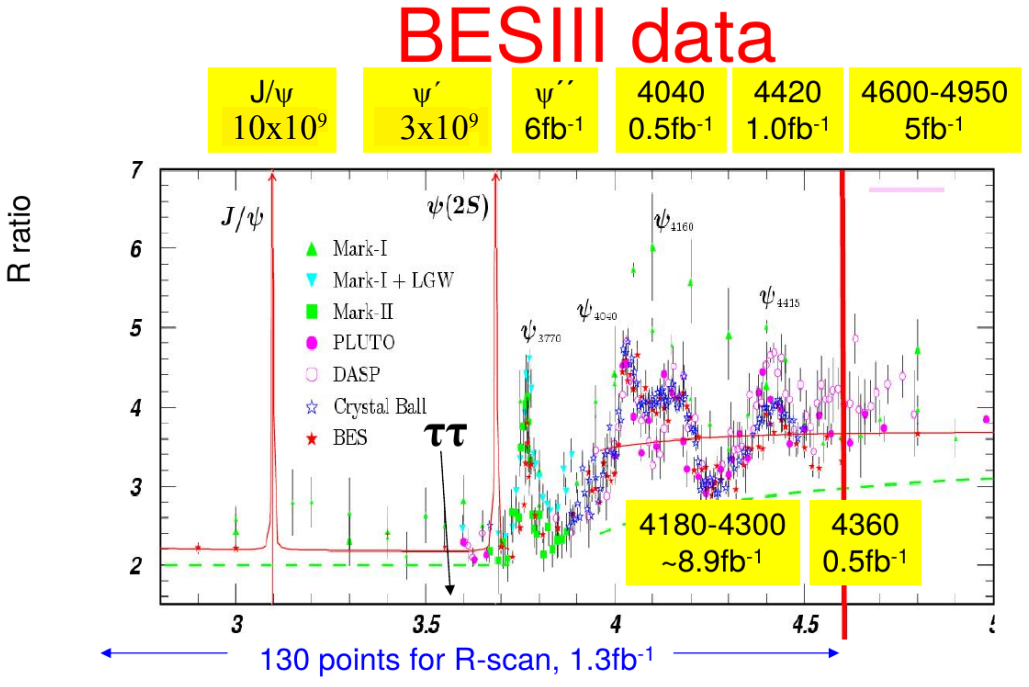
YEAR	CWR	EDITING	DONE	TOTAL
2022 (3/12 Mo.)	13	8	3	24
2021	1	3	74	78
2020	1	0	51	52
2019	0	0	45	45

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

- Light hadron spectroscopy
- Charmonium physics and XYZ states
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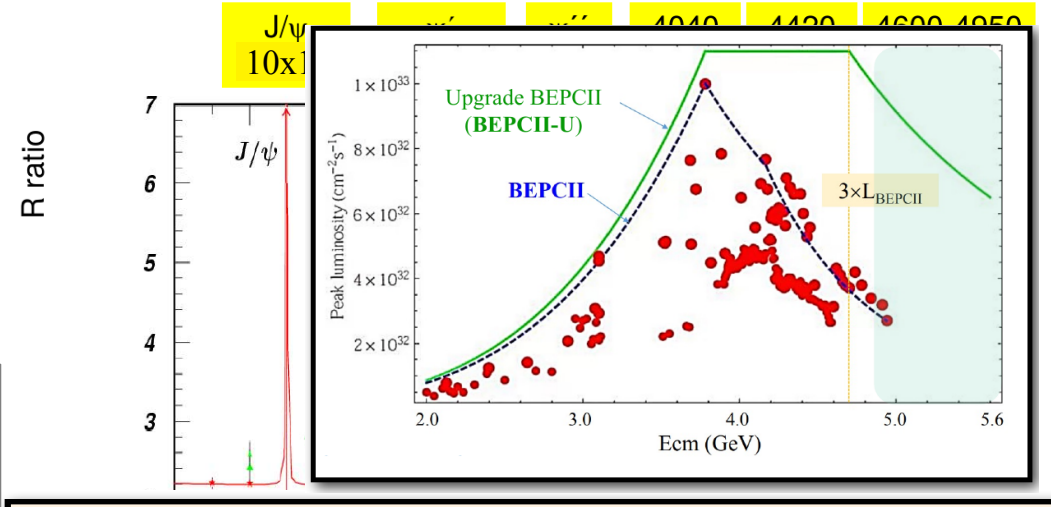
Future Physics Programme of BESIII

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

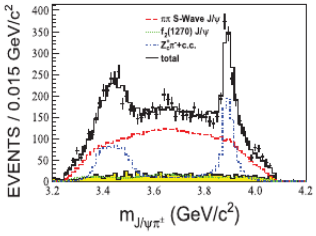
$2 \times M(\Omega_c^0) = 5390.4$ MeV

Highlights from BESIII

Charged charmonium-like states Z_c

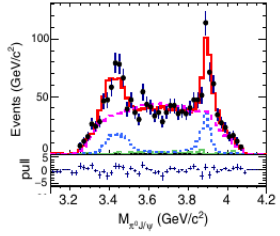
$e^+e^- \to \pi Z_c(3900)$

$e^+e^- \to \pi^\pm(\pi^\mp J/\psi)$



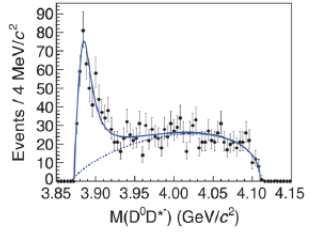
PRL 119, 072001 (2017)

$e^+e^- \to \pi^0(\pi^0 J/\psi)$



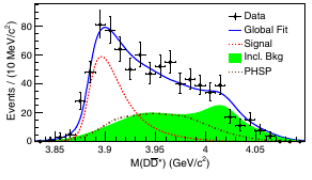
PRD 102, 012009 (2020)

$e^+e^- \to \pi^\pm(D\bar{D}^*)^\mp$



PRL 112, 022001 (2014)

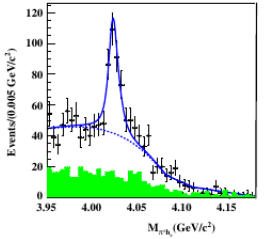
$e^+e^- \to \pi^0(D\bar{D}^*)^0$



PRL 115, 222002 (2015)

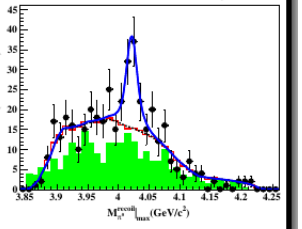
$e^+e^- \to \pi Z_c(4020)$

$e^+e^- \to \pi^\pm(\pi^\mp h_c)$



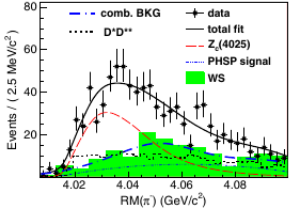
PRL 111, 242001 (2013)

$e^+e^- \to \pi^0(\pi^0 h_c)$



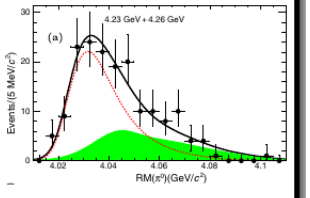
PRL 113, 212002 (2014)

$e^+e^- \to \pi^\pm(D^*\bar{D}^*)^\mp$



PRL 112, 132001 (2014)

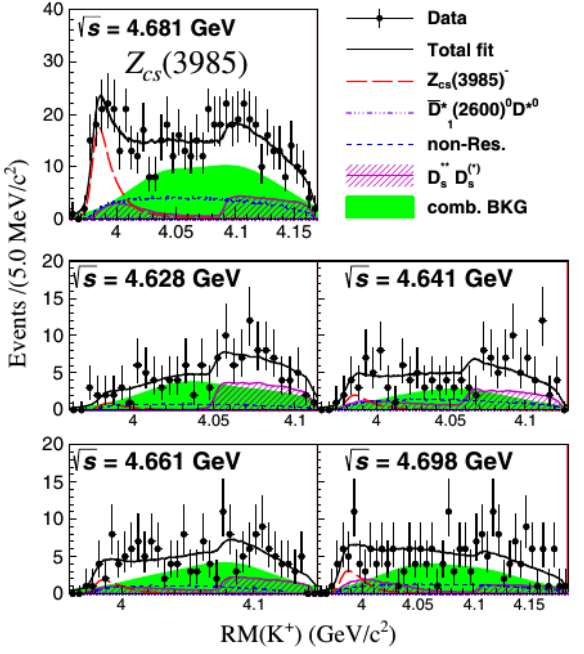
$e^+e^- \to \pi^0(D^*\bar{D}^*)^0$



PRL 115, 182002 (2015)

$e^+e^- \to K^+(D_s^- D^{*0} + D_s^{*-} D^0)$

PRL 126, 102001 (2021)



$$m_{\rm pole}[Z_{cs}(3985)^-] = (3982.5^{+1.8}_{-2.6} \pm 2.1)\ {\rm MeV}/c^2,$$
$$\Gamma_{\rm pole}[Z_{cs}(3985)^-] = (12.8^{+5.3}_{-4.4} \pm 3.0)\ {\rm MeV}.$$

Credit: R. Mitchel, 2021

Polarization and entanglement in baryon–antibaryon pair production in electron–positron annihilation

The BESIII Collaboration

Nature Physics **15**, 631–634 (2019) | Cite this article

Abstract

Particles directly produced at electron–positron colliders, such as the J/ψ meson, decay with relatively high probability into a baryon–antibaryon pair[1]. For spin-1/2 baryons, the pair can have the same or opposite helicites. A non-vanishing phase $\Delta\Phi$ between the transition amplitudes to these helicity states results in a transverse polarization of the baryons[2,3,4]. From the joint angular distribution of the decay products of the baryons, this phase as well as the parameters characterizing the baryon and the antibaryon decays can be determined. Here, we report the measurement of $\Delta\Phi = 42.4 \pm 0.6 \pm 0.5°$ using $\Lambda \to p\pi^-$ and $\bar{\Lambda} \to \bar{p}\pi^+$, $\bar{n}\pi^0$ decays at BESIII. We find a value for the $\Lambda \to p\pi^-$ decay parameter of $\alpha_- = 0.750 \pm 0.009 \pm 0.004$, 17 ± 3% higher than the current world average, which has been used as input for all Λ polarization measurements since 1978[5,6]. For $\bar{\Lambda} \to \bar{p}\pi^+$ we find $\alpha_+ = -0.758 \pm 0.010 \pm 0.007$, giving $A_{CP} = (\alpha_- + \alpha_+)/(\alpha_- - \alpha_+) = -0.006 \pm 0.012 \pm 0.007$, a precise direct test of charge–parity symmetry (CP) violation in Λ decays.

Oscillating features in the electromagnetic structure of the neutron

The BESIII Collaboration

Nature Physics **17**, 1200–1204 (2021) | Cite this article

Abstract

The complicated structure of the neutron cannot be calculated using first-principles calculations due to the large colour charge of quarks and the self-interaction of gluons. Its simplest structure observables are the electromagnetic form factors[1], which probe our understanding of the strong interaction. Until now, a small amount of data has been available for the determination of the neutron structure from the time-like kinematical range. Here we present measurements of the Born cross section of electron–positron annihilation reactions into a neutron and anti-neutron pair, and determine the neutron's effective form factor. The data were recorded with the BESIII experiment at centre-of-mass energies between 2.00 and 3.08 GeV using
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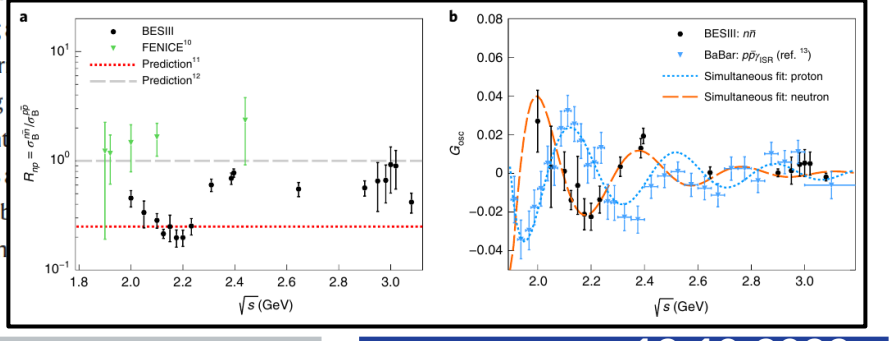

JINR group at BESIII (current activities)

Physics

- Light hadron spectroscopy
  - light meson spectroscopy and search for glueball states
- Charmonium states
  - study of the production properties
- decays R values, QCD and τ physics
  - phase difference between strong and EM phases in J/ψ
  - study of fragmentation functions
- Internal refereeing, RG

Software, computing, ML

- Software and analysis tools development and maintenance
- Distributed computing
- Machine learning algorithms for track finding and vertex reconstruction

Participants of the JINR BESIII project

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

NRC KI — PNPI: A. Sarantsev

JINR group provides no hardware contribution to the BESIII experiment!

Publications, Conference talks, Education

Publications (the last three years)

- BESIII physics and related
  - "Partial-Wave Analysis of $J/\psi \to K^+K^-\pi^0$", M. Ablikim et al., Phys.Rev.D 100 (2019) 3, 032004
  - "Scalar isoscalar mesons and the scalar glueball from radiative J/ψ decays", A.V. Sarantsev, I. Denisenko, U. Thoma, E. Klempt, Phys.Lett.B 816 (2021) 136227
  - "Search for the tensor glueball", E. Klempt, K.V. Nikonov, A.V. Sarantsev, I. Denisenko, Phys.Lett.B 830 (2022) 137171
- ML
  - "Tracking on the BESIII CGEM inner detector using deep learning", Computer Research and Modeling, 12 (2020), 1361
  - "Deep learning for track recognition in pixel and strip-based particle detectors", arXiv:2210.00599
  - proceedings

Conference talks (the last three years)

- 7 conference talks in the last three years
- a number of talks on ML

Qualification works

- 7 master theses
- 1 PhD thesis

Summary

- BESIII is a very successful experiment. It has been operating since 2009 and has collected unprecedentedly large data sets in the tau-charm energy region. More than 400 papers have been published.
- The collider upgrade has been approved and scheduled for 2025. The BESIII experiment will play the leading role in its physical domain at least until 2030.
- The JINR BESIII group contributes to physical analysis, maintaining software, and computing.
- A rich physics program and availability of unique data sets make it easy to extend the JINR's group involvement in physics studies (limited by manpower at the moment).
- Very interesting R&D on the use of ML for tracking is underway, using real BESIII data. It has a great potential for future collider experiments.
- Our participation in BESIII is crucial for training of young scientists.
- Some studies at BESIII are complimentary to specific tasks at SPD and Super C-Tau Factory project.

Thank you!