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METHODS OF PHYSICAL EXPERIMENT

Data Processing of FARICH Prototype Tests on "Electron Beam Facility" from VEPP-4M Complex

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Abstract—The SPD experiment for the NICA collider is currently under development. For efficient π- and K-mesons separation at the end-cap section of the SPD detector with a confidence level better than 3σ, a Cherenkov ring imaging detector system based on focusing aerogel (FARICH) is proposed. In the spring of 2025, new aerogel samples of multilayer monoblocks were synthesized. A prototype FARICH detector was tested on the electron beam of the VEPP-4M complex. This paper presents the results of testing the prototype with the new aerogel samples, and describes the data processing from the experiment.

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INTRODUCTION

The SPD (Spin Physics Detector) experiment for the NICA (Nuclotron-based Ion Collider fAcility) collider (Russia, Dubna, JINR) is currently under development. Its goal is to study the spin structure of nucleons in proton-proton and deuteron-deuteron collisions with momenta up to 27 GeV/c.

According to the preliminary estimates, which indicate that in the end-cap section of the detector, the momenta of π- and K-mesons can reach up to 6 GeV/c. For efficient particle identification with a confidence level better than 3σ (in terms of *StdDev*), a Cherenkov ring imaging detector system based on focusing aerogel (FARICH) is proposed [1].

Budker Institute of Nuclear Physics (Novosibirsk, Russia) is a member of SPD collaboration. It participates in the development of the universal particle detector. The FARICH system is being developed at BINP in collaboration with Institute of Catalysis SB RAS [2].

FARICH TECHNIQUE

RICH detector allows direct measurement of the speed of charged particles by measuring the Cherenkov angle:

$$\cos\theta_{\mathrm{Ch}} = \frac{1}{n\beta}.$$

The main contribution to the resulting error is made by uncertainty of emission point over all radiator thickness. In the FARICH technique every layer of the radiator has its own thickness with a different refractive index to create a pattern of overlapping circles on the photodetector. This allows for a decrease in the resulting error of the reconstructed angle. The scheme of FARICH is shown in Fig. 1.

NEW AEROGEL SAMPLES

In the spring of 2025, the Institute of Catalysis synthesized new aerogel samples (SiO_2), including multilayer monolithic radiators with a maximum refractive index below 1.04 (for the SPD experiment) with a thickness of about 40 mm (see Fig. 2).

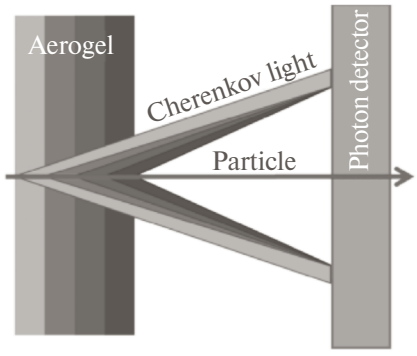


Fig. 1. A schematic diagram explaining the FARICH concept. n_i—radiator refractive index.

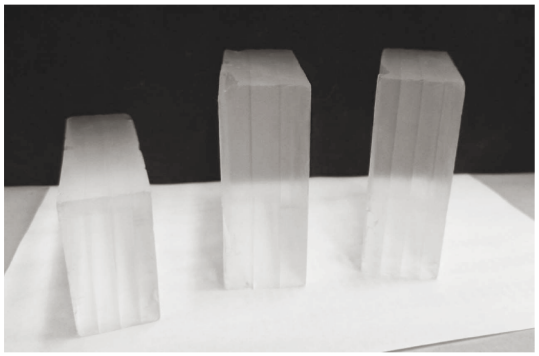


Fig. 2. New multilayer monolithic samples.

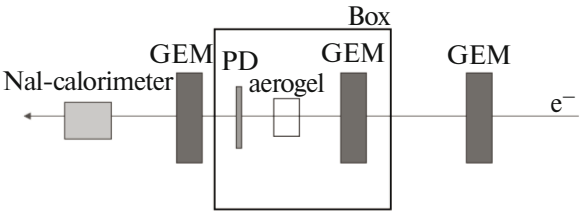


Fig. 3. The scheme of the experiment. GEM—gas electron multipliers are used as a tracking system with $\sigma_x, \sigma_y, \sim 50\,\mu m$; PD—photodetector; the Box is for light insulation; NaI-calorimeter is for measuring the electron energy.

e^--BEAM TESTS

A prototype of FARICH detector, assembled using these new radiators, was tested on the "electron beam" of the VEPP-4M complex [3]. The electron energy was 2.5 GeV (with fluctuations of about 3.0%). The tests were performed with new aerogel samples at various distances from the photodetector to the output surface of the radiator. As a photodetector an assembly of four PMTs H12700 made by Hamamatsu was used, each with an 8×8 array of 6×6 mm pixels. The tests with and without masks simulating a 3.4×3.4 mm pixel were also performed. The scheme of the experiments is shown in Fig. 3. In addition, tests were carried out with radiators at different distances from the photodetector.

PROCESSING AND RESULTS

Since there are plenty of scattered photons and PMT noise, which must be filtered out as they significantly degrade the quality of the determination of the $x0, y0, R$ of the rings. So, cuts based on data from the tracking system, timing information, and calorimeter data were applied. Also, during the tests, an induced signal was observed across the entire photosensitive area of the PMT (see Fig. 4), which was caused by electrons passing through the PMT. Thus, such events were rejected since the parasitic hits cannot be separated from Cherenkov photons via time information or amplitude analysis.

According to the processing of the monolithic 4-layer (see Fig. 5) with $n_{max} \le 1.04$, the $\langle R \rangle$ of the rings is $(55.90 \pm 0.01\,\text{mm})$ with a spatial resolution of about 2.6 mm without masks and 1.6 mm with the mask. Without the mask, the average number of photoelectrons $\langle N_{ph.e.} \rangle$ is 17; in the case with the mask, it is 3.3. Thus, the π/K-separation for the non-masked case is about 4.0σ at $P = 6$ GeV/c. A prototype based on the $3.4\times3.4\,\text{mm}^2$ pixel is expected to achieve a confidence level of about 5.5σ at $P = 6$ GeV/c. Additionally, a comparison between 3-layer and 4-layer

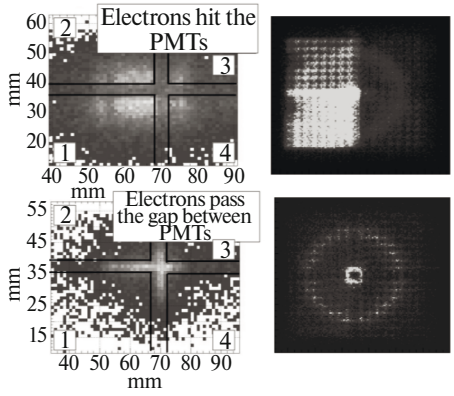


Fig. 4. The hitmap of the electrons at PD plane and the corresponding ring images. The numbers and lines describe the PMTs.

samples with the same $\langle n \rangle = 1.03$ and the mask is performed (see Fig. 6). Since the single photon resolution of both samples is almost equal (8.1 mrad against 7.0 mrad), the 3-layer option appears to be preferable due to its stability and simplicity of production. The same result was obtained in tests with a 6 mm pixel. The tests to check the focal length of the prototype with 3 and 4 layer samples were also carried out. The results for monolithic samples with the mask are shown in Fig. 6. The best resolution for both samples was obtained at a length of about 200 mm.

CONCLUSIONS

A FARICH prototype was assembled using newly synthesized samples of aerogel with $n_{max} \le 1.04$ and tested at the electron beam facility of VEPP-4M complex.

According to the processing, the PID capability of π/K-separation of FARICH for SPD is about 4.0σ at $P = 6$ GeV/c with a pixel 6.0×6.0 mm. Such results satisfy the requirements.

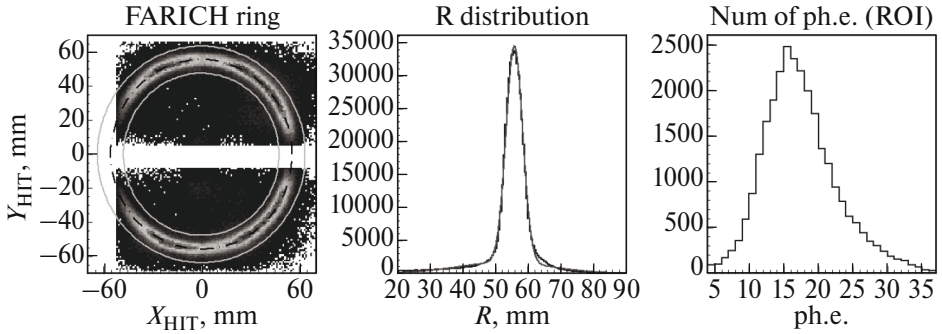


Fig. 5. The Cherenkov ring image from a 4-layer sample without the mask (left). Obtained R distribution (center) and fitted with a double gaussian function. The spectrum of the number of photoelectrons (right).

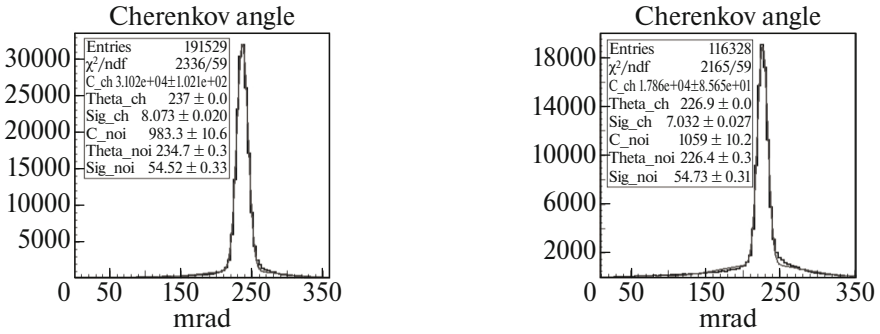


Fig. 6. The distributions of the reconstructed angles from 3-layer (left) and 4-layer sample (right). Parameter from approximation named "Sig_ch" is single photon resolution.

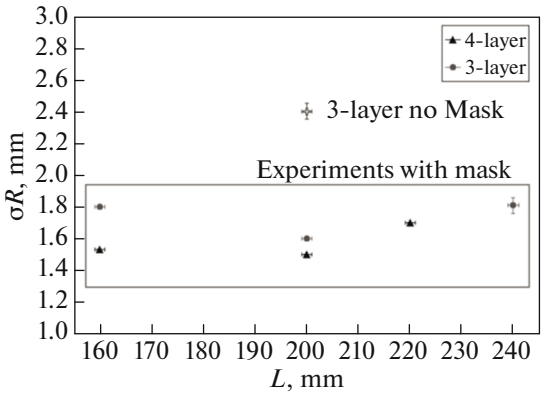


Fig. 7. Measurement of the spatial resolution of the prototype at different distances from the radiator to the photodetector.

A comparison between 3-layer and 4-layer monolithic samples was performed.

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CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

REFERENCES

1. V. Abazov et al. (SPD Collab.), "Technical design report of the spin physics detector at NICA," Natural Science Review **1**, 1 (2024). https://doi.org/10.54546/naturalscirev.100101
2. A. Yu. Barnyakov, M. Yu. Barnyakov, V. S. Bobrovnikov, A. R. Buzykaev, A. F. Danilyuk, V. L. Kirillov, S. A. Kononov, E. A. Kravchenko, and A. P. Onuchin, "Focusing aerogel RICH (FARICH)," Nucl. Instrum. Methods Phys. Res., Sect. A **553**, 70–75 (2005). https://doi.org/10.1016/j.nima.2005.08.073
3. G. N. Abramov, R. R. Ahmetshin, A. Yu. Barnyakov, V. E. Blinov, V. S. Bobrovnikov, A. R. Buzykaev, D. N. Grigoriev, V. F. Kazanine, E. A. Kravchenko, S. A. Kononov, V. N. Kudryavtsev, V. V. Kaminsky, L. I. Shekhtman, A. P. Onuchin, and V. N. Zhilich, "Measurement of the energy of electrons extracted from the VEPP-4M accelerator," J. Instrum. **11**, P03004 (2016). https://doi.org/10.1088/1748-0221/11/03/p03004

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