ISSN 1547-4771, Physics of Particles and Nuclei Letters, 2026, Vol. 23, No. 5, pp. 637–640. © Pleiades Publishing, Ltd., 2026.

METHODS
OF PHYSICAL EXPERIMENT

Reference Tracking System for Performance Studies of Small Straw Tracker Prototypes for the Future SPD Detector at the NICA Collider

M. Banchshikova[a, b, *], E. Kuznetsova[b, d], A. Lapkin[c], S. Romakhov[c], D. Sosnov[d], V. Bautin[c], K. Salamatin[c], T. Zholdybayev[b], and T. Enik[c]

[a] *Al-Farabi Kazakh National University, Almaty, 050040 Kazakhstan*

[b] *Institute of Nuclear Physics, Almaty, 050032 Kazakhstan*

[c] *Joint Institute of Nuclear Research, Dubna, Moscow oblast, 141980 Russia*

[d] *Konstantinov Petersburg Nuclear Physics Institute, National Research Centre "Kurchatov Institute," Gatchina, Leningrad oblast, 188300 Russia*

**e-mail: margaretbanshchicova@gmail.com*

Received December 5, 2025; revised March 20, 2026; accepted April 20, 2026

Abstract—This paper presents performance studies of small straw tracker prototypes developed for further application in SPD NICA. To evaluate straw tracker prototype performance, reference tracking and timing system was used. Data collected during a muon test beam campaign at the SPS H4 beam line was analyzed.

DOI: 10.1134/S1547477126700615

INTRODUCTION

The Spin Physics Detector (SPD) at the NICA collider aims to study the nucleon spin structure [1]. Spin asymmetry measurement program of the SPD requires precise charged-particle tracking.

In SPD a straw tracker will be used for precise tracking and optionally for particle identification at small track momenta [2]. Straw tracker is an attractive solution because it allows for high spatial resolution, signal uniformity and stable operation at high rates.

To assess performance of early stage tracker prototypes, test beam measurements are performed with a dedicated setup containing reference tracking and timing systems. This work presents analysis of simultaneous hits recorded by the reference tracking system, and study of the correlation between straw responses and reference tracks, serving as a basis for test beam data quality validation.

MATERIALS AND METHODS

The performance of straw tracker prototypes is evaluated using data collected during a muon test beam campaign at the SPS H4 beam line at CERN with the StrawTrackerRD setup. The setup is shown in Fig. 1.

The reference tracking system consists of Timepix4 [3] and MicroMegas (MM) detectors. Most of the MicroMegas detectors (MM0, MM2, MM3, MM4) measured coordinates along X-axis, while MM5 measured both the X and Y-axis coordinates. The active area of MM 0, 2, 3 is 3×3 cm^2, the strip pitch is 250 μm; MM4 and MM5 have a larger readout area of 10×10 cm^2, and the strip pitch of 400 um. Timepix4, a silicon pixel detector, with 448×512 pixels of 55×55 μm, was also used as a reference tracker.

Two scintillators provided muon timing, allowing reconstruction of the ionization electron drift time in the straw, and thus reconstruction of track coordinates with the straw tracker. Two prototypes were studied: one with 10 mm straws, another with 5, 10, and 20 mm straws.

RESULTS AND DISCUSSION

When a charged particle crosses silicon sensor of Timepix4, it induces signal in several pixels. Besides those pixels, Timepix4 received four external signals from scintillators 0 and 3, from the scintillator coincidence and from the straw readout system STM-VMM.

For each event, clusters of silicon pixels were identified. The spatial distribution of 10^5 clusters recorded by Timepix is shown in Fig. 2.

In the distribution above, clusters with high occupancy can be clearly distinguished, four of them correspond to the mentioned above external inputs. The distribution of the number of hits per cluster, Fig. 3, was obtained.

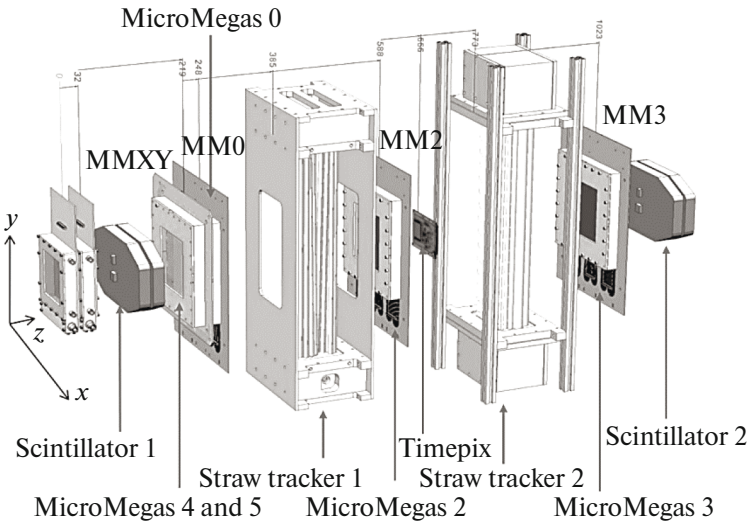


Fig. 1. StrawTrackerRD setup construction.

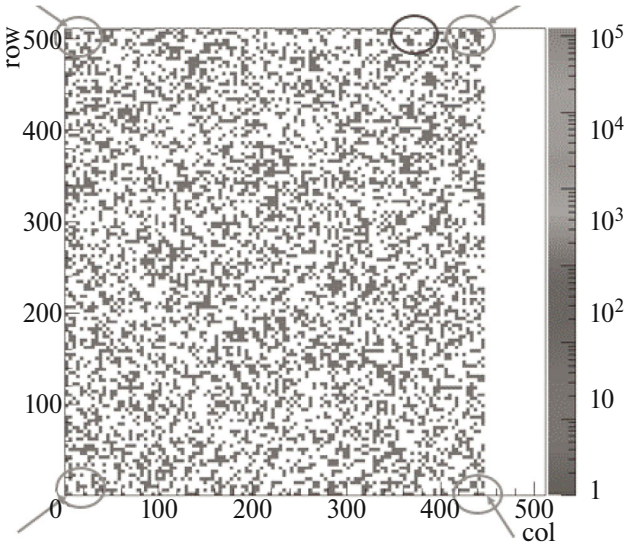


Fig. 2. 2D cluster position distribution.

For Micromegas, the number of detectors that have at least one hit in a given event was studied. The corresponding distribution is shown in Fig. 4.

Also the active Micromegas detector ID distribution is shown in Fig. 5. MM1 was not used in this data taking.

According to this distribution, MM4 and MM5 have more entries. It is in agreement with the fact that those MicroMegas detectors have larger readout area.

Correlations between hit coordinates measured with different Micromegas in a given event are shown in Fig. 6. For MM 0, 2, 3 only part of active area was readout due to a lack of readout electronics.

The correlation between two detectors helps assess data quality. The cluster coordinates show a linear relation, indicating proper alignment except for MM0, which seems to have a slight shift out of the center.

Merged ST-VMM and Timepix data were used to correlate straw signal time with the Timepix cluster coordinate, resulting in the RT curve for a single straw shown in Fig. 7.

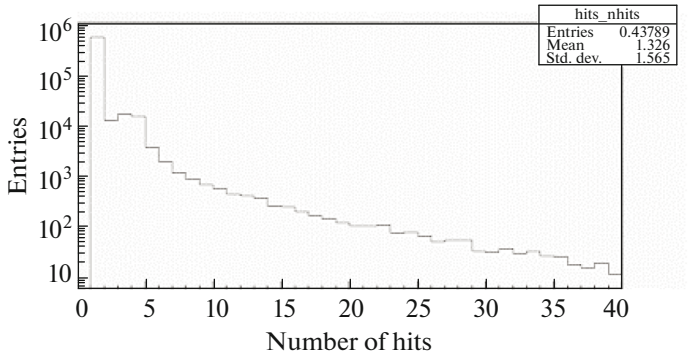


Fig. 3. Number of hits per cluster.

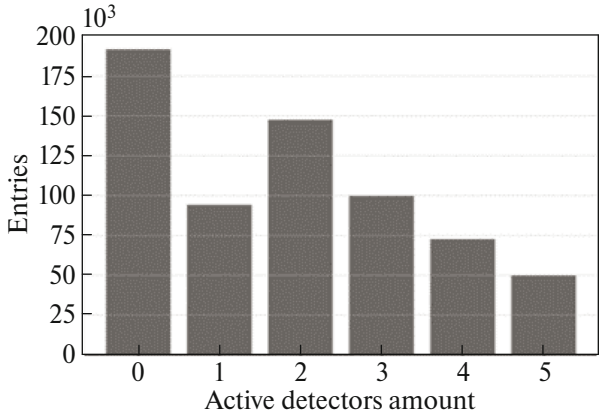


Fig. 4. The number of MicroMegas detectors with at least one hit in a muon event.

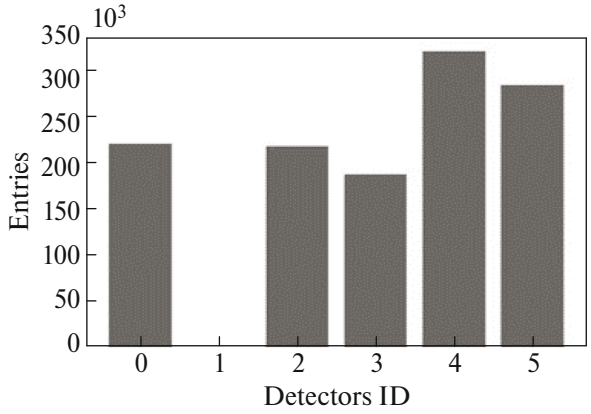


Fig. 5. MM detector ID distribution.

Timepix coordinate system is used for track position measurements, so the straw center is around 7 mm. The U-shaped dependence reflects that the drift time decreases when particle track is near the anode wire and increases when it is farther away.

CONCLUSIONS

Several data quality checks have been done during the test beam data taking. The 2D Timepix occupancy distribution enabled identification and masking of noisy channels. MicroMegas correlation and ID plots were used to assess alignment of the reference tracker. A preliminary RT curve was obtained for a single straw using merged Timepix and straw data, with further analysis ongoing using the complete reference tracking. These results emphasize the key role of reference tracking in calibrating and validating Straw Tracker prototypes for future application in SPD NICA.

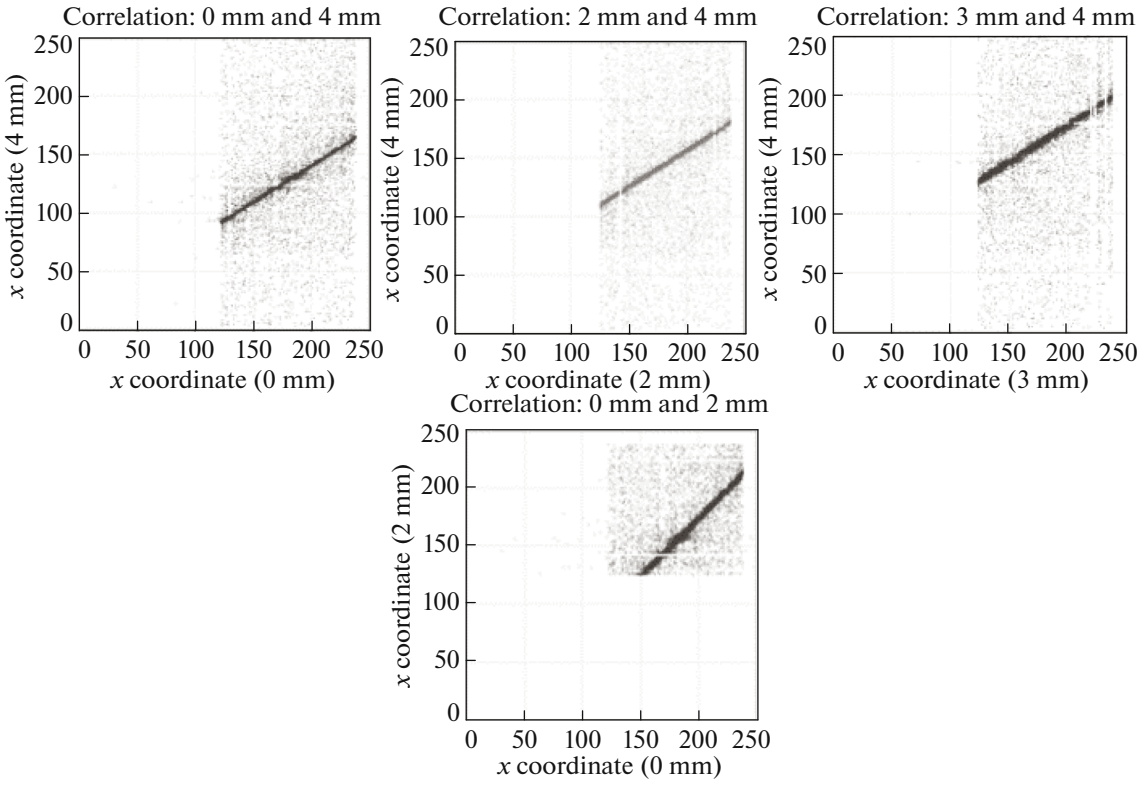


Fig. 6. Correlations between different MM.

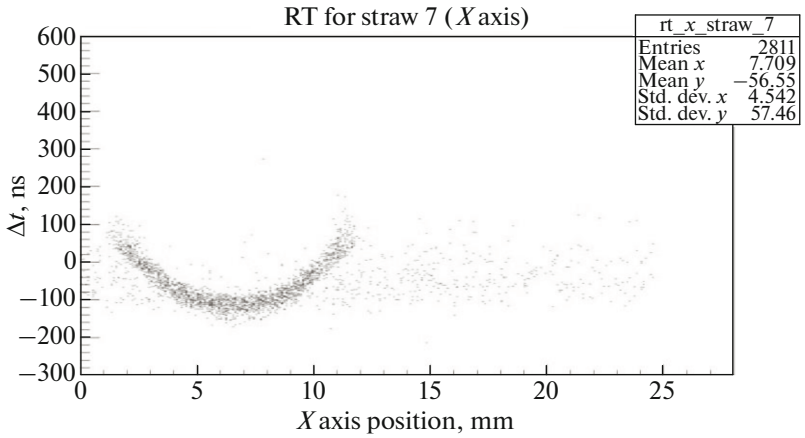


Fig. 7. RT-curve for a single straw.

FUNDING

This work was supported by ongoing institutional funding. No additional grants to carry out or direct this particular research were obtained.

CONFLICT OF INTEREST

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

REFERENCES

1. G. Trubnikov, A. Butenko, V. Golovatyuk, A. Guskov, M. Kapishin, V. Kekelidze, R. Lednicky, I. Meshkov, and A. Sorin, "NICA heavy-ion collider at JINR (Dubna). Status of accelerator complex and first physics at NICA.," J. Phys.: Conf. Ser. **2586**, 012013 (2023). https://doi.org/10.1088/1742-6596/2586/1/012013
2. E. Mosolova and E. Kuznetsova, "Implementation of the straw tracker realistic simulation and straw hit reconstruction in SPDroot package," J. Phys.: Conf. Ser. **3089**, 012004 (2025). https://doi.org/10.1088/1742-6596/3089/1/012004
3. X. Llopart, J. Alozy, R. Ballabriga, M. Campbell, R. Casanova, V. Gromov, E. H. M. Heijne, T. Poikela, E. Santin, V. Sriskaran, L. Tlustos, and A. Vitkovskiy, "Timepix4, a large area pixel detector readout chip which can be tiled on 4 sides providing sub-200 ps timestamp binning," J. Instrum. **17**, C01044 (2022). https://doi.org/10.1088/1748-0221/17/01/c01044

Publisher's Note. Pleiades Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.
AI tools may have been used in the translation or editing of this article.