Status of Spin Physics Detector at NICA

Alexandr Gribowsky on behalf of the SPD collaboration,
Joint Institute for Nuclear Research, Dubna, Russia
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Introduction

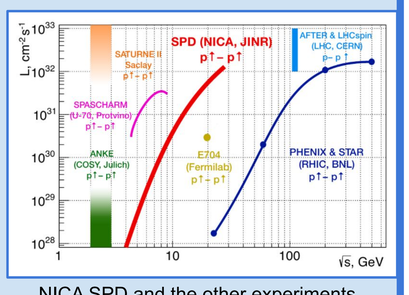
The **S**pin **P**hysics **D**etector (SPD) [1][2] is one of the two large experimental facility at the NICA collider under construction at JINR (Dubna). The collaboration includes 300 scientists from 23 institutes from 10 countries and individual contributors.

The goal of the studies at SPD is measurement of different spin observables in polarized *p–p*, d–d and p–d collisions sensitive to the polarized gluonic structure of the nucleon.

Beginning of data taking for SPD after 2025.

Physics program includes:

- probe gluon distributions in production of charmonia, open charm and prompt photons [3];
- spin effects in elastic scattering and hyperon production, study of multiquark correlation, dibaryon resonances, exclusive reactions, open charm and charmonia near threshold [4].



NICA SPD and the other experiments with polarized protons

NICA accelerator complex

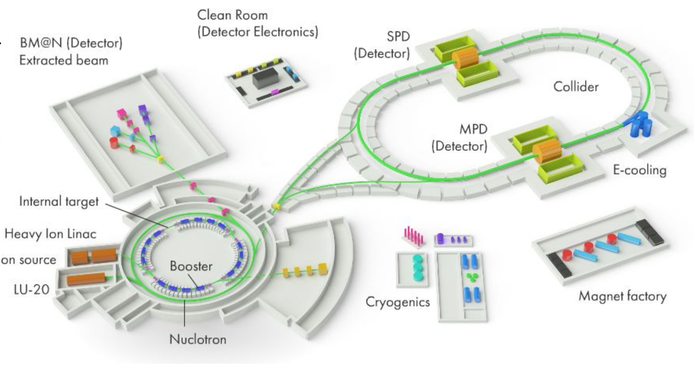
NICA (**N**uclotron-based **I**on **C**ollider F**a**cility) is a new accelerator complex designed at the Joint Institute for Nuclear Research (Dubna, Russia) to study properties of dense baryonic matter and problems of nucleon spin [5].

NICA includes: injection complex, new superconducting Booster synchrotron, the existing superconducting heavy ion synchrotron Nuclotron, collider having two new superconducting storage rings, new beam transfer channels.

The collider orbit length is 503 m. The beam will be divided into 22 bunches, each 60 cm long. The bunch crossing and interacting rates are 12.5 MHz and 3 MHz, respectively.

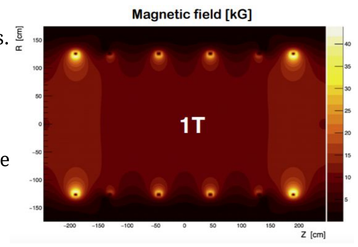
Protons and deuterons with longitudinal and transverse polarization in the energy range up to $\sqrt{s_{NN}}$ = 27 GeV and $\sqrt{s_{NN}}$ = 12.6 GeV, respectively, with luminosities up to 10^{32} cm^{-2}s^{-1} for protons.

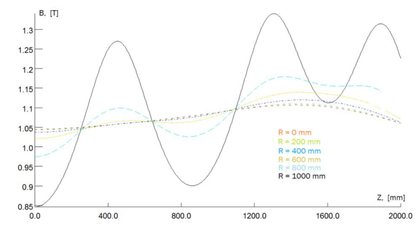
Heavy ions (up to gold) in the energy range up to $\sqrt{s_{NN}}$ = 11 GeV (for Au^{+79}, in the nucleon-nucleon CMS) at the collider, with an average luminosity of 10^{27} cm^{-2}s^{-1}.

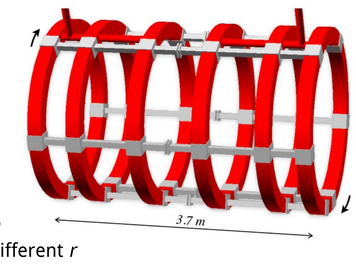


Magnetic system

- System of 6 isolated superconductive coils.
- Every coil consists of 60 turns of NbTiCu cable with the 10 kA current.
- The amount of material depends on the necessary ampere-turns of the coil and the achievable current density.
- The longitudinal variation of an axial magnetic field is varied from 5% to 12%.







Field calculation results: B_z as function of z at different r

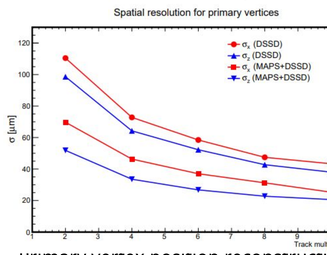
Vertex detector

Vertex spatial resolution < 100 μm.

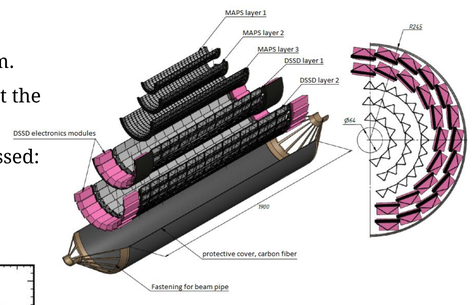
Primary purpose is to reconstruct the D meson decay vertices.

Two different versions are discussed:

- 5 DSSD layers;
- 3 MAPS and 2 DSSD layers.



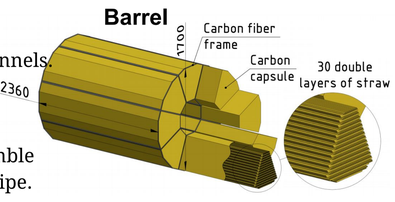
Primary vertex position reconstruction for two configurations

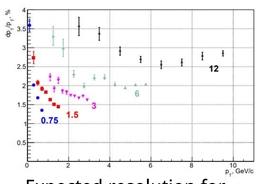


- Double Side Silicon Detector (**DSSD**), orthogonal strips, pitch 95 μm - 281 μm.
- Monolithic Active Pixel Sensors (**MAPS**), pixel size 29 μm × 27 μm.

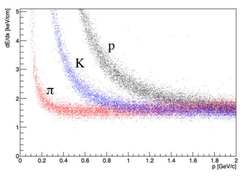
Straw tracker

- Main tracker with about 50k readout channels.
- Energy deposition registration opens possibility to particle identification.
- The design provides a possibility to assemble the tracker in the presence of the beam pipe.
- Spatial resolution is expected to be 150 μm and the drift time is about 120 ns for tubes of 1 cm diameter.

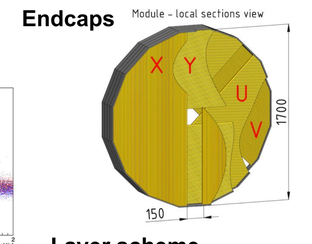




Expected resolution for the p_t of muons with various momenta



Particle identification using dE/dX measurements



Electromagnetic calorimeter

- 4π acceptance with projective geometry.
- Sampling structure with 200 layers of a 1.5 mm scintillator and 0.5 mm lead with Moliere radius of 2.4 cm.
- Radiation length 18.6X_0 and 20.4X_0 for barrel and endcaps, respectively.
- Energy resolution at 1 GeV is estimated to be 5%.
- Time resolution is 175ps in the energy range of 50÷1550 MeV.

Electromagnetic calorimeter module prototype

Range (muon) system

- '2 in 1' function – filtering of muons and rough estimate of hadronic energy (due to its sampling structure).
- 4 nuclear interaction lengths provide uniform muon filtering in all directions.
- Mini Drift Tubes (MDT) provide two-coordinate readout with wires and strips running perpendicularly.

- Muon identification is performed via muonic pattern recognition.
- Neutron identification is performed by combining range system signals with the electromagnetic calorimeter and the inner trackers.

Signals patterns for different particles

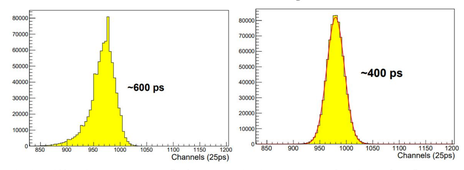
Beam-beam counter

Functions:

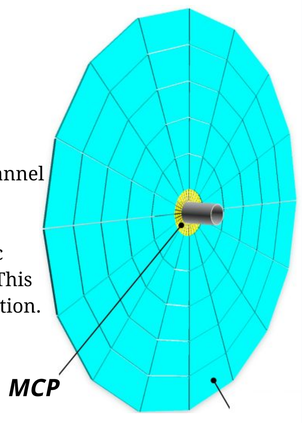
- measurement of the azimuthal asymmetries;
- monitoring of beam collisions;
- precise determination of the collision time t_0.

The detector should consist of two parts:

- the inner part will use fast segmented MicroChannel Plate (MCP) detectors and will operate in high vacuum;
- the outer part will be produced from fast plastic scintillator tiles with time resolution of 400 ps. This resolution was obtained using time-walk correction.

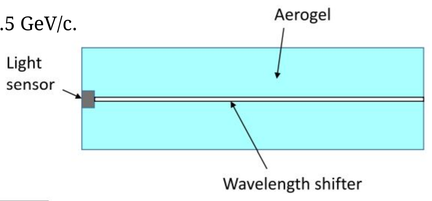


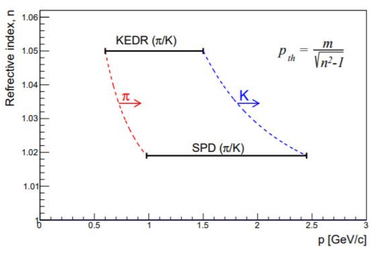
Scintillation part of the BBC time resolution before *(left)* and after *(right)* time-walk correction



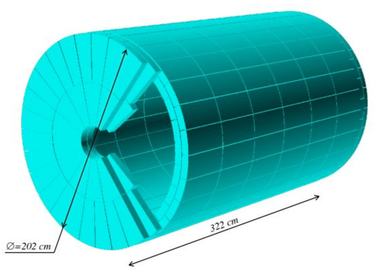
Aerogel Cherenkov counters

- π/K separation between 1 and 2.5 GeV/c.
- Up to 6 photoelectrons (with 2 photoelectrons threshold).
- detection efficiency 99.3±0.1%.





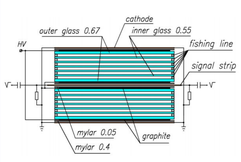
Momentum intervals where the π/K separation is possible.

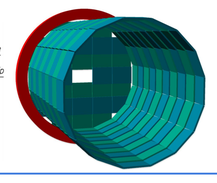


Time-of-flight system

TOF based on multigap timing resistive plate chamber

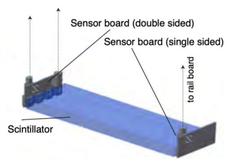
- Widely used in JINR experiments.
- Fixed size of modules.

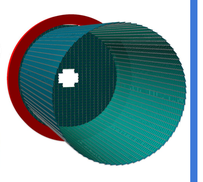




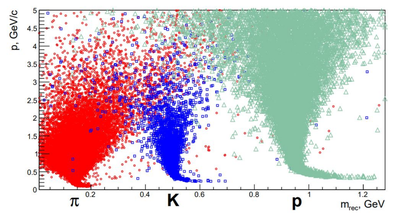
Scintillator-based TOF

- Easier to assemble.
- Two times more readout channels.
- require a detailed R&D.



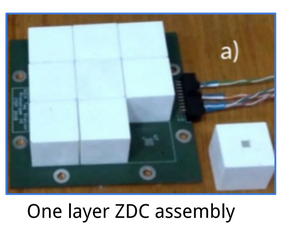


- Withstand charge particle rate 0.1 kHz/cm^2 for barrel and 1 kHz/cm^2 for endcaps near beam axis.
- Time resolution about 60 ps.
- π/K separation up to 1.5 GeV/c.
- Minimum flight distance 1 m.

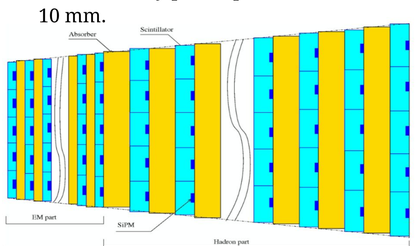


Zero-degree calorimeter

- time resolution 150÷200 ps.
- energy resolution for neutrons 50÷60%/ √ E ⊕8÷10%.
- neutron entry point spatial resolution 10 mm.



One layer ZDC assembly

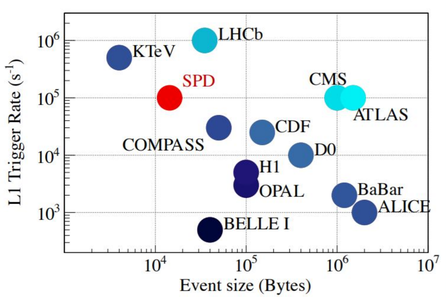


Main goals:

- luminosity measurement;
- local polarimetry with forward neutrons;
- spectator neutron tagging;
- time tagging of the events for event selection.

Data acquisition system and computing

- No hardware trigger to avoid possible biases
- Minimal dead time due to DAQ operating in a triggerless mode.
- Fast reconstruction of the SPD events and suppression of the background ones at least by a factor of 50.
- Expected raw data stream 20 GB/s or 200 PB/year
- Online filter to reduce data by oder of magnitude ~10 PB/year



References

[1] V. Abazov et al., Conceptual design of the Spin Physics Detector, arXiv:2102.00442.

[2] SPD collaboration website http://spd.jinr.ru/.

[3] A. Arbuzov et al, On the physics potential to study the gluon content of proton and deuteron at NICA SPD, Progress in Particle and Nuclear Physics 119 (2021) 103858, arXiv:2011.15005.

[4] V. Abramov et al, Possible studies at the first stage of the NICA collider operation with polarized and unpolarized proton and deuteron beams, arXiv:2102.08477.

[5] NICA project website http://nica.jinr.ru.

Contact e-mail: grias1994@gmail.com