

The 8-th International Conference on Particle Physics and Astrophysics (ICPPA-2026)
27-30 October 2026, Moscow, Russia

SPRINT project at NICA

V.P. Ladygin on behalf of SPRINT@NICA group

SPRINT@NICA mission

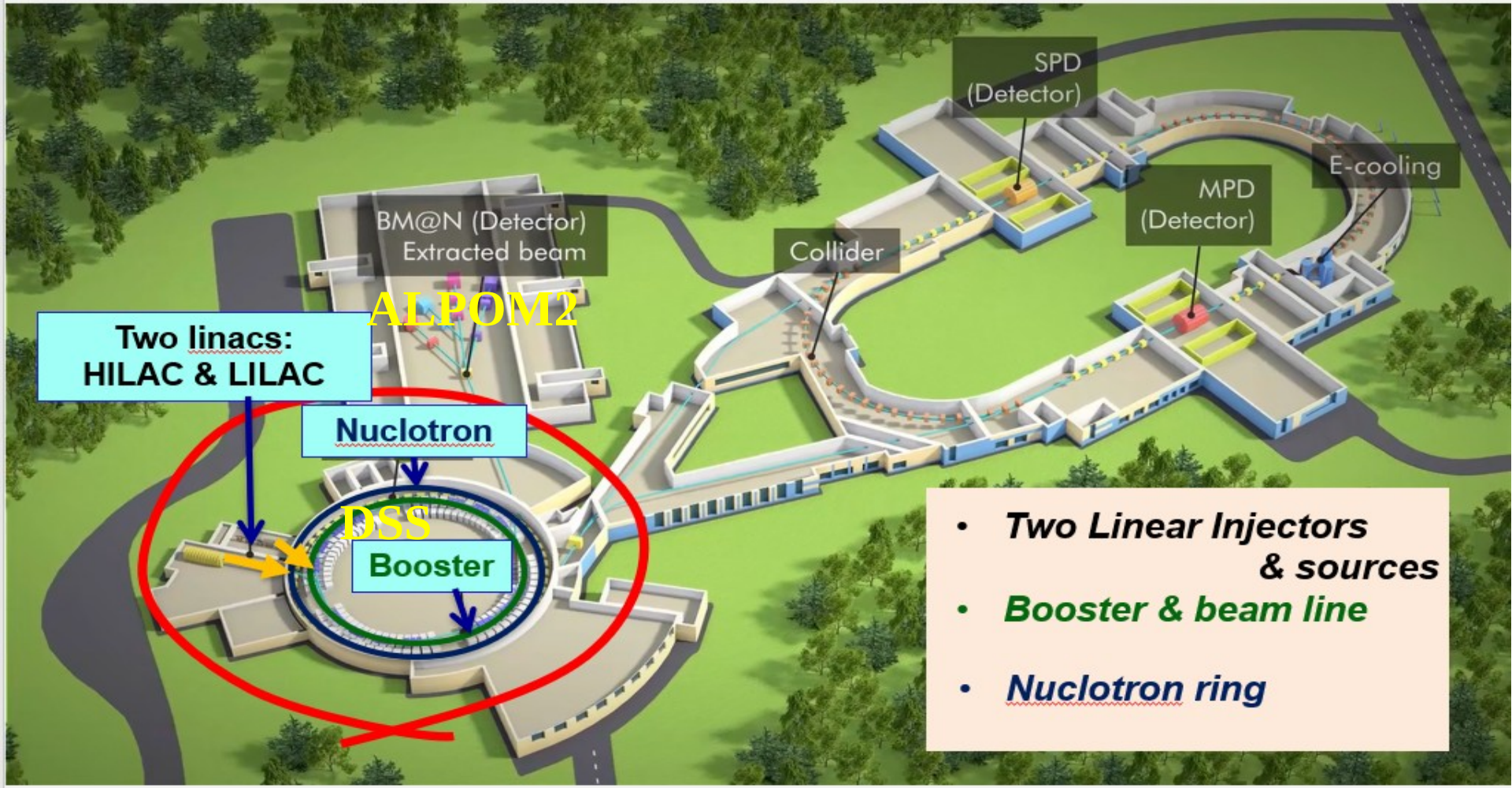
The main goal of the SPRINT@NICA (Spin Physics Research INfrastructure and Technologies @ NICA) project is to provide the research infrastructure and to develop the technologies for the current and planned spin studies at Nuclotron/NICA.

Main directions of planned developments are:

- **high intensity polarized beams of deuterons and protons**
- **beam polarimetry (LE, HE, CNI, APol, local etc.)**
- **techniques of the spin manipulation to provide Spin Transparency (ST) mode at Nuclotron/NICA**
- **secondary polarized beams (neutrons, protons, HI)**
- **polarized targets (^{3}He)**
- **preparation of the high precision spin experiments (dichroism/birefringence, axionlike particles search, EDM etc.)**

Working group: JINR, MIPT, ITP, INR RAS, INP BSU ….

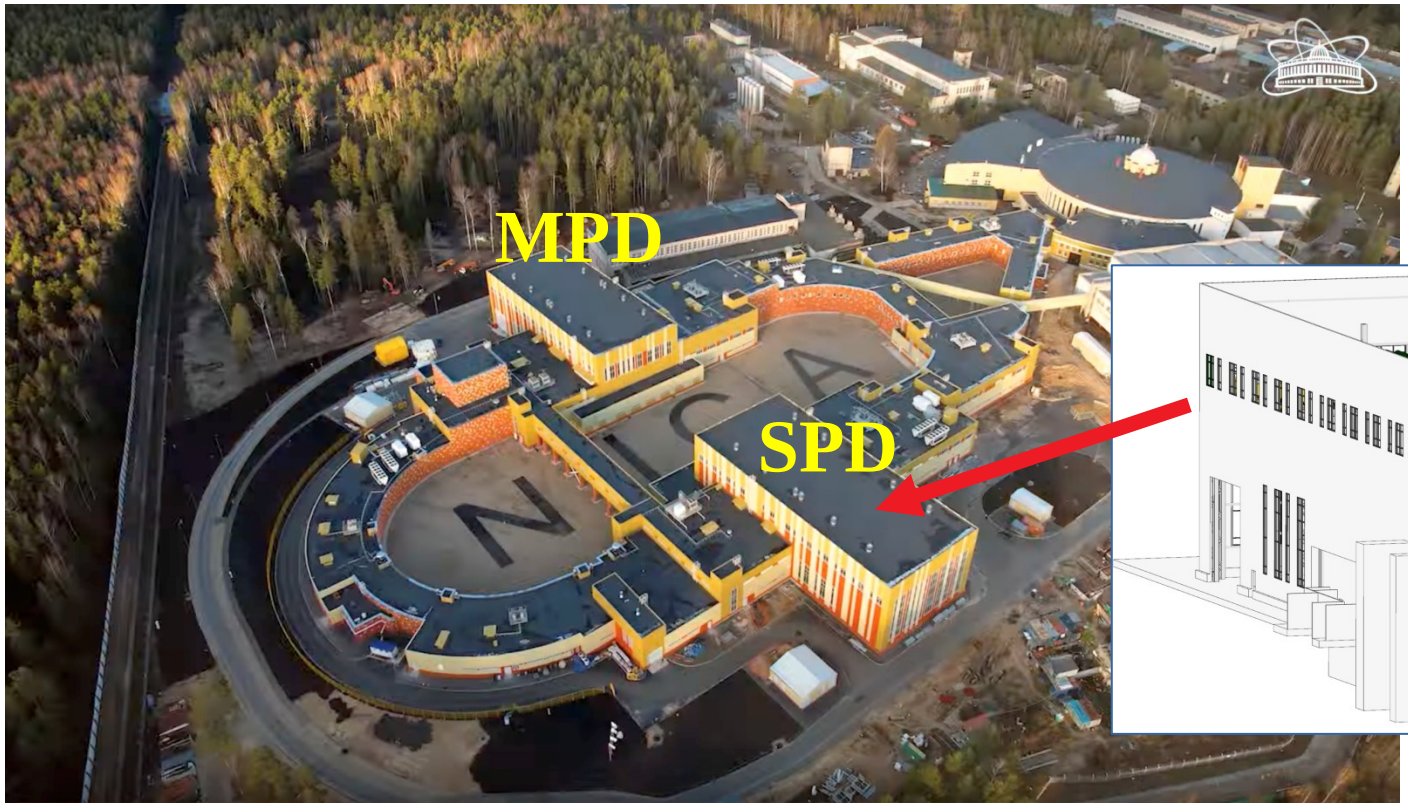
NICA in 2025-2026

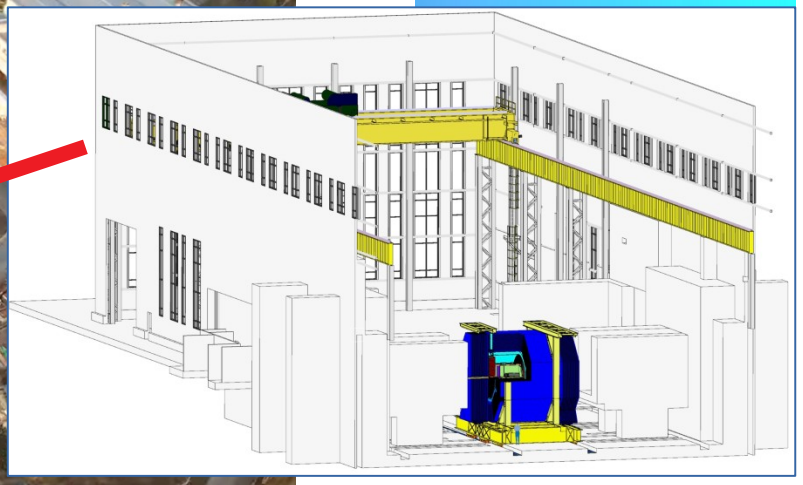


Injection complex is already in commissioning for few years (FT mode).
Run 2025-2026 achievements:

n·10⁸ ^{124}Xe ions at 1.6-3.8 GeV/n at Nuclotron,
Simultaneous circulation in both rings at NICA is achieved!

SPD at NICA in 2026



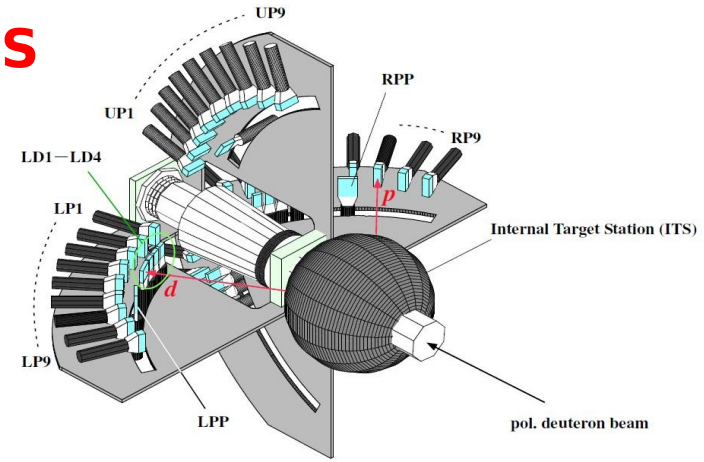


SPD hall

There are plans to study the detector prototypes at the SPD collision point in the fixed target mode (Au -target) in current run with HI beam.
These studies will be continued in the collider mode (perhaps, including deuterons).
SPD is one of the main targets of SPRINT project.

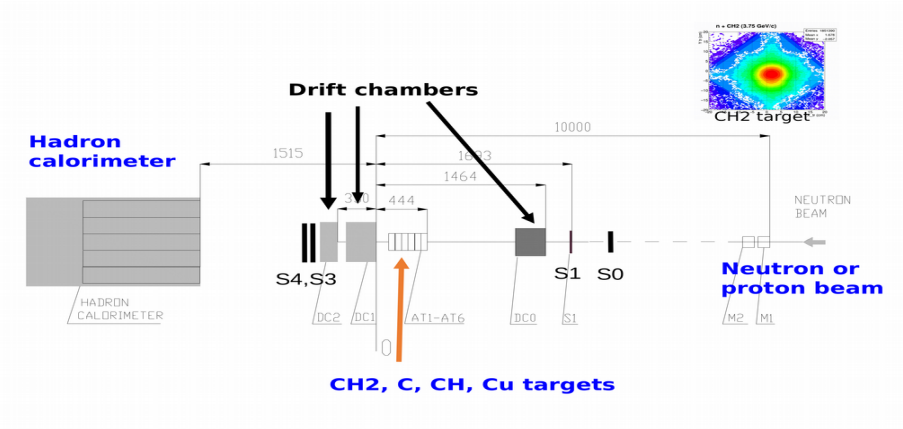
Requirements of Fixed Target experiments to polarized beam facility

DSS



Intensity:
~5·10^9 ppp for CH_2 target
~5·10^{10} ppp for nuclear targets
Beams polarizations
Deuterons
Pzz=-1.4,+0.8
Pz=±0.75
Protons
P= ±0.75

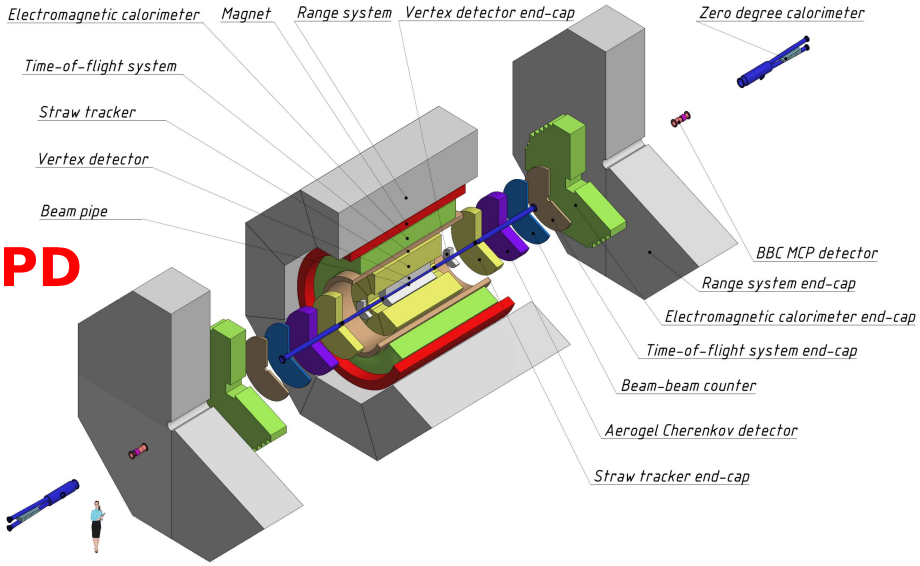
ALPOM-2



Intensity:
~10^{11} ppp
Beams polarizations:
Deuterons
Pz=±0.55-0.75
Protons
P= ±0.75

Goals are to increase the beams intensities and proton beam polarization.
Possibility to have sideway components of the polarization in future.

SPD requirements to polarized beam facility



SPD

- polarized and nonpolarized pp- , dd–collisions
- $p\uparrow p\uparrow(p)$ at $\sqrt{s_{pp}} = 12 \div 27$ GeV
- $d\uparrow d\uparrow(d)$ at $\sqrt{s_{NN}} = 4 \div 13$ GeV
- $L_{av} \approx 10^{+32}$ cm^{-2}s^{-1} (at $\sqrt{s_{pp}} \geq 27$ GeV)

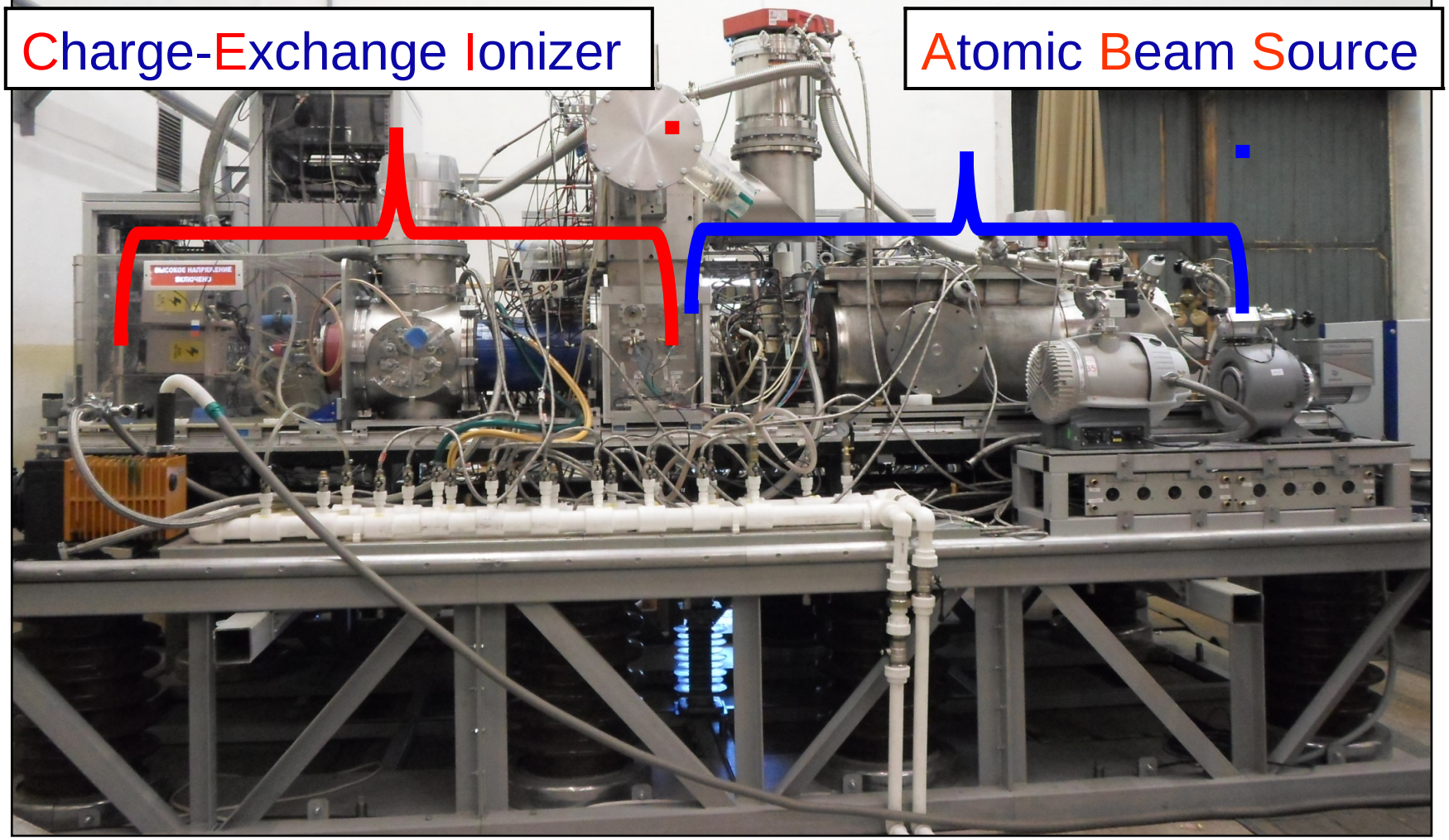
- sufficient lifetime and polarization degree (few hours, ~70%)
- longitudinal and transverse polarization at the SPD IP
- pd- collision mode should be available

The facility operation in pp – mode at $\sqrt{s_{pp}} = 27$ GeV reaching average luminosity of 10^{+32} cm$^{-2}\cdot$s^{-1} remains the first priority task for coming years.

General View of SPI

Charge-Exchange Ionizer

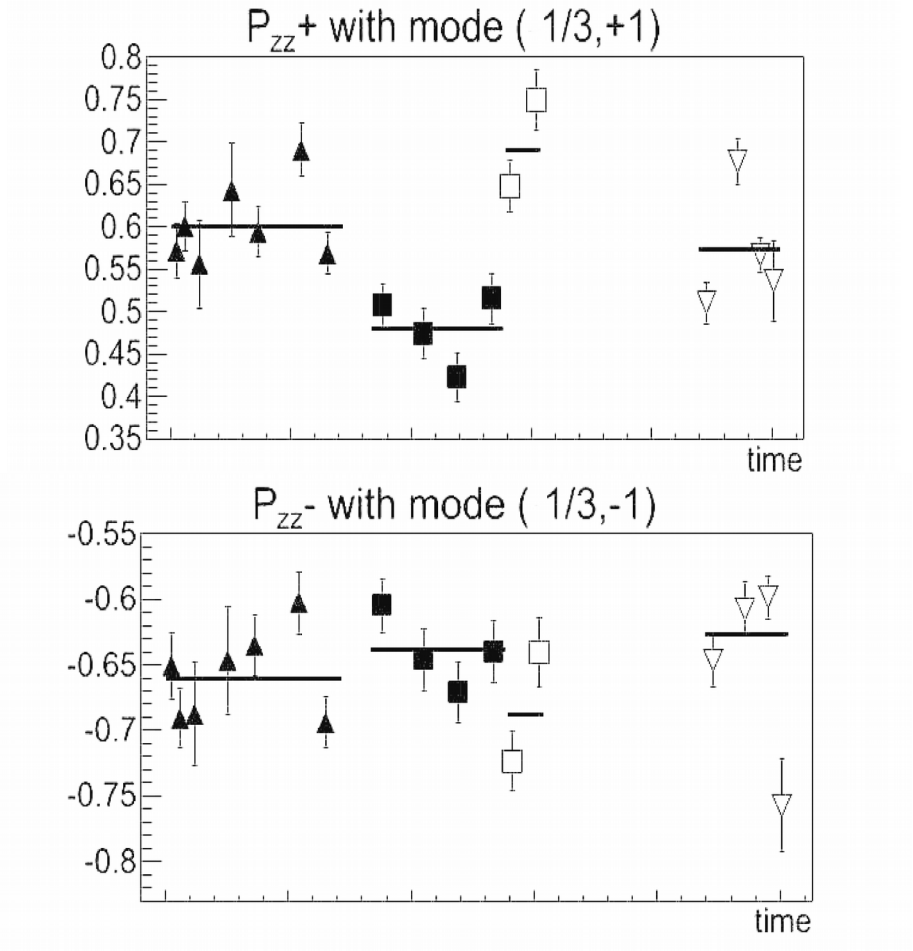
Atomic Beam Source

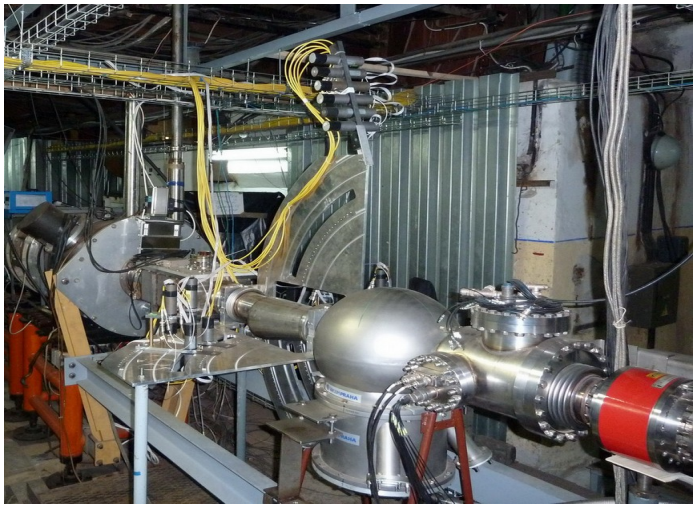


SPI was put into operation in 2016-2017 with deuterons (tested with protons).
SPI current and polarization (for deuterons) are ~3 mA and 70-75%.

Plans are to increase the current up to ~10 mA (by use the transverse injection of atoms).

Vector and tensor deuteron beam polarizations using dp- elastic scattering at 270 MeV at ITS

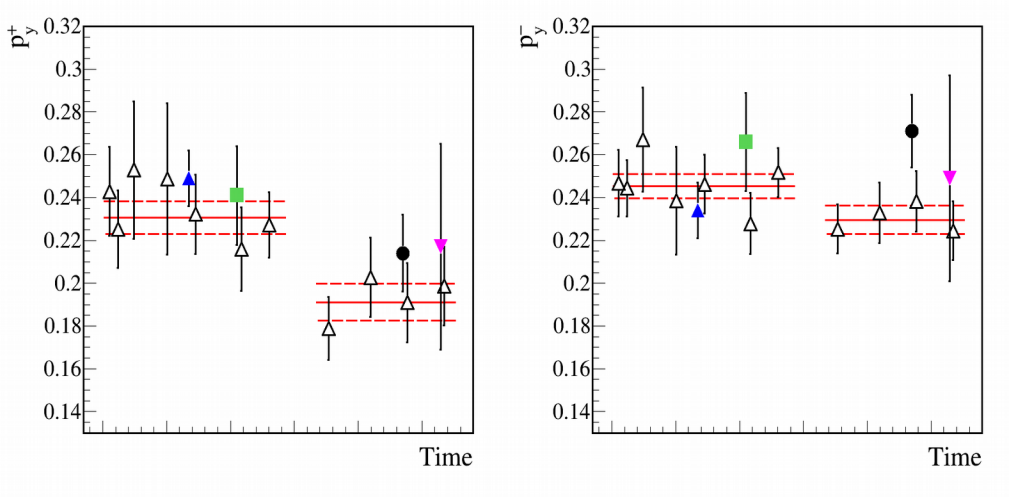


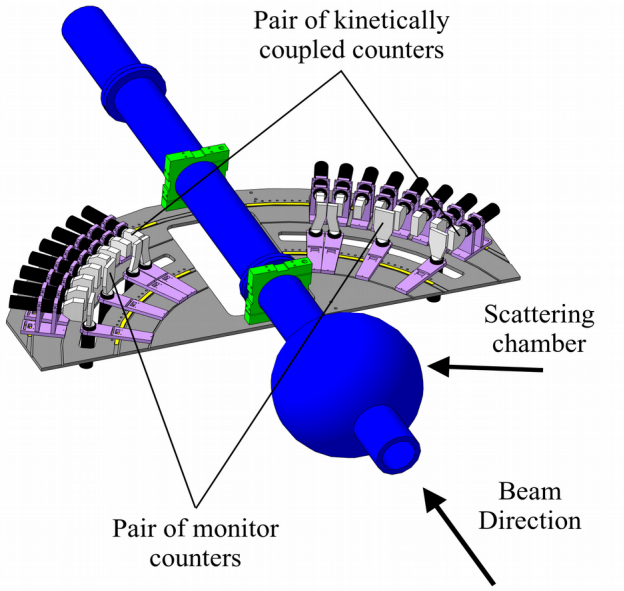


P.K.Kurilkin et al.,
NIM A642 (2011) 45.

SPI was tuned for 6 spin modes (p_z,p_{zz}) = (1/3,1), (1/3,-1), (0,+1), (0,-2), (-2/3,0),(+1,0).

Vector polarization of the deuteron beam using dp- elastic scattering at 270 MeV and pp-quasielastic scattering at ITS





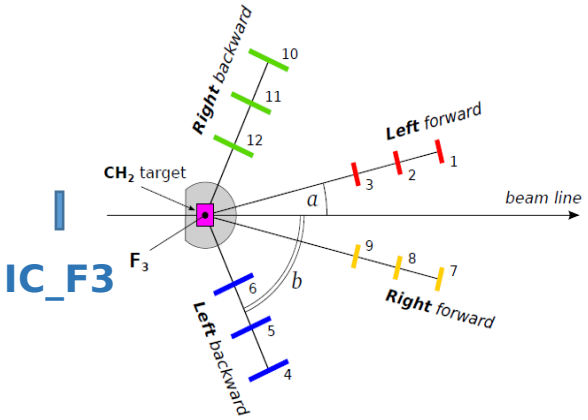
- **Vector component of the deuteron beam polarization has been measured at 500, 650, 550 and 200 MeV/nucleon using pp-quasielastic scattering.**
- **Detectors placed in the horizontal plane only were used.**
- **Analyzing power values from SAID were used to evaluate of the beam polarization values for the pp-quasi- elastic scattering measurements.**

Both methods give similar results!

I.S.Volkov et al.,
NIM A1094 (2027) 172118

Upgrade is in progress:
A.A.Terekhin et al.,
Phys.Part.Nucl. 54 (2023) 634

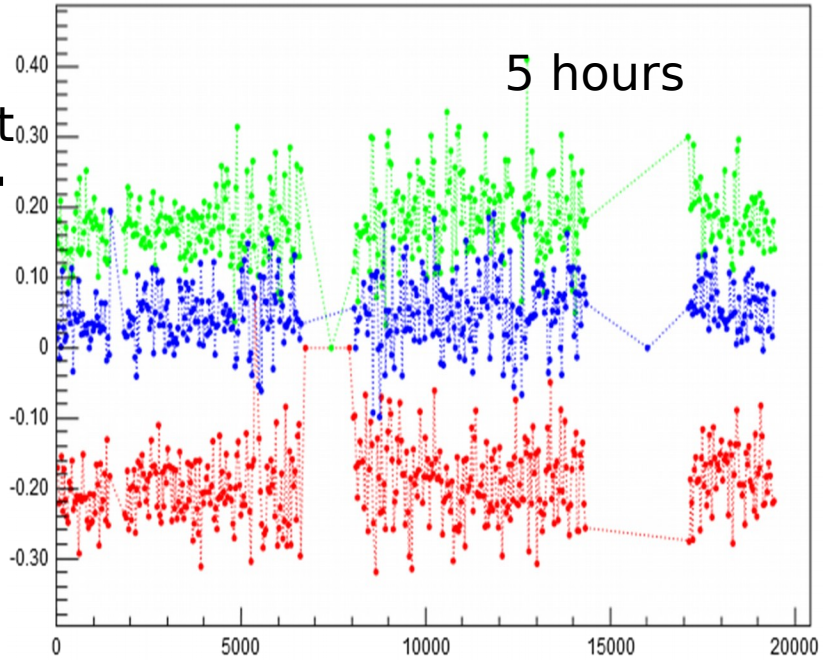
Deuteron extracted beam polarization measurements (vector component) using pp- quasielastic scattering





each point corresponds to one spill.

$$\frac{\text{Left-Right}}{\text{IC_F3}}$$



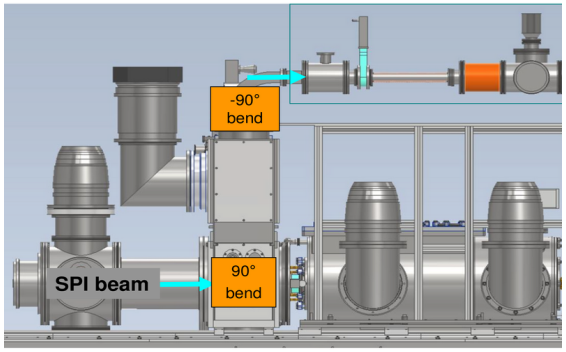
The polarization in one mode is two times lower than the other one

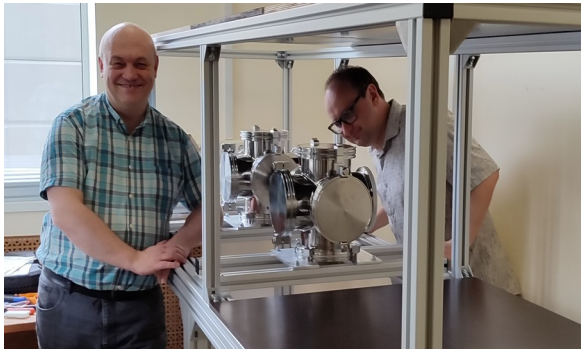
$$P(+) - P(-) = 0.96 \pm 0.05$$

Upgraded polarimeter:
L.S.Azhgirey et al., NIM A497 (2003)340.

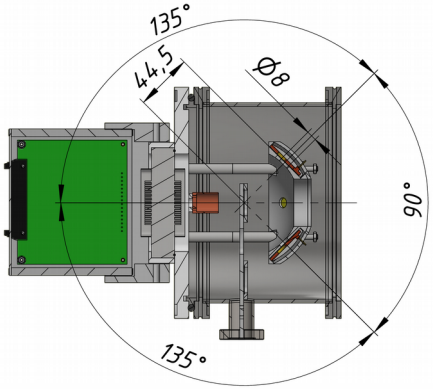
HE tensor polarimeter is needed!

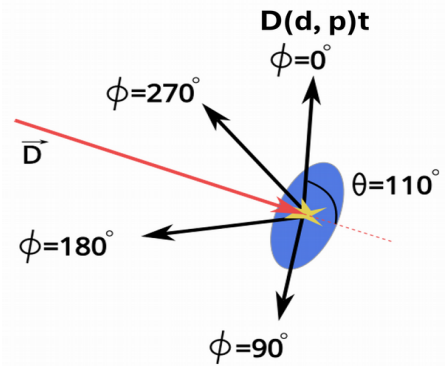
LE polarimetry developments



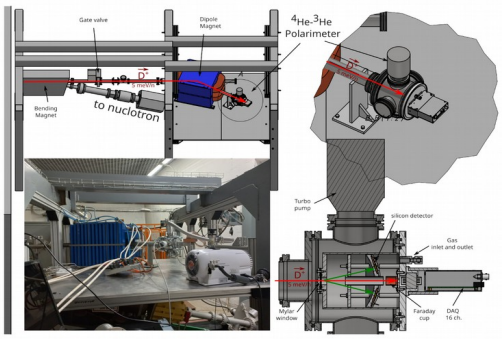


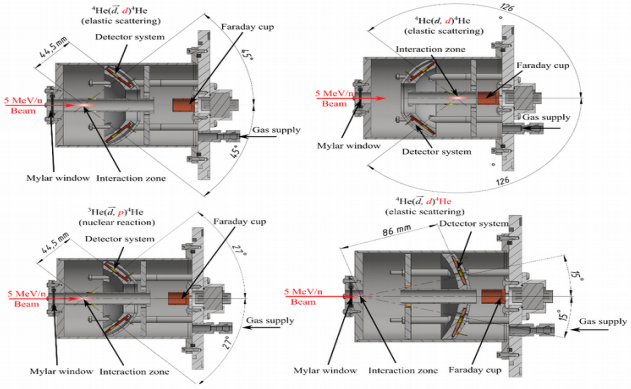
Lamb-Shift Polarimeter- LSP (at 5 keV) for protons (and deuterons) is under development by MIPT-INR-JINR.





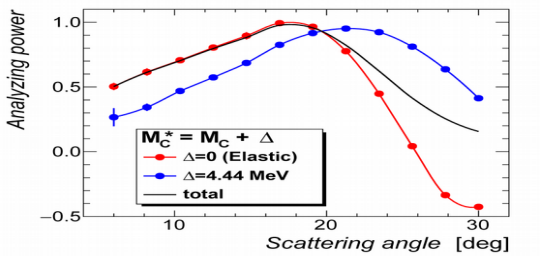
Nuclear-Reaction Polarimeter- NRP (at the SPI exit) for protons and deuterons. Optimization of the geometry and detector choice.





Polarimeter for Polarized Protons and Deuterons- PPPD at the energy of 5 MeV/n after RFQ&LINAC.
^{3}He(p,p)^{3}He for protons.
^{3}He(d,p)^{4}He reaction for the both vector and tensor polarizations of deuterons.
^{4}He(d,d)^{4}He for fast check of deuteron vector polarization.

Absolute proton polarimetry developments



APol 3D view



1. Proton-carbon elastic scattering at 200 MeV at the scattering angle of 16.2° in lab. has very large analyzing power close to an absolute value

$$A = 0.993 \pm 0.003$$

Elastic events will be selected using sets of scintillation detectors with absorbers.

The polarimeter can be installed at the Nuclotron ITS.

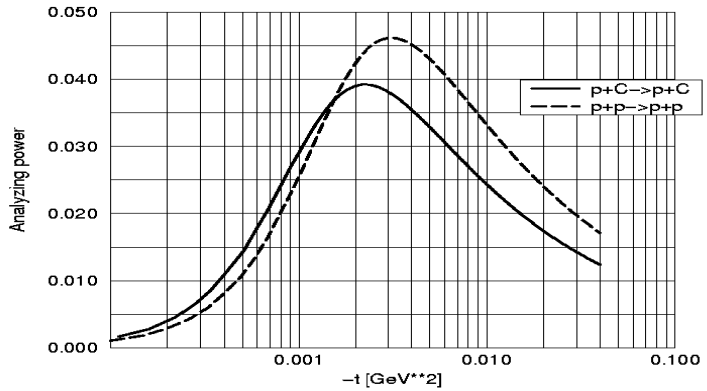
2. Since for pp- elastic scattering beam and target analyzing powers equal:

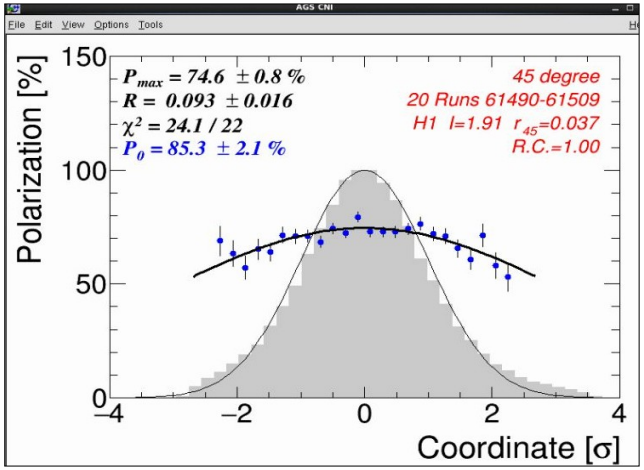
$$A_{beam} = A_{target}$$

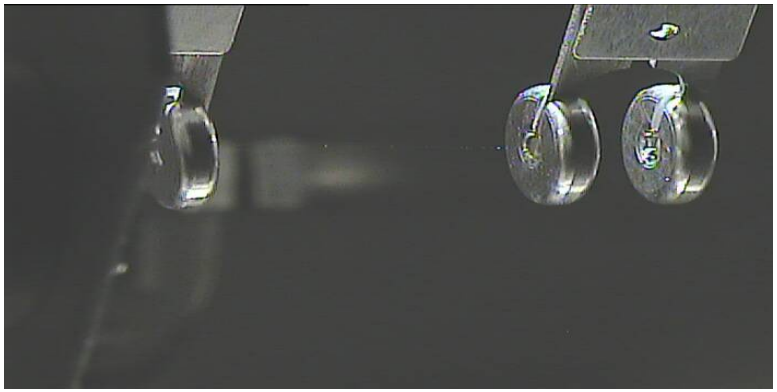
the polarization of the proton beams can be obtained using left-right asymmetry from polarized H-jet target by an absolute method.

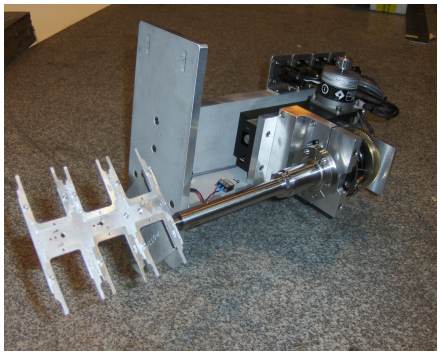
The ABS is ready, chamber and detection system are under construction.

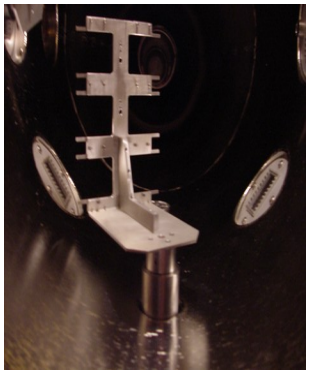
CNI proton polarimetry developments











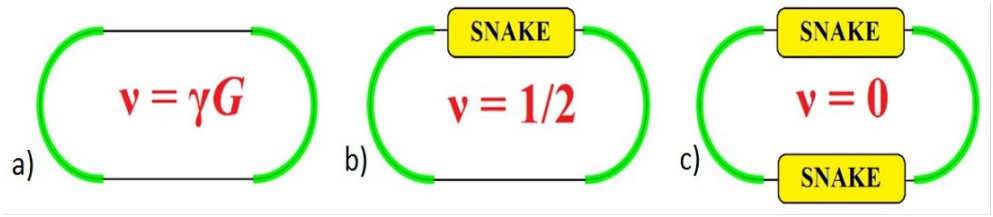
Very thin carbon strip target-20um x 25 nm

CNI proton polarimetry at NICA energies is not an absolute method because of non-zero spin-flip hadron amplitude (AGS results).

The selection of the events will be provided by the detection of the recoil carbon using SSD.

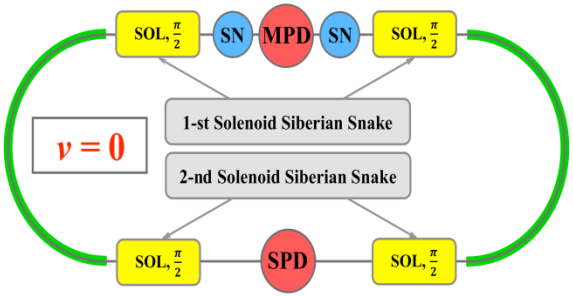
CNI polarimeters will be able to measure the proton beam polarization profiles using advanced ribbon target.

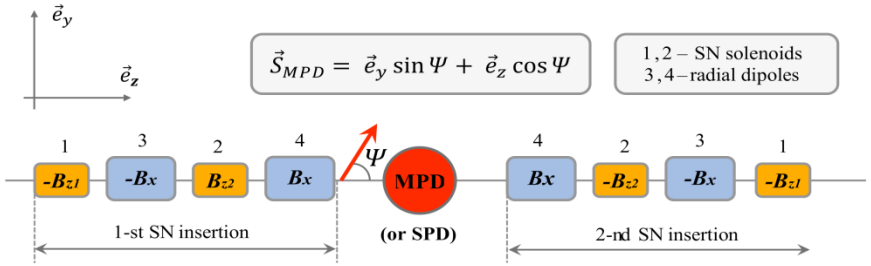
Proton spin manipulation at NICA



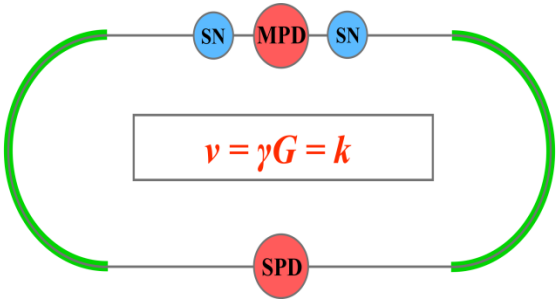
RHIC

LE-regime





HE-regime



Spin transparency (ST) mode with ν=0 is very well suited to the SPD physics tasks.

Realistic scenario.

LE-regime: ST up to $\sqrt{s_{pp}}$ = 6-7 GeV using ~12 T·m Siberian snakes in each ring.

HE-regime: ST at the integer resonances k at $\sqrt{s_{pp}}$ > 6-7 GeV (E_p = 0.108+k·0.523 GeV).

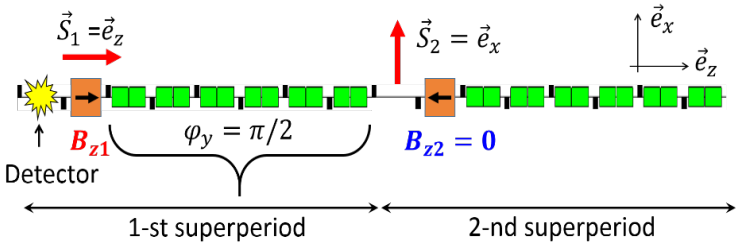
Details:

Yu.N.Filatov,Phys.Part.Nucl.56 (2025) 363.

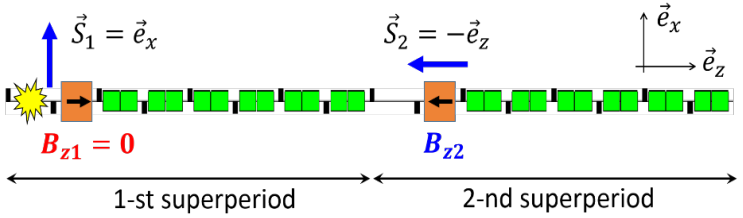
E.M.Syresin et al., Phys.Part.Nucl.52(2021) 997.

Proton spin manipulation at Nuclotron

Stage 1.
Nuclotron with Spin Navigator based on 2 additional weak solenoids
Experimental verification of the ST mode at integer spin resonance γG=2 (108 MeV)



Longitudinal polarization at the detector



Radial polarization at the detector

Stage 2.
Nuclotron with Spin Navigator based on regular correction dipoles
Experimental verification of the ST mode at integer spin resonance γG=7 (2723 MeV)

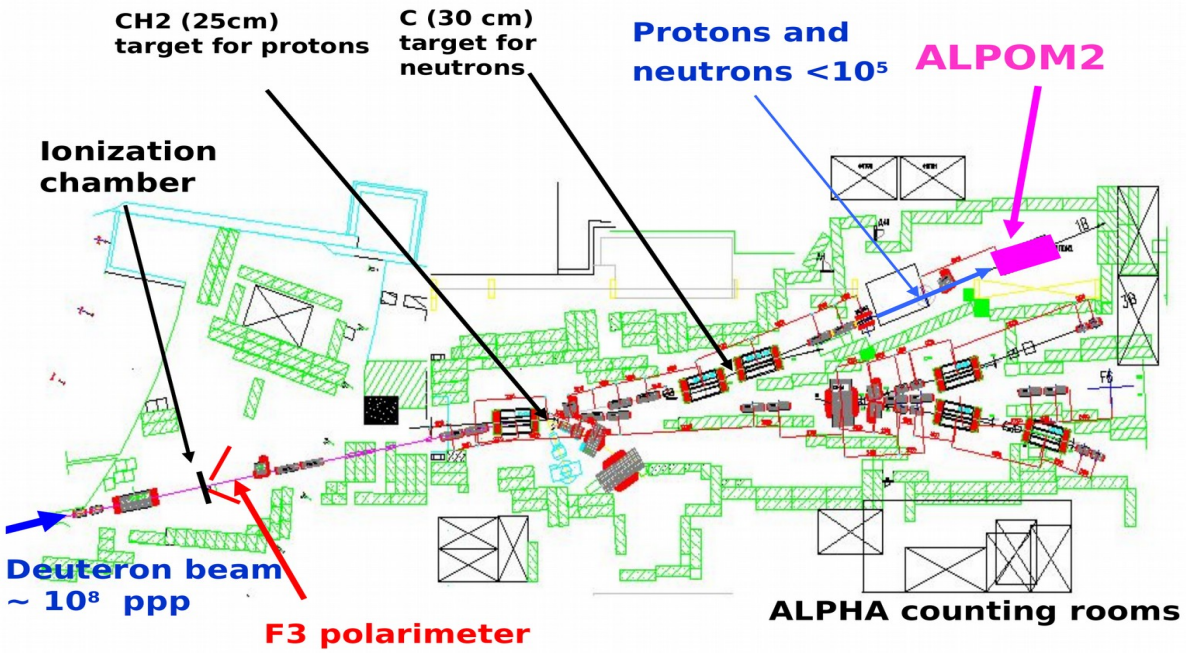
Stage 3.
Modernized Nuclotron with ~12 T·m solenoidal Siberian snake
ST mode up to proton energy of 13.5 GeV

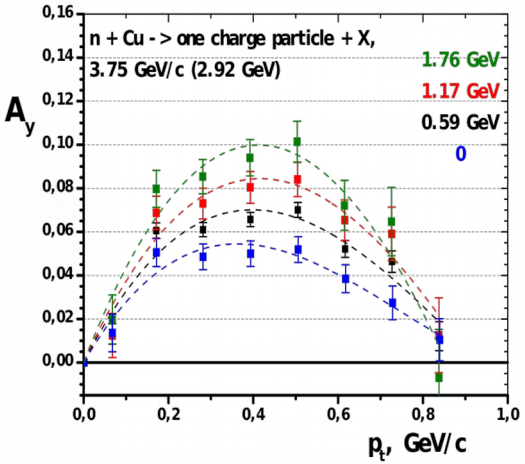
Experimental proof of ST requires serious upgrade of the proton beam polarimetry at Nuclotron

Supported by:

RFBR 20-02-00808, RSF 22-42-04419, RSF 25-72-30005

Secondary proton and neutron polarized beam at Nuclotron



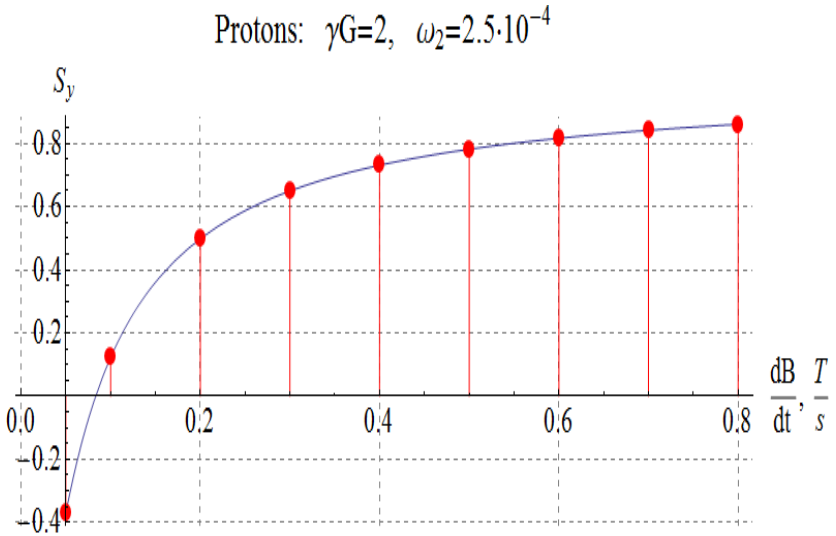


S.N.Basilev et al., Eur.Phys.J.A 56 (2020) 26

Required intensity for physics is ~10^{11} ppp

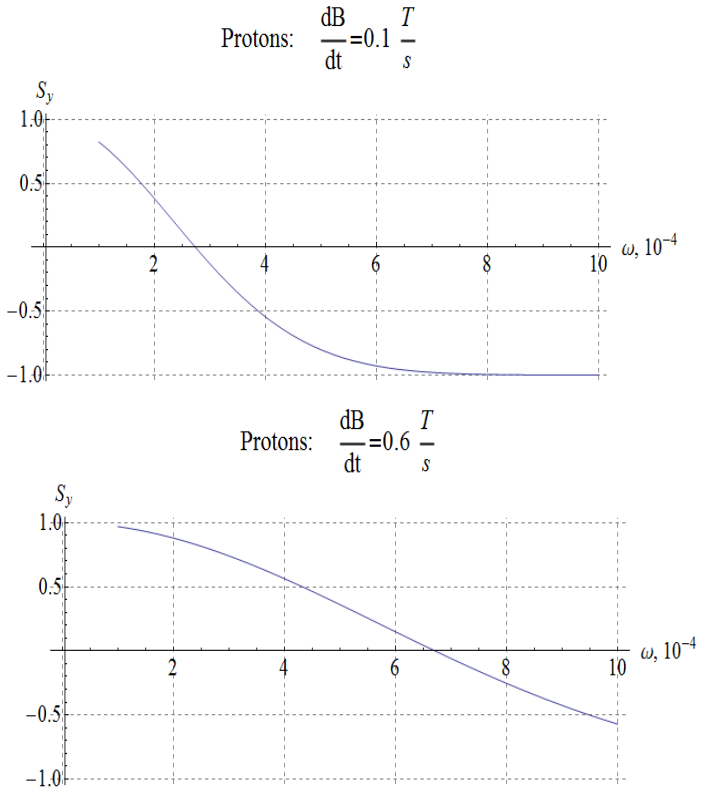
The beam line was built for spin correlation np- scattering experiment: the upgrade of existing polarized target is under consideration.

Experiment on the low integer resonances strength study



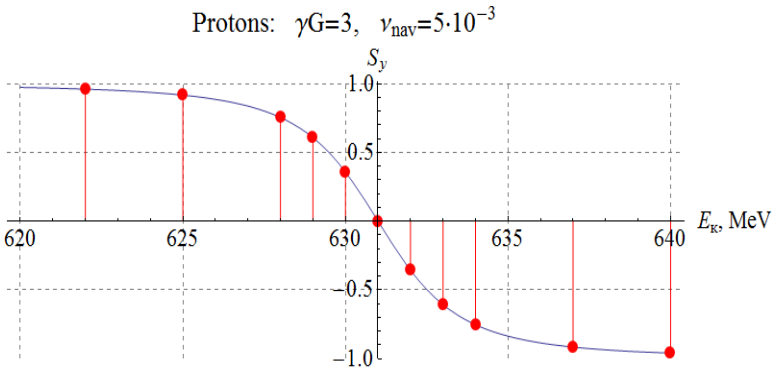
Measurements of the integer resonance γG=k=2 strength (Tkin=108 MeV)

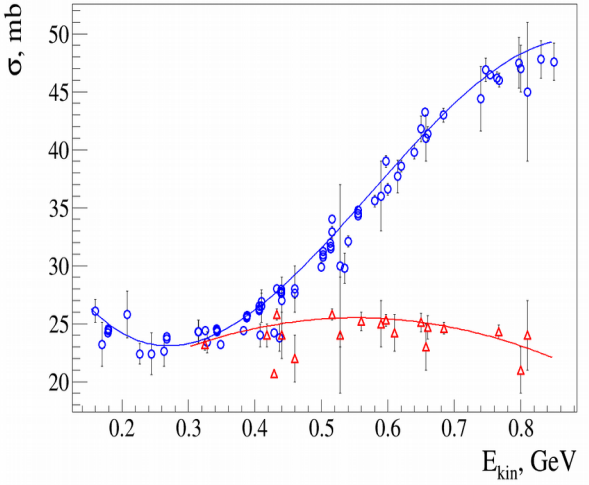
Measurements of the proton beam polarization at 100 and 120 MeV at different dB/dt



Yu.N.Filatov et al.,
JETP Lett. 116 (2022) 413;
JETP Lett. 118 (2023) 387.

Experiment on the adiabatic passage of the γG=3 resonance

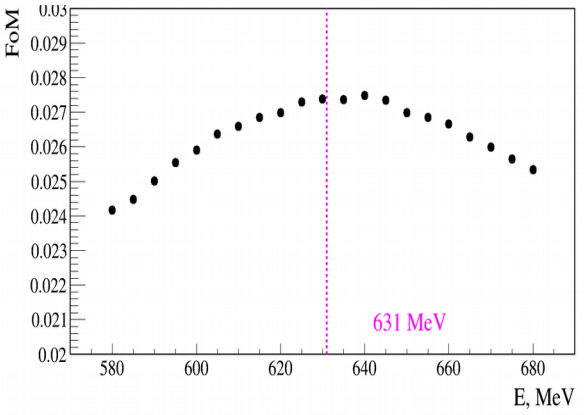




Measurements of the beam polarization the integer resonance γG=k=3 (Tkin=631 MeV)

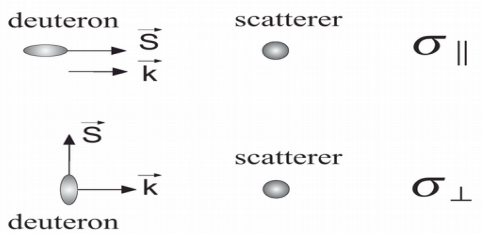
Measurements of the proton beam polarization at 610-650 MeV with small energy steps (1 MeV) using current polarimeter at Nuclotron ITS.

$$F = \sqrt{\frac{1}{N_{tot}} \frac{\sigma_{el}^{pp}}{\sigma_{tot}} \sum_i [N_i \cdot A_i^2]}$$

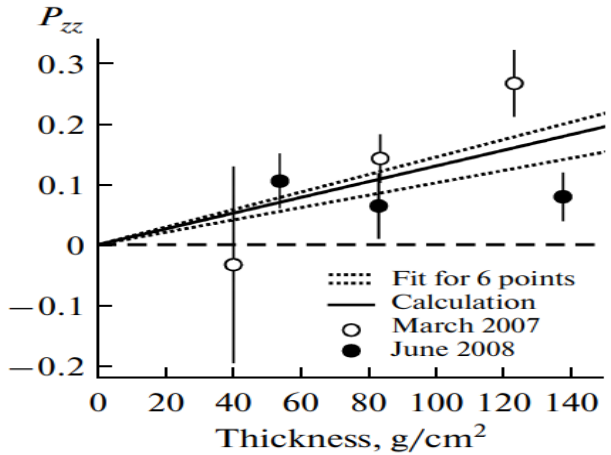


The final goal is to prove the possibility of Spin- Transparent mode at integer resonances (for SPD at NICA)

Deuteron spin dichroism at Nuclotron at 270 MeV



$$p_{zz}(l) = \frac{I_{+1}(l) + I_{-1}(l) - 2 \cdot I_0(l)}{I_{+1}(l) + I_{-1}(l) + I_0(l)} \approx \frac{2}{3}\rho\, l(\sigma_0 - \sigma_1) = -\frac{8\pi}{3}\,\rho\, l\frac{\mathrm{Im}(d_1)}{k}$$



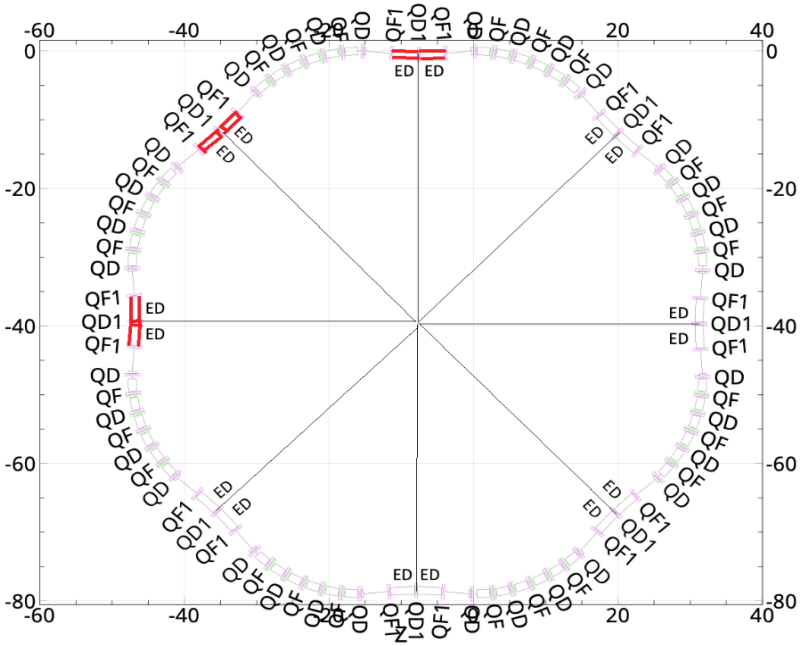
Nuclotron results with the extracted 5 GeV/c deuteron beam.

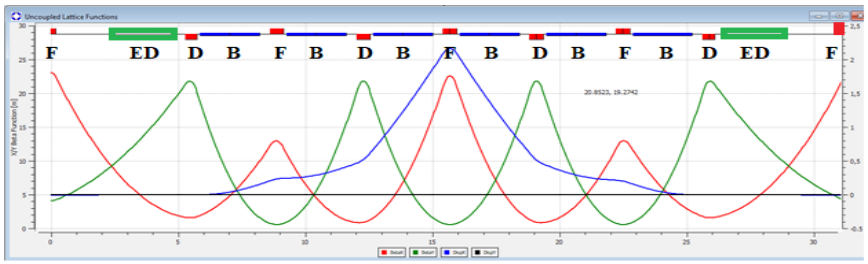
-Spin dichroism effect is one of the phenomena acquiring by the deuteron beam passing through the nonpolarized target.

-The method is the measurement of the tensor polarization acquiring by a nonpolarized deuteron beam moving in Nuclotron and passing through the very thin internal target.

-The polarization measurements will be provided by the vector-tensor deuteron polarimeter based on the measurements of dp- elastic scattering at 270 MeV.

Deuteron EDM studies at 270 MeV





Option for Nuclotron in "quasi-frozen spin" mode with electrostatic deflectors (ED)

-Search for EDM of nucleons and nuclei is necessary to understand the origin of CP violation and baryogenesis in the Universe.

-The method is the measurement of the transverse polarization appearing for the longitudinally polarized particles.

-Several options of the magnetic optics are under consideration:
-NICA with bypasses,
-modernized Nuclotron ring,
-separate low energy (~300 MeV) ring.

-The polarization measurements must be provided by the 2π-deuteron polarimeter based on the measurements of dC scattering at 270 MeV.

SPRINT@NICA group

JINR: V.V.Fimushkin, A.V.Butenko, E.A.Butenko, N.V.Dunin, K.A.Ivshin, M.V.Kulikov, S.A.Kostromin, V.P.Ladygin, V.E.Laryonov, E.M.Syresin, A.N.Solovev, I.S.Volkov, V.A.Lebedev, E.E.Donets, V.V.Bleko, N.M.Piskunov, A.Ya.Silenko, O.V.Teryaev, Yu.N.Uzikov

MIPT: Yu.N.Filatov, A.N.Zelenski, S.V.Vinogradov, S.N.Zhabin, I.S.Yudin, A.A.Chernikova, E.D. Tsyplakov, I.V. Lilienberg, A. I. Chernyshov, A.B. Borisov

INR RAS: A.E.Aksentiev, A.S.Belov, Yu.V.Senichev, S.D.Kolokolchikov, A.A.Melnikov, P.Palamarchuka

ITP: N.N.Nikolaev

STL Zaryad: A.M.Kondratenko, M.A.Kondratenko

INP BSU: V.G.Baryshevsky, S.V.Anischenko, A.A.Gurinovich

BINP SB RAS: D.K.Toporkov

The group is growing.

New peoples with their ideas are welcome.

1. Spin Physics Research INfractrucrure and Technologies at NICA (SPRINT@NICA)

V.P. Ladygin on behalf of SPRINT@NICA group

Talk 26-th International Spin Symposium (SPIN-2025)
22-26 September 2025, Qingdao, China, ***PoS(SPIN2025) 152***

2. Several talks at RuPAC'25

15-19 September 2025, St.Petersburg, RF
Accepted in Phys.Part.Nucl.Lett.

3. >20 talks at DSPIN-2026

7-12 September 2026, Dubna , RF

4. Several reviews in Natural Sci.Rev.

V.V.Fimushkin et al., Natural Sci.Rev. 3 (2026) 200608
V.G.Baryshevsky, Natural Sci.Rev. 3 (2026) 200607
B.Gou et al., Natural Sci.Rev. 3 (2026) 200802
Yu.N.Filatov et al., to be published in Natural Sci.Rev. (2026)

Conclusion

SPRINT@NICA project is devoted to developments of the research infrastructure and the technologies for the current and planned spin experiments at Nuclotron/NICA.

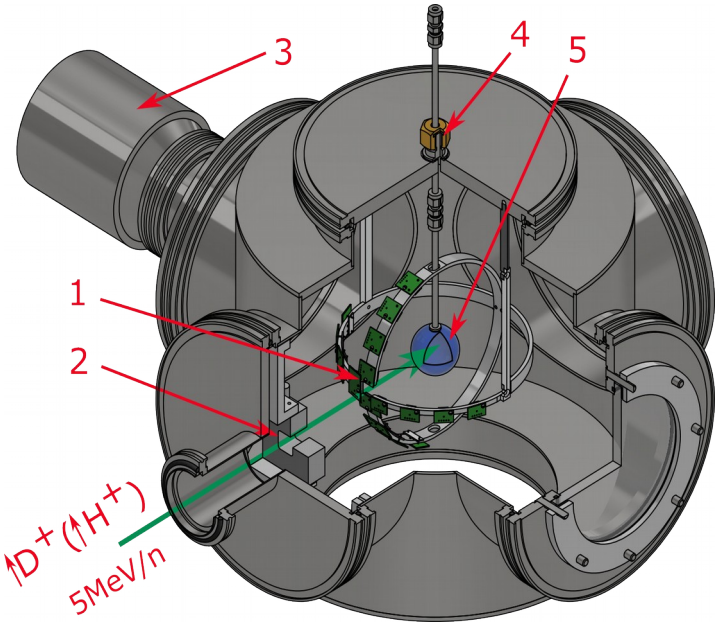
Several fixed target experiments are already working at Nuclotron using polarized beams provided by new SPI. Part of research infrastructure is ready. They are the drivers of the SPRINT developments together with SPD at least up to 2030.

Main directions of planned activity within SPRINT@NICA are further development of the high intensity polarized beams and corresponding beam polarimetry, experimental verification of Spin Transparency mode and preparation of the high precision spin experiments.

Draft of the SPRINT@NICA CDR -end 2026

Thank you for the attention!

LE polarimetry developments



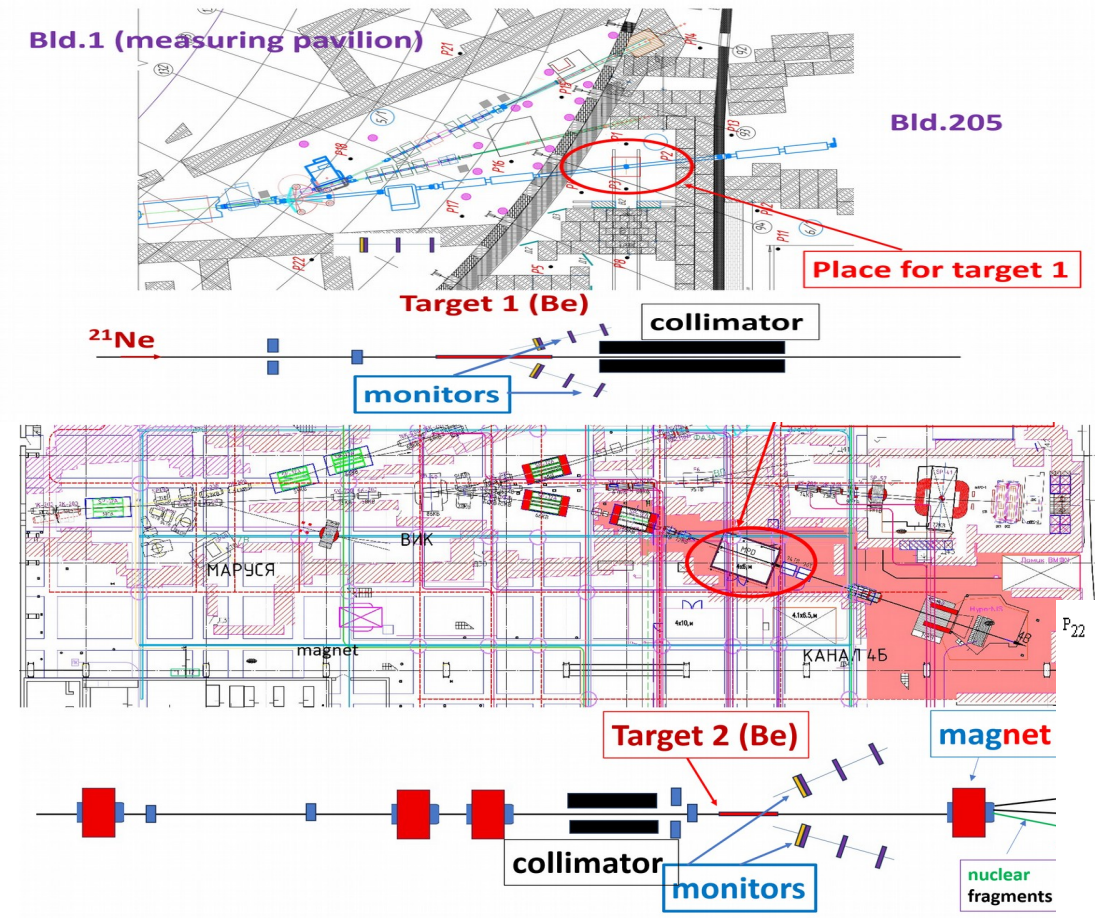
1 - array of 16 silicon detectors with an active area of 5x20 mm each
2 - variable diaphragm
3 - turbomolecular pump
4 - gas inlet syste
5 - a high-pressure (3 bar) mylar spherical target (**150 μm**)

Deuteron(proton) energy is 5 MeV/nucleon after RFQ&LINAC.

The ^{3}He target (3bar) enables to measure both the proton polarization using ^{3}He(p,p)^{3}He elastic scattering reaction and the vector and tensor polarizations of deuterons using ^{3}He(d,d)^{3}He elastic scattering as well as ^{3}He(d,p)^{4}He reaction.

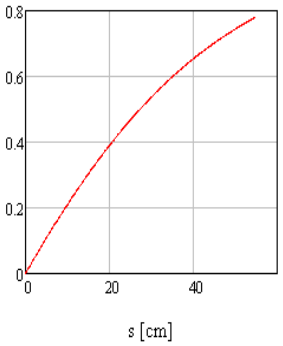
The detection of the secondary particles will be provided by the silicon detectors. The detector positions can be adjusted according reaction kinematic.

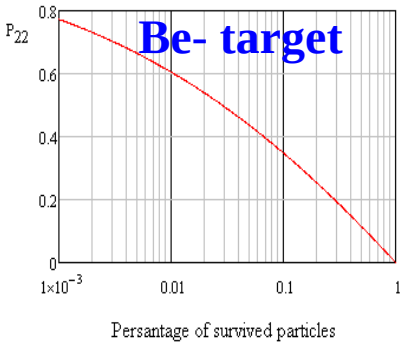
Tensor polarized ^{21}Ne beam at Nuclotron



-Method is based on the large quadrupole deformation of ^{21}Ne (β_2=0.463).

-Tensor polarization appears after passing through the thick nuclear target (Be-20cm).





~10^7-10^8 ^{21}Ne ions/spill with the tensor polarization ~0.4 will be available for physics.

SPRINT@NICA steps

Meetings:

1. Beam Polarimetry at Nuclotron/NICA

12.11.2025, LHEP JINR -done, munutes are uploaded.

2. Spin Manipulation Techniques at Nuclotron/NICA

26.11.2025, LHEP JINR -done, munutes are uploaded.

3. Polarized Beams, Sources and Targets at Nuclotron/NICA

18.02.2026, LHEP JINR -done, munutes are uploaded.

4. High Precision Spin Experiments at Nuclotron/NICA (must include also first test experiments)

04.03.2026, LHEP JINR -done, munutes are uploaded.

Draft of the SPRINT@NICA CDR -end 2026