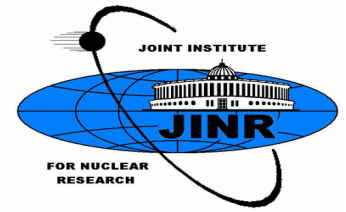
# Spin Physics Research INfractrucrure and Technologies at NICA (SPRINT@NICA)

*V.P. Ladygin*

*SPRINT @NICA: Beam Polarimetry Meeting*

*12.11.2025, LHEP JINR*


# 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*

**+Several talks at RuPAC'25**

*15-19 September 2025, St.Petersburg, RF*

# SPRINT@NICA mission

**The main goal of the SPRINT@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 ….***

# SPRINT@NICA group

## JINR

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

## 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**

## ITP

**N.N.Nikolaev**

## STL Zaryad

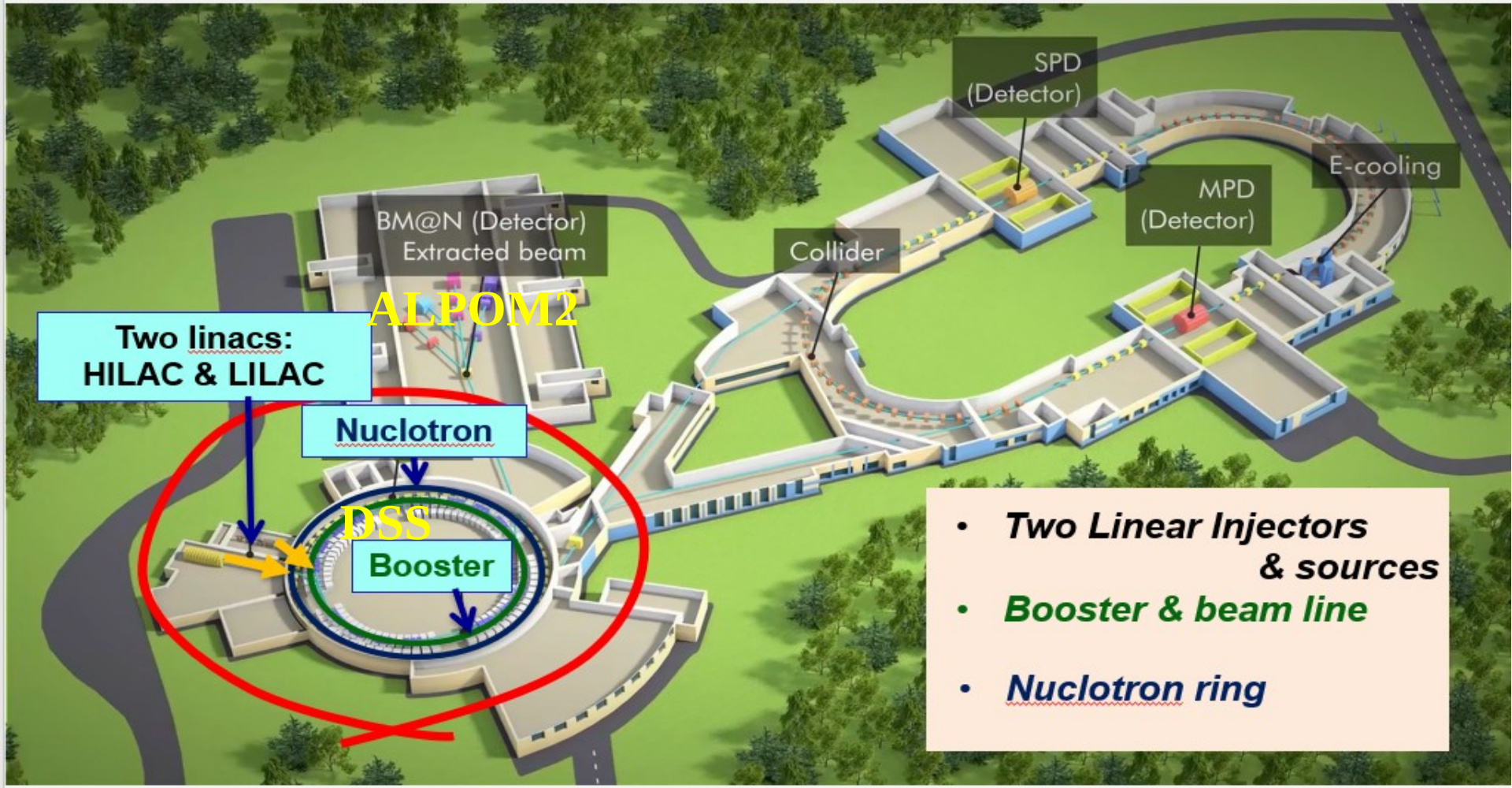
**A.M.Kondratenko, M.A.Kondratenko**

## INP BSU

**V.G.Baryshevsky, S.V.Anischenko, A.A.Gurinovich**

**New peoples with their ideas are welcome!**

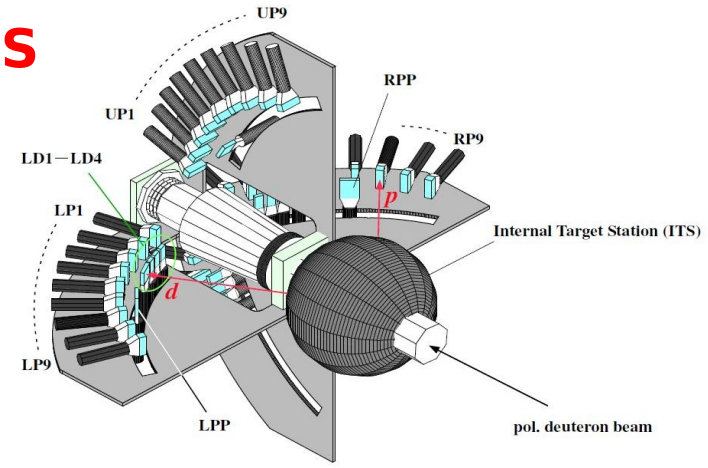
# NICA in 2025




**Injection complex is already in commissioning for few years (FT mode).**
**Run-2023 achievements: 5-8·10⁶ $^{124}$Xe ions at 3.9 GeV/n.**
**Run-2025 started in February also with $^{124}$Xe.**
**Injection to NICA is planned to the end of 2025.**

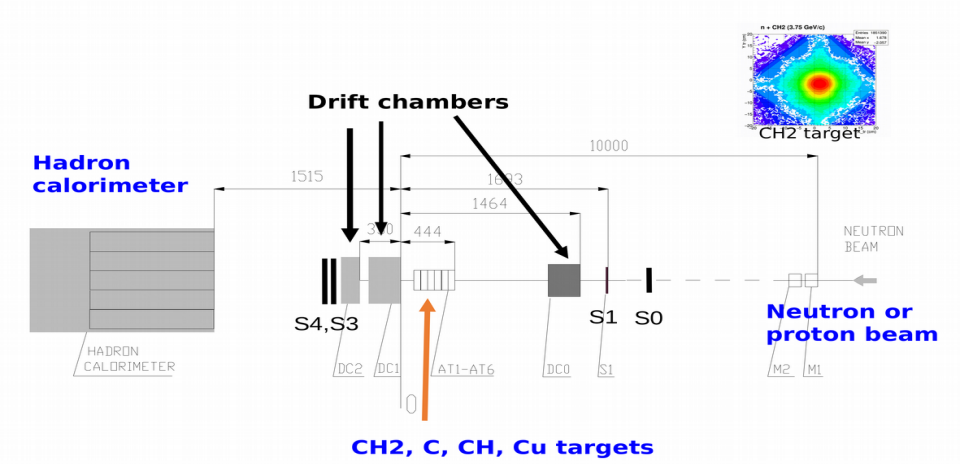
# Requirements of Fixed Target experiments to polarized beam facility

## 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**

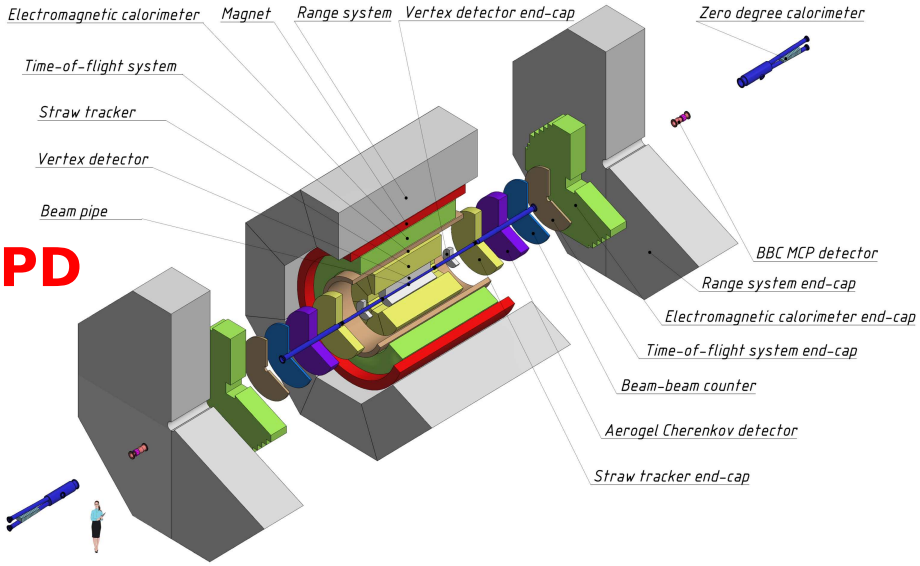
## ALPOM-2




**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.**

# 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.**

# SPRINT@NICA next steps

**Meetings:**

**1. Beam Polarimetry at Nuclotron/NICA**
**12.11.2025, LHEP JINR**

**2. Spin Manipulation Techniques at Nuclotron/NICA**
**26.11.2025, LHEP JINR**

**3. Polarized Beams, Sources and Targets at Nuclotron/NICA**
**February 2026, LHEP JINR**

**4. High Precision Spin Experiments at Nuclotron/NICA**
**(must include also first test experiments)**
**February-March 2026, LHEP JINR**

**31.12.2025 -Deadline of the PoS SPIN2025 (6 pages)**
**September 2026 – DSPIN2026? (SPRINT day+ plenary talk?)**

***Draft of the SPRINT@NICA CDR -end 2026***

# Goal of current meeting

**1. Revise the status of the Beam Polarimetry at Nuclotron/NICA**

**2. Upgrade of the polarimeters at Nuclotron/NICA**

**3. Ideas of new polarimeters  at Nuclotron/NICA**

**4. Absolute polarimetry at Nuclotron/NICA**

**5.  Polarization standards for deuteron and proton beams**

***Contributions to the draft of the  SPRINT@NICA CDR***

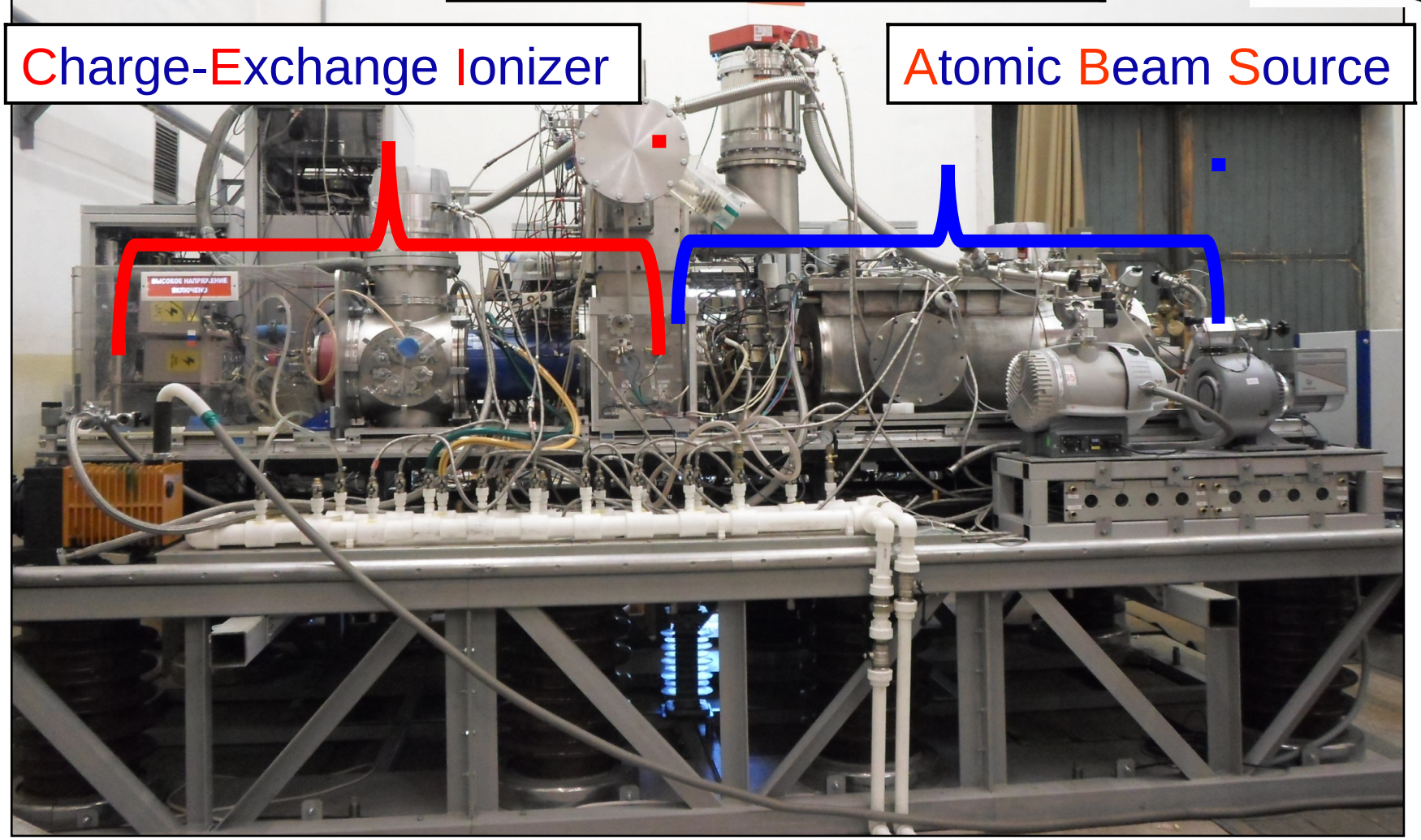
# Welcome!

# Backup slides

# General View of SPI

Charge-Exchange Ionizer

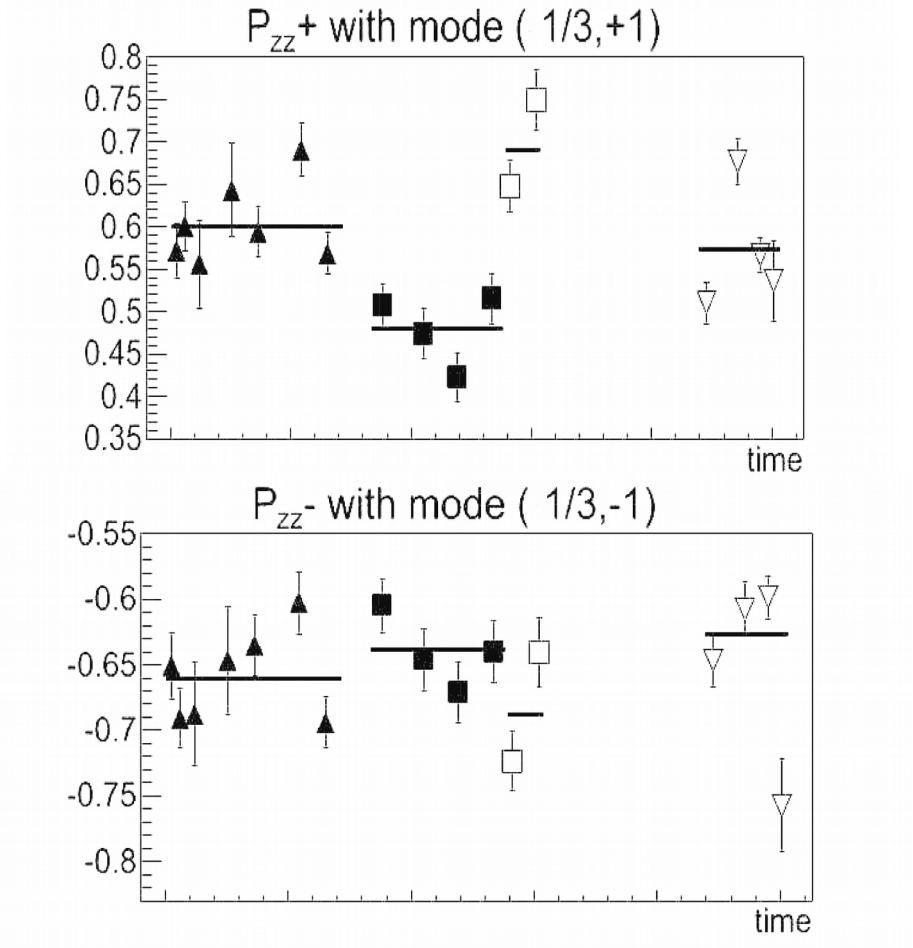
Atomic Beam Source

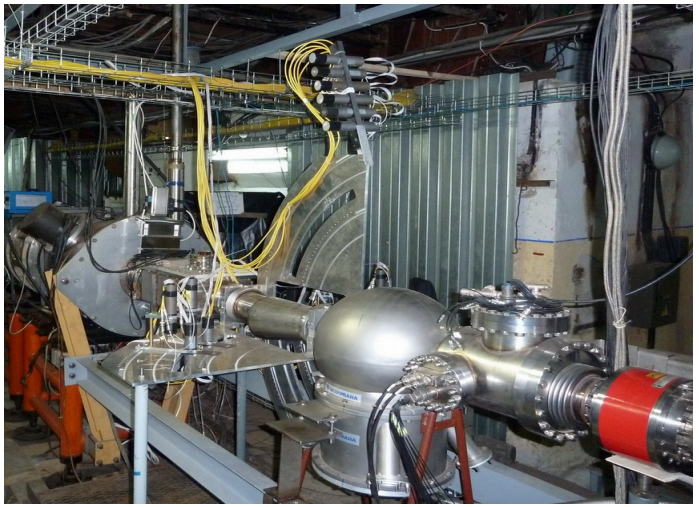


**SPI was put into operation in 2016-2017 with deuterons (tested with protons).**
**SPI current and polarization (for deuterons) are ~3 mA and 70-75%.**

**Plans are to increase the current up to ~10 mA. (See V.V.Fimushkin talk)**

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

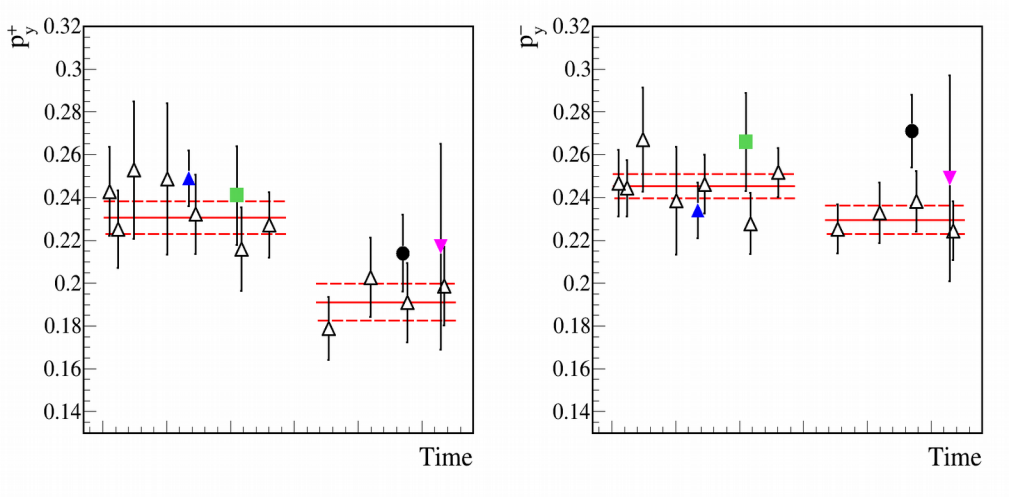


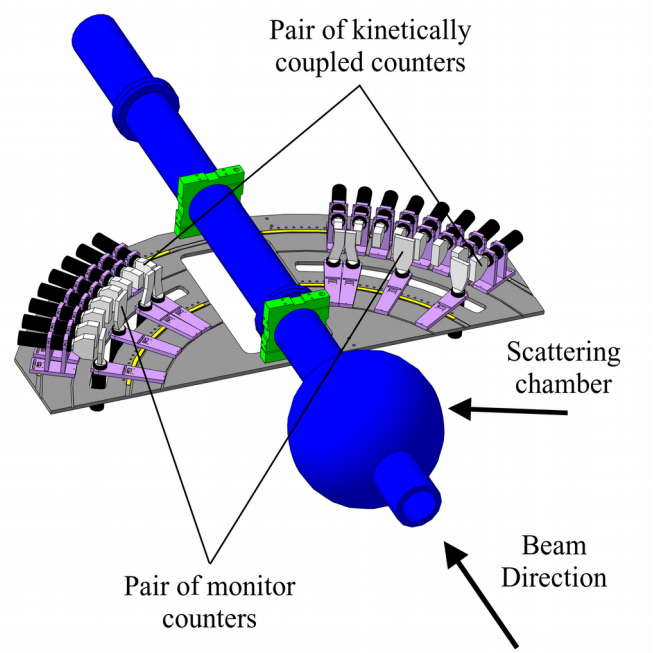



**P.K.Kurilkin et al.,**
**NIM A642 (2011) 45.**

**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.**

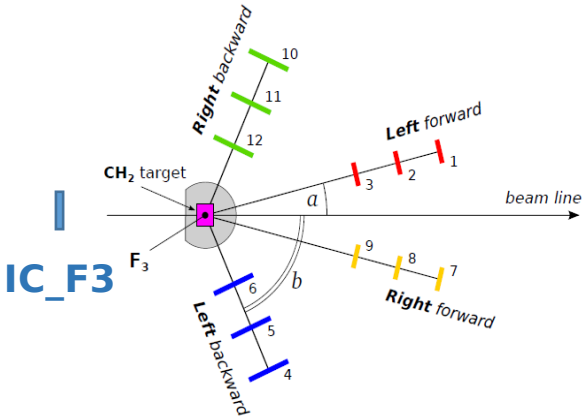
**Both methods give similar results!**

**I.S.Volkov et al., Phys.At.Nucl. 87 (2024) 459**

**Upgrade is in progress:**

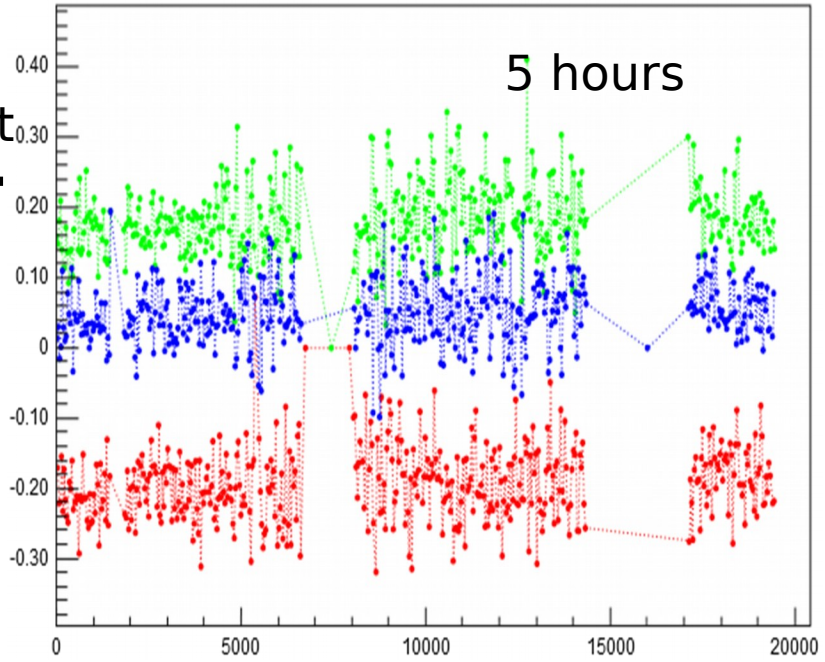
**A.A.Terekhin et al., Phys.Part.Nucl. 54 (2023) 634**

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




each point corresponds to one spill.

$$\frac{\text{Left-Right}}{\text{IC\_F3}}$$



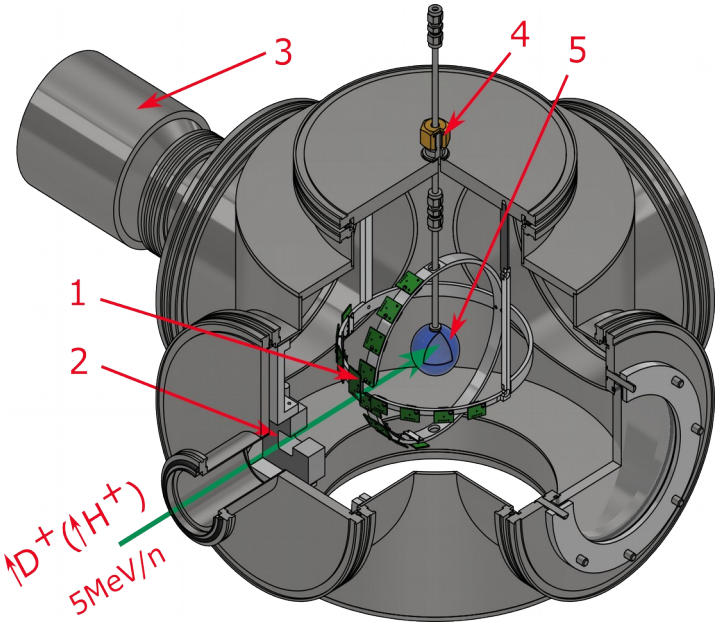

**The polarization in one mode is two times lower than the other one**

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

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

**HE tensor polarimeter is needed!**

# LE polarimetry developments




**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**)

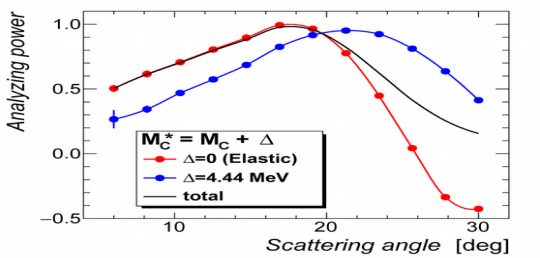
**Under construction!**
**See V.V.Fimushkin talk**

**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.**

# 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:

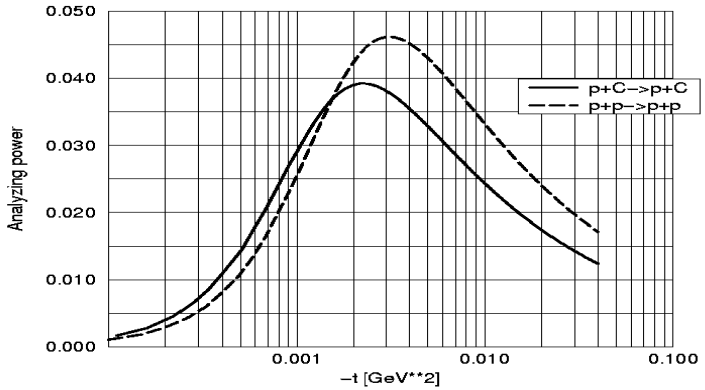
$$A_{beam} = A_{target}$$

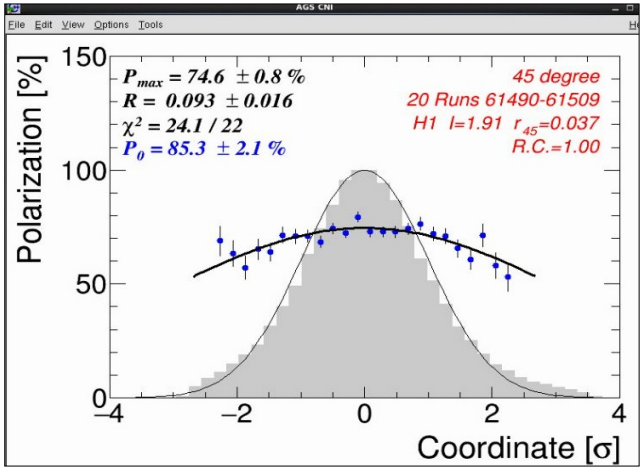
the polarization of the proton beams can be obtained using left-right asymmetry from polarized H-jet target by an absolute method.

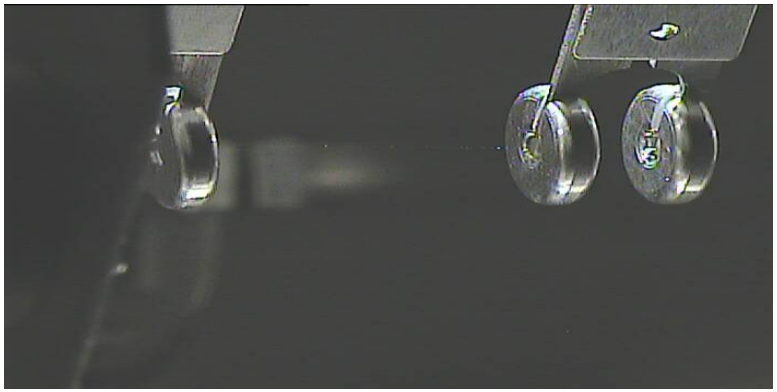
The ABS is ready, chamber and detection system are under construction.

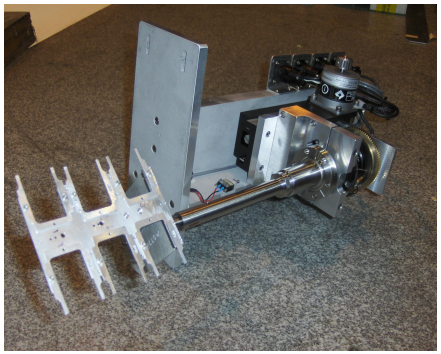
V.V.Fimushkin, M.V.Kulikov

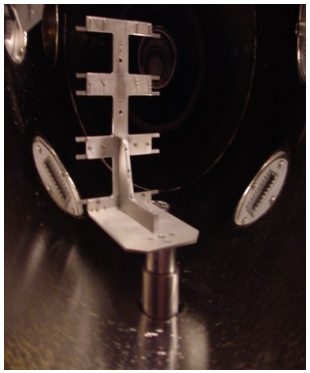
# CNI proton polarimetry developments







Very thin carbon strip target-20um x 25 nm

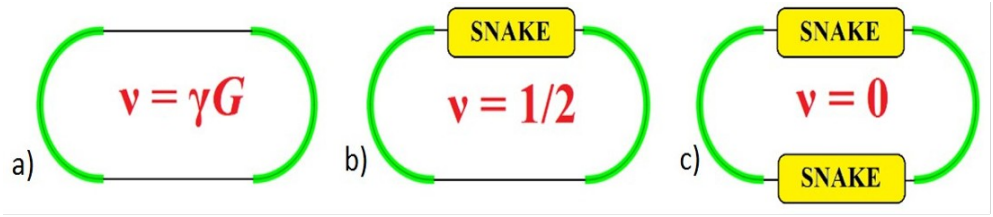
**CNI proton polarimetry at NICA energies is not an absolute method because of non-zero spin-flip hadron amplitude (AGS results).**

**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.**

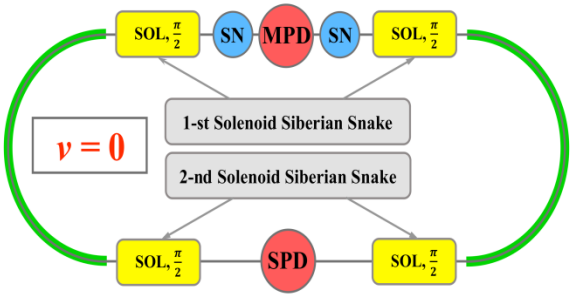
**V.V.Fimushkin, A.N.Zelenski**

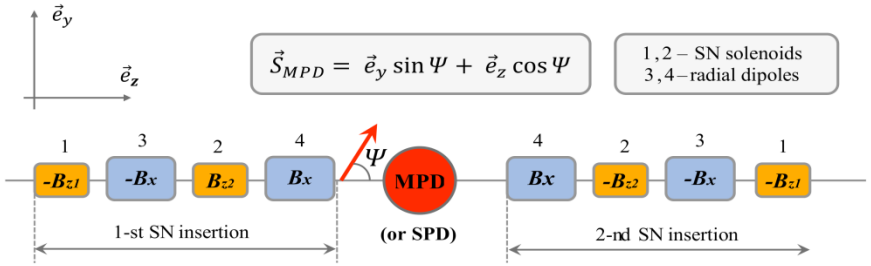
# Proton spin manipulation at NICA



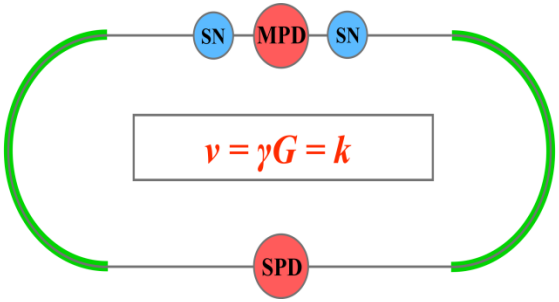

RHIC

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).**

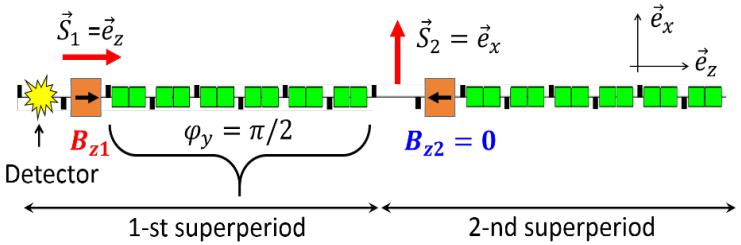
**Details:**

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

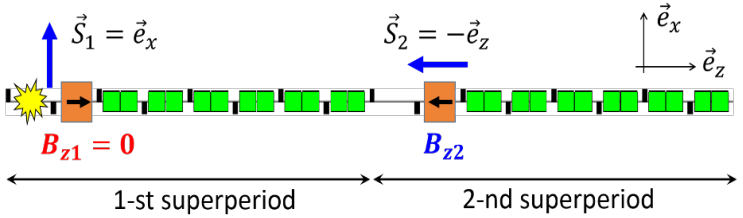
E.M.Syresin et al., Phys.Part.Nucl.52(2021) 997.

# 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**

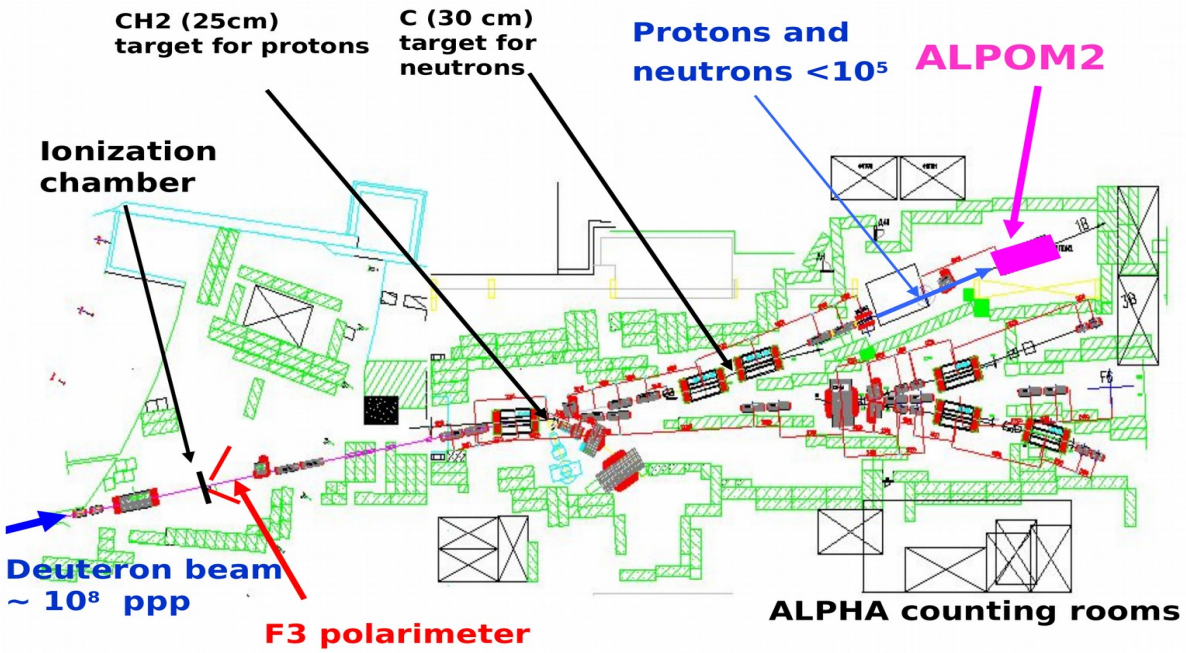
**Experimental proof of ST requires serious upgrade of the proton beam polarimetry at Nuclotron**

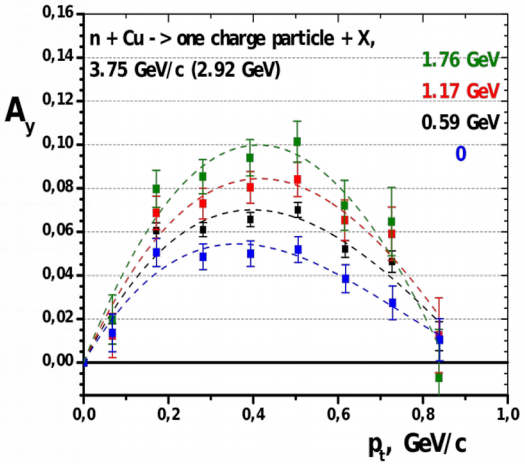
Yu.N.Filatov, A.M.Kondratenko

**Supported by:**

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

# Secondary proton and neutron polarized beam at Nuclotron



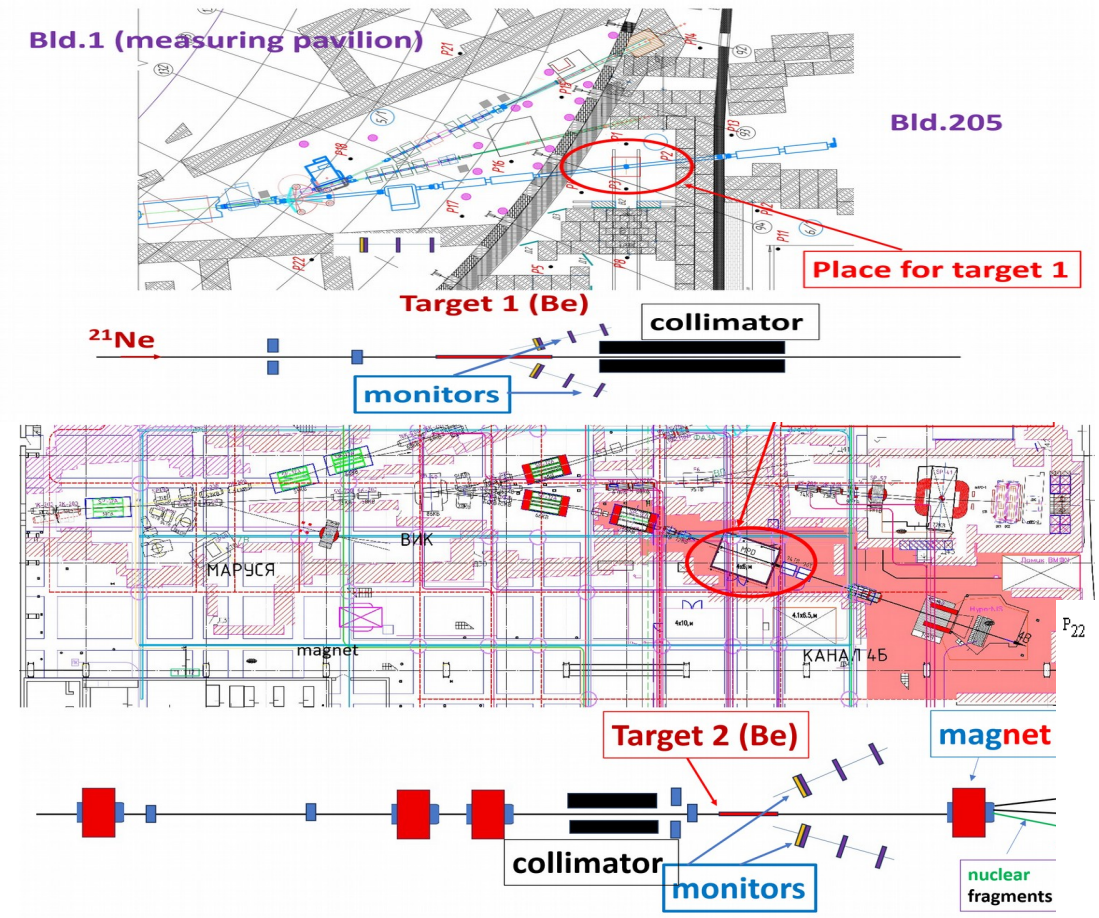




S.N.Basilev et al., Eur.Phys.J.A 56 (2020) 26

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

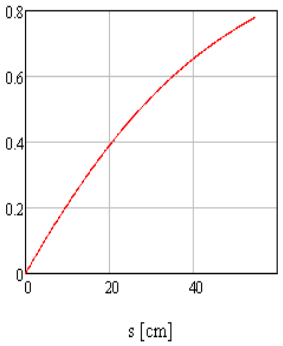
The beam line was built for spin correlation np- scattering experiment: the upgrade of existing polarized target is under consideration.

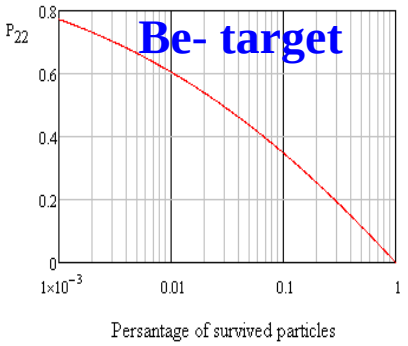
# Tensor polarized $^{21}$Ne beam at Nuclotron




-Method is based on the large quadrupole deformation of $^{21}$Ne ( $\beta_2$=0.463).

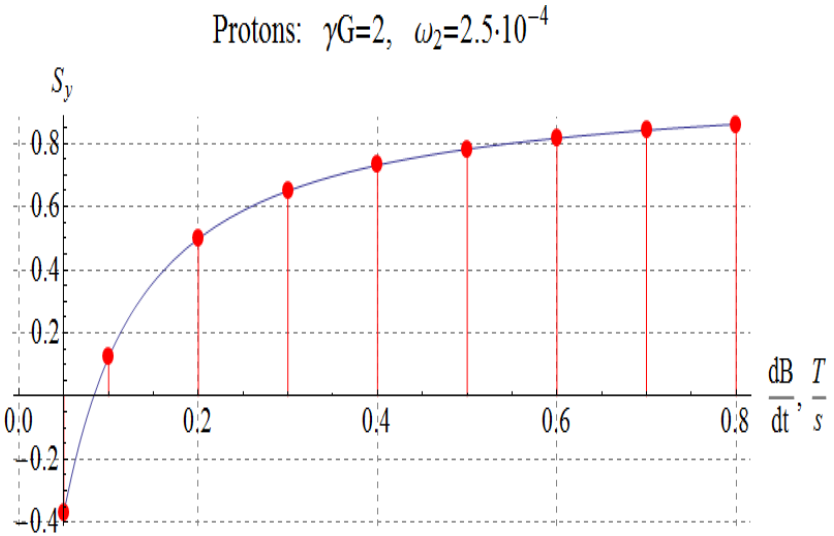
-Tensor polarization appears after passing through the thick nuclear target (Be-20cm).

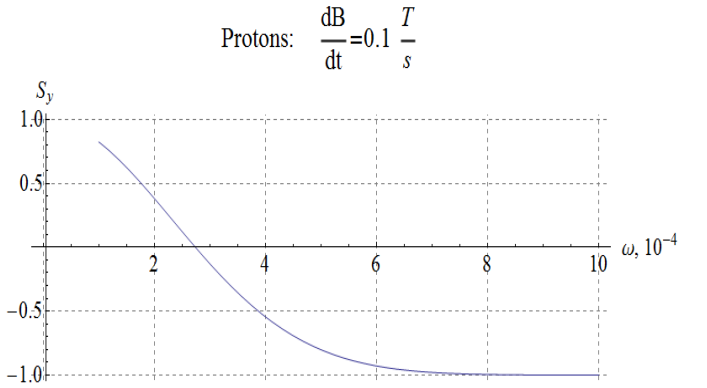


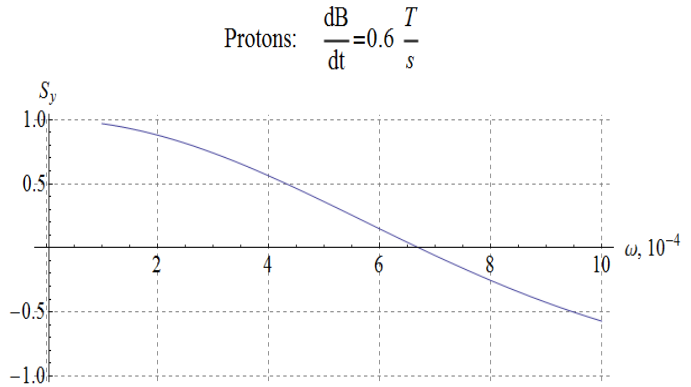




~$10^7$-$10^8$ $^{21}$Ne ions/spill with the tensor polarization ~0.4 will be available for physics.

# New experiments on the proton spin manipulation



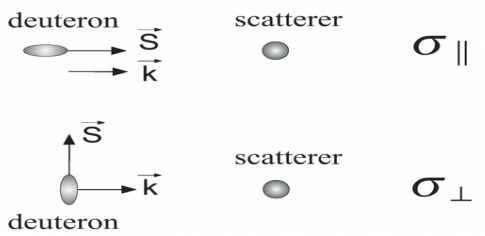

**Measurements of the integer resonance γG=k=2 power (Tkin=108 MeV)**

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

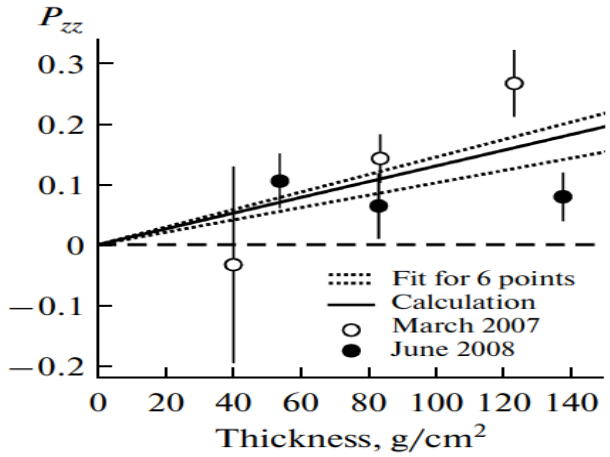
**Yu.N.Filatov et al.,**
**JETP Lett. 116 (2022) 413;**
**JETP Lett. 118 (2023) 387.**

**The final goal is to prove the possibility of Spin- Transparency 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.**

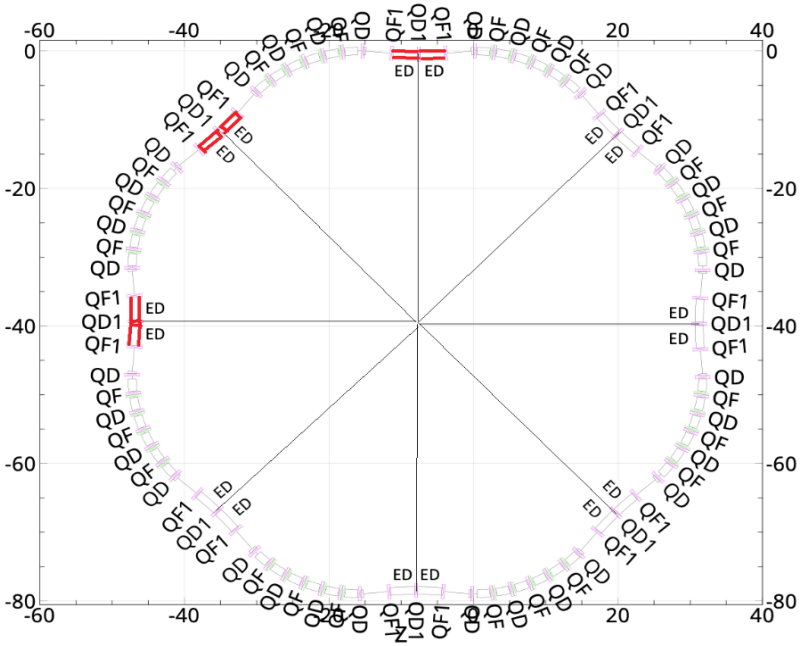
**-Spin dichroism effect is one of the phenomena acquiring by the deuteron beam passing through the nonpolarized target.**

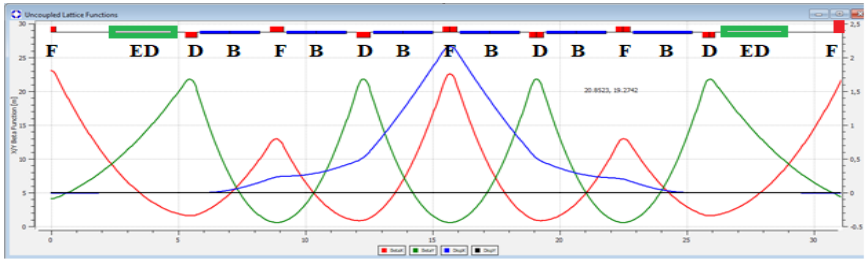
**-The method is the measurement of the tensor polarization acquiring by a nonpolarized deuteron beam moving in Nuclotron and passing through the internal target.**

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

**V.G.Baryshevsky et al.,**
**arXiv: 2508.11718v1[nucl-th]**

# 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.**

**N.N.Nikolaev, Yu.V.Senichev et al.**

# 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.**

**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.**

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**New peoples with their ideas are welcome!**

**Thank you for the attention!**