Physics program for the first stage of the NICA SPD experiments

Overview of the SPD NICA:

beam parameters & operation scenarios

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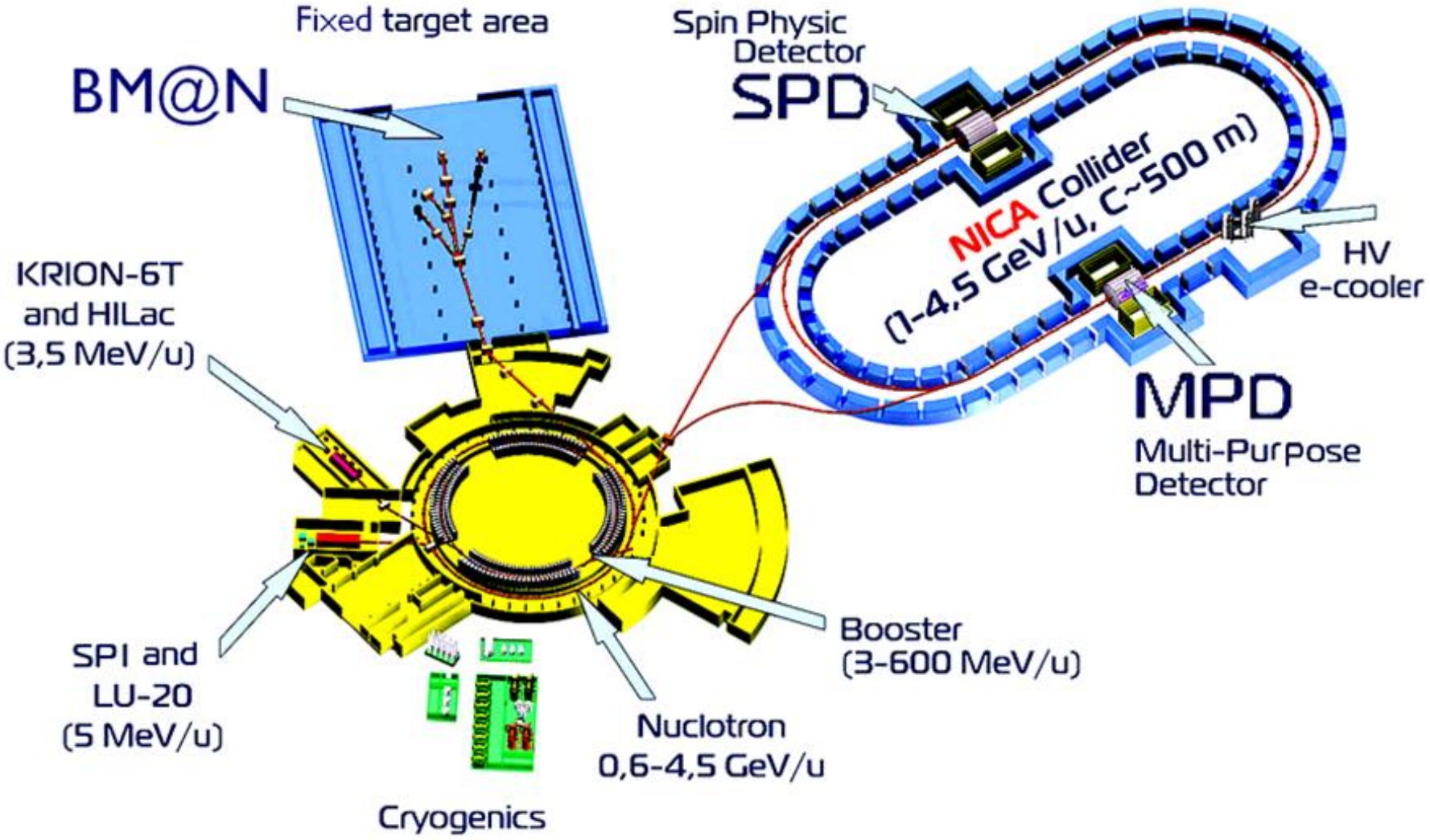
NICA Complex Main Components



General requirements to the beam facility, 2018

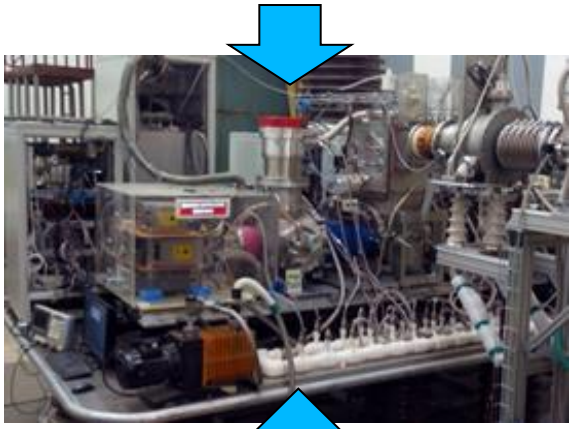
- **polarized and non-polarized p-; d–collisions**
- **p↑p↑(p)** at $\sqrt{s_{pp}}$ **= 12 ÷ 27 GeV** (5 ÷ 12.6 GeV kinetic energy)
- **d↑d↑(d)** at $\sqrt{s_{NN}}$ **= 4 ÷ 13 GeV** (2 ÷ 5.5 GeV/u kinetic energy)
- **L_{av} ≈ 1·10e32 $cm^{-2}s^{-1}$ (at $\sqrt{s_{pp}}$ ≥ 27 GeV)**

- *sufficient lifetime and polarization degree (few hours, 70%)*
- *longitudinal and transverse polarization in MPD and SPD*
- pd *collision mode should be available*

The facility operation at pp – mode at $\sqrt{s_{pp}}$ = 27 GeV reaching average luminosity of 1·10E32 cm-2·s-1 remain the 1st priority task for coming years.

Polarized beams at the Laboratory (LHEP)

- **d↑-** was accelerated in 1986 (Synchrophasotron); Nuclotron - in 2002. Spin resonance at 5.6 GeV/u.
- **p↑-** was first obtained in 2017. The first test was performed after analysis of the spin resonances.
- Ion source SPI was used.



d↑; p↑:

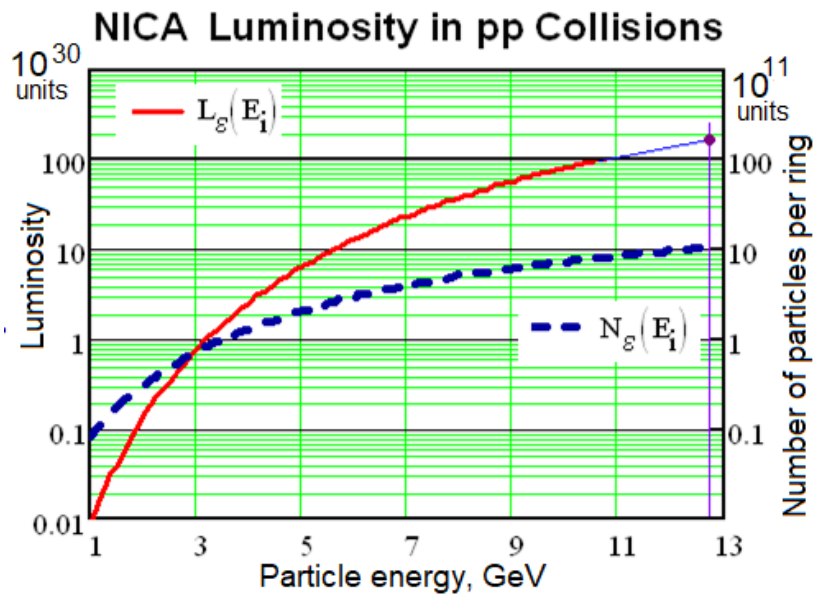
- RFQ input – up to 3 mA, t ≈ 100 mks;
- Particle number - 1.5·10e11 for 8 mks;
- The spin modes (p_z,p_{zz}): (0,0), (0,-2), (2/3,0) and (-1/3,+1) were adjusted;
- Polarisation degree - 80 %

NUCLOTRON

- 6 AGeV SC SYNCHROTRON
- CIRCUMFERENCE – 250 m
- MAGNETIC FIELD – 2 T
- THE FIELD RAMP – 1 T/s
- ONE-TURN INJECTION
- INJECTION ENERGY 5 MeV/u

- The RFQ, put limit for proton energy - 5 MeV at the linac LU-20 output (instead of 20 MeV). The new proton and light ion linac "LILAC" is now manufacturing . The LILAC output energy is 12 MeV.

NICA pp-collisions luminosity



Parameter	beam energy	
	2.0 GeV	7.2 Gev
Nuclotron Dipole Field Ramp up, T/s	0.6	0.6
Nuclotron Dipole Field Ramp down, T/s	1.0	1.0
Magnet field flat top duration, s	0.5	0.5
Total useful cycle duration, s	1.62	4.02
Dipole Magnetic Field	0.42	1.22
Acceleration time, s	1.67	1.67
Number of accelerated protons per pulse	$7 \cdot 10^{10}$	$7 \cdot 10^{10}$
Number of cycles to store $2 \cdot 10^{13}$ particles	2x285	2x285
Collider filling time at cycle duration, s	923.4	2291
Preparation of the beam in the collider (cooling, bunching emittance formation), s	100	100
Magnetic field ramp in the collider, T/s	0.06	0.06
Acceleration time from E_i to 12.6 GeV	~ 27	~ 13
Luminosity life time (30% polarization degradation due to spin resonances), s	5400	5400
Beam deceleration up to the new injection	~ 1.7	~ 0.8
Total cycle duration, s	6450	7803
Working part, %	~ 83	~ 70

❑ IP parameters: **β** = 35 cm, bunch length **σ** = 60 cm
bunch number – 22, collider perimeter **C** = 503 m

$L_{peak} \approx 1.8 \cdot 10^{32}$ cm-2·s-1 ➡ $L_{av} \approx (10^{32}$cm-2·s-1) **1.5 - 1.25**

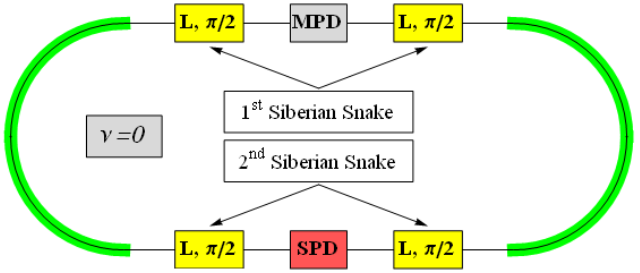
- The tests on polarized p-beam injection, storage, electron cooling can be started at ~2 GeV energy level from the beginning of the collider operation. The intensity of 5·10e8 ppp can be provided;
- The LILAC could be put into operation not earlier 2023-24.

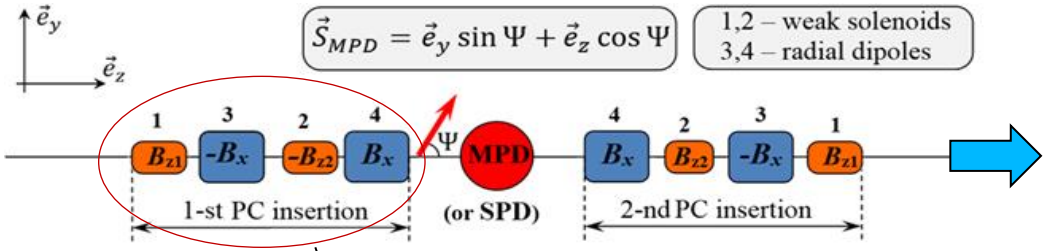
Polarization control at $\nu_s = 0$. Spin-flip in ST

Technology of "Siberian snake" was proposed for NICA

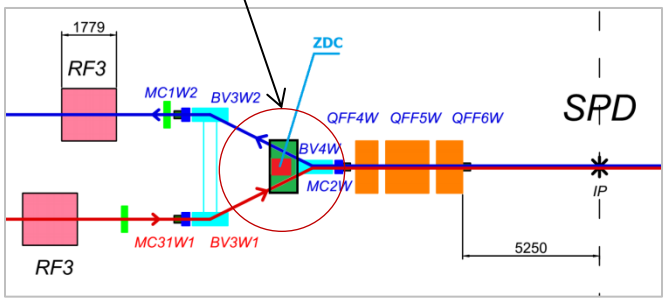
Analysis of different "snakes" (dipole, spiral dipole, solenoid) was performed: solenoidal structure is optimal.

p: $(B_{||}L)_{max}=4\times(5\div25)$T·m, d:$(B_{||}L)_{max}=4\times(15\div80)$T·m

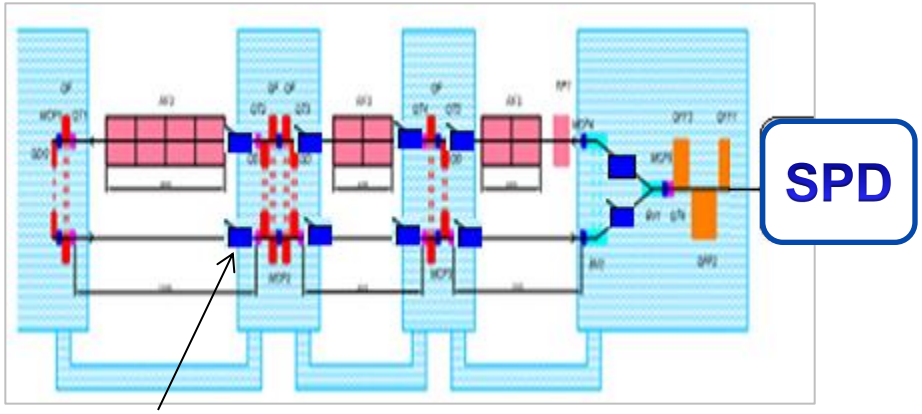




Ψ — angle between the polarization and the particle velocity. The field integral of 0,6 T·м, provides $\Delta\nu = 0.01$ for protons and $\Delta\nu = 0.003$ for deuterons. Minimum spin reversal time - 1 ms for protons and 10 ms for deuterons.



The collider lattice fragment where weak "navigator" solenoids are installed



Places where spin control dynamic 6 T solenoids could be installed

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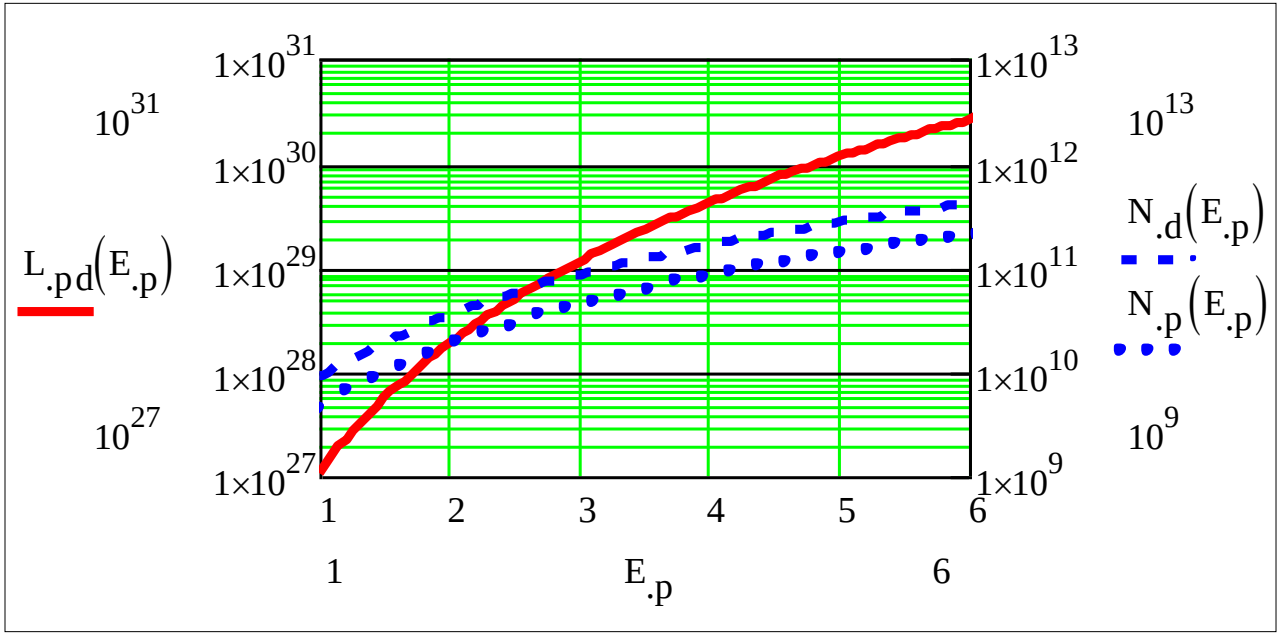
NICA dp-collisions: luminosity & scenarios

2 IP, but the Luminosity optimized for 1 IP



- N_d , N_p - are particle number per bunch;
- Storage mode are necessary;
- Bunch number - 22

- Both injection chains are used. HILAC cannot provide polarized particles:
- Single asymmetry measurements only.
- Preparatory tests on storage, electron cooling (?) and experiments can be started over full energy range from the beginning of the collider operation;
- **Lower energy scenario:** Extraction from Nuclotron at 1-1.5 GeV, storage, deceleration, bunch formation,

Further tasks of spin research program at NICA

- Continue operation and further improvement of polarized ion source SPI, waiting beam time at Nuclotron – 2021-2022;
- Upgrade of the polarimeters: linak output; coasting beam; extracted beam; new polarimeter for proton energy above 6 GeV – 2020-2023;
- Manufacturing of the 6T SC-solenoid model; for the SPD test bench -2021-2022;
- Design and manufacturing equipment for the SPD test bench at the collider - 2020-2023;
- LILAC manufacturing and tests – 2020-2025;
- Analysis of 3He(2+) polarized ion source based on the SPI upgrade.

CONCLUSION

The results obtained during last years demonstrate progress in the development of spin research infrastructure at LHEP

We have polarized deuteron and proton beams

Nevertheless, list “to do” is long