NICA Operation in Polarized Proton & Deuteron Mode: Status of Preparation

A.Kovalenko

A. (*JINR, Dubna*)

SPD Meeting_12 October 2017, LHEP, JINR, Dubna

The contributors to the polarized program in the facility systems design and carrying out of the experiments at Nuclotron/NICA complex

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- A.S.Belov, V.N. Zubets, A.V. Turbabin *(INR, Moscow);* A.M.Kondratenko, M.A.Kondratenko (*STL "Zaryad", Novosibirsk*), Yu.Filatov (*MPTI,Moscow/JINR,Dubna*),

Outline

- Introduction
- The facility concept in polarized mode
- Polarized d- and p-beams at Nuclotron in 2016-17
- Future plan

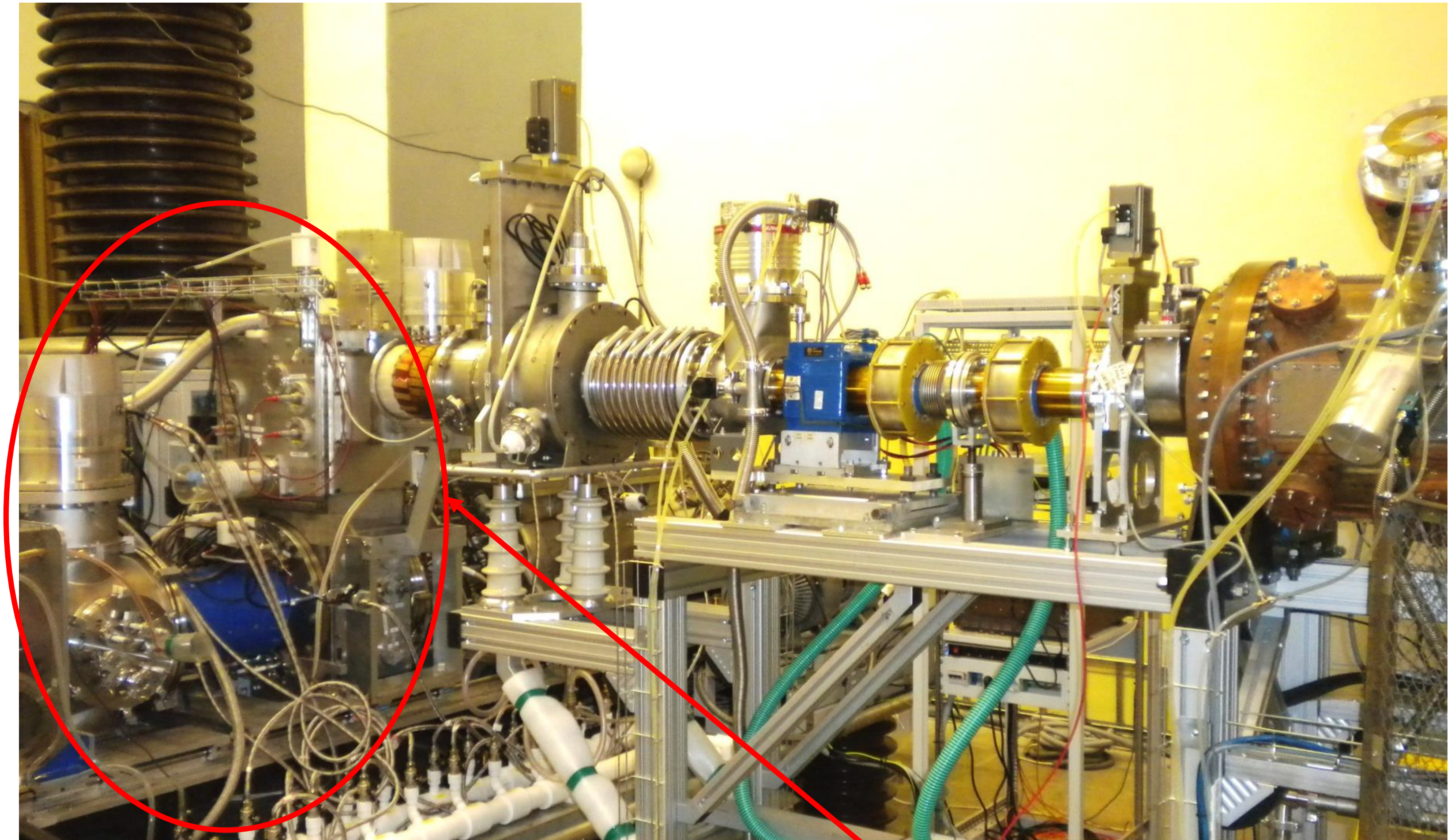
Introduction

Real progress was achieved at our facility in the development of infrastructure of spin physics research since the SPIN2015

- The SPI ion source, the new RFQ pre-accelerator were commissioned; the polarimeters at three points: at the linac output, at the Muclotron warm straight section and at the extraction line were upgraded

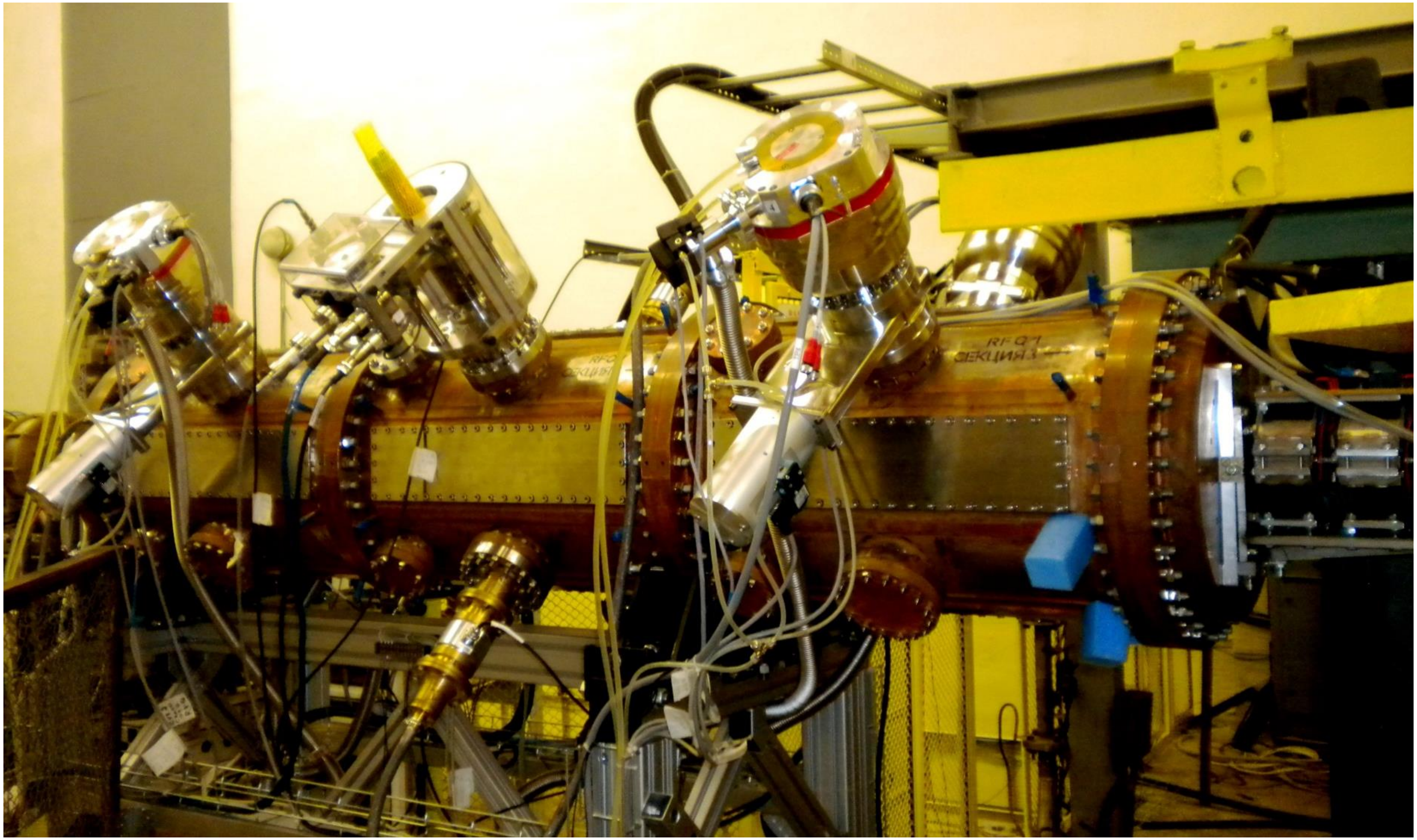
- Polarized d - beam is available now for physics and
- Polarized p - beam was first otaimed and available for polarization monitoring at circulating and extracted modes

Implementation of polarized beam program (1)



Equipment of new polarized ion source SPI and LEBT part of beam channel to RFQ section

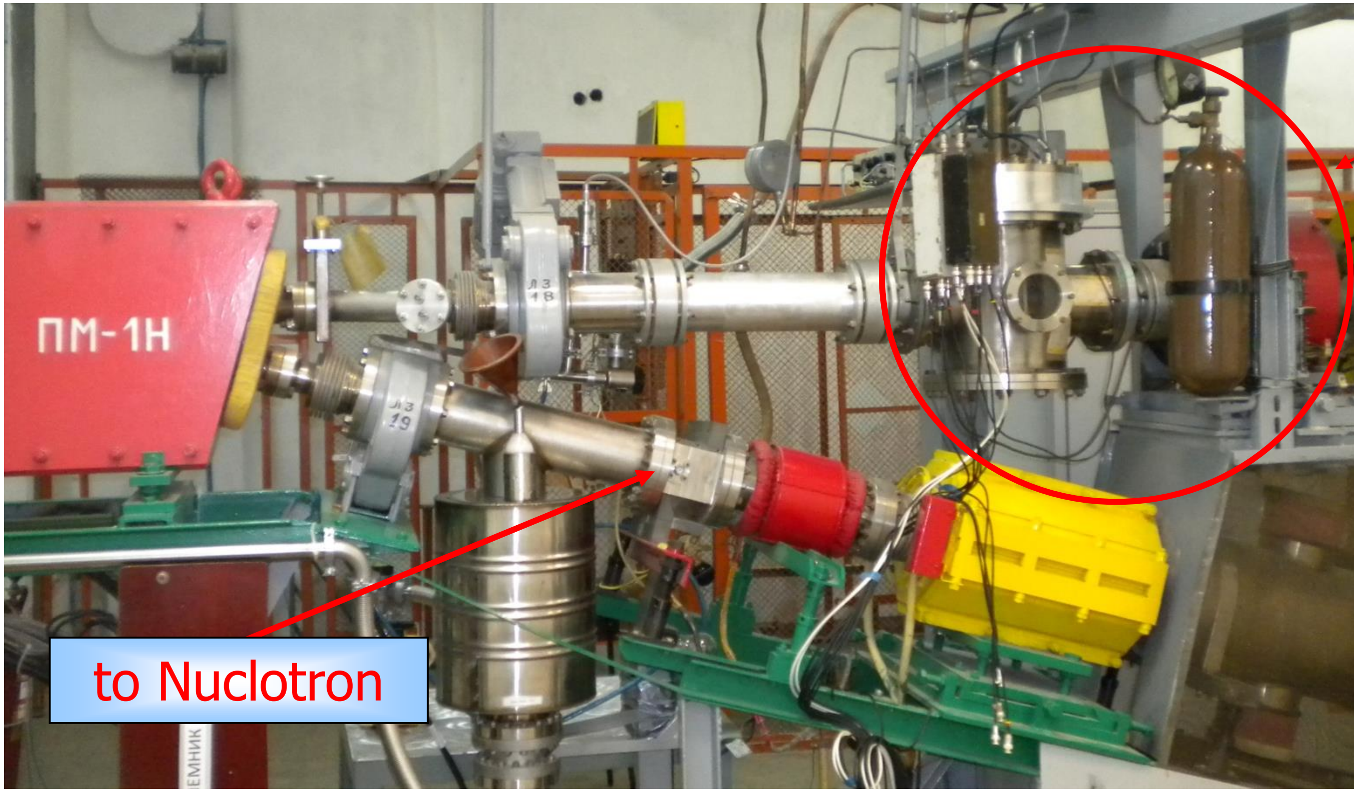
Implementation of polarized beam program (2)



New RFQ section – pre-injector LU-20

A.D.Kovalenko

Implementation of polarized beam program (3)

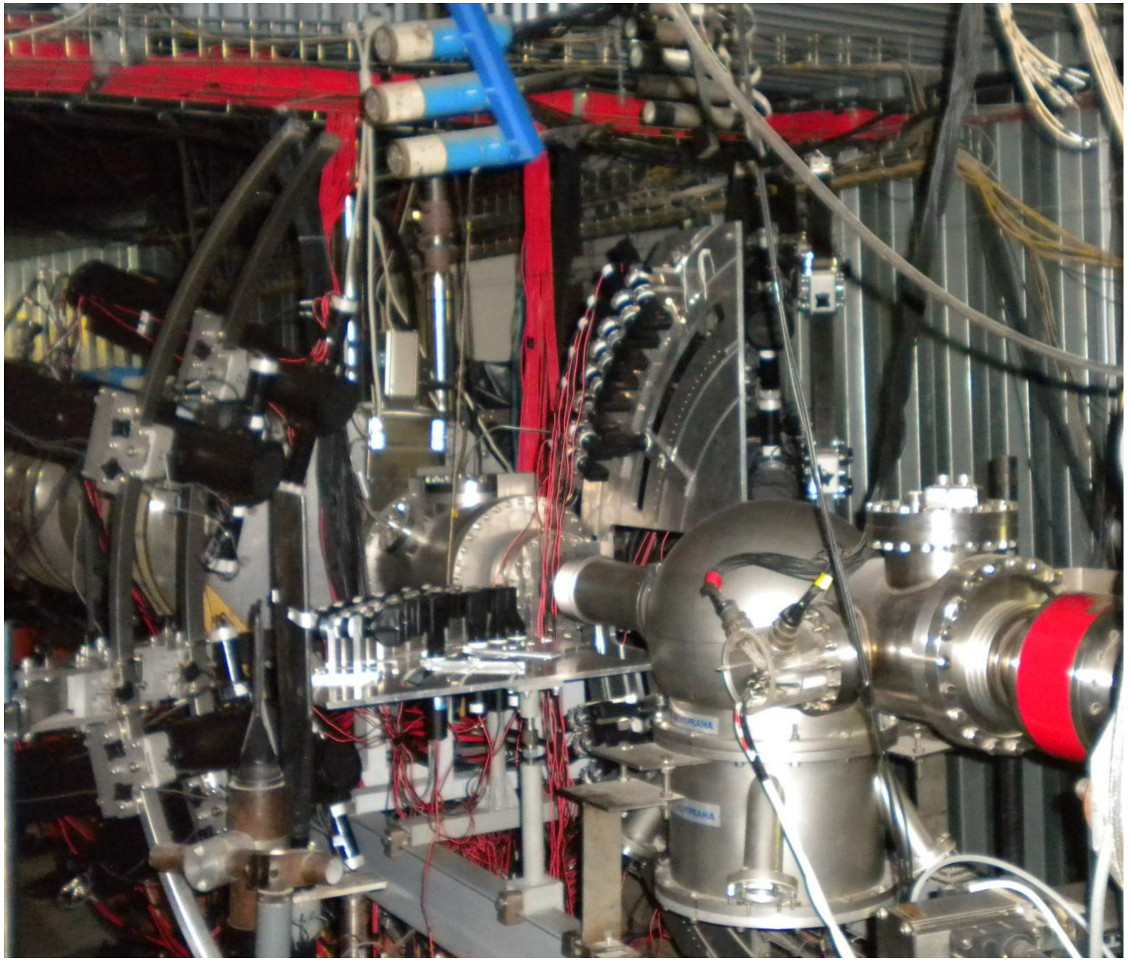


polarimeter

D.Krivenkov
L.Zolin,
V.Nikitin,
V.Avdeichikov
M.Aver'yanov
et al.

Output beam channels from linac LU-20

Implementation of polarization program (4)



V.Ladygin
et al.

Proton and deuteron polarimeter at Nuclotron ring

Implementation of polarization program (5)

N.Piskunov
R.Shindin
K.Legostaeva
A.Livanov

et al.

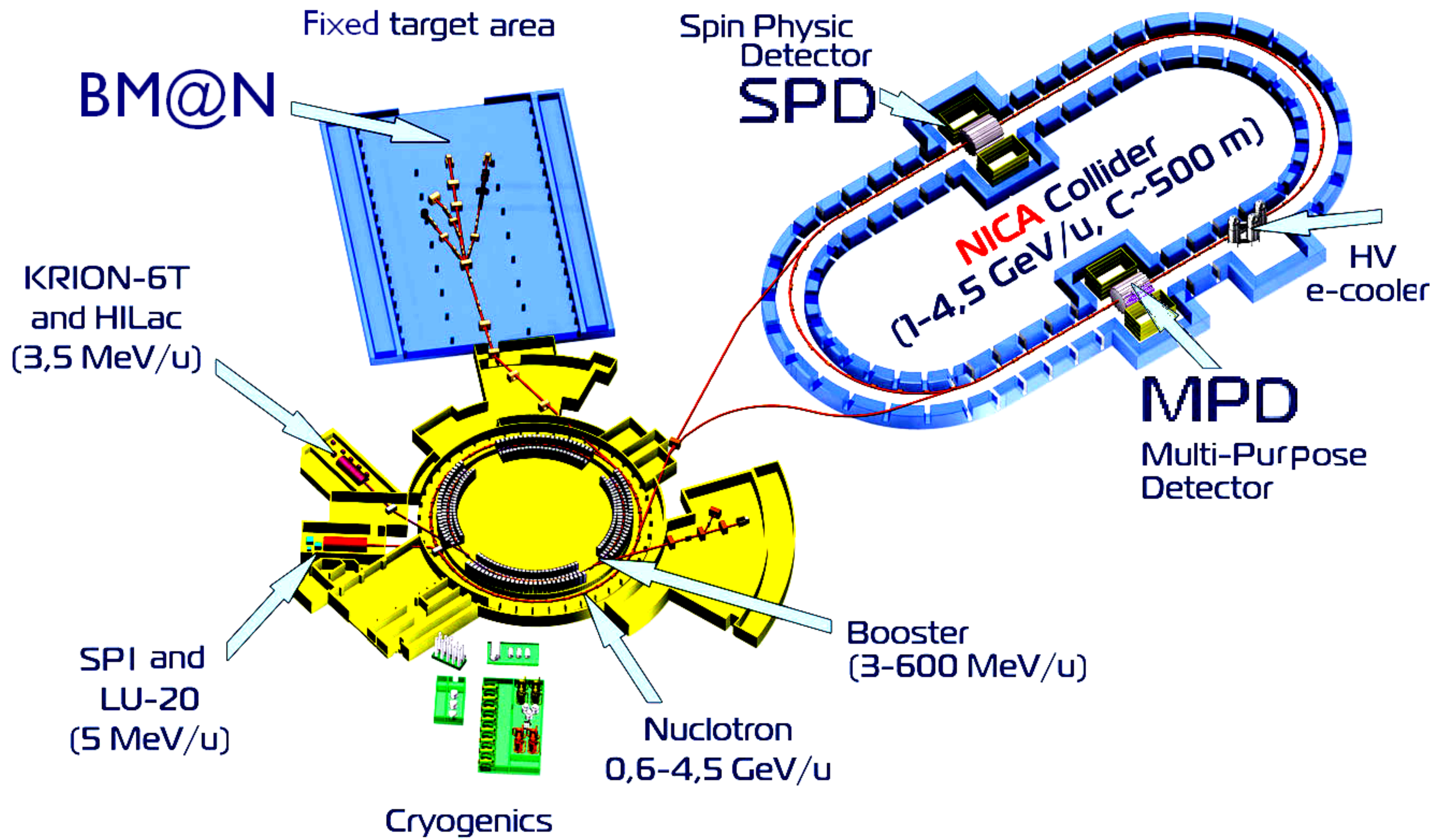
Proton and deuteron polarimeter at Nuclotron extracted beam (focus F3 point)

Requirements to the facility in polarized mode

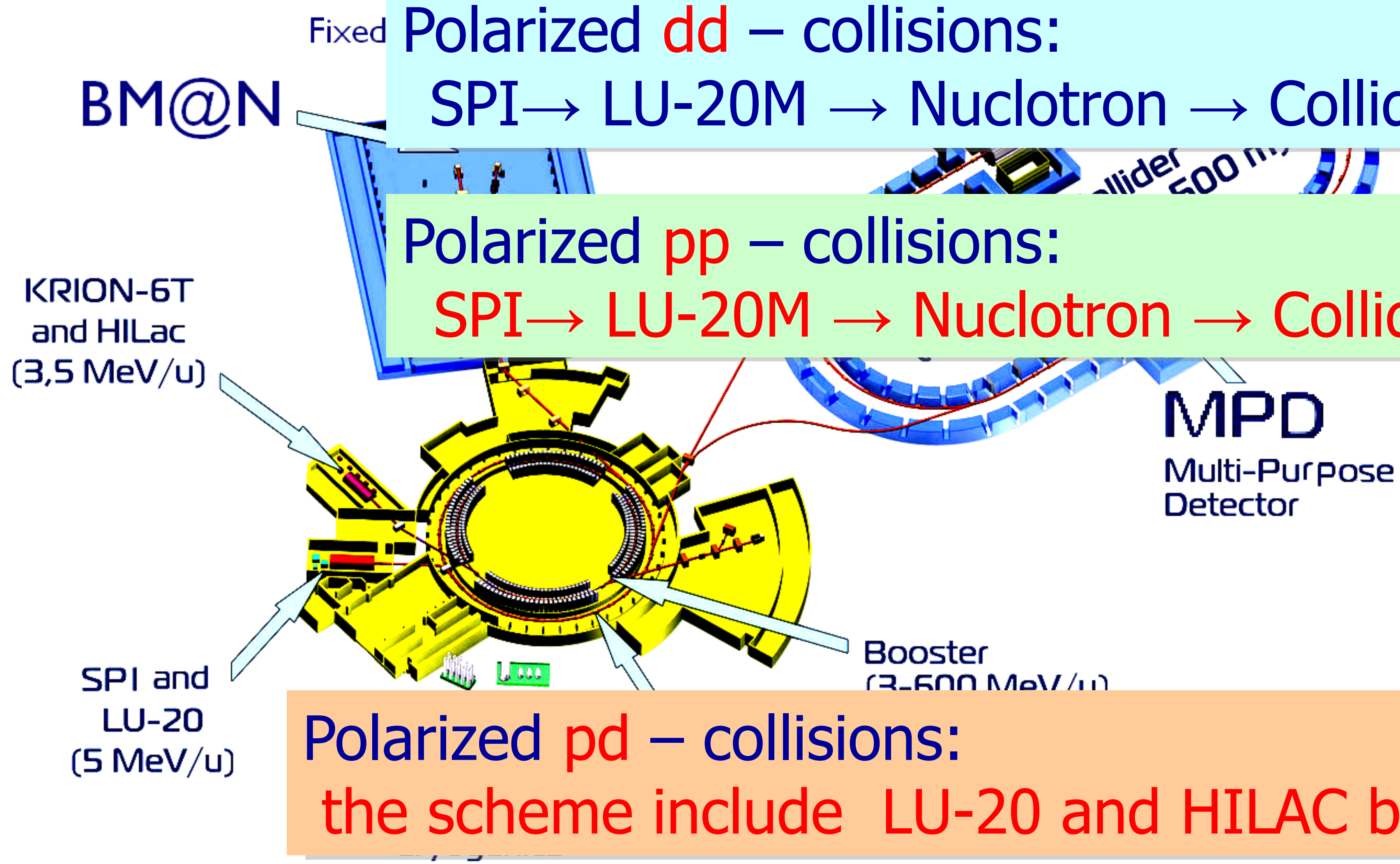
- **polarized and non-polarized p-; d–collisions**
- **p↑p↑(p)** at $\sqrt{s_{pp}}$ **= 12 ÷ 27 GeV** (5 ÷ 12.6 GeV kinetic energy)
- **d↑d↑(d)** at $\sqrt{s_{NN}}$ **= 4 ÷ 13 GeV** (2 ÷ 5.5 GeV/u kinetic energy)
- $\mathbf{L_{average}}$ ≈ $1 \cdot 10E32\ cm^{-2}s^{-1}$ (at $\sqrt{s_{pp}} \geq 27$ GeV)
- sufficient lifetime and degree of polarization
- longitudinal and transverse polarization in MPD/SPD
- asymmetric collision mode, pd, should be possible

We concentrate design efforts at the pp-mode that need extremely high the peak and average luminosity

Superconducting accelerator complex NICA
(Nuclotron based Ion Collider fAcility)



NICA operation in Polarized Mode (1)



Polarized dd – collisions:

SPI→ LU-20M → Nuclotron → Collider

Polarized pp – collisions:

SPI→ LU-20M → Nuclotron → Collider

Polarized pd – collisions:

the scheme include LU-20 and HILAC both

NICA operation in Polarized Mode (2)

- **d↑-** was accelerated at the Synchrophasotron in 1986; at the Nuclotron in 2002. No dangerous spin resonances up to 5.6 GeV/u.

- **p↑-** was not accelerated at the facility up to 2017. The first test was performed at Nuclotron after more detailed analysis of the problem of spin resonances at real operation conditions of the accelerator.

(presentation by Yu. Filatov et al., DSPIN_2017.)

NICA operation in Polarized Mode (3)

- To control the polarization direction world famous technology of a “Siberian snake” *(Yu. S. Derbenev and A. M. Kondratenko, 10th Int. Conf. on High Energy Accel. v.2, p.70 ,Protvino, 1977)* was proposed to be used for the Nuclotron/NICA complex

- The analyses of different “snake” structures (dipole, spiral dipole, solenoid) have shown that solenoidal structure is optimal in the NICA energy range due to minimal impact to the close orbit excurtions.

NICA operation in Polarized Mode (4)

At first, our concept was the following: p↑ are accelerated up to 5-6 GeV in the Nuclotron with dynamic solenoidal Siberian snake → transfer to collider rings → storage, stochastically cooled and are accelerated further up to 13.5 GeV in the collider rings.

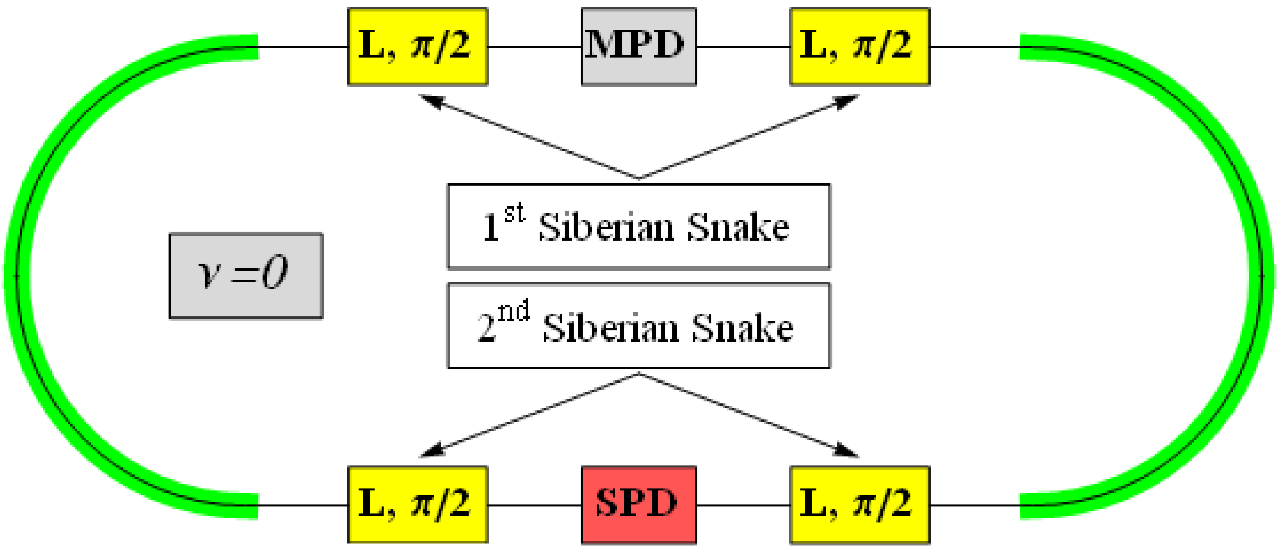
Recent solution: p↑ acceleration at Nuclotron limited to 1 - - 2 GeV without strong snake → formation and stochastic cooling (optionally) of a bunch → bunch transfer to collider ring → storage, acceleration up to the needed energy (max. 13.5 GeV) in the collider rings.

Finally, the parameters are optimized to reach average luminosity at the level of 1x10E32 at 2x13.5 GeV c.m. collision energy.

Polarization control in the Collider at $\nu_s = 0$ (1)

Solenoidal Snake at particle momentum:

p=(2.5÷13)GeV/c



Necessary integral of the magnetic field

protons:

$(B_{||}L)_{max}=4\times(5\div25)$ T·m

deuterons:

$(B_{||}L)_{max}=4\times(15\div80)$ T·m

Polarization control in the Collider at $\nu_s = 0$ (2)

Spin Transparency Mode in the NICA Collider with Solenoid Siberian Snakes for Proton and Deuteron Beam

A D Kovalenko[1], A V Butenko[1], V A Mikhaylov[1], M A Kondratenko[2], A M Kondratenko[2] and Yu N Filatov[1,3]

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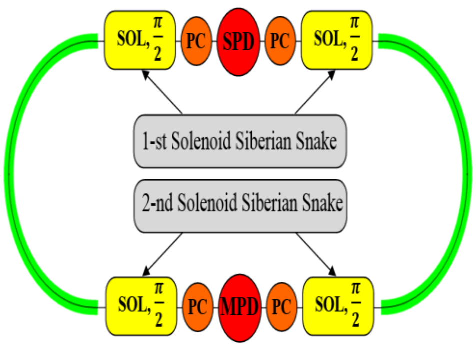
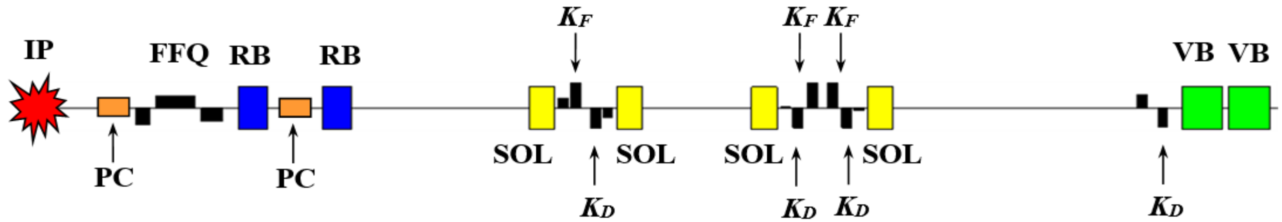
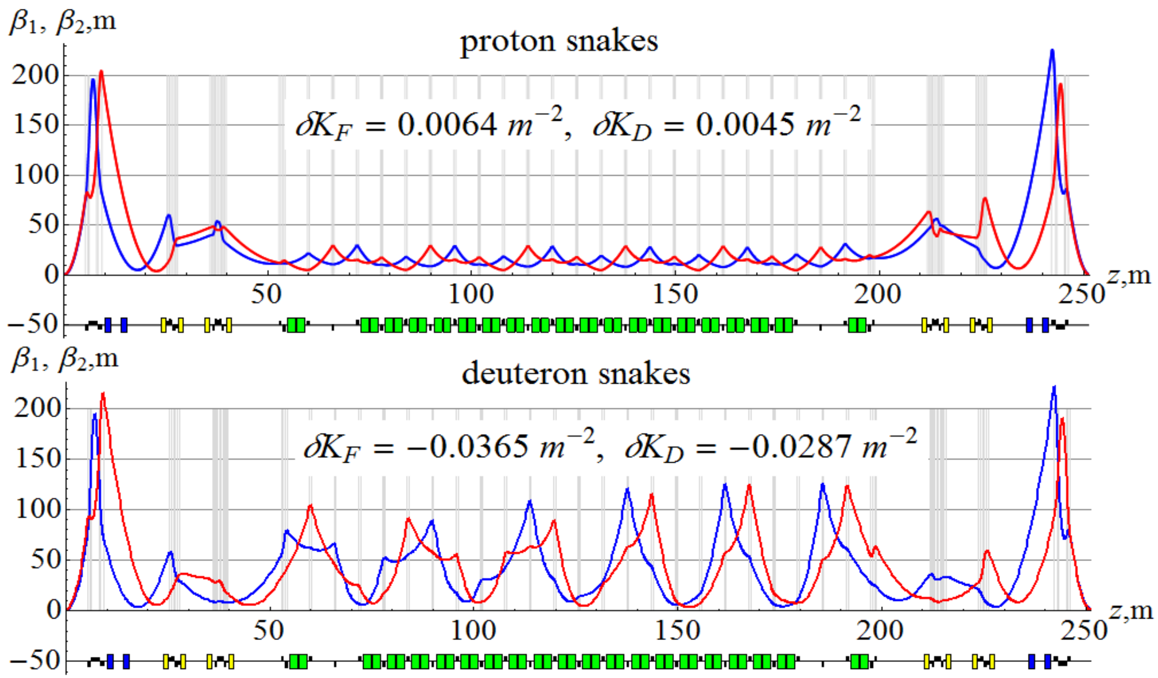
[3]Moscow Institute of Physics and Technology, 141700, Dolgoprudny, Russia

Polarization control in the Collider at $\nu_s = 0$ (3)

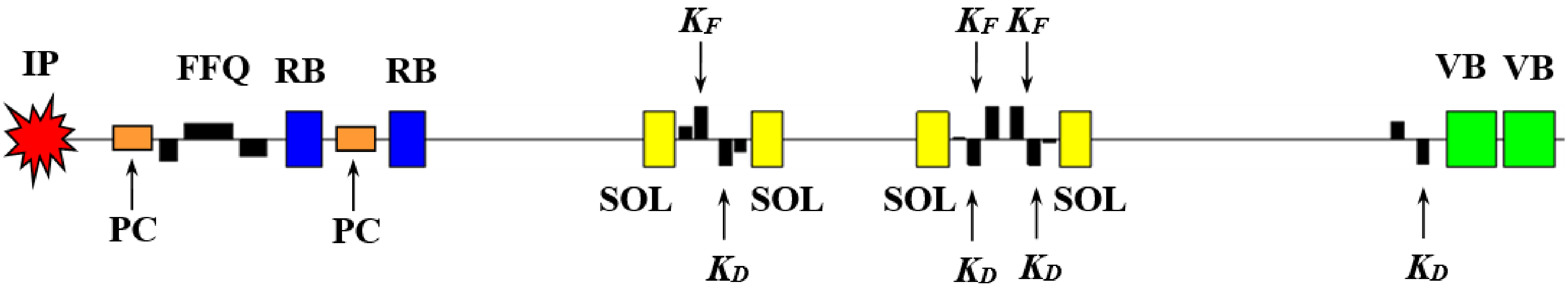


Spin Transparency Mode in the NICA Collider with Solenoid Siberian Snakes for Proton and Deuteron Beam





Polarization control in the Collider at $\nu_s = 0$ (4)



SOL – 6T Solenoid of 1.2 m (One Siberian Snake = 8×SOL)

PC – Polarization Control Weak Solenoid

VB – arc's Vertical-field Bending magnets

RB – Radial-field Bending magnets

FFQ – Final Focus Quadrupoles

δK_F, δK_D – gradient deviation of focusing and defocusing quadrupoles for snake matching

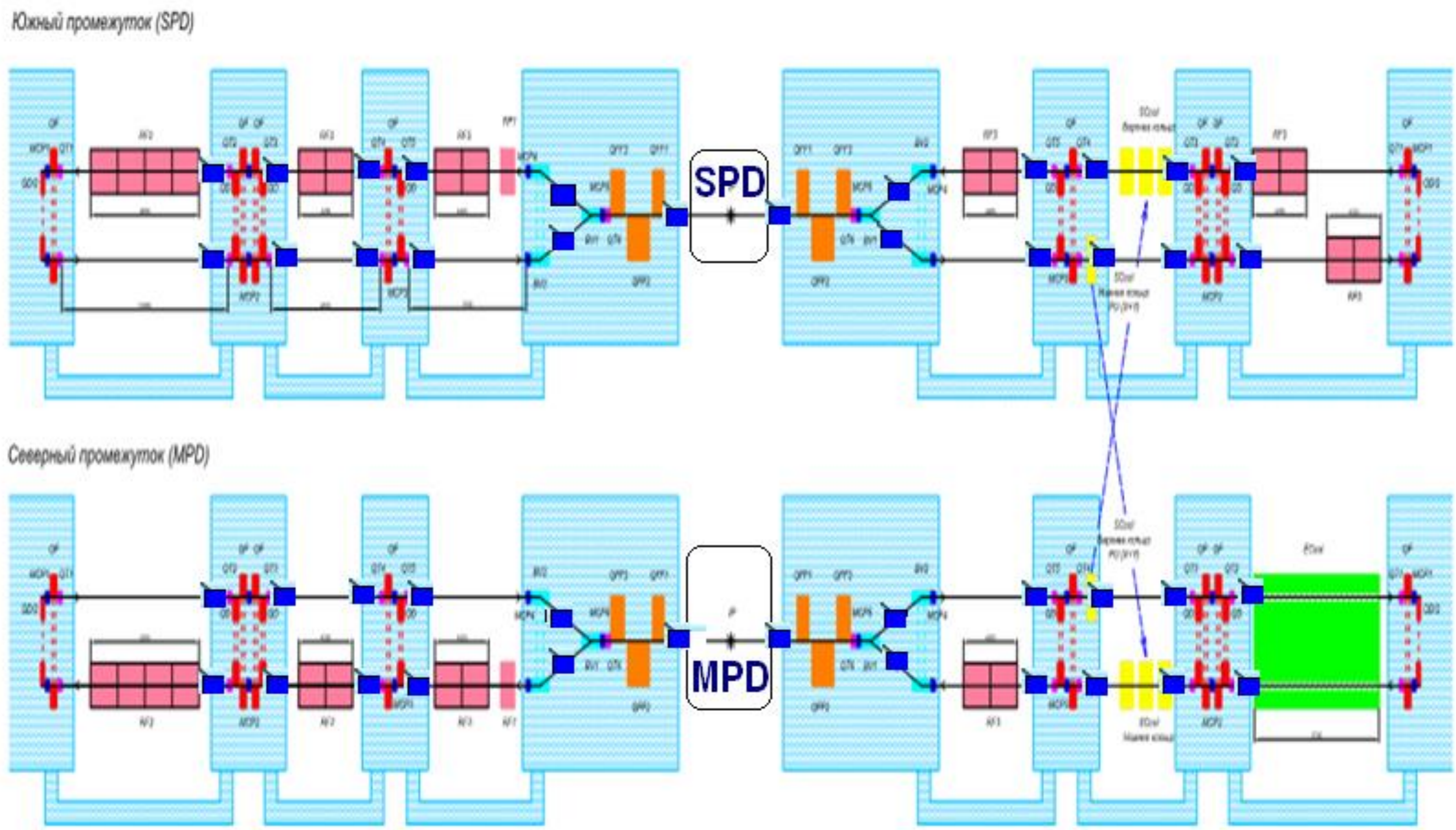
$$K_F = K_{F0} + \delta K_F \,, \qquad K_D = K_{D0} + \delta K_D$$

$$K_{F0} = 0.519 \text{ m-2}, \quad K_{D0} = 0.504 \text{ m-2}$$

We do not compensate the coupling of betatron oscillations by means of additional quadrupoles in our matching scheme.

Polarization control in the Collider at $\nu_s = 0$ (6)

option 1: combination of the solenoids and RF



polarization control equipment

Polarization control in the Collider at $\nu_s = 0$ (6)

- The proposed scheme is suitable for any type of the particles.
- The scheme provides the desired polarization direction in both IP's (MPD and SPD detectors), and gives also a possibility of simple decision the problems of polarization matching at injection and at polarimetery points as well.

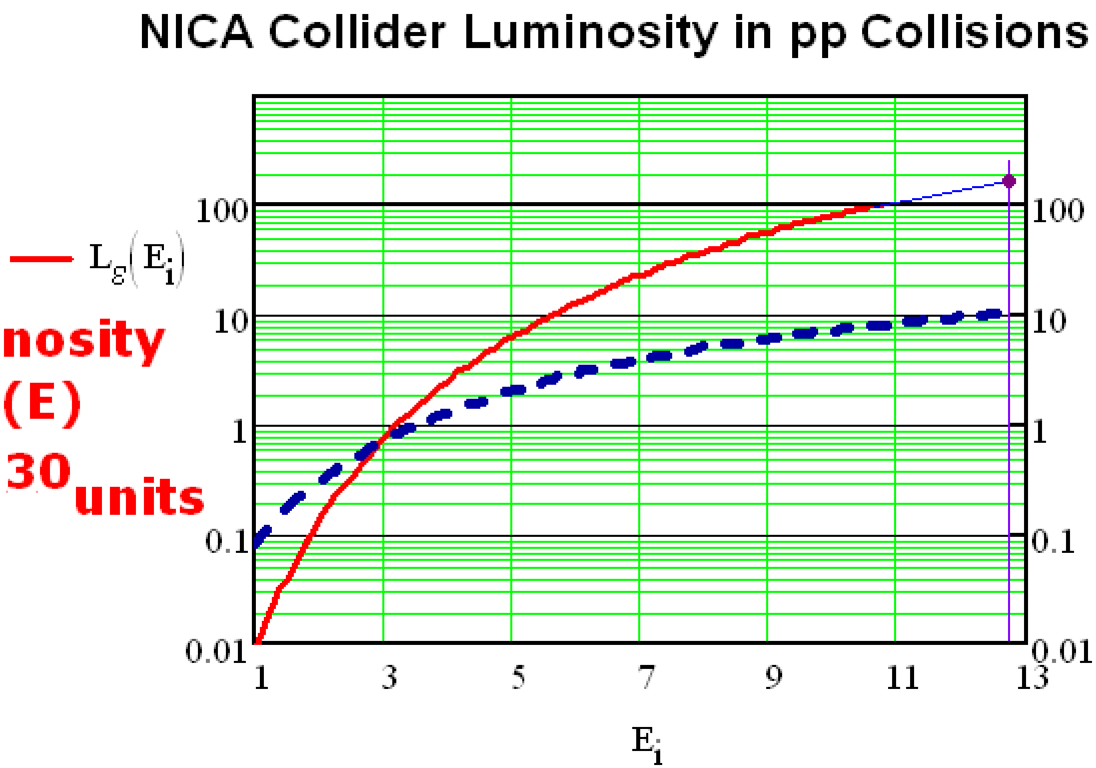
Limitations: 1 – available space at the ring; 2 – deuteron momentum ≤ 30% of max. if the polarization direction should be changed at 90 degree.

Polarization control in the Collider at $\nu_s = 0$ (7)

option 2: the solenoids instead of some RF modules

Start option could be: the solenoids instead of SPD (provide the experiments at MPD with polarized beams)

NICA pp-collisions peak luminosity (1)



Luminosity L(E) in 10^{30} units

Lpeak ≈ $1.8 \cdot 10^{32}$ cm-2·s-1

particle number per bunch in 10^{11} units

maximum proton number in each ring – $2.2 \bullet 10^{13}$

Proton energy E in GeV

❑ IP parameters: **β** = 35 cm, bunch length **σ** = 60 cm (not optimized), **bunch number** – 22, collider perimeter **C** = 503 m

from I.N.Meshkov 29/11/2012

NICA pp-collisions peak luminosity (2)

Main problems and limitations:

1. Proper beam intensity from the ion source and Nuclotron (**~10E11 per cycle**)
2. Maximum possible pulse repetition rate (**0.2 Hz**)

Necessary stored particle number in the collider is reached after 220 injection pulses and will take not more than ½ hour to fill the ring with 1.5-2.0 GeV polarized protons in this case.

3. Storage in the collider ring (bunched or coasting beam?), acceleration from ***~2 to 12.7 GeV (or to the experiment energy), formation of bunch parameters corresponding to the maximum luminosity.***

Other problems: transition energy, polarization degradation, microwave instabilities, beam-beam effects, etc.

The further tasks towards realization of polarization research program at Nuclotron/NICA

- Improvement of the polarized ion source;
- The RFQ pre-injector and LU-20 front end upgrade;
- Upgrade of polarimeters: linac output; circulating beam; extracted beam; test the new approach to proton polarization measurements above 4 GeV;
- Design and tests of the 6 T SC-solenoid module;
- Further simulations of polarized beam dynamics in the Nuclotron and NICA collider especially at long time scale, 10E4 s, simulation of bunch storage process, analysis of instabilities.

THANK YOU

FOR YOUR ATTENTION

NICA REQUEST: is based at the LoI

LoI: Spin Physics Experiments at NICA-SPD with polarized proton and deuteron beams

compiled by the Drafting Committee: I.A.Savin, A.V.Efremov, D.V.Peshekhonov, A.D.Kovalenko, O.V.Teryaev, O.Yu.Shevchenko, A.P.Nagajcev, A.V. Guskov, V.V. Kukhtin, N.D. Topilin.

presented at the JINR PAC for Particle Physics on 25–26 June 2014.

PAC Recommendations:

….The PAC regards the SPD experiment as an essential part of the NICA research program and encourages the authors of the Letter of Intent to prepare a full proposal and present it at one of the forthcoming meetings of the PAC. …

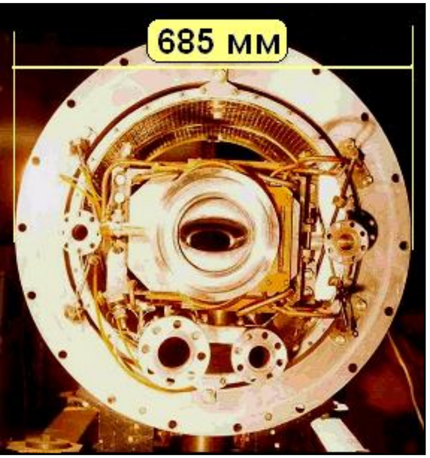
The results were reported and regular discussed by the FERMY/NICA SPIN community

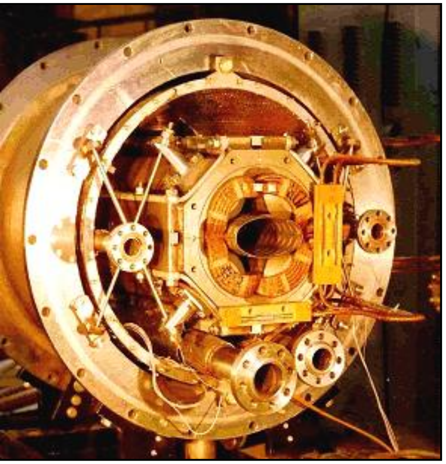
Regular SPIN@FERMI/NICA Teleconferences

1. **A D Krisch** *(Michigan)*
2. **Alex Chao**
3. **Alexander Belov**
4. **Alexander Dutton**
5. **Alexander. Kovalenko**
6. **Anatoly Kondratenko**
7. **Austin Tai**
8. **Chris Quigg**
9. **Christine Aidala**
10. **Dennis W Sivers**
11. **Man Hung**
12. **Donald Crabb**
13. **Ernest Courant**
14. **Erik Ljungman**
15. **Foivos Antouiinakis**
16. **Francisco Kalyckyj**
17. **Giuseppe Fidecaro**
18. **Greg Bock**
19. **Herman B White Jr**
20. **Hikaru Sato**
21. **Igor Savin**
22. **Ioanis Kourbanis**
23. **J D Bjorken**
24. **Jacob A Askari**
25. **Jessica K Thompson**
26. **John Peoples**
27. **John R O'Fallon**
28. **Karl Slifer**
29. **Katsuya Yonehara**
30. **Lawrence Jones**
31. **Marc L Kaducak**
32. **Maria Fidecaro**
33. **Mei Bai**
34. **Mike Syphe**
35. **Mikhail Ukhanov**
36. **Milorad Popovic**
37. **Paul Reimer**
38. **Pier J Oddone**
39. **Richard Raymond**
40. **Rolland Johnson**
41. **Sergey Troshin**
42. **Spencer Haupert**
43. **Steve Holmes**
44. **Steven Geer**
45. **Stuart D Henderson**
46. **Thomas Roser**
47. **Vasiliy Morozov**
48. **Victor K. Wong**
49. **Vladimir A Anferov**
50. **W T H vanOers**

Polarized Protons at Nuclotron (1)

Necessary solenoid can be manufactured base on a hollow Nuclotron-type SC cable and the new SC wire.





Critical current of Nuclotron magnets at B = 2 T, dB/dt = 4 T/s, f = 1.0 Hz exceed 8000 A.

Suitable NbTi wire was designed by the Bochvar company for **6 T, 1 T/s** magnet of SIS300 R&D program.