Polarized deuterons and protons at NICA

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JINR, LHEP March 17-19, 2013

OUTLINE

- Spin physics requirements
- NICA layout in polarized mode
- Polarization control schemes
- Technical concept of the schemes
- Polarized pp - expected luminosity
- Polarized pp – operation scenario
- Program "SPRINT"
- Outlook

Spin Physics Requirements

The SPD program includes the studies of

- Drell-Yan processes,
- J/Ψ production processes,
- Spin effects in elastic $p{\uparrow}p{\uparrow}$, $p{\uparrow}d{\uparrow}$ and $d{\uparrow}d{\uparrow}$ scattering,
- Spin effects in inclusive high-pT reactions,
- Polarization effects in heavy ions collisions

Polarized beams of protons and deuterons requirements:

- **longitudinal** and **transverse** polarizations in MPD and SPD detectors
- $p{\uparrow}p{\uparrow}$ $\sqrt{s_{pp}} = 12 \div 27$ GeV ($5 \div 12.6$ GeV kinetic energy)
- $d{\uparrow}d{\uparrow}$ $\sqrt{s_{NN}} = 4 \div 13.8$ GeV ($2 \div 5.9$ GeV/u ion kinetic energy)
- $L_{average} \geq 1 \cdot 10E31$ $cm^{-2}s^{-1}$ (at $\sqrt{s_{pp}} = 27$ GeV)
- Sufficiently large lifetime of beam polarization
- Spin flipping at a high frequency (desirable mode)

Some additional conditions of the facility operaton in polarized proton and deuteron mode

Seminar LFVE, Dubna,

11 January, 2013

Some additional conditions of the facility operaton in polarized proton and deuteron mode

- Для организации столкновения поляризованных nn - и np-столкновений, необходимы места для размещения станций мечения стрипинговых протонов (возможно и нейтронов, если невозможно организовать столкновения поляризованных p и d).

- Необходима быстрая побанчевая система определения светимости на уровне ошибок ~ 10^{-4}. (!?)

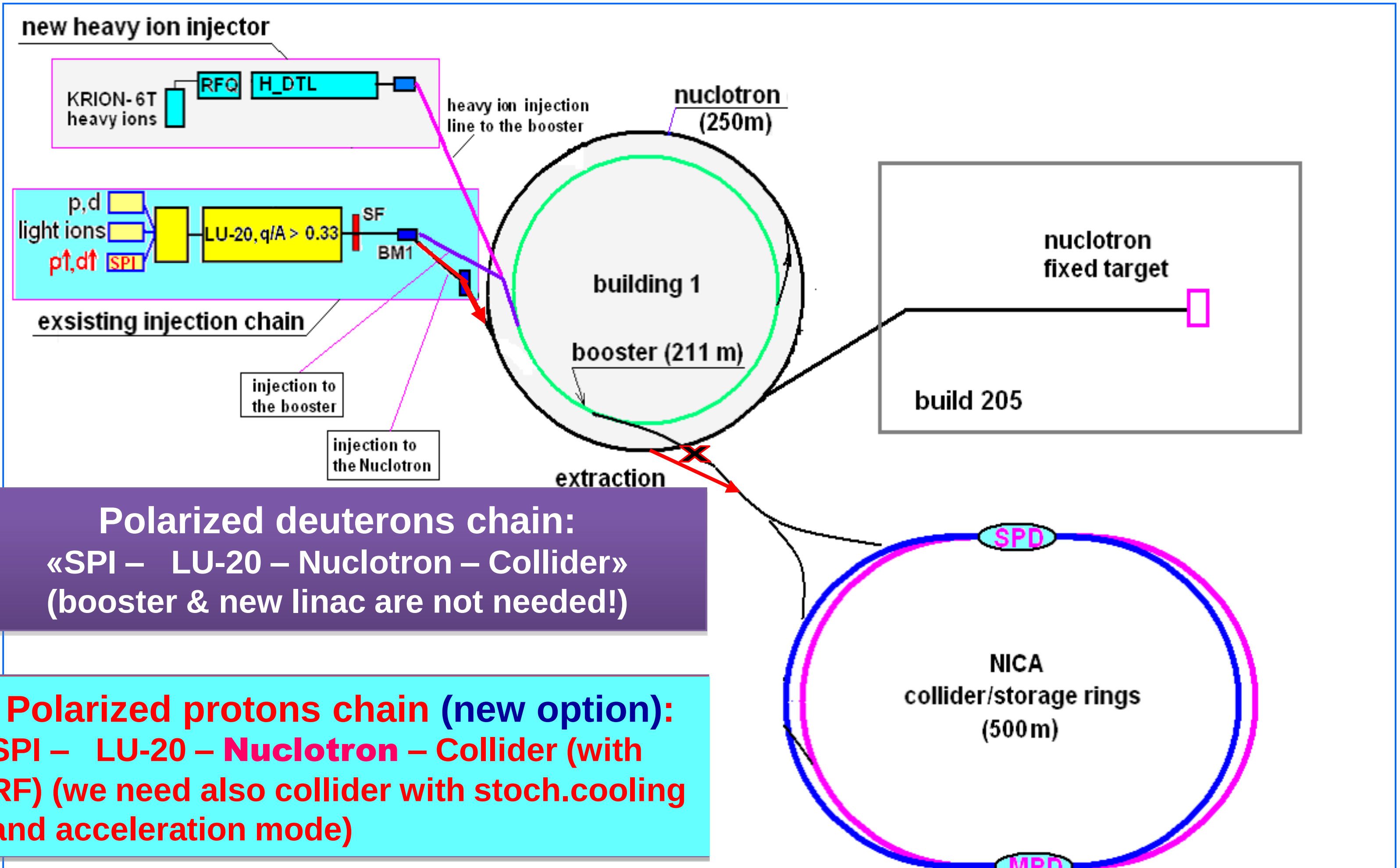
- Инжекция должна обеспечивать возможность формировать задаваемую последовательность чередования поляризации, плюс заполнение банчами без поляризации.

- Необходима система синхронизации прохождения банчей через место встречи (она нужна и для неполяризованной моды работы) и система мечения поляризации банчей.

- Необходимо организовать столкновения разных поляризованных пучков: pd-, pHe-, dHe с разными энергиями пучков.

- Для абсолютного определения поляризации пучков необходима струйная поляризованная мишень.

NICA Layout in Polarized Mode

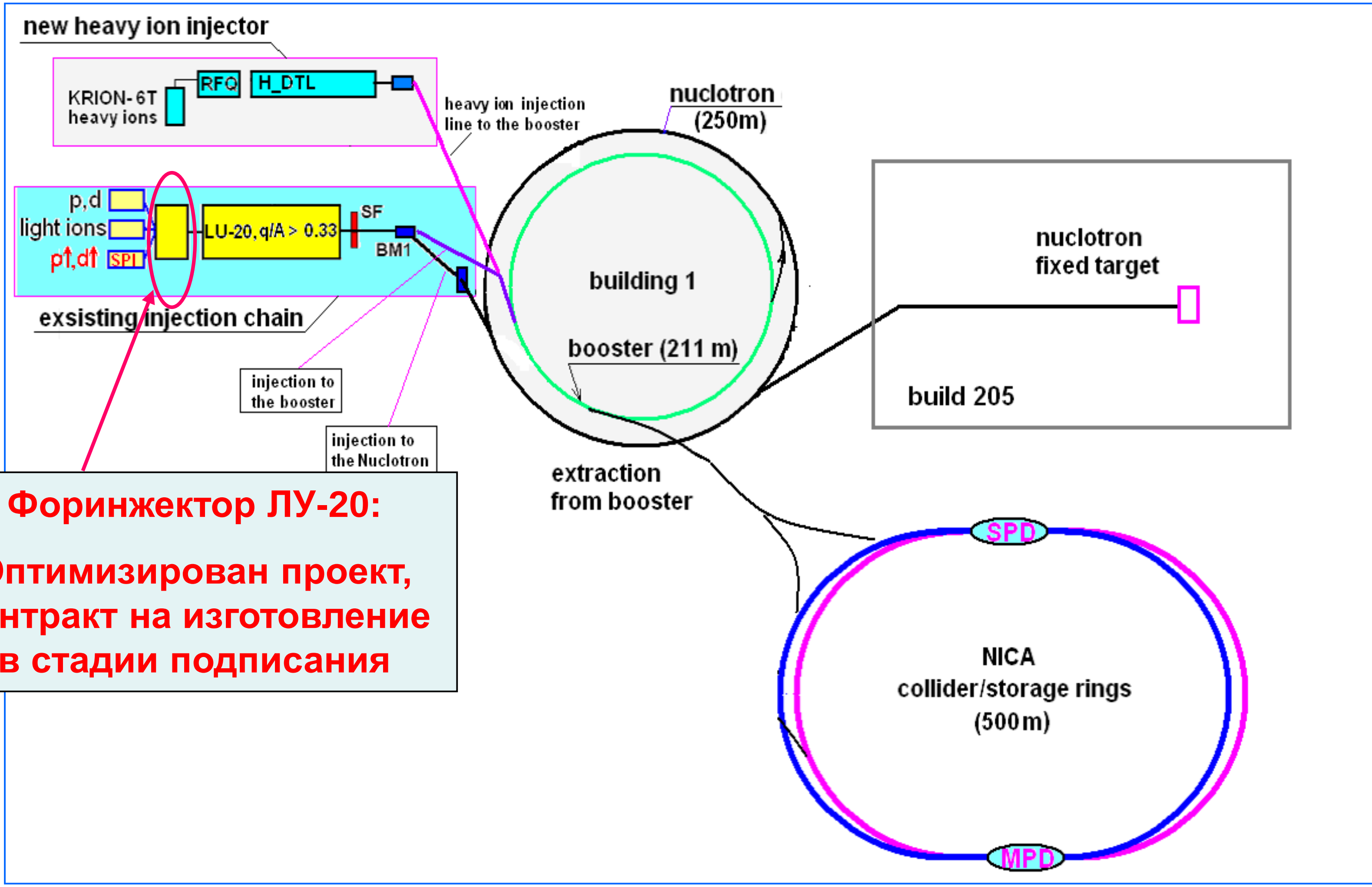


Polarized deuterons chain:
«SPI – LU-20 – Nuclotron – Collider»
(booster & new linac are not needed!)

Polarized protons chain (new option):
SPI – LU-20 – Nuclotron – Collider (with RF) (we need also collider with stoch.cooling and acceleration mode)

A.Kovalenko, N.Agapov, Yu.Filatov, V.Kekelidze, R.Lednicky, I.Meshkov, V.Mikhaylov, A.Sidorin, A.Sorin, G.Trubnikov. The NICA Facility in polarized proton operation mode. IPAC'11, San Sebastian, Spain, 4-9 Sept. 2011, paper TUPZ004.
http://oraweb.cern.ch/pls/ipac2011/TOC.htm

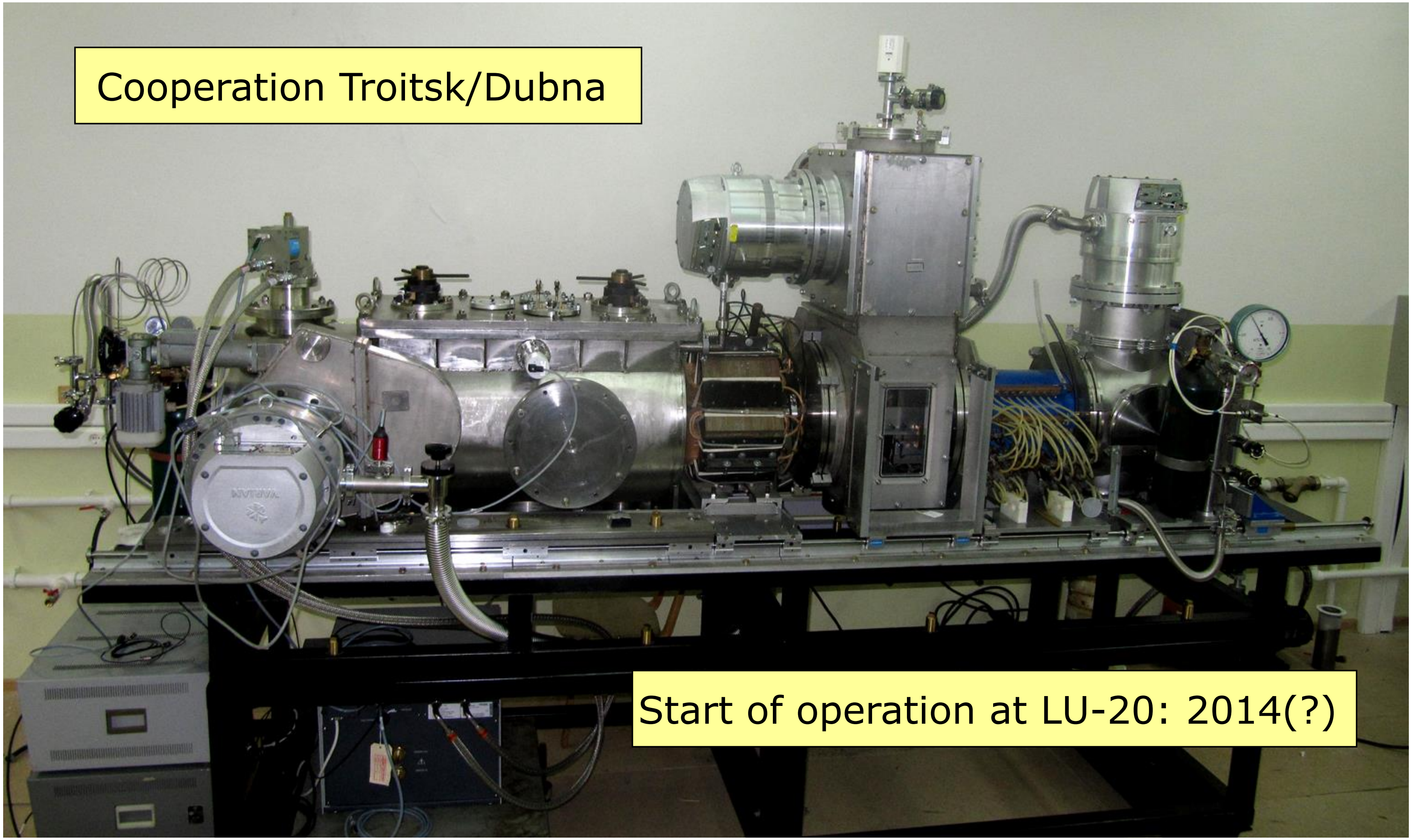
NICA Layout in Polarized Mode



Форинжектор ЛУ-20:

Оптимизирован проект, контракт на изготовление в стадии подписания

SPI – view on test bench at LFVE



SPI - Source of Polarized Ions

Status of the polarized ions source for the JINR accelerator complex [1]

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Abstract

The project assumes the design and construction of a universal high-intensity source of polarized deuterons (protons) using a charge-exchange plasma ionizer. The output $D^+\uparrow$ $(H^+\uparrow)$ current of the source is expected to be at a level of 10 mA. The polarization will be up to 90 % of the maximal vector (± 1) for $D^+\uparrow$ $(H^+\uparrow)$ and tensor (+1, -2) for $D^+\uparrow$ polarization. Realization of the project is carried out in close cooperation with INR of the RAS (Moscow). The equipment available from the CIPIOS ion source (IUCF, Bloomington, USA) is partially used for the Dubna setup. The new source at the JINR Nuclotron accelerator facility will make it possible to increase the polarized deuteron beam intensity up to the level of 10^{10} d/pulse. The first results of the source of polarized atoms testing are presented.

Схемы управления поляризацией в Нуклотроне и коллайдере НИКА

- Для получения **поляризованных d - пучков** в Нуклотроне доп. оборудования не требуется, вплоть до E ~ 5.6 ГэВ/н. (резонанс)

- Основная проблема с дейтронами в коллайдере – изменение ориентации спина (**большой интеграл магнитного поля).**

- Проблема получения **поляризованных протонных пучков в Нуклотроне,** (а также и в бустере, if any…) – спиновые резонансы. **Решение реалистично при ограничении энергии протонов в синхротроне до 5-6 ГэВ и дальнейшем доускорении их до 12.5 ГэВ (или выше) коллайдере.**

- Проблем с поляризованными протонами в коллайдере особых нет, но следует проанализировать появление спиновых резонансов при ускорении поляризованных протонов в диапазоне от 5 до 13 ГэВ.

Proton polarization control at Nuclotron

Polarized proton beam acceleration at the Nuclotron with the use of the solenoid Siberian Snake

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SPIN'2012, Dubna, September, 2012

Abstract

The possibility of polarized protons acceleration up to 6 GeV at the Nuclotron is analyzed. Proton beam acceleration by application of full and partial Siberian Snakes are considered. Compensation of the betatron coupling introduced by the solenoids is done by a compact insert of quadrupoles with a certain symmetry of their tilt angles around the orbit direction. Such a scheme has a shorter total length of the quadrupoles than the known compensation schemes. The Snakes installed within one, 3.2 m long, or two, 2×3.2 m long, straight sections of the Nuclotron lattice are considered.

Polarization control at NICA collider

Polarized Deuterons and Protons at NICA@JINR

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SPIN'2012, Dubna, September, 2012

Abstract

The novel scheme of proton and deuteron polarization control in the NICA collider at Dubna is proposed. By means of two Siberian Snakes with solenoid magnetic field the beam spin tune is shifted to the "zero" spin resonance vicinity, whereas manipulation of the polarization is realized by "weak" field solenoids. The scheme makes it possible to obtain any desired direction of the polarization in the both MPD and SPD detectors for any sort of the particles. The possibility of the beam polarization control in the orbit plane at any azimuth of the collider magnetic arcs exists also. The last gives necessary flexibility of optimal matching the beam polarization at injection into collider and at the polarimetery monitor points.

Proton polarization control at Nuclotron

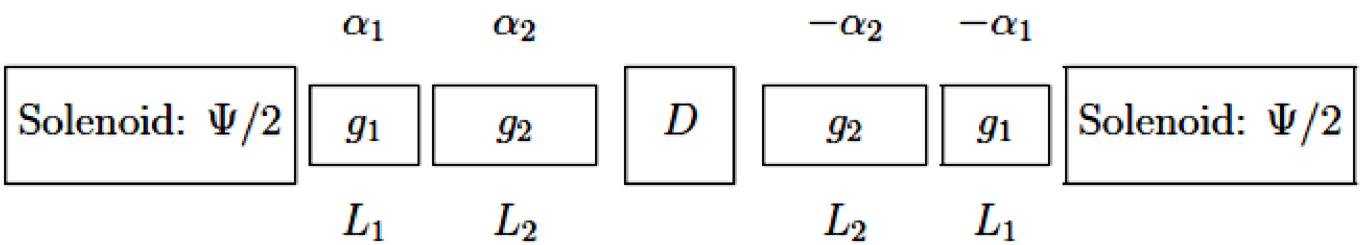


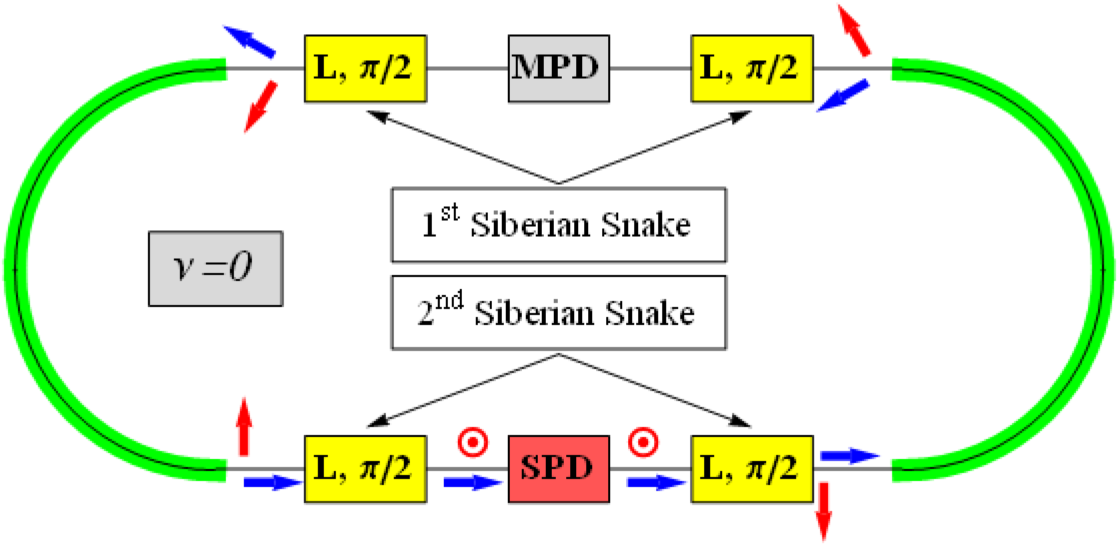
Figure 3: Structure of the Snake installed in two neighboring parts of the straight section separated by structural D-quadrupole.

Calculated values of the solenoid magnetic field and compensated quadrupole gradients in the cases of full and partial Snakes at $\gamma = 6$ are presented in Table 1.

Snake	$B_\parallel L_\parallel$, T·m	$B_\parallel$, T	$\frac{\partial B_y}{\partial x}$, T/m	L, m	L_{tot}, m
Full	21	15	75	1.8	3.2
		6	30	2.9	6.4
Partial	8.5	5	75	1.45	3.2
		2	30	2.28	6.4

Polarization control scheme in the Collider with spin tune ν = 0

If the two identical Siberian Snakes will be inserted in the opposite straight sections of the collider, then the spin tunes is equal to zero for any energies.



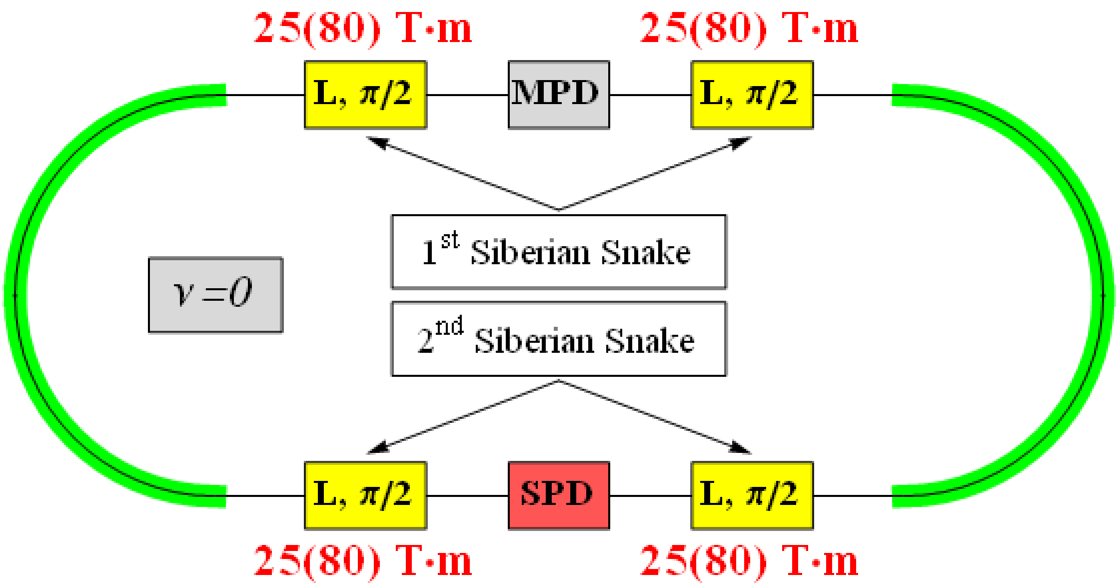
Blue arrows correspond to the case of longitudinal polarization in SPD, whereas the red ones – to vertical polarization in SPD

Any arbitrary polarization direction of the particle is repeated after each turn. Thus, the possibility to stabilize any direction of the polarization at any point of the particle orbit by means of a small longitudinal field for different particle species is occurred.

Polarization control scheme in the Collider with spin tune $\nu = 0$

Solenoid-based Siberian Snake

$(B_{||}L)_{max} = 2 \times 25$ T·m (protons),
$(B_{||}L)_{max} = 2 \times 80$ T·m (deuterons)

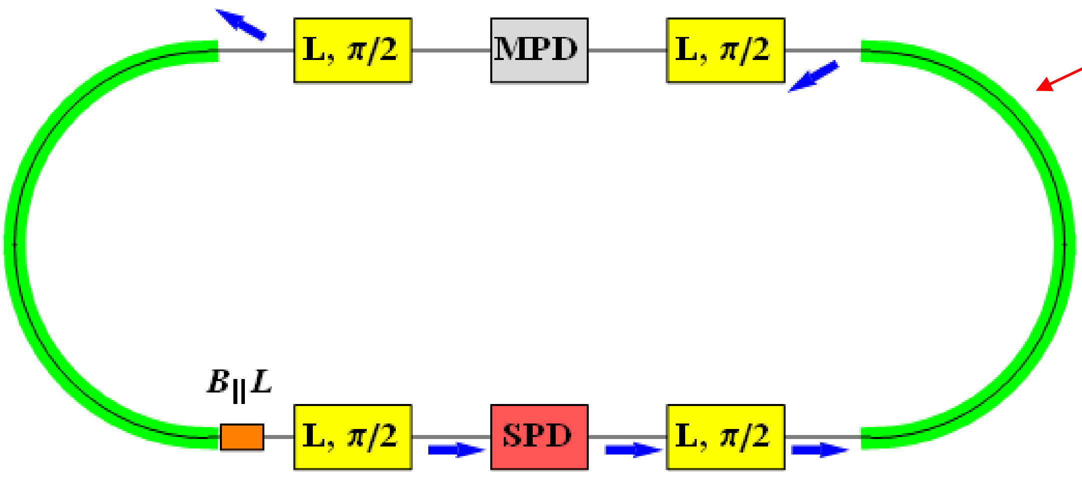


Solenoids with stationary fields of $B_{max} \sim 12.5 \div 17$ T can be used to obtain necessary integrals of longitudinal fields.

Cooperation with the US, European and Russian Laboratories is desirable in the designing of such solenoids

Polarization control in the Collider by means of small longitudinal field integrals

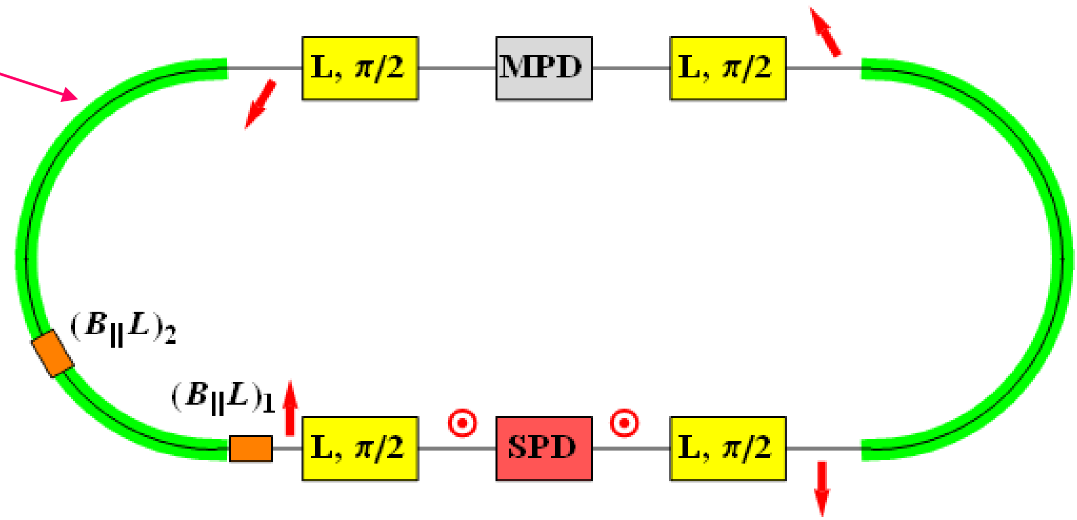
L – polarization in SPD



Maximum field integral for protons and deuterons:

$B_{||}L$<0,5 T·m

Vertical polarization in SPD

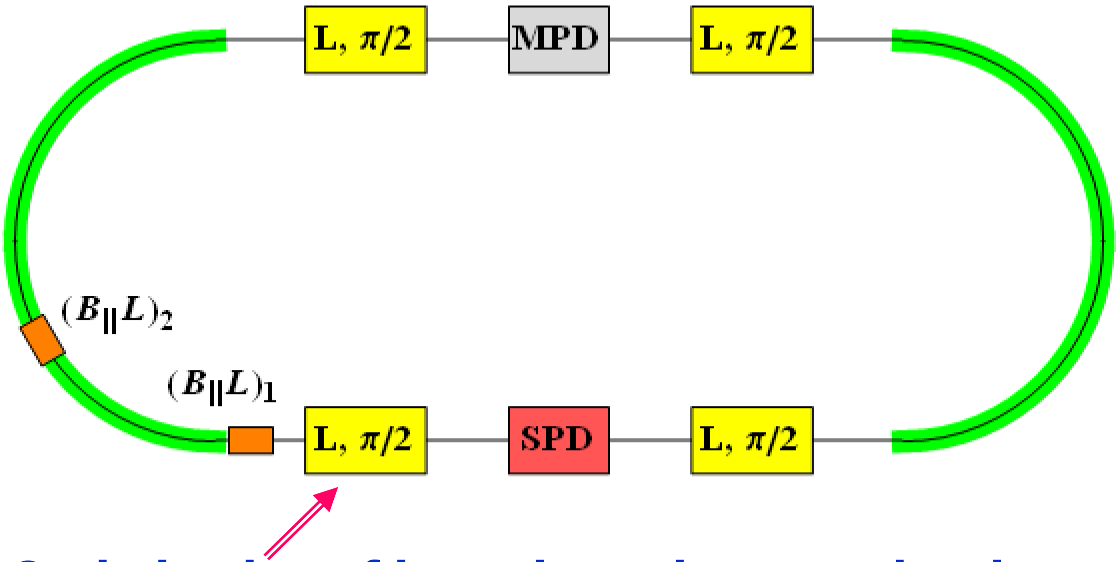


Maximum field integral for protons and deuterons:

$(B_{||}L)_{1,2}$< 0,5 T·m

A.D.Kovalenko

Polarization control in the Collider by means of small longitudinal field integrals



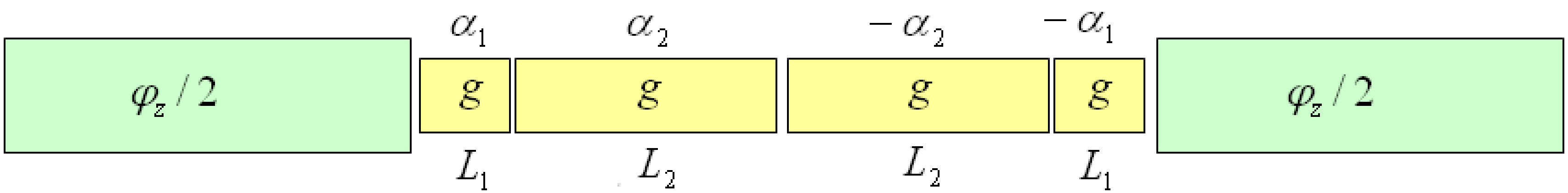
Maximum field integral for protons and deuterons:

$(B_{||}L)_{1,2} < 0{,}5$ T·m

Optimization of insertion scheme makes it possible:

- **standartization of the high field solenoid sections;**
- **to provide staging of installation the snakes equipment into the collider;**
- **unification of system elements, let say: 1 m solenoid section of 12.5 T each. Thus, combination of two such sections is satisfied to the protons of the maximum energy and can be used for the deuterons up to the momentum 1/3 of the maximum.**

The scheme of the solenoid coupling compensation



$\alpha_1 = \frac{\pi}{4}, \ \alpha_2 = -\frac{\pi}{8}$ are angles between quadruples normal and vertical accelerator axis

$g = \partial B_y / \partial x$ is quadruples gradient $\quad g \propto \sqrt{\varphi_z}$

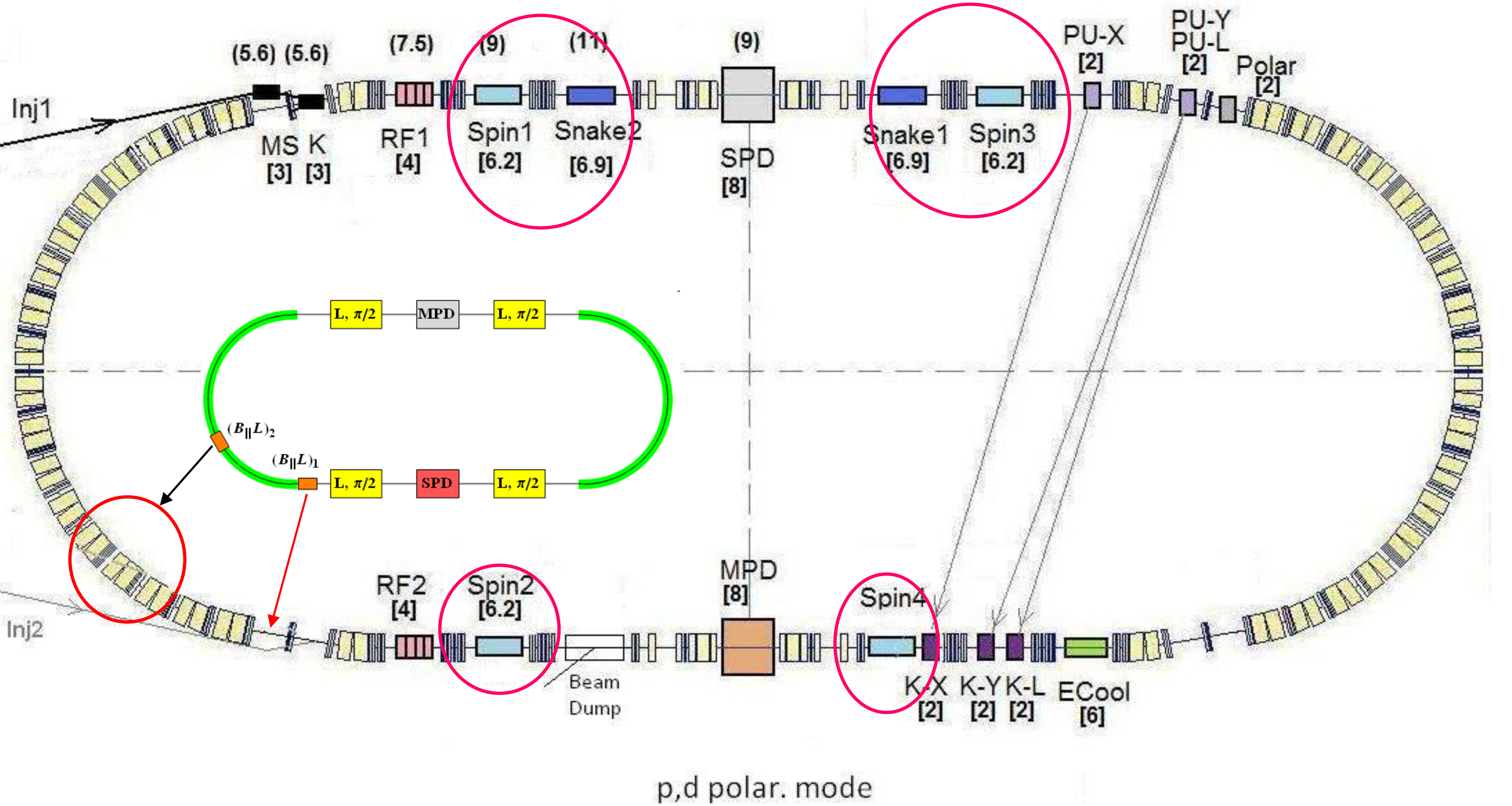
The estimated parameters:

$B_{||}L$=80 T·m, E=14 GeV, g=75 T/m $L_g=2(L_1+L_2)\approx 3$ m

$B_{||}L$=0,5 T·m, E=14 GeV, g=30 T/m $L_g=\approx 1{,}4$ m

The final optimization of the quadrupoles should follow to matching conditions with the lattice.

Scheme of NICA collider ring



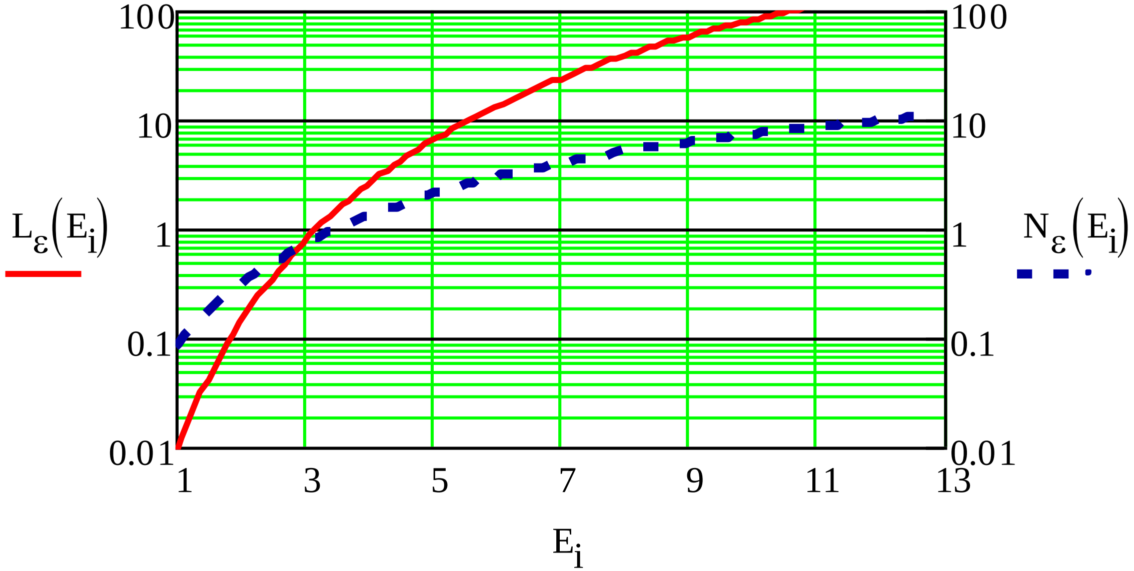
Conclusions for NICA-Spin mode

- The novel scheme of spin direction control in NICA collider suitable for any type of the particles is proposed.
- The scheme, designed for protons need lower longitudinal field integral than at the single-snake one. Deuteron polarization control looks much more feasible.
- The scheme provides the desired polarization direction in the both IP's (MPD and SPD detectors), and gives also a possibility of simple decision the problems of polarization matching at injection and polarimetery
- Realization of both as single - and multi - turn Spin Flipping systems are possible in such system

NICA pp-collisions peak luminosity

29 November 2012 (I.N.Meshkov)

NICA Collider Luminosity in pp Collisions



- IP parameters: **β** = 35 cm, bunch length **σ** = 60 cm (not optimized), **bunch number** – 22, collider perimeter **C** = 503 m
- **Proton energy E** in GeV, particle number per bunch N(E) in 10^11 units, maximum proton number in each ring – 2.2•10^13 .
- **Luminosity L(E) in 10^30 units**.

NICA polarized pp-collisions scenario and average luminosity

Parameter	Value
Nuclotron Dipole Field Ramp up, T/s Nuclotron Dipole Field Ramp down, T/s	0.6 1.0
Magnet field flat top duration, s	0.5
Total useful cycle duration, s	3.17
Dipole Magnetic Field at 6 GeV protons, T Acceleration time, s	~ 1 1.67
Number of accelerated protons per pulse	$5\cdot10^{10}$
Number of cycles to store $2\cdot10^{13}$ particles Collider filling time at cycle duration 5s, s	400 2000
Collider filling time at cycle duration 7s, s	2800
Preparation of the beam in the collider (cooling, bunching emittance formation), s	1000
Magnetic field ramp in the collider, T/s	0.6
Acceleration time from 6 GeV to 12.6 GeV	~ 1.7
Luminosity life time (30% polarization degradation due to spin resonances), s Beam deceleration up to the new injection	5400 ~ 1.7
Total cycle duration, s **Working part, %**	~ 8400/9200 64.3/58.7

- **Average luminosity at E = 12.6 GeV:**

$\langle L\rangle = (1.1\text{-}1.3)10^{32}$ 1/(cm²·s).

Spin Physics Research Infrastructure

SPRINT –

Spin Physics Research Infrastructure at NucloTron

Цель проекта – создание инфраструктуры для проведения экспериментов на пучках поляризованных дейтронов и протонов ускорительного комплекса Нуклотрон – НИКА

Состояние инфраструктуры для такого рода экспериментов в настоящее время не отвечает требуемому современному уровню.

Проект SPRINT должен охватить все необходимые аспекты проблемы и в результате обеспечить возможность поддержки всех планируемых экспери-ментов на пучках комплекса Нуклотрон – НИКА

Project SPRINT

Project SPRINT Status

Deuteron polarimetery

4.1 Concept

4.2 Low energy polarimeter

4.3 Internal target polarimeter

4.4 Extracted beam polarimetry

Этот раздел в определенной степени проработан. Однако требуется дальнейшее развитие с учетом возникающих задач по повышению точности измерения поляризации и оперативности контроля.

Project SPRINT Status

Proton polarimetery

5.1 CNI polarimetry (in the collider rings)

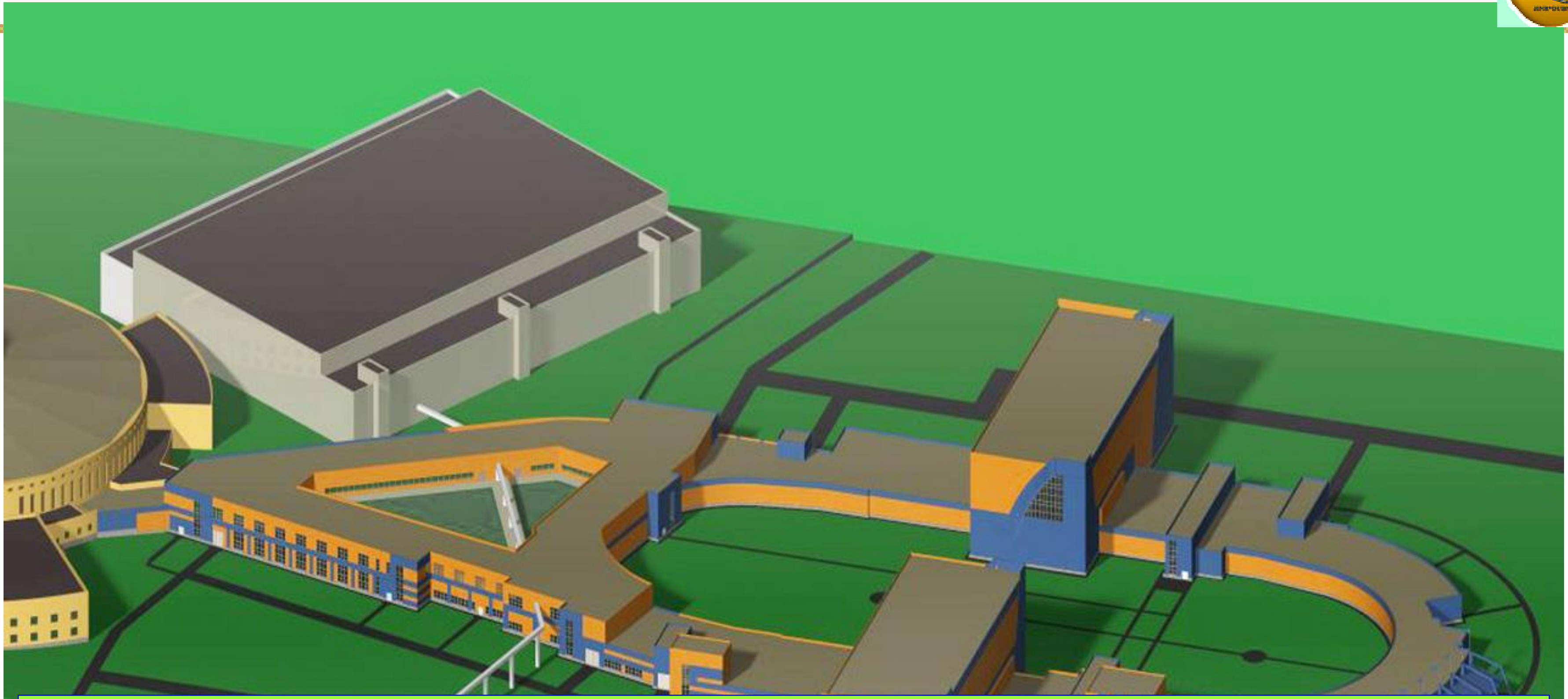
5.2 Absolute calibration of polarization

5.3 Local polarimetry for MPD and SPD

Proton beam polarization measurements can be performed by the deuteron polarimeter at the Nuclorton internal beam up to the momentum of 3-4 GeV.

Collaboration: JINR, МИФИ, ИТЭФ, BNL.

Outlook: Status of the NICA construction



- Preparations to tender, Russian state expertise;
- Goal for 2013: to start NICA collider infrastructure realization work

THANK YOU

FOR YOUR ATTENTION