OPPORTUNITIES OF SPIN PHYSICS AT NICA

A.P. Nagaytsev, I.Savin,

JINR , Dubna

1. NICA Project.
2. Polarized beams at NICA.
2. Proposed measurements.
3. LOI preparation.
4. Conclusions.

IWHSS 2013

International Workshop on Hadron Structure and Spectroscopy

Erlangen, 22-24 July 2013

Topics
- Longitudinal and Transverse Spin Structure of the Nucleon
- Fragmentation Functions
- Hadron Spectroscopy

- Search for Exotic Resonances
- Transverse Momentum Dependent Parton Distribution Functions
- Generalized Parton Distributions
- Primakoff Reactions
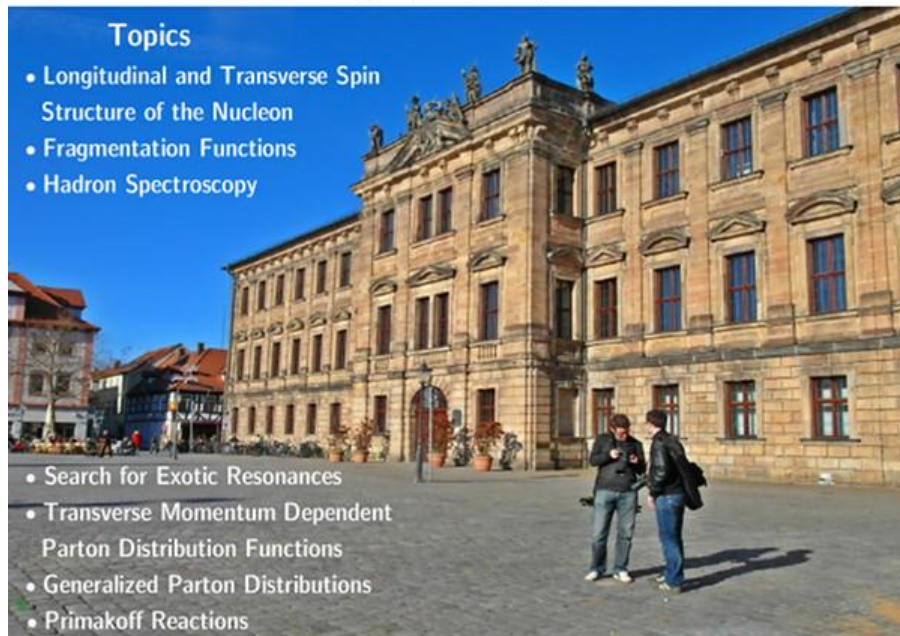
NICA Project.
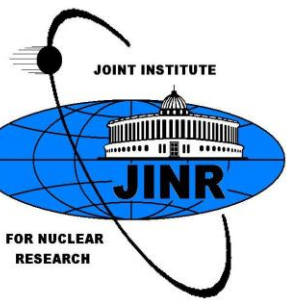
The NICA project is aimed at study of

- the hot and dense baryonic matter;
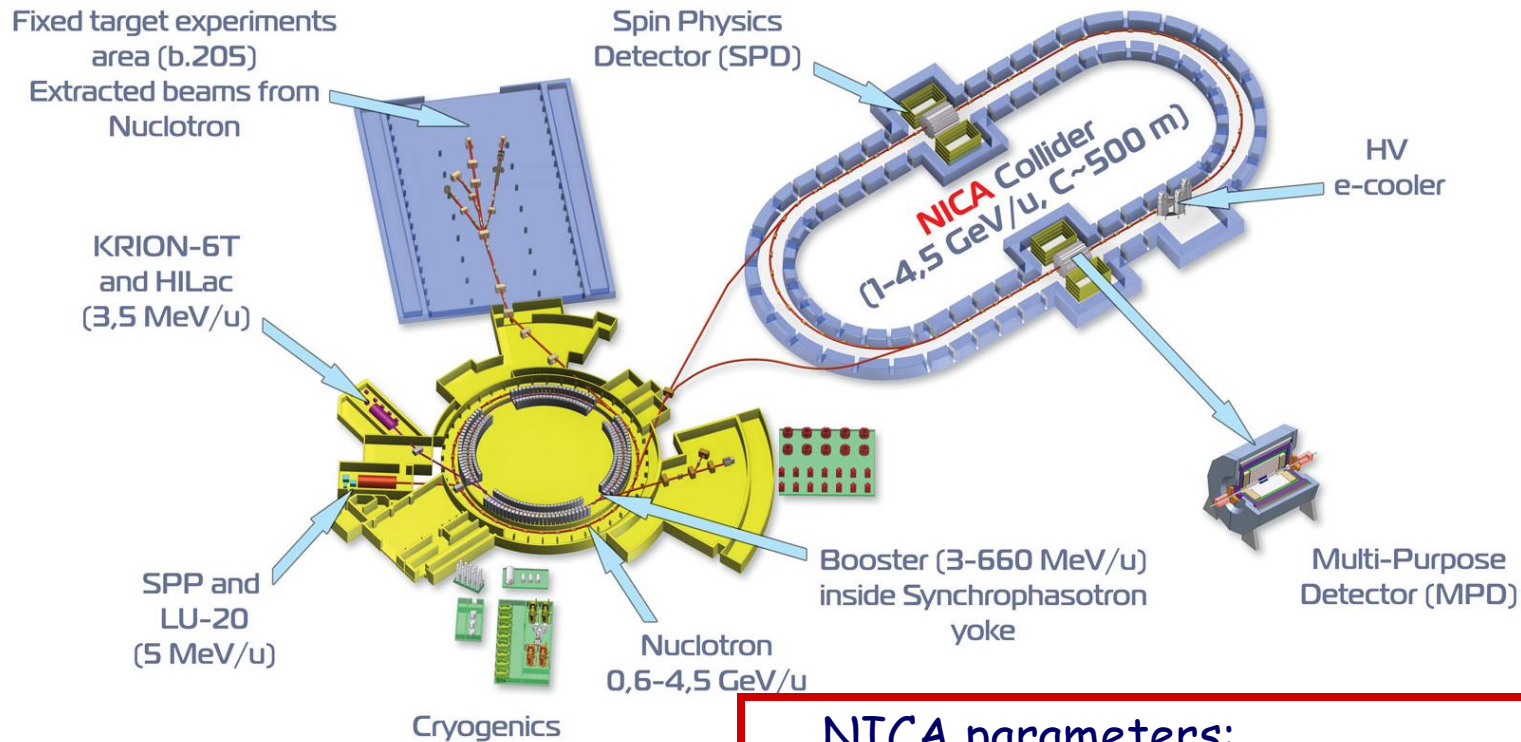
- the nucleon spin structure and polarized phenomena.

It requires development of the accelerator complex which will be able to produce high intensity relativistic heavy ion and polarized proton and deuteron beams.

accelerator facility

FT experiment area

Collider

New Linac

Lu 20

Booster
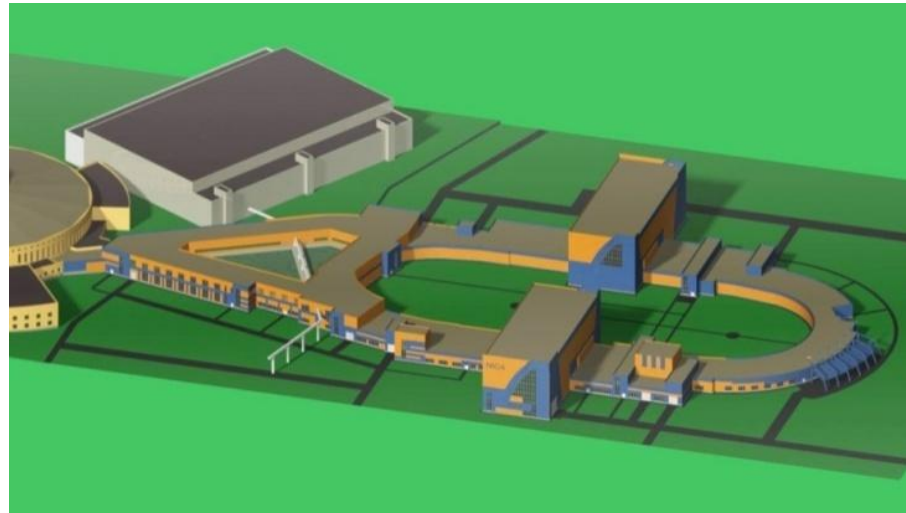
Nuclotron
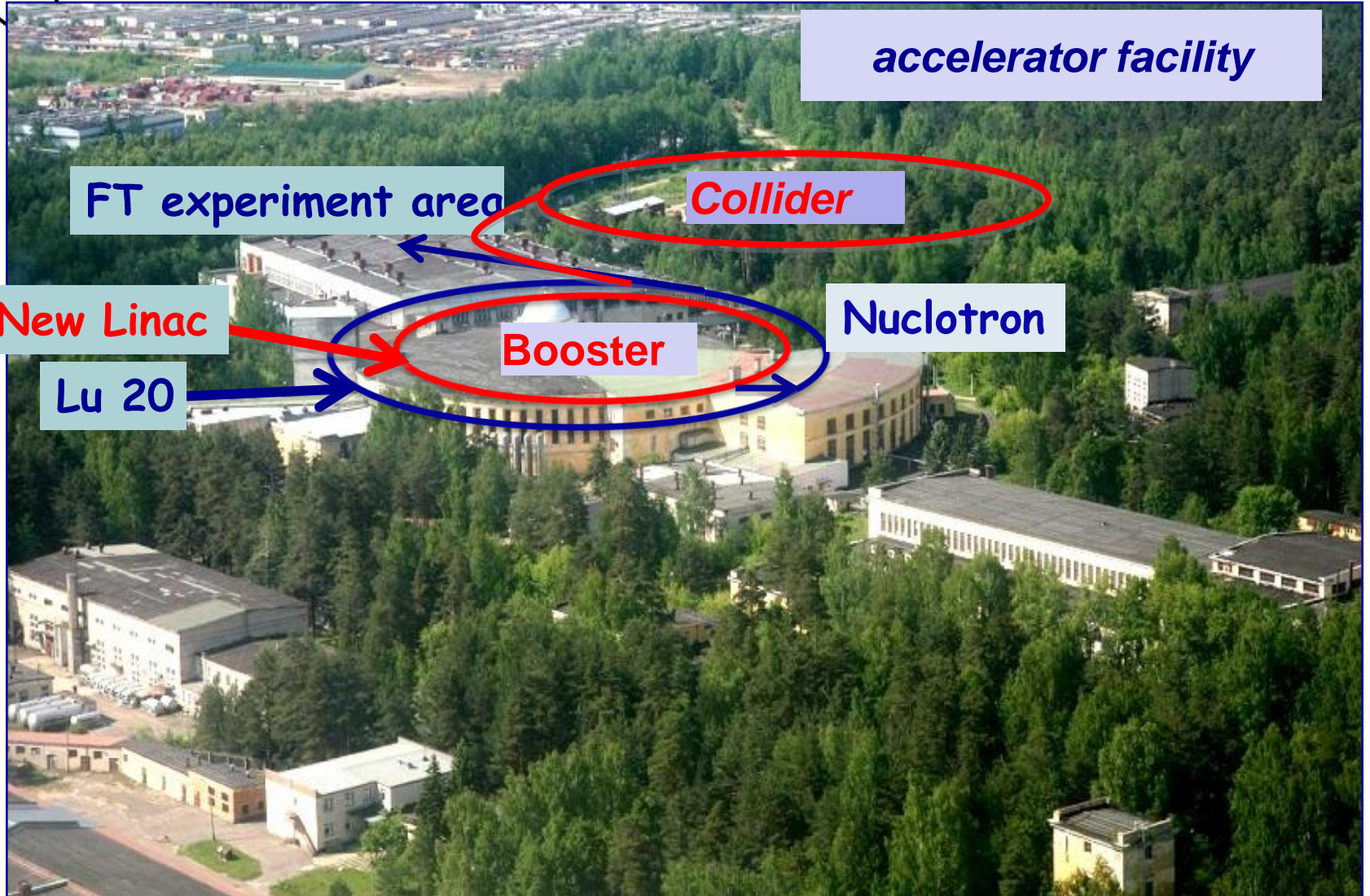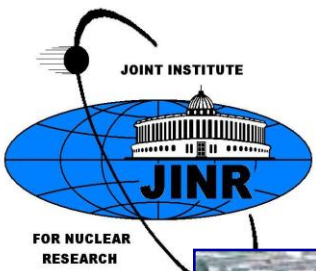
NICA Project.

Superconducting accelerator complex NICA
(Nuclotron based Ion Collider fAcility)

Fixed target experiments area (b.205)
Extracted beams from Nuclotron

Spin Physics Detector (SPD)

NICA Collider (1-4,5 GeV/u, C~500 m)

HV e-cooler

KRION-6T and HILac (3,5 MeV/u)

SPP and LU-20 (5 MeV/u)

Cryogenics

Nuclotron 0,6-4,5 GeV/u

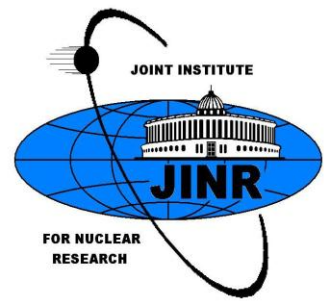Booster (3-660 MeV/u) inside Synchrophasotron yoke

Multi-Purpose Detector (MPD)

NICA parameters:
Energy range: $\sqrt{s_{NN}}$ = 4-11 GeV/n
Beams: from p to Au
Luminosity: L~10^{27} (Au), >10^{32} (p)
Detectors: MPD (ions), SPD (spin physics)

NICA Project.
Spin Physics at NICA.

The purpose of Spin Physics program at NICA is the study of the nucleon spin structure with high intensity polarized light nuclear beams collider option with the light nuclear beams with the proton and deuteron ones.

Collider can allow us to reach high collision proton energy up to $\sqrt{s} \sim 26$ GeV with the luminosity $> 10^{32}$ cm^2/s (for $\sqrt{s} \sim 26$ GeV) .

For deuteron beams the collision energy per nucleon up to $\sqrt{s} \sim 12$ GeV with the average luminosity up to 10^{31} cm^2/s (for $\sqrt{s} \sim 12$ GeV) .
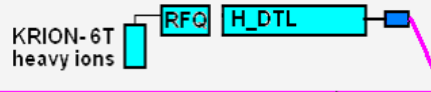
Both proton and deuteron beams can be effectively polarized (longitudinal and transversal).

All these advantages give us unique possibilities to investigate at NICA the polarized phenomena and nucleon spin structure - one of the main tasks of the modern high energy physics.
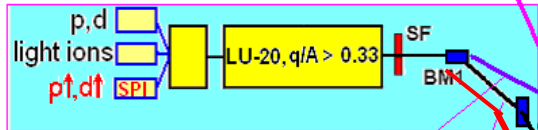
Polarised beams at NICA.

new heavy ion injector

KRION-6T heavy ions — RFQ — H_DTL

heavy ion injection line to the booster

p,d
light ions
p↑,d↑ SPI — LU-20, q/A > 0.33 — SF BM

exsisting injection chain

injection to the booster

injection to the Nuclotron

nuclotron (250m)

building 1

booster (211 m)

extraction

nuclotron fixed target

build 205

SPD

NICA collider/storage rings (500m)

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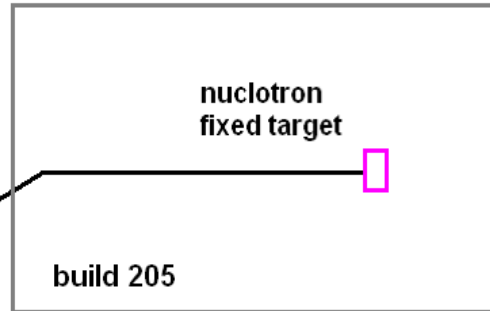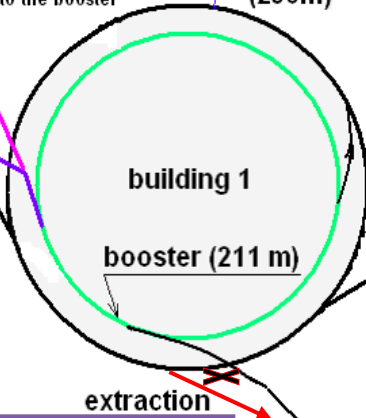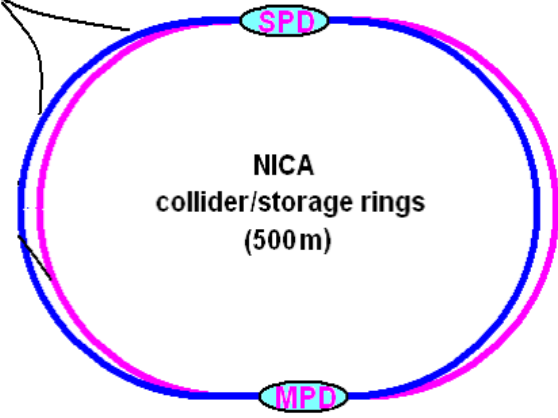
Polarized deuterons chain:
«SPI –   LU-20 – Nuclotron – Collider»
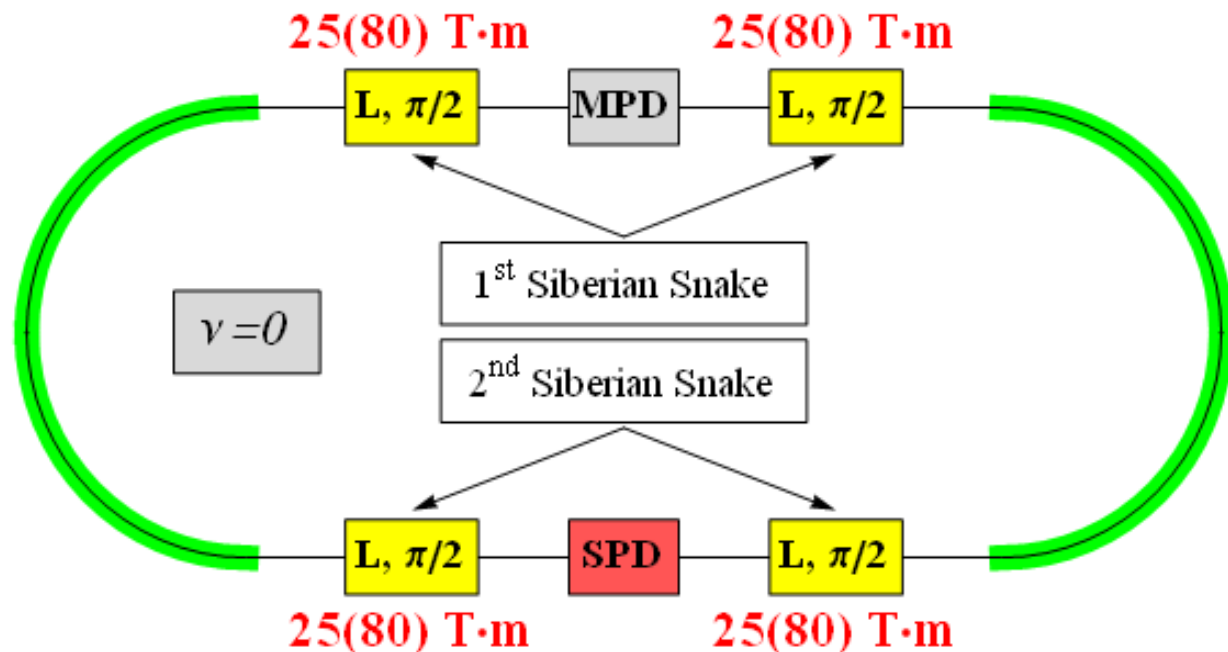(booster & new linac are not needed!)

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

http://theor.jinr.ru/~praha/2013/

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IWHSS, Erlangen, 22-24 July, 2013

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Polarised beams at NICA.

Solenoid-based Siberian Snake

$(B_{||}L)_{max}=2\times25$ **T·m (protons),**
$(B_{||}L)_{max}=2\times80$ **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.

Polarised beams at NICA.
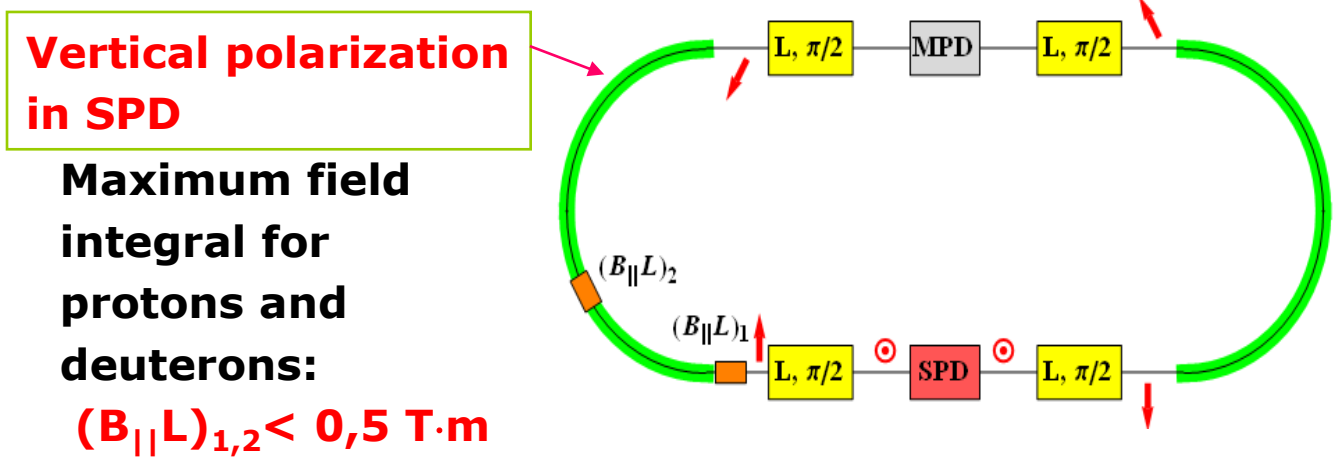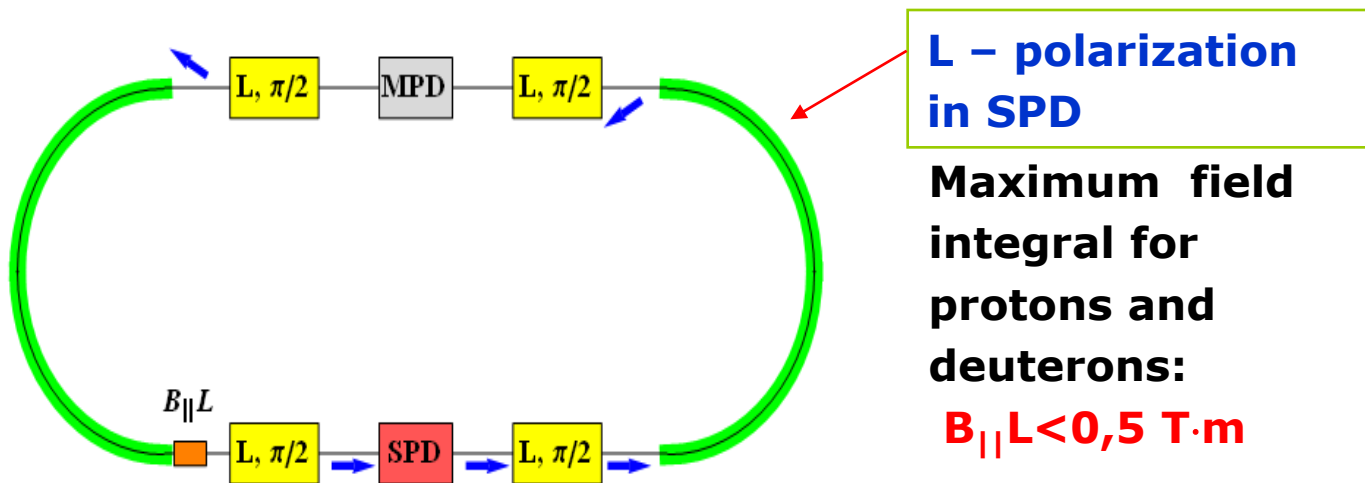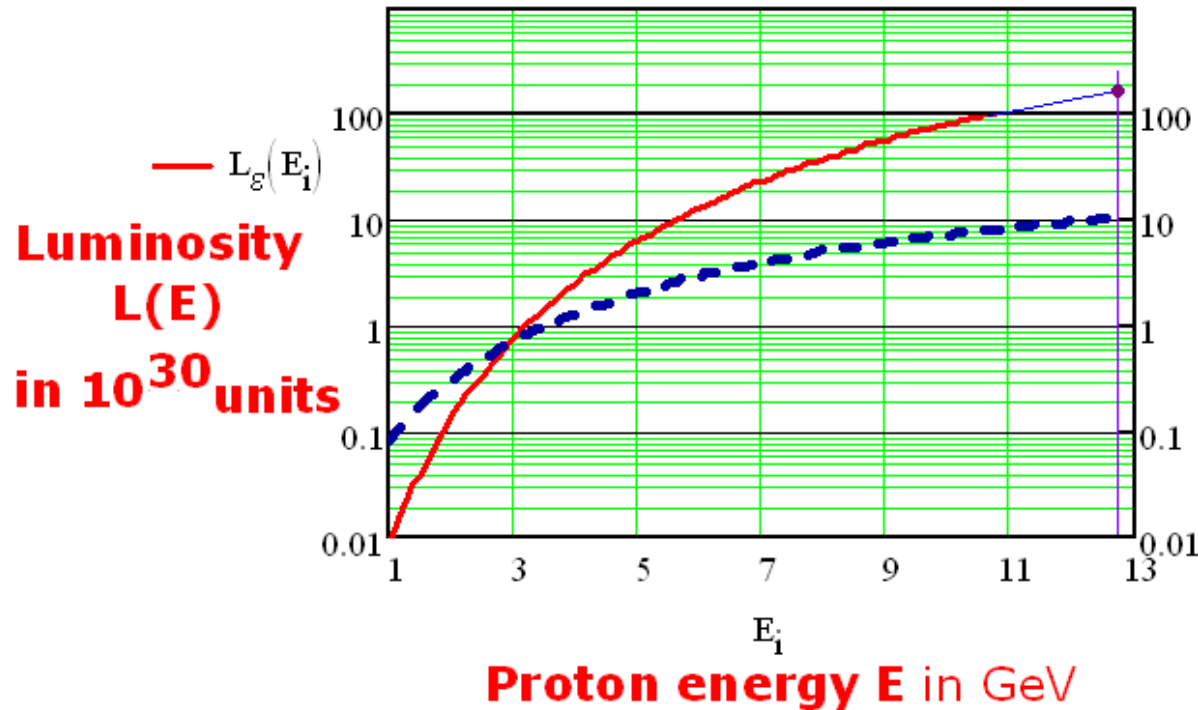

L – polarization in SPD

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**

Polarised beams at NICA.

NICA Collider Luminosity in pp Collisions

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

— $L_\varepsilon(E_i)$

$- -$ $N_\varepsilon(E_i)$

particle number per bunch in 10^{11} units maximum proton number in each ring – $2.2 \cdot 10^{13}$

E_i

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

Report by A.Kovalenko, Workshop NICA-SPIN-Prague, Charles University, 08 July, 2013
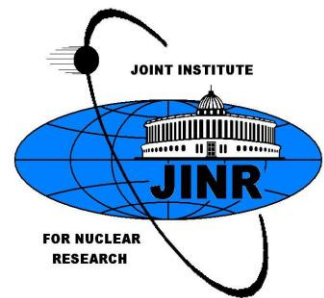
Proposed measurements.

The following subjects are under consideration:
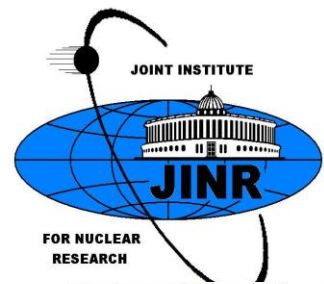
► DY processes.

► J/Ψ production processes.

► Prompt photons.

► Studies of elastic reactions.

► Spin effects in one and two hadron production processes.

► Spin effects in inclusive high-p_T reactions.

► Final spin states effects and polarization effects in heavy ion collisions.

Proposed measurements. DY processes.

Extraction of unknown (poor known) parton distribution functions (PDFs):

$$p(D)p(D) \to \gamma^* X \to l^+ l^- X$$

Boer-Mulders PDF

$$p^\uparrow(D^\uparrow)p(D) \to \gamma^* X \to l^+ l^- X$$

Sivers PDFs
(Efremov,... PLB 612 (2005), PRD 73(2006));

$$p^\uparrow(D^\uparrow)p^\uparrow(D^\uparrow) \to \gamma^* X \to l^+ l^- X$$

Transversity PDF (Anselmino, Efremov, ...)

$$p^\uparrow(D^\uparrow)p(D) \to \gamma^* X \to l^+ l^- X$$
$$p(D)p(D) \to \gamma^* X \to l^+ l^- X$$

Transversity and first moment of Boer-Mulders PFDs
(Sissakian, Shevchenko, Nagaytsev , Ivanov, PRD 72(2005), EPJ C46 ,2006 C59, 2009)

$$p^\to(D^\to)p^\leftarrow(D^\leftarrow) \to \gamma^* X \to l^+ l^- X$$

Longitudinally polarized sea and strange PDFs and tenzor deuteron structure (Teryaev, ...)

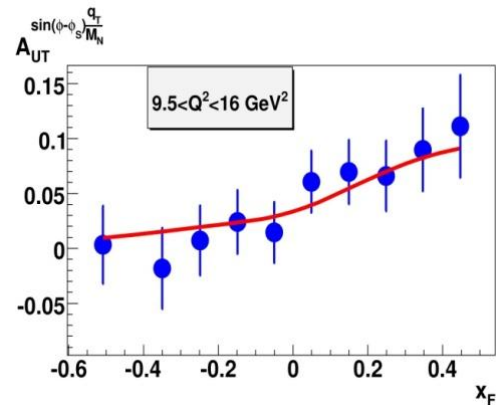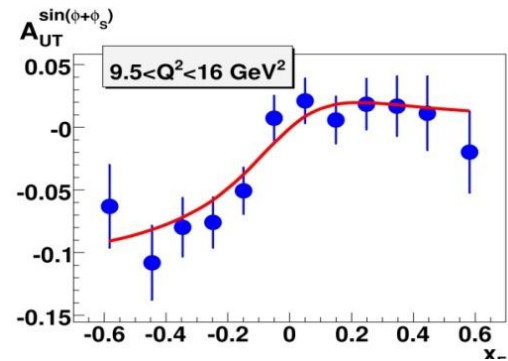The same PDFs from J/ψ production processes ($\sqrt{s} \leq 10 GeV$).

$A_{UT}^{\sin(\phi+\phi_S)}$

9.5<Q^2<16 GeV^2

$A_{UT}^{\sin(\phi-\phi_S)\frac{q_T}{M_N}}$

9.5<Q^2<16 GeV^2

Estimated for one year of data taking. 100 K DY events

The measurement of pretzelosity PDF is also under consideration.

$$\left. h_1^\perp(x, \mathbf{k}_T) \right|_{SIDIS} = - \left. h_1^\perp(x, \mathbf{k}_T) \right|_{DY}$$

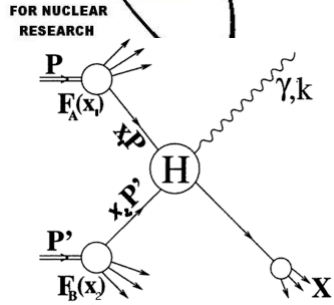$$\left. f_{1T}^\perp(x, \mathbf{k}_T) \right|_{SIDIS} = - \left. f_{1T}^\perp(x, \mathbf{k}_T) \right|_{DY}$$

Test of our understanding of T-odd effects within QCD and the factorization approach to the processes sensitive to transverse parton momenta.

Proposed measurements. Prompt photons.

$q\,g \rightarrow q\,\gamma$

$q\,qbar \rightarrow g\,\gamma$

Prompt photons produced in pp interaction

Access to gluon Sivers function via STSA:

$$\mathbf{A_N} = \frac{\sigma^\uparrow - \sigma^\downarrow}{\sigma^\uparrow + \sigma^\downarrow}$$

$$\sigma^\uparrow - \sigma^\downarrow = \sum_i \int_{x_{min}}^{1} dx_a \int d^2\mathbf{k}_{Ta} d^2\mathbf{k}_{Tb} \frac{x_a x_b}{x_a - (p_T/\sqrt{s})\,e^y} [q_i(x_a, \mathbf{k}_{Ta}) \Delta_N G(x_b, \mathbf{k}_{Tb})$$

$$\times \frac{d\hat\sigma}{d\hat t}(q_i G \rightarrow q_i\gamma) + G(x_a, \mathbf{k}_{Ta}) \Delta_N q_i(x_b, \mathbf{k}_{Tb}) \frac{d\hat\sigma}{d\hat t}(G q_i \rightarrow q_i\gamma)]$$

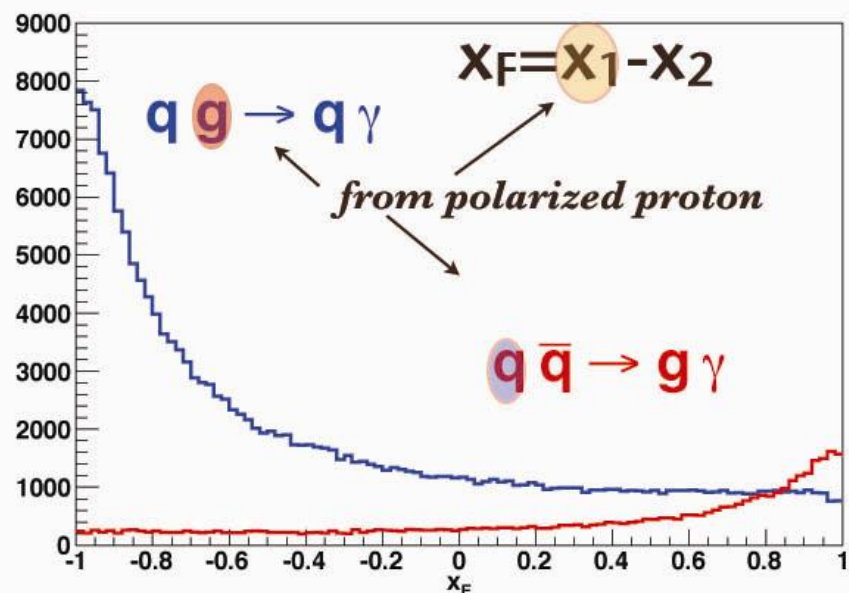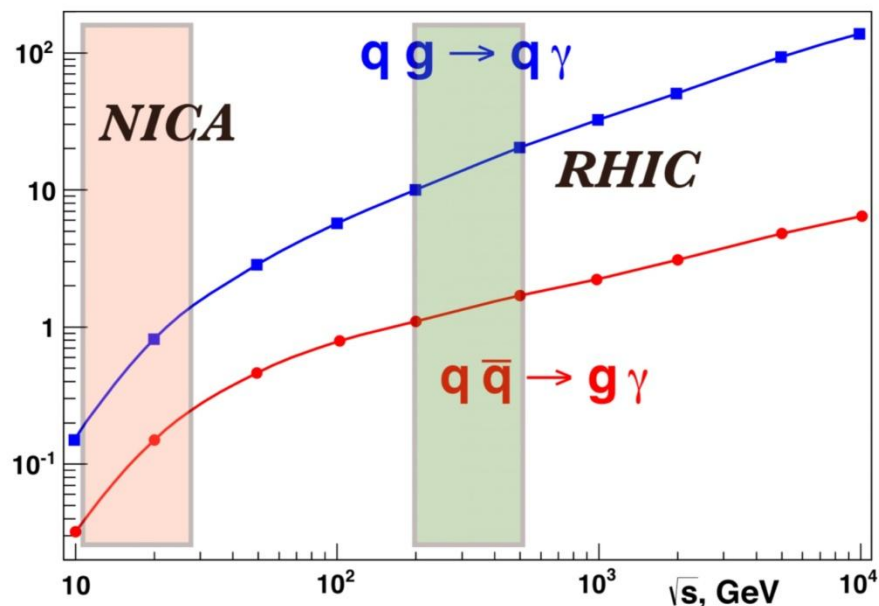**Access to gluon polarization via DLSA:**

$$A_{LL} = \frac{(\sigma_{++} + \sigma_{--}) - (\sigma_{+-} + \sigma_{-+})}{(\sigma_{++} + \sigma_{--}) + (\sigma_{+-} + \sigma_{-+})}$$

$$A_{LL} \sim \frac{\Delta g(x_1)}{g(x_1)} \cdot \left[\frac{\sum_q e_q^2 [\Delta q(x_2) + \Delta\bar q(x_2)]}{\sum_q e_q^2 [q(x_2) + \bar q(x_2)]} \right] + \left[x_1 \leftrightarrow x_2 \right]$$

Report by A.Guskov, Workshop NICA-SPIN-Prague, Charles University, 08 July, 2013
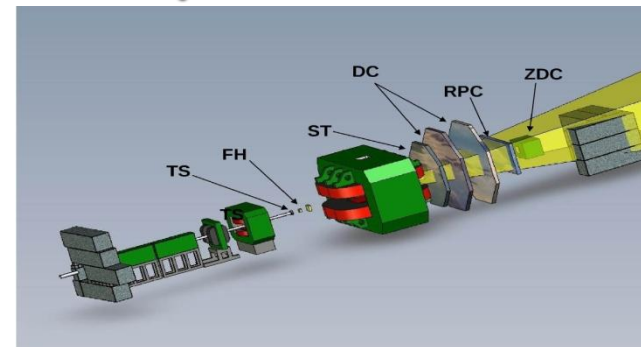
Proposed measurements.
Prompt photons.

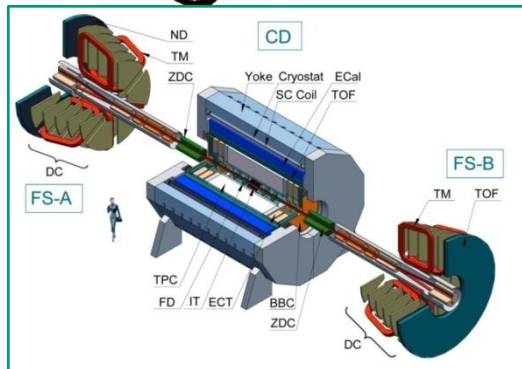PYTHIA 6, pp collider mode with √s = 26 GeV

Report by A.Guskov, Workshop NICA-SPIN-Prague,
Charles University, 08 July, 2013

Proposed measurements.
Final spin states effects,
Polarization effects in heavy ion collisions.


Initial and final state spin effects with SPD/MPD/BM@N

The following polarization observables are also under consideration:
- Polarization of Λ as a probe of formation of isotropic matter;
- Correlations of Λ polarization with charge separation as a complementary
  signal for CP-violation in dense matter ,
- Transverse handedness as a probe for collective orbital momentum of the matter,
- Tensor polarization of dileptons as a complementary probe of matter formation,
  dilepton production mechanisms and collective orbital momentum,
- T-odd and T-even effects - vector and tensor polarization
- Rotating QCD matter
- Spin effects - search for signs of global rotation
- Chiral Vortical Effect & neutron asymmetries.

**Report by O.Teryaev, Workshop NICA-SPIN-Prague,
Charles University, 08 July, 2013**
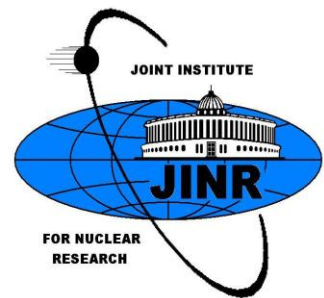
LoI preparation.

LoI for spin physics experiments at NICA is under preparation. Several international workshops **NICA-SPIN 2013** are organized.

The first workshop was in Dubna (see **http://nica.jinr.ru/files/Spin_program/NICA-SPIN2013/program.html**),

the second one was in Prague **(http://nica.jinr.ru/files/Spin_program/SPIN-Praha-2013/index.html)**,
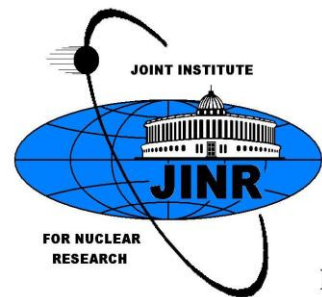
the third one will be at Dubna during the DSPIN2013 workshop (**http://theor.jinr.ru/~spin/2013**).

XV WORKSHOP ON HIGH ENERGY SPIN PHYSICS

— DSPIN-13

Dubna, Russia, October 8 - 12, 2013

Participants are welcomed !

LoI preparation.

Draft 21.07.13_updated

Letter of Intent.

Nec sine te, nec tecum vivere possum. (Ovid)*

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

(Updating list of participants)

F. Ahmadov[1], V. A. Anosov[1], N.V. Anfimov[1], A. S. Belov[5], M.Bodlak[8], A.V. Butenko[1], A.P. Cheplakov[1], I. E. Chirikov-Zorin[1], S.V. Donskov[6], A.V. Efremov[1], Yu. N. Filatov[1,3], V. V. Fimushkin[1], M. Finger (jun.)[7], M. Finger[7], A.V. Guskov[1], Yu.I. Ivanshin[1], A.V. Ivanov[1], V. Jary[8], A. Janata[7], N. Javadov[1], V.D. Kekelidze[1], A.P. Kobushkin[4], A. M. Kondratenko[2], M.A. Kondratenko[2], A. D. Kovalenko[1], O.M. Kouznetsov[1], Z.V. Krumshtein[1], V.V. Kukhtin[1], P.K. Kurilkin[1], L.V. Kutuzova[1], V.P. Ladygin[1], R. Lednicky[1], J. Matousek[7], G.V. Meshcheryakov[1], V.A. Mikhaylov[1], Yu.V. Mikhaylov[6], V.V. Myalkovskiy[1], A. P. Nagaytsev[1], J. Novy[8], M. Pesek[7], D.V. Peshekhonov[1], V.D. Peshekhonov[1], V.A. Polyakov[6], Yu.V. Prokofichev[1], V.K. Rodionov[1], N. S. Rossiyskaya[1], V.D. Samoylenko[6], I. A. Savin[1], O.Yu. Shevchenko[1], S.S.Shimanskiy[1], M. Slunechka[7], V. Slunechkova[7], E. A.Strokovsky[1], O.V.Teryaev[1], M. Tomasek[8], N.D.Topilin[1], A.V. Turbabin[5], M.Virius[8], V. Vrba[8], E.V. Zemlyanichkina[1], V. N. Zubets[5]

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*Neither without you, nor with you one can live.

[1] Joint Institute for Nuclear Research, Dubna, Russia
[2] Science and Technique Laboratory Zaryad, Novosibirsk, Russia
[3] Moscow Institute of Physics and Technology, Dolgoprudny, Russia
[4] Bogolyubov Institute for Theoretical Physics, Kiev, Ukraine
[5] Institute for Nuclear Research of Russian Academy of Sciences, Moscow
[6] Institute for High Energy Physics, Protvino, Russia
[7] Charles University in Prague, Faculty of Mathematics and Physics, Czech Republic
[8] Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering

LoI preparation.

The design of Spin Physics Detector (SPD) is based on the requirements for the measurements of the DY, J/Ψ, photon and meson productions. These requirements are the following:

- Almost 4π geometry;
- precision vertex detector;
- precision tracking system;
- precision momentum measurement;
- good particle identification capabilities;
- high trigger rate capabilities.

Muon Detectors • Barrel TOF • Calorimetry • EMC • Silicon Microvertex • Tracking • Central Tracker (Straw Tube Tracker)
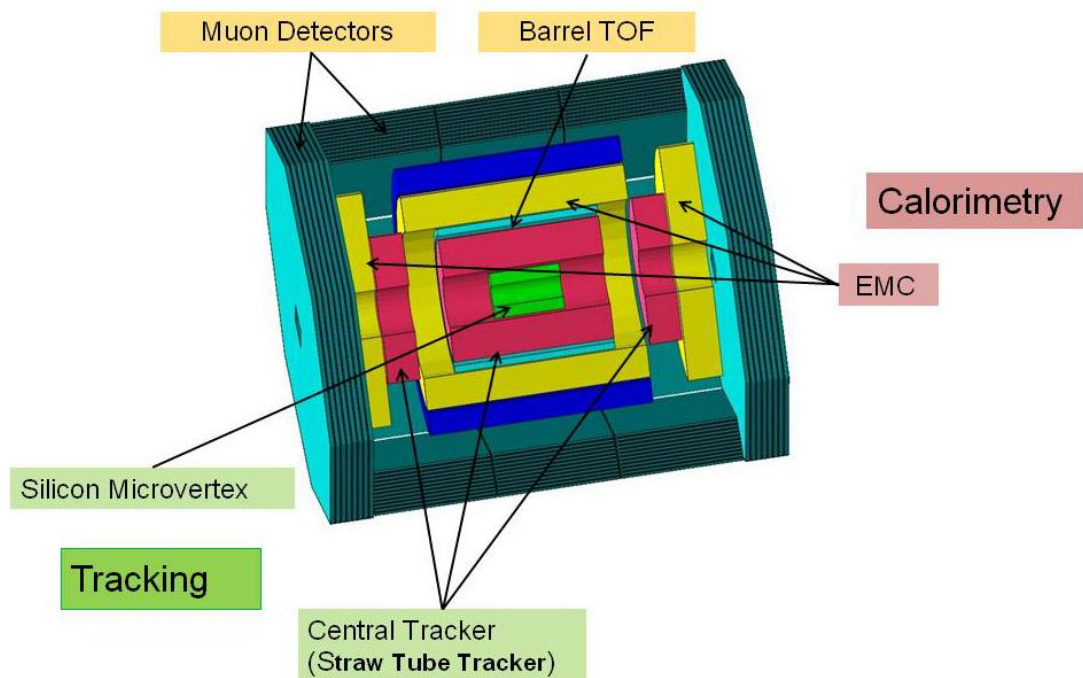
Conclusions.

The project on NICA Spin studies is under preparation at 2nd interaction point of the collider. The LoI preparation is in progress.

The purpose of proposed measurements is the study of the nucleon spin structure with high intensity polarized light nuclear beams.

- high collision proton (deuteron) energy up to $\sqrt{s} \sim 26(12)$ GeV
- the average luminosity up to $\sim 10^{32}$ cm^2/s
- both proton and deuteron beams can be effectively polarized.

The main topics are:

1. Studies of DY processes with longitudinaly and transversely polarized p and D beams. Extraction of unknown (poor known) parton distribution functions (PDFs).
2. PDFs from J/Ψ production processes.
3. Spin effects in one and two hadron production processes.
4. Prompt photons.
5. Cross sections, helicity amplidudes and double spin asymmetries (Krisch effect). in elastic reactions.
6. Final spin states effects and polarization effects in heavy ion collisions.

Thanks for your attention

Collaborators are welcomed !