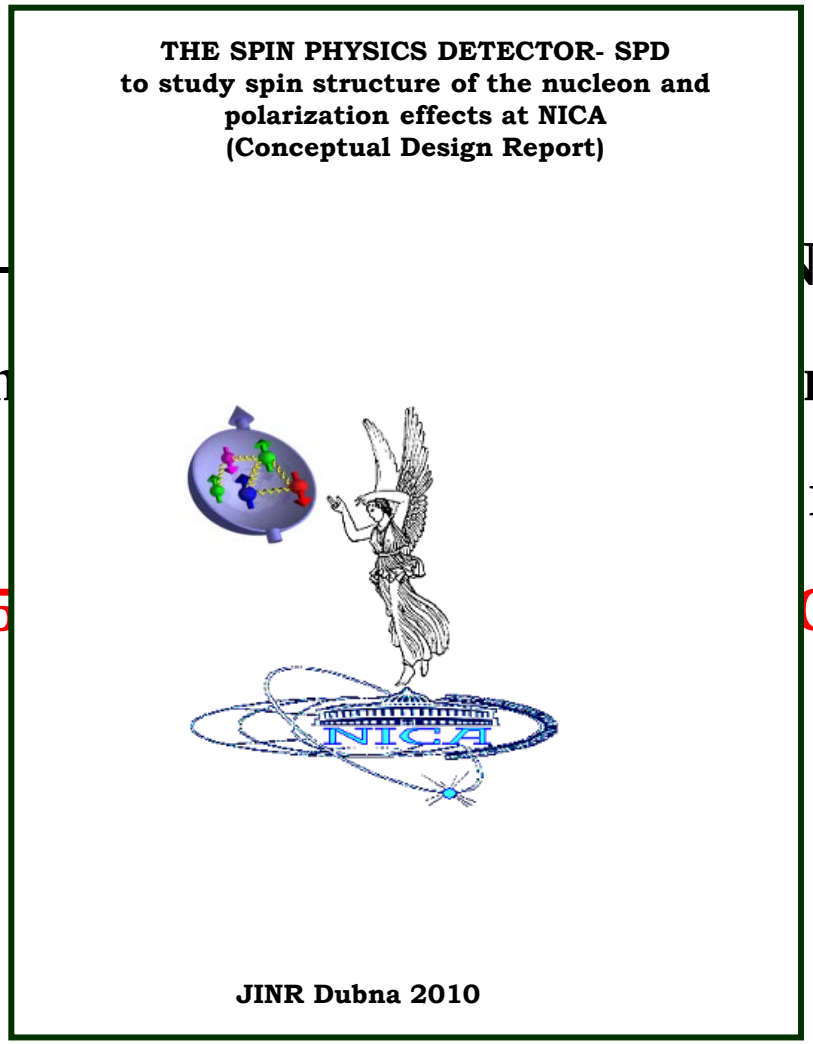
# Spin physics at the NICA

D.Peshekhonov
on behalf of the NICA community

# Polarized program of the NICA Project




The Nuclotron-

NICA) is aimed to

collider experin

nd has to provide

- the ion-ion and

range 1 - 4.5 GeV

- polarized p-p (5

GeV) collisions

# PROPOSED MEASUREMENTS

**The following subjects are under consideration:**

- **DY processes**
- **J/Y production processes**
- **Studies of elastic reactions**
- **Spin effects in one & two hadrons production processes**
- **Spin *effects* in inclusive high-$p_T$ reactions**
  - **$p_T$ ~ 2 GeV/c anomaly investigations with the light nuclei**
  - **high $p_T$ triggers for Probing Cold High Dense Nuclear Matter**
- **Polarization effects in heavy ion collisions (MPD)**
- **Spectroscopy of quarkonia with any available decay modes**

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# PROPOSED MEASUREMENTS

**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, …)**

$p^\uparrow(D^\uparrow)p(D) \to \gamma^* X \to l^+ l^- X$ — **Transversity and first moment of Boer-Mulders PFDs (Sissakian, Shevchenko, Nagaytsev , Ivanov, PRD 72(2005), EPJ C46 ,2006 C59, 2009)**

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

$p^\rightarrow(D^\rightarrow)p^\leftarrow(D^\leftarrow) \to \gamma^* X \to l^+ l^- X$ — **Longitudinally polarized sea and strange PDFs and tenzor deuteron structure (Teryaev, …)**

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

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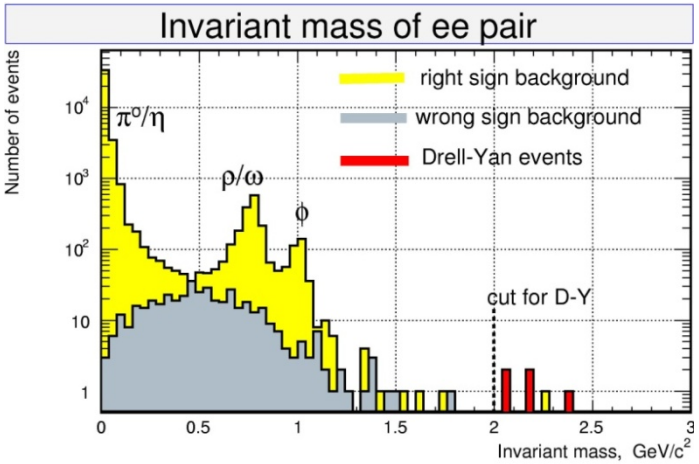
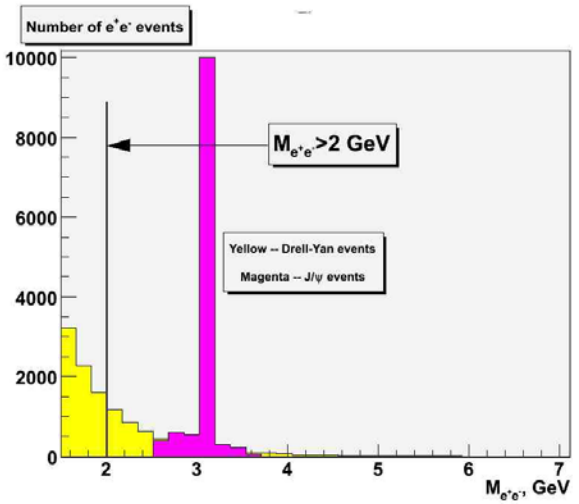
# Estimations for 1 month of data taking.
# For 3 years of data taking: ~100K DY events

| | $\sigma_{DY}$, total, nb | L, cm $^{-2}$s$^{-1}$ | K events |
|---|---|---|---|
| PAX, √s=14.6 GeV | 2 | $10^{30}$ | ~10 |
| NICA, √s=20 GeV | 1 | $10^{30}$ | 5 |
| NICA, √s=26 GeV | 1.3 | $10^{30}$ | 7 |

| Cut on Q, GeV | 1.5 | 1.6 | 1.7 | 1.8 | 1.9 | 2.0 |
|---|---|---|---|---|---|---|
| NICA, √s=20 GeV | | | | | | |
| $\sigma_{DY}$, total, nb | 2.5 | 1.9 | 1.6 | 1.3 | 1.1 | 0.9 |
| # per month (in K) | 14 | 11 | 9 | 7 | 6 | 5 |
| NICA, √s=26 GeV | | | | | | |
| $\sigma_{DY}$, total, nb | 3.3 | 2.7 | 2.3 | 1.9 | 1.6 | 1.3 |
| # per month (in K) | 18 | 15 | 13 | 10 | 9 | 7 |
| PAX, √s=14.6 GeV | | | | | | |
| $\sigma_{DY}$, total, nb | 5.1 | 4.3 | 3.5 | 2.9 | 2.5 | 2.1 |
| # per month (in K) | 24 | 21 | 17 | 14 | 12 | 10 |

| √s , GeV | 20 | 26 | √s , GeV | 20 | 26 |
|---|---|---|---|---|---|
| $\sigma_{J/\psi}$ , $B_{\mu\mu}$ , nb | 10 | 16 | $\sigma_{DY}$ , nb | 0.9 | 1.3 |
| # per month (in K) | 55 | 88 | # per month (in K) | 5 | 7 |



## QUESTIONS

1. is Nuclotron able to be the base of the new complex?
2. Resources and support to be actual (in time-scale)
3. Is it possible to make such machine (for experiments with heavy ions and light polarized particle) ?

## ANSWERS

1. Yes (intensity, energy, stable operation, ..) already demonstrated
2. Russian federal program: megaprojects. NICA is IN
3. Yes. TDR for the accelerator part is in progress →

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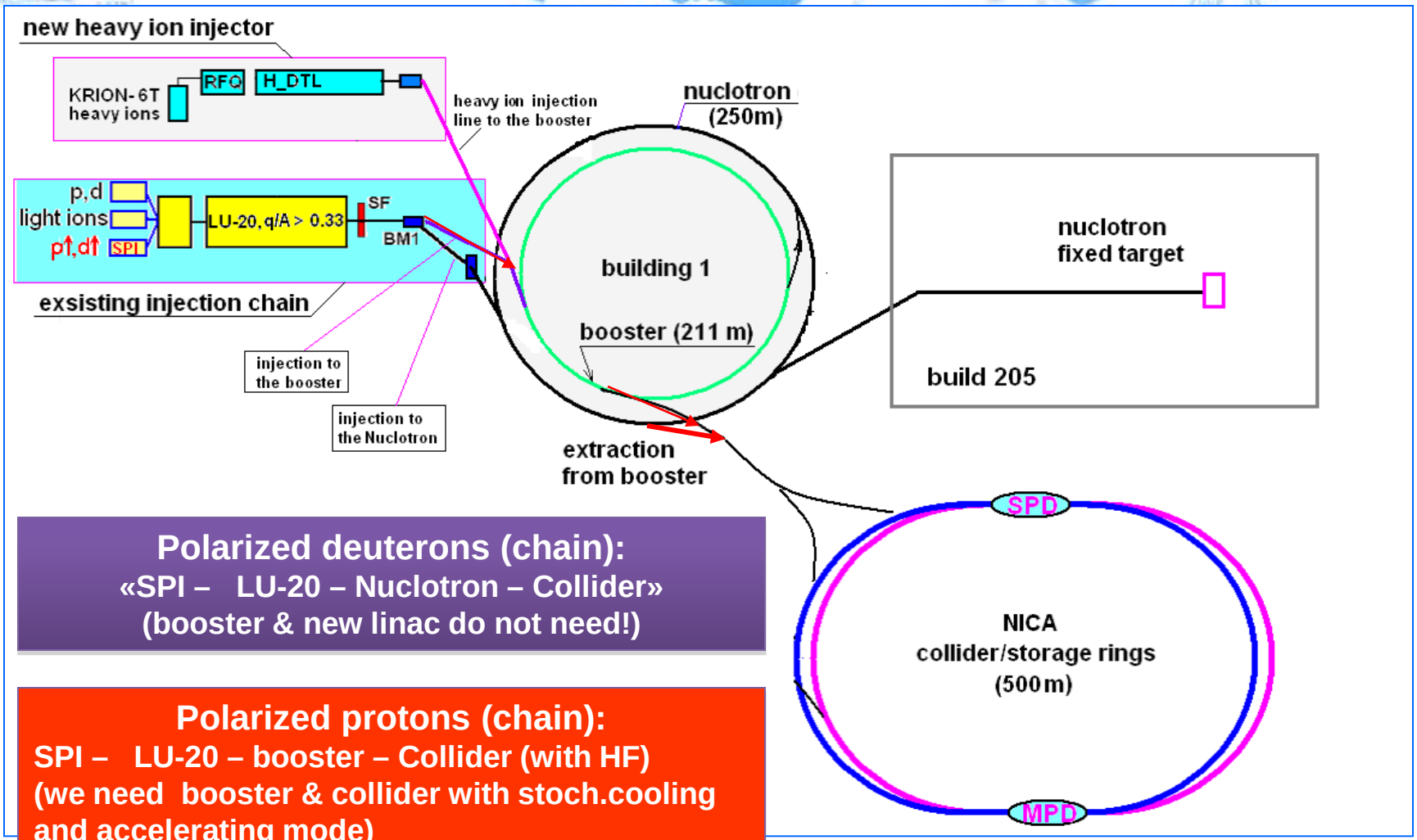
# Structure of the complex NICA




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

**Polarized protons (chain):**
**SPI – LU-20 – booster – Collider (with HF)**
**(we need booster & collider with stoch.cooling and accelerating 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

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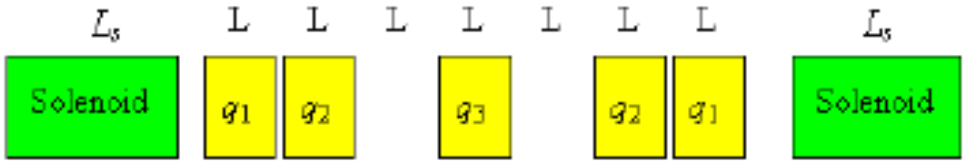
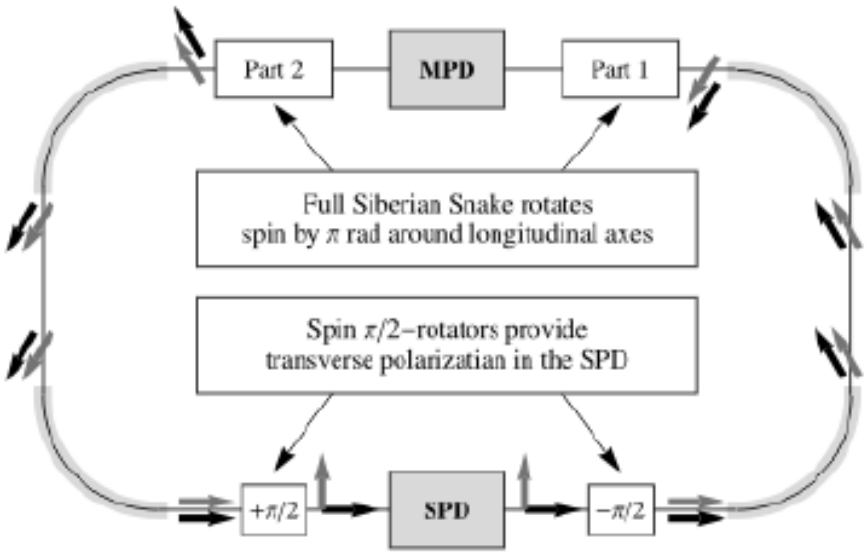
**Polarized protons:**

- new ion source with intensity 10^10 protons per pulse;
- LU-20 with new RFQ section;
- booster with the spin control insertion and accelerating RF station;
- fast extraction system from the booster directly to the collider rings;
- RF station for the proton beam acceleration/de-acceleration



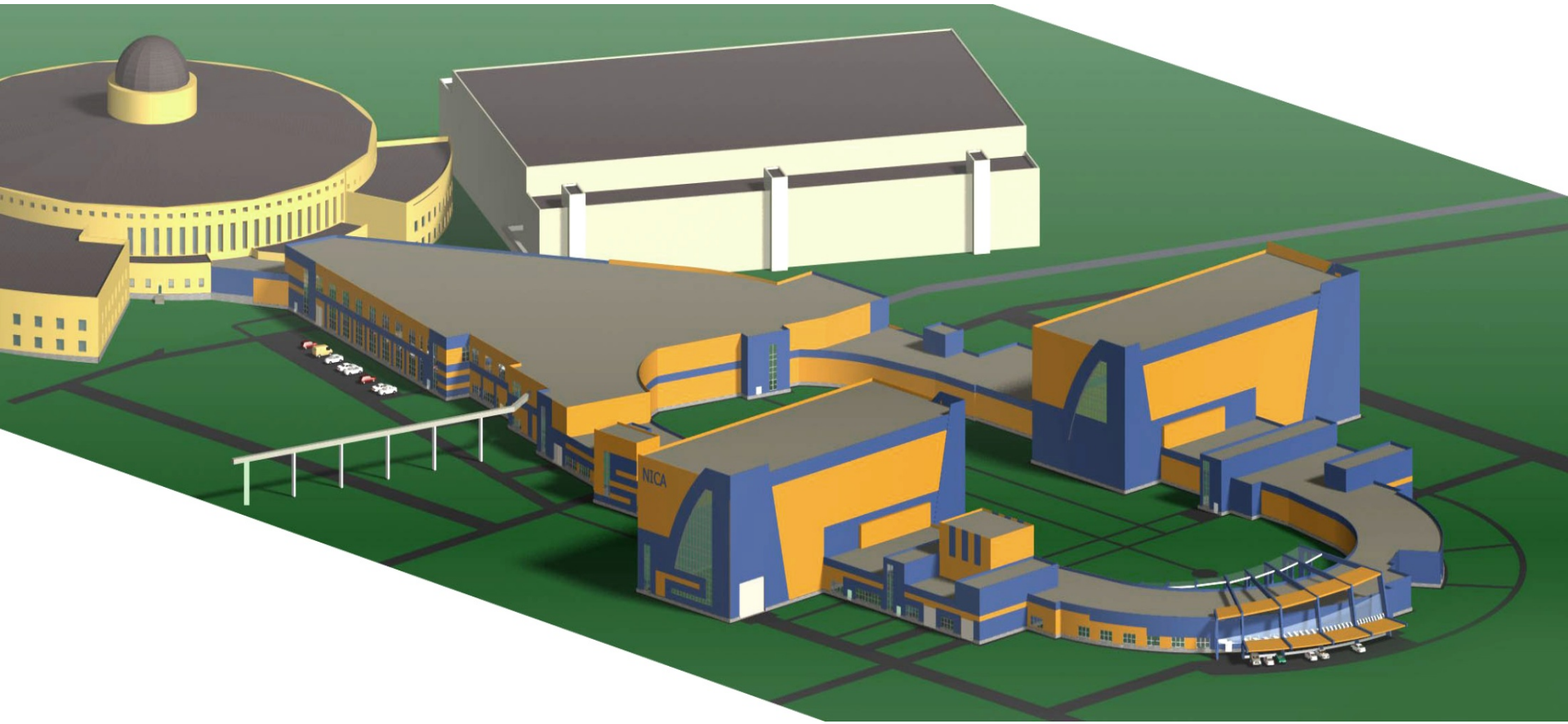

The use of Siberian Snake with longitudinal Magnetic fields is proposed to suppress dangerous spin resonances in the booster.



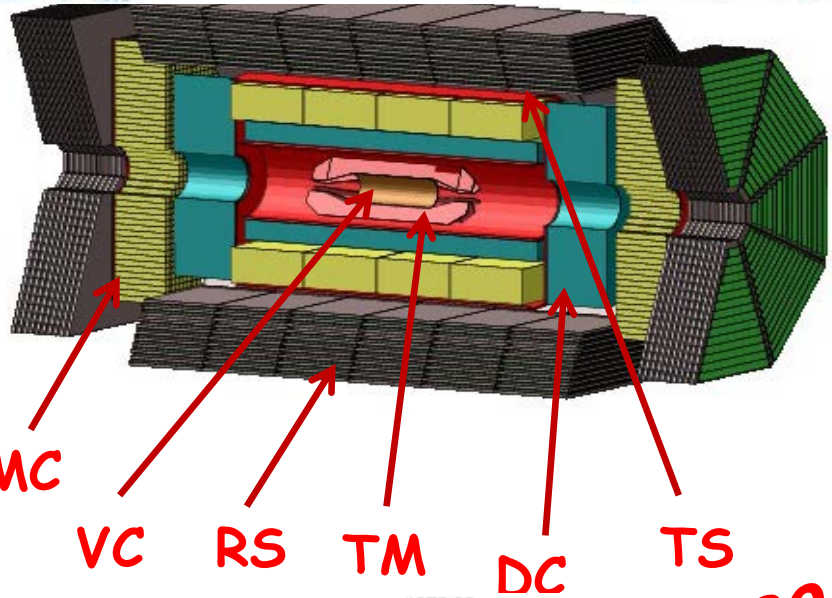

The “Siberian Snake” insertions installed in the opposite with respect to the SPD straight sections and spin rotators installed directly in front of the SPD setup are used to change spin orientation from longitudinal to transverse.
The polarization direction control in the NICA collider (black arrows are correspond to longitudinal and grey ones to transverse directions, respectively )

# NICA Collider Structure

# Accelerator complex NICA (artistic view)



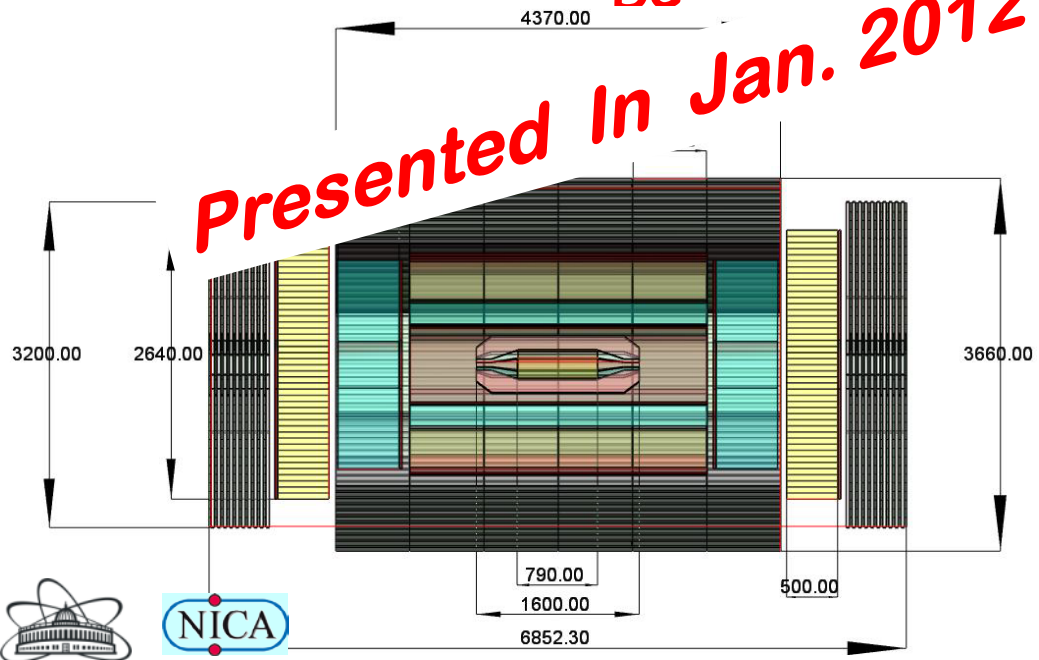
# SPD




Proposed scheme of the SPD:

- Torroid magnet system (TM)
- Silicon detectors (VC)
- Drift chambers (DC)
- EM Calorimeter (EMC)
- Muon System (RS)
- Trigger System (TS)
- EndCap detectors with RS, tracking system and EMC

Presented In Jan. 2012 at JINR PP PAC




SPD sizes: ~ 6.8 m along beams
~ 3.8 m in diameter

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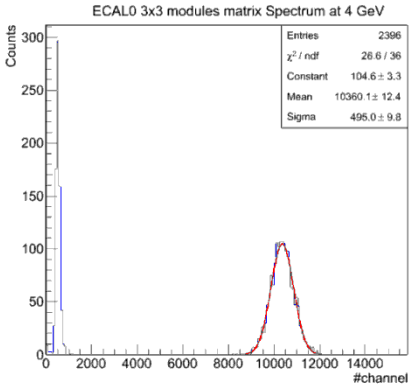
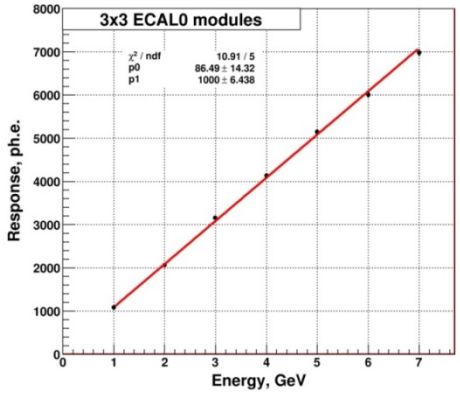
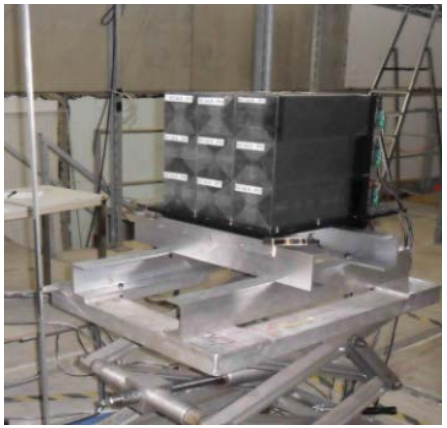
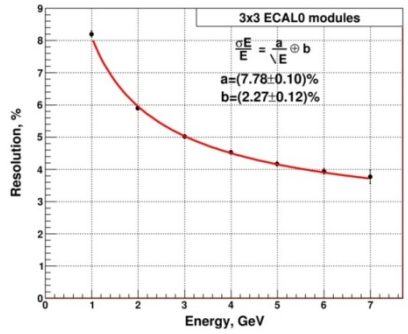
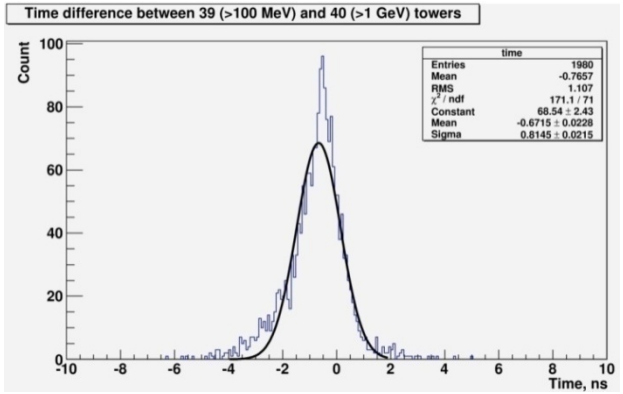
# EMC

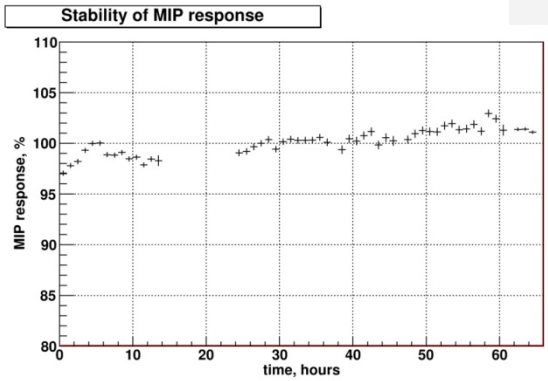





ECAL0 for COMPASS-II as EMC prototype for SPD

Tests in 2007-2011 at PS-T9 and COMPASS beams.

Module production in ISMA, Kharkov

MAPDs from Zicotek

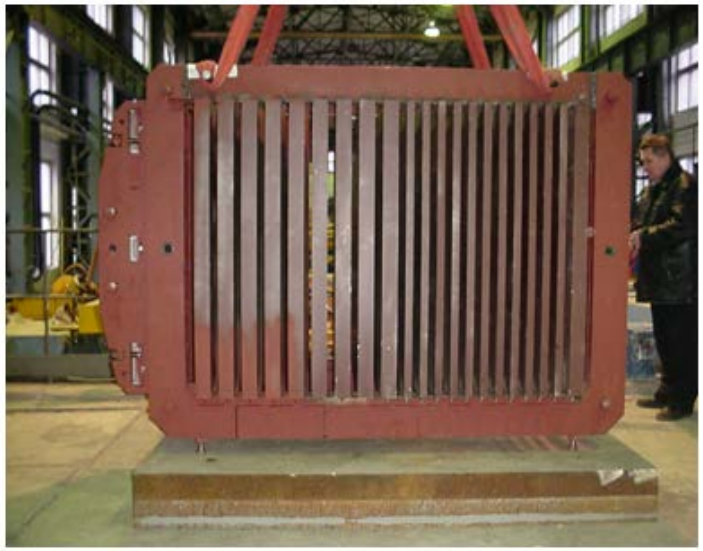
Assembling and testing in JINR

# RS

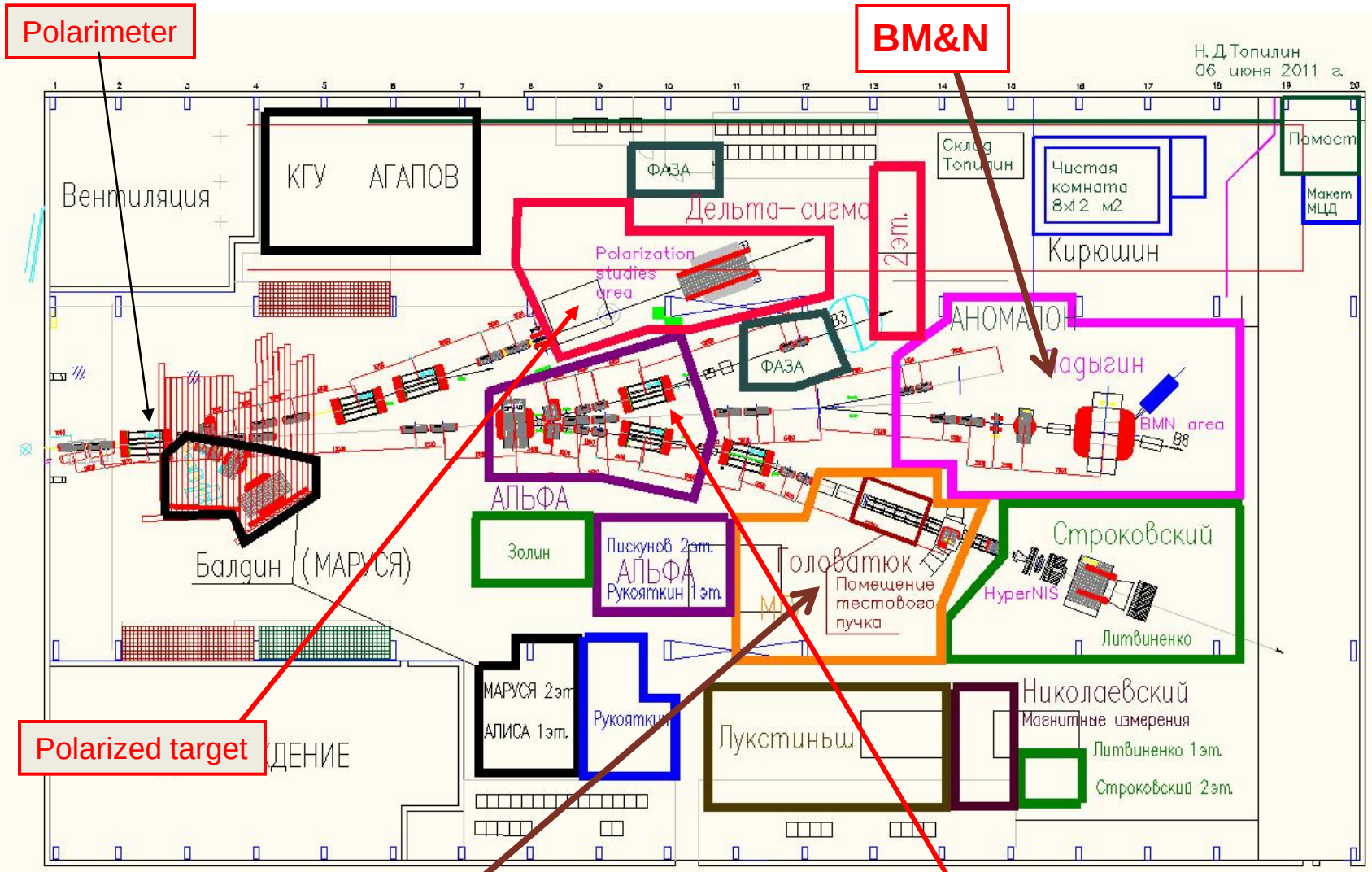
1. Direct calibration of RS structure with μ, π, p
   - μ/π rejection factor
   - "Muon calorimetry"
   - " Hadron calorimetry"
2. Study of readout schemes with long strips (two coordinates).

Full Scale Prototype (2x4 m2) at CERN/COMPASS: put in operation, runs smoothly at high muon halo flux (~10 kHz/cm2), wire signals are observed

(left) - Range System prototype (Fe absorber and support structure) in vertical position (for tests with cosmic);
(right) - RS prototype in horizontal (beam test) position



# Nuclotron fix target zone



# Spin Physics Research Infrastructure @ NucloTron (project SPRINT in preparation)

1 **Polarized Ion Source (JINR, INR)**
2 **Polarized d- and p-beams necessary parameters**
3 **Deuteron beam polarimetry (JINR)**
- 3.1 Low energy polarimeter
- 3.2 Internal target polarimeter
- 3.3 Extracted beam polarimetry

4 **Proton beam polarimetry** (Colleagues from BNL)
- 4.1 **CNI polarimetry**
- **4.2 Absolute calibration of the beam polarization**
- **4.3 Local polarimetry for SPD**

5 **Polarized targets**
- 5.1 Solid polarized proton target (JINR)
- 5.2 Polarized $^3$He target **(JINR)**

6 **Equipment polarized beam transfer lines**
7 **Polarization data acquisition**

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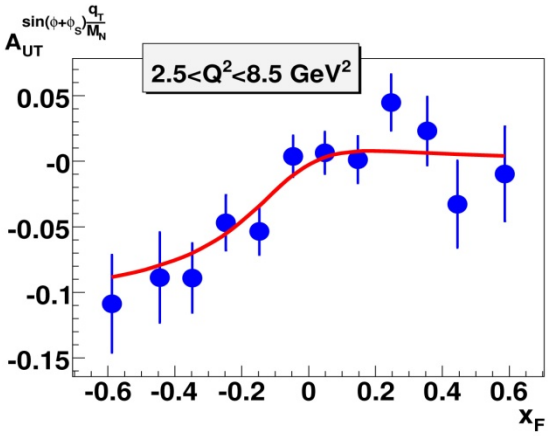
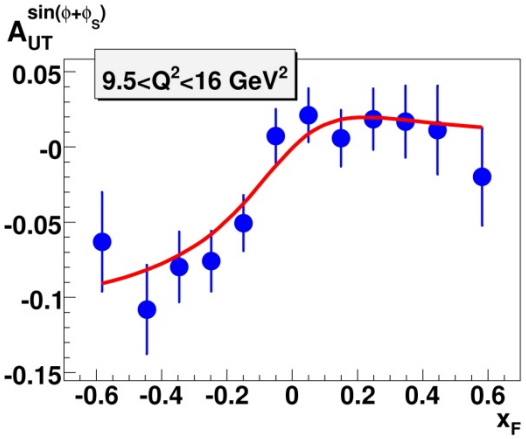
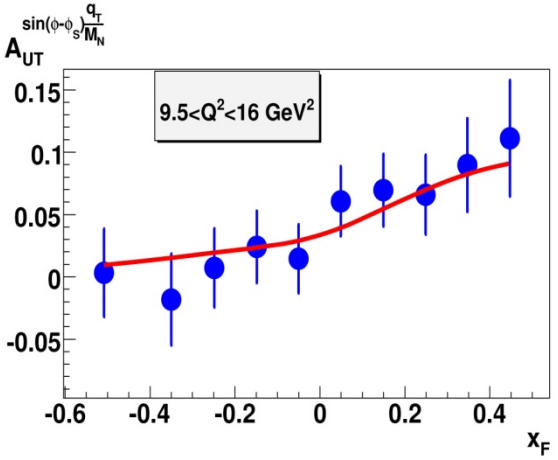
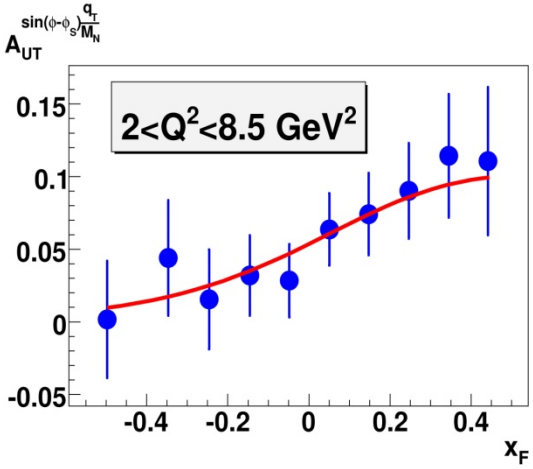
# Thank you for attention



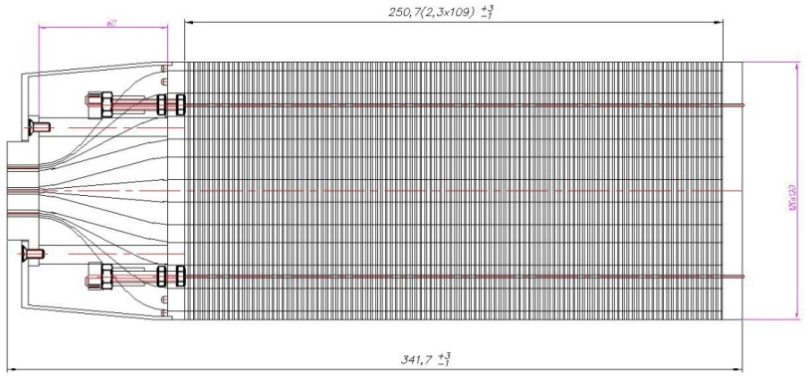

A.N. Sissakian, O.Yu. Shevchenko, A.P. Nagaytsev, O.N. Ivanov, Phys.Part.Nucl.41:64-100,2010.

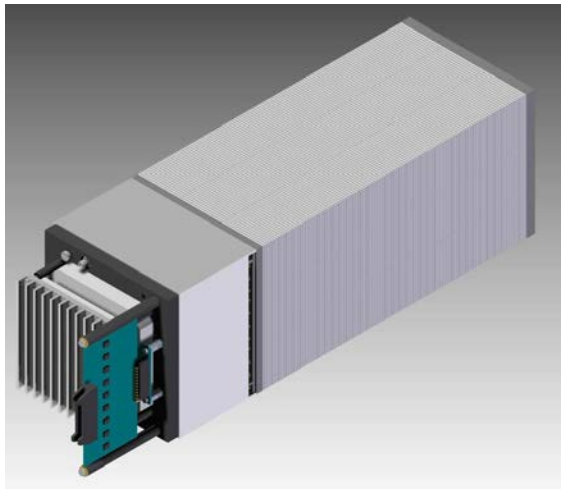
The set of original software packages (MC simulation, generator etc.) were developed for the feasibility studies of DY polarized processes

The SSA asymmetries. Top:access to transversity and Boer-Mulders PDFs. (Sissakian, Shevchenko, Nagaytsev,PRD 72 (2005), EPJ C46 (2006))

Bottom: access to Sivers PDFs (Efremov,… PLB 612(2005), PRD 73(2006));

Alsymmetries are estimated for 100 K DY events



| | |
|---|---|
| **Technology** | **Shashlyk** |
| **Scintillator** | **Polystyrene Kharkov** |
| **Absorber** | **Lead** |
| **Number of layers** | **109** |
| **Sc / Pb plates thickness, mm** | **1.5/0.8** |
| **Pb/Sc plates dimension, cm** | **12.0x12.0** |
| **Moliere radius, cm** | **3.5** |
| **Radiation length, cm** | **1,64** |
| **Number of tower** | **9** |
| **Fiber** | **BICRON BCF91AMC d=1.2 mm** |
| **Number of fibers per tower** | **16** |
| **Diam. of bundle, mm** | **6.5** |
| **Light guide** | **Winston cone glued to photodetector** |
| **Photodetector** | **MAPD -Zecotek** |
| **Total thickness, cm** | **25.2(~ 15 X0 )** |
| **ADC** | **MSADC** |
| **Thermostabilization** | **Peltier cooler** |

**Module**:

- size is 12x12 $cm^2$
- 9 cells, size is 4x4 $cm^2$
- 9 MSADC channels
- Temperature stabilization system ( Peltier element, electronics)
- 9 Amplifiers
- 9 light collection system
- Control system (LED, Laser)
- Power supply

The project on NICA Spin studies is under preparation at 2nd interaction point of the collider.
(first version of CDR for SPD , June 2010, http://nica.jinr.ru/files/Spin_program/spd_cdr.htm )

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 $10^{30}$-$10^{31}$ $cm^2/s$
- both proton and deuteron beams can be effectively polarized.

The main topics are:

1. Studies of MMT-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 baryon, meson and photon productions.
4. Studies of spin effects in various exclusive reactions.
5. Diffractive processes studies.
6. Cross sections, helicity amplidudes and double spin asymmetries (Krisch effect). in elastic reactions.
7. Spectroscopy of quarkoniums.

NICA Spin program plans:

2012-2014 – CDR and TRD preparation, SPD collaboration, R&D

2015-2018 – R&D, Detectors production

# Polarized program of the NICA Project

**The purpose of Spin Physics program at NICA is the study of the nucleon spin structure with high intensity polarized light nuclear beams**

**NICA collider option with the light nuclear beams with the proton and deuteron ones.**

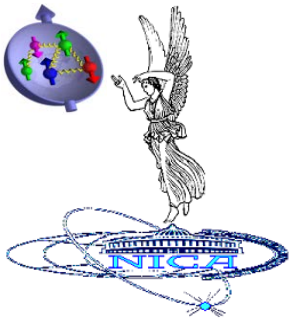
**Collider can allow us to reach collision proton energy $\sqrt{s}$ ~ 2 - 26 GeV with the luminosity up to $10^{31}$-$10^{32}$ cm$^2$/s.**

**For deuteron beams the collision energy per nucleon $\sqrt{s}$ ~ 1 -12 GeV with the average luminosity up to $10^{30}$-$10^{31}$ cm$^2$/s.**

**Both proton and deuteron beams can be effectively polarized.**

**All these advantages give us unique possibilities to investigate at NICA the polarized phenomena which are of crucial importance for the solution of the nucleon spin problems- one of the main tasks of the modern high energy physics**

**THE SPIN PHYSICS DETECTOR- SPD**
**to study spin structure of the nucleon and polarization effects at NICA**
**(Conceptual Design Report)**




**JINR Dubna 2010**

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