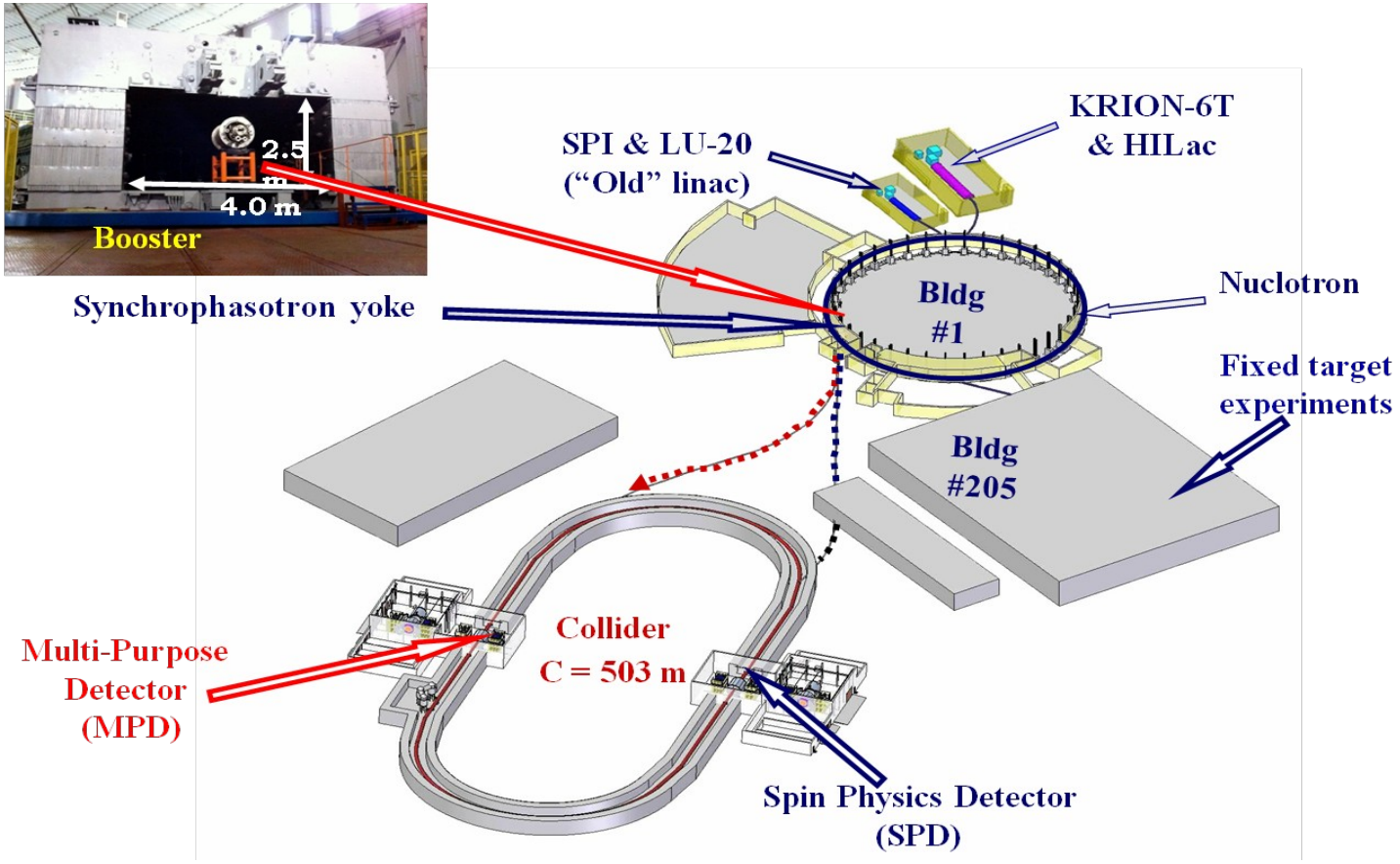
SPD EXPERIMENT AT NICA.

Introduction. NICA Project.

Nuclotron-based Ion Collider fAcility (NICA)



SPD EXPERIMENT AT NICA.

Introduction. 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

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

For deuteron beams the collision energy per nucleon up to $\sqrt{s}$ ~ 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

SPD EXPERIMENT AT NICA.
PROPOSED MEASUREMENTS.

The following subjects are under consideration:

- DY processes
- J/Ψ production processes
- Studies of elastic reactions
- Spin effects in one and two hadron production processes
- Spin effects in inclusive high-p_T reactions
- Polarization effects in heavy ion collisions (MPD)
- Spectroscopy of quarkonia with any available decay modes

SPD EXPERIMENT AT NICA.

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

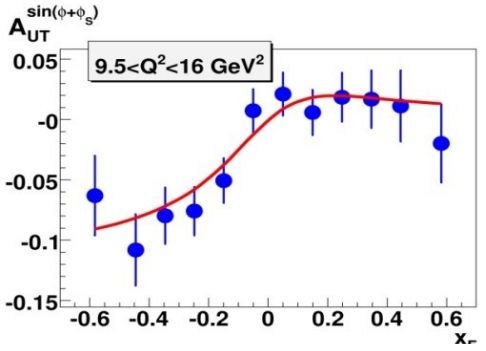
$p^\uparrow(D^\uparrow)p(D) \to \gamma^* X \to l^+ l^- X$ Sivers PDFs (Efremov,... PLB 612 (2005), PRD 73(2006));

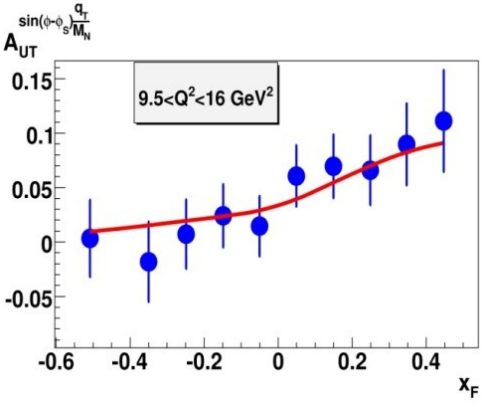
$p^\uparrow(D^\uparrow)p^\uparrow(D^\uparrow) \to \gamma^* X \to l^+ l^- X$ Transversity PDF (Anselmino, Efremov, ...)

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

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

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

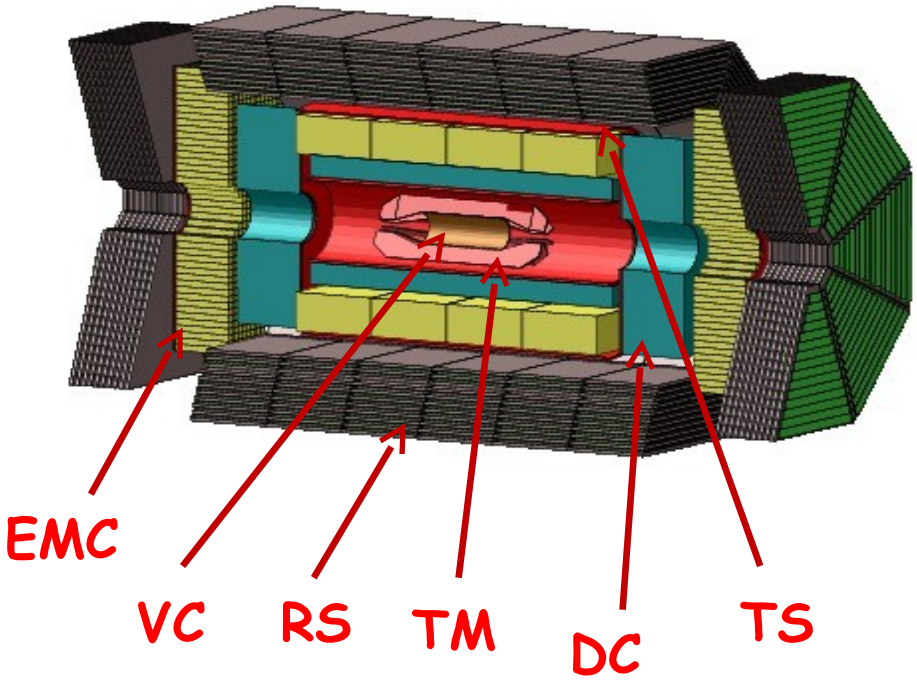




"Polarization effects in Drell-Yan processes",
Sissakian A. N.,Shevchenko O. Yu.,Nagaitsev A. P.,Ivanov O. N.
Physics of Particles and Nuclei, Volume 41, Issue 1, pp.64-100,
MAIK award for 2010.

SPD EXPERIMENT AT NICA.

SPD.



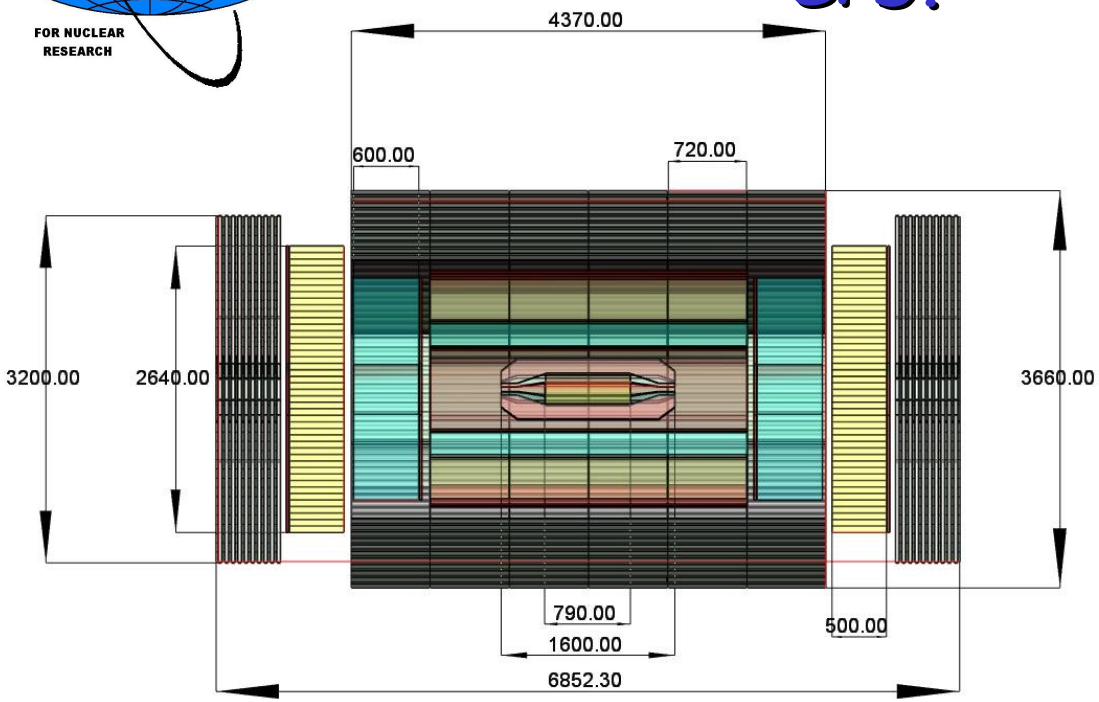
Proposed scheme of the SPD:

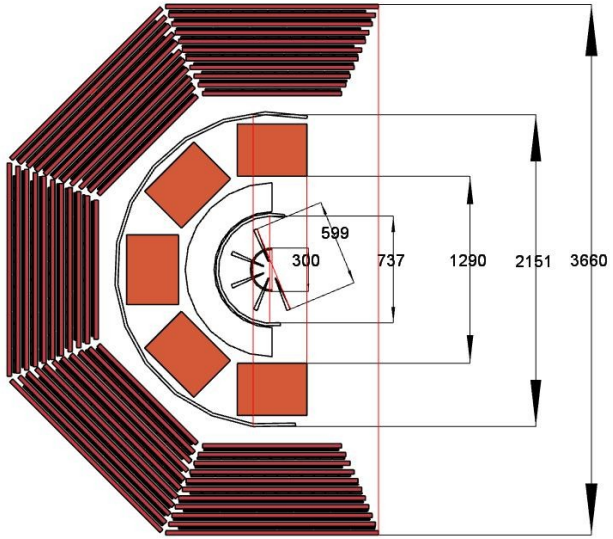
- Toroid magnet system (TM)
- Silicon detectors (VC)
- Drift chambers (DC)
- EM Calorimeter (EMC)
- Range System (RS)
- Trigger System (TS)
- End-Cap detectors with RS, tracking system and EMC

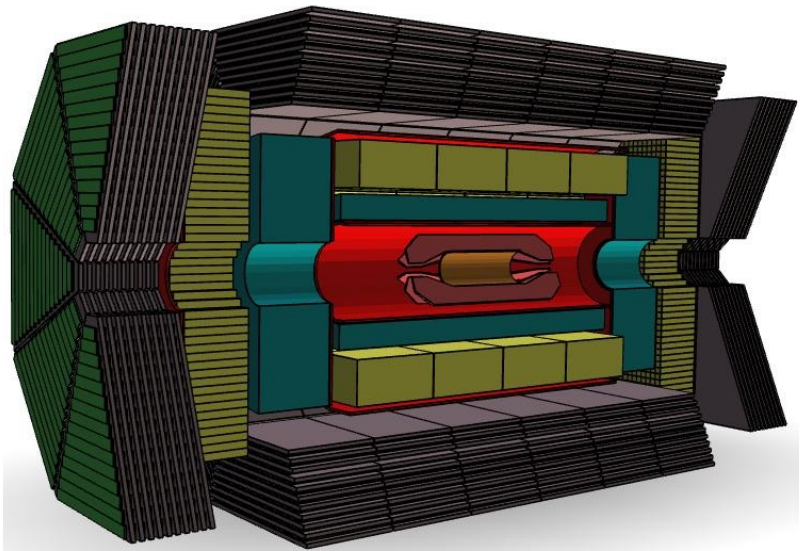
SPD sizes: ~ 6.8 m along beams
~ 3.7 m in diameter

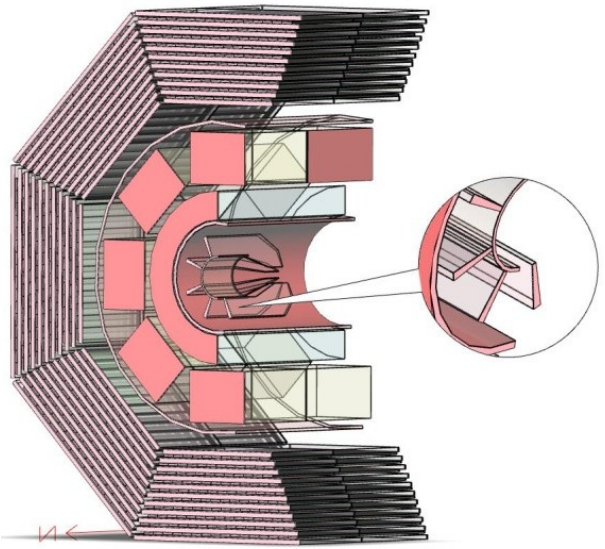
SPD EXPERIMENT AT NICA.

SPD.





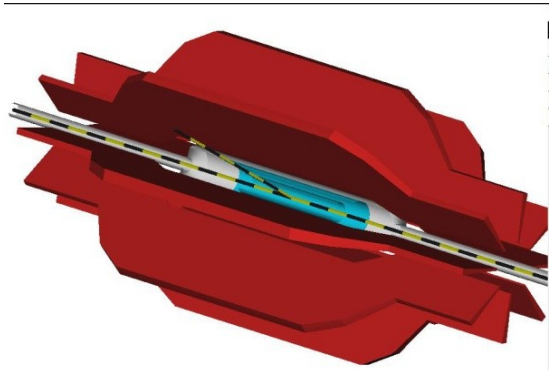


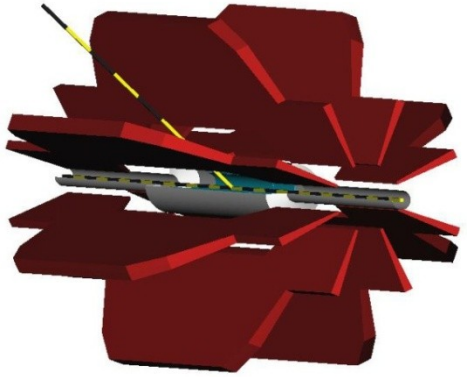


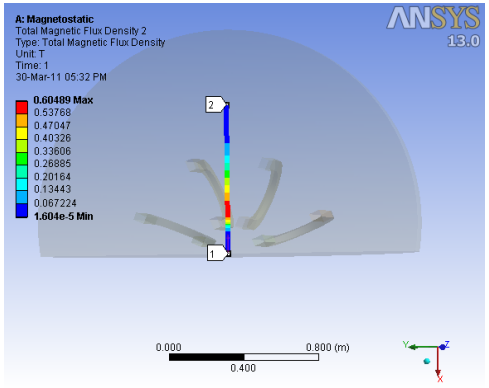
SPD EXPERIMENT AT NICA.

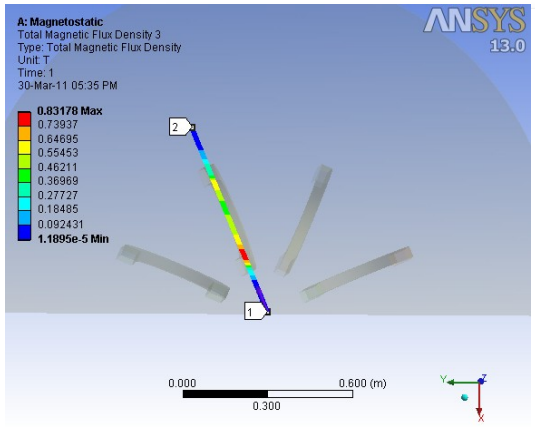
SPD.Toroid magnet.

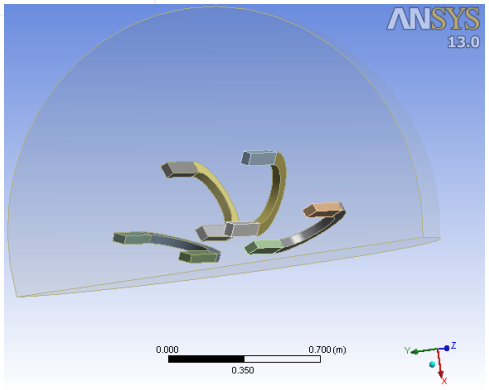
- 8 coils
- ~100 x 40 cm coils
- average integrated field: ~ 0.8 - 1.0 Tm
- acceptance ~ 80 %

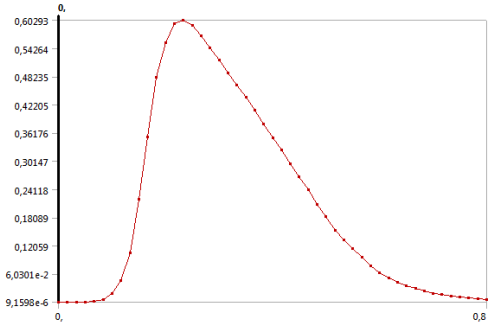


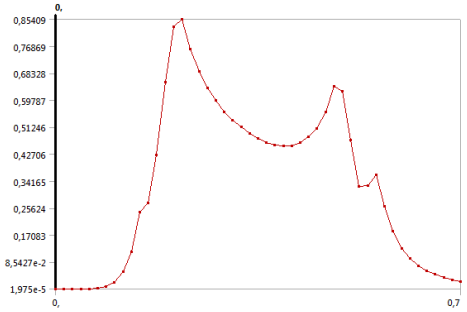


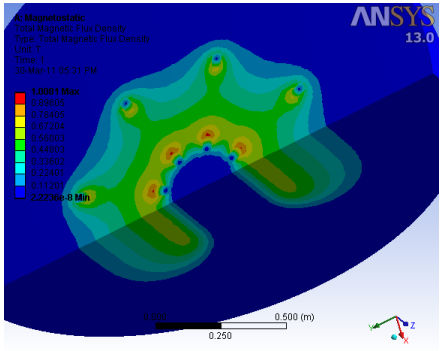








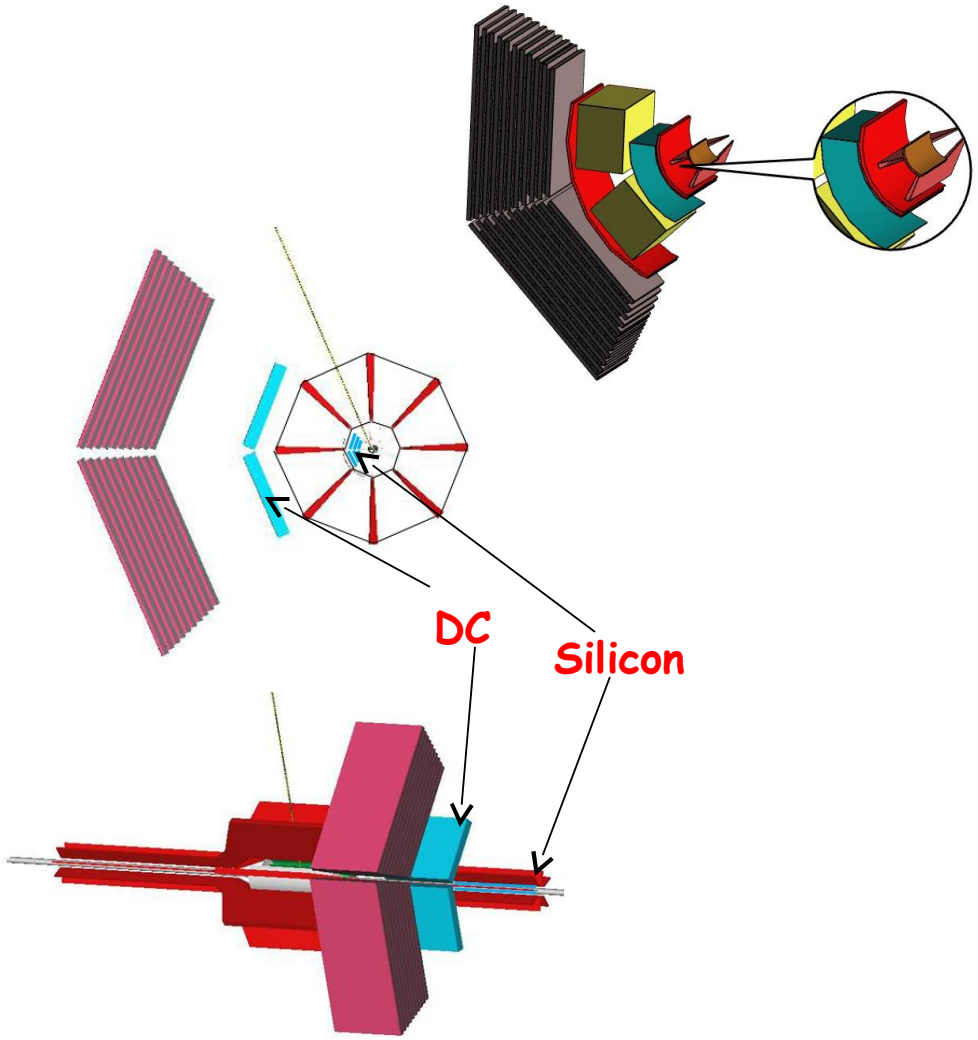




Done by Pivin R.

SPD EXPERIMENT AT NICA.

SPD.Vertex detector and DC.



Several layers of double-sided Silicon strips can provide a precise vertex reconstruction and tracking of the particles before they reach the magnet.

The design should use a small number of silicon layers to minimize the radiation length of the tracking material.

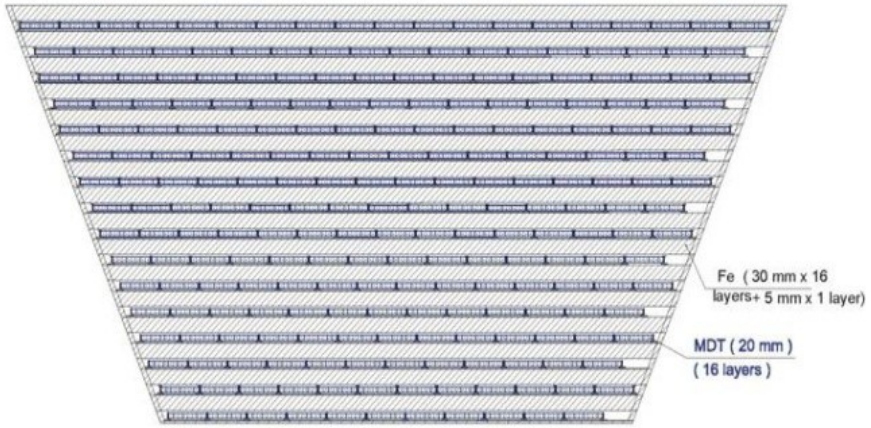
With a pitch of 50-100 μm it is possible to reach spatial resolution of 20-30 μm.

This spatial resolution would provide precision of the vertex reconstruction about 50-80 μm, and permits to reject the secondary decays of mesons into leptons.

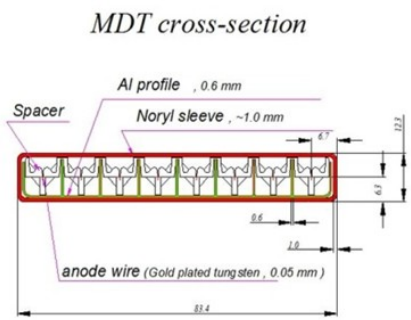
The coordinate resolution of 150-200 μm can be achieved with conventional Drift Chambers. The chambers can be assembled as modules consisting of several pairs of tracking planes with wires at 30 ; 0 ; 0 ; +30 deg. with respect to the direction parallel to the magnetic field lines. This can provide the momentum resolution of the order of 1-3 % over the kinematic range of the detector.

SPD EXPERIMENT AT NICA.

SPD.Range System.



The system of MDT layers alternating with Fe layers called Range System (RS) is used in SPD as muon detector and main element of Particle Identification System.
It can provide clean muon identification for muon momenta greater than 1 GeV.
The combination of responses from EM calorimeter and RS can be used for the identification of pions and protons in the wide energy range.
RS provides good coordinate accuracy.



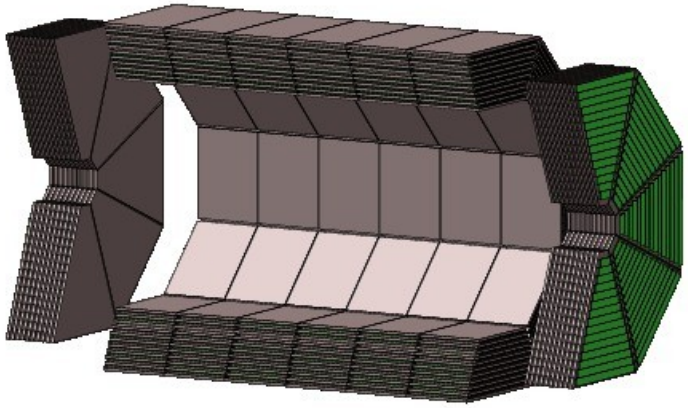
Plots are from " Muon TDR for PANDA ", PANDA Collab., November 2011

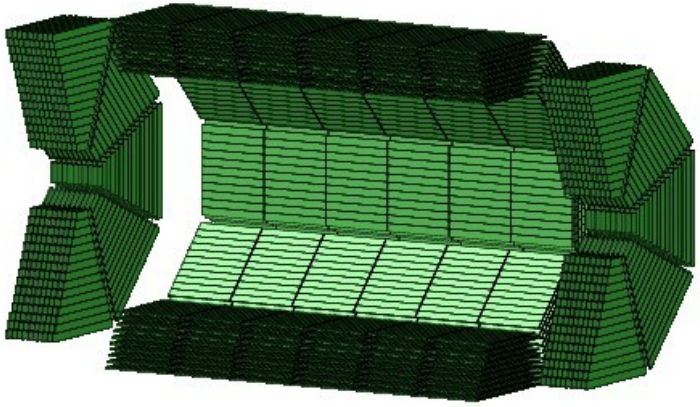
V.Abazov et al., Instrum.Exp.Tech.53:648-652,2010, Prib.Tekh.Eksp.5:32-36,2010.

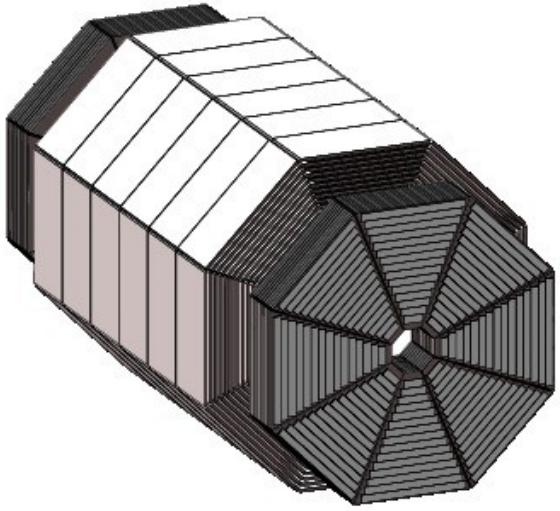
DLNP group, leader G.Alexeev

SPD EXPERIMENT AT NICA.

SPD.Range System.







The Range System consists of two parts:
Barrel and two End-caps.

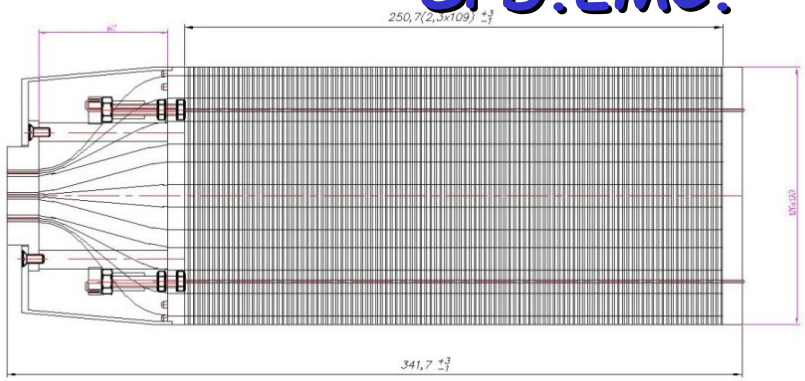
The preliminary sizes of RS are following:
about 6.8 m along beam line and 3.7 m in diameter.

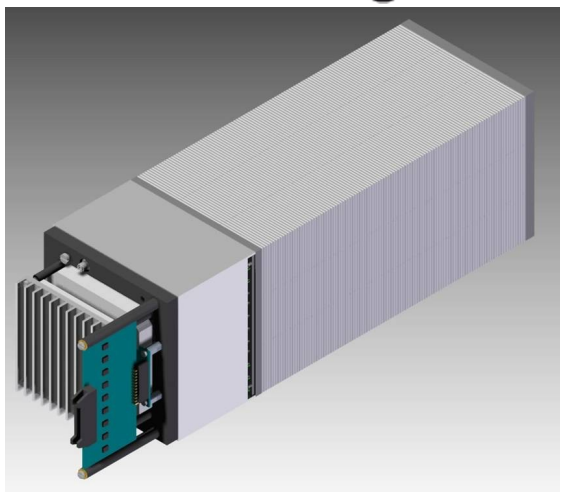
The RS designed with consists of 4140 MDT units for barrel,
2x1200 units for End-caps.

Total: 6540 ch.

SPD EXPERIMENT AT NICA.

SPD.EMC.





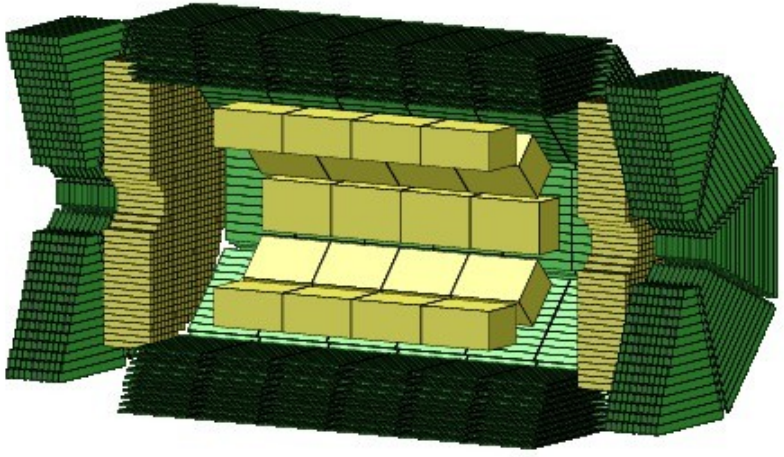
Technology	**Shashlyk**
Scintillator	**Polystyrene Kharkov**
Absorber	**Lead**
Number of layers	**109**
Sc / Pb plates thickness, mm	**1.5/0.8**
Pb/Sc plates dimension, cm	**12.0x12.0**
Moliere radius, cm	**3.5**
Radiation length, cm	**1,64**
Number of towers	**9**
Fiber	**BICRON BCF91AMC d=1.2 mm**
Number of fibers per tower	**16**
Diam. of bundle, mm	**6.5**
Light guide	**Winston cone glued to photodetector**
Photodetector	**MAPD, Zecotek**

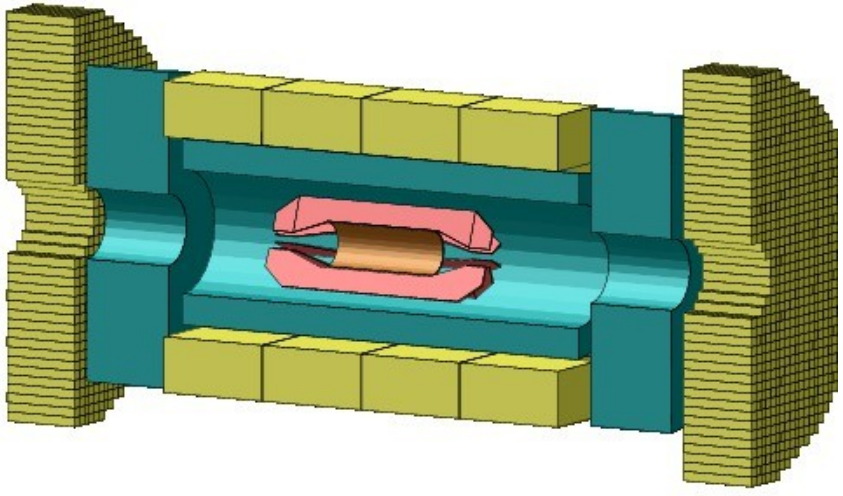
Module:

- 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

SPIN PHYSICS AT NICA.

SPD.EMC.





- The calorimeter consists of ``shashlyk'' modules with the application of new readout based on AMPD technology.

- The module design is defined with R&D performed in COMPASS.

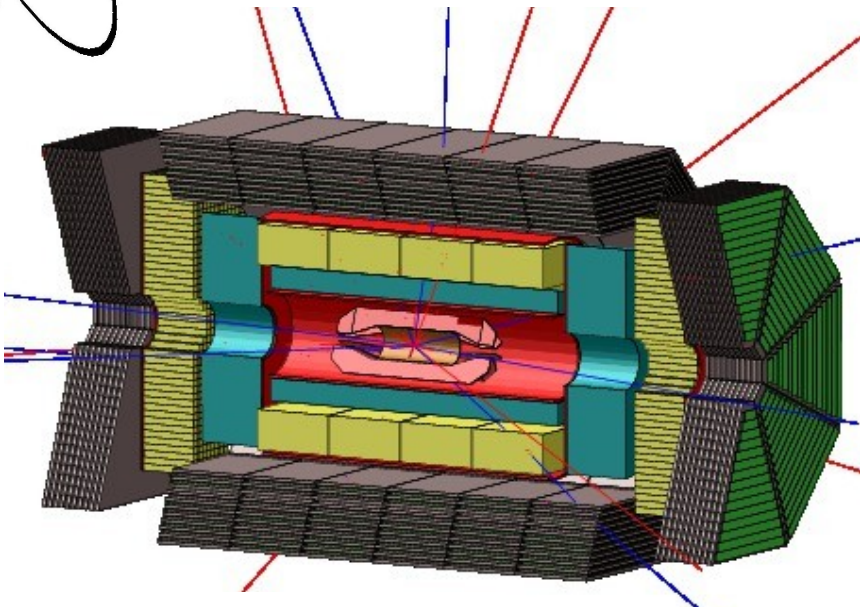
- The calorimeter will be used for the
- triggering of DY electrons.

- There are three parts of EM:
  barrel and two end-caps with
  4384 of 9th towers modules (39465 ch.)

  Module production in ISMA, Kharkov
  AMPDs from Zicotek
  Assembling and testing in JINR

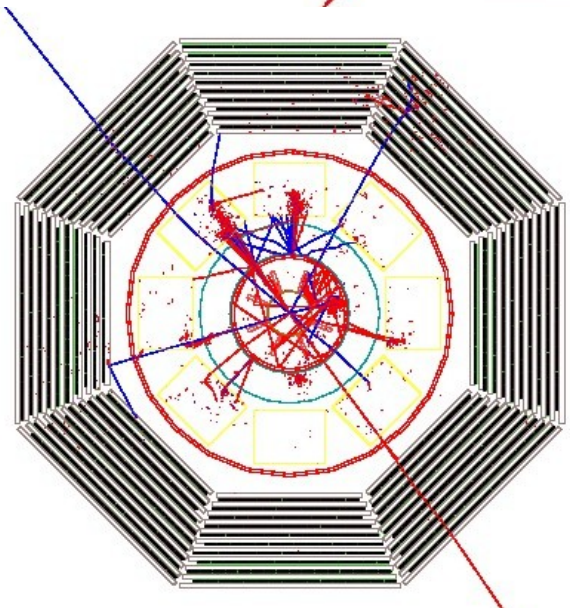
SPIN PHYSICS AT NICA.

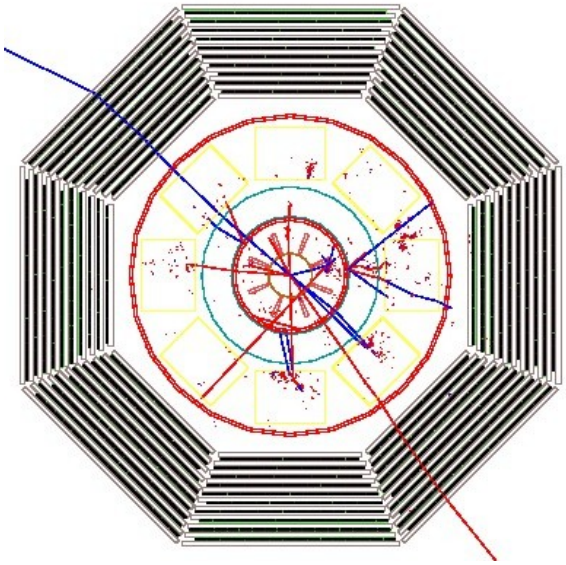
SPD.MC studies.

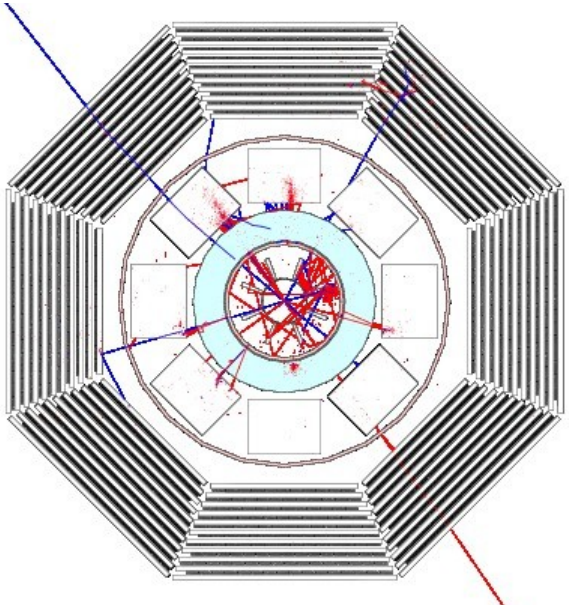


Simulation of DY in SPD

- for pp beams with E=12.6 GeV;
- pure DY events;
- PYTHIA generator was used;
- VC, DC, EMC,RS have to be fired.

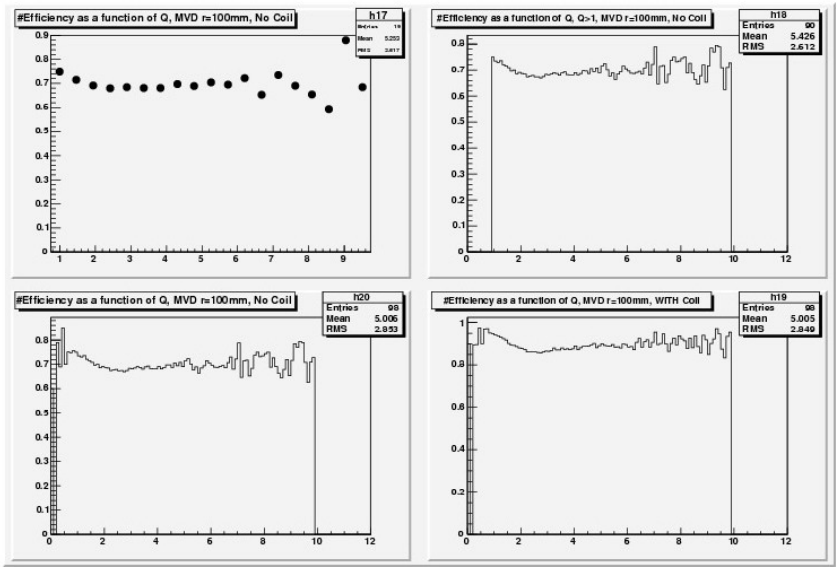


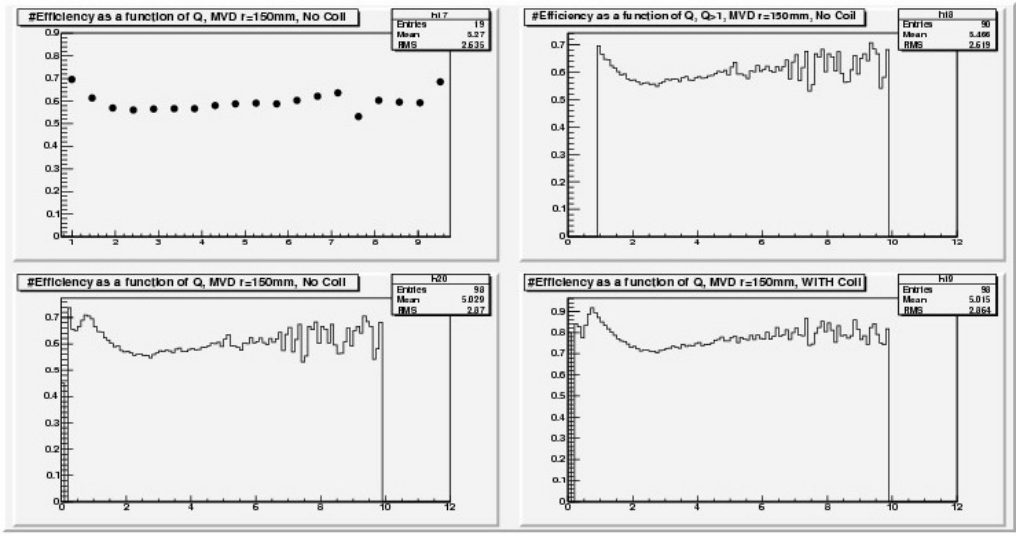




SPIN PHYSICS AT NICA.

SPD.MC studies.





Geometrical effciencies for DY events with two various position of Vertex detector:

- left plots are at 10 cm from beam line;
- right plots are at 15 cm from beam line.

Total efficiencies are ~ 0.6 - 0.7

MC studies by Rodionov V., Macharashvili G. and Meshcheryakov G.

SPIN PHYSICS AT NICA.

Estimations were done for 1 month of data taking.
For 3 years of data taking: we expect to take ~100K DY events

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

Cut on Q, GeV	1.5	1.6	1.7	1.8	1.9	2.0
NICA, $\sqrt{s}$=20 GeV						
σ_{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, $\sqrt{s}$=26 GeV						
σ_{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, $\sqrt{s}$=14.6 GeV						
σ_{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

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

SPD EXPERIMENT AT NICA CONCLUSIONS.

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 $\sqrt{s}$ ~ 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 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 TDR preparation, SPD collaboration, R&D

2015-2018 – R&D, Detectors production

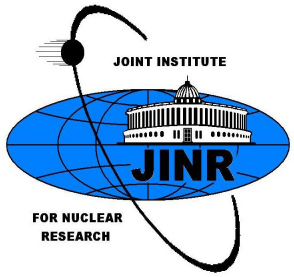
SPIN 2012

2012 International Spin Physics Symposium be held at the Joint Institute for Nuclear Research, Dubna, Russia.

The JINR physicists have been involved in high energy spin physics experiments in many world centers (CERN, FAIR, DESY, BNL and others) and also in Dubna. Experiments at Nuclotron with polarized deuteron beams have given very interesting results to study various spin problems. Currently JINR physicists are actively working on preparation of the spin programme at Nuclotron-M and future Nuclotron based Ion Collider fAcility (NICA).

The Next Spin Symposium SPIN 2012

...will be at Dubna!



SPIN 2012

PRELIMINARY PROGRAM

- Spin Structure of Hadrons
- Spin in Hadronic Reactions
- Spin Physics with Photons and Leptons
- Spin Physics in Nuclear Reactions and Nuclei
- Fundamental Symmetries and Spin Physics beyond the Standard Model
- Acceleration, Storage, and Polarimetry of Polarized Beams
- Polarized Ion and Lepton Sources and Targets
- Future Facilities and Experiments
- Medical and Technological Applications of Spin Physics

http://spin2012.jinr.ru/

SPIN 2012

PARALLEL SESSIONS & CONVENERS

1. Spin Structure of Hadrons
Efremov Anatoly (BLTP JINR, Dubna)
Leader Elliot (London)
Kurek Krzysztof (Warsaw)

2. Spin in Hadronic Reactionsa
Vasiliev Alexander (Protvino)
Mochalov Vasily (Protvino)
Messchendorp J.G. (Groningen)

3. Spin Physics with Photons and Leptons
Savin Igor (JINR, Dubna)
Mallot Gerhard (CERN)

4. Spin Physics in Nuclear Reactions and Nuclei
Strokovsky Evgeny (JINR, Dubna)
Garcon Michel (Saclay)

5. Fundamental Symmetries and Spin Physics beyond the Standard Model
Teryaev Oleg (BLTP JINR, Dubna)
Prok Yelena (Jefferson Lab)

6. Acceleration, Storage, and Polarimetry of Polarized Beams
Meshkov Igor (JINR, Dubna)
Derbenev Yaroslav (Jefferson Lab)

7. Polarized Ion and Lepton Sources and Targets
Usov Yury (JINR, Dubna)
Belov Alexander (Moscow)

8. Future Facilities and Experiments
Nagaytsev Alexander (JINR, Dubna)
Denisov Oleg (Torino)
Akopov Norair (Yerevan)

9. Medical and Technological Applications of Spin Physics
Syresin Eugene (JINR, Dubna)
Heil Werner (Mainz, Germany)

http://spin2012.jinr.ru/conveners.html

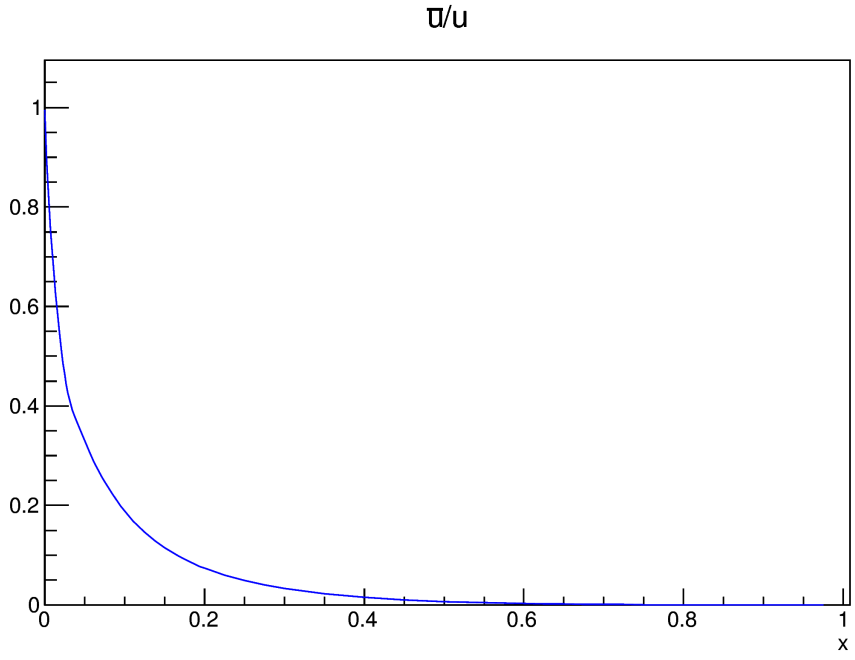
Additional slides

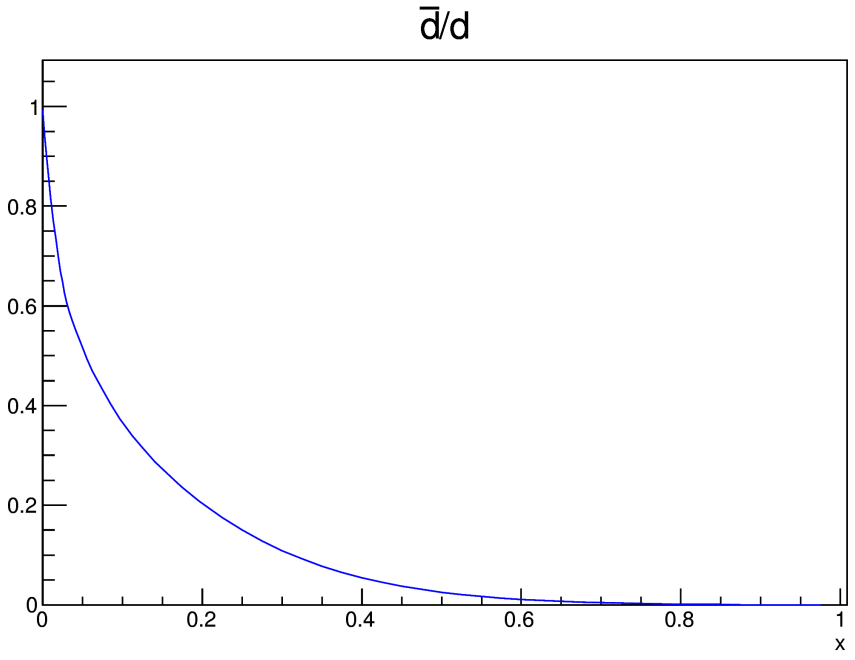
SPD EXPERIMENT AT NICA

R.R. Akhunzyanov, JINR , Dubna

1. Introduction. NICA Project.
2. Proposed measurements.
3. Proposal on SPD.
4. Conclusions.

SPIN PHYSICS AT NICA.





SPD EXPERIMENT AT NICA.

NICA Project.

The facility will have to provide:

- ion-ion (Au) and ion-proton collisions

  $1 \div 4.5$ GeV/u, $L \sim 10^{27}$ cm^{-2}s^{-1},

- collisions of polarized proton-proton (deuteron-deuteron) beams

  5-12.6 GeV (2-5.8 GeV/u), $L > 10^{30}$ cm^{-2}s^{-1},

- Fixed target experiments,
- Experiments with internal target,
- Two interaction points (IP). Two detectors.

The Multi Purpose Detector (MPD), aimed for experimental studies of hot and dense strongly interacting QCD matter and search for possible manifestation of signs of the mixed phase and critical endpoint in heavy ion collisions.

The second one is used for the Spin Physics Detector (SPD).

SPIN PHYSICS AT NICA.

NICA Project.

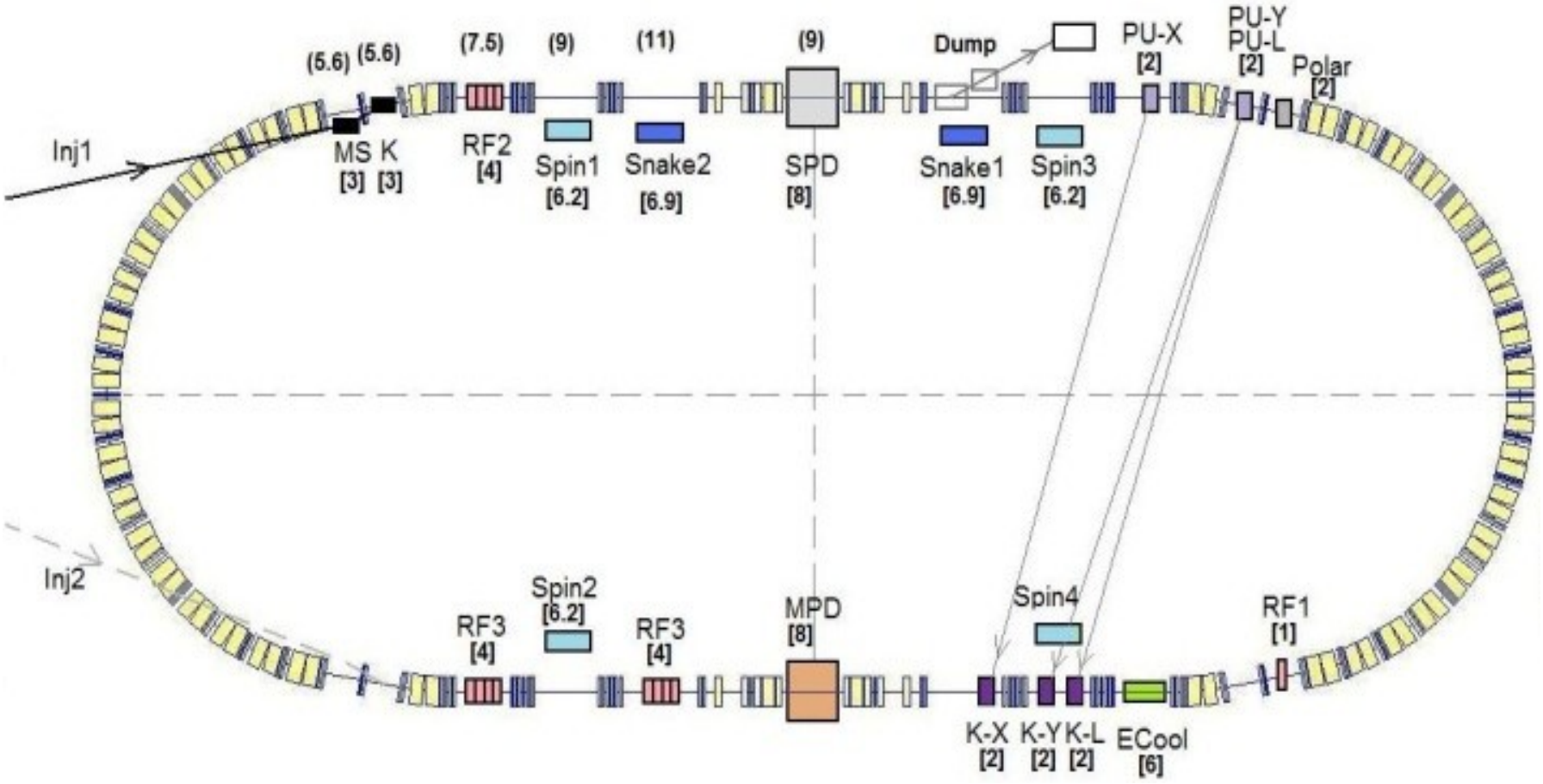
The goal of the NICA project is construction at JINR of the new accelerator facility that consists of

- cryogenic heavy ion source,
- source of polarized protons and deuterons,
- "old" linac LU-20,
- a new heavy ion linear accelerator,
- a new Booster-synchrotron,
- the existing proton synchrotron Nuclotron,upgraded to Nuclotron-M,
- two new superconducting storage rings of the collider,
- new set of transfer channels.

http://nica.jinr.ru

SPIN PHYSICS AT NICA.

NICA Project.

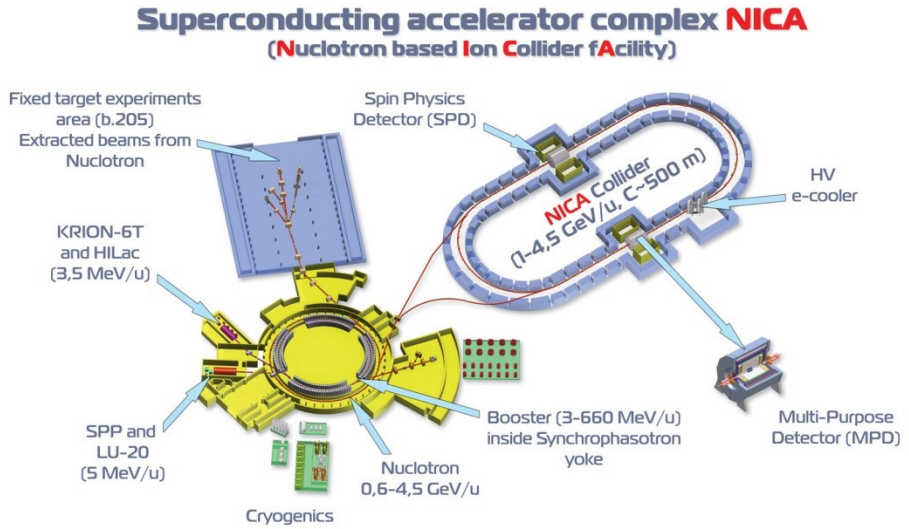


SPIN PHYSICS AT NICA.

NICA Project.

NICA collider parameters

Ring circumference, m		503,04	
Number of bunches		23	
Rms bunch length, m		0.6	
Beta-function in the IP, m		0.35	
Ring acceptance (FF lenses)		40 π mm mrad	
Long. acceptance, dp/p		±0.010	
Gamma-transition, γ_{tr}		7.091	
Ion energy, GeV/u	1.0	3.0	4.5
Ion number per bunch	$2.75 \cdot 10^8$	$2.4 \cdot 10^9$	$2.2 \cdot 10^9$
Rms momentum spread, 10^{-3}	0.62	1.25	1.65
Rms beam emittance, h/v, (unnormalized), π·mm·mrad	1.1/ 1.01	1.1/ 0.89	1.1/ 0.76
Luminosity, $cm^{-2}s^{-1}$	1.1e25	1e27	1e27
IBS growth time,sec	186	702	2540



NICA Project.

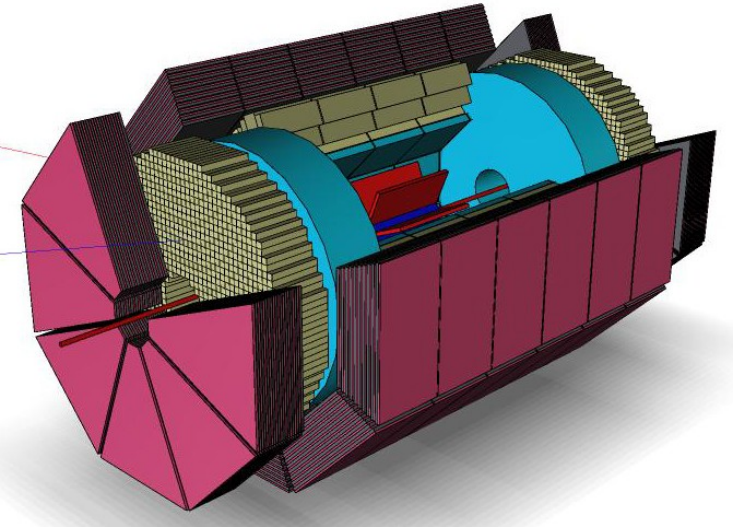
NICA Project Concept & Status

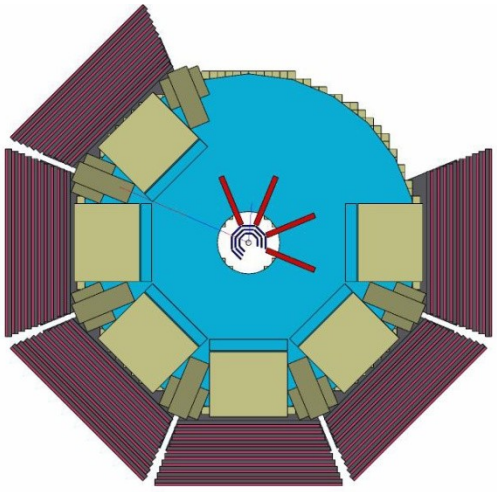
Parameter	Project	Status (April 2011)
Max. magn. field, T	2.05	2.05
Magn. rigidity, T·m	45	45
Cycle duration, s	2.0	5.0
B-field ramp, T/s	2.0	1.0
Accelerated particles	p–U, p↑, d↑	p–Xe, d↑
Max. energy, GeV/u	12.6(p), 5.87(d) 4.5($^{197}Au^{79+}$)	3.5 (d), 1.5 ($^{124}Xe^{42+}$)

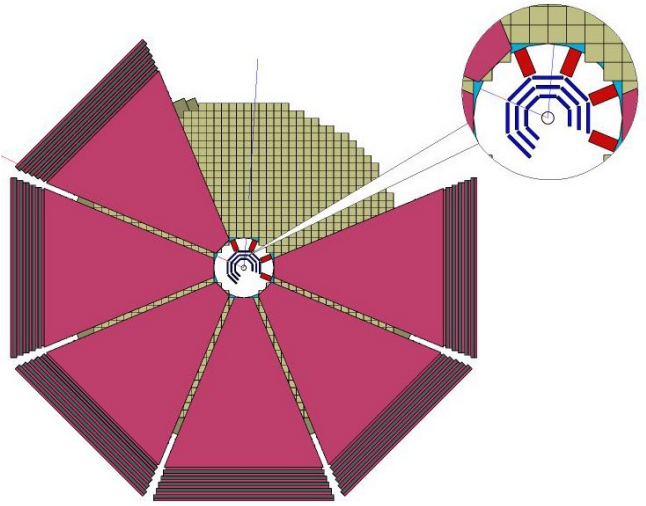
Planned parameters of polarized proton beams

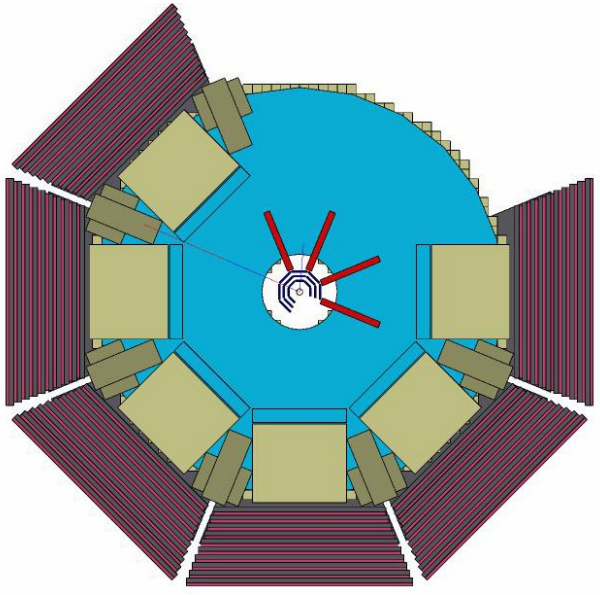
Energy, GeV	5	12
Proton number per bunch	6E10	1.5E10
Rms relative momentum spread	10E-3	10E-3
Rms bunch length, m	1.7	0.8
Rms (unnormalized) emittance, $\pi \cdot mm \cdot mrad$	0.24	0.027
Beta-function in the IP, m	0.5	0.5
Lasslet tune shift	0.0074	0.0033
Beam-beam parameter	0.005	0.005
Number of bunches	10	10
Luminosity, $cm^{-2} \cdot s^{-1}$	1.1E30	1.1E30

SPD Detector



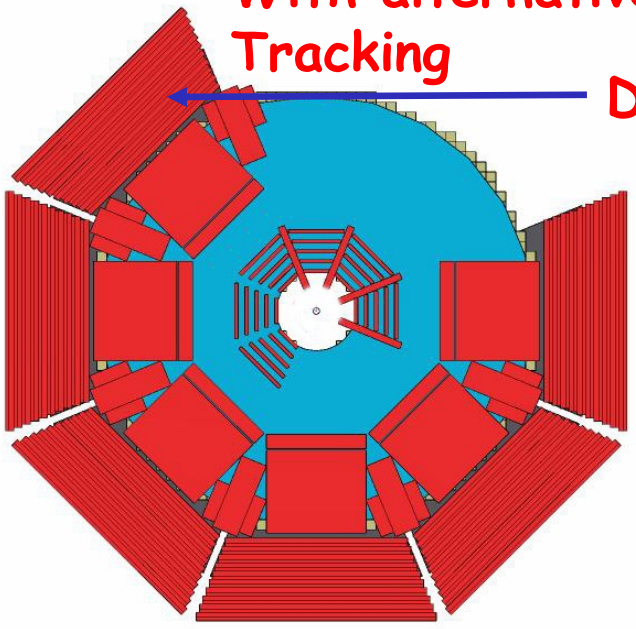






With alternative Tracking

DC



Two stage of SPD is possible.

I stage
TPC – EM ?
Only some parts of RS

II stage
Finalize RS
EM production

Status of other experiments

Experiment	Status	Remarks
E615	Finished	Only unpolarized
NA10,38,50	Finished	Only unpolarized
E886, 906	Running	Only unpolarized
RHIC	Running (collider)	Detector upgrade for DY measurements
PANDA	Plan > 2016	With low s (~40 GeV^2)
PAX	Plan > 2016	Preparation in progress

NICA collider

The main requirements to the NICA polarized beam can be summarized as follows:

1. The luminosity at level of 10^{30}- 10^{32} $см^{-1}s^{-1}$, for wide energy beams range 5 -12 GeV for proton.
2. At injection it is necessary to provide, that the direction a spin coincided with a vector direction a spin precession in rings.
1. To control on the beams polarization the special locations of polarimeters are necessary, it can be set-ups with gas polarized target (or jet target).
4. To safe beams polarization at long time it is necessary to install the "the Siberian snakes».
5. To minimize the systematical uncertainties for asymmetry measurements it is necessary to provide the spin rotation-that will demand inserts similar to item 4 and number of the superperiods in accelerator up to grater than 4.
6. To provide various spin orientations it is necessary, to equip IP with duplicators (including combinations longitudinal-transersel polarization).
7. To provide of polarized nn and np-collisions, it is necessary to install the stations of stripping protons (probably and neutrons) at the rings. Fixed target experiment.
8. It is necessary to create the system of luminosity measurements with relative accuracy ~ 1% . Using SPD ?
9. The injection system should provide possibility to form the sequence of injection cycles with different spin states (longitudinal, transverse, non polarized).
10. To provide the tenzor polarized deuteron beams and corresponding possibility to operate spin orientation .
11. It is necessary to provide the collisions of polarized beams with different kind of particles:

    protons-deuteron, protons-helium, deuteron-helium at different energies.