ISHEPP-2018

STATUS of NICA-SPIN PROGRAM

A.D.Kovalenko

for NICA-SPIN team

OUTLINE

- Nuclotron-M/NICA@JINR
- Layout in polarized mode
- Implementation of polarized beam program
- Nuclotron operation
- SPD status
- Near future plans
- Strategic goals

Events in Spin 2018

SPIN Praha 2018

International Workshop on Spin Physics at NICA (SPIN-Praha-2018)

SPD NICA

9-13 July 2018
Charles University, Prague
Europe/Prague timezone

http://SPIN-Praha-2018

- Overview
- General Information
- Program Advisory Committee
- Organizing Committee
- List of registrants
- Scientific Programme
- Timetable
- Accommodation
- Transportation
- Registration Form
- Fee
- Visa Application
- Contacts

OVERVIEW

This International Workshop on Spin Physics Experiments at NICA (SPIN-Praha-2018) is the next in the series of meetings on problems of symmetries and polarization phenomena in Particle and Nuclear Physics and Astrophysics related to the particles' spin. They have begun with the first meeting of this series at the Joint Institute for Nuclear Research, Dubna, i
in Czech Republic. Links to the Web sites of the p
/doku.php?id=conferences.

Events in Spin 2018

All aspects of SPD set-up, physics proposals and polarized beam necessary parameters were presen-ted and discussed

Events in Spin 2018

All aspects of SPD set-up, physics proposals and polarized beam necessary parameters were presen-ted and discussed

8 reports from NICA including 1 plenary

Requirements to the facility in polarized mode

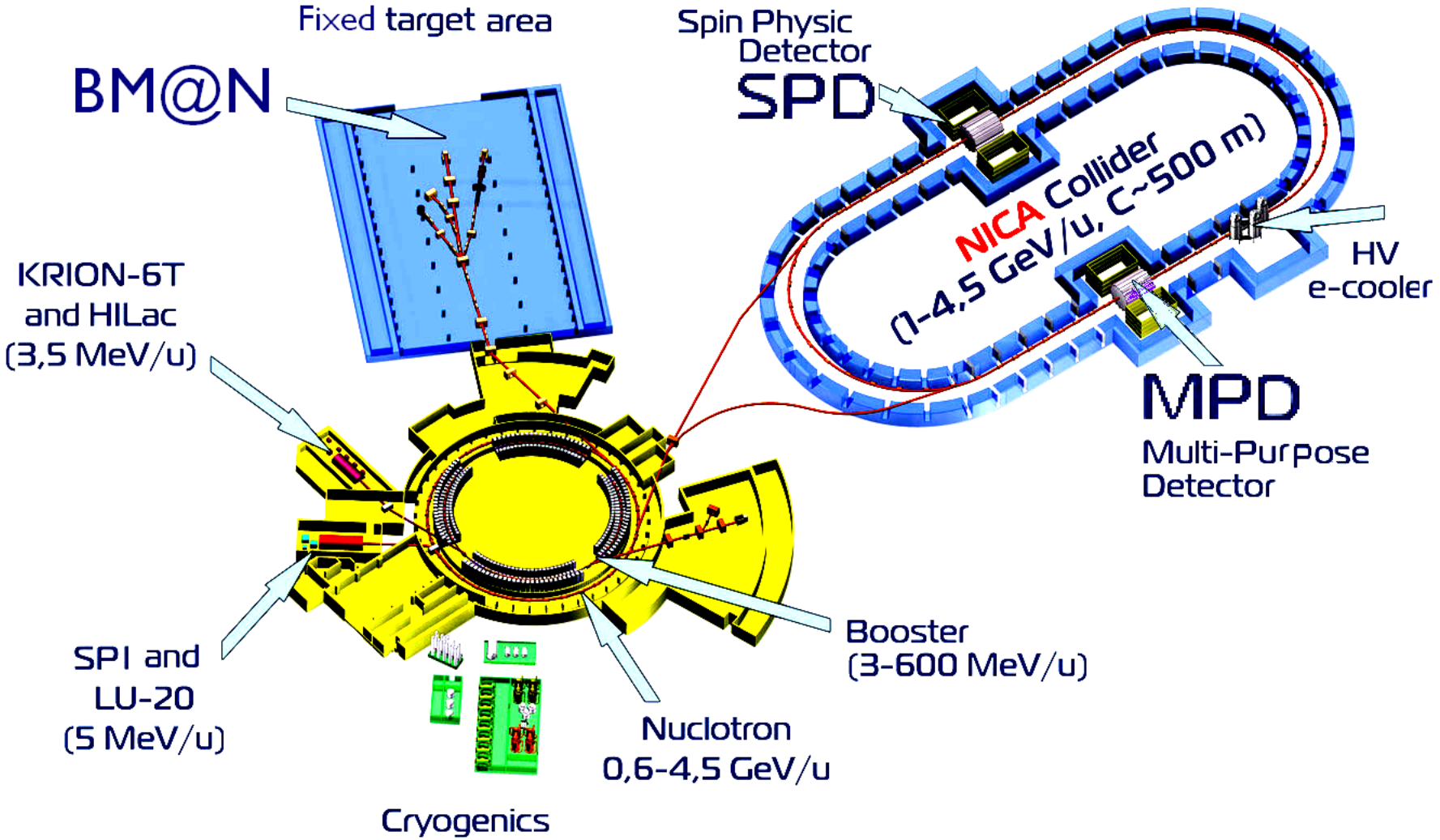
- **polarized and non-polarized p-; d–collisions**
- **p↑p↑(p)** at $\sqrt{s_{pp}}$ **= 12 ÷ 27 GeV** (5 ÷12.6 GeV kinetic energy)
- **d↑d↑(d)** at $\sqrt{s_{NN}}$ **= 4 ÷ 13 GeV** (2 ÷5.5 GeV/u kinetic energy)
- $\mathbf{L_{average}} \approx 1 \cdot 10e32\ cm^{-2}s^{-1}$ (at $\sqrt{s_{pp}} \geq 27$ GeV)
- sufficient lifetime and degree of polarization
- longitudinal and transverse polarization in MPD/SPD
- asymmetric collision mode, pd should be possible

Tasks for development of polarization research at Nuclotron-M/NICA Complex

- New polarized proton and deuteron source – SPI
- New RFQ pre-injector and **LU-20 upgrade**
- Upgrade of the polarimeters:
  - at the linac output
  - at circulating beam in Nuclotron ring
  - at the extracted beam
- Design of absolute polarimeter for the collider rings
- Design of the Solenoidal Snakes System
- Further simulations of polarized beam multi-turn dynamics in the Nuclotron and NICA collider

- SPD Project

NICA operation in Polarized Mode (1)



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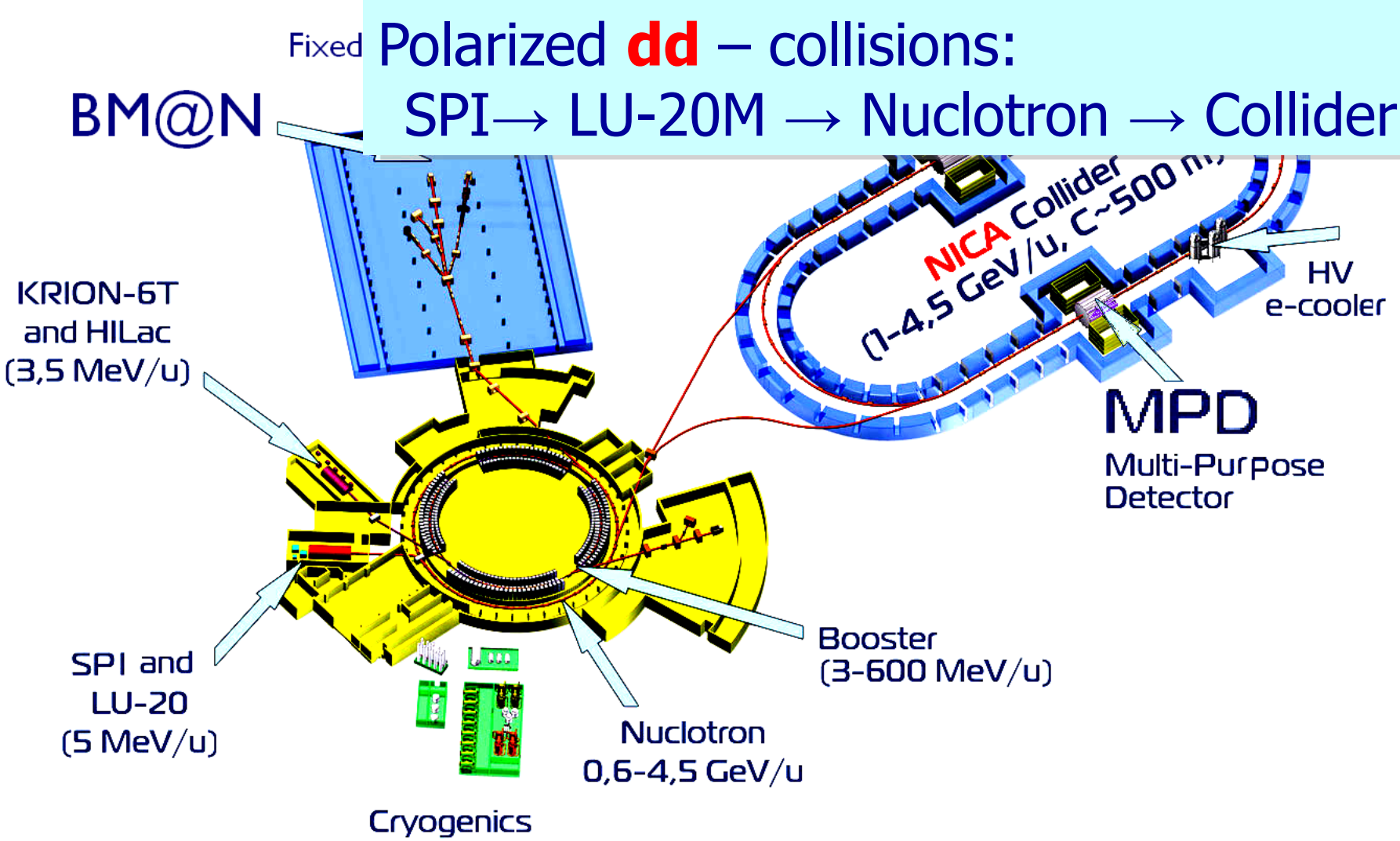
Polarized **dd** – collisions:
SPI→ LU-20M → Nuclotron → Collider



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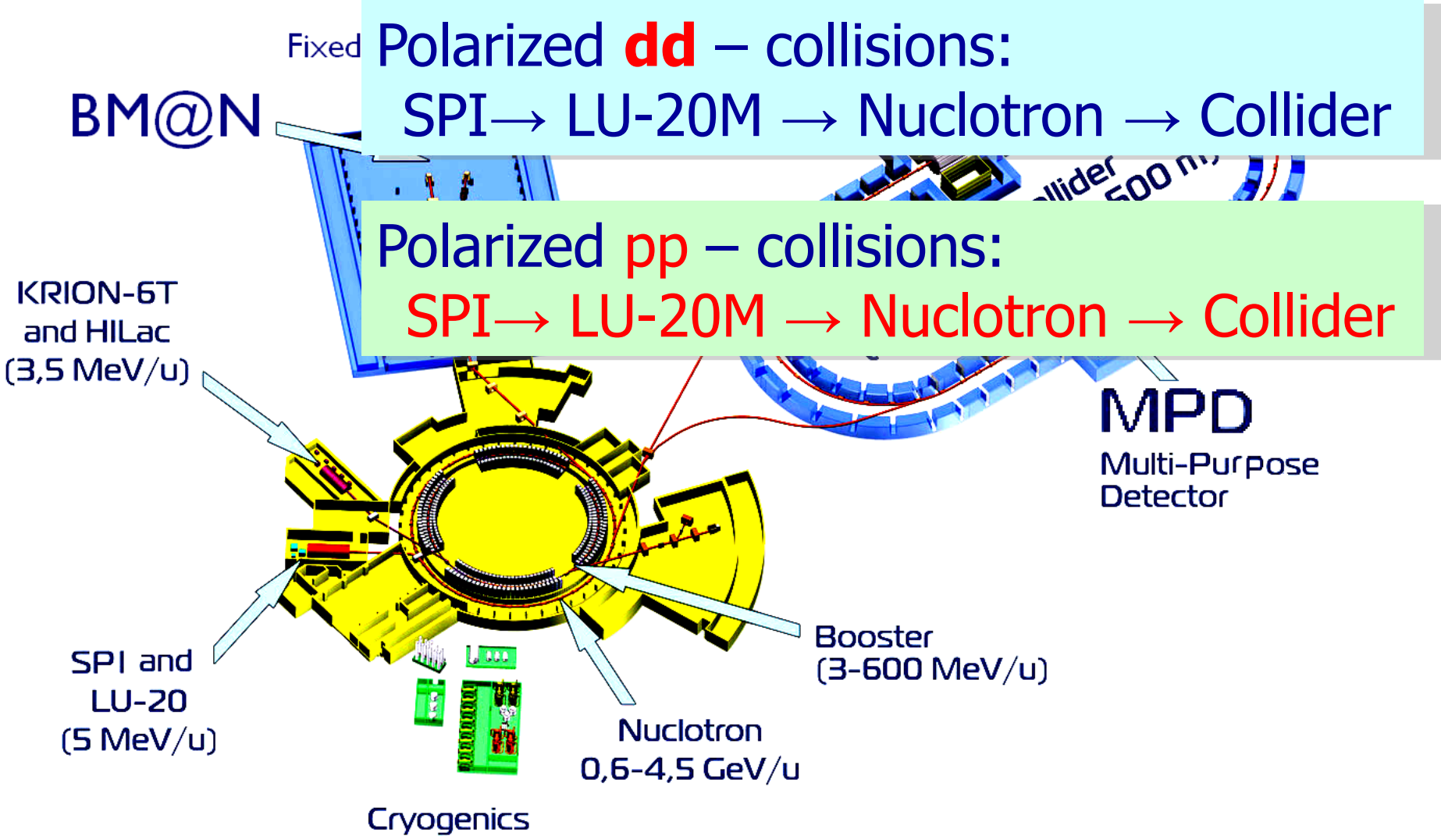

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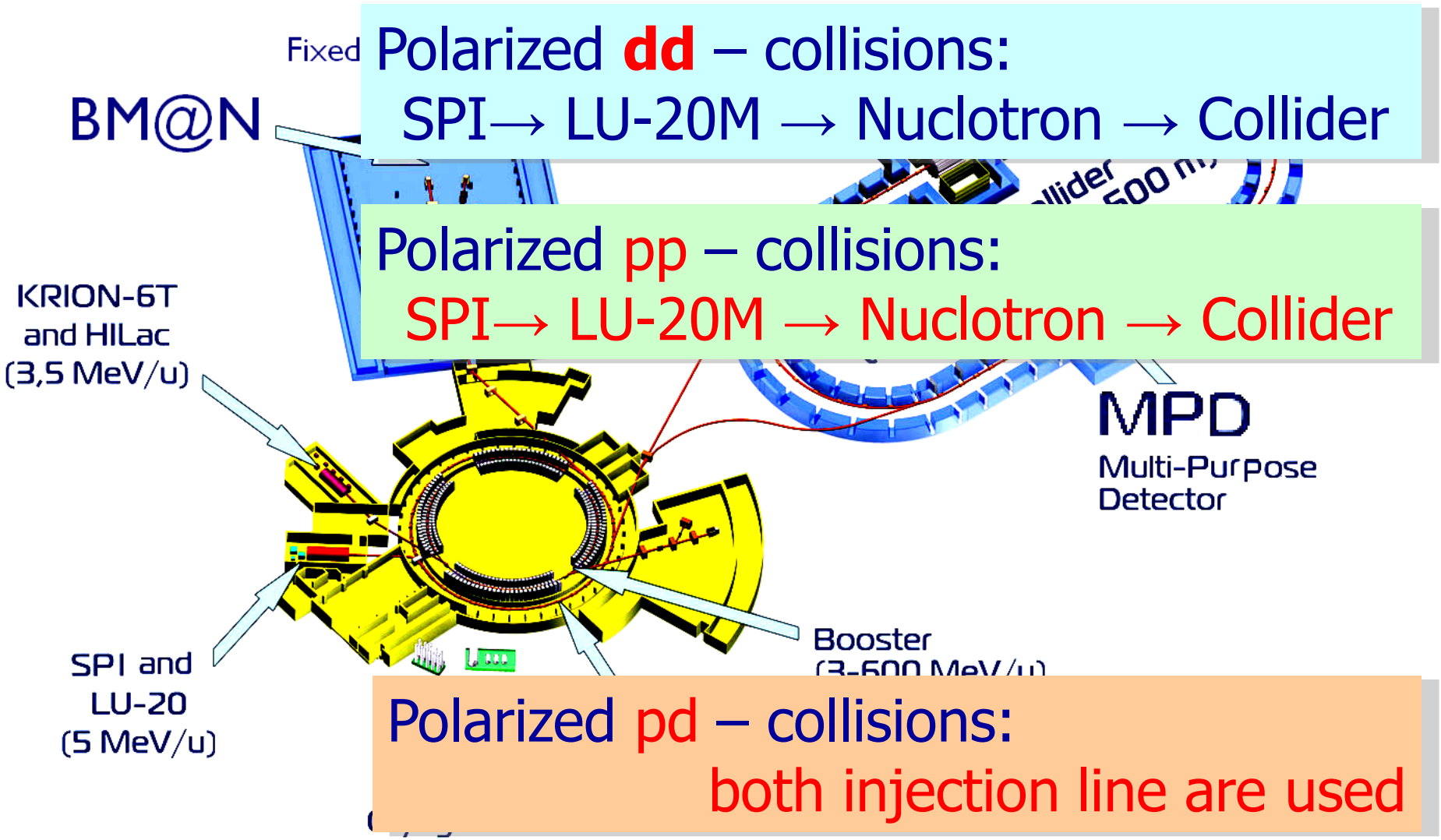


Polarized **dd** – collisions:
SPI→ LU-20M → Nuclotron → Collider

Polarized pp – collisions:
SPI→ LU-20M → Nuclotron → Collider

Polarized pd – collisions:
both injection line are used

NICA operation in Polarized Mode (2)

• d↑-beam was accelerated at the Synchrophasotron in 1986; at the Nuclotron in 2002. No dangerous spin resonances up to 5.6 GeV/u. The beam was used for physics data taking. New ion source SPI – 2016. The source parameters can provide the intensity of 5e10 pp.

NO OTHER FACILITY WHERE POLARIZED DEUTERON BEAM IS AVAILABLE

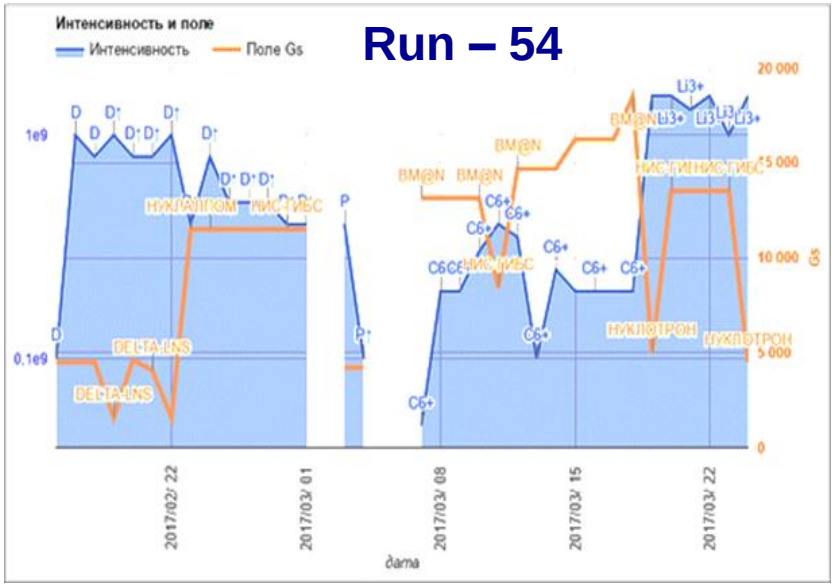
• p↑- beam was first accelerated at the facility in 2017. The problem (at Nuclotron, NICA booster and collider) – spin resonances. Proposed by NICA-team systems of a spin control made this task practically solvable.

NICA operation in Polarized Mode (3)

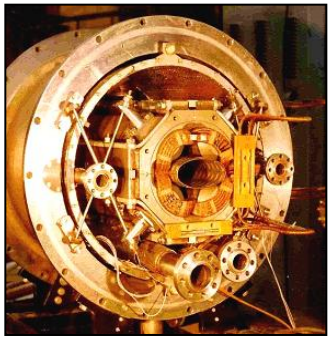
Despite of the NICA design and construction, the Nuclotron was running for physics data taking, detectors test and accelerator tasks.

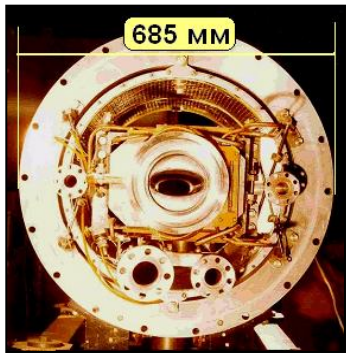
- **Run – 53 (**d↑, Li) *October – December,* ***2016***
- **Run – 54 (**d↑,p↑), C *February – March,* ***2017***
- **Run – 55 (** C**,** Ar**,** Kr,) *February. – April,* ***2018***

Data from the Nuclotron duty book are presented below.

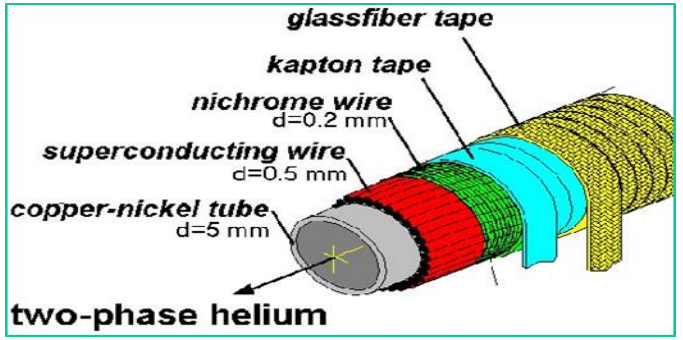


Nuclotron – key element of the new project





A. M. Baldin, A. A. Smirnov, L.G. Makarov et al



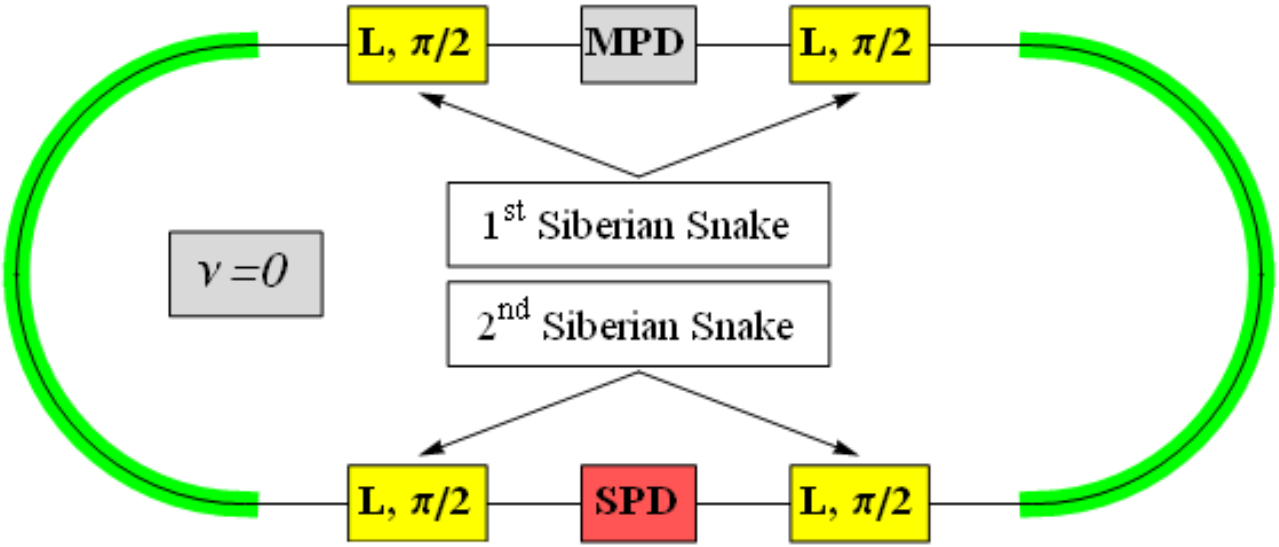
- 6 AGeV STRONG FOCUSING SYNCHROTRON
- SINGLE TURN INJECTION
- INJECTION ENERGY – **20 MeV PROTONS**
- \- 5 MeV/u DEUTERONS
- MAXIMUM MAGNETIC FIELD – 2 T
- THE FIELD RAMP – **1 T/s**

LILAC+

A. V. Butenko et al

Polarization control in Collider: spin tune $\nu = 0$

Solenoid-based Siberian Snake at particle momentum:



p=(2.5÷13)GeV/c

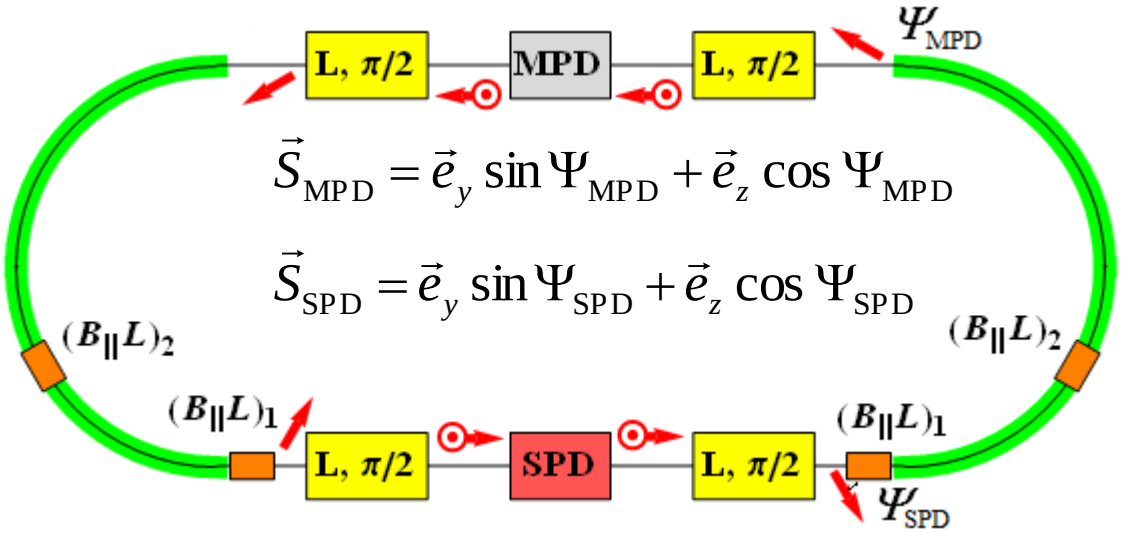
protons:

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

deuterons:

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

Polarization control in Collider: weak solenoids



$$\varphi_{z1} = \pi\nu \frac{\sin(\varphi_y - \Psi_{SPD})}{\sin\varphi_y}$$

$$\varphi_{z2} = \pi\nu \frac{\sin\Psi_{SPD}}{\sin\varphi_y}$$

$$\Psi_{MPD} = \gamma G\pi + \Psi_{SPD}$$

$\varphi_{zi} = (1+G)(B_{||}L)_i / B\rho$ - the spin rotation angles in the solenoids

$\varphi_y = \gamma G\alpha$ - the spin rotation angle between weak solenoids

α - the orbit rotation angle between the weak solenoids

Ψ_{SPD}, Ψ_{MPD} - the angles between the polarization and velocity directions in SPD and MPD detectors

Polarization control in Collider: summary

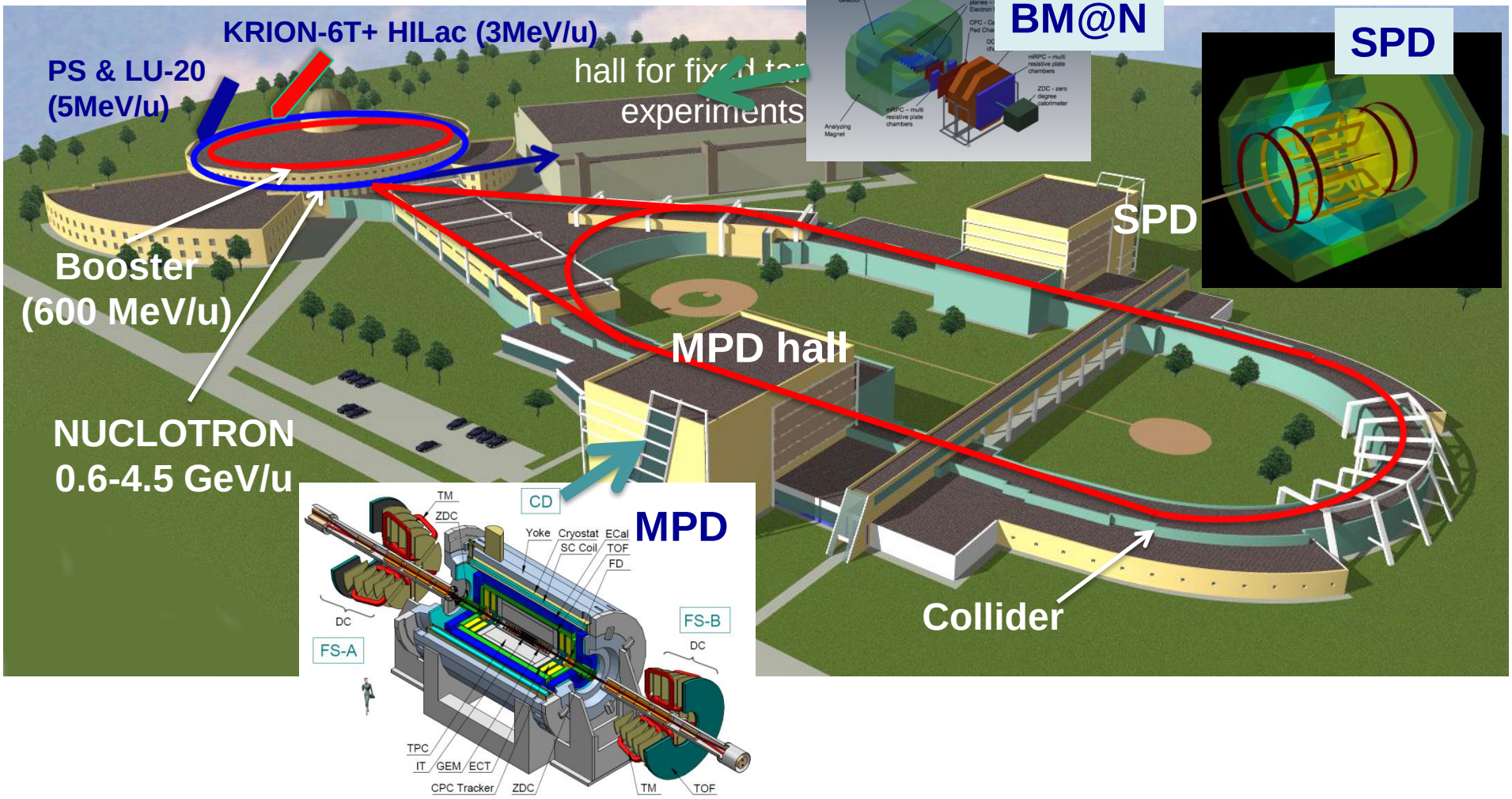
- The proposed scheme is suitable for any type of the particles. Necessary manipulations are provided without re-installations of the equipment at the magnetic system.

- 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 at polarimetry points

SPD at Collider: (from talk by R.Tsenov at SPIN2018)

existing facilities

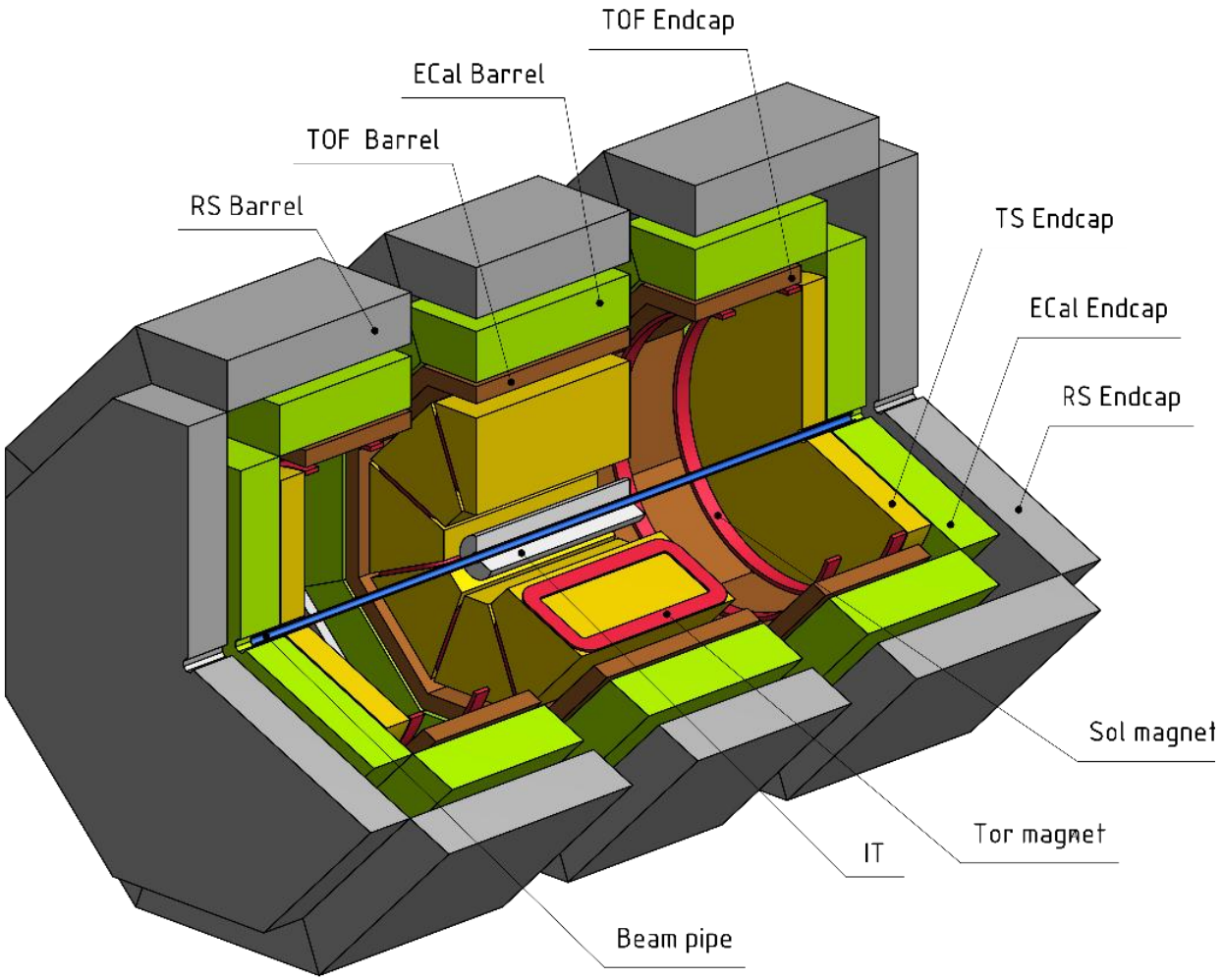
to be constructed



SPD at Collider: general requirements

- close to 4π geometrical acceptance;
- high-precision (~50 μm) and fast vertex detector;
- high-precision (~100 μm) and fast tracker,
- good particle ID capabilities;
- efficient muon range system,
- good electromagnetic calorimeter,
- low material budget over the track paths,
- trigger and DAQ system able to cope with event rates at luminosity of 10^{32} cm-2 s-1,
- modularity and easy access to the detector elements, that makes possible further reconfiguration and upgrade.

SPD at Collider: general view



SPD at Collider: hybrid magnetic system

½ model symmetry

$$B^{(z)}(x,y,0)=0.$$

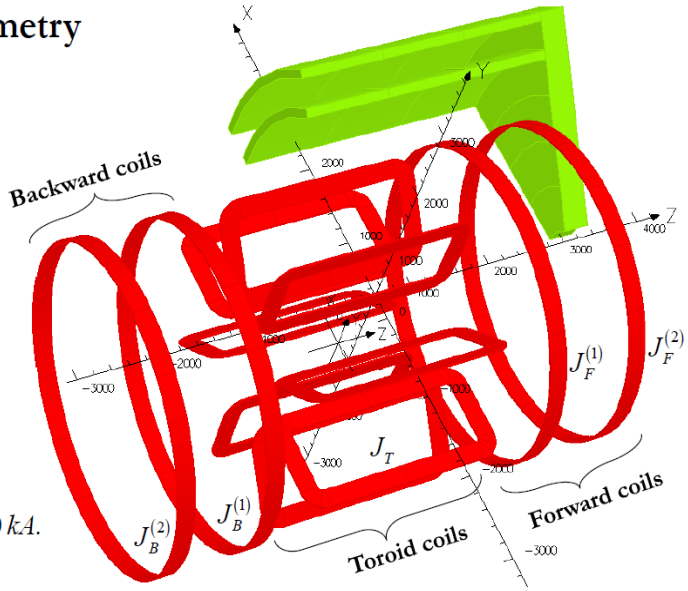
$$J_T = 40\frac{A}{mm^2},$$

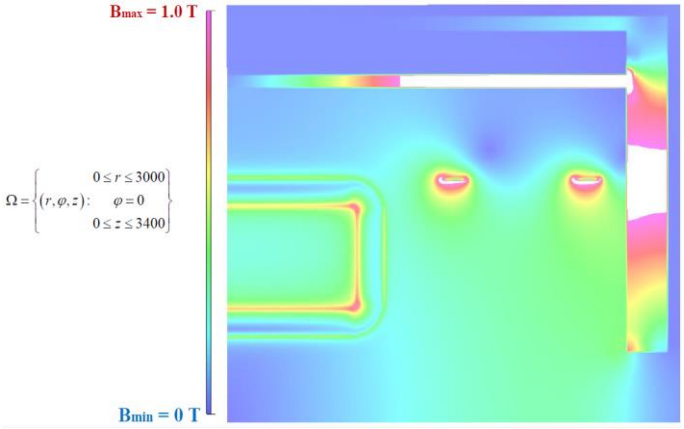
$$J_{B\backslash F}^{(1,2)} = \pm 80\frac{A}{mm^2},$$

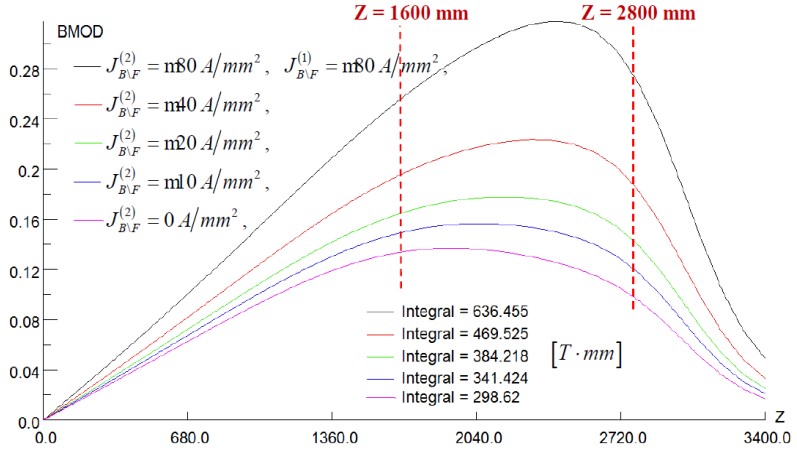
$$S = 200\times 20\, mm^2,$$

$$I_T = J_T \cdot S = 160\, kA,$$

$$I_{B\backslash F} = J_{B\backslash F}\cdot S = \pm 320\, kA.$$







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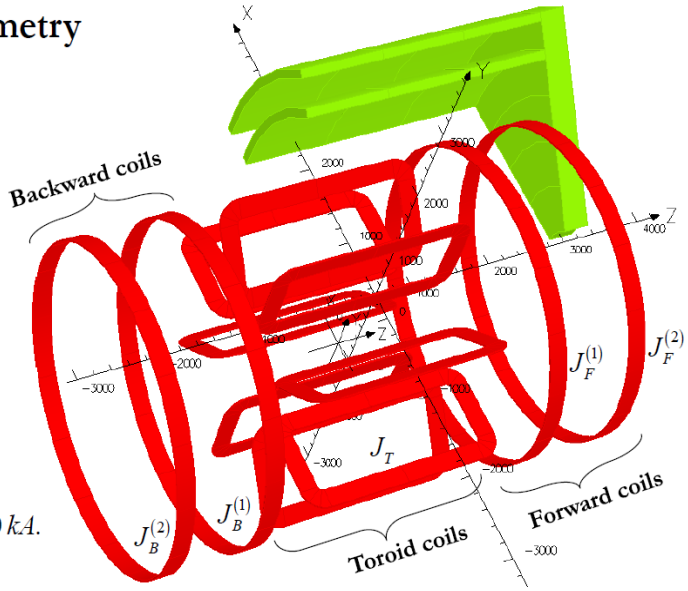
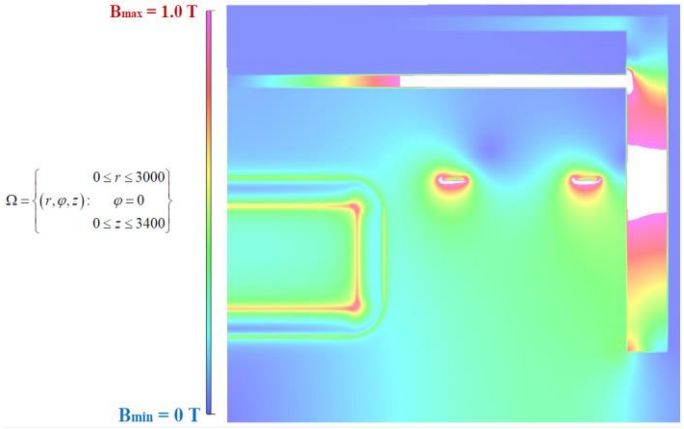
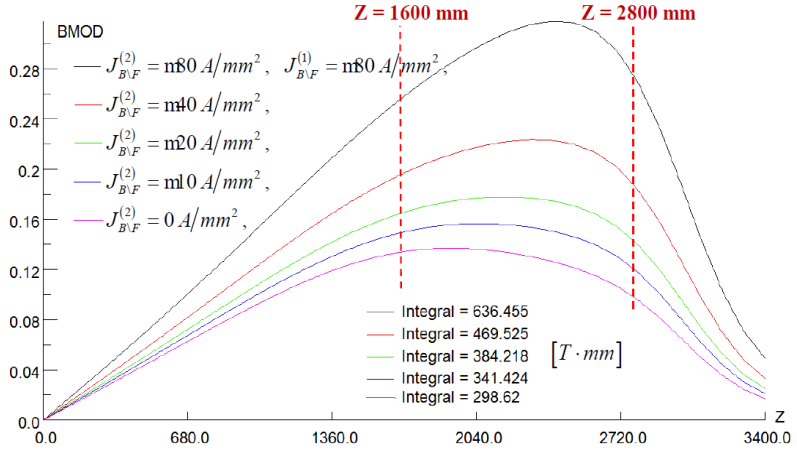


Nuclotron/ITER technology of superconducting coils





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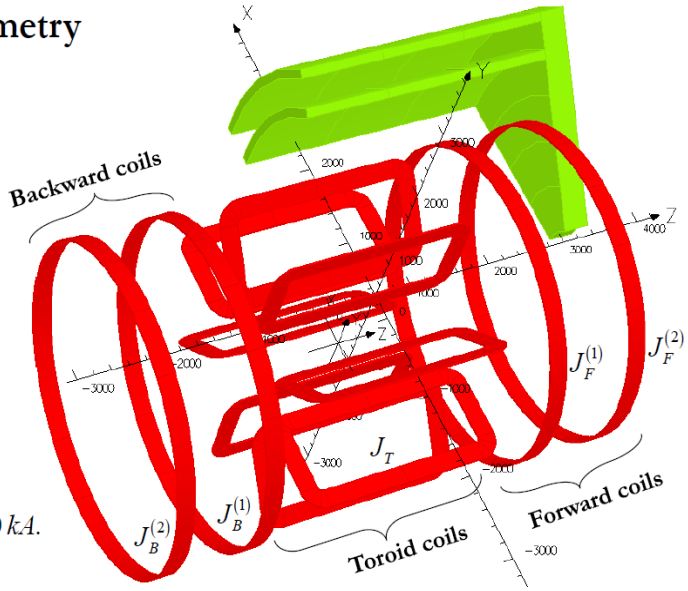

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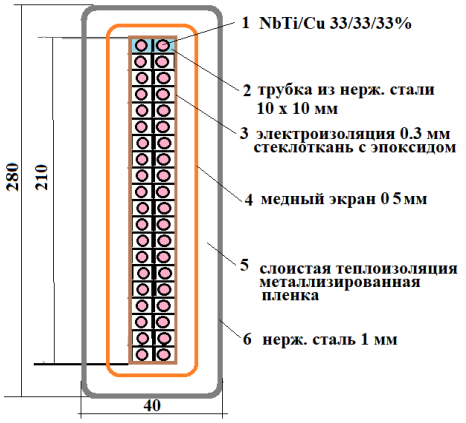

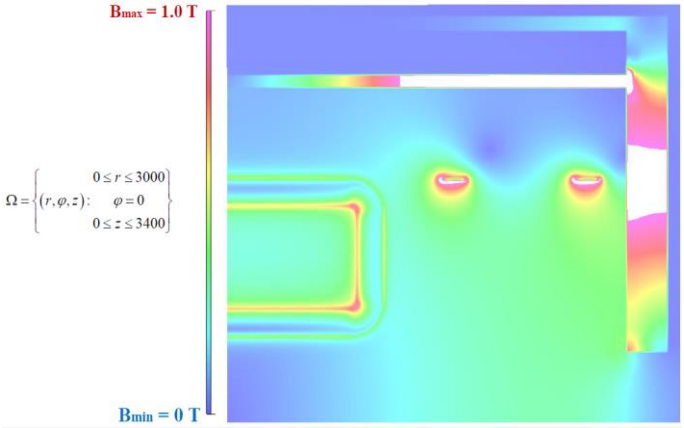

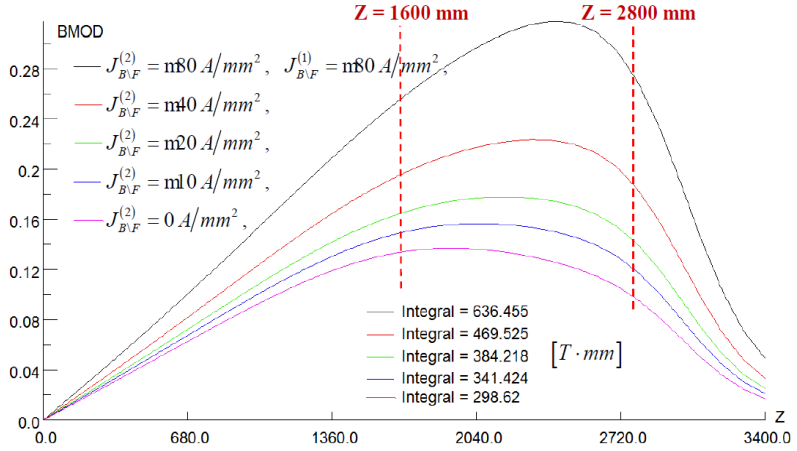

SPD Roadmap

- Writing up of a formal JINR project for the SPD design *(i.e. for preparation of the Conceptual and Technical Design Reports)* and submission of the project to the PAC for Particle Physics:
  - status report presented at the PAC meeting in Jan. 2018;
  - submission of the application to the PAC in Nov. 2018 for their meeting in Jan. 2019;
- Setting up of the collaboration and election of its management bodies (2019);
- Signing of an MoU based on "*Regulations for the organization of experiments conducted by international collaborations using the capabilities of the JINR basic facilities*" *http://www.jinr.ru/wp-content/uploads/JINR_Docs/Regulation_for_the_organization_of_experiments_eng.doc* (2019).

Strategic Goals – for a long future program

- **Electron-Ion Collider:**

- **Search for EDM – electric dipole moment**

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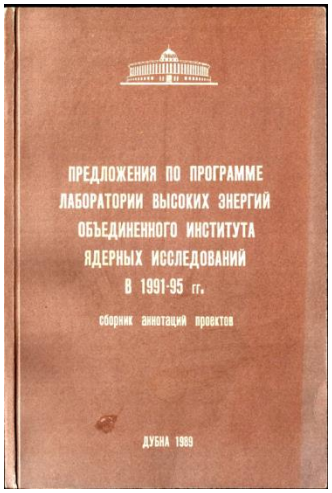

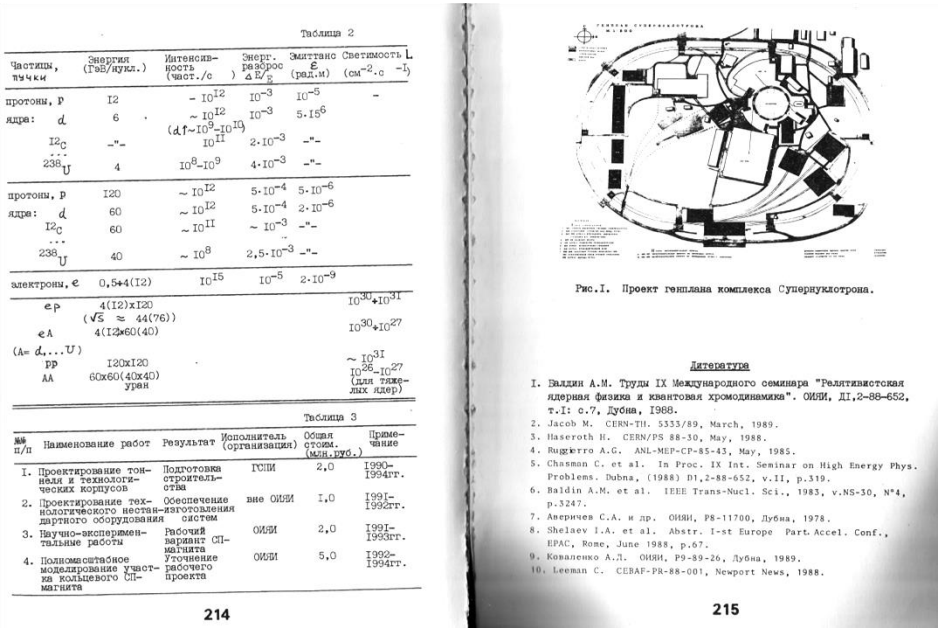

Таблица 2

Частицы, пучки	Энергия (ТэВ/нукл.)	Интенсивность (част./с)	Энерг. разброс $\Delta E/E$	Эмиттанс ε (рад.м)	Светимость L ($см^{-2}.с^{-1}$)
протоны, p	I2	$\sim 10^{12}$	10^{-3}	10^{-5}	-
ядра: d	6	$\sim 10^{12}$ ($df \sim 10^{9}-10^{10}$)	10^{-3}	$5 \cdot 10^{-6}$	
$I2_C$	-"-	10^{11}	$2 \cdot 10^{-3}$	-"-	
238_U	4	$10^{8}-10^{9}$	$4 \cdot 10^{-3}$	-"-	
протоны, p	I20	$\sim 10^{12}$	$5 \cdot 10^{-4}$	$5 \cdot 10^{-6}$	
ядра: d	60	$\sim 10^{12}$	$5 \cdot 10^{-4}$	$2 \cdot 10^{-6}$	
$I2_C$	60	$\sim 10^{11}$	$\sim 10^{-3}$	-"-	
238_U	40	$\sim 10^{8}$	$2,5 \cdot 10^{-3}$	-"-	
электроны, e	0,5+4(I2)	10^{15}	10^{-5}	$2 \cdot 10^{-9}$	
ep	4(I2)xI20 ($\sqrt{s} \approx 44(76)$)				$10^{30}+10^{31}$
eA	4(I2)x60(40)				$10^{30}+10^{27}$
(A= d,...U) pp	I20xI20				$\sim 10^{31}$
AA	60x60(40x40) уран				$10^{26}-10^{27}$ (для тяжелых ядер)

Таблица 3

№№ п/п	Наименование работ	Результат	Исполнитель (организация)	Общая стоим. (млн.руб.)	Примечание
I.	Проектирование тоннеля и технологических корпусов	Подготовка строительства	ГСПИ	2,0	I990-I994гг.
2.	Проектирование технологического нестандартного оборудования	Обеспечение изготовления систем	вне ОИЯИ	I,0	I99I-I992гг.
3.	Научно-экспериментальные работы	Рабочий вариант СП-магнита	ОИЯИ	2,0	I99I-I993гг.
4.	Полномасштабное моделирование участка кольцевого СП-магнита	Уточнение рабочего проекта	ОИЯИ	5,0	I992-I994гг.

214

Рис.I. Проект генплана комплекса Супернуклотрона.

Литература

I. Балдин А.М. Труды IX Международного семинара "Релятивистская ядерная физика и квантовая хромодинамика". ОИЯИ, Д1,2-88-652, т.I: с.7, Дубна, I988.
2. Jacob M. CERN-TH. 5333/89, March, 1989.
3. Haseroth H. CERN/PS 88-30, May, 1988.
4. Ruggierro A.G. ANL-MEP-CP-85-43, May, 1985.
5. Chasman C. et al. In Proc. IX Int. Seminar on High Energy Phys. Problems. Dubna, (1988) D1,2-88-652, v.II, p.319.
6. Baldin A.M. et al. IEEE Trans-Nucl. Sci., 1983, v.NS-30, N°4, p.3247.
7. Аверичев С.А. и др. ОИЯИ, Р8-11700, Дубна, 1978.
8. Shelaev I.A. et al. Abstr. I-st Europe Part. Accel. Conf., EPAC, Rome, June 1988, p.67.
9. Коваленко А.Д. ОИЯИ, Р9-89-26, Дубна, 1989.
10. Leeman C. CEBAF-PR-88-001, Newport News, 1988.

215

- **Search for EDM – electric dipole moment**

Strategic Goals – for a long future program

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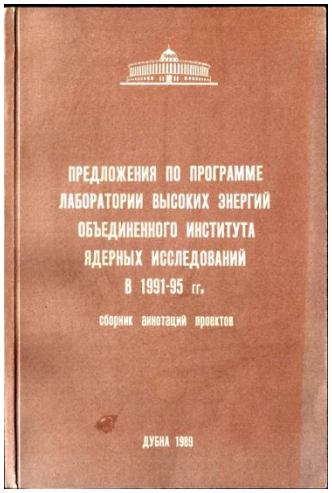

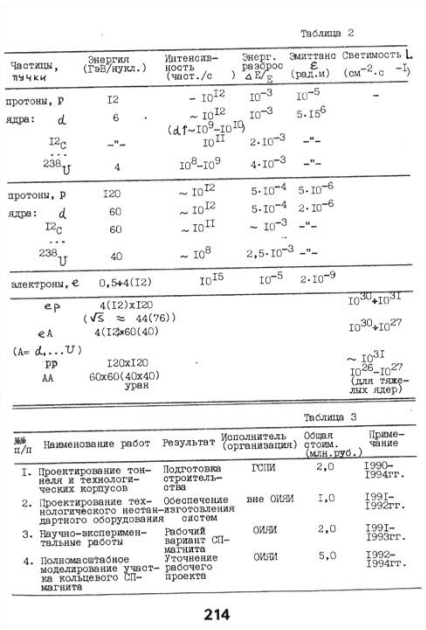

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214

Рис.I. Проект генплана комплекса Супернуклотрона.

Литература

I. Балдин А.М. Труды IX Международного семинара "Релятивистская ядерная физика и квантовая хромодинамика". ОИЯИ, Д1,2-88-652, т.I: с.7, Дубна, I988.
2. Jacob M. CERN-TH. 5333/89, March, 1989.
3. Haseroth H. CERN/PS 88-30, May, 1988.
4. Ruggierro A.G. ANL-MEP-CP-85-43, May, 1985.
5. Chasman C. et al. In Proc. IX Int. Seminar on High Energy Phys. Problems. Dubna, (1988) D1,2-88-652, v.II, p.319.
6. Baldin A.M. et al. IEEE Trans-Nucl. Sci., 1983, v.NS-30, N°4, p.3247.
7. Аверичев С.А. и др. ОИЯИ, P8-11700, Дубна, 1978.
8. Shelaev I.A. et al. Abstr. I-st Europe Part. Accel. Conf., EPAC, Rome, June 1988, p.67.
9. Коваленко А.Л. ОИЯИ, P9-89-26, Дубна, 1989.
10. Leeman C. CEBAF-PR-88-001, Newport News, 1988.

215

- **Search for EDM – electric dipole moment**

Feasibility of measuring EDM in spin transparent particle optic systems of a storage rings/colliders. NICA collider rings can be used for this task.

Summary

- The NICA-SPIN program at polarized protons and deuterons is in progress;
- Important tests of the new elements of the injector facility and polarimetry were performed in 2016 – 17;
- Real steps were made on the SPD set-up design - preparation of the project was started;
- Operation at polarized deuterons can be considered as a commissioning program for the NICA Collider.

- ***It is very necessary to continue operation of the Nuclotron with polarized deuteron and proton beams in parallel with heavy ions.***

THANK YOU

FOR YOUR ATTENTION