Status of the NICA project at JINR

V.Kekelidze, A.Kovalenko, R.Lednicky, V.Matveev,
I.Meshkov, A.Sorin, G.Trubnikov - Joint Institute for Nuclear Rsearch

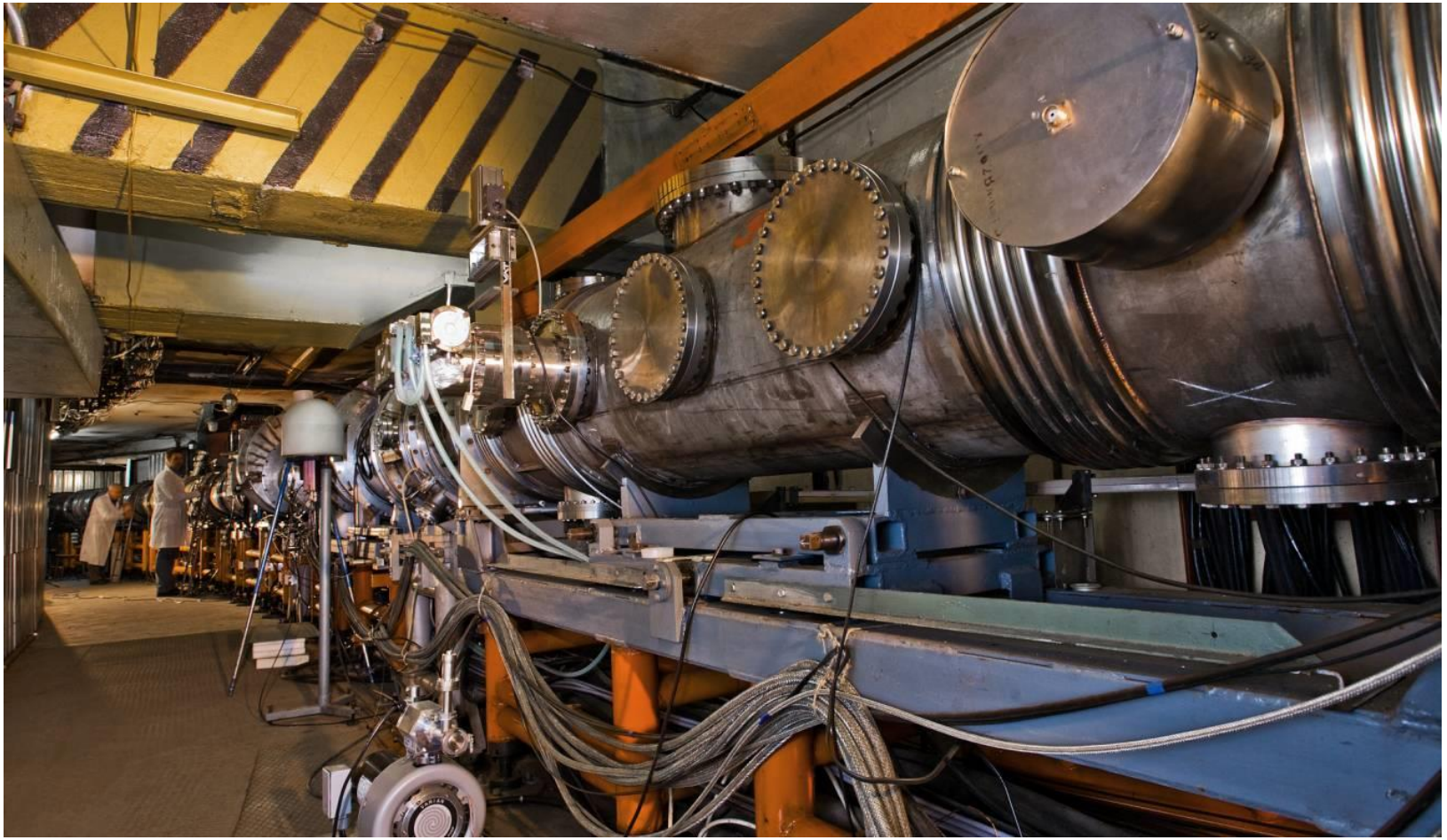
XXII International Baldin Seminar on High Energy Physics Problems, Dubna, 2014

NICA (Nuclotron based Ion Colider fAcility) – the flagship project in HEP of Joint Institute for Nuclear Research (JINR)

Main targets of "NICA Complex":

- ***study of hot and dense baryonic matter***
- *investigation of nucleon spin structure, polarization phenomena*
- *development of accelerator facility for HEP @ JINR providing intensive beams of relativistic ions from p to Au polarized protons and deuterons with max energy up to* $\sqrt{S_{NN}}$ *= 11 GeV (Au^{79+}) and =27 GeV (p)*

Synchrotron **Nuclotron,** in operation since 1993
– *based on superconducting magnets developed in Dubna*

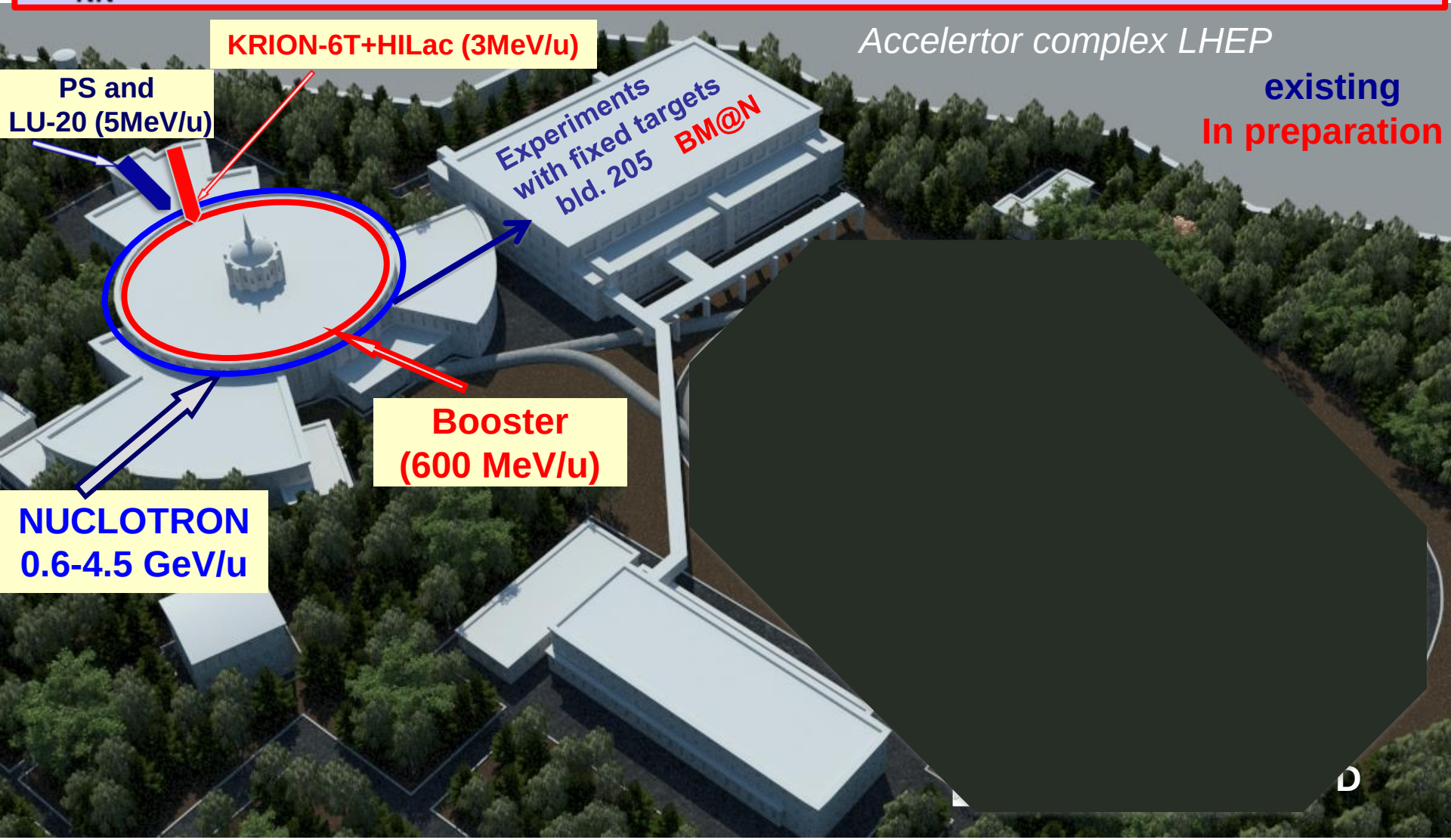


Nuclotron provides accelerated proton and ion beams (up to *Xe42+, A=124*) with energies up to 6 AGeV (Z/A = 1/2)

Complex NICA

Collider basic parameters:

$\sqrt{s_{NN}}$ = **4-11** GeV; ***beams****: from* **p** to **Au**; **L~10^{27}** cm^{-2} c^{-1} (Au), **~10^{32}** cm^{-2} c^{-1} (p)



NICA – basic milestones

- The project of **NICA complex** is approved **2010**
- The 1-st stage of **Nuclotron** modernization is completed **2010**

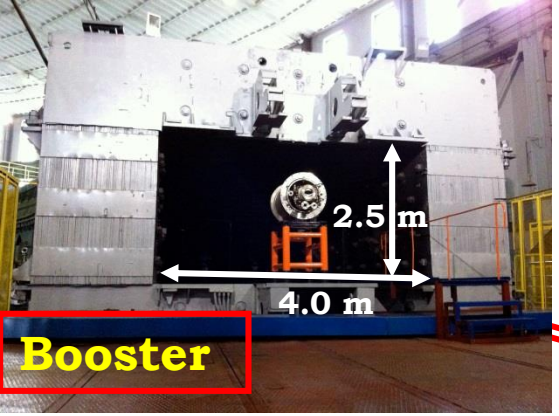
  10 runs have been carried out in **2010 – 2014**

- The projects: approval – completion
  - ✓ **accelerator complex** **2010 – 2019**
  - ✓ **MPD (MultiPurpose Detector)** **2010 – 2019**
  - ✓ **experiment with fixed target BM@N (I stage)** **2012 - 2017**
- The project preparation for **Spin Physics Detector (SPD)**

  is in progress

Status of the accelerator complex

NICA – Stage I



SPI & ЛУ-20 ("Od" linac)

KRION-6T & «New» HI linac

Synchrophasotron yoke

Nuclotron

Fixed target experiments 2014

Nuclotron facility today

NICA – Stage I – 2017

Nuclotron Beams

Parameter	Project (2017)		Achieved	
Magnetic field, T	2.0 (Bρ = 42.8 T·m)		2.0	
Field ramp, T/s	1.0		0.8	
Repetition period, s	5.0		8.0	
	Energy, GeV/u	Ions/ cycle	Energy, GeV/u	Ions/ cycle
Light ions ⇒ d	6.0	$5 \cdot 10^{10}$	5.6	$1 \cdot 10^{10}$
Heavy ions	*With KRION-6T & Booster*		*Without KRION-2*	
$^{40}Ar^{18+}$	4.9	$2 \cdot 10^{10}$	3.5	$5 \cdot 10^{6}$
$^{56}Fe^{26+}$	5.4	$1 \cdot 10^{10}$	2.5	$2 \cdot 10^{6}$
$^{124}Xe^{48/42+}$	4.0	$2 \cdot 10^{9}$	1.5	$1 \cdot 10^{3}$
$^{197}Au^{79+}$	4.5	$2 \cdot 10^{9}$	---	---
Polarized beams	*With SPI & Siberian snake*		*With POLARIS*	
p↑	11.9	$1 \cdot 10^{10}$	---	---
d↑	5.6	$1 \cdot 10^{10}$	2.0	$5 \cdot 10^{8}$

NICA – Stage III : Collider of polarized beams

Source of Polarized p↑ & d↑ Ions SPI

Collaboration: INR (Troitsk) & JINR

SPI test at Nuclotron with d↑ is planned for winter 2015.

It will be beginning of new stage of experiments with polarized beams at Nuclotron.

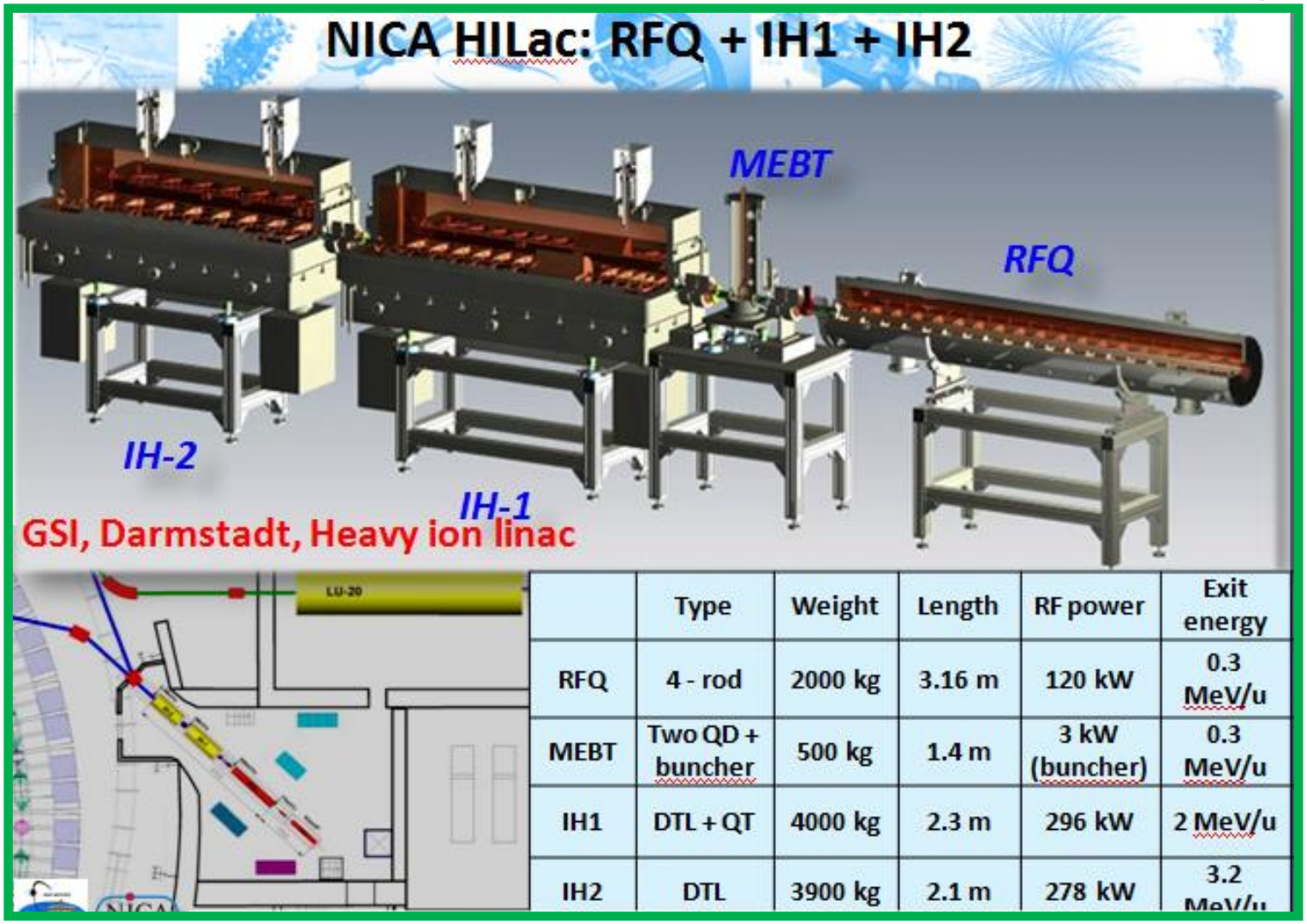
Krion-6T (*Electron String Ion Source*)

Project parameters: *magnetic filed up to 6.0 T, electron energy up to 15 keV*

Test bench in 2013:

- *B= 5.4 T reached in a robust regime;*
- *produced beams*: $Au^{30+} \div Au^{32+}$, $6 \cdot 10^8$ ppp, repetition rate 50 Hz

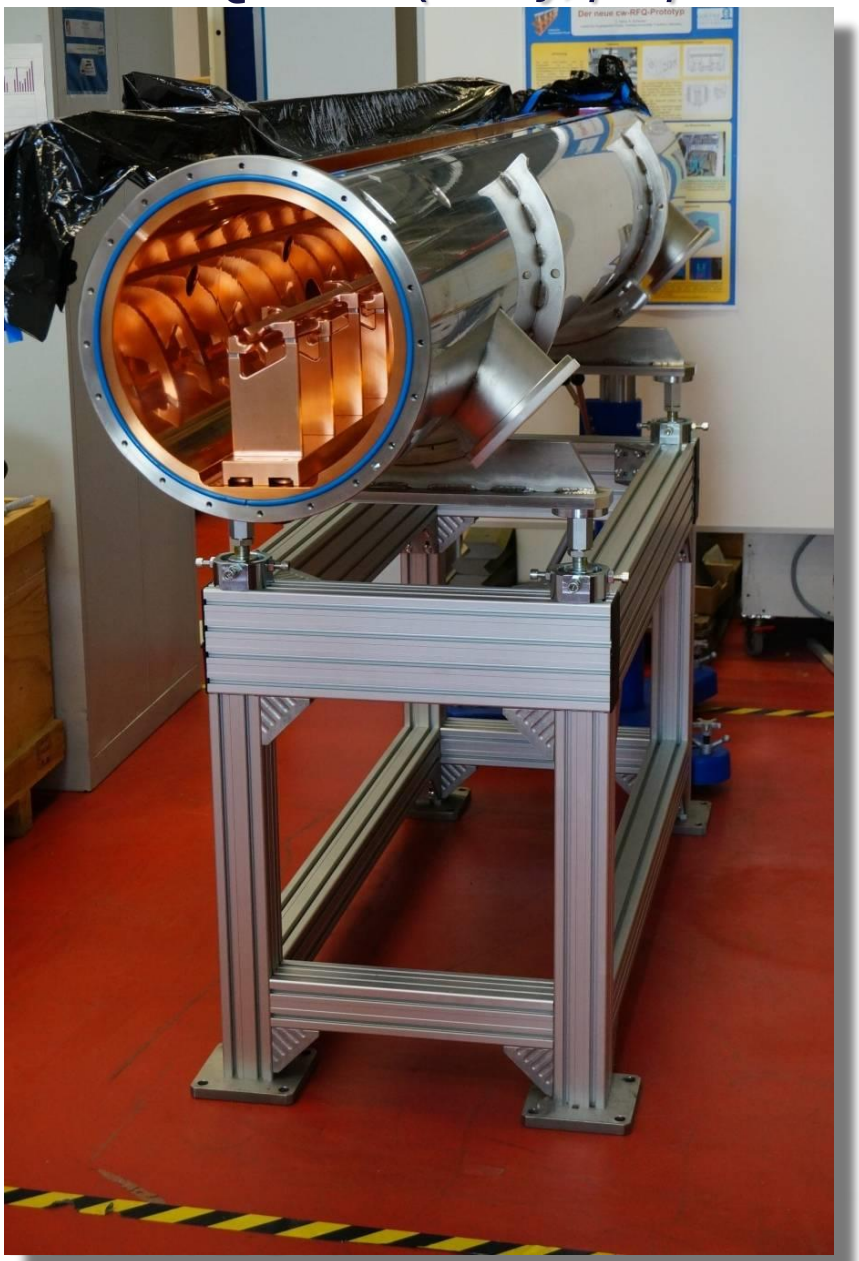
HILac: *high current (10 mA) heavy ion Linac,*
the first Linac with transistor RF amplifier



	Type	Weight	Length	RF power	Exit energy
RFQ	4 - rod	2000 kg	3.16 m	120 kW	0.3 MeV/u
MEBT	Two QD + buncher	500 kg	1.4 m	3 kW (buncher)	0.3 MeV/u
IH1	DTL + QT	4000 kg	2.3 m	296 kW	2 MeV/u
IH2	DTL	3900 kg	2.1 m	278 kW	3.2 MeV/u

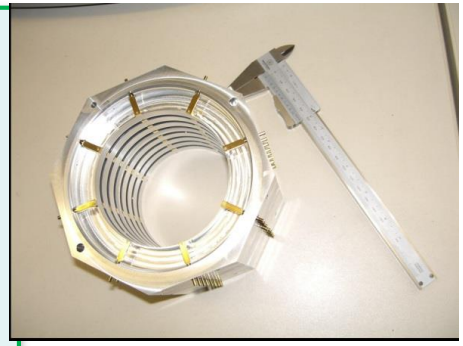
Design and fabrication by "BEVATECH OHG" Germany, Offenbach/Main,
to be delivered at JINR ***in 2015***

RFQ Tank*(ready, prepared for delivery to JINR)*



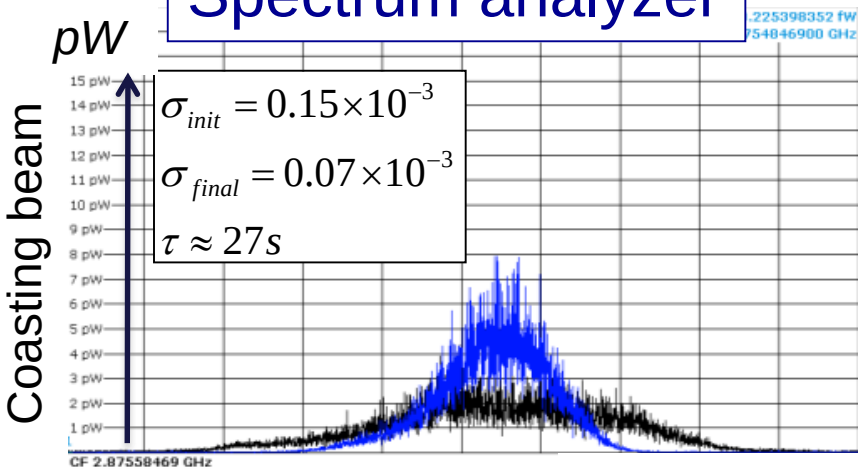
Stochastic Cooling System

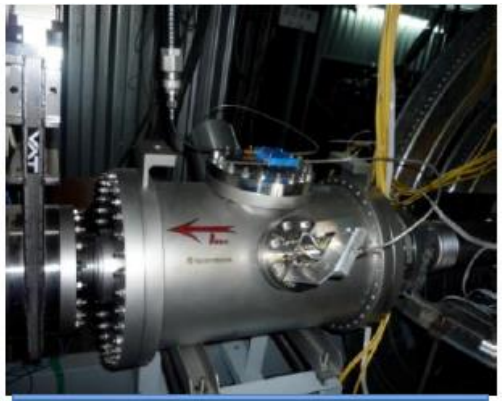
SCS at Nuclotron
- is a prototype for the NICA Collider:
W= **2-4** HGz,
P = up to **60** W
Collaboration:
JINR-IKP FZJ-CERN



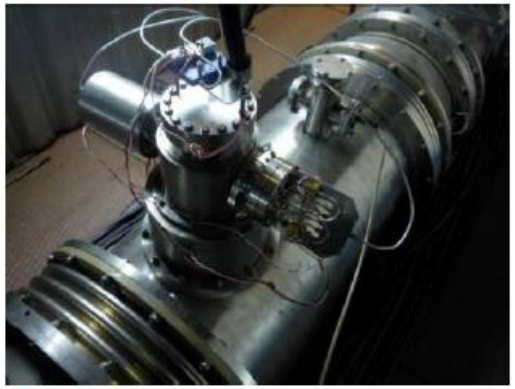
Ring slot-coupler RF structure (design FZJ)

Spectrum analyzer

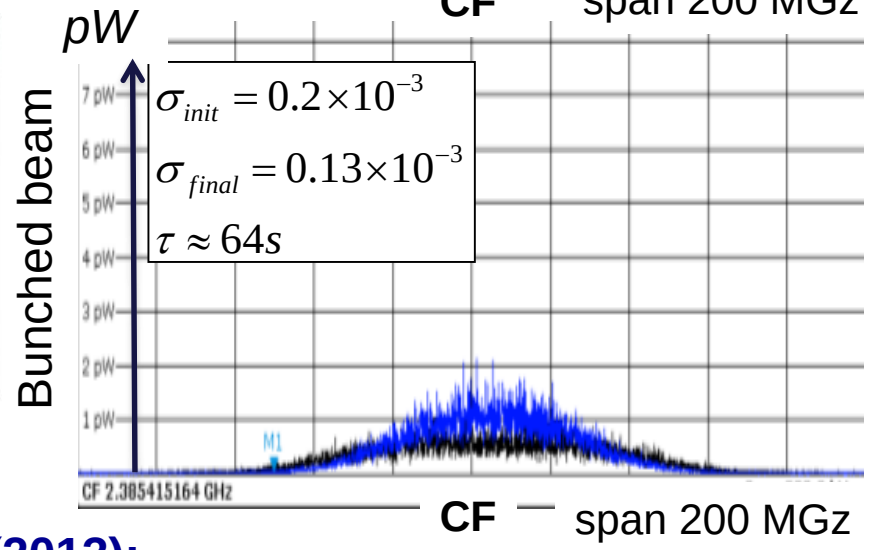




Kicker station



Pick-Up station



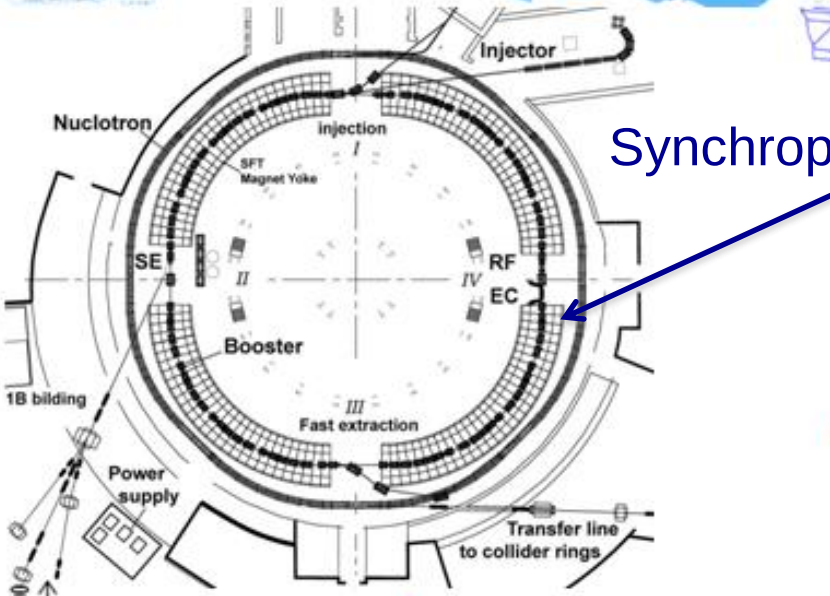
Experimental results (2013):
stochastic cooling of the carbon (C6+) beam, E = 2.5 GeV/u

The Booster

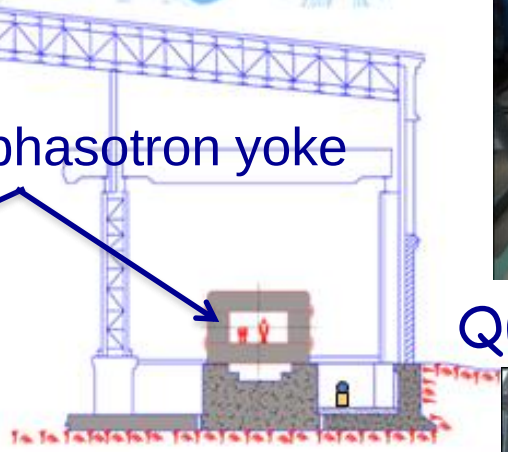
Booster synchrotron: *C = 211m,*
*25 T*m, 600 MeV/u for Au^{31+}*
ultra high vacuum, electron cooling

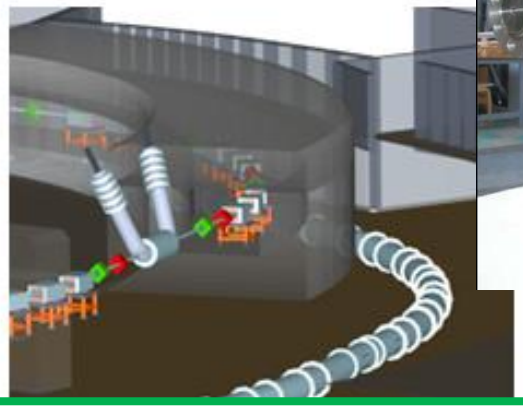
Dipole SC magnet

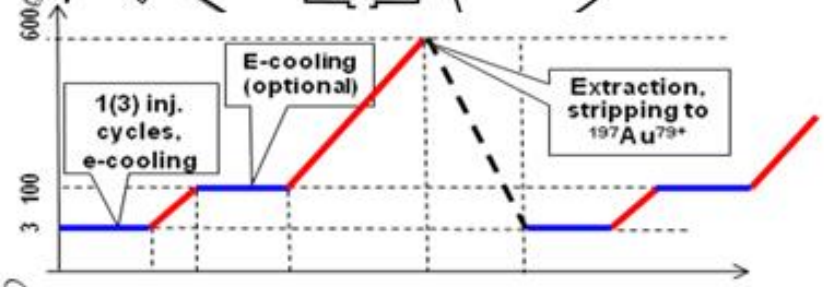
Quadrupole SC magnet



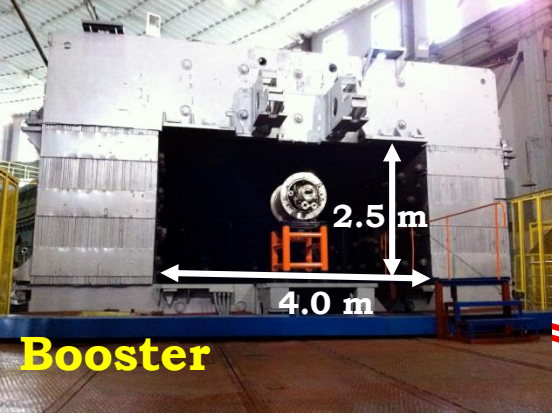
Synchrophasotron yoke







NICA – Stages II & III



SPI & ЛУ-20 ("Od" linac)

KRION-6T & «New» linac

Synchrophasotron yoke

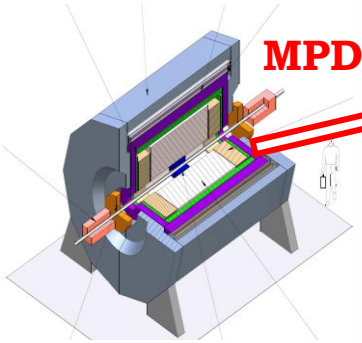
Bldg #1

Nuclotron

Fixed target experiments

Bldg #205

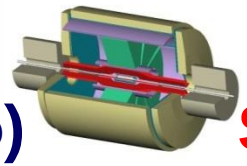
BM@N 2017



NICA – Stage II - 2019

ysics

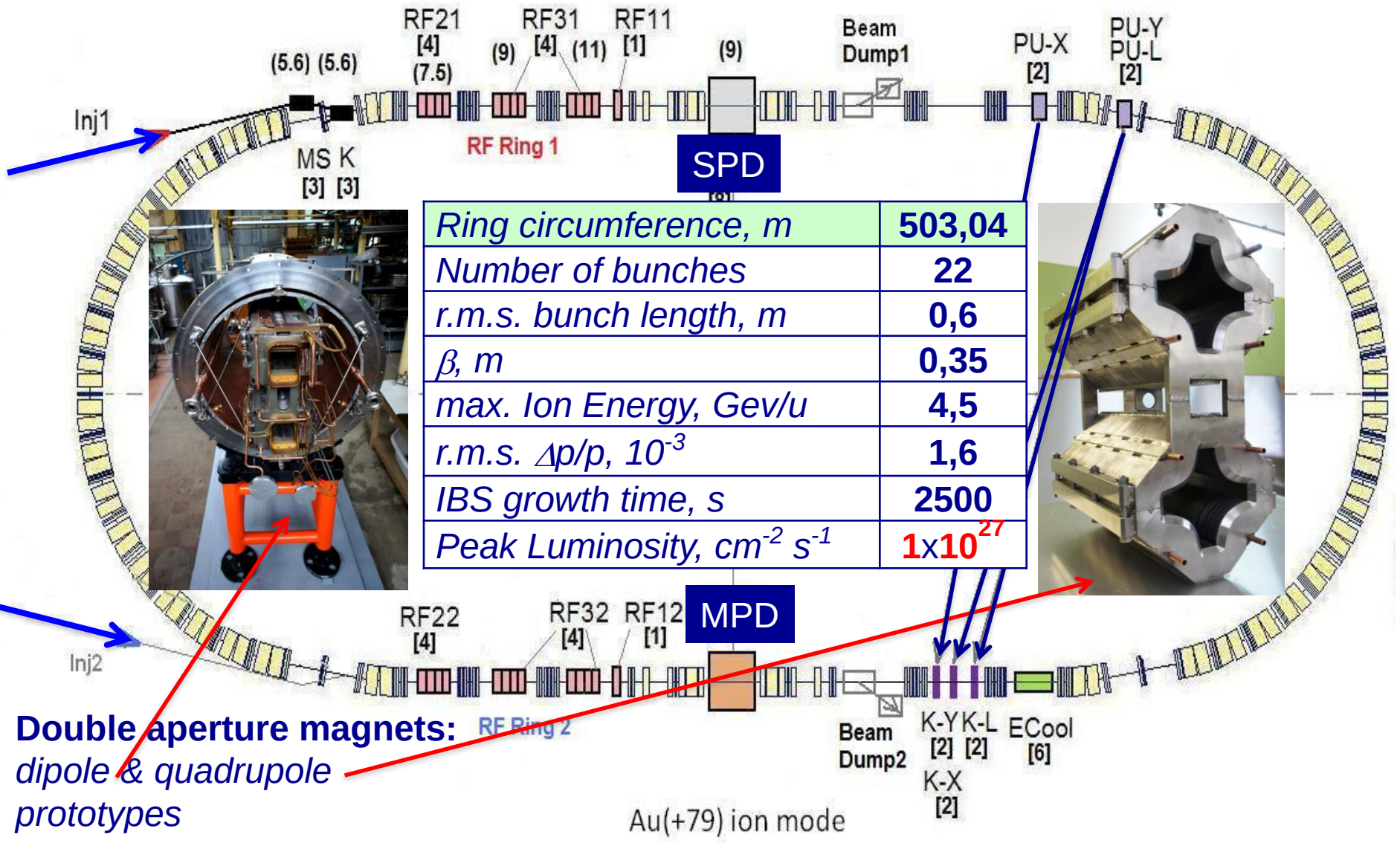
r (SPD)



Stage III

The Collider

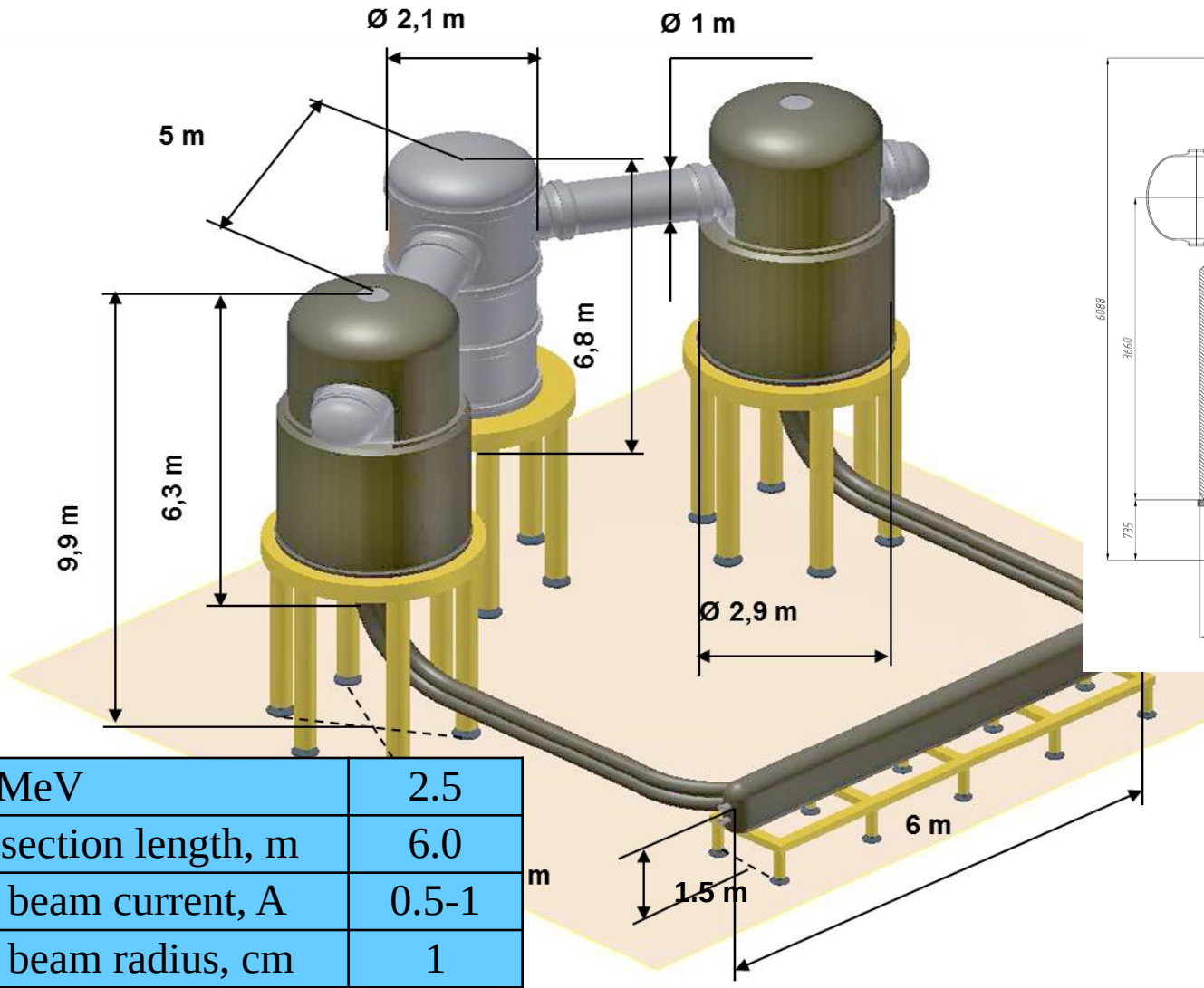
45 T*m, *4.5 GeV/u for* ***Au^{79+}***

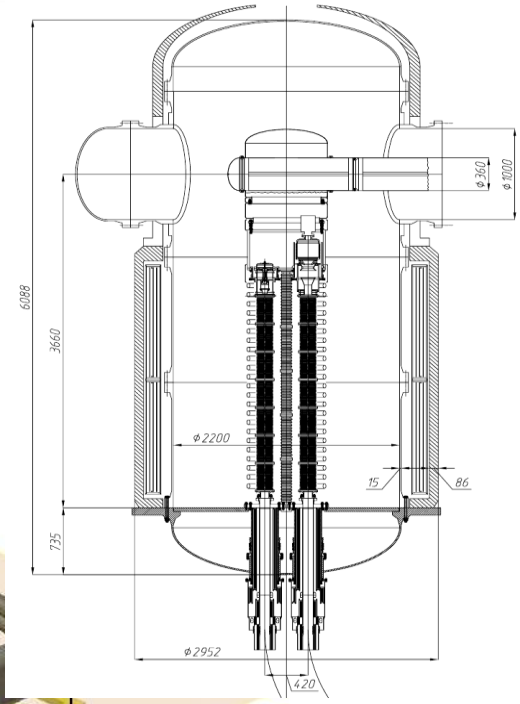


Ring circumference, m	**503,04**
Number of bunches	**22**
r.m.s. bunch length, m	**0,6**
β, m	**0,35**
max. Ion Energy, Gev/u	**4,5**
r.m.s. $\Delta p/p$, 10^{-3}	**1,6**
IBS growth time, s	**2500**
Peak Luminosity, $cm^{-2}\ s^{-1}$	**1×10^{27}**

Double aperture magnets:
dipole & quadrupole prototypes

Electron cooling system for Collider



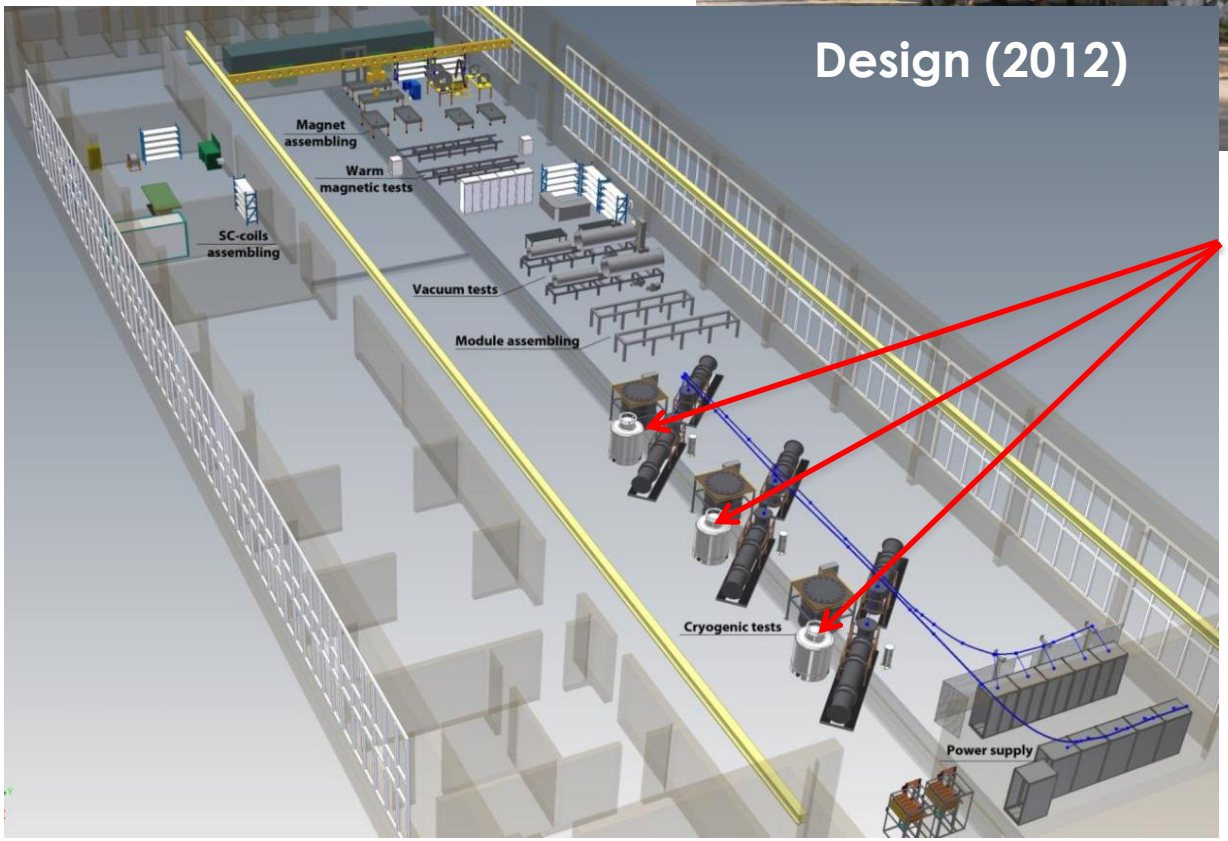


Design drawing of the HV tank

E_max, MeV	2.5
Cooling section length, m	6.0
Electron beam current, A	0.5-1
Electron beam radius, cm	1
B field at cooling section, T	0.1-0.3

Workshop at LHEP JINR for SC magnet assembly & tests

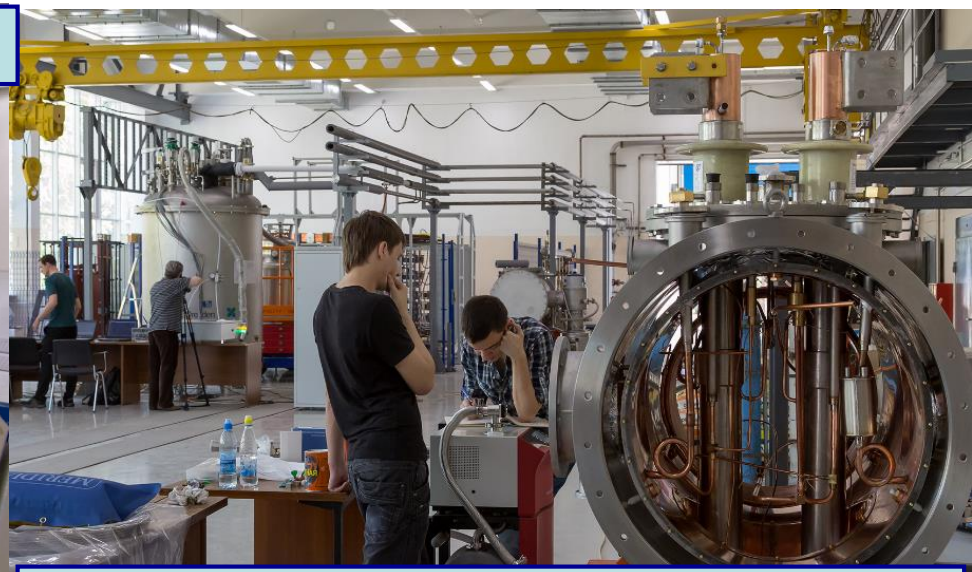
*~ **450** SC magnets will be assembled & tested in the workshop for **NICA** & SIS-100 **FAIR***



***3** cryogenic stations with **6** arms for tests of **6** modules in parallel*

The workshop starts magnet production in Dec. 2014

cable machine has been put in operation



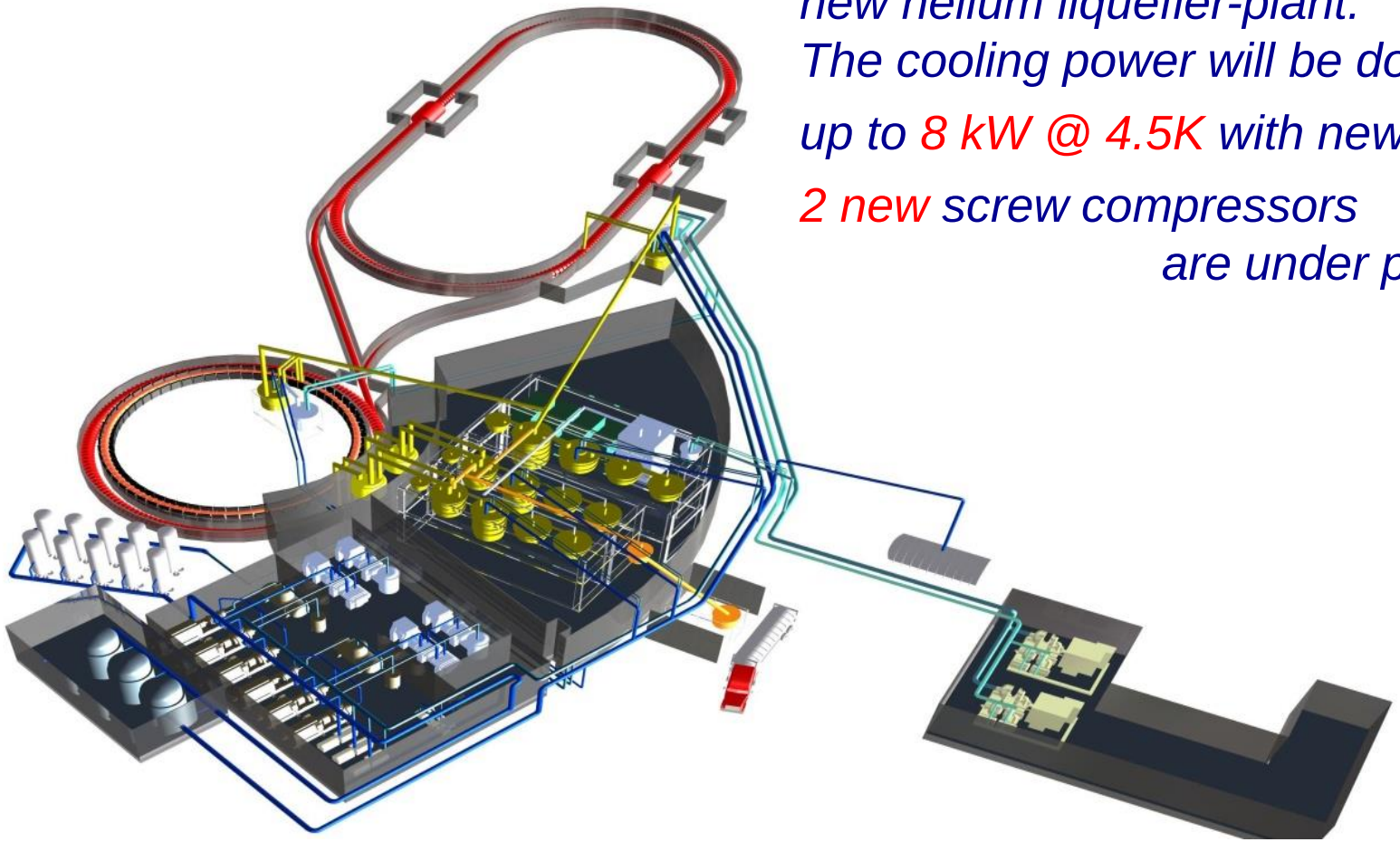
the I-st arm has been put in operation

28 Aug. 2014

workshop is ready for coil production

JINR cryogenic complex

Technical design project is in the final stage:
new helium liquefier-plant.
The cooling power will be doubled
up to 8 kW @ 4.5K with new plant;
2 new screw compressors
are under production



The bld. 32 will be reconstructed
to accommodate the new Cryo Complex

Experiments at NICA:

MultiPurpose Detector (MPD)

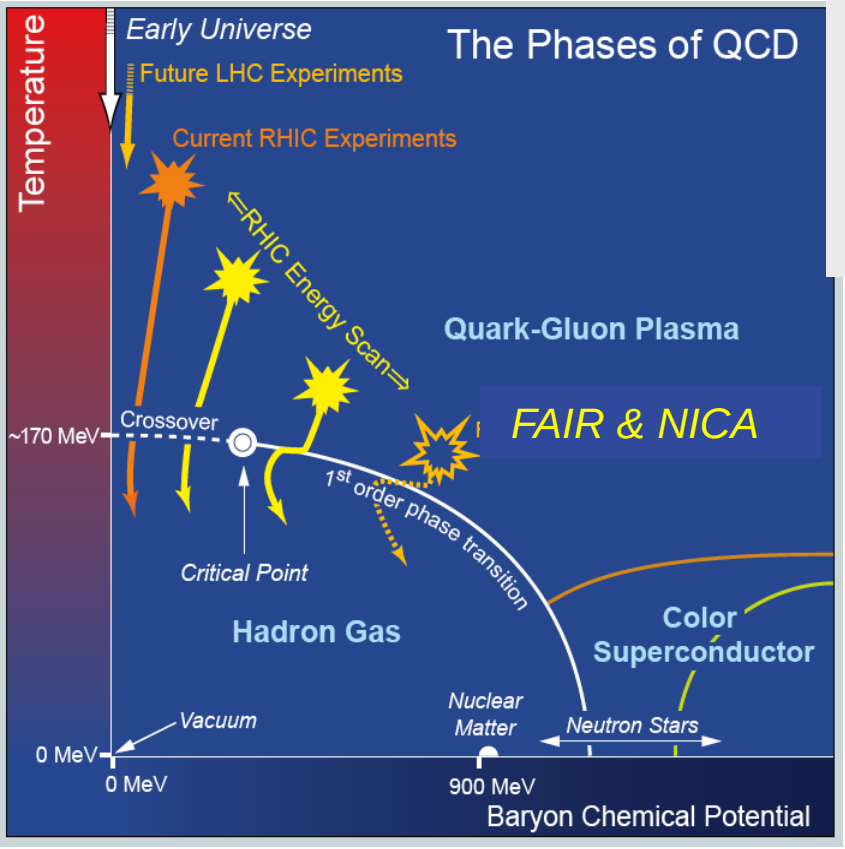
at the Collider

and

Baryonic Matter at Nuclotron (BM@N)

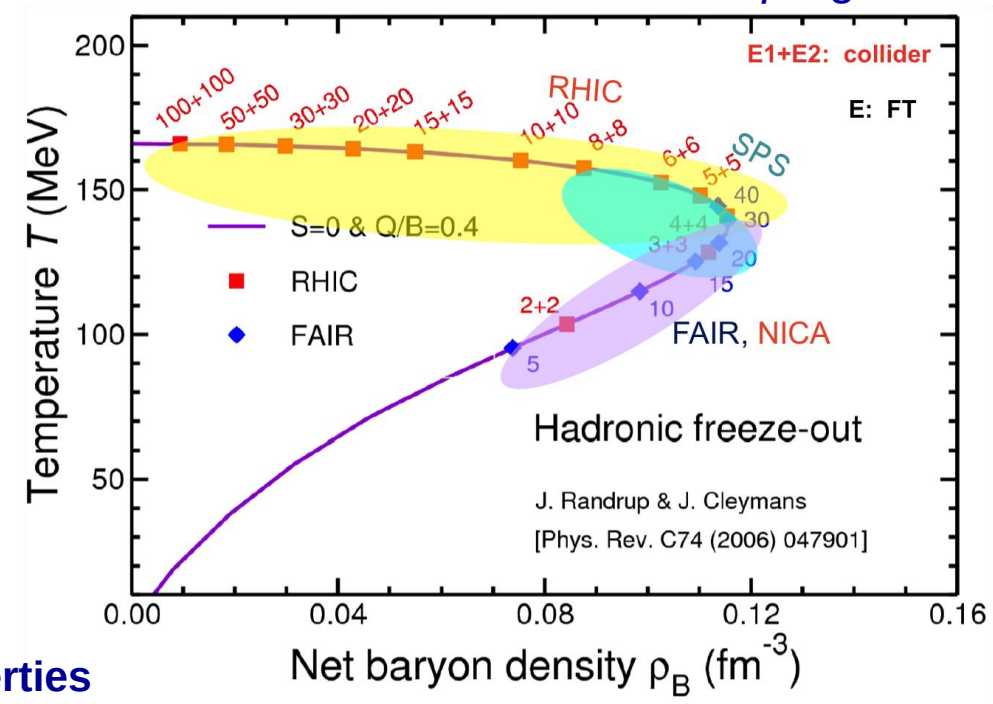
at extracted Nuclotron beam

Physics



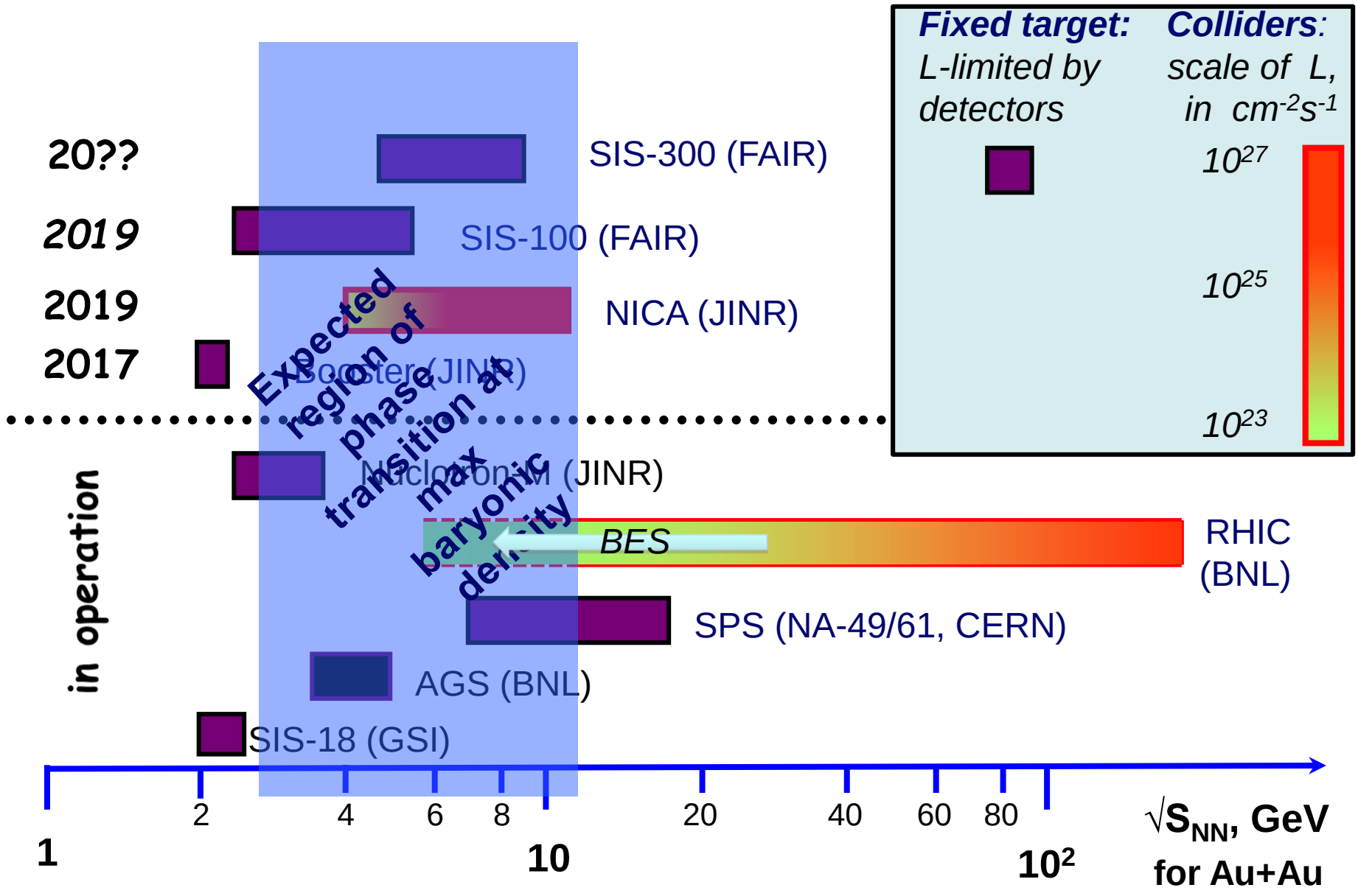
QCD matter at NICA :

- *Highest net baryon density*
- *Energy range covers onset of deconfinement*
- *Complementary to the RHIC/BES, FAIR and CERN experimental programs*



- **Bulk properties, EOS** - *particle yields & spectra, ratios, femtoscopy, flow*
- **In-Medium modification of hadron properties**
- **Deconfinement (chiral), phase transition at high ρ_B** - *enhanced strangeness production*
- **QCD Critical Point -** *event-by-event fluctuations & correlations*
- **Strangeness in nuclear matter** - *hypernuclei*

Present and future HI machines



NICA White Paper – International Effort

NICA

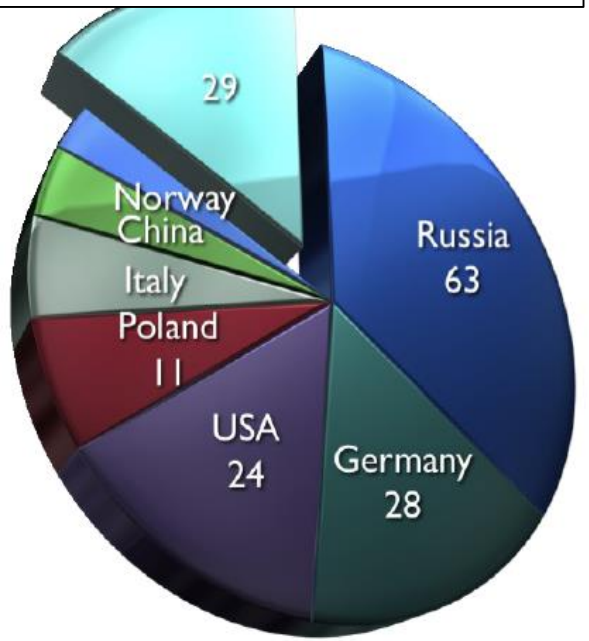
Draft v 8.03
January 24, 2013

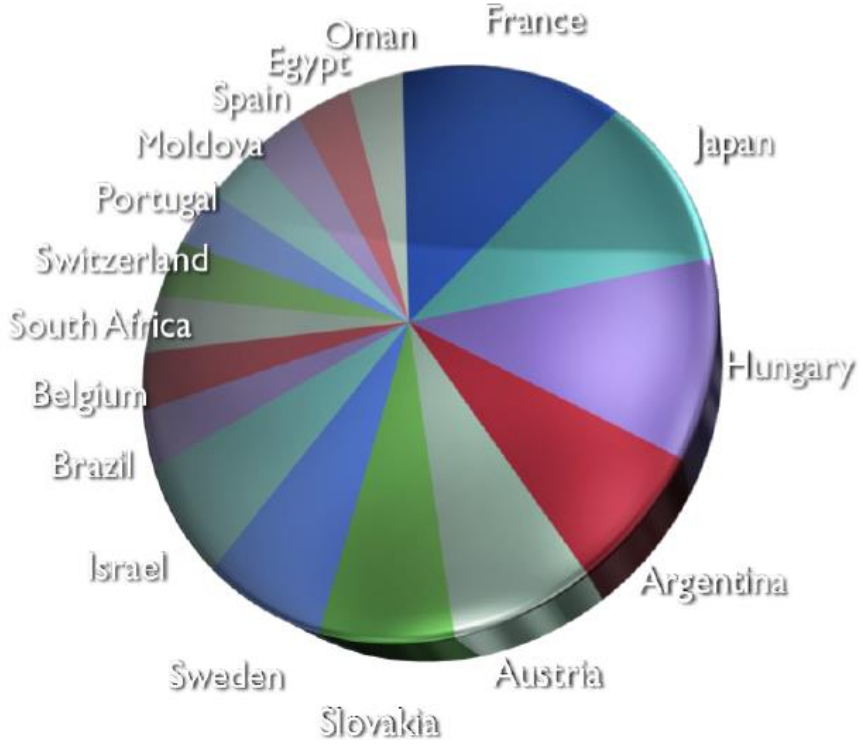
SEARCHING for a QCD MIXED PHASE at the
NUCLOTRON-BASED ION COLLIDER FACILITY
(NICA White Paper)

Statistics of White Paper Contributions

111 *contributions:*
188 *authors from* **70** *centers in* **24** *countries*

Indicates wide international interest to the physics at MPD & BM@N



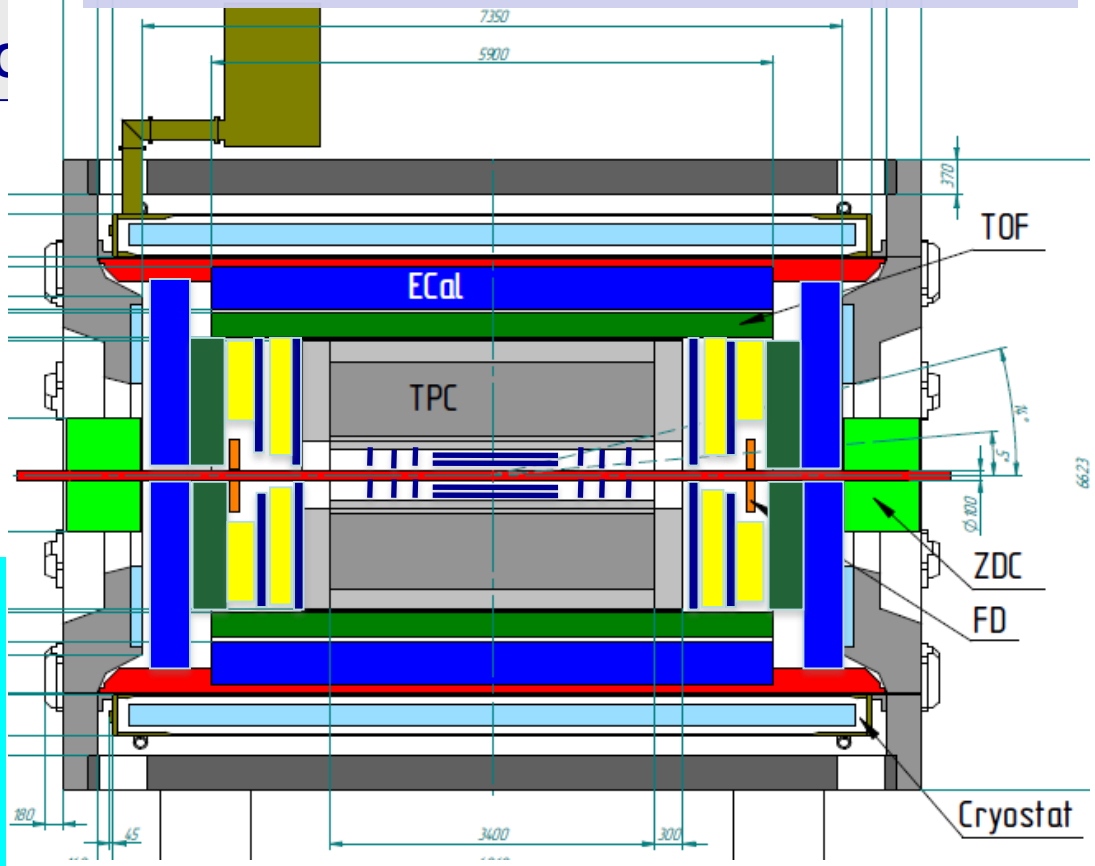


MPD detector for Heavy-Ion Collisions @ NICA

Tracking: up to |η|<2 (TPC)
PID: hadrons, e, γ (TOF, TPC, ECAL)
Event characterization:
centrality & event plane (ZDC

Stage 1: TPC, TOF, ECAL, ZDC, FD

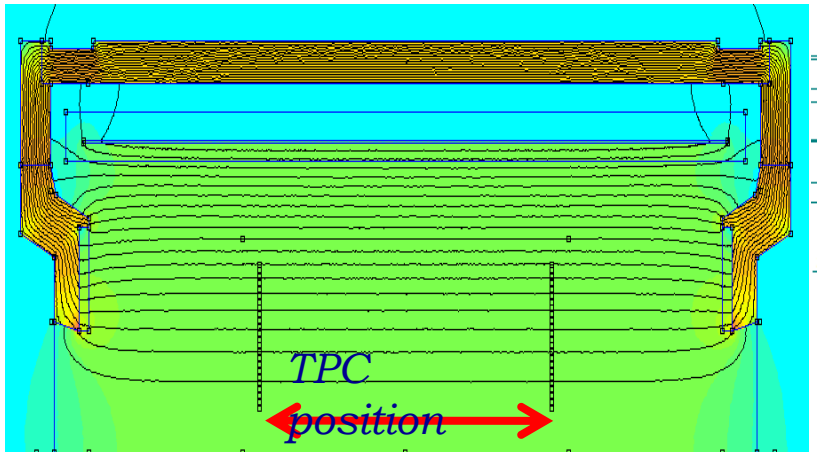
Stage 2: IT + Endcaps (tracker, TOF, ECAL)



Superconducting solenoid:

B_0=0.66 T

high level (~ 10^{-4}) of magnetic field homogeneity at the TPC position



MPD Solenoid

Packages:

- ***S**upport Structure*
- *Yoke*

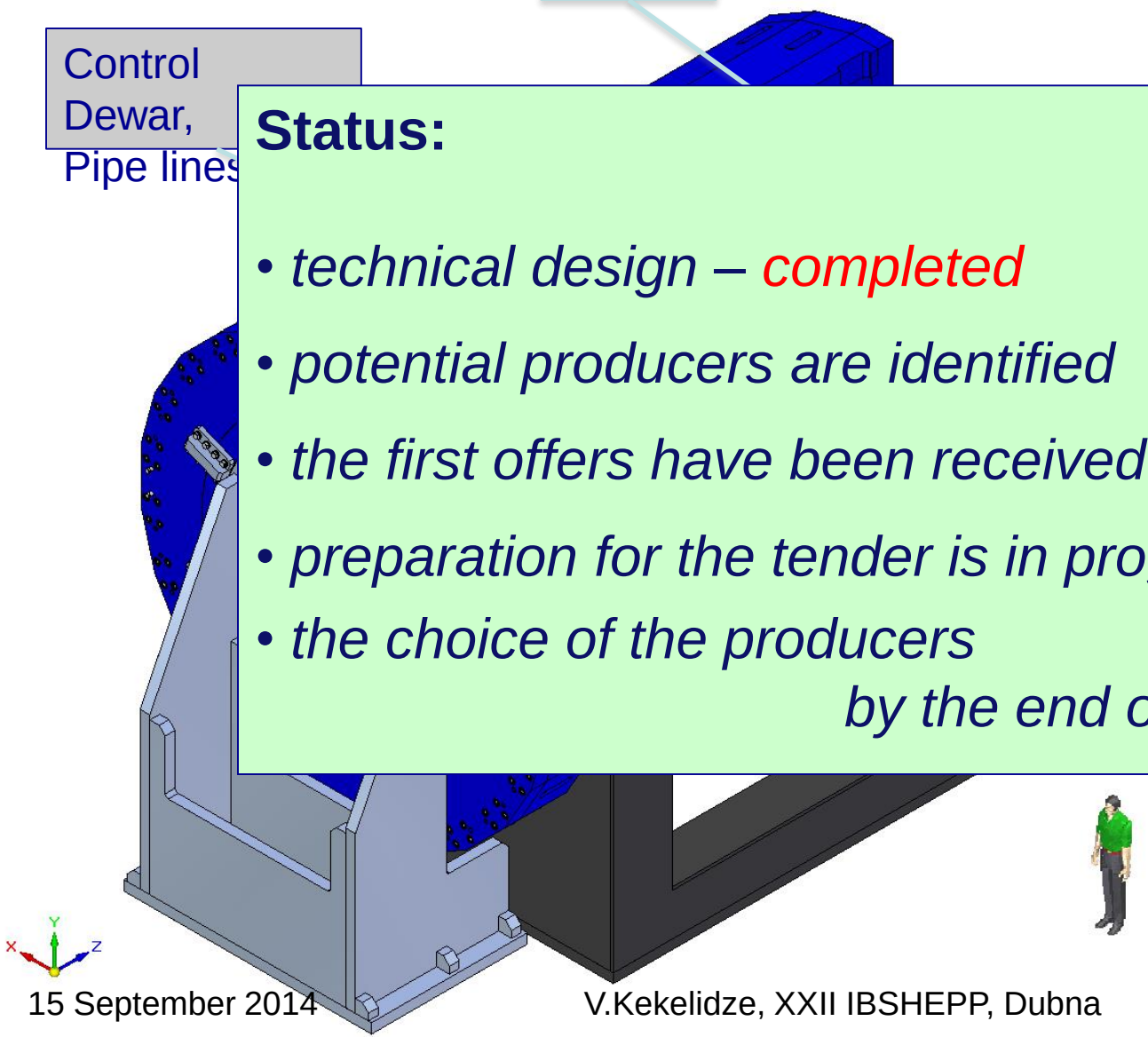
SC coil

Control Dewar, Pipe lines

lass + Cryostat
m System
enic System
oils + Cooling
tem
l System

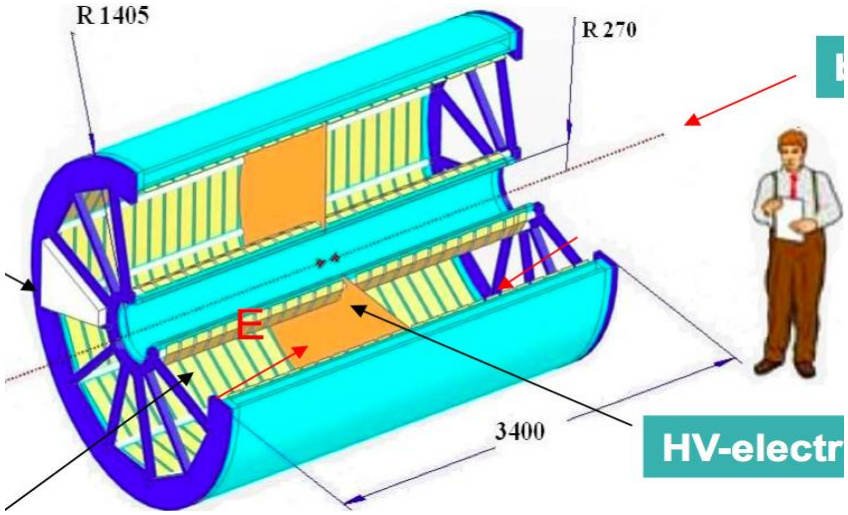
Status:

- *technical design – completed*
- *potential producers are identified*
- *the first offers have been received*
- *preparation for the tender is in progress*
- *the choice of the producers by the end of 2014*



TPC- *technical project approved, fabrication stage*

Dia. =3000 mm, L = 3400 mm, FEE = 120 000 ch, $\delta p/p < 2\%$



FEC-64 prototype
(ALTERA FPGA,
ALTRO, PASA chips)

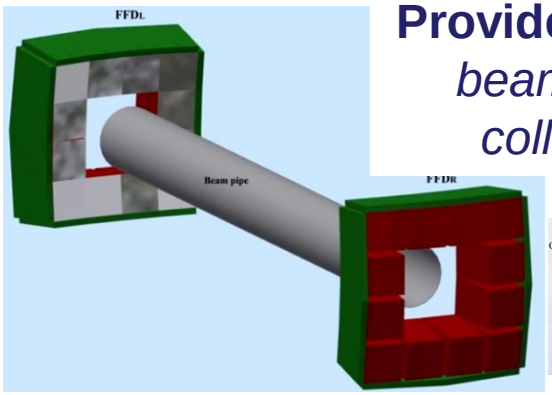
Cylinder C2, preparation for vacuum tests

Cylinder C3 manufactured in Dec. 2013

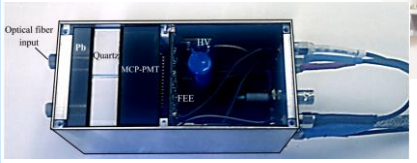
Time of Flight system (TOF)

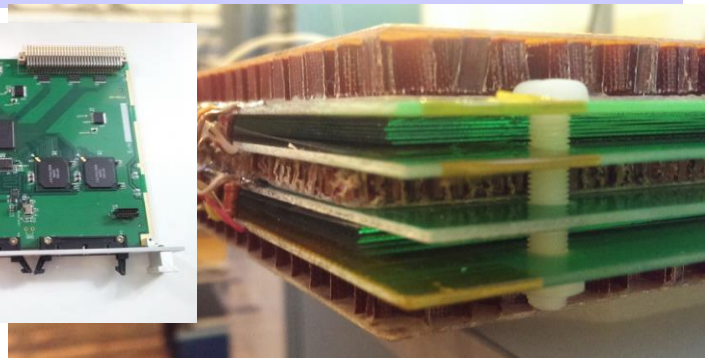
Fast Forward Detector (FFD): *production stage*

mRPC – TDR has been prepared, *ready for mass production*



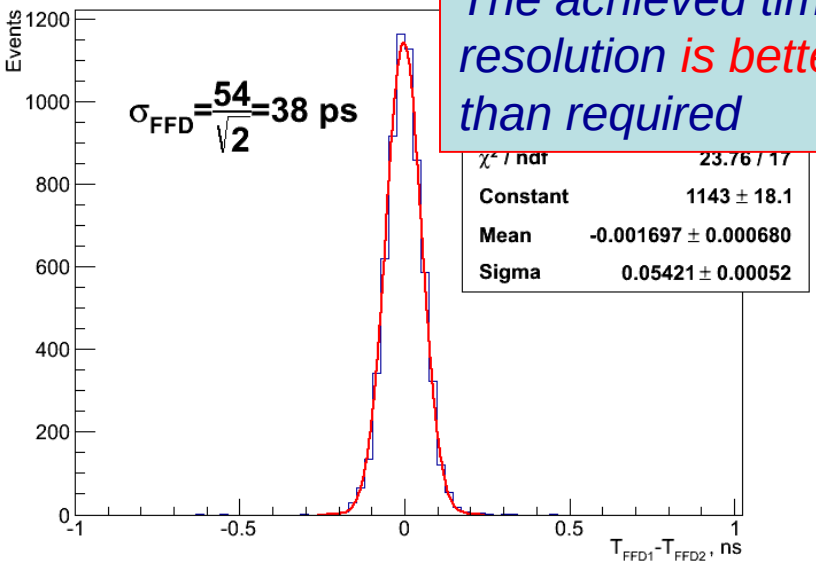
Provides: *T0 for TOF, beam adjustment & collision L0-trigger*

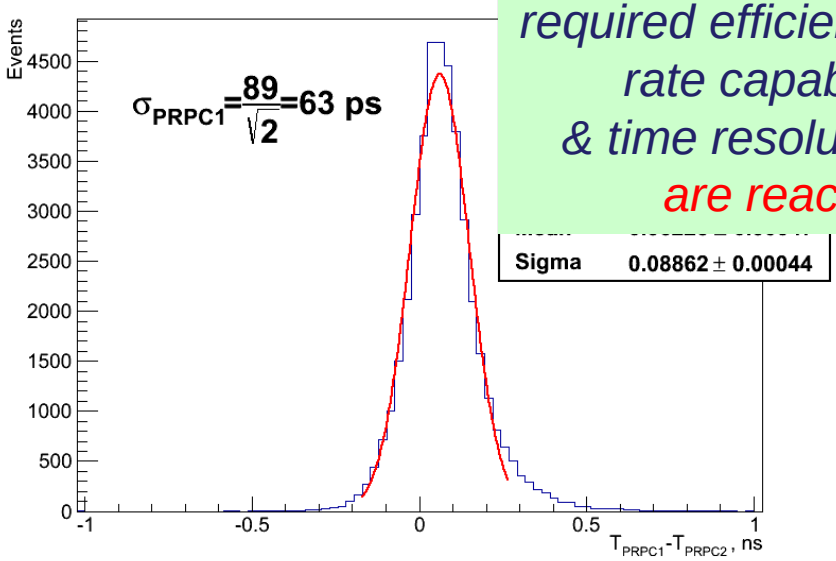




Zhu Weipinga, Wang Yi, Feng Shengqin, Wang Jingbo, Huang Xinjie, Shi Li, V. Babkin, V. Golovatyuk, M. Rumiantcev, G. Eppley, T. Nussbaum, ***NIM A 735, 277–282, 2014***

The achieved time resolution is better than required





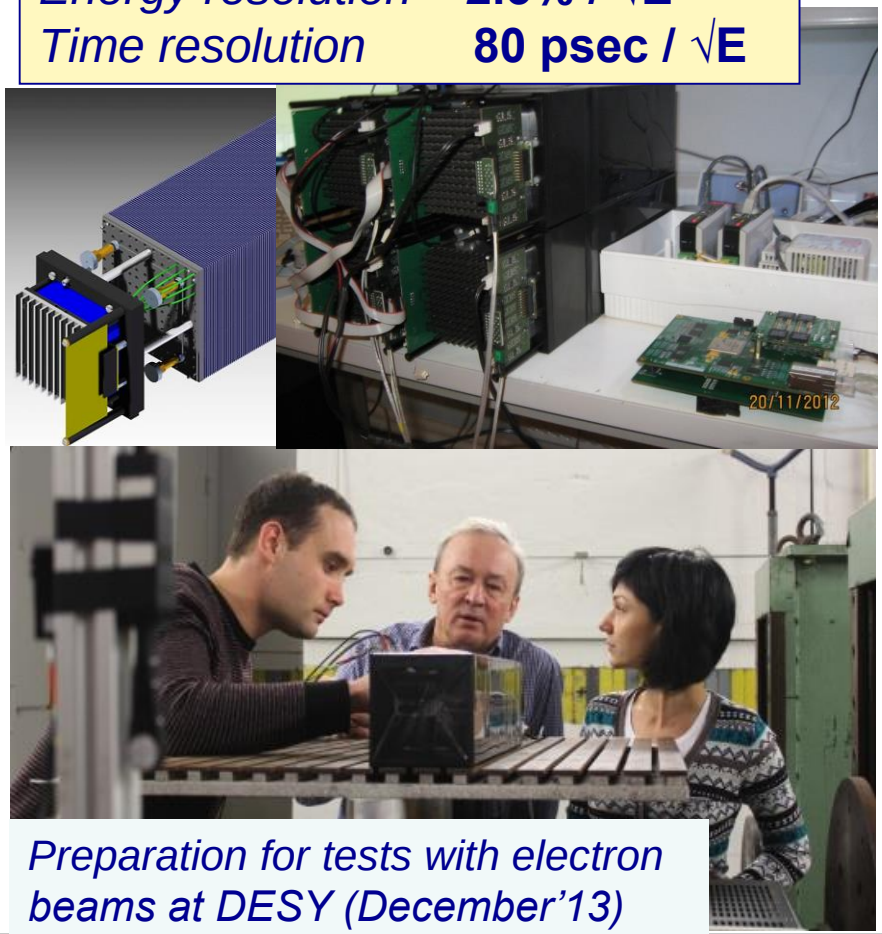
required efficiency, rate capability & time resolution are reached

Calorimetry

ECAL – *TDR - in preparation*

L ~35 cm (~ 14 X_0), Pb+Scint. (4x4 cm^2)
read-out: WLS fibers + MAPD

Energy resolution **2.5% / √E**
Time resolution **80 psec / √E**

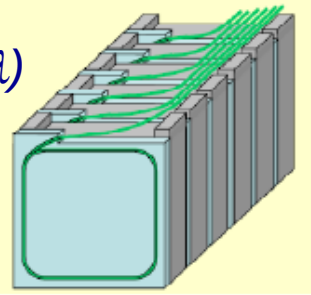


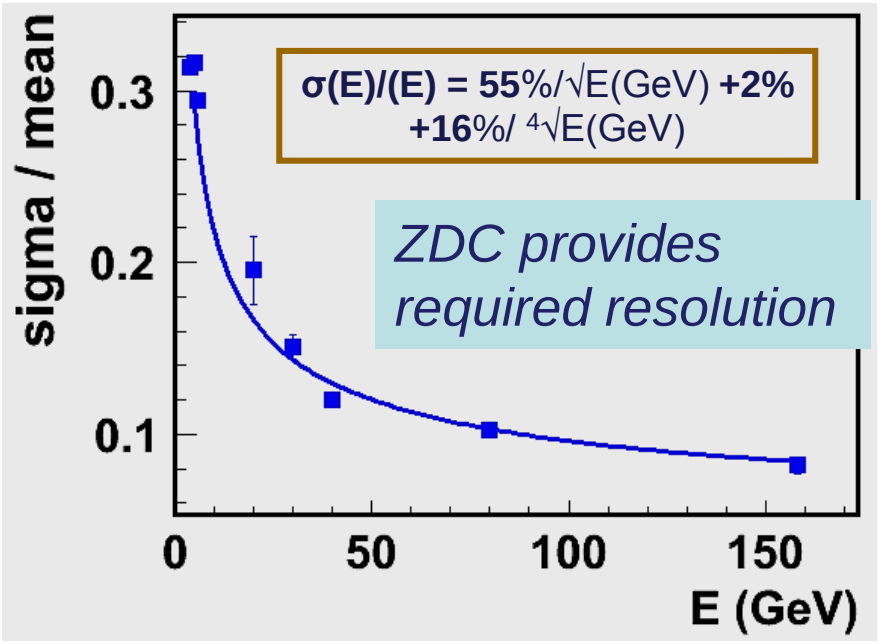
Preparation for tests with electron beams at DESY (December'13)

Zero Degree Calorimeter (ZDC): TDR stage

ZDC coverage: 2.2<|η|< 4.8

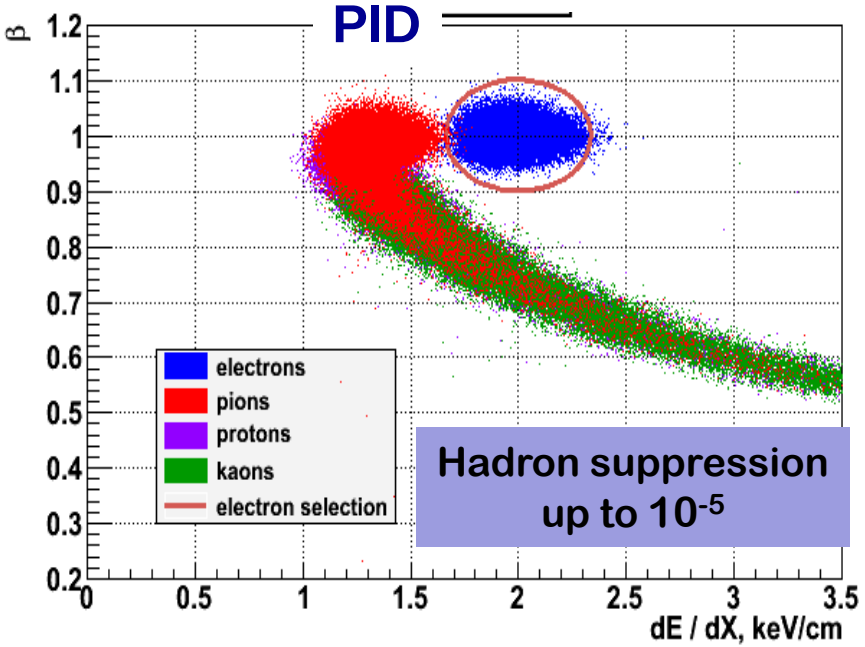
Pb-scintillator sampling (5λ)
Read-out: fibers+ AvalanchePD

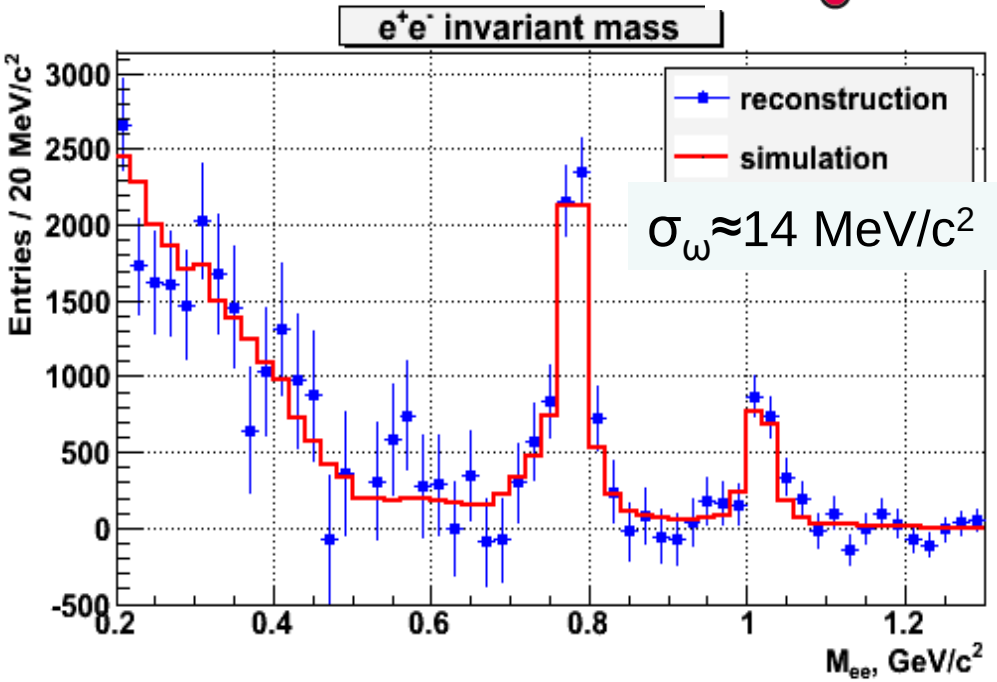




ZDC provides required resolution

MPD performance for dileptons

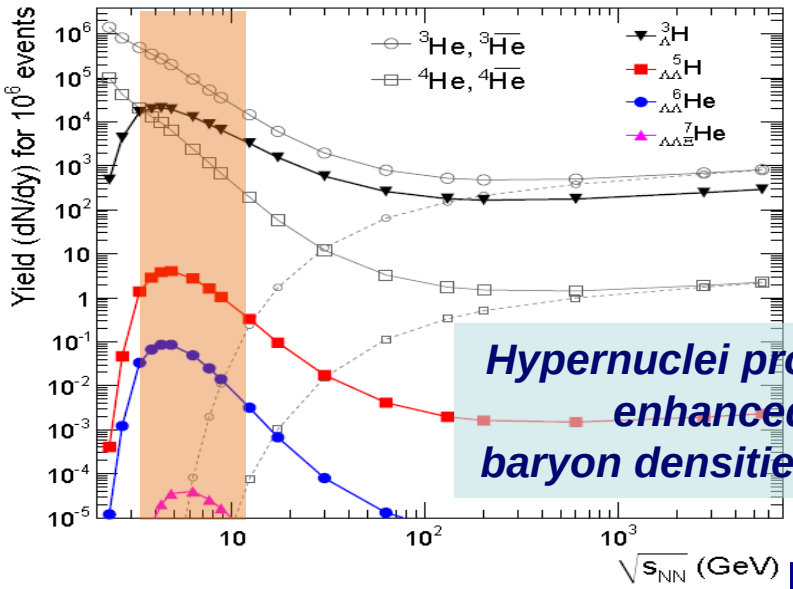




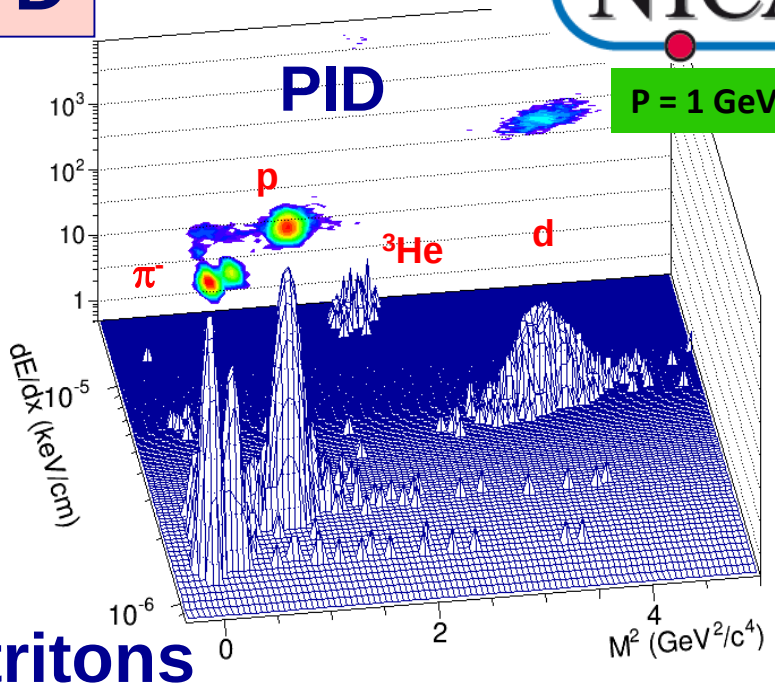
Yields, central Au+Au st $\sqrt{s}$ = 8.8 GeV/u

Particle	Yields		Decay mode	BR	Effic. %	Yield/1 w
	4π	y=0				
ρ	31	17	e+e-	$4.7 \cdot 10^{-5}$	35	$7.3 \cdot 10^{4}$
ω	20	11	e+e-	$7.1 \cdot 10^{-5}$	35	$7.2 \cdot 10^{4}$
φ	2.6	1.2	e+e-	$3 \cdot 10^{-4}$	35	$1.7 \cdot 10^{4}$

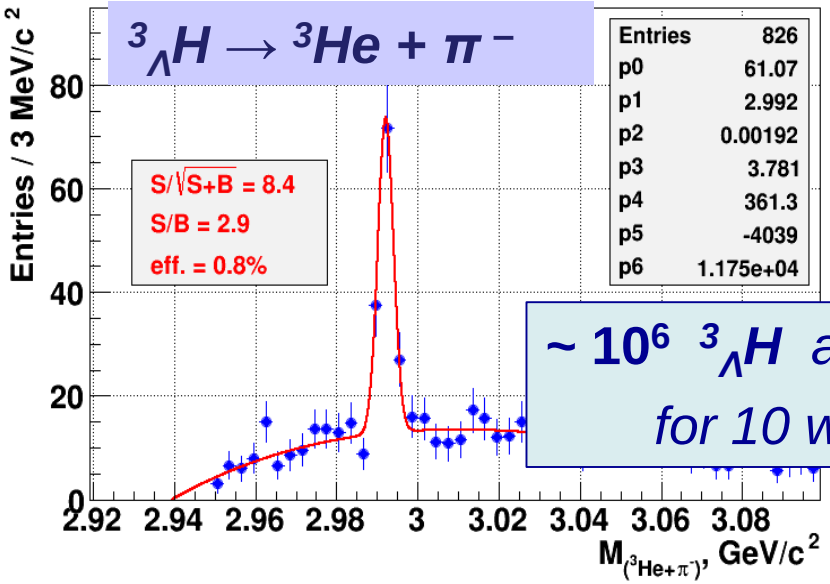
Hypernuclei @ MPD

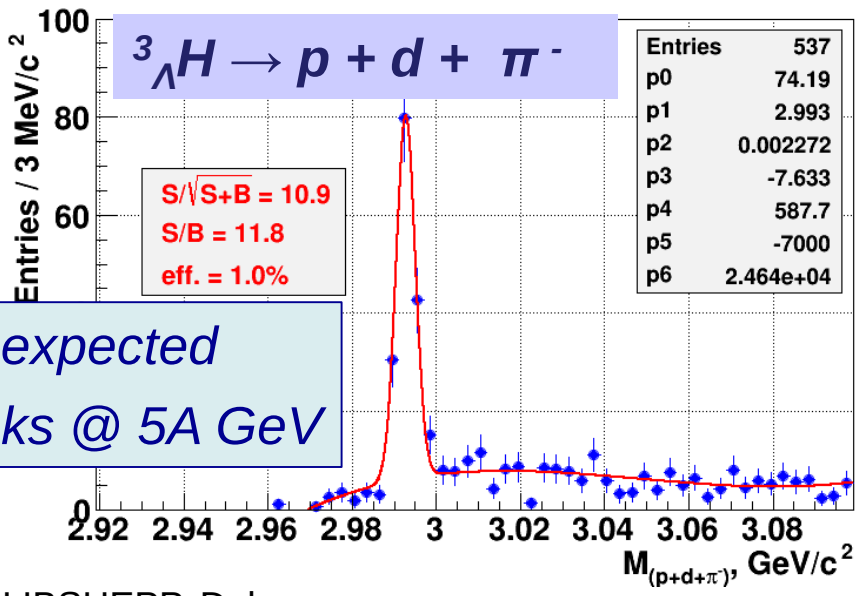


Hypernuclei production enhanced at high baryon densities (NICA)



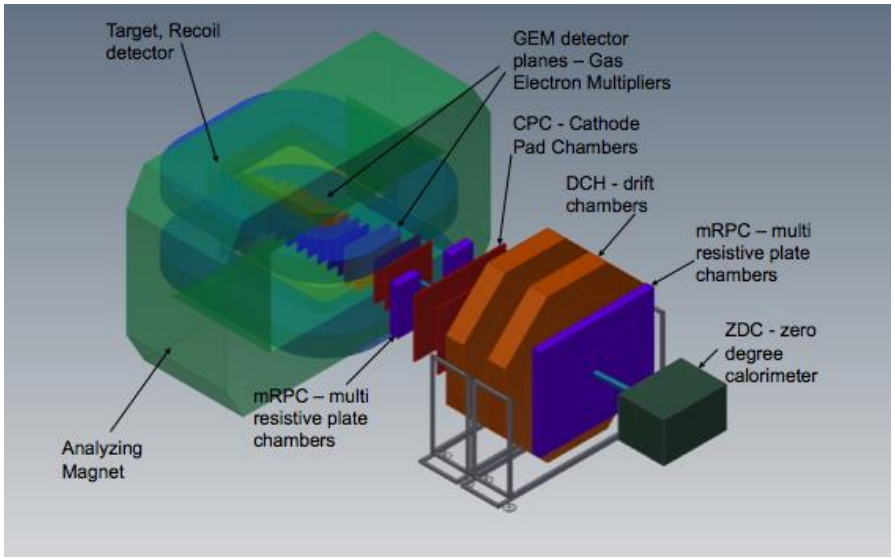
Hypertritons





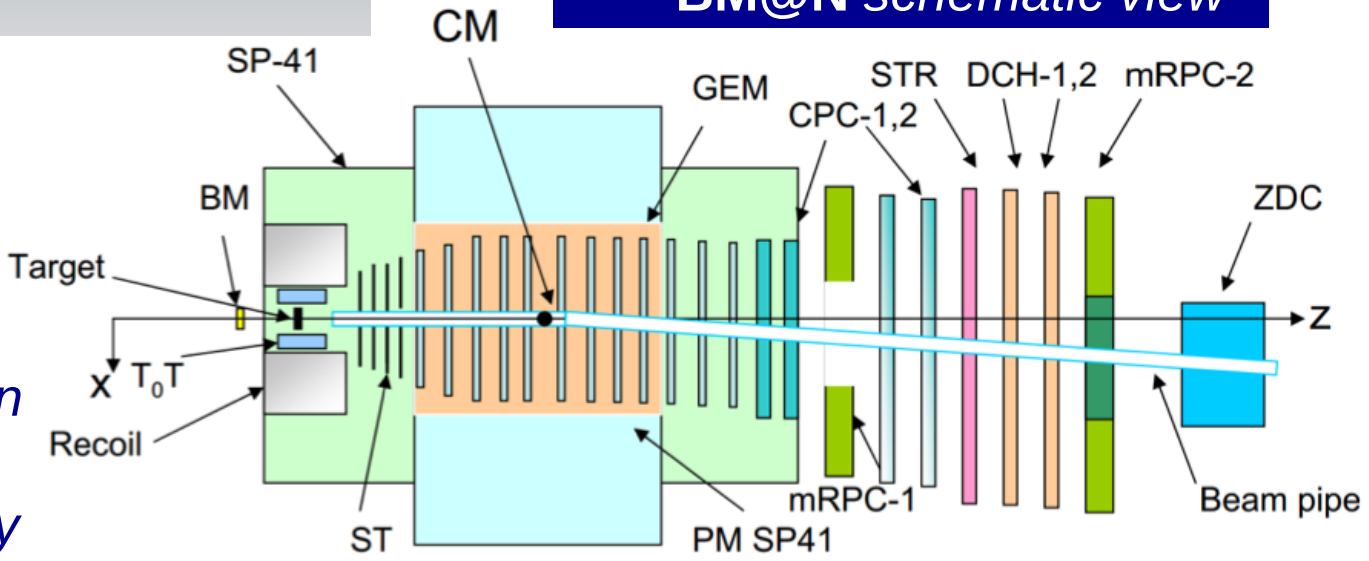
~ 10^6 $^3_\Lambda H$ *are expected for 10 weeks @ 5A GeV*

BM@N (Baryonic Matter at Nuclotron): *the 1st stage*



Collaboration of scientific centers:
INR, SINP MSU, IHEP + S-PSUniversity (Russia);
GSI, Frankfurt U., Gissen U. (Germany):
+ CBM-MPD IT-Consortium,

BM@N *schematic view*



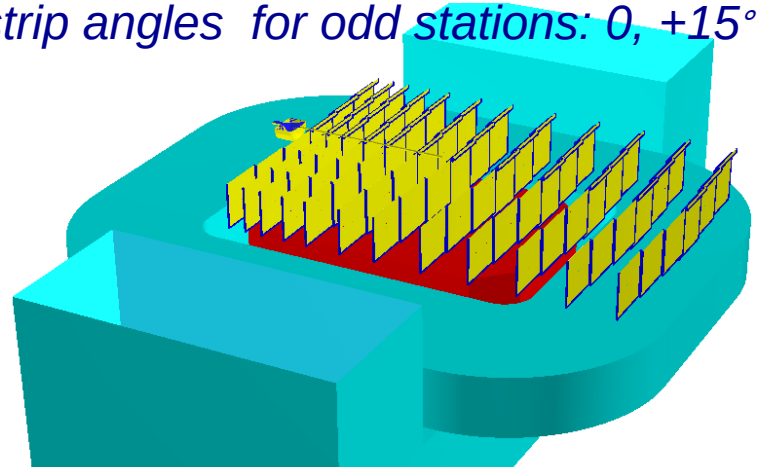
Physics:

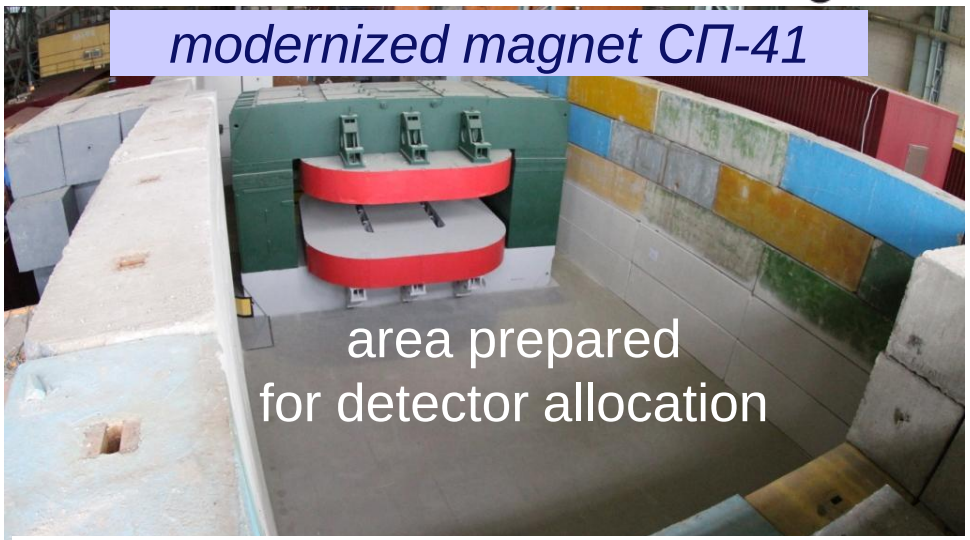
- ✓ *in-medium effects for strangeness & vector mesons*
- ✓ *hyperon production*
- ✓ *hadron femtoscopy*
- ✓ *electromagnetic probes (optional)*

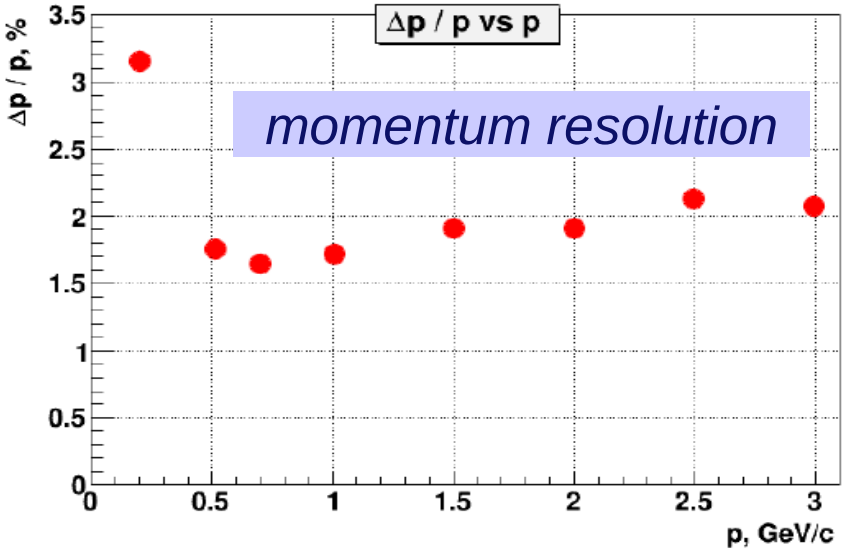
GEM station tracking

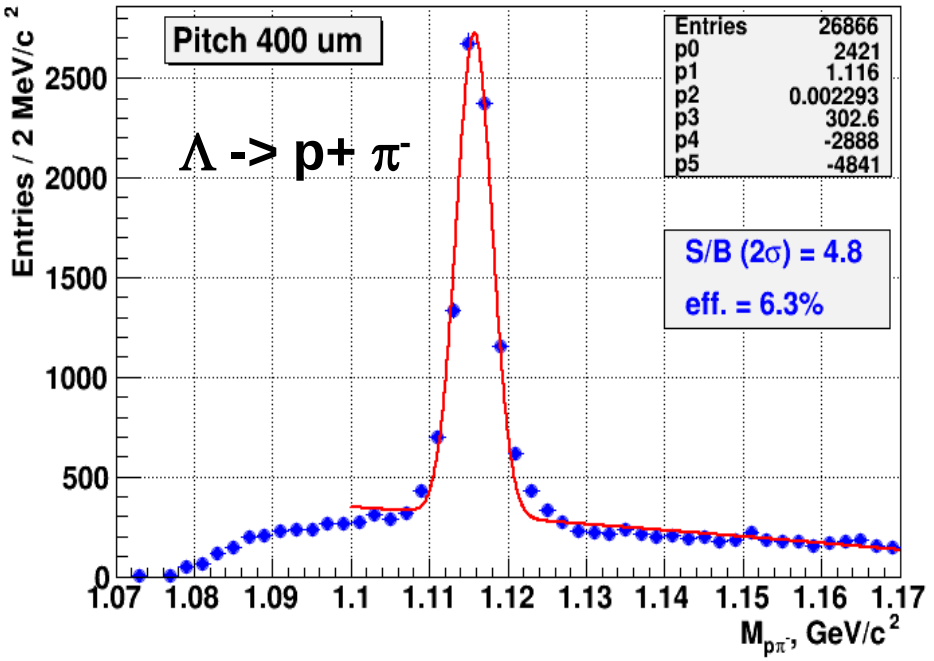
12 GEM stations:

- *1-4 stations strip pitch 0.4 мм*
- *5-12 stations - 0.8 мм*
- *strip angles for odd stations: 0, +15°*









SPD (Spin Physics Detector) at NICA

Collider provides both:
transversally & longitudinally
polarized ***p*** & ***d***
with energy up to $\sqrt{S}$ = ***27 GeV***

The issues to be studied:

- *MMT-DY processes*
- *J/Ψ production processes*
- *Spin effects in inclusive high-p_T reactions*
- *Spin effects in one and two hadron production processes*
- *Polarization effects in heavy ion collisions*

The Collaboration is forming

Project is under preparation

NICA Complex Civil Engineering

The State Expertise – Oct. 2013
International tender – 2013

Preparatory works completed - 2014
1-st contract with General Contractor – 2014

Civil construction will be completed by 2018

Start up version of NICA Collider:

commissioning is foreseen in 2019

NICA Collaboration

Concluding remarks

- **NICA complex has a potential for competitive research** ***in the fields of dense baryonic matter and spin physics***
- **Construction of the *accelerator complex* and its elements** ***are in progress***
- **Constructions of both detectors BM@N & MPD** ***are progressing as well***
- **The SPD project is in preparation**
- **The international collaboration around the NICA is growing**
- **New partners are invited to join NICA**

Thank you!