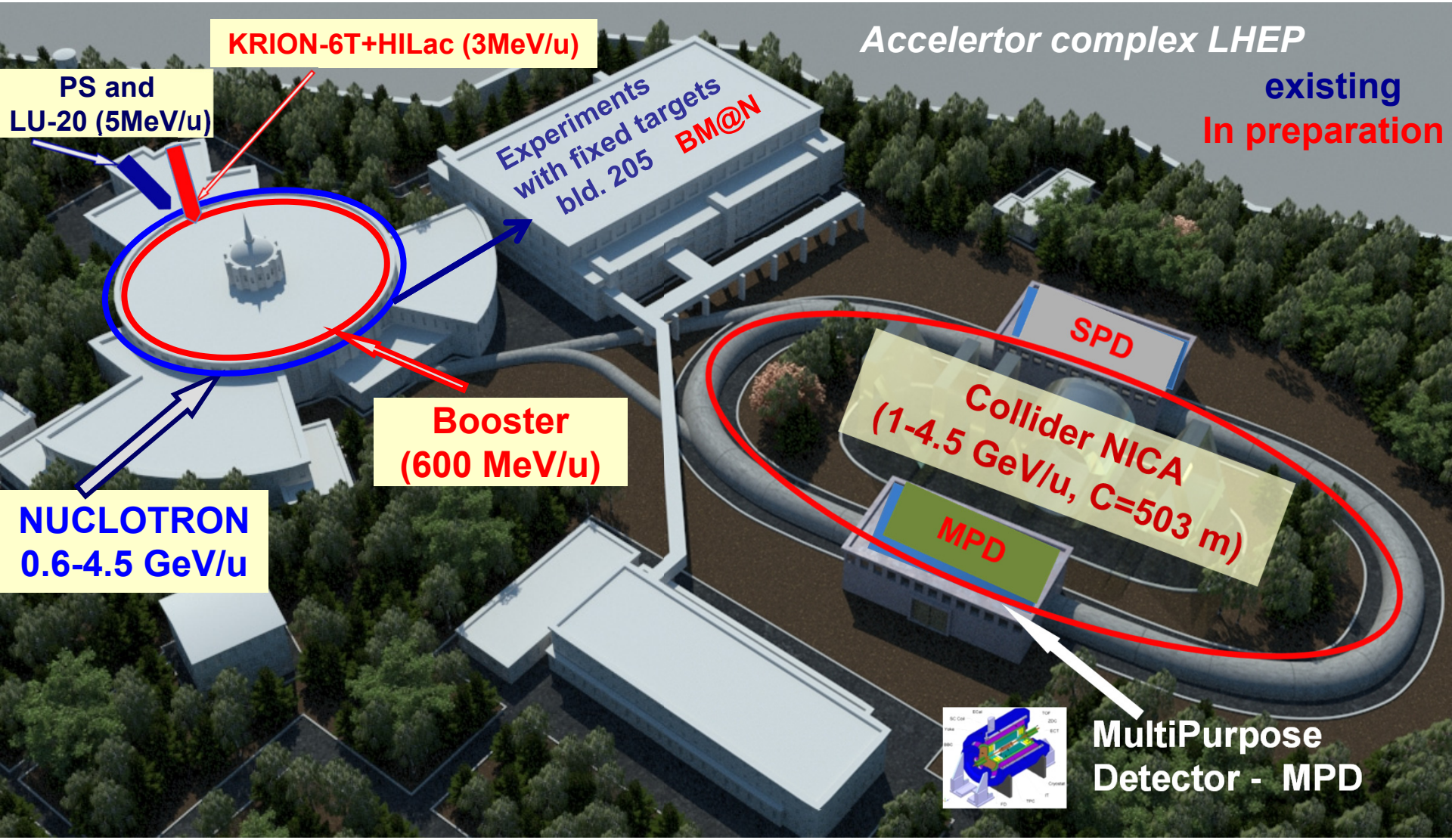
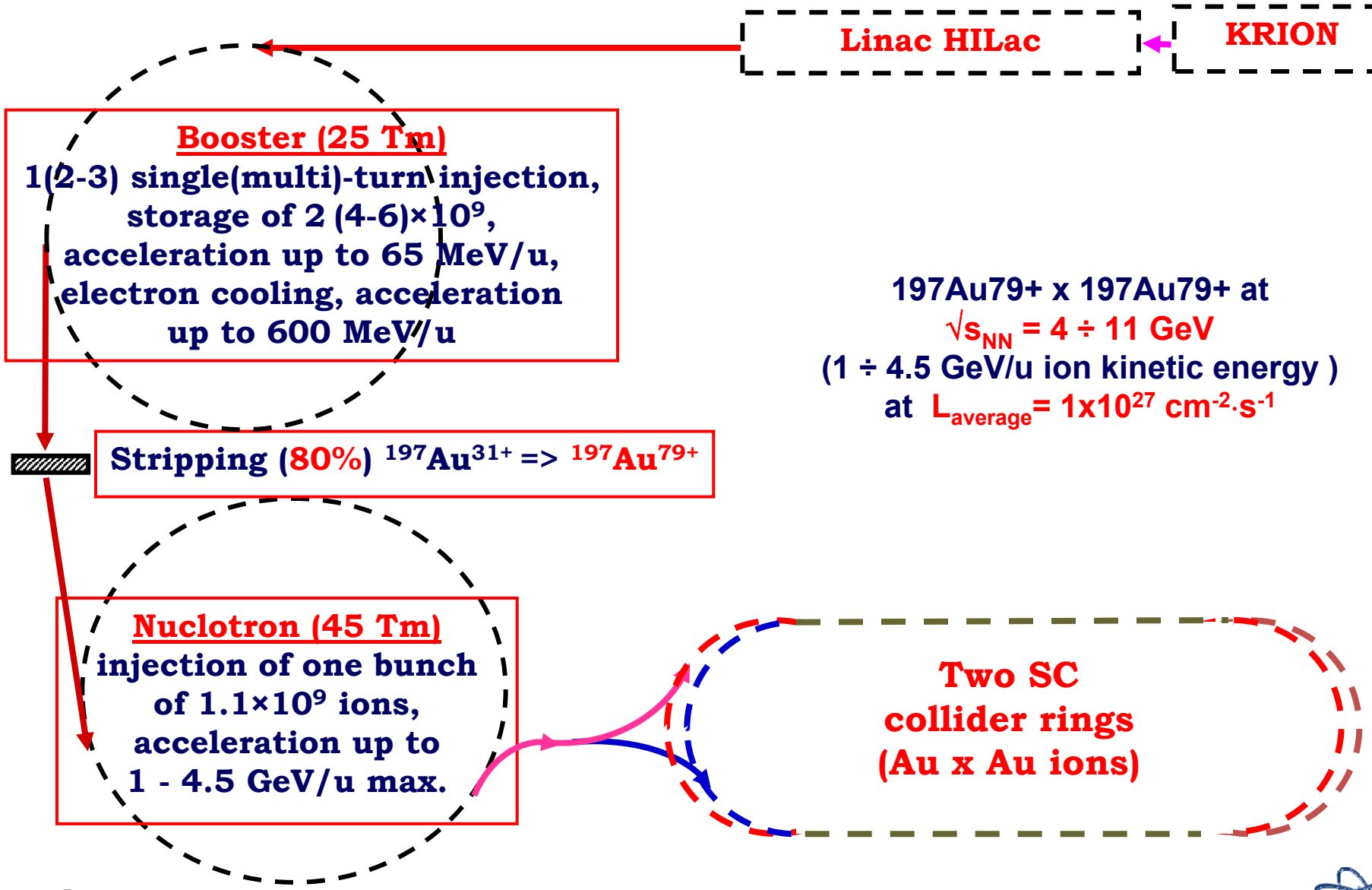
Injection complex development for the NICA project

Joint Institute for Nuclear Research
Andrei Martynov
On behalf of accelerator division of LHEP/JINR

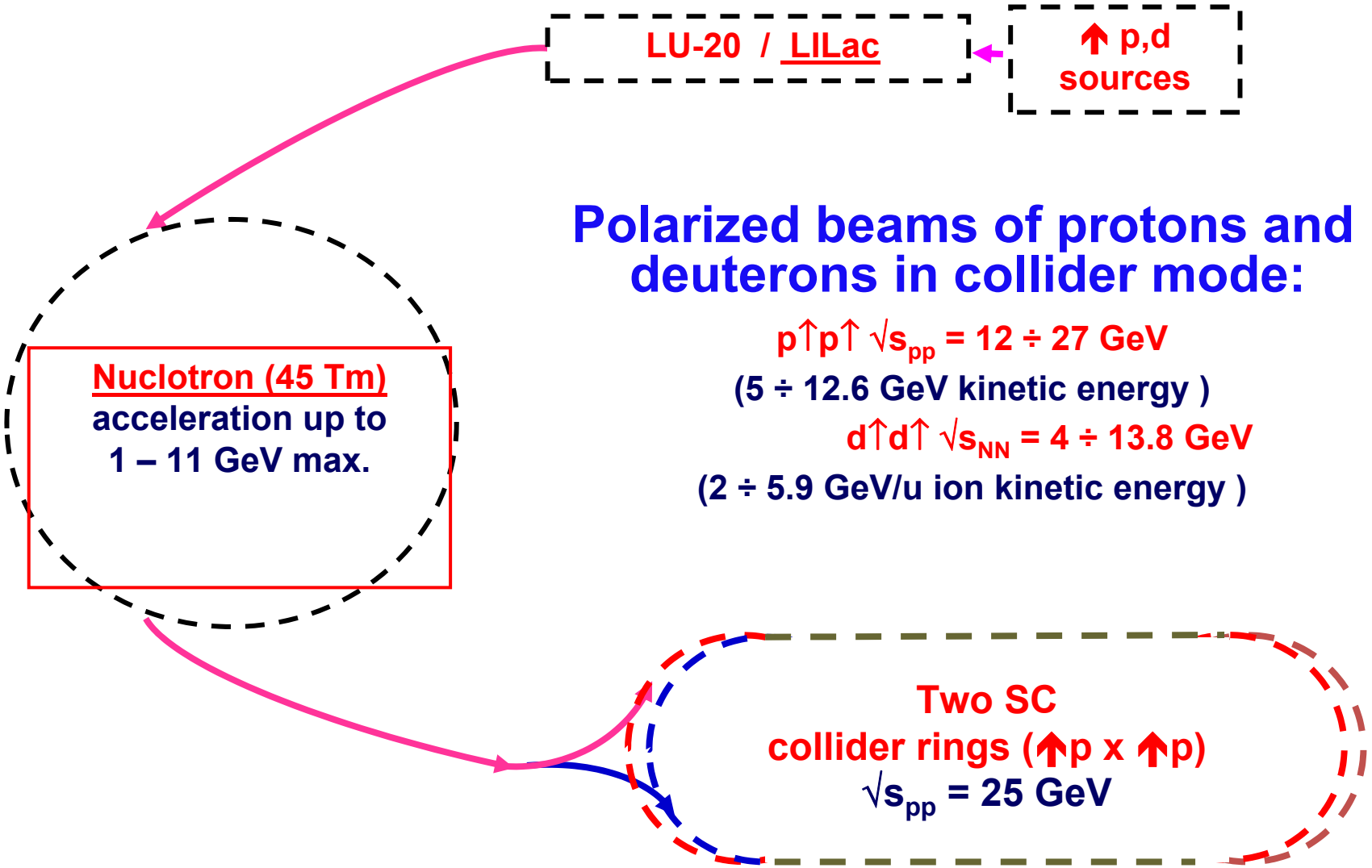
Complex NICA, JINR, Dubna



NICA accelerator complex (2021)



NICA accelerator complex



Polarized beams of protons and deuterons in collider mode:

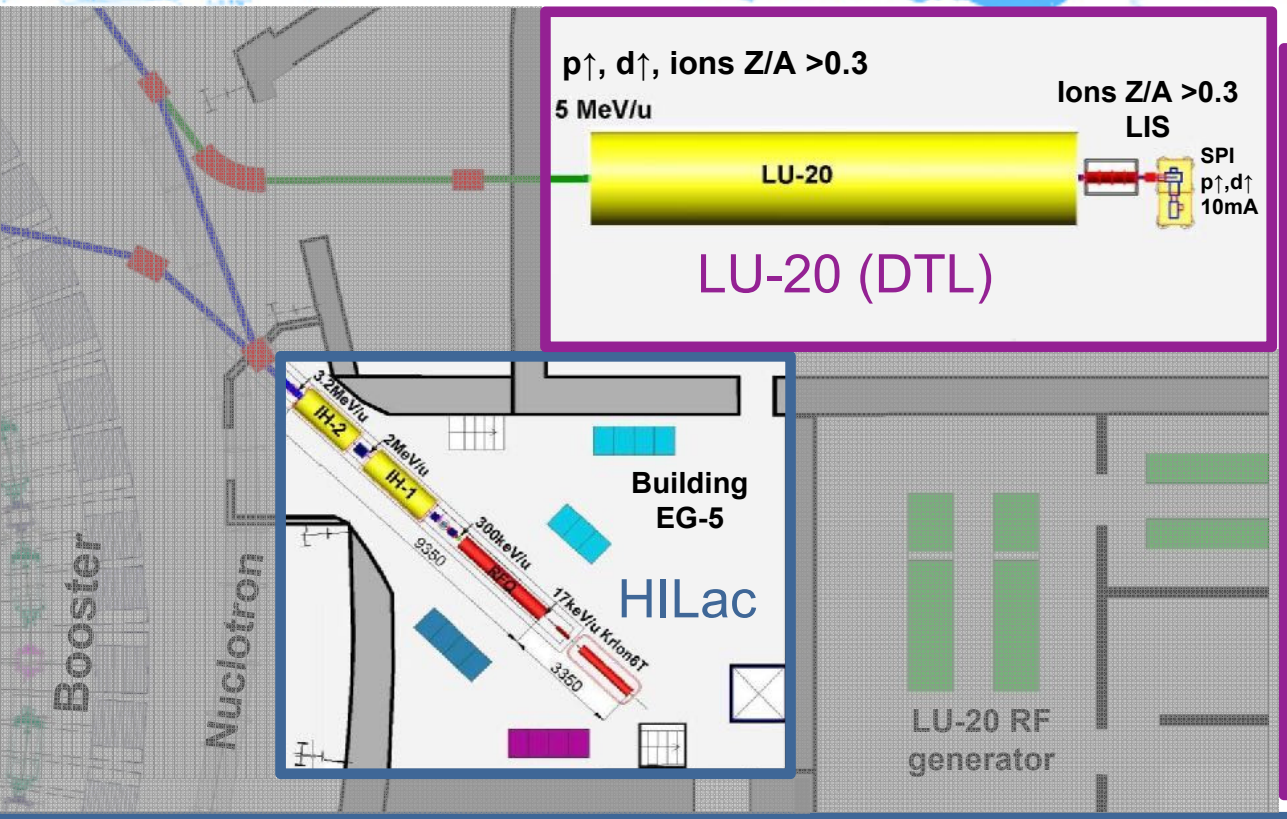
$p\uparrow p\uparrow \sqrt{s_{pp}} = 12 \div 27$ GeV

(5 ÷ 12.6 GeV kinetic energy)

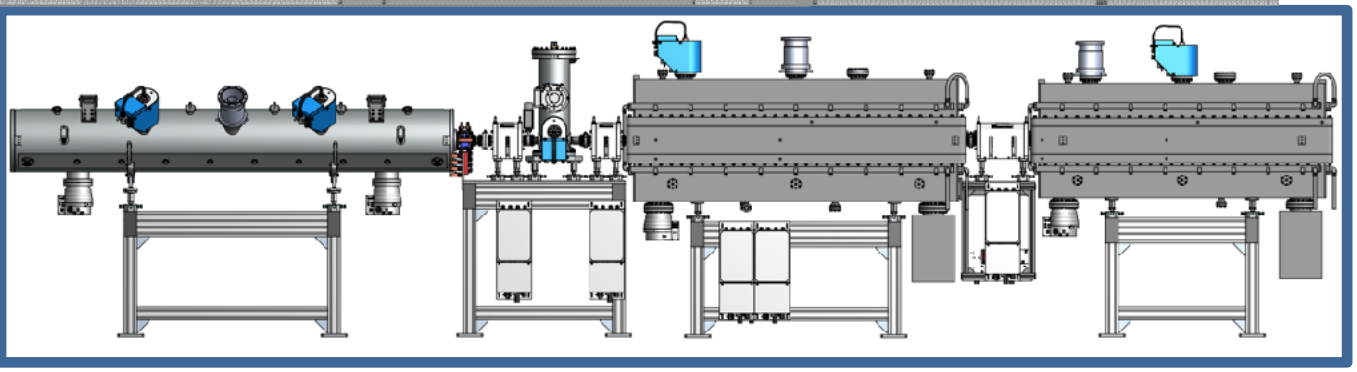
$d\uparrow d\uparrow \sqrt{s_{NN}} = 4 \div 13.8$ GeV

(2 ÷ 5.9 GeV/u ion kinetic energy)

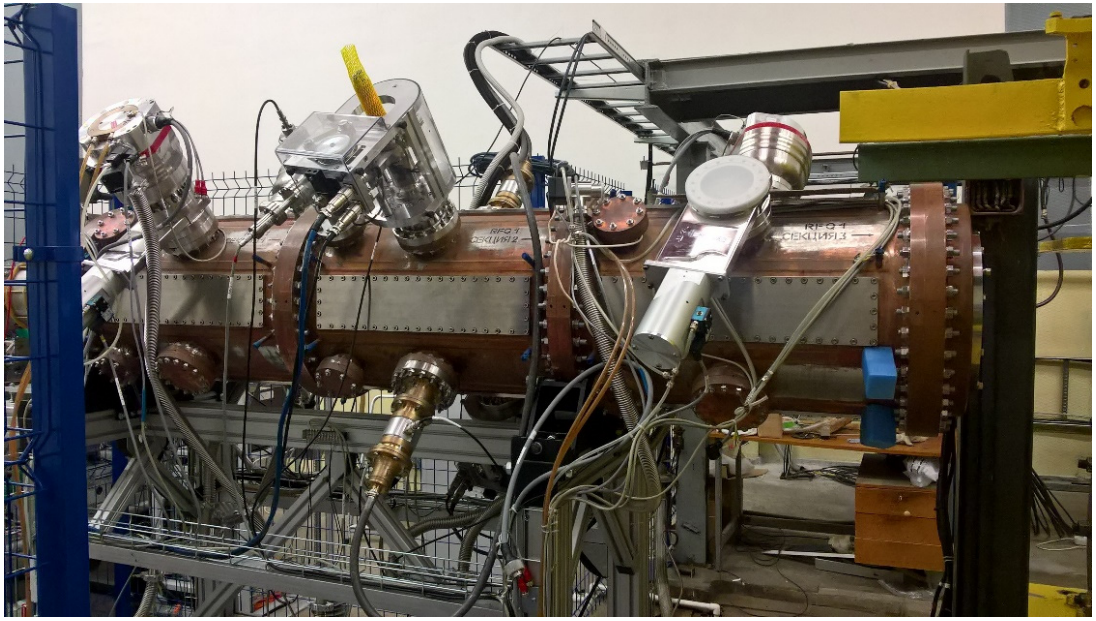
NICA Injectors Today



2*βλ Mode



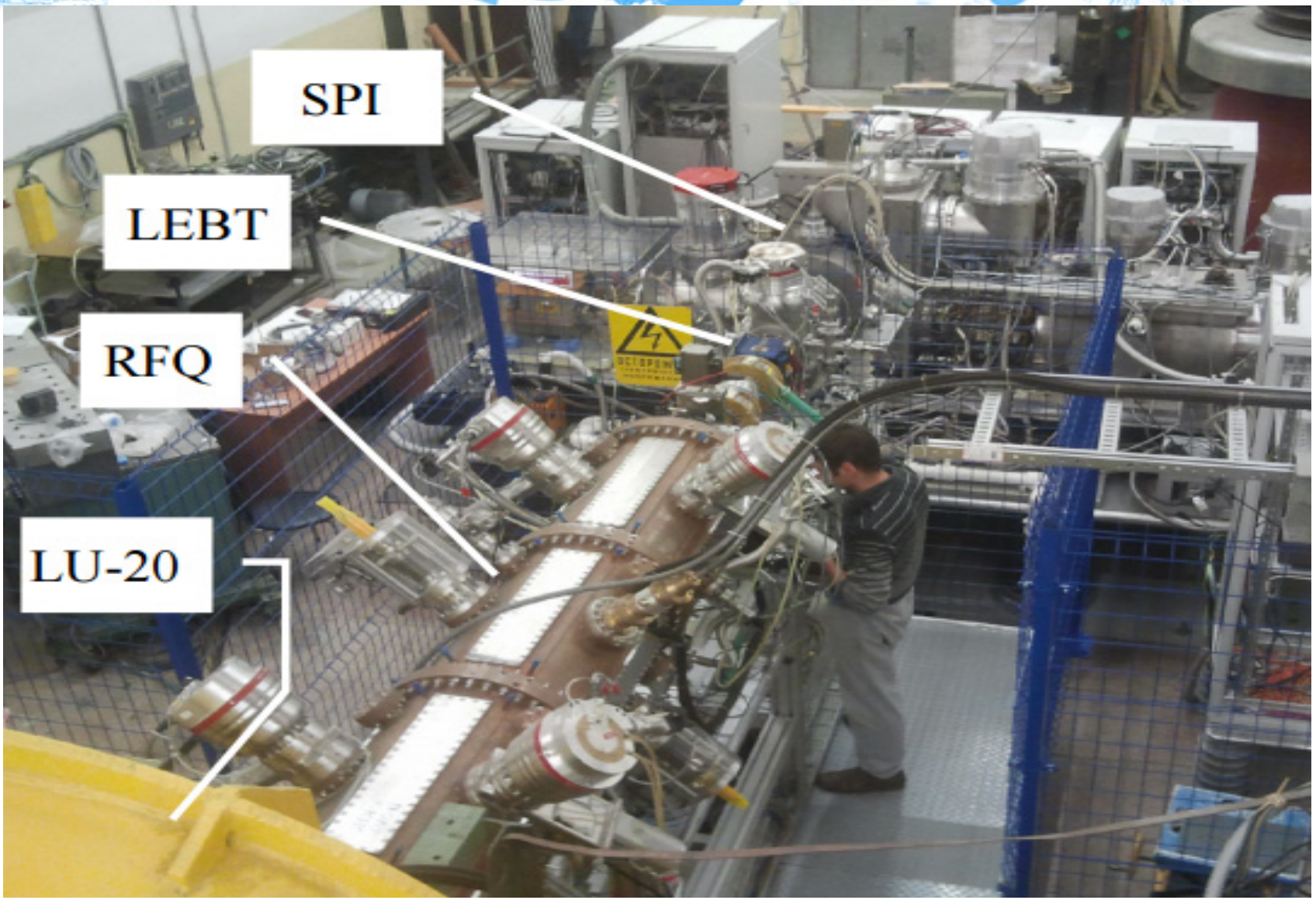
RFQ as a new injector for LU-20 (DTL)



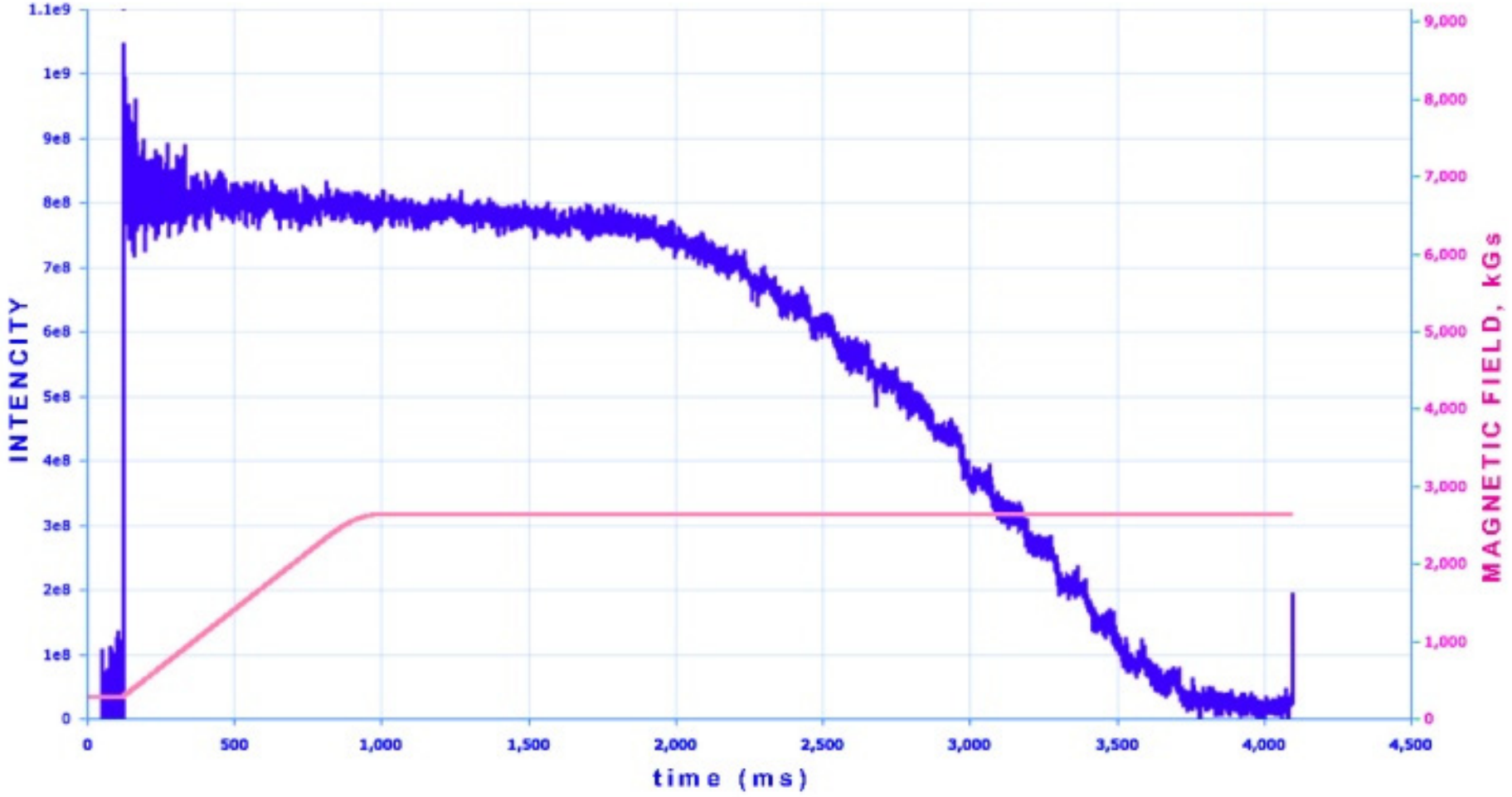
Developed by collaboration of JINR, ITEP, VNIITF (Snezhinsk), MEPHi (2016)

q/A	1.0	0.5	≥ 0.3
Injection energy, [keV]	31	61.8	103
Max current, [mA]	10	20	10
Output energy [keV/u]	156		
Norm emittance (output) [π·cm·mrad]	≤ 0.5		
RFQ length, [m]	2.2		
Transmission, %	> 85%	> 89%	> 93%
In LU-20 acceptance with buncher	70 %	71 %	80 %
In LU-20 acceptance without buncher	15 %	15 %	20 %

Ion source installation



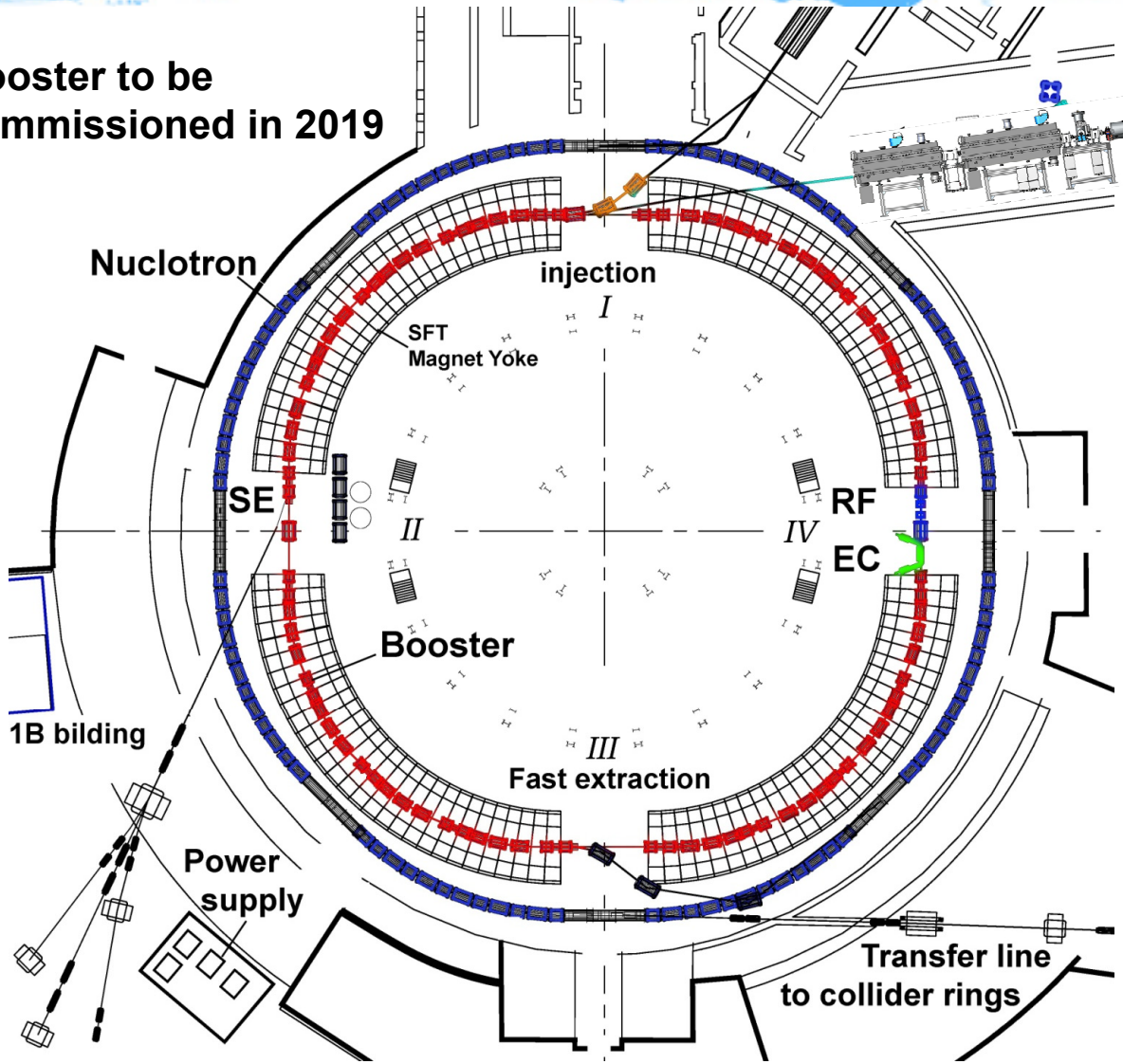
Polarized deuteron acceleration: Intensity 2÷5*10^8 per cycle



Deuteron Spin Structure experiment, internal target of the Nuclotron

New NICA Booster for heavy ions

Booster to be commissioned in 2019

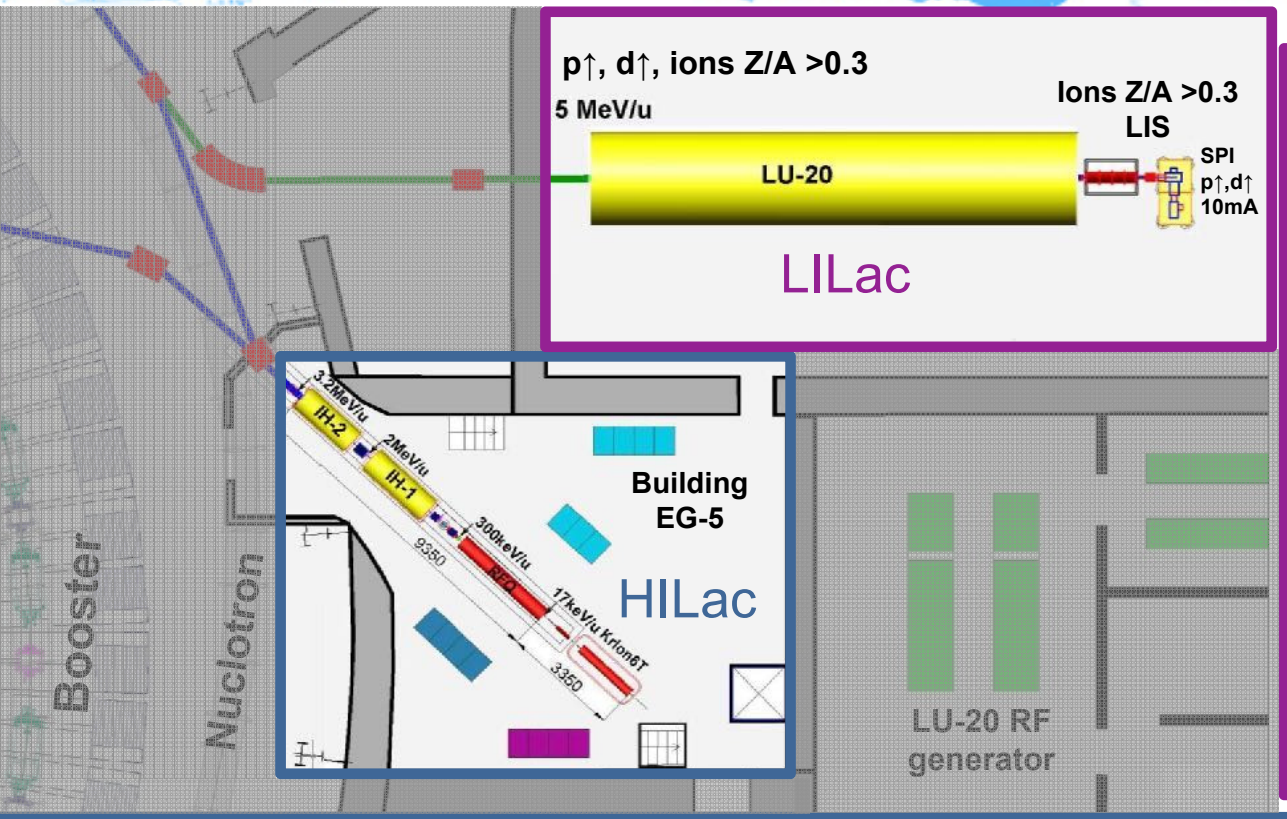


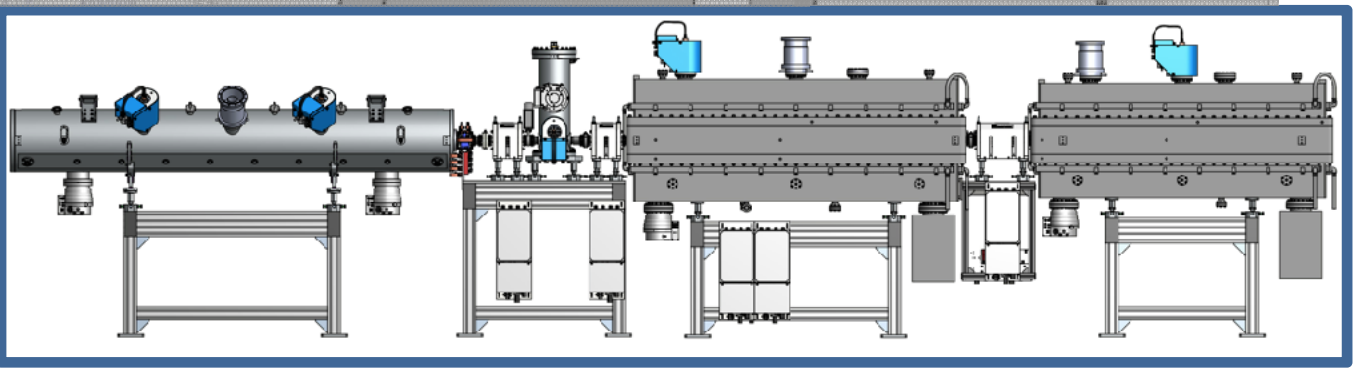
HILac

	Booster
Magnetic rigidity, T/m	25
Radius, meters	211
Beam intensity, particles per pulse	2-6x10^9
Max. energy	600 MeV/u

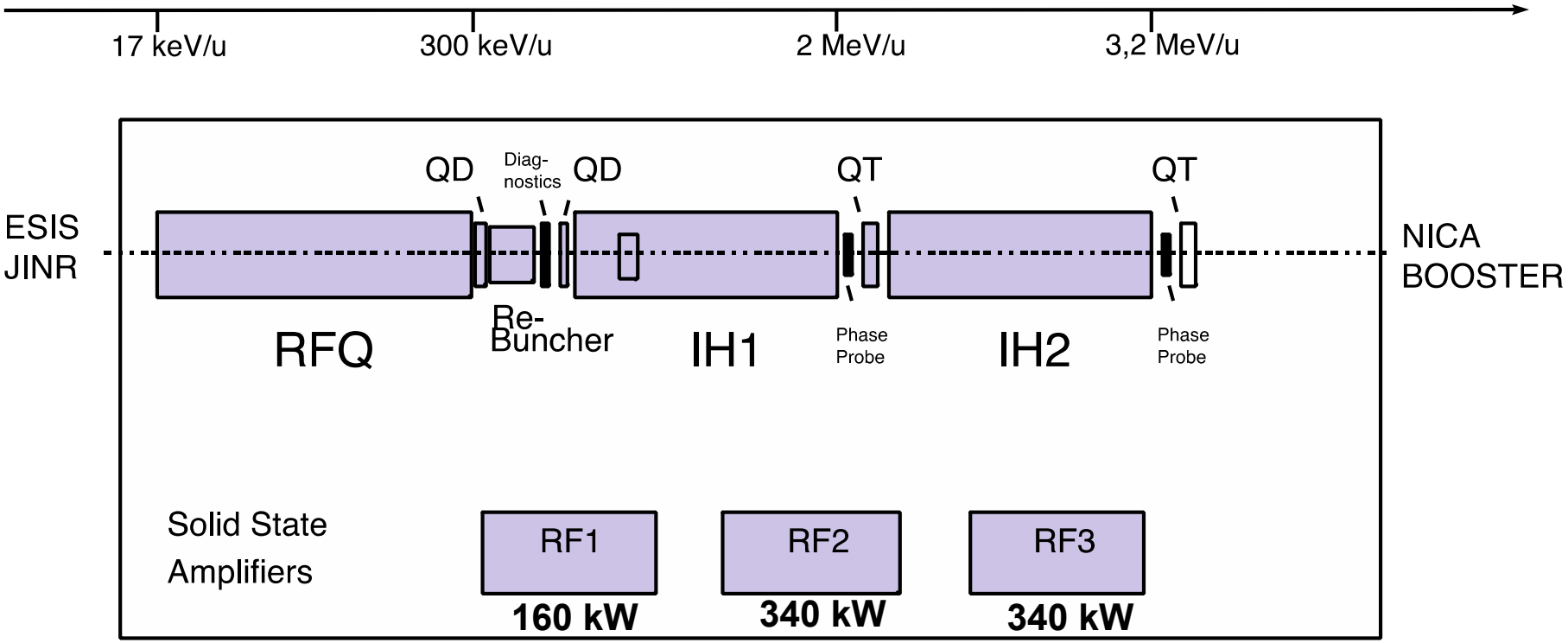
Dipoles	
Number of dipoles	40
Maximum magnetic field, T	1.8
Effective field length, m	2.2
Bending angle, deg	9.0
Curvature radius, m	14.09
Vacuum chamber, mm^2	128x64
Quadrupoles	
Number of quadrupoles	48
Field gradient, T/m	19.7/-20.3
Effective field length, m	0.4

NICA Injectors



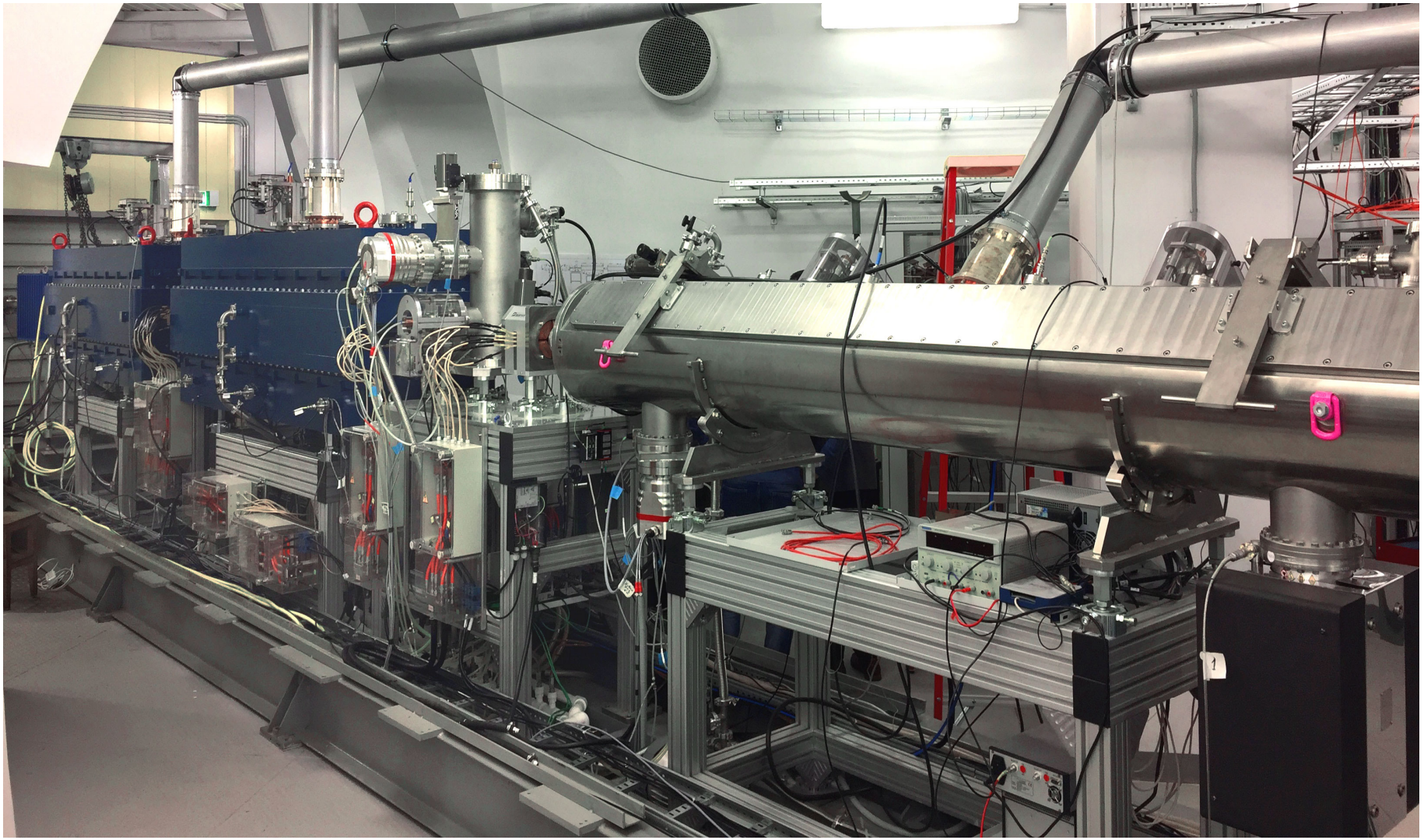


HILAC Setup



Bevatech GmbH (Germany)

HILAC at the injector building

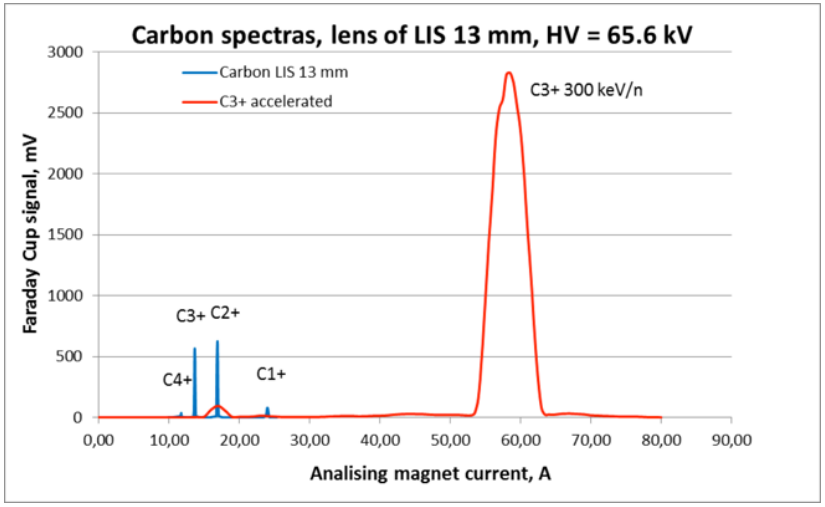


HILAC Parameters

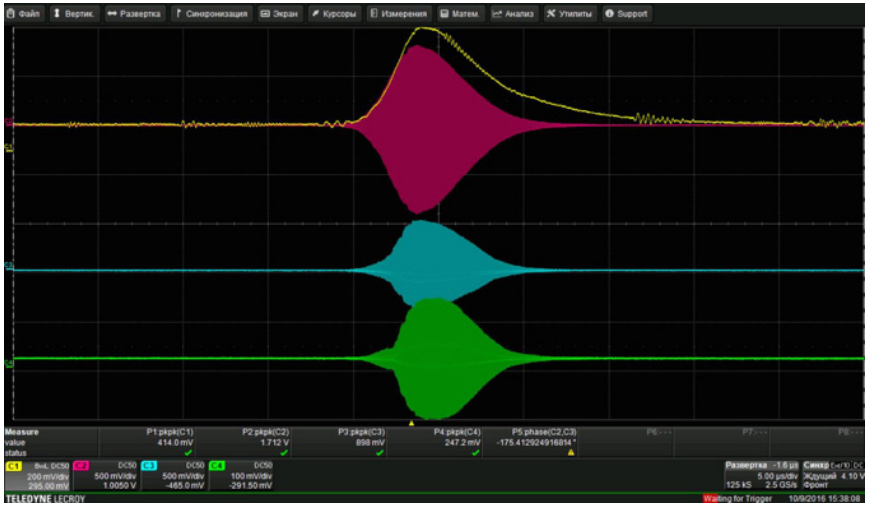
Parameter	Value HILAC
A/q (max)	6.25 for 10 mA Au^{32+}
A/q (min)	1 for ⩽ 2 mA p
Frequency	100.625 MHz
RF amplifier (RFQ/IH)	140 kW / 340 kW
Repetition rate	⩽ 10 Hz
Max. pulse length RF	200 µs
Pulse length beam	30 µs
E_{in} RFQ/E_{out} RFQ	17 AkeV/300 AkeV
Transmission RFQ	90 %
E_{out} IH-DTL (2xIH)	3.2 AMeV
Total Transmission HILac after LEBT	≥80 %
ε_{in} (trans, norm)	0.6/0.4 π mm mrad

Design Parameter HILAC

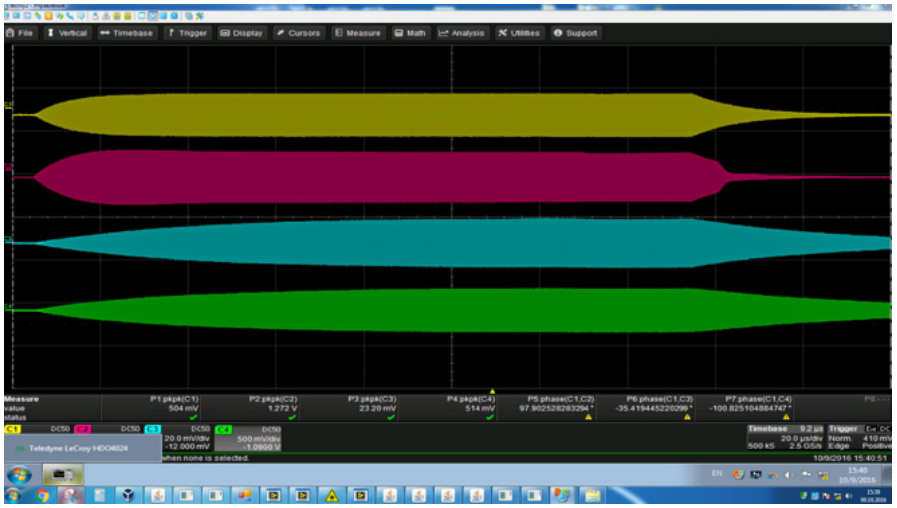
Commissioning HILAC



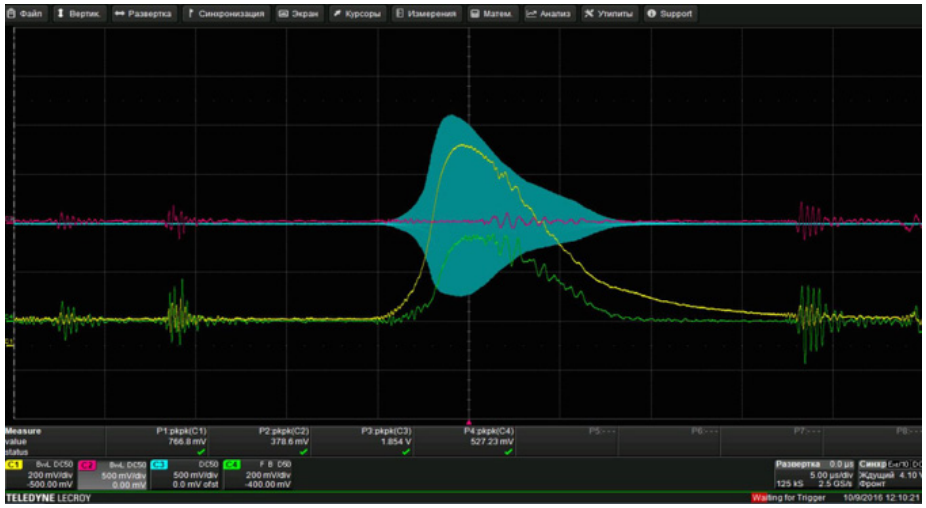
1. RFQ at nominal energy of 300 AkeV



3. Phaseprobe Signals MEBT, IH 1 & IH 2



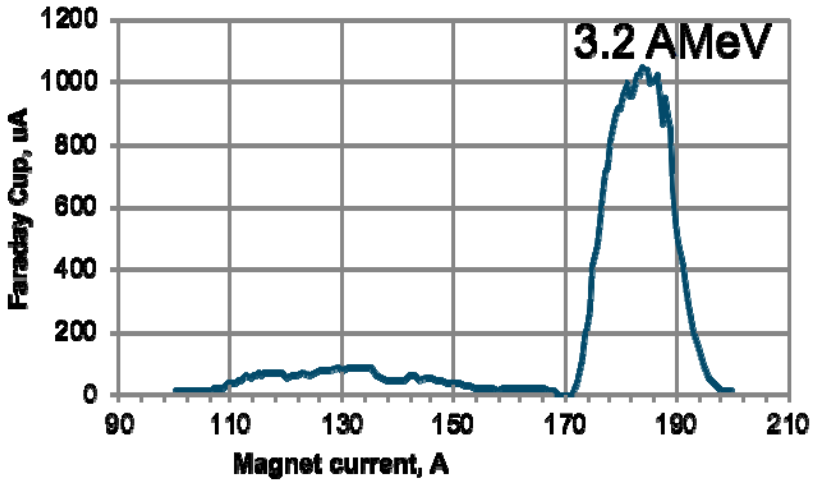
2. All 4 cavities are in transient oscillation



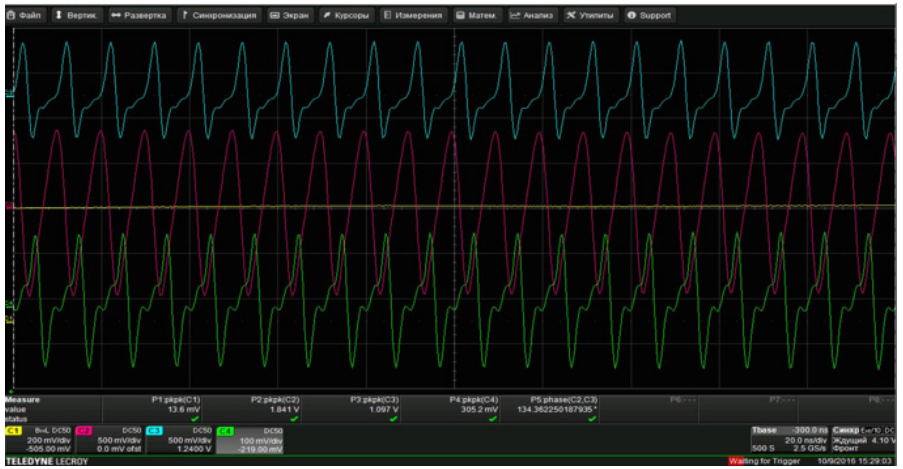
4. ICTs RFQ & IH 2

Commissioning HILAC

1.a. Energy spectrum after HILac

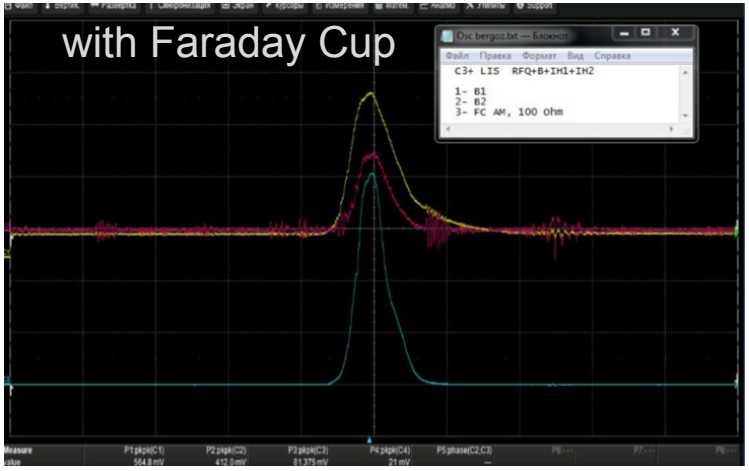


1.b. Corresponding phase probe signals



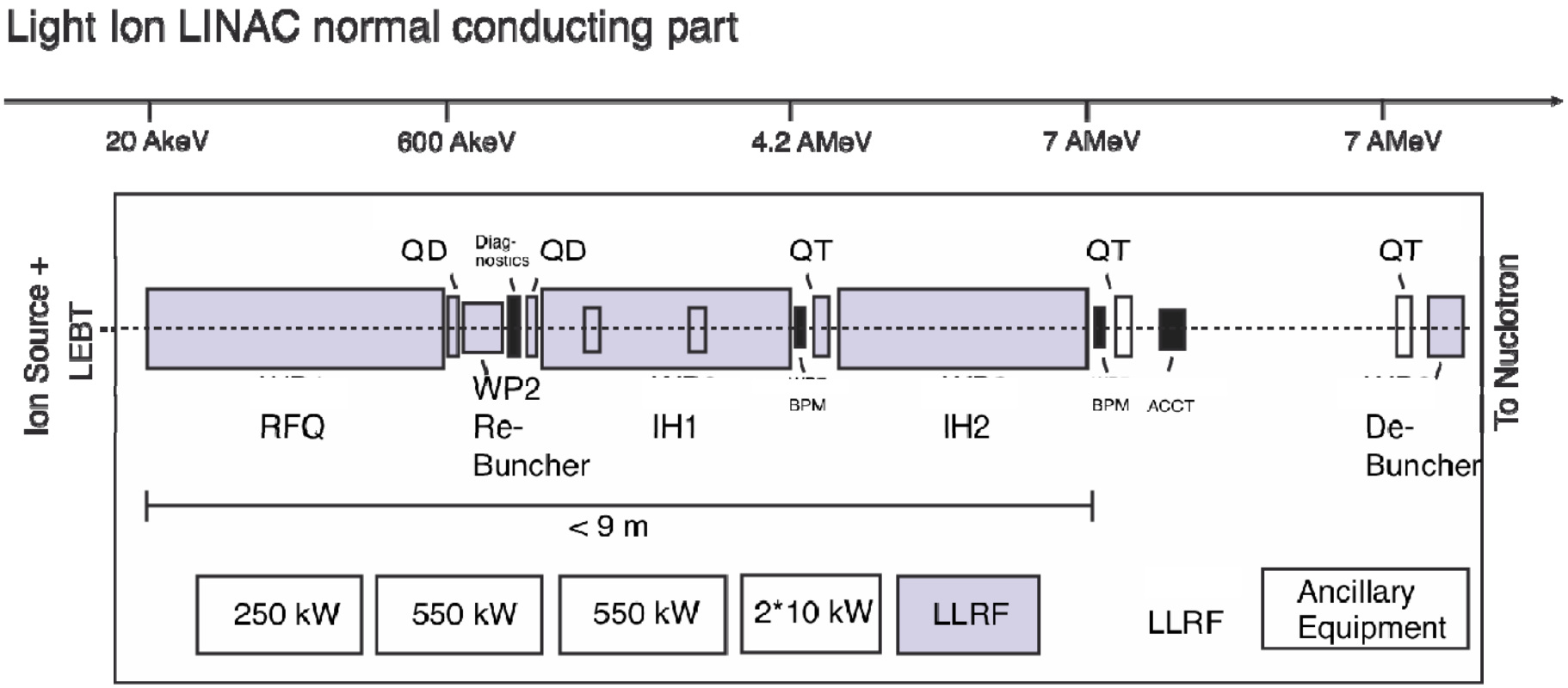
2. Energy spectrum IH 1 Dipole spectrometer

3. Transmission measurement



LILac Concept

LILac Setup



Bevatech GmbH (Germany)

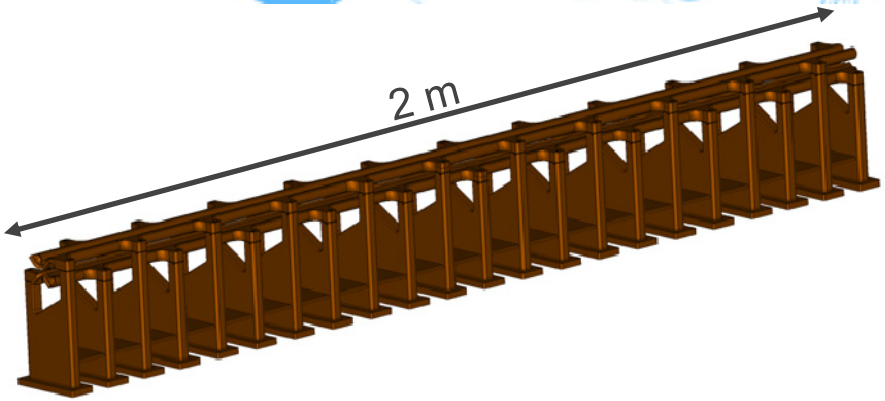
LILAC Parameters

Parameter	Value LILAC (TDR)
A/q (max)	3 for 15 mA C^{4+}
A/q (min)	1 for 5 mA protons
Frequency	162.5 MHz
RF amplifier (RFQ/IH)	250 kW / 550 kW
Repetition rate	5 Hz
Max. pulse length RF	300 µs
Pulse length beam	30 µs
E_{in} RFQ/E_{out} RFQ	30 AkeV / 600 AkeV
Transmission RFQ	90 %
E_{out} IH-DTL (2xIH)	7 AMeV
Total Transmission LILac after LEBT	≥80 %
$\varepsilon_{in,rms}$ (trans, norm)	0.15 π mm mrad

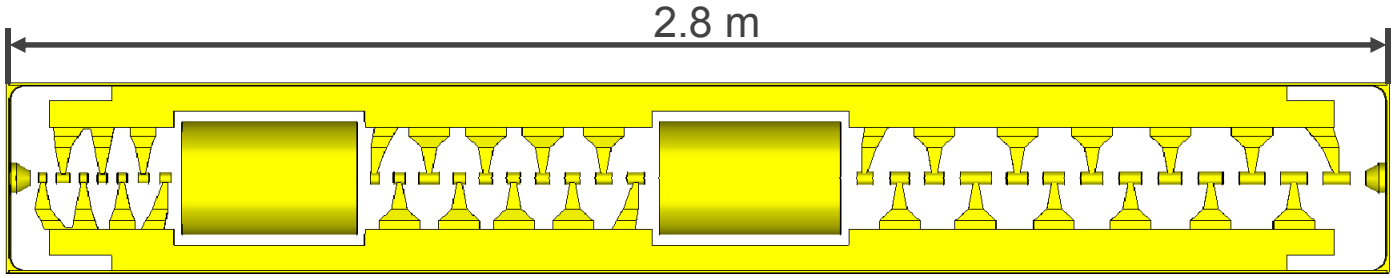
Design Parameter LILAC

NICA – LILac Cavities

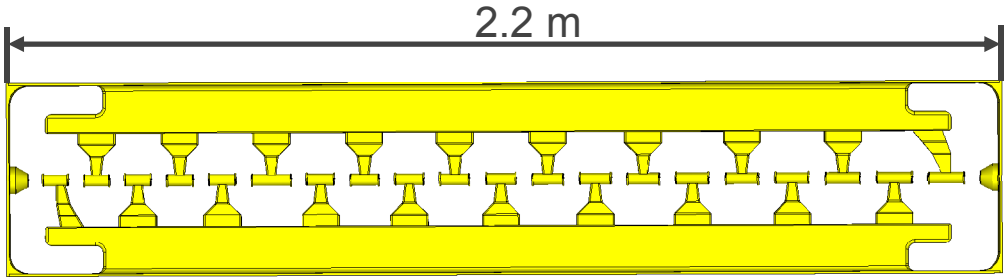
4-rod RFQ
- 162.5 MHz
- 2 m length
- 22 stems



IH1
- 162.5 MHz
- 2.8 m length
- 0.5 m width & height
- 28 stems
- 2 internal lenses

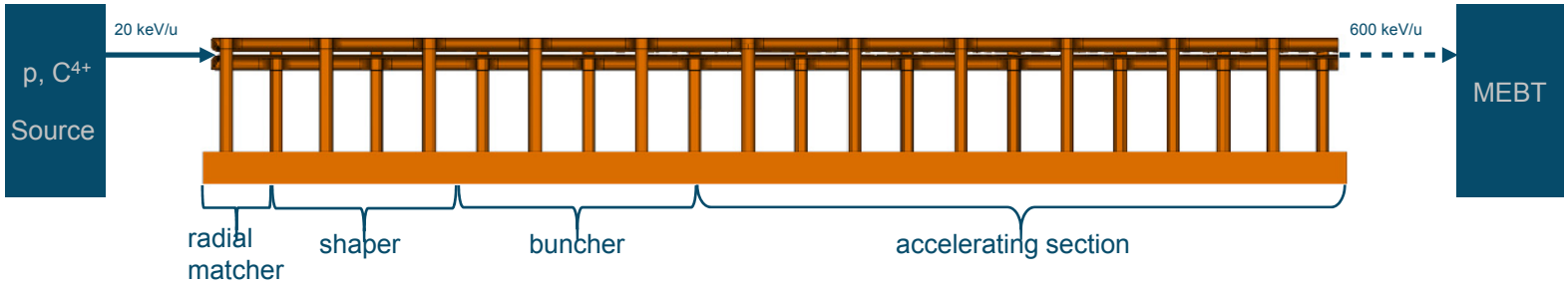


IH2
- 162.5 MHz
- 2.2 m length
- 0.5 m width & height
- 20 stems



NICA – LILac Layout

RFQ

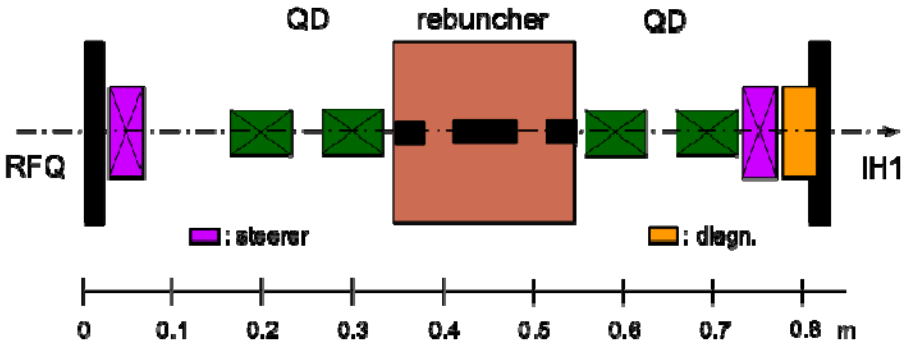


Cavities
- RFQ
- 2 IH-DTLs
- Re-Buncher
- De-Buncher

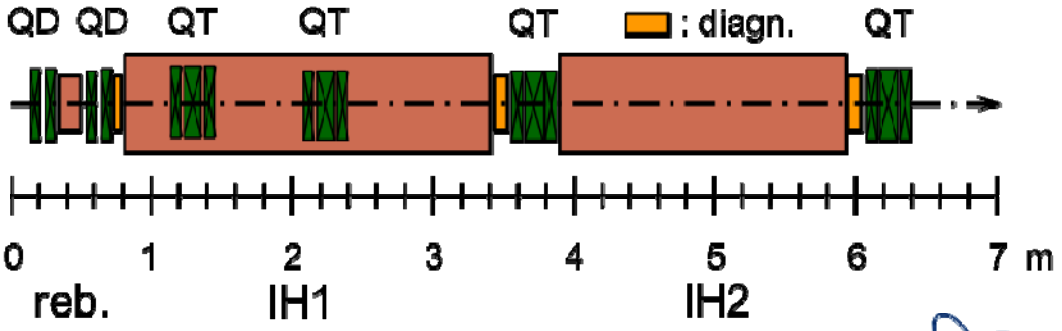
Magnets
- 2 QD
- 2 internal QT (in IH1)
- 3 QT
- 2 steering magnets

Diagnostics
- 2 ACCTs
- 3 BPMs

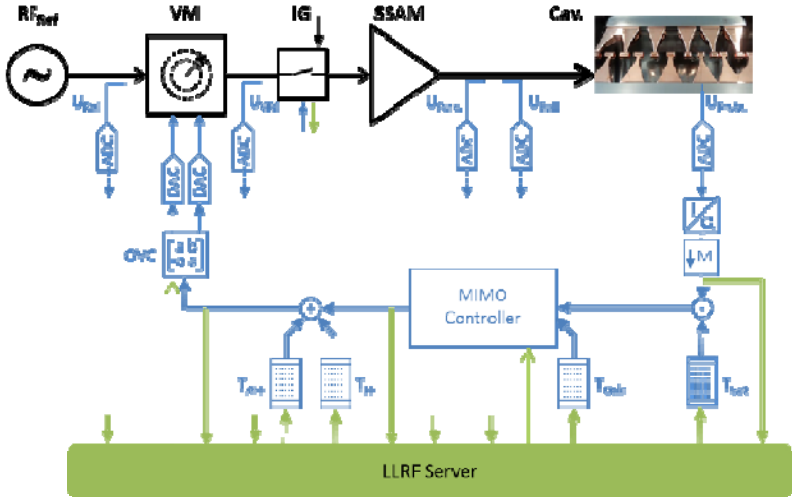
MEBT

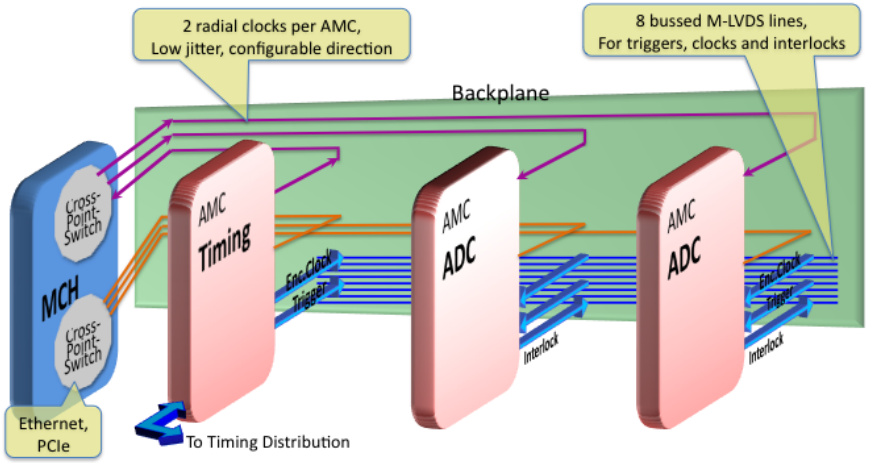


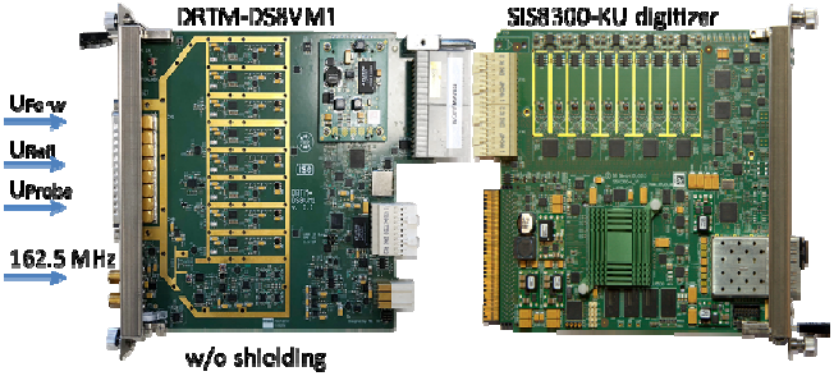
MEBT
+
IH-DTL

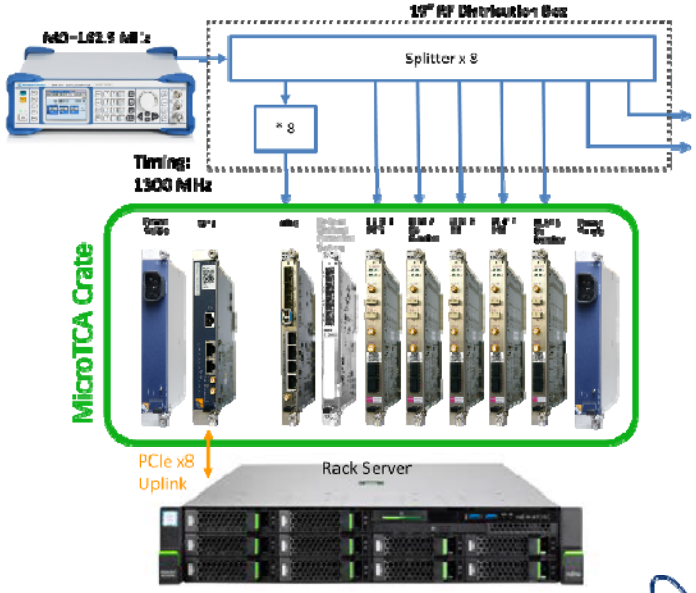


LILac LLRF based on MTCA-4

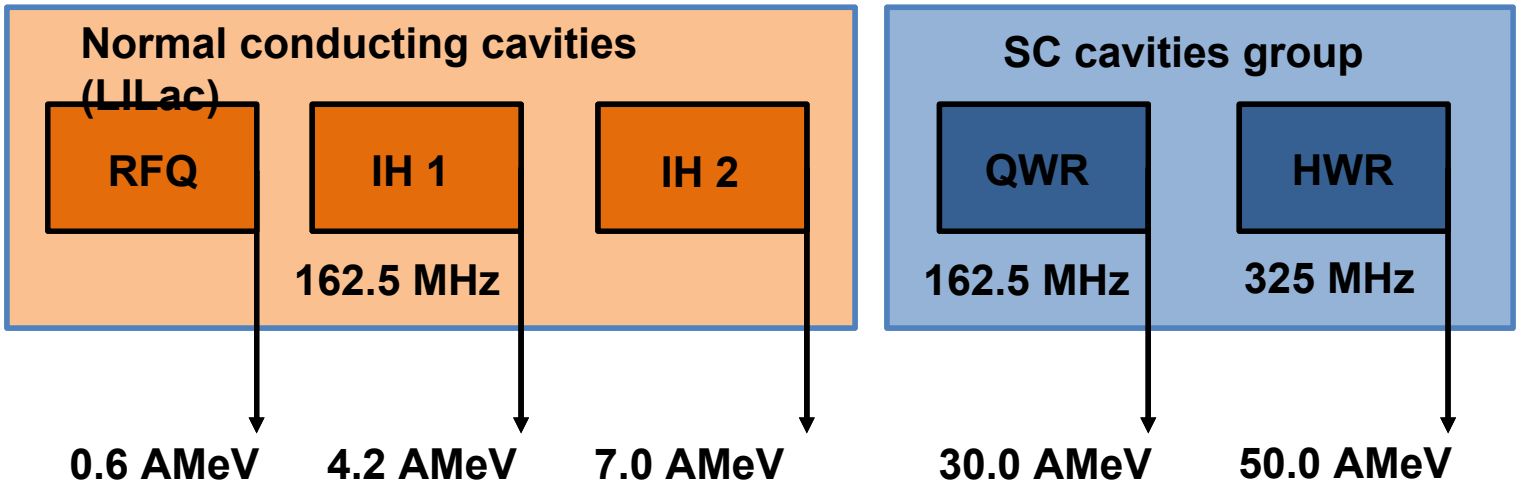


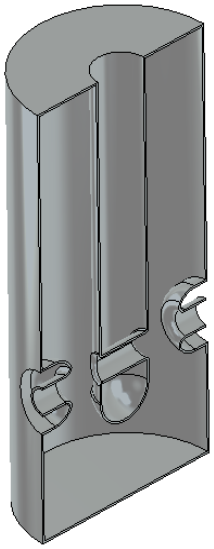




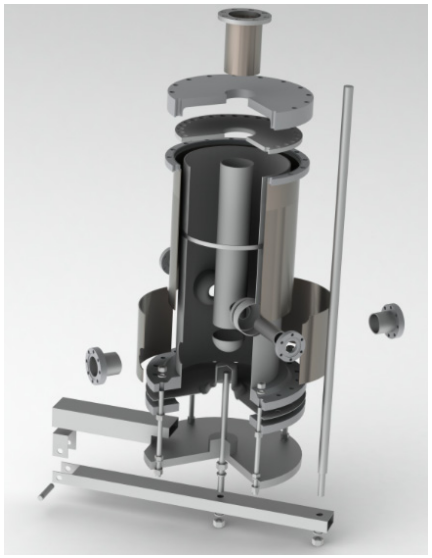


Superconducting linac





General view of 162,5 MHz QWR

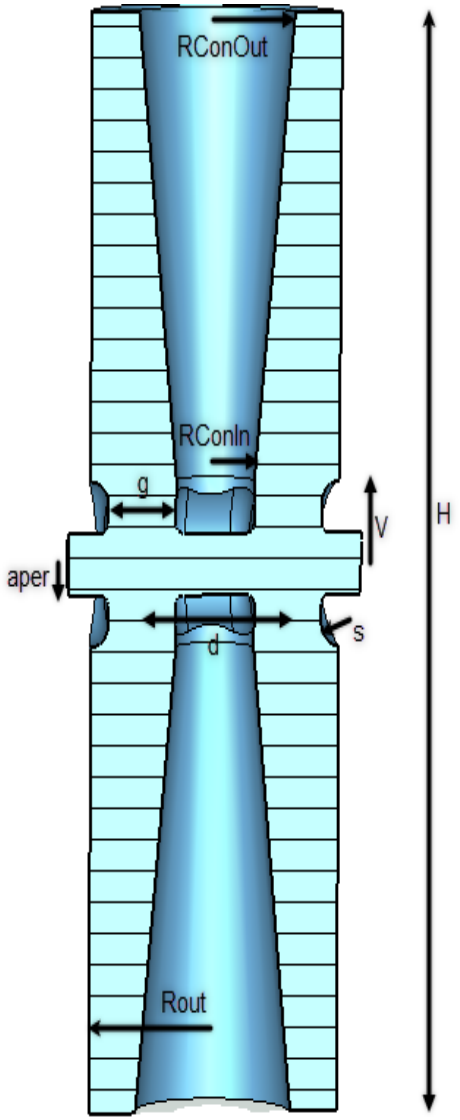


3D model for copper prototype manufacturing (RF and measurement loops are not visible)
MEPHi (Russia)

1st group SC cavities design - QWR

Parameter	Value
Frequency, MHz	162.5
Geometrical velocity, β_g	0.12
Maximal RF field on the axe, $E_{acc\ max}$, MV/m	6.0
Ratio of the peak electric surface field to the accelerating field, E_p/E_{acc}	6.4
Ratio of the peak surface magnetic field to the accelerating field, B_p/E_{acc}, mT/(MV/m)	11.4
Effective shunt impedance, r/Q_0, Ohm	488
Geometric factor, $G=R_s/Q$, Ohm	37
Transit time factor, TTF_0	0.88

2nd group: HWR with conical central conductor



In cooperation with MEPHI

HWR type	Cylind-rical	Conical
Operating frequency, *f*, MHz	325	
Geometrical velocity, β_g	0.21	
Cavity height, mm	431	448
Cavity radius, mm	97	97
Ratio of the peak electric surface field to the accelerating field, E_p/E_{acc}	3.9	3.3
Ratio of the peak surface magnetic field to the accelerating field, B_p/E_{acc}, mT/(MV/m)	7.3	5.6
Effective shunt impedance, r/Q_0, Ohm	252	303
Geometric factor, $G=R_s/Q$, Ohm	57	58

Summary

- Lu-20 has been modernized and demonstrates stable performance in acceleration runs with new RFQ
- New Heavy ion linac HILAC has been commissioned and ready for operation with booster synchrotron
- New Ion sources have been developed and tested during last Nuclotron runs
- Synchrotron “Nuclotron” demonstrated good performance and is ready for injection into NICA collider
- Booster ring is under construction and scheduled for first beam run in 2019
- New light ion linac LILAC consisting of normal conducting- and SC-cavities for energies up to 50 MeV/u is under development

Thank you for attention!

Summary