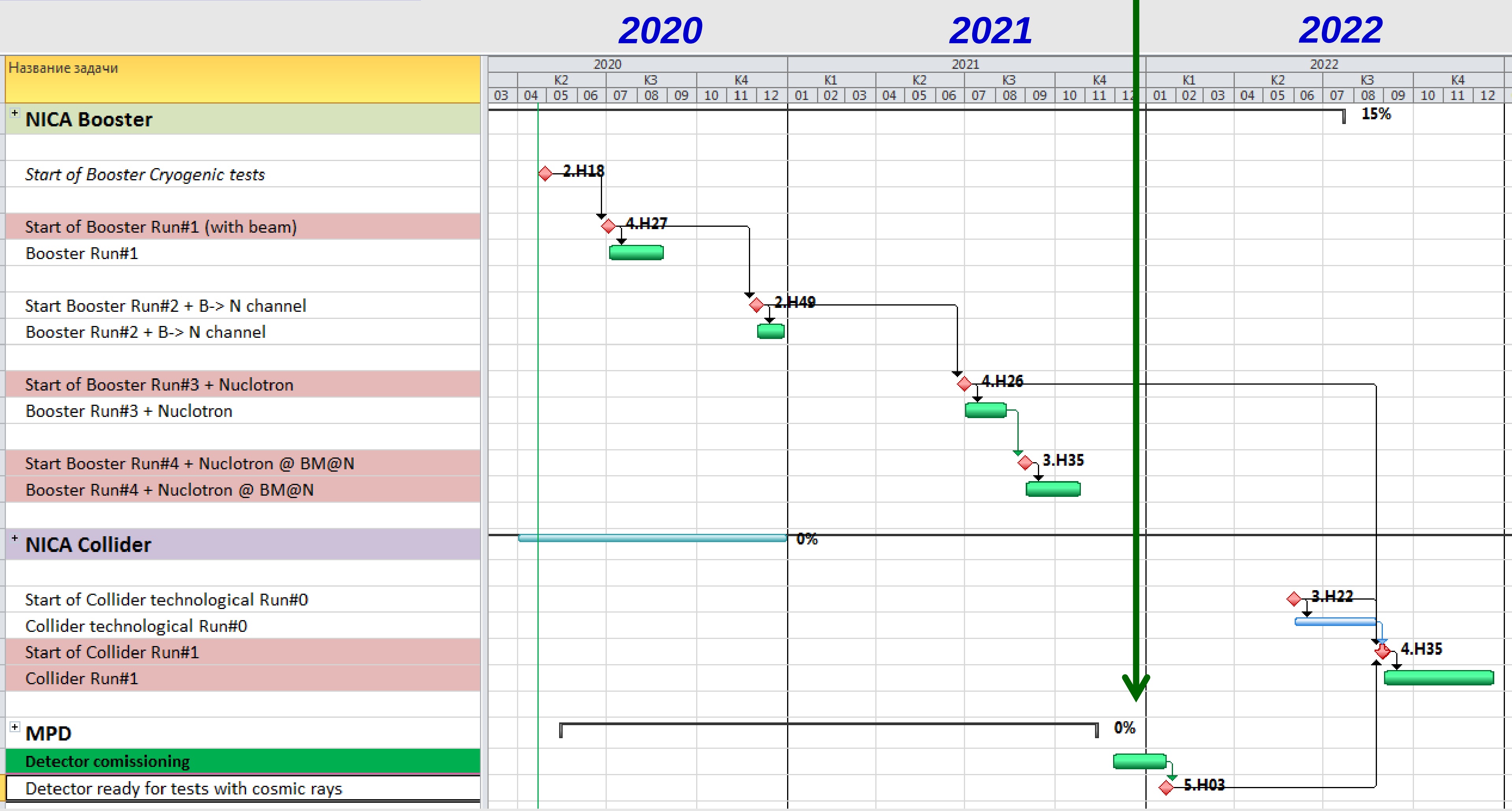
Construction and commissioning of the NICA Complex

Key run-milestones

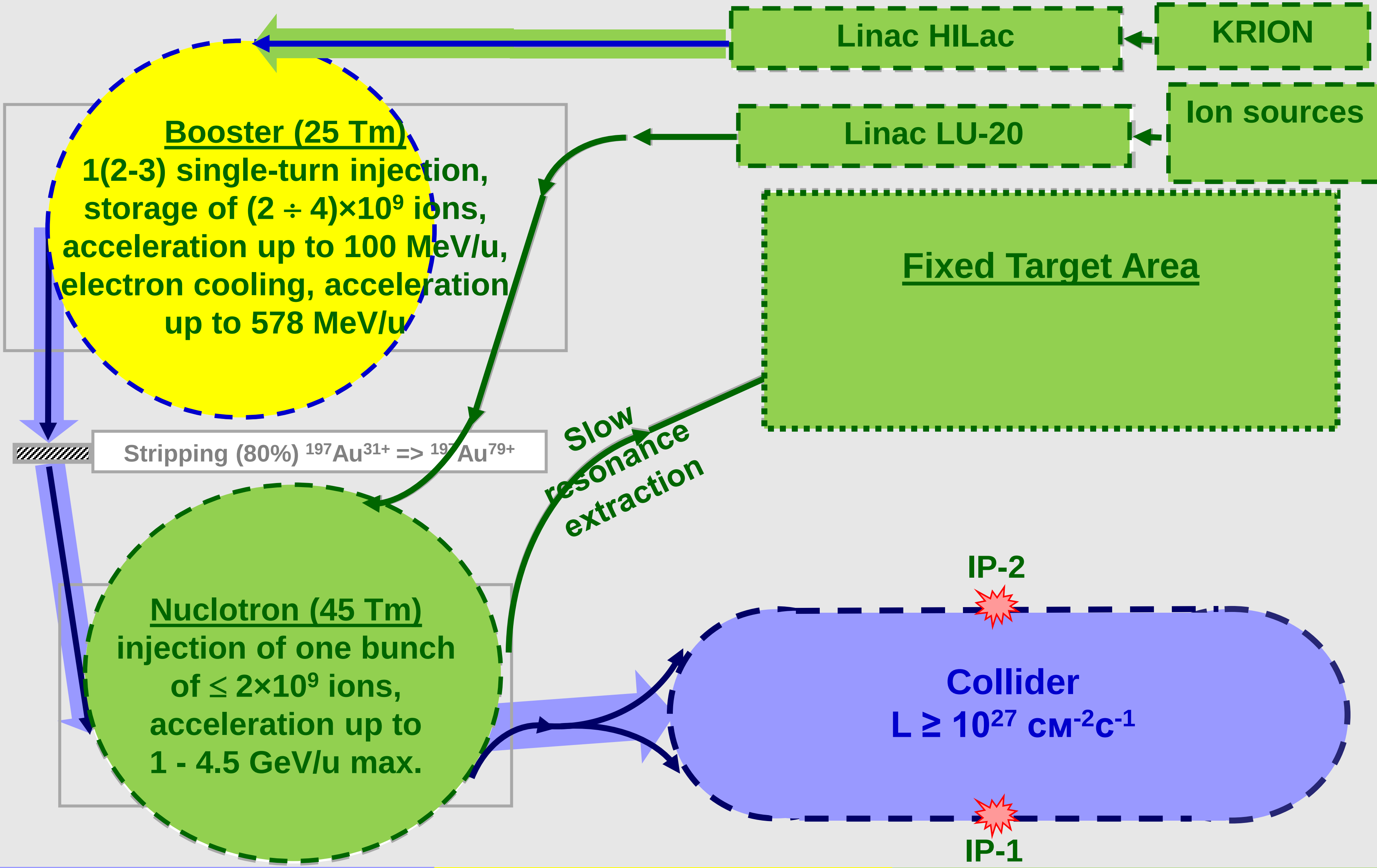
Previous MPD meeting

W47, 2021



Facility components – status

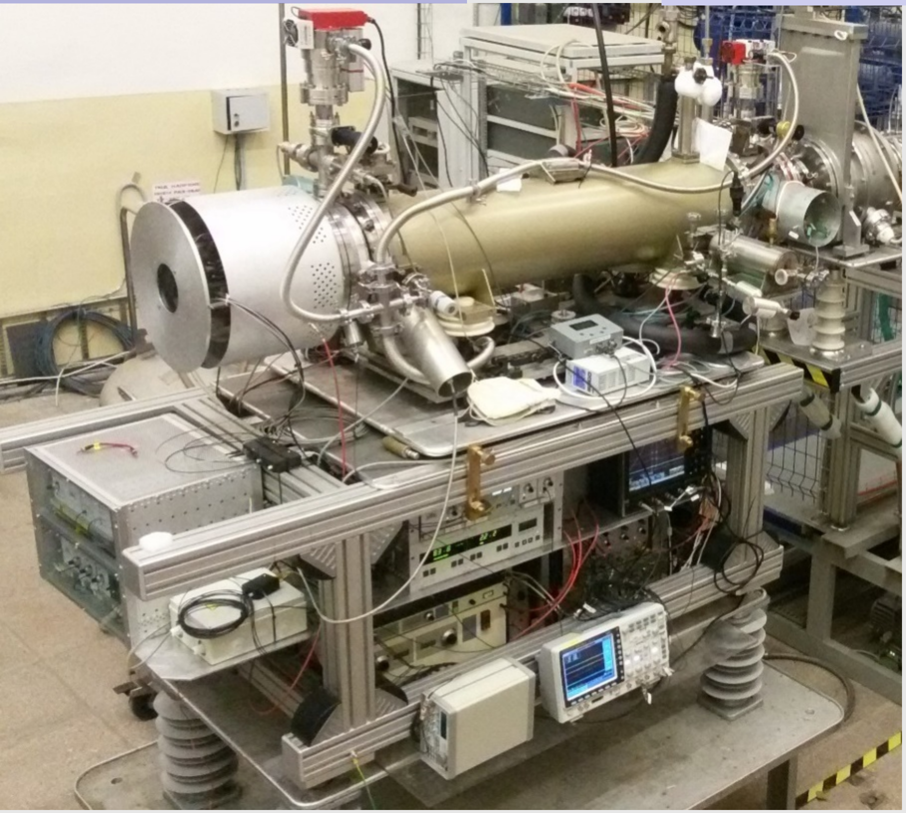
2020



work in progress | assembly | commissioned / existing

ESIS "KRION -6T" heavy ion source

- Development in progress

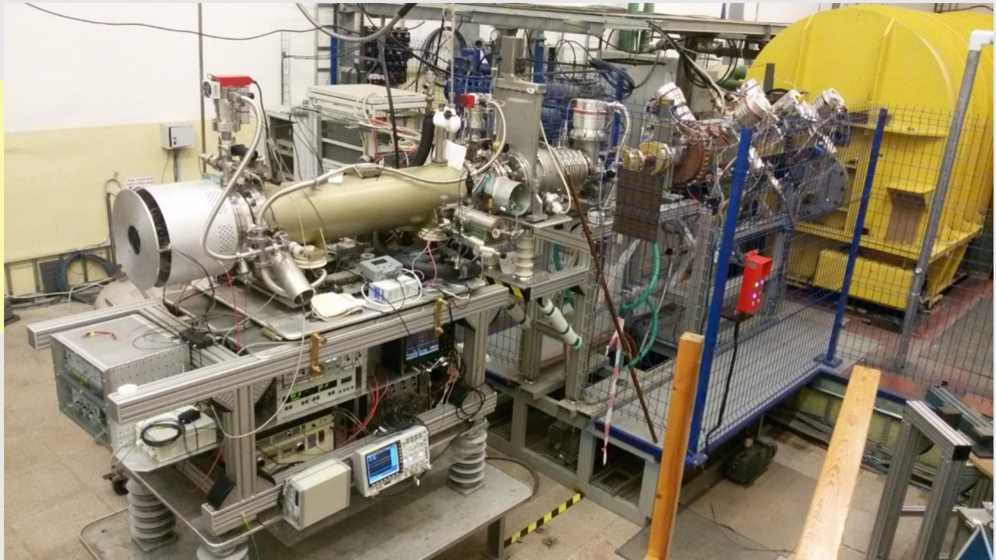


Theoretical and **achieved** parameters:

1) **Magnetic field up to B= 6.0 T, (5.0 T)**
2) **Energy of electron string $E_e \leq 25keV$ ($E_e \leq 12keV$)**

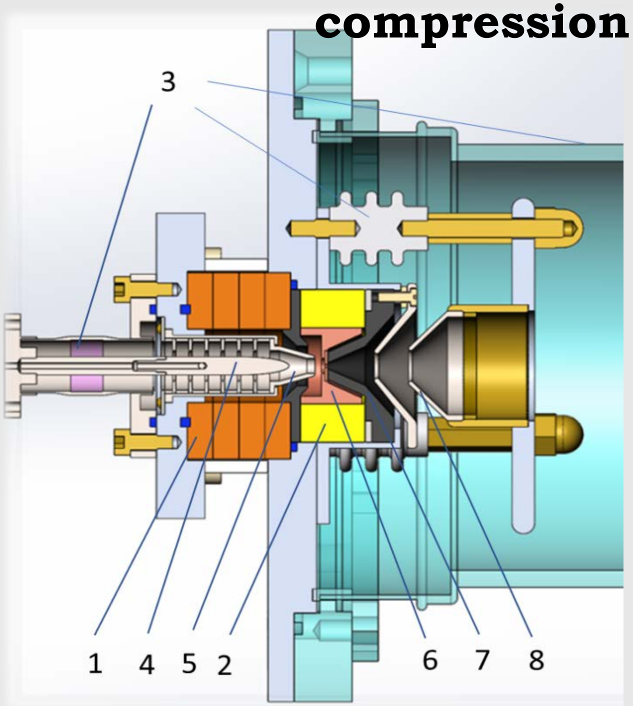
Ions species/charge state	Au^{31+} (Au^{51+}), Bi^{34+}
Expected ion int. *N_i*	2÷4 x 10^9 ppp Au^{31+} (5x10^8, 2019) (up to 6 x 10^8 ppp for Bi $^{34+}$ 2020)
Repetition rate	50 Hz (for Au^{31+}) 50÷100 Hz, 2018 3÷5 Hz for -Au^{51+}
Extraction time form the ESIS	8 ÷ 30 x 10^{-6} s
RMS emittance	0.6 π mm mrad (for 8 x 10^{-6} s extraction time);
Peak current in pulse	up to 10 mA

- KRION 6T was used during Nuclotron RUN #55 (March 2018) for SRC & BM@N experiments (Ar & Kr beams)

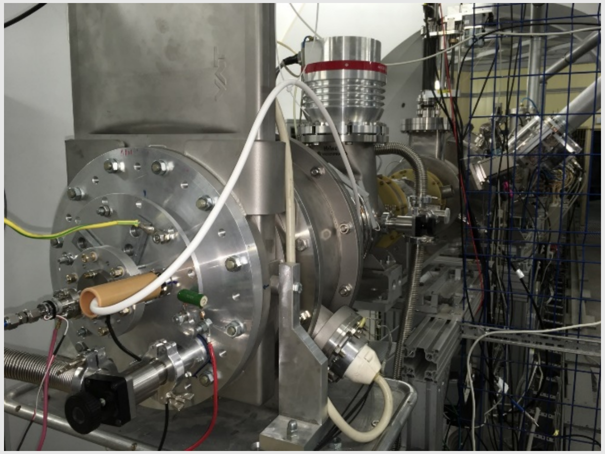


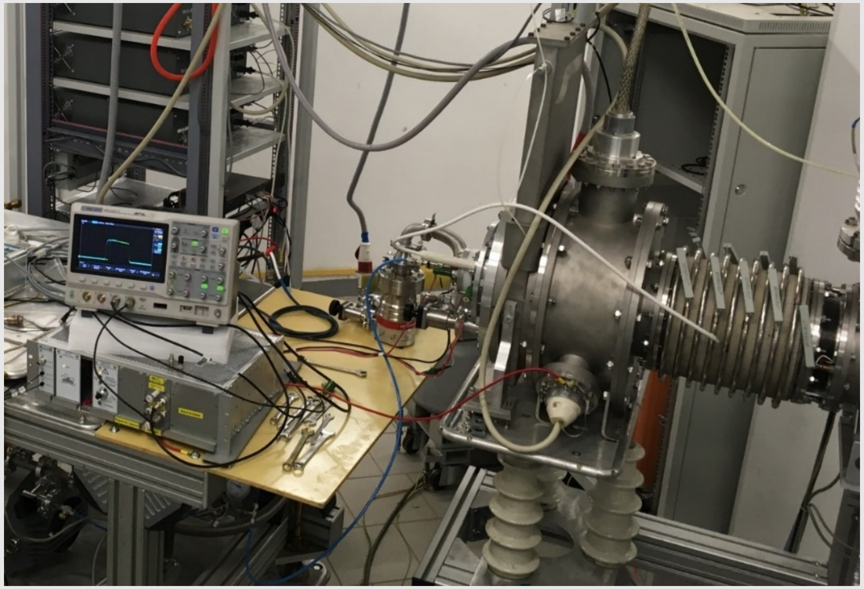
Ion source for commissioning

Ion source with a cold magnetron cathode and magnetic plasma compression.



For the Booster commissioning the He^{1+} ion beam will be used.



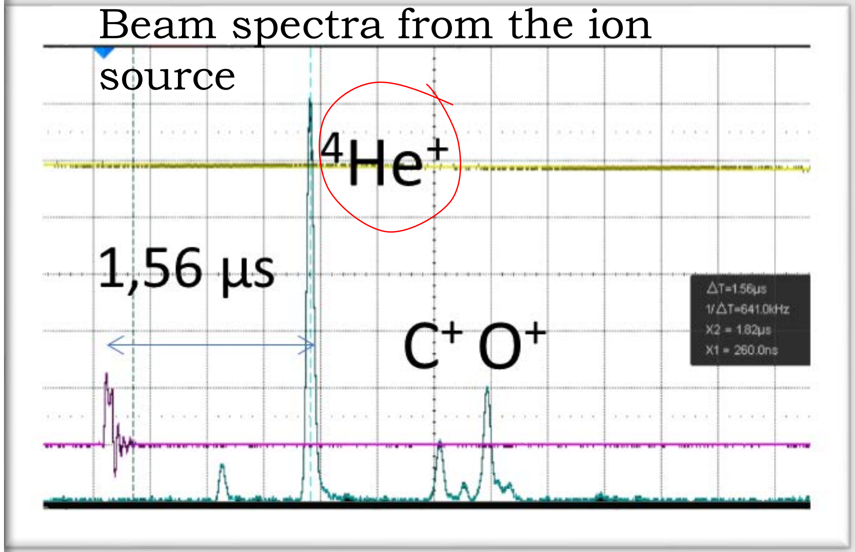


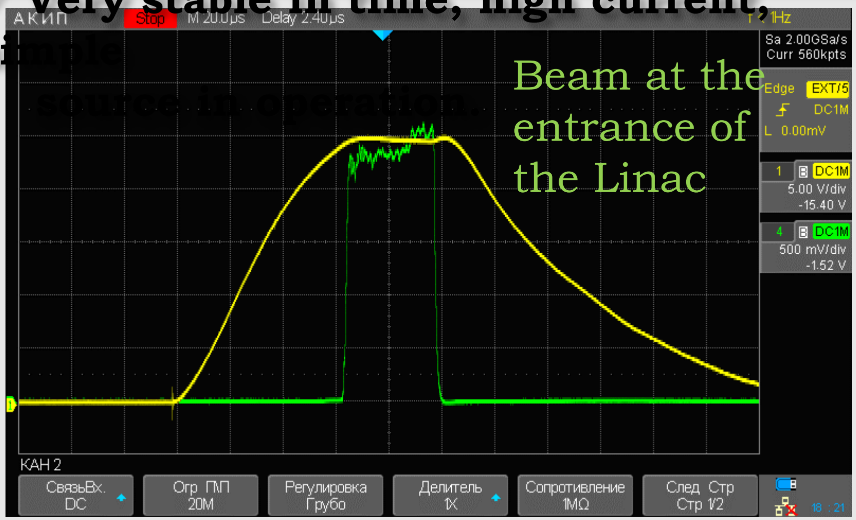
Ion Source Design:
1 - ring ferrite magnets, 2 - ring NdFeB magnets,
3 - ceramic insulator, 4 - magnetron anode,
5 - magnetron cathode, 6 – anode, 7 - emission electrode, 8 - extracting electrode

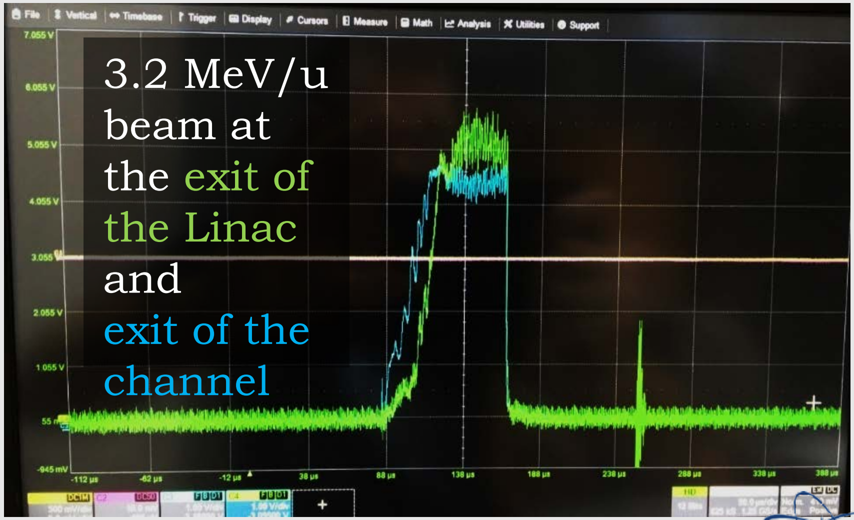
Ion source for commissioning

Why do we plan to use He^{1+} ions?

- ✓ **“Mono” beam after the linear injector (no other species) 99% of He^{1+}**
- ✓ **A/q = 4 more closer to the project beam for the linac and Booster ring (compare to other possible ions). Magnetic rigidity.**
- ✓ **Good beam for measuring of integral vacuum conditions in the ring beam pipe.**
- ✓ **Very stable in time, high current, simple source in operation.**





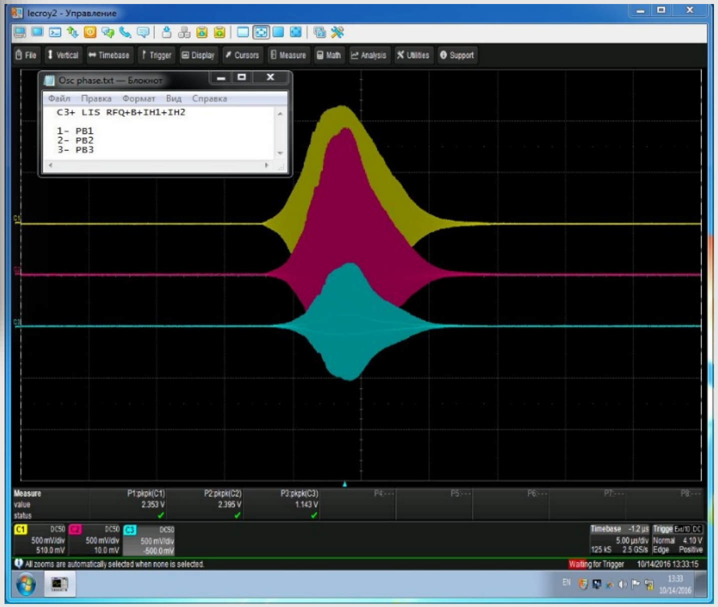


Last beam time in summer 2020 with the new source, He^{1+} beam q/A=0.25

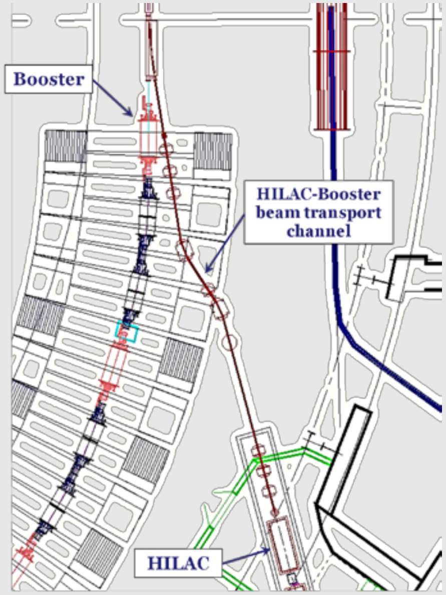
A/q (Target Ion Au^{31+})	***6.25***
Beam current	***< 10 emA***
Repetition rate	***< 10 Hz***
Output energy	***3.2 MeV/u***

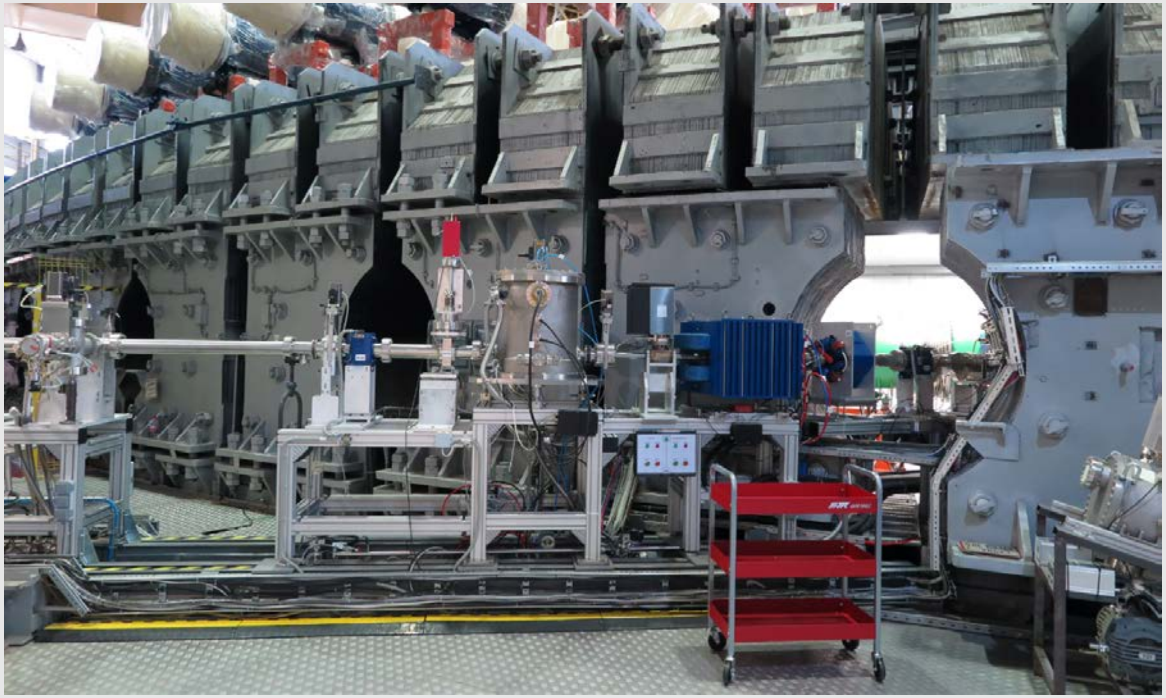
Transmission of Carbon 3+ ions about 75% from RFQ to the exit of the HILAc, 3.2 MeV/u

Phase probes signals
RFQ (red), IH1 (yellow), IH2 (blue)



❑ Injection to Booster channel

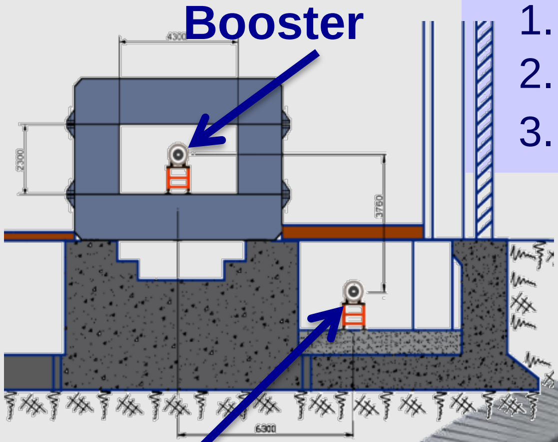


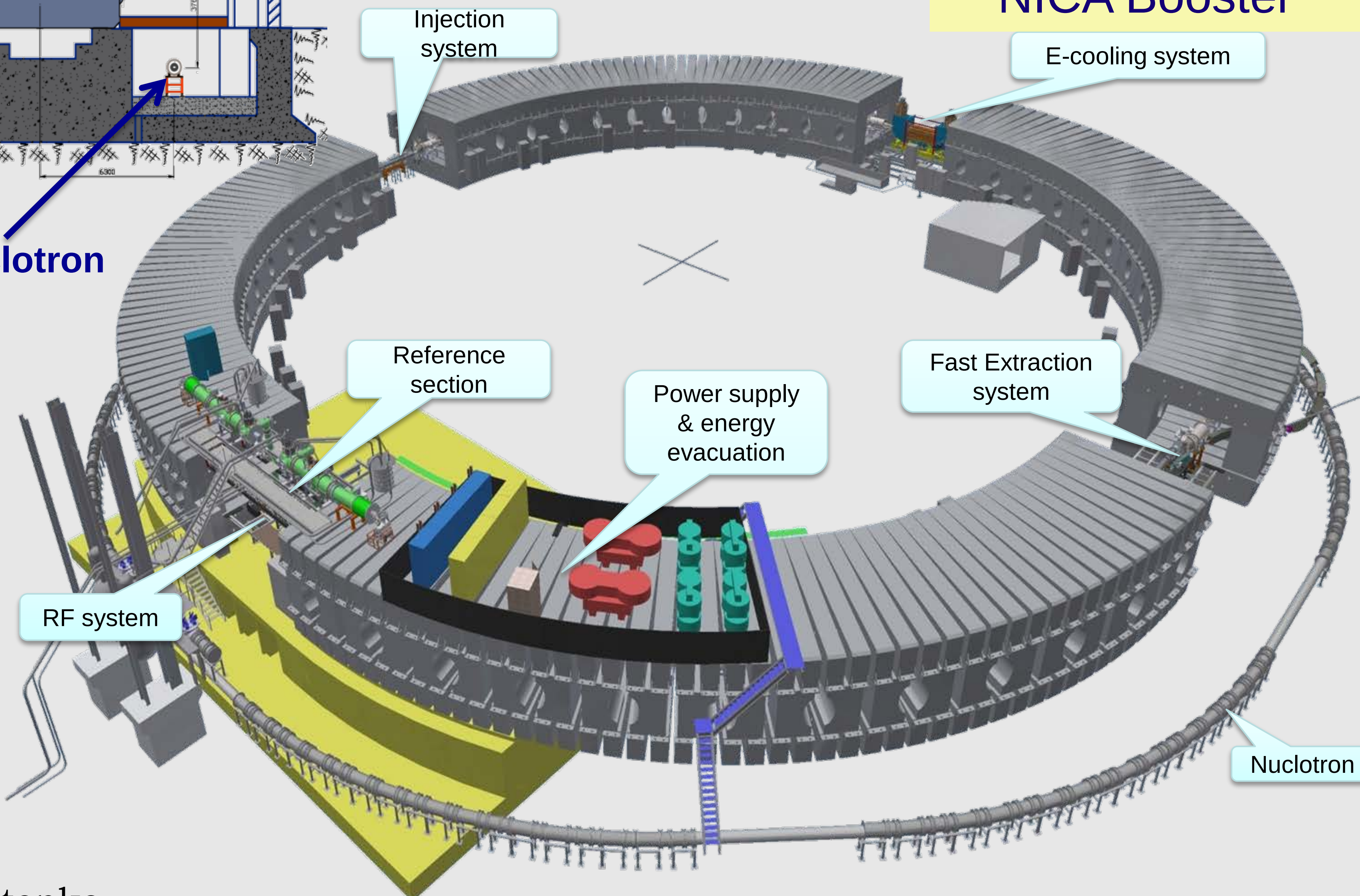


- Beam transmission – 75%

NICA Booster

1. “Prepare” beam from KRION – HILAc for stripping (578 MeV/u)
2. Store ions at injection energy (multiple injection)
3. Cool the beam @ 60 MeV/u => small 6D emittance





Magnets' system

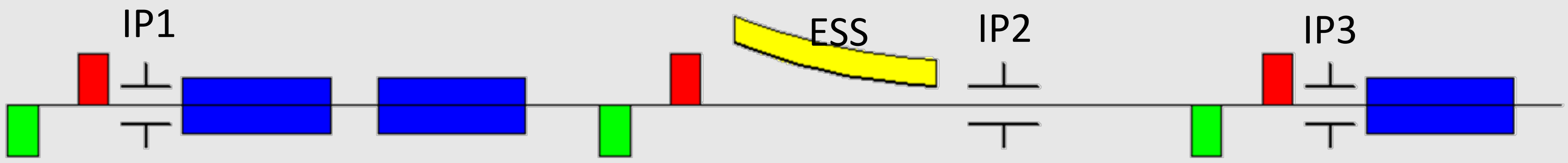
- All elements – installed
- Beam pipe + high vacuum volume assembled and closed
- Magnets' isolation volume 100% closed in arcs

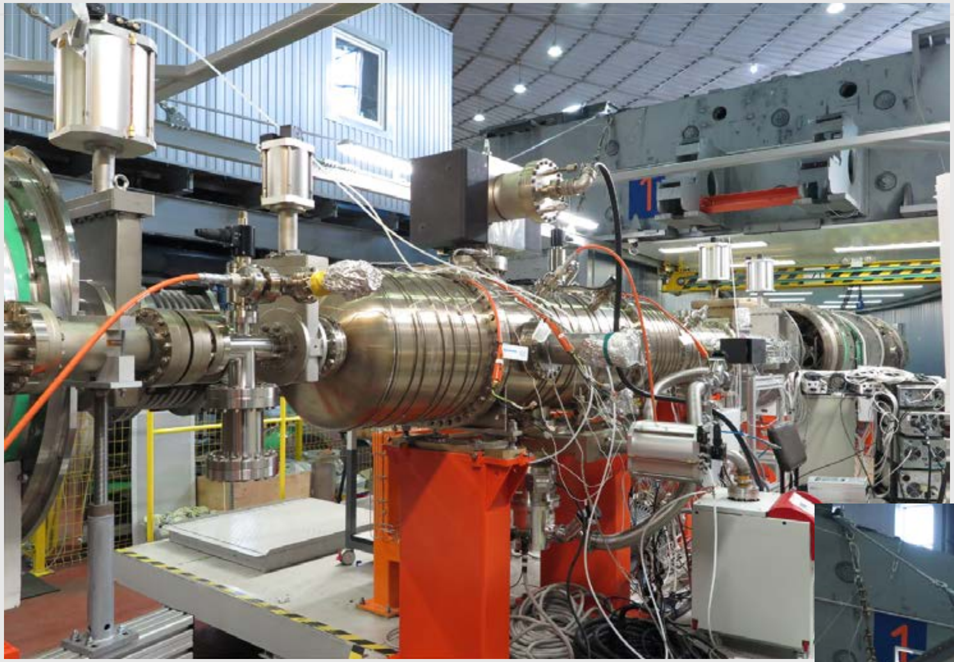
(some connections in straight sections are under assembly)

NICA Booster

Systems	Readiness	Comments
Injection system	90%	ESS – Ok, IP3 isolation volume under assembly
Magnets (dipoles & quadrupoles)	100%	Tested and installed
Beam pipe (UHV)	100%	Final assembly & testing
Insulation volume (gaps between modules)	100%	Assembled
Cryogenic bypasses in straight sections, ends	75%	Under mounting & assembly
Reference section left half-ring	70%	All elements are installed, communications under assembly
Reference section right half-ring	70%	All elements are installed, communications under assembly
Vacuum system (pumping)	100%	For commissioning
Main power supply system	100%	Tested, under commissioning
Energy evacuation system	100%	Under testing
Quench detection, machine safety	90%	Under assembly and testing
RF system	100%	Under commissioning
Electron cooling section	100%	Under commissioning
Beam extraction	100%	Only vacuum part for 1st stage
Beam diagnostics	90%	Under installation
Main control system, thermometry, steering…	100%	For commissioning

Injection to Booster system





Systems	Readi ness	Comments
Injection system	90%	ESS – Ok, IP3 isolation volume under assembly

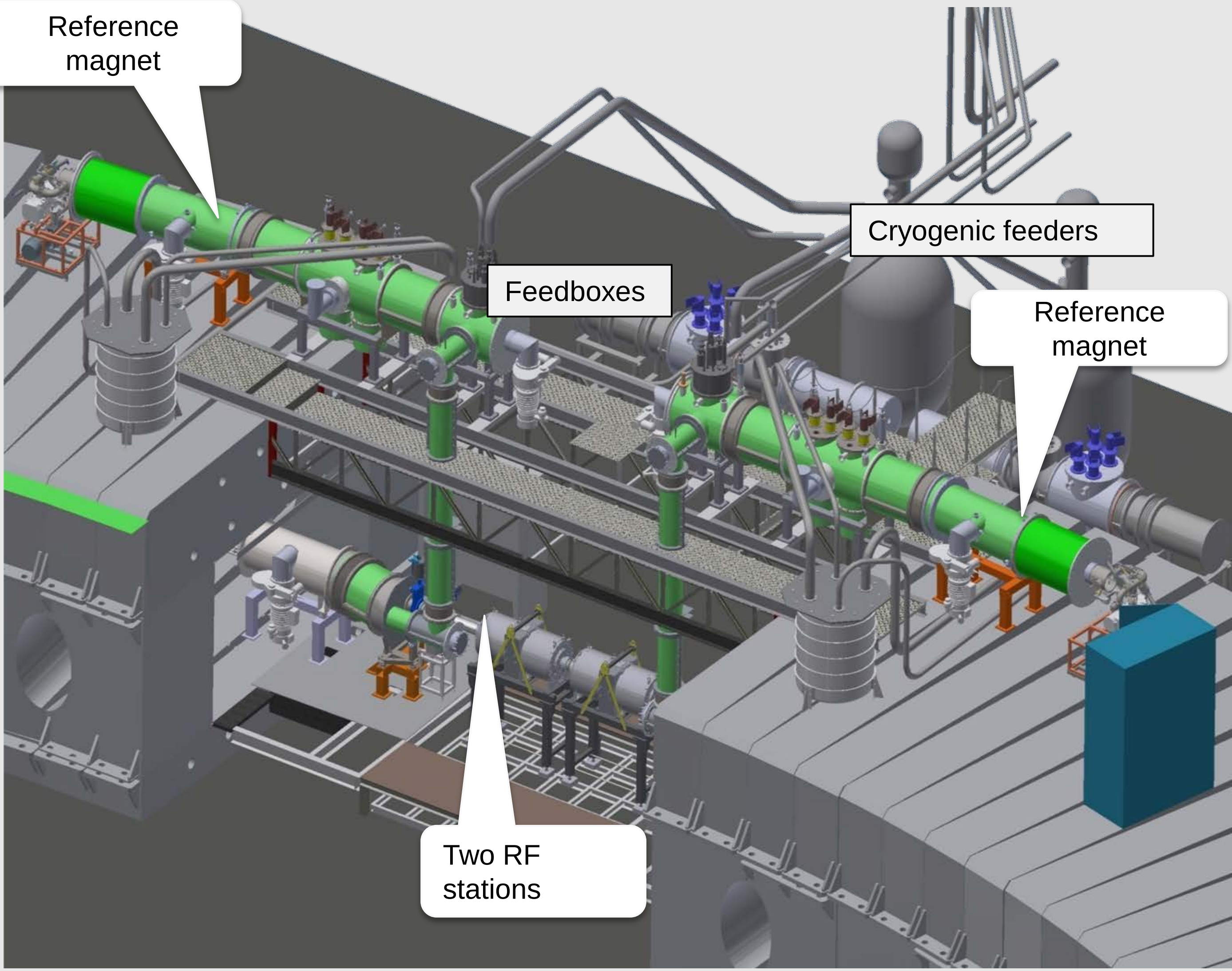
- The beam injection with minimal ion losses

The beam injection by the following methods:

- single-turn injection
- multiturn injection
- multiple injection

❑ Reference magnets' unit

- RF-stations assembled and tested



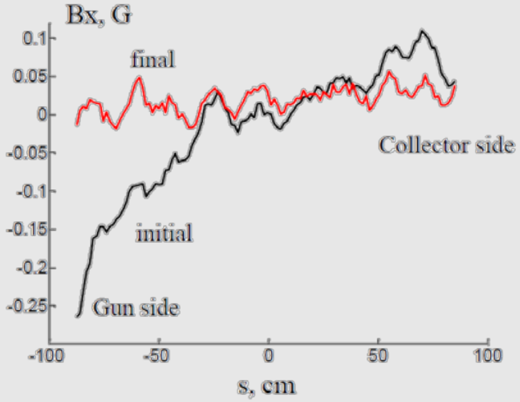
Systems	Readiness	Comments
Reference section left half-ring	70%	All elements are installed, communications under assembly
Reference section right half-ring	70%	All elements are installed, communications under assembly

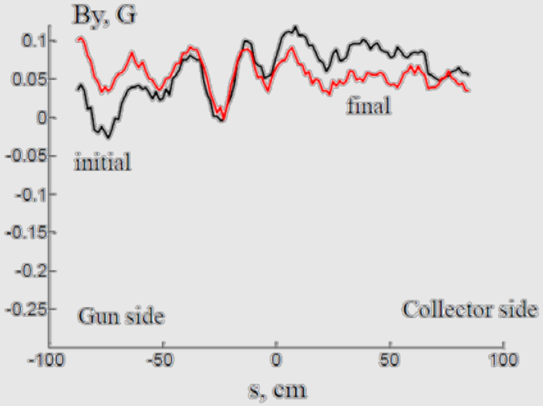
❑ Reference magnets' unit

- Assembling of this unit should define the start of Booster commissioning

Electron cooler

Achieved parameters	Value
Electron energy, keV	30
Electron current, mA	900
Magnetic field, kGs	1
Filed homogeneity	2×10^{-5}
Vacuum pressure, Pa	3×10^{-9}
Total power, kW	120



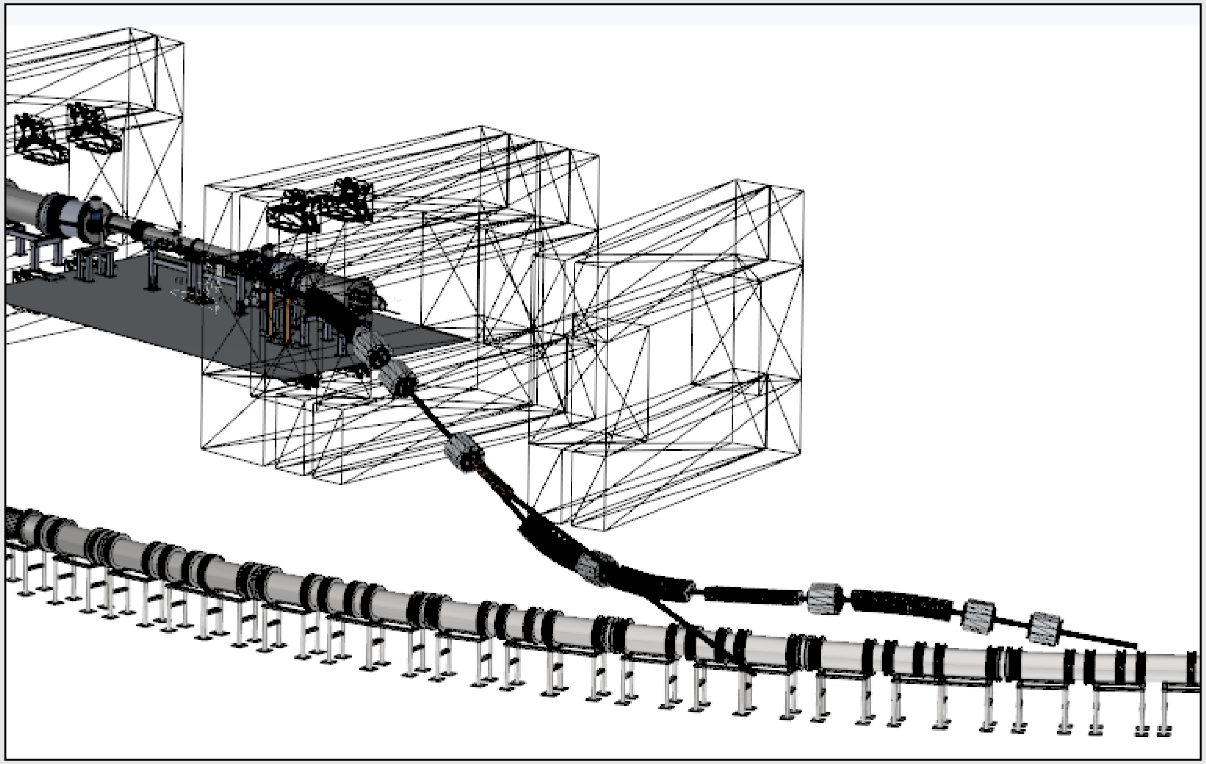


- Ready for Booster commissioning

Power supply and energy evacuation system

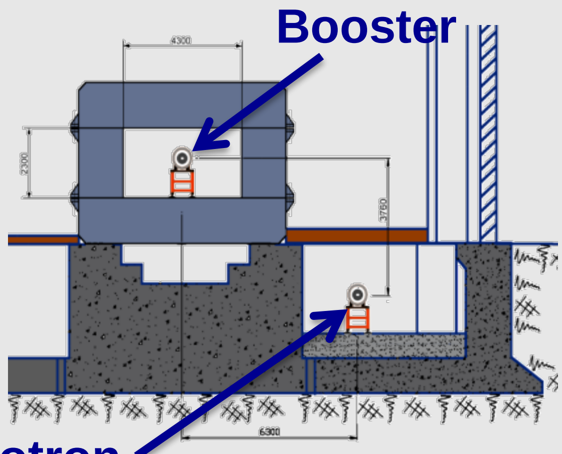
- Ready for Booster commissioning

❑ Booster-Nuclotron transfer channel

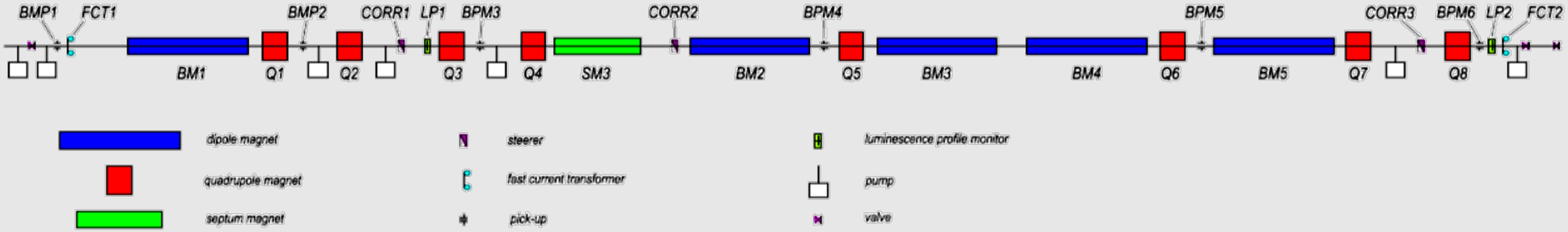


production @ BINP

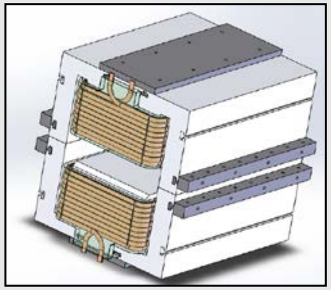
- 6 months delivery delay
- Mar 2021 – start of mounting



- Beam transport with minimal losses
- Separation of neighbor charge states
- Au31+ ions stripping



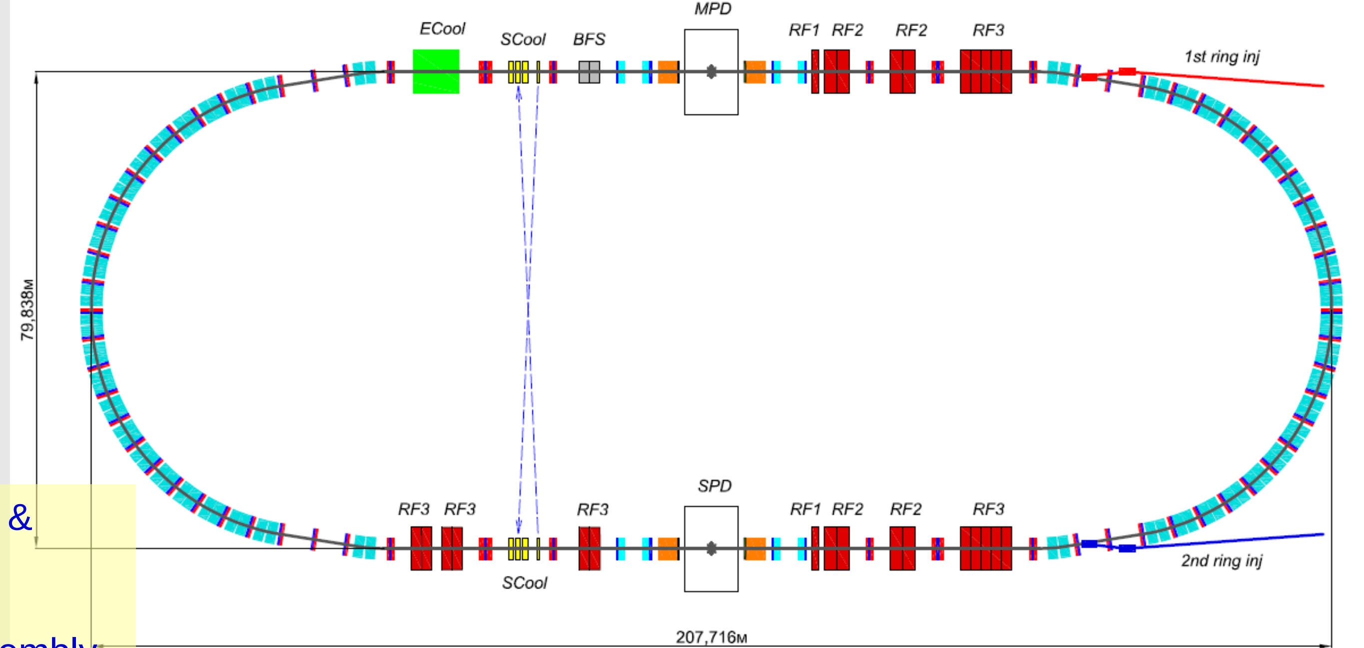
Nuclotron – Collider channel (Sigma-Phi)



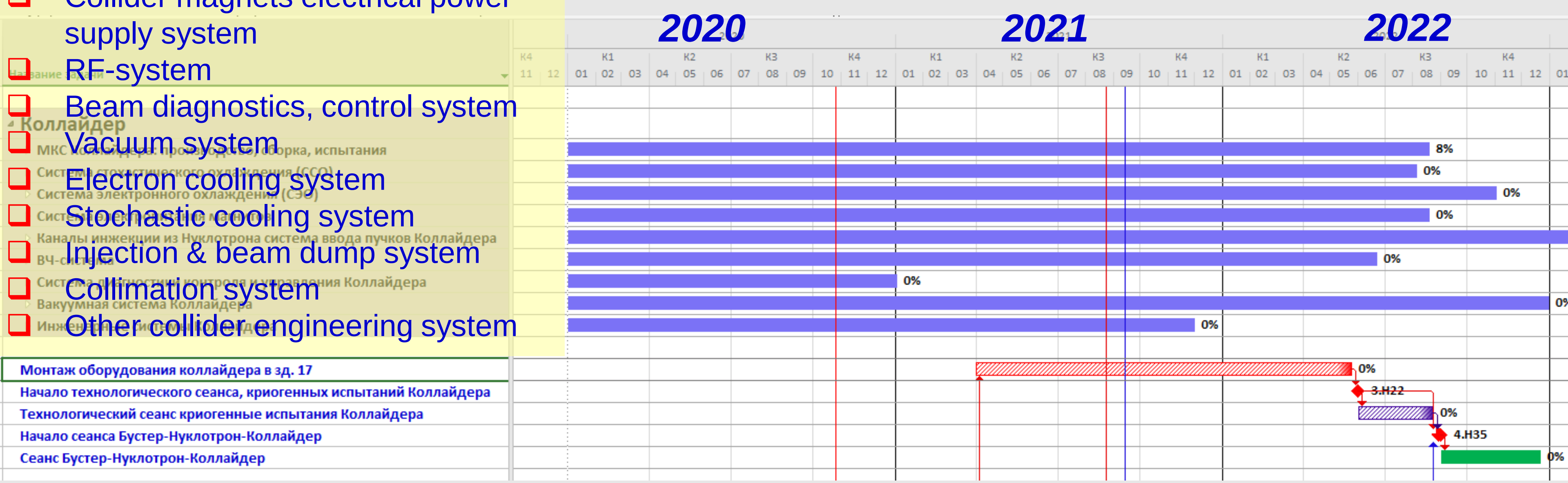
- magnets- completeness 100%
  delivery 12.2020
- beam pipes and diagnostics
  - completeness 90%
  delivery 12.2020
- power supplies- completeness 10%
  delivery 07.2021
- assembly and testing- **04.2021 > 11.2021**

Magnetic element	Number	Effective length, m	Max. magnetic field (gradient), T (T/m)
Long dipole	21	2	1.5
Short dipole	6	1.2	1.5
Quadrupole Q10	22	0.353	31
Quadrupole Q15	6	0.519	31
Steerer	33	0.466	0.114

Collider



- Magnet modules – assembly & tests
- Reference super period construction, production, assembly
- Collider magnets electrical power supply system
- RF-system
- Beam diagnostics, control system
- Vacuum system
- Electron cooling system
- Stochastic cooling system
- Injection & beam dump system
- Collimation system
- Other collider engineering system

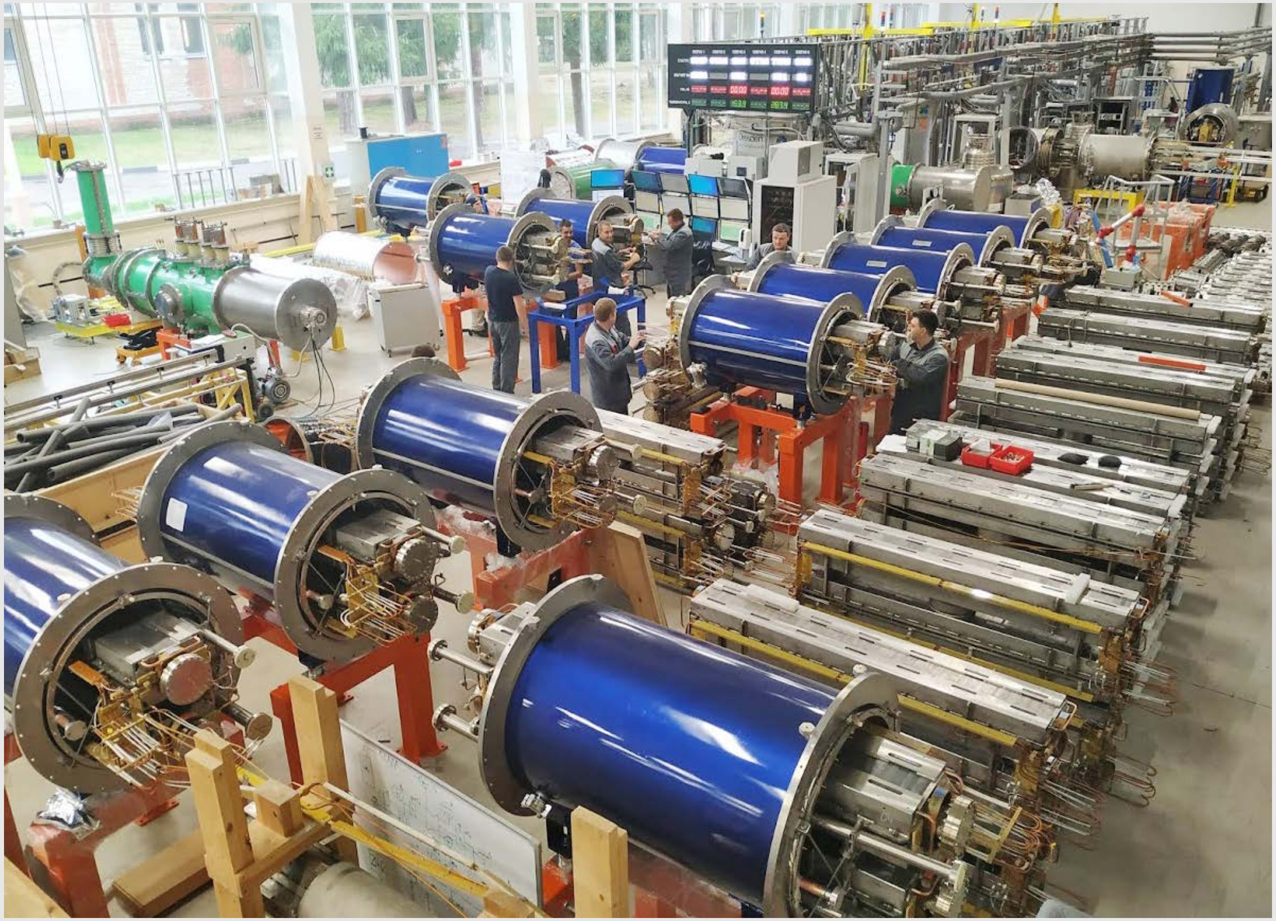


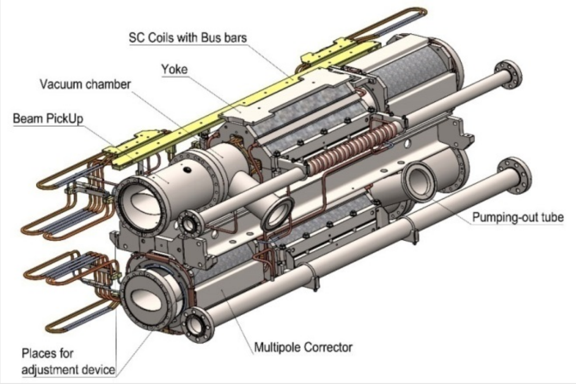
- Run 1 start W36, 2022

❑ Collider

Magnetic system: design, production & testing of SC magnets

Collider magnetic system			
Dipoles (total 80)	**%, compl.**	**Quadrupoles (total 70+12)**	**%**
Magnet yokes	100		63
Vac. Shells	100		100
Beam pipes	100		30
Ni-screens	90		70
SC-coils	70		60
Tested 65%		5%	

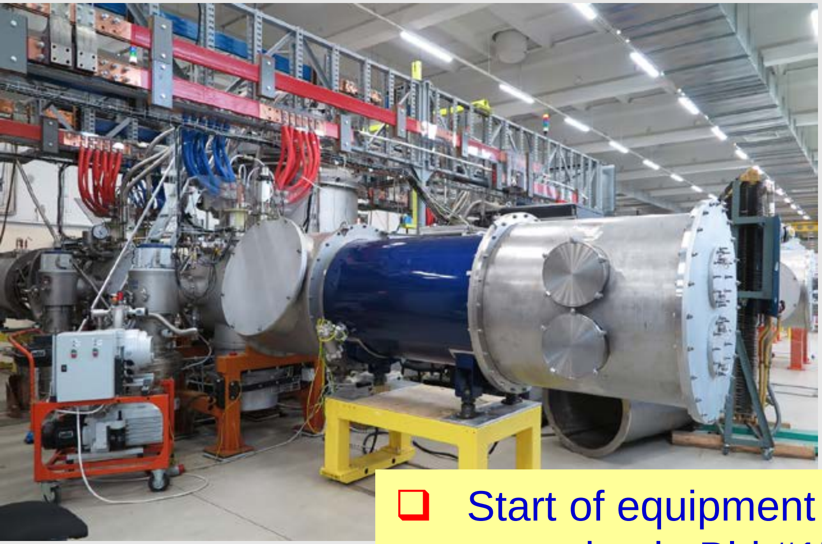




❑ Collider

Magnetic system: design, production & testing of SC magnets

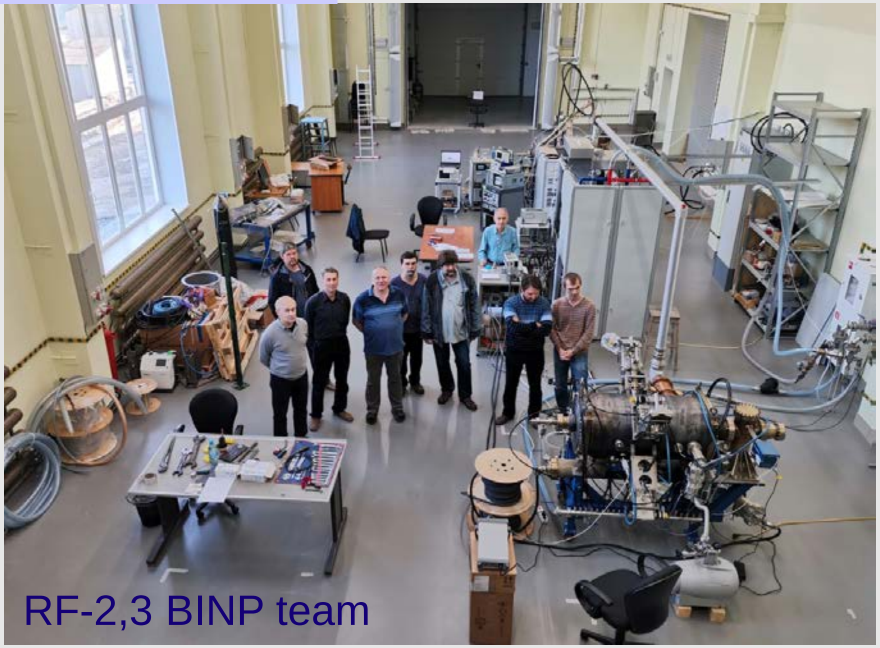
- 46% of dipole magnets are ready for the mounting at the ring



❑ Start of equipment mounting in Bld #17
W26, 2021

❑ Collider

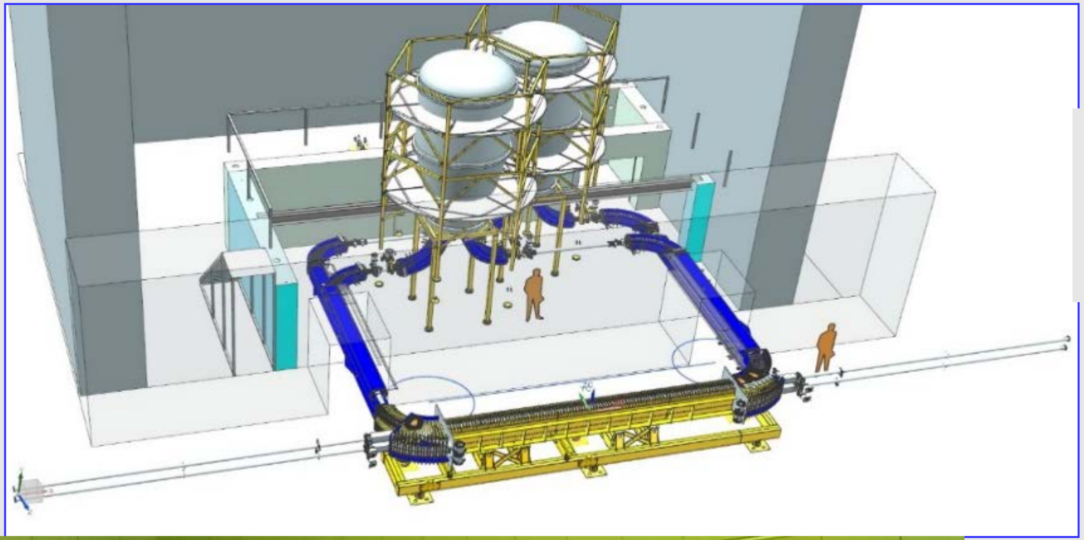
RF-system



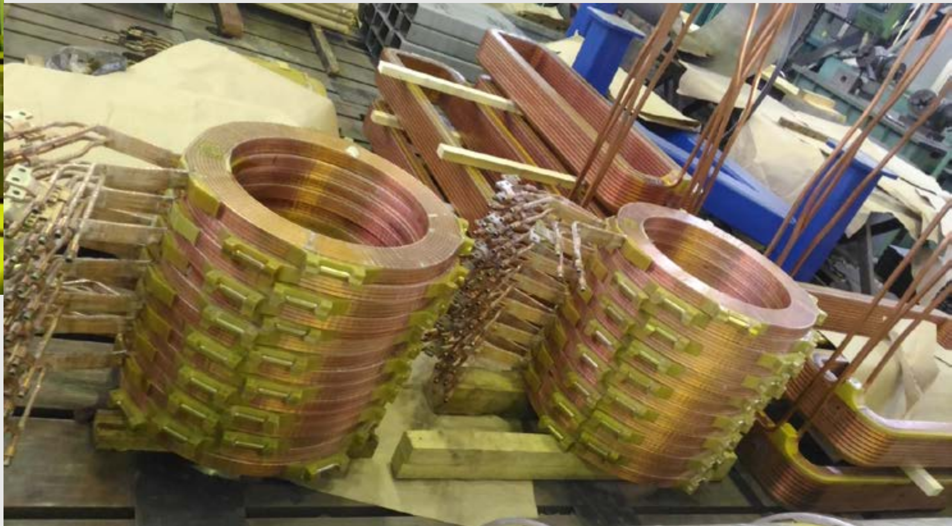
- ❑ Ready for mounting 2021

❑ Collider

E-cooling system

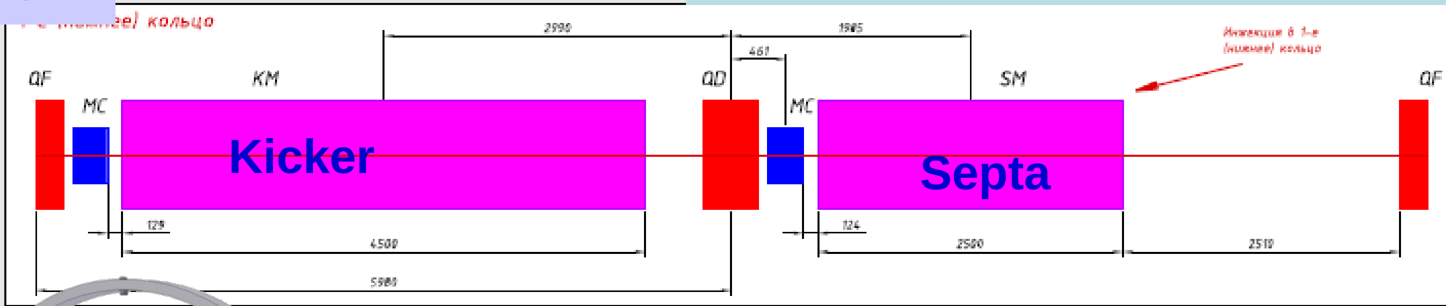


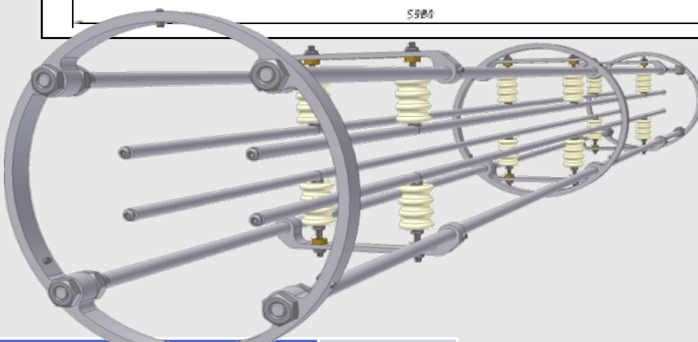
- under construction @ BINP
- delivery to JINR - end 2021
- assembly and tests => beg 2022



Collider

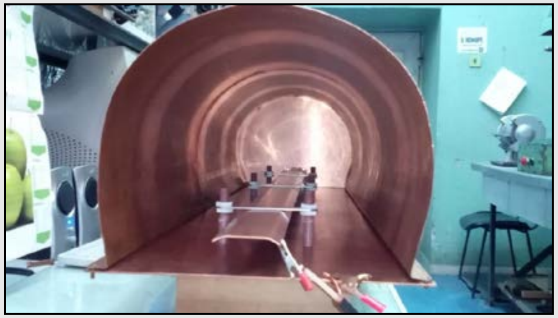
Injection system





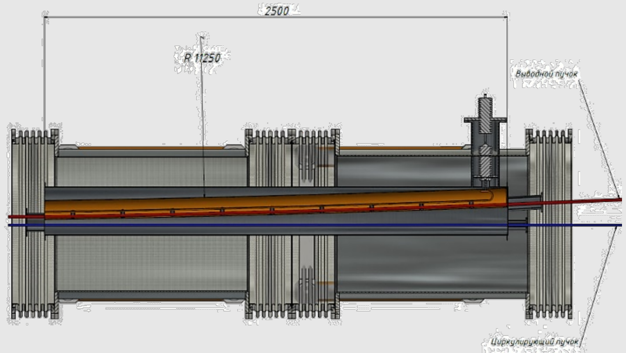
Length, m	4.5
Max magnetic field, T	0.1
Pulse duration, ns: rise plateau fall	 200 200 200
After-kick amplitude, plateau level	≤1.5%
After-kick duration, ns	≤160

- Concept of the kicker and its power supplies is under development.
- Effects of after-kicks to the stack are estimated. Concept of measures against after-kicks has been developed.



Length, m	2.5
Max magnetic field, T	1
Aperture, mm×mm	45×45
Septum thickness, mm	3
Pulse shape	semisinusoidal
Pulse duration, μs	~ 10

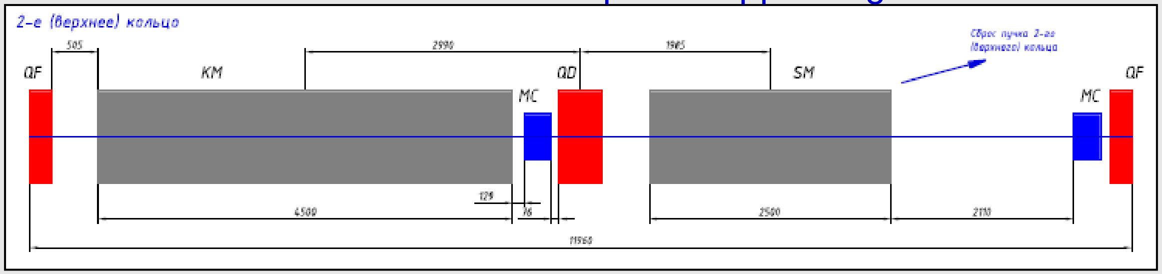
- Technical design is in progress
- Concept of power supply has been developed

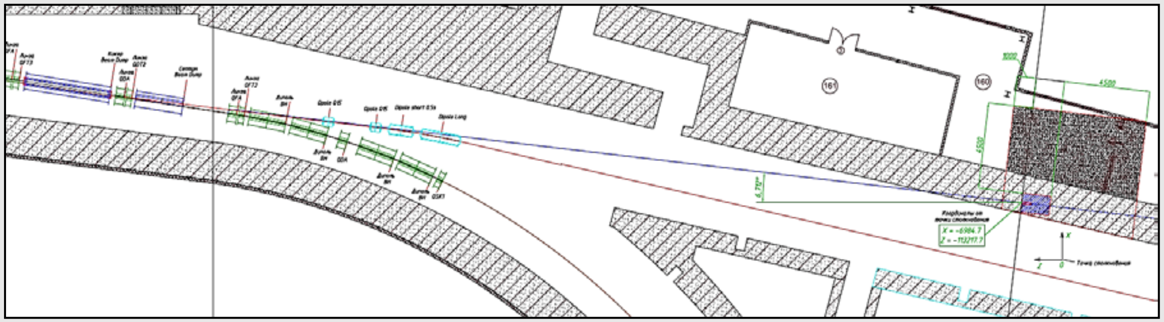


Collider

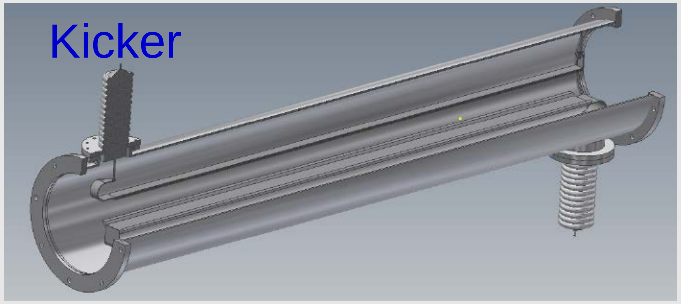
Beam dump system

Beam dump from upper ring

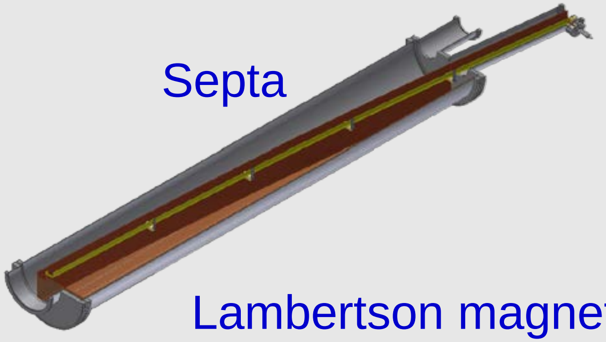




Kicker

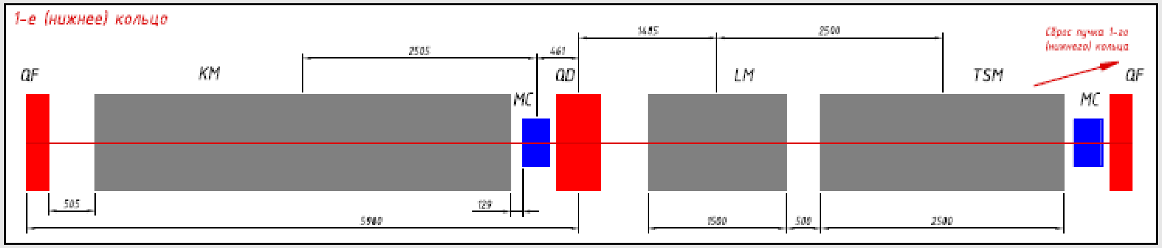


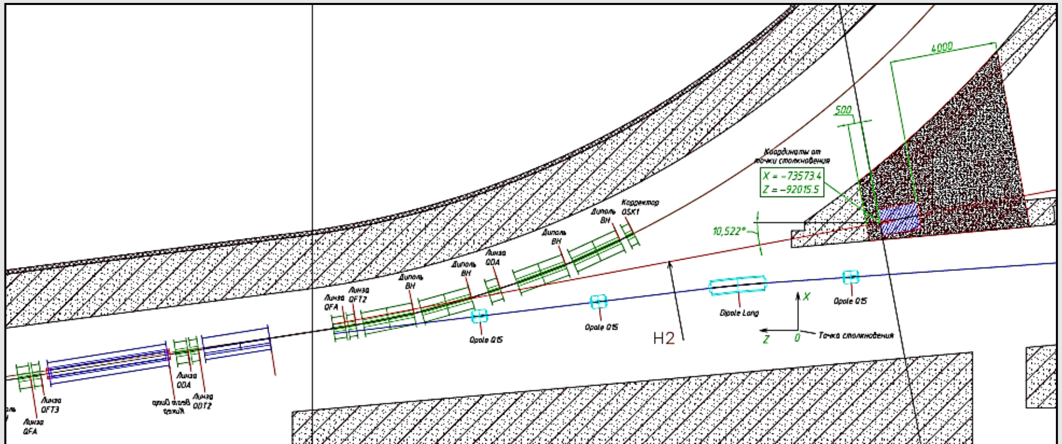
Septa

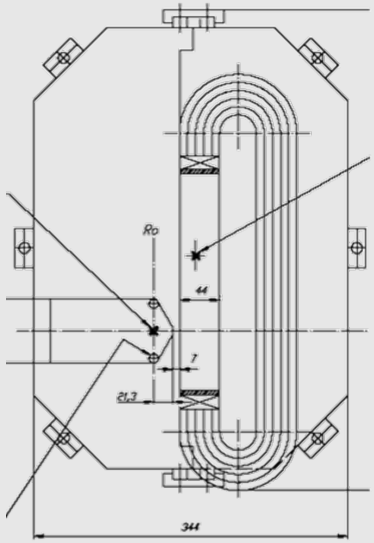


Lambertson magnet

Beam dump from lower ring



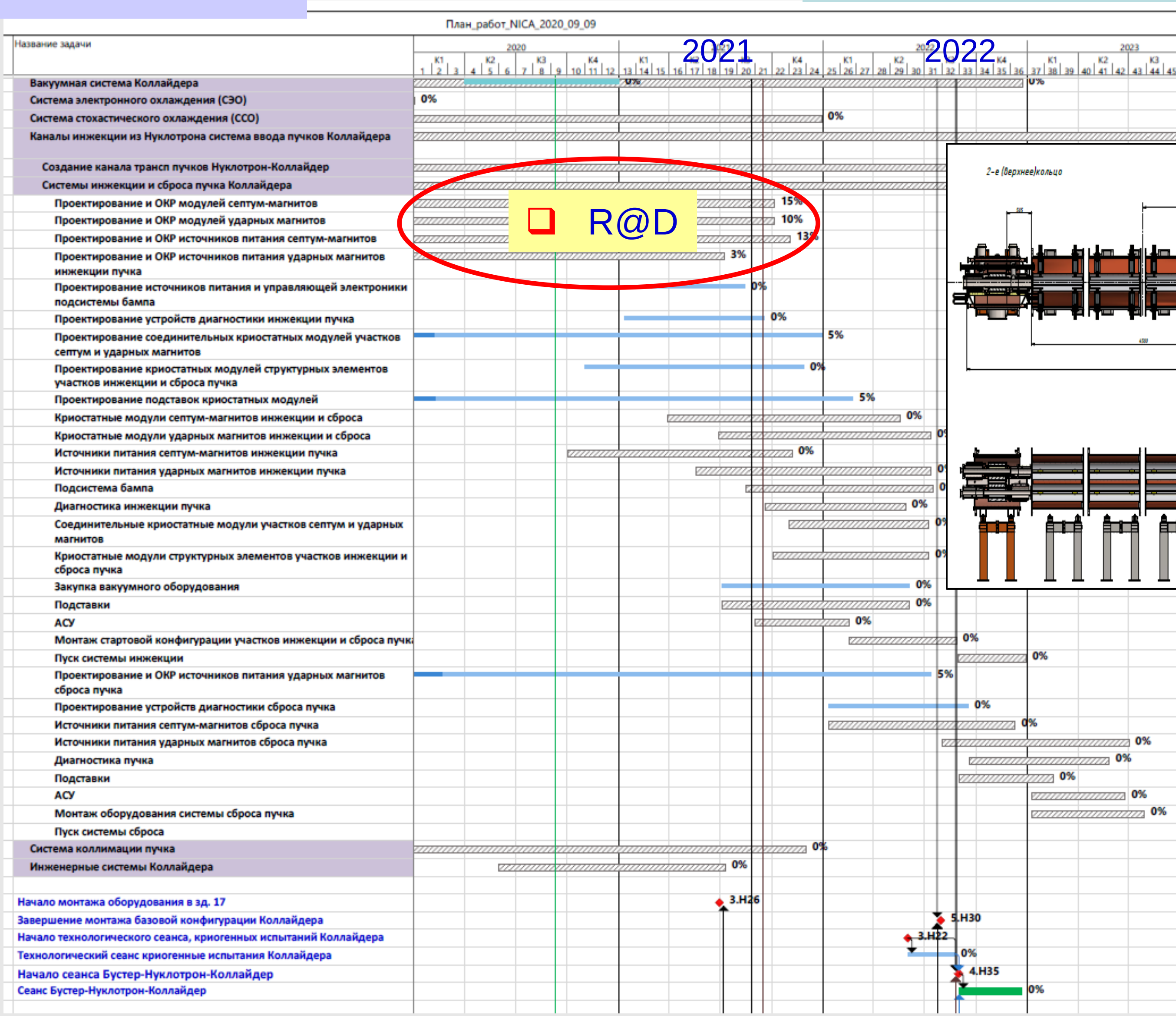


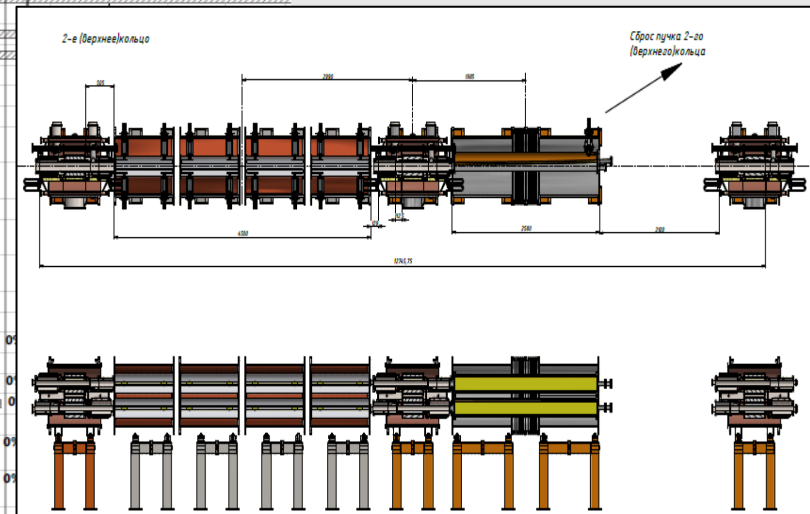


- R@D started

❑ Collider

Injection & beam dump system





Critical path

❑ Collider building

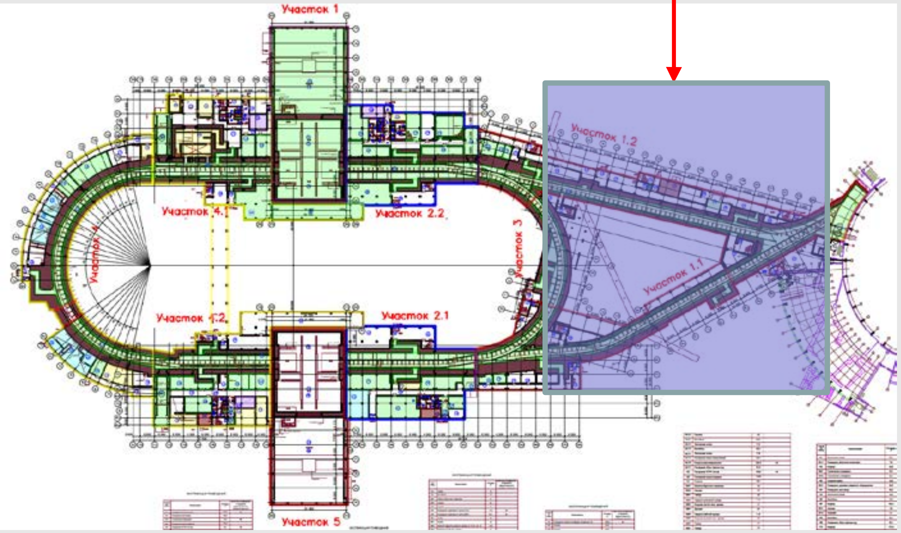
08.09.2020

2021-2022

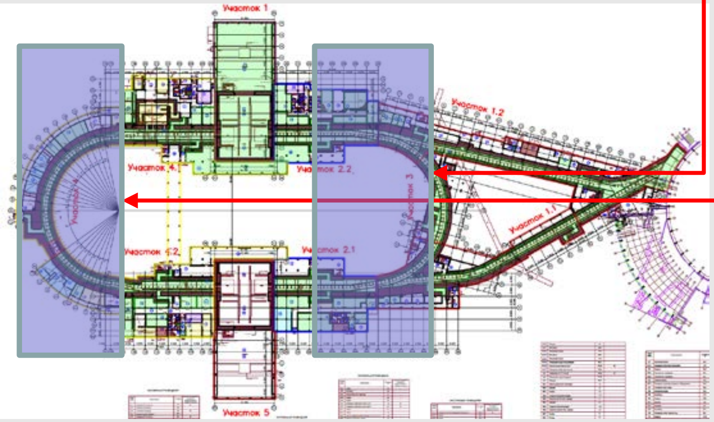
- ❑ Collider systems assembly
- ❑ Nuclotron-Collider channel assembly
- ❑ Start of assembly works – Apr, 2021

yesterday

Nuclotron-Collider transfer channels' gallery

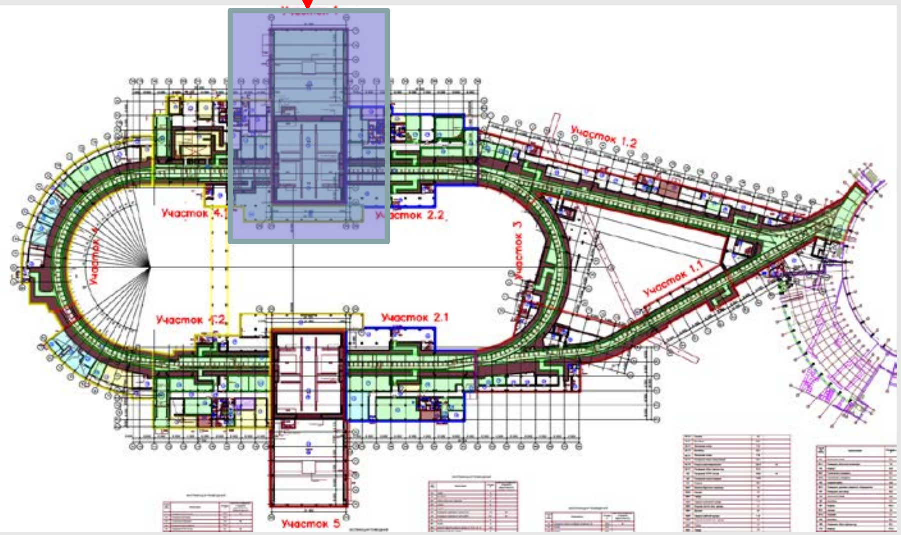


- ❑ Ready for equipment assembly W13, 2021



- East arc - ready for Collider equipment mounting W26, 2021
- -magnets storage area
- West arc - ready for Collider equipment mounting W39, 2021

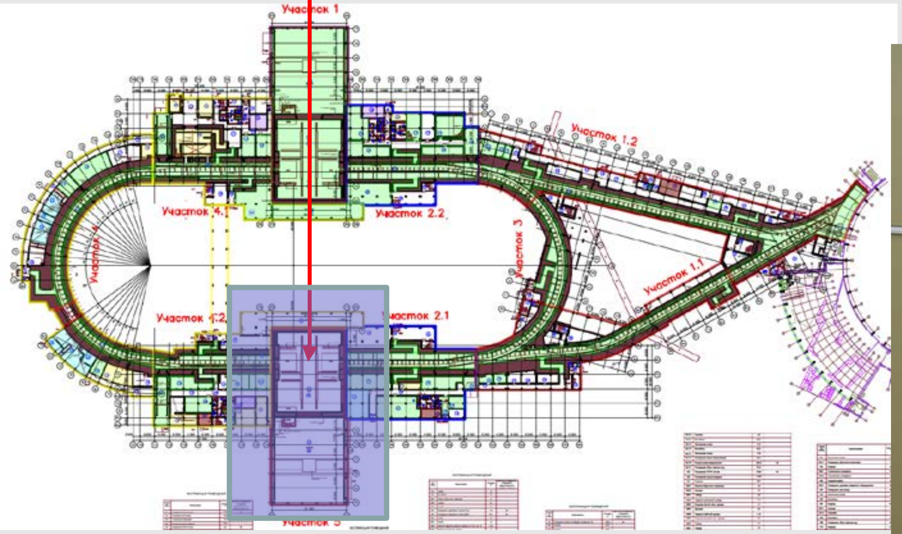
MPD Hall



2020

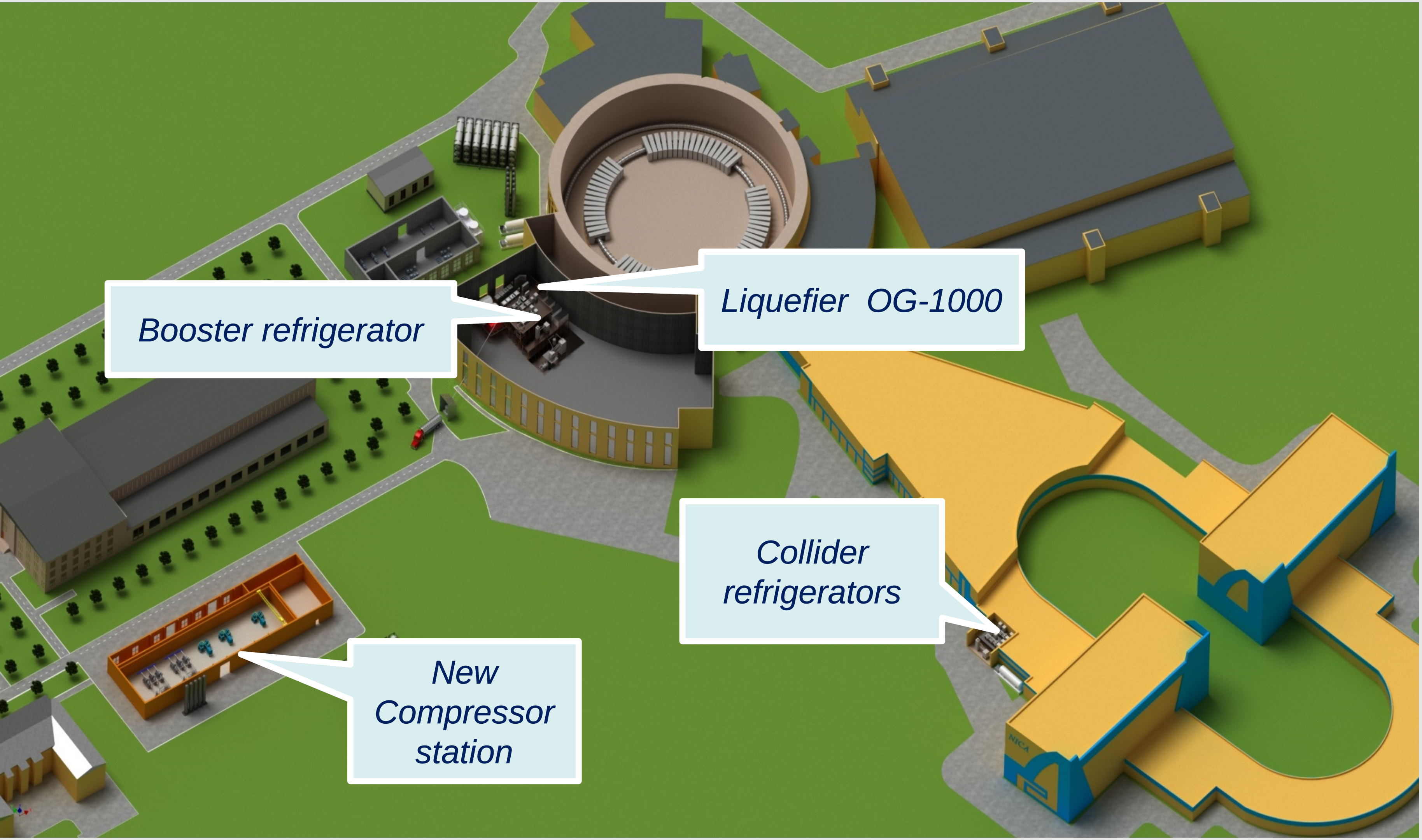
- ❑ Ready for detector yoke assembly
- ❑ MPD hall completed W49

- MPD yoke assembling - started

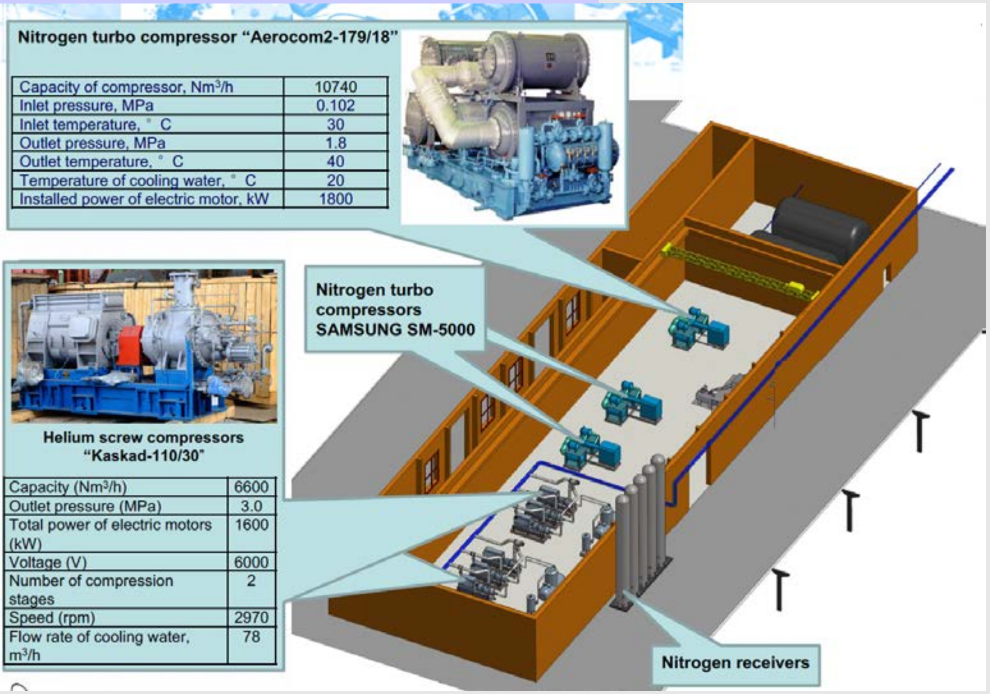


- Ready for equipment assembly
  W22, 2021

NICA complex cryogenic infrastructure

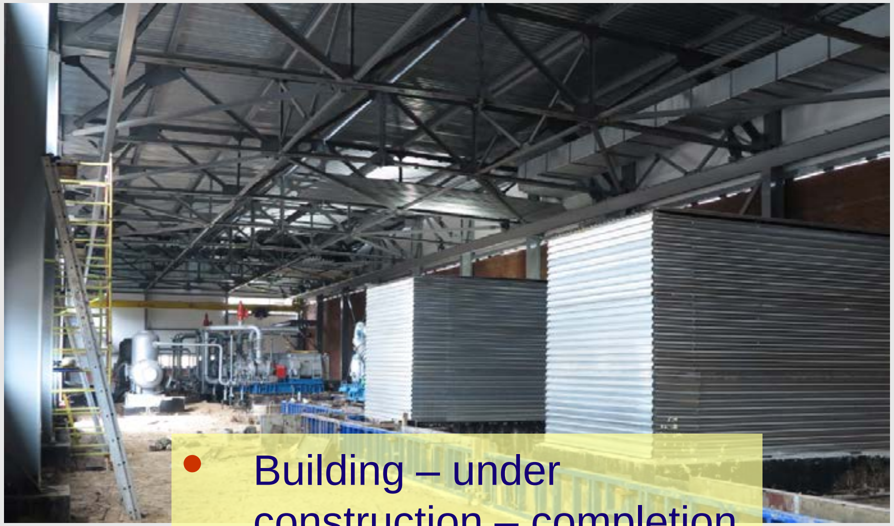


New compressor station



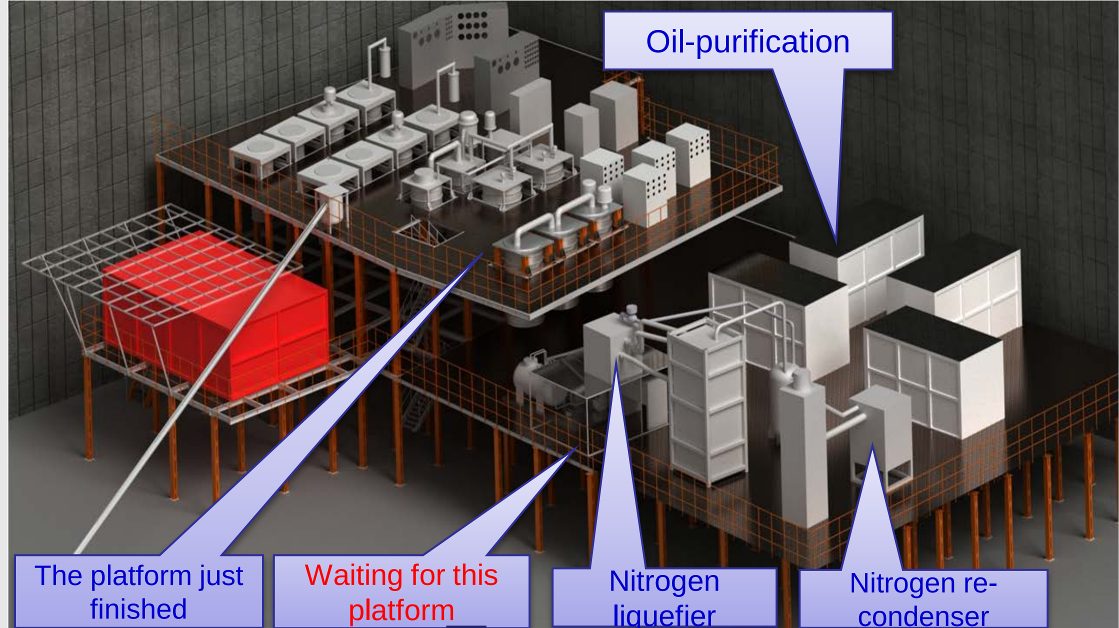
Capacity of compressor, Nm³/h	10740
Inlet pressure, MPa	0.102
Inlet temperature, °C	30
Outlet pressure, MPa	1.8
Outlet temperature, °C	40
Temperature of cooling water, °C	20
Installed power of electric motor, kW	1800

Capacity (Nm³/h)	6600
Outlet pressure (MPa)	3.0
Total power of electric motors (kW)	1600
Voltage (V)	6000
Number of compression stages	2
Speed (rpm)	2970
Flow rate of cooling water, m³/h	78



- Building – under construction – completion March, 2021
- Station completion – Aug 2021

Central cryogenic plant Bld #1b



- New Booster LHe Cold Box – assembled, commissioning - Dec, 2020
- System automation is in progress

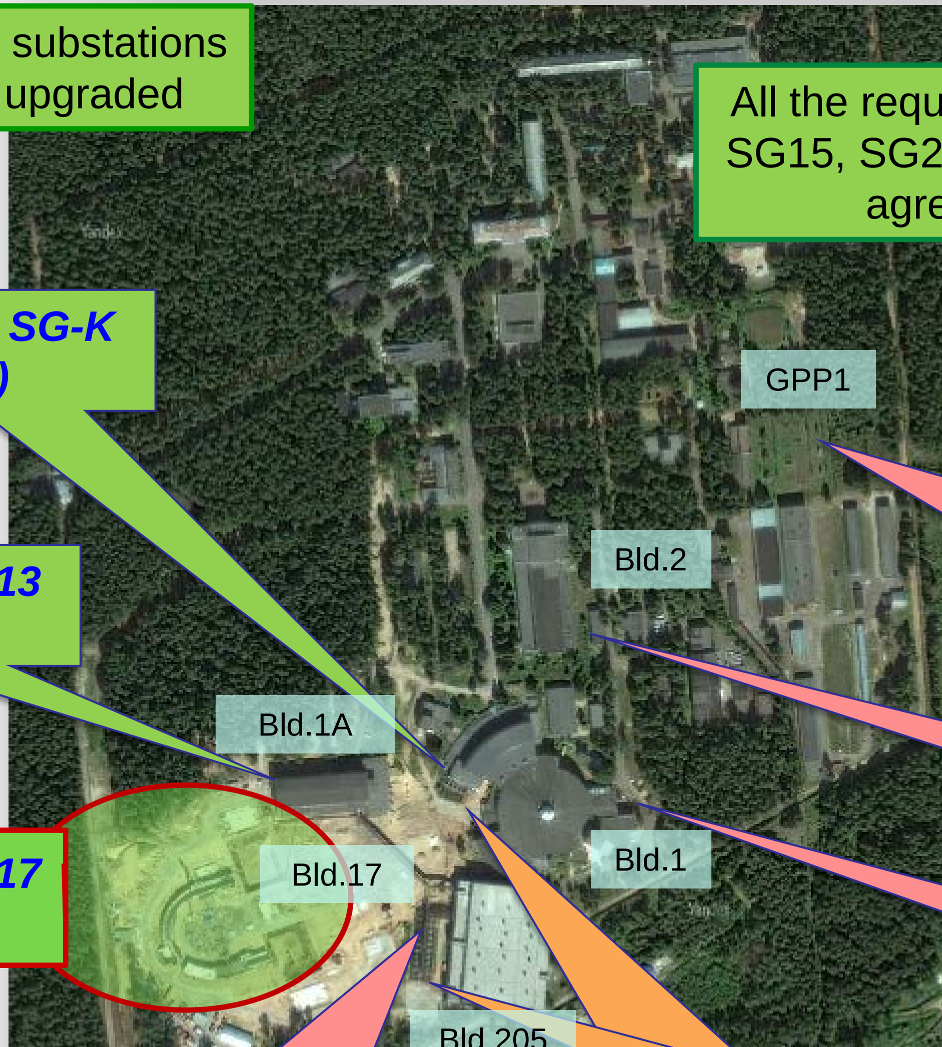
- Construction works started
- Central cryogenic plant completed – Jul, 2021

Power infrastructure

LHEP site power consumption should be **doubled**

SG 13, SG-K substations have been upgraded

All the required documentation SG12, SG15, SG21 has been developed and agreed in all authorities



Substation SG-K (1MW)

Substation SG13 (10MW)

5 substation bld.17 (11MW)

Main substation step-down GPP1 (40.8 MW)

Substation SG21 (12MW)

Substation SG12 (1.7MW)

Substation SG15 (8MW)

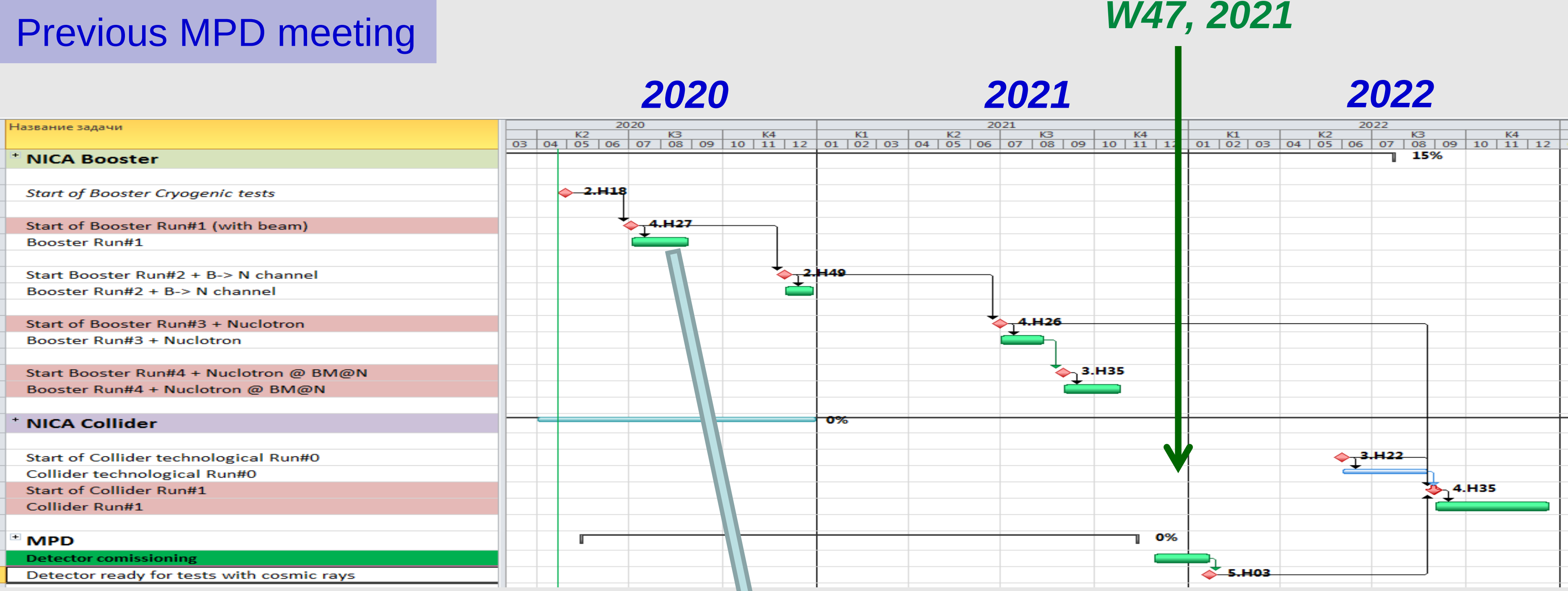
Power supply system for beam channel

Electrical infrastructure

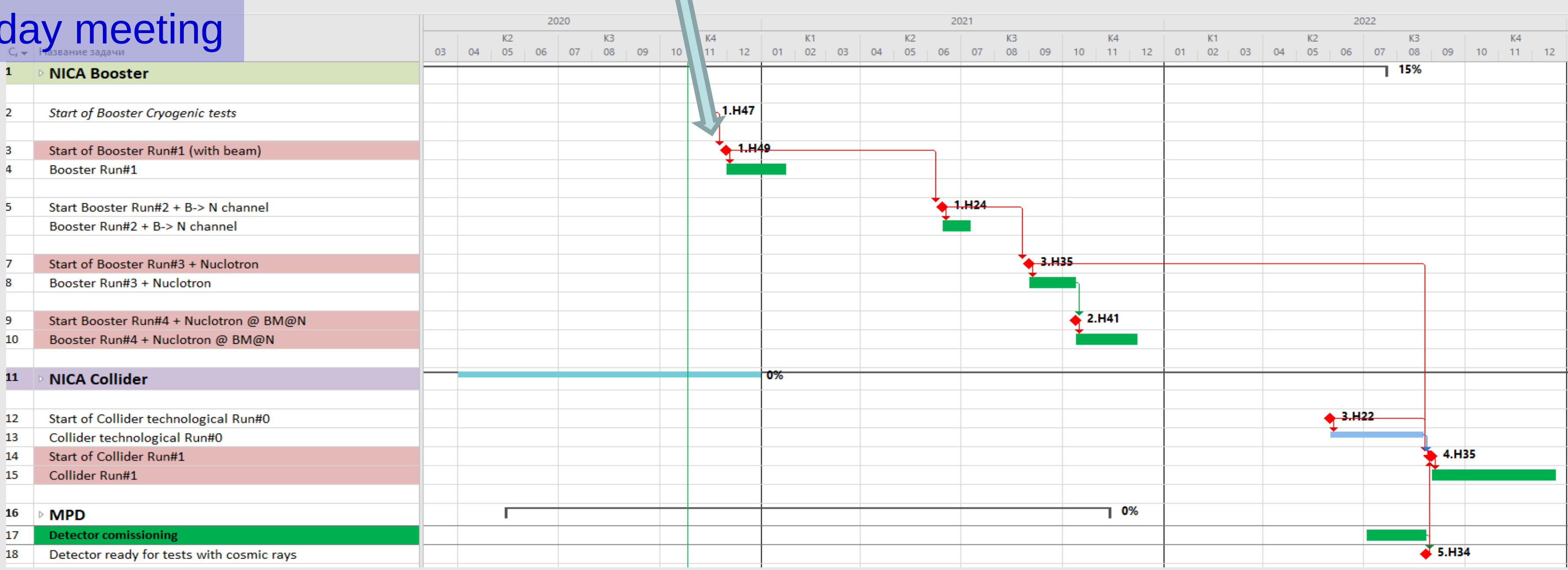
Substations of Bld 17

- Substations of Bld #17 (11 MW) – completely finished Dec, 2020

Previous MPD meeting



Today meeting



- Construction of NICA complex in progress
- All technical decisions are taken
- Some design work is finishing
- 6 month of delay due to objective reasons

❑ Thank you for your attention!