Range (muon) System Status and Plans for 2025

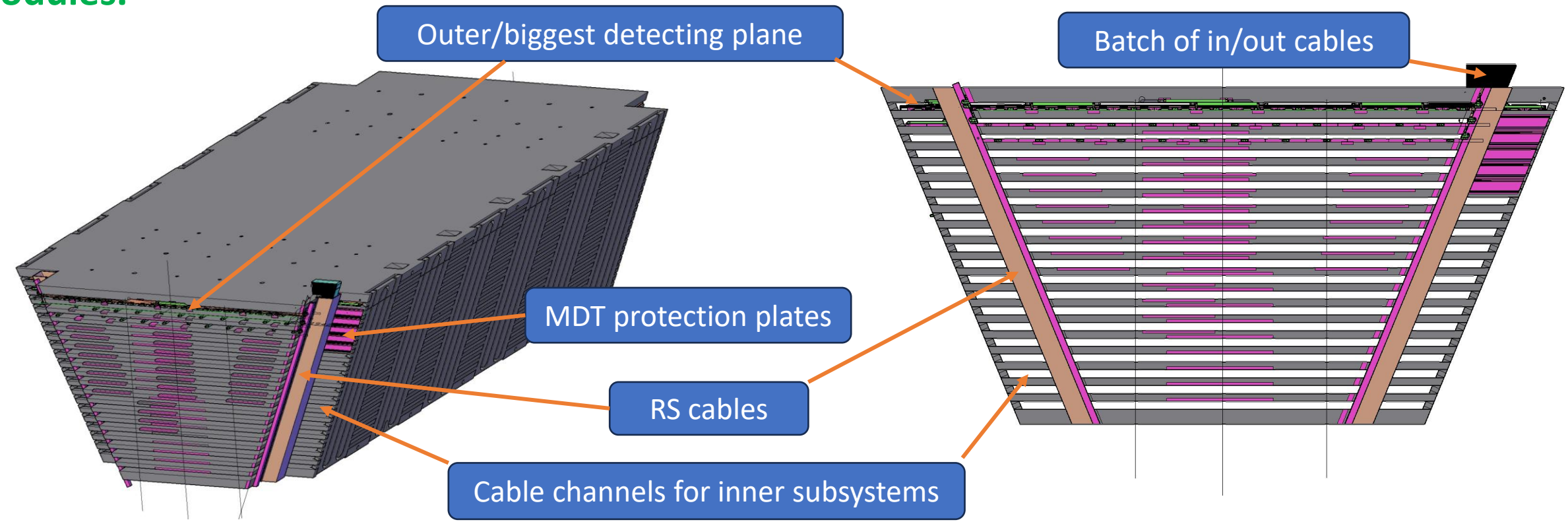
G.Alexeev, SPD Collaboration meeting, Erevan, 13.05.2025

- Participation in developing the engineering Yoke design, especially in part concerning the impact of MDT detectors and electronics
- Deployment of MDT test production equipment is in progress
- Execution of pre-production contract JINR-Minsk/Integral on amplifier chips (Ampl-8.53) is in progress
- Pre-production contract JINR-Minsk/Integral on preamplifier and discriminator chips (Ampl-8.11R-G5, Disc-8.17) is under discussion
- Tests on data transmission from digital FDM-192 module to L1 concentrator have been successfully performed using SerDes interface (also important: 2 modified FDM-192 modules have been ordered at Moscow State University, work on developing configuration files (firmware) for FPGA have been continued)
- Main parameters of strip board (capacity and wave imperdace) were measured with Detector Layer Prototype (DLP)
- Preparations to the beam tests (Cherenkov counter at LINAC-200 and Range System Prototype at NUCLOTRON beam) are in progress
- Participation in development of PID algorithms for pion-to-muon separation: setting up DBSCAN clustering algorithm and study various machine learning algorithms for muon identification

- **Plans for the rest of 2025**
- **Conclusion**

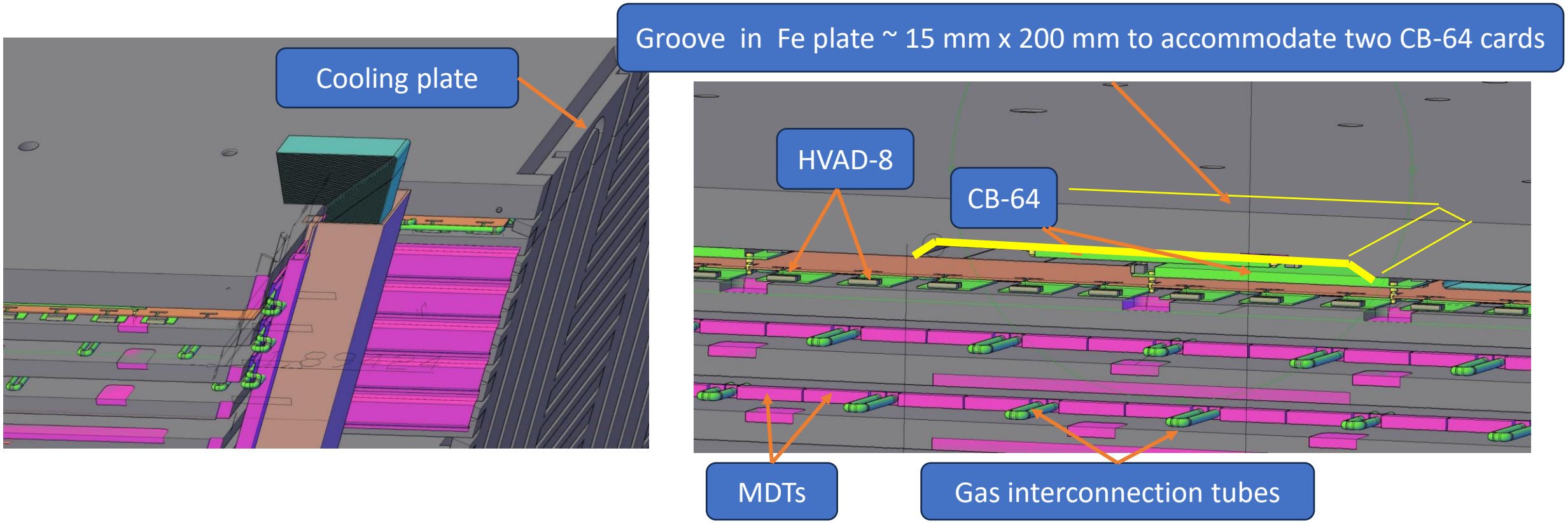
Final 3D engineering version of one (out of 6) “regular” Yoke/Barrel module

After delivery of 3D conceptual model of RS to VBLHEP (Design Bureau №2), we presently concentrate on developing 3D model(s) for all slots of RS (starting from “regular” Yoke/Barrel modules), including: MDT detectors, honeycomb strip board, analog FEE cards, cabling inside/outside, gas pipelines and inter-connections, etc. **---> important information on additional mechanical treatment of steel plates prior to the welding them into the Yoke modules.**



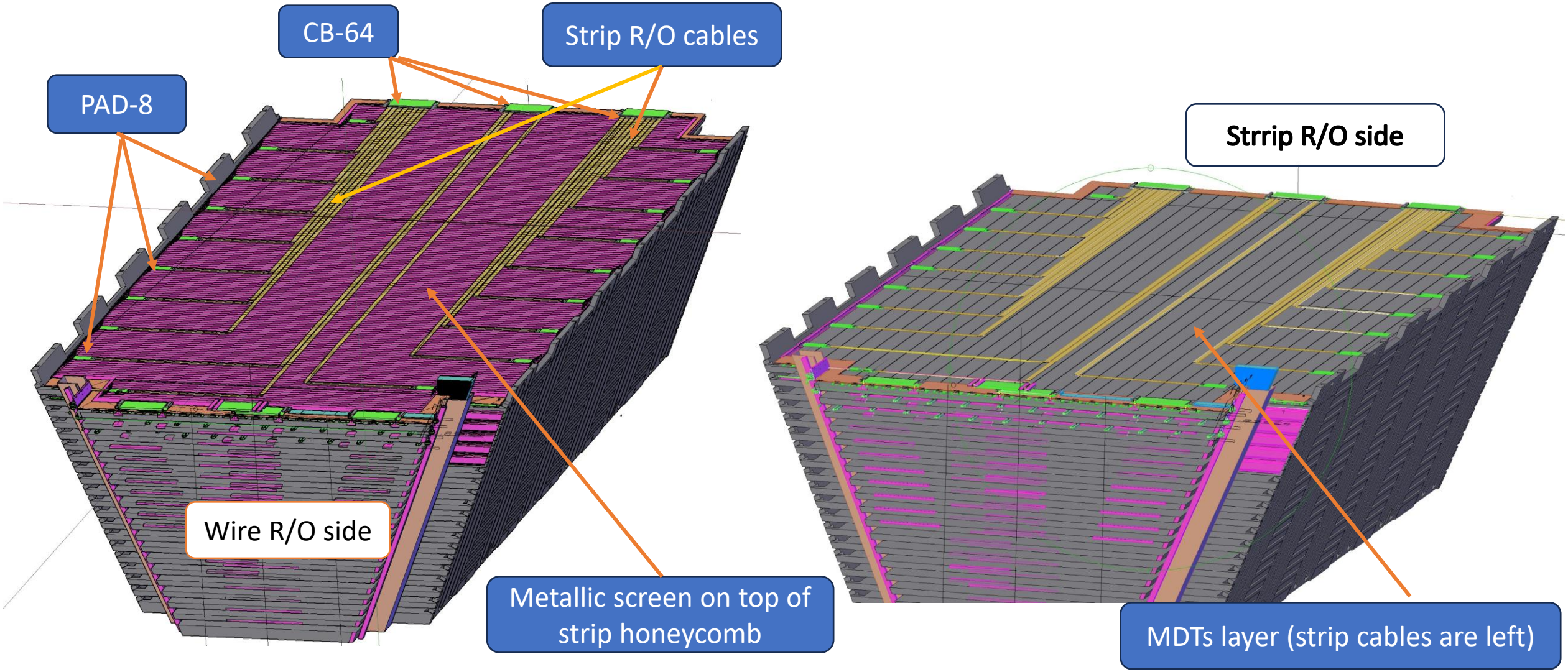
3D view of the outer layers (MDT detectors and electronics) in “regular” Yoke/Barrel module

Reading out the signals from detecting layer is based on three 8-channel chips (Ampl-8.53, Ampl-8.11R-G5, Disc-8.17) organized in three boards (**H**igh **V**oltage distributor + **A**mplifier + **D**iscriminator -> **HVAD-8**, **P**reamplifier + **A**mplifier + **D**iscriminator -> **PAD-8**, **C**ommutation **B**oard -> **CB-64** (8 input cables/8-ch each/ from wires/strips -> 2 output cables /32-ch each/) -> serves 2 inputs of digital FEE module **FDM-192** (6 inputs, 32-ch each).



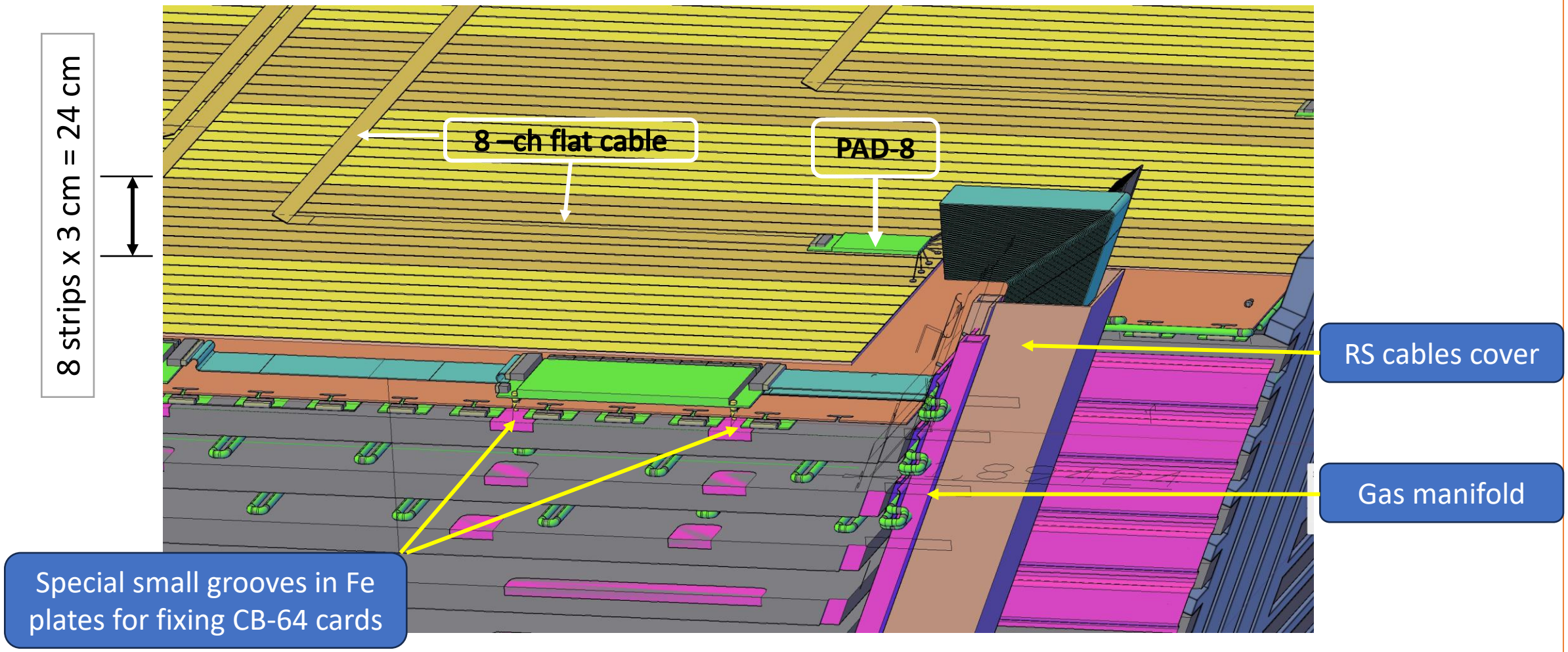
Barrel module (left: outer 60 mm Fe plate removed, right: 5mm honeycomb removed)

Wire signal cables go to the one edge, strip signals – to another



Magnified 3D view with removed 60 mm plate:

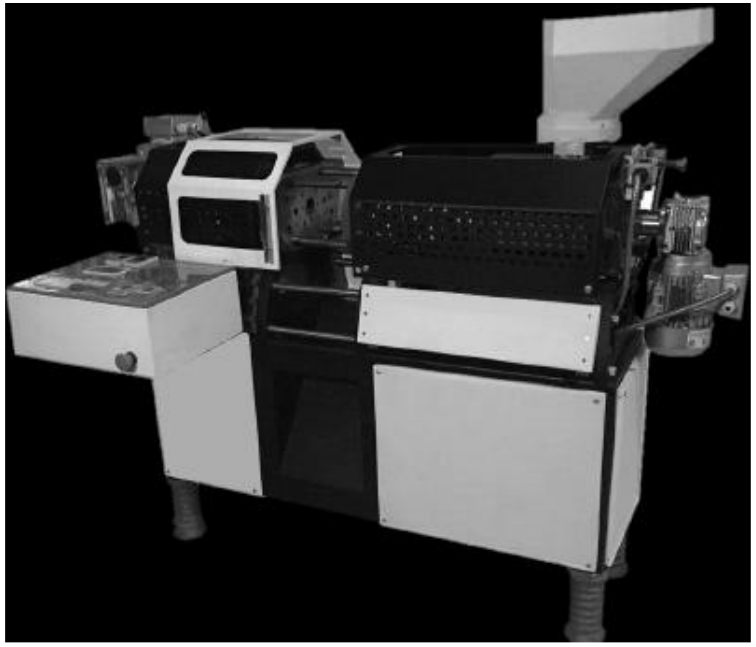
One PAD-8 board serves 8 strips 3 cm each, thus covering 24 cm of space along Z-axis



Injection molding machine for MDTs plastic details (FORMHOLDER-200/300, Novosibirsk)

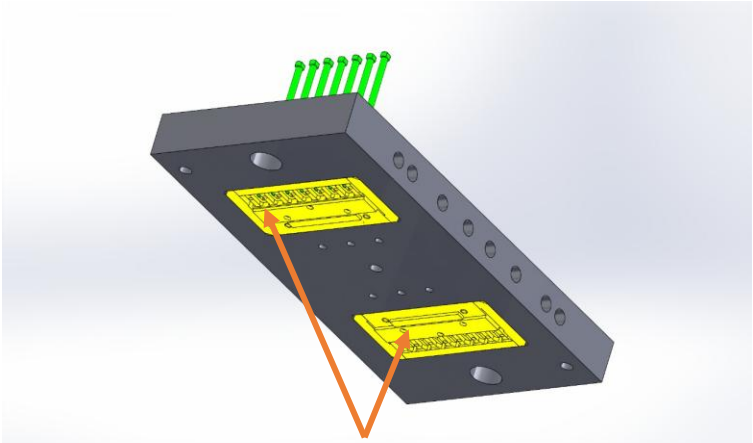
The decision was taken to produce small plastic pieces of MDT detectors in our Lab. The advantages are the following: lower cost, lower bureaucracy, higher flexibility with changing design, occupation of Lab personnel, etc.

Apparatus view in assembled shape



Just arrived to the Lab, April 2025

MDT detector has 5 small plastic details. **Press-forms for them are being designed in the Lab**. Below one of them is shown (punch for MDT's wire holder basement)

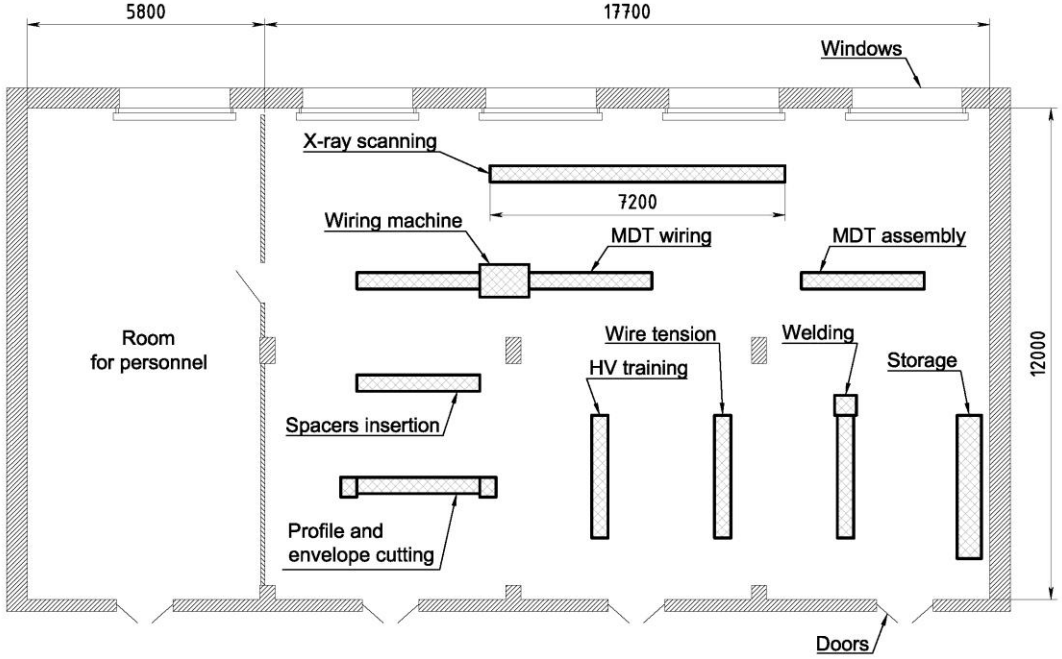


Two imprints of wire holder basement

MDT machinery test area (deployed at old DLNP synchrocyclotron complex)

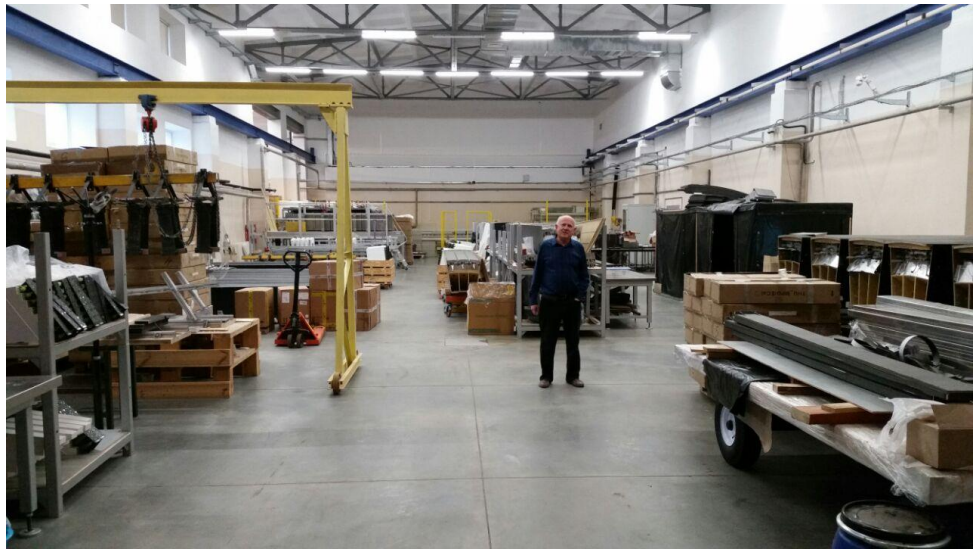
The present area for MDT production and tests will be temporary used until main production area at VBLSHEP (bld.42) is busy with MPD/NICA equipment

Plan of the room witn deployed machinery



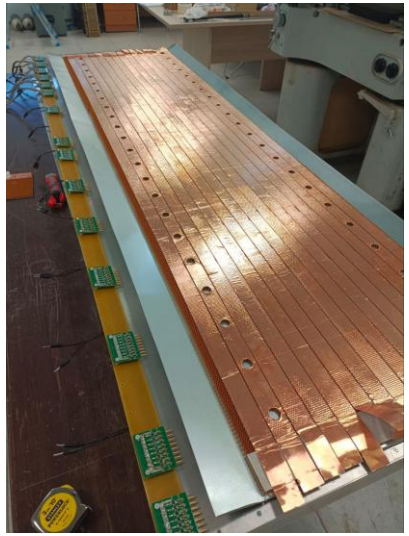
Place of deployment the full MDT assembly conveyor

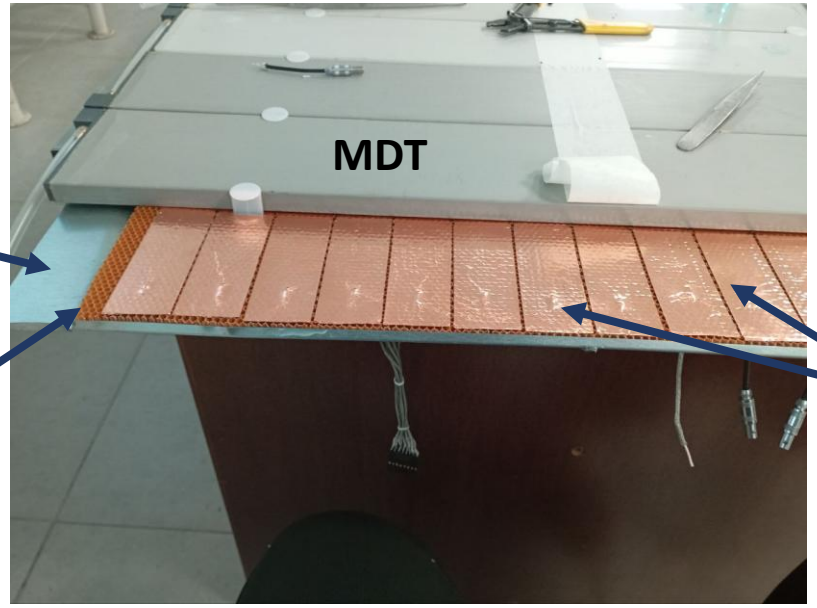
(VBLSHEP lab, bld. 42 – presently used for production/storage of MPD/NICA goods /EMC, TOF/)



Enough space to deploy the MDT production and test equipment, to be used later in 2026

Detector Layer Prototype (DLP)

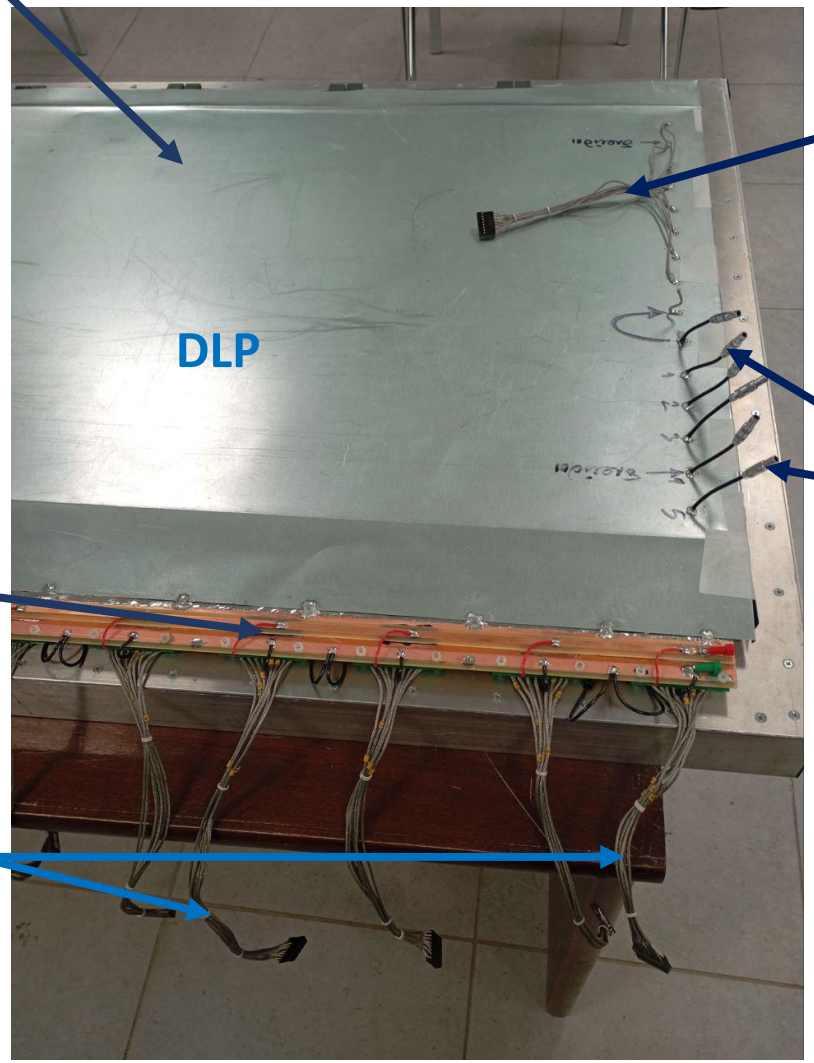


DLP recent assembly consists of 60 cm long MDTs, 2 m long strips (3cm width), 5mm thick honeycomb (air gap) with 3mm cells, new type of blades (cylindrical) and 0,3 mm thick iron (zinc plated) shielding cover. (**corresponds to new concept of stirp board)**

Fully assembled and ready for R&D tests

DLP General R&D Tasks



DLP is designed to:

- study new “air” stripboard parameters and strip signal R/O
- study influence of material choice and peculiarities of assembly technological process on strip R/O parameters
- study shielding efficiency
- develop optimal technological process of full scale detecting layer assembly
- study strip registration efficiency

DLP: measurement of strip wave impedance and capacity

Results obtained using DLP:

Strip capacity =189pF/m (for max strip length - 491pF)

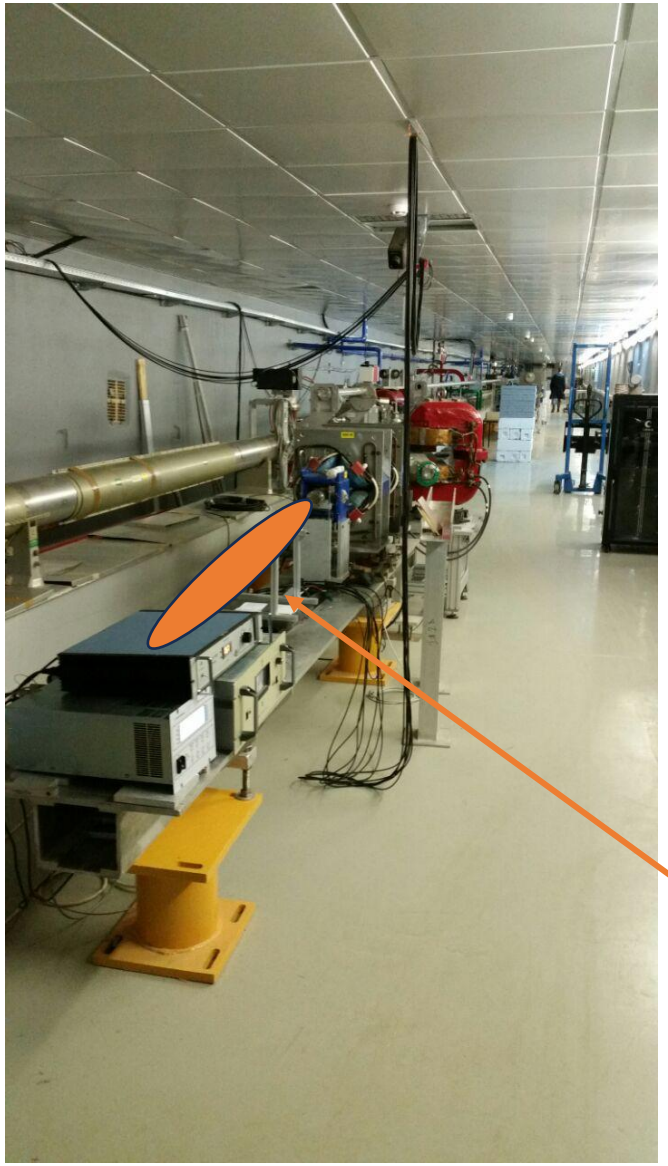
Strip wave impedance = 21 Ohm

The new concept of the "air" strip board provides a wave impedance of 21 Ohm - the matching resistors will form the corresponding voltage dividers with the input impedances of the amplifiers (5 Ohm Ampl-8.53 or 0.3 Ohm Ampl-8.11R.G-5), improving their high-voltage protection. The measured result is within the calculated range and can be slightly improved by adjusting the assembly technology.

Strip maximum capacity (491pF) fits Ampl-8.53 and Ampl-8.11R.G-5 detector capacity rating of 500pF.

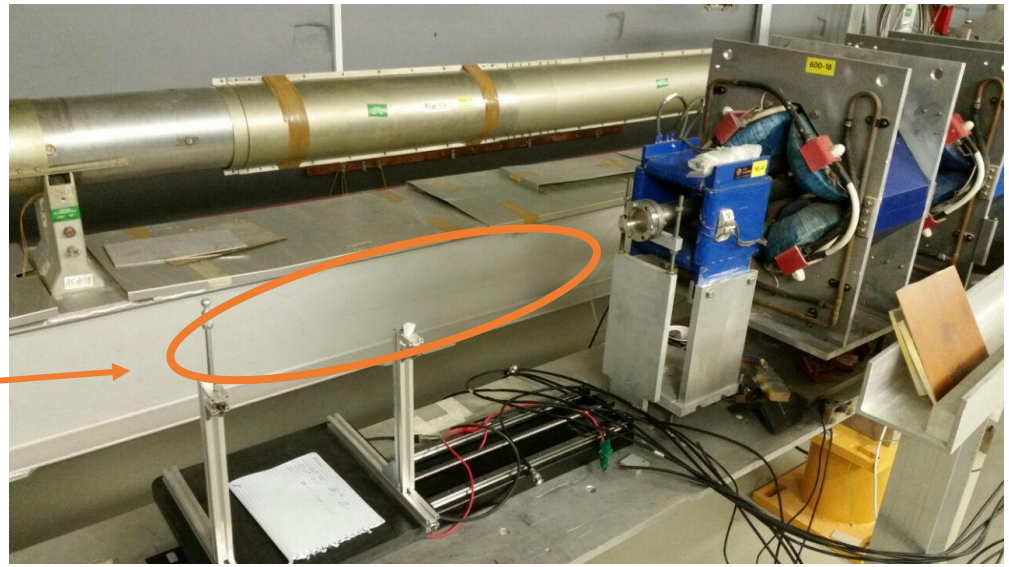
DLNP LINAC-200

(place for pressurized Cherenkov counter test/calibration with 200 MeV electrons)

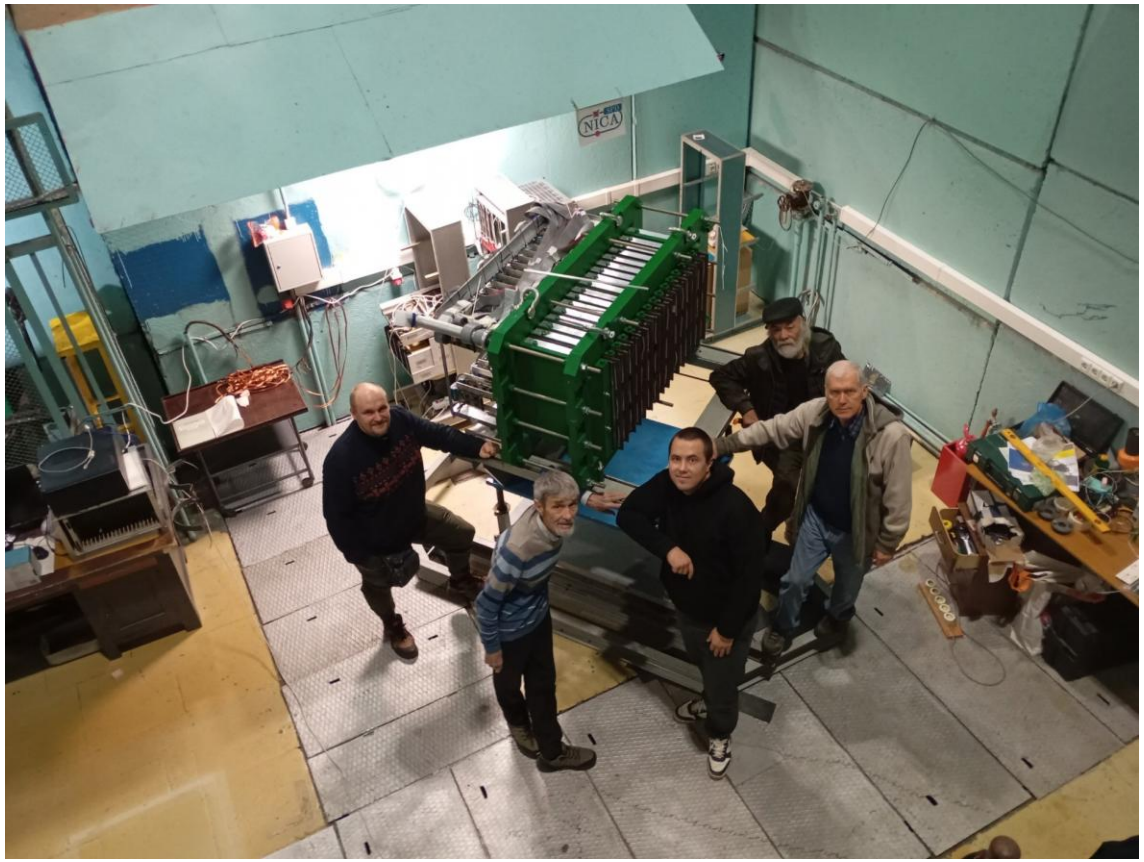


The maximal LINAC-200 energy of 200 MeV was selected as most close to the minimal available at Nuclotron test beam – 400 MeV. So, we expect to have Cherenkov counter calibrated on electrons at proper energy range for the main studies (0,4 – 1,5 GeV) with Range System Prototype at Nuclotron

Position of Cherenkov counter at final focus of LINAC



RS Prototype at work position at NUCLOTRON Test Beam Area, waiting for the beam



Plans for the rest of 2025

- Finish of 3D engineering model of the Yoke in part concerning the impact of MDT detectors and electronics
- Start of the MDT assembly and test areas at DLNP (old cyclotron zone)
- Tests of the first set of amplifier chips (Ampl-8.53) from Integral/Minsk
- Signing the contract with Minsk on FEE chips (Ampl-8.11R-G5, Disc-8.17) preproduction
- Development and debugging of data exchange protocol between FDM-192 and L1 concentrator, production of of specialized VME crates prototypes for FDM-192 placement (Moscow State University)
- Development of strip readout technology (analog cards and strip boards)
- Tests of Cherenkov counter with electron beam of DLNP LINAC-200
- Start testing of RS Prototype with Nuclotron test beam +/- (e, μ, π, K), p, n, d
- Correction of plan for RS construction (preliminary)
- Participation in development of PID algorithms for pion-to-muon separation using test beam data

CONCLUSION

- We are migrating from pure R&D stage to combined R&D&Production stage
- No visible ‘show stoppers’ are observed so far for design works
- The closer we approach the mass production stage the more we need increase in manpower