SPD Collaboration meeting, Samara, 24 October, 2023

Range System Status Report

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on behalf of SPD Muon Group

- **Main result:**

  - FEA analysis conducted for combined gravity and magnetic forces applied to the full SPD setup demonstrates no critical zones

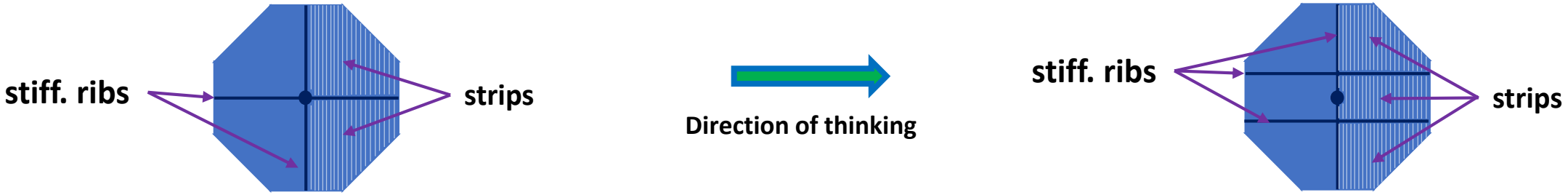
- **Current activities:**

  - Testing/tuning of new/"final" SPD digital FDM-192 FEE card (Moscow State University)
  - Testing/tuning of DAQ system for prototype readout (to be used at Nuclotron)
  - Development of "local DAQ" for tests of small MDTs assemblies
  - Development of the layout for detecting plane analog FEE, cables and power buses
  - The contract on amplifier chip (Ampl-8.53) preproduction at INTEGRAL (Minsk) is close to be signed (expected in November 2023 with execution by December 2024)
  - The AGRISOVGAS installed new equipment to be used for mass production of the main MDTs element – thin wall aluminum profile, and expect a contract with JINR
  - Development of PID algorithms for pion-to-muon separation (see report of Alexander Verkheev, this meeting)

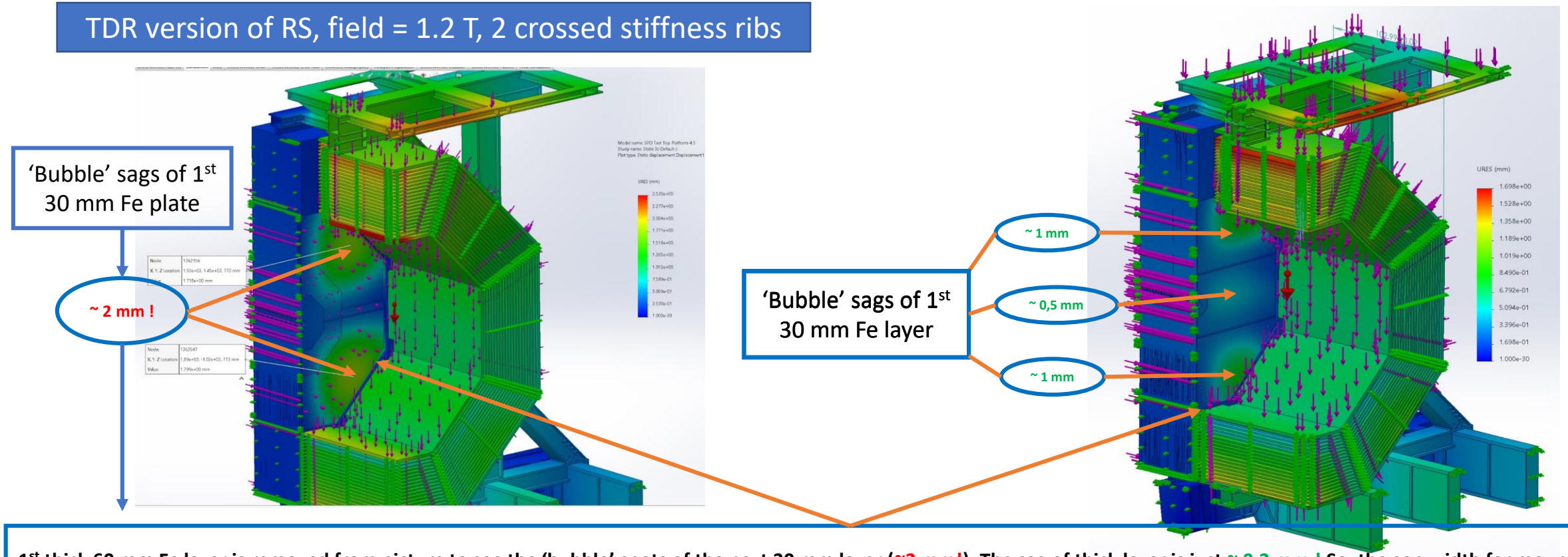
- **Plans for 2024**
- **Conclusion**

FEA analysis conducted for combined gravity and magnetic forces applied to the full SPD setup demonstrates no critical zones

(analysis is made by Alexander Samartsev/JINR on the basis of magnetic forces map provided by Evgeny Antokhin/INP, Budker)



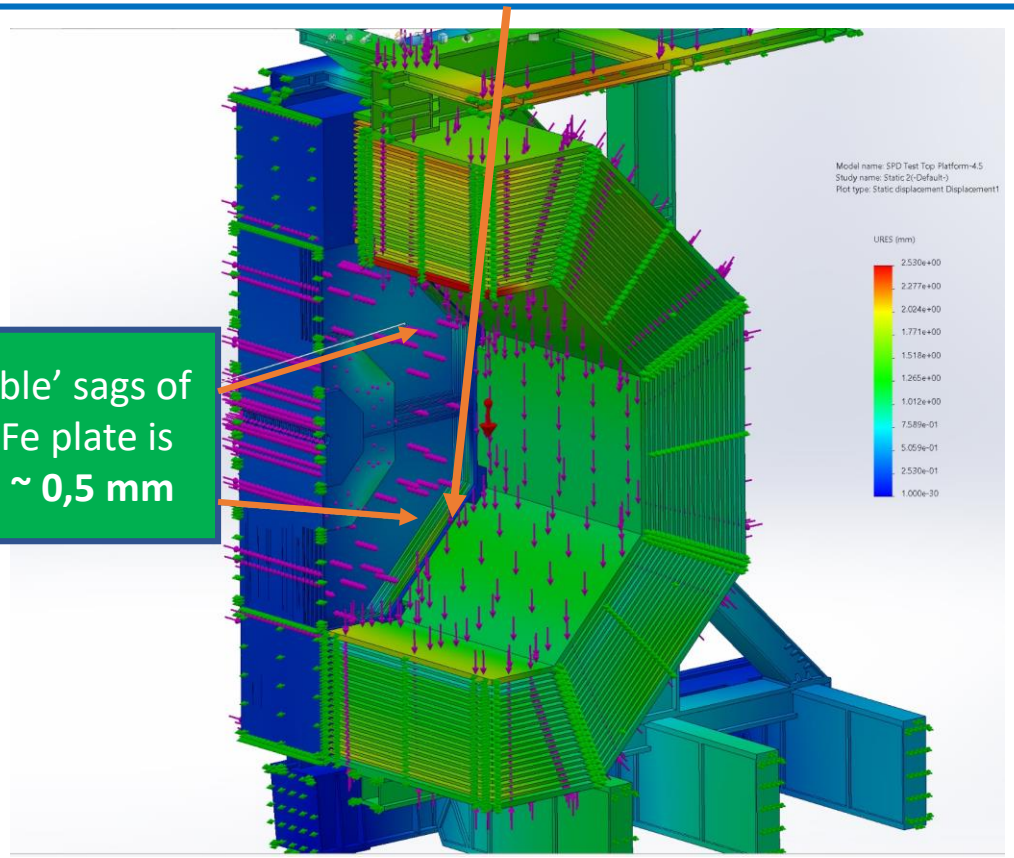
TDR version of RS, field = 1.2 T, 2 crossed stiffness ribs



1st thick 60 mm Fe layer is removed from picture to see the 'bubble' spots of the next 30 mm layer (~2 mm!). The sag of thick layer is just ~ 0,3 mm ! So, the gap width for mounting the detecting plane decreased by ~ +0,3 - 2 = - 1,7 mm! It is almost twice larger then our present limit 1 mm (comparable with expected mechanical accuracy after manufacturing and assembly)

Effect of magnetic field (penetration in just few first Fe layers of End Caps) may/should be used to minimize impact of additional strengthening ribs on the number of strip boards/channels

First 6 layers are removed to see small effect of magnetic field in depth of End Caps (field penetrates only in few layers)



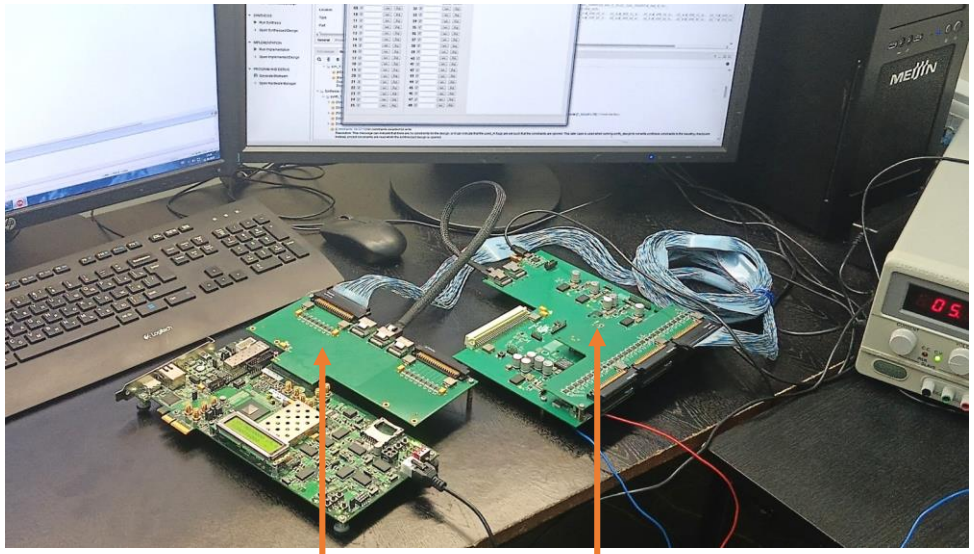
'Bubble' sags of 7th Fe plate is just **~ 0,5 mm**

Main conclusions :

- Additional magnetic forces do not influence RS dramatically
- Main effect is on End Caps, Barrel is slightly sensitive
- TDR version of RS requires small modification – adding of one more horizontal stiffness rib
- Negative consequence of that is increase in number of strip boards/channels by 50%
- **Using peculiarity of magnetic field in End Caps it is possible to combine 1-rib and 2-ribs solutions to minimize the increase in number of strip readout channels: first planes (out of 20 in total) have 2 ribs and the rest – just 1 rib. Optimal solution requires additional more detailed calculations.**

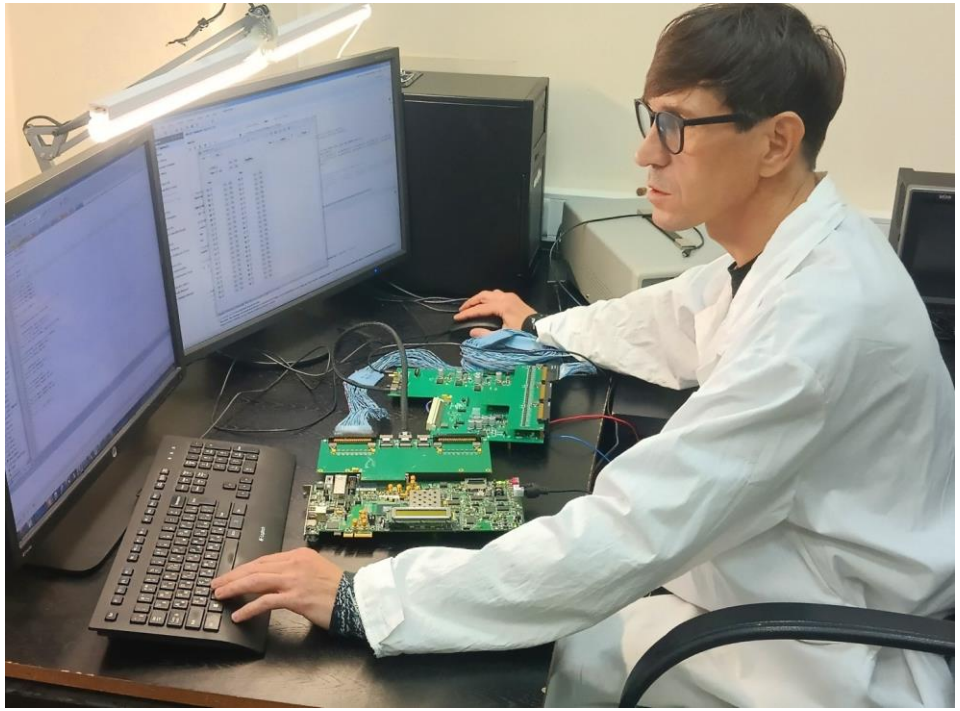
Testing/tuning of new digital FEE prototype FDM-192 card (Moscow State University)

Stand for debugging of FDM-192 unit and data exchange protocol between FEE and L1 concentrator (SPD DAQ)



FDM-192 card

Evaluation board on the basis of Artix 7-200T FPGA (kit) with Mezzanine card (developed by our Muon team)



Developer of FPGA firmware for FDM-192 unit (Andrey Ainikeev, MSU)

Testing/tuning of DAQ system for prototype readout (to be used at Nuclotron)

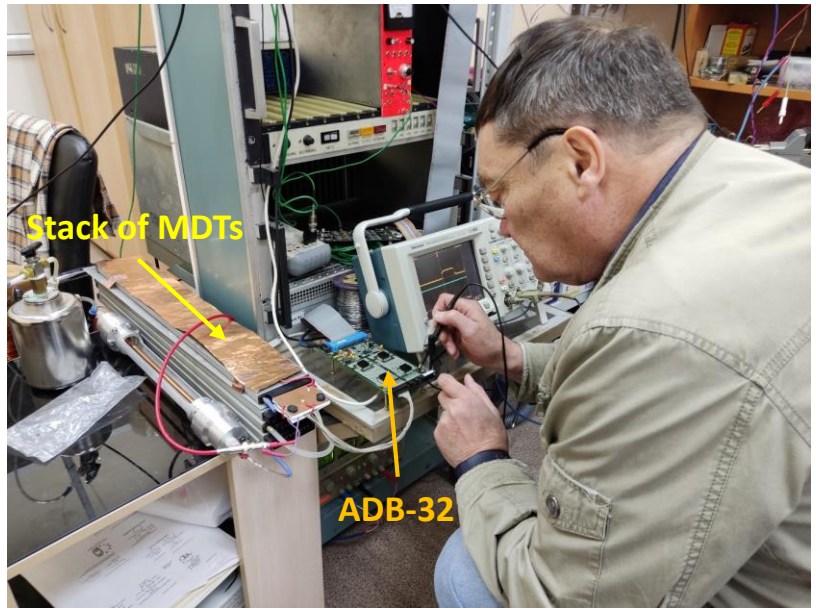
RS Prototype: fully operational (MDT detectors, HV, LV supplies, gas system) except for R/O system (part of MFDM-192 units and DAQ system) at Nuclotron hall

DAQ System: Trigger Control System, GeSiCA units (7/JINR + 2 borrowed from AMBER/CERN -> start thinking on how to replace them…)

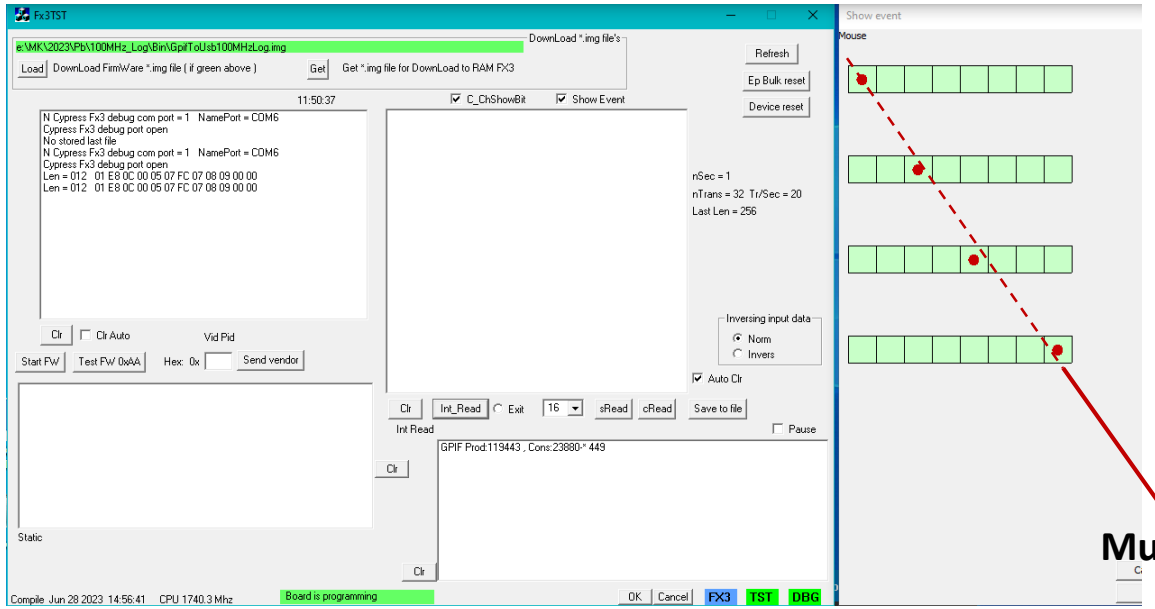
Digital FEE VME crate with 7 MFDM-192 units

DAQ crate

‘Local DAQ’ for testing of small MDTs assemblies

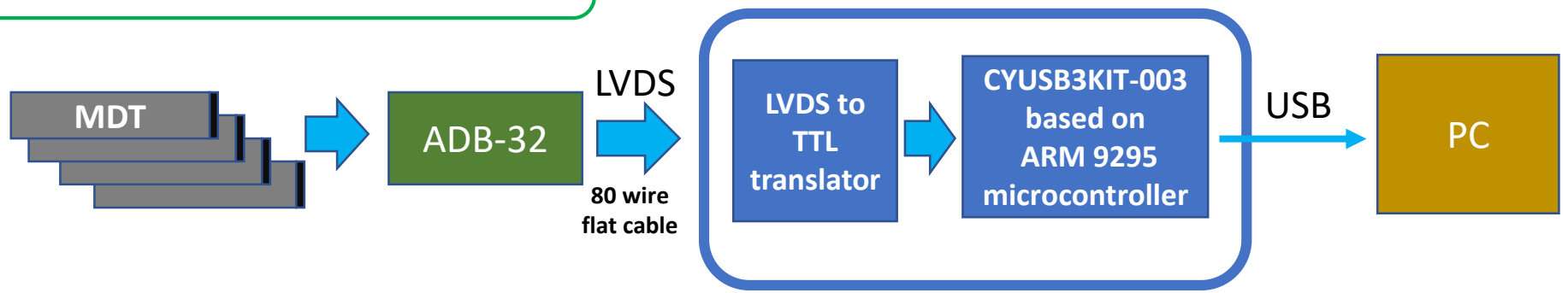


Screenshot of Local DAQ interface

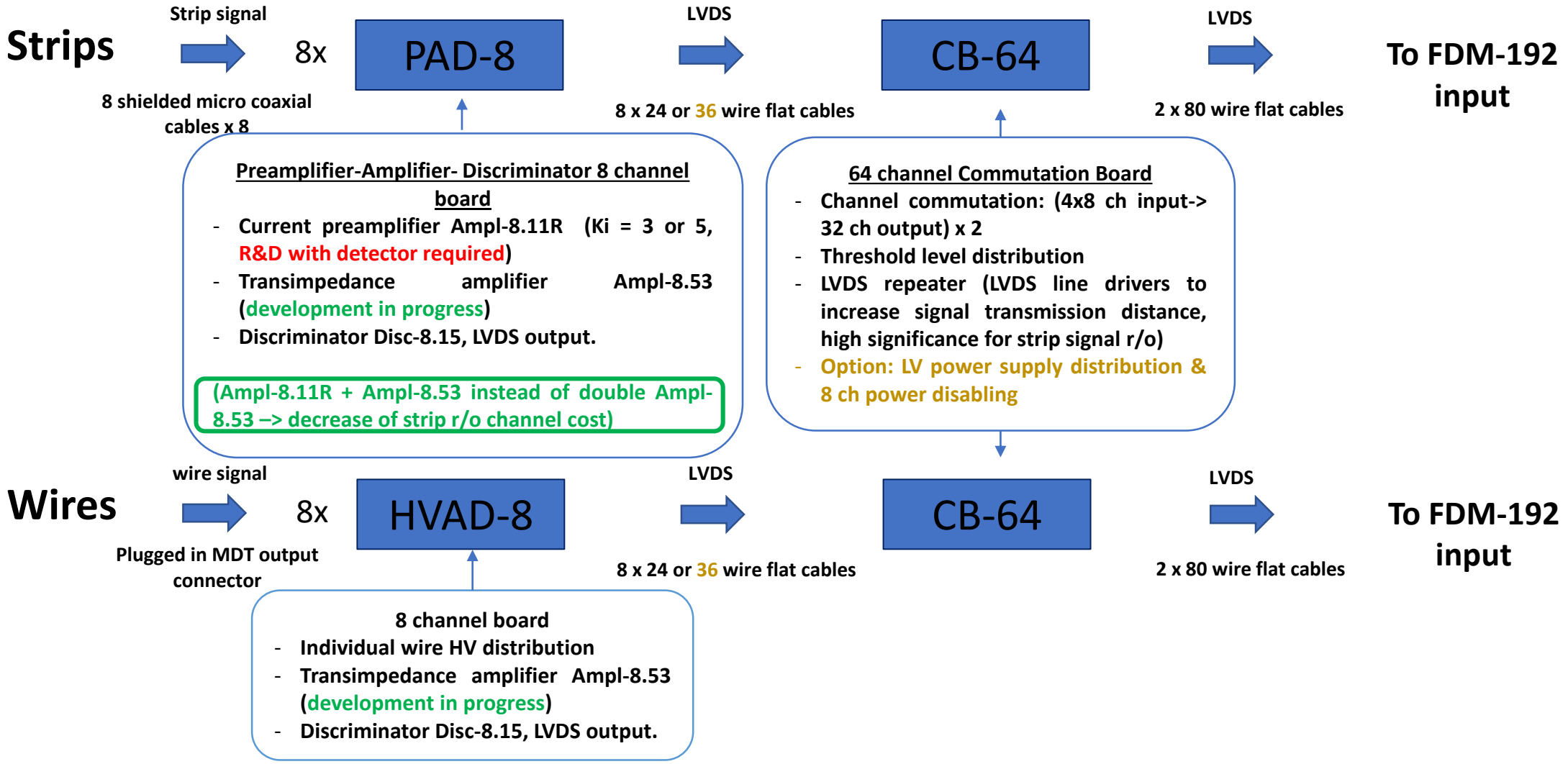


‘Local DAQ’ module operates in both external trigger and autorun modes

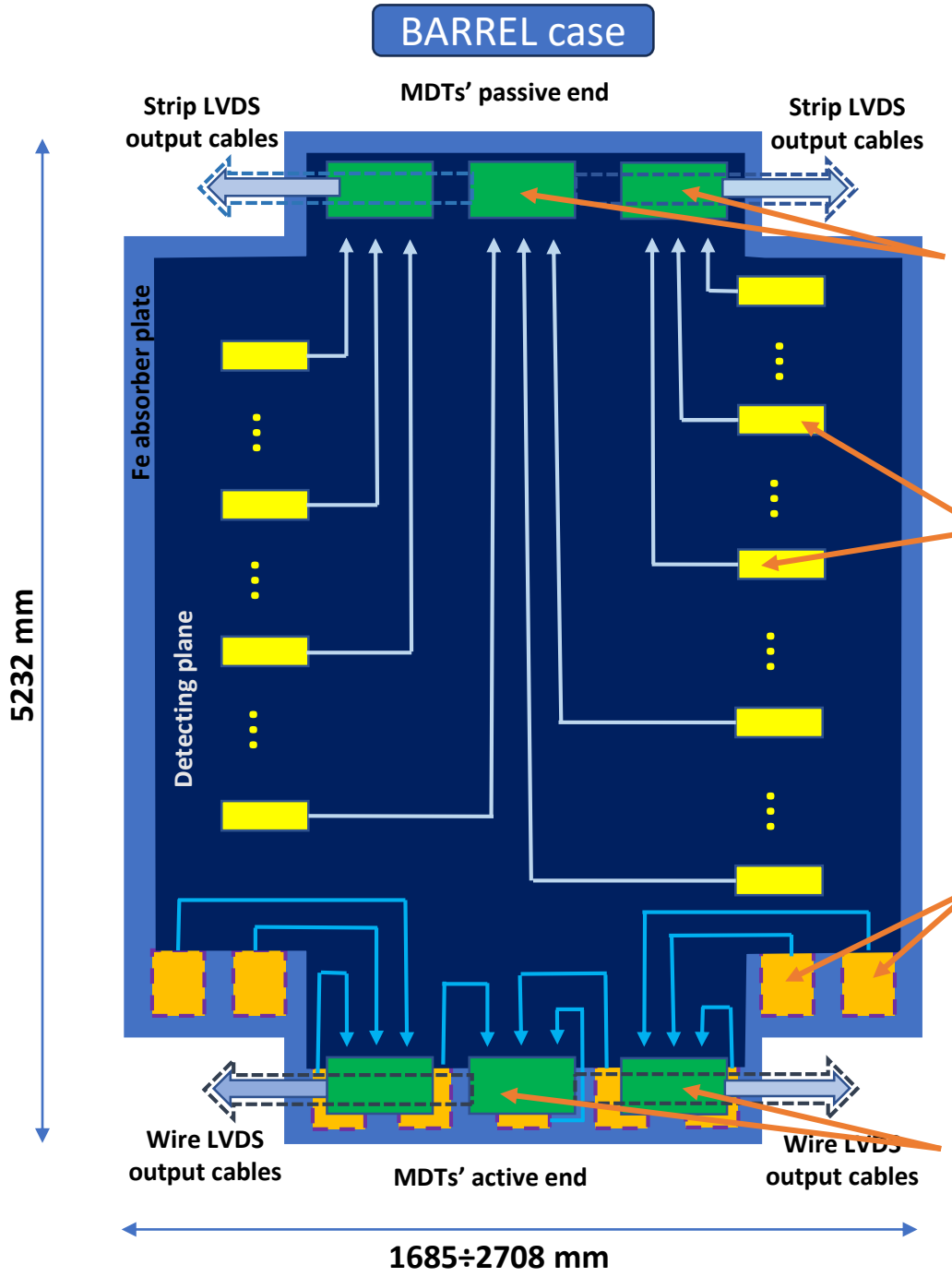
‘Local DAQ’ module, 32 channels



Wire and strip analog readout block diagram



Analog FEE 'logistics'



CB-64 (strip r/o)

Allocated on the top of the plane at the very edge of the back side (passive end), 3 cards per plane (6 output flat cables), accessible, need special tool for disassembly

PAD-8

Allocated on the top along the plane sides close to the edge (at maximum gap width), connected to strips with micro coaxial cables through the holes in detecting plane shielding, 21 cards per detecting plane, inaccessible during SPD life time !

HVAD-8

Plugged in MDT active ends, 19-31 cards depending on detecting plane, mostly accessible

CB-64 (wire r/o)

Allocated on the top of the plane at the very edge of the front side (active end), 2-4 cards per plane (4-8 output flat cables), accessible, need special tool for disassembly

Particle Reconstruction in RS

(MC performed for the full SPD setup)

Input, 50k $J/\psi \to \mu\mu$ sqrt(s) = 27 GeV:

- hits in Barrel: (x, y) of wires at layers and z of strips
- hits in EndCaps: (y, z) of wires and x of strips

Clustering (forms group of hits) is unsupervised machine learning technique that groups data points into clusters based on their similarities.

DBSCAN algorithm performance:
purity of 0.97 and v-measure of 0.98.

Classification (Particle Identification) is a common task in machine learning that involved predicting the class or category of a given input data point

Decision tree, Random Forest, XGBoost performance:
precision ~ 0.94-0.95, recall ~ 0.89-0.90.

CNN have shown a good result in recall metric – 0.96.

Plans for 2024

- Repeat FEA mechanical calculations for SPD setup with magnetic forces (after getting more field information from Novosibirsk team)
- Optimize End Caps and Barrel (up and down modules) designs
- Put RS prototype in operation with DAQ at Nuclotron test area
- Get new digital FEE FDM-192 card ready
- Continue MDT plane prototyping with stand-imitator
- Start study of pressurized Cherenkov counter with cosmic
- Get Ampl-8.53 chips from INTEGRAL
- Continue PID algorithms study

CONCLUSION

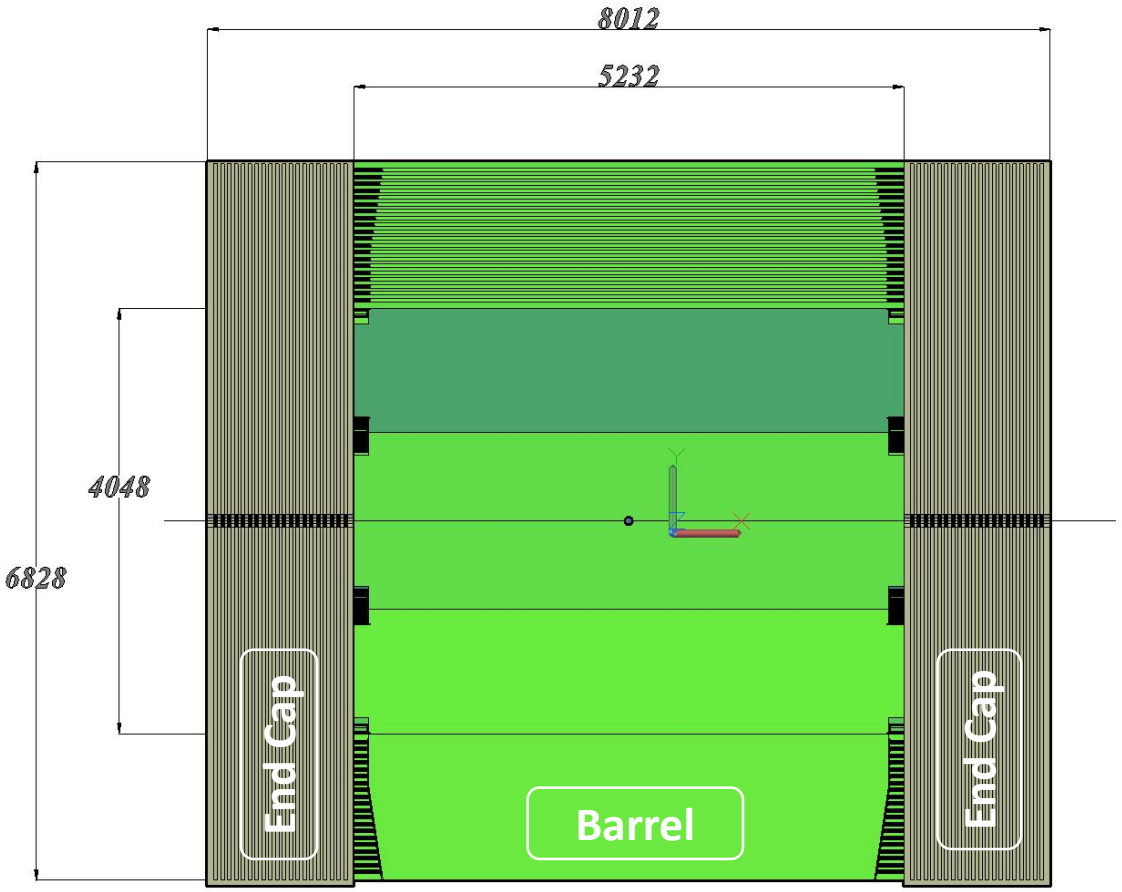
Addition of magnetic forces to gravity does not change mechanical behavior of SPD setup dramatically – it is not ‘show stopper’. Effect of magnetic field is mostly observed in End Caps and it may be minimized by simple measures. R&D and engineering works (analog and digital FEE, ‘logistics’ of electronic cards and cables in slots of absorber) are progressing. Contacts with industry (INTEGRAL/Belarus, AGRISOVGAZ/Russia) are reliable.

Backup slides

New sizes of SPD: +10 cm/R & +/-15 cm/longitudinally, absorber structure of RS left the same

(vertical cross section)

Main consequences of final/bigger size: 1) green light to design of solenoid, 2) more space for inner detectors, 3) higher load on support frame and infrastructure -> need to modify/strengthen them (done)



Total weight of new SPD setup: 1267 (+113) ton

Barrel: 536 (+54,4) ton (*)
End Caps: 471,3 (+23,3) ton
Support & Transportation: 119,7 (+35,3) ton
Inner detectors & Solenoid: 100 ton
Upper platform: 40 ton

……

(*) Barrel/8 modules = 67 ton (within crane capacity)

New SPD setup

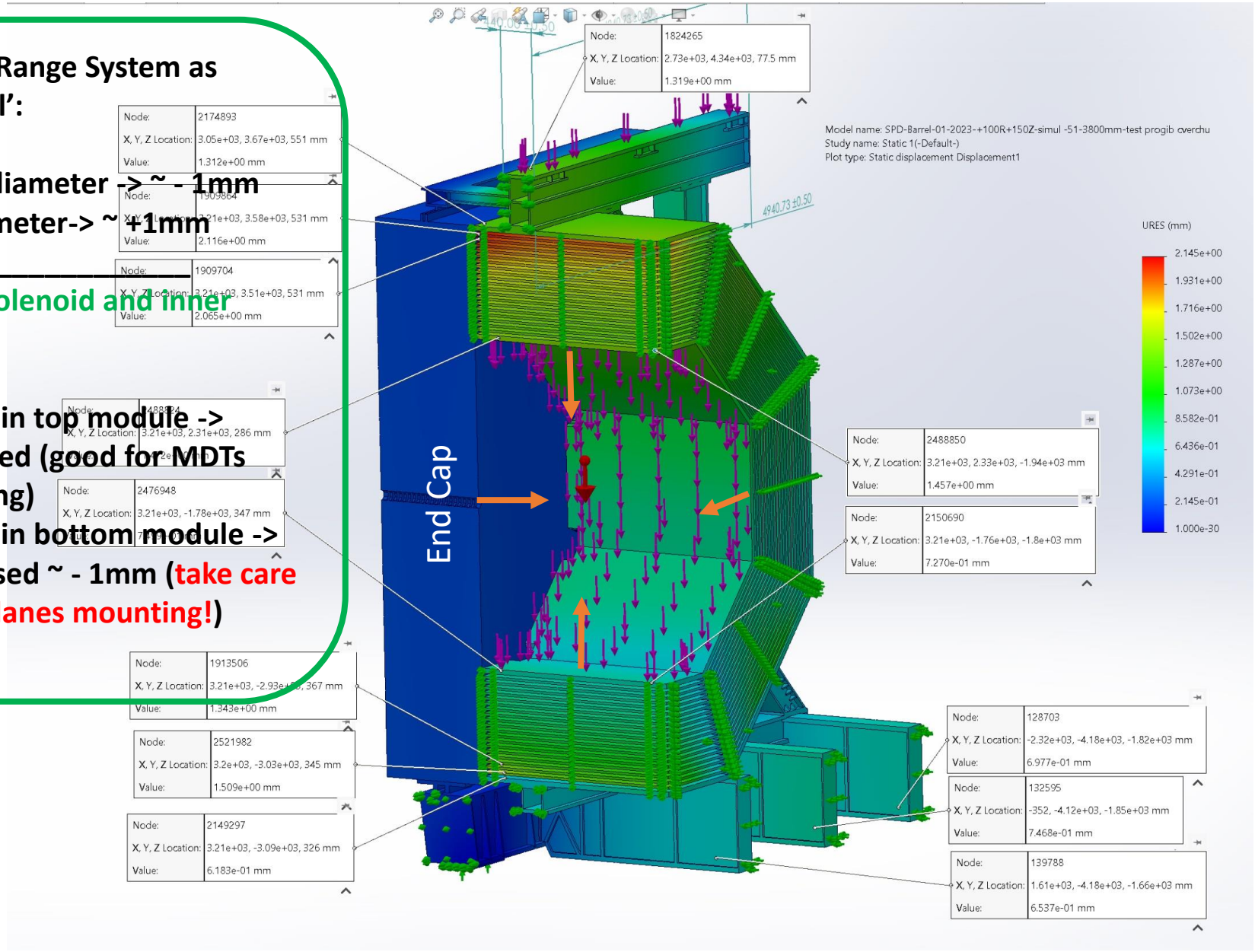
(quarter of setup is shown – due to symmetry of the simulation tasks)

New geometry of Range System as compared to 'ideal':

- **Vertical inner diameter -> ~ - 1mm**
- **Horizontal diameter-> ~ +1mm**

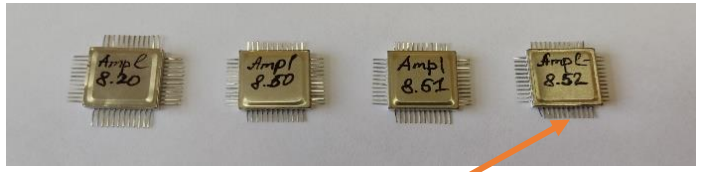
No problems for solenoid and inner detectors!

- **Absorber slots in top module -> slightly increased (good for MDTs planes mounting)**
- **Absorber slots in bottom module -> slightly decreased ~ - 1mm (take care during MDTs planes mounting!)**



With magnetic field additional forces (yellow arrows) setup must be considered also. They complicate picture for RS, but do not change the loads to the floor

Development of low input impedance amplifier chips: from Ampl-8.3 to Ampl-8.53

Ampl-8.3 → 

→ Ampl-8.53 → **To be used in RS analog front-end electronics**

Used for:
D0/FNAL,
COMPASS&AMBER/CERN,
PANDA/FAIR (project) muon systems

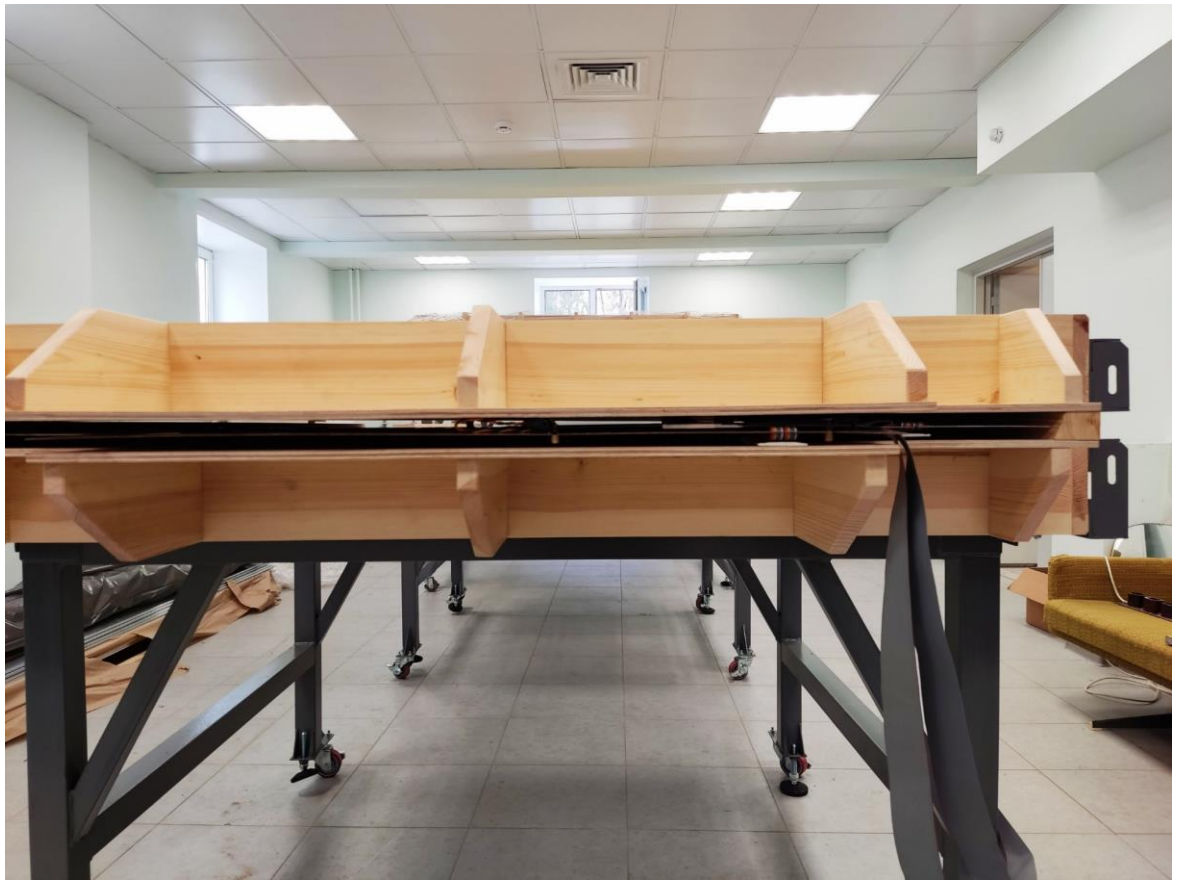
R&D stage to the version Ampl-8.52 tested at CERN and Minsk

Chip with new (compared to Ampl-8.52) optimized topology is being developed now in Minsk (group of M.A. Baturitsky)

Contract with Integral (Minsk) on Ampl-8.53 amplifier preproduction is under discussion. In case of signing the contract this summer we may have first bunch of chips in summer 2024

Full-size stand-imitator to study: optimal design of MDTs detecting layer with strip board, analog front-end electronic cards deployment for wires and strips readout, cabling in/out the absorber slot

Detecting plane mockup (MDTs, strip board, analog FEE cards and cables) inside the slot 30 mm of stand-imitator: rather dense space !



Preliminary impression after assembly of detector plane into the slot of stand-imitator -> 30 mm gap is close to practical limit