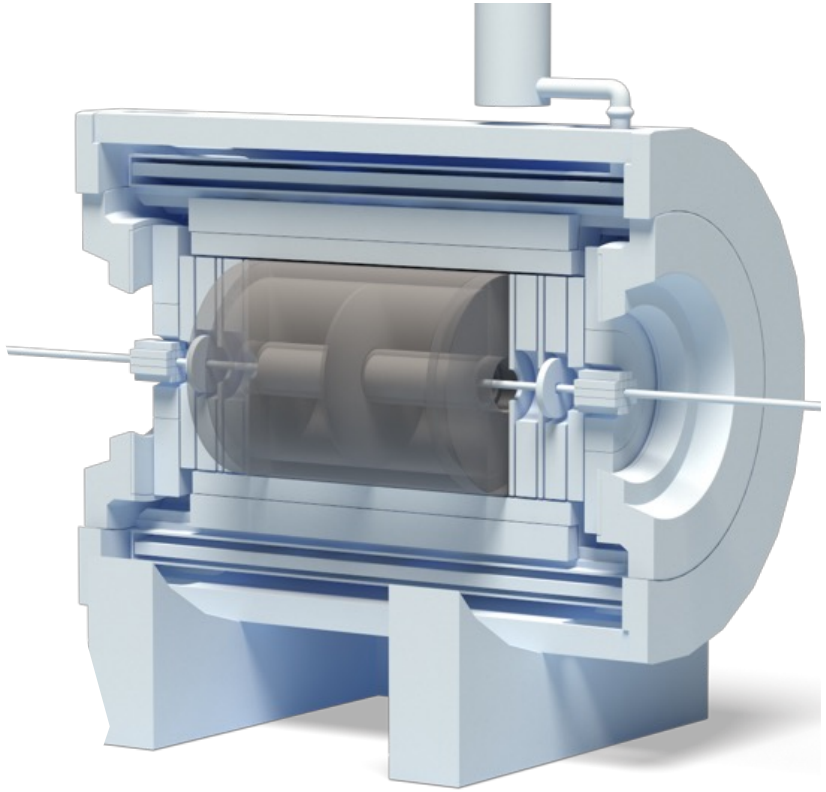
Time Projection Chamber Assembling

Stepan Vereschagin, on behalf of the TPC/MPD group, VBLHEP, JINR



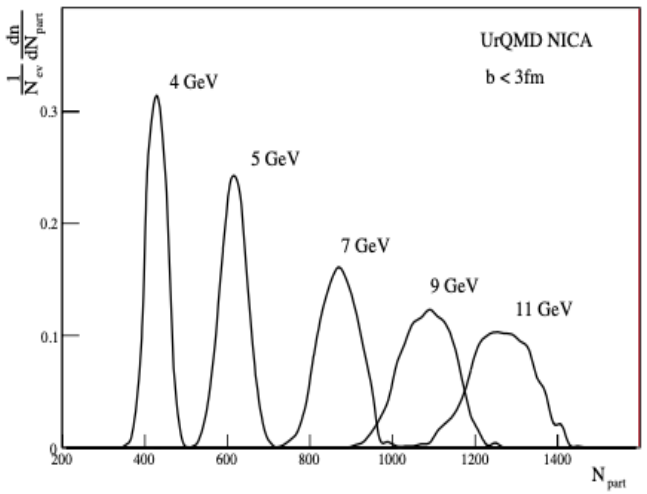
Outline

NICA Complex

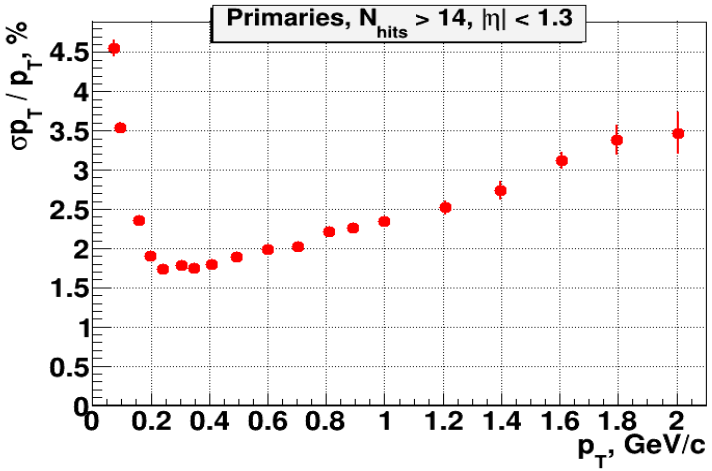
https://nica.jinr.ru/

http://mpd.jinr.ru/

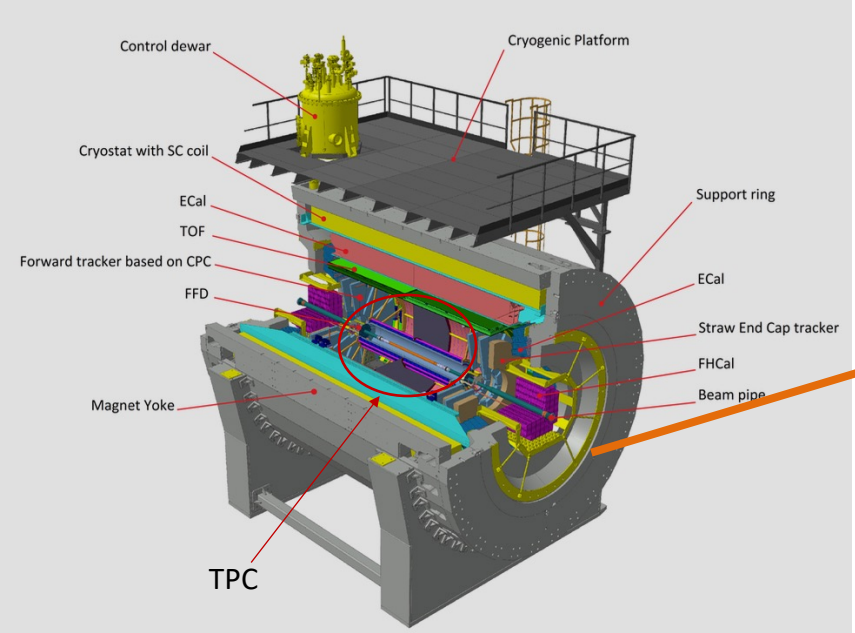
MPD experimental setup



Charged multiplicity distributions in central Au + Au collisions (b < 3 fm) calculated by UrQMD.



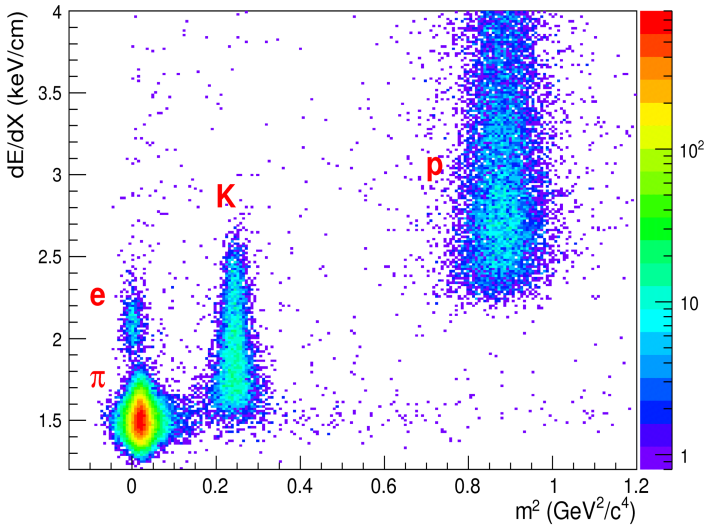
MPD Stage II



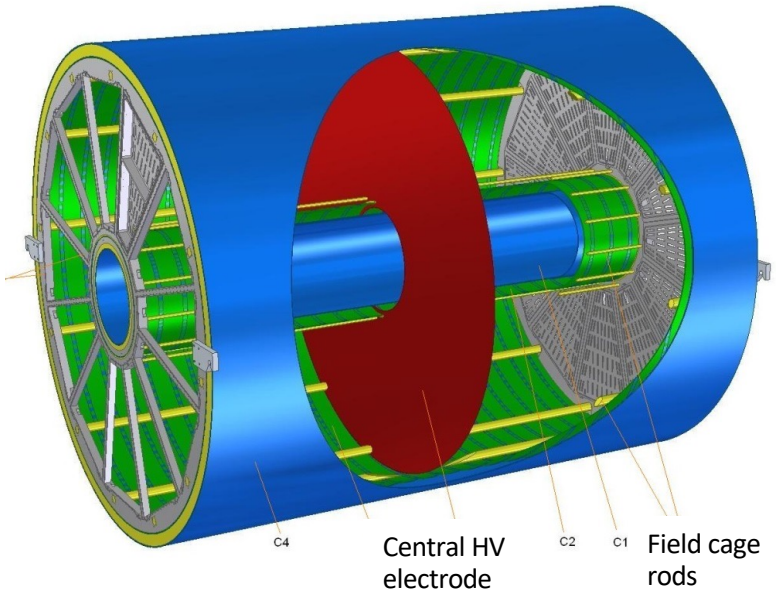
MPD stage I detectors:

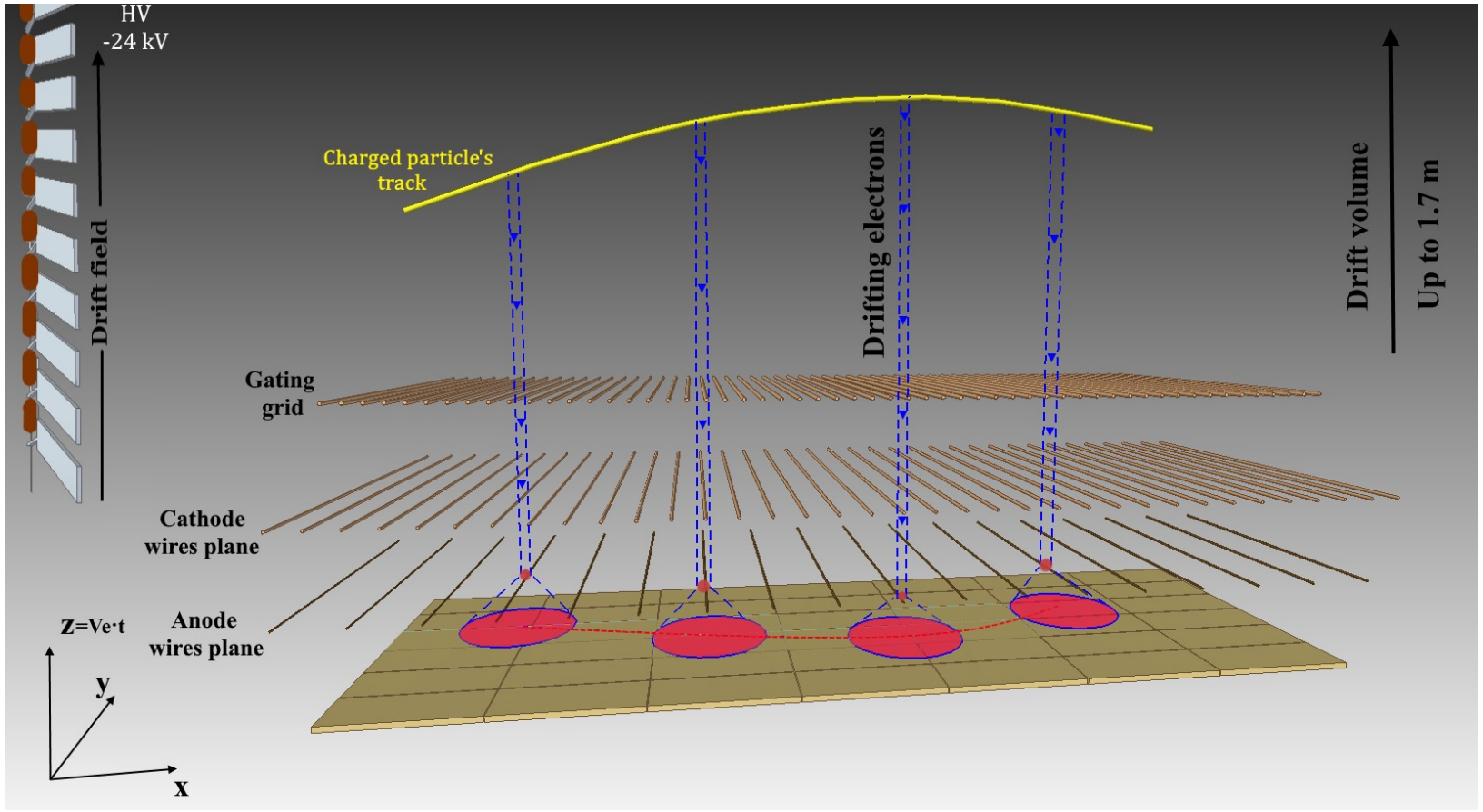
- **ECal:** Electromagnetic Calorimeter
- **FFD:** Fast Forward Detector
- **TOF:** Time of Flight system
- **FHCal:** Forward Hadron Calorimeter
- **TPC**: Time Projection Chamber

Magnet assembly in the MPD Hall



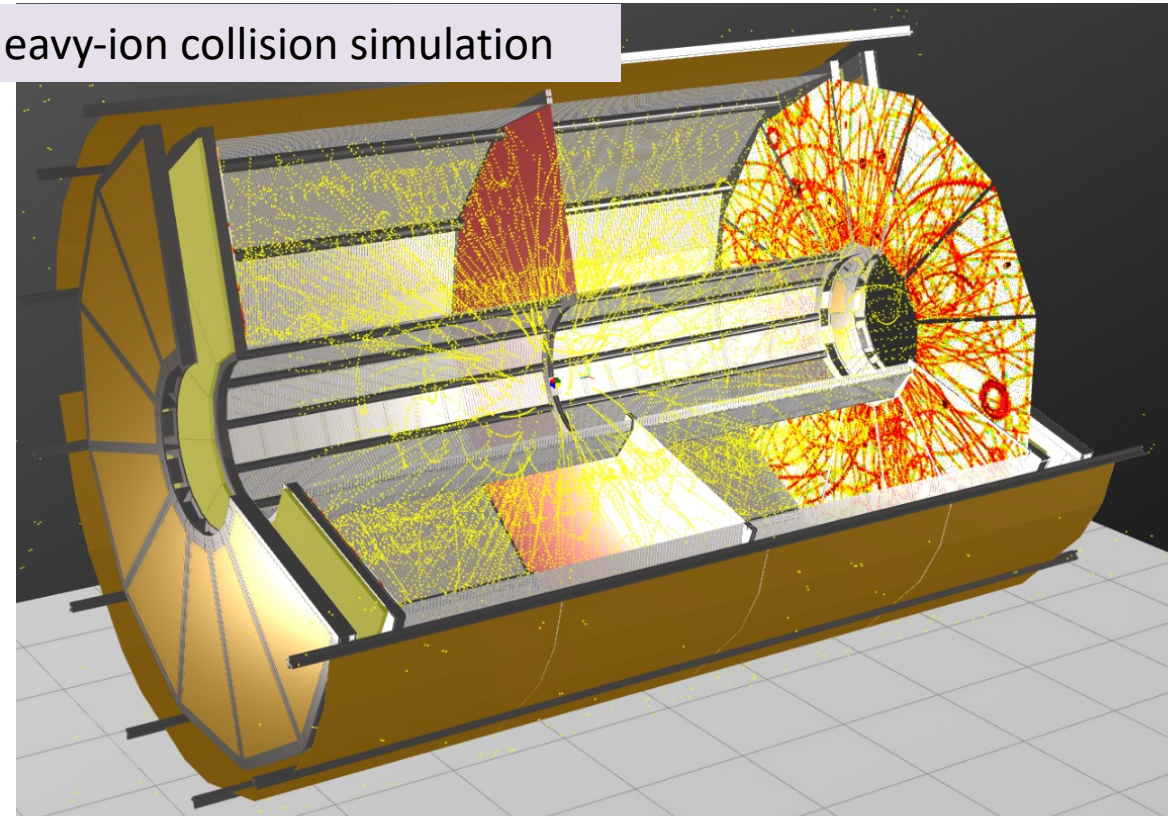
TPC operational principle





TPC design requirements and main parameters

Heavy-ion collision simulation



The TPC/MPD design requirements:

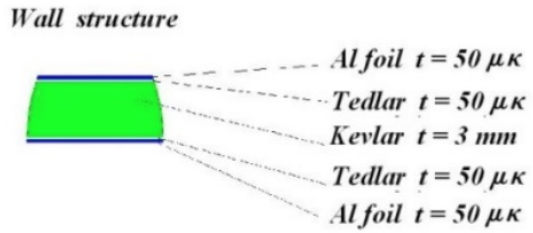
- The overall acceptance: η < 1.2
- The momentum resolution for charged particles is under 3% in the transverse momentum range 0.1 < pt < 1 GeV/c
- Two-track resolution is of about 1 cm
- Hadron and lepton identification by dE/dx measurements: with a resolution better than 8%
- Operation trigger rate: 7 KHz

TPC main parameters:

Item	Dimension
Length of the TPC	340cm
Outer radius of vessel	140cm
Inner radius of vessel	27 cm
Outer radius of the drift volume	133cm
Inner radius of the drift volume	34cm
Length of the drift volume	170cm (of each half)
HV electrode	Membrane at the center of the TPC
Electric field strength	~140V/cm;
Magnetic field strength	0.5 Tesla
Drift gas	90% Ar+10% Methane, Atmospheric pres. + 2 mbar
Gas amplification factor	~ 10^4
Drift velocity	5.45 cm/μs;
Drift time	< 30μs;
Temperature stability	< 0.5°C
Number of readout chambers	24 (12 per each end-plate)
Segmentation in ϕ	30°
Pad size	5x12mm^2 and 5x18mm^2
Number of pads	95232
Pad raw numbers	53
Pad numbers after zero suppression	< 10%
Maximal event rate	< 7 kHz (Lum. 10^{27})
Electronics shaping time	~180 ns (FWHM)
Signal-to-noise ratio	30:1
Signal dynamical range	10 bits
Sampling rate	10 MHz
Sampling depth	310 time buckets

TPC cylinders

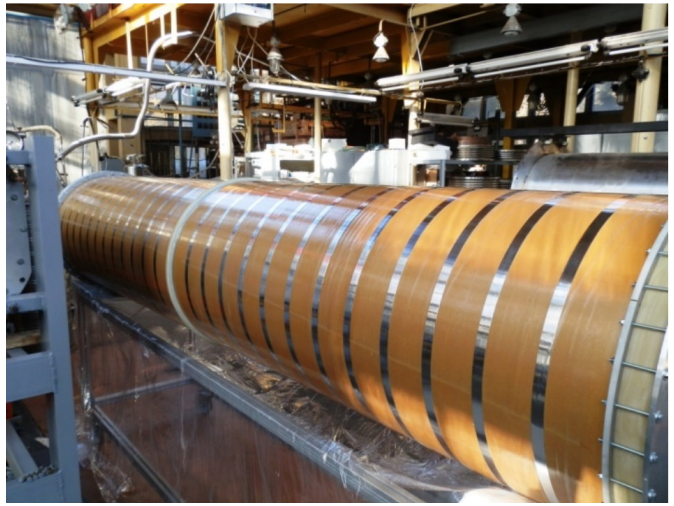
C1 cylinder



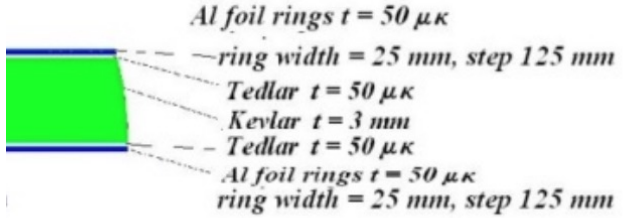
D_{in} = 540 mm, L = 3400 mm

C3 cylinder

D_{in} = 2660 mm, L = 3400 mm

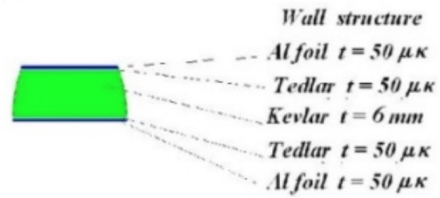


C2 cylinder



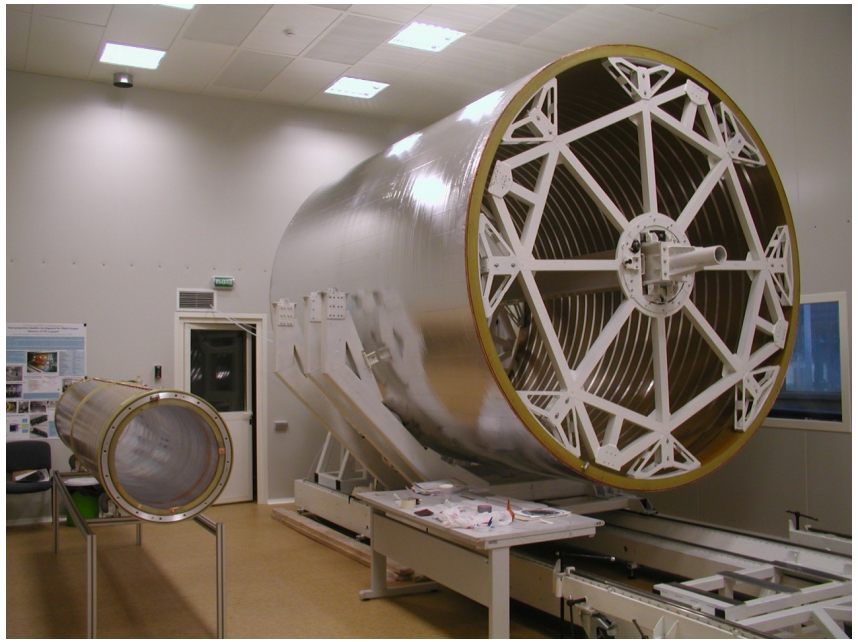
D_{in} = 676 mm, L = 3400 mm

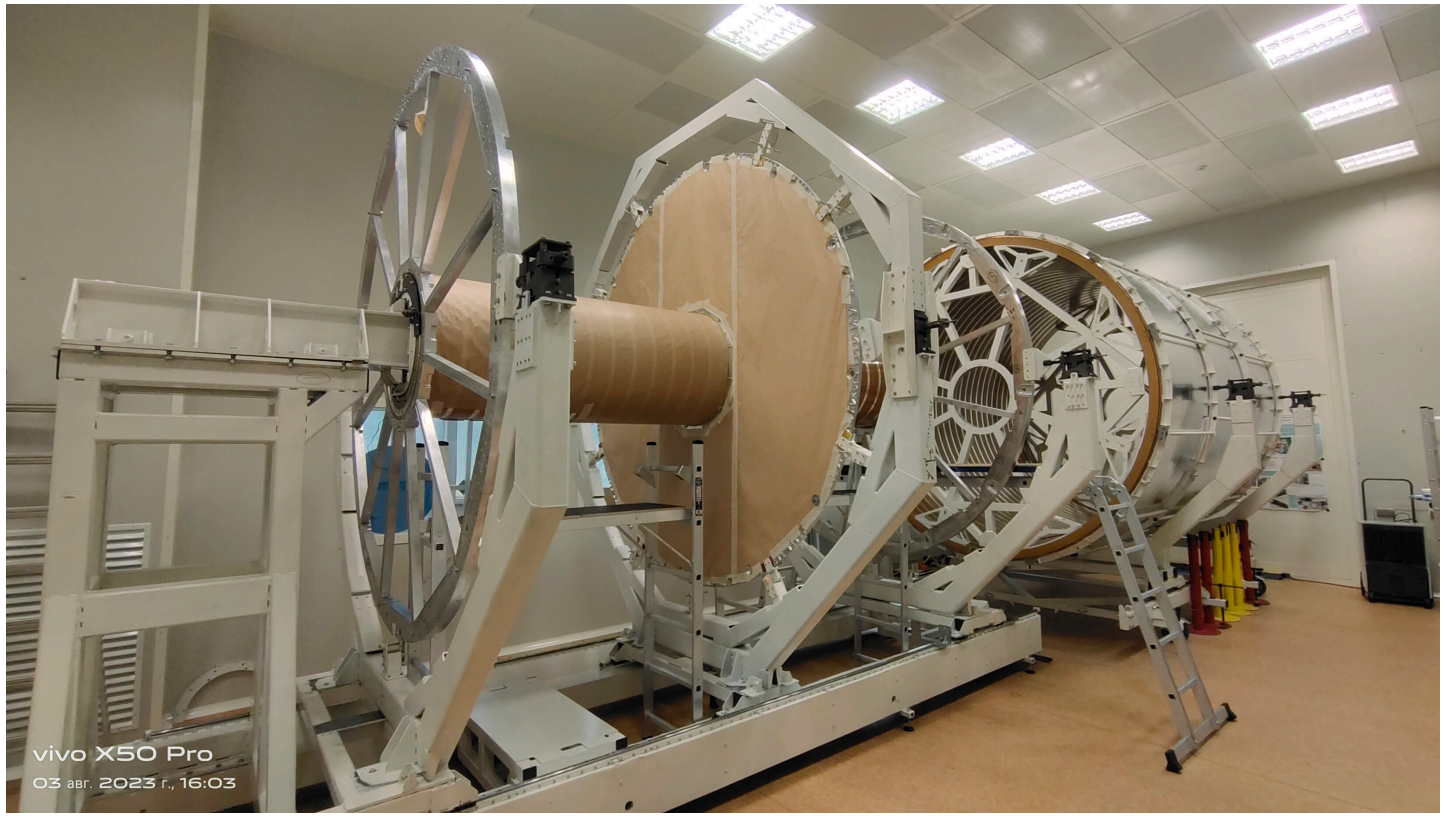
C4 cylinder



D_{in} = 2802 mm,
L = 3400 mm

TPC cylinders assembly

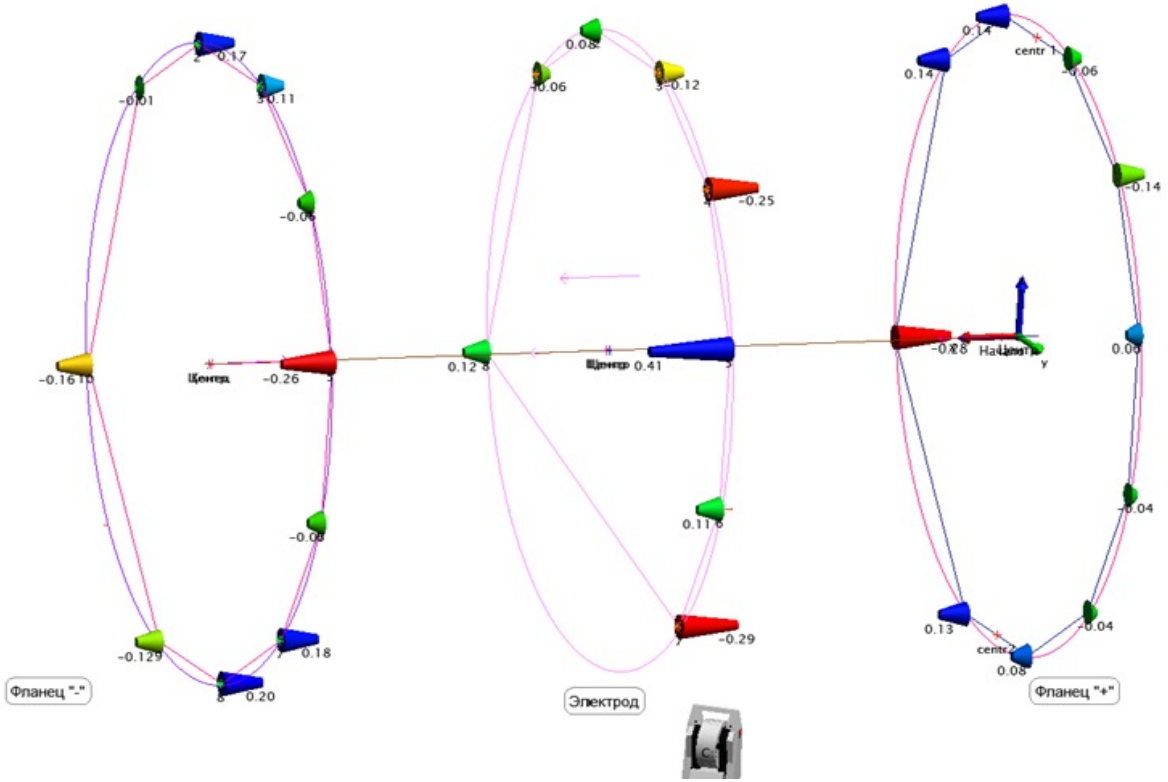




TPC body was assembled with test rods to check TPC geometry by laser tracker AT-402

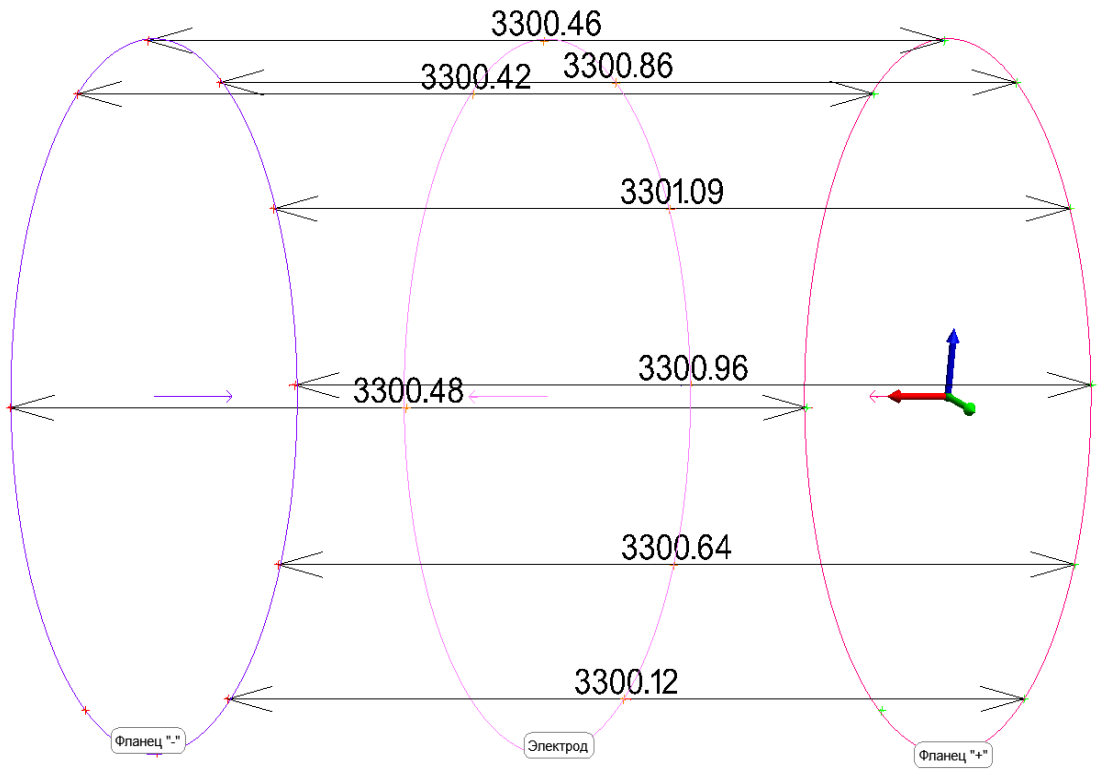
TPC vessel assembling

Flanges and HV electrode unflatness



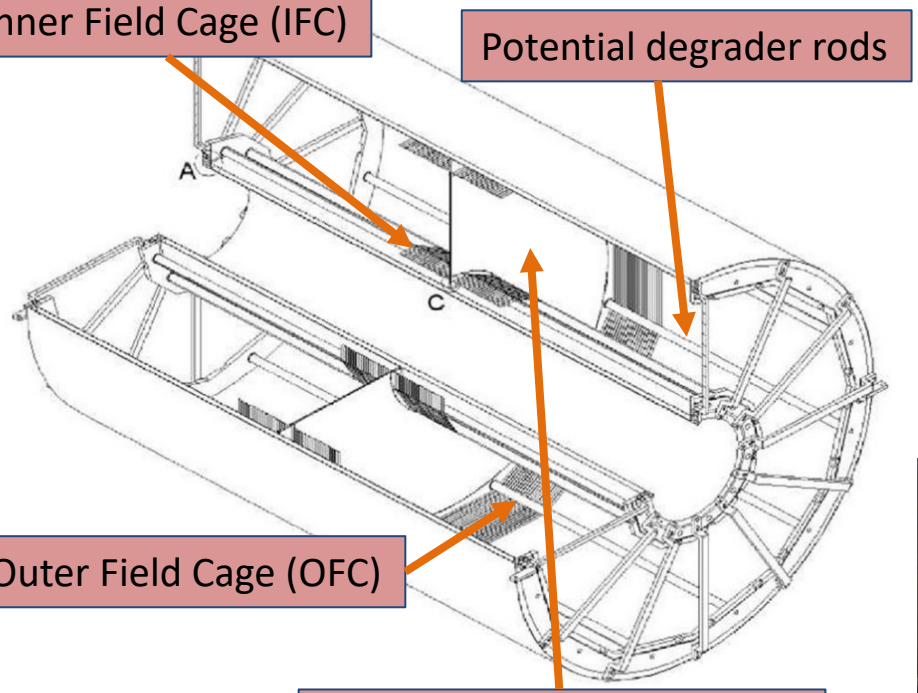
Flanges unflatness is about 0.5 mm
HV electrode unflatness is about 0.7 mm

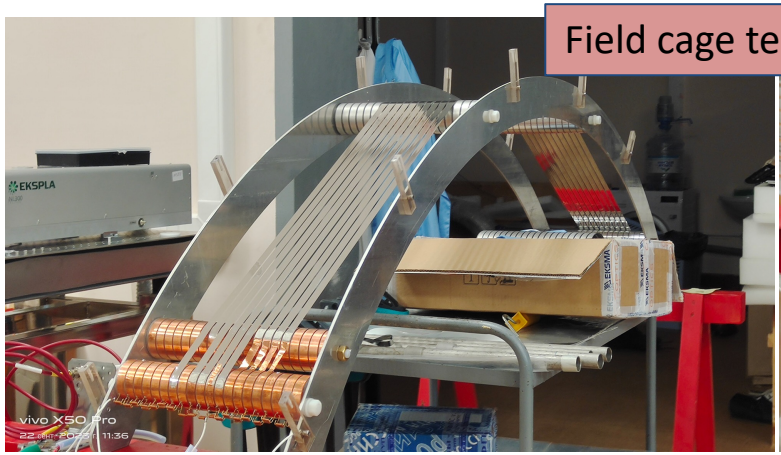
Flange to flange distance

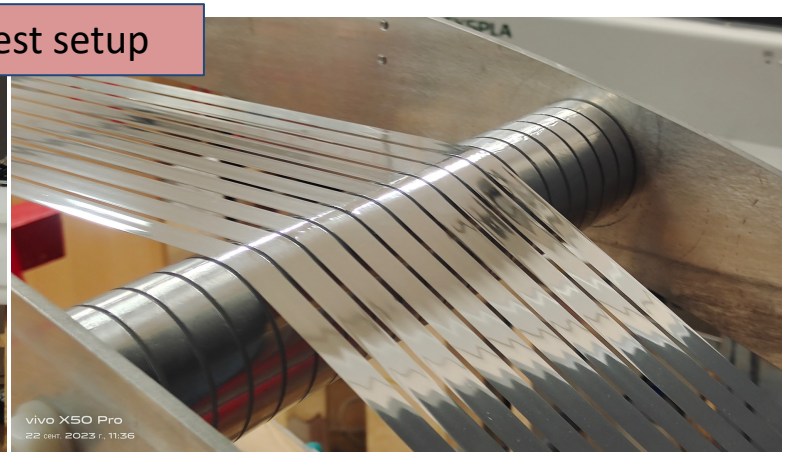


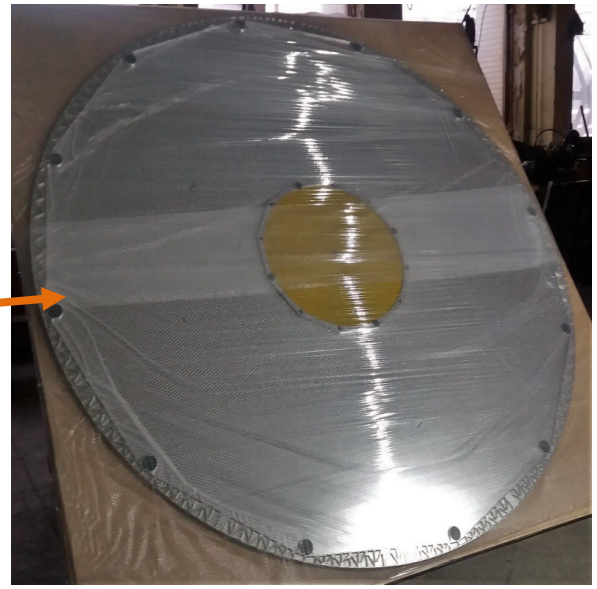
L=(3300.5 +/-0.5) mm
(nominal – 3300.0 mm)

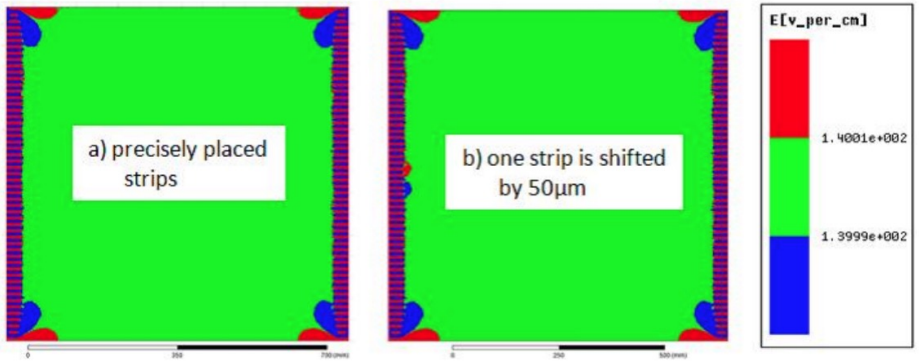
Field cage and high-voltage electrode









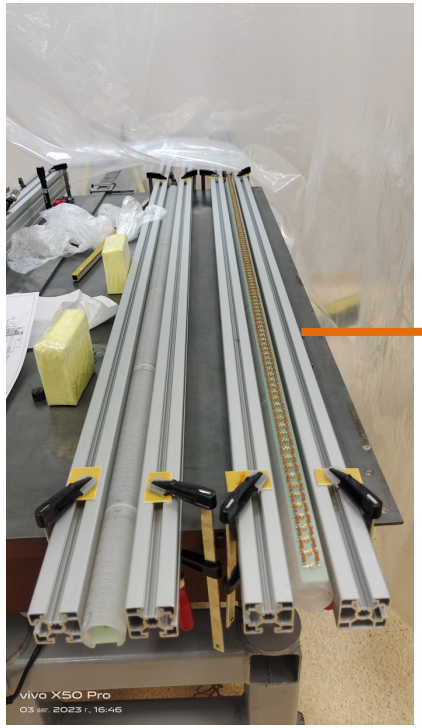


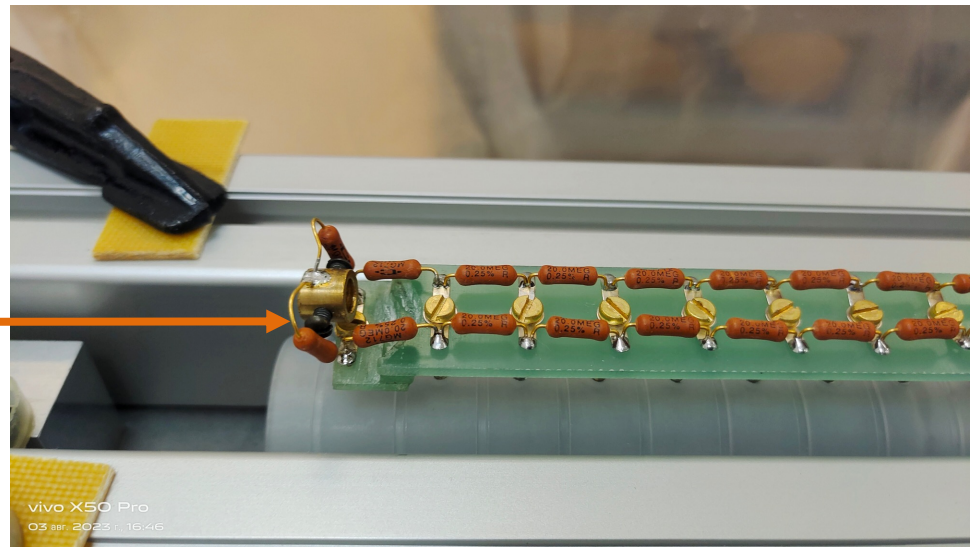
The field distortions in the drift volume defined by Mylar strip system

The non-uniformity of the electric field inside the sensitive TPC volume has to be not more than 10^{-4} relative to nominal value (140 V/cm P10 gas mixture).

Potential degrader rods and HV membrane connector

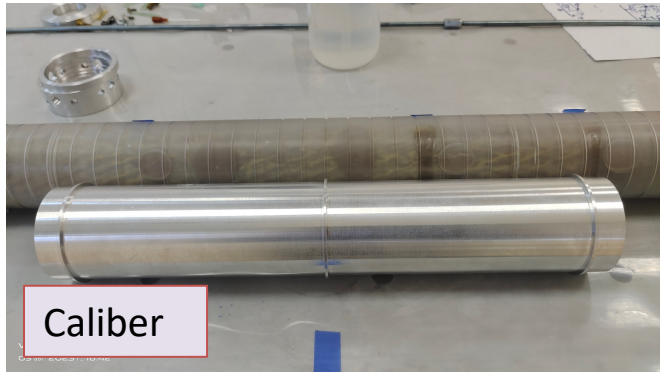
Al foil gluing



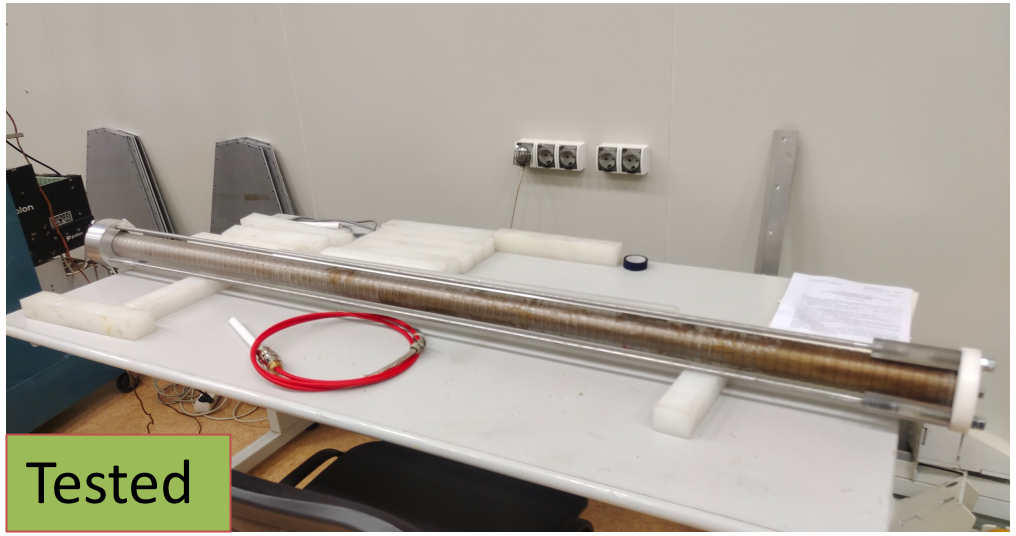


tools

Glue point per point

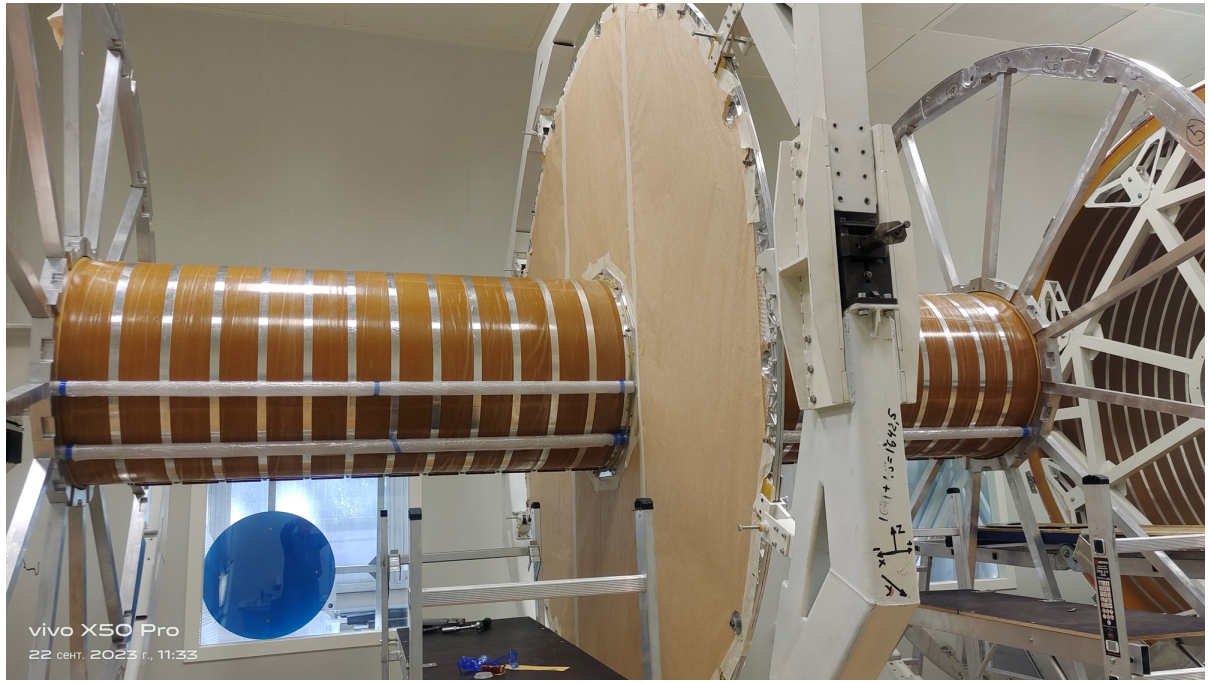


Caliber



Tested

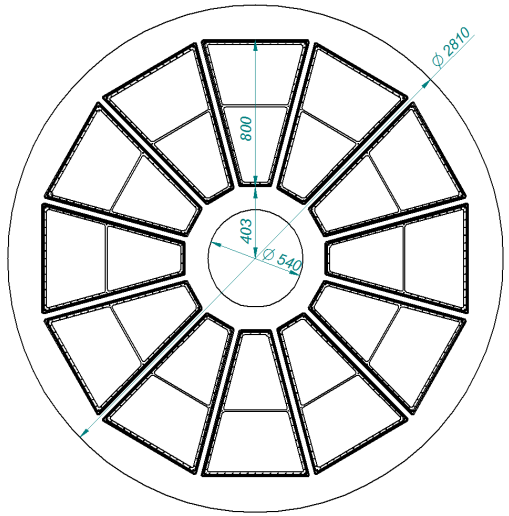
Field cage assembly



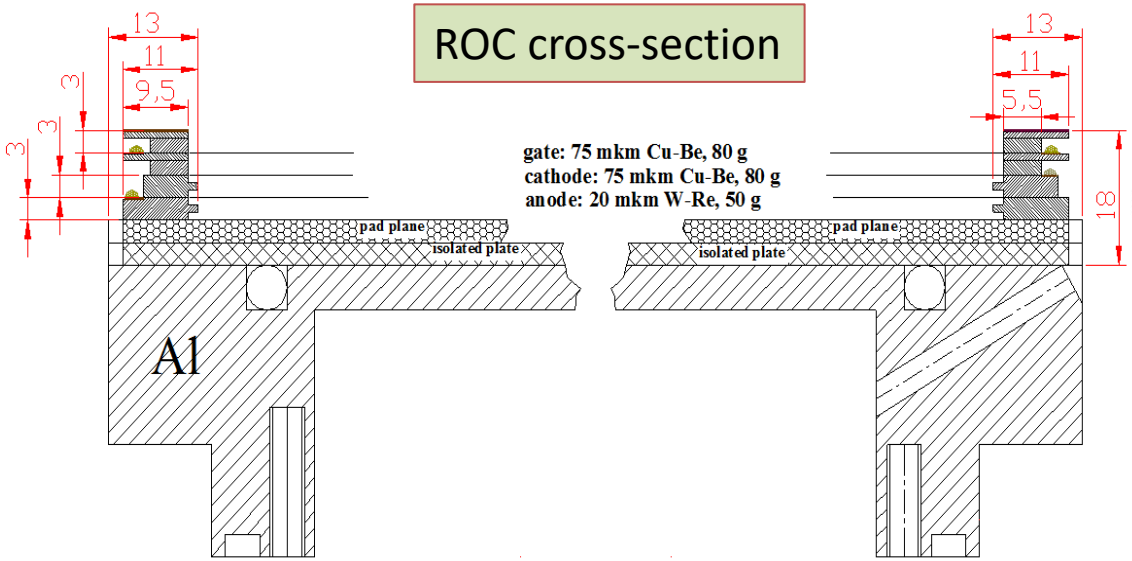
Inner field cage rods installation
20% installed

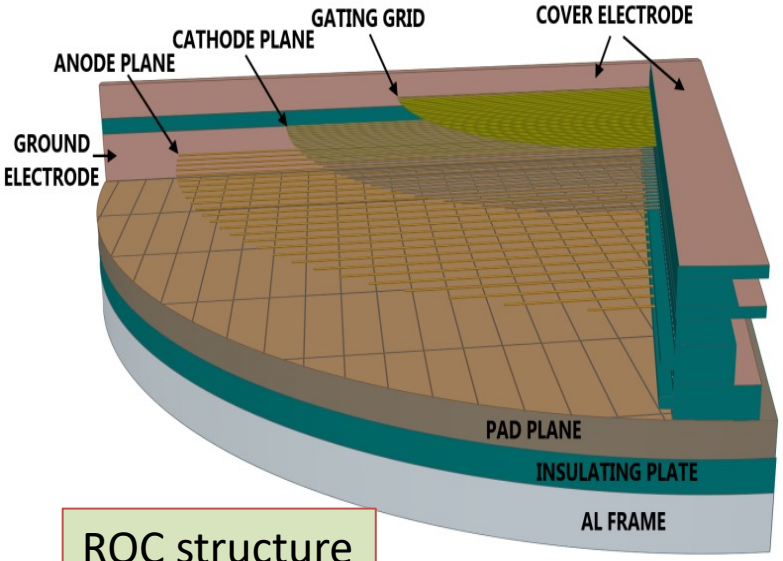
Read-Out chambers (ROC)

ROCs location

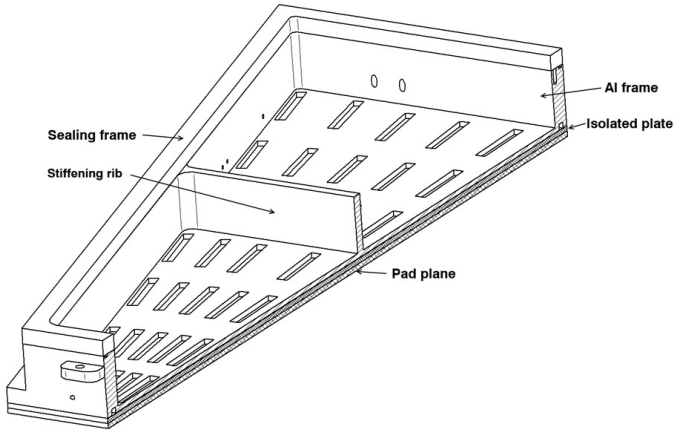


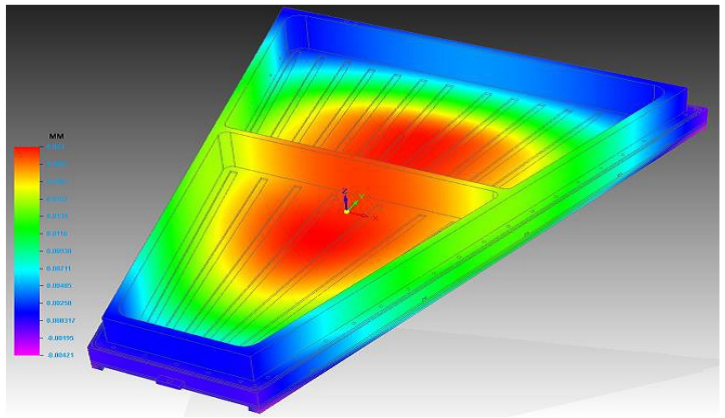
ROC cross-section





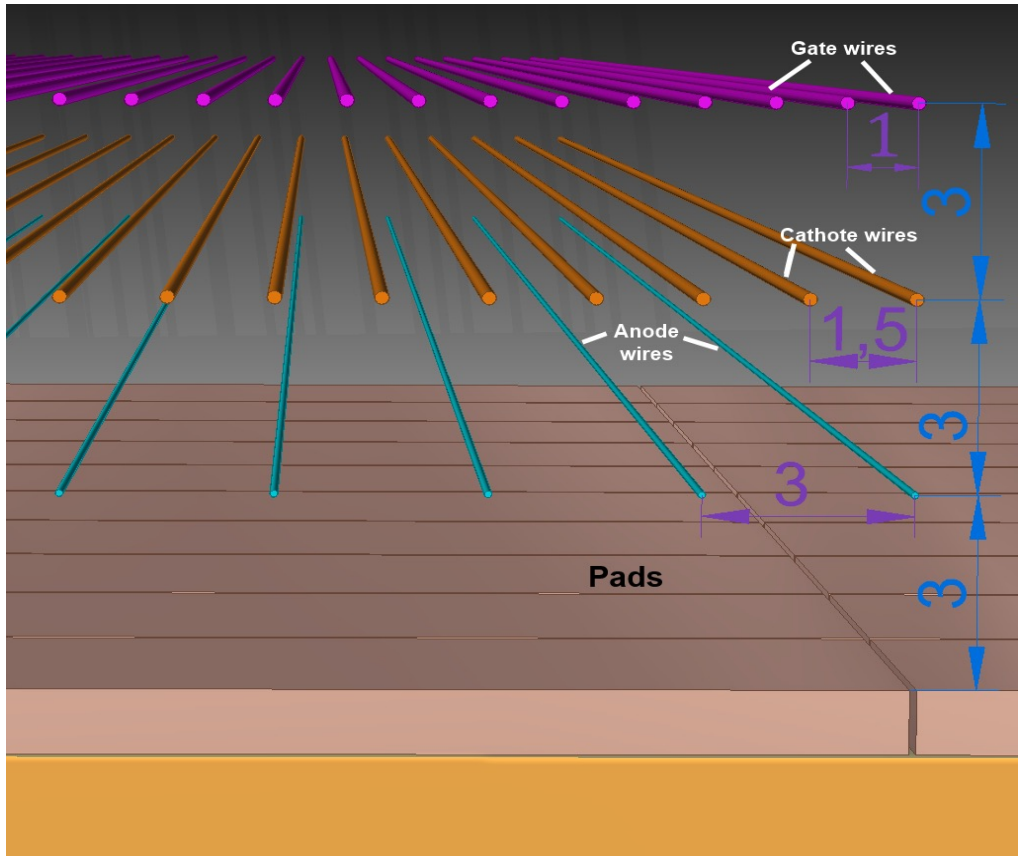
ROC structure

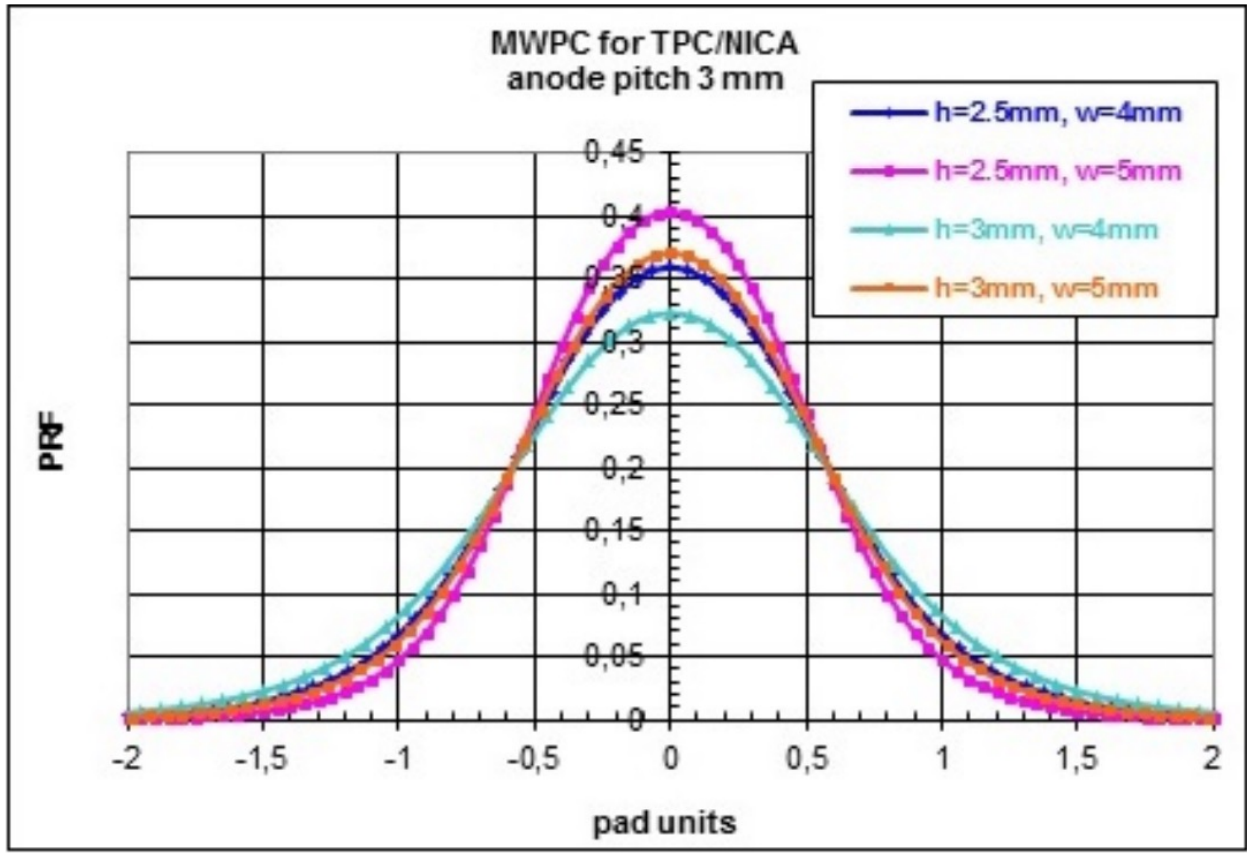




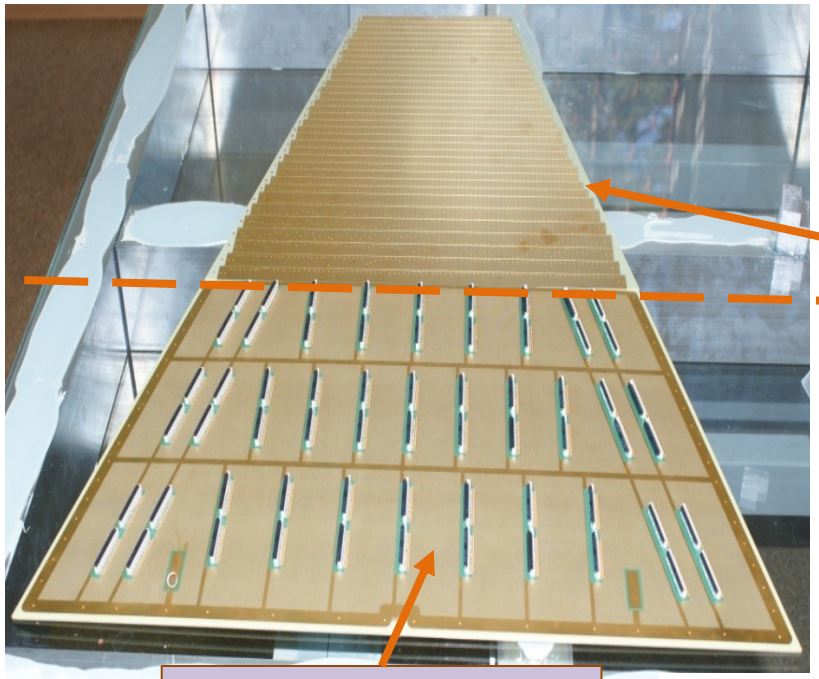
Finite element calculation of the chamber deformation caused by the wire tension (F = 800 N) and overpressure 5 mBar. The maximum deformation is **27 µm**

Pad Response Function





PadPlane overview

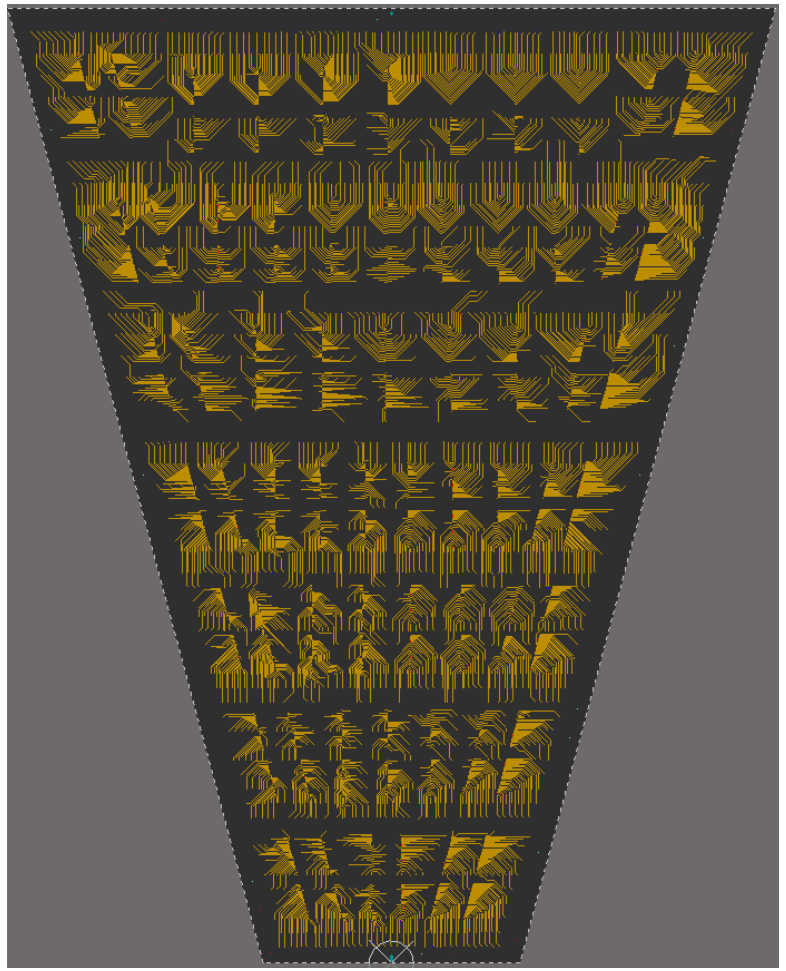


ReadOut connectors

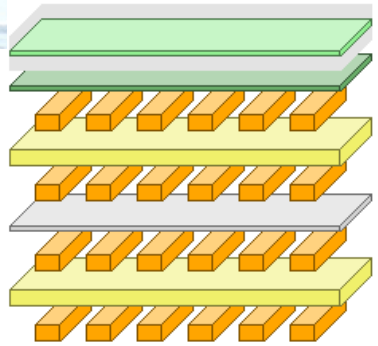
Pads

PadPlane structure
pad raw number: 53
rectangle shape
- small pads 5×12 mm^2
- large pads 5×18 mm^2

Total number of signal pads per one ROC: 3968



PadPlane PCB structure



Connectors layer

Routing layer

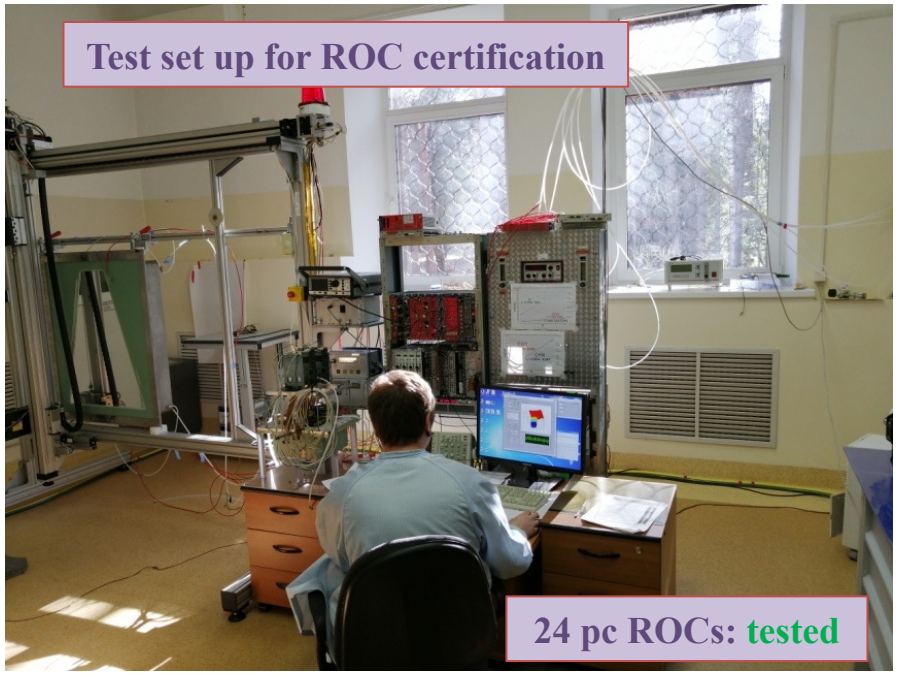
GND layer

Pads layer

Layer Name	Type	Material	Thickness (mm)
Top Overlay	Overlay		
Top Solder	Solder Mask/Co...	Surface Material	0.01016
Top Layer	Signal	Copper	0.018
Dielectric1	Dielectric	Core	1
Signal Layer 1	Signal	Copper	0.035
Dielectric2	Dielectric	Prepreg	1
Signal Layer 2	Signal	Copper	0.035
Dielectric3	Dielectric	Core	1
Bottom Layer	Signal	Copper	0.018

ROCs production status

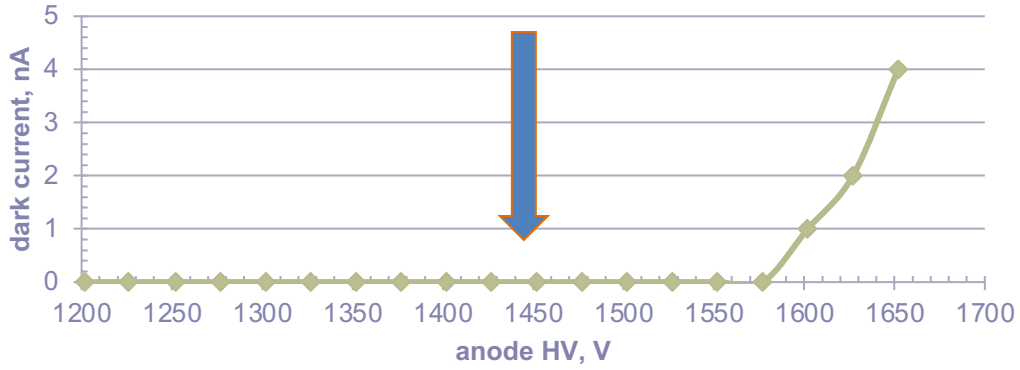
24 pc. of serial ROCs + 4 spare are READY

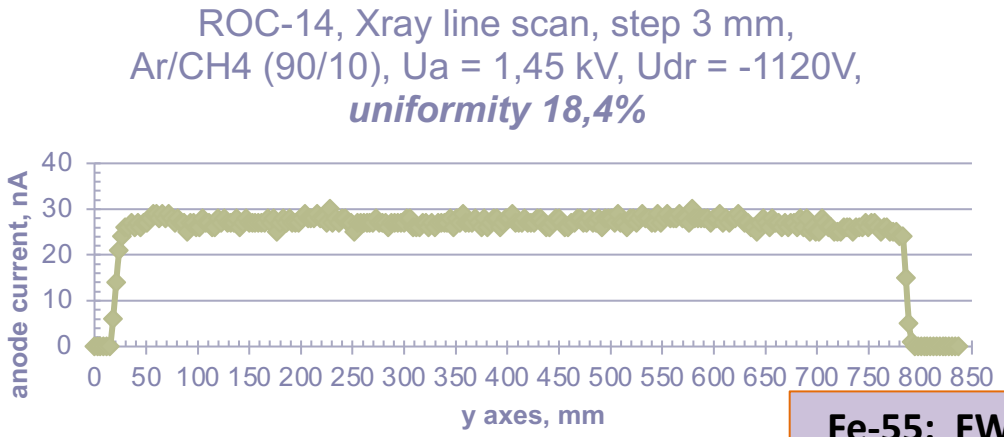


Test set up for ROC certification

24 pc ROCs: tested

Test procedure:
- counting plateau
- dark current
- energy resolution (Fe-55)
- uniformity of gas gain
  - ✓ linear scan
  - ✓ area scan

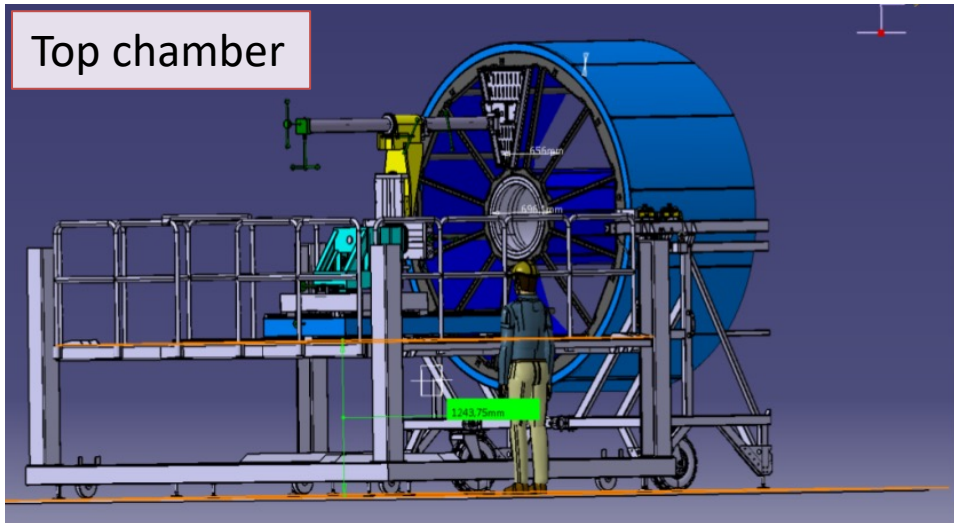




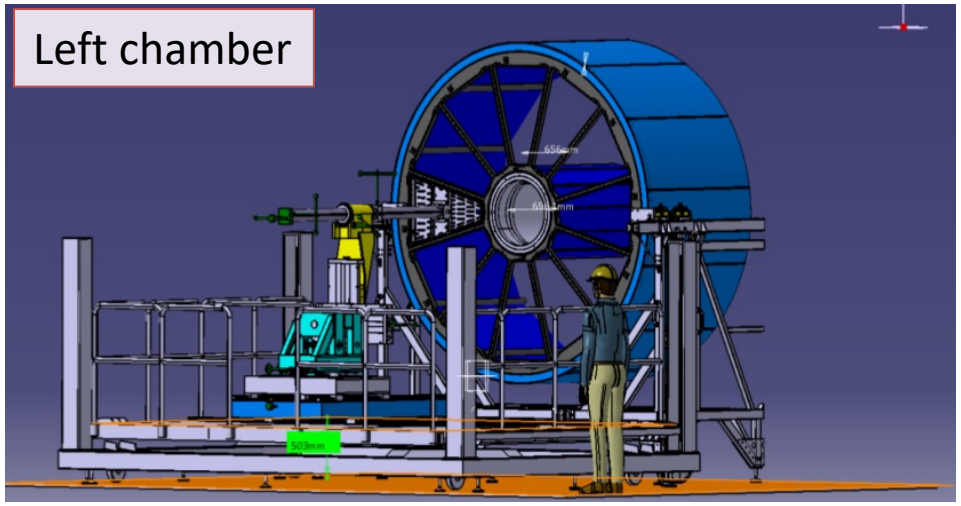
Fe-55: FWHM ~ 20%

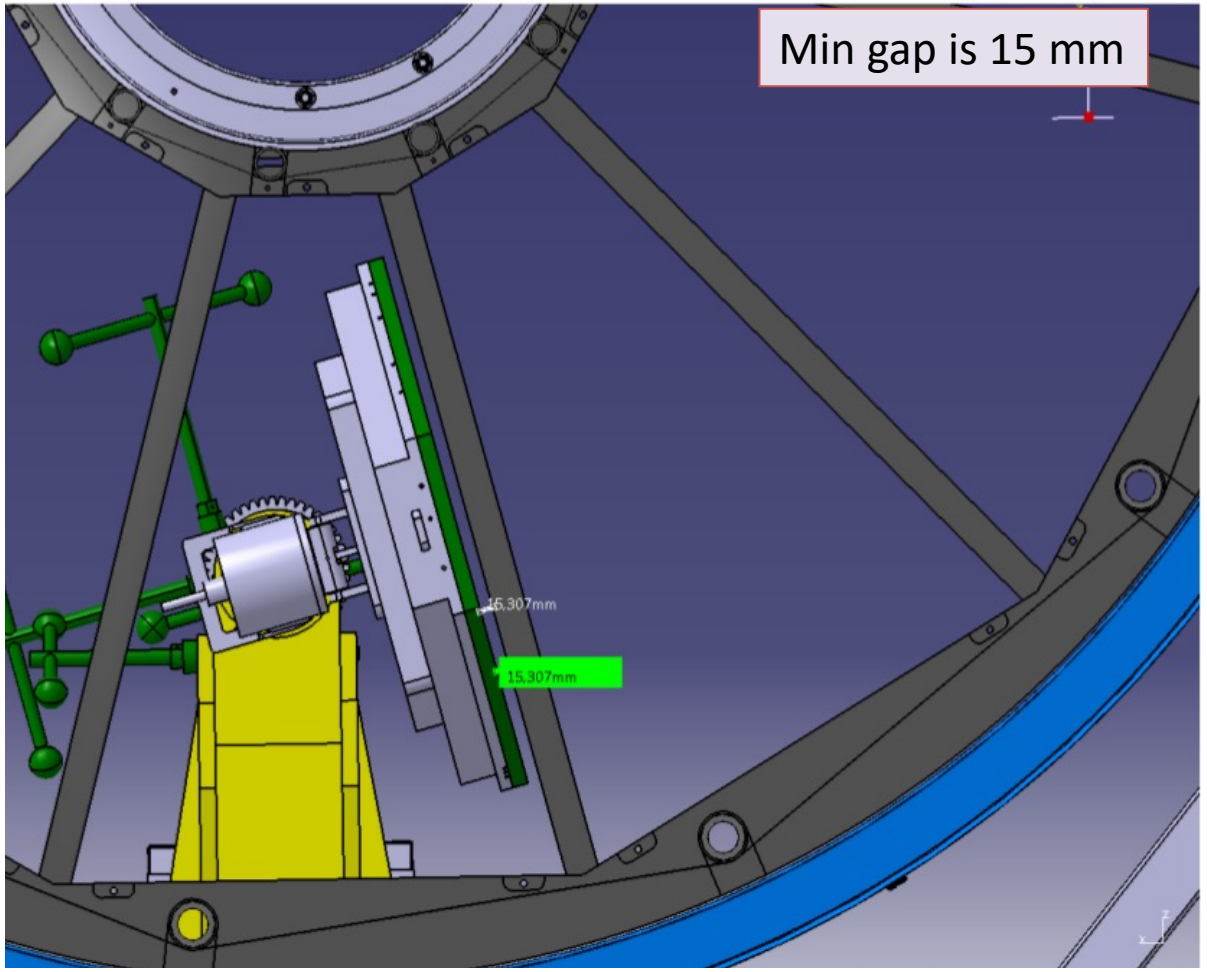
ROC chamber installation

Top chamber



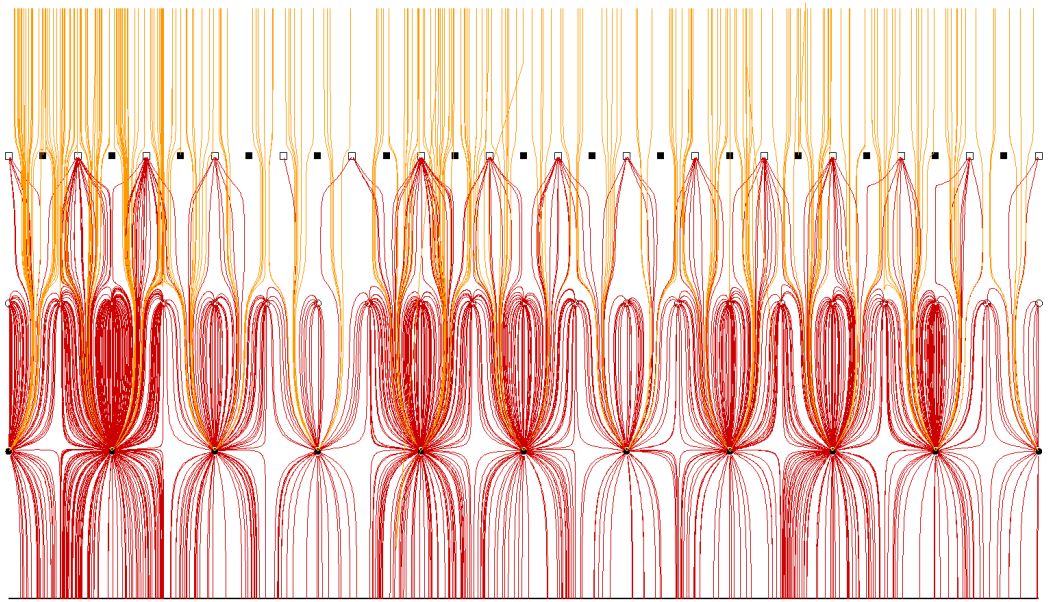
Left chamber





Gating grid system

Ion drift lines

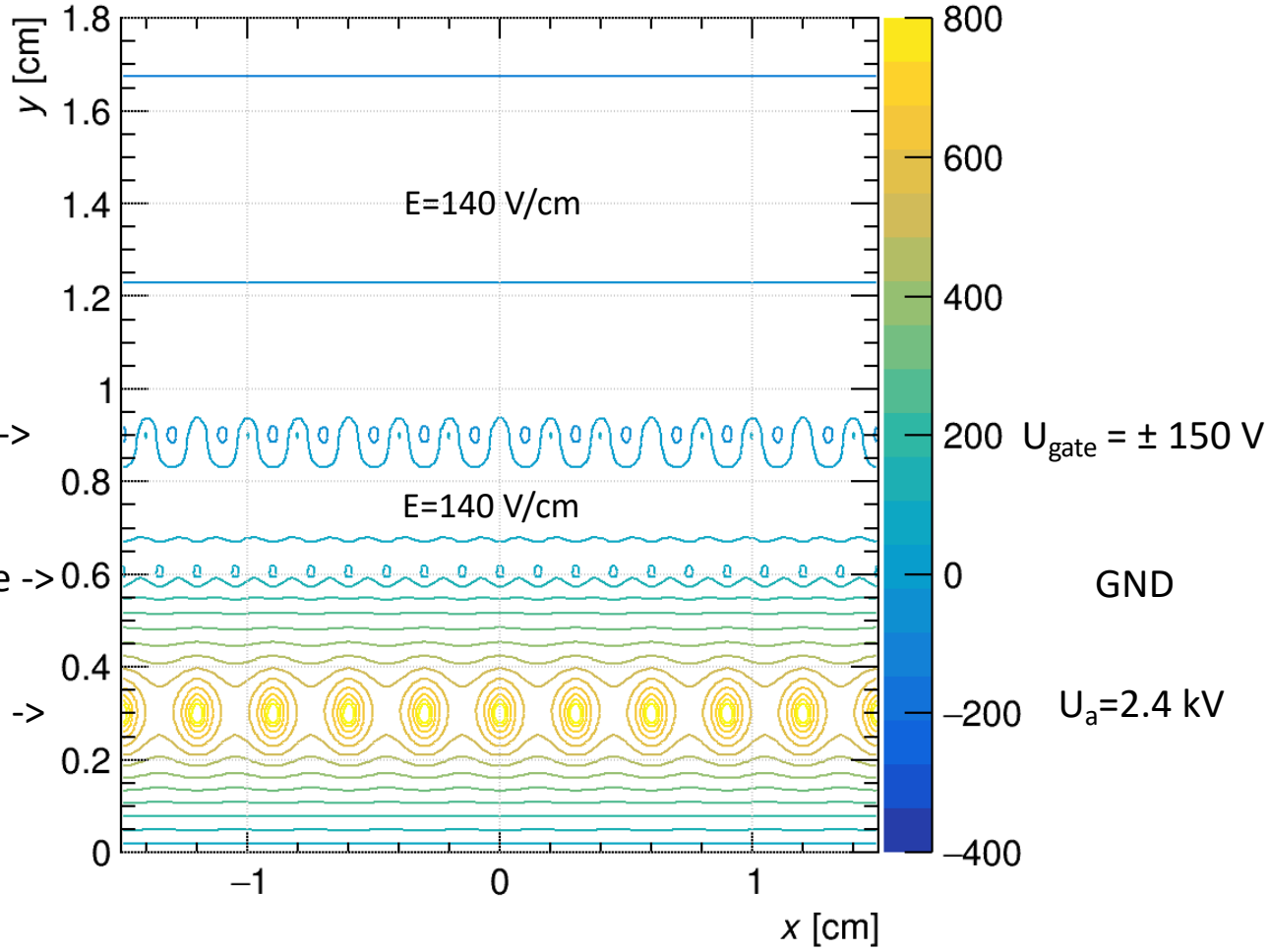


<- Gate ->

<- Cathode ->

<- Anode ->

Shape of the TPC equipotentials

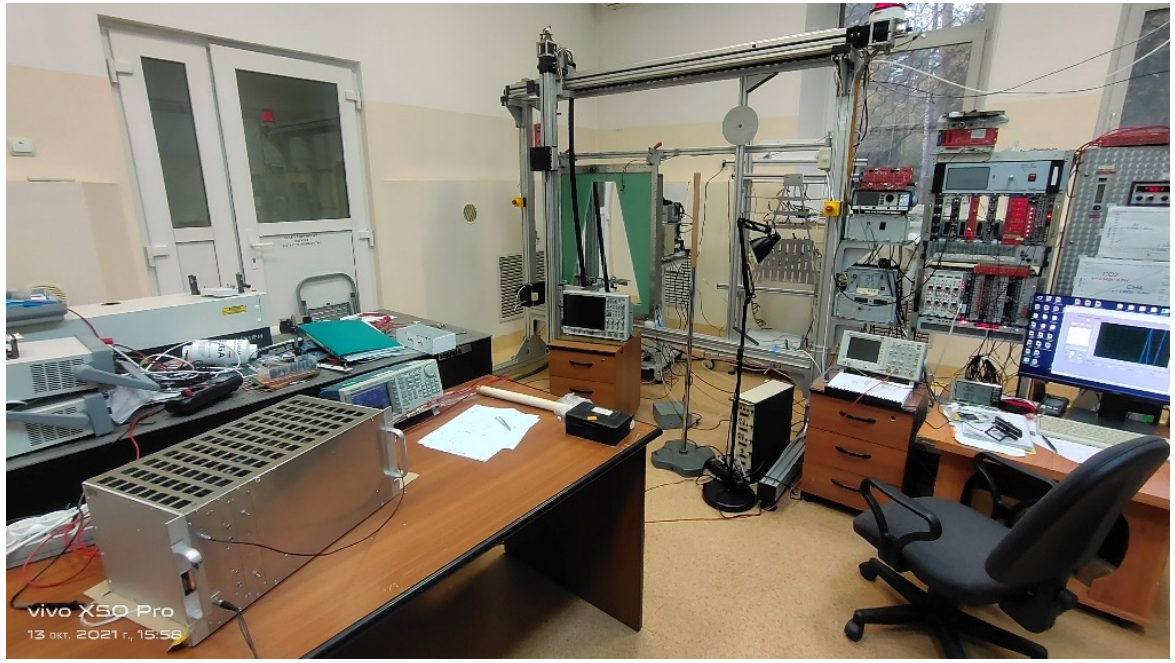


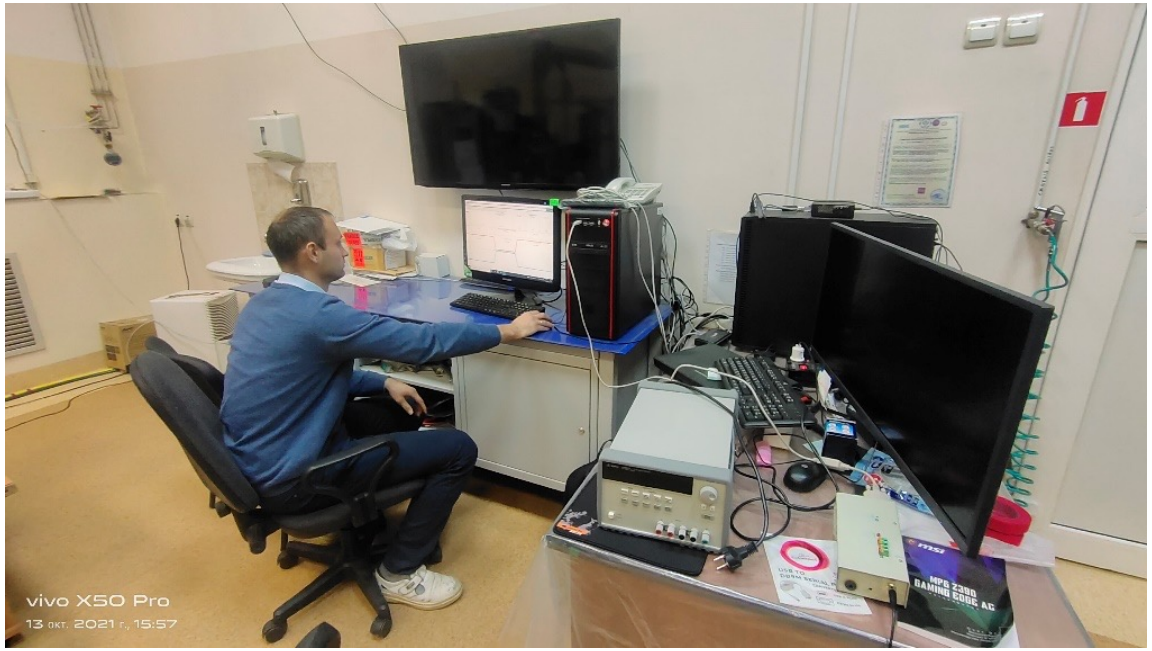
U_{gate} = ± 150 V

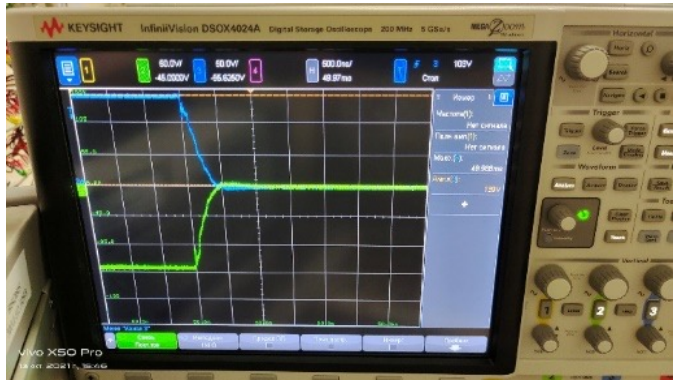
GND

U_a=2.4 kV

Gating grid system test setup



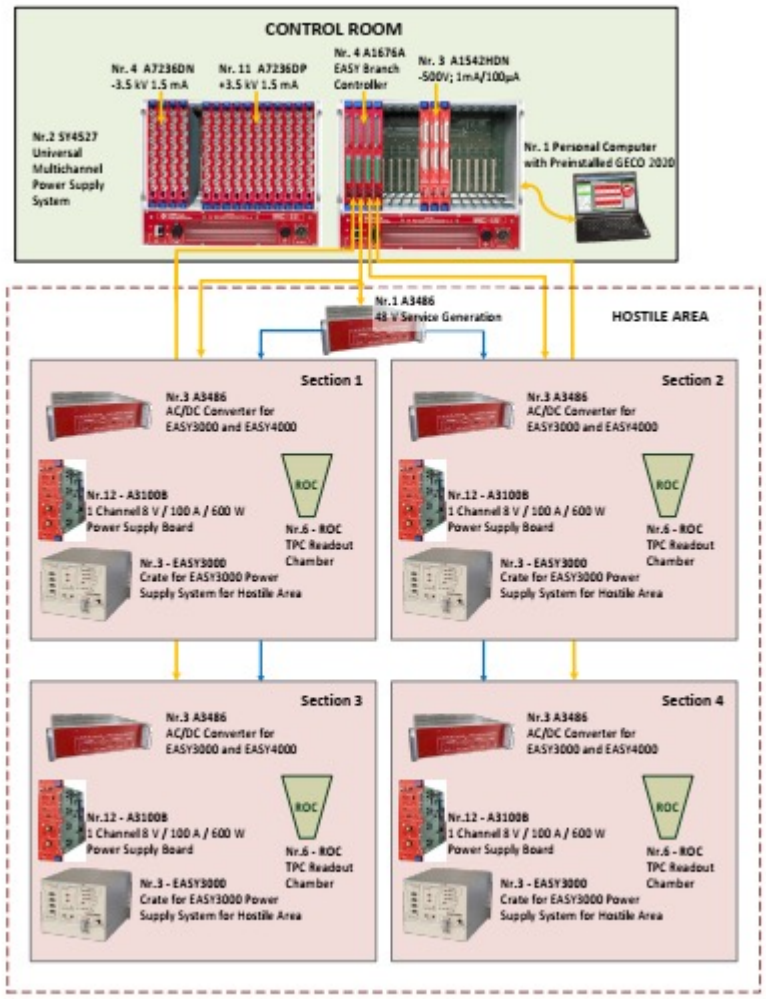




Pulse rise time
- 500 ns: OK

Mass-production: in progress
Delivery to JINR: Dec. 2023

Low voltage and High voltage power supply



LV&HV system based on CAEN rad. hard design:
(up to 2000 Gauss and 15 kRad)

- **power converters A3486 AC/DC (380 V -> 48 V): 15+3 pc**
- **EASY3000 crates: 14+2 pc**
- **LV module - A3100B (8V/100A): 48+8 pc**
- **LV module - A3100HBP (14V/50A): 6+2 pc**
- **HV modules –A3540P (+4kV/1mA): 8+3 pc**
- **HV modules –A3540N (- 4kV/1mA): 2+2 pc**

Status:

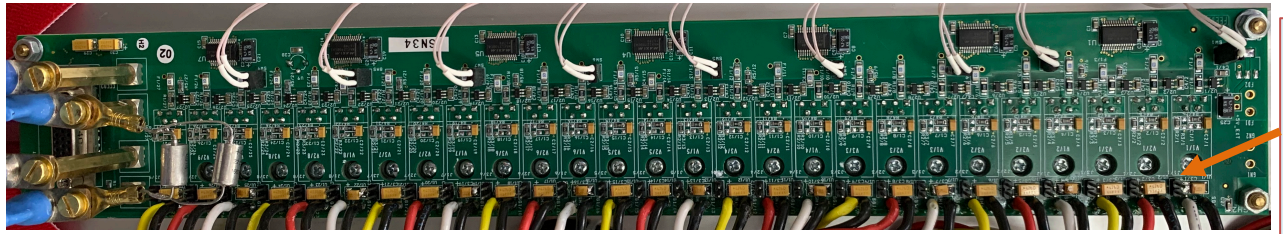
LV+HV system: JINR-CAEN contract was signed

***Expected delivery date to JINR:* was delivered**

test system: testing is ongoing

LV cables (halogen free, low smoke), S=50 mm2: was delivered

HV cables: was ordered



Low voltage distribution board. Designed in INP BSU (Minsk)

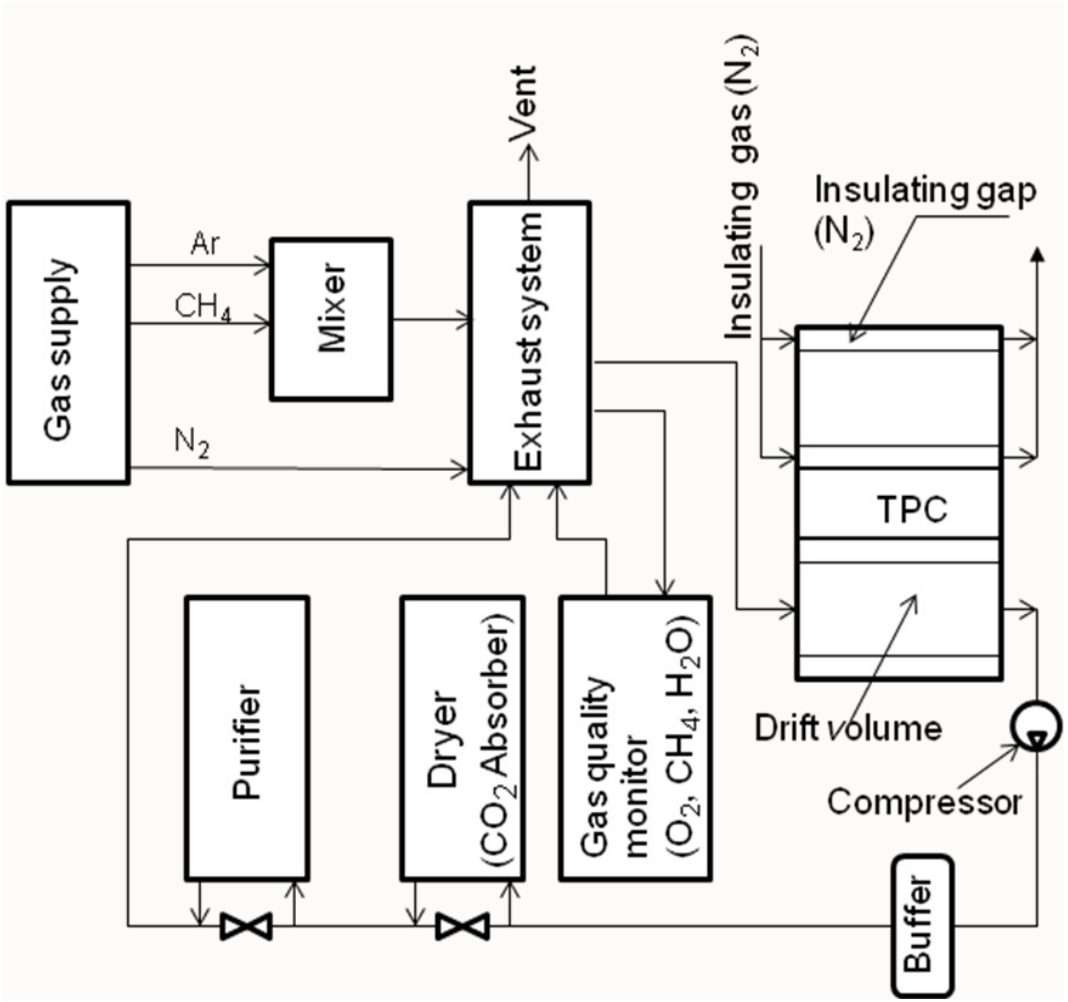
Gas system scheme

Gas system main features:

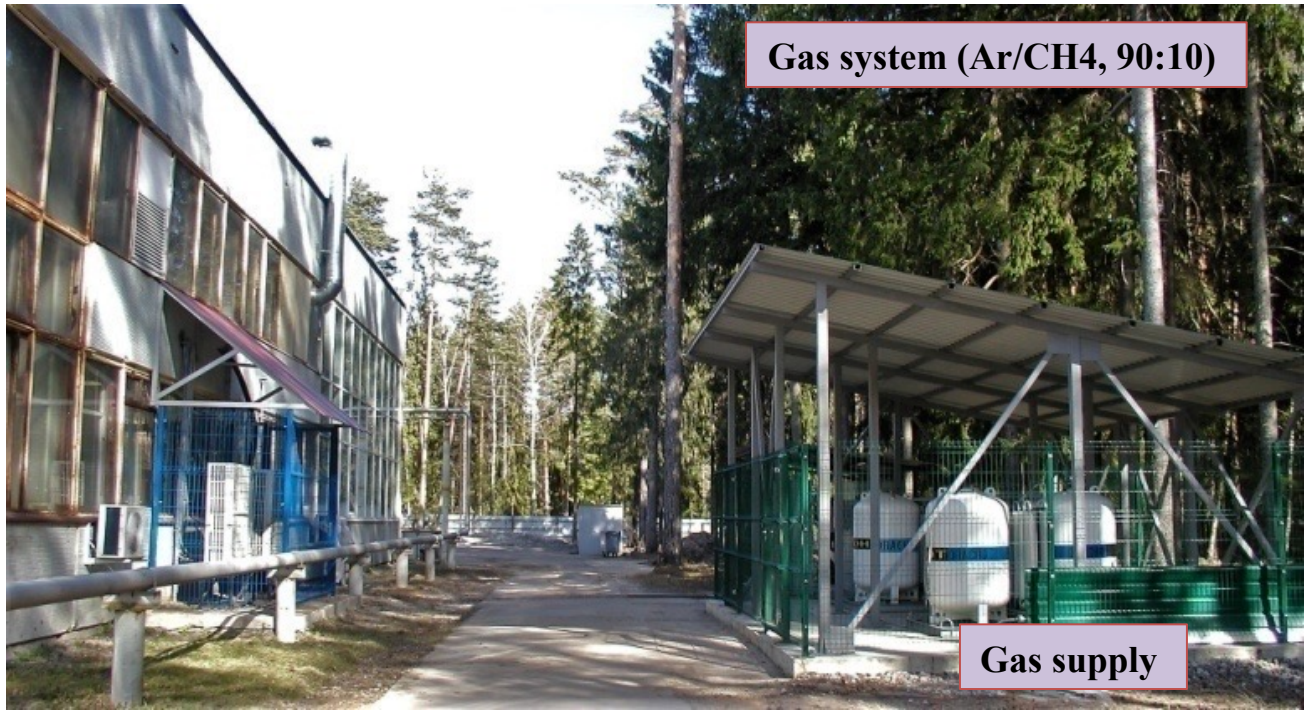
- Drift gas mixture: 90%Ar + 10%CH_4 (P10);
- Insulating gas: N_2;
- Operating pressure: atmospheric + 2.0 ± 0.03 mbar;
- Drift volume: 17640 liters;
- Insulating gaps volume: 2380 liters;
- Oxygen content: 5 ppm;
- Moisture content: 10 ppm;
- Recirculation rate of outer loop: 30 L/min;
- Recirculation rate of inner loop: 20 L/min

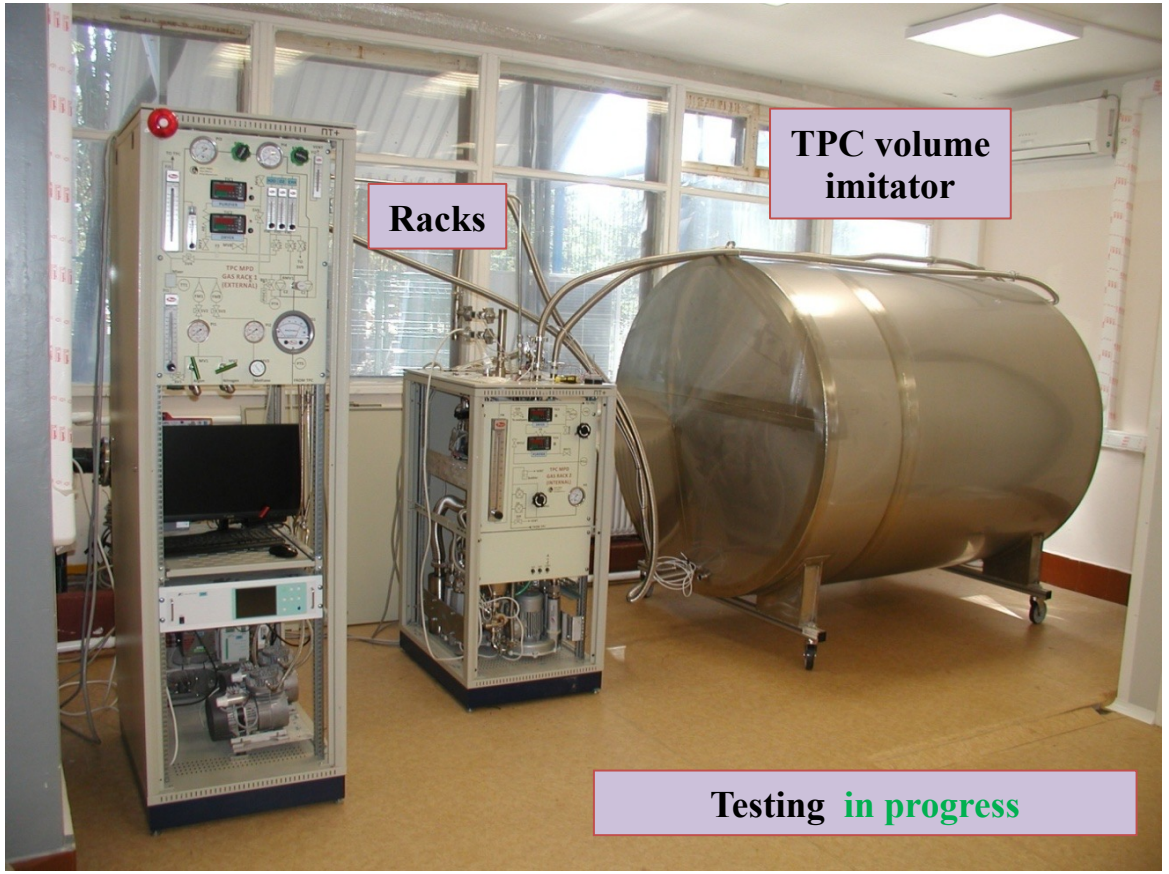
Gases consumption:

Mode	Argon, m^3	Methan, m^3	Nitrogen, m^3
TPC purging	84	5.4	36
Experiment:			
Per day	7.8	0.86	8.6
Per month	234	25.9	259

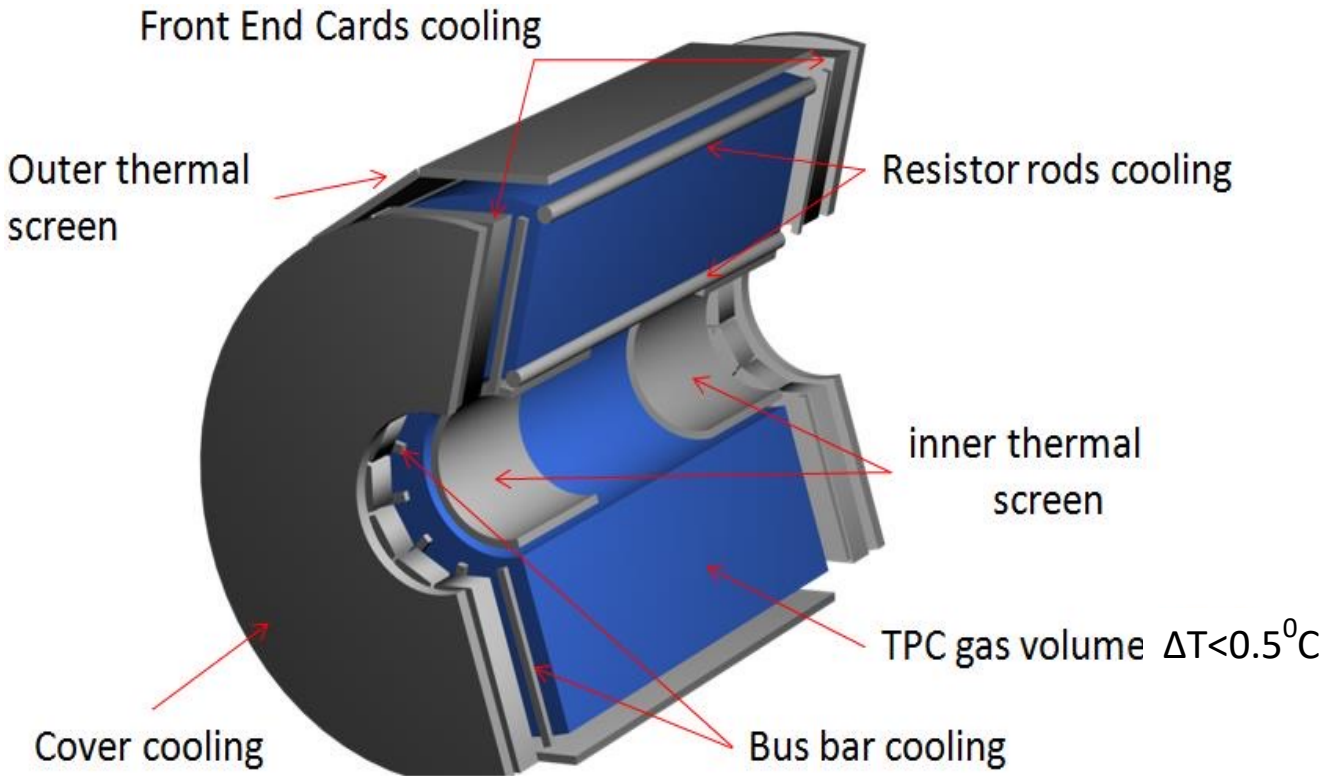


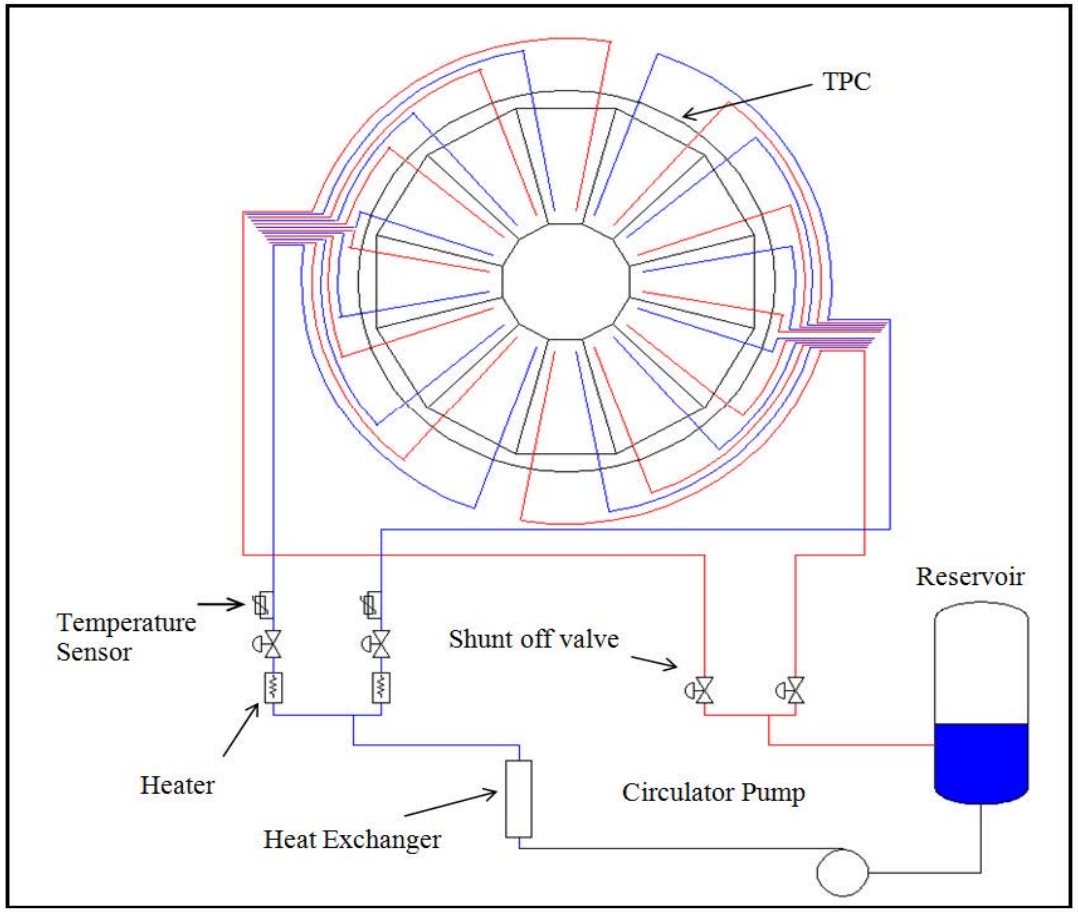
Gas system


Gas system (Ar/CH4, 90:10)
Gas supply

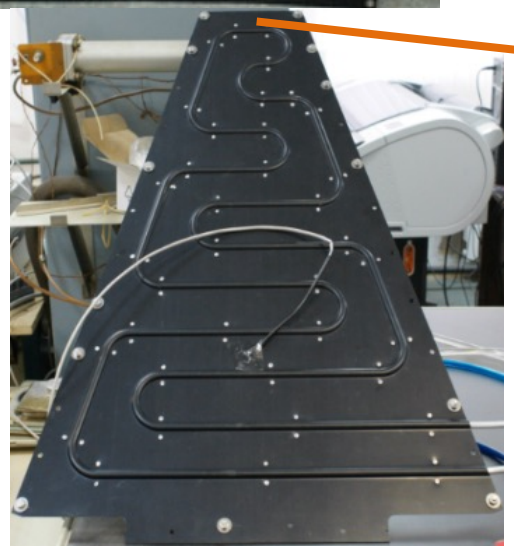

Racks
TPC volume imitator
Testing in progress

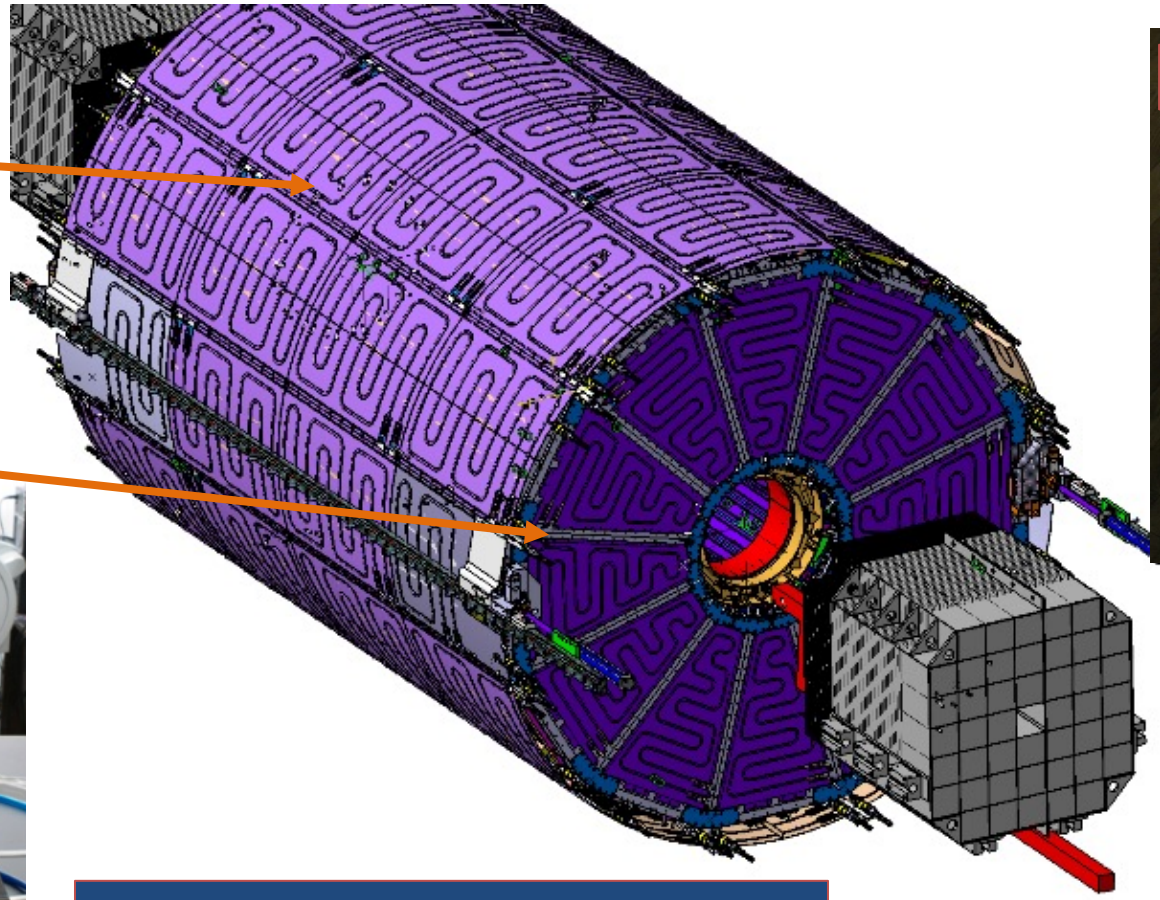
Cooling system





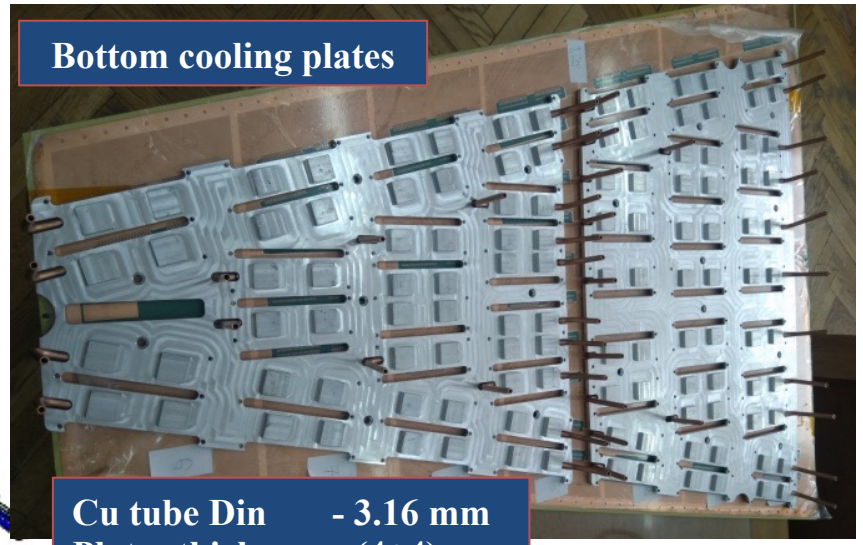
Cooling plates





FEE cooling plates

Bottom cooling plates



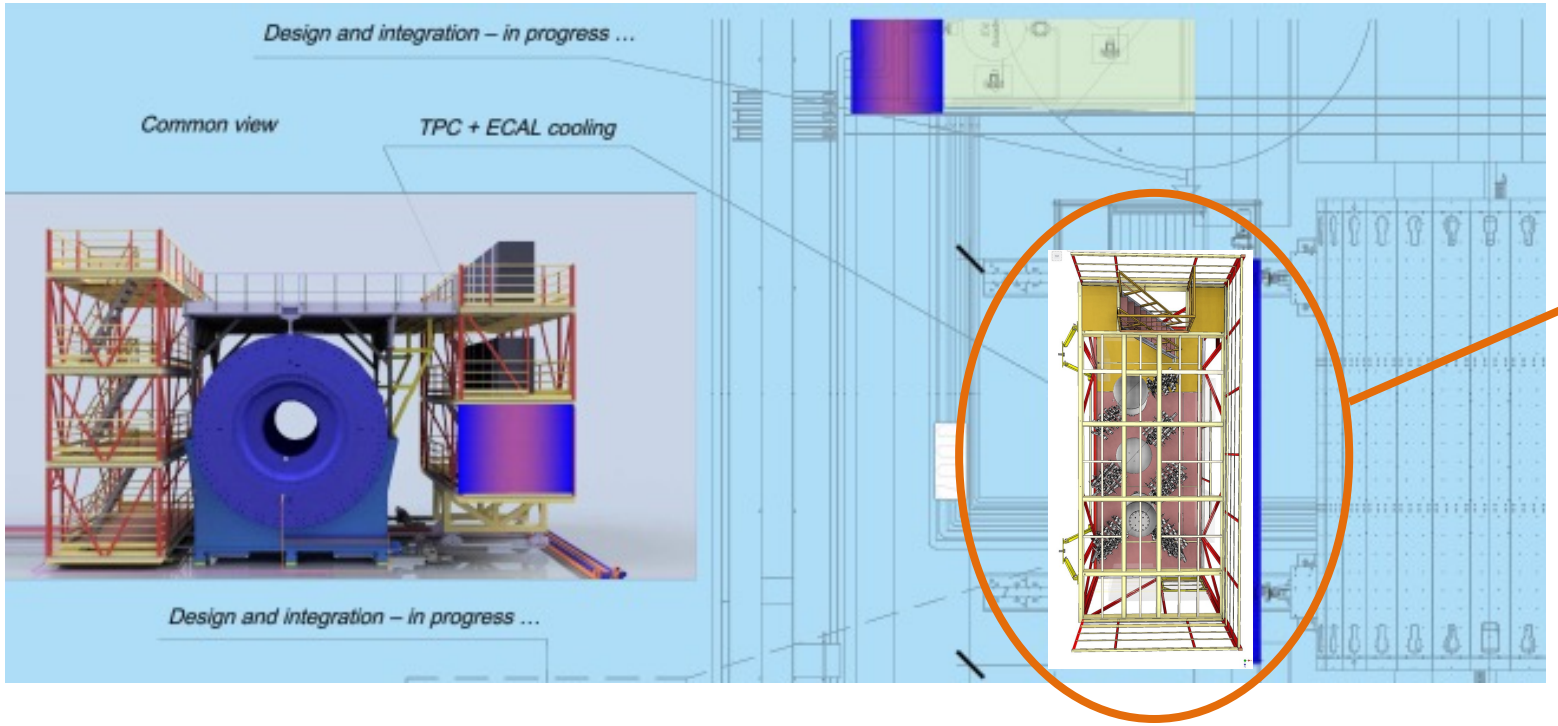
Cu tube Din - 3.16 mm
Plates thickness - (4+4) мм

Set of top cooling plates

Full set of panels was delivered

Cooling system position

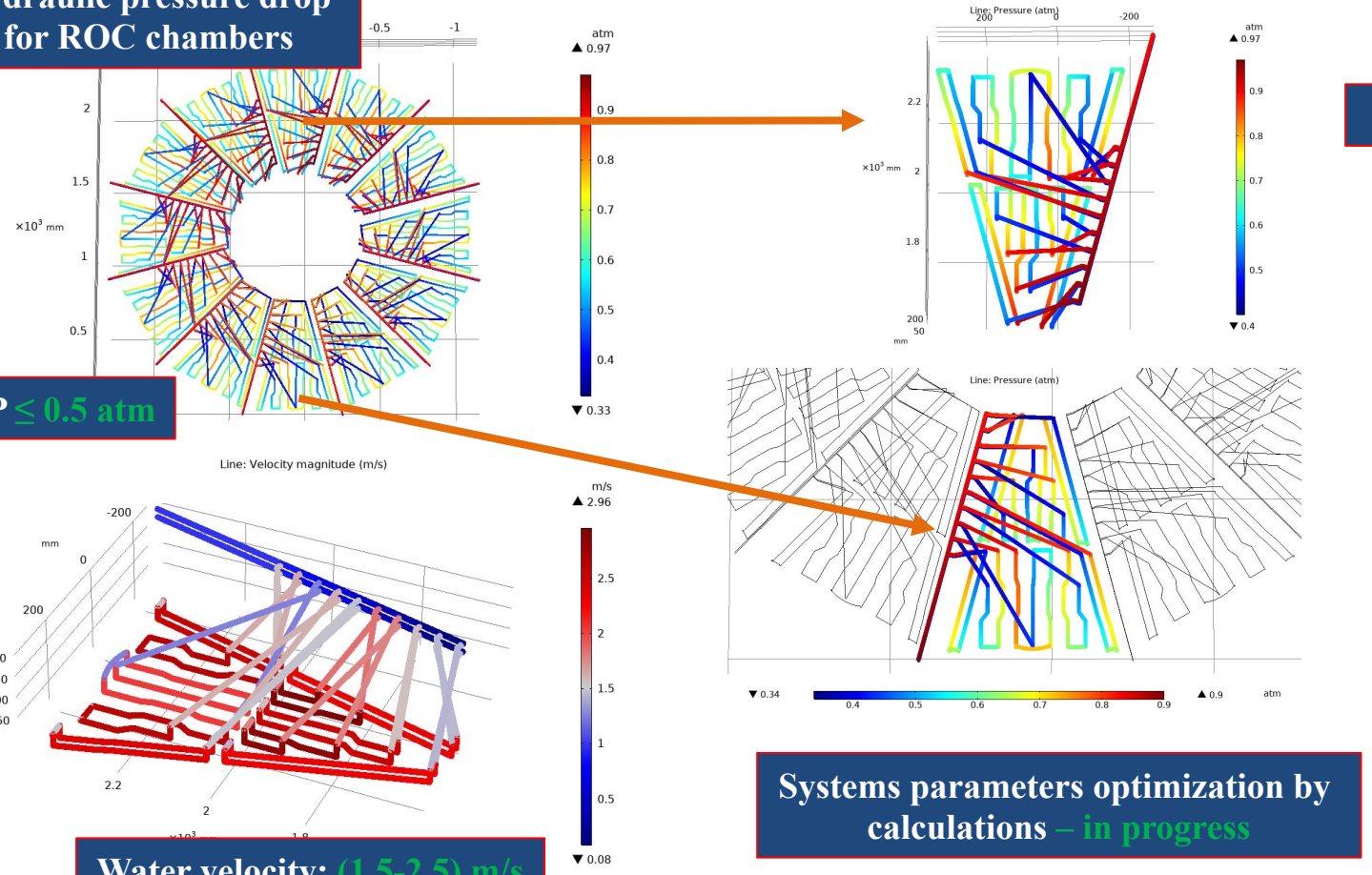
NEW cooling system position –> 2-nd floor of a additional platform – design and optimization in progress



cooling system equipment arrangement

Serial cooling system calculations

Hydraulic pressure drop for ROC chambers

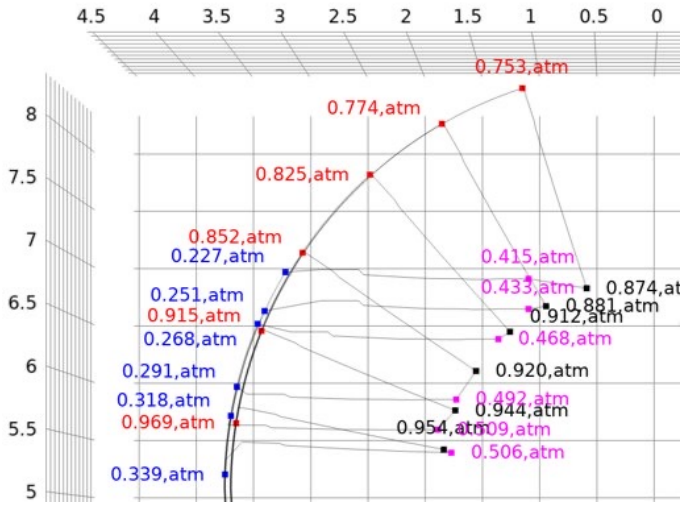


dP ≤ 0.5 atm

Water velocity: (1.5-2.5) m/s

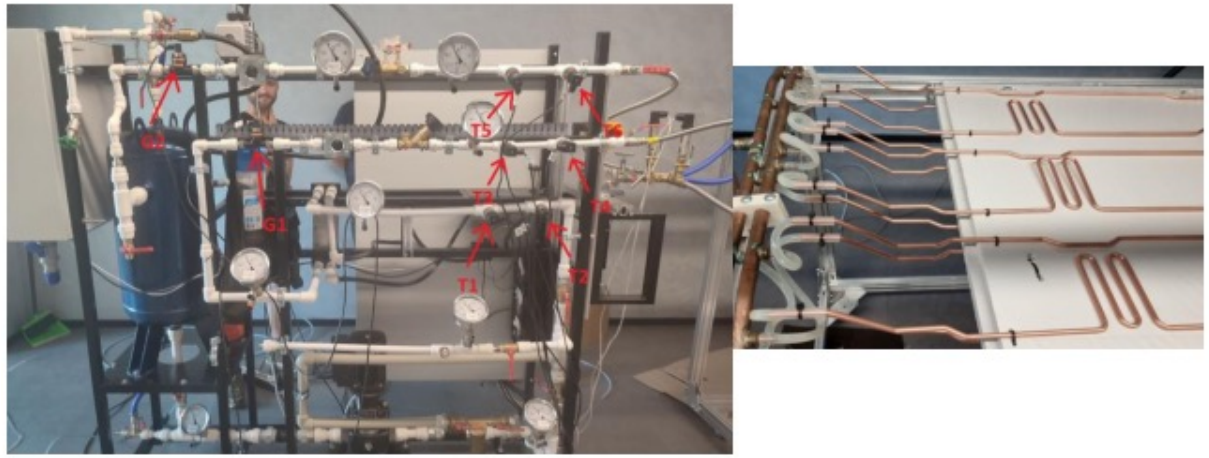
Systems parameters optimization by calculations – in progress

TPC system pressure with water column height



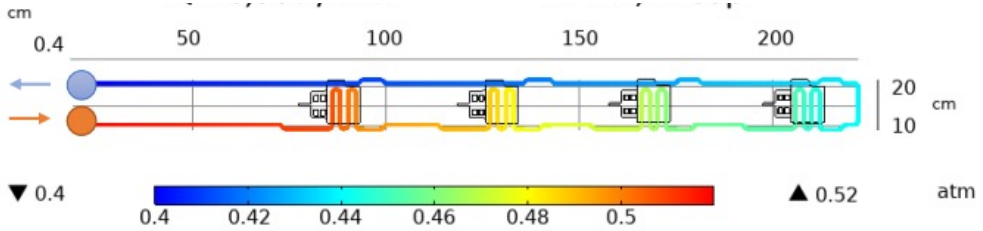
Test setup measurement results

Comparation of experimental and calculated test results

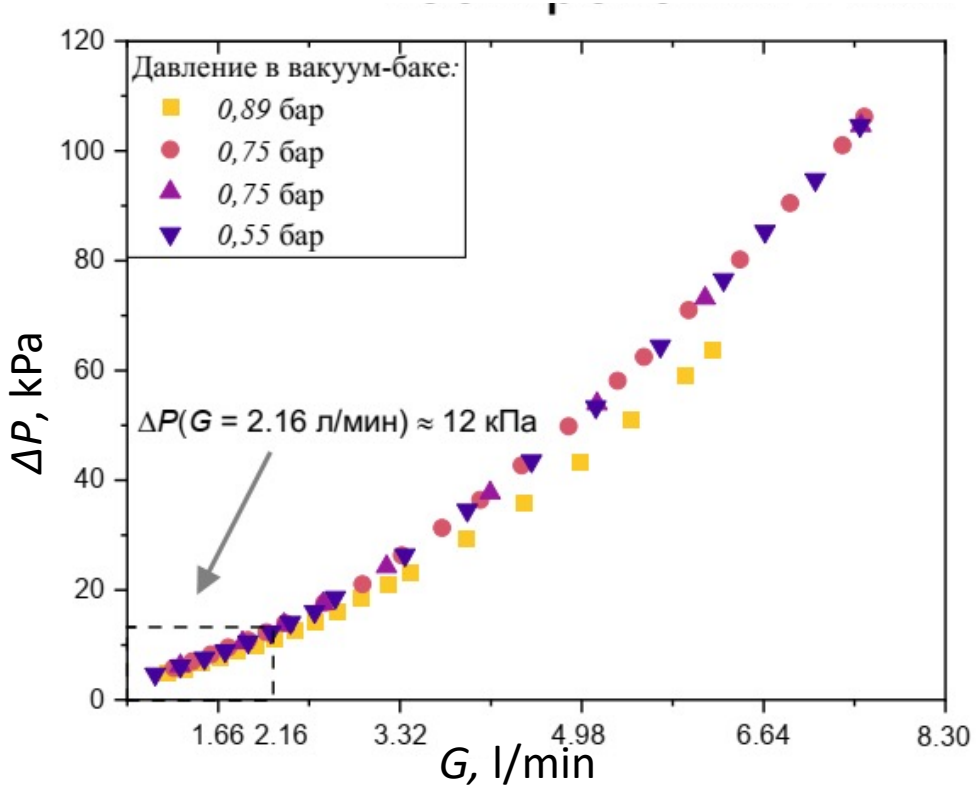


Picture of the panel test setup

Q = 0.36 l/min ΔP = 0.12 bar

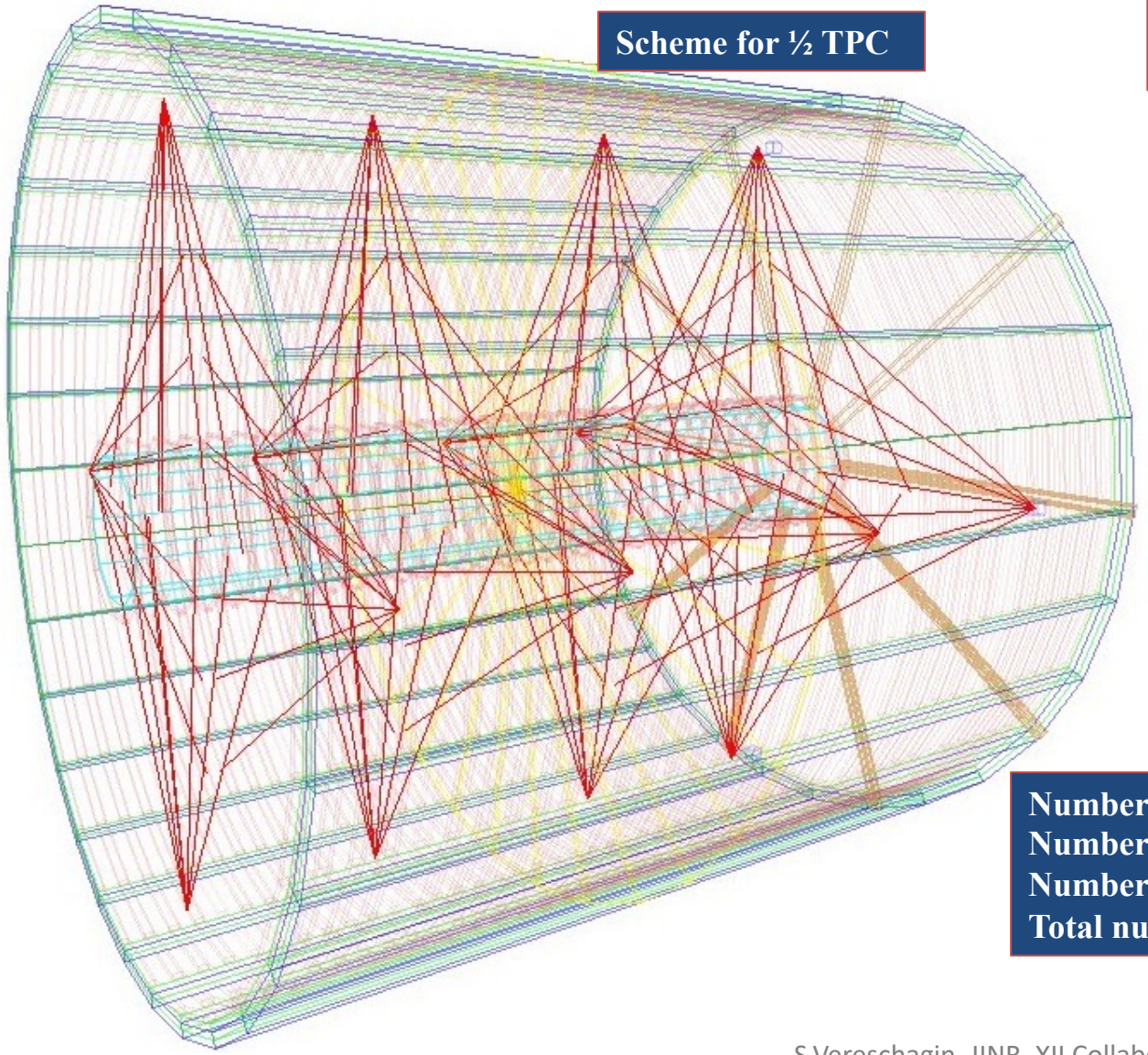


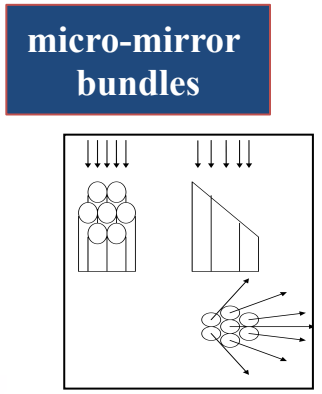
Design pressure drop of the panel ΔP = 0.12 bar at coolant flow Q = 0.36 l/min

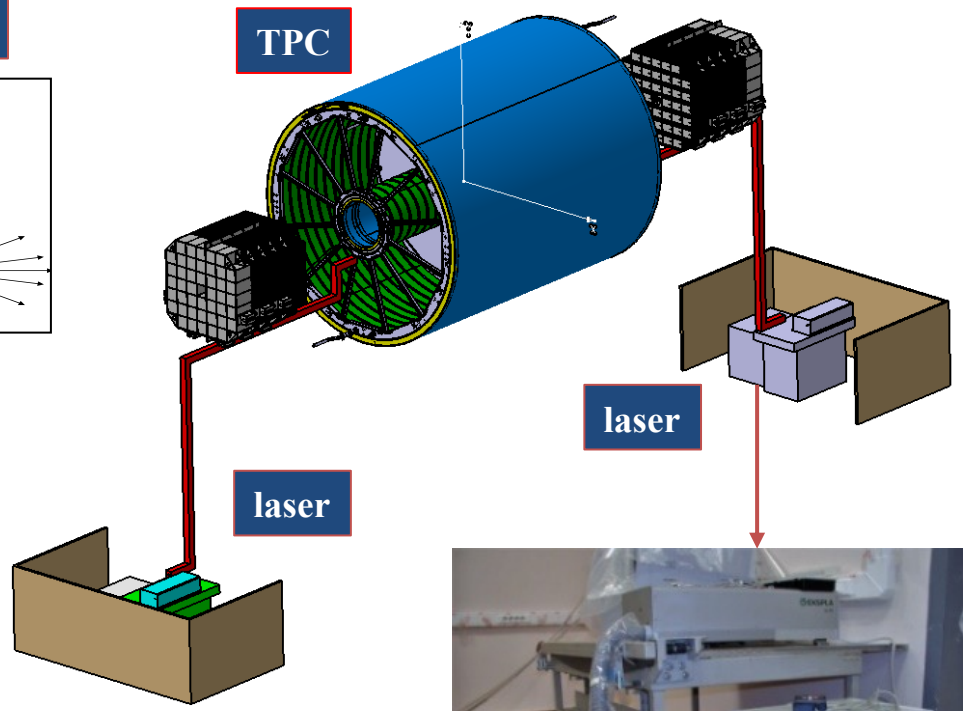


Experimental pressure drop across six panels ΔP as function of volumetric flow rate coolant Q pressure in the tank P_{tank} {0.89, 0.75, 0.55} bar

Laser calibration system

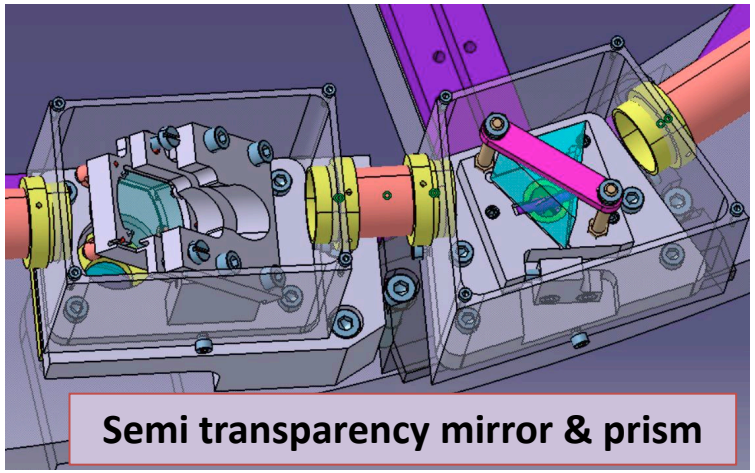




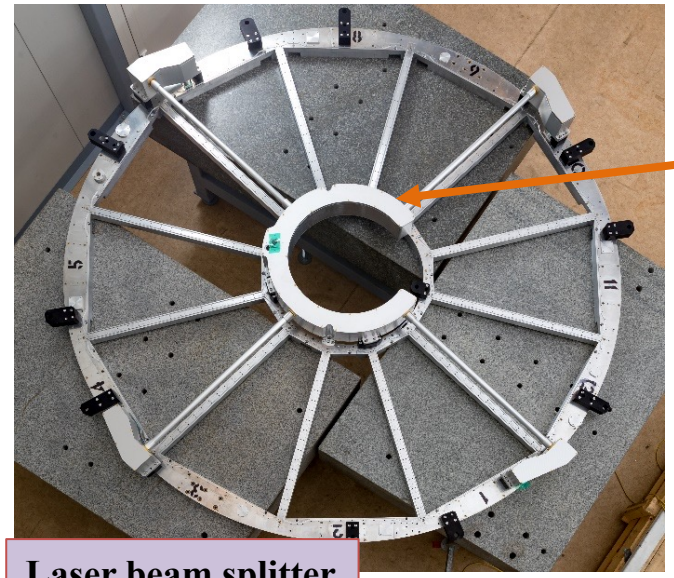


Number of laser "planes": 4
Number of micro-mirrors bundles per plane: 4
Number of beams from micro-mirrors bundle: 7
Total number of laser "tracks" (N =112x2): 224

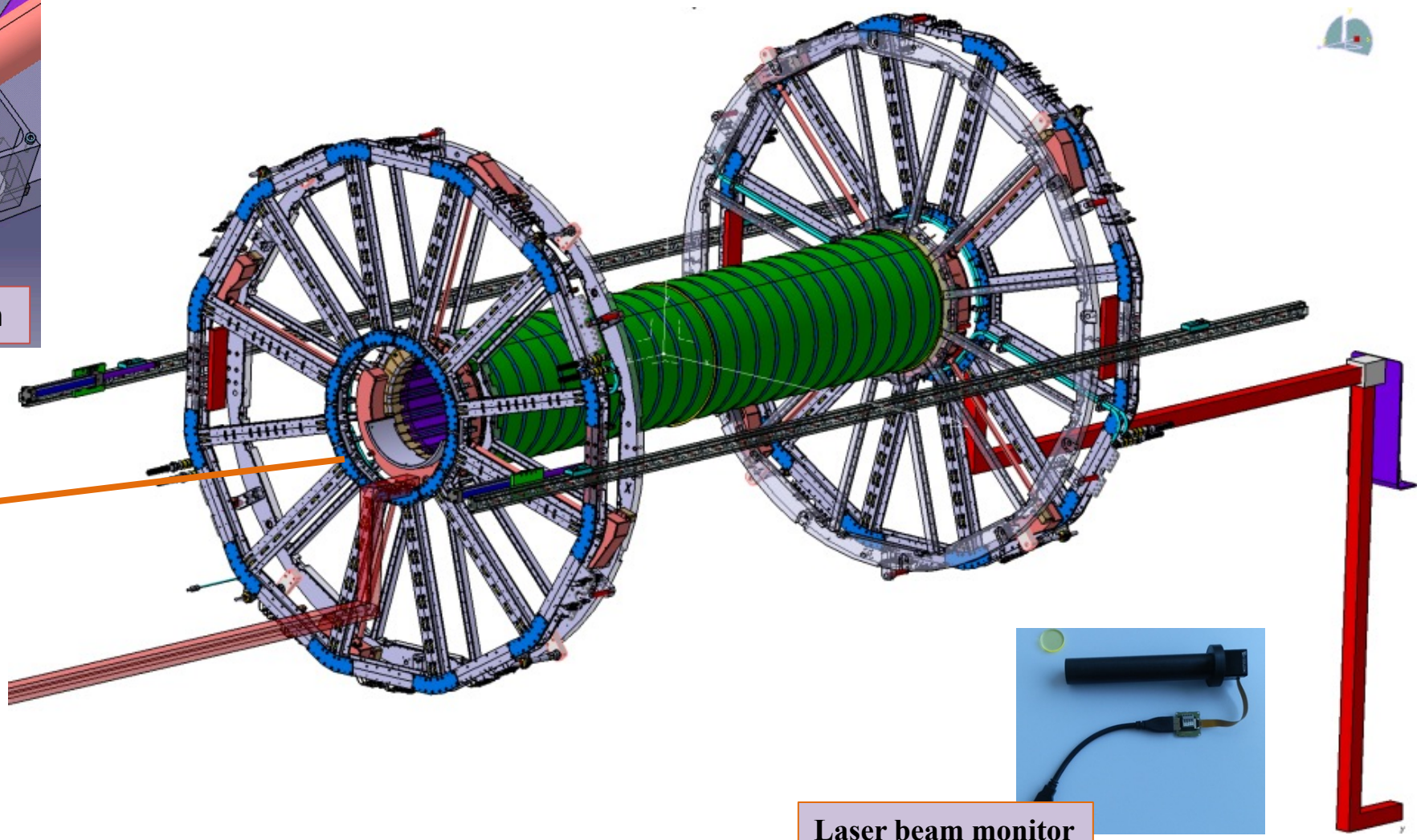
Laser calibration system



Semi transparency mirror & prism



Laser beam splitter



Laser beam monitor

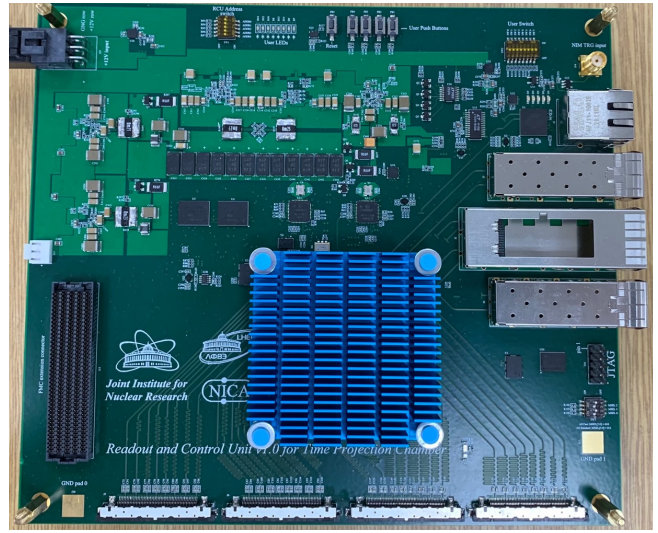
TPC/MPD data acquisition system main parts

Front-End-Cards (FEC): 1488 pc., 95 232 10-bit ADCs in total

1488 ×

Readout and Control Units (RCU): 24 pc. in total

24 ×



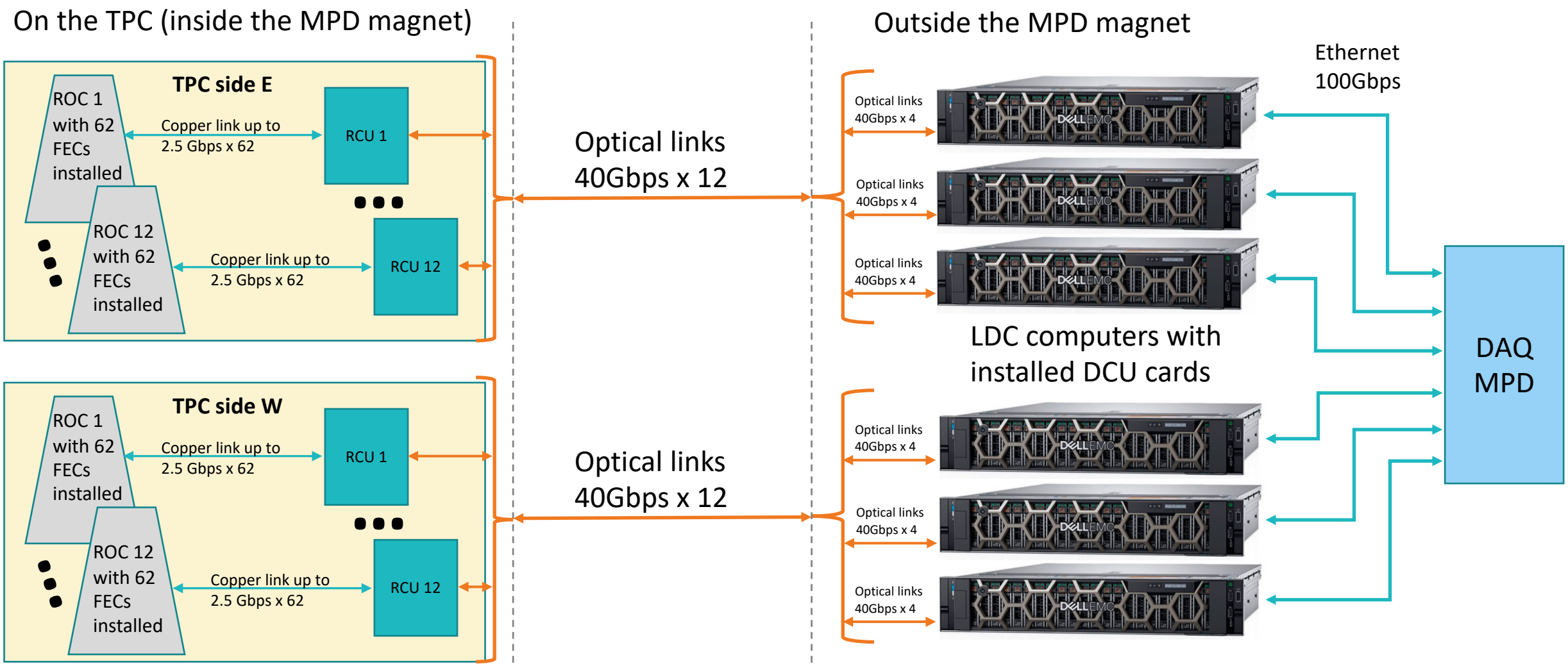
Data Concentrator Units (DCU): 6 pc. in total

6 ×

Local Data Concentrator (LDC) servers: 6 pc. in total

6 ×

TPC/MPD DAQ conceptual scheme



Front-End Card

Double-desk FEC formfactor: a) SAMPA board; b) Controller board;

- The total number of registration channels: 64
- Maximum input charge in a linear range: 100 fC
- ADC resolution: 10 bit
- ENC: les than 1000 e^-
- Readout serial interface: up to 2.5 Gbps
- The total number of monitored values of current, voltage, and temperature: 16

➢SAMPA chips management via FPGA high speed interface

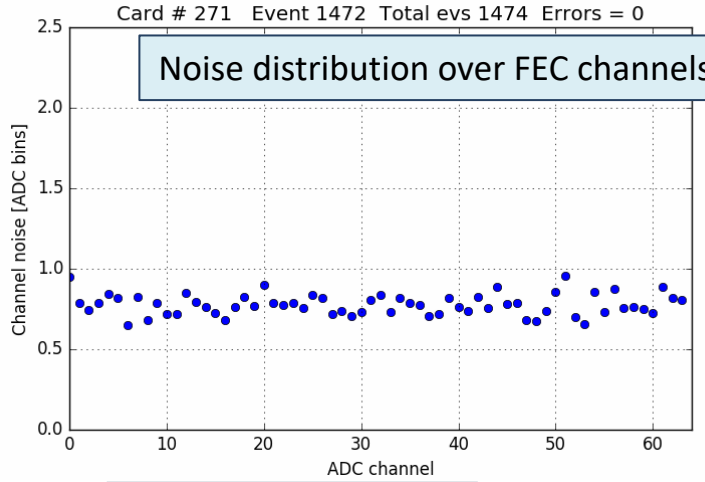
➢*Double-PCB FEC provides opportunities for possible upgrade of the card readout.*

➢*Transfer of data and trigger signals was realized with the same high-speed serial interface.*

➢*Onboard circuit and embedded protection functionality against SEU are provided.*

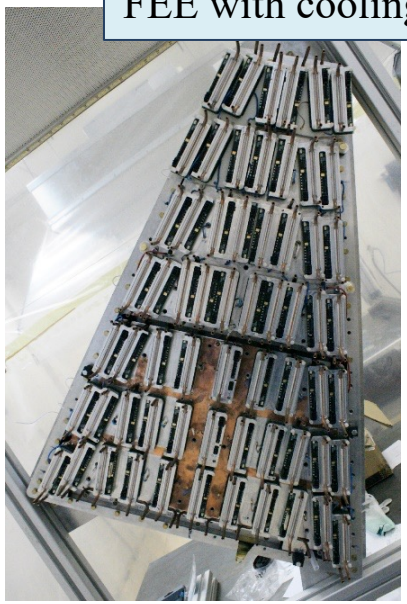
➢*Remote system update for FEC firmware was provided.*

Noise distribution over FEC channels

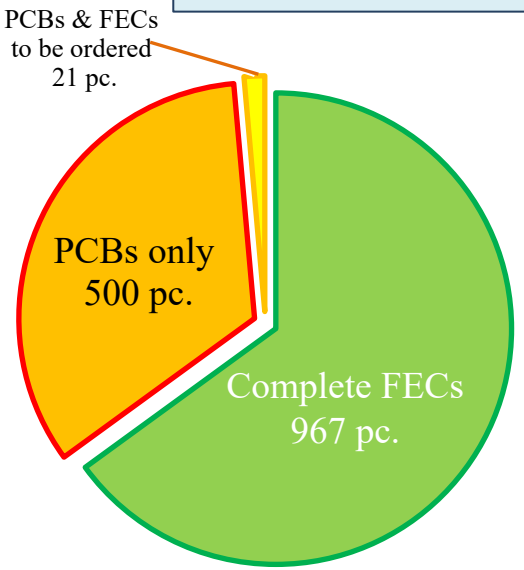


1LSB = 625 e^-

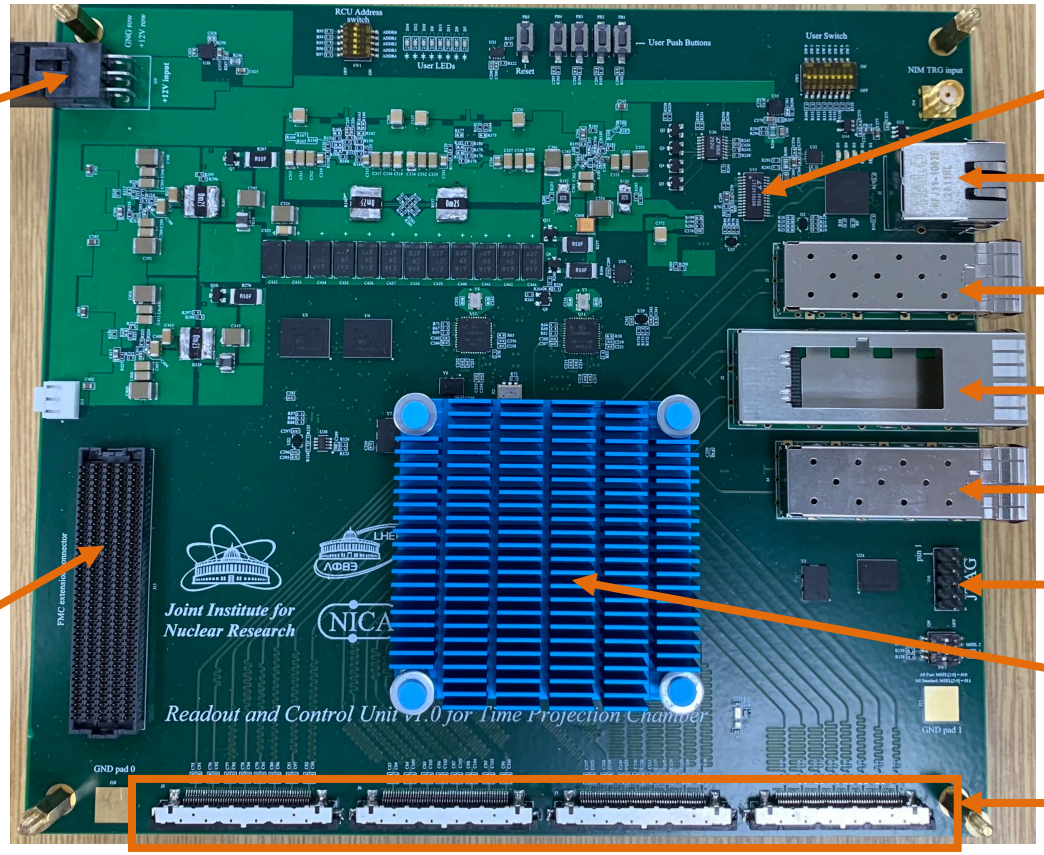
FEE with cooling



FEC production status:



Readout and Control Unit

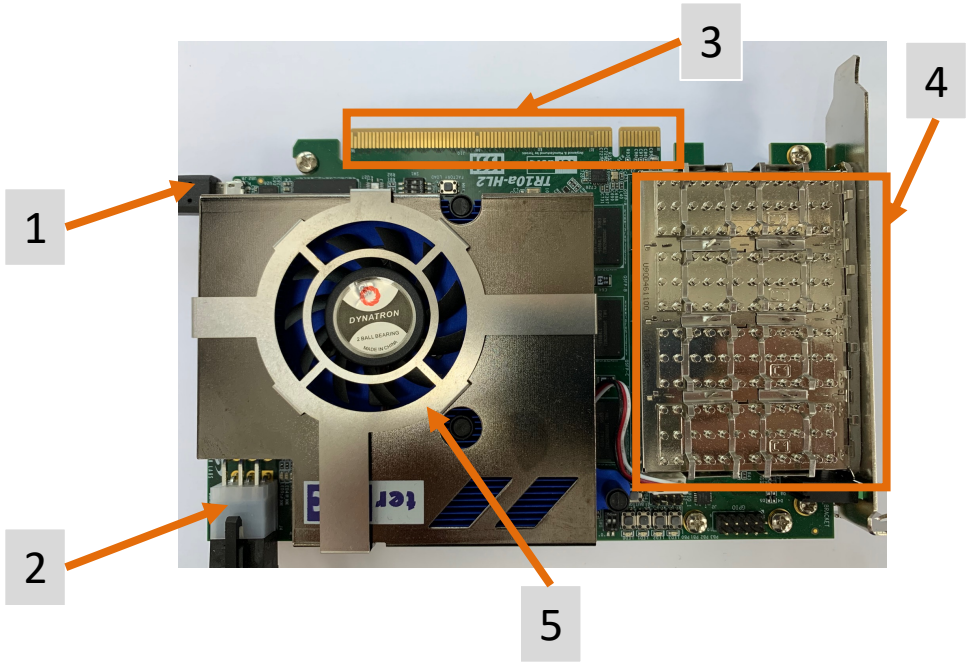


1. PS connector (+12 V)
2. 16-ch. ADC (health monitoring)
3. RJ45 connector (NIOS Ethernet 1Gbps)
4. SFP+ connector (optical trigger up to 10 Gbps)
5. QSFP connector (data transfer interface up to 40 Gbps)
6. SFP+ connector (spare optical channel up to 10 Gbps)
7. JTAG connector (FPGA programming end debugging + spare management channel)
8. Arria 10 GX FPGA
9. FECs XCVR connectors 64 full duplex channels
10. Multifunctional connector with GPIO pins and 2 spare XCVR

Main **RCU** functionality:

- Receiving data packets from 62 FECs;
- Buffering data with subsequent transmission to the DCU via optical channel;
- Organizing high-speed management channel to the FECs;
- Organizing FECs synchronization;

Data Concentrator Unit and Local Data Concentrator server



DELL R740XD rack unit

Receiving data via PCIe of the DCU card and after transmitting it to the MPD DAQ via 100G Ethernet

DCU card based on commercial development board

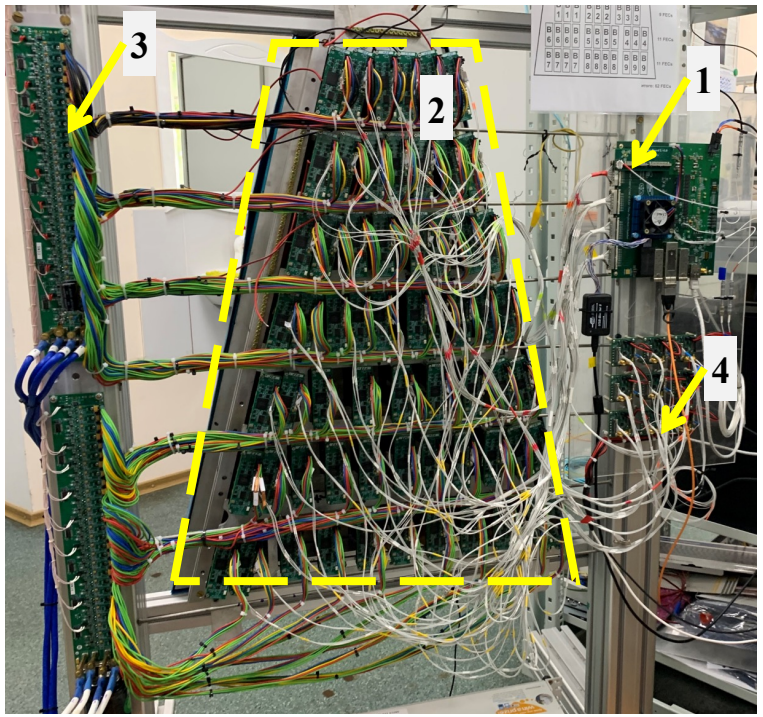
1) USB connector for onboard usb-blaster;
2) PS connector +12 V;
3) PCIe gen 3 x16 connector (double x8);
4) 4 QSFP connectors for data taking and management;
5) Arria 10 GX FPGA;

DCU functionality:

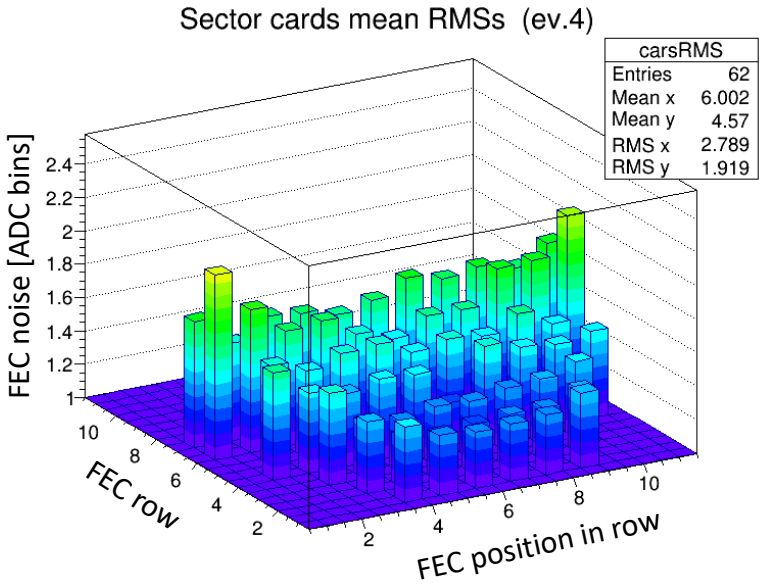
- Receiving data packets from four RCUs;
- Organizing high-speed management channel via PCIe;
- Managing of all downstream devices (RCUs, FECs);
- Buffering data with subsequent transmission to the server memory via PCIe ;

ReadOut Chamber DAQ test setups

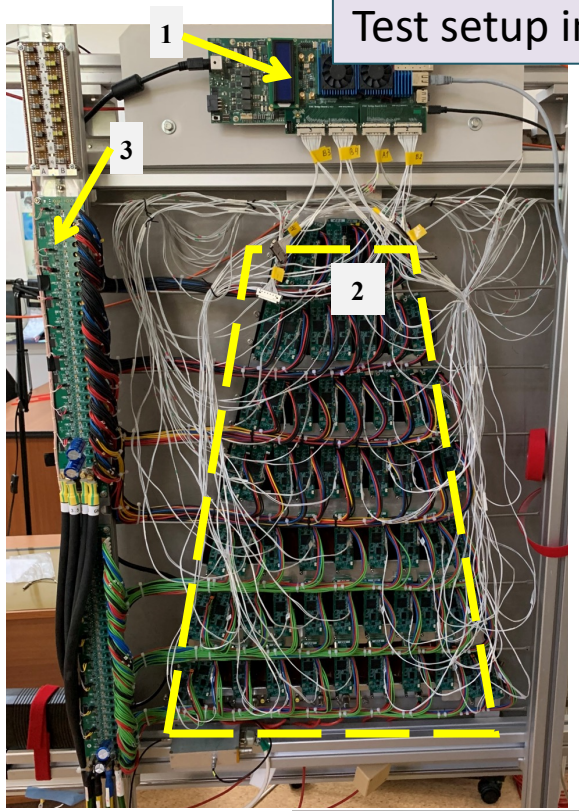
Test setup in bld. 201

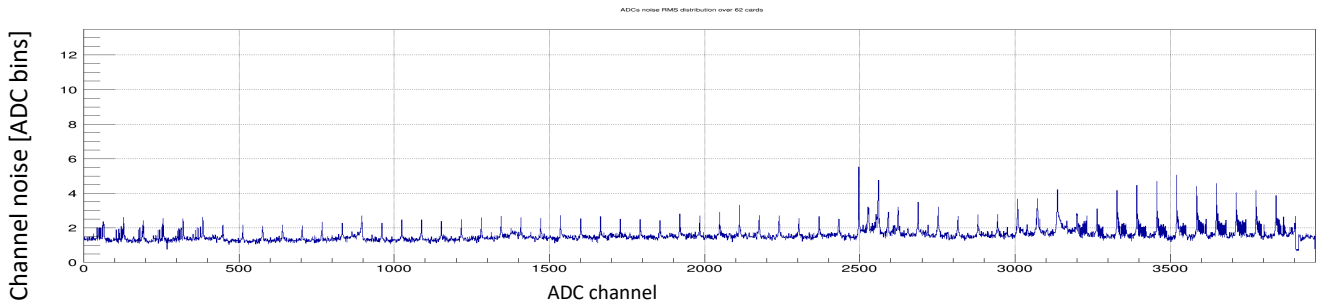


1. RCU64 (left) and RCU32 (right)
2. FECs on the ROC (62 pc)
3. LVDB modules
4. Clock fanout



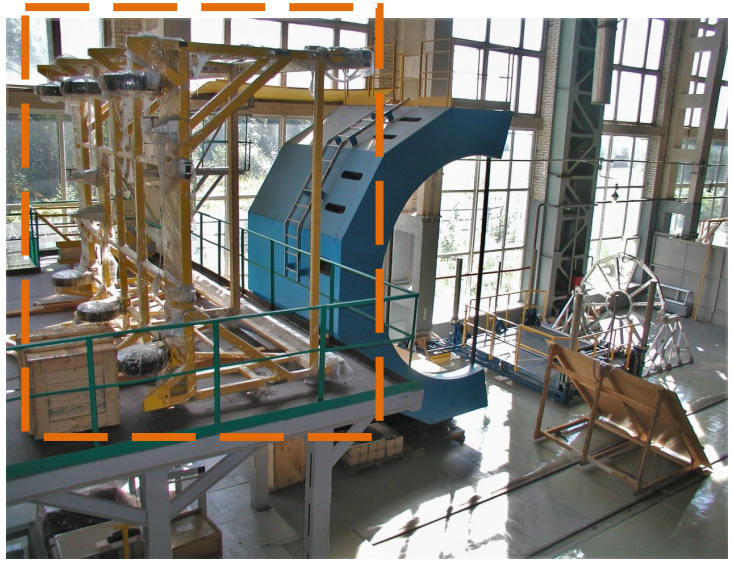
Test setup in bld. 40

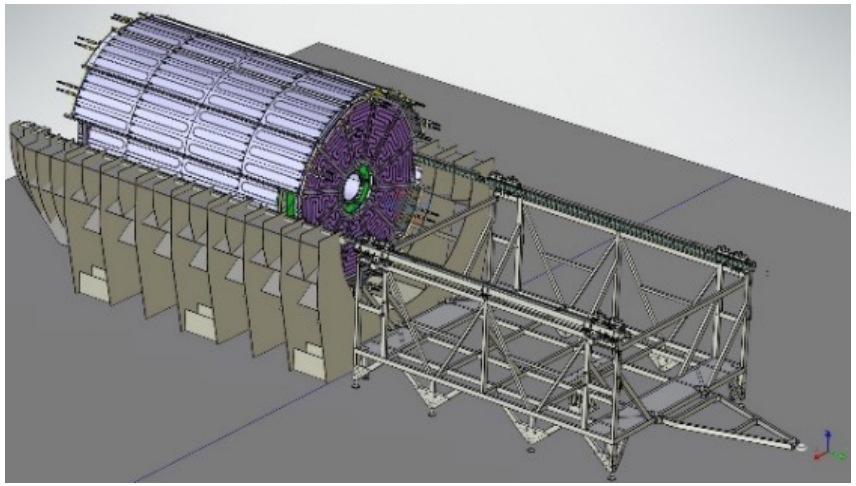


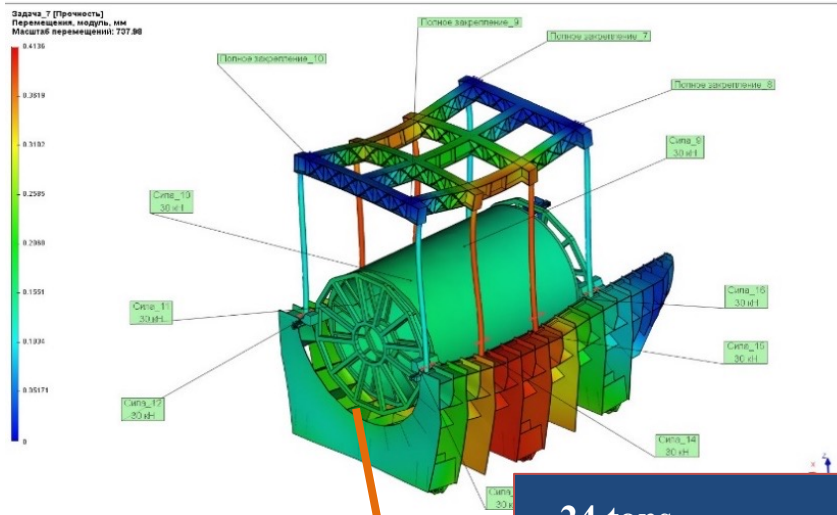


Vital element of the ROC data acquisition system is microcoaxial cable assembly based on μcoax 36 AWG cables and Hirose FX15, FX16 series connectors.

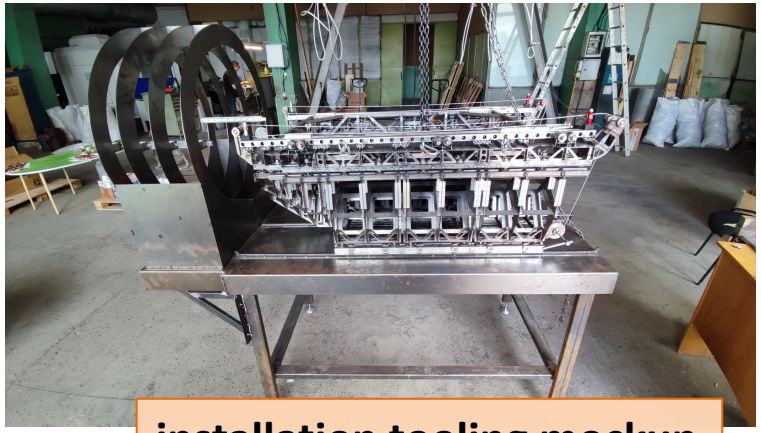
Tooling for Installation TPC to MPD



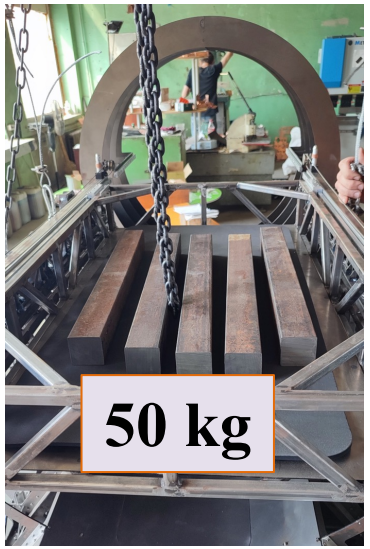




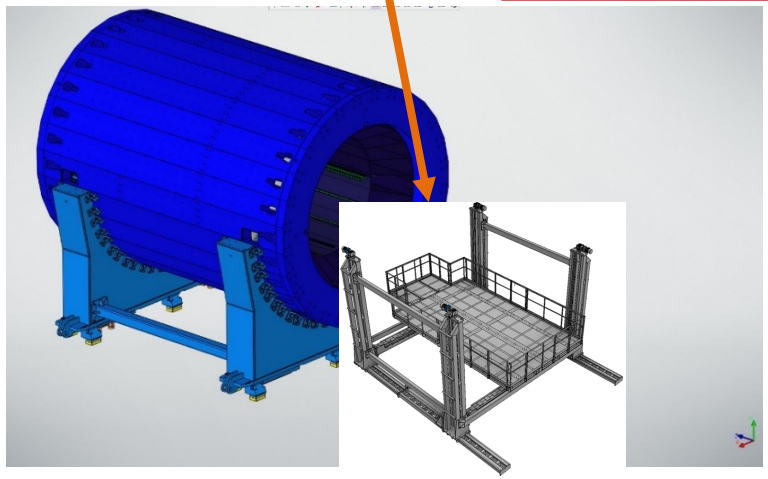
24 tons,
Maximum sagging
is 0.41 mm



installation tooling mockup

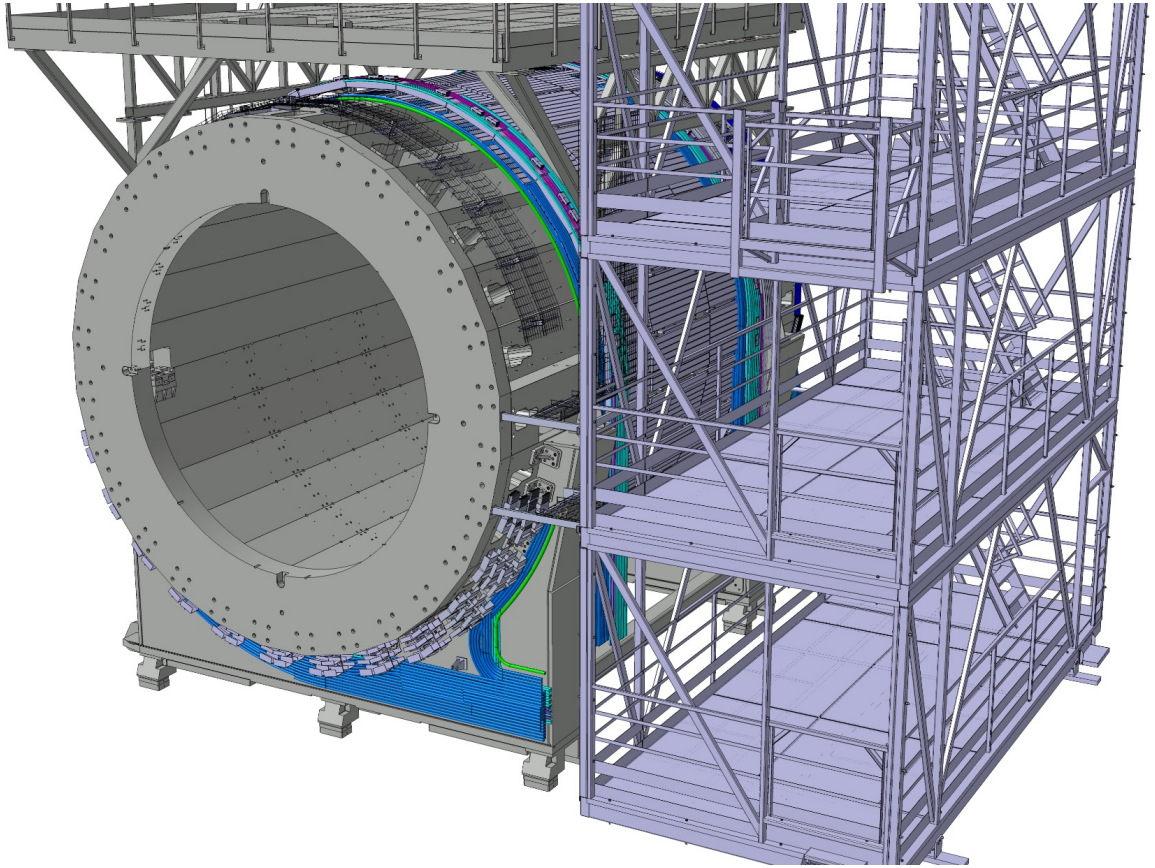


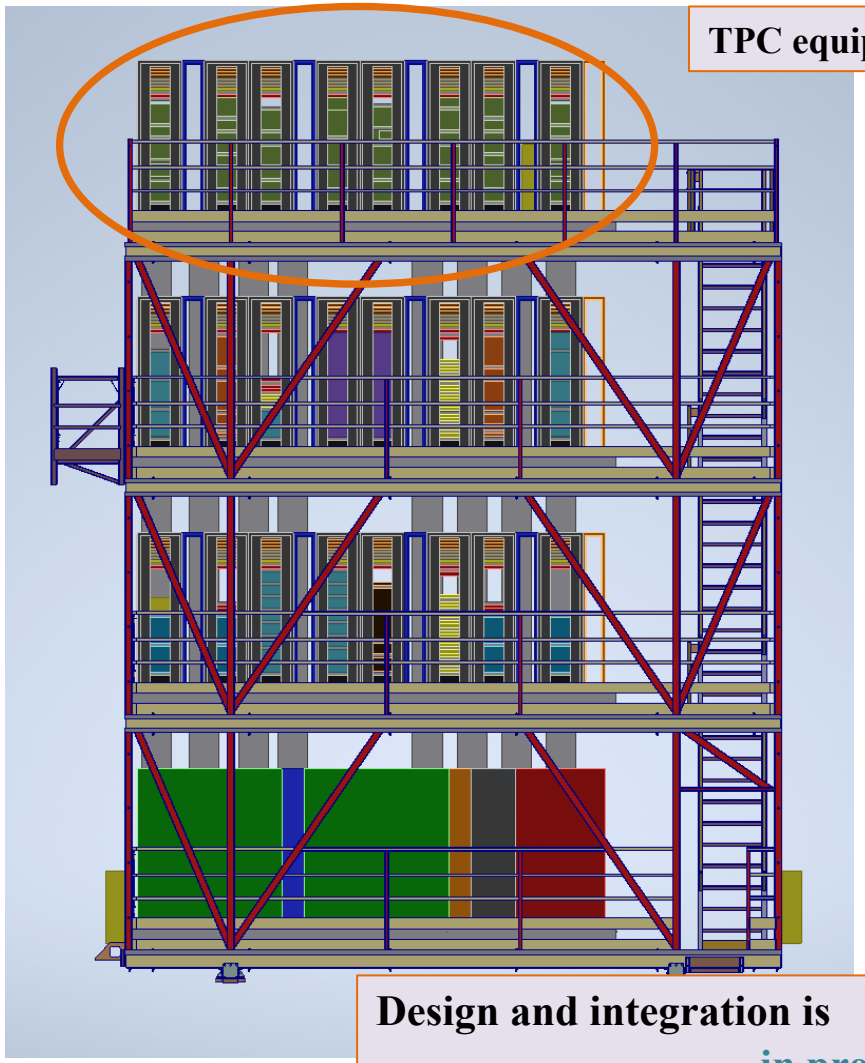
50 kg



NICA-MPD-Platform (NMP)

Common view

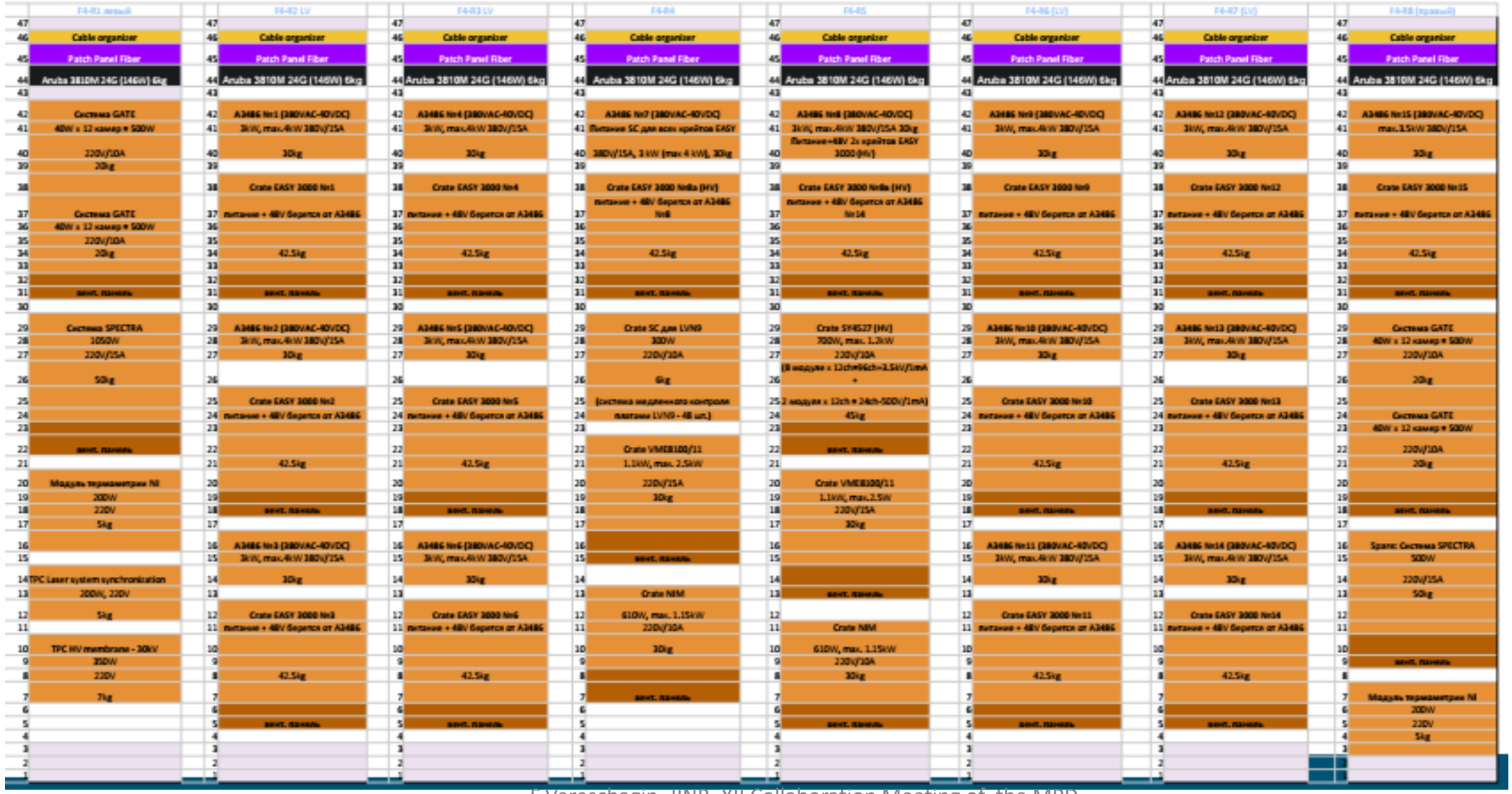




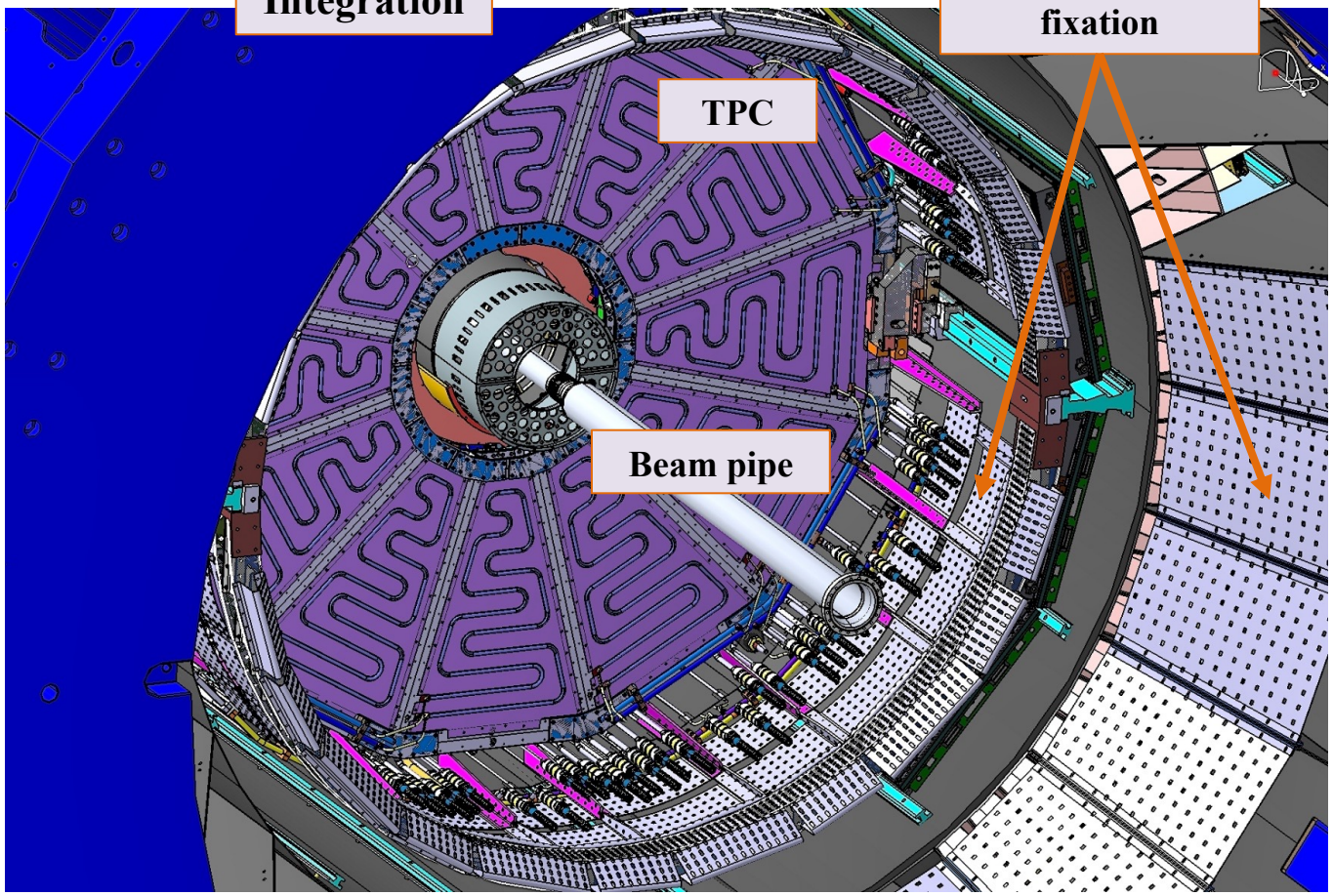
Design and integration is in progress …

MPD electronic platform

TPC equipment racks composition (4th floor)

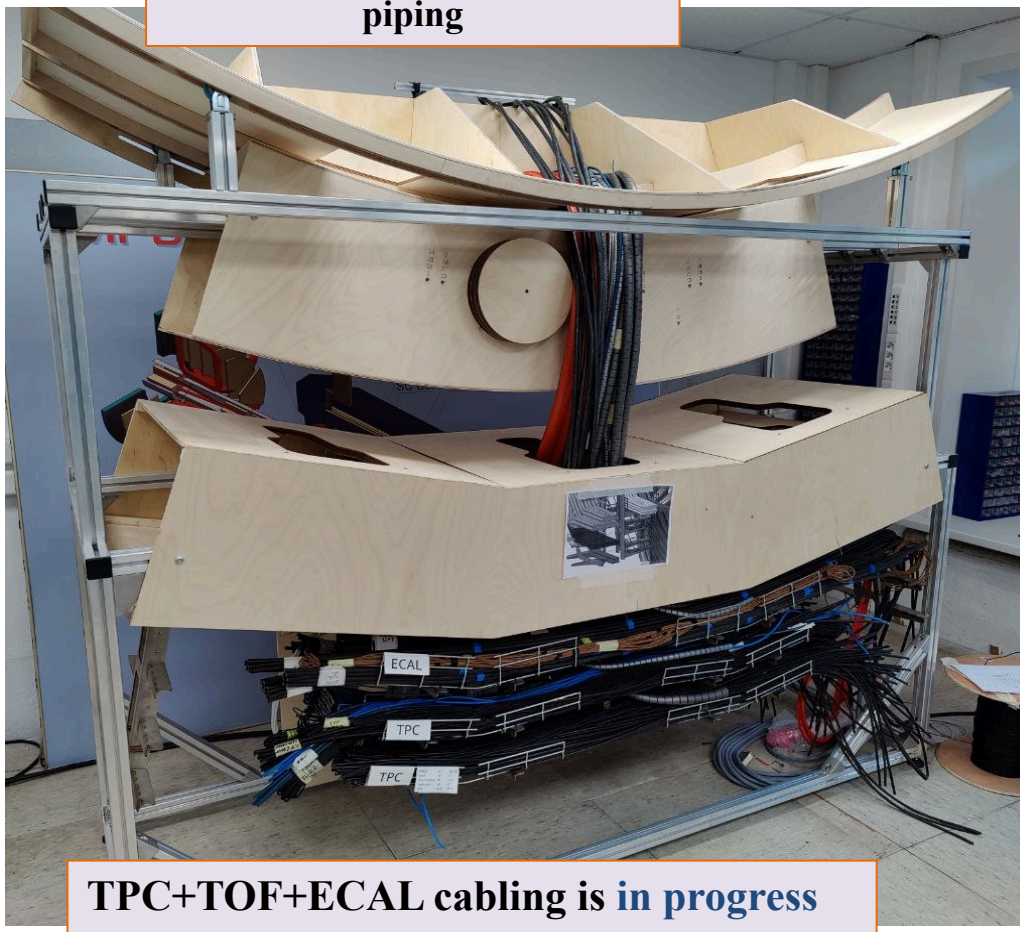


TPC cabling and piping



Structure design - in progress

Prototype for cabling and piping



TPC+TOF+ECAL cabling is in progress
Piping is not started yet

Time schedule

TPC assembling:		
Field cage assembly:	July 2023	→ Nov 2023
HV tests:	August 10 2023	→ Nov 2023
TPC vessel ready (glue by epoxy):	August 30 2023	→ Dec 2023
Laser beams position measurements:	Sept 2023	→ Jan 2024
TPC vessel tightness measurements:	Oct 2023	→ Jan 2024
24 ROC chambers installation:	Nov-Dec 2023	→ Feb 2024
TPC tests: laser tracks and cosmic test:	Jan-Sept 2024	→ March - Sep 2024
Integration TPC to MPD:		
TPC racks (8pc) + cabling:	Oct – Dec 2024	
TPC rails (2pc manufacture and delivery):	Dec 30 2023	
Rails installation to ECAL support structure:	May 2024	
Tooling for installation TPC to MPD:		
Design optimization + prototype 1:5:	Done	
Tooling manufacture (9 month):	Aug 2024	
Delivery to JINR:	Aug 30 2024	
TPC+ECAL cooling systems:		
systems delivery:	Apr 2024	
commissioning:	Sept 30 2024	
TPC installation to MPD:	Oct 1-Nov 30 2024	
MPD commissioning:	Jan 10 - Feb 2025	

Thank you for your attention!