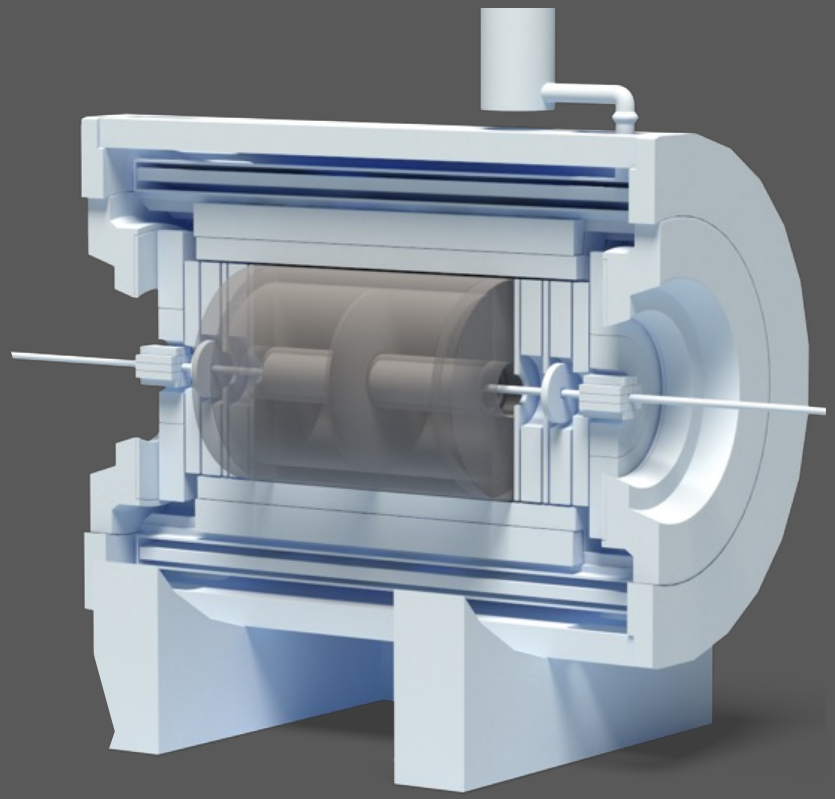
Time-projection chamber for MPD

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



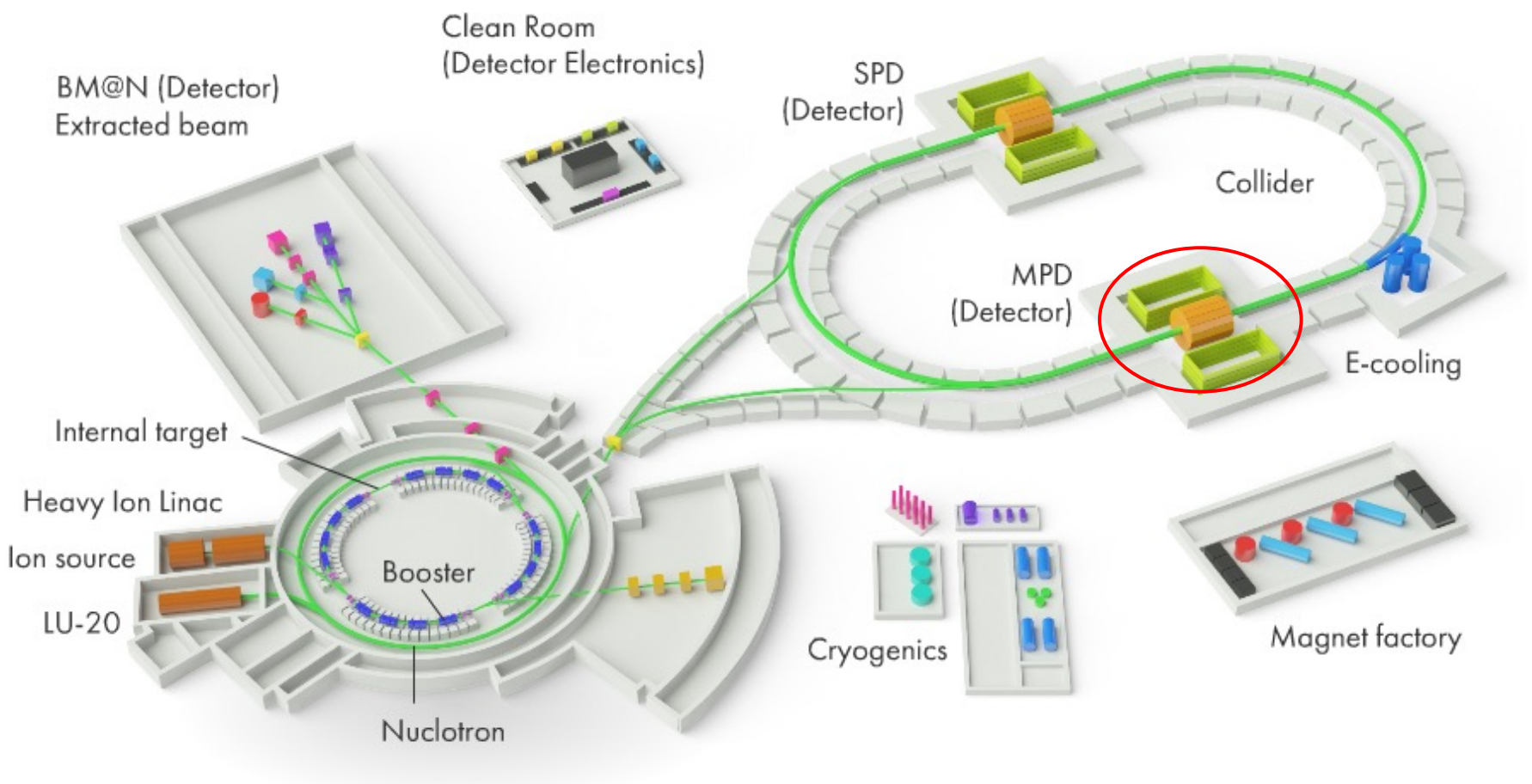
JOINT INSTITUTE
FOR NUCLEAR RESEARCH

NICA

NICA MPD

Outline

NICA Complex

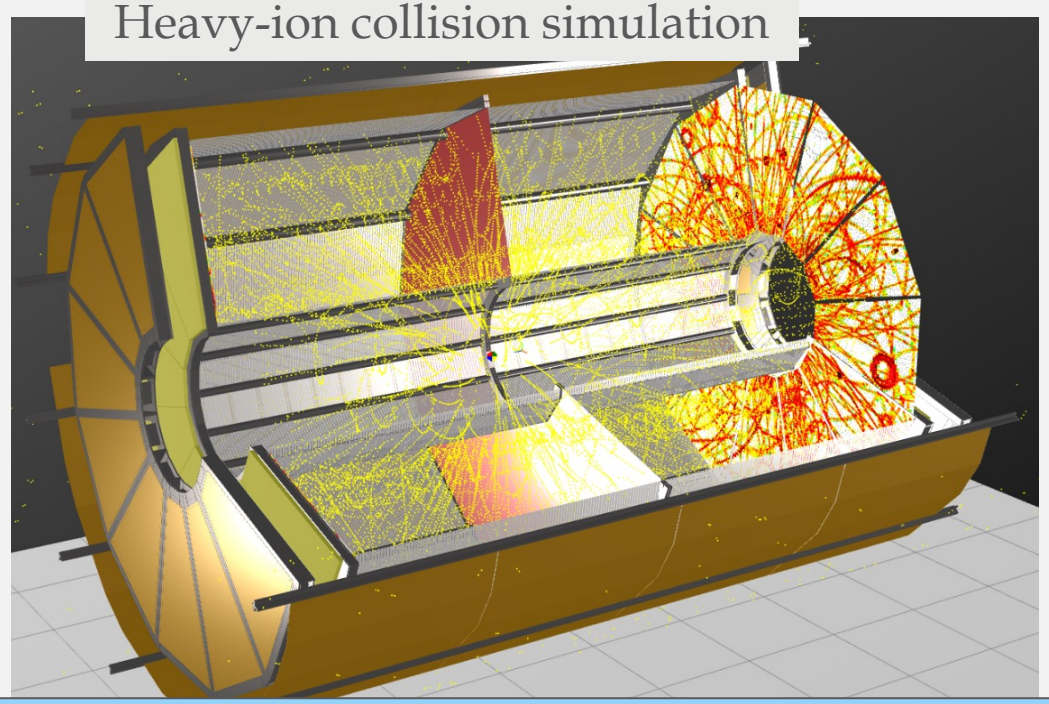


For details on the NICA project look into the presentations: **"Mega-science challenges of the NICA project"** (Vladimir Kekelidze) and **"NICA accelerator complex"** (Andrey Butenko)

https://nica.jinr.ru/
http://mpd.jinr.ru/

TPC design requirements and main parameters

Heavy-ion collision simulation

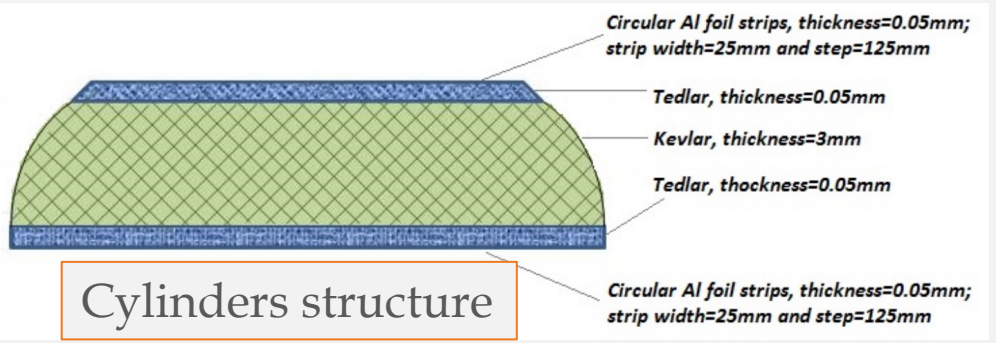


The TPC/MPD design requirements:

- The overall acceptance: $\eta < 1.2$
- 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

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 and HV electrode

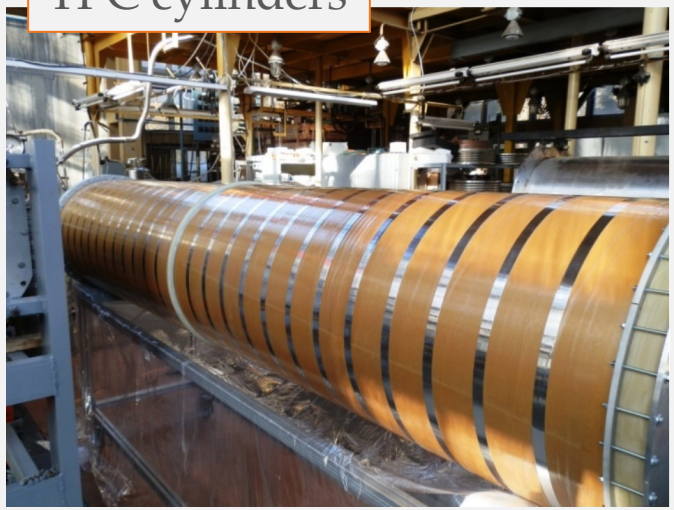


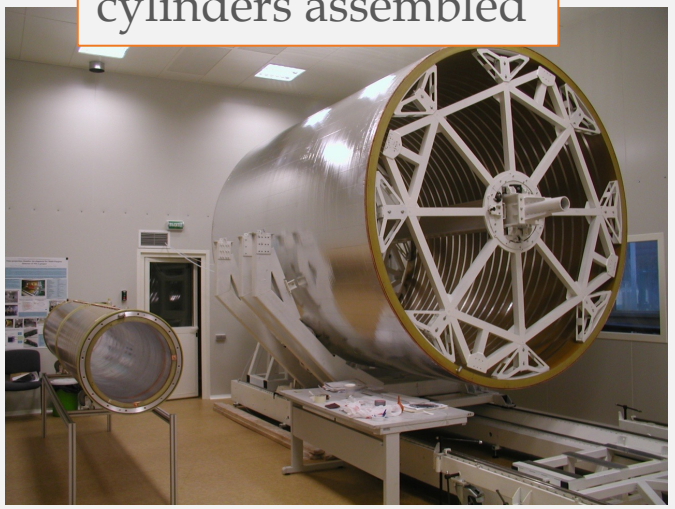
Cylinders structure

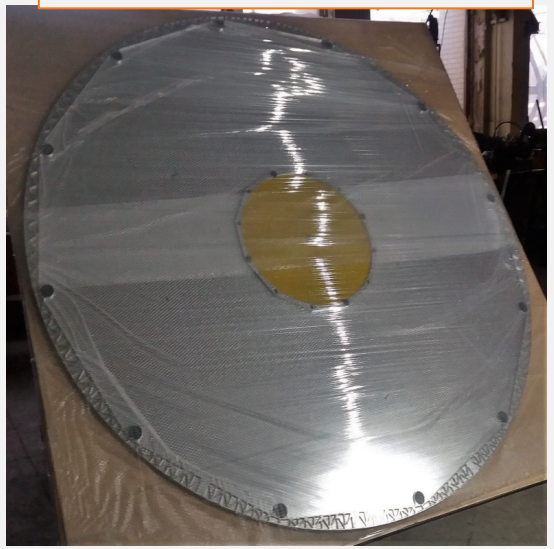
TPC cylinders

C1-C2 and C3-C3 cylinders assembled

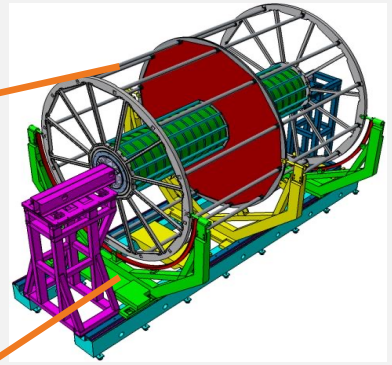
Central HV electrode



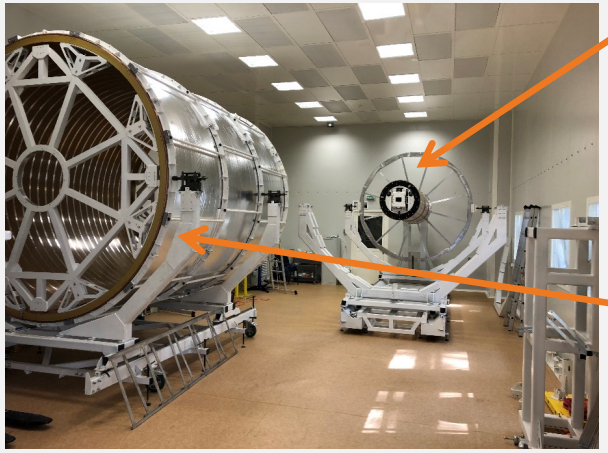


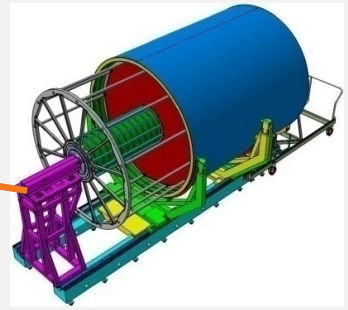


TPC body assembling



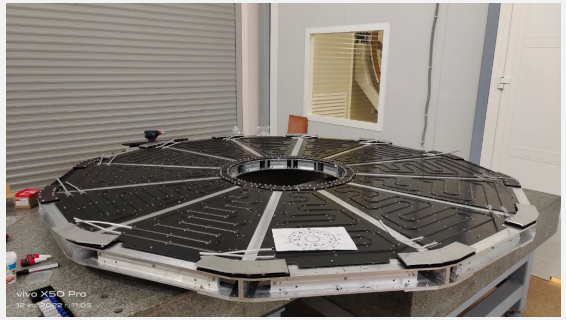
C1-C2 and C3-C4 cylinders: assembled
TPC service wheels: assembled
HV membrane: tested
Field Cage assembly: July 2023
TPC body ready: August 2023



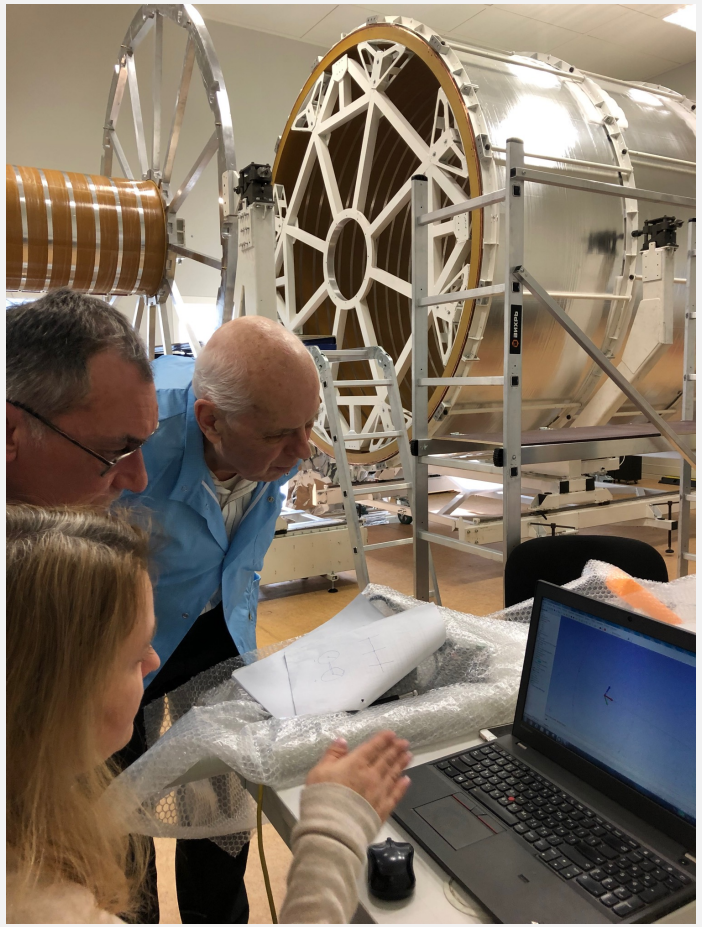


Flange

Service wheel



The body assembling

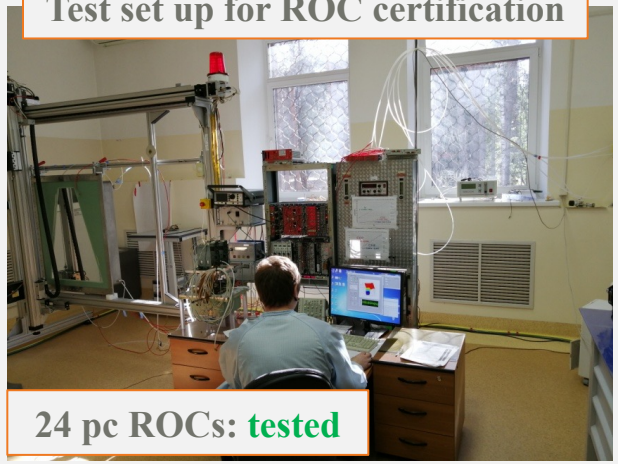


TPC body was assembled with test rods to check TPC geometry by laser tracker AT-402 : misalignment between 2 flanges, HV electrode and C1-C2 cylinder - is about 0.5 mm.

The goal is to improve misalignment.

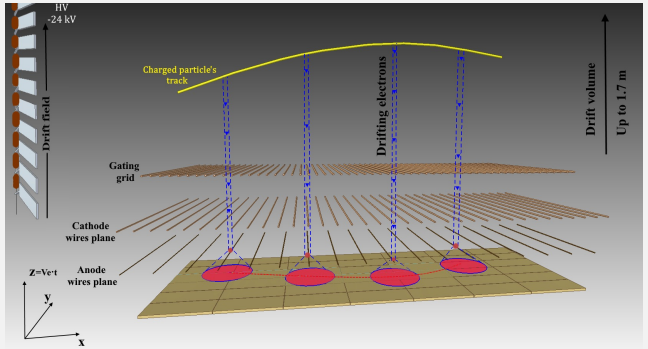
Read-Out Chambers (ROC)

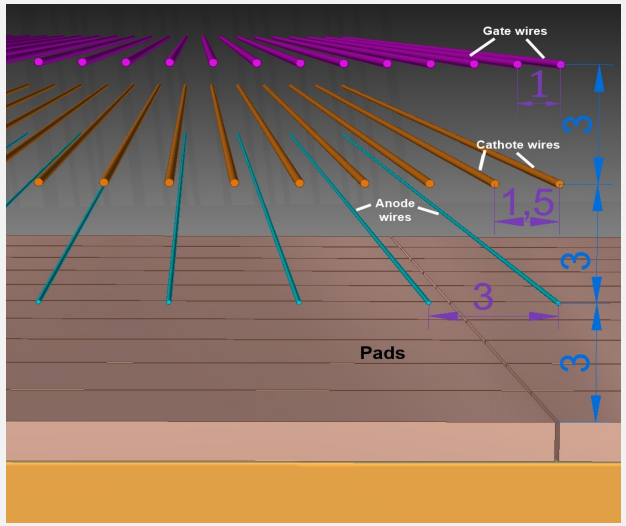
Test set up for ROC certification



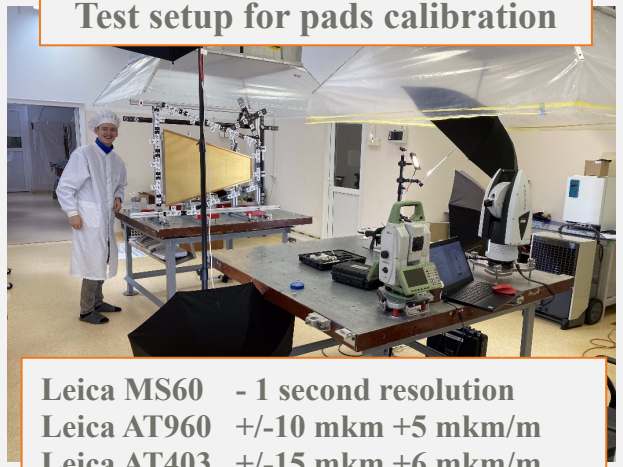
24 pc ROCs: tested

24 pc. of serial ROCs + 4 spare are READY



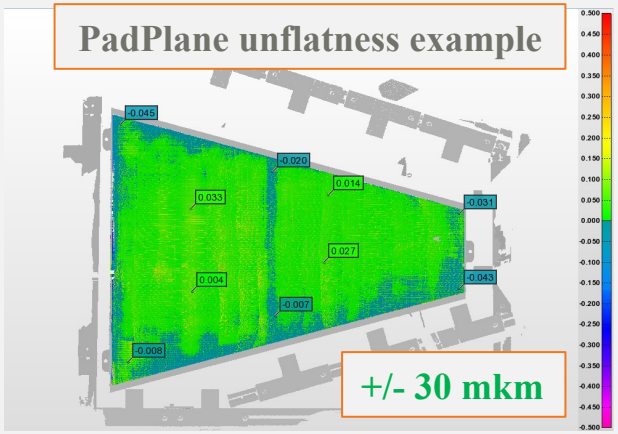


Test setup for pads calibration



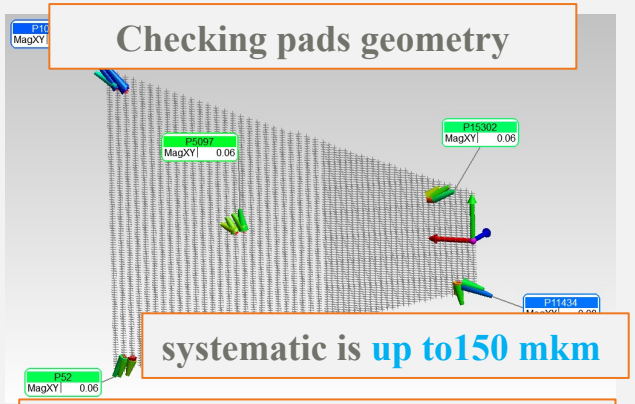
Leica MS60 - 1 second resolution
Leica AT960 +/-10 mkm +5 mkm/m
Leica AT403 +/-15 mkm +6 mkm/m
Scanner AS1+AT960 +/-50 mkm

PadPlane unflatness example



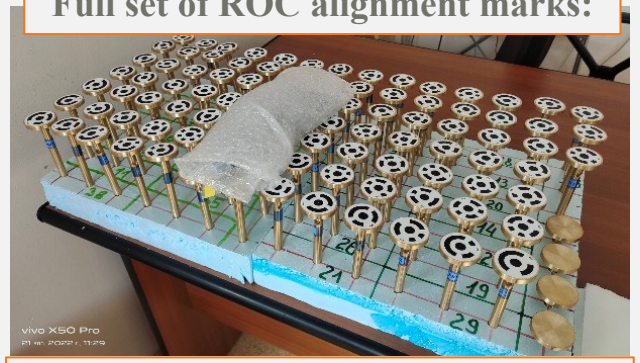
+/- 30 mkm

Checking pads geometry



systematic is up to150 mkm

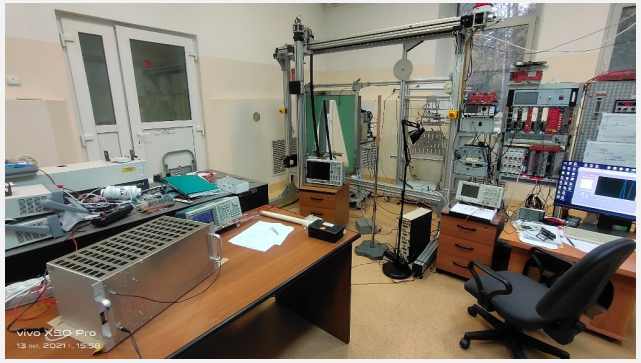
Full set of ROC alignment marks:



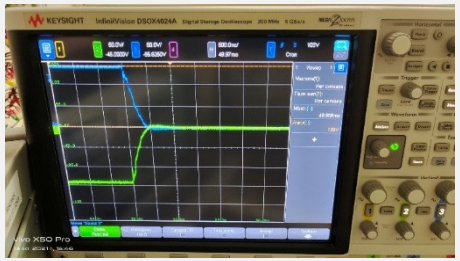
Our target is to measure coordinates of installed marks and 3968 pads in respect to the "reference hole" in each ROC.

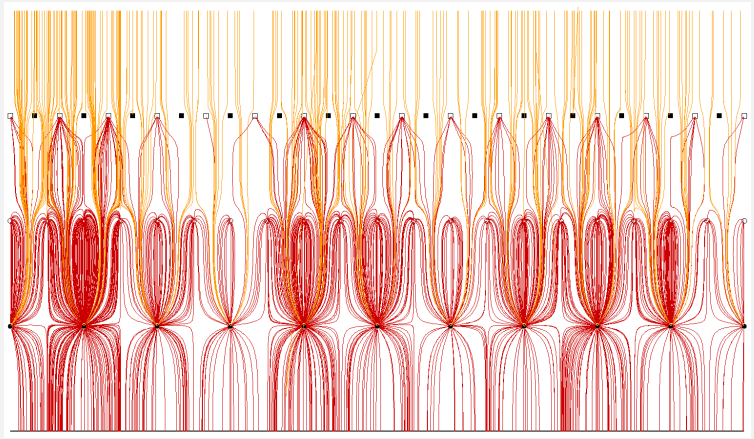
Gating grid system

ROC gating grid system: test setup



Pulse rise time is 500 ns: OK





<- Gate ->

<- Cathode ->

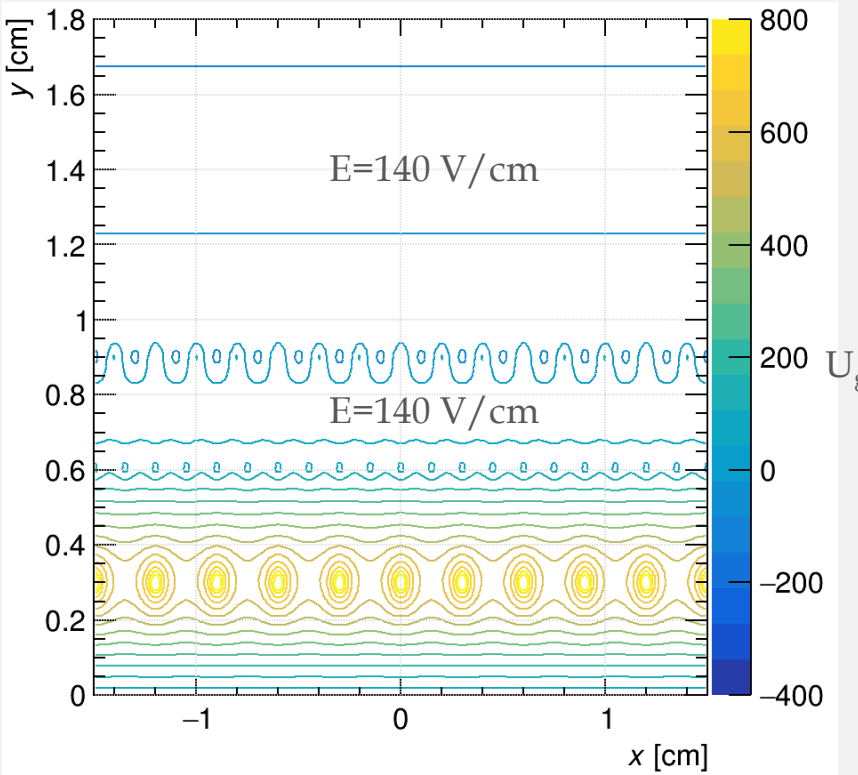
<- Anode ->

Ion drift lines

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

Shape of the TPC equipotentials:

HV = -22 kV

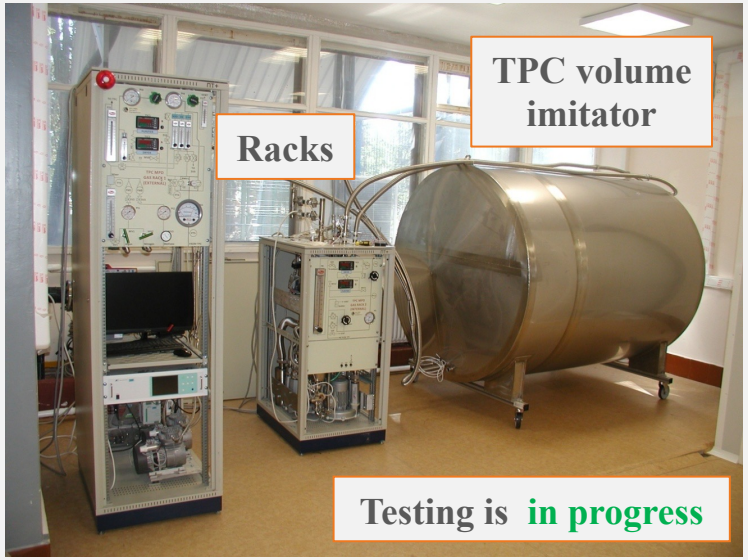


U_{gate} = ± 150 V

GND

U_a=2.4 kV

Gas system

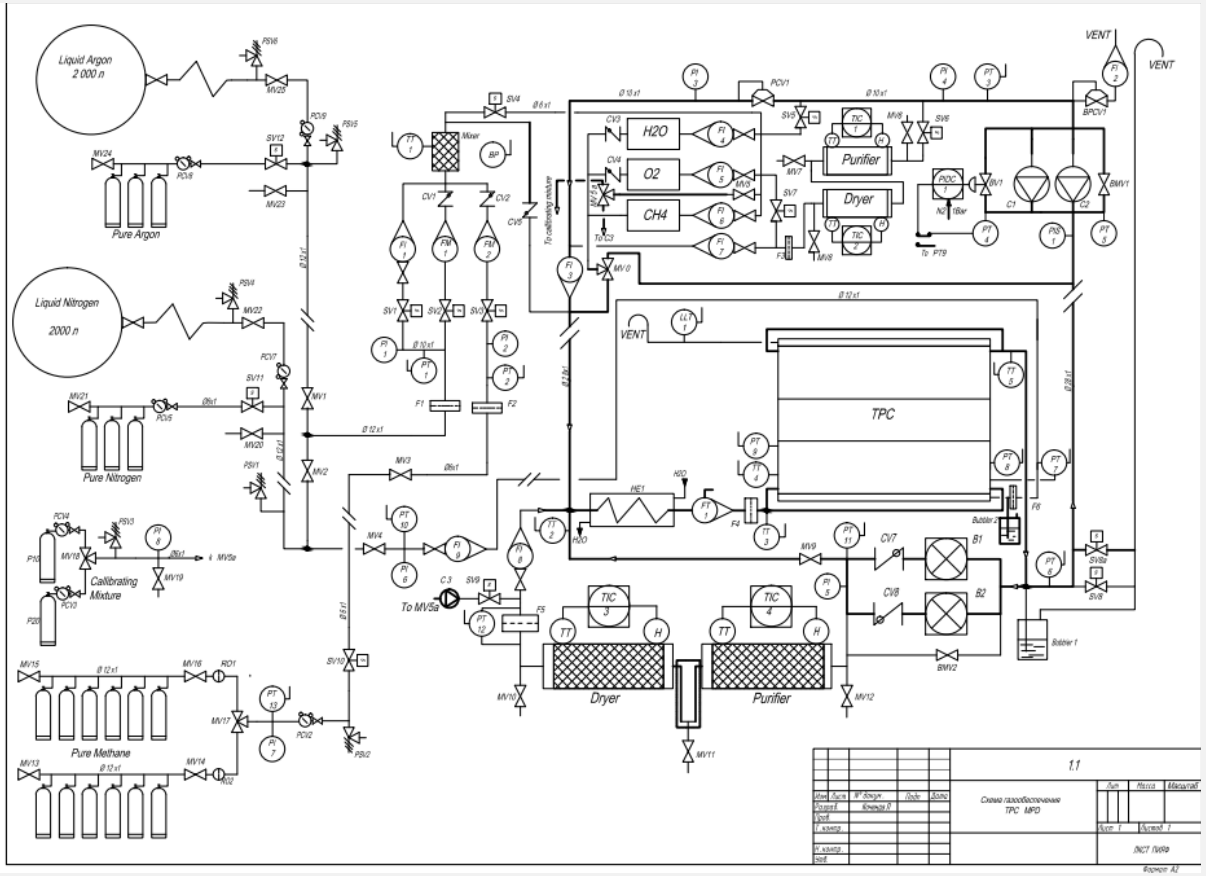


Gas system main features:

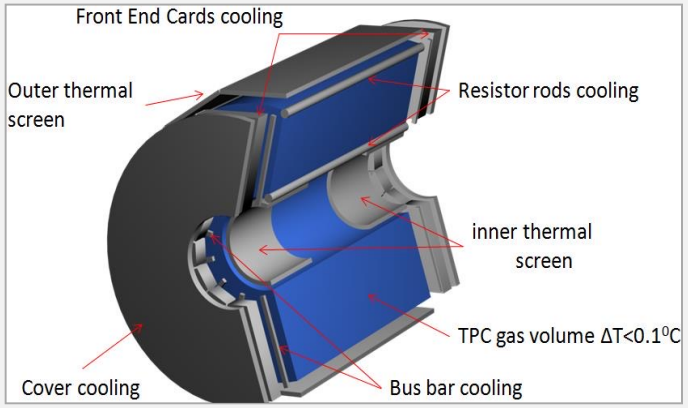
- Drift gas mixture: 90%Ar + 10%CH_4 (P10);
- Insulating gas: N_2;
- Operating pressure: atmospheric + 2.0 ± 0.03 mbar;
- Drift volume: 17640 liters;
- Insulating gaps volume: 2380 liters;
- Oxygen content: 20 ppm;
- Moisture content: 10 ppm;
- Recirculation rate of outer loop: 30 L/min;
- Recirculation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

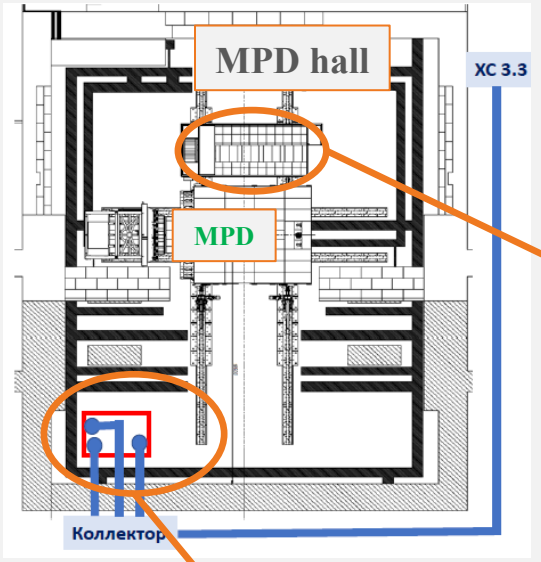
Gases consumption:

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

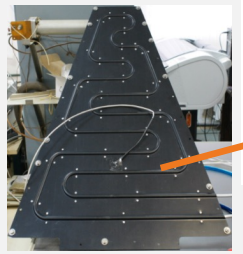


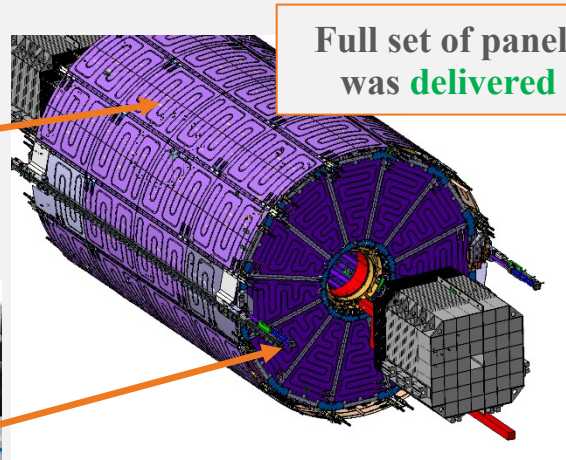
Cooling system



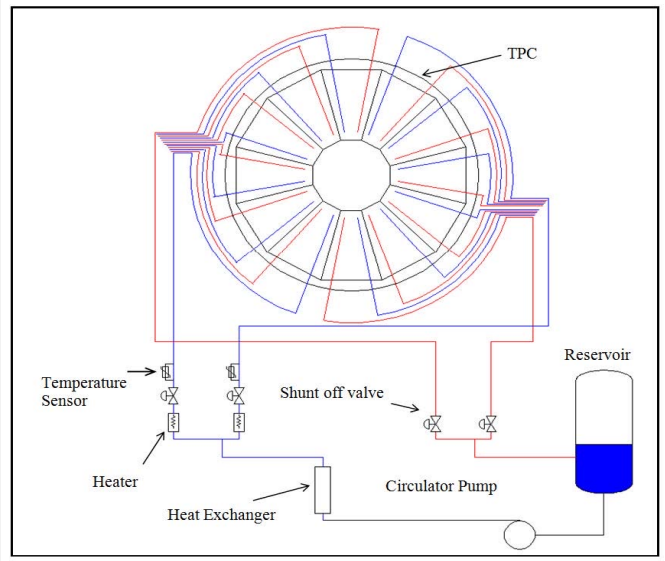


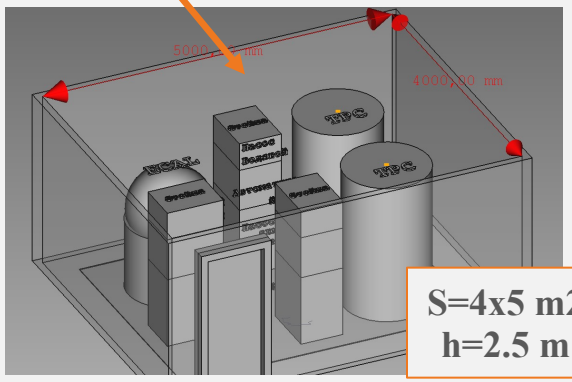
S=1.2x3.6 m2
h=2.2 m





Full set of panels was **delivered**

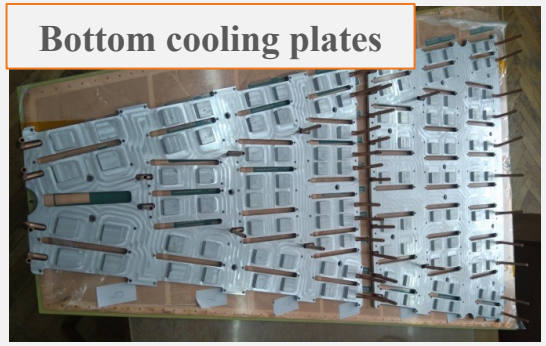




S=4x5 m2
h=2.5 m

FEE cooling plates

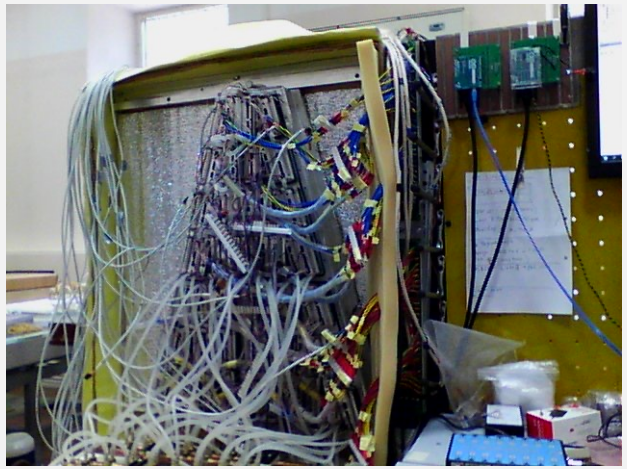
Bottom cooling plates

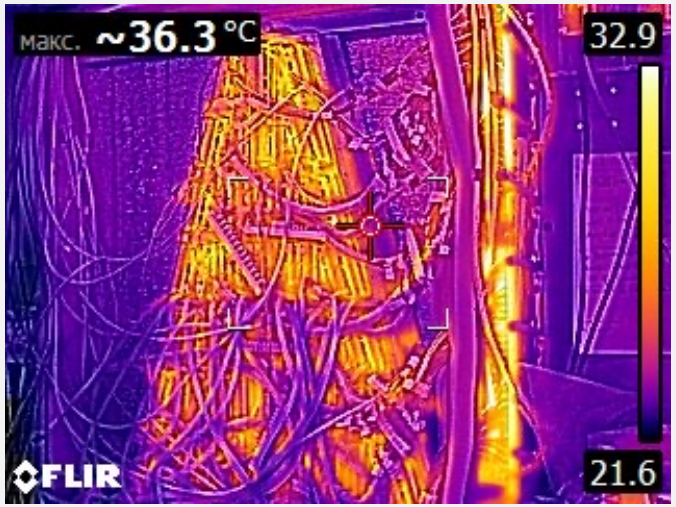


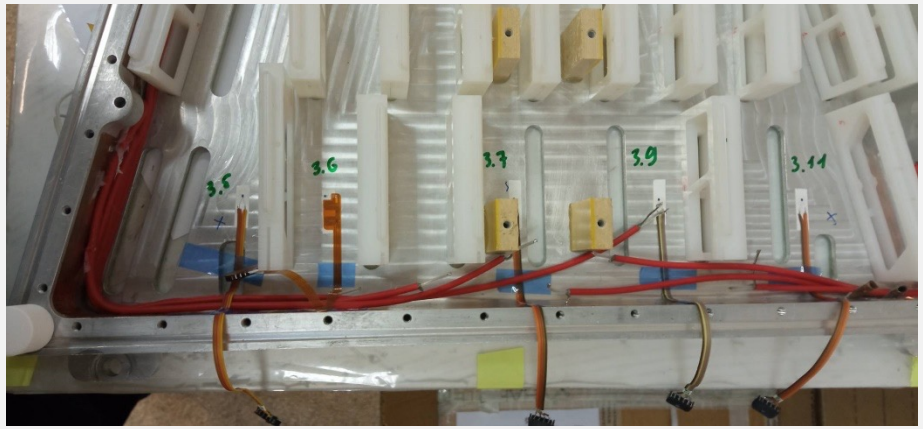
Set of top cooling plates

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

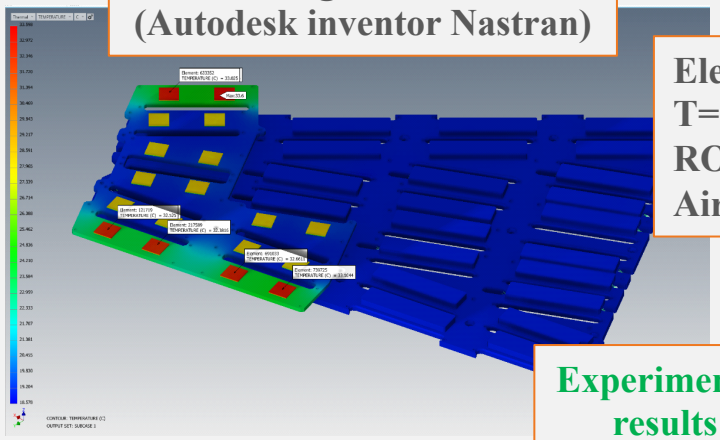
Cooling prototype







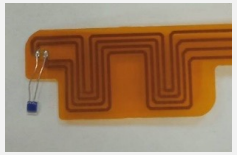
Cooling simulation
(Autodesk inventor Nastran)

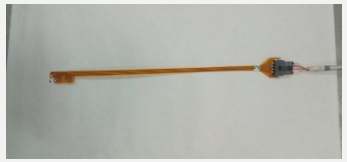


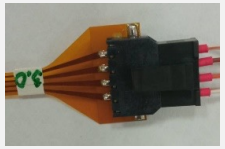
Electronics water:
T=19 C
ROC water: T=22 C
Air: T=23 C

Experimental and simulation results are compatible

T sensor based on Pt100





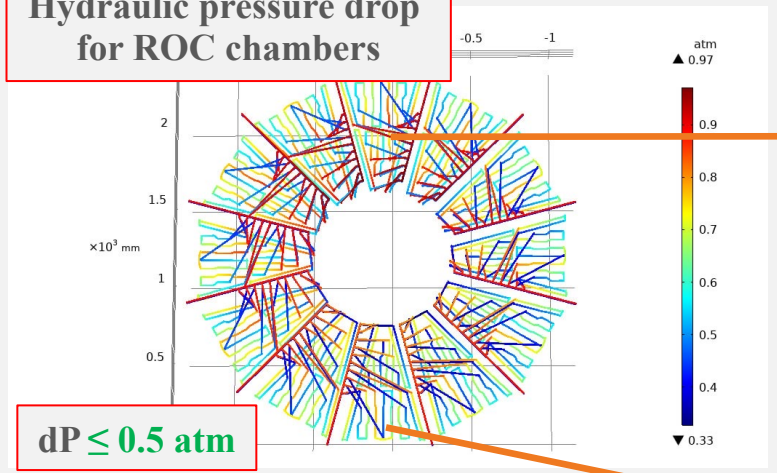


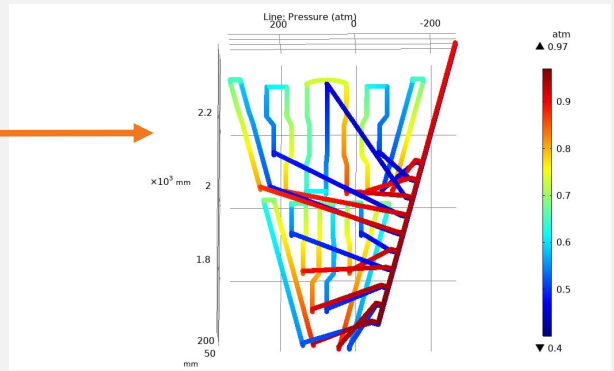
Air: T=23 degree (C)

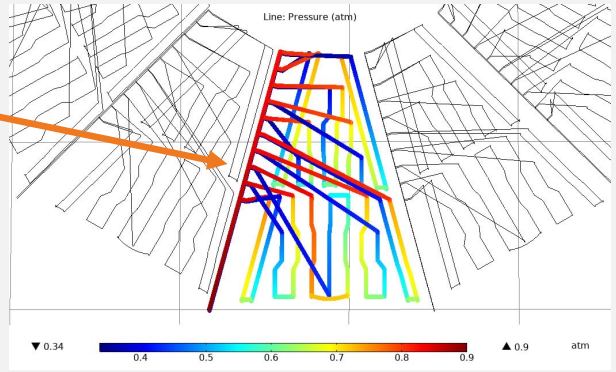
Water FECs T (C)	Water ROC T(C)	SAMPAs dT (C)	FPGAs dT (C)	Pads dT (C)	ROC dT (C)	T Min (C)	T Max (C)	Comments
17	25	3÷5	7	0.27	0.6	18	33	
19	22	3÷5	7	< 0.2	0.2	20	35	optimum

Serial cooling system

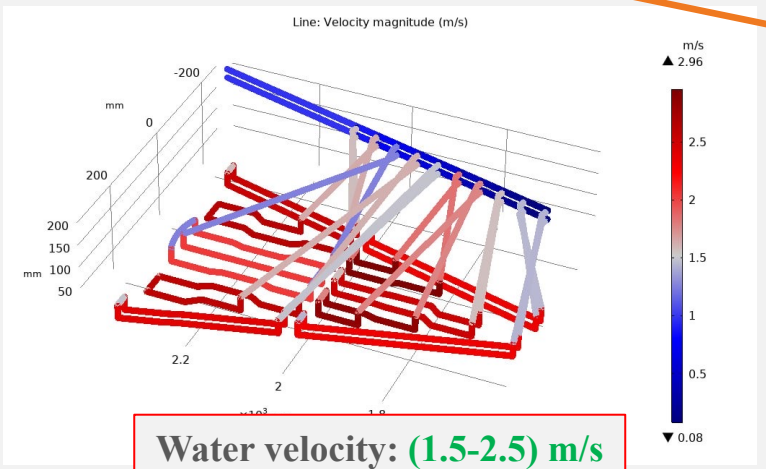
Hydraulic pressure drop for ROC chambers







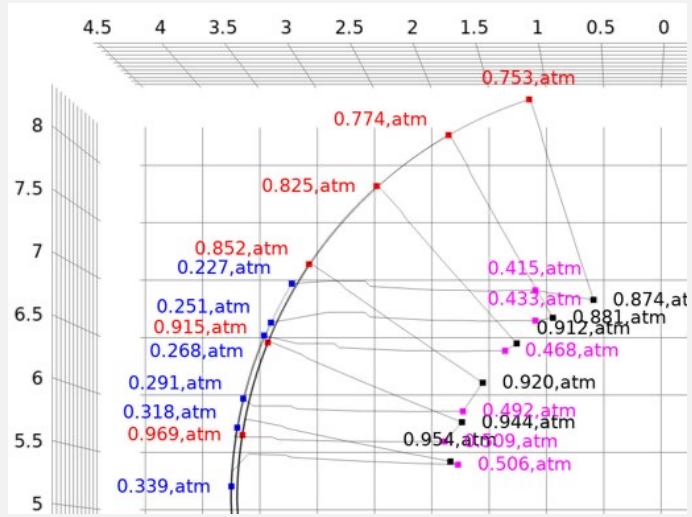
dP ≤ 0.5 atm

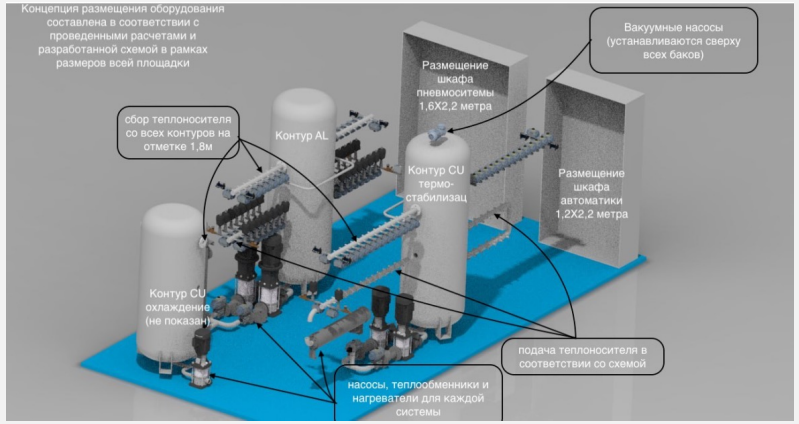


Water velocity: (1.5-2.5) m/s

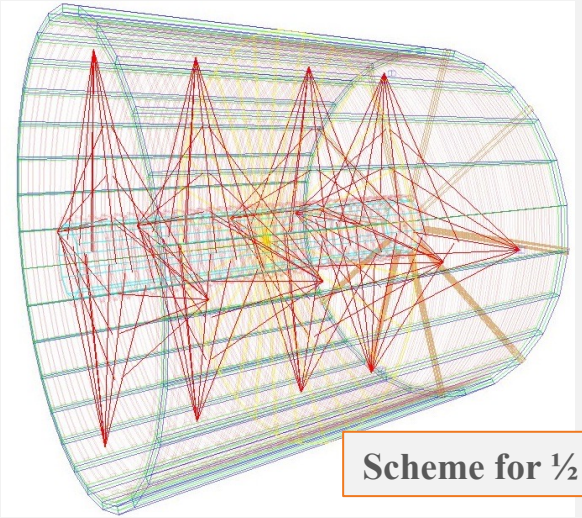
Systems parameters optimization by calculations – in progress

TPC system pressure with water column height

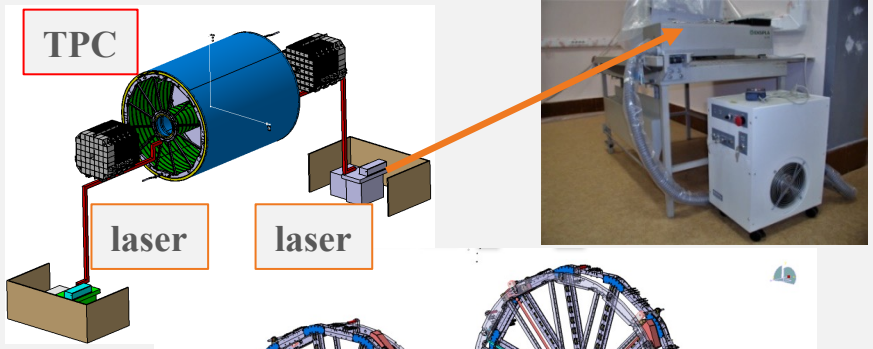


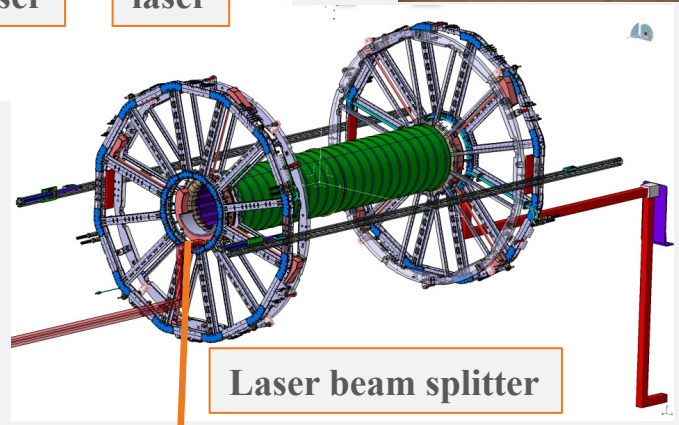


Laser calibration system

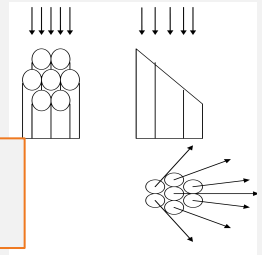


Scheme for ½ TPC

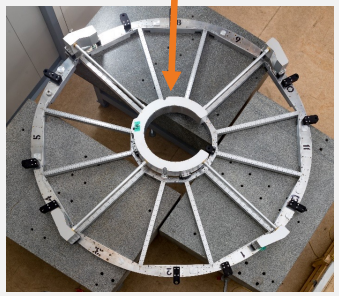


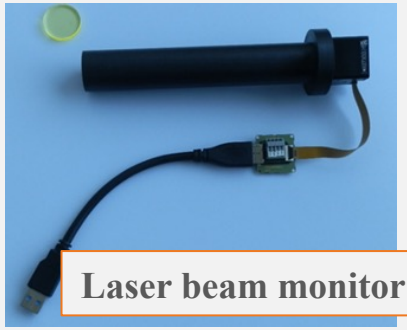


Number of laser "planes": 4
Number of micro-mirrors bundles per plane: 4
Number of beams from micro-mirrors bundle: 7
Total number of laser "tracks" (N =112x2): 224



micro-mirror bundles





TPC laser calibration for electron drift velocity (root version)

MPD

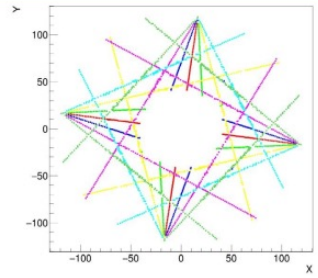
Bychkov A.

Space-charge distortion in TPC volume change the electron drift velocity (≤ 1sec.)– corrections are needed.

Reconstructed hits of the laser grids

Reasons:

- Variation in drift velocity caused by gas mixture, temperature, pressure and electric field variation.
- Radial inhomogenities of magnetic and electric field.
- Space charge distortions due to high multiplicity in nucleus-nucleus collisions.
- TPC misalignment in the magnet and existence of the global E X B effect.



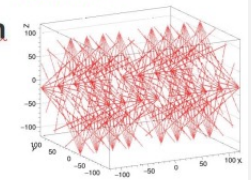
TPC electron drift velocity calibration (standalone fast version)

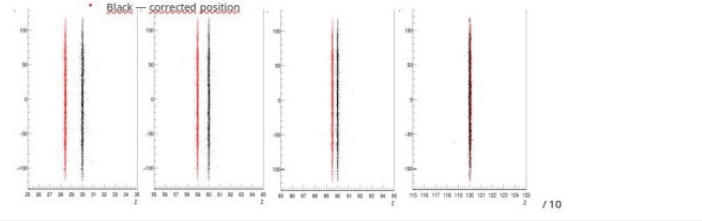
MPD

Bychkov A.

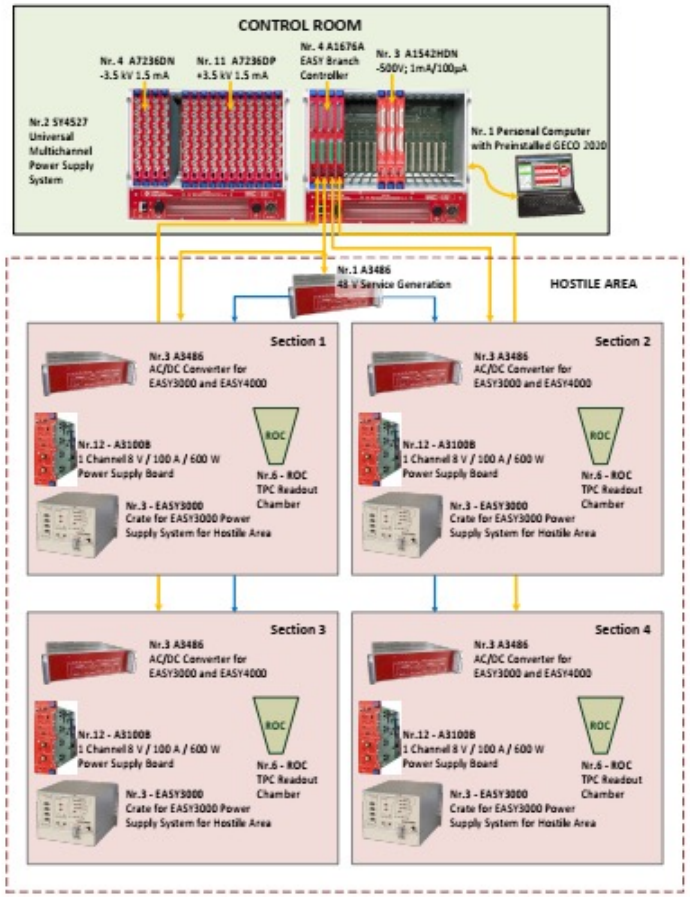
Test for drift velocity correction

- Source data
  - True drift velocity = 5.5 cm/μs
  - Simulated drift velocity = 5.4 cm/μs
  - Test on laser grid itself
    - Red — measured position
    - Black — corrected position





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:

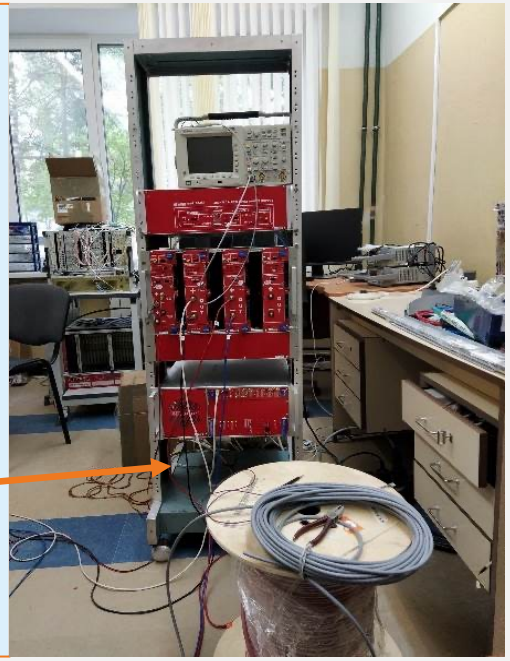
LV+HV system: JINR-CAEN contract was signed

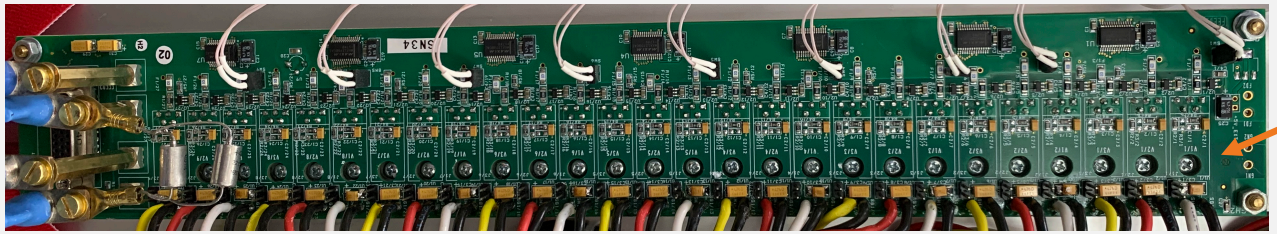
Expected delivery date to JINR: August 2023

test system: testing is ongoing

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

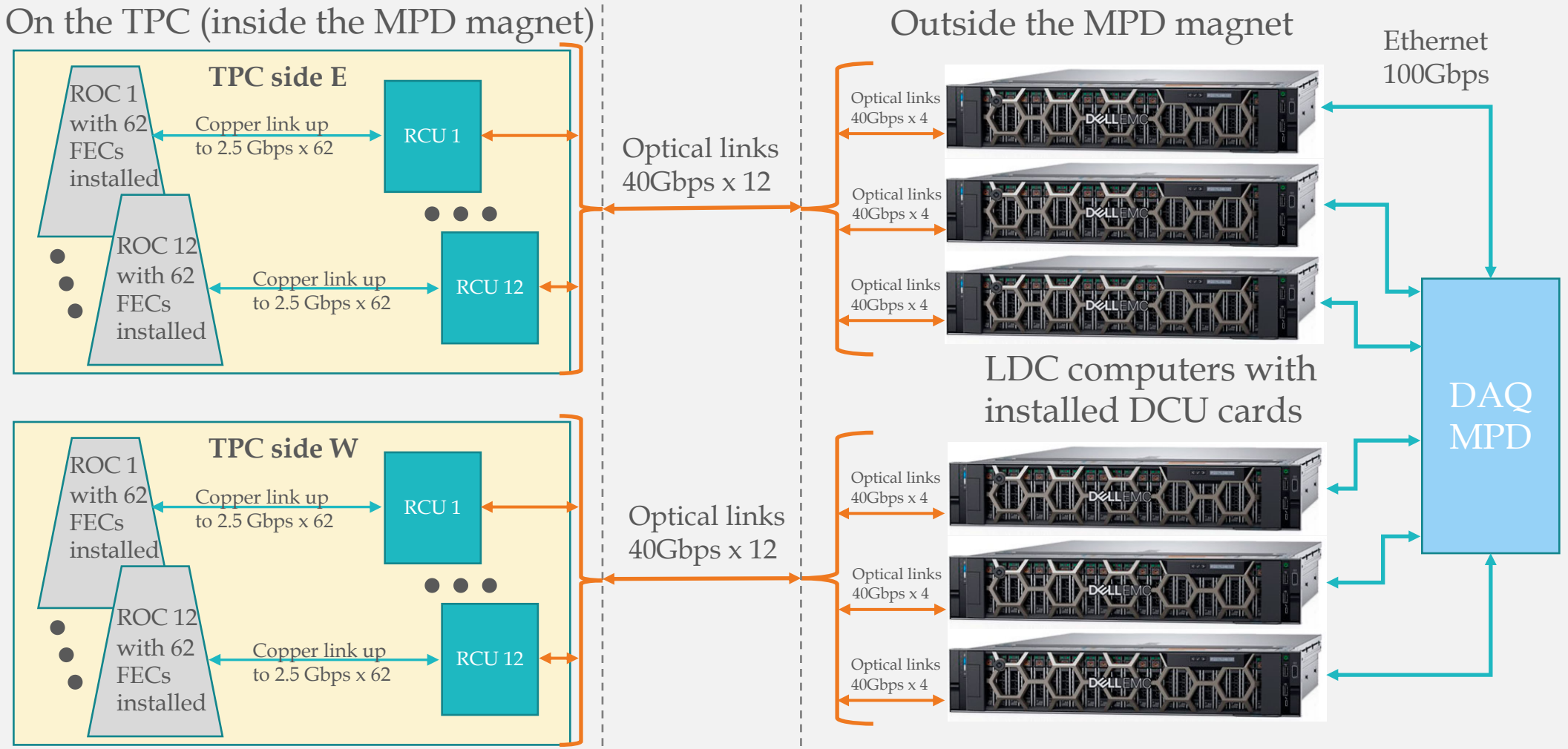
HV cables: was ordered





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

TPC data acquisition system (DAQ)



DAQ main parts:

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

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

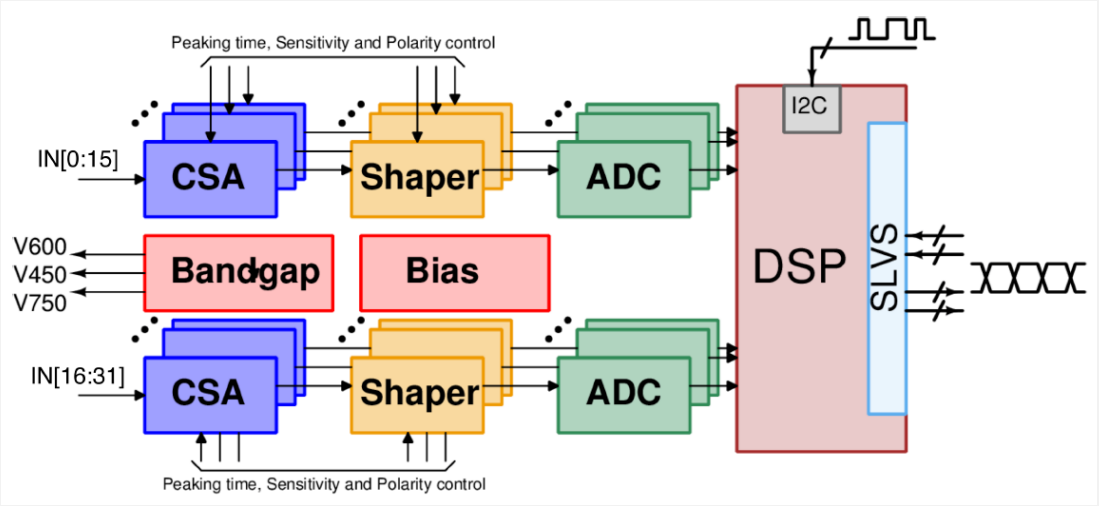
Data Concentrator Units (DCU): 6 pc. in total

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

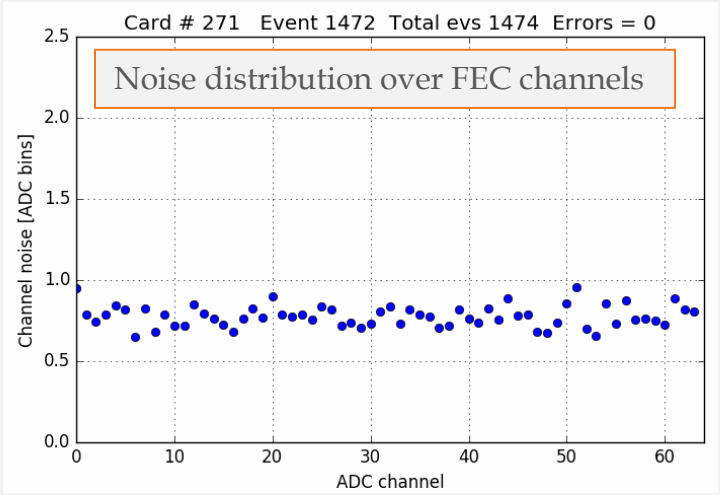
Front-End Electronics

- 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

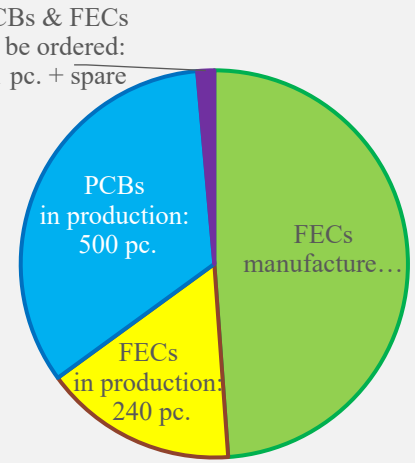
FECs with cooling radiators



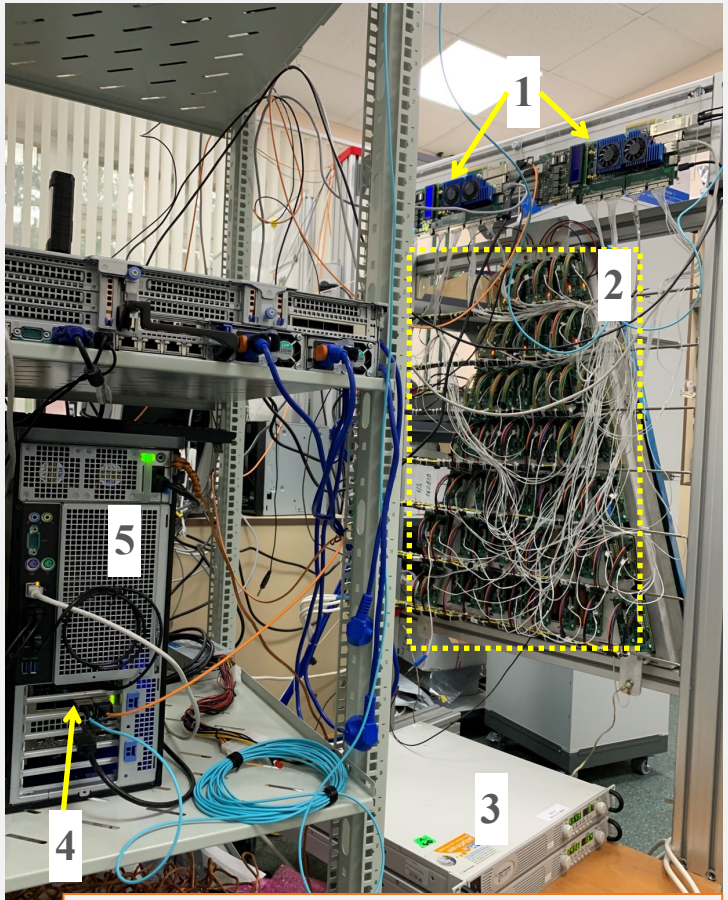
[1] J. Adolfsson, et al., SAMPA chip: the new 32 channels ASIC for the ALICE TPC and MCH upgrades, JINST 12 (04) (2017) C04008.



FECs production status:

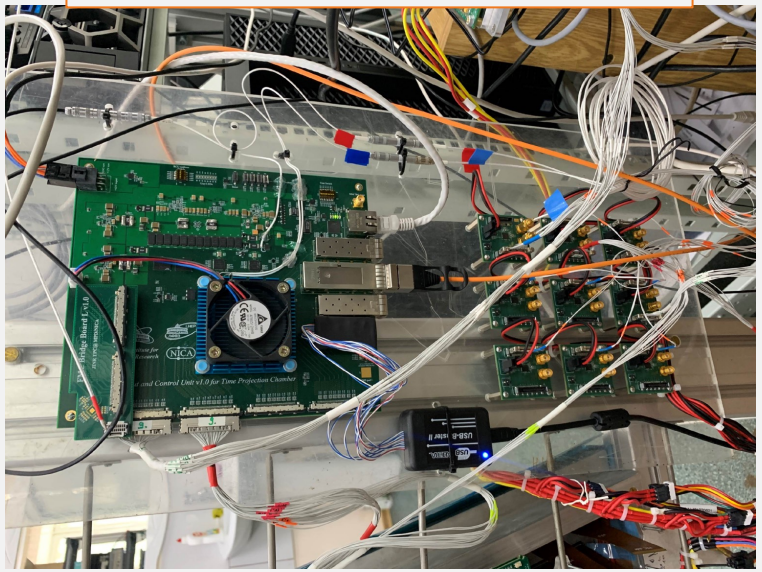


ReadOut Chamber DAQ test setup

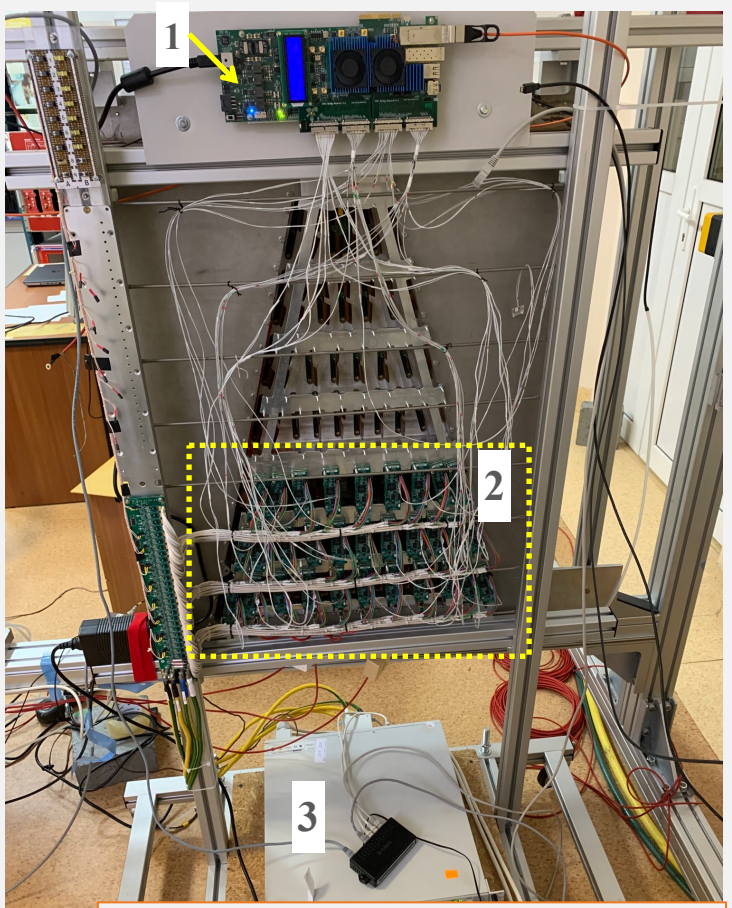


Test setup at building 201, VBLHEP

RCU-64 controller testing with FEE



1. RCU prototypes
2. FECs on the ROC (62 pc. left and 31 pc. right)
3. LV power supply
4. DCU card connected with RCUs via fibers
5. Readout server

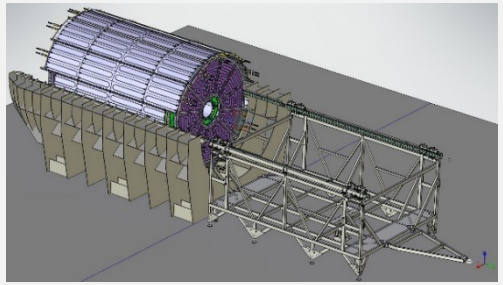


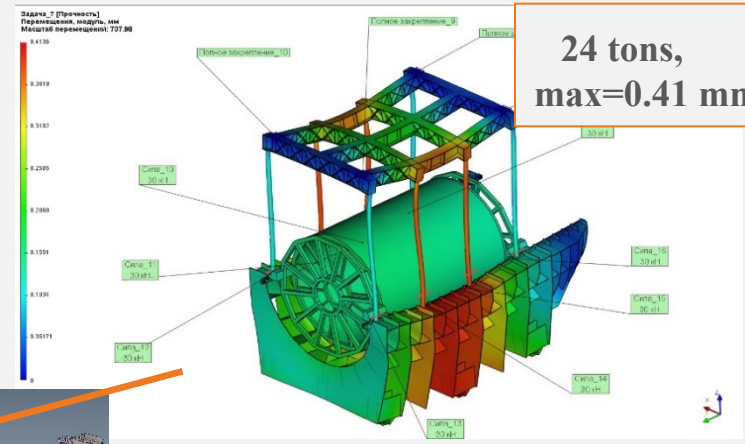
Test setup at building 40, VBLHEP

Tooling for installation TPC to MPD

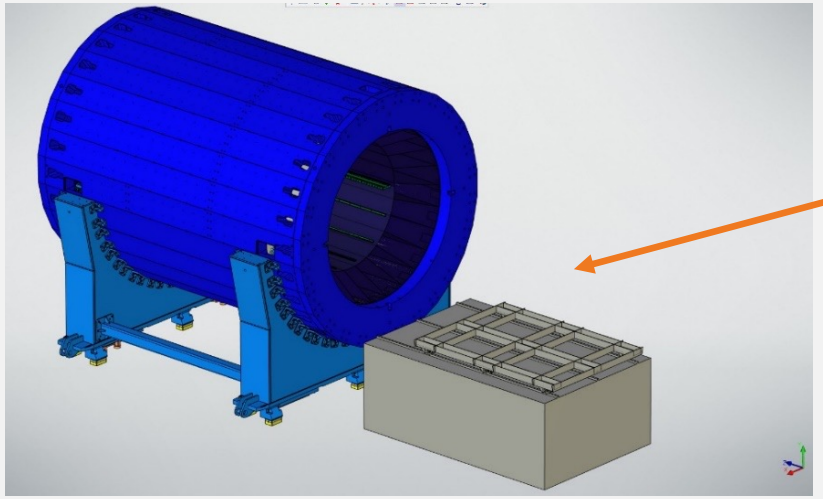
Bld. 217

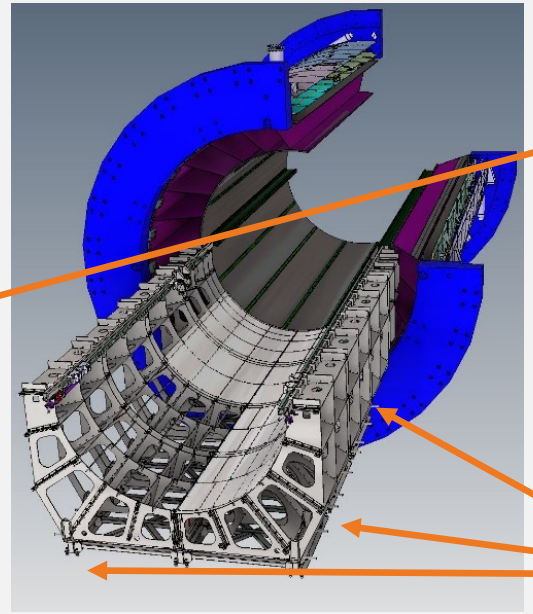
MPD building

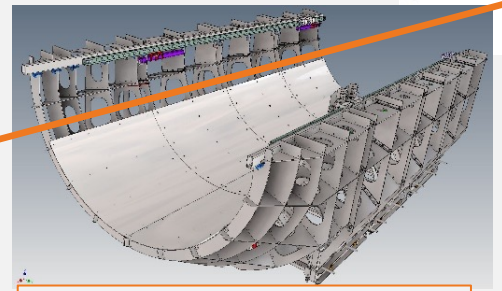




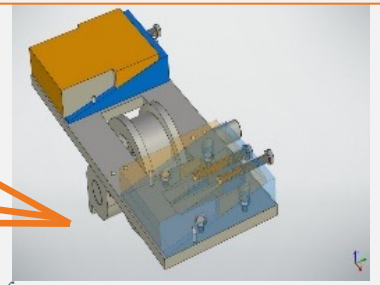
24 tons,
max=0.41 mm







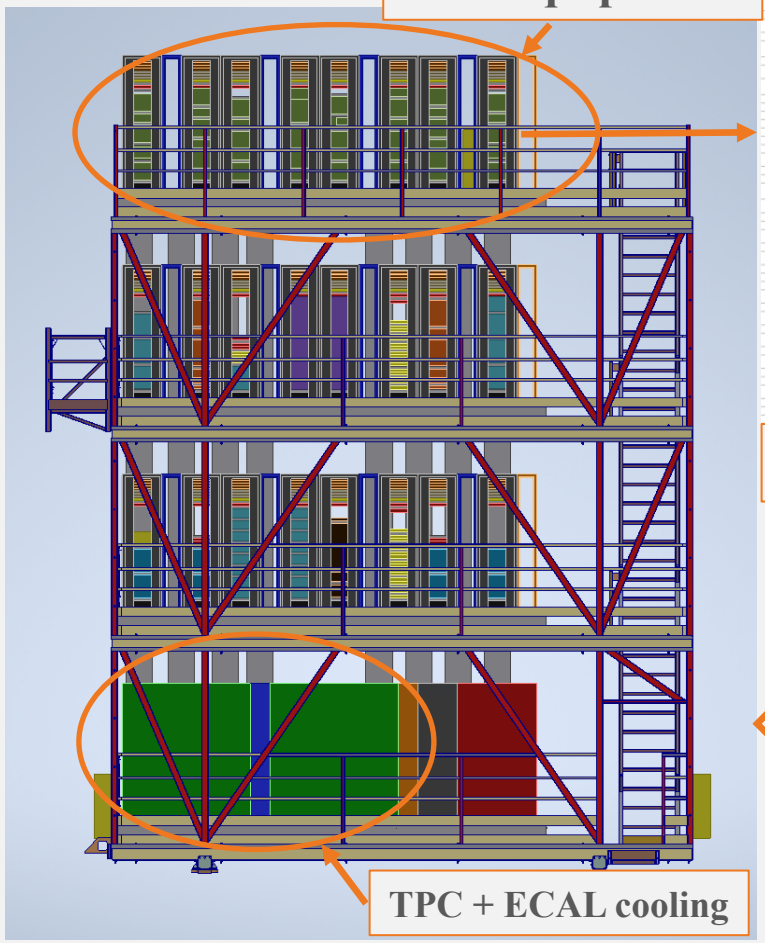
4 units for adjustment X, Y, Z



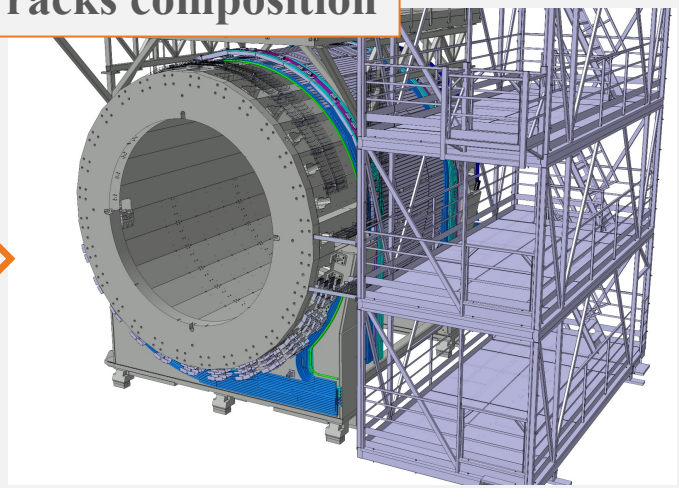
Design under optimization,
Prototype 1:5:
June 2023

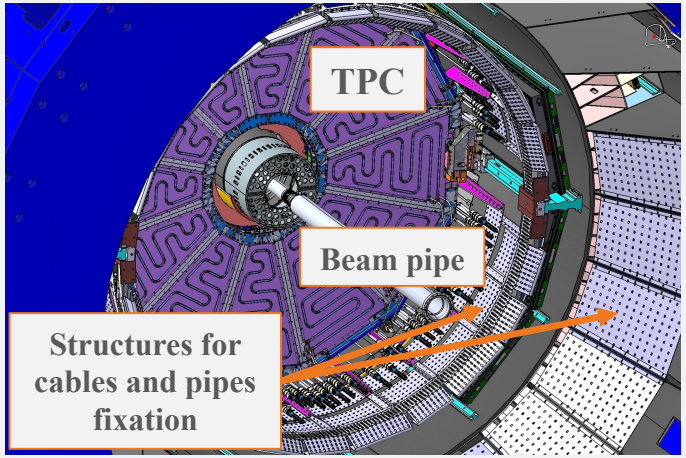
Tooling manufacture –
July 2023-Feb 2024
Delivery to JINR –
Spring 2024

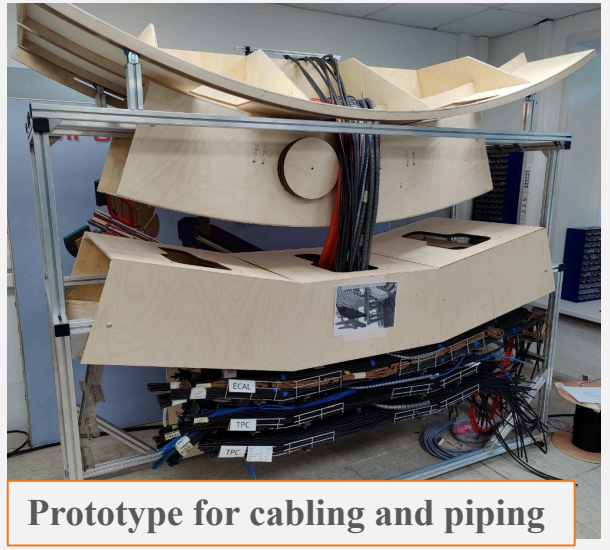
TPC engineering infrastructure



MPD platform







Time schedule

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

Thank you for your attention!