Time-Projection-Chamber for MPD NICA Project

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On behalf of the TPC team:

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TPC/MPD Collaboration

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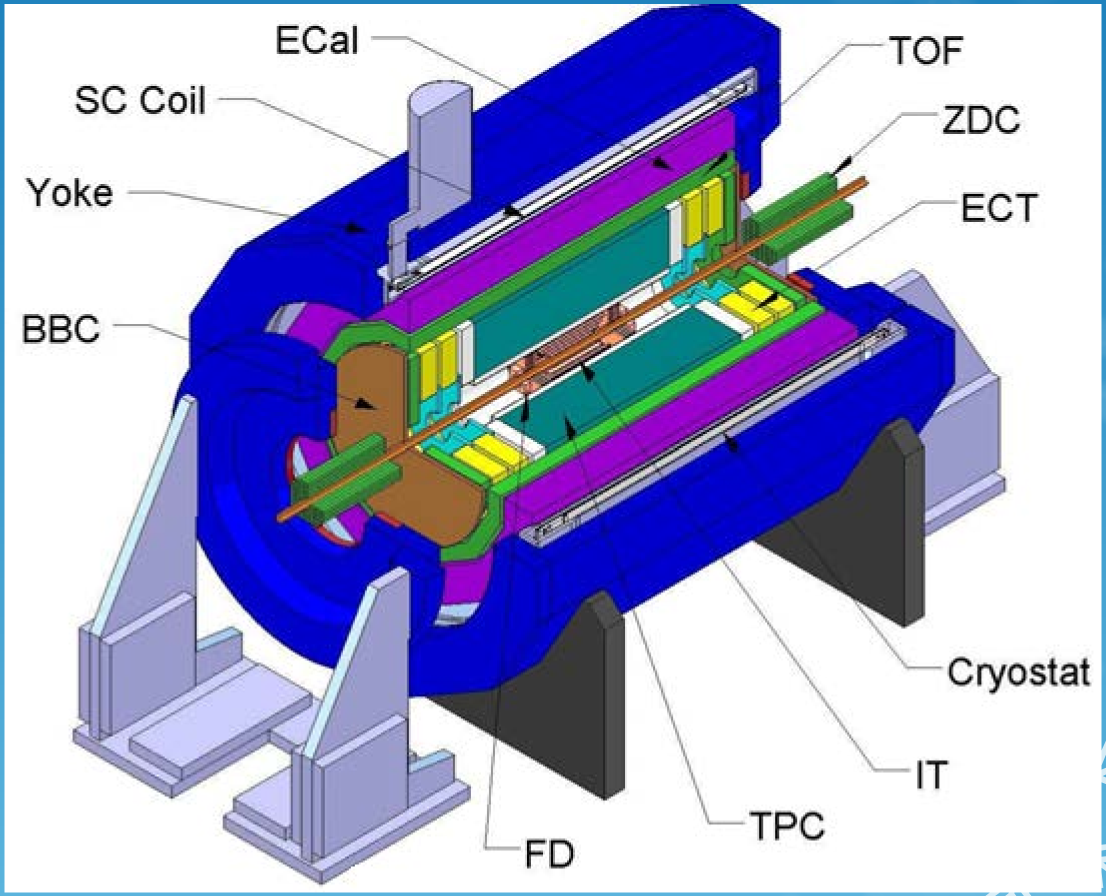
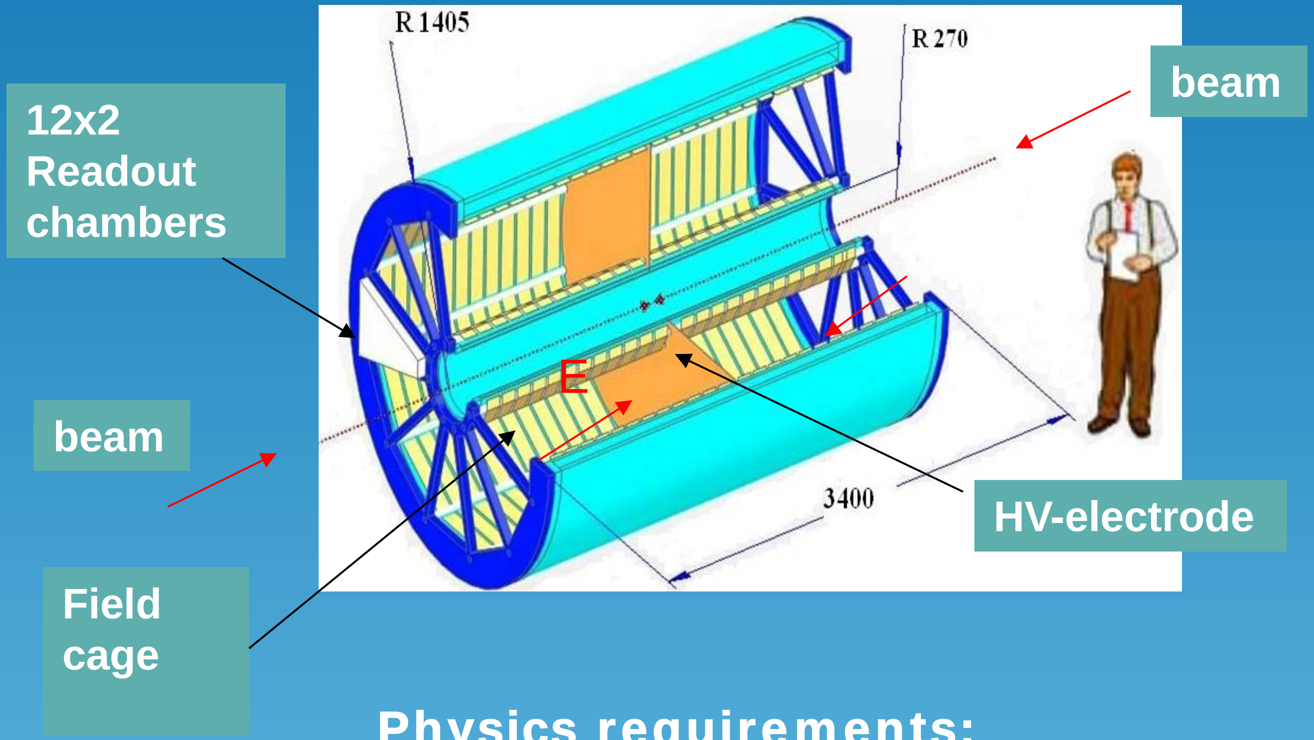
General view of the MultiPurpose Detector (MPD) NICA project

- SC Coil - superconductor solenoid
- IT - inner detector
- ECT - straw-tube tracker
- TPC - time-projection chamber
- TOF - time-of-flight stop counters
- FD - The fast forward detectors
- ZDC - zero degree calorimeter
- BBC - beam-beam counter



TPC design overview



Physics requirements:

The overall acceptance on |η|~ 1.2
The momentum resolution ~ 3% in p_t interval from 0.1 to 1 GeV/c
Two-track resolution ~ 1 cm.
Charged particle multiplicity ~ 1000 in a central collisions
Hadron and lepton identification by dE/dx measurements with resolution better than 8%

Main parameters of the TPC

Length of the TPC	**340 cm**
Outer radius of cylinder	**140 cm**
Inner radius of cylinder	**27 cm**
Length of the drift volume	**170cm (of each half)**
Magnetic field strength	**0.5 Tesla**
Drift gas	**90% Ar+10% CH_4**
Temperature stability	**0.5°C**
Gas amplification factor	**~ 10^4**
Number of readout chambers	**24 (12 per end plate)**
Pad size	**$5x12mm^2$ and $5x18mm^2$**
Number of pads	**95 232**
Pad raw numbers	**53**
Maximal trigger rate	**~5 kHz**
dE / dx	**better than 8 %**
$\Delta p/p$	**~ 3 % in $0.1 < p_t < 1$ GeV / c**

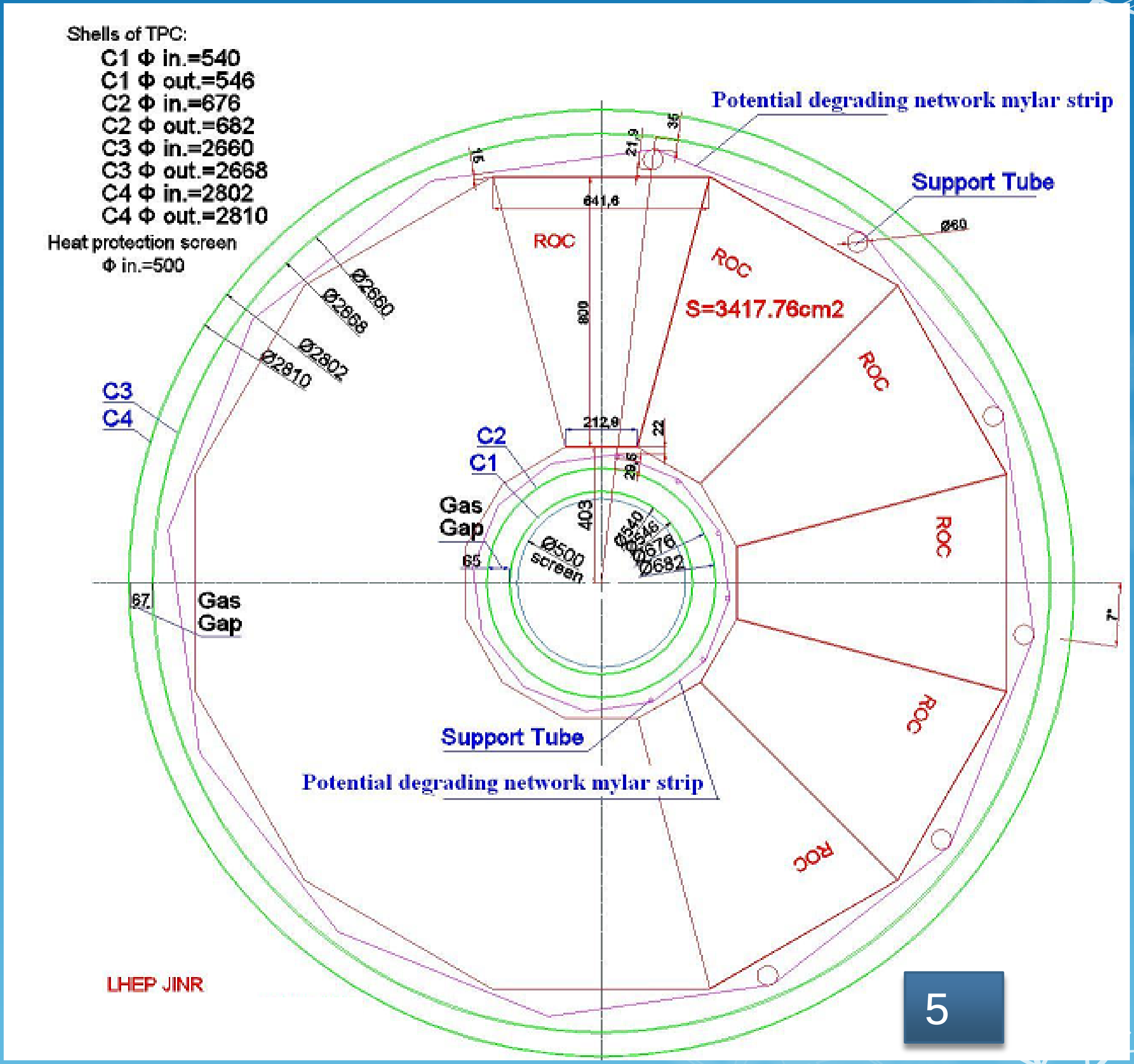
The front view of the TPC

Four cylinders (green circles: C1 - C4) are required to make the complete field-cage structure.

All four TPC cylinders are under construction in Russian Industry as monolithic Kevlar composite constructions. Kevlar thickness is 4 mm.

Such an approach allows one to minimize problems with gluing of field cage parts and fragments.

Moreover, we suppose to mount field cages, central electrode and end plates as independent precisely adjusted constructions which will be inserted between Kevlar cylinders and fixed together mechanically and with epoxy.

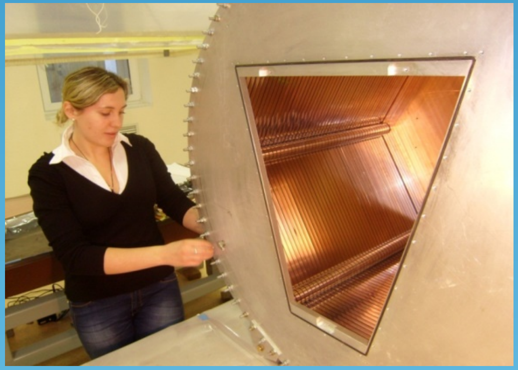


Construction of TPC cylinders

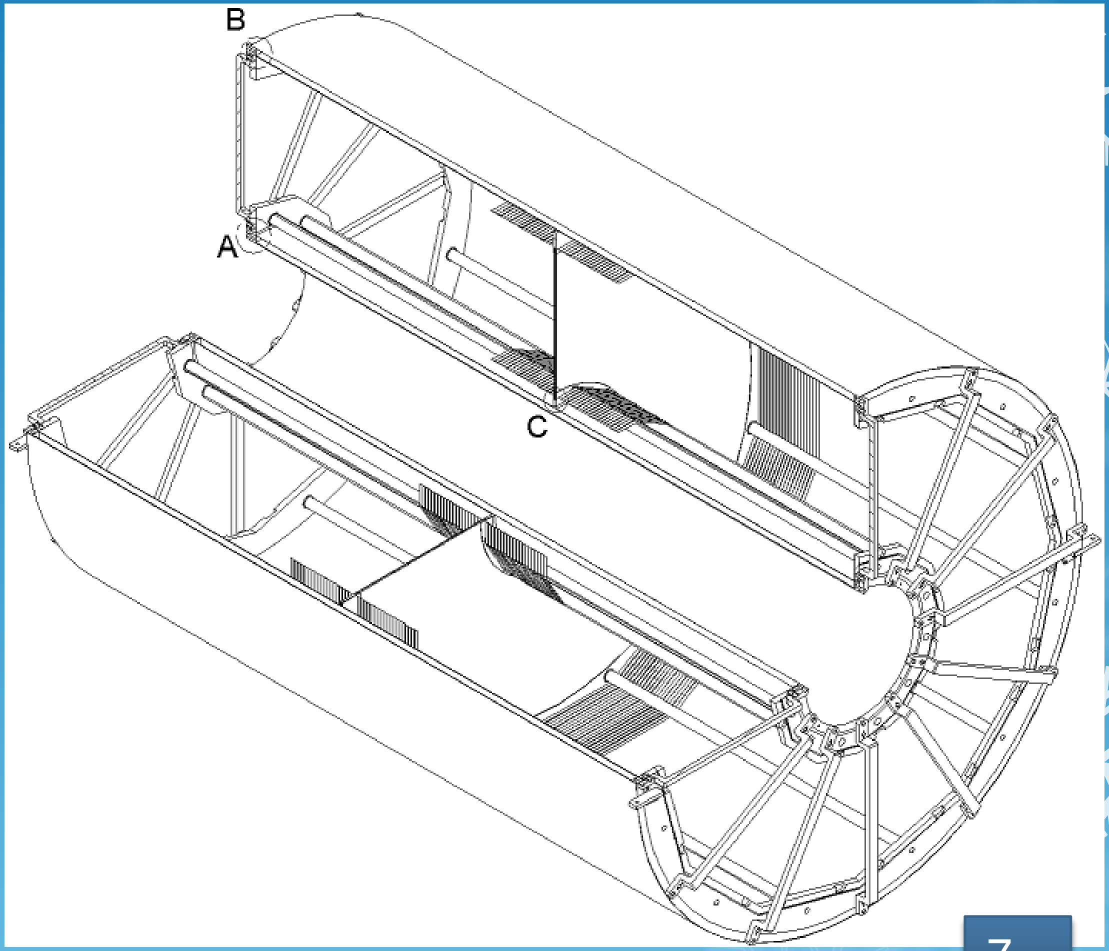
- Material : Kevlar
- Thickness: 4 mm
- Length: 3.4 m
- Diameter: 2.8 m
- Deformation in operational position is less than 100 mkm

Field cage and central cathode plane

TPC prototype field cage

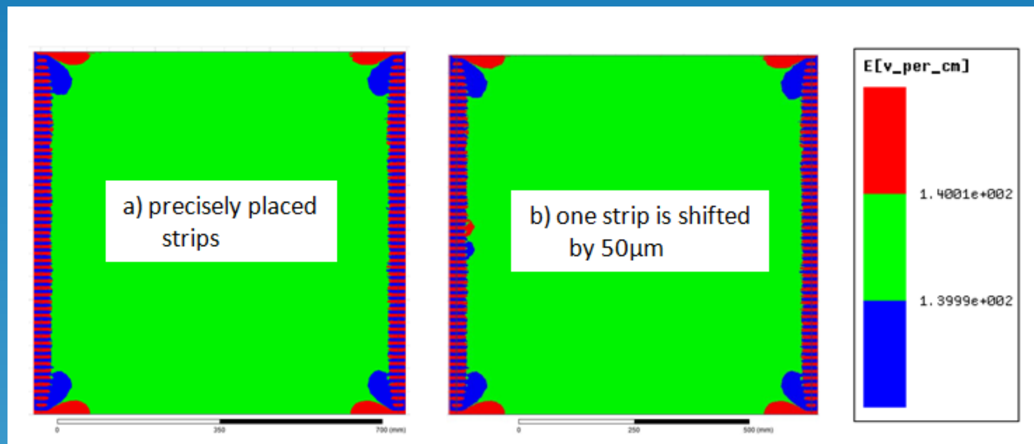


TPC prototype under constraction



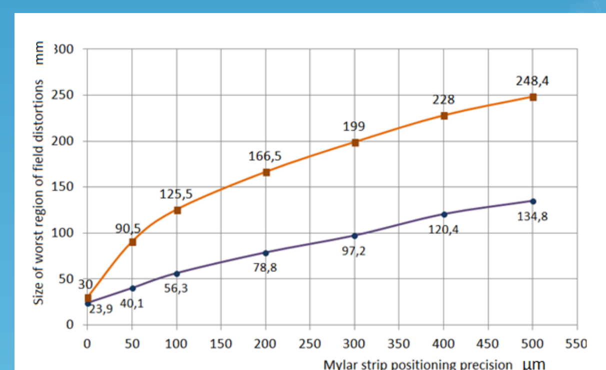
Field cage

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



The field distortions in the drift volume defined by mylar strip system a) precisely placed strips b) one strip is shifted by 50µm

The distortions are down to 10^{-4} at ~23mm from the strip surface inward drift space. The positioning precision of the strips into nominal place has to be not worst than 50µm.

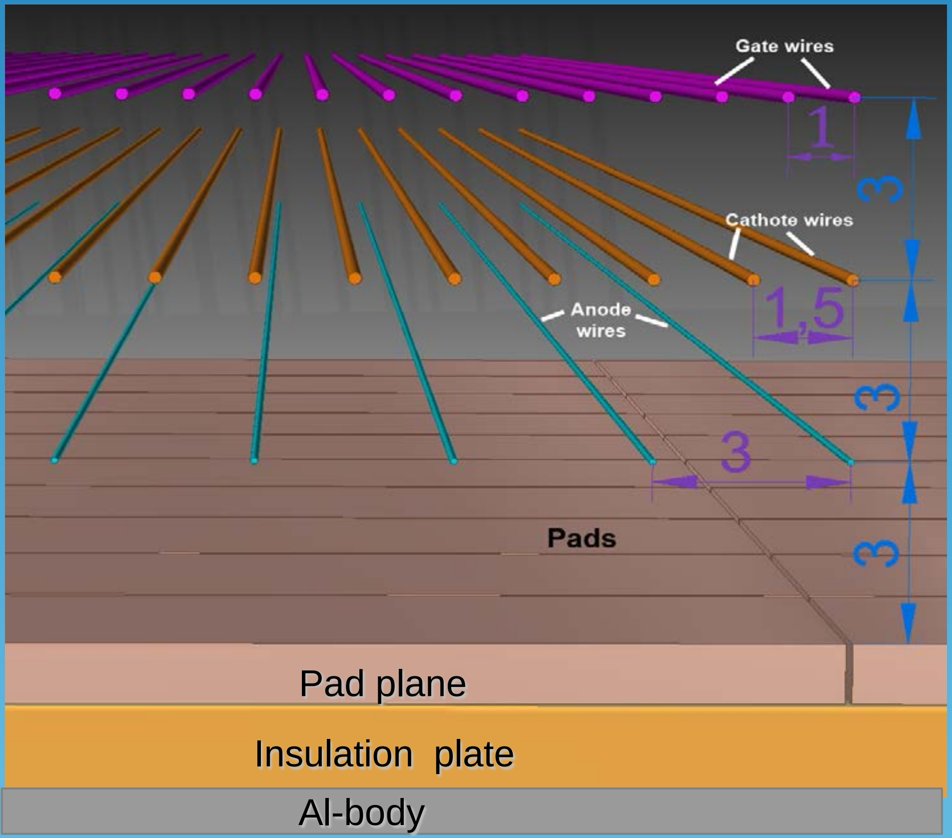


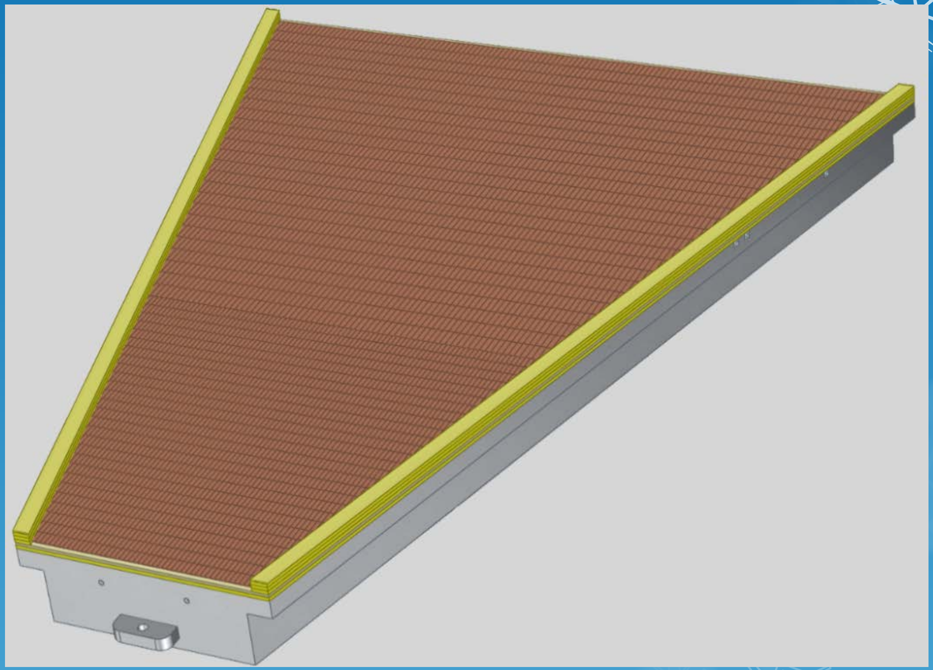
✔Along the line parallel the strip surface(orange line)
✔Inward the drift space (violet line)

The dependence of the size of the worst region with the field distortion more than 10^{-4}

Readout chamber

Structure of readout chamber:
- three wire planes
- pad plane
- insulation plate
- trapezoidal aluminum frame





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

Wires structure
- anode wire pitch 3 mm
- cathode wire pitch 1,5 mm
- gate wire pitch 1 mm
- wires gap 3 mm

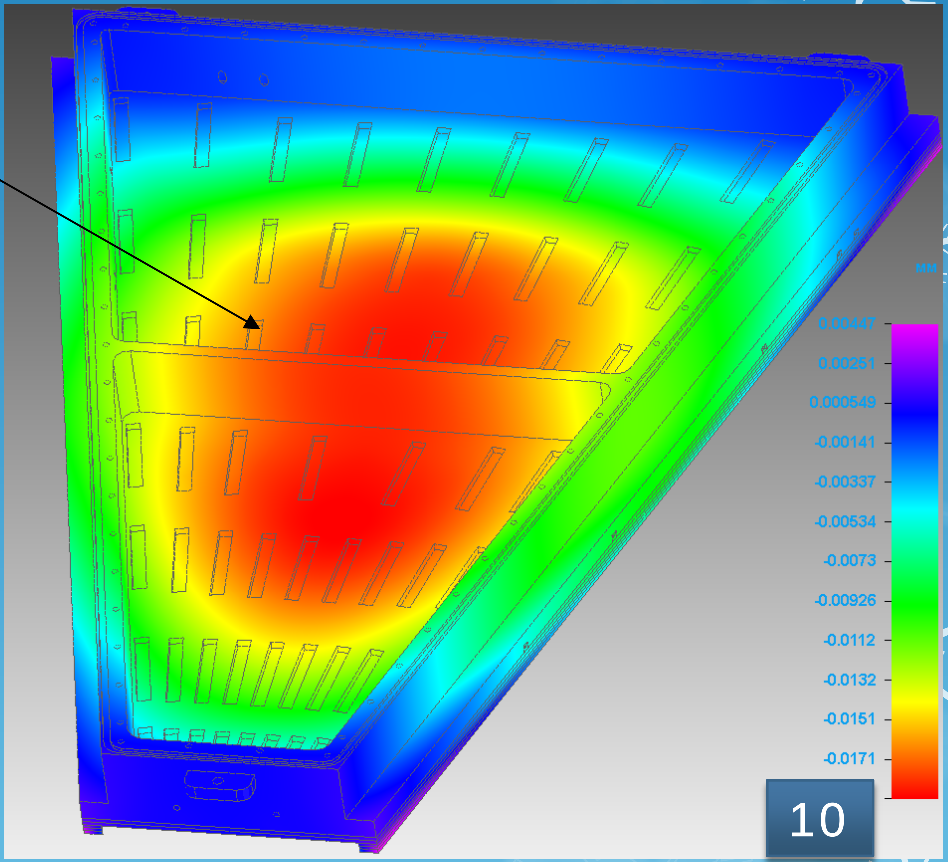
TPC readout chamber: Al body

- The aluminum frame provides the overall mechanical stability of the readout chamber. Its stability against deformation caused by wire stretching has to provide as minimal as possible overall deformation less than the expected wire sag caused by electrostatic forces.

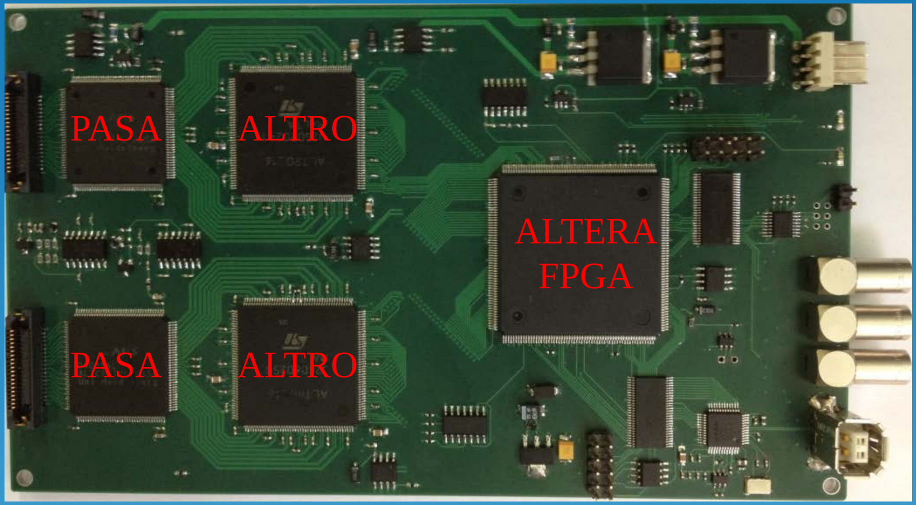
- The frame is reinforced by stiffening rib

- The deformations do not exceed 27 mkm at the total wire tension ~ 800 N and over pressure inside TPC up to 5 mBar

Finite element calculation of the deformation of the readout chamber caused by the wire tension and over pressure inside TPC

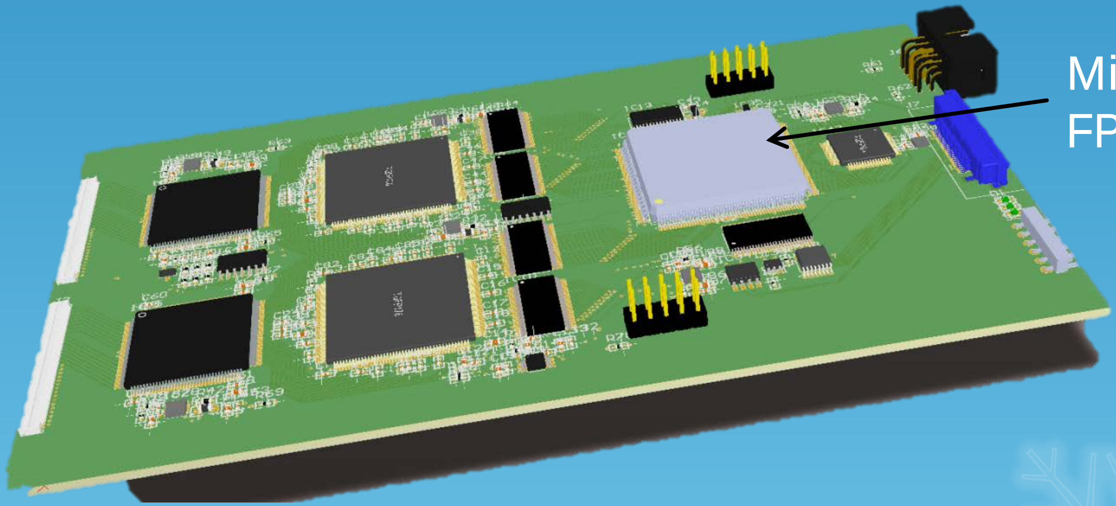


Front-End Electronics



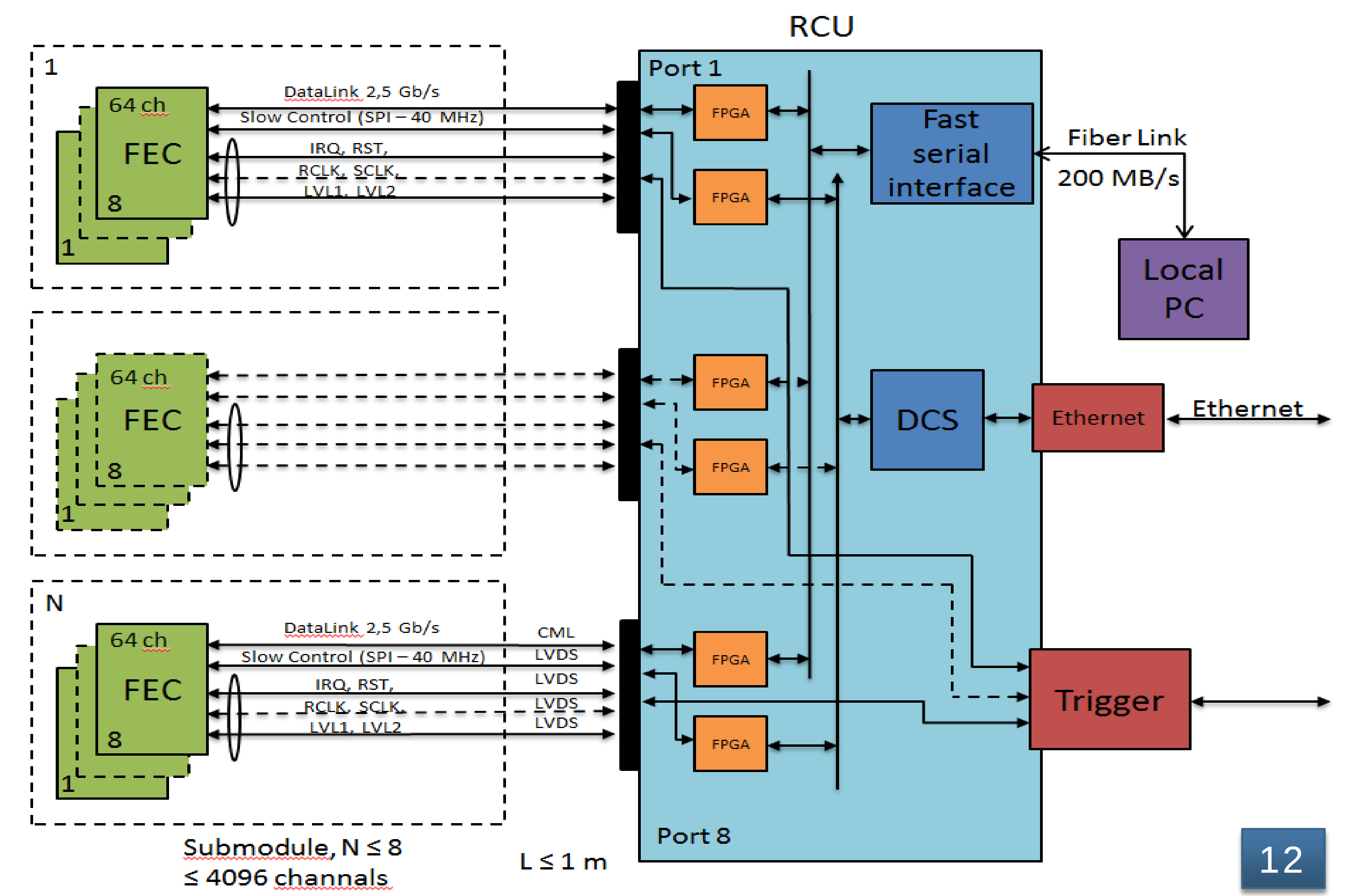
Front-End Electronics prototype (USB2.0)

- Signal to noise ratio, S/N - 30
- σ_{NOISE} < 1000e^{-} (C=10-20 pF)
- Dynamic Range - 1000
- Zero suppression
- Buffer (4 / 8 events)

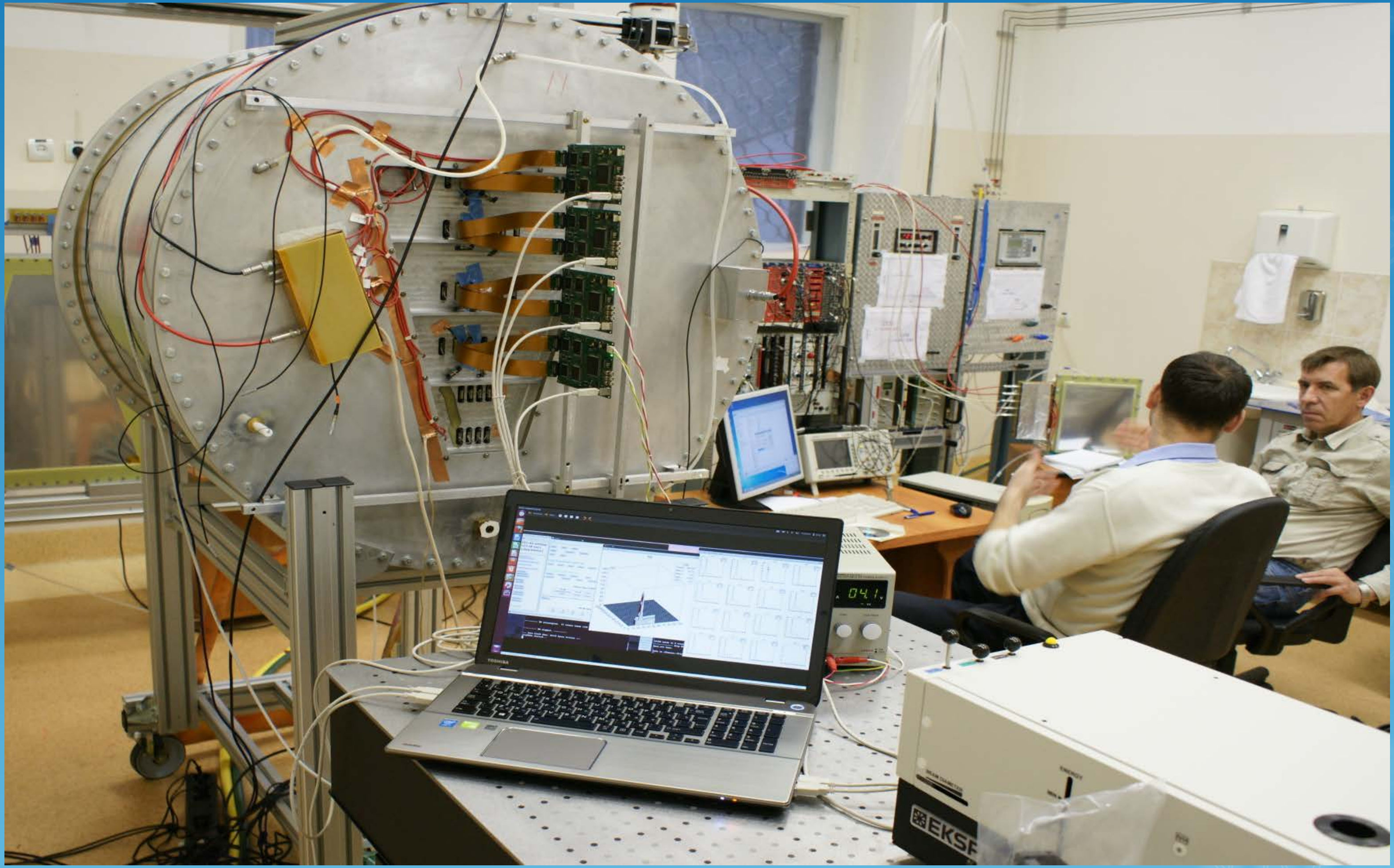


3d-model of the new Front-End Electronics

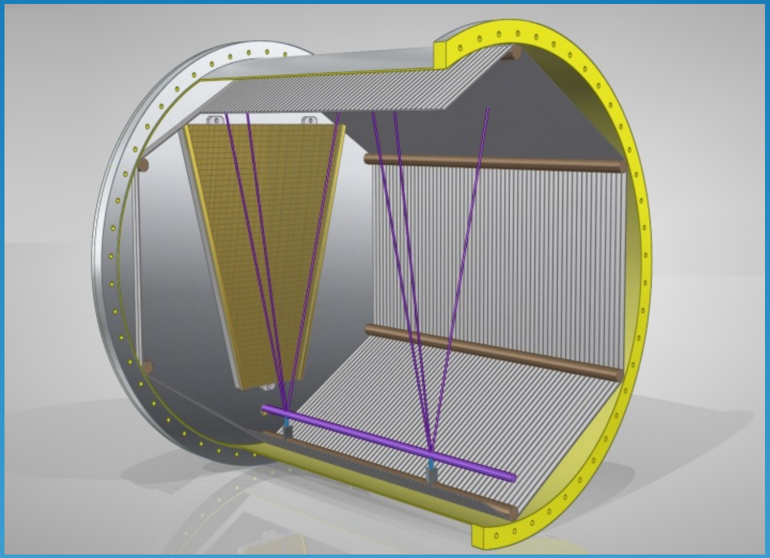
Block diagram of FEE base



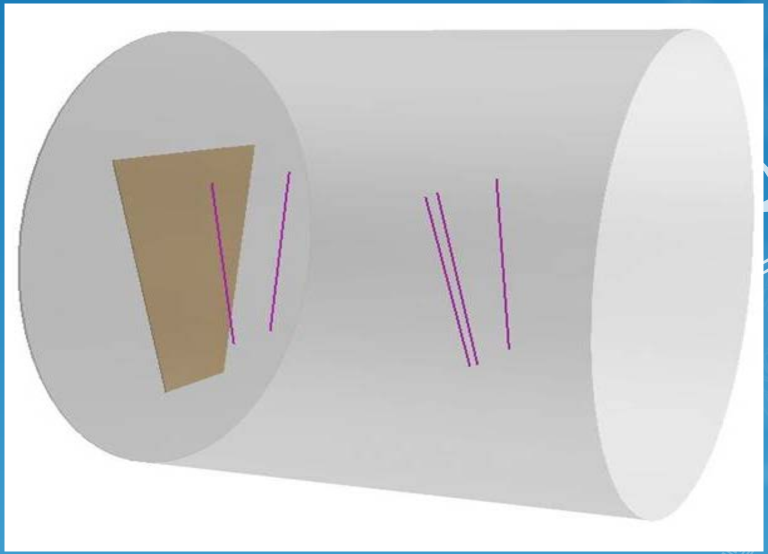
FEE Testing



TPC testing



General view of the laser beams inside TPC.

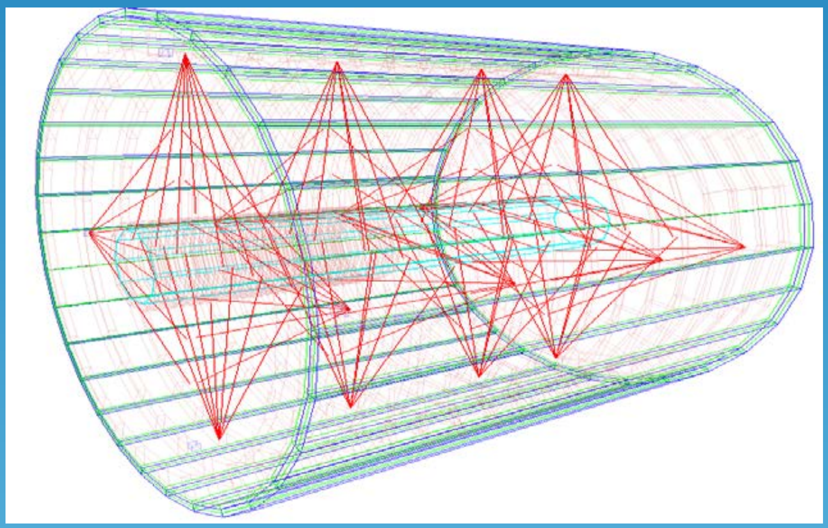


UV laser tracks reconstructed in Prototype 1.

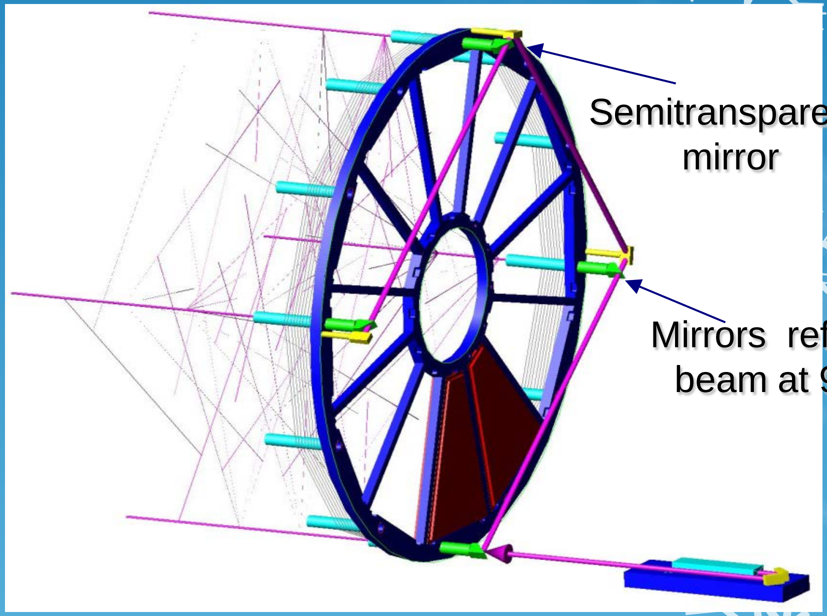
Prototype 1 under preparing to test with UV laser.

TPC Laser Calibration System

In order to minimize the error in the absolute position measurement by TPC, it is necessary to take into account both static and time-dependent distortions in the drift path of the ionization cloud. A calibration system that can reproduce fiducial tracks is needed to monitor the TPC performance. This calibration system will be based on the UV laser.



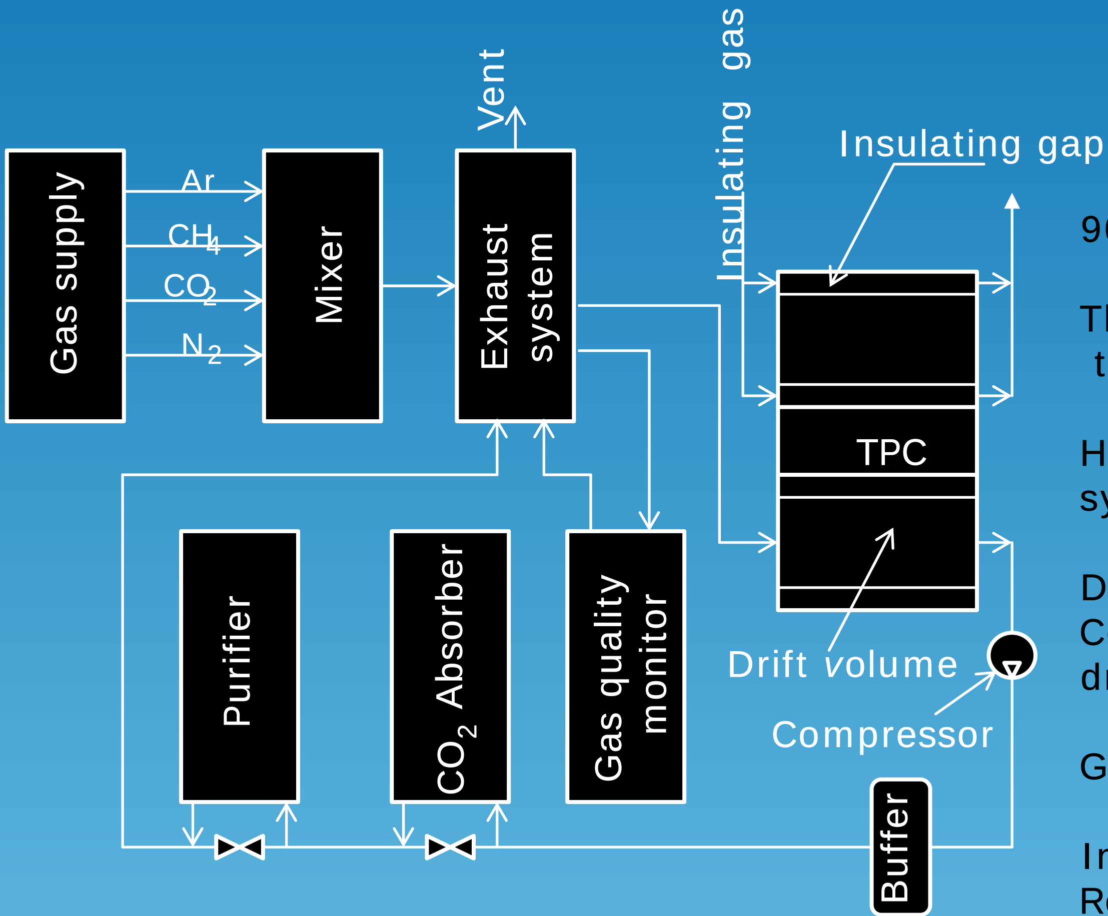
There are 224 laser beams whole TPCin



Laser *NL313-10*

Scheme of high power laser beam splitting into 112 “tracks” of 1 mm diameter.

TPC gas system



Schematic view of the TPC gas system structure

Requirements

90%Ar+10%CH_4

The drift volume is 18500 liters, the insulating gaps – 4800 liters

Hermetically closed-loop gas circulation system

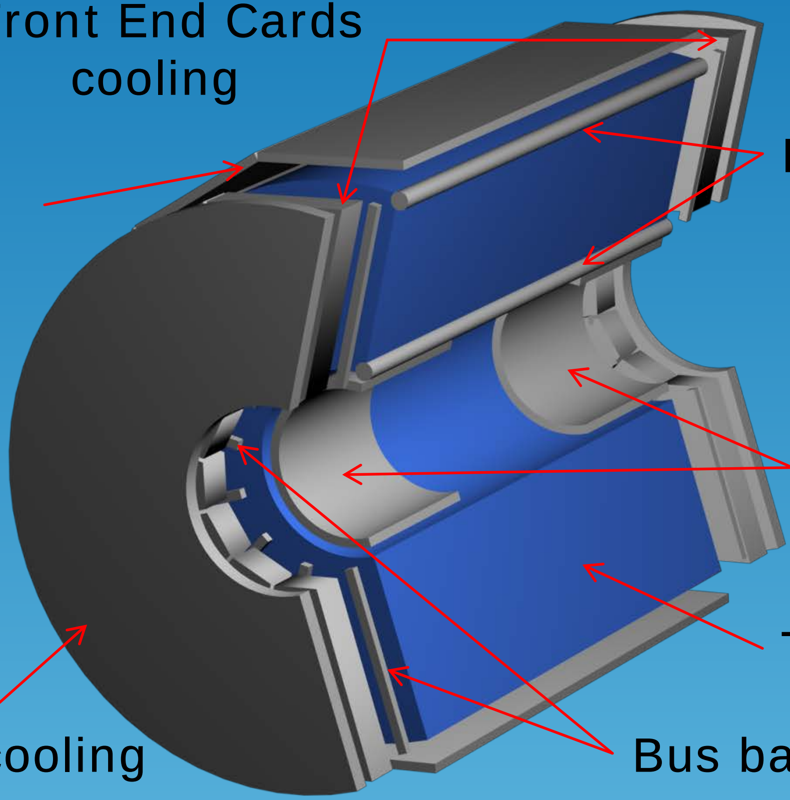
Dryer and purification in return line
Continuous monitoring of gas gain and drift velocity – gas chromatograph

Gas mixture temperature control - 0.5 K

Internal TPC pressure – 2 mbar
Recirculation flow - 3.8 m^3/h

TPC Cooling Scheme

Preliminary estimation



FEE/ROC dissipation < 400 W
Resistor rods 2 x 8 W
Bus bar < 500 W

TPC cooling system

Flow rate:
- FEEC: 24 x 1m³/h
- ROC Covers: 24 x 0.2 m³/h
- Thermal screen: 24 x 0.5 m³/h

Total flow: **40 m³/h**

Total heat to be removed: up to **10kW**

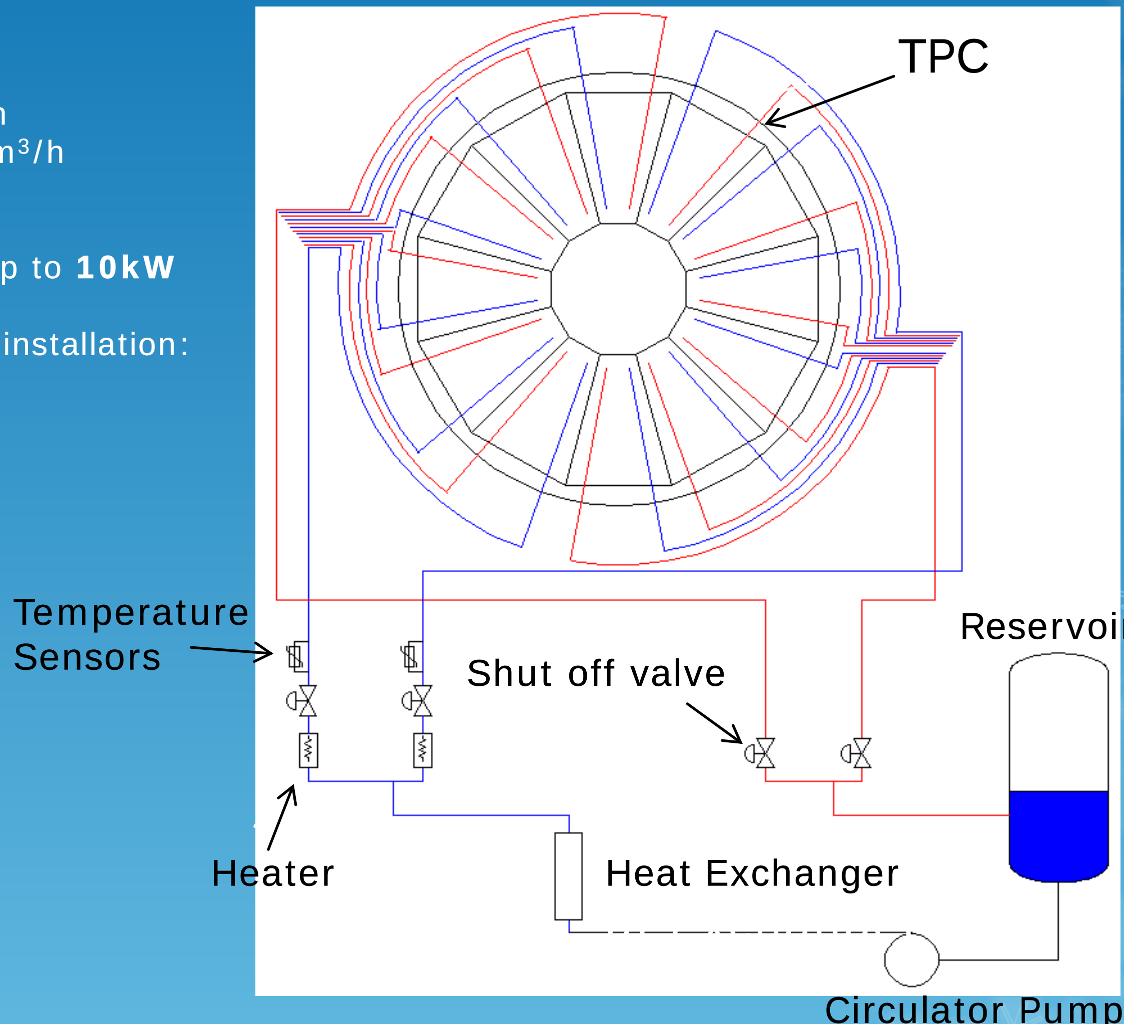
Total Volume of water in the installation: **600L**

Installed Electrical Power:
- Pump: 11kVA
- Heaters: 26kVA

Total Power: **37kVA**

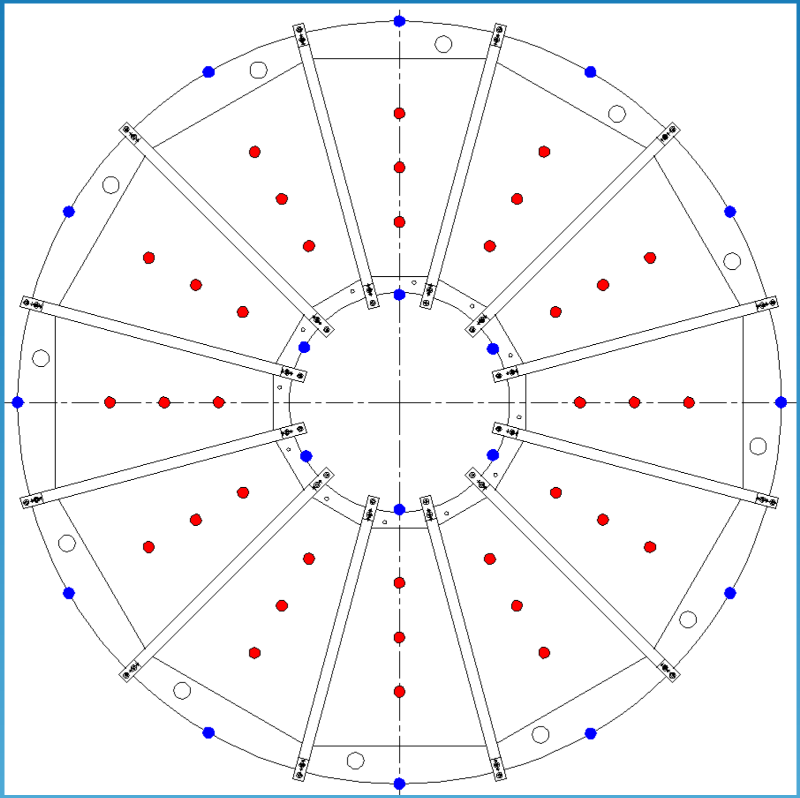
Number of Circuits:
- FEEC: 12+12
- ROC Covers: 2+2
- Therm screen: 12+6
- Resistor rods: 2+4

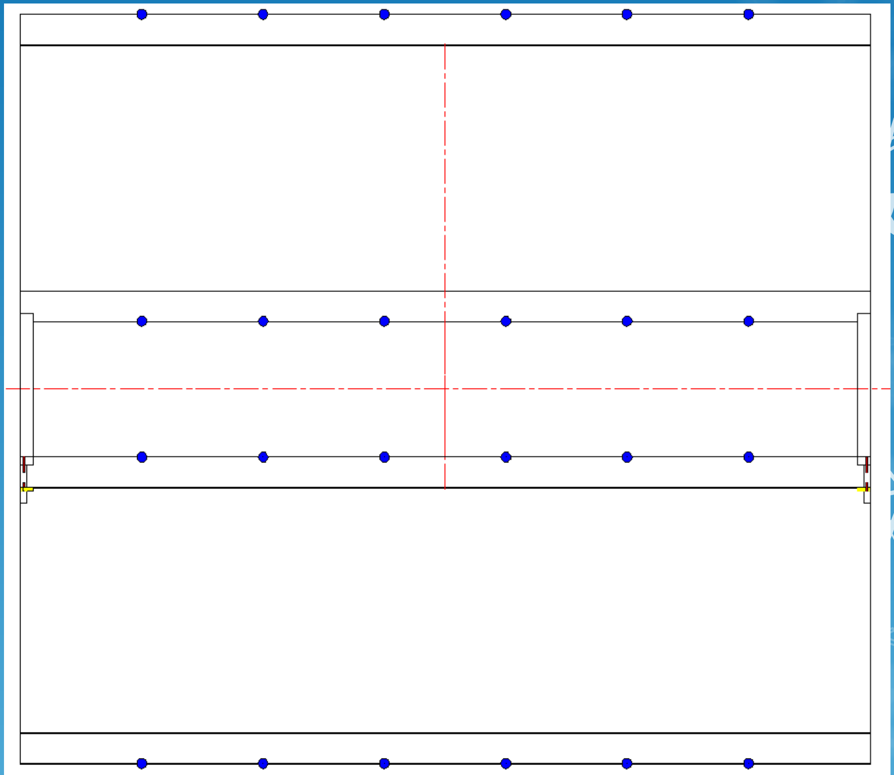
Total: 52



pressure in cooling loops is kept below atmospheric pressure

Temperature Monitoring





Sensors: **blue** – on the field cage, **red** on the chambers

Location	Outer Field cage	Inner Field cage	ROC modules
Number of the sensors	72	36	72

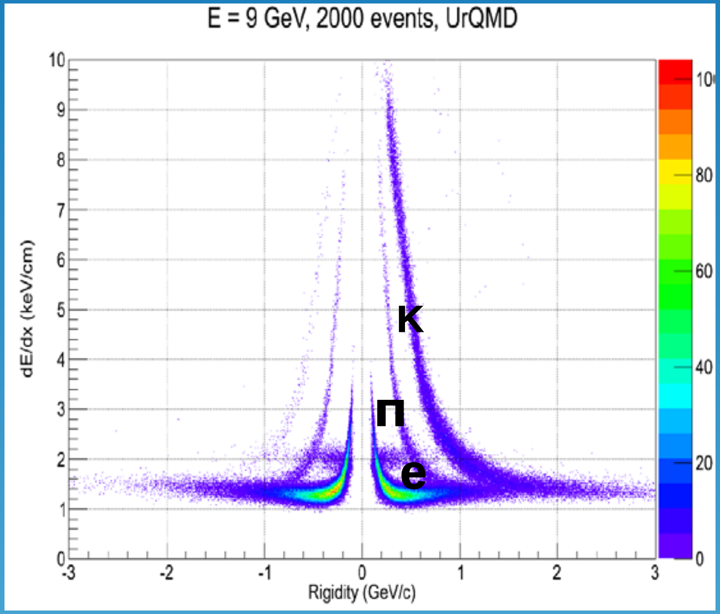
Conclusion

- ✓ Design of main parts of TPC are performed.
- ✓ Three of fours TPC cylinders are constructed.
- ✓ Technological Prototype TPC was designed, constructed and tested with laser beam and cosmic.
- ✓ Readout Chamber (RoC) is designed and full size prototype is under construction.
- ✓ The prototypes of FEE are constructed and tested.
- ✓ Software is under developing.
- ✓ Laser calibration system is designed.
- ✓ Gas and Cooling systems are under designing.

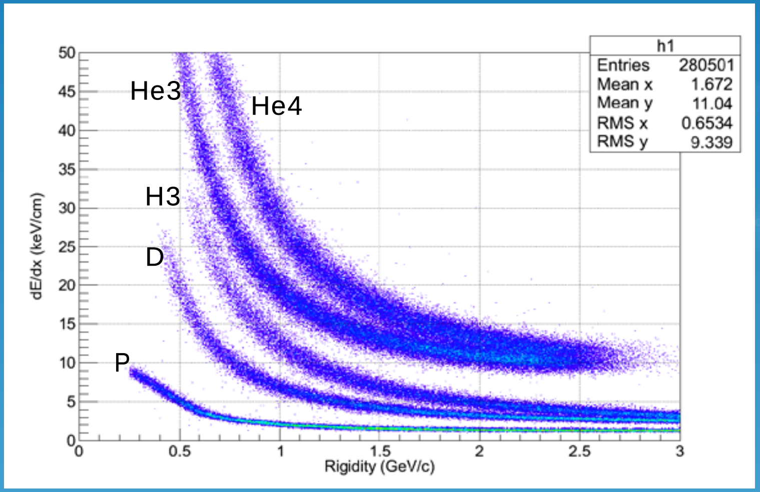
Thank you for attention!

and welcome to collaboration.

ENERGY LOSS



The energy loss distribution in the MPD TPC



TPC FEE input full scale amplifier ~ 200 fC
It is ~ 30-40 MIP energy loss

PID: Ionization loss (dE/dx)
Separation:
e/h – 1.3..3 GeV/c
π/K – 0.1..0.6 GeV/c
K/p – 0.1..1.2 GeV/c

QGSM Au+Au central collision
9 GeV, b=1fm

Main parameters of the TPCs

Dimension	STAR TPC	ALICE TPC	MPD TPC
Length of the TPC	420 cm	500 cm	400 cm
Outer Diameter of Vessel	400 cm	500 cm	280 cm
Inner Diameter of Vessel	100 cm	170 cm	54 cm
Cathode Potential	28 kV	100 kV	28 kV
Drift Gas	Ar + CH_4 (90:10)	Ne + CO_2 + N_2 [85.7 : 9.5 : 4.8]	Ar + CH_4 (90:10)
Drift Velocity	5.45 cm/μs	2.65 cm/μs	5.45 cm/μs
Number of Readout Sectors	12×2 = 24	2×2×18 = 72	12×2 = 24
Number of Pads	136 608	557 568	95 232
Pad Rows	13 – inner subsector 32 – outer subsector	32 – inner chamber 64 – outer chamber	53
Pad Size	2.85×11.5 mm^2 – inner subsector 6.2×19.5 mm^2 - outer subsector	6×10 and 6×15 mm^2	5×12 mm^2 and 5×18 mm^2
Magnetic Field	0.25 T, 0.5 T	0.5 T	0.5 T
Electronics	ALTRO based	ALTRO based	ALTRO based
dE/dx resolution	7.0%	5.0%	8.0%

ALICE TPC FEE

FEC in Cu sandwich

6 cables per FEC

128 ch/FEC