15th Vienna Conference on Instrumentation

Time-projection chamber development for Multi-Purpose Detector of NICA project

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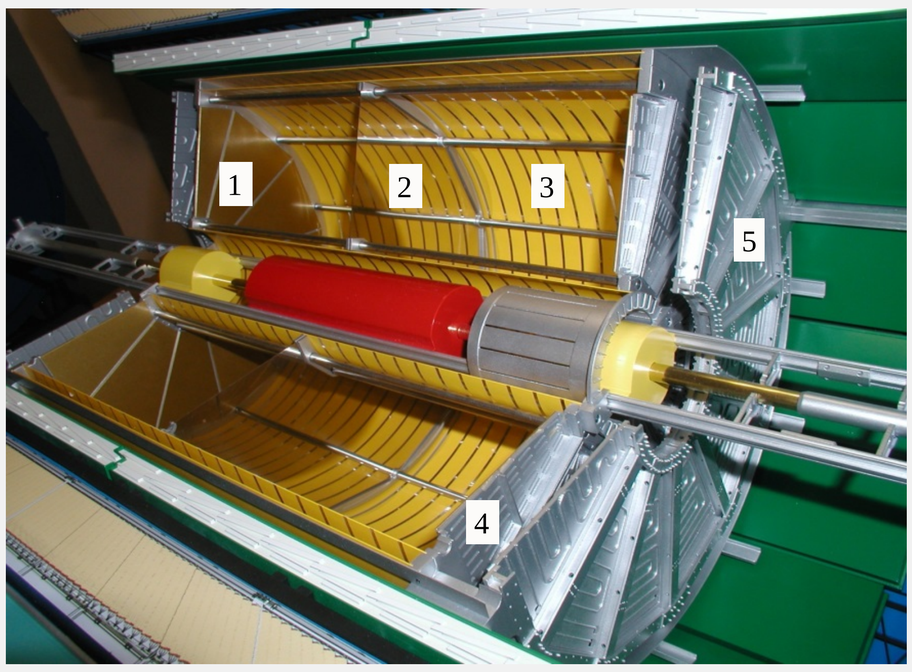
Abstract: Under the JINR scientific program to study of the hot and dense baryonic matter, a new accelerator complex - the Nuclotron-based Ion Collider fAcility (NICA) is under construction. The Multi-Purpose Detector (MPD) will operate at one of the collider interaction points and it is optimized to investigate heavy-ion collisions in the energy range from 4 to 11A GeV.
Time Projection Chamber (TPC) is proposed as the central part of the tracking system of the MPD detector. It is the natural choice for three-dimensional imaging of complex events in heavy-ion experiments. Together with the time of flight and inner tracker detectors, the TPC detector provides tracking, pattern recognition, vertex reconstruction and charged-particle identification. The TPC has a cylindrical body with a diameter of 2.8 m and length of 3.4 m and is placed in the magnet with solenoidal field of 0.5 T. The sensitive volume contains 17.6 m³ of argon-methane mixture. The detector will register charged products of heavy ion collisions and provide registering events with a trigger rate up to 7 kHz.
The report presents parameters of the TPC and development status of its sub-systems such as: the field cage and high-voltage electrode, readout chambers, laser calibration system, temperature stabilization system, gas system, front-end electronics and others. TPC assembling procedure and infrastructure are presented in the report as well.

The TPC/MPD design requirements:

- The overall acceptance - $\eta < 1.2$
- The momentum resolution for charged particles - under 3% in the transverse momentum range $0.1 < pt < 1$ GeV/c
- Two-track resolution - of about 1 cm
- Hadron and lepton identification by dE/dx measurements - with a resolution better than 8%
- Data flow rate – up to 100 GBps at trigger rate 7 KHz

Central part of the MPD mock up with TPC cut.



1- MWPC; 2 - HV electrode; 3 - Field cage; 4 - FEE position; 5 - End cap thermal screen.

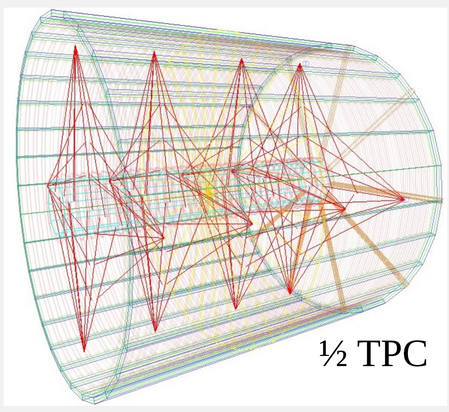
TPC parameters:

Item	Dimension
Length of the TPC	340 cm
Outer radius of vessel	140 cm
Inner radius of vessel	27 cm
Outer radius of the drift volume	133 cm
Inner radius of the drift volume	34 cm
Length of the drift volume	170 cm (of each half)
HV electrode	Membrane at the center of the TPC
Electric field strength	~140 V/cm
Magnetic field strength	0.5 T
Drift gas at atmospheric pres. + 2 mbar	90% Ar + 10% Methane
Gas amplification factor	~ 10^4
Drift velocity	5.45 cm/μs
Drift time	31 μs
Temperature stability	< 0.5°C
Number of end-cap MWPC	24 (12 per each end-plate)
End-cap segmentation in φ	30°
MWPC cathodes segmentation	95232 pads
Pad raw number per MWPC	53
Pad sizes	5x12 mm^2 and 5x18 mm^2
Charge amplifier peaking time	165 ns
Signal-to-noise ratio	30:1
ADC conversion range	10 bits
ADC sampling rate	10 MHz
Sampling depth	310 time buckets
Estimated pad occupancy for central heavy ion collisions	< 10%
Maximal event rate	< 7 kHz (Lum. 10^{27} cm^{-2} s^{-1})

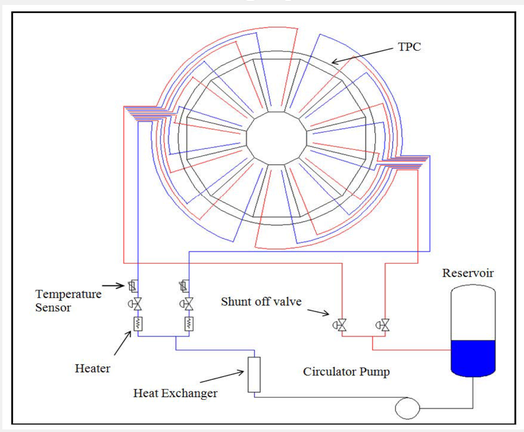
Clean room and tooling for TPC assembly

Tooling for ROC chamber installation into TPC

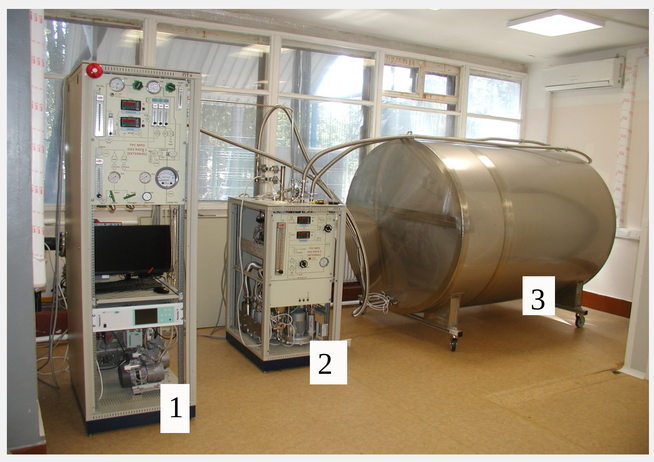
Scheme of laser beam distribution of TPC laser calibration system



Schematic view of the TPC cooling system



Test setup of the TPC gas system

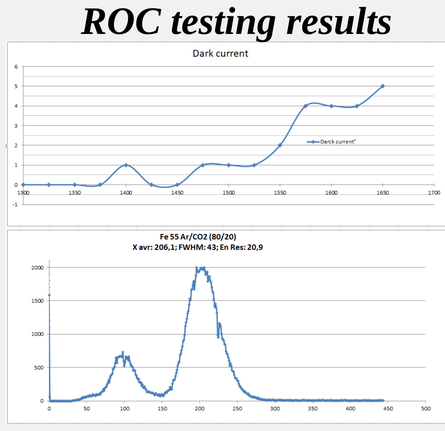


1,2 – gas system racks; 3 – TPC volume imitator.

In order to minimize the error in the absolute position measurement by the TPC, it is necessary to account for both – the static and time-dependent distortions in the drift path of the ionization cloud. The static distortions are the result of non-uniformities in B and E fields. A calibration system which provides absolute positional references is needed to develop a deconvolution procedure, which determines the absolute spatial position from the row pad and time bucket information. Time-dependent distortions can be caused by changes in gas performance, in environmental variables (temperature or atmospheric pressure), or by spontaneous failures. The calibration system which reproduces fiducial tracks is needed to monitor the TPC performance.

ROC under testing

ROC testing results

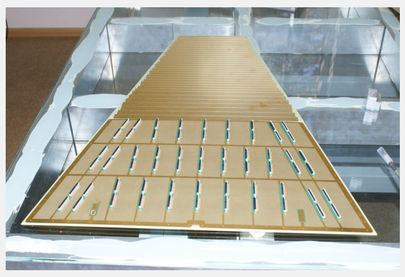


C3 TPC cylinder

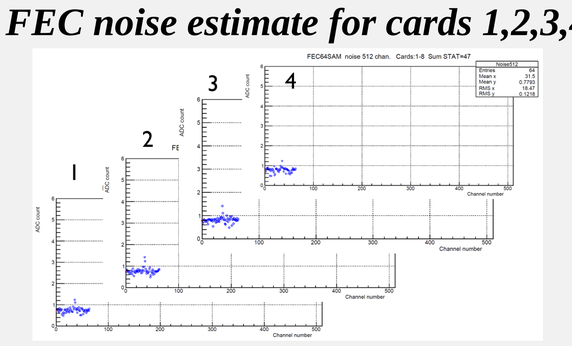
HV electrode prototype

TPC flange under leak testing

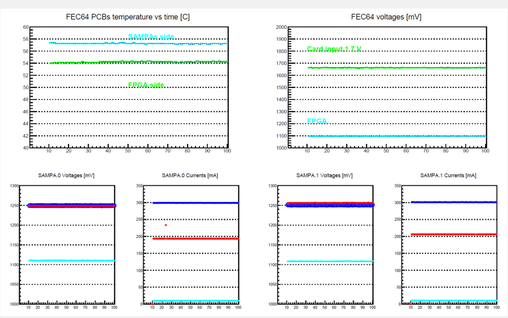
Two-parts PadPlane



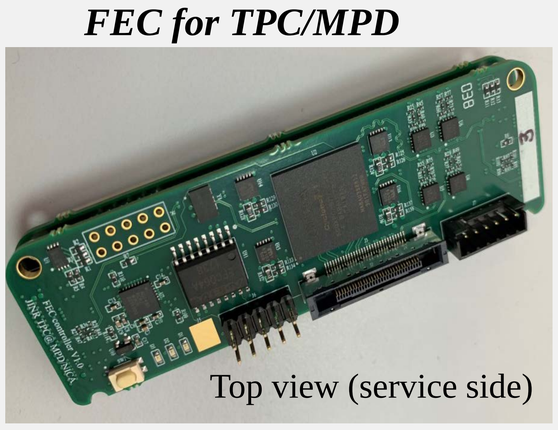
FEC noise estimate for cards 1,2,3,4

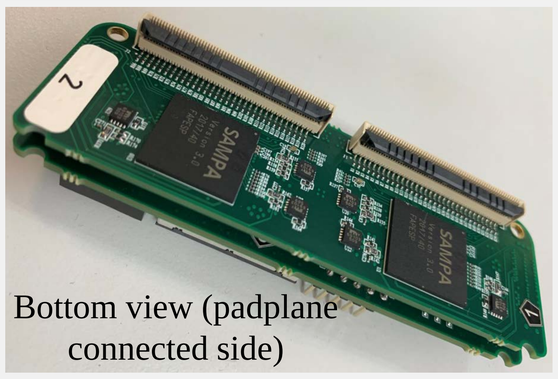


FEC slow control data

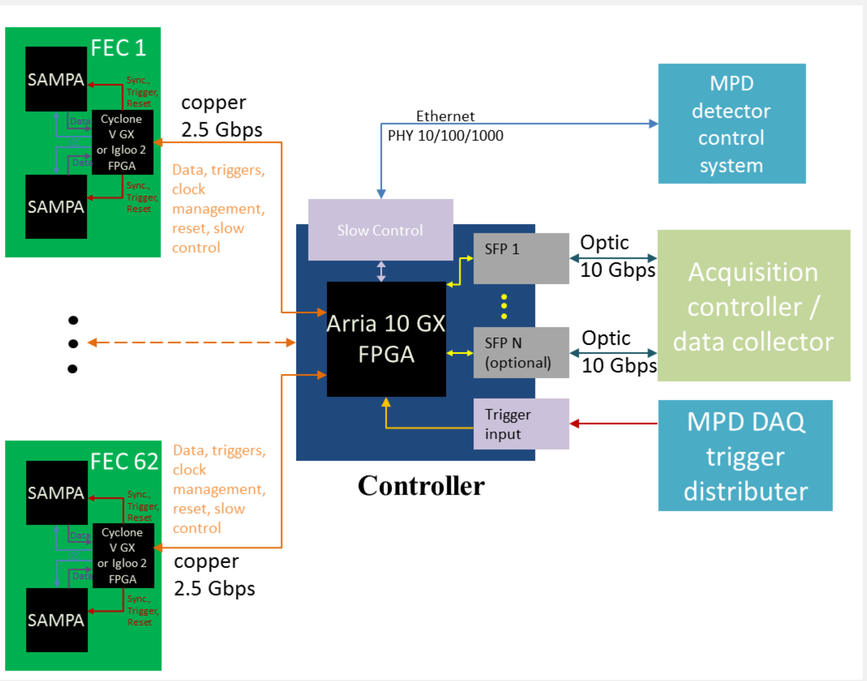


FEC for TPC/MPD





Block diagram of one chamber readout



Main parameters of the FEC are:

- The total number of registration channels – 64
- Input signal dynam. range – 100 fC
- ADC resolution – 10 bit
- ENC – les than $1000e^-$
- SAMPA chip configurations and control via FPGA
- Readout serial interface – up to 2.5 Gbps

Half ROC readout prototype system for FEE development, FECs and detector studies