STATUS OF THE TIME PROJECTION CHAMBER FOR THE MPD/NICA PROJECT

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Abstract. *The Time-Projection Chamber (TPC) is the main detector for tracking and identification of charged particles in the Multi-Purpose Detector (MPD) at new accelerator complex the Nuclotron-based Ion Collider Facility (NICA) in Joint Institute for Nuclear Research (JINR), Dubna city, Moscow region. The status of the TPC construction is presented.*

Keywords: *NICA, MPD, particle tracking detectors, gas detectors, time projection chamber, TPC, assembling tool.*

1. **Introduction**

Within the framework of the JINR scientific program on study of hot and dense baryonic matter a new accelerator complex the Nuclotron-based Ion Collider Facility (NICA) [1, 2] is under realization. It will operate at luminosity up to 10^{27} cm^{-2} s^{-1} for Au^{79+} ions. Two interaction points are foreseen at the NICA for two detectors which will operate simultaneously. One of these detectors, the Multi-Purpose Detector (MPD), is optimized for investigations of heavy- ion collisions [3, 4]. The MPD cross-section is shown in Fig.1.

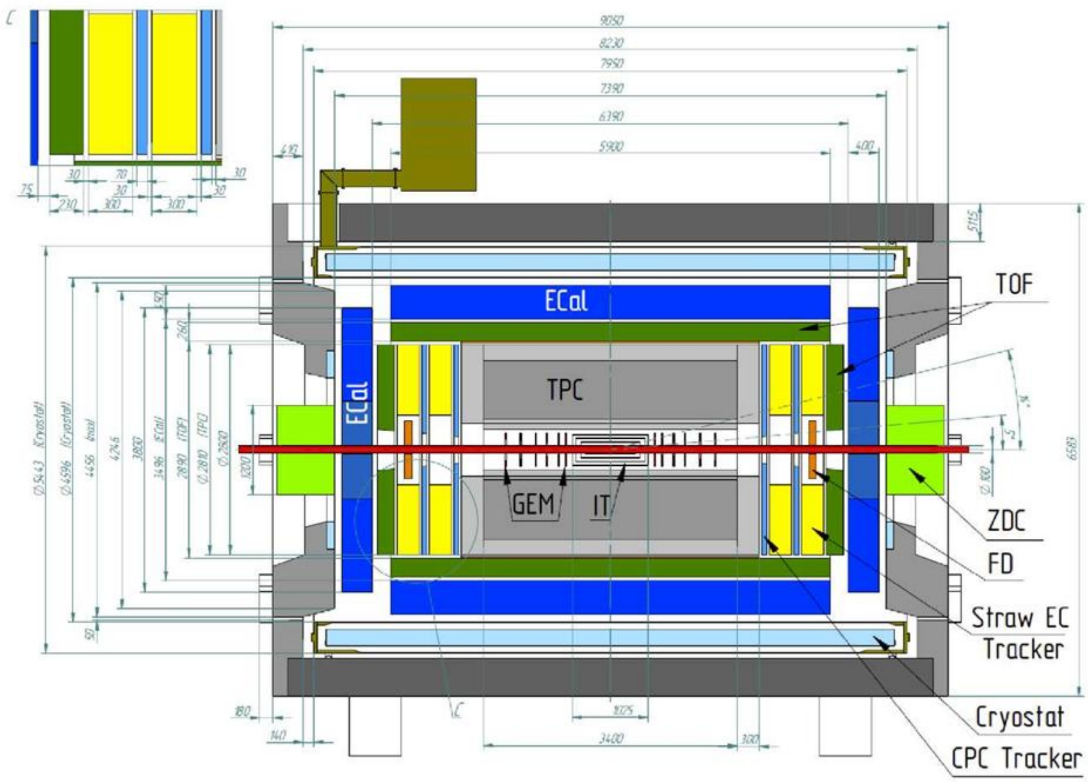

Figure 1. MPD cross-section

The MPD envisaged experimental program includes simultaneous measurements of observables that are presumably sensitive to high-density effects and phase transitions. The observables measured on the event-by-event basis are particle yields, their phase-space distributions, correlations, and fluctuations.

2. **TPC performance**

The Time-Projection Chamber (TPC) is the main tracking detector of the MPD. It is a well-known detector for 3-dimensional tracking and particle identification for high multiplicity events. The TPC/MPD will provide:

– the overall acceptance of $|\eta| < 1.2$;

– the momentum resolution for charge particles under 3% in the transverse momentum range $0.1<p_t<1$GeV/c;

– two-track resolution of about 1 cm;

– hadron and lepton identification by dE/dx measurements with a resolution better than 8%.

These requirements must be satisfied at the NICA design luminosity, charged particle multiplicity up to ~ 1000 in central collisions and the event rate about 7 kHz.

MPD ambitious physics program requires excellent tracking and particle identification (PID) performance over a significant fraction of the final state phase-space. For example, an extension of the MPD tracking (and PID) ability from the rapidity region $|\eta| < 1$ up to $|\eta| < 2$ (right to the geometrical acceptance limit) will allow us to increase the proton statistics in an event by 50% which is very important in the search for the critical end point (CEP).

The first results of physics simulation of the MPD TPC tracking performance to obtain for TPC response model are described in [5] and some significant results is shown in Fig.2: the momentum resolution – better than 2%, track reconstruction efficiency – about 100%, dE/dx resolution – 7.7%. This model is based on a simplified approach to the clusters and hits production algorithm a so-called “gaussian smearing” is used, i.e. each TPC hit produced by the Geant transport program is randomly displaced in longitudinal and transverse directions according to the space resolution parameters measured for similar detectors (0.5 mm and 1.0 mm for transverse and longitudinal gaussian sigmas). TPC tracking performance study based on the realistic detector response simulation and respectively tuned cluster, hit and track finding procedures [5].

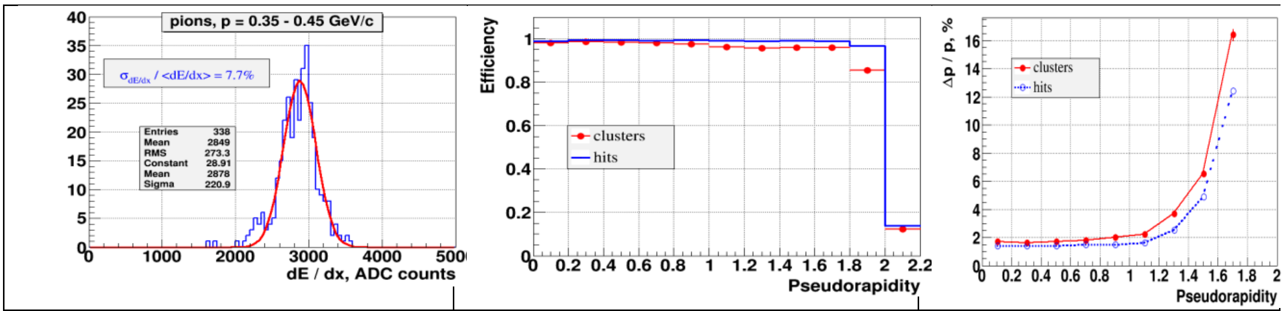

Figure 2. The relative transverse momentum resolution as a function of pseudorapidity $|\eta|$ (left); track reconstruction efficiency as a function of pseudorapidity for primaries with momentum > 0.2 GeV/c (center); pions identification by dE/dx measurements for particles with p = (0.35÷0.45) GeV/c (right) [5].

3. **TPC design**

The TPC design and structure are similar to those of the TPCs used in the STAR, ALICE and NA49 experiments [6, 7, 8].

The TPC being a large but conceptually simple detector must be constructed with very high precision to reduce nonlinear systematic effects. High stability of the mechanical structure and uniformity of the drift field, the temperature, the drift gas purity and the gas gain have to be provided to get precise track reconstruction and energy-loss measurements.

3.1. TPC operation conditions

The TPC is a detector of charge particles produced by the nuclear-nuclear collisions inside the NICA collider. Momentum dP/P and energy dE/E resolution depends on the TPC design and the solenoid magnetic field.

The TPC body must be rigid with the minimum deformation under gravity and non sensitive to the magnetic field. The TPC radiation length must be minimal for good matching with the inner and the external trackers. Track reconstruction is based on drift time and R-φ coordinate measurement of primary clusters.

Electric field inside the TPC drift volume must be uniform and stable in time to achieve high precision for the track reconstruction. Stability of the TPC gas mixture composition is very important. O_2 and H_2O admixture must be at level of 20 ppm and 10 ppm. The TPC drift volume temperature stability must be at the level of one degree. Laser calibration system will be used for monitoring of drift time velocity and for taking electric field distortion into account.

The layout of the TPC is shown schematically in Fig. 3. In outline the TPC consists of hollow cylinder the axis of which is aligned with the beams from NICA and is parallel to the uniform solenoid magnetic field [9, 10]. The TPC has an inner diameter of D=54cm, an outer diameter of D=280cm, and an overall length along the beam direction of L=340cm. Since the amount and position of material traversed by particles in the MPD inner detectors have an impact on the performance of the outer detectors the material budget of the TPC has to be kept as low as possible. The TPC barrel overall thickness $X/X_0=(6\div12.5)\%$ for $\eta=(0 \div 1.31)$ is acceptable.

The active gas volume of the TPC is bounded by coaxial field cage cylinders with a pad plane readout structure at both end-caps. The uniform electric field in the active volume required for drift electrons is created by a thin central HV electrode together with a voltage dividing network at the surface of the outer and inner cylinders and at the readout end-cap chambers. Monolithic full-size plastic cylinders will be used for the TPC field cage construction.

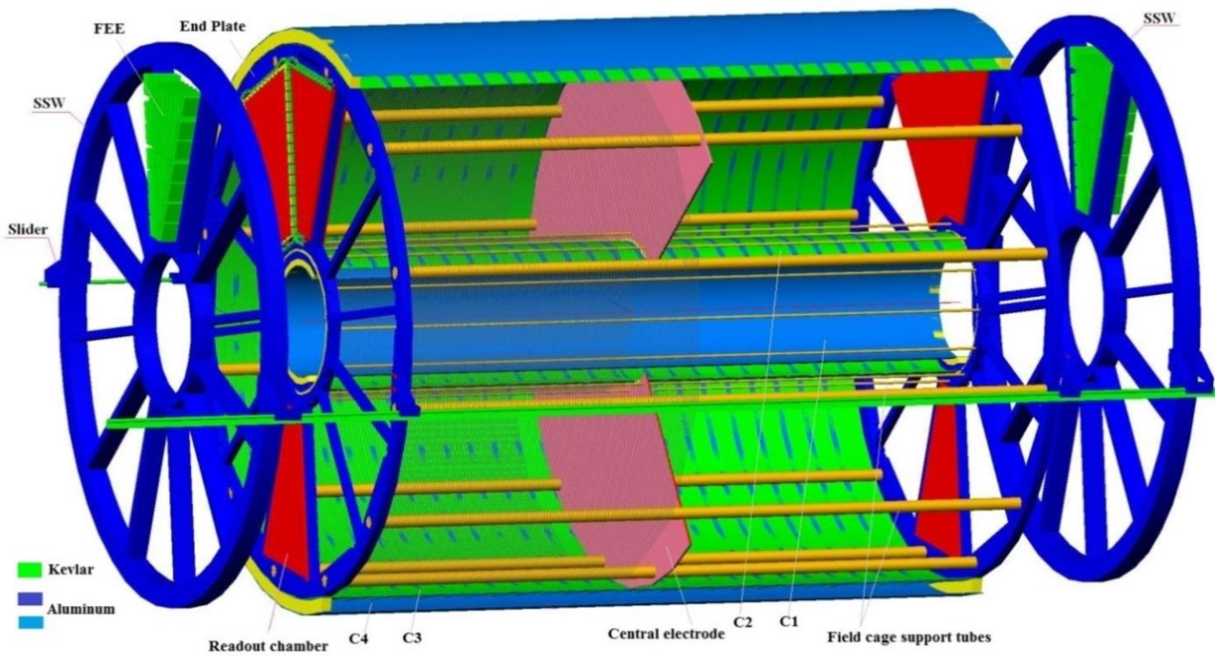

Figure 3. The schematic view of the TPC. SSW- service support wheel, FEE - front end electronics, C1÷C4 – TPC cylinders, Central electrode = HV electrode, Field cage support tubes – structure for TPC field cage, Readout chamber (N=24 pc), Slider –TPC & SSW support and adjust structure, End Plate – TPC flange.

It has been shown that radial magnetic and electric field components have to be not more than of order $5.2*10^{-4}$ [4] to reach the required value of transverse momentum resolution. Hence, the mechanical structure and electric field defining network have to be designed in a way to keep radial field non-uniformity at $\sim10^{-4}$.

The TPC readout system is based on the Multi-Wire Proportional Chambers (MWPC) with cathode pad readout. Image charges are induced on an array of pads and are recorded as a function of time. For given drift gas mixture and a fixed wire geometry the gas gain is determined by high voltage applied to the anode wires. The electrostatic and gravitation forces lead to variations in gas gain along the anode wires. These variations can be controlled by calibrating the signal response with the injection of radioactive Kr^{83} into the drift gas. This method was applied in [7, 8] and it was shown the overall gas gain variation (electronics and wire amplification) of the order of 10% can be corrected with 0.5% precision.

The gas mixture of 90% argon and 10% methane (P10) is supposed to be used in the TPC. The gas over-pressure has to be as small as possible to reduce the multiple scattering in the TPC gas. The TPC active volume must be sufficiently gastight to keep the oxygen level below 20 ppm for minimizing primary ionization loss in the TPC drift volume. Operating on the peak of the voltage-velocity curve (for argon-methane mixture at E=140V/cm) makes the drift velocity stable and low-sensitive to small variations in temperature and pressure. The thermal isolation of the TPC must guarantee the temperature stability about 0.5°C over the active gas volume [7].

The TPC readout system is to be based on the MWPCs with cathode readout pads, mounted in two end-caps of the TPC cylinder and each covering 30° in azimuth. The basic design parameters of the TPC are summarized in Table.

Table 1.The basic design parameters of the TPC

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	163cm (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	$\sim 10^4$
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 (at Luminosity $L\sim10^{27}$)
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

The TPC main sub-systems are:
– TPC body (includes field cage, flanges and others);
– readout chambers (ROC);
– FE electronics and DAQ;
– laser calibration system;
– TPC cooling system;
– TPC gas system.

4. **TPC assembling tool**

Since the TPC field cage containment cylinders are not differ significantly each form other in size the TPC assembling will be done at horizontal position of each elements. The TPC assembling tool is under design and will be produced by Russian industry.

The arrangement for TPC assembling is shown schematically in Fig.4.

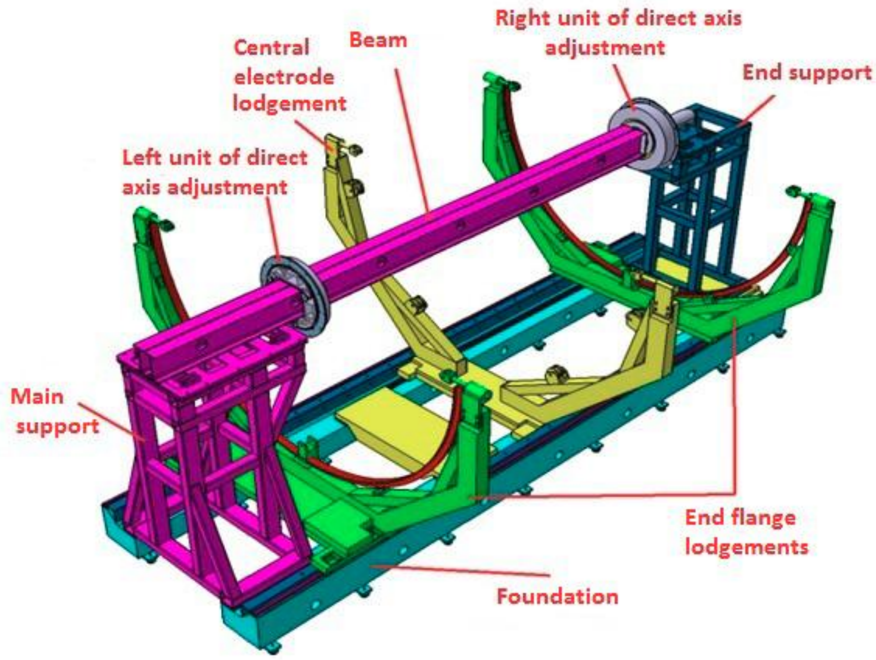

Figure 4. Schematic view of the TPC assembling tool

The pair of precisely positioned rails placed on flat surface, the strong "arm" I-beam with adjustable units, a system of moving lodgments and a special mobile platform create mechanical structure for step-by-step assembling of the TPC field cage elements and final TPC assembling.

5. **Conclusion**

The main design parameters, performance and assembling tool of Time Projection Chamber for MPD detector to be built for the heavy-ion experimental program at future collider NICA at JINR are overviewed. The TPC will be an adequate device of MPD for tracking and identification of charge particles in the MPD/NICA project.

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СТАТУС ВРЕМЯ-ПРОЕКЦИОННОЙ КАМЕРЫ ПРОЕКТА MPD/NICA

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Аннотация. *Время-проекционная камера (Time Projection Chamber, TPC) является главным трековым детектором и детектором идентификации заряженных частиц в многофункциональном детекторе (Multi-Purpose Detector, MPD) для нового ускорительного комплекса для тяжёлых ионов коллайдерного типа на основе Нуклотрона (Nuclotron-based Ion Collider Facility, NICA) в Объединенном Институте Ядерных Исследований, г. Дубна, Московская область. В статье представлен статус конструкции TPC.*

Ключевые слова: *NICA, MPD, детекторы частиц, газовые детекторы, время-проекционная камера, TPC, монтажное устройство.*