Gas detectors for particle identification at the MPD experiment

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Abstract

The MultiPurpose Detector (MPD) [1] which will be located at the NICA accelerator is designed for the study of properties of hot and dense matter created in heavy-ion collisions, in particular, for the search of the mixed quark-hadron phase.

Particle identification (PID) of charged hadrons is achieved by the time-of-flight (TOF) measurements which are complemented by information about energy loss (dE/dx) from the TPC and IT detector systems. In order to separate pions from kaons in the momentum range 0-2.5 GeV/c and protons from kaons in the range 0-4.5 GeV/c, TOF has to have time resolution better than 100 ps. The barrel TOF system have a length of 5 m and radius of 1.2 m. As a base element of the TOF detector we consider a 10 gap mRPC with a strip(pad) readout.

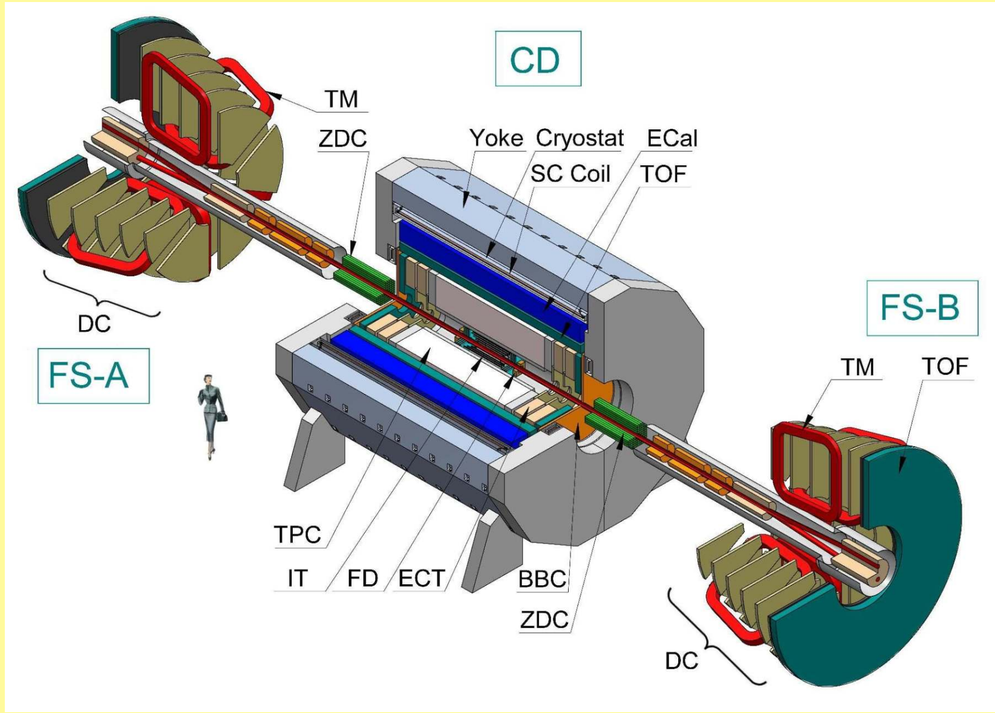
A large time projection chamber (TPC) is the main tracking device of the MPD spectrometer. TPC is 3m long and 2.2 m in diameter. The active gas volume of the TPC is bounded by coaxial field cage cylinders with instrumented pad-plane end-caps at both ends. The TPC will register spatial coordinates of 50 points for each track traversing the field cages. Magnetic field of 0.5 T strength will provide the required resolution for charged particles of 0.1-3 GeV/c momentum. Using the information about ionization loss from TPC makes possible to improve the efficiencyof /K separation.

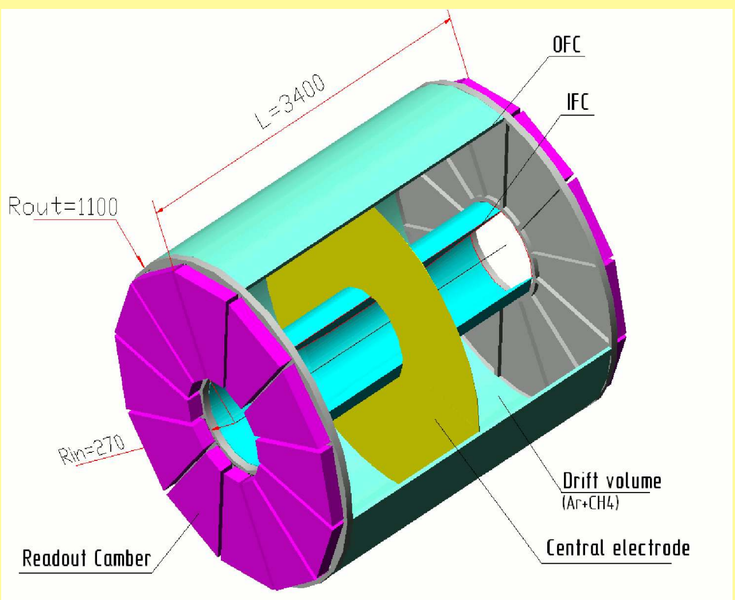
MPD design

The design concept of a detector which would be capable to exploit the broad physics potential of the high luminosity NICA collider is a challenging task. The detector to explore phase diagram of strongly interacting matter in a high track multiplicity environment has to cover a large phase space, be functional at high interaction rates and comprise high efficiency and excellent particle identification capabilities. The MPD detector layout is shown on the right. It comprises the central detector (**CD**) and two forward spectrometers **FS-A** and **FS-B** (optional).

The main systems of the MPD detector:

1. Particles Identification (**PID**) system:
   – Time Projection Chamber (**TPC**) is measure momentum and *dE/dx* of charged particles;
   – Time of Flight (**TOF**) for charged particles identification by time-of-flight;
   – Electromagnetic Calorimeter (**ECal**) to identify electrons and photons and measure their energy.
2. Tracking system:
   – Inner Tracker (**IT**) provide precise tracking and vertex determination;
   – Time Projection Chamber (**TPC**) is the main device for tracking;
   – Endcap Straw Tracker (**ECT**) is provide tracking for particles travailing in forward direction;
   – **TOF & ECal** can used for additional tracking information.
3. Trigger system used for trigger definition and centrality determination:
   – Fast Forward Detectors (**FD**);
   – Beam-Beam Counters (**BBC**);
   – Zero Degree Calorimeters (**ZDC**).



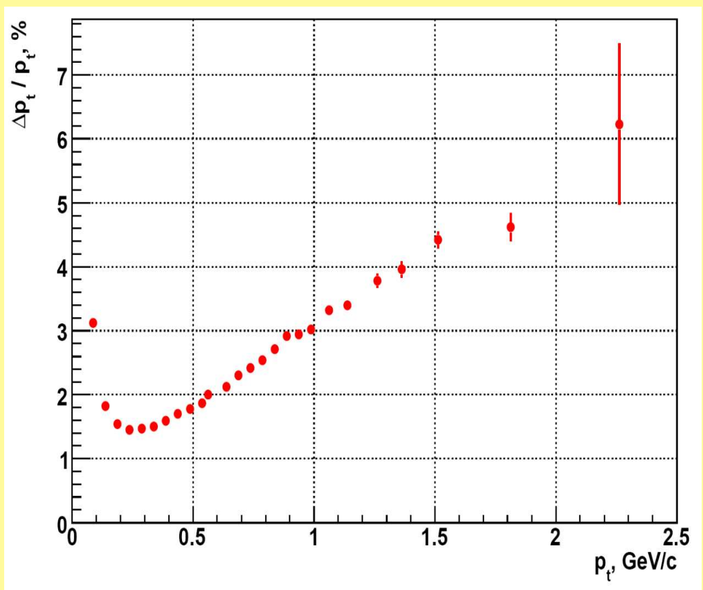


Time Projection Chamber

TPC is shown schematically on the left. Main parameters of the TPC:

Length of the TPC (of the drift volume)	340 cm (150 cm (of each half))
Outer radius (of the drift volume)	110 cm (100 cm)
Inner radius (of the drift volume)	27 cm (35 cm)
Electric field strength	~140 V/cm
Drift gas	90% Ar+10% CH_4, (atm.pr. + 2 mbar)
Drift velocity	5.45 cm/ s
Number of readout chambers	24 (12 per end plate)
Number of pads	~80000(< 10% after zero suppression)
Pad size	4 x 10 mm in inner sector area 6 x 12 mm in outer sector area
Spatial resolution	z ~1 mm, x ~0.6 mm, y ~0.8 mm
dE/dx resolution	8% (50 samples x 2 cm)
Maximum rate	5 – 6 kHz (Lum. $10^{27}cm^{-2}s^{-1}$)

Relative momentum errors of *p/p* 2 ÷ 3% can be achieved for particles in the momentum range up to 1 GeV/c, as shown on the right figure.

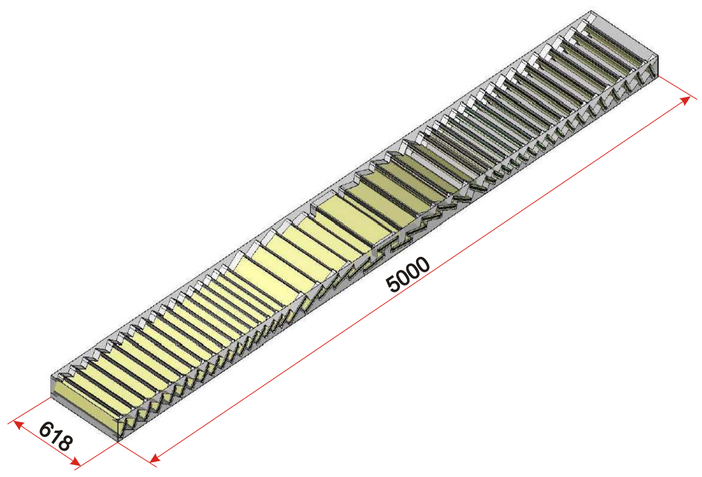


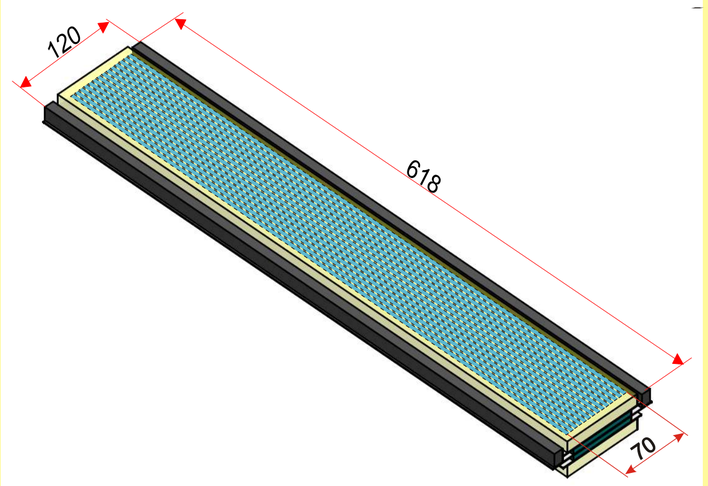
Time of Flight system

Main parameters of the TOF system:

Length of the TOF barrel	500 cm
Radius of the barrel(time-of-flight base)	~120 cm
Radius of the TOF endcap (outer)	110 cm
(inner)	40 cm
TOF barrel module width	62 cm
MRPC strip pitch	0.5 cm
MRPC gap	10 x 200 m (fishing line spacer)
MRPC resistive layers	400 m (“Glaverbel” glass)
Number of channels in the barrel	~10000
Gas mixture	90% $C_2H_2F_4$ + 5% iC_4H_{10} + 5% SF_6
Time resolution	<100 ps

Two types of MRPC will be used in the MPD TOF. One of the types shown in the figure on the right. This type has 14 readout stripes. Signals will be read from both ends of each strip. Thus good time and position resolution will be achieved.





Particle identification

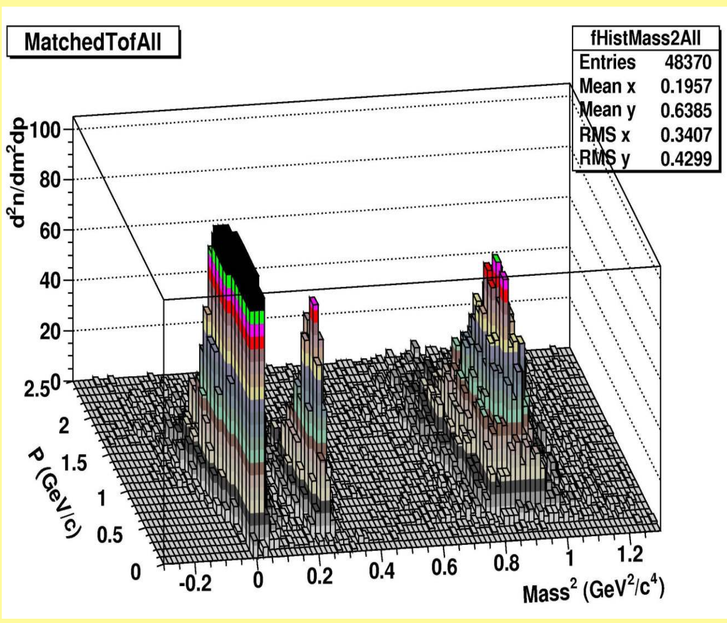
The squared mass m^2 for a detected track is calculated using the information about the reconstructed momentum (p), flight path length (l) and time-of-flight (t) as follows:

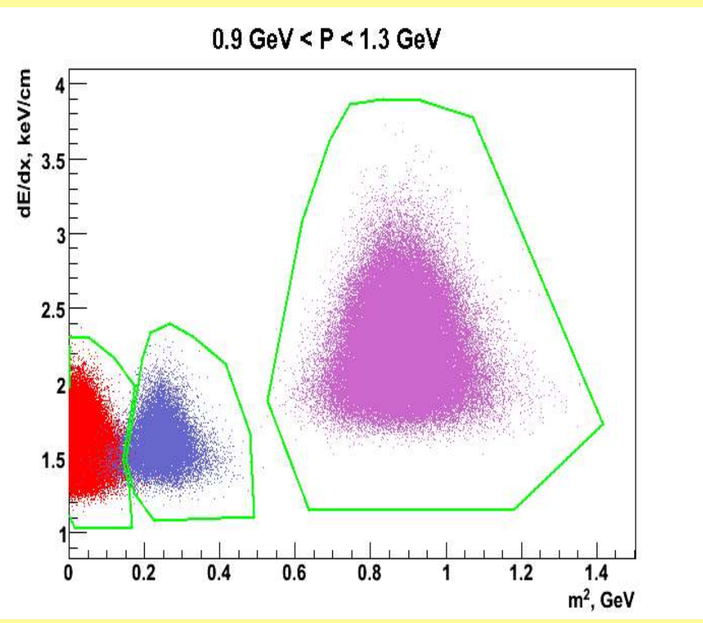
$$m^2 = p^2\left(\frac{ct^2}{l^2} - 1\right)$$

Using the results of simulation (with time resolution of 100 ps), the calculated mass for the particles detected in the barrel TOF system is plotted on the left.

From the right figure one may conclude that information on ionization loss from TPC improves the TOF separation for K in the momentum region up to 1.5 GeV/c. The green lines shown the regions of particle species selection that were used to estimate the loss due to PID and corrections for particle misidentification. The corresponding coefficients are tabulated in the table.

	K		p
Efficiency	0.99	0.96	1.0
Contamination	0.0061	0.0171	0.0





References: 1. The MultiPurpose Detector – MPD. Conceptual Design Report. JINR, 2009. http://nica.jinr.ru/files/CDR_MPD/MPD_CDR_en_0.7.pdf