Time Projection Chamber for MPD/NICA

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Results presented in the report are obtained by MPD TPC team:

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The scientific program of the MPD includes the following topics:

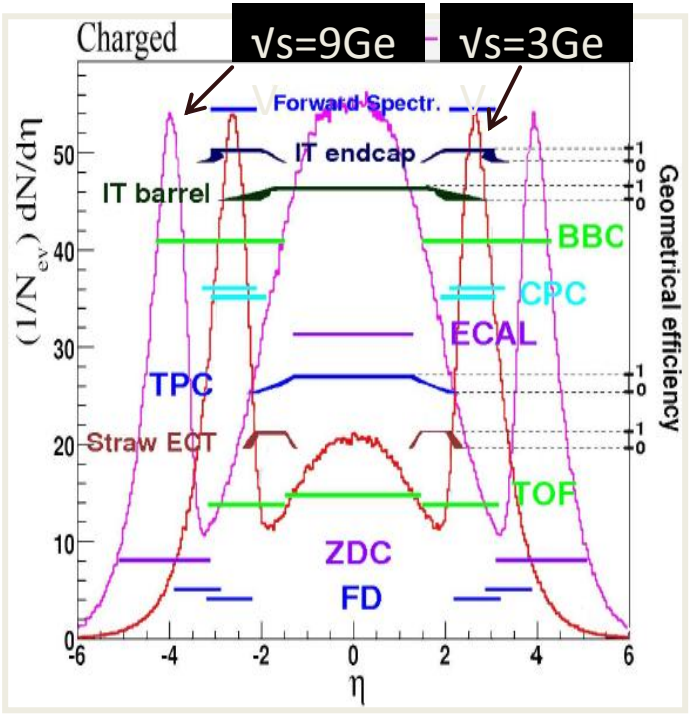
> Particle yields and spectra (π, K, p, clusters, Λ, Ω)

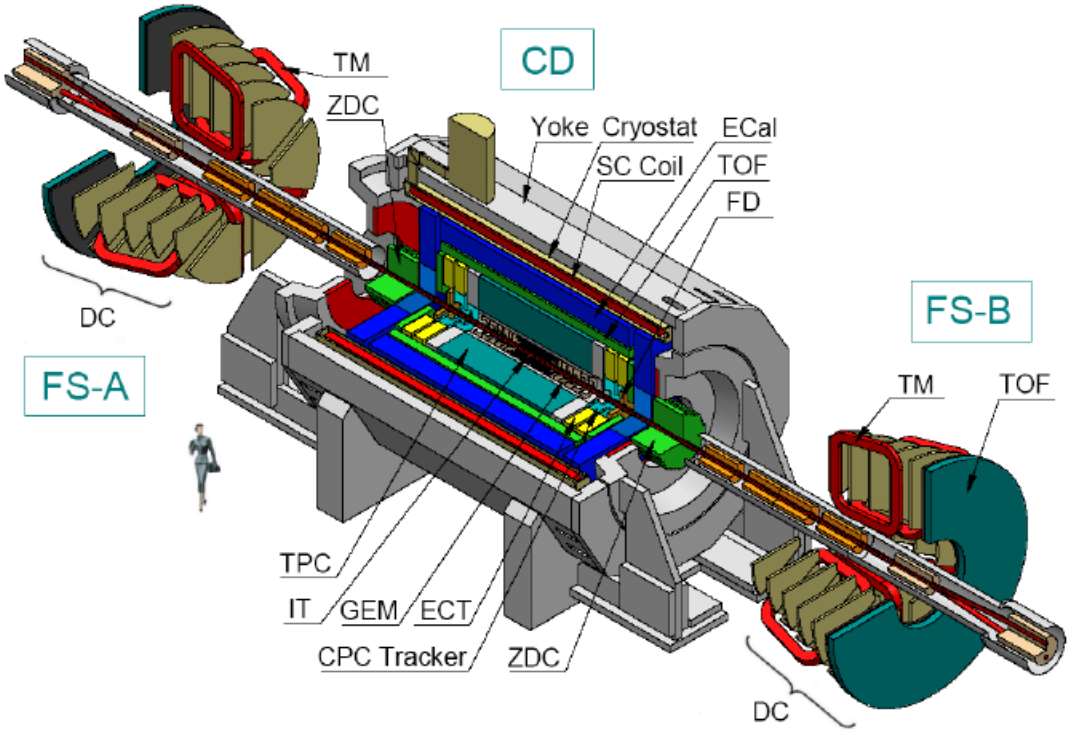
> Event-by event fluctuation

> Femtoscopy with π, K, p, Λ

> Collective flow of identified hadron species

> In-medium modification of vector mesons

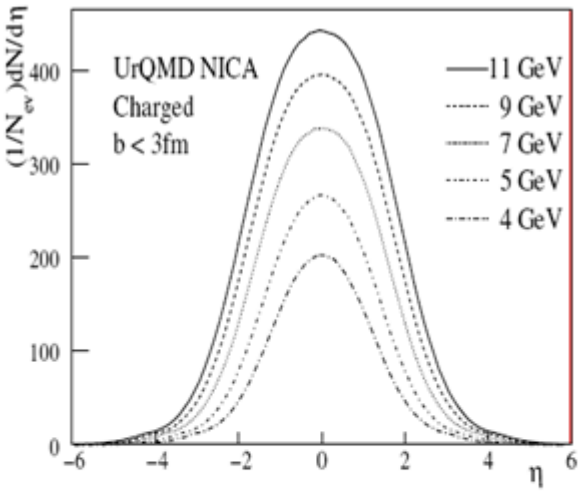




Observables	Detectors in use
Yields & spectra	TPC, ZDC, barrel TOF & ECAL end-cap tracker + end-cap TOF & ECAL
Di-leptons	TPC, barrel TOF & ECAL end-cap tracker + end-cap TOF & ECAL
Event-by-event fluctuations	ZDC, barrel TOF & ECAL end-cap tracker + end-cap TOF & ECAL
Flow	TPC,TOF, event plane detector (extended ZDC) end-cap tracker + end-cap TOF & ECAL
Hyperons, hyper-nuclei, charm	TPC, IT

Charge particle distributions of Au-Au collisions

- Au+Au collisions $\sqrt{s_{NN}}$ = 4-11 GeV (UrQMD)
- Event rate (design luminosity, σ_t=6.8 barn)~7 kHz
- charged dn/dy ~ 500 at midrapidity
- $\langle p_t \rangle$ ~ 600 MeV/c (K^+, $|\eta|<1.0$)



Pseudorapidity distribution of charged particles in central Au+Au collisions (b<3fm) calculated by UrQMD

Part.	4 GeV		7 GeV		11 GeV	
	4π	$\lvert\eta\rvert < 1$, $p > 100$ MeV/c	4π	$\lvert\eta\rvert < 1$, $p > 100$ MeV/c	4π	$\lvert\eta\rvert < 1$, $p > 100$ MeV/c
charged	430	250	870	430	1300	550
p	170	91	160	63	160	49
n	200	110	180	68	170	53
π^+	110	65	310	160	470	230
π^-	120	78	340	170	520	240
π^0	120	72	340	180	510	240
K^+	12	7.6	38	19	57	24
K^-	1.3	0.82	12	6.2	26	12
K^0	12	7.7	38	19	57	26
Λ	10	6.2	26	12	31	12
Σ^+	3.4	2.1	8.0	3.7	9.2	3.6
Σ^-	4.0	2.4	8.8	4.0	10	3.8
Σ^0	3.2	1.9	7.9	3.6	9.4	3.8
Ξ^-	0.16	0.11	0.87	0.42	1.7	0.66
Ξ^0	0.13	0.077	0.86	0.42	1.3	0.62
Ω^-	0.003	0.002	0.022	0.011	0.038	0.015

The requirements on TPC

-efficient tracking up to pseudorapidity region lηl=1.2

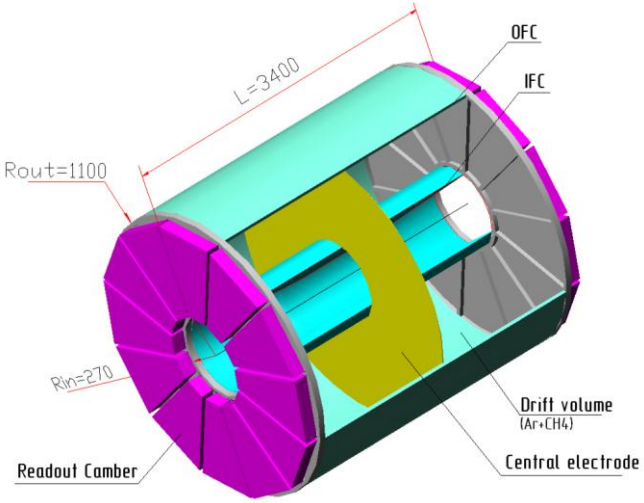
- the momentum resolution for charge particles ~2% at the transverse momentum of 300 Mev/c

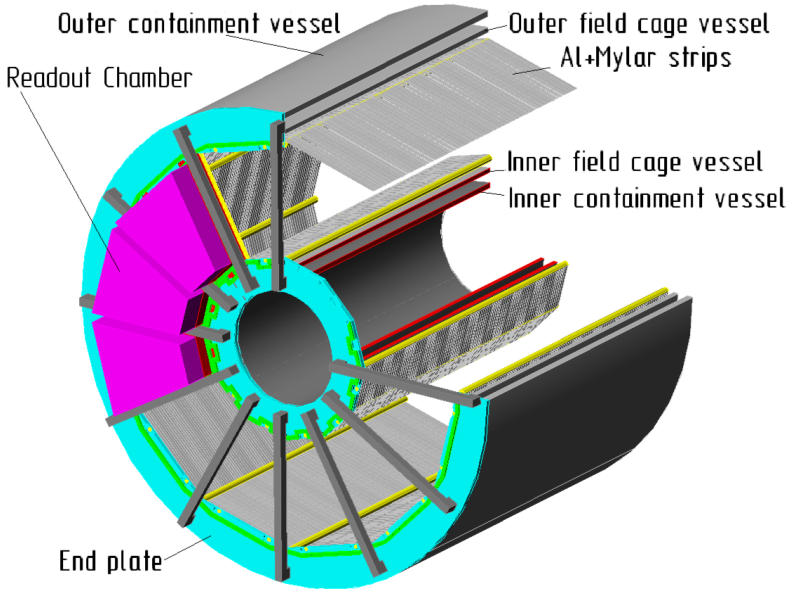
- the two-track resolution has to be about 1 cm

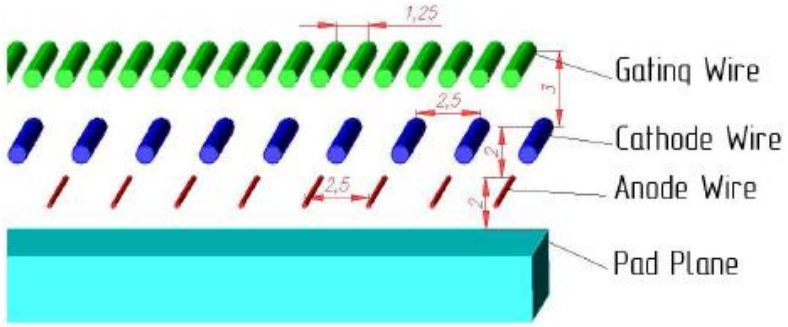
- a dE/dx resolution better than 8% is desirable for hadron and lepton identification

A design luminosity - 10^{27} cm^{-2} s^{-1} for Au+Au collisions
Interaction rate ~ 7 kHz

Schematic view of MPD TPC and readout chamber







TPC ingredients

-Readout wire chambers
- Field cage
- Gas system
- Laser calibration system
- Readout electronics

TPC SIMULATION (pad sizes)

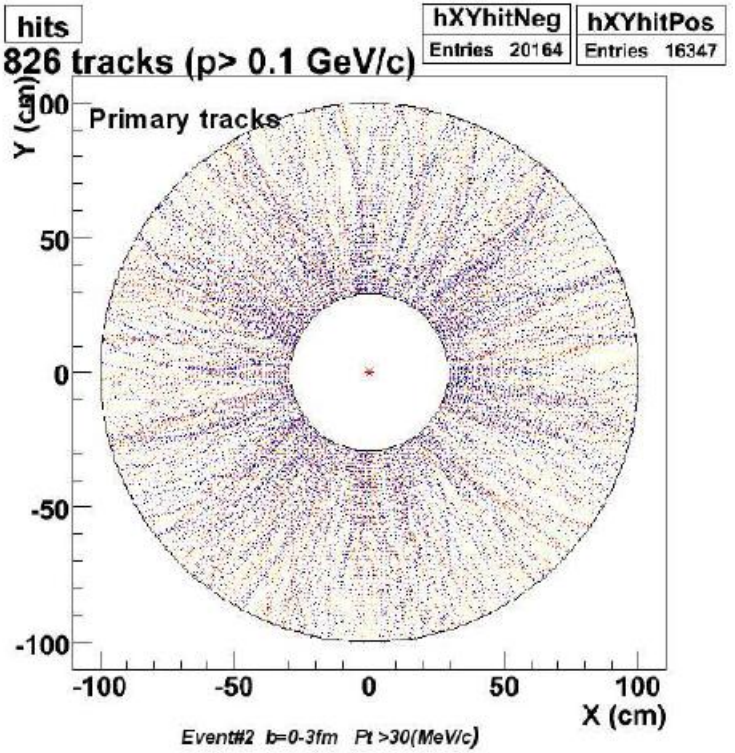
Allison and Cobb relation

$$\frac{\Delta dE/dx}{dE/dx} = \frac{0.96}{2.35} N^{-0.46} l^{-0.32}$$

dE/dx ~7% ⟺ number $N = 40$ of pad rows, $l = 1.2$ cm the plength

16% tracks occupy the about 10 cm area around the inner field cage wall

41 rows of 5x12 mm² in the pad plane area



central $Au + Au$ collision at $\sqrt{s_{NN}} = 9\,GeV$

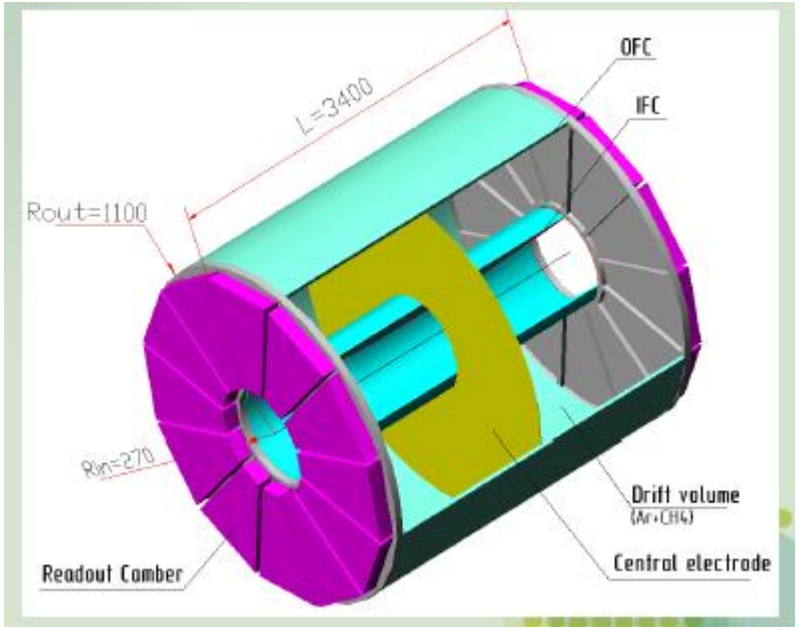
Basic parameters of the MPD TPC:

TPC length – 360cm
Outer radius – 110cm
Drift volume outer radius – 95cm
Inner radius – 27cm,
Drift volume inner radius – 40cm
Length of drift volume – 150cm
Electric field strength – 140V/cm
Magnetic field strength – 0.5 Tesla
Drift gas – 90% Argon + 10% Methane

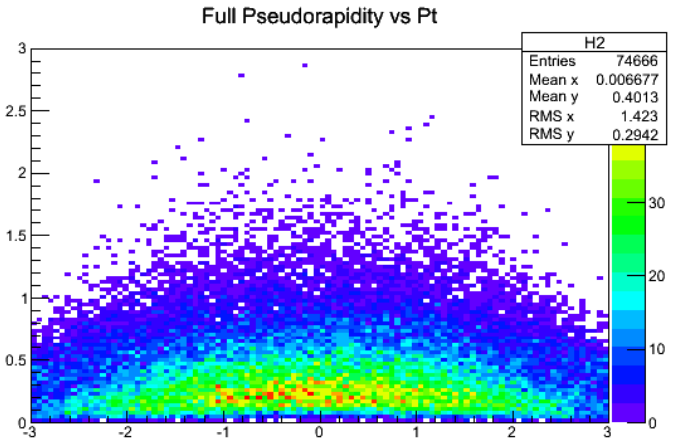
Readout: 2x12 sectors (MPWC + pads or GEM)
Number of pads – 80000
Pad size – 5x12mm

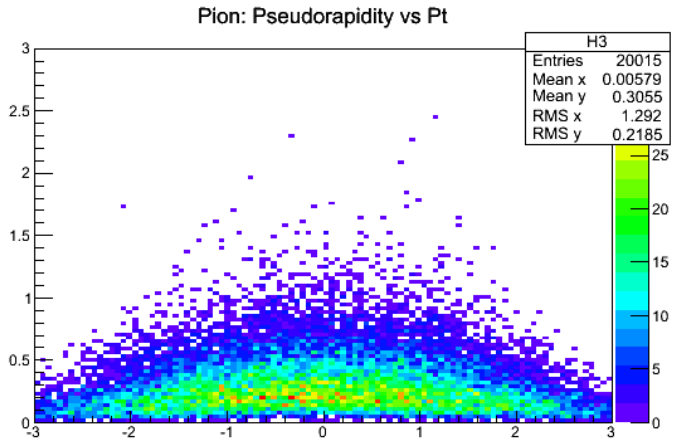
Signal dynamical range – 10 bits
Sampling rate – 12.5 MHz

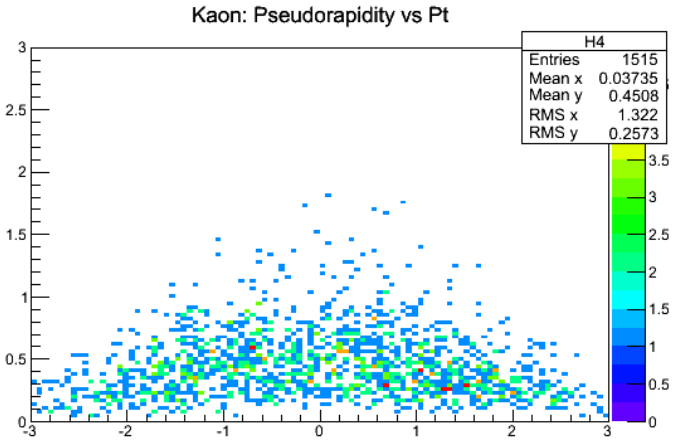
- low material budget in barrel part, max. transparency for forward tracking
- high event rates (up to ~ 7kHz)
- Small distortions, $B_r/B_z < 5*10^{-4}$

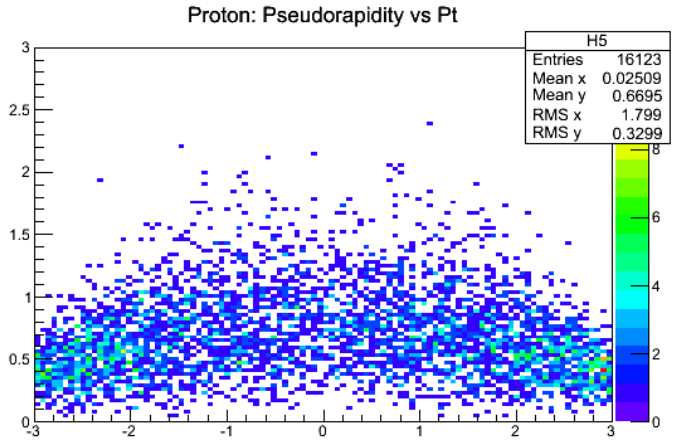


TPC acceptance





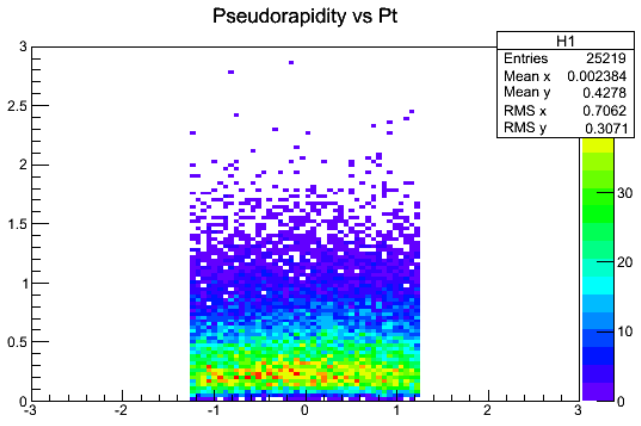


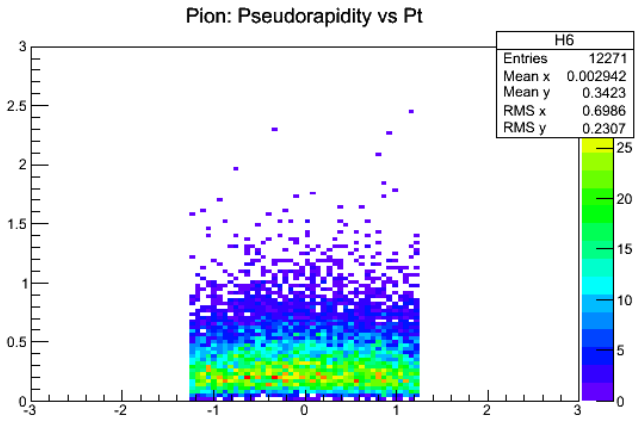


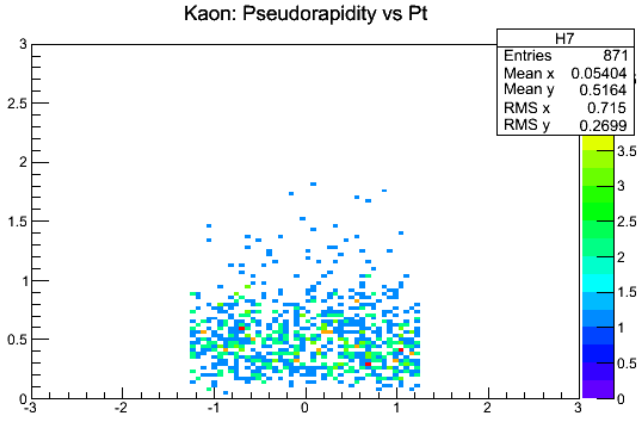
Primary particles: 74666
All: 2288588

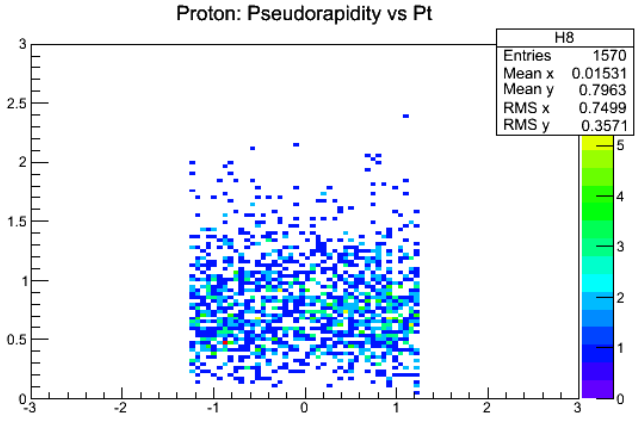
UrQMD, min.bias, 9GeV

TPC acceptance





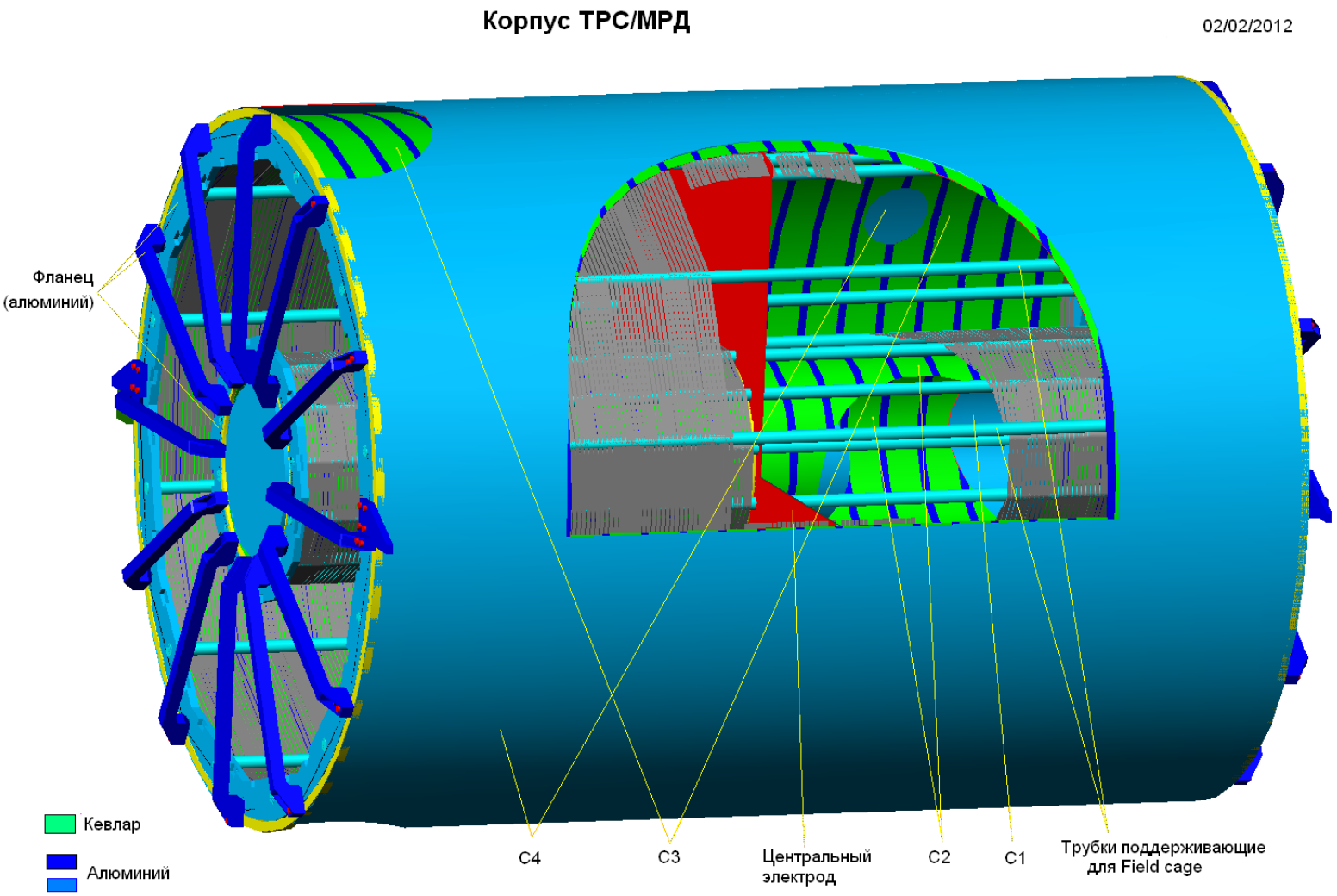




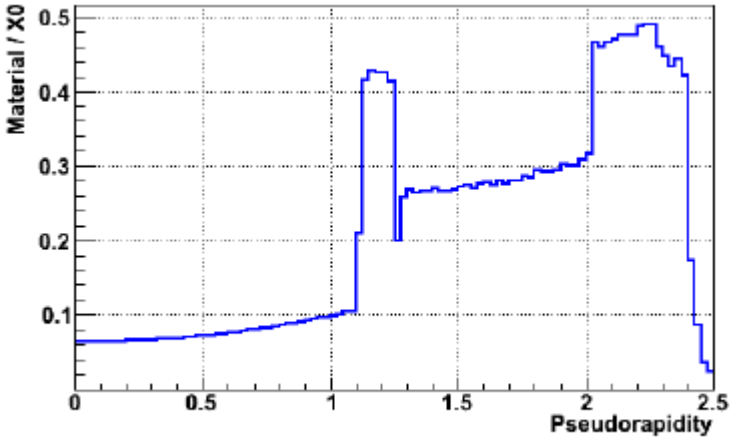
Particles in TPC: 25219
All (1.255): 33.7757%
Pi: 61.309%
K: 57.4917%
P: 9.73764%

TPC length = 3000mm, $|\eta| = 1.25$ UrQMD, min.bias, 9GeV

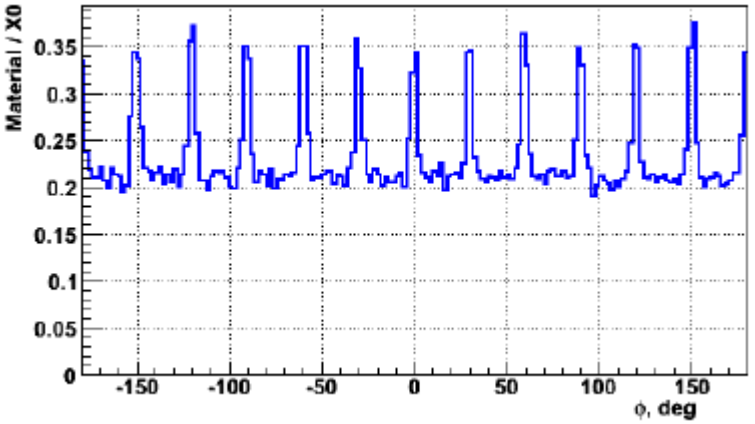
TPC DESIGN


Корпус TPC/МРД
02/02/2012
Фланец
(алюминий)
Кевлар
Алюминий
C4
C3
Центральный
электрод
C2
C1
Трубки поддерживающие
для Field cage

Material budget

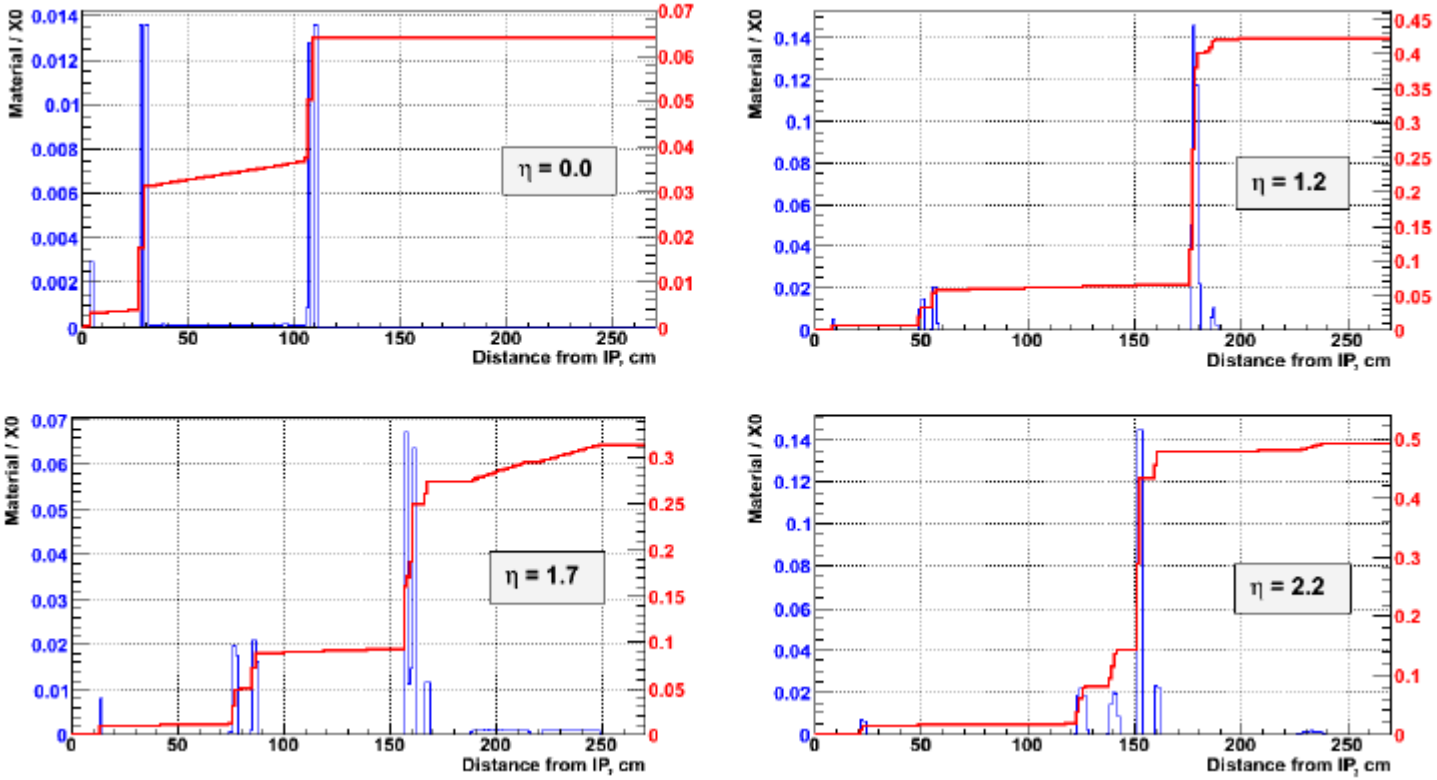


Material density as function of η. The density increase at η=1.2 and 2.0 is due to the inner and outer flanges of TPC.



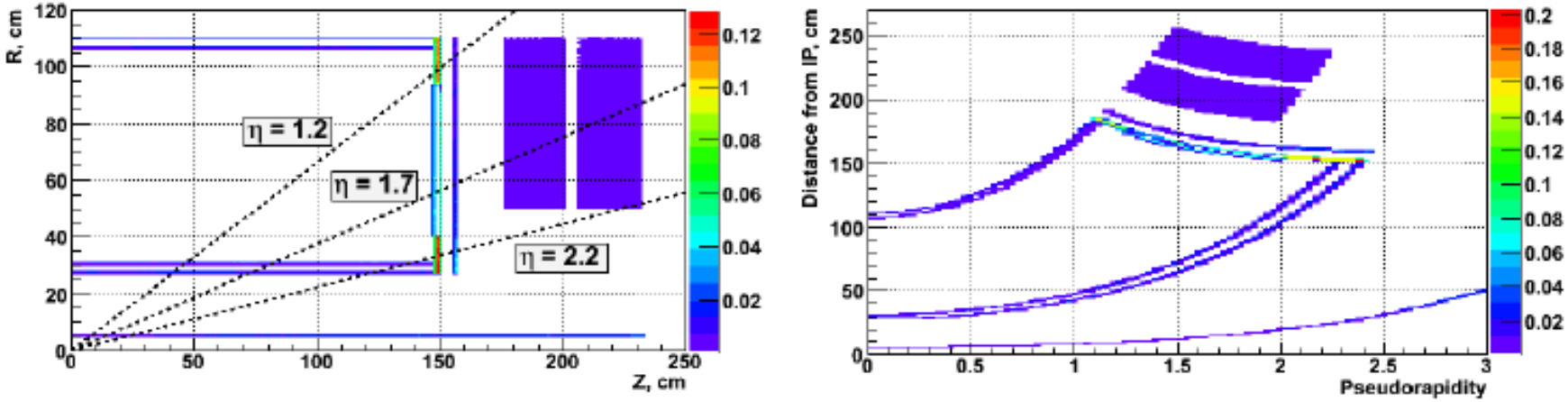
Material in the TPC end plate (averaged over η) as a function of the azimuthal angle. The periodic peaks represent support bars of the TPC.

Material budget



The present estimate of material budget (in X_0) in the MPD as a function of distance from IP for different peudorapidities: 0, 1.2, 1.7, 2.2. The cumulative estimate is shown in red, whereas the spikes (in blue) demonstrate materials described in the present version of the MPD geometry ("v3").

Material budget



The present estimate of material budget (in X_o) in the MPD: (on the left) in R-Z plane and (on the right) in terms of pseudo-rapidity versus distance to the IP.

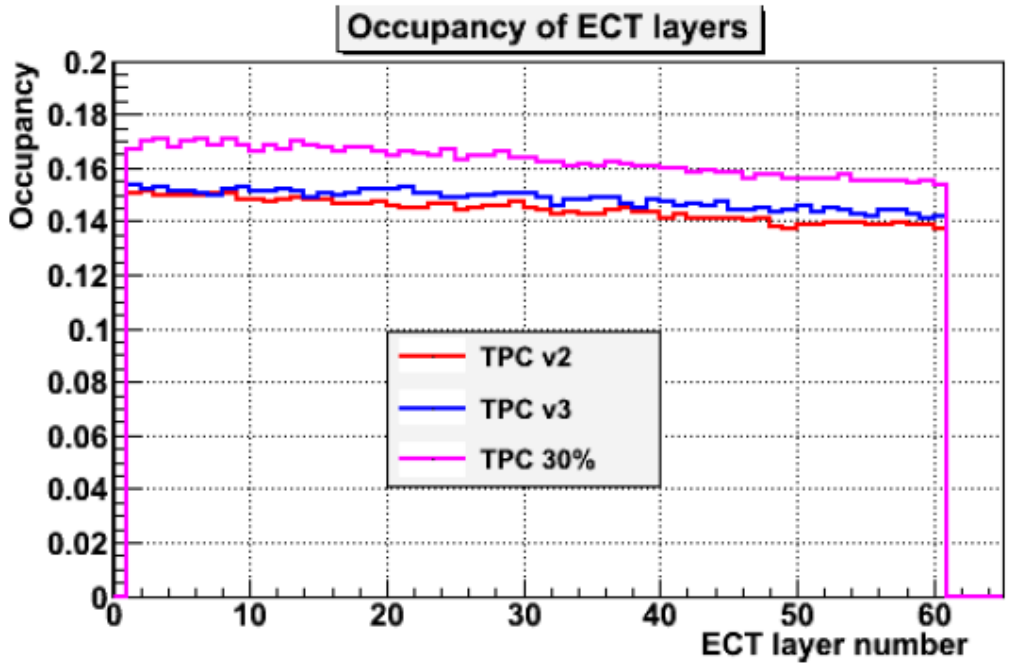
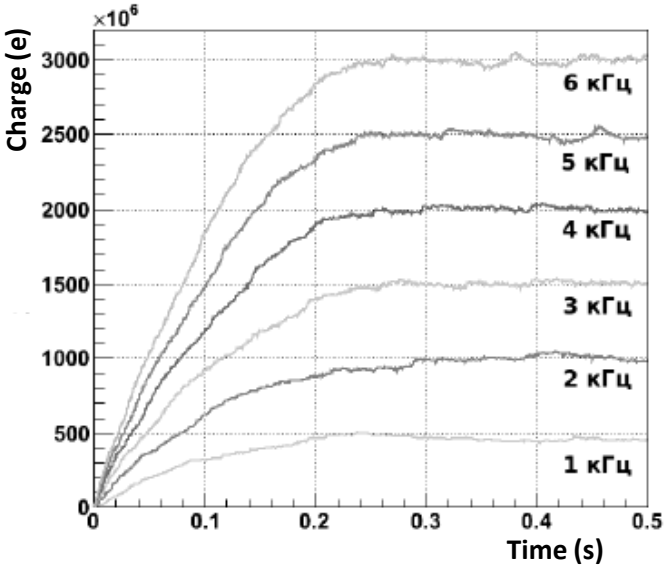
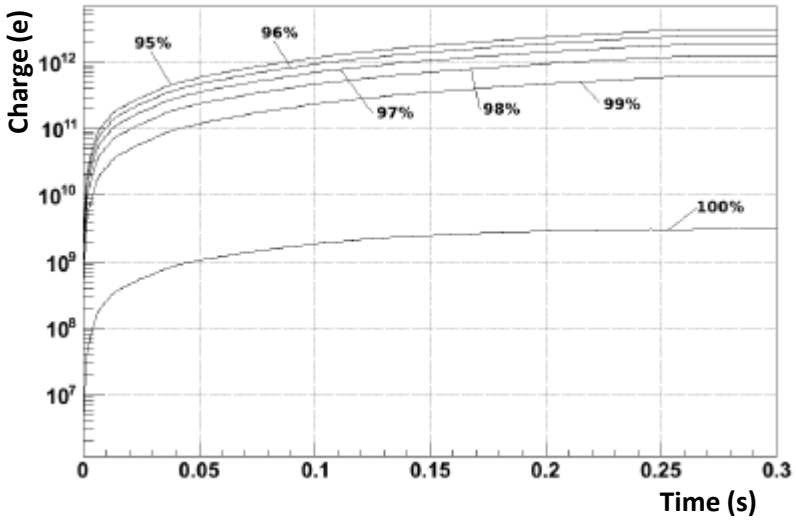


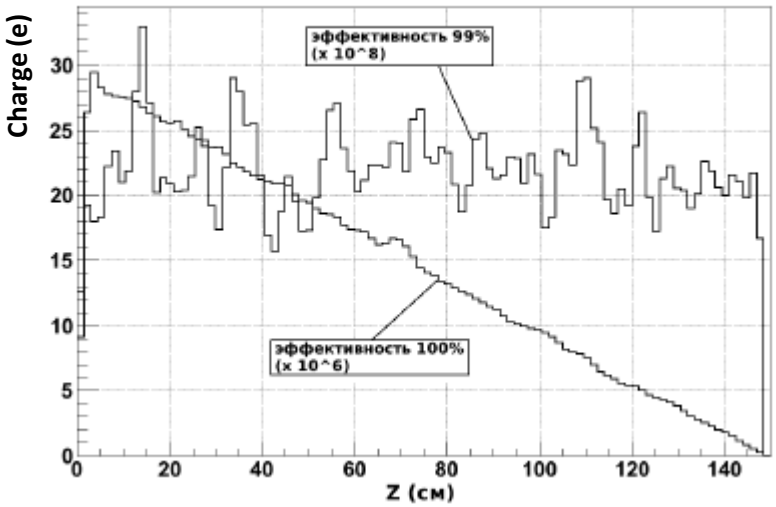
Fig. 9. *Occupancy in the ECT tracker for several TPC design options.*

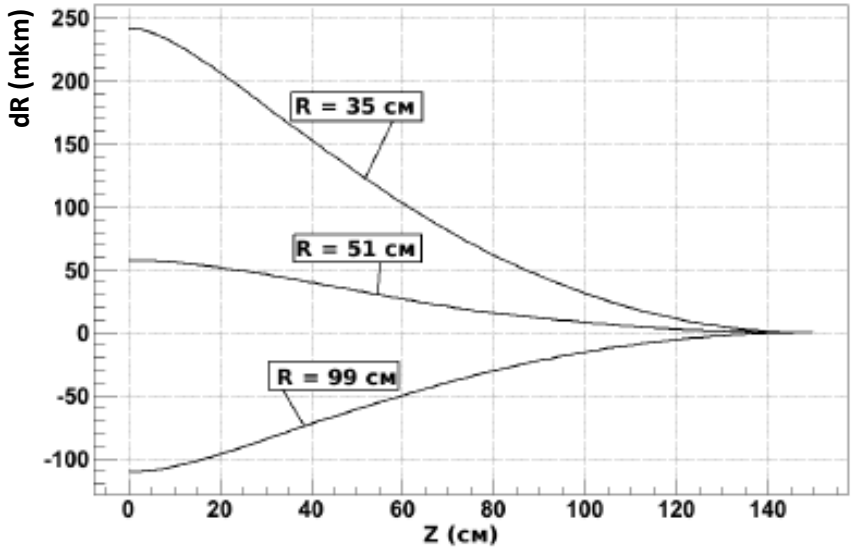
It should be noted that the amount of the material did not change significantly since the current TPC design has been implemented (in "v3"). In Fig. 9 the occupancy in different layers of the end-cap tracker (ECT) is shown for several TPC design options – v2, v3 and with the extra material. As one can see, even for the most conservative assumption (30% of radiation length in the end-plate and extra ~30% in support bars to account for some missing construction elements) the straw tube occupancy does not increase noticeably.

Positive charge pile-up

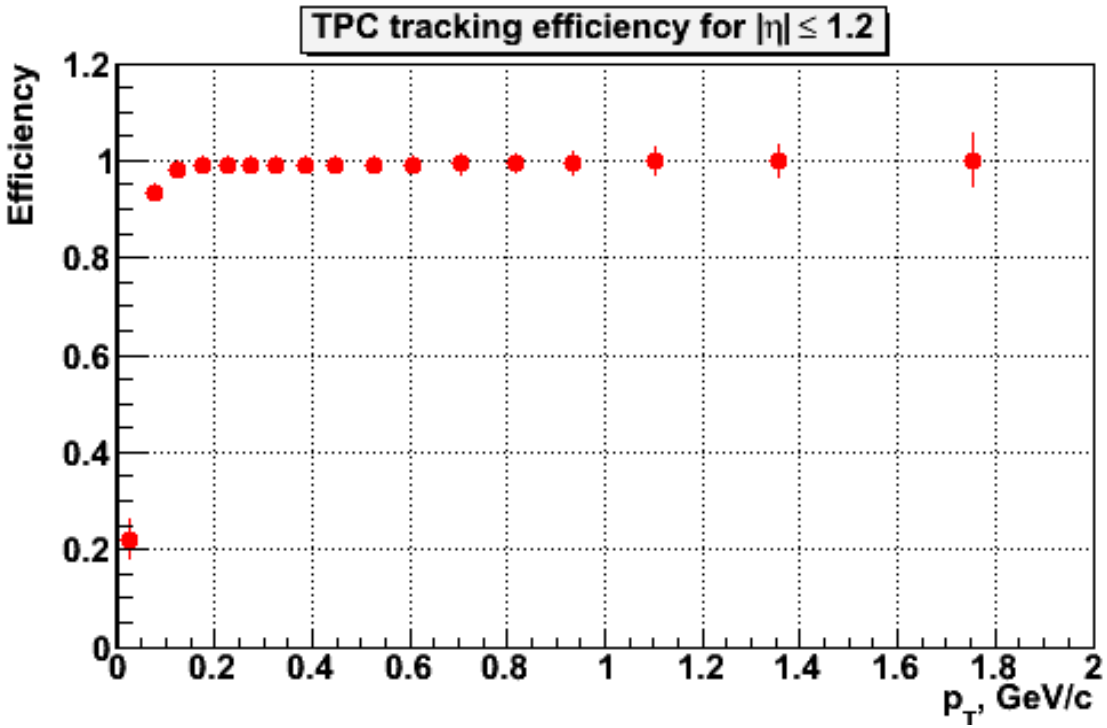








TRACKING EFFICIENCY

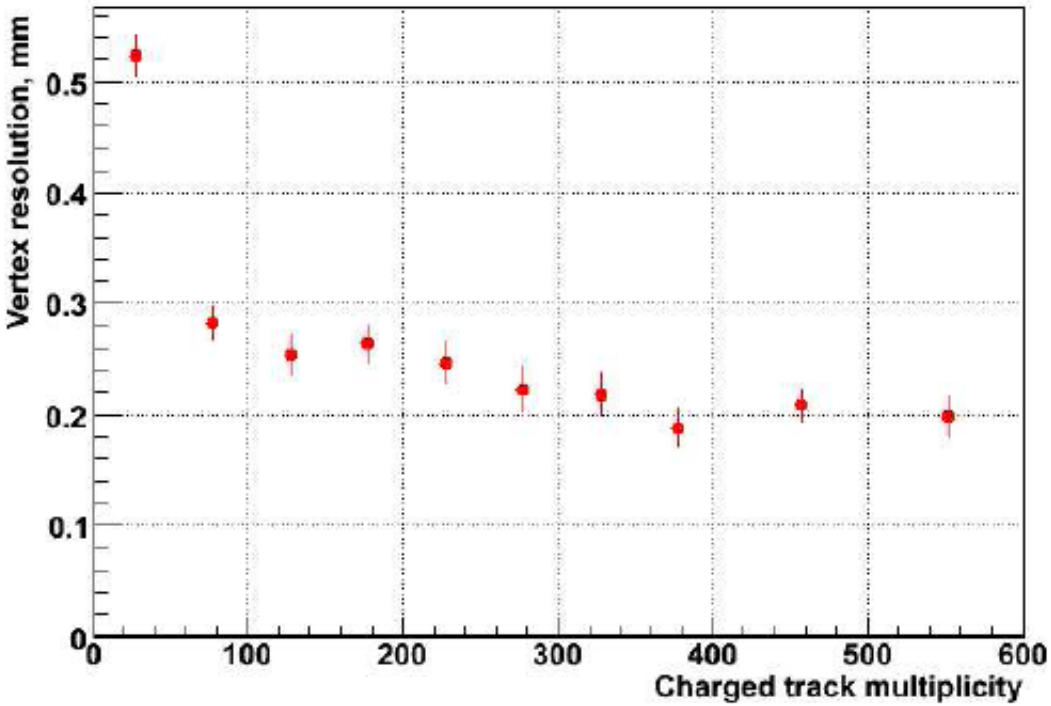


Tracking efficiency as a function of particle transverse momentum

No significant dependence on the transverse momentum

Efficiency drops rapidly below 200MeV/c ⇨ particle spiral up inside the TPC

VERTEX RESOLUTION

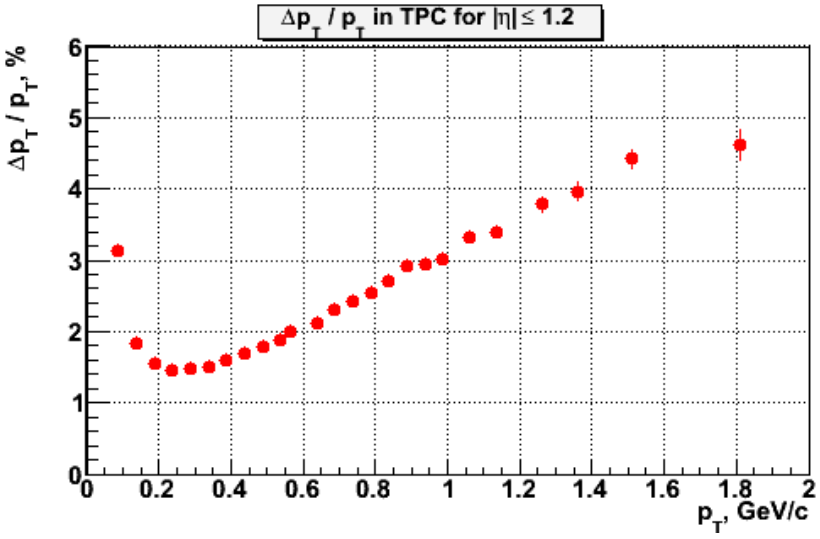


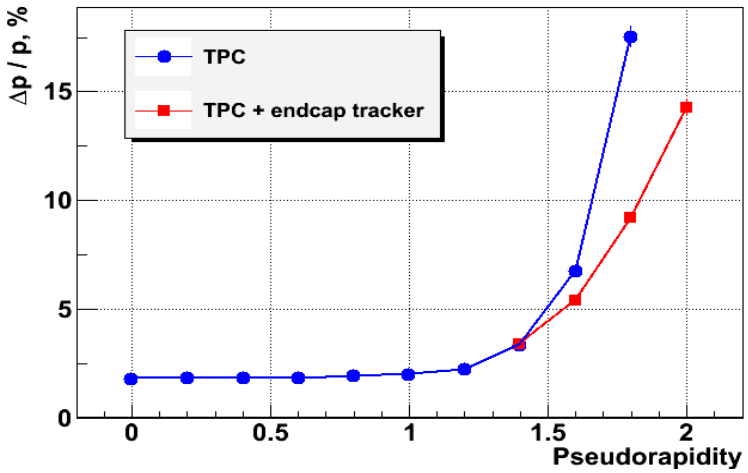
The primary vertex position resolution along the beam axis versus the reconstructed primary track multiplicity in TPC

The primary vertex resolution is found as the RMS of the distribution of the primary tracks extrapolation at the origin.
The global average of this distribution is the vertex position.

In the azimuth direction resolution is better, the value of 200µm is expected to be achieved

MOMENTUM RESOLUTION

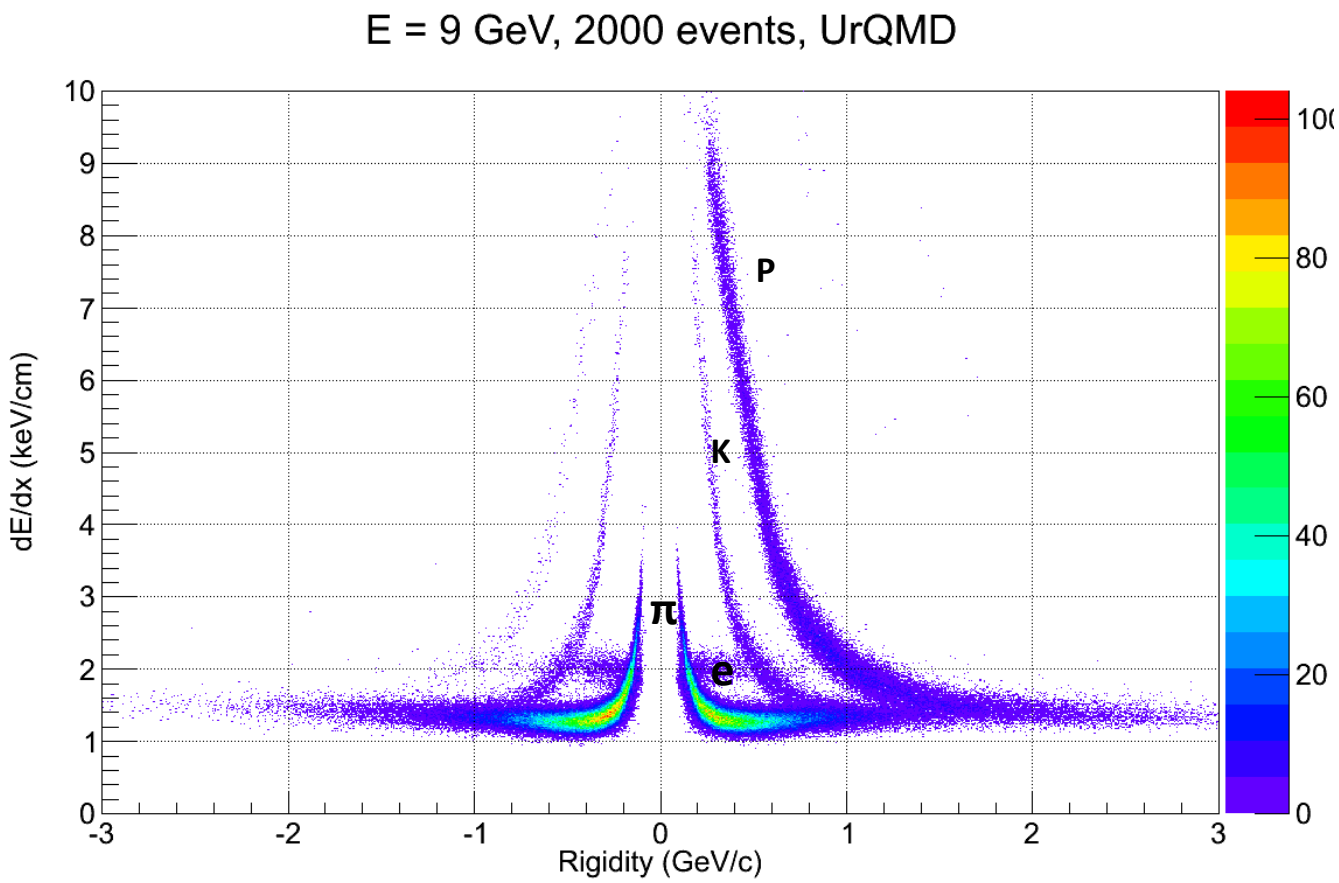




Charge particle transverse momentum resolution.

Relative momentum resolution Δp/p ~ 2-3% can be obtained in the momentum range up to 1 GeV/c

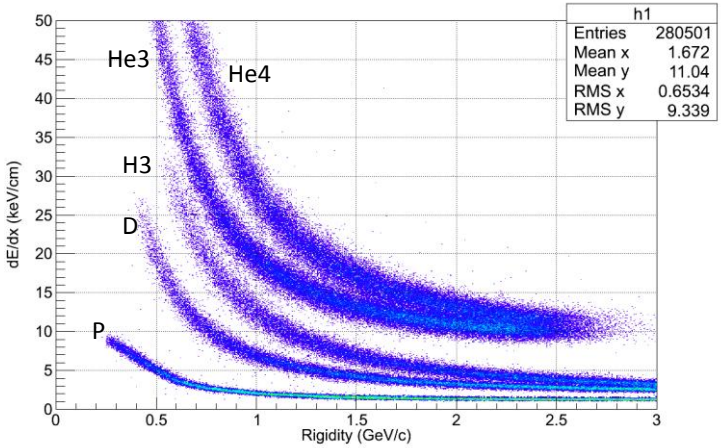
ENERGY LOSS

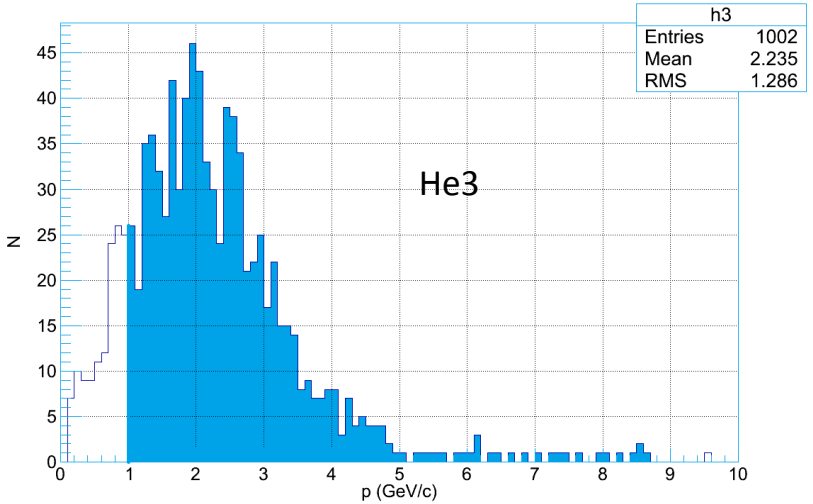


PID: Ionization loss (dE/dx)
Separation:
e/h – 1.3..3 GeV/c
π/K – 0.1..0.6 GeV/c
K/p – 0.1..1.2 GeV/c

The energy loss distribution in the MPD TPC

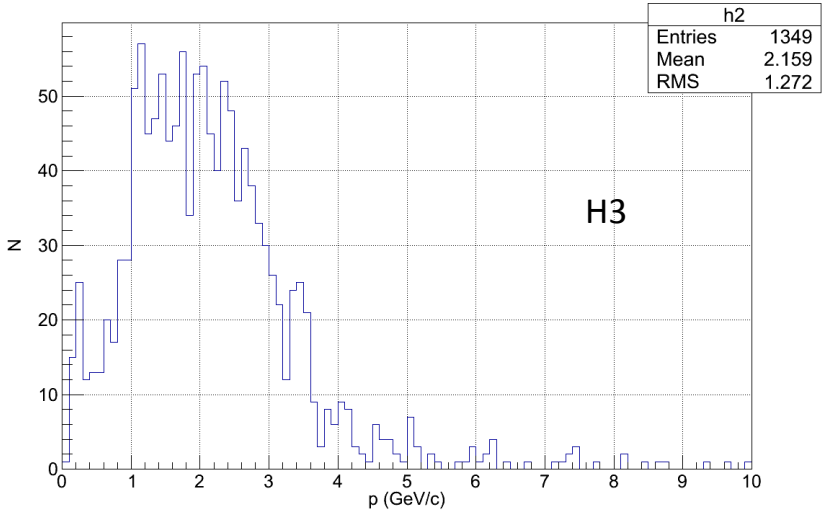
Light nuclei in TPC



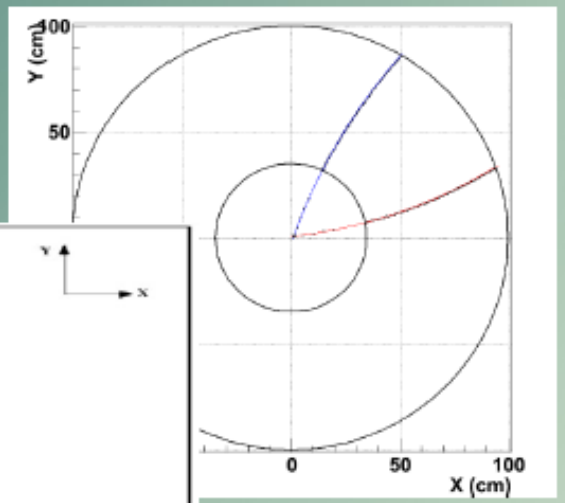


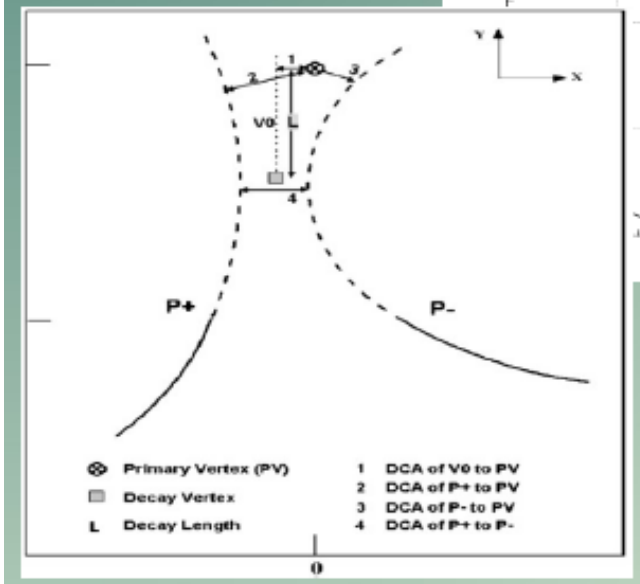
TPC FEE input full scale amplifier ~ 250 fC
It is ~ 30-40 MIP energy loss

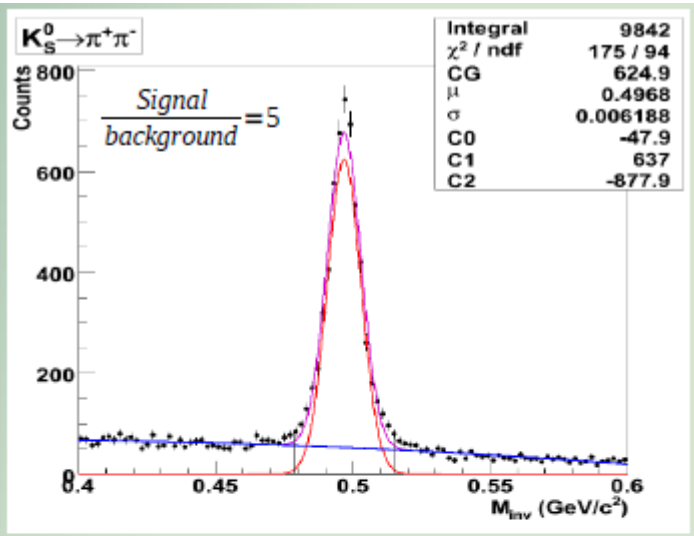
QGSM Au+Au central collision
9 GeV, b=1fm



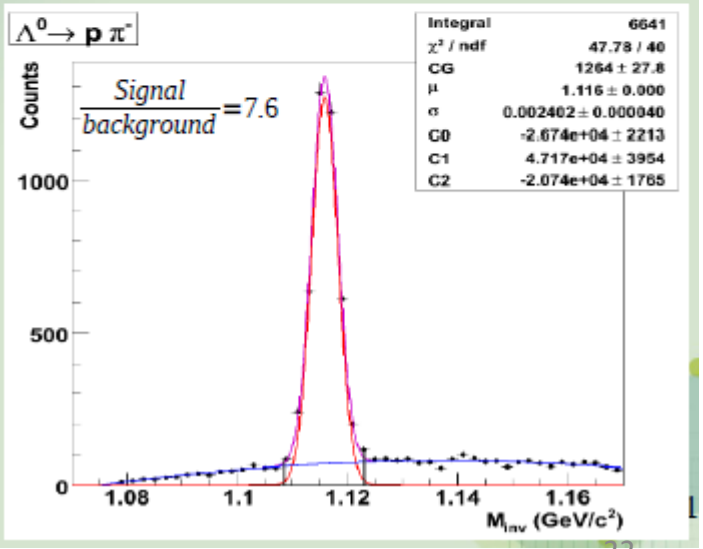
Strange particles reconstruction







UrQMD AuAu
√s = 9 GeV/u
b = 0 - 3
1000 events



DCA (cm)	Λ^0	K_s^0
Positive to primary vertex	>0.2	>0.2
Negative to primary vertex	>1.0	>0.2
Between daughters	<0.5	<0.5
Decay length	>0.5	>0.5

Hyperons

41529 central (0-3 fm) Au+Au @ 9 GeV

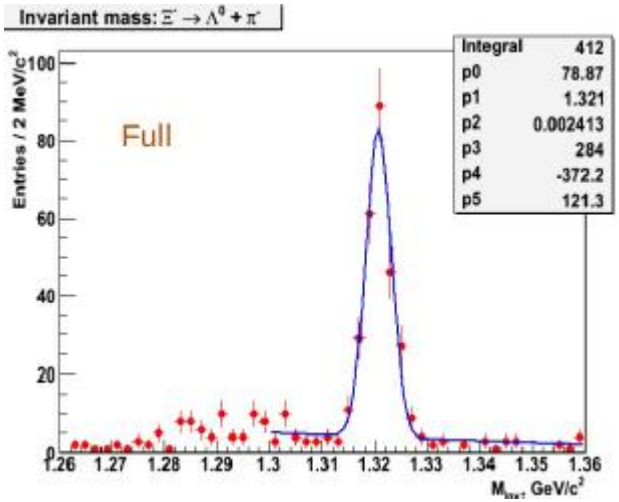
Track acceptance: in TPC with $|\eta| < 1.3$, $N_{hits} \geq 10$ & reaching outer TPC layer

"Perfect" particle ID

Ξ^- analysis (10k events)

Cut	+ ITS
Λ selection	As above
Mass$_\Lambda$	±3σ
DCA$^\Lambda_{PV}$, mm	> 1.5
χ^{2K}_{PV}	> 100
DCA$^K_{PV}$, mm	> 3.0
DCA$^{K\Lambda}_{\Xi}$, mm	< 1.5
DCA$^\Xi_{PV}$, mm	< 1.0
λ_Ξ, mm	> 10.0

With ITS:
Eff. = 3.8%
S / B (±3σ) = 245 / 18 ≈ 13.7
S / √(S+B) ≈ 15.1

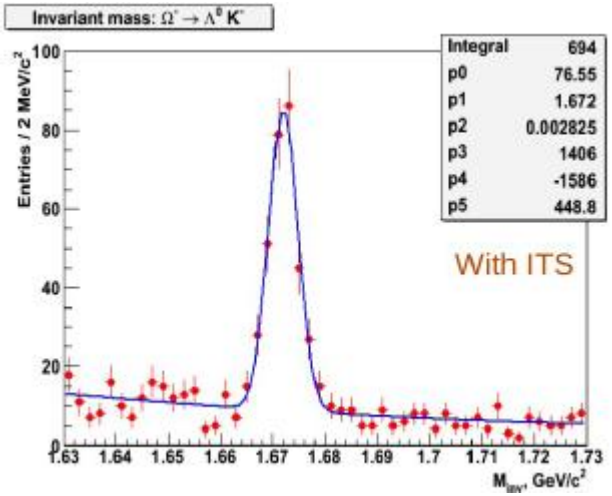


Ω^- analysis (200k events)

Cut	Only TPC	+ ITS
Λ selection	As above	As above
Mass$_\Lambda$	±3σ	±3σ
DCA$^\Lambda_{PV}$, mm	> 2.0	> 2.0
χ^{2K}_{PV}	> 10	> 26
DCA$^K_{PV}$, mm	> 5.0	> 2.0
DCA$^{K\Lambda}_{\Omega}$, mm	< 3.0	< 1.2
DCA$^\Omega_{PV}$, mm	< 2.5	< 5.0
λ_Ω, mm	> 10.0	> 10.0

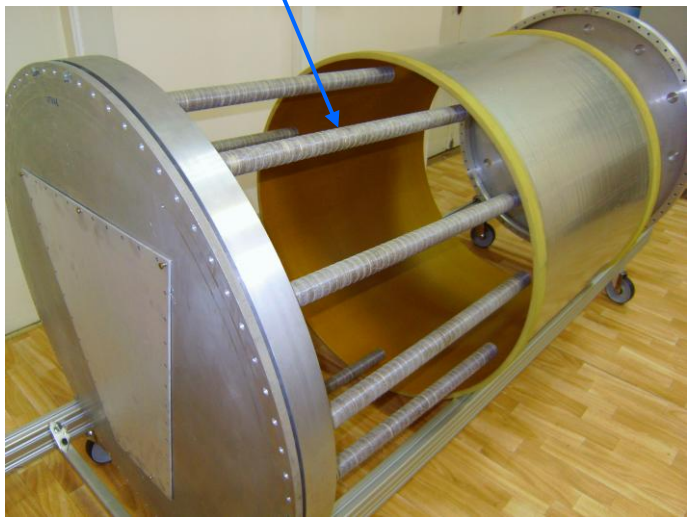
Only TPC:
Eff. ≈ 1.3%
S / B (±3σ) = 211 / 238 ≈ 0.9
S / √(S+B) ≈ 10.0

With ITS:
Eff. ≈ 2.1%
S / B (±3σ) = 286 / 59 ≈ 4.9
S / √(S+B) = 15.4



Technological Prototype of TPC / MPD developed with industry

Field Cage Rods

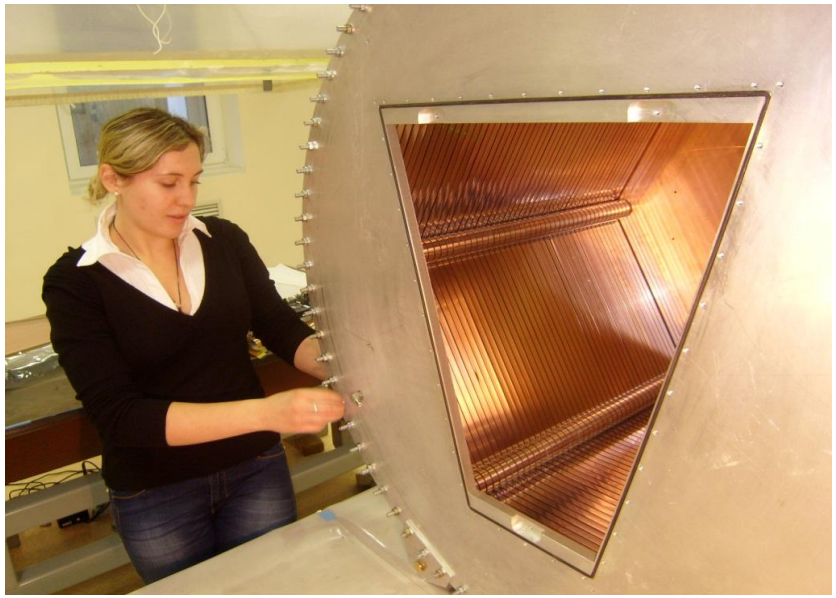


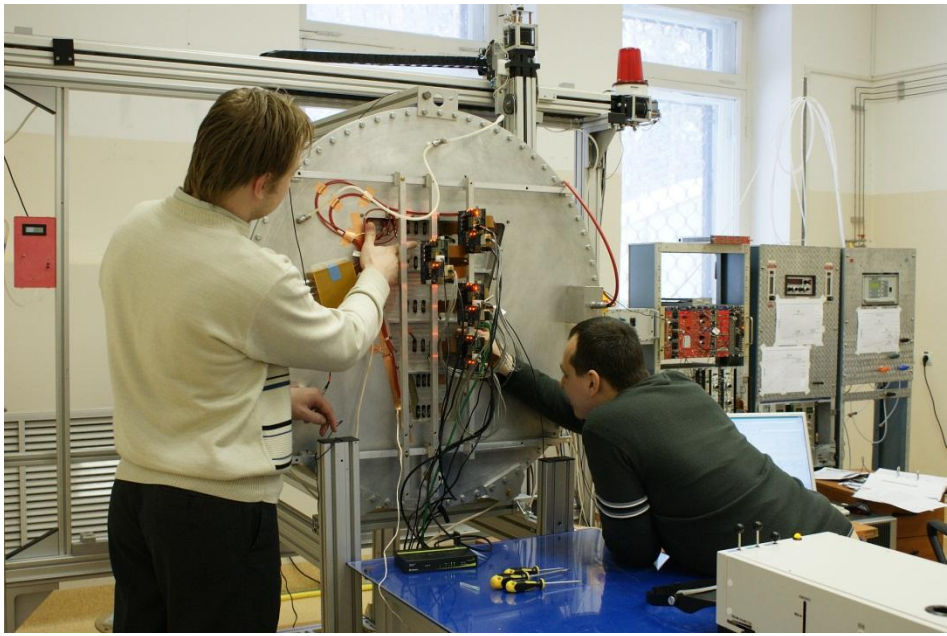
Assembling of the Prototype with Field Cage

Diameter - 950 mm
Length - 900 mm
Wall thickness - 2 mm
Weight ~ 9 kg

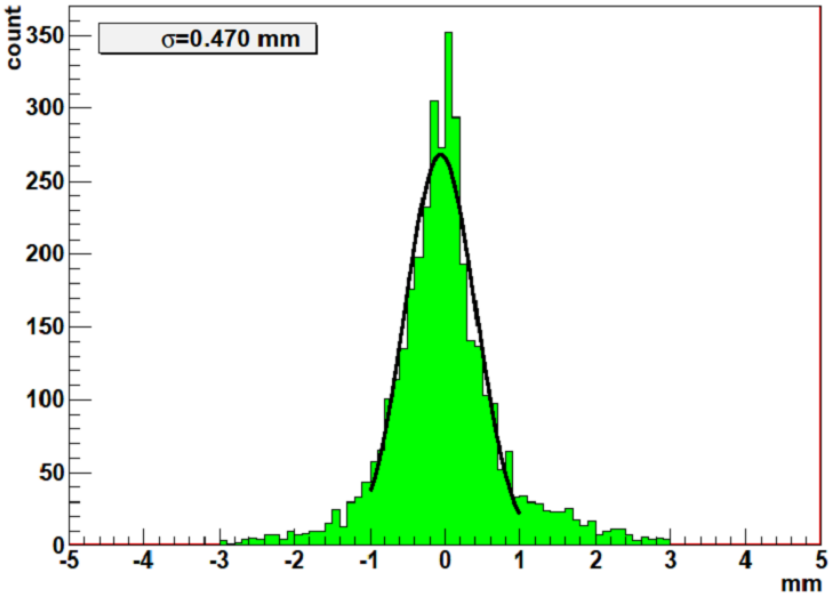
Material:
Kevlar laminated by Tedlar film

TPC prototype : field cage and laser system

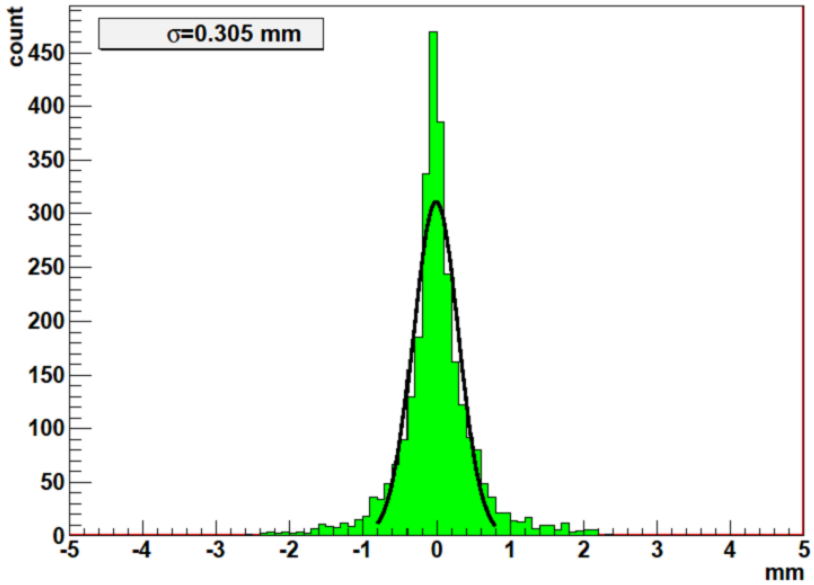




Prototype test with cosmic ray and UV laser



Space resolution for cosmic tracks



Space resolution for UV laser beam

FEE for TPC/MPD

PASA and ALTRO chips are using for prototyping and are considered as an option for TPC FFE

Number of channels	80 000
Full scale amplifier input	250 fC
Noise (ENC)	< 1000 e-
Conversion gain	~ 10 mV/fC
Crosstalk	< 0,3%
Shaping time	~ 180 ns
Sampling rate	12.5 MHz
Signal dynamical range	10 bits
Tail correction after 1 μs	~ 0,1%
Power consumption	~ 25 mW/channel

Summary

The MPD TPC is adapted for heavy ion physics at centre of mass energies 3-11 GeV/nucleon and meet all requirements for this .

Low TPC material budget in barrel and end caps is consistent with current MPD setup.

Design and construction of TPC parts in industry are in progress.

Technological Prototype TPC (with RoC, Pad Plane and 256 channels FEE) is under testing with UV laser and cosmic rays.

Thank you for attention