Multi Purpose Detector for NICA

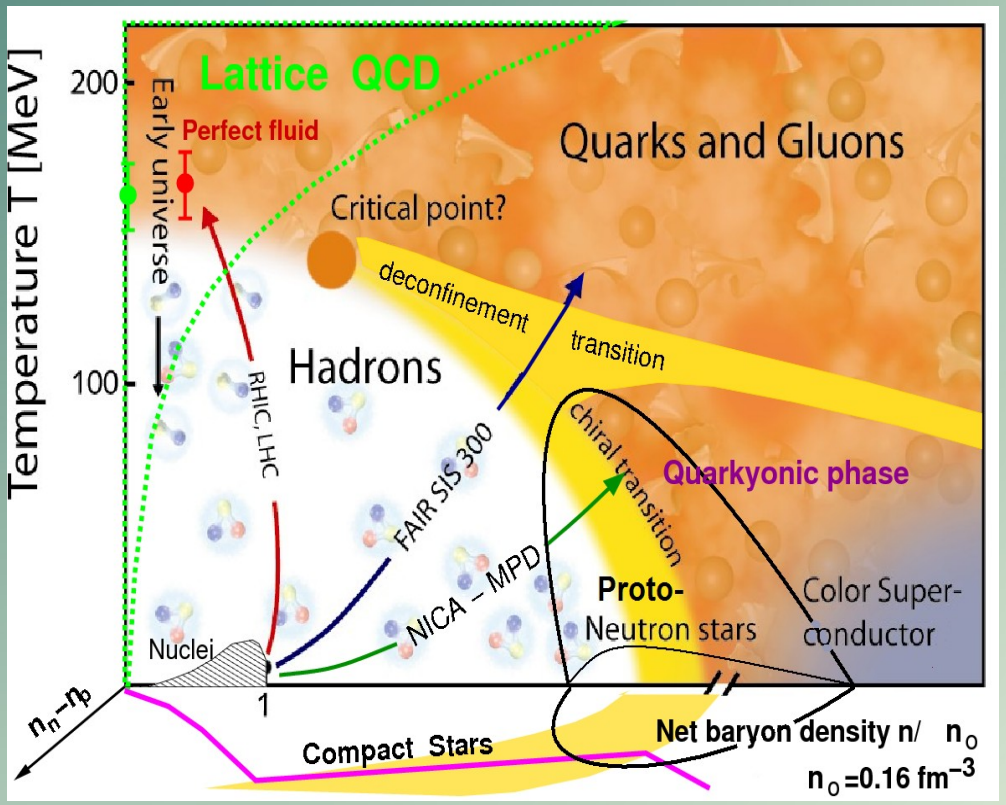
Rogachevsky Oleg

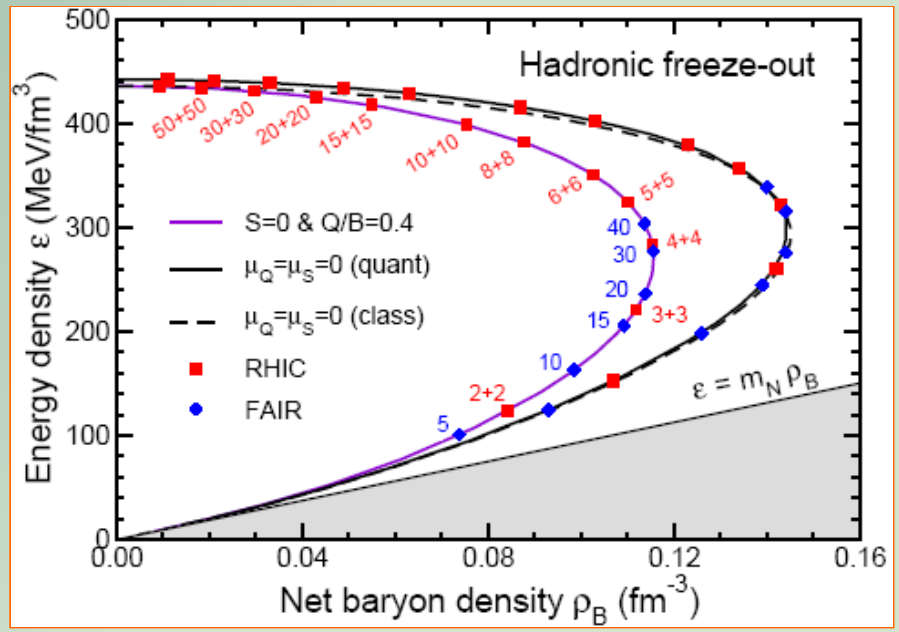
for MPD collaboration

CPOD 2010

Dubna

Physics problem





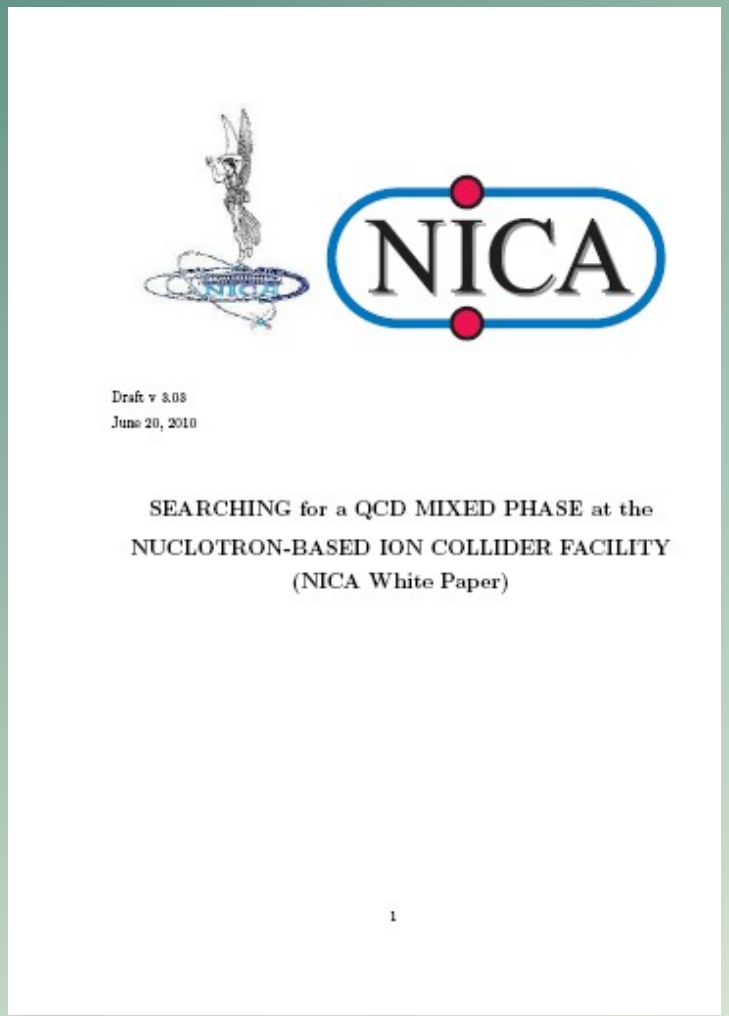
J. Randrup and J. Cleymans,

Phys. Rev. C74, 047901 (2006).

Study of in-medium properties of hadrons and nuclear matter equation of state, including a search for possible signs of deconfinement and/or chiral symmetry restoration phase transitions and QCD critical endpoint

NICA White Paper

http://theor.jinr.ru/twiki-cgi/view/NICA/WebHome



I. General aspects

II. Phases of QCD matter at high baryon density

III. Femtoscopy, correlations and fluctuations

IV. Mechanisms of multi-particle production

V. Electromagnetic probes and chiral symmetry in dense QCD matter

VI. Local P and CP violation in hot QCD matter

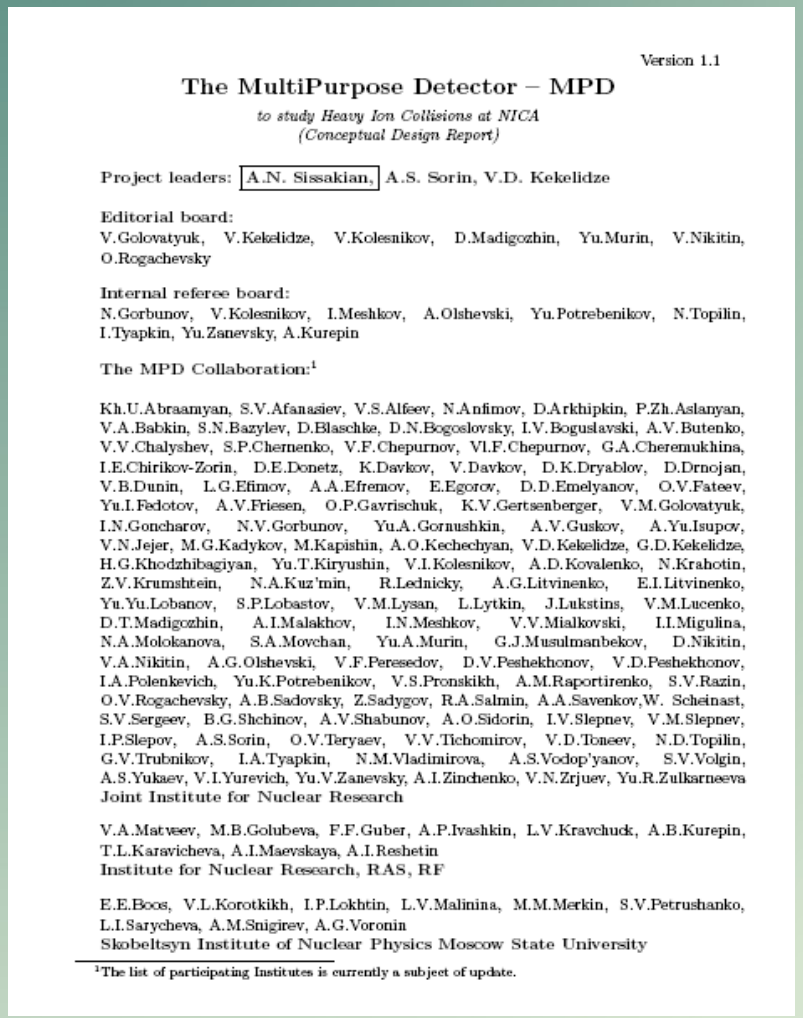
VII. Cumulative processes

VIII. Polarization effects and spin physics

IX. Related topics

MPD Conceptual Design Report

http://nica.jinr.ru



Version 1.1

The MultiPurpose Detector – MPD

to study Heavy Ion Collisions at NICA
(Conceptual Design Report)

Project leaders: A.N. Sissakian, A.S. Sorin, V.D. Kekelidze

Editorial board:
V.Golovatyuk, V.Kekelidze, V.Kolesnikov, D.Madigozhin, Yu.Murin, V.Nikitin, O.Rogachevsky

Internal referee board:
N.Gorbunov, V.Kolesnikov, I.Meshkov, A.Olshevski, Yu.Potrebenikov, N.Topilin, I.Tyapkin, Yu.Zanevsky, A.Kurepin

The MPD Collaboration:[1]

Kh.U.Abraamyan, S.V.Afanasiev, V.S.Alfeev, N.Anfimov, D.Arkhipkin, P.Zh.Aslanyan, V.A.Babkin, S.N.Bazylev, D.Blaschke, D.N.Bogoslovsky, I.V.Boguslavski, A.V.Butenko, V.V.Chalyshev, S.P.Chernenko, V.F.Chepurnov, Vl.F.Chepurnov, G.A.Cheremukhina, I.E.Chirikov-Zorin, D.E.Donetz, K.Davkov, V.Davkov, D.K.Dryablov, D.Drnojan, V.B.Dunin, L.G.Efimov, A.A.Efremov, E.Egorov, D.D.Emelyanov, O.V.Fateev, Yu.I.Fedotov, A.V.Friesen, O.P.Gavrischuk, K.V.Gertsenberger, V.M.Golovatyuk, I.N.Goncharov, N.V.Gorbunov, Yu.A.Gornushkin, A.V.Guskov, A.Yu.Isupov, V.N.Jejer, M.G.Kadykov, M.Kapishin, A.O.Kechechyan, V.D.Kekelidze, G.D.Kekelidze, H.G.Khodzhibagiyan, Yu.T.Kiryushin, V.I.Kolesnikov, A.D.Kovalenko, N.Krahotin, Z.V.Krumshtein, N.A.Kuz'min, R.Lednicky, A.G.Litvinenko, E.I.Litvinenko, Yu.Yu.Lobanov, S.P.Lobastov, V.M.Lysan, L.Lytkin, J.Lukstins, V.M.Lucenko, D.T.Madigozhin, A.I.Malakhov, I.N.Meshkov, V.V.Mialkovski, I.I.Migulina, N.A.Molokanova, S.A.Movchan, Yu.A.Murin, G.J.Musulmanbekov, D.Nikitin, V.A.Nikitin, A.G.Olshevski, V.F.Peresedov, D.V.Peshekhonov, V.D.Peshekhonov, I.A.Polenkevich, Yu.K.Potrebenikov, V.S.Pronskikh, A.M.Raportirenko, S.V.Razin, O.V.Rogachevsky, A.B.Sadovsky, Z.Sadygov, R.A.Salmin, A.A.Savenkov,W. Scheinast, S.V.Sergeev, B.G.Shchinov, A.V.Shabunov, A.O.Sidorin, I.V.Slepnev, V.M.Slepnev, I.P.Slepov, A.S.Sorin, O.V.Teryaev, V.V.Tichomirov, V.D.Toneev, N.D.Topilin, G.V.Trubnikov, I.A.Tyapkin, N.M.Vladimirova, A.S.Vodop'yanov, S.V.Volgin, A.S.Yukaev, V.I.Yurevich, Yu.V.Zanevsky, A.I.Zinchenko, V.N.Zrjuev, Yu.R.Zulkarneeva
Joint Institute for Nuclear Research

V.A.Matveev, M.B.Golubeva, F.F.Guber, A.P.Ivashkin, L.V.Kravchuck, A.B.Kurepin, T.L.Karavicheva, A.I.Maevskaya, A.I.Reshetin
Institute for Nuclear Research, RAS, RF

E.E.Boos, V.L.Korotkikh, I.P.Lokhtin, L.V.Malinina, M.M.Merkin, S.V.Petrushanko, L.I.Sarycheva, A.M.Snigirev, A.G.Voronin
Skobeltsyn Institute of Nuclear Physics Moscow State University

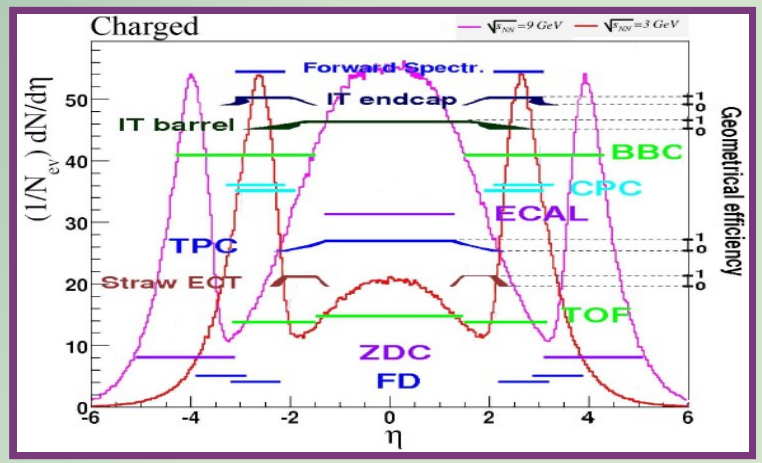
[1]The list of participating Institutes is currently a subject of update.

1. MPD Physics Goals
2. MPD Concept
3. Trigger, DAQ and Computing
4. Integration and Services
5. Simulation and Detector Performance
6. Physics Performance
7. MPD Project Cost and Timelines

MPD tasks

The NICA/MPD project is aimed to study of hot & dense baryonic matter at A=1–197, $\sqrt{S_{NN}}$ = 4 – 11 GeV/u, L = 10^{27} $cm^{-2}s^{-1}$

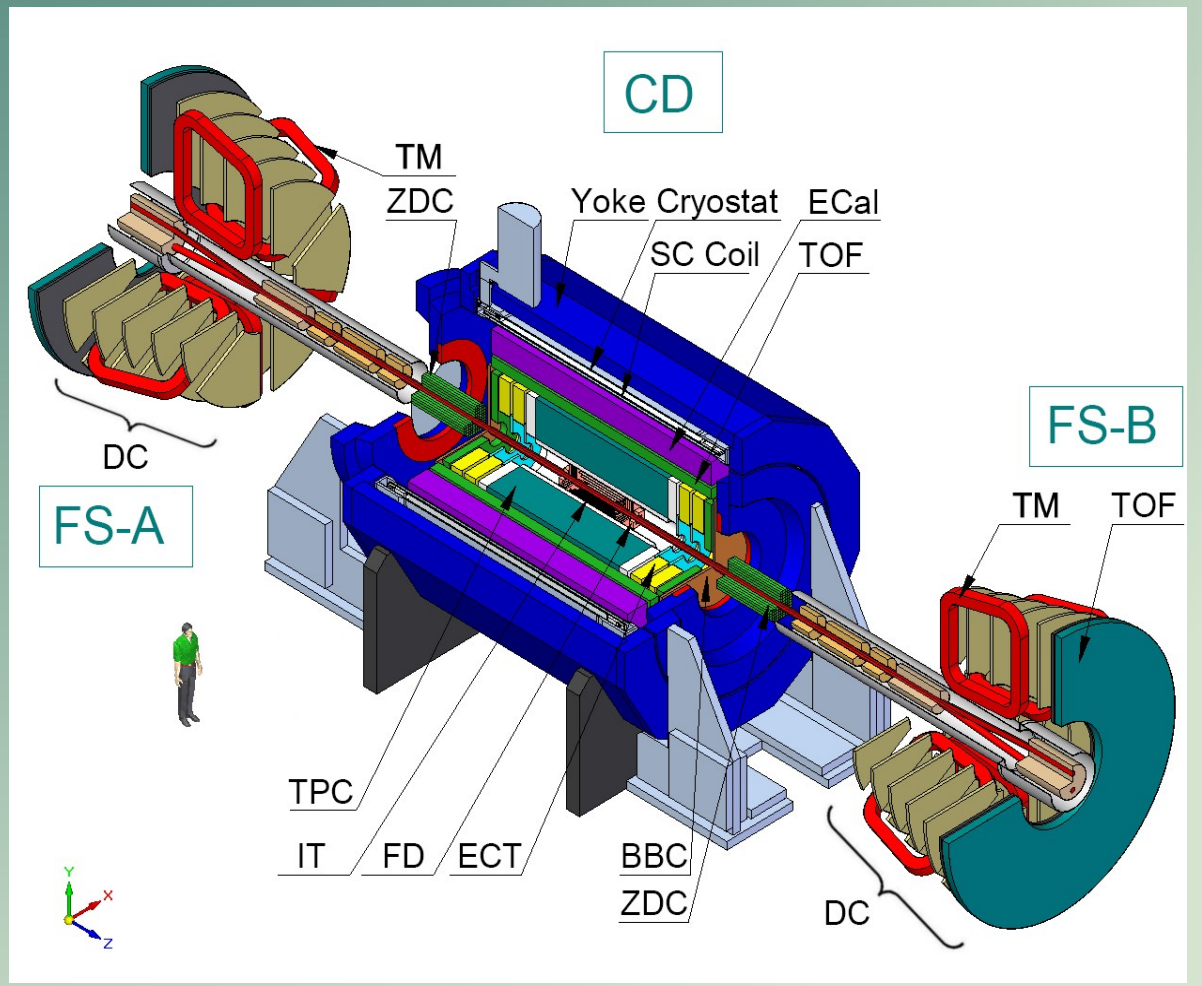
- bulk observables (hadrons):
  4π particle yields
- multi-strange hyperon production :
  yields & spectra
- electromagnetic probes
- event-by-event fluctuation in
  hadron productions
- correlations involving π, K, p
- directed & elliptic flows for
  identified hadrons



Particle yields in Au+Au collisions $\sqrt{s_{NN}}$ = 7.1 GeV
Luminosity L = $10^{27}cm^{-2}s^{-1}$ Event rate (central) 700 Hz

Particle (mass)	Multi-plicity	decay mode	BR	ε (%)	yield (s^{-1})	yield 10w
K^+ (494)	55	--	--	20	$7.7\cdot10^3$	$4.6\cdot10^{10}$
K^- (494)	16	--	--	20	$2.2\cdot10^3$	$1.3\cdot10^{10}$
ρ (770)	23.6	e^+e^-	$4.7\cdot10^{-5}$	2	$1.6\cdot10^{-2}$	$9.4\cdot10^4$
ω (782)	14.2	e^+e^-	$7.1\cdot10^{-5}$	2	$1.4\cdot10^{-2}$	$8.6\cdot10^4$
φ (1020)	2.7	e^+e^-	$3\cdot10^{-4}$	2	$1.1\cdot10^{-2}$	$6.8\cdot10^4$
Ξ^- (1321)	2.4	$\Lambda\pi^-$	1	4	67	$4.0\cdot10^8$
Ω^- (1672)	0.16	ΛK^-	0.68	2	1.5	$9.2\cdot10^6$
D^0 (1864)	$7.5\cdot10^{-4}$	$K^+\pi^-$	0.038	1	$2.0\cdot10^{-4}$	1200
J/ψ (3097)	$3.8\cdot10^{-5}$	e^+e^-	0.06	5	$8.0\cdot10^{-5}$	480

MPD design



1-st stage

barrel part

Magnet, TPC, TOF, Ecal,

ZDC, FFD, BBC …

2-nd stage

IT, ECT ...

3-d stage

FS (optional ?)

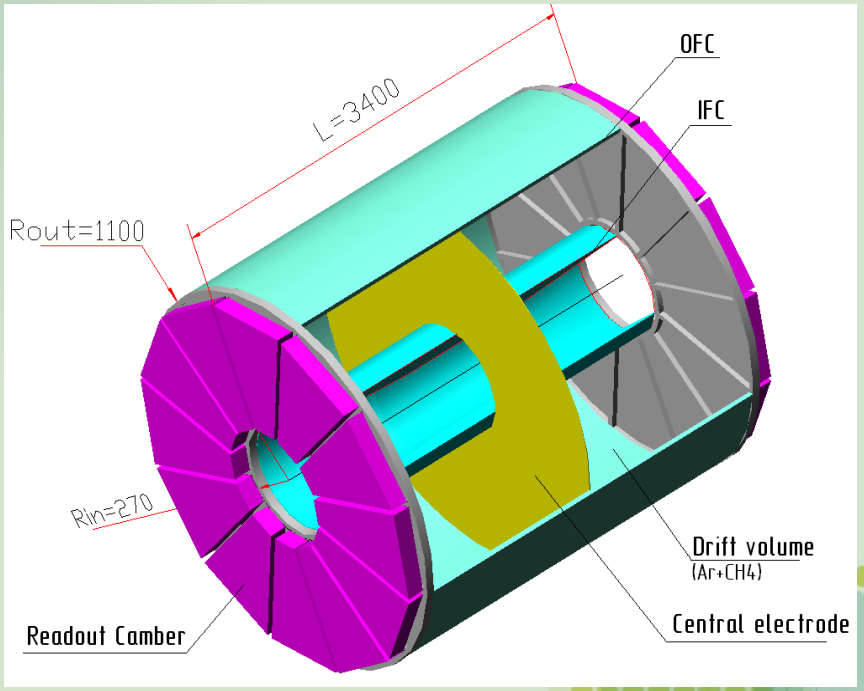
...

TPC design

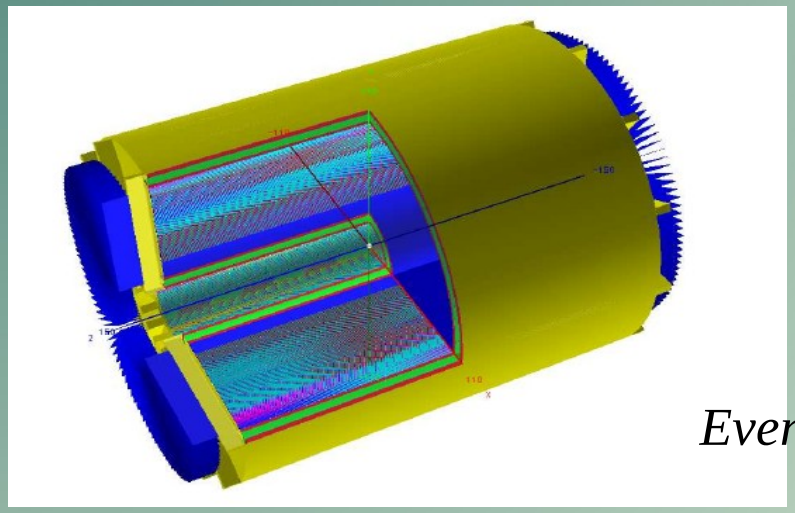
Item	Dimension
Length of the TPC	340cm
Outer radius	110cm
Inner radius	27cm
Outer radius of the drift volume	100cm
Inner radius of the drift volume	35cm
Length of the drift volume	150cm (of each half)
Cathode	Membrane at the center of the TPC
Electric field strength	~140 V/cm
Magnetic field strength	0.5 Tesla
Drift gas	90% Ar+10% Methane at Atmospheric + 2 mbar
Drift velocity	5.45 cm/μs
Drift time	$\sim 28\mu$s
Transverse diffusion	230 $\mu m/\sqrt{cm}$ at magnetic field 0.5 Tesla
Longitudinal diffusion	360 $\mu m/\sqrt{cm}$
Number of readout chambers	24 (12 per end plate)
Multiplisity (central collision)	~ 800
Number of pads	~ 80000
Pad numbers after zero suppression	$< 10\%$
Pad size	4x10 mm in inner sector area 6×12 in outer sector area
Spatial resolution	$\sigma z \sim 1$ mm, $\sigma x \sim 0.6$ mm, $\sigma y \sim 0.8$ mm
$\Delta E/dX$ resolution	$\sim 8\%$ (75 samples× 2 cm)
Maximum rate	$\sim 5-6$ kHz (Lum. 10^{27}cm^{-2}s^{-1})
Electronics shaping time	~180 ns (FWHM)
Signal to noise ratio	20:1
Signal dynamical range	10 bits
Sampling rate	12.5 MHz
Sampling depth	350 time buckets

Requirements

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

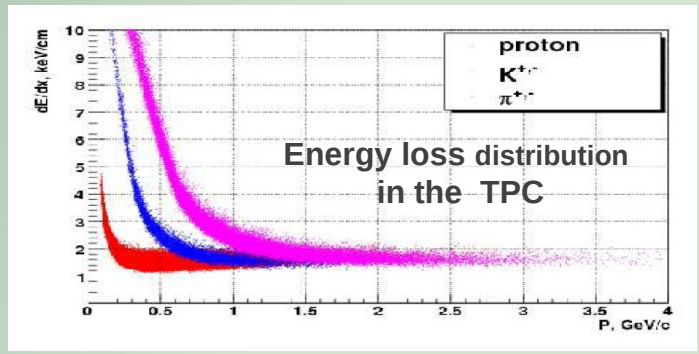


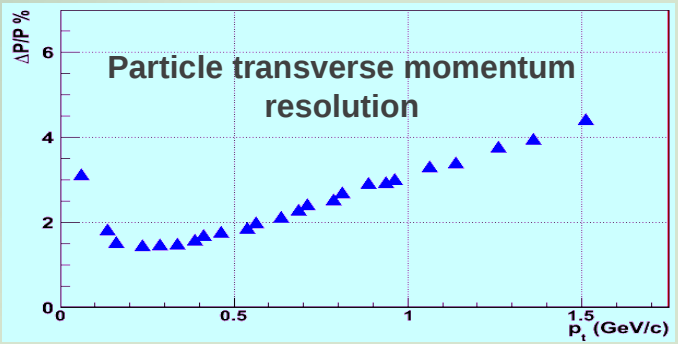
TPC performance

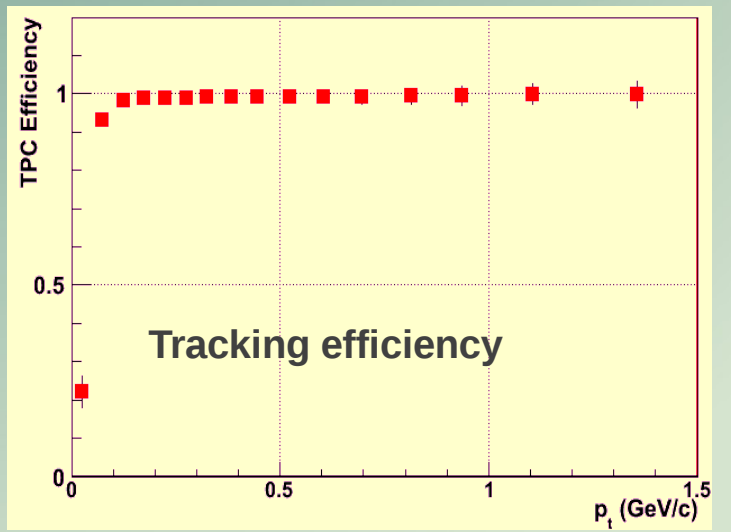


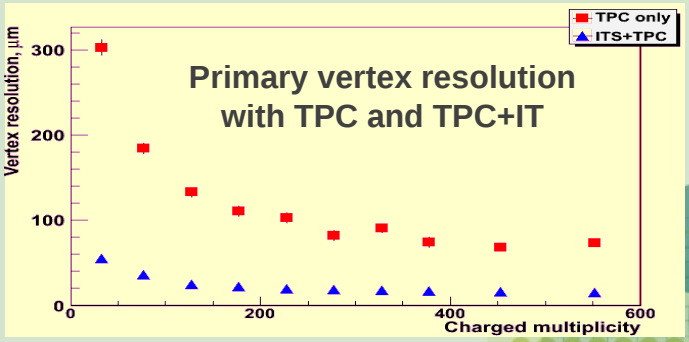
$|\eta| \leqslant 1$

$Event\ \ rate \approx 7\ kHz$

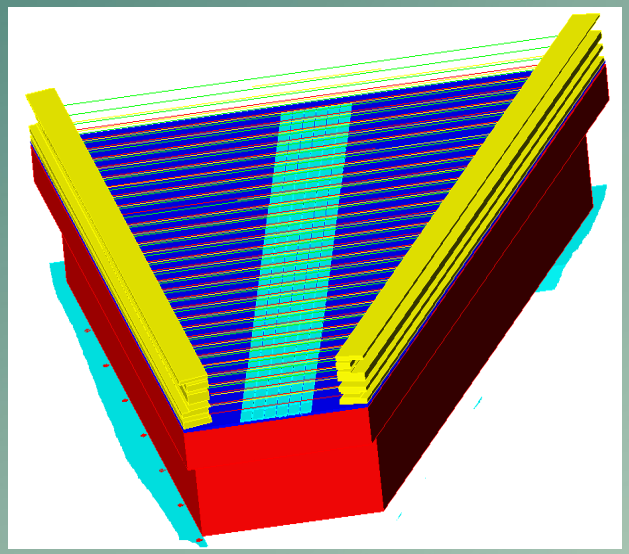


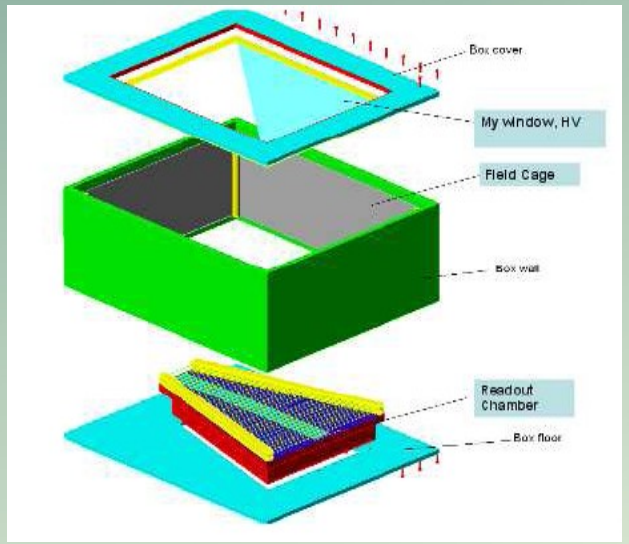






TPC prototype





Pad Plane:

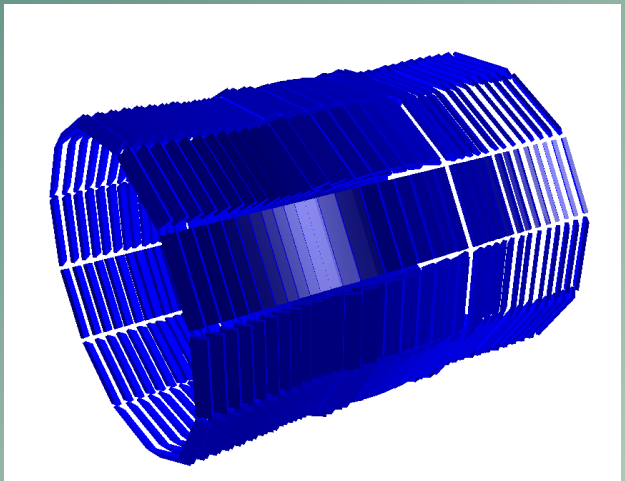
- **Two sets of 4x10 mm and 6x12 mm pads**
- **256 channels of readout electronics**

Electric field – 140 v/см

Drift distance – 40 см

TOF performance

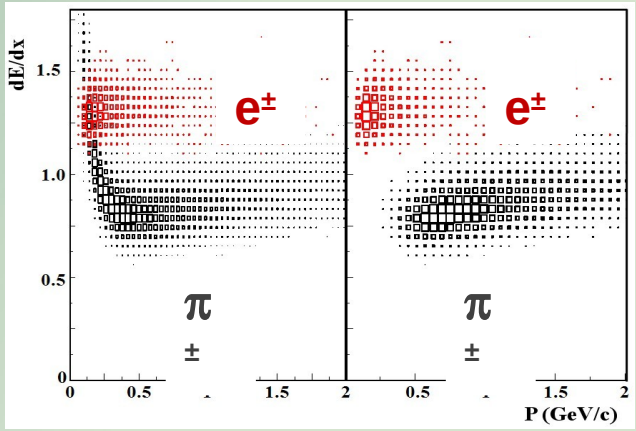
Multigap RPC



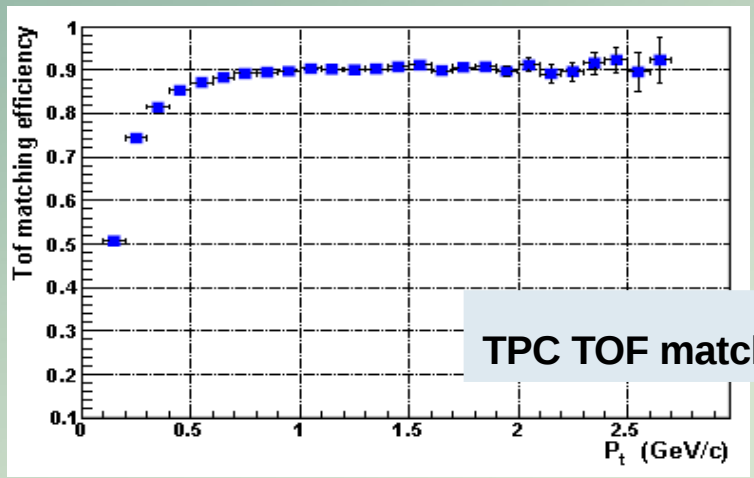
$$|\eta| \leqslant 1.2$$
$$\sigma_{ToF} = 100\ ps$$

$$m^2 = p^2\left(\frac{c^2T^2}{L^2} - 1\right)$$

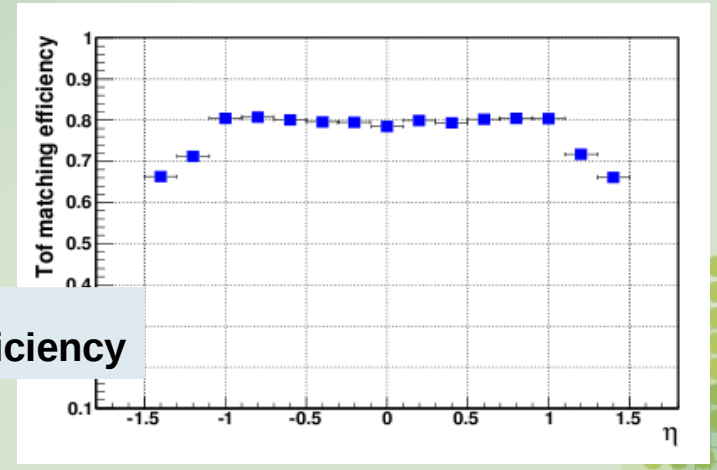
e/π separation efficiency



TPC dE/dx + TOF information improve e/π separation

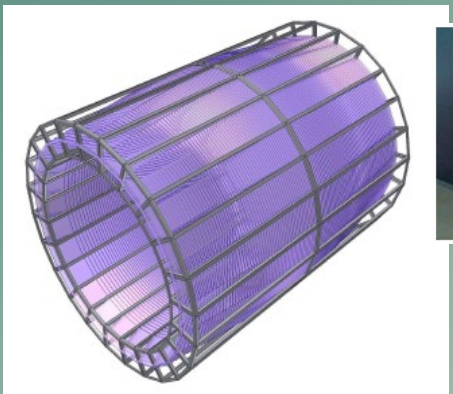


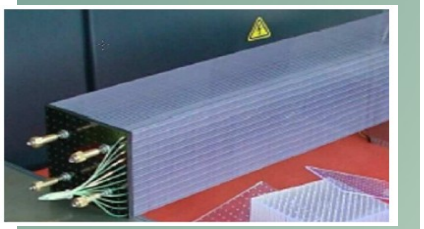
TPC TOF matching efficiency



EMC performance

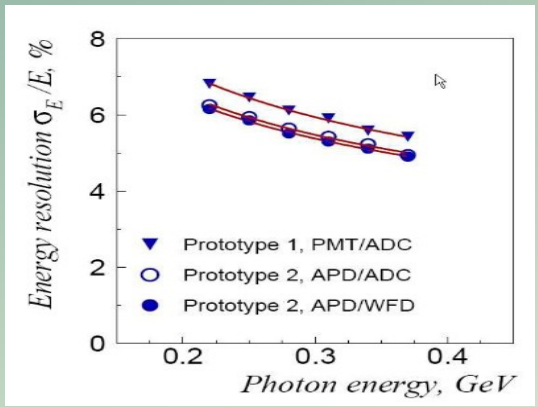
n/γ separation efficiency

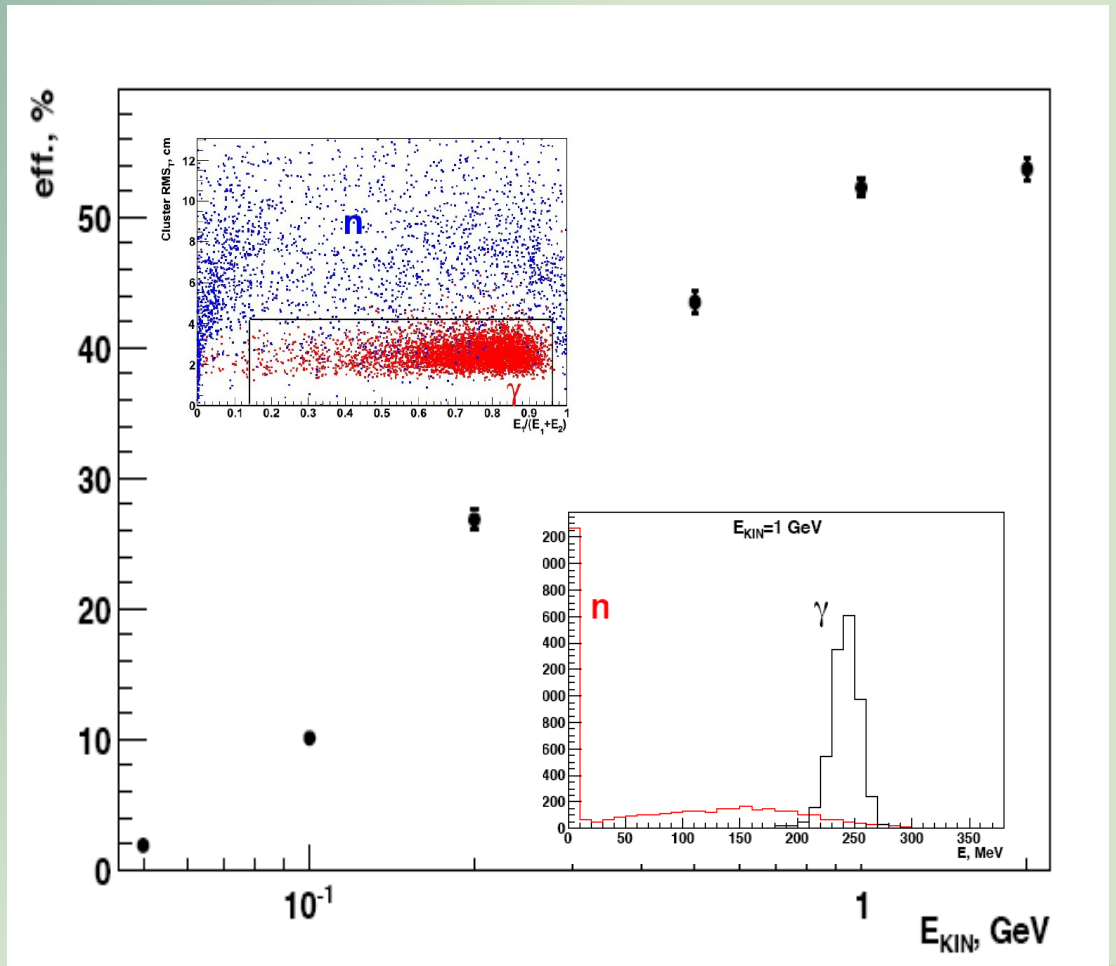




$\sim 18X_0$

$$\sigma(E)/E = (1.96 \pm 0.1)\% \otimes (2.74 \pm 0.05)\%/\sqrt{(E)(GeV)},$$

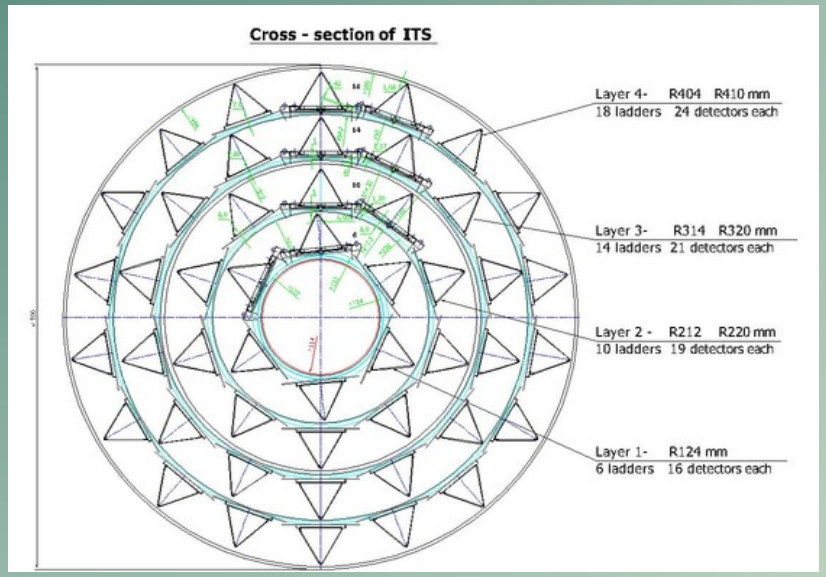


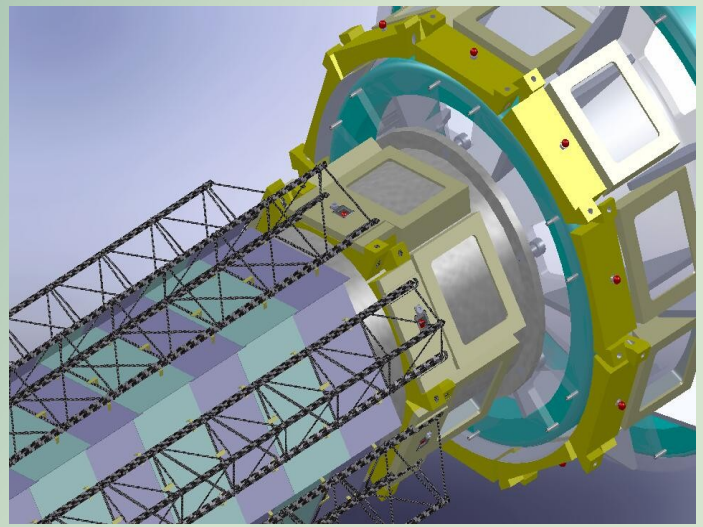


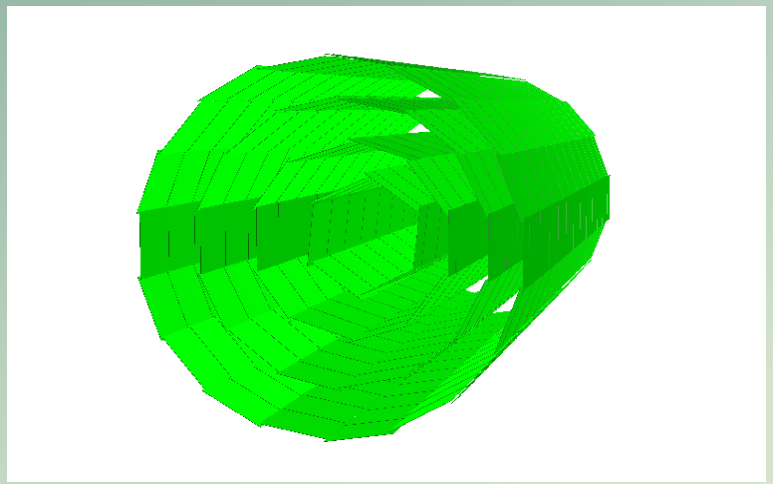
Efficiency of neutron identification - 95% with 3% of photon contamination

ITS progress

Important for strange particles and hyperons study



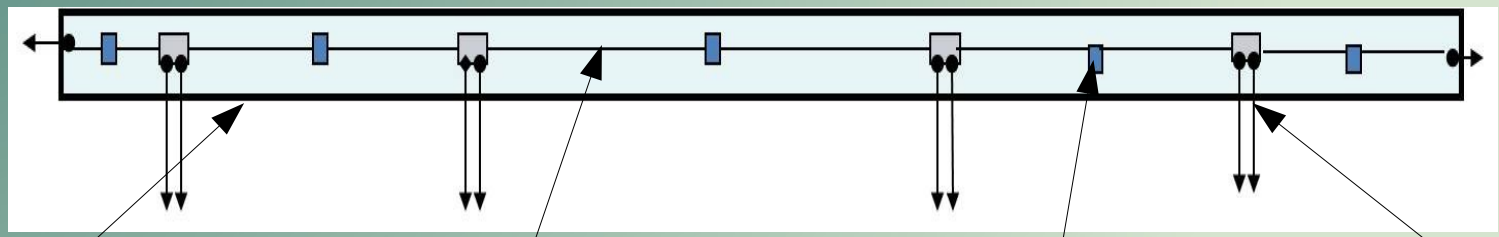




Results for physics analyses will be shown later

ECT progress

Granulated thin walled drift tubes

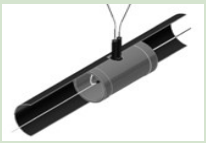


straw

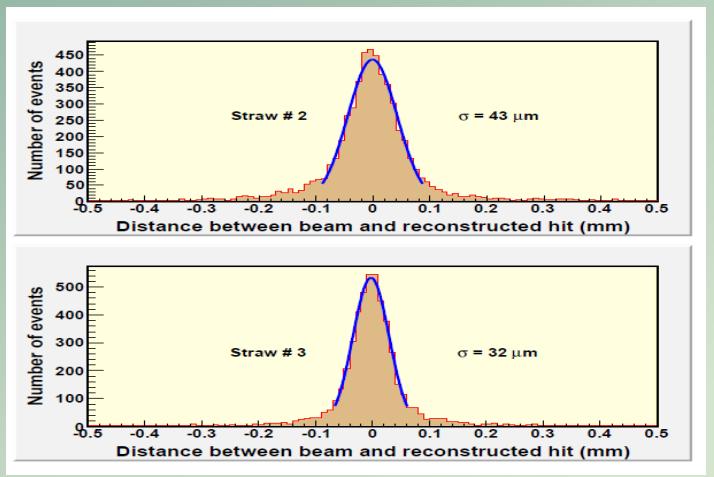
anode segments
(any length along the anode)

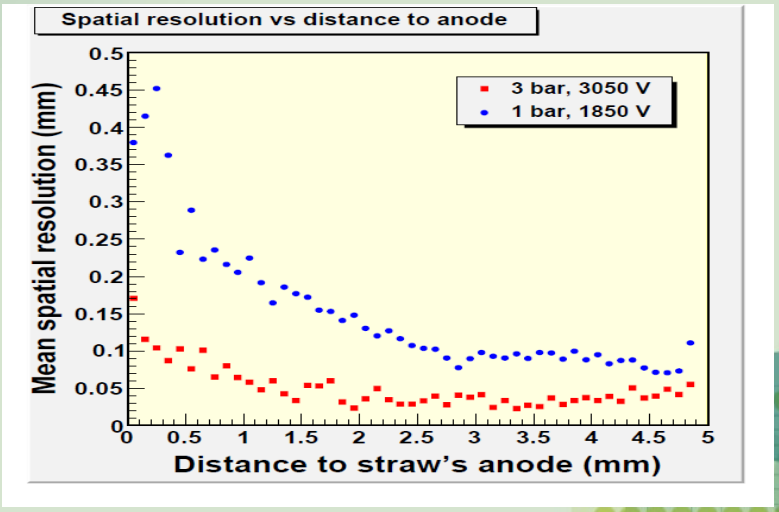
low mass/size exotic
spacers and joints

wires for the external
connections



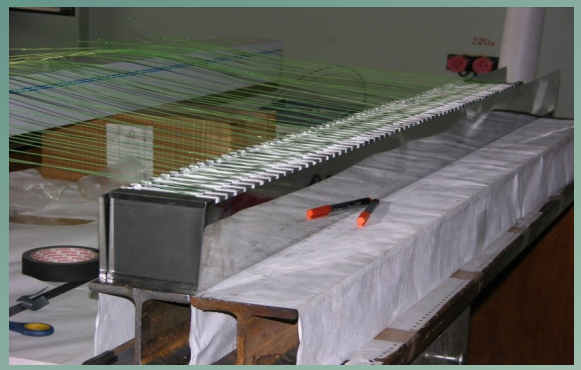
Beam test at SPS 2009



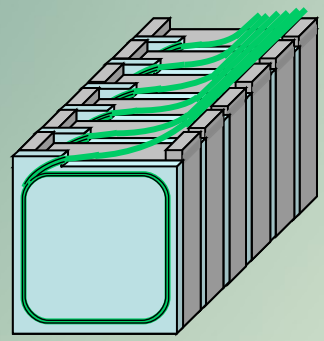


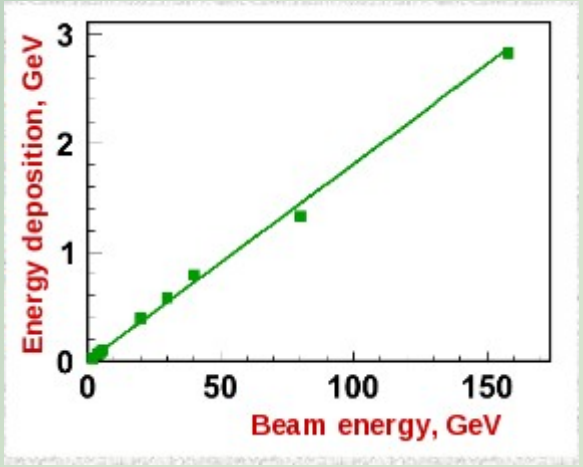
ZDC prototype

Transverse size 10x10 cm², length~160 cm, weight ~120 kg.



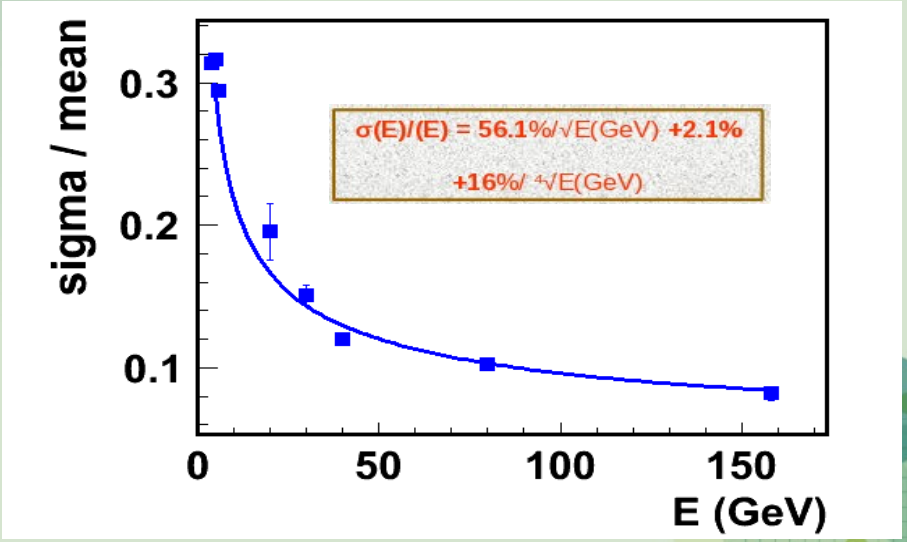
60 lead/scintillator sandwiches.



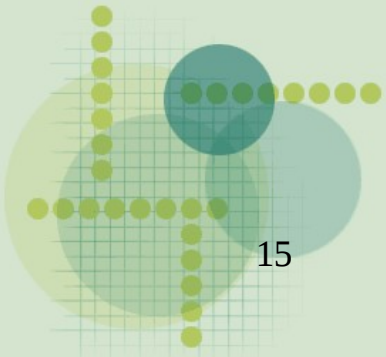


Energy resolution v.s. beam energy in range 4-158 GeV

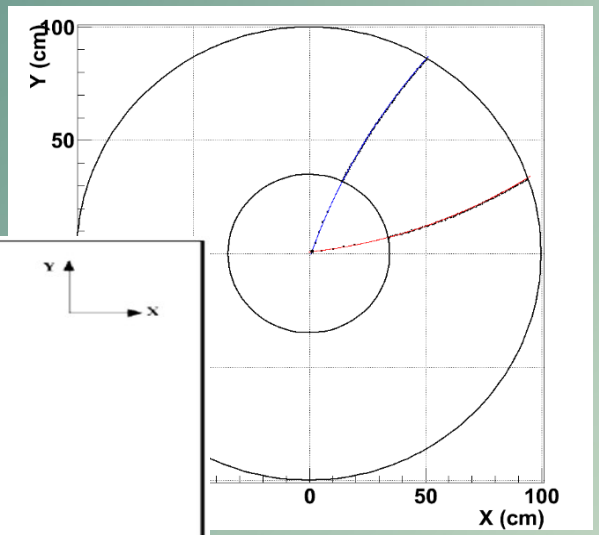
Beam test of 3x3 supermodule at low energies (May 2010)

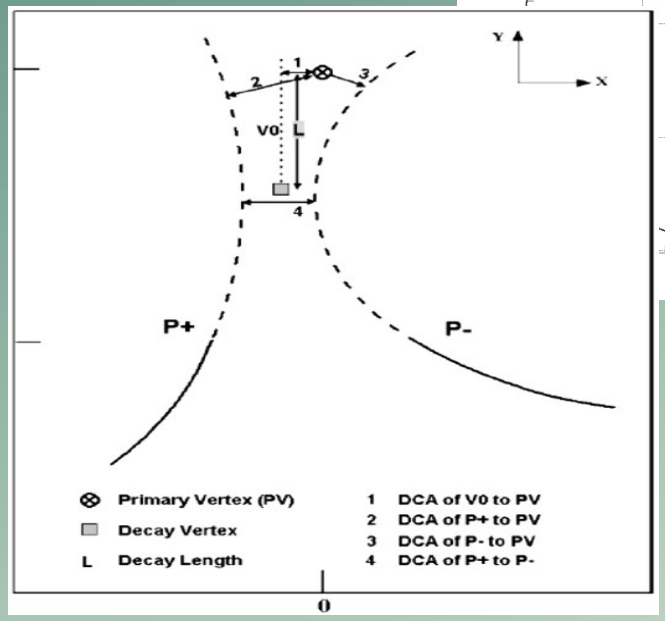


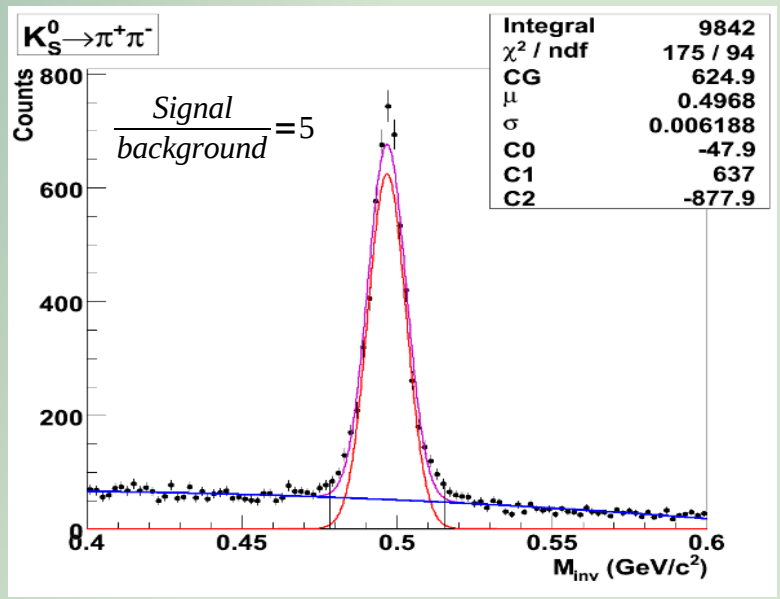
Physics Analyses Feasibility Study



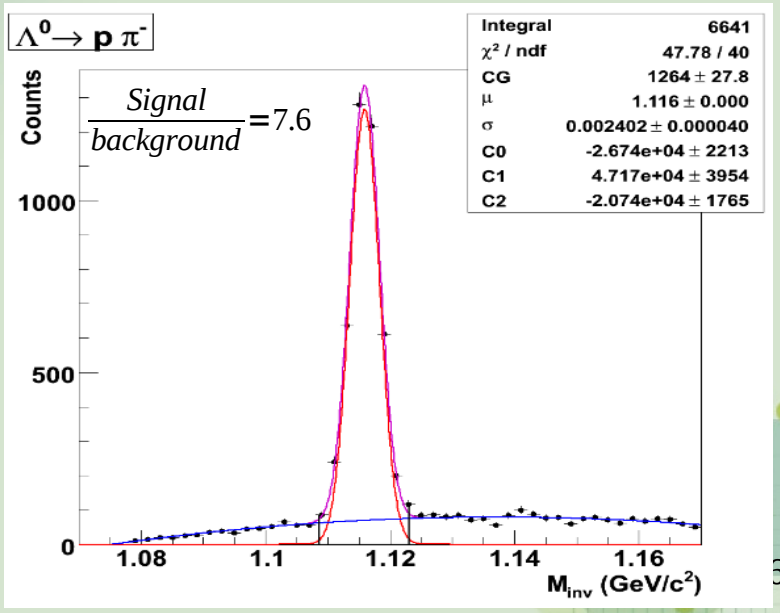
Strange particles reconstruction







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

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^{Λ}_{PV}, mm	> 1.5
χ^{2K}_{PV}	> 100
DCA^{K}_{PV}, mm	> 3.0
$DCA^{K\Lambda}_{\Xi}$, mm	< 1.5
DCA^{Ξ}_{PV}, mm	< 1.0
λ_{Ξ}, mm	> 10.0

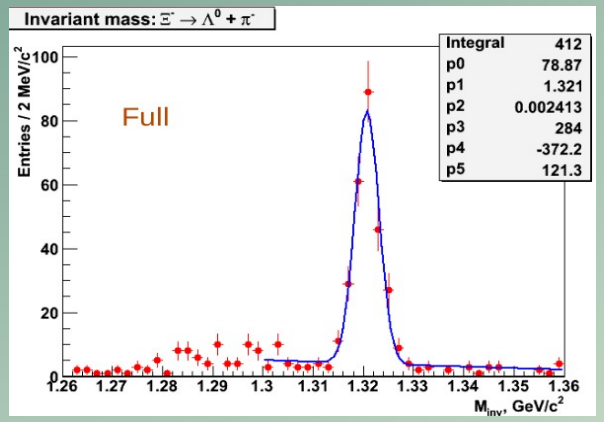
With ITS:
Eff. ≈ 3.8%
S / B (±3σ) = 245 / 18 ≈ 13.7
S / √(S+B) ≈ 15.1

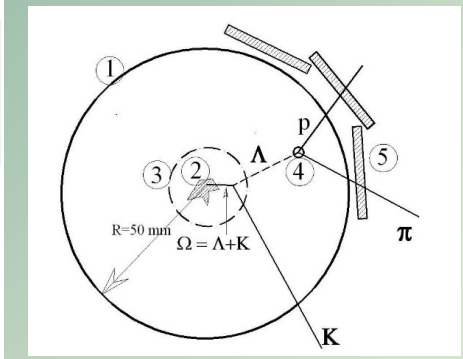
Ω^- analysis (200k events)

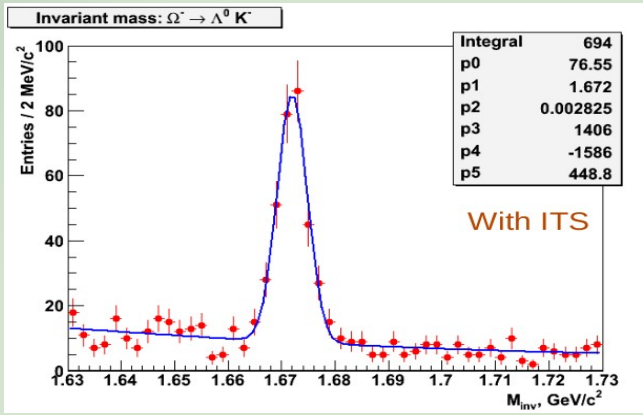
Cut	Only TPC	+ ITS
Λ selection	As above	As above
$Mass_{\Lambda}$	±3σ	±3σ
DCA^{Λ}_{PV}, mm	> 2.0	> 2.0
χ^{2K}_{PV}	> 10	> 26
DCA^{K}_{PV}, mm	> 5.0	> 2.0
$DCA^{K\Lambda}_{\Omega}$, mm	< 3.0	< 1.2
DCA^{Ω}_{PV}, mm	< 2.5	< 5.0
λ_{Ω}, mm	> 10.0	> 10.0

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



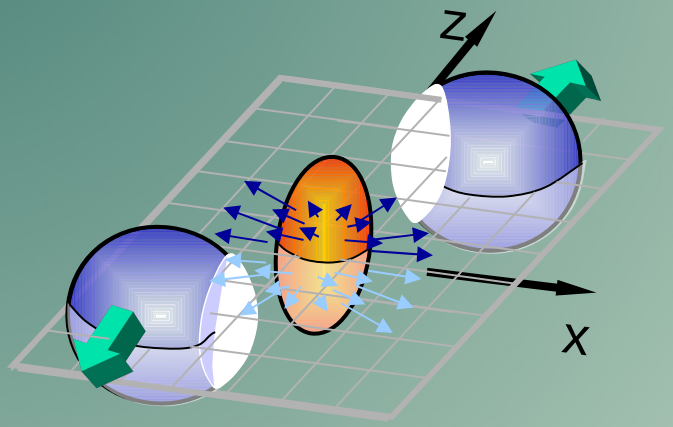




Estimated particle yields (central AuAu collisions at √s = 9 AgeV, event rate 300 Hz)

Particle	Multiplicity	Decay mode	BR	ε, %	Yield, s-1	Yield, 10w
Λ(116)	53.447	$p\pi^-$	0.639	8.0	$1.3 \cdot 10^3$	$7.9 \cdot 10^9$
$\Xi^-(1321)$	0.64	$\Lambda\pi^-$	1	3.8	7.3	$4.4 \cdot 10^7$
$\Omega^-(1672)$	$7.3 \cdot 10^{-2}$	ΛK^-	0.678	2.0	0.4	$2.7 \cdot 10^6$

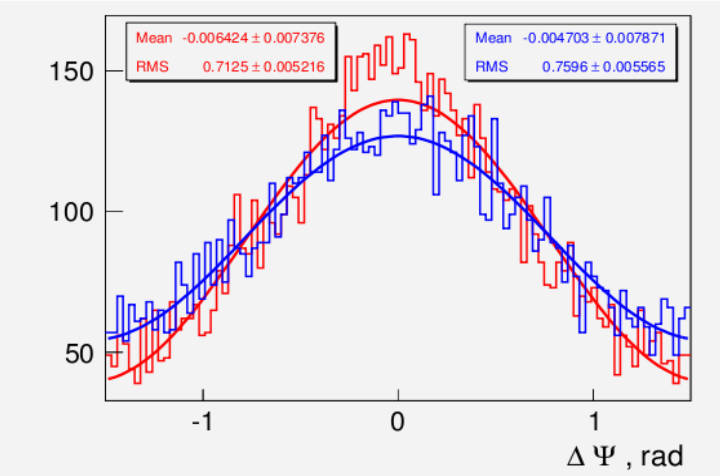
Flows



$$\frac{dN_\alpha}{d\varphi} \propto 1 + 2v_{1,\alpha}\cos(\Delta\varphi) + 2v_{2,\alpha}\cos(2\Delta\varphi) + \ldots$$

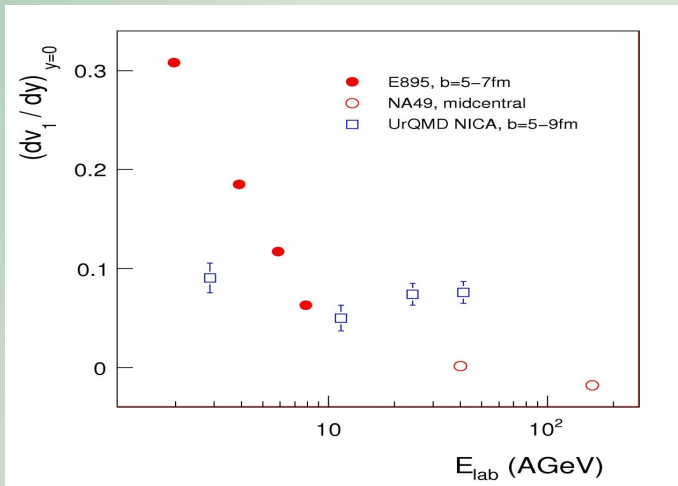
$$\Delta\varphi = \varphi - \Psi_{RP}$$

Reaction plane



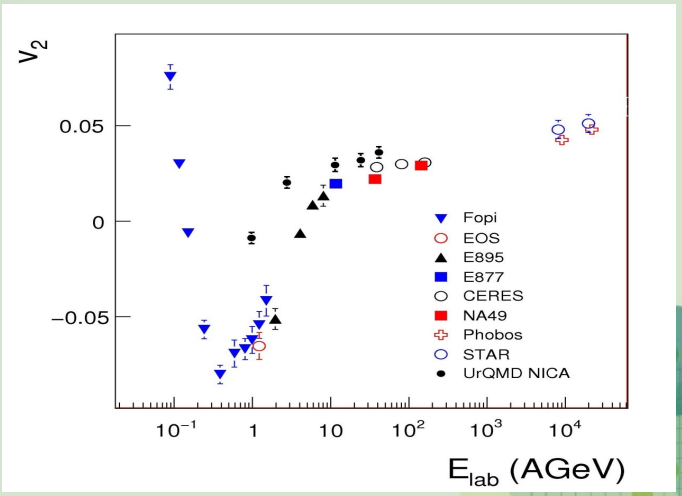
$$v_1 = \left\langle \frac{p_x}{p_T} \right\rangle$$

Direct

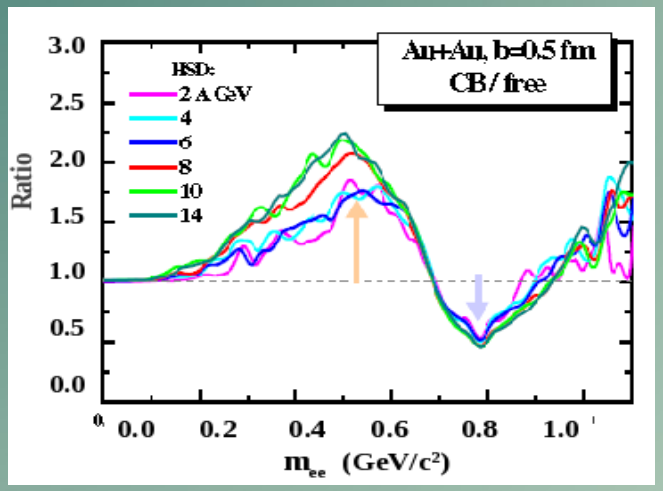


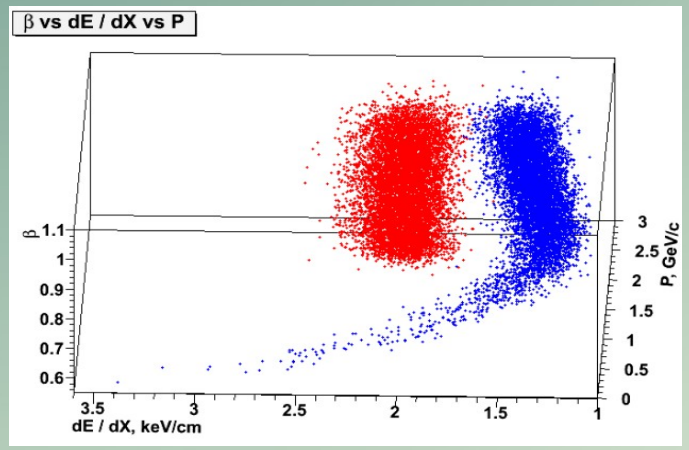
$$v_2 = \left\langle \frac{p_x^2 - p_y^2}{p_x^2 + p_y^2} \right\rangle$$

Elliptic

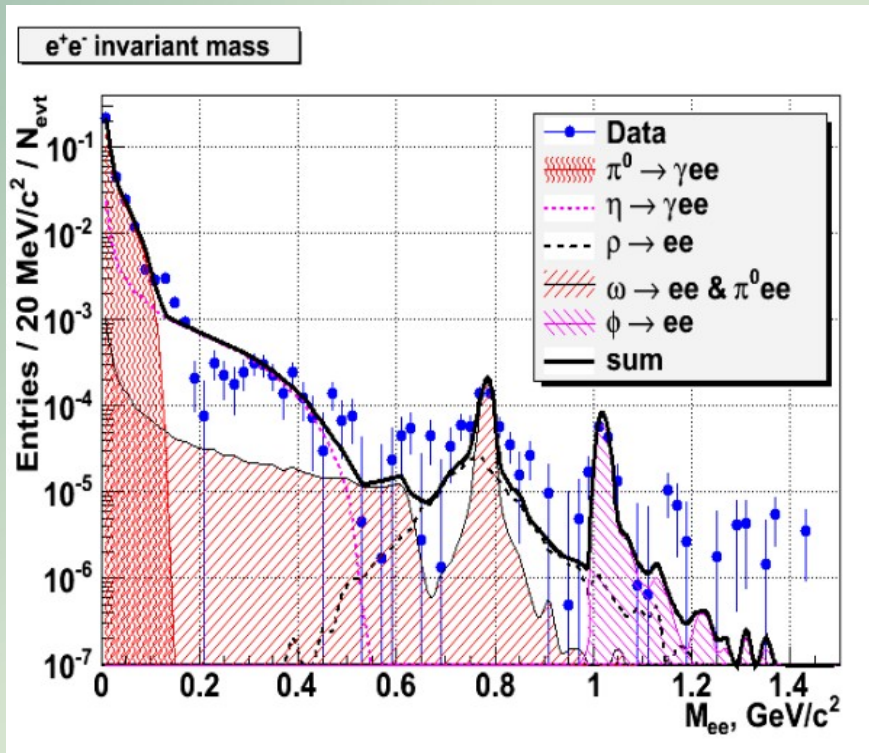


Dileptons





20M events: Pluto hadron cocktail with decays to electron pairs
10k events: UrQMD central (0-3 fm) Au+Au @ 7 GeV (25 GeV fixed target)

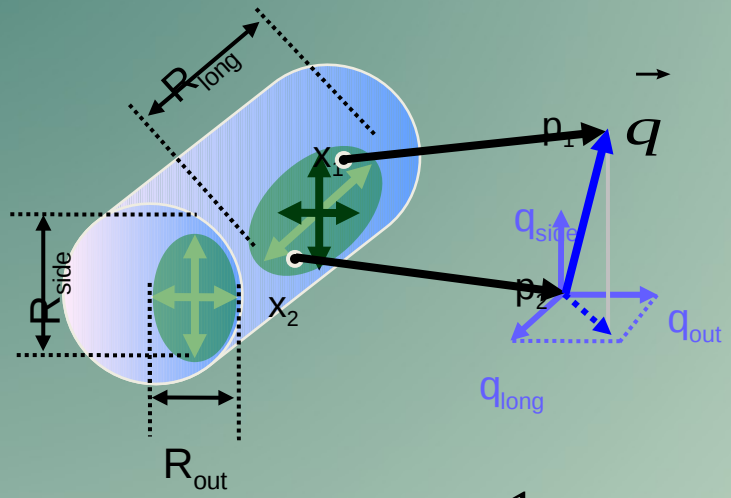


Electron selection:

if (p >= 0.3 && dE/dX > 1.7 || p < 0.1 && dE/dX < 2.2)

if (p_t > 0.1 && p < 0.3) ellipse in β-dE/dX

Femtoscopy



Can be measured with MPD

	π^+	π^-	π^0	K^+	K^-	K^0	p	n	Λ	$\bar{\Lambda}$	Ξ
π^+	+	+	+	+	+	+	+	+	+	+	+
π^-		+	+	+	+	+	+	+	+	+	+
π^0			+	+	+	+	+	+	+	+	+
K^+				+	+	+	+	+	+		
K^-					+	+	+	+	+		
K^0						+	+	+	+		
p							+	+	+		
n								+	+		
Λ									+		
$\bar{\Lambda}$											
Ξ											

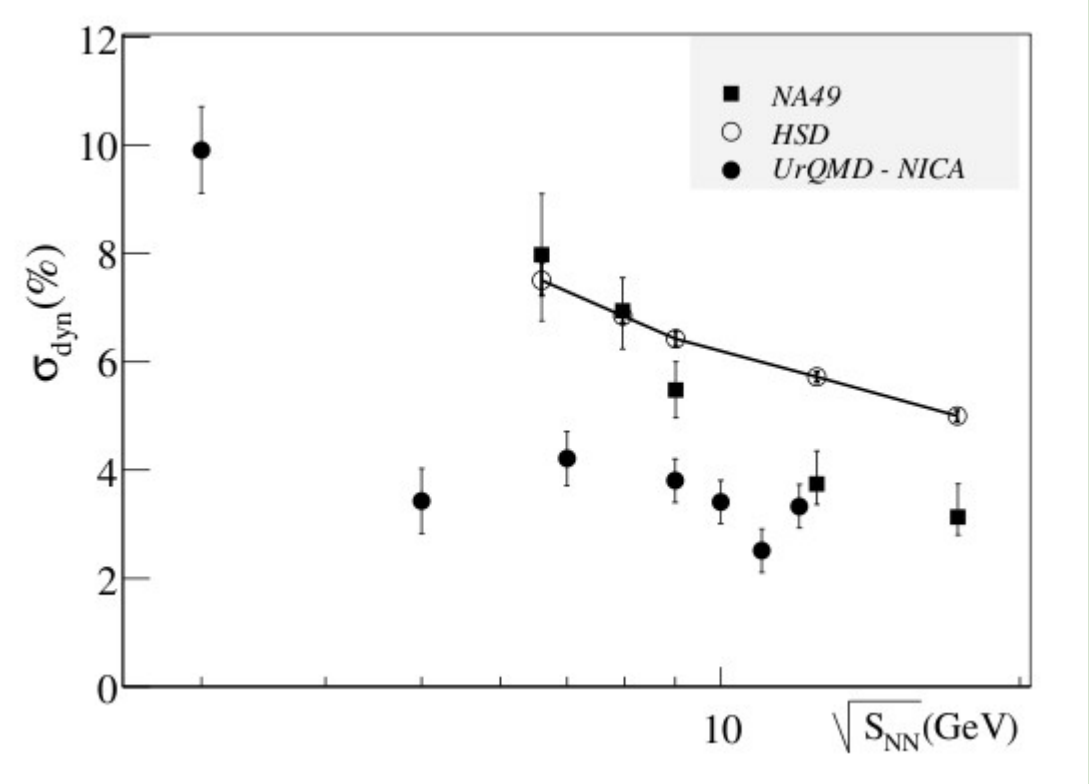
$$\vec{q} = \vec{p}_2 - \vec{p}_1 \qquad \vec{k} = \frac{1}{2}(\vec{p}_2 + \vec{p}_1)$$

$$C(p_1, p_2) = \frac{P(p_1, p_2)}{P(p_1)P(p_2)} = \frac{real\ event\ pairs}{mixed\ event\ pairs}$$

$$C(\vec{q}, \vec{k}) = 1 + \lambda(\vec{k})\, e^{-q_{out}^2 R_{out}^2 - q_{side}^2 R_{side}^2 - q_{long}^2 R_{long}^2}$$

Fluctuations

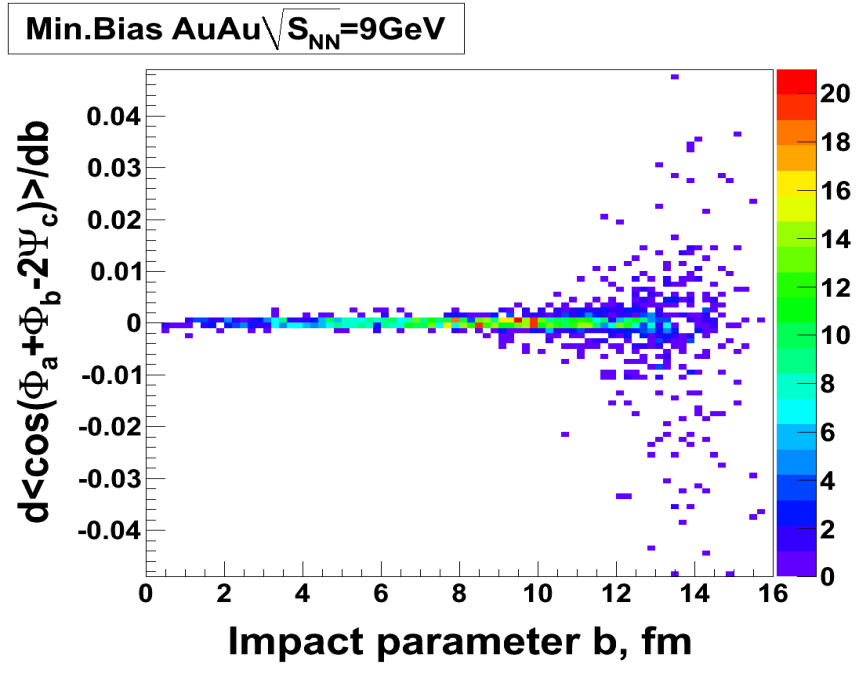
event-by-event dynamical fluctuations for K/π-ratio



Chiral Vortaic Effect estimation

Neutron asymmetries @ NICA

(O.Teryaev's report & arxive 1006.1331 (hep-ph))

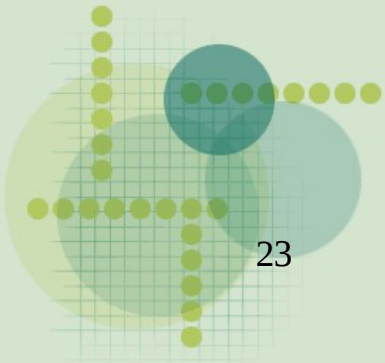


MPD collaboration

- **Joint Institute for Nuclear Research**
- Institute for Nuclear Research, RAS, **RF**
- Bogolyubov Institute for Theoretical Physics, NAS, **Ukraine**
- Nuclear Physics Institute of MSU, **RF**
- Institute Theoretical & Experimental Physics, **RF**
- St.Petersburg State University, **RF**
- Institute of Applied Physics, AS, **Moldova**
- Institute for Nuclear Research & Nuclear Energy BAS, Sofia, **Bulgari**a
- Institute for Scintillation Materials, Kharkov, **Ukraine**
- State Enterprise Scientific & Technology Research Institute for Apparatus construction, Kharkov, **Ukraine**
- Particle Physics Center of Belarusian State University, **Belarus**
- Department of Engineering Physics, Tsinghua University, Beijing, **China**
- Physics Institute Az.AS, **Azerbaidjan**

Members of the Collaboration

- JINR ~ 100
- Other institutes 54



SUMMARY

Work in progress according to the time schedule

Timeline of the MPD works

	Stage/Year	2009	2010	2011	2012	2013	2014	2015	2016
1	MPD Conceptual Design Report								
2	MPD TDR								
3	**R&D program**								
	TPC								
	TOF								
	ZDC								
	Si inner tracker								
	EMC								
	Straw Tracker								
	DAQ								
4	**Production and tests (the 1st stage detectors)**								
	Superconducting Magnet of MPD								
	TPC								
	EMC								
	ZDC								
	TOF barrel								
	Slow Control								
	DAQ								
	Installation& Commissioning								
	Si inner tracker								
5	**Production and tests (the 2nd stage detectors)**								
	TOF(EndCap)								
	Straw Tracker								
	DAQ								
	Slow Control								
	Installation								
6	**Production and tests (the 3rd stage, Forward Spectrometer)**								
	Toroidal Magnet construction								
	Coordinate detectors production								
	Coordinate detector testing								
	Installation& Commissioning								