MultiPurpose Detector (MPD)
at
NICA

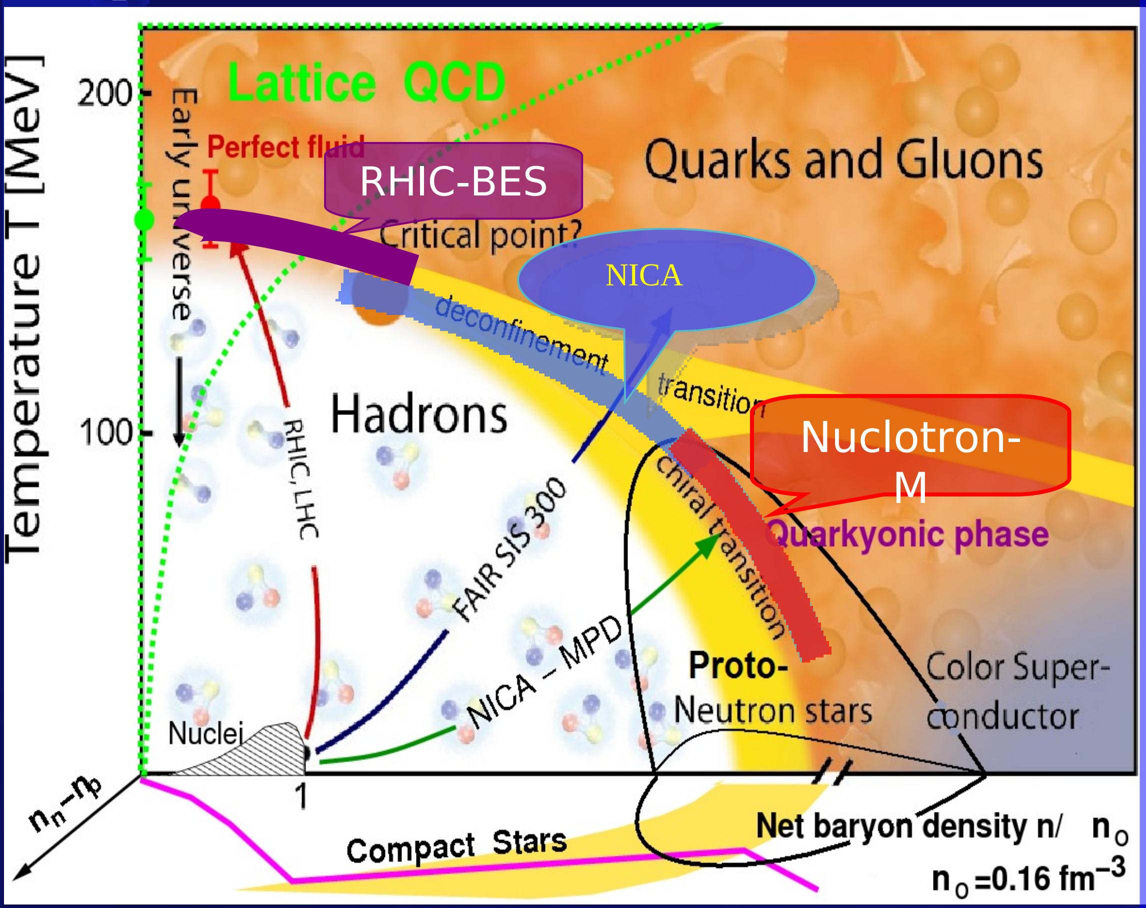
Status Report

NICA/JINR-FAIR Bilateral Workshop

Frankfurt Institute for Advanced Studies (FIAS)

April 2 - 4, 2012

QCD phase diagram. Prospects for NICA



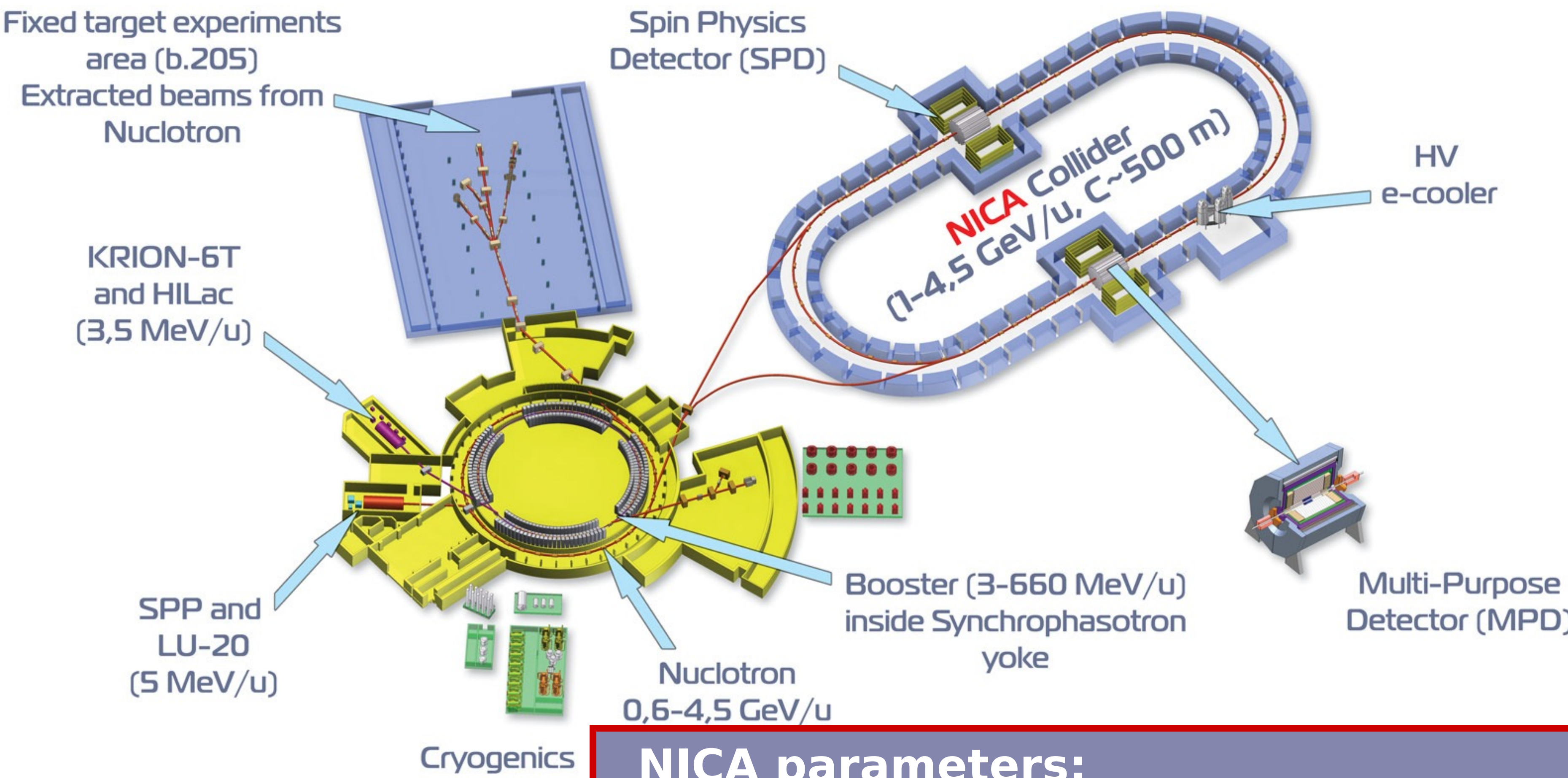
Energy Range of NICA

unexplored region of the QCD phase diagram:

- Highest net baryon density
- Onset of deconfinement phase transition
- Strong discovery potential:
  a) Critical End Point (CEP)
  b) Chiral Symmetry Restoration
  c) Hypothetic Quarkyonic phase
- Complementary to the RHIC/BES, FAIR, CERN & Nuclotron-M experimental programs

NICA facilities provide unique capabilities for studying a variety of phenomena in a large region of the phase diagram

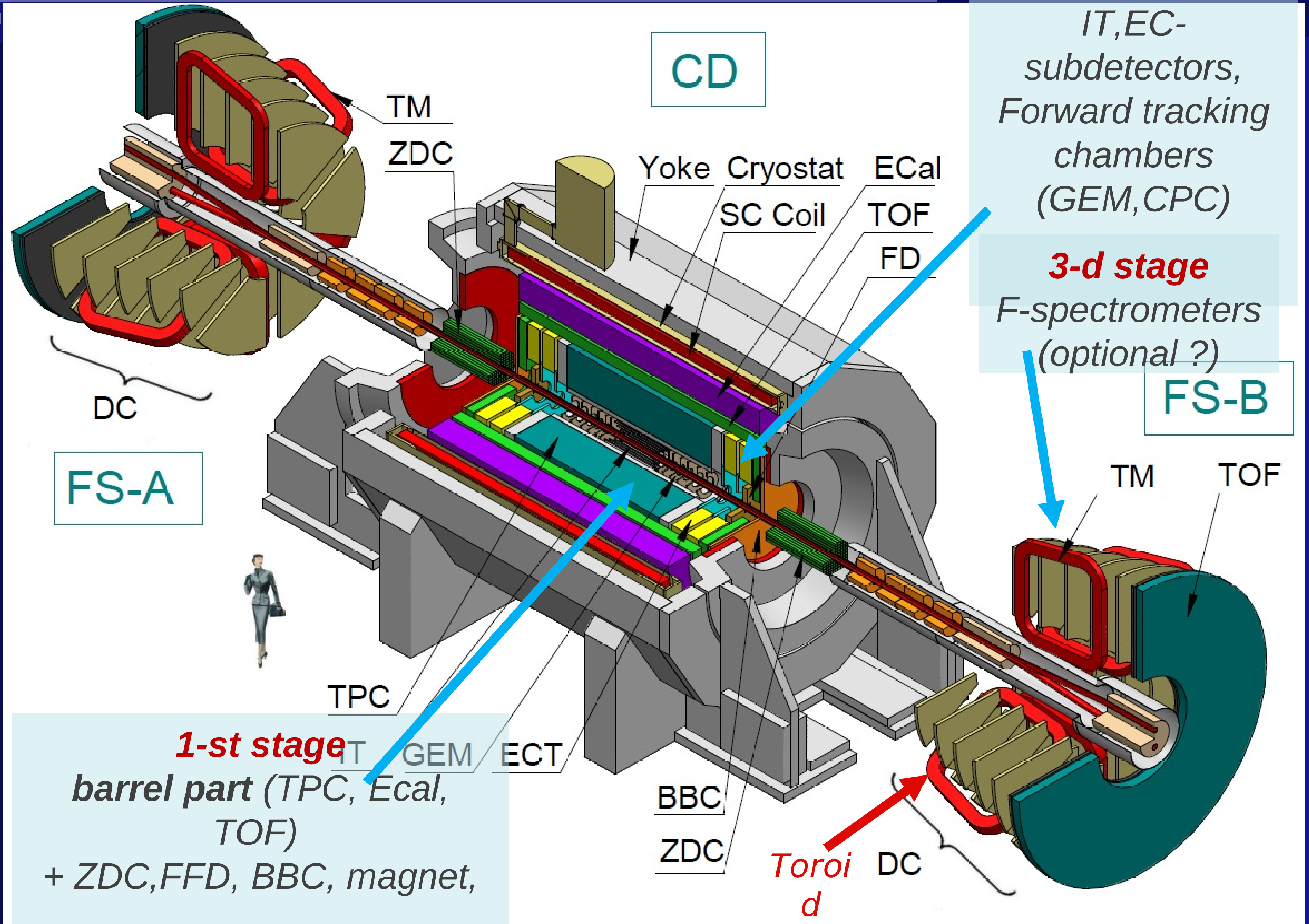
Superconducting accelerator complex NICA
(Nuclotron based Ion Collider fAcility)



NICA parameters:

- Energy range: $\sqrt{s_{NN}}$ = 4-11 GeV
- Beams: from p to Au
- Luminosity: L~10^{27} (Au), 10^{32} (p)
- Detectors: MPD (ions), SPD (spin physics)

3 stages of putting into operation



2-nd stage
IT,EC-subdetectors, Forward tracking chambers (GEM,CPC)

3-d stage
F-spectrometers (optional ?)

1-st stage
***barrel part** (TPC, Ecal, TOF)*
+ ZDC,FFD, BBC, magnet, ...

MPD Observables

I stage: ***mid rapidity region*** *(good performance)*

- ***Particle yields and spectra (π,K,p,clusters,Λ, Ξ ,Ω)***
- ***Event-by-event fluctuations***
- ***Femtoscopy involving π, K, p, Λ***
- ***Collective flow for identified hadron species***
- ***Electromagnetic probes (electrons, gammas)***

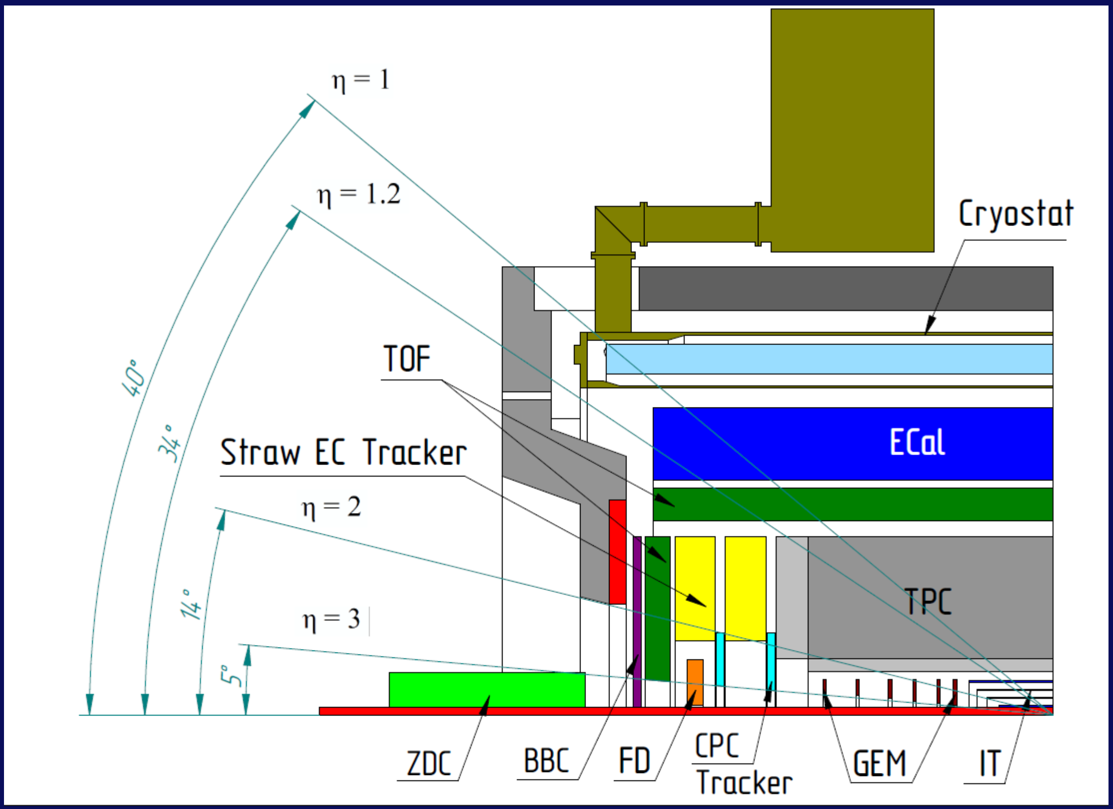
II stage: ***extended rapidity + ITS***

.....

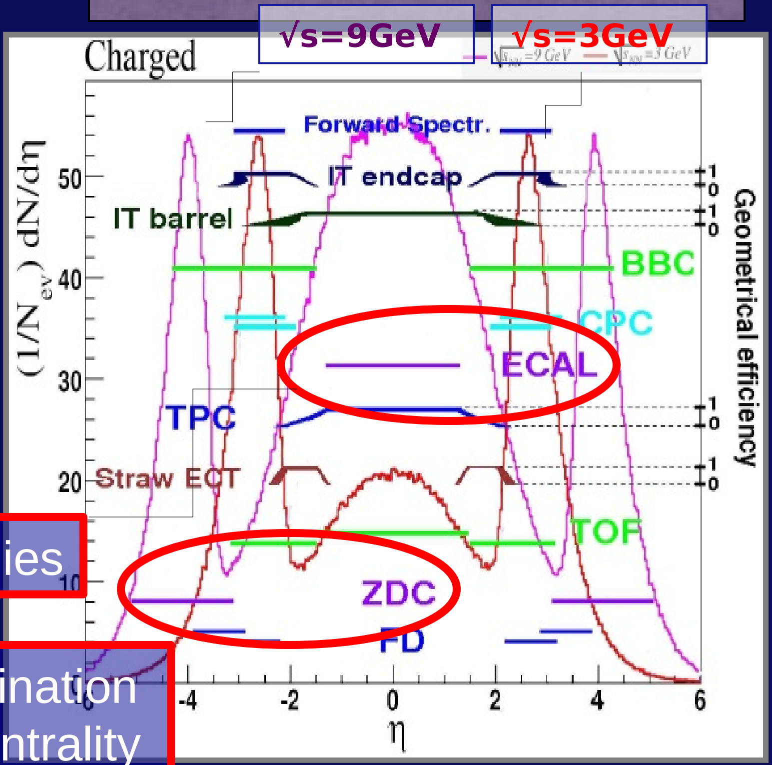
- ***Total particle multiplicities***
- ***Asymmetries study*** *(better reaction plane determination)*
- ***Di-Lepton precise study*** *(ECal expansion)*
- ***Charm***
- ***Exotics (soft photons, hypernuclei)***

Measurements regarded as complementary to RHIC/BES and CERN/NA61,
However, higher statistics & (close to) the total yields for rare probes at MPD
No boost invariance at NICA – more accurate source parameters fit without rapidity cut
Rapidity dependence of the fireball thermal parameters will be possible at NICA

Coverage of angles



Acceptance (B=0.5 T):
Full azimuthal
IT (|h|<2.5)
TPC (|h|<2)
ECAL (|h|<1.2)
FD (2<|h|<4)
TOF (|h|<3)
ZDC (|h|>3)



ECal coverage for Di-Lepton studies

ZDC coverage for determination of the reaction plane & centrality

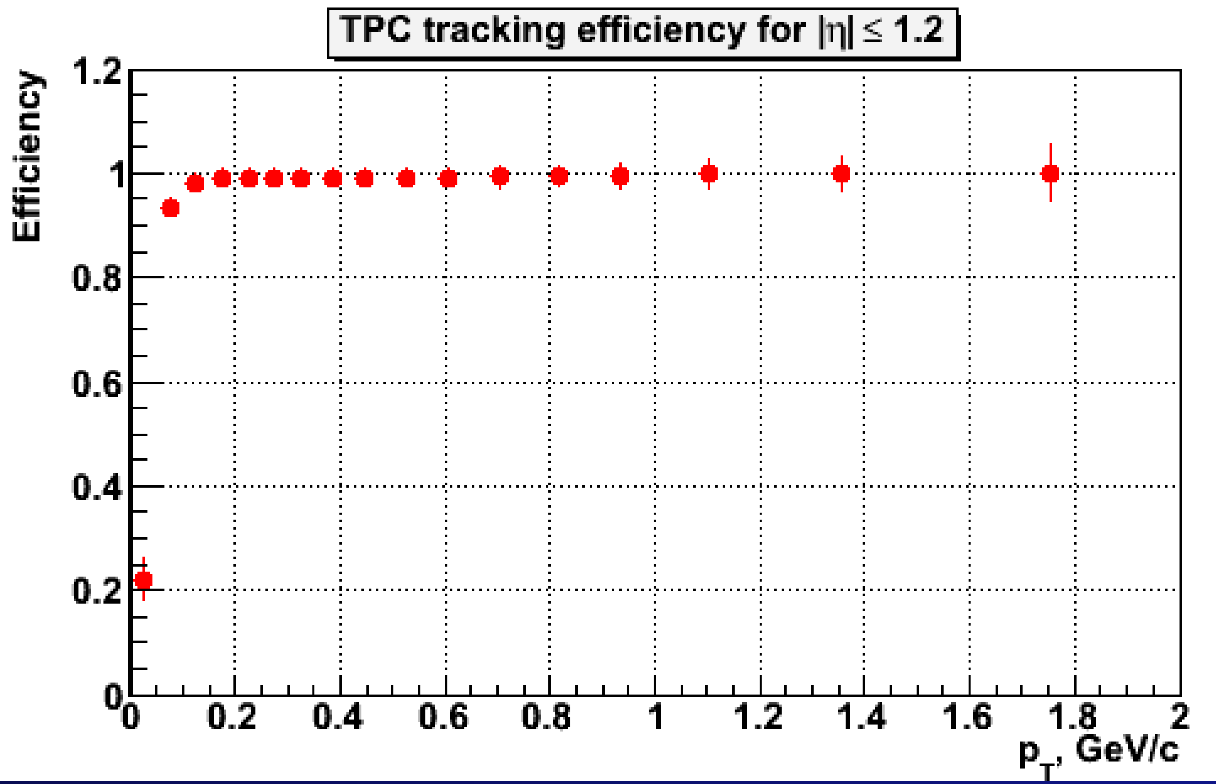
Particle yields, Au+Au @ $\sqrt{s_{NN}}$ = 8 GeV *(central)*

Expectations for 10 weeks of running at L = $10^{27} cm^{-2}s^{-1}$ *(duty factor = 0.5)*

Particle	Yields 4π	Yields y=0	Decay mode	BR	*Effic. %	Yield/10 w
π^+	293	97	----	---	61	$2.6 \cdot 10^{11}$
K^+	59	20	---	----	50	$4.3 \cdot 10^{10}$
p	140	41	---	----	60	$1.2 \cdot 10^{11}$
ρ	31	17	e+e-	$4.7 \cdot 10^{-5}$	35	$7.3 \cdot 10^{5}$
ω	20	11	e+e-	$7.1 \cdot 10^{-5}$	35	$7.2 \cdot 10^{5}$
φ	2.6	1.2	e+e-	$3 \cdot 10^{-4}$	35	$1.7 \cdot 10^{5}$
Ω	0.14	0.1	ΛK	0.68	2	$2.7 \cdot 10^{6}$
D^0	$2 \cdot 10^{-3}$	$1.6 \cdot 10^{-3}$	$K^+\pi^-$	0.038	20	$2.2 \cdot 10^{4}$
J/ψ	$8 \cdot 10^{-5}$	$6 \cdot 10^{-5}$	e+e-	0.06	15	10^{3}

***Efficiency includes the MPD acceptance, realistic tracking and particle ID.**
Particle Yields from experimental data (NA49), statistical and HSD models.
Efficiency from MPD simulations. Typical efficiency from published data (STAR)

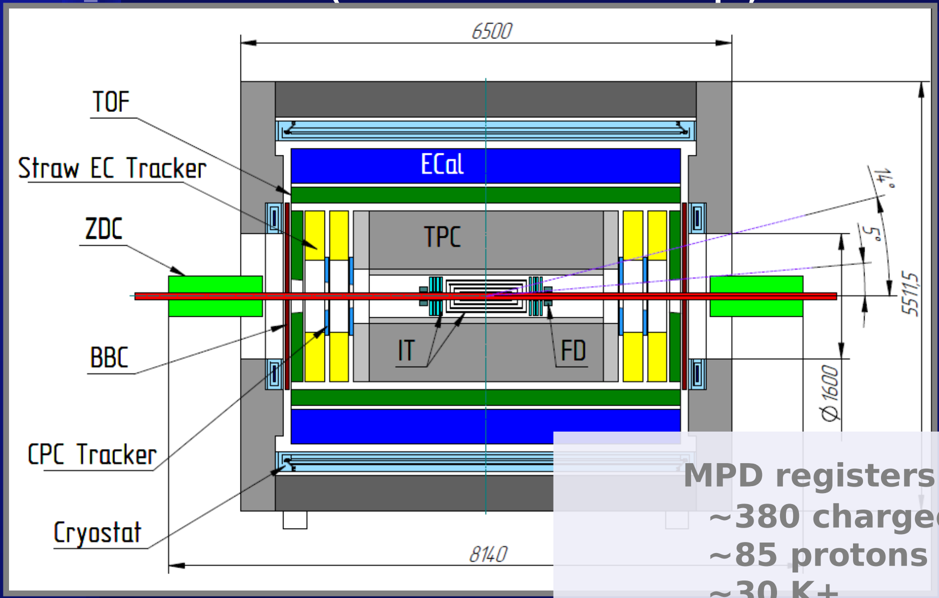
MPD performance: *tracking, PID*

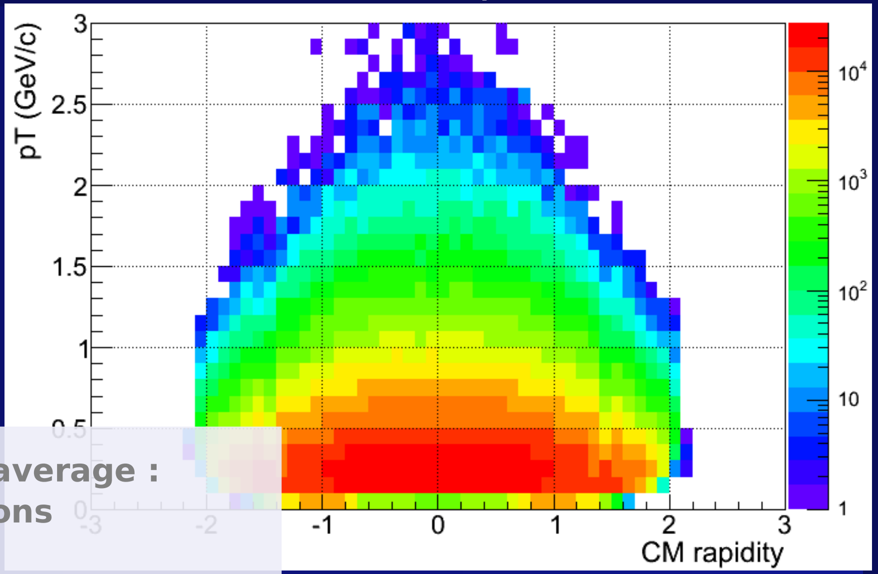


Low-p cutoff ~ **100 MeV** for a **0.5 T** magnetic field

MPD phase-space coverage

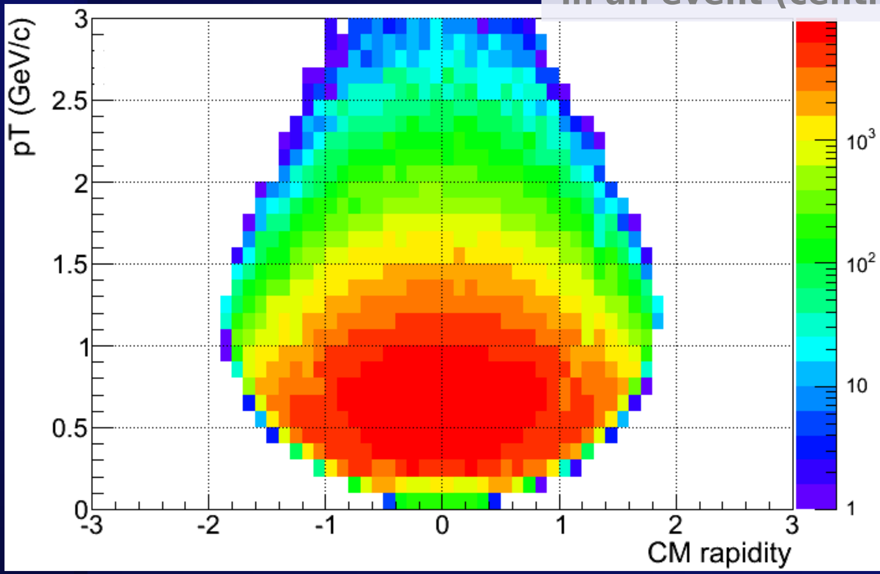
(barrel+endcap, **no ITS,** identified hadrons)

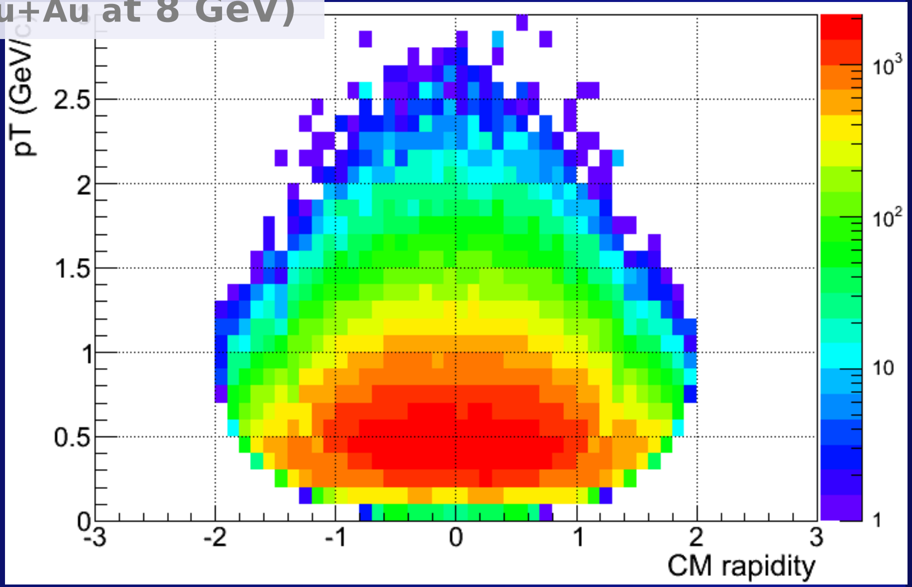




MPD registers on average :
- ~380 charged pions
- ~85 protons
- ~30 K+

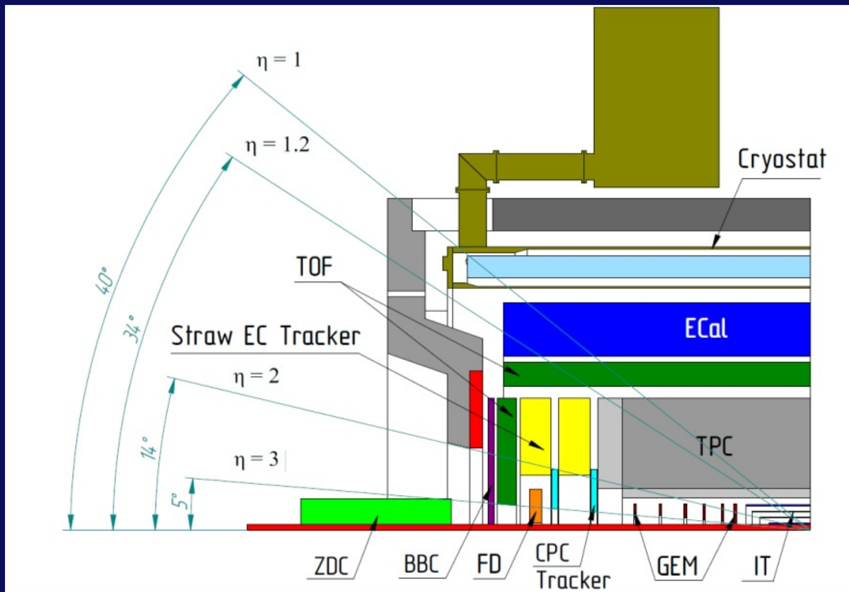
in an event (central Au+Au at 8 GeV)

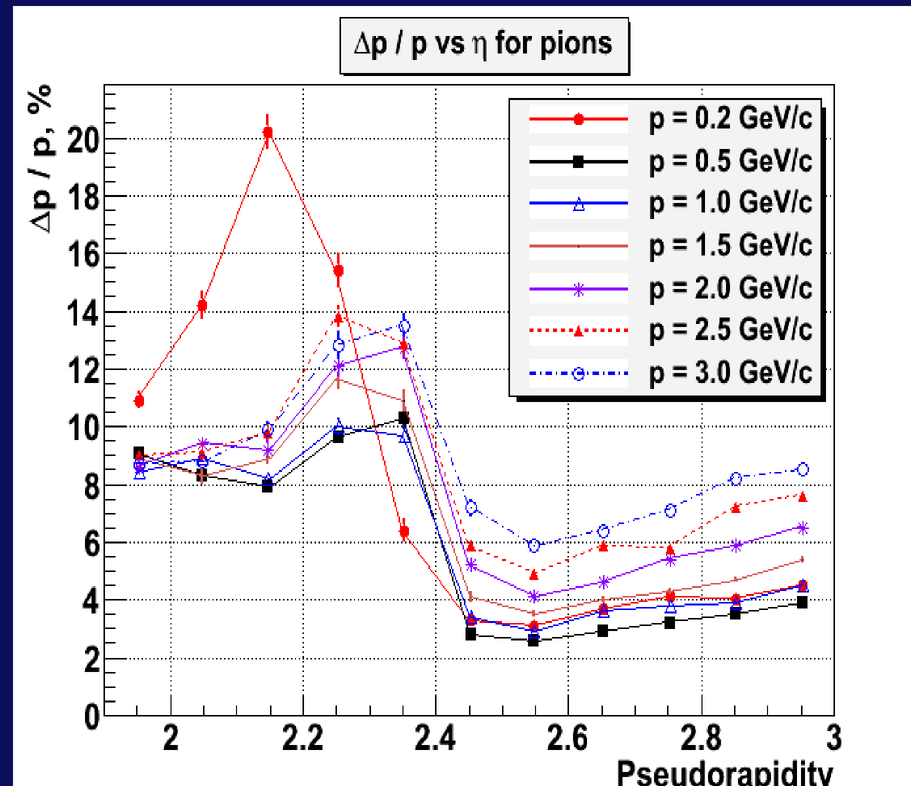


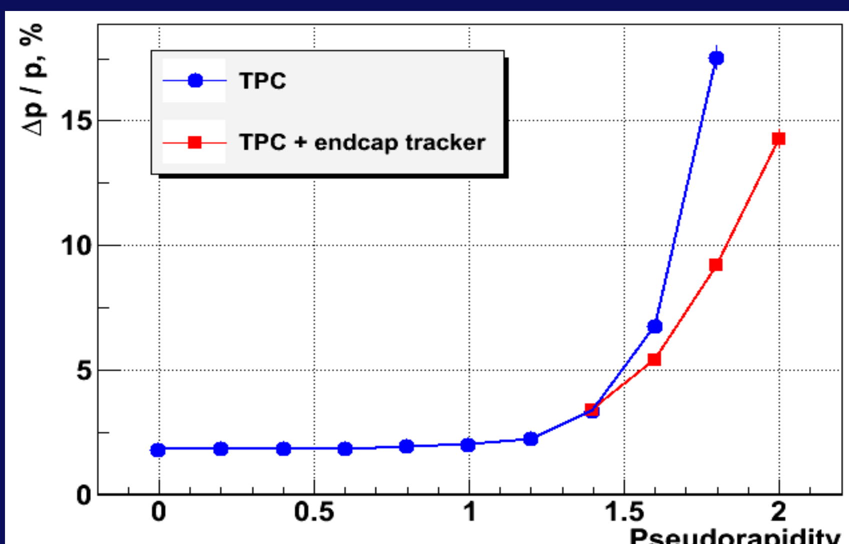


Tracking capability in the Forward direction

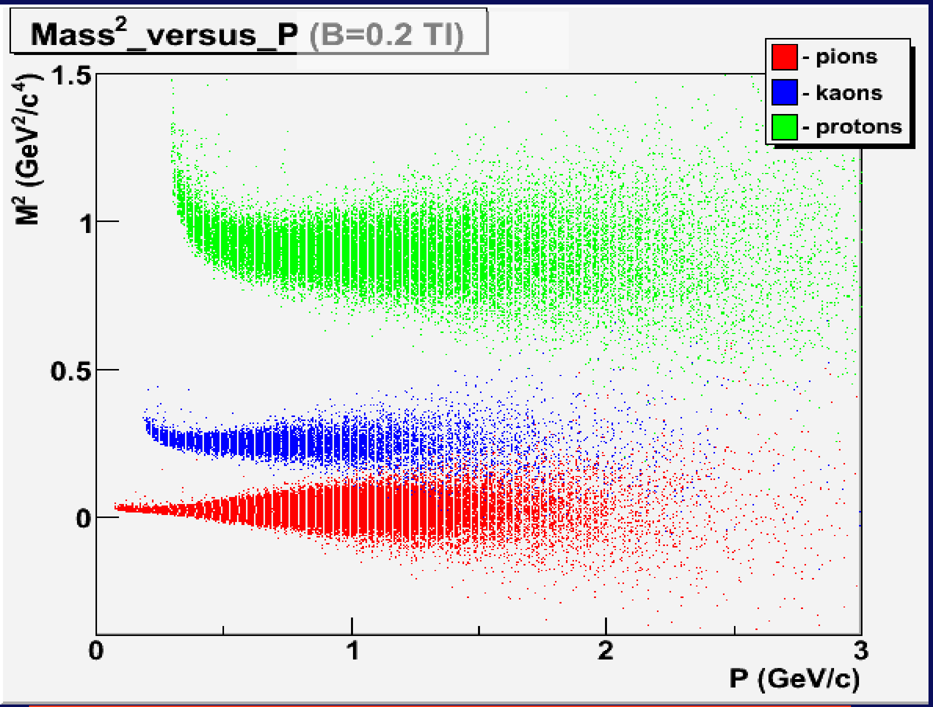
(momentum resolution)

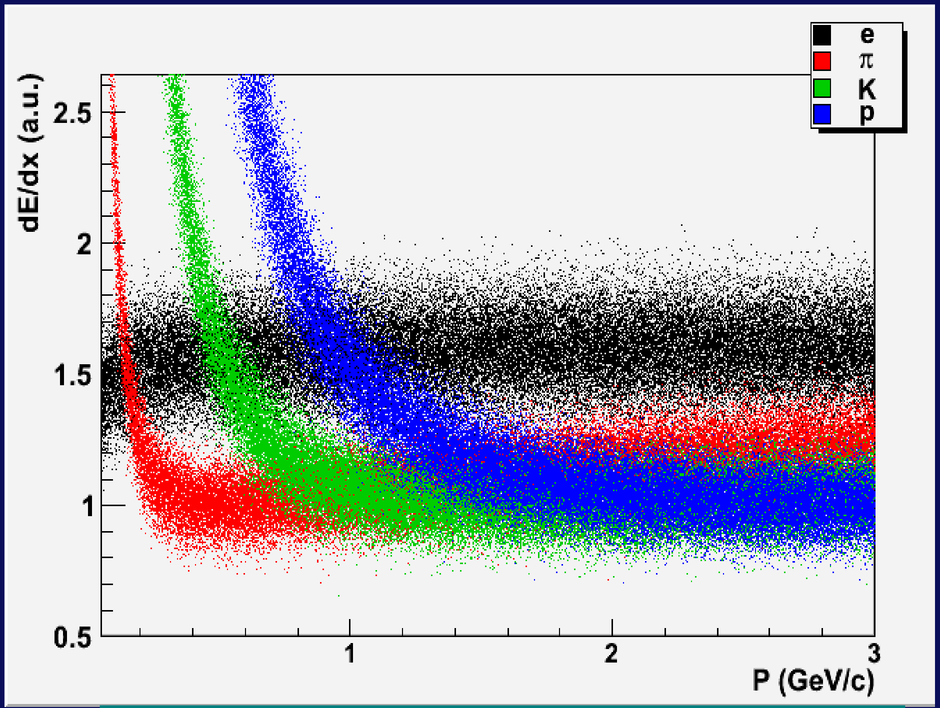






Particle IDentification in MPD





PID: *Time Of Flight*
Separation: e/h – 0.1..0.35 GeV/c
π/K – 0.1..1.5 GeV/c
K/p – 0.1..2.5 GeV/c

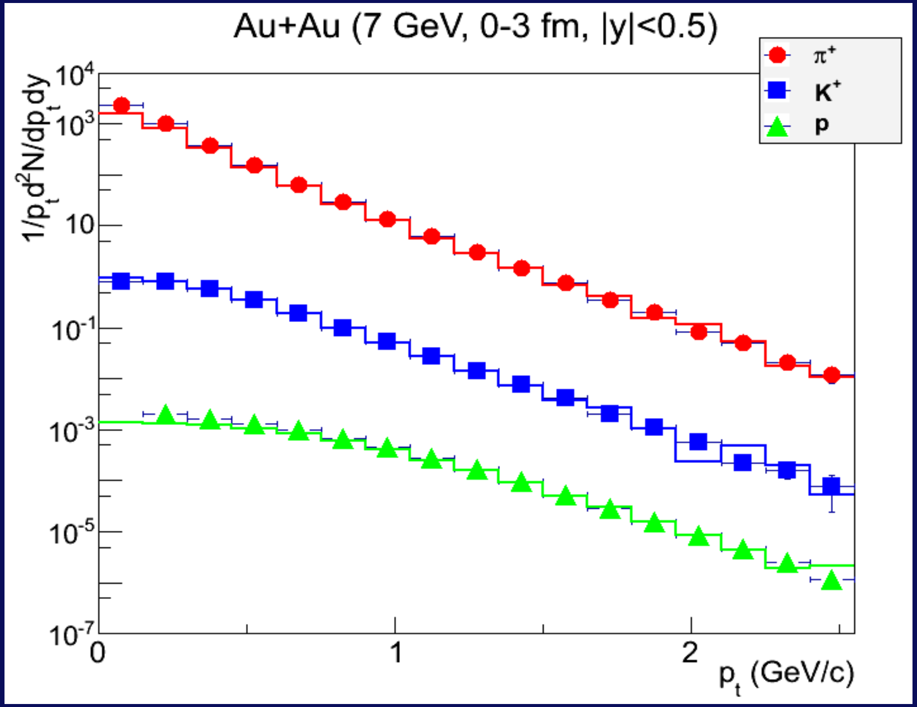
PID: *Ionization loss (dE/dx)*
Separation: e/h – 1.3..3 GeV/c
π/K – 0.1..0.6 GeV/c
K/p – 0.1..1.2 GeV/c

- **Coverage**: *$|\eta| < 1.4$, p_t=0.1-2 GeVc barrel $|\eta| < 2.6$, pt=0.1-2 GeVc barrel+EC*
- **Matching eff.**: *> 85% at $p_t > 0.5$ GeV/c*
- **PID:** *2σ π/K ~ 1.7 GeV/c, (π,K)/p ~ 2,5 GeV/c*

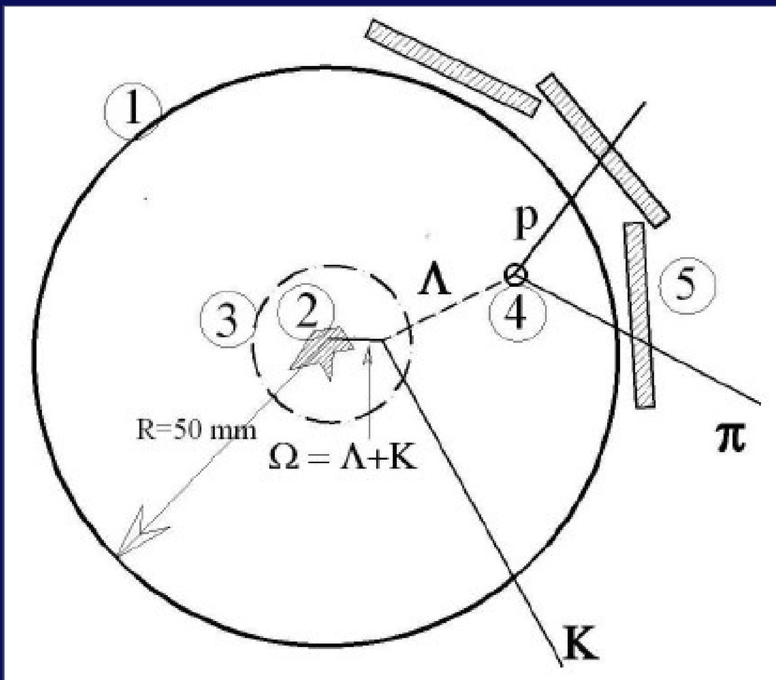
Hadron spectra and yields in MPD

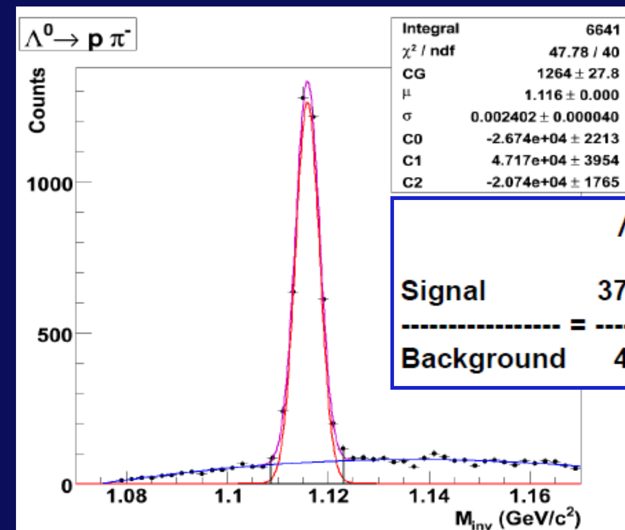
1st Stage

- *Full reconstruction chain, realistic PID, corrections from simulations*
- *Hadron spectra at midrapidity: large p_T-coverage*
- *Forward rapidities: extrapolations to unmeasured regions under development*

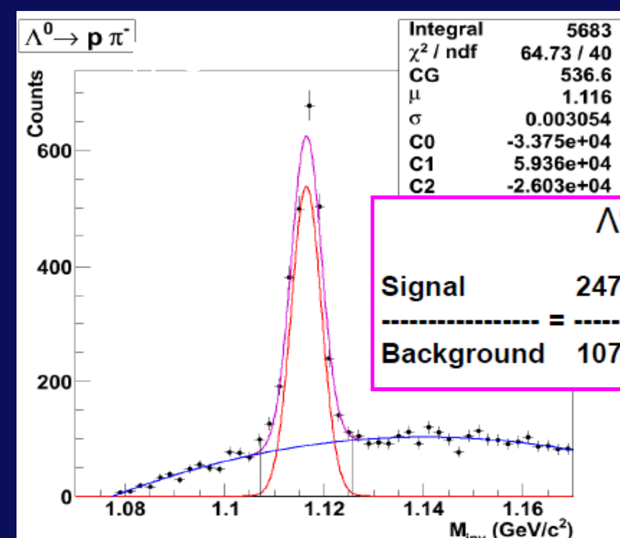


V0 performance (TPC+ITS)





	Λ^0		K_s^0
Signal	3796		4845
----------------- =	------- = 7.6;		------- = 5
Background	498		962

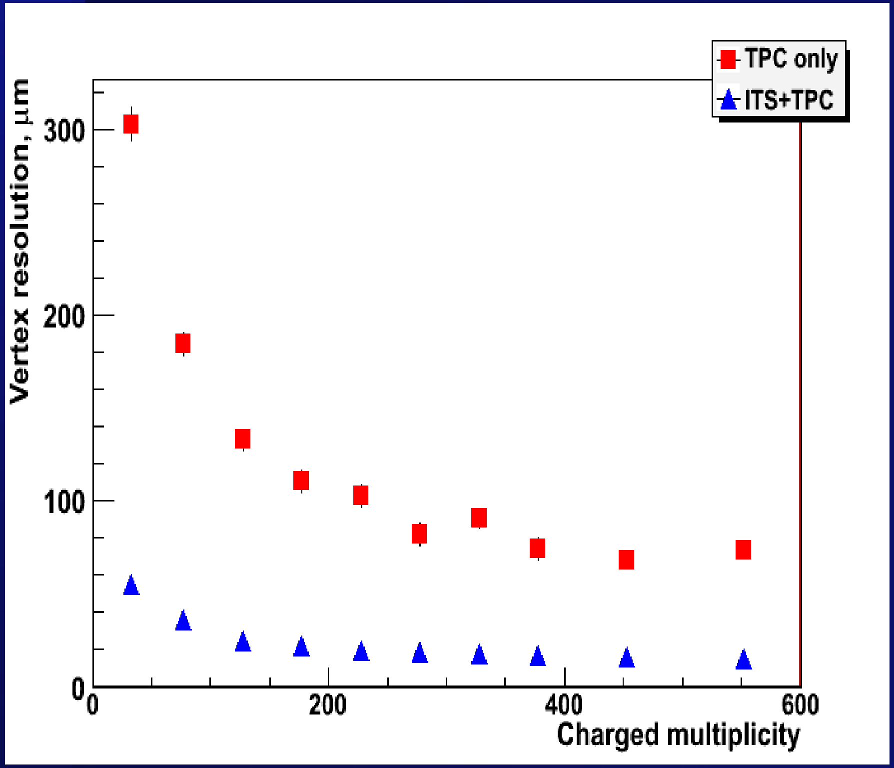


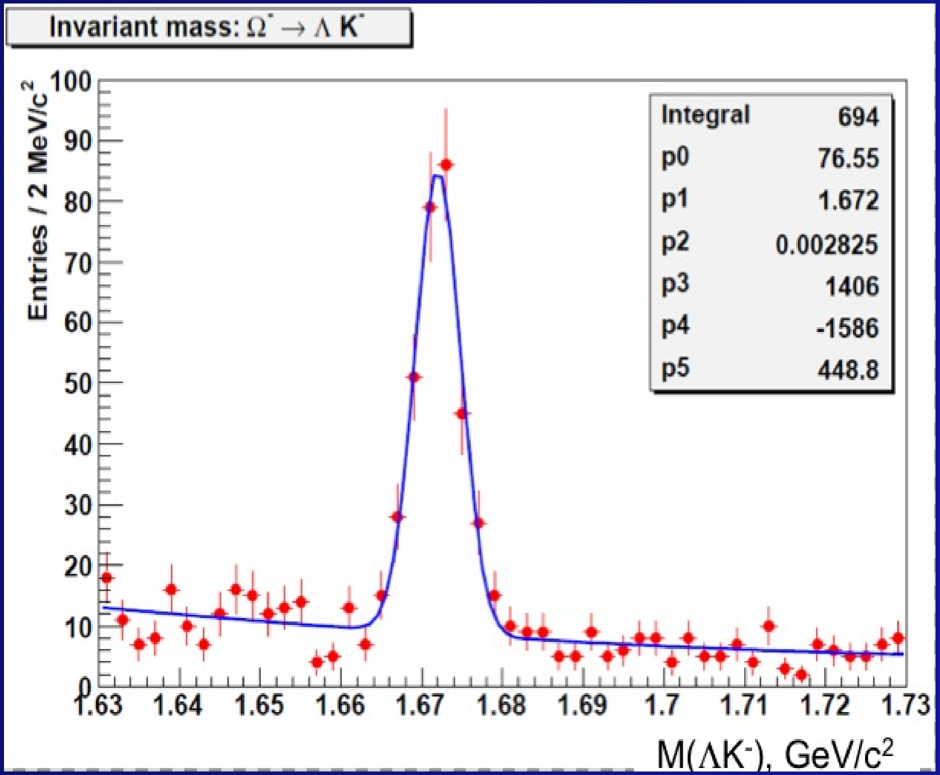
	Λ^0		K_s^0
Signal	2476		3155
----------------- =	------- = 2.3;		-------- = 1.3
Background	1070		2362

- **Improved Signal-to-Background ratio (S/B) with the vertex IT detector**

$\Omega^- \to \Lambda K^-$

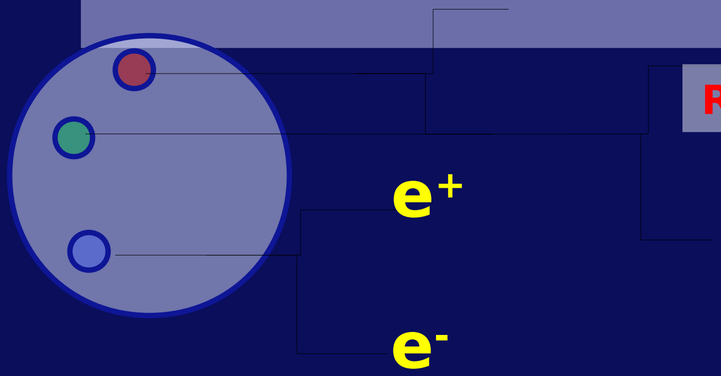
decay reconstruction (vertex + particle ID)





Study of lepton pair production

- *In-medium modification of vector meson properties may signal on partial chiral symmetry restoration in heavy ion collisions*
- *Dileptons as penetrating probes of the fireball interior – no FSI*
- *Existing experimental data underestimated by the vacuum spectral functions for 0.3 GeV < Mee < 0.7 GeV*

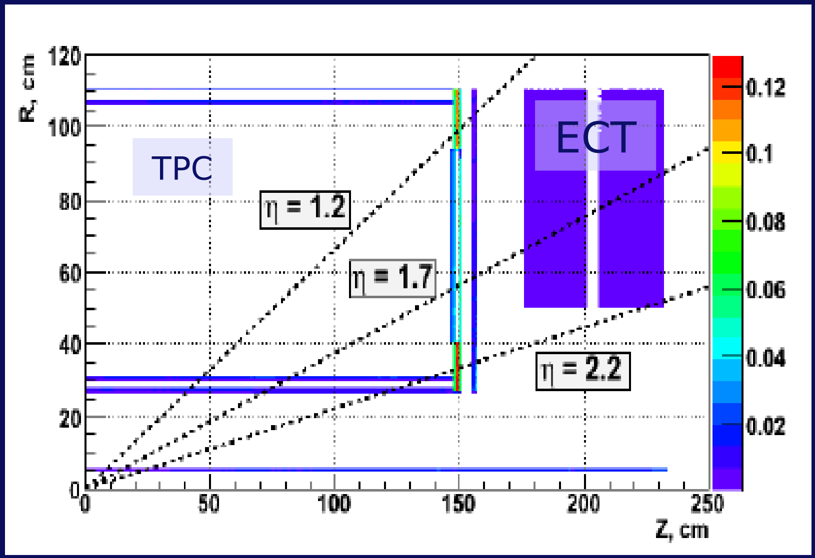


Required experimental mass resolution ~ 10 MeV

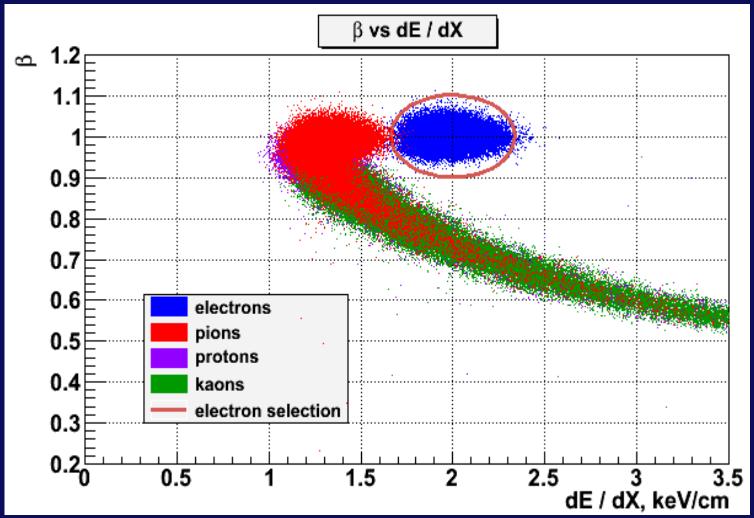
ω : $c\tau$ = **23 fm** M=783 MeV, Γ=8 MeV
φ : $c\tau$ = **44 fm** M=1019 MeV, Γ=4 MeV
ρ : $c\tau$ = **1.3 fm** M=768 MeV Γ=149 MeV

MPD detector relevant features:

- Low material budget
- Electron ID via combined dE/dx & TOF
- Extra hadron suppression by ECAL
- High event rate allowing studying of dielectron continuum up to a large pT

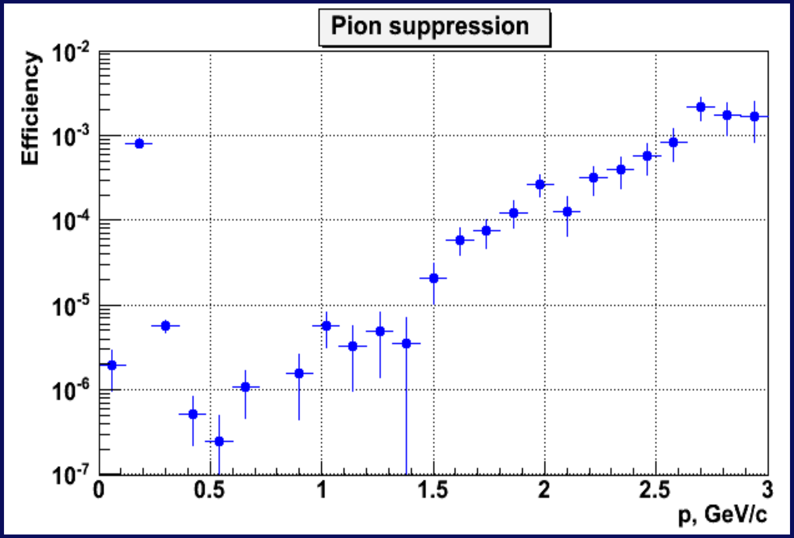


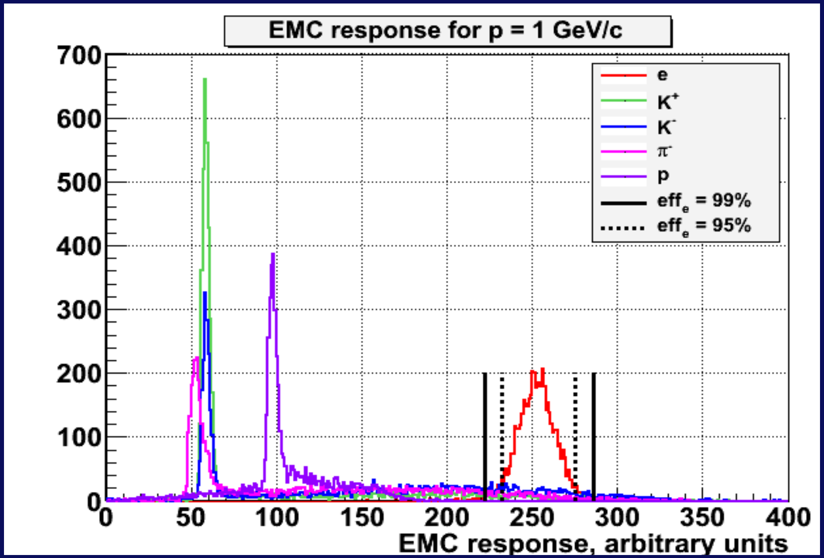
Dileptons



- Input : central Au+Au at 7 GeV, Pluto + UrQMD
- track selection and e-conversion suppression
- PID by dE/dx and TOF, hadron suppression ~ 10^{-5}
- Extra suppression by ECAL

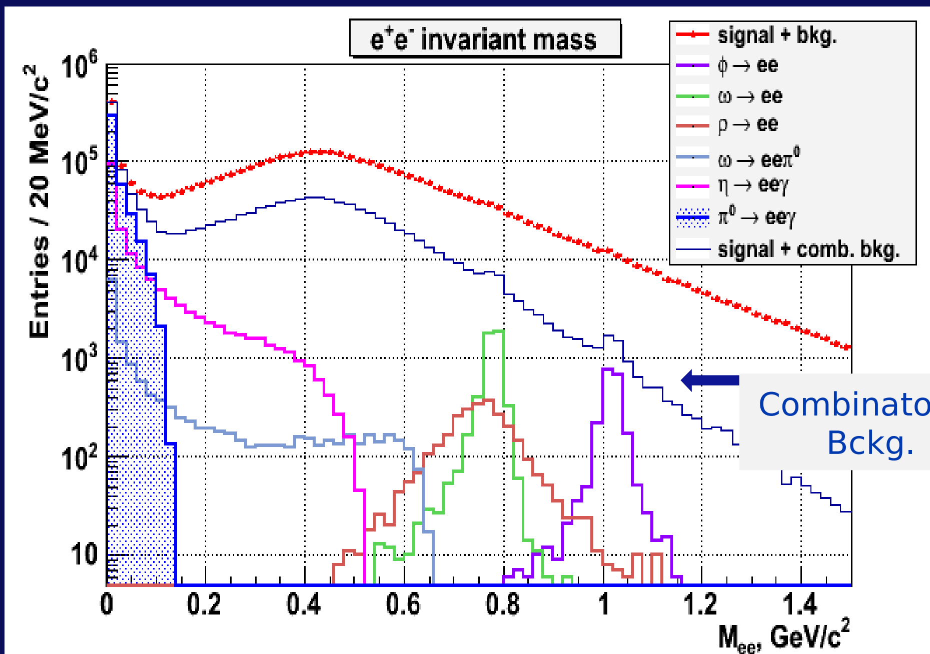
Selection: |η| < 1.2, # of TPC points ≥ 20
0.2 p<2 GeV/c
Efficiency: **35%**
misID contamination:
-**19.0**% *(w/o **ECAL** signal)*
- **1.4**% *(with **ECAL** signal)*

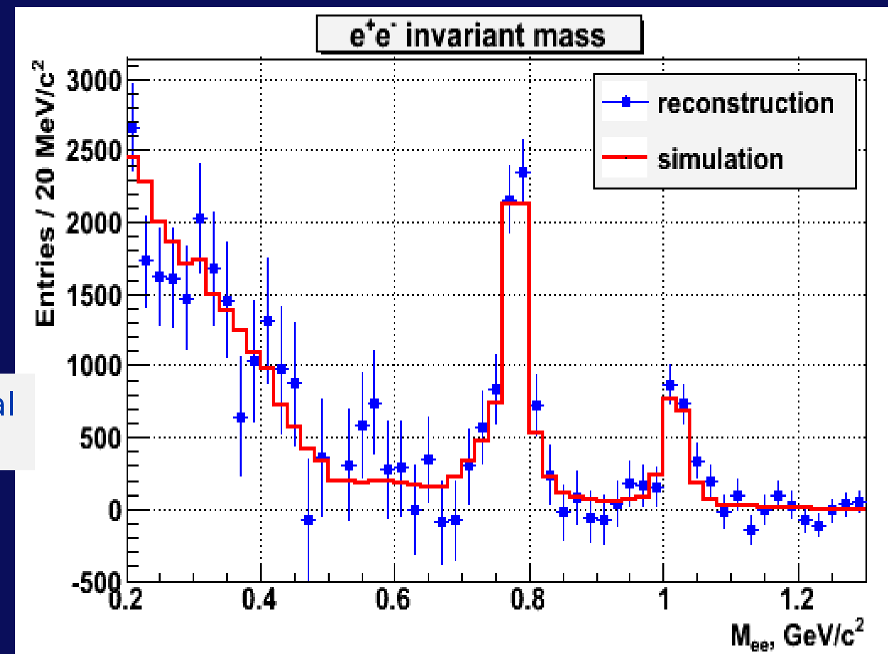




Dilepton invariant spectra

(simulation -> reconstruction)





NICA-MPD:

σ_φ = 17 MeV, S/B = 0.045

σ_ω = 14 MeV, S/B = 0.047

NA49 (φ) S/B = 2%

STAR (ω,φ) S/B = 4-6%

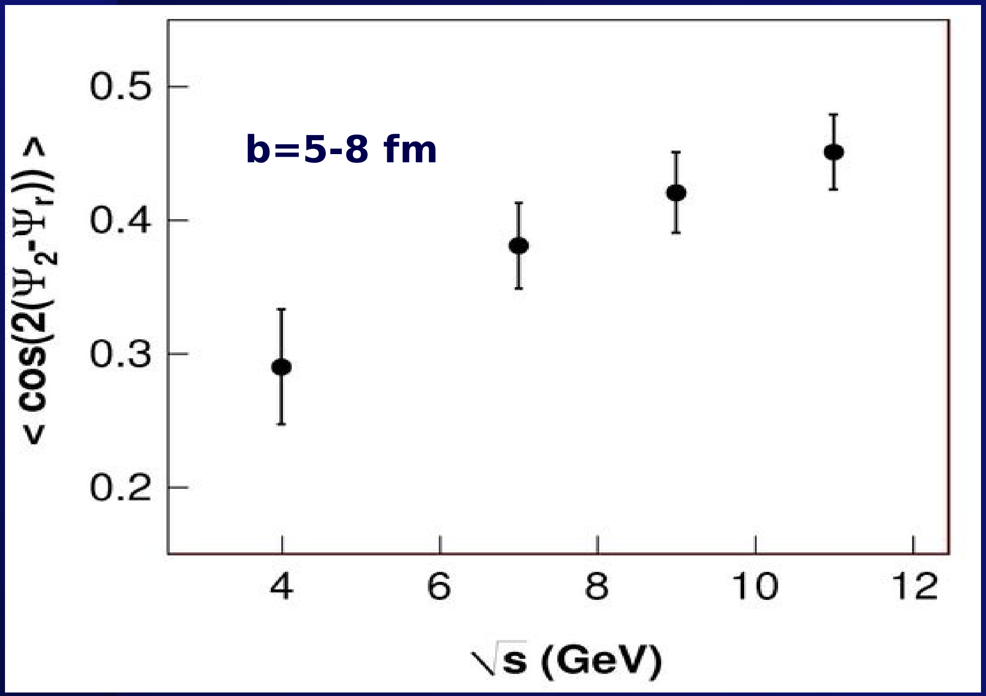
CERES (0.2<Mee<1.2 GeV/c^2) S/B = 17% (!)

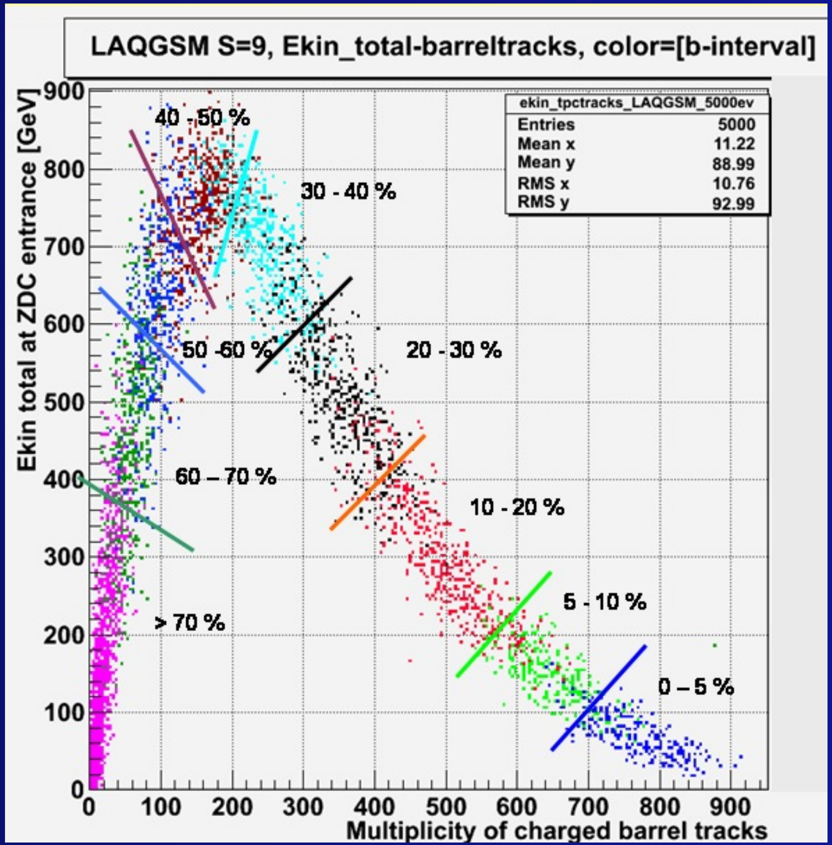
Source of a large background so far: conversion electrons and misidentified hadrons

Flow @ MPD

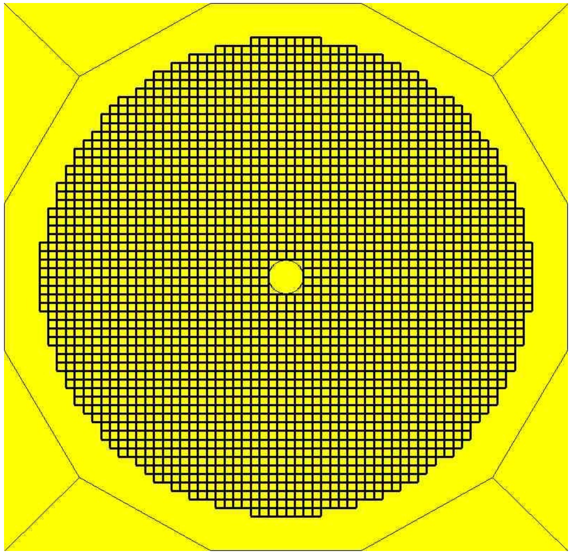
- ✓ MPD capability for event plane determination: v2 in TPC and v1 at high rapidities **(potential for improvements up to a factor of 2)**
- ✓ v2 in TPC by a ‘two sub-events method’ to avoid autocorrelations
- ✓ Measurement of spectators of both colliding nuclei; centrality determination by track multiplicity and spectator energy deposit

Event plane resolution



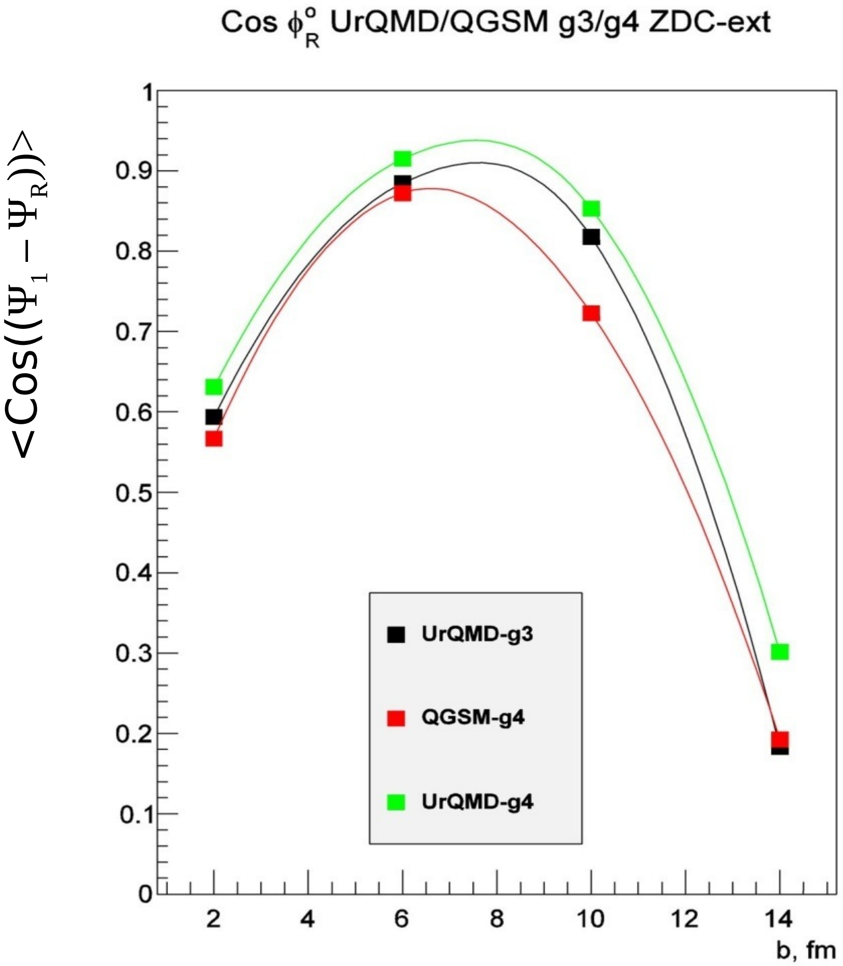


Extended ZDC detector (2<η<5) improves RP resolution at low and medium b



V.Kapishin

Event plane resolution (ext-ZDC)



- L = 120 (60) cm
- 5 < R < 71 cm, 1<θ<14° (2<η<5)
- Cell dimensions= 2.5x2.5 (5x5,10x10) cm
- $w_i = \Sigma E_{loss}$ in active layers as weights
- No π/p identification
- Geant 3 vs Geant 4

EVO Meeting of DAC, *17 January 2012*

Experts:

J. Cleymans, H.H. Gutbrod, Nu Xu, L. Riccati, E.Tomasi, I.Tserruya

FEEDBACK

to the MPD Detector Advisory Committee Report presented at PAC-PP on January 23rd 2012

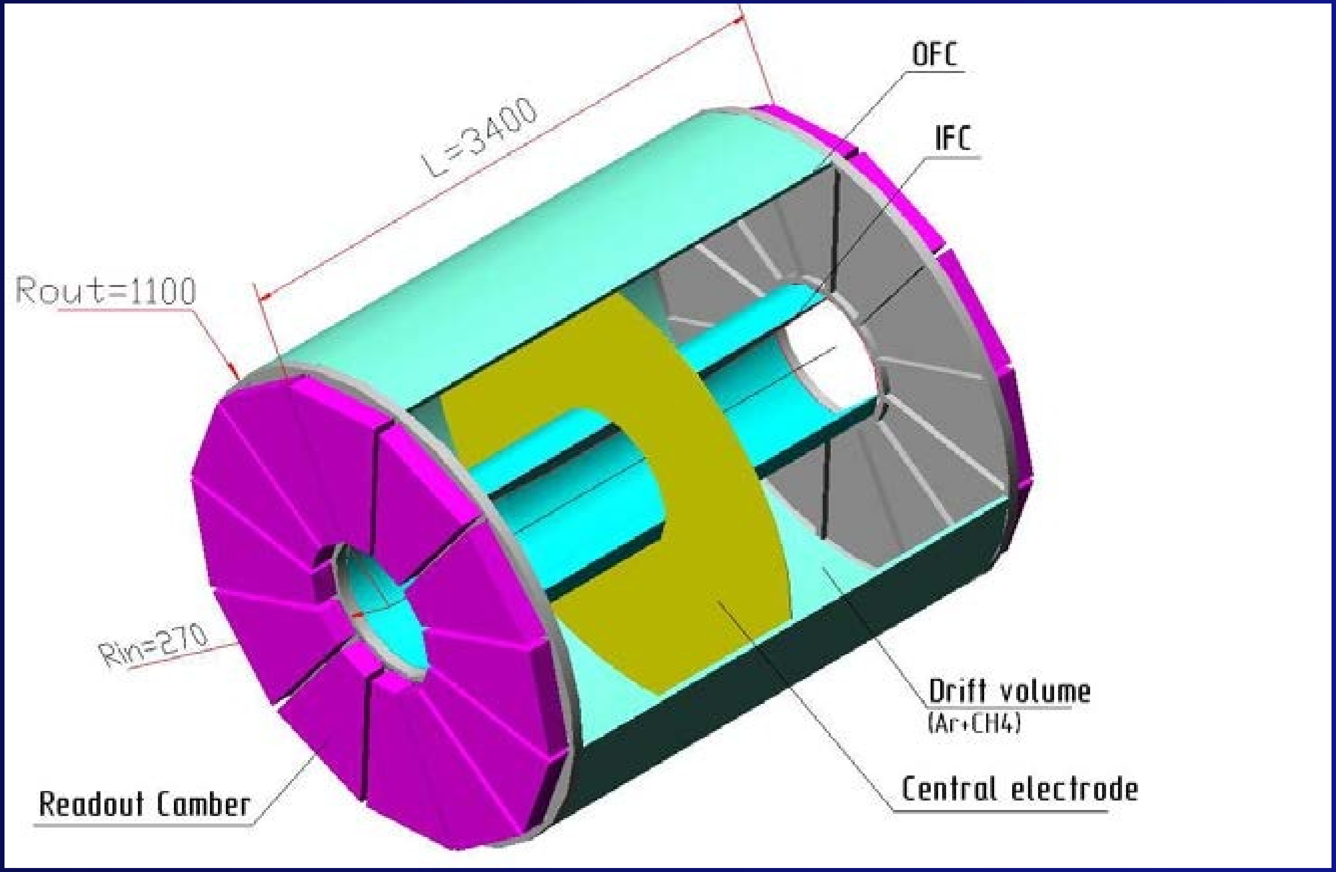
Discussed issues:

- *Staging*
- *Coverage of Phase Space*
- *Reaction plane determination*
- *Event generators*
- *Particle Identification*
- *Di-Leptons*

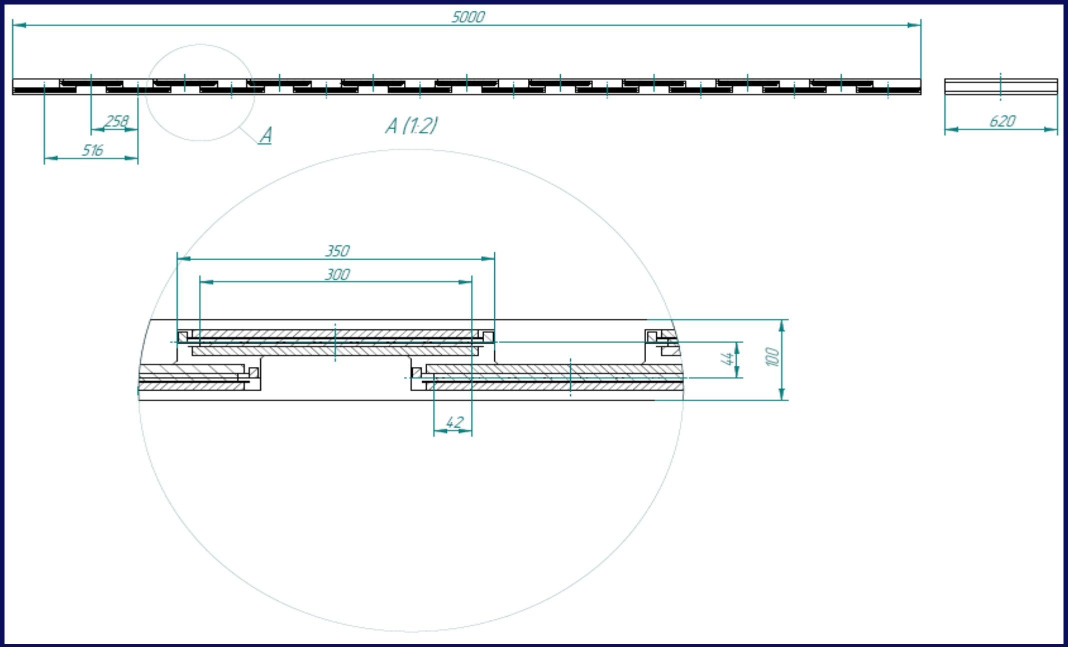
Progress in R&D

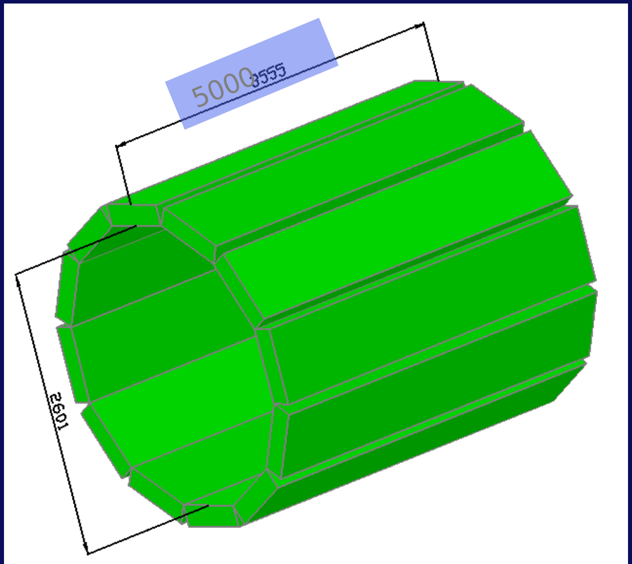
TPC design

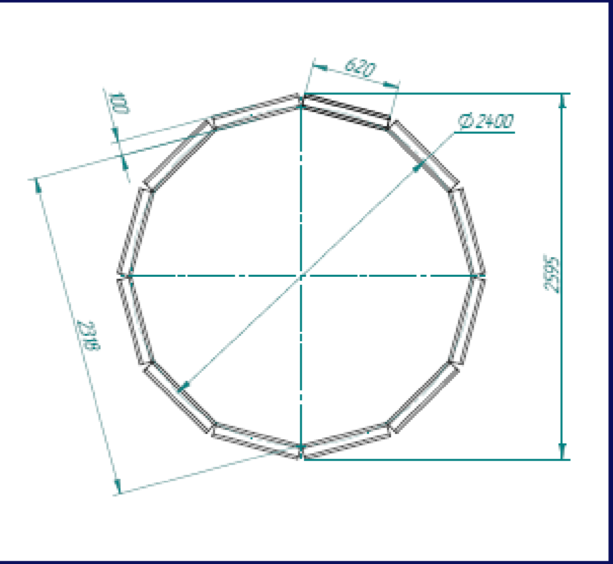
Details in the
report of Stepan Razin



TOF design







In sector → 19 mRPCs; 1 mRPC has 24 strips (60x2) cm²

In sector → 19 mRPC x 24 strips =456 channels

In barrel → 12 sectors;

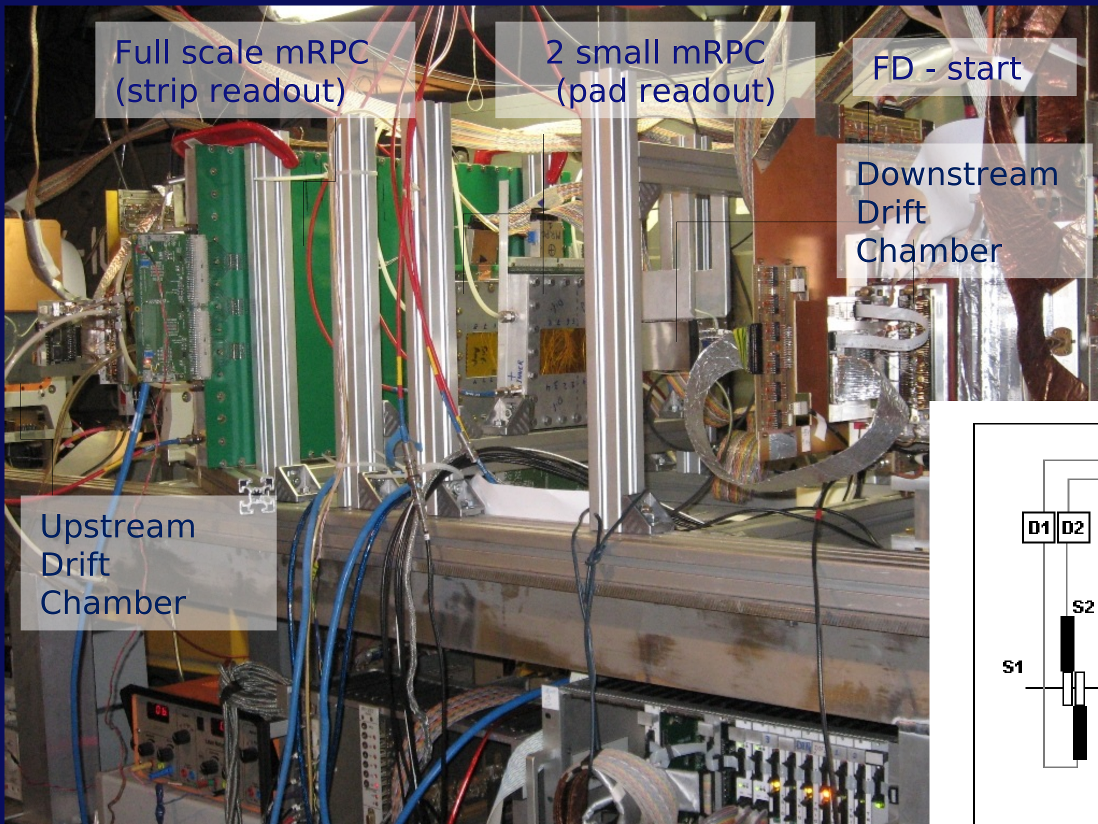
In barrel → 19 mRPC x 12 sectors =228 mRPC

In barrel → 228 mRPC x 24 strips = 5472 channels;

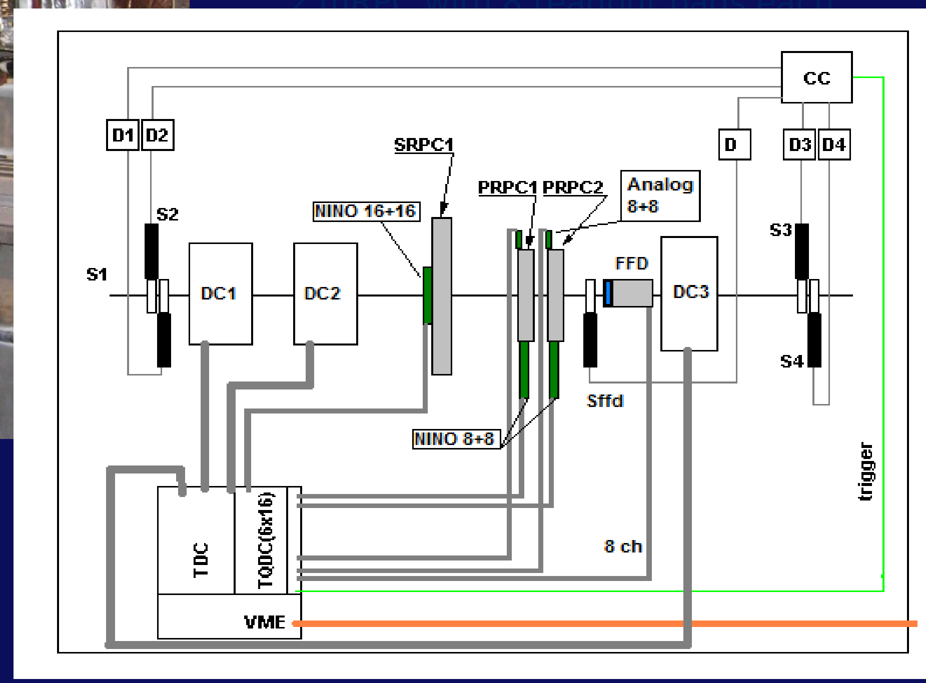
In case if readout from both sides = 10944 channels=1368 chips NINO(8ch)

We have enough electronics for barrel TOF

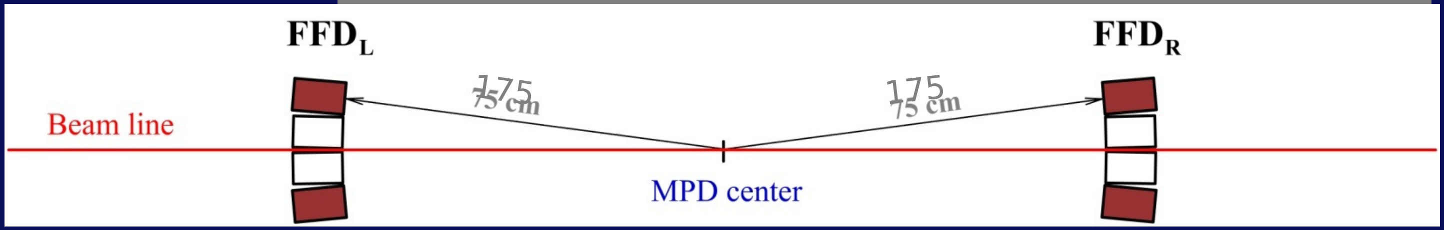
Experimental Setup for TOF prototypes test in the NUCLOTRON beam line *(Run 44, December 2011)*



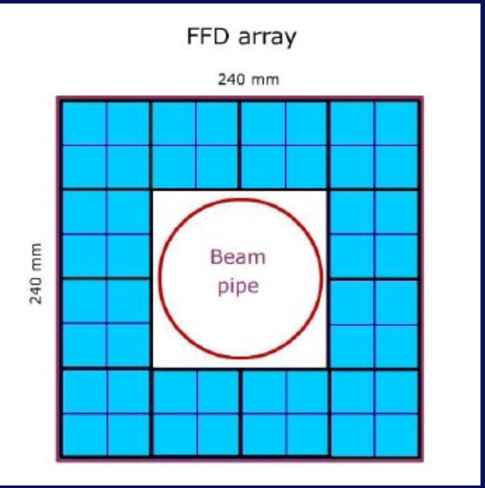
16 strips were readout from both sides
2 mRPC with 8 readout pads each

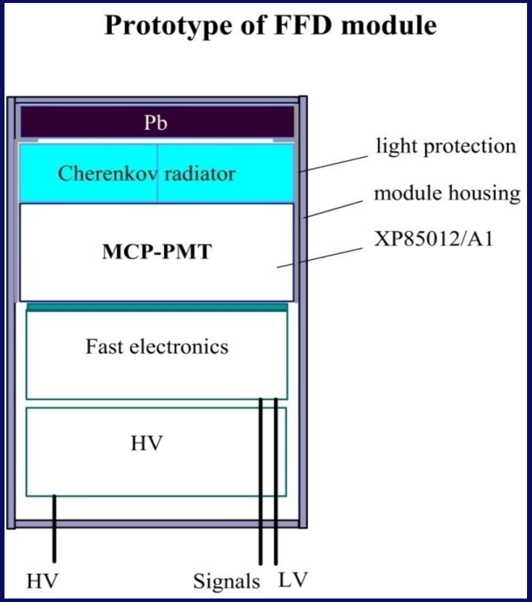


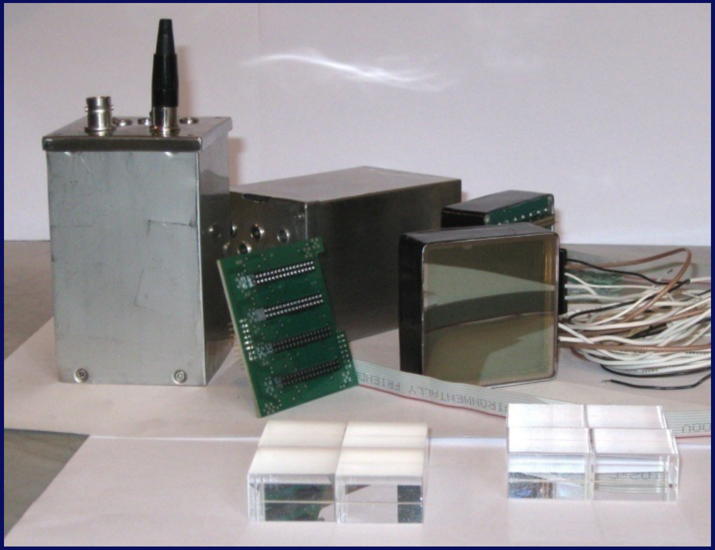
Fast Forward Detector (FFD)

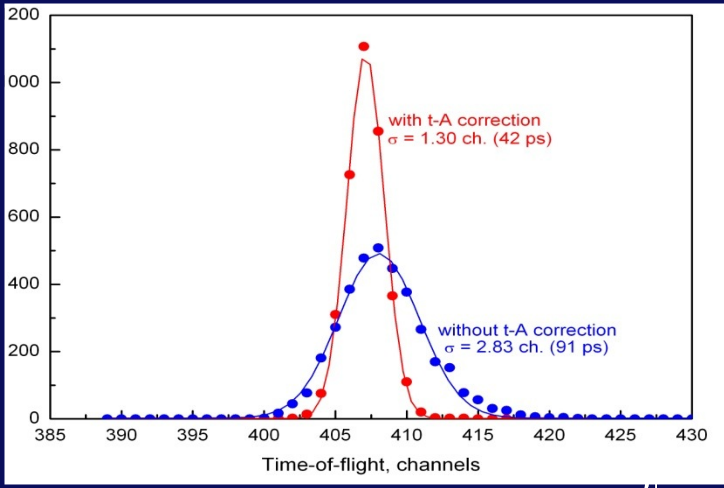


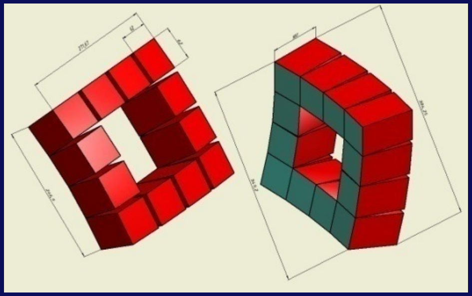
FFD: quartz Cherenkov radiator with micro-channel plate PMT





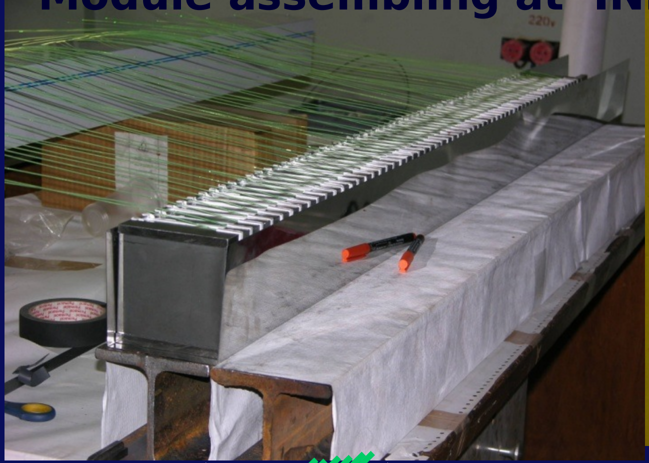


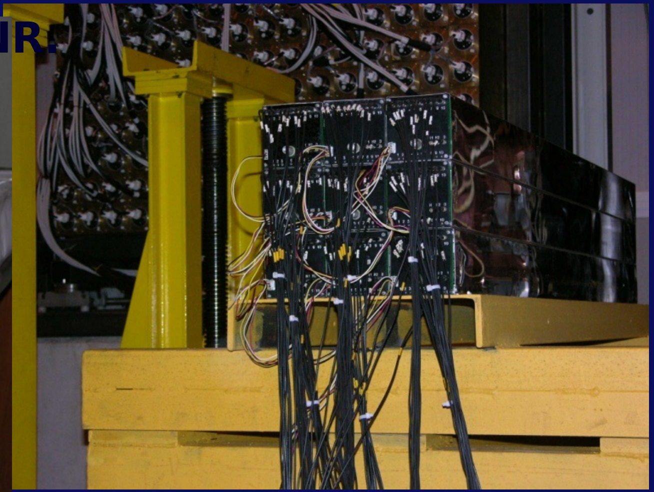




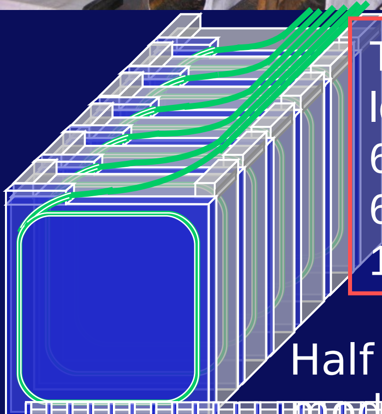
ZDC Beam test at *CERN*

Module assembling at INR:



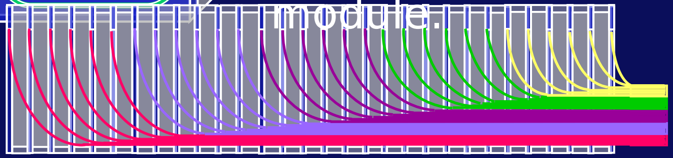


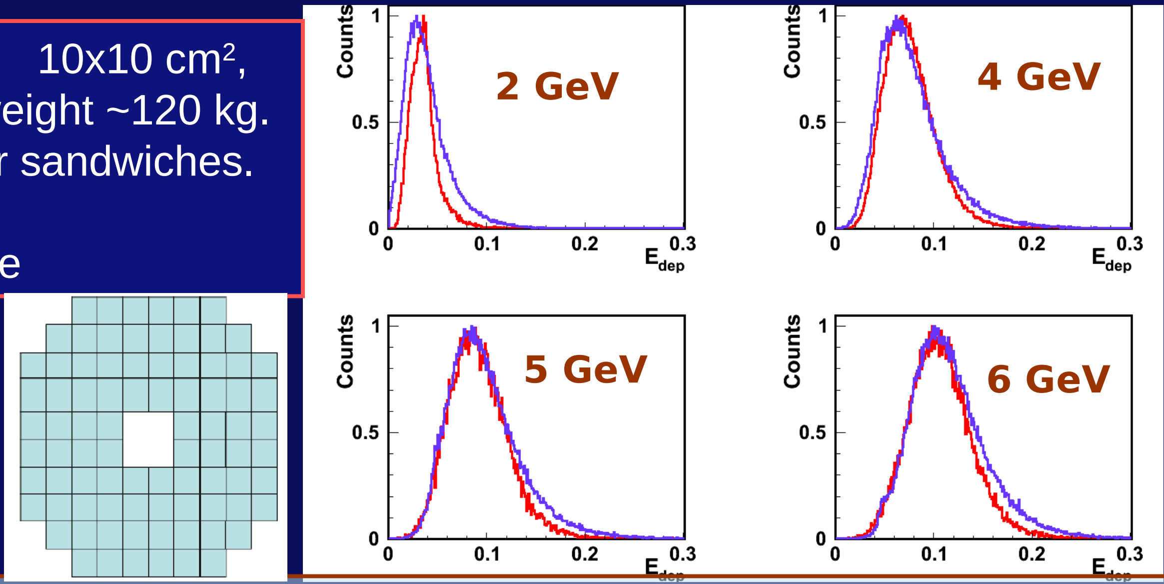
Tasks of beam test:
- *E resolution at 1-6 GeV*
- *detector performance at NICA energies*
- *performance of new MAPDs with high dynamical range (Sadygov-Dubna-Zecotek)*
- *feasibility of calibration of individual sections with μ*



Transverse size 10x10 cm^2, length~160 cm, weight ~120 kg.
60 lead/scintillator sandwiches.
6 fiber/MAPD
10 MAPDs/module

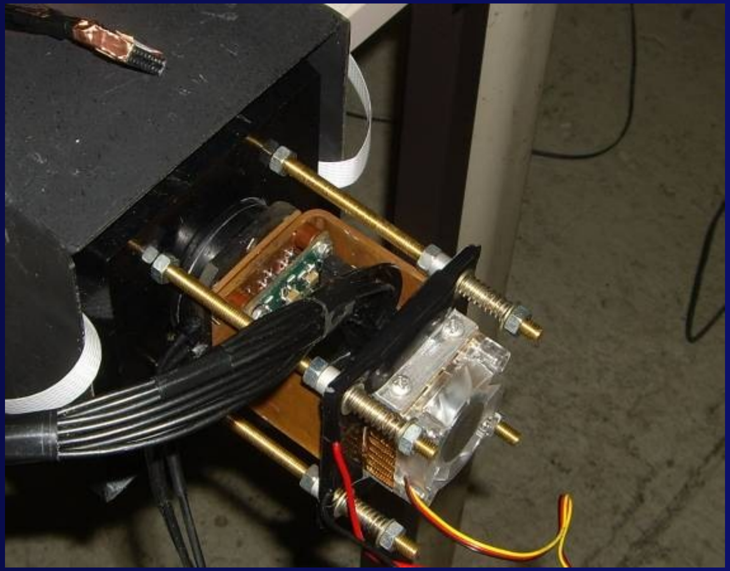
Half of module:

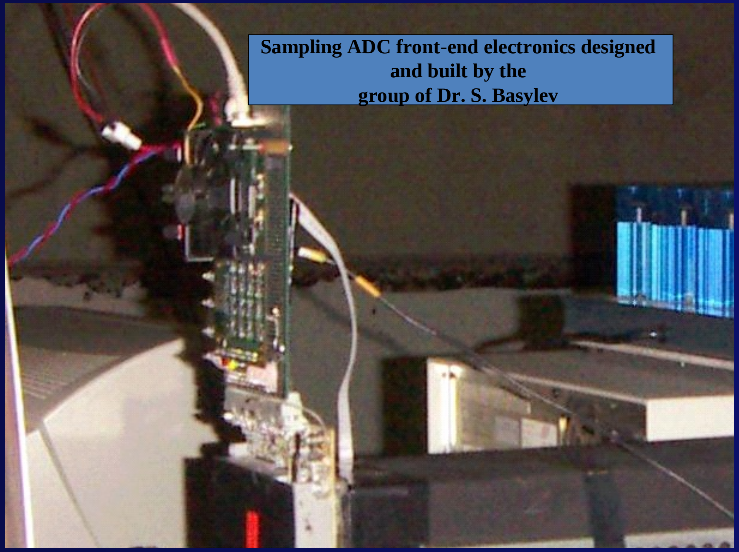




- *Experimental and MC spectra (good agreement at > 2 GeV); studies are required at 2 GeV*
- *The energy resolution of 3x3 supermodule: ~56% (stochastic term) + 3.7% (constant term).*

ECAL-ReadOut





Sampling ADC front-end electronics designed and built by the group of Dr. S. Basylev

Straw Tracker

Inner Tracking System (ITS)

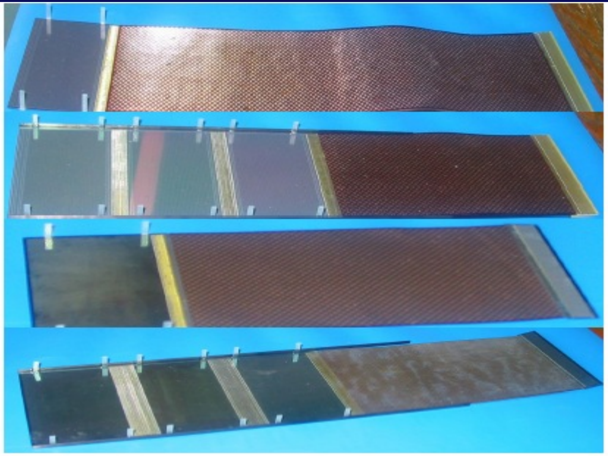


Figure 1: Prototypes of CBM STS sensitive modules.

- 4 cylindrical & disk layers
- 300 μm double-sided silicon microstrip detectors, pitch - 100 μm
- Thickness/layer ~ 0.8% X_0
- Barrel: R=1-4 cm, coverage $|\eta|<2.5$
  806 sensors of 62x62 mm^2
- Disks: under optimization
- resolution: σ_z = 120 μm, $\sigma_{r\phi}$ = 23 μm

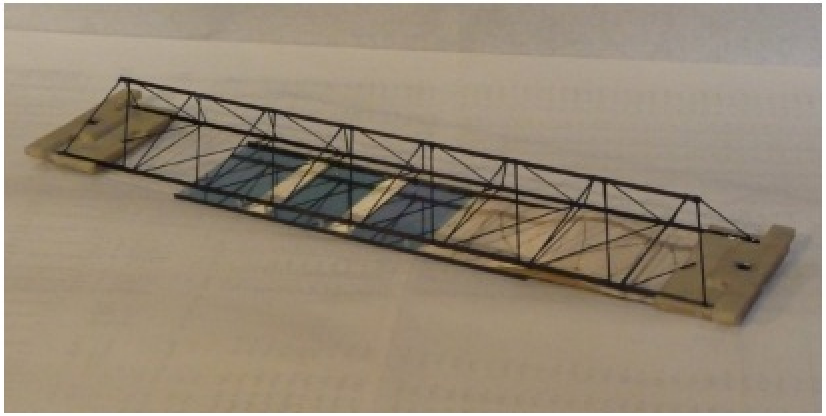
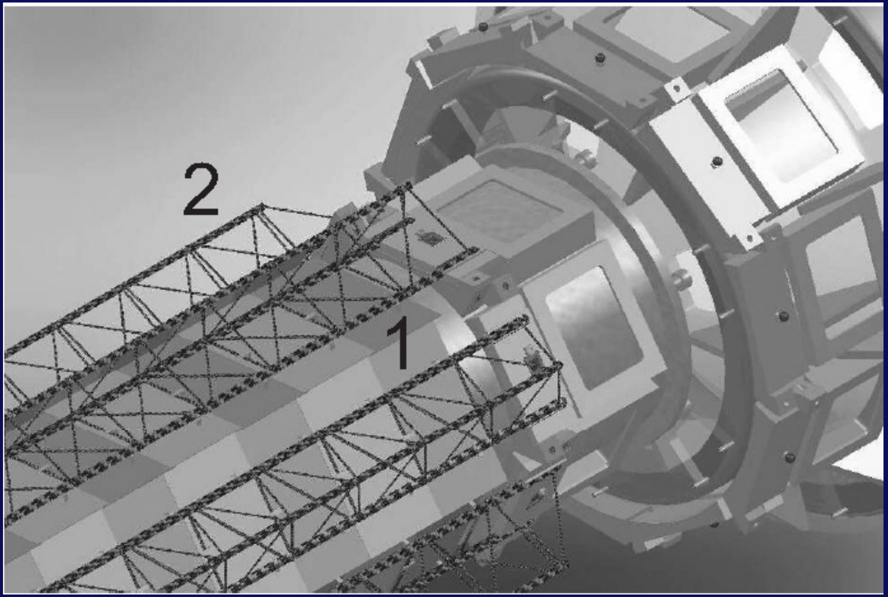
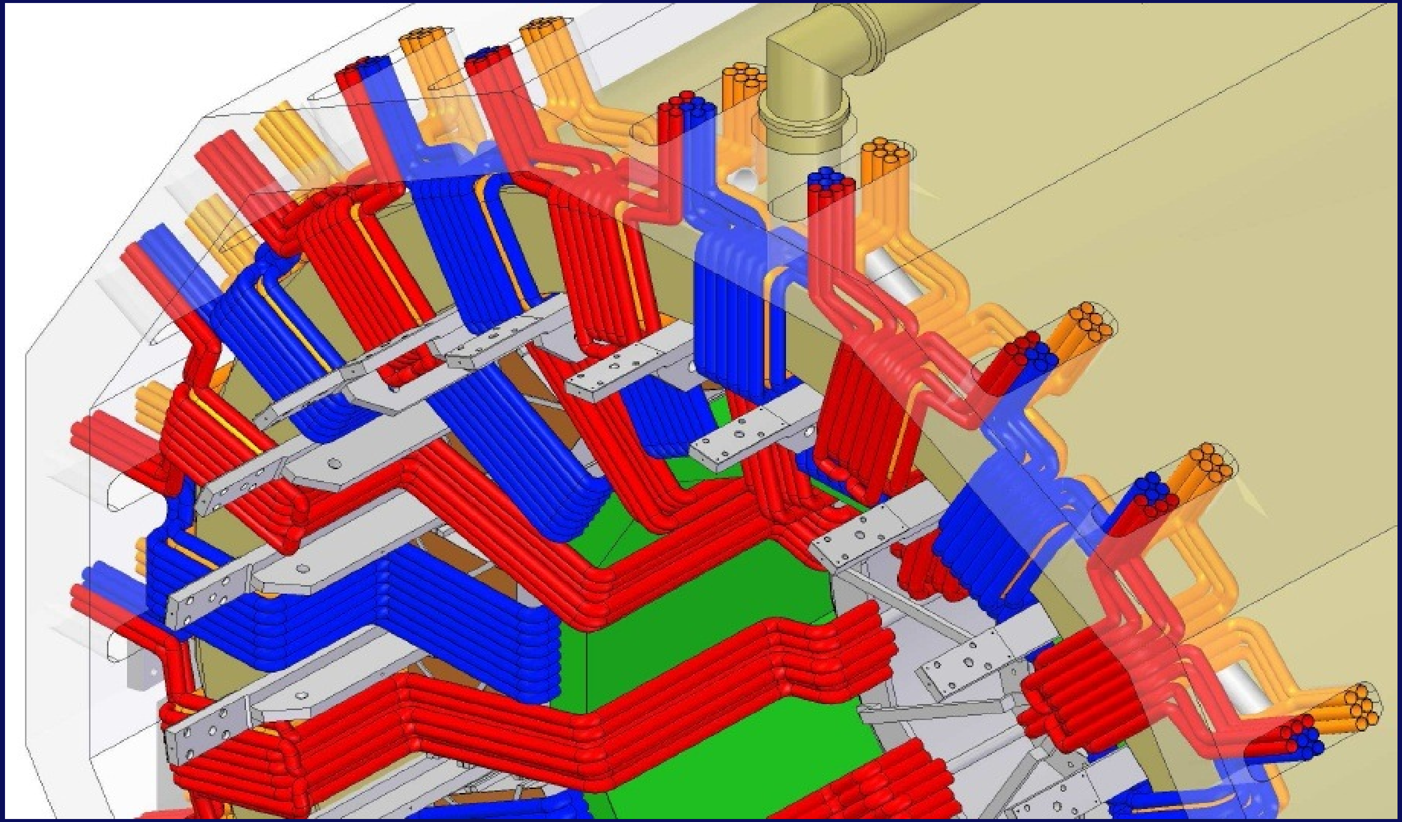
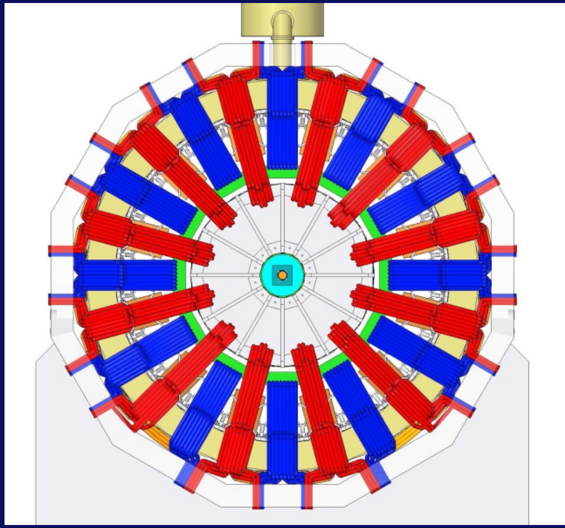


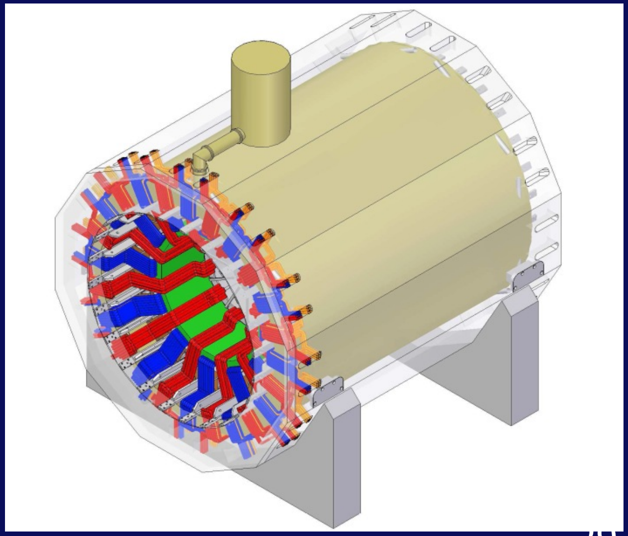
Figure 2: Prototype of the ladder of the CBM STS (super-module) with one sensitive detector module built of three sensors



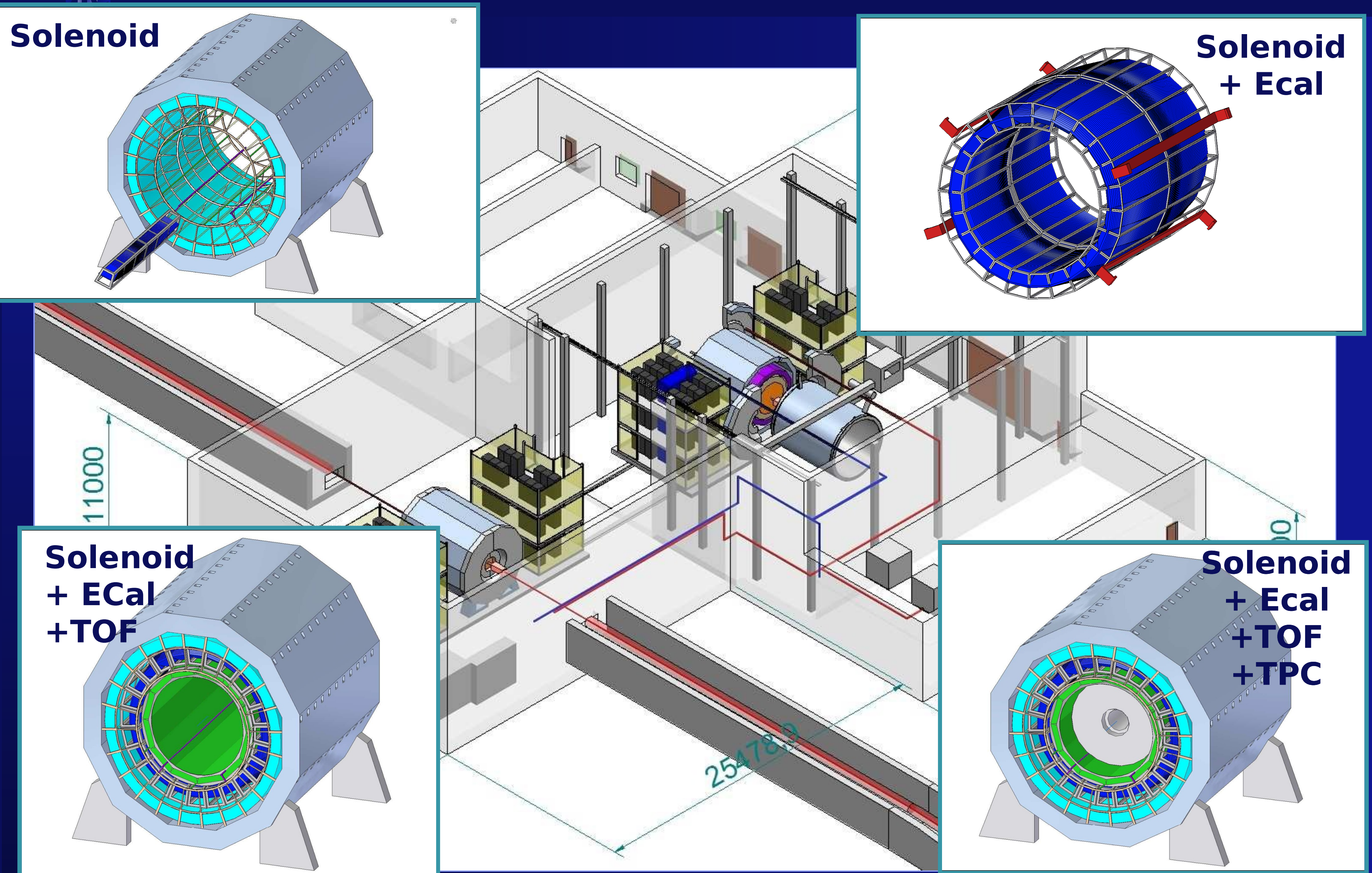




Cabling and cooling lines scheme



Assembly and maintenance



Timetable of MPD construction and commissioning

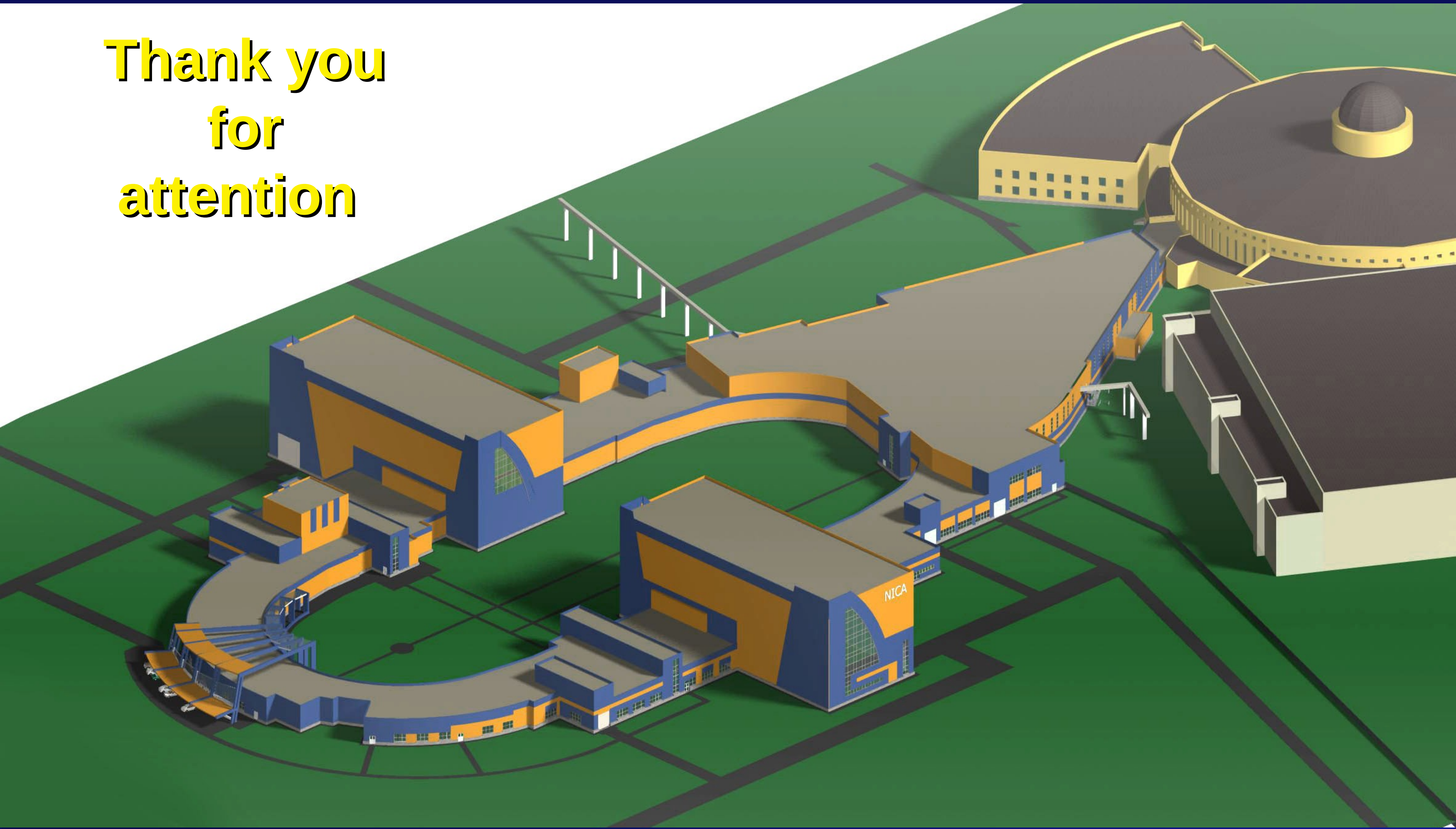
	Stage/Year	1	2	3	4	5	Total
	Budget profile for MPD ----→	1080	12500	15500	9300	2560	**40940**
1	**Experimental Hall**						
	NICA Hall Construction						
	Electricity,water & infrastructure						
	Crane(construction & certification)						
2	**Superconducting Magnet**						
	Magnet TDR and Tender						
	Call for Tender-Yoke,SC,trim coils						
	Contracts signing						
	Construction of Iron York & SC						
	Transportation						
	Cryogenics for Solenoid						
	Assembling & Commiss. of Solenoid						
	Field measurements						
3	**TPC**						
	TPC Assembling workshop						
	TPC Construction						
	TPC tests						
	TPC installation and Commissioning						
4	**TOF**						
	TOF Assembling area						
	Test area of TOF mRPC						
	TOF Mass Production and test						
	TOF installation & Commissioning						
5	**ECal modules production**						
	ECal Assembling in sectors						
	ECal installation & Commissioning						
6	**ZDC construction and installation**						
7	**Electronics, Network and**						
	DAQ production &implementation						
	Control Room construction						
	Slow Control system implementation						
	Computing for Data taking & network						
8	**Detector Assembling**						
9	**Commissioning and Cosmic Tests**						

Start up minimum

Summary

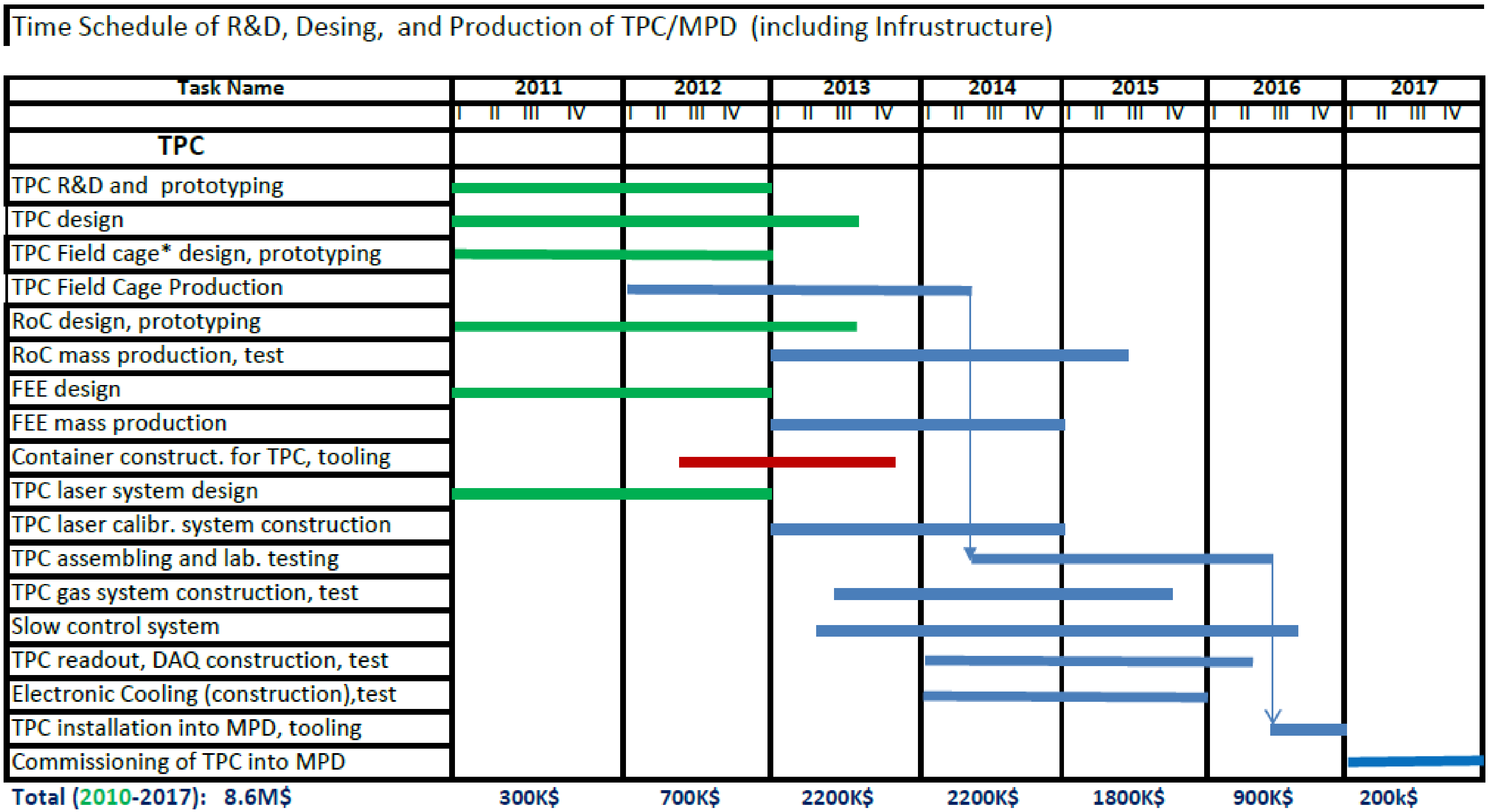
- The MPD design - close to completion
- External referee's advices are very essential & will be taken into account
- We would be grateful for the continuation of regular expertise
- The MPD technical project preparation is under progress
- The key milestones should be defined/corr. asap
- The major element production/construction should start-up in 2012

Thank you for attention



spare

Time schedule of TPC design and construction

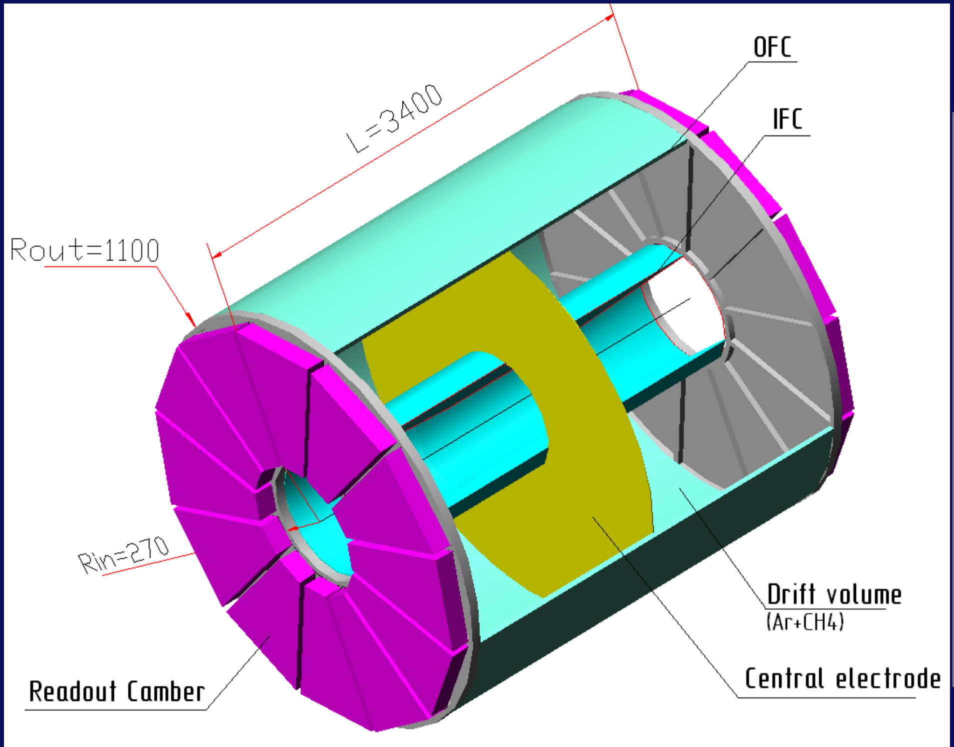


R&D, Design, Prototyping Cost - 1,5 M$ (2010-2013) — **R&D, Design, Prototyping**

Productin Cost - 6,85 M$ (2012-2017) — **Production**

Infrustructure Cost - 0,25 M$ (2012-2013) — **Inftrustructure**

Time Projection Chamber (TPC)



TPC is a heart of MPD

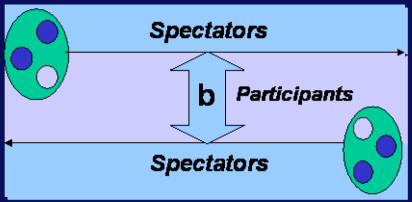
Main Parameters

Size: 3.4 m (length) x 2.2 m (diameter)
Drift Length: 150cm
Electric field: 140V/cm
Magnetic field: 0.5 T (max.)
Gas: 90% Argon + 10% Methane
Readout: 2x12 sectors (MWPC+ pads or GEM)
Pad size – 5x12 mm in all sector area
Total # of pads: ~80 000
Rate capability: ~ 7 kHz

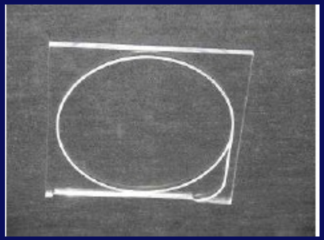
Performance required

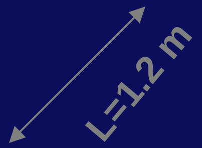
Spatial resolution: $\sigma_{r\phi}$~300 μm, σ_z~ 2 mm
Two track resolution: < 1 cm
Momentum resolution: Δp/p < 3% (0.2<p<1 GeV/c)
dE/dx resolution: < 8%
Max. multiplicity: ~ 1000 (central collision)

Zero Degree Calorimeter



. measures the energy deposited by spectators.
- event centrality determination (offline b-selection)

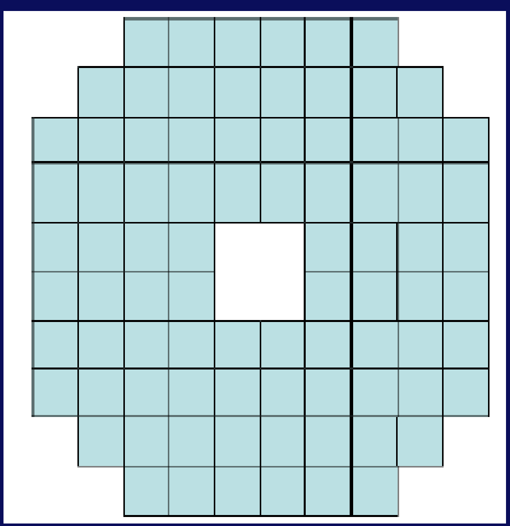


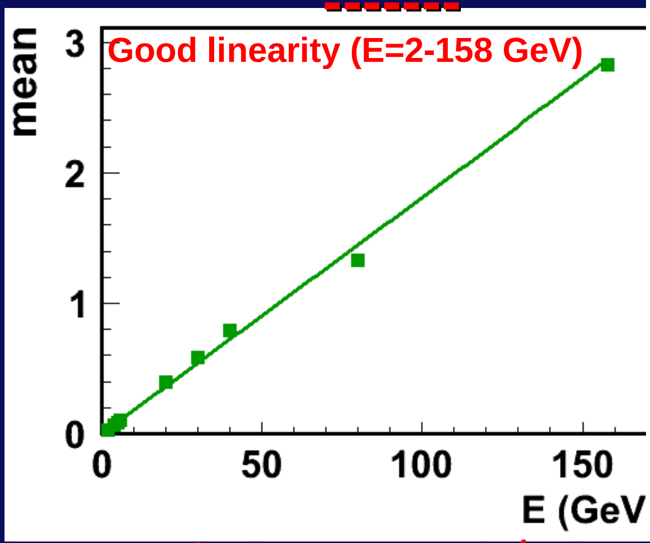


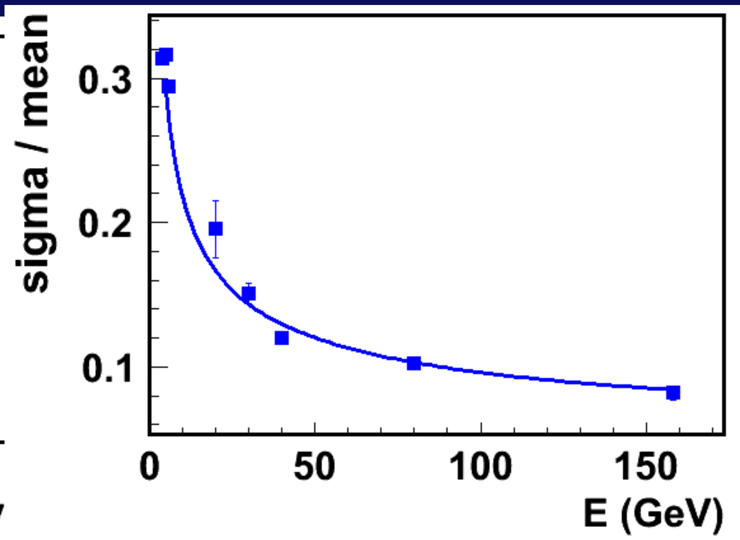
80 modules 5x5 cm²

- Pb(16mm)+Scint.(4mm) sandwich
- 60 layers of lead-scintillator (1.2m, 5λ)
- 1mm WLS fibers + micropixel APD

------ Beam test of ZDC at SPS/CERN (NICA energies) -------







Design resolution ~ 60%/ √E is proven

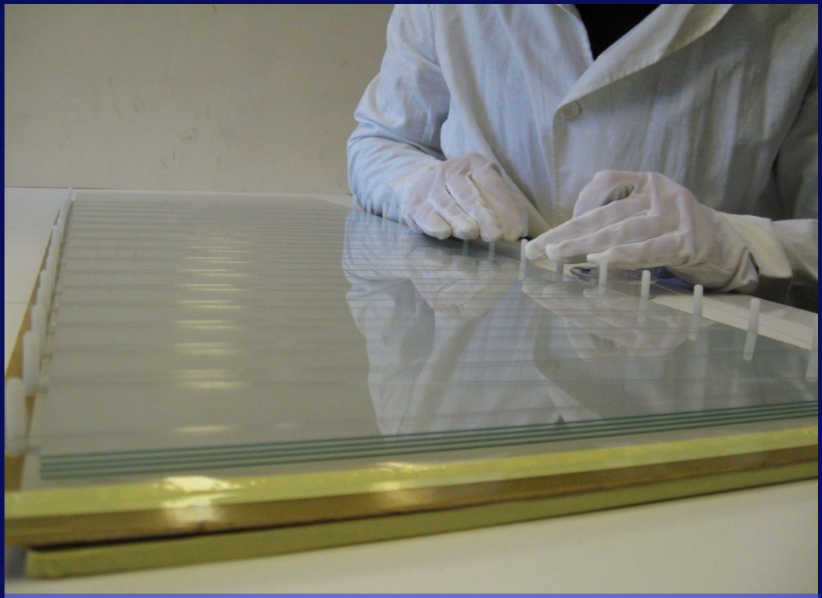
MPD system coordinators

Magnet	**-** *A.Vodopianov*
TPC	- *Yu. Zanevsky*
ECal	- *A.Ol'chevsky, I.Tyapkin*
TOF	- *V.Golovatyuk (+ Beijin Uni)*
Straw EndCap	- *V.Peshekhonov*
ZDC	- *A.Kurepin (INR RAS)*
CPC	- *Yu.Kiryushin*
FFD	- *V.Yurevich*
ITS	- *Yu.Murin (RI RAS))*
DAQ	- *S.Bazylev*
Analysis	- *V.Kolesnikov*
SoftWare	- *O.Rogachevsky (PNPI)*
Integration	- *N.Topilin*

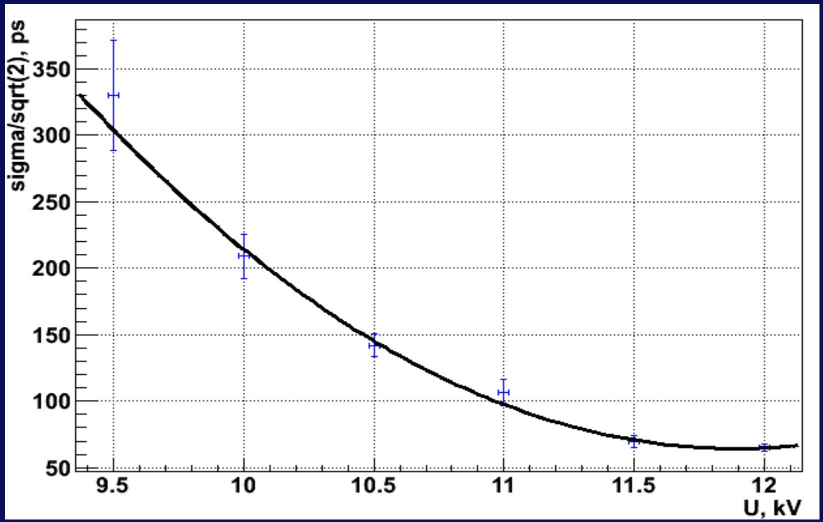
Technical coordinator – V.Golovatyuk

Physics coordinators R.Lednicky
A.Sorin

Full scale prototype tests



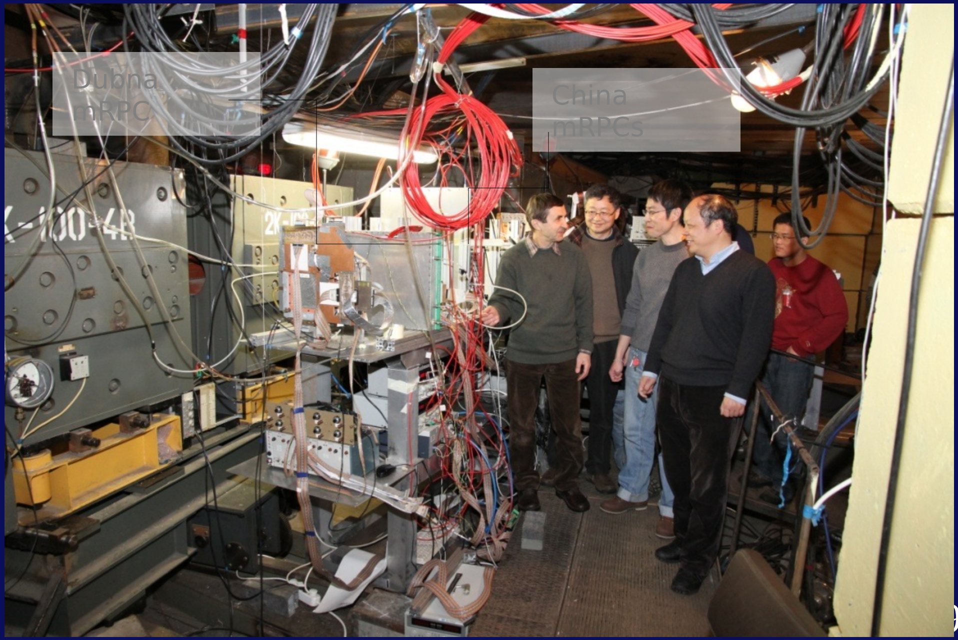
Assembling of a full-scale RPC prototype with strip readout



Time resolution of the first RPC prototype with active area 7 x 14 cm² . Time resolution < 100 ps.

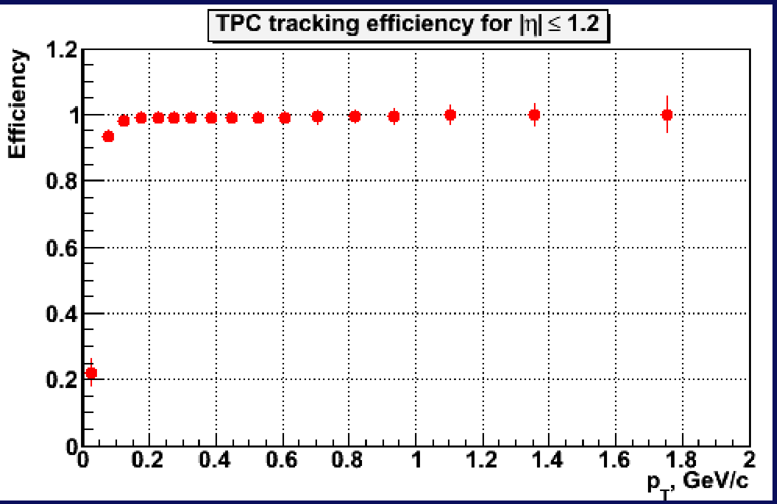
Fig. 2.78: A prototype mRPC plate with the read-out strips.

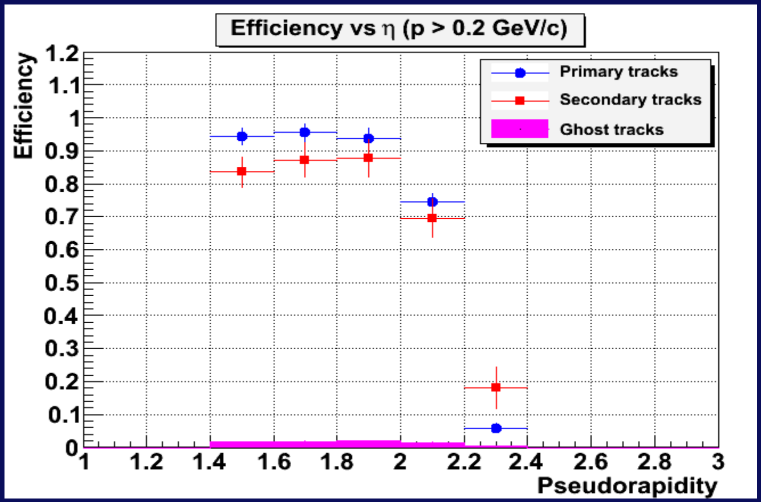
Beam tests for MPD at Nuclotron Dubna (Russia), Beijing and Hefei (China)

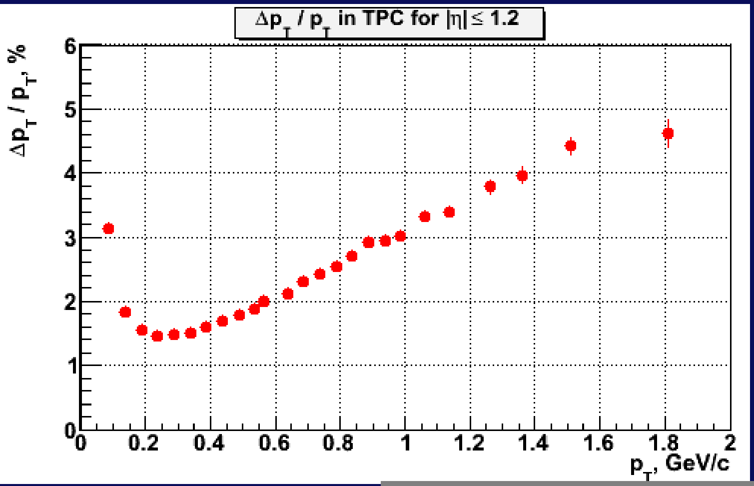


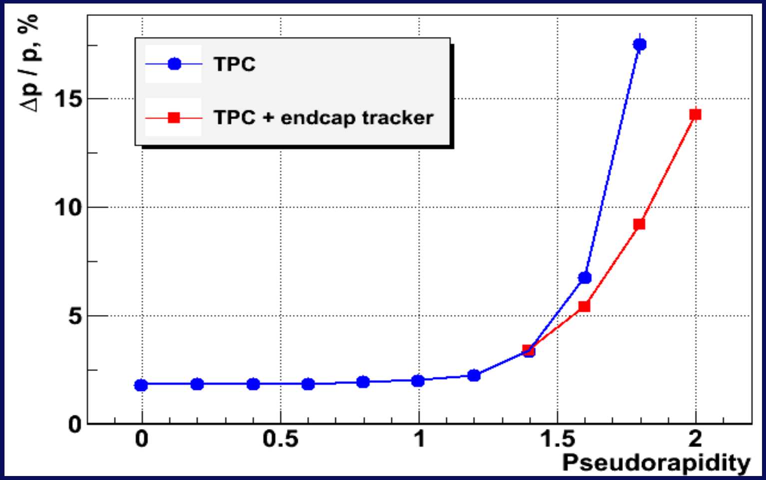
MPD performance

Tracking, PID









- $\Delta p/p < 3\%$ at $p_t < 1$ GeV/c (barrel)
- $\Delta p/p < 15\%$ for the endcap region
- TPC+IT tracking : $s_{r\varphi}, s_Z \sim 40$ mm

Forward Spectrometer

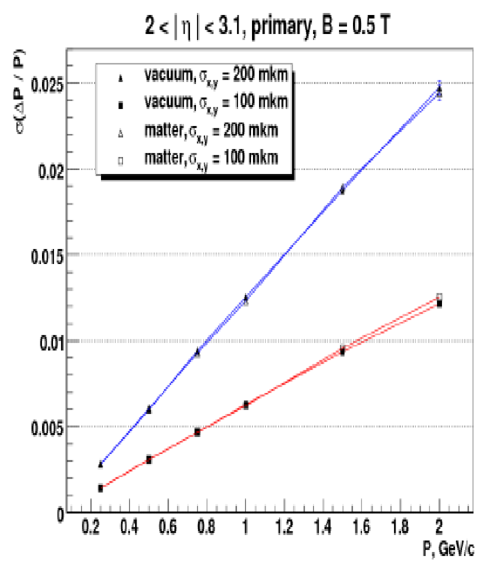
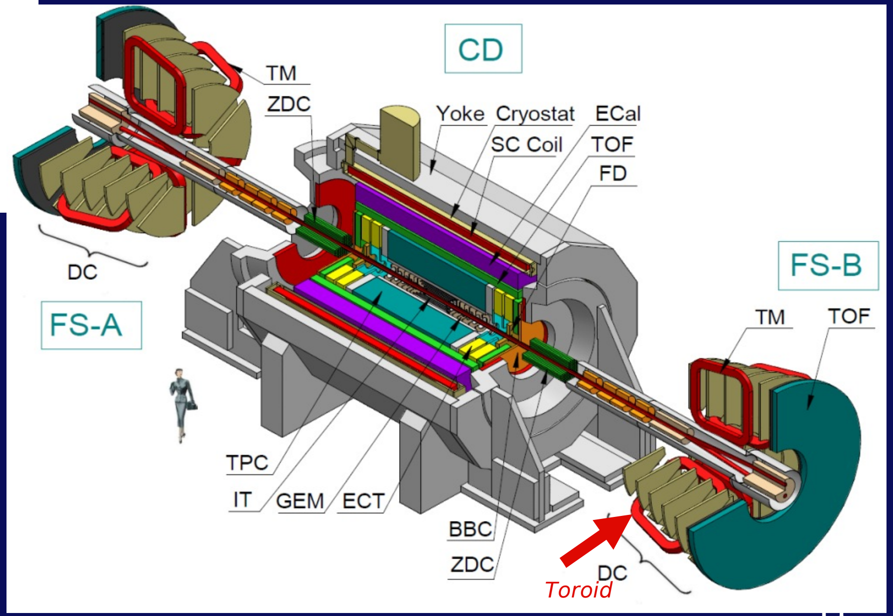
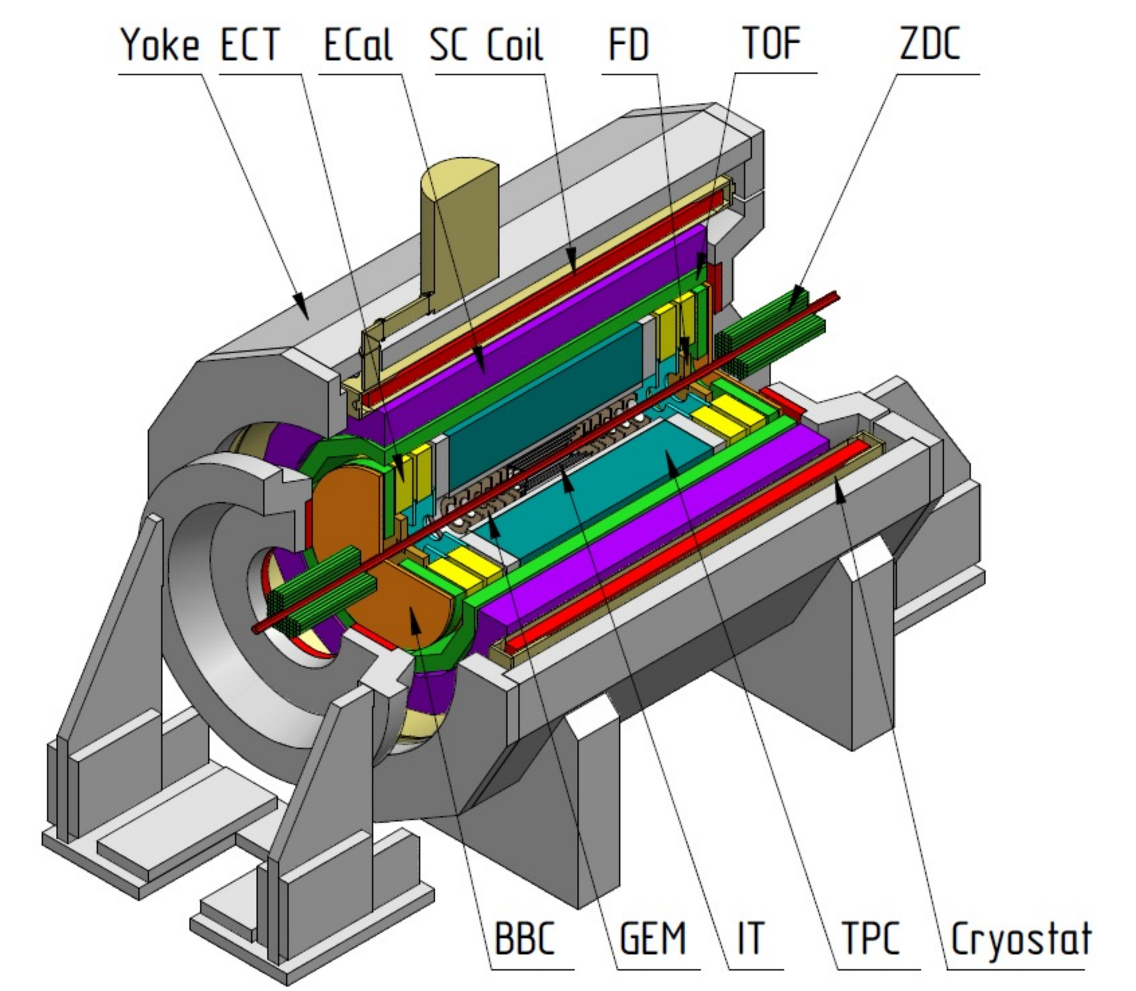


Fig. 2.138: Momentum resolution of Forward Spectrometer as a function of particle momentum. Two lines represent coordinate resolution of tracker 200 μm (top line) and 100 μm (bottom line).



The MPD Apparatus

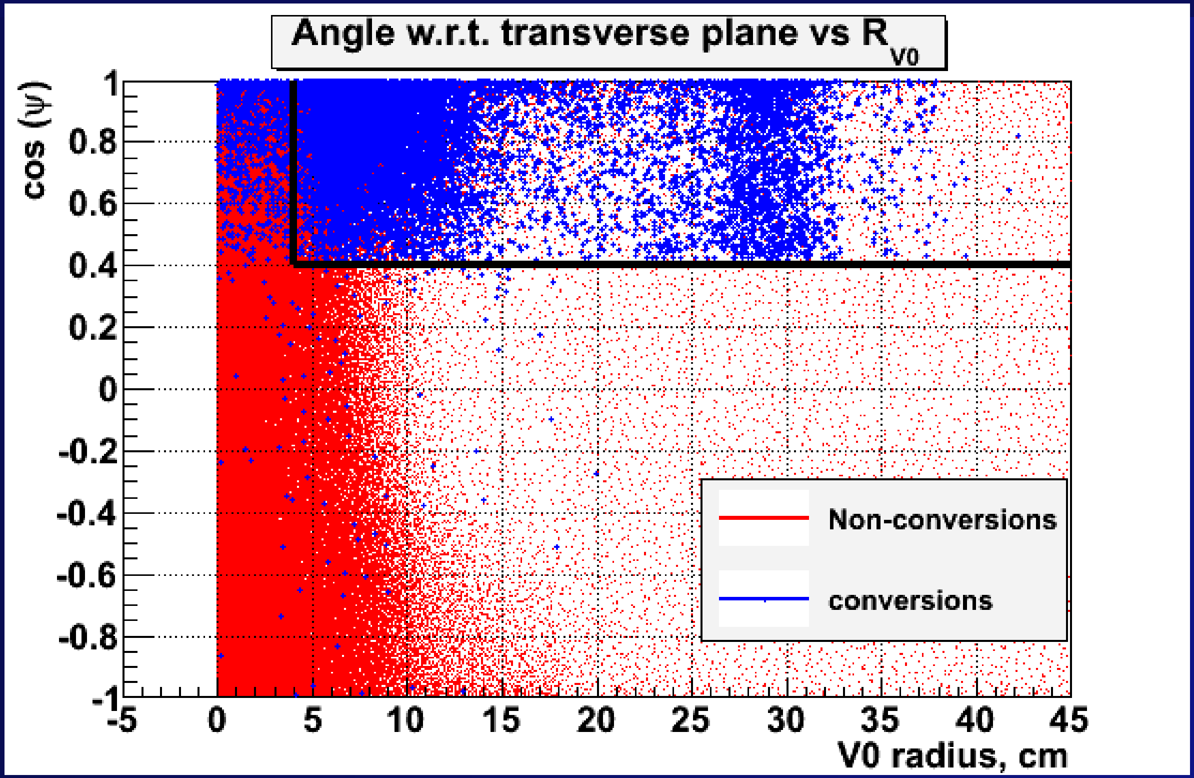


- **Active volume**
  5 m (length) x 4 m (diameter)
- **Magnet**
  0.5 T superconductor
- **Tracking**
  TPC – the main tracker,
  straw EndCapTracker,
  microstrip Si (IT) for vertexing,
  forward tracking (GEM, CPC)
- **Particle ID**
  hadrons(TPC+TOF), π^0,γ (ECAL),
  e^+e^-(TPC+TOF+ECAL)
- **Centrality & T0 timing**
  ZDC FD

MPD Advantages:

- **Hermeticity, homogenous acceptance (2π in azimuth)**
- **Low material budget**
- **High event rate capability**

Rejection of conversion electrons in MPD



$\cos(\psi) = ([\mathbf{p}_1 \times \mathbf{p}_2],\mathbf{B}) / |[\mathbf{p}_1 \times \mathbf{p}_2]| / |\mathbf{B}|$

Selection: V0 > 4cm && cos(ψ) > 0.4

NICA/MPD. Bulk observables (1st Stage)

Particle spectra, yields, ratios:

- Basic information about the fireball properties:
  thMapping the QCD phase diagram in the (T-μ_B) plane
  termodynamics, chemistry, expansion
- Underlying dynamics, signal of deconfinement:
  non-monotonic behavior in hadron production
- Search for the Critical Point: particle number fluctuations, etc.

MPD detector relevant features:

- Large phase-space coverage
- Tracking and PID up to high pseudorapidities
- Precise event characterization

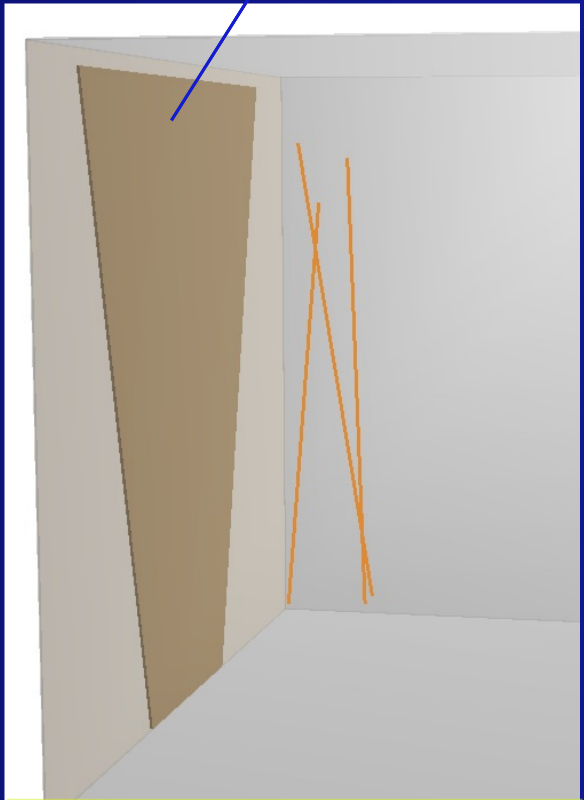
Assembling and Testing of Prototype '0'

Two prototypes are constructed:
- Prototype '0'
- Technological prototype (constructed with INDUSTRY)

Testing of Prototype '0'

The **Prototype '0'** is tested with UV laser and cosmic rays.

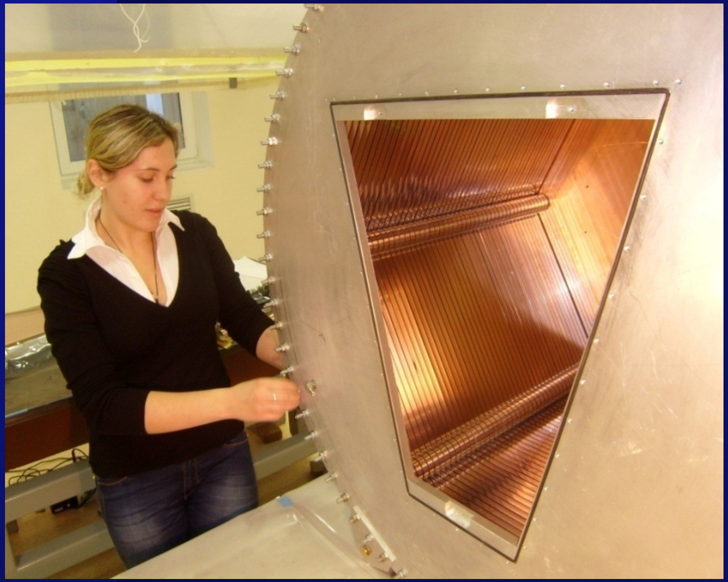
Pad Plane



Reconstructed tracks of cosmic ray in Prototype '0'

- *Drift length = 40 cm, E drift = 140 v/cm*
- *Pad Plane in readout chamber ; Pad size - 6 x 12 mm*
- *256 channels of FEE*
- *2 quartz windows for laser beam*
- *Obtained Spatial resolution*
  - *for UV Lase beam – 0,3 mm*
  - *for cosmic rays - 0,4 mm*

Technological Prototype of TPC / MPD



Preliminary assembling of Technological Prototype TPC in November 2011.
Start of the Prototype testing is planning on February 2012.

Technological prototype of TPC's inner tube

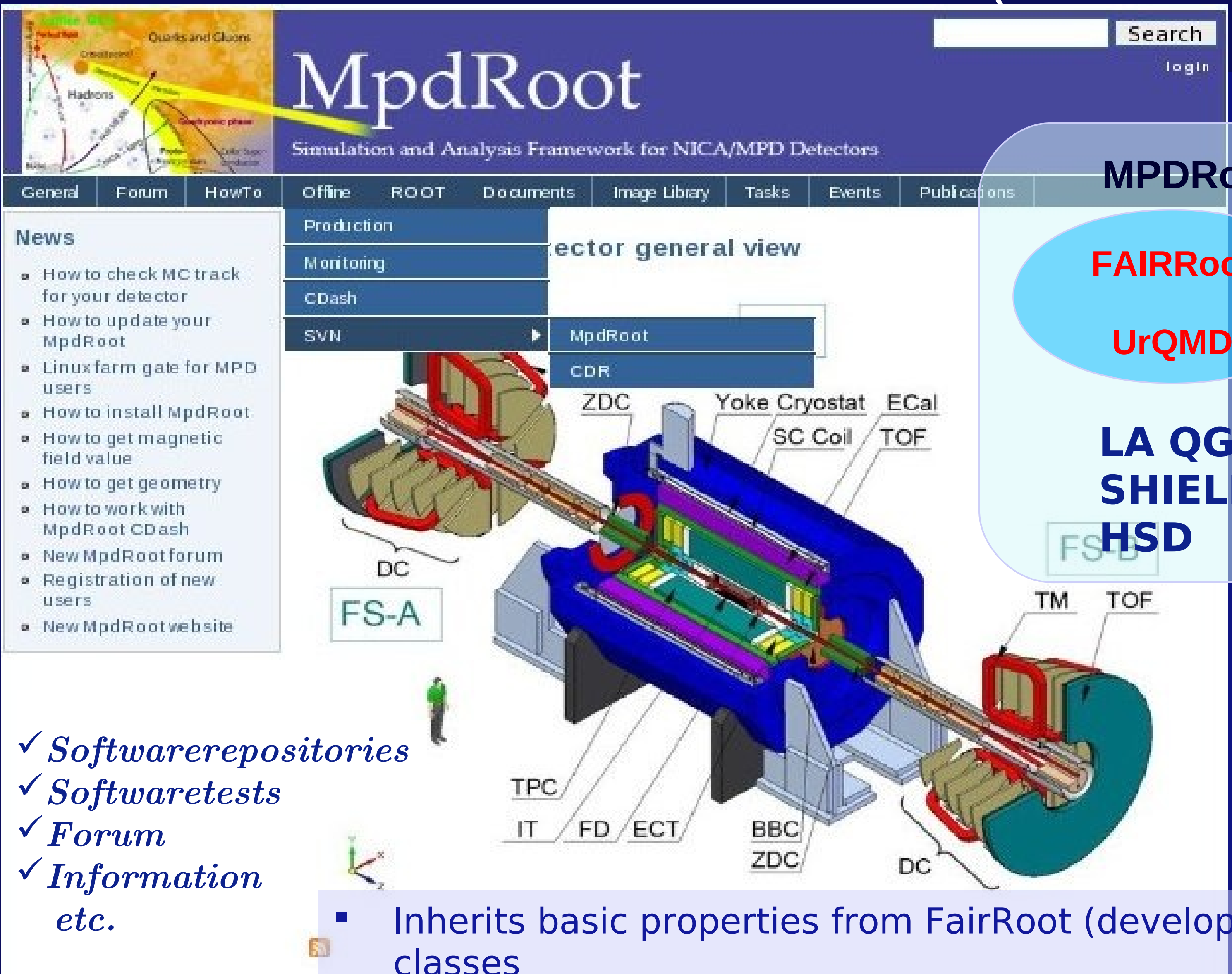
Diameter = 0.57 m,

Length = 3.0 m

Material:
Kevlar laminated by Tedlar film

Diameter - 950 mm
Length - 900 mm
Wall thickness - 2 mm
Weight ~ **10 kg**

Framework for MPD (…+ models)



MPDRoot

FAIRRoot

UrQMD

LA QGSM
SHIELD
HSD

nucleus-nucleus models

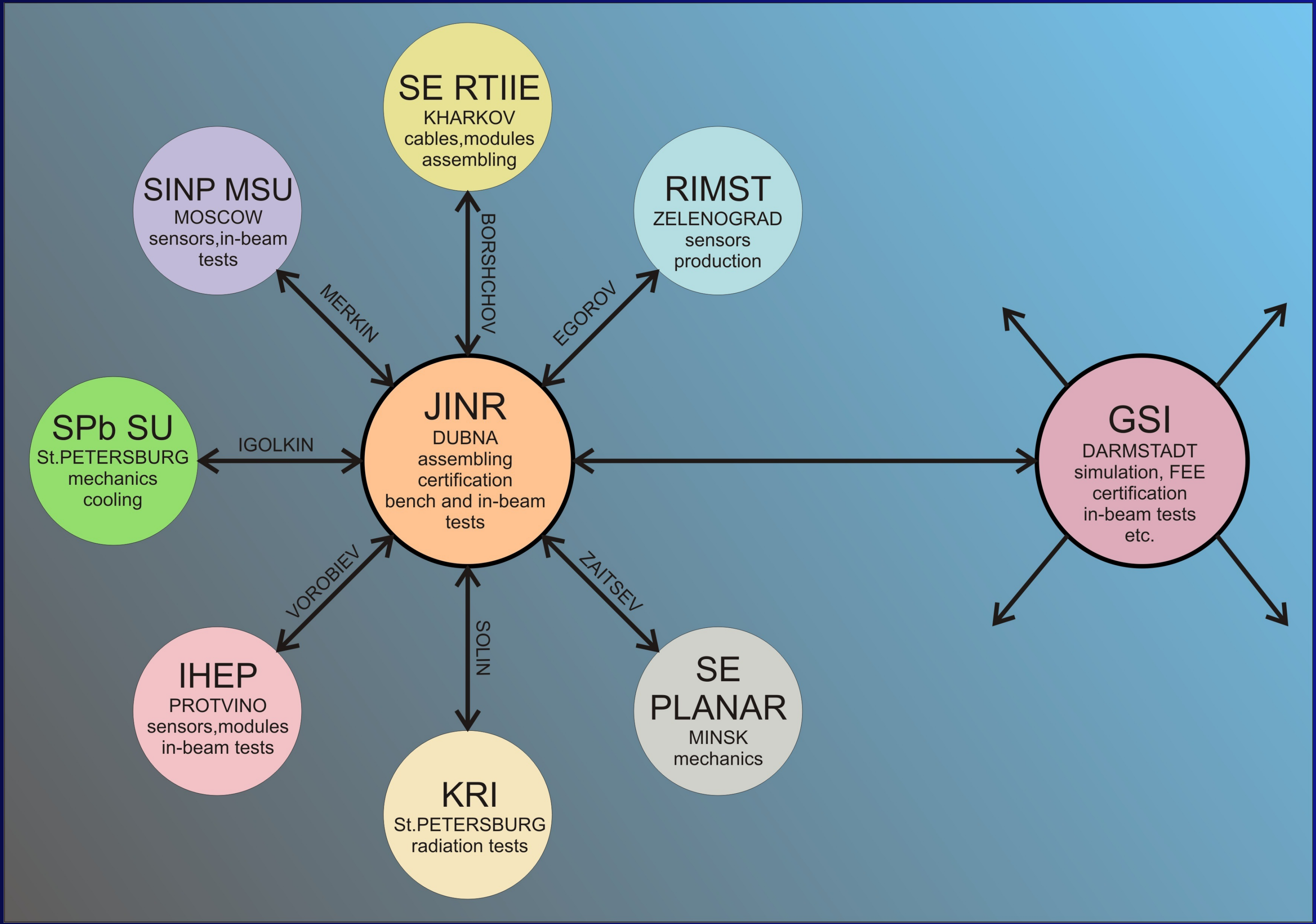
- ✓ *Softwarerepositories*
- ✓ *Softwaretests*
- ✓ *Forum*
- ✓ *Information*

  etc.

- Inherits basic properties from FairRoot (developed at GSI), C++ classes
- Extended set of event generators for heavy ion collisions
- Detector composition and geometry; particle propagation by GEANT3/4

CBM-MPD consortium structure

(for VD module development)



MPD staging

is driven

- on one hand, by the goal

to start energy scan as soon as the first beam are available

(simultaneously with detector & machine final commissioning)

- on the other hand,

by the present constrains in resources & manpower

the conditions to be fulfilled:

- ***keeping flexibility for upgrading towards interesting physics***
- ***foreseeing possibility of new technology implementations***
- ***foreseeing fields of activities for new potential collaborators***