MPD Detector at NICA

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On behalf of the MPD team

FAIRNESS, 16-21 September 2013, Berlin

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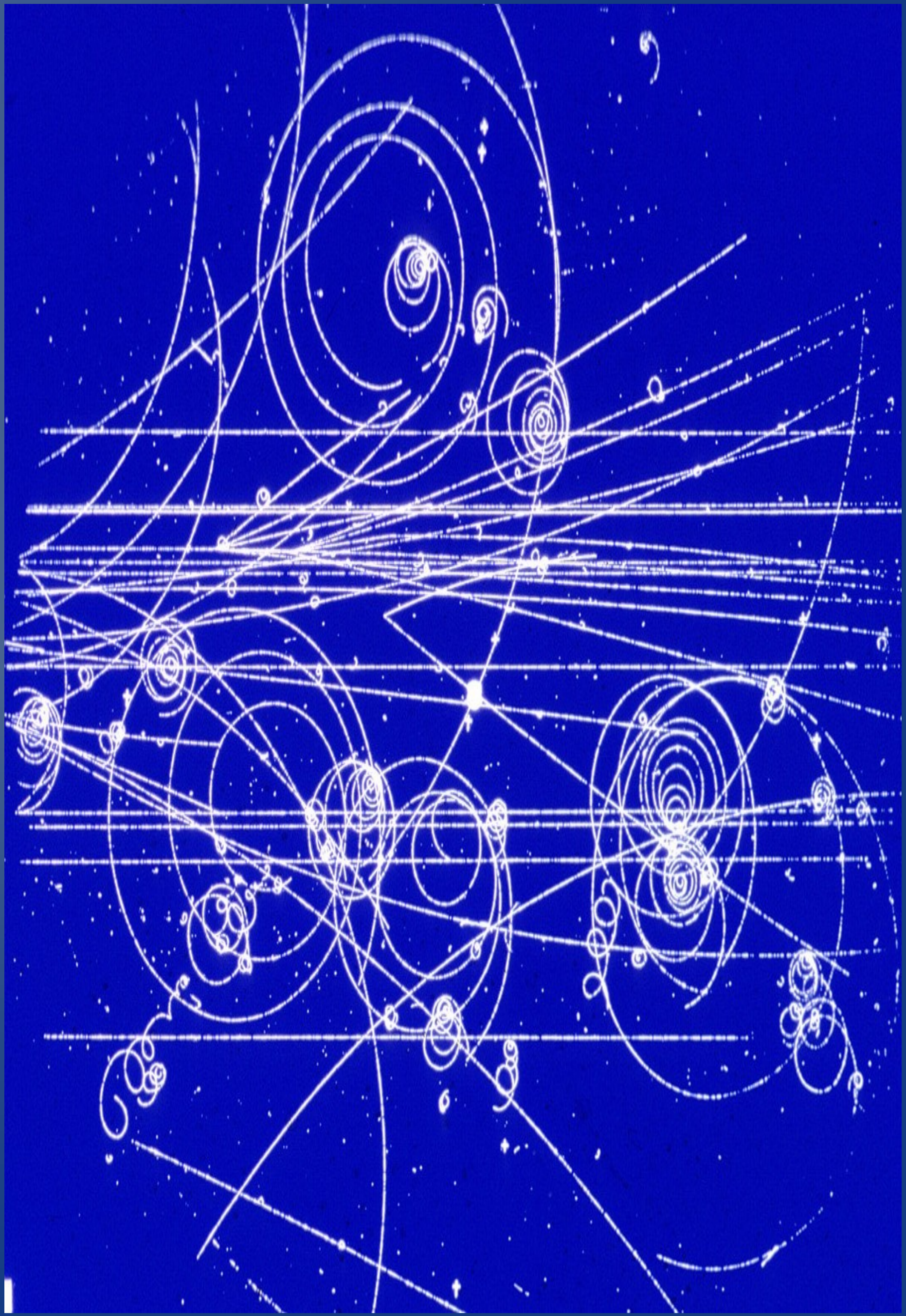

Superconducting accelerator complex NICA

NICA: Nuclotron-based Ion Collider fAcility

Location: VBLHEP, JINR, Dubna, Russia


INTERNATIONAL INTERGOVERNMENTAL ORGANIZATION
JINR
Dubna
JOINT INSTITUTE FOR NUCLEAR RESEARCH


I.
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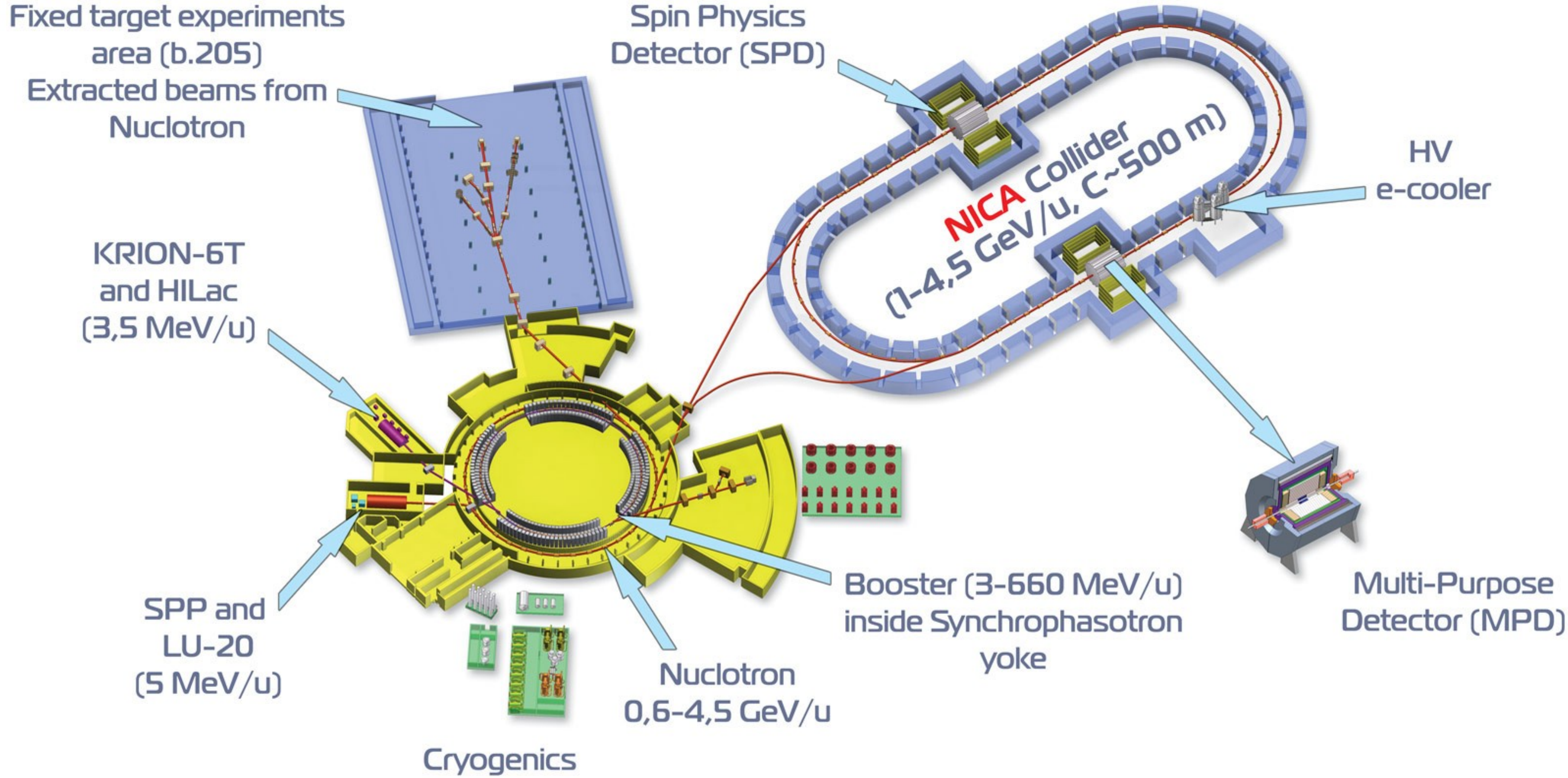
Superconducting accelerator complex NICA

(Nuclotron based Ion Collider fAcility)

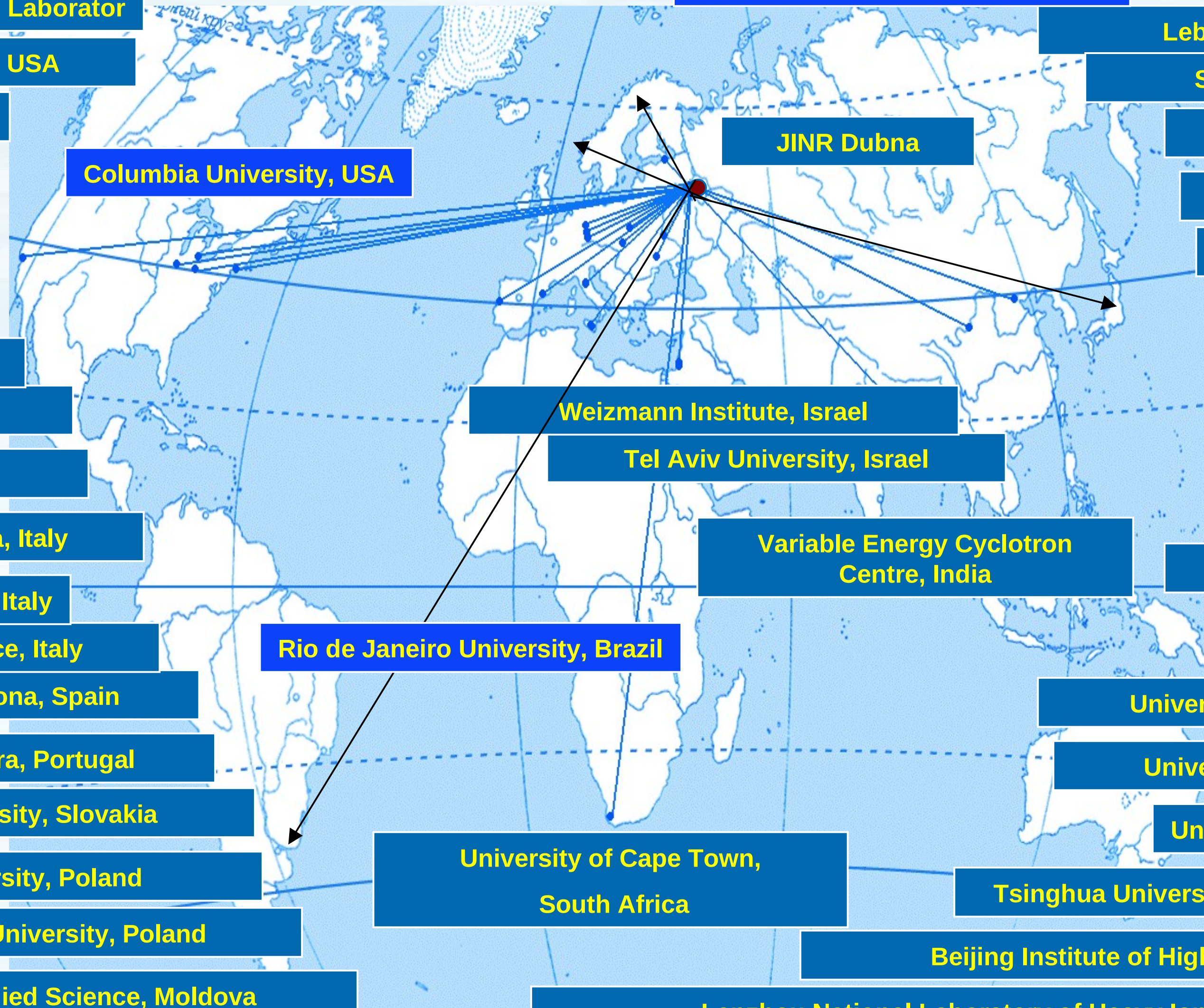


NICA parameters

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

Contributions to NICA Physics Programme

49 scientific centers *in* **21 Countries (8 JINR members)**



Arizona State University, USA
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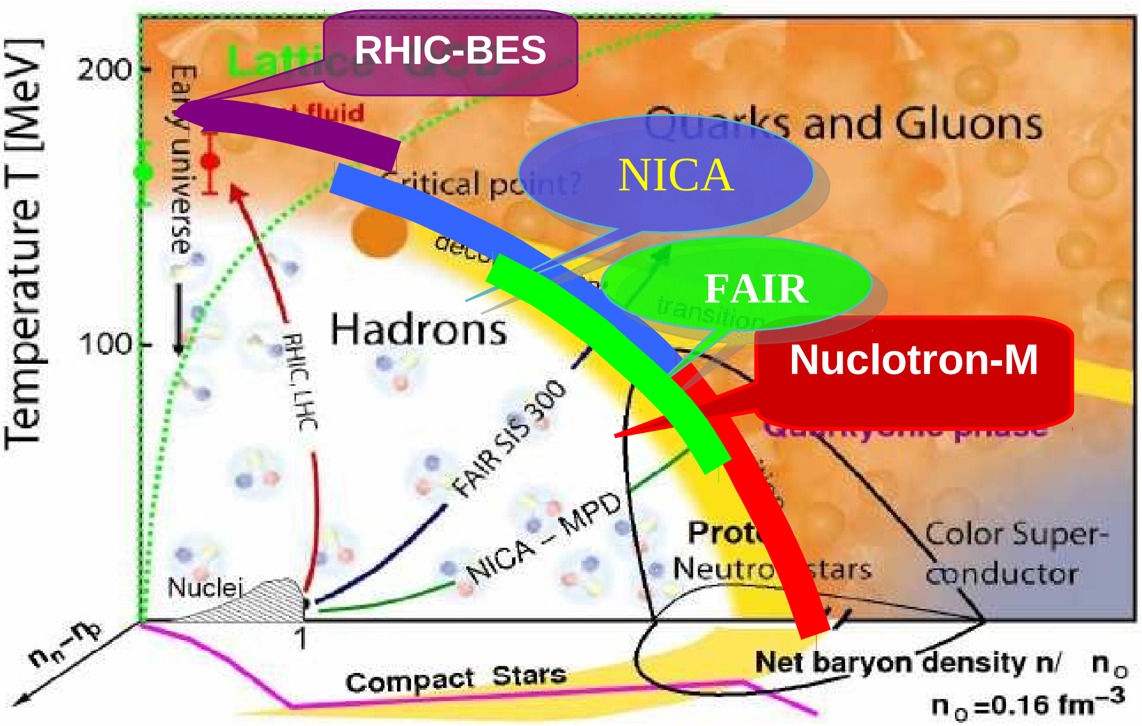
FIAS Frankfurt, Germany
University of Frankfurt, Germany
University of Giessen, Germany
University of Bielefeld, Germany
Tsinghua University, Beijing, China
Beijing Institute of High Energy Physics, China
Lanzhou National Laboratory of Heavy Ion Accelerator, China

QCD phase diagram. Prospects for NICA

Heavy Ion Collisions at NICA: to explore the phase diagram of strongly interacting matter in the region of highly compressed and hot baryonic matter.



Energy Range of NICA

The most intriguing and 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 and Nuclotron-M experimental programs**

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

Staging of MPD at NICA

MPD staging is driven by:
- *the goal* to start energy scan as soon as the first beams are available (simultaneously with detector and machine final commissioning)
- the present constrains in resources and manpower

3 stages:

1-st stage
Mid rapidity tracking + PID
Year of completion: 2017

2-nd stage
Vertex detector and tracking at forward rapidities
Year of completion: 2020

3-d stage
Forward spectrometers (optional)
Year of completion: after 2020

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

NICA Physics Plan for 2017-2019

In the beginning an energy-system size scan will be performed at NICA/MPD with the listed beam species varying the collisions energy from 4 to 11 GeV in steps of 1-2 GeV.

Beam	Luminosity ($cm^{-2} c^{-1}$)	
	$\sqrt{s}$=4 GeV	$\sqrt{s}$=11 GeV
p	10^{32}	10^{32}
^{12}C	$4 \cdot 10^{28}$	$2 \cdot 10^{29}$
^{64}Cu	$6 \cdot 10^{27}$	$3.5 \cdot 10^{28}$
^{124}Xe	$8 \cdot 10^{26}$	$6 \cdot 10^{27}$
^{197}Au	$1.5 \cdot 10^{26}$	10^{27}

Measurements of π, K, (anti)p, (anti)hyperons, light (anti)nuclei and dilepton spectra as a function of energy, system size, centrality, transverse momentum, rapidity and azimuthal angle.

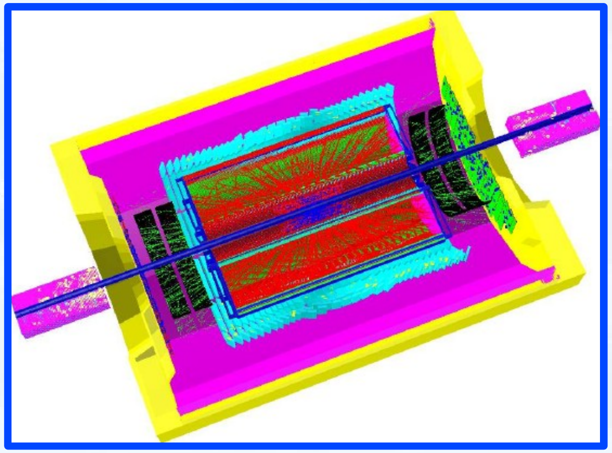
MPD Observables

I stage:: mid rapidity region

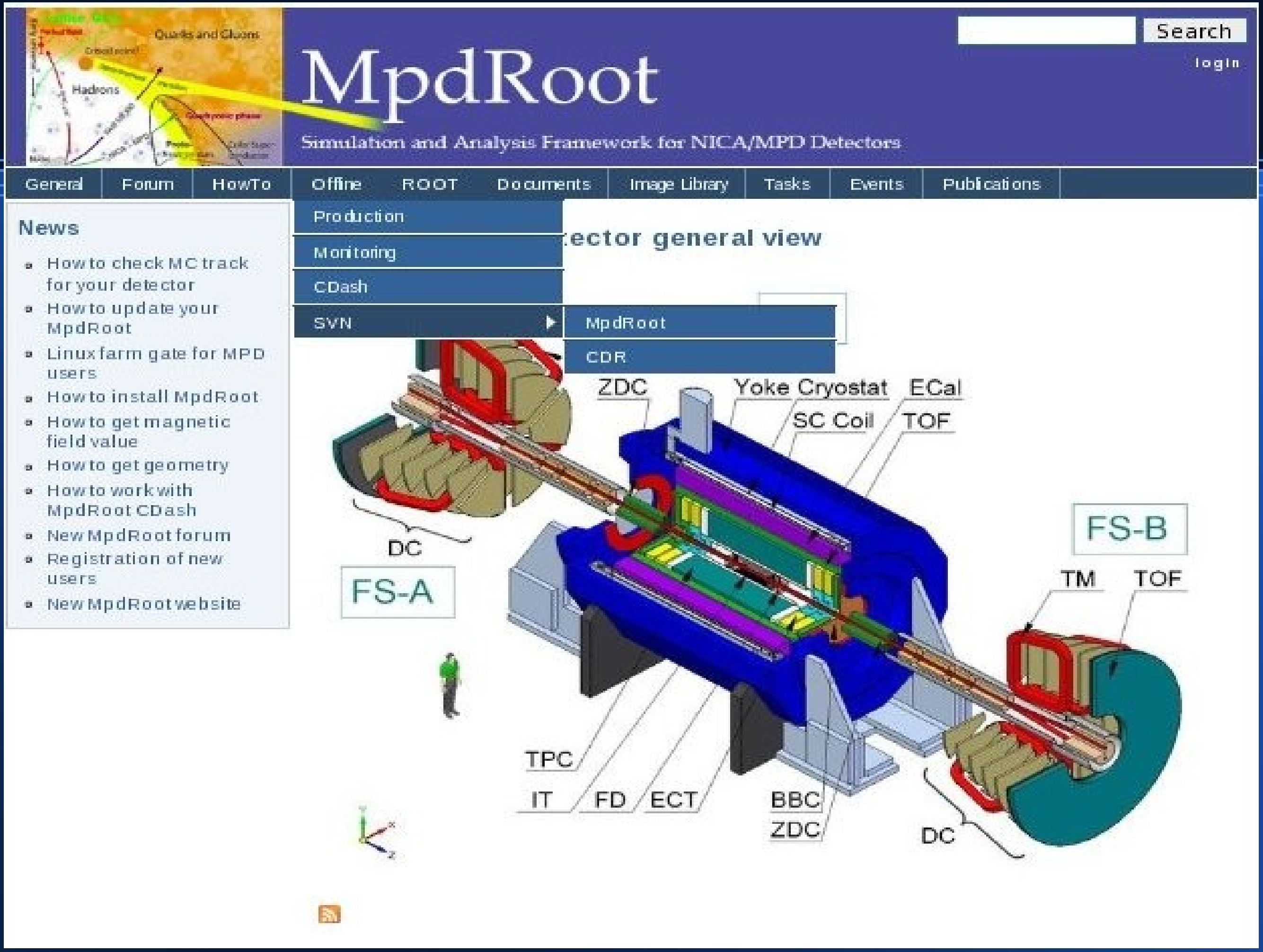
~Particle yields and spectra (π,K,p,Λ, Ξ ,Ω)
~Event-by-event fluctuations
~Femtoscopy involving π, K, p, Λ
~Collective flow for identified hadron species
~Electromagnetic probes (electrons, gammas)

II stage:: extended rapidity + IT

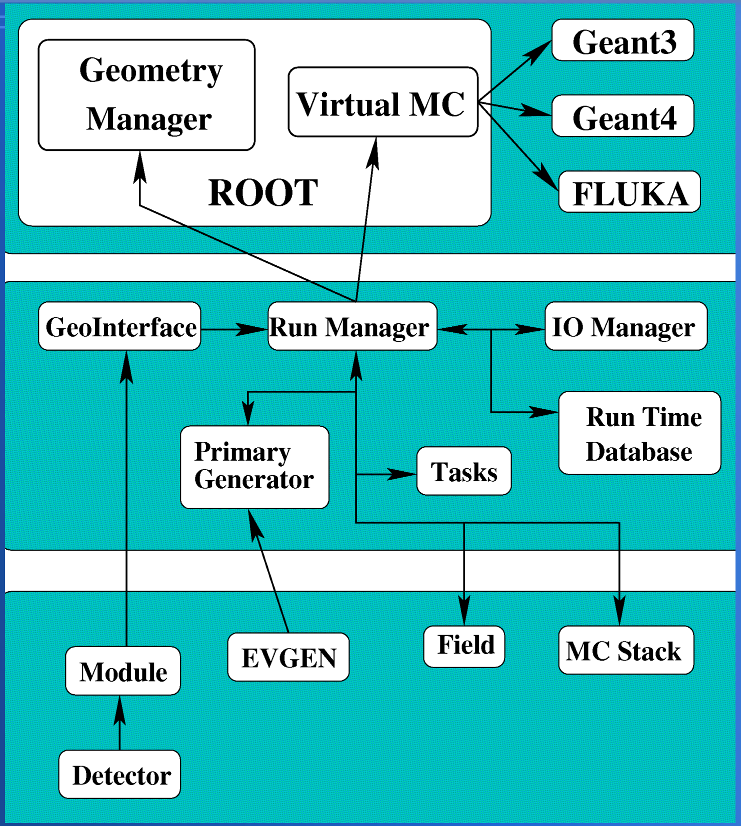
~Total particle multiplicities
~Asymmetries study
~Di-Lepton precise study
~Charm
~Exotics (soft photons, hypernuclei)



Simulation and Analysis Framework for MPD detector

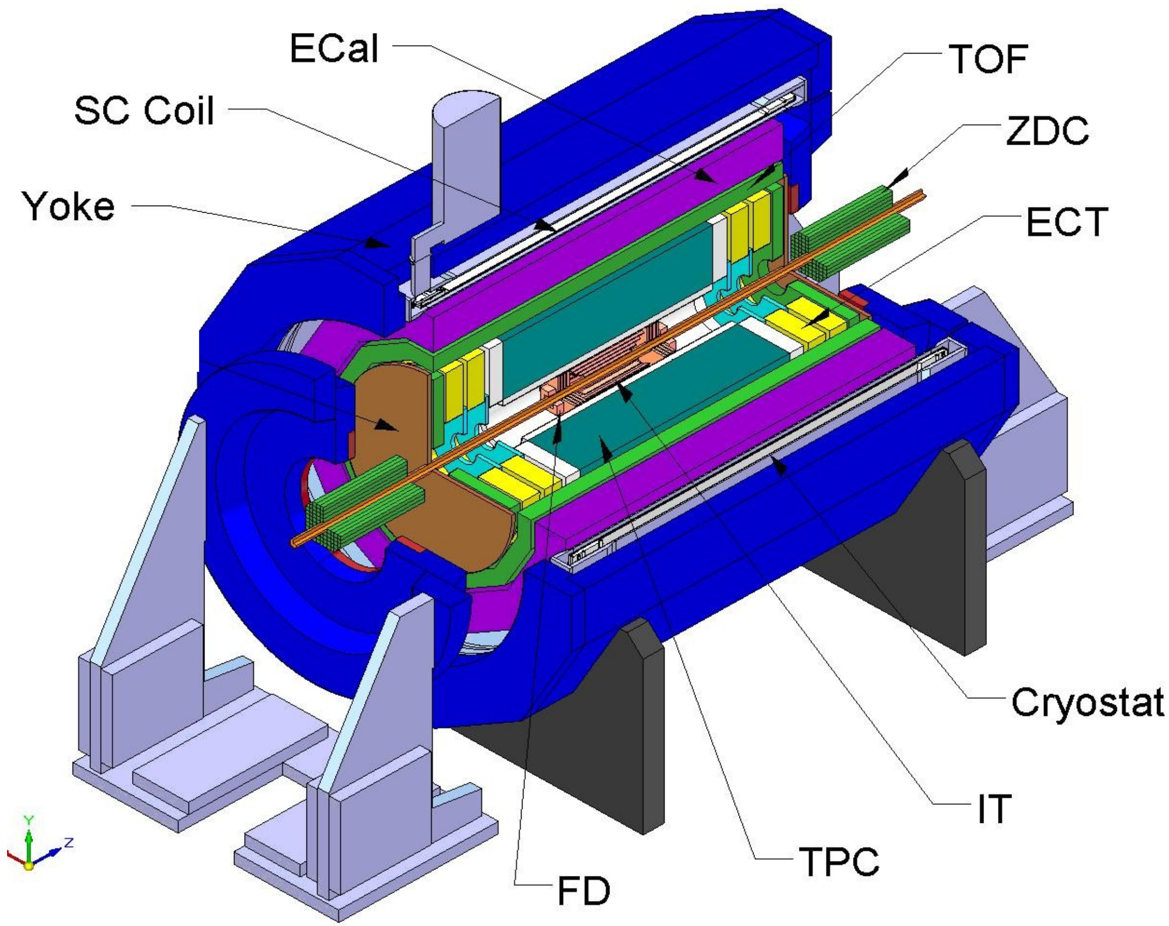


http://mpd.jinr.ru



- MpdRoot inherits basic properties from FairRoot (developed at GSI), C++ classes
- Extended set of event generators for heavy ion collisions (UrQMD, LAQGSM, HSD)
- Detector composition and geometry; particle propagation by GEANT3/4
- Advanced detector response functions, realistic tracking and PID included

Multi-Purpose Detector MPD at NICA



Central Detector Volume:
9.0 m (Length)
6.6 m (Diameter)

Magnet :
0.5 T superconductor
(1st stage)

Tracking :
TPC (1st stage, $|\eta|<2.0$)
ECT, IT (2nd stage, $|\eta|<2.5$)

Particle ID :
TOF, ECAL, TPC
(1st stage, $|\eta|<1.5$)

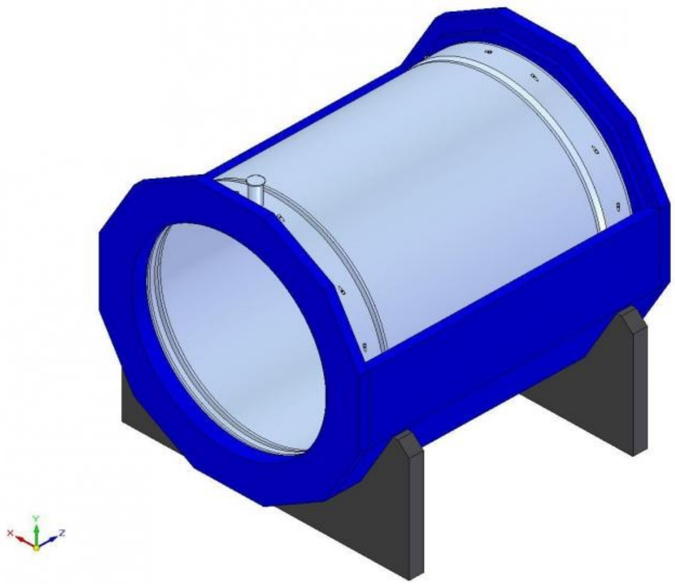
Triggering : FD
(1st stage, $2.0<|\eta|<4.0$)

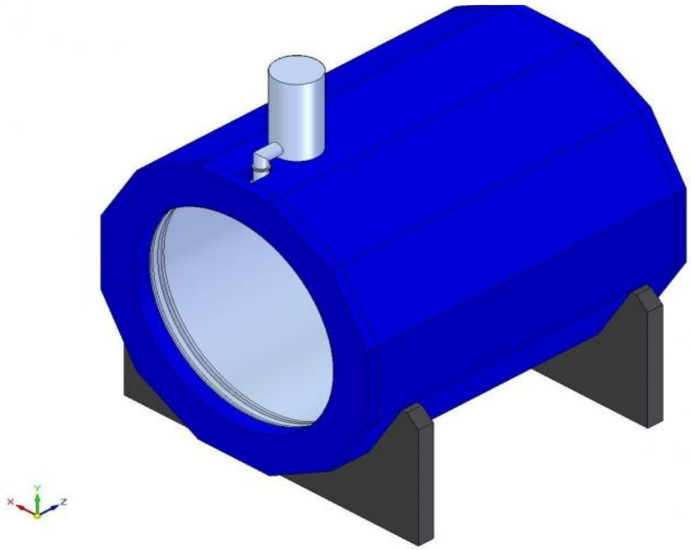
Centrality : ZDC
(1st stage, $2.2<|\eta|<4.8$)

MPD Advantages:

***Hermeticity, homogenous acceptance (2π in azimuth), low material budget**
***Excellent tracking performance and powerful PID**
***High event rate capability and careful event characterization**

MPD Superconducting Solenoid





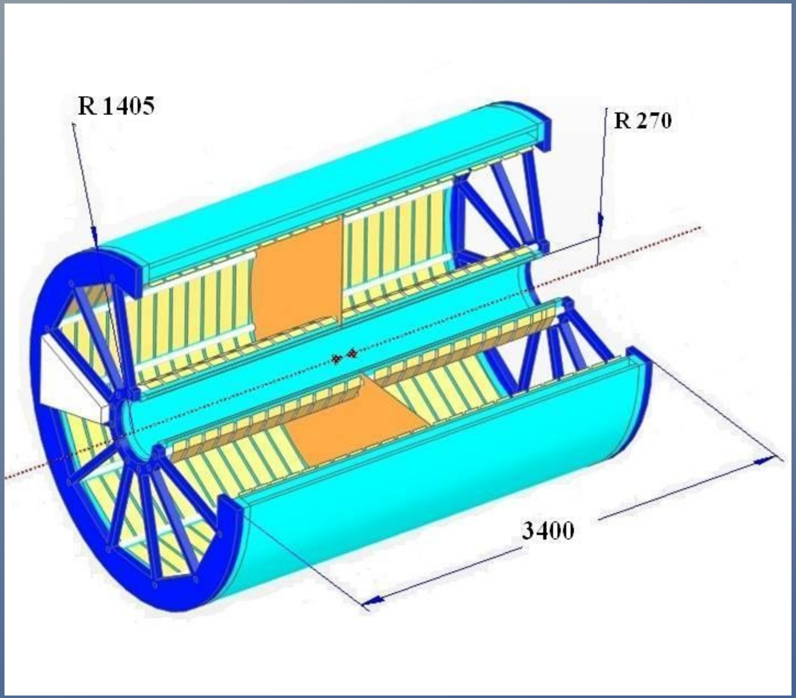
The main requirements for the solenoid are:

- **The magnetic field in the area of the tracker is 0.5 T**
- **Homogeneity (~0.1 % inhomogeneity)**

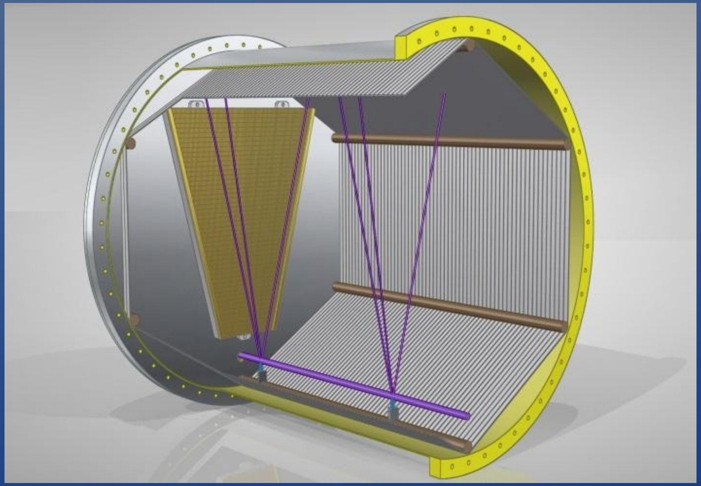
Cryostat	
Inner radius, m	2.0
Outer radius, m	2.3
Length, m	5.7
Iron Yoke	
Incircle radius of the yoke, m	2.4
Circumcircle radius of the yoke, m	2.67
Distance between pole tips, m	5.24
Length of the yoke, m	6.4

The MPD solenoid is a magnet with a thin superconducting NbTi winding and flux return yoke.

Time Projection Chamber
TPC



Length of the TPC	340cm
Outer radius	140cm
Inner radius	27cm
Length of the drift volume	170cm (of each half)
Electric field strength	~140 V/cm
Drift gas	90% Ar+10% Methane at Atmospheric + 2 mbar
Drift velocity	5.45 cm/μs
Drift time	~ 28μs
Number of pads	~ 110 000
Pad size	4x12 mm^2 5x18 mm^2
Interaction rate	7 kHz



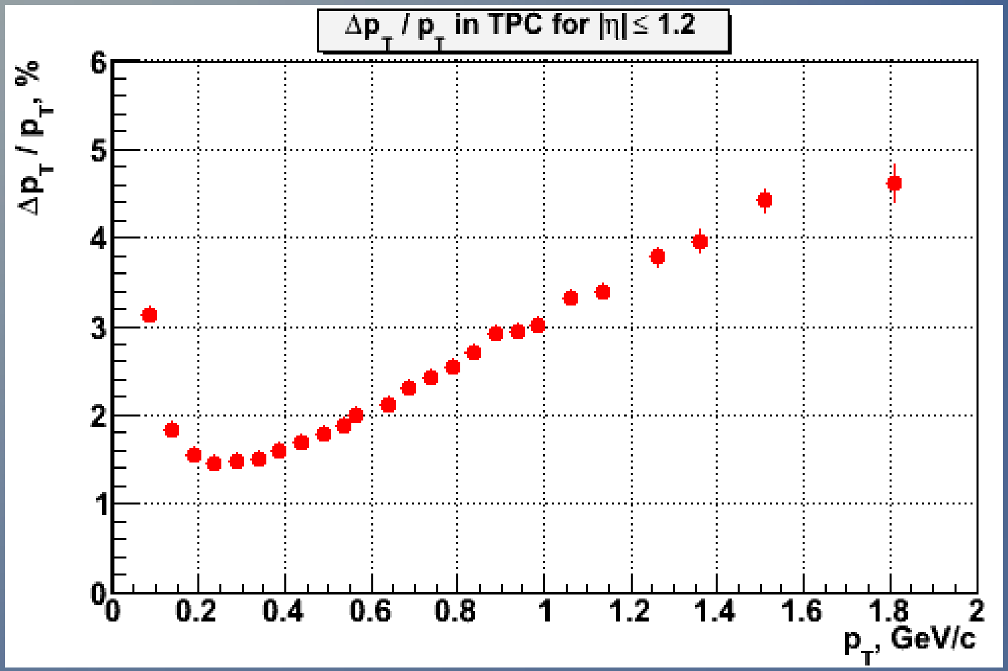
Requirements to the TPC performance:

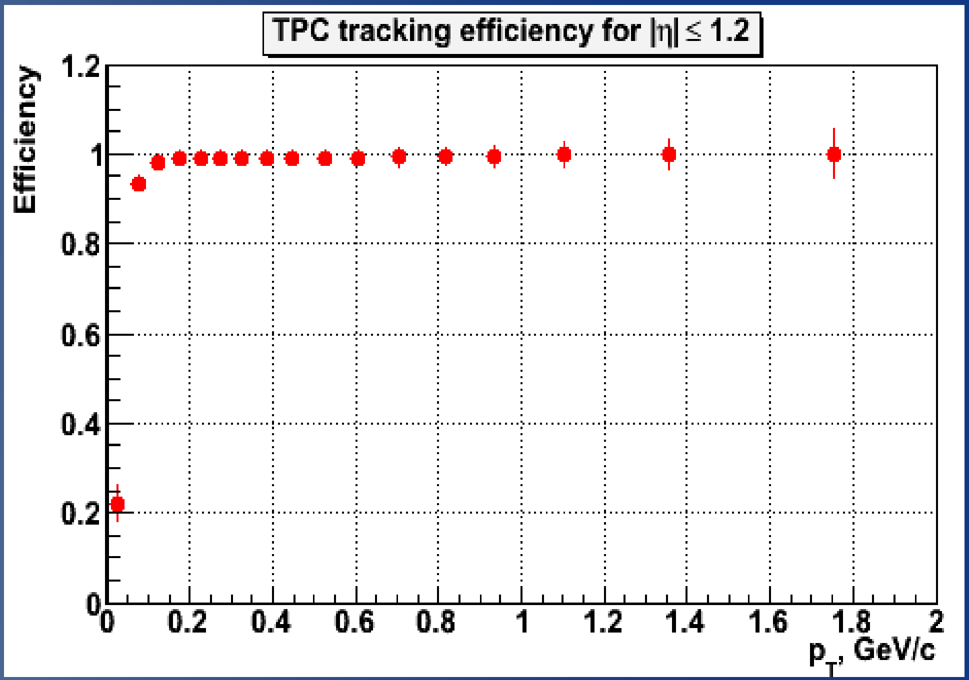
*Provide efficient tracking in pseudorapidity region |η| < 2.0

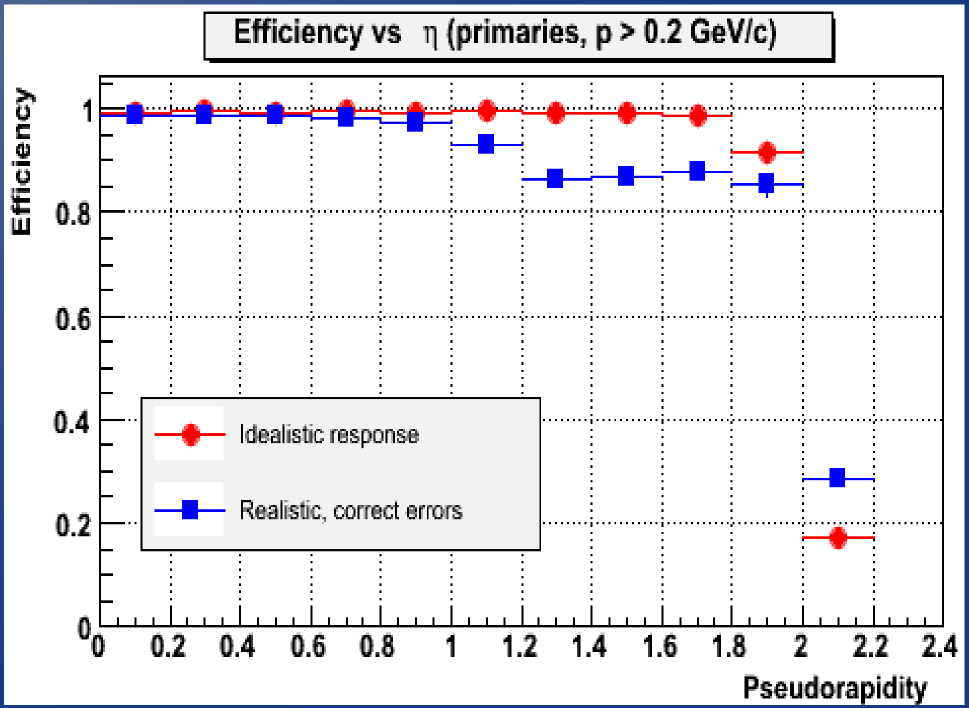
*Momentum resolution for charged particles ~ 2% at p_t = 300 Mev/c

*dE/dx resolution better than 8%

MPD TPC Tracking Performance







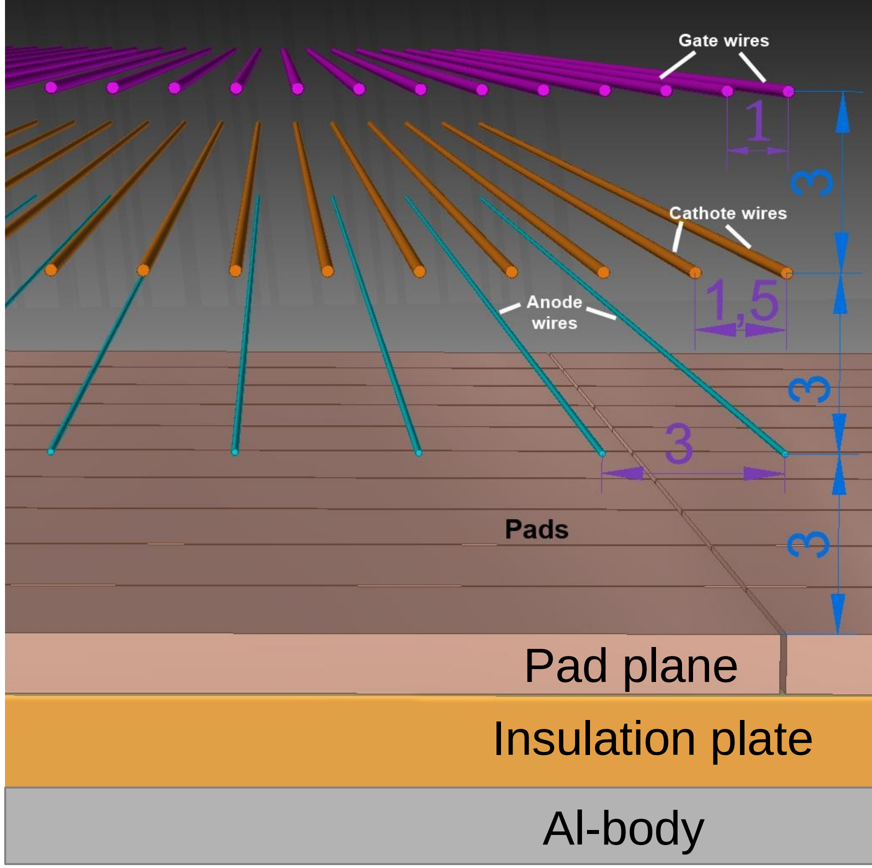
* Momentum resolution < 3% at p_t < 1.0 Gev/c

* Efficiency ~ 100 % for p_t > 0.15 GeV/c

* Efficiency > 85 % for $|\eta|$ < 2.0

TPC *Readout Chambers*

The readout system is based on the Multi-Wire Proportional Chambers (MWPC) with cathode readout pads.

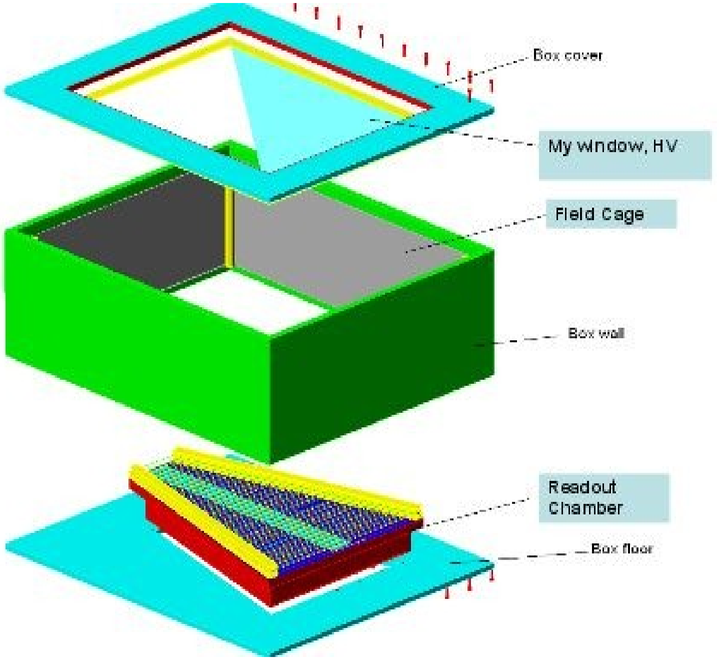


Structure of readout chamber:

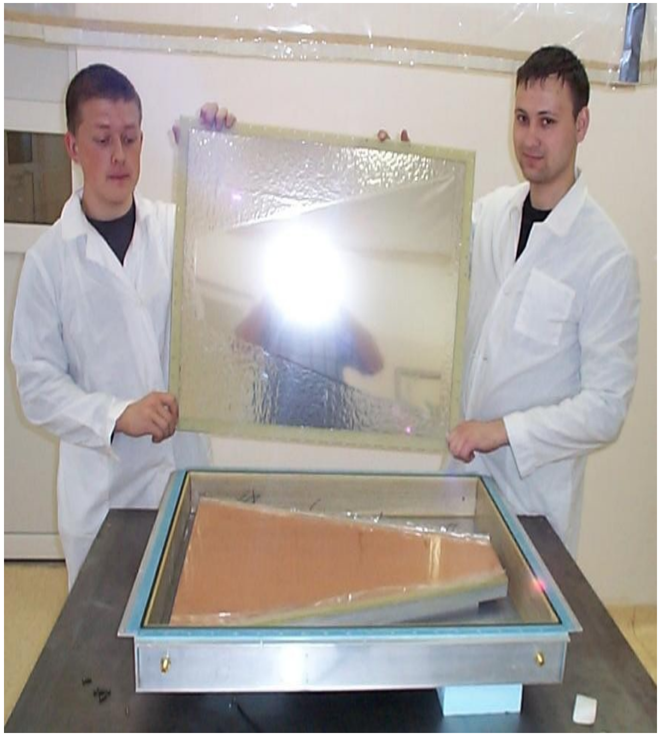
- three wire planes
- pad plane
- insulation plate
- trapezoidal aluminum frame

Wires structure:

- anode wire pitch 3 mm
- cathode wire pitch 1.5 mm
- gate wire pitch 1 mm
- wires gap 3 mm



Prototype of ReadOut Chamber →



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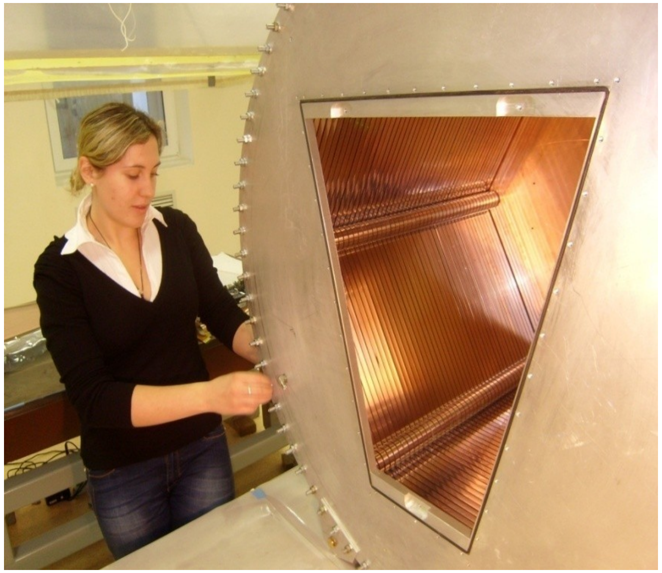
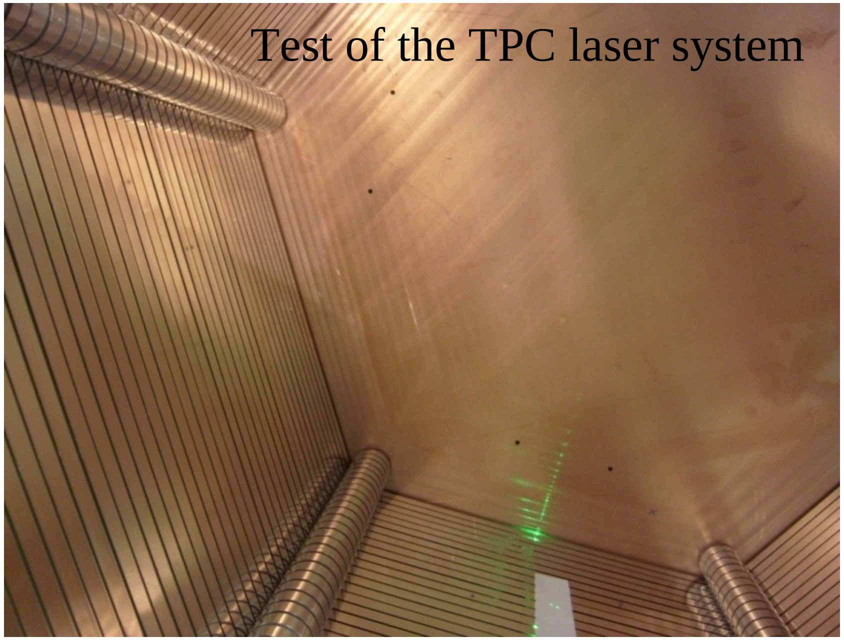
TPC prototypes

The general view of the TPC Prototype

Field Cage prototype

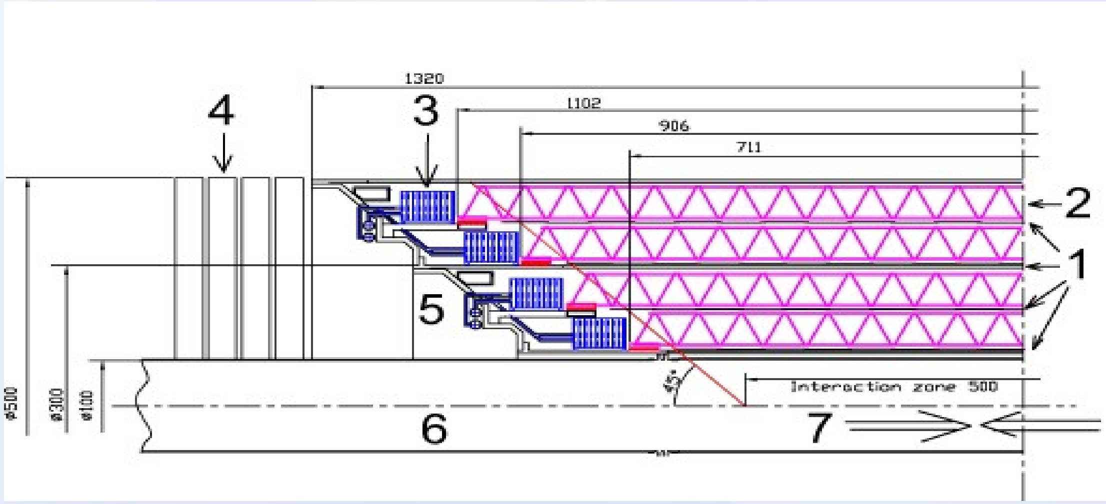
FEC-64 prototype (PASA/ALTRO)

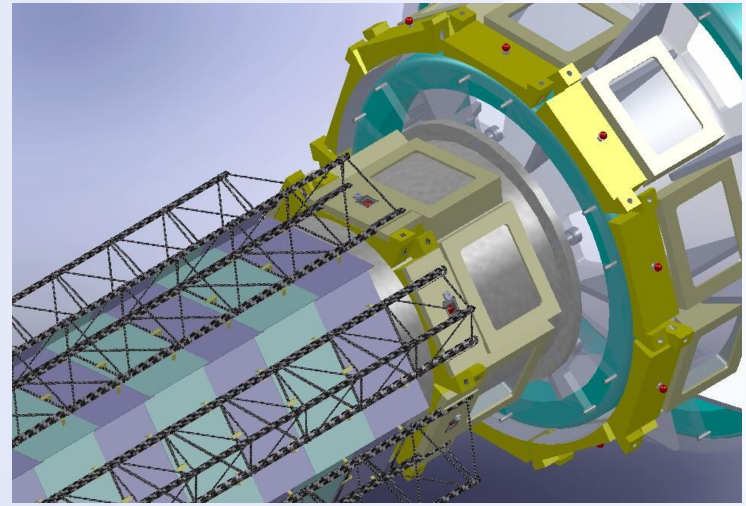




Test of the TPC laser system

Inner Tracker System - ITS





Conceptual layout of ITS with a side view of its quarter: 1 - silicon strip detectors of the cylindrical part of ITS; 2 - carbon fiber support; 3 - front end electronics; 4 - disc detectors; 5 - cooling system elements; 6 - accelerator chamber; 7 - collider beams

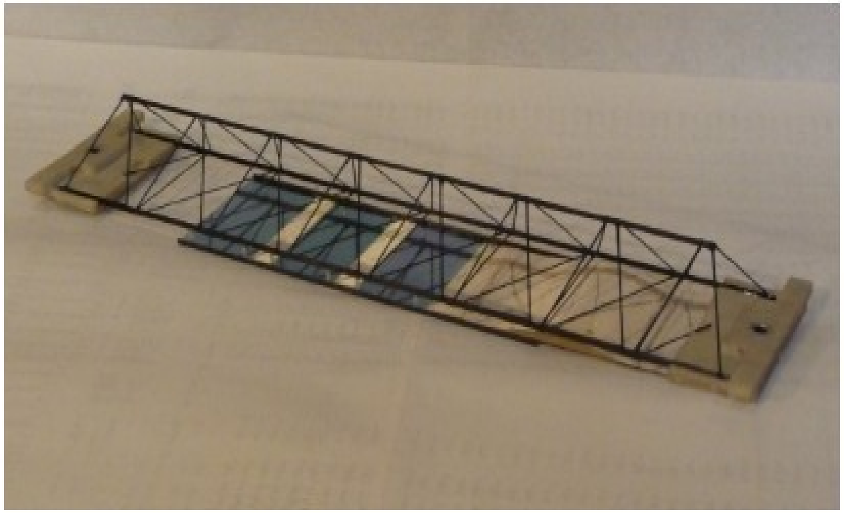
ITS tasks:

1. Improvement of track reconstruction closed to the interaction point.
2. Precise primary and secondary vertexes reconstruction.
3. Enhancement of multistrange hyperons reconstruction capability.

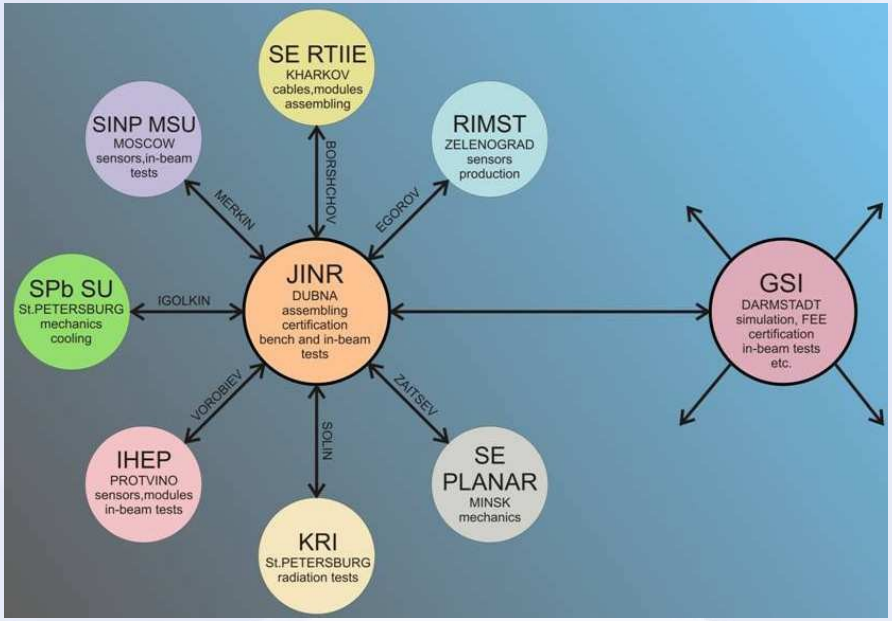
*4 cylindrical & disk layers
*300 μm double-sided silicon strip detectors
*Barrel: R=1-4 cm, coverage |η|<2.5, 806 sensors of 62x62 mm^2
*Disks: under optimization

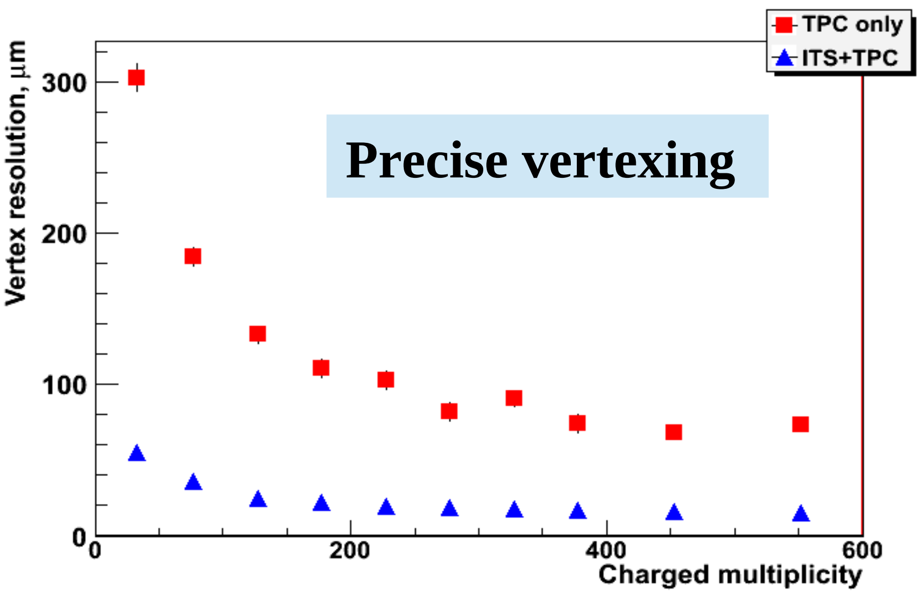
ITS prototype and performance

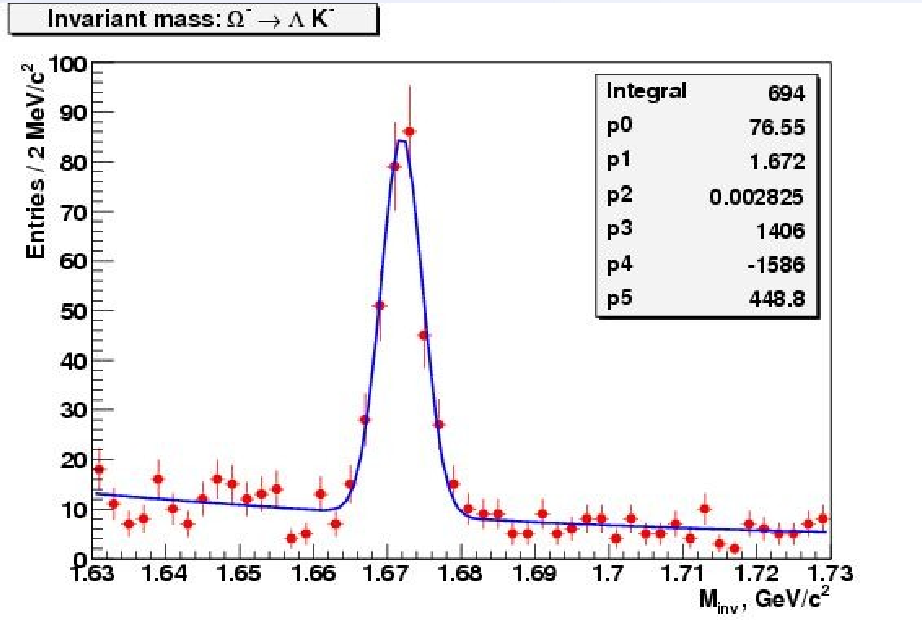
Prototype of the ladder of the CBM STS with one sensitive detector module built of three sensors



Structure of the CBM - MPD STS Consortium







Excellent V0 capabilities

Time of Flight System - TOF

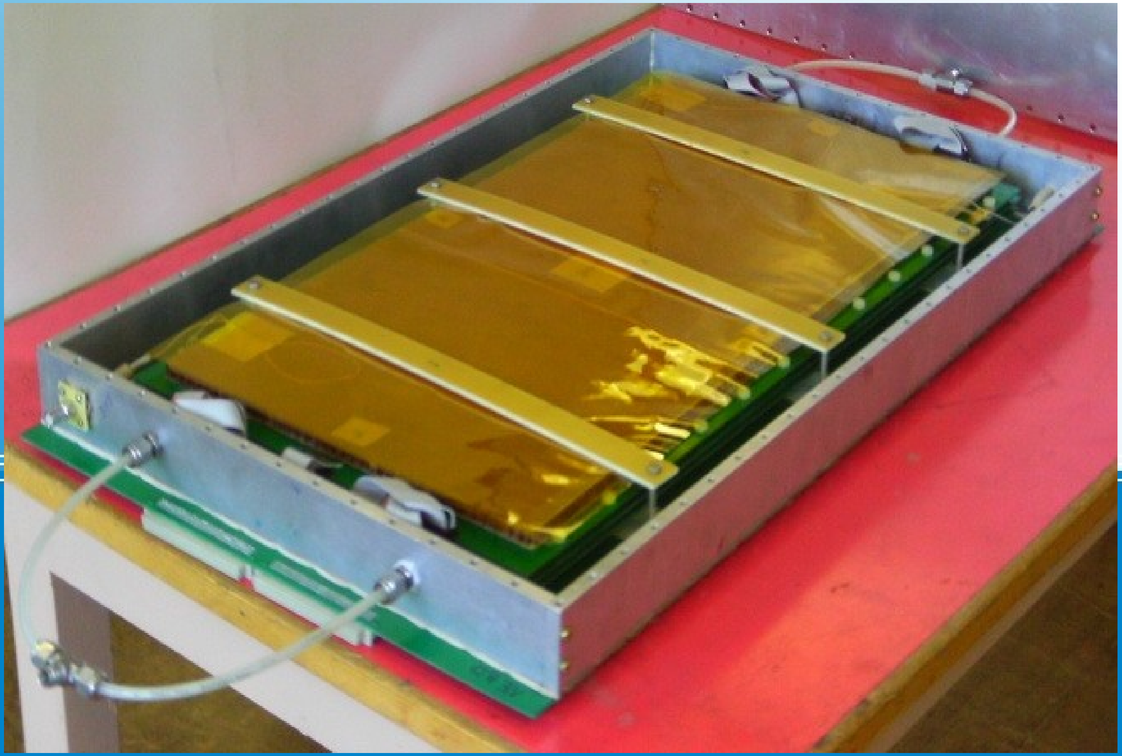
Requirements to the TOF system:

– large phase space coverage $|\eta| < 3.0$
– high combined geometrical and detection efficiency (better than 80%)
– identification of pions and kaons with $0.1 < pt < 2$ GeV/c
– identification of (anti)protons with $0.3 < pt < 3$ GeV/c

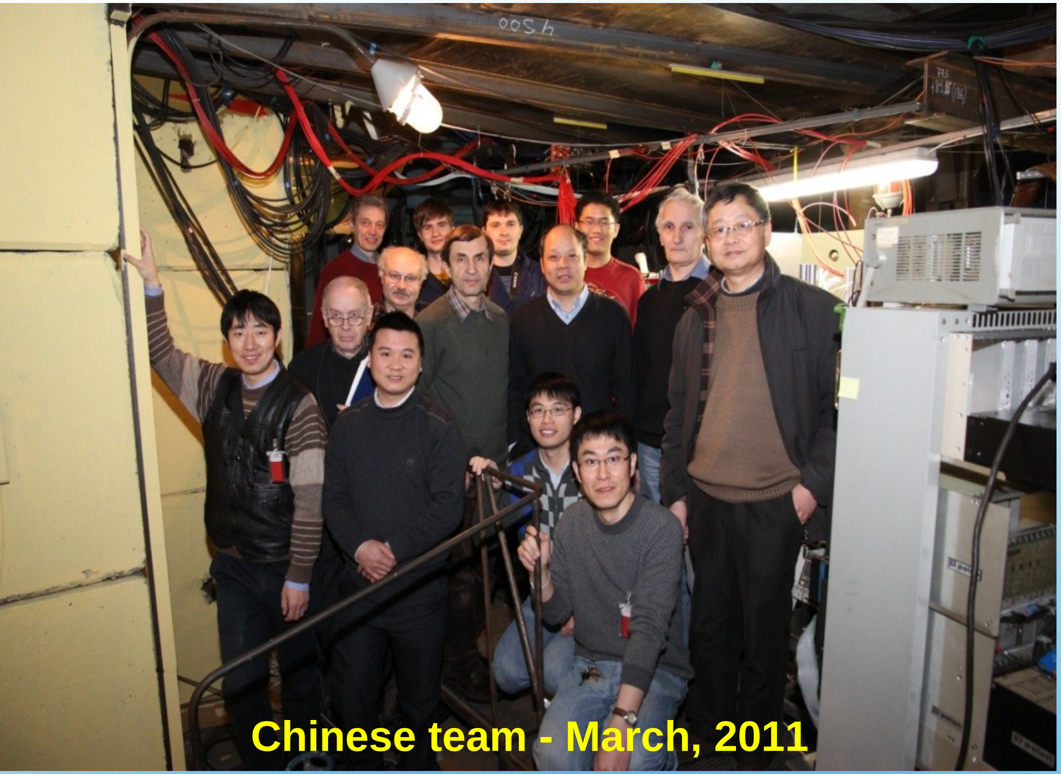
Barrel: 5 m (length), 2.5 m (diameter), 1st stage
Endcap: 2 x 2.5 m (diameter) disks, 2nd stage
Segmentation (barrel):
12 sectors x 19 mRPC x 24 strips (60x2)cm^2
# of readout channels – 10 944
10944 channels = 1368 chips NINO
geometrical efficiency ~ 90%

TDC VL-32

A full-scale double-stack mRPC prototype

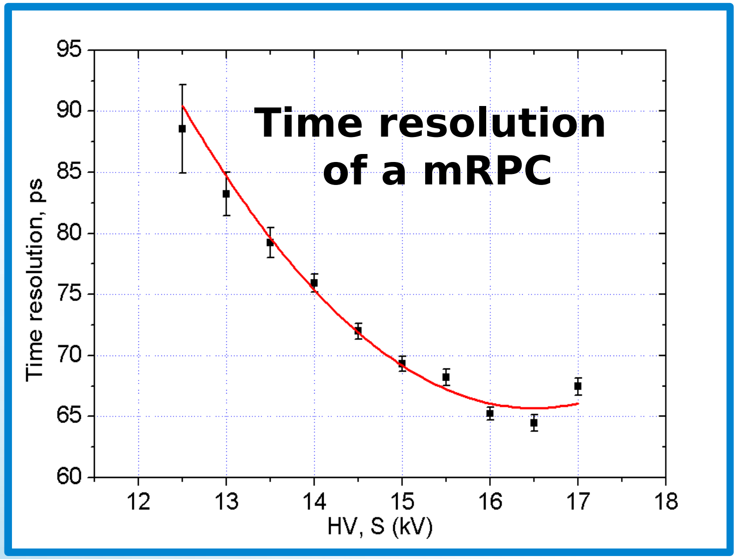


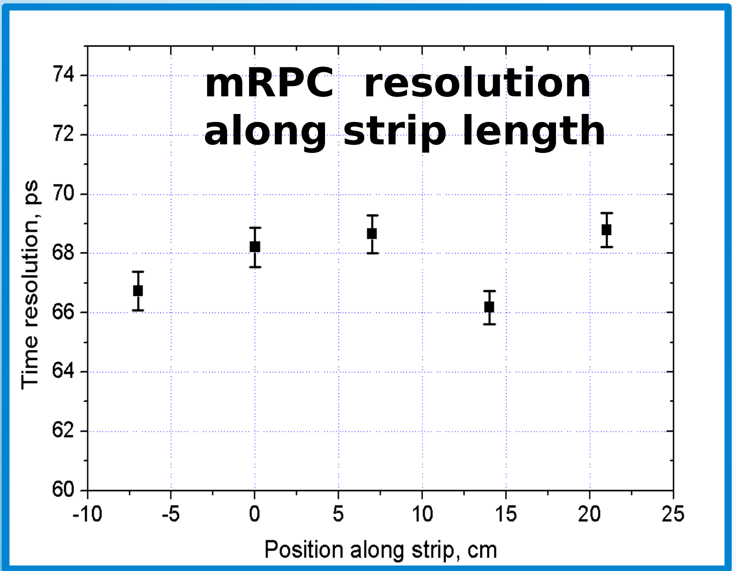
Beam tests at NUCLOTRON - Dubna (Russia), Beijing and Hefei (China)



Chinese team - March, 2011

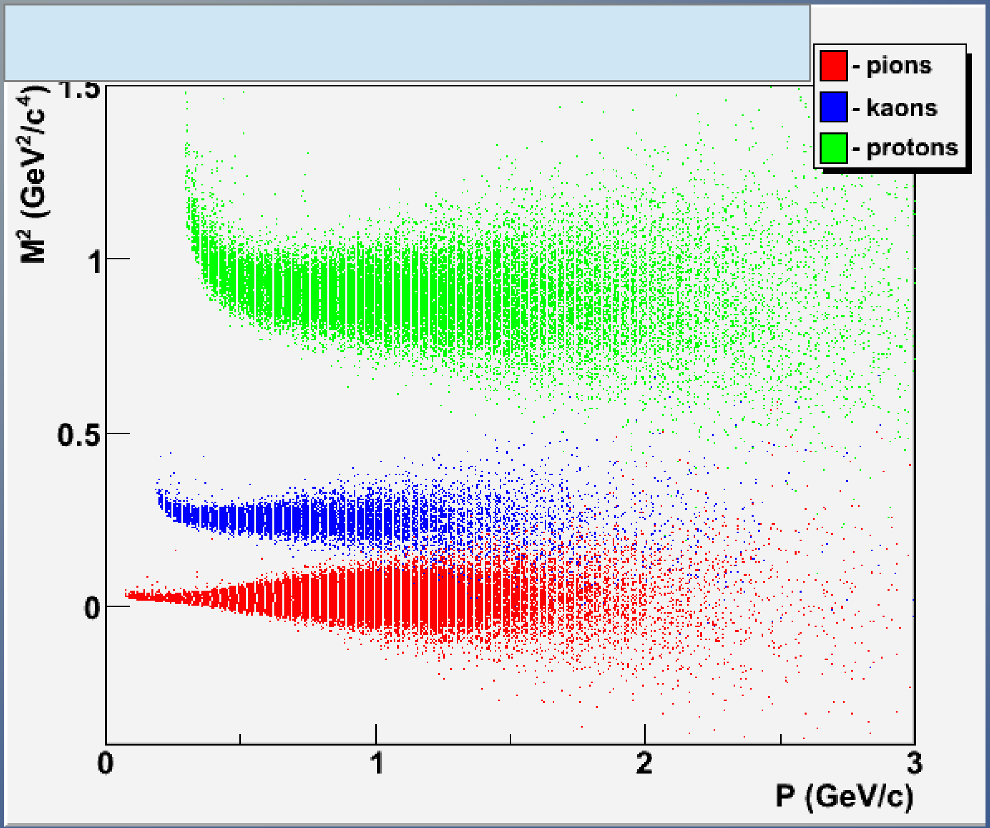
Experimental setup for TOF prototypes tests
March, 2013

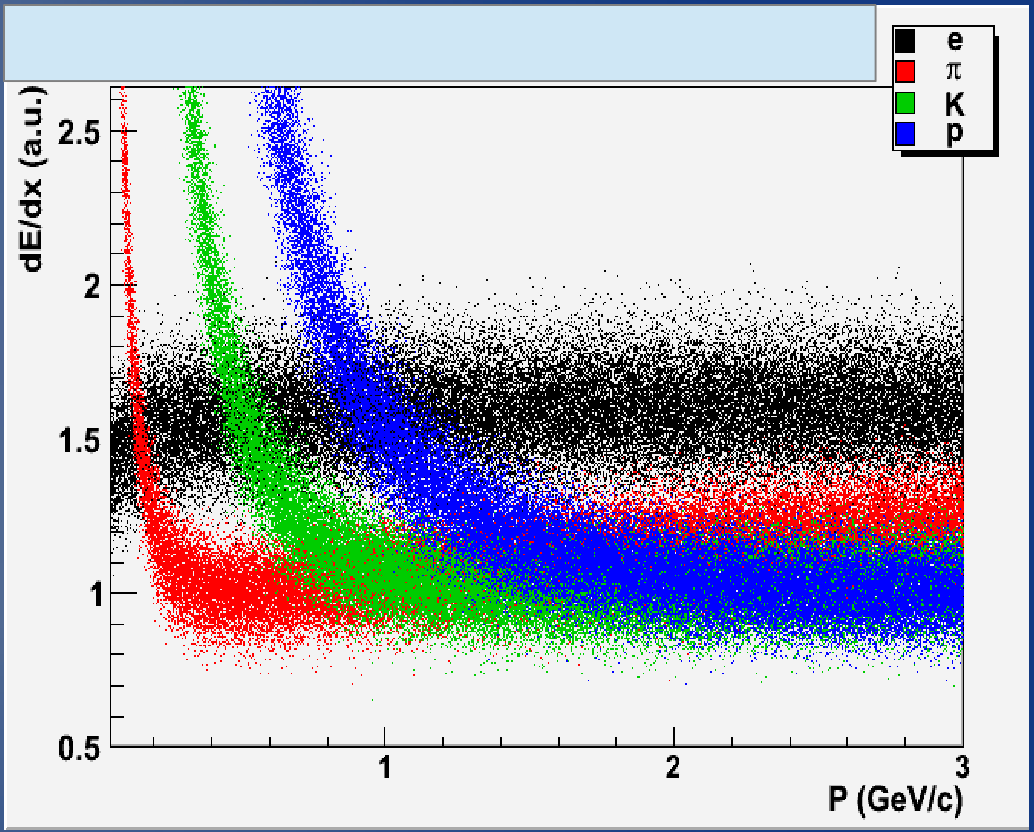




*Time resolution σ < 70 ps achieved for a double-stack mRPC module
*The resolution does not depend on coordinate

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

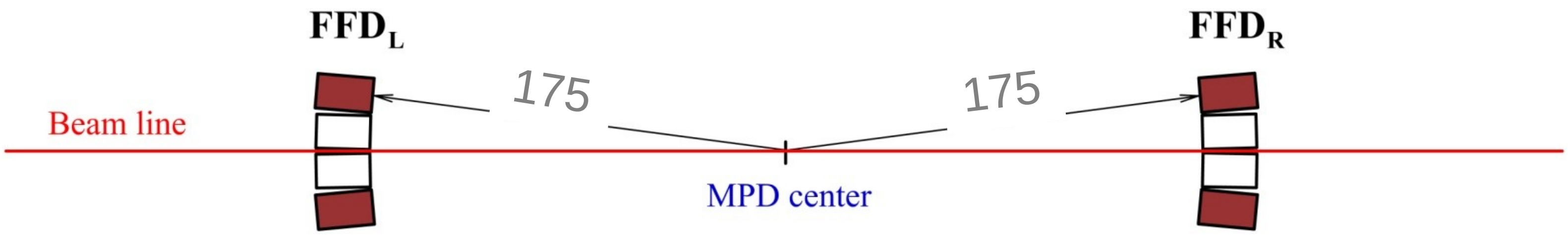
PID: *Ionization loss (dE/dx)*

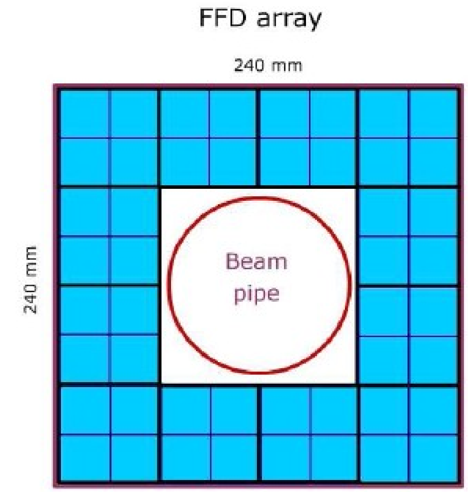
Separation: e/h – 1.3-3 GeV/c

π/K – 0.1-0.6 GeV/c

K/p – 0.1-1.2 GeV/c

Fast Forward Detector - FFD

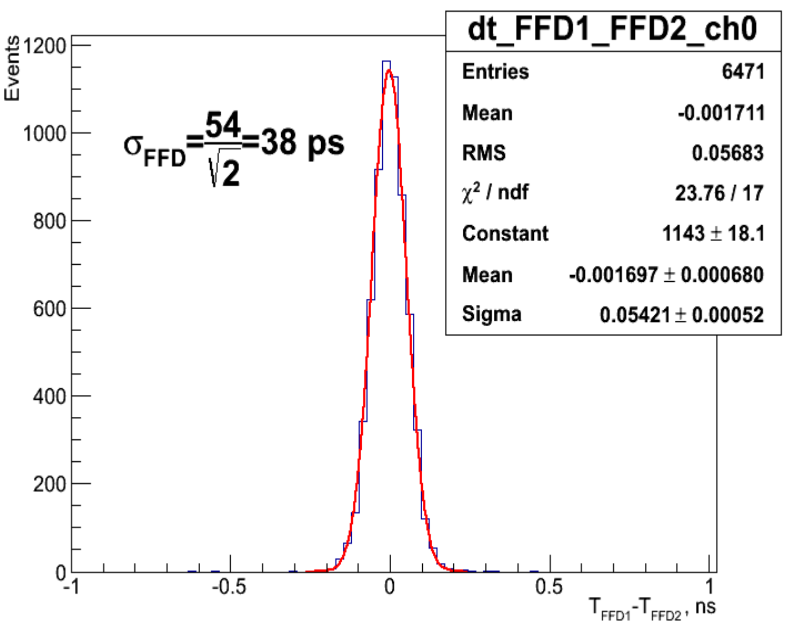




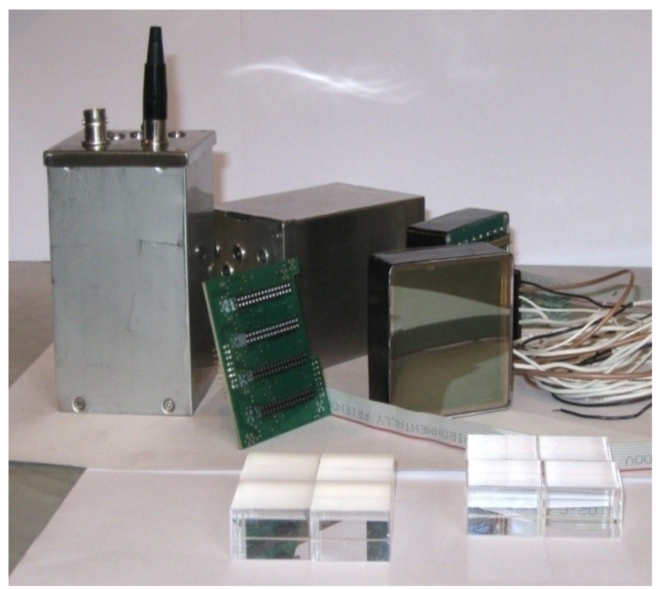
Aims of FFD:

(1) fast determination of a nucleus-nucleus interaction
(2) generation of a start pulse for TOF
(3) adjustment of beam-beam collisions in the center of MPD
(4) operative control of the collision rate and interaction point position

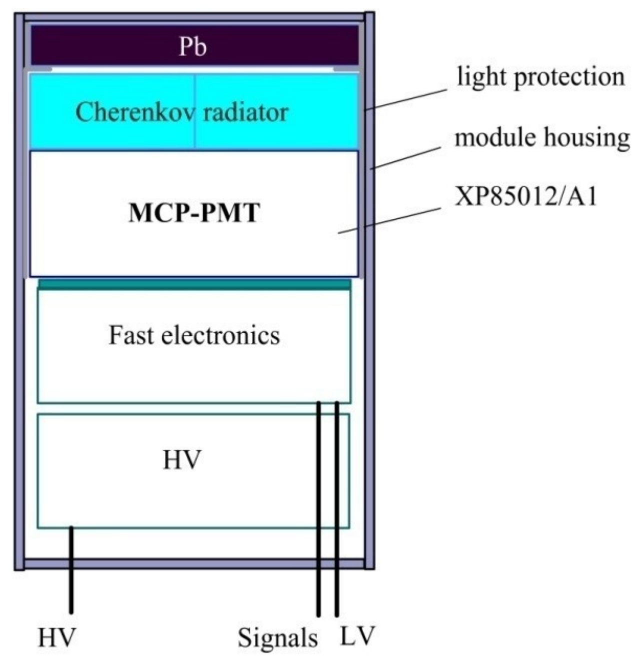
FFD: quartz Cherenkov radiator with micro-channel plate PMT



Time difference (T1-T2) for 2 FFD modules



Prototype of FFD module



EndCap Tracker - ECT

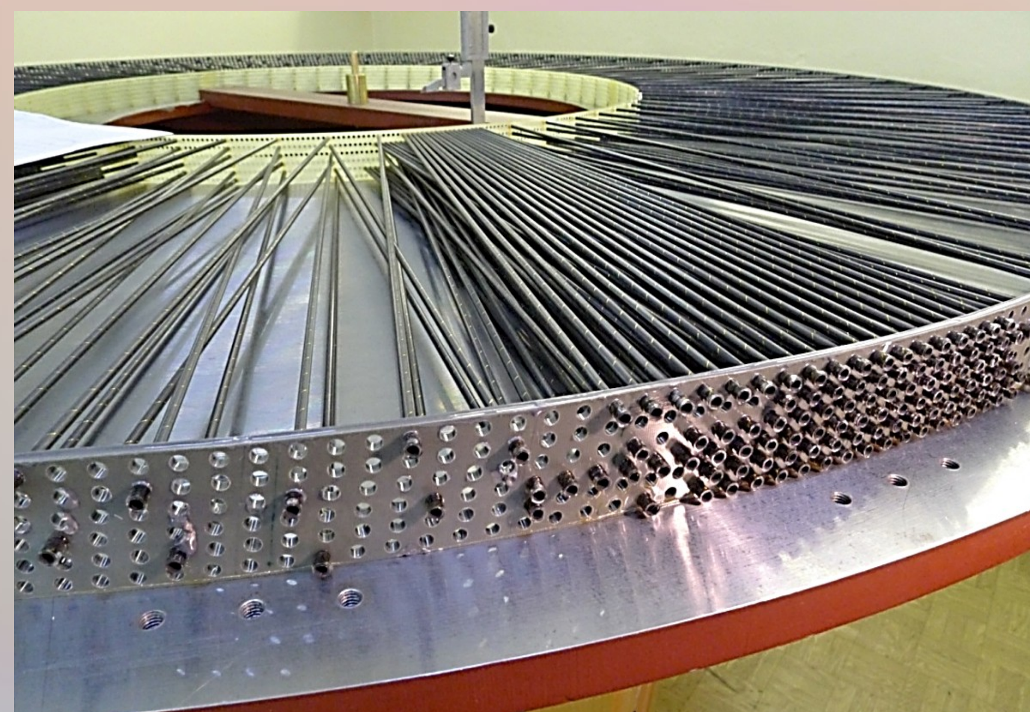
ECT full size prototype
Max. deviation $\Delta R < 300\ \mu m$
for a R=1.1 m wheel

***phase space coverage $1 < |\eta| < 2.2$**

***provides charged particle momentum measurement**

***combined TPC and ECT momentum resolution ~ 5%**

***Carbon-coated straws with an inner and outer graphite cover**
***Straws of 4 mm in diameter**



Electromagnetic Calorimeter - ECAL

Tasks:

*Measurement of the spatial position and energy of electrons and photons

*Particle identification (due to high time resolution)

Requirements to ECAL:

*High segmentation of the calorimeter

*Energy resolution - about 3%

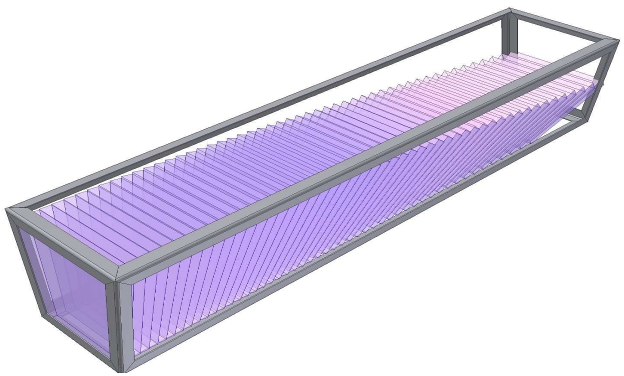
*Sub-nanosecond time-of-flight measurements

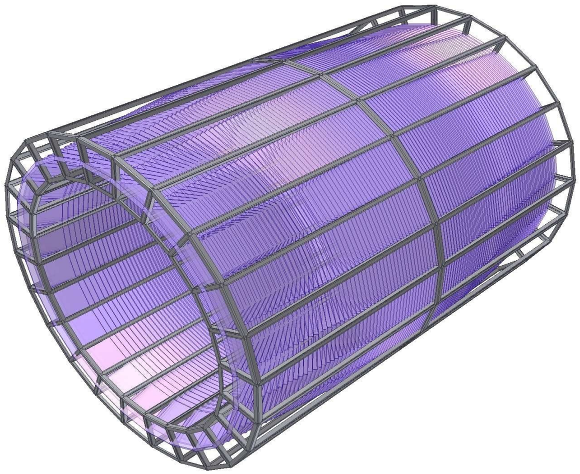
***Pb-scintillator ECAL of "shashlyk"-type:**

~Pb (0.35 mm)+Plastic Scintillator (1.5 mm)

~L ~35 cm

~read-out: WLS fibers + MAPD (Micropixel Avalance PhotoDiode)





Setup for testing ECAL prototypes

Zero Degree Calorimeter - ZDC

ZDC coverage: 2.2<|η|< 4.8

Tasks:

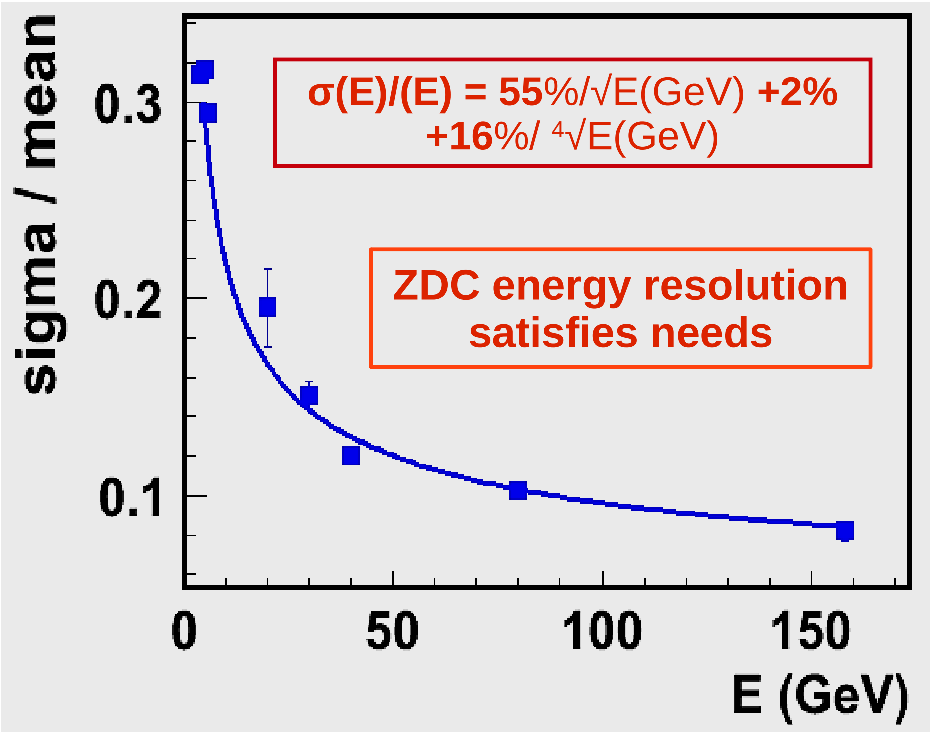
*Event centrality determination (offline b-selection)
*Event plane determination
*Measurement of the energy deposited by spectators

Lead/Scintillator sandwich:

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

ZDC prototypes (JINR)

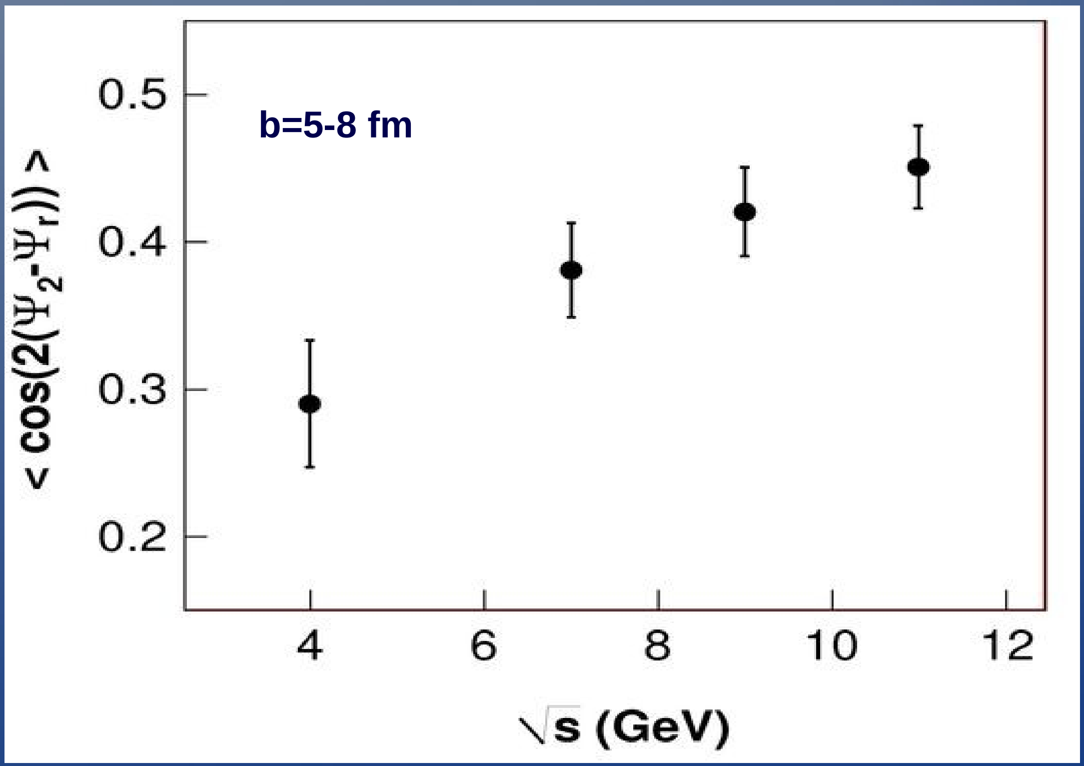
Beam tests of ZDC modules

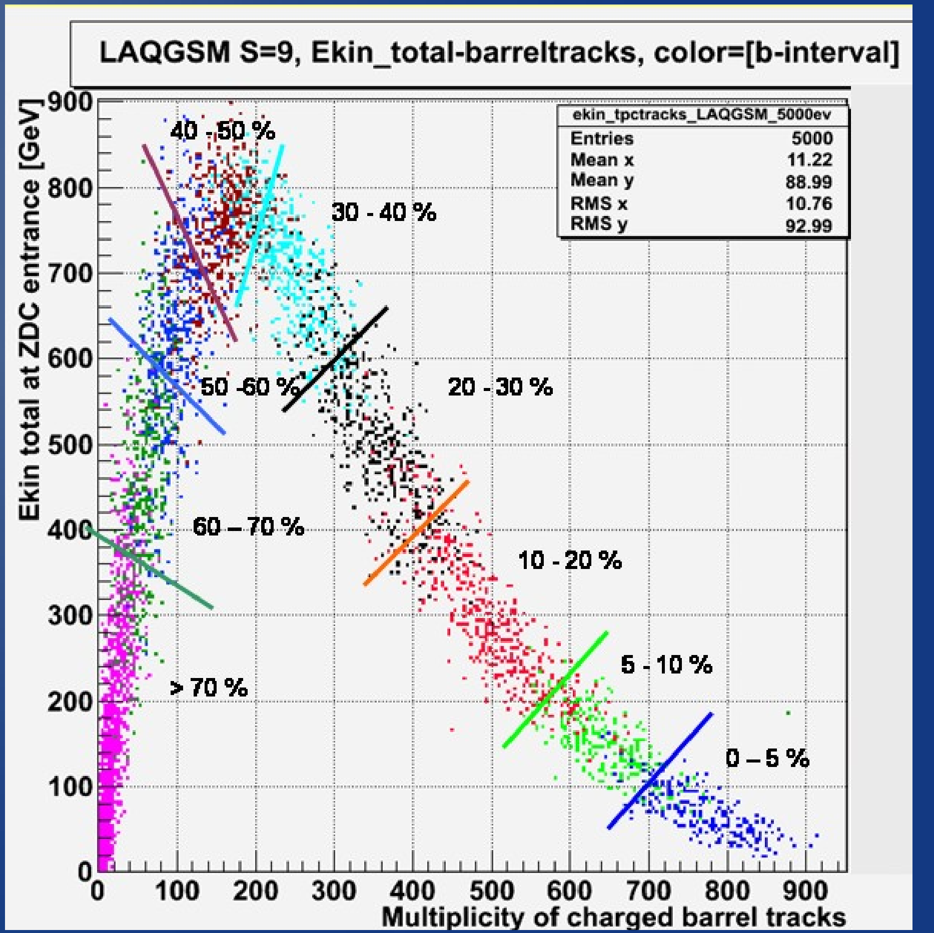


Flow Analysis at NICA/MPD

*MPD capability for event plane determination: v2 in TPC and v1 at high rapidities
*Measurement of spectators of both colliding nuclei;centrality determination by track multiplicity and spectator energy deposit

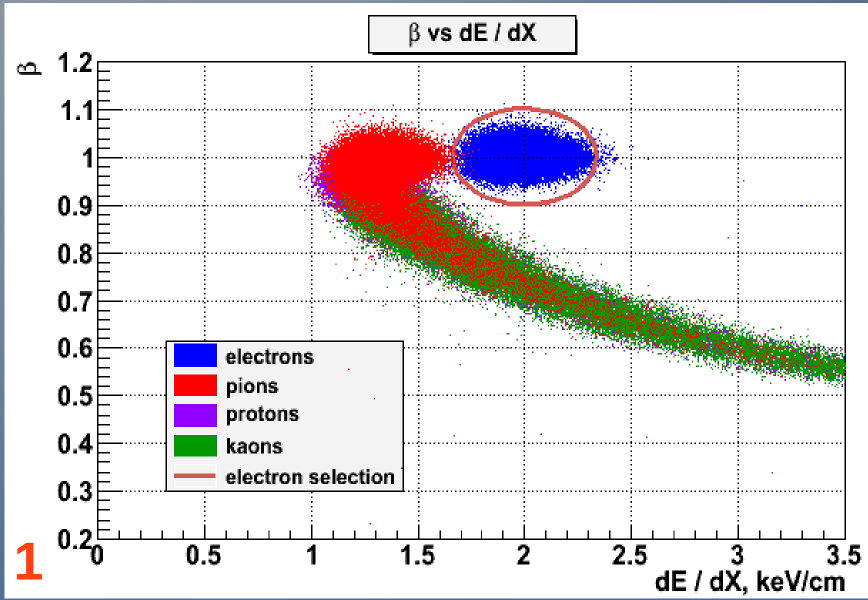
Event plane resolution for central events





Dileptons. Prospects for NICA

NICA's energy range very well suited to fill an important niche ($4<\sqrt{s}<11$ GeV):
-Unveil the onset of the low-mass region (LMR) pair enhancement
-Study LMR signal under highest baryon density conditions



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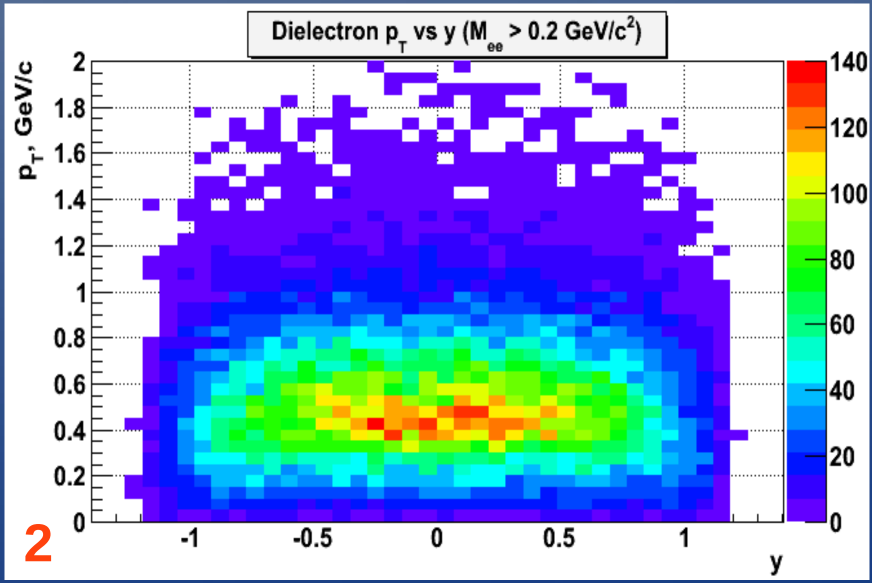

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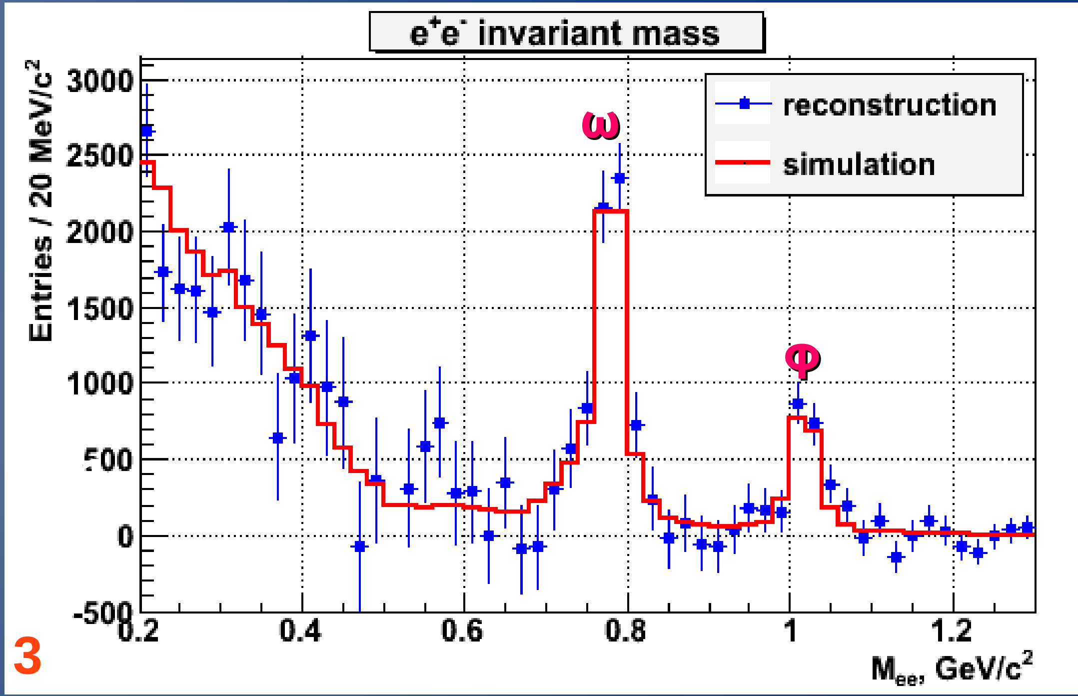


3

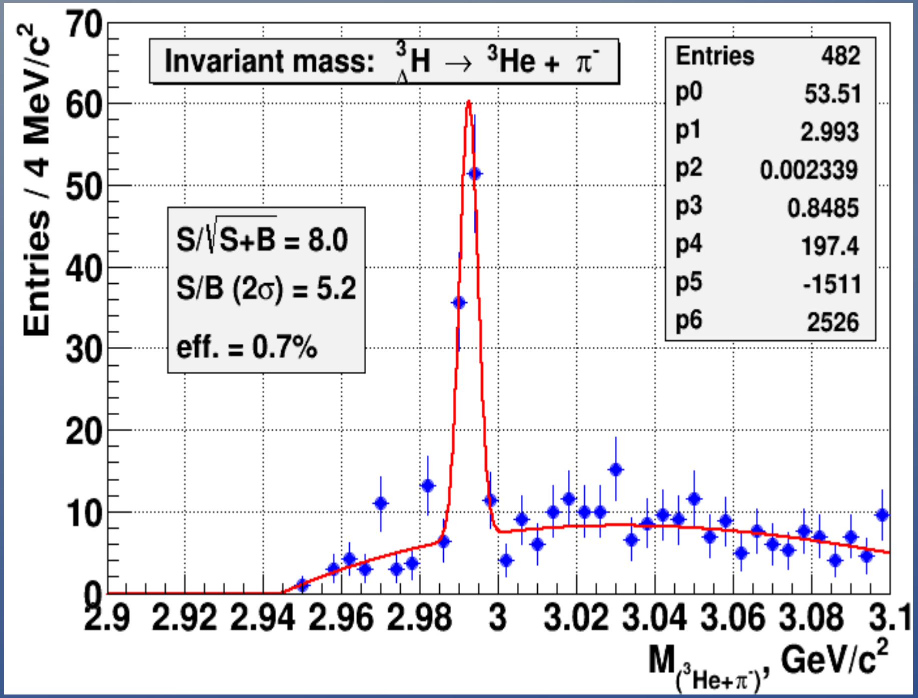
Fig. 1. Electron ID (dE/dx and TOF)
Fig. 2. Phase-space distribution of dileptons
Fig. 3. Invariant mass for dileptons in central Au+Au at $\sqrt{s}$ = 7 GeV (background subtracted)

Measurement of hyper-tritons at NICA/MPD

Feasibility study (V. Vasendina)

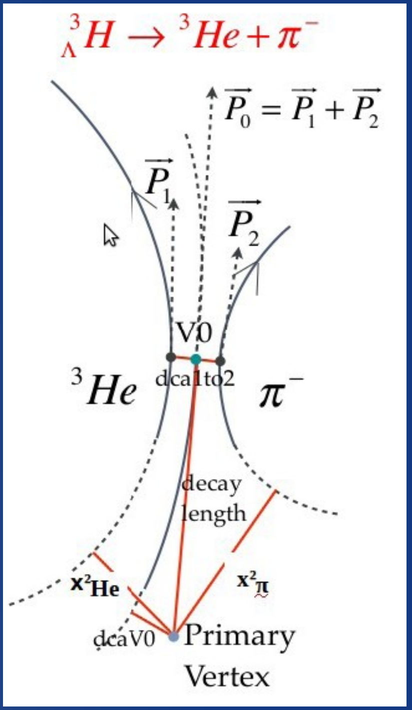
Motivation

- Study of YN interactions in nuclear matter
- Enhanced production of multi-strange composites at high baryon densities



Analysis

- 400k central Au+Au at 5 A GeV (LAQGSM model [1])
- Realistic tracking and secondary vertex finding technique
- Selection by track quality cuts and PID



Measurements of $_{\Lambda}^{3}H$ at NICA/MPD is feasible

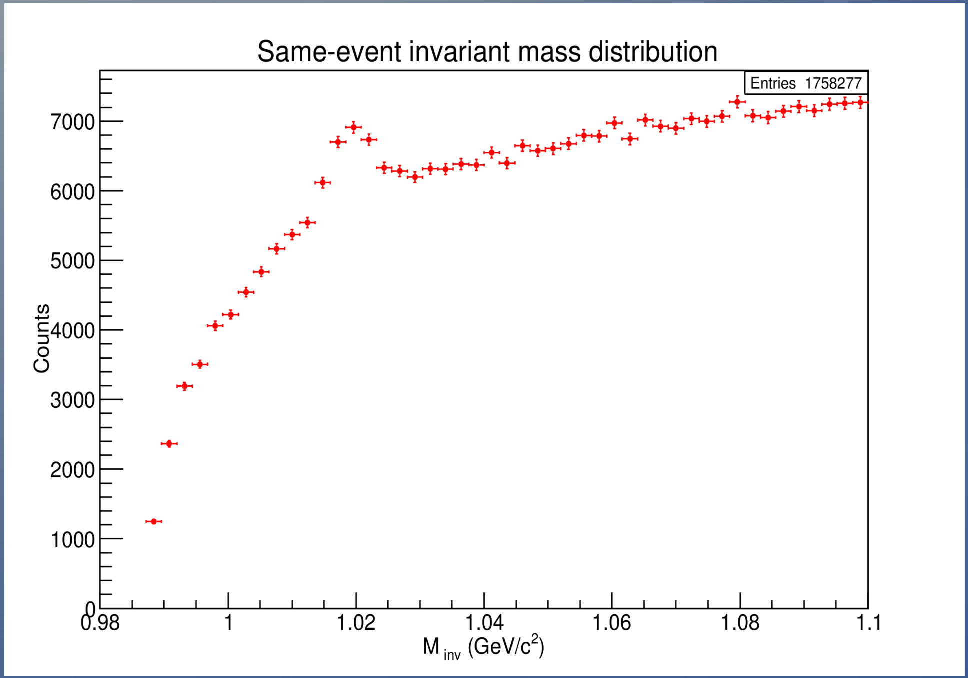
[1] J. Steinheimer, K. Gudima, et al, Phys. Lett. B 714 (2012) pp 85-91

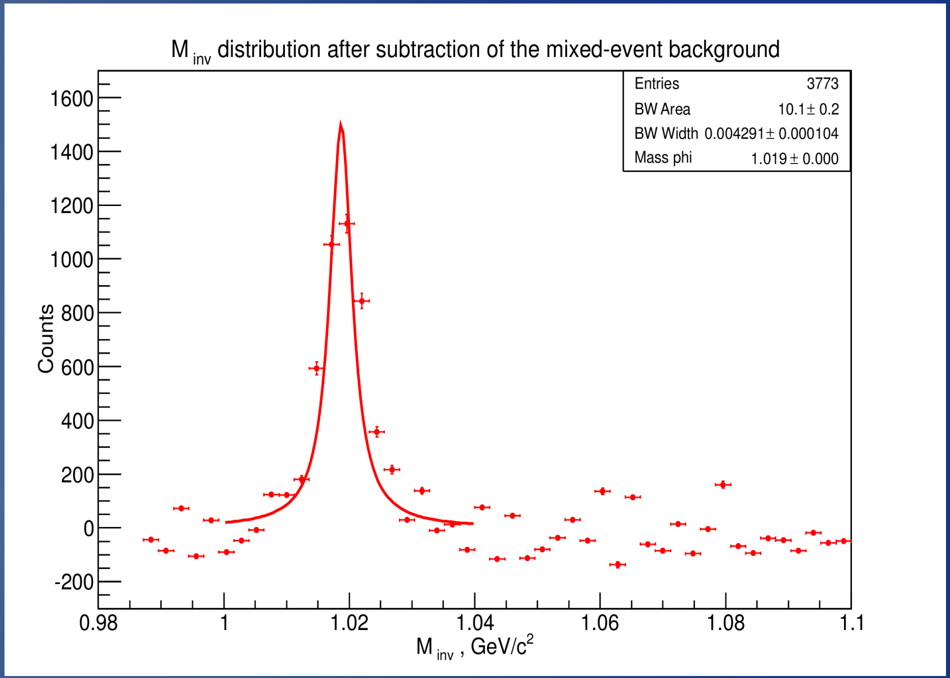
Measurement of φ(1020) at NICA/MPD

(L. Yordanova)

Motivation

- Measurement of φ-meson production and elliptic flow to probe the characteristics of the medium created in ultra-relativistic nucleus-nucleus collisions at NICA/MPD





Analysis

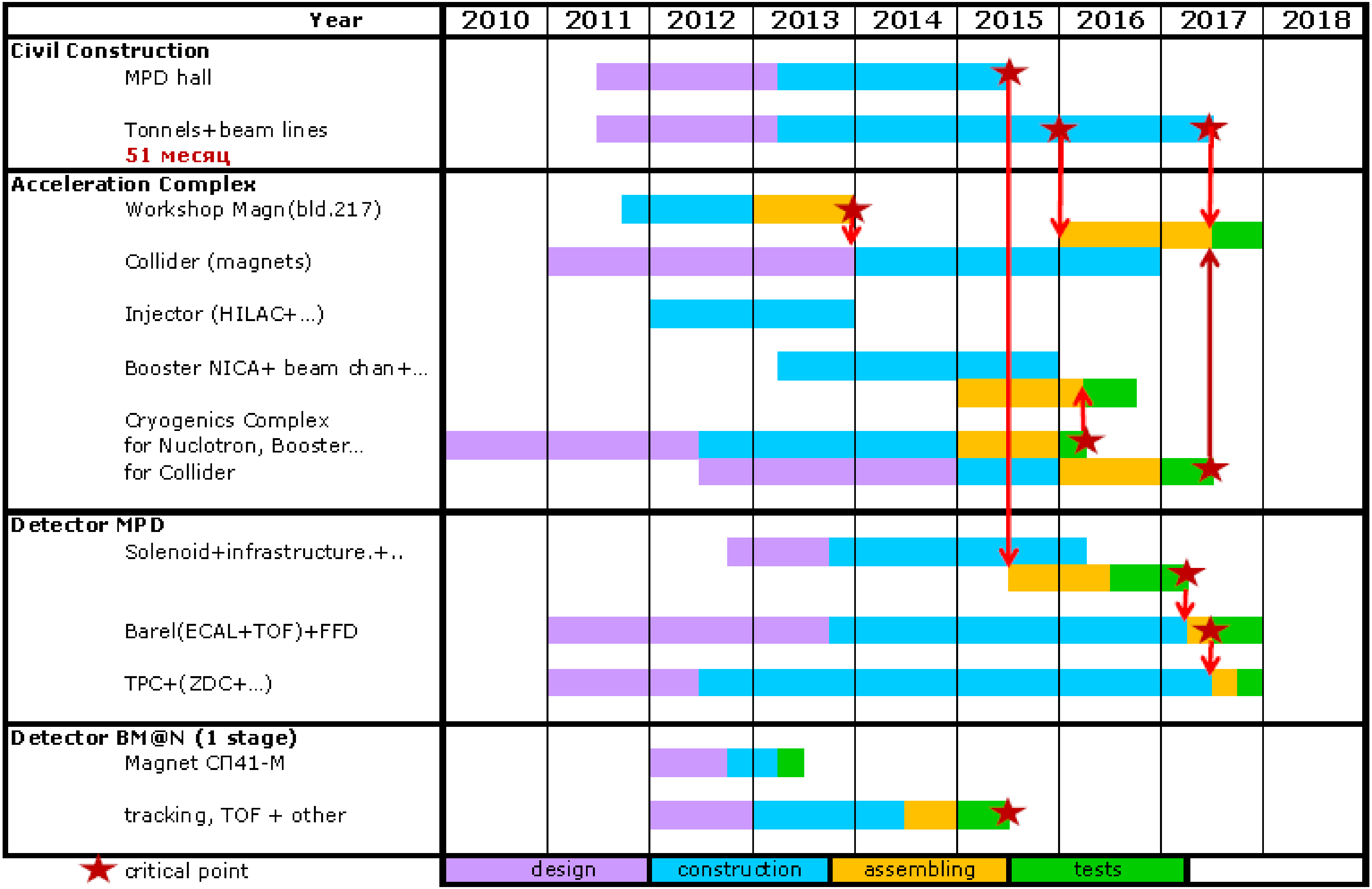
*Channel of decay: $\varphi \longrightarrow K^+K^-$
*Same-event invariant mass distribution
*Usage of mixed-event background
*Breit-Wigner fit function
*70k central Au+Au at $\sqrt{s}$ = 11 GeV
 (UrQMD model)
*Selection by track quality cuts and PID

BW Width = 0.004291 ± 0.000104 (GeV/c^2)
M_{inv} = 1.019540 ± 0.000012 (GeV/c^2)
S/√(S+B) = 18.11

$$M_{inv} = \sqrt{((E_1+E_2)^2 - (p_{x1}+p_{x2})^2 - (p_{y1}+p_{y2})^2 - (p_{z1}+p_{z2})^2)}$$

$$BW(m_{inv}) = \frac{1}{2\pi}\frac{A.W}{(m-m_\phi)^2+(W/2)^2}$$

NICA project timetable



Summary

The MPD detector has many advantages and meets all the ambitious physics requirements for exploring phase diagram of strongly interacting matter in a high track multiplicity environment.

The MPD detector covers a large phase space; it is functional at high interaction rates; comprises high efficiency and excellent particle identification capabilities; it is based on the recent detector developments and has comparatively reasonable cost.

NICA facilities provide unique capabilities for studying fundamental properties of the theory of strong interactions (QCD).

The MPD Collaboration consists of 195 scientists
from JINR (110) and other Institutions (85)

Participating Institutions : JINR + 18 Institutes from 9 countries

***Experienced scientists** - heavy-ion experiments at GSI,SPS, BNL (HADES, WA98, NA45, NA49, STAR,PHENIX, ALICE)
***Young scientists** - about 40% of the Collaboration

Thank you for your attention!