The First Open Day of the NICA Complex
The Multi-Purpose Detector (MPD) experiment

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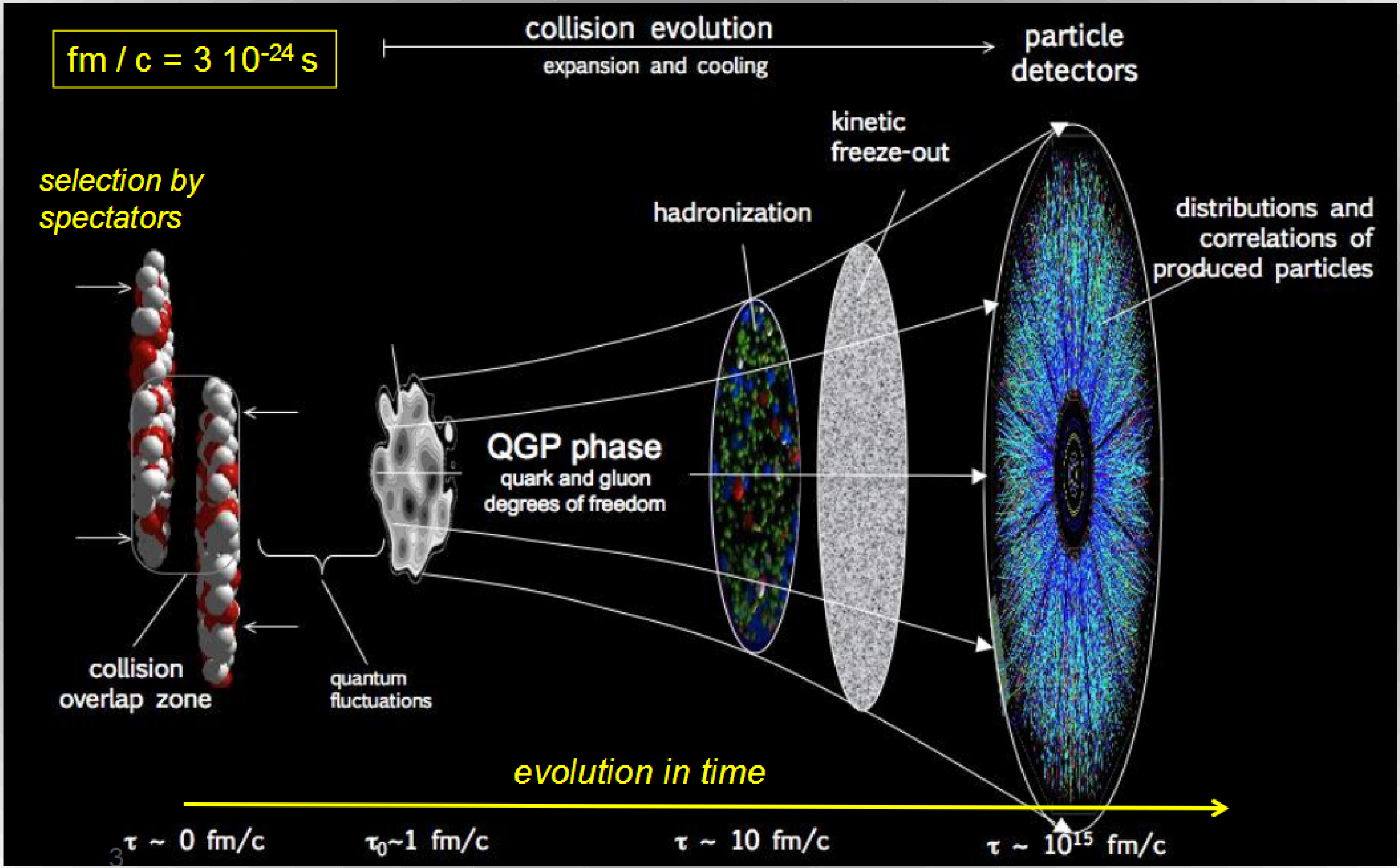
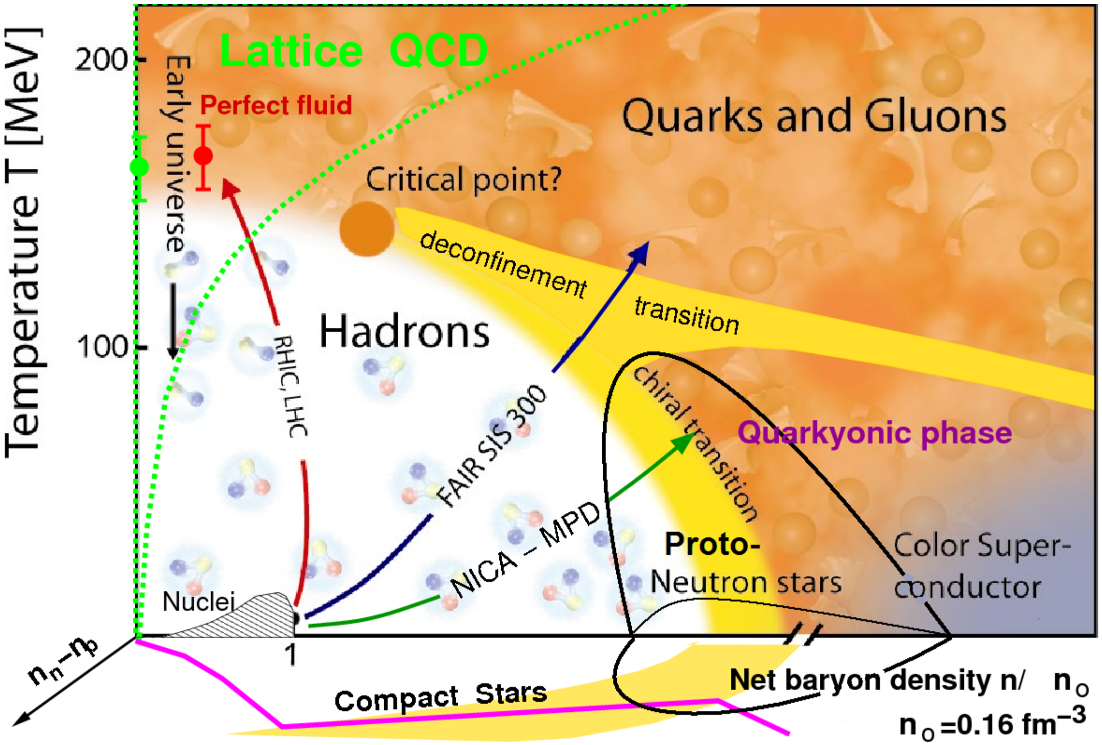
Outline

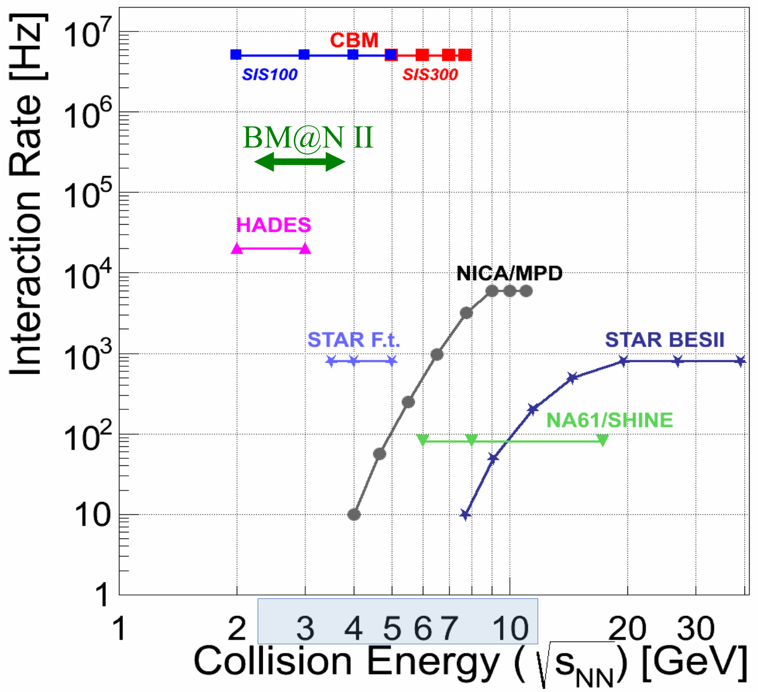
1. Introduction and Motivation
2. The Nuclotron-based Ion Collider Facility
3. The Multi-Purpose Detector
4. MPD sub-detector systems
5. Physics Feasibility studies at MPD
6. A call for collaboration
7. Summary

Relativistic Heavy-Ion Collisions & Quark-Gluon Plasma



Motivation

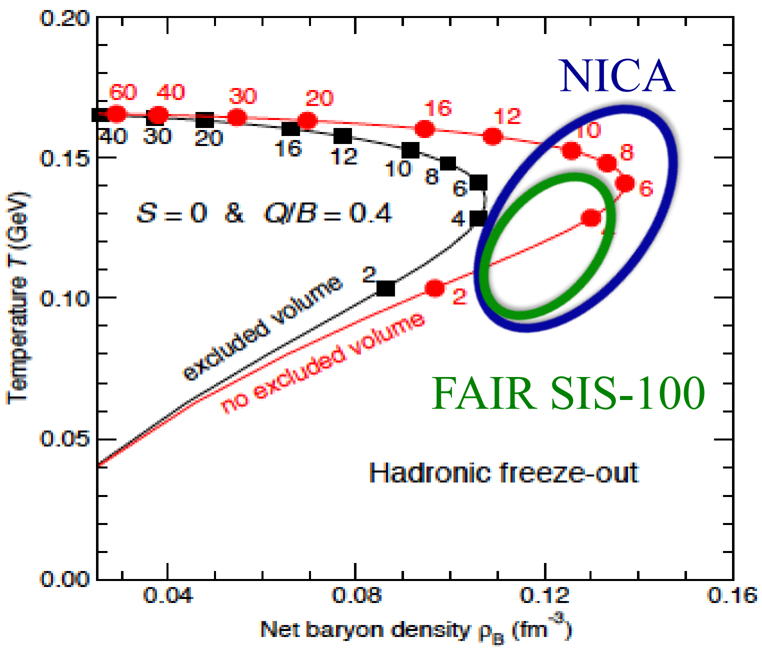




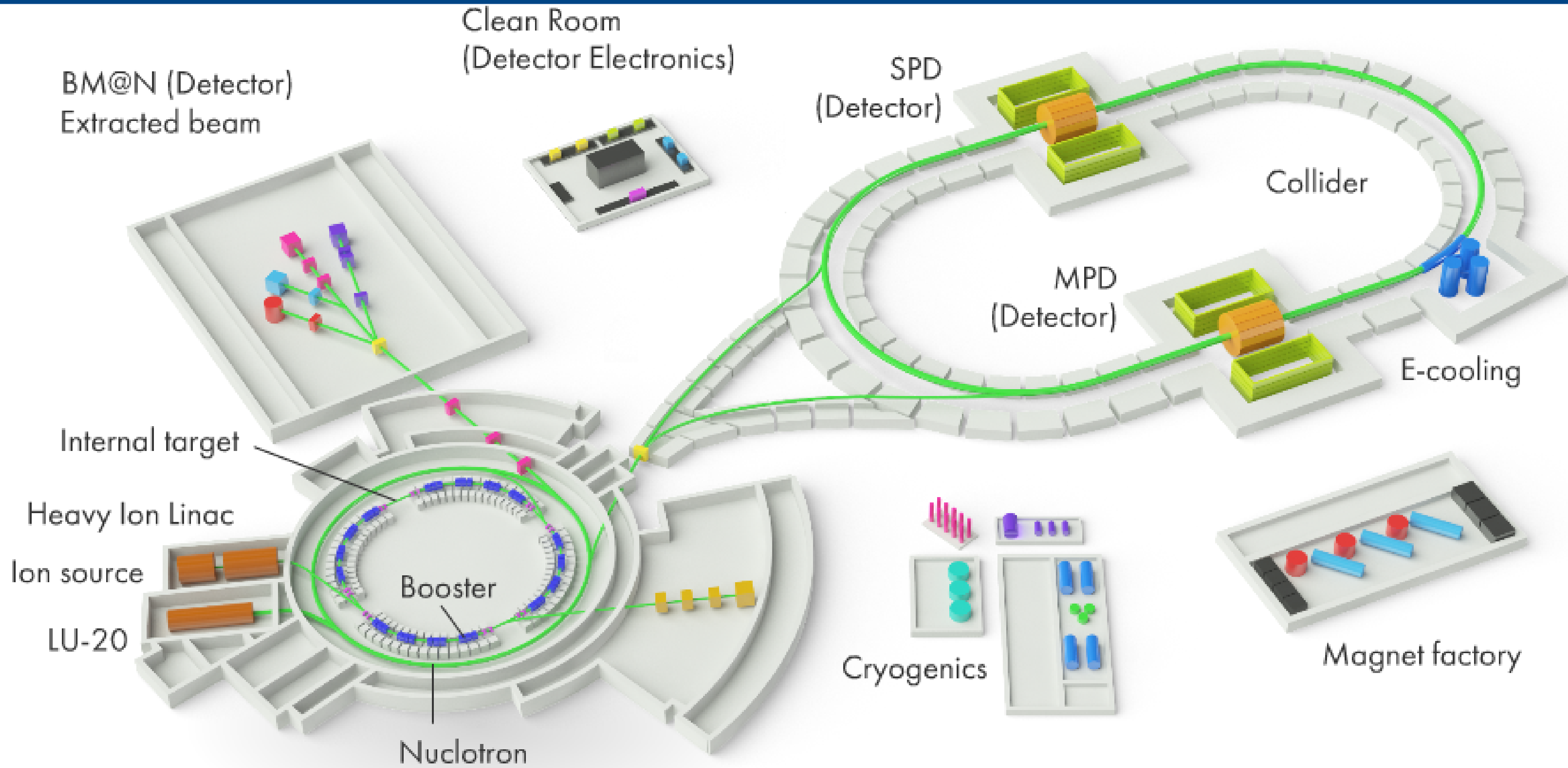
* State of HIC experiments
* Study Hot and Dense Barionic Matter
* Highest Net Barion Density
* Equation of State, Bulk properties
* Deconfinement, Phase Transition , Critical Point
* Observables:

Multiplicity, Spectra, Ratios, Critical phenomena,
Collective Flow, strangeness enhancement,
Event-by-event fluctuations, Femtoscopy,
EM decays of resonances and much more

NICA White Paper and CBM Physics Book



Nuclotron-based Ion Colider fAcility NICA

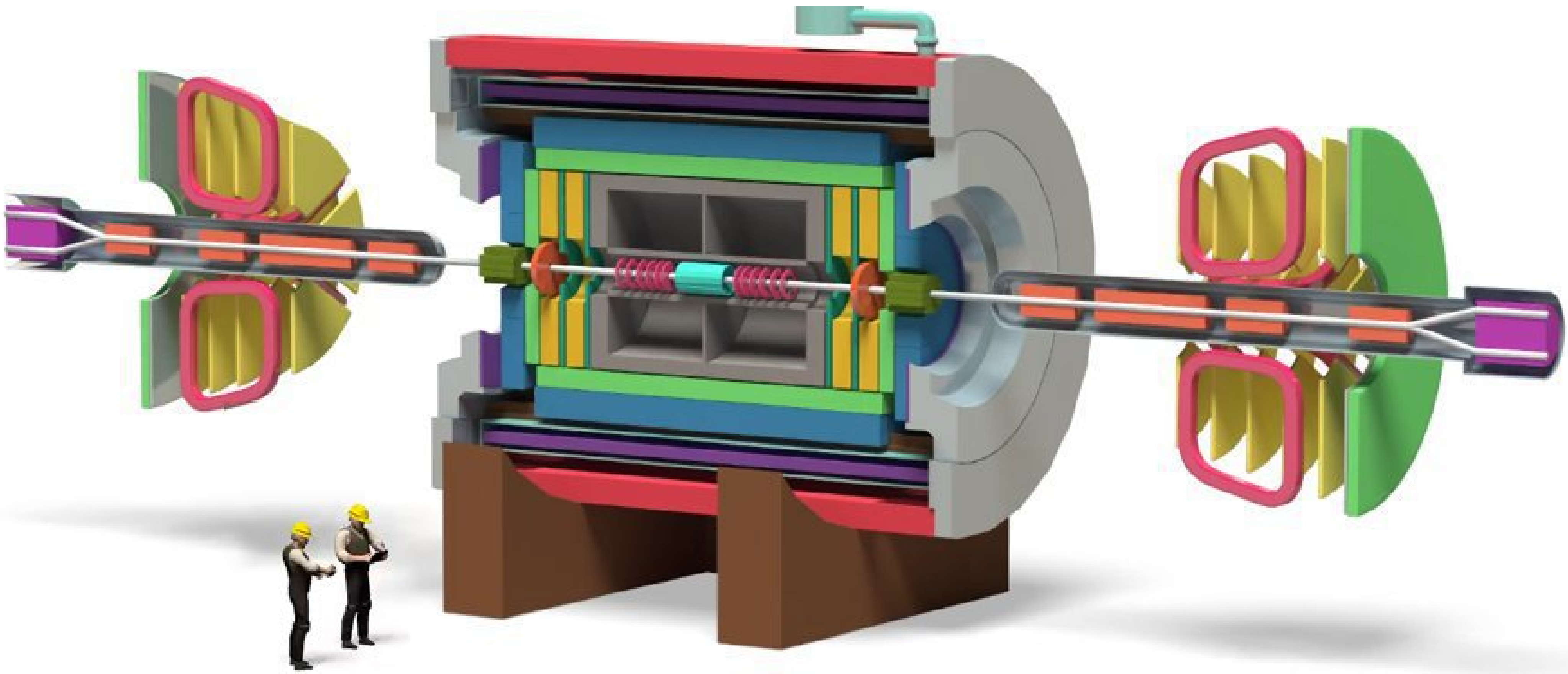


* Cryogenics: 8 kW, He @ 4.5K, 1000 l/h
* Magnet factory – SC magnets for booster, collider and SIS-100
* Injection complex: 4 sources, 2 linacs
* Booster,* Nuclotron * Collider
* AA (up to $^{197}Au^{79+}$), AB, pp and dd polarized beams
* 3 Detector Programs: BM@N, MPD, SPD

A very nice tour is organized!

* $\sqrt{s_{AuAu}} = 11$ GeV
* $L_{AuAu} = 10^{27}\,cm^{-2}s^{-1}$
* $\sqrt{s_{pp}} = 27$ GeV
* $L_{pp} = 10^{32}\,cm^{-2}s^{-1}$

Multi-Purpose Detector MPD



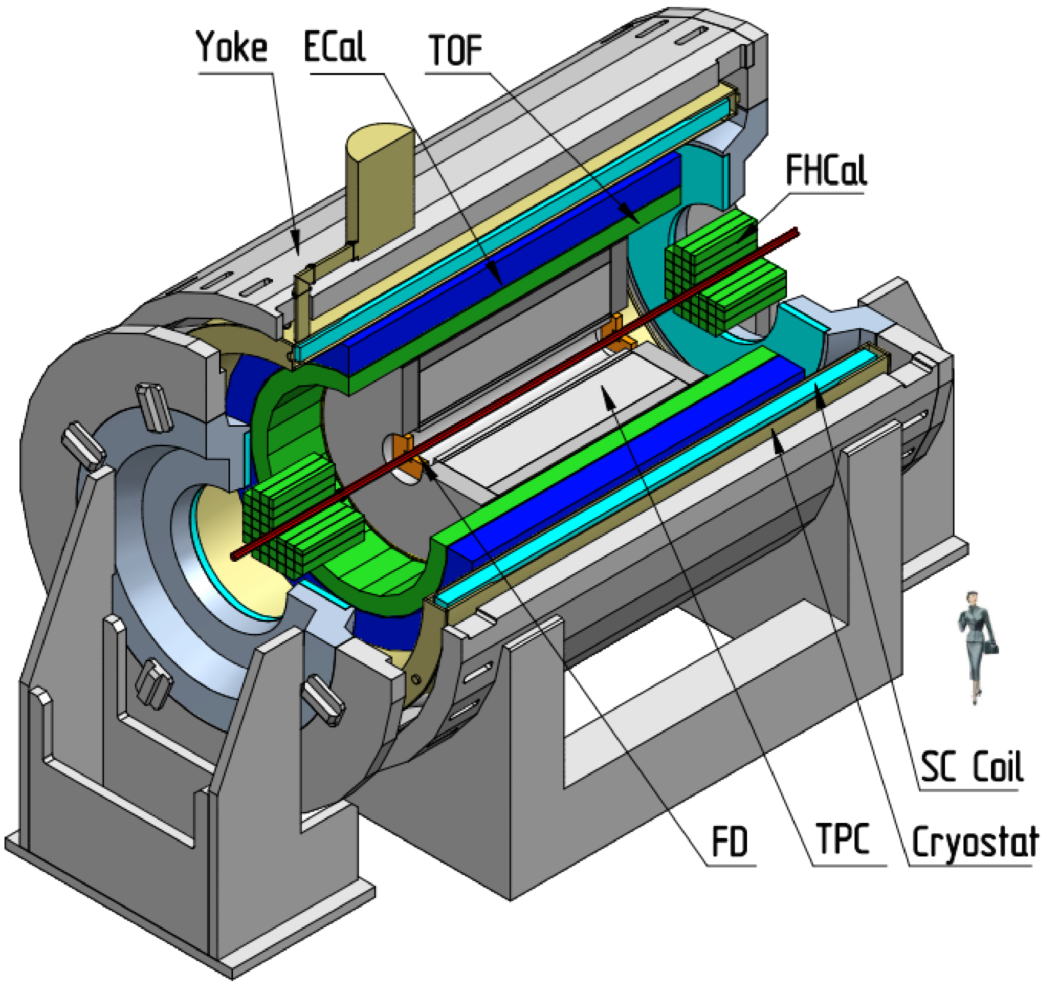
Three stages are planned

1. Barrel setup: TPC, TOF, ECal, FHCal, FFD (by the end of 2020)

2. Addition of IT and GEM close to interaction point

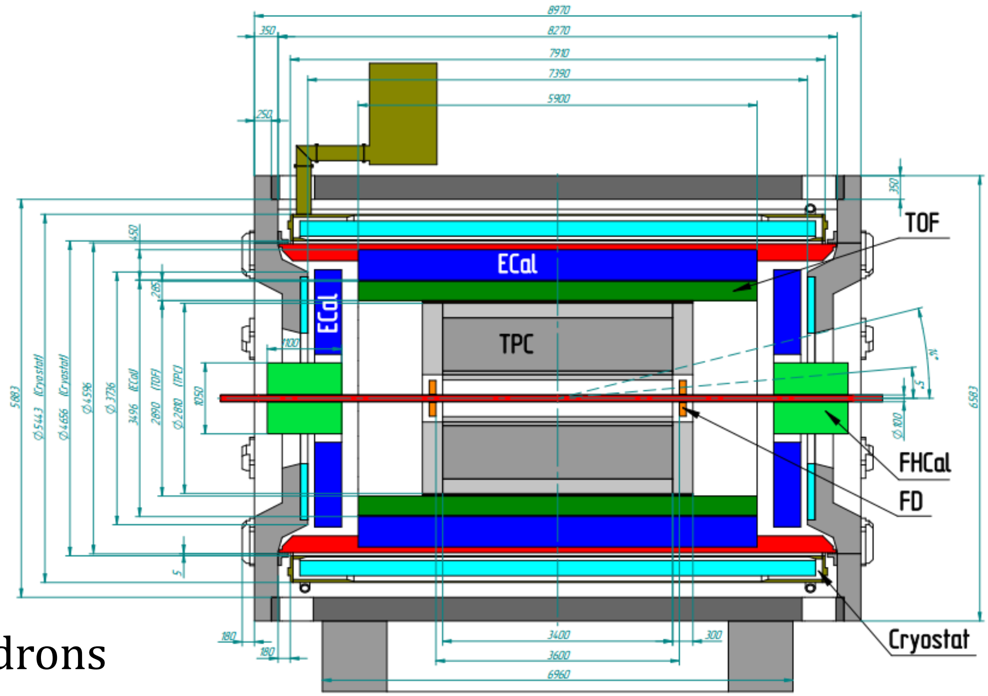
3. Addition of Forward Spectrometers for forward(backward) rapidity

MPD stage 1



Required features:
* Precise tracking and ID
* High Multiplicity and Rate
* Low Material Budget

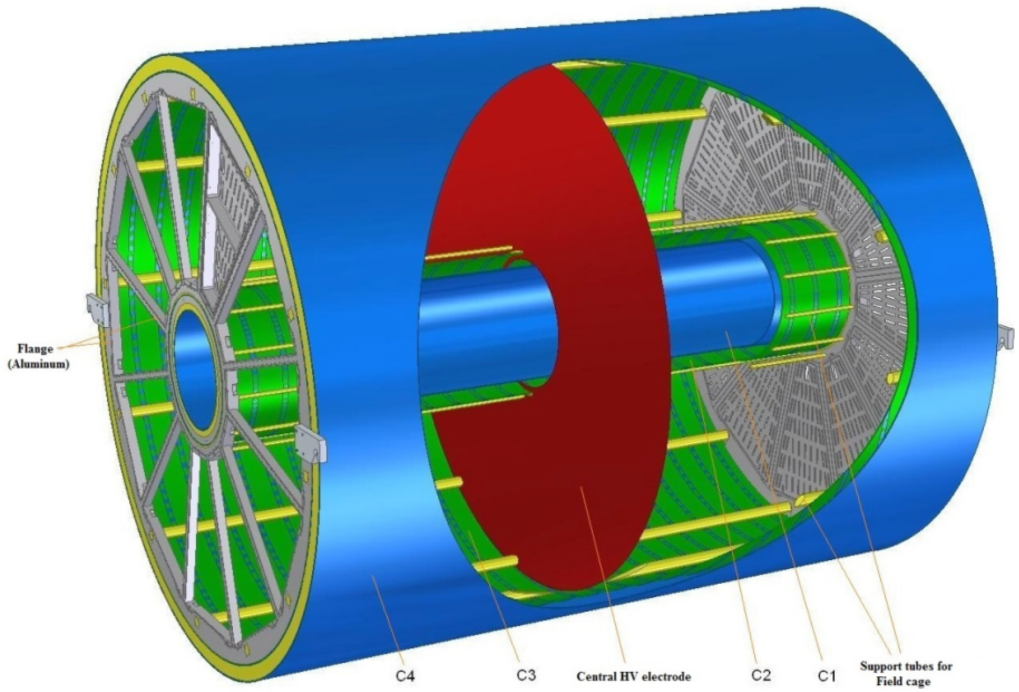
1st stage:
TPC Time Projection Chamber
TOF Time of Flight System
ECal Electromagnetic Calorimeter
FHCal Forward Hadron Calorimeter
FFD Fast Forward Detector



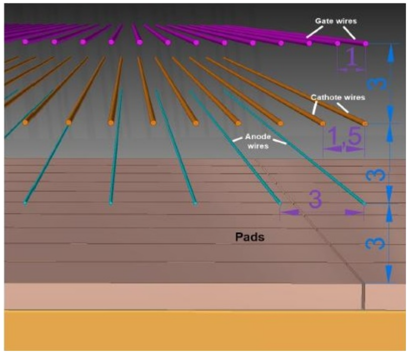
* Particle yields and spectra
* Event-by-event fluctuations
* Femtoscopy involving π, K, p, Λ
* Collective flow for identified and reconstructed hadrons
* Electromagnetic probes (electrons, gammas), vector, mesons

Time-Projection Chamber TPC

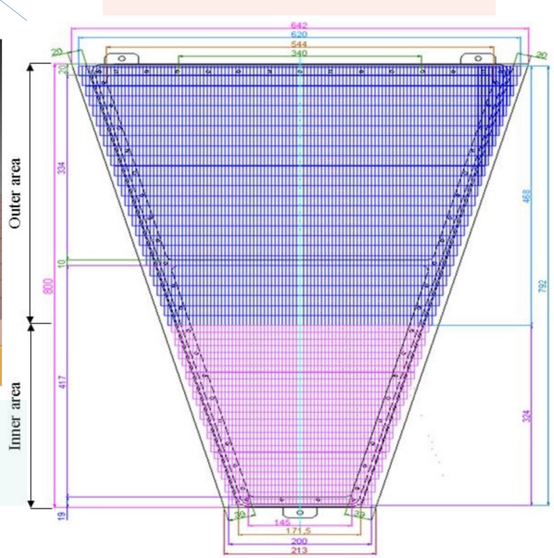
* Main tracking detector for MPD
* Provides dE/dx through charge collection
* Central HV anode, Ar/CH4 (90/10) gas,
* Read-out Chambers - MWPC, Cathode pads
* Energy Loss resolution of ~8%
* Precise tracking and Particle Identification
* Accurate determination of primary vertex
* Precise p_T resolution up to $|\eta| < 1.5$
* Most prototyping done, mass production

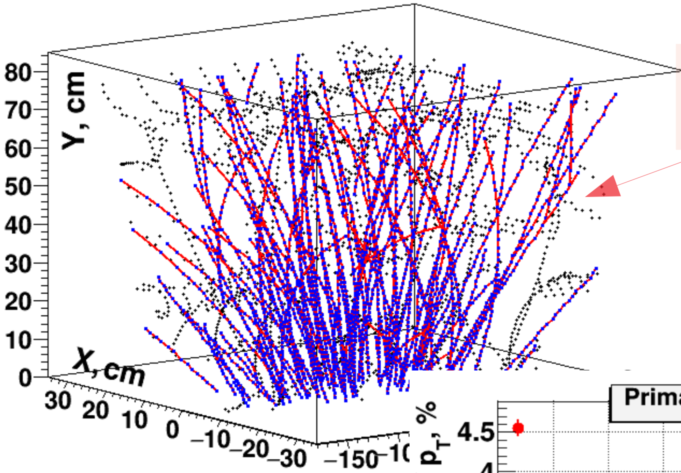


Cathode Pad Readout

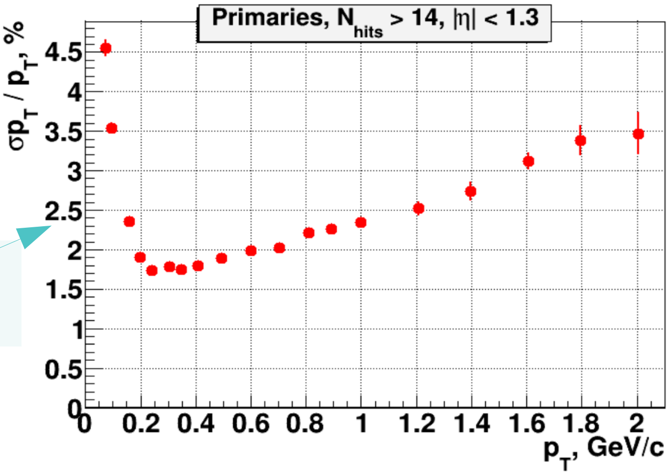


Multi-Wire Proportional Chambers



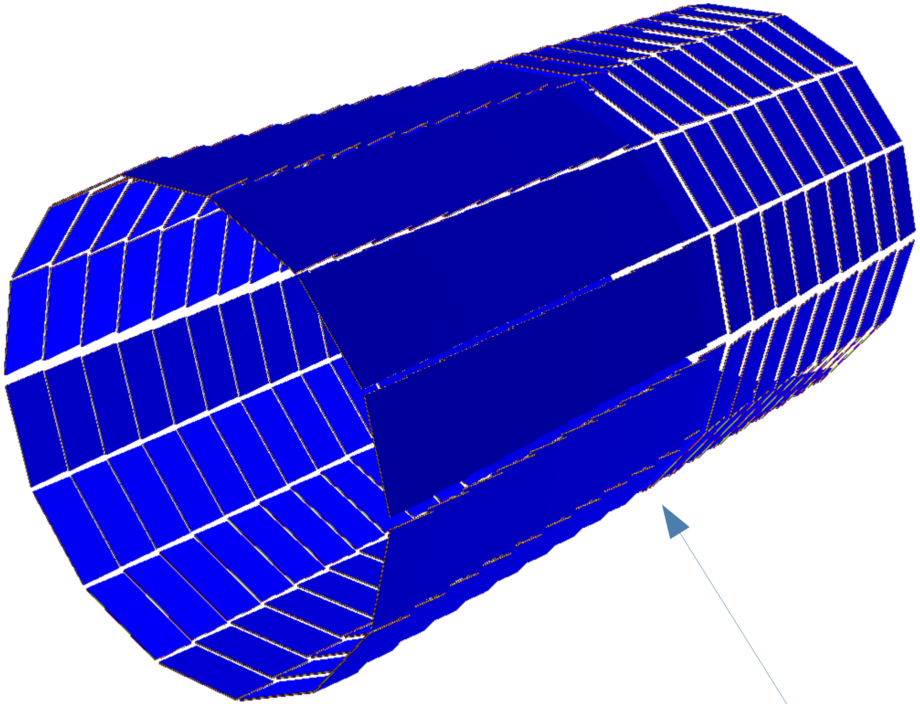


Tracking – 2 pass Kalman Filter based



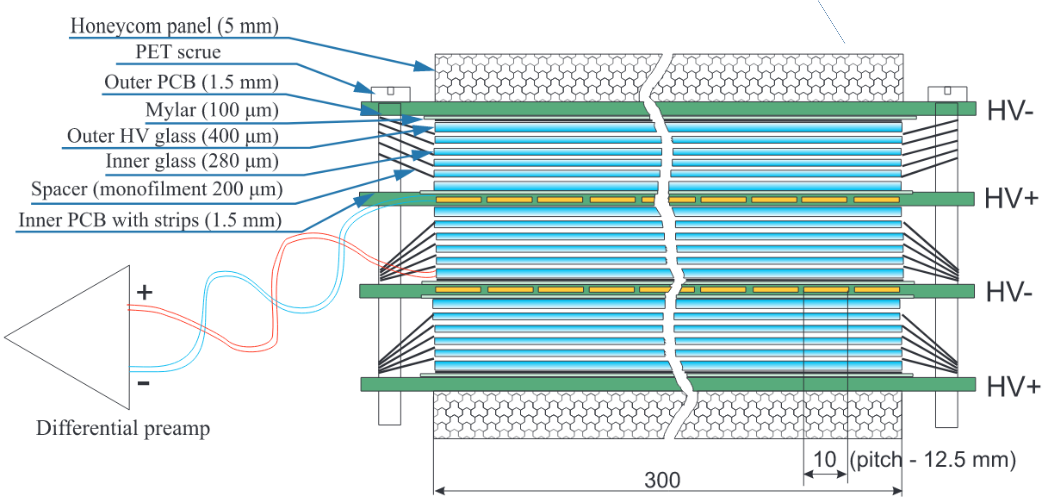
Good Transverse Momentum Resolution

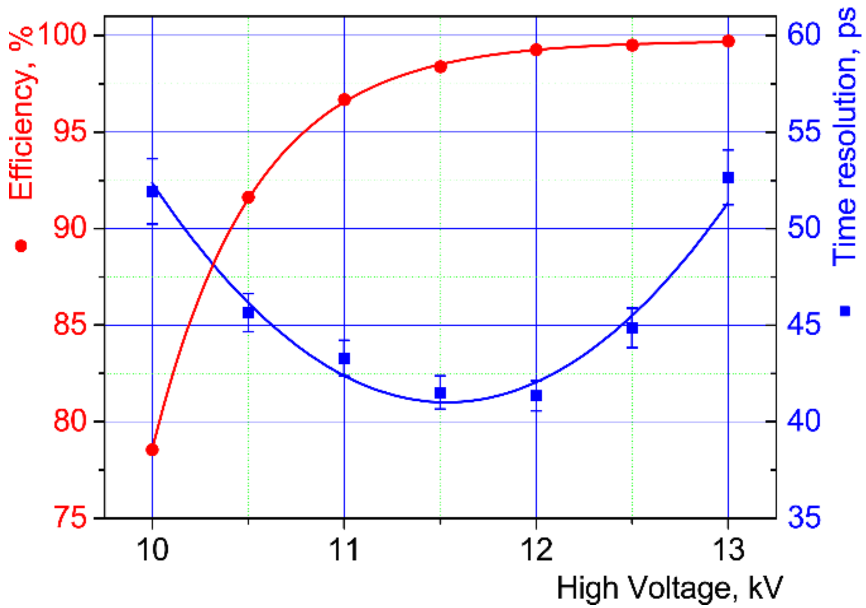
Time of Flight System TOF



* Three stacks of
  Multi-gap Resistive Plate Chambers
* Main elementin of
  TOF-400 and TOF-700 walls at BM@N,
  TOF-Barrel and TOF-Endap at MPD.
* Fast Front-end electronics (NINO based)
* TOF hits matched with TPC tracks
* Provides time of particle flight which along with momentum is used for velocity or mass determination and particle identification.

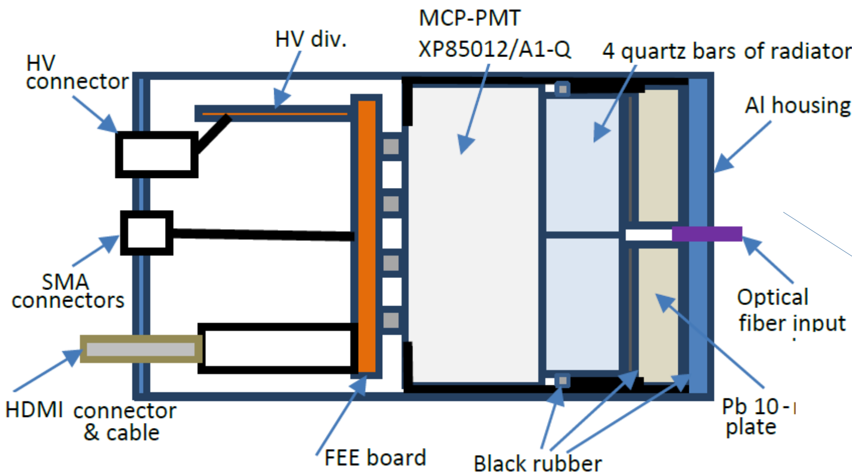
$$M^2 = (p/q)^2\left(\frac{c^2t^2}{l^2} - 1\right)$$





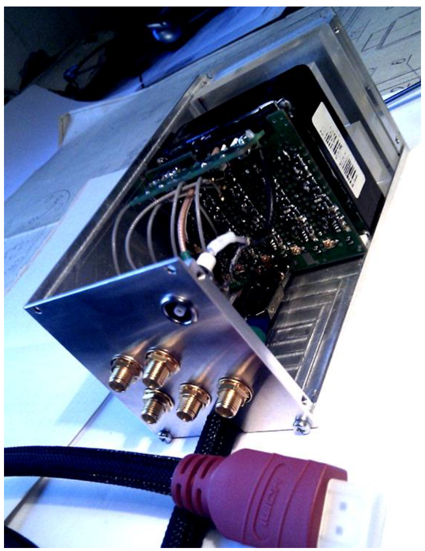
BM@N December 2016 test run:
* Time resolution of ToF-700 chamber ~65 ps
* Time resolution of ToF-400 chamber ~53 ps

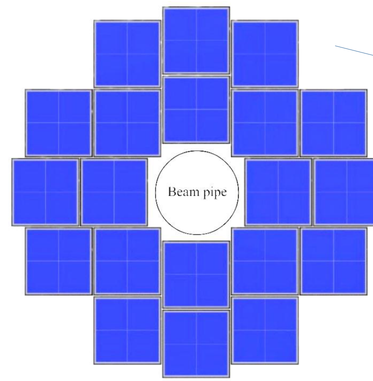
Fast Forward Detector FFD

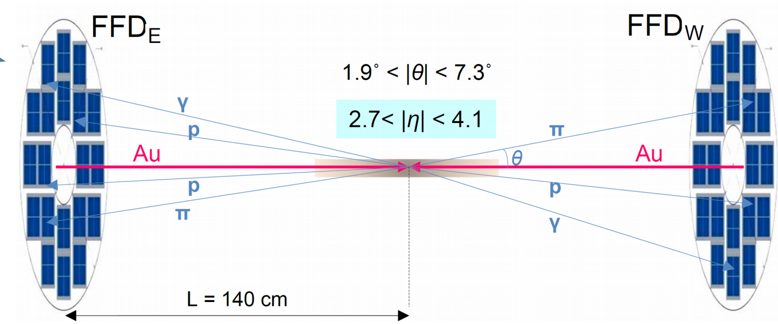


TOF needs a start trigger!

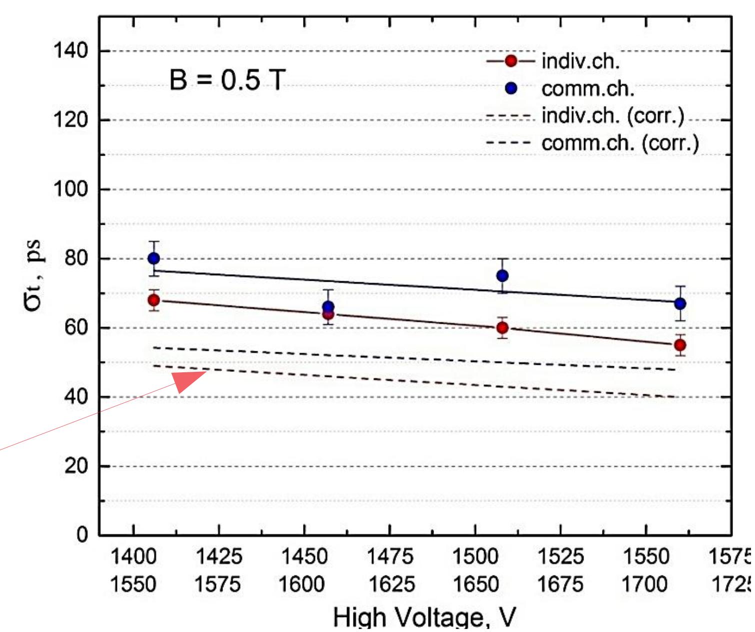
Detects high-energy photons by conversion to electrons in a 10 mm Pb plate The electrons pass through a quartz radiator generating Cherenkov light, collected by a photo cathode





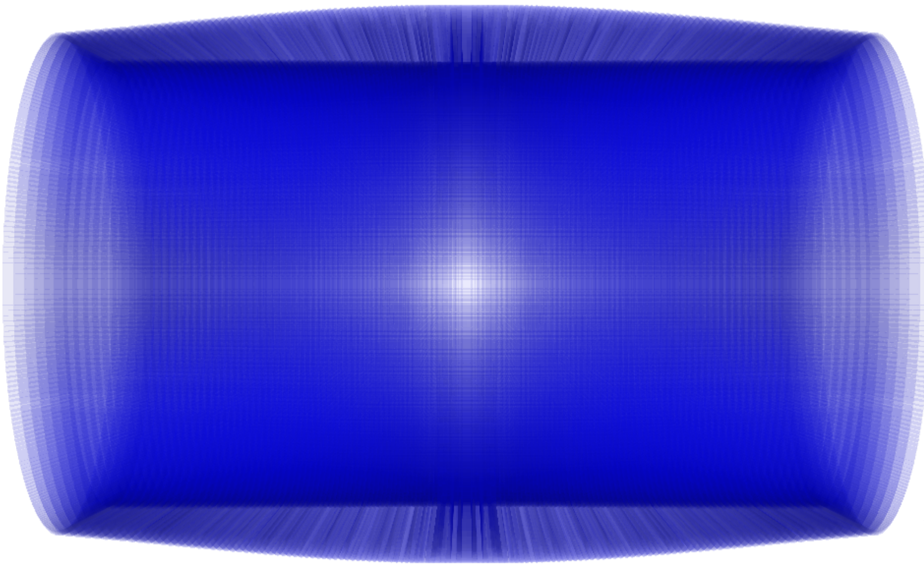


Number of arrays:	2
Number of modules:	20 × 2
Number of channels:	80 × 2



Main goals of the FFD:
* Fast and effective triggering of collisions
* Generation of the start pulse for the TOF
* Time resolution of a single module(+electronics) in MPD is $\sigma_{FFD} \approx 44$ ps

Electromagnetic Calorimeter ECal



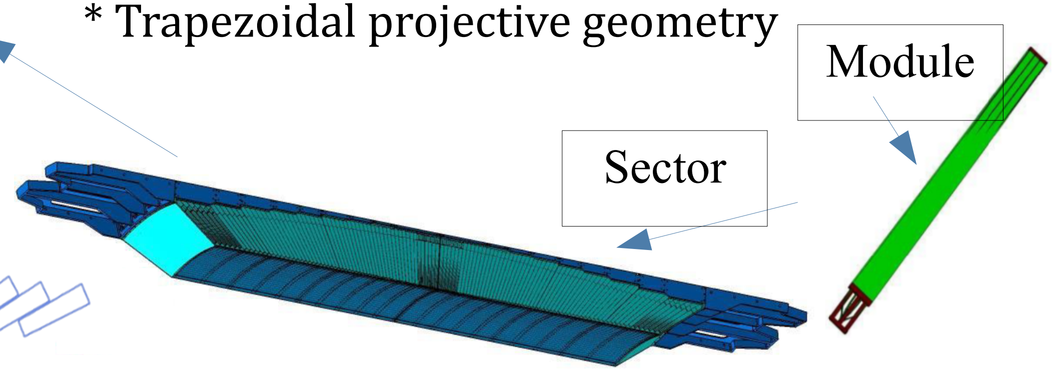
* ECal will provide measurements for electromagnetic and hadronic showers
* Modules are a shashlyk (skewer) type

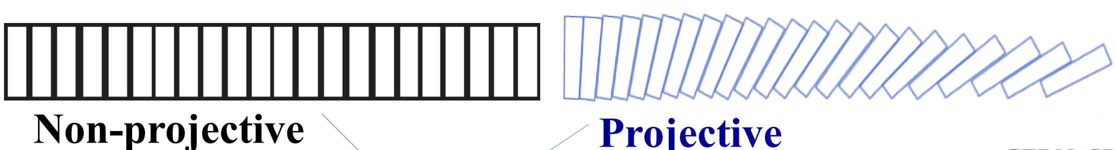
Total number of modules : 43008

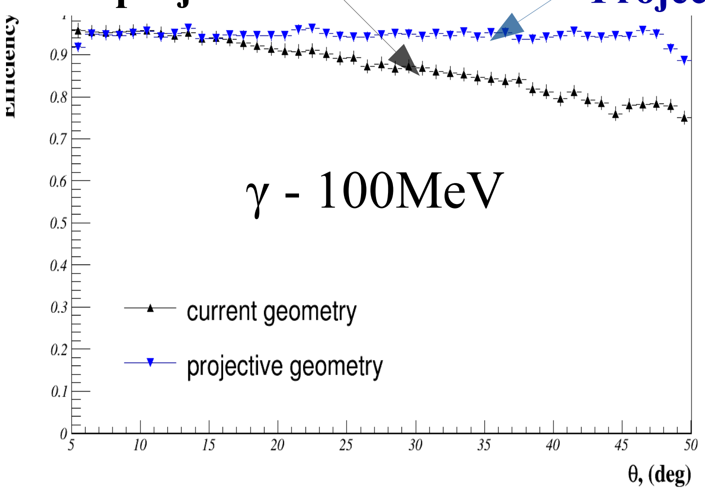
221 Pb plates (0.3 mm)

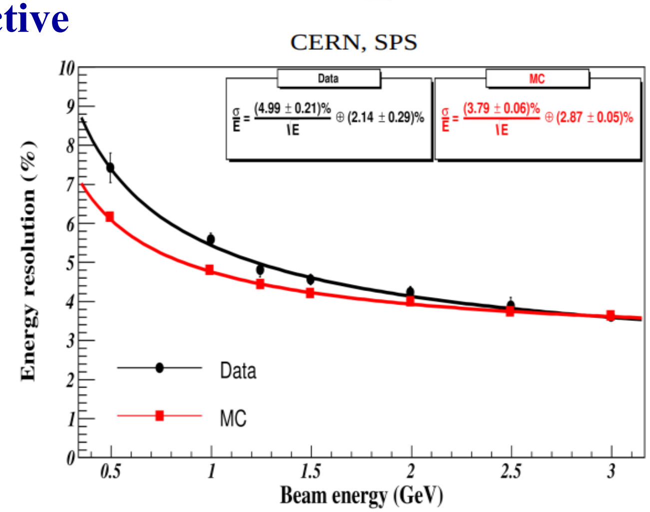
221 FscScint C_9H_{10} (1.5 mm)

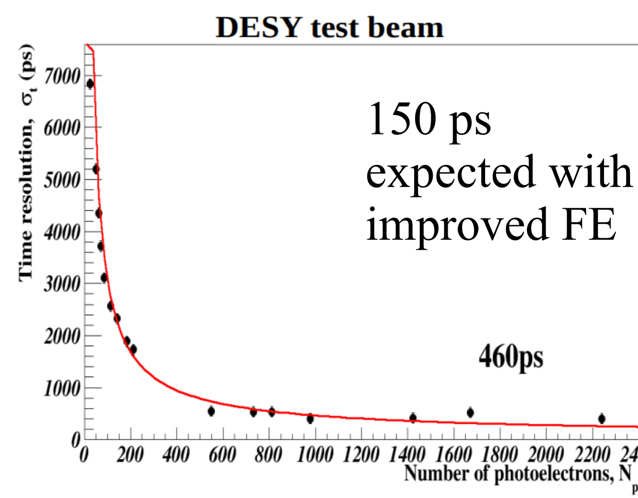
* Light is carried by Wave Length Shifting Fibers to HAMAMATSU MAPD phot counters.
* Trapezoidal projective geometry



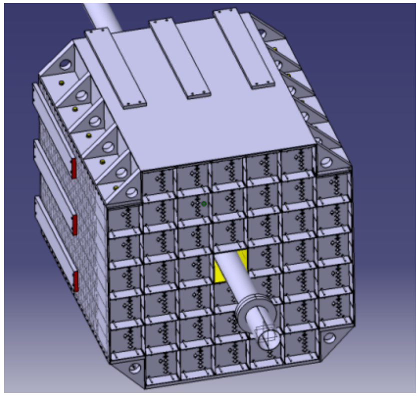


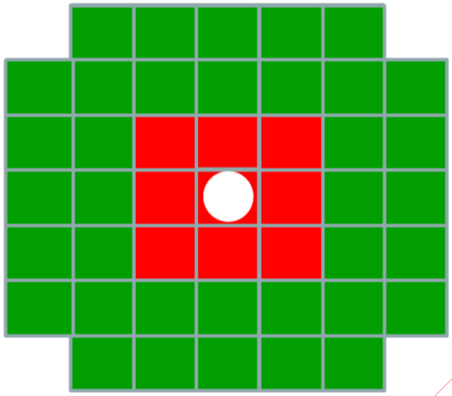






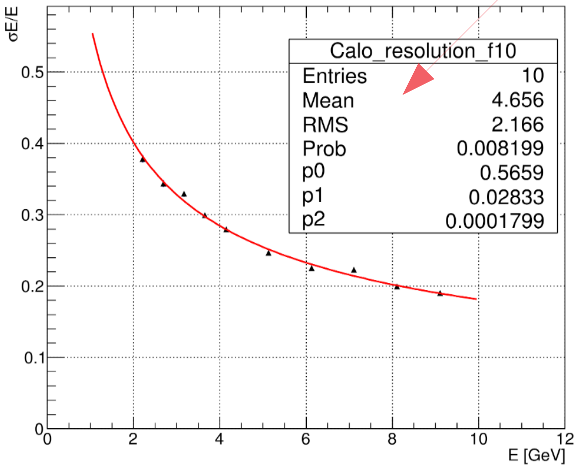
Forward Hardron Calorimeter FHCal,

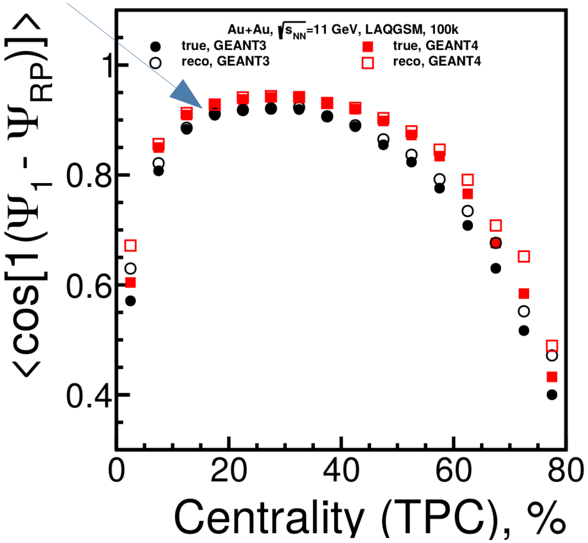


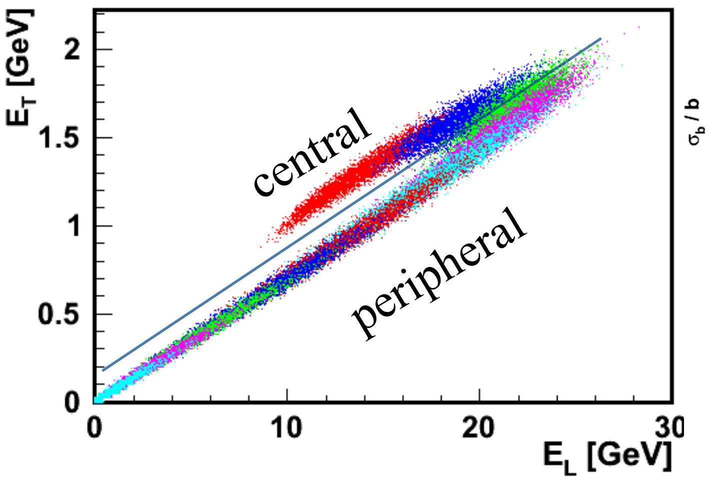


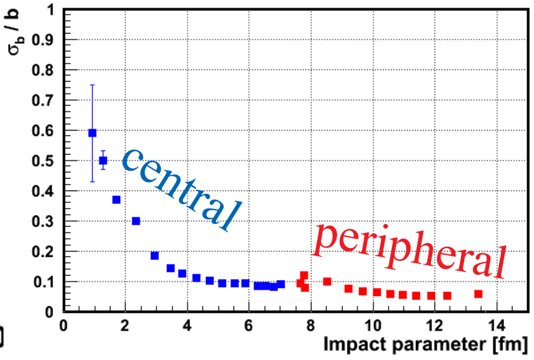
Measures the energy of non-interacting nucleons and fragments (spectators) in AA collisions.
Lead-scintilator 4:1, WLS fibers, SiPM
Two arms x 44 modules 2.0< η <5.0

Main goals of FHCal:
* Provide good **energy** resolution
* **Centrality** Determination with good resolution
* Important for **Event-Plane** reconstruction



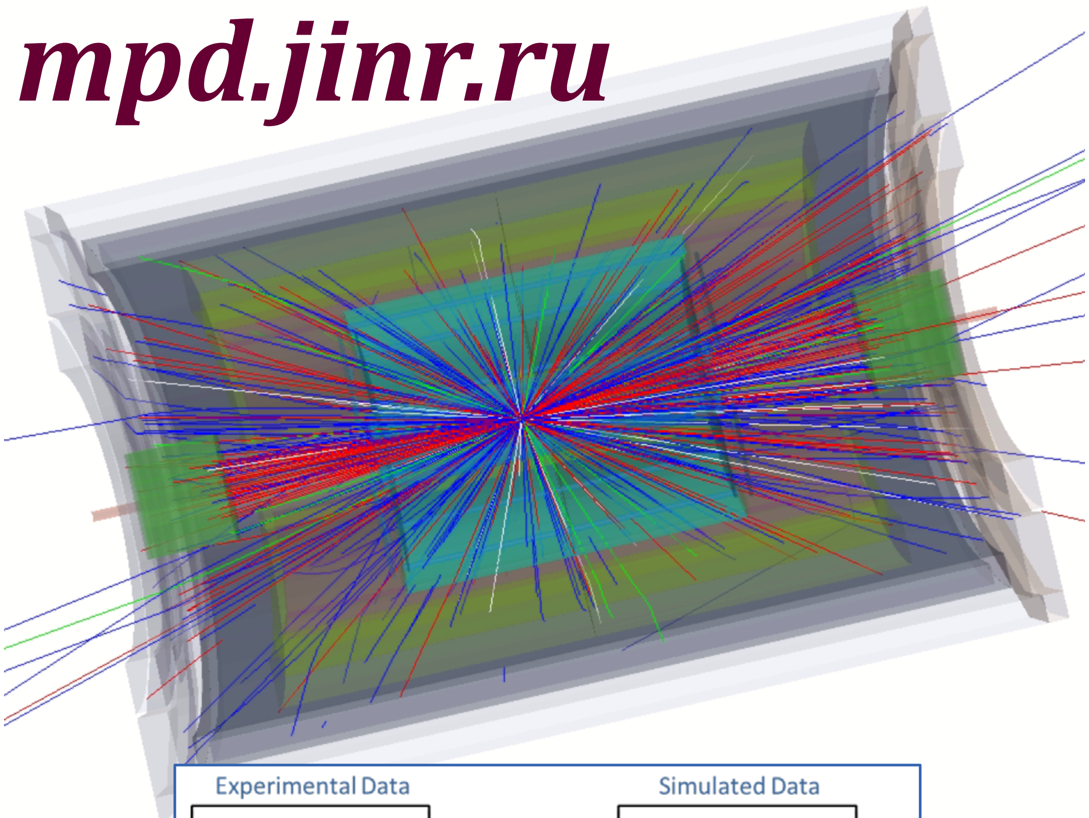




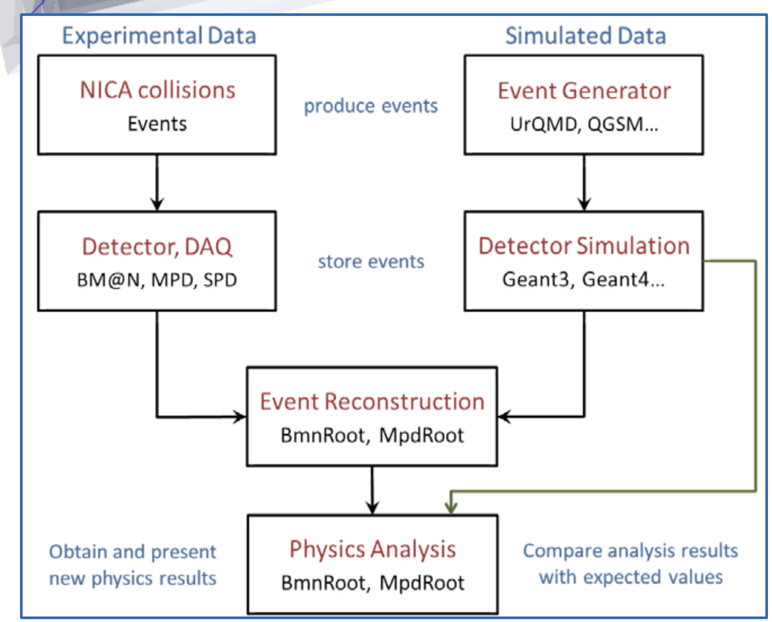


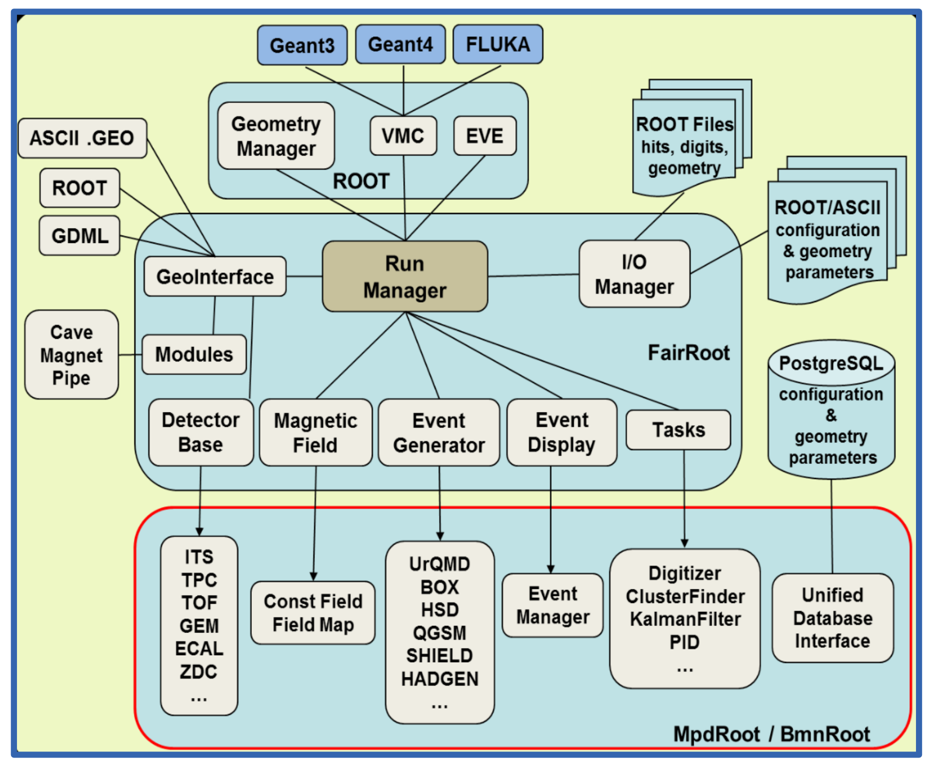
MPDROOT: Software and Analysis

mpd.jinr.ru

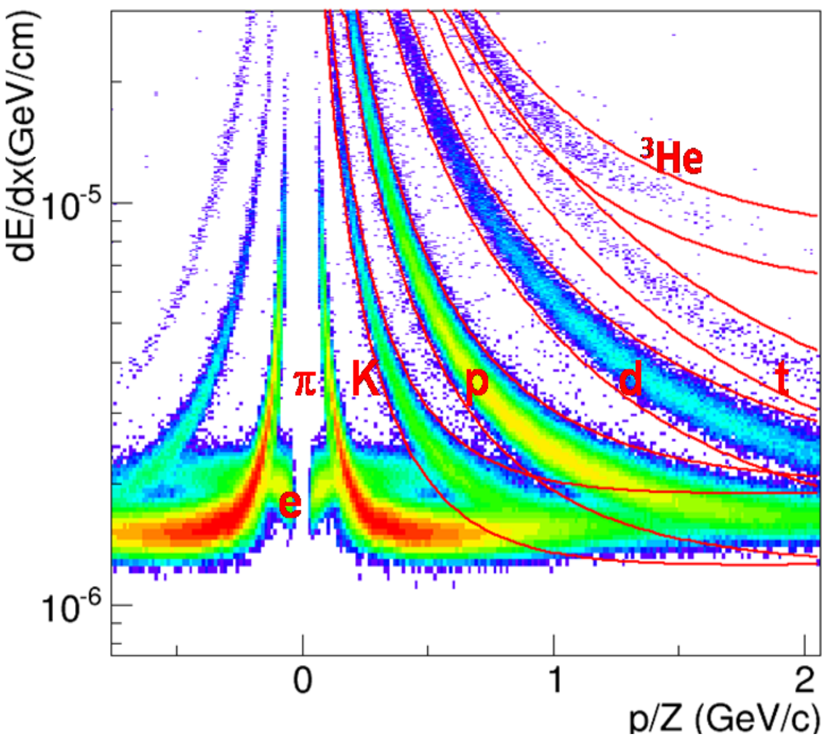


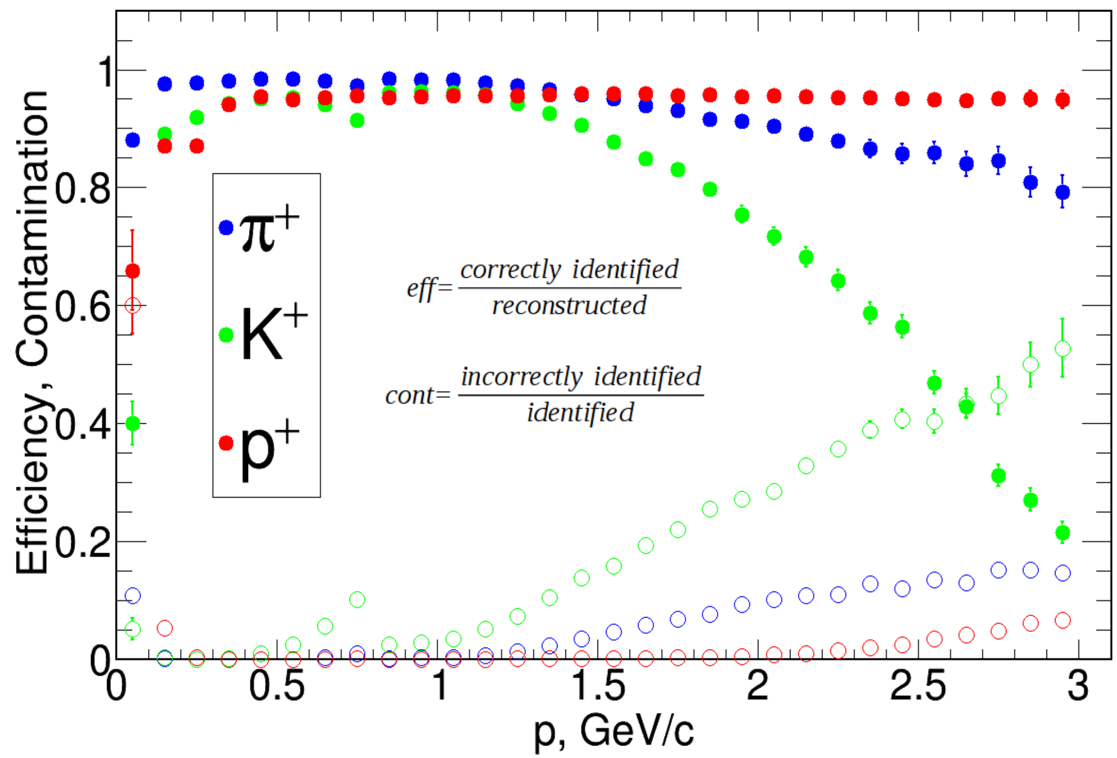
* **MPDROOT** is based on **FAIRROOT**
* Has good **modularity**
* Many packages serve as base
* Provides interfaces for **event generators**
* Full MC simulation chain, **Geant4**
* **Realistic** event reconstruction
* Tools for detector performance est.
* Unified Database
* **Physics analysis** frameworks for
  simulated feasibility studies
  (real data studies eventually)

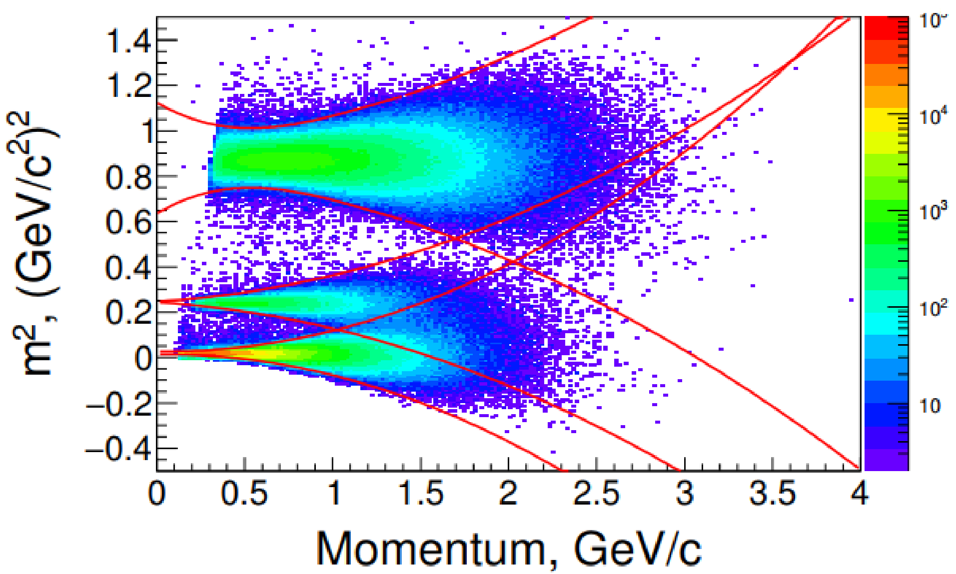




Particle Identification





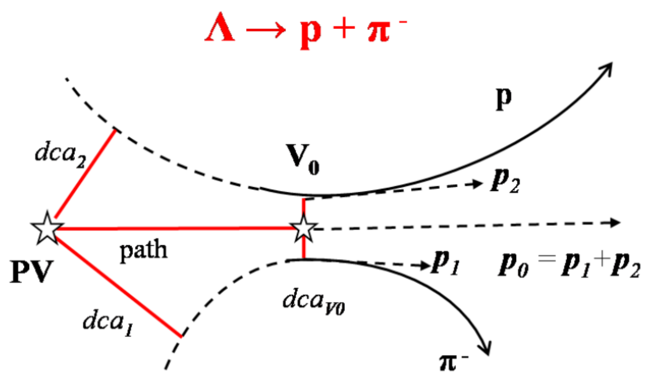


Particle Identification Based on:
* Energy Loss in TPC
* Mass^2 based on TOF
* Multiplicity parametrization

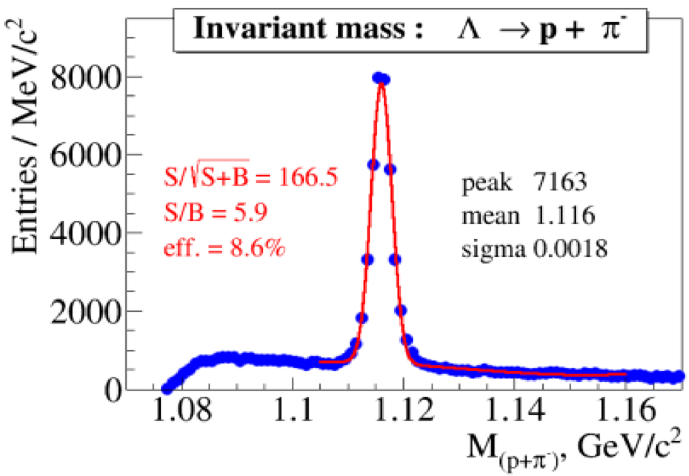
* π/K separation up to 1.5 GeV/c
* π/p separation up to 3 GeV/c

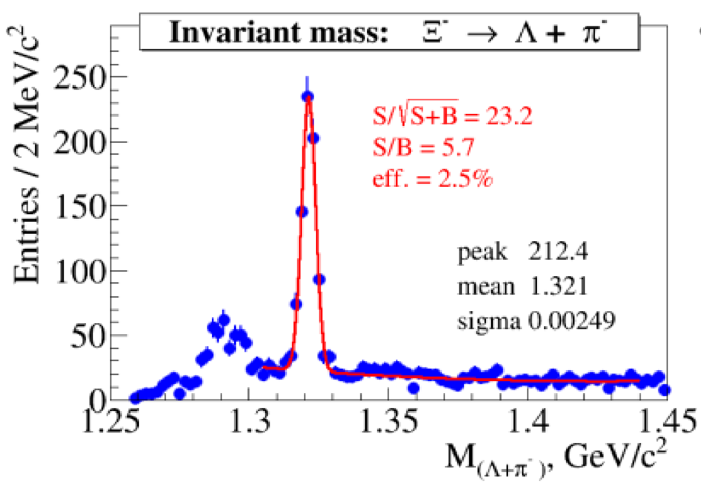
A A Mudrokh and A I Zinchenko
doi:10.1088/1742-6596/798/1/012071

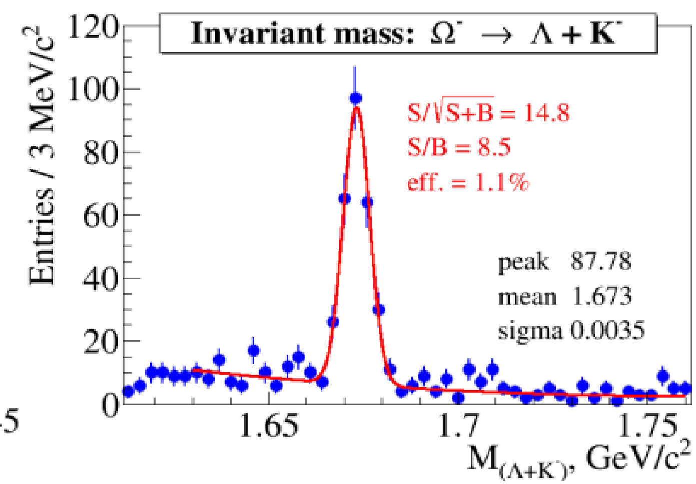
Hyperon Reconstruction at MPD



* Production of strange particles is of particular Interest.
* Enhanced production of multi-strange hadrons in A+A collisions (Ξ, Ω) (relative to pp) was predicted as a signal for the QGP formation.
* The enhancement of the strangeness was observed at SPS and RHIC, and is more pronounced for hyperons with larger strangeness content







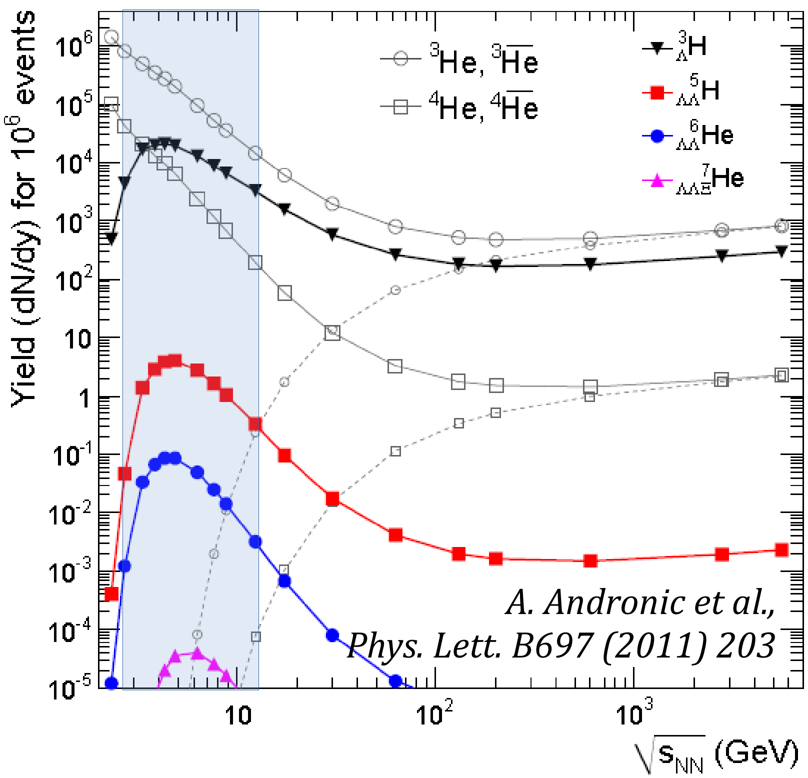
Yields for 10 weeks

Particle	Λ	$\bar{\Lambda}$	Ξ^-	$\bar{\Xi}^+$	Ω^-	$\bar{\Omega}^+$
Expected yield	$5.8 \cdot 10^9$	$7.3 \cdot 10^7$	$2.9 \cdot 10^7$	$1.6 \cdot 10^6$	$1.4 \cdot 10^6$	$2.9 \cdot 10^5$

D. Suvarieva, A. Zinchenko et al.
doi:10.1088/1742-6596/668/1/012121

These results are good but the most recent ones presented by Alexander Zinchenko are even better!

Hypernuclei Reconstruction at MPD



* Production of hypernuclei through coalescence of Λ with light fragments is enhanced at high baryon densities

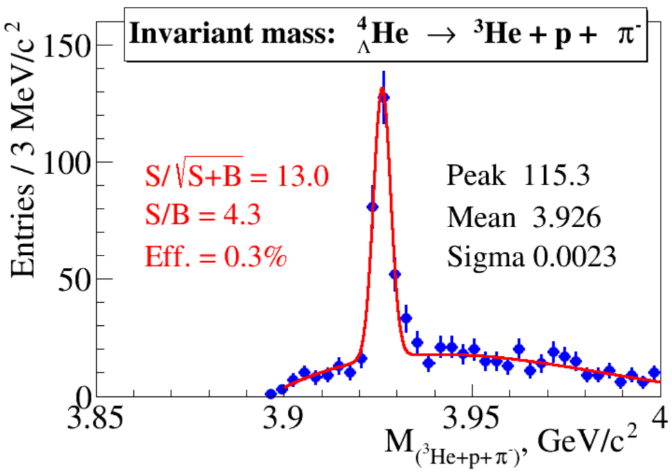
* Maximal yield predicted forNICA energy ranges

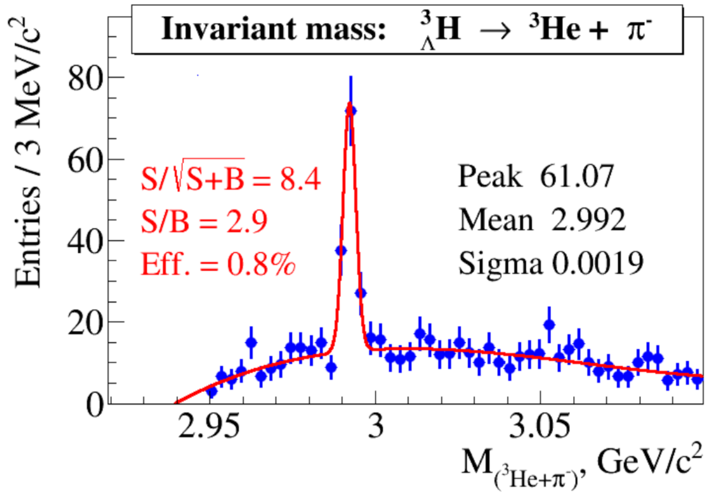
* Measurements on Y-N interaction: EOS, astrophysics

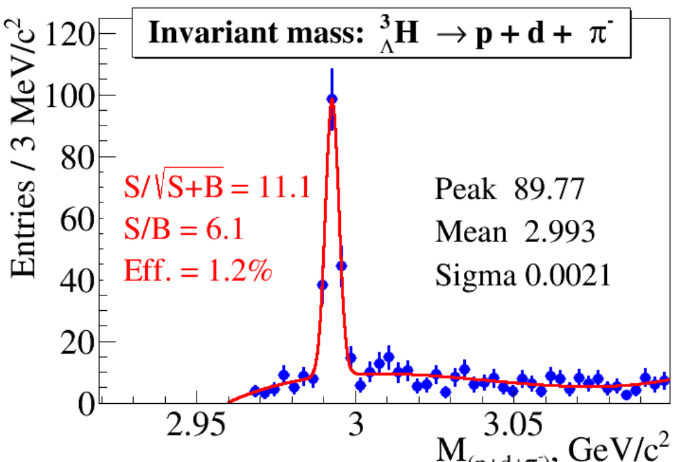
* Important for Model predictions and QCD

Hypernuclei production will be a very interesting research program at the at the NICA energy range!

~ 10^3 $^3_\Lambda$H are expected in 10 weeks



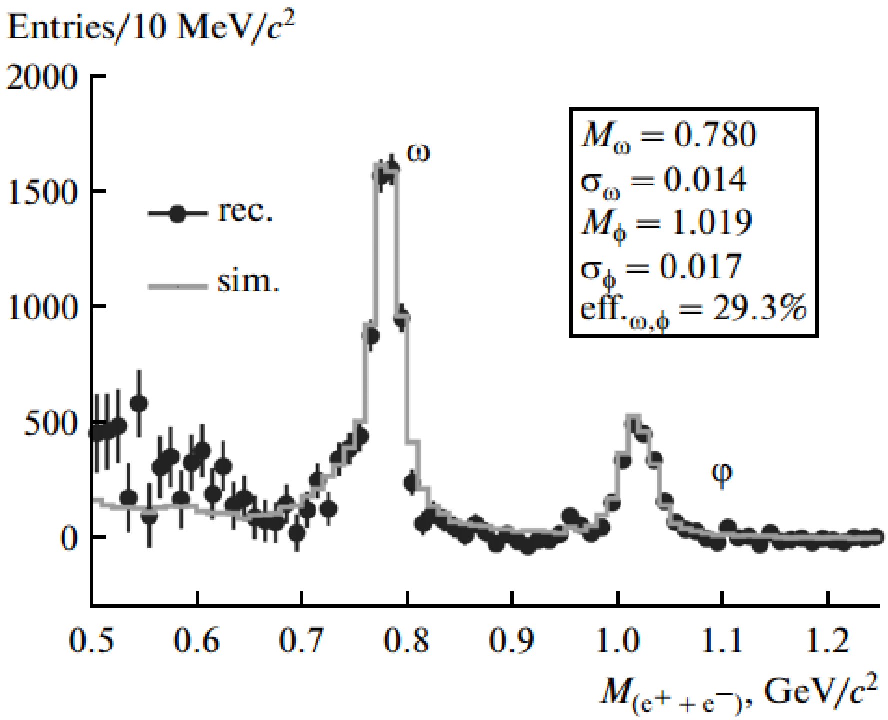




M. Ilieva, A. Zinchenko et al.
doi:10.1088/1742-6596/668/1/012104

Dileptons (EM probes)

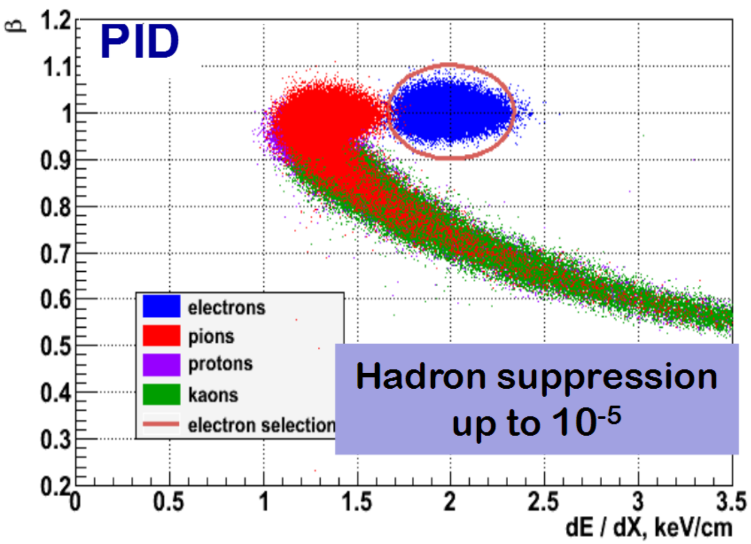
Dileptons can be emitted by a variety of sources. Reconstruction of low-mass vector mesons ***ρ, ω, ϕ*** by measuring their dileptonic decay channels is one of top priorities...

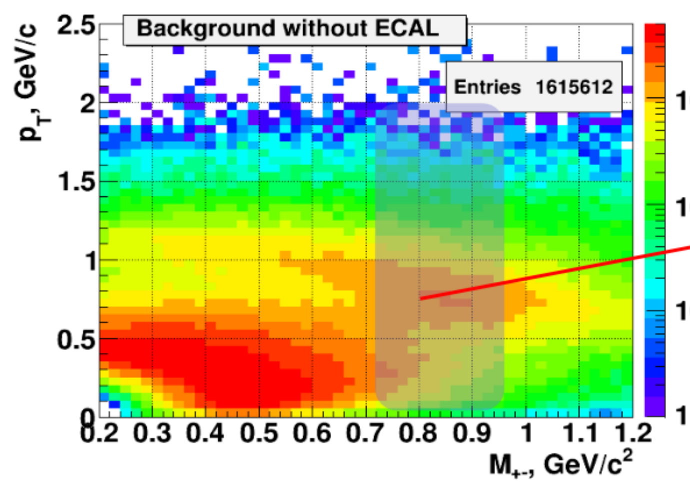


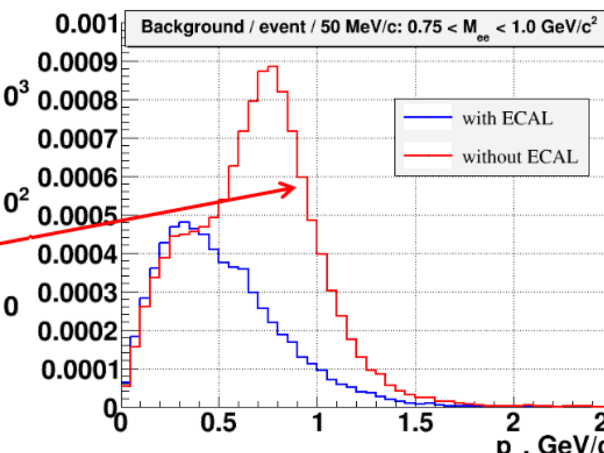
Good probes to indicate medium modifications of spectral functions due to chiral symmetry restoration in HIC;(The effect is proportional to baryon density)

Yields, central Au+Au st $\sqrt{s_{NN}}$ = 8.8 GeV/u

meson	Yields		Yield/1 w
	4π	y=0	
ρ	31	17	$7 \cdot 10^4$
ω	20	11	$7 \cdot 10^4$
φ	2.6	1.2	$1.7 \cdot 10^4$

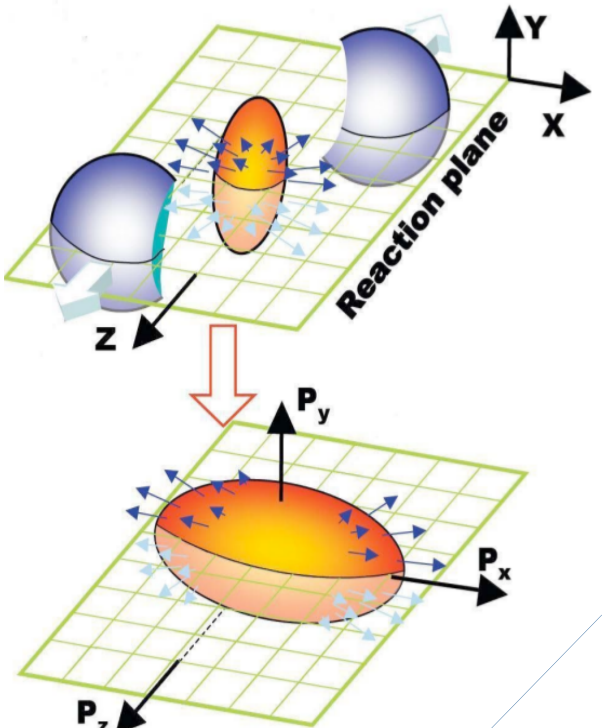






A. Zinchenko et al.
doi:10.1134/S10637788151 30359

Anisotropic Flow at MPD



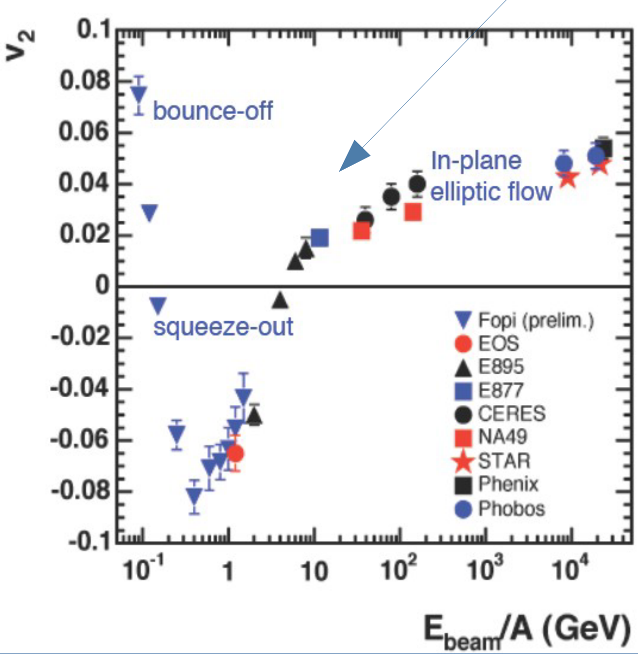
In HIC a non-zero imp par leads to:
* Spatial anisotropy
* Pressure gradiet
* Momentum anisotropy
* Fourier expansion→Flow v_n

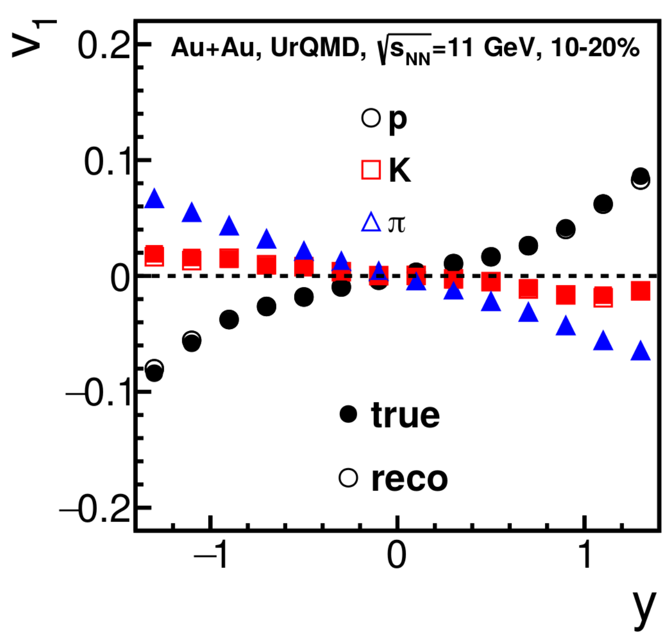
$$v_n(p_T, y) = \langle \cos[n(\phi - \Psi_n)] \rangle$$

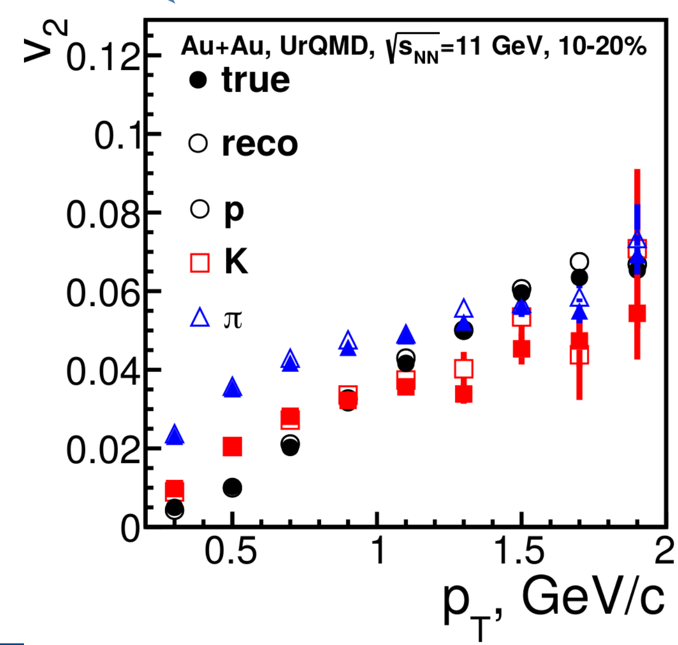
* FHCal is used to determine the event-plane angle
* Better event-plane resolution
* Event-plane not dependent on TPC tracking
* The **RECO** and **TRUE** values of differential flow coefficients are in a **good agreement.**

At Nuclotron-NICA energy range elliptic flow
As a function of energy changes sign.
Both directed and elliptic flow can
signal a first order phase transition

P. Parfenov, et al.
doi: 10.18502/ken.v3i1.1766





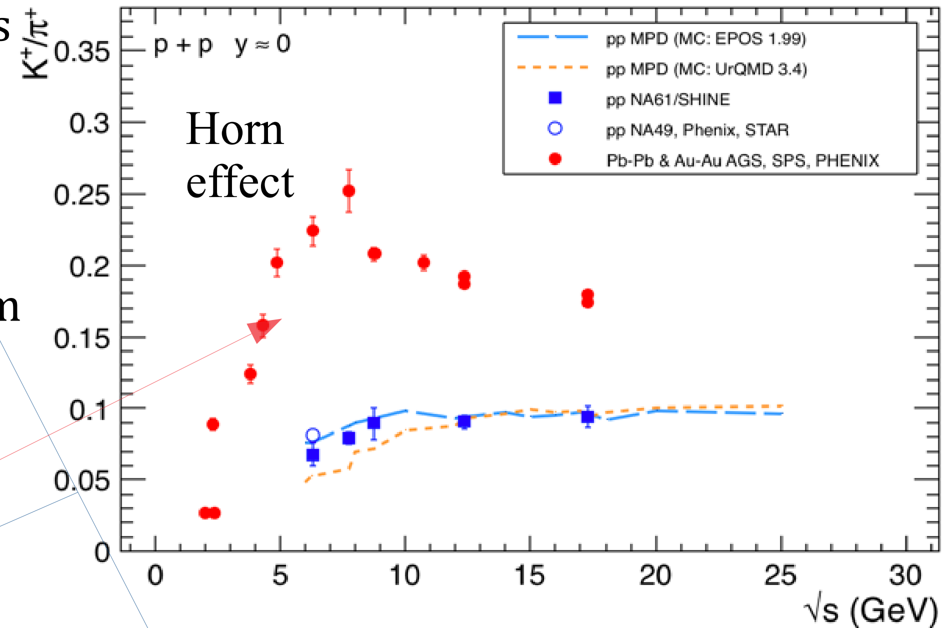


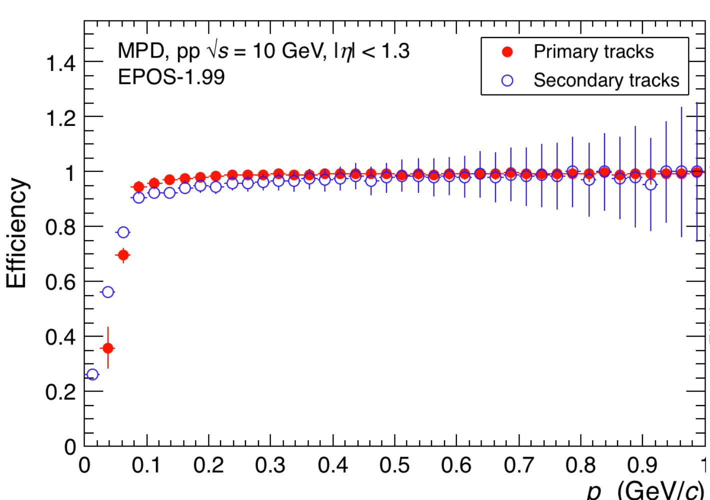
proton-proton collision studies at MPD

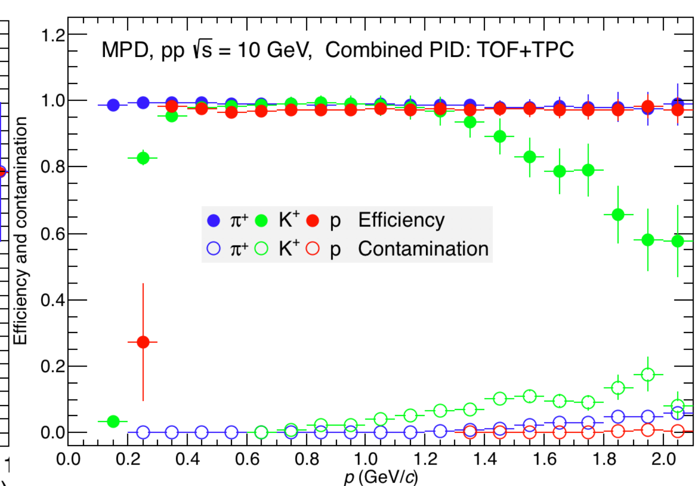
The study of observables in proton-proton collisions and other light systems establish a baseline for nucleus-nucleus interaction studies

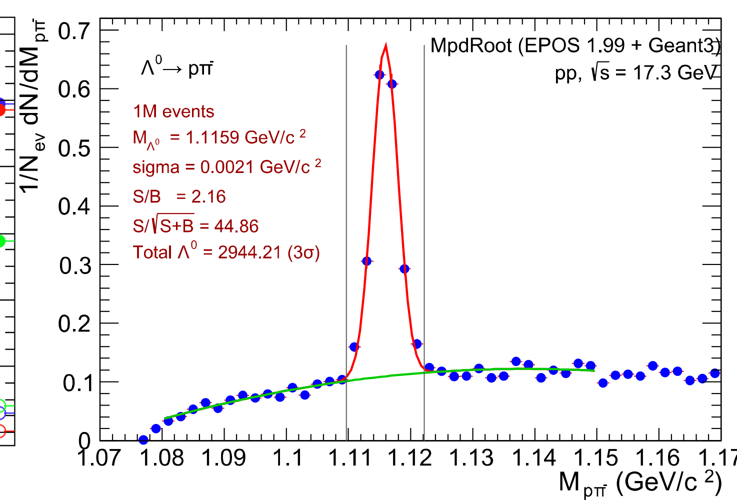
* A good tool for detector performance studies
* Study of fluctuations and correlations of in-medium properties as function of the system size.
*R_{AA} – nuclear modification factor
*Horn effect - posible signature of deconfinement

Study carried out by K. Shtejer

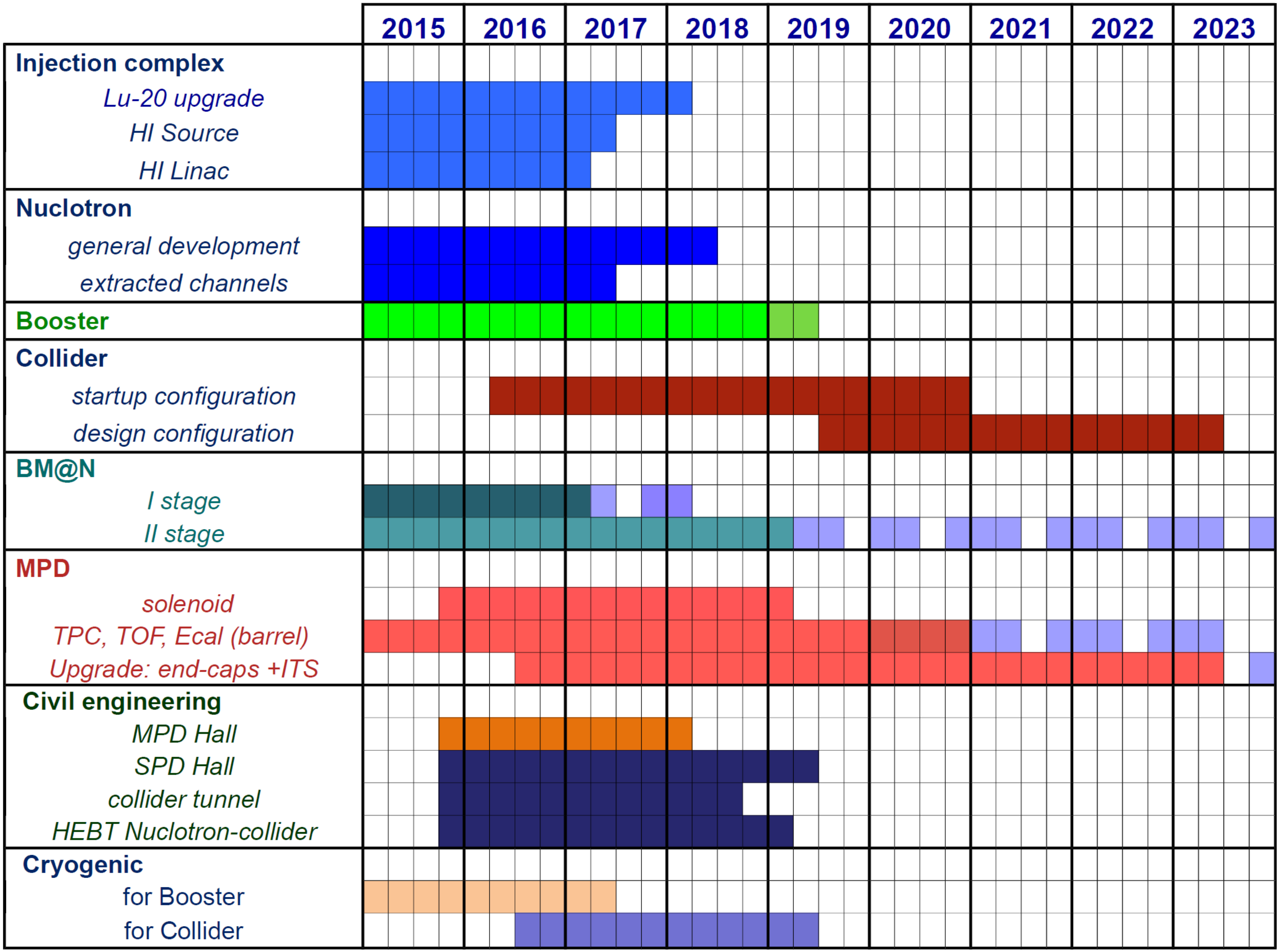








NICA Timetable



Technical Design Reports http://mpd.jinr.ru/doc/mpd-tdr/ running time

Civil Engineering

Collaboration

At present, JINR has 18 full member and 6 associate member states from 5 continents.
30 countries are interested and taking part in the NICA collaborations.

The second collaboration meeting of the MPD and BM@N experiments at the NICA Facility was held at JINR/VBLHEP on October 29-30, 2018
Important decisions and elections were made, a vast amount of research was demonstrated!

Welcome to join the NICA collaborations!

Contact : Alexander Kovalenko Prof, Deputy Director VBLHEP, kovalen@dubna.ru

Australia
Azerbaijan
Armenia
Belarus
Bulgaria
Brazil
Vietnam
Germany
Greece
Georgia
India
Italy
Kazakhstan
China
DPRK

Moldova
Mongolia
Poland
Romania
Russia
Serbia
Slovakia
USA
Czech Republic
Ukraine
Uzbekistan
France
SAR
Japan
CERN

Summary

In the landscape of Heavy Ion Collisions the NICA accelerator facility will provide a variety of physics experiments, a wide range of collision energies, at varying system sizes and resulting physics observables.

The Multi-Purpose Detector is designed with a good acceptance, low material budget in a modular configuration in upgrade stages. The main sub-detector systems of MPD are near the end of design stages and mass production and assembly of full systems will start very soon.

Several Feasibility Studies, based on realistic simulations highlight the good capabilities of MPD and the viability of several research programmes.

The NICA community is open to accept new collaboration proposals.


Thank you!