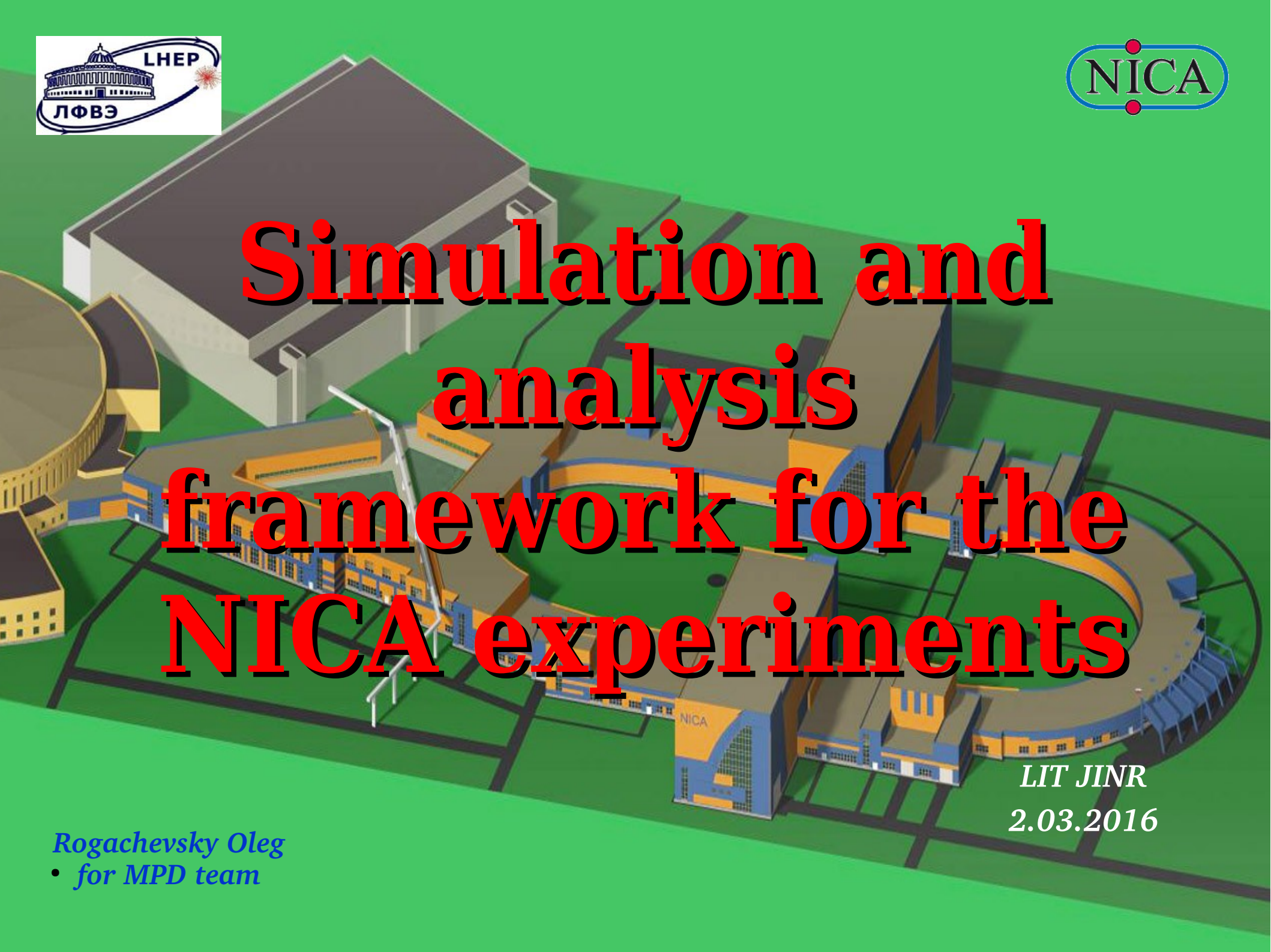



# Simulation and analysis framework for the NICA experiments

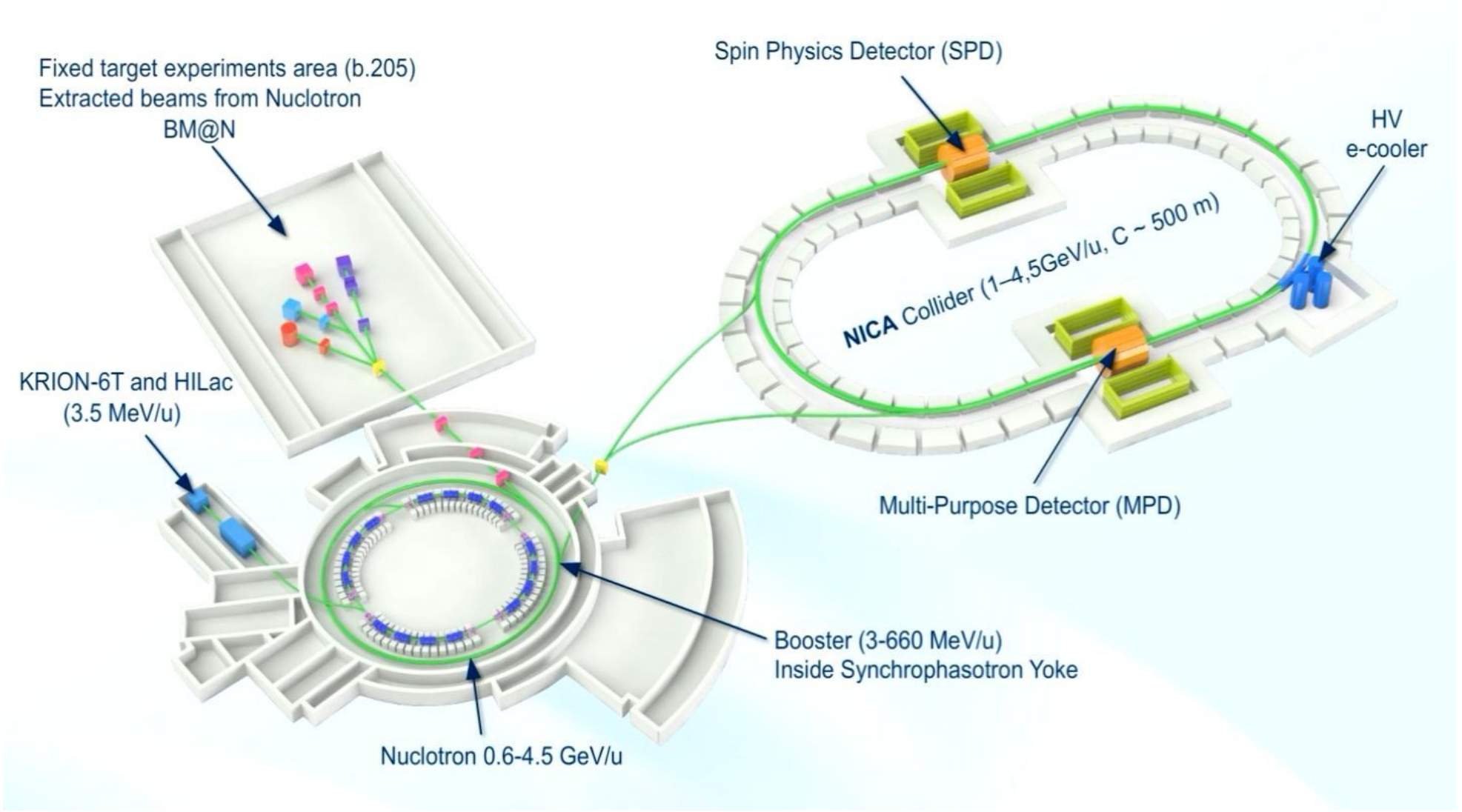
*LIT JINR*

*2.03.2016*

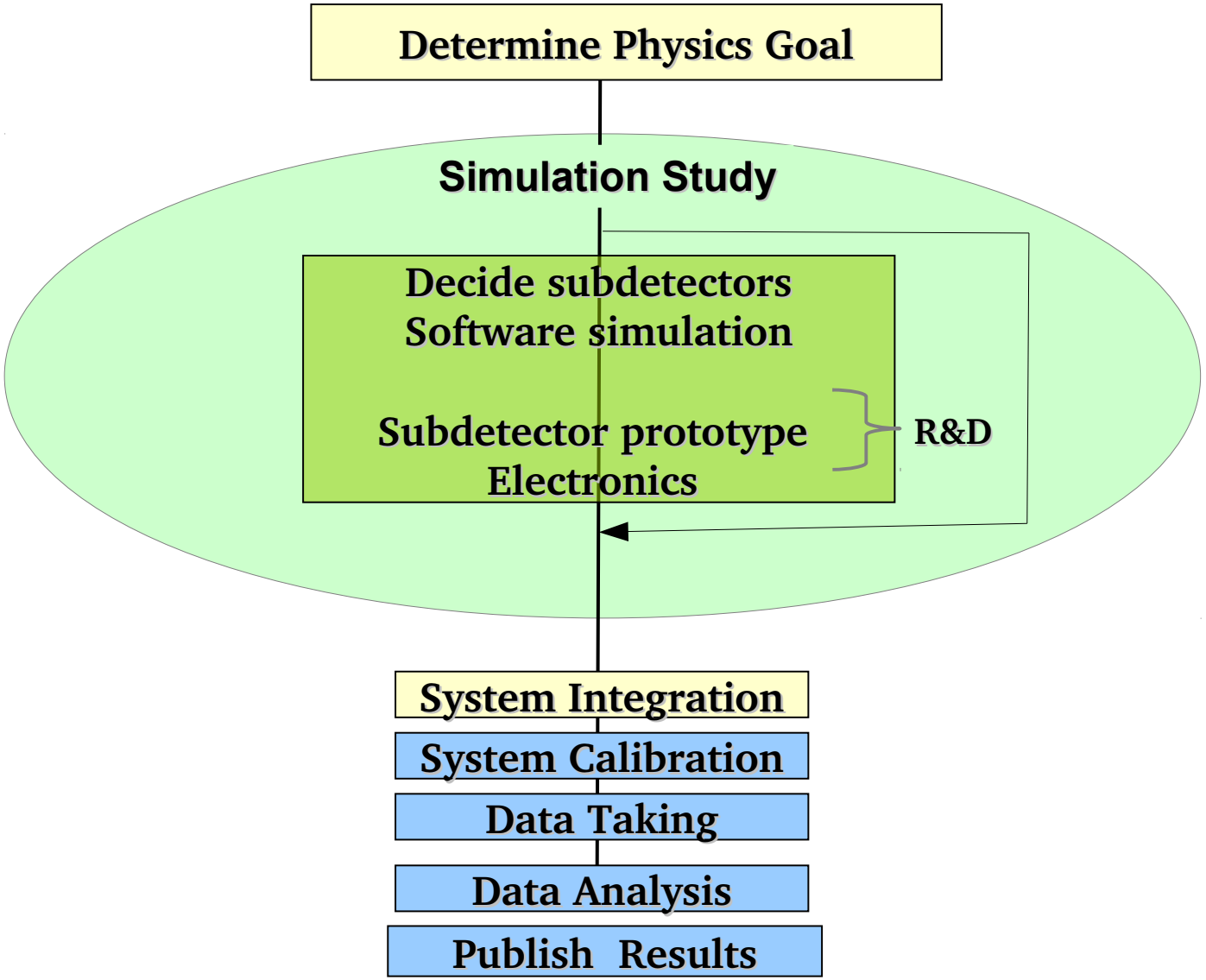
*Rogachevsky Oleg*

- *for MPD team*

# Nuclotron based Ion Collider fAcility

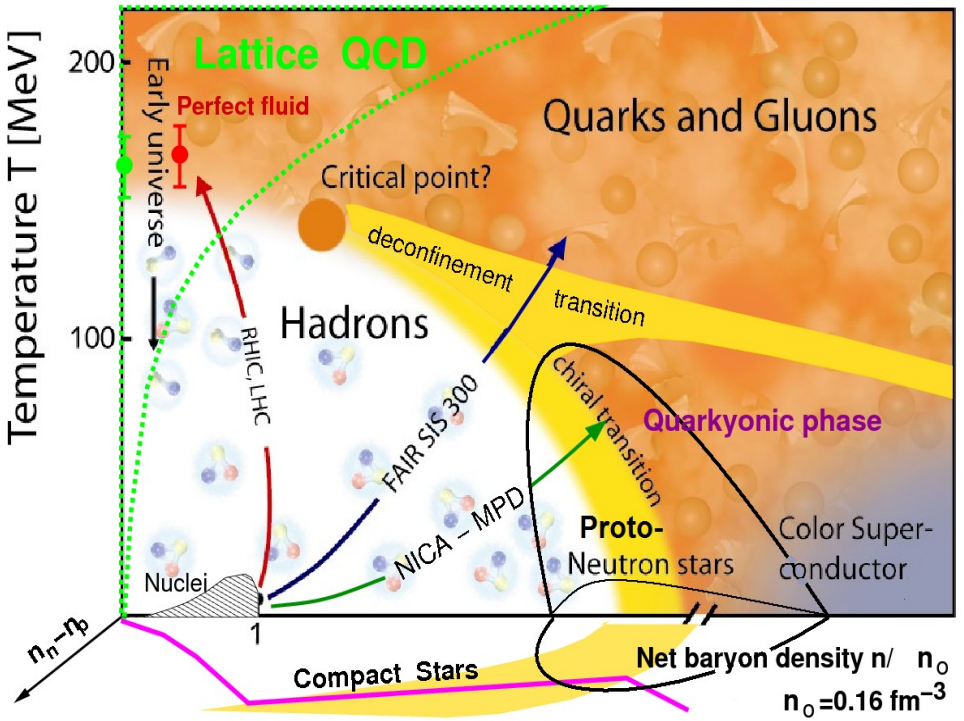


# Global sketch of HEP experiment



# Goal

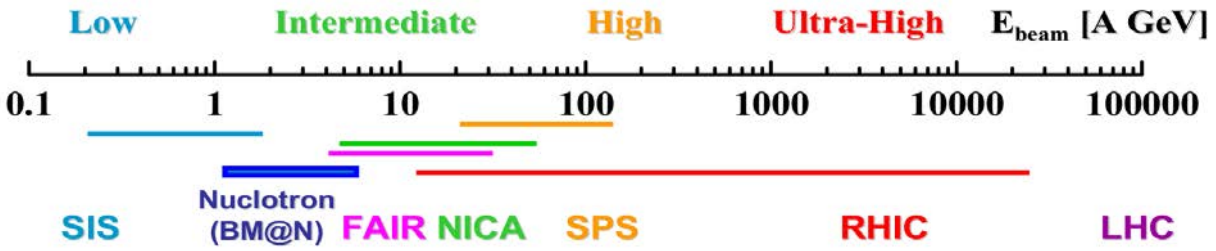
The collision of two heavy nuclei which approach and smash against each other with almost the speed of light creates in the laboratory the primordial state of matter, called Quark-Gluon Plasma (QGP). The QGP expands like a fireball, cools and finally turns into ordinary matter.




"The very goal of the NICA facilities is the search for the mixed phase (MPD = "mixed phase detector") of quark matter and baryon rich hadronic matter as a consequence of a first order phase transition, bearing strong analogies with a liquid-gas phase instability."

NICA priorities

http://theor0.jinr.ru/twiki-cgi/view/NICA/WebHome



# FairRoot universe

**2004** — Start testing the VMC concept for CBM

**2004** — First Release of CbmRoot

**2006** — Panda decided to join-> FairRoot: same Base package for different experiments

**2006** — MPD (NICA) start also using FairRoot

**2010** — R3B joined

**2010** — ASYEOS joined (ASYEOSRoot)

**2011** — EIC (Electron Ion Collider BNL) EICRoot

**2011** — GEM-TPC seperated from PANDA branch (FOPIRoot)

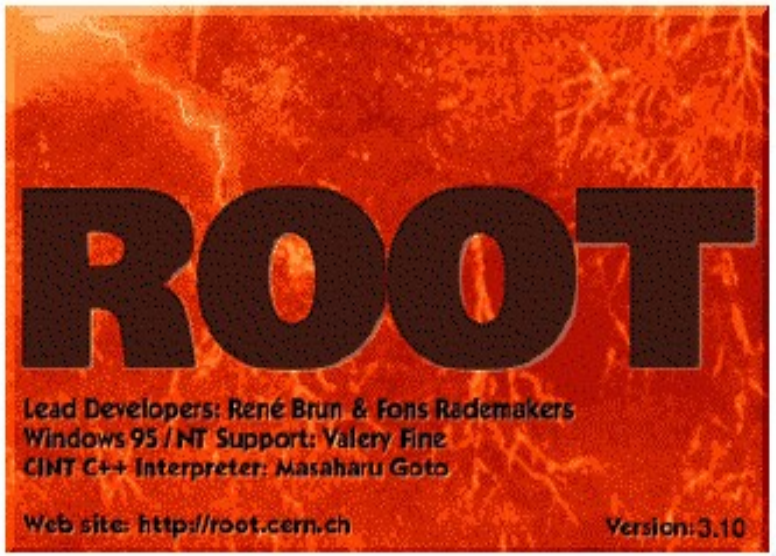
**2012** — SOFIA (Studies On Fission with Aladin)

**2012** — CALIFA (CALorimeter for the In Flight detection of γ rays and light charged pArticles )

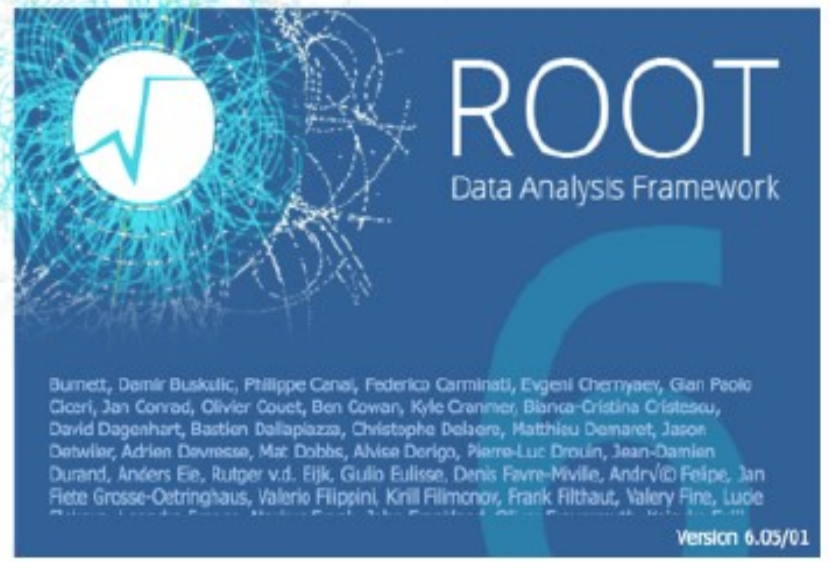
**2013** — SHIP - Search for Hidden Particles

**2014** — ENSAR-ROOT Collection of modules used by structural nuclear phsyics exp.

# 20 years of ROOT evolution



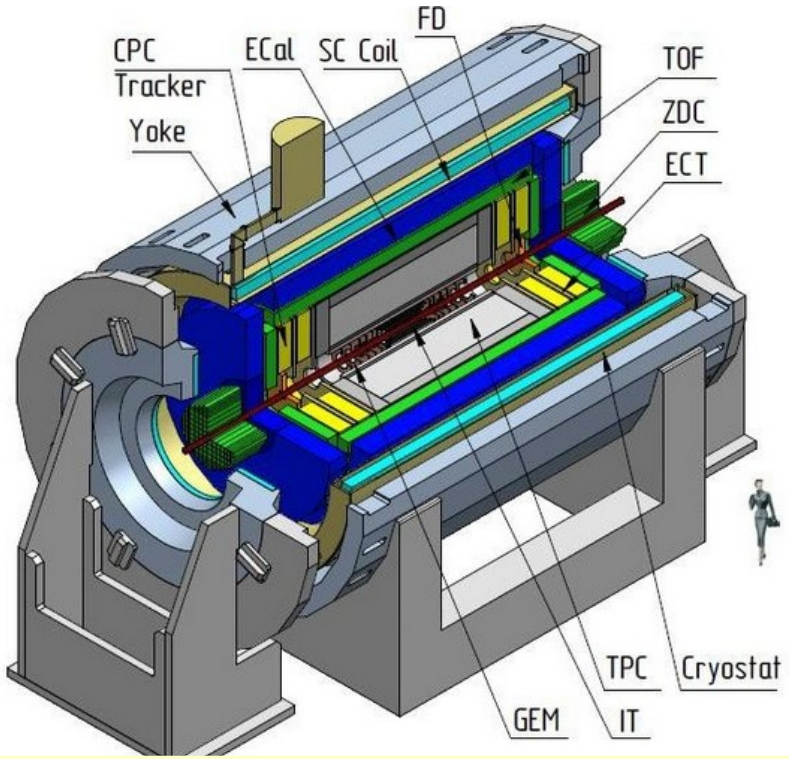


# Simulation Framework for MPD&BM@N


http://mpd.jinr.ru/

- ✓ *News*
- ✓ *Software repositories*
- ✓ *Software tests dashboard*
- ✓ *Forums*
- ✓ *Database for physics run*
- ✓ *Information etc.*

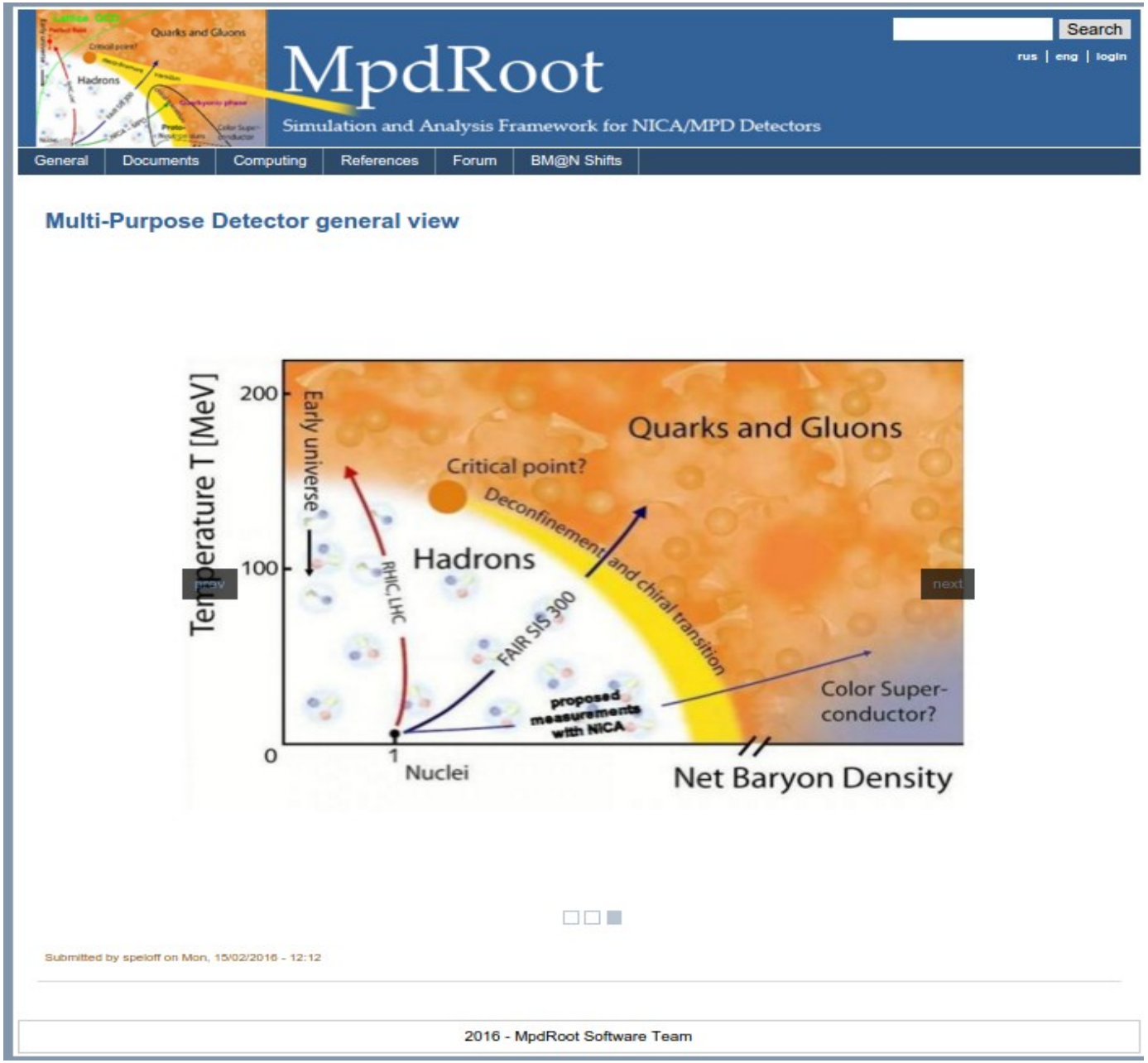



**Physics Models**

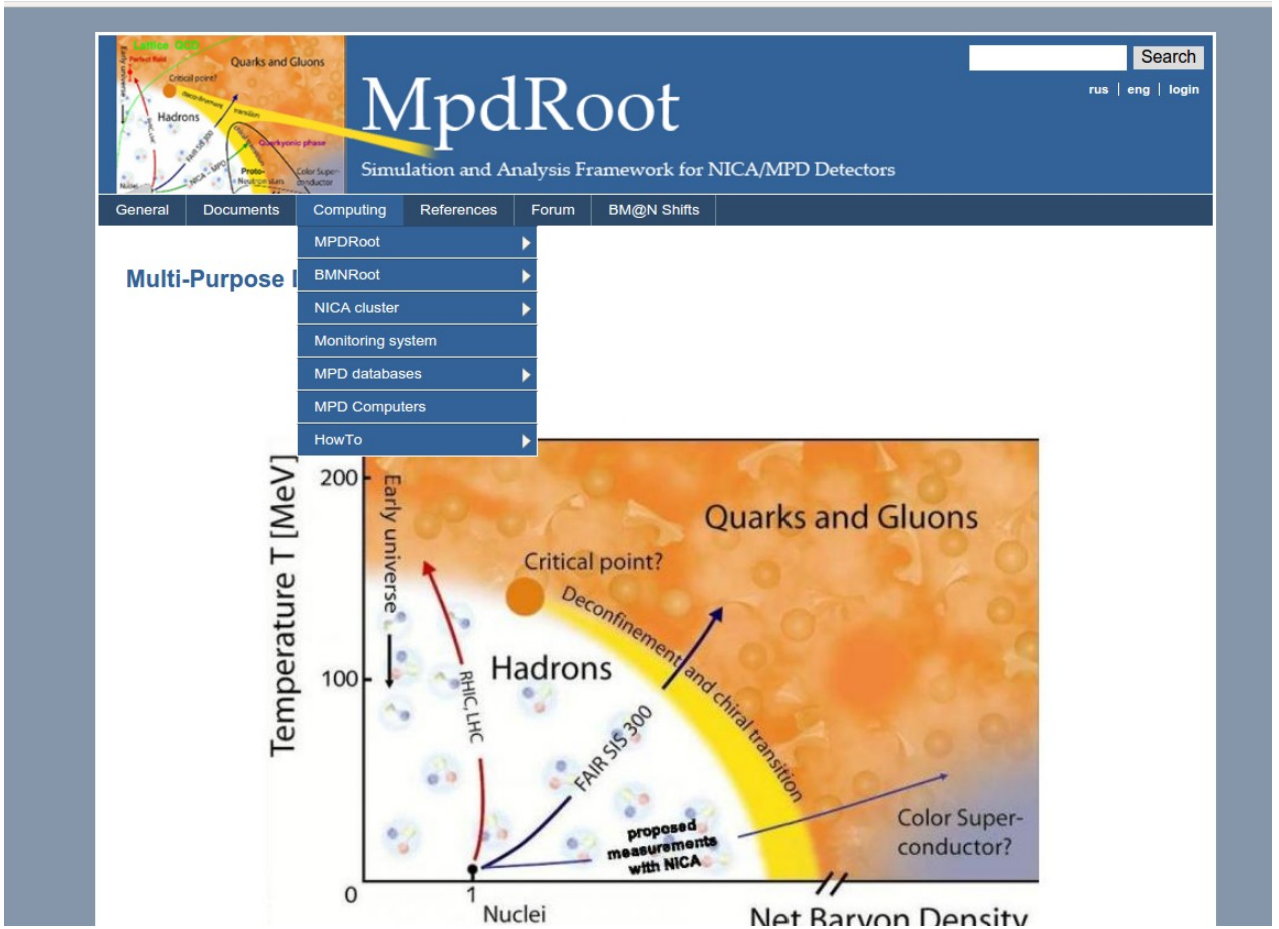
UrQMD
Hybrid UrQMD
LA QGSM
SHIELD on fly
HSD
PHSD
3 Fluid Dynamics
PLUTO

- 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
- Advanced detector response functions, realistic tracking and PID included
- Event display for Monte-Carlo and experimental data

# MPDROOT


MpdRoot
Simulation and Analysis Framework for NICA/MPD Detectors
Search
rus | eng | login
General
Documents
Computing
References
Forum
BM@N Shifts
Multi-Purpose Detector general view
Temperature T [MeV]
200
100
0
Early universe
Quarks and Gluons
Critical point?
Deconfinement and chiral transition
Hadrons
RHIC, LHC
FAIR SIS 300
proposed measurements with NICA
Color Super-conductor?
1
Nuclei
Net Baryon Density
prev
next
Submitted by speloff on Mon, 15/02/2016 - 12:12
2016 - MpdRoot Software Team

# MPDROOT


MpdRoot
Simulation and Analysis Framework for NICA/MPD Detectors
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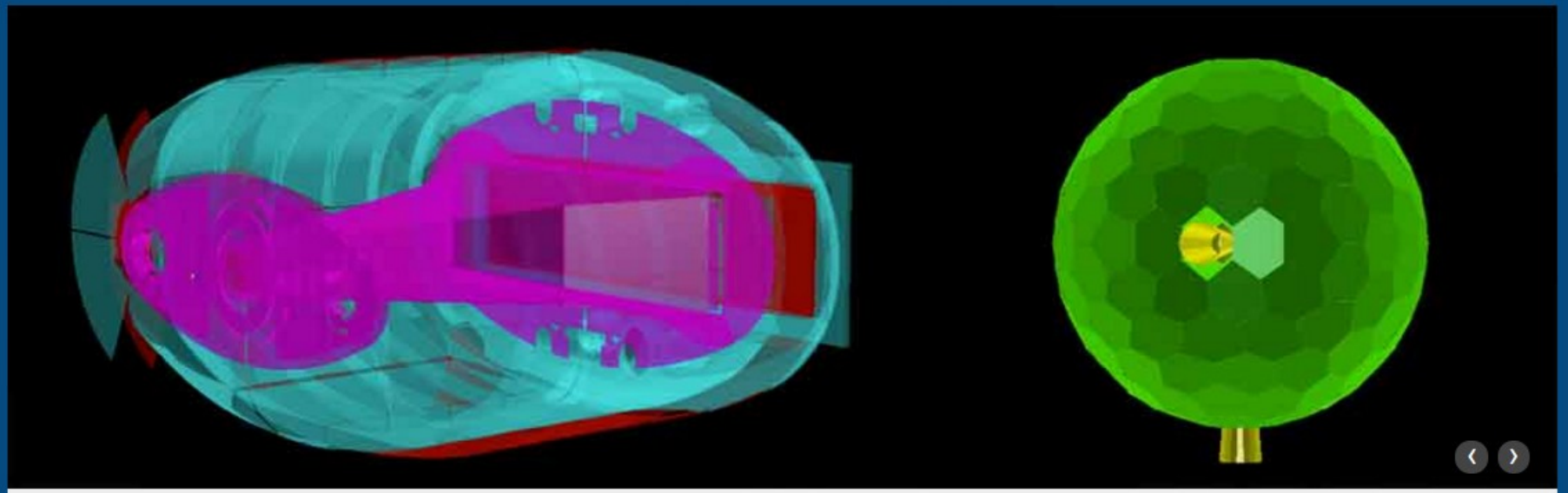
Computing
References
Forum
BM@N Shifts
MPDRoot
BMNRoot
NICA cluster
Monitoring system
MPD databases
MPD Computers
HowTo
Multi-Purpose
Temperature T [MeV]
200
100
0
Early universe
RHIC, LHC
Quarks and Gluons
Critical point?
Deconfinement and chiral transition
Hadrons
FAIR SIS 300
proposed measurements with NICA
Color Super-conductor?
1
Nuclei
Net Baryon Density

# FairSoft

FairRoot

SEARCH

HOME | INSTALLATION | CLASS DOCUMENTATION | REPOSITORY | ABOUT | HOWTO | @GSI | CONTACT



## FairRoot STICKY

OCT 04

The FairRoot framework is fully based on the ROOT system. The user can create simulated data and/or perform analysis with the same framework. Moreover, Geant3 and Geant4 transport engines are supported, however the user code that creates simulated data do not depend on a particular monte carlo engine. The framework delivers base classes which enable the users to construct their detectors and /or analysis tasks in a simple way, it also delivers some general functionality like track visualization. Moreover an interface for reading magnetic field maps is also implemented.

**Posted By** adminUser

read more

## New FairSoft patch releases

### Experiment Frameworks

R3BRoot Logo

R3BRoot - Simulations and data analysis for R3B

### Recent content

New FairSoft patch releases
florian

Installing CbmRoot
adminUser

Installing the external packages
Mohammad

# FairSoft

## Included Packages

- cmake 3.3.2 (only installed if installed version is to old)
- gtest 1.7.0
- gsl 1.16
- boost 1_59_0
- Pythia6 416
- HepMC 2.06.09
- Pythia8 212
- Geant4 10.01.p2
- xrootd 4.1.1
- ROOT v5.34.34 or v6.04.02
- Pluto v5.37
- Geant321+_vmc v2-0
- VGM v4-3
- G4VMC v3-2
- MillePede V04-03-01
- ZeroMQ 4.1.3
- Protocoll Buffers 2.6.1
- Nano Message 0.6-beta

In case the python bindings are build the following additional packages will be installed

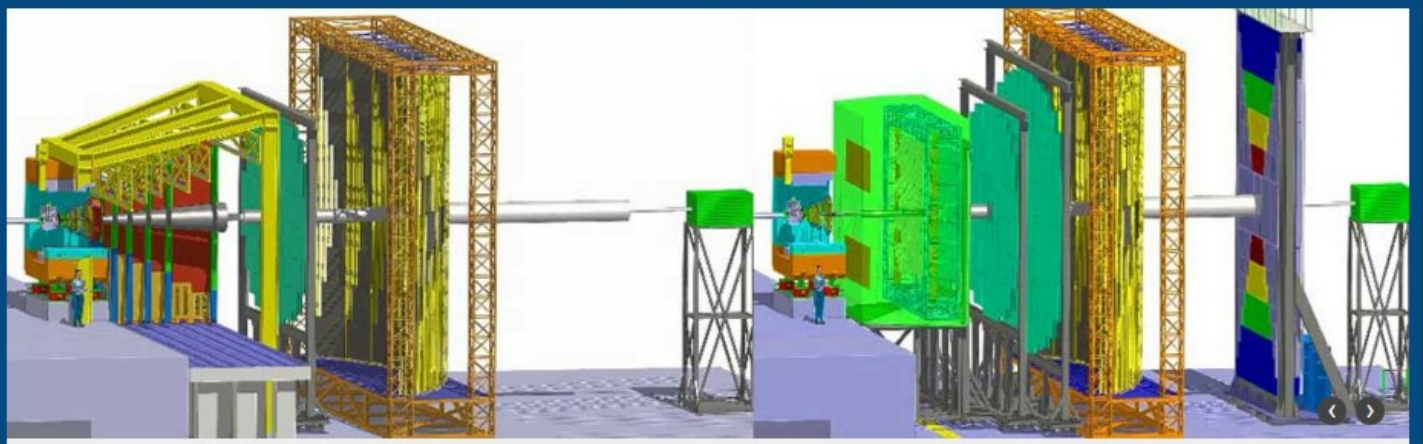
- XercesC 3.1.2
- G4Py Version which comes with Geant4

# OS dependences

FairRoot

SEARCH

HOME | INSTALLATION | CLASS DOCUMENTATION | REPOSITORY | ABOUT | HOWTO | @GSI | CONTACT



Home » Installation

## Build Prerequisites

Before installing FairRoot many other packages are necessary. Some of them can be installed using the package manager of the used Linux distribution, but many others have to be installed from sources. This is necessary because many of these programs can't be installed using the package manager or FairSoft need the programs compiled with special settings.

To make the installation procedure as easy as possible we provide an additional package called FairSoft (sometimes also called "external packages") which takes care of the installation of all needed programs in the right order and with the right compilation flags. In the end all additional software is installed in one directory.

The FairSoft package contains a configuration scripts which checks if all the needed system packages are installed. If some of the system packages are missing the configuration script will stop with a detailed error message. The complete list of needed system packages can be found in the DEPENDENCIES file. This file contain also complete command lines to install the needed packages on the most common Linux systems.

The only prerequisite for the FairSoft installation on Linux or Mac OSX systems is CMake which has either to be installed using the package manager or from the sources which can be downloaded from here.

The instructions how to install FairSoft can be found here.

‹ Installation | up | Install Build Prerequisites on Mac OSX ›

### Experiment Frameworks

R3BRoot Logo — R3BRoot - Simulations and data analysis for R3B

### Recent content

New FairSoft patch releases
florian

Installing CbmRoot
adminUser

Installing the external packages
Mohammad

New FairRoot patch releases
florian

Install Build Prerequisites on Mac OSX
florian

New FairRoot release v-15.11 available

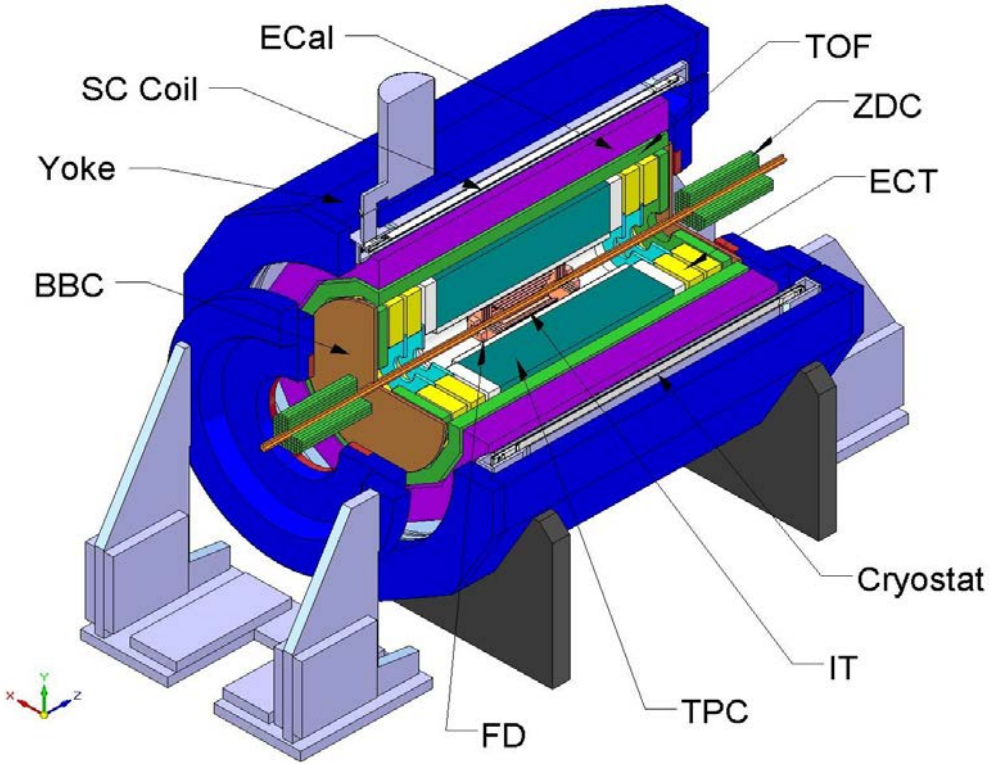
# Detector simulation

- ✔ Interaction of interest
- ✔ Geometry of the system
- ✔ Materials used
- ✔ Particles of interest
- ✔ Generation of test events of particles
- ✔ Interactions of particles with matter and EM fields
- ✔ Response to detectors
- ✔ Records of energies and tracks
- ✔ Analysis of the full simulation at whatever detail you like
- ✔ Visualization of the detector system and tracks

GEANT

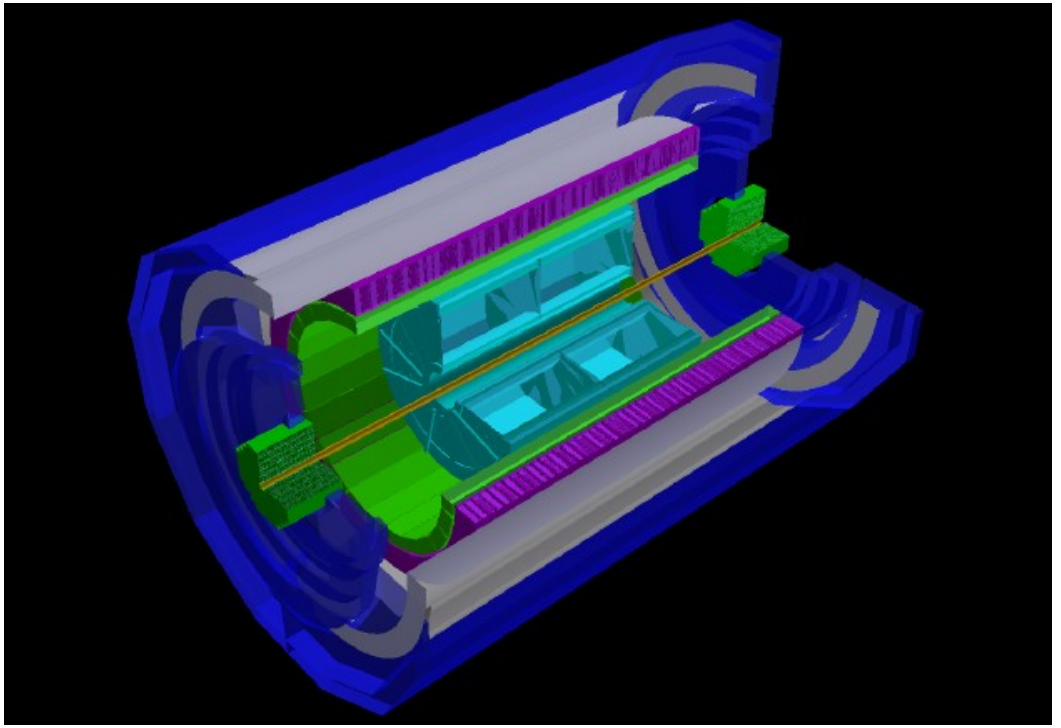
Experiments framework

# Multi Purpose Detector




Stage 1

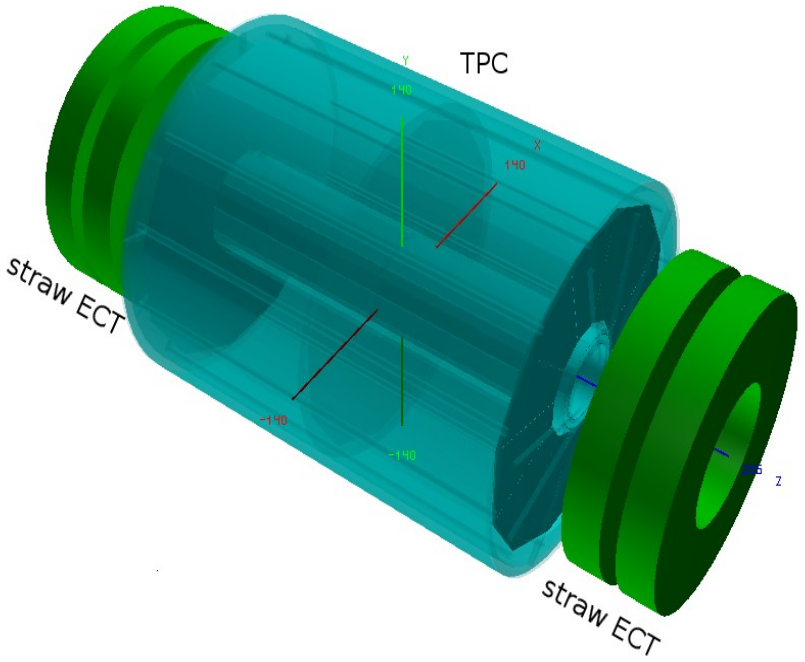
TPC,TOF, ECAL, ZDC, FFD



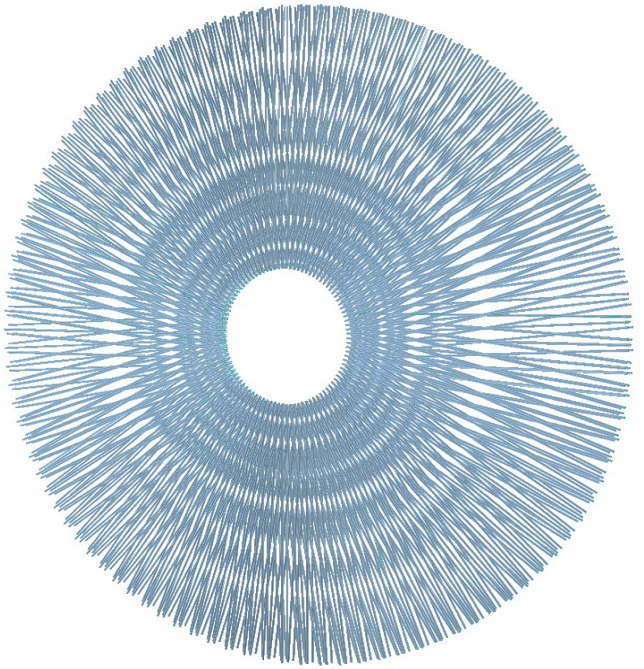
Stage 2

Stage 1 +
ITS,ETOF, EEMC, ECT, CPC

# MPD subdetectors

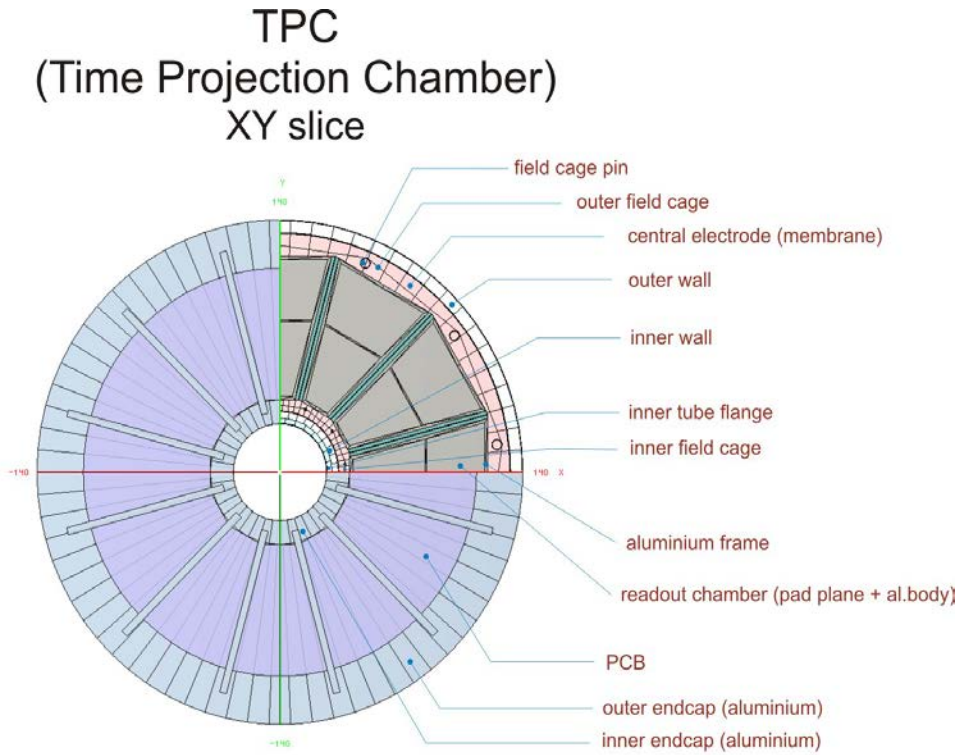



TPC with Straw tube tracker

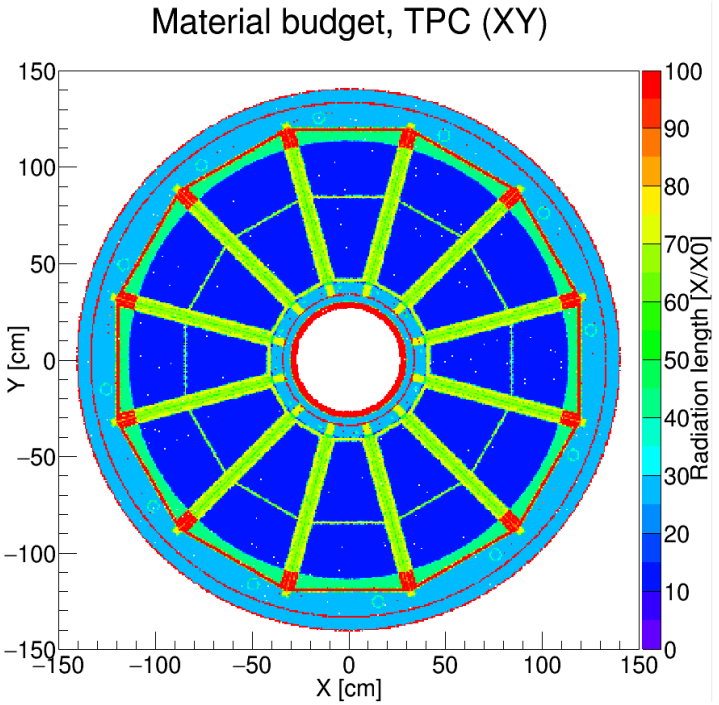


Straw tube tracker

# MPD subdetectors




TPC detailed view

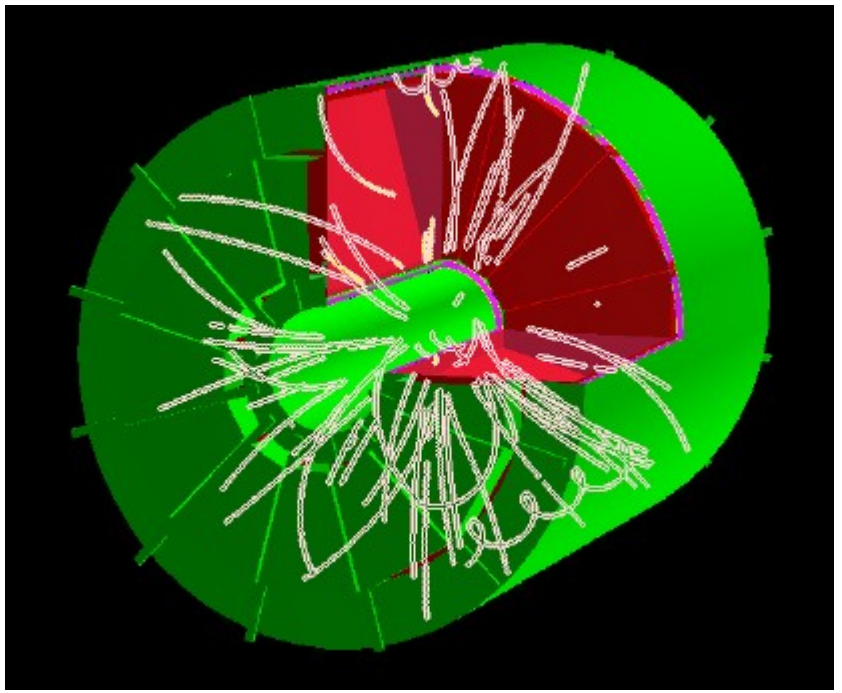


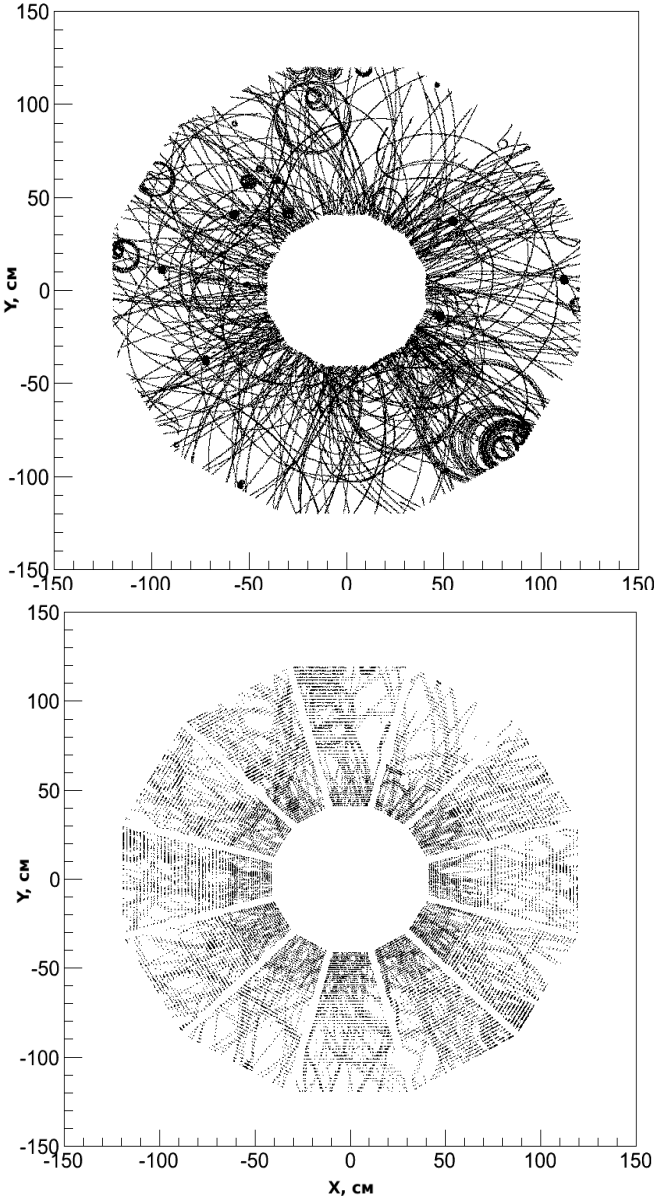

Radiation thickness

# Reconstruction chain

- Hits reconstruction in subdetectors
- Tracks reconstruction
- Searching for track candidates in main tracker
- Track propagation using Kalman filter
- Matching  with other detectors
- Vertex finding
- Particles identification
- Physics analysis

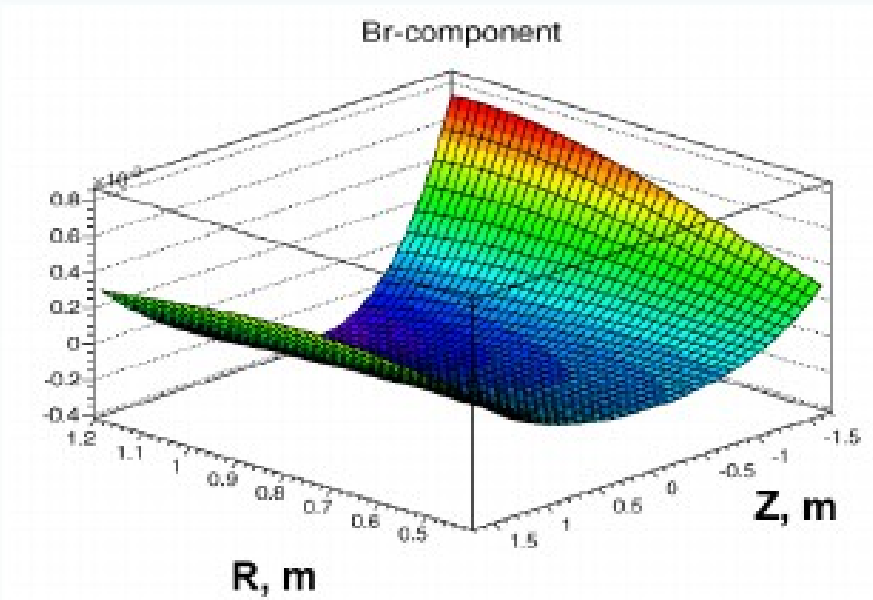
# Clustering in TPC

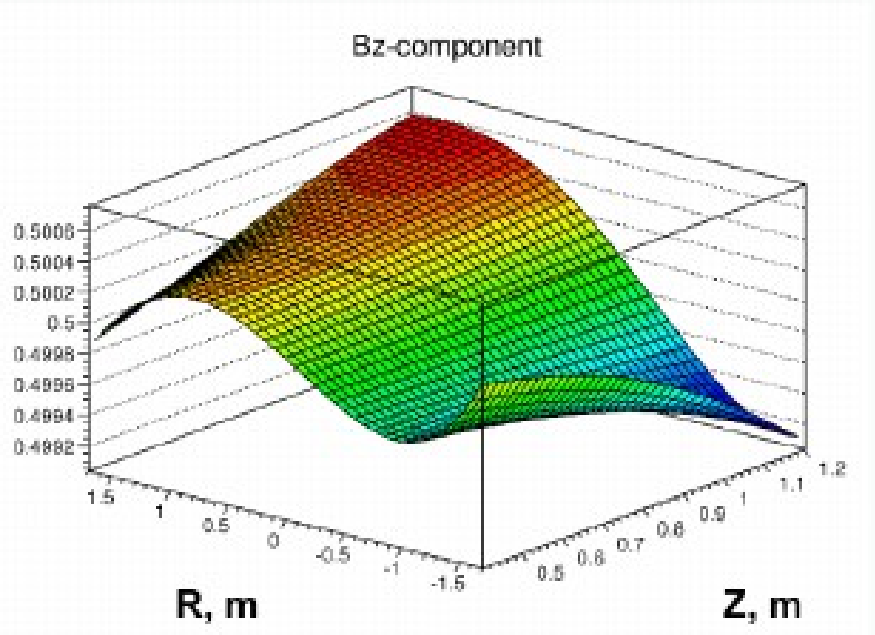




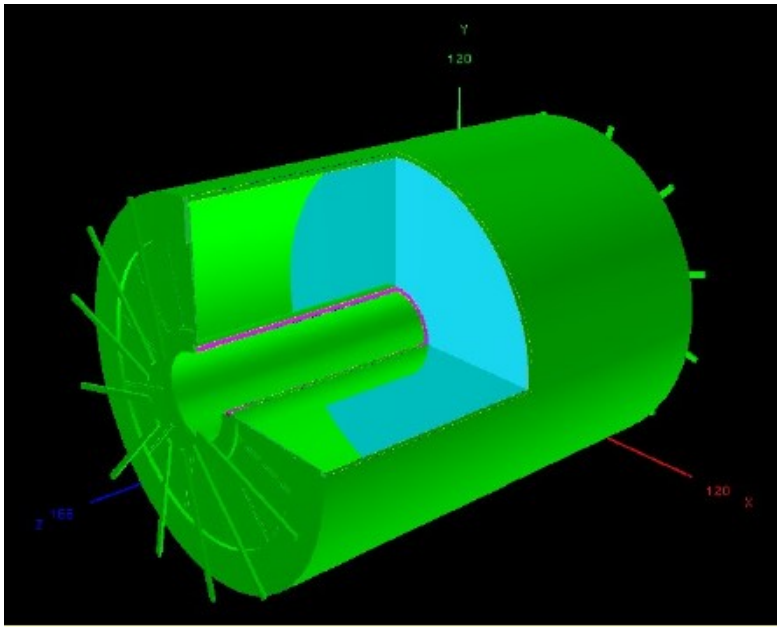
# MPD magnetic field

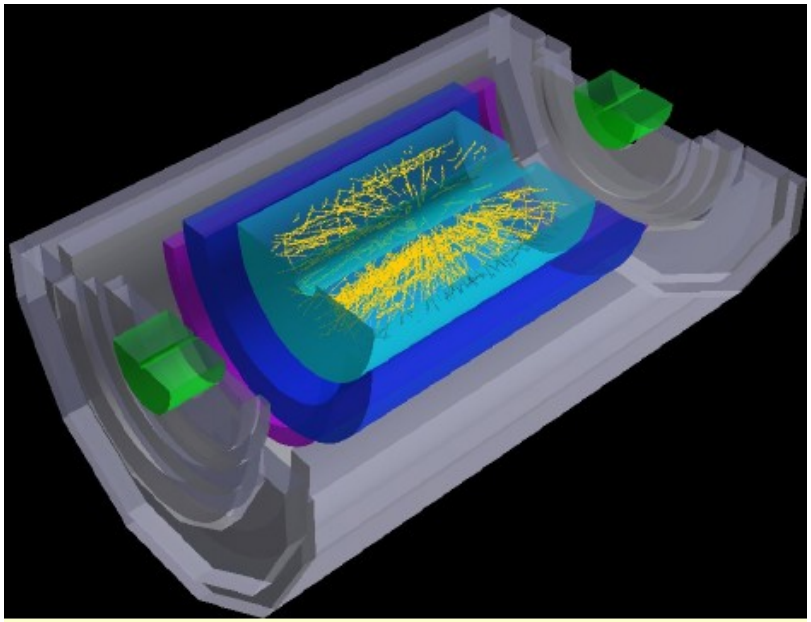
- Transition from a constant magnetic field to the real field map.
- Interpolation of the field between the map nodes using $L(r,z) = \sum_{i=1}^{5}\sum_{j=1}^{5} a_{ij} r^i z^j$

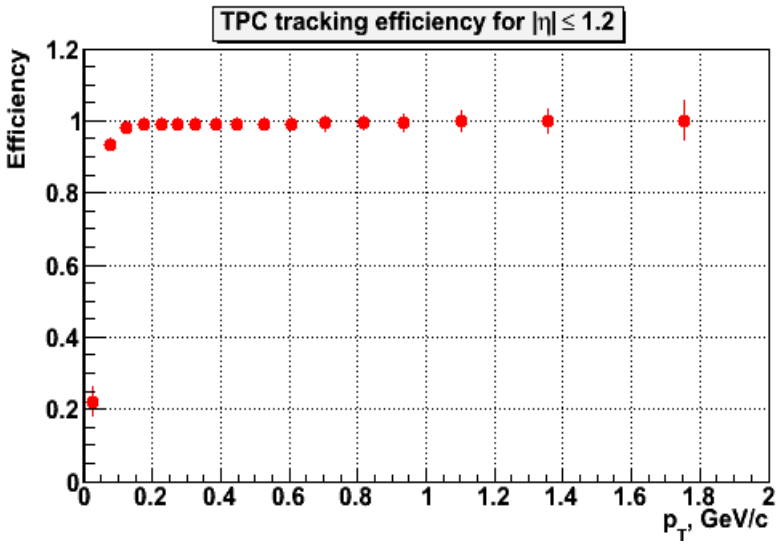


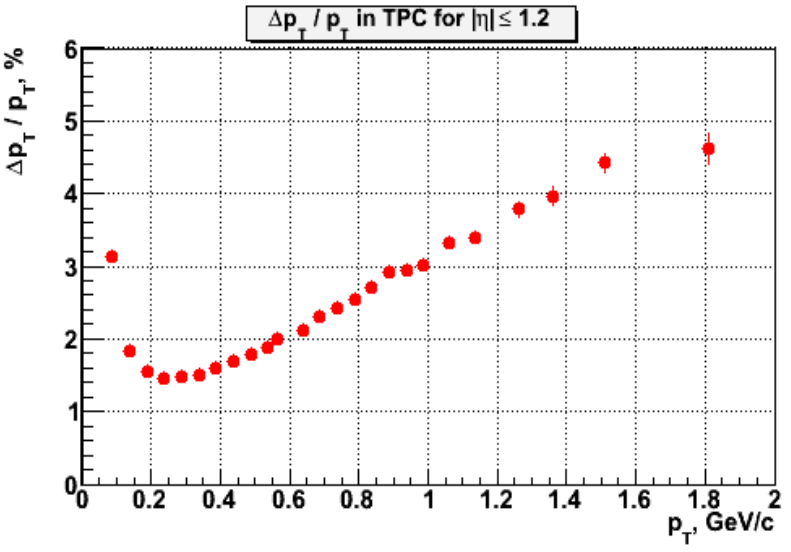



# Tracking

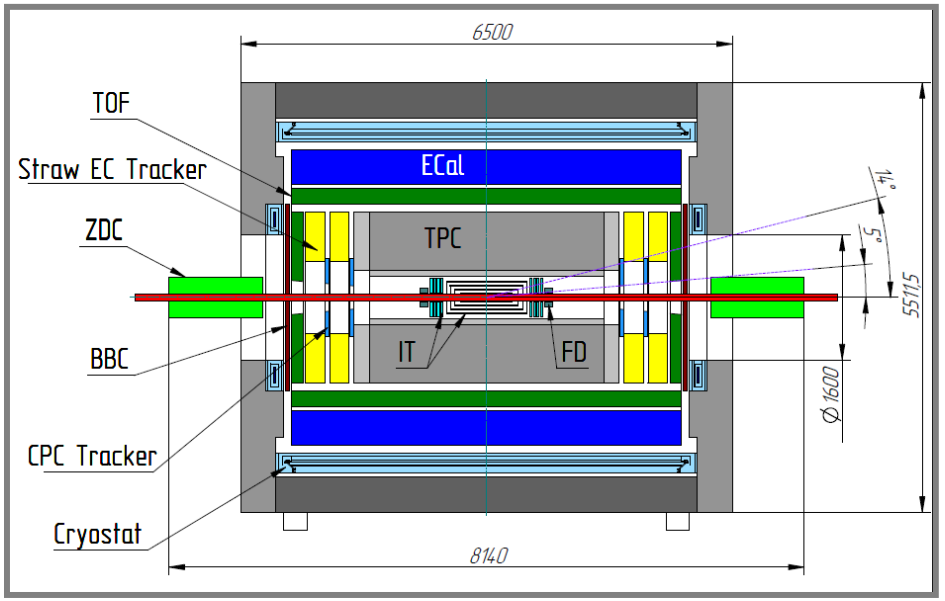


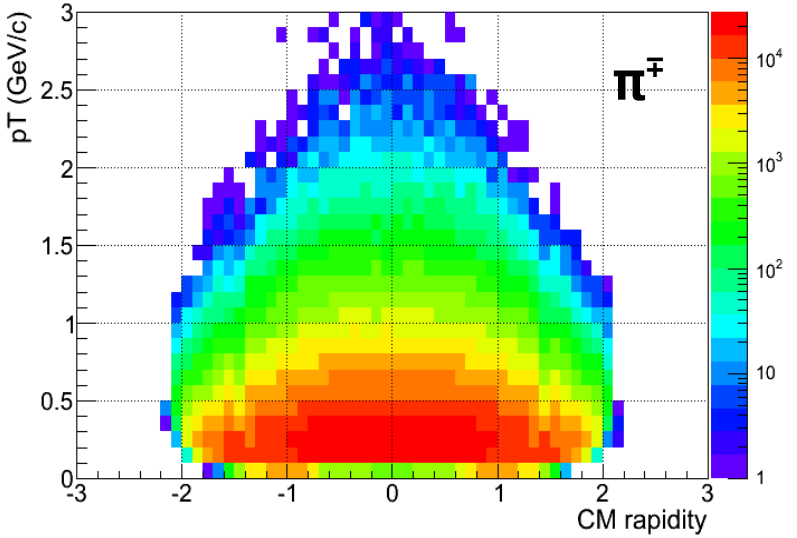


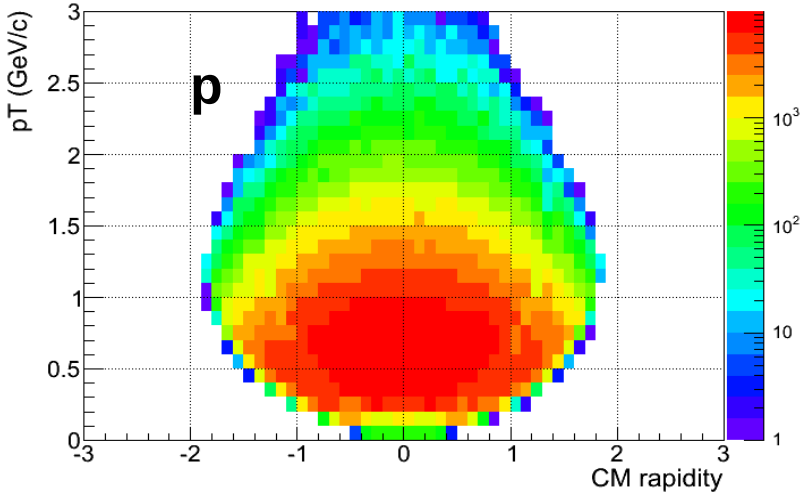

TPC tracking efficiency for |η| ≤ 1.2
Efficiency
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
p_T, GeV/c

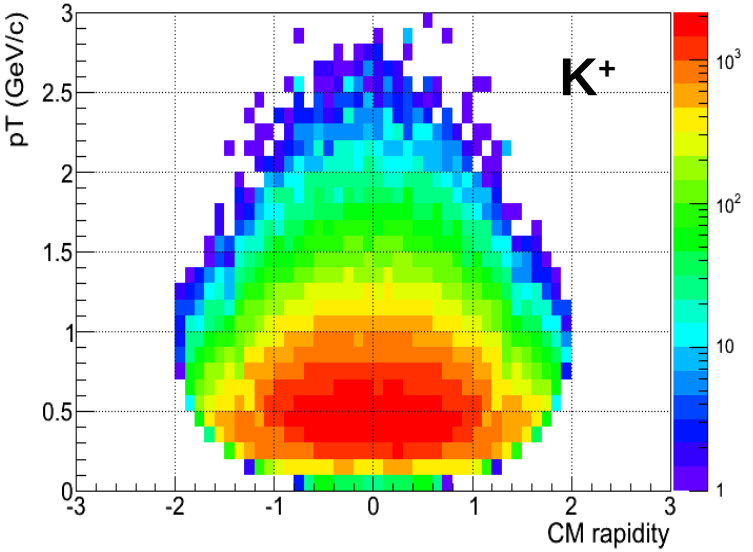

Δp_T / p_T in TPC for |η| ≤ 1.2
Δp_T / p_T, %
6
5
4
3
2
1
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
p_T, GeV/c

# MPD acceptance

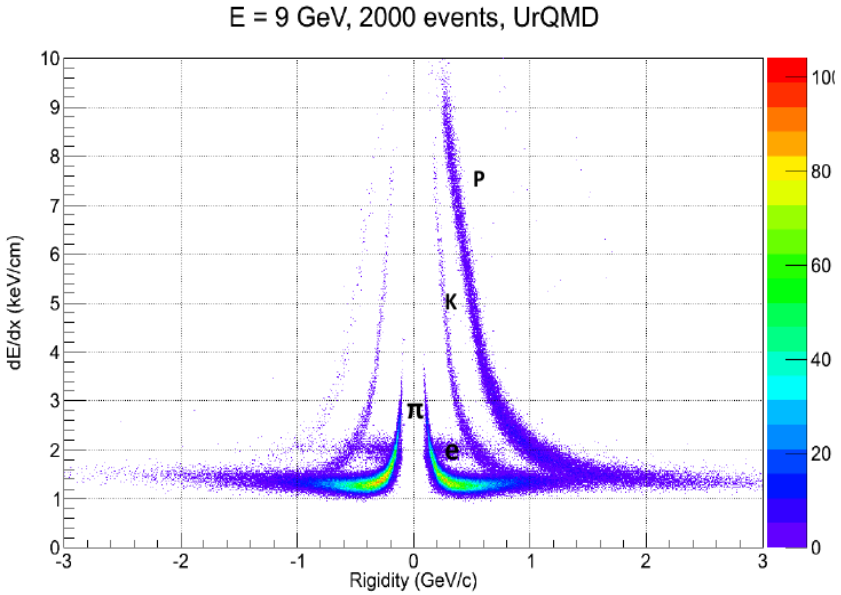


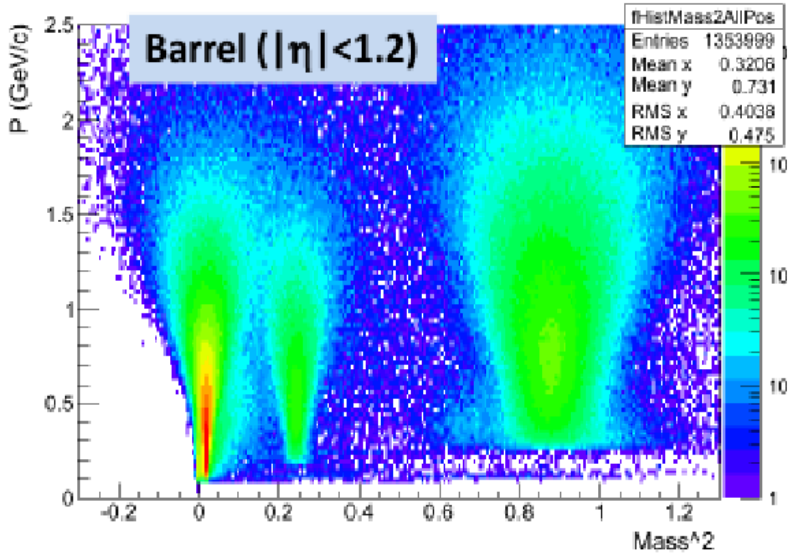
# Charged particle ID in TPC & TOF

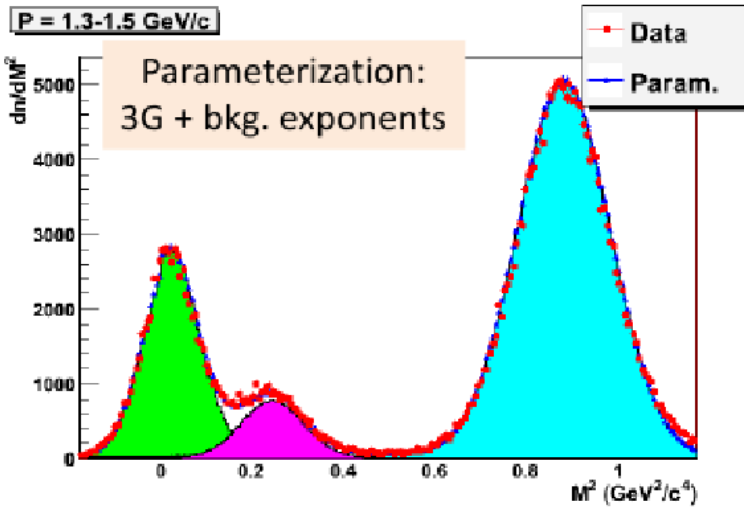



TPC
PID: Ionization loss (dE/dx) Separation:
e/h – 1.3..3 GeV/c
π/K – 0.1..0.6 GeV/c
K/p – 0.1..1.2 GeV/c

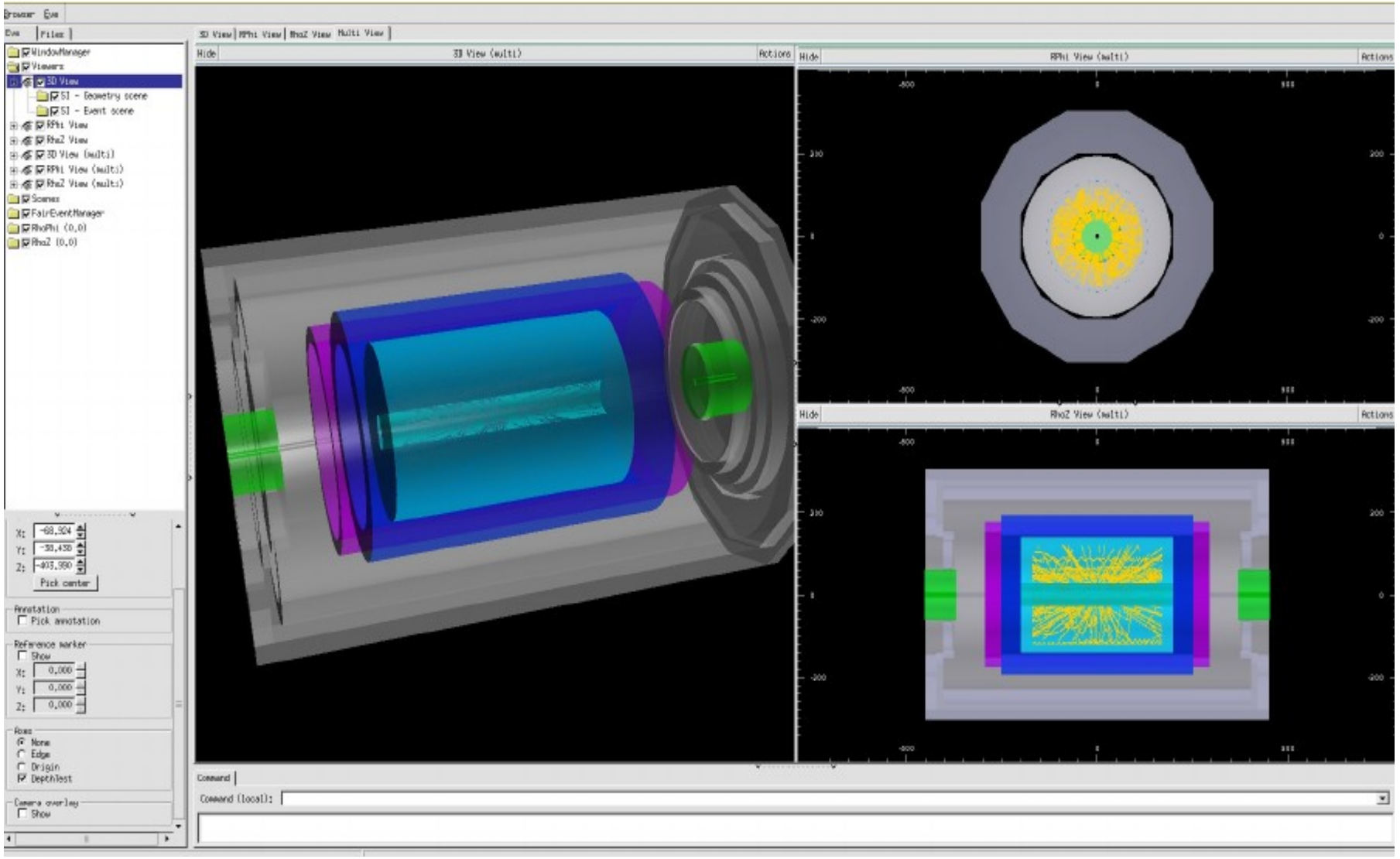
**MPD PID (TOF):**

- π/K separation up to p=1.7 GeV/c, above 2 GeV/c - extrapolating the fitted 3G parameters
- Protons up to 3 GeV/c
- dE/dx provide extra PID capability for electrons and low momentum hadrons



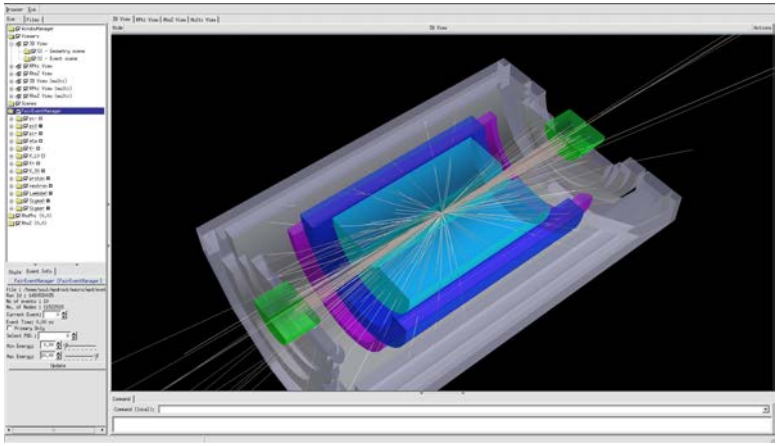



# MPD Event Display

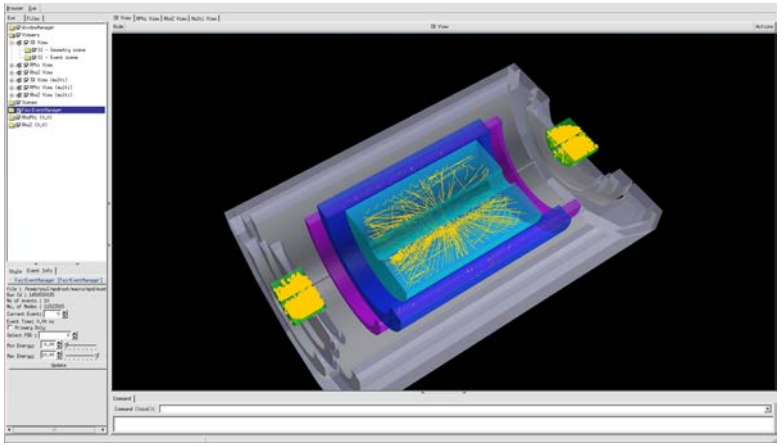


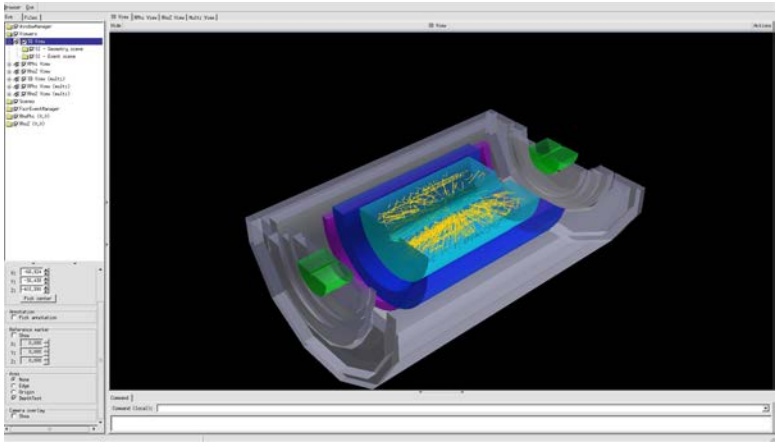
# Particle reconstruction in TPC

GeoTracks

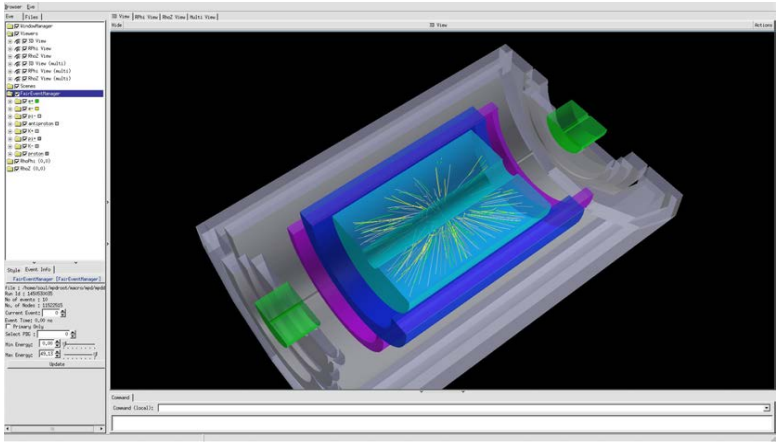


MC points



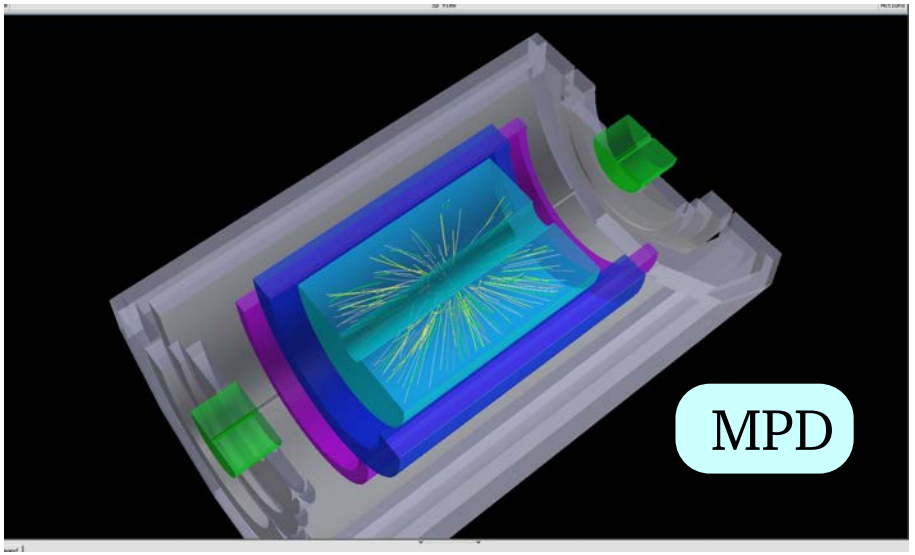


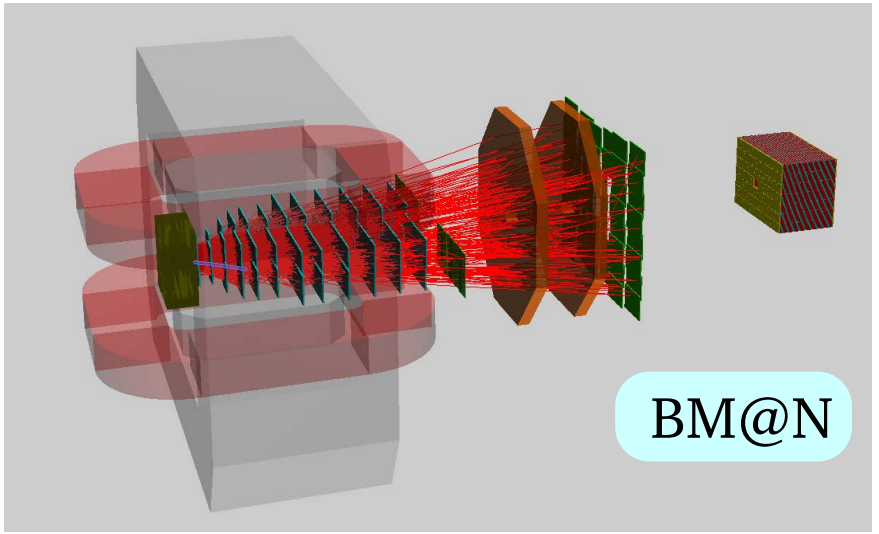
Hits



reconstructed tracks

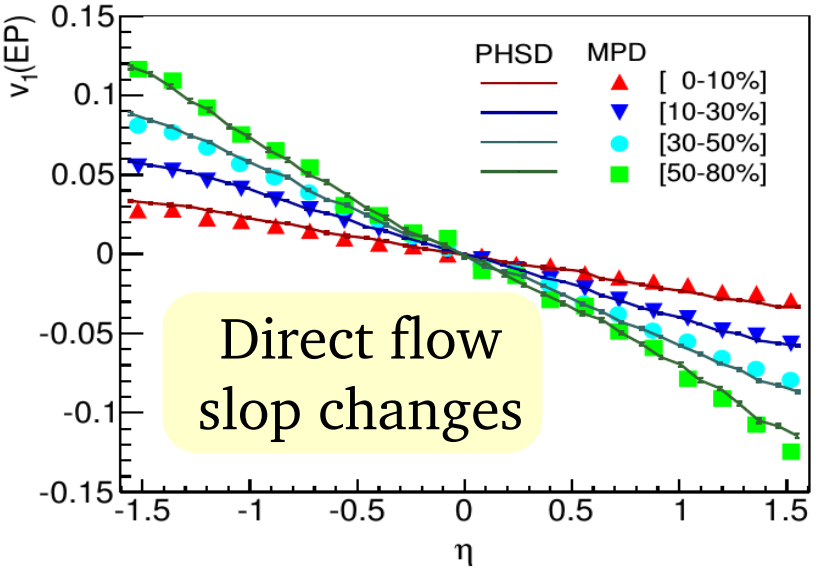
Event display for reconstructed tracks



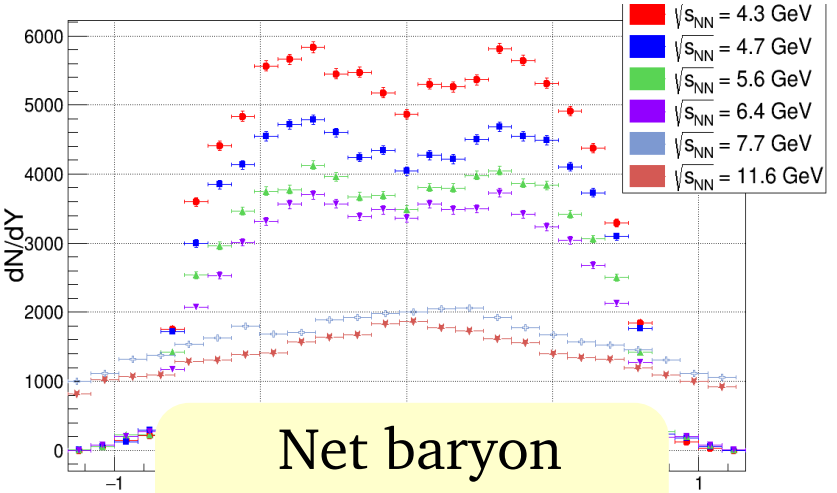




NICA energy scan

New physics with the MC generators

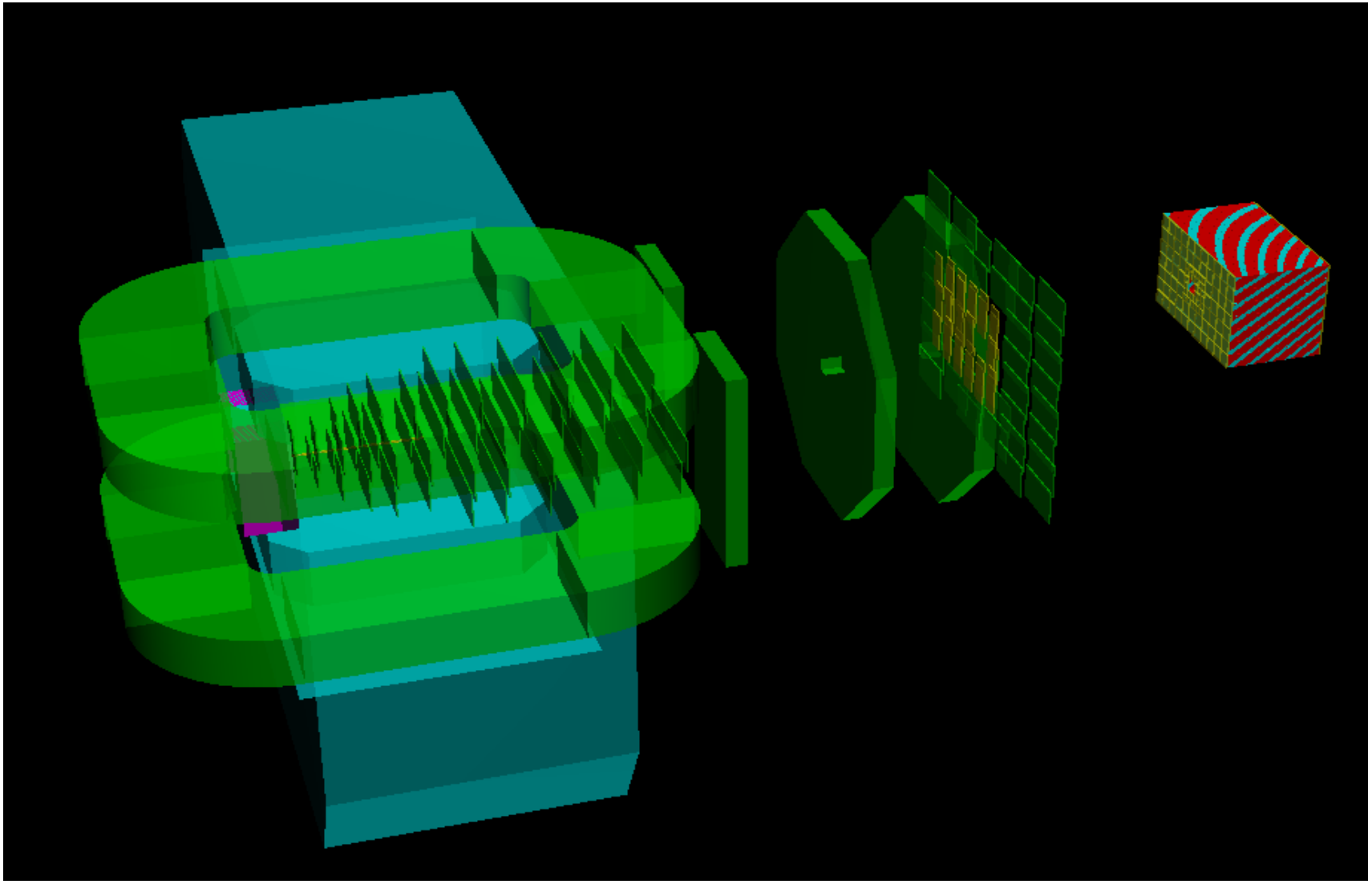



Direct flow slop changes

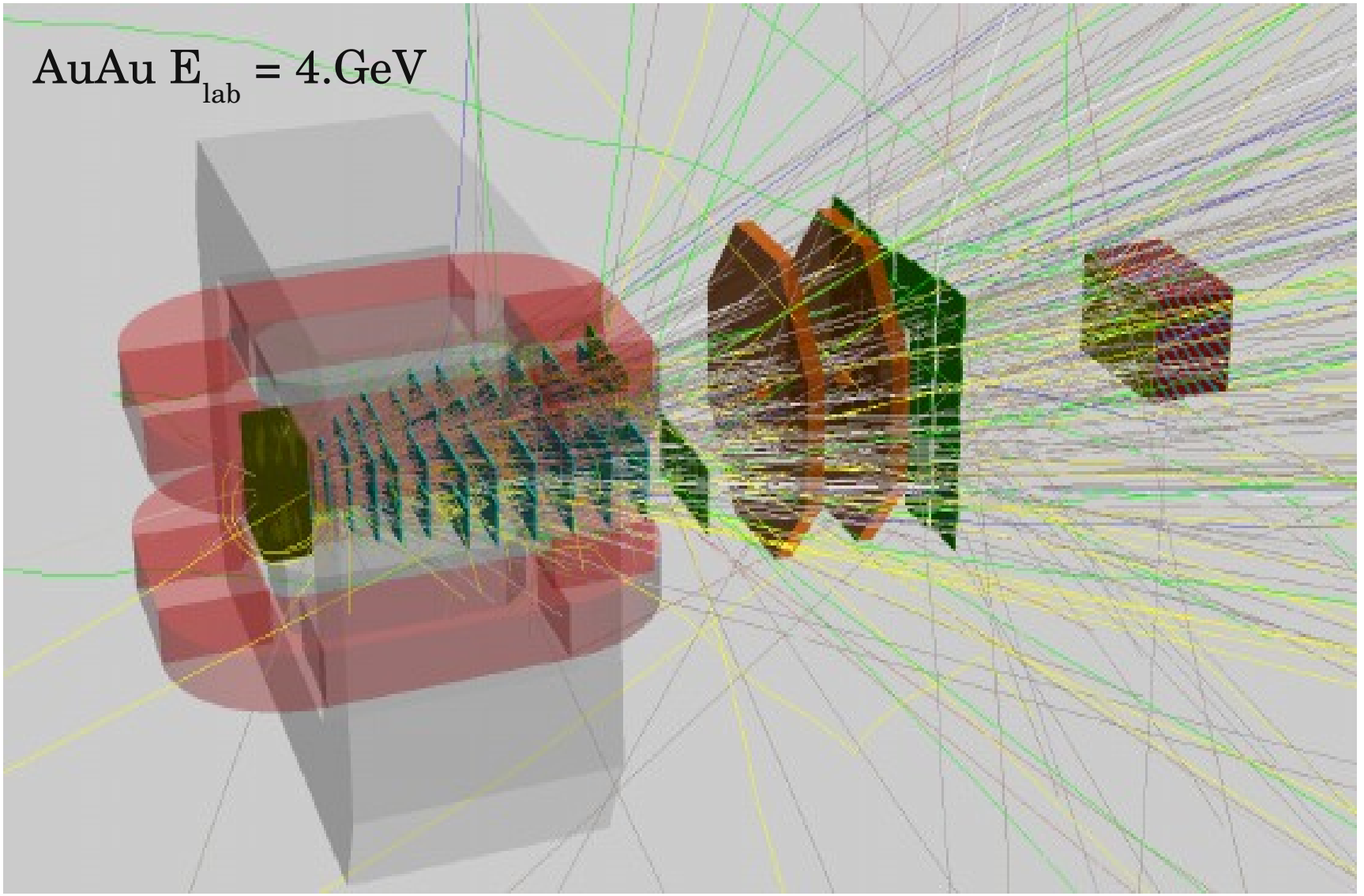



Net baryon rapidity curvature

# Barionic Matter @ Nuclotron

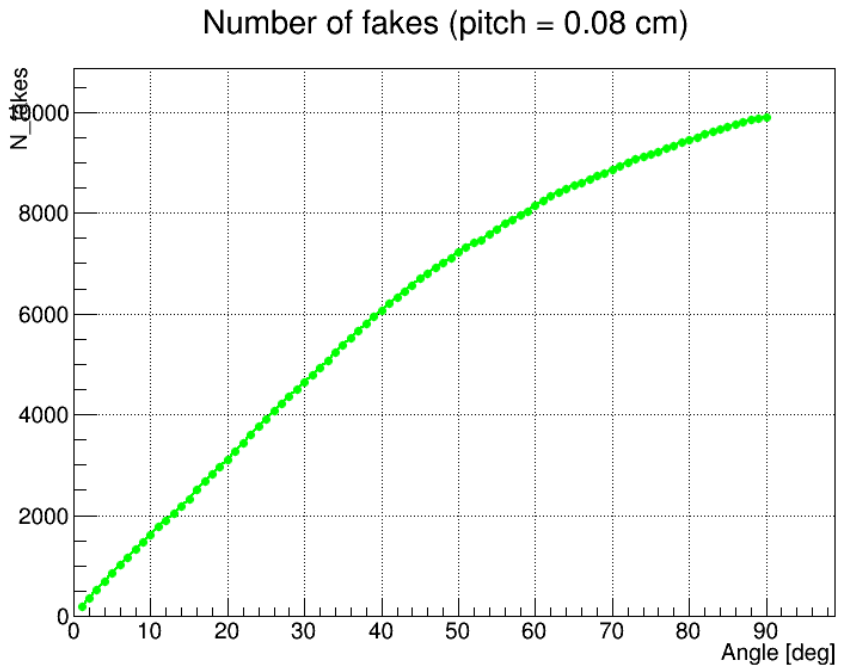


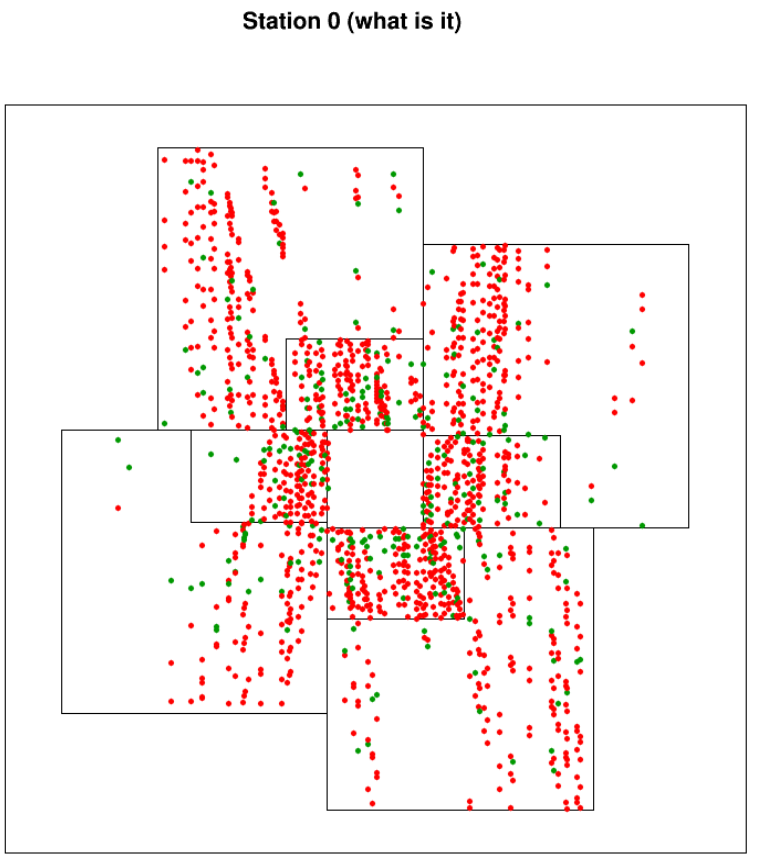
# Monte-Carlo tracks



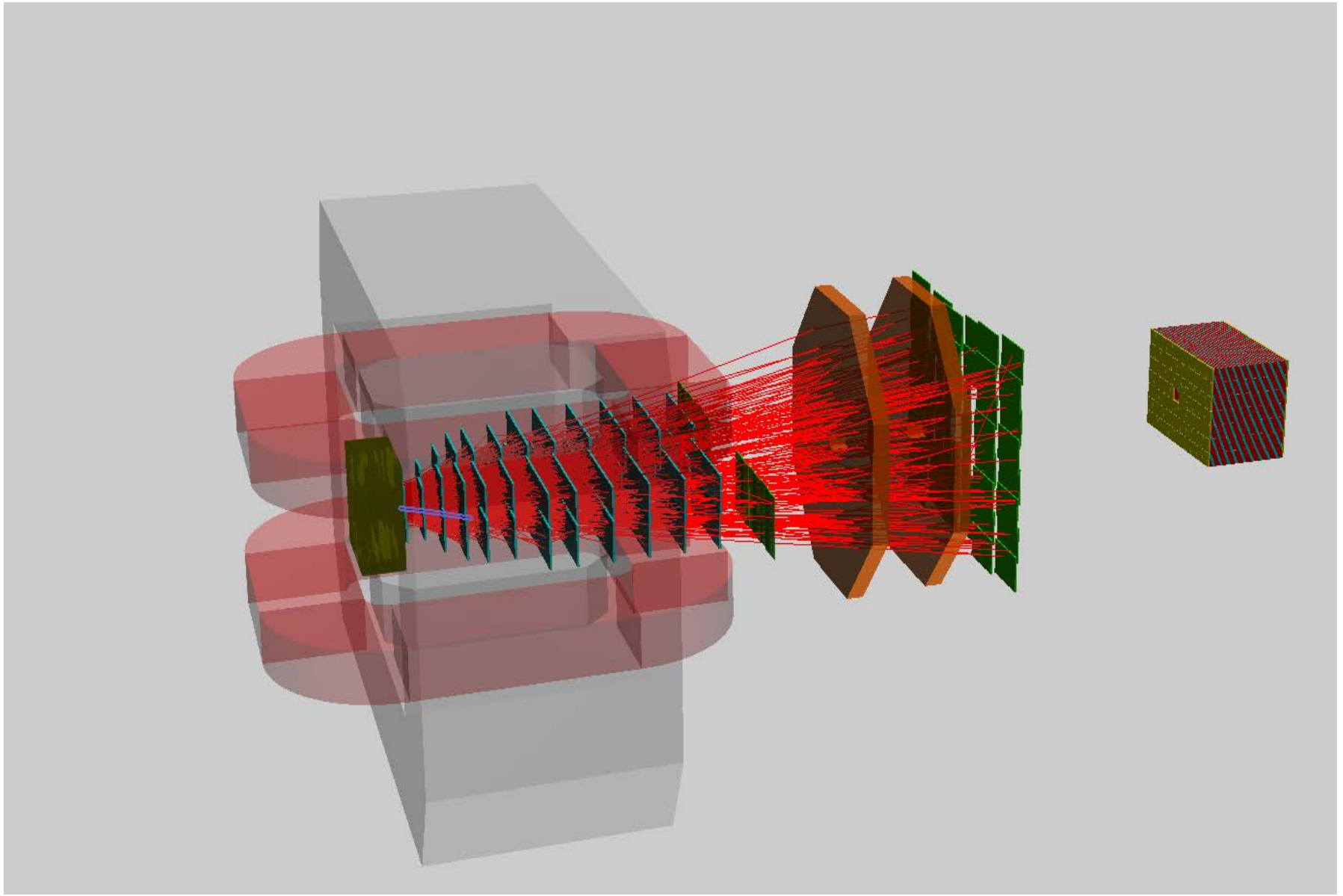
# GEM hits reconstruction

- ✔ Realistic hitfinder in GEM plane
- ✔ Fake hits production is implemented



# Reconstructed tracks

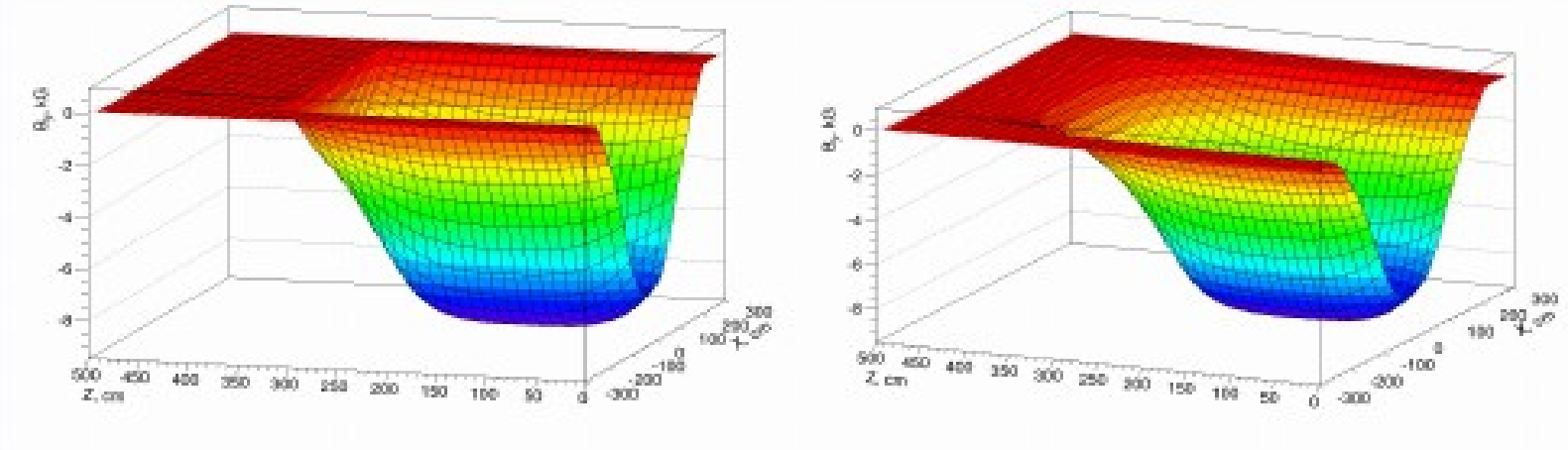


# BM@N magnetic field

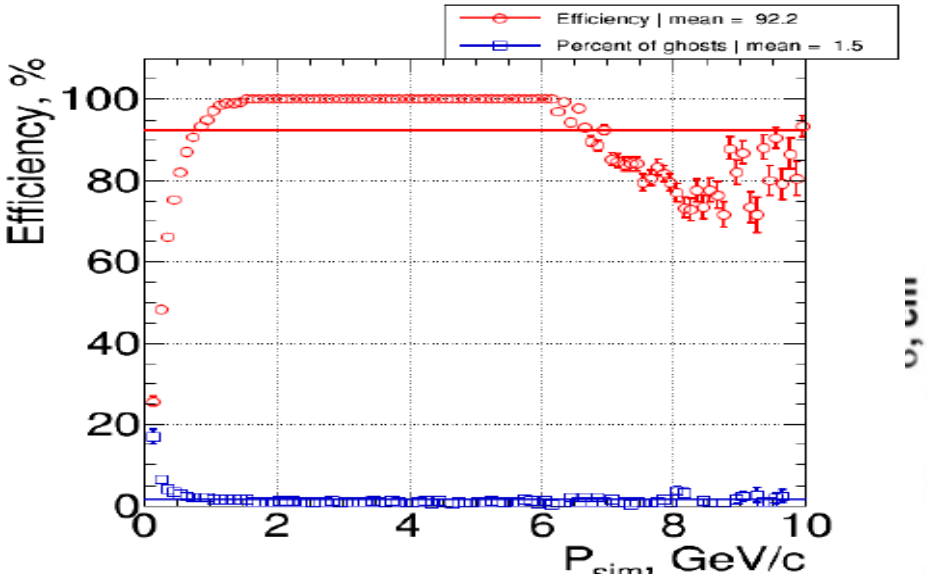
- Transition from a constant magnetic field to the real field map.
- Interpolation of the field between the map nodes.
- Extrapolation of the field map to out-of-magnet region.

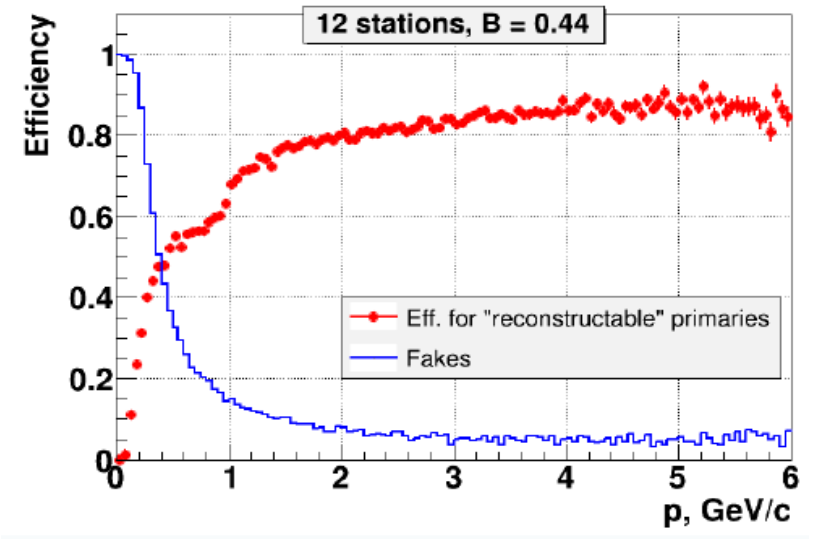
$$B_{comp}(x,y,z) = C(x,y) \cdot e^{-\frac{(z-\mu(x,y))^2}{2\sigma(x,y)^2}}$$

$$\lim_{z\to\infty} B_{comp}(x,y,z) = 0$$

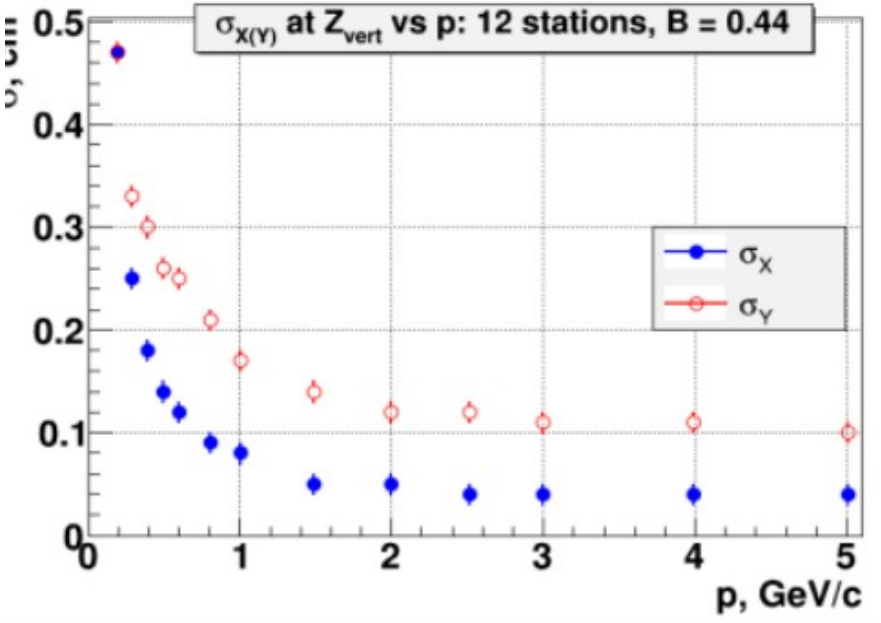


# Tracking in GEM




L1 (CBM) tracking
Implementation for GEM

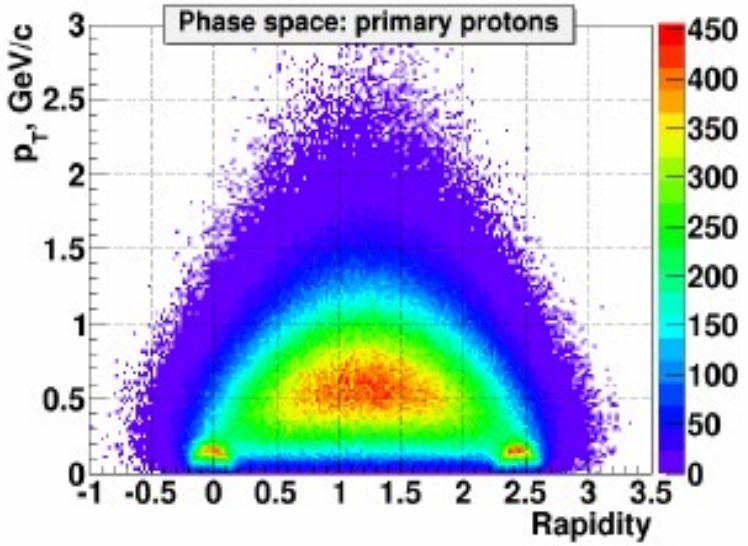


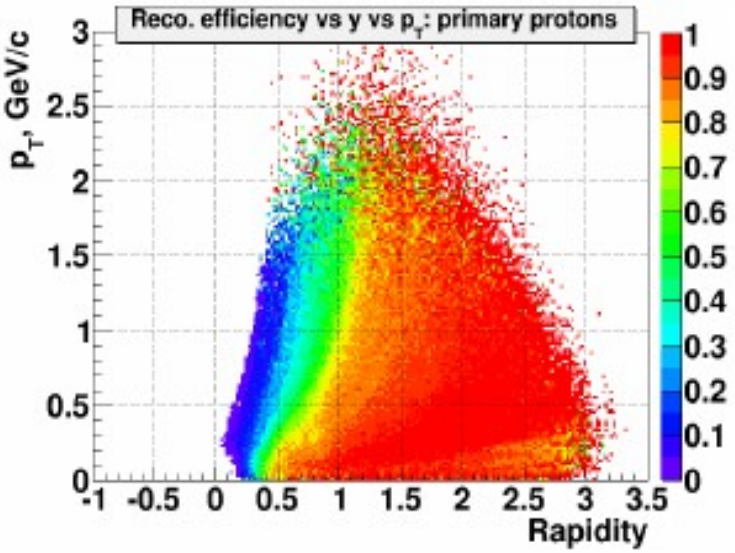

Coordinates transformation
With LIT kalman filter

G.Ososkov presentation

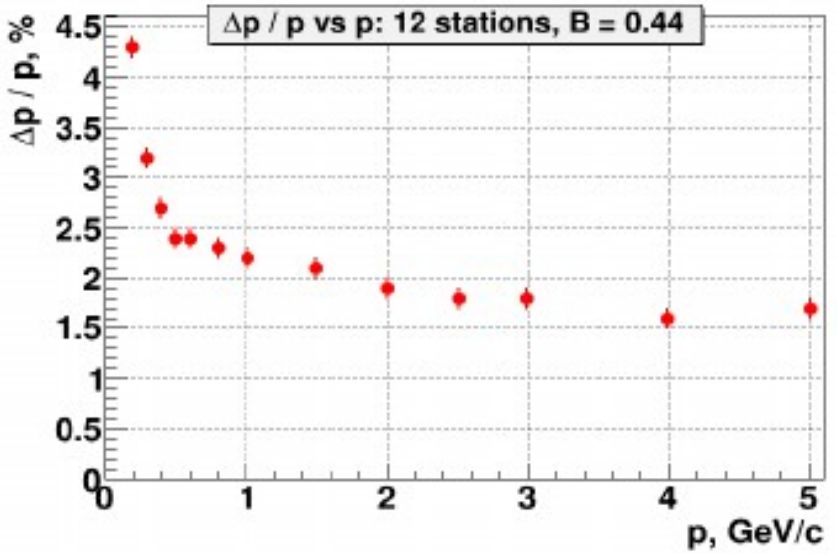
# GEM tracker properties

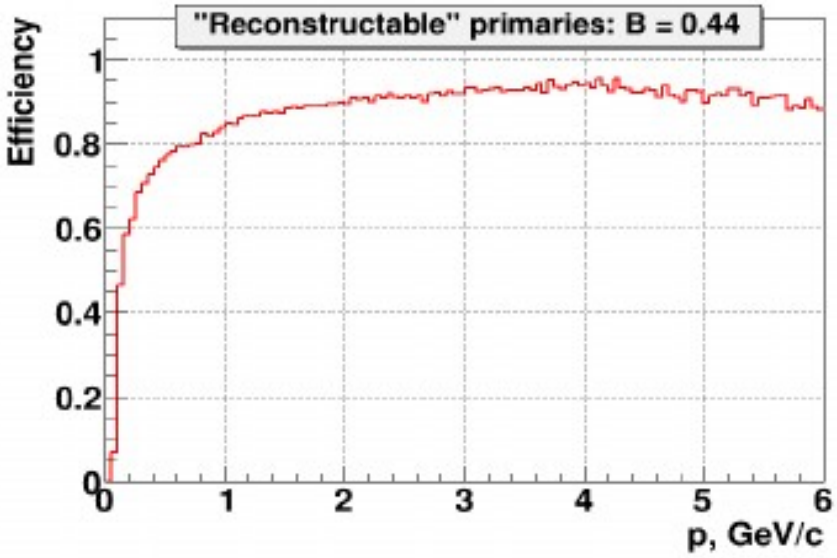
Phase space / acceptance to primary protons:



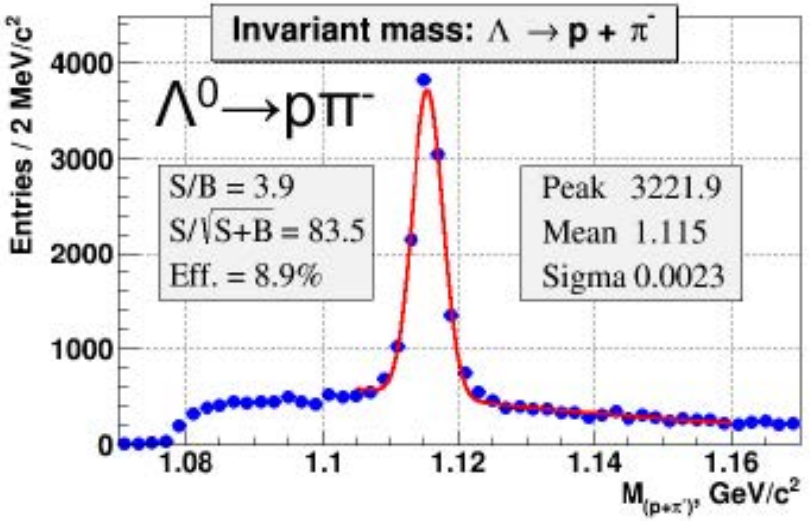




Momentum resolution / detection efficiency

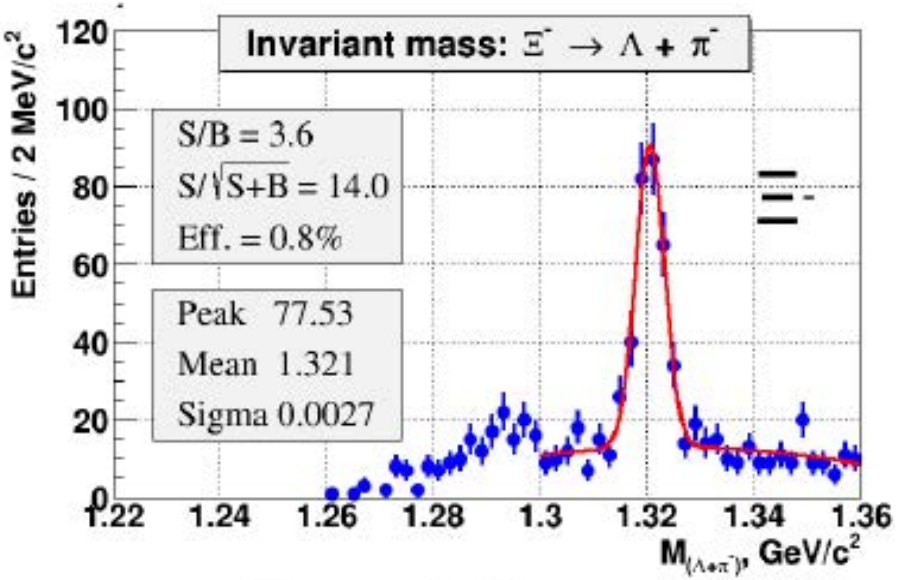


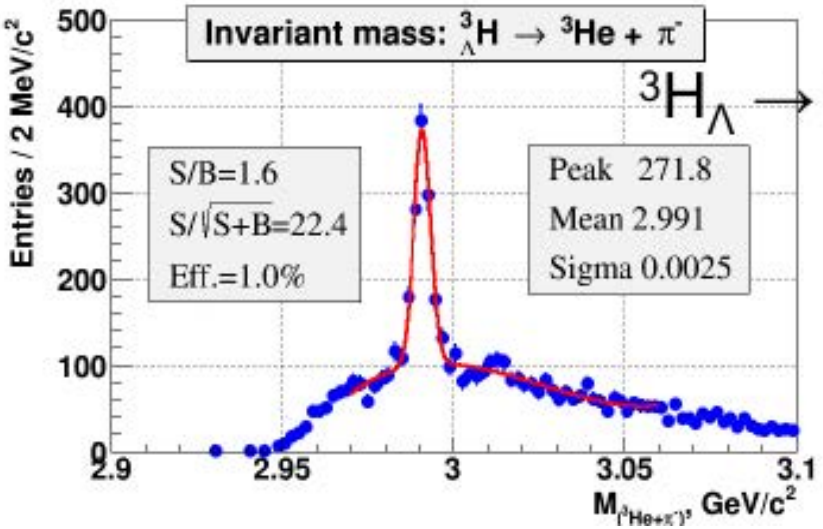
# Physics at BM@N




Au+Au, 4.5 AGeV, UrQMD, 900k central

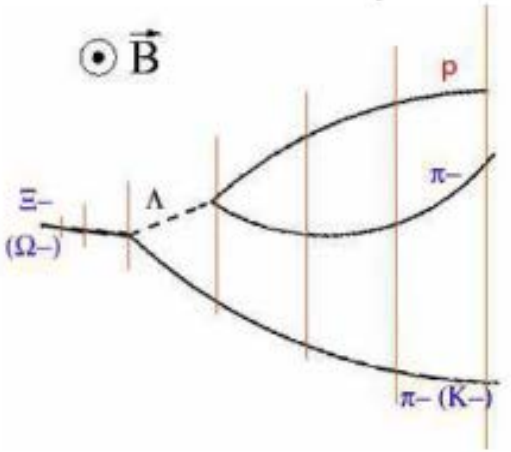



Au+Au, 4.5 AGeV, 2M central events

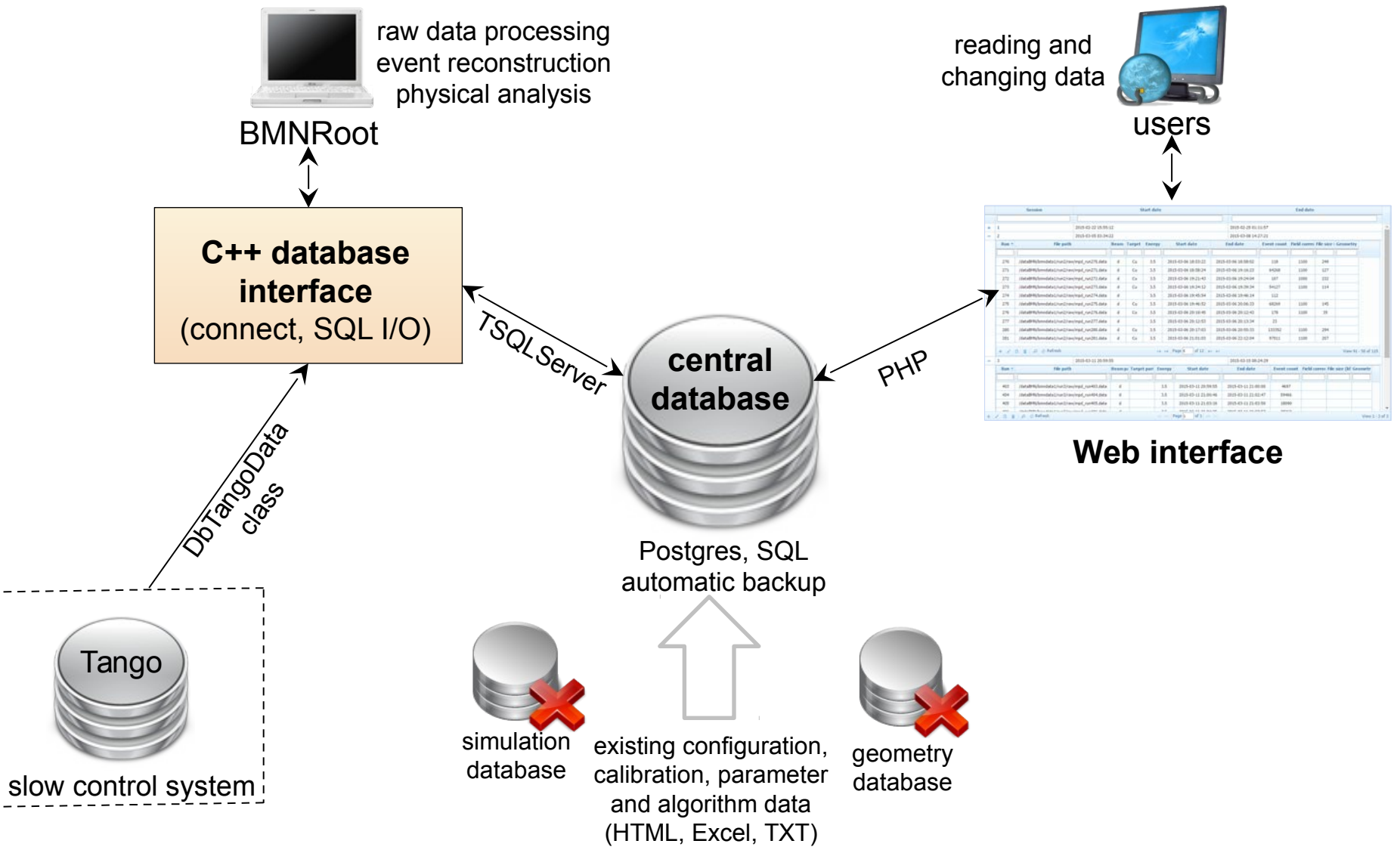



$^3H_\Lambda \rightarrow {}^3He\ \pi^-$

$\Xi^- \rightarrow \pi^- + \Lambda^0 \rightarrow p\pi^-$



# Data... Data... Database



# NICA distributed computing

LHEP
NICA cluster

WUT
Poland

Sosny
Belarus

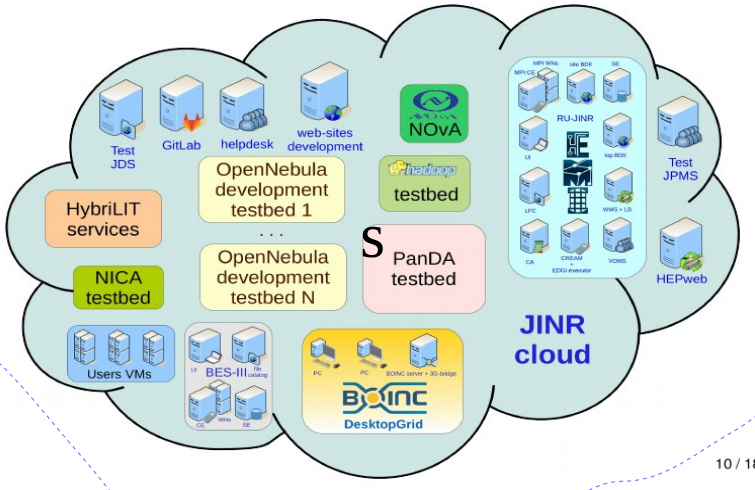
LIT

**Ферма пакетной обработки задач**

**2015 год: Октябрь**

| Лаборатория | Количество задач | Процессорное время (килоSPECint2000*час) | Астрономическое время (килоSPECint2000*час) |
|---|---|---|---|
| mpd | 4813 | 152843.92 | 153237.43 |
| ЛТФ | 116 | 44997.57 | 19532.57 |
| lrb | 114 | 34700.43 | 8036.72 |
| ЛЯП | 337 | 22376.83 | 22509.78 |
| lbes | 2964 | 6780.05 | 8656.51 |
| ЛИТ | 21 | 1510.31 | 880.43 |
| ЛЯР | 2 | 165.14 | 52.40 |

**Суммарное использование процессорного времени: 263374.26 килоSPECint2000*в час**



# MONTE CARLO GENERATORS for NICA/FAIR physics

- Ultrarelativistic Quantum Molecular Dynamics (UrQMD)
- Quark Gluon String Model
- Shield

} Nuclear fragments

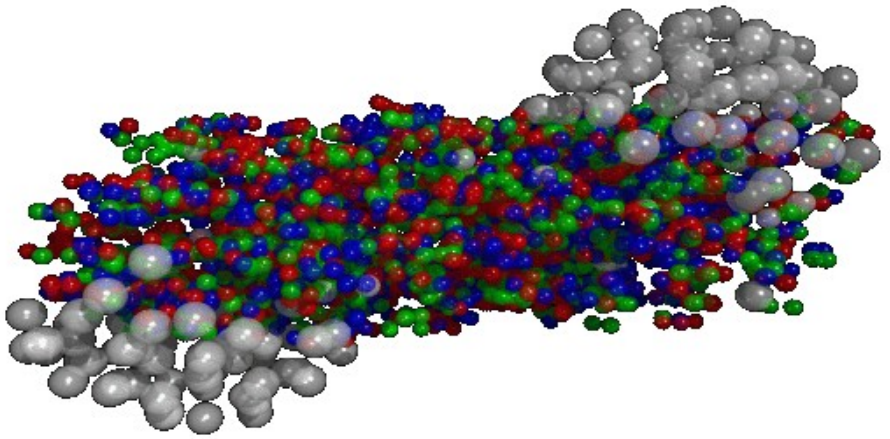
- Parton Hadron String Dynamics
- Hybrid UrQMD
- EPOS

} Femtoscopy

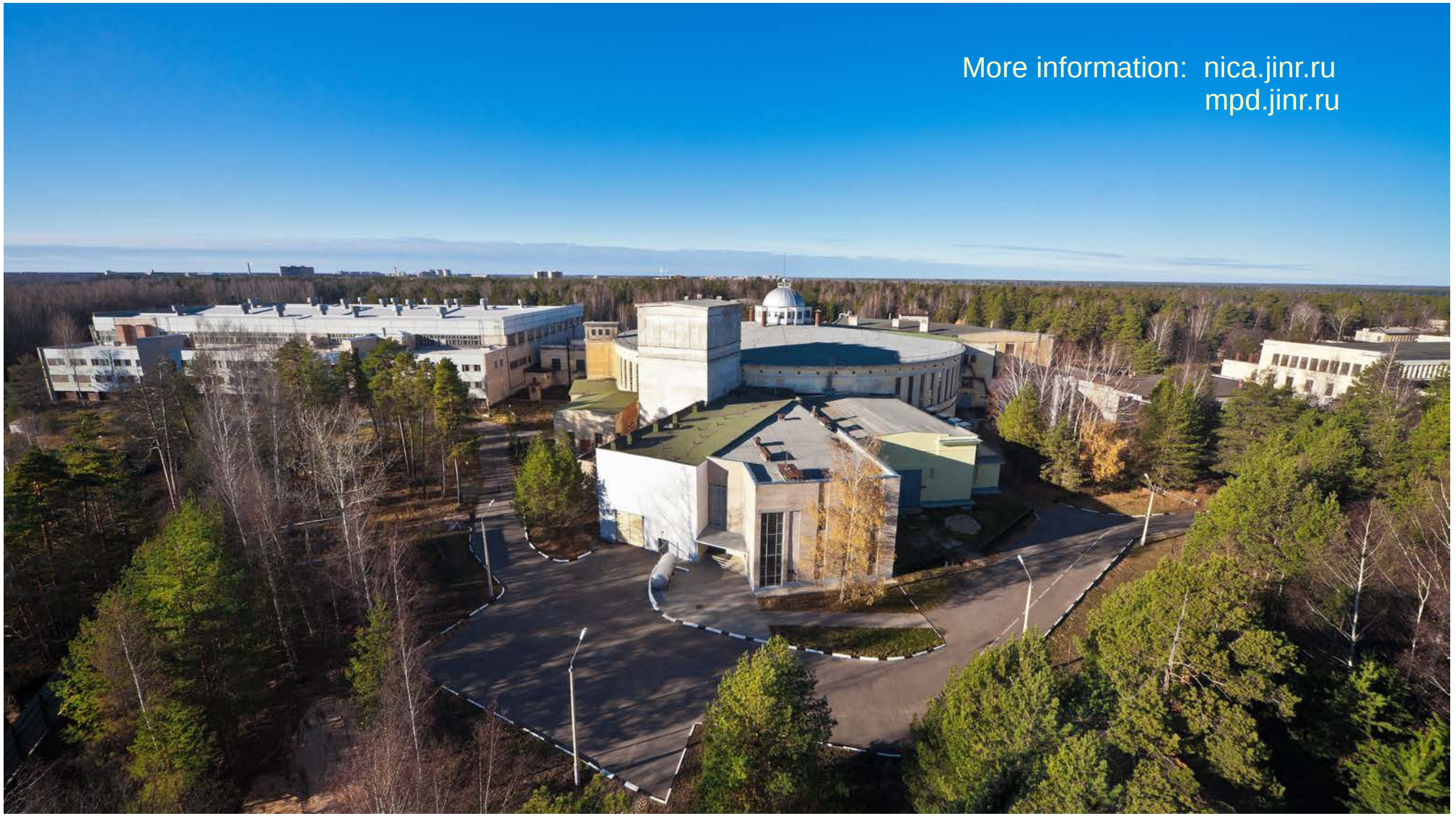
} Flows

- vHLLE UrQMD
- 3 Fluid Dynamics model

baryon stopping power

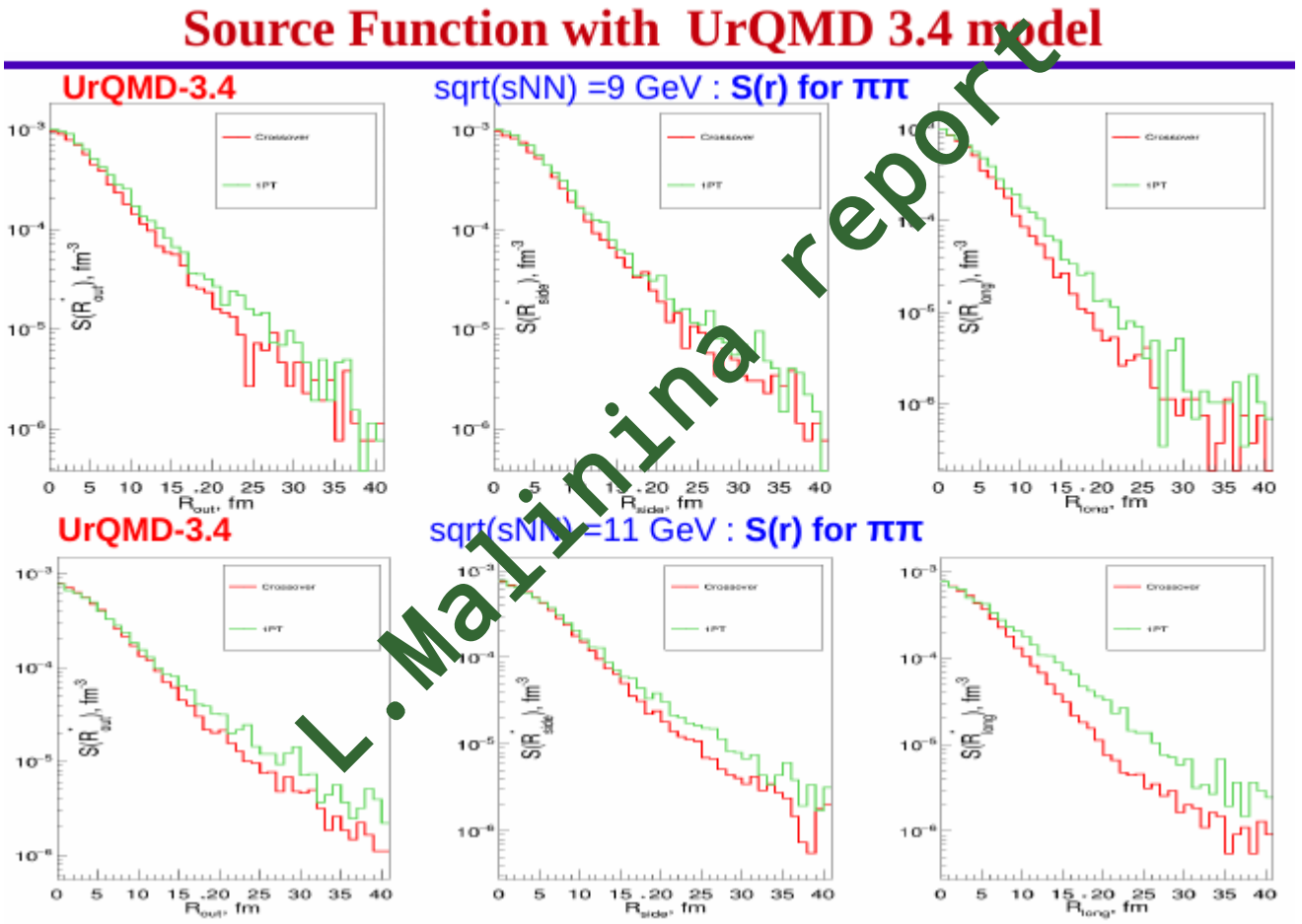


# Thank you for attention



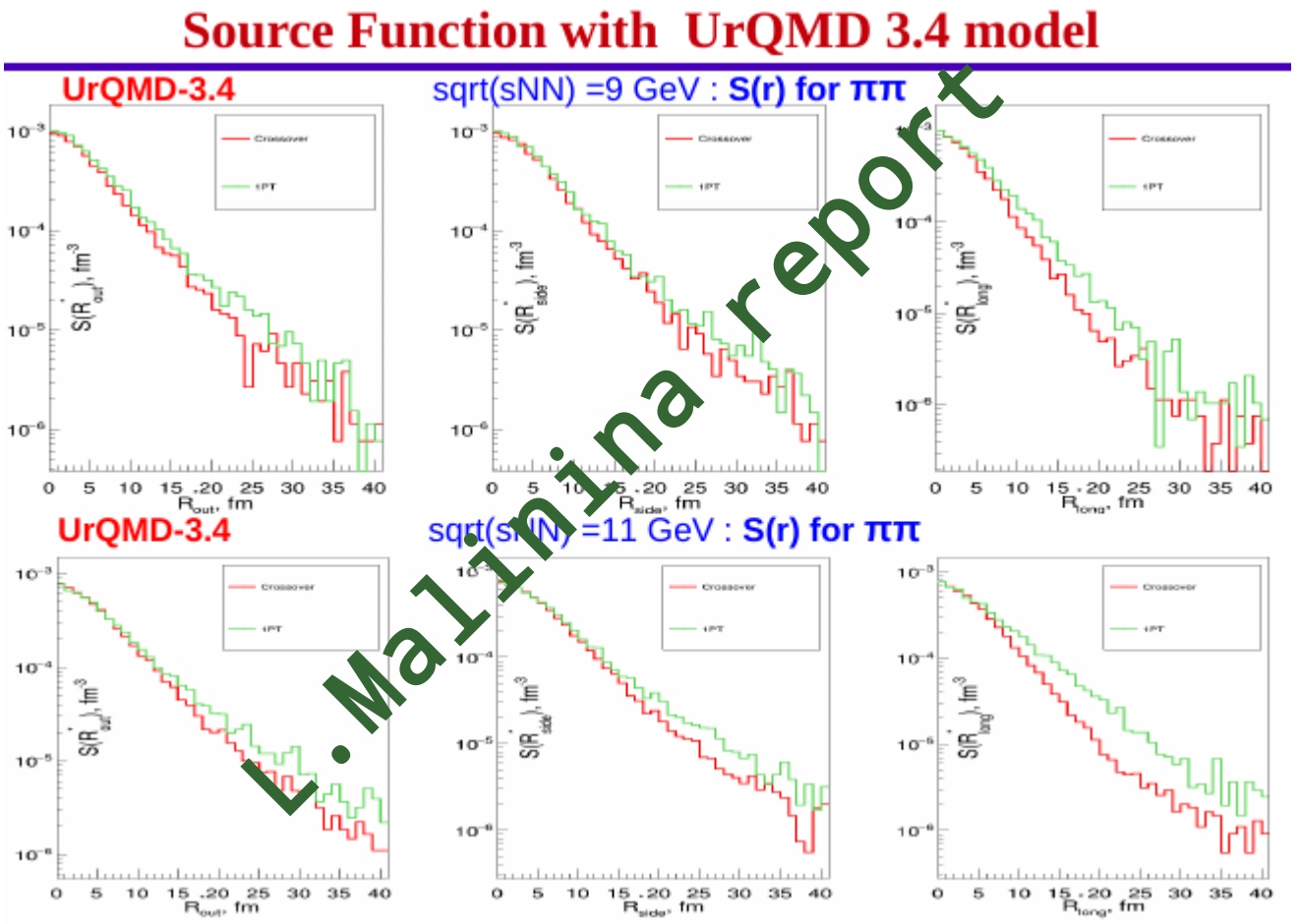
# vHLLE + UrQMD model

Radii versus kT with vHLLE+UrQMD model for ππ at 7.7 ; 11.5 GeV
Source Function with vHLLE + UrQMD model for ππ at 7.7 ; 11.5 GeV



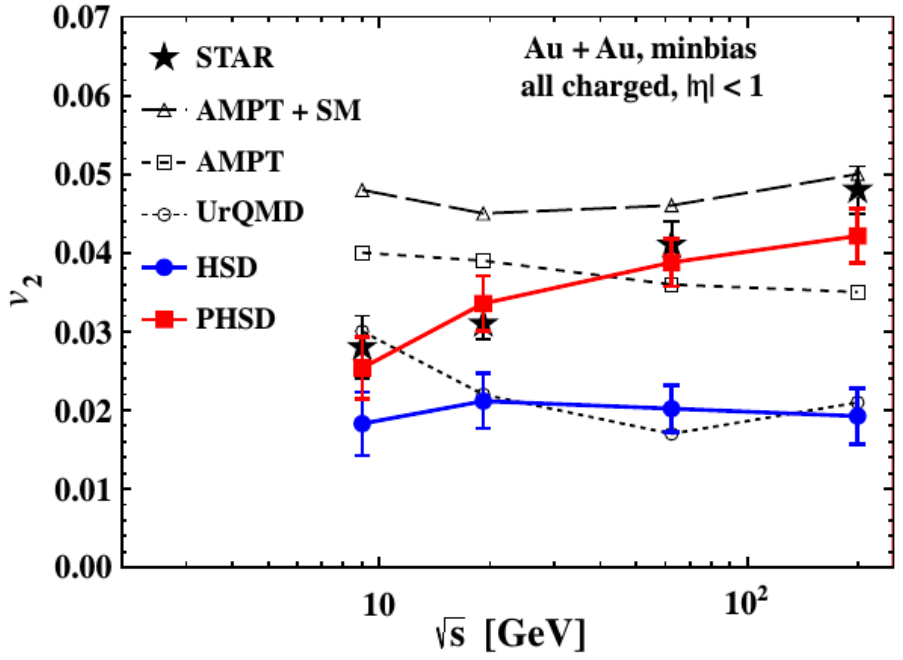
# UrQMD 3.4 model

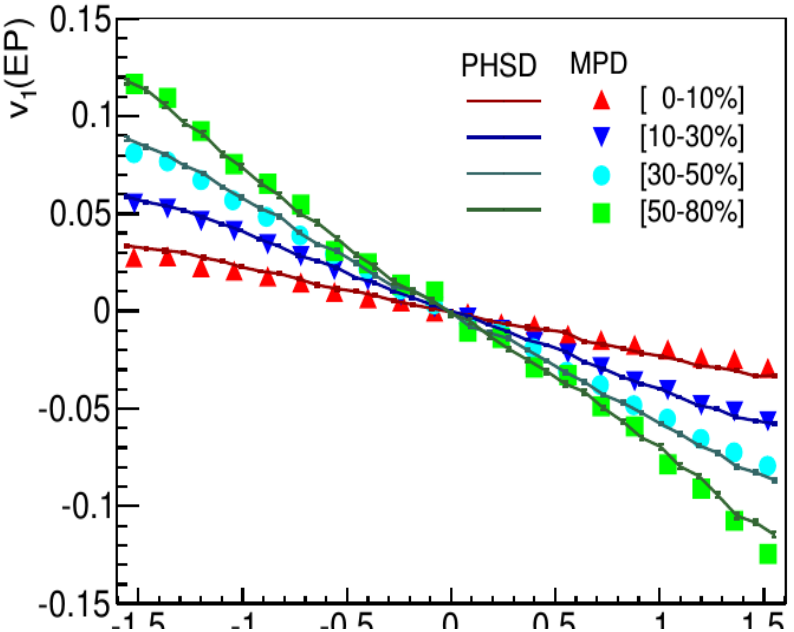
Source Function with UrQMD 3.4 model for ππ at 5; 7 ; 9; 11 GeV

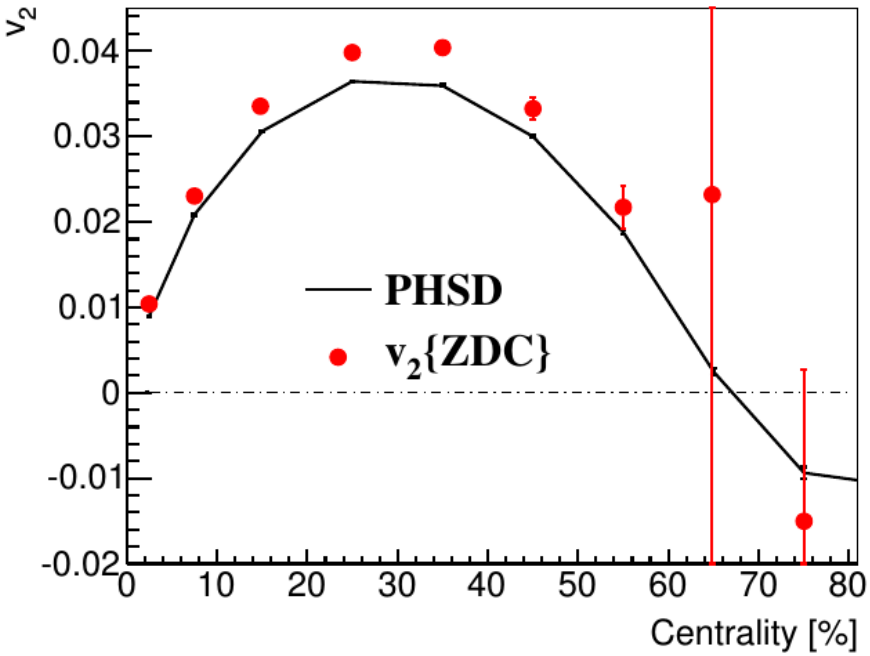


# PHSD Model: Flows @ MPD

V.Voronyuk

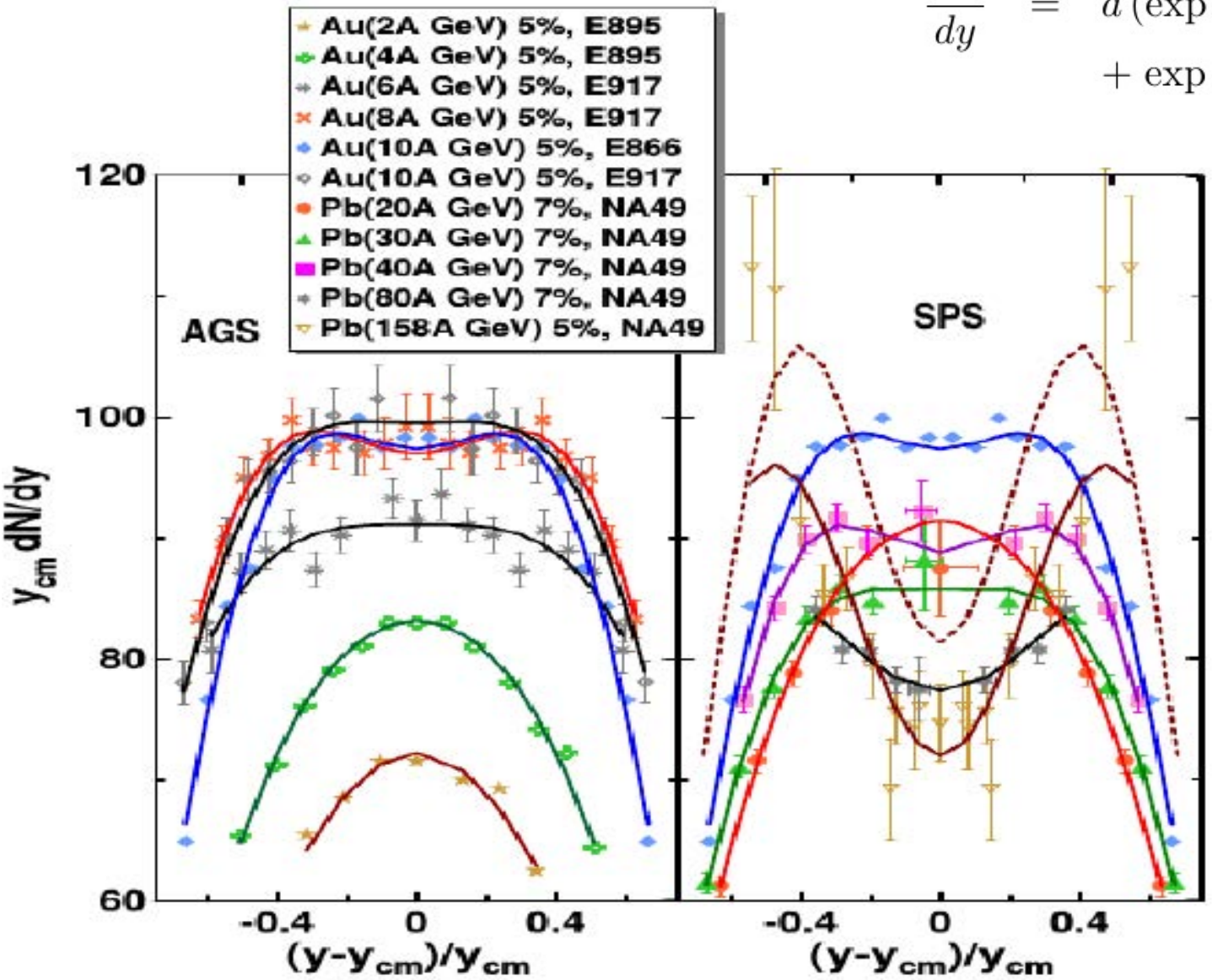


# Baryon stopping power

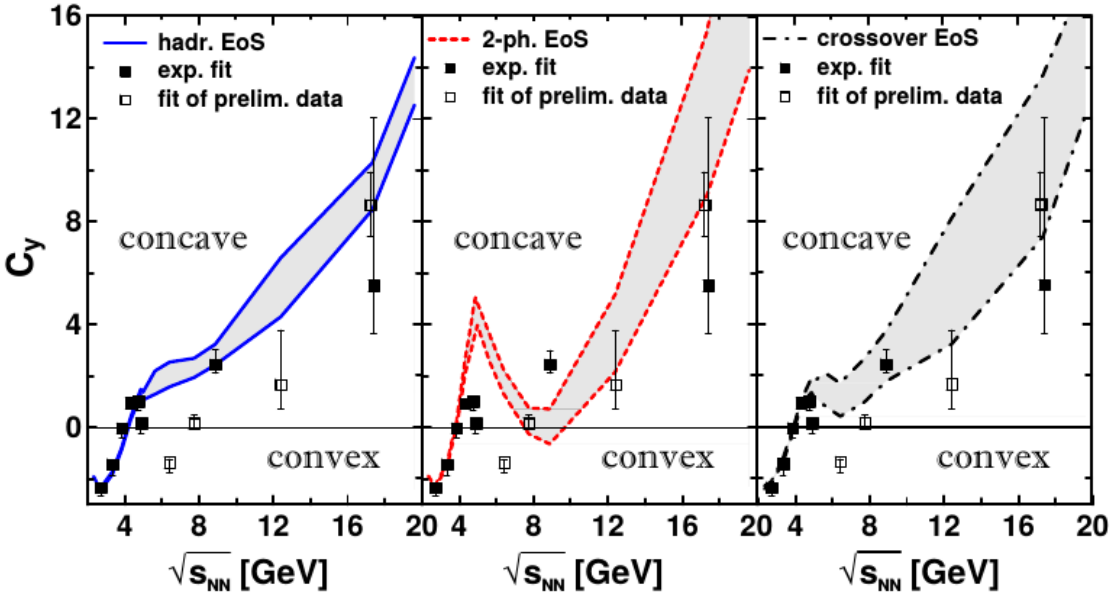
$$\frac{dN}{dy} = a\left(\exp\left\{-(1/w_s)\cosh(y-y_s)\right\} + \exp\left\{-(1/w_s)\cosh(y+y_s)\right\}\right)$$



# 3FD Model: Baryon stopping power

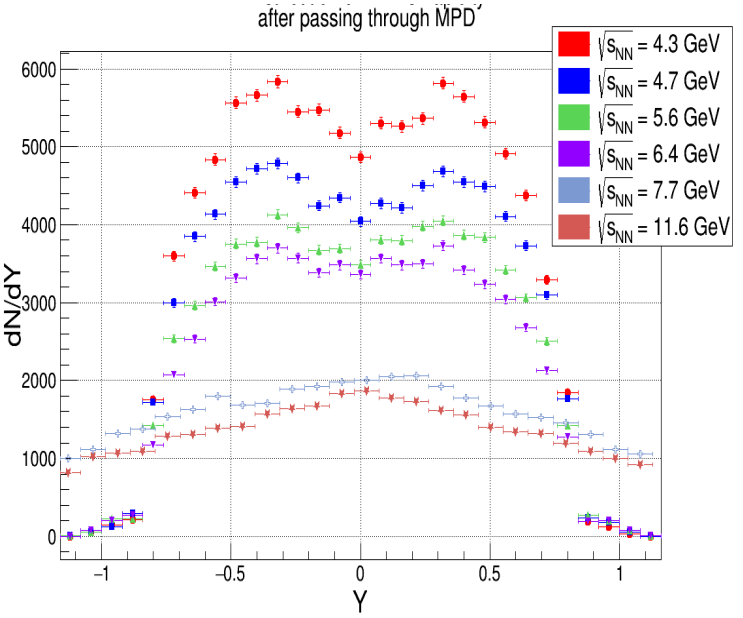
model

$$C_y = \left(y_{\text{beam}}^3 \frac{d^3N}{dy^3}\right)_{y=0} \Big/ \left(y_{\text{beam}} \frac{dN}{dy}\right)_{y=0} = (y_{\text{beam}}/w_s)^2 \left(\sinh^2 y_s - w_s \cosh y_s\right)$$




Yu.B. Ivanov, PL B721 (2013) 123
arXiv:1211.2579

experiment



# NICA physics

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


Draft v 10.01
January 24, 2014

SEARCHING for a QCD MIXED PHASE at the
NUCLOTRON-BASED ION COLLIDER FACILITY
(NICA White Paper)

Contents

# 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*** *(Endcap Calorimeter)*
- ***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*

# NICA physics

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