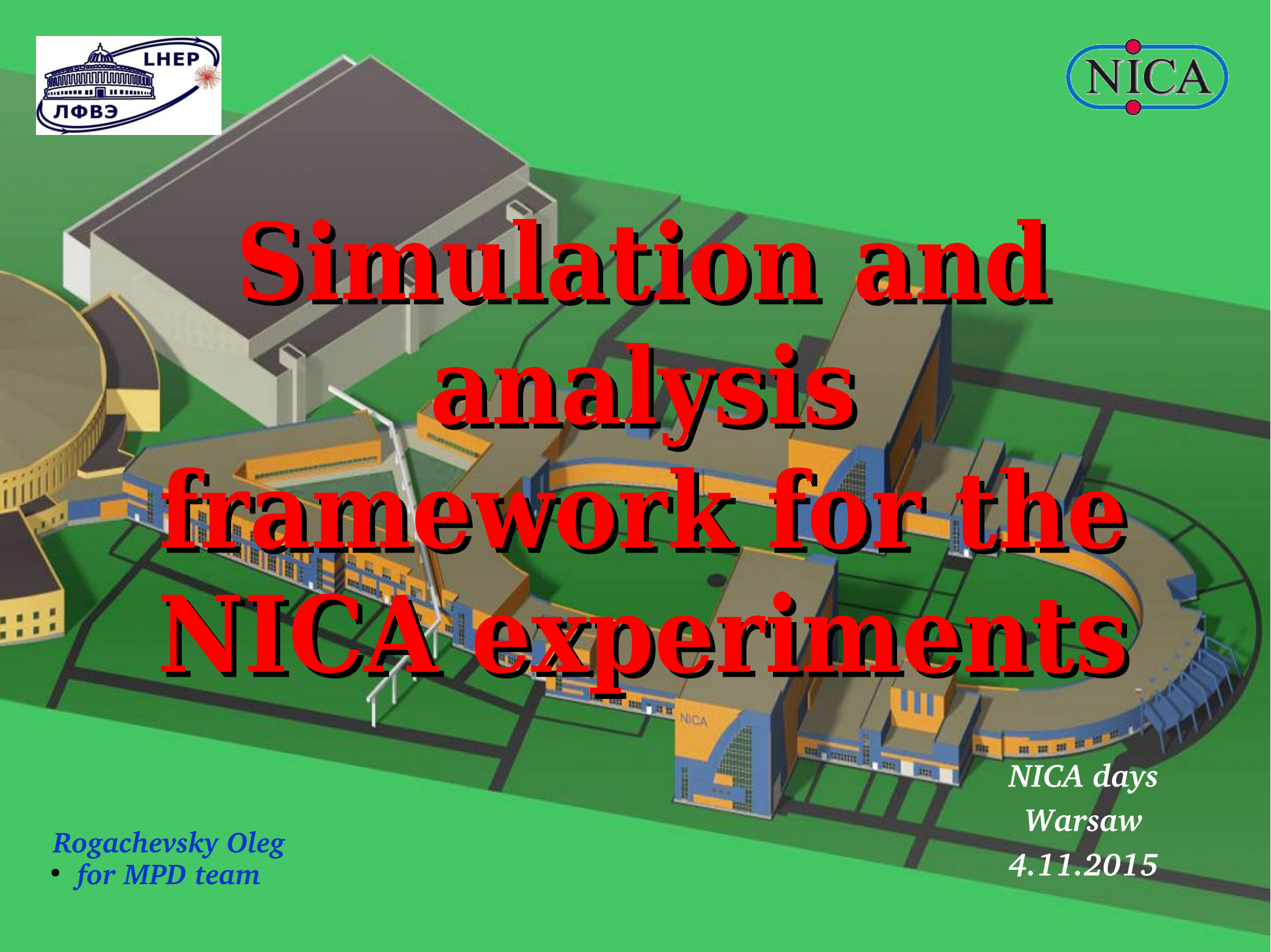
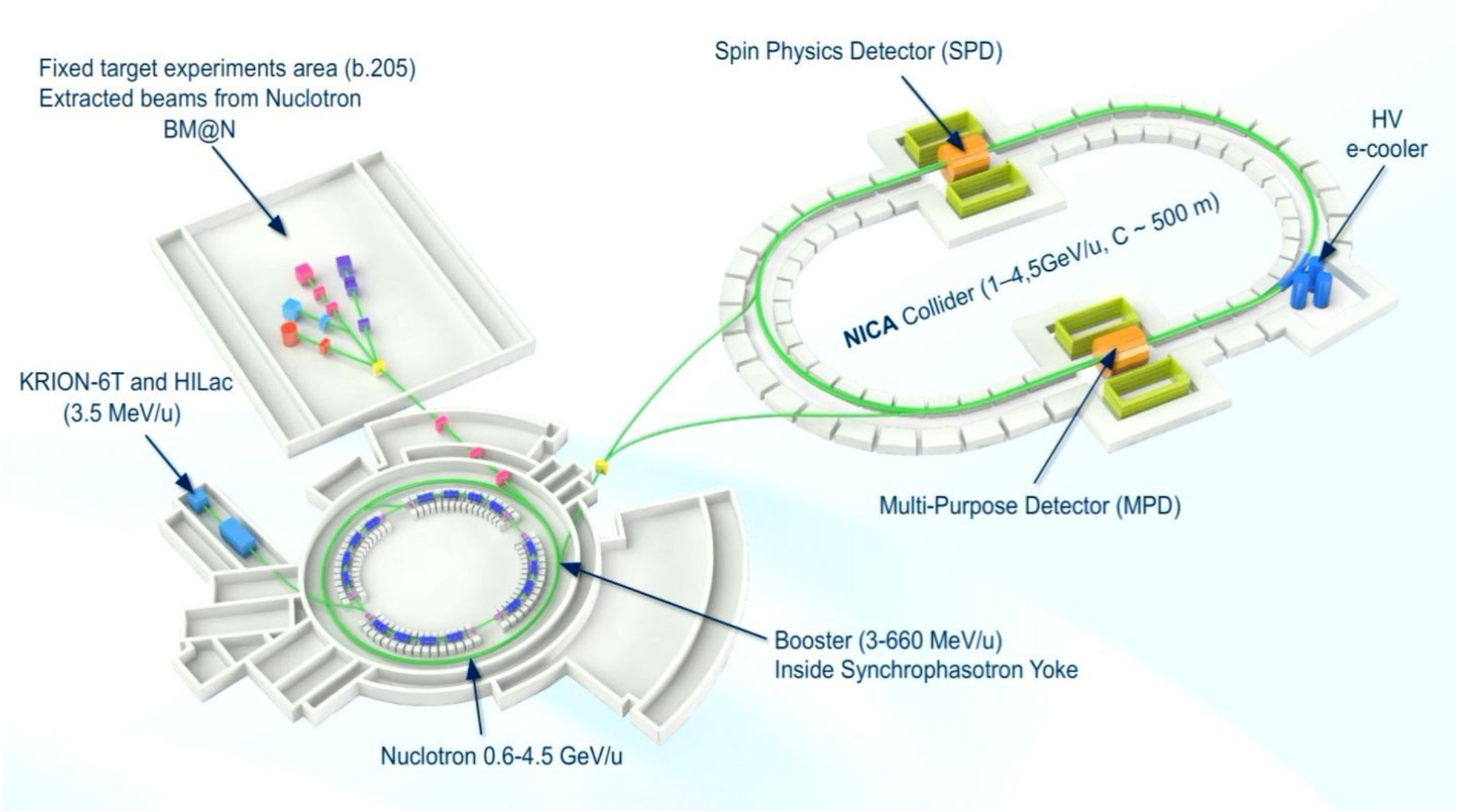


Simulation and analysis framework for the NICA experiments

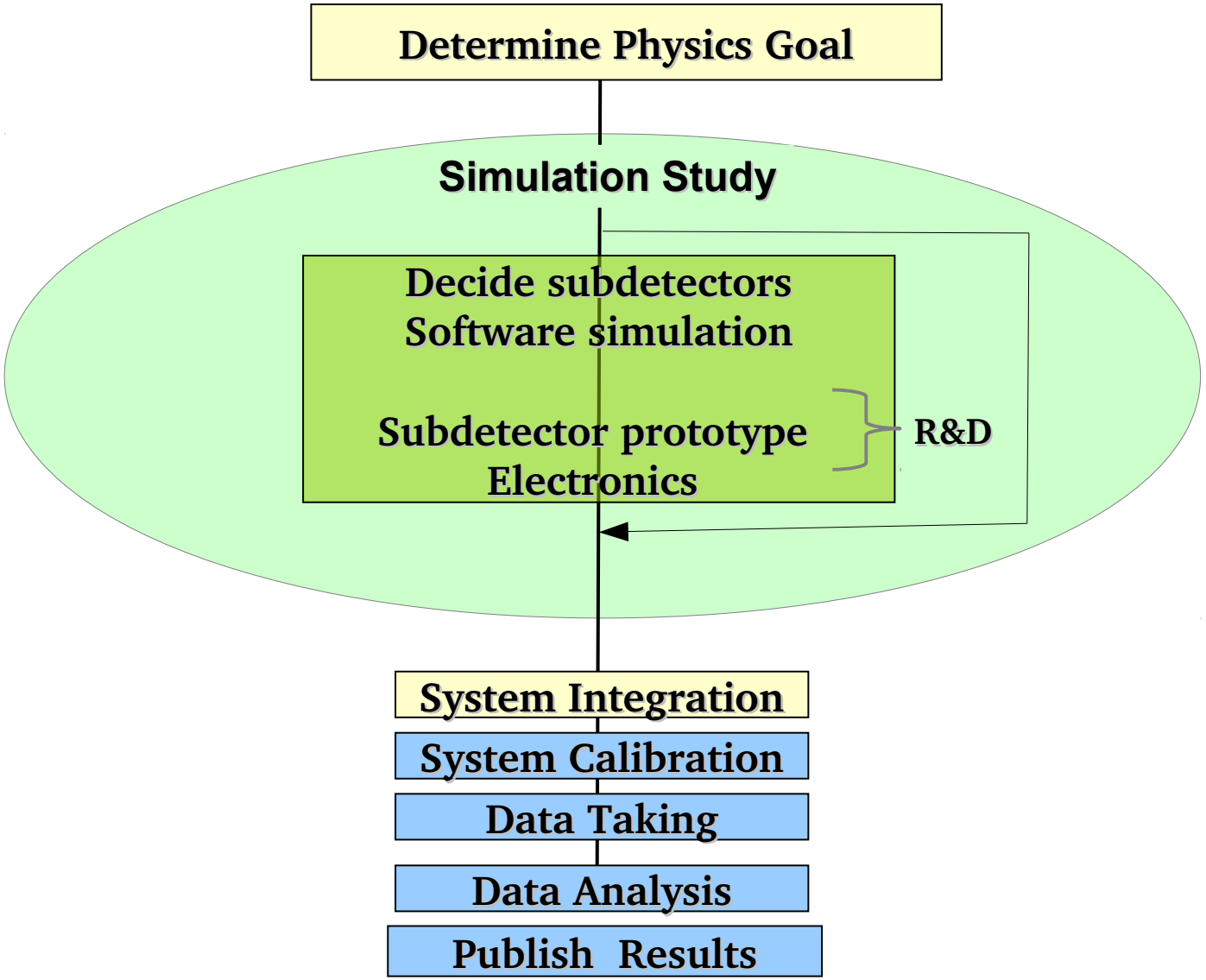
Rogachevsky Oleg
- *for MPD team*

NICA days
Warsaw
4.11.2015

Nuclotron based Ion Collider fAcility

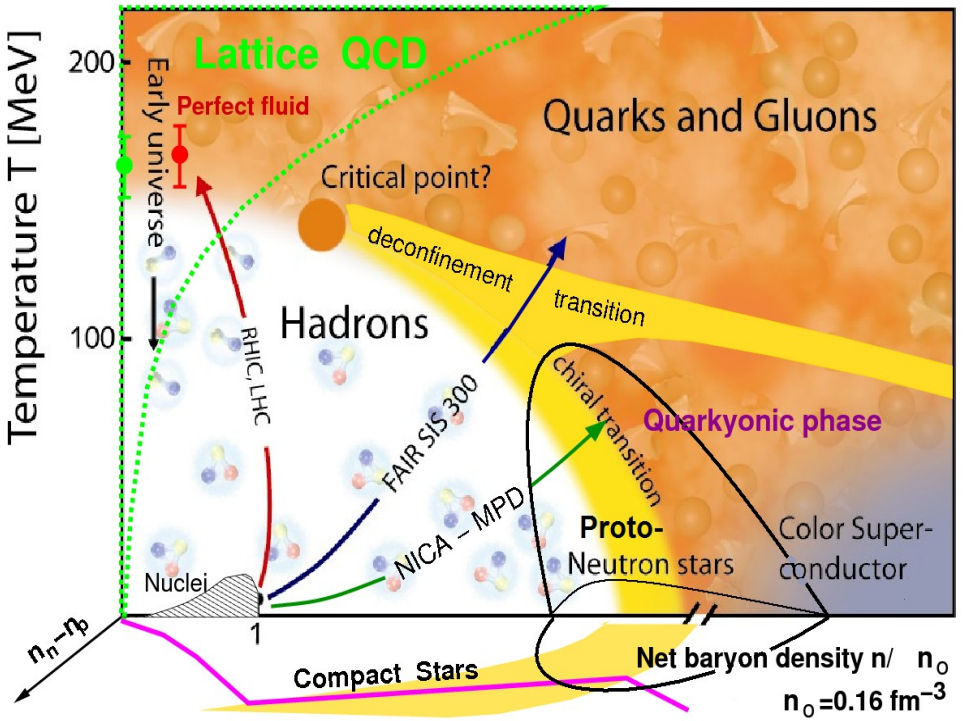


Global sketch of HEP experiment



Goal

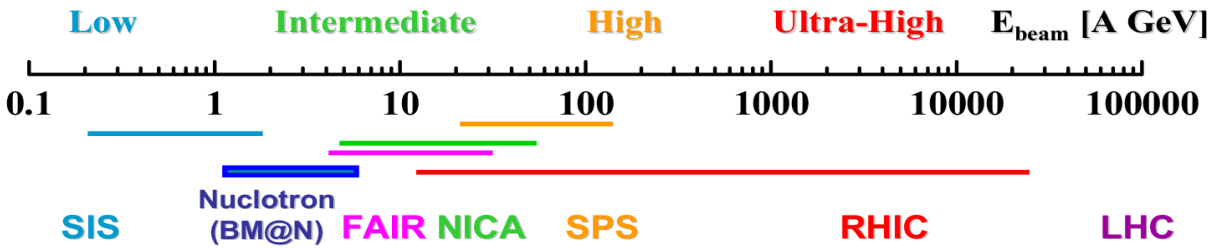
The collision of two heavy nuclei which approach and smash against each other with almost the speed of light creates in the laboratory the primordial state of matter, called Quark-Gluon Plasma (QGP). The QGP expands like a fireball, cools and finally turns into ordinary matter.



"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

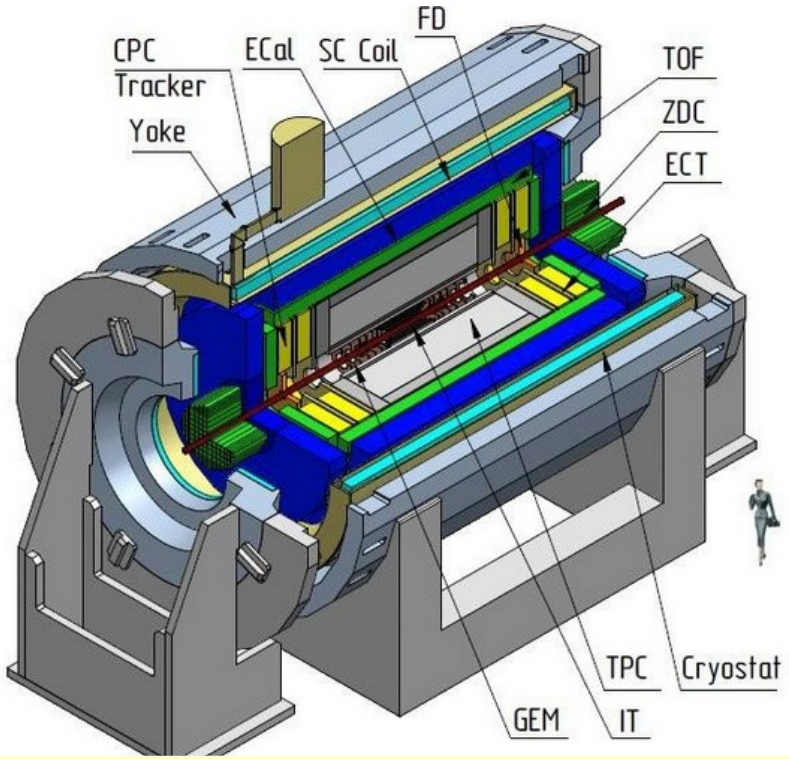
http://theor0.jinr.ru/twiki-cgi/view/NICA/WebHome



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

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)

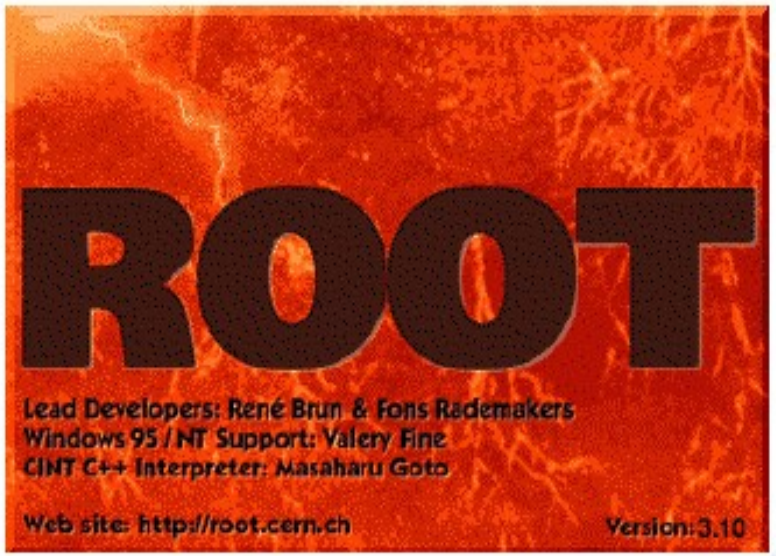
2012 — SOFIA (Studies On Fission with Aladin)

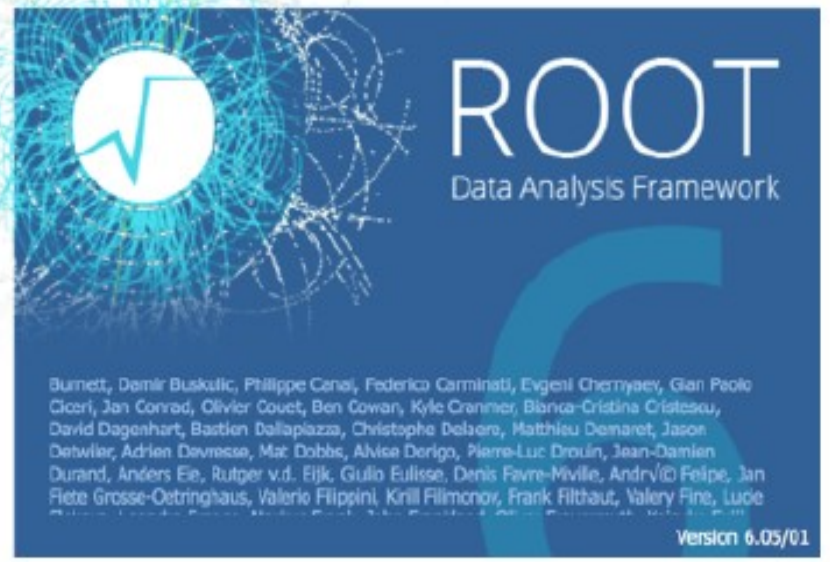
2012 — CALIFA (CALorimeter for the In Flight detection of γ rays and light charged pArticles)

2013 — SHIP - Search for Hidden Particles

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

20 years of ROOT evolution





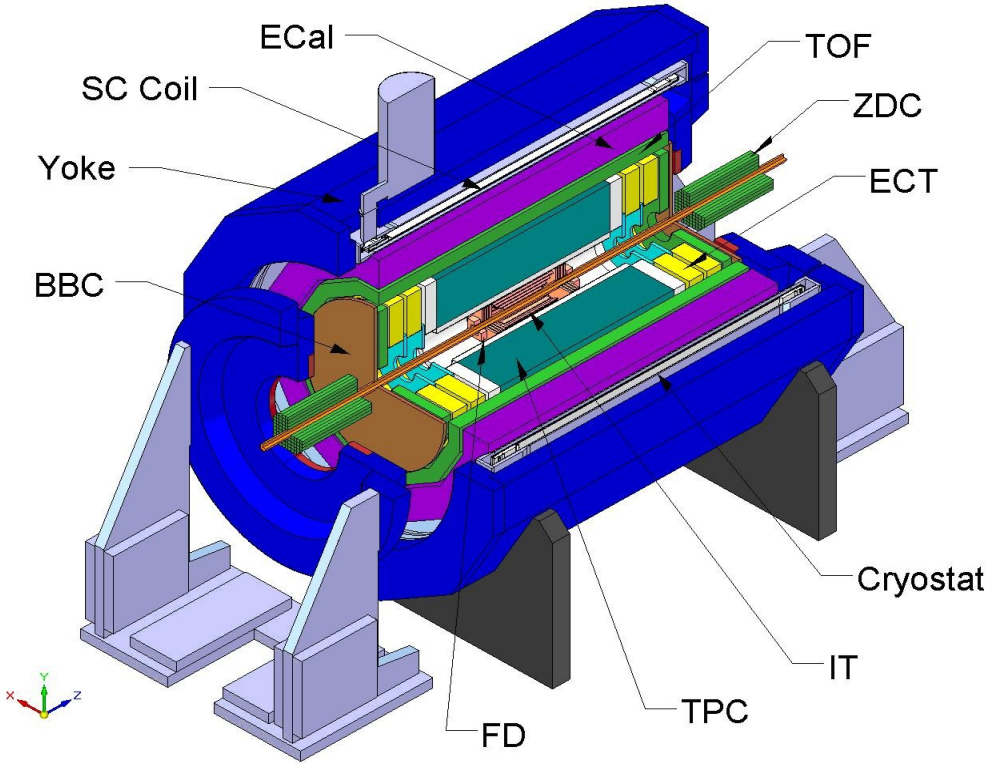
Detector simulation

- ✔ 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

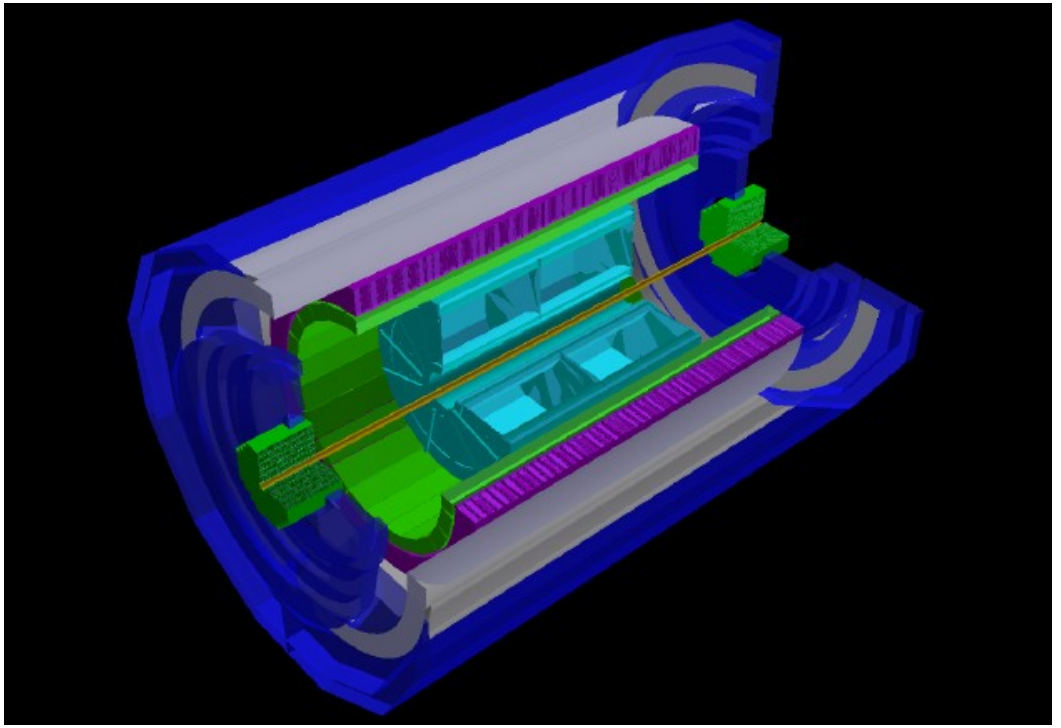
Experiments framework

Multi Purpose Detector



Stage 1

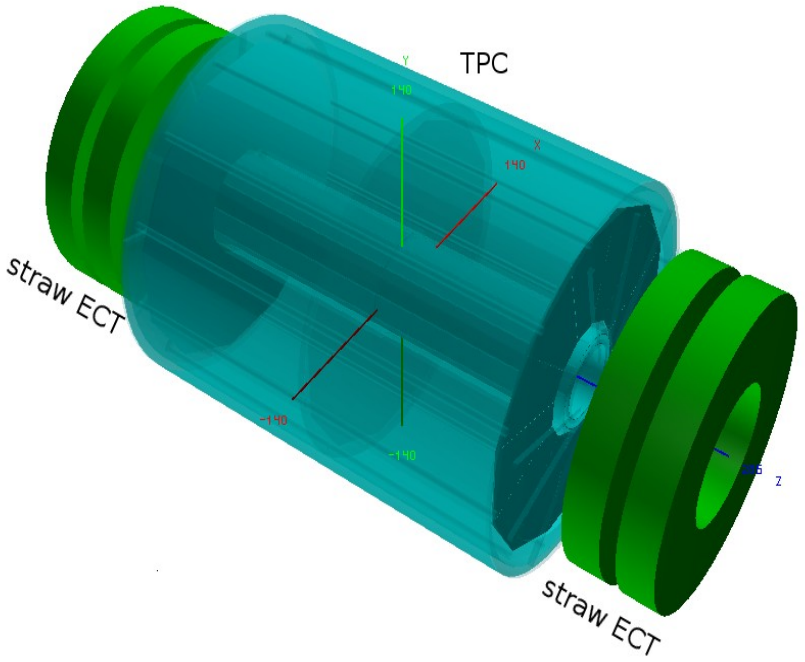
TPC,TOF, ECAL, ZDC, FFD



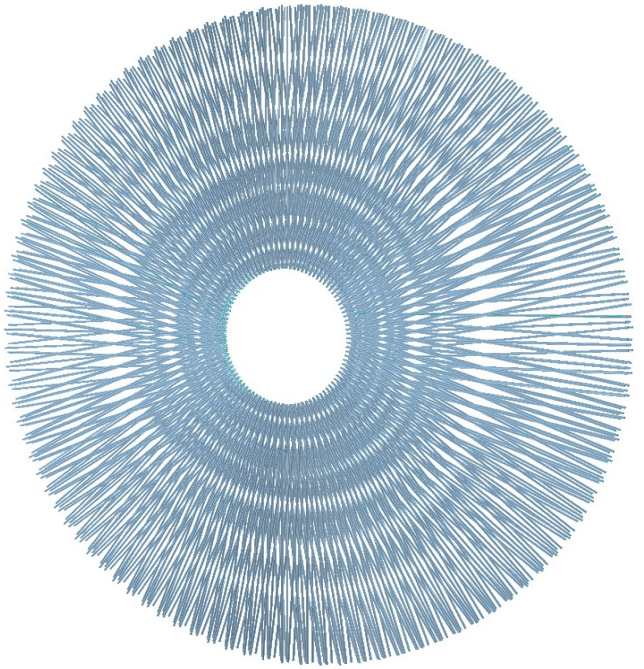
Stage 2

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

MPD subdetectors

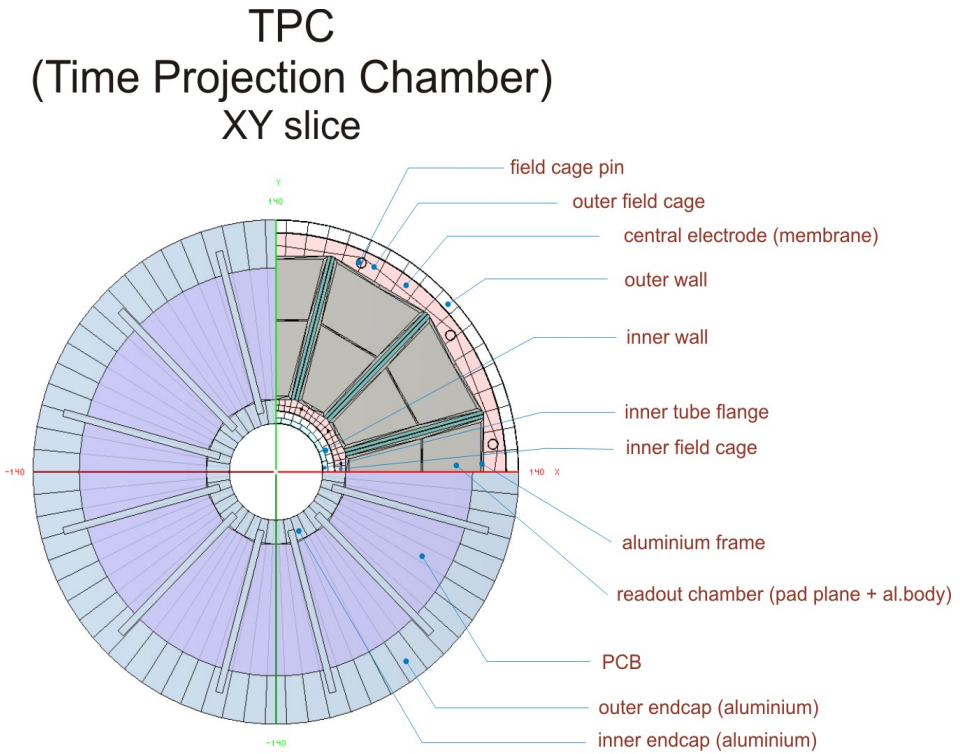


TPC with Straw tube tracker

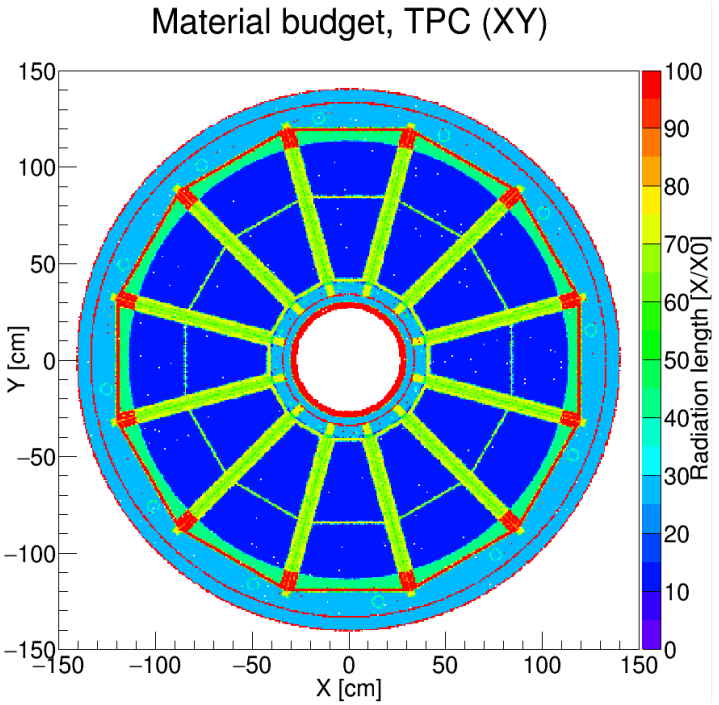


Straw tube tracker

MPD subdetectors



TPC detailed view

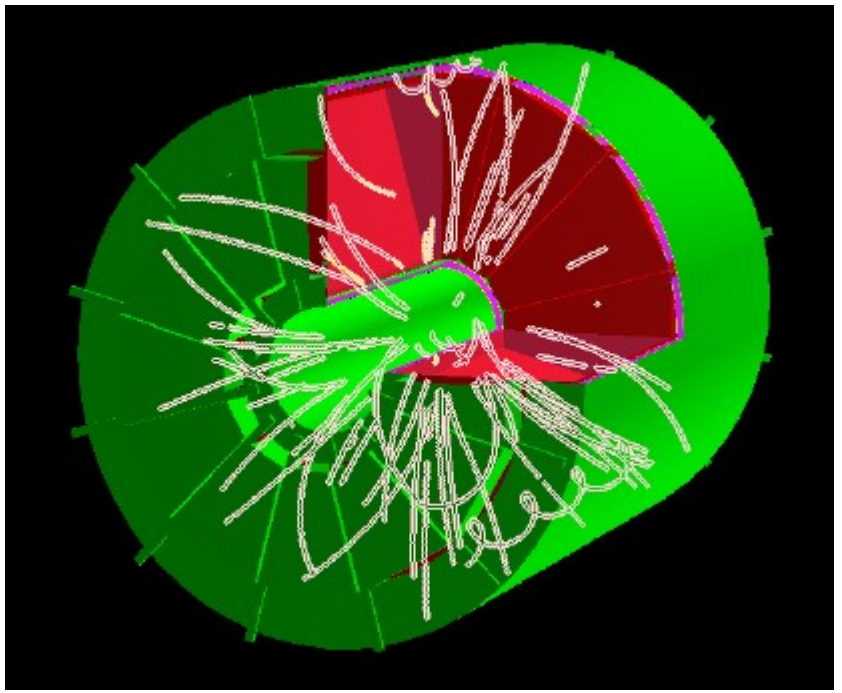


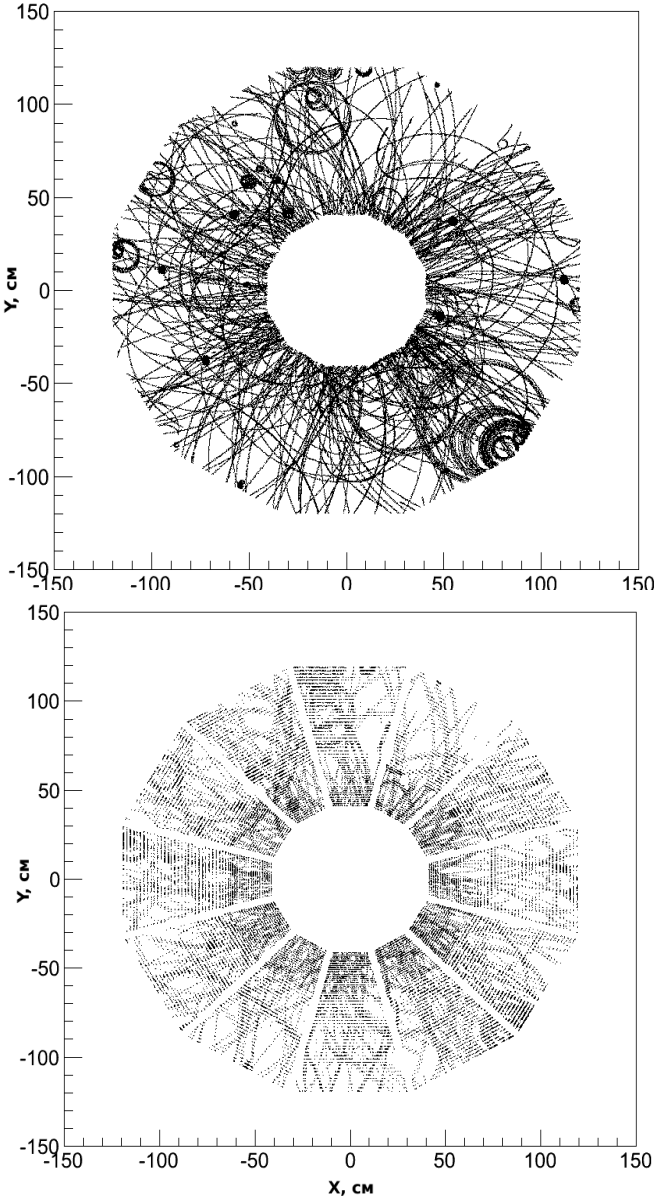
Radiation thickness

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

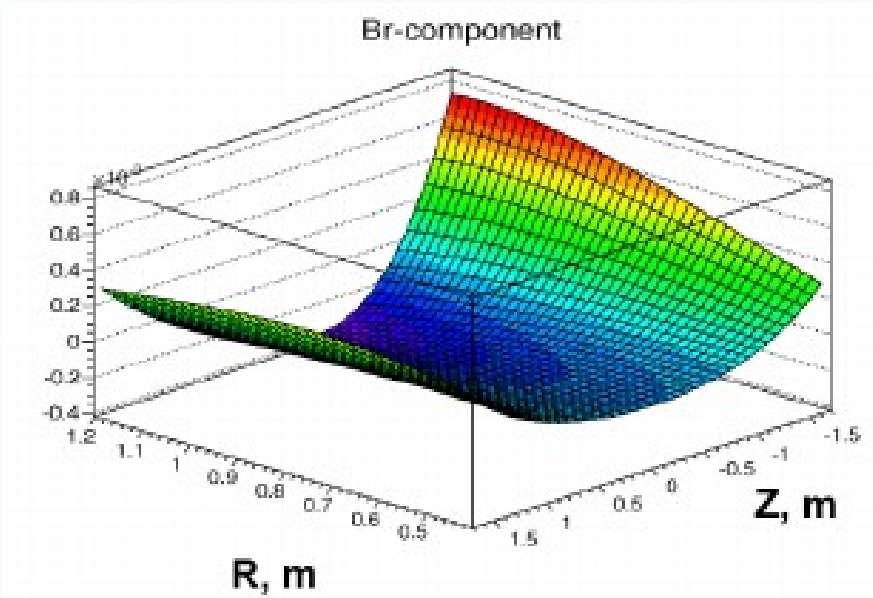
Clustering in TPC

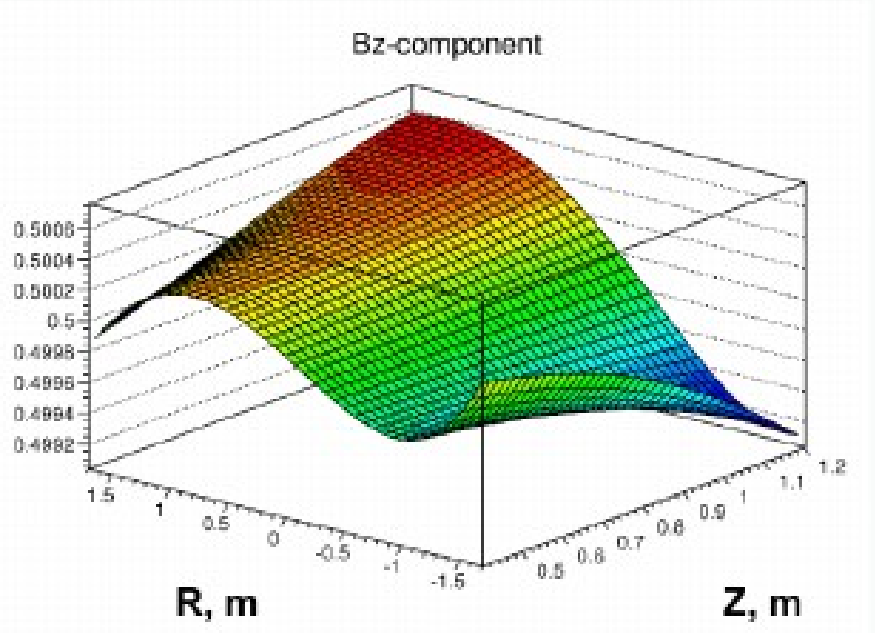




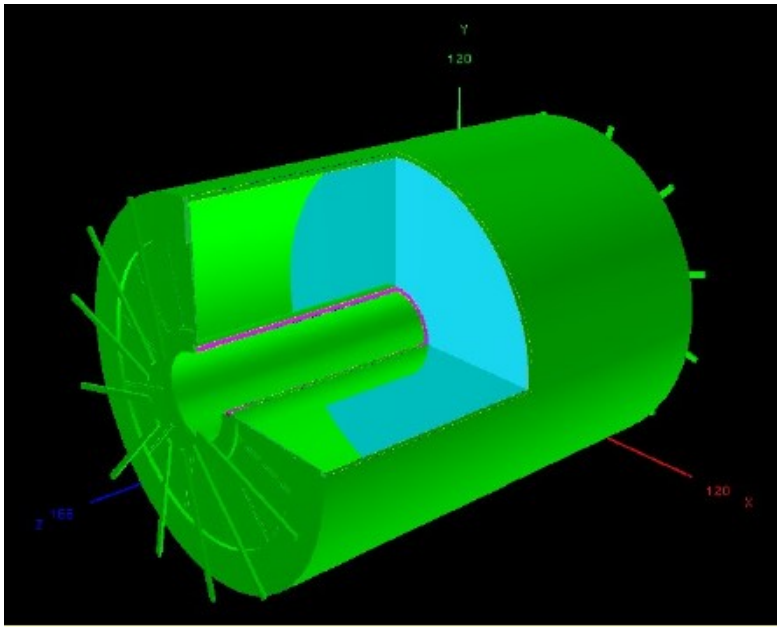
MPD magnetic field

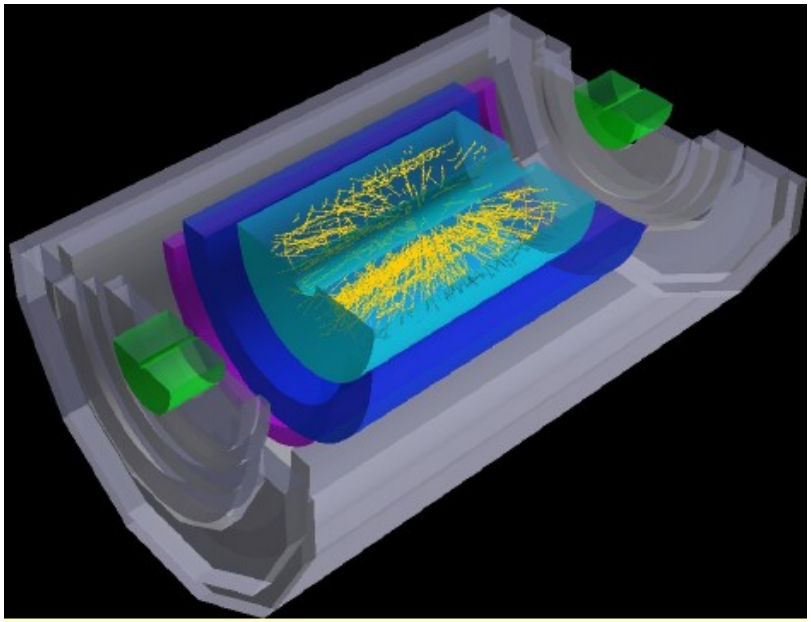
- Transition from a constant magnetic field to the real field map.
- Interpolation of the field between the map nodes using $L(r,z) = \sum_{i=1}^{5}\sum_{j=1}^{5} a_{ij} r^i z^j$

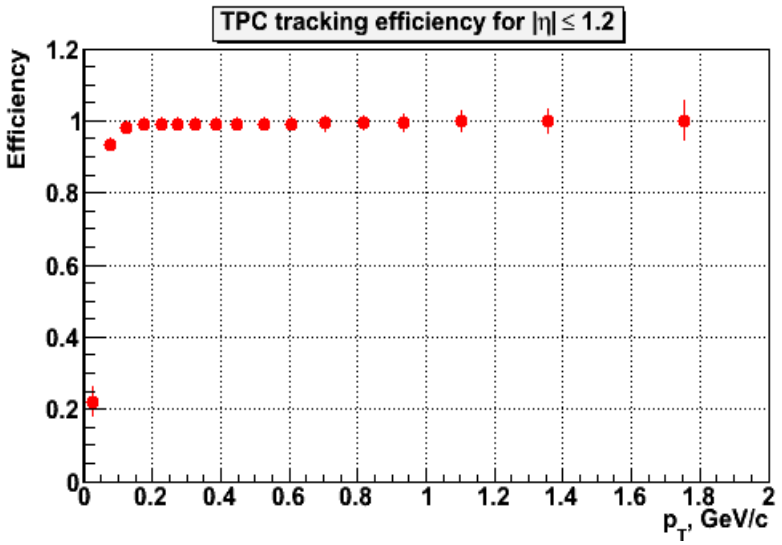


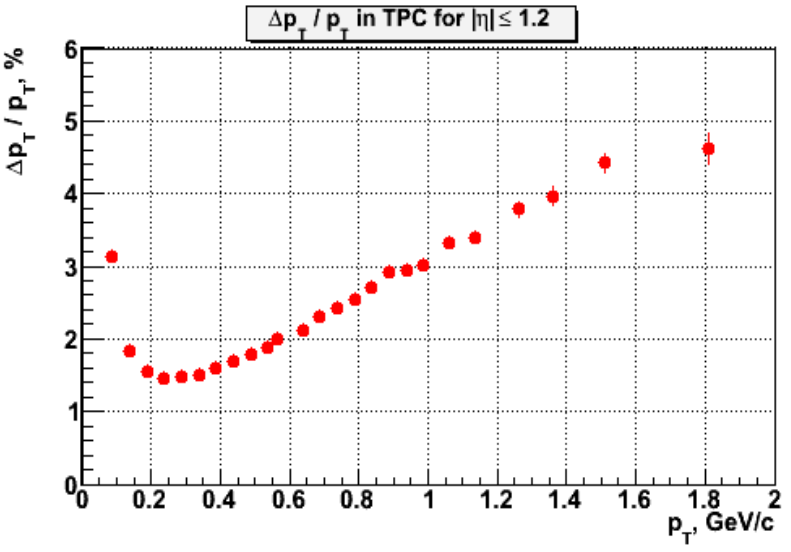


Tracking

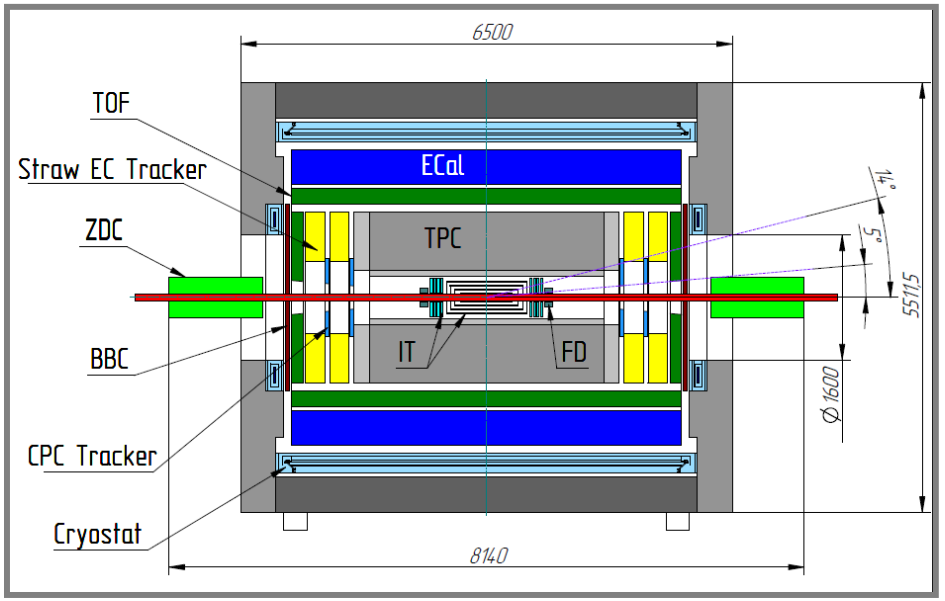


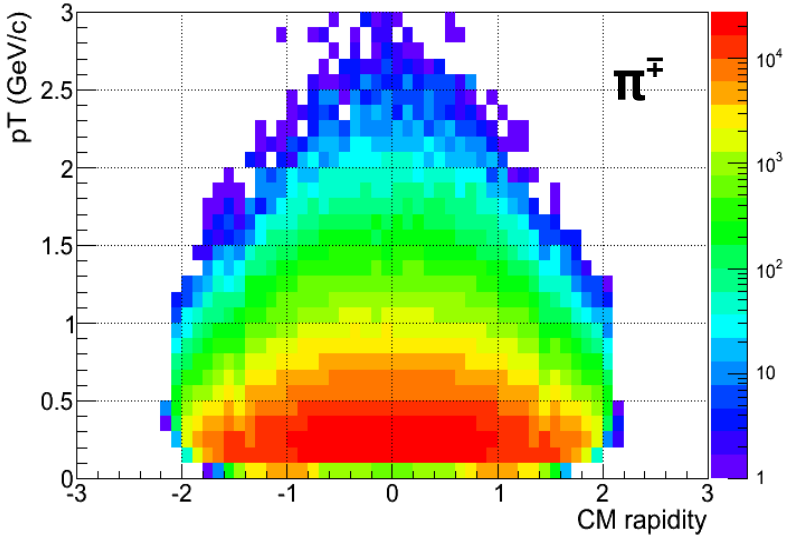


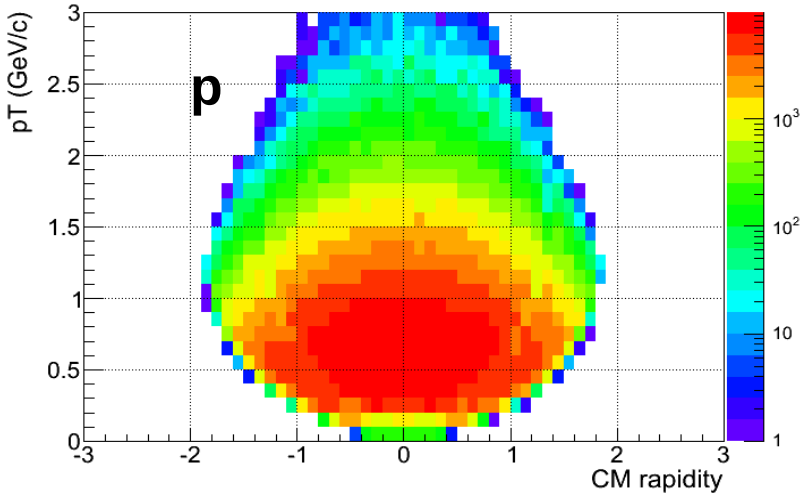

TPC tracking efficiency for |η| ≤ 1.2
Efficiency
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
p_T, GeV/c

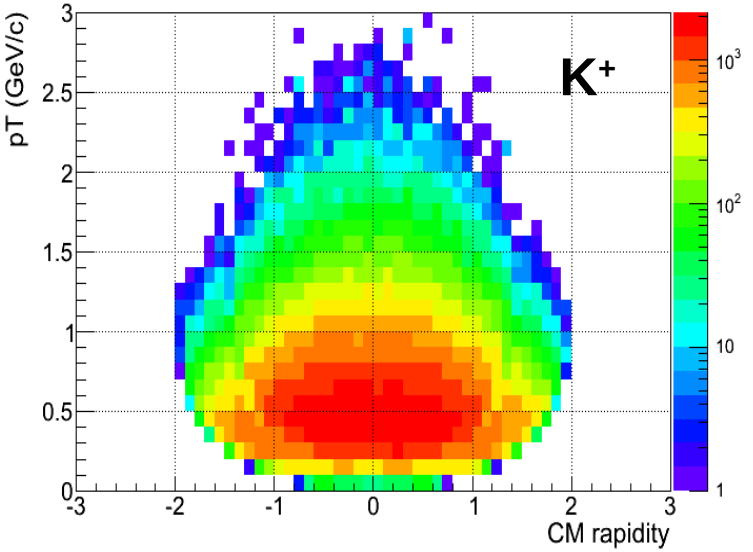

Δp_T / p_T in TPC for |η| ≤ 1.2
Δp_T / p_T, %
6
5
4
3
2
1
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
p_T, GeV/c

MPD acceptance

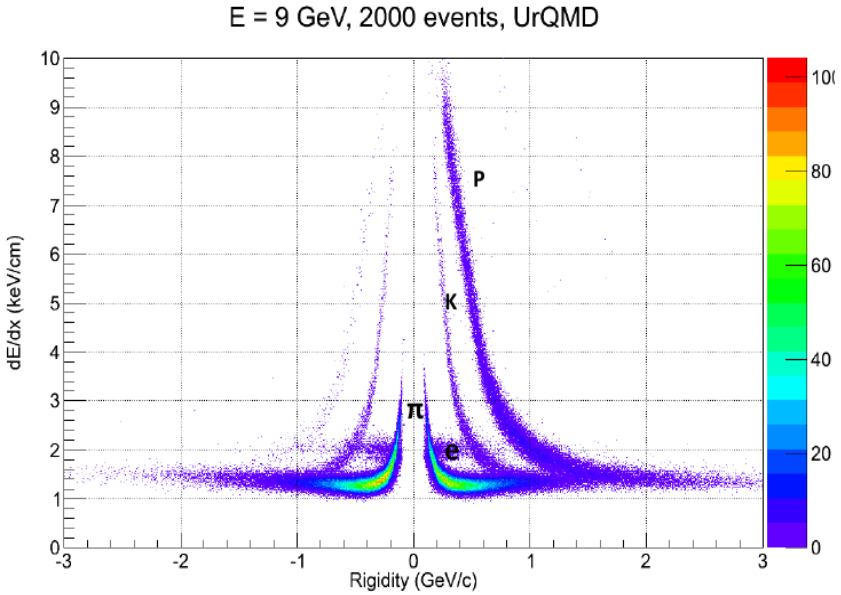








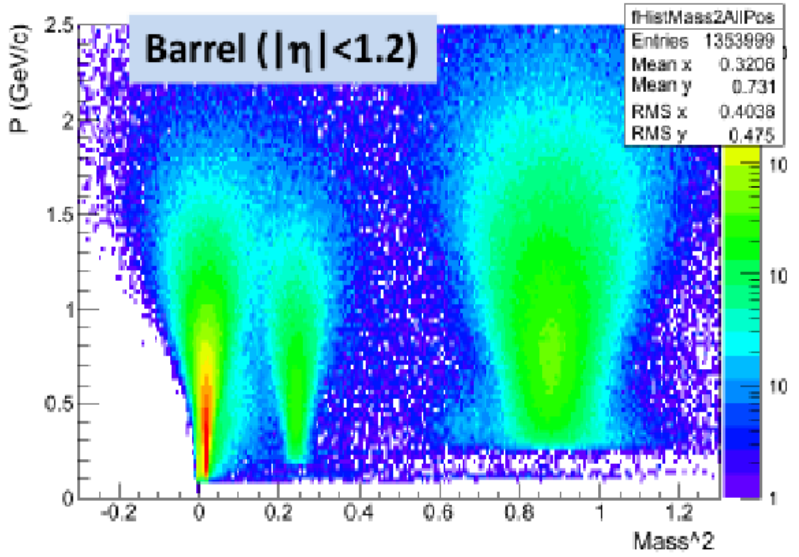
Charged particle ID in TPC & TOF

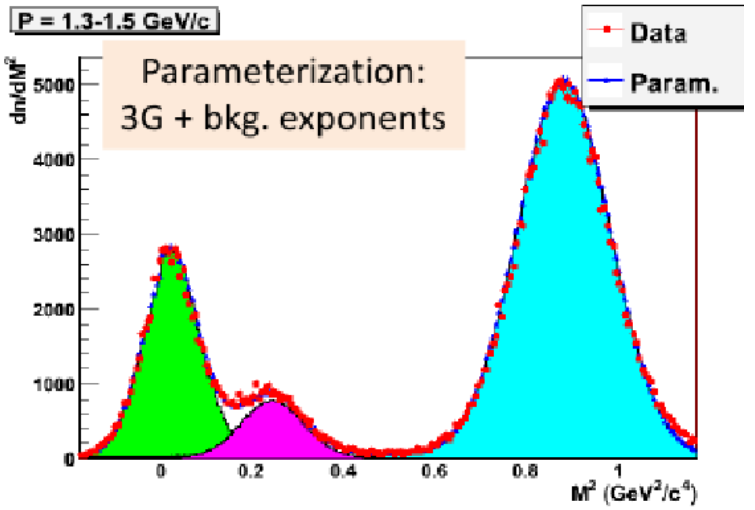


TPC
PID: Ionization loss (dE/dx) Separation:
e/h – 1.3..3 GeV/c
π/K – 0.1..0.6 GeV/c
K/p – 0.1..1.2 GeV/c

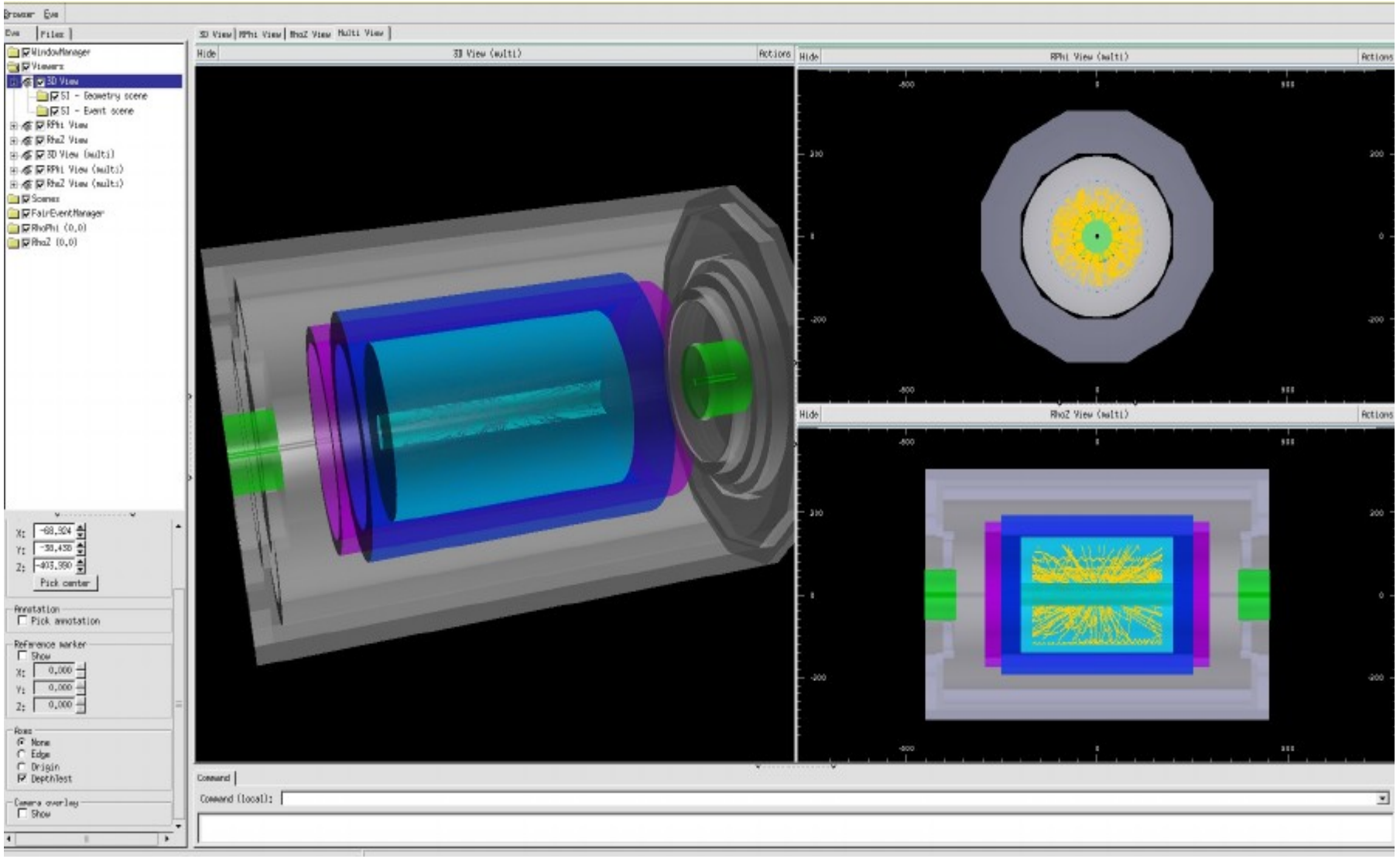
MPD PID (TOF):

- 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



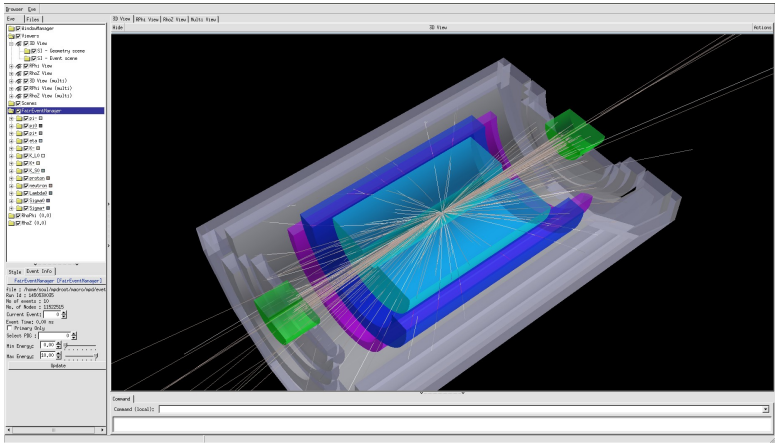


MPD Event Display

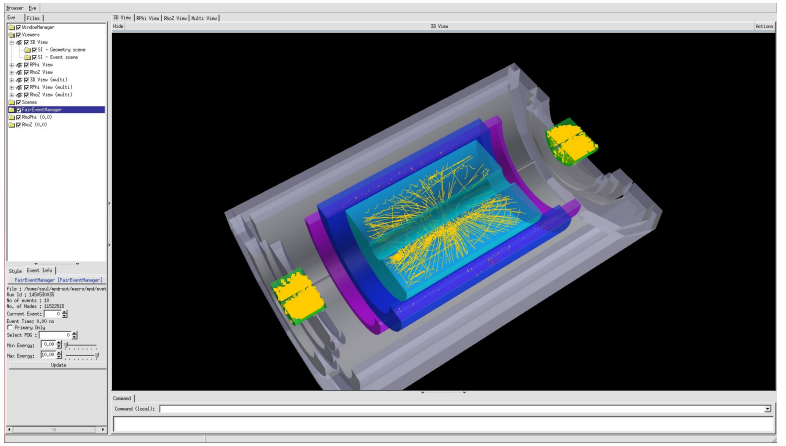


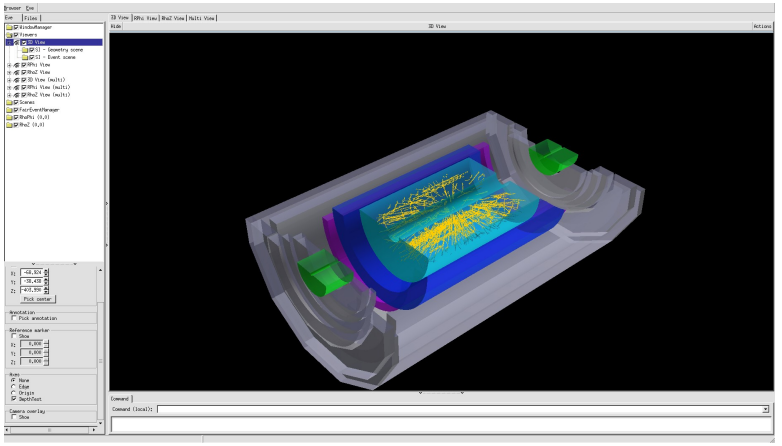
Particle reconstruction in TPC

GeoTracks

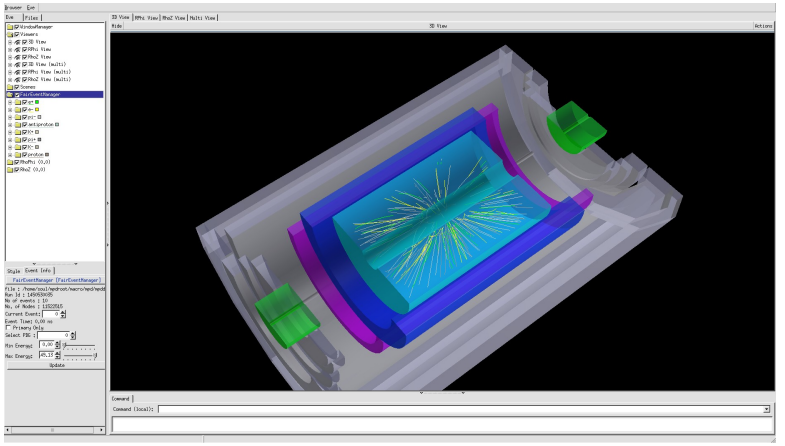


MC points



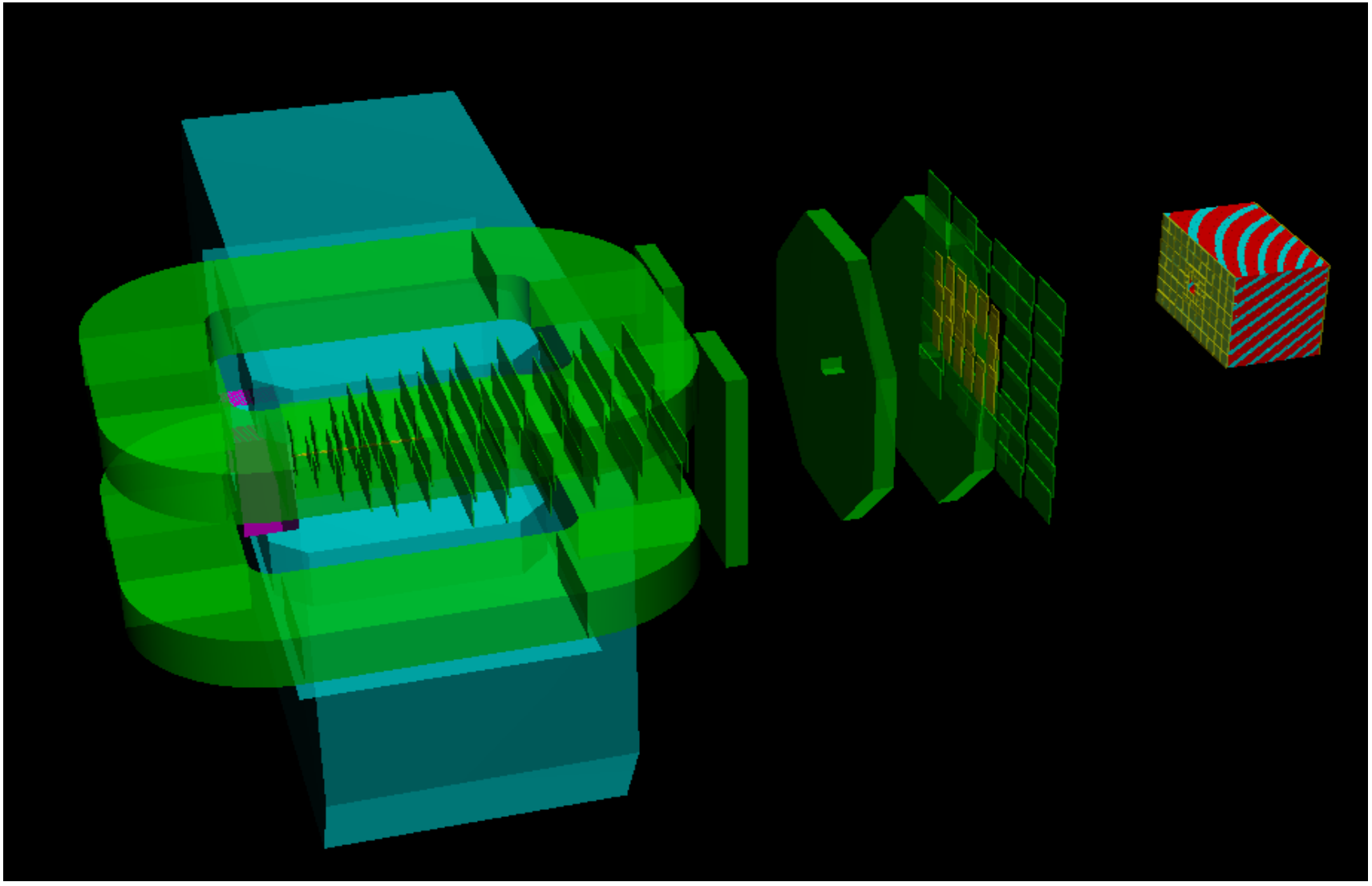


Hits

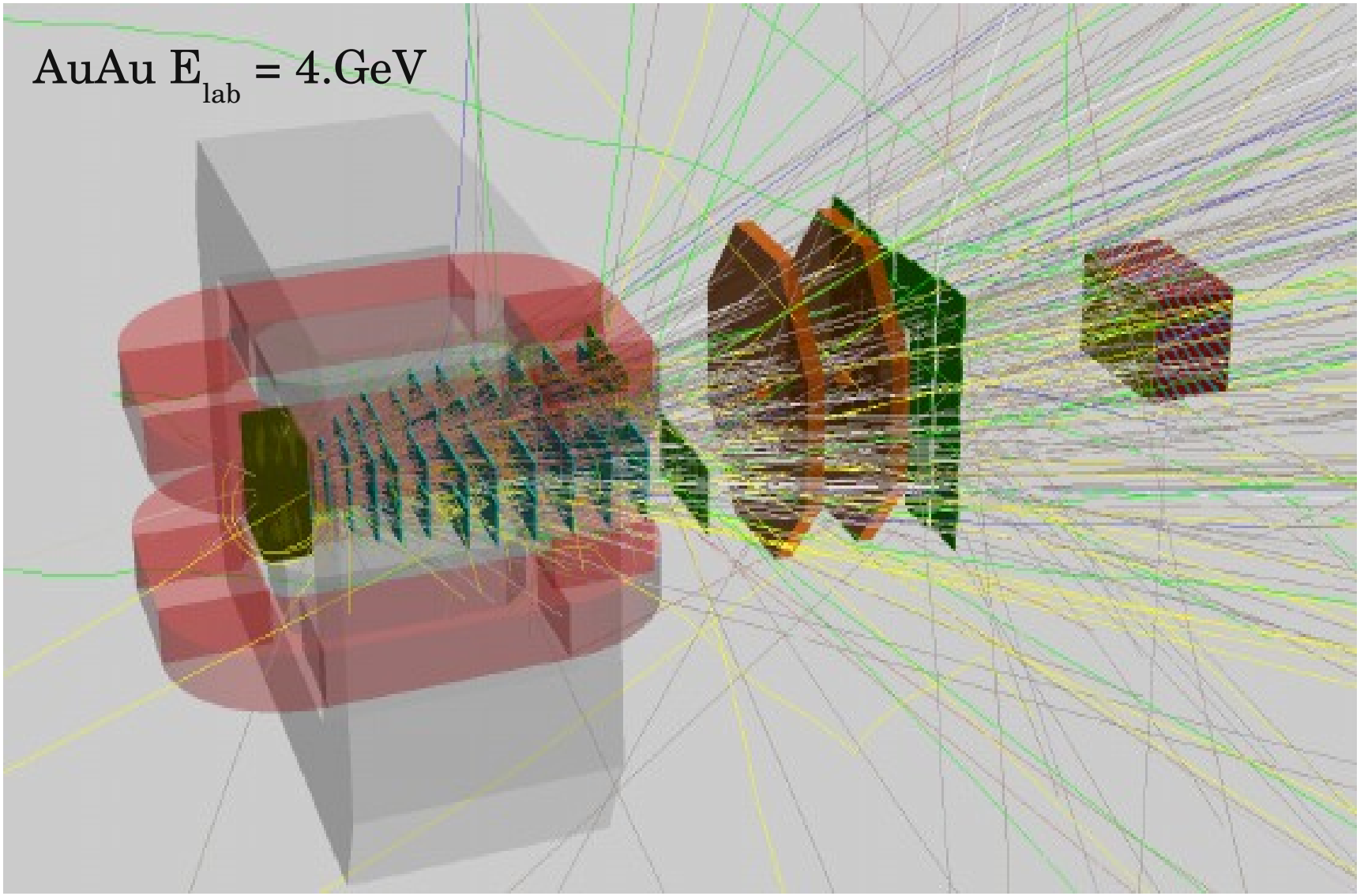


reconstructed tracks

Baryonic Matter @ Nuclotron

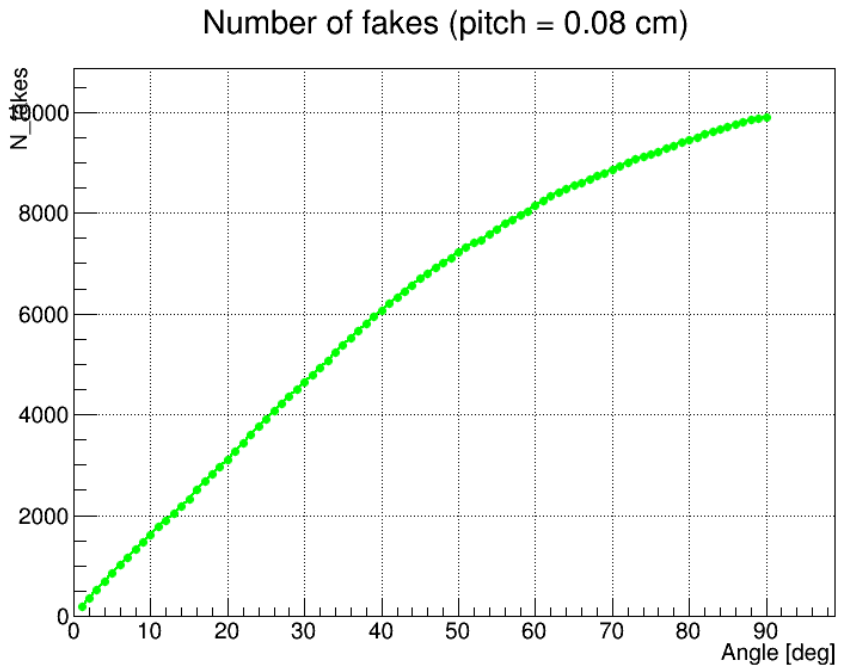


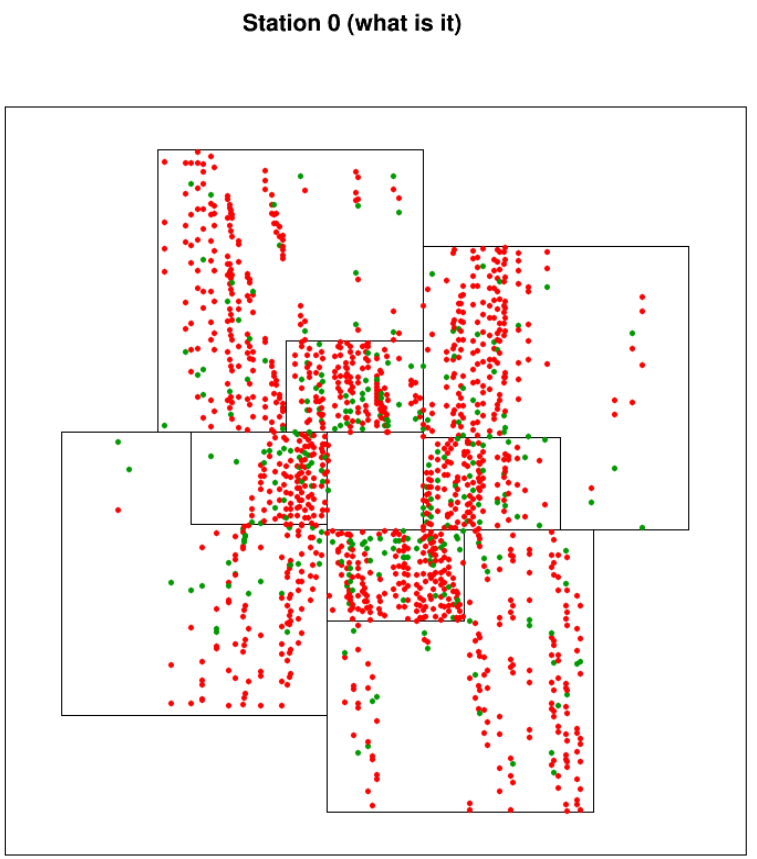
Monte-Carlo tracks



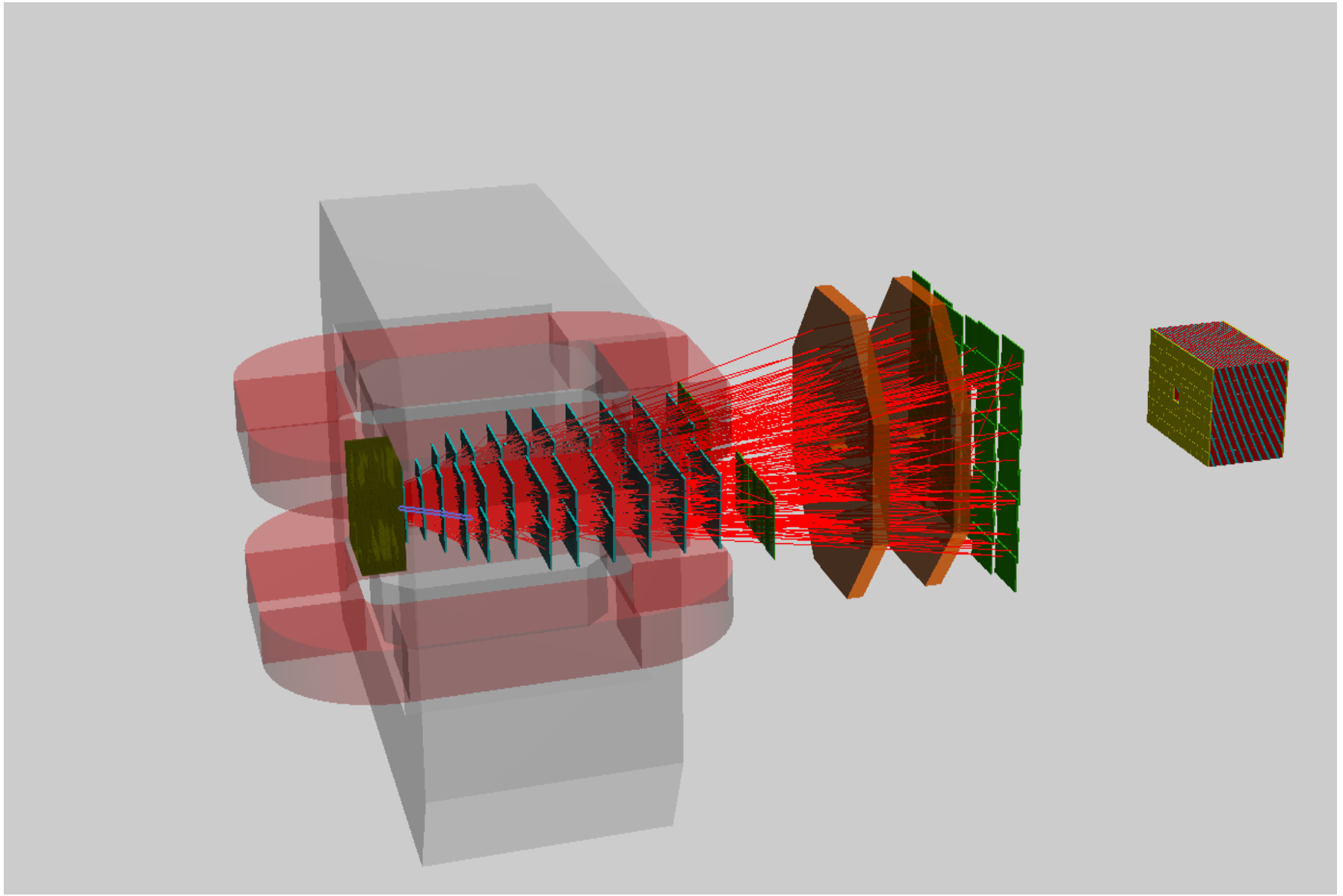
GEM hits reconstruction

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





Reconstructed tracks

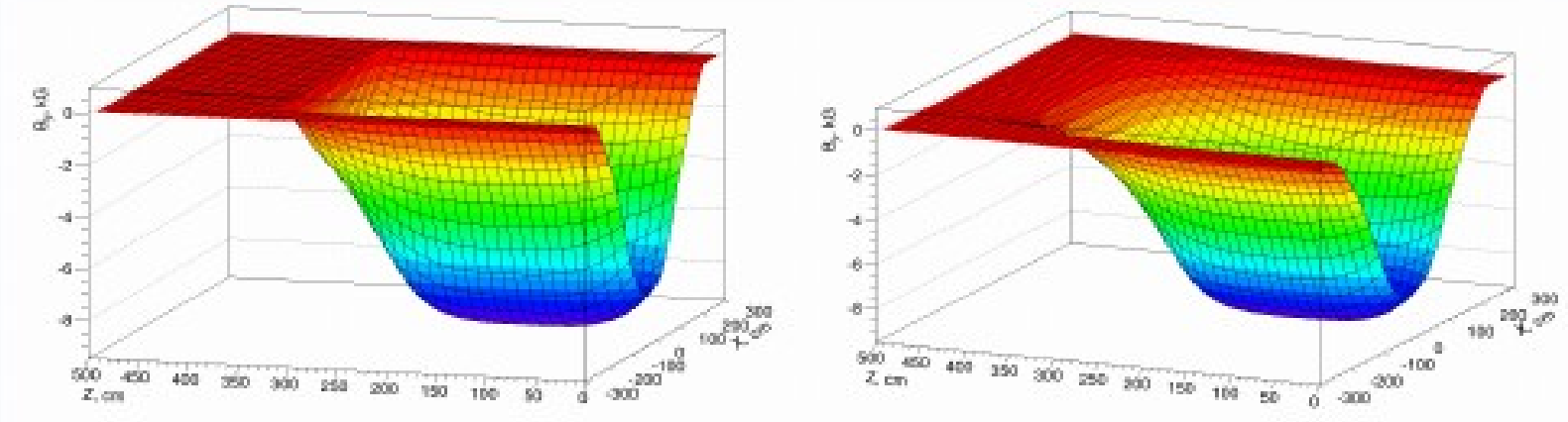


BM@N magnetic field

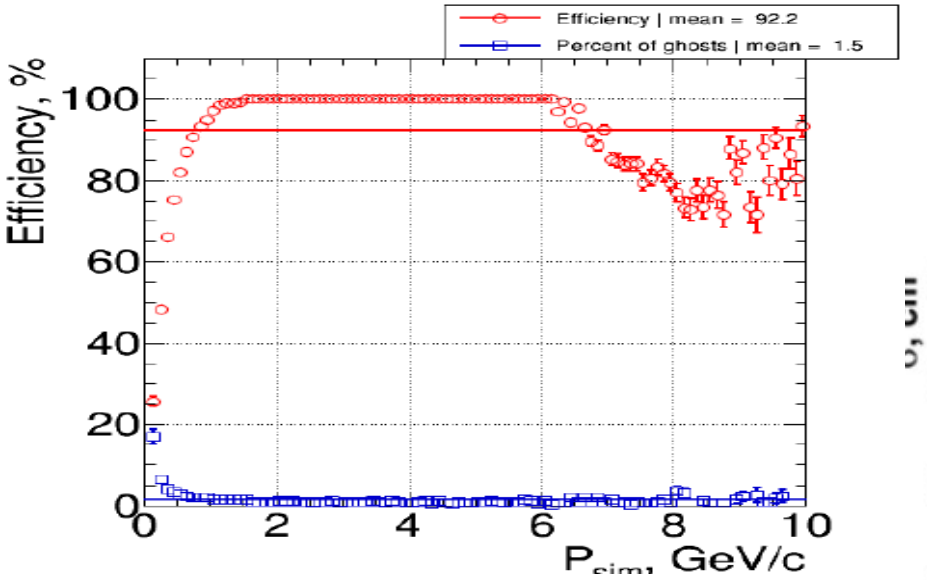
- Transition from a constant magnetic field to the real field map.
- Interpolation of the field between the map nodes.
- Extrapolation of the field map to out-of-magnet region.

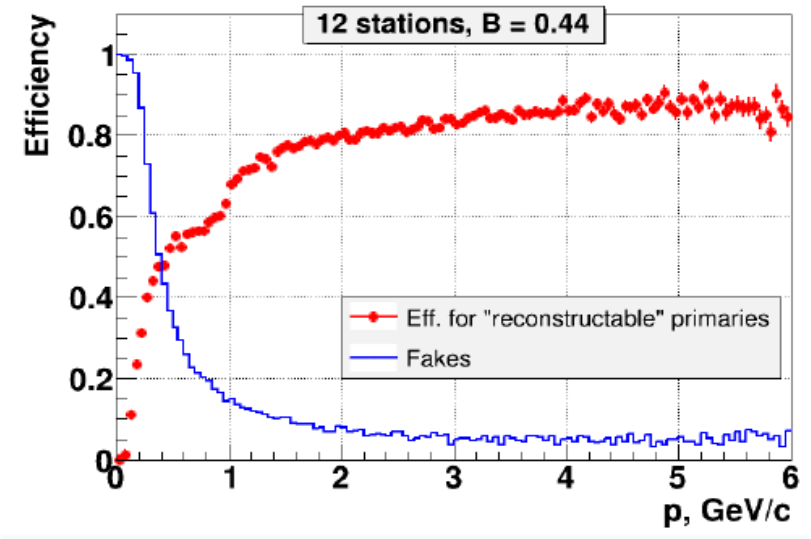
$$B_{comp}(x,y,z) = C(x,y) \cdot e^{-\frac{(z-\mu(x,y))^2}{2\sigma(x,y)^2}}$$

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

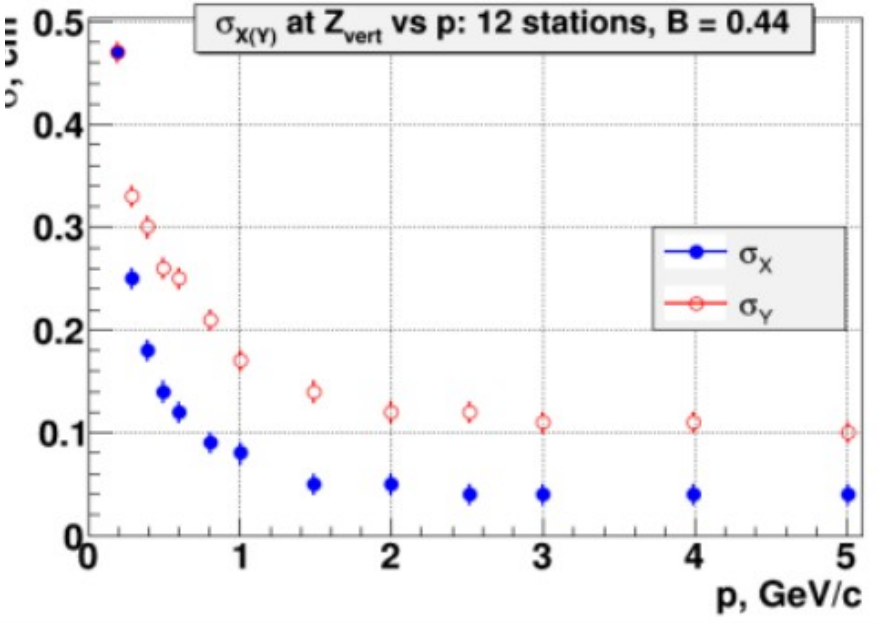


Tracking in GEM





L1 (CBM) tracking
Implementation for GEM

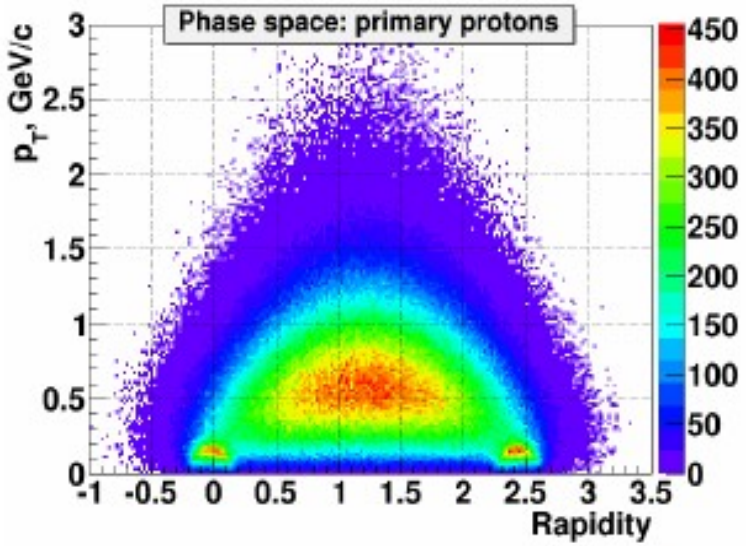


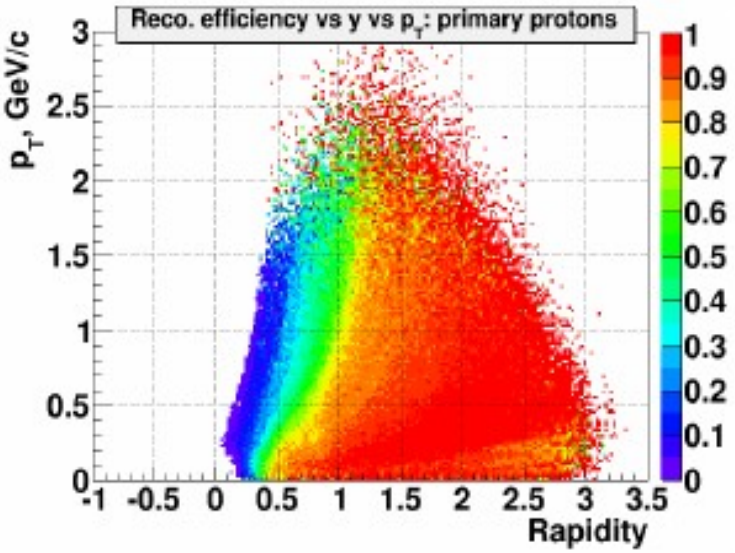
Coordinates transformation
With LIT kalman filter

G.Ososkov presentation

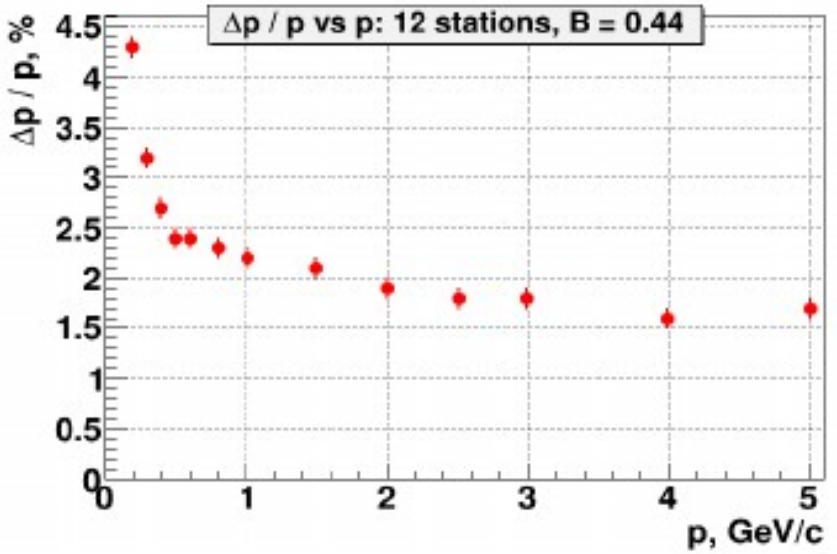
GEM tracker properties

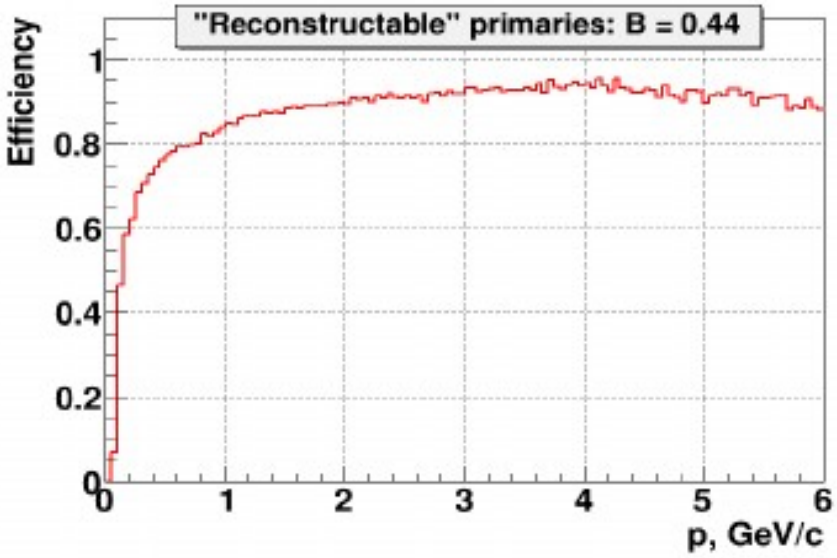
Phase space / acceptance to primary protons:



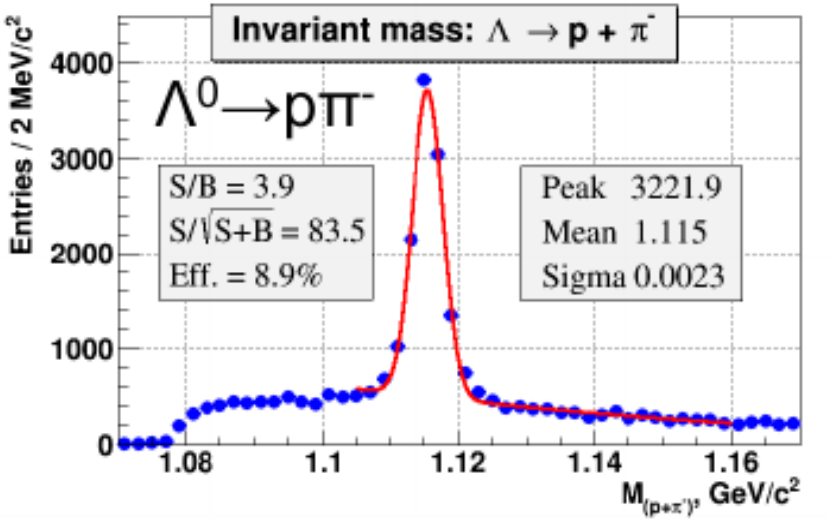


Momentum resolution / detection efficiency

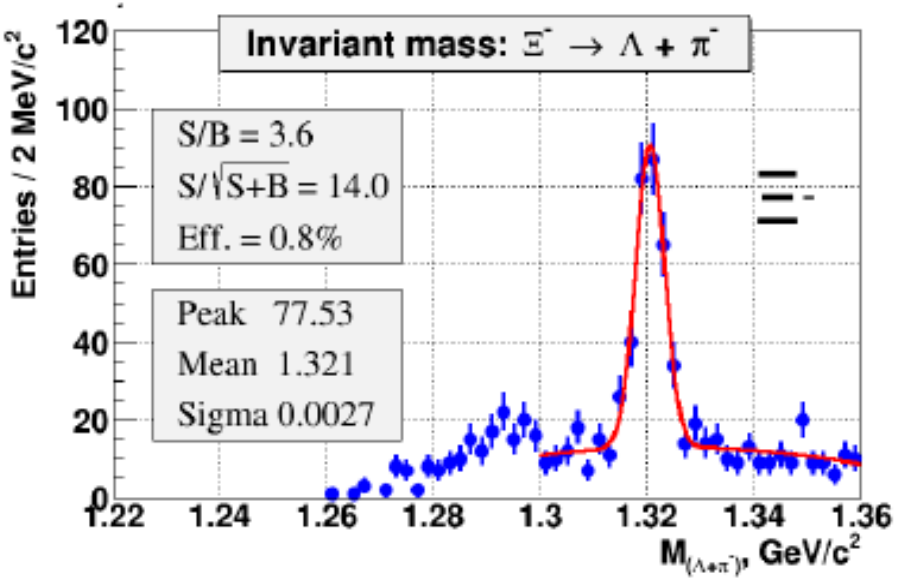




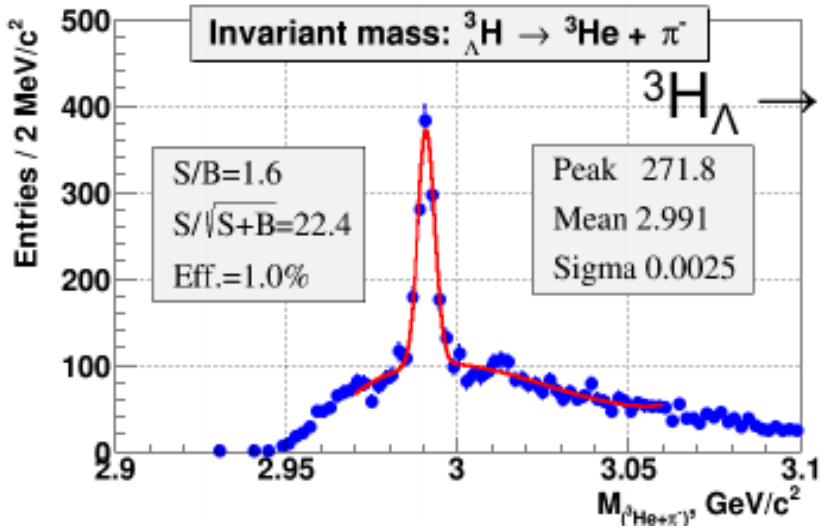
Physics at BM@N



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

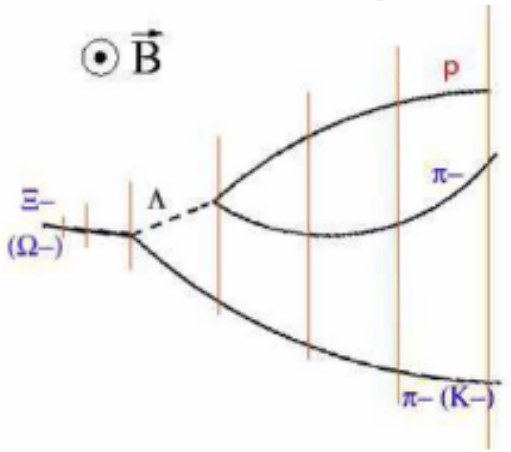


Au+Au, 4.5 AGeV, 2M central events

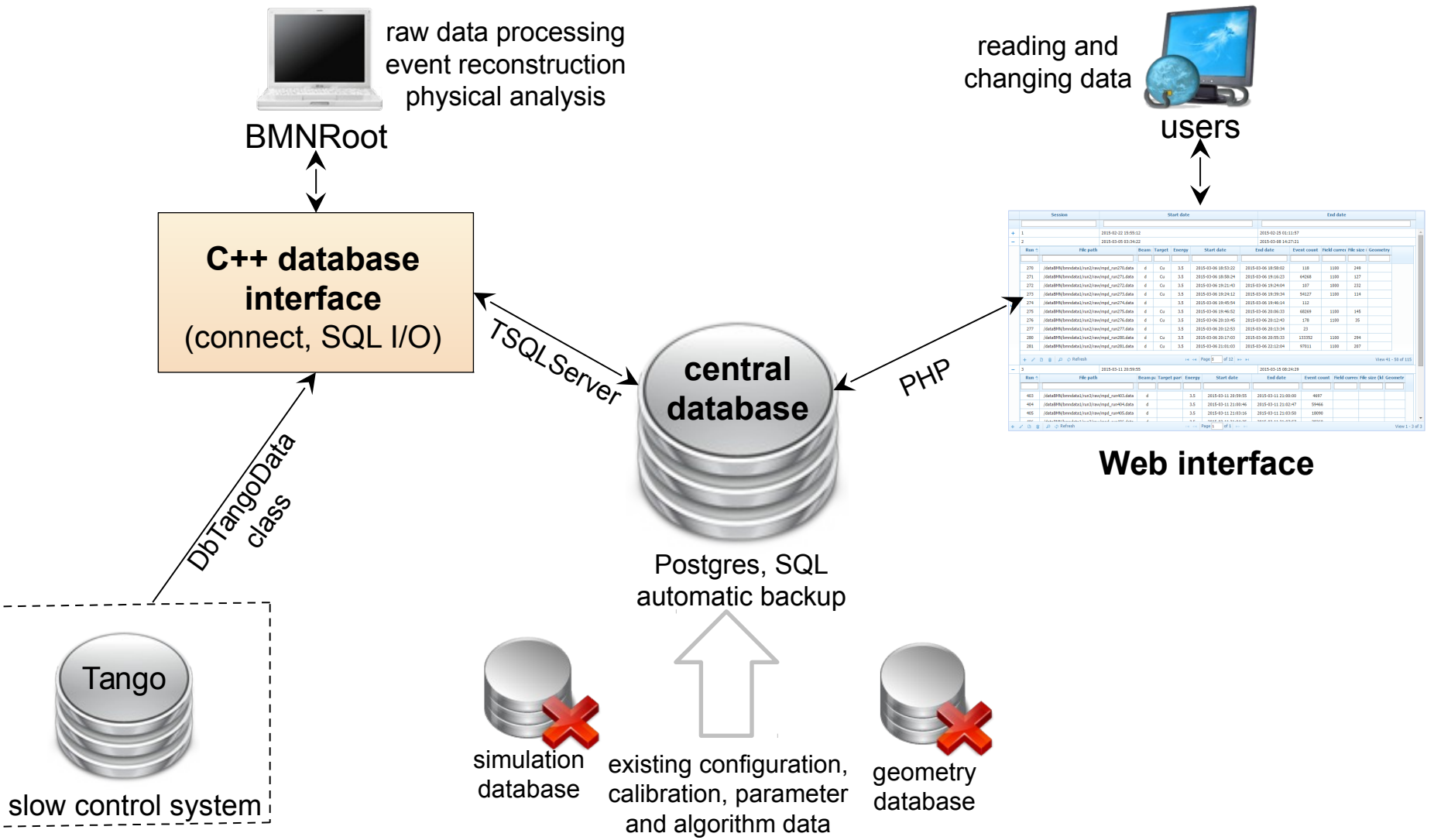


$^3H_\Lambda \rightarrow {}^3He\ \pi^-$

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



Data... Data... Database



NICA distributed computing

LHEP
NICA cluster

WUT
Poland

Sosny
Belarus

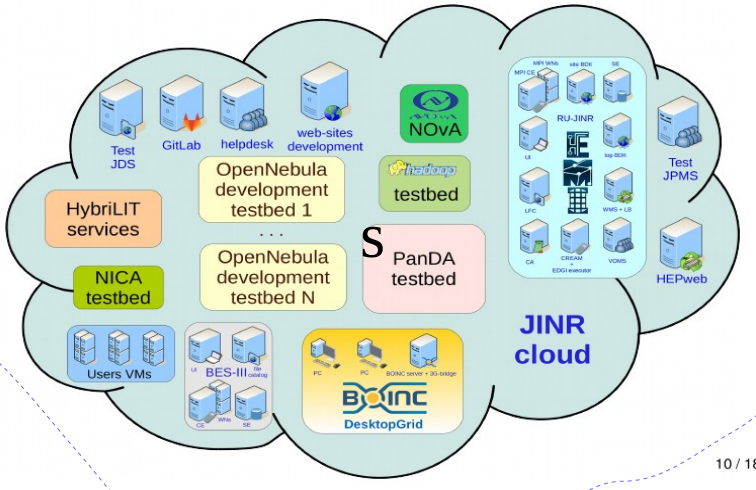
LIT

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



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

MONTE CARLO GENERATORS for NICA/FAIR physics

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

} Nuclear fragments

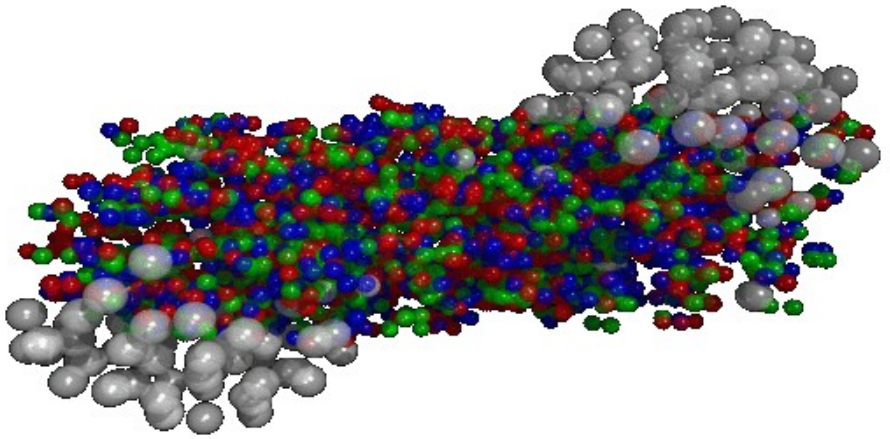
- Parton Hadron String Dynamics
- Hybrid UrQMD
- EPOS

} Femtoscopy

} Flows

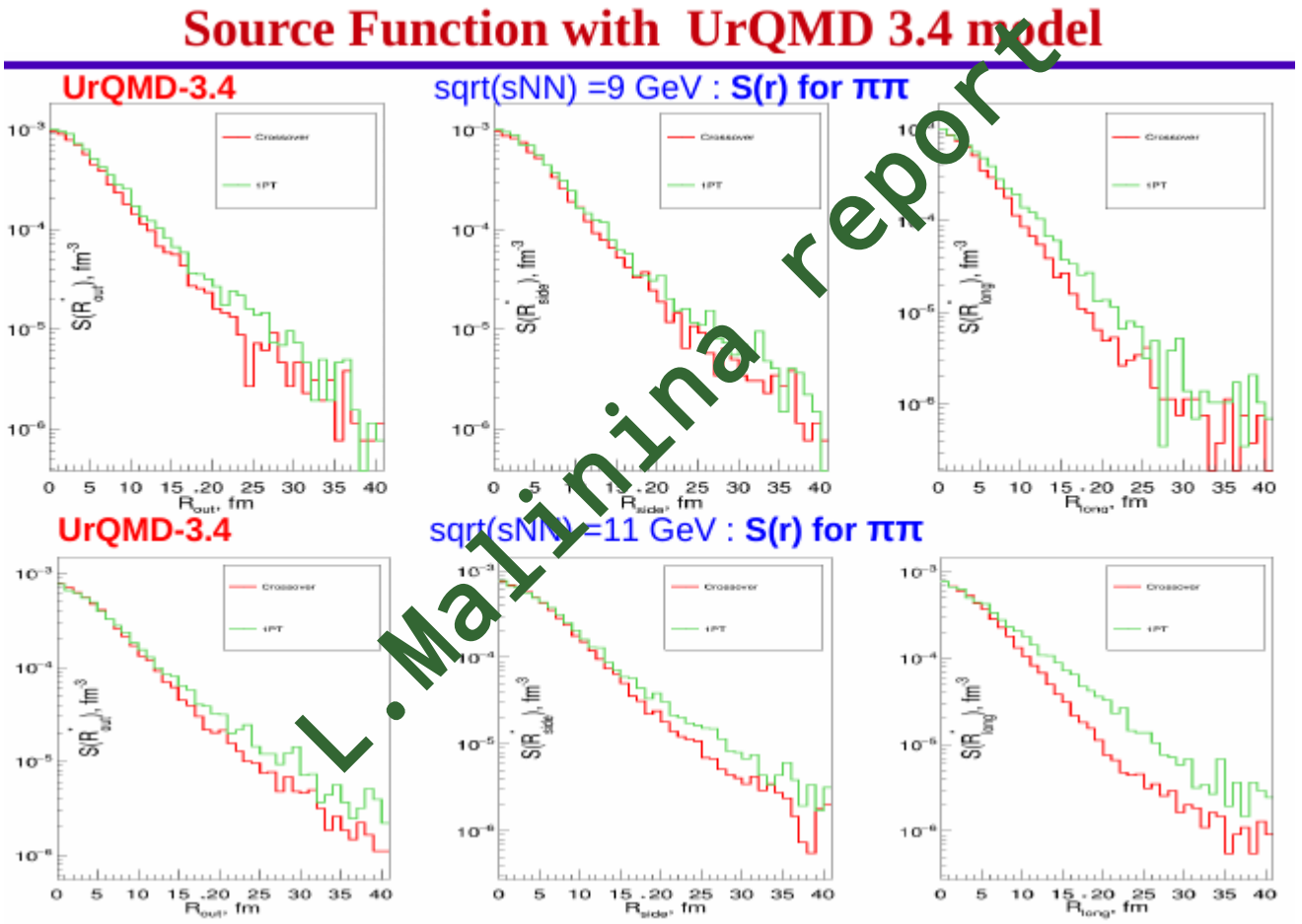
- vHLLE UrQMD
- 3 Fluid Dynamics model

baryon stopping power



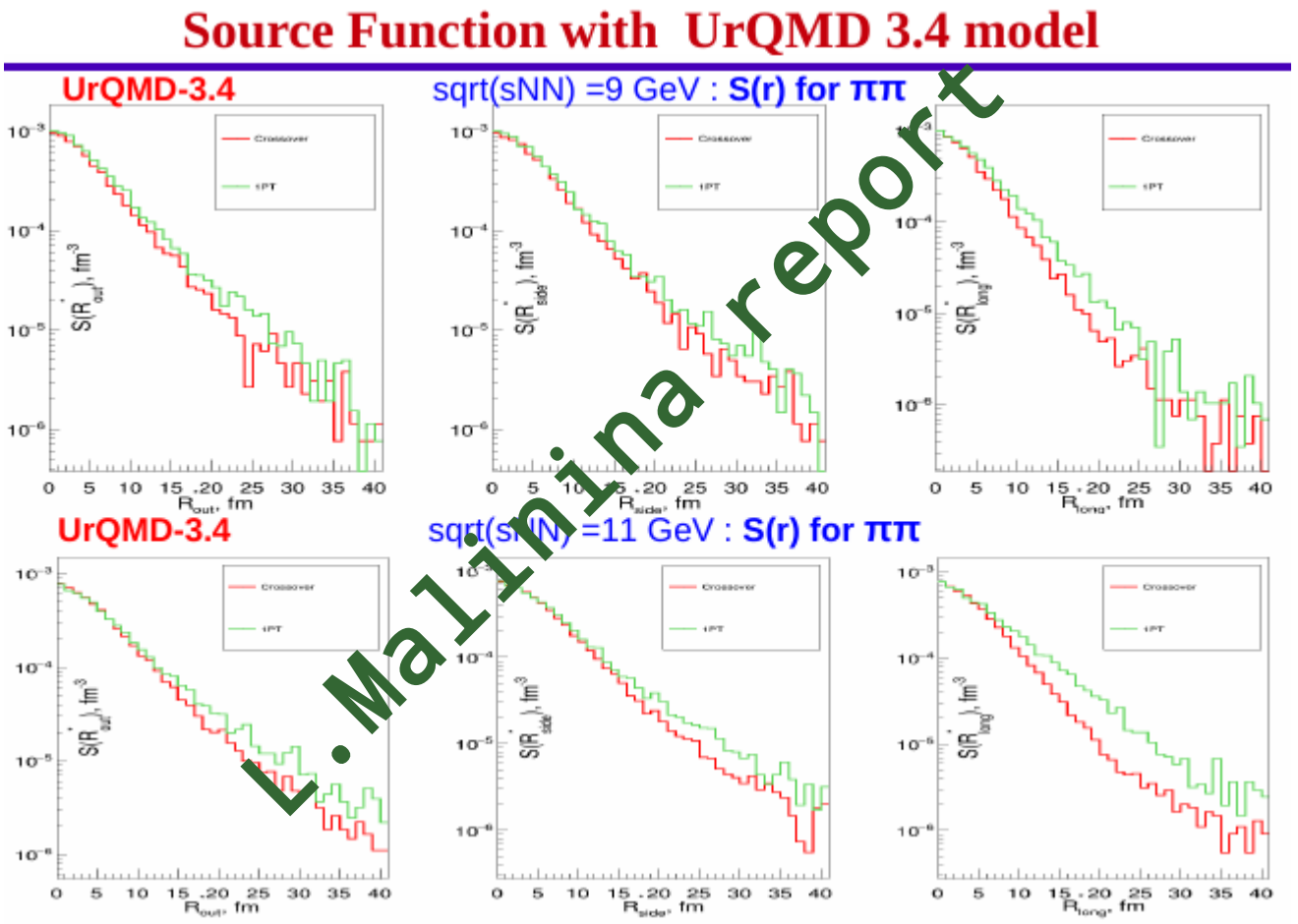
vHLLE + UrQMD model

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



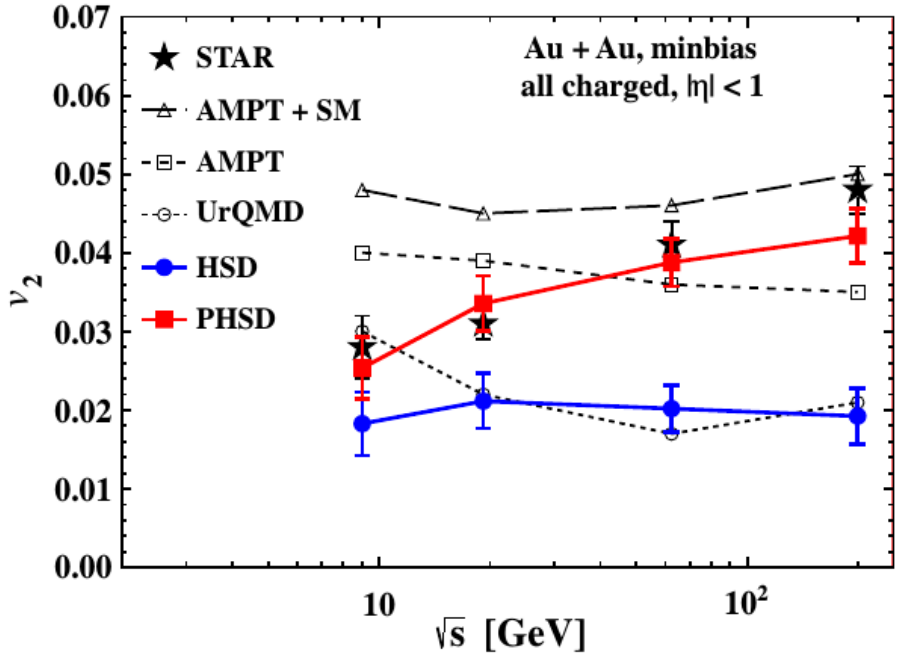
UrQMD 3.4 model

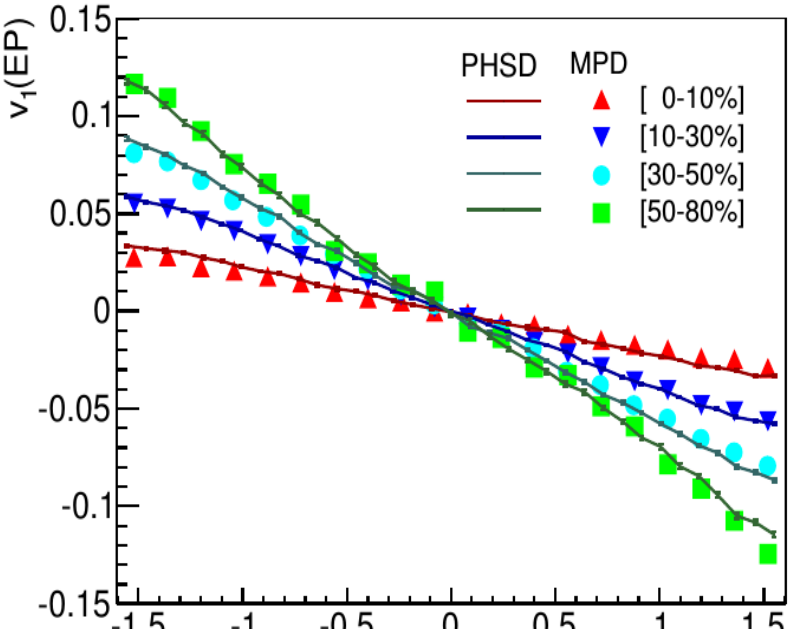
Source Function with UrQMD 3.4 model for ππ at 5; 7 ; 9; 11 GeV

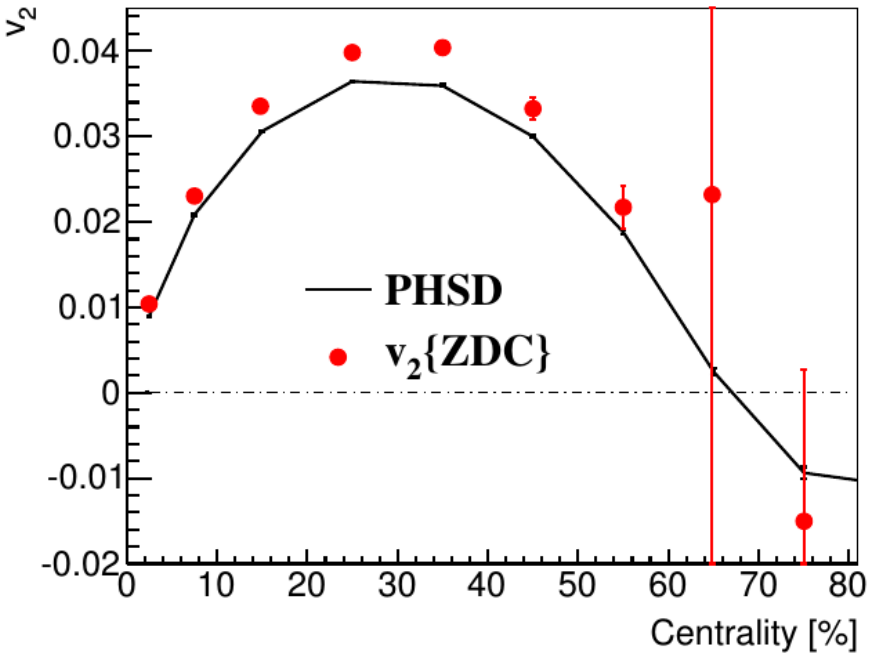


PHSD Model: Flows @ MPD

V.Voronyuk

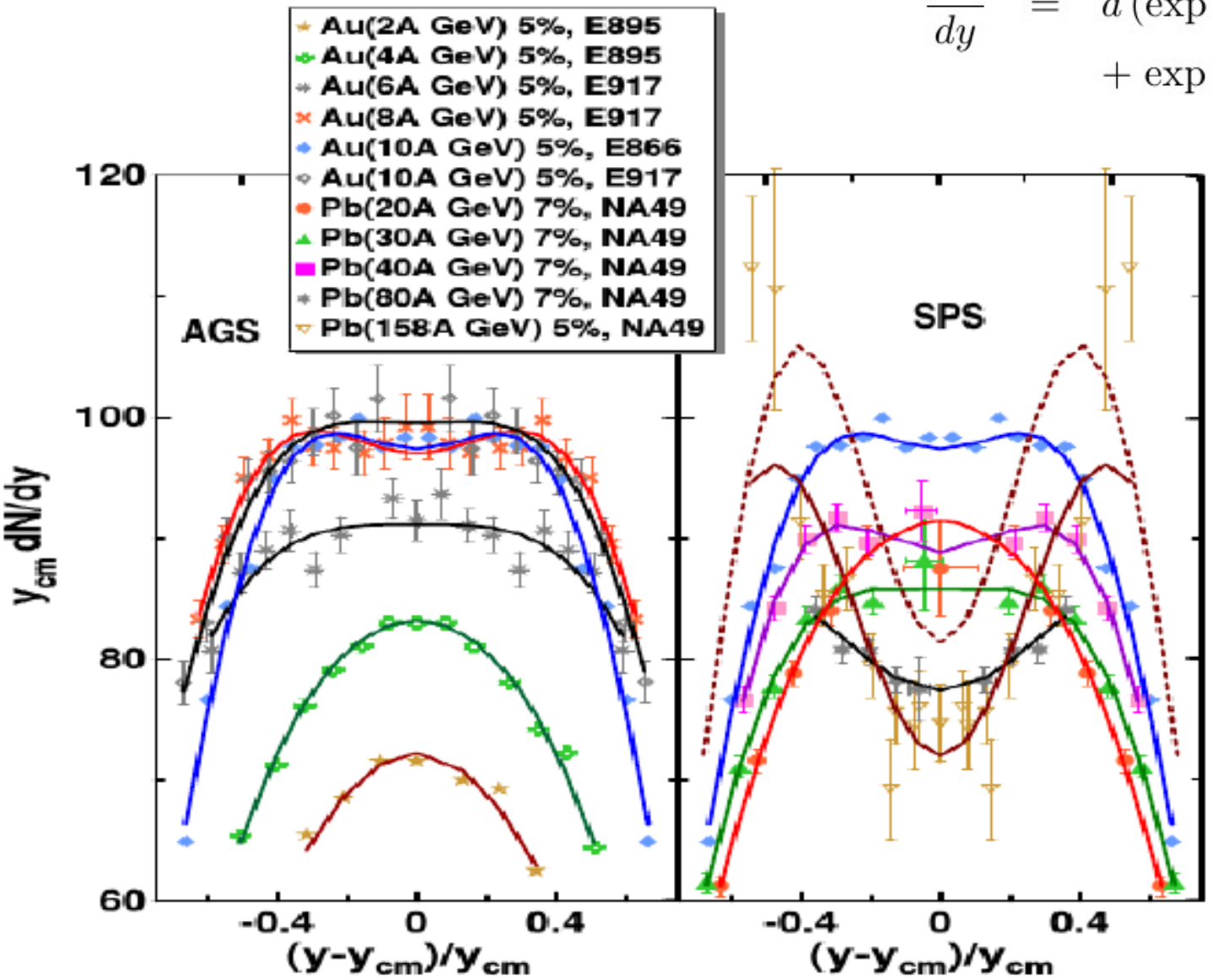






Baryon stopping power

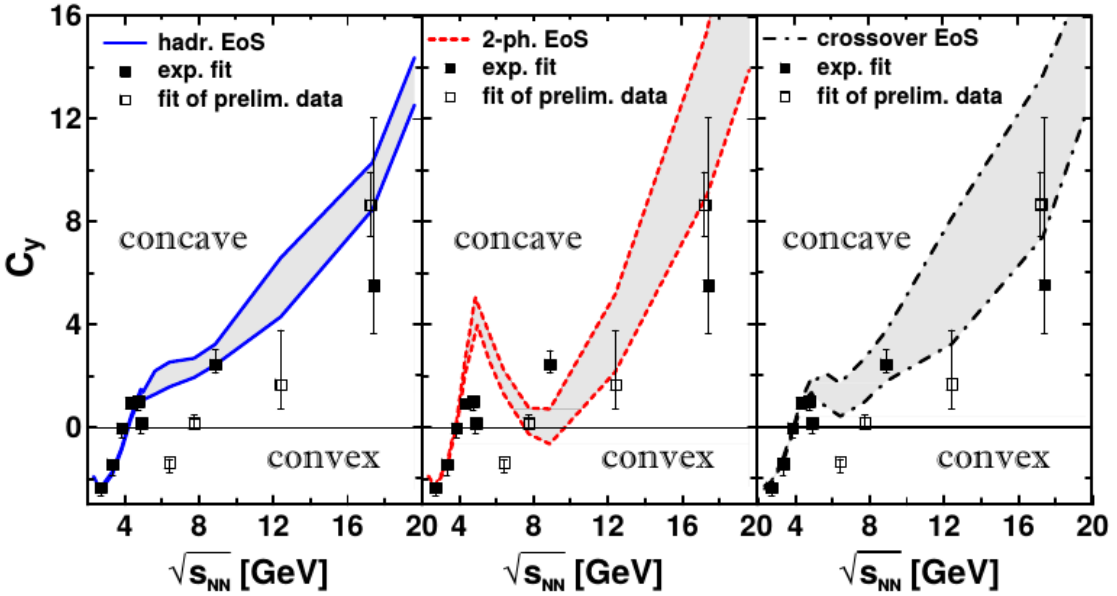
$$\frac{dN}{dy} = a\left(\exp\left\{-(1/w_s)\cosh(y-y_s)\right\} + \exp\left\{-(1/w_s)\cosh(y+y_s)\right\}\right)$$



3FD Model: Baryon stopping power

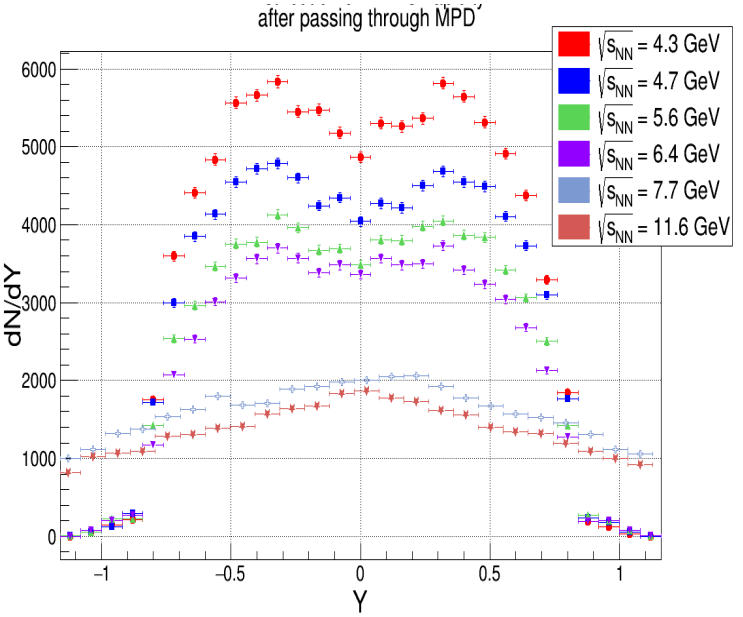
model

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



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

experiment



Thank you for attention