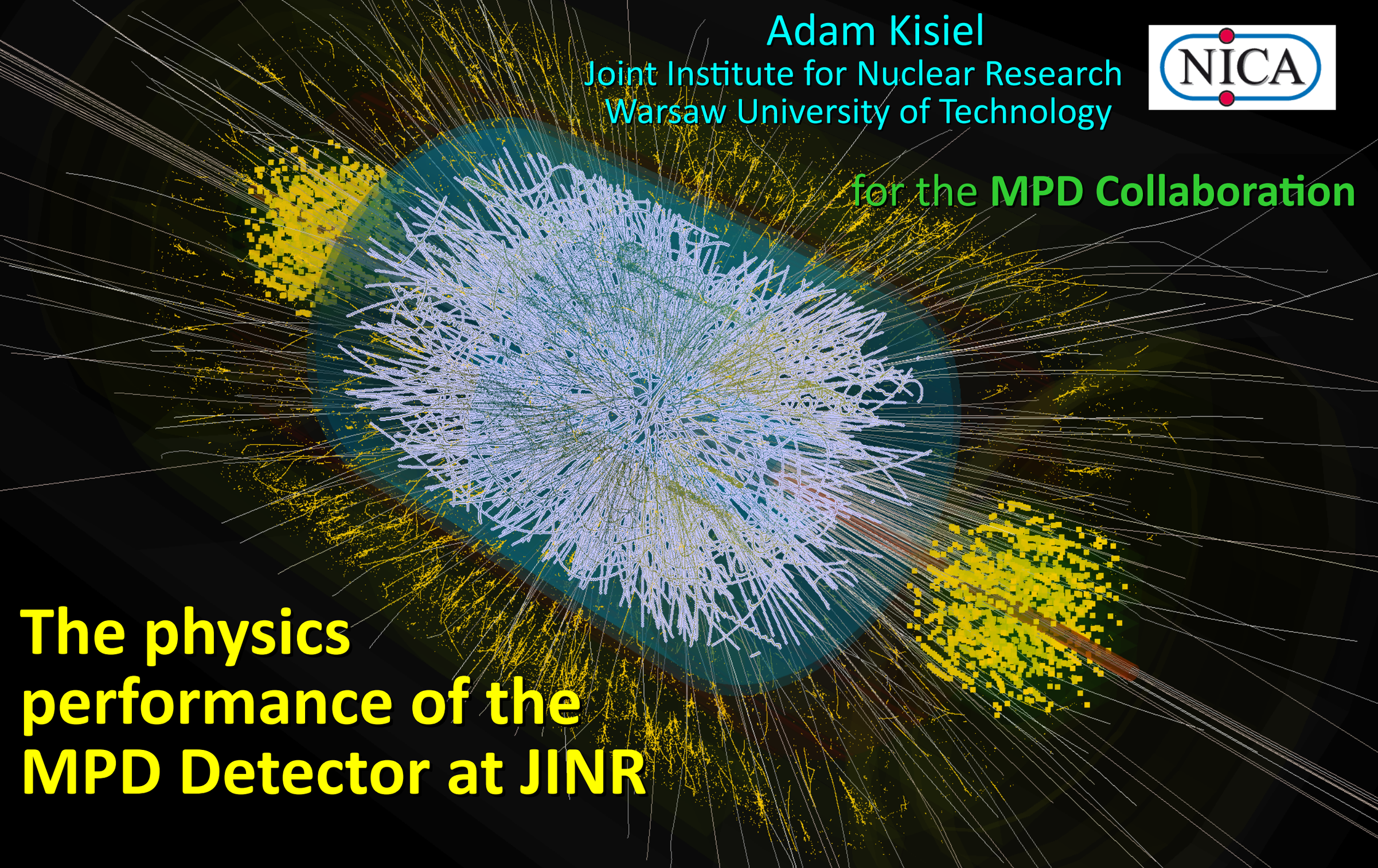
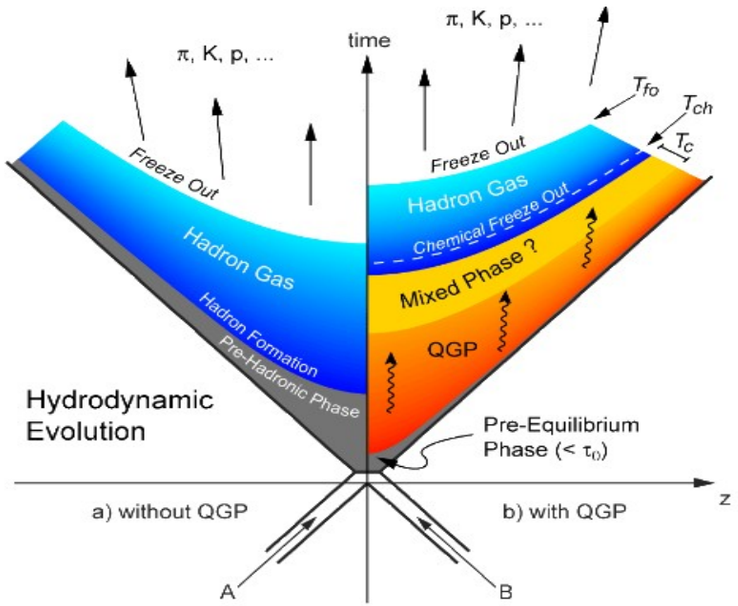


Adam Kisiel
Joint Institute for Nuclear Research
Warsaw University of Technology

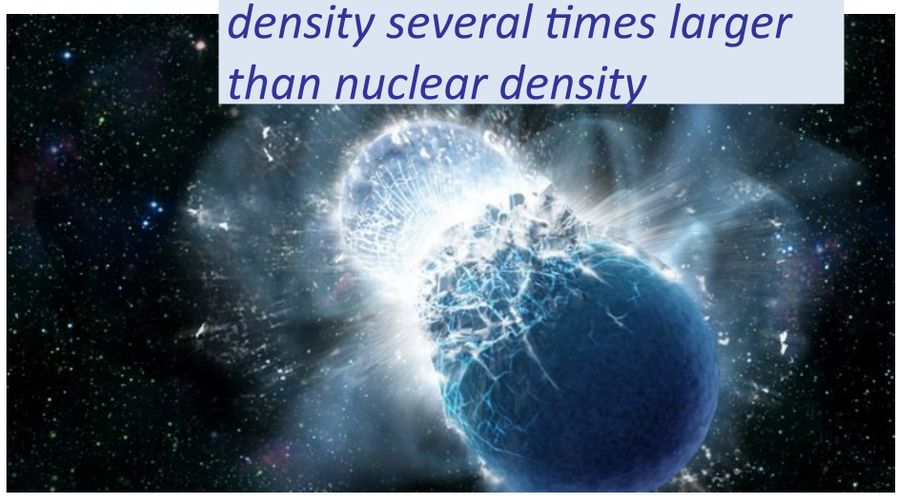
for the **MPD Collaboration**

The physics performance of the MPD Detector at JINR

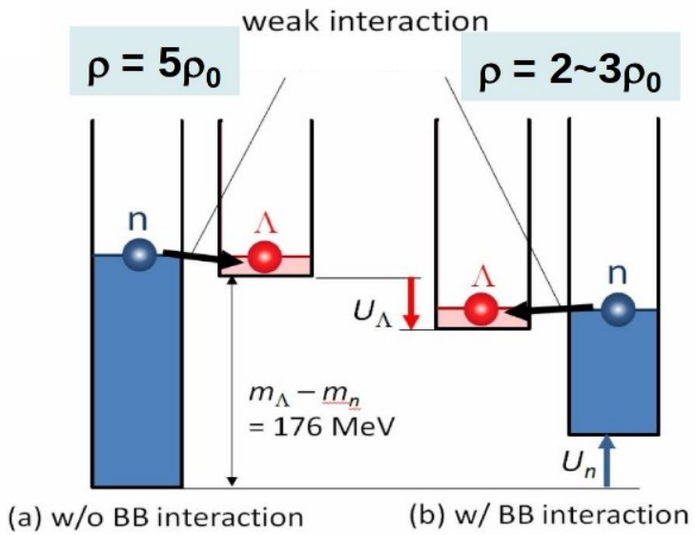
Unexplored phase space in QCD diagram



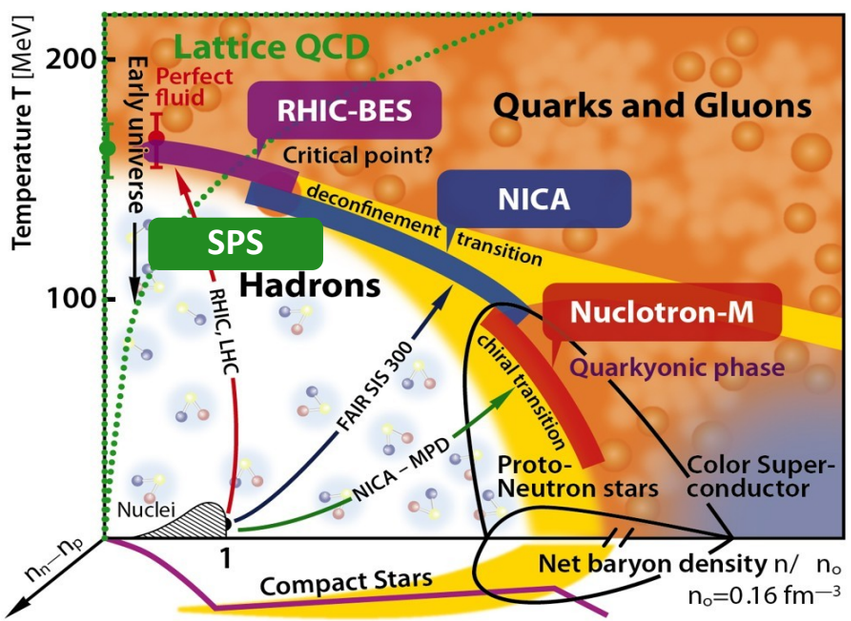
core of neutron stars reaches density several times larger than nuclear density

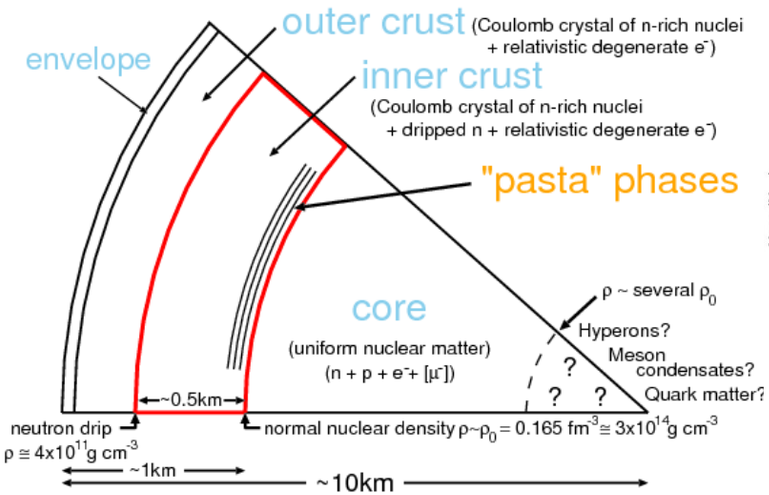


Credit: LIGO Collaboration

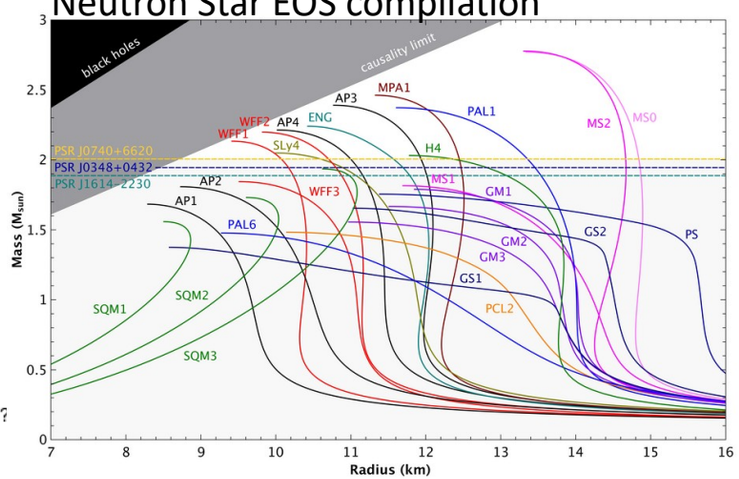


H. Tamura, Hadron 2017

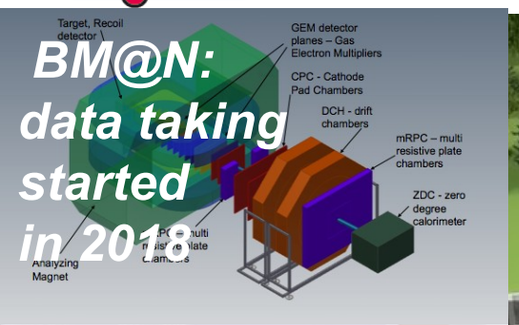




Neutron Star EOS compilation



NICA Accelerator Complex in Dubna



BM@N: data taking started in 2018

SPD TDR - 2021

SPD (Detector)

E-cooling

MPD (Detector)

BM@N (Detector)
Extracted beam

Collider - 2022

Collider

applied research infrastructure- 2021

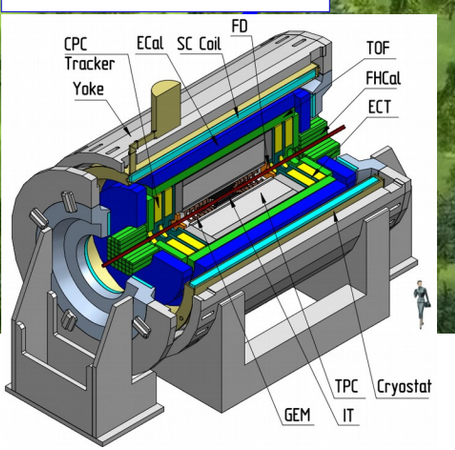
Nuclotron

Booster - 2020

Booster

Nuclotron (c=251,5 m)

MPD - 2021



NICA Center - 2021

Status of the Accelerator Complex

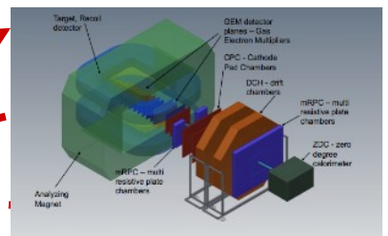
Linac HILac ← **KRION**

Linac LU-20 ← **Ion sources**

Booster (25 Tm)

storage of
$(2 \div 4)\times10^9$ ions,
acceleration
up to 600 MeV/u

Fixed Target Area



BM@N *put in operation in 2018*

Stripping (80%) $^{197}Au^{31+}$ => $^{197}Au^{79+}$

Nuclotron (45 Tm)

injection bunch
~ 2×10^9 ions
acceleration up to
1 - 4.5 GeV/u

Two SC collider rings

IP-2

$\sqrt{s_{NN}}$ = **4 – 11** GeV (Au+Au)

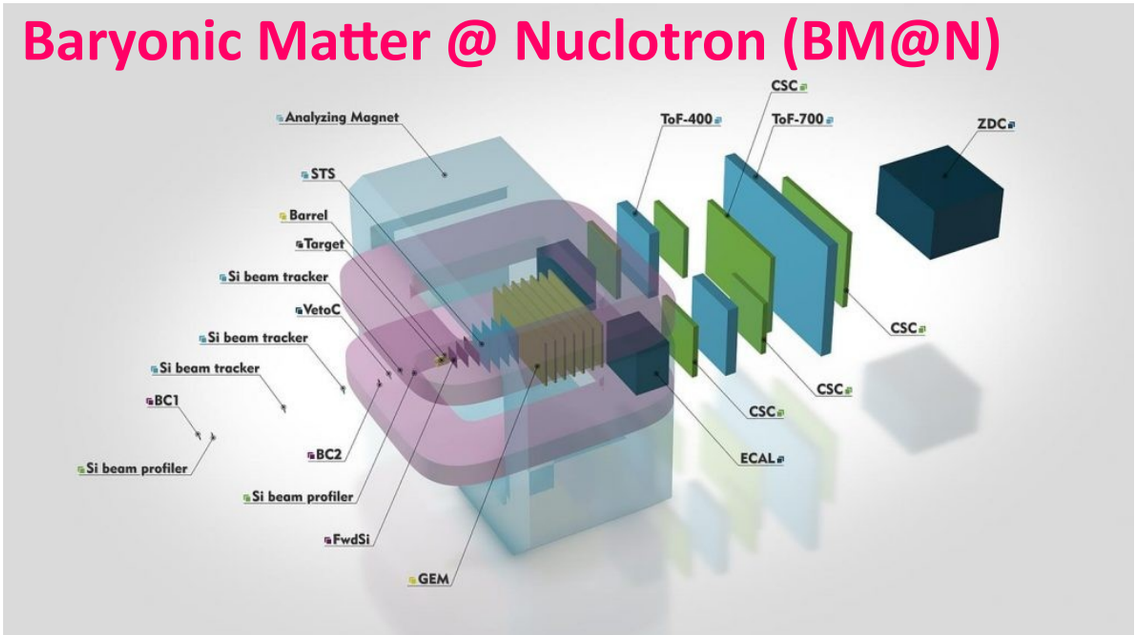
L = 1 x 10^{27} $cm^{-2}\,s^{-1}$

~ 2 x 22 injection cycles
22 bunches per ring

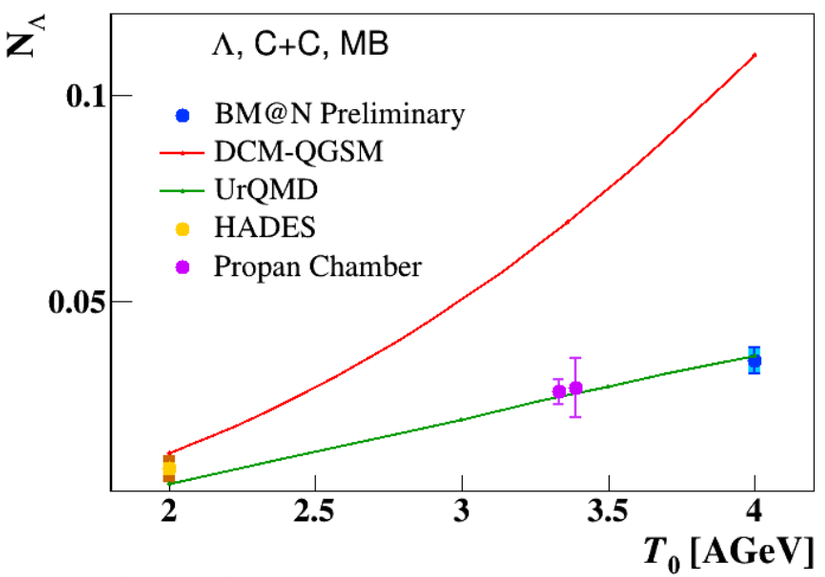
IP-1

First physics from BM@N at NICA

Baryonic Matter @ Nuclotron (BM@N)



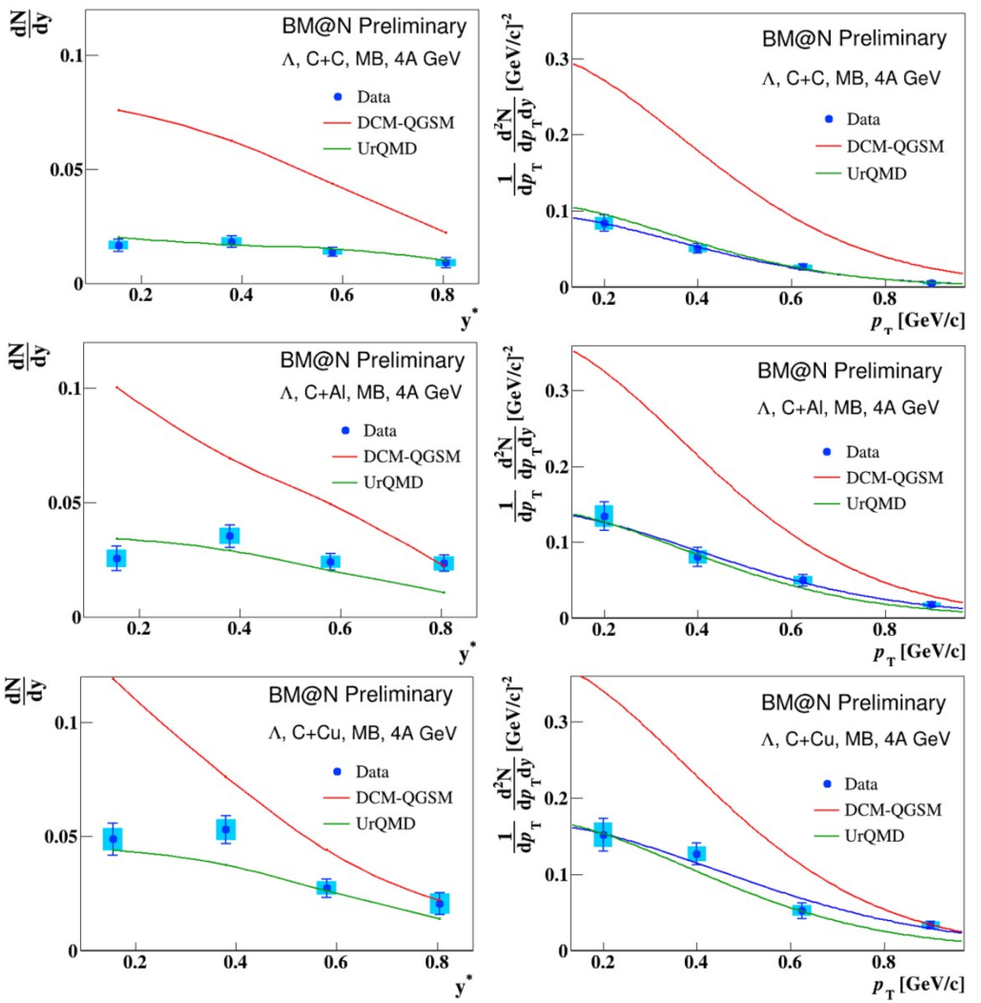
Λ yield in min bias C+C interactions



BM@N: Λ hyperon yield in 4 AGeV Carbon-nucleus interactions

Λ yield as a function of rapidity in c.m.s.

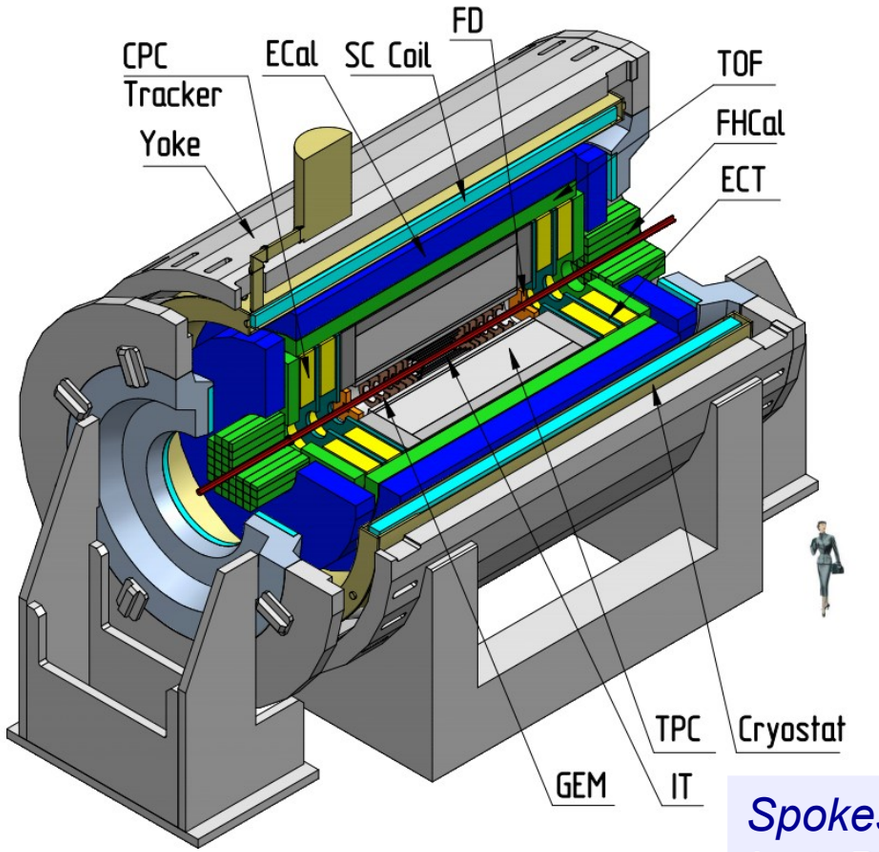
Λ yield as a function of transverse momentum



Analyses of experimental data in Ar, Kr beams and SRC data in carbon beam are in progress

courtesy of the BM@N experiment

Multi-Purpose Detector (MPD) Collaboration



***11** Countries, **475** participants,*
38** Institutes and **JINR

NICA

*Spokesperson: **Adam Kisiel***
*Inst. Board Chair: **Fuqiang Wang***
*Project Manager: **Slava Golovatyuk***

*AANL, Yerevan, **Armenia;***
*Baku State University, NNRC, **Azerbaijan;***
*University of Plovdiv, **Bulgaria;***
*University Tecnica Federico Santa Maria, Valparaiso, **Chile;***
*Tsinghua University, Beijing, **China;***
*USTC, Hefei, **China;***
*Huizhou University, Huizhou, **China;***
*Institute of Nuclear and Applied Physics, CAS, Shanghai, **China;***
*Central China Normal University, **China;***
*Shandong University, Shandong, **China;***

*IHEP, Beijing, **China;***
*University of South China, **China;***
*Three Gorges University, **China;***
*Institute of Modern Physics of CAS, Lanzhou, **China;***
*Palacky University, Olomouc, **Czech Republic;***
*NPI CAS, Rez, **Czech Republic;***
*Tbilisi State University, Tbilisi, **Georgia;***
Joint Institute for Nuclear Research;
*FCFM-BUAP (Mario Rodriguez) Puebla, **Mexico;***
*FC-UCOL (Maria Elena Tejeda), Colima, **Mexico;***
*FCFM-UAS (Isabel Dominguez), Culiacán, **Mexico;***
*ICN-UNAM (Alejandro Ayala), Mexico City, **Mexico;***
*CINVESTAV (Luis Manuel Montaño), Mexico City, **Mexico;***
*Institute of Applied Physics, Chisinev, **Moldova;***
*WUT, Warsaw, **Poland;***
*NCNR, Otwock – Świerk, **Poland;***
*University of Wrocław, **Poland;***
*University of Warsaw, **Poland;***
*Jan Kochanowski University, Kielce, **Poland;***
*Belgorod National Research University, **Russia;***
*INR RAS, Moscow, **Russia;***
*MEPhI, Moscow, **Russia;***
*Moscow Institute of Science and Technology, **Russia;***
*North Osetian State University, **Russia;***
*NRC Kurchatov Institute, ITEP, **Russia;***
*Kurchatov Institute, Moscow, **Russia;***
*St. Petersburg State University, **Russia;***
*SINP, Moscow, **Russia;***
*PNPI, Gatchina, **Russia;***

MPD Physics Programme

Global observables

- Total event multiplicity
- Total event energy
- Centrality determination
- Total cross-section measurement
- Event plane measurement at all rapidities
- Spectator measurement

Spectra of light flavor and hypernuclei

- Light flavor spectra
- Hyperons and hypernuclei
- Total particle yields and yield ratios
- Kinematic and chemical properties of the event
- Mapping QCD Phase diagram

Correlations and Fluctuations

- Collective flow for hadrons
- Vorticity, Λ polarization
- E-by-E fluctuation of multiplicity, momentum and conserved quantities
- Femtoscopy
- Forward-Backward corr.
- Jet-like correlations

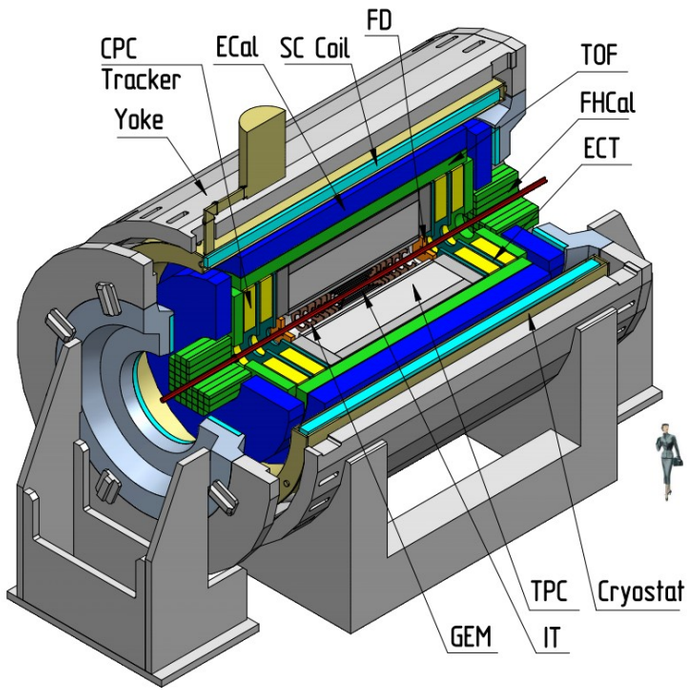
Electromagnetic probes

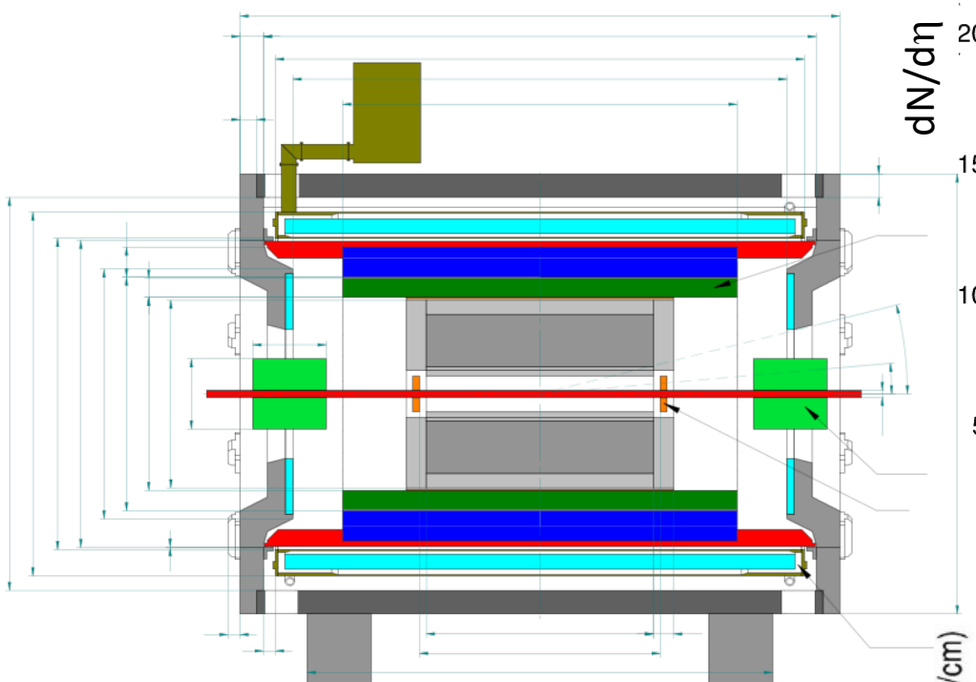
- Electromagnetic calorimeter measurements
- Photons in ECAL and central barrel
- Low mass dilepton spectra and search for in-medium modification of resonances and intermediate mass region

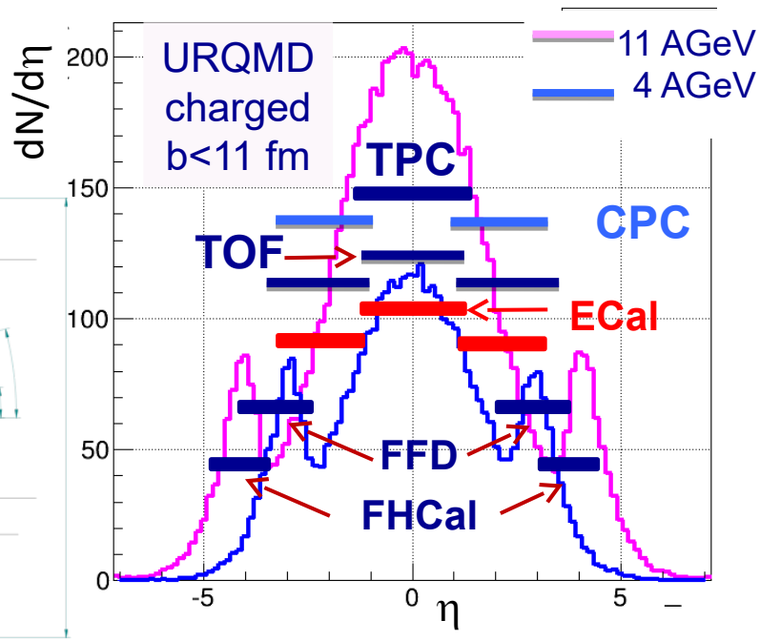
Heavy flavor

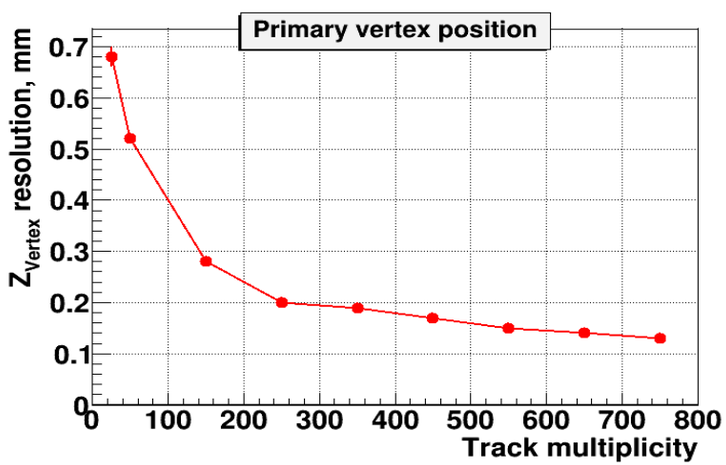
- Study of open charm production
- Charmonium with ECAL and central barrel
- Charmed meson through secondary vertices in ITS and HF electrons
- Explore production at charm threshold

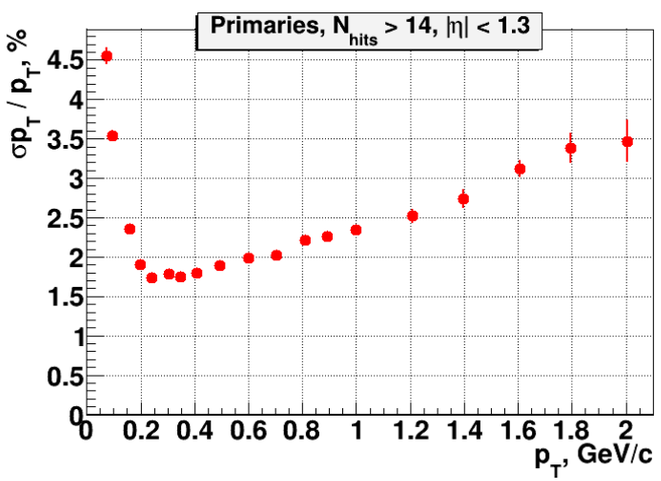
MPD 1st stage

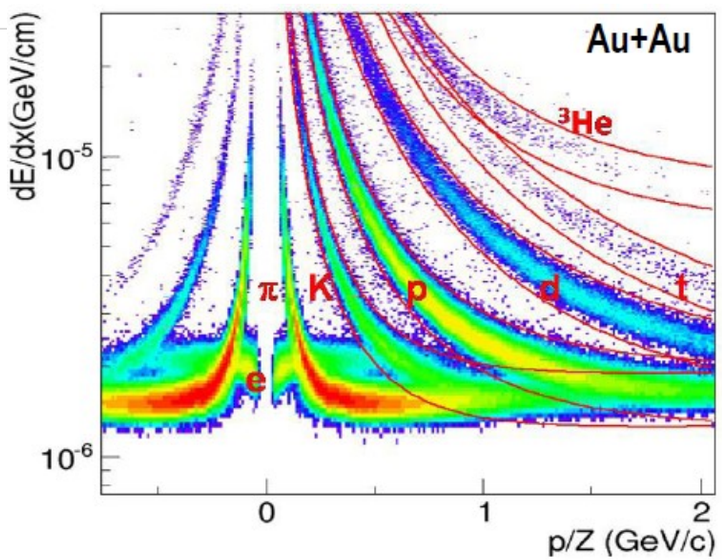












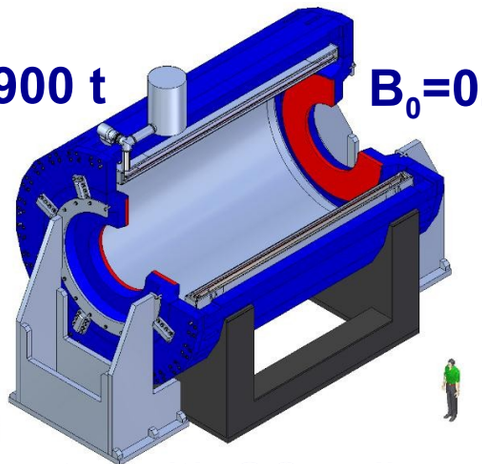
- 2π in azimuth, 3-D tracking (TPC), Powerful PID (TPC, TOF): - π/K up to 1.5 GeV/c, - K/p up to 3 GeV/c, Low material budget, High rate (<=6 kHz)

MPD Systems in production

SC Solenoid

~ 900 t

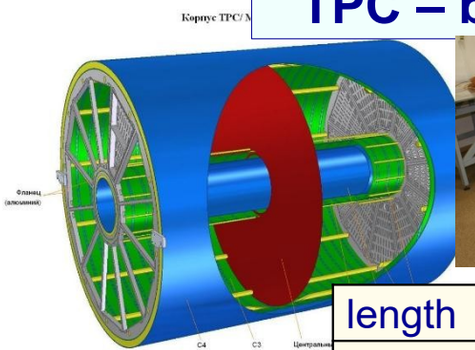
B_0=0.5 T



Yoke – produced & delivered

cryostat with SC coil - ready for cold tests

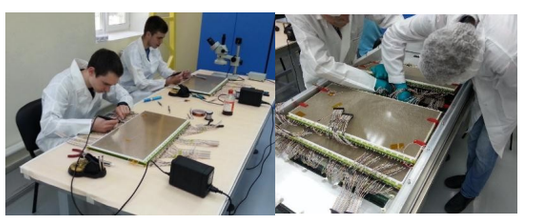
TPC – basic tracker



length	*340 см*
out Radii	*140 см*
N chan.	***95 232***

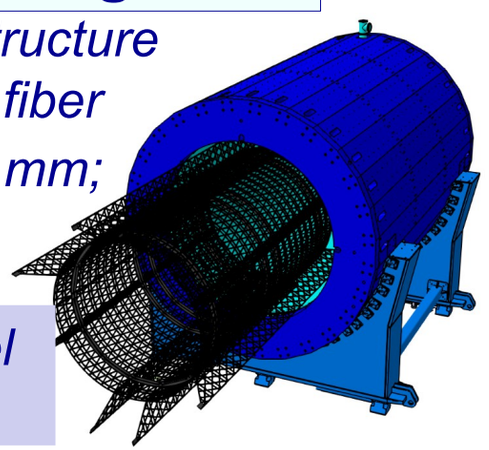
TOF system

280 *MPRC's*
13 440 *ch.*



Integration

support structure of carbon fiber sagite ~ ***5*** *mm; 0,13* X_0



ECal *barrel* ***~ 100*** *t*

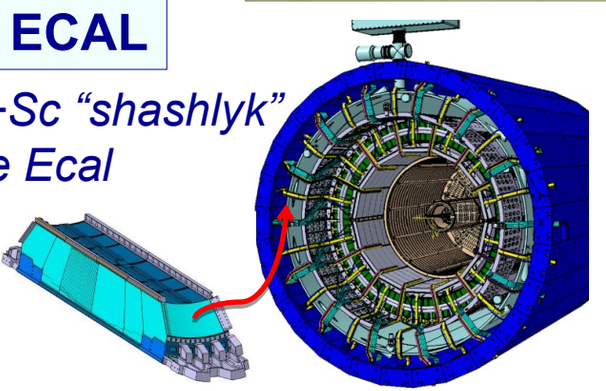
MAPS-based ITS, Y. Murin, Poster @ Future Facilities #46

MPD design, V. Babkin, Poster @ Future Facilities #40

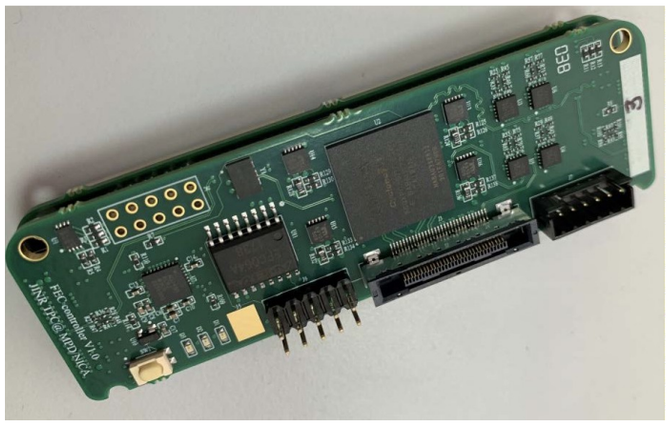
~ **39 000** modules

ECAL

Pb+Sc "shashlyk" type Ecal



MPD Time Projection Chamber



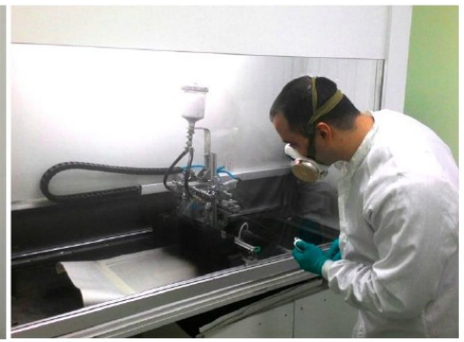
update - 25.11.2018 Time Schedule Design and Construction cost of TPC

Task Name	2011-2014	2015	2016	2017	2018	2019	2020	2021
	I II III IV	I II III IV	I II III IV	I II III IV	I II III IV	I II III IV	I II III IV	I II III IV
TPC R&D and Prototyping								
TPC development* (drawings e.t.c.)								
Production of flanges and other parts								
FIELD cage development, prototyping								
Field cage (Inn and Out) production								
ROC development, prototyping								
ROC mass production, test								
FEE development								
FEE mass production								
TPC readout, DAQ production, test								
TPC Slow control system								
TPC Assembling hall (Bld.217)								
LASER calibr. system design								
LASER calibr. system production								
COOLING syst.develop., prod, test								
GAS syst-develop., prod, test								
TPC assembling and lab. testing								
TPC installation into MPD, tooling								
Commissioning of TPC with MPD								

item	Date
Testing FEC v1.0 finished	Feb. 2019
Receive SAMPA V4 chips at Dubna 4500 (all)	June 2019
32 preproduction vervion 2.1 FE Card assembled (1/2ROC)	Jul. 2019
Testing of half ROC equipped with FE Cards	Aug. – Dec.2019
Production FE Cards for 1 ROC and Testing 2020	Dec. 2019-Apr.
Instrumentation and test ROC 2, 3, 4	May 2020
Production FE Cards for the first 10 ROCs (Total 14)	July 2020
Production FE Cards for the second 10 ROCs (Total 24)	August 2020

MPD Time-of-Flight

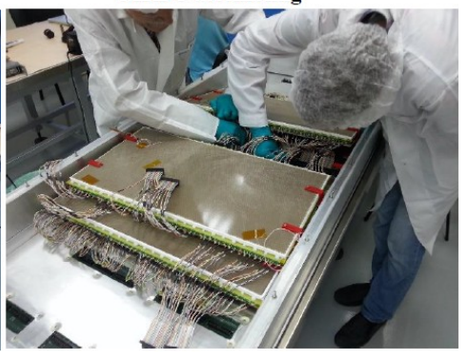

Ultrasonic wave glass cleaning

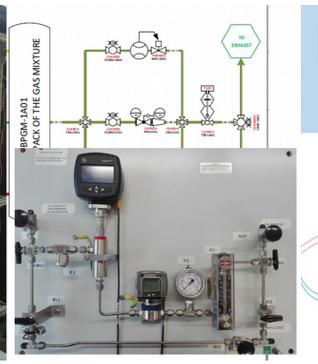

Painting of the HV conductive layer


MRPC assembling

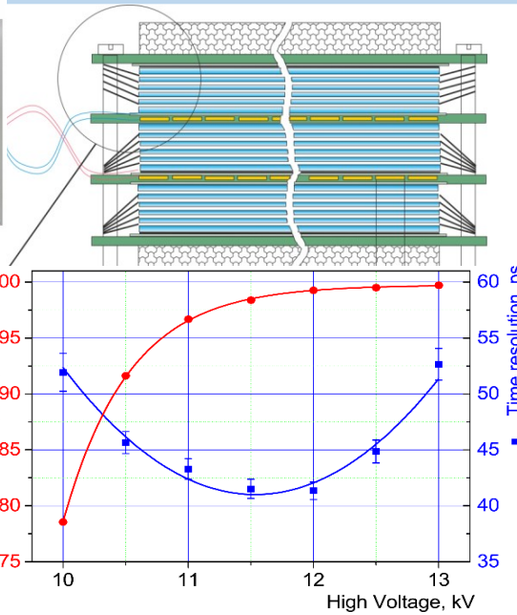

Optical quality control


Cables and connectors soldering


Detectors installation to the TOF box



Dimensions of sensitive area
600 x300 mm^2



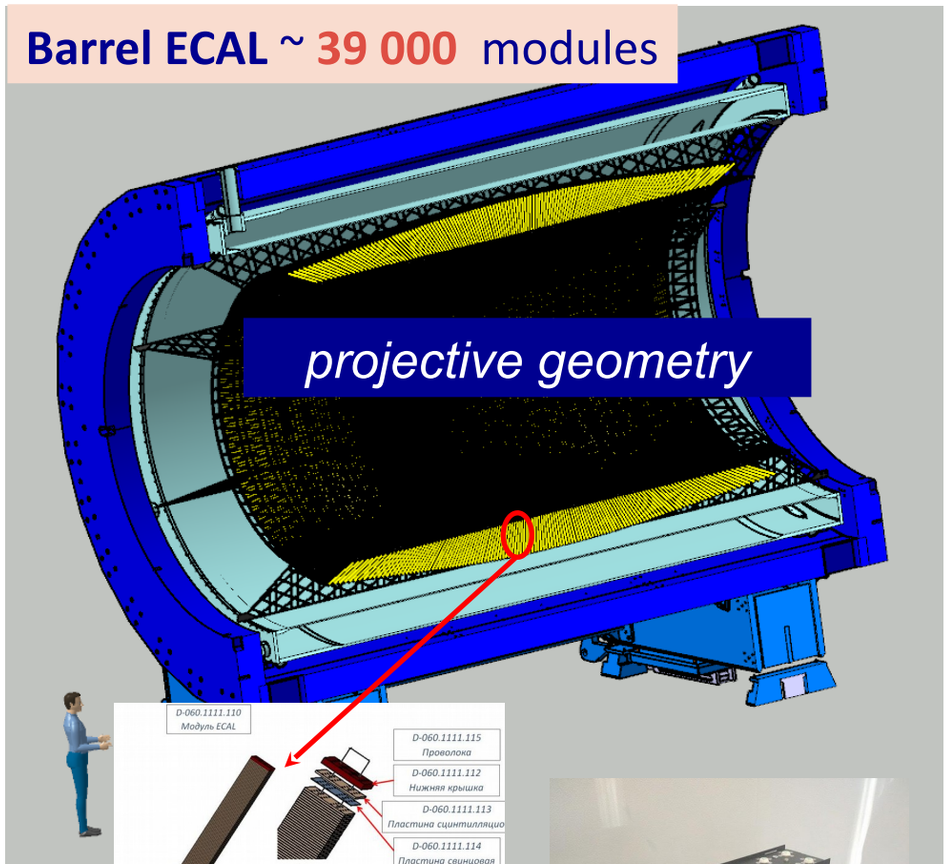
Single detector time resolution: 50ps

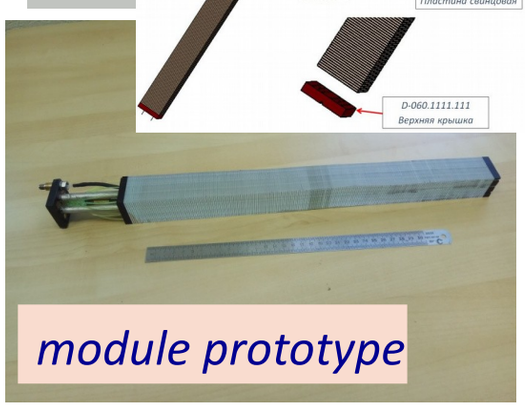
	Number of detectors	Number of readout strips	Sensitive area, m^2	Number of FEE cards	Number of FEE channels
MRPC	1	24	0.192	2	48
Module	10	240	1.848	20	480
Barrel	280	6720	51.8	560	**13440** (1680 chips)

Purchasing of all detector materials completed
So far 25% of all mRPCs are assembled
At IIIrd quater of 2020 all mRPCs will be assembled.
Assembled half sectors of TOF are under Cosmics tests
Investigation of solutions for detector integration and technical installations

Electromagnetic Calorimeter (ECAL)

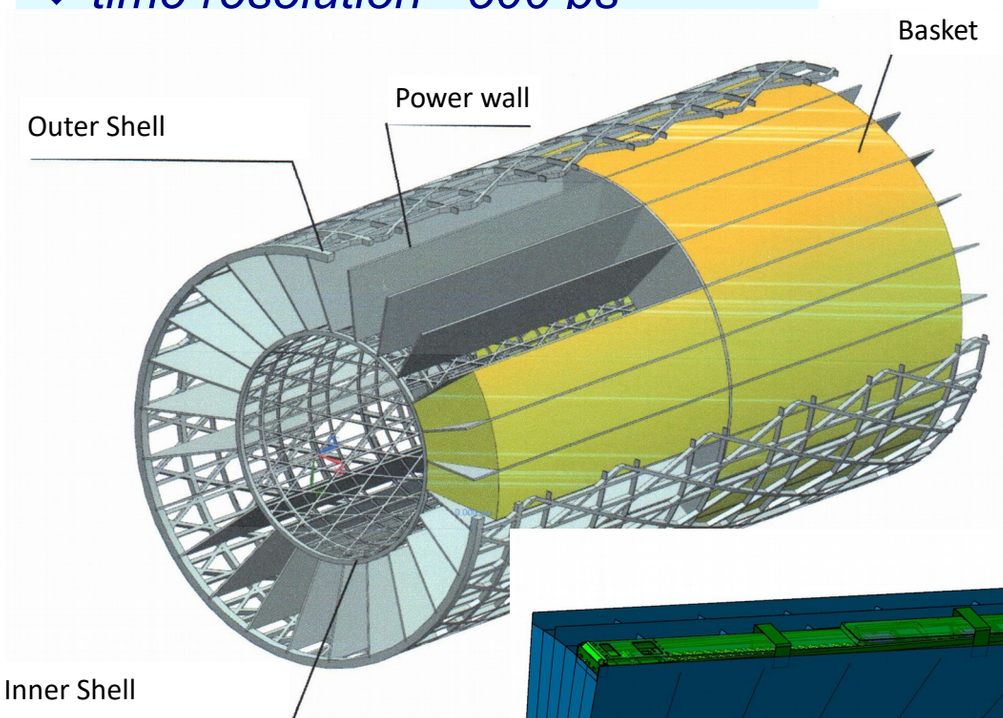
Barrel ECAL ~ 39 000 modules

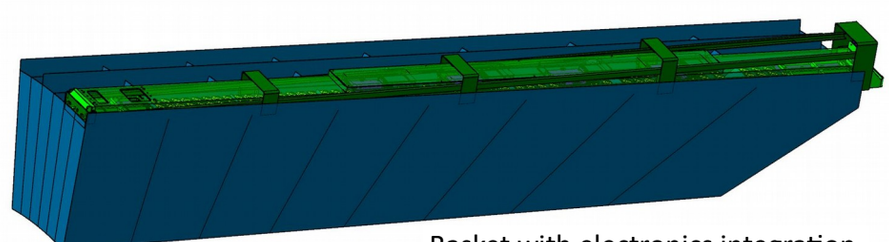




- *Pb+Sc "Shashlyk"*
- *read-out: WLS fibers + MAPD*
- *L ~35 cm (~ 11.8 X_0)*
- *Segmentation (4x4 cm^2),*
- *σ(E) better than 5% @ 1 GeV;*
- *time resolution ~500 ps*

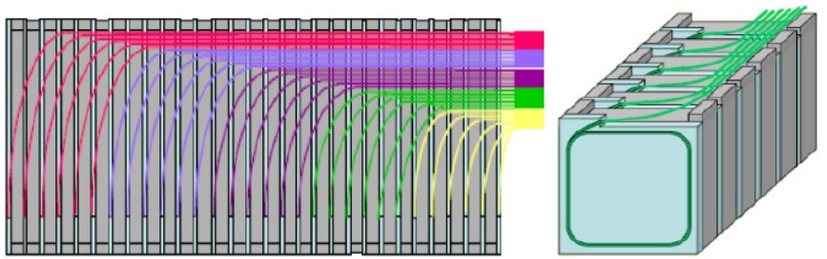
Technical specification for ECAL modules ready
Production started in two sites in Russia, soon in China
First module installation expected in IIIrd QTR of 2020
Calibration and test ongoing



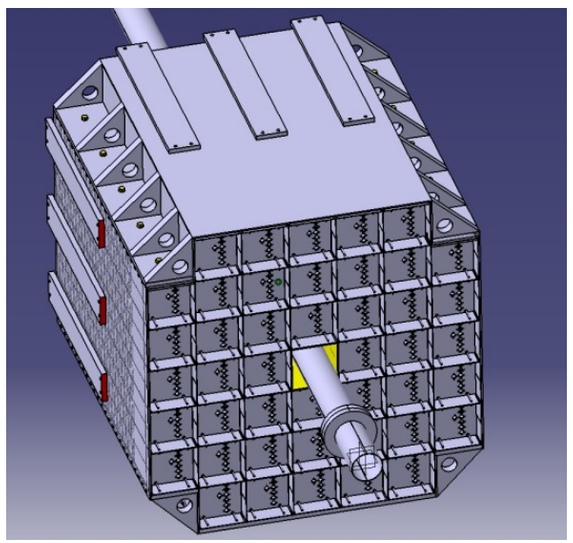


Basket with electronics integration

Forward Detectors: FHCal and FFD

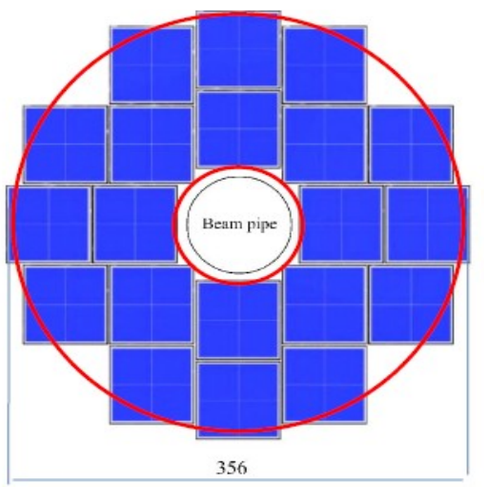


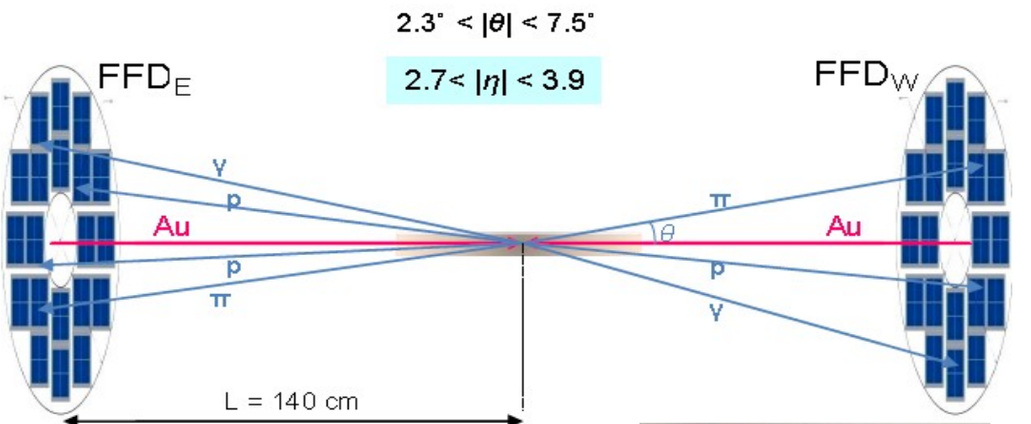
- Two-arms at ~3.2 m from the interaction point.
- Each arm consists of 45 individual modules.
- Module size 150x150x1100cm^3 (55 layers)
- Pb(16mm)+Scint.(4mm) sandwich
- 7 longitudinal sections
- 6 WLS-fiber/MAPD per section
- 7 MAPDs/module



1. Plan to have 100 modules in September 2019, Produced modules are under test on Cosmic
2. FE Electronics is under production – will be ready at the end of 2019
3. Design of the Support platform for FHCal is under way

array of 20 modules
Planacon MCP-PMTs
80 +20 channels

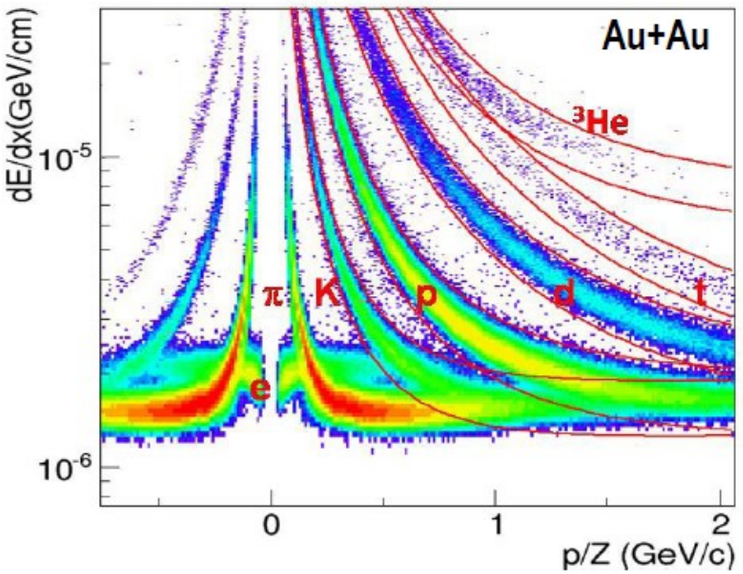


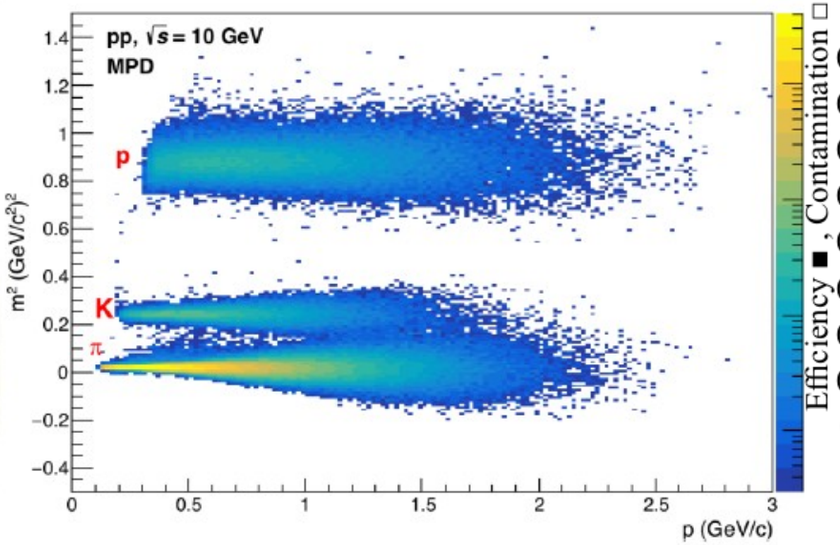


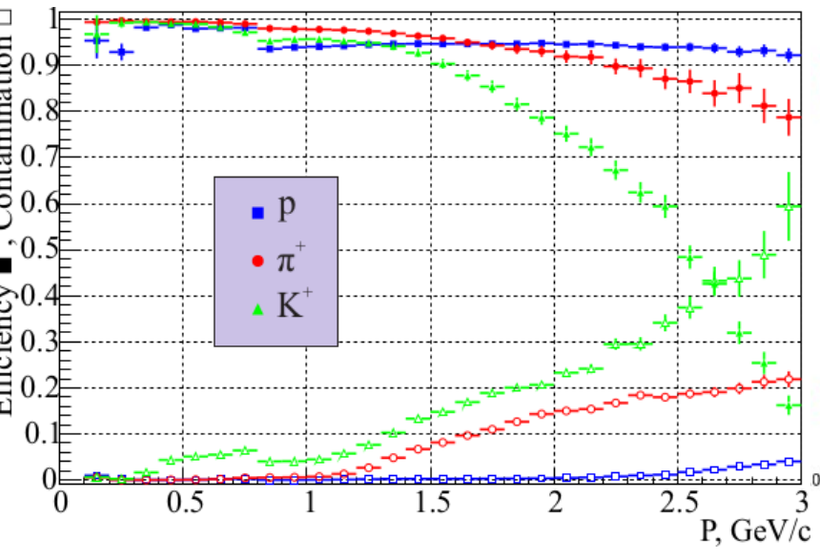
15 mm quartz radiator
10 mm lead converter

time resolution < 50 ps

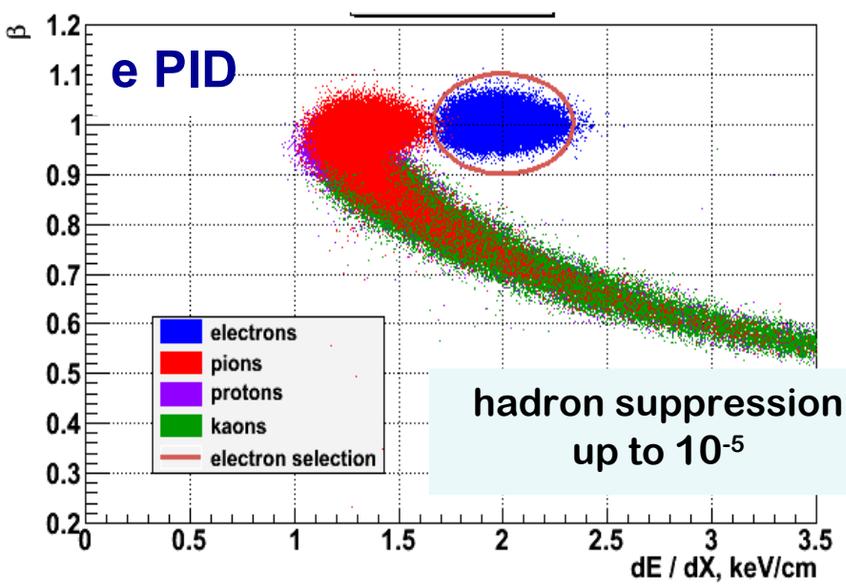
PID Performance in MPD







Efficiency and Contamination

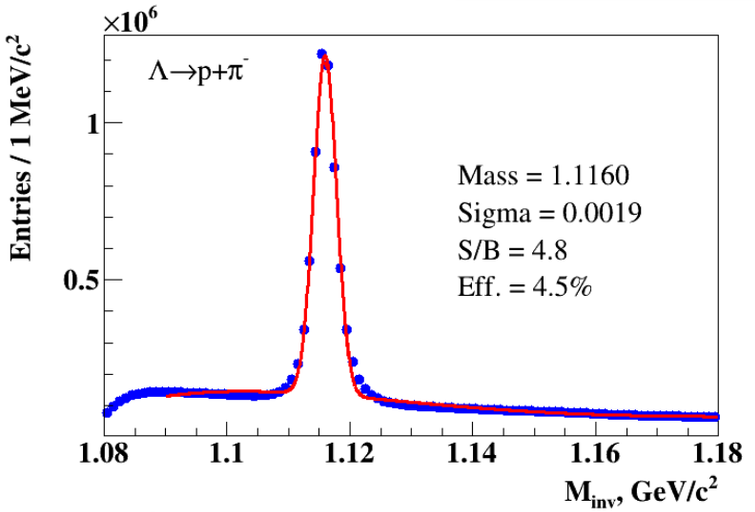


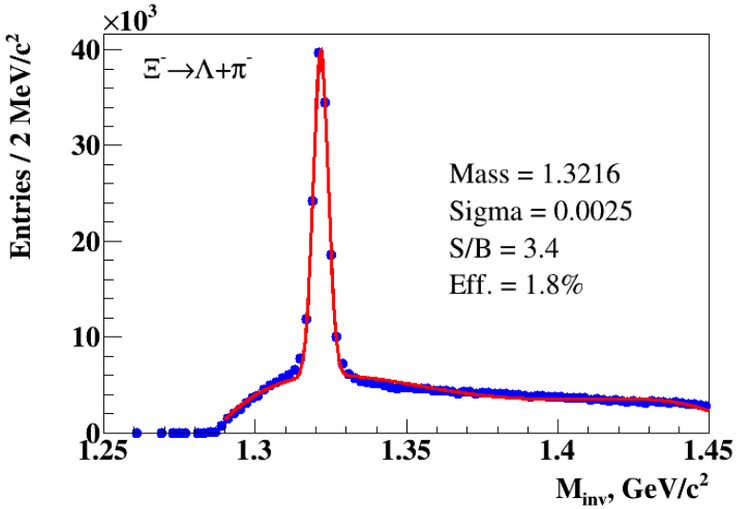
hadron suppression up to 10^{-5}

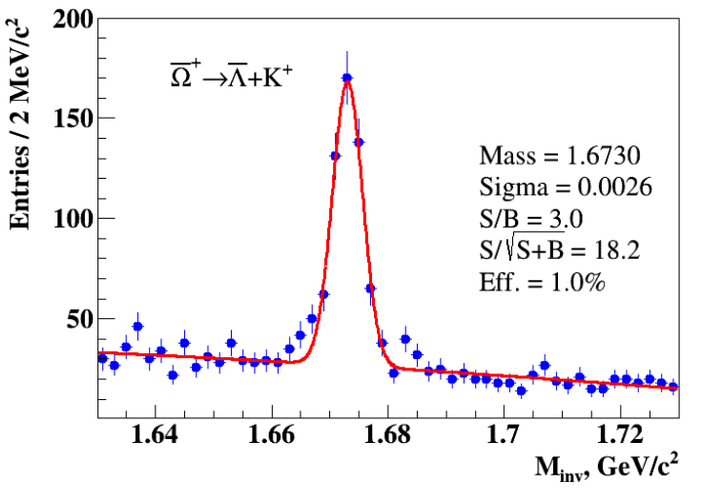
- Combined (dE/dx+TOF) PID for hadrons provides π/K up to 2 GeV/c and K/p up 3 GeV/c
- An extra hadron suppression in the electrons will be provided by ECAL

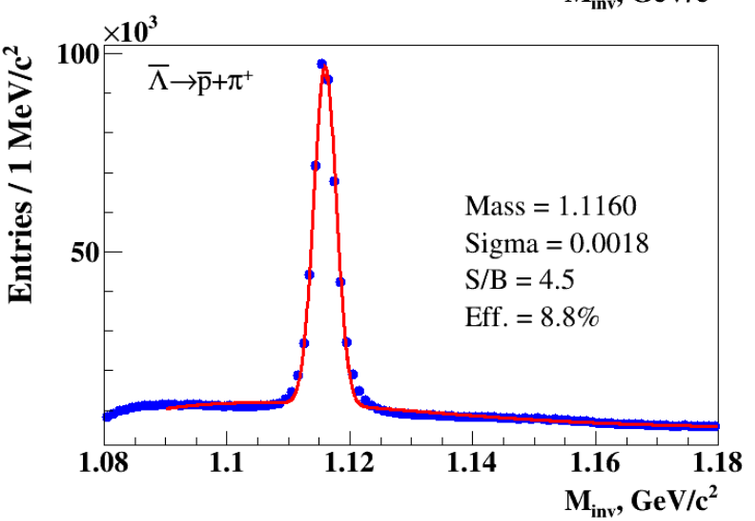
Strange and multi-strange baryons

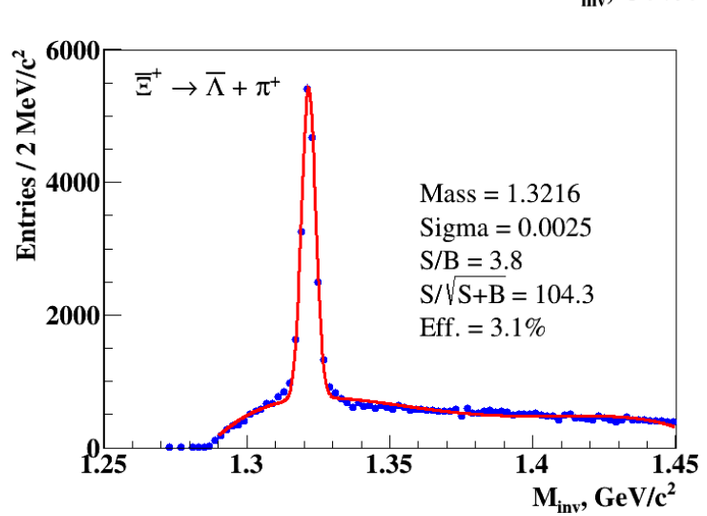
Stage'1 (TPC+TOF): Au+Au @ 11 GeV, PHSD + MPDRoot reco.

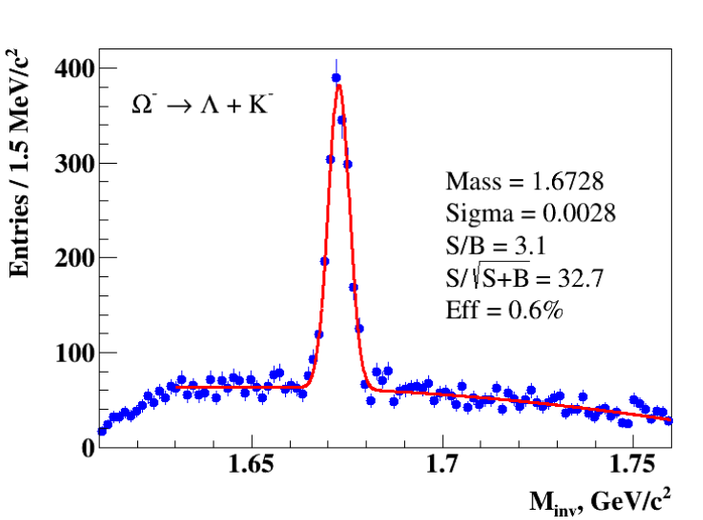






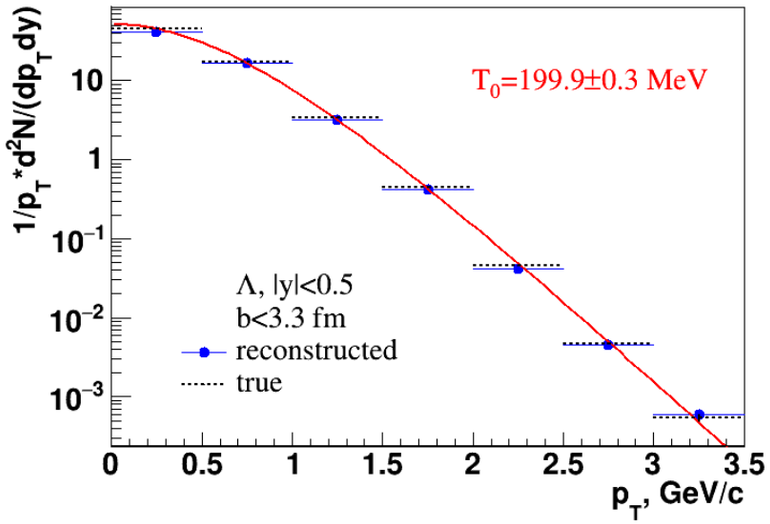


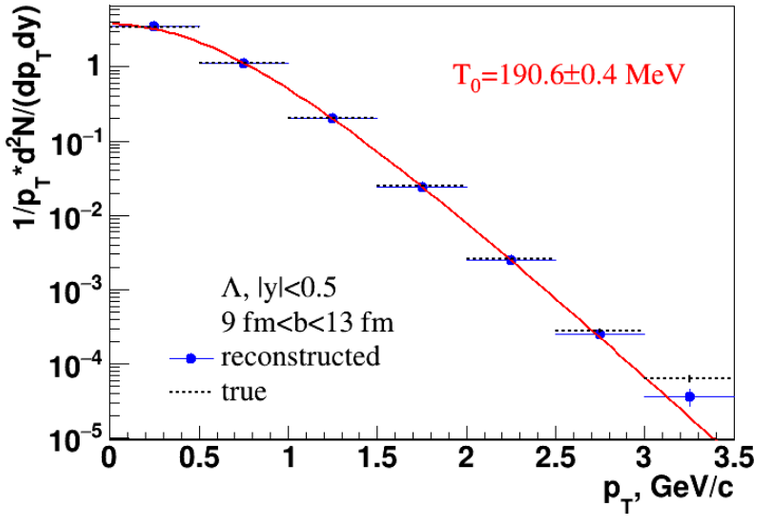


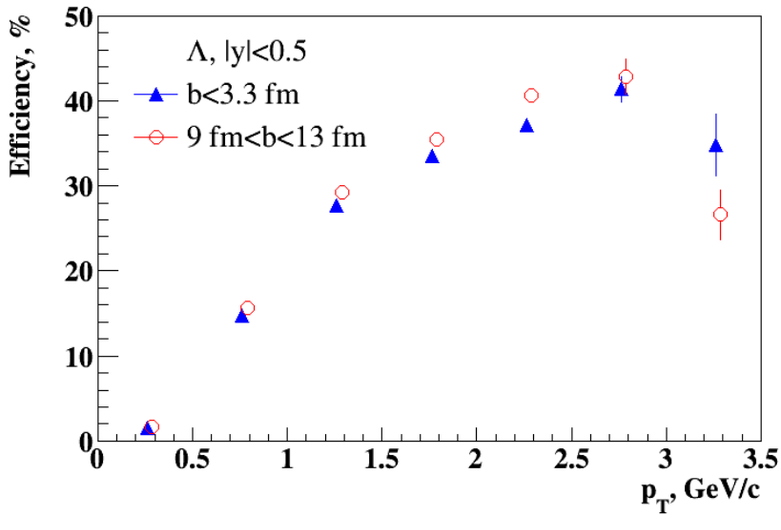


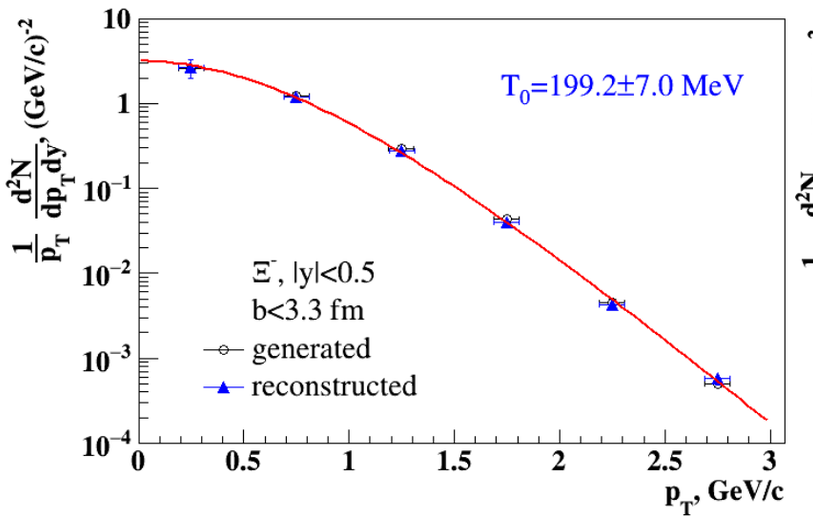
particle	Λ	anti-Λ	Ξ⁻	anti-Ξ⁺	Ω⁻	anti-Ω⁺
yield in 10week	$3 \cdot 10^8$	$3.5 \cdot 10^6$	$1.5 \cdot 10^6$	$8.0 \cdot 10^4$	$7 \cdot 10^4$	$1.5 \cdot 10^4$

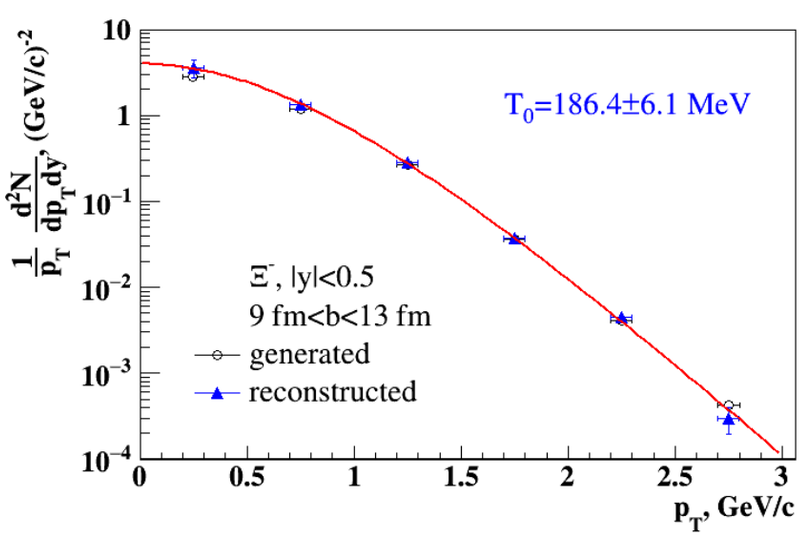
Efficiency and p_T spectrum

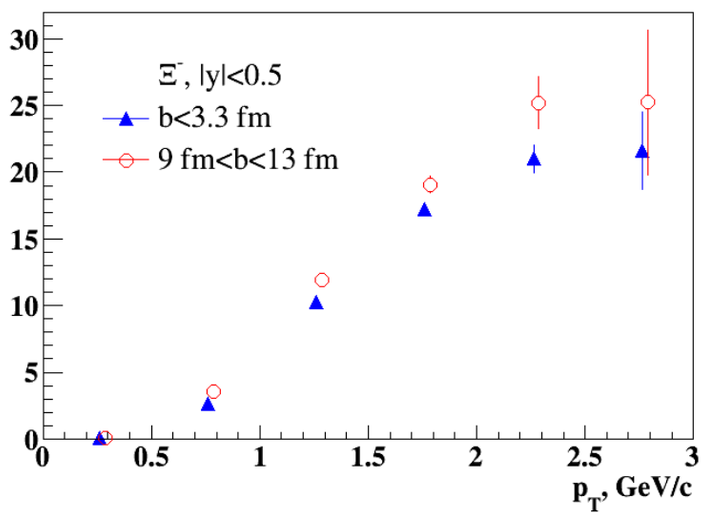










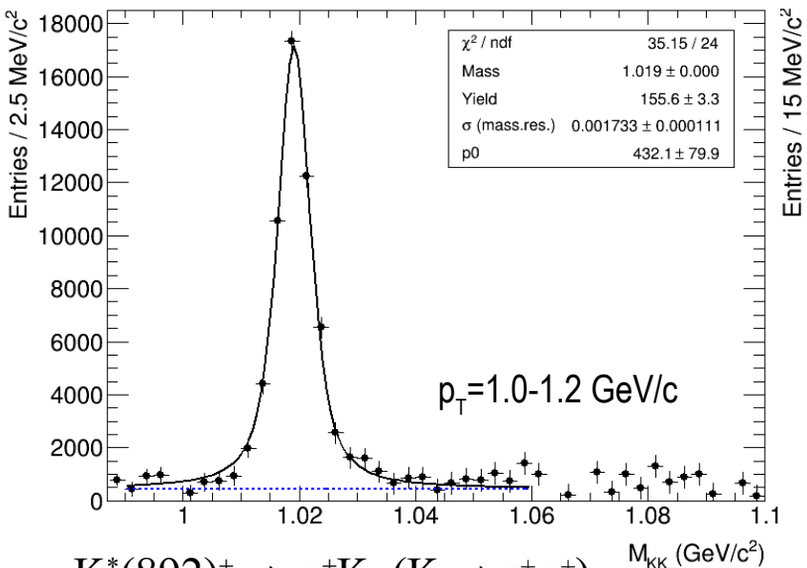


Full p_T spectrum and yield extraction, reasonable efficiency down to low p_T

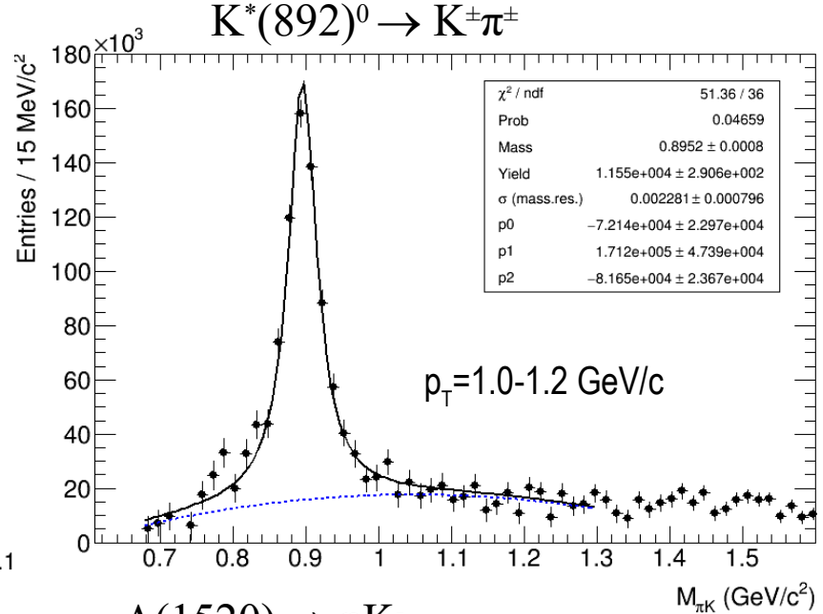
Resonances at MPD

· Minbias Au+Au@11 (UrQMD) · Full reconstruction and realistic PID · Topology cuts and secondary vertex · Event mixing for background

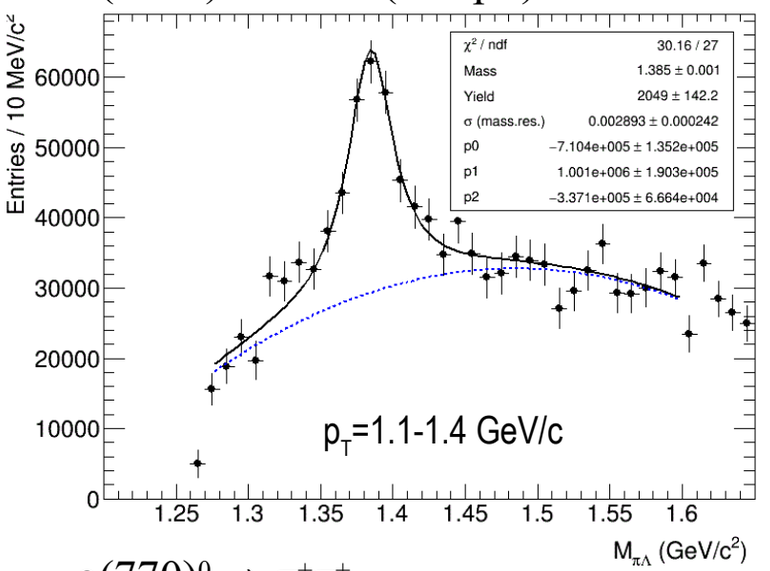
$\phi(1020) \rightarrow K^+K^-$,



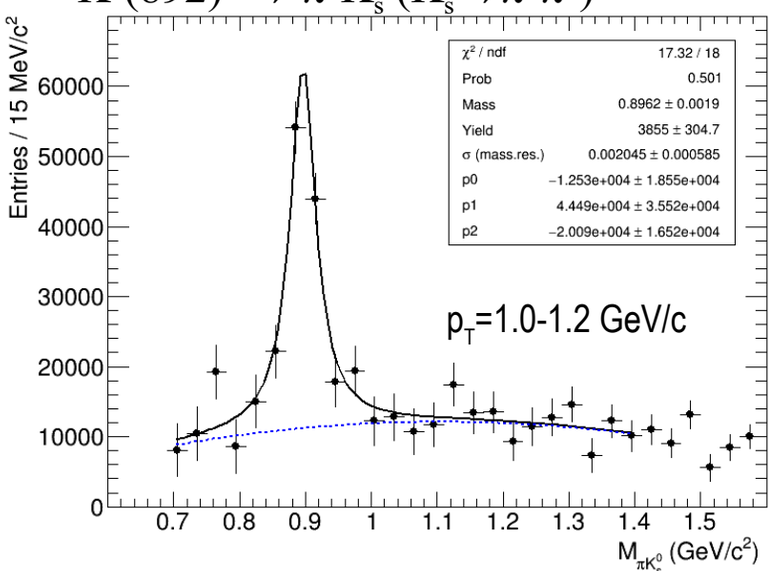
$K^*(892)^0 \rightarrow K^{\pm}\pi^{\pm}$



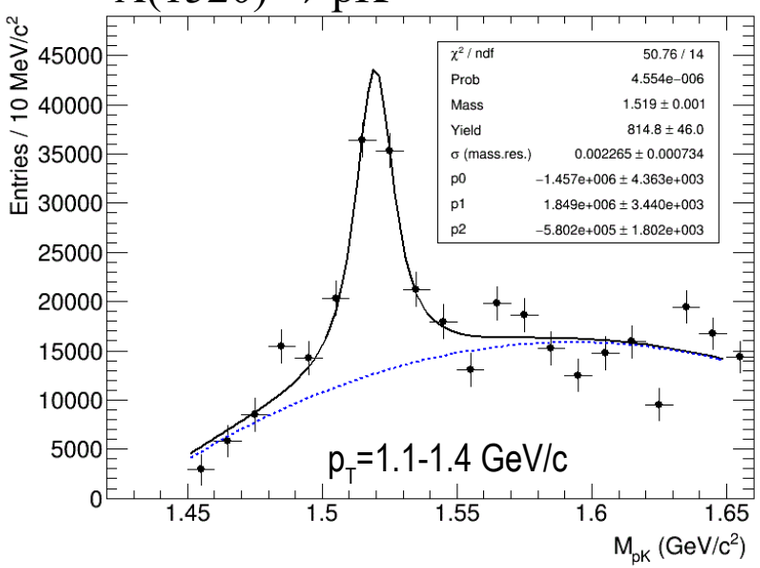
$\Sigma(1385)^{\pm} \rightarrow \pi^{\pm}\Lambda$ ($\Lambda \rightarrow p\pi$)



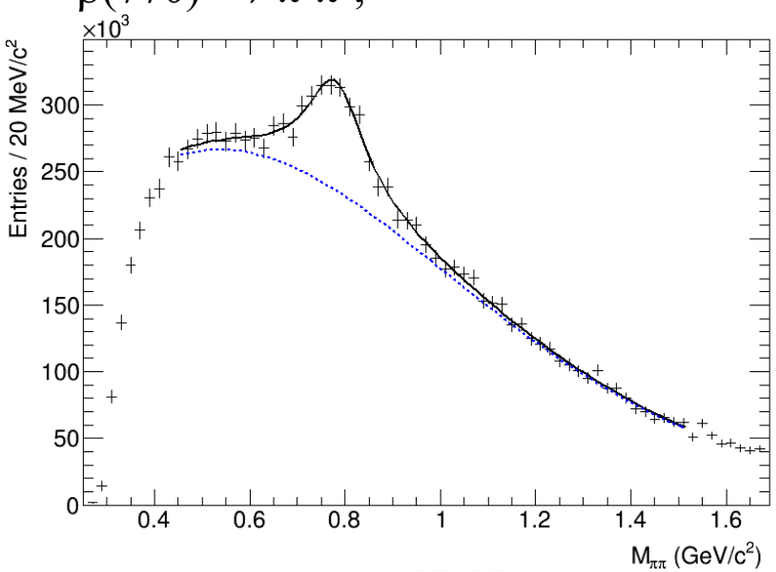
$K^*(892)^{\pm} \rightarrow \pi^{\pm}K_s$ ($K_s \rightarrow \pi^+\pi^+$)



$\Lambda(1520) \rightarrow pK^-$

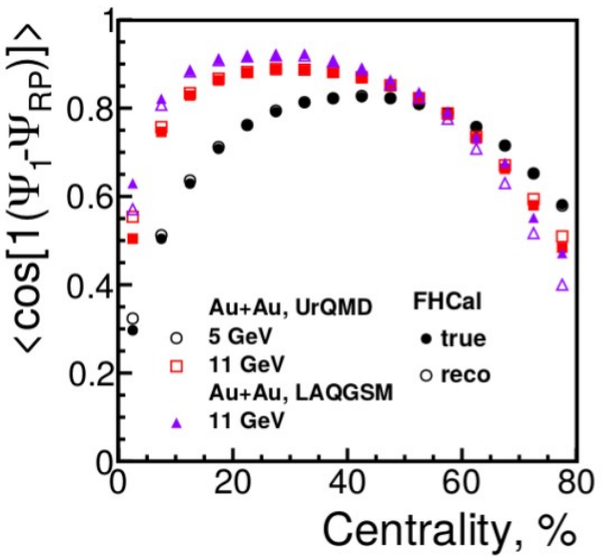


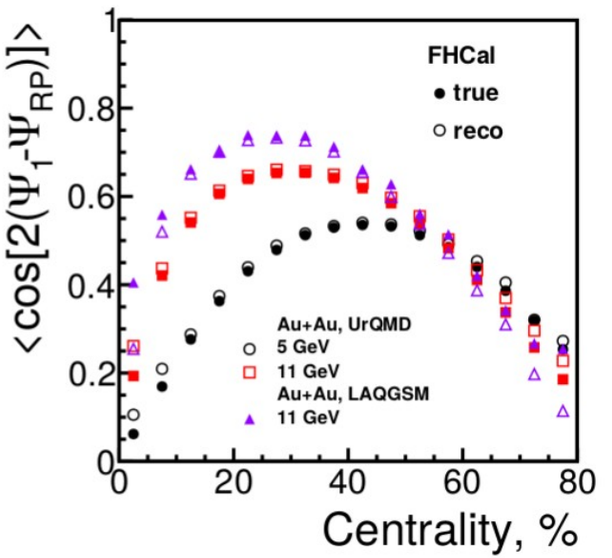
$\rho(770)^0 \rightarrow \pi^{\pm}\pi^{\pm}$,

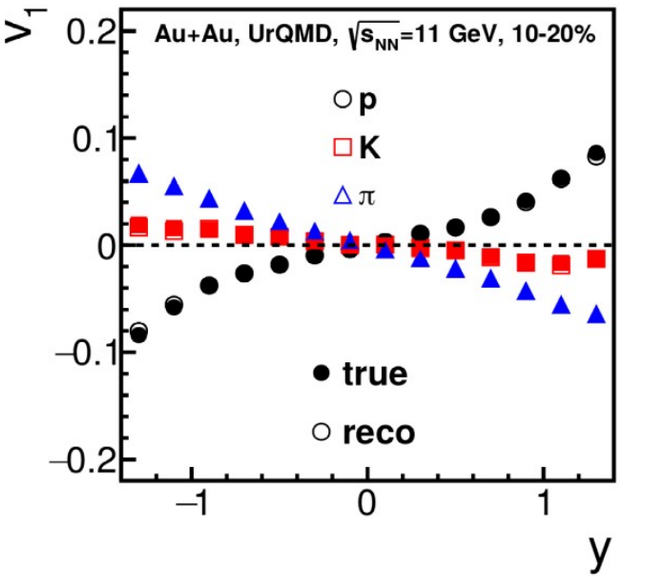


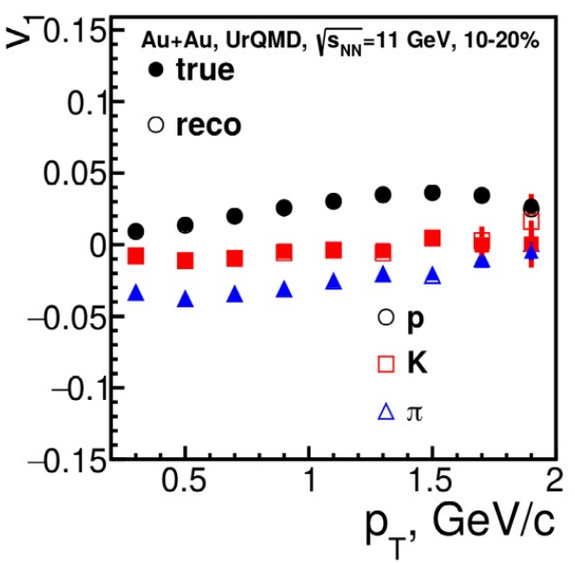
Performance of collective flow studies

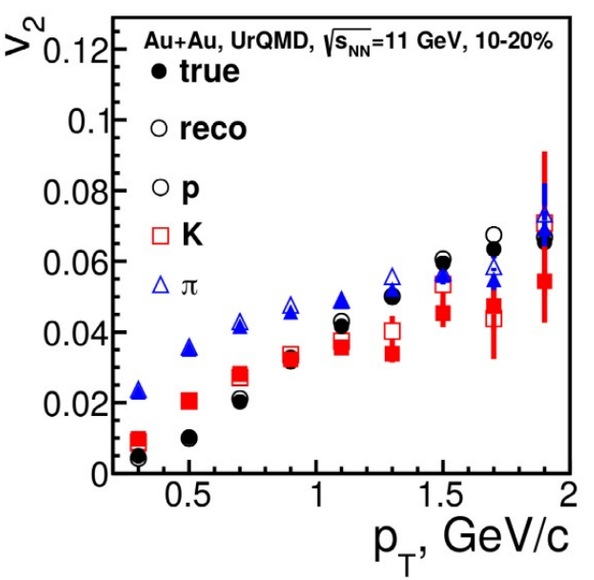
Au+Au, $\sqrt{s_{NN}}$ = 11 GeV, UrQMD, GEANT3 + MPDRoot reco.

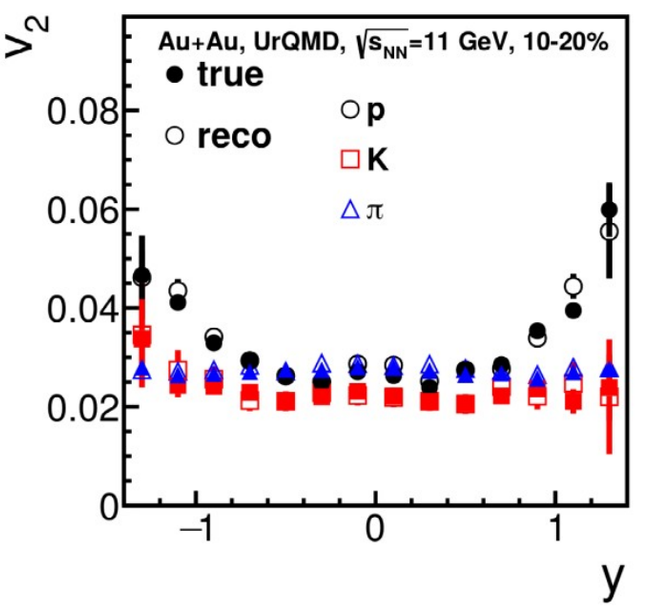












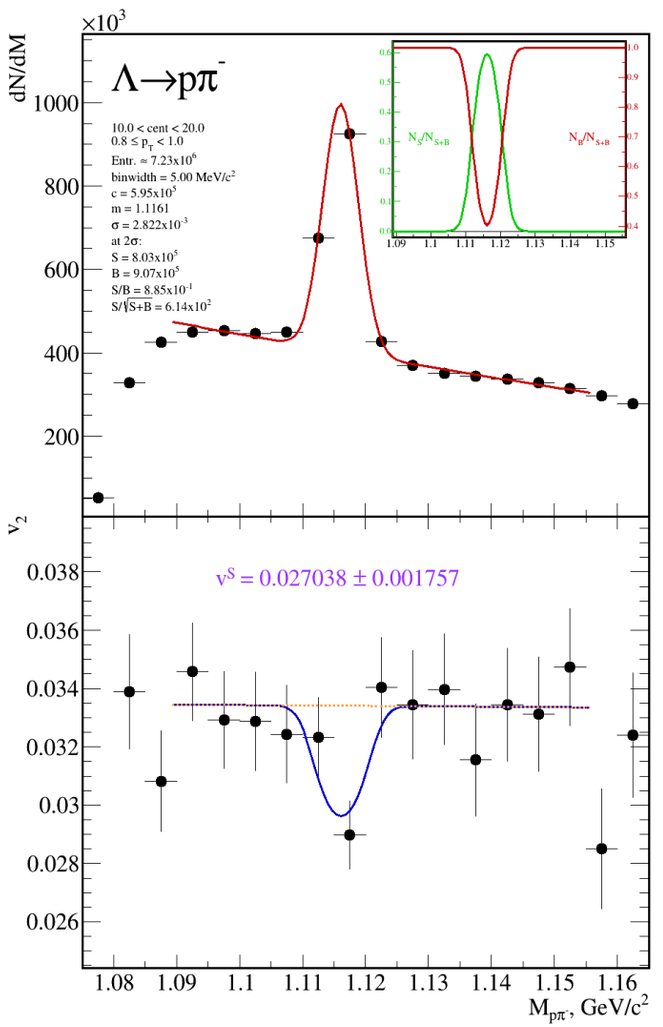
Anisotropic Flow of Reconstructed Decays

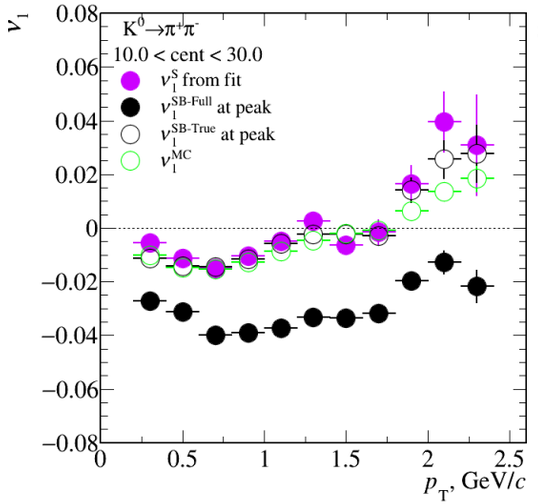
$$v_2^{SB}(m_{inv},p_T) = v_2^{S}(p_T)\frac{N^{S}(m_{inv},p_T)}{N^{SB}(m_{inv},p_T)} + v_2^{B}(m_{inv},p_T)\frac{N^{B}(m_{inv},p_T)}{N^{SB}(m_{inv},p_T)}$$

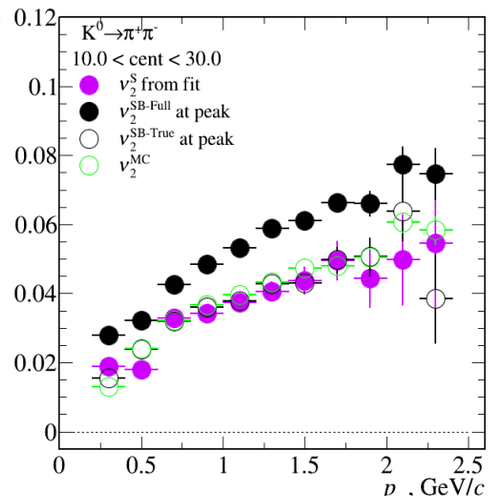
Extracted flow signal after fit
Measured flow (s+bg) at peak region

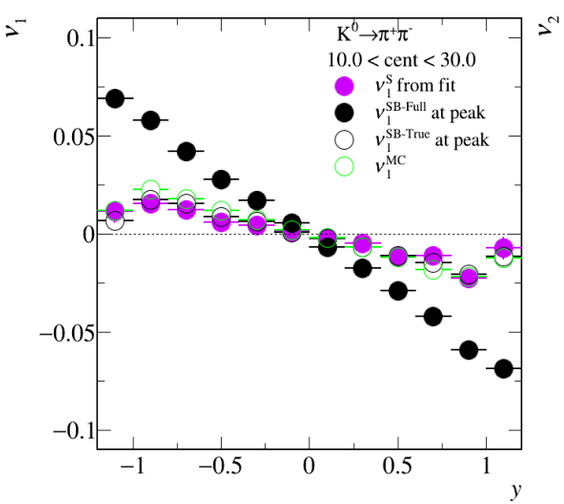
Measured flow only for True
Measured flow from MC/model

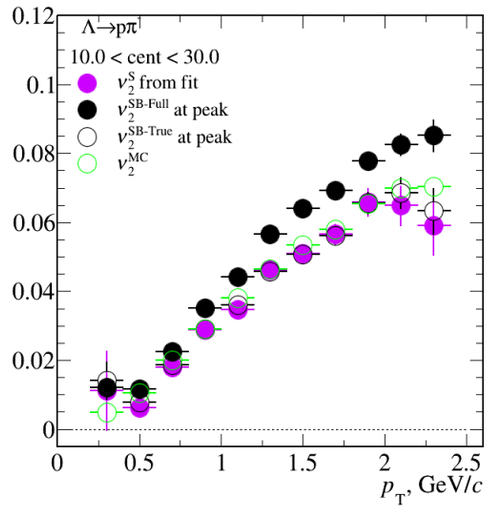
Cuts not optimised for S/B

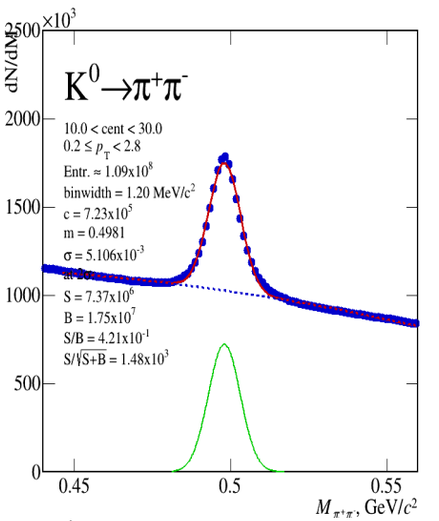


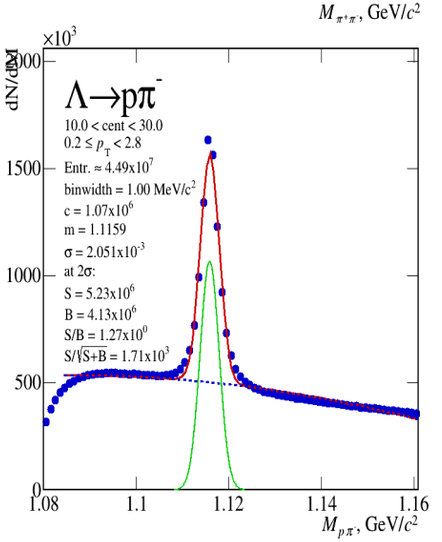












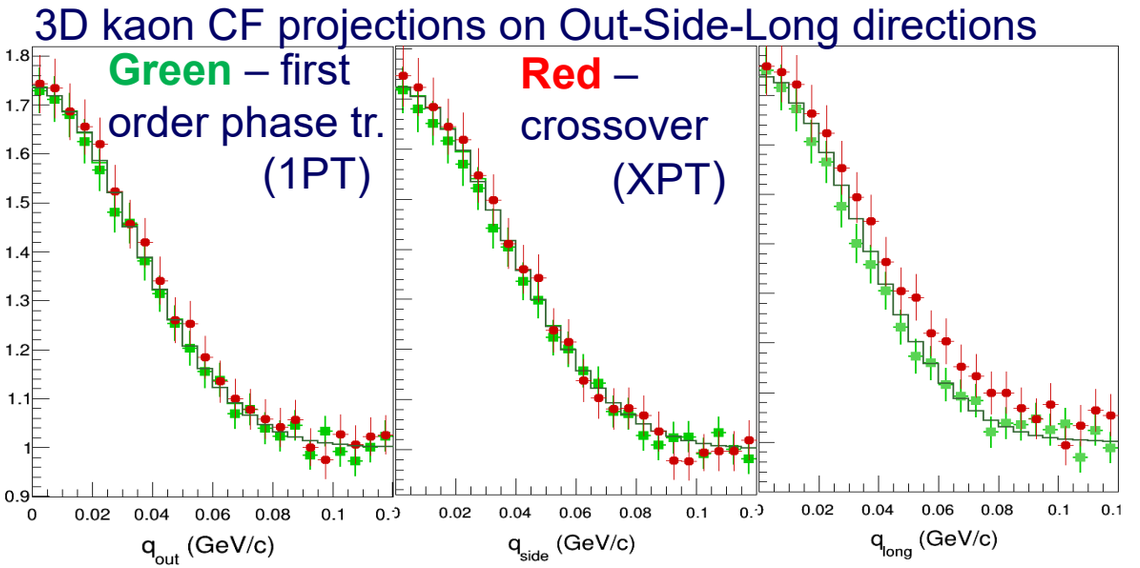
Performance of the MPD Detector for the Study of Multi-strange Baryon Production in Heavy-ion Collisions at NICA

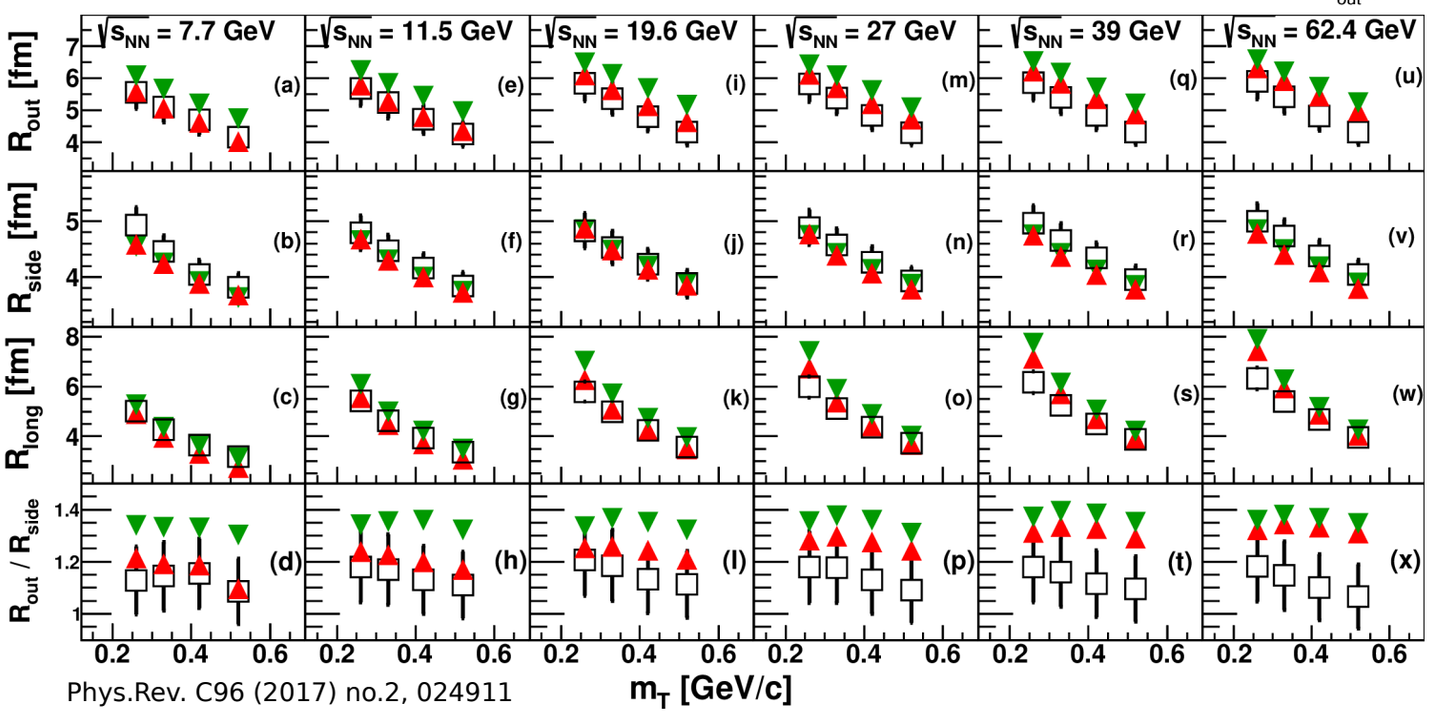
N. Geraksiev, V. Kolesnikov, V. Vasendina, A. Zinchenko for the MPD Collaboration

Poster @ Future Facilities #42

Femtoscopy in MPD

- MC input: vHLLE+UrQMD model implements hydro stage with different EoS, tuned to reproduce experimental data
- Data set : Au+Au collisions at 11 GeV, MPD full reconstruction chain
- Kaon particle ID and (CF) reconstruction





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Study of collective effects, space-time characteristics of the emitting source at kinetic freeze-out, collision dynamics and quark-hadron phase transitions

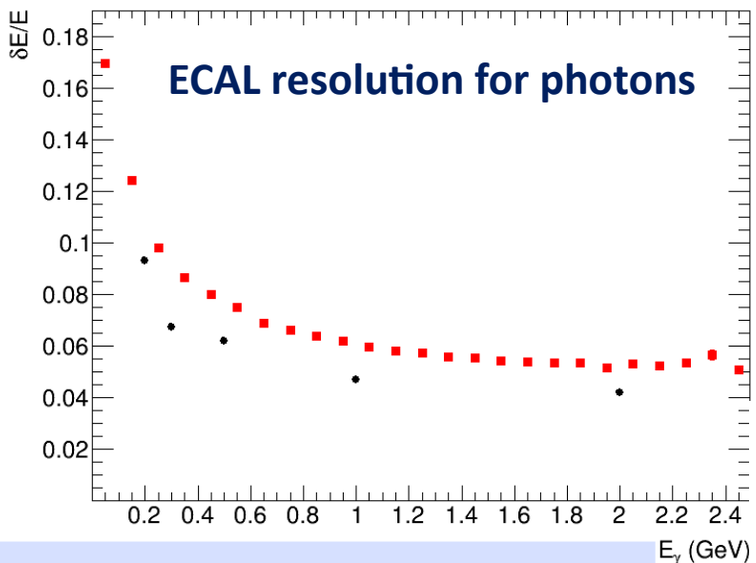
Electromagnetic Calorimeter simulation

- Realistic ECAL reconstruction & analysis – large acceptance ECAL with good energy resolution: ideal tool for measurement of neutral mesons in a wide momentum range

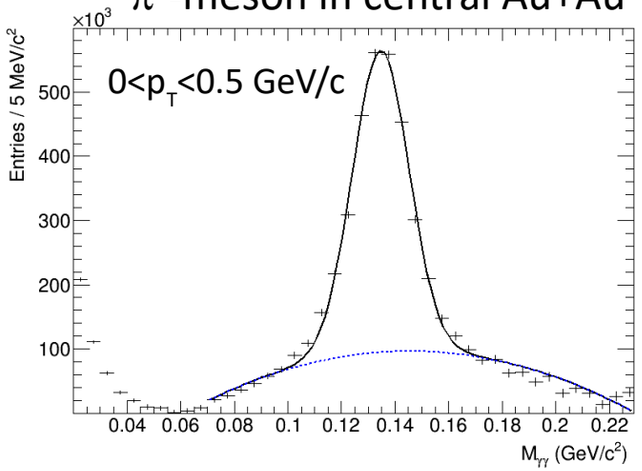
π^0 in MPD/ECal, Y. Huang, Poster @ Future Facilities #44

Black markers – single photons

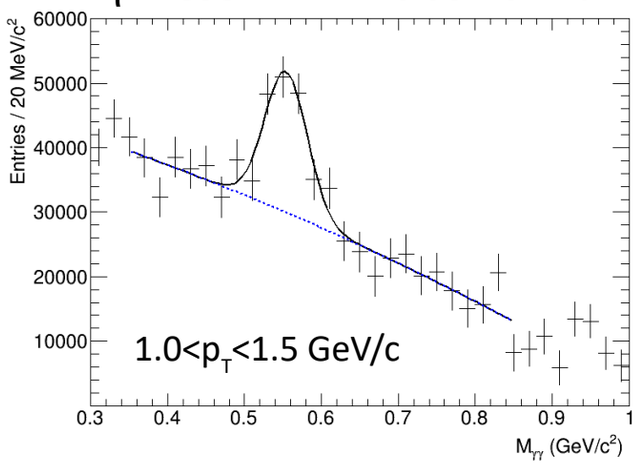
Red markers – UrQMD, minbias AuAu@11



π^0-meson in central Au+Au

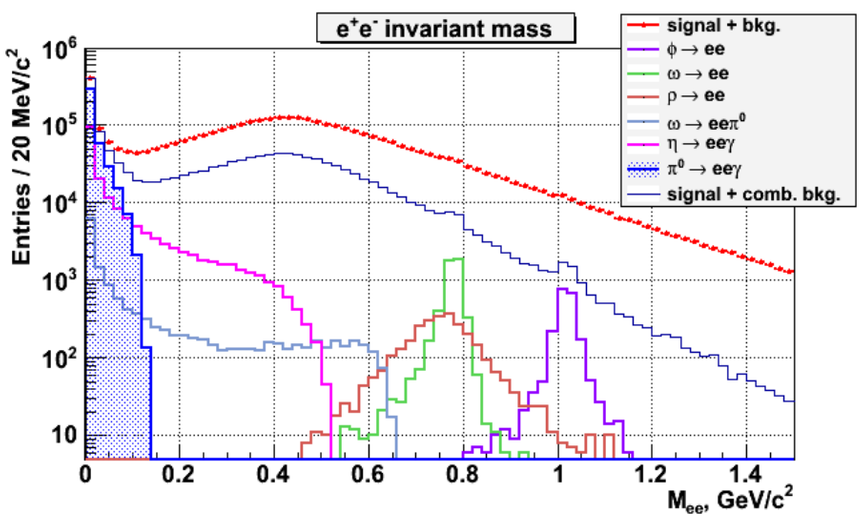


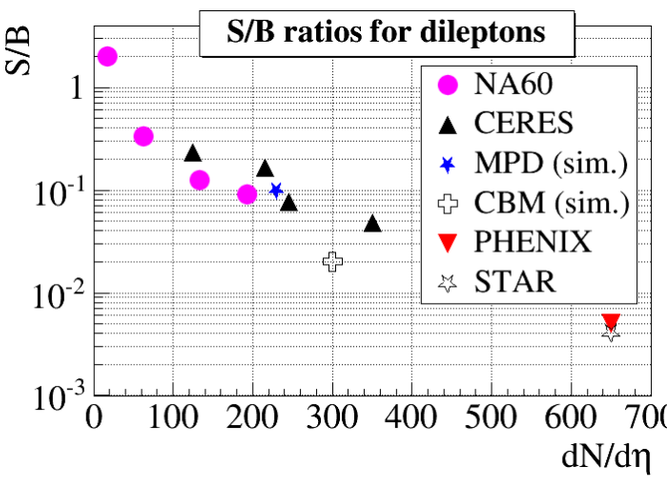
η-meson in minbias Au+Au



Yields, central Au+Au at $\sqrt{s_{NN}}$ = 8.8 GeV

Particle	Yields 4π	Yields y=0	Decay mode	BR	Effic. %	Yield /1 w
ρ	31	17	e+e-	$4.7 \cdot 10^{-5}$	35	$7.3 \cdot 10^4$
ω	20	11	e+e-	$7.1 \cdot 10^{-5}$	35	$7.2 \cdot 10^4$
ϕ	2.6	1.2	e+e-	$3 \cdot 10^{-4}$	35	$1.7 \cdot 10^4$

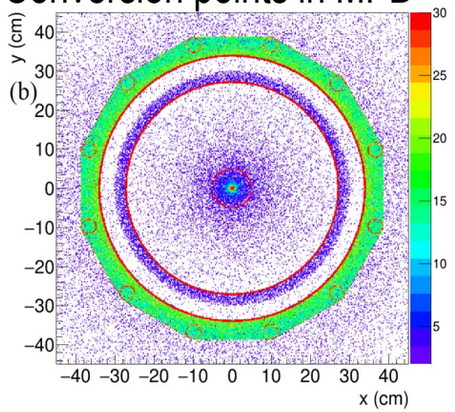


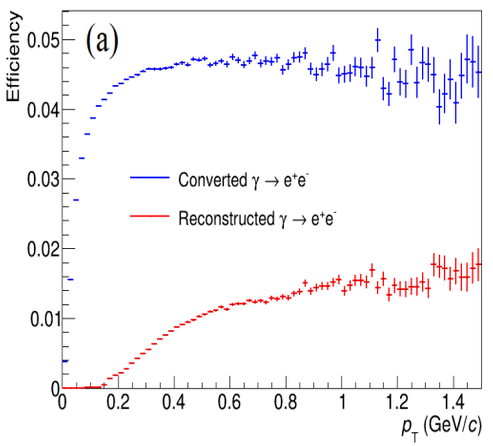


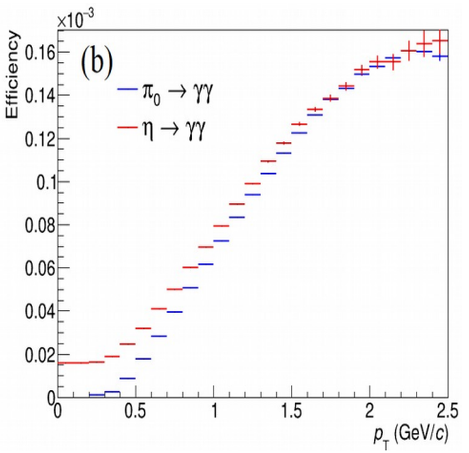
π^0 and η Reconstruction via conversion

- Photon reconstruction, complimentary to ECAL
- Direct photons, neutral mesons, geometry scan etc …
- Minbias AuAu@11, UrQMD - conversion on the beam pipe and inner layers of the TPC

Conversion points in MPD



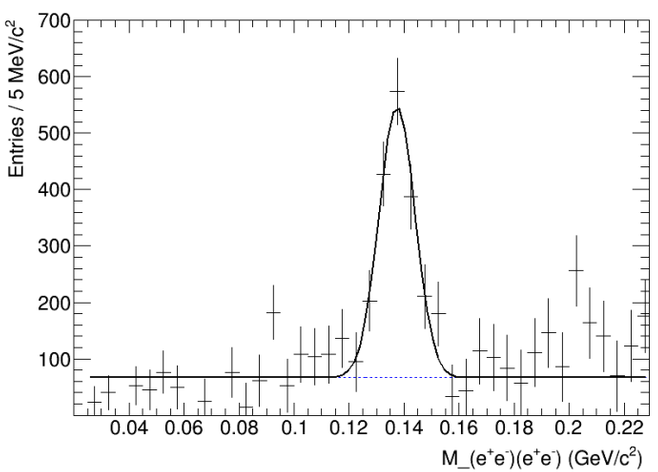




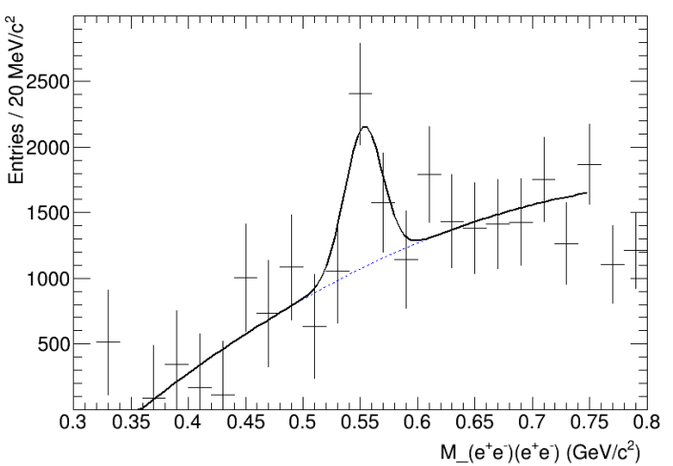
α) γ-conversion efficiency in the beam pipe & TPC vs p_T

b) MPD efficiency for π^0 and η reconstruction vs meson's p_T

$\pi^0 \rightarrow \gamma\gamma \rightarrow (e^+e^-)(e^+e^-)$



$\eta \rightarrow \gamma\gamma \rightarrow (e^+e^-)(e^+e^-)$



- Standard MPD configuration allows to reconstruct π^0 and η via conversion pairs

Summary

- NICA allows to access less-explored area of the QCD phase diagram with direct connection to astrophysics
- First stage of NICA Complex operational, data analysis ongoing
- Construction of the Booster and NICA Collider on schedule
- All components of the MPD 1st stage detector advanced in production, commissioning expected for 2020-2021
- Performance studies for full physics program under way