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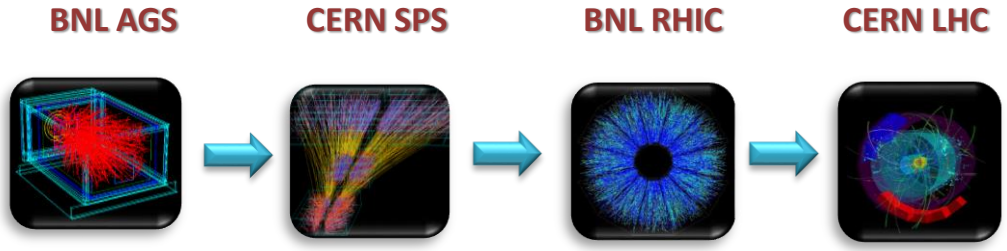
for the MPD Collaboration

Status of the MPD experiment at NICA

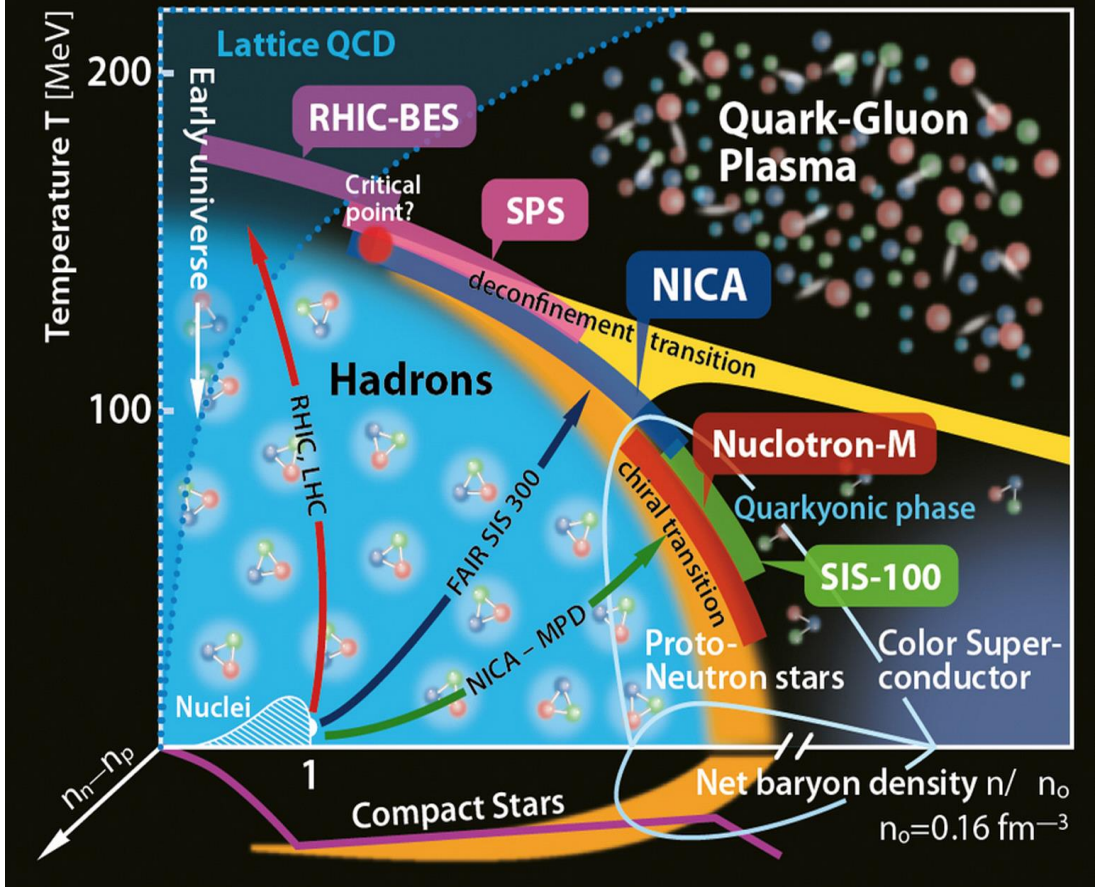
The Critical Point and Onset of Deconfinement Conference (CPOD 2021) ,
March 15 - 19, 2021

Scan of the phase diagram of QCD matter

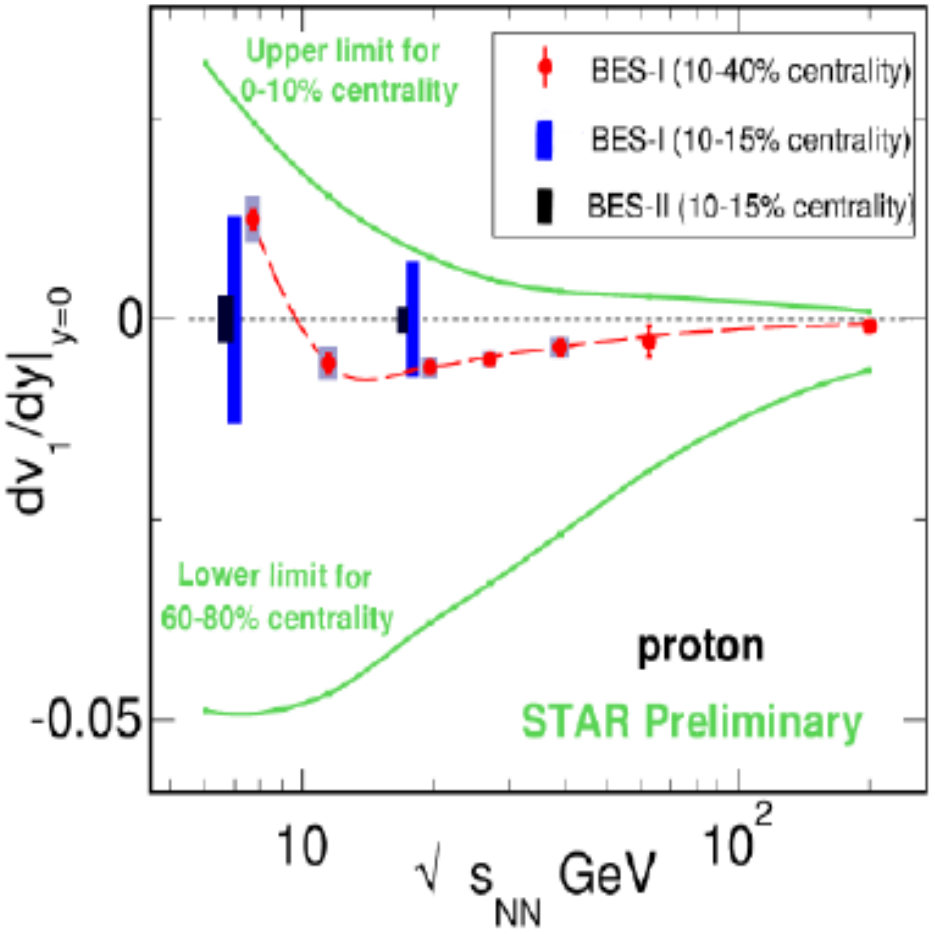


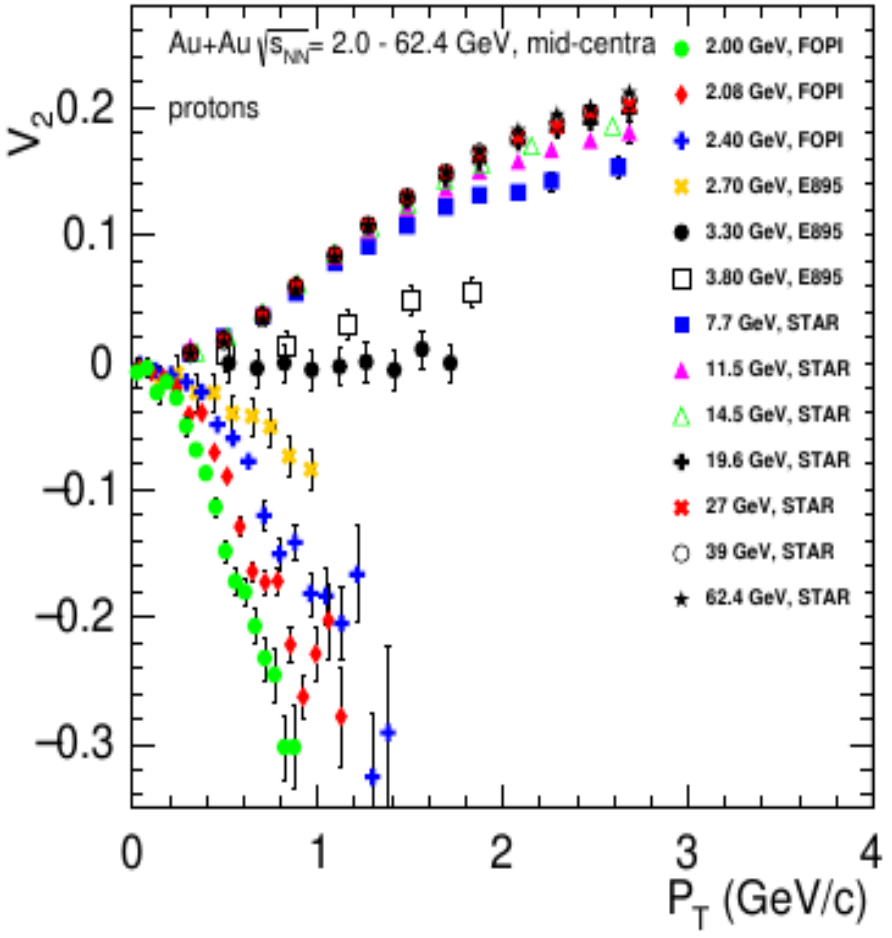
Facility	SPS	RHIC	LHC	NICA	SIS100	J-PARC-HI	HIAF
Laboratory	CERN	BNL	CERN	JINR	GSI FAIR	J-PARC	Huizhou
Experiment	NA61	STAR	ALICE, ATLAS, CMS, LHCb	BM@N MPD	HADES CBM	JHITS	CEE
Start data taking	2009	2010	2009	2018 2021	2025	2025	2024
CMS Energy [GeV/(N+N)]	5.1–17.3	3.0 - 200	2700 - 5500	2.7 - 11.0	2.3 – 4.7	1.9 – 6.2	1.8 - 2.7
Type of measurements	energy, size	energy	energy	energy	energy	energy	energy

Current & future measurements



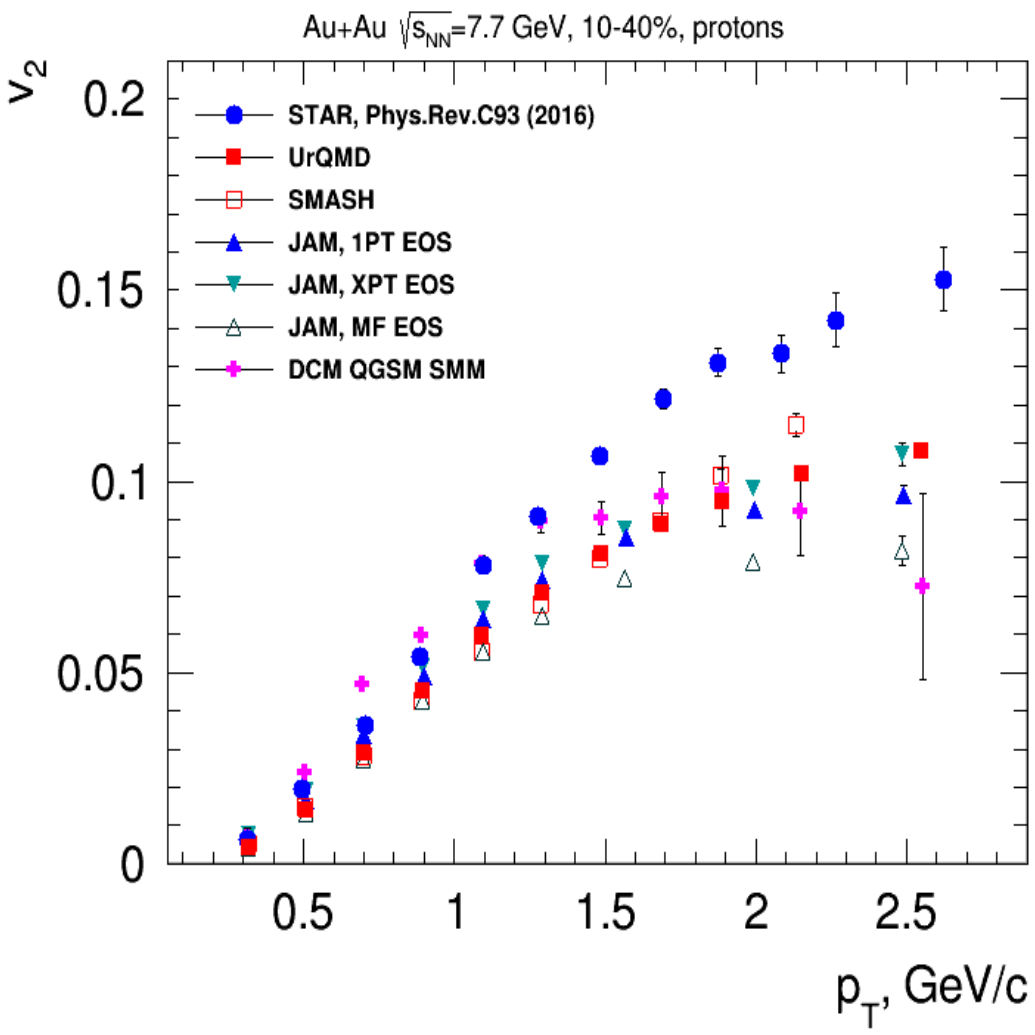
Anisotropic Flow at NICA energies

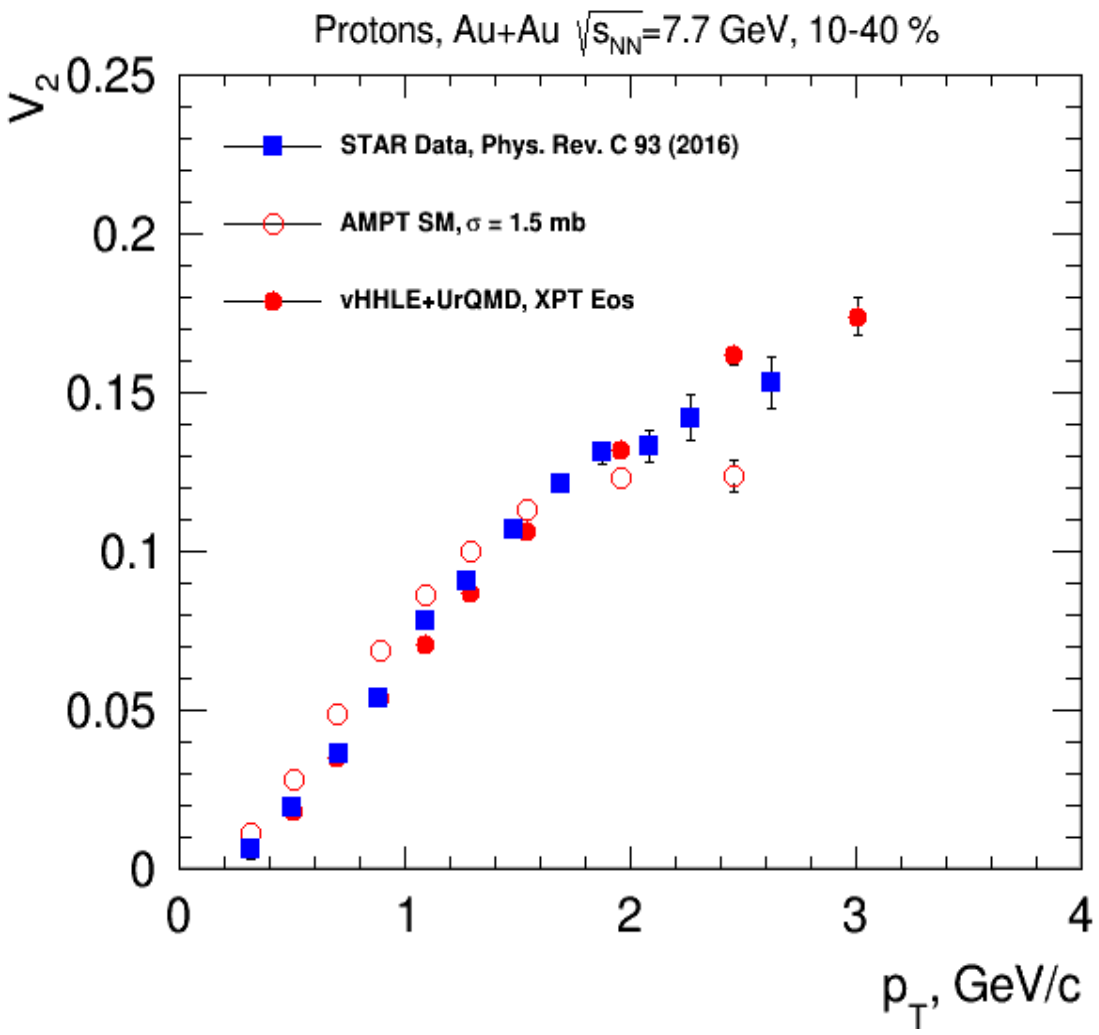




Anisotropic flow at NICA energies is a delicate balance between:
(i) the ability of pressure developed early in the reaction zone and
(ii) the passage time for removal of the shadowing by spectators

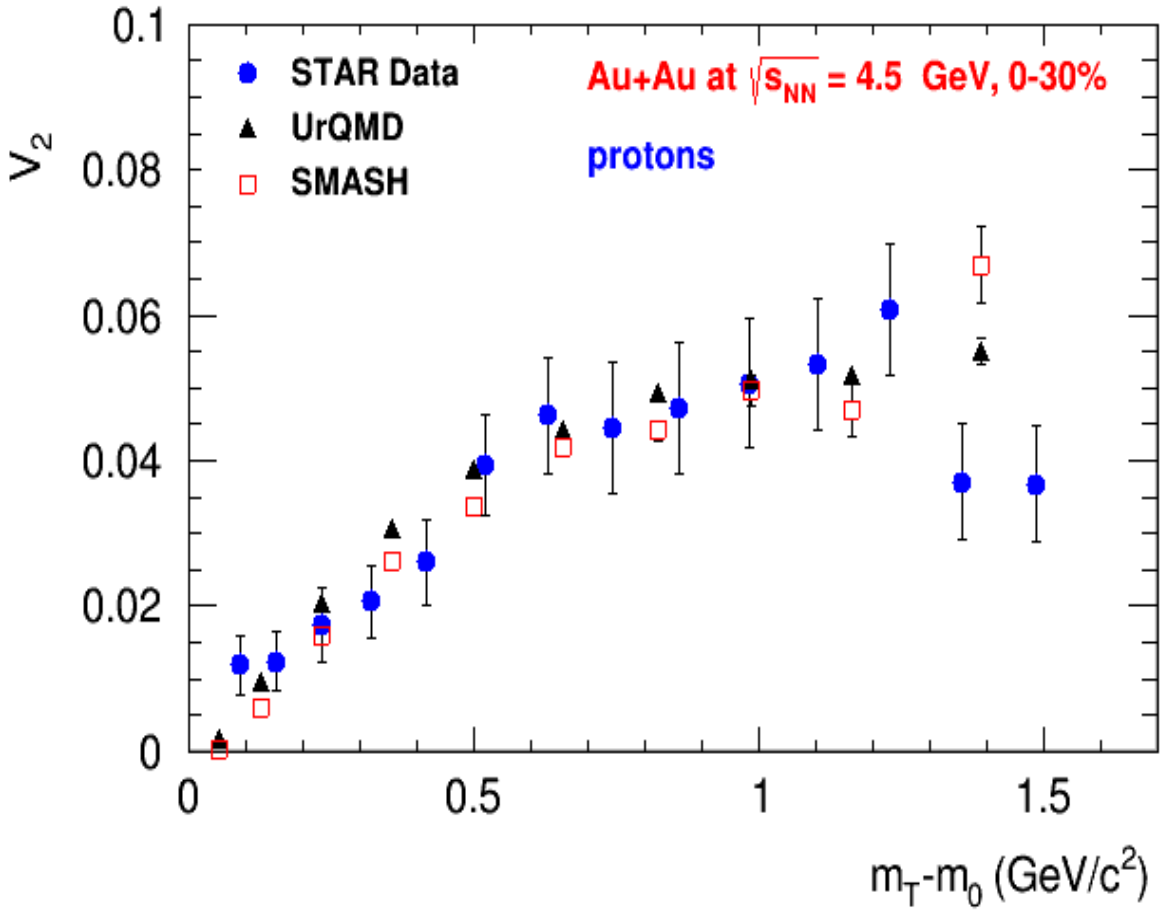
Elliptic flow at NICA energies: Models vs Data comparison

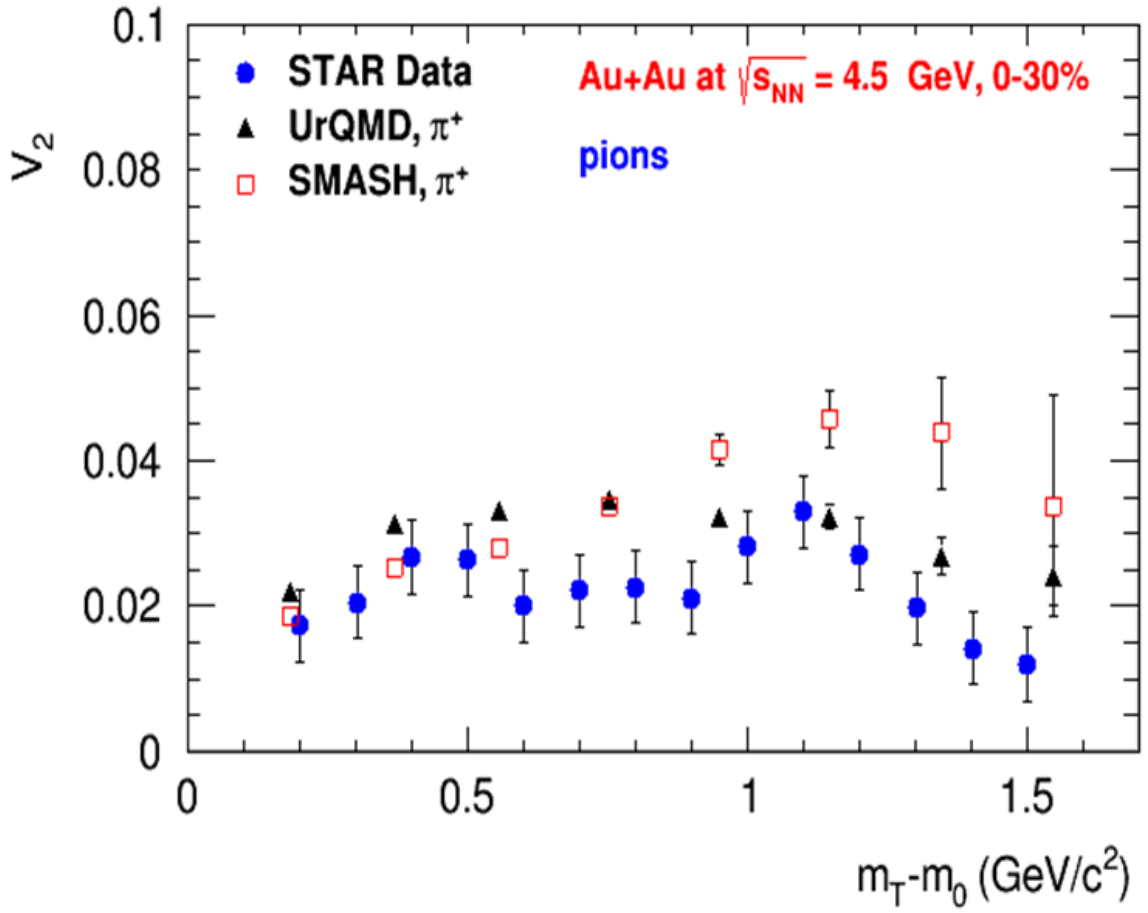




Pure String/Hadronic Cascade models give smaller v_2 signal compared to STAR data for Au+Au $\sqrt{s_{NN}}$=7.7 GeV and above

Elliptic flow at NICA energies: Models vs Data comparison





Pure String/Hadronic Cascade models give similar v_2 signal compared to STAR data for Au+Au $\sqrt{s_{NN}}$=4.5 GeV

NICA Accelerator Complex in Dubna

BM@N: data taking started in 2018

SPD TDR - 2021

SPD (Detector)

Collider - 2022

BM@N (Detector)
Extracted beam

Collider

MPD (Detector)

E-cooling

applied research infrastructure- 2021

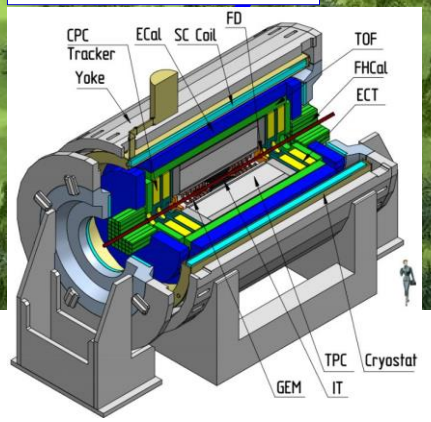
Nuclotron

Booster

Nuclotron (c=251,5 m)

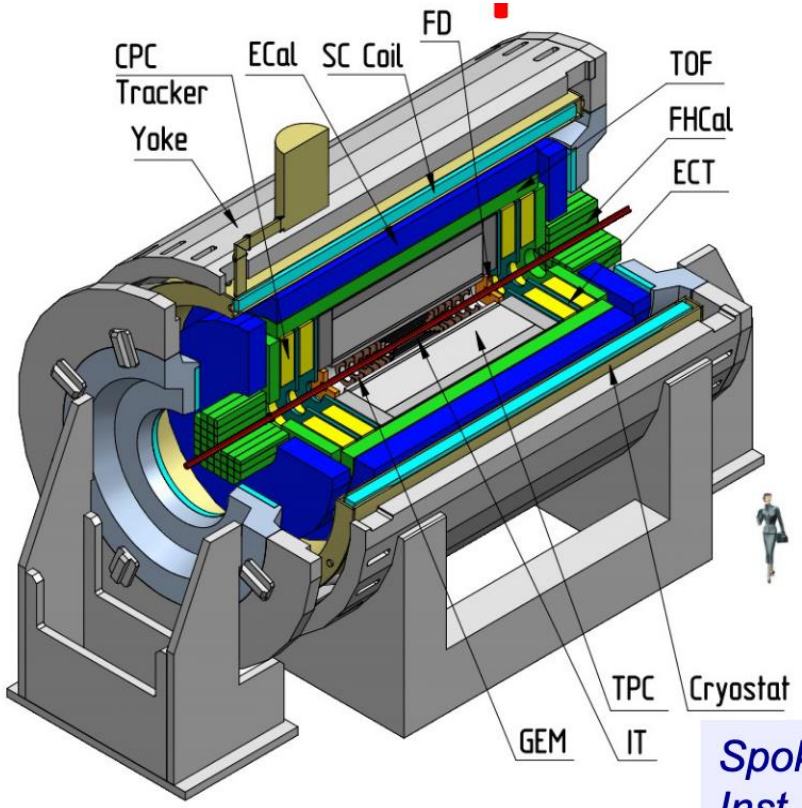
Booster - 2020

MPD - 2022



NICA Center - 2022

Multi Purpose Detector (MPD) Collaboration



***11** Countries, **>500** participants,*
41** Institutes and **JINR

NICA

***485** Members on the*
MPD Author List

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

Deputy Spokespersons:
Victor Riabov, Zebo Tang

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*University of Plovdiv, **Bulgaria;***
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*Tsinghua University, Beijing, **China;***
*USTC, Hefei, **China;***
*Huzhou 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;***
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*University of Warsaw, **Poland;***
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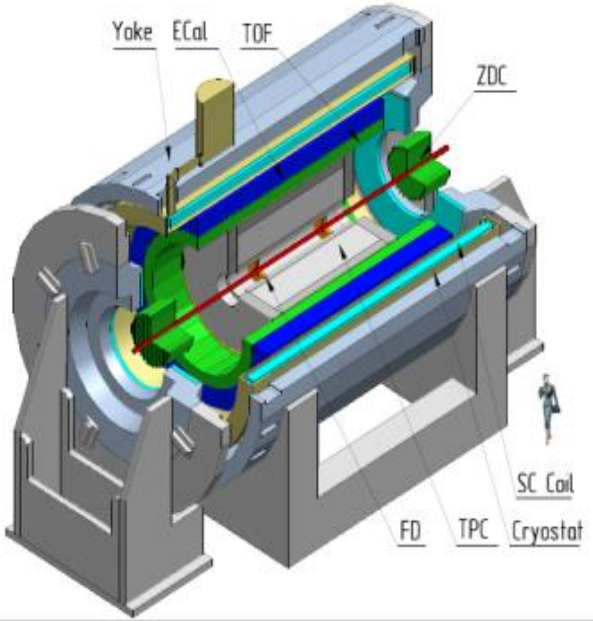
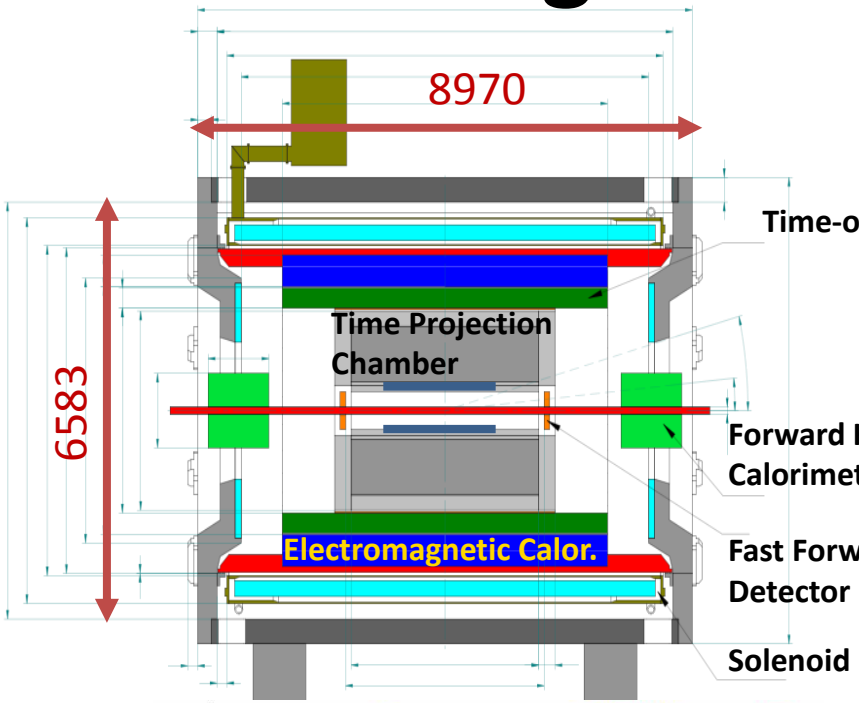
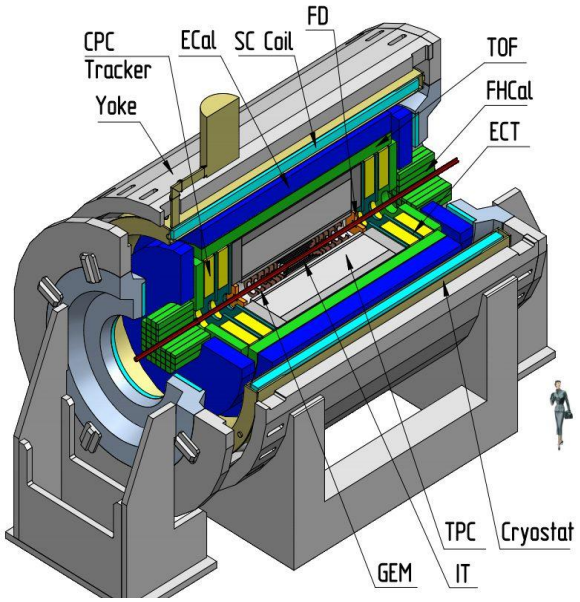
*INR RAS, Moscow, **Russia;***
*MEPhI, Moscow, **Russia;***
*Moscow Institute of Science and Technology, **Russia;***
*North Osetian State University, **Russia;***
*NRC Kurchatov Institute, ITEP, **Russia;***
*Kurchatov Institute, Moscow, **Russia;***
*St. Petersburg State University, **Russia;***
*SINP, Moscow, **Russia;***
*PNPI, Gatchina, **Russia;***

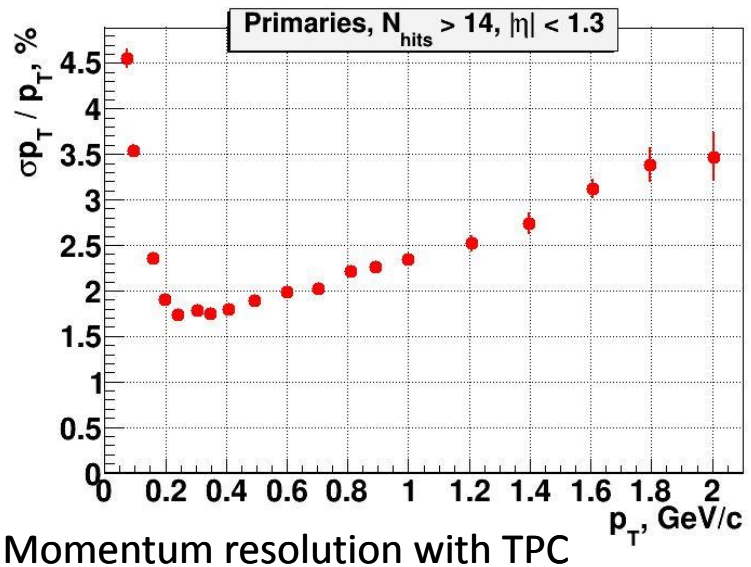
MPD - stage I and II



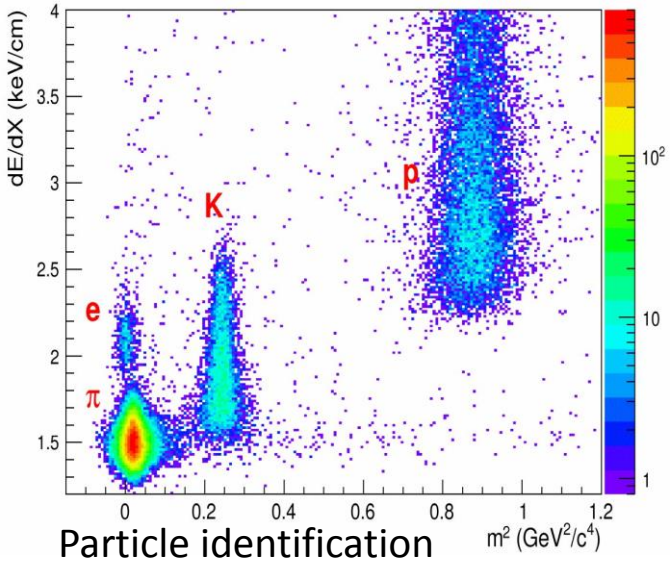


MPD - Stage II

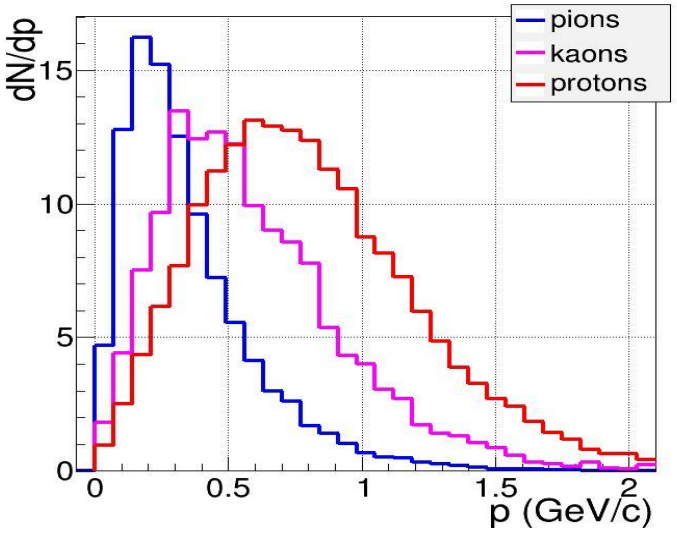




Momentum resolution with TPC



Particle identification



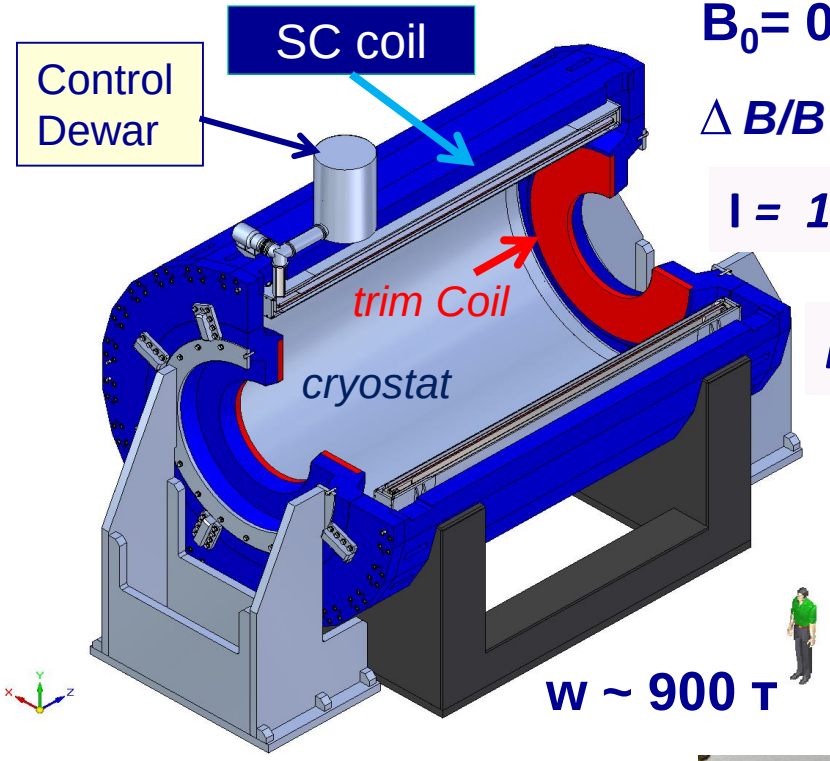
Momentum dist. of secondary particles

MPD Civil Construction status

- MPD Hall ready for limited scope of equipment installation, remaining works still ongoing

MPD Hall crane weight test

MPD Superconducting Solenoid



B_0= 0.5T

$\Delta B/B \sim 3x10^{-4}$

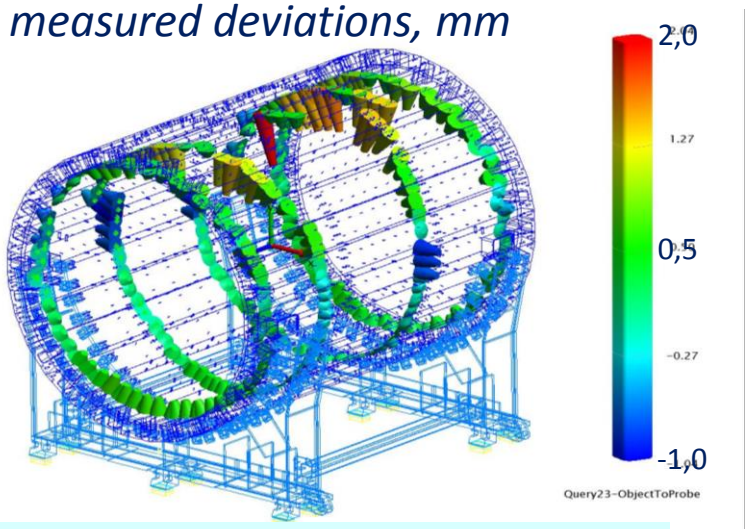
I = 1790 A

E = 14.6 MJ

w ~ 900 т

*test assembly of the **magnet yoke**: required accuracy is confirmed*

measured deviations, mm



Cryostat with SC coil delivered from Italy

stages	dates
magnet complete assembly with the cryostat, power & cryogenics supply, & test	February-September 2021
magnetic field measurements	Oct.-Nov. 2021
ready for detector installation	Dec. 2021

Milestones of MPD assembling in 2020-2022

Year 2020

1. July 15th - MPD Hall and pit are ready to store and unpack Yoke parts
2. August - The first 13 plates of Magnet Yoke are assembled for alignment checks
3. Sept 15 - Oct 1st - Solenoid is ready for transportation from ASG (Italy)
4. November 6th - Solenoid arrived in Dubna
5. Nov-Dec - Assembling of Magnet Yoke at JINR

Year 2021

6. Jan- Sep - Preparation for switching on the Solenoid (Cryogenics, Power Supply et cet.)
7. Oct - Nov - Magnetic Field measurement
8. Dec - Installation of Support Frame

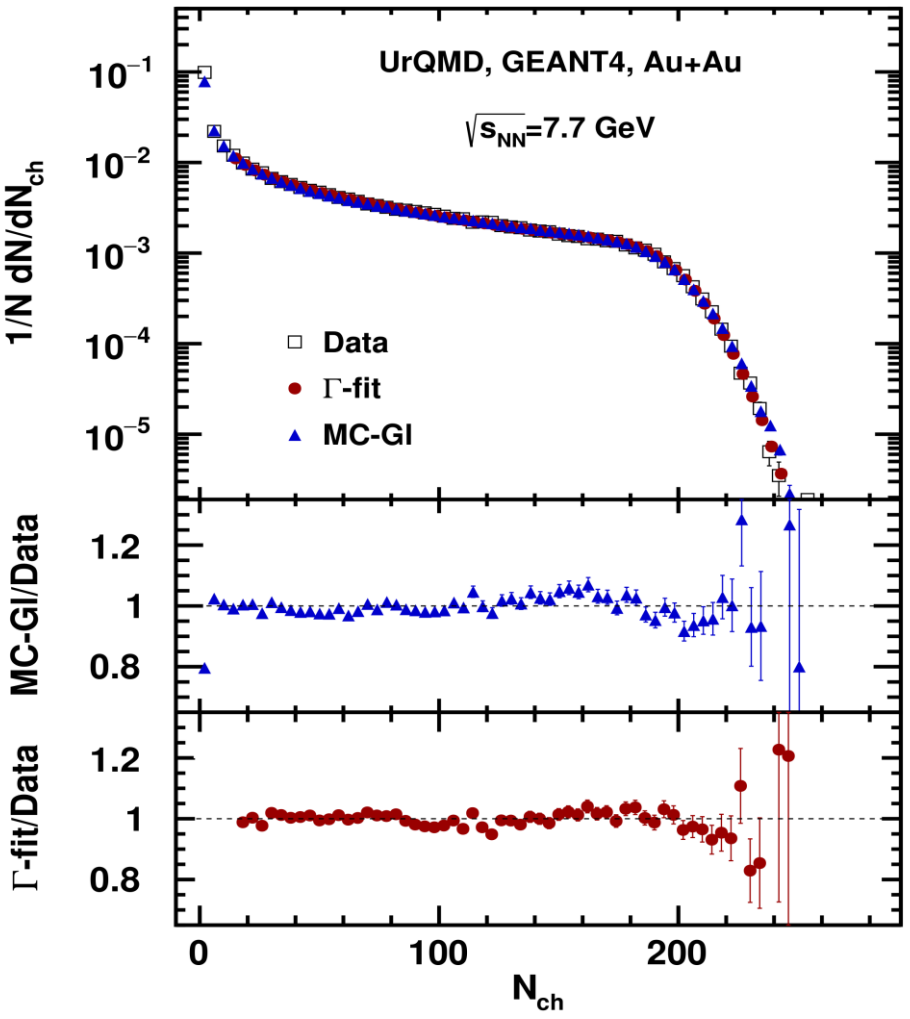
Year 2022

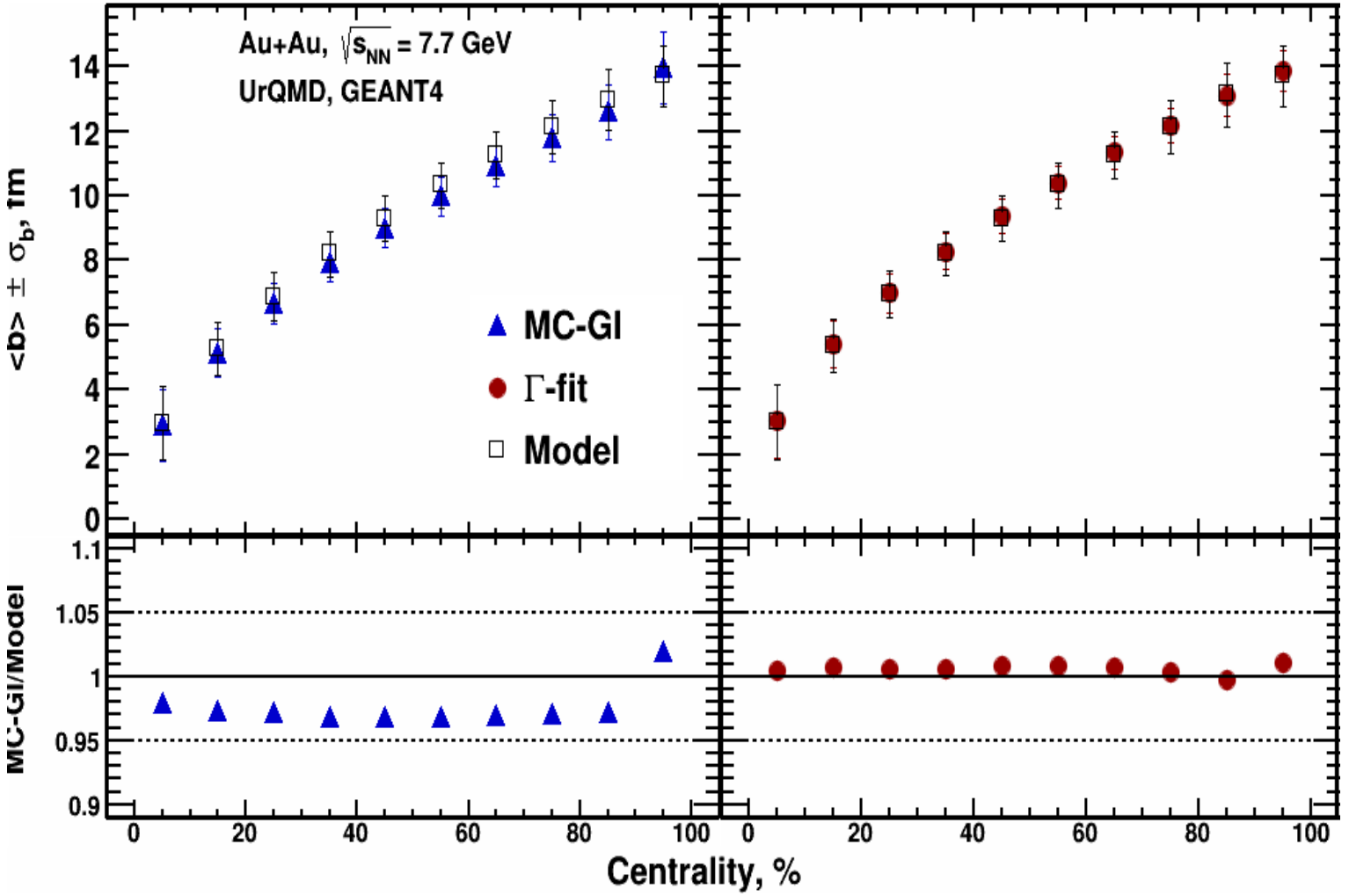
9. Jan- Jun - Installation of TOF, TPC, Electronics Platform, Cabling
10. Jul - Installation of beam pipe, FHCal, Cosmic Ray test system
11. Jul-Dec - Cosmic Ray tests
12. December - Commissioning

- **Year 2023**

13. **March - Run on the beam**

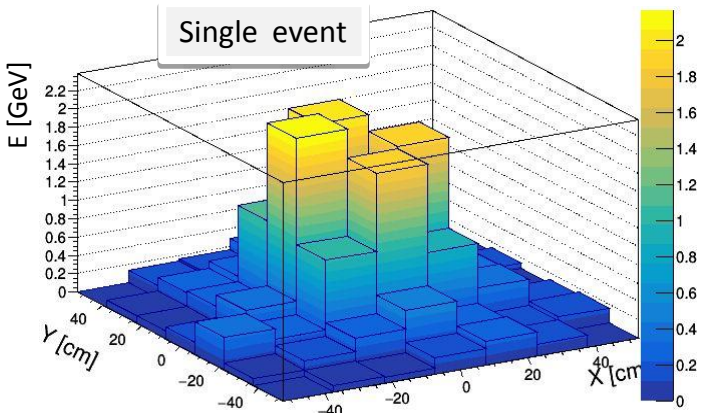
Centrality determination in MPD : multiplicity of charged particles

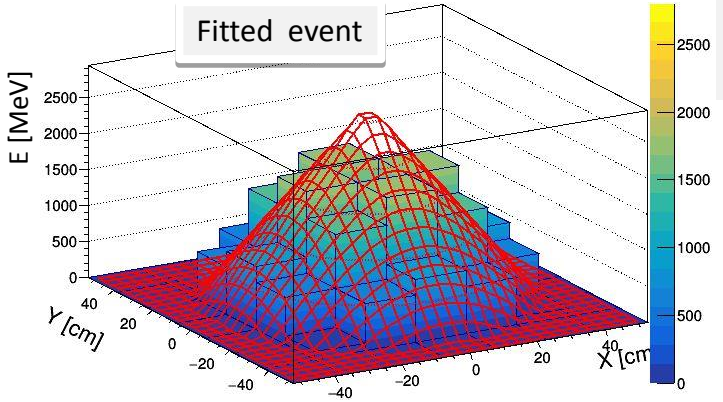




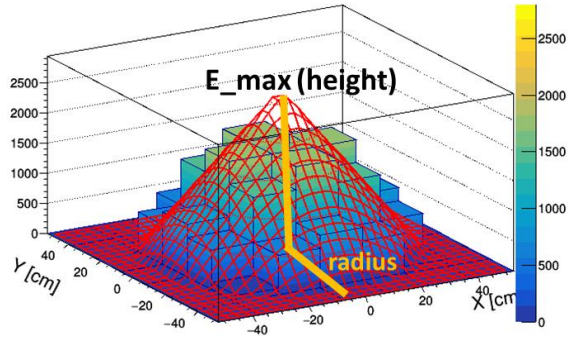
Centrality using energy of spectators in FHCal

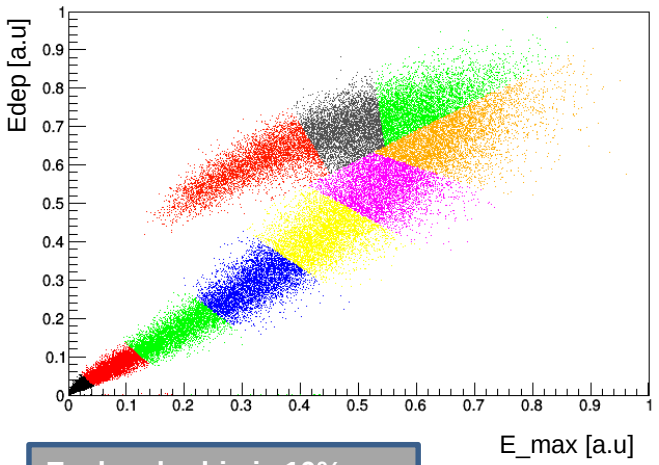
Energy distribution in FHCal modules



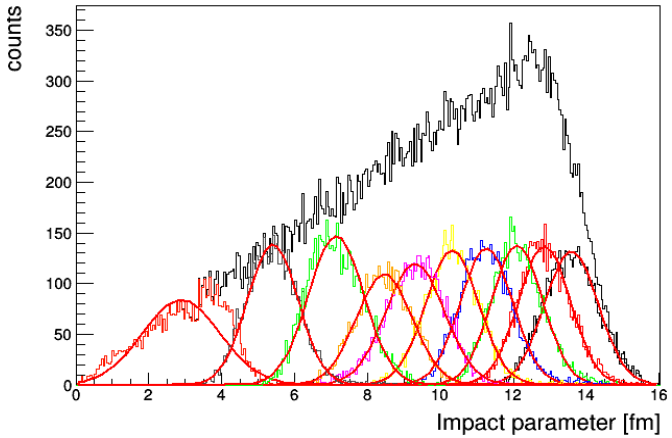


Initially we have experimental energy deposition E_{dep} in FHCal.





Each color bin is 10% fractions of the total number of events.



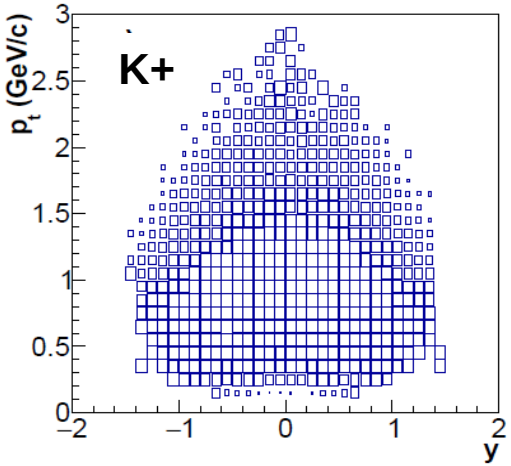
Centrality resolution

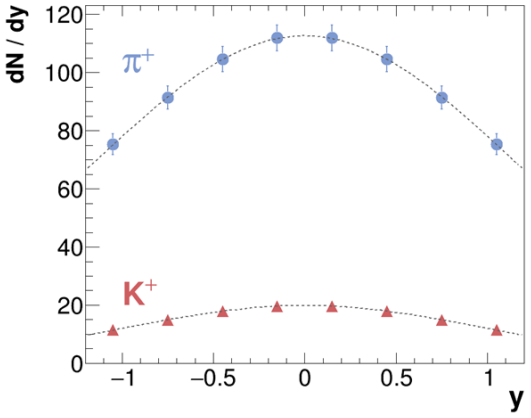
Hadroproduction with MPD

- **Particle spectra, yields & ratios are sensitive to bulk fireball properties and phase transformations in the medium**
- **Uniform acceptance and large phase coverage are crucial for precise mapping of the QCD phase diagram**

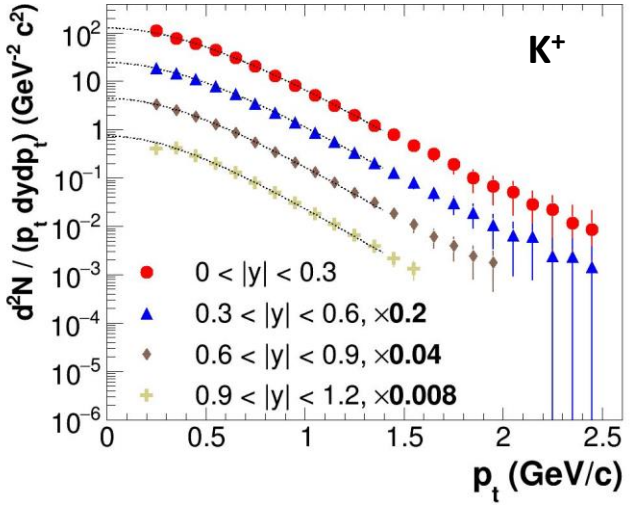
✓ *0-5% central Au+Au at 9 GeV from the PHSD event generator, which implements partonic phase and CSR effects*

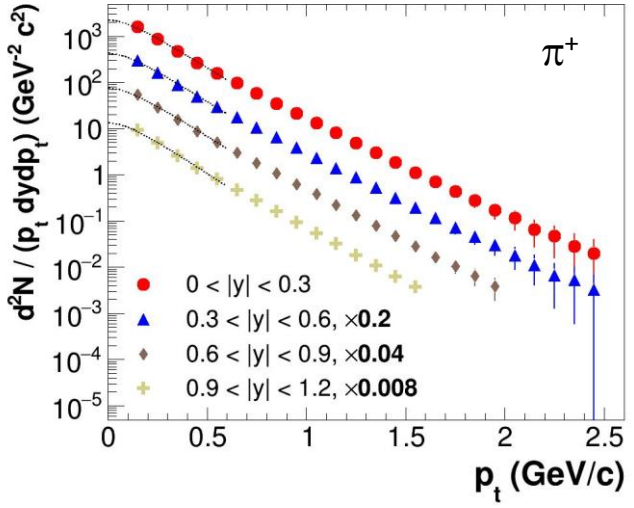
✓ *Recent reconstruction chain, combined dE/dx+TOF particle ID, spectra analysis*





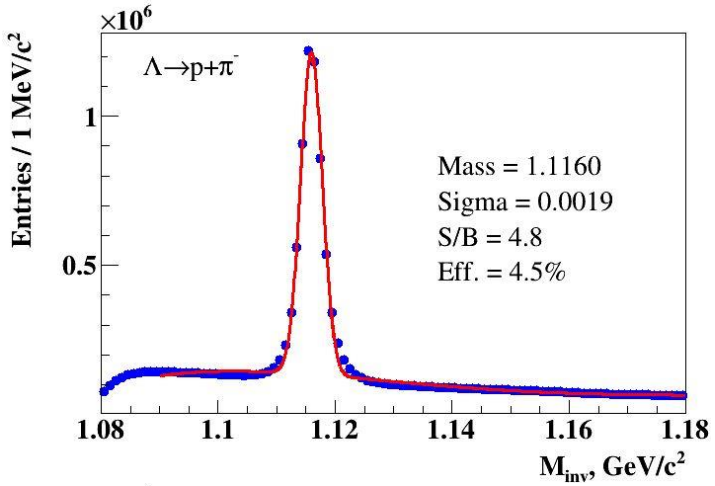
- MPD provides large phase-space coverage for identified pions and kaons (> 70% of the full phasespace at 9 GeV)
- Hadron spectra can be measured from p_T=0.2 to 2.5 GeV/c
- Extrapolation to full p_T-range and to the full phase space can be performed exploiting the spectra shapes (see BW fits for p_T-spectra and Gaussian for rapidity distributions)

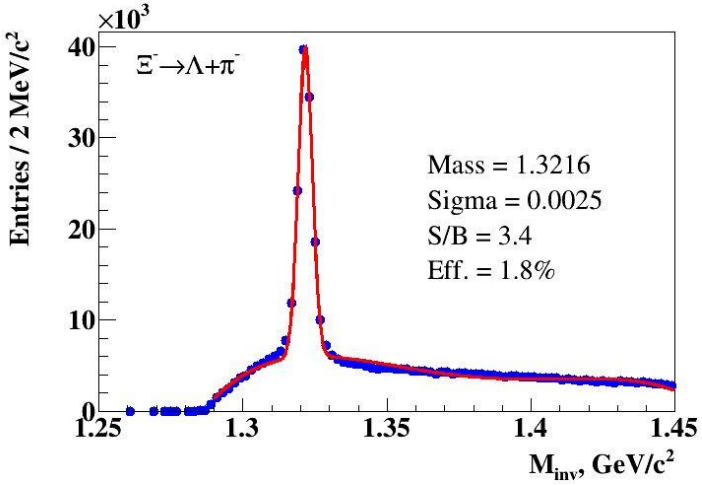


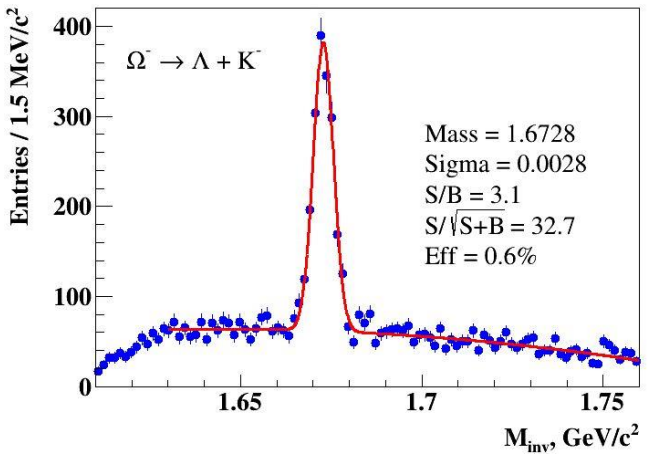


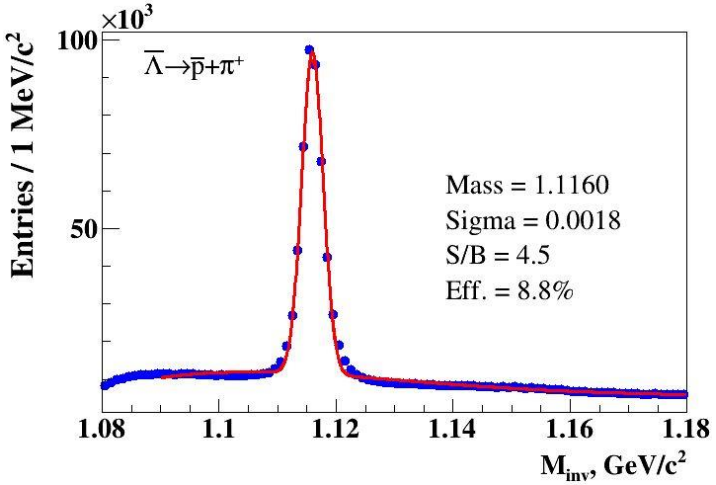
Strange and multi-strange baryons

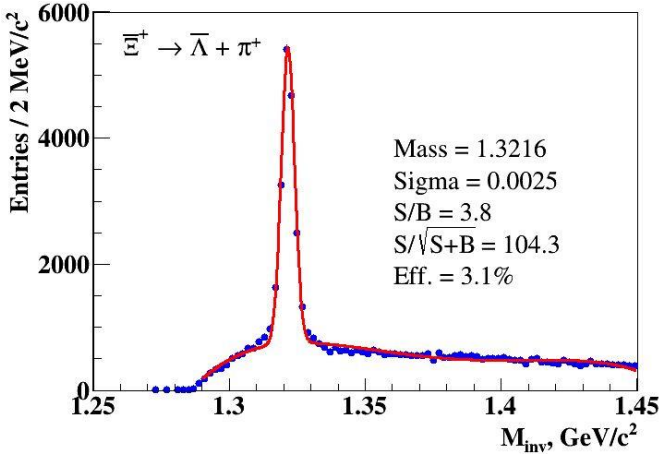
Stage'1 (TPC+TOF): Au+Au @ 11 GeV, PHSD + MPDRoot reco.

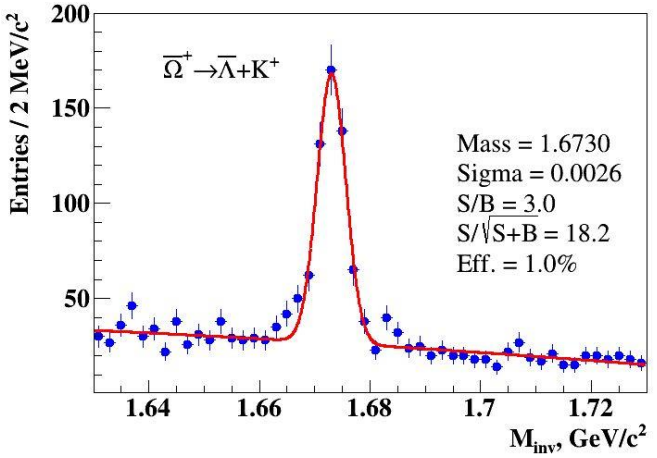






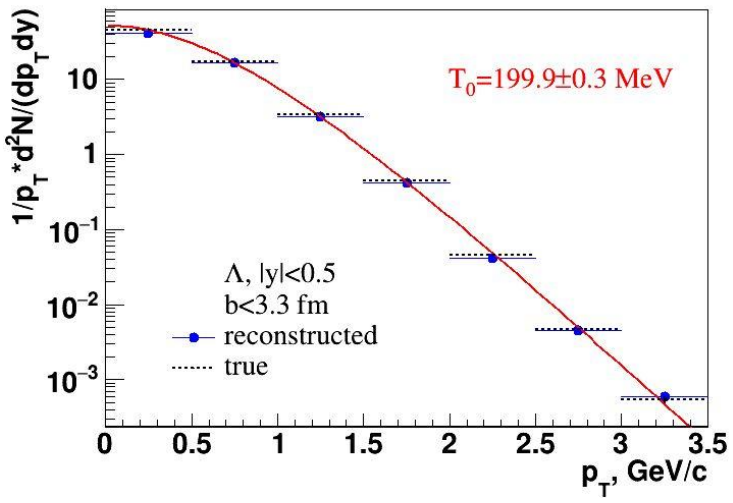


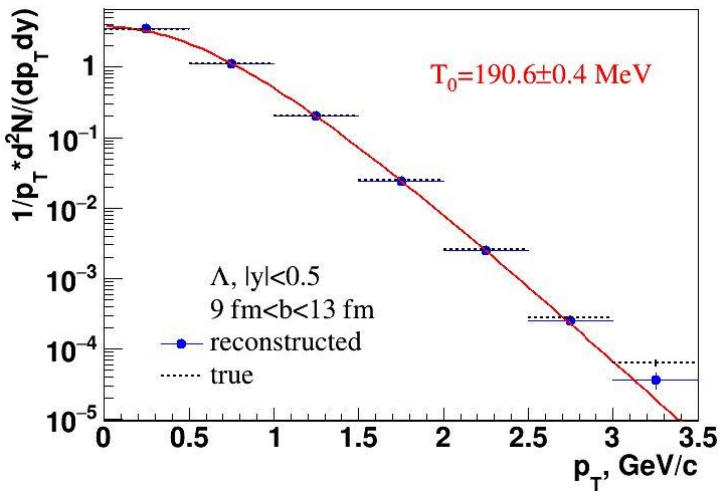


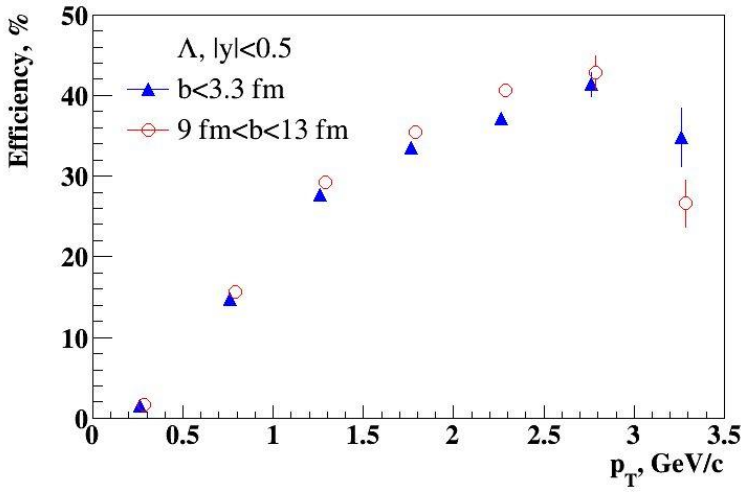


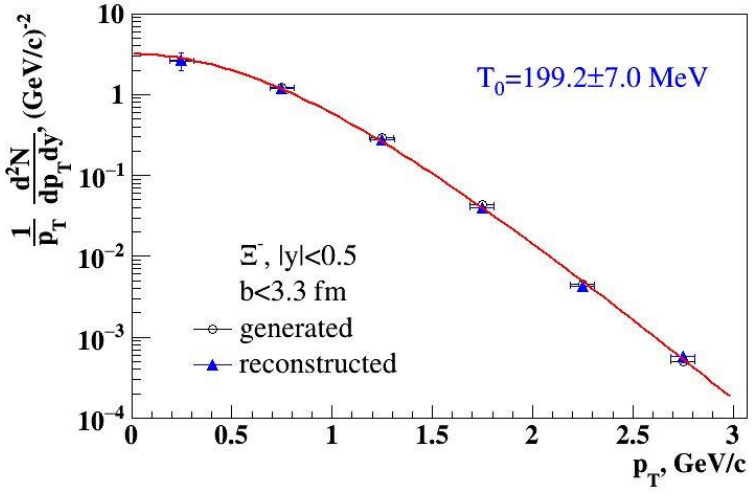
particle	Λ	anti-Λ	Ξ⁻	anti-Ξ⁺	Ω⁻	anti–Ω⁺
yield in 10 weeks	$3 \cdot 10^8$	$3.5 \cdot 10^6$	$1.5 \cdot 10^6$	$8.0 \cdot 10^4$	$7 \cdot 10^4$	$1.5 \cdot 10^4$

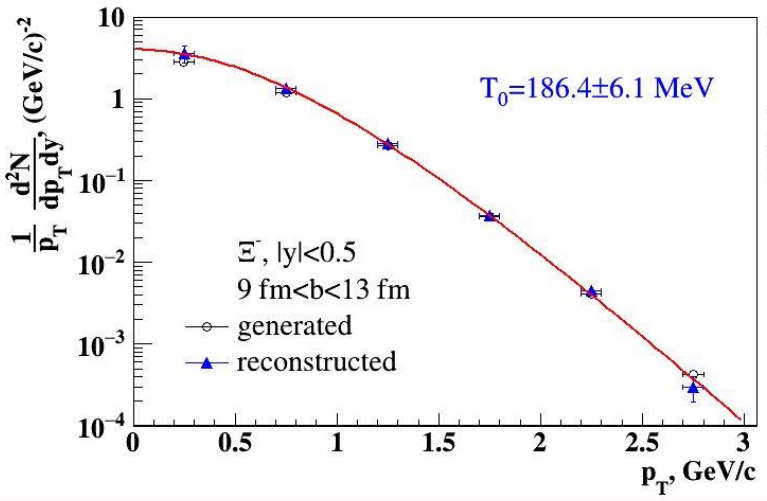
Efficiency and p_T spectrum

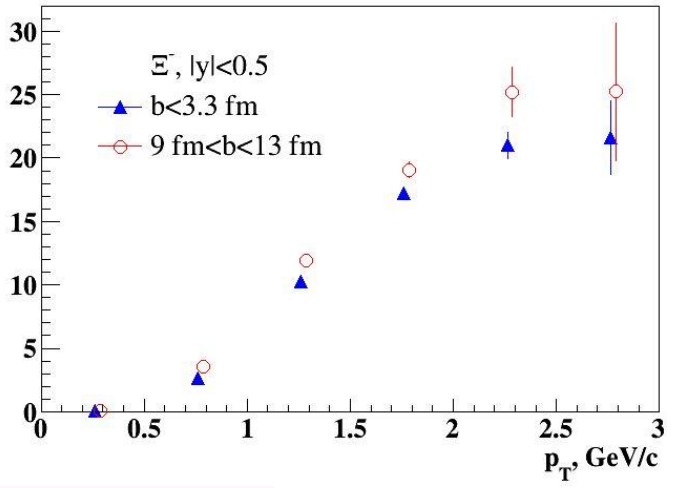






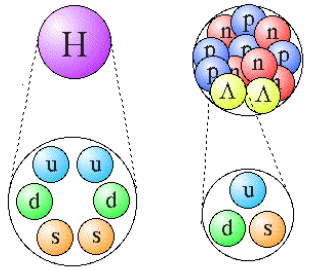






Full p_T spectrum and yield extraction, reasonable efficiency down to low p_T

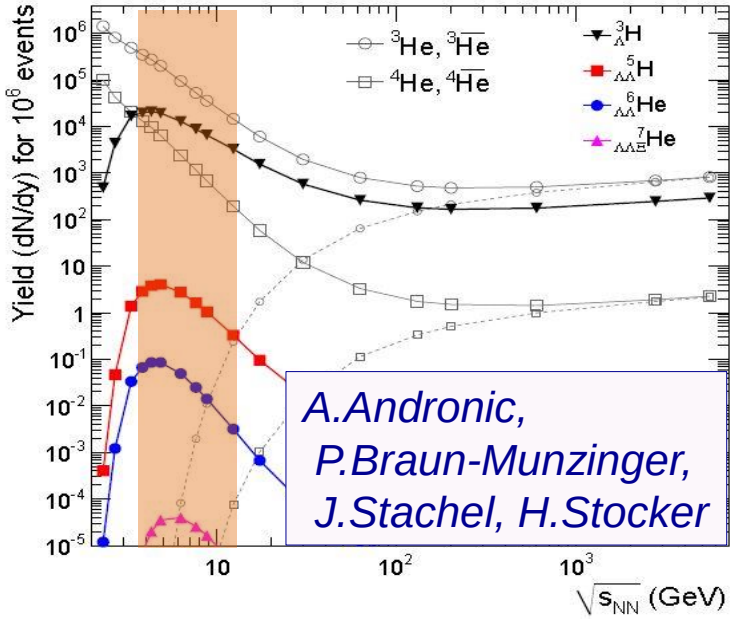
Hypernuclei at MPD

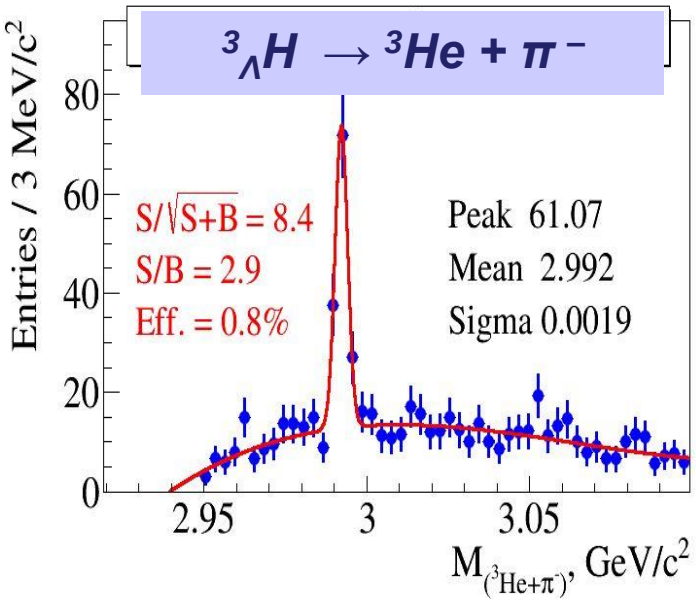


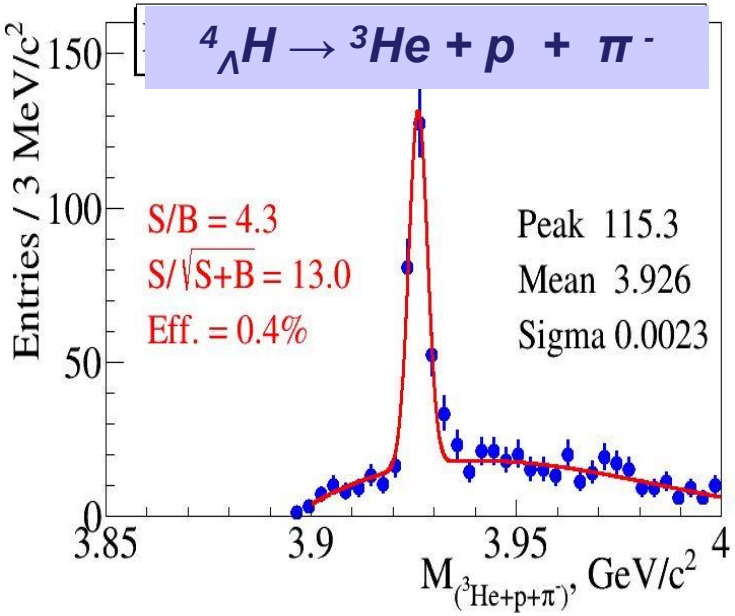
astrophysical research indicates the appearance of hyperons in the dense core of a ***neutron star***

Stage 2: *central* ***Au+Au*** *@* ***5*** *AGeV; DCM-QGSM*

hyper nucleus	yield in 10 weeks
$^{3}_{\Lambda}$He	$9 \cdot 10^5$
$^{4}_{\Lambda}$He	$1 \cdot 10^5$



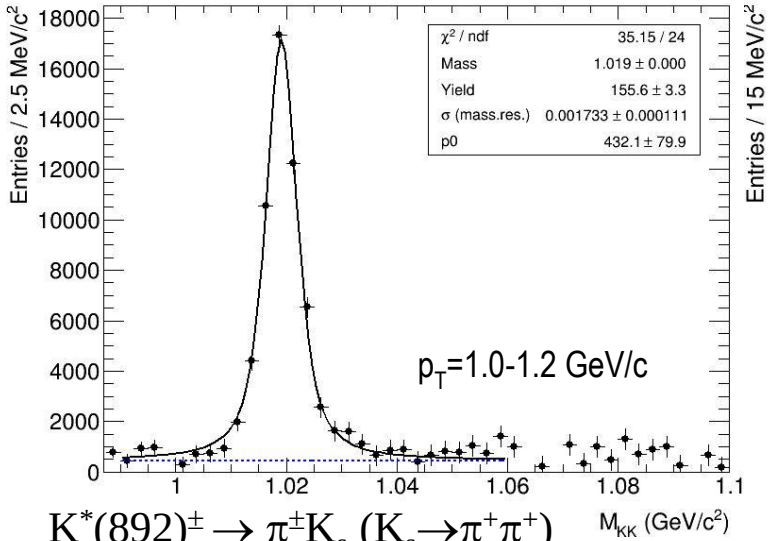




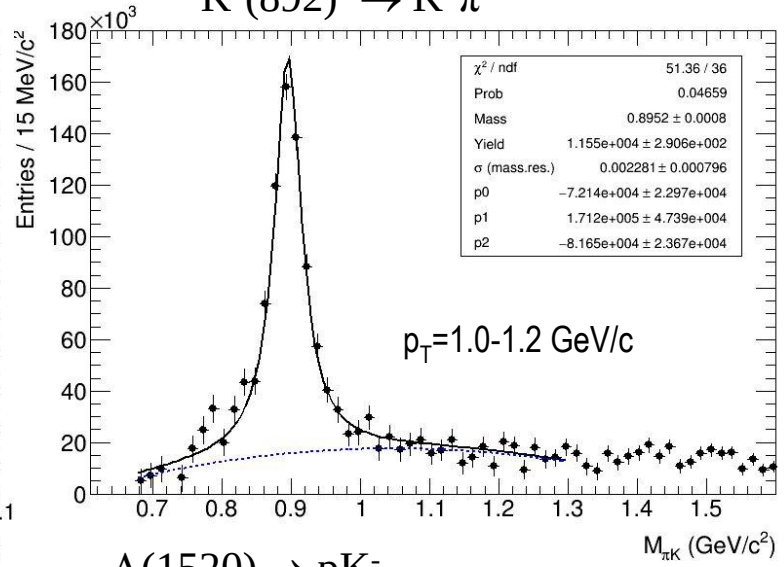
Resonances at MPD

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

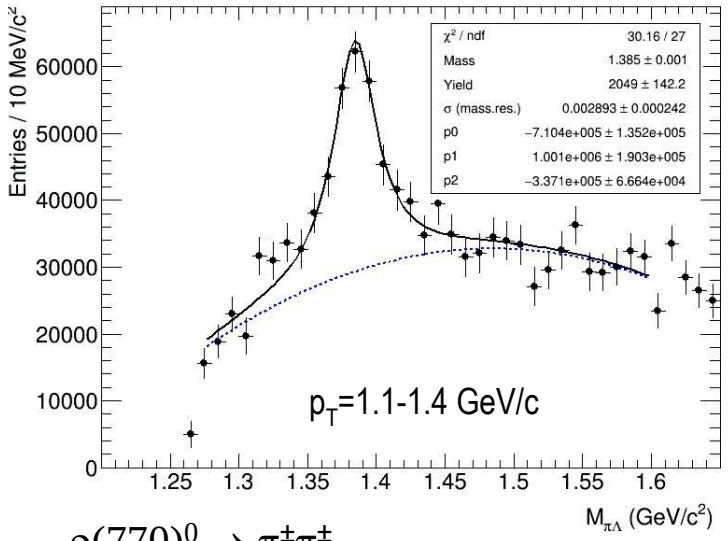
$\phi(1020) \rightarrow K^+K^-$



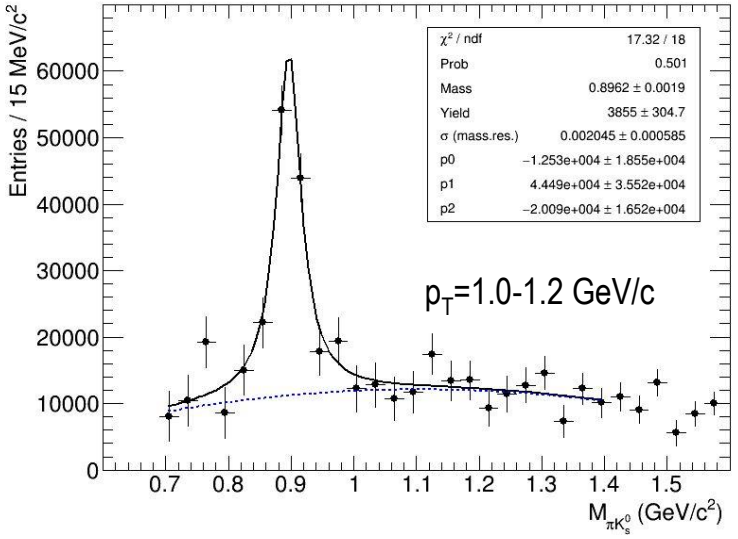
$K^*(892)^0 \rightarrow K^{\pm}\pi^{\pm}$



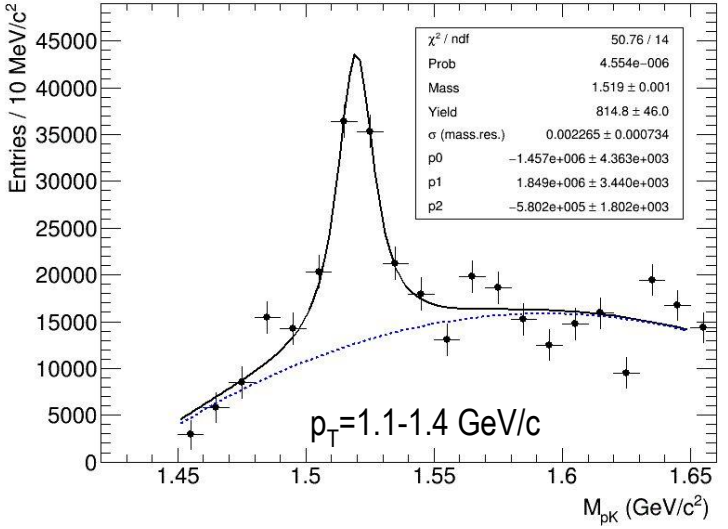
$\Sigma(1385)^{\pm} \rightarrow \pi^{\pm}\Lambda$ ($\Lambda \rightarrow p\pi$)



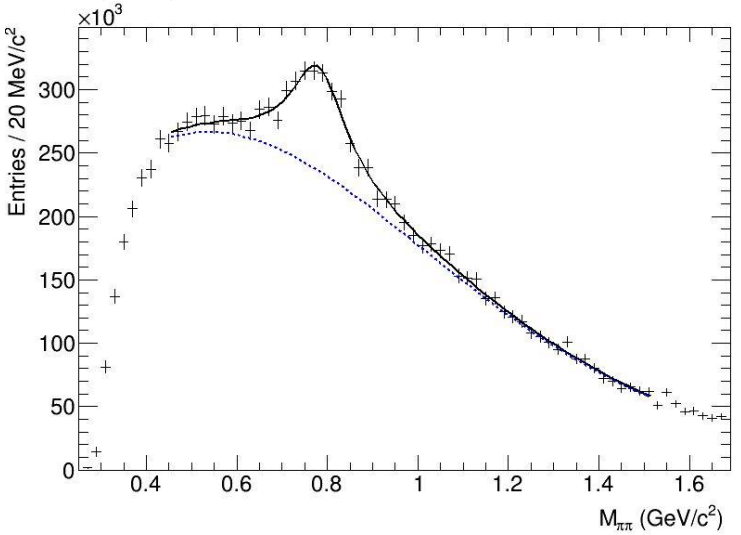
$K^*(892)^{\pm} \rightarrow \pi^{\pm}K_s$ ($K_s \rightarrow \pi^+\pi^+$)



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

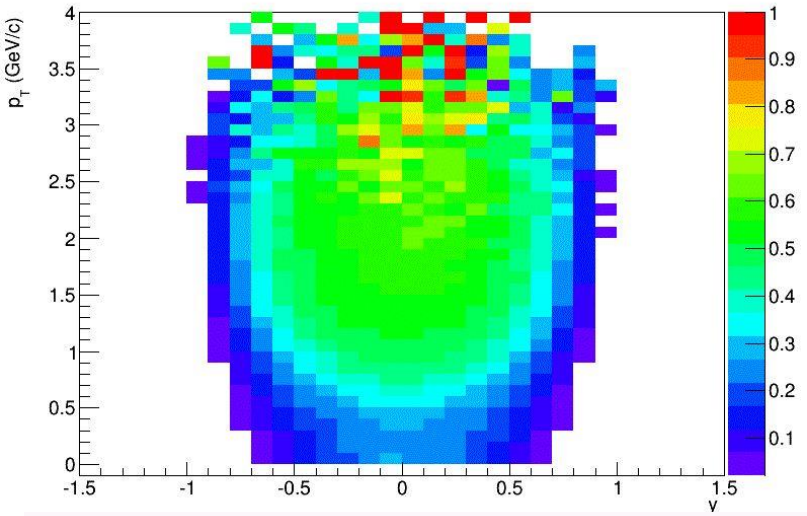


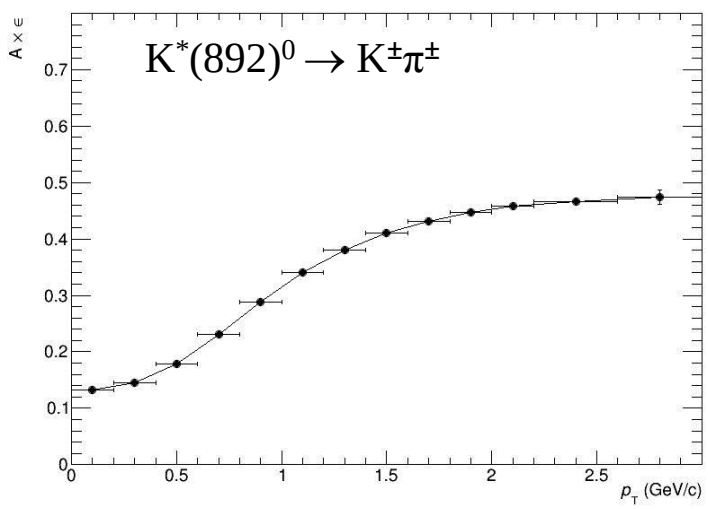
$\rho(770)^0 \rightarrow \pi^{\pm}\pi^{\pm}$

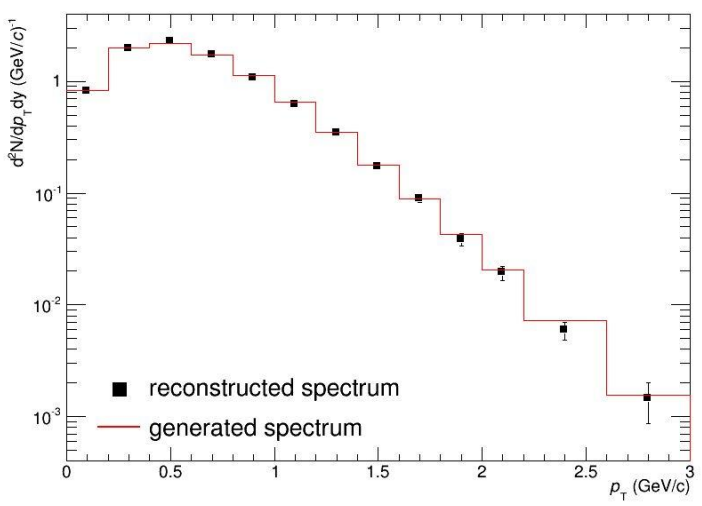


Efficiencies and closure tests examples

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

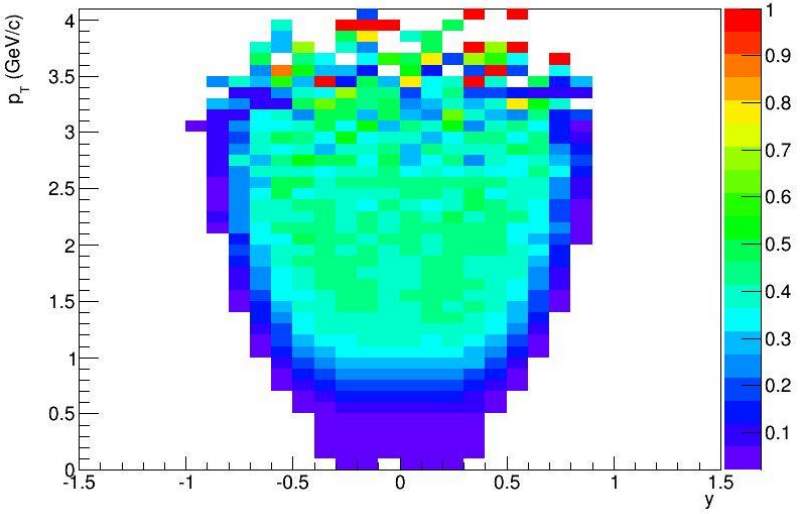


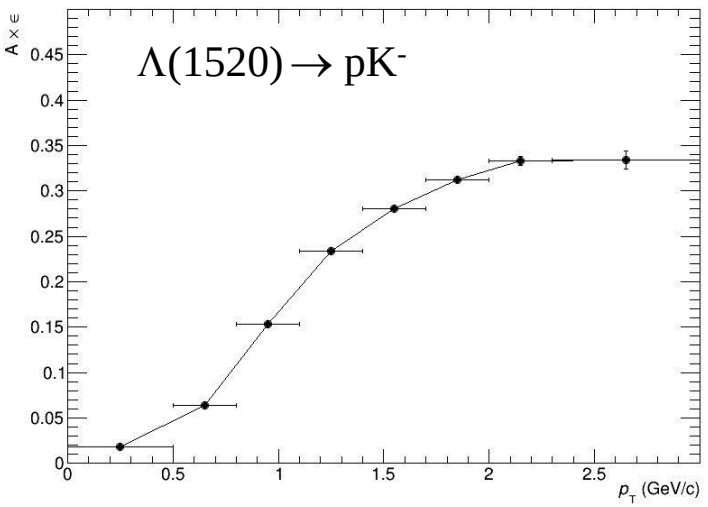


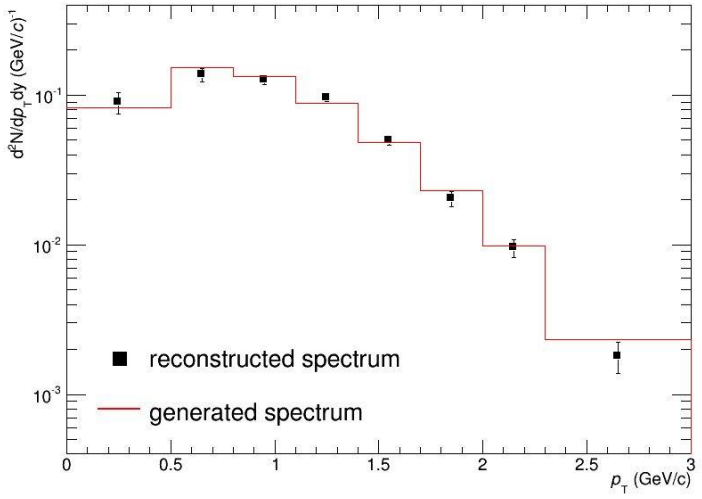


Reconstruction efficiency

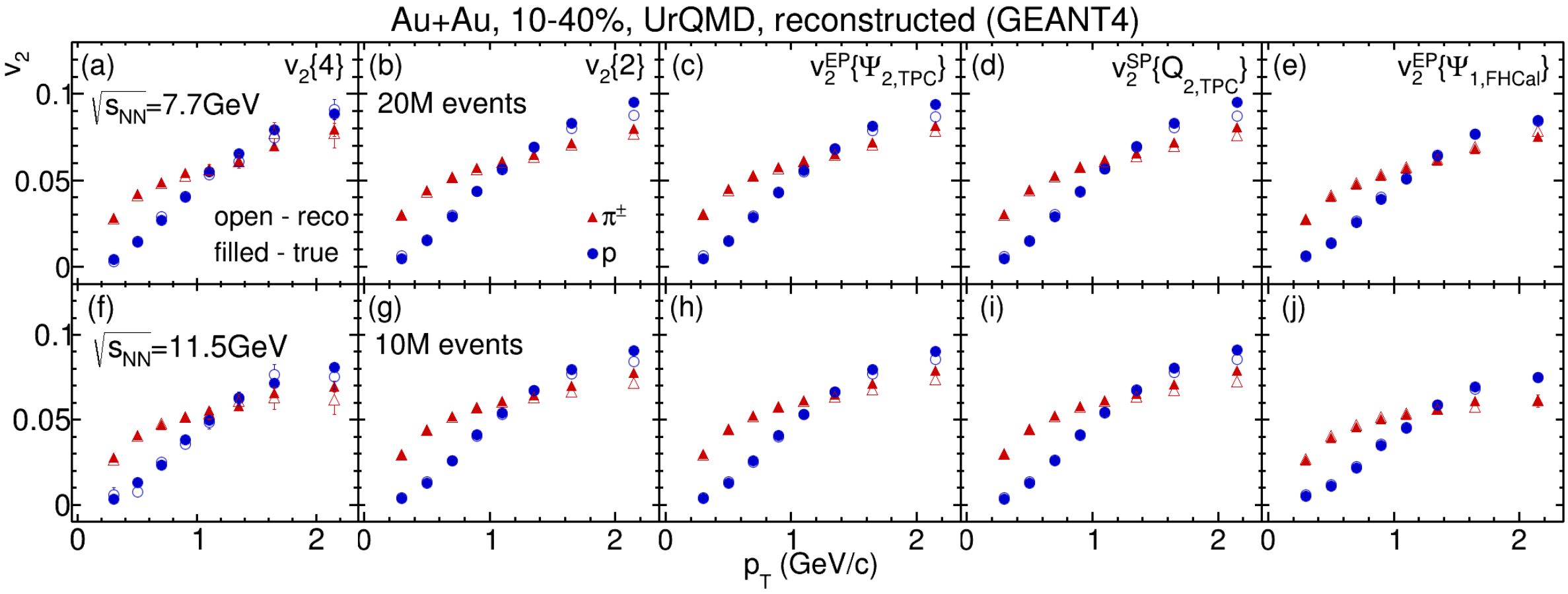
Closure Test







Performance study of v_2 of pions and protons in MPD



Reconstructed and generated v_2 of pions and protons have a good agreement for all methods

Summary

- The NICA Accelerator Complex in construction with important milestones achieved and clear plans for 2021 and 2022
- All components of the MPD 1st stage detector advanced in production, commissioning expected for 2022
- Intensive preparations for the MPD Physics program with initial beams at NICA in 2023

Thank you for you attention

Backup

Setup, event and track selection

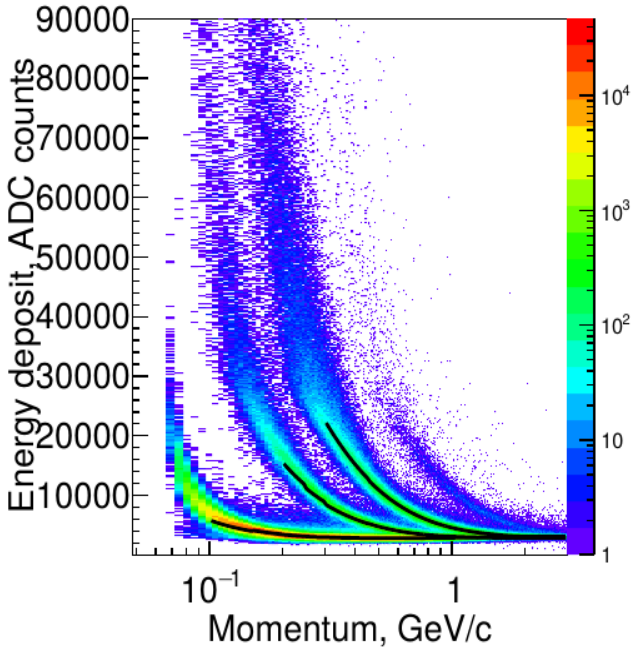
Model → GEANT4 → Reconstruction → Flow analysis

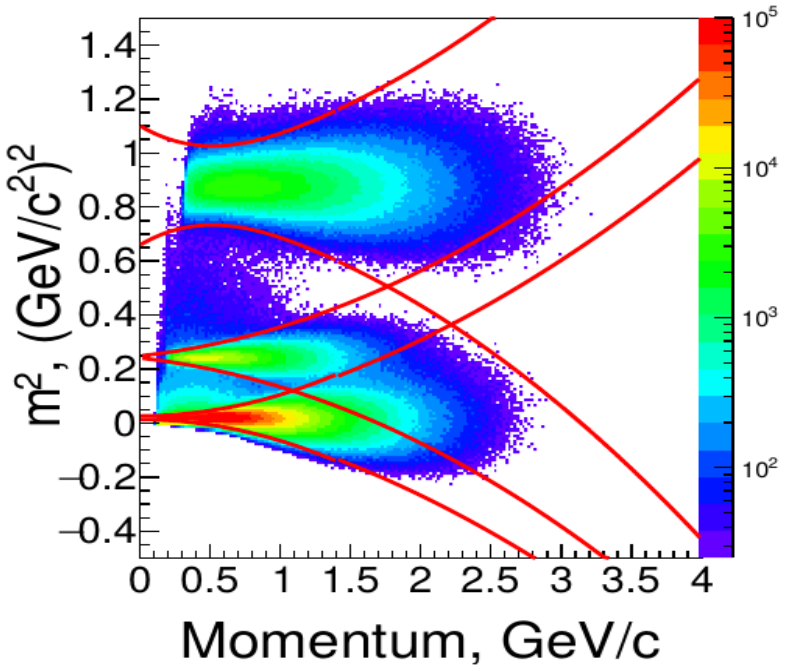
- Au+Au: UrQMD
  - N_{events} = 10 M *at* $\sqrt{s_{NN}}$ = 4.5, 11.5 GeV
  - N_{events} = 25 M *at* $\sqrt{s_{NN}}$ = 11 GeV (for K^0, Λ)
  - N_{events} = 20 M at $\sqrt{s_{NN}}$ = 7.7 GeV
- Bi+Bi:
  - N_{events} = 17 M *at* $\sqrt{s_{NN}}$ = 7.7 GeV

- TPC
- FHCal
- TOF
- ...

Event classification:
- Track multiplicity
- FHCal energy

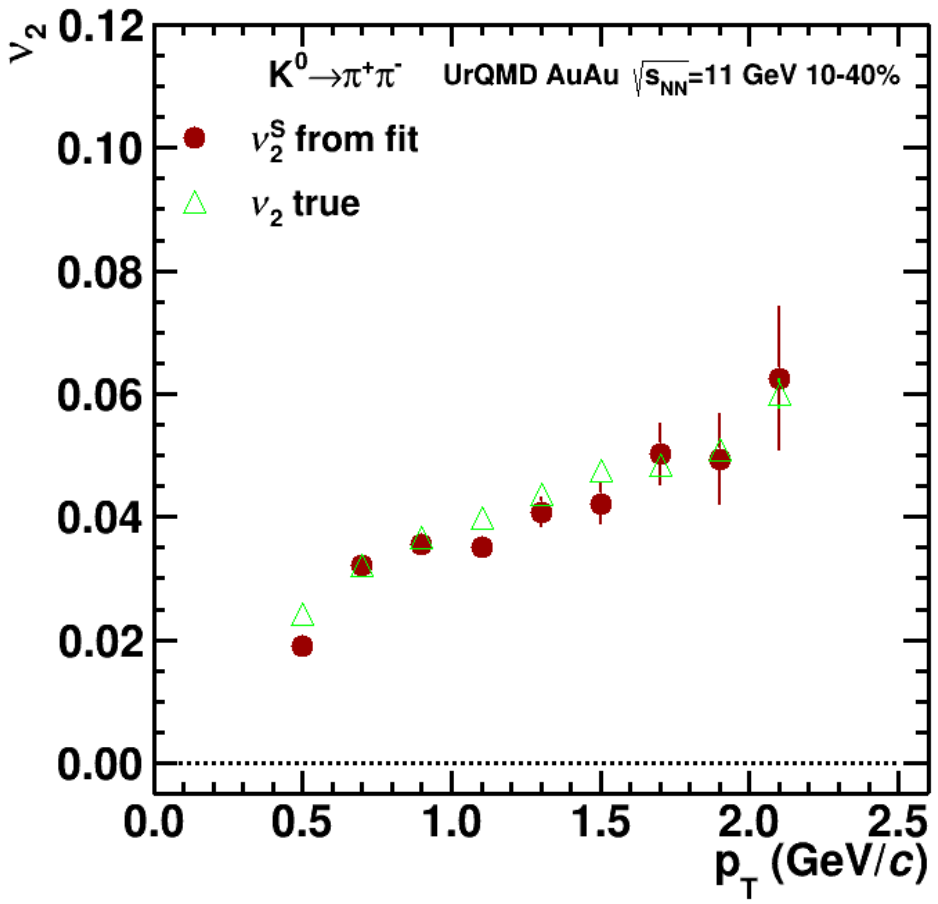
Track selection:
- $N_{TPC\ hits} > 16$
- $0.2 < p_T < 3$ GeV/c
- $|\eta| < 1.5$
- PID based on TPC+TOF (MpdPid)

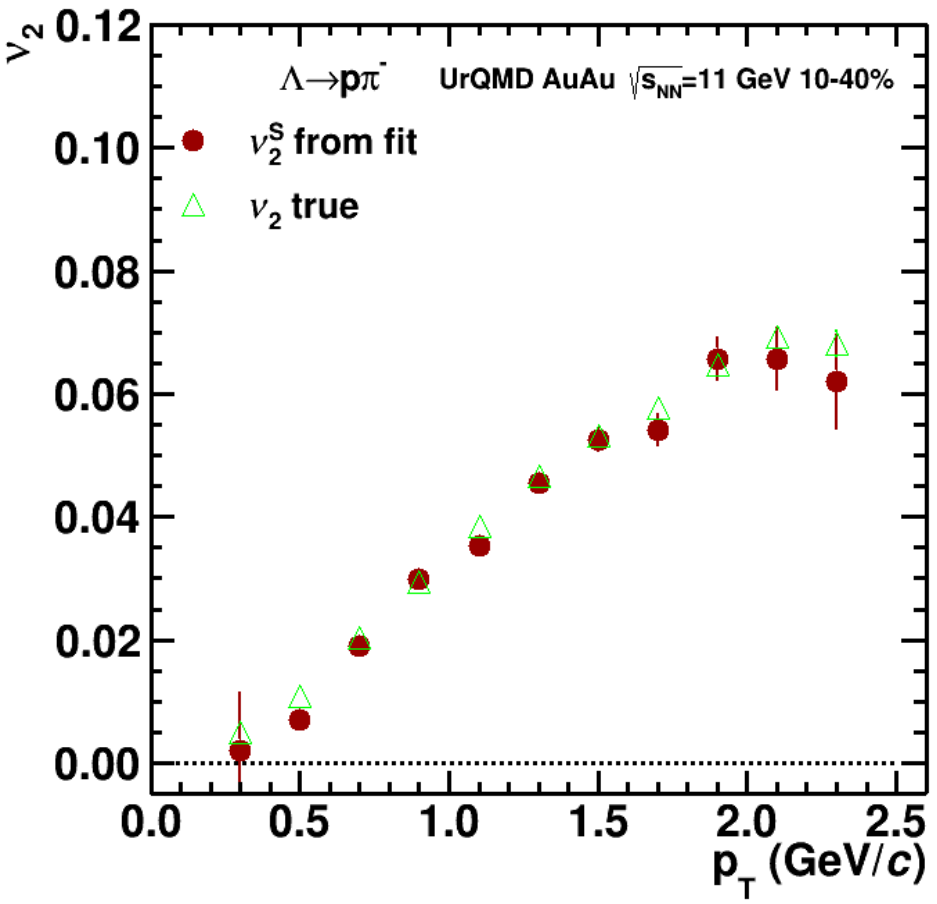




MPDRoot, August 2020

Performance study for v_2 of V0 particles





Reasonable agreement between reconstructed and generated v_2 signals for both K^0 and Λ

Event plane method using v_1 of particles in FHCal

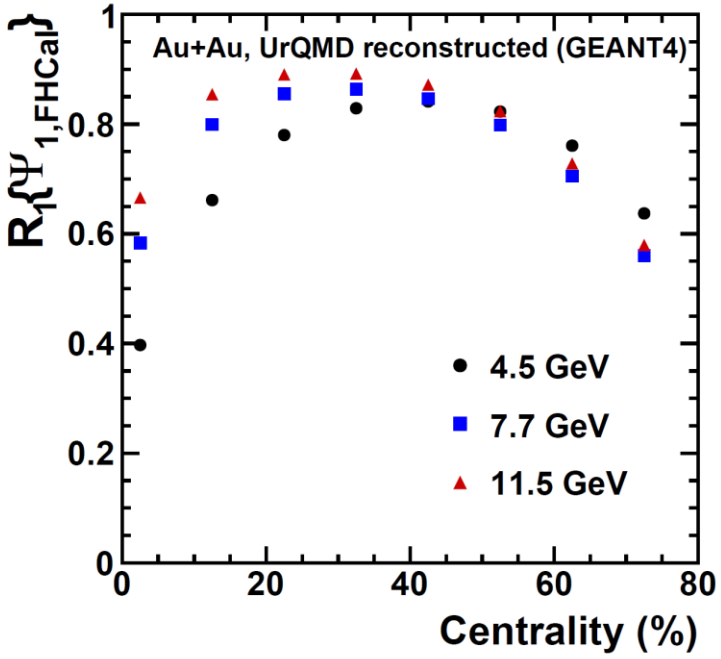
Using v_1 of particles in FHCal to determine Q_n

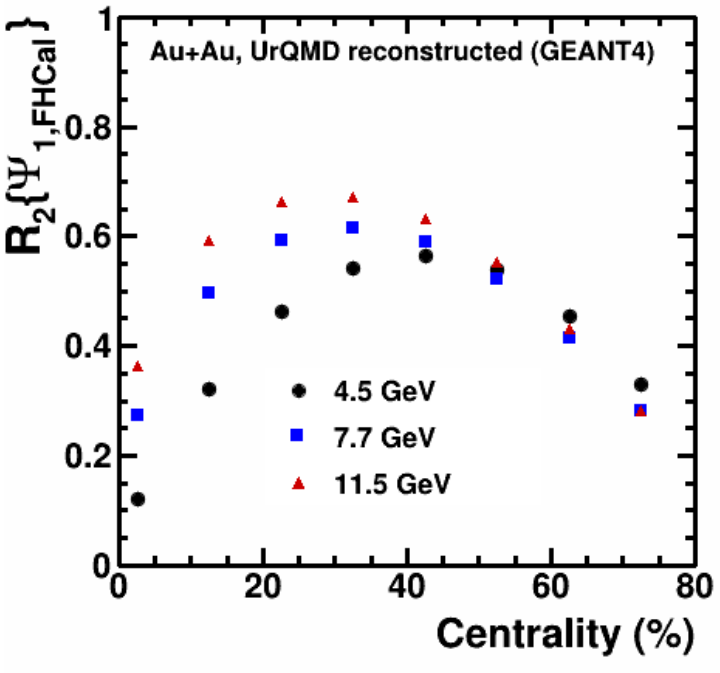
$$Q_1 = \frac{\sum E_i e^{i\varphi_i}}{\sum E_i}, \Psi_{1,\mathrm{FHCal}} = \tan^{-1}\left(\frac{Q_{1,y}}{Q_{1,x}}\right) \quad (1)$$

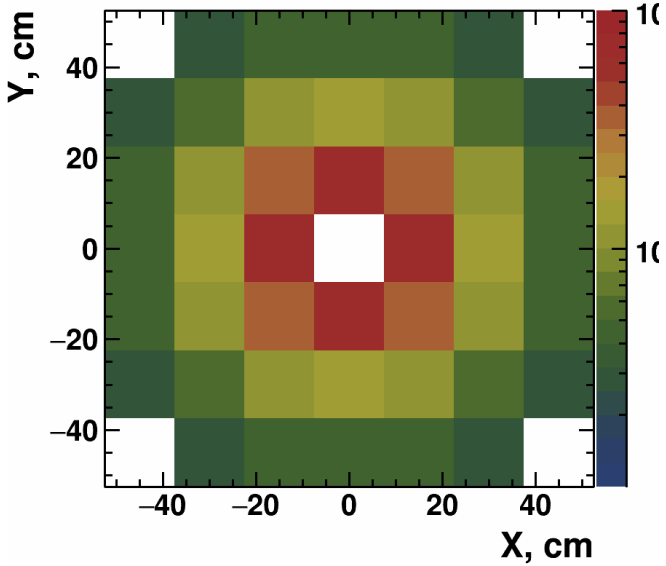
E – energy deposition in FHCal modules ($2<|\eta|<5$)

$$R_n\{\Psi_{1,\mathrm{FHCal}}\} = \langle \cos[n(\Psi_{\mathrm{RP}} - \Psi_{1,\mathrm{FHCal}})] \rangle \quad (2)$$

$$v_2\{\Psi_{1,\mathrm{FHCal}}\} = \frac{\langle \cos[n(\varphi - \Psi_{1,\mathrm{FHCal}})] \rangle}{R_n\{\Psi_{1,\mathrm{FHCal}}\}} \quad (3)$$







Energy distribution in FHCal