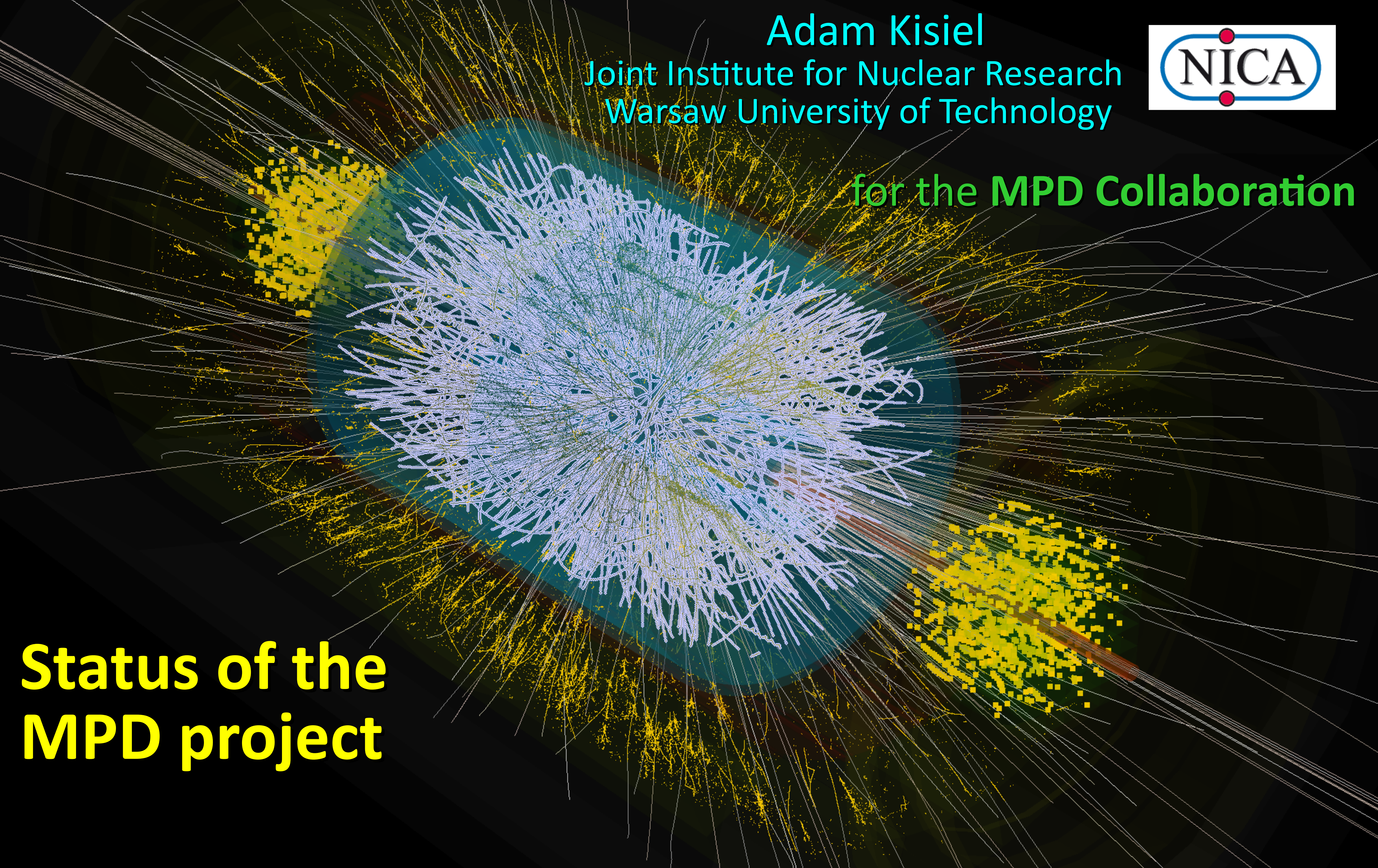
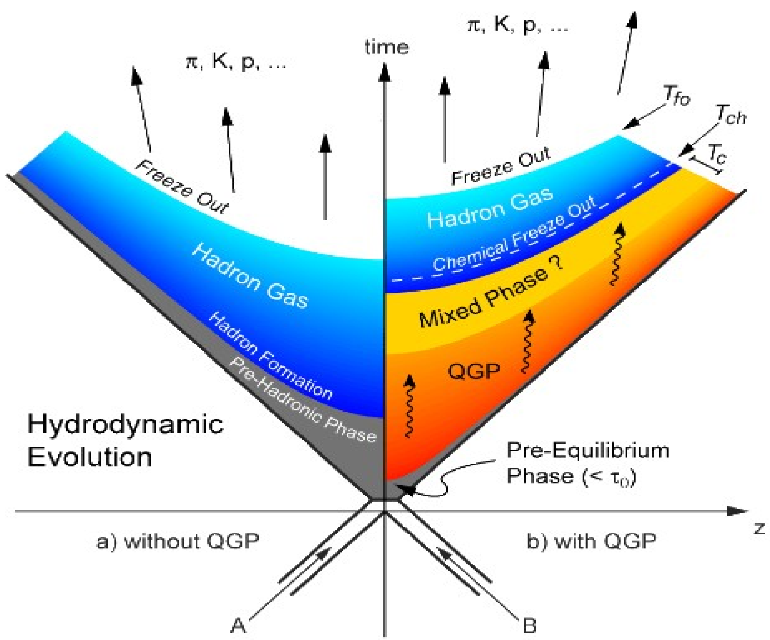
Adam Kisiel
Joint Institute for Nuclear Research
Warsaw University of Technology

for the **MPD Collaboration**



Status of the MPD project

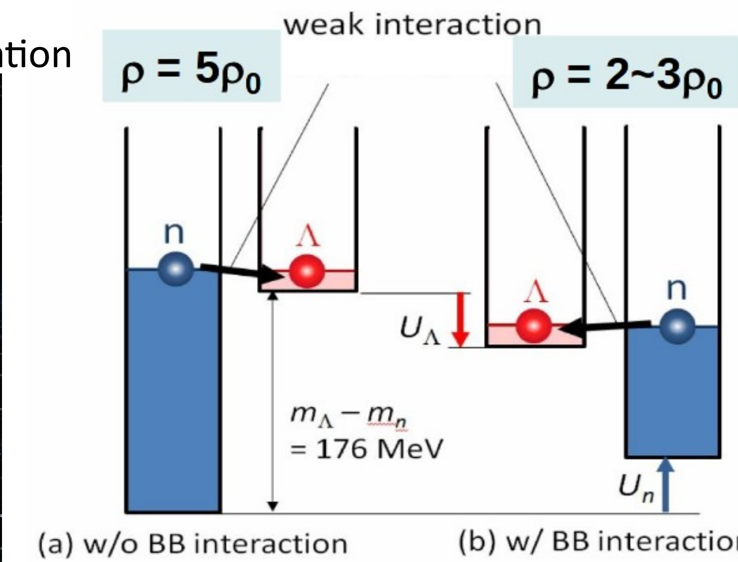
Unexplored phase space in QCD diagram



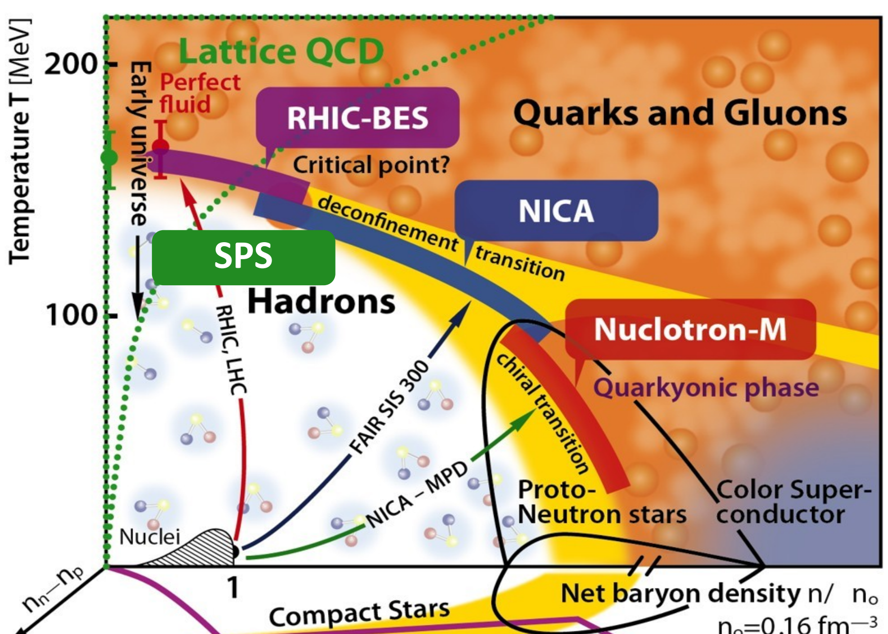
core of neutron stars reaches density several times larger than nuclear density

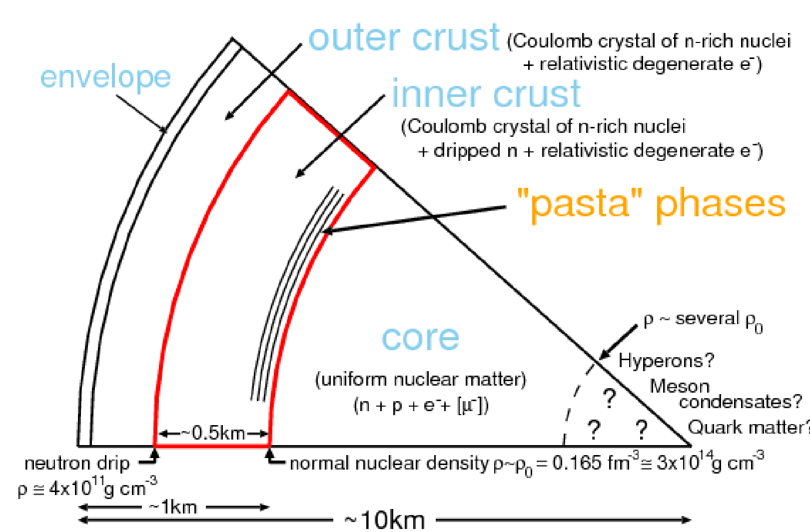
Credit: LIGO Collaboration

neutron star mergers probe region of high density and moderate temperature – phase transition?

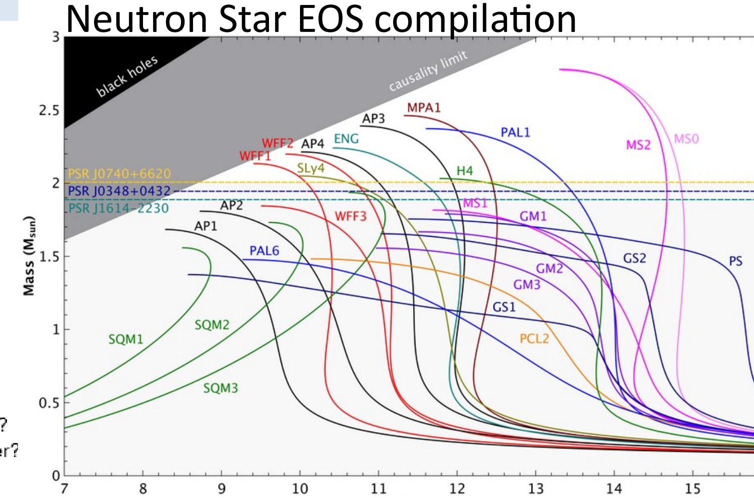


H. Tamura, Hadron 2017



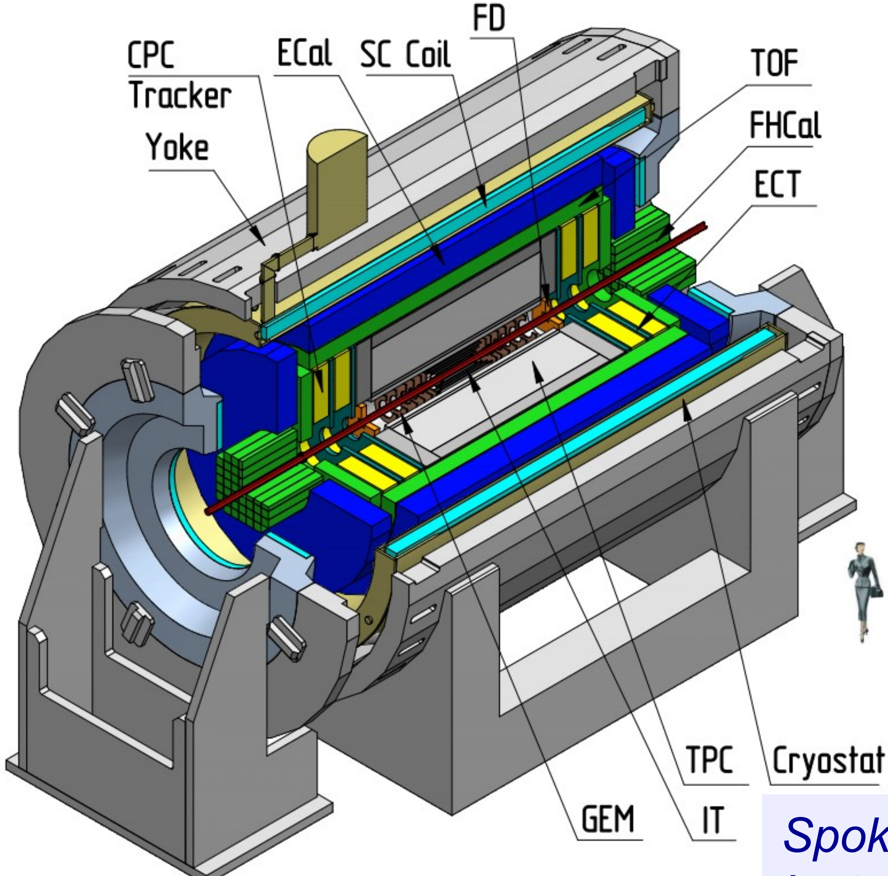


Neutron Star EOS compilation



Multi-Purpose Detector (MPD) Collaboration

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



*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**;*
*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**;*
***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**;*

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

Deputy Spokespersons:
Victor Riabov, Zebo Tang

IV-th Collaboration Meeting and NICA Days 2019

- 3rd conference in NICA Days series (previous: 2015 and 2017) coupled to the IVth MPD Collaboration Meeting
- Hosted in the Center for Innovation and Technology Transfer Management of the **Warsaw University of Technology**
- Co-organizers: **National Center for Nuclear Research** in Świerk and **University of Jan Kochanowski** in Kielce
- Honorary patrons:
  - The **Minister of the Science and Higher Education** of Poland
  - The **Rector** of the Warsaw University of Technology
- 216 registered international participants
- >70 submitted talks
- Poster session

Memorandum of Understanding

- Memorandum of Understanding formalizes the participation of the Institution in the Collaboration, defines its rights and obligations
- Each institution required to sign a Memorandum of Understanding, between itself, the host laboratory and the Collaboration, with Obligations and intentions of each institution included in the „Appendix no. 3"
- MoU the basis for further negotiations with the funding agencies
- Currently MPD MoU signed for: **Mexican** Consortium MexNICA, **Poland**: WUT, NCBJ, Warsaw University, UJK in Kielce, University of Wrocław, **Czech Republic**: Palacky University, NPI CAS, **Azerbaijan**: NNRC Baku, **Bulgaria**: Plovdiv University, **Russian Federation**: SPSU, INR RAS, SINP MSU

MPD Executive Council

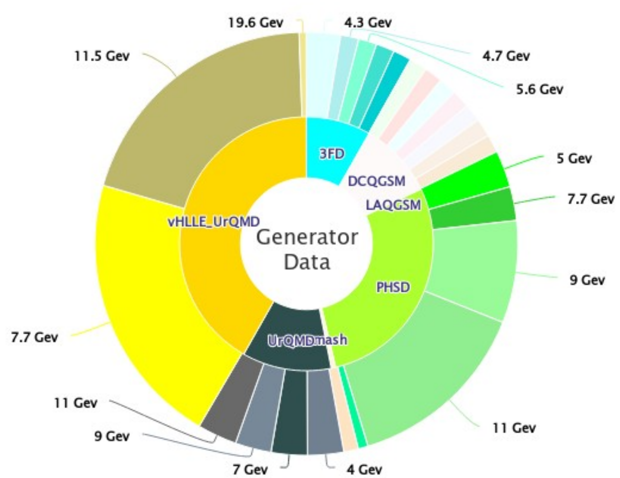
- “The Executive Council directs the execution of the MPD project. It shall establish scientific priorities for the experiment. It shall review and act on recommendations of the Spokesperson regarding all issues of major importance to the Collaboration.
- The Executive Council may appoint review committees and task forces to provide advice on technical, scientific and technological decisions, as needed.
- The Executive Council composition:
  - **Vadim Kolesnikov, Yi Wang, Alejandro Ayala, Alexander Zinchenko, Oleg Rogachevsky, Arkadiy Taranenko**, **Ilya Sleyuzhenkov**, **Andrei Dolbilov**
- Some of the topics discussed at the EC meetings:
  - IT tools and computing resources for the collaboration
  - Reports from major oversight committee meetings (DAC, Programme Advisory Committee, NuPECC, ECFA, etc.)
  - Common Fund: rules, spending items
  - Execution of Monte-Carlo requests

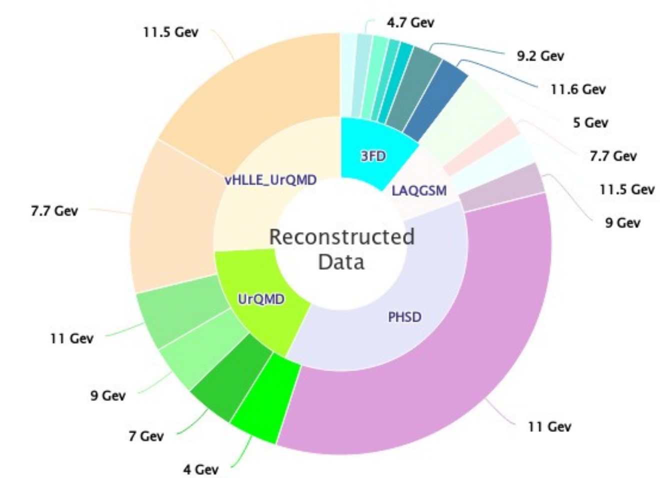
Computing for the NICA Megaproject on the GOVORUN

- HybriLIT computing resources available for MPD Collaborators
- Full MPD software suite available
- Used for massive Monte-Carlo productions
- Dirac framework used to connect other computing centers

MPD Monte-Carlo DB

Records Statistic Find





DIRAC THE INTERWARE

2019 - software team (contact e-mail: amoshkin@jinr.ru)

Significant new computing at LHEP

- Upgrade of the exisiting dedicated NICA Cluster ongoing
- Final computing capabilities provided to the end users, official opening during the previous JINR Scientific Council, recent upgrage to full capacity:
  - 5000 job slots
  - Up to 10 PB of additional disk space (5 PB+5 PB replica, EOS filesystem)
  - Negiotiations ongoing on the division of resources between MPD, BM@N, and SPD
- Successfuly tested for massive production of Monte-Carlo events for new physics performance studies (500 central UrQMD events at top energy per day per core)

MPD Civil Construction status

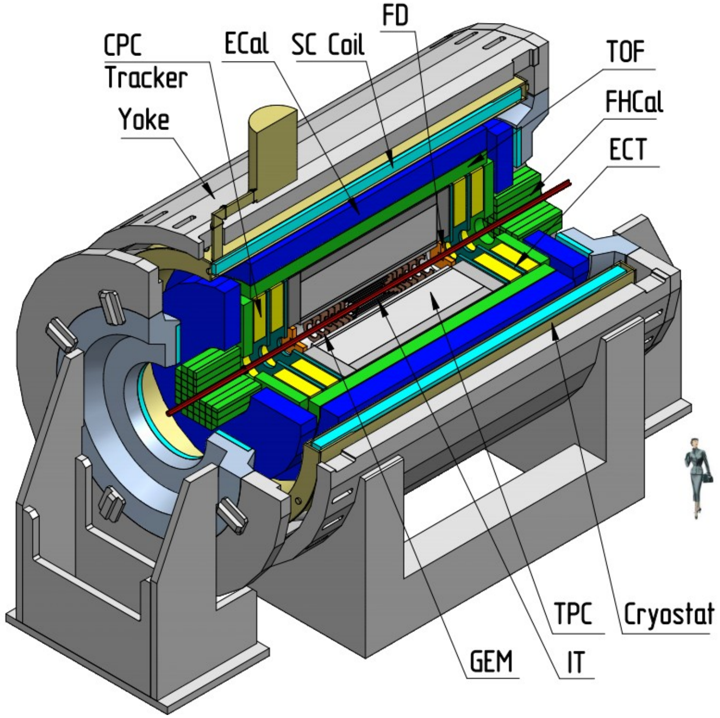
- MPD Hall close to ready for equipment installation

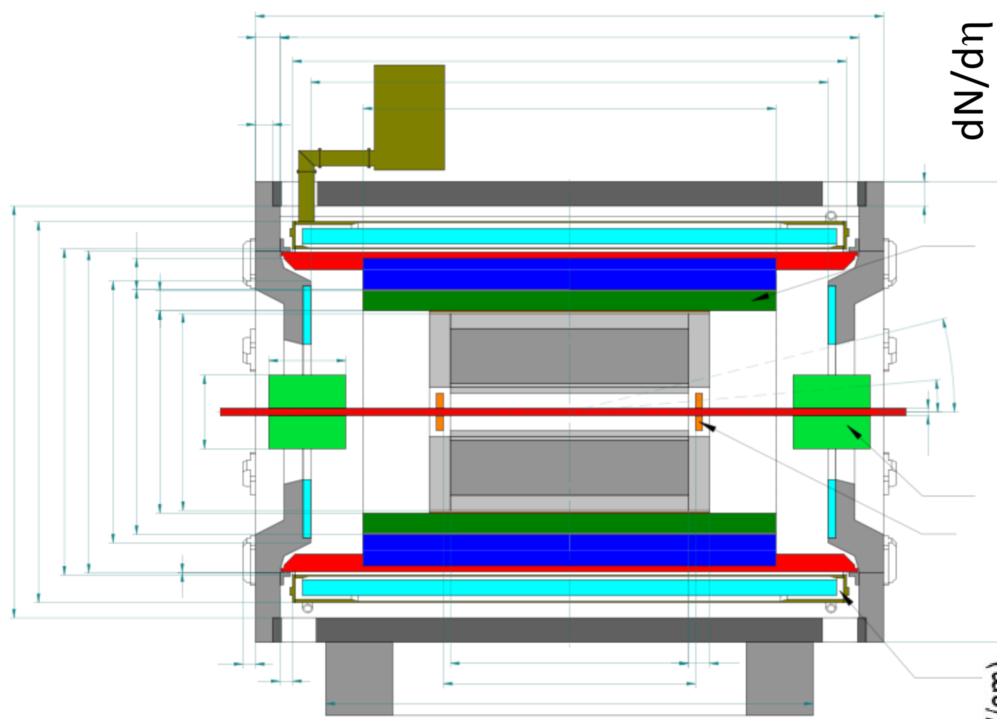
MPD Hall external covering

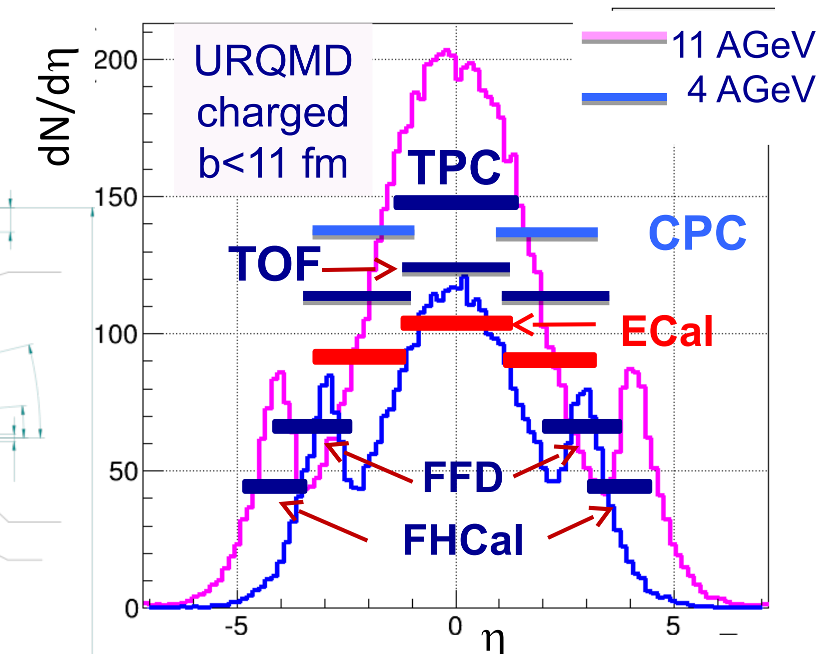
MPD Hall crane weight test

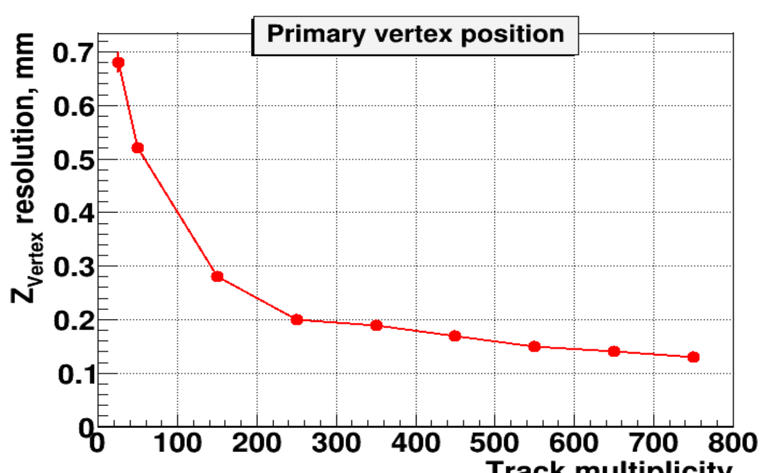
Transportation of MPD Magnet Yoke parts into the MPD pit (inside MPD Hall)

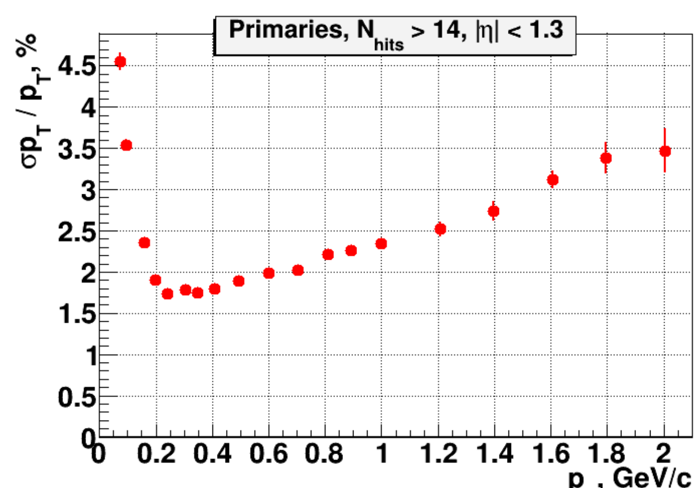
MPD 1st stage

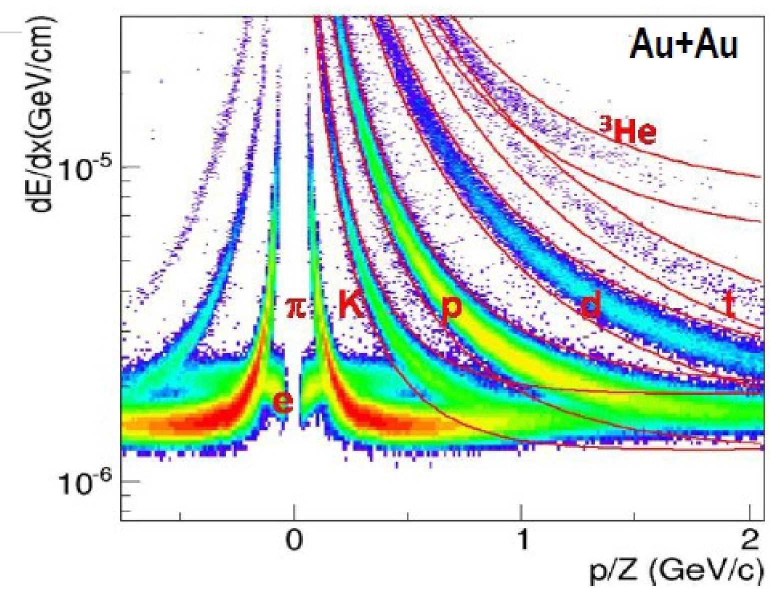












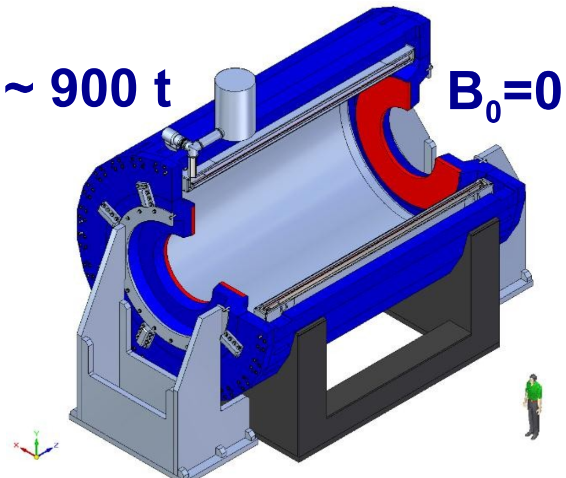
- 2π in azimuth, 3-D tracking (TPC), Powerful PID (TPC, TOF): - π/K up to 2.0 GeV/c, - K/p up to 3 GeV/c, Low material budget, High rate (<=6 kHz)

MPD Systems in production

SC Solenoid

~ 900 t

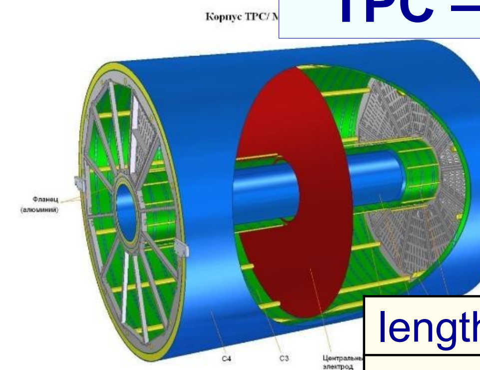
B_0=0.5 T



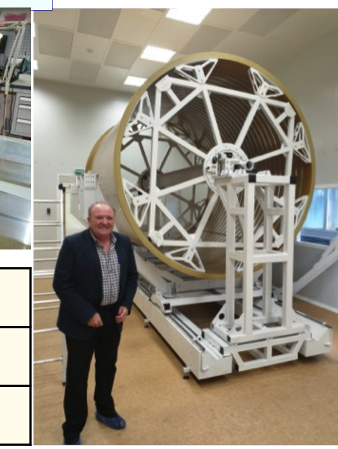
Yoke – produced & delivered

cryostat with SC coil - ready for cold tests

TPC – basic tracker



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



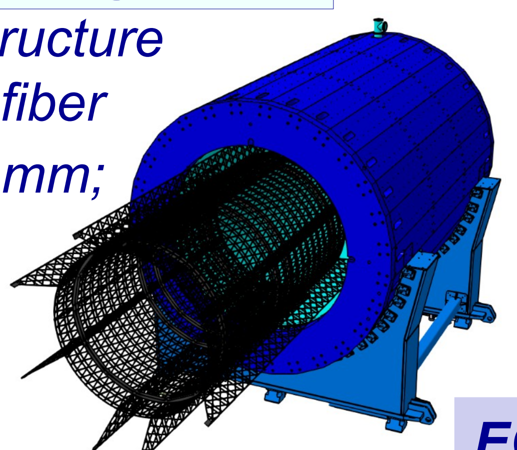
TOF system

Integration

support structure of carbon fiber

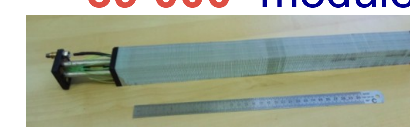
sagite ~ ***5*** *mm;*

0,13 X_0



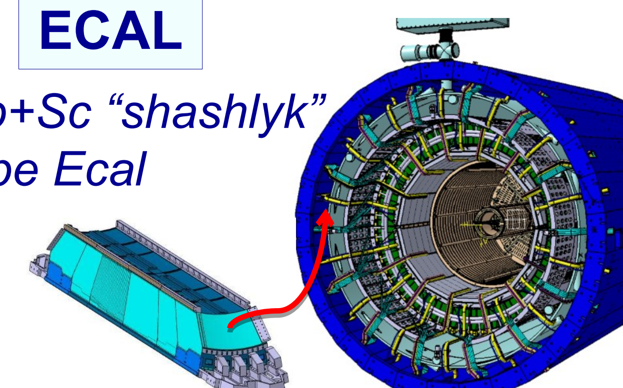
ECal *barrel ~* ***100*** *t*

~ **39 000** modules

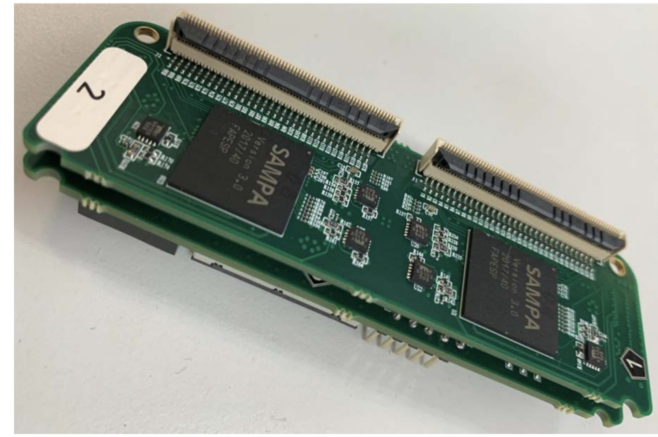


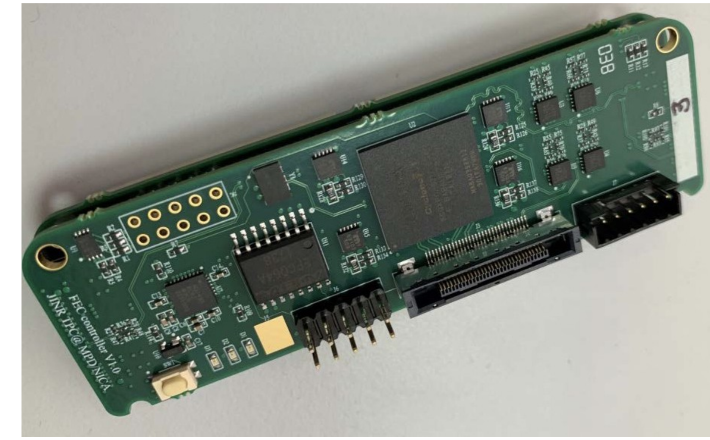
ECAL

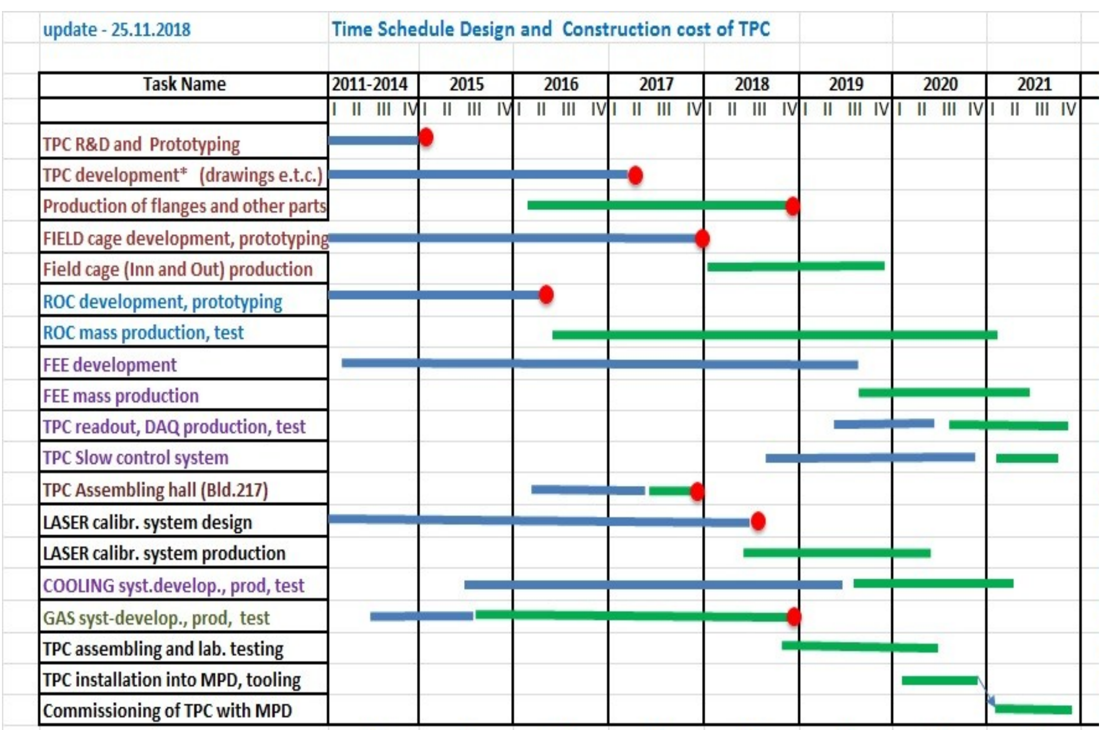
Pb+Sc "shashlyk" type Ecal



MPD Time Projection Chamber



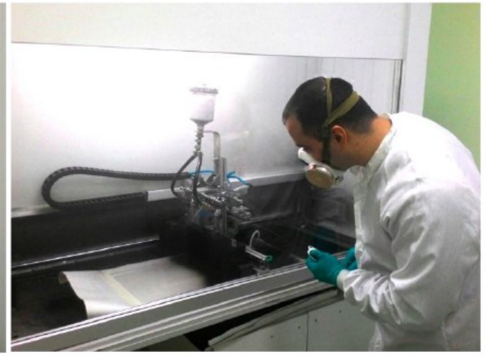




item	Date
Testing FEC v1.0 finished	Feb. 2019
Receive SAMPA V4 chips at Dubna 4500 (all)	June 2019
32 preproduction vervion 2.1 FE Card assembled (1/2ROC)	Jul. 2019
Testing of half ROC equipped with FE Cards	Aug. – Dec.2019
Production FE Cards for 1 ROC and Testing 2020	Dec. 2019-Apr.
Instrumentation 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

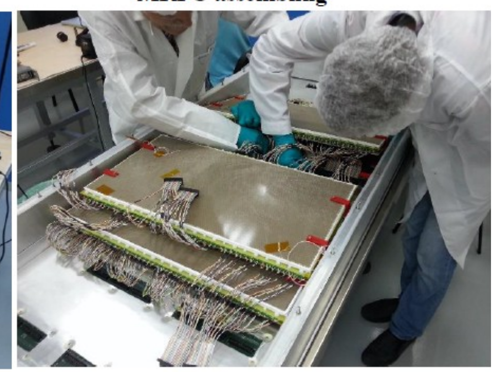


Painting of the HV conductive layer

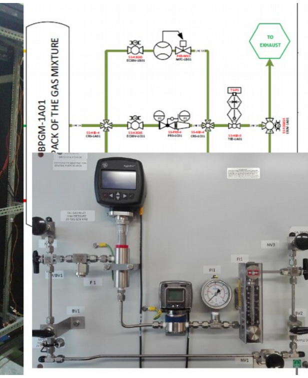
MRPC assembling

Optical quality control

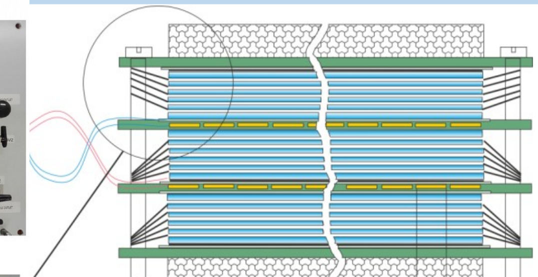
Cables and connectors soldering

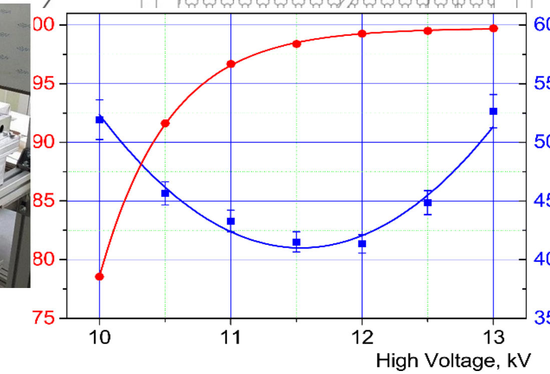


Detectors installation to the TOF box



Dimensions of sensitive area 600 x300 mm^2





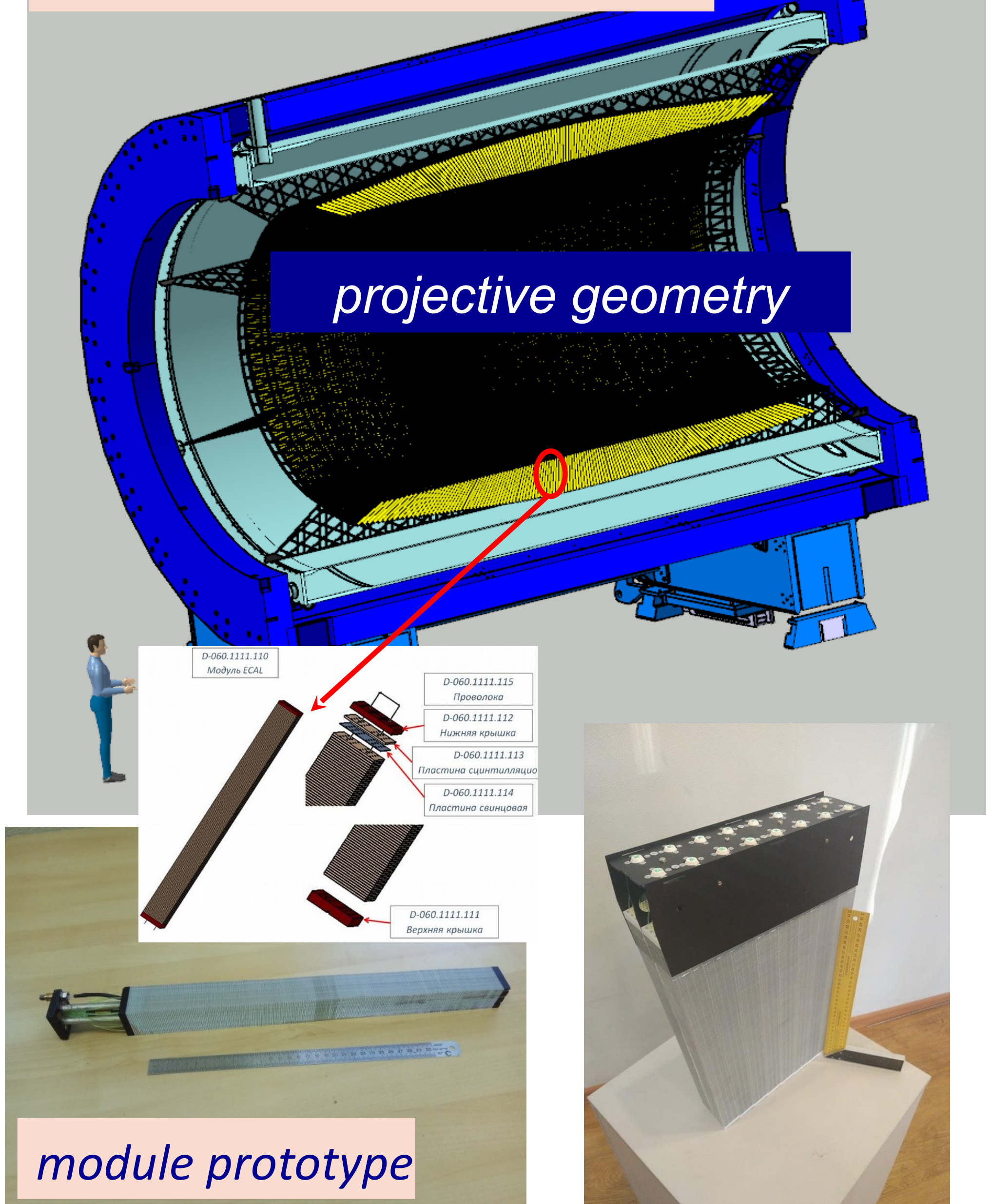
Single detector time resolution: 50ps

	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)

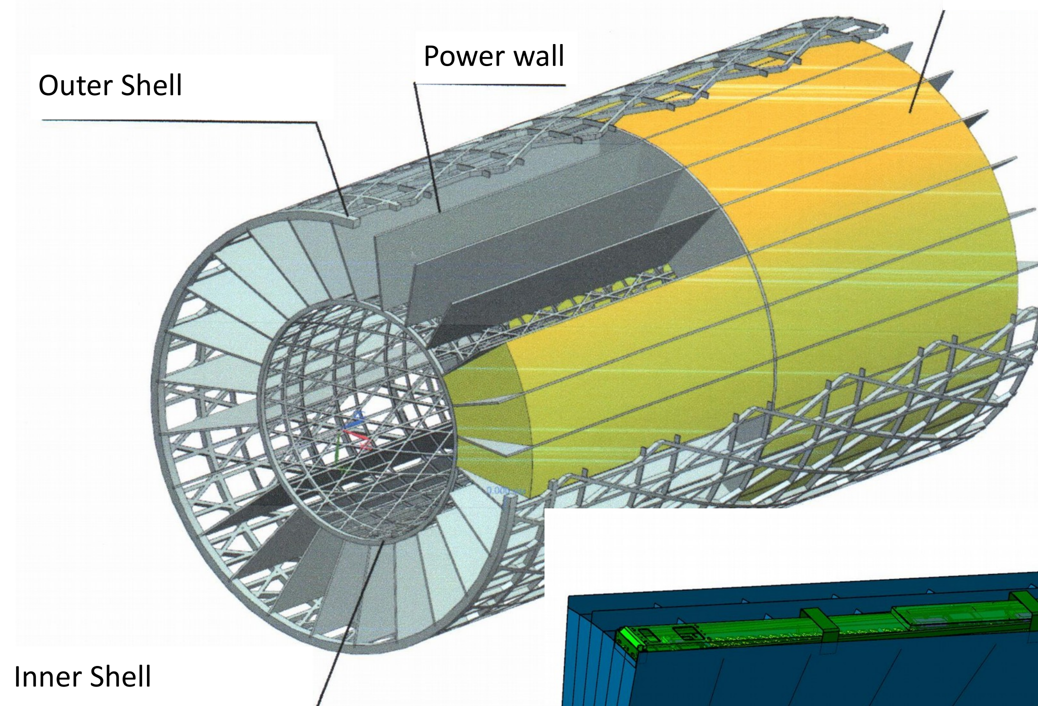
Barrel ECAL ~ 39 000 modules

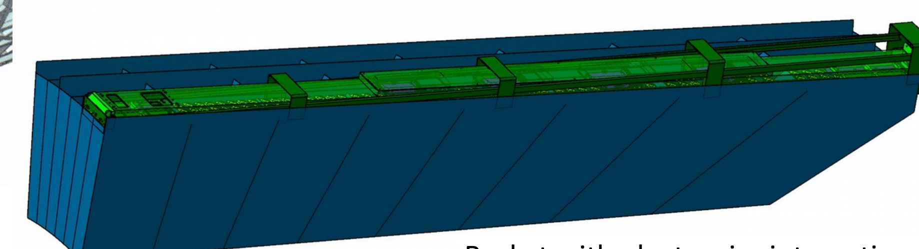


module prototype

- *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*

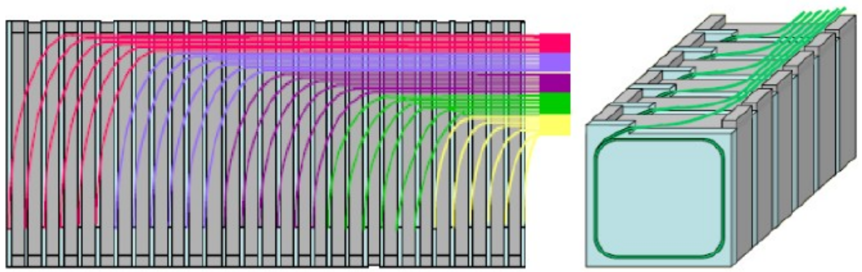
Technical specification for ECAL modules ready
Production started in two sites in Russia, soon in China
First module readiness expected in IIIrd QTR of 2020
Calibration and test ongoing



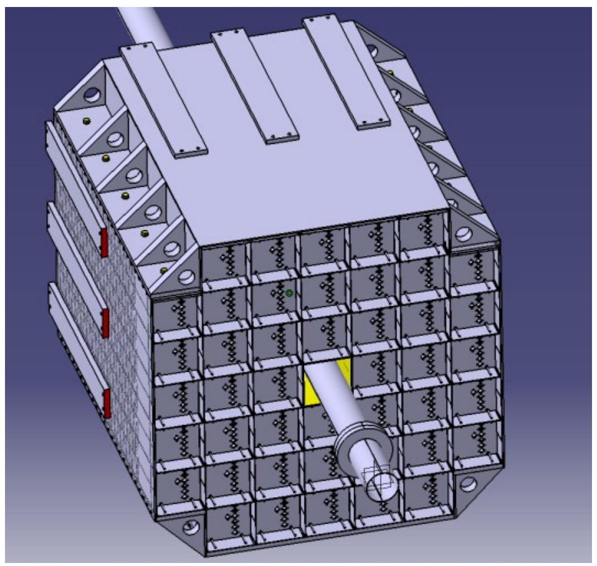


Basket with electronics integration

Forward Detectors: FHCal and FFD

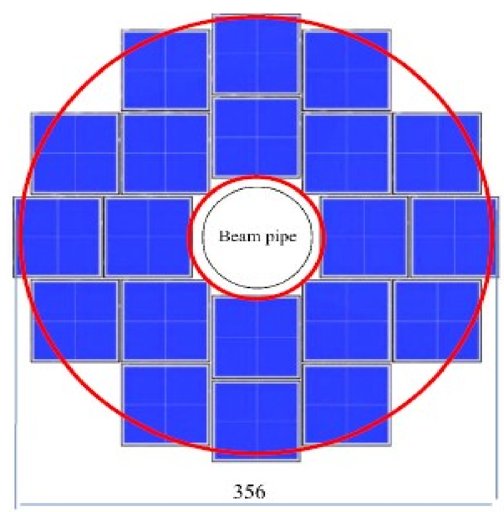


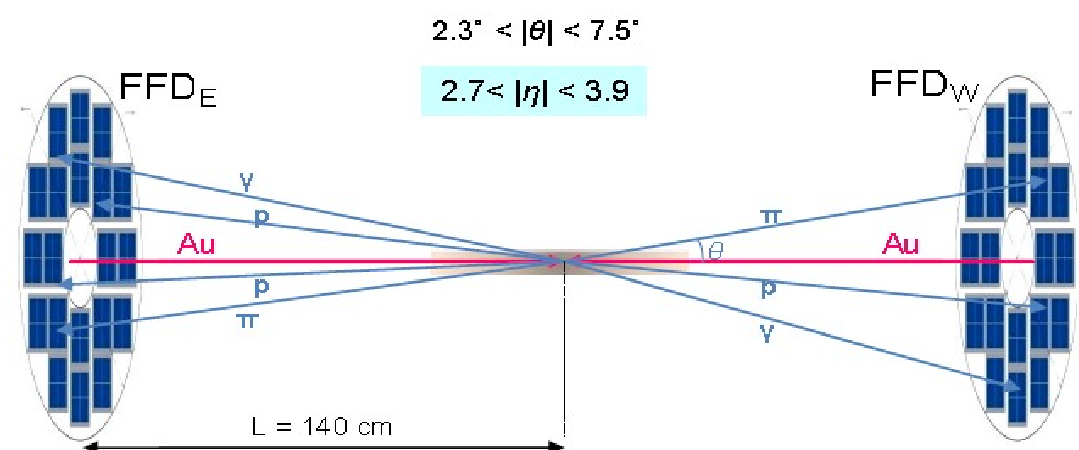
- Two-arms at ~3.2 m from the interaction point
- Each arm consists of 45 individual modules
- Module size 150x150x1100cm³ (55 layers)
- Pb(16mm)+Scint.(4mm) sandwich
- 7 longitudinal sections
- 6 WLS-fiber/MAPD per section
- 7 MAPDs/module



1. All modules produced according to plan, 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

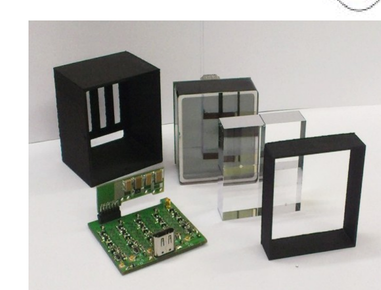
array of 20 modules
Planacon MCP-PMTs
80 +20 channels





15 mm quartz radiator
10 mm lead converter

time resolution < 50 ps



Milestones of MPD assembling in 2020-2021 (optimistic scenario)

Year 2020

1. March 1st - MPD Hall and pit are ready to store and unpack Yoke parts
2. April – May - Magnet Yoke is assembled for alignment checks
3. May - Solenoid is ready for transportation from ASG (Italy)
4. June – - Solenoid delivered to Dubna
5. July – August - Assembling of Magnet Yoke and Solenoid at JINR
6. July – September - Preparation for switching on the Solenoid (Cryogenics, Power Supply et cet.)
7. Octber – November - Magnetic Field measurement
8. December - Installation of Support Frame

Year 2021

9. January – April - Installation of subsystems, Electronics Platform, Cabling
10. May - Commissioning
11. June - Readiness for Cosmic Ray tests

Physics Working Groups

- „The Physics Working Groups shall be the environment in which all official MPD physics results are developed, certified and readied for publication. The analysis working groups shall be the environment in which MPD software tools are developed, tested, certified and made available to any MPD member. The physics and analysis working groups conveners form the physics council that is chaired by the Spokesperson."
- 5 Physics Working Groups Created
- Every physicist in MPD is expected to join at least one PWG
  - Web and e-mail tools to manage PWG creation and operation are deployed and used, based on propositions from the JINR IT team
- Each group is led by two co-convenors, responsible for the group operation

MPD Physics Programme

G. Feofilov, A. Ivashkin

Global observables

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

V. Kolesnikov, Xianglei Zhu

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 Diag.

K. Mikhailov, A. Taranenko

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

V. Riabov, Chi Yang

Electromagnetic probes

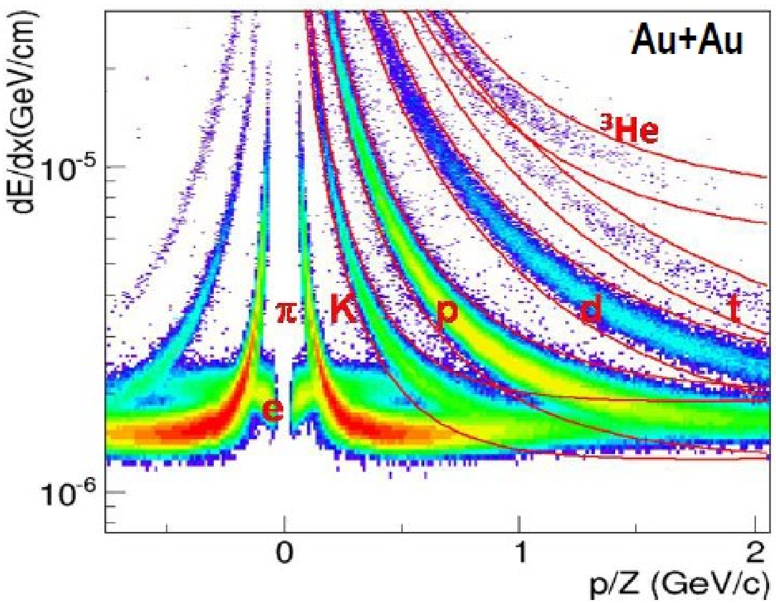
- Electromagnetic calorimeter meas.
- Photons in ECAL and central barrel
- Low mass dilepton spectra in-medium modification of resonances and intermediate mass region

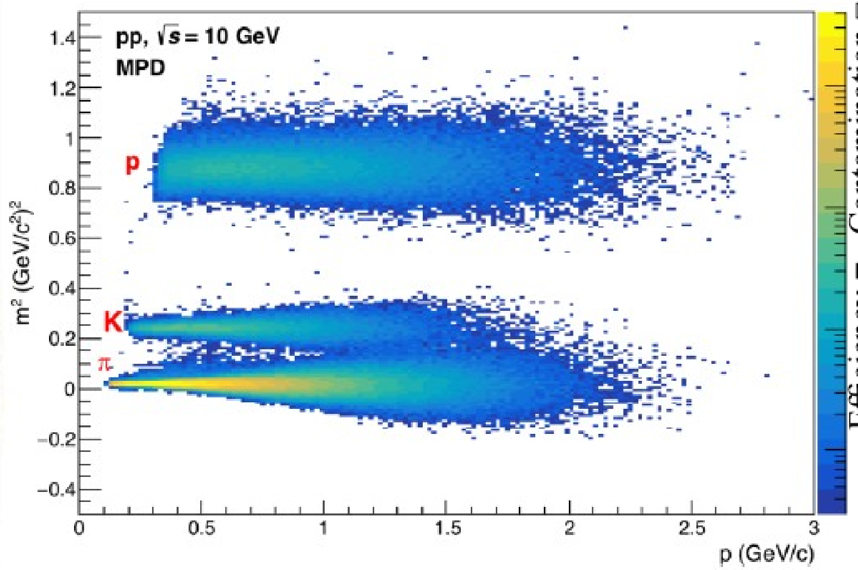
Wangmei Zha, A. Zinchenko

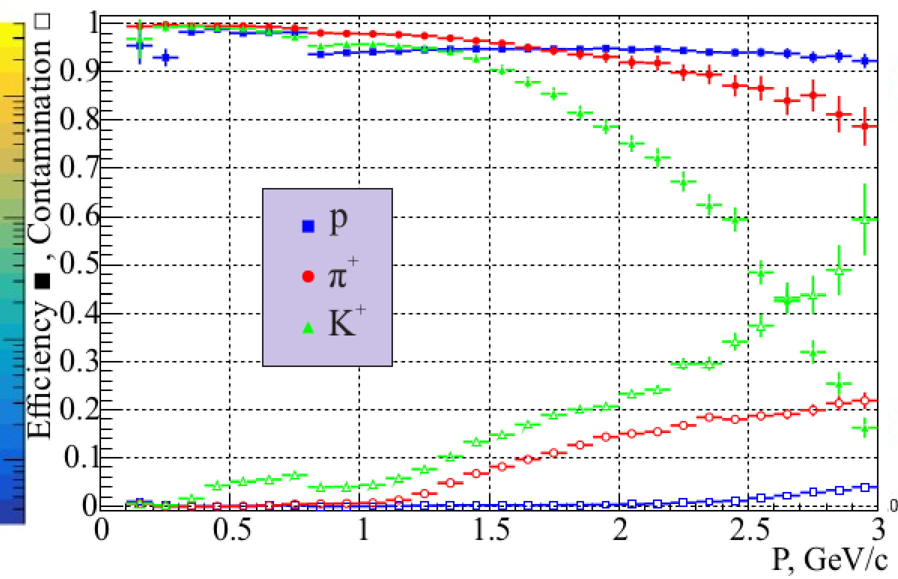
Heavy flavor

- 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

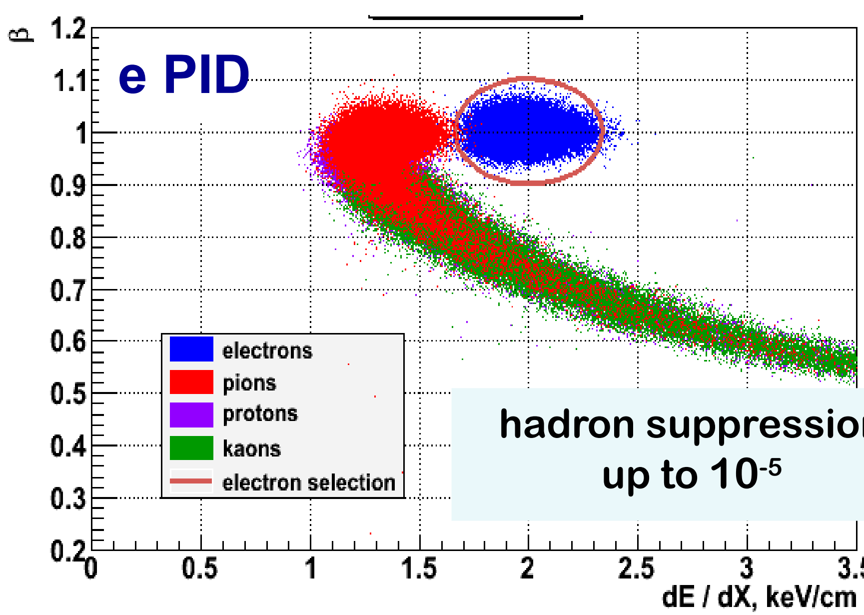
PID Performance in MPD







Efficiency and Contamination



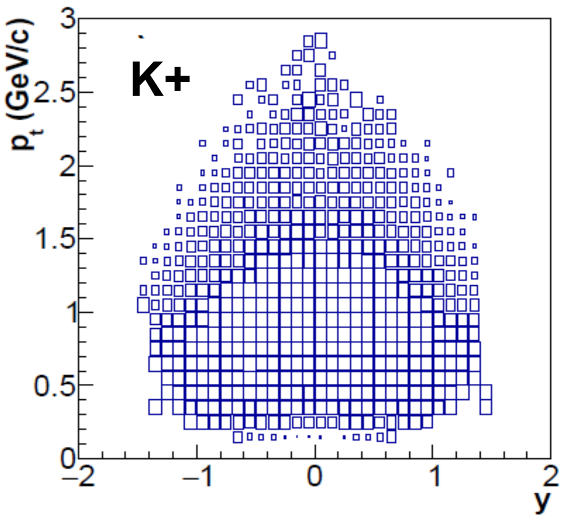
hadron suppression up to 10^{-5}

- 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

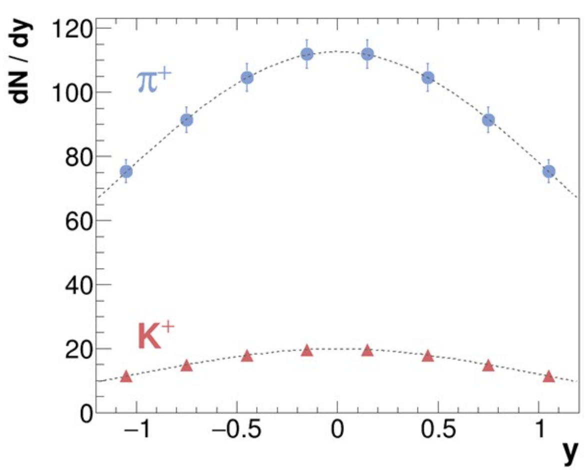
Hadroproduction with MPD

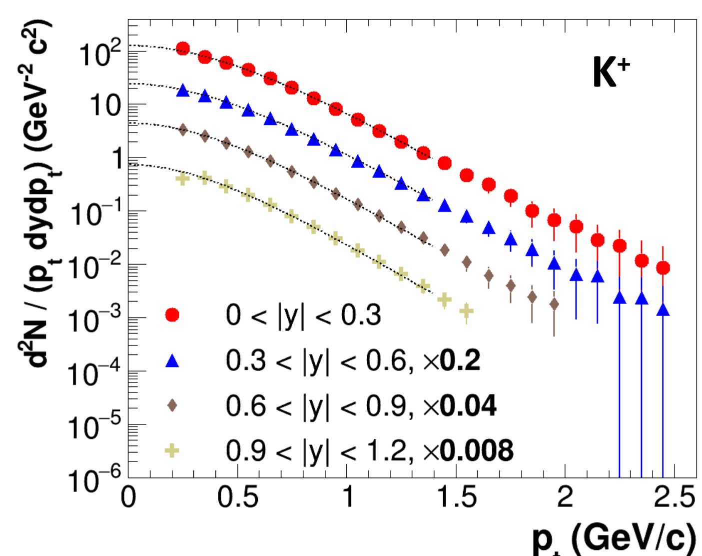
- Particle spectra, yields & ratios are sensitive to bulk fireball properties and phase transformations in the medium
- Uniform acceptance and large phase coverage are crucial for precise mapping of the QCD phase diagram

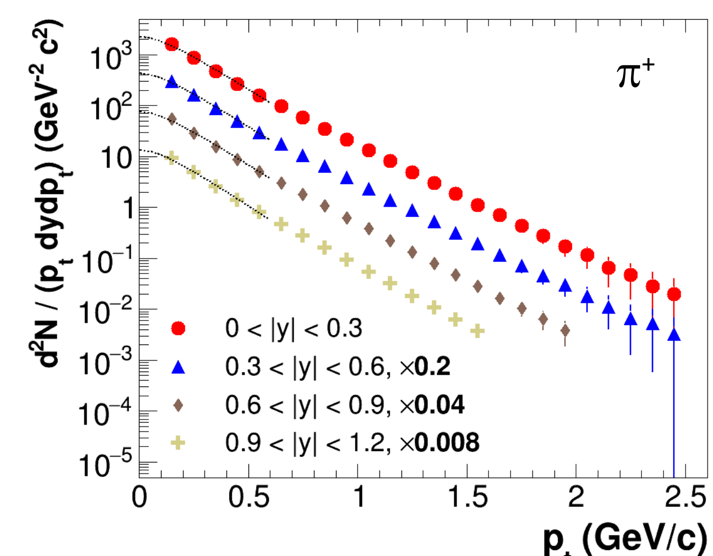
✓ *0-5% central Au+Au at 9 GeV from the PHSD event generator, which implements partonic phase and CSR effects*
✓ *Recent reconstruction chain, combined dE/dx+TOF particle ID, spectra analysis*



- 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)

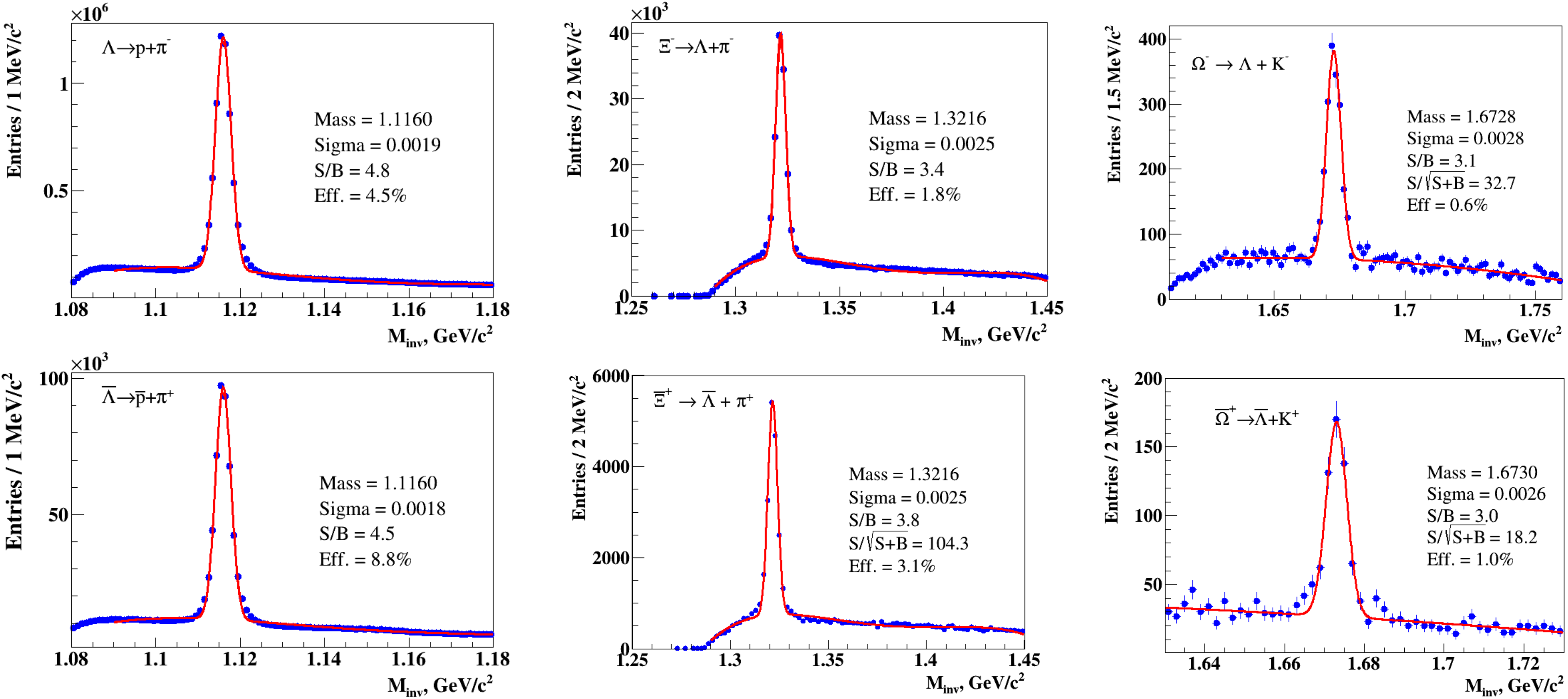






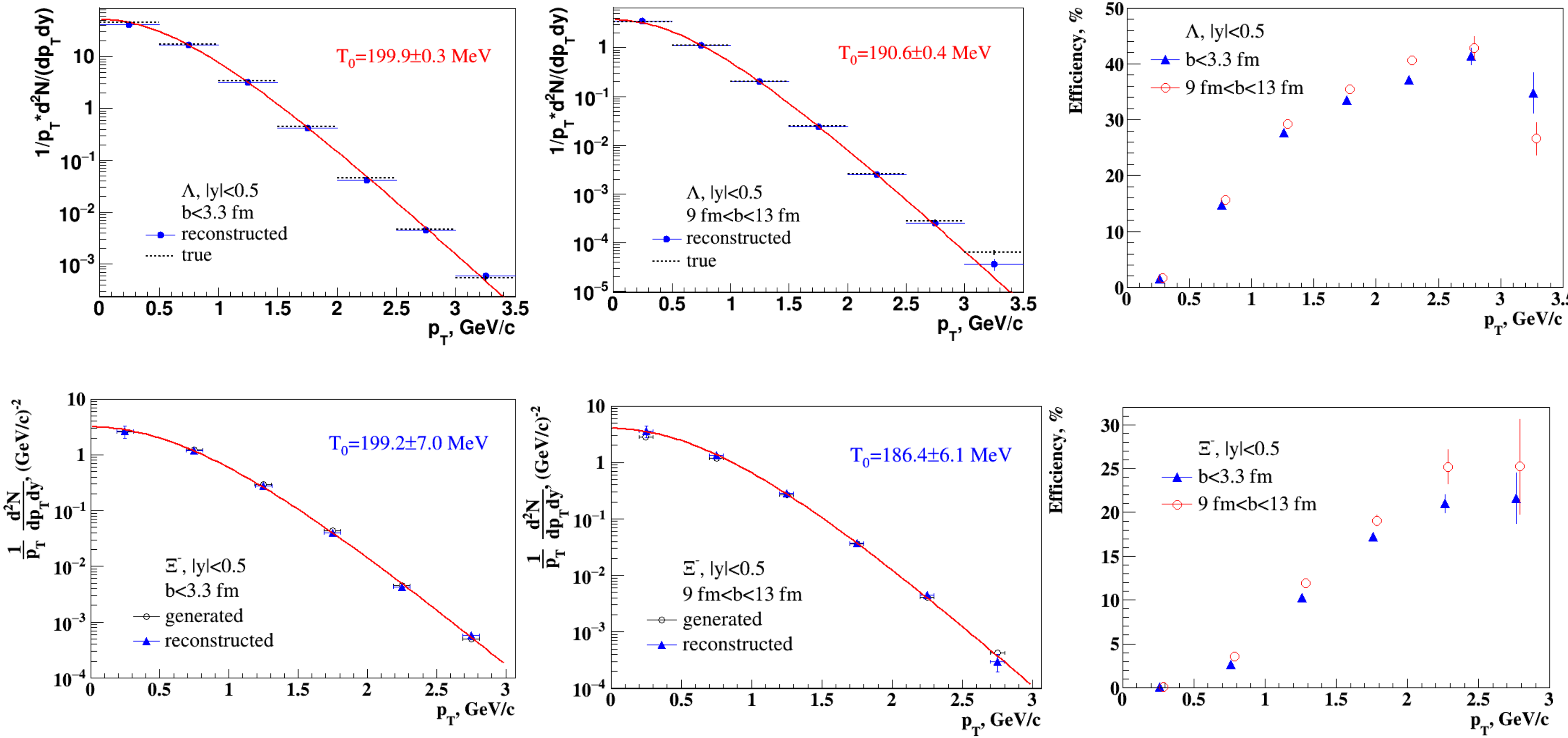
Strange and multi-strange baryons

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



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

Efficiency and p_T spectrum

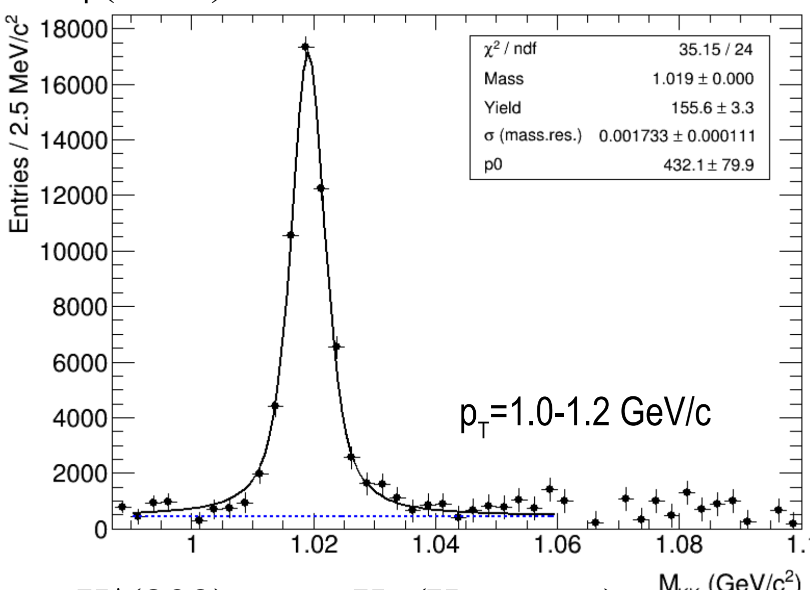


Full p_T spectrum and yield extraction, reasonable efficiency down to low p_T

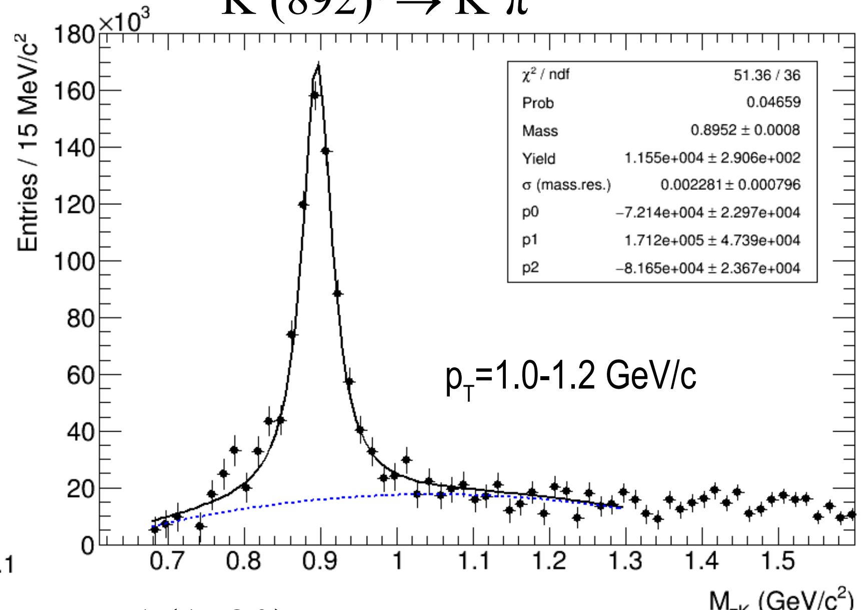
Resonances at MPD

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

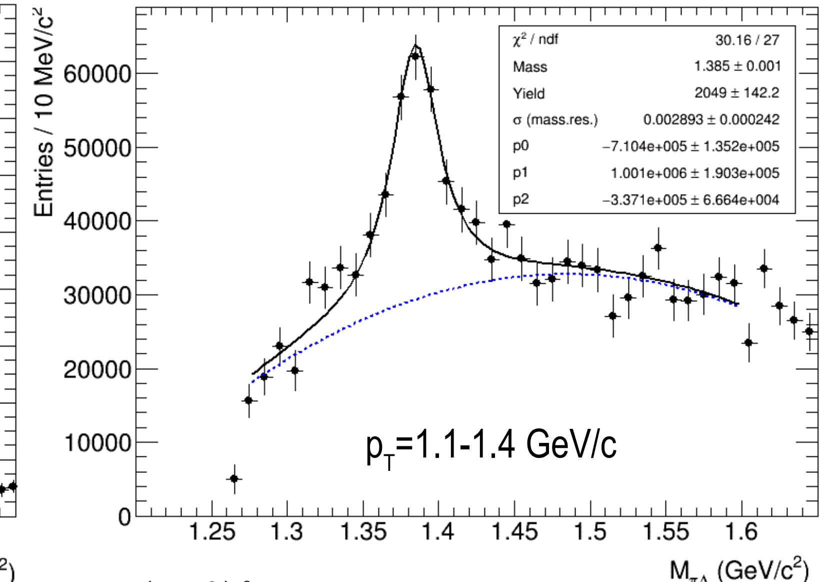
$\phi(1020) \rightarrow K^+K^-$



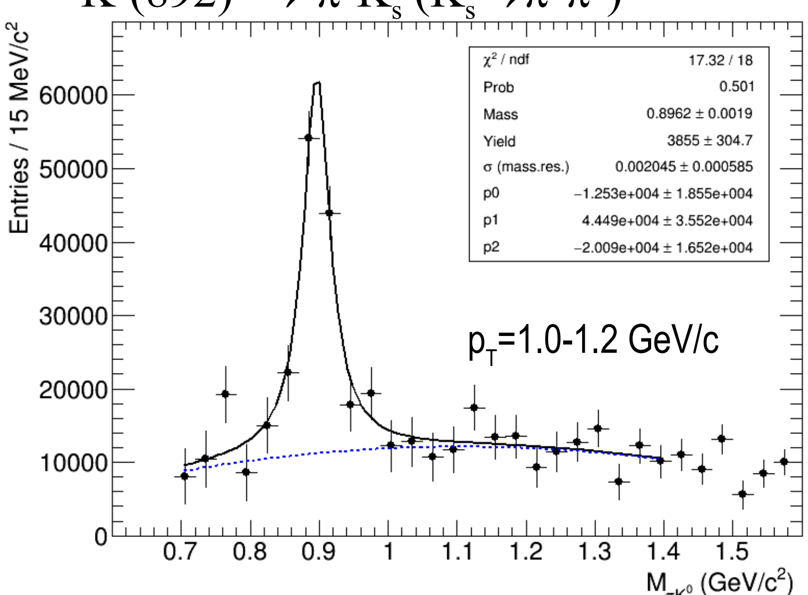
$K^*(892)^0 \rightarrow K^\pm\pi^\pm$



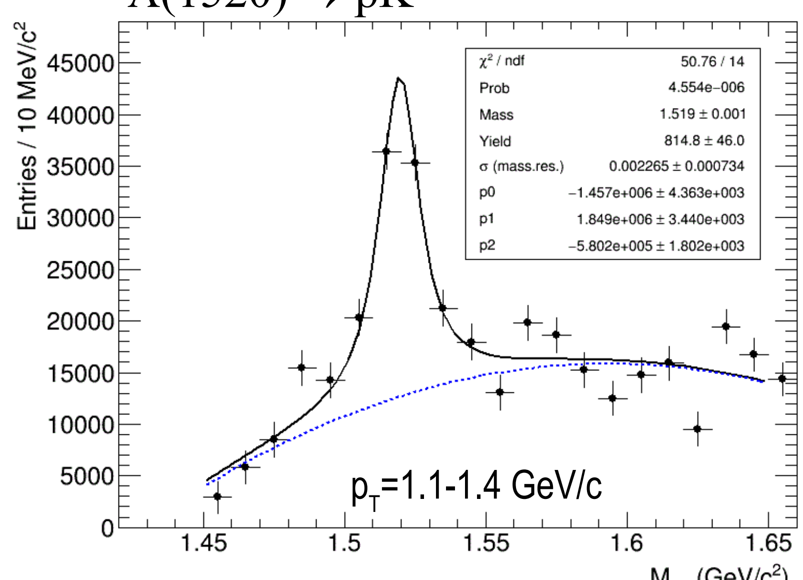
$\Sigma(1385)^\pm \rightarrow \pi^\pm\Lambda$ $(\Lambda \rightarrow p\pi)$



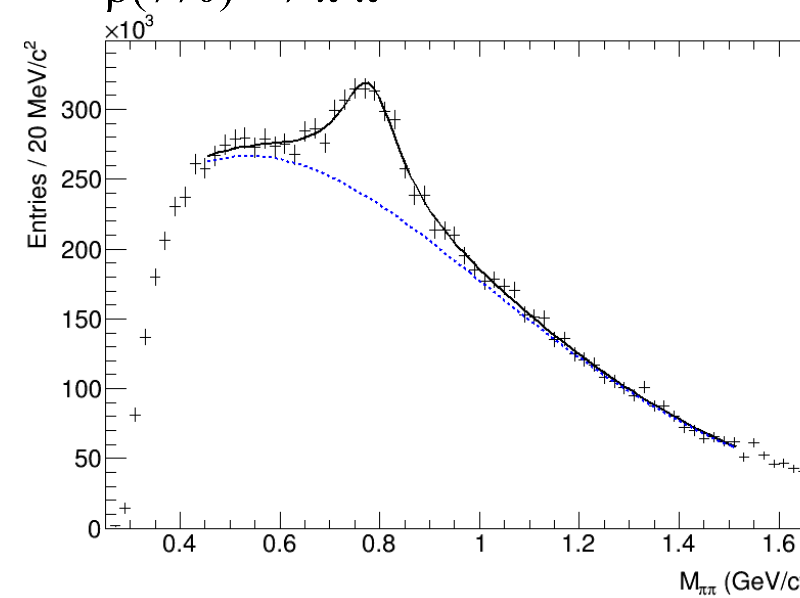
$K^*(892)^\pm \rightarrow \pi^\pm K_s$ $(K_s \rightarrow \pi^+\pi^+)$



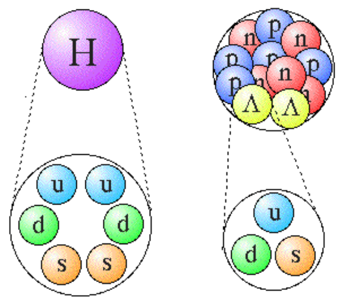
$\Lambda(1520) \rightarrow pK^-$



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



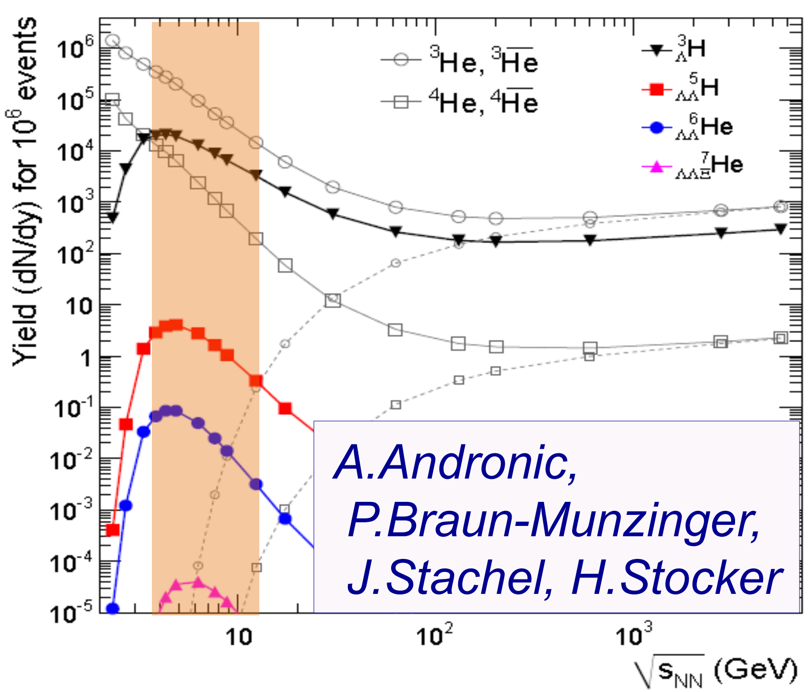
Hypernuclei at MPD

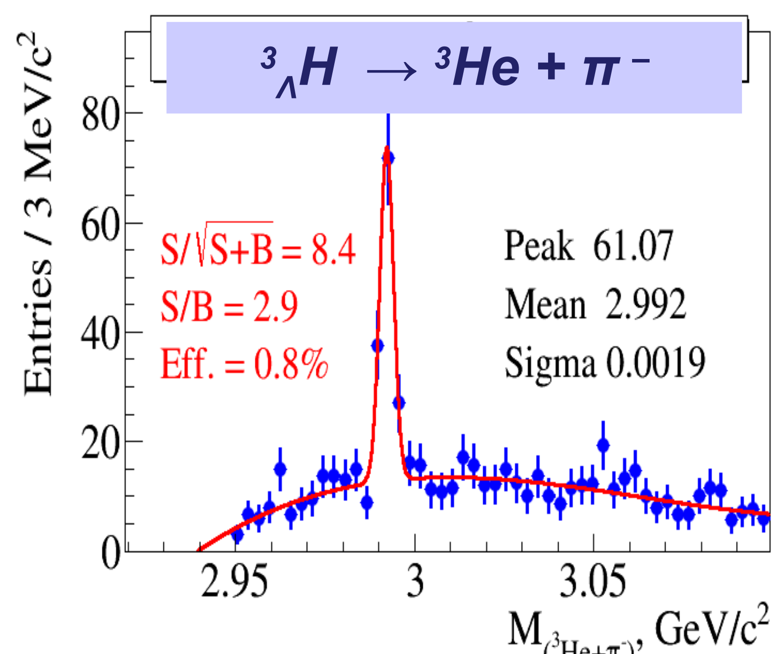


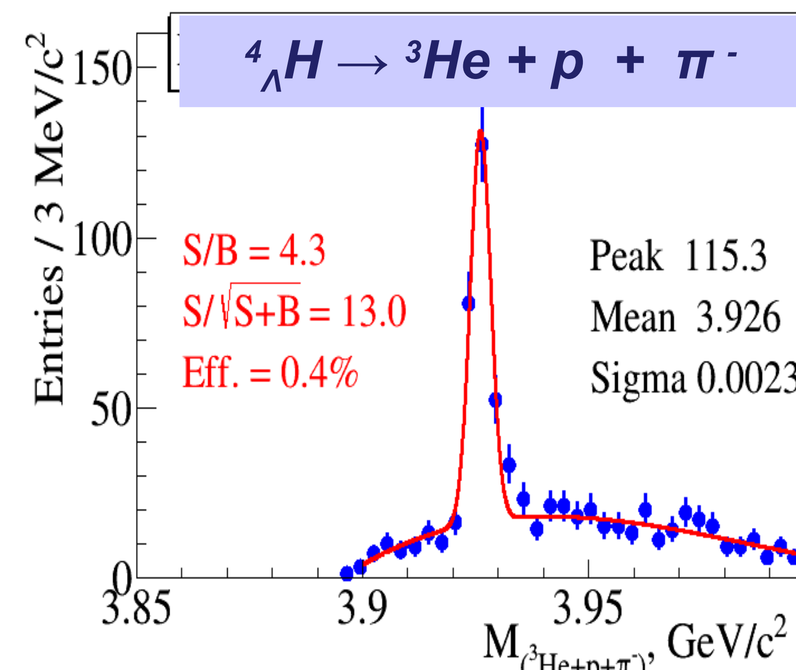
*astrophysical research indicates the appearance of hyperons in the dense core of a **neutron star***

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

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

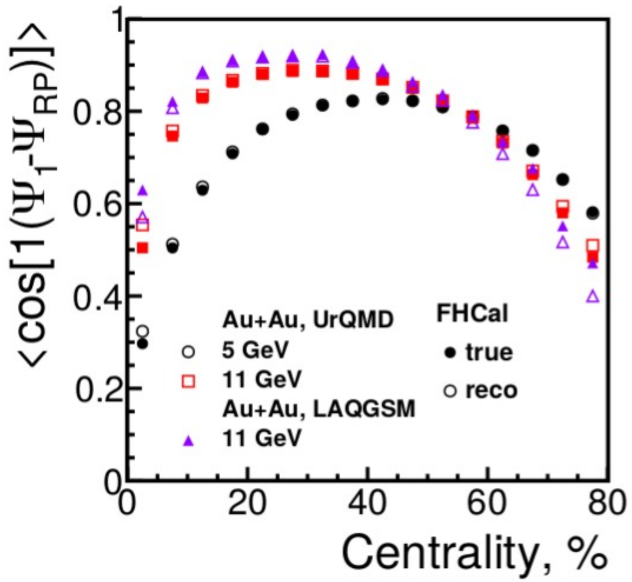


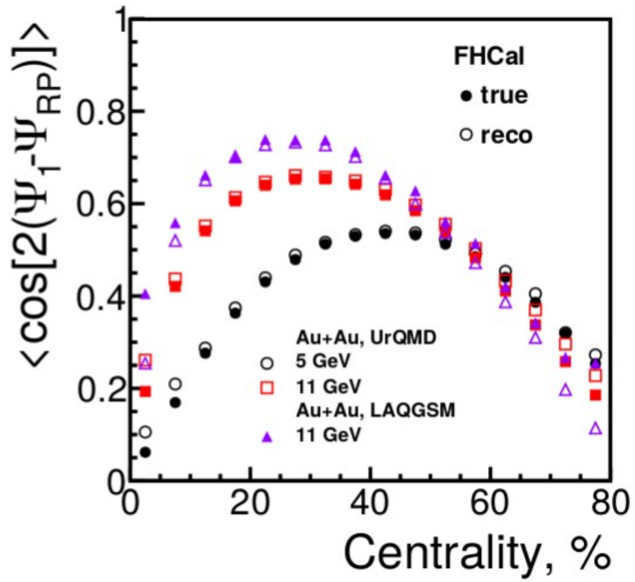


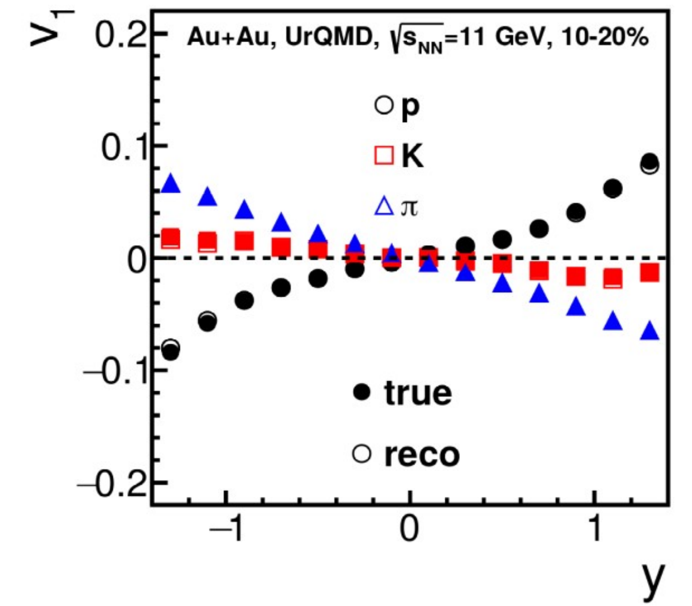


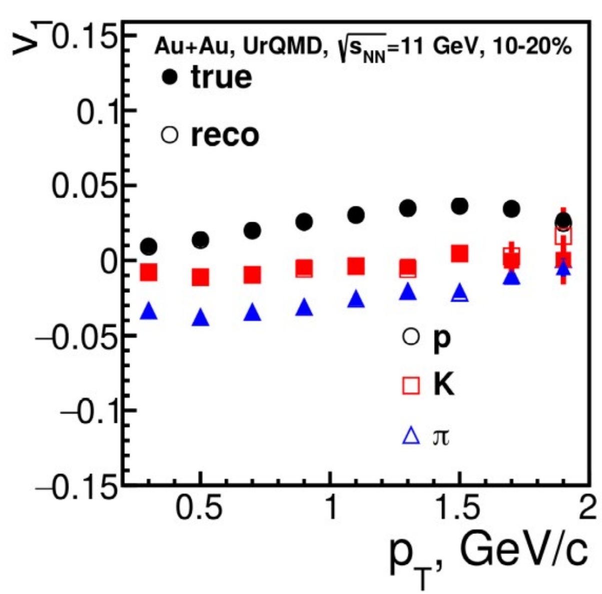
Performance of collective flow studies

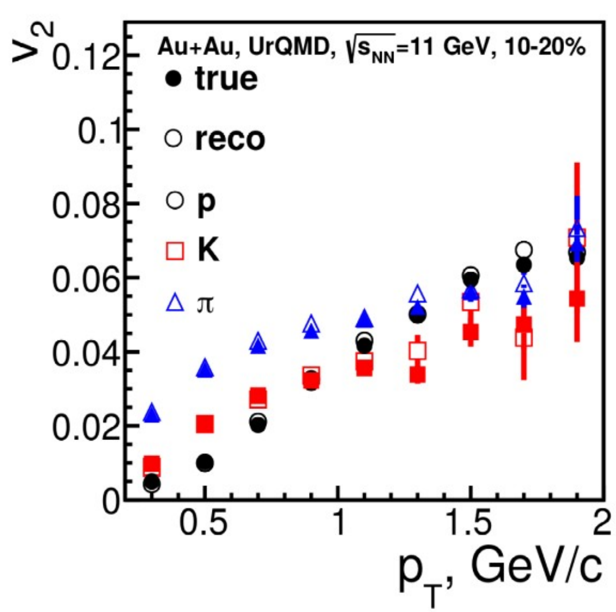
Au+Au, $\sqrt{s_{NN}}$ = 11 GeV, UrQMD, GEANT3 + MPDRoot reco.

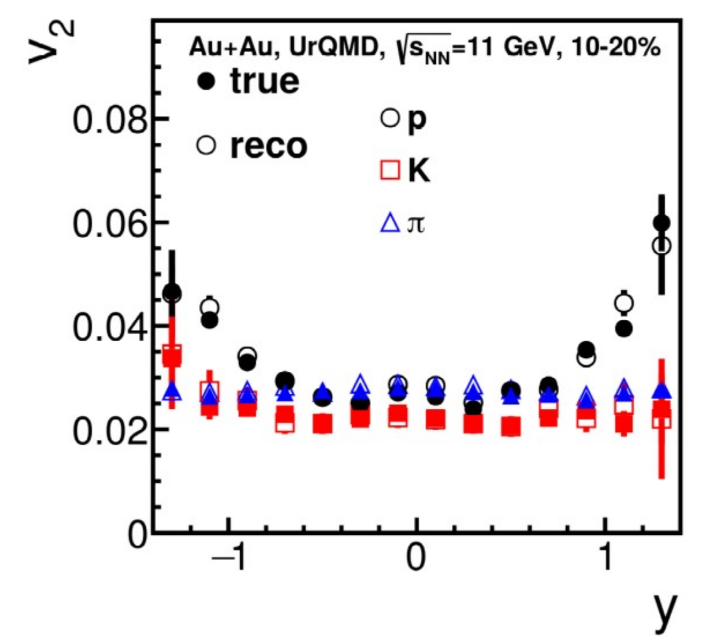












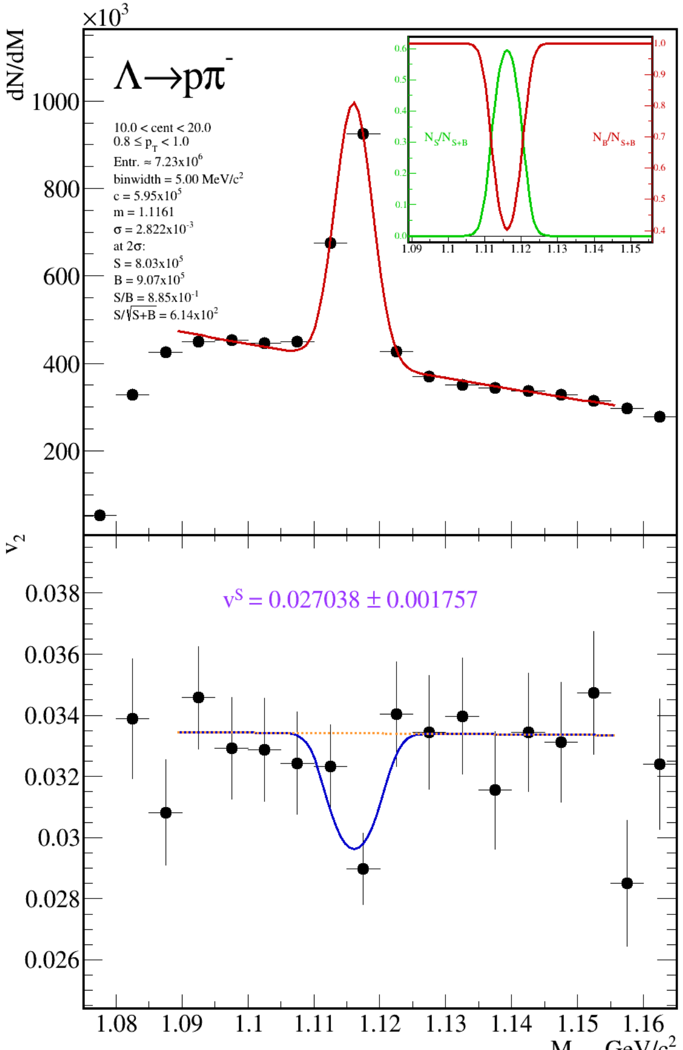
Anisotropic Flow of Reconstructed Decays

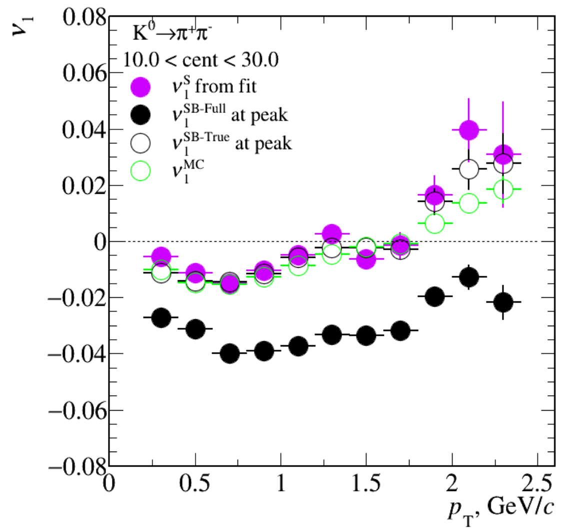
$$v_2^{SB}(m_{inv},p_T) = v_2^{S}(p_T)\frac{N^S(m_{inv},p_T)}{N^{SB}(m_{inv},p_T)} + v_2^{B}(m_{inv},p_T)\frac{N^B(m_{inv},p_T)}{N^{SB}(m_{inv},p_T)}$$

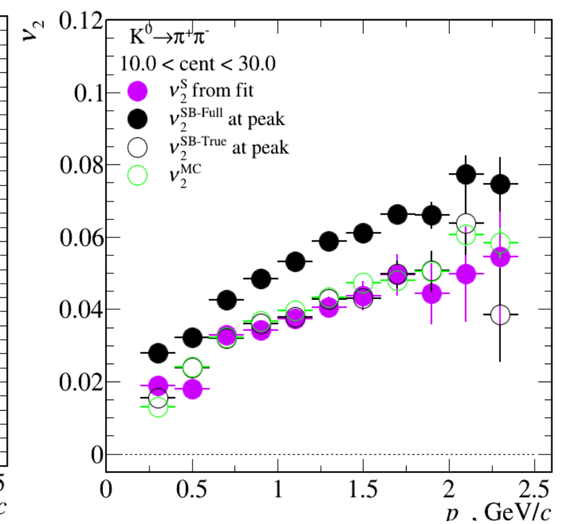
Extracted flow signal after fit
Measured flow (s+bg) at peak region

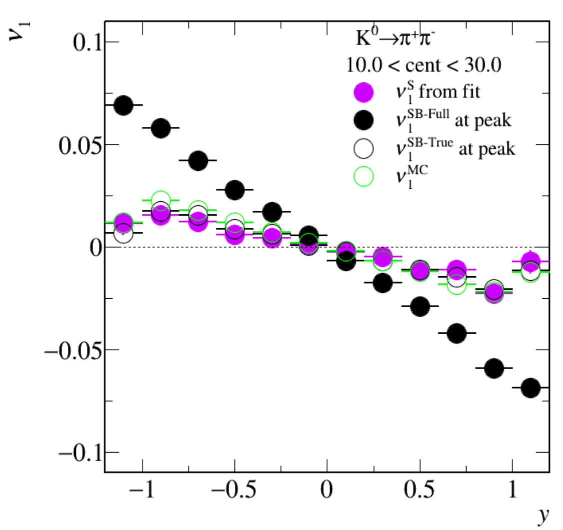
Measured flow only for True
Measured flow from MC/model

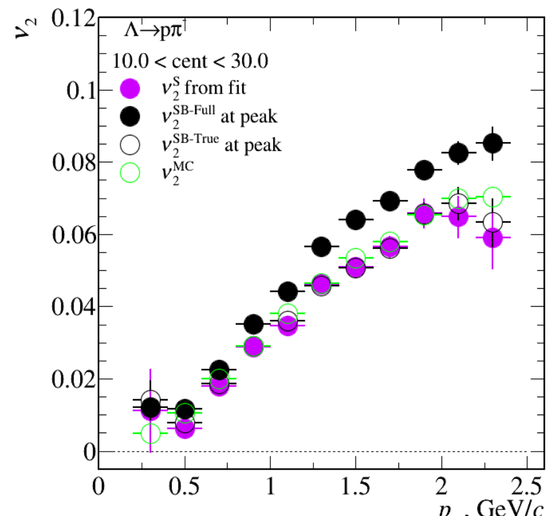
Cuts not optimised for S/B

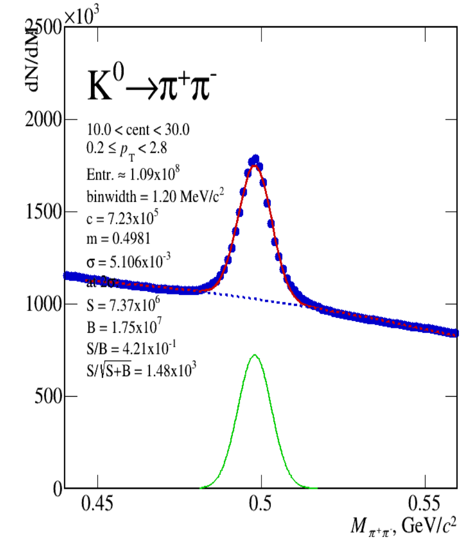


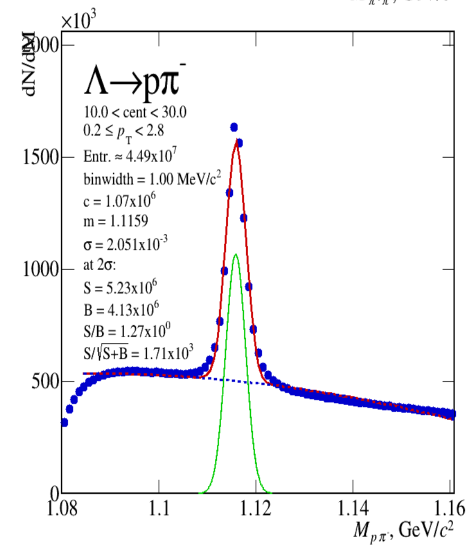










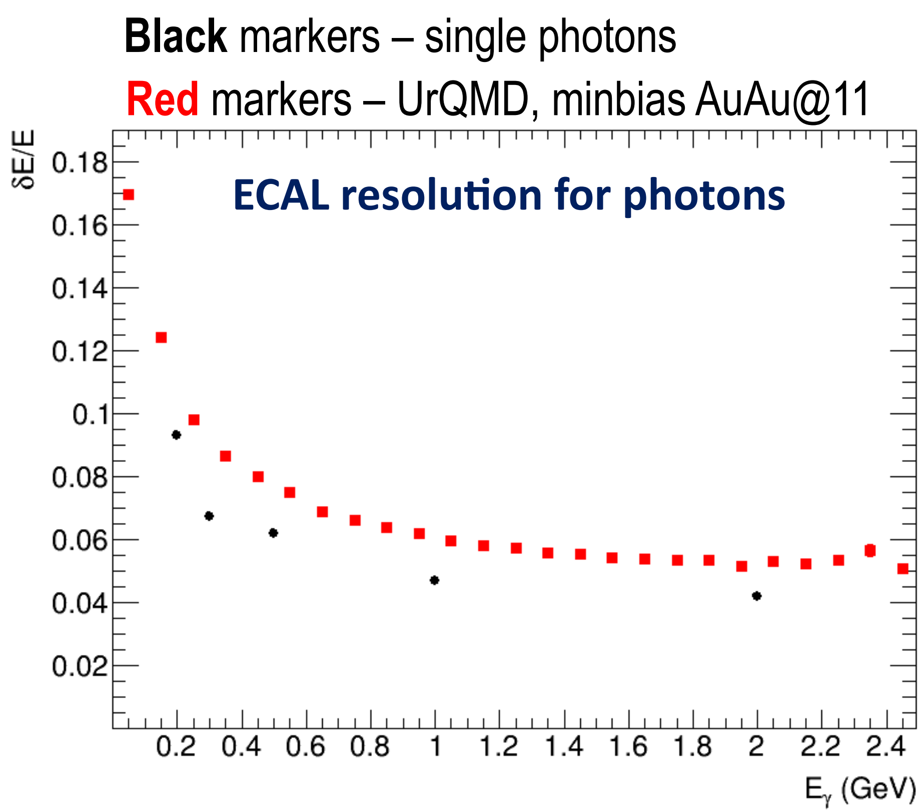


Performance of the MPD Detector for the Study of Multi-strange Baryon Production in Heavy-ion Collisions at NICA

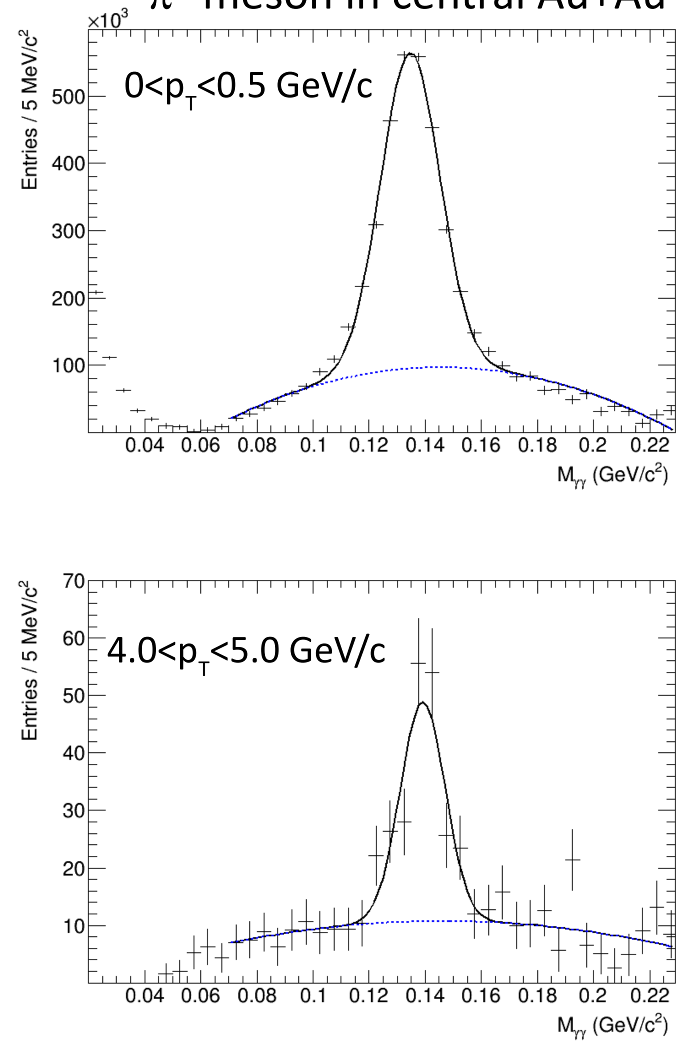
N. Geraksiev, V. Kolesnikov, V. Vasendina, A. Zinchenko for the MPD Collaboration

Electromagnetic Calorimeter simulation

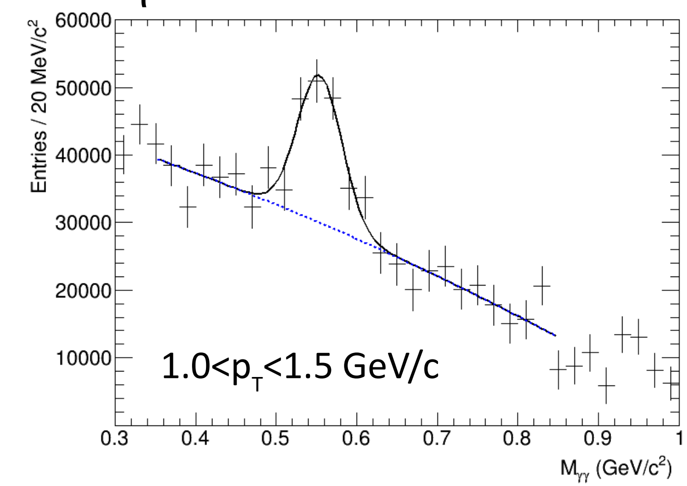
- Realistic ECAL reconstruction & analysis – large acceptance ECAL with good energy resolution: ideal tool for measurement of neutral mesons in a wide momentum range



π^0-meson in central Au+Au

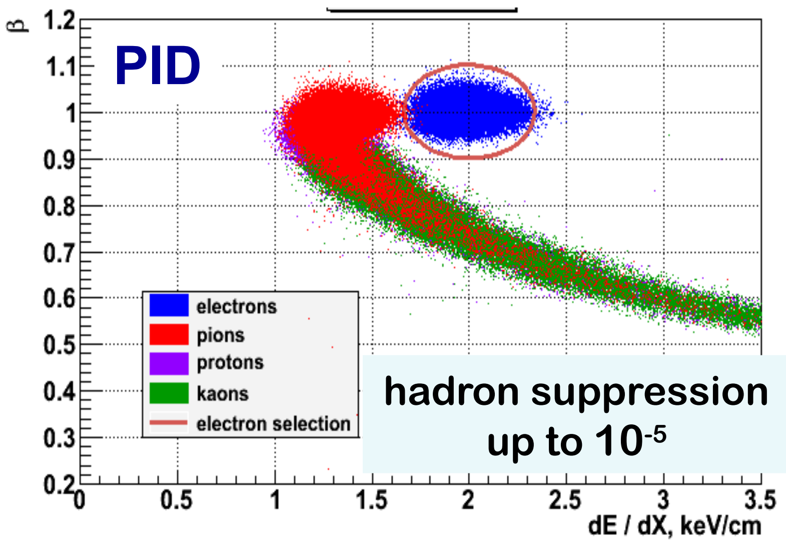


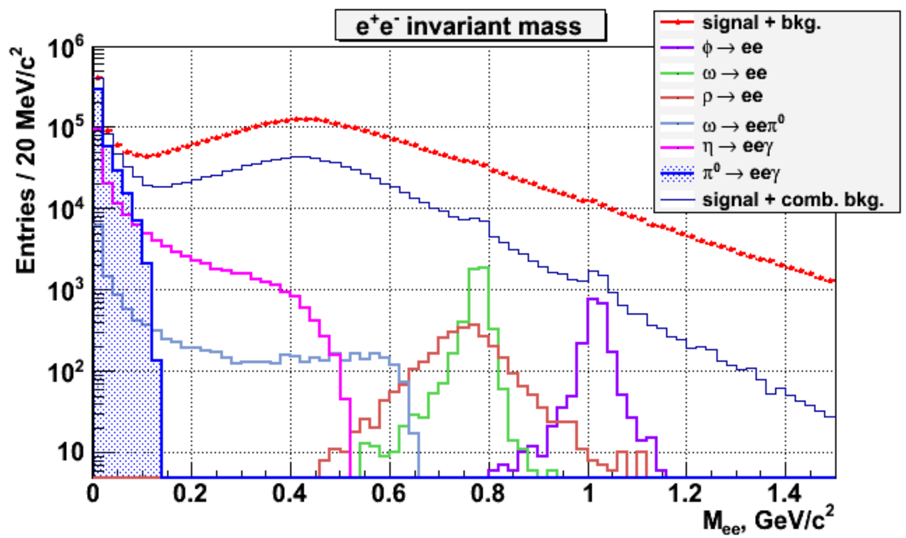
η-meson in minbias Au+Au

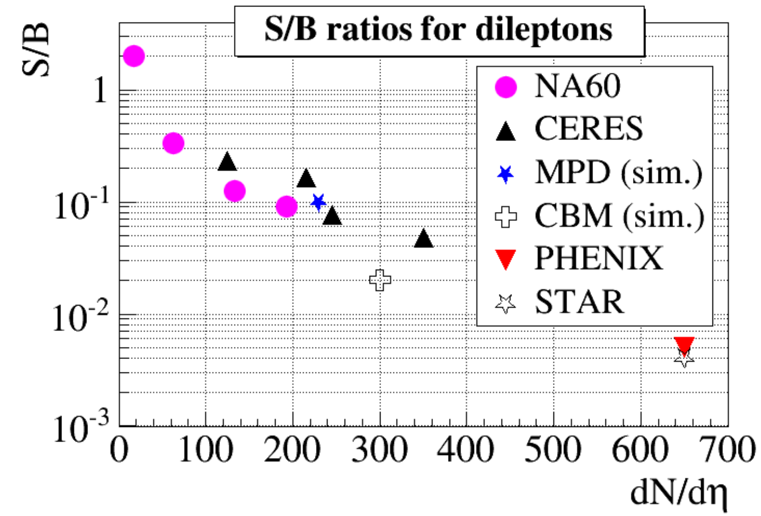


Prospects of dilepton studies

- **Event generator:** *UrQMD+Pluto (for the cocktail) central Au+Au @ 8 GeV*
- **PID**: *dE/dx (from TPC) + TOF (σ ~100 ps) + ECAL*

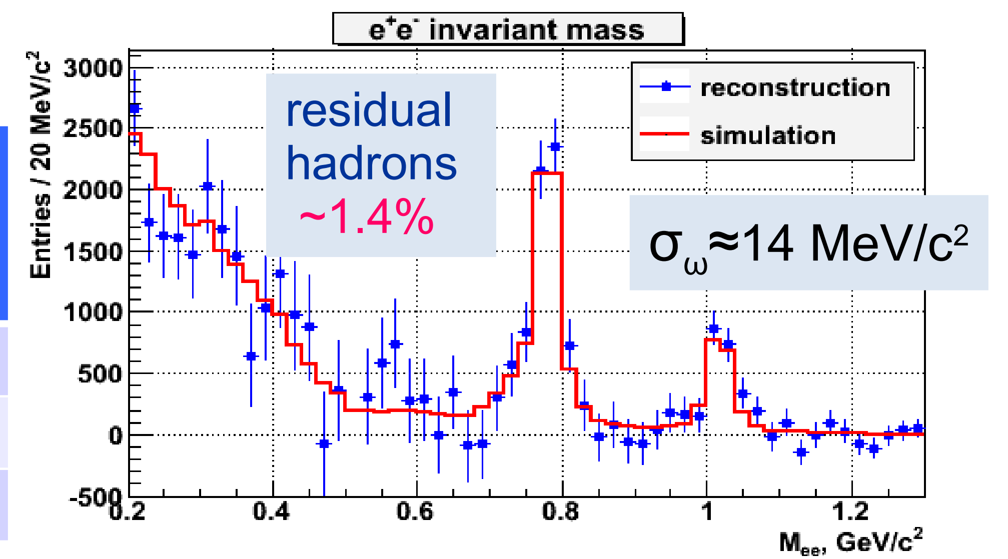






Yields, central Au+Au at $\sqrt{s_{NN}}$ = 8.8 GeV

Particle	Yields		Decay mode	BR	Effic. %	Yield /1 w
	4π	y=0				
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	$1.7 \cdot 10^4$



Physics results dissemination

- Preparation of the „First Physics in MPD" document on the request of the JINR Scientific Council
- Recent and planned status reports of MPD detector construction and physics readiness:
  - Quark Matter 2019 (Wuhan, China)
  - Strangeness in Quark Matter 2019 (Bari, Italy)
  - Workshop on the QCD Phase Structure at High Baryon Density Region (Wuhan, China)
  - A Workshop on Heavy Flavor and Dilepton Production in Relativistic Heavy-Ion Collisions (HeFe2019) (Hefei, China)
  - Winter Workshop on Nuclear Dynamics (Puerto Vallarta, Mexico)

Summary

- MPD allows to access less-explored area of the QCD phase diagram with direct connection to astrophysics
- Collaboration formation is finished, focus now on formal agreements and organic growth
- All components of the MPD 1st stage detector advanced in production, commissioning expected for 2021
- Performance studies for full physics program under way