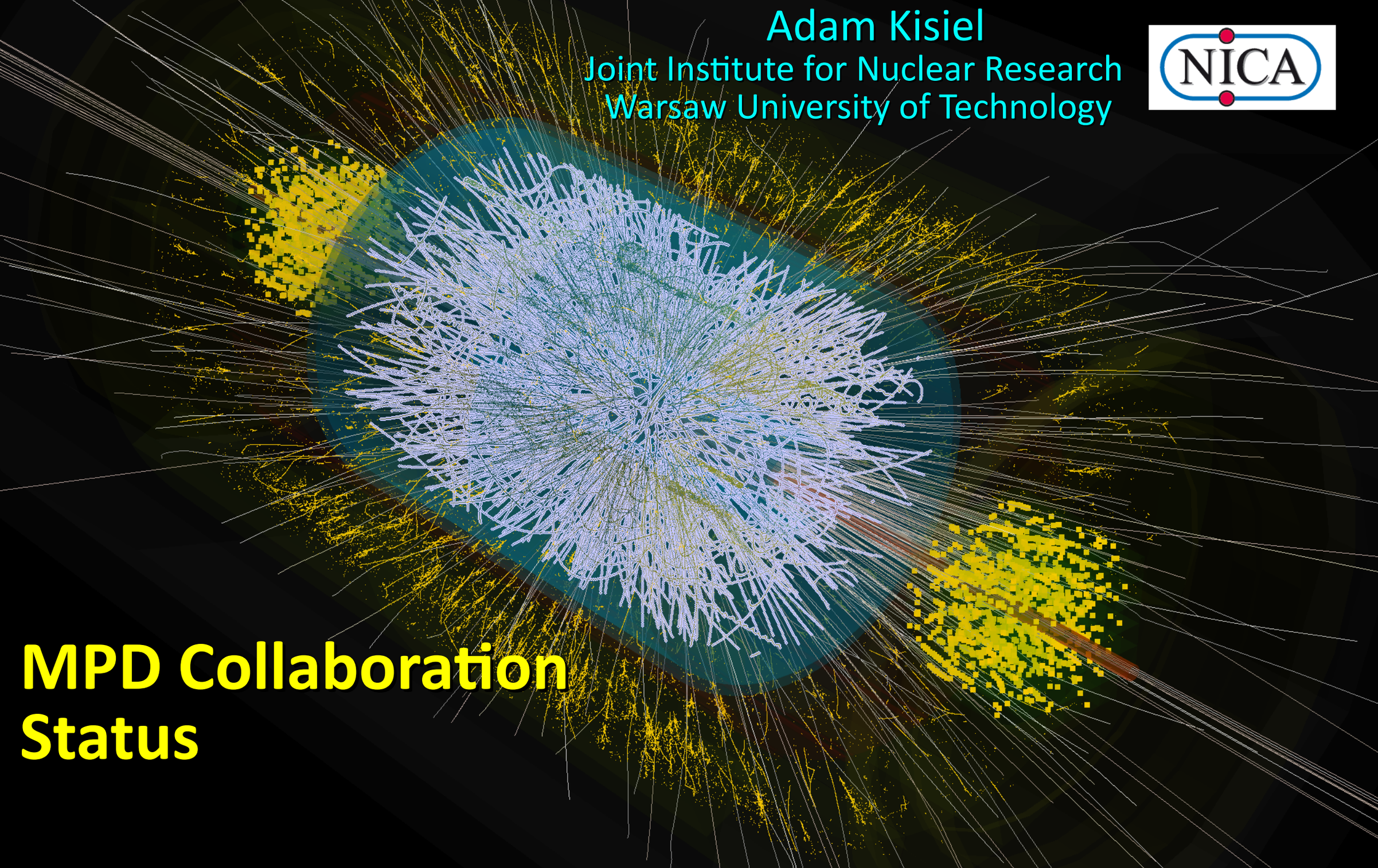
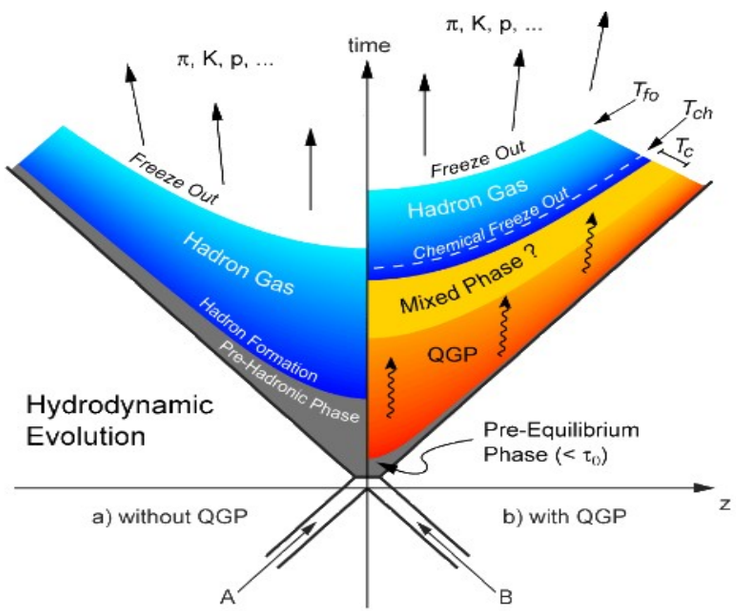


Adam Kisiel
Joint Institute for Nuclear Research
Warsaw University of Technology

MPD Collaboration Status

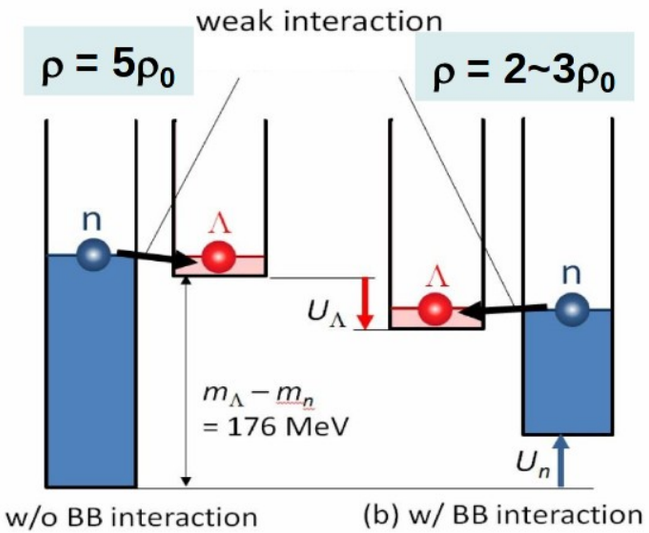
Unexplored phase space in QCD diagram



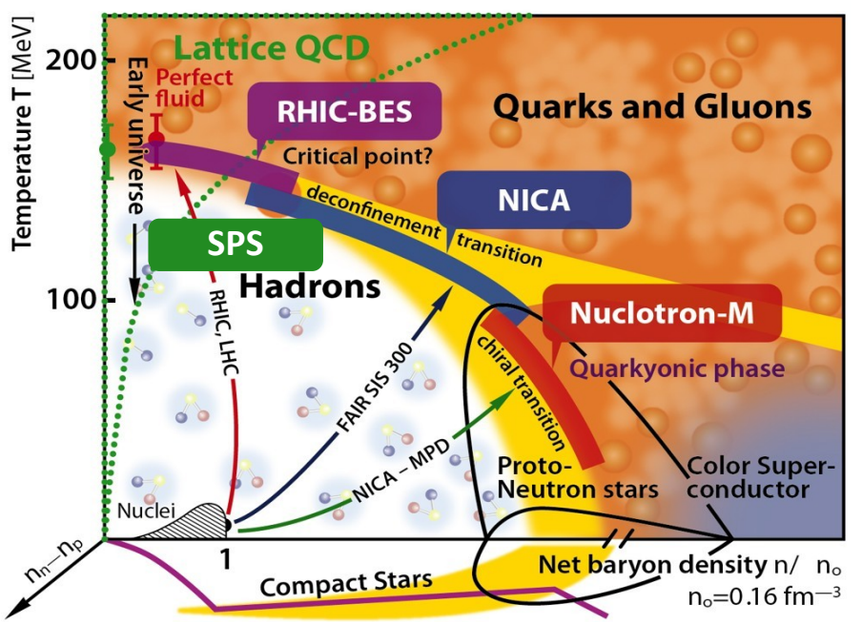
core of neutron stars reaches density several times larger than nuclear density

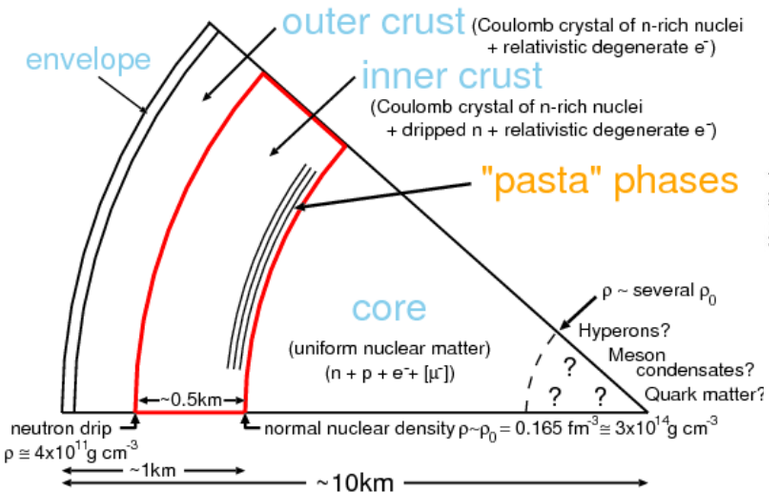
Credit: LIGO Collaboration

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

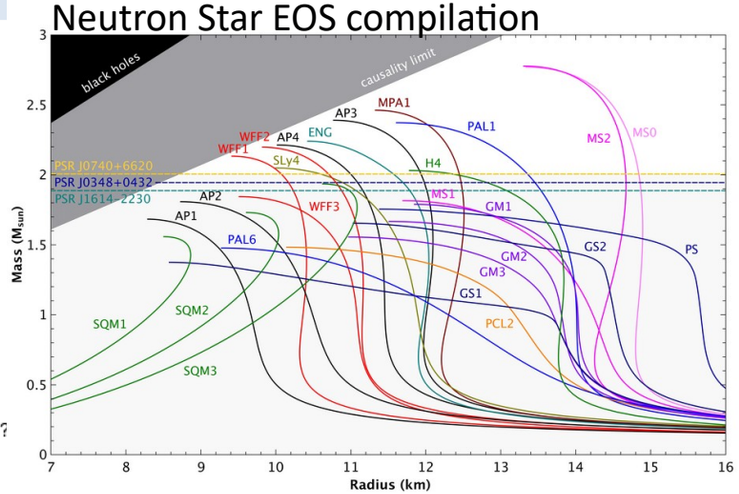


H. Tamura, Hadron 2017

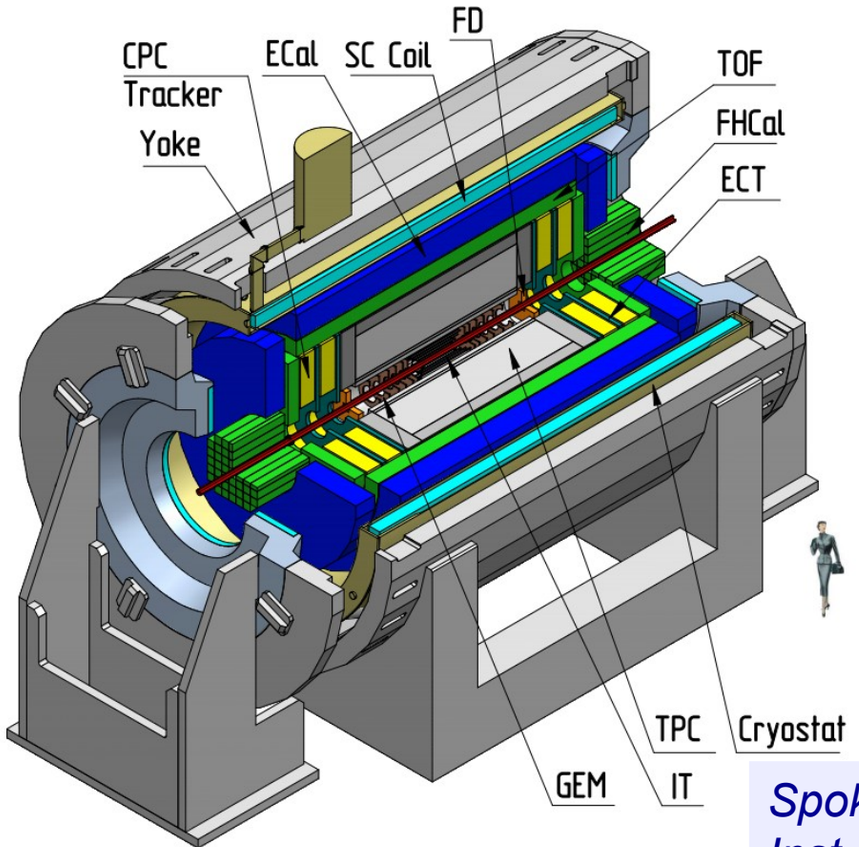




Neutron Star EOS compilation



Multi-Purpose Detector (MPD) Collaboration



***11** Countries, **498** participants,*
38** Institutes and **JINR

NICA

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

Deputy Spokespersons:
Victor Riabov, Zebo Tang

Vote today:
University of Silesia

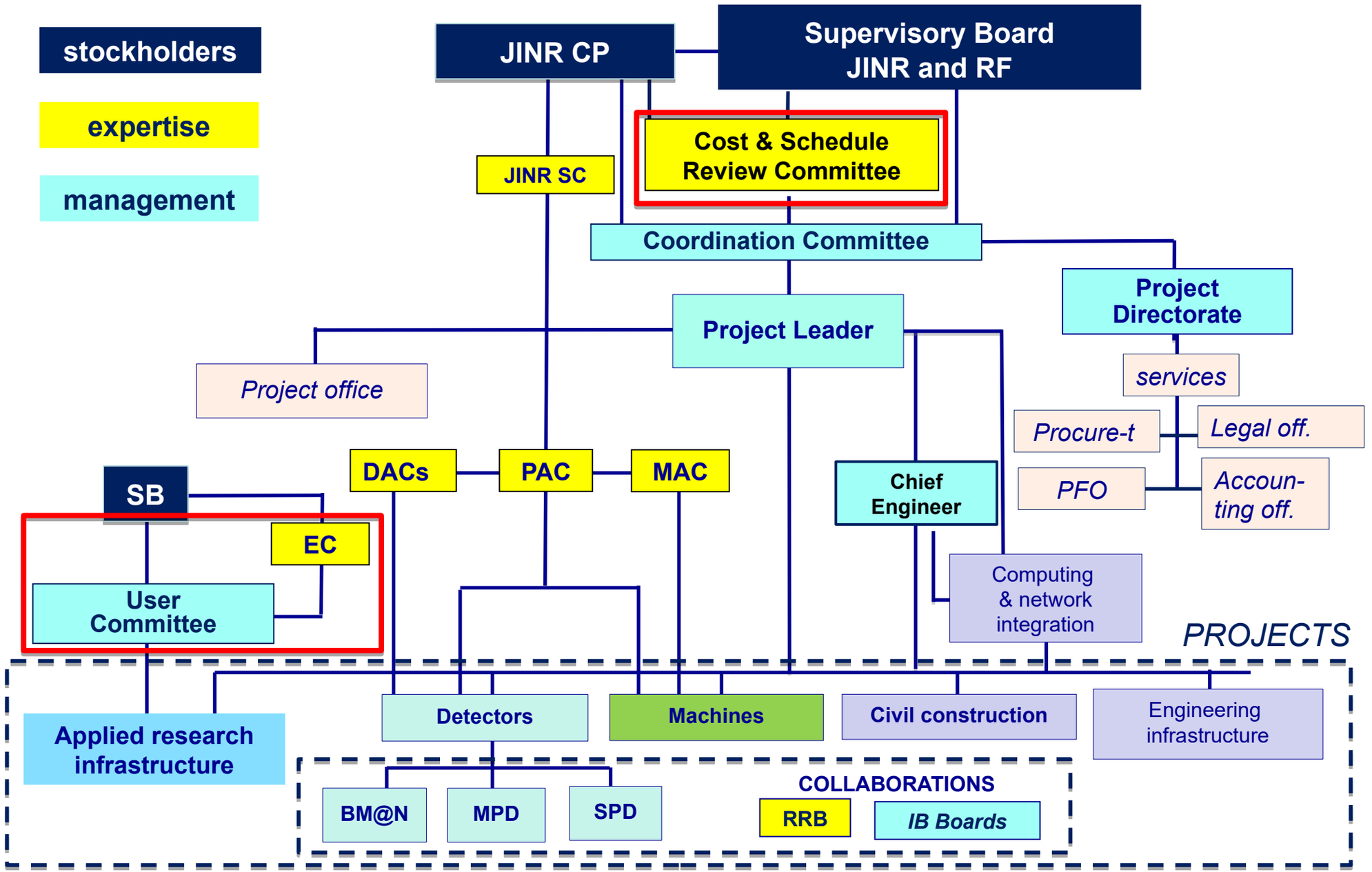
*AANL, Yerevan, **Armenia;***
*Baku State University, NNRC, **Azerbaijan;***
*University of Plovdiv, **Bulgaria;***
*University Tecnica Federico Santa Maria, Valparaiso, **Chile;***
*Tsinghua University, Beijing, **China;***
*USTC, Hefei, **China;***
*Huzhou University, Huizhou, **China;***
*Institute 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;***

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 ready 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, Belgorod State University, MIPT Moscow, NRC „Kurchatov Institute” - ITEP

Project management and expertise structure



Recent MPD status reports

- Russian Federation funding agencies indicated a start-up date for the NICA Accelerator Complex as 2022
- Current planning of the Complex, including the startup of MPD is considered within this timeframe
- Recent reports on the status of the MPD realization (02.2020):
  - The Program Advisory Committee for Particle Physics
  - The Detector Advisory Committee of MPD
  - The Scientific Council of the JINR
  - The Cost & Schedule Review Committee of JINR
- General feedback is positive with identification of critical milestones of project realization and the general statement that the schedule is „ambitious”

MPD First Physics Document

First Physics with MPD Experiment
at the NICA Accelerator Complex*

Vladimir D. Kekelidze, Adam Kisiel,† and Viacheslav Golovatyuk‡
Joint Institute for Nuclear Research, Dubna, Moscow Region, Russian Federation
(MPD Collaboration)
(Dated: February 17, 2020)

The Nuclotron-based Ion Collider fAcility (NICA) is in construction at the Joint Institute for Nuclear Research (JINR). The accelerator complex will consists of several components, specifically the Nuclotron accelerator, the Booster support accelarator, two ion sources, as well as the NICA collider ring with the corresponding transfer lines from Nuclotron. The expected date of putting the NICA collider ring in operation is N-th Month of 202X. At the same time the Multi-Purpose Detector (MPD) has been designed to operate at NICA. Components of MPD are currently in production. The assembly of the detector on-site is expected to start on March of 2020, while on May of 2021 the detector setup will start the commisioning, to be ready for datataking on first beam from NICA.

This documents details the preparation schedule for the construction and commisionning of MPD. It presents the plans for the first physics measurements at NICA and puts them into context of existing and planned physics experiments in the area of QCD phase diagram investigation.

CONTENTS

* A report for the Scientific Council of JINR
† Also at Faculty of Physics, Warsaw University of Technology, Warsaw, Poland.
‡ Second.Author@institution.edu

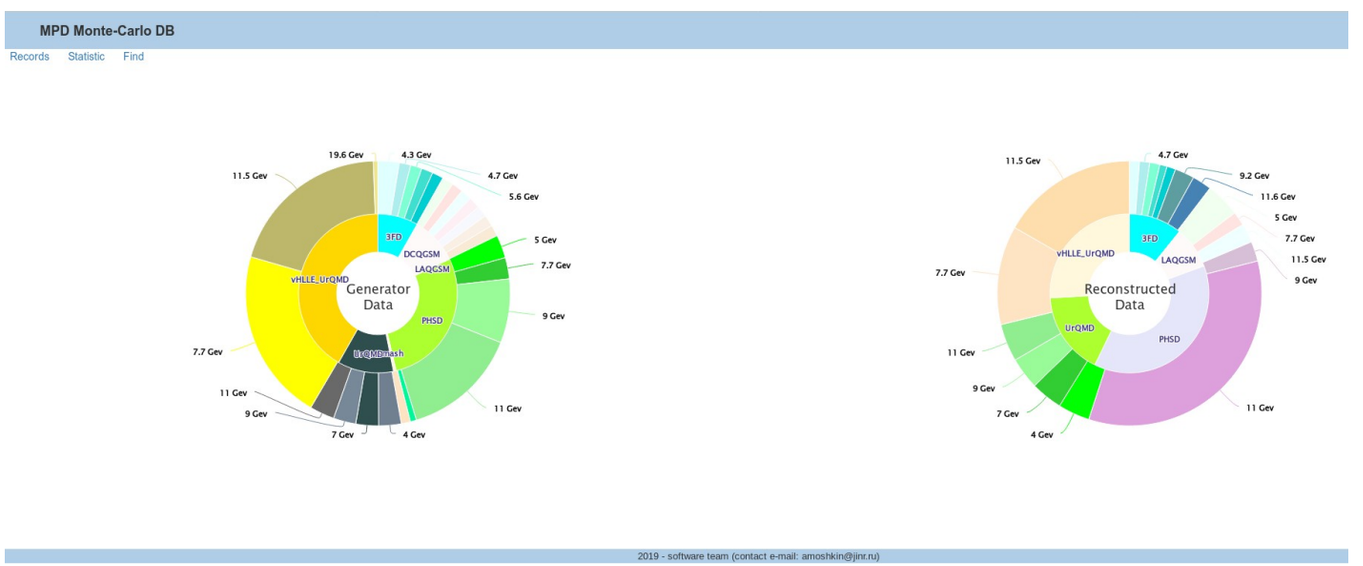
- In preparation on the request of the „Supervisory Board of JINR and RF”
- Report on expected physics results on the first run of MPD
- Initial running plan for the NICA Complex (beam types, collision energies)
- Status of the readiness of the MPD detector subsystems
- Calibration and computing readiness
- Selection of physics observables with largest discovery potential for the initial datasample
- Schedule for preparation of first scientific publications from MPD data

MPD Executive Council

- The Executive Council composition:
  - **Vadim Kolesnikov, Yi Wang, Alejandro Ayala, Alexander Zinchenko, Oleg Rogachevsky, Arkadiy Taranenko**, **Ilya Sleyuzhenkov**, **Andrei Dolbilov**
- We thank **Oleg Rogachevsky** and **Arkadyi Taranenko** for their first term at the Executvie Council. The elections for the two posts will be held by the Institutional Board today.
- Some of the topics discussed at the EC meetings:
  - Progress on MPD installation
  - IT tools and computing resources for the collaboration
  - Reports from major oversight committee meetings (DAC, Programme Advisory Committee, NuPECC, ECFA, Scientific Council, Cost&Schedule Review Committee, etc.)
  - Common Fund: rules, spending items
  - Execution of Monte-Carlo requests
  - Preparation and execution of MPD Collaboration Meetings
  - New initiatives and detectors in development (MPD ITS TDR)

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
- Establishing communications with LIT team



DIRAC
THE INTERWARE

- DIRAC infrastructure enables integration of heterogenous computing resources at multiple sites
- Provide single access point for end users for MPD Computing
- First tutorials given by LIT staff to selected MPD users
- Will be provided to all MPD Collaborators

Report **Friday**
Software&Computing session

Significant new computing at LHEP

Report **Friday**
Software&Computing session

- 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)
- Still needs work on stability (shared disk performance)
- Request to provide more transparent information to the user on the cluster status and plans for works/upgrades

Electronic tools for communication

- Resources being actively used by the Collaboration
  - General purpose mailing list: MPD_Coll_List(at)maillist.jinr.ru
  - The MPD Forum (based on the Discourse web forum platform) http://mpdforum.jinr.ru
  - Specific mailing lists for: Executive Council, Physics Council, Institutional Board, new lists can be created on request
  - The INDICO system (coupled to Vidyo conference platform) for planning, execution and archiving of MPD meetings
  - ZOOM system for videoconferencing
- Resources in active development and being kept up to date:
  - General NICA webpage with MPD section: http://mpd.jinr.ru
  - MPD Software webpage: http://mpdroot.jinr.ru
  - „New" MPD-dedicated webpage: http://mpd.jinr.ru/experiment

MPD Civil Construction status

- MPD Hall close to ready for equipment installation

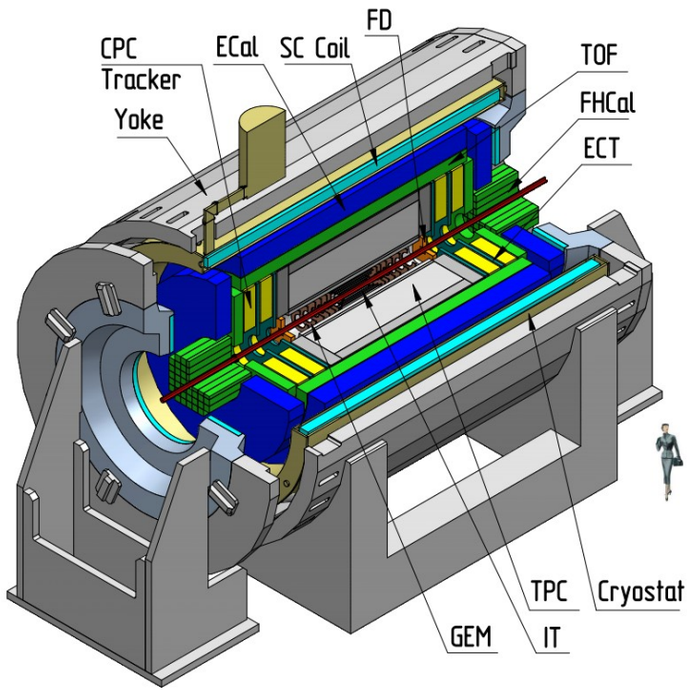
MPD Hall external covering

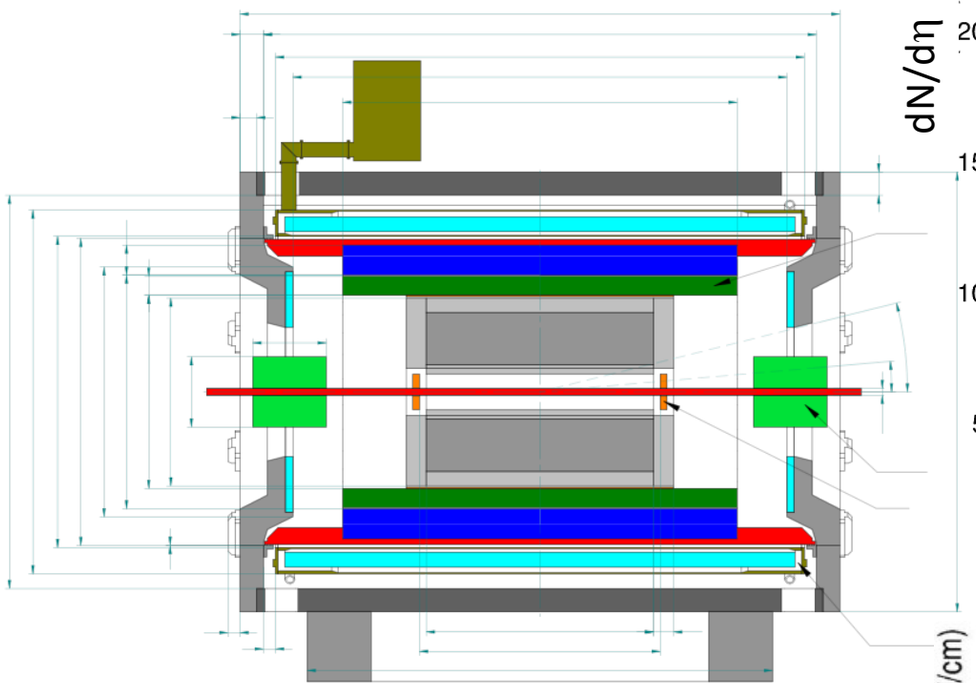
MPD Hall crane weight test

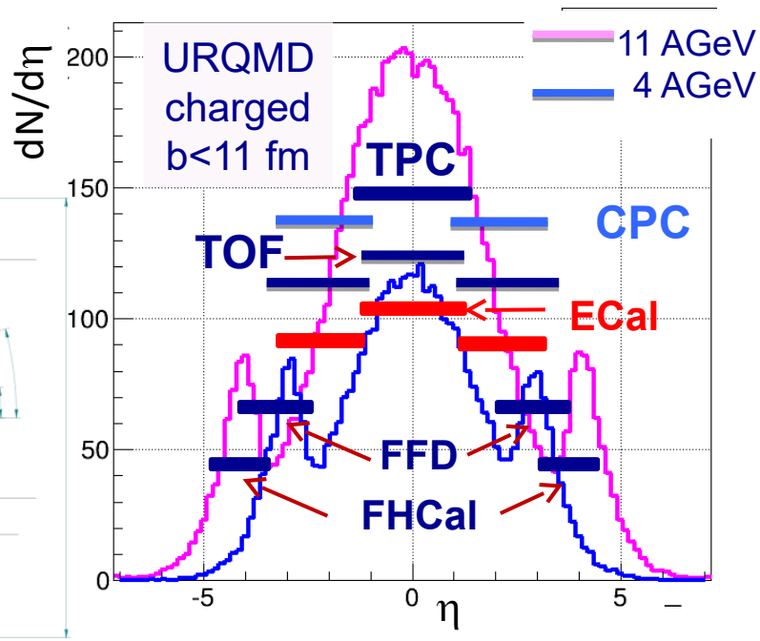
Transportation of MPD Magnet Yoke parts into the MPD pit (inside MPD Hall)

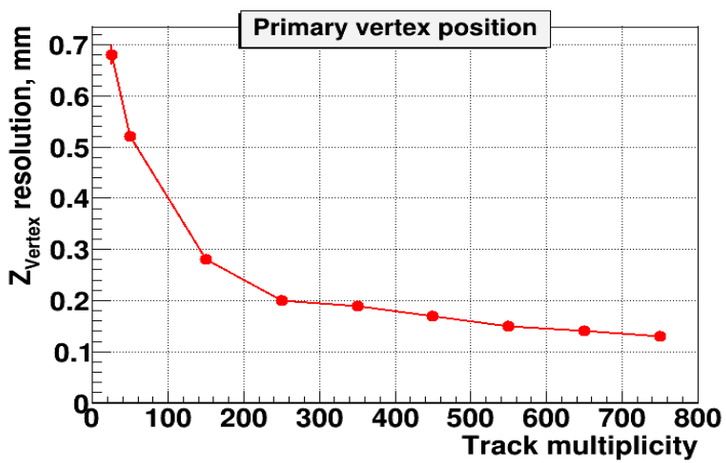
Session **Thursday**
S. Golovatyuk et al.

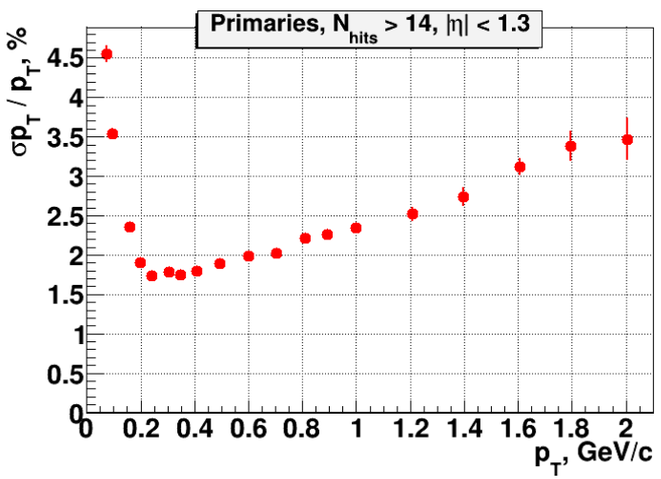
MPD 1st stage

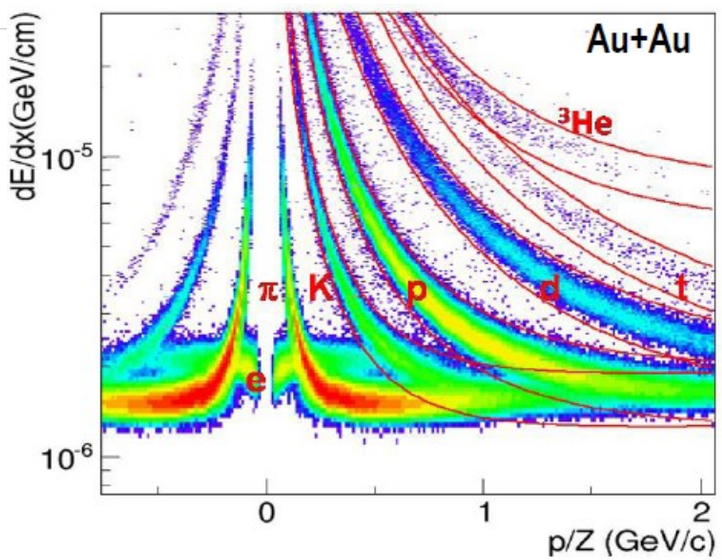












- 2π in azimuth, 3-D tracking (TPC), Powerful PID (TPC, TOF): - π/K up to 2.0 GeV/c, - K/p up to 3 GeV/c, Low material budget, High rate (<=6 kHz)

Milestones of MPD assembling in 2020-2021 (revised for pandemic ...)

Year 2020

1. April 30th - MPD Hall and pit are ready to store and unpack Yoke parts
2. May – June - Magnet Yoke is assembled for alignment checks
3. August - Solenoid is ready for transportation from ASG (Italy)
4. September - Solenoid delivered to Dubna
5. November - Assembling of Magnet Yoke and Solenoid at JINR
6. December - Preparation for switching on the Solenoid (Cryogenics, Power Supply et cet.)

Year 2021

7. February – March - Magnetic Field measurement
8. April - Installation of Support Frame
9. May – September - Installation of subsystems, Electronics Platform, Cabling
10. November - **Commissioning of MPD**
11. December - **Readiness for Cosmic Ray tests**

Report **Thursday**
S. Golovatyuk

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.”
- 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
- Regular operation of PWGs is already underway

1st Session **Friday**

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

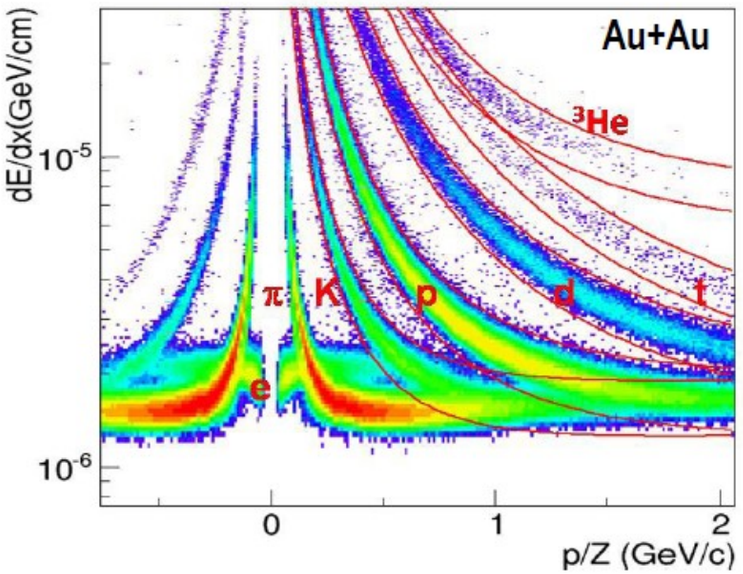
- Electromagnetic calorimeter meas.
- Photons in ECAL and central barrel
- Low mass dilepton spectra in-medium modification of resonances and intermediate mass region

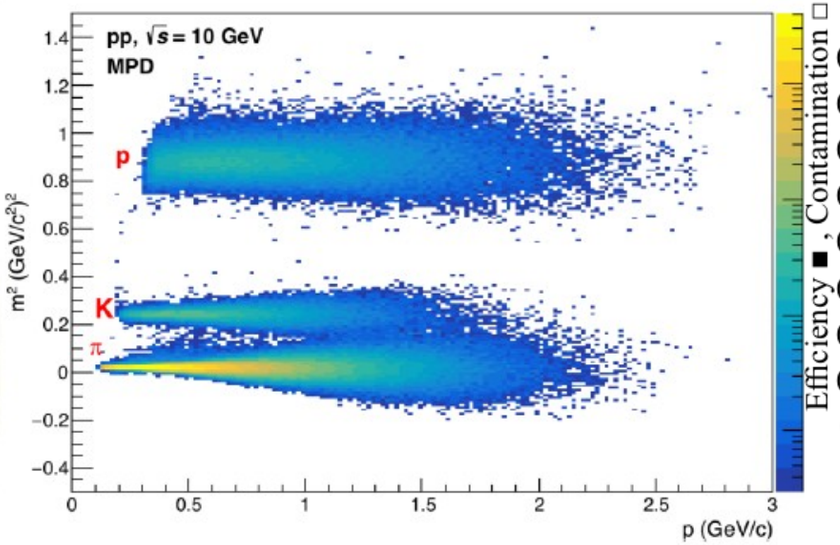
Wangmei Zha, A. Zinchenko

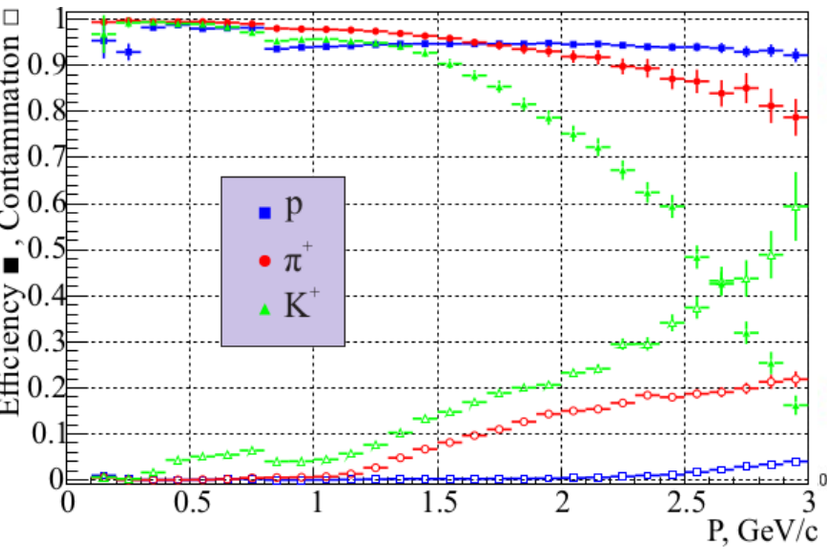
Heavy flavor

- 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

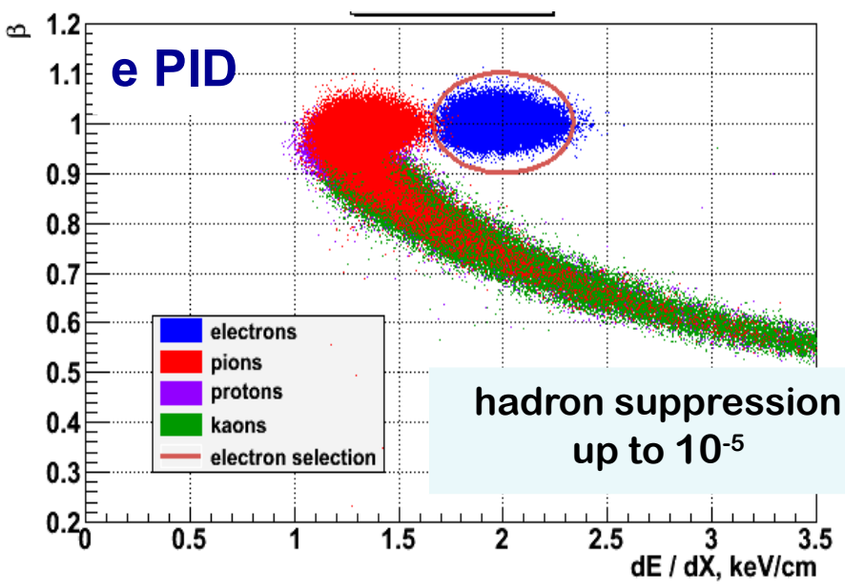
PID Performance in MPD







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

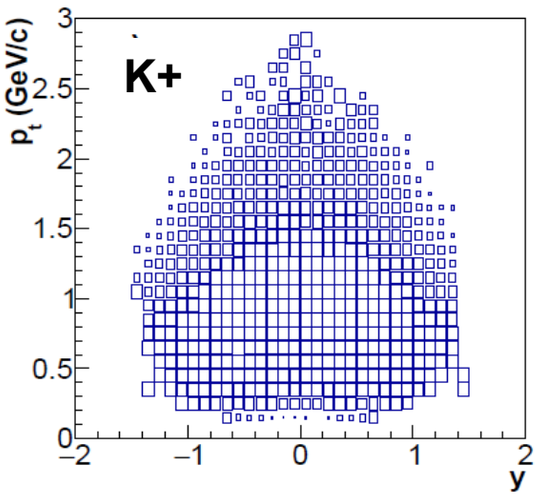
1st Session **Friday**

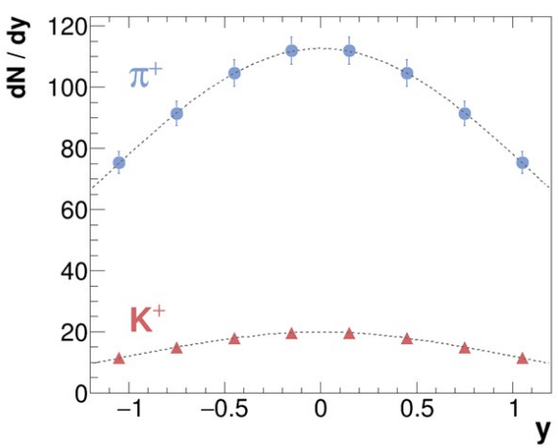
Hadroproduction with MPD

- **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**

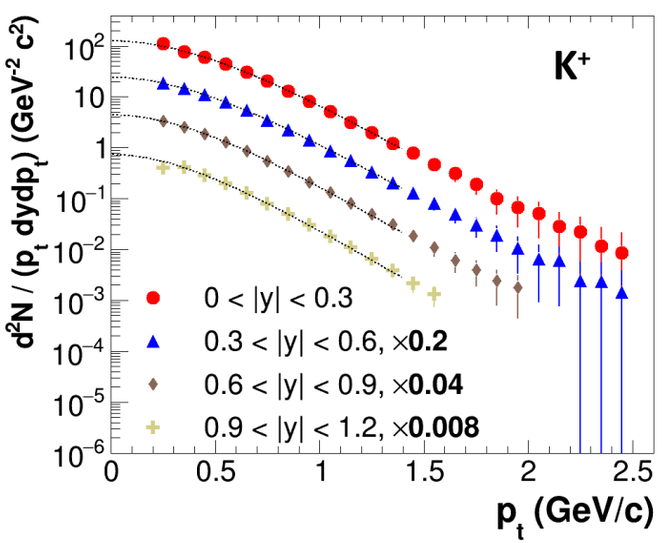
✓ *0-5% central Au+Au at 9 GeV from the PHSD event generator, which implements partonic phase and CSR effects*

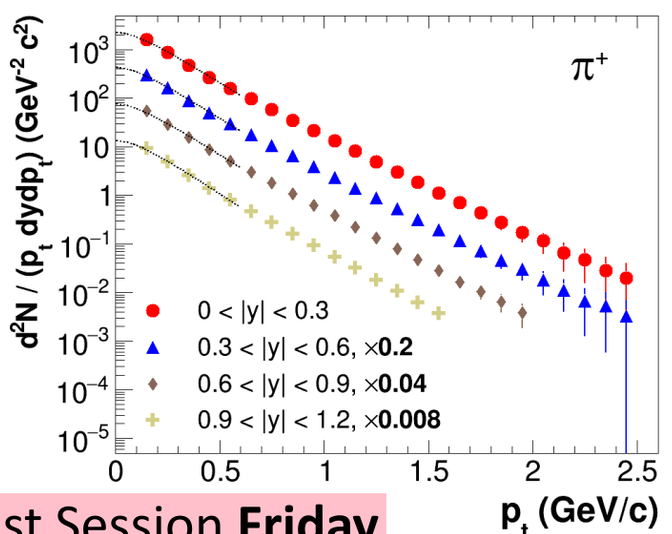
✓ *Recent reconstruction chain, combined dE/dx+TOF particle ID, spectra analysis*





- 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)

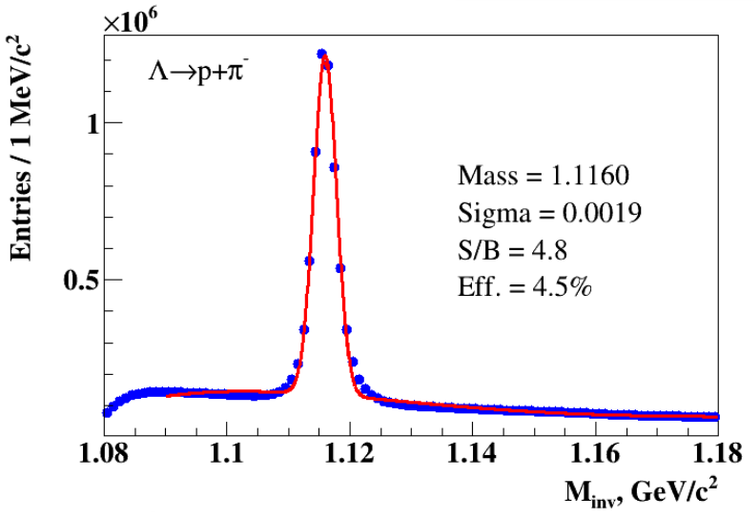


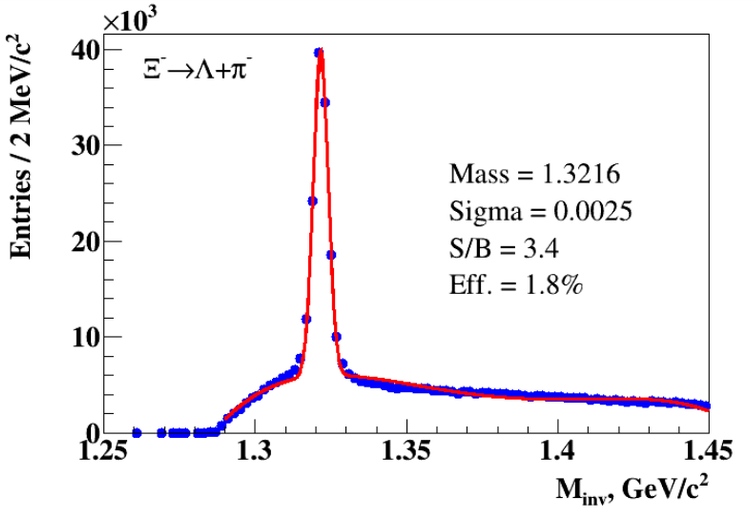


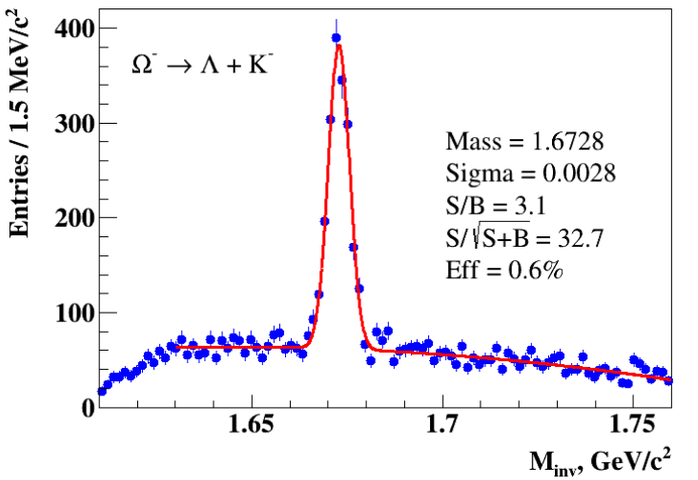
1st Session **Friday**

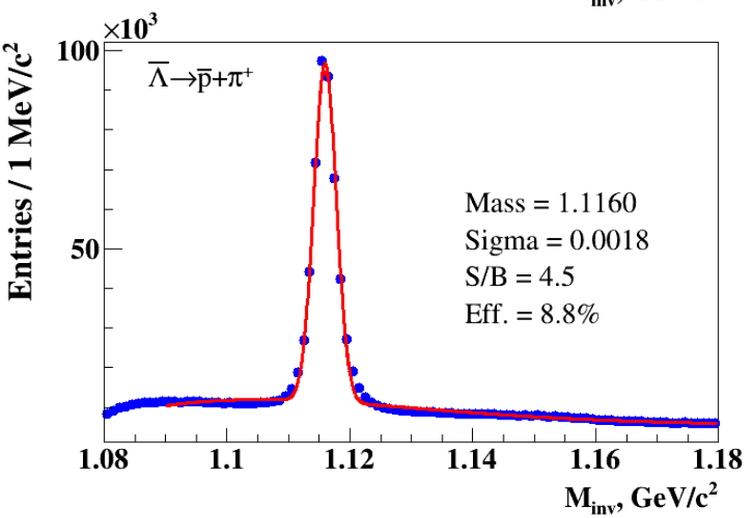
Strange and multi-strange baryons

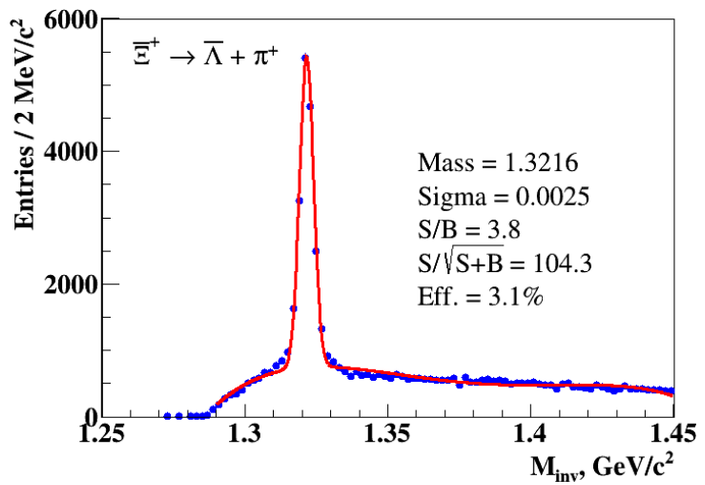
Stage'1 (TPC+TOF): Au+Au @ 11 GeV, PHSD + MPDRoot reco.

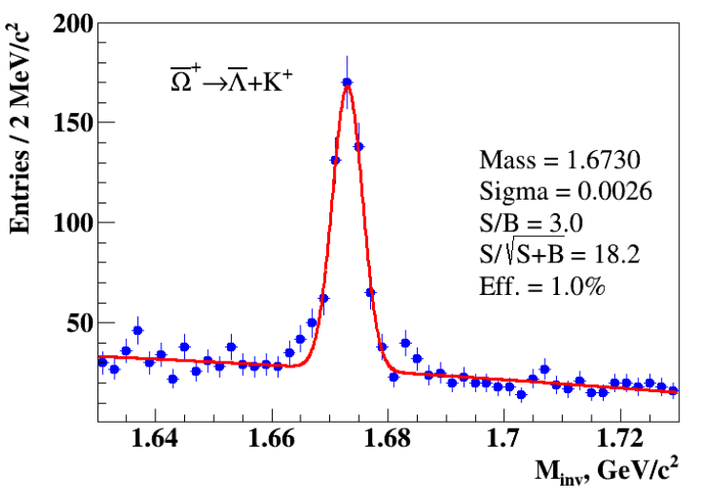








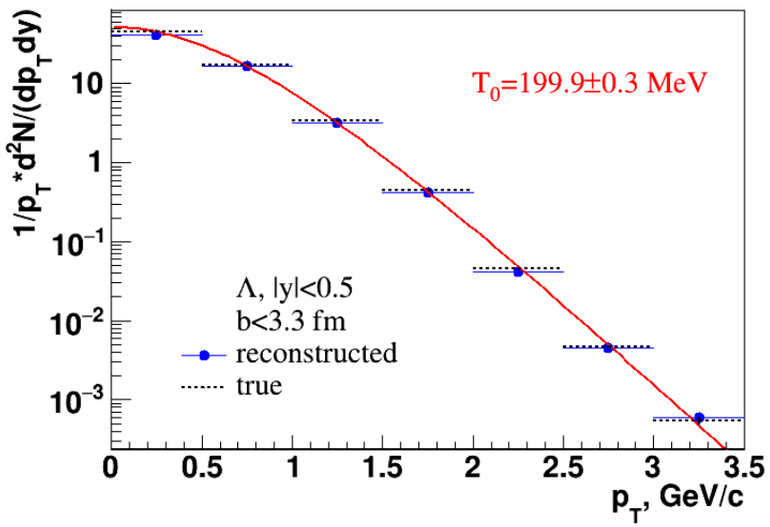


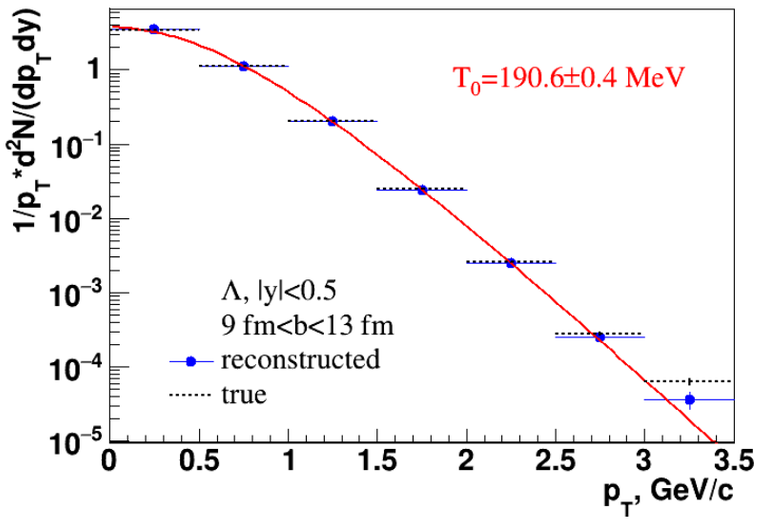


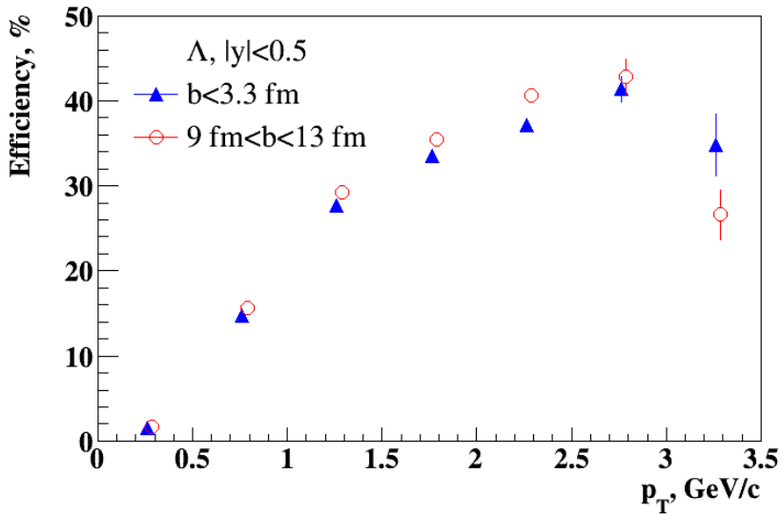
particle	Λ	anti-Λ	Ξ⁻	anti-Ξ⁺	Ω⁻	anti–Ω⁺
yield in 10weeks	$3 \cdot 10^8$	$3.5 \cdot 10^6$	$1.5 \cdot 10^6$	$8.0 \cdot 10^4$	$7 \cdot 10^4$	$1.5 \cdot 10^4$

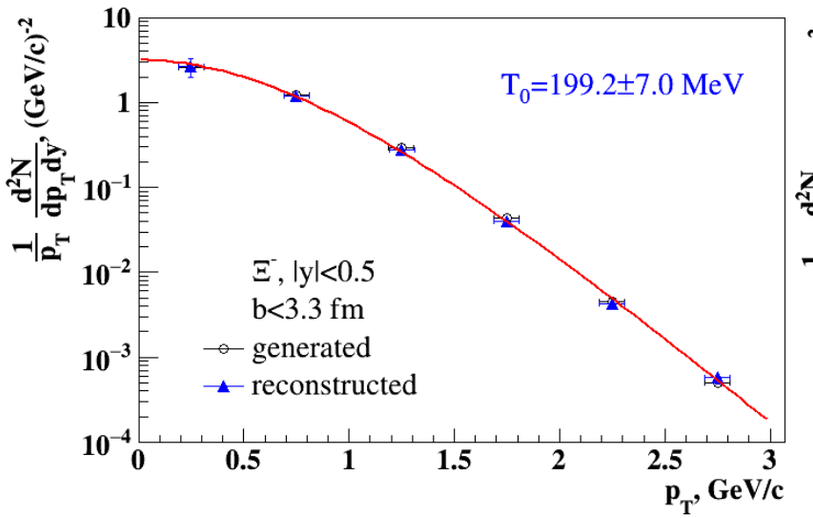
1st Session **Friday**

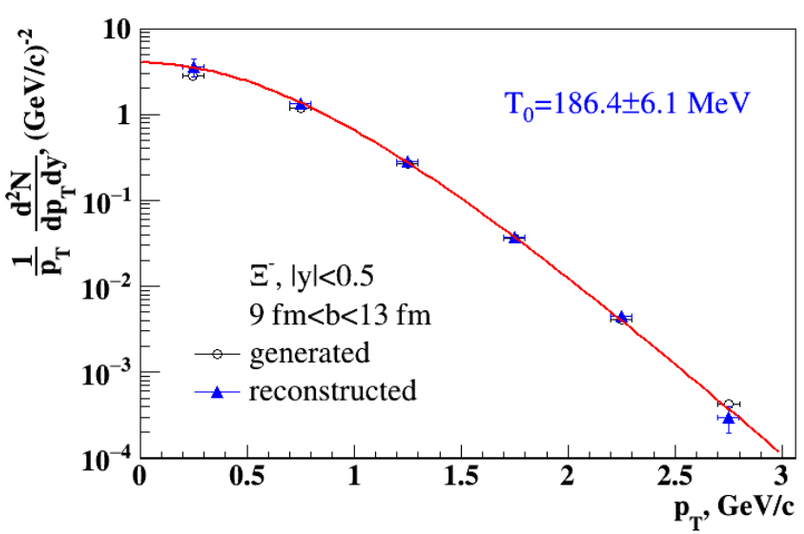
Efficiency and p_T spectrum

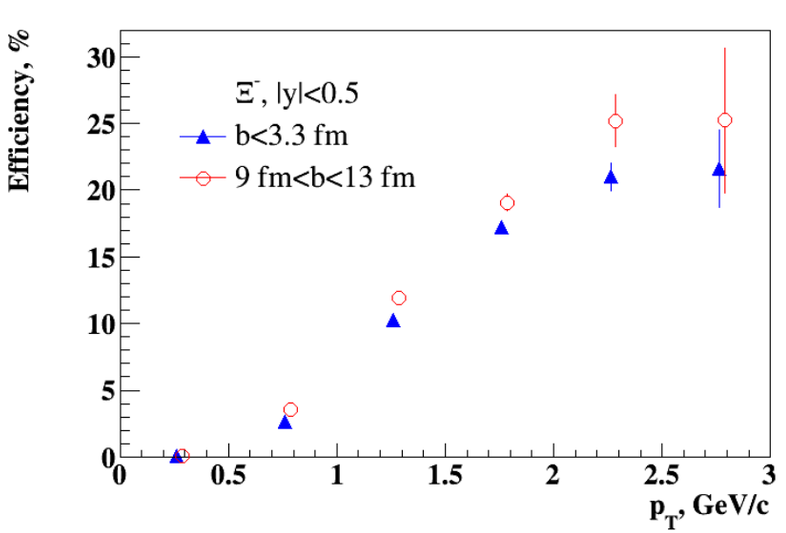












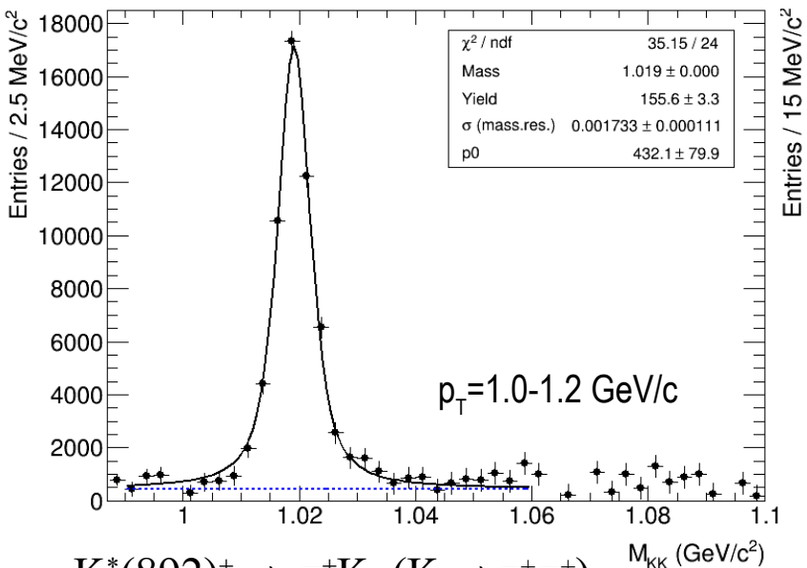
Full p_T spectrum and yield extraction, reasonable efficiency down to low p_T

1st Session **Friday**

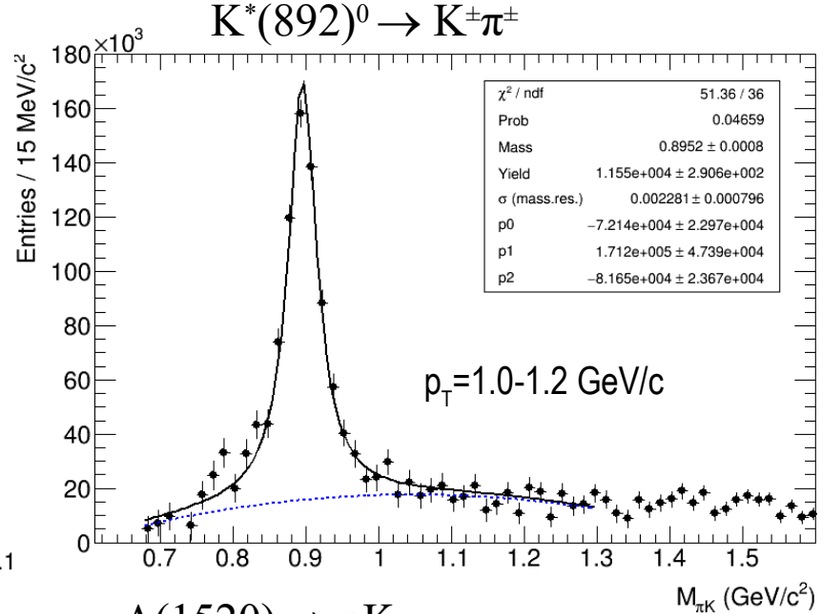
Resonances at MPD

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

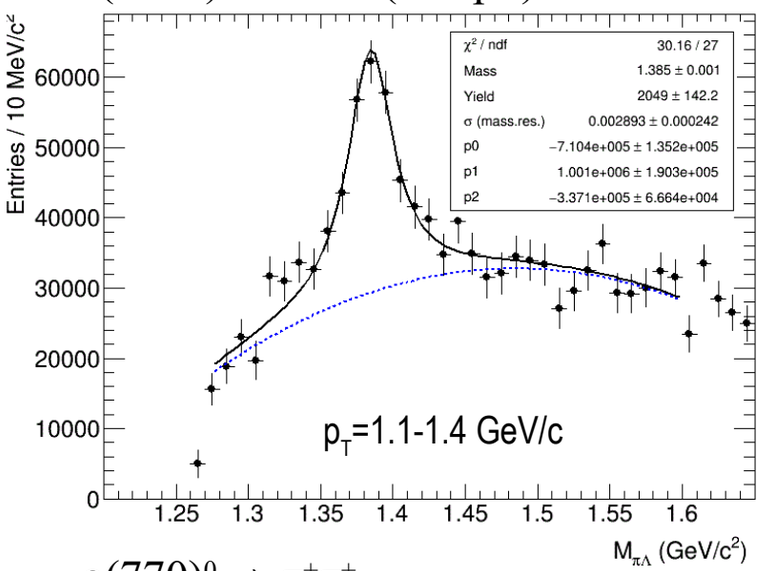
$\phi(1020) \rightarrow K^+K^-$



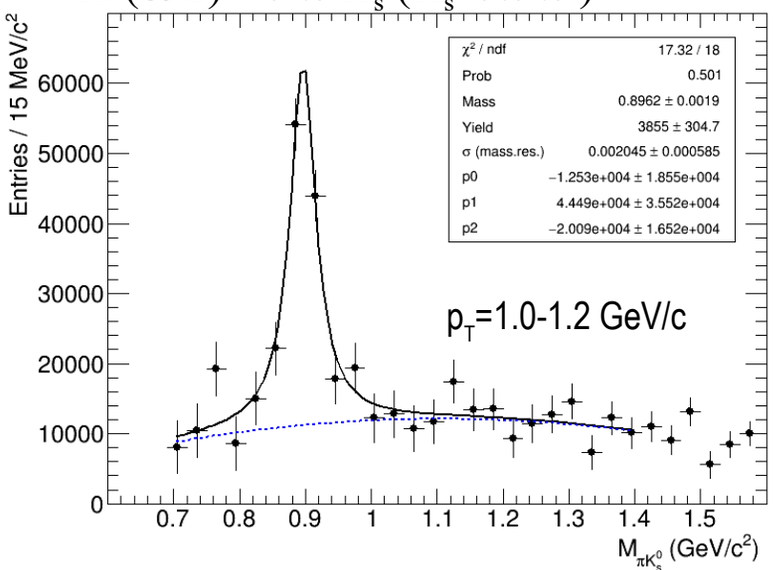
$K^*(892)^0 \rightarrow K^{\pm}\pi^{\pm}$



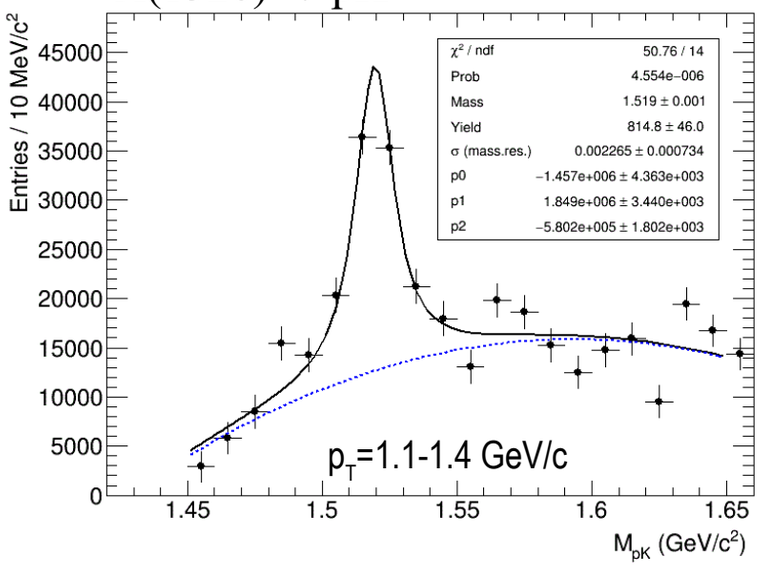
$\Sigma(1385)^{\pm} \rightarrow \pi^{\pm}\Lambda\ (\Lambda \rightarrow p\pi)$



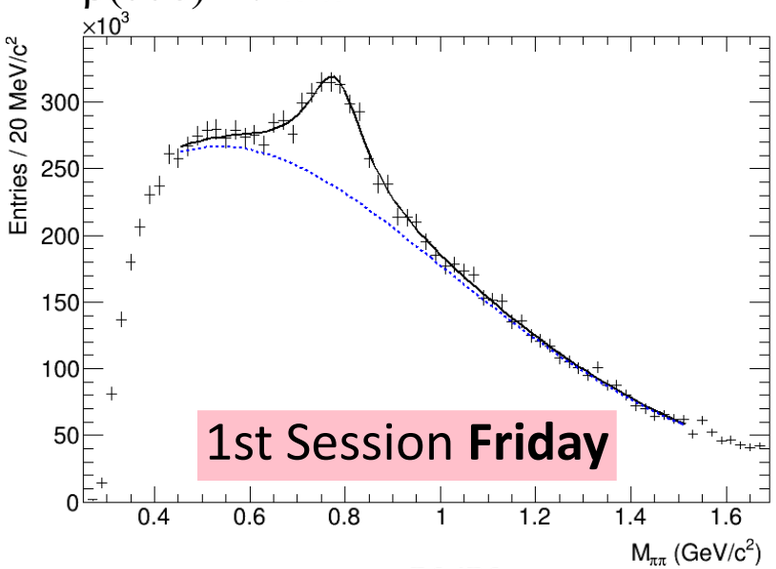
$K^*(892)^{\pm} \rightarrow \pi^{\pm}K_s\ (K_s \rightarrow \pi^+\pi^+)$



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



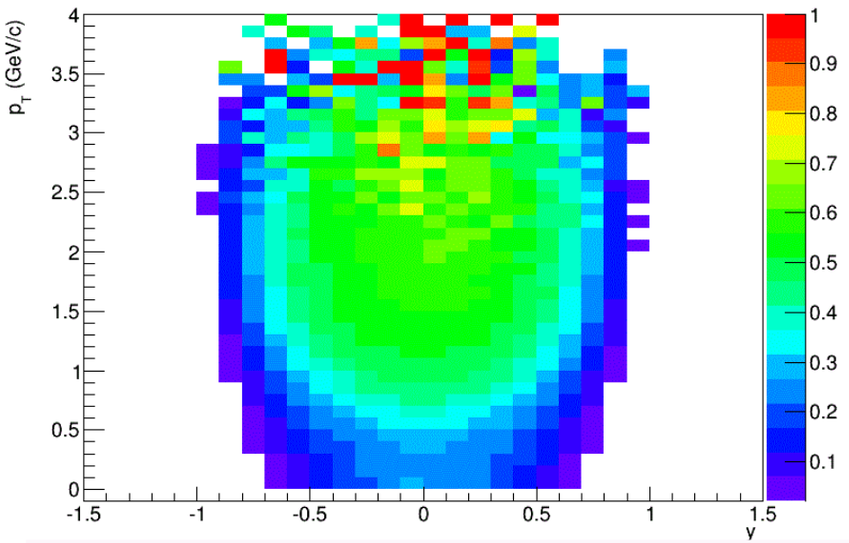
$\rho(770)^0 \rightarrow \pi^{\pm}\pi^{\pm}$

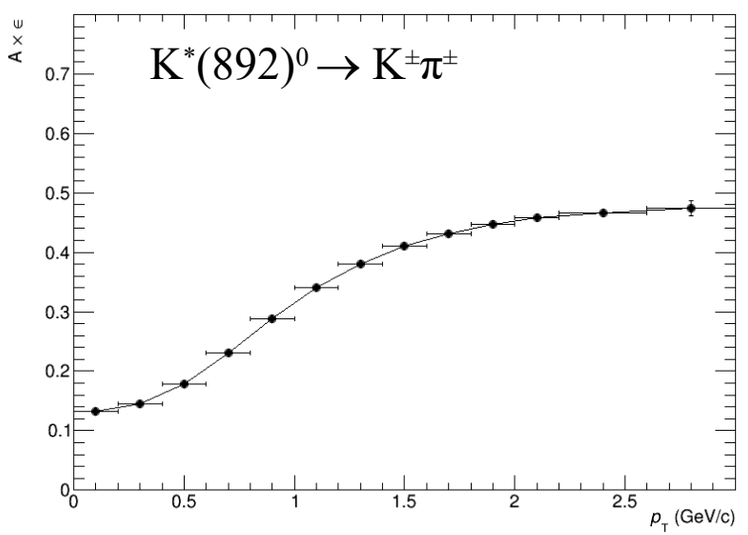


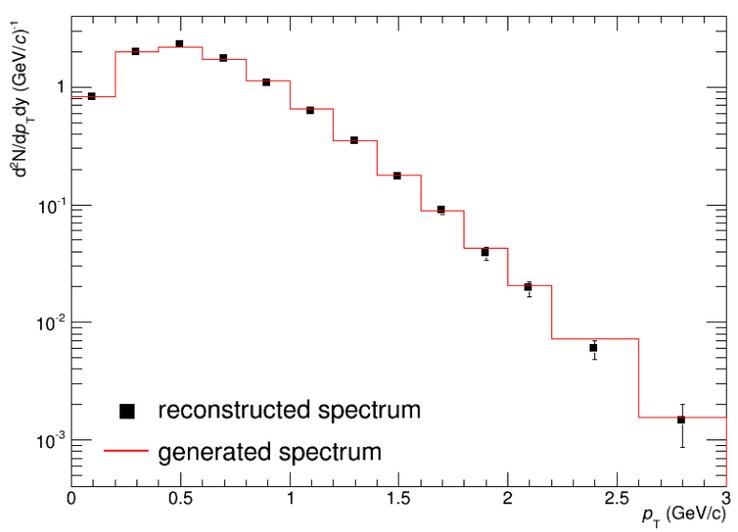
1st Session **Friday**

Efficiencies and closure tests examples

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

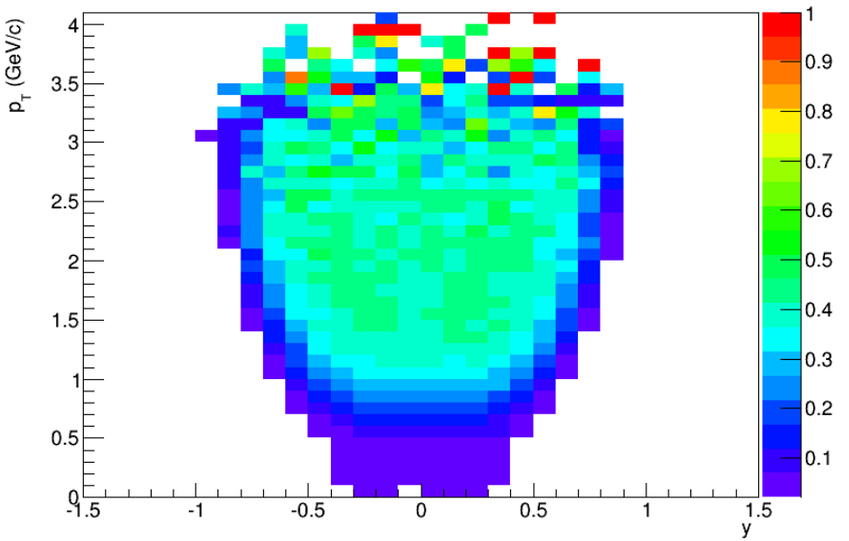


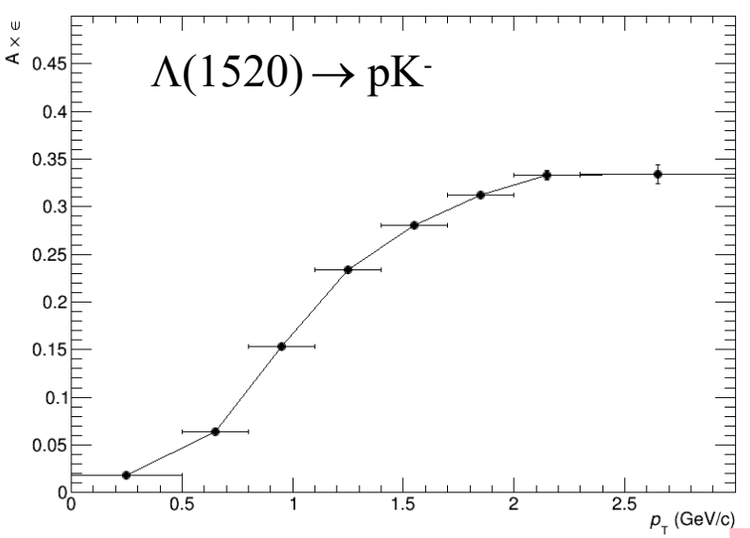


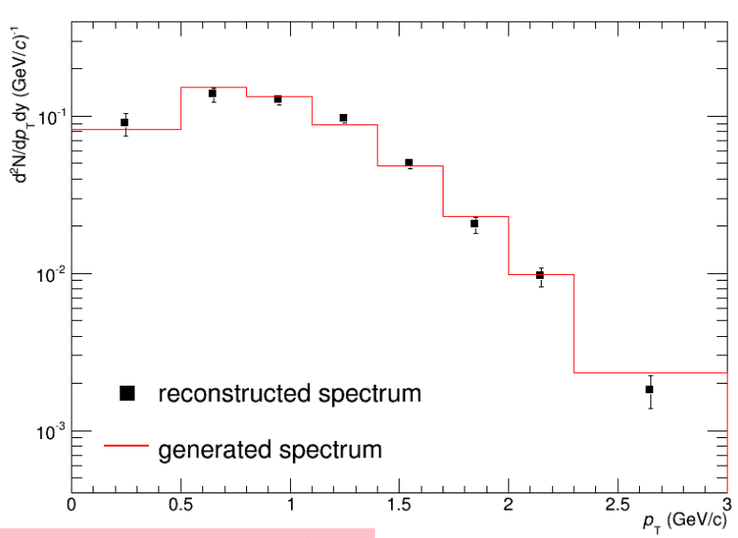


Reconstruction efficiency

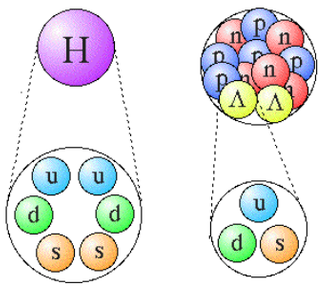
Closure Test







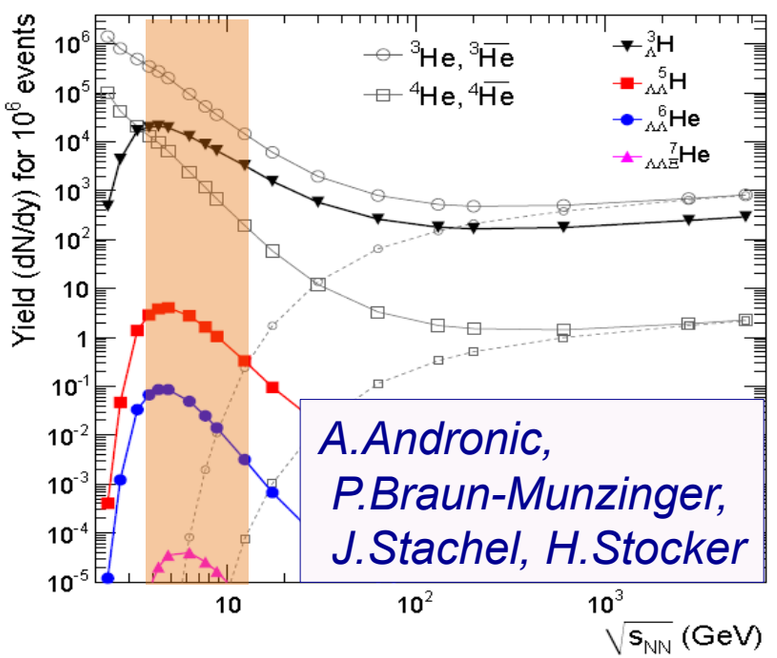
Hypernuclei at MPD

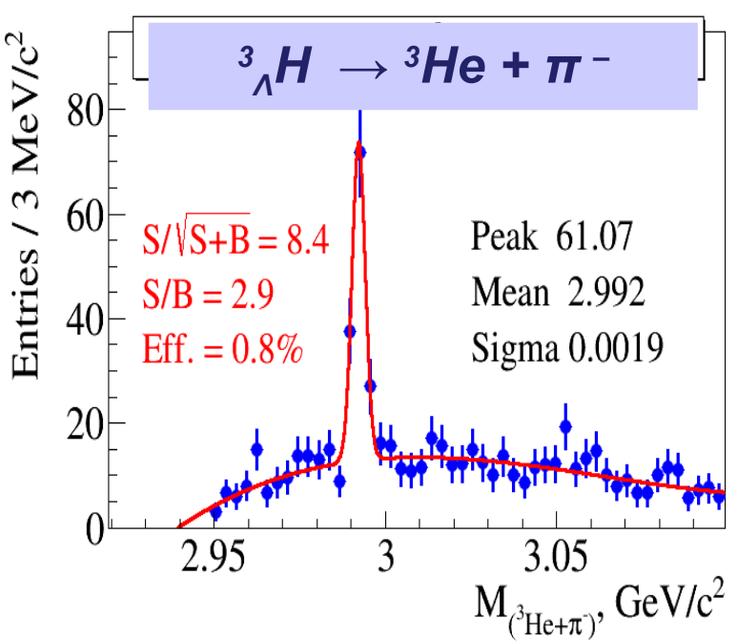


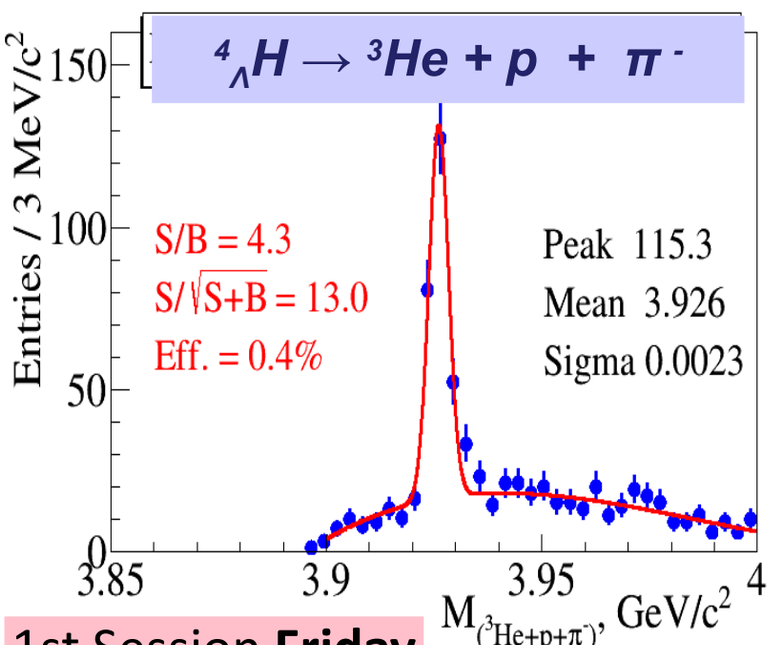
astrophysical research indicates the appearance of hyperons in the dense core of a ***neutron star***

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	$1 \cdot 10^5$



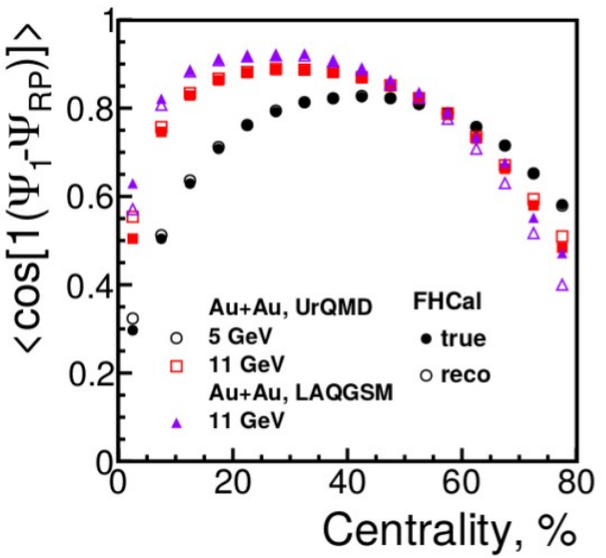


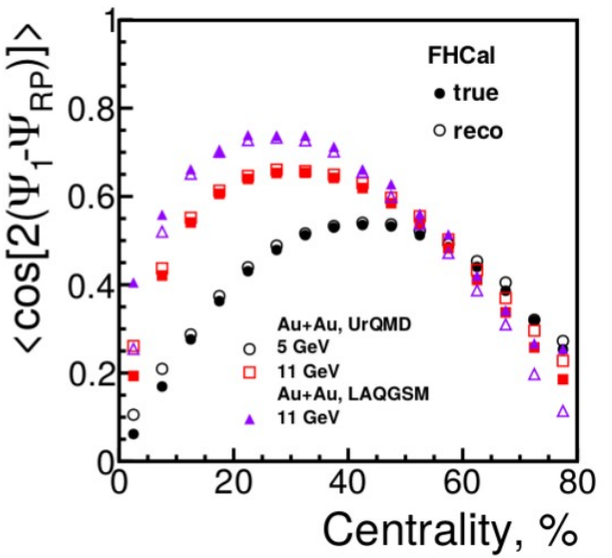


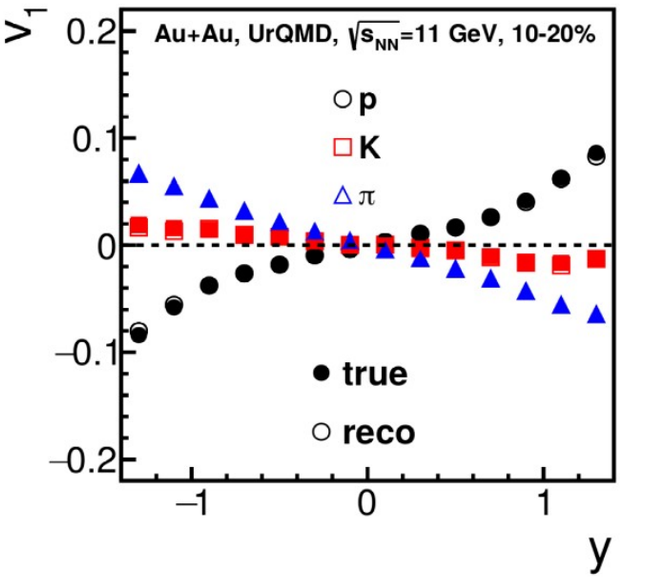
1st Session **Friday**

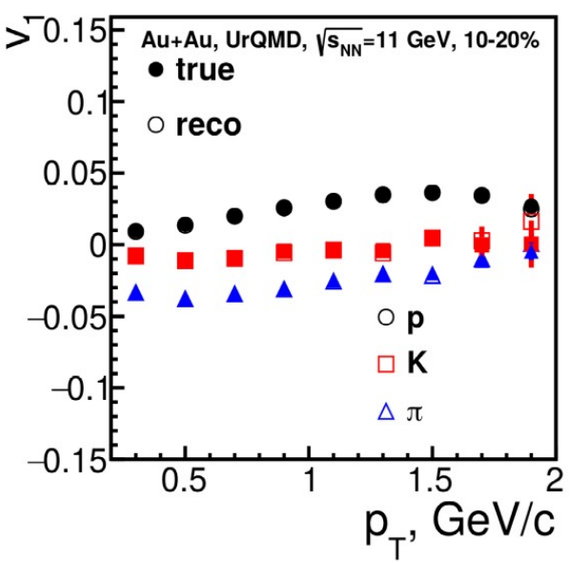
Performance of collective flow studies

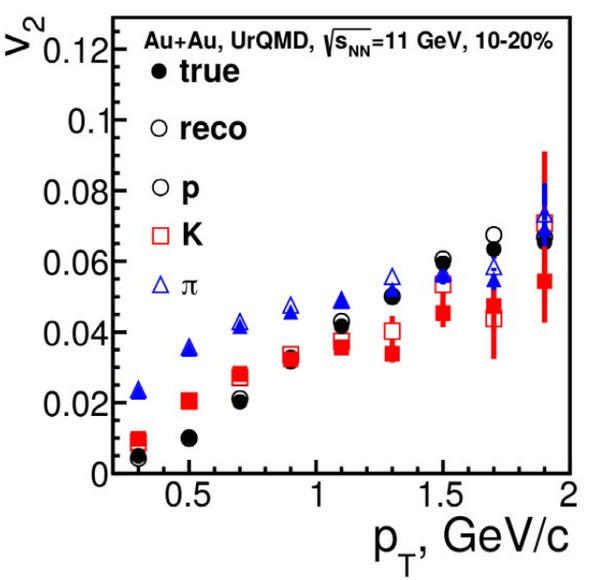
Au+Au, $\sqrt{s_{NN}}$ = 11 GeV, UrQMD, GEANT3 + MPDRoot reco.

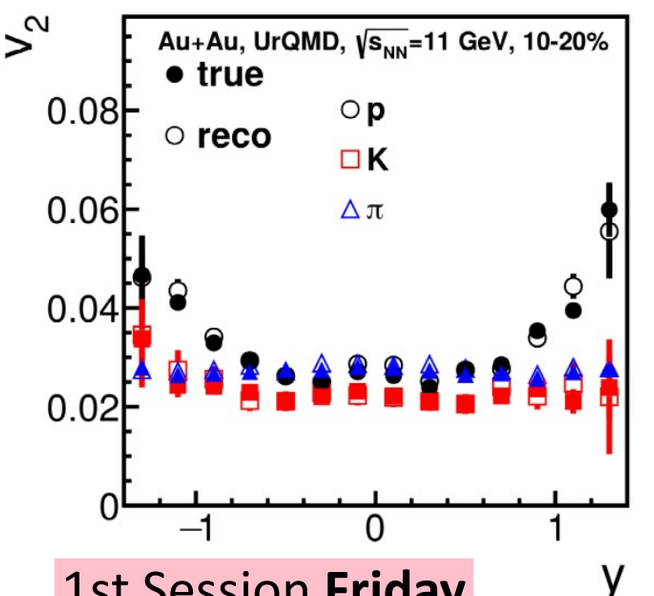












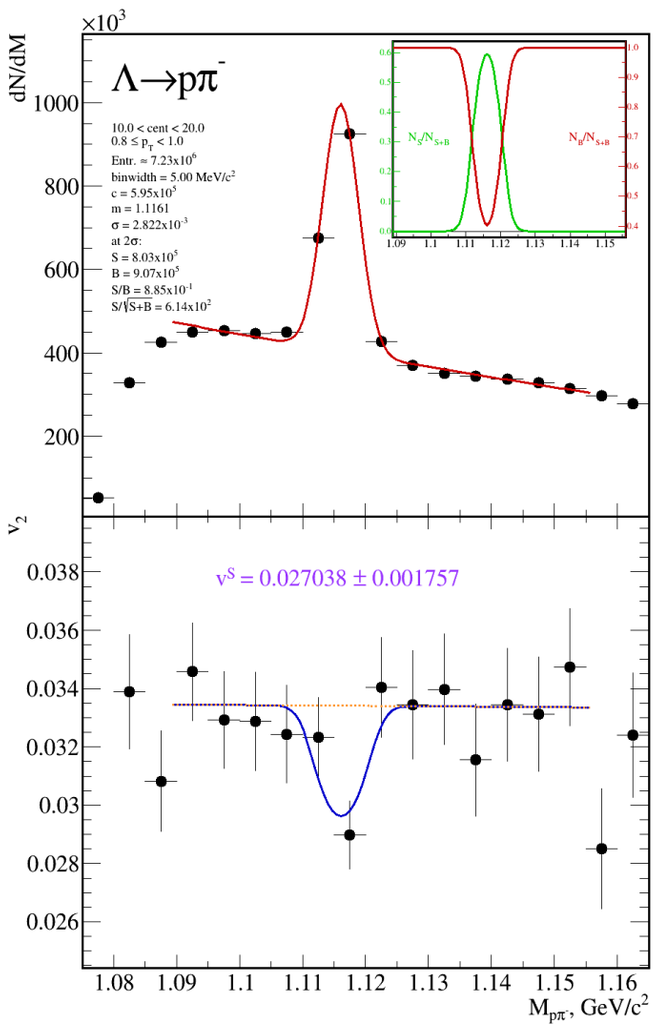
1st Session **Friday**

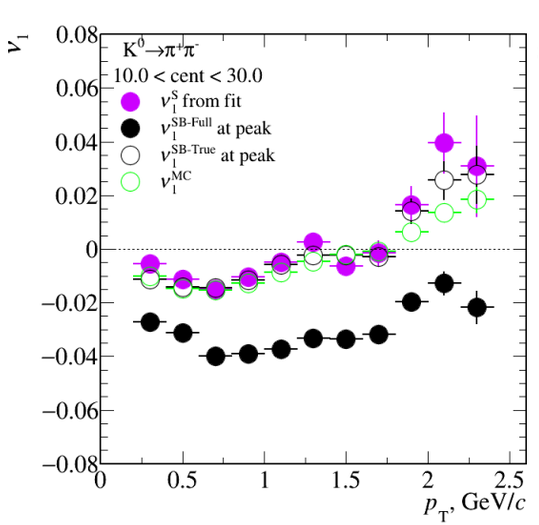
Anisotropic Flow of Reconstructed Decays

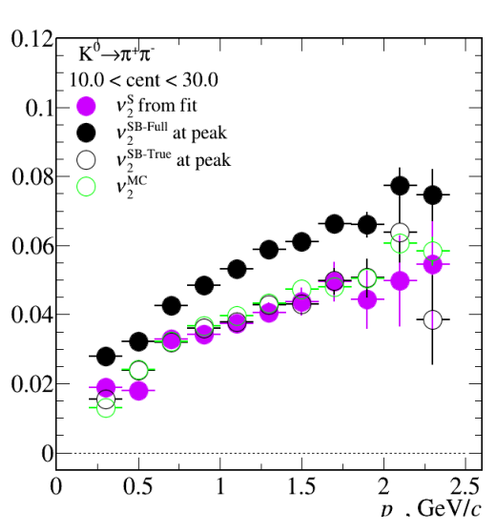
$$v_2^{SB}(m_{inv},p_T) = v_2^{S}(p_T)\frac{N^{S}(m_{inv},p_T)}{N^{SB}(m_{inv},p_T)} + v_2^{B}(m_{inv},p_T)\frac{N^{B}(m_{inv},p_T)}{N^{SB}(m_{inv},p_T)}$$

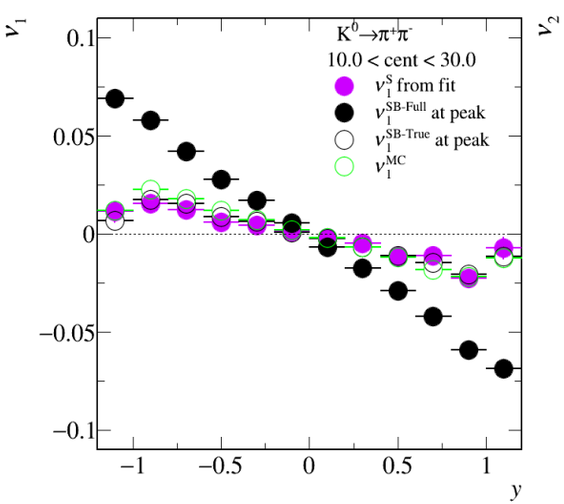
Extracted flow signal after fit
Measured flow (s+bg) at peak region
Measured flow only for True
Measured flow from MC/model

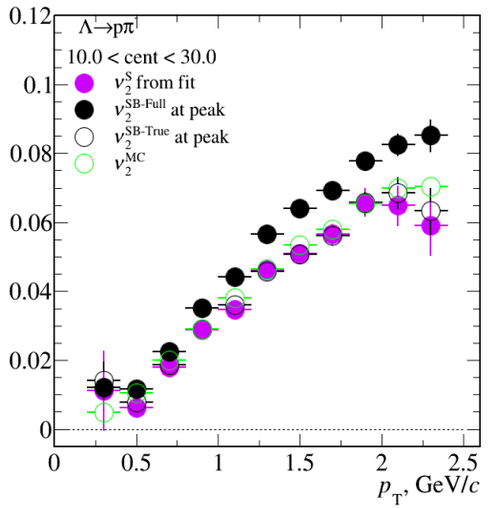
Cuts not optimised for S/B

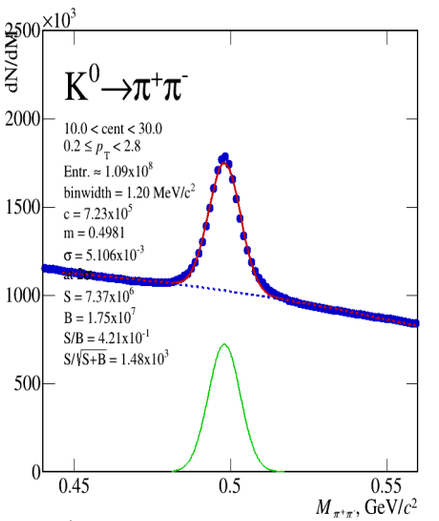


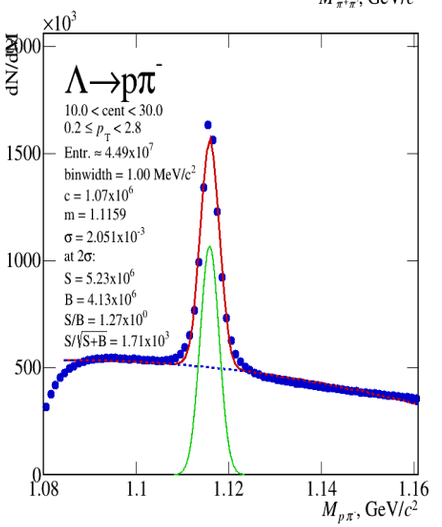










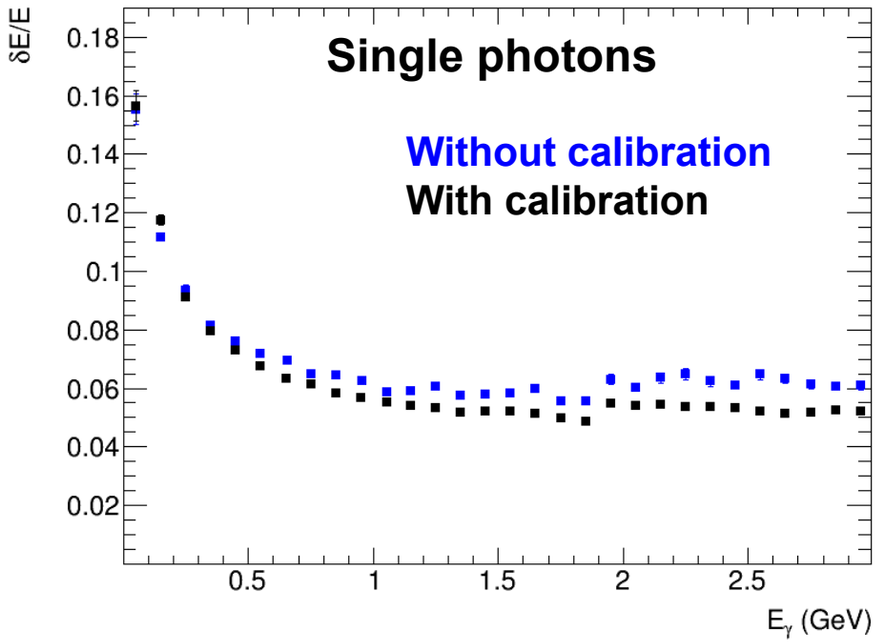


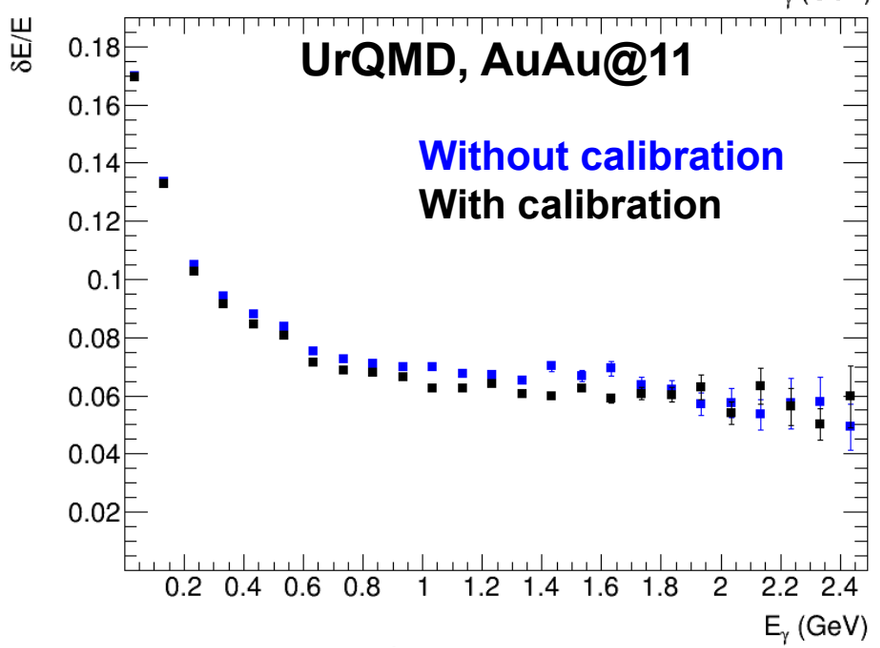
Performance of the MPD Detector for the Study of Multi-strange Baryon Production in Heavy-ion Collisions at NICA

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

Adam Kisiel, JINR/WUT

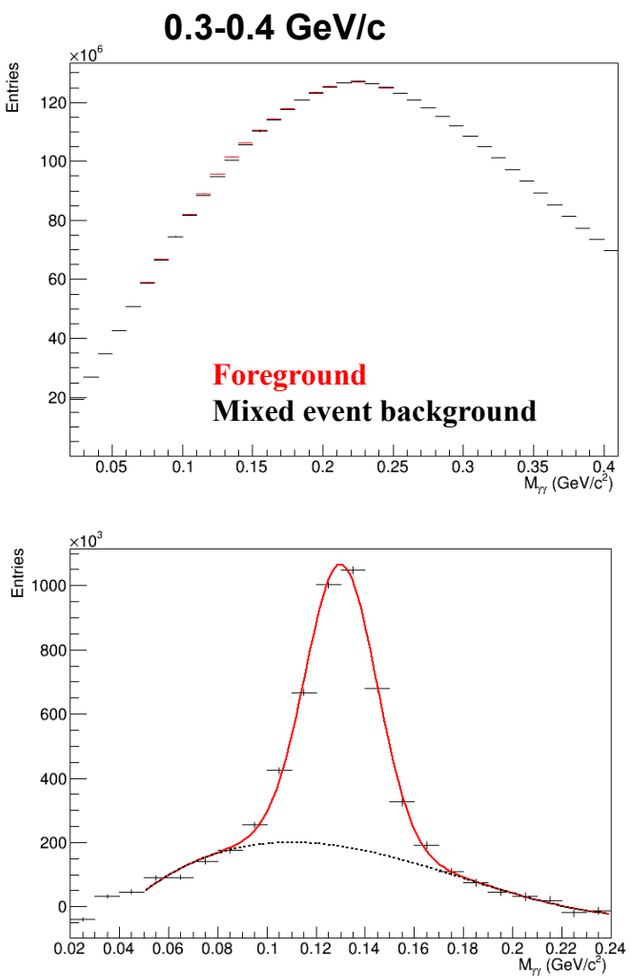
Electromagnetic Calorimeter simulation



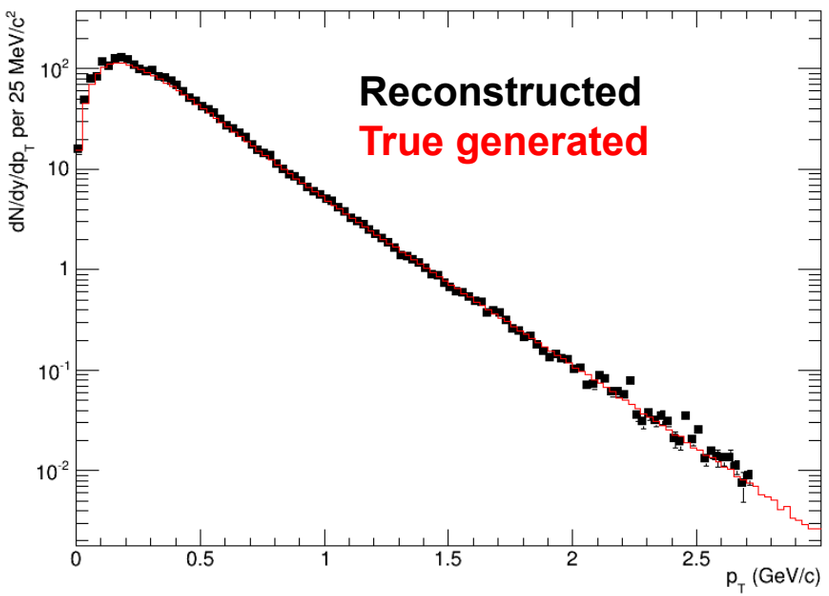


- Realistic ECAL reconstruction & analysis – large acceptance ECAL with good energy resolution: ideal tool for measurement of neutral mesons in a wide momentum range

π^0-meson in central Au+Au



Closure Test

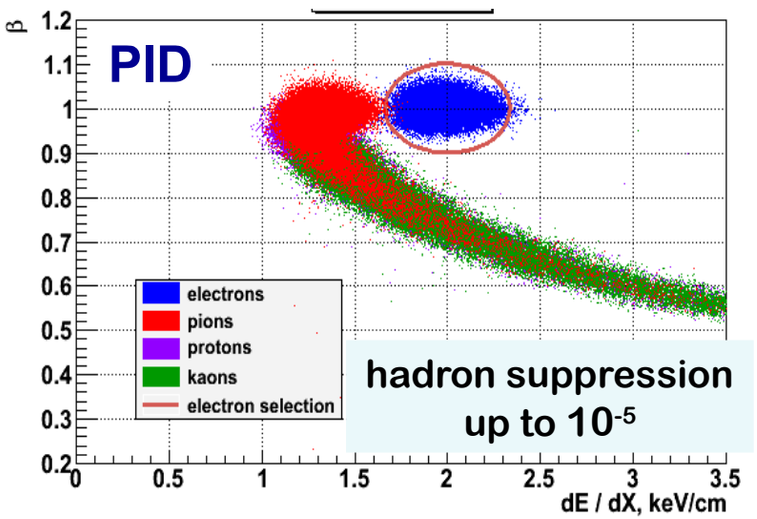


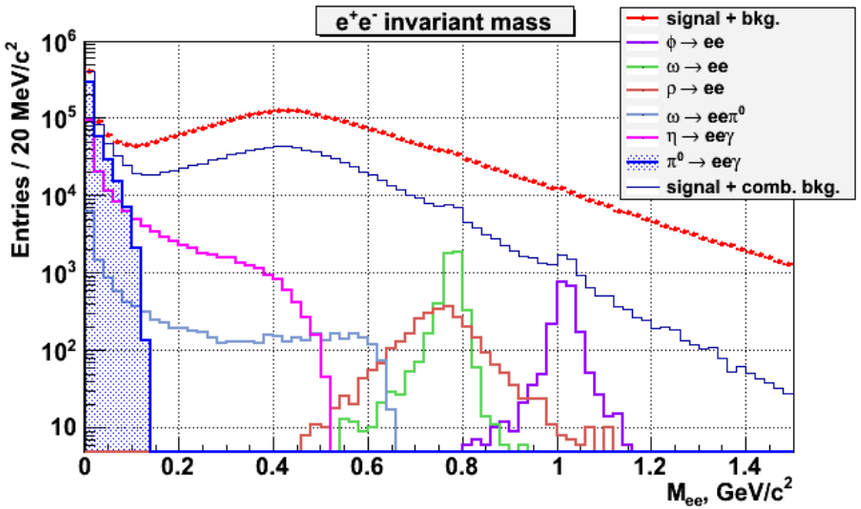
4M events UrQMD AuAu @ 11 GeV

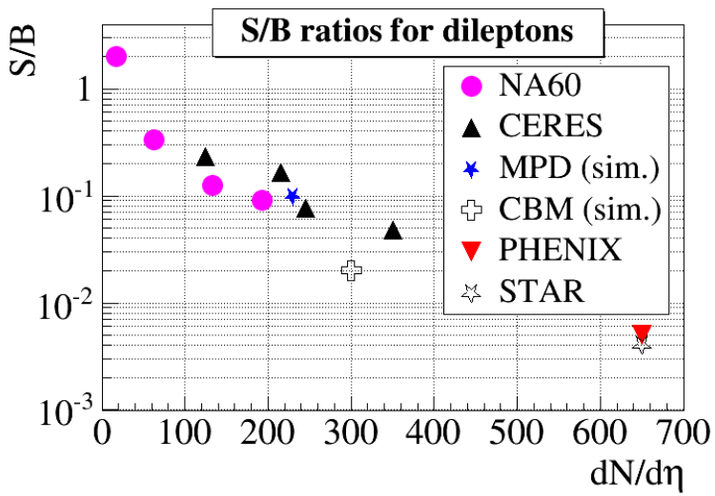
1st Session **Friday**

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*

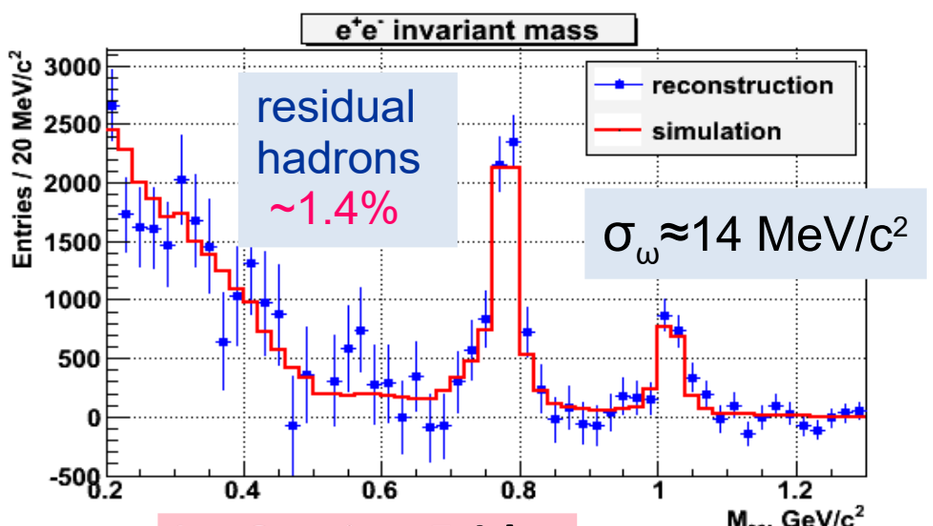






Yields, central Au+Au at $\sqrt{s_{NN}}$ = 8.8 GeV

Particle	Yields 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	$1.7 \cdot 10^{4}$



1st Session **Friday**

MPD First Physics Document preparation

- Request from the JINR management for publication of the document as a MPD Collaboration paper in a journal
  - Proposals from selected journals discussed in the Executive Council
  - Will be presented to the Collaboration for comments
- Dedicated Editing Committee working on the text (current version 41 pages long)
- Main paragraphs of the document:
  - The NICA Complex construction schedule and expected initial performance
  - Readiness of the MPD Experiment
  - Triggering and data rate
  - Computing and software requirements
  - Physics Goals
  - Plans for First-day MPD Physics

Main points of the text

- In discussion with the NICA Accelerator division the following initial beam parameters were proposed:
  - Bizmuth beams (^{209}Bi+^{209}Bi collisions) – stability of the heavy-ion source, efficiency of the beam accelerator complex
  - Initial beam energy: $\sqrt{s}$=9 GeV – maximum reasonably safe energy without the need for acceleration/deceleration in NICA
  - Initial luminosity – at least 10^{24} cm^{-2}s^{-1} with reasonably fast ramp-up to at least 10^{25} cm^{-2}s^{-1}.
- Beam parameters need to be approved by the Machine Advisory Committee
- Complete input from all major subsystems of MPD, and subsystems in approval, included descriptions of MPD Magnet, Electronics Support Infrastructure, TPC, TOF, ECAL, FHCal, FFD, MCORD, MiniBeBe

Session **Thursday**, all Sessions **Friday**

Main points of the text (cont.)

- Description of common systems: Slow Control System an Data Acquisition
- Description of triggering system and expected data rate
- MPD Software and computing readiness, including data reconstruction and calibration
- Main physics goals of the MPD experiment
- Specific plans for first-day physics and its discovery potential
- Key first-day observables: Centrality determination, particle yields and their ratios, mean hadron transverse energy, identified yields and ratios, hyperon and resonance reconstruction, directed and elliptic flow, electromagnetic signals, two-particle interferometry

Summary

- Entering routine operation of main MPD structures
- Collaboration formation is finished, focus now on formal agreements and organic growth
- Definition of formal deadlines for MPD project milestones
- All components of the MPD 1st stage detector advanced in production, commissioning expected for 2021
- Performance studies for full physics program under way