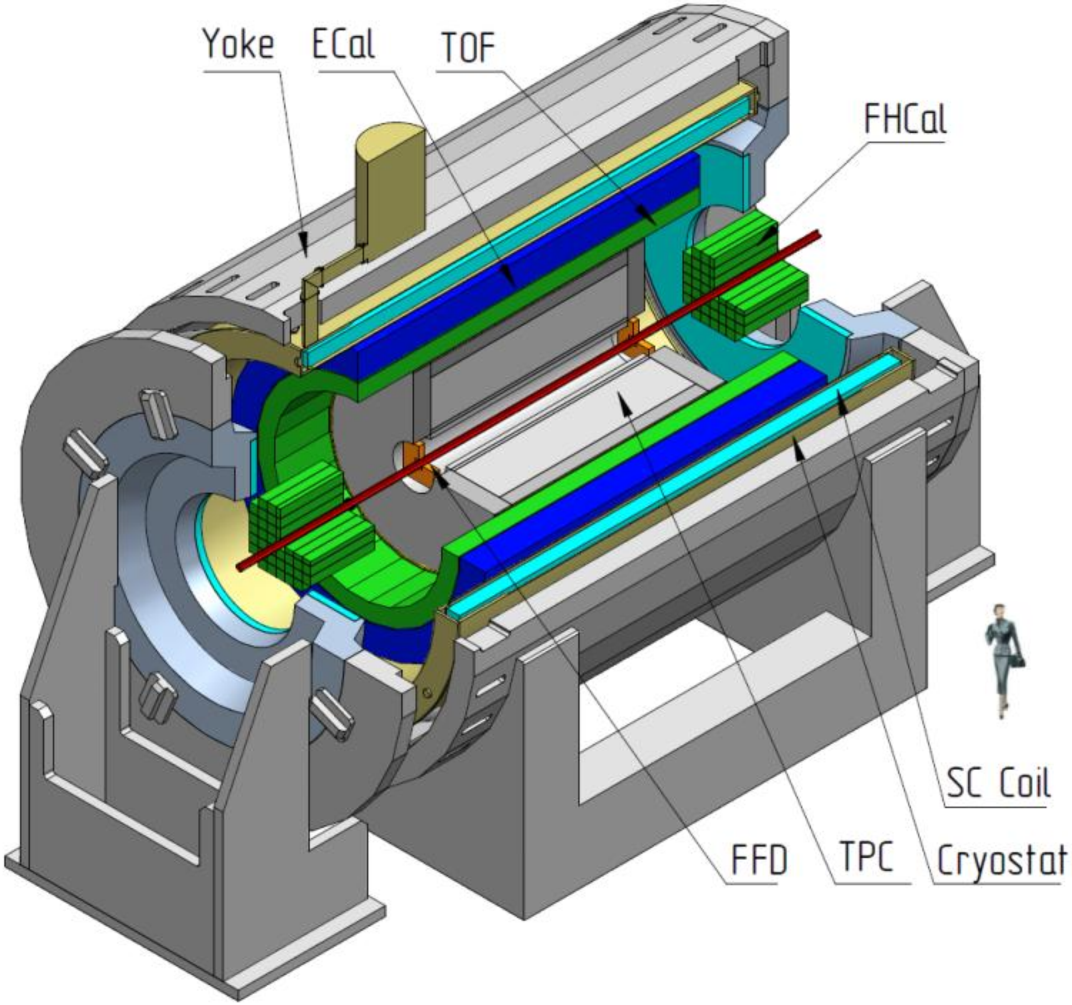
Nuclotron based Ion Colider fAcility

Участие ОФВЭ в эксперименте MPD-NICA

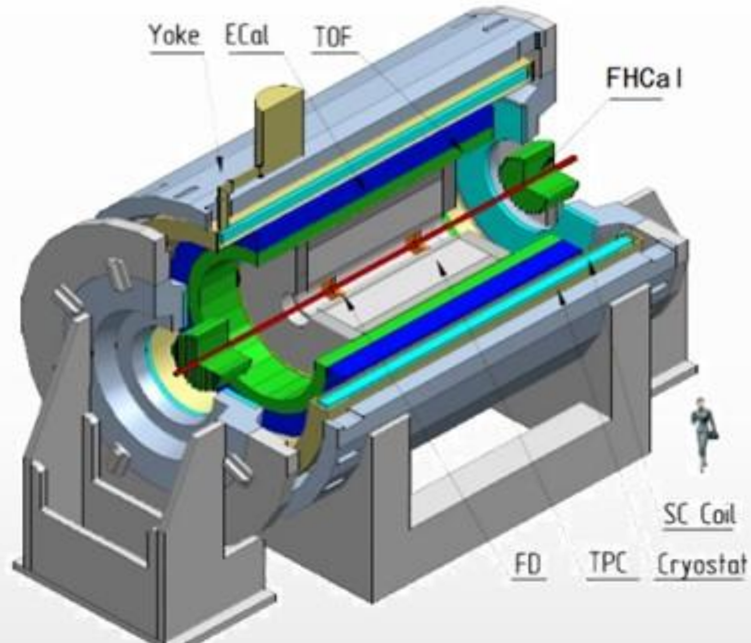
Михаил Малаев (ЛРЯФ)



Multi-**P**urpose **D**etector (MPD) Collaboration

MPD *International Collaboration was established in* ***2018***
to construct, commission and operate the detector

12 *Countries,* ***>500*** *participants,* ***38*** *Institutions and* ***JINR***



Organization

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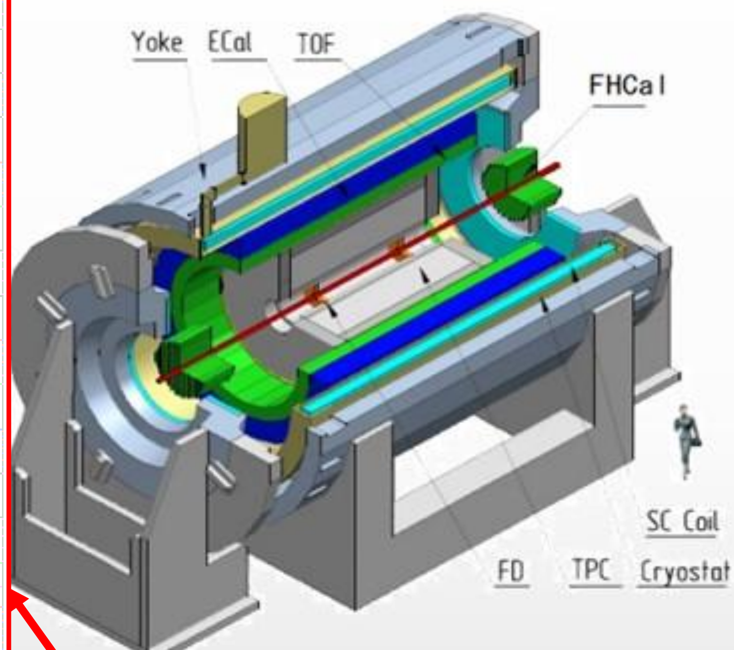
*ollaboration was established in **2018***
mission and operate the detector



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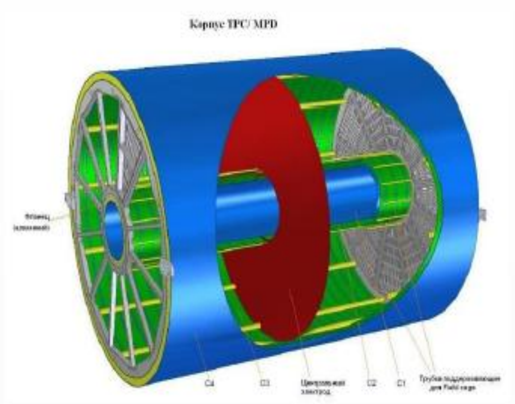
*Institute of Physics and Technology, **Mongolia**;*

TPC gas system

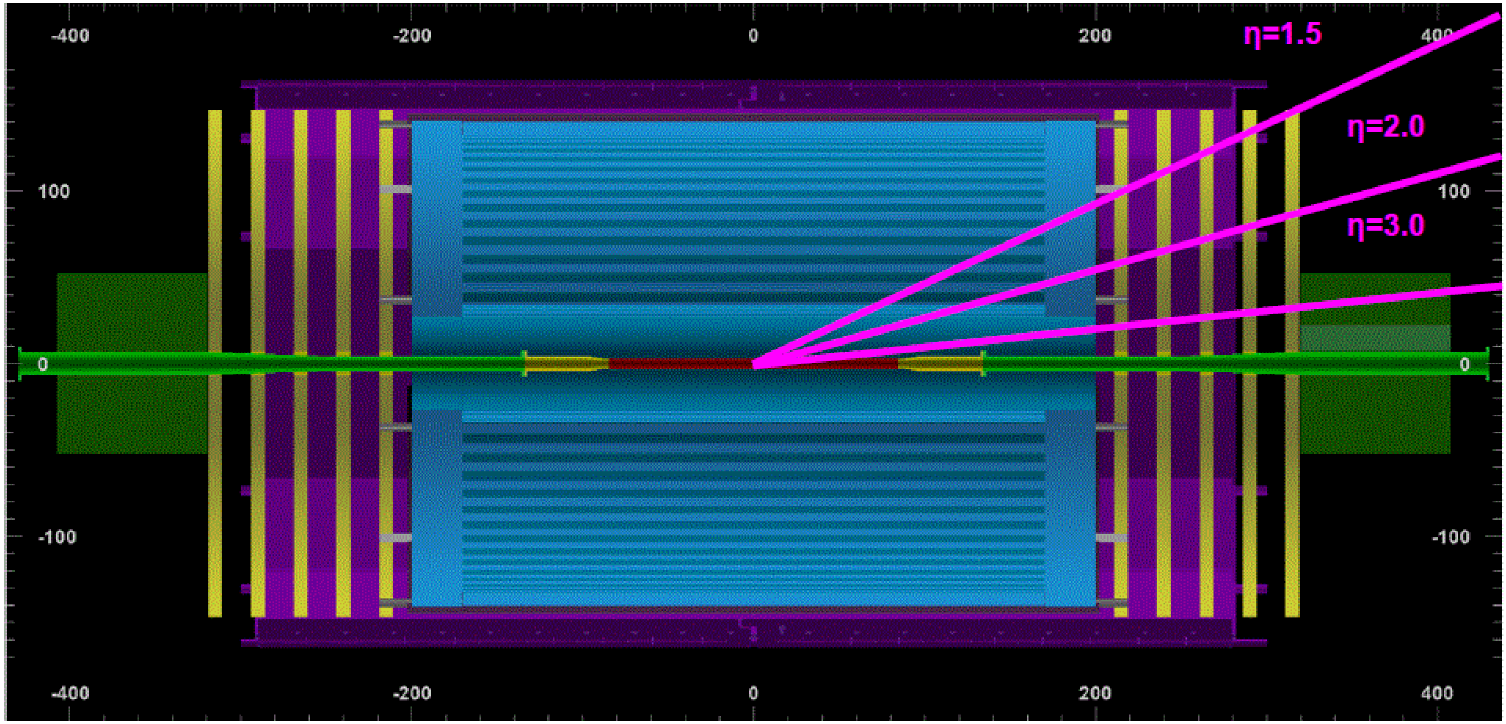


length	*340 см*
outer Radii	*140 см*
inner Radii	*27 см*
gas	*90%Ar+10%CH_4*
drift velocity	*5.45 см / μs;*
drift time	*< 30 μs;*
# R-O chamb.	*12 + 12*
# pads/ chan.	***95 232***
max rate	*< 7kGz (L= 10^{27})*

TPC MPD gas system was designed in 2014 and assembled at PNPI in 2016. It provides (Ar + 10% Methane) gas mixture to the TPC detector at the correct differential pressure (2mbar). The system operates nominally as a closed circuit gas system with the majority of gas recirculation through the detector. The TPC MPD gas system is the first system designed in our laboratory with two recirculation circuits. The inner circuit provides fast gas mixture exchange in the detector at large flowrate. The outer one provides quality control of the mixture, fresh gas supply, pressure stabilization etc. The slow control for the gas system is based on single DAQ32 module.

https://lkst.pnpi.nw.ru/projects/nica/tpc/

Forward upgrade for MPD (FWD)



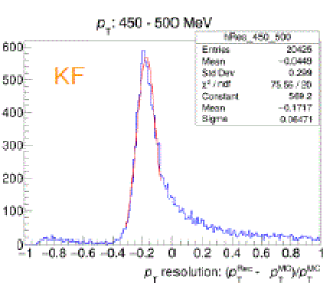
Basic FTD geometry and hit producer:

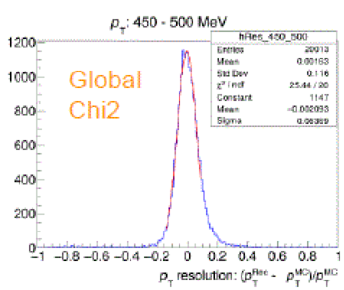
- 5 tracking layers placed between 210 and 300 cm
- Thickness per layer: 0.2% X_0
- Gaussian smearing in x and y with σ = 100 μm

Momentum resolution with ACTS

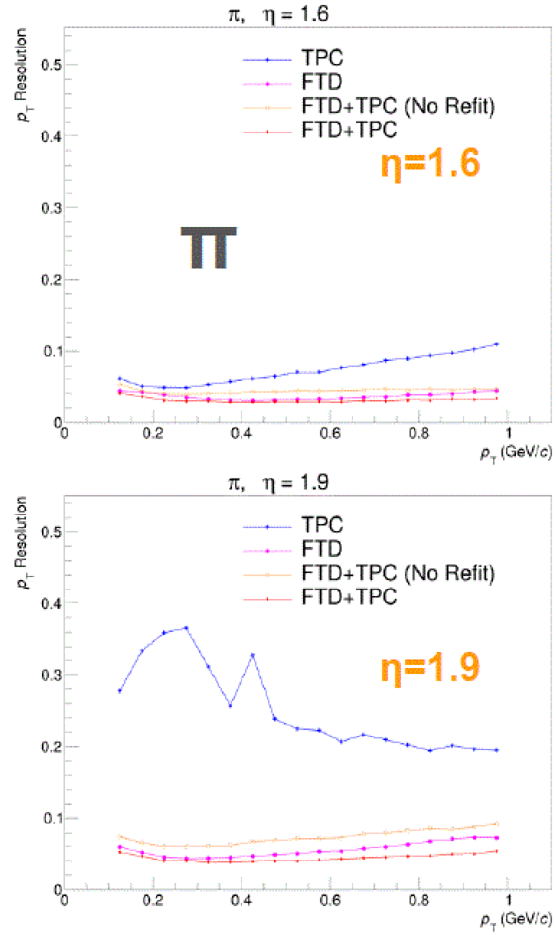
- TPC tracking resolution is reasonable up to η~1.5
- FTD helps to extend track reconstruction up to η~2.0
- Best results with combined TPC+FTD tracking

Resolution from TPC-only fit for pions at eta = 1.6

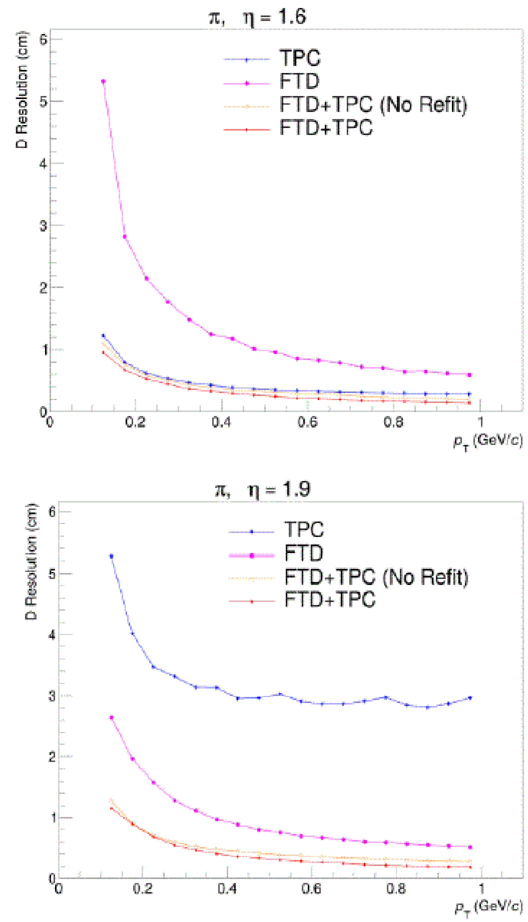




Momentum resolution



DCA resolution



Straw-tube wheel geometry

Straws:
- Ultrasonic welding technology
- Straw diameter: 5 mm
- Wall thickness (mylar): 20 um
- Al metallization 70 nm
- Tungsten wire: d = 20 um
- Ar/CO_2 gas mixture
- Internal overpressure of 1 bar

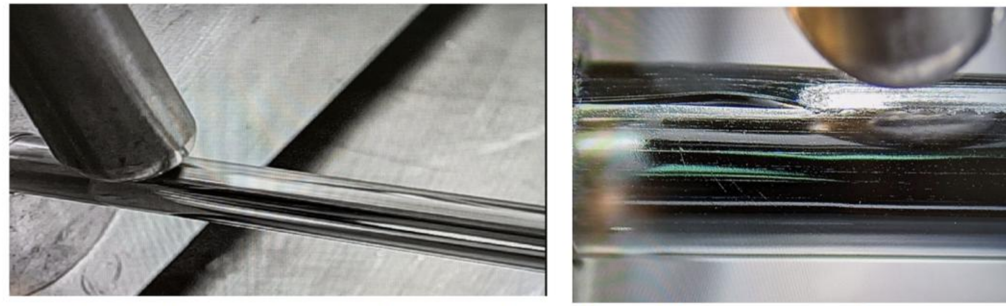
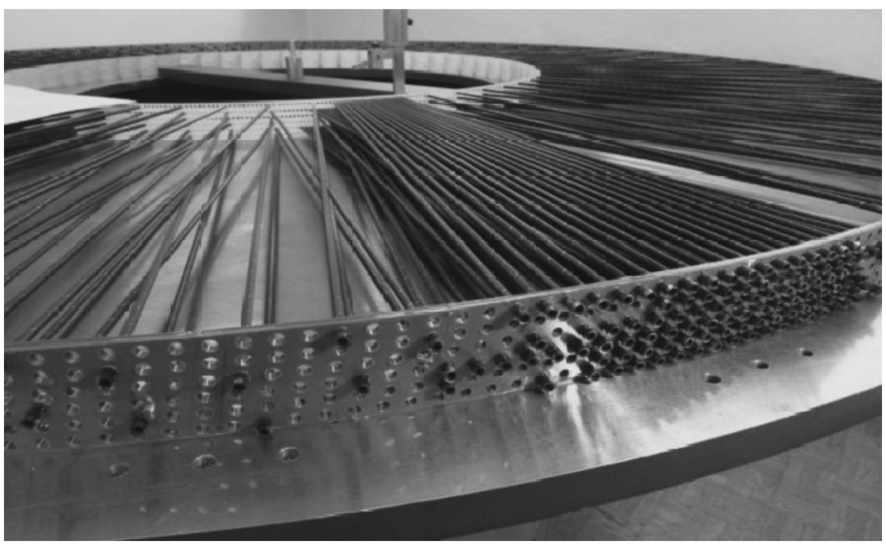


Figure 2: An ultrasonic head and a straw during the welding process (left) and a zoomed view of the seam during the welding(right).

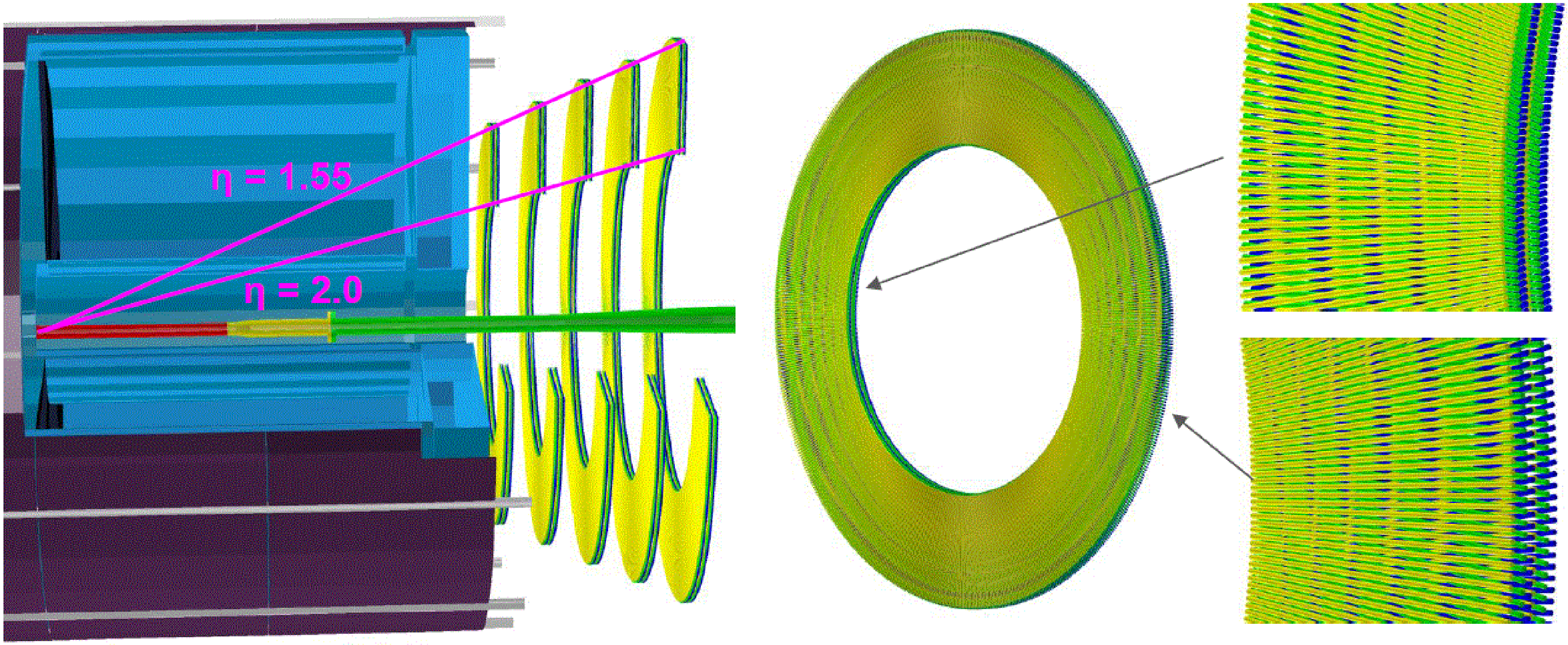
T. Enik et al, PoS(TIPP2023) 125

6 layers per station with RUV stereo angles: 0, +7°, –7°, 0, +7°, –7°



Phys.Part.Nucl.Lett. 9 (2012) 163
Phys.Part.Nucl.Lett. 12 (2015) 113

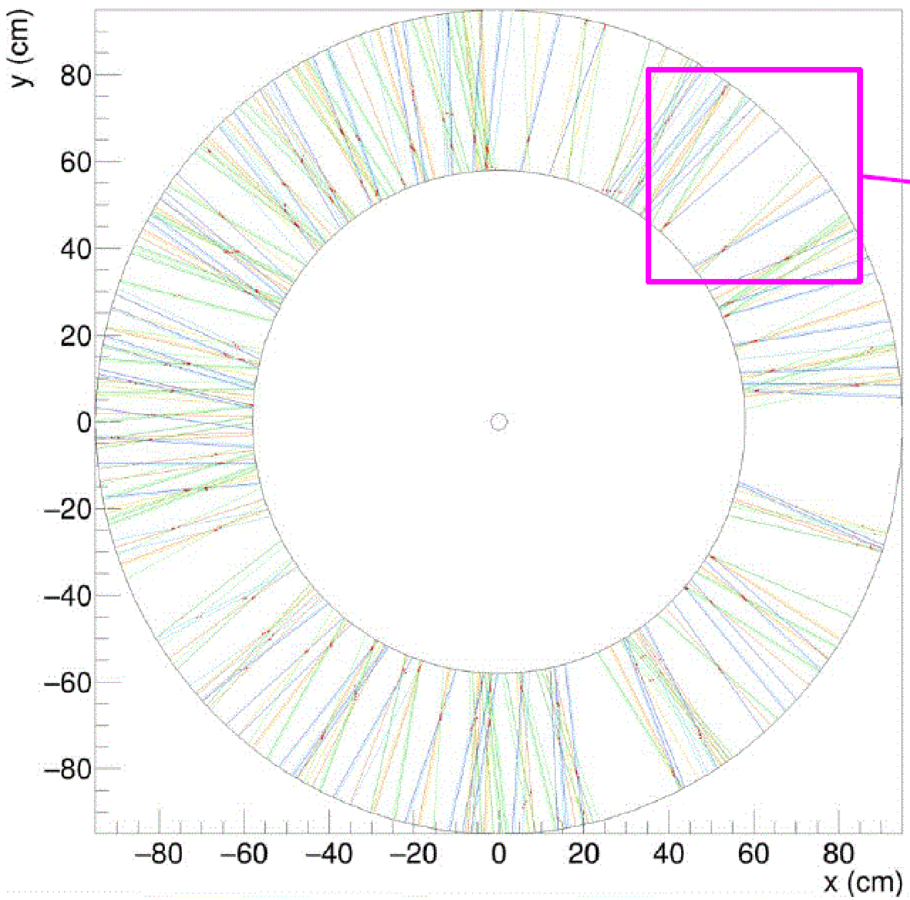
Implementation in MpdROOT

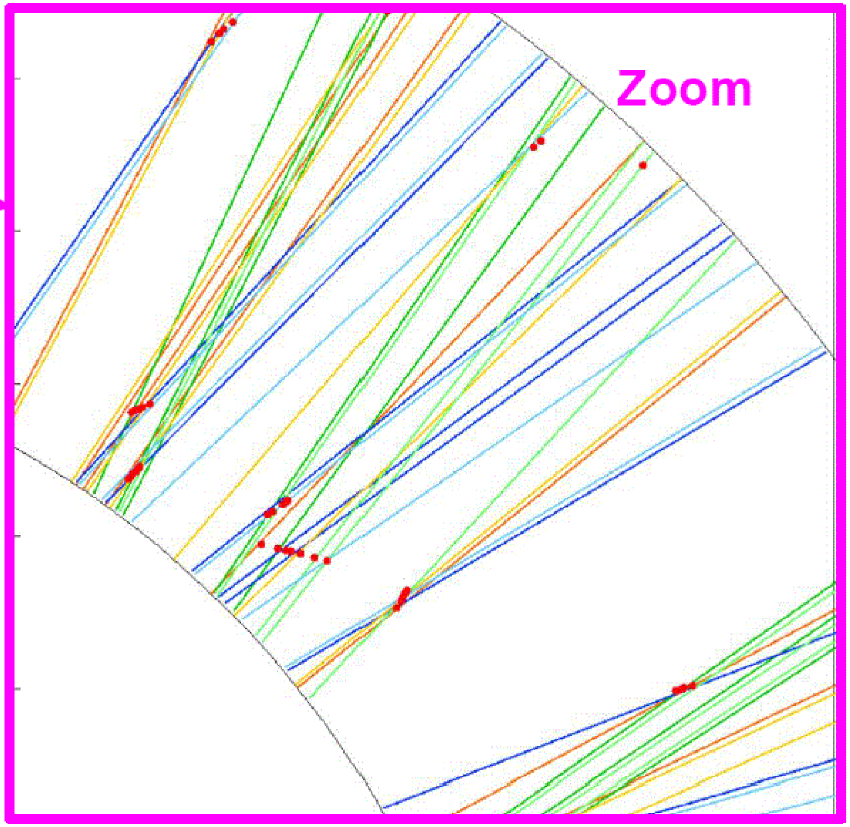


- R_{min} from 58 to 82 cm, R_{max} from 95 to 134 cm. ΔR from 37 to 52 cm
- 6 layers per station with RUV stereo angles: 0, +7°, –7°, 0, +7°, –7°
- Distance between straw centers: 6 mm ar R_{min} → ~9.8 mm distance ar R_{max}
- Number of straws per layer from 606 to 860 → Total for 2 sides: ~43968 channels

- Radiation length ~ 0.1 - 0.15% per station
- Better than initial estimates assuming 0.2% per station

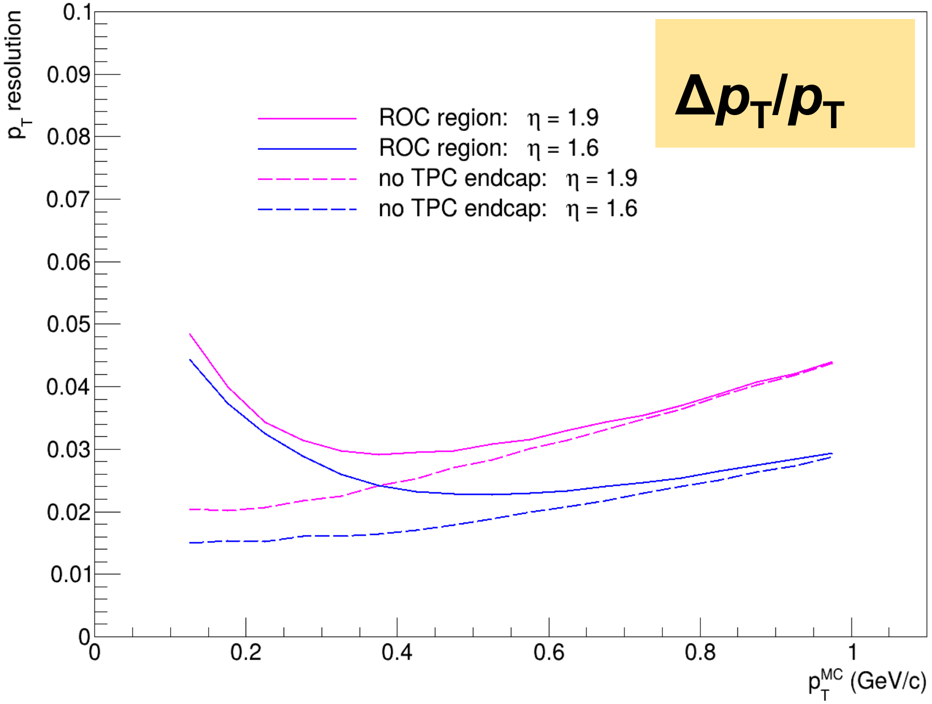
Straw-tube wheel geometry

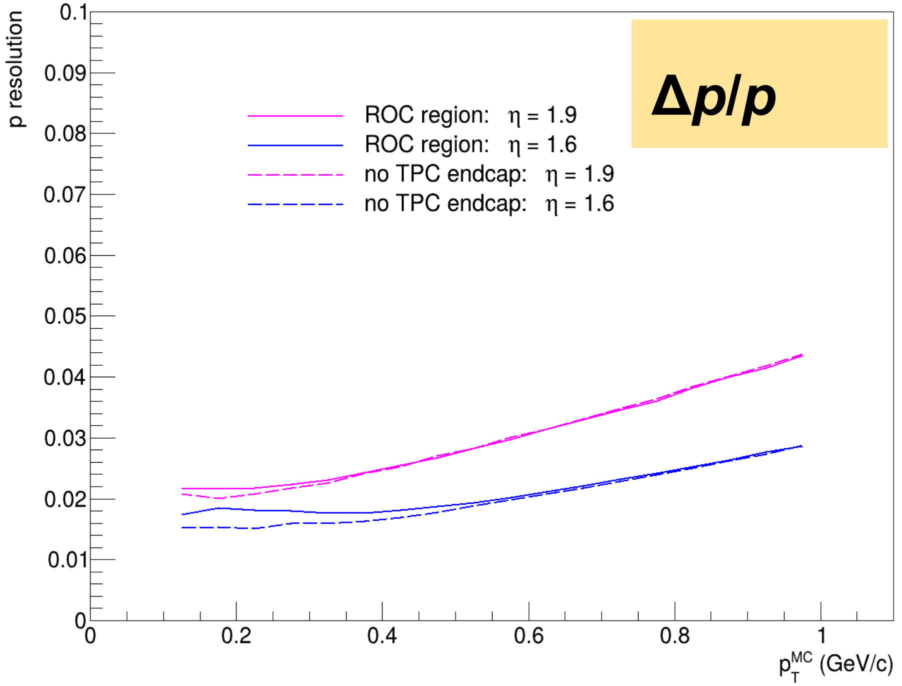




- Implemented simplified straw-tube hit producer (no left/right ambiguity yet)
- Uniform occupancy up to ~8% → looks reasonable
- Relatively small fraction of fake intersections (ghosts)

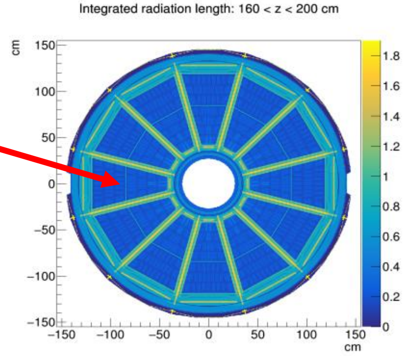
Momentum resolution with ACTS





- Single-pion events
- Reasonable transverse momentum resolution < 5%
- Multiple scattering in TPC endcap mostly affects low p_T
- Full momentum resolution is less affected

ROC region



Summary (FWD)

- Implemented TPC and TPC+FTD tracking with ACTS
- Considering straw-tube wheels as a baseline detector technology:
  - ✓ Uniform occupancy up to 8% in central events
  - ✓ Track resolution looks reasonable (<5% at $p_T \sim 1$GeV/c)
- Evaluating other detector options

MPD physics program

G. Feofilov, P. Parfenov

Global observables

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

V. Kireev, 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

D. Peresunko, 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

2^{nd} collaboration paper

- MPD physics performance studies in Bi+Bi collisions at $\sqrt{s_{NN}}$ = 9.2 GeV

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MPD physics performance studies in Bi+Bi collisions at $\sqrt{s_{NN}} = 9.2$ GeV

R. Abdulin[20], V. Abgaryan[1], R. Adhikary[16], K.G. Afanaciev[16,13], S.V. Afanaciev[16], G. Agakishiev[16], E.I. Alexandrov[16],
I.N. Alexandrov[16], M. Alvarado-Hernández[14], D.I. Andreev[16], S.V. Andreeva[16], T.V. Andreeva[16], E.V. Andronov[28],
N.V. Anfimov[16], A. Anikeev[21], A.V. Anufriev[28], A.A. Aparin[16], R. Arteche-Diaz[16], V.I. Astakhov[16], T. Aushev[23],
S.P. Avdeev[16], G.S. Averichev[16], A.V. Averyanov[16],A. Ayala[14], V.N. Azorskiy[16], L. Bavichev[32], V.A. Babkin[16],
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N. Barbashina[21], V. Barbasová[23], V.M. Baryshnikov[16], K.D. Basharina[16], A.E. Baskakov[16], V.G. Bayev[13],
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Y. Berdnikov[24], F. Berezov[22], M. Bhattacharjee[16], W. Bietenholz[14], D. Blau[19], G.A Bogdanova[31], D.N. Bogoslovsky[16],
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G.V. Mescheriakov[16], N.A. Molokanova[16], S. Morozov[10], A.A. Moshkin[16], S.A. Movchan[16], A.N. Moybenko[16],
K.A. Mukhin[16], Yu.A. Murin[16], S. Musin[10], G.G. Musulmanbekov[16], V.V. Mytsin[16], E.E. Muravkin[16], L. Nadderd[37],
R.V. Nagdasev[16], Yu. Naryshkin[20], A.V. Nechaevskiy[16], V.A. Nikitin[16], V.A. Novoselov[16], I.A. Olexs[16], A.G. Olshevski[16],
O.E. Orlov[16], V. Papoyan[1], P.E. Parfenov[16,21], S.S. Pargicky[16], M.E. Patiño-Salazar[14], S.V. Patronova[16],
V.A. Pavlyukevich[16], I.S. Pelevanyuk[16], V.A. Penkin[16], D. Peresunko[19], D.V. Peshekhonov[16], V.A. Petrov[16], V.V. Petrov[28],
A.V. Piliar[16], A. Piloyan[1], S.M. Piyadin[16], M.N. Platonova[31], D.V. Podgainy[16], M. Pokidova[20], V.N. Popov[28],
D.S. Potapov[16], D.S. Prokhorova[28], N.A. Prokofiev[28], D.I. Priakhina[16], I. Pshenichnov[10], A.M. Puchkov[28], N. Pukhaeva[22,16]
A. Pyatigor[2], J. Qin[35], F. Ratnikov[8], A. Raya[15], V. Rekovic[37], M. Reyes-Gutiérrez[15], S. Reyes-Peña[16], A. Riabov[20],
V. Riabov[20], Yu. Riabov[20], S.P. Rode[16], A. Rodríguez-Alvarez[16], O.V. Rogachevsky[16], V.Yu. Rogov[16], V.A. Rudnev[28],
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V.A. Samsonov[16], A.A. Savenkov[16], S. Savenkov[10], S.A. Sedykh[16], T.V. Semchukova[16], A.Yu. Semenov[16],
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Y. Shen[29], A.D. Sheremetiev[16], A.I. Sheremetieva[16], S. Shi[17], M.O. Shitenkov[16], E.E. Shmanay[27], S.V. Shmatov[16],
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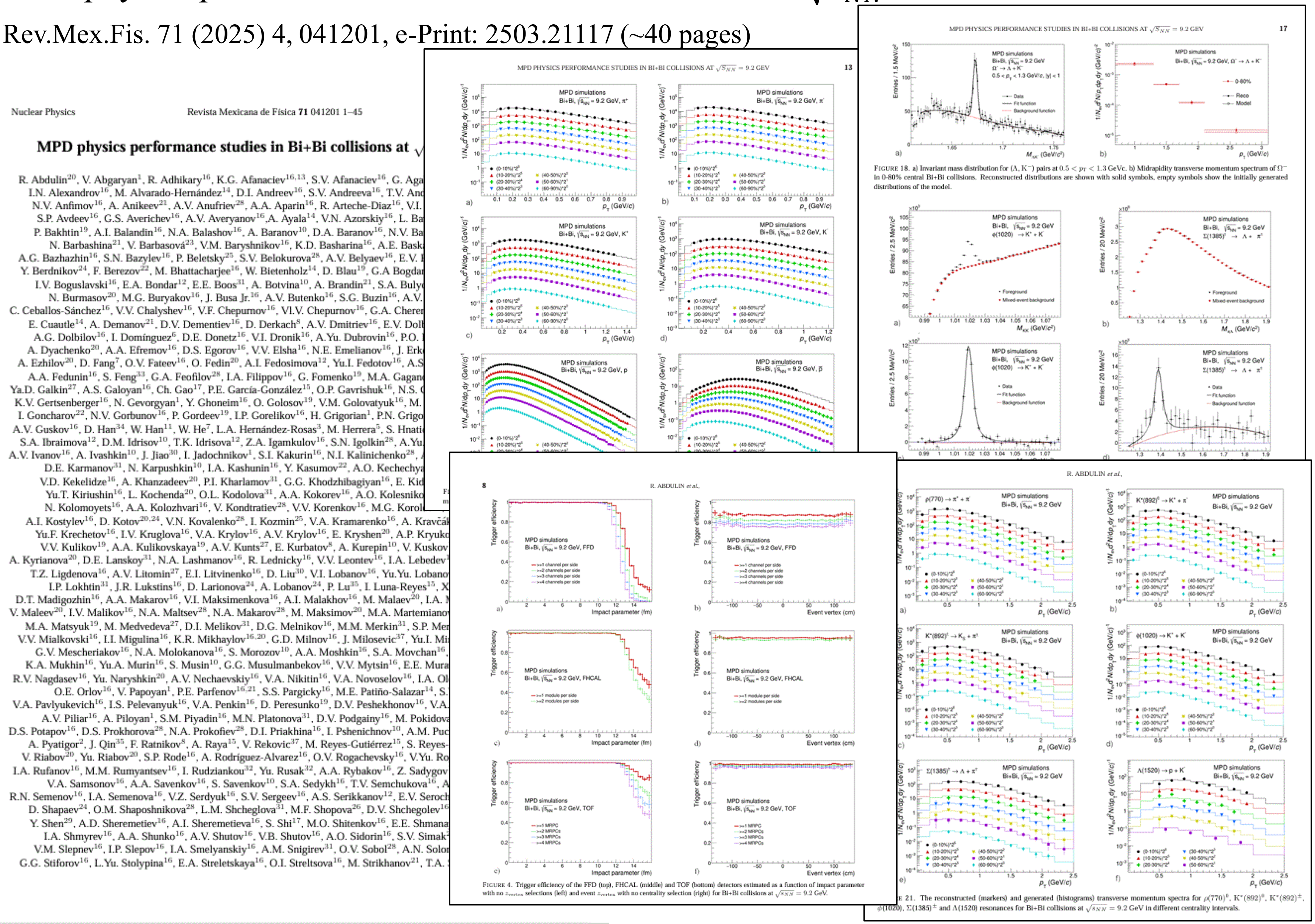
2nd collaboration paper

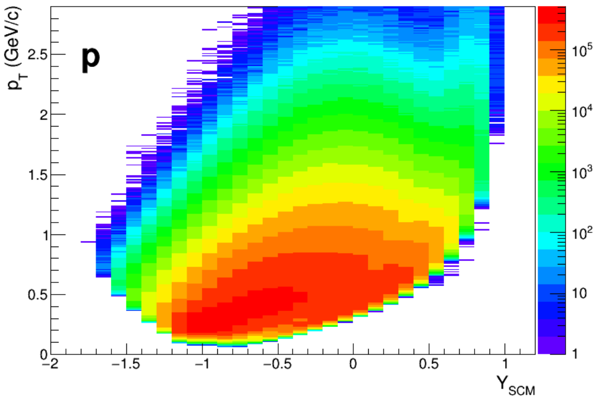
- MPD physics performance studies in Bi+Bi collisions at $\sqrt{s_{NN}}$ = 9.2 GeV

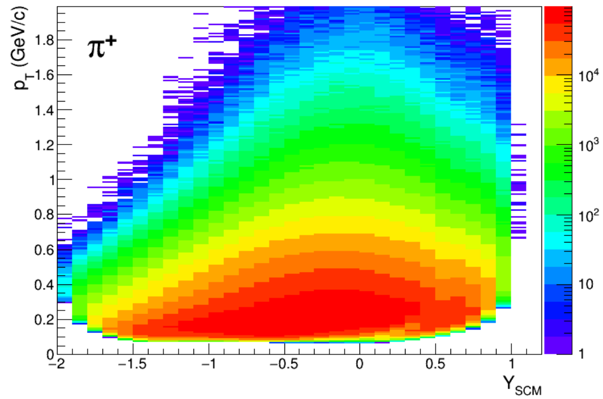
Rev.Mex.Fis. 71 (2025) 4, 041201, e-Print: 2503.21117 (~40 pages)

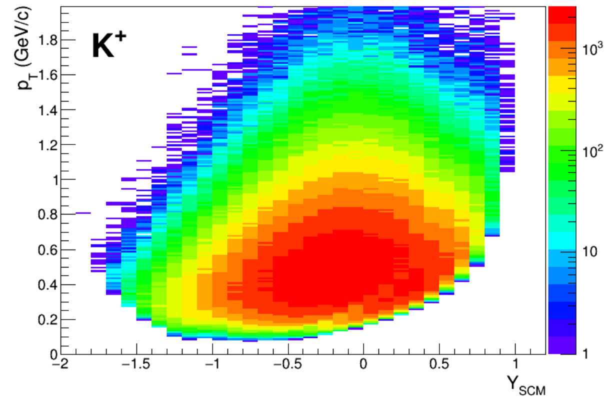


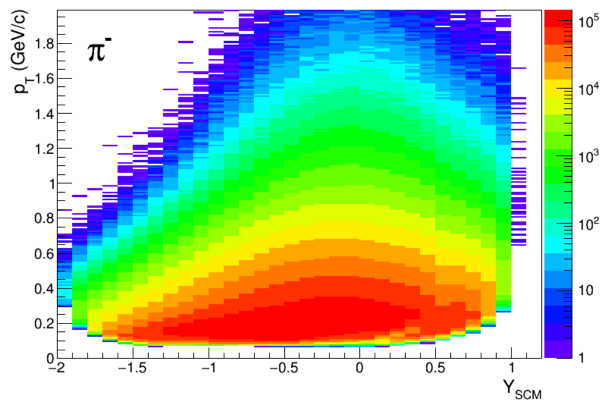
Light Hadrons

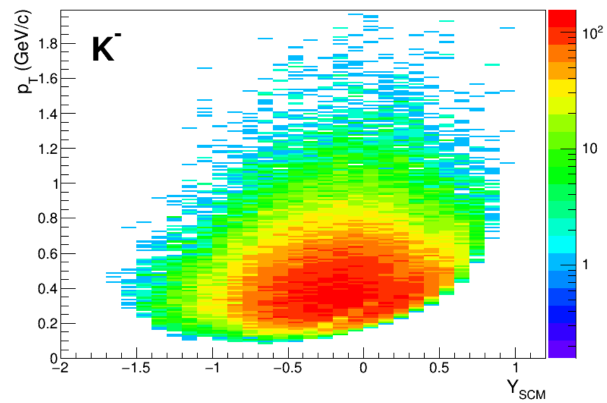
❖ Data: Request 36, XeW@2.5 AGeV (fixed target mode), 15M UrQMD events











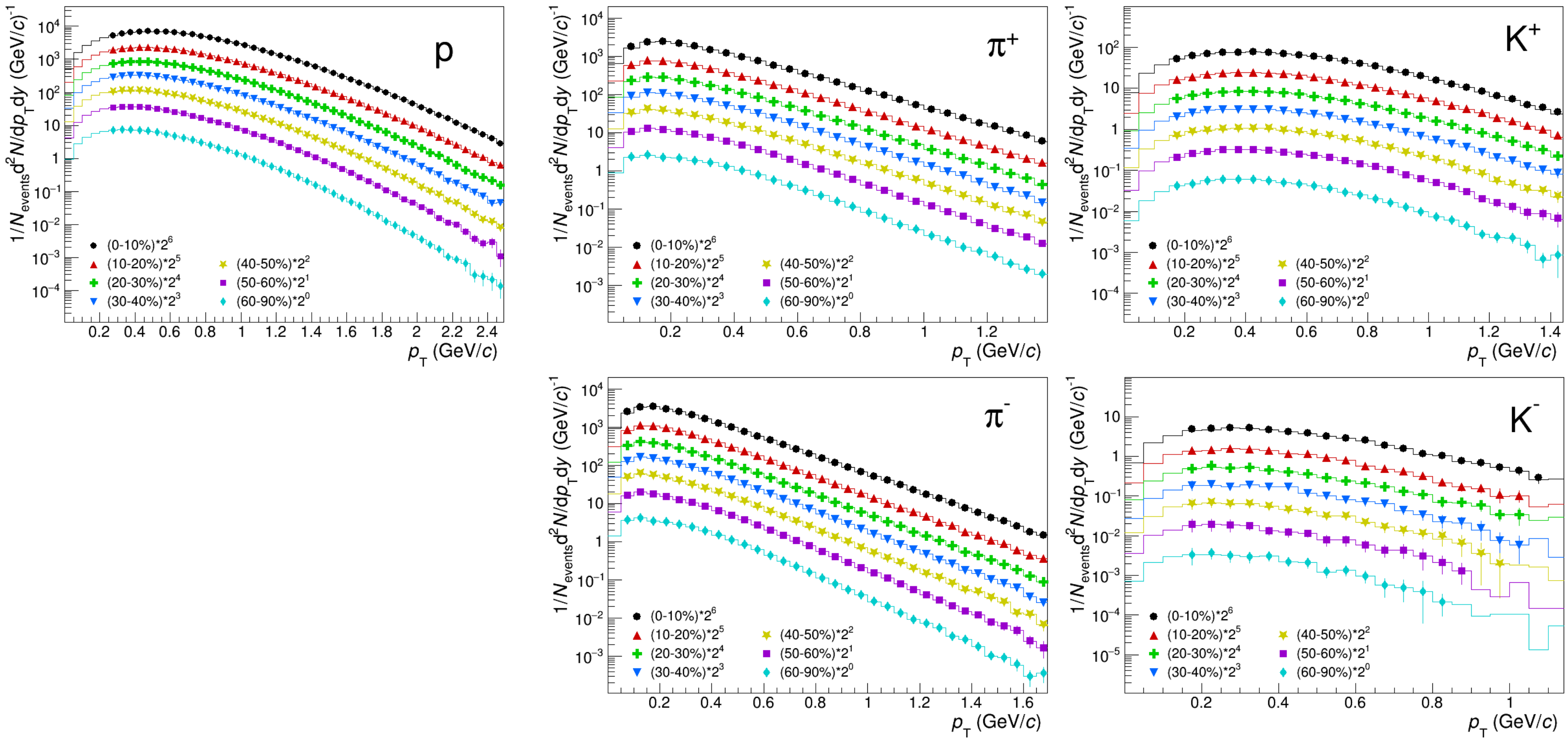
❖ $-1.3 < y_{CMS} < -1.0$:
- ✓ Pions: $p_T > 0.05$ GeV/c
- ✓ Kaons: $p_T > 0.1$ GeV/c
- ✓ Protons: $p_T > 0.15$ GeV/c

❖ $-1.5 < y_{CMS} < -1.0$:
- ✓ Pions: $p_T > 0.05$ GeV/c
- ✓ Kaons: $p_T > 0.2$ GeV/c
- ✓ Protons: $p_T > 0.35$ GeV/c

❖ $-1.0 < y_{CMS} < -0.5$:
- ✓ Pions: $p_T > 0.05$ GeV/c
- ✓ Kaons: $p_T > 0.1$ GeV/c
- ✓ Protons: $p_T > 0.1$ GeV/c

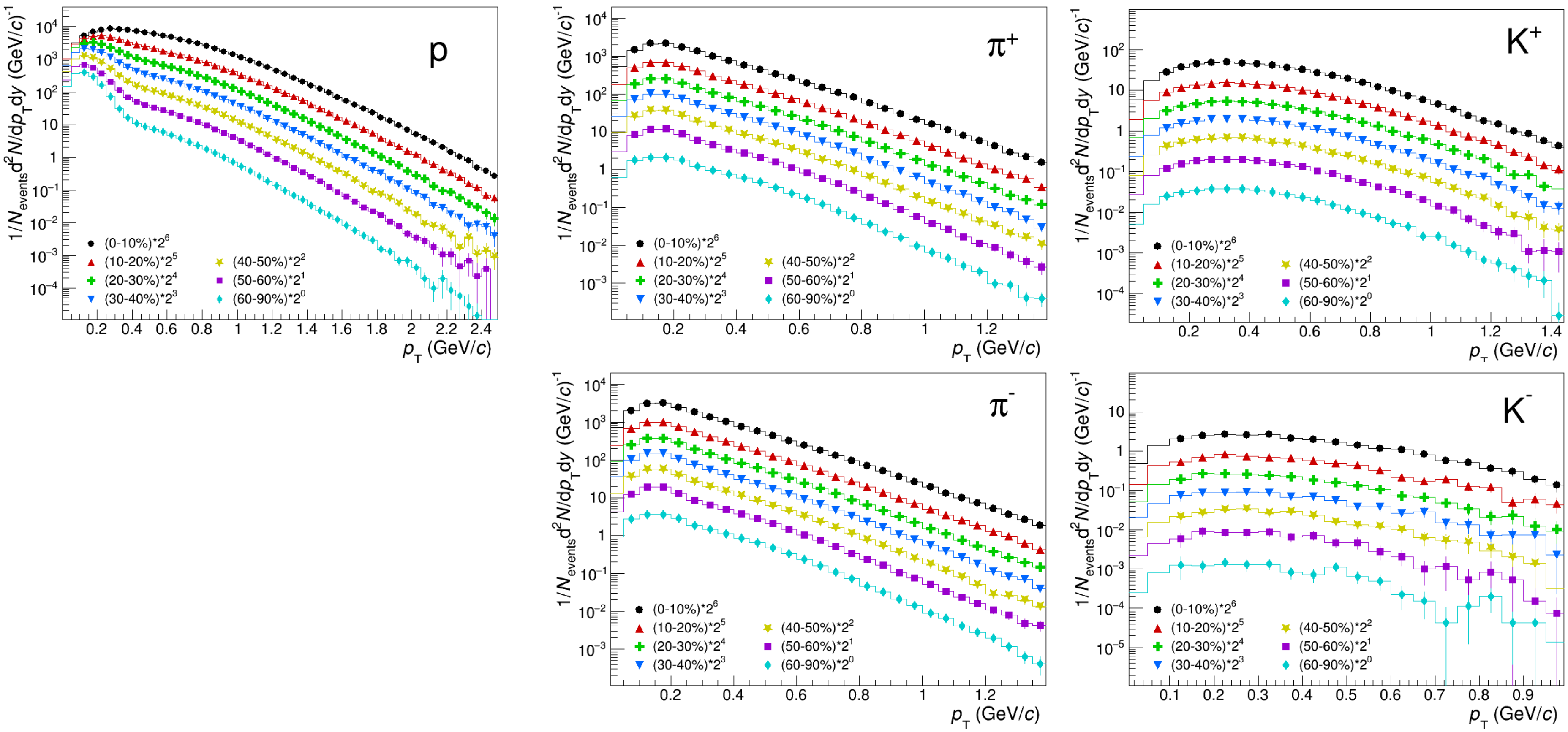
❖ $-0.5 < y_{CMS} < 0$:
- ✓ Pions: $p_T > 0.05$ GeV/c
- ✓ Kaons: $p_T > 0.15$ GeV/c
- ✓ Protons: $p_T > 0.25$ GeV/c

Light Hadrons ($-0.5 < Y_{cms} < 0.$)



- Start at p_T ~ 250 MeV/c for protons, 50 MeV/c for pions, 150 MeV/c for kaons
- Measured spectra sample ~80-90% of the total yields for protons, 96% for pions, 93(80-88)% for K^+(K^-), main losses at low p_T

Light Hadrons $(-1.0 < Y_{cms} < -0.5)$

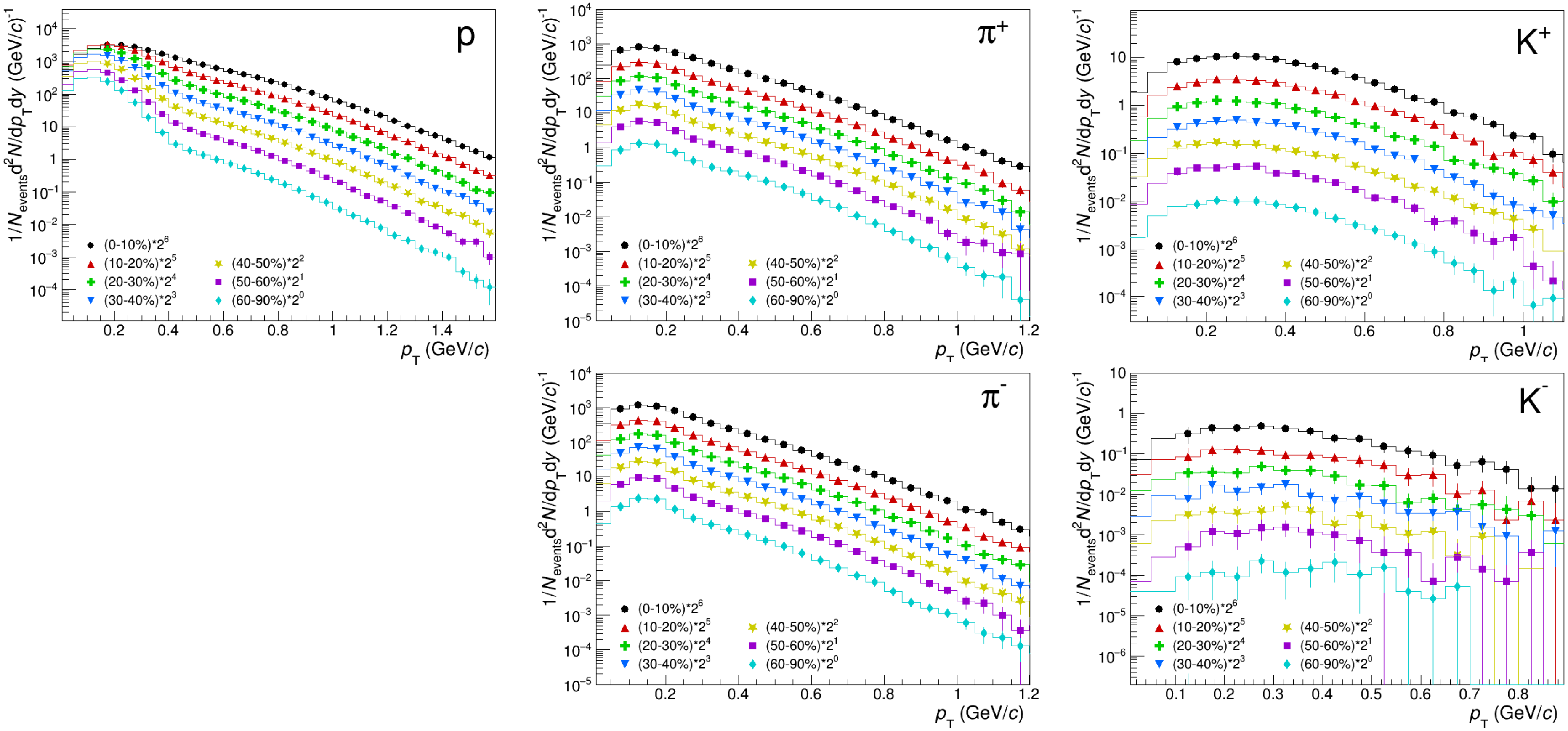


- Start at p_T ~ 100 MeV/c for protons, 50 MeV/c for pions, 100 MeV/c for kaons
- Measured spectra sample ~70-90% of the total yields for protons, 96% for pions, 95(90)% for $K^+(K^-)$, main losses at low p_T

NICA

Light Hadrons ($-1.3 < Y_{cms} < -1.0$)

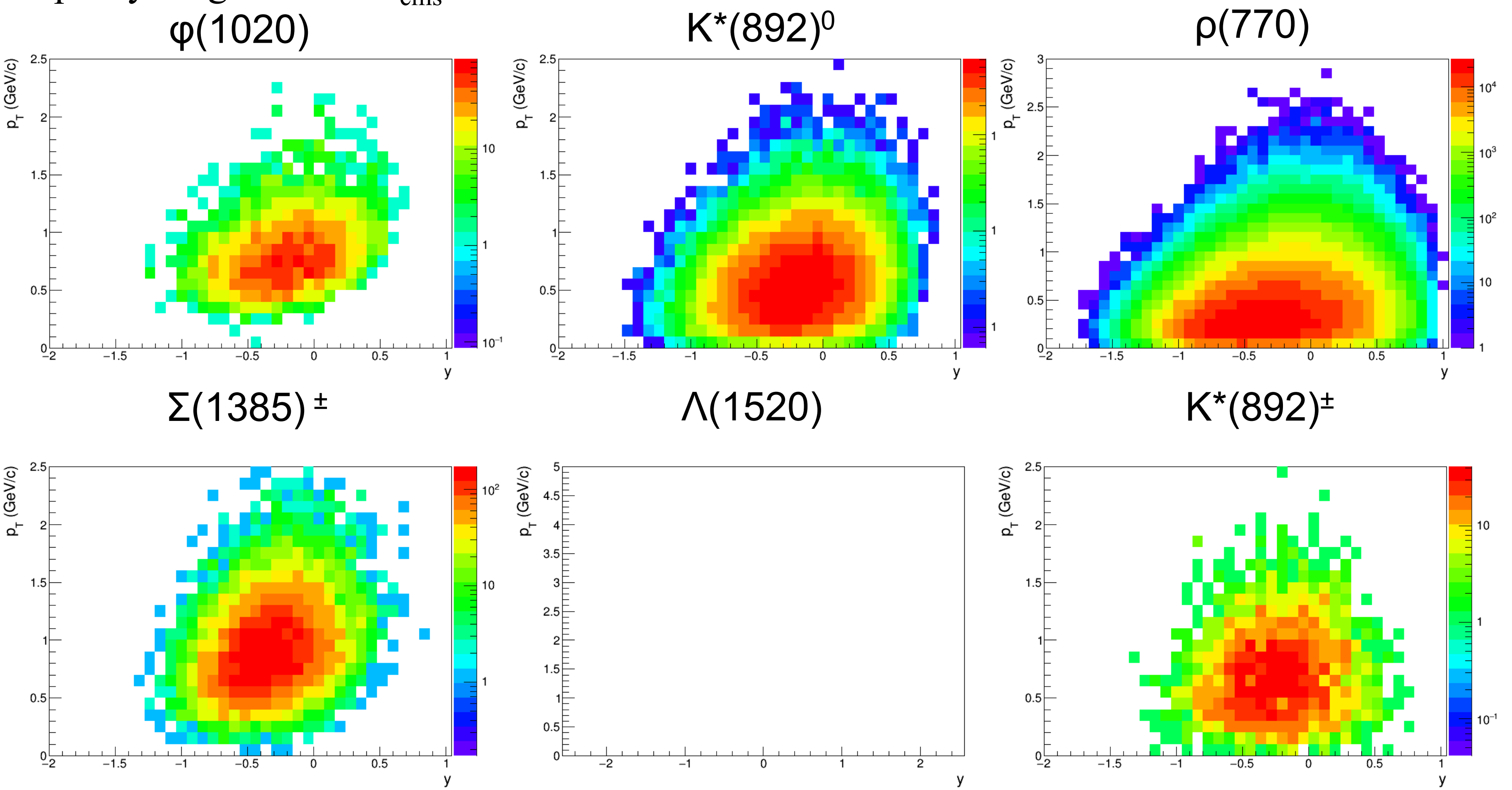
ПОЛИТЕХ
Санкт-Петербургский политехнический университет Петра Великого



- ❖ Start at p_T ~ 150 MeV/c for protons, 50 MeV/c for pions, 100 MeV/c for kaons
- ❖ Measured spectra sample ~40-80% of the total yields for protons, 95% for pions, 92(90)% for $K^+(K^-)$, main losses at low p_T

Short-lived resonances

- Data: Request 36, XeW@2.5 AGeV (fixed target mode), 15M UrQMD events
- Rapidity range: $-1.0 < Y_{cms} < 0$.

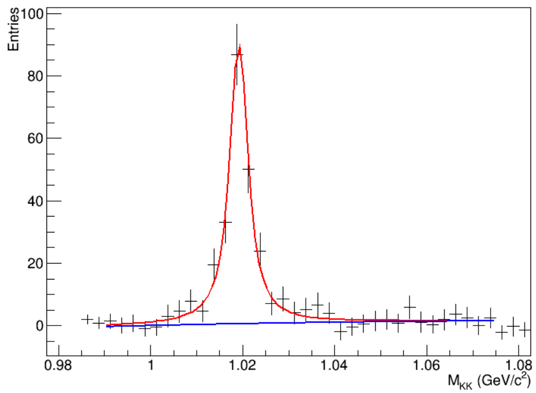


- Wide p_T range acceptable, $-1.0 < y_{cms} < 0$.
- Measurements are possible from 0 momentum for $K^*(892)^{\pm}$, $K^*(892)^0$, $\rho(770)$ and from ~0.2 GeV/c for $\varphi(1020)$ and $\Sigma(1385)^{\pm}$, no $\Lambda(1520)$

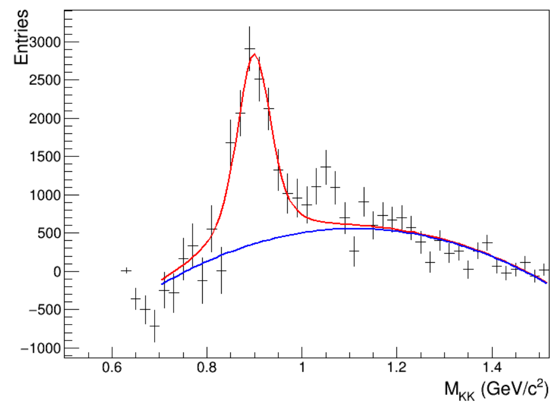
Short-lived resonances

- Data: Request 36, XeW@2.5 AGeV (fixed target mode), 15M UrQMD events
- Rapidity range: $-1.0 < Y_{cms} < 0$.

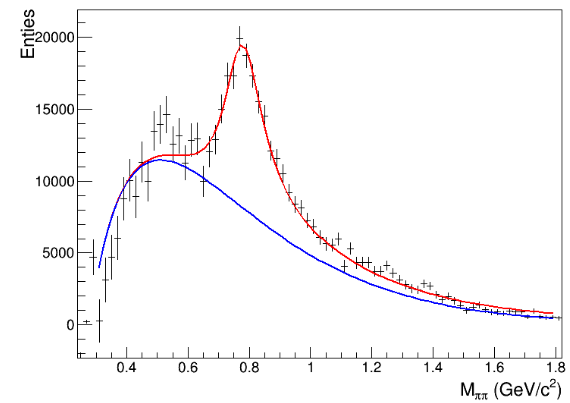
φ(1020)

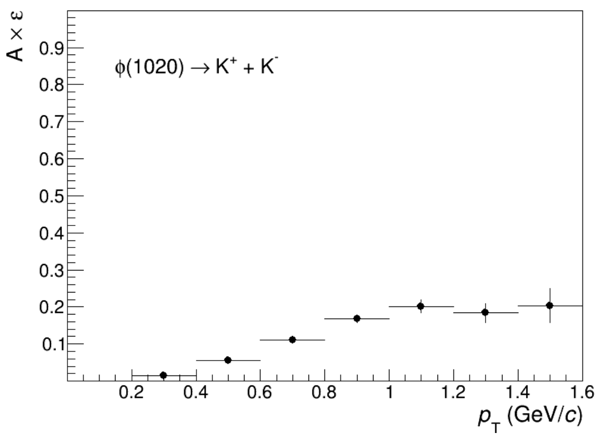


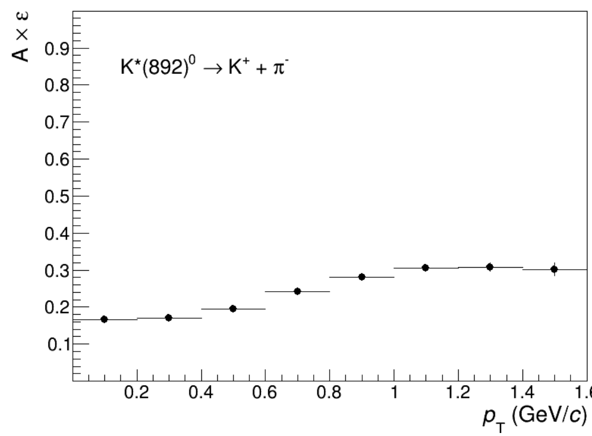
K*(892)^0

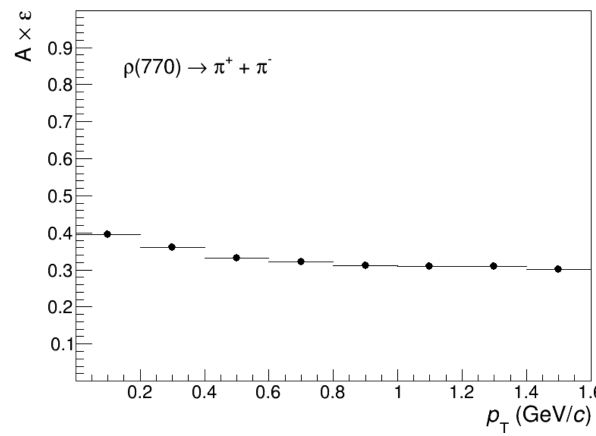


ρ(770)





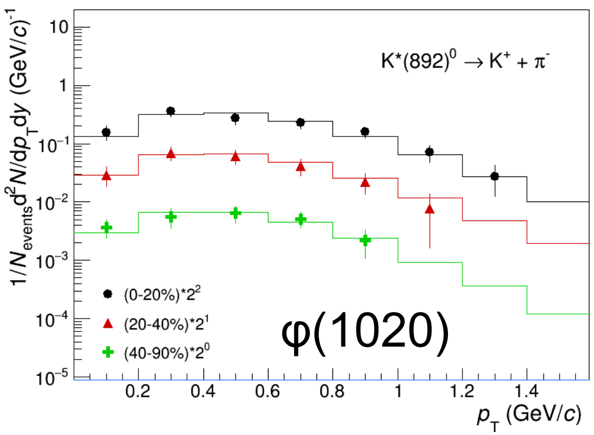


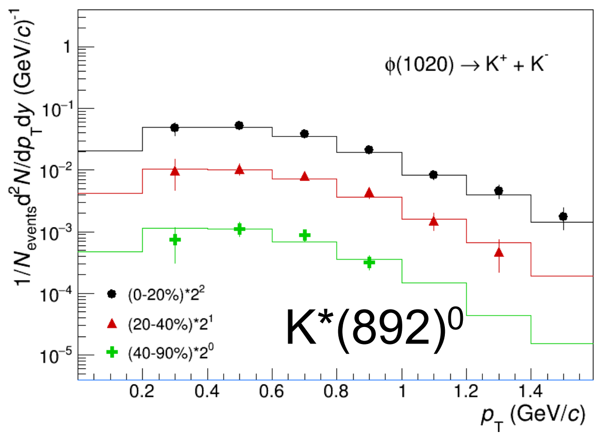


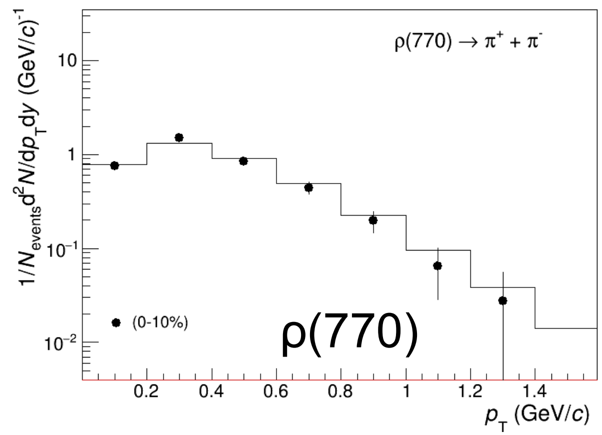
- Signal can be reconstructed at $p_T > 0$ for ρ(770), K*(892)^0, at $p_T > 0.2$ GeV/c for φ(1020), high-p_T reach is limited by available statistics

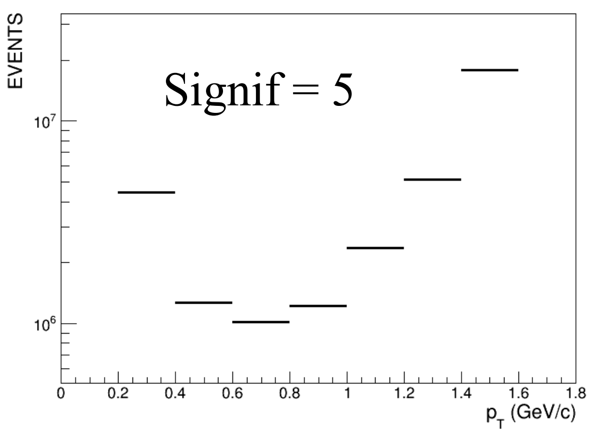
MC closure tests

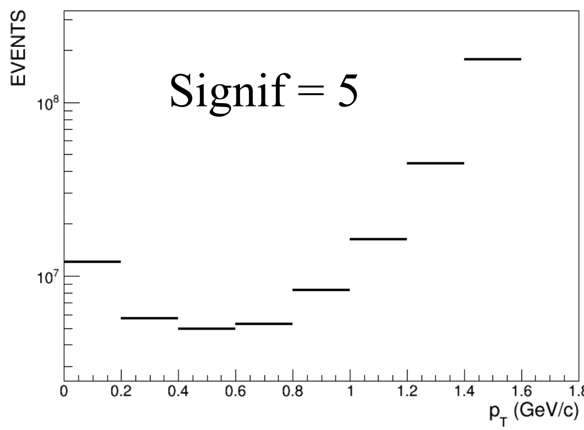
❖ Full chain simulation and reconstruction, p_T ranges are limited by the possibility to extract signals

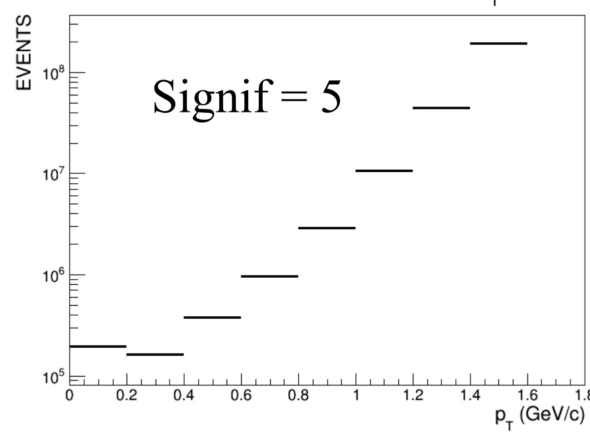












❖ Reconstructed spectra match the generated ones within uncertainties

❖ First measurements for resonances in centrality dependent analysis will be possible with accumulation of ~ 10^8 A+A events

❖ Measurements are possible starting from ~ zero momentum → sample most of the yield, sensitive to possible modifications

Statistics - 2025

- **Publications:**
  - 1 – Collaboration Paper
  - 4 – Proceeding
  - 3 – Other Publications

- **Conferences & Seminars & Reports:**
  - 7 – Conferences
  - 1 – Blocked Conference
  - 1 – Seminar
  - 13 – Reports on Collaboration and Cross PWG meetings

- **Grants and other financial support:**

Statistics - 2025

- **Publications:**
  - 1 – Collaboration Paper
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- **Conferences & Seminars & Reports:**
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  - 13 – Reports on Collaboration and Cross PWG meetings

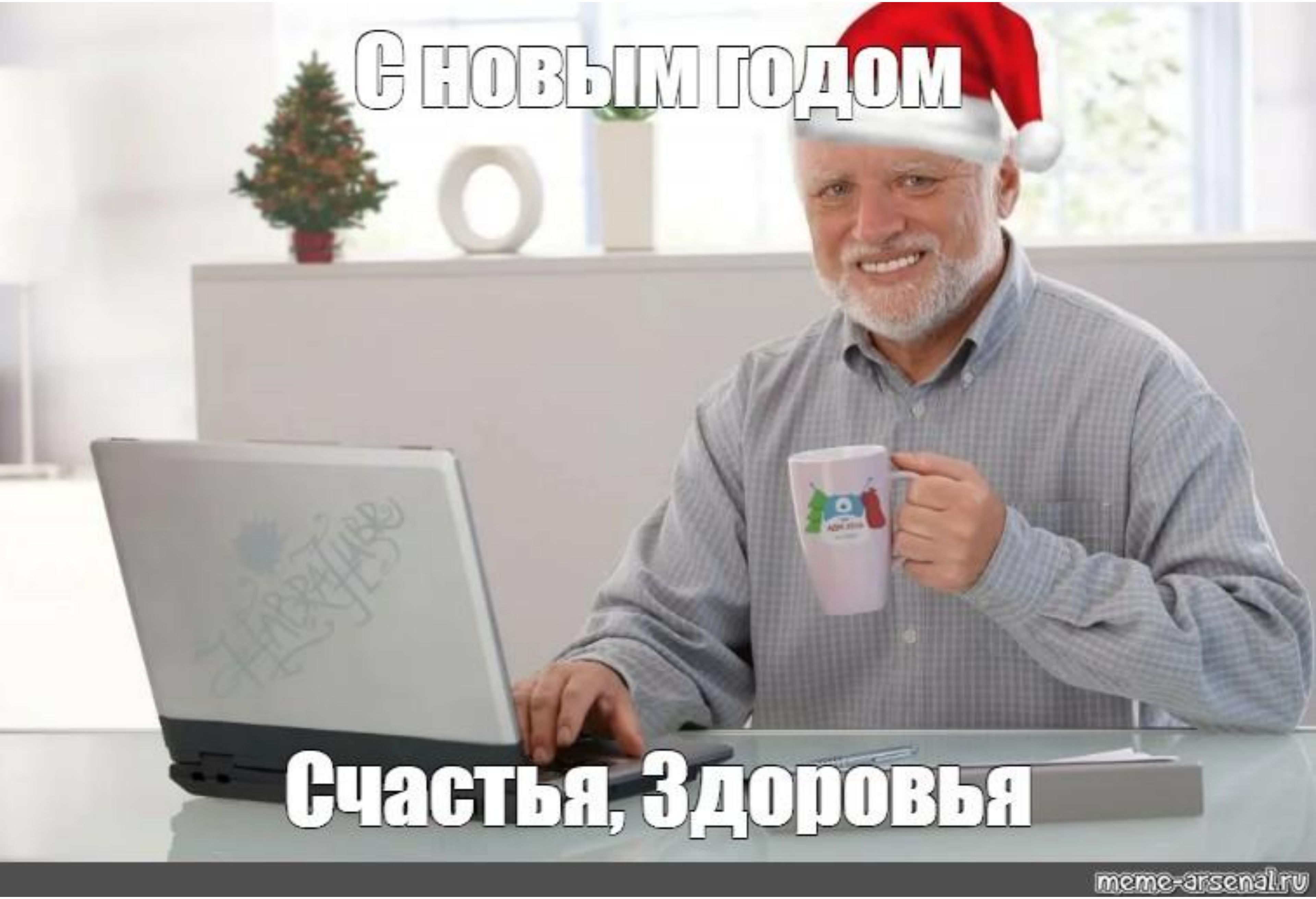
- **Grants and other financial support:**

Summary

❖ Физическая программа эксперимента MPD не окончательная и каждый вклад важен

❖ Сотрудники ПИЯФ участвуют в работе многих рабочих групп в коллаборации MPD и вносят свой вклад в полученные результаты

❖ Новые участники приветствуются!


С новым годом
Счастья, Здоровья
meme-arsenal.ru

BACKUP

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1. Бердников Я. А., Иванищев Д. А., Котов Д. О., Малаев М. В., Рябов А. Ю. Возможности измерять свойства заряженных $K^*(892)$-мезонов и $\Sigma(1385)$-барионов в столкновениях ядер висмута при энергии 9,2 ГэВ в ускорителе NICA на экспериментальной установке MPD // Научно-технические ведомости СПбГПУ. Физико-математические науки. 2025. Т. 18. № 2. С. 119–131.
2. Бердников Я. А., Иванищев Д. А., Котов Д. О., Малаев М. В. Возможности измерять свойства идентифицированных заряженных адронов в столкновениях ядер ксенона с неподвижной вольфрамовой мишенью при энергии 2,5*A* ГэВ в детекторе MPD на ускорителе NICA // Научно-технические ведомости СПбГПУ. Физико-математические науки. 2025. Т. 18. № 4. С ??– ??.
3. R. Abdulin, Ivanishchev D., Malaev M., et. al. MPD physics performance studies in Bi + Bi collisions at $\sqrt{s_{NN}} = 9.2$ GeV // Revista Mexicana de Física. 2025. Vol. 71. No. 4. Pp. 041201.
4. Berdnikov Ya. A., Ivanishchev D. A., Kotov D. O., Malaev M. V., and Riabov A. Yu. Feasibility Study for Resonance Reconstruction in Bi + Bi Collisions at $\sqrt{s_{NN}} = 9.2$ GeV in the MPD Detector at NICA // Physics of Particles and Nuclei Letters. 2025. Vol. 22. No. 1. Pp. 175–180. DOI: 10.1134/S1547477124702054.
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6. Н. Бурмасов, Е. Крышень, "ACTS-based track reconstruction for the forward detector in the MPD experiment at NICA", International Journal of Modern Physics E (принята к публикации)
7. V. G. Riabov, “Performance of the trigger system of the MPD experiment”, Physics of Atomic Nuclei. 2025. Vol. 88, No. 2. Pp. 297-301
8. V. Riabov, “Status Of the MPD Experiment: Towards the First Data Taking”, Phys.Part,Nucl.Lett., 22 (2025) 1, 207-212

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1. Berdnikov Ya., Ivanishchev D., Kotov D., Malaev M., Riabov A. Study of production of phi(1020)- and charged K*(892)-mesons and charged Sigma(1385)-baryons In collision of bismuth nuclei at 9.2 GeV in the MPD experiment at NICA, Сессия-конференция секции ядерной физики Отделения физических наук Российской академии наук, посвященной 70-летию со дня рождения академика РАН Валерия Анатольевича Рубакова, Россия, Москва, 17–21 февраля 2025, ОФН РАН.
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2. Бердников Я.А., Иванищев Д.А., Котов Д.О., Малаев М.В. Возможность изучения свойств заряженных адронов в Xe+W столкновениях при энергии 2.5A ГэВ на установке MPD в ускорителе NICA, LXXV Международная конференция «ЯДРО-2025. Физика атомного ядра и элементарных частиц. Ядерно-физические технологии» (LXXV International Conference «NUCLEUS-2025. Nuclear physics and elementary particle physics. Nuclear physics technologies»), Россия, Санкт-Петербург, 1–6 июля 2025, СПбГУ.
https://indico.spbu.ru/event/1/contributions/348/
3. Е. Крышень, "Implementation of ACTS-based track reconstruction for the forward detector in the MPD experiment at NICA", 11th International Conference "Distributed Computing and Grid Technologies in Science and Education" (GRID'2025), Дубна, 7–11 июля 2025 г.
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4. Н. Бурмасов, "ACTS-based track reconstruction for the forward detector in the MPD experiment at NICA", LXXV Международная конференция "ЯДРО-2025. Физика атомного ядра и элементарных частиц. Ядерно-физические технологии", Санкт-Петербург, 1–6 июля 2025 г.
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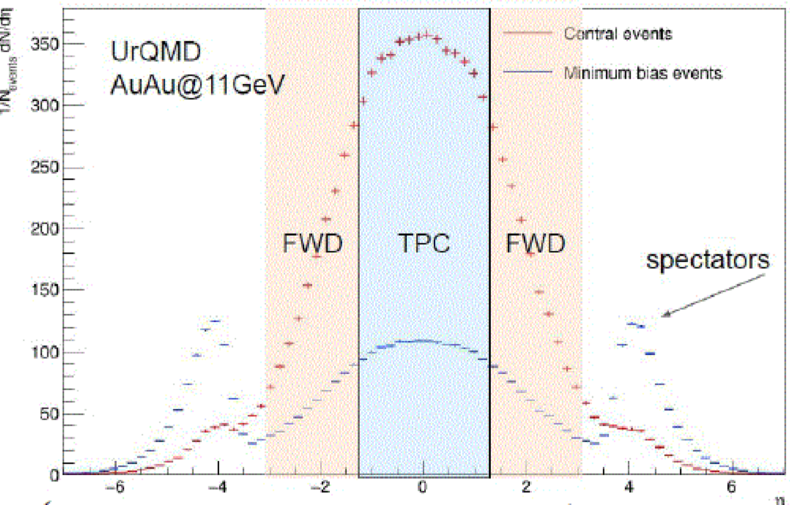
https://indico.inr.ac.ru/event/5/contributions/10/
7. V. Riabov, “Status of experiments at NICA facility”, LomCon 2025, 21-27 August 2025
https://lomcon.ru/wp-content/uploads/2025/08/22nd_Lomcon_programme.pdf

FWD Motivation

Pseudorapidity coverage



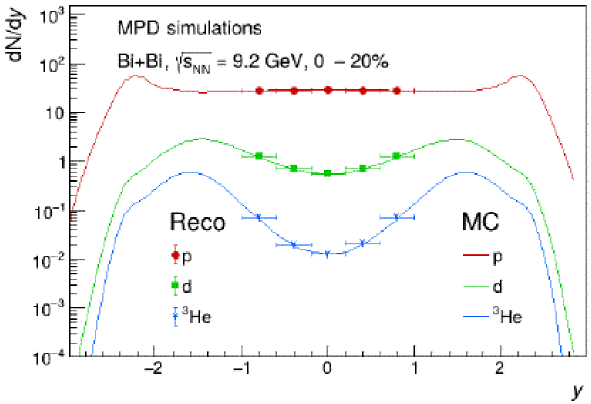
- TPC позволяет регистрировать примерно 55% частиц, рождающихся в центральных столкновениях. Форвардный трековый детектор может поднять этот показатель > 80 %.
- Позволяет улучшить точность различных наблюдаемых и открывает возможности для изучения новых эффектов:
  - ✓ Определение полных выходов и отношений выходов частиц и тестирование различных эффектов статистической модели, таких как the kink, the horn, the step, the dale и др.;
- ✓ Расширенный диапазон по псевдобыстроте открывает возможность исследований барионной аномалии в форвардной области в диапазоне импульсов от 1 до 4 ГэВ, где с точки зрения модели коалесценции оказывается важен именно полный импульс частиц;

- ✓ Расширенный диапазон по псевдобыстроте открывает возможность исследований барионной аномалии в форвардной области в диапазоне импульсов от 1 до 4 ГэВ, где с точки зрения модели коалесценции оказывается важен именно полный импульс частиц;

- ✓ Расширяет возможности исследования двухчастичных корреляций, так как позволяет лучше изолировать пик, связанный с корреляциями частиц в струях и распадах резонансов. Кроме того, расширенный диапазон по псевдобыстроте значительно увеличивает статистику в исследованиях многочастичных корреляций;
- ✓ Важно для прецизионных измерений зависимости направленного потока (коэффициента v1) от псевдобыстроты, изменение знака которого ожидается при энергиях коллайдера NICA;
- ✓ Измерения полных выходов частиц также важны для исследований флуктуаций барионного заряда и поиска критической точки на диаграмме ядерной материи;
- ✓ Позволяет расширить программу других исследований, например позволяет исследовать зависимость поляризацию Λ -гиперонов от быстроты, изучать различные аспекты непертурбативной КХД, такие как дифракционное рождение частиц, рождение инстантона и т.д.;
- ✓ Позволит более точно определять центральность столкновений и плоскость реакции;
- ✓ Внедрение триггерной электроники для форвардного трекера также позволит значительно улучшить триггерные возможности эксперимента, особенно в столкновениях малых систем;
- ✓ Работа форвардного детектора в режиме непрерывного считывания может значительно увеличить статистику, набираемую в протон-протонных столкновениях, что также позволит изучать различные аспекты физической программы эксперимента SPD.

FWD Motivation

- the horn and the step effects at forward rapidities
- light nuclei: interplay of coalescence and baryon stopping mechanisms
- anisotropic flow: limiting fragmentation mechanism, temperature dependence of QGP etc.
- thermal photons via conversions on TPC endcaps
- global polarization of Λ hyperons: rapidity dependence?
- improve precision of centrality and reaction plane determination
- improved trigger efficiency for small systems
- possibility to access various observables of the SPD physics program
- aspects of non-perturbative QCD, e.g. diffractive studies, QCD instanton
- and more …



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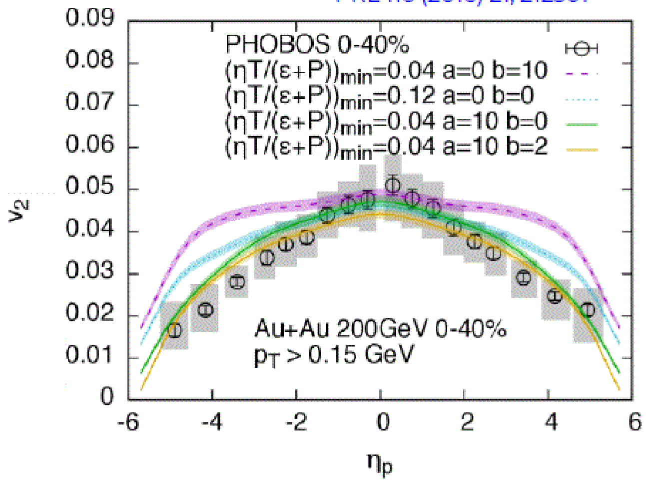
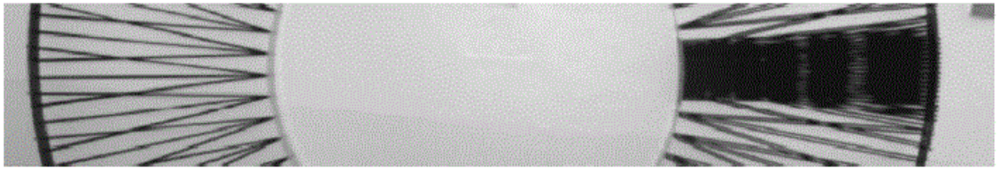
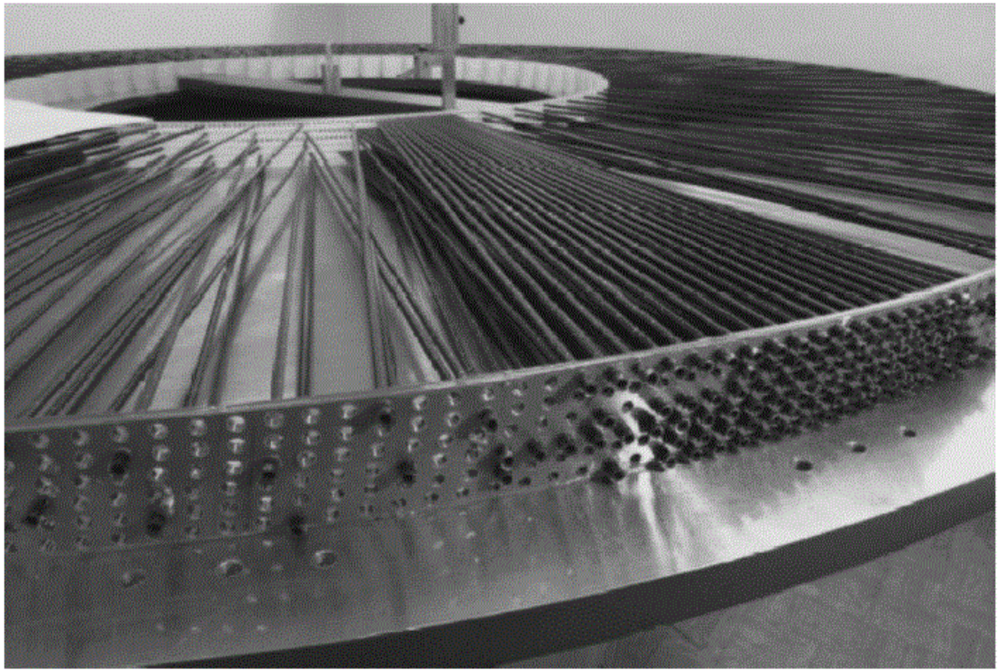


Straw-tube wheel geometry

- R_{min} = 50 cm
- R_{max} = 110 cm
- Straws:
    - Inner diameter: 4 mm
    - Kapton wall thickness: 40 um
    - Wire diameter: 30 um
    - Ar/CO_2 gas mixture
    - winding technology
    - reinforced with carbon fiber
- 5.23 mm distance between straw centers at R_{min}
- 10 stations per side
- 6 layers per station with RUV stereo angles: 0, +7°, –7°, 0, +7°, –7°
- 600 straws per layer
- 72000 channels (2 sides)





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Straw-tube wheel geometry

- Ultrasonic welding technology
- Straw diameter: 5 mm
- Wall thickness (mylar): 20 um
- Al metallization 70 nm
- Tungsten wire: d = 20 um
- Ar/CO_2 gas mixture
- Internal overpressure of 1 bar

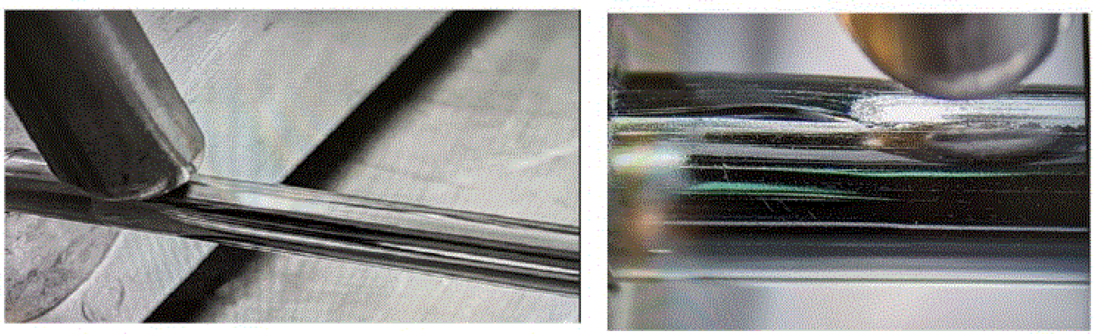

Figure 2: An ultrasonic head and a straw during the welding process (left) and a zoomed view of the seam during the welding(right).

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Standalone tracking with ACTS

- Created “parallel world” in ACTS
- Replacing tubes with strip-like plane surfaces
- Strip thickness = 0.025% X_0
- Straw-tube hits smeared with 100 um resolution and converted to 1D ACTS measurements
- Kalman Filter used to fit the measurements