Dilepton measurements in MPD experiment at NICA

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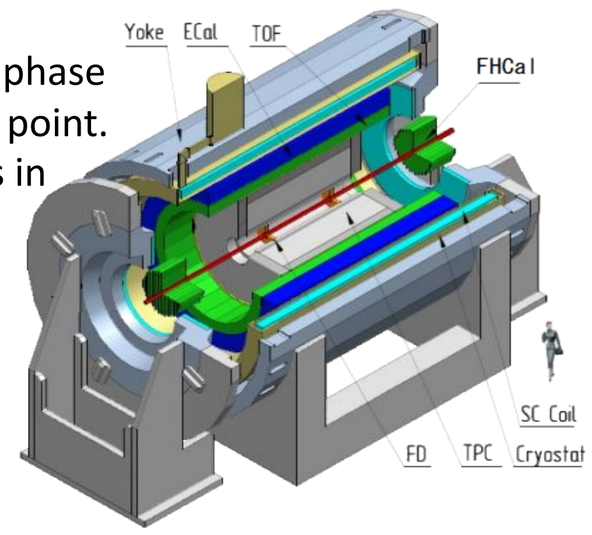
Motivation

- Dileptons are powerful diagnostic probes of the hot and dense nuclear medium.
- Characterize two properties of the medium: deconfinement of the partons and chiral symmetry restoration [1,2]: their invariant mass spectra provide insights into lifetime and initial temperature of the fireball.
- Interacts only electromagnetically, preserving the information about the time of their production.
- They are produced in almost all stages of the evolution of heavy-ion collisions.

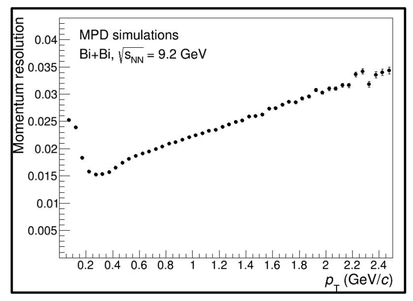
MPD at NICA

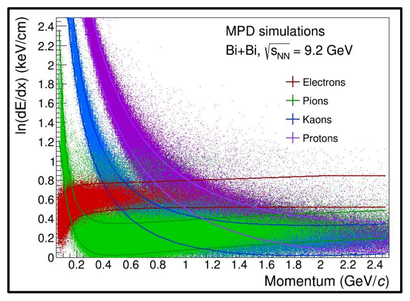
- Multi-Purpose Detector (MPD) is a flagship experiment at NICA, commissioning in 2026 [3,4].
- Modes of operation: Fixed target ($\sqrt{s_{NN}}$ = 2.4-3.5 GeV) and Collider ($\sqrt{s_{NN}}$ = 4-11 GeV).
- Objectives: search for order of phase transition and QCD critical end point.
- Strategy: High luminosity scans in energy and system size.
- Same apparatus for scans with benefits of collider geometry.
- Suitable for dilepton measurements: e^+e^- pairs

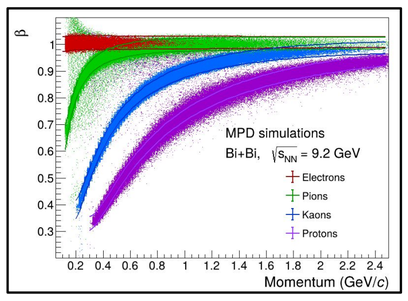


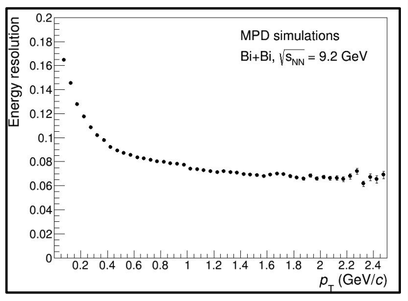
Electron Identification

- MPD provides excellent track reconstruction and particle identification with the help of TPC, TOF and ECal.
- In addition, purity reaches almost 100% due to the exceptional electron-hadron separation through ECal above p_T > 1 GeV/c: crucial for dilepton analysis.





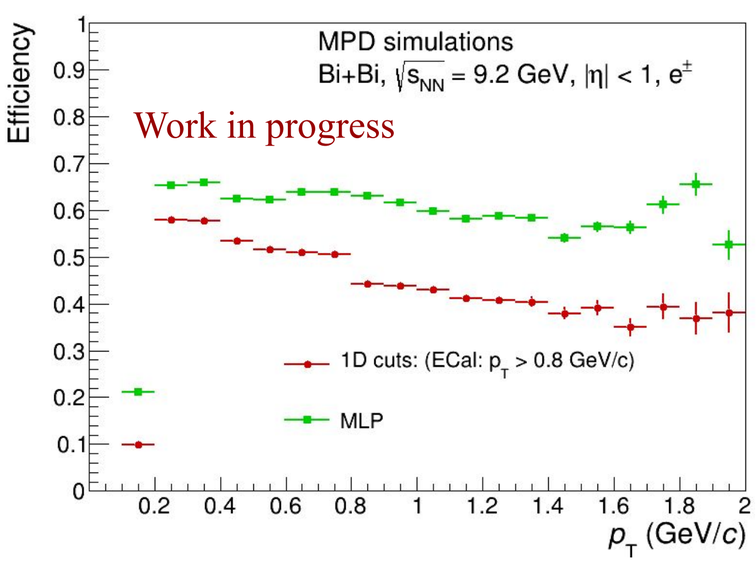


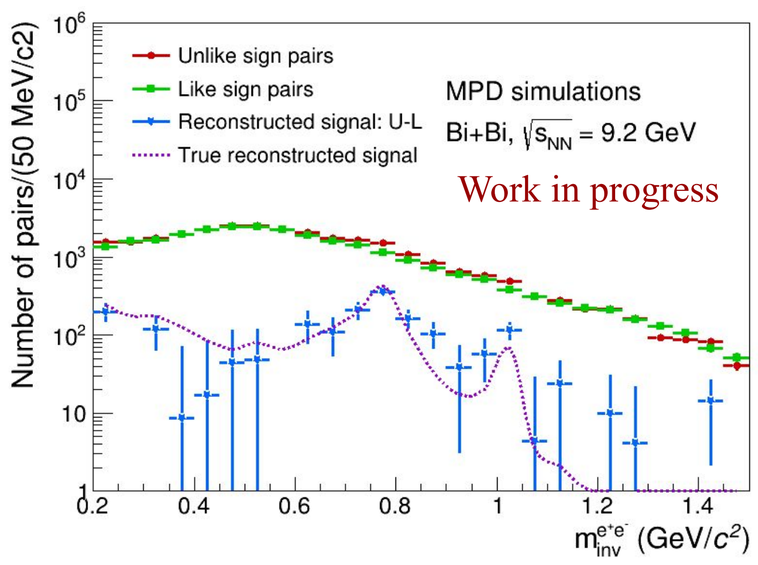


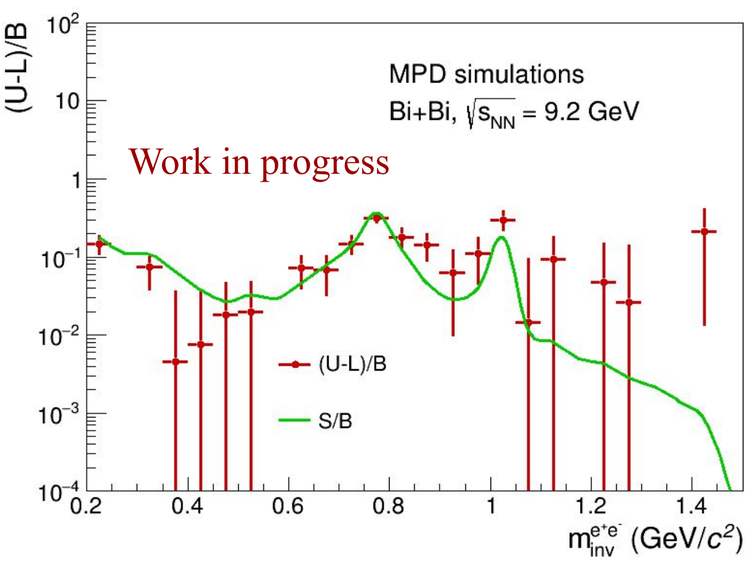
Results

- Challenges in dielectron measurements:
  - Small multiplicities as well as branching ratios of the signal dielectron sources compared to the background: analyses are statistics hungry.
  - Huge combinatorial background (CB) from photon conversions and Dalitz decays pairs: when one of the legs is not reconstructed.
- UrQMD event generator is used to simulate heavy-ion events: 15 million minimum bias Bi+Bi collisions at $\sqrt{s_{NN}}$ = 9.2 GeV.

- Dielectron cocktail shapes and multiplicities in UrQMD were matched to those from PHSD event generator.
- To improve statistical significance, branching ratios of dielectron sources, except π^0 and η dalitz decays, were enhanced by factor 20.
- Machine learning neural network methods such as Multi-layer Perceptrons (MLP) is used to enhance the electron identification performance of the MPD.
- Combinatorial background is removed using various analysis methods and techniques.







S/B ratio up to 10% can be obtained in the invariant mass range 0.2 to 1.5 GeV/c^2, however, a few hundred million events are required for meaningful signal measurements.

References

1. M.P. Lombardo, J. Phys G35, 104019 (2008).
2. K. Fukushima, J. Phys G35, 104020 (2008).
3. MPD Collaboration, V. Abgaryan et al., Eur. Phys. J. A 58 (2022) 140.
4. MPD Collaboration, R. Abdulin et al., e-Print: 2503.21117 [nucl-ex]

Conclusions

- MPD is well equipped to measure dielectrons using dedicated sub-systems.
- Improvement in electron identification using Machine Learning tools.
- S/B up to 10% is measurable: more statistics needed for meaningful signal.
- Results are work in progress: higher statistics sample is being produced.
- Ongoing efforts to further suppress combinatorial background.