Low-mass, low-momentum virtual photon measurements at SIS18

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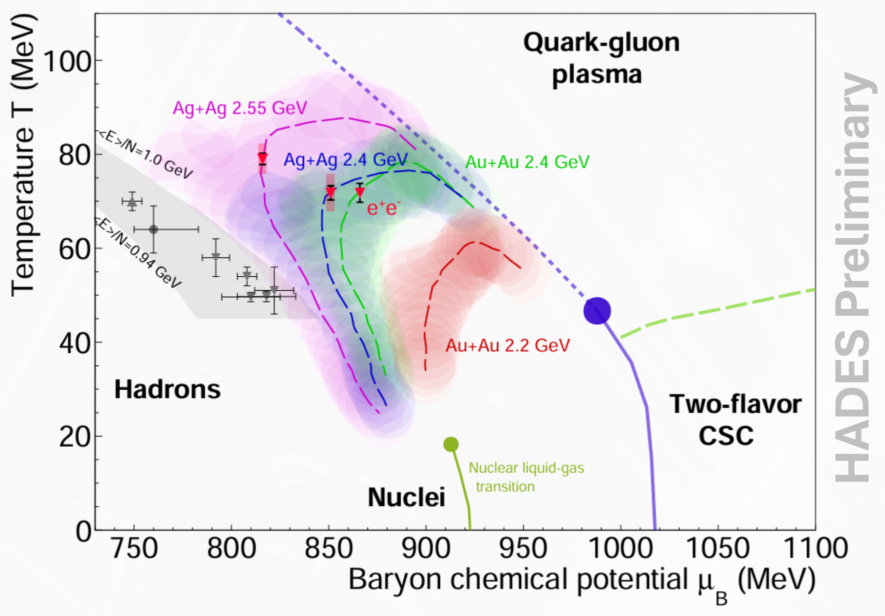
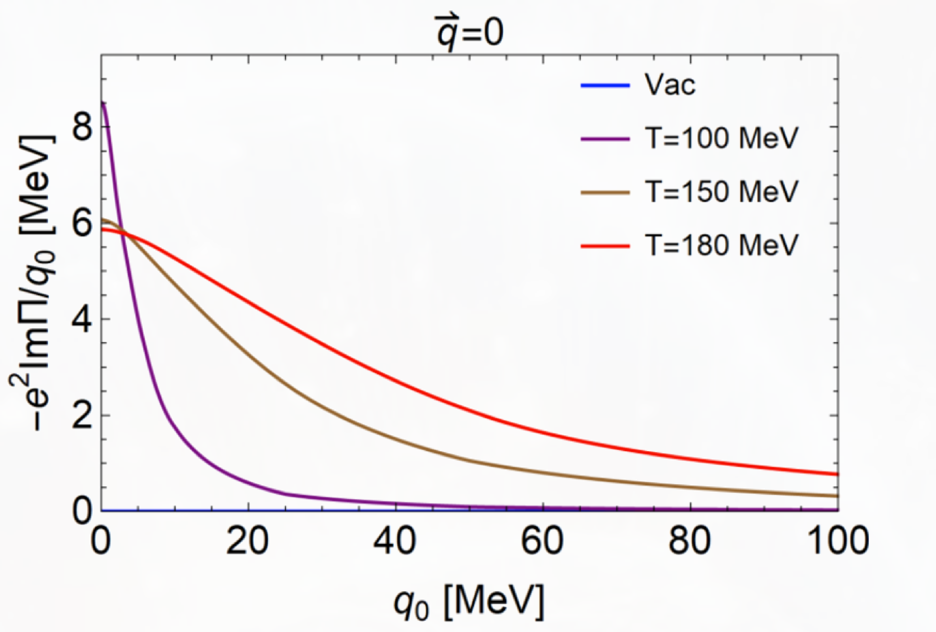
HADES

Motivation

- Study the phase structure of QCD at high baryon chemical potential and low temperature
- Possible realization of color superconductivity [1]

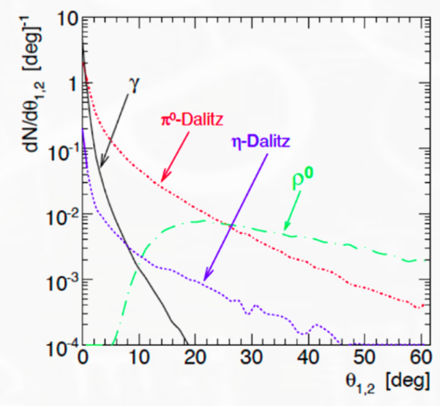


- Extract transport properties of the matter such as electrical conductivity
- Dilepton yield at $p_{ee} = 0\ MeV/c$, $M_{ee} \to 0\ MeV/c^2$ [2]



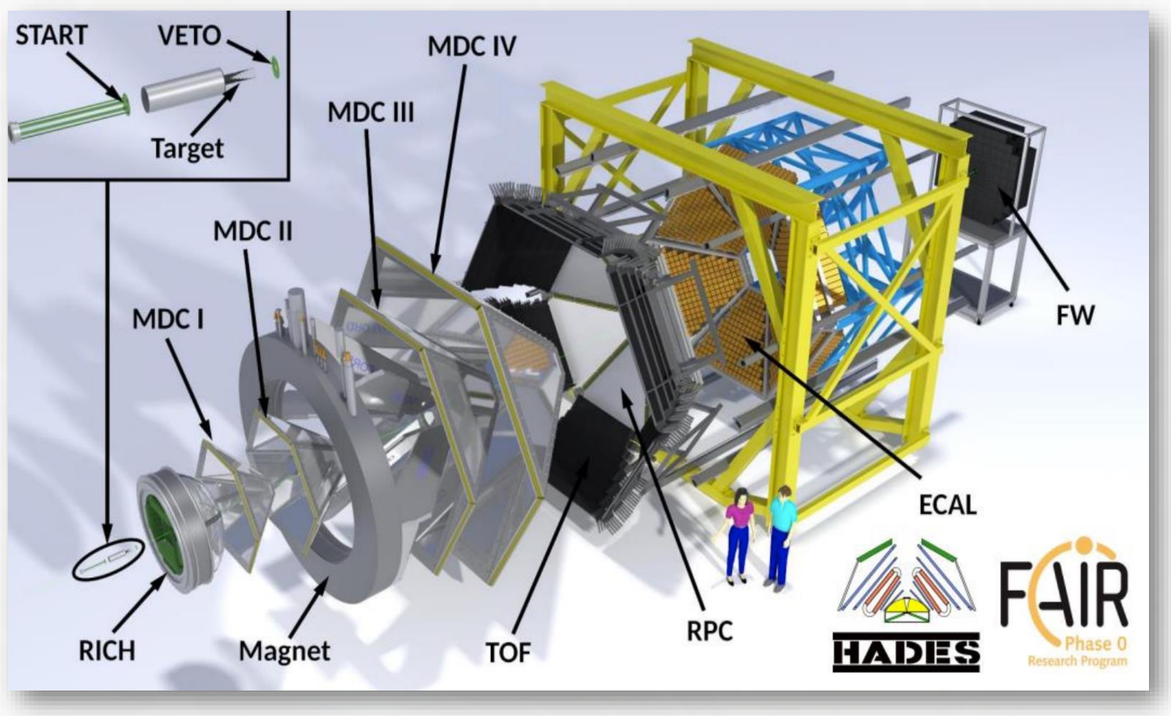
Experimental Challenges

- Dileptons are rare probes (BR ~ 10^{-5})
  - Require large data sets
  - 300 million Ag+Ag events at $\sqrt{s_{NN}} = 2.42\ GeV$ analyzed
- Acceptance: Low – momentum tracks bent out of acceptance by magnetic field
  - Dedicated run with a reduced magnetic field intensity
- Photon conversion in low – mass region of dilepton spectrum
  - Opening angle cut
- Background of π^0, η Dalitz decays
  - Precise knowledge of hadronic cocktail
  - Reference measured in pp/pn collisions



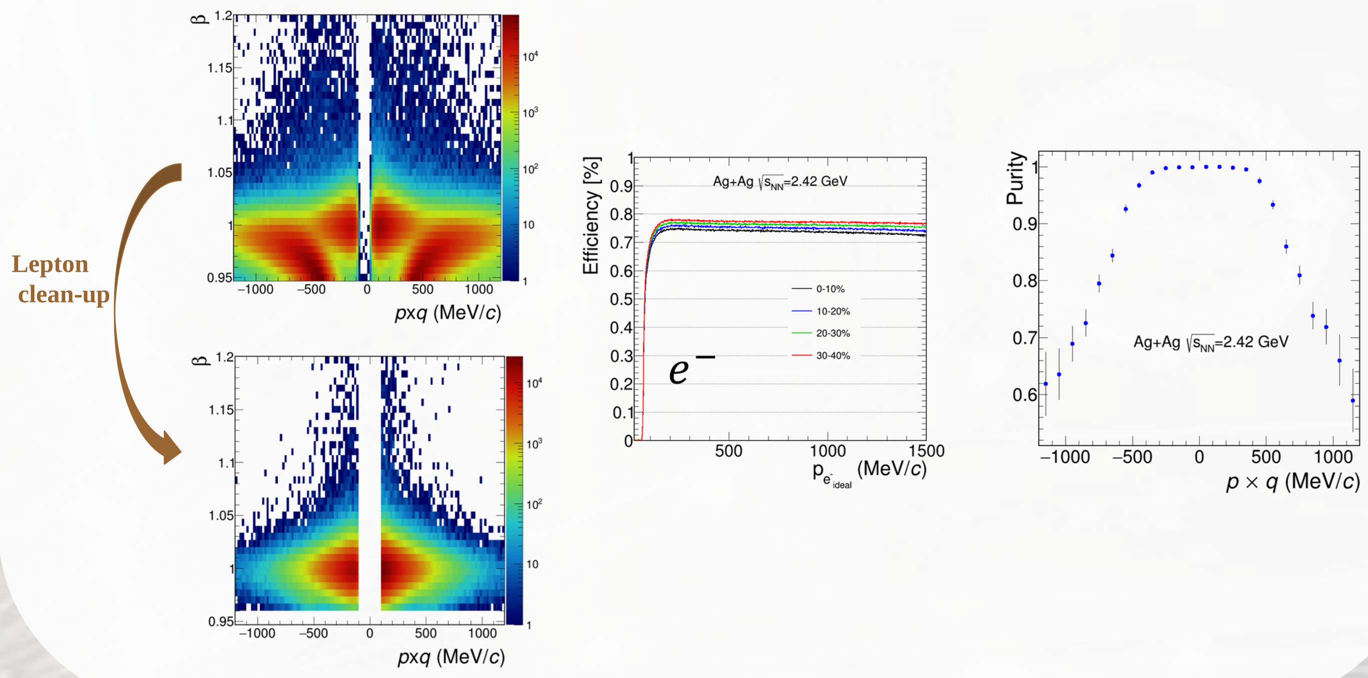
High Acceptance Di-Electron Spectrometer

- Fixed-target experiment at GSI, Germany
- Heavy-ion collisions at energies of $\sqrt{s_{NN}} = 2 - 3\ GeV$
- Large acceptance $0^o < \varphi < 360^o$, $18^o < \theta < 85^o$
- Low mass Mini Drift-Chambers used for tracking
  - Optimized for low-material budget to minimize the probability of photon conversion
- Lepton identification with RICH, TOF, RPC, ECAL



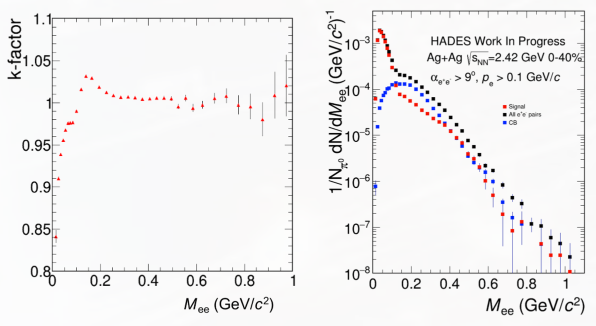
Lepton identification

- Reference analysis of Ag+Ag at $\sqrt{s_{NN}} = 2.42\ GeV$, nominal field
- Focus on low-momentum leptons
- Reconstruction of e^+ and e^- with high efficiency (~75%) and high purity

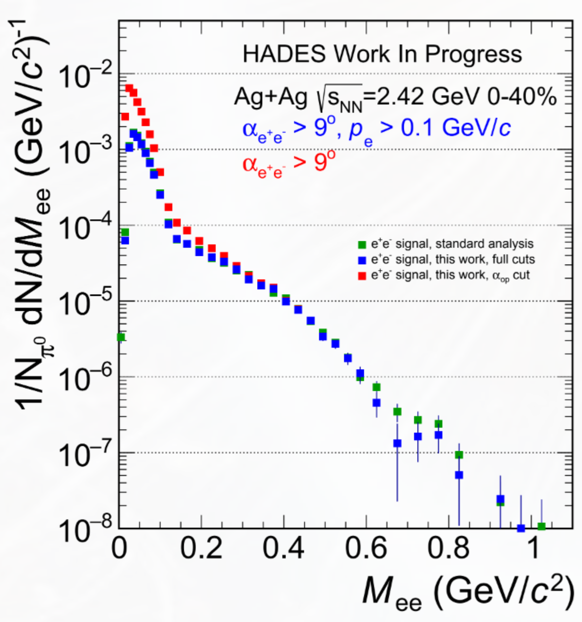


Signal Reconstruction

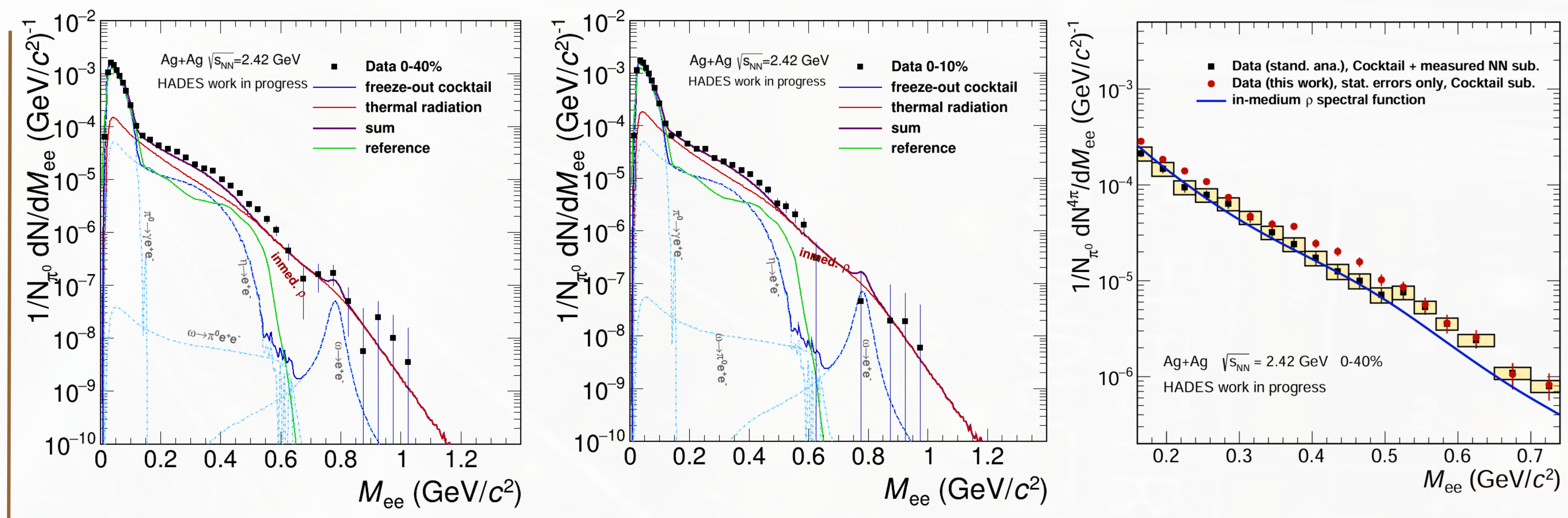
- $\frac{dN_{Signal}}{dM} = \frac{dN_{+-}}{dM} - \frac{dN_{CB}}{dM}$
- Combinatorial background (CB) estimated via same-event and mixed-events methods
- $\frac{dN_{CB}}{dM} = 2k\sqrt{\frac{dN_{++}}{dM} \cdot \frac{dN_{--}}{dM}}$
- $k = \frac{\frac{dN^{mix}_{+-}}{dM}}{\sqrt{\frac{dN^{mix}_{++}}{dM}\frac{dN^{mix}_{--}}{dM}}}$



- Charge asymmetry correction in the low-mass region
- Efficiency corrected by embedding simulated $e^{\pm}$ into experimental data
- Momentum smearing via Crystal Ball fits
  - Allows for extrapolation to low momenta



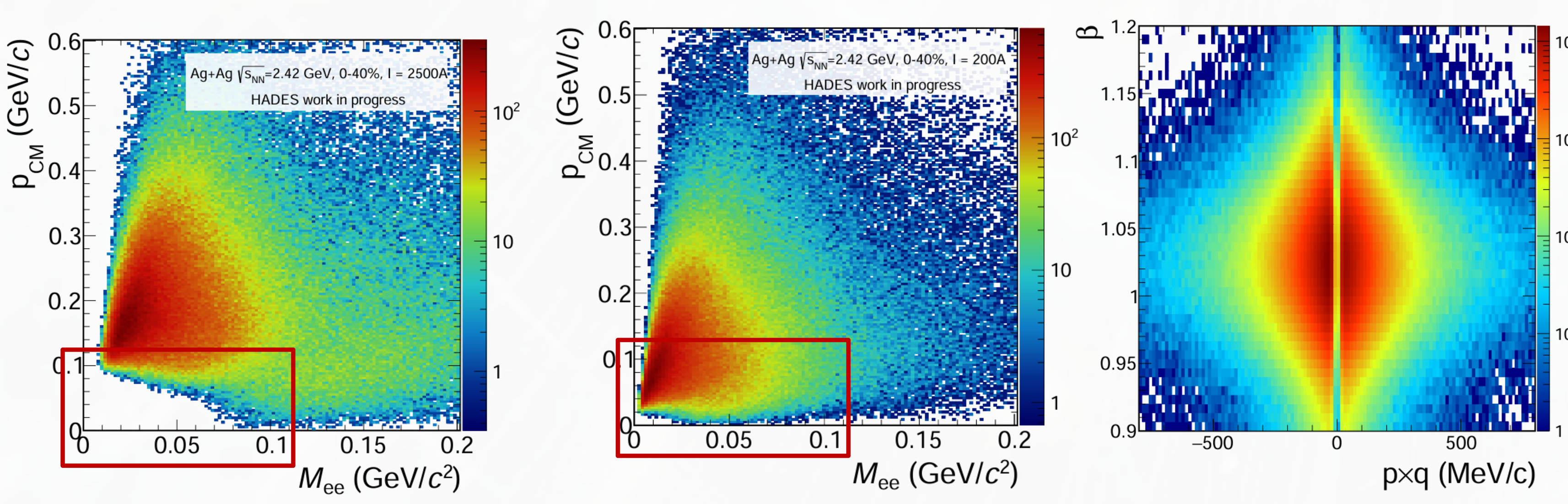
- Removing cut on minimum lepton momentum
  - Higher acceptance in the low-mass region



- Efficiency corrected spectra in the acceptance of HADES
- Excess radiation extracted
- Freezeout cocktail simulated with Pluto [3]
- Detector response simulated with GEANT [4]

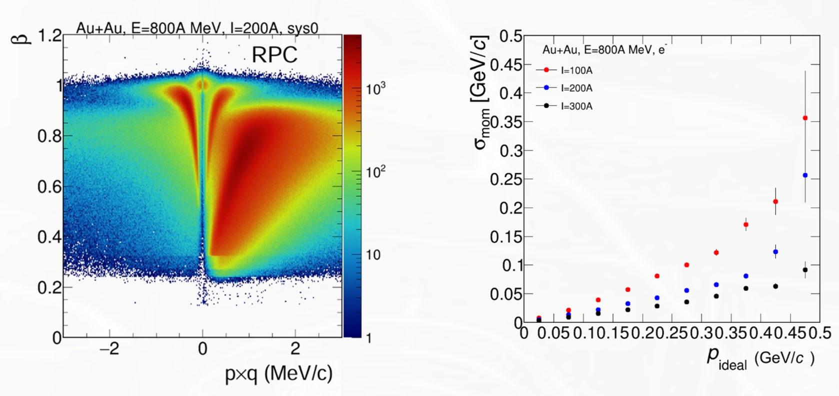
Low Magnetic Field Studies

- Ag+Ag $\sqrt{s_{NN}} = 2.42\ GeV$ nominal field (70% of max. field) vs. low field (5% of max. field)
- Real data of all e⁺e⁻ pairs
- Phase-space coverage in the region of interest

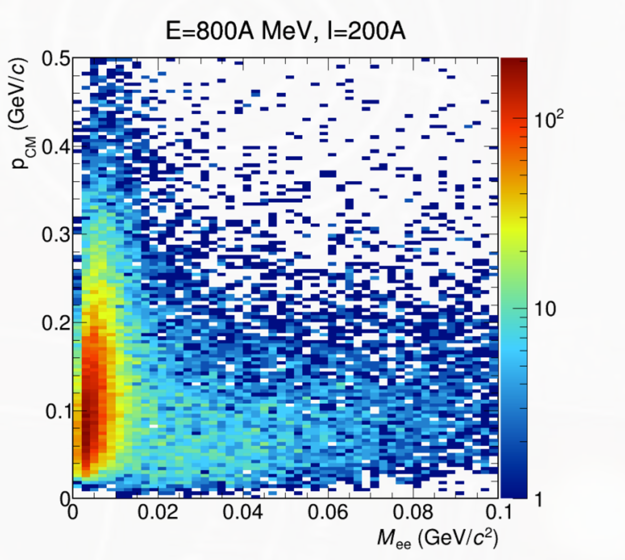


- Only 5h of data taking
- 140 million events analyzed
- Very good lepton identification even at 5% of max. field

- 2024 HADES beam-time
  - Au+Au $\sqrt{s_{NN}} = 2.23\ GeV$, $\sqrt{s_{NN}} = 2.14\ GeV$ nominal field
  - 3 billion events collected to be analyzed



- Prospects for 2025 HADES beam-time
  - Au+Au $\sqrt{s_{NN}} = 2.23\ GeV$, low field
  - 250 million events to be collected
  - Simulations indicates a better phase-space coverage with a reduced magnetic field
  - Good momentum resolution for electron identification and separation from pions and protons



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[1] T. Nishimura, Y. Nara, J. Steinheimer, arXiv:2311.14135 (2023)
[2] J. Atchison, R. Rapp, Nucl. Phys. A 1037 (2023) 122704
[3] I. Froehlich *et al.*, arXiv:0708.2382
[4] S. Agostinelli *et al.*, Nucl. Instrum. Meth. A 506 (2003)