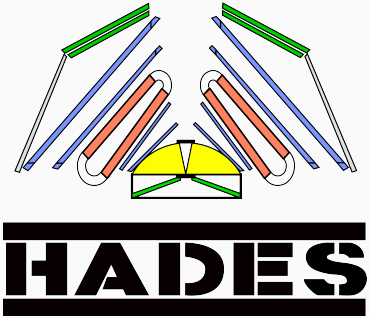
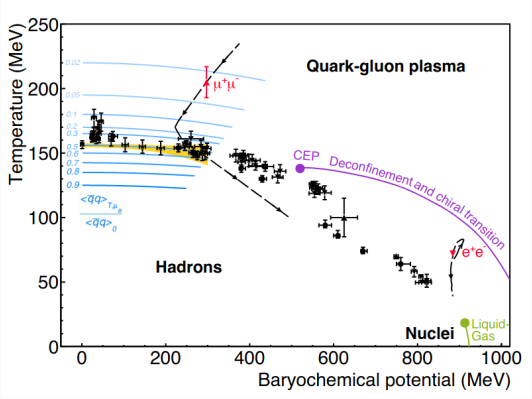


Dielectron measurements with the HADES at GSI

Baryons 2022 - International Conference on the Structure of Baryons, 07.11.-11.11.2022

Jan-Hendrik Otto for the HADES collaboration, JLU Gießen
08/11/2022

HADES Physics Program



Nature Physics volume 15, pages 1040–1045 (2019)

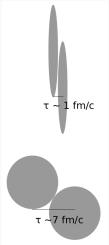
- Explore high net-baryon region of the QCD phase diagram
- Focus on rare and penetrating probes

  → **Virtual and real photons**, that probe all different stages of heavy ion collisions: Initial NN collisions → Fireball → Decay of hadronic resonances
- Address various aspects of baryon-meson coupling

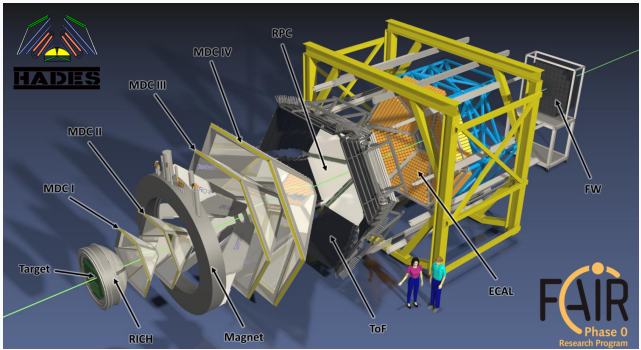
→ **Heavy ion collisions at** $\sqrt{s_{NN}} = 2 - 3\ GeV$

- HADES collision dynamics strongly differs from high energy collisions

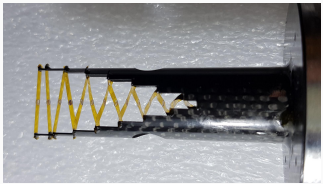
→ **Pion and nucleon beams** e.g. for reference



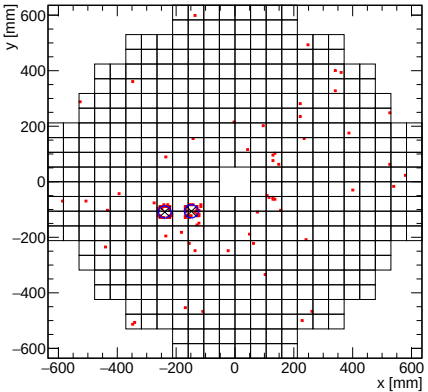
The High Acceptance DiElectron Spectrometer

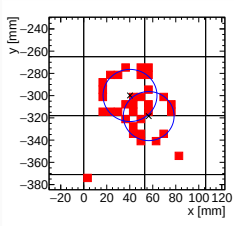


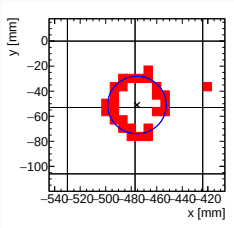
- Fixed target experiment at SIS18 (GSI, Germany)
- Magnet spectrometer
- Low mass Mini-Drift-Chambers (MDCs)
- Time of flight walls RPC and ToF
- NEW: Upgraded RICH detector and added ECal for electron and photon detection
- Almost full azimuth angle coverage and polar angles between $18^{\circ} - 85^{\circ}$
- 15-fold ($25\ \mu m$, $\Delta z = 3.7\ mm$) segmented target
- Accepted trigger rate 16 *kHz* for HIC, 50 *kHz* for elementary reactions



The upgraded HADES RICH detector







- High electron efficiency due to $N_\gamma \sim 16$ in low noise environment
- Pion suppression of $\sim 10^5$ up to $1\,GeV/c$ momentum
  $\rightarrow$ Electron purity of $P > 99\%$ at low momenta; $P \sim 90\%$ at high momenta
- Recognition of conversion pairs even with opening angle $\alpha = 0°$

$\rightarrow$ Unprecedented precision in dielectron measurements ($S/B \sim 1$)

Dielectron measurements with the HADES

- $\rightarrow$ $Ag + Ag$ at $\sqrt{s_{NN}} = 2.55\,GeV$
- $\rightarrow$ $Au + Au$ at $\sqrt{s_{NN}} = 2.42\,GeV$ (Nat. Phys. V15, p 1040–1045 (2019))
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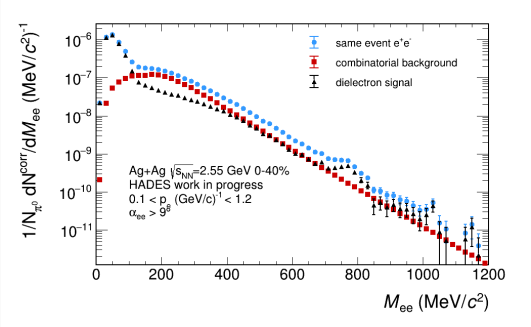
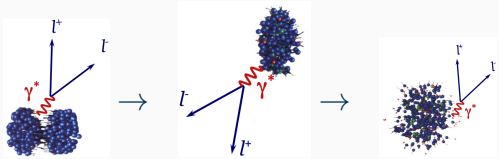
- $\rightarrow$ $p + Nb$ and $p + p$ at $\sqrt{s_{NN}} = 3.18\,GeV$ (j.physletb.2012.08.004)

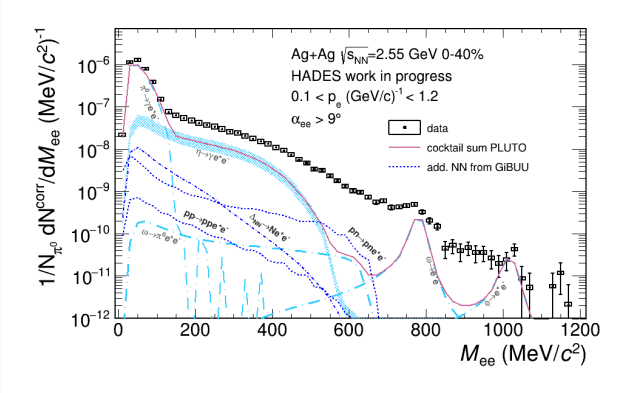
Pair invariant mass distribution





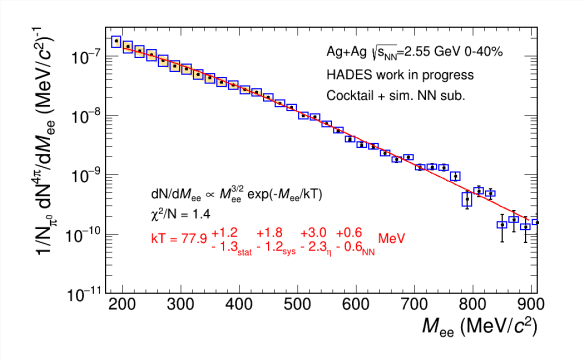
- Efficiency correction based on single electron simulation embedded into real data (in p, θ, ϕ)
- $< BG_{+-} >= 2k\sqrt{< FG_{++} >< FG_{--} >}$
- BG from mixed-event technique for $M_{ee} > 400\, MeV/c^2$
- Dielectron signal consists of virtual photons emitted throughout the whole collision
  - → Access the contribution of the hot and dense phase by subtracting the other contributions

Extracting the in-medium contribution

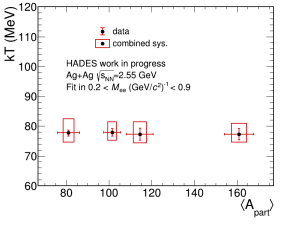


- Initial NN contribution
  - → Use model calculations to compensate for currently missing NN reference
  - → pp and pn simulated using GiBUU 2021 release (Phys. Rept. 512 (2012) 1-124) modeling $NN = 0.54\,pp + 0.46\,pn$ (analogue to Physical Review C, 6, 102.064913)
- Freeze-out hadrons
  - → PLUTO simulations of leptonic decays of relevant hadrons (no $\rho \rightarrow$ in-medium contribution)
  - → Multiplicities measured in same data set
- Strong excess beyond simulated sources

Temperature of the medium

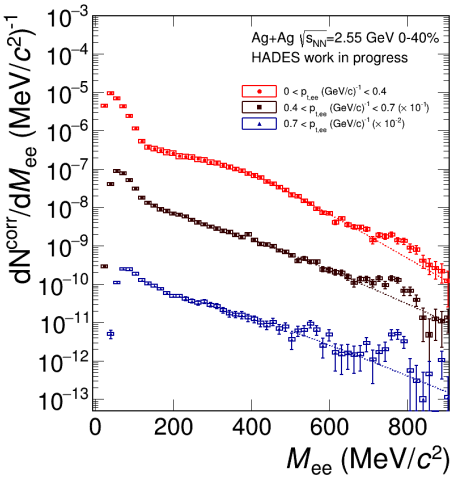


- Subtraction of hadronic cocktail and simulated initial NN contributions reveals excess radiation (Fireball radiation, ρ)
- Acceptance corrected medium radiation looks like thermal
- Mean temperature of the fireball from thermal fit
- Minor temperature dependence on centrality



p_t dependent dielectron spectra

- Perform analysis in bins of transverse pair momentum
- Broad excess over continuum in low momentum data develops into peak structure in high momentum data at $M_{ee} \sim 770\,MeV/c$
  $\rightarrow$ Select for 'in' and 'out' the medium
- High p_t data shows also an enhancement above the continuum at around $M_{ee} \sim 550\,MeV/c^2$
  - Currently under investigation



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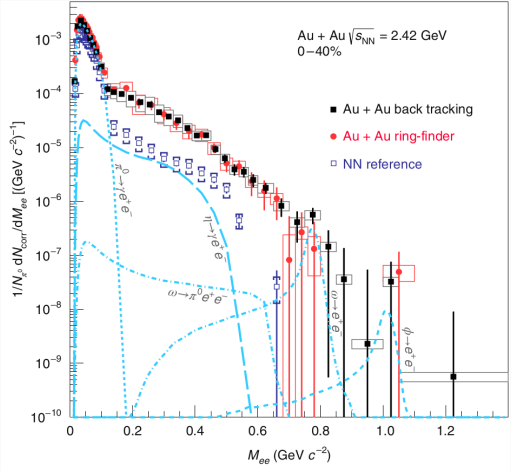
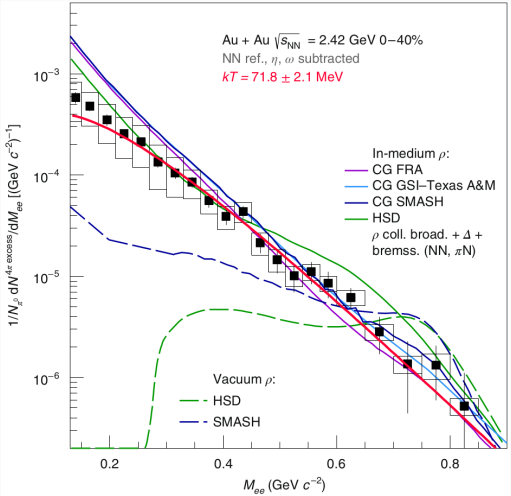
HADES Au+Au measurement

- Analysis performed similarly to presented $Ag + Ag$ data, but data was taken before the RICH upgrade ($S/B \sim 0.1 - 0.2$ instead of $S/B \sim 1$)
- NN reference measured at the same energy by HADES
  $\longrightarrow$extraction of the in-medium contribution straight forward



HADES Au+Au measurement

- Subtraction of NN reference, η (sub-threshold production in A+A) and ω reveals in-medium contribution
- Structureless, near exponential falling spectrum (as in Ag+Ag) indicates a strong medium modification of the ρ meson required in theory to describe the data



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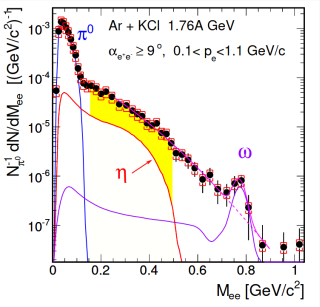
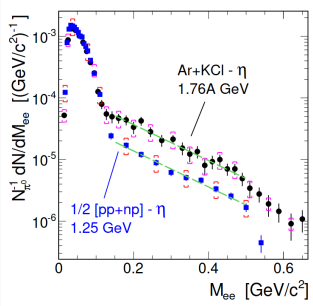
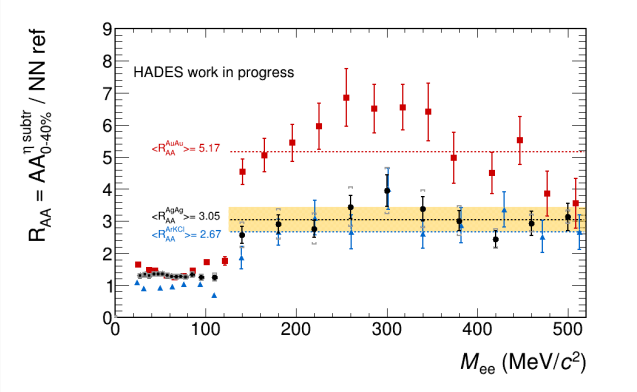


- Data show a clear excess in dielectron production compared to freeze-out hadrons in the intermediate mass region



- Comparison to elementary systems indicates the onset of processes not accounted for in the reference system
- Ar+KCl is not a superposition of NN collisions (differently than C+C)

The dielectron excess ratio R_{AA}



- R_{AA}: Dielectron yield in A+A collisions normalized to elementary reactions
- At small M_{ee} the π^0 Dalitz yield dominates $\rightarrow$ slight excess only
- The dielectron excess observed in A+A collisions in comparison to elementary reactions clearly increases with system size

AuAu, ArKCl data published in Nature Physics volume 15, pages 1040–1045 (2019)

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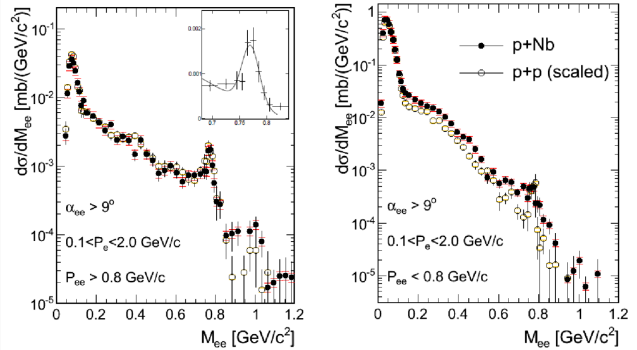
$p + Nb$ and $p + p$ at $\sqrt{s_{NN}} = 3.18\,GeV$



data scaled with the nuclear modification factor R_{pA} for comparison

- High momentum data (left) shows slightly lower dielectron yield in p+Nb compared to p+p due to nuclear absorption of relevant mesons, but identical shape
  $\rightarrow$ Second generation particles have lowered momentum and contribute to low momentum data
- In low momentum data, p+Nb shows a strong excess below the ω pole-mass which is addressed to the ρ
- The $\omega \rightarrow e^+e^-$ peak completely vanishes (as in Ag+Ag) indicating absorption much stronger than feeding from secondary interactions

Summary

- HADES offers a unique possibility to study dilepton production in the high density region of the QCD phase diagram
- The upgraded HADES spectrometer (RICH) allows for high efficient electron identification paired with high pion suppression and conversion recognition
  $\rightarrow$ Unprecedented quality of dielectron spectra
- Extracting the in-medium (ρ) contribution from the dielectron yield allows to study properties of the hot and dense medium
  $\rightarrow$ structureless, near exponential spectrum suggests a thermal production and strong medium modification of the ρ
- The observed excess beyond elementary reactions scales with the system size
- Momentum dependent modifications of the dielectron spectra observed

The HADES collaboration