



RECENT RESULTS OF HADES

Joachim Stroth Goethe University Frankfurt / GSI **YSTAR 2016** NEWPORT NEWS, November 2016



Program

ember 16-17, 2016

Selected results addressing the role of resonances in particle production in heavy-ion collision

- $_{\circ}$ Introduction
- Strangeness production in A+A, p+A, p+p, $+\pi$ A
 - Comparison to statistical hadronization model
 - ... to transport
 - Contribution of ϕ decay to K- yield
- Dielectron production in A+A, p+A, p+p, $+\pi$ A
 - $_{\circ}$ The in-medium ho meson
 - $\circ \rho$ -baryon coupling
- $_{\circ}$ Outlook

Experimental Approach to QCD Phases

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3



LQCD: Z. Fodor et al., hep-lat/0402006 Condensate: B.J. Schaefer and J. Wambach, private communication HADES data: M. Lorenz et al., Nucl. Phys. A (2014) QM14

A. Andronic et al., Nucl. Phys. A 837 (2010) 65 J. Cleymans et al., Phys. Rev. C 60 (1999) 054908





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- µ_B [MeV]
 MADAI.us transitions located at finite net-baryon densities?
- Is there an exotic phase where chiral symmetry is restored but quarks still confined?



The HADES Spectrometer



- $_{\odot}$ Six-coil superconducting toroid (CLAS like,B
 ho < 0.6 Tm)
- $_{\odot}$ Six identically instrumented sectors (2 π in ϕ , 18° < heta < 85°)
- Four planes of low-mass drift-chambers (MDC)
 - lower momentum cut-off 80 MeV/c2
- $_{\odot}$ RICH with solid CSI photo-cathode based UV detector
- $_{\odot}$ Two different time-of-flight systems
 - $_{\odot}~$ 64-fold segmented scintillator rods ($heta > 45^{\circ}$)
 - \circ RPC cells ($\theta < 45^{\circ}$)
- $_{\circ}$ Forward hodoscope (scintillator b
- CVD based t0 detector
- Event rates up to 50 kHz low-multiplicity (8 kHz Au+Au)
 e+e- pair acceptance 35%
- Mass resolution 2 % (r/w region)



HADES combined with π -beam



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- Momentum: 0.6 GeV/c
- Pion tracking with two double-sided silicon strip detectors in the beam line
- Improved conditions in 2018 due to FAIR upgrade
- Intensities (2014 run)
 - Primary beam:
 - > 10¹¹ N (2 AGeV) /spill
 - Secondary p beam:
 - ➢ 10⁶ p-/spill
 - Spill: 4s cycle



HADES Au+Au data

- Beam: 1.5 x 10⁶ Au ions per second
- LVL1 trigger rates of up to 8 kHz 0
 - \succ 7 · 10⁹ events recorded
- LVL1 trigger on 40% most central coll.

d/⁴He

2000

3000









7

strangeness production

(Strange) particle production; Au+Au 1.23A GeV

• All strange hadrons are produced below the free NN threshold: $K^+\Lambda$ (-160 MeV); K^+K^- (-470 MeV) • Canonical suppression applied in THERMUS (R_c), ϕ not affected



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Ξ^- production



Unexpected yield observed in two systems: Ar+KCl, p+Nb
 No signal in Au+Au 1.23 AGeV, too far below threshold



Transport approaches to "sub-threshold" strangeness prod.



- Production through "multi-step" processes
- $_{\odot}$ Three different transport models compared. UrQMD, IQMD, HSD
- Two (IQMD, HSD) have implemented Kaon potentials



11

$_{\odot}$ About 25% of the K^- come from (late) ϕ decay at low energies

 \circ Can be modelled in a SHM using a canonical description (R_c)

 In transport, the observed production can be modelled assuming production through decays of heavy resonances



Extension of the excitation function to lower energies

Sub-threshold strangeness production is a true challenge for transport!

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World data from: C. Blume & C. Markert, Prog. Part. Nucl. Phys. 66 (2011) 834

Strangeness production in p+p (3.5 GeV) collisions

- $_{\odot}$ Can help to constrain unknown cross sections in transport models
- $_{\circ}$ However, medium effects might change the situation substantially already in cold matter
 - Tuned versions usually result in better agreement but do not remove principle model dependences.
- Provides access to exclusive channels (best analyzed using PWA)



Analyses by TUM group



14

dielectrons



e⁺e⁻ Pairs from pp and np Reactions – the DLS puzzle

- HADES has measured inclusive di-electron spectra in elementary collision to provide a reference
- Remarkable iso-spin dependence found at 1.25 GeV beyond trivial effects (dipole)





Theoretical Interpretations of the "Isospin Effect"

- One-boson exchange including radiation from the internal line yields enhanced emission at high invariant masses.
- Can be viewed as off-shell (cloud cloud) $\pi \pi$ collision!



R. Shyam, U. Mosel [arXiv:1003.3343]



M. Bashkanov, H. Clement [arXiv:1312.2810]

Dileptons From Au+Au Collisions (1.23A GeV)

- Strong contribution from the medium, almost exponential distribution
- Driven by in-medium ho decay.







Exclusive reconstruction of $\pi N \rightarrow Ne^+e^-$ reactions



- \circ π -momentum tuned to second resonance region (0.7 Gev/c)
- \circ Resonance decomposition of 2- π channel from PWA (Bonn-Gatchina)
- No further normalization for "predicted" dielectron yield
- Provides axcess to time-like transition formafactors of baryons.



The role of virtual pions in dilepton production

 $_{\odot}$ three different collision systems, three surprises but likely the same underlying mechanism



Inclusive dielectrons from p+p collisions @ 3.5 GeV

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- GiBUU calculation with intermediate ρ mesons R \rightarrow N $\rho \rightarrow$ N e⁺e⁻
- Resonance population from "educated guess"
 - all Res. 10⁰ S₃₁(1620) D₃₃(1700) F₃₅(1905) da/dm_{ee} [µb/GeV] 10⁻¹ 10⁻² 10⁻³ 0.2 0.6 0.8 0.4 0 dilepton mass mee [GeV]

- Inclusive dielectron spectrum
- Dalitz decays strongly suppressed
- $_{\circ}$ $\,$ pure QED from factor for R-decays





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YSTAR 2016, JLAB, Joachim Stroth

π°:	17 ± 2.7 ± 1 mb
Δ:	7.5 ± 1.7 mb
η:	1.14 ± 0.2 mb
ω:	0.273 ± 0.07 mb
ρ:	0.223 ± 0.06 mb

p+Nb:

 ω production suppressed for momenta p < 800 MeV/c







future

HADES FAIR Phase-0 Preparation

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sc-CVD diamond start detector

23

Detector upgrades

- ECAL (PSP 1.1.2.4)
- RICH-700 (synergy with CBM UV detector)
- FW-Tracker (synergy with PANDA straws)
- FW-RPC (detector elements mostly existing)
- MDC-FEE (PSP 1.1.2.4, 1.1.2.5)
- FW-Wall (synergy with CBM PSD)
- **START** (synergy with CBM t_0 detector)

Up to 50 kHz interaction rate, improved electron-id, detection of photons, large acceptance for exclusive processes.

Planned physics runs (2018-2022)

- we anticipate three long runs, i.e.:
 - π+(CH2)n/LH2: baryon electromagnetic transition form factors, baryonic resonances with strangeness.
 - p+A/p+p: strangeness/vector mesons in medium. Hyperon spectroscopy.
 - A+A: medium system size at maximal energy, multi-strange baryons, dileptons.

ECAL based on OPAL lead glass



Secondary pion beam in combination with dilepton spectrometer is world-wide unique!

The HADES collaboration

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- HADES has collected high-statistics data on A+A and elementary collisions, including exclusive channels.
- Au+Au data mark the "lowest-energy" point of the beam-energy scan to explore the QCD phase diagram
- Interesting observations in sub-threshold strangeness production.
 - particle production in agreement with SHM
 - unexpected yield of cascade
- Next at FAIR Phase-0 @ SIS18:
 - 3-4 years running with yet improved spectrometer performance
 - heavy collision systems and pion induced reactions.