In-Medium Properties of Vector Mesons in a Transport Approach

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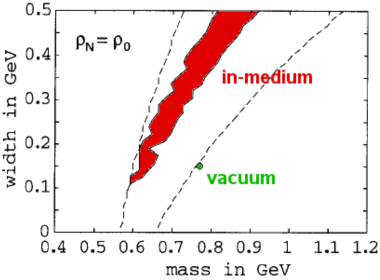
Outline

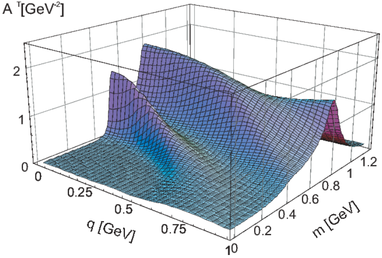
1. motivation: in-medium physics
2. the GiBUU transport model
3. dileptons from HADES:
   p + p @ 3.5 GeV
   p + Nb @ 3.5 GeV
4. conclusions

[not covered here: photoproduction of omega mesons on nuclei, as measured by CB/TAPS, cf. EPJ A47 (2011)]

Motivation: Hadrons in Medium

- how do vector mesons behave inside a hadronic medium?
- Hatsuda/Lee: mass shift $m_V^*(\rho)/m_V \approx 1 - \alpha(\rho/\rho_0)$, $\alpha \approx 0.16 \pm 0.06$
- collisional broadening (LDA): $\Gamma_{coll} = \rho < v_{rel}\sigma_{VN} >$
- extended sum-rule analysis by Leupold/Peters/Mosel, including finite width (NPA 628, 1998)
- coupling to resonances can introduce additional structures in the spectral function (Post, 2003)



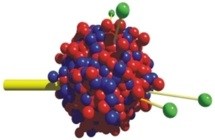


The GiBUU Transport Model

- BUU-type hadronic transport model
- unified framework for various types of reactions (γA, eA, νA, pA, πA, AA) and observables
- BUU equ.: space-time evolution of phase space density

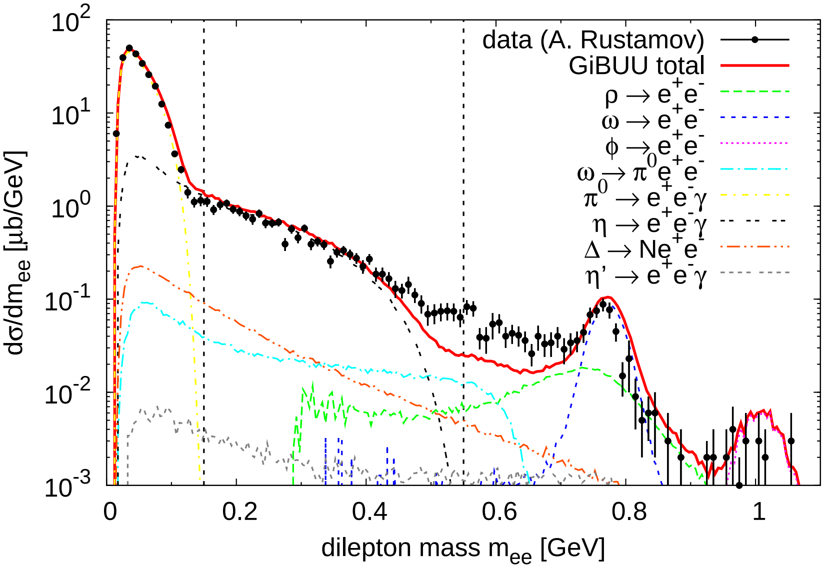
$$\left(\partial_t + (\nabla_{\vec{p}} H_i)\nabla_{\vec{r}} - (\nabla_{\vec{r}} H_i)\nabla_{\vec{p}}\right) f_i(\vec{r}, t, \vec{p}) = I_{coll}[f_i, f_j, ...]$$

- Hamiltonian H_i:
  - hadronic mean fields, Coulomb, "off-shell potential"
- collision term I_{coll}:
  - decays and scattering processes (2- and 3-body)
  - low energy: resonance model, high energy: PYTHIA
- http://gibuu.physik.uni-giessen.de



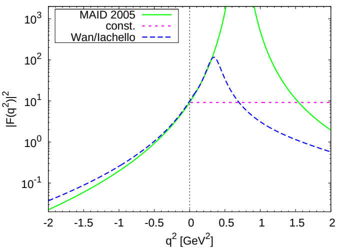
GiBUU
The Giessen Boltzmann-Uehling-Uhlenbeck Project

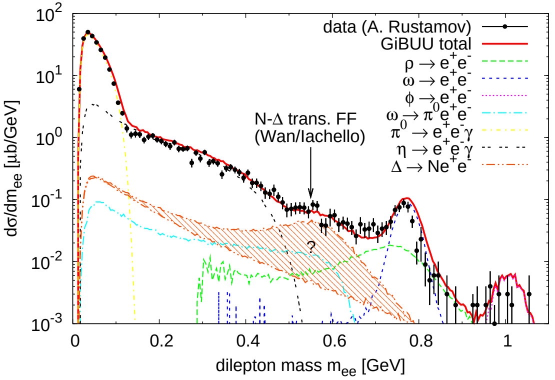
p+p @ 3.5 GeV, mass spectrum



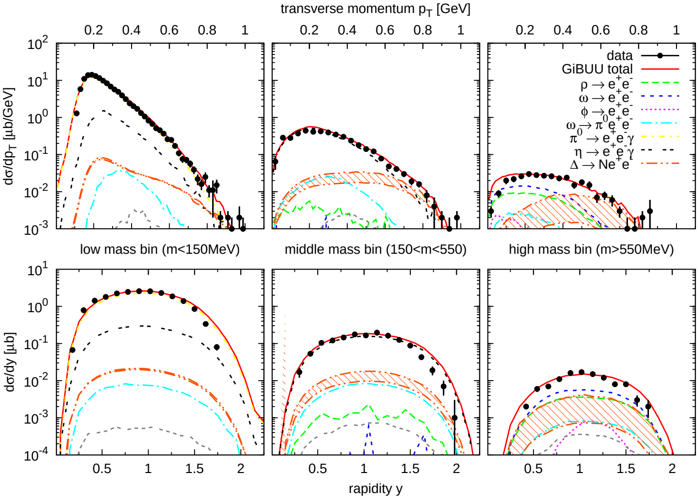
Δ Dalitz decay

- transition form factor $\Delta \to N\gamma^*$
  - space-like region: data from electroproduction
  - basically unknown in time-like region (no data)
- best available guess for time-like region:
  two-component quark model (Wan/Iachello, IJMP A20, 2005)
  $F \sim (1 - \gamma e^{i\theta} q^2)^{-2} \cdot F_\rho(q^2)$





p+p @ 3.5 GeV, p_T and rap. spectra



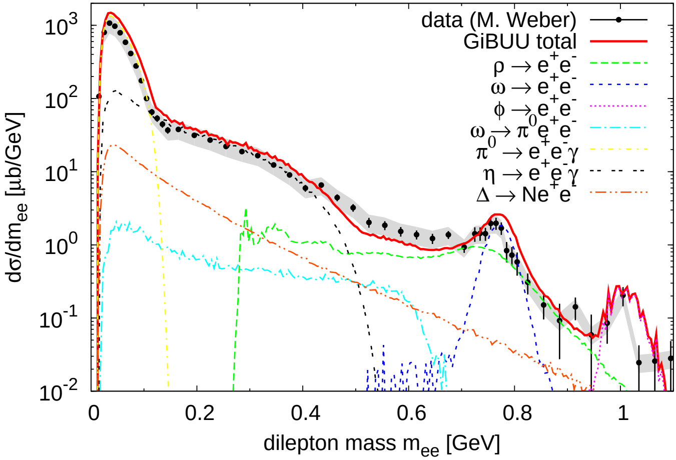
- p_T: perfect agreement (when including Delta FF!)
- small discrepancies at forward rapidity (filtering problem?)

Next Step: p+Nb@3.5 GeV

- cocktail composition basically fixed by p+p
  (elementary cross sections, branching ratios, form factors, ...)
- use p+p as a base line for p+Nb
- additional medium effects:
  1) FSI, absorption, rescattering
  2) secondary production processes
  3) modified spectral functions
- vector mesons in medium:
  ρ: sensitive to direct modification of mass spectrum?
  ω/ϕ: transparency ratio / absorption
- unfortunately p+p still leaves us with some uncertainties
  (largest one: Delta form factor)

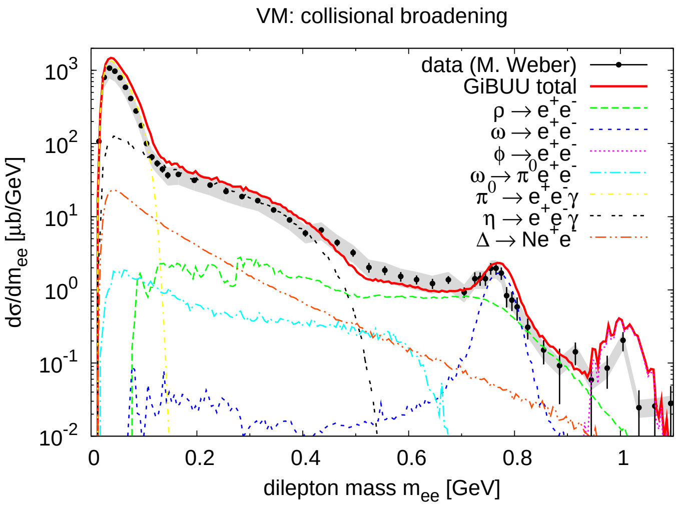
p+Nb@3.5 GeV, mass spectrum

VM: vacuum spectral functions



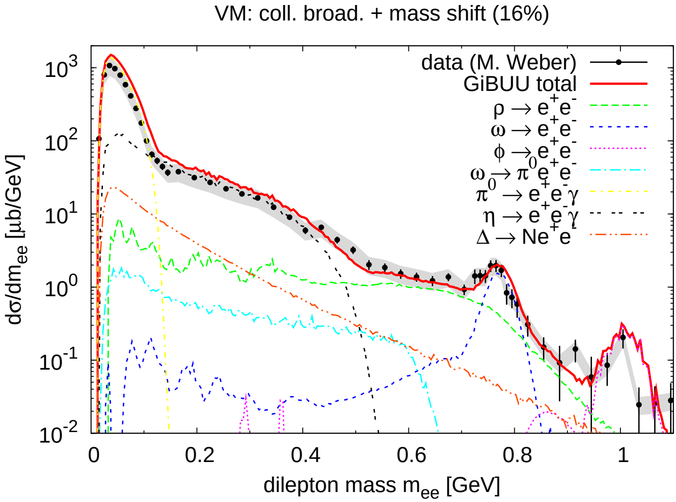
- Delta: no form factor needed
- omega absorption: consistent with TAPS transparency ratio

p+Nb@3.5 GeV, mass spectrum



- consistent treatment of collisional broadening / absorption
- slightly better agreement

p+Nb@3.5 GeV, mass spectrum



- rho strength shifted downward
- even better agreement

Conclusions

1. VM properties in (cold) nuclear matter:
   a challenging problem!

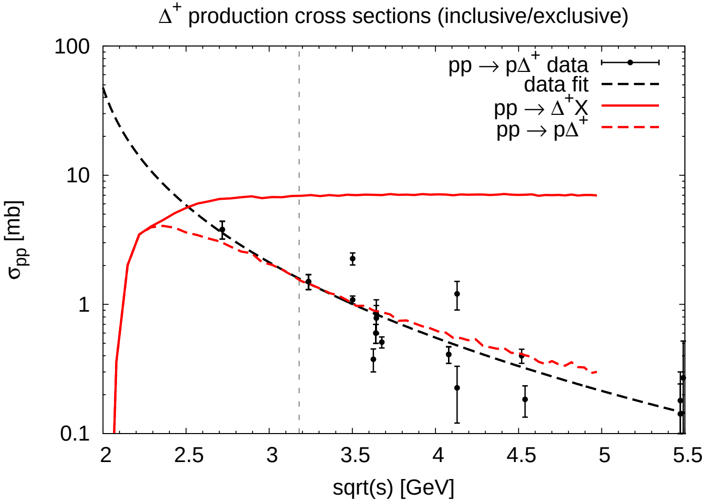
2. GiBUU: a valuable tool to study in-medium physics

3. HADES: we need to understand elementary reactions before we can draw hard conclusions on p+A and A+A

   (in particular: we need to understand the transition form factor of the Delta Dalitz decay)

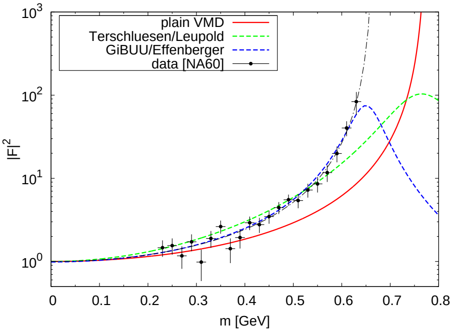
Back-Up Slides

Delta cross section



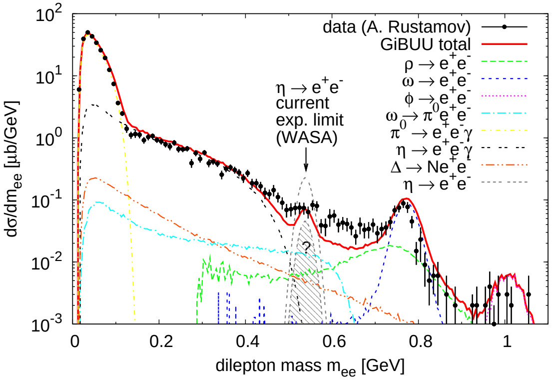
ω Dalitz decay: $\omega \to \pi^0 e^+ e^-$

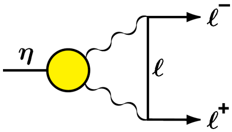
- inclusive ω production cross section fixed by $\omega \to e^+e^-$, BR($\omega \to e^+e^-$) well known: $7.2 \cdot 10^{-5}$
- ω Dalitz branching also well known
- form factor fixed by NA60 data (Arnaldi et al., PLB 677)



DIRECT η DECAY: $\eta \to e^+e^-$

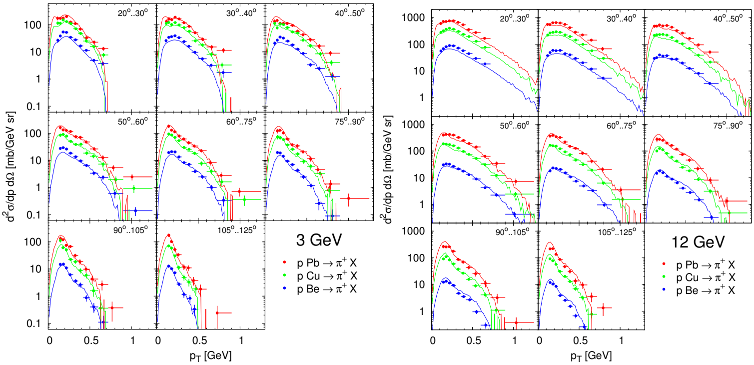
- exp. upper limit (WASA, Berlowski et al., PRD 77, 2008): $BR(\eta \to e^+e^-) < 2.7 \cdot 10^{-5}$
- HADES might be able to push down this limit ...
- theor. prediction (Browder et al., PRD 56, 1997): $BR(\eta \to e^+e^-) \approx 10^{-9}$





Pion Observables

- pions are important for normalization
- can serve as a cross check for dilepton spectra
- GiBUU nicely describes inclusive pion data by HARP (Gallmeister, NPA 826, 2009)



Slow vs. fast sources