Dilepton production at SIS energies with the GiBUU transport model

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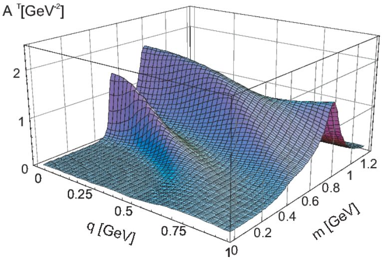
Outline

1. motivation: in-medium physics
2. the GiBUU transport model
3. dileptons from elementary reactions
   p + p, d + p
   p + Nb

   see arXiv:1203.3557 [nucl-th]
4. outlook: heavy-ion collisions
   C + C
   Ar + KCl
5. conclusions

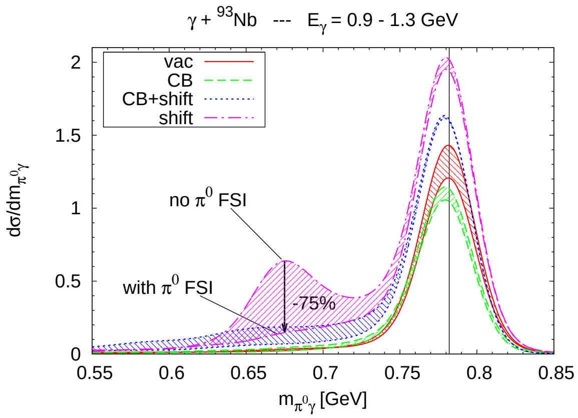
Motivation: Hadrons in Medium

- how do vector mesons behave inside a hadronic medium?
- Brown/Rho, Hatsuda/Lee:
  mass shift (restoration of chiral sym.)
  $m_V^*(\rho)/m_V \approx 1 - \alpha(\rho/\rho_0)$,
  $\alpha \approx 0.16 \pm 0.06$
- collisional broadening (LDA):
  $\Gamma_{coll} = \rho < v_{rel}\sigma_{VN} >$
- QCD sum rules (Leupold, NPA 628, 1998)
- coupling to resonances can introduce additional structures in the spectral function (Post, 2003)



Why Dileptons? No FSI!

- drawback of hadronic decay modes: strong final-state interaction of the decay products
- example: $\omega \to \pi^0 \gamma$ (measured by CBELSA/TAPS in photoproduction experiments)



more on ω photoprod.:

- S. Friedrich, HK 30.4 (Mi)
- F. Dietz, HK 38.3 (Do)

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

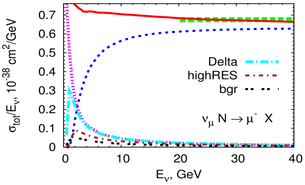
$$\left(\partial_t + (\nabla_{\vec{p}} H_i)\nabla_{\vec{r}} - (\nabla_{\vec{r}} H_i)\nabla_{\vec{p}}\right) f_i(\vec{r}, t, \vec{p}) = I_{coll}[f_i, f_j, ...]$$

- 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
- O. Buss et al., Phys. Rept. 512 (2012),
  http://gibuu.physik.uni-giessen.de

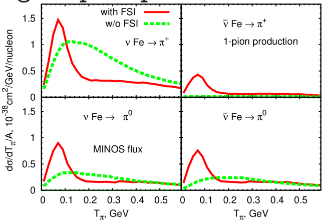
GiBUU
The Giessen Boltzmann-Uehling-Uhlenbeck Project

Neutrinos in GiBUU

$\nu A \rightarrow \ell X$



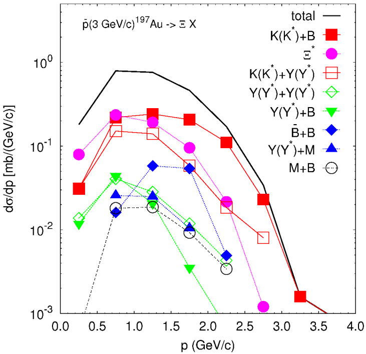
e.g. 1-pion production on Fe



O. Lalakulich, arXiv:1203.2935

Strangeness production in $\bar{p}A$ reactions

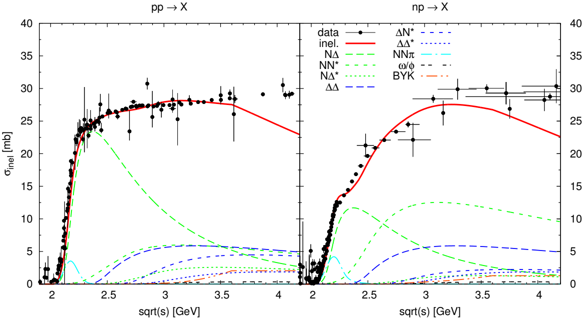
Predictions for PANDA



A. Larionov, HK 39.2 (Do)

- $NN \to NR, \Delta R$ (R : Δ, 7 N^* and 6 Δ^* states)
- based on Teis RM [Z. Phys. A 356, 1997] with several extensions
- resonance parameters and decays taken from Manley/Saleski
- all π, η and ρ mesons produced via R decays (ω, ϕ: non-res.)
- good descr. of total NN cross sections up to $\sqrt{s} \approx 3.5 GeV$

	rating	M_0 [MeV]	Γ_0 [MeV]
$P_{11}(1440)$	****	1462	391
$S_{11}(1535)$	***	1534	151
$S_{11}(1650)$	****	1659	173
$D_{13}(1520)$	****	1524	124
$D_{15}(1675)$	****	1676	159
$P_{13}(1720)$	*	1717	383
$F_{15}(1680)$	****	1684	139
$P_{33}(1232)$	****	1232	118
$S_{31}(1620)$	**	1672	154
$D_{33}(1700)$	*	1762	599
$P_{31}(1910)$	****	1882	239
$P_{33}(1600)$	***	1706	430
$F_{35}(1905)$	***	1881	327
$F_{37}(1950)$	****	1945	300

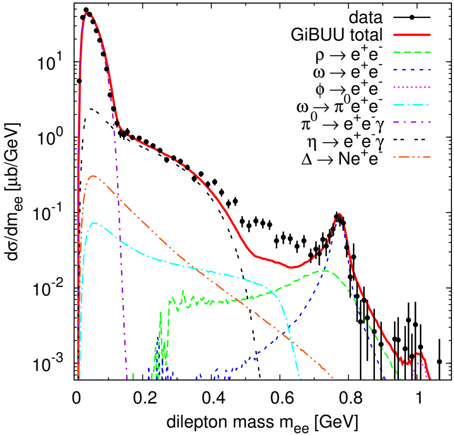


ELEMENTARY REACTIONS

- if we want to investigate in-medium effects, we better make sure we understand the dilepton signal from elementary collisions (in the vacuum)
- this is not a trivial task and represents the most important prerequisite for understanding the heavy-ion collisions
- HADES has measured:
  p+p at 1.25, 2.2 and 3.5 GeV
  d+p at 1.25 GeV

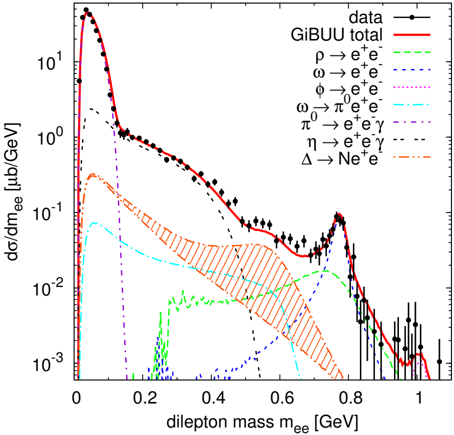
p+p at 3.5 GeV

- first try: using PYTHIA string model
- some tuning needed
- 'gap' at intermediate masses
- question: which process could fill this gap?

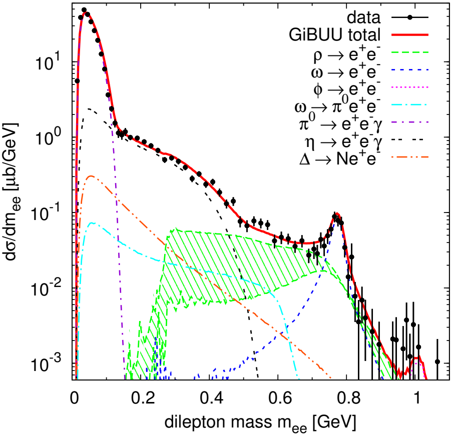


p+p at 3.5 GeV

- use em. transition form factor for Δ Dalitz decay
- naive VMD form factor would overshoot the data
- two-component quark model by Wan/Iachello seems to give a good fit
  [Int. J. Mod. Phys. A 20 (2005)]
- but: is this really a proper model of the Δ FF?

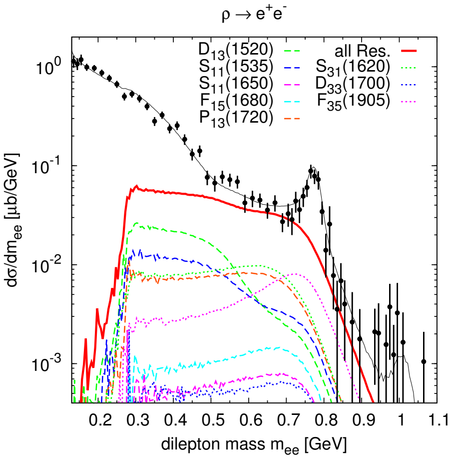


- now: use resonance model
- ρ production via baryonic resonances
- $R \to \rho N \to e^+e^- N$
- low-mass part enhanced by light resonances (and $1/m^3$ factor from dilepton decay width)



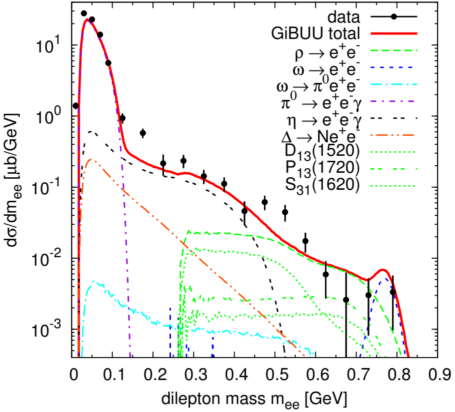
p+p at 3.5 GeV: resonance contributions

- ρ channel is given by a mix of several resonance contributions
- shape depends on the mass of the resonance and angular momentum of the decay
- contributions of single resonances not well constrained, but good agreement in total
- cross check from πN mass spectra needed!

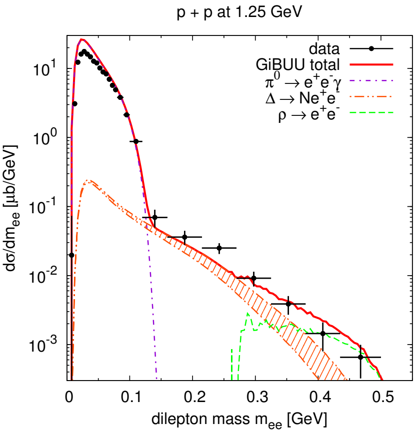


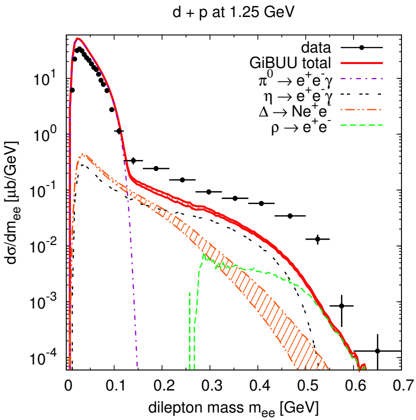
p+p at 2.2 GeV

- again: resonance production gives improvement over phase-space ρ
- but: data suggest that relative strengths of resonance contributions are not quite right
- $D_{13}(1520)$ underestimated, $P_{13}(1720)$ overestimated?



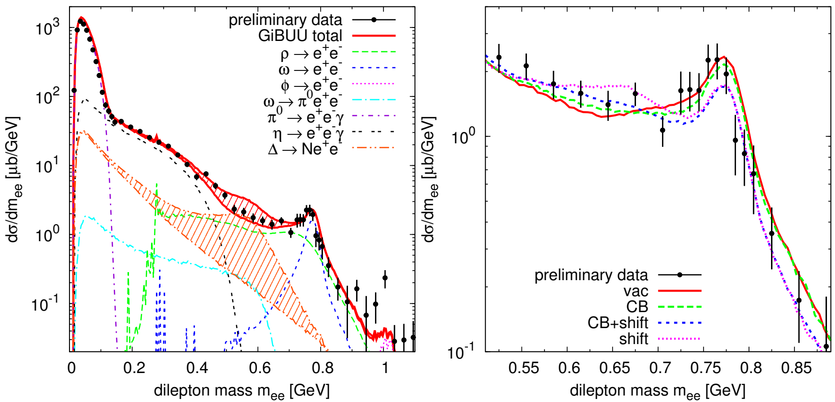
P+P / D+P at 1.25 GeV





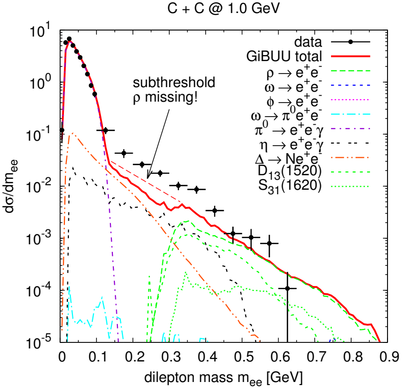
- slight deviation in pion channel (ang. distr.? accept. effects?)
- p+p overall well described, d+p misses factor 2-10
- reason not completely clear, OBE models might help (Shyam)

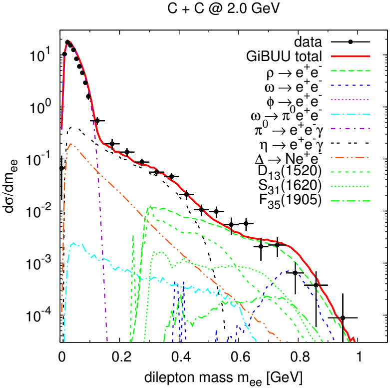
p+Nb at 3.5 GeV



- after p+p@3.5 is fixed: good overall agreement in p+Nb (without Δ FF!)
- moderate medium modifications (VM spectral functions)
- note: data still preliminary

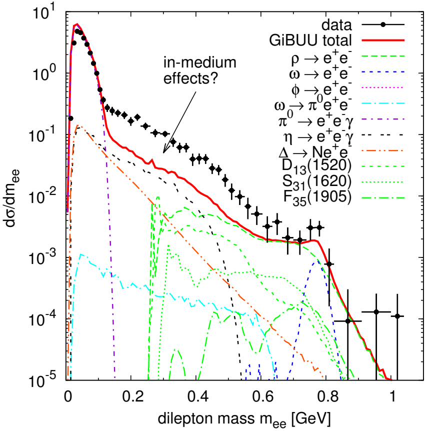
$^{12}C + {}^{12}C$ at 1.0 and 2.0 GeV

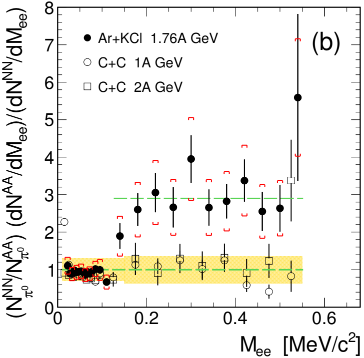




- C+C is a light system, can be described roughly by a superposition of NN collisions
- 2 GeV data well described by GiBUU
- some discrepancies at 1 GeV ("deuteron problem"?)

$^{40}Ar + {}^{39}K^{35}Cl$ at 1.76 GeV





- Ar+KCl seems to show some excess over NN ($\sim$ factor 3)
- GiBUU with vacuum SF: similar discrepancy
  $\Rightarrow$ room for in-medium effects

Conclusions

1. elementary p+p reactions well understood
   with resonance model description
   (higher resonances are important!)

2. some problems remaining in d+p (at low energies)

3. p+Nb: good agreement with data
   (moderate medium modifications)

4. to do for heavy-ion reactions:
   comparison with p_T, y spectra and pion data
   investigation of in-medium effects (VM + Res)
   $^{197}Au + {}^{197}Au$ at 1.25 GeV