Lessons from Justus Liebig and Ulrich Mosel

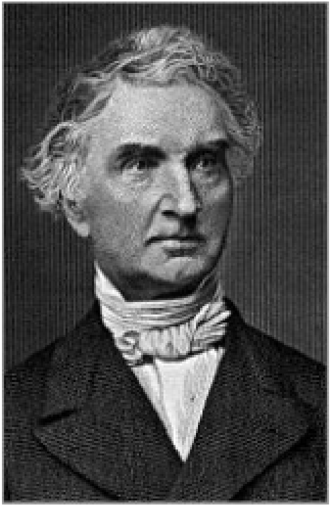
Stefan Leupold

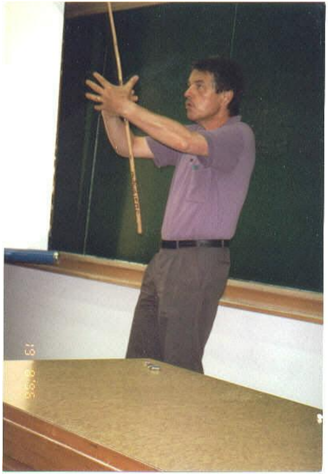
UPPSALA UNIVERSITET

former affiliation: Justus-Liebig-Universität Giessen

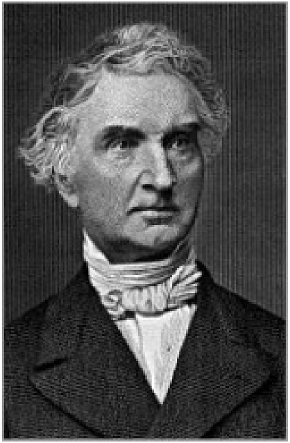
Obergurgl, Austria, Feb. 2011

The academic who is who





Justus von Liebig

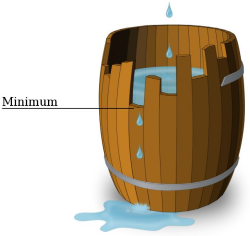


- 1803-1873
- regarded as one of the greatest chemistry teachers of all time
- “father of the fertilizer industry”
- founder of company “Liebig Extract of Meat Company” (bouillon cube)

Liebig's law of the minimum

- principle developed in agricultural science by Carl Sprengel (1828)
- popularized by Justus von Liebig

$\rightsquigarrow$ growth is not controlled by the total of resources available, but by the scarcest resource (limiting factor)



Liebig's barrel

- often also physics is not one-dimensional (observed effect $\not\rightsquigarrow$ unique reason)

$\rightsquigarrow$ side feeding, coupled-channel effects can be important

The anti-Mosel approach

- use simplest possible model which incorporates standard physics

$\hookrightarrow$ does not describe data

$\hookrightarrow$ conclude that you have found new, fancy physics

UPPSALA UNIVERSITET

The anti-Mosel approach

- use simplest possible model which incorporates standard physics

$\hookrightarrow$ does not describe data

$\hookrightarrow$ conclude that you have found new, fancy physics

The Mosel approach

- try as much as possible to describe data by standard effects
- in particular consider side feeding, coupled channels

Table of Contents

Coupled-channel K matrix

- typically hadronic reactions have sizable inelasticities

$\hookrightarrow$ coupled-channel treatment

- take unitarity serious: $S^\dagger S = 1 \qquad (S = 1 + 2iT)$

$\hookrightarrow$ $\mathrm{Im}\, T = T^\dagger T \qquad \Leftrightarrow \qquad \mathrm{Im}\, T^{-1} = -1$

$\hookrightarrow$ use exact relation

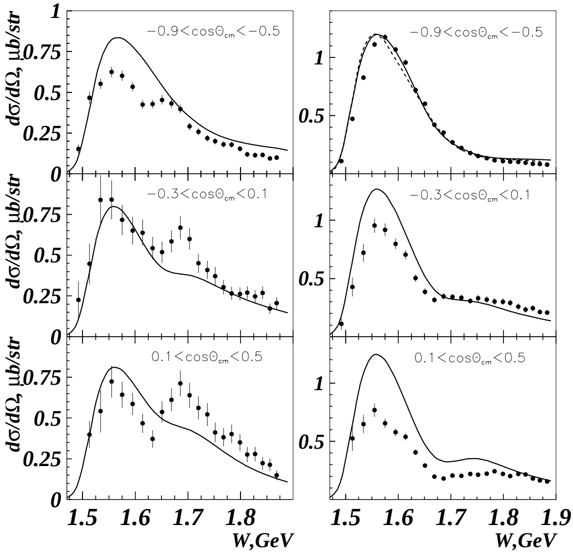
$$T = \frac{1}{K^{-1} - i} = \frac{K}{1 - iK}$$

with two-particle irreducible kernel K
(i.e. $\mathrm{Im}K = 0$ in physical region)

- approximate K by tree-level s-, t- and u-channel processes
- included channels: πN, γN, ηN, ωN, $K\Lambda$,...

Feuster, Penner, Shklyar,...

Photoproduction of η on neutron



Kuznetsov et al., Phys. Lett. B647, 23, 2007

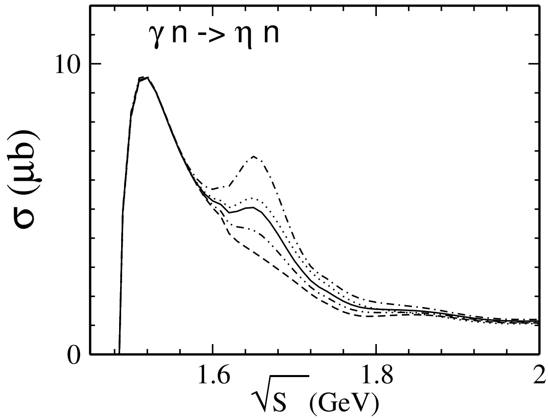
Photoproduction of η on neutron

- peak at about 1.66 GeV for neutron, but not for proton
- Polyakov explanation: pentaquark state
  (non-exotic partner of θ^+ with mass 1.675 GeV)
- experimental complication: deuteron data

$\rightsquigarrow$ partial wave analysis complicated, momentum smearing

Giessen K-matrix explanation

peak is just interplay of conventional $S_{11}(1650)$ and $P_{11}(1710)$



Shklyar, Lenske, UMo, Phys. Lett. B650, 172, 2007

The era of spectral functions

- spectral functions emerge from coupling a single state to a continuum (e.g., decays, scattering)
- interesting aspect: if continuum states have/get also spectral functions

↪ changes induce changes

↪ self consistency important

The era of spectral functions

- spectral functions emerge from coupling a single state to a continuum (e.g., decays, scattering)
- interesting aspect: if continuum states have/get also spectral functions

$\hookrightarrow$ changes induce changes

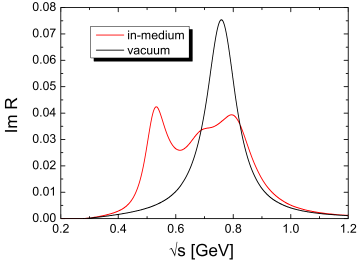
$\hookrightarrow$ self consistency important $\rightsquigarrow$ yes, we can!

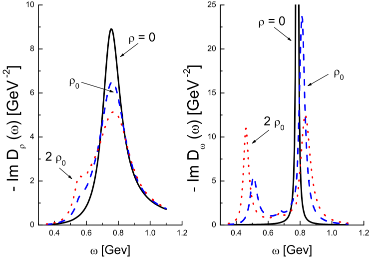
$\hookrightarrow$ Giessen group calculated spectral functions for

- hadron resonances in matter (Post, Mühlich) $\rightsquigarrow$ impact on QCD sum rules
- nucleons in nucleus (Lehr)
- quarks in matter (Frömel)
- quarks in nucleon (Eichstädt $\rightsquigarrow$ previous talk)

Spectral information from many-body theory

Example 1: rho meson in cold nuclear matter





resonance model with parameters from $\pi N \to (2\pi)N$,

Post/Leupold/UMo,

Nucl.Phys.A741 (2004) 81

dynamical generation of resonances,

Lutz/Wolf/Friman,

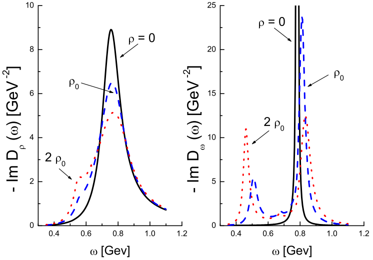
Nucl.Phys.A706 (2002) 431

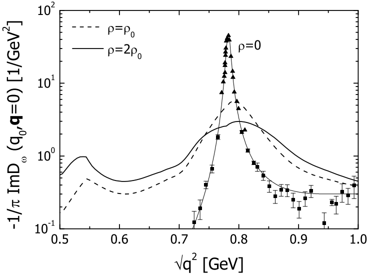
results differ due to different input from/interpretation of elementary reactions (here: strength of coupling ρ-N-$N^*(1520)$)

UPPSALA UNIVERSITET

Spectral information from many-body theory

Example 2: omega meson in cold nuclear matter





dynamical generation of resonances,

Lutz/Wolf/Friman,

Nucl.Phys.A706 (2002) 431

coupled-channel K-matrix

for πN, ωN, $K\Lambda$, . . .

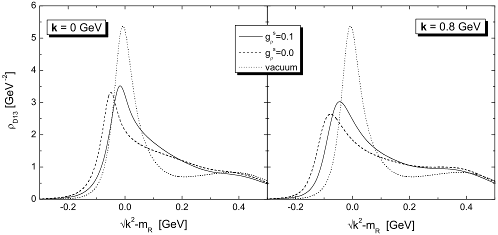
Mühlich/Shklyar/Leupold/UMo/Post,

Nucl.Phys.A780 (2006) 187

similar results (but different from results of other groups . . .)

Spectral information from many-body theory

Example 3: $N^*(1520)$ baryon in cold nuclear matter



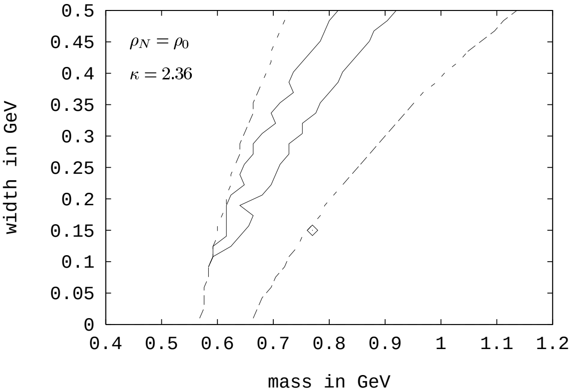
Post/Leupold/UMo,

Nucl.Phys.A741 (2004) 81

- from all examples:
  typically sizable in-medium changes of hadron properties:
  - collisional broadening
  - not much of a mass shift
  - new structures (resonance-hole excitations)

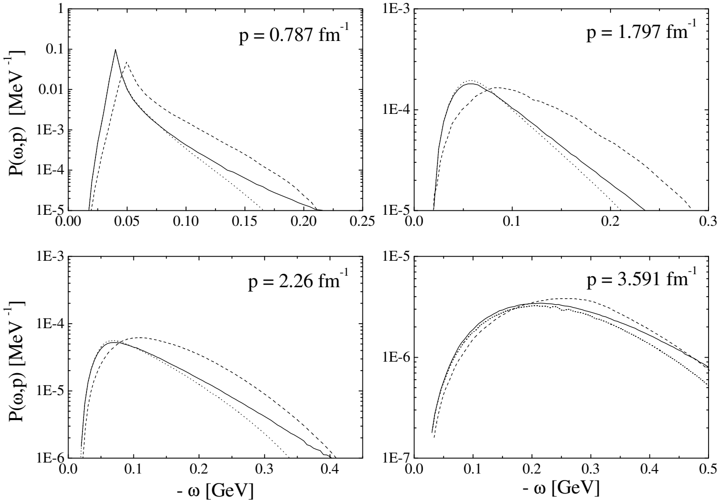
Impact on QCD sum rule analysis

QCD sum rules for rho meson in nuclear medium do not predict mass shift but correlation between mass and width



Leupold, Peters, UMo, Nucl. Phys. A628 (1998) 311

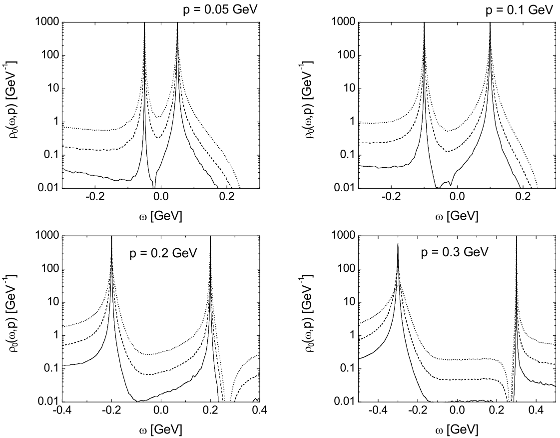
Spectral function for nucleons in nucleus



important finding: details of interaction irrelevant

Lehr, Effenberger, Lenske, Leupold, UMo, Phys. Lett. B483, 324, 2000

Spectral function for quarks in cold matter



interactions
from NJL model

Frömel, Leupold, UMo, Phys. Rev. C67, 015206, 2003

Coupled-channel BUU

The anti-Mosel approach

- use simplest possible model which incorporates standard physics

$\hookrightarrow$ does not describe data

$\hookrightarrow$ conclude that you have found new, fancy physics

The Mosel approach

- try as much as possible to describe data by standard effects
- in particular for reactions on nuclei consider side feeding, coupled channels, final-state interactions

Coupled-channel BUU

The anti-Mosel approach

- use simplest possible model which incorporates standard physics

$\hookrightarrow$ does not describe data

$\hookrightarrow$ conclude that you have found new, fancy physics

The Mosel approach

- try as much as possible to describe data by standard effects
- in particular for reactions on nuclei consider side feeding, coupled channels, final-state interactions

$\leadsto$ transport theory, GiBUU

Transport theory

describe, e.g., $\gamma + A \to h + X$ by transport theory

- succession of single scattering events, e.g.
  - $\gamma + N_1 \to h + X,\ h + N_2 \to h + N_2, \ldots \rightsquigarrow$ rescattering
  - $\gamma + N_1 \to h' + X,\ h' + N_2 \to h + X, \ldots \rightsquigarrow$ cross feeding
- definitely appropriate for (very) low densities
- can account for finite size of medium (nucleus) and finite duration of reaction
- coupled-channel treatment (cross feeding)
- beyond Glauber (non straight-line, cross feeding), but no quantum interference between different scatterings

one particular model:

The Giessen Boltzmann-Uehling-Uhlenbeck transport model

Institut für Theoretische Physik, JLU Giessen

GiBUU

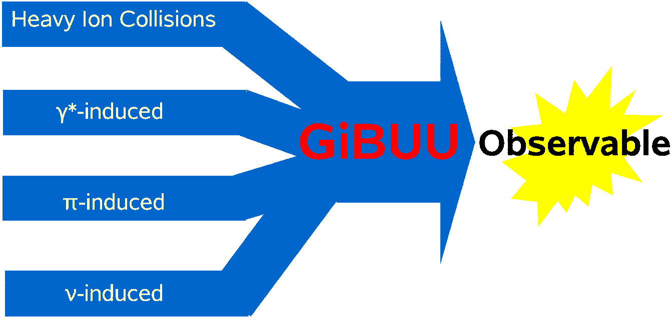
The Giessen Boltzmann-Uehling-Uhlenbeck Project

The GiBUU transport model

- input: elementary reaction rates

$\hookrightarrow$ theoretical and experimental understanding of elementary reactions mandatory

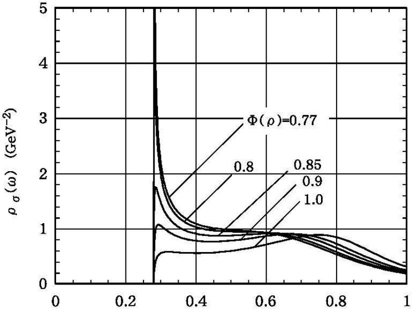
- universal framework for various observables



Example: sigma meson

- suppose sigma and pion (chiral partners) become degenerate at chiral restoration

↪ sigma mass drops and width shrinks (limited phase space)
(with increasing density ρ and dropping order parameter $\Phi(\rho)$)



Hatsuda/Kunihiro/Shimizu, Phys.Rev.Lett.82 (1999) 2840

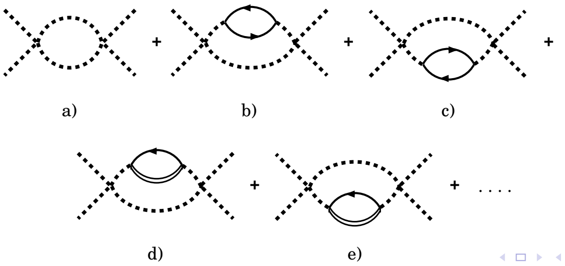
Sigma meson in nuclear matter

- dropping mass model predicts that spectral strength of sigma meson moves downwards

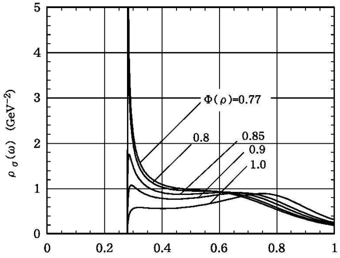
  (Hatsuda/Kunihiro/Shimizu, Phys.Rev.Lett.82 (1999) 2840)

- alternative scenario with same qualitative result:
  - sigma meson dynamically generated in pion-pion scattering
  - dressing of pions by resonance-hole loops,... shifts strength downwards

  (Chiang/Oset/Vicente-Vacas, Nucl.Phys.A644 (1998) 77)

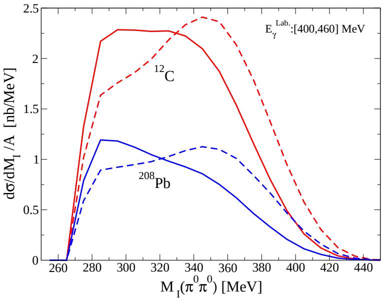


Double pion production and sigma meson



Hatsuda/Kunihiro/Shimizu,

Phys.Rev.Lett.82 (1999) 2840



Roca/Oset/Vicente-Vacas,

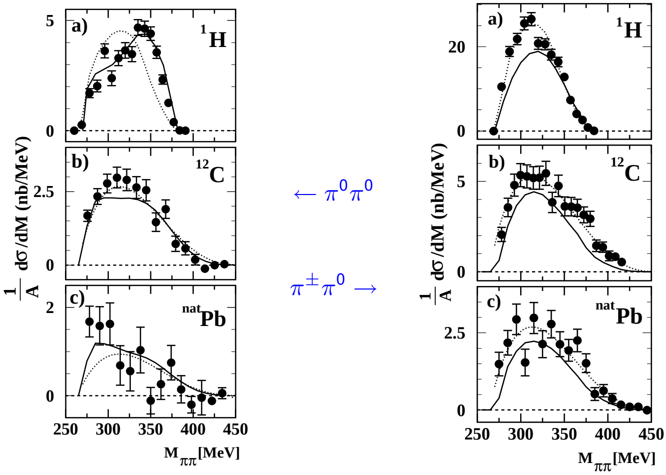
Phys.Lett. B541 (2002) 77

expect to see downward shift in $\pi^0\pi^0$, but not in $\pi^\pm\pi^0$

UPPSALA UNIVERSITET

Double pion production and sigma meson II

expect to see downward shift in $\pi^0\pi^0$, but not in $\pi^\pm\pi^0$



TAPS@MAMI, Phys.Rev.Lett.89 (2002) 222302

Double pion production and sigma meson III

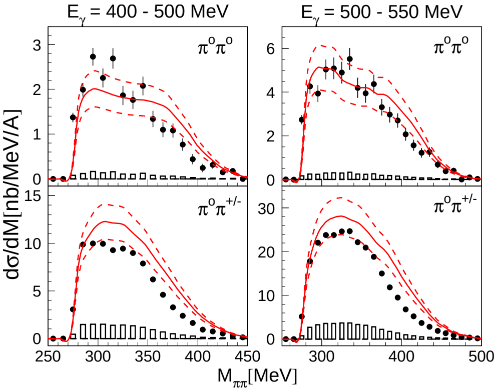
- alternative (transport) scenario: scattering of pions in the medium shifts strength downwards

$\hookrightarrow$ should be similar for $\pi^0\pi^0$ and $\pi^\pm\pi^0$

Double pion production and sigma meson III

- alternative (transport) scenario: scattering of pions in the medium shifts strength downwards

$\hookrightarrow$ should be similar for $\pi^0\pi^0$ and $\pi^\pm\pi^0$



experiment:

$\gamma+^{40}$Ca, TAPS@MAMI,

Eur.Phys.J.A32 (2007) 219

theory:

Buss et al. (GiBUU),

Eur.Phys.J.A29 (2006) 189

BUU summary

- one should be cautious with claims that fancy in-medium effects are seen (dropping masses, many-body effects, . . .)

$\hookrightarrow$ first check if there is mundane explanation by standard transport theory (successive scatterings)

$\hookrightarrow$ need sophisticated transport approach, in particular
  - precise elementary input (e.g. also reactions on neutrons)
  - one code which describes many reactions (γA, πA, pA, AA)

- input for transport and for many-body field theory: elementary reaction rates

$\hookrightarrow$ theoretical and experimental understanding of elementary reactions mandatory

UPPSALA UNIVERSITET

Decoupling theorem

- first met Ulrich in 1992 at GSI theory workshop ("Rauischholzhausen workshop") in Rauischholzhausen

Decoupling theorem

- first met Ulrich in 1992 at GSI theory workshop ("Rauischholzhausen workshop") in Rauischholzhausen
- same time: European soccer championship 1992

Decoupling theorem

- first met Ulrich in 1992 at GSI theory workshop ("Rauischholzhausen workshop") in Rauischholzhausen
- same time: European soccer championship 1992 ("We are red, we are white, we are Danish dynamite")

Decoupling theorem

- first met Ulrich in 1992 at GSI theory workshop ("Rauischholzhausen workshop") in Rauischholzhausen
- same time: European soccer championship 1992 ("We are red, we are white, we are Danish dynamite")

- decoupling theorem: In every conceivable Universe Ulrich and soccer are uncorrelated.

Decoupling theorem

- first met Ulrich in 1992 at GSI theory workshop ("Rauischholzhausen workshop") in Rauischholzhausen
- same time: European soccer championship 1992 ("We are red, we are white, we are Danish dynamite")
- decoupling theorem: In every conceivable Universe Ulrich and soccer are uncorrelated.
- prediction: Whatever Ulrich will do during his retirement, it will not be soccer.

Summary

Lessons from Ulrich:

- coupled-channel effects are important
- think twice,

Summary

Lessons from Ulrich:

- coupled-channel effects are important
- think twice, i.e. do not get swept away with the wave of enthusiasm about fancy new physics
- work hard to find mundane explanations

Summary

Lessons from Ulrich:

- coupled-channel effects are important
- think twice, i.e. do not get swept away with the wave of enthusiasm about fancy new physics
- work hard to find mundane explanations
- do not become a “Fachidiot”
  - change research topic after some time
  - see and use cross relations:

  $\rightsquigarrow$ one transport code for many reactions

  $\rightsquigarrow$ elementary hadron and in-medium physics

Summary

Lessons from Ulrich:

- coupled-channel effects are important
- think twice, i.e. do not get swept away with the wave of enthusiasm about fancy new physics
- work hard to find mundane explanations
- do not become a "Fachidiot"
  - change research topic after some time
  - see and use cross relations:
  - ⇝ one transport code for many reactions
  - ⇝ elementary hadron and in-medium physics
- stress your own work —

Summary

Lessons from Ulrich:

- coupled-channel effects are important
- think twice, i.e. do not get swept away with the wave of enthusiasm about fancy new physics
- work hard to find mundane explanations
- do not become a “Fachidiot”
  - change research topic after some time
  - see and use cross relations:
  - $\rightsquigarrow$ one transport code for many reactions
  - $\rightsquigarrow$ elementary hadron and in-medium physics
- stress your own work — sorry, I failed again