Dilepton Production in γA and pA reactions

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Outline

- Introduction
- Physics Motivation
- Experimental Situation
- Calculating Dilepton Spectra
- My Results (so far)
- Offshell Transport
- Outlook/To-Do

Introduction

- aim: study e^+e^- spectra from elementary nuclear reactions (γ- and p-induced) to learn about in-medium properties of vector mesons
- active experiments: g7@JLAB, E325@KEK, HADES@GSI
- NOT discussed here: heavy-ion collisions
- advantages of elementary collisions:
  - cleaner environment, nucleus close to ground state
  - defined density, predicted effects are large enough at ρ_0
- also NOT discussed: hadronic decays of vector mesons
- advantage of dileptons: interact only electromagnetically, undisturbed by strong nuclear forces
  $\Rightarrow$ can carry in-medium information outside
  (only small Coulomb corrections)

The Hadronic Cocktail

hadronic sources contributing to the dilepton spectrum:

direct decays:

- $\rho^0 \longrightarrow e^+e^-$
- $\omega \longrightarrow e^+e^-$
- $\phi \longrightarrow e^+e^-$

Dalitz decays:

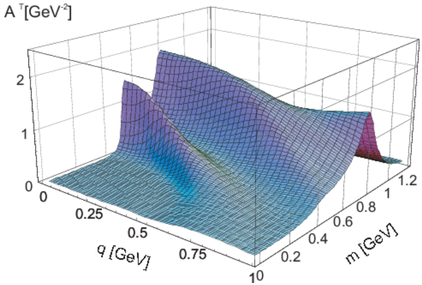
- $\omega \longrightarrow \pi^0 e^+e^-$
- $\pi^0 \longrightarrow e^+e^-\gamma$
- $\eta \longrightarrow e^+e^-\gamma$
- $\Delta \longrightarrow Ne^+e^-$

plus "non-hadronic" contributions:

- Bethe-Heitler process: $\gamma N \longrightarrow Ne^+e^-$
  (direct photoproduction of a lepton pair)
- ...

Physics Motivation

- investigate in-medium properties of vector mesons
- theoretical predictions:
  - collisional broadening
  - mass drop

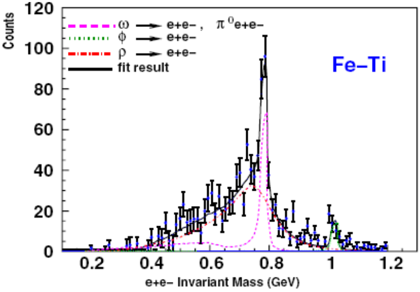


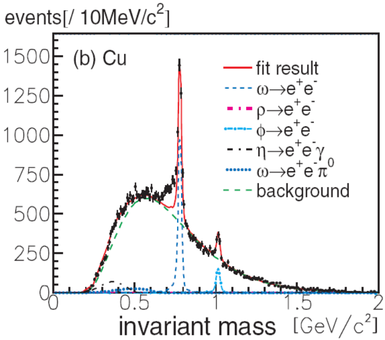
- Brown/Rho (effective Lagrangian approach):
  $m_V^*(\rho_0)/m_V \approx 0.8$
- Hatsuda/Lee (using QCD sum rules):
  $m_V^*(\rho)/m_V \approx 1 - \alpha(\rho/\rho_0)$, $\alpha \approx 0.16 \pm 0.06$
  $\leftrightarrow$ (partial) chiral symmetry restoration in medium?

G7@JLAB vs. E325@KEK

- $\gamma A \rightarrow e^+e^-X$
- $E_\gamma \approx 0.6...3.8 GeV$
- no significant mass shift: $\alpha = 0.02 \pm 0.02$
- consistent with collisional broadening

- $pA \rightarrow e^+e^-X$
- 12 GeV protons
- mass shift: $\alpha = 0.092 \pm 0.002$
- no broadening!





Calculating Dilepton Spectra

- easiest case: γp reaction (elementary process)
- mass-differential cross section for $\gamma p \to VX \to e^+e^-X$:

$$\frac{d\sigma}{d\mu} = \sigma_{\gamma N \to VX}(s) 2\mu \mathcal{A}_V(\mu) \frac{\Gamma_{V \to e^+e^-}(\mu)}{\Gamma_V(\mu)}$$

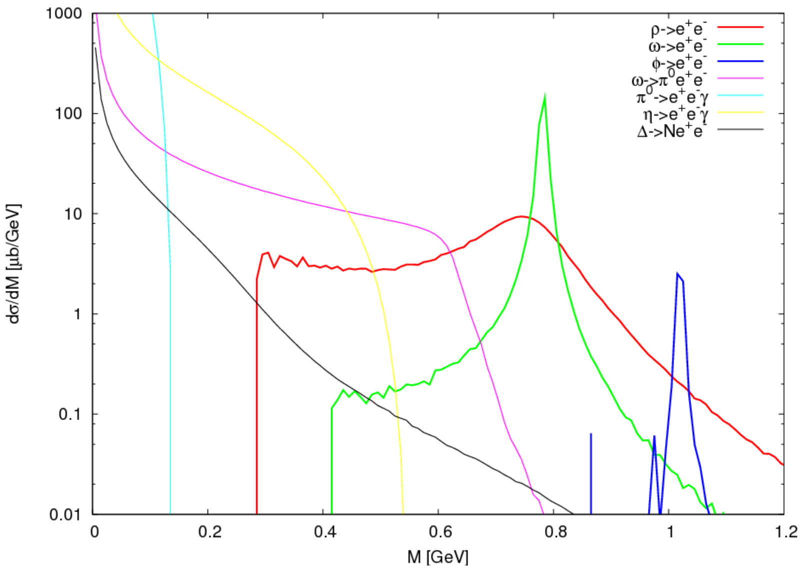
- $\sigma_{\gamma N \to VX}(s)$: inclusive photoproduction of a VM
- $V \to e^+e^-$ decay width (from VMD):

$$\Gamma_{V \to e^+e^-}(\mu) = C_V \frac{m_V^4}{\mu^3}$$

- on a nucleus (using GiBUU transport model):

$$\frac{dN_{V \to e^+e^-}}{d^3p\,d\mu} = \int_0^\infty dt\,d^3r \frac{1}{(2\pi)^3} F_V(\vec{r}, t, \vec{p}, \mu) \frac{\Gamma_{V \to e^+e^-}(\mu)}{\gamma}$$

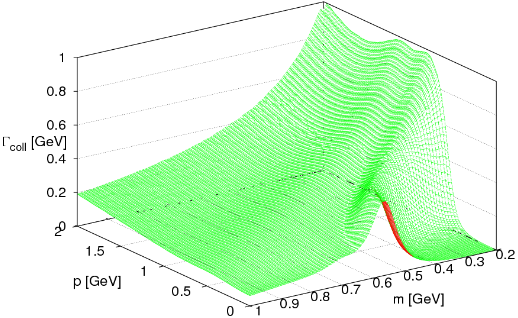
$p + {}^{12}C$ @ 12GeV



ρ->e+e-
ω->e+e-
ϕ->e+e-
ω->π0e+e-
π0->e+e-γ
η->e+e-γ
Δ->Ne+e-
dσ/dM [μb/GeV]
1000
100
10
1
0.1
0.01
0
0.2
0.4
0.6
0.8
1
1.2
M [GeV]

Collisional Broadening

- in medium: $\Gamma_{tot} = \Gamma_{vac} + \Gamma_{coll}$
- $\Gamma_{coll} = \rho < v_{rel}\sigma_{VN} >$
- assumptions: infinite nuclear matter, low density, T=0
- in practice: calculate this once for each particle and put it in a discrete 4-dim. lookup table: $\Gamma_{coll}(m, |\vec{p}|, \rho_p, \rho_n)$



Off-Shell Transport

- usually: off-shell term neglected in BUU equation ($\rightarrow$ particles propagate with fixed mass)
- when in-medium effects are included, particles need to come back to their 'mass shell' in vacuum
- off-shell term is simulated by an 'off-shell potential':

$$m = m_0 + \Delta\mu$$

$$\Delta\mu(\vec{r},\vec{p}) = \Delta\mu(\vec{r}_0,\vec{p}_0)\frac{\Gamma_{tot}(\vec{r},\vec{p})}{\Gamma_{tot}(\vec{r}_0,\vec{p}_0)}$$

- simplified approach (used earlier):

$$\Delta\mu(\vec{r}) = \Delta\mu(\vec{r}_0)\frac{\rho(\vec{r})}{\rho(\vec{r}_0)}$$

Outlook / To-Do List

- implement more $\gamma N \to X$ channels (backgrounds)
- finish off-shell transport
- investigate the influence of in-medium effects on the dilepton spectrum
- compare with data: KEK, HADES
  (requires applying their cuts & acceptance)
- resolve discrepancy in interpretation of JLAB and KEK data?