Study of the ω mesons photoproduction off nuclei with the Gluex detector
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Abstract

We propose to study the photoproduction of ω mesons on complex nuclei with the GlueX detector in the photon beam energy range between 5 GeV and 9 GeV.
Production of ω's in coherent photoproduction $\gamma A \to \omega A$ provides a possibility to measure the total cross section of transversely polarized ω mesons with nucleon $\sigma_T(\omega N)$.
The investigation of incoherent photoproduction $\gamma A \to \omega A'$ (A' - nuclear excitation or its break-up products) allows one to extract the total cross section of the longitudinally polarized ω mesons with nucleon $\sigma_L(\omega N)$, which has not yet been measured!!!
We plan to measure the spin density matrix elements of ω mesons on various nuclei, which provides an opportunity to estimate the value of $\sigma_L(\omega N)$.

Outline

1) Introduction
2) ω mesons photoproduction in coherent region and extraction of the total cross section of transversely polarized mesons interaction with nucleons $\sigma_T(\omega N)$.
3) ω mesons photoproduction in incoherent region and extraction of the total cross section of longitudinally polarized mesons with nucleons $\sigma_L(\omega N)$.
4) Summary

Introduction

In the late 60's and early 70's many experiments on vector mesons $V(\rho, \omega, \phi)$ photoproduction off nuclei $\gamma + A \to V + A$ have been done at SLAC,DESY,Cornell etc. Such type investigations allows to check the predictions of vector dominance model (VDM) and quark model, which for instance predict $\sigma(\rho N) = \sigma(\omega N) = \frac{\sigma(\pi^+ N) + \sigma(\pi^- N)}{2}$

The vector particle can be trasversely $\lambda = \pm 1$ or longitudinally $\lambda = 0$ polarized. The challenge of polarization impact on strong interaction at that time does not even considered.

Why!!! The reasons look as follows:

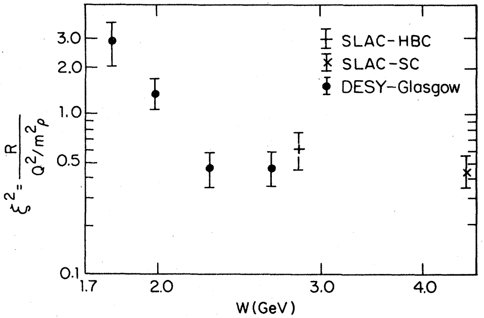
1) In the naive quark model the total cross sections considered as independent of vector meson polarization $\sigma_T(VN) = \sigma_L(VN)$.

2) In the coherent photoproduction only tranverse vector mesons can be produced. As the coherent photoproduction is huge and has clear and unique theoretical predictions the extraction of $\sigma(VN)$ has been done from this part of the cross section.

3)As to the incoherent region to extract $\sigma_L(VN)$ one has to pick out the process, where the bulk of longitudinally vector mesons produced, which is not the case for ρ, φ photoproduction where s-channel helicity conservation takes place.

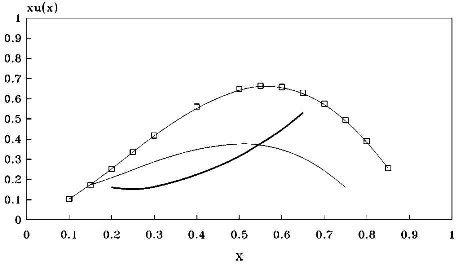
The first indications that interactions of vector mesons with nucleon depend on its polarization come from the ρ and φ electroproduction on protons. The ratio of the production cross section can be represented as $R = \frac{\sigma(\gamma_L p \to V_L p)}{\sigma(\gamma_T p \to V_T p)} = \xi^2 \frac{Q^2}{m_\rho^2}$, where the parameter ξ^2 corresponds to the ratio of longitudinal to transverse ρ^0 total cross sections $\xi^2 = \frac{\sigma_L(\rho p)}{\sigma_T(\rho p)}$.

The same quantity for φ meson: $\xi^2 = 0.33 \pm 0.08$



Valence quark distributions and vector mesons polarization

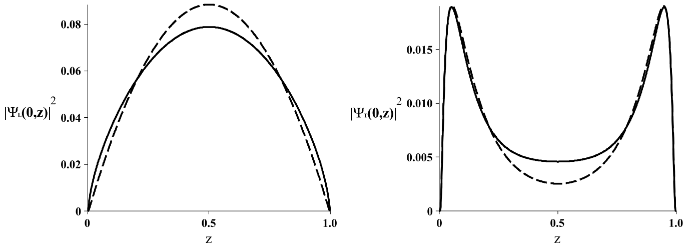
As was shown by B.Ioffe and A.Oganesian (Phys. Rev. D63,09606,2000) the distribution of valence quarks in the transversely and longitudinally polarized vector mesons is significantly different, which should lead to different interactions of polarized mesons with nucleons.

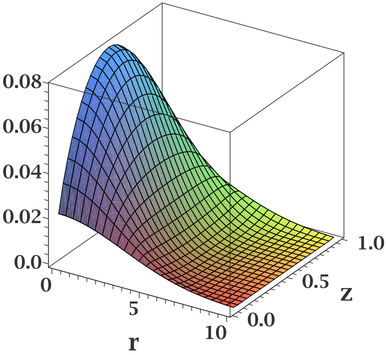


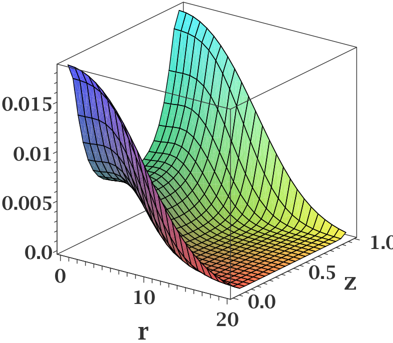
Constituent quarks distribution in vector meson and it polarization

J.Forshaw and R.Sandapen (JHEP 11,037,2010; Phys.Rev. Lett. 109,081601,2012)
Dipole model of strong interaction.

$$\sigma^{L(T)}(VN) = \int |\Psi^{L(T)}(r,z)|^2 \sigma(r) d^2 r dz$$




0.08
0.06
0.04
0.02
0.0
0
5
10
r
0.0
0.5
1.0
z


0.015
0.01
0.005
0.0
0
10
20
r
0.0
0.5
z

ω photoproduction in coherent process $\gamma A \to \omega A$

Why omega?
In ρ, φ photoproduction on nucleon at small momentum transfer mesons are transversely polarized as a photon $\lambda = \pm 1$ (S-channel helicity conservation). On the other hand in $\gamma + N \to \omega + N$ at JLab energies the essential contribution gives the pion exchange. For instance at $E_\gamma = 5 GeV$ the contribution of pion exchange and diffraction (Pomeron exchange) are almost equal.Unlike diffraction the pion exchange leads to copious production of longitudinally polarized omega mesons.
On the other hand amplitudes with exchange of particle with isotopic spin one (pion in our case) has different signs in photoproduction on proton and neutron. Thus in coherent production where one has to sum the elementary production amplitudes the contribution of pion exchange cancelled, which leads to production of only transversely polarized omega mesons.
Thus from the absorption of ω's in the coherent photoproduction one can extract only $\sigma_T(\omega N)$.

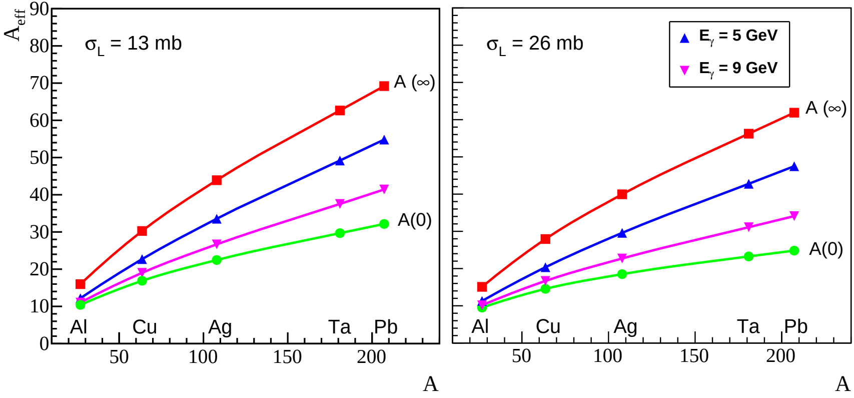
ω photoproduction in incoherent process $\gamma A \to \omega A'$

$$\frac{d\sigma_A(q)}{dt} = \frac{d\sigma_0(q)}{dt}(\rho_{00}N(0,\sigma_L) + (1-\rho_{00})N(0,\sigma_T))$$
$$N(0,\sigma) = \int \frac{1-\exp(-\sigma\int\rho(b,z)dz)}{\sigma}d^2b$$

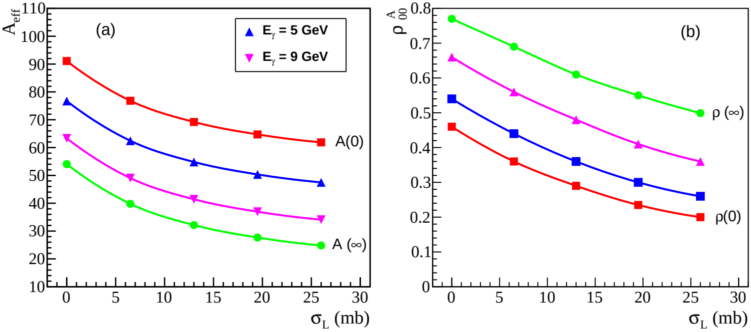
$\frac{d\sigma_0(q)}{dt}$, ρ_{00}-nucleon. If $\sigma_T = \sigma_L$ the nuclear transparency gets the well known form $A_{eff} = \frac{d\sigma_A}{dt}/\frac{d\sigma_0(q)}{dt} = N(0,\sigma)$. The relation between the spin density matrix elements in photoproduction off nuclei ρ^A_{00} and nucleons ρ_{00} in this approach reads:

$$\rho^A_{00} = \frac{N(0,\sigma_L)}{\rho_{00}N(0,\sigma_L) + (1-\rho_{00})N(0,\sigma_T)}\rho_{00}$$

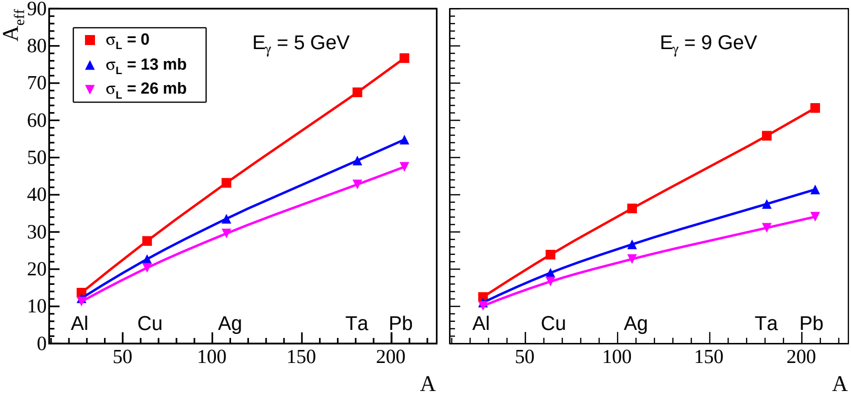
If $\sigma_T = \sigma_L$ the spin density matrix elements on nucleon and nuclei are the same. On the other hand the dependence of the ρ^A_{00} on mass number A indicates that the interaction of vector mesons with different polarizations with matter is diverse.



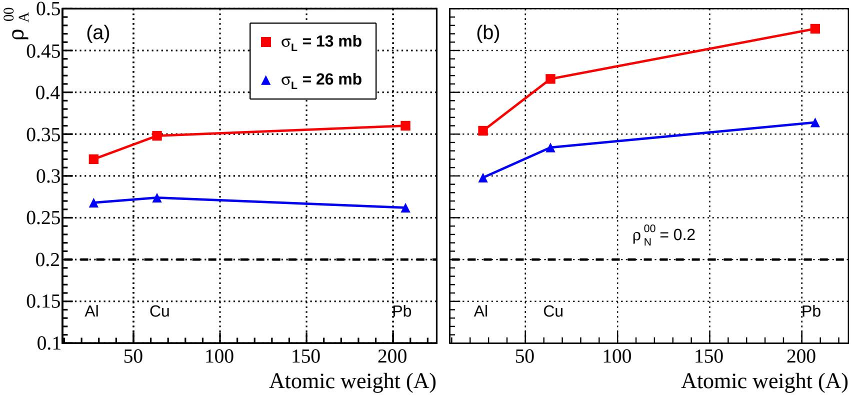
A_{eff}
90
80
70
60
50
40
30
20
10
0
σ_L = 13 mb
A (∞)
A(0)
Al
Cu
Ag
Ta
Pb
50
100
150
200
A
σ_L = 26 mb
E_γ = 5 GeV
E_γ = 9 GeV
A (∞)
A(0)
Al
Cu
Ag
Ta
Pb
50
100
150
200
A



(a)
E_γ = 5 GeV
E_γ = 9 GeV
A(0)
A (∞)
A_{eff}
σ_L (mb)
(b)
ρ (∞)
ρ(0)
ρ^A_{00}
σ_L (mb)



A_{eff}
σ_L = 0
σ_L = 13 mb
σ_L = 26 mb
E_γ = 5 GeV
E_γ = 9 GeV
0
10
20
30
40
50
60
70
80
90
Al
Cu
Ag
Ta
Pb
50
100
150
200
A



(a)
(b)
σL = 13 mb
σL = 26 mb
ρ 00 A
ρ 00 N = 0.2
Al
Cu
Pb
Atomic weight (A)

Conclusions

1) From the coherent photoproduction $\gamma + A \to \omega + A$ one can obtain the value of the transverse cross section $\sigma_T(\omega N)$.
Two experiments: DESY 70,E_γ=5.7GeV $\omega \to \pi^0\gamma$;, Cornell 70,E_γ=6.8GeV $\omega \to \pi^0\pi^+\pi^-$;
$\sigma(\omega N) = \sigma(\rho N) = 27 \pm 6mb$
2) From the incoherent photoproduction $\gamma A \to \omega + A'$ one can extract the longitudinal cross section $\sigma_L(\omega N)$. Never measured!!!
To use this unique challenge GlueX has to measure:
a) Differential cross section of ω photoproduction on the set of nuclei in the interval of transfer momentum $0 < |t| < 0.6GeV^2$ and photon energy $5GeV < E_\gamma < 12GeV$
b) The spin density matrix elements ρ_{00} on the nucleon and a set of nuclei.
Such measurement allow to get for the first time a unique information on impact of vector mesons polarization on their interaction with matter!!!