Omega mesons photopoduction of nuclei. A challenge for GlueX.

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Photoproduction on nuclear targets at GlueX, 29 April 2016

Introduction

1.Photoproduction of ω mesons off nuclei and impact of polarization on meson-nucleon interaction. E.Chudakov, A.Somov, S.G., Phys.Rev. C93, 015203 (2016); arXiv:1508.00422[hep-ph]

2.**Study of ω mesons photoproduction off nuclei with the Gluex detector.**
E.Chudakov, A.Somov, S.G., A Letter of Intend to Jefferson Lab PAC-43, 2015

3.**The impact of vector mesons polarization on meson nucleon interaction.**
S.G., Jour.of Physics: Conference Series 678, 012033 (2016)

Vector mesons $V = \rho, \omega, \phi...$ can be transversely ($\lambda = \pm 1$) or longitudinally ($\lambda = 0$) polarized.

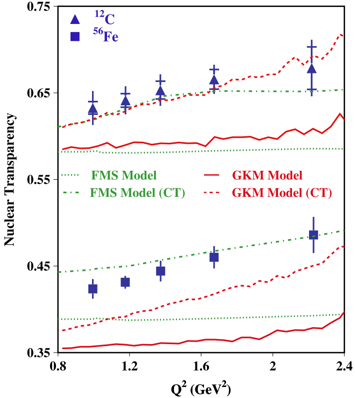
Has the polarization the impact on their interaction with nucleons and nuclei?

Color transparency versus vector meson polarization.

Why the knowledge of $\sigma_T(VN)$ and $\sigma_L(VN)$ is important?

Color Transparency: According to QCD hard exclusive processes select configurations where the quarks are close together forming a color neutral object with transverse size $r \approx 1/Q$.

Nuclear Transparency: $T_A = \frac{d\sigma_A}{Ad\sigma_N}$ for $A(e, e'\rho^0)$



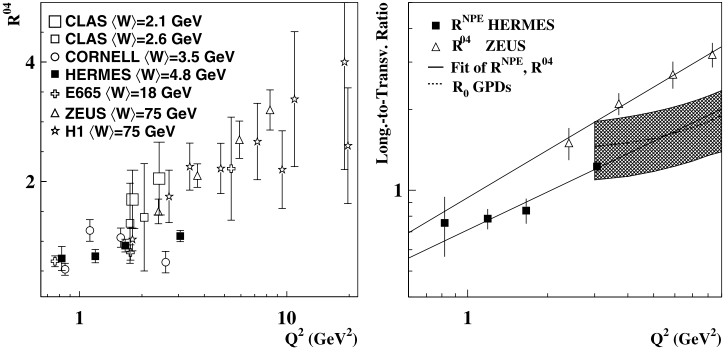
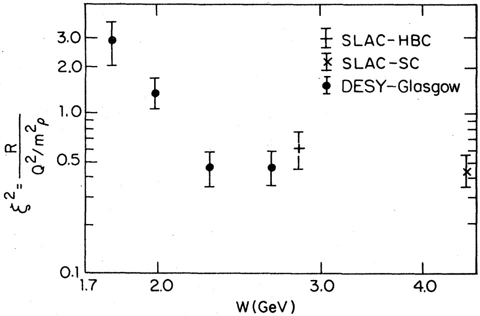


Figure: Q^2 dependence of the longitudinal-to-transverse cross section ratio for exclusive ρ^0 production on the proton.

If $\sigma_T(\rho N) \gg \sigma_L(\rho N)$ the Nuclear transparency would grow with Q^2 !!!

The ratio of the cross sections of ρ^0 electroproduction 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 $\xi = \frac{\sigma_L(\rho p)}{\sigma_T(\rho p)} \approx 0.7$. For φ meson: $\xi^2 = 0.33 \pm 0.08$



Valence quark distributions and the vector mesons polarization. B.Ioffe & A.Oganesian (2000)

The distribution of valence quarks in the transversely and the longitudinally polarized vector mesons is significantly different, which should lead to different interactions of polarized mesons with nucleons.

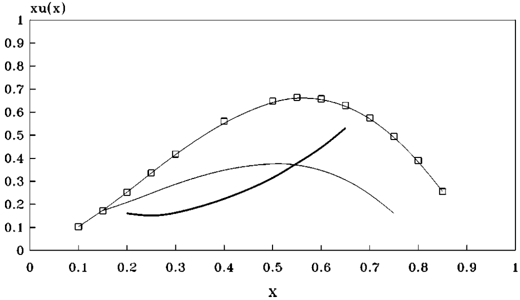


Figure: The valence quarks distributions in ρ meson:Top-longitudinally polarized meson; bottom=transverse polarization.

Constituent quarks distribution in vector meson.

In AdS/QCD (Brodsky & G.de Teramond) light-front wave functions depend on meson polarization.
J.Forshaw & R.Sandapen (2010)

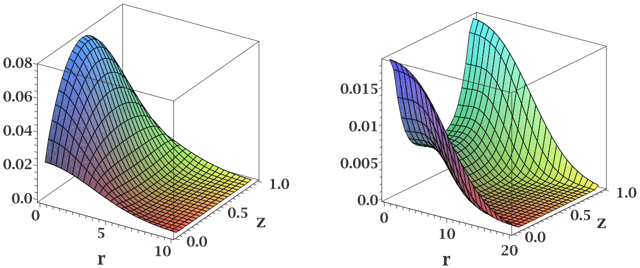


Figure: The longitudinal (left) and transverse (right) light-cone wavefunctions squared.

Color dipole model.

Before the interaction the high energy photon (real or virtual) dissosiates to quark-antiquark pair, which interacts with a target as color dipole.

$$\sigma^{L(T)}(\gamma N) = \int |\Psi_{\gamma}^{L(T)}(r,z,Q^2)|^2 \sigma(r) d^2 r dz$$

$$\sigma^{L(T)}(\gamma N \to VN) = \int \Psi_{\gamma}^{L(T)}(r,z)\sigma(r)\Psi_{\rho}^{L(T)}(r,z) d^2 r dz \qquad (1)$$

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

$$\sigma(r) = \sigma(s)\left(1 - exp(-r^2/r_0^2)\right) \qquad (2)$$

1) Boosted Gaussian (BG) B.Kopeliovich,N.Nikolaev et al.
2)The light-front wavefunction : J.Forshaw& R.Sandapen (FS)

$$\Phi(r,z) = \sqrt{z(1-z)} exp(-\frac{k^2 z(1-z) r^2}{2}) \qquad (3)$$

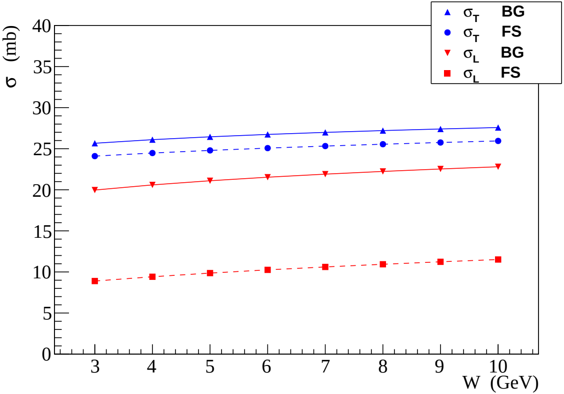


Figure: Solid lines: Boosted Gaussian (BG) wave functions for transverse (blue) and longitudinal (red) mesons.
Dashed lines: The same for Forshaw&Sandapen (FS) wave functions

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

Why omega?
In $\gamma + N \to \omega + N$ at JLab energies the essential is pion exchange. 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 the coherent production off nuclei where one has to sum the elementary production amplitudes, the contribution of pion exchange cancelled leading to production of only transversely polarized omega mesons.
From the absorption of ω's in the coherent photoproduction one can extract only $\sigma_T(\omega N)$.

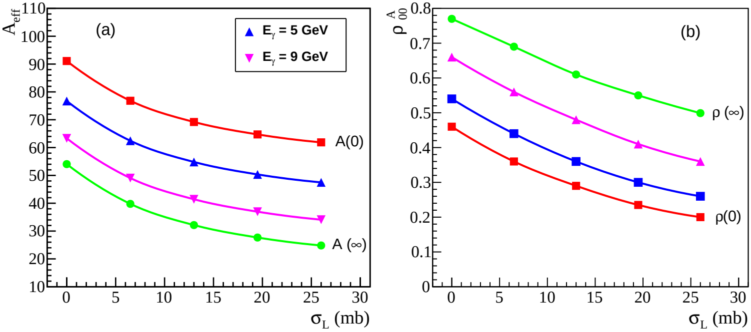
ω photoproduction in the incoherent process $\gamma A \to \omega A'$

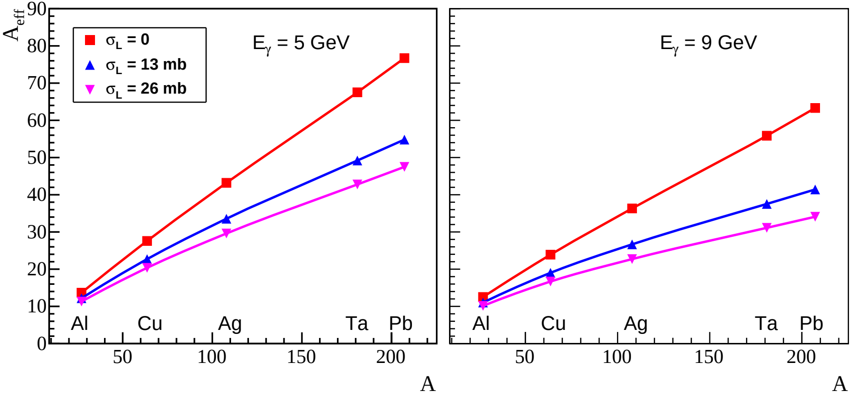
$$
\begin{aligned}
\frac{d\sigma_A(q)}{dt} &= \frac{d\sigma_0(q)}{dt}(\rho_{00}N(0,\sigma_L) + (1-\rho_{00})N(0,\sigma_T)) \\
N(0,\sigma) &= \int \frac{1-\exp(-\sigma\int\rho(b,z)dz)}{\sigma} d^2b
\end{aligned}
$$

$\frac{d\sigma_0(q)}{dt}$, 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)
E_γ = 5 GeV
E_γ = 9 GeV
A_{eff}
A(0)
A (∞)
σ_L (mb)
(b)
ρ^A_{00}
ρ (∞)
ρ(0)
σ_L (mb)



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

Summary

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 1970,E_γ=5.7GeV $\omega \to \pi^0\gamma$;, Cornell 1970,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 the ω photoproduction on the set of nuclei in the interval of transfer momentum $0 < |t| < 0.6GeV^2$ and photon energy $5GeV \leq E_\gamma \leq 10GeV$
b) The spin density matrix elements ρ_{00} on the nucleon and a same set on nuclei.
Such measurement allow to get for the first time a unique information on impact of vector mesons polarization on their interaction with matter!!!