Vector mesons production off nuclei at the new planned QCD facility at CERN.

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Has vector mesons polarization impact on their interaction with matter?

Vector mesons $V = \rho, \omega, \varphi, K^*(892) etc.$ can be transversely (helicity $\lambda = \pm 1$) or longitudinally $\lambda = 0$ polarized.

1. The only way to measure the interaction of unstable particle with nucleon is investigation of it absorption in nuclei!!!

2. 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 $r \sim 1/Q$. Such effect is well known in QED in photoproduction of e^+e^- pairs (Chudakov effect). The effect of color transparency is seen in electroproduction of vector mesons off nuclei as a grows of nuclear transparency $T_A = \frac{d\sigma_A}{Ad\sigma_N}$ with the mass of virtual photon.

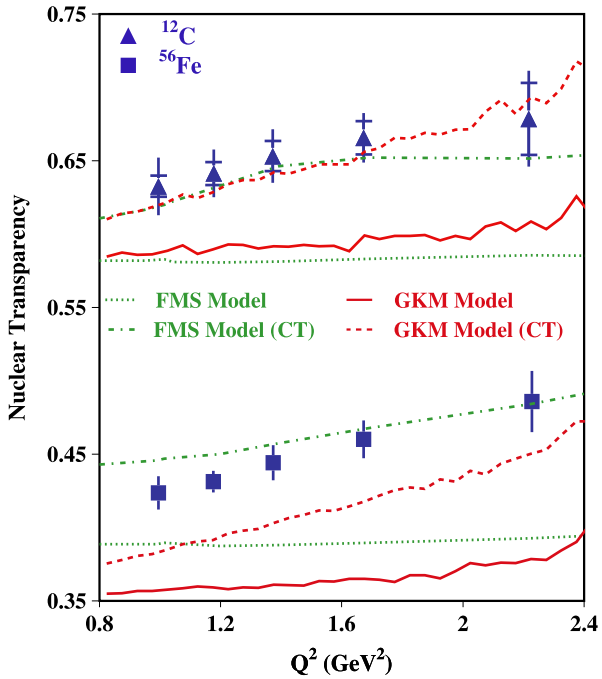
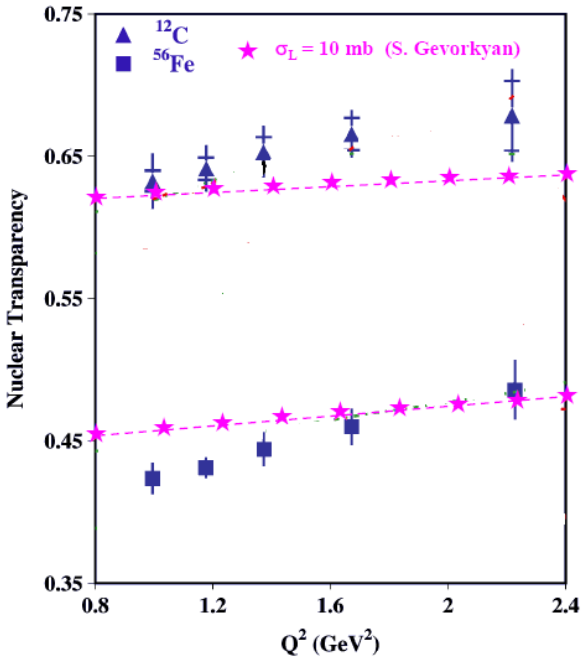


Figure: Nuclear transparency $T_A = \frac{d\sigma(\gamma^* A \to \rho A')}{A d\sigma(\gamma^* N \to \rho N)}$ as a function of Q^2. Experimental data from CLAS, JLab.



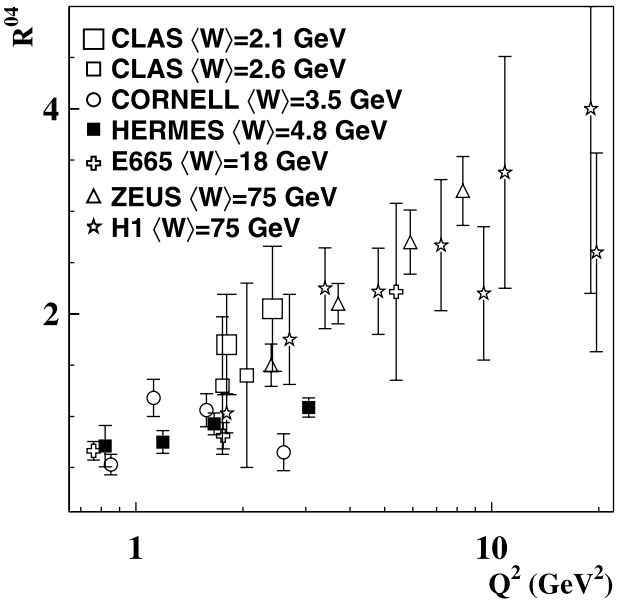


Figure: Nuclear transparency as a function of Q^2 (left). Q^2 dependence of the ratio of the longitudinal-to-transverse cross sections for exclusive ρ^0 electroproduction on proton. HERMES(right).

If $\sigma_L(VN) \ll \sigma_T(VN)$ the rise of nuclear transparency with Q^2 can be partially due to weaker absorption of longitudinally polarized vector mesons compared with transverse one.

Deuteron interaction with the matter

Initially unpolarized beam of deuterons acquire tensor polarization after traversing a foil of spin-zero target. Spin dichroism leads to the appearance of tensor polarization.
Tensor polarization:

$$P_{zz}(z) \approx \frac{2}{3}(\sigma_0(dC) - \sigma_{\pm 1}(dC))\rho z$$

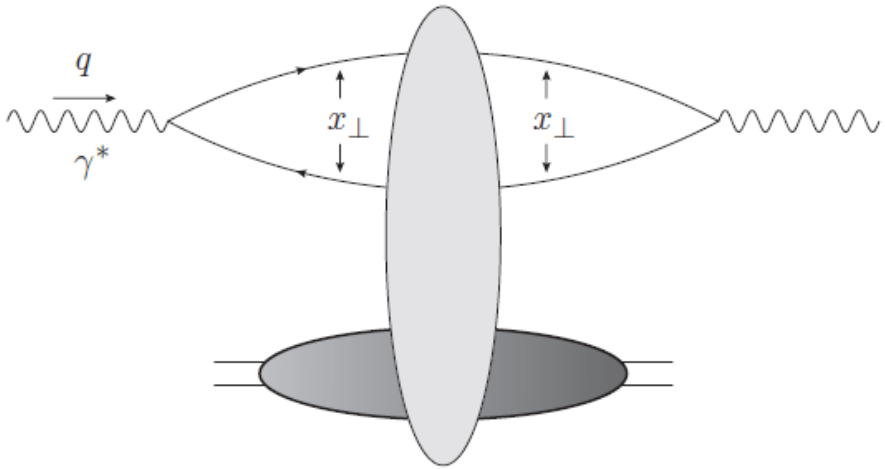
H. Seyfarth et al. Phys. Rev. Lett.,2010, Juelich $E_d = 10 - 20$ **MeV**
L. Azhgirey et al. Phys. Part. Nucl. Lett., 2010 JINR $p_d = 5$**GeV/c**
Deuterons interaction in the target depends on its polarization as a result of D-wave in the deuteron wave fnction

Color dipole model of strong interaction.

At high energies the photon (real or virtual) fluctuates to colorless quark-anti-quark pair, which interacts with a target as a color dipole $\sigma(r \to 0) \sim r^2 log(r)$.

$$\sigma_{L(T)}(\gamma N) = \int |\Psi^{\gamma}_{L(T)}(Q^2, r, \alpha)|^2 \sigma(r) d^2 r d\alpha$$

$r \equiv x_\perp$ - the transverse distance in $q\bar{q}$ pair; α- the part of light cone momentum carried by quark; $(1-\alpha)$-anti-quark



$$\sigma^{L(T)}(VN) = \int |\Psi_V^{L(T)}(r,z)|^2 \sigma(r) d^2 r dz; \sigma(r) = \sigma_0(s)\left(1 - e^{-\frac{r^2}{R^2(s)}}\right)$$

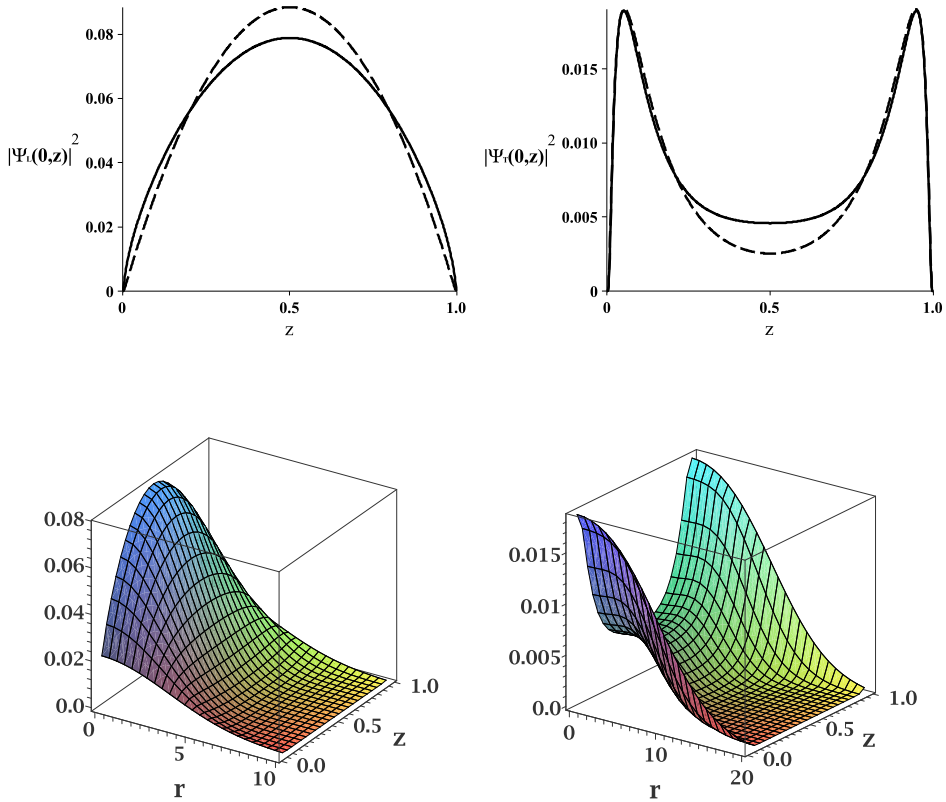


Figure: Quarks distribution in longitudinally (left) and transversely (right) polarized vector meson.

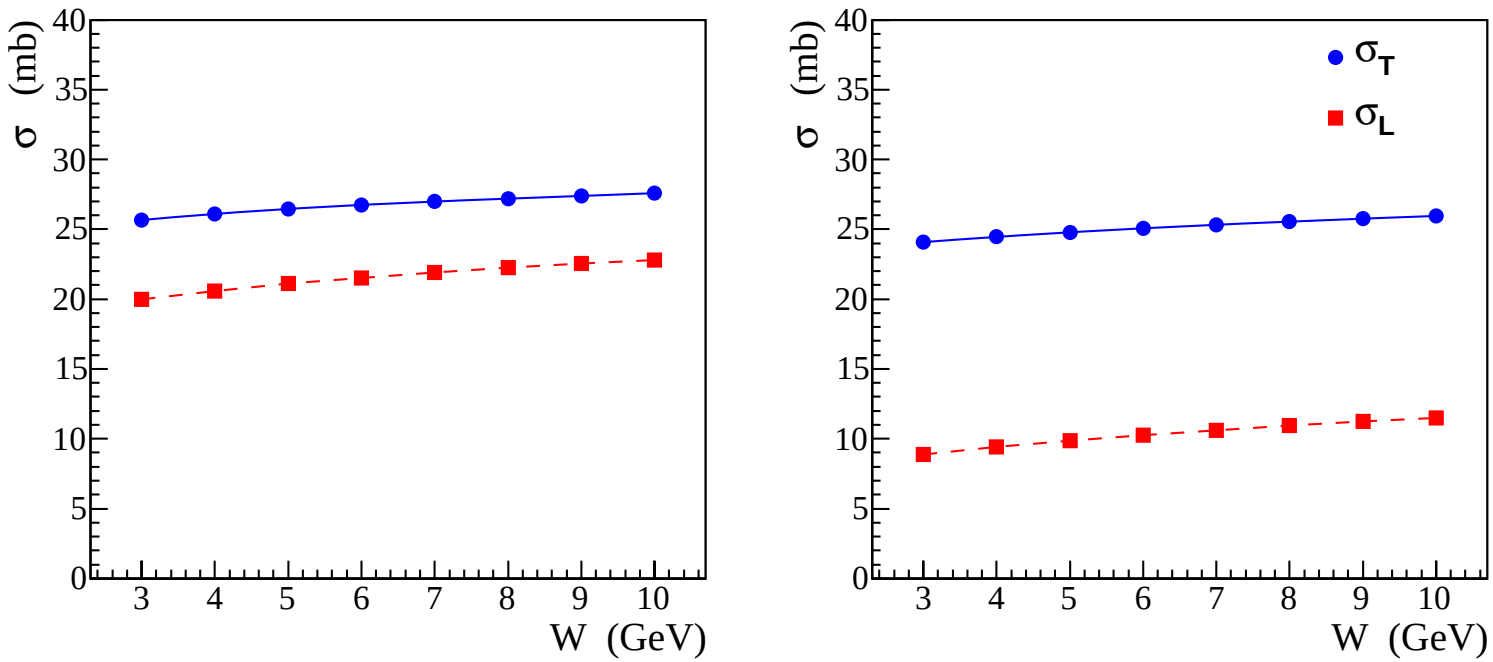


Figure: Boosted Gaussian (Kopeliovich, Nikolaev) (left). Relativistic quark model (Forshaw & Sandapen) (right)

The determination of $\sigma_L(VN)$.

1) ITEP: $\pi^- + A \to \rho^0 + A'$, G.Leksin et al. p_π=3.7 GeV/c; C,Ne, Preprint ITEP 1973; p,C,Al,Cu,Pb, Yad. Phys. 1978.
Spin density matrix element $\rho_{00} \approx 0.7$ Result: $\sigma(\rho N) = 27.6 \pm 4.5 mb$.
From coherent photoproduction:$\sigma(\rho N) = 31.3 \pm 2.3 mb$
On the other hand taking into account the possibility of ρ mesons decay in nuclei leads to much smaller cross section.
2) $\pi^+ + Ne \to \rho^0(f(1270)) + A', p_\pi = 3.5 GeV/c$
Argon: B.Chaudhary et al. Nucl. Phys. 1973;
Accounting of vector meson decay in nuclei leads to $\sigma(\rho N) \approx 12 mb$ in sharp disagreement with photoproduction data!!!!
From our point of view this is a result of longitudinal polarized ρ mesons dominance

Proposal for M2 beam line of the CERN SPS

The vector meson lifetime in the laboratory system $\tau = \frac{p_V}{m_V \Gamma_V}$. Thus to solve the problem one has to measure charge exchange vector mesons production off nuclei at energies where decays take place out of the nuclei!!!

We propose to measure the production of light vector mesons $V = \rho, \omega, \varphi, f(1270)$ on nuclei targets by pions $\pi^- + A \to V + A'$ and kaons beams $K^- + A \to K^*(892) + A'$ at energies E=20-100GeV and transfer momenta $0 < t < 0.5(GeV/c)^2$.

This allows for the first time determine the longitudinal cross section $\sigma_L(VN)$!!!

O.Denisov "A New QCD facility at the M2 beam line of the CERN SPS" Arxiv:1808.00848

Proposal for JLAB

In coherent production by real photons $\gamma A \to VA$ only transversally polarized vector mesons produced. From the other hand in incoherent photoproduction of ω mesons at JLAB energies $\gamma + A \to \omega + A'$ the longitudinally polarized ω mesons can be produced. Thus we proposed to investigating their absorption in nuclei extract $\sigma_L(\omega N)$ accounting that transverse cross section $\sigma_T(\omega N)$ is known from coherent photoproduction.

1. E. Chudakov, S.G., A.Somov "Photoproduction of ω mesons off nuclei and impact of polarization on meson-nucleon interaction." Phys. Rev. 2016

2."Study of ω mesons photoproduction off nuclei with the Gluex detector."LOI PAC-43,2015

3."Photoproduction of vector mesons on nuclei with GlueX" Proposal PAC45, 2017

Production of vector mesons $K^*(892)$ at LHC.

Alice collaboration measured the polarization of $K^*(892)$ in $pp \to K^*(892)X$ and $Pb + Pb \to K^*(892)X$ as a function of centrality and kaons transverse momenta.

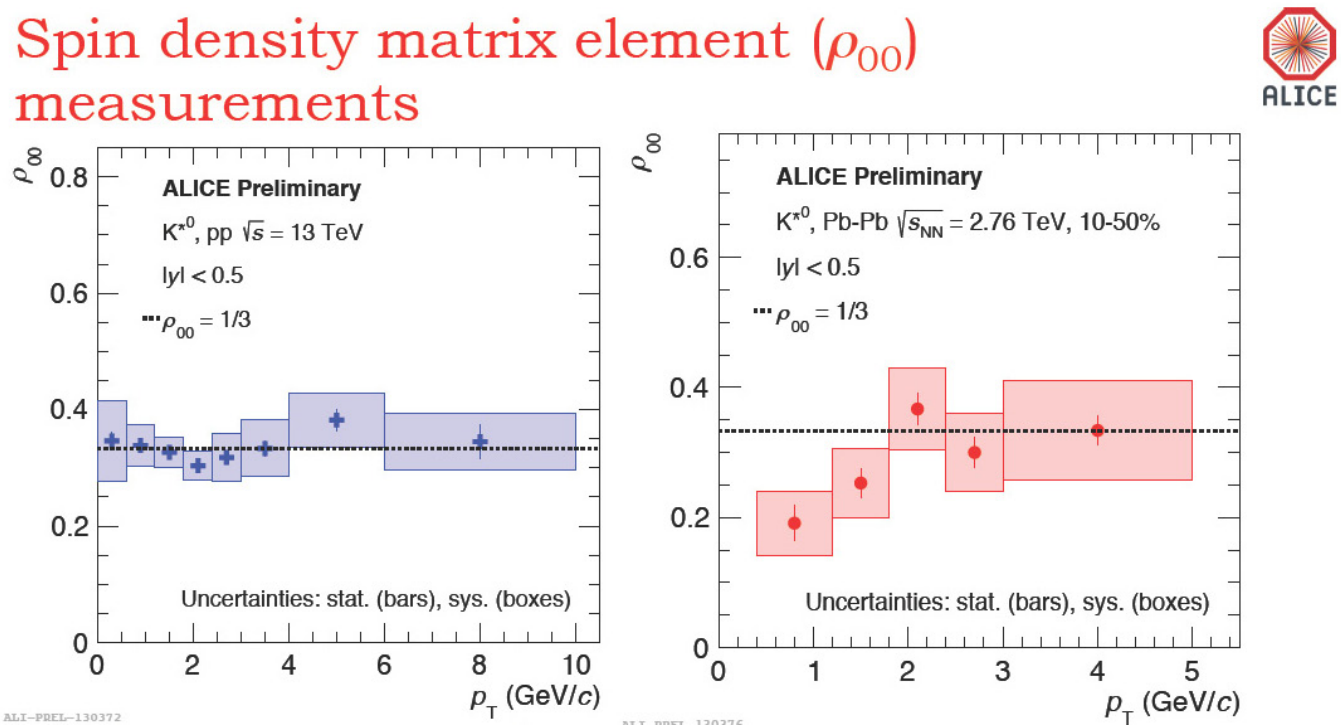


Figure: Left: The dependence of ρ_{00} on the transverse momenta of K^{*0} in the reaction $p + p \to K^{*0} + X$; Right: The same dependence in lead-lead collisions $Pb + Pb \to K^{*0} + X$

Thank you for attention