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IN PURSUIT OF NEW PHYSICS WITH K^+ SCATTERING ON NUCLEI AT INTERMEDIATE ENERGY

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Abstract

A new model (*a la* Glauber) for hadron–nuclei interaction at intermediate energy (IE) is proposed. We utilized the principal assumptions as in the approaches of others authors describing (in the framework of the models without QGP) J/Ψ suppression in nuclear collisions at high energy. Yet, a number of new ingredients (noneikonal corrections, correlations of nucleons in the nuclei, *etc.*) are introduced. We show that experimental data on the cross sections of K^+–nuclei interaction at IE cannot be described by the well-elaborated Glauber model. In comparison with other authors, the model improve the agreement between theory and data but remain the "window" for some "exotics". (This results have been obtained without fitting any new parameters.) The nature of that "exotics" (mass reduction, or "swelling",*etc.*) will be discussed later.

1 Introduction

The contemporary theory of strong interaction-Quantum Chromodynamics (QCD) predicts, that *at high nuclear density* a new state of matter (quark-gluon plasma-QGP) will be formed. One of the principal motivation for the ultrarelativistic heavy ion experiments is the study of the signals of the existence of QGP. In this new stage of matter deconfinement of quark takes place and hadron masses are reduced to zero (restoration of chiral symmetry takes place). However, chiral symmetry is partially restored in medium, for example, in nuclei, *i.e.*, below the critical density. Reduction of hadron masses in medium has been predicted as an effect of partial restoration of chiral symmetry in nuclear matter. In the last years a lot of theoretical and experimental work has been devoted to the search of a signals of such anomalous properties of hadrons in the nuclear environment (in-medium effects) [1–5].

At the same time, the problem of the investigation of the changing of masses of particles is rather complicated. In that situation it is helpful to attack the discussed problem by studding different nuclear reactions, to find others occasions without doubt.

2 The model

Following Glauber [6] the amplitude for a projectile-target elastic scattering, assumes the general form:

$$f(\vec{q}) = \frac{ik}{2\pi}\int e^{2i\vec{q}\cdot\vec{b}}\Gamma(\vec{b})d\vec{b}, \quad \Gamma(\vec{b}) = 1 - e^{2i\chi(\vec{b})} = \frac{1}{2\pi ik}\int e^{-i\vec{q}\cdot\vec{b}}f(\vec{q})d\vec{b} \tag{1}$$

$$\chi_N(\vec{b},\vec{r}_1,\cdots,\vec{r}_A) = \sum_{j=1}^{A}\chi_j(\vec{b}-\vec{s}_j),\ \Gamma_N(\vec{b},\vec{r}_1,\cdots,\vec{r}_{A)} = 1-e^{2i\chi_N(\vec{b},\vec{r}_1,\cdots,\vec{r}_{A)}} \tag{2}$$

where b is the impact parameter, and χ is the corresponding phase shift function. More explicitly, for projectile–nucleus scattering, Eq.(1) can be cast into the form:

$$F(\vec{q}) = \frac{ik}{2\pi}\int e^{i\vec{q}\cdot\vec{b}} < |\Gamma_N(\vec{b},\vec{r}_1,\cdots,\vec{r}_{A)}| > d\vec{b}, \tag{3}$$

where $\vec{s_j}$ is a component of the radius–vector $\vec{r_j}$ of the j^{th} target–nucleon in the direction perpendicular to the incident momentum $\vec{k}$, while the brackets $< >$ denote the target ground–state average. The parameters of kaon–nucleon amplitudes were taken from the well–known Martin phase shifts [7].

Further, given the corresponding projectile–target nucleon amplitudes $f(q)$, one can express the above projectile–target nucleus amplitude in the **parameter–free** way. It is then a straightforward matter to determine the total cross section for the case of K$^+$– target nucleus scattering according to the optical theorem. The total and reaction cross sections may then be approximated by

$$\sigma_t = 4\pi\int_0^\infty \mathrm{Re}\big[1 - e^{i\chi(b)}\big]bdb, \qquad \sigma_r = 2\pi\int_0^\infty \big[1 - e^{-2\mathrm{Im}\chi(b)}\big]bdb, \tag{4}$$

where $\chi(b)$ is the nuclear phase shift function. For scattering in the case when the potential is spherically symmetrical, an eikonal expansion of $\chi(b)$ is given by S.J. Wallace [8] in the form:

$$\chi(b) = \sum_n \frac{\mu^{n+1}}{k(n+1)!} \left(\frac{b}{k^2} \frac{\partial}{\partial b} - \frac{\partial}{\partial k} \frac{1}{k} \right)^n \int_{-\infty}^{\infty} V^{n+1}(r) dz, \tag{5}$$

$$V(r) = \frac{2\pi i}{\mu} f(0) \rho(r), \tag{6}$$

where $\rho(r)$ is the nuclear density and $f(0)$ is the average forward scattering amplitude of kaon interaction with moving intranuclear nucleons. The Fermi momentum distribution of nucleons was taken from newly experimental data. The calculation was performed by Monte Carlo method. (For detail see Ref. [9].

3 Results and outlook

To examine the nuclear interior, the K$^+$-meson at IE is regarded as a unique probe due to its long mean free-path in the nuclear matter.

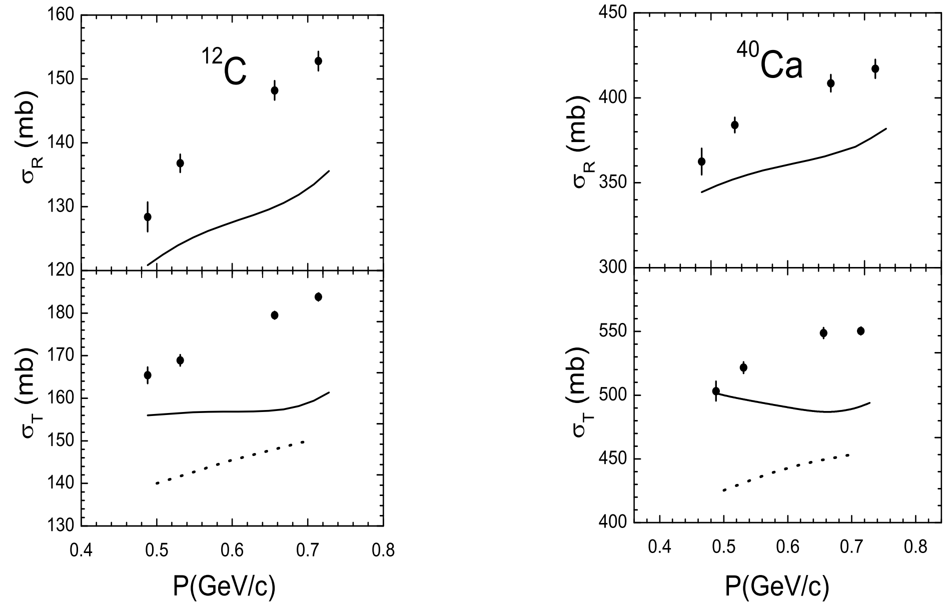

Figure 1: The calculated and experimental total and reaction cross sections for K$^+$ - meson interaction with nuclei vs. kaon momentum. The solid lines denote the prediction of our model. The experimental data are from Ref. [10] The dotted lines demonstrate the theoretical results of Ref. [11]

A detailed analysis of the cross sections of K$^+$ - nuclei interactions at IE is presented. We can see that our calculated cross sections for K$^+$ meson interactions fail to describe the experimental data. It seen an universal discrepancy between the theoretical models and data for particles (K$^+$-mesons) interacting in deep regions of the nucleus. (It worth noticing that our results have been obtained without fitting any new parameters.) In comparison with other authors, the model improves the agreement between theory and data but remain the "window" for some "exotics". The nature of that "exotics" (mass reduction, or "swelling", *etc.*) will be discussed latter. The discrepancy between calculations and data on K$^+$ - nuclei scattering my be regarded as one of more probable signal of new physics in nuclear collisions. (It is just the contrary what was obtained by many authors for J/Ψ suppression in relativistic nuclei collision and color transparency). In conclusion, our model can be used to resolve puzzling discrepancy of theory and data on pion-nuclei collision at IE (see, *e.g.*, Ref. [4]).

References

[1] G.E. Brown *et al.*, *Phys. Rev. Lett.* **60**, 2723 (1988).

[2] A. Gal, E. Friedman, *Phys. Rev. Lett.* **94**, 072301 (2005).

[3] A. Gal, E. Friedman, *Phys. Rev.* **C73**, 015208 (2006).

[4] E. Friedman and A. Gal, arXiv:nucl-th/0705.3965v2 Aug 07 2007.

[5] E. Oset *et al.*, arXiv:nucl-th/0702022v1 Feb 07 2007.

[6] R.J. Glauber, Theory of high-energy scattering, in *Lectures in Theoretical Physics*, ed. W.E. Brittin and L.G. Dunham, (Interscience Publishers, Inc., New York, 1959) p. 315.

[7] B.R. Martin, Nucl. Phys. **B94** 413 (1975).

[8] S.J. Wallace, Ann. Phys. (N.Y.) **78**, 190 (1973).

[9] S.M. Eliseev and T.H. Rihan, *Phys. of At. Nucl.* **60**, 918 (1997).

[10] A.Gal, *Nucl. Phys.*, **A639**, 485c (1998).

[11] M.F. Jiang *et al.*, Phys. Rev. **C51**, 857 (1995).

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