K^+-nucleon amplitudes in the nuclear medium below 800 MeV/c

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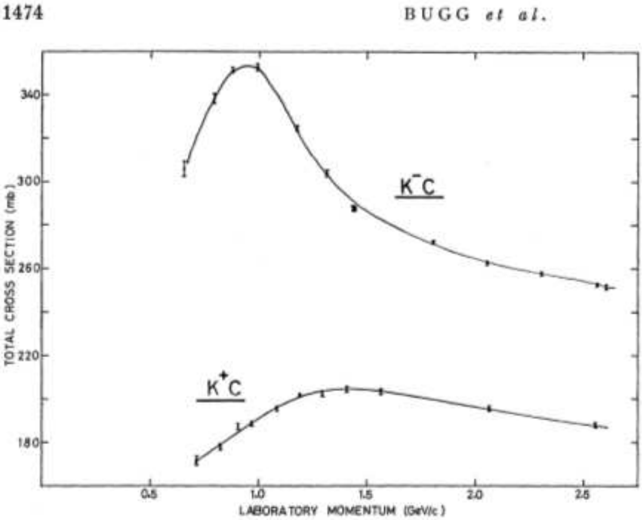
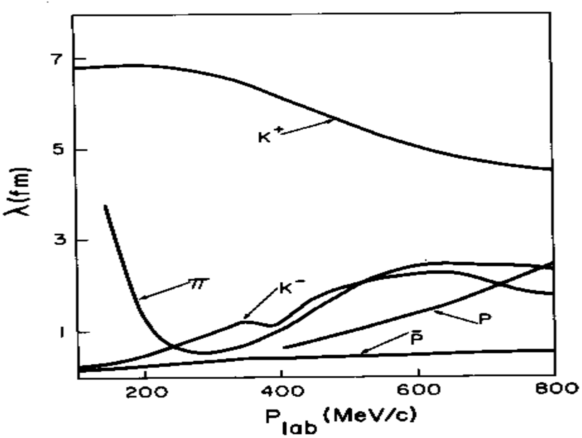
Meson-nucleus potentials may display properties of meson-nucleon interaction in the medium,
e.g. the (3,3) resonance in pion-nucleon interaction.

Outline

- Deeply penetrating K^+ below 800 MeV/c
- σ_T on C: modification of the nucleon in the medium?
- Dedicated experiment: ^{6}Li,C,Si,Ca. Extended analysis
- Applying in-medium kinematics to K^+
- Results and discussion



Bugg et al., Phys. Rev. 168 (1968) 1466.



K^+: the most penetrating strongly-interacting probe,

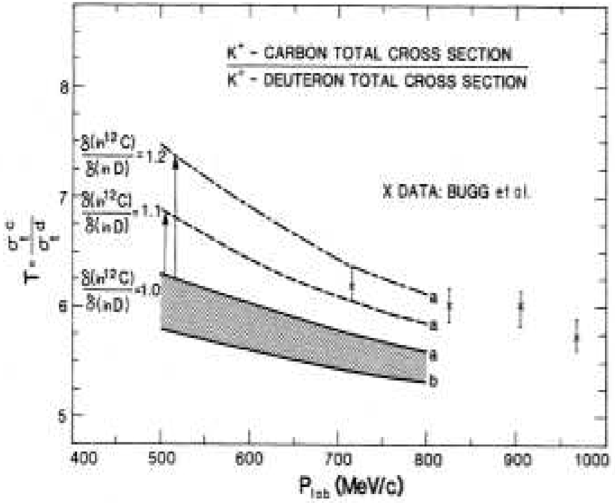
$$\lambda = 1/\rho\sigma_T$$

Kaon-Nucleon Total Cross Sections from 0.6 to 2.65 GeV/c
D.V. Bugg et al.,
Phys. Rev.168 (1968) 1466

Measured σ_T for $K^{\pm}$ on p, d and some points on C.

For K^- $\sigma_T(\text{C}) < 6\sigma_T(\text{D})$, as expected.

For K^+ $\sigma_T(\text{C}) > 6\sigma_T(\text{D})$.



P.B.Siegel, W.B. Kaufmann, W.R. Gibbs, PRC 31 (1985) 2184.

K^+ as a probe of partial deconfinement in nuclei

P.B.Siegel, W.B. Kaufmann, W.R. Gibbs

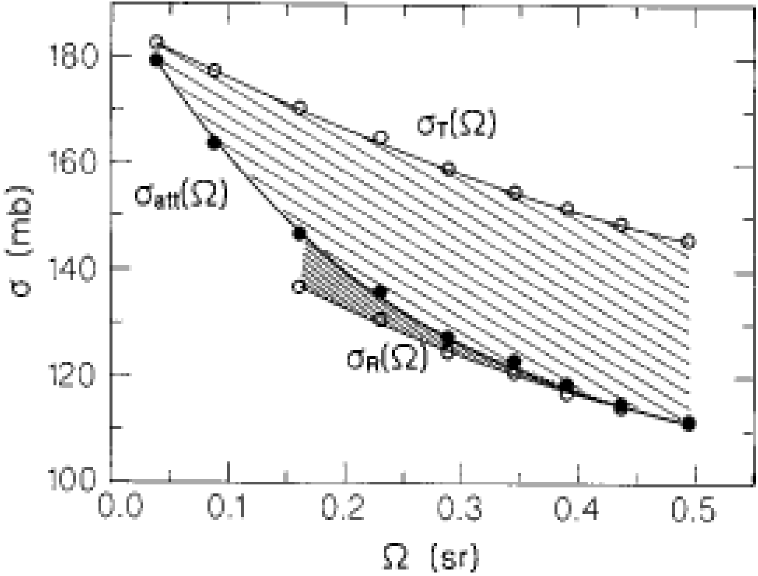
PRC 31 (1985) 2184

'It is shown that conclusions can be drawn in regard to fundamental structure of nuclear material from the scattering of K^+ mesons from nuclei. A calculation of the ratio K^+-carbon to K^+- deuteron total cross sections is presented which includes traditional medium corrections and their uncertainties.

That this calculation falls well below the available data suggests more exotic mechanisms. In particular, models for the distribution of quarks involving an increased confinement range can be tested.'

1992-1994 measurements of σ_T for K^+ on D, ^{6}Li, C, Si, Ca at BNL, published results at 4 momenta (20 points).

1996-97 self-consistent analysis of the same experiment, deriving also σ_R for ^{6}Li, C, Si, Ca yielding a total of 32 data points (in addition to D).
E. Friedman, A. Gal et al., PRC 55 (1997) 1304;
E. Friedman, A. Gal, J. Mareš, PLB 396 (1997)21;
NPA 625 (1997) 272.



180
160
140
120
100
σ (mb)
0.0
0.1
0.2
0.3
0.4
0.5
Ω (sr)
σT(Ω)
σatt(Ω)
σR(Ω)

σ_T for K^+ (in mb).

p_{lab} (MeV/c)	488	531	656	714
3×D	76±1.8	81.5± 1.0	84.5± 0.7	86.0± 0.6
^{6}Li	77.5±1.1	80.7± 0.7	86.4± 0.7	88.5± 0.6

Accept ^{6}Li as reference values.
rms charge radius of ^{6}Li LARGER than rms charge radius of ^{12}C.
Average density of ^{6}Li less than 50% of normal nucleus.

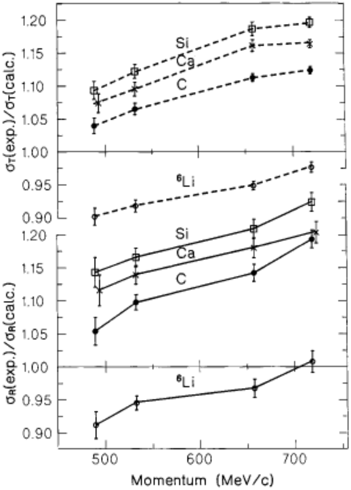


FIG. 2. Ratios between experimental and calculated cross sec-
ons based on a $t\rho$ potential: total cross sections — dashed curves
pper part); reaction cross sections — solid curves (lower part).
he curves serve merely to guide the eye.

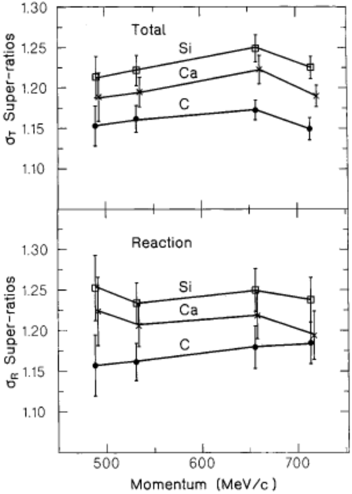


FIG. 3. Super ratios relative to ^{6}Li: experimental cross sections relative to calculated values using a $t\rho$ potential, divided by the corresponding ratios for ^{6}Li.

K^+-nucleon hard core radii in complex nuclei

R.J. Peterson

PRC 60 (1999) 022201

The present analysis uses K^+-nuclear data to infer the size of the repulsive hard core radius between the K^+ and nucleons within nuclei by altering a single parameter, the average S-wave phase shift. The resulting hard core radii, larger than seen in free space, increase with nuclear densities.

Including a full list of references.

New analysis 2015

Use the Mandelstam variable s in the nuclear medium
$s = (E_K + E_N)^2 - (\vec{p}_K + \vec{p}_N)^2$,

$$E_K = m_K - B_K, \qquad E_N = m_N - B_N.$$

In the nuclear medium $\vec{p}_K + \vec{p}_N \neq 0$.
Averaging over angles, $(\vec{p}_K + \vec{p}_N)^2 \rightarrow (p_K)^2 + (p_N)^2$.
Substituting locally:

$p_K^2/2m_K \rightarrow -B_K - \mathrm{Re}\ V_{\mathrm{opt}}^K - V_c$, (for exotic atoms)

$p_N^2/2m_N \rightarrow T_N(\rho/\bar{\rho})^{2/3}$, (Fermi Gas model)

Defining $\delta\sqrt{s} = \sqrt{s} - E_{\rm th}$ with $E_{\rm th} = m_K + m_N$, then to first order in $B/E_{\rm th}$ and $(p/E_{\rm th})^2$ one gets

$$\delta\sqrt{s} = -B_N\rho/\bar{\rho} - \xi_N[T_N(\rho/\bar{\rho})^{2/3} + B_K\rho/\rho_0] + \xi_K[{\rm Re}\ V_{\rm opt} + V_c(\rho/\rho_0)^{1/3}],$$

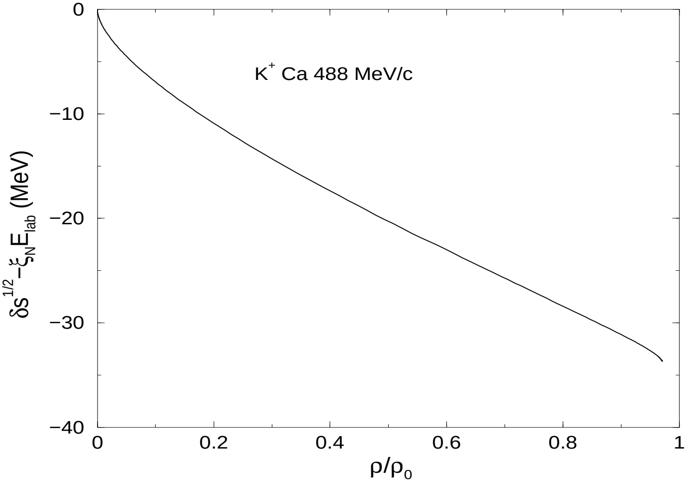
with $\xi_N = m_N/(m_N + m_K)$, $\xi_K = m_K/(m_N + m_K)$, and $\bar{\rho}$ the average nuclear density.

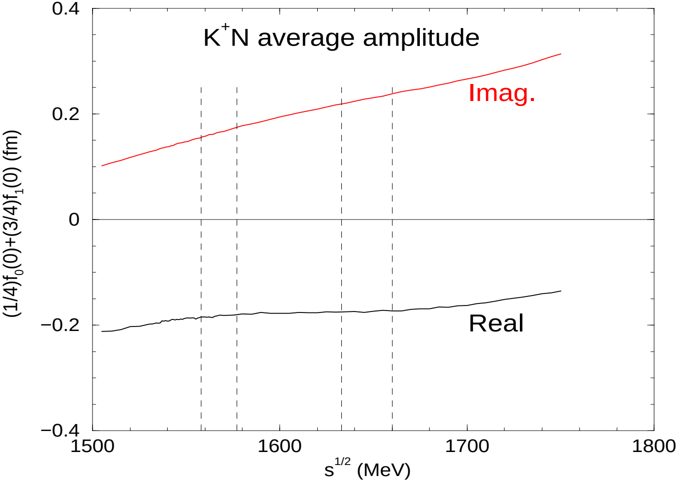
The specific ρ/ρ_0 and $\rho/\bar{\rho}$ dependence ensures that $\delta\sqrt{s} \to 0$ when $\rho \to 0$. E.F. and A. Gal, NPA 899 (2013) 60.

Self-consistent solution required for Re $V_{\rm opt}$, establishing DENSITY TO ENERGY TRANSFORMATION.

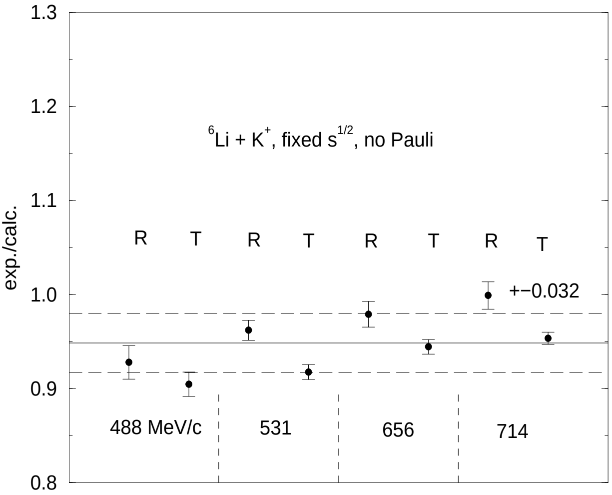
For scattering scenarios

$$\delta\sqrt{s} = \xi_N E_{\rm lab} - B_N \rho/\bar{\rho} - \xi_N [T_N (\rho/\bar{\rho})^{2/3} + V_c (\rho/\rho_0)^{1/3}] + \xi_K {\rm Re}\ V_{\rm opt}.$$

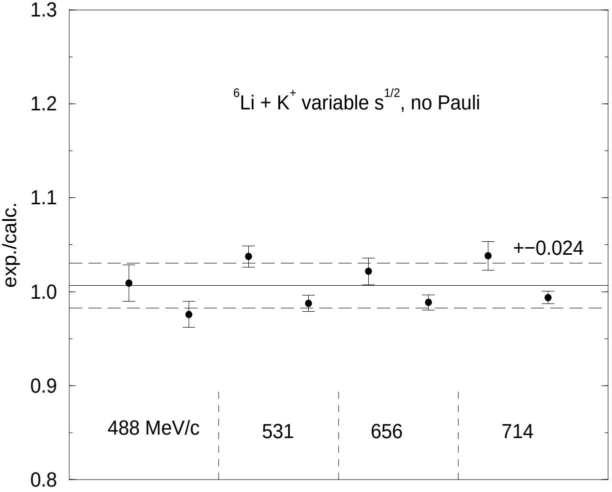




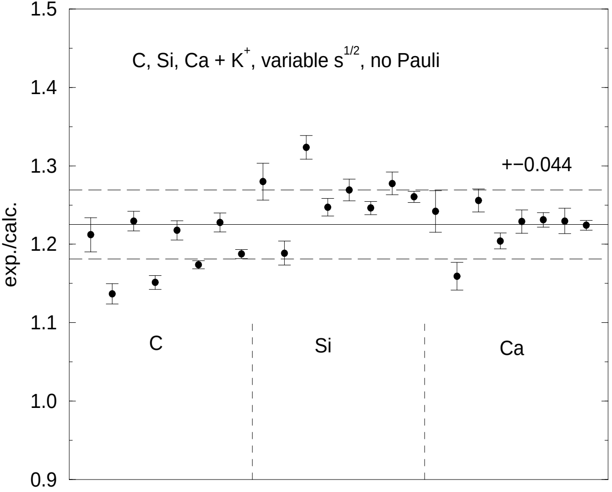
K+N average amplitude
Imag.
Real
0.4
0.2
0
−0.2
−0.4
1500
1600
1700
1800
s1/2 (MeV)
(1/4)f0(0)+(3/4)f1(0) (fm)

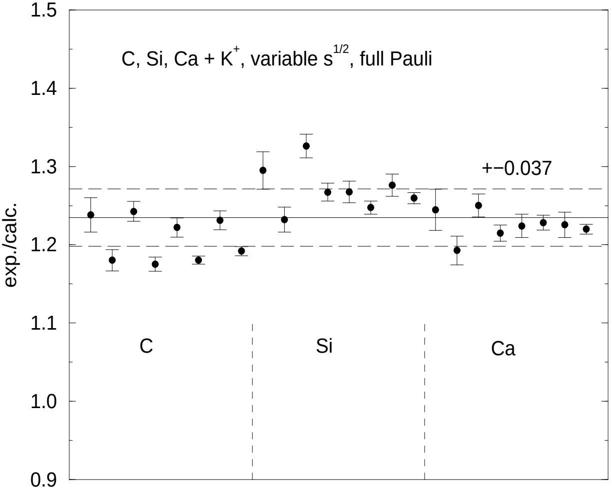


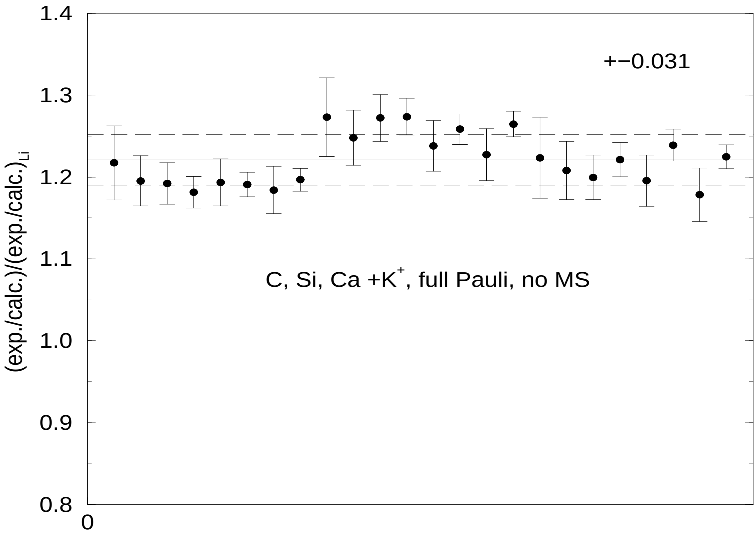
^{6}Li + K$^+$, fixed s$^{1/2}$, no Pauli
exp./calc.
1.3
1.2
1.1
1.0
0.9
0.8
R T R T R T R T
+−0.032
488 MeV/c
531
656
714



^{6}Li + K$^+$ variable s$^{1/2}$, no Pauli
exp./calc.
+−0.024
488 MeV/c
531
656
714
1.3
1.2
1.1
1.0
0.9
0.8


C, Si, Ca + K+, variable s1/2, no Pauli
+−0.044
exp./calc.
1.5
1.4
1.3
1.2
1.1
1.0
0.9
C
Si
Ca


C, Si, Ca + K$^+$, variable s$^{1/2}$, full Pauli
+−0.037
exp./calc.
1.5
1.4
1.3
1.2
1.1
1.0
0.9
C
Si
Ca



A clear (22±3)% enhancement in nuclei.

Results and Disscussion

The first test of our in-medium kinematics (or sub-threshold algorihtm) with truly deep-penetrating particles.

Able to test separately the different elements, i.e. the variable energy and the Pauli correlations. Each contributes to better agreement with the experimental energy dependence.

Enhancements of (22$\pm$3)% of K^+ reaction and total cross section on C, Si and Ca is confirmed. This is the first 'precision' analysis to yield a quantitative result for the enhancement.

Future experiments might enable testing the various theories that have been suggested to explain the enhancement.

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Acknowledgemdnts

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