RECENT PROGRESS IN ANTIPROTON-ATOM COLLISIONS

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INTRODUCTION

Deceleration of negatively charged particles in matter plays a decisive role in the field of experimental physics with exotic atoms. Although at velocities much larger than the Bohr velocity, i.e. \( v \gg c/137 \), it is generally expected that the cross sections for atomic collision processes (ionization, excitation, etc.) are independent of the projectile's charge, care has to be taken at intermediate and low velocities, where the Born approximation is no longer valid.

With the advent of low energy antiprotons at LEAR (CERN), an important step towards the understanding of negative particle interactions with atoms has become possible\textsuperscript{1}. The quality of the \( \bar{p} \) beam allows to measure energy loss and ionization cross sections to impact energies as low as 50 keV. In this paper, a brief summary of recent results from the LEAR experiment PS194 is given, emphasizing ionization of noble gases and the studies of energy loss in Silicon targets.

IONIZATION

In continuation of earlier experiments\textsuperscript{2}, the ratio of single to double ionization cross sections for antiproton impact on Helium, Neon and Argon has been measured. Results are now available for the entire range of impact energies from 65 keV to 20 MeV (see Fig. 1). The surprising enhancement for antiproton impact as compared to proton impact on Helium is seen for all the energies below \( \approx 10 \) MeV.

For energies above 0.5 MeV, this effect was found to result from an enhancement of the double ionization cross section alone. At the lower energies, a reduced single ionization cross section is expected for antiproton impact, yielding again an enhancement in the measured ratio. Similar results as for Helium are obtained for Neon and Argon ionization. Details of the experiment and results are described in\textsuperscript{3}).
ENERGY LOSS AND BARKAS-EFFECT

The theory of energy loss of fast charged particles in matter is based on calculations by Bethe\(^4\), who derived the stopping power in the first Born approximation. Hence the Bethe result is proportional to the projectile charge squared, \(Z_1^2\). It was thus a surprise, when Barkas et al. found that the range of negative pions was longer than that of positive pions of equal momentum, and the effect was due to a difference in the stopping power stemming from the opposite charge of the particles. The reduction in \(dE/dx\) of negative particles was later investigated with sigma-hyperons, pions and muons, but these measurements suffer from the poor quality of the particle/antiparticle beams used.

![Graph](image)

Fig. 1. Measured ratio \(R = \sigma''/\sigma'\) for antiproton impact on Helium. Recent data covering the energy range from 65 keV to 20 MeV are compared to a fit through proton data (solid line).

The so-called Barkas effect was interpreted as a polarization effect in the stopping material, appearing as the next term (proportional to \(Z_1^3\)) in the implied Born expansion of the energy loss. Similar deviations from a strict \(Z_1^2\) dependence also emerge from an analysis of the stopping power of protons, alpha particles and Li\(^3\) projectiles. An overview of the experimental and theoretical status of the Barkas effect has been given by Andersen\(^5\).