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Slow Monopole Signals in Water and Ice Detectors

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Abstract: This paper points out that for slow monopoles energy losses due to ionization can be completely dominated by baryon-number violating interactions releasing large amounts of energy with strong interaction cross sections.

Introduction

While no reliable direct observations have yet been made of magnetic monopoles, they are attractive objects from a theoretical point of view as the existence of just one automatically implies the quantization of electric charge. Many theories of physics beyond the standard model contain magnetic monopoles naturally. Monopoles can also simply be hypothesized to just "exist", but their theoretical status is unclear. For general references, see [1, 2, 3, 6, 7, 8, 5].

Clearly, magnetic monopoles have electromagnetic interactions. At high energies, a magnetic monopole can be thought of as carrying an electric field with it of $\gamma\vec{v} \times \vec{B}$, where γ is the usual Lorentz contraction factor, $\vec{v}$ is the velocity, and $\vec{B}$ is the magnetic field of the monopole at rest. As $\vec{v} \to c$ (the highly relativistic limit), the monopole then looks like a charge of $Z = 1/2\alpha \sim 137/2$. (Here and hence we consider the lowest magnetic charge possible). Thus a relativistic monopole is a bit like minimum-ionizing charged particle depositing about 6 GeV/(g cm^{-2}), which looks nothing like a high energy proton or nuclear interaction. For slow monopoles, of course, one might expect arbitrarily low energy losses, but there are other, less obvious mechanisms that come into play!

Much more spectacular are the strong-interaction processes in which a monopole can participate. The generic process is one of

$$p + \text{Monopole} \to \ell + \text{Monopole} + X$$

where X is a collection of other particles with net baryon and lepton number equal to zero and ℓ is a lepton. The simplest case of this is "monopole-catalyzed baryon number violation" giving $p \to$ $e^+\pi^0$.

The cross section expected is a typical strong interaction cross section of about 10^{-26} cm^2. The reason for this is the following: the s-wave wavefunction for a charged fermion in the field of a magnetic monopole is infinite at the origin. Any wavefunction then with any admixture of s-wave will then get "sucked into the monopole" with infinite probability.

The net result is that a slow monople can release an almost limitless quantity of energy as it travels through a scintillating detector, giving rise to an incredibly obvious signal. More detailed results for various detectors are in preparation[4].

Conclusions

Baryon number violation interactions can result in huge amounts of energy being released by a monople passing through matter. Such signatures could be interesting in a variety of detectors not necessarily designed with searches for such monopoles in mind.

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