ISTITUTO NAZIONALE DI FISICA NUCLEARE
Sezione di Genova

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Relativistic Tests

M. Conte

Dipartimento di Fisica and INFN Sezione di Genova
Via Dodecaneso 33, 16146 Genova, Italy

Abstract

In this paper we propose to use as a tool for relativistic tests light ions capable of emitting e.m. radiation. Single-ionized Helium atoms look to be the most appropriate particles.

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The lifetimes of the weak interaction decays and the frequencies of the photons emitted by a source are the main tools in most of the special and/or general relativity tests. Here we propose to subject to very strong accelerations a partially ionized atom, since its residual electron(s) generate the wanted radiation while its charge allows an easy manipulation of its motion. Single-ionized Helium (He^{+1}) atoms are the lightest stable particles fulfilling these requirements. We consider experiments where the particle velocity can change either its direction or its modulus by means of electric and/or magnetic fields. Let us start with the variation of direction. A beam of ions rotating in a storage ring can yield information on the effects of the centripetal force, here coinciding with the Lorentz force. More in detail we intend to measure the eventual extra effects on the energy, or frequency, of the emitted photons, beyond the normal Doppler shifts. We could use the low energy proton ring COSY [1] at Jülich. Hence, setting this ring for 3 GeV/c protons, a Helium ion with the same momentum is characterized by

$$\beta\gamma = \frac{p}{M_{\rm He}c} = \frac{3}{3.725} = 0.627 \quad \Longrightarrow \quad \begin{cases} \beta = 0.627 \\ \gamma = 1.283 \end{cases} \tag{1}$$

having considered that the Helium rest mass is $M_{\rm He} = 6.64 \times 10^{-27}$ kg $= 3.725$ GeV/c^2. Moreover, the ions revolving in the COSY bending magnets, of radius $\rho = 7$ m, undergo a centripetal acceleration

$$a_{\rm c} = \frac{(\beta c)^2}{\rho} = 5.05 \times 10^{15}\ {\rm m \cdot s^{-2}} = 5.15 \times 10^{14} g \tag{2}$$

where $g \simeq 9.81$ ms^{-2} is the Earth gravity acceleration. Obviously, the variation of the particle energy will be negligible. It will be interesting to compare these data to those ones obtained [2] at CERN with U.R. muons ($\beta_\mu = 0.9994$), rotating in a ring of radius $\rho = 7$ m, when a centripetal acceleration $a_{\rm c} = 1.28 \times 10^{16}$ ms^{-2} $= 1.31 \times 10^{15}$ g was realized and a remarkable accordance with special relativity forecasts was found.

As regards to the variation of the velocity modulus, we could implement a very simple experiment. A commercial 100 kV d.c. generator can be used for bringing the kinetic energy of the single-ionizes Helium atoms from zero up to 100 keV. Then the same d.c. generator can bring down to rest the same ions, via a simple couple of electrodes separated by a 1 cm gap, obtaining thus an electric field

$$E = 10^5\ {\rm V \cdot cm^{-1}} = 10^7\ {\rm V \cdot m^{-1}} \tag{3}$$

In this case we are in a fully non-relativistic situation, since the speed of 100 keV Helium ions is

$$v = \sqrt{\frac{2eV}{M_{\rm He}}} = 2.197 \times 10^6\ {\rm m \cdot s^{-1}} \qquad \text{or} \qquad \beta = 7 \times 10^{-3} \quad (\gamma \simeq 1) \tag{4}$$

Hence, from the 2-nd principle of the Galilei-Newton mechanics, we have

$$a_{\rm E} = \frac{eE}{M_{\rm He}} = 2.41 \times 10^{14}\ {\rm ms^{-2}} = 2.46 \times 10^{13}\ g \tag{5}$$

where e is the elementary charge. In both experiments, the excitation of the He^{+1} atomic levels can be realized by any mean such as laser beam, electron bombardment, radio-frequency, etcetera.

References

[1] R. Maier, *Cooler Synchrotron COSY - performances and perspectives*, Nucl. Instr. Meth. A **390**, 1 (1997).

[2] J. Bawley *et al.*, Nuclear Physics B **150**, 1 (1979).