



High Energy Physics - Phenomenology

# Requiem for an FCHAMP?

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Fractionally charged massive particles (FCHAMPs) appear in extensions of the standard model, especially those with superstring constructions. The lightest FCHAMP would be absolutely stable and any produced during the early evolution of the Universe would be present today. The production, annihilation, and survival of  $L$ , a lepton with electroweak but no strong interactions, of mass  $m_L$  and charge  $Q_L$  (in units of the positron charge) are explored. Since massive charged particles behave like baryons, primordial nucleosynthesis and the cosmic background radiation temperature anisotropies limit the FCHAMP relic density leading to constraints on the  $Q_L - m_L$  relation. Further constraints are provided by the invisible width of the  $Z$  and by accelerator searches for massive, charged particles. We exploit the fact that in the early Universe the negatively charged  $L$  will combine with alpha particles and protons forming tightly bound, positively charged states. The Coulomb barriers between these positively charged bound states and the free  $L^+$  suppress late time annihilation in the Galaxy and on Earth, limiting any late-time reduction of relic FCHAMP pairs. The surviving FCHAMP abundance on Earth is orders of magnitude higher than the limits from terrestrial searches for fractionally charged particles, appearing to close the window on FCHAMPs. However, as  $Q_L$  approaches an integer these searches become increasingly insensitive, leaving some "islands" in the  $Q_L - m_L$  plane which may be explored by searching for FCHAMPs in the cosmic rays.

Comments: 13 pages, 9 figures, version accepted for publication in PRD, including a new constraint from the D0 experiment

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