Tagging radon daughters in low-energy scintillation detectors

Kevin B McCarty

Princeton University Physics Department, Princeton, NJ 08544, USA

Email: kmccarty@princeton.edu

Abstract. One problematic source of background in scintillator-based low-energy solar neutrino experiments such as Borexino is the presence of radon gas and its daughters. The mean lifetime of the α-emitter ^{214}Po in the radon chain is sufficiently short, 0.24 ms, that its decay, together with that immediately preceding of ^{214}Bi, is easily recognized as a "coincidence event." This fact, combined with the capability of α/β pulse-shape discrimination, makes it possible to tag decays of ^{222}Rn and its first four daughters via a likelihood-based method.

1. Introduction

Low-energy scintillation detectors, such as the solar neutrino detector Borexino [1], are plagued by radon and its daughter isotopes. These isotopes (including α-emitters, due to the phenomenon of α quenching in organic scintillators) generate background in the sub-MeV energy window.

Happily, the four daughters produced following a ^{222}Rn decay are short-lived, $\tau_{1/2} < 30$ min. Given observation of a ^{214}Bi/^{214}Po coincidence event ("BiPo"), it is thus very probable that the original ^{222}Rn decay and the following decays of ^{218}Po and ^{214}Pb took place within the previous 4 hours. If the rate of other background events is not too high, the decay events of radon and its daughters may be picked out—not statistically, but individually. A likelihood-based method used in doing so takes into account the observed positions, energies, and α/β discrimination parameter values of each event during the 4-hr time window preceding the BiPo, as well as the time separation of each possible pair of events.

2. Monte Carlo simulation and Counting Test Facility data

A simple Monte Carlo simulation of Borexino data, with pessimistic assumptions about the background, yielded a success rate for the likelihood-based algorithm of > 96% in identifying each of the three isotopes ^{222}Rn, ^{218}Po, ^{214}Pb. The probability for a neutrino event to be falsely identified as a radon-chain decay was < 1%. A 1/20-scale Counting Test Facility prototype [2] is less shielded from external γ rays and therefore has a higher average event rate per unit mass. Analogous simulations for CTF predicted a success rate of ~95% for the two α-emitters, and 87% in identifying ^{214}Pb β decays. An analysis of 177 BiPo coincidences in real CTF data further indicated the potential utility of the method [3]. The possibility of similar event tagging in the ^{238}Th chain may also be foreseen.

References

[1] Alimonti G *et al*. 2002 *Astropart. Phys.* **16** 205

[2] Alimonti G *et al*. 1998 *Nuc. Inst. Meth.* A **406** 411

[3] McCarty K 2006 *The Borexino Nylon Film and the Third Counting Test Facility* (Ph. D. thesis, Princeton University) chapter 8 pp 388–400