Negative Pion Absorption in Water and Light Material

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The knowledge of the π^- free-decay probability at rest in water is important for the design of moderators at modern spallation neutron sources insofar as these devices are to be utilized as high intensity neutrino sources. The presence of $\overline{\nu}_e$ contamination from μ^- decay following the $\pi^- \rightarrow \mu^- \overline{\nu}_\mu$ decay at rest limits the sensitivity of measurements of neutrino oscillation parameters, particularly if continuous beams are used. The calculation of unwanted backgrounds and consequent difficulty of data analysis depend rather crucially on this number, which has not been measured to date.

The canonical explanation of π^- free-decay in light material by the presence of metastable states in the pionic atom would not lead us to expect appreciable π^- free-decays in water. However, theoretical arguments [1] have recently been brought to our attention which postulate an entirely different mechanism based on the significant difference in the low energy ionization loss mechanisms for negative and positive particles. In this picture the cross section for negative particles in hydrogen at less than 10 eV reaches $\sigma_H \sim \pi(F.T.)^2$, where $F.T.$ is Fermi-Teller limit of about 0.53 Å, whereas in He a fraction (undetermined) of the low energy π^- has much smaller cross sections for ionization loss and subsequent capture, and therefore undergo free decay.

The TRIUMF E930 experiment is to measure the fraction and the lifetime of such delayed components, if any, at a sensitivity of better than 0.1 %. The primary mode of search is to detect delayed electrons at 70 MeV from the decay $\pi^- \rightarrow e\overline{\nu}$. Ease of detection of such electrons more than compensates for disadvantages due to the small branching ratio of the mode (1.2×10^{-4}). Other modes to be sought are $\pi^- + p \rightarrow n + \gamma$, $\pi^- + p \rightarrow n + \pi^0$, and $\pi^- + O \rightarrow X + p$. These modes will let us confirm $\pi^- \rightarrow e\overline{\nu}$ results and provide extra information for better understanding of the process that would lead to free decay of stopped π^-.

A 75 MeV/c π^- beam is stopped at rates of 10–30 KHz in an 8-mm thick water target after passing though two beam counters. The decay (and reaction) products are observed by two arm telescope systems located at $\pm 90^o$. Each telescope consists of three plastic counters spanning about 2–5 % in solid angle followed by a large NaI crystal ($46\mathrm{cm}^\phi \times 51$ cm or $36\mathrm{cm}^\phi \times 36$cm). Data are taken with and without a 2-mm thick lead converter between the first and the second telescope counters to enhance photon conversion. Data are also taken with a π^+ beam to calibrate the system and provide normalization; in the $\pi^- \rightarrow e\overline{\nu}$ mode, first order acceptance factors cancel when the yields are compared.

Other possible moderator materials, such as Beryllium, will be tested as well. Data taking is in progress at the time of writing.

References

[1] S. Ovchinnikov, private communication.