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Laser trapped ^{6}He as a probe of the weak interaction and a test of the sudden approximation

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Synopsis Correlations between β decay products are sensitive observables to look for exotic contributions to the weak interaction excluded by the Standard Model of particle physics. To precisely measure the $\beta-\nu$ angular correlation parameter, $a_{\beta\nu}$, in ^{6}He β decay, the radioactive atoms are trapped in a magneto-optical trap and the momentum of β particles and ^{6}Li recoil ions are measured in coincidence. The shake-off process, leading to higher charge states of the Li, plays an important role in this observation and must be studied carefully. Its study provides stringent tests of the sudden approximation for atomic calculations in this few electron system.

The study of $\beta-\nu$ correlations in the ^{6}He β decay is ideal to search for tensor-like contributions to the weak interaction. Its pure Gamow-Teller decay is free from branching and mixing ratios related uncertainties and its simple atomic and nuclear structures allow to perform ab initio calculations for recoil and radiative corrections.

Up to 2×10^{10} ^{6}He/s are produced via the ^{2}H(^{7}Li,^{3}He)^{6}He nuclear reaction by impinging a 15 μA deuteron beam, accelerated at 18 MeV with the tandem Van de Graaff at the University of Washington, onto a liquid lithium target. To be manipulated by lasers, noble gas atoms first have to be excited to their metastable state. An RF-discharge brings a small fraction of the atoms into the 2^3S_1 state which is then focused by means of a transverse cooling stage and injected in a zero crossing Zeeman slower. A 2-dimensional focusing setup sits at the zero-crossing, taking advantage of the quadrupolar magnetic field, and re-focus the slow atomic beam towards our first trap. The trapping efficiency is optimized by increasing the fluorescence signal from a large ^{4}He trap. For ^{6}He, an additional laser beam at 706 nm ($2^3P_2 \rightarrow 3^3S_1$) increases the detection efficiency and allows to detect less than 10 atoms in our trap.

The β decay is studied in a second trap isolated from the first by a low conductance tube and a shutter. The trapped atoms are periodically pushed out of the first MOT and then guided by a 2-dimensional blue-detuned optical dipole trap towards the second MOT. Surrounding the second trap are a β detector which triggers our acquisition system, an electrode array to collect the recoiling ions and a microchannel plate detector to detect them. Trap properties and dynamics can be studied by collecting Penning ions resulting from He(2s)+He(2s) and He(2s)+residual gas collisions.

Different charge states of the recoiling ^{6}Li ions, resulting from the β decay and potentially followed by single or double shake-off emission, can be distinguished by their time-of-flight distributions. However, due to their recoil energy distribution (up to 1.4 keV) and their angular correlation with the β particles, an accurate measure of $a_{\beta\nu}$ requires a precise knowledge of the shake-off probabilities. In particular, the dependence on recoil energy and electronic state population need to be studied. A similar study has been performed in the case of the ^{6}He$^+$ β decay [1] and found in very good agreement with theoretical calculations relying on the sudden approximation. Our experiment with a two-electrons system also allows to look for double shake-off emission and test the e^--e^- correlation.

Our dedicated setup will be presented at the conference along with early results for both $\beta-\nu$ correlations and shake-off emissions.

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