A New Detector System for Measuring the Bound State Beta-decay of Fully Ionized ^{205}Tl at the ESR

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Fully ionized $^{205}Tl^{81+}$ is unstable against a bound state β^- decay to hydrogen like $^{205}Pb^{81+}$:

$$ {}^{205}_{81}\mathrm{Tl}^{81+}_{1/2^+} \rightarrow {}^{205}_{82}\mathrm{Pb}^{81+}_{1/2^-} + \bar{\nu}. \quad (1)$$

The matrix-element of this transition to the first excited state in ^{205}Pb (at 2.3 keV) also governs the probability of neutrino capture in atomic ^{205}Tl (threshold 53.6 keV):

$$ \nu + {}^{205}_{81}\mathrm{Tl}^{0}_{1/2^+} \rightarrow {}^{205}_{82}\mathrm{Pb}^{1+}_{1/2^-} + e^-. \quad (2)$$

Therefore it plays a major role for a possible geological determination of the solar neutrino flux integrated over the last about 20 million years [1]. On the other hand it could be used to interpret an anomalous isotopic ratio of ^{205}Tl/^{203}Tl in meteorites as an extinct radioactivity with regards to s-process nucleosynthesis short-time before the formation of the solar system [2].

To measure the half life of the bound state β^--decay of ^{205}Tl, a beam of bare $^{205}Tl^{81+}$-ions at approximately 360 MeV per nucleon will be stored in the heavy ion storage ring ESR at the GSI Darmstadt for several hours. $^{205}Pb^{81+}$-ions generated during this time will then be stripped to $^{205}Pb^{82+}$ by turning on the internal gas-jet target. Finally the following dipole magnet will distract the $^{205}Pb^{81+}$-ions, leading them straight towards the detector system.

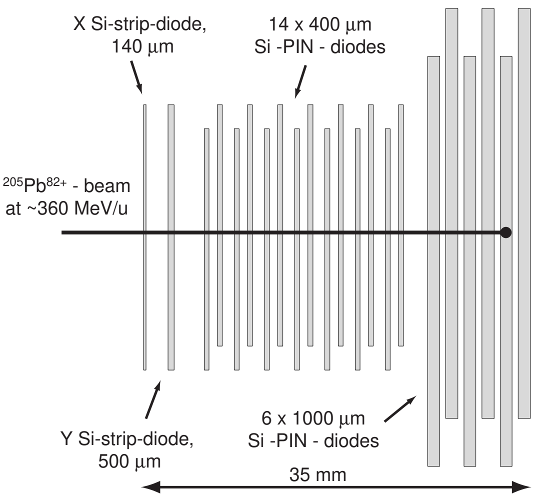

Fig. 1: Schematic view of the detector system.

The detector system for this approved experiment is designed to be of a higher selectivity than the one used in a similar experiment, proving the bound state β^--decay of $^{187}Re^{75+}$ [3]. It should provide a clear identification of the ^{205}Pb-ions and a sufficient discrimination of background, which mostly consists of ^{205}Tl-ions scattered at the gas-jet target. The detector developed to accomplish these requirements consists of two position sensitive Si-strip diodes (x and y) for measuring the charge to mass ratio. To determine the nuclear charge Z, a stack of 20 Si-PIN-diodes ($14 \times 400\ \mu$m and $6 \times 1000\ \mu$m thick) is placed behind the Si-strip-diodes. This gives a total thickness of 12.24 mm (28.41 g/cm^2) Si, sufficient to stop the incoming ions (see fig.1).

A prototype of this detector was built and tested with a $^{238}U^{90+}$ beam at 296.7 MeV/u in December 1999 at the GSI Darmstadt.

The Si-strip-diodes were proven to deliver a precise position information. Fig.2 shows the arithmetic mean ΔE of the energy-loss signal of all Si-PIN-diodes as a result of a very preliminary analysis of the data. The resolution of the energy-loss ΔE is $\delta(\Delta E)/\Delta E = 1.35\%$ (FWHM). Considering a predicted difference between the energy-losses of ^{205}Pb and ^{205}Tl, $\Delta E_{Pb} - \Delta E_{Tl} = 2.43\%$, it should be easily possible to distinguish Pb and Tl in the future experiment. The signals towards lower energies are supposed to come from fragmentation within the detector and have to be studied in more detail.

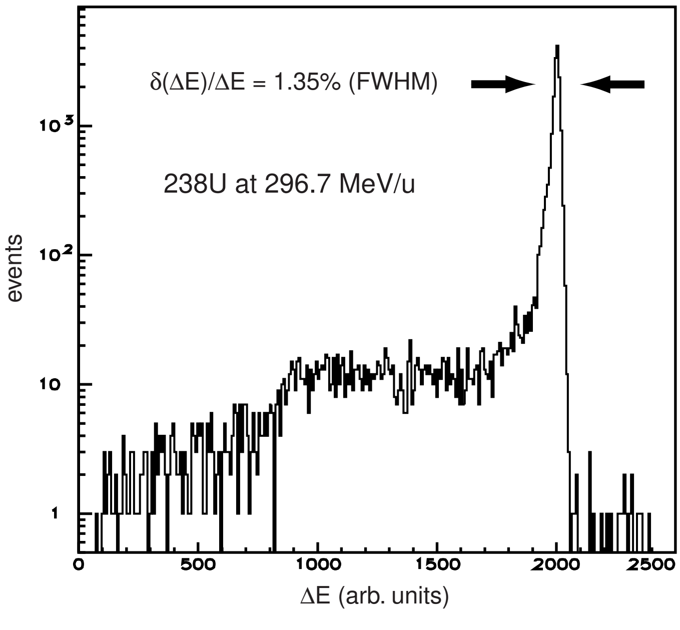

Fig. 2: Arithmetic mean of the energy-loss of all Si-PIN-diodes.

References

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