Preparations for a New Decay Rate Measurement of the Negative Positronium Ion ◇

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The negative positronium ion Ps^- is a fundamental leptonic three-body system ($e^+e^-e^-$) and as such purely described by QED to a very good approximation. The most recent and first relativistic calculation [1] leads to a decay rate of $\Gamma = 2.087963(12)\,\mathrm{ns}^{-1}$. With a calculated binding energy of $-0.326\,\mathrm{eV}$ only the ground state ist stable against dissociation. It decays via e^+e^- annihilation in any photon number, with a greatly favoured 2γ decay channel. Only two decay rate measurements are available, with the most recent value [2] of $\Gamma = 2.089(15)\,\mathrm{ns}^{-1}$.

In order to exploit the unprecedented positron intensity of the worldwide strongest positron source NEPOMUC at the Garching neutron source FRM-II, the experimental setup for the Ps^- experiment, developed at the Max-Planck-Institut für Kernphysik in Heidelberg, was transferred to the NEPOMUC positron beam line in Garching [3]. The schematic setup of the experiment is shown in Fig. 1. Slow positrons impinge on a 5 nm thin Diamond Like Carbon (DLC) foil, where they form Ps^- with a probability of $\approx 10^{-4}$. They are accelerated across a variable length gap and the count rate of ions surviving the flight is detected. Therefore the ions are post-accelerated by a 30 kV high voltage and their two electrons are stripped off at a second DLC foil. The remaining positrons are magnetically transported to a silicon detector, which is cooled down to $-20\,°\mathrm{C}$ in order to reduce background noise.

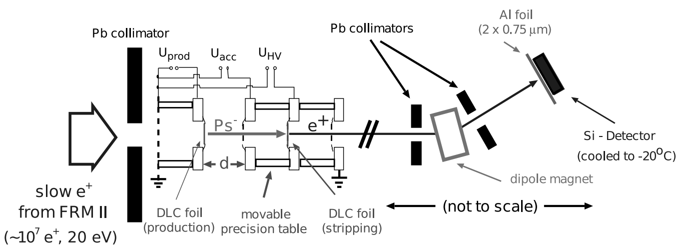

Fig. 1: Decay rate measurement setup at the FRM-II.

In addition to the modifications described in [3], further improvements were made in order to reduce background contributions: A magnetical chicane was introduced with a dipole acting as magnetic filter.

Results from a short commissioning beamtime finished recently show a count rate of Ps^- ions of up to $5\,\mathrm{s}^{-1}$ with a signal-to-background ratio of 25 : 1. A typical spectrum of this measurement is shown in Fig. 2. The positron beam delivers approximately 10^7 (remoderated) positrons per second with an energy of 20 eV. By the end of the next, already scheduled, production experiment it is expected to achieve a new decay rate value which is more accurate than the one reported in [2] by a factor of ≈ 5.

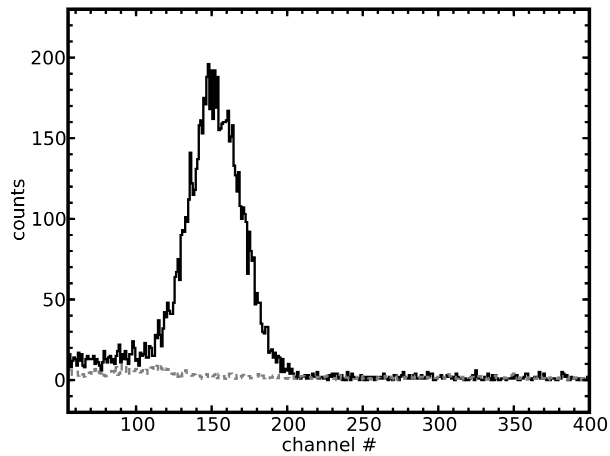

Fig. 2: Typical spectrum recorded during a short commissioning measurement with $U_{\mathrm{acc}} - U_{\mathrm{prod}} = 5\,\mathrm{kV}$ and a data acquisition time of 2000 s (solid line). The peak shows the stripped positronium ions. The background spectrum (dashed line) was recorded for a 30 mm gap distance relative to the gap distance of the first spectrum.

With the high positron flux provided by NEPOMUC, new experiments with Ps^- come into reach. Preparations are on the way to measure the off-resonant photodetachment cross section at the two energies provided by the fundamental and the first harmonic mode of a Nd:YAG laser. These values have only been calculated [4] so far and await verification by experiment. Therefore a laser system has been acquired, which delivers a 1064 nm beam with 200 W average power or a 532 nm beam with 100 W average power, each at a repetition frequency of 10 kHz. The laser beam will be coupled into a cavity, producing a *light curtain*, which will be traversed by the Ps^- beam. The resulting (ortho-)positronium rate is expected to be $\approx 40\,\mathrm{s}^{-1}$. Higher rates of the order of $10^4\,\mathrm{s}^{-1}$ can be achieved by pulsing the incident positron beam as well. With this technique an energy tunable, pure ortho-positronium beam becomes available, which allows e. g. the precision study of the $1^3S_1 \rightarrow 2^3S_1$ transition.

Future experiments may also explore the Feshbach resonances expected to be seen in the resonant photodetachment cross section for determining the binding energy of Ps^-.

References

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