

# Experiments with the Negative Positronium Ion

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## 1. Introduction

Consisting only of stable leptons ( $e^+e^-e^-$ ), the positronium negative ion is the probably simplest bound three-particle system accessible to experiment. With its constituents being stable, point-like particles of equal mass, this exotic ion is an interesting object to study the quantum-mechanical Coulombic three-body problem. This is especially true due to the absence of perturbations from strong interactions. Accordingly, quite a few theoretical studies of this exotic ion can be found in the literature. However, experimental data is largely unavailable.

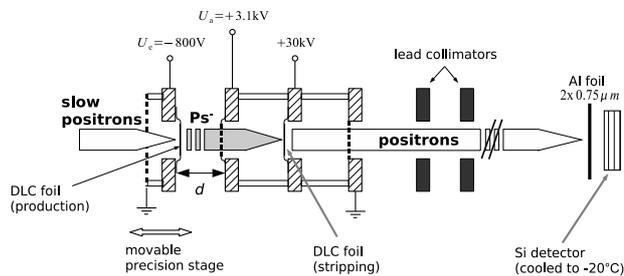


Fig. 1: Setup for measuring the decay rate of  $\text{Ps}^-$ .

## 2. Measurement of the Decay Rate

The aim of our project is to investigate the negative positronium ion in more detail. For this purpose, an apparatus has been built at the Max-Planck-Institut für Kernphysik in Heidelberg to produce  $\text{Ps}^-$  from a beam of low-energy positrons. Using a  $^{22}\text{Na}$  laboratory positron source with an intensity of about  $10^5$  moderated  $e^+$ /s, a new method for measuring the decay rate of the positronium ion has been developed. A schematic illustration of the experiment is shown in Fig. 1: positronium ions are produced from positrons of a few hundred eV hitting a very thin diamond-like carbon foil. To measure their decay rate, they are accelerated across a precisely variable acceleration gap  $d$ , and the count rate of surviving  $\text{Ps}^-$  ions is monitored. For detection, the ions are postaccelerated and stripped by a stripper foil. After the stripping process, the oppositely charged positrons experience another accelerating field and they are finally detected on a Si detector. Employing this setup, an improved measurement has been published in 2006 [1].

So far, the error is still dominated by statistics and the analysis of the systematic errors has shown that an improvement in precision by about a factor of four seems feasible. As measurements of other properties of  $\text{Ps}^-$  also need a much stronger source of moderated positrons, the experiment has been moved to the NEPOMUC facility at the FRM-II research reactor in Garching.

After transferring the setup to the FRM-II and performing first tests at NEPOMUC, several improvements and modifications have been made in order to adapt the ex-

periment to the NEPOMUC positron beam and to further minimise systematic uncertainties. An MCP beam diagnostics station has been added to check the position and diameter of the positron beam. Further, a new design of the  $\text{Ps}^-$  production/detection setup makes the measurement insensitive to angular misalignments of the positron beam with respect to the axis of the chamber, and a lead collimator upstream of the production target helps to reduce the background due to 511 keV annihilation  $\gamma$ -rays.

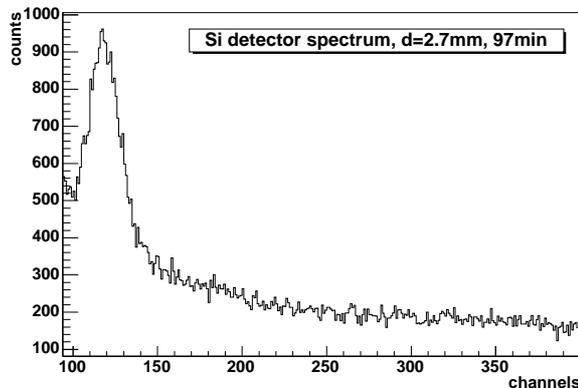


Fig. 2: A spectrum recorded during the November 2006 beamtime at the NEPOMUC facility. The peak due to stripped positronium ions is clearly visible. The grid-foil voltage was  $U_a - U_e = 3900$  V.

Recently, after developing a new procedure for adjusting the beam to the production foil, the first clean  $\text{Ps}^-$  signal at NEPOMUC was detected. According to first estimates, the rate was about a factor of 25 higher than in the Heidelberg experiments. Figure 2 shows a spectrum recorded during these measurements with the peak due to stripped positronium ions standing out clearly. A considerable background reduction was achieved after inserting a pair of lead collimators in front of the detector.

It is certainly possible to increase the observed positronium ion rate by another factor of 2–3 because the positron beam could not be operated at its maximum intensity due to technical problems with an oxygen leak valve on the source side during the last beamtime.

## 3. Outlook

We expect that about 100 times the  $\text{Ps}^-$  count rate of the Heidelberg experiment can be achieved by further optimisation. Such a rate is sufficiently high to make a new measurement of the decay rate of  $\text{Ps}^-$ , which is scheduled to be performed soon. Additionally, the high intensity of the NEPOMUC source brings other properties of the positronium ion within reach of experiments for the first time.

## References

[1] F. Fleischer *et al.*, Phys. Rev. Lett. **96** (2006) 063401.