# PIONIC HYDROGEN

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The measurement of the hadronic shift and broadening of the ground state in pionic hydrogen gives access to fundamental properties of the pion–nucleon interaction. Ongoing improvement in the calculation of strong–interaction phenomena by Heavy-Baryon Chiral Perturbation Theory allows predictions with an accuracy of a few per cent, which should be experimentally tested (see [1, 2] and references therein).

New techniques that have been originally developed for the precision spectroscopy of X-rays from antiprotonic hydrogen [3] and for the determination of the charged pion mass [4] will be used in a new series of measurements [5, 6]. The final aim is to achieve an accuracy for the hadronic broadening $\Gamma_{1s}$ of about 1%, which is an improvement of almost one order of magnitude as compared to previous precision experiments [7]. A similar improvement is also expected for the hadronic shift $\epsilon_{1s}$.

The first goal of the new experiment is to establish a shift value independent of pressure. Such a pressure dependence could originate from the formation of complex molecular structures like $(\pi pp)^{+}pee$ [8]. The $\pi\mathrm{O}(6h-5g)$ transition, which is not affected by the strong interaction, serves as energy calibration. At lower pressures, a simultaneous measurement of both the hydrogen $3p-1s$ and the oxygen line is possible. This allows an energy calibration basically free of systematic errors.

In late 2000, an engineering run took place at the $\pi$E5 high–intensity pion channel at the Paul-Scherrer-Institut (PSI). The experimental set-up was similar to the one used for the pion mass measurement [4]. As target, a cryogenics system was installed in the center of the cyclotron trap, where about 1% of the incoming pions are stopped in gas at normal temperature and pressure. Higher densities are achieved by cooling. The X-rays were reflected in first order by a spherically bent silicon Bragg crystal cut along the 111 plane. To keep aberrations small, the crystal was covered by an aperture restricting the reflecting area horizontally to 60 mm. A large-area array of Charge-Coupled devices (CCDs) served as an X-ray detector. The response function of the spectrometer was obtained from the $\pi\mathrm{C}^{12}(5g-4f)$ transition, which is close in energy (2973.8264 eV) to the pure electromagnetic $\pi^{-}p(3p-1s)$ transition energy 2878.808 eV.

With a $\mathrm{H_2/O_2}$ mixture at a gas density of 3.5 bar equivalent, count rates of about 20 per hour were achieved (Fig. 1). The peak–to–background was improved significantly compared to the previous experiments. In total, 750 and 1100 events were recorded in the oxygen and the hydrogen line. This already yields an accuracy for the shift which is slightly better than that of earlier results because of the absence of systematic errors in the energy calibration. A preliminary value is

$$\epsilon_{1s} = 7.080 \pm 0.035 \quad \text{eV} \qquad \text{(attractive)} \tag{1}$$

which is in agreement with the result of the previous experiment $\epsilon_{1s} = 7.102 \pm 0.038$ eV [7].

From the limited statistics of the engineering run, no conclusions can be drawn on density effects yet. A high–statistics run for the shift measurement is foreseen in summer 2001. Further measurements will investigate in detail the pressure dependence of the line widths of various pionic hydrogen transitions to establish the pure hadronic effect with the envisaged accuracy.

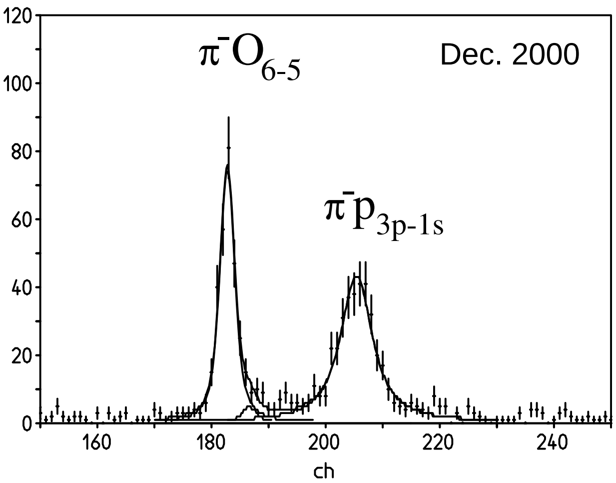


Figure 1: Simultaneously recorded reflections of the $\pi\mathrm{O}(6-5)$ calibration transition and the $\pi^{-}p(3-1)$ transition. The spectrum displays about $\frac{1}{3}$ of the total statistics accumulated for the $\mathrm{H_2/O_2}$ mixture.

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