Performance of a Position-Sensitive Gas Detector for Hard X Rays

M. Czanta[1], C. Strietzel[2], G. Menzel[1], S. Toleikis[1], H.F. Beyer[1], D. Liesen[1], E. Förster[3], T. Ludziejewski[1], B. Manil[4], T. Stöhlker[1], J. Tschischgale[3], A.H. Walenta[2],
[1] GSI Darmstadt, [2] Universität Siegen, [3] FSU zu Jena, [4] Université de Paris

To compare with the results of modern QED calculations [1] for the ground-state Lambshift, sophisticated experiments have been devised based on the spectroscopy of Lyman-alpha lines of very heavy hydrogenlike ions. A technique for achieving the desired energy accuracy of $1-2$ eV could be crystal spectrometry. In the x-ray optical scheme proposed [2] a two-dimensional position-sensitive detector is required with a high spatial resolution in the direction of dispersion corresponding to about 100 μm. The dispersion for 100 keV x rays amounts to only 0.6 μm/eV challenging the performance of the x-ray detector.

To meet the absorption requirements, the detector which was developed by the University of Siegen in collaboration with GSI consists of a drift chamber which includes Xe gas at pressures up to 40 bar at a sufficient depth. The position information is derived from the dominant photoeffect. Applying a homogeneous electric field, the drift time of the created charge carriers serves as the most accurate measure for the position of absorption of the primary photon limited by the range of the photoelectron of less than 100 μm. The photoelectrons drift to a net of anode wires, lead to an avalanche in the nearly cylindrical field close to the wires and give an amplified electronical signal. The anode wires are read out separately and deliver an additional depth information while the cathode next to the wires consists of stripes which are connected to and read out via a resistive chain to give a position resolution of some millimeters perpendicular to the direction of dispersion.

All signals created are further amplified and then sampled by FADCs. The sampling rates range up to 100 MHz. The FADC board is connected to a standard PC with a fast 32 bit PCI I/O card. With the developed and optimized read-out software event rates up to 200 Hz for events of 6400 data points can be processed [3].

Experiments were conducted to study the detector's performance. For this purpose, a moveable lead slit was positioned in front of the detector to investigate the position resolution in the drift direction. The timing signal which is essential for the determination of the drift times and hence the position information was realized by the usage of a $\gamma-\gamma$ cascade of a radioactive ^{182}Ta source. With an achieved triggering rate of 100 Hz, the rate of coincidence was about 0.4 Hz for a 1 mm broad slit. By defined movements of this slit it was shown that the drift velocity is constant over the whole chamber. In addition, a small slit movement of 210 μm was carried out. From the results it can be concluded that the spatial uncertainty is less than 200 μm.

For experiments with the crystal spectrometer using bare ions and electron capture in the internal gas target of the ESR, a large charge-exchange rate is needed, leading to a high rate of drift-time triggers from the particle detector. With a new data acquisition method, such rates can now be handled up to some Megahertz. The results of a beamtime in December 1998 are visualized in Fig. 1. Because of the higher mean free path of the Xe fluorescence photons in comparison with that of the photoelectrons, they were separated. The offset of about 70 counts corresponds to the recorded random events, while the high plateau is created by events correlated with triggers, its flatness expressing an equal distribution of all possible drift times over the whole width of the sensitive volume of 20 mm. The rising edges correspond to a spatial width of less than 200 μm. The small peak to the right side arises from the events behind the wires.

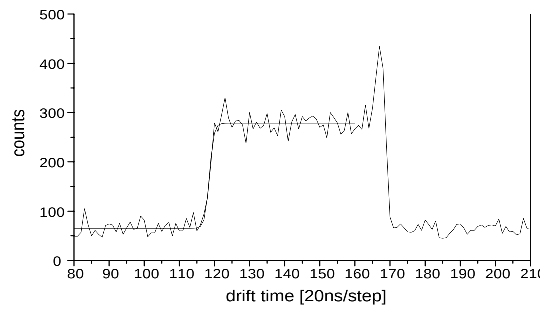

Figure 1: Drift-time spectra after fluorescence separation.

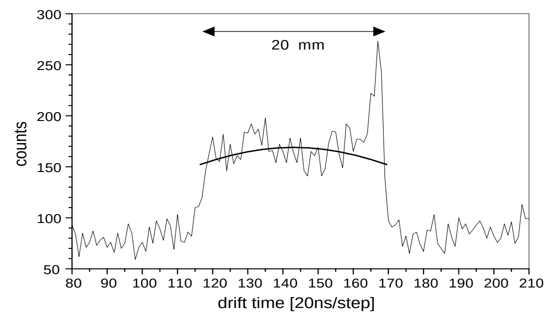

Figure 2: Experimental data of drift times created by fluorescence photons and theoretical distribution.

As a consequence of the finite mean free path of the fluorescence photons, their integrated intensity is lower close to the edges of the sensitive volume than in its midst. The intensity observed is consistent with an uniform distribution for the creation of fluorescence photons. This was demonstrated by the Monte Carlo simulation [4] shown in Fig. 2 fitting the experimental data reasonably well.

An envisaged beamtime in April 1999 with the crystal spectrometer promises to be one more step towards the observation of QED effects with an improved resolution.

References

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