An Experimental Setup for the Search for Deeply Bound Pionic Atoms

H. Gilg, A. Gillitzer, J. Homolka, P. Kienle, M. Knülle, W. Schott, R. S. Hayano [a], K. Itahashi [a], T. Yamazaki [a], T. Baumann [b], H. Geissel [b], G. Münzenberg [b], A. Schröter [b], H. Irnich [c], and N. Iwasa [d]
[a] University of Tokyo [b] GSI Darmstadt [c] Universität Gießen [d] Rikkyo University, Japan

It was proposed [1] to search for deeply bound pionic states in lead in direct transfer reactions using a 600 MeV deuteron beam at GSI Darmstadt. The ^{3}He ejectiles from the ^{208}Pb(d,^{3}He)$\pi^-\otimes^{207}$Pb reaction will be momentum analysed by the Fragment Separator (FRS). A structure in their energy spectrum corresponding to negative Q values below the threshold for free π^- production would demonstrate the population of bound pionic states.

The essential part of the experimental setup is a set of four fast minidrift chambers together with a segmented scintillation start detector placed at the central focal plane of the FRS. Here the horizontal and to less precision also the vertical position and the angle of the particle trajectories will be measured. For the identification of the ^{3}He ions at the presence of a huge background of protons from deuteron break up the time of flight from the central to the final FRS focal plane and the energy loss is measured.

Although the high total particle rate due to the proton background (up to 10^6/s) requires fast detectors the event trigger rate for ^{3}He ions is expected to be rather low ($\leq$ 100 Hz). Thus it is possible to reduce the number of ~ 600 drift time signals by multiplexing. A fast multiplexer has been built which converts a group of 16 channels into one drift time information and one pulse height signal for the address of the hit wire within a time interval of 100 ns. The signals from the 48 wires per drift chamber plane are grouped in such a way that every third wire is fed into one multiplexer unit in order to keep cross talk from adjacent wires as low as possible.

The complete setup of drift chambers was installed at the GAMS magnet at the tandem accelerator laboratory and tested togethter with the full readout electronics using a 26 MeV proton beam with strongly reduced intensity. The magnet was used to vary the position of the proton beam at the detectors. The drift time was measured relative to a scintillation stop counter. A drift time spectrum for one of the 36 multiplexer channels corresponding to 16 wires is shown in Fig.1 where one unit corresponds to 2.5 ns, a corresponding spectrum of the wire adresses is shown in Fig. 2. Entries in the spectrum of the wire number in Fig.2 above channel 16 are due to two or more hits. As can be seen in Fig.2 the pulse height spread of the multiplexer output is sufficiently small so that the region between the peaks corresponding to the wire addresses is clean to a level of less than 10^{-4}. The performance of the chambers as a function of the cathode and potential wire voltage was investigated, the proton rate was increased up to 50 kHz. The drift time spectra and the wire number spectra were not affected by the high count rate.

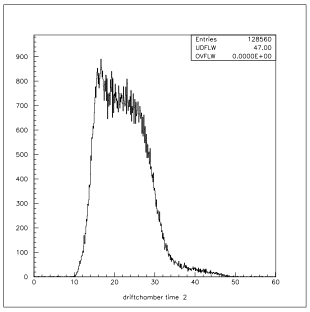

Fig. 1: Drift time spectrum of a group of 16 wires from the fast multiplexer

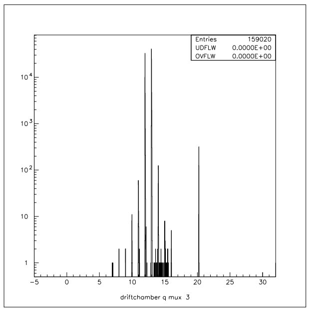

Fig. 2: Number of the hit wire from the pulse height signal of the multiplexer

A crucial condition for the success of the experiment is the total Q value resolution which results from contributions from various sources:

a) the momentum spread of the d beam,
b) its horizontal width at the target,
c) the target thickness,
d) ion optical aberrations of the FRS and
e) the position resolution at the dispersive focal plane.

These contributions could be estimated from a test experiment and machine tests at GSI and from the detector tests:

a) The momentum spread of a ^{12}C beam of 300 AMeV was measured by Schottky diagnosis in the SIS to be in the range $\Delta p/p \sim 4\cdot10^{-4}...8\cdot10^{-4}$. A similar value $\Delta p/p \approx 5\cdot10^{-4}$ was found by a position measurement at the FRS central focal plane using a high resolution gas microstrip detector [2], gaining a factor of two by correcting for the dependence of the momentum on the time after start of extraction, resulting in $\delta Q/Q \approx 0.4$ MeV.

b) The horizontal width of the beam at the target was measured to be $\Delta x \sim 1.5$ mm. In order to exclude contributions from a more extended beam halo ^{208}Pb target stripes of 1 mm or 2 mm width will be used yielding $\delta Q/Q \approx 0.15$ MeV.

c) The contribution of the target thickness of 50 mg/cm^2 is $\delta Q/Q \approx 0.36$ MeV.

d) Ion optical aberrations of the FRS were investigated in the ^{12}C test experiment using a 1 mm diameter hole target and the MWPCs at all FRS focal planes. Thus second order matrix elements were determined. The details of this measurement are described in a separate contribution [3].

e) Since the position resolution of the drift chamber is better than 0.5 mm its contribution to the Q value resolution can be neglected.

Thus a total Q value resolution of 0.5 MeV seems to be achievable. This would allow to identify the bound states if the theoretically predicted cross sections for the population of the pionic states and for background processes are correct.

References

[1] T. Yamazaki et al., Proposal GSI-S160 (1993)
[2] K. Zeitelhack et al., this report p. 104
[3] H. Gilg et al., this report p. 102