High-resolution ERD Utilizing a New Q3D Focal-plane Detector

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Irradiation damage is one of the main limits for high–resolution ERD analysis performed at the Q3D magnetic spectrograph. Thus, the ratio of detection cross section to damage cross section has to be maximized in order to keep irradiation damage as small as possible. This can be done using a large solid angle of detection and reducing the energy per nucleus of the utilized ion beam [1].

The strong kinematic energy shift due to a variation in scattering angle usually limits the solid angle of detection and, therefore, has to be corrected for, if a relative energy resolution of about 5×10^{-4} is desired. The multipole element of the Q3D magnetic spectrograph is an ion–optical element, which is used to correct for the kinematic shift up to the third order. The procedure is described in detail in Ref. [2] and requires information on the scattering angle for each event. In earlier experiments the angular information was obtained by two independent position measurements using two proportional counters positioned near the focal plane of the Q3D magnetic spectrograph with a distance of 6 cm apart from each other. The originally achieved angular resolution of about 35 mrad implicates two disadvantages: At first, it limits the accuracy of the on–line correction by adjusting the multipoles and secondly, a numerical off–line correction is prevented, because the poor angular resolution would be transferred into a poor energy resolution. An additional problem arises due to the aspired minimization of irradiation damage requiring ion–beam energies of 0.1 to 0.3 A MeV, which is much less than used in previous experiments [1]. This implicates an increasing angular spread in the entrance foil of the proportional counters as well as a reduced energy deposition in the detector gas and, therefore, a further decrease of the angular resolution. To overcome these limitations, another concept for the focal–plane detector is introduced.

According to the experiment's geometry a larger scattering angle and, therefore, smaller recoil energy is related to a longer flight path of the detected ions through the Q3D and vice versa. For this reason the scattering angle is revealed by a time–of–flight (TOF) measurement. The new focal–plane detector providing an intrinsic timing resolution better than 1 ns was originally set up for nuclear experiments [3] and consists of a single–wire proportional counter and a solid–state detector array (Fig. 1).

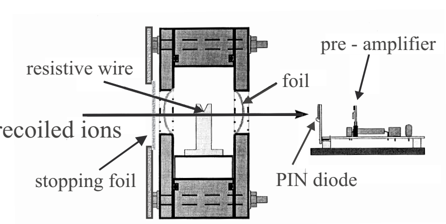

Fig. 1: Cross section of the focal–plane detector of the Q3D.

Having passed the position–sensitive proportional counter the recoiled ions are stopped within the 1.4 m long solid–state detector consisting of 128 silicon PIN diodes (11×11 mm^2 each, 10×10 mm^2 active), where a residual energy and a timing signal are generated. To get a TOF signal a pulsed beam is used which is generated by a buncher system at the low–energy side of the Munich tandem accelerator and a chopper at the high–energy side.

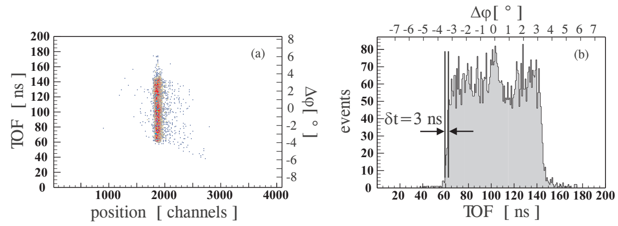

Fig. 2: (a)TOF–position spectrum of $^{12}C^{5+}$ ions recoiled off a 5 $\mu g/cm^2$ thick carbon foil, perpendicularly penetrated by 20 MeV ^{35}Cl ions. The projection towards the time axis (b) reveals an overall timing resolution of about 3 ns.

The achieved overall timing resolution of about 3 ns (Fig. 2) corresponds to an angular resolution of about 4 mrad at an angular acceptance of 110 mrad. Thus, the angular resolution has been improved by one order of magnitude compared to that obtained using the old focal–plane detector.

Path–length differences of the scattered ions detected at different angles induce a rotation in the angle–energy spectra, which is opposite to the rotation caused by kinematic effects. The ion–optical performance of the Q3D gives the possibility to correct for the sum of both effects by optimization of the incident angle [2]. The angular resolution of about 4 mrad enables an additional correction using a software procedure. Slopes of ±80 mrad per 1 % of relative energy loss in angle versus energy spectra can be numerically corrected for providing a relative energy resolution better than 5×10^{-4}. The result of both corrections is shown in Fig. 3.

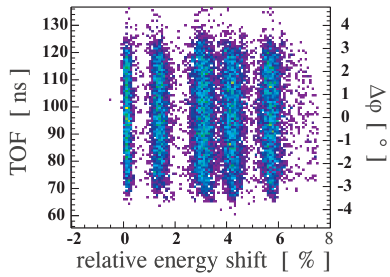

Fig. 3: Angle–energy spectrum of $^{13}C^{5+}$ ions recoiled of a $^{13}C/^{12}C$ multilayer sample.

The introduced method of angular correction is good enough to fully correct for all the energy shifts induced by the large solid angle of detection. As the described performance holds even for recoil energies of a few MeV, projectile energies of 0.1 A MeV to 0.3 A MeV can be utilized.

References

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[2] G. Dollinger, Nucl. Instr. Meth. **B79** (1993) 513
[3] C.Albrecht, diploma thesis, TU München, 1994