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MINIBALL: The first gamma-ray spectrometer using segmented, encapsulated germanium detectors for studies with radioactive beams

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Abstract. MINIBALL is a new spectrometer of position-sensitive Ge detectors designed for nuclear-structure studies at the REX-ISOLDE (D. Habs *et al.*, Prog. Part. Nucl. Phys. **38**, 111 (1997)) radioactive-beam facility at CERN. It combines high efficiency and high granularity, using pulse-shape analysis and 6-fold segmented Ge detectors.

PACS. 29.30.-h Spectrometers and spectroscopic techniques

1 Spectrometers for exotic beams

Nuclei far from stability are of key interest at the present time. They provide tests for existing nuclear-structure models and new physics such as halo nuclei and new shell closures. Data on nuclei which are important in the astrophysical r- and rp-processes and probing the neutron and proton drip lines are also of interest to a wider community. Such nuclei can be studied by Coulomb excitation or transfer [1] The very low beam intensities available at such facilities make a high-efficiency γ-ray detector a prerequisite. However, the use of inverse kinematics yielding recoil velocities of the order of 5% c produces significant Doppler broadening of the γ lines, so one must have good angular resolution (high granularity). In order to obtain high efficiency and high granularity at the same time, and at reasonable cost, new techniques must be used. MINIBALL has adopted a new approach which is the combination of segmented Ge detectors and pulse-shape analysis [2–4].

2 Pulse-shape analysis

The rising flank of the signal from a Ge detector is a function of the migration time of the charge carriers to the electrode, which, in turn, depends on the radial position of the interaction. We define a quantity called the "time to steepest slope" for this signal which has been shown experimentally to be proportional to the radius [5]. By segmenting the outer electrode and monitoring the signals on each electrode, we can determine in which segment the interaction took place. Furthermore, transient signals are induced on the neighbouring segments by mirror charges and the relative amplitude of these mirror charges indicates the relative distance to the two segment boundaries. Using these pieces of information, it has been shown, in experiments with collimated sources, that each segment of the MINIBALL detector can be divided up into about 16 pixels giving about two-orders-of-magnitude improvement in the granularity of the whole detector [5].

3 Digital electronics

In order to process the pulse-shape information, special electronics is required. MINIBALL has made use of commercially available digital electronics from Xia. This single width CAMAC module has four complete spectroscopic channels which digitise the incoming signals with 12 bit 40 MHz sampling ADCs. Filtering and triggering is performed using a field programmable gate array and further processing using a digital signal processor. User code written specially for MINIBALL performs the pulse-shape analysis on-line and everything is buffered for transfer by fast CAMAC level 1 at 2.5 Mwords/s. Times are synchronised between modules by using a common 40 MHz clock signal generated externally.

4 Results

MINIBALL has been used in many experiments with stable (Cologne) and radioactive (CERN) beams. Prior to

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that, tests were made in inverse kinematics which show that Doppler correction after the full pulse-shape analysis improves the resolution by a factor of 3. The Cologne data also show that the desired efficiency has been achieved and that campaign was used to study several nuclei of current interest in low-spin nuclear physics. The CERN data on heavy Na and Mg isotopes show that radioactive nuclei can be studied by both Coulomb excitation and transfer.

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