Position-Sensitive Si Detectors for In-Beam Tracking at the R^{3}B Setup*

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An effective way for accessing the most rare and short-lived isotopes is to produce them via fragmentation of a high-energy primary beam on a thick reaction target and consequently separate the fragments to select the ions of interest. The separation is obtained using a fragment separator consisting of magnetic multipole elements. The resulting secondary beam is typically a cocktail beam of various isotopes which often have a large momentum spread. Several diagnostic tools along the beam line are necessary to identify the isotopes of interest and measure their momenta. These detector tools need to be as precise as possible, but with minimum material so that they do not introduce further spread in the ions' momenta. The possible near-target in-beam tracking detectors for the R^{3}B setup at GSI constitute an active area of research and development within the collaboration. We present here the status of such investigations regarding position-sensitive Si detectors.

For most experiments in the R^{3}B setup it is necessary to know the incoming and outgoing angles of the ions (to and from the target) with a resolution better than 1 mrad. In addition, a precise charge identification before and after the target is essential. In the past decade we have successfully used for simultaneous charge and position measurements a set of three 2-D position-sensitive Si detectors [1] of 300 μm thickness and with an active area of 4.5 x 4.5 cm^2 (two before and one after the target and before the magnet).

However, during this time we have also identified some limitations of the particular detector type, which become more prominent considering the new possibilities offered by the new superconducting magnet to be used in the setup in the near future. Namely these limitations are: 1) their rate capabilities are limited to few tens of kHz, 2) their thickness introduces an angular straggling which in most cases dominates the position resolution of the detector, 3) the size of the detector after the target is limiting the acceptance of the outgoing fragments.

In a recent 2012 experiment we have replaced these detectors with thinner and larger (6.3 x 6.3 cm^2) 2-D position-sensitive Si detectors [2] in order to minimize the latter two limitations. In particular we have replaced the two detectors before the target with 200 μm thick detectors and the one between the target and the magnet with a 100 μm thick detector. The results and a comparison with the older detector type are summarized in Table 1. From these results it is clear that although we gain in angular straggling and coverage we obtain worse performance for the larger and thinner detectors. This is attributed to the smaller energy loss and the larger capacitance of these detectors. Furthermore the rate limitation is still present and in the face of the more intense beams delivered by the FAIR facility this is an important drawback that needs to be addressed.

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Table 1: The main characteristics (active area (a.a.), thickness (d)) and the performance (charge resolution (δZ/Z) and position resolution (δx) in σ values) are shown for the different types of position-sensitive Si detectors. The results were obtained using a ^{136}Xe beam at ∼500 MeV/A. The last lines present results calculated with ATIMA for the angular straggling (a.s.) and energy straggling (e.s.) divided by energy loss (e.l.). The measured charge resolution is limited by the energy straggling.

	Hamamatsu S5378	Micron TL63-200	Micron TL63-100
a.a. [cm^2]	4.5 x 4.5	6.3 x 6.3	6.3 x 6.3
d [μm]	∼300	∼200	∼100
δZ/Z [%]	0.6	0.8	1.1
δx [μm]	100	150	350
a.s. [mrad]	0.4	0.33	0.23
e.s./e.l.[%]	1.3	1.6	2.3

We are currently exploring different Si detector types such as microstrip detectors and position sensitive strip detectors to be used instead of the 2-D position sensitive Si detectors. One of the obvious advantages of strip detectors is that the total beam rate is shared between the strips enabling overall higher-rate capabilities. At the same time the capacitance is smaller and the signal to noise ratio is expected to improve. In the microstrip detectors the position is reconstructed from the strip that "fired". In the resistive strip type detector, one (or both) sides of the detector is divided into resistive strips of about 1–2 mm wide and the position along the strip is determined through the charge division measured at the two ends. The position reconstruction is one dimensional minimizing the non-linearities observed from the 2-D position sensitive Si detector and simplifying the position dependency of the total energy. The size of such detectors can reach an active area of 10 x 10 cm^2, which should suffice our needs for acceptance, and their thickness can be as low as 100 – 150 μm.

References

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