Si detectors for Time of Flight measurements at the Super-FRS

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The beam diagnostics of the Super-FRS consists of several stations located along the pre- and main-separator [1]. In case of experiments with slow extracted-beams, it has to provide unambiguous fragment identification on event-by-event basis. Thus, position, energy-loss and Time of Fligth (ToF) measurements are mandatory. The ToF detector at the mid-focal plane should cover an active area of about 380 x 50 mm^2 and stand relativistic heavy ion rates up to 10^7 per spill over the whole area. Two ToF detectors located at the end of the Low- and High-Energy Branches of the Super-FRS should have an active area about 200 x 50 mm^2 and stand a rate of up to 10^6 ions per spill. The required time resolution of the ToF detectors is below 50 ps. Radiation-hard material (e.g. diamond) was considered to be a proper choice for the ToF systems of the Super-FRS. Recently, it turned out that the technology of producing large diamond detectors is not yet well established and the material price is very high. Radiation-hard planar Si detectors have been suggested to be an alternative solution.

Few Si detectors with different thickness (100, 300 and 600 μm) and different topology have been tested. Their arrangement is shown on Fig. 1. The active size (~25 mm^2) has been selected in order to have the same capacity of a single strip of a full-size Si-strip detector.

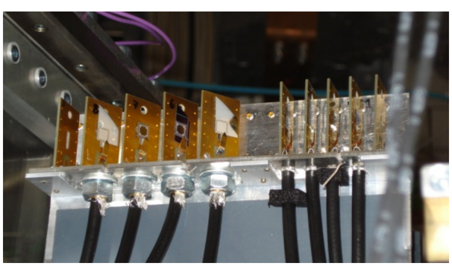

Figure 1: Si detector setup.

Beam test results

Two beam tests using ^{197}Au at 750 MeV/u and ^{238}U at 370 MeV/u have been performed at the FRS and HTD beam lines, respectively. The not amplified energy loss signals have been digitised using an oscilloscope with 4 GHz bandwith and sampling of 5 GS/s. The waveforms have been analyzed offline. A typical signal shape is shown in Fig. 2 for the 300 μm sample. The rise time of the 600, 300 and 100 μm thick detectors was ~700, 500 and 400 ps, respectively. The time jitter, calculated using a method similar to the one implemented in a leading edge discriminators with amplitude corrections, was found to be 20-40 ps (see Fig. 3). The measured energy resolution was close to few percent. The large dynamic range foreseen at the Super-FRS might be covered using amplifiers with moderate gain. After a high dose irradiation using ^{238}U ions, corresponding to 1kGy (1-3 weeks running at the Super-FRS), no deterioration of the timing properties has been observed.

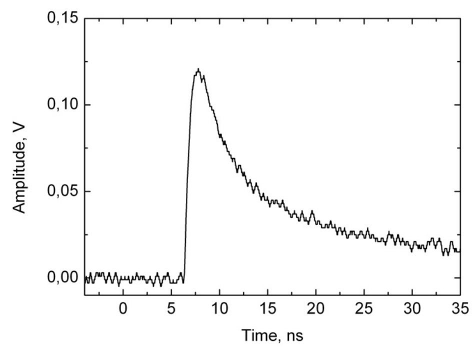

Figure 2: Typical shape of the signal of 300 μm Si detector irradiated by ^{197}Au ions.

Additionally, Si strip detectors can provide a position resolution comparable to the tracking detectors of the Super-FRS.

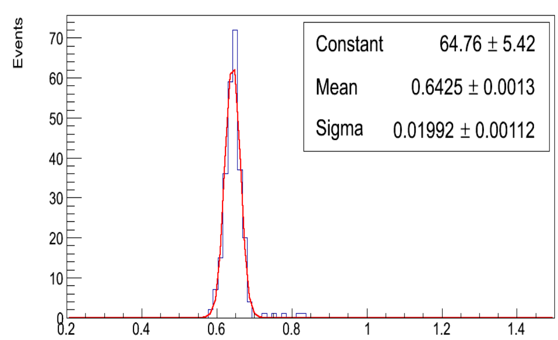

Figure 3: Time jitter of the 300 μm Si detector.

The data obtained in these two tests will help in developing a new prototype with a larger size (~40 cm^2). This prototype is planned to be tested in 2013-2014 together with a broad-band amplifiers (PADI, TAQUILA) and a TDC with resolution below 25 ps. An alternative electronics could be a fast sampling ADC with FPGA data processing on board.

References

[1] M. Winkler et al., Super-FRS Desing Status Report, GSI Annual Report 2010, p. 133.