Status of the $(p, 2p)$ silicon tracker for upcoming fission experiments with the SAMURAI spectrometer

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For studying the fission induced by the $(p, 2p)$ reaction with RI beams of heavy unstable nuclei[1)], a $(p, 2p)$ setup with high missing mass resolution will be installed[2,3)]. Therefore a collaboration between RIKEN and TUM is developing two major new detector components: A time-of-flight (TOF) detector assembly to determine the energy of light charged particles, and a silicon tracker array presented here. Typical energies of the detected protons range 80 to 200 MeV, resulting in a low energy loss of 60 to 150 keV.

The silicon tracker is a two-arm setup with three layers of 100 μm thick, single-sided strip detectors with a pitch of 100 μm[3)]. The strips of the first two layers are oriented vertically to determine the first-order polar angles, while the third layer strips are oriented horizontally. With an additional beam tracking by drift chambers in front of the target, we derive high-resolution reconstruction for both polar and azimuthal angles. Results of Geant4 simulations with 3-mm-thick CH_2 show an expected angular resolution of $\sigma \sim 3$ mrad.

The silicon wafers were designed by M. Sako and purchased by RIKEN. They were sent to TUM in November 2015. The PCB design and the electronics for readout are from TUM. Preliminary tests of the individual detector PCBs were conducted in Munich before the PCBs were subsequently shipped to Japan where integration into the BABIRL DAQ system was performed.

For one detector, maximum trigger rates of 15 kHz in raw data mode and 50 kHz in zero suppressed, pedestal corrected mode (normal mode) were achieved. These rates are currently limited by the data transfer to the BABIRL-DAQ computer and have to be scaled down by the number of detectors for the full setup to 1 kHz. Using a coincidence trigger signal from beam tracking detectors and the abovementioned TOF detectors, we expect only rates below 100 Hz in a typical experimental scenario at HIMAC and RIBF.

The small energy loss in the silicon renders the detector noise level a critical issue. The noise level can be evaluated in raw data mode with random triggers (pedestal run).

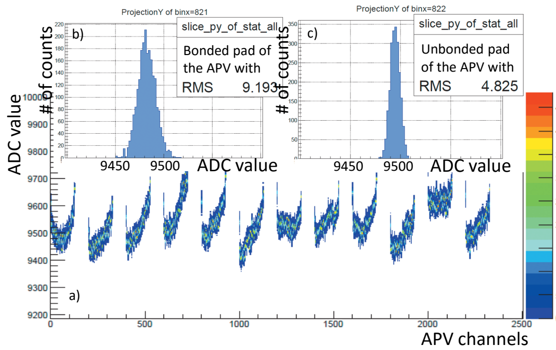

Fig. 1. Pedestal run of the first layer with 768 strips. Here they are divided into 12 groups representing the 12 APV25s with 128 channels each (64 bonded).

Figure 1(a) shows the ADC values for all the APV channels used for the detector in the first layer where every second channel is bonded. Typical noise levels for bonded channels are in the range of $\sigma = 10$ ADC units, see Fig. 1(b), while the unbonded, reference channels in Fig. 1(c) show a more narrow distribution of $\sigma = 5$ ADC units. With a calibration of 0.5 to 0.6 keV per ADC unit, we expect a signal to noise ratio of 10:1 in the experiment. Recently performed runs of cosmic ray measurements (energy loss of 35 keV) validate this expectation, and the protons were clear above the set 5 σ thresholds.

This new setup was tested at the end of February 2016 at HIMAC with the reactions of $^{16}O(p, 2p)^{15}N$ and $^{132}Xe(p, 2p)$ fission each with $E = 290$ MeV/nucleon and 10^5 pps in inverse kinematic. In particular, for the first reaction we will be able to demonstrate the missing mass spectroscopy based on our setup by reconstructing kinetic curves for the first excited state at 6.3 MeV with an uncertainty better than $\sigma = 1$ MeV.

References
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