A diamond start detector array for the HADES pion beam

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Requirements

The secondary pion beam produced by a high intensity 2AGeV primary N beam from the SIS18 differs significantly from standard beams: the beam spot at the HADES target has a diameter of about σ ≈ 1 cm with large tails mainly due to the wide momentum range of about 6% causing 2nd order deviations along the transport line [1]. The latter cause reactions at the compact beam-pipe in front of the pion target. Thus, the start detector has to fulfil several points:

1) rejecting pions from the beam halo
2) providing monitoring of the beam focus
3) providing a start time of the reaction for particle identification via time-of-flight (≈100 ps)
4) mounted close to the reaction target under strict space and power limitations.
5) high efficiency for minimum ionizing particles
6) position resolution of ≈ 1mm σ for reconstruction of the reaction point on a segmented target

Design

To fulfil the above requirements a compact array of 9 single crystal diamond detectors has been designed with low noise preamplifiers directly attached to the segmented diamonds (see Fig. 1). The diamond size amounts to 4.6*4.6 mm^2, the thickness to 300µm. For better position resolution and to keep readout capacitance low, each diamond is divided into 4 quadrants. The array is build out of two PC boards mounted inside the Hades Rich detector directly behind each other 13 cm upstream of the reaction target. They are supported by three 33 cm long PCB rods which also contain the 36 signal lines as Cu stripes in inner (well shielded) layers. A set of 6 low noise, single stage booster and shaper amplifiers outside the vacuum pipe supplements the analogue setup. All amplifiers are based on the RF transistor BFP720.

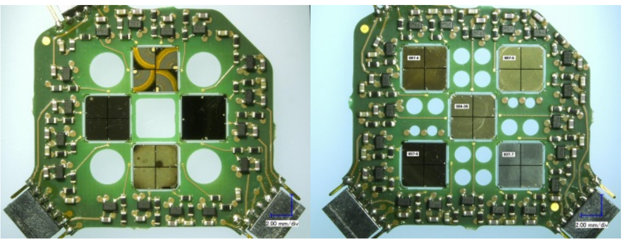

Figure 1: Two PCB boards containing 4/5 segmented diamonds and 16/20 preamplifiers. Both form a 14*14 mm^2 array with 36 pixel.

Results

The two dimensional position distributions of pions dominantly reacting with a target of 12 mm diameter is shown in Fig. 2. The spatial size of a detector channel amounts to 2.3*2.3 mm^2. Due to the distance of 13 cm between target and start detector, the angle of incidence of the pions is needed to obtain a radial hit point on the target. This angle can be obtained from the X,Y position on a tracking stage upstream in the beam-line [2].

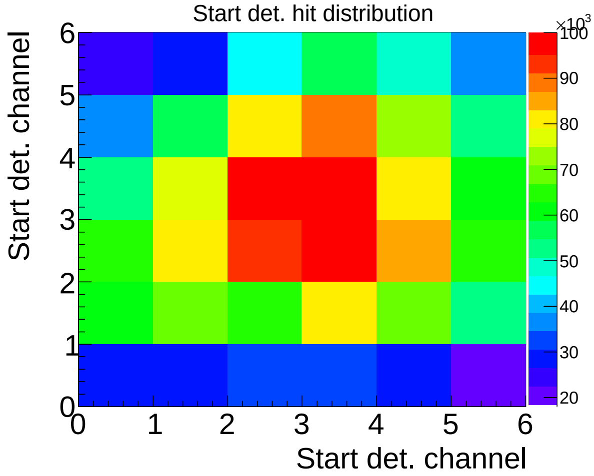

Figure 2: Intensity distribution of the secondary pion beam on the start detector triggered by target reactions.

The time resolution achieved during the beam time in September 2014 was only σ ≈ 190 ps, about a factor 2 above the value expected from tests with single diamonds. It is mainly due to a limitation of the HV to 200V due to charging-up effects of the mounting points at the corners of the diamonds when irradiated with a high flux of charged particles.

Improvements

In order to improve the time resolution the HV limitation due to an exponentially increasing leakage current for some diamonds when irradiated has to be removed. This is currently under investigation. Operation at a HV of 600 V could be achieved for a different mounting procedure of the diamonds in a test setup. This yields a factor ≈ 2.5 faster drift times of electrons and holes resulting in larger signals with shorter rise times. A test with MIPS (2.9 GeV protons) at COSY resulted in a resolution of σ = 90 ps.

References

[1] B. Ramstein et. al., Optimization of the HADES secondary pion beam spectrometer, this scientific report
[2] J.Wirth et. al., Tracking Pions with CERBEROS at the HADES spectrometer, this scientific report

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