Diamond Detectors for the R^{3}B Experiment at FAIR, Darmstadt ◇

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1. Introduction

Diamond is an ideal material for radiation hard detectors for tracking and TOF measurement of heavy ions. We develop such detectors from polycrystalline CVD diamond for the R^{3}B experiment (Reactions with Relativistic Radioactive Beams) [1] in Darmstadt at FAIR (Facility for Antiproton Ion Research).

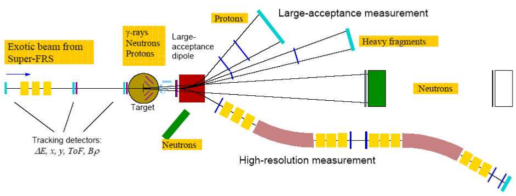

Fig. 1: The R^{3}B experiment at FAIR in Darmstadt.

In detailed test series on small samples we quantified a time resolution to $\sigma\tau \approx$ 60ps, a detector efficiency of 98 %, a charge collection efficiency of 15 % and a radiation hardness up to a dose of $2.5 \cdot 10^{13}$ ions/cm^2 (^{16}O at an energy of 117 MeV). [2]

2. Detector Layout

The detector substrate material is a 100 μm thick layer of polycrystalline (PC) CVD diamond of size $2.54 \times 2.54\,\mathrm{cm}^2$. The one side used for position measurement is segmented in 128 strips with a pitch of 200 μm and gaps of 20 μm. This is done by metallization with aluminum and lithographic methods. The gaps have to be so small to get full efficiency even if particles hit just inbetween the strips. [3]

The back side is used for TOF measurement. It is divided in 16 aluminum strips each with a gap of 50 μm.

3. Electronics

The back side is read out by 2 GHz broadband preamplifiers followed by an leading edge discriminator and a standard TDC.

For readout of the position side we use new frontend boards based on the APV chip, which was developed for the readout of the silicon microstrip detectors in the CMS tracker at LHC. Each of its 128 channels includes a low noise preamplifier, a shaper and an analogue pipeline with 192 stages and a clock frequency of 40 MHz which allows a deadtime free readout. A power of 2.3 mW per channel makes it suitable for use in vacuum. The linear range is 8 mips corresponding to a typical energy loss signal of a medium mass (Z < 25) heavy ion in a layer of 100 μm PC diamond.

The mode of operation is as follows. A write pointer circulates continuously with 25 ns intervals. The trigger marks the column x and the current output is bidirectional differential using 2 lines ± (1 mA).

For the digital control of the APV the R^{3}B GTB interface board was modified and equipped with a 12 bit ADC. So we can use existing hard- and software and it is compatible to MBS data acquisition used at GSI (Gesellschaft für Schwerionenforschung) data acquistion.

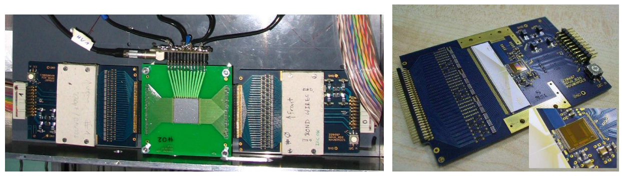

Fig. 2: Left picture: Setup: A 1" diamond with APV FE board on both sides for the position measurement and the broadband preamplifiers for the readout of back side. Right picture: The new FE board with APV chip. The insert shows the APV chip in detail.

4. Test Experiments

To test a full medium size tracking system we used a ^{129}Xe beam of 600 MeV/u and an intensity of 10^5 s^{-1} at the FRS (Fragment Seperator) at GSI.

A compact stack of two detectors was mounted in air at the FRS middle focus to measure particle positions with respect to each other. Each detector was read out by two APV chips.

Figure 3 shows the position correlation of particles in the two detectors. The intrinsic resolution is in the order of 200 μm. The additional structures shown in figure 3 are related to signal coupling of non neighbouring channels due to the PCB layout.

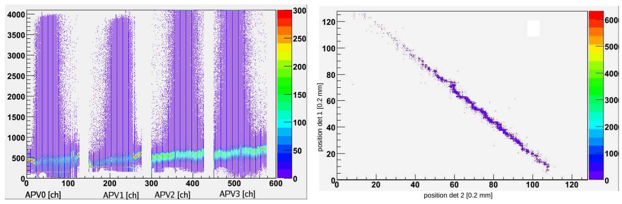

Fig. 3: Left picture: Raw data of all four APV chips. Right picture: Position correlation of the two detectors

5. Summary and Outlook

The presented detector tests showed the successful operation of a medium size micro strip diamond detector for heavy ions. The principle of the full readout device was shown as well as the expected position resolution. Current work is focused on simultaneous operation of TOF and position readout where currently resolution suffers from crosstalk.

The first test of a full scale R^{3}B target tracking device (5×5 cm^2) is expected to be performed in 2008.

References

[1] R^{3}B-Collaboration, Technical Proposal for the Design, Construction, Commissioning and Operation of R^{3}B, Dec 2005

[2] S. Schwertel *et al.*, "Diamond Detectors for the R^{3}B Experiment", Scientific report 2007, GSI, Darmstadt

[3] S. Schwertel *et al.*, Annual report 2006, p. 81

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