Diamonds as timing detectors for MIPS: The HADES proton-beam monitor and start detectors

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Introduction

Diamond detectors are well known for their radiation hardness and high drift speeds of both electron and holes making them ideal as start detectors placed in the beam. However, due to the large effective energy needed to create electron hole pairs (13 eV) the charge created by minimum ionizing particles (MIPS) traversing the diamond is marginal (8000 pairs for a 300 µm thick diamond) [1]. In the following a dedicated, low noise readout scheme is described as well as its application as a start detector for protons in the HADES experiment.

Diamond Readout

Mono-crystalline diamonds with two different detector sizes of 3.5×3.5 mm² (4 segments) and 4.7× 4.7mm² (8 segments) were used with thicknesses of 300µm and 500µm, respectively. This results in both cases in a segment capacitance of 0.25 pF only. RF transistors with low input capacitance (0.2 pF) were closely attached to the diamond (see fig. 1). The bias current was reduced to an extremely small value leading to a relatively large input impedance of about 2 k Ω. This results in an integration of the primary charge signal.

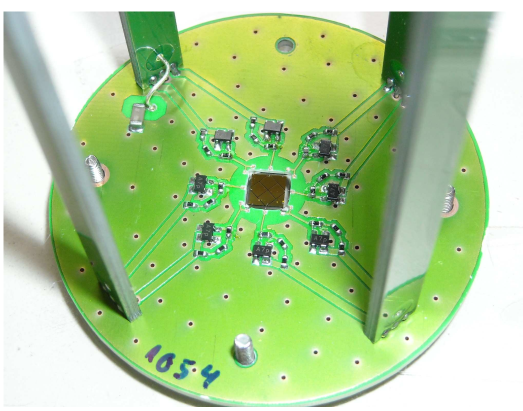

Figure 1: PC board (ϕ =50 mm) with the diamond (4.7× 4.7 mm²) in the centre surrounded by 8 amplifiers.

Final shaping is done by an external amplifier resulting in risetimes (10%-90%) of 1.2 ns (300µm) and 1.35 ns (500µm), respectively.
It should be mentioned that for such a design it is absolutely necessary to keep the stray capacitances at a minimum. E.g. the bias current is provided via 3 resistors in series in order to reduce their capacitive coupling.
The power consumption of a single amplifier amounts to slightly less than 5mW.

Results

The diamonds were exposed to proton beams with energies from 1.2 GeV to 3.5 GeV and rates of up to 3×10^6 /s /10mm². Fig. 2 shows the time resolution measured with leading edge discriminators between two diamonds. After correcting for the intrinsic resolution of the TDC's used and some walk correction, the single diamond resolution amounted to about 100 ps.

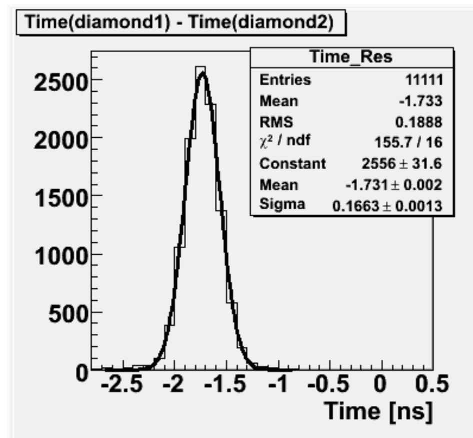

Figure 2: Time resolution for 1.8 GeV protons between two mono-crystalline diamonds without any correction.

From the signal to RMS-noise ratio of about 23 (300µm) and 27 (500µm) one expects a time resolution of about 65 ps for both thicknesses.
The detection efficiency was determined to be ≥ 95%.

Outlook

Due to continuous progress in the development of low noise transistors the signal to RMS-noise ratio can be improved by nearly 50% at 10% shorter risetime based on up to date SiGe:C technology (simulation result only). In particular, tiny housings provide less stray capacitance.
The total area of all components of such amplifier amounts to only 2 mm² including solder pads.

References

[1] Talks at the 4th NoRHDia Workshop, GSI, Darmstadt June 8 - June 10, 2008
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http://www-norhdia.gsi.de/talks/4th/A_Schuettauf.pdf: Diamond detectors in FOPI