Development of Diamond Detectors for Heavy Ion Measurements at GSI Darmstadt

GSI Contribution to the RD42 Collaboration Status Report 1997

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During the past year we have continued to develop the procedures for the characterization of CVD diamond samples suitable for applications in heavy ion experiments. Pulse height distribution measurements based on a single-pulse analysis with a broad-band digital-storage oscilloscope of a resolution of 10 GS/s (Giga Samples/second) are established [1], as well as I-U-characteristic measurements with an electrometer. About 15 CVD-diamond samples from different growth processes are metallized with chromium-gold electrodes in-house and were tested with various heavy-ion beams.

The first milestone of the year '97 was reached in January. We were able to show that heavy ion diamond detectors operate properly with broad-band low-noise 50 Ω preamplifiers. In a test run with uranium ions of 1 GeV/amu [2] an intrinsic time-of-flight resolution of σ = 39 ps was achieved, even without optimized electronics and signal-transfer lines.
Consequently, a new low-cost 3.5 GHz preamp suitable for the amplification of the ultra-fast and weak diamond signals has been developed and successfully tested. The FWHM of the single-pulse amplitude is of the order of 1 ns after 30 m high-quality cable. Nevertheless, even pulse-height distributions from Americium α particles are well separated from the electronic noise [3a][3b]. The narrow width of the signal in conjunction with low noise amplification allows the counting of particle rates well beyond 10^8/s with a single readout channel [4]. The limit is given by the capacitance of the diamond detector.

The development of the tools needed for the preparation of usable heavy-ion diamond detectors proceeds at a satisfactoral pace. Different layouts are forseen for the metallisation. Last year, a 20 x 20 mm² sample with a thickness of 120 µm was used to test interdigital structured electrodes [5]. The aim is to achieve precise high-rate counting in a nondestructive transmission mode with thin, large-area detectors. While the signal shape is excellent [6], the collection of charge suffers from the inhomogeneous electric field. Therefore, different kinds of interdigital electrodes are presently calculated to improve the collection efficiency for such kind of detectors.

Our first goal for the year 1998 is the installation of diamond detectors for heavy ion beam diagnostic applications. Beam intensity and beam profile measurements, as well as detailed beam spill structure investigations [7] are planed. Three diamond samples with a size of 30x30 mm² have been received. Strip- respectively pixel-metallisation with segments in the order of millimeters will be applied. First tests are in preparation for the middle of the year.

Another goal in 1998 is the development of diamond detectors able to operate as start detectors (*) for heavy ion experiments. The requirements here are radiation hardness, low mass, low nuclear charge Z, active areas of several square centimeters, high speed and a time resolution in the order of 100 ps. The development of a prototype start detector for the HADES experiment (**) at GSI is planed to be completed by the end of 1998.

In parallel to the ultra-fast readout electronics a low-noise current-sensitive amplifier with a shaping time of 5 ns and a dynamic range of 1:2000 is under development [8]. This fast integrating readout is needed by all experiments, which are limited by todays CAMAC, VME or FAST BUS electronics to process diamond signals. With this front-end electronics we will test the proportionality of the diamond pulse height to the Z^2 of the charged particle hitting the detector. To investigate systematically this important question, a beam time at GSI's Fragment Separator is forseen for spring '98. This high-resolution spectrometer is able to focus any fragment from a heavy projectile, well separated and identified by mass and nuclear charge, onto the diamond detectors.

(*) The start detector defines the zero time of the experiment.
It must be segmented to handle beam intensities of 10^8 /s

(**) HADES = High Acceptance Di-Electron Spectrometer, an experiment for the search of subthreshold ρ- and Ω-mesons.

Publications 1997

(1) P. Moritz et al., „Diamond Detectors for Beam Diagnostics in Heavy Ion Accelerators" to be published in the proceedings of the DIPAC 97, Frascati

(2) E. Berdermann et al., „Diamond Detectors for Heavy Ion Measurements", to be published in the proceedings of the XXXVI International Winter Meeting on Nuclear Physics", Bormio 98, Italy

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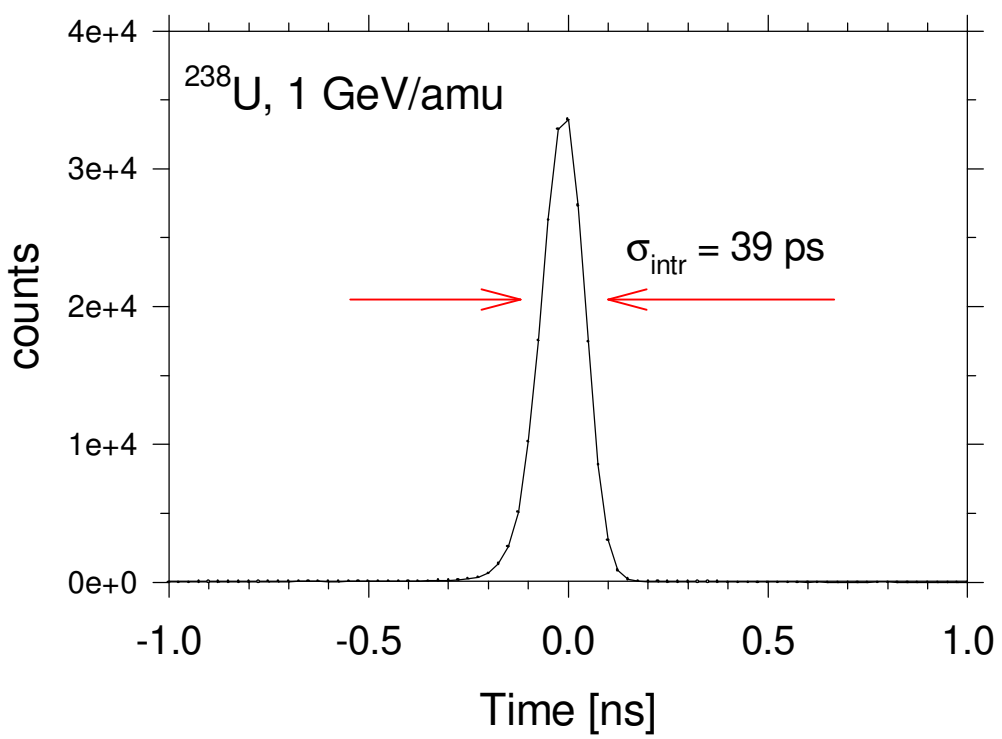
[2] Intrinsic time resolution well below 50 ps, measured with ^{238}U ions of a kinetic energy of 1 GeV/u.

Diamond versus diamond



Two diamond detectors with a thickness of 120 µm and a lucite-scintillator counter were placed perpendicularly to the beam axis, one after another. In front of the whole setup a second lucite-scintillator detector was used as an active veto collimator. The diamond detectors were bombarded with a uranium beam with an intensity of 10^5 ions/s. The coincidence between the scintillator and the veto provides the common start for the TDC.

Electronics: preamps ORTEC 9306, 50 Ω, gain 80,

TDC Philips 7186H, 25 ps/channel.