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A Position Sensitive Beam Monitor for a Dust Accelerator

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Abstract

To ascertain a dust particle's trajectory in the beam line a new developed position sensitive detector is implemented in the beam line of the Heidelberg dust accelerator. It has been calibrated recently, so that the detector signals could be mapped to a position. Additionally an idealised simulation calculated the expected signals. The accuracy of the detector for various SNR has been determined and represents the position sensitive detector as a valuable and reliable component of a dust accelerator.

1. Introduction

Investigating the dynamical and physical properties of cosmic dust can reveal a great deal of information about both the dust and its many sources. Over recent years several spacecrafts (e.g. Cassini, Stardust, Galileo) have successfully characterised cosmic dust using a variety of techniques.The accurate and reliable interpretation of collected spacecraft data requires a comprehensive programme of terrestrial instrument calibration. For this, μm and sub-μm sized dust particles are charged and accelerated by an electrostatic accelerator to speeds in excess of 100 km/s.
The position sensitive beam monitor was built to determine a particle's position in the beam line by using the charge induced by the passing dust particle. Depending on the particle's position a different amount of charge is induced on conductive plates that can be amplified and analysed [2].

2. Design

The position sensitive beam monitor includes four pairs of copper coated PCB plates of 1007.5mm^2 area facing its opposite with a distance of 15mm. The pairs are perpendicular to its neighbouring pairs so that a dust particle's displacement from the center can be detected in every direction. One plate of each pair is grounded, the other one is connected to a collective

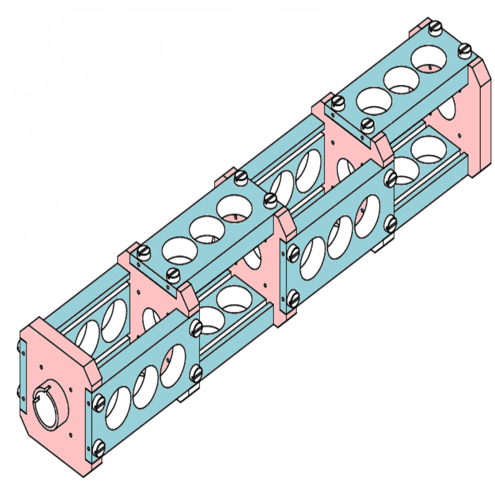

Figure 1: Rack of the position sensitive detector. Blue symbolizes PEEK, red copper. The detecting plates are justified perpendicular to the PEEK plates and not shown in this sketch.

charge amplifier. The pairs are separated by copper orifices to shield them from each other. Charged dust particles passing this set up induce charge on the PCB plates that is higher the closer the particle passes the measuring plate. Thus, the signal can be recorded by one channel of the oscilloscope, and the position of the particle relative to the plates is derived by the relative heights of the sequent signals.
The advantage here is that all four detecting plates are connected to the same charge amplifier, so that no further calibration of amplifying devices is necessary.
Subsequently a signal produced by the position sensitive detector shows four charge peaks in which the first and third give information about the horizontal position of the passing particle and the second and forth peak give information about the vertical position, see figure 2.

3. Simulation

A signal produced by the position sensitive detector not only varies depending on the passing dust parti-

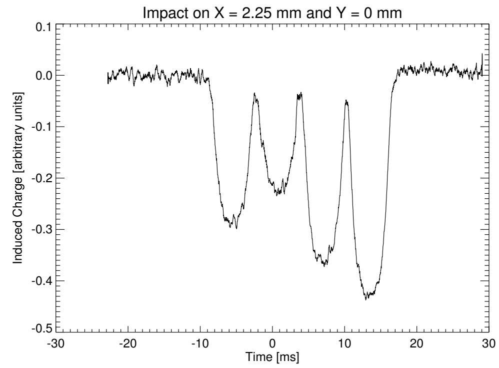

Figure 2: Signal recorded with the position sensitive detector.

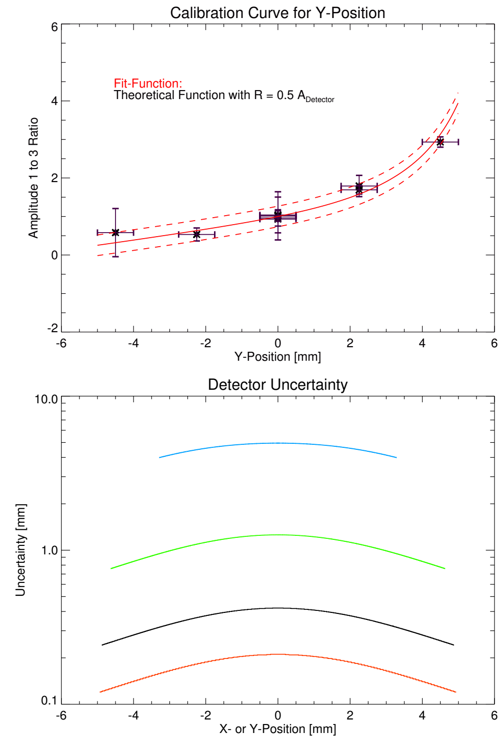

Figure 3: **Above:** Calibration curve for horizontal displacement. **Bottom:** Accuracy of the position sensitive detector for 9dB, 15dB, 20dB and 23dB signal-to-noise ratio from top to bottom.

cle's position but is also dependent of the dimension of the detecting plates, the copper cylinder shielding of the set up and orifices between the detecting plate pairs [3]. To understand the effect of these components for the signal forms for different particle positions in the beam line a simulation has been calculated with COULOMB [1].
The simulated signals were generated for different particle trajectories. From the relative peak height two calibration curves were produced for horizontal and vertical displacement to map the signals to a position. Each simulation was found to fit the measured data.

4. Calibration

To map the signals to a position a second independent position measurement has to be applied. Thus a segmented target was installed behind the position sensitive detector. It was coated with eleven $1mm^2$ conductive segments at well known positions that were each connected to a charge amplifier. On impact a target induces a charge signal on the segment it hit and thus the position can be determined.
A calibration curve has been fitted to the data for horizontal and vertical displacement of the center as shown in figure 3. The curve describes the ratio of induced charge by a particle between two conductive plates dependent of its position. By calculating the curve that best fits the data the effective measuring plate area was found to be half the size of the actual plates used in the detector set up. This tolerance is due to loss of charge by shielding and particle movement.

4.1 Presicion

The precision of the position sensitive detector is limited by the noise and disturbance induced on the charge amplifiers. The accuracy depending on the particles position for different signal-to-noise ratios was calculated and plotted in figure 3.
Induced charge ratios from particles that pass through the center of the position detector show larger inaccuracy in position than particles focused away from the center. At about 8dB signal-to-noise ratio the uncertainty of the detector becomes larger than the beam line itself. Actual recordings tend to have a signal-to-noise ratios more than 20dB and thus have a position accuracy better than 0.3mm.

References

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