A low energy x-ray Compton polarimeter prototype

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Abstract
To learn about the dynamics of atomic transitions in the mid- and high-Z regime it is of great importance to perform a reliable measurement of the polarization of emitted x-rays from the reaction channel of interest. To cover an energy range from 1 keV to ~30 keV we have developed a Compton polarimeter prototype to determine the degree of linear polarization of this radiation. The concept is based on a passive low-Z scatterer (e.g. Si, SiC, PE) in which the emitted x-rays will undergo Compton scattering and in a subsequent step they will be deposited on a ~3.5 mm thick pixelated HPGe detector (work inspired by reference [1]). The back side contact of this detector is segmented with a 19-pixel hexagonal pattern. The asymmetry of the scattering distribution is a signature of the degree of linear polarization. The detector may be used as a 19-pixel x-ray detector or in combination with a scatterer as Compton polarimeter. The readout stage is split into two parts. The first part is a cryogenically cooled FET input stage and the second stage is built from discrete charge sensitive preamplifiers operating at room temperature.

Results of the first tests

- Spectroscopic result of pixel #4. A spectrum of an Am-241 source with the rightmost and the Si55 peak (gamma line indicating an energy resolution of 600 eV at 59.5 keV measured at a shaping time of 2 μs).
- Coincident measurement of the energy signal of two neighbouring pixels. Events where the energy of the x-ray was deposited on a ~3.5 mm thick pixelated HPGe detector (work inspired by reference [1]) will be distributed on several pixel contacts during their transport in the drift field.
- Time spectrum of pixel #4 versus #5. Shown is the time difference of the arrival times of coincident detector signals generated by a single event. This is equivalent to the detector’s time resolution relative to a fast external signal.

Description of the detector system

- The size of the HPGe-detector is 20 mm x 20 mm.
- The detector thickness is ~3.5 mm.
- The boron-implanted detector contact is structured with a 19-pixel hexagonal pattern, surrounded by a guard-ring.
- The 19 pixels have a hexagonal shape.
- The detector bias voltage (~HV) is applied to the amorphous Germanium contact (a-Ge contact), which is the not structured front contact.
- The operating temperature is ~LN₉ temperature (77 K).
- The detector is irradiated on the not structured contact.

In this project we tested an alternative to the wire bonding connection technology for interfacing the FET input with the detector contact. Here spring-loaded contact pins were employed.

Polarization of photons

- For the energy range from 1 keV to ~30 keV we have developed a Compton polarimeter prototype to determine the degree of linear polarization of this radiation.
- The concept is based on a passive low-Z scatterer (e.g. Si, SiC, PE) in which the emitted x-rays will undergo Compton scattering and in a subsequent step they will be deposited on a ~3.5 mm thick pixelated HPGe detector.
- The back side contact of this detector is segmented with a 19-pixel hexagonal pattern.
- The asymmetry of the scattering distribution is a signature of the degree of linear polarization.

Simulations

- Geometrical model for the simulation. The hexagonal pixels are simplified to cylindrical pixels (2 mm diameter, 4 mm length).
- A 3D digital model of a detector head, showing two adjacent HPGe detectors and the PCB with spring-loaded contact pins and FETs as well as the scatterer in front of the detectors.
- Geometric view of the simulation. The hexagonal pixels are simplified to cylindrical pixels (2 mm diameter, 4 mm length).
- Different scatter-observer geometry models were simulated:
  a) scatterer from polyethylene and a tungsten blocking absorber to avoid the direct x-ray.
  b) scatterer from polyethylene close to the detector without tungsten blocking absorber.

References


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