Design, Construction, and Test of a Charged Particle Detector

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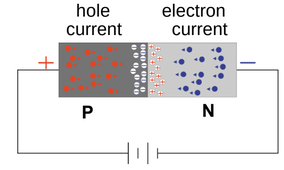
INTRODUCTION

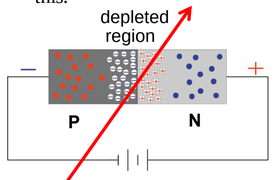
In nuclear physics experiments that involve the production of multiple nuclei, it is often essential to selectively detect recoiling particles along with emitted gamma rays to ensure accurate results. Achieving this level of selectivity requires the use of specialized charge particle detectors that are operated in kinematic coincidence with gamma ray detectors. This powerful combination of detectors allows for the identification and tracking of charged particles while simultaneously detecting gamma rays emitted from nuclear reactions. By detecting both recoiling particles and gamma rays, researchers can better understand the underlying mechanisms of nuclear reactions and identify new isotopes with unique properties.

SOLID STATE SILICON DETECTOR

The basic element of a solid-state silicon detector is a diode constructed by joining together p-type (more electron holes) and an n-type (more electrons) silicon doped material.

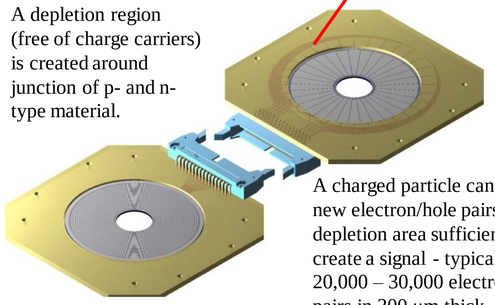


Current flow through diode if connected like this.



For use as particle detector diode needs to be connected in opposite way.

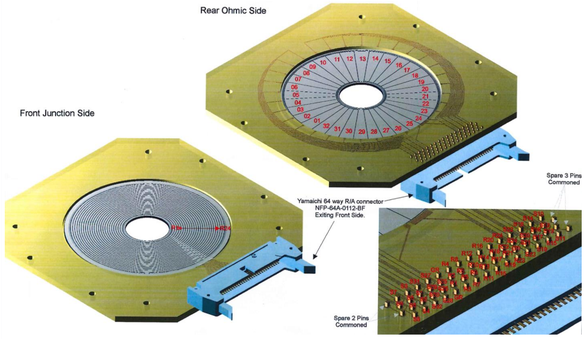
A depletion region (free of charge carriers) is created around junction of p- and n-type material.



A charged particle can create new electron/hole pairs in depletion area sufficient to create a signal - typically 20,000 – 30,000 electron/hole pairs in 300 μm thick material.

THE MICRON S3 DETECTOR

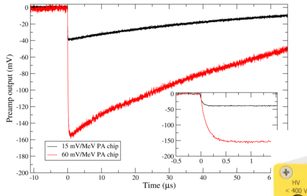
The S3 detectors are manufactured by Micron Semiconductor Ltd. They are annular double-sided silicon detectors having an inner radius of 1.1 cm, and an outer radius of 3.5 cm. These detectors have on one surface a 24-fold segmentation in the radial direction (rings), & on the other surface a 32-fold segmentation in the ϕ direction (sectors) [1].



By recording in which ring and in which sector energy is deposited, the pixel of interaction and hence, the scattering angle can be determined.

PREAMPLIFIER

The S3 detector delivers 56 signals but establishes a segmentation into 768 pixels of about 1 mm by 5 mm in size each. At a typical distance of 3.0 cm from the target, this translates into an angular resolution of about 1. 5◦in θ and 11. 3◦in ϕ. The reduce noise, these signals are preamplified close to the detector before processing.

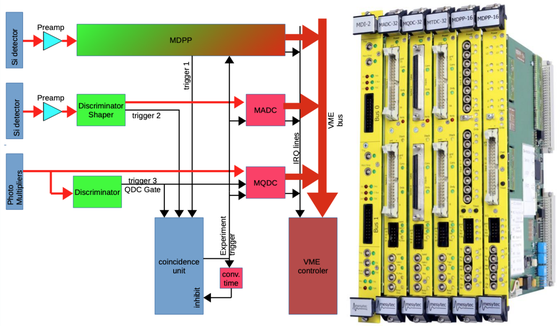


Preamplifier signals from ^{244}Cm α particles.

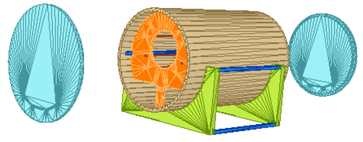
Mesytec MPR-16: A multichannel preamplifier module specially designed for single or double sided multistrip silicon detectors [2].

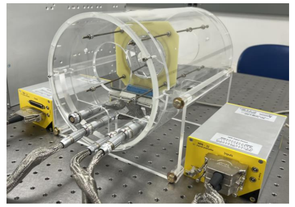
SIGNAL PROCESSING

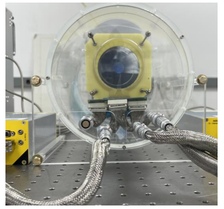
The preamplified signals are processed and digitized by a mesytec MDPP-32 module. This is a fast high-resolution time and amplitude digitizer. It is internally realized as a 32-channel adjustable low noise amplifier and a variable differentiation stage, followed by filters and 80 MHz sampling ADCs. The digitized data are analyzed in an FPGA and reconstructed with highest precision. This allows to achieve unique timing and amplitude resolution.



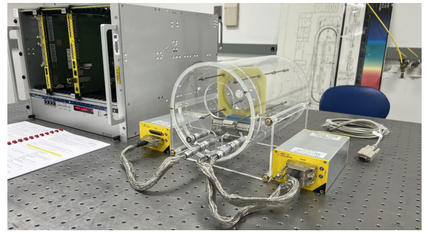
DETECTOR ENCLOSURE





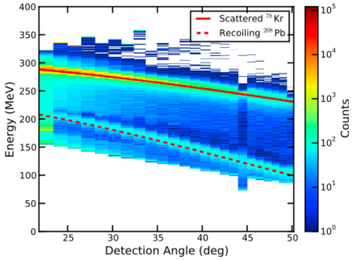


DETECTOR SETUP



SAMPLE SPECTRA

Sample particle identification of scattered ^{78}Kr and recoiling ^{208}Pb in the forward S3 detector. Calculated kinematic lines for each particle species show the energy at a given scattering angle. The separation between the energies of the Kr and Pb allows for clear discrimination in analysis [2].



REFERENCES

[1] Micron Semiconductor Ltd, http://www.micronsemiconductor.co.uk/product/s3/

[2] Mesytec, https://www.mesytec.com/products/nuclear-physics/MPR-16.html

[3] E. Lunderberg, *et al.*, Nucl. Instrum. Meth. Phys. Res. 885, 30 (2018).

ACKNOWLEDGEMENTS

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