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Simulating Timing Performance of Resistive Detectors with Garfield++

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With the stringent requirements on the performance and robustness of timing detectors under the unprecedented conditions of future high energy physics experiments, contemporary detector designs are being refined with the incorporation of resistive elements for increased operational stability. Thorough simulations of the signal formation process and noise sources in these devices are therefore crucial for comprehending and optimizing their performance.

In this presentation, the Garfield++ simulation chain for evaluating the performance of resistive timing detectors will be discussed, covering strategies for simulating large avalanches, signal induction in the presence of resistive elements, contributions from the front-end electronics, and signal arrival time corrections. Along the way concrete examples, such as the resistive plane PICOSEC Micromegas (MM), will be highlighted. Emphasis will be placed on the contribution of resistive elements, such as diamond-like carbon layers, to signal formation —particularly to the leading edge of the signal. In addition to influencing the signal induction on the readout electrodes, resistive elements also contribute to the noise power spectrum of the detector.

Given the crucial role of the signal-to-noise ratio in the timing performance, a breakdown of the different noise sources will be provided, especially for the Johnson–Nyquist noise arising from the resistive elements. Following Nyquist's work, the complex impedance Z(f) of the detector, as seen by the input of the front-end electronics, will be identified as the key quantity defining the thermal noise power spectrum. Analytical expressions for Z(f) will be presented for some toy examples, while for more complex detector geometries a numerical methodology using the finite element method will be outlined.

These strategies are applicable across resistive gaseous detector technologies such as (multi-gap) resistive plate chambers, resistive Micromegas (MM), and μRWELL. In the final part of the presentation, a brief illustration will be provided on how these simulations can be extended to solid state detectors such as silicon photomultipliers, AC-coupled LGADs, and 3D diamond sensors.

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