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Examining ICARUS Cosmic Muon Signal Shapes

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Quantifying Detector Uncertainties

In the search for new physics, such as sterile neutrinos, we must compare our **experimental data** to the null hypothesis, which is provided by **simulations**. However, to be confident in our conclusions, we need to be able to differentiate imperfections in our simulations, detector effects, and unknown unknowns from new physics. For this reason, we need to accurately quantify **ICARUS detector systematic uncertainties**.

Cosmic Muon Waveforms

Since neutrinos may follow unknown physics, we hope to quantify ICARUS detector systematics by studying **cosmic muons**. When cosmic muons interact with the liquid argon in ICARUS, charged particles are released, and driven by an electric field, they pass through three planes of wires. These planes are oriented such that the **path** and **energy loss** of the cosmic muons can be **reconstructed** from the **waveforms** produced in the wires.

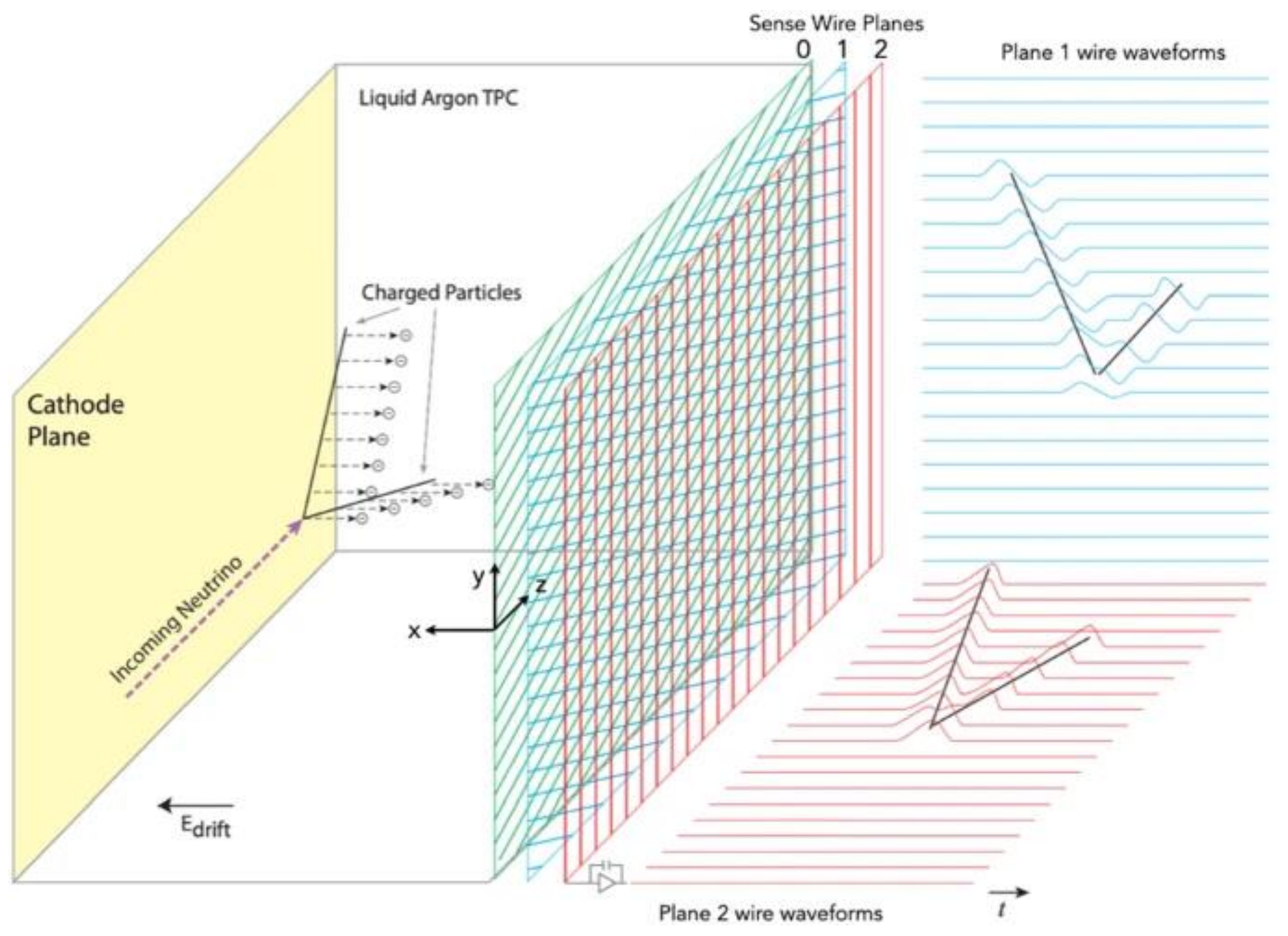

Fig. 1: Simplified model of ICARUS detector and how cosmic muons produce waveforms.

Comparing Fits of Waveforms

Each waveform can be deconvoluted into a waveform that expresses the signal in one of the wires as a function of time. By comparing **fits of waveforms from Monte Carlo simulations** to **fits of waveforms from experimental data**, we can begin to calculate our detector systematic uncertainties, but first, **we need to determine the best way to fit these waveforms.**

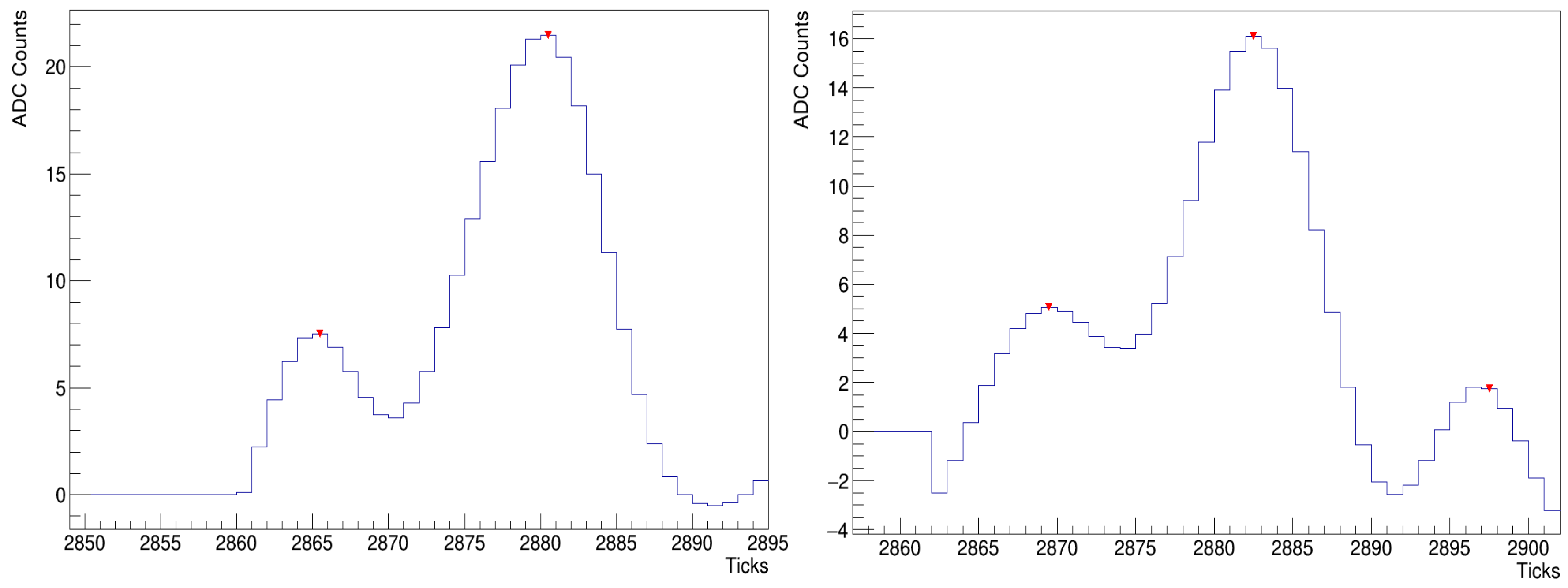

Fig. 2 & 3: Waveforms produced by Monte Carlo simulations. After deconvolution, waveforms show ADC counts, a discretized measure of the signal in a wire, as a function of ticks on the sampling clock.

Evaluating Gaussian Fits of Waveforms

As a first attempt, we fit the cosmic muon waveforms as **Gaussians**. To evaluate how well Gaussians describe these waveforms, we focused on waveforms from simulations with a **single peak**, and we found the **peak** and **full width at half maximum (FWHM)** for each waveform.

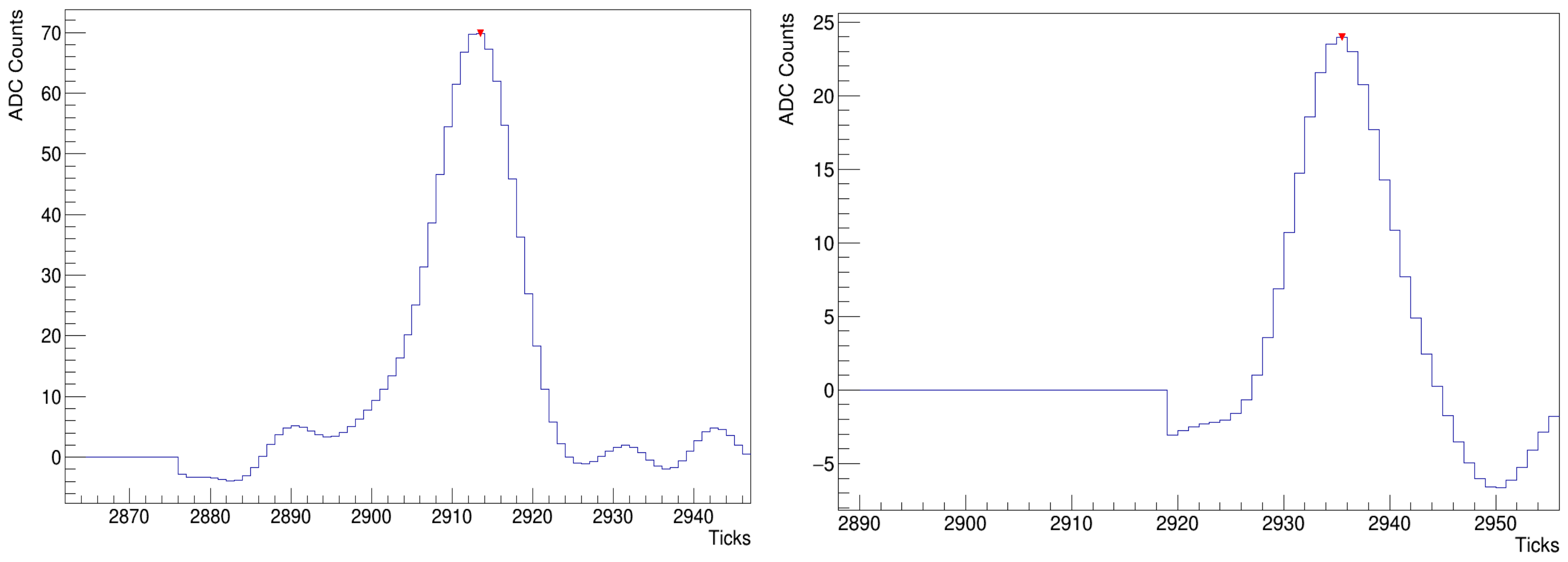

Fig. 4 & 5: Waveforms with a single peak, produced by Monte Carlo simulations.

Peak and FWHM Distributions

To understand how these peak and FWHM values varied, we plotted **peak** and **FWHM distributions** for the waveforms. If these waveforms are well described by Gaussians, the peak and FWHM distributions of the **waveforms** should **closely match** with the peak and FWHM distributions of the corresponding **Gaussians**.

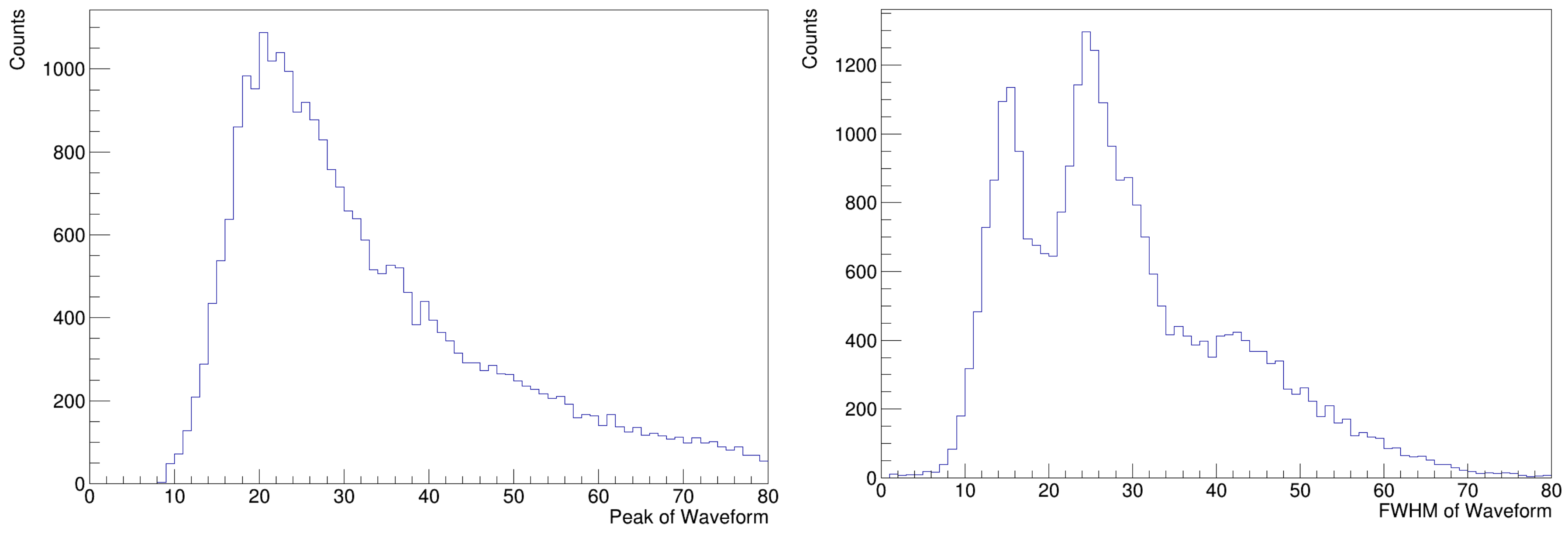

Fig. 6 & 7: Plot of peak distribution (left) and FWHM distribution (right) of waveforms with a single peak, where the waveforms were produced by Monte Carlo simulations.

Future Work

Next, we plan to characterize these quantities across the **detector geometry** and see how the peak and FWHM of waveforms depend on the **location** of the hit in the detector. Ultimately, by comparing these distributions with the peak and FWHM distributions of the Gaussian fits, we can determine how accurately Gaussians can represent these waveforms.

Acknowledgements

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