Determining the Viability of Extracting Delta-Resonance Form Factor Information from Preapproved Experiments in the SBS Program in Hall A

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Abstract

This work determines if the data from Super Bigbite Spectrometer (SBS) experiments in Hall A that have already collected data or plan to collect data can be used to extract information about resonance form factors. These experiments were designed to produce data that gives information about the form factors of protons or neutrons, but sometimes, the interaction of the electron scattering off the nucleon, can leave the nucleon in an excited state. These excited nucleons are called baryon resonances and their form factors are much less well known than that of ground state protons and neutrons. Using Monte Carlo simulations created with GEANT4, this work develops a framework for determining if data from an SBS experiment can give meaningful information about delta resonance form factors. The simulations output ROOT files were analysed using the ROOT data analysis software as well as Python scripts.

Software

GEANT4

- GEANT4 is a Monte Carlo simulation software created by CERN, the European organization for Nuclear Research, that makes simulating physics experiments easy.
- A Monte Carlo simulation relies on repeated random generation of values for each event.
- G4SBS is a package written on top of GEANT4 by Jefferson Lab Hall A scientists that includes different prewritten detector and experimental configurations.

ROOT

- The output of a GEANT4 simulation is a ROOT file.
- ROOT is a data analysis software that was also written by CERN.
- ROOT stores the data for each event in a tree and provides tools for easy graphing and implementation of experimental cuts.

Introduction

Form Factors

- A form factor in particle physics is a function that mathematically expresses how a particle differs from a point-like representation.
- The scattering probability for a certain particle can be represented as the scattering probability for a point particle multiplied by a term involving the square of the form factors.

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma}{d\Omega}_{\text{point-like}} |F(q^2)|^2 \qquad [1]$$

Above: conceptual simplification   Below: Rosenbluth formula

$$\left(\frac{d\sigma}{d\Omega}\right) = \left(\frac{d\sigma}{d\Omega}\right)_{Mott} \cdot \left[G_E^2\left(Q^2\right) + \frac{\tau}{\epsilon} G_M^2\left(Q^2\right)\right] / (1+\tau) \qquad [2]$$

- In general, form factors encode information about the internal structure and distribution of electric and magnetic fields in a particle.

Delta Resonance

- A standard nucleon consists of three quarks and has a mass of around 940 MeV.
- If an electron interacts with a nucleon in a scattering event and transfers some of its energy to the nucleon, there is a chance that the nucleon will go into an excited state called a baryon resonance.

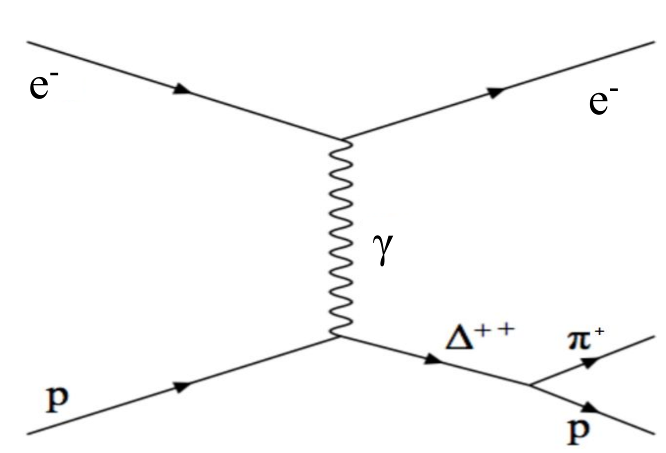

Figure 1: the excitation of a proton into a delta resonance

- Delta resonances are very unstable and exist for less than 10e-23 seconds making them difficult to study.
- Protons and neutrons excite into different types of delta resonances.

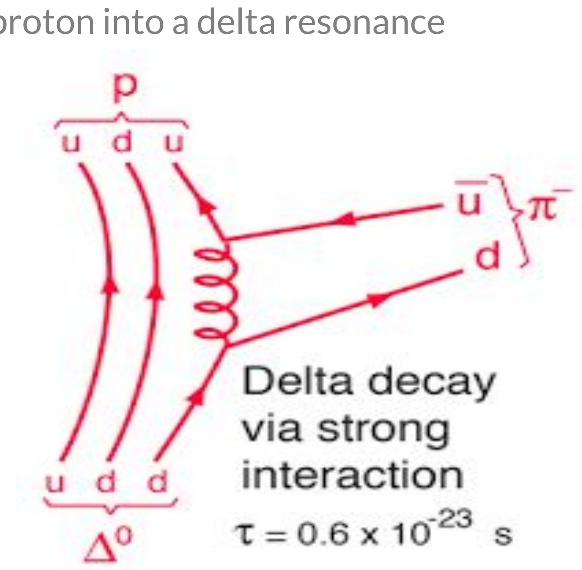

Figure 2: the de-excitation of a delta resonance into a proton.

Methodology

Simulations

- G4SBS was used to create Monte Carlo simulations of the GMN and GEP experiments from Hall A.

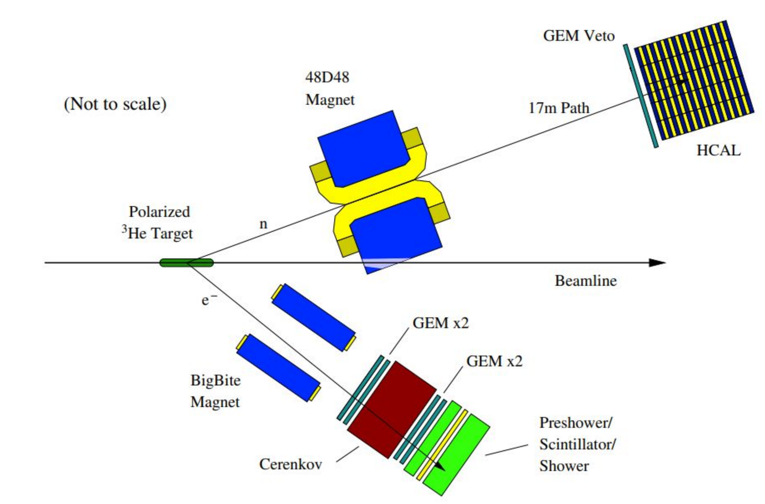

Figure 3: Setup of the SBS experiment to measure the neutron electric form factor from Ref. [1]

- Visualization scripts were also created using the G4SBS software package.

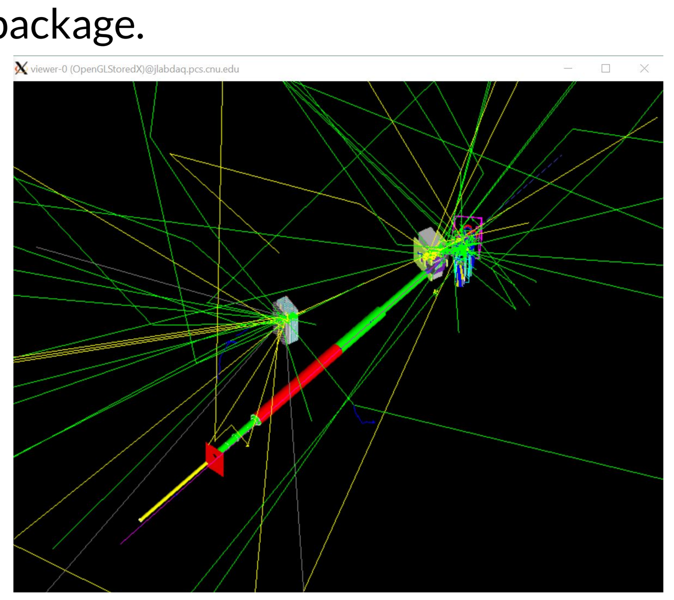

Figure 4: GEANT4 visualization of the GEN experiment in Hall A

Analysis

- The data from the simulations were output as ROOT files and were analysed using a combination of ROOT and Python scripts.

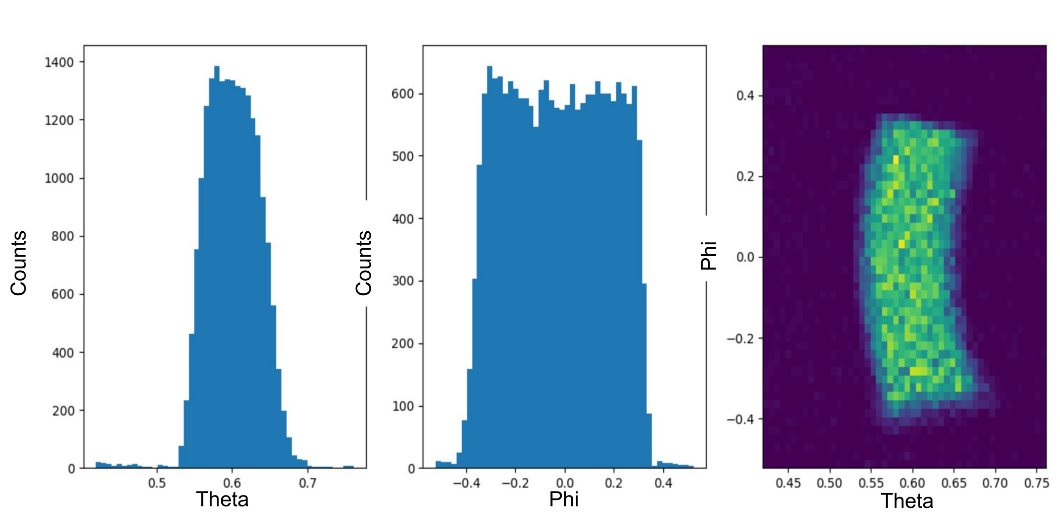

Figure 5: Example of a plot generated from a Python script using ROOT data. Left: Theta vs. count histogram Middle: Phi vs. count histogram Right: Phi vs. Theta 2D histogram

Next Steps

- This project lays the groundwork for a continuing effort to develop a "run group" proposal.
- This type of proposal asks to analyze data collected by the SBS collaboration in other approved experiments.
- The run group proposal will aim to contribute new physics by looking at a new reaction channel that is not included in the other experiments, namely, the excitation to delta resonances and extraction of the delta form factor.
- For this proposal, the analysis needs to show that this reaction channel is present at a useful rate in the approved experiments.

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References

[1] https://www.jlab.org/exp_prog/proposals/proposal_updates/PR12-09-016_pac35.pdf
[2] Re, Leonard. Characterization of three GEM chambers for the SBS front tracker at JLab Hall A. Radiation Effects and Defects in Solids. 2018 Oct. https://doi.org/10.1080/10420150.2018.1528607
[3] Stoler, Paul. Baryon form factors at high Q2 and the transition to perturbative QCD. 1993 April. https://doi.org/10.1016/0370-1573(93)90088-U

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