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Reconstruction of Mesons From Decay Products Using the CLAS12 Detector

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Background

- Hadrons have two or more quarks and include mesons and baryons. Hadrons are strongly interacting; therefore, they are essential to understanding the strong force – the fundamental force that binds quarks together.
- Mesons are composed of one quark and one anti-quark. They facilitate forces between baryons. A meson octet is shown in Fig. 2.
- Baryons consist of three quarks. Known for comprising protons and neutrons (collectively known as nucleons).
- Quarks are the elementary constituents that compose all hadrons. They play a key role in the construction of baryons and mesons (Fig. 2).
- The reconstruction of mesons from decay products helps us understand the strong force, particle interactions, nuclear structures, and refining theoretical models in particle physics.

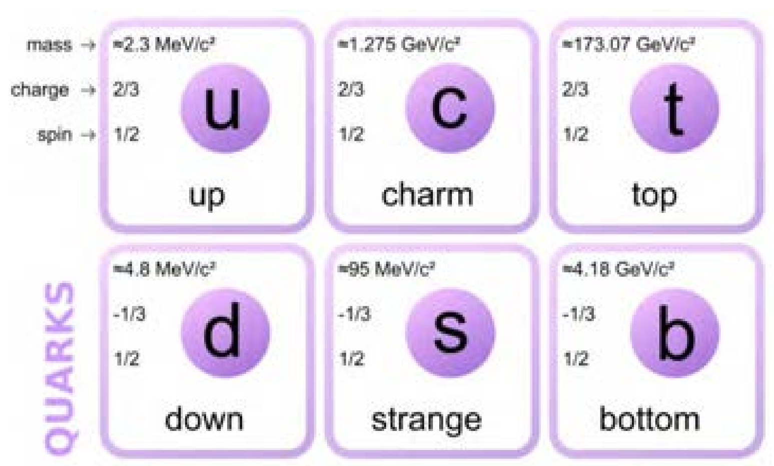

Figure 1: Three Generations of Quarks

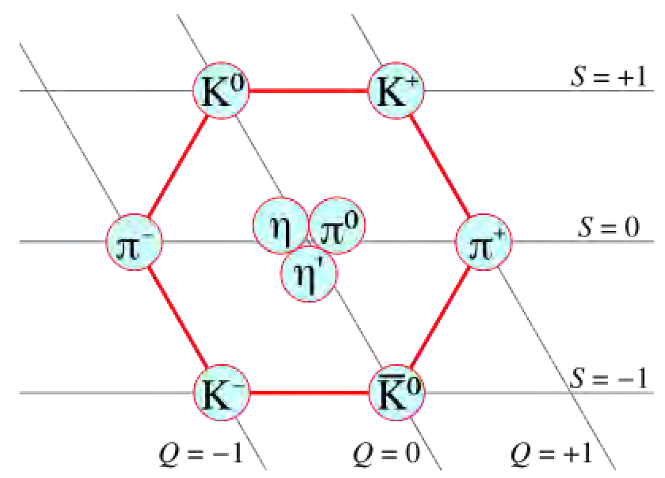

Figure 2: The Meson Octet

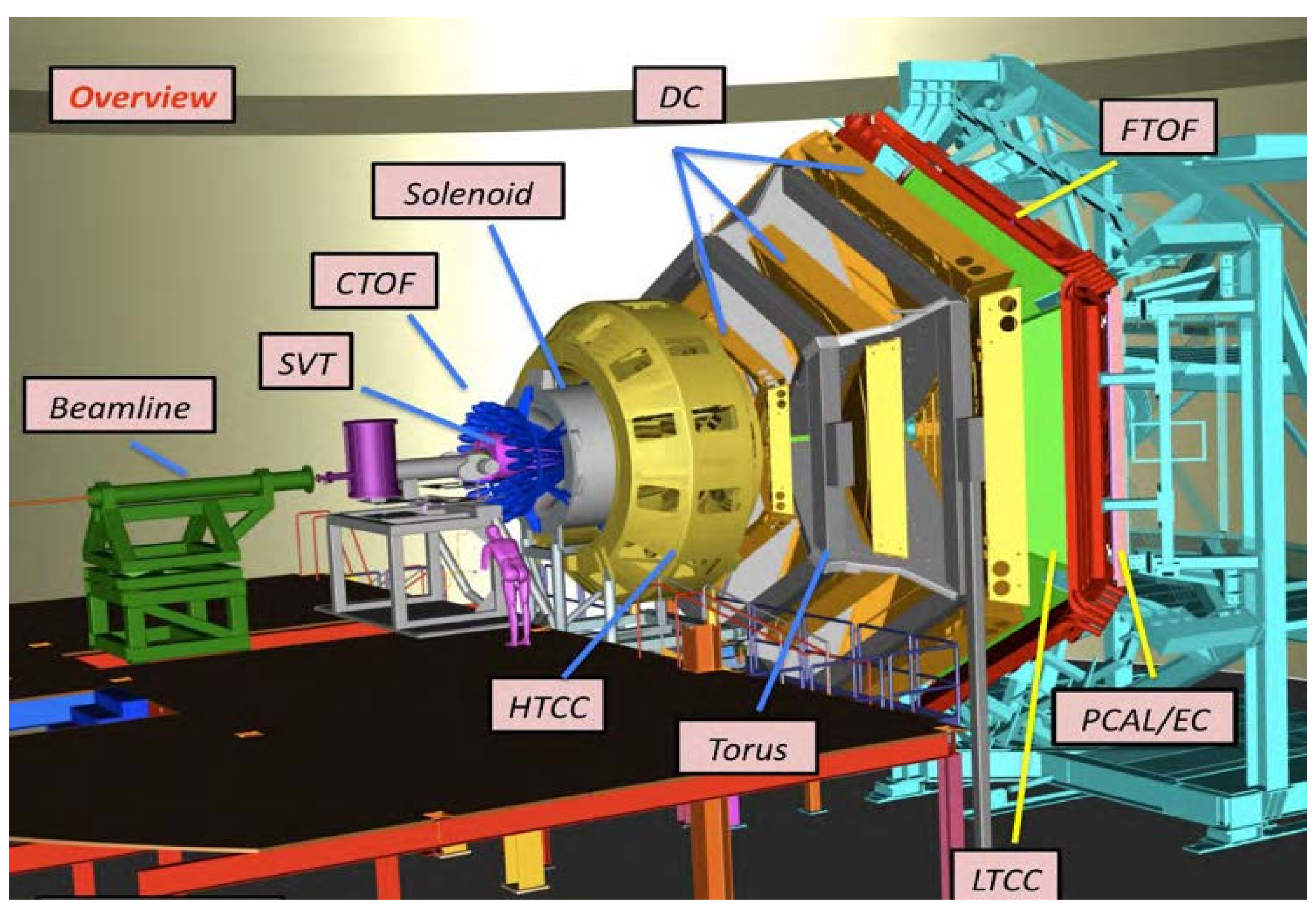

Figure 3: Model of the CLAS12 Detector

Methodology

- ROOT is a widely used data analysis framework in particle physics for processing data, statistical analysis, and visualization.
- C++ is the programming language used for implementing algorithms and data analysis within the ROOT framework.
- Utilized a Linux-based operating system (e.g., CentOS7)
- Kinematics: special relativity. In the analysis of particle decay processes and reconstructing meson properties, the principles of special relativity can be applied. This involves considering concepts such as time dilation, length contraction, and relativistic energy-momentum relationships/collisions.

Experiment: CLAS12 Detector

- Hall B Beamline has beam energy ≤11 GeV.
- SVT: Silicon Vertex Detector. Plays a part in the Central Detector and is used to measure the momentum and determine the vertex of charged particles.
- CTOF: Central Time-of-Flight. Used in the identification of charged particles (PID) emerging from the target via their time-of-flight (TOF).
- Solenoid: a superconducting magnet that surrounds the beam line to produce the main field in the beam direction. It provides the magnetic field for particle tracking.
- HTCC: High Threshold Cherenkov Counter. Part of the detector systems for reliable identification of scattered electrons.
- DC: Drift Chambers. Includes 18 wire chambers with a total of 24,192 sense wires. Measures the momentum of charged particles emerging from the target.
- Torus: Superconducting coils around the beamline that produces a field primary in the azimuthal (φ) direction.
- LTCC: Low Threshold Cherenkov Counter. The detector is used for pion/kaon discrimination.
- FTOF: Forward Time-of-Flight. Measures the time of flight from emerging charged particles from the target.
- ECAL: Electromagnetic Calorimeters. Used primarily for the identification of electrons, protons, pion to gamma plus gamma decays, and neutrons.

Data and Analysis

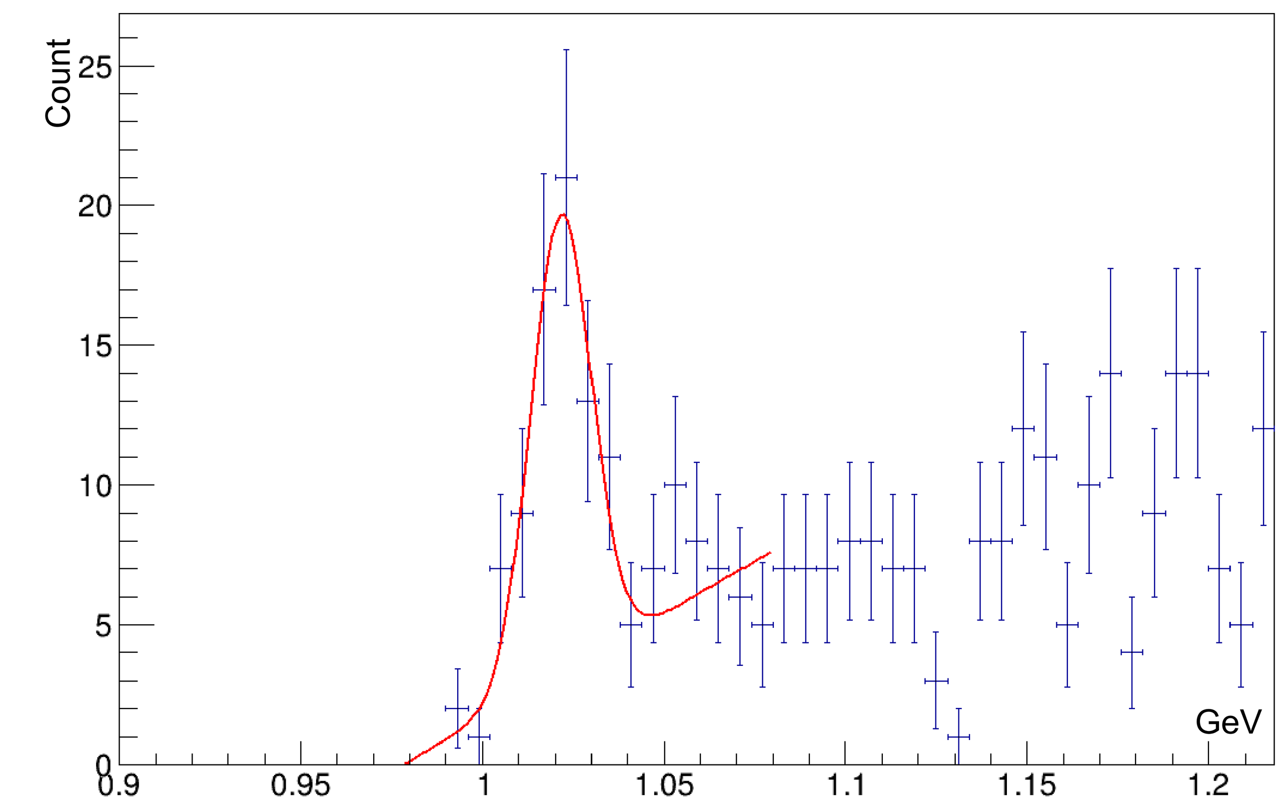

Figure 4: Histogram of the Invariant Mass of the K^+K^- System. Meson resonance at 1021.62 +/- 1.54 MeV (consistent with $\varphi \rightarrow K^+K^-$).

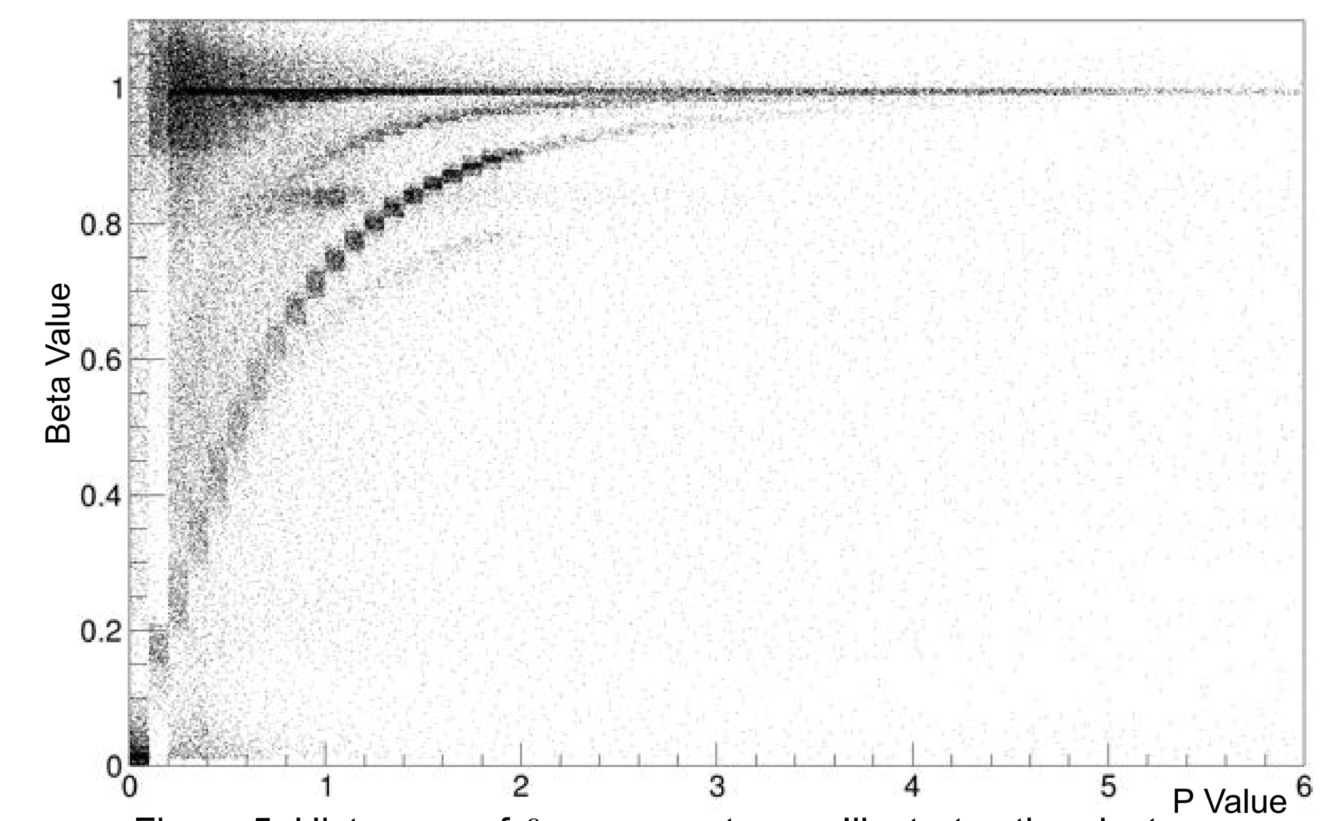

Figure 5: Histogram of β vs momentum-z. Illustrates the electron, pion, kaon, and proton. As the momentum of each particle increases, their beta value becomes almost indistinguishable.

Future Analysis

Will work on reconstructing more complicated reactions. Investigations in reactions such as the reaction of $e\,p \rightarrow e\,p\,K^+\,K^-\,X$, where is considered the "missing" particle. This would involve kinematic reconstruction of four vectors, Monte Carlo simulations, and much more complex analysis. Diving into these complex reconstructions will provide valuable insight into the properties of the strong force.