Conceptual Studies for the π^0 Hadronic Calorimeter

Katya Gilbo
George C. Marshall High School
Intern of Catholic University of America

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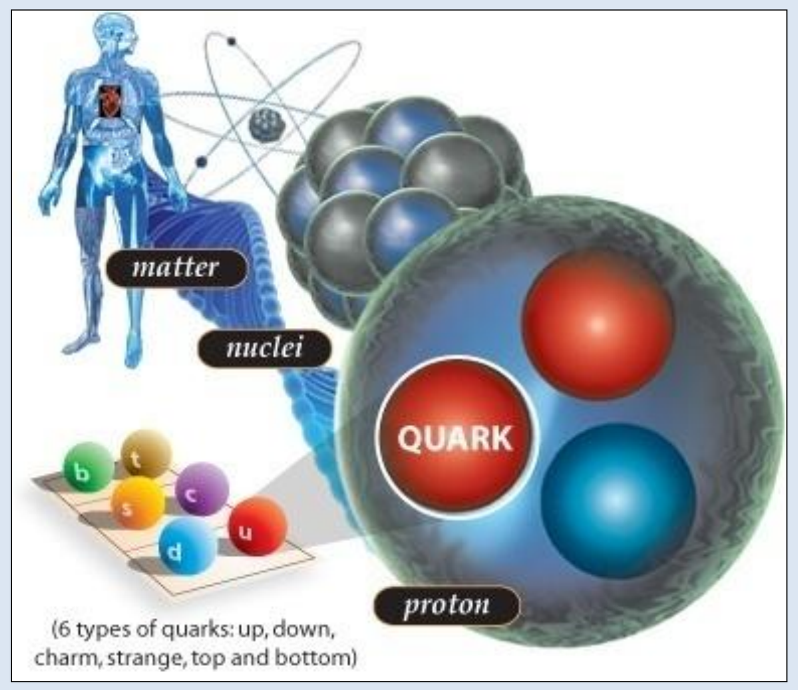
PHYSICS MOTIVATION

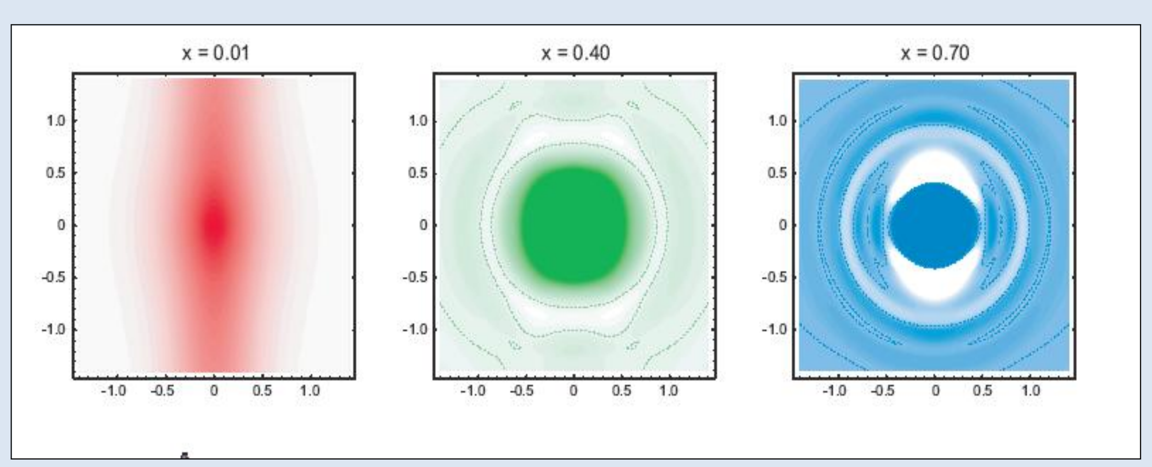
Understanding the Composition of the Universe



In order to understand matter, and even the human structure, physicists have looked deeper and deeper into the composition of matter, from atoms to protons to quarks.

Our group is investigating the structure of the charged and neutral pion and the charged kaon, and the way their quark constituents interact through the strong force. The neutral pion's properties and the additional strange quark in the kaon are opportune to study the proton's substructure through General Parton Distributions (GPDs), which describe the movements, placements, and momenta of the quarks inside the proton.

Ex. Of General Parton Distributions



How will the group study these particles?

- A beam of high energy electrons , powered via Jefferson Laboratory's particle accelerator, will scatter off a stationary proton target in Hall C, producing a pion or kaon.
- Neutral pions have a very short mean lifetime and decay into two real photons. Kaons are positively charged and so one has to distinguish them from other positively charged particles like protons and pions.
- To analyze the neutral pion and the kaon and their decay products, we need dedicated detectors.
- Since the neutral pion quickly decays into two photons, a hadronic calorimeter can be placed in the photons' trajectory, measuring the photons' energy, and thus the pion's energy and momentum, as energy and momentum are both conserved
- For the kaon reaction, the most efficient detection method is an aerogel Cerenkov detector.
- Both cases rely on detector performance, and thus it is important to evaluate the conceptual design and all components of the detector carefully.

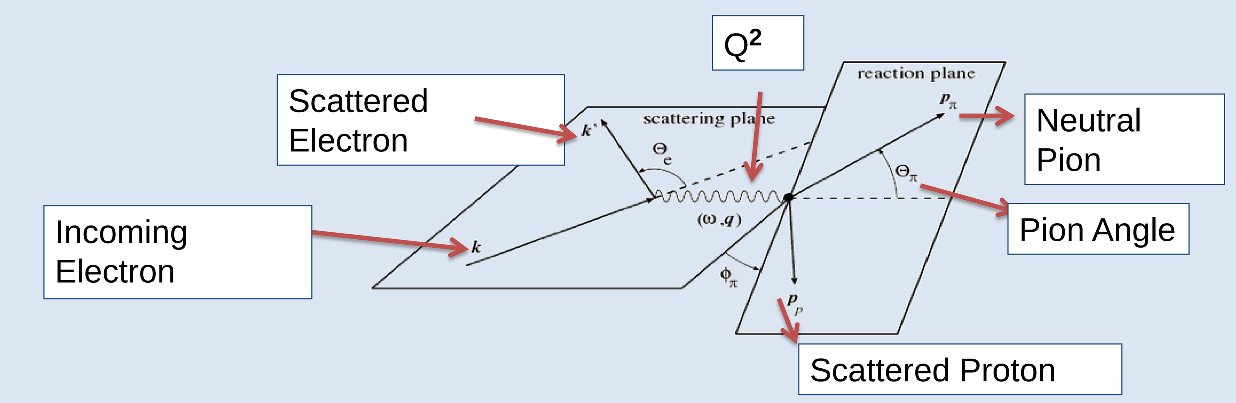
RESEARCH QUESTION

How do we evaluate the performance of detectors for the identification of pi0 decay photons in exclusive neutral pion production and the components of detectors to identify kaons in charged kaon production?

Experimental Setup at JLAB Hall C

PROCEDURE

1. Write an Excel program to calculate the pion angle, pion energy, and pion momentum from input values of Q^2 (the squared four-momentum transfer carried by virtual photon or "the resolution of the experiment"), **W** (center of mass energy), and the **electron beam energy.**



2. The program calculates PERFECT pion value results, which means the pion detector (hadron calorimeter) is also PERFECT. Simulate real life pion values using normal inverse distribution:

- The Norm. Inv. Function requires a known average and standard deviation. The average is the PERFECT pion value, while the standard deviation is the calorimeter accuracy.

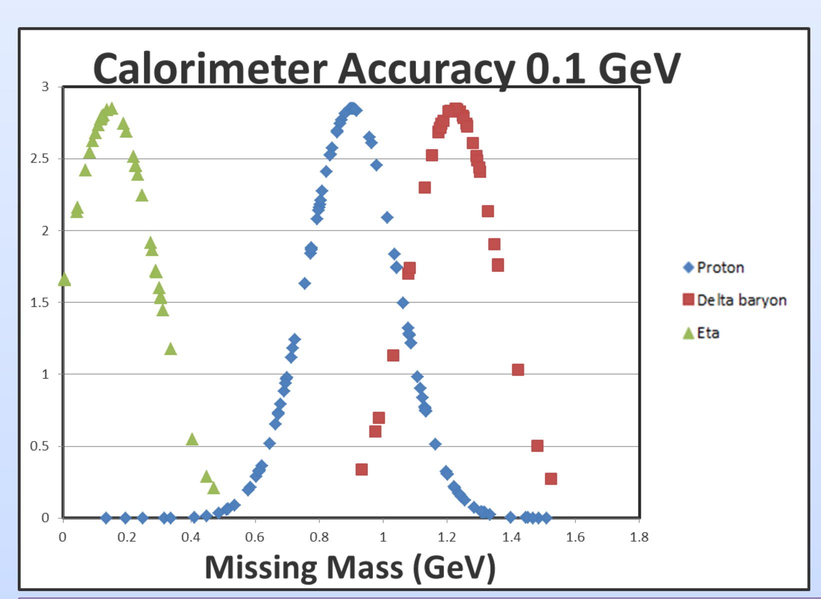
3. Calculate the mass of the only undetected particle through the conservation of mass and energy:

Total Energy (Known) – All Detected Energies= "Energy of Undetected Particle" or "missing energy"

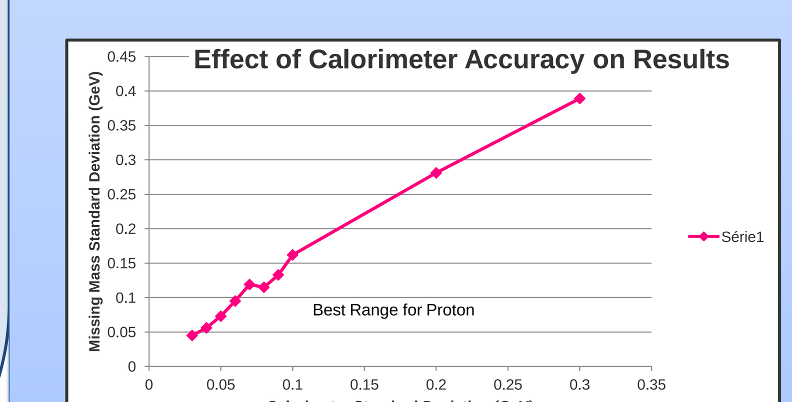
- Through missing energy and missing momentum, we can calculate what the undetected particle is.
  - If it **is 0.938 GeV**, then it must be a proton!
  - We are looking at the desired reaction!

4. Gaussian distribute resulting missing (undetected) masses with certain Calorimeter accuracies.

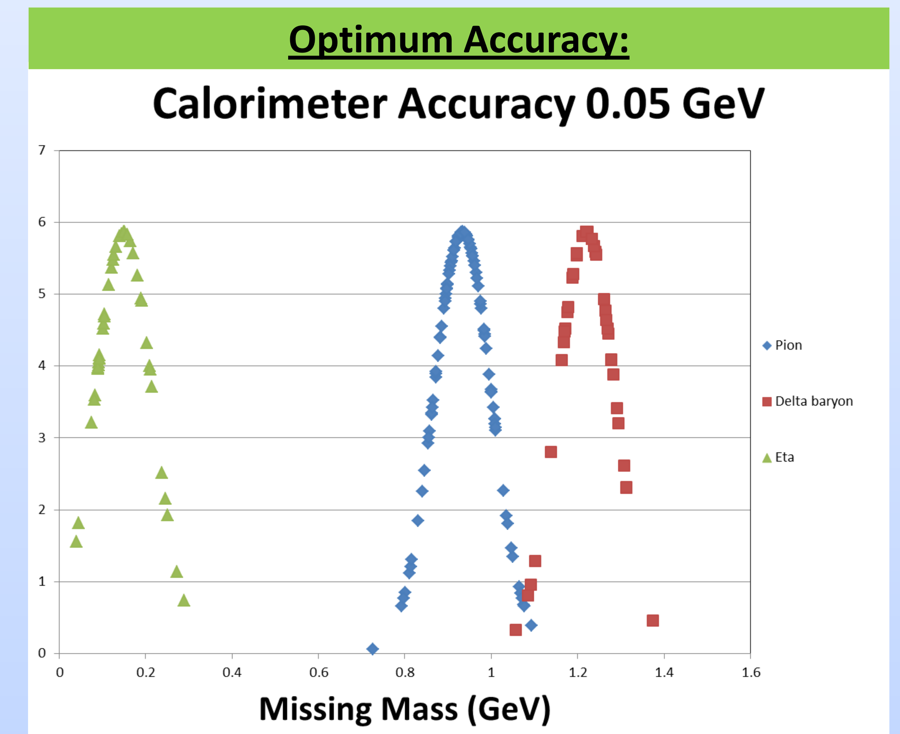
RESULTS



Calorimeter STD: 0.1 GeV
Proton Missing Mass STD: 0.14 GeV
Proton Mass Mean: 0.938 GeV
Eta Mass Mean: 0.15 GeV
Delta Mass Mean: 1.2 GeV



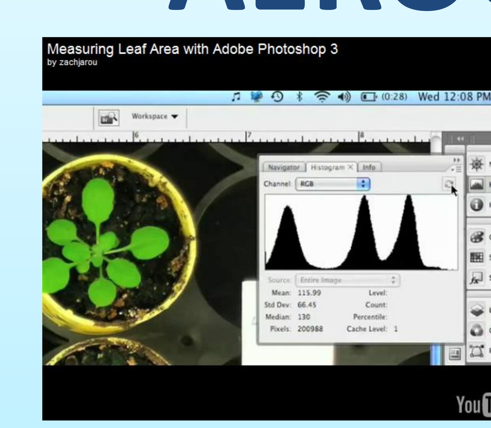
Optimum Accuracy:

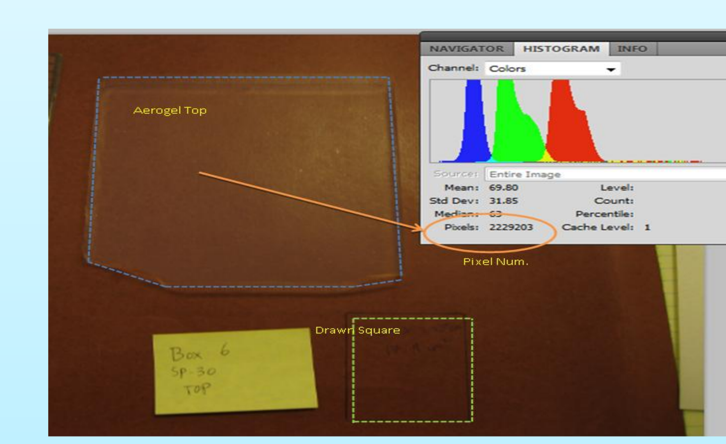


Proton Missing Mass STD: 0.068 GeV

The accuracy of our calorimeter (accuracy of 0.05 GeV) is enough to spot a difference between a calculated proton and the two more common particles (Delta Baryon and Eta). We can now choose the right calorimeter structure and composition for this accuracy. Finding the suitable accuracy for the calorimeter is an important step toward creating a pion detector and understanding the proton's quark structure.

AEROGEL STUDY





The most economic way to identify charged kaons is with an aerogel Cerenkov Detector. It is important to accurately determine the refractive index of the aerogel tiles as the index affects the experimental outcome. To carry out the measurements with minimum handling of the very fragile tiles, I modified a biological technique for measuring leaf areas for measuring aerogel density.

n=1+0.21(p),

where n is the index, p is density

Acknowledgements

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