Simulations of Light Collection Efficiency

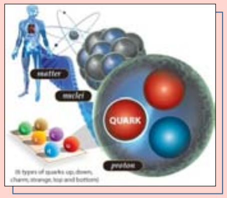
JLab Hall C 12 GeV Kaon Aerogel Cherenkov Detector

By Laura Rothgeb

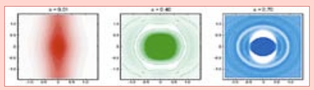
Physics Motivation

Protons, neutrons and electrons are the building blocks of matter, but each of these particles is made up of yet smaller pieces.

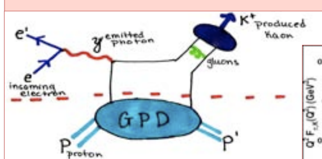
What are these most fundamental pieces of matter? How do we study the structure of the atomic nucleus?

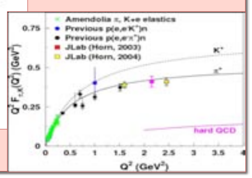


Generalized Parton Distributions (GPDs) provide a framework to understand the internal structure of nucleons.



Using hard scattering kaon electro-production data we can construct the GPD of the proton and find the kaon form factor. To construct GPDs, these data must conform to the model of hard QCD scattering (hard-soft factorization theorems).





JLab Hall C 12 GeV Kaon Aerogel Detector

At 12 GeV Jlab we need detectors capable of distinguishing the positively charged kaon from other particles, such as the proton, to carry out our strangeness physics program. A threshold Aerogel Cherenkov is the most economic solution to identify kaons in Hall C.

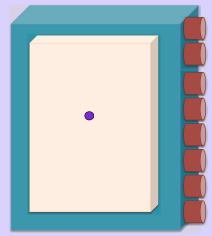
The Kaon Aerogel Cherenkov Detector is designed to detect kaons over a momentum range of 2-8 GeV.

When a kaon passes through the aerogel above the threshold, a flash of light (Cherenkov Radiation) is emitted. This light is collected by photomultiplier tubes (PMTs) on either side of the aerogel. The PMTs transmit an analyzable signal via the photoelectric effect.

Light Guide Simulations

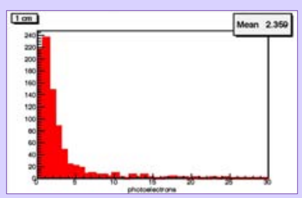
One of the important characteristics of such a detector is the light collection efficiency. There are several sources of loss of light, e.g., reflections of the walls, absorption in aerogel material, etc. Thus, it is important to evaluate the efficiency of the light guides between the PMT window and the aerogel.

A FORTRAN Monte Carlo simulation was written to model the Kaon Aerogel Cherenkov Detector allowing for manipulating the detector geometry to simulate the effects of light guides on the detector efficiency.



The simulation tracks photons emitted by Cherenkov radiation through the detector and calculates the total number of photoelectrons produced and detected based on the input specifications.

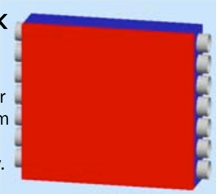
To validate the simulation, a prototype of the detector was built during the summer. The extension volume simulates the light guide in the full detector. Preliminary tests with a large light guide (8x8 cm cube) gave a 23% detection efficiency.



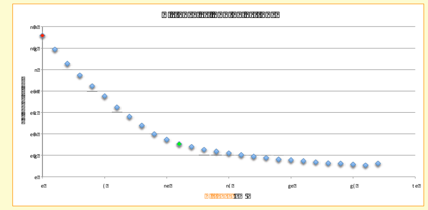
Measured number of photoelectrons with a 1 cm thick aerogel layer in the aerogel casing

Outlook

GEANT4 simulation using the GEMC framework is currently being developed to model the Kaon Aerogel Cherenkov Detector under experimental conditions. This program will allow for more detailed simulations of detector response and light guide efficiency.

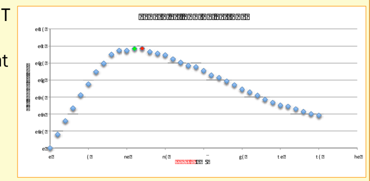


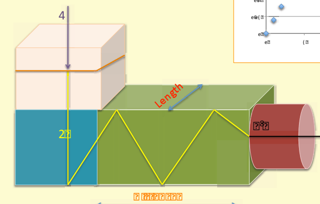
Simulation Results



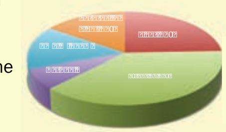
Efficiency decreases as distance between PMT window and Aerogel increases.

Efficiency increases as PMT window is exposed, and decreases as length of light guide exceeds dimensions of PMT window.





Inner surface of extension box can be changed to compare effects of various reflective materials. The Mylar lining of the extension volume absorbed 37% of the emitted photons.



Conclusion

Geometry of light guides have a drastic effect on the light collection efficiency. Light is lost mainly due to increased surface area of the light guide between the aerogel and the PMT window in which the photons are absorbed. The experimental detection efficiency of the prototype is consistent with the results of the simulation.

Acknowledgements

Dr. Tanja Horn
Nathaniel Hlavin, Kevin Wood, Michael Metz, Katya Gilbo
Dr. Maurizio Ungaro, Dr. Douglas Higginbotham
The Catholic University of America Nuclear Physics Group
Thomas Jefferson National Accelerator Facility
American Physical Society Division of Nuclear Physics, CEU

Research supported in part by NSF grants PHY-1019521 and PHY-1039446