Kaon Aerogel Cherenkov Detector

Project Update

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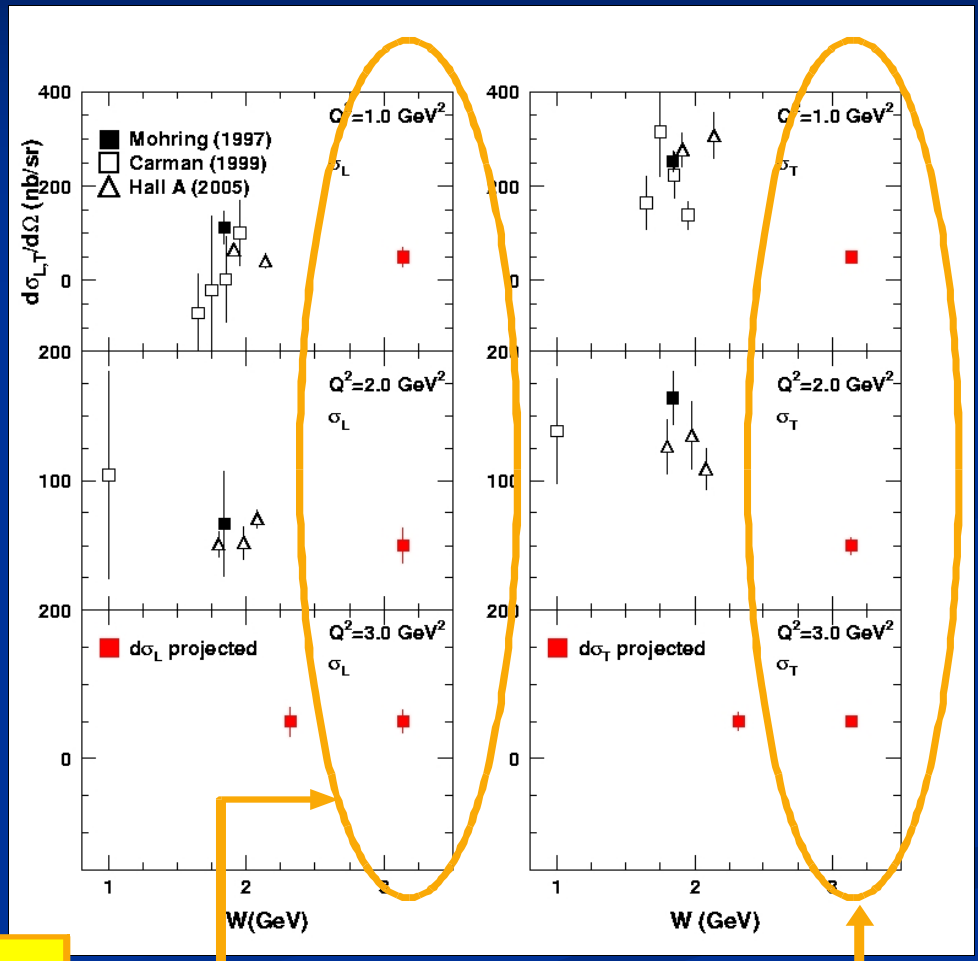
Outline

- Brief Physics Motivation
- Component Characterization
  - Large Diameter PMTs
  - Aerogel
- Detector Construction

Example of Kaon physics at JLab 12 GeV: L/T Separated Cross Sections

- Approved Experiment E12-09-011 will provide first L/T separated cross-section data above the resonance region (W > 2.5 GeV)
- Onset of Kaon Factorization
- Understanding of Hard Exclusive Reactions
  - QCD Model Building
  - Coupling Constants



E12-09-011: Precision data for W > 2.5 GeV

T. Horn et al.

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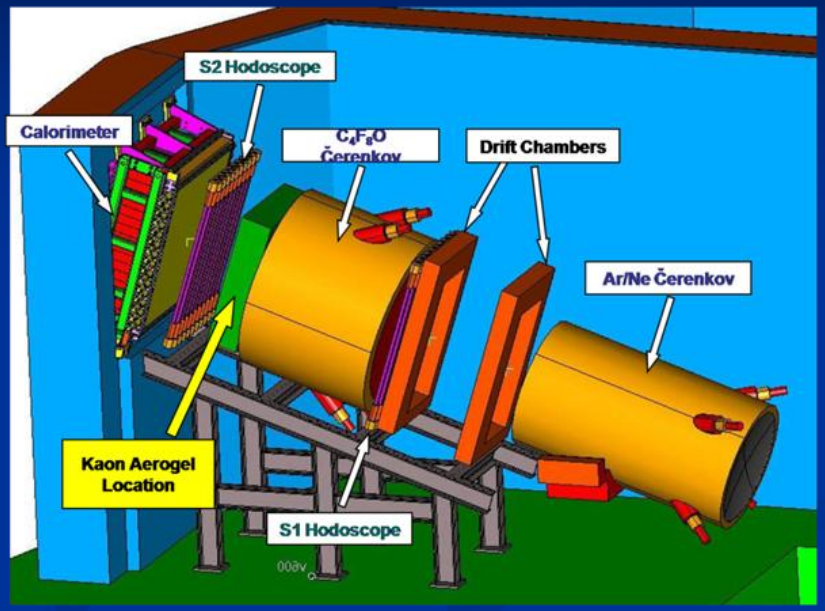
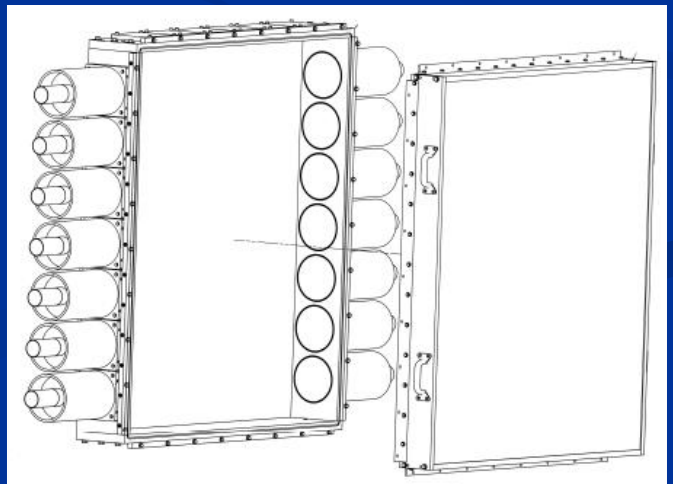
SHMS Detector System

- SHMS base detector system provides particle identification for *e*, π, *p* over the full momentum range
  - Noble gas Cherenkov: e/π
  - Heavy gas Cherenkov: π/K
  - Lead glass: e/π
- The lack of p/K+ separation does not allow a strange physics program in Hall C at 11 GeV with only the base equipment



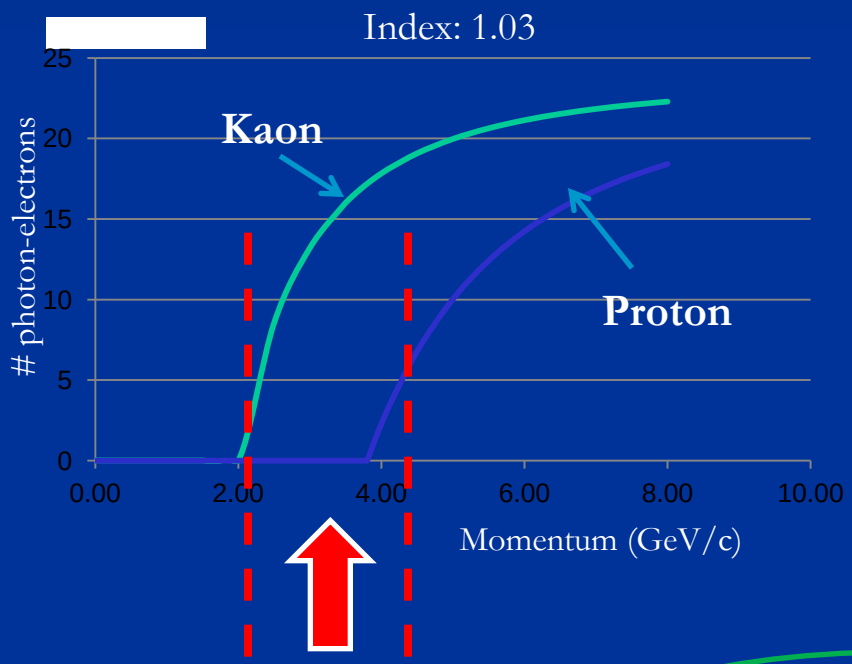
http://galileo.phys.virginia.edu/classes/sajclub/JLab_Upgrade.html

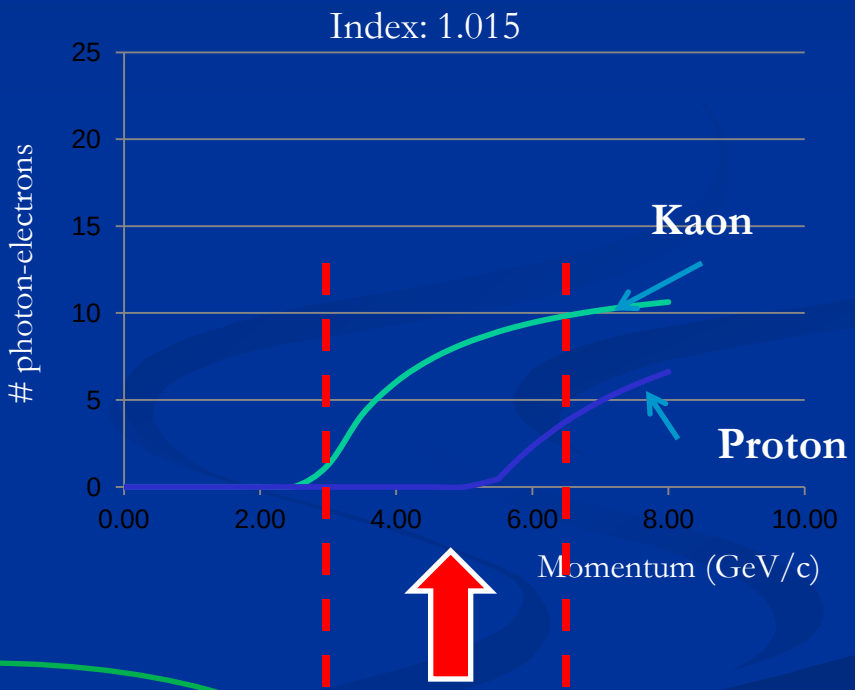
Need Kaon Aerogel Cherenkov for Strangeness Physics program at JLab



Aerogel refractive indexes

➢ Selecting the refractive index of the aerogel, one can select the range for Proton/Kaon distinguish

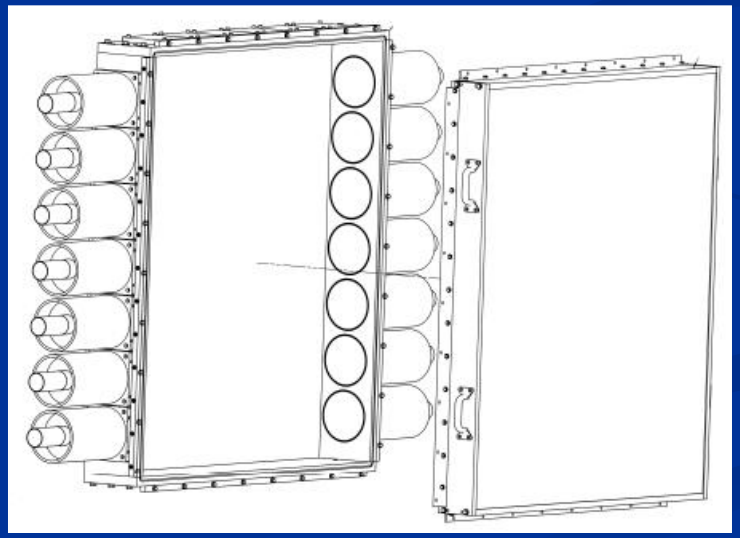




Cover the full Kaon momentum range: from 2.5 to 7.1 GeV/c

Kaon aerogel Detector Design

- Diffusion box covered with reflective material, e.g., Millipore
  - Dimensions of the box: 1.1m x 1.0m x 0.5m
- 3 refractive Indices of Aerogel to cover full range of momentum (removable tray -> flexibility)
  - Aerogel thickness ~10 cm
  - Indices: 1.03, 1.02, and (1.015 or 1.010)
- Seven 5-inch PMTs on each vertical side
  - Option to have six more on the top



Kaon Aerogel Cherenkov Project

- NSF-MRI Consortium: Development of a Kaon Detection System
  - PI: The Catholic University of America (Tanja Horn)
  - co-PI: University of South Carolina (Yordanka Ilieva)
  - co-PI: Mississippi State University (Dipangkar Dutta)
  - co-PI: Catholic University of America (Franz Klein)
  - co-PI: Florida International University (Joerg Reinhold)
  - Yerevan Group (Hamlet Mkrtchyan, Vardan Tadevosyan, Arthur Mkrtchyan, Arshak Asaturyan, Simon Zhamkochyan)

- Current Status: Project close to completion
  - Dry assembly of detector at CUA in next few weeks
  - Full assembly and tests at JLab afterwards
  - Some additional component tests ongoing

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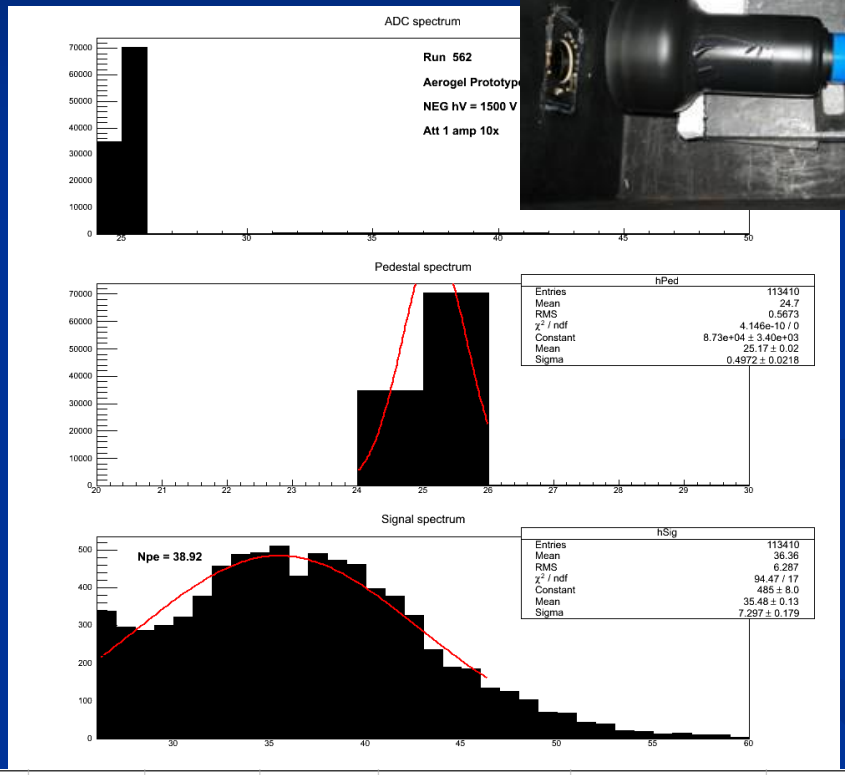
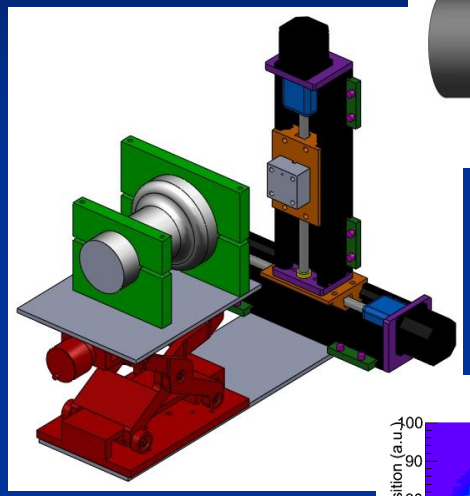
PMT Gain Testing

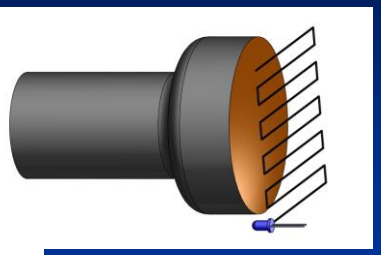
- ~70 5-inch PMTs have been tested for Gain with an LED over a range of high voltages.
- Primarily used ROOT scripts to analyze histograms.
- Data recorded in online catalog, which can be accessed from our wiki: http://www.vsl.cua.edu/cua_phy/index.php/Main_Page

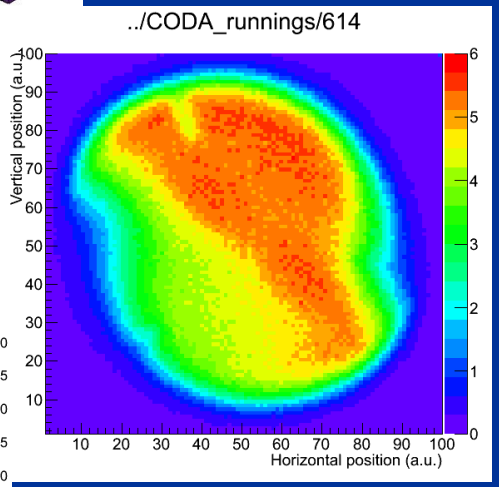


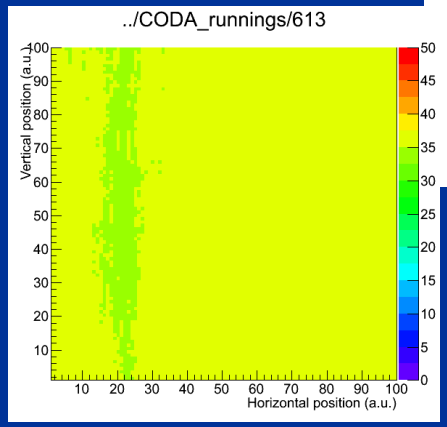
PMT s/n	Base s/n	LED intensity (V)										
09592	76	2.5										
Run (#)	hV (V)	Pedestal (channel)	Pedestal Error	SEP (channel)	SEP Error	Pedestal Height	SEP Height	SEP Width	Gain	Statistical Gain Error	Statistical Gain Error	Gain Error
1881	1600	73.05	0.01	87.85	0.10	6938 ± 80.8	1339 ± 14.8	20	2.29E07	1.55E05	457122.807277642	4.83E05
1882	1700	73.05	0.01	97.08	0.16	6800 ± 78.4	806.1 ± 8.3	35	3.71E07	2.48E05	742206.82830282	7.82E05
1887	1800	72.96	0.01	111.7	0.3	7000 ± 78.0	504.7 ± 5.0	53	5.98E07	4.64E05	1196549.8347254	1.28E06
1888	1900	73.02	0.01	134.2	0.3	6300 ± 77.0	321.8 ± 3.0	80	9.45E07	4.64E05	1889646.84792204	1.95E06
1889	2000	72.79	0.01	164.8	0.5	7426 ± 78.4	213 ± 2.0	135	1.42E08	7.72E05	2841883.07416323	2.94E06
1890	2100	72.9	0.0	207.4	0.8	6800 ± 76.7	153.7 ± 1.6	200	2.08E08	1.24E06	4154257.94451641	4.33E06
1891	2200	72.8	0.0	265	1.0	7452 ± 79.0	113.5 ± 1.3	280	2.97E08	1.54E06	5936419.15937587	6.13E06
1892	2300	72.28	0.01	348.2	1.8	7199 ± 76.7	78.39 ± 0.93	380	4.26E08	2.78E06	8522251.68811128	8.96E06
1893	2400	71.72	0.01	459.2	2.6	6614 ± 73.5	57.67 ± 0.73	560	5.98E08	4.02E06	11967969.2813474	1.26E07

PMT Uniformity Scanning





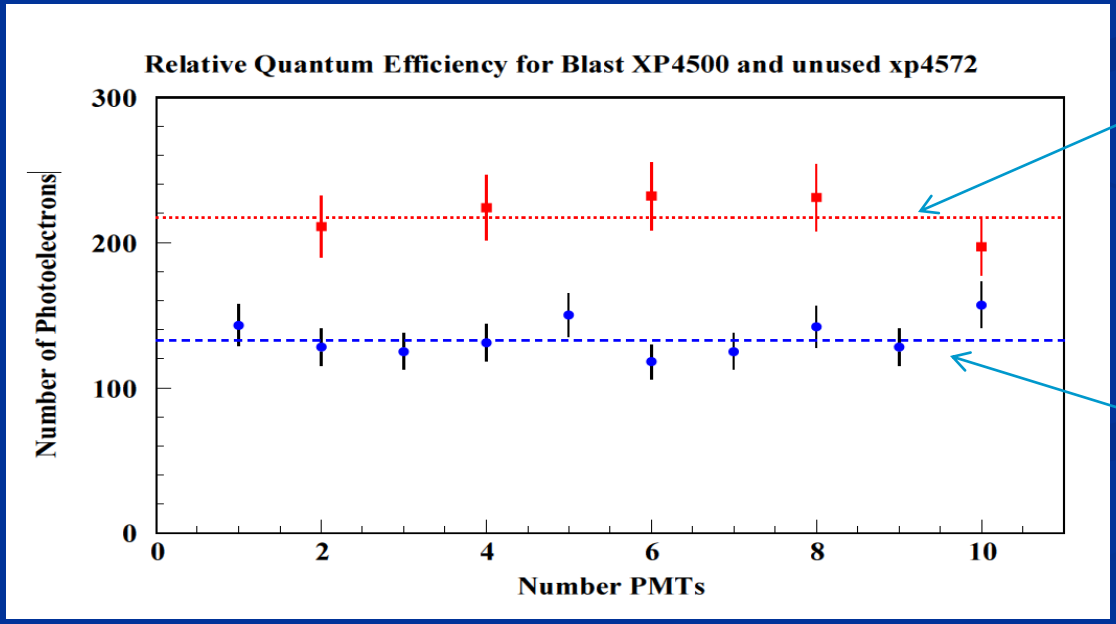




- Stepper motor scanned PMT window with blue LED.
- Showed PMT window uniformity.
  - Apparent irregularity is a feature of the PMT geometry, i.e., the first stage dynode.
- Thanks to Dr. Segal (JLab) for stepper motor.
- Reference PMT used to verify constant light intensity from LED

Quantum Efficiency Puzzle

- Yerevan Group has made relative tests at JLab with BLAST PMTs to be used in aerogel detector and HMS spare PMTs.
- QE of BLAST tubes consistently ~40% smaller.
- Tests ongoing with CUA setup to investigate.

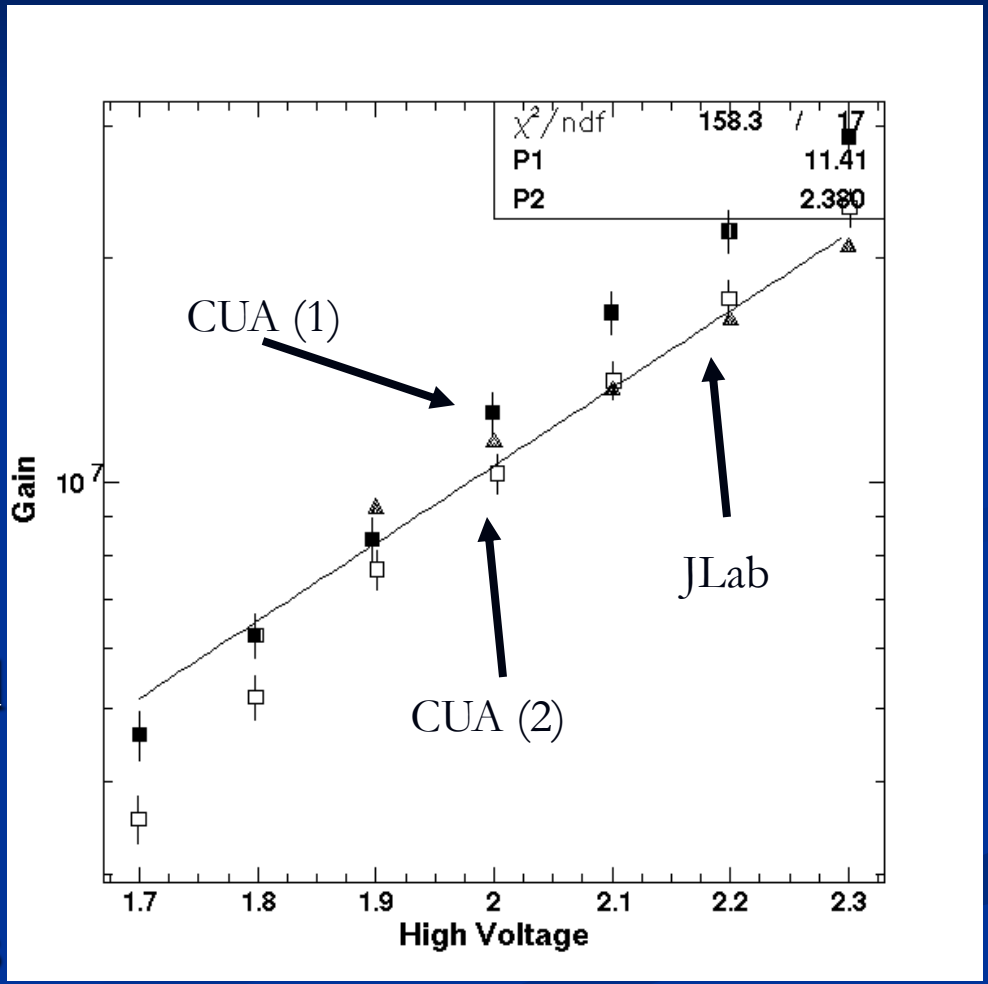


Spare HMS PMTs
randomly selected

BLAST PMTs

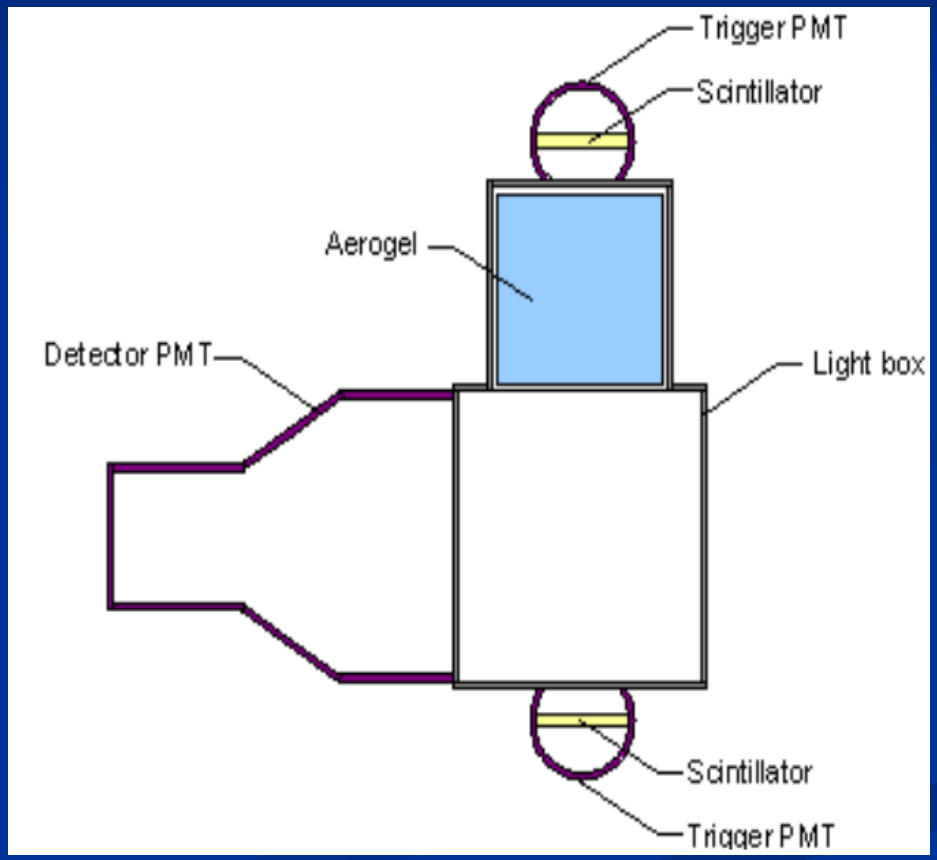
Quantum Efficiency Testing

- Tests have been conducted to compare CUA and JLab experimental setups.
- Gain results may be compared to find out discrepancy between setups. (2 CUA setups and JLab setup shown here)
- Results appear to have good correlation, QE tests will begin.

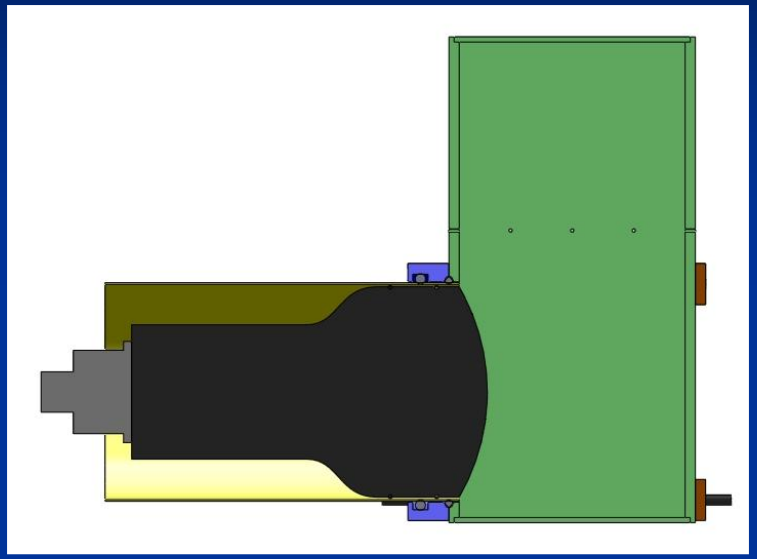


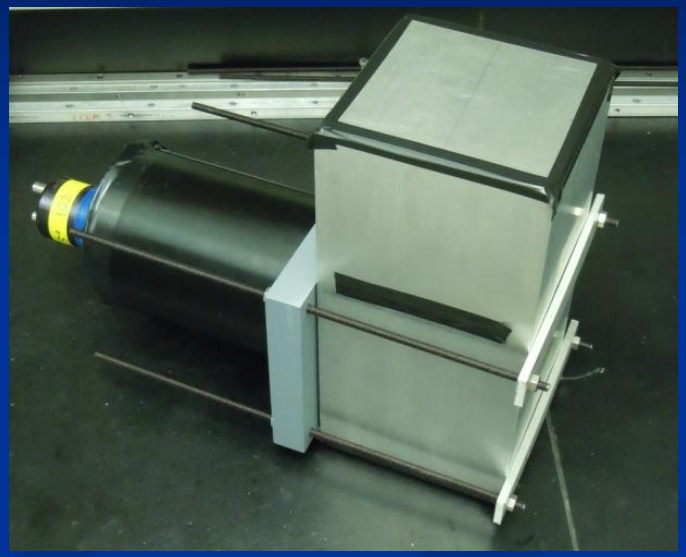
Combined PMT and Aerogel Testing

- Further Tests needed to with PMT and Aerogel together to investigate combined performance.
- Variations in PMT/Aerogel performance may or may not produce suitable combined results
- Cosmic setup will be used for these tests.



Prototype





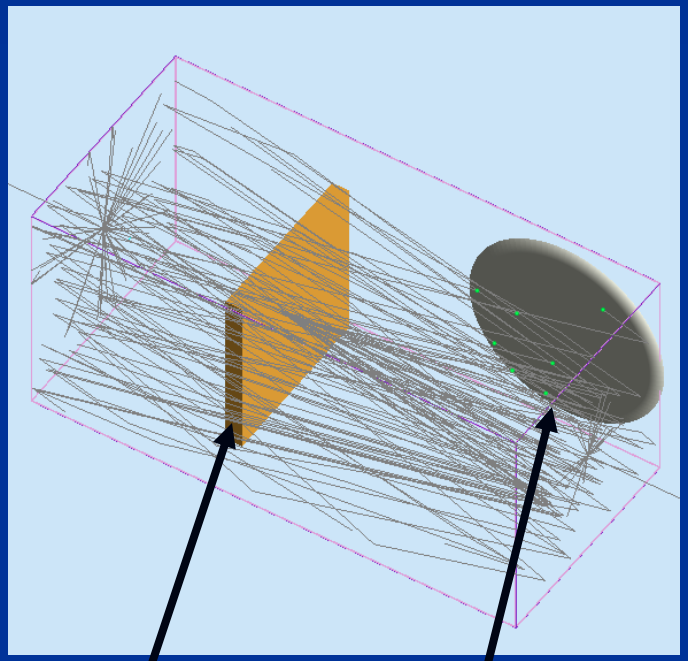
Photo/Diagram credit M.A.P. Carmignotto

- Combined Setup also serves as prototype of full detector.
- Experiments ongoing at CUA with this prototype.

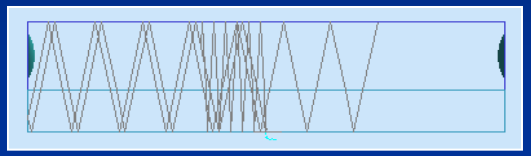
Simulations

- GEANT 4 Monte Carlo (GEMC) Simulations for both Prototype and full Detector are being conducted.

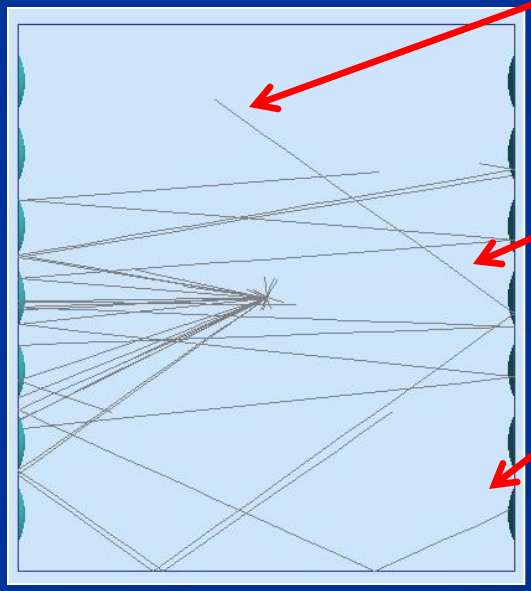
Prototype



Upper view of the simulation



Detector view of a simulation, showing just a few Cerenkov photons



Photon absorbed in aerogel or Millipore

Photon reflection on the walls

Photon detected by this PMT

Figure Credit to L. Rothgeb and M.A.P. Carmignotto

Aerogel Coating

- There appears to be some yellowing of the aerogel tiles.
- Radiation Damage, Aging? Could tie into hydrophobic properties?
  - Tests on Hall A aerogel detectors showed yellowing due to sub-micron contaminants in air used to flush detector [S. Marrone, Il Nuevo Cimento, Vol 24, N.1 (2009)]
- Chemical Testing will occur at CUA's Vitreous State Laboratory (VSL), courtesy Dr. Marek Brandys.

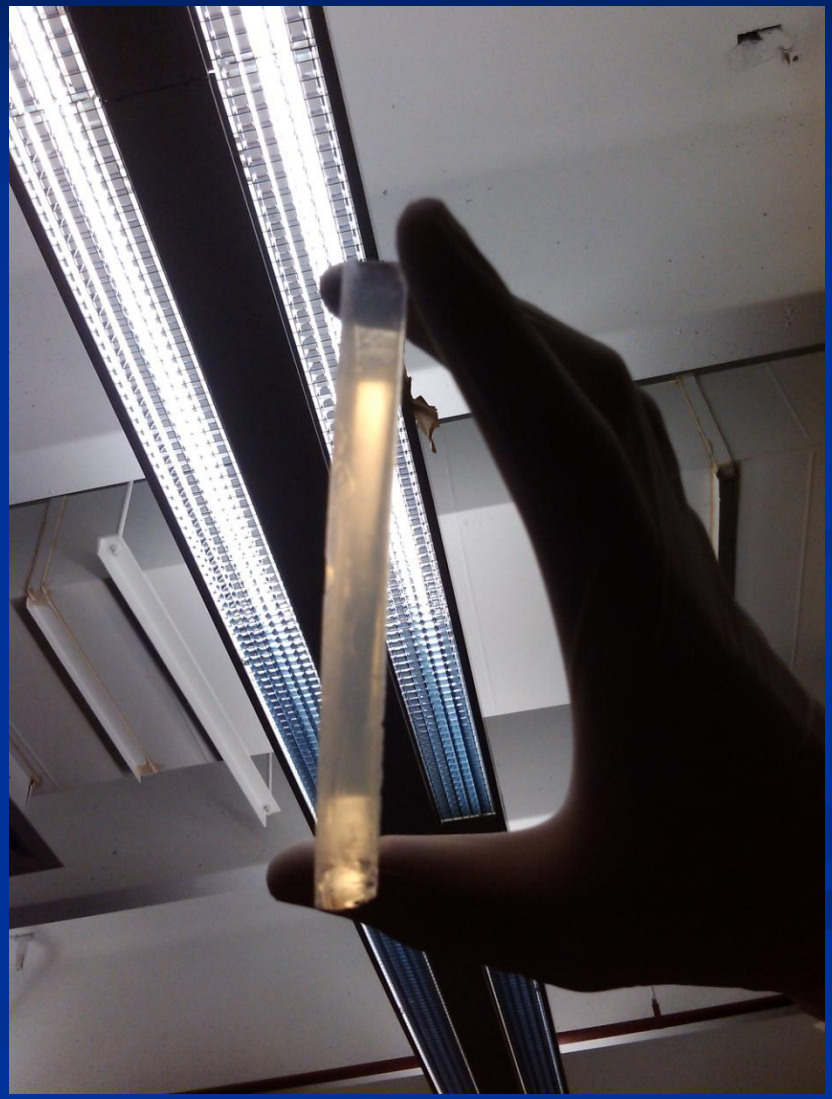


Photo credit: Daniel Rice

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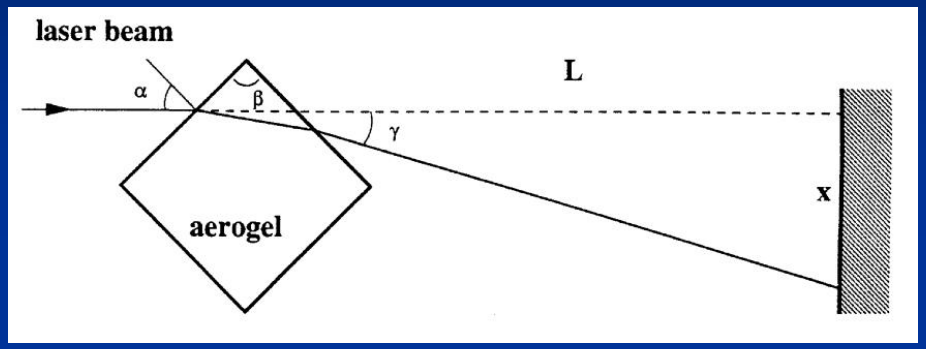
Aerogel Refractive Index



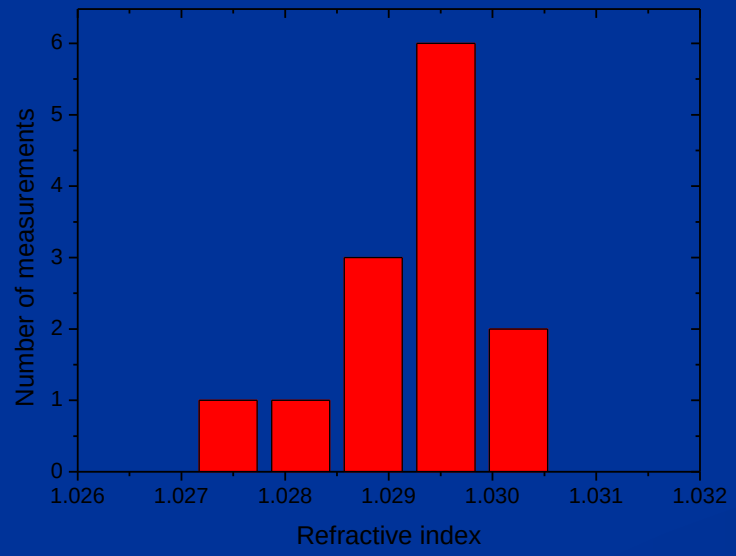


Figure Credits to M. A. P. Carmignotto

- Optical Tests utilizing Snell's Law are underway to accurately verify refractive index of aerogel.
- Tested method with current tiles
  - Preliminary Results are in (~1.029 for 1.03 tile), there will be continued optimization of the method and error analysis
- Can be used to characterize samples from Novosibirsk and JFCC (~1.010?)
  - Third refractive index option

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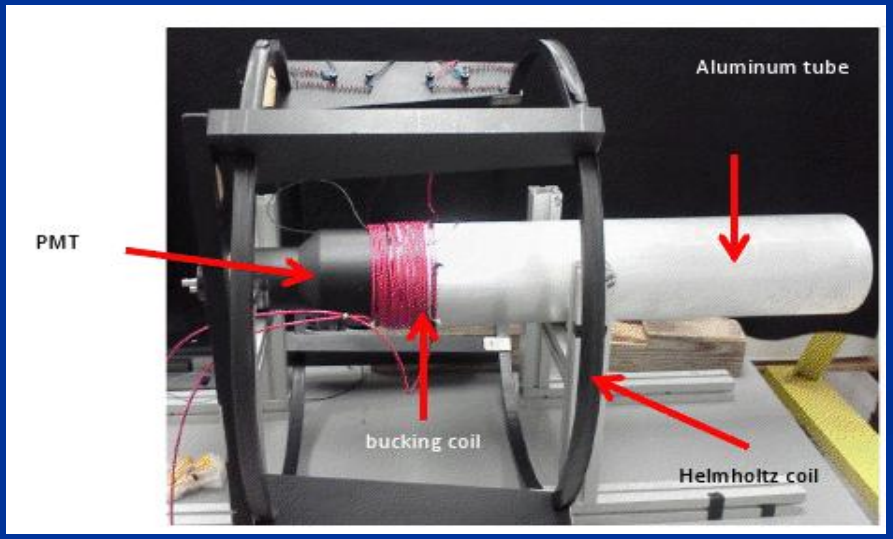
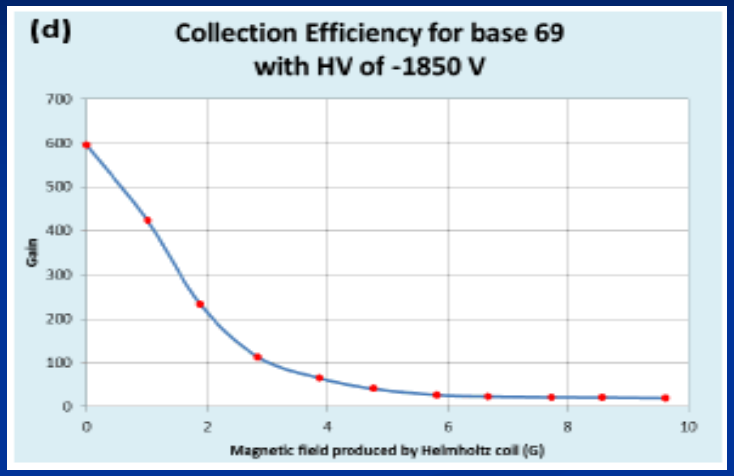
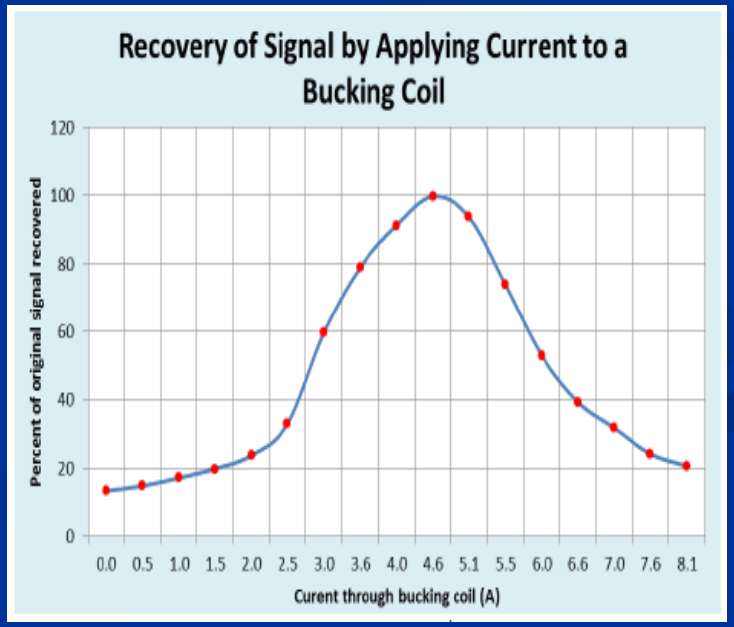
Magnetic Bucking Coil

- An FIU student, Andira Ramos, conducted experiments to investigate the collection efficiency of PMTs in a strong magnetic field.
- The use of a magnetic bucking coil allowed for near full signal recovery







All figures credit to Andira Ramos, FIU

Reflective Materials

- Some questions have been raised about the options for the reflective coating of the light-box portion of the detector.

http://3.bp.blogspot.com/-6MGwBT9BilY/TeviWale1II/AAAAAAAAAO4/_uKr24fJPxQ/s1600/mirror-wall-glass-pouring.jpg

Reflective Materials

H. Mkrtchyan

- At JLab typically used 2-3 layers of Millipore filter paper
- Options used successfully in other experiments, e.g., BLAST, include are reflective paints
  - Most of these are based on barium sulfate (BaSO4), e.g., Spectraflect
- Hall A collaboration finds that Millipore as good as paints [NIM 154 (1978) 253]
- Additional concern with paints are chemical reactions and sensitivity to humidity

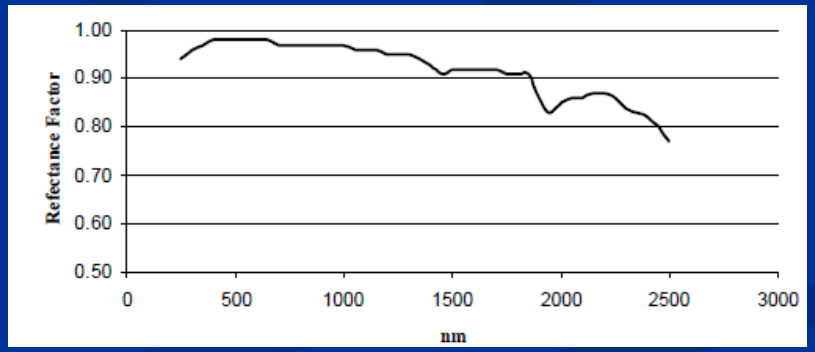
TABLE I

Measured reflection coefficients in % for different coatings.

Wavelength (nm)	Millipore 1 layer[a]	Millipore 3 layers[a]	NE 560 4 layers[b]	$BaSO_4$ powder[c]	Eastman 4 layers[d]	Eastman 8 layers[d]
315	85.4 ± 2.5	88.8 ± 2.0	–	87.9 ± 2.1	94.3 ± 1.1	97.5 ± 0.5
365	94.3 ± 2.1	94.4 ± 1.1	33.1 ± 4.5	94.1 ± 1.1	94.4 ± 1.1	–
400	95.6 ± 0.8	96.3 ± 0.7	87.1 ± 2.3	96.6 ± 0.7	92.2 ± 1.4	97.7 ± 0.5
420	96.1 ± 0.8	96.8 ± 0.6	90.9 ± 1.7	96.9 ± 0.6	94.4 ± 1.1	97.8 ± 0.4
450	96.7 ± 0.7	97.5 ± 0.5	92.4 ± 1.4	97.2 ± 0.6	95.2 ± 0.9	97.9 ± 0.4
500	96.9 ± 0.6	98.1 ± 0.4	93.0 ± 1.3	97.5 ± 0.5	95.6 ± 0.9	98.0 ± 0.4
520	96.9 ± 0.6	98.2 ± 0.4	93.1 ± 1.3	97.6 ± 0.5	95.6 ± 0.9	98.0 ± 0.4
550	96.9 ± 0.6	98.1 ± 0.4	93.3 ± 1.3	97.6 ± 0.5	95.9 ± 0.8	98.0 ± 0.4
600	97.3 ± 0.5	98.0 ± 0.4	93.5 ± 1.2	97.0 ± 0.6	96.9 ± 0.6	98.0 ± 0.4

[a] Millipore filter type GSWP 00010 (obtainable from Millipore Benelux SA).
[b] Reflector paint NE 560 (manufactured by Nuclear Enterprises); four layers applied with brush.
[c] $BaSO_4$, white standard, DIN 5033, produced by Merck, applied as described by M. Nonaka, Lighting, research and technology 6 (1974) 30.
[d] Eastman white reflectance coating (manufactured by Eastman-Kodak), applied with sprayer. The thickness of 8 layers is 0.4 mm.

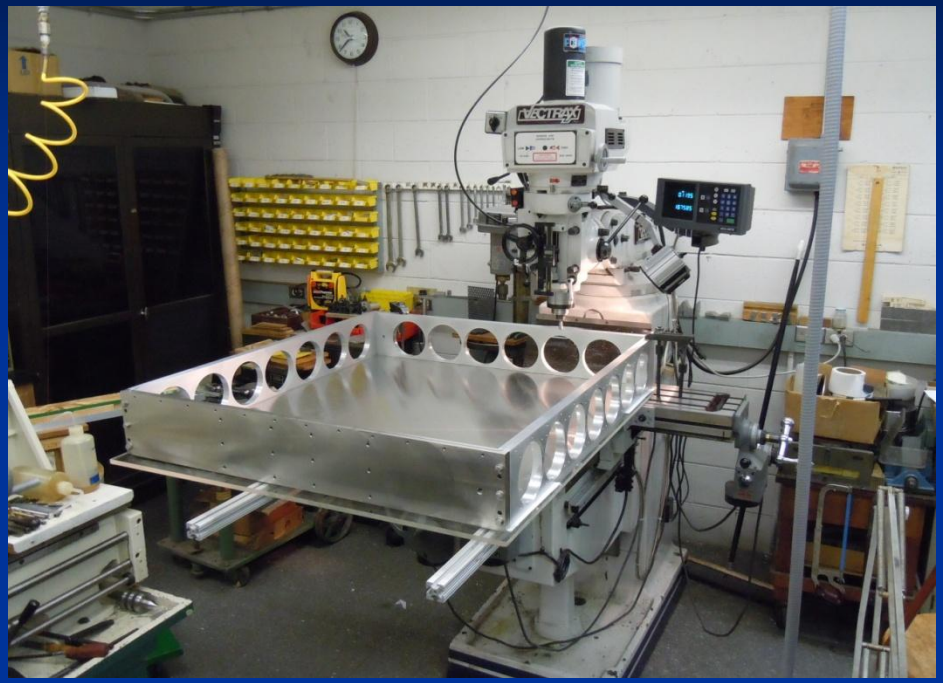
Millipore BaSO4

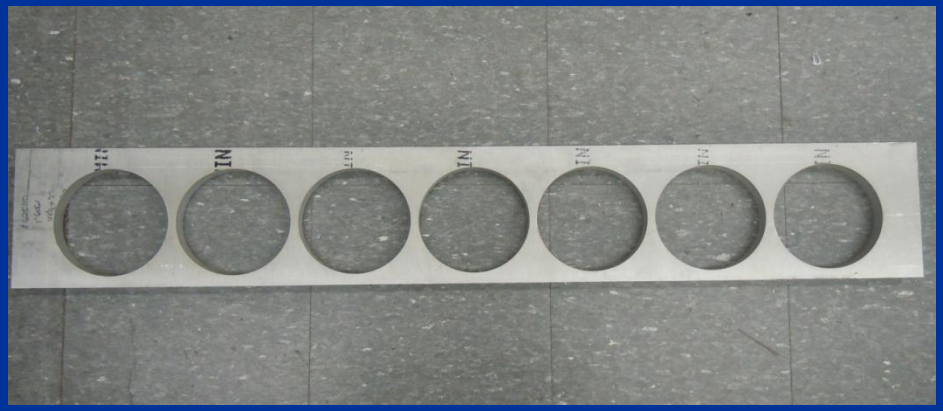


Spectraflect

The default reflective material for our aerogel detector is Millipore

Detector Construction





- Detector Construction has been completed by VSL at CUA.
- Dry assembly upcoming

Conclusion

- Several tools developed for component characterization of such detectors.
- Results appear positive for detector performance!
- Construction Completed
- Project nearing completion!

Acknowledgements

- All members of Kaon Aerogel Cherenkov Project
- Special thanks to CUA group, Dr. Tanja Horn, Marco A. P. Carmignotto, Laura Rothgeb, and others.

Photo Credit: Daniel Rice

BACKUP

SHMS $(e,e'K^+)$ Program in Hall C

- To date four experiments have been approved for Hall C at 11 GeV
- Range of kaon momenta that needs to be covered largely given by the Kaon factorization experiment

Experiment	Physics Motivation	SHMS Momenta (GeV/c)	Worst Fore/Bkd Rate Ratio
Color Transparency (E12-06-107)	• vanishing of *h-N* interaction at high *Q*. • exclusive π, *K* production from nuclei.	5.1-9.6	1(K):10(p)
SIDIS p_T (E12-09-017)	• extract mean k_T of u,d,s quarks in proton. • SIDIS $\pi^{\pm}$, $K^{\pm}$ production.	1.5-5.0	
SIDIS R (E12-06-104)	• Measure the ratio $R=\sigma_L/\sigma_T$ • SIDIS, $\pi^{\pm}$, $K^{\pm}$ production.	1.5-5.0	
Kaon Factorization (E12-09-011)	• study of soft-hard factorization in exclusive K^+ production. • L/T separations vs. Q^2, *t*.	2.6-7.1	1(K):3(p)

There is a strong kaon program proposed for Hall C. We need a kaon detector!