Aerogel Threshold Cherenkov Detectors for HMS & SHMS Spectrometers at JLab Hall C

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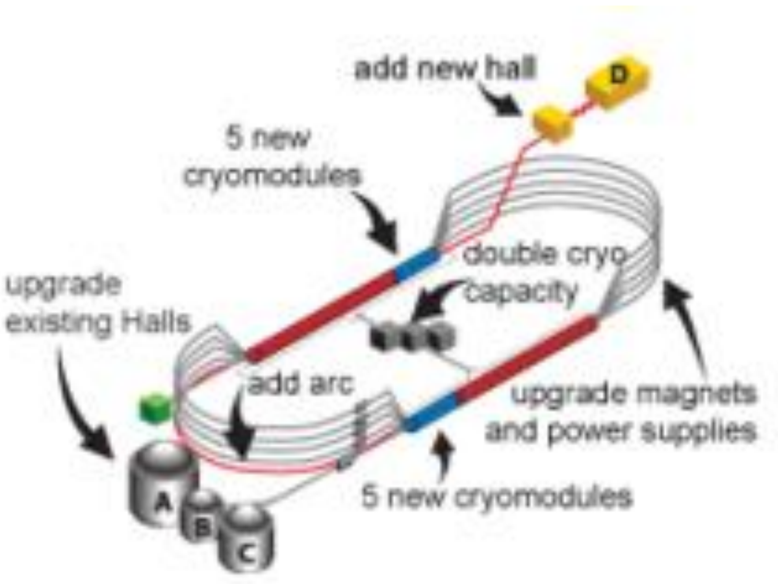
Outline

- Jefferson Lab and its CEBAF accelerator
- JLab experimental Hall C and its basic detectors
- YerPhI group contribution in Hall C
- Design and construction Aerogel detectors for Hall C
- HMS and SHMS Aerogel Detector performance
- Summary & Discussions

Thomas Jefferson National Accelerator Facility

- **Thomas Jefferson National Accelerator Facility** (**TJNAF**), called **Jefferson Lab**, is a US National Lab located in Newport News, VA (~200 miles from Washington).
- It also known as the **Continuous Electron Beam Accelerator Facility** (**CEBAF**).
- Jefferson Lab employs more than 750 people, and more than 2,000 scientists from around the world have conducted research using the facility.
- CEBAF operation annual budged is ~$200 million

Jlab and CEBAF Accelerator History



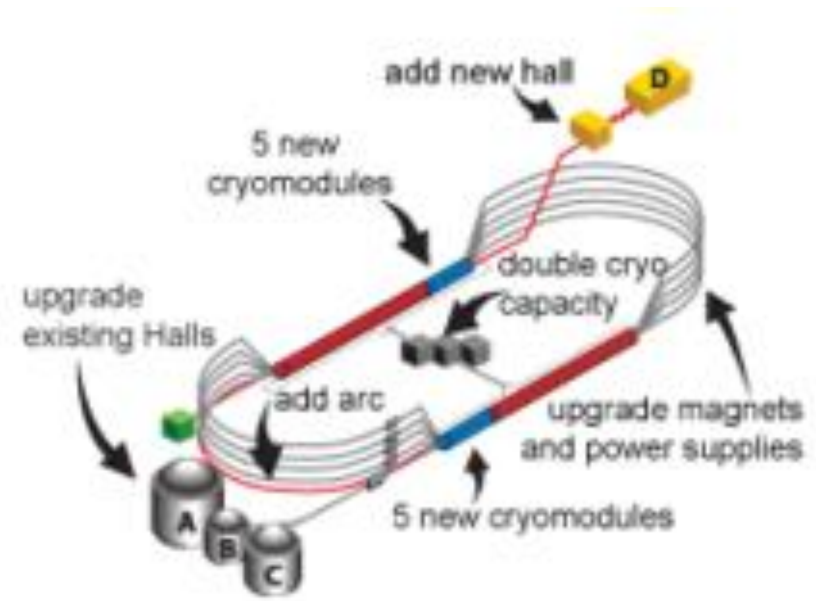
- Jefferson Lab and its Continuous Electron Beam Accelerator Facility (CEBAF) was founded in 1984.
- The name was changed to TJNAF (Thomas Jefferson National Accelerator Facility), and the construction was appropriated in 1986.
- On February 13, 1987, the construction of the CEBAF accelerator begun.
- First beam was delivered to Hall C in 1994.

- The design energy of 4 GeV for the beam was achieved during the year 1995.
- Operations with three experimental Halls A, B and C was achieved on June 1998.
- In 2000 the CEBAF reached energy of 6 GeV.
- Plan for energy upgrade to 12 GeV electron beam and construction of fourth experimental area Hall D was approved in 2001. Upgrade was started on 2009.
- May 18, 2012 the original 6 GeV CEBAF accelerator shut down for the replacement of the accelerator components for the 12 GeV upgrade.
- March 2017: the end of 12 GeV upgrade project, start of commissioning and beginning of 12 GeV experimental program in Hall A, B, C and D.

CEBAF Accelerator

CEBAF consist of an injector, two superconducting linac, two sets of arcs and systems of beam extraction from the accelerator and separation between halls.

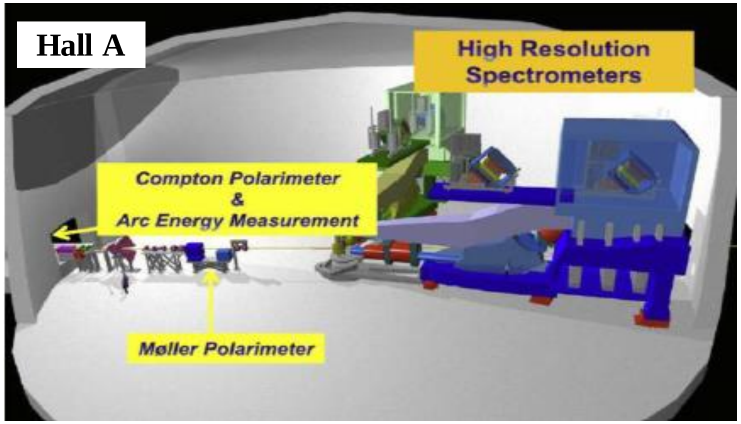
The injector provide quasi-continuous electron beam with bunches frequency up to 499 MHz per each hall and accelerator frequency is 1.497 MHz.



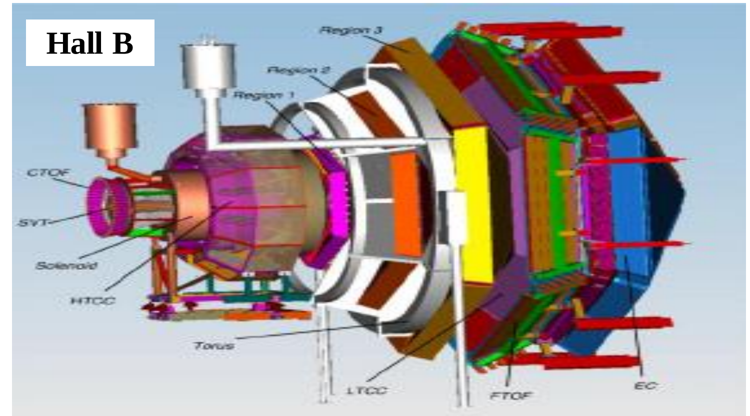
Electron Beam

- Every fourth pulse to each hall
- Simultaneous delivery 4 halls
- Hall repetition rate (min-max) 31.2-499 MHz, beam pulse τ~2ps
- Injector Energy ~100 MeV
- Linac Energy 1200 MeV (each)
- Beam Energy 0.8-12.0 GeV
- Maximum current 200 μA
- Beam polarization > 85%
- Luminosity up to 10^{38} cm^2/s
- Transverse size ~200 μm
- Energy spread dE/E ~10^{-4}

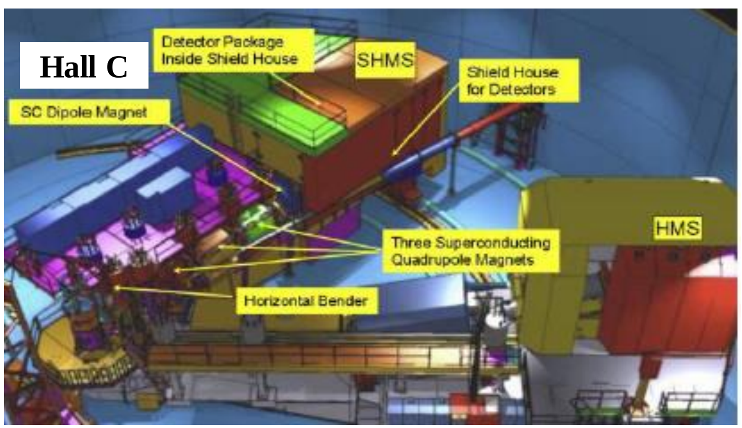
CEBAF Experimental Halls at 12 GeV



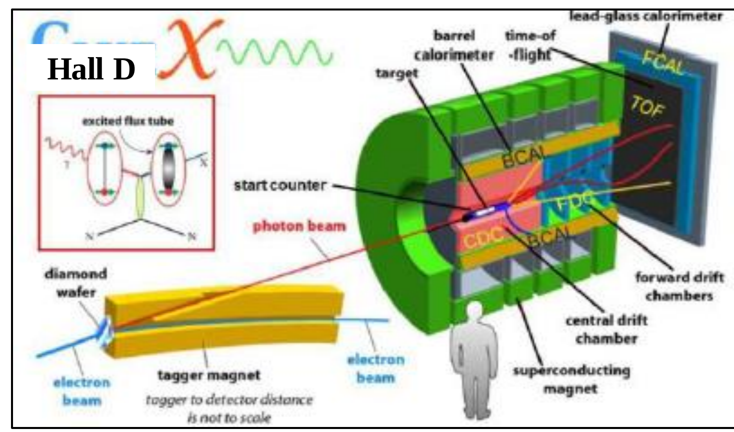
Hall A base equipment are two identical spectrometers (HRR & HRL) with a momentum resolution ~2×10^{-4}. Cherenkov counters, lead-glass calorimeters and scintillators provide excellent particle identification at luminosity ~ $10^{38} cm^{-2} s^{-1}$. The research program include nucleon structure functions, form factors & properties of the nuclear medium.



Hall B is equipped with a large acceptance spectrometer CLAS12 consisting of two superconducting magnets: a six-sector torus with maximum field 2.3 T and a ~1 m long solenoid with a maximum field 5 T.. Its detector package include silicon-strip vertex tracker, RICH & preshower. CLAS12 have luminosity ~ $10^{35} cm^{-2} s^{-1}$. .



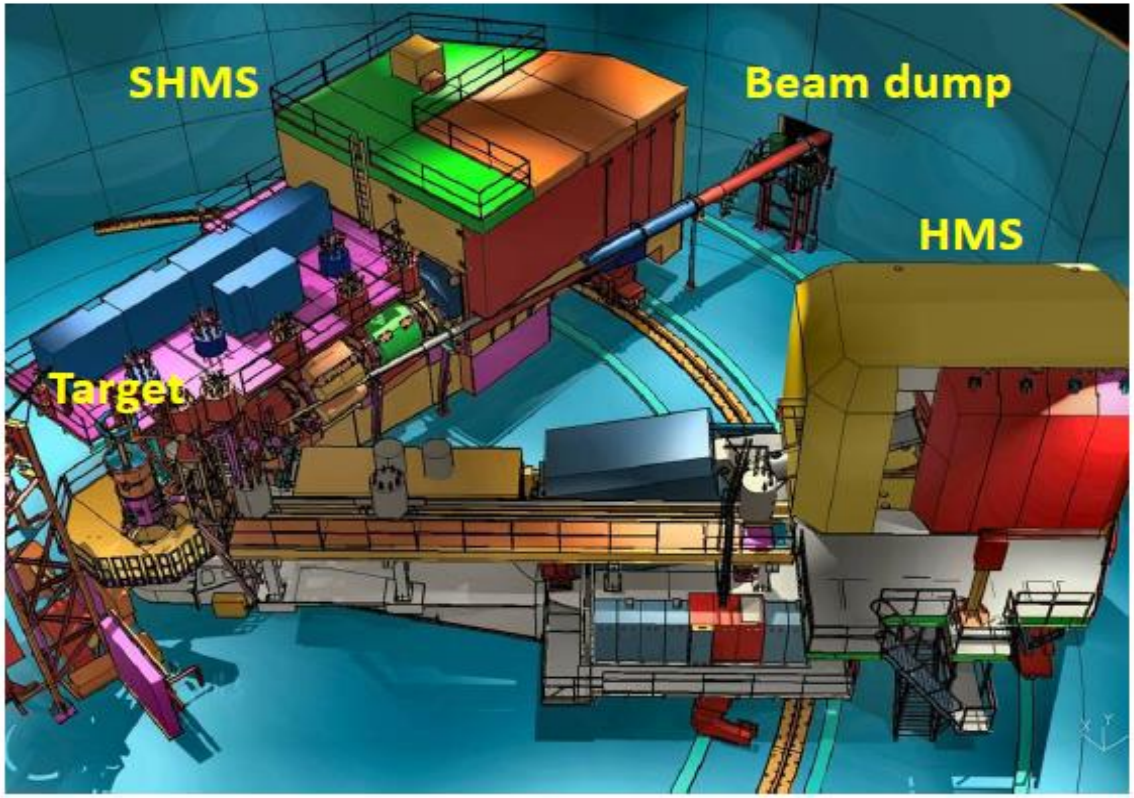
In the Hall C a new SHMS spectrometer have been installed within the framework of CEBAF 12 GeV upgrade. A pair of HMS & SHMS spectrometers allows for high-precision Inclusive, DIS, SIDIS cross section measurements and L/T separations in valence quark region.



Hall D GlueX detector is designed to conduct experiments on the polarized photon beam and for the study of new exotic states. It is hermetic solenoidal detector optimized for tracking of charged particles and detection of neutral particles.

Hall C base equipment at 12 GeV

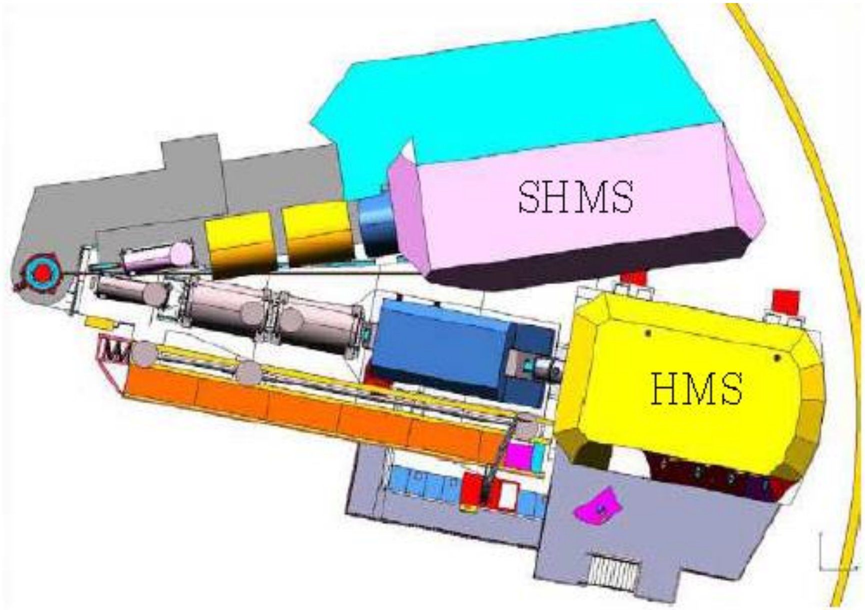
- The Hall C base experimental equipment consists of two magnetic spectrometers: the High Momentum Spectrometer (HMS) and the Super High Momentum Spectrometer (SHMS) .
- Depending on the requirements of the experiments, they can detect either negatively or positively charged particles by choosing the magnetic field configuration.

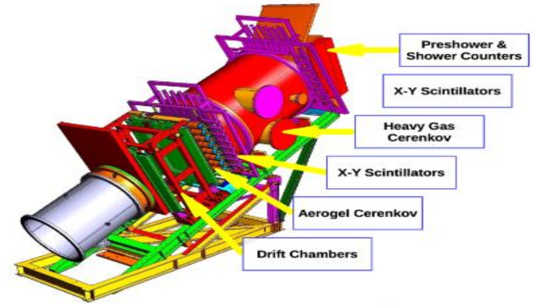


SHMS parameters:
Magnets: (HB)QQQD
P: 2 -- 11 GeV/c
ΔP: (-10% , +22%)
δP: 0.03%-0.08%
θ: 5.5 ° -- 40°
Δ Ω: 4.0 msr

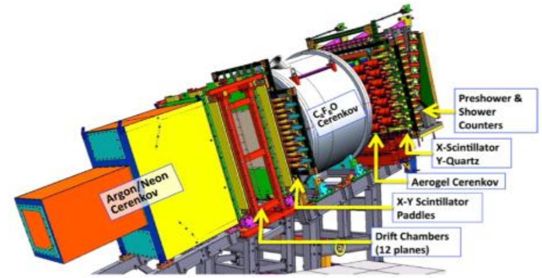
HMS parameters:
Magnets: QQQD
P: 0.5 – 7.5 GeV/c
ΔP: (-10% , +10%)
δP: 0.1%
θ: 12.5 ° -- 90°
Δ Ω: 6.0 msr
L: 10^{38} $cm^{-2}s^{-1}$

Hall C base equipments at 12 GeV





HMS



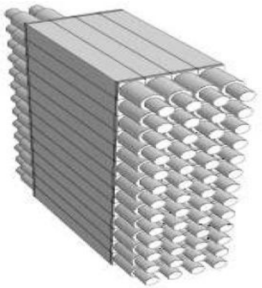
SHMS

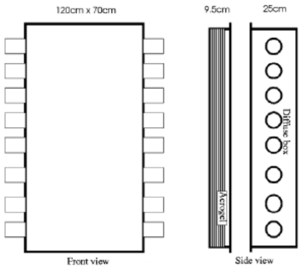
- The HMS is designed to detect secondary products of reactions in the momentum range from 0.5 to 7.3 GeV/c, while the SHMS momentum range extends up to about 12 GeV/c.
- Both spectrometers were equipped with a pair of drift chambers, pairs of timing scintillator hodoscopes for trigger formation, gas Cherenkov detectors and electromagnetic calorimeters.
- Particle identification relies on time-of-flight measurements at lower momentum, an electromagnetic calorimeter and Cerenkov detectors. Cerenkov detector filled with heavier gases such as C_4F_8O can provide π/K/p identification only in a limited momentum range.
- The hadron identification in the momentum range above a few GeV/c represents a challenge for Cherenkov detectors.
- To complete the PID capability of the HMS & SHMS an additional PID detectors needed**.**

YerPhI group contribution in Jlab Hall C

At 6 GeV energy era:

▪ Design and construction lead-glass electromagnetic calorimeters for SOS and HMS spectrometers, and threshold aerogel Cherenkov detector for HMS.



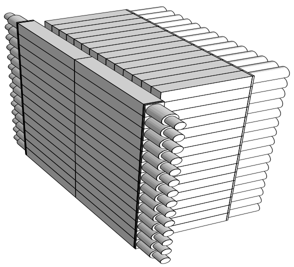


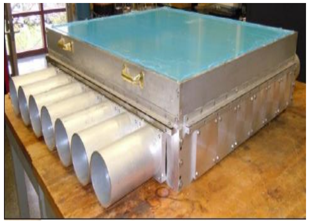
▪ Participation in installation, data taking and analysis in more than ~50 experiments

▪ Proposed and carried out first semi-inclusive charged pion electroproduction experiment E-00-108, “Duality in Meson Electroproduction”..

At 12 GeV energy era:

▪ Design and construction electromagnetic calorimeter and aerogel Cherenkov detector for SHMS spectrometer





▪ Proposed new experiments (in collaboration with Jlab & CUA):

- E12-06-104, “Measurement of the Ratio R=$\sigma L/\sigma T$ in Semi-Inclusive DIS”
- E12-09-017, “Transverse Momentum Dependence of Semi-Inclusive π-production”
- E12-13-007, “Measurement of Semi-Inclusive π^0 Production“. Required construction of the Neutral Particle Spectrometer (NPS).

▪ YerPhI group will played leading role in construction of PbWO calorimeter for NPS.

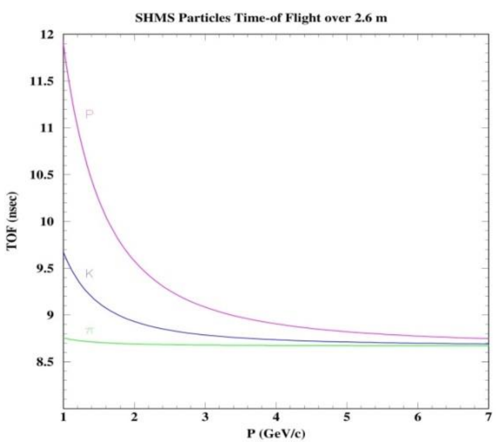
PID in HMS and SHMS

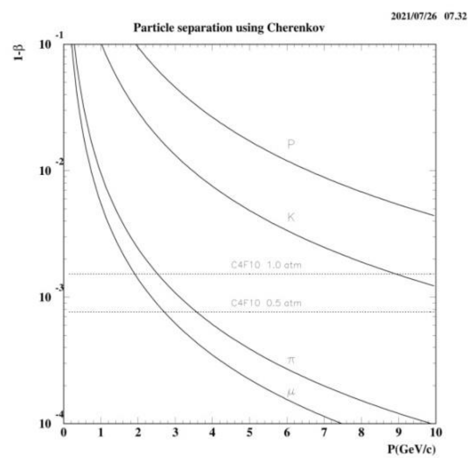
• For particle identification (PID) a combination of Time-of-Flight (TOF), threshold gas Cherenkov counter and segmented lead-glass electromagnetic calorimeter is used.

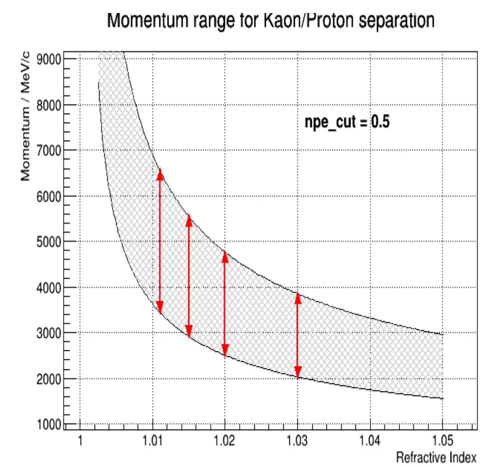
• In addition, for coincidence measurements, use of the coincidence time difference between scattered electrons and secondary hadrons is very efficient. But even with perfectly calibrated detectors, π/K/p separation deteriorates with momentum $\Delta t \sim 1/P^2$.

• TOF is effective at low momentum, but it becomes useless above $P \sim 2.5$ GeV/c.

• In addition, in this range hadrons tend to become above the detection threshold in gas Cherenkov detectors, making π/K/p separation more difficult.







• To complete the PID capability of the spectrometers additional Cherenkov detectors with an index of refraction $1.006 < n < 1.03$ is needed for good hadron identification at $P > 3$ GeV/c.

• In fact traditional gas and liquid radiators have a refractive index smaller of 1.0018 (C_5F_{12}) or larger than 1.27 (liquid C_6F_{14}).

• To avoid the use of gases at high pressure or in unmanageable liquefied form, the possible way to close the gap in refractive indices is aerogel, that can produced with *n* from 1.004 to 1.110.

Silica Aerogel

From Google Wikipedia:

Aerogel is a synthetic porous ultralight material derived from a gel, in which the liquid component for the gel has been replaced with a gas without significant collapse of the gel structure. Aerogels are produced by extracting the liquid component of a gel through supercritical drying or freeze-drying.

Aerogel was first created by Samuel Stephens Kistler in 1931, as a result of a bet with Charles Learned over who could replace the liquid in "jellies" with gas without causing shrinkage. The first aerogels were produced from silica gels. Kistler's later work involved aerogels based on alumina and chromium .

A time and cost effective fabrication method was found only in the late 1970s, when France decided to store rocket fuels in porous materials. Since then, an explosive growth of specific application in the scientific community has stimulated new techniques for the production of aerogel with remarkable optical quality.

Aerogel is currently produced in a chemical process that provides a very transparent and hydrophobic polymer gel, while old aerogel was fabricated in a way to lead to hydrophillic.

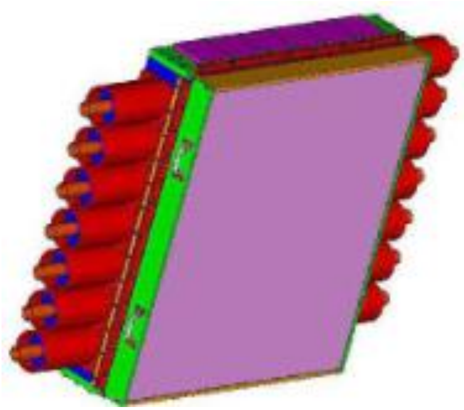
Best quality aerogel material are produced by Matsushita Electric Works (Japan) and Boreskov Institute of Catalysis & Budker Institute of Nuclear Physics (Novosibirsk, RF)

Aerogel as a medium for Cherenkov Detector

- Aerogel is a unique material that can have a refractive index between those typical for gases and liquids (as small as n = 1.004 and as high as n = 1.110).
- It is a transparent, highly porous n$SiO_2 + 2n(H_2O)$ material.
- The density of the aerogel ranging from $\rho = 0.008$ to 0.55 g/cm^3, and directly related to its refractive index $n = 1 + \alpha \times \rho$, where $\alpha = 0.22\text{-}0.25$ cm^3/g.
- Aerogel transmittance can be significantly changed if the aerogel absorbs the humidity from the surrounding environment.
- To eliminate this effect, some aerogel manufacturers use a hydrophobic coating on the tiles. This makes it possible to use the aerogel material in detectors for a long period of time without requiring special flushing with dry gas or any periodic maintenance.
- The first successful attempt to use silica aerogel in Cherenkov counter made by Cantin et al. in 1973 [NIM, 118 (1974) 177].
- Since then, an explosive growth of specific application in the scientific community has stimulated new techniques for the production of aerogel with higher optical quality.
- Silica Aerogel is now widely used in high energy physics experiment as a medium for the Cherenkov and RICH detectors

Design Specifications of Detectors

- Sensitive area: 120×70 cm² (HMS) and 110x100 cm² (90×60 cm² for the lowest index) (SHMS)
- Radiator thickness: ~9 cm for both detectors
- Detector depth: ≤ 30 cm (to fit in detector stack)



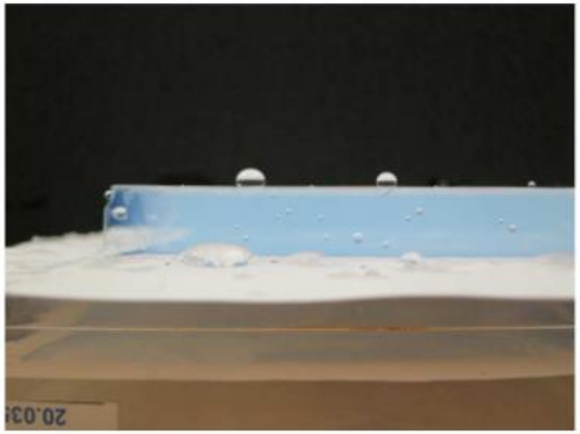
- Diffusion box scheme for collecting Cherenkov light. The photon detection probability is directly proportional to the fraction of detector surface covered by PMTs. An increase in the area covered by PMTs results in an increase of the number of photons detected.

- Taking into account requirements of Hall C experiments and momentum range of spectrometers, we chose aerogels with indexes of refraction of n = 1.030 and 1.015 for HMS, and n=1.030, 1.020, 1.015 and 1.011 for SHMS.
- The n = 1.03 aerogel allows for good pion/proton separation up to 4 GeV/c, while the n = 1.015 aerogel material can be used for pion/kaon separation in the momentum range 1-3 GeV/c, and for pion/proton separation up to 6 GeV/c.

- We used Aerogels commercially available from Japanese Fine Ceramics Center (JFCC) for n=1.011 and 1.015, and Matsushita Electric Works (Japan) for n=1.02 and n=1.03 for the SHMS. They are known to be highly transparent, hydrophobic and have a light output which is almost linear with the radiator thickness.

Humidity test of Aerogel material

- For the construction of the HMS & SHMS Aerogel ˇCerenkov detector we has used material with hydrophilic coating.
- To check the hydrophobicity of the aerogel, we kept some samples of the tiles for 24 hours at the relative humidity 84±2%, and later at 91±2%.
- No significant change of the refractive index, were observed: the average change in refractive index due to humidity was measured to be less than +0.00010.
- Finally, drops of water were added directly on the aerogel surface for a "wettability test".
- The contact angle of the water droplets to the aerogel surface was measured.



- For a hydrophilic surface the contact angle is expected to be less than 90 degrees, while hydrophobic surfaces have contact angles of more than 90 degrees.
- Our tests confirm that the aerogel tiles used in the detectors are hydrophobic.

Dimensions of Aerogel tiles

- To estimate possible difference in size between aerogel tiles, first for the randomly selected samples the thickness and the width were measured.
- For the measurement of the thickness each aerogel tile was placed in between two aluminium plates. Using a calliper, we measured the thickness of each tile from the distance between these two aluminium plates.
- Similar, a calliper was used to measure the lateral width of each tile of the selected sample of aerogel. The distance between two opposite sides of the tiles was measured in several points, and an average over these measurements was considered as the tile width.

Tray	Width (mm)	Thickness (mm)
1.030	113.10 ± 0.40	11.58 ± 0.07
1.020	110.82 ± 0.59	11.42 ± 0.33
1.015	111.83 ± 0.22	11.10 ± 0.15
1.011	112.28 ± 0.35	10.93 ± 0.10

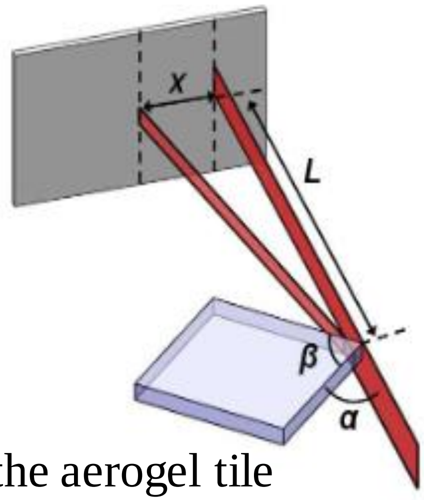
When the dimensions of all the tiles were measured, the differences in block sizes were determined, the tiles with different sizes were divided into groups. This helped to minimize possible difficulties during stacking.

T. Horn, H. Mkrtchyan, et al., Nucl. Instrum. Meth.A 842 (2017) 28-47

Aerogel Refractive Index

The refractive index of a sample of aerogel tiles were measured with a technique based on Snell's Law. It consists of measuring the refraction of a beam of light (red, λ~670 nm) incident on one corner of an aerogel tile (as shown in picture).

The beam of light is incident on the tile at an angle α with respect to the normal to the surface of its corner. The fraction of light goes through the tile, refracted and hits a screen placed at a distance L from the tile. Refraction in the aerogel bends the incident light, so that it is separated from the part of the beam that does not go through the aerogel by a distance x on the screen.



From these variables and the angle β between two sides of the aerogel tile (90° in our case), one can determine the refractive index n of the tile using,

Tray	Refractive Index
1.030	1.0303 ± 0.0007
1.020	1.0198 ± 0.0009
1.015	1.0152 ± 0.0004
1.011	1.0111 ± 0.0003

$$\frac{n}{n_{air}} = \sqrt{\frac{sin^2(\alpha)+sin^2(\gamma)}{sin^2(\beta)} + 2\frac{\sin(\alpha)\sin(\gamma)}{\tan(\beta)\sin(\beta)}},$$

$$\gamma = tan^{-1}\left(\frac{x}{L}\right) - \alpha + \beta, and$$

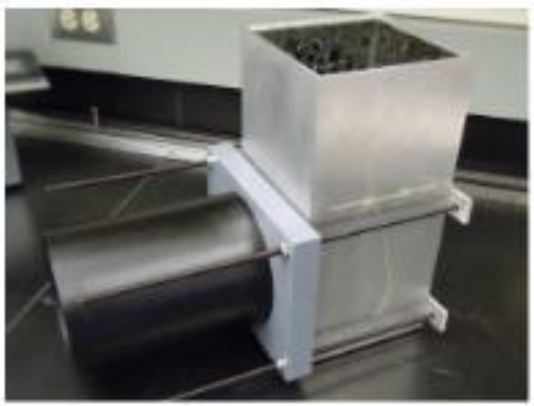
$$n_{air} = 1.000265$$

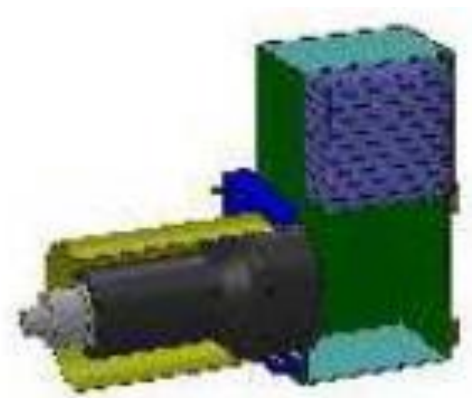
The dominant source of systematic uncertainties ($\pm 0.7 \times 10^{-3}$) is the measurement of the angles α and β.

T. Horn, H. Mkrtchyan, et al., Nucl. Instrum. Meth.A 842 (2017) 28-47

Aerogel Detector Prototype

- Several features of the detector like the selection of reflector material or thickness of the aerogel radiator required careful studies before the final assembly.
- A prototype counter was constructed to study and optimize these features of the actual detector.
- The prototype was a combination of a small aerogel tray (which can be filled with up to 14 aerogel tiles) and a diffusion box viewed by a single PMT.



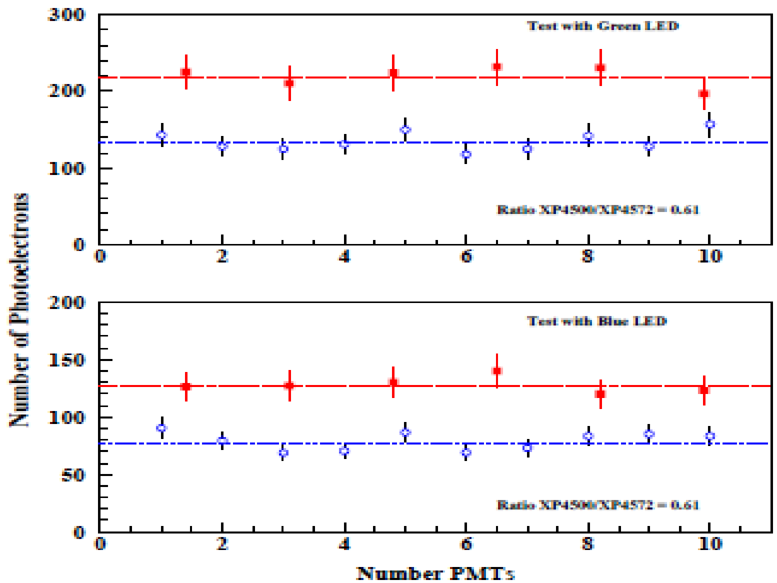


- The internal surface of the prototype was covered with Millipore material or aluminized Mylar as reflective material.
- This single-PMT prototype allowed studies of, e.g., different reflective materials covering the walls of the detector, comparative light yield of the different aerogel refractive indices, and optimization of performance with PMTs.

Selection of Phototubes: XP4500 or XP4572

The main requirements for PMT selection were high quantum efficiency, low noise, high gain at relatively low high voltage and good single photoelectron resolution. For all PMTs the gain dependence on high voltage, and relative quantum efficiency were measured. For randomly selected PMTs we studied photocathode uniformity.

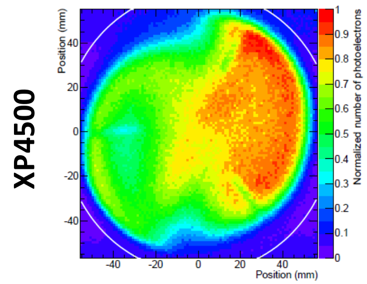
Randomly selected samples of XP4500 and XP4572 have been test with Blue & Green LED



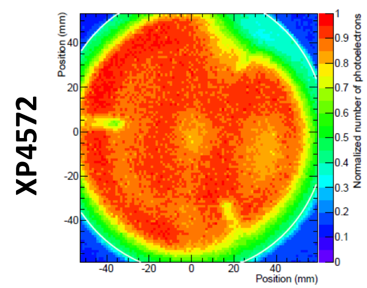
QE of XP4500 PMTs is ~40% lower than that of XP4572

We has selected 5 inch diameter and ten-stage Photonis XP4572 PMTs with a 20% quantum efficiency for our detectors.

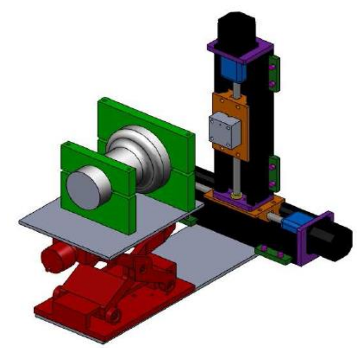
Photocathode 2D scan



(a) PMT XP4500



(b) PMT XP4572



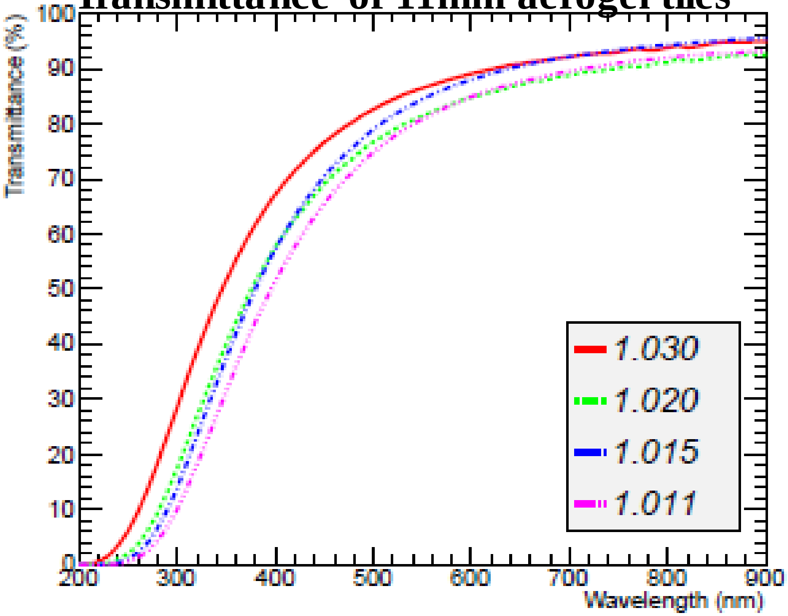
For XP4572 the region of highest efficiency covers almost the entire scanned region. This may explain observation of low QE for XP4500.

Aerogel Transmittance

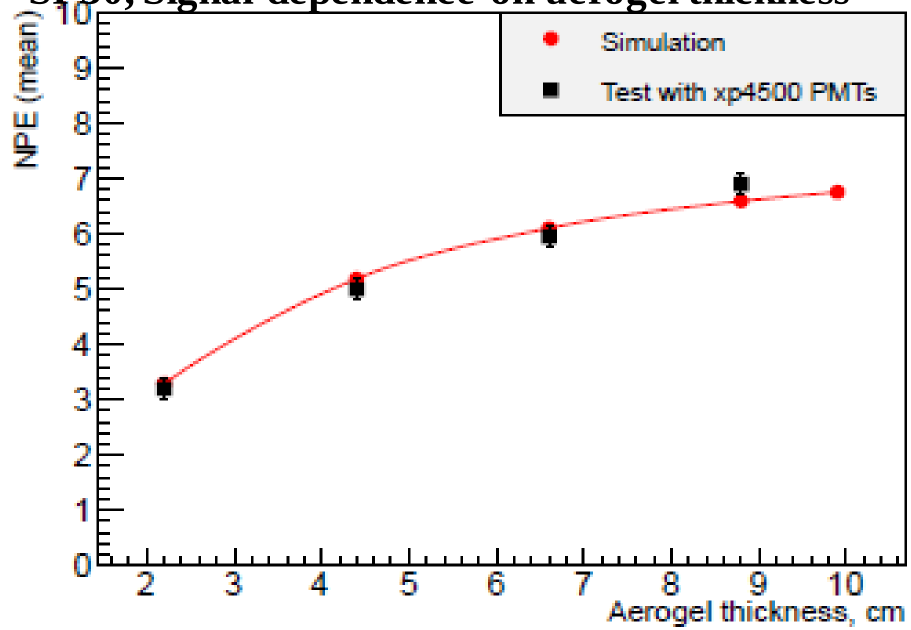
Perkin/Elmer LAMBDA 750 UV/Vis/NIR Spectrophotometer was used to measure the light transmittance for a randomly selected sample of aerogel tiles for each nominal refractive index.

To check the relative optical quality of the aerogel material we have measured the light yield generated by cosmic muons using the single counter (prototype).

Transmittance of 11mm aerogel tiles



SP30, Signal dependence on aerogel thickness



At small wavelength (λ < 300 nm) light absorption and scattering is significant.

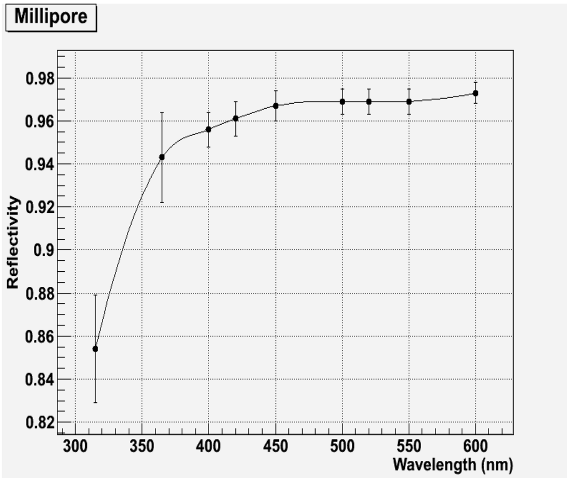
However, this does not have a negative impact on the detector performance, as it is outside the PMT's quantum efficiency range.

The number of photoelectrons as a function of aerogel thickness nearly linear up to 9 cm,

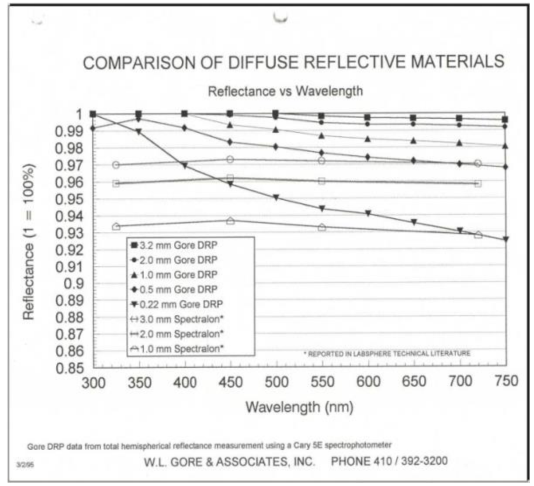
For thicknesses of more than 11 cm the light yield clearly saturates (solid curve is a polynomial fit).

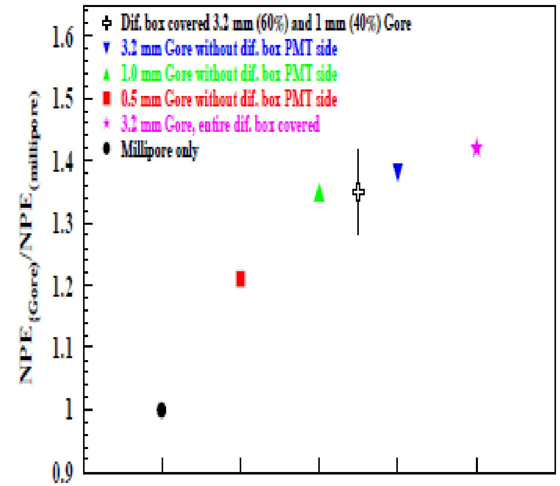
Chose of the Reflector material: Millipore vs Gore

Millipore



Gore and Spectralon





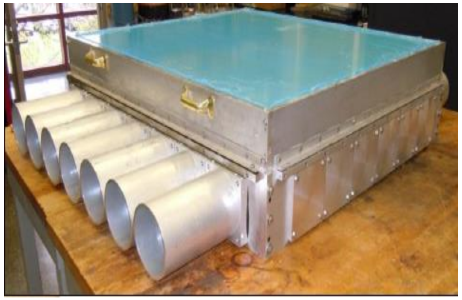
- **Millipore has quite low (~0.92) reflectivity at 400nm**
- **Gore has reflectivity >0.99 in all QE range of the PMTs**

The inner walls of the diffusion box of the HMS aerogel detector and its two trays (n=1.030 and 1.015) were covered with Millipore paper "Membrane GSWP-0010".
We are covered the Diffusion box internal surface of SHMS aerogel with 3.2 mm (60%) and 1.0 mm (40%) thickness Gore reflector (DRP-1.0-12×30-PSA).
For the two lower refractive index trays (SP-15 and SP-11), in order to optimize light collection, we used 1 mm thick Gore diffusive170 reflector material (DRP-1.0-12x30-PSA).

Gore reflector have improved the detector performance ~35% compared to the Millipore.
Our measurement (open cross) is in good agreement with the MC simulations

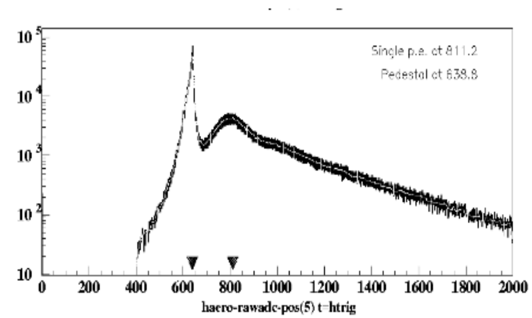
Aerogel Detector Assembling

- In order to stack the material, each tile dimension was first measured and the differences in block sizes determined.
- Taking into account the tolerances on the actual aerogel material thickness inside the aerogel diffusion boxes, the tiles were layered in 9 or 8 stacks, making the total thickness of aerogel radiator was 9 cm (over ~700 tiles).
- The layers were shifted relative to each other by about 2-3 cm to prevent any dead zones inside the aerogel volume.
- The PMTs are sealed into their housing using a light-tight synthetic rubber (RTV103 Black Silicone Sealant). The whole assembly is sealed light-tight.
- The close spacing of the metal shields from photocathode of PMT's required to keep the cathode at ground potential, while positive high voltage was applied to the anode (to reduce the noise level).
- To compensate for the low gain of the chosen PMT, we modified their High Voltage bases by inserting an amplifier in the HV dividers as a sequential.

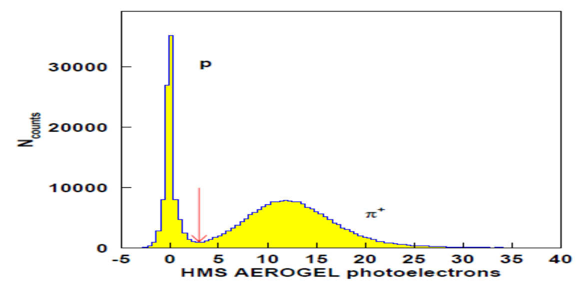


HMS Aerogel Detector Performance

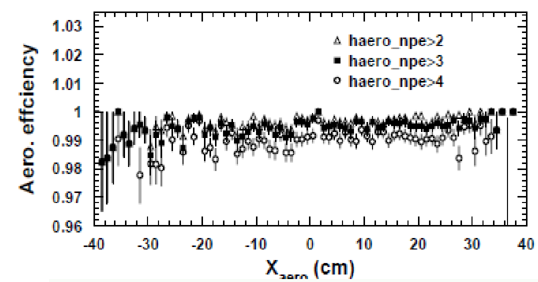
Calibration of each PMT was performed at different applied high voltages, by measuring the Single Photo-Electron peak position. This allowed us to roughly equalize the response functions for PMTs, and to determine their gains at a given high voltage.



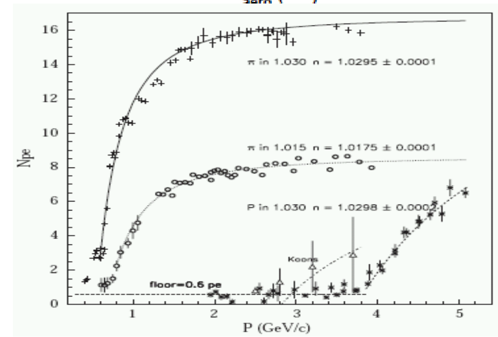
The total number of photo-electrons for protons and pions at HMS spectrometer momentum P = 3.1 GeV/c in aerogel with index of refraction n = 1.030. One can see very clean separation of protons and pions.



Pion detection efficiency of the HMS Aerogel detector with tray n = 1.030 along x-coordinate (vertical axis) for different cuts on number of photoelectrons (N > 2, 3 or 4).

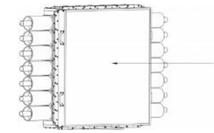


The momentum dependence of number of photoelectrons (Npe) for 2 types of aerogel material and for different particles (experimental data and fits to them are shown).

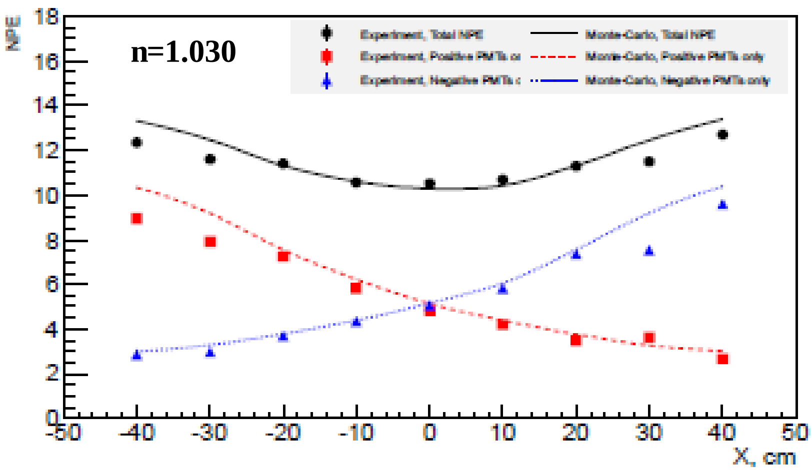


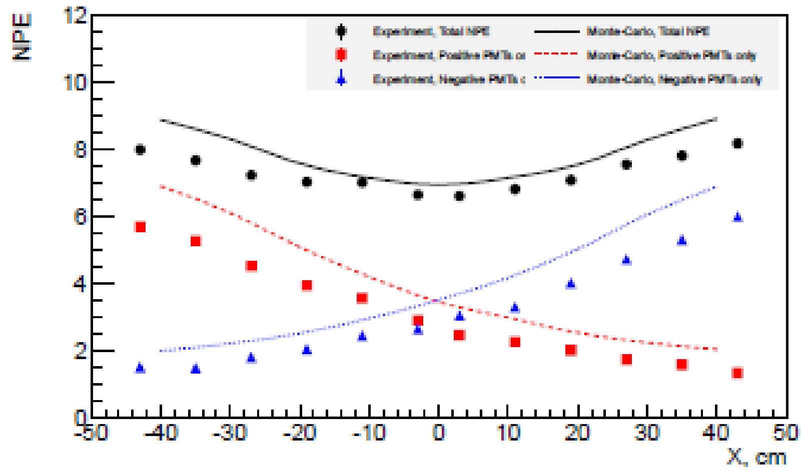
R.Asaturyan et al., Nucl. Instr. Methods A 548 (2005) pp. 364-374

SHMS Aerogel Detector Performance

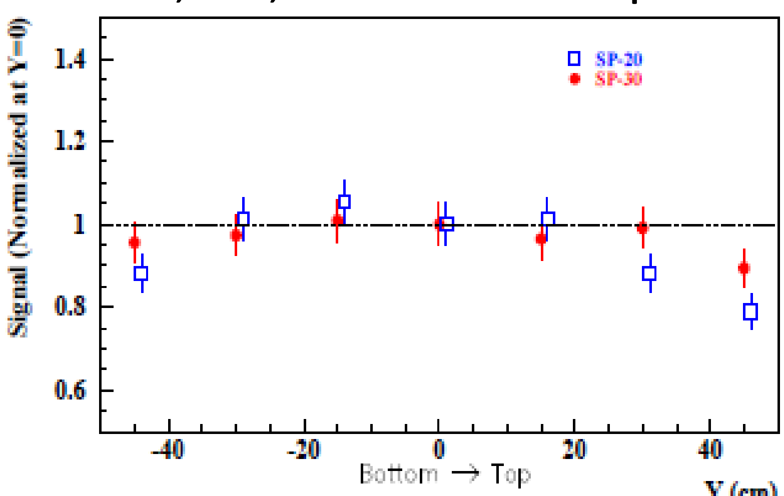


Data show a signal increase at either edges of the detector (close to PMTs).
The slight symmetry is caused by an imbalance of the QE of the left & the right side PMTs.



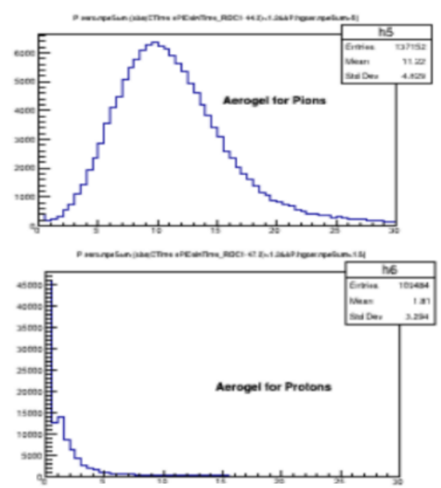


SP30,SP20 , Vertical coordinate dependence



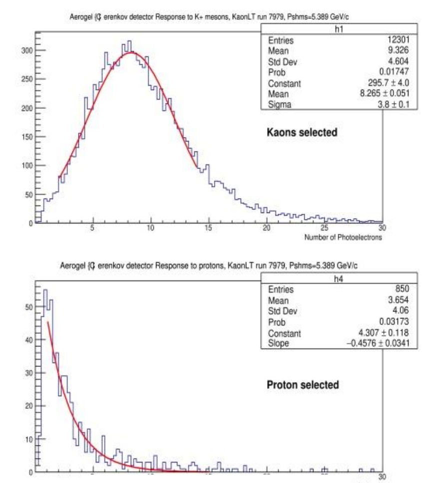
No significant vertical coordinate dependence.

π /p separation in SP15



P=3.319 GeV/c

K/p separation in SP11



P=5.389 GeV/c

T Horn et al., Nucl. Instr. Methods A 842 (2017) pp. 28-47

Experiments with use of HMS and SHMS Aerogel Detectors

- **HMS Aerogel Detector has been used at CEBAF 6 GeV energies:**
  - E-01-004 (Fpi-2), "The Charged Pion Form Factor"
  - E-00-108 (Duality), "Duality in Meson Electroproduction"
  - E-01-107 (CT), "Measurement of Pion Transparency in Nuclei"

It was not used since 2006, was damaged while being in the HMS hut in 2006-2011 (probably due to accumulation of He. Needs refurbishing & new PMTs)

- The **SHMS Aerogel Detector has been used after CEBAF 12 GeV upgrade:**
  - E12-06-101, "Measurement of the Charged Pion Form Factor to High Q2"
  - E12-06-104, "Measurement of the Ratio R=σL/σT in Semi-Inclusive Deep-Inelastic Scattering"
  - E12-09-002, "Precise Measurement of pi+/pi- Ratios in Semi-inclusive Deep Inelastic Scattering Part I: Charge Symmetry violating Quark Distributions"
  - E12-09-011, "Studies of the L-T Separated Kaon Electroproduction Cross Section from 5-11 GeV"
  - E12-09-017, "Transverse Momentum Dependence of Semi-Inclusive Pion Production"

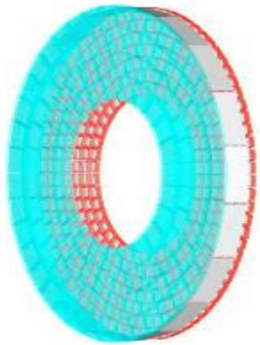
It is still in good working condition. But it would be good to buy an extra amount of n = 1.011 aerogels to fill the full effective area of the tray.

SUMMARY

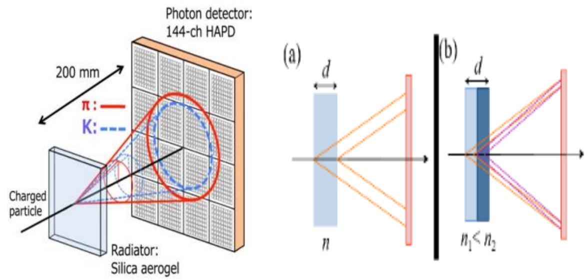
- We have constructed Aerogel detectors with refractive indices n=1.030, 1.020, 1.015, and 1.011 for the HMS & SHMS magnetic spectrometers in Jlab HallC.
- Each detector consists of one diffusion box and several exchangeable trays (2 for HMS & 4 for SHMS) loaded with a different aerogel materials.
- The optical quality of all aerogel material, such as index of refraction, transmittance and light yield was studied in detail.
- The photosensors were also characterized carefully, in particular their gain and quantum efficiency. For the final assembly XP4572 were selected.
- The particle identification properties of the HMS & SHMS spectrometers in Hall C have been significantly improved by adding aerogel threshold detector.
- These detectors enhanced the capabilities of the spectrometers in distinguishing protons from pions on the level of $\sim 10^{-3}$ (for n = 1.030 aerogel) with a pion detection efficiency better than 99% in the 1-4 GeV/c momentum range.
- The tray combination allowed for identification of kaons from 1 GeV/c up to 7.2 GeV/c, reaching $\sim 10^{-2}$ proton and $\sim 10^{-3}$ pion rejection, with kaon detection efficiency better than 95%.
- Aerogel detectors have been used in Hall C experiments since 2003 for identification of π/K/p and demonstrated high quality performance.

Thanks for Your Attention !

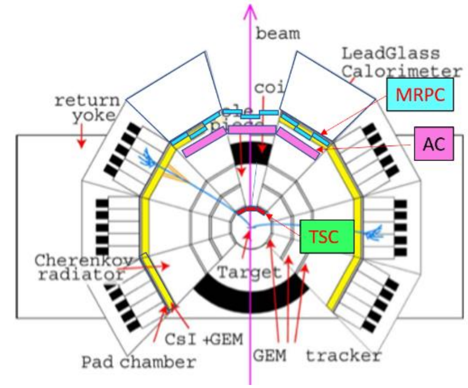
Examples: Aerogel Detectors in Experiments



Schematic Drawing of the Bell II FARICH detector. The blue and red discs show the aerogel radiator and photodetector modules (I. Adachi et al., NIM A 553, 146-151, 2005)



The principle of π/K identification for the ARICH counter.. Single layer (a) and (b) the focusing dual-layerm(from S. Iwata et al., PTEP 2016.Issue 3, Mar 2016)



J-PARC E16 spectrometer at KEK to study ϕ→K+K-. AC denotes Aerogel Counter (H. Sako et al., KEK proposal: https://j-parc.jp>hadron>pac_2007)

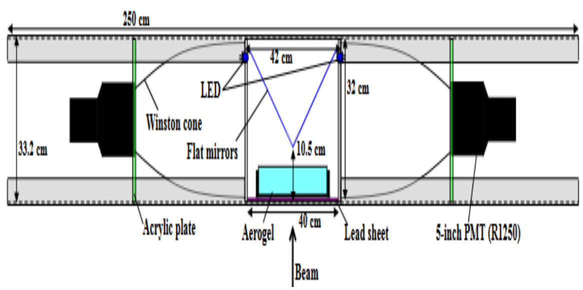
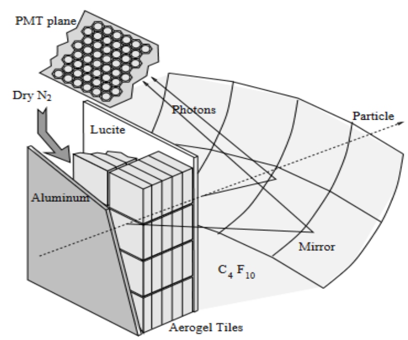
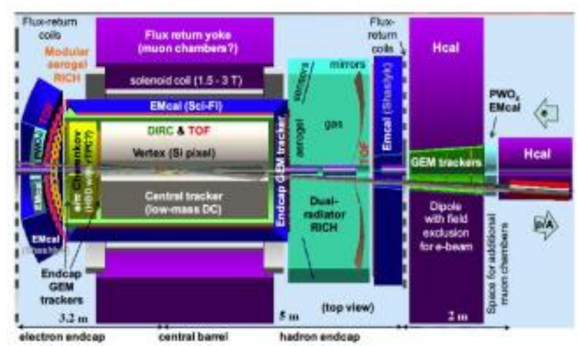


Diagram of a single module Beam Hole Photon Veto detector of the KOTO, or K_L^0 decay experiment at **To**kai (from Y. Maeda et al., arXiv:1412.6880 [phys-ins-det] 22 Dec2014)

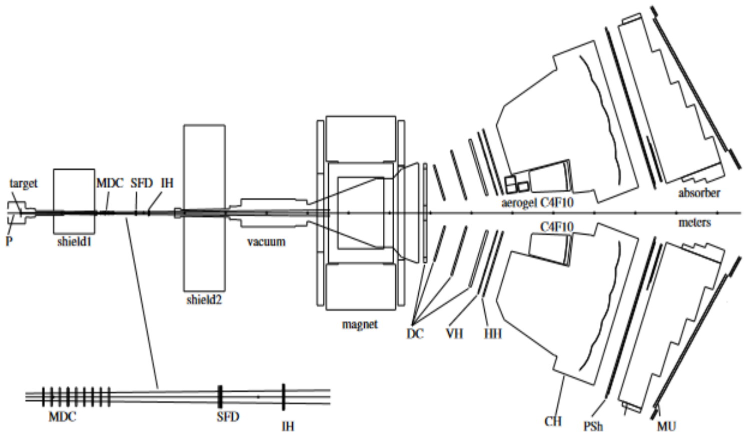


Basic geometry of the HERMES dual radiator RICH (from N. Akopov et al., arXiv:0104033.[phys-ins-det] 8 Apr 2001)

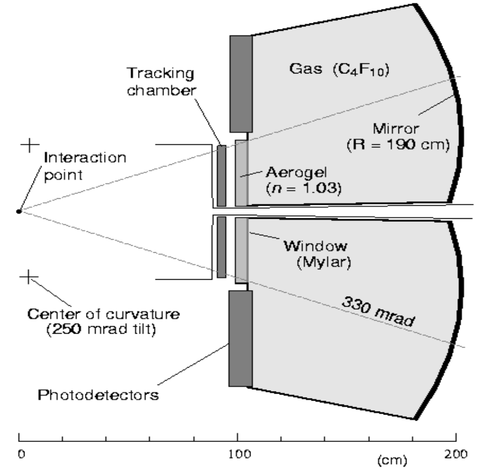


Dual radiator RICH (dRICH), aerogel and gas, for EIC (from E. Cisbani presentation, DIRC 2019 workshop,, Sep 2018)

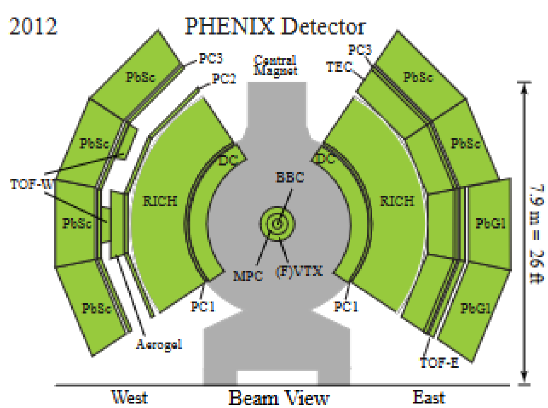
Examples: Aerogel Detectors in Experiments



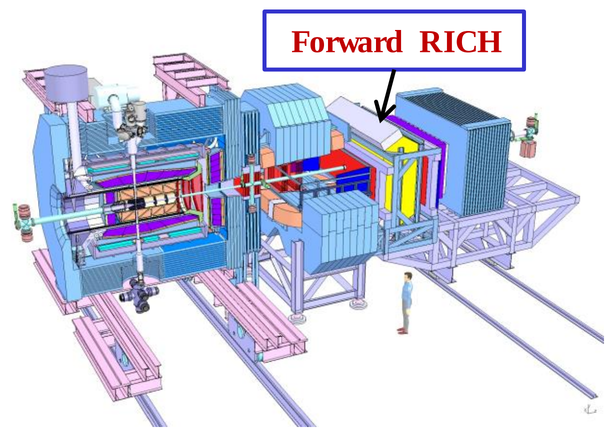
Schematic Drawing of the DIRAC detector at CERN (from A. Benelli et al., EPJ Web of Conf. 37, 011011, 2012)



Schematic Drawing of the LHCb RICH with aerogel and gas radiator (from R.W. Forty, LHC-B/96-5)

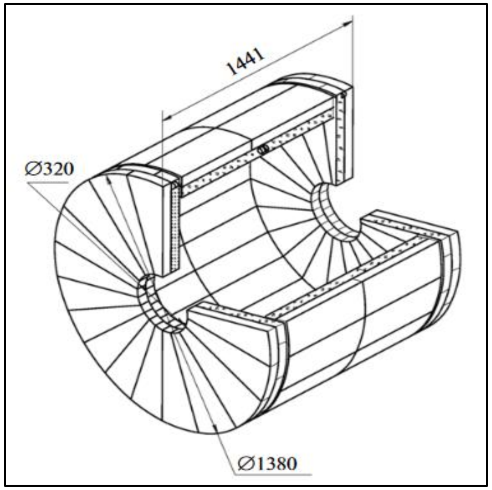


PHENIX experiment at RHIC (from C. Aidala et al., arXiv:1311.3594v2 [physics.ins-det] 14 Fev 2014)

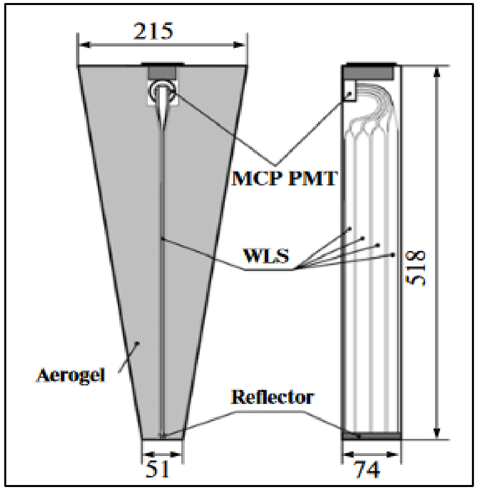


PANDA detector (from S. Kononov report, 10th Int.Workshop RICH2018)

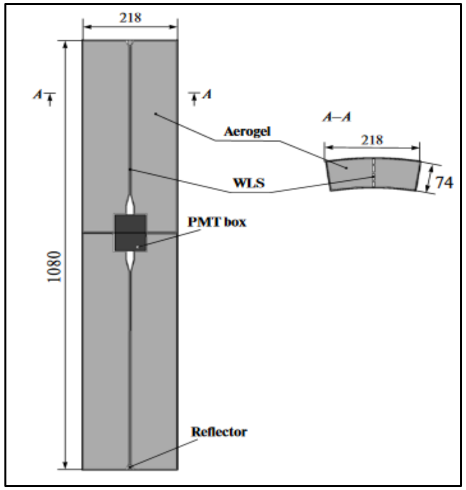
ASHIPH (Aerogel, SHIfter, Photomultiplier) system of the KEDR



ASHIPH system of the KEDR counter (V.V. Anashin et al., ISSN 1063-7796, Phys.Particl. Nucl, 44 (2013) 657–702).



ASHIPH endcap counter of KEDR developed by BINP (A.Yu. Barnyakov et al., Rad. Phys. Chem.75 (2006)862)



ASHIPH endcap two barrel counters in a single housing.

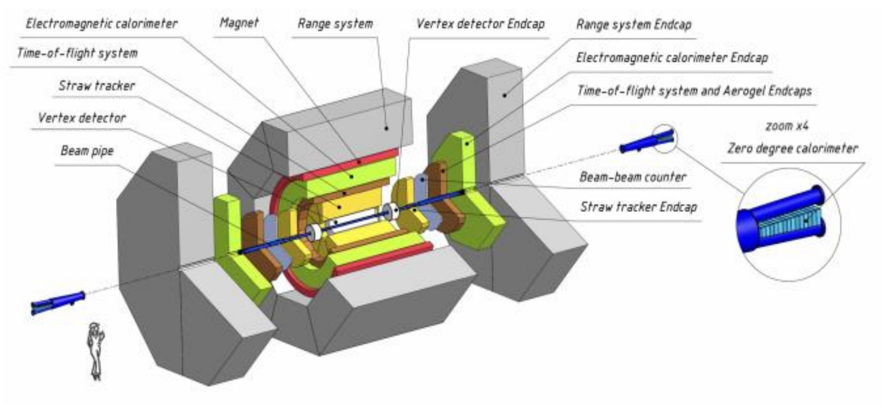
A particle from the point of beam interaction with P > 0.6 GeV/ c passed through shifters simultaneously in two layers of counters. A probability that a particle with a P > 0.6 GeV/c might fall into the shifter in a single layer is 10%, for a momentum of 1.5 GeV/c, 5%..

For the most of particles the data from two layers can be used, which improves quality of PID. Walls of the counters are covered with the 750 μm thick diffusive-reflective material based on polytetrafluorethylene (PTFE) having the 97–98% reflection coefficient.

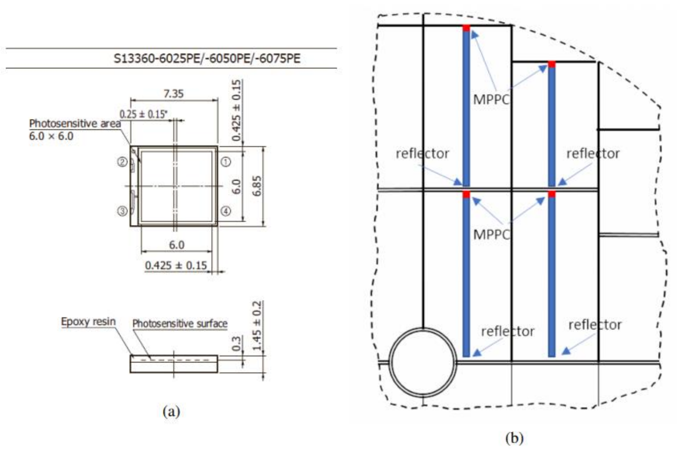
Cherenkov light from aerogel is collected on the wavelength shifter, reradiated at λ~500 nm. Its ~50% falls in the conditions of the total internal reflection, propagates as through a light guide to the multialkali photocathode PMT (made in Novosibirsk) connected via an optical contact to one of the wavelength shifter ends. A reflector made of PTFE is installed at the opposite end.

Aerogel Detector for SPD

- SPD aerogel detector would be similar to KEDR
- It will be inserted in the end-cap between the beam-beam counters and TOF
- Aerogel with n = 1.02 will allow for π/K separation in the range P = 1.0-2.5 GeV/c
- With effective light collection it is expected 5-7 photoelectrons per 10 cm thickness
- The endcap aerogel detector will consist of two layers with a shifted position of the wavelength shifters in each layer with respect to each other.
- Each layer has 100 mm thickness, the surface of a layer is composed of 28 rectangular aerogel tiles of dimensions up to 200×400 mm². The innermost tiles are machined so that their form fits a circular beam pipe.
- An output 3 ×12 mm² surface of the shifter is attached to 2 MPPC Hamamatsu S13360-6075, each having 6×6 mm² photosensitive area, 50% photon detection efficiency and high gain, 4×10^{6}. An option to use 4 MPPC S13360-3060 with a 3×3 mm² sensitive area, and 40% photon detection efficiency also is considered.



General layout of the SPD setup



(a) Drawings of the MPPC Hamamatsu S13360-6075. (b) Wavelength shifters (blue) and light sensors MPPC in the aerogel layer

Aerogel Detector Assembling