SHMS NGC Cerenkov

Donal Day
University of Virginia

Hall C Readiness Review
August 24 & 25, 2016
Newport News
Outline

- HMS
  - Recent Performance
- SHMS Nobel Gas Cerenkov
  - How it got done
  - Design Principles and Constraints
- Expected Performance
  - Construction Details
  - Status
  - Extra Parts
  - Acknowledgements
  - Extra Slides
We have done this before

**Figure 3.13:** Čerenkov detector geometry.
How it got done

- Design and Simulation UVa
- Tank Drawings and Fabrication JLAB
- Design Procurement/Fabrication of everything inside the tank; mirrors, pmts, mirror mounts, pmt mounts, etc: UVa
- Glass blanks: 43 by 43 cm by 3mm with R = 135 cm Rayotek Scientific, Inc
- Measure Shapes Apex Metrology
- Roughness Examination UVa's Zygo white light interferometer
- Glass Coating: Al followed by MgF₂ UV reflectance to exceed 75% (at 150 nm) CERN EP-DT Group
- PMTs and and bases: 14 stage, low noise, 5 inch quartz window, positive HV: 9823QKB04 (PMT) and C643KFP-01 (divider) ET Enterprises Ltd, Electron Tubes, UK
- Magnetic Shields Ad-Vance Magnetics
- Gas Handling JLAB
- Tedlar Dupont
- Window and Port Foam Seals Precision Sheet Metal Fabrication
Recent HMS Cerenkov Performance

5 inch Burle PMT 8854 coated with WLS

Nuclear Dependence of R: E04-001 2007 Vahe Mamyan UVa

1% effect confirmed at https://hallcweb.jlab.org/elogs/Jan05+Experiments/384
<table>
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<th>Experiment</th>
<th>p (GeV/c)</th>
<th>Req'd e⁻:π⁻ Disc.</th>
<th>Spec'd NG Cerenkov</th>
<th>Spec'd Calorimeter</th>
<th>Total Expected</th>
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<td>E12-06-101 (Fpi-3)</td>
<td>2.2 - 8.1</td>
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<td>E12-06-104 (σ_L/σ_T)</td>
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<td>50:1</td>
<td>&gt;200:1</td>
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<td>E12-07-103 (pion factorization) (d)</td>
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<td>(HMS Cerenkov gives up to 300:1 now)</td>
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<td>&gt;10⁴:1</td>
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SHMS PID Requirements: negative polarity

4 overlapping spherical mirrors
R = 135 cm, 43 by 43 cm
2 m of active length
Noble gas at 1 Atm
Choice of gases

Argon up to 6 GeV and a mixture of Argon and Neon up to 11 GeV

Threshold condition: 

$$(1 - \beta) < (n - 1)$$

$$\cos \theta = \frac{1}{\beta n}$$
Full Featured Geant 4 Simulation

V Mamyany, M. Yurov
Photoelectron Yield

\[ N_e = 2\pi a \left(1 - \frac{1}{\beta^2 n^2}\right) \int_{\lambda_1}^{\lambda_2} e_c(\lambda)QE(\lambda)G(\lambda) \frac{d\lambda}{\lambda^2} \int_0^L dx \]

\[ = AL \left(1 - \frac{1}{\beta^2 n^2}\right) \]

---

**Reflectance %**

**QE %**

**Tube (5)**

- R1584 UV glass: \( 219 \) \( 5.9 \) \( 185 \) \( 650 \) Neon
- ET 9823QKB Quartz: \( 349 \) \( 9.4 \) \( 154 \) \( 620 \) Neon

200 cm active length, 80% of vendor’s QE
Photoelectron Yield

\[ N_e = 2 \pi a \left( 1 - \frac{1}{b^2n^2} \right) \int_{\lambda_1}^{\lambda_2} \varepsilon_c(\lambda)QE(\lambda)G(\lambda) \frac{d\lambda}{\lambda^2} \int_0^L dx \]
\[ = AL \left( 1 - \frac{1}{b^2n^2} \right) \]

Tube (5)

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<th>( \lambda_1 )</th>
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<td>ET 9823QKB Quartz:</td>
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<td>154</td>
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200 cm active length, 80% of vendor’s QE
Mirror Installation
Overlap with beveled edges
PMTs
Tuning

Green laser illuminating whole of acceptance

Red pencil laser probing range of angles
# Materials in path of electron

## Materials in path of electron in NGC Cerenkov

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<th>Item</th>
<th>Material</th>
<th>Z/A =</th>
<th>Atomic mass</th>
<th>Density (g/cm³)</th>
<th>RL (g/cm²)</th>
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<th>Thickness (cm)</th>
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*See http://pdg.lbl.gov/2014/AtomicNuclearProperties/HTML/polyvinylchloride_PVC.html

| Total RL (with argon) | 0.042 |
| Percent from mirror  | 58.2  |

## Magnetic Field at PMTs

Max $B_x$ is 16.2 Gauss

Max $B_x$ is 2.9 Gauss

Steve Lassiter, Hall C
SHMS Detector Working Group Meeting
Aug. 26, 2010

6-inch shield made of 0.040” Ad-Vance Ad-Mu-80
Detector Efficiency

We can assume that the photoelectrons have a Poisson distribution $W(N, \tilde{N}) = \frac{\tilde{N}^N e^{-\tilde{N}}}{N!}$ for registering $N$ photoelectrons when $\tilde{N}$ are expected. If by $P(N)$ we denote the probability for the detector (PMT and associated circuitry) to record the pulses due to $N$ photoelectrons, we can write the efficiency of the detector as $\varepsilon = \sum_{N=0}^{\infty} W(N, \tilde{N}) P(N)$. Let us assume that $P(N)$ is of the form

$$P(N') = \begin{cases} 0, & N' \leq N - 1; \\ 1, & N' \geq N. \end{cases}$$

i.e.: there is a threshold for the detection of $N$ photoelectrons. Then the efficiency is of the form

$$\varepsilon = 1 - e^{-\tilde{N}} \left( 1 + \sum_{N'=1}^{N-1} \frac{\tilde{N}^{N'}}{N'!} \right).$$

Hence, we have the efficiency functions

$$\varepsilon_1 = 1 - e^{-\tilde{N}}, \quad \varepsilon_2 = 1 - e^{-\tilde{N}}(1 + \tilde{N}), \quad \varepsilon_3 = 1 - e^{-\tilde{N}}(1 + \tilde{N} + \tilde{N}^2/2), \quad \varepsilon_4 = 1 - e^{-\tilde{N}}(1 + \tilde{N} + \tilde{N}^2/2 + \tilde{N}^3/6),$$

etc.


As in all experiments there are events coming from reactions other than the one the experiment wants to study. These events are regarded as a background. Different types of detectors are constructed to decrease the number of background events in order to achieve the experiment's specific precision goals. For this experiment there are two detectors used for particle identification, a threshold Čerenkov detector described in Section 2.7.3, and an electromagnetic lead-glass calorimeter described in Section 2.7.4.

The main background in this experiment is from negative pions produced by charge exchange reactions. The ratio of pions to electrons varied from 0.1 to 30 for all runs. In this experiment the Čerenkov cut required that the number of photoelectrons be bigger than 2 ($n_{pe} > 2$), and the ratio of the Calorimeter track energy divided by the energy $E'$, $hsshtrk/E'$, is greater than 0.7.

Figure 30: HMS calorimeter track energy $hsshtrk/E'$ vs number of Čerenkov photoelectrons. The magenta line shows the Čerenkov cut, the red line shows the Calorimeter cut.

Figure 31: First plot: HMS calorimeter total energy $hcal/E'$ distribution when the number of photoelectrons are higher than 0 but less than 2. Second plot: The Čerenkov cut efficiency as a function of scattered energy.

Figure 32: HMS central momentum is 0.71 GeV. Top plot: HMS calorimeter track energy $E_{track}/E'$ ($hsshtrk/hse$) distribution without Čerenkov cut (the blue line) and with Čerenkov cut $> 2$ (the red line). Bottom plot: The $E_{track}/E'$ distribution after Čerenkov cut $> 2$ and $E_{track}/E' > 0.7$ cut (the red hatched area). The solid blue area is the pion contamination.
• Ar/Ne mixed using its own MFC system in gas shed
• Very similar to wire chamber gas system
  • 1 atm, slow flow rate to maintain gas mix purity
• Initial fill done using high-flow circuit (~100 scfh)
  • switch to low-flow circuit to maintain (~60 sccm)
• System protected against overpressure by pop-off valves, multiple overpressure/relief bubblers, and automated valve attached to Photohelic switch/gauge
• Gas flows electronically monitored and logged
Backup & Status

• Two HMS mirrors

• Three NGC mirrors

• Four 5 inch Hamamatsu UV glass (suitable for coating)

• One 5 inch ET Quartz tube

• Huge inventory of experience

• Assembled and tuned detector in ESB with nitrogen flowing since October 2015

• Ready for installation and checkout
Acknowledgements

• Howard Fenker
• Brad Sawatsky
• Bert Metzger
• Vahe Mamyang
• Nicholas Philips
• Mikhail Yurov
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• David Wimer
• Garth Huber
• Dan Abrams
• Jixie Zhang

• Dien Nguyen
• Matt Caplan
• Tyler Cody
• Matt Biondi
• Thomas Schneider
• Tosh Rijal
• Thanakorn Iamsasri
• Cole Smith
• Matthew Nelson
• Melissa Goldman
• Stephen Washington

https://hallcweb.jlab.org/doc-private/ShowDocument?docid=794
Extra Slides
Faro Arm in Astronomy at UVa

Coordinate measuring machines (CMM)

APEX Metrology, Zeiss G2 Calypso
Mirrors - the glass

We worked with Rayotek of San Diego which claimed great experience in slumping glass.

They were 1 year late - the shapes were very good.

We specified $R = 135\text{cm}$

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Red line is laser pointer path for PMT position tuning
MC produced electron vertical and horizontal angles as a function of X and Y at the front of the NGC window.