SHMS NGC Cerenkov

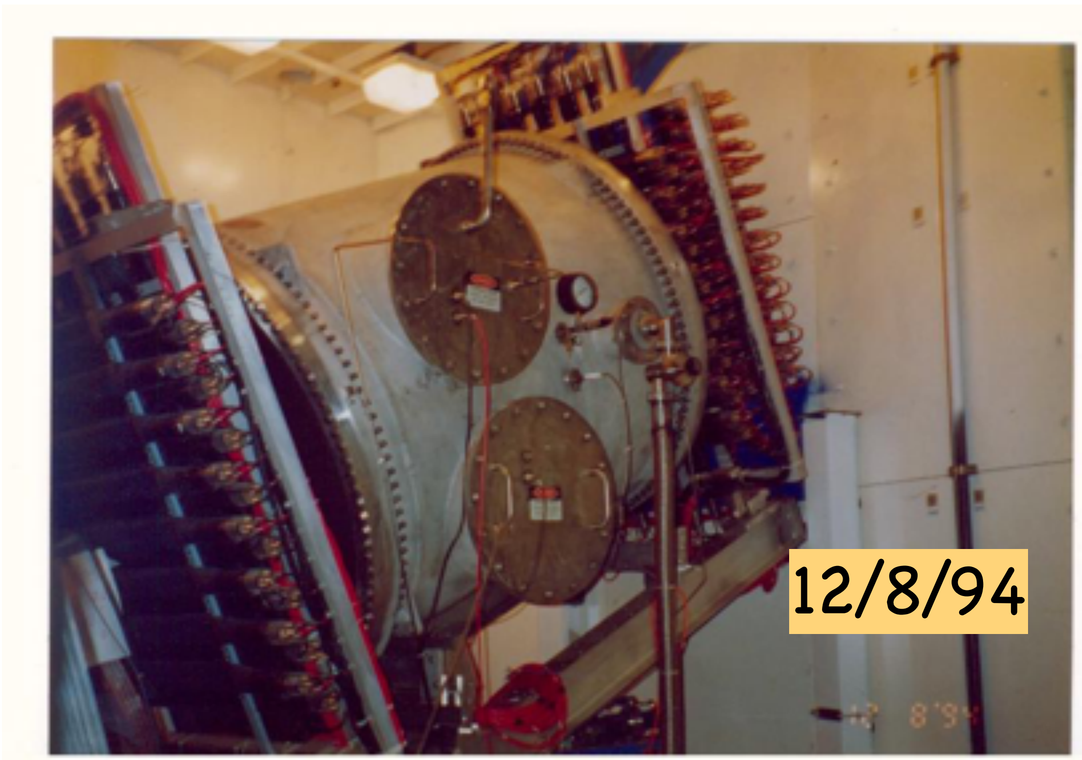
Donal Day
University of Virginia

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



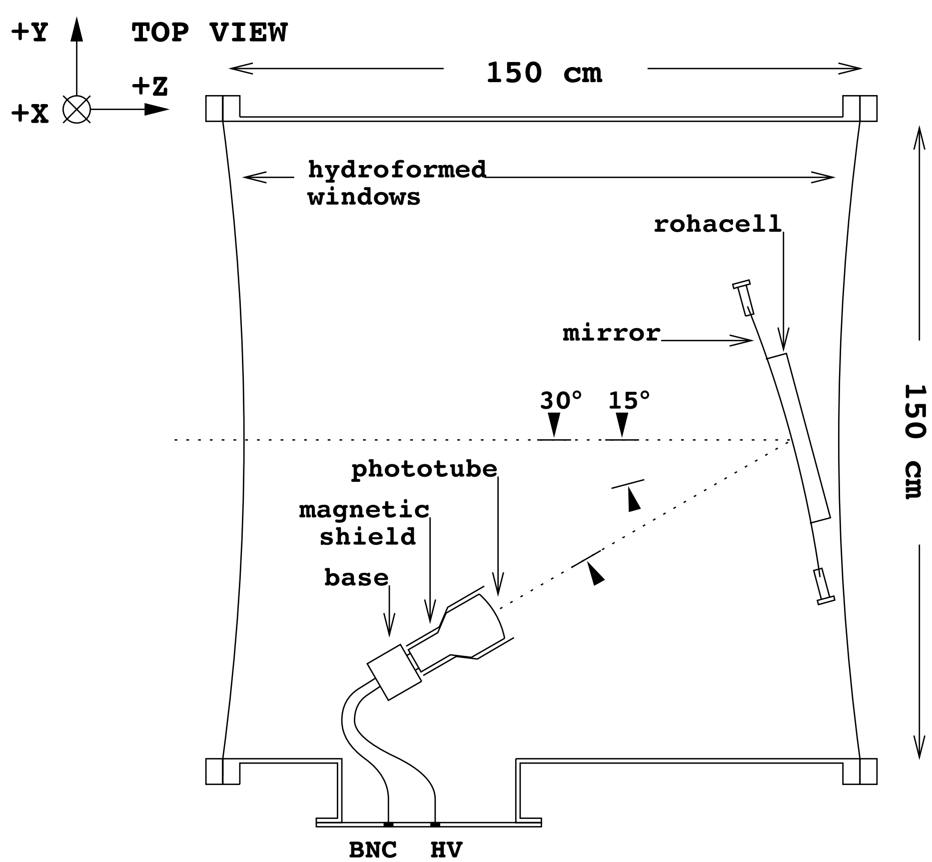
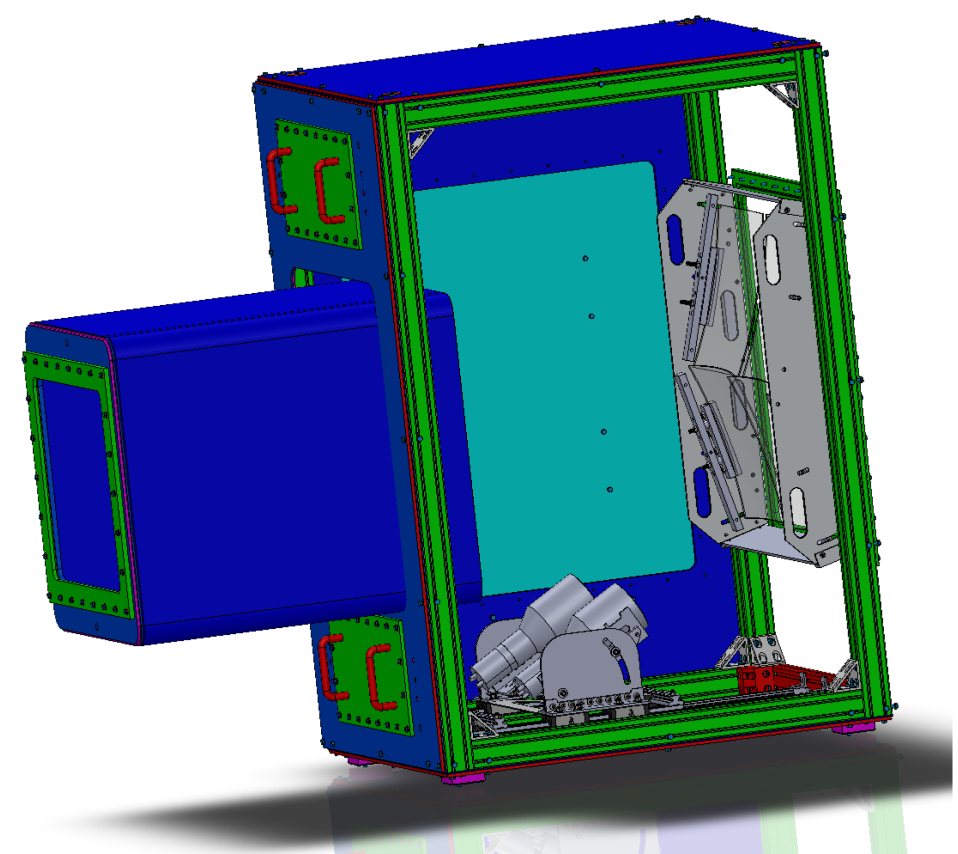


Figure 3.13: Čerenkov detector geometry.



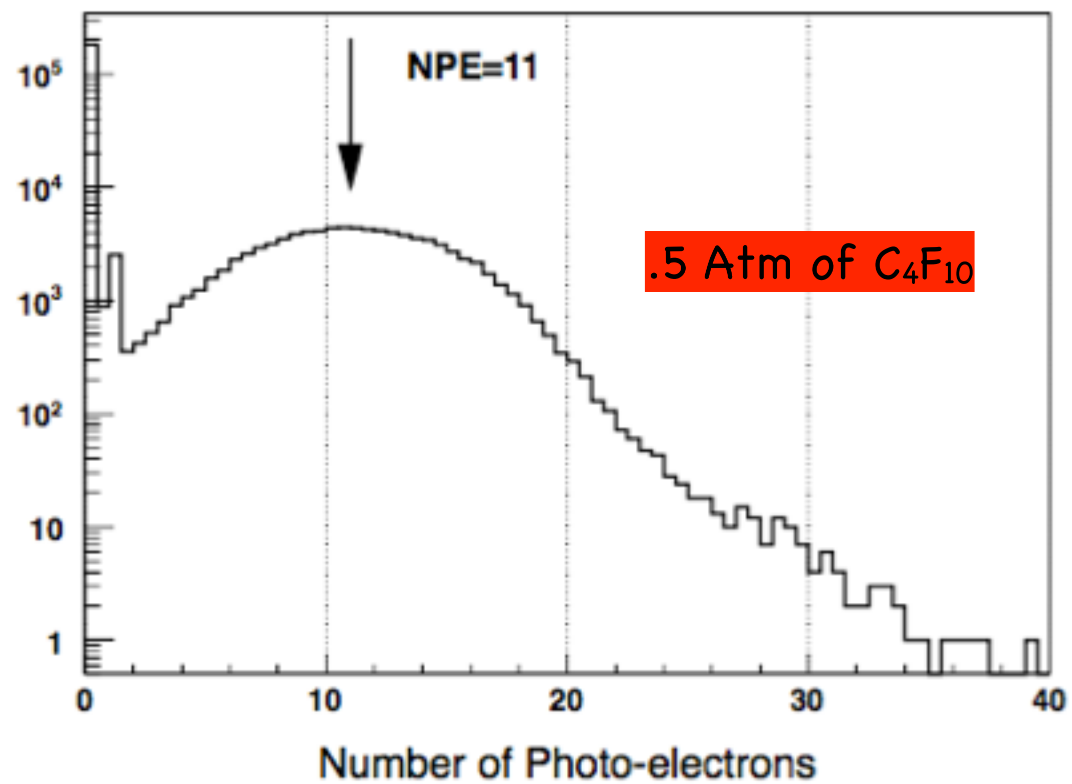
How it got done

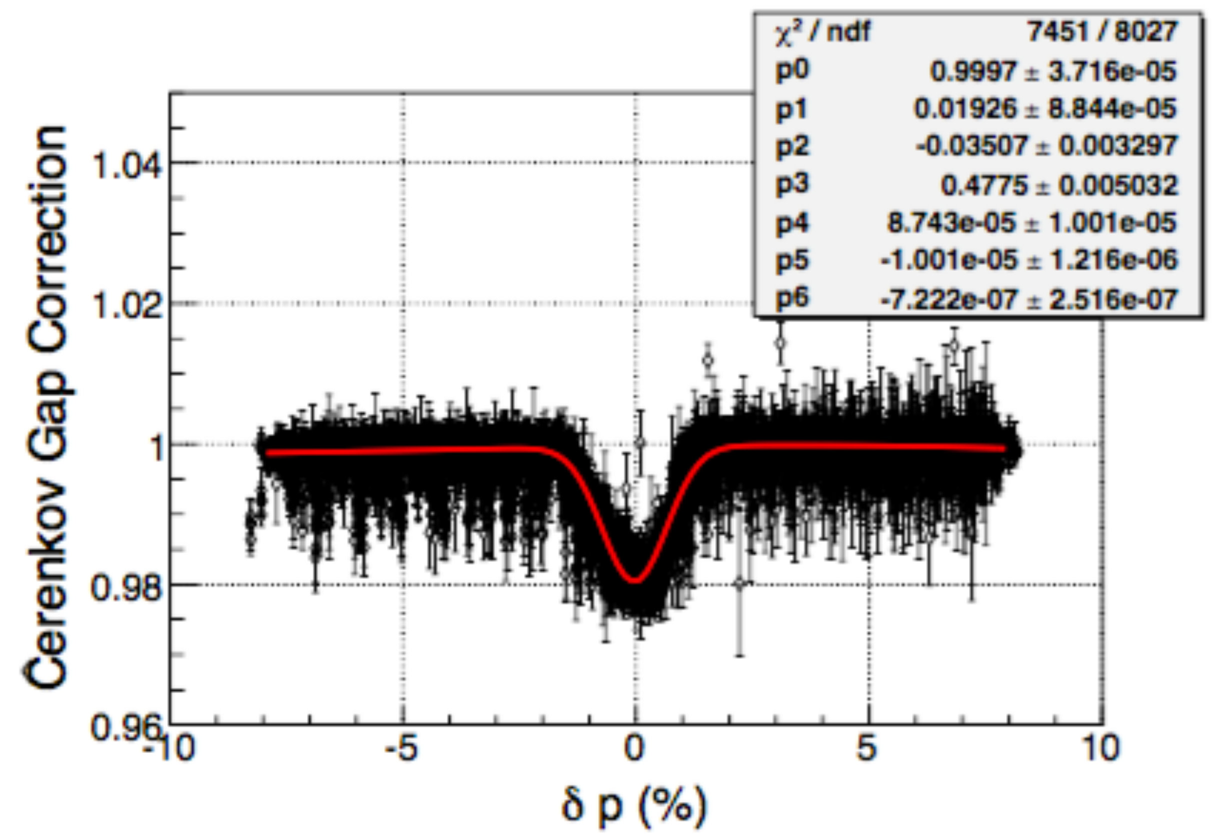
- Design and Simulation UVa
- Tank Drawings and Fabrication JLAB
- Design Procurement/Fabrication of everything inside the tank; mirrors, pmts, mirror mounts, pmt mounts, etc: UVa
- Glass blanks: 43 by 43 cm by 3mm with R = 135 cm Rayotek Scientific, Inc
- Measure Shapes Apex Metrology
- Roughness Examination UVa's Zygo white light interferometer
- Glass Coating: Al followed by MgF_2 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

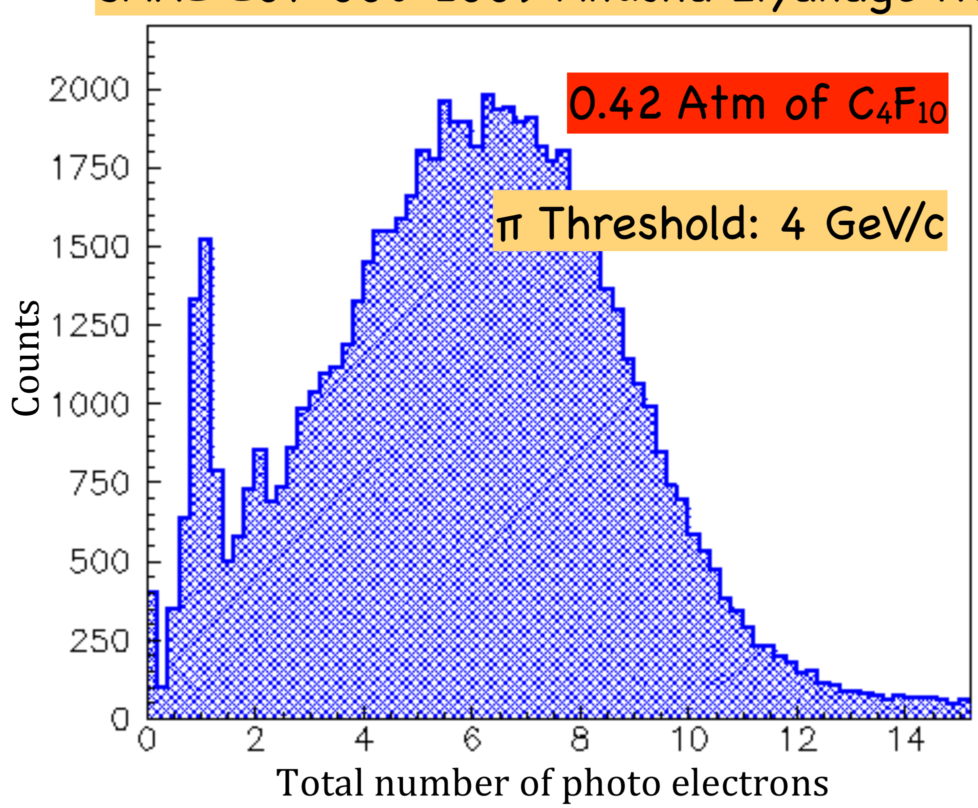
5 inch Burle PMT 8854
coated with WLS

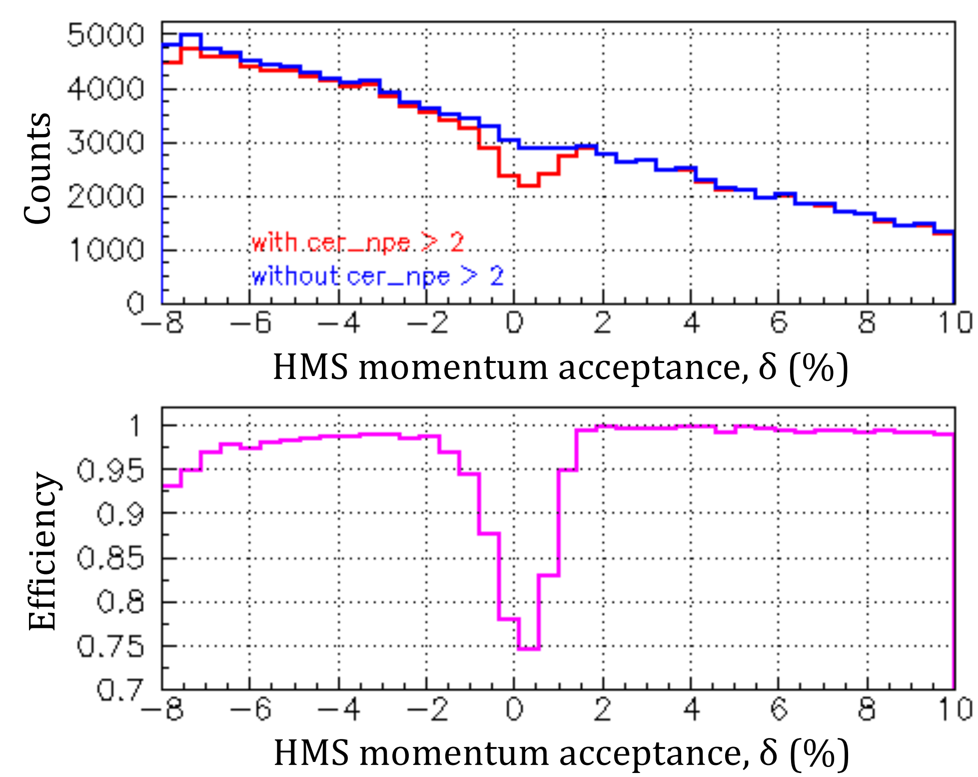
Nuclear Dependence of R: E04-001 2007 Vahe Mamyan UVa





SANE E07-003 2009 Anusha Liyanage HU



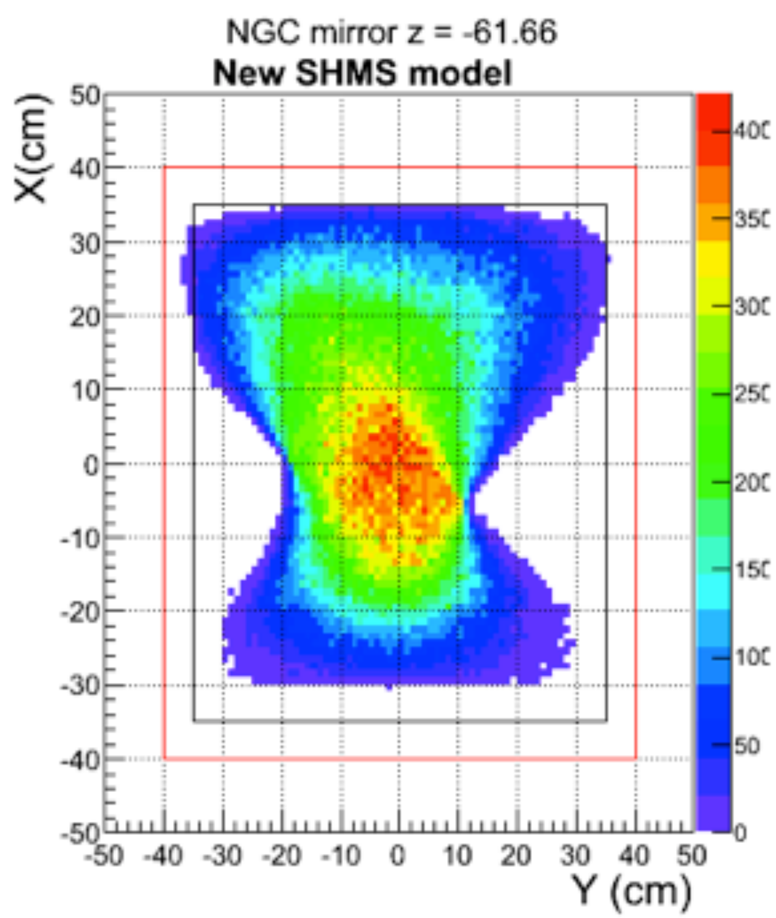


Efficiency dip at mirror overlap

1% effect confirmed at https://hallcweb.jlab.org/elogs/Jan05+Experiments/384

SHMS PID Requirements : negative polarity

Experiment	p (GeV/c)	Req'd $e^-:\pi^-$ Disc.	Spec'd NG Cerenkov	Spec'd Calorimeter	Total Expected
E12-06-101 (Fpi-3)	2.2 - 8.1	$4.5 \bullet 10^3$:1	50:1 (HMS Cerenkov gives up to 300:1 now)	>200:1 (1000:1 above 6 GeV/c)	$>10^4$:1
E12-06-104 (σ_L/σ_T)	5.4 - 5.8	10^3:1			
E12-07-103 (pion factorization) (d)	2.4 - 8.5	10^3:1			
E12-06-105 (x>1)	4.8 -10.6	$5 \bullet 10^3$:1			
E12-06-110 (c)	2.2 - 6.8	10^3:1			
E12-06-121 (g_2^n, d_2^n)	6.3 - 7.5	$>10^2$:1			



4 overlapping spherical mirrors

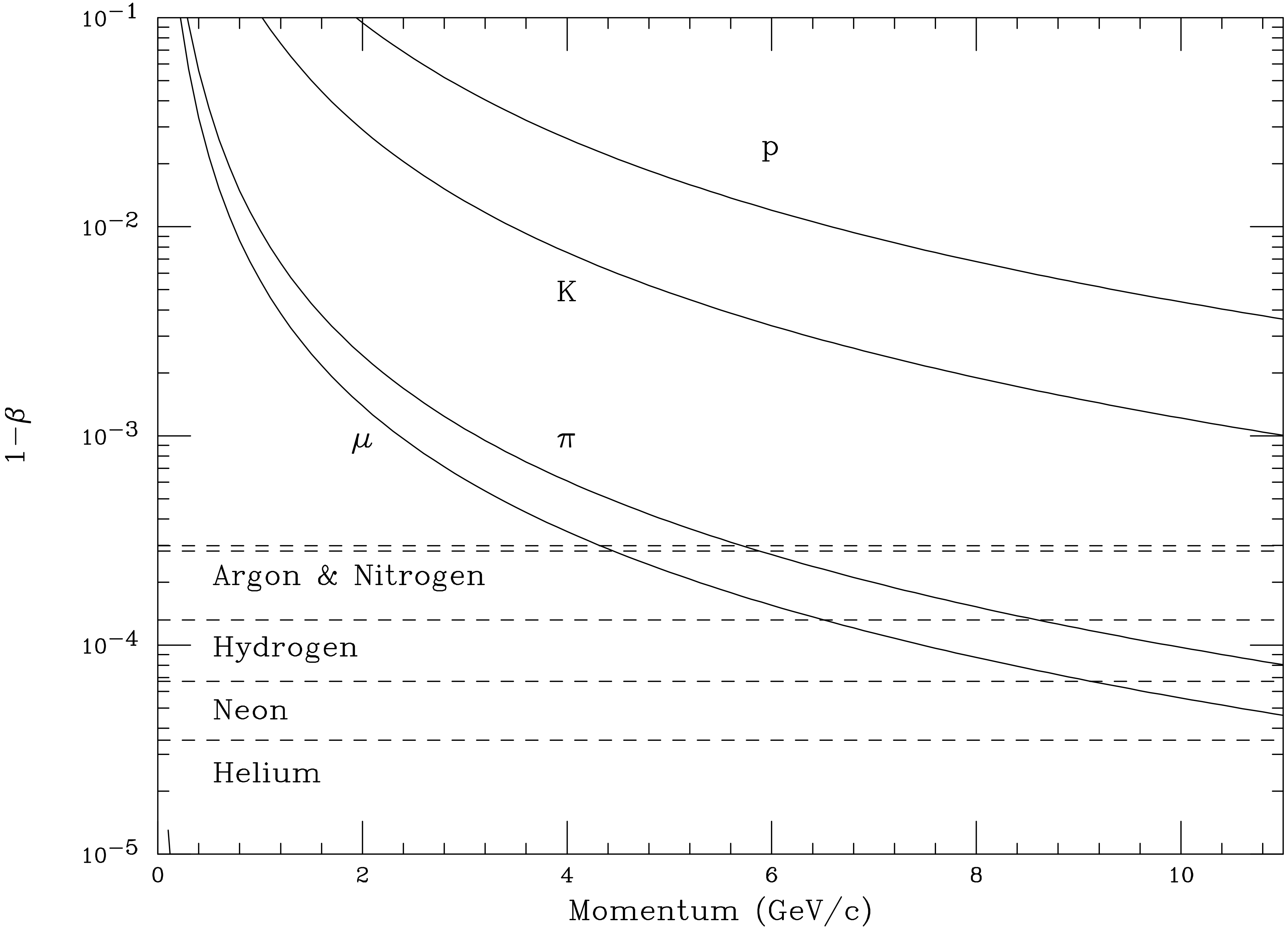
R = 135 cm, 43 by 43 cm

2 m of active length

Noble gas at 1 Atm

Threshold condition : $(1 - \beta) < (n - 1)$

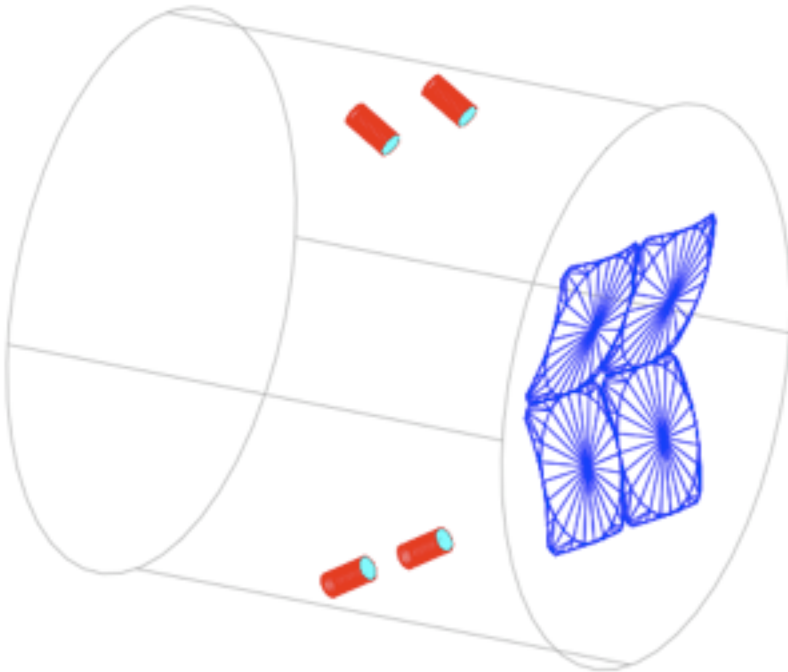
$$\cos\theta = \frac{1}{\beta n}$$

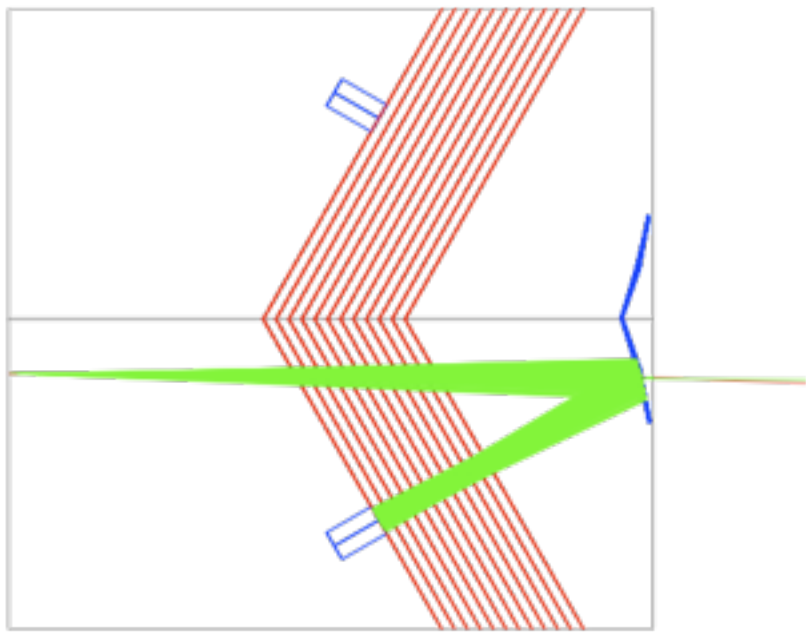


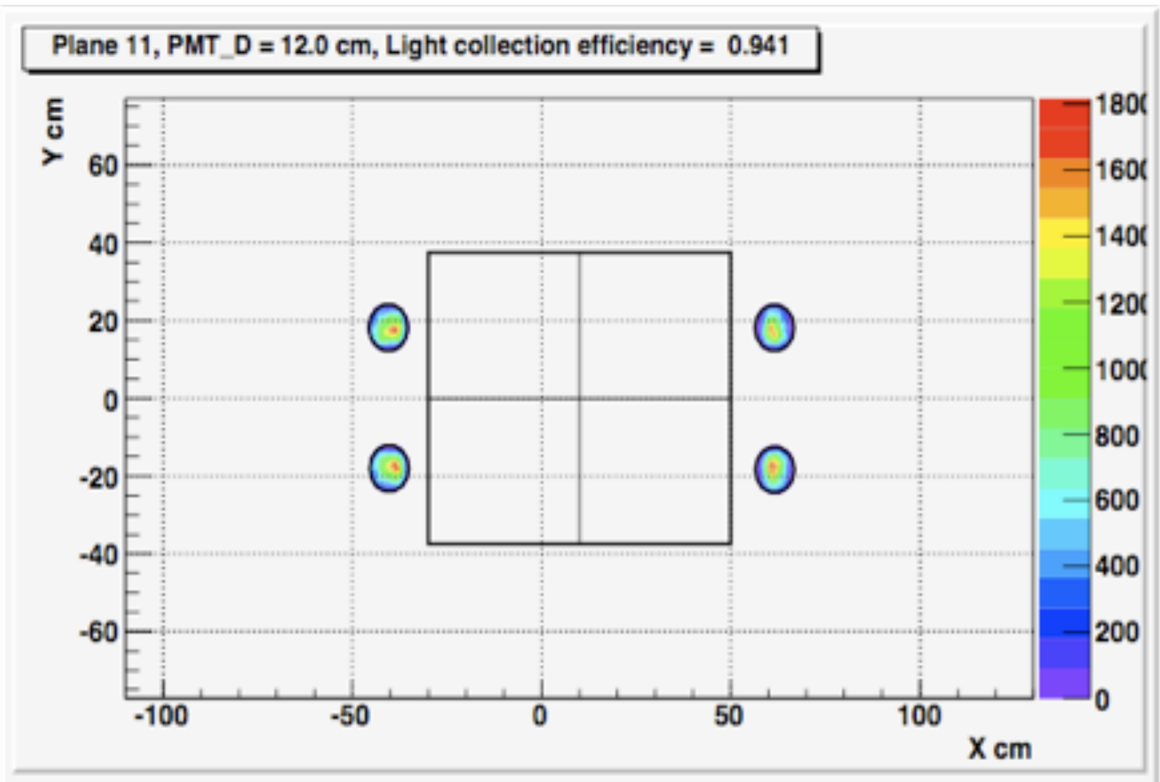
Choice of gases

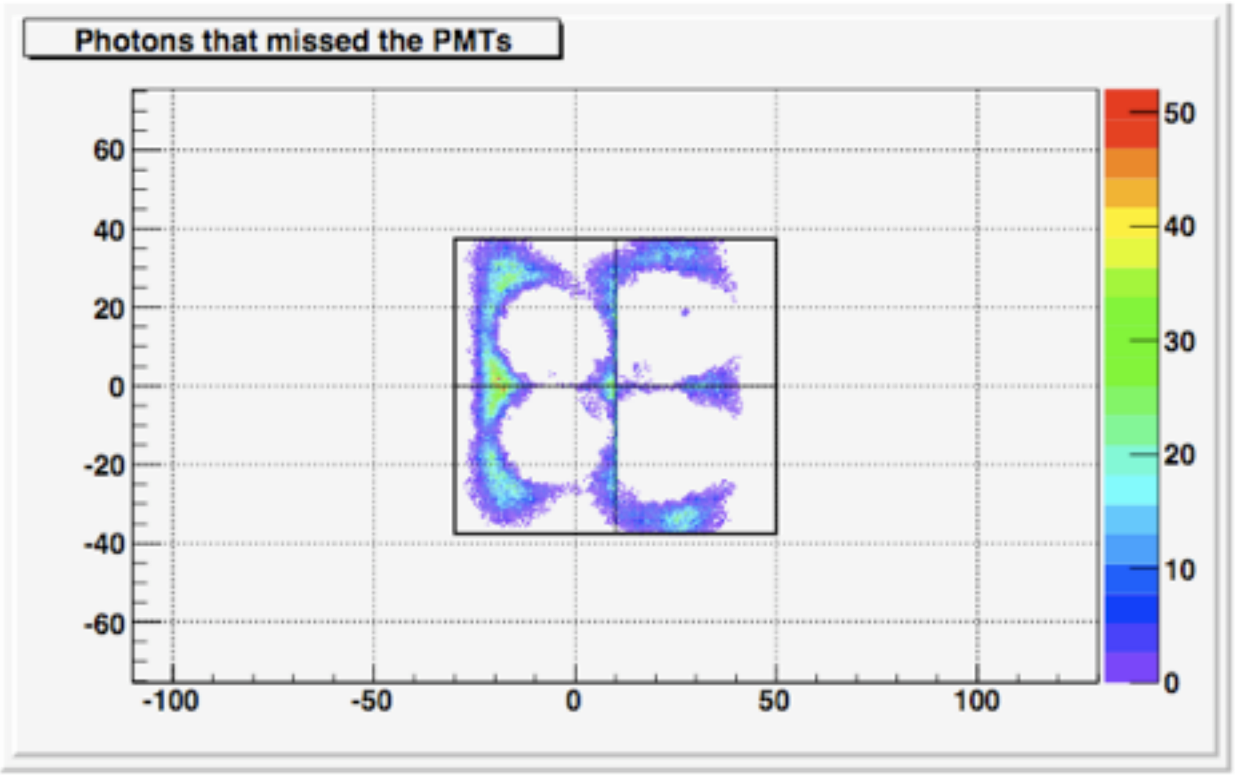
Argon up to 6 GeV and a mixture of Argon and Neon up to 11 GeV

Full Featured Geant 4 Simulation







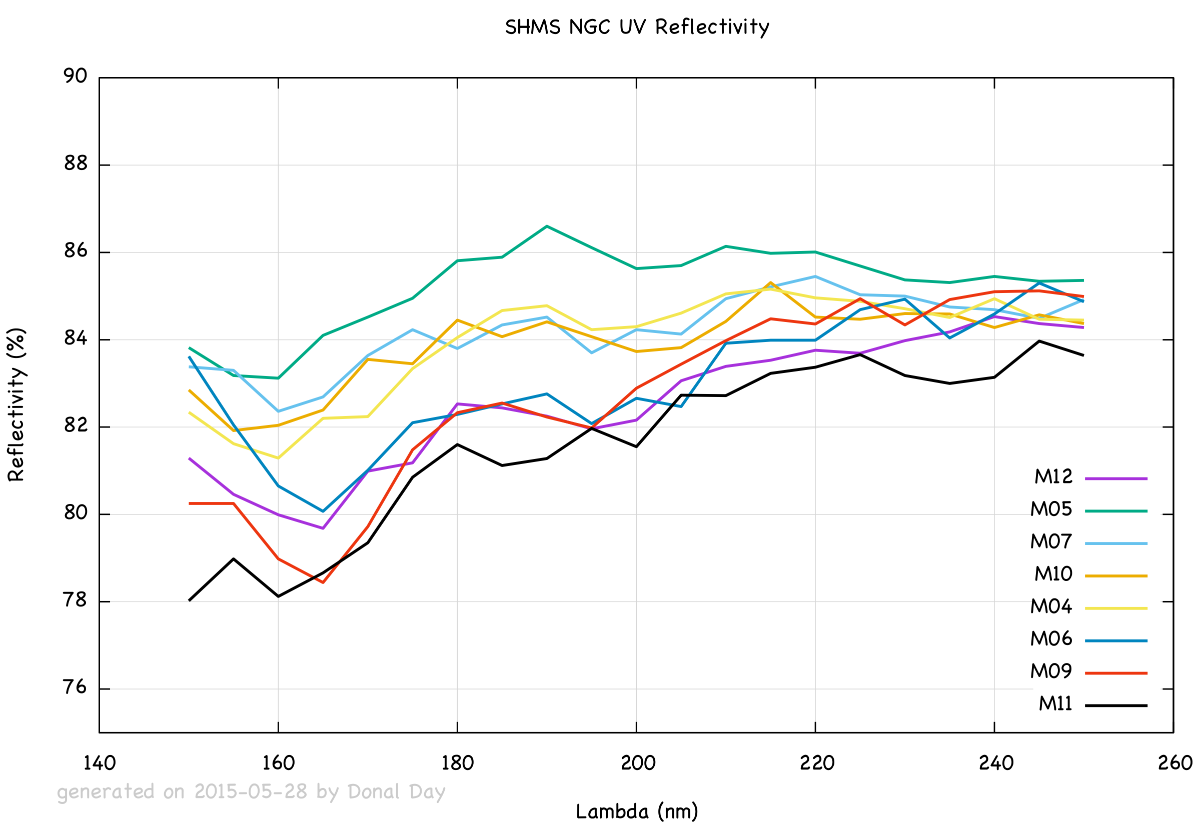


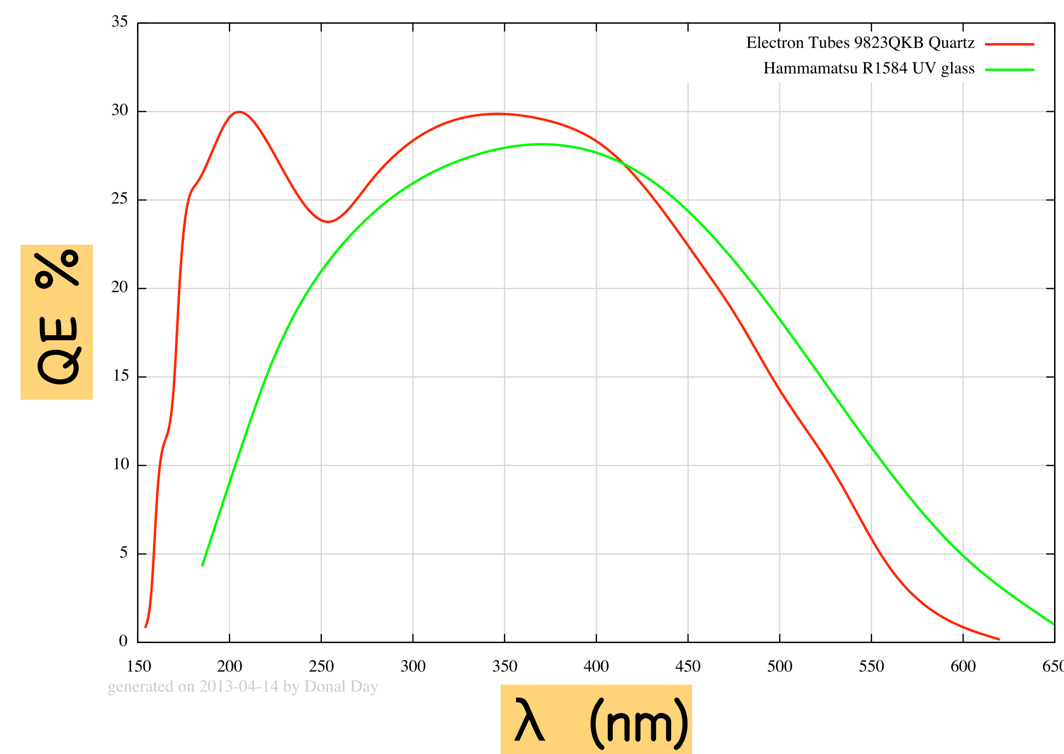
V Mamyan, M. Yurov

Photoelectron Yield

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

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





Tube (5)	A	N_e	λ_1	λ_2	
R1584 UV glass:	219	5.9	185	650	Neon
ET 9823QKB Quartz:	349	9.4	154	620	Neon

Argon 4x

200 cm active length, 80% of vendor's QE

Photoelectron Yield

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

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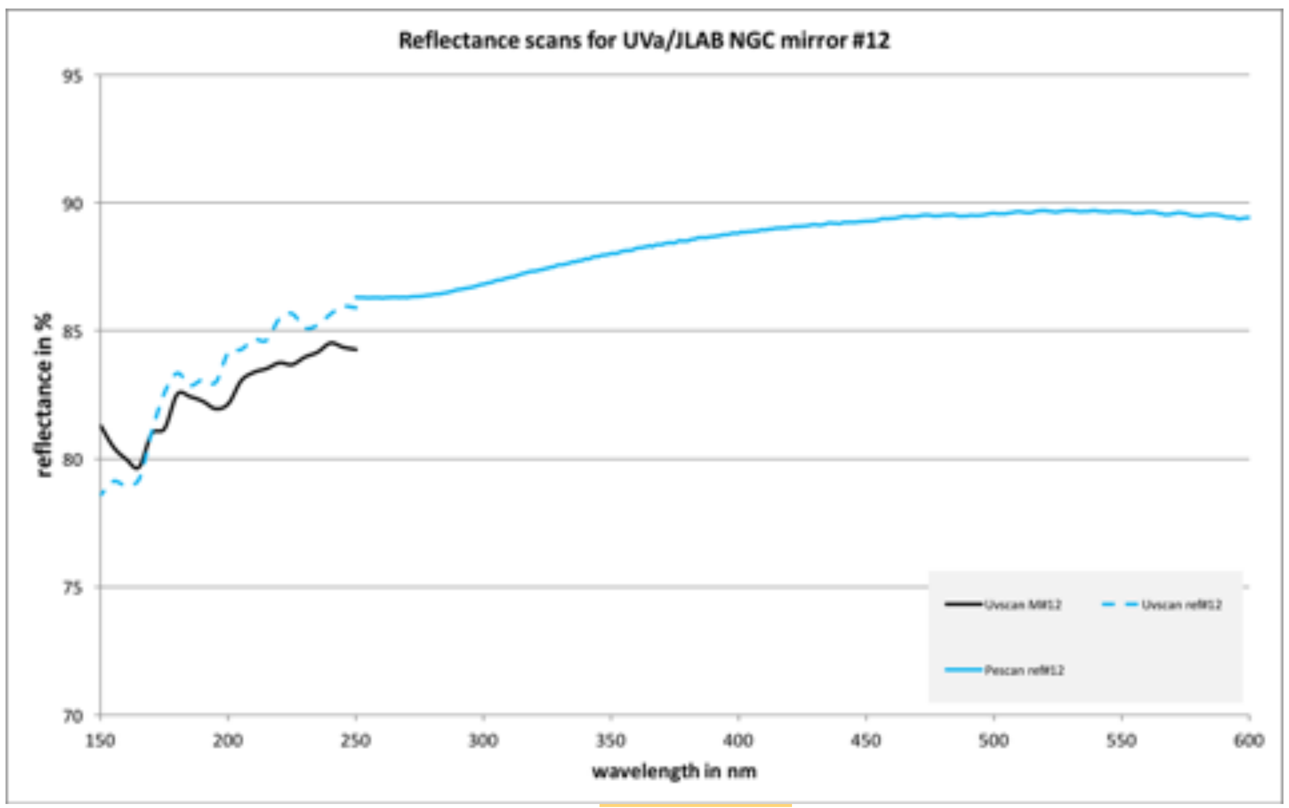

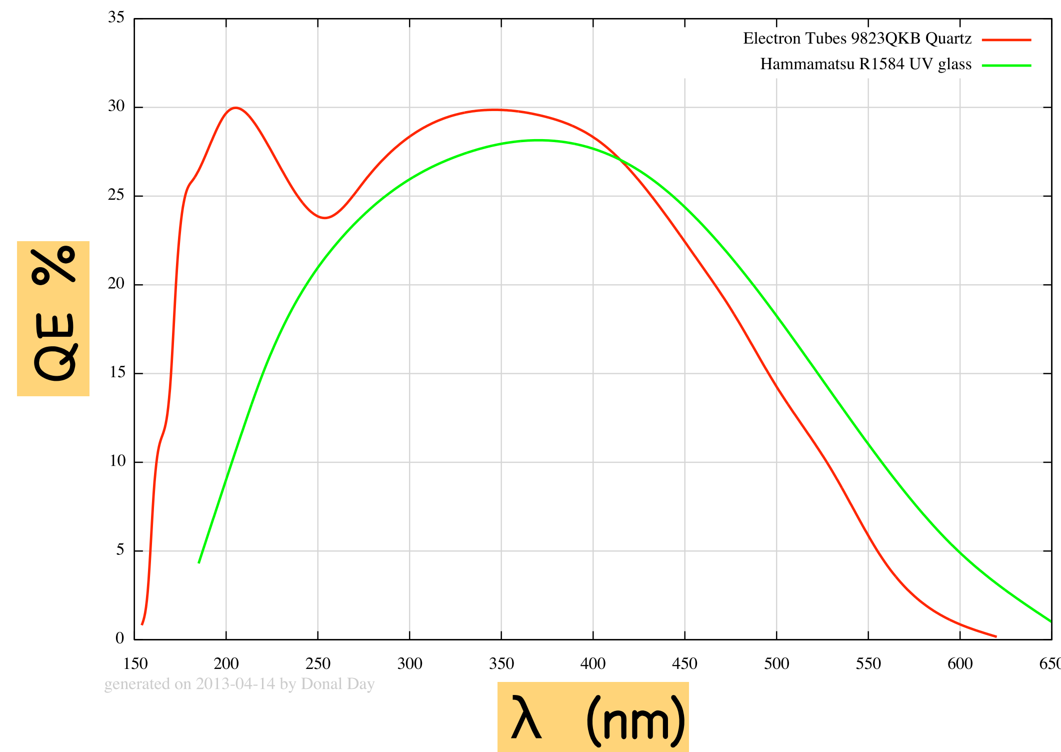

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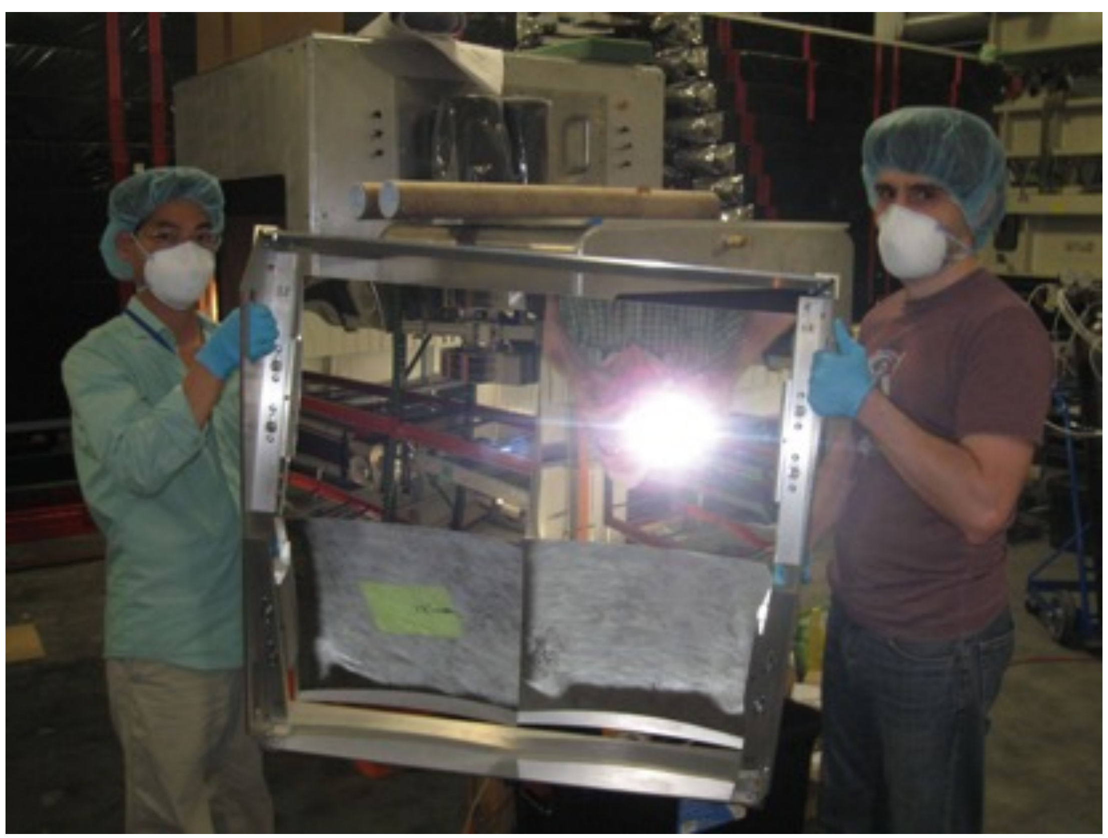
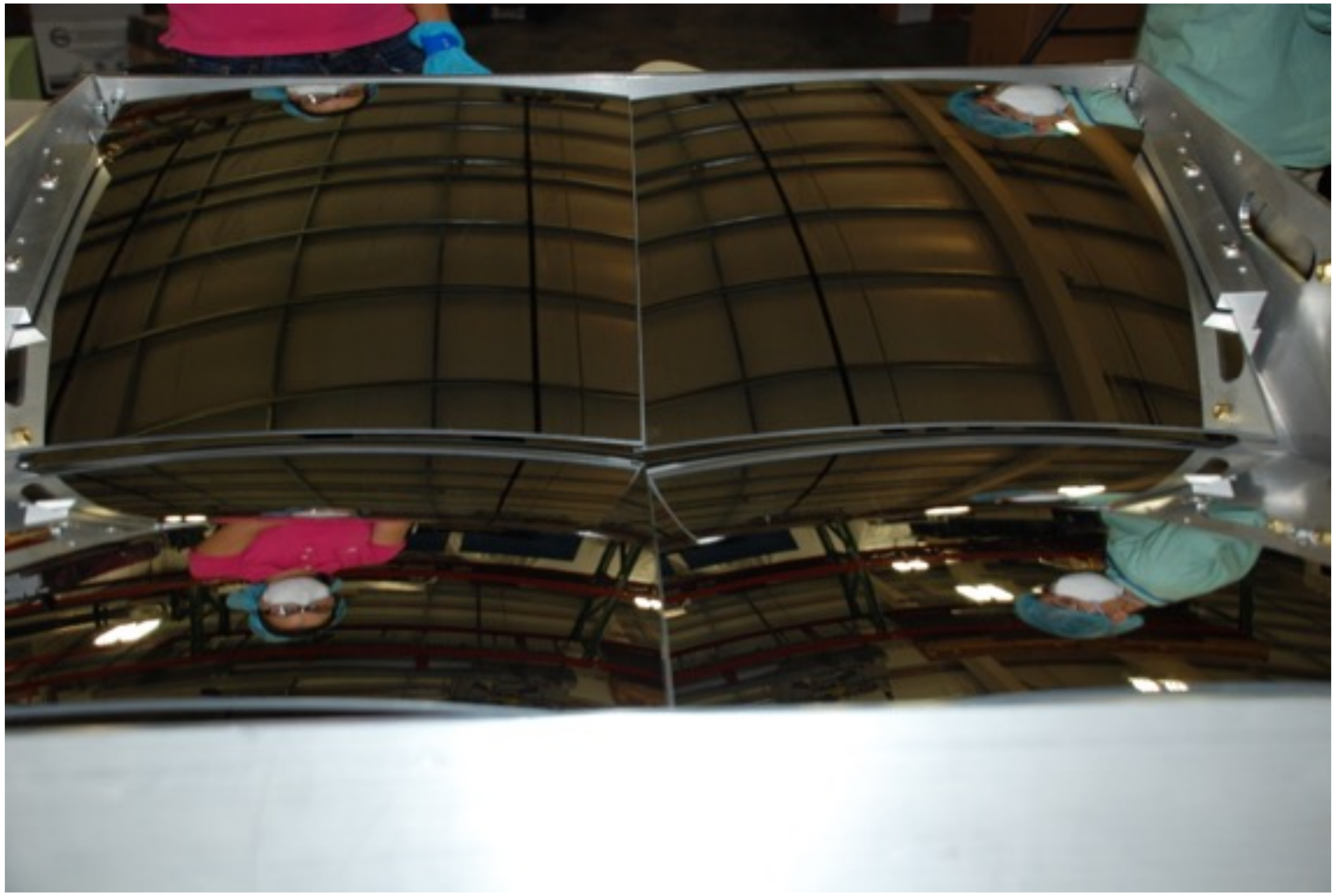
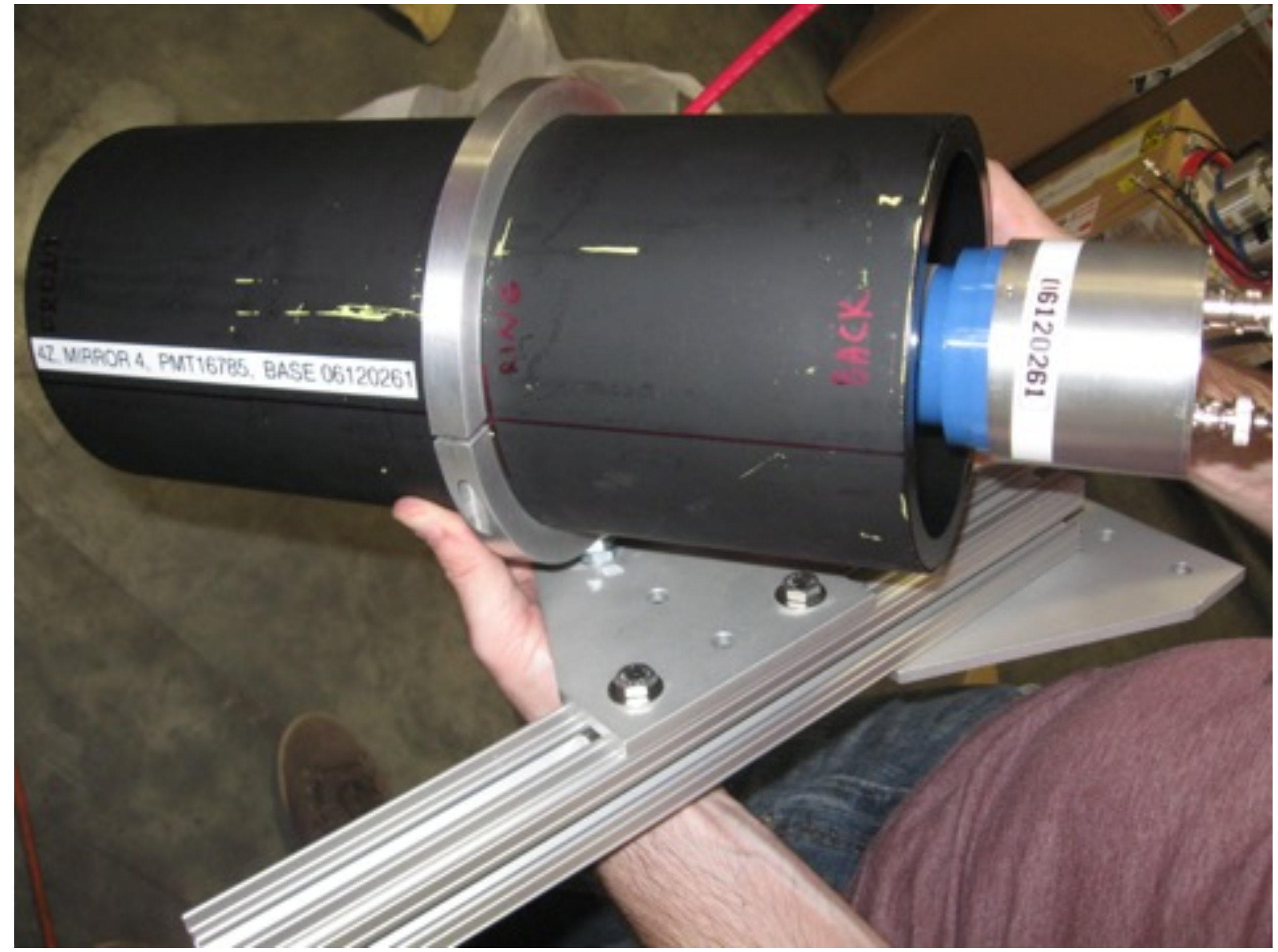
Mirror Installation

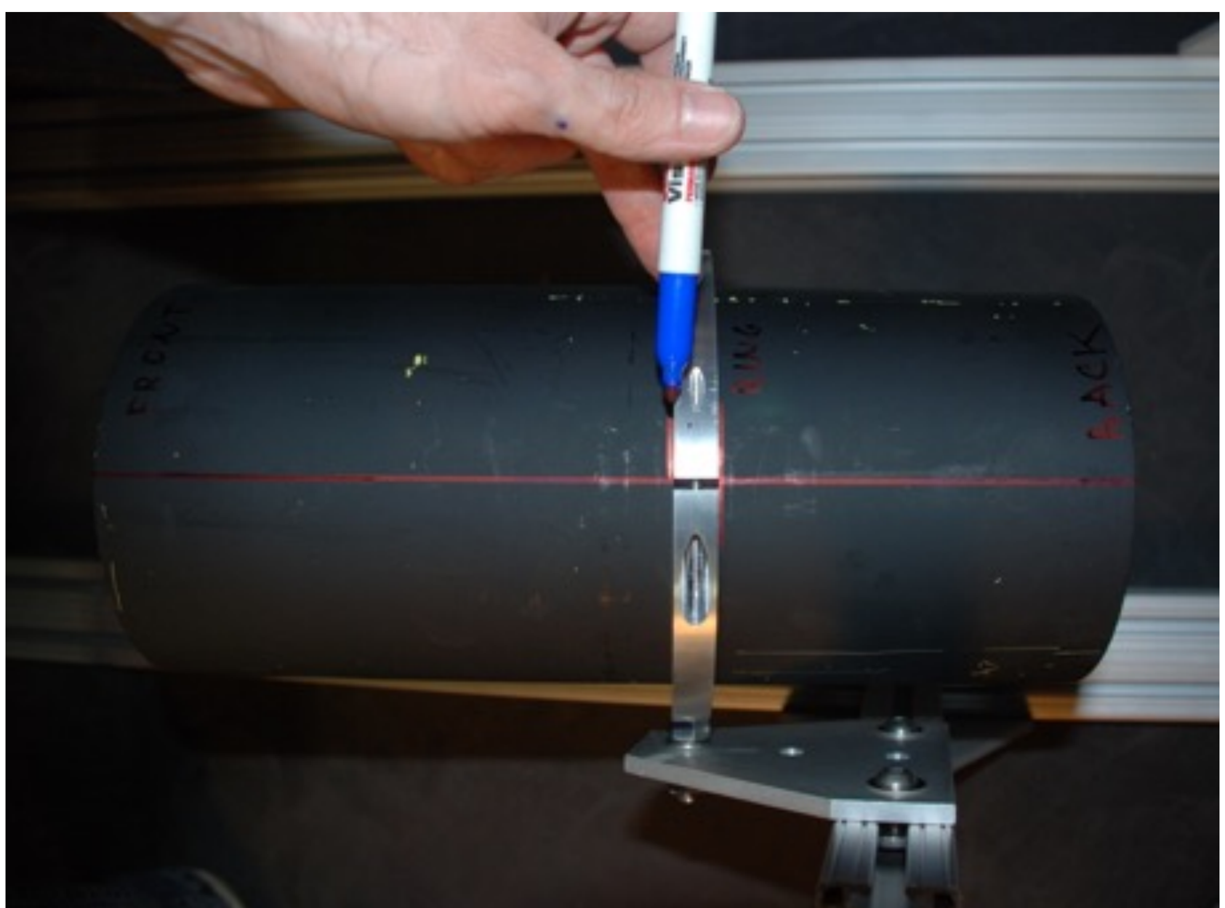


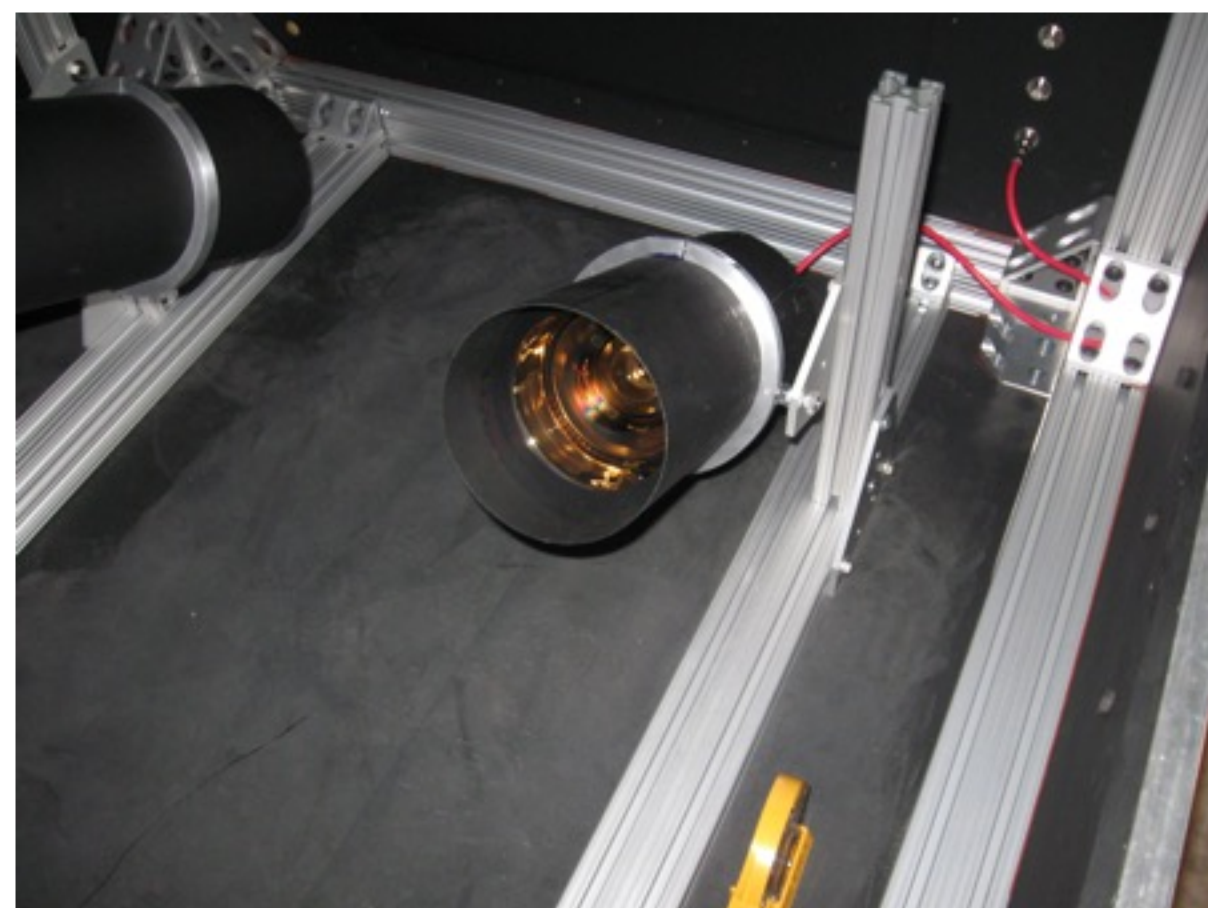
Overlap with beveled edges



PMTs

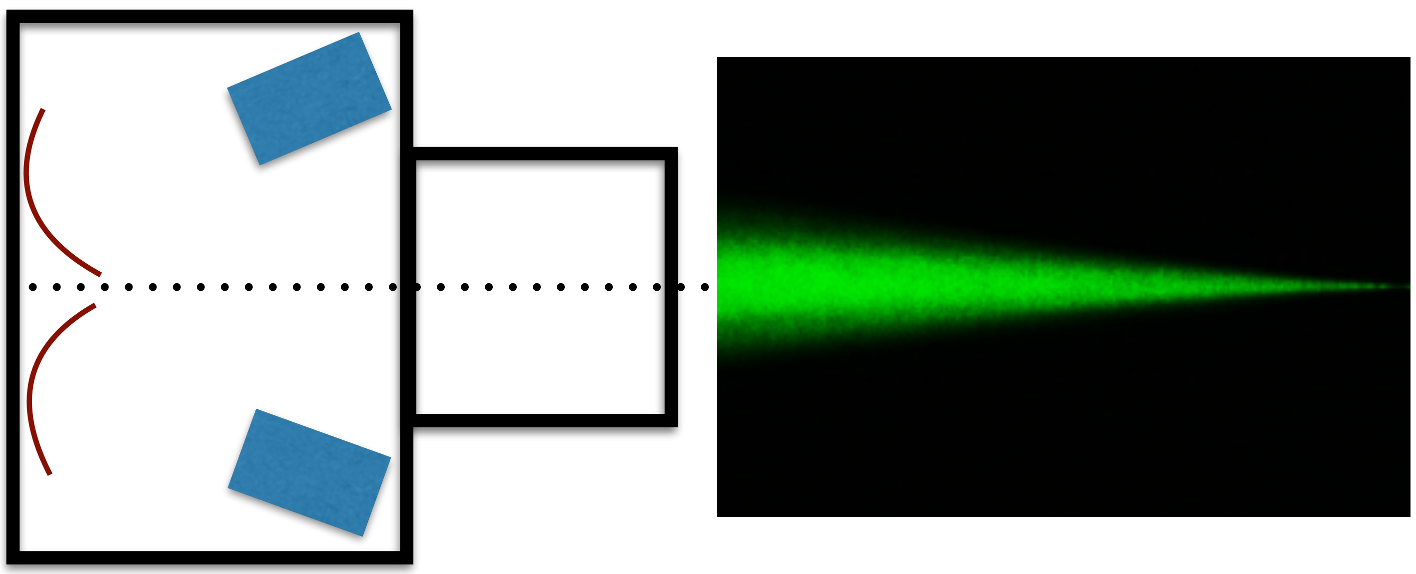


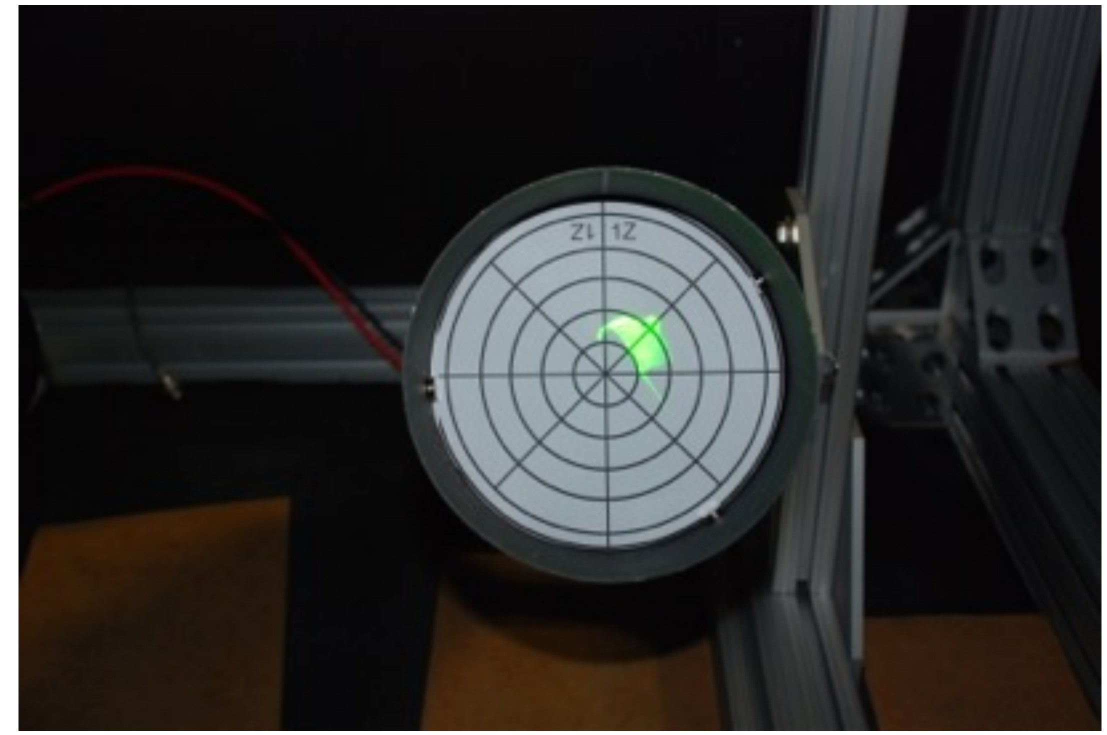




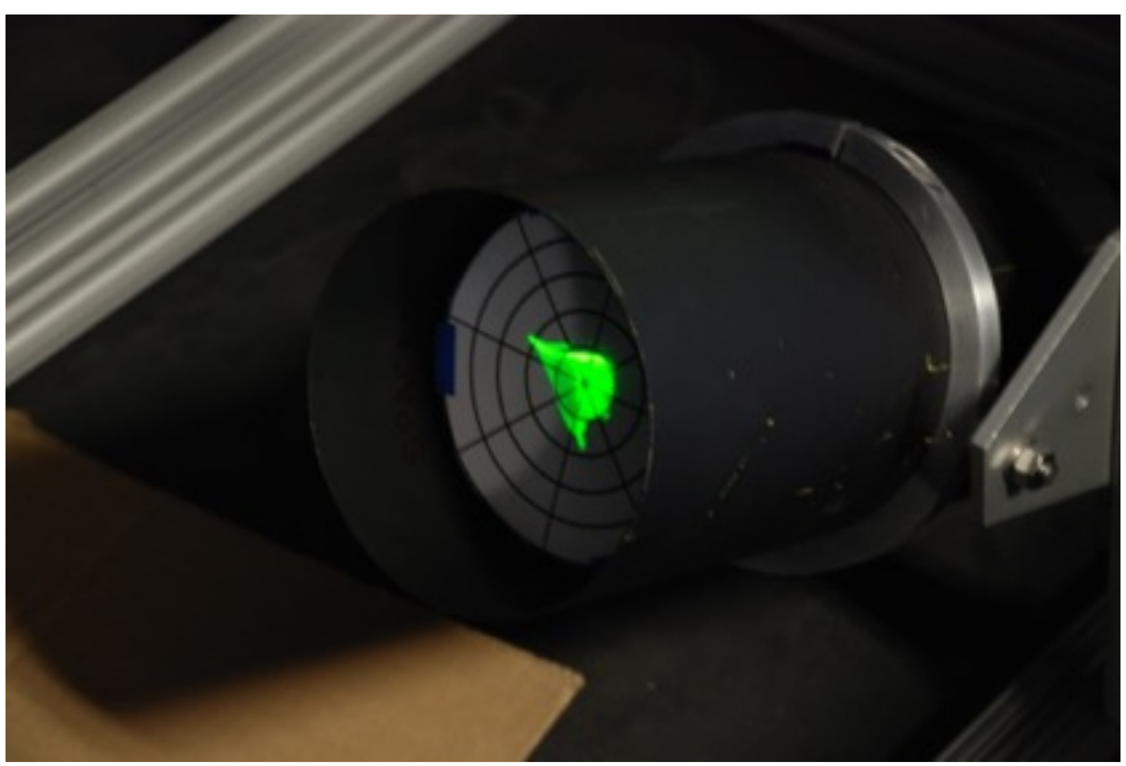
Tuning

Green laser illuminating whole of acceptance





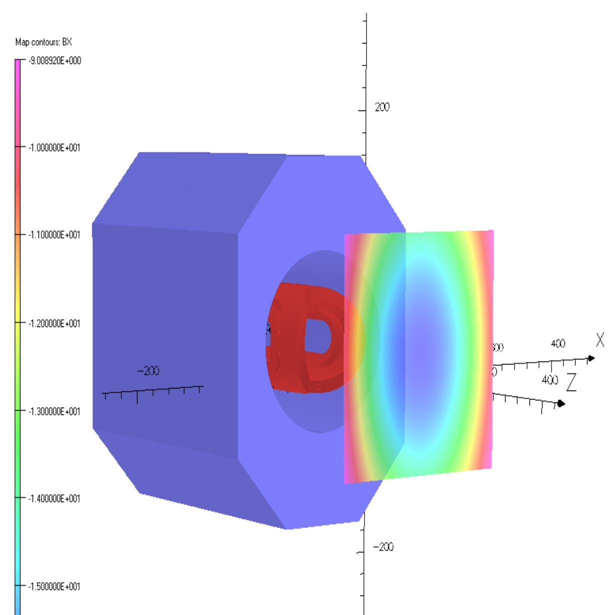
Red pencil laser probing range of angles



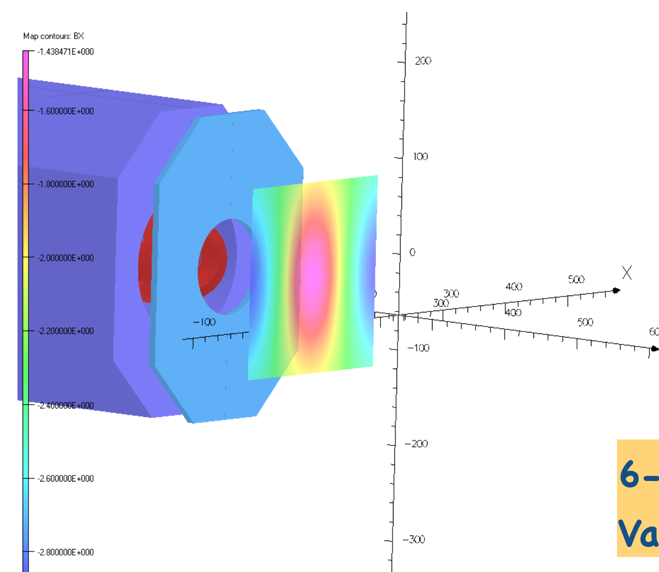
Materials in path of electron

Materials in path of electron in NGC Cerenkov										
Item	**Material**	**Z**	**Atomic mass**	**density (g/cm^3)**	**RL (g/cm^2)**	**RL (cm)**	**Thickness(in)**	**Thickness (cm)**	**# RL**	**Source**
Entrance Window^*	Tedlar ((CH2CHCl)n)	Z/A =	0.51201	1.3	25.51	19.63	0.002	0.00508	0.000259	PDG
Gas	Ar	18	39.948	1.66E-03	19.55	1.17E+04		200	0.017036	PDG
	Ne	10	20.18	8.39E-04	28.93	3.45E+04		200	0.005797	PDG
Glass	SiO2			2.2	27.05	12.29		0.3	0.024410	PDG
Exit Window	Tedlar ((CH2CHCl)n)	Z/A =	0.51201	1.3	25.51	19.63	0.002	0.00508	0.000259	PDG
							Total RL (with argon)		0.042	
*See http://pdg.lbl.gov/2014/AtomicNuclearProperties/HTML/polyvinylchloride_PVC.html							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 $W(N,\bar{N}) = \frac{\bar{N}^N e^{-\bar{N}}}{N!}$ for registering N photoelectrons when $\bar{N}$ 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 $\epsilon = \sum_{N=0}^{\infty} W(N,\bar{N})P(N)$. 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

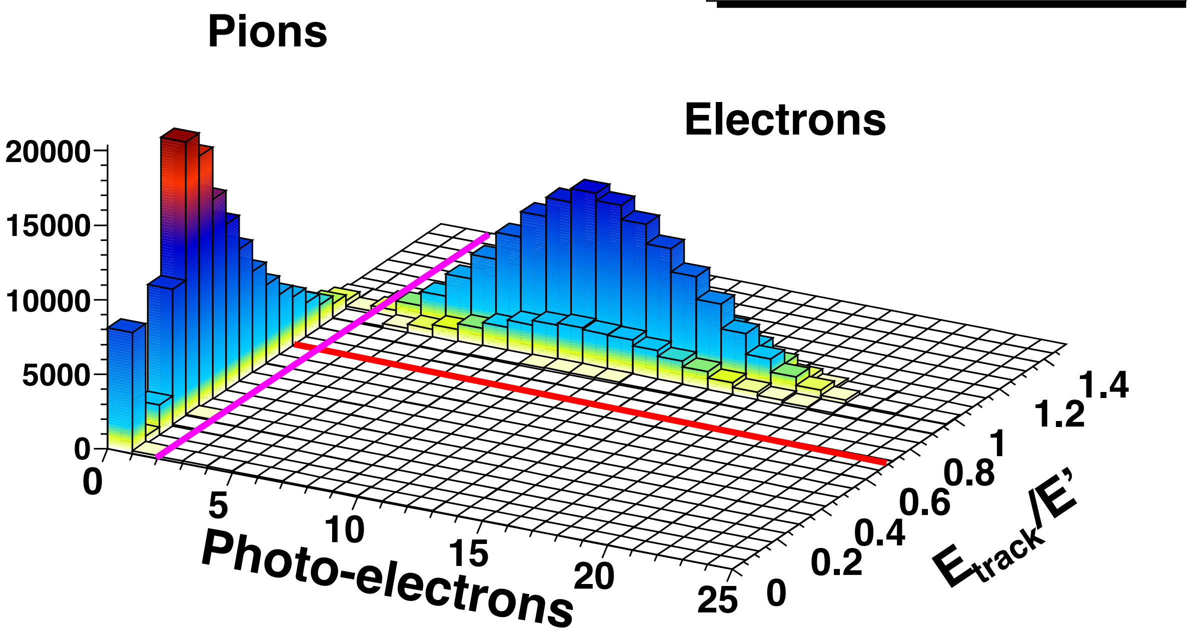
$$\epsilon = 1 - e^{-\bar{N}} \left(1 + \sum_{N'=1}^{N-1} \frac{\bar{N}^{N'}}{N'!} \right).$$

Hence, we have the efficiency functions

$$\begin{aligned} \epsilon_1 &= 1 - e^{-\bar{N}}, && 26\% \\ \epsilon_2 &= 1 - e^{-\bar{N}}(1+\bar{N}), && 32\% \\ \epsilon_3 &= 1 - e^{-\bar{N}}(1+\bar{N}+\bar{N}^2/2), && 92\% \\ \epsilon_4 &= 1 - e^{-\bar{N}}(1+\bar{N}+\bar{N}^2/2+\bar{N}^3/6), && 100\% \\ &\text{etc.} \end{aligned}$$

π Rejection

Rosen07 R_N π/e from .1 to 30



Electrons N_{pe} > 2, ShrTrk > 0.7

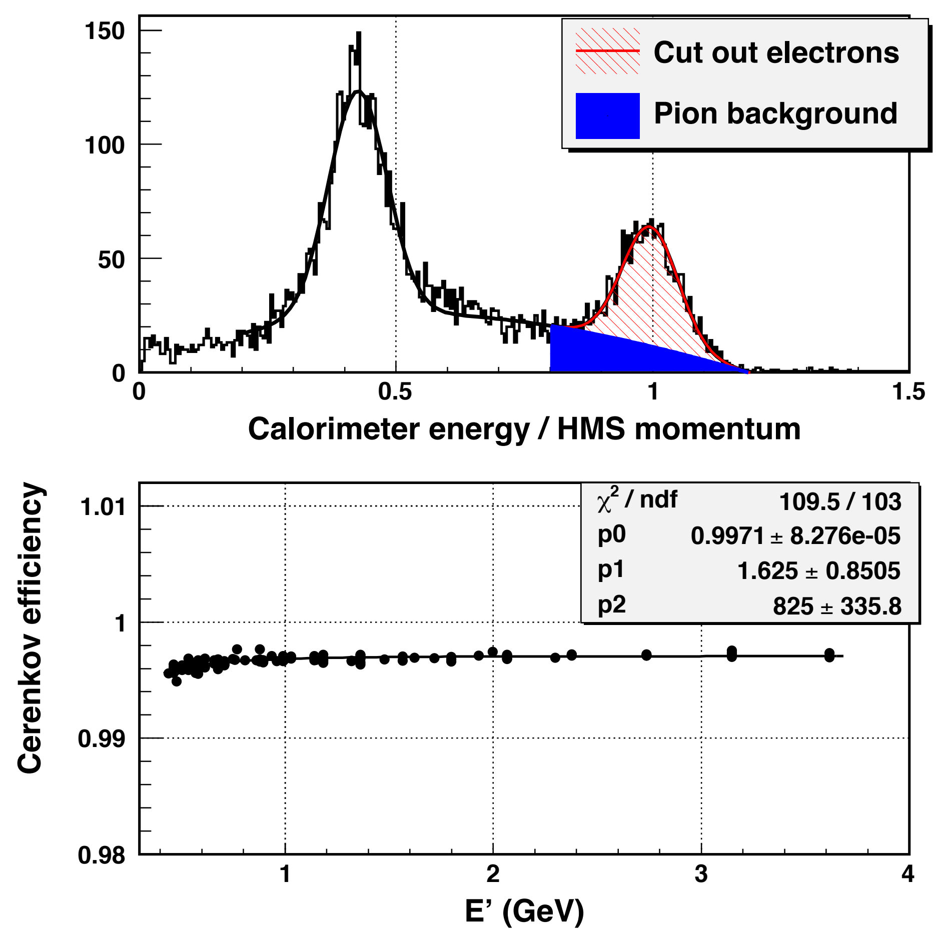


Figure 31: First plot: HMS calorimeter total energy hcal_et/E′ distribution when number of photoelectrons are higher than 0 but less than 2. Second plot: The Čerenkov cut efficiency as a function of scattered energy.

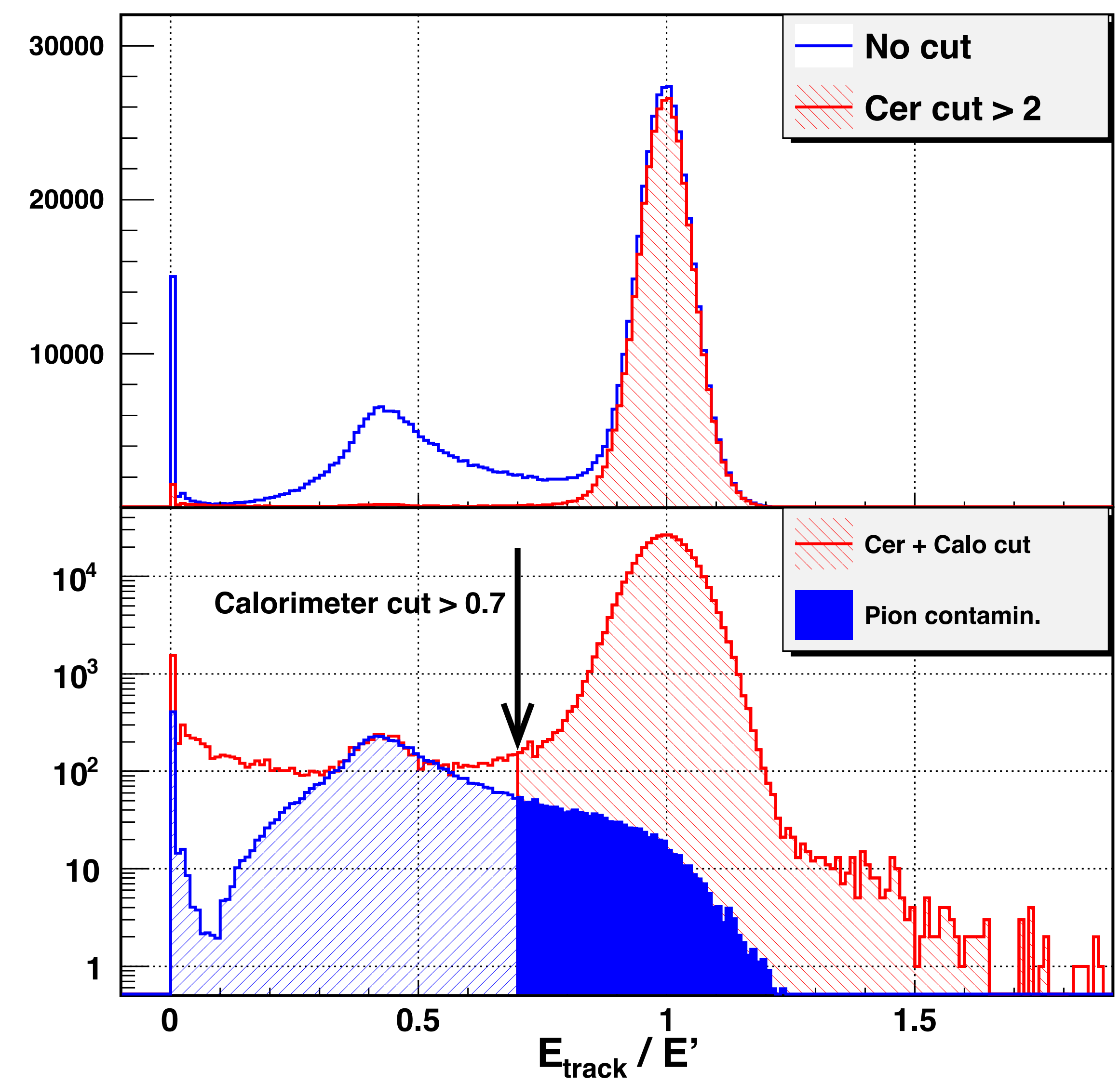
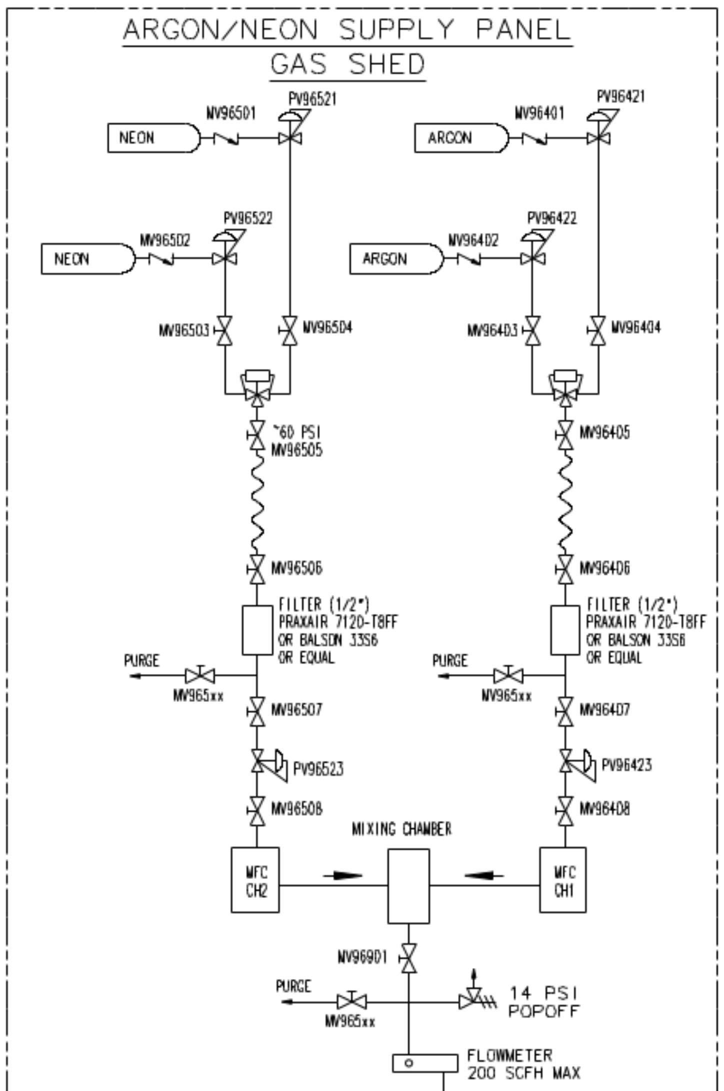
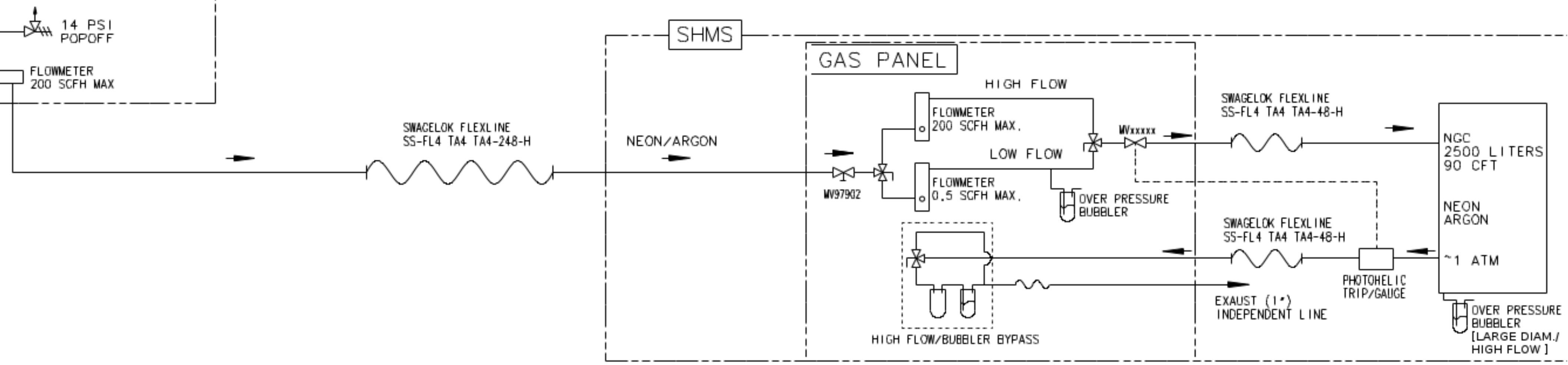


Figure 32: HMS central momentum is 0.71 GeV. Top plot: HMS calorimeter track energy E_{track}/E' (hsshtrk/hse) distribution without Čerenkov cut (the blue line) and with Čerenkov cut > 2 (the red line). Bottom plot: The E_{track}/E' distribution after Čerenkov cut > 2 and E_{track}/E' > 0.7 cut (the red hatched area). The solid blue area is the pion contamination.

NGC Gas System





- 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

Brad Sawatsky, Responsible

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 Mamyan
- Nicholas Philips
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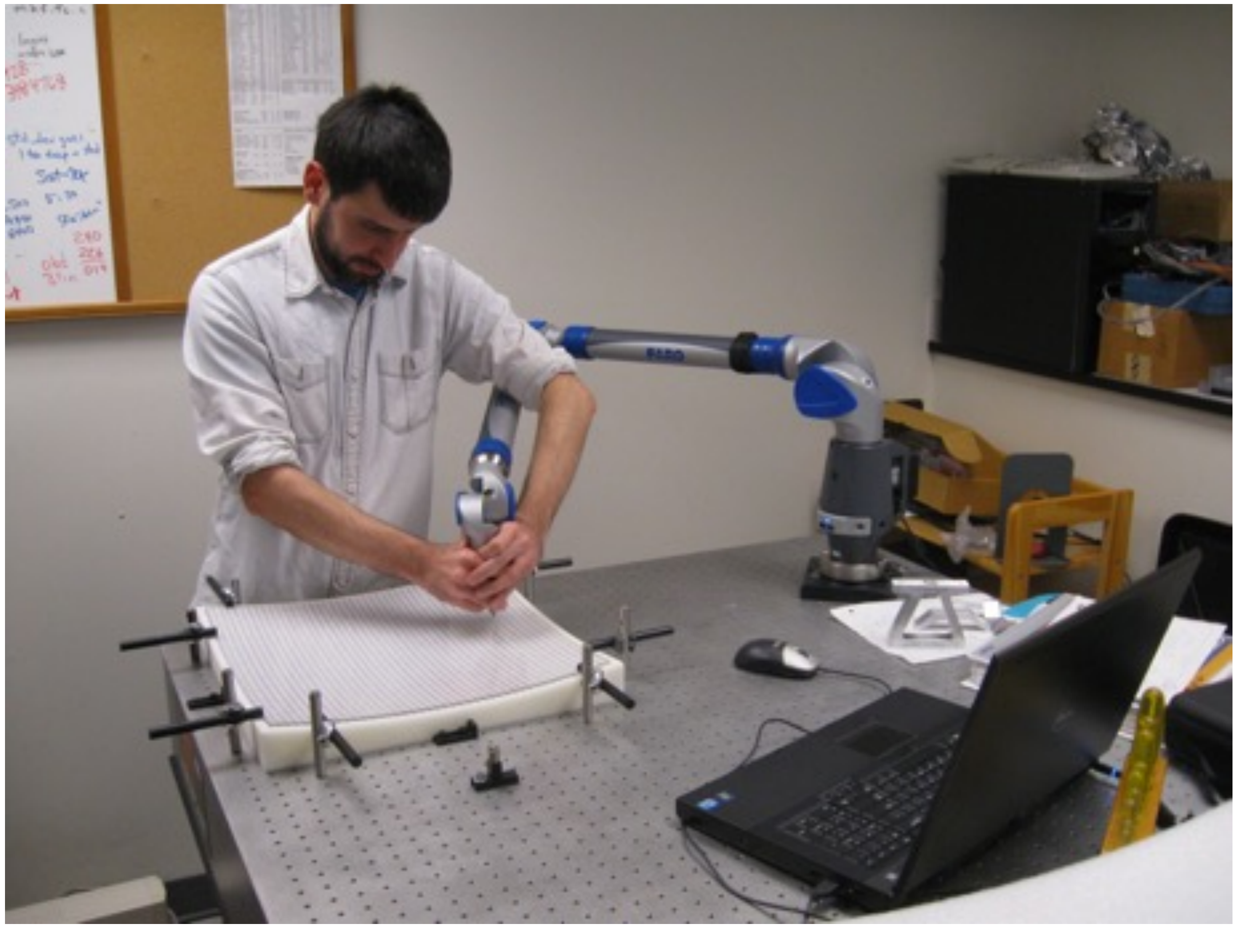
- Garth Huber
- Dan Abrams
- Jixie Zhang
- Dien Nguyen
- Matt Caplan
- Tyler Cody
- Matt Biondi
- Thomas Schneider
- Tosh Rijal
- Thanakorn Iamsasri
- Cole Smith
- Matthew Nelson
- Melissa Goldman
- Stephen Washington

https://hallcweb.jlab.org/doc-private/ShowDocument?docid=794

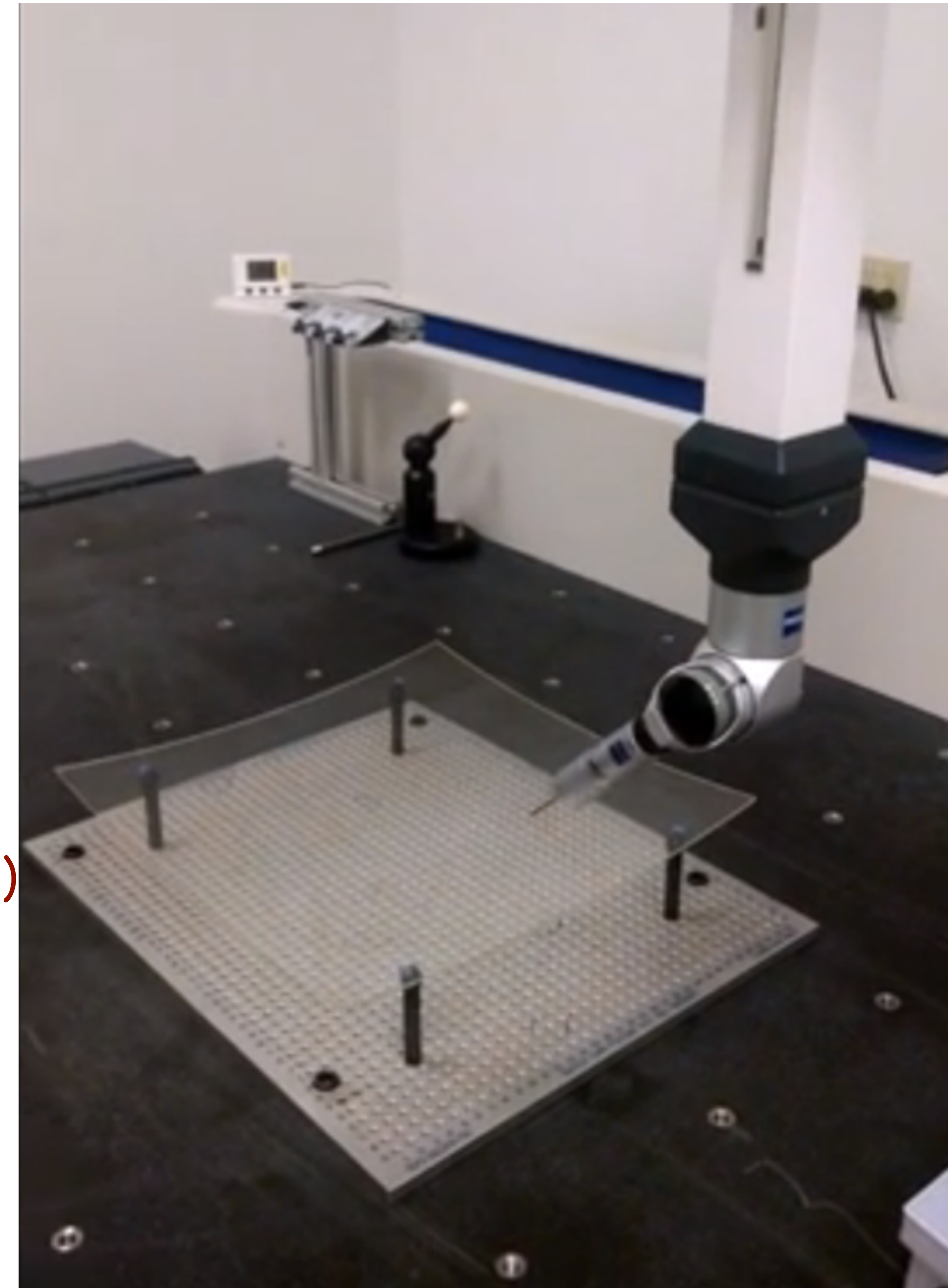
Extra Slides



Faro Arm in Astronomy at UVa

Coordinate measuring machines (CMM)

APEX Metrology, Zeiss G2 Calypso



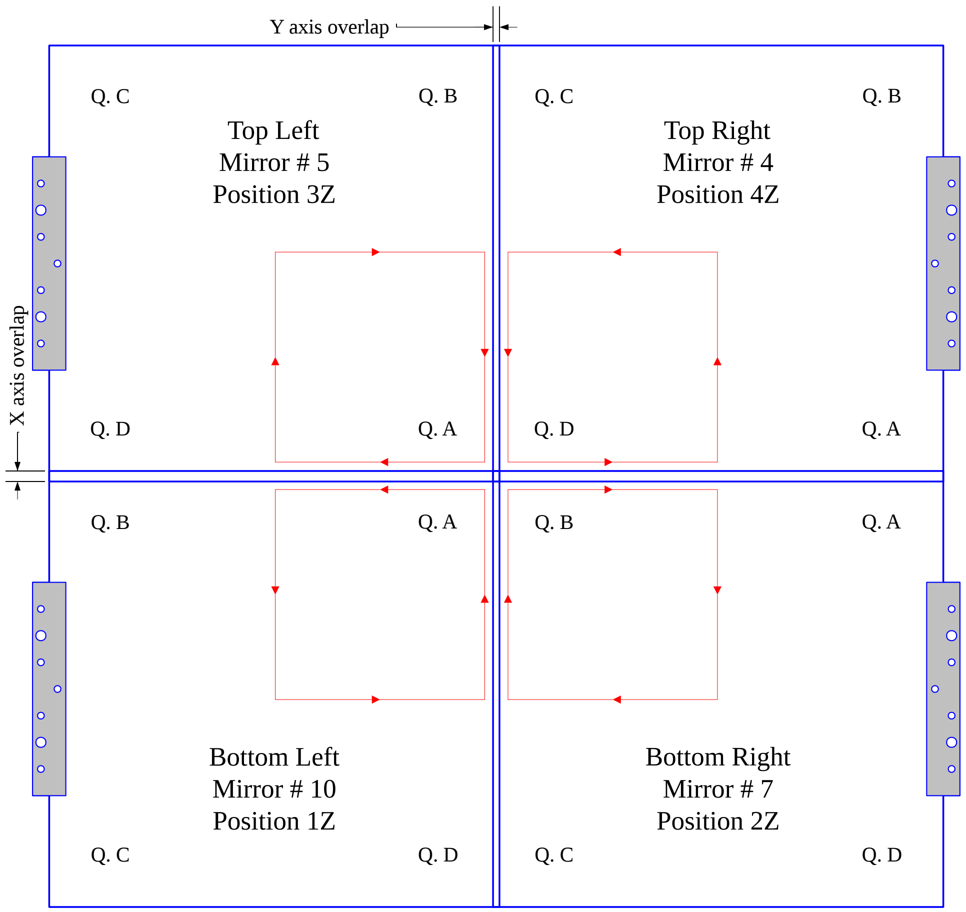
Mirrors - the glass

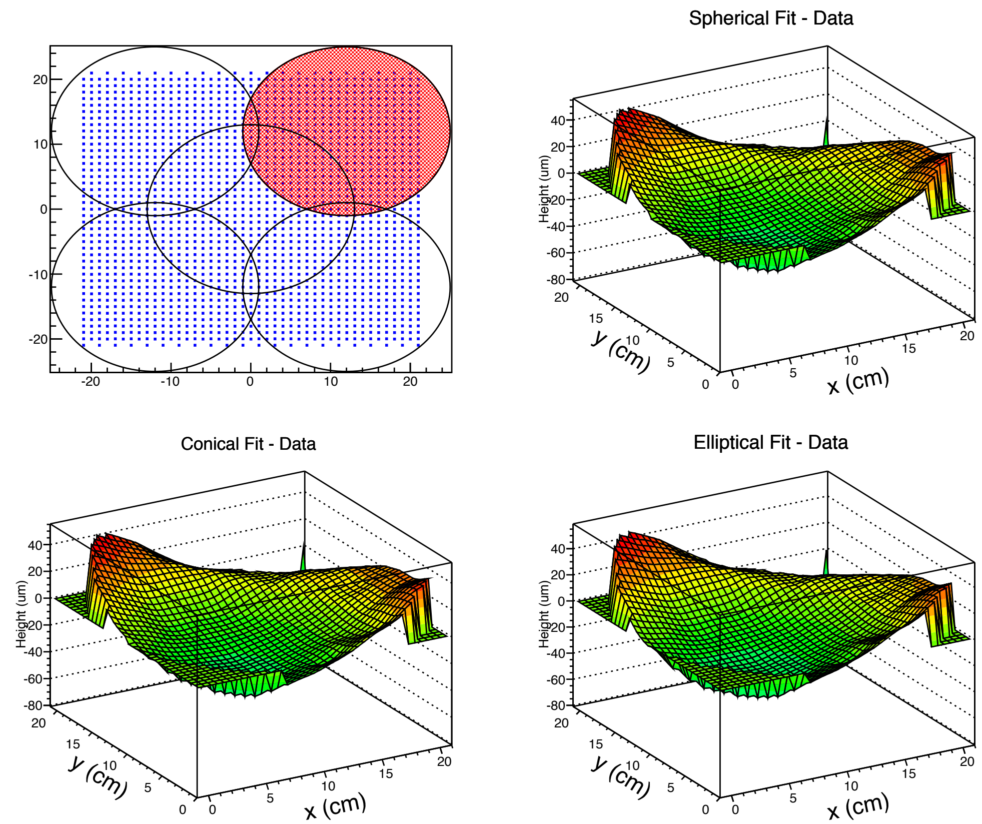
We worked with Rayotek of San Diego which claimed great experience in slumping glass.

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

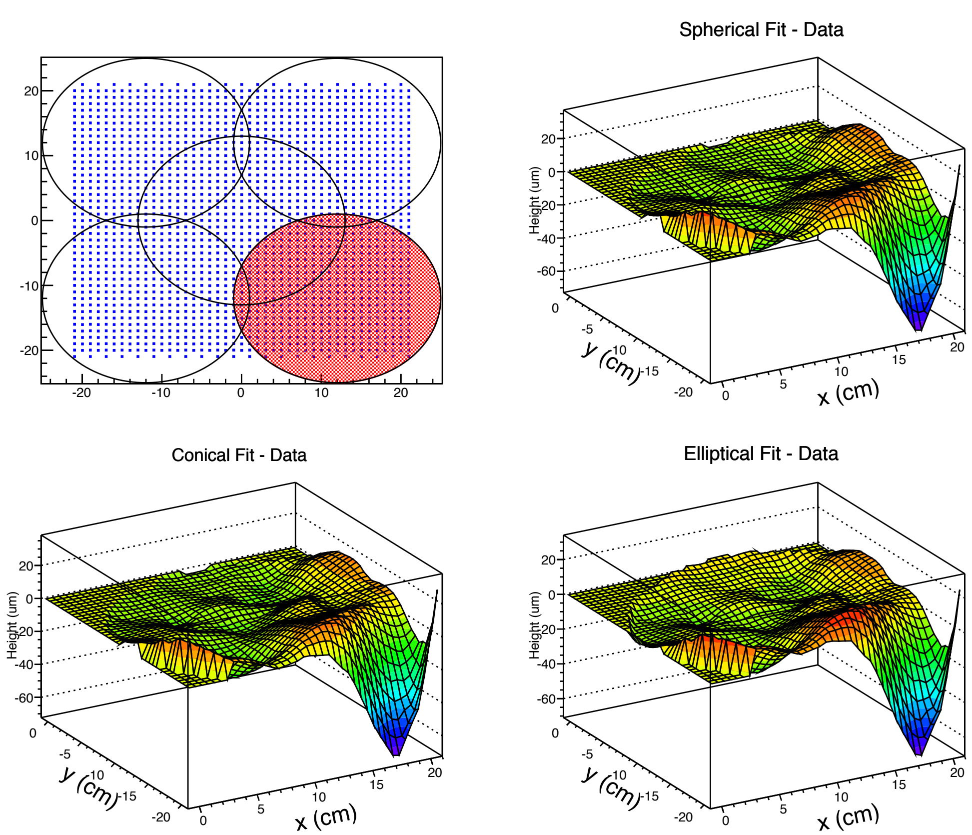
We specified R = 135cm

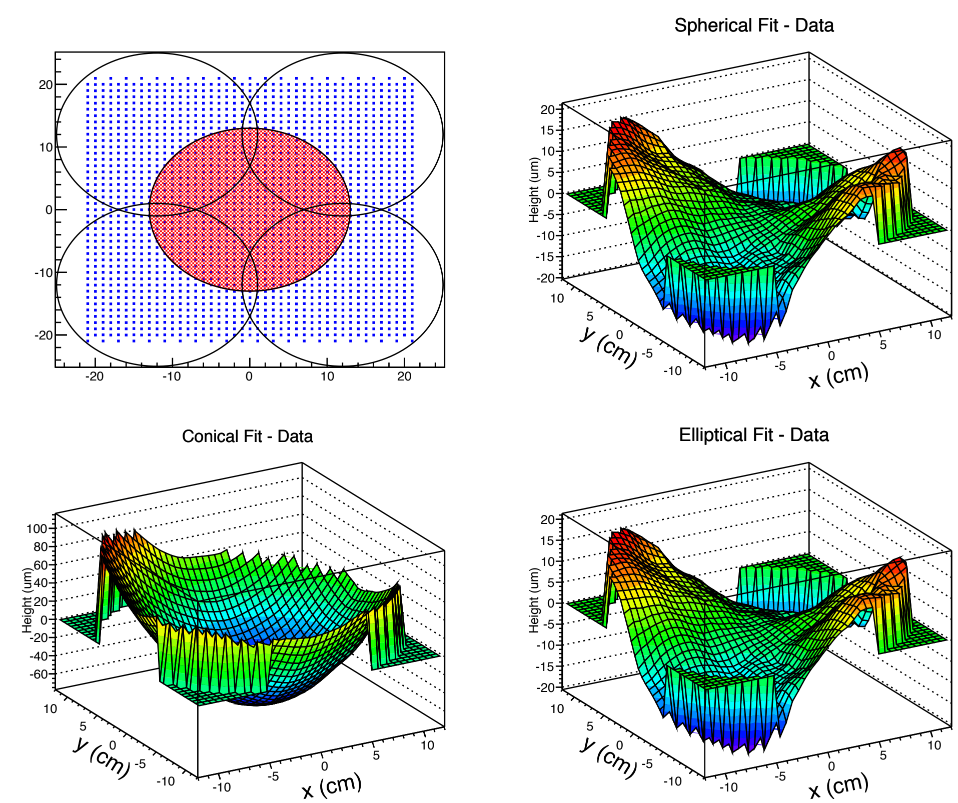
Rating		1	2	3	4	5	6	7	8	9	10
Mirror #		12	0	8	10	5	7	4	6	9	11
radius, cm	Z	132.9	133.2	133.2	133.4	133.3	134.1	133.2	133.3	133.0	135.7
	O	132.6	132.6	132.6	132.6	132.6	133.5	132.6	132.6	132.0	134.9
	A	133.1	133.9	133.4	133.5	133.4	134.5	135.9	133.3	134.1	137.5
	B	133.3	133.1	133.1	135.3	132.7	134.4	133.7	135.0	133.7	136.3
	C	133.0	133.1	135.3	135.0	137.1	133.9	133.5	133.2	133.3	135.5
	D	134.0	135.6	133.1	133.3	134.3	136.1	133.9	134.6	134.8	134.6
dev_min, um	Z	-198.5	-295	-309	-348	-516	-225.2	-450.3	-244.0	-674	-738
	O	-17.8	-13	-15	-19	-12	-32.1	-14.6	-23.5	-32	-58
	A	-85.8	-91	-60	-78	-66	-128.5	-297.7	-170.5	-106	-501
	B	-34.4	-17	-69	-197	-9	-38.0	-182.7	-190.1	-180	-325
	C	-19.8	-92	-174	-211	-326	-105.7	-69.1	-75.5	-37	-100
	D	-184.8	-207	-90	-75	-97	-120.7	-96.0	-224.2	-663	-96
dev_max, um	Z	78.8	70	179	132	129	114.5	100.4	119.1	91	550
	O	17.1	15	12	18	10	18.2	10.6	15.7	26	20
	A	28.6	47	42	45	37	99.6	126.7	88.0	67	329
	B	23.2	8	100	86	10	78.5	39.4	72.9	37	438
	C	22.7	37	135	112	183	61.0	34.5	30.5	46	103
	D	60.8	125	39	47	68	40.3	40.0	163.6	64	182
dev_sig, um	Z	23.5	40	50	48	64	32.8	49.4	38.1	47	103
	O	7.3	6	4	8	4	9.8	4.1	6.5	11	13
	A	14.5	25	20	20	17	29.8	67.5	35.2	27	113
	B	7.3	4	18	43	3	12.3	19.2	39.9	14	76
	C	6.6	18	58	55	90	15.1	16.2	16.7	17	30
	D	23.0	56	10	11	29	16.8	22.4	38.6	51	27





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.