SHMS Heavy Gas Čerenkov
June 2012 Update

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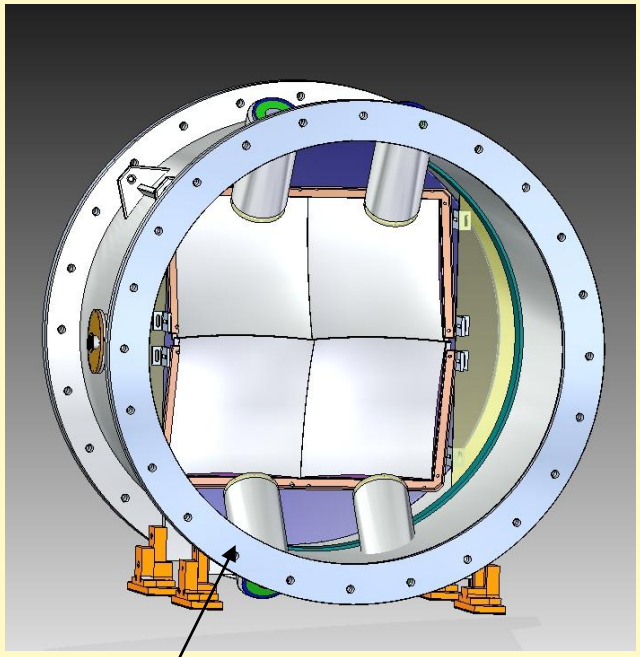
UNIVERSITY OF REGINA

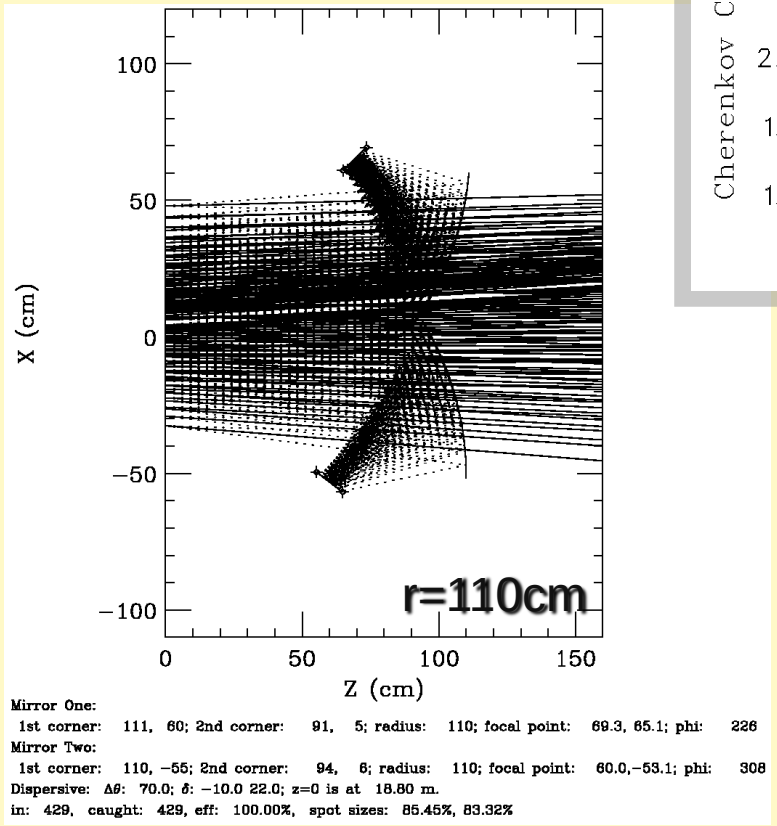
Hall C User's Summer Workshop. June 23, 2012.

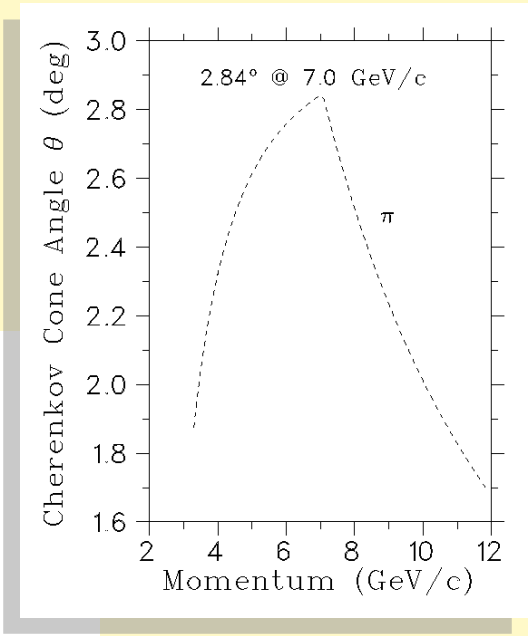
SHMS Heavy Gas Čerenkov Overview

Cylindrical aluminum vessel filled with C_4F_8O @ 0.3<P<1.0 atm.



Inner Diameter now reduced from 74” to 72”.





Hardest to collect all light at 7 GeV/c.

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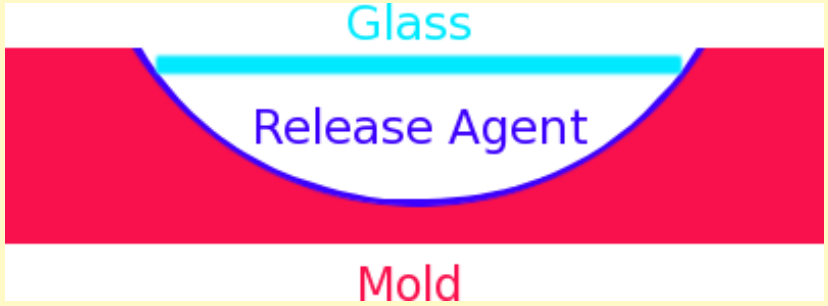
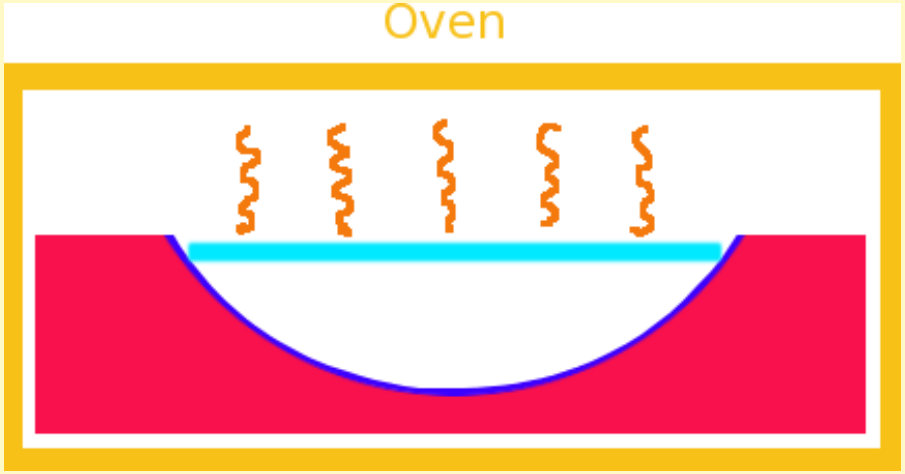
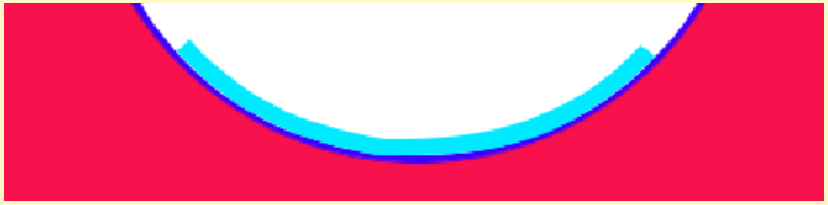
How Slumped Mirror Blanks are Made







Stage 1:

- Spread release agent onto the spherical mold.
- Place flat glass onto the mold.

Stage 2:

- Place mold into the oven.
- Glass slumps toward the mold.

Important:

- **The glass is not slumped all the way to the mold.**
- **Front surface should have fewer imperfections than back surface.**
- **The mirror will be slightly non-spherical. If we are lucky, it will be closer to parabolic shape.**

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Mirror Curvature Data via Computerized sensor

- **Dumur Industries (Regina) acquired mirror surface data with a computerized sensor.**
  → 3x3cm grid, <0.01mm accuracy.

DATA FIT WITH CONIC FORMULA :

$$(1+\kappa)r^2 - 2Rr + (z - z_0)^2 = 0$$

where:

r = distance in (x, y) plane from (x_0, y_0)

R = radius of curvature at (x_0, y_0)

κ = CONIC CONSTANT

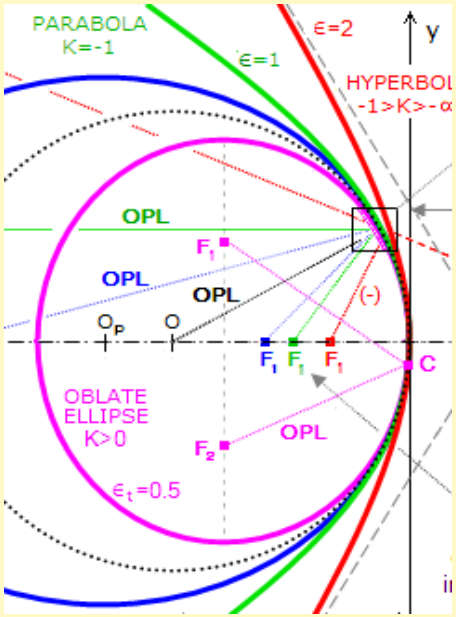
= 0 sphere

= -1 parabola

$0 < \kappa$ oblate elipsoid

$-1 < \kappa < 0$ prolate elipsoid

$\kappa < -1$ hyperboloid



- **Nearly all mirrors displayed some degree of oblateness.**
  - Possibly due to contraction of glass during cooling after slumping.
- **The worst mirrors had varying curvature across their surface, due to various deformations.**

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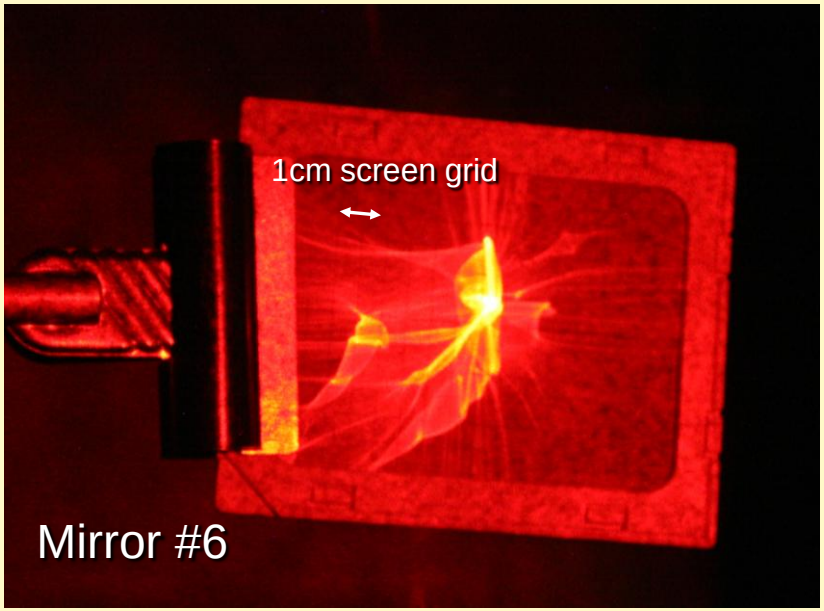
Laser Reflection Test and Overall Results

- **Cross-check digital position measurements against an optical test.**
- We diffused a laser beam using a concave lens so that full mirror was illuminated, and looked at light reflected from the **uncoated** mirror blank.
- Tests the global mirror performance, as opposed to the local distortions.



Mirror	#6	#10	#11	#12
R(cm)	112.9	112	111.7	112.1
K	0.94	0.42	0.75	0.84

Conclusions:

- Mirrors with better fitted *K* and *R* values had better reflected spot in the optical test.
- All mirrors have fitted ***K > 0*** (Oblate) and ***R > 110cm.***
- **Mirror #6, #10, #11, #12 selected for use in the detector.**
- **Mirror #7, #9 as reserve mirrors.**
- **Mirror #2, #8 were sent for aluminization test.**
- **Mirror #6 fitted parameter is used for the Geant 4 simulation study.**

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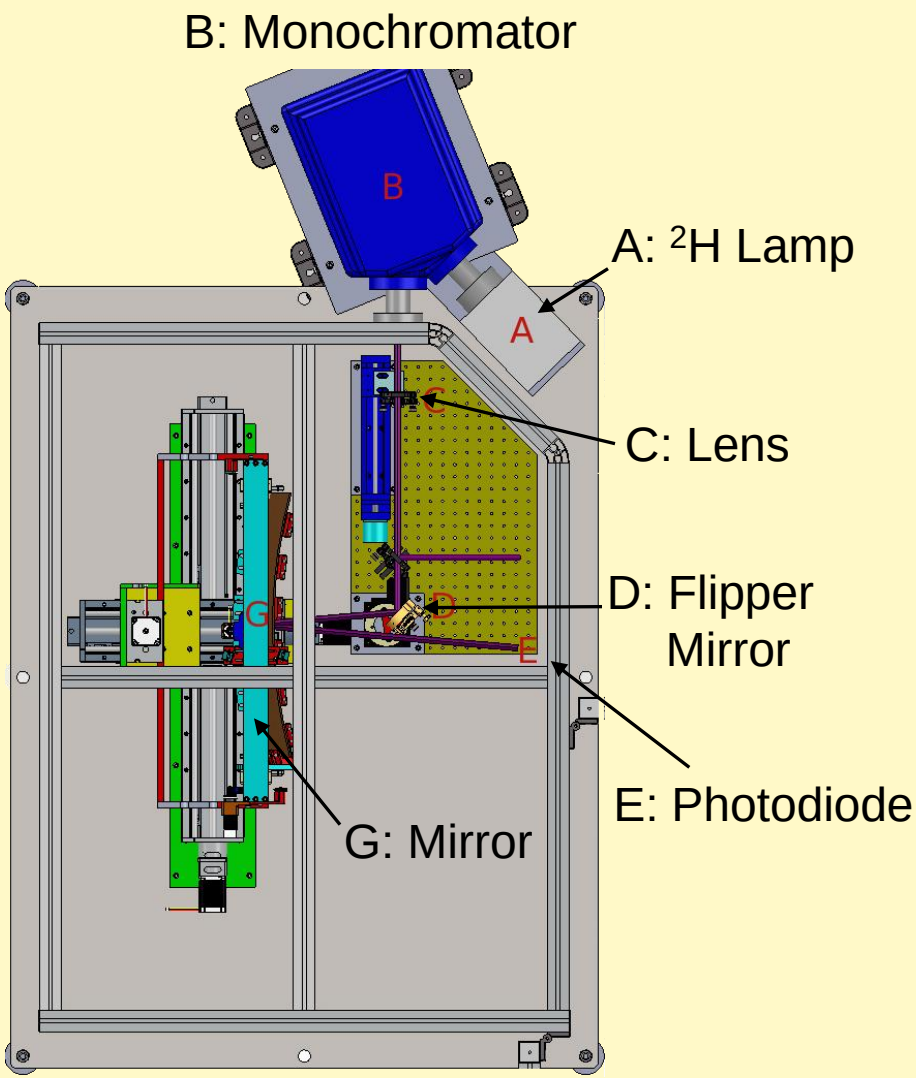
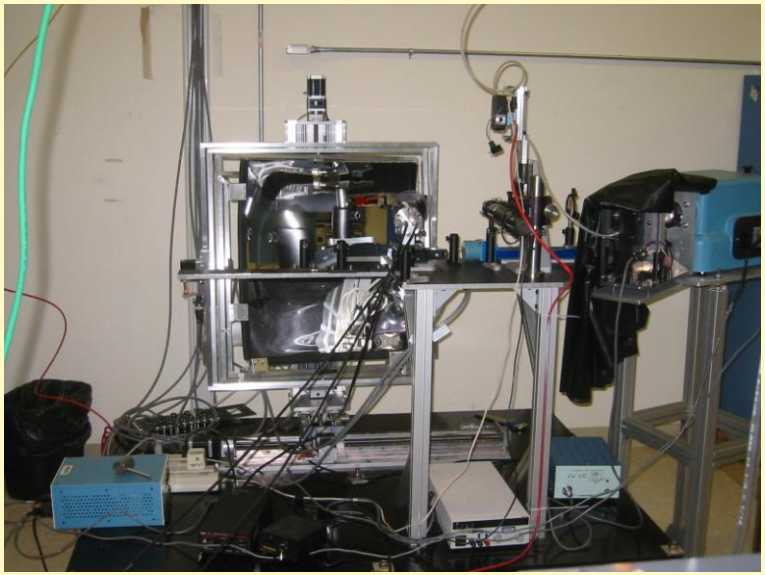
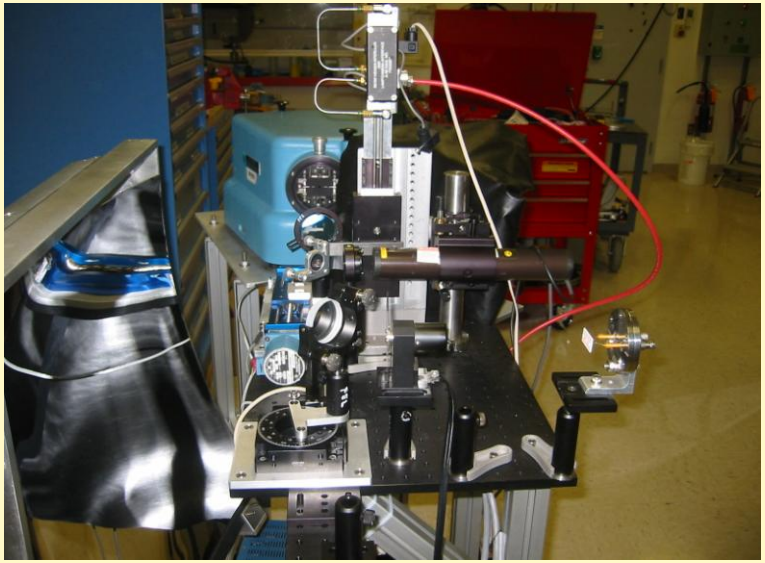
Mirror Reflectivity Setup at JLab FEL







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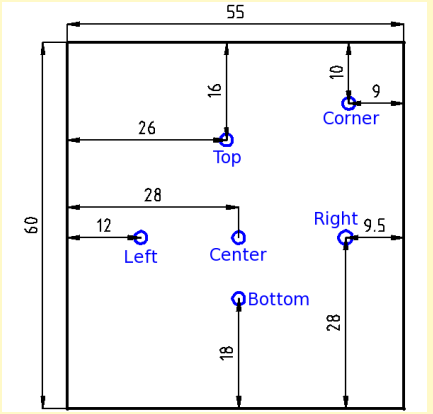
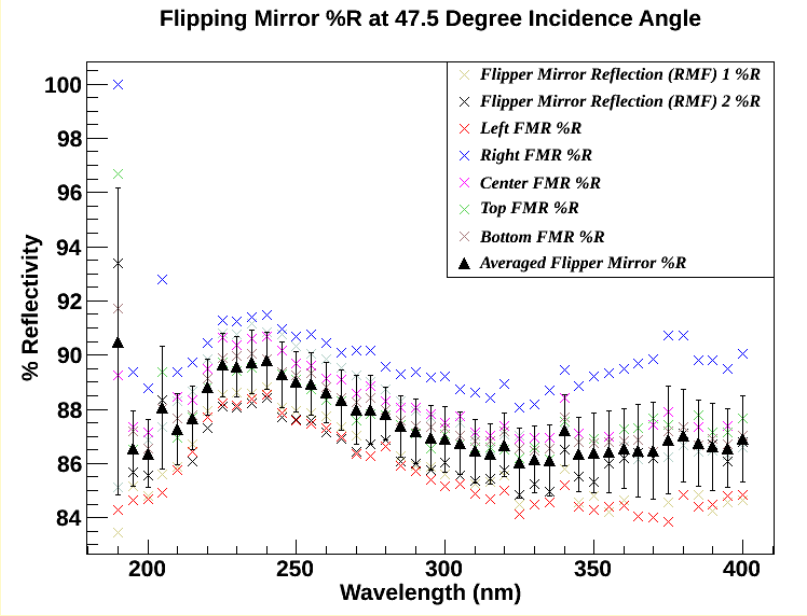
May 17, 2012 Reflectivity Measurement Results

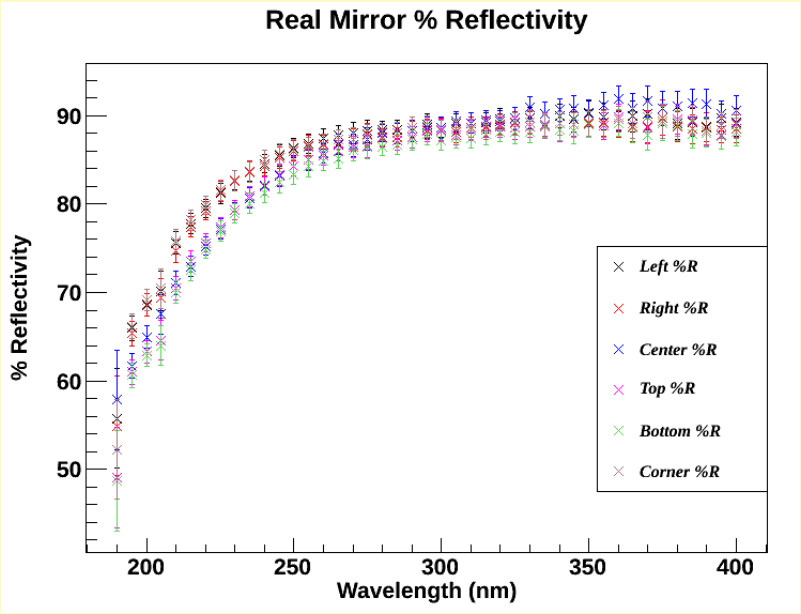
- For each measurement:
  1. Source→Detector.
  2. Source→Flipper Mirror→Detector.
  3. Source→Flipper Mirror→Real Mirror→Detector.



$$R = \frac{Signal(Path\ 2)}{Signal(Path\ 1)}$$

$$R = \frac{Signal(Path\ 3)}{Signal(Path\ 2)}$$

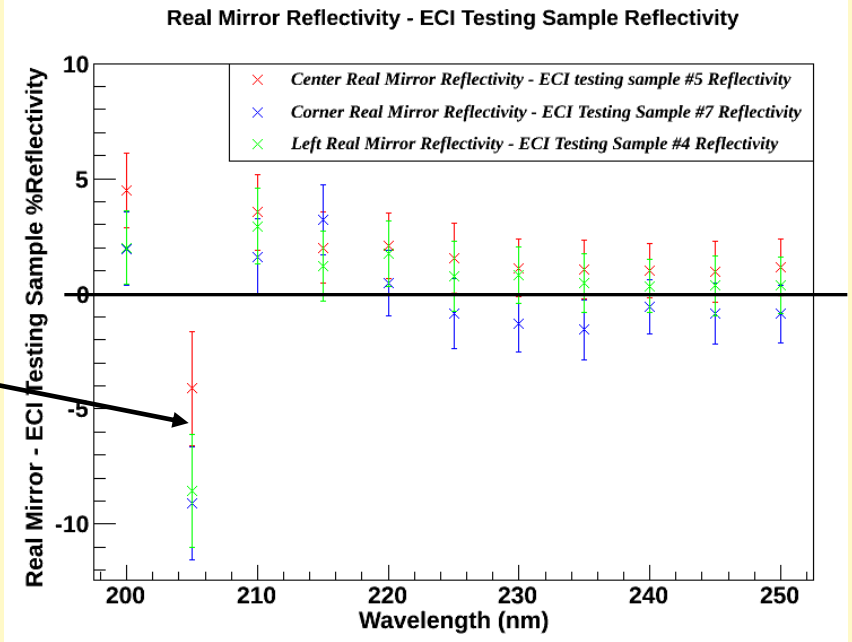




Reflectivity Measurements Summary

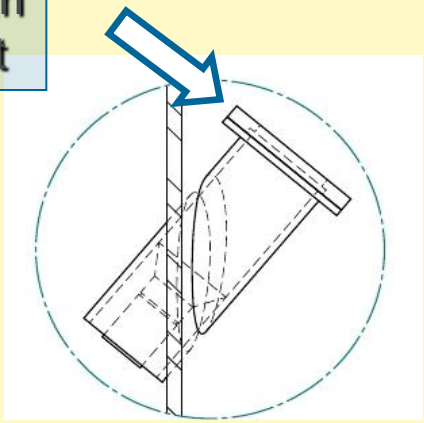
- Reflectivity Measurements provided by ECI were for 1” coupons at various locations around mirror in aluminization chamber.
  - JLab Measurements are on full size mirror #8.
  - Two sets of measurements agree well.
    - JLab measurement slightly higher 0-3%.
- **ECI aluminization is acceptable. They can do our “good” mirrors now.**

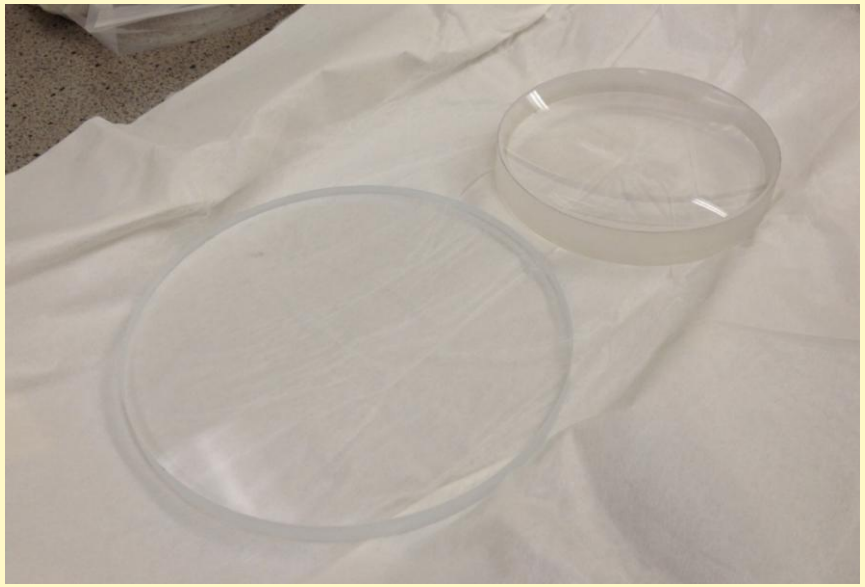
Ratio is low because ECI data have a spike here.



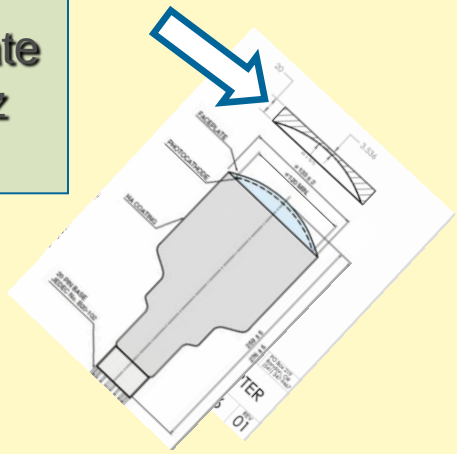
Quartz (Corning 7980) Windows and Adapters have arrived

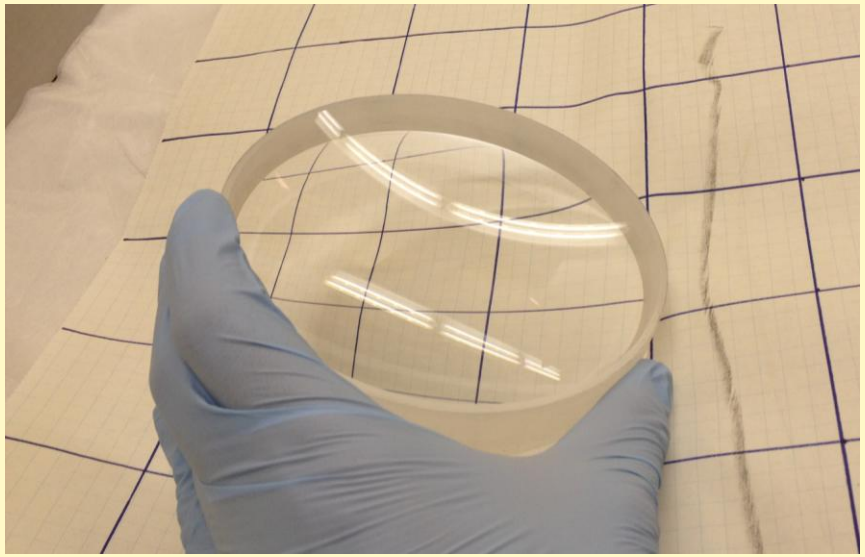
PMT views gas enclosure through a quartz viewport





An adapter is needed to mate PMT to quartz viewport.





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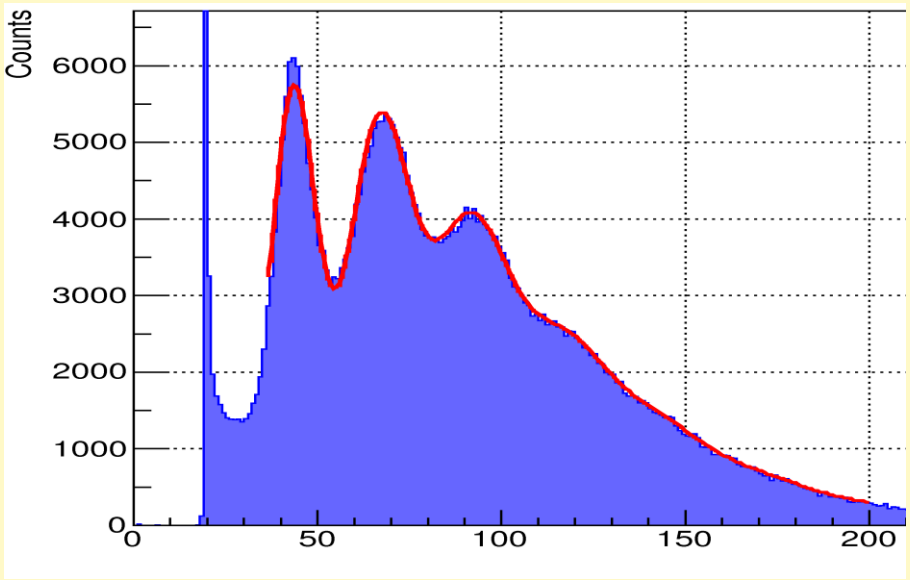
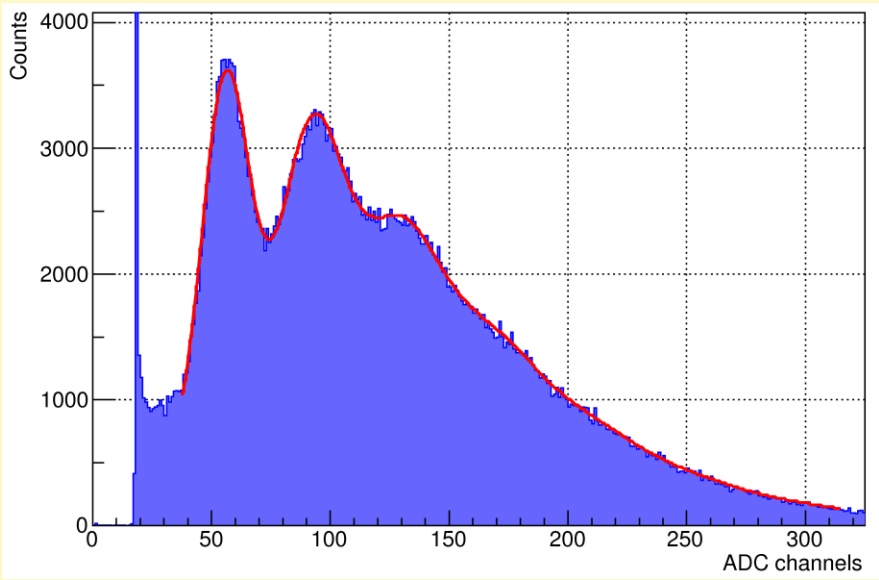
PMT Q/A Measurements

Burle 8554 5” PMT
Serial#: J0992499 94-43
-2050V



Hamamatsu R1584 5” PMT
Serial#: LA0271
-2050V



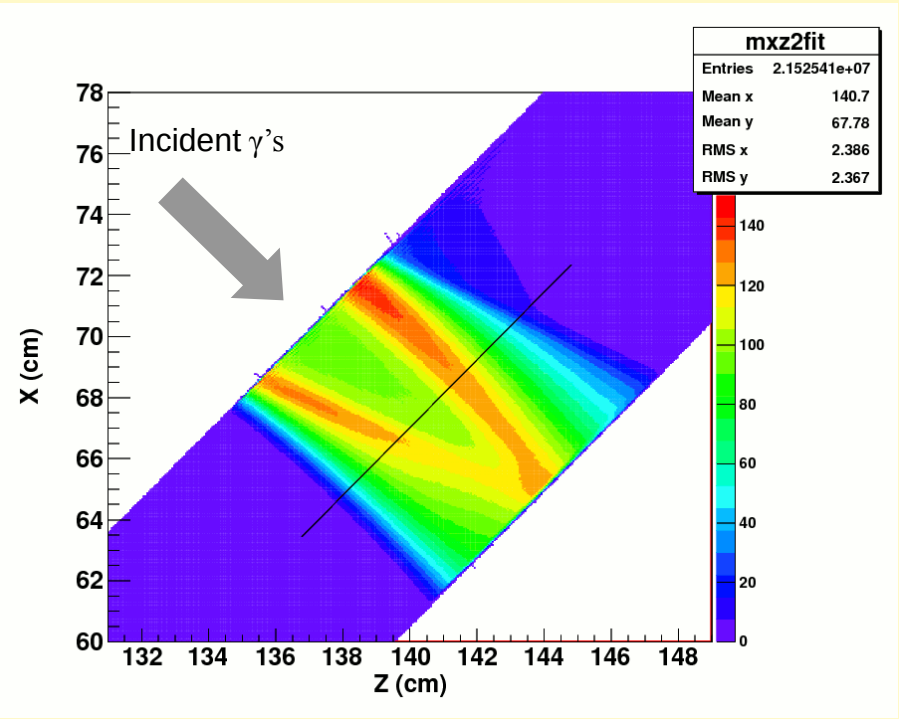
- Typical spectra for a Burle PMT and a Hamamatsu PMT, under the same conditions.
- Burle 8854 was found to have slightly higher resolution and lower gain than the Hamamatsu R1584, as expected.

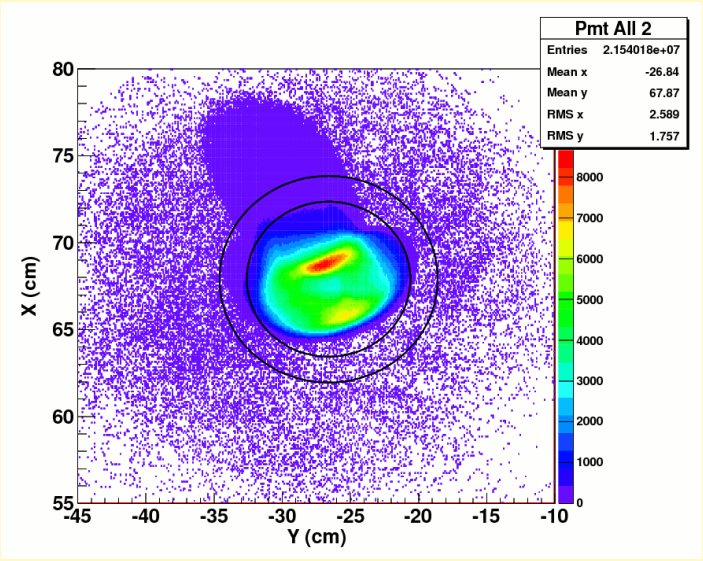
Incorporate Oblate Mirror Shape in Geant4

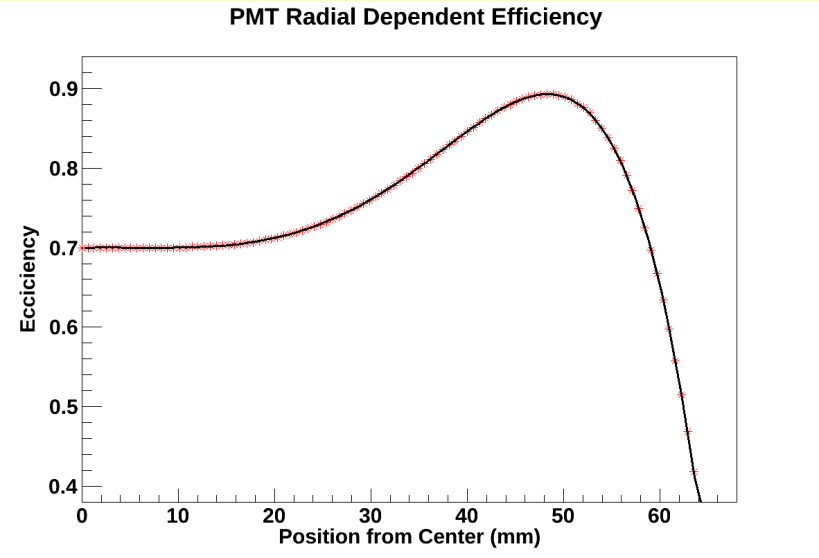
- Use General Ellipsoid quadratic surface construction.
  - Ellipsoid parameterization is different than conic section parameterization typically used in optics but provides an acceptable fit to mirror data.
- Use Mirror #6 parameters (neither best nor worst one):

```
G4double X_SemiAxis = 751.236;
G4double Y_SemiAxis = 745.89;
G4double Z_SemiAxis = 492.952;

 // Interception Box
 G4Box    *solidBox  = new G4Box("mirbox", dx_width , dy_width , dz_width + MirrThikn / 2.0);

 // Oblateness mirror curvature
 G4Ellipsoid *InnerOblate = new G4Ellipsoid("innerObl", X_SemiAxis, Y_SemiAxis, Z_SemiAxis, 0.0, 0.0 );
 G4Ellipsoid *OuterOblate = new G4Ellipsoid("outerObl", X_SemiAxis+MirrThikn, Y_SemiAxis+MirrThikn,
    Z_SemiAxis+MirrThikn, 0.0, 0.0 );

 solidOblateSub = new G4SubtractionSolid("oblsub", OuterOblate, InnerOblate);
 solidOblateInter = new G4IntersectionSolid("boxsphint" , solidBox , solidOblateSub, 0, G4ThreeVector(
    0.0 , 0.0 , 492.952 + MirrThikn / 2.0));
```

Detailed optimization of PMT position and angle





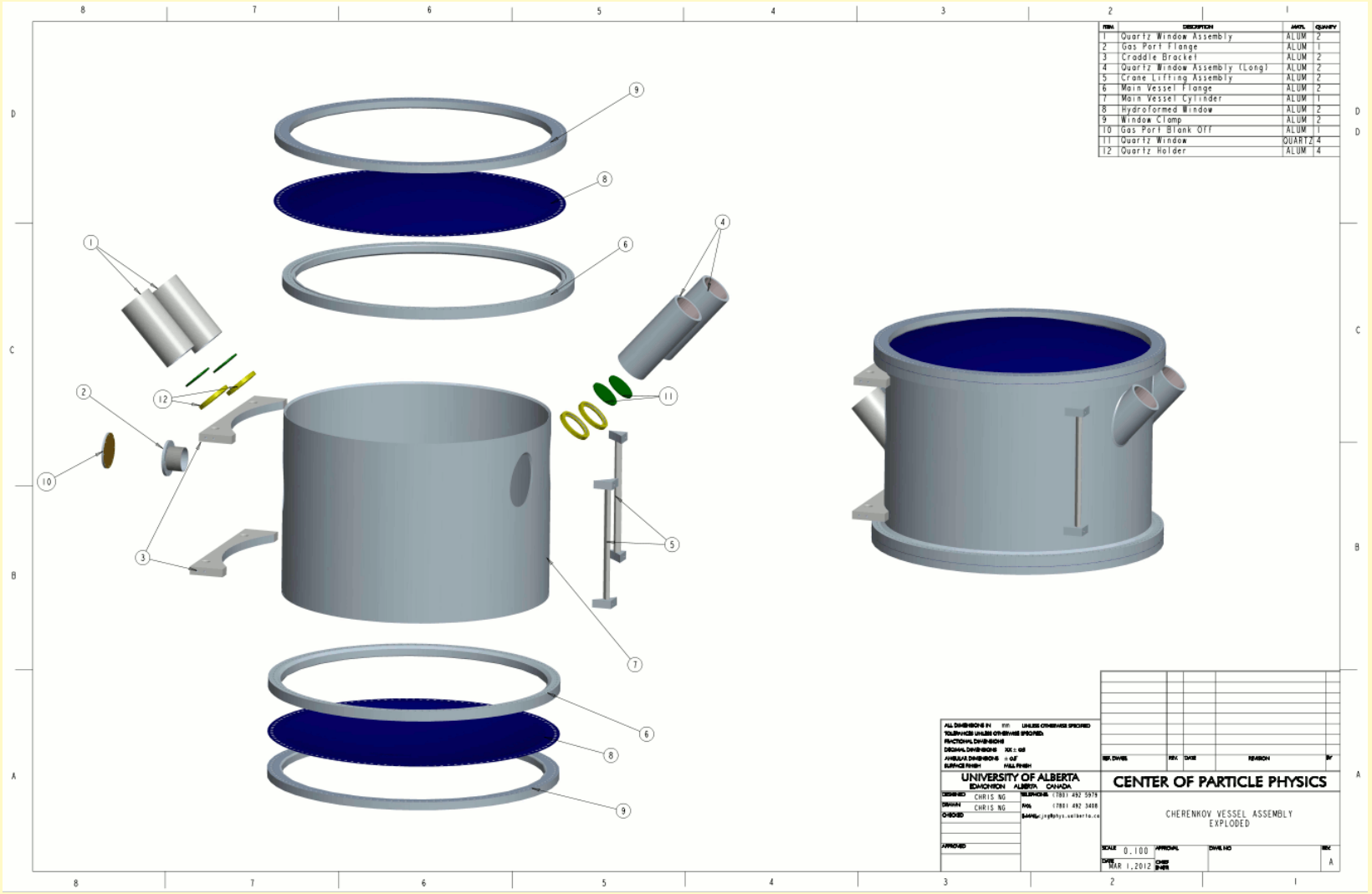


Simulations included:

- Realistic oblate mirror shape.
- Position dependent PMT response.
- Reflectivity curve provided by vendor.

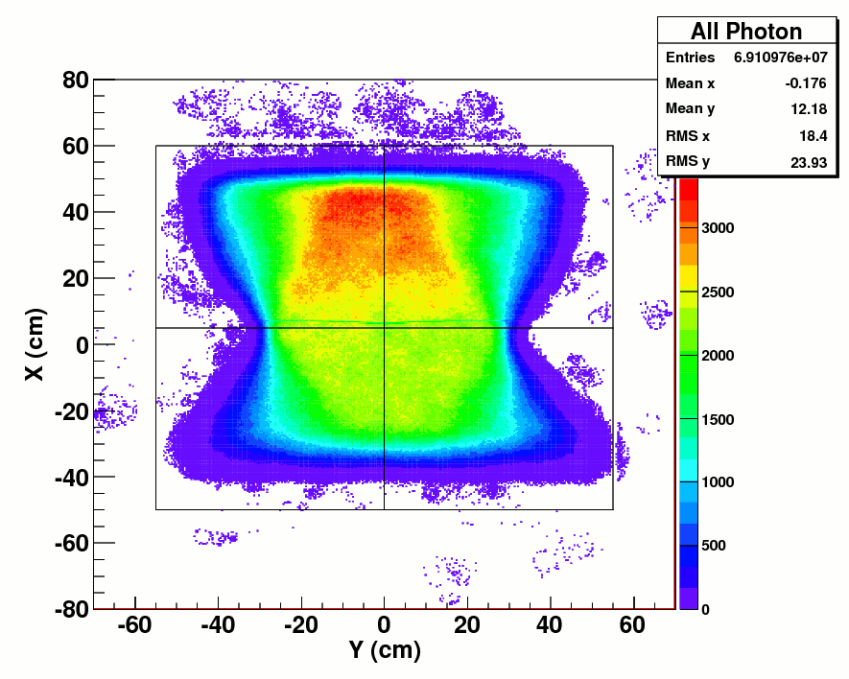
Engineering Review of Construction Drawings Completed

- Best bid received from HAI Precision Waterjets, Trenton, ON.
- Procurement paperwork is in final stages.

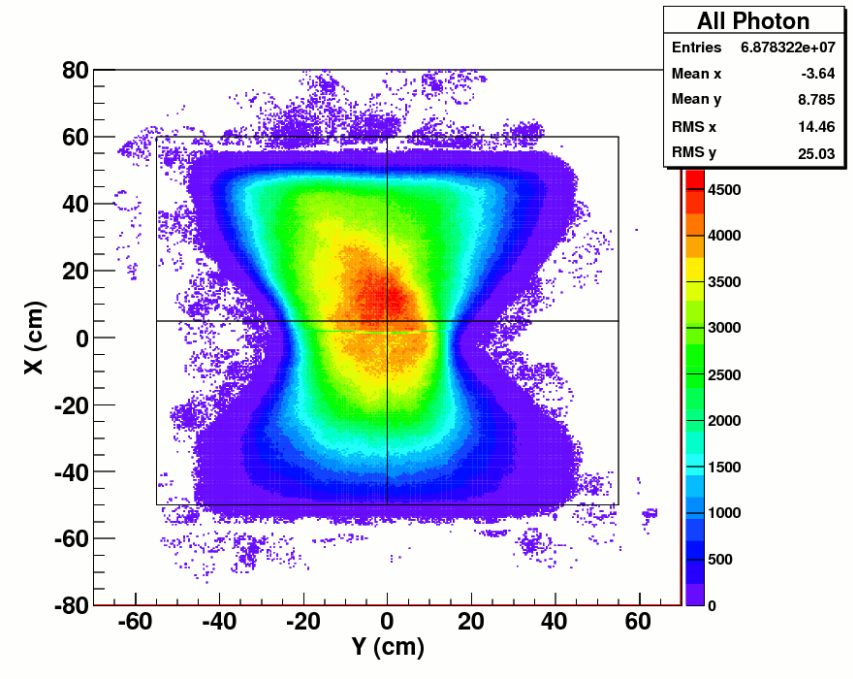


New SHMS Envelope Implications

- **New envelope information unfortunately provided after vessel design was finalized.**
  - Most particles now cross focal plane where 4 mirrors interleave.
- **We need to re-optimize mirror tilt angles before deciding how far to raise detector.**



OLD Envelope (5cm offset)



NEW Envelope (? offset)

SHMS Noble Gas Cerenkov

Status report

Donal Day
June 2012

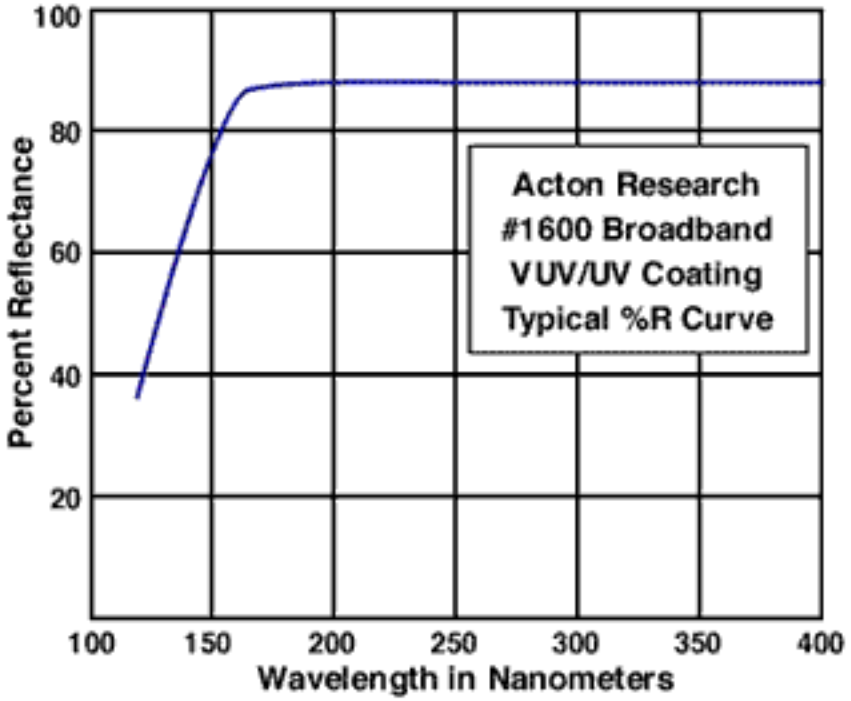
- Where we are (have been)?
- What is next?
- When will we get there?

Vendors lined up

Glass blanks

Rayotek Scientific Inc.
San Diego, CA. 92121
www.rayotek.com
An ISO 9001:2008 company
Promise spectral surface, $\Delta R < 0.1$ mm

Acton Optics & Coatings
Princeton Instruments
Acton, MA 01720
www.actonoptics.com

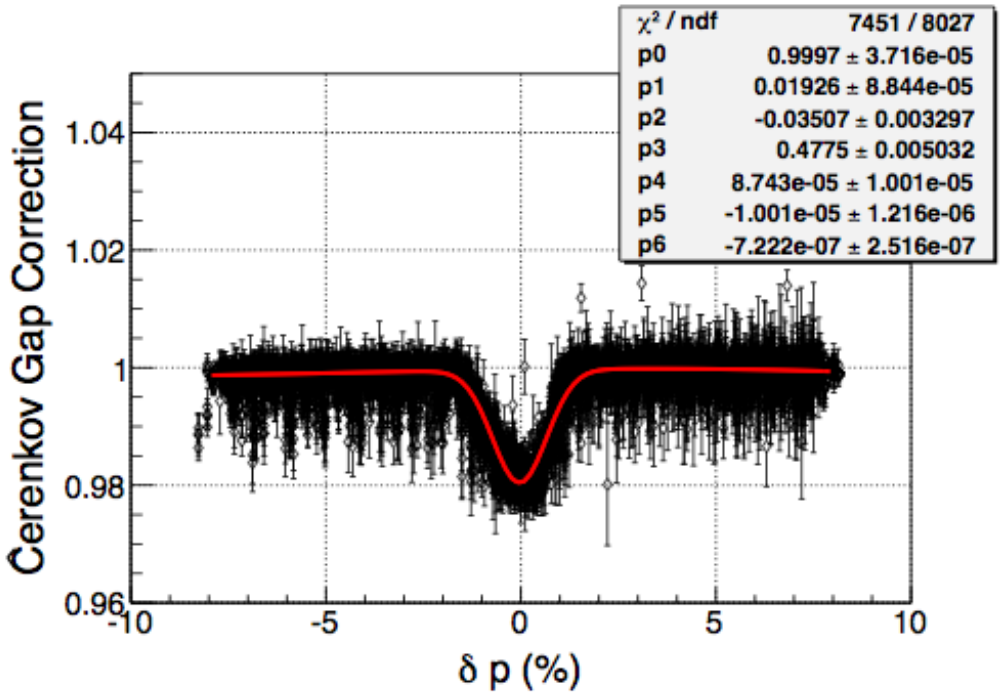


Coating

Even Rayotek indicates that R/R_0 worsens at the edges of the glass

Not a problem if you use a single mirror - the edges are at the edges of your acceptance. But here our edges are in the center of our acceptances

Could this explain the efficiency gap in the HMS Cerenkov?



Rayotek can slump an oversized piece of glass and cut to size afterwards

Before we take up this extra expense we will simulate the effect in GEANT4

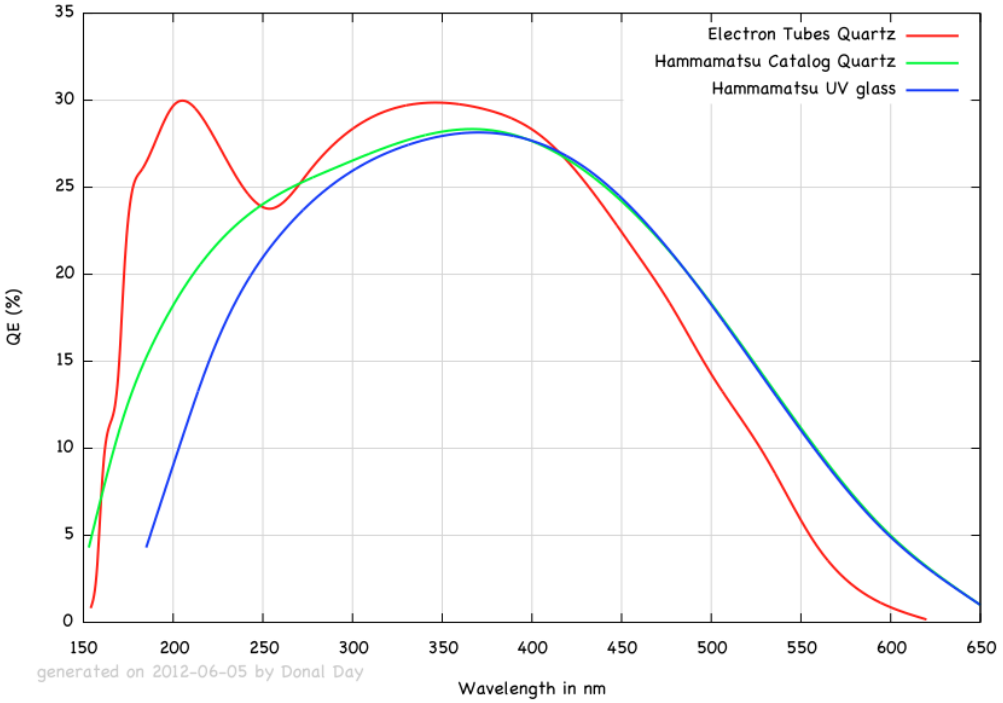
- Find the optimum position assuming a perfectly spherical mirror
- Change the radius of the mirrors
- Look at the collection efficiency at the edges.

Escalating Tube prices

Hammamatsu (1584) (UV glass)
$3300 (08/2009) (shield, no base)
$4400 (02/2011) (includes base and shield)
$9360 (02/2012) (includes base and shield)

Electron Tubes 9823QB (Quartz)
$7125 (base and shield)

Compare the responses



9823QB estimate for N_e about 60% greater than R1584.

Obviate the need of WLS?

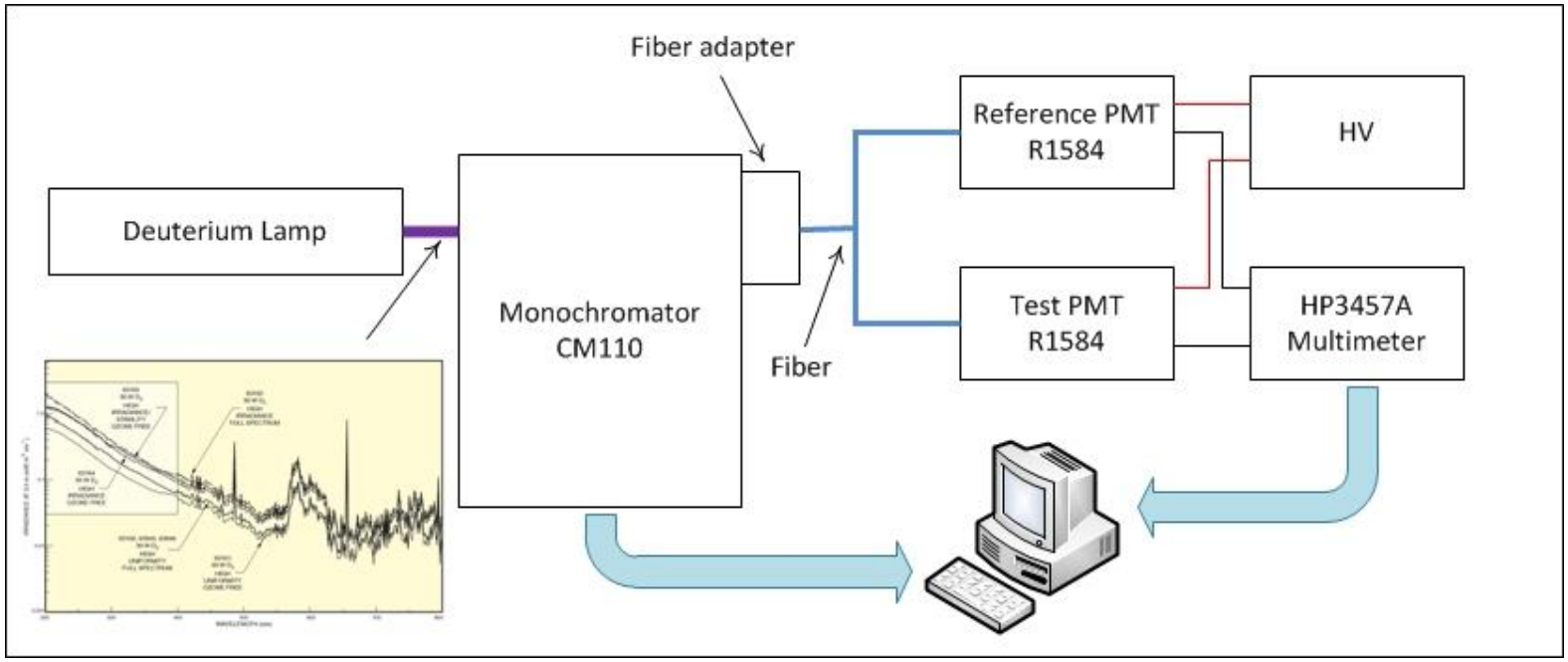
We plan to test the WLS on our R1584 in any case before we make decision.

Company	Tube	Size (in)	λ_1 (nm)	λ_2 (nm)	A cm^{-1}	N_e
Hamamatsu	R1836	5	160	650	296	8.5
Hamamatsu	R1584, UV glass	5	185	650	233	6.3
Electron Tubes	9823QB	5	164	620	341	10

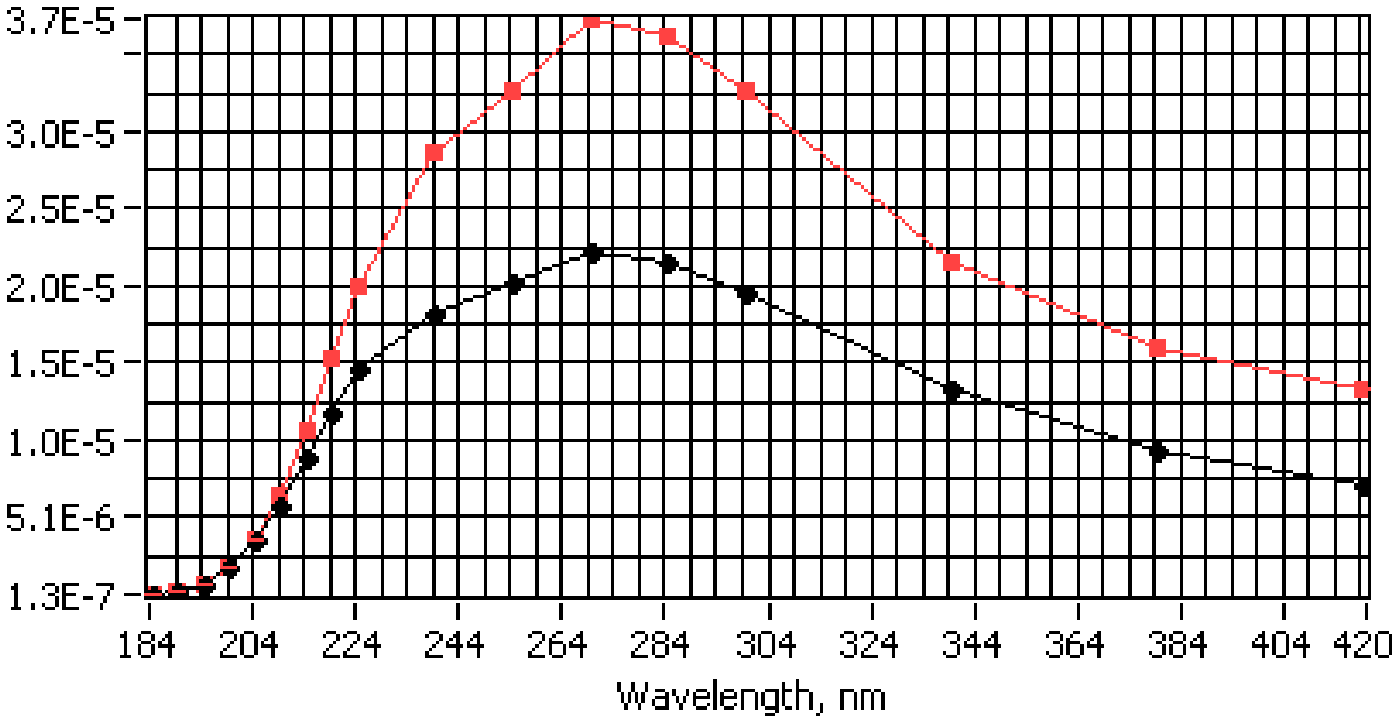
Table 1: Estimates of A and N_e for a 220 cm Neon volume at 1 atm (11 GeV pion threshold) for various PMTs using 80% of the manufacturer's claim for QE and assuming no absorption. The Hamamatsu R1836 has a quartz window.

PMT testing Setup

- Setup a testing system to estimate PMT spectral response before and after coating
- Photocathode relative sensitivity tests. We will make measurements before and after coating (in progress)



Response versus wavelength

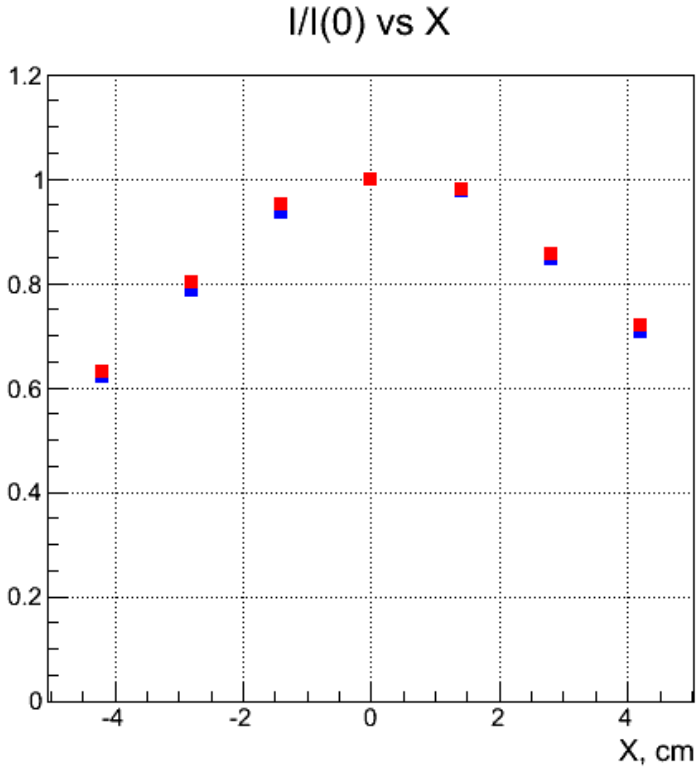


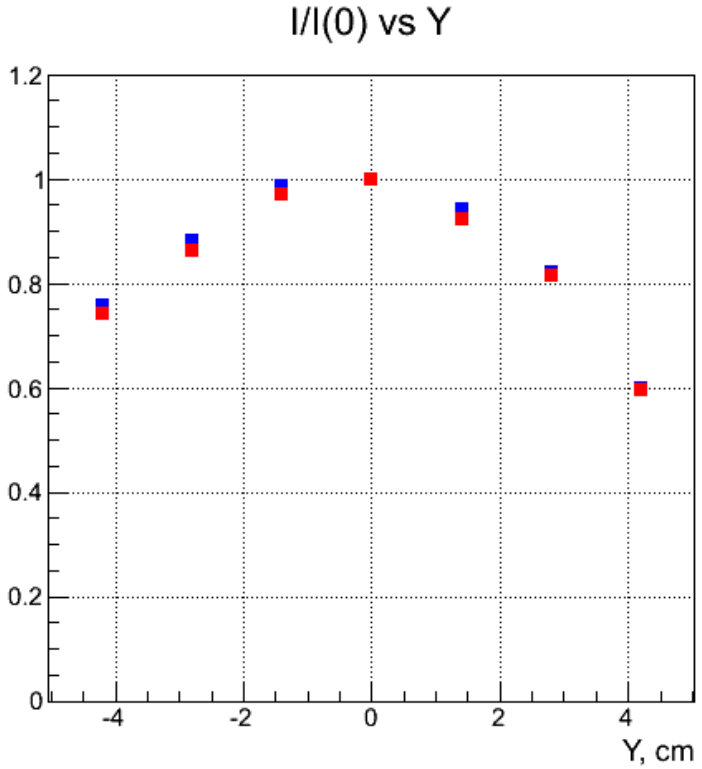
Location: center of PMT

Issue: Too much light to run at R1584 operating voltage (1600 vs 1900)

Solution: Neutral density filter but where to insert?

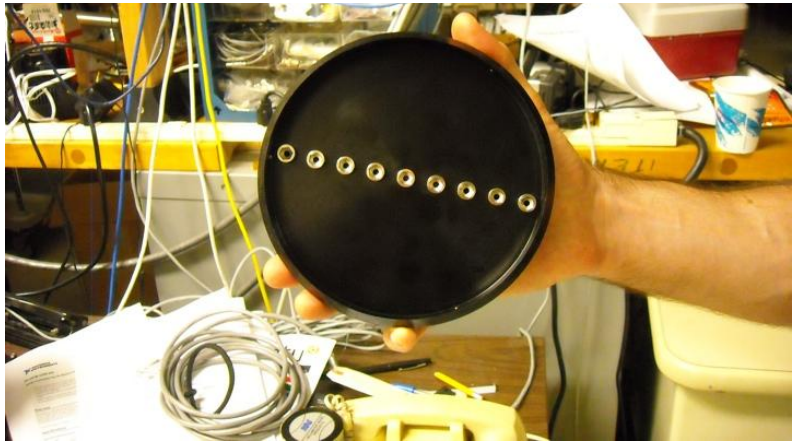
What is the collection efficiency across the PMT?

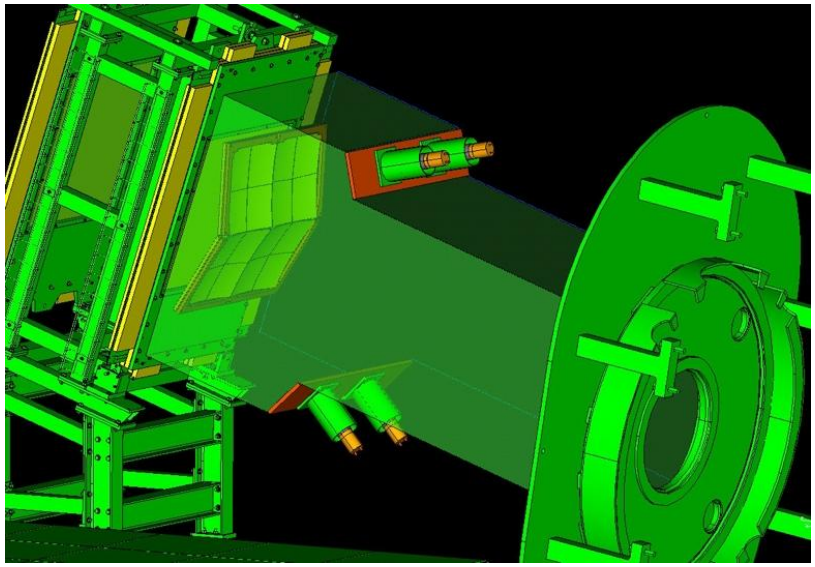


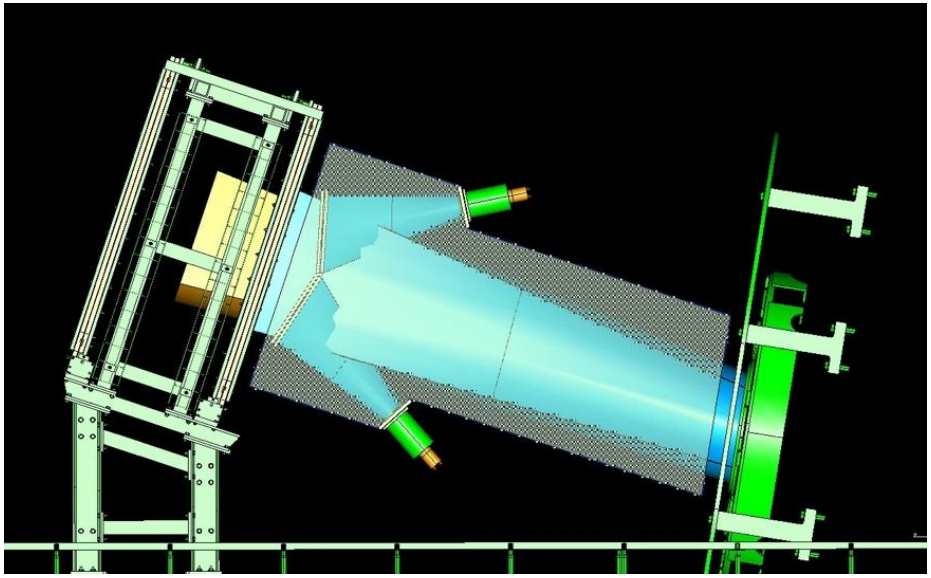


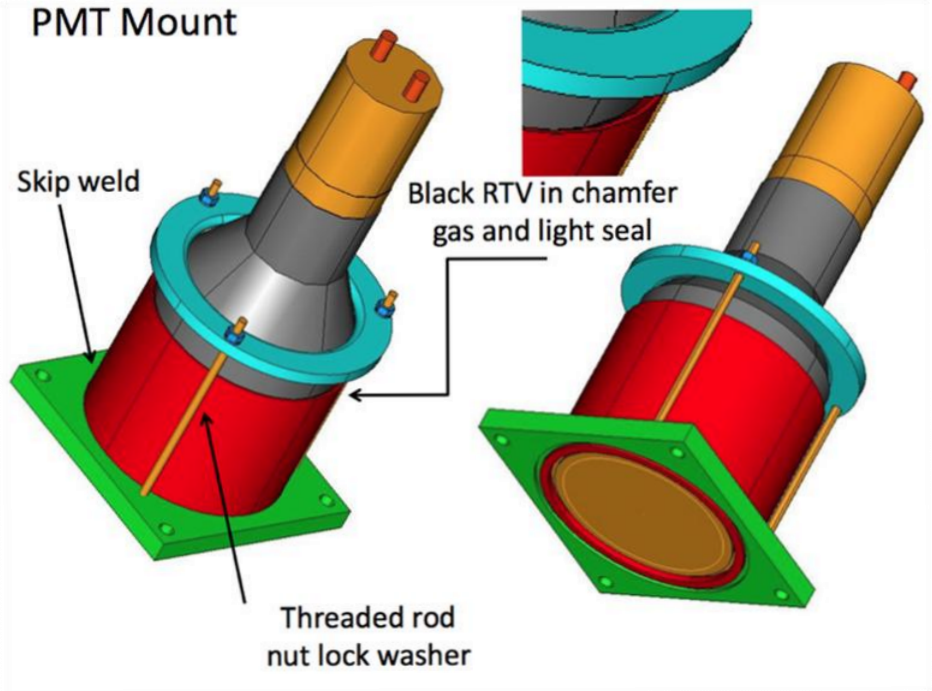
@ 200 nm

2 measurements









Bert Metzger

To Do List for this summer

- Studies of PMT WLS
  - Test response of uncoated PMT (done)
    - coat with WLS at Fermilab
    - test again and compare
      - make a judgment about results
- Collection efficiency across photocathode (in progress)
- Update simulation with new bundle of rays (soon to begin)
- Study efficiency at edges of mirrors that might arise from variations in the radius of curvature (soon to begin)
- Continue to communicate with Bert Metzger on tank
  - revise & improve design
- Purchase phototubes, mirrors and coating (next 8-10 weeks)
- Keep leaning forward!

Mikhail Yurov (gs) and Patrick Garziglia (ug)

From: "Dudley, Betsy (bmd2n)" <bmd2n@eservices.virginia.edu>
Subject: Oracle Account
Date: May 15, 2012 3:03:53 PM EDT
To: "Day, Donal (dbd)" <dbd@virginia.edu>
Cc: "Hall, Patricia (pla)" <pla@eservices.virginia.edu>

This is to inform you an award has been set up with Transaction Controls

AWARD NUMBER: GG11542

PROJECT NUMBER: 140338

PRINCIPAL INVESTIGATOR: Day, D.

PERIOD: 05/07/2012 – 02/08/2014

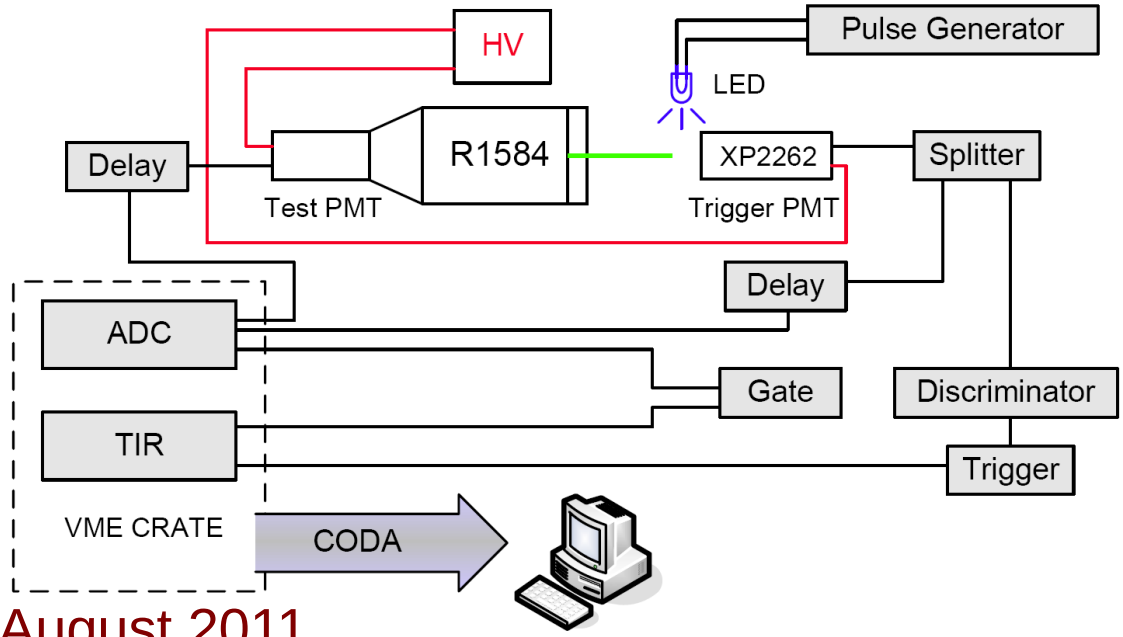
SPONSOR: U.S. DOE – National Lab. – Jefferson Science Associates, LLC

TITLE: AS-PHYS-Noble Gas Cerenkov

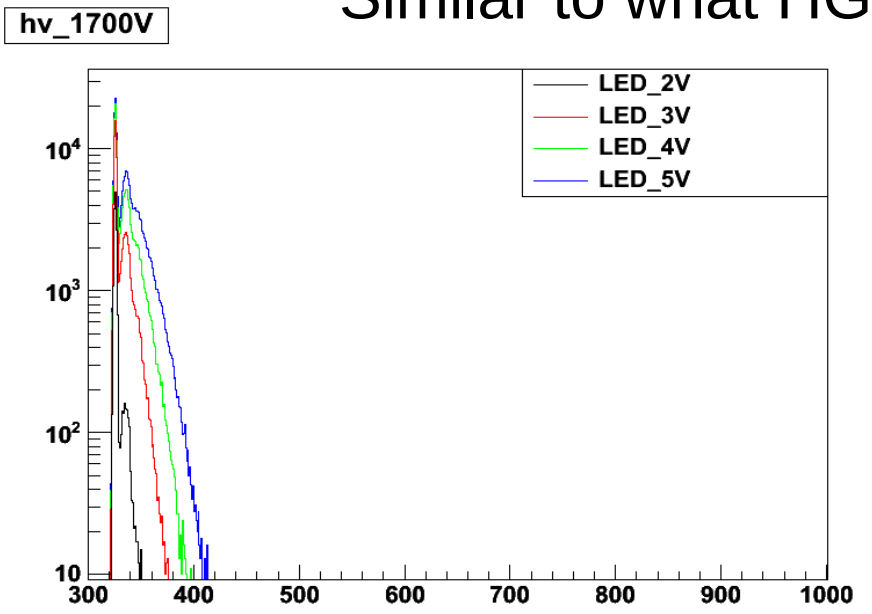
Award arrives at UVA

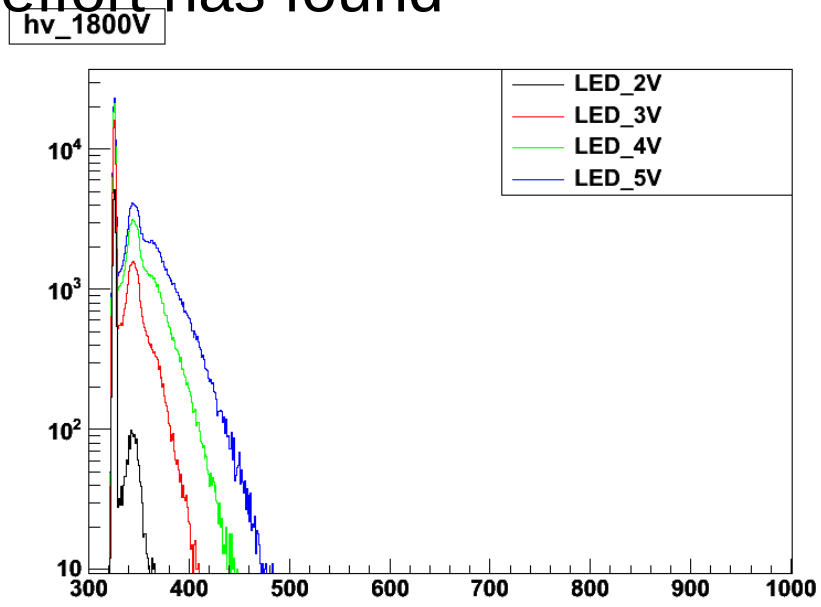
Single photo-electron peak

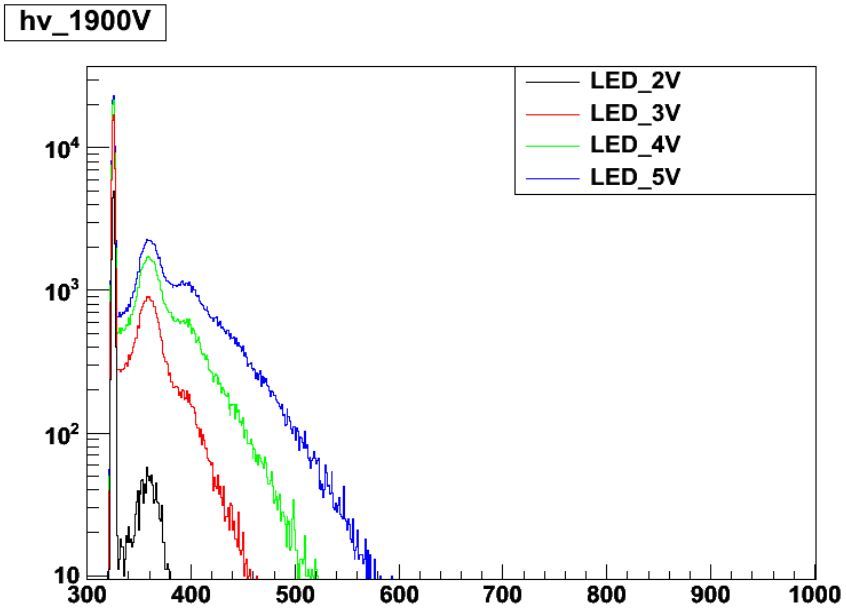
- Setup
  - Light Source: LED controlled with Pulse Generator, 10ns signal width
  - Test PMT (R1584), Reference PMT (XP2262), Cap with Fiber holders, Fiber to minimize amount of light
  - Discriminated pulse of the Reference PMT serves as a trigger
  - Delayed signals from Test and Reference PMTs are sent to V792 ADC board
  - CODA based DAQ

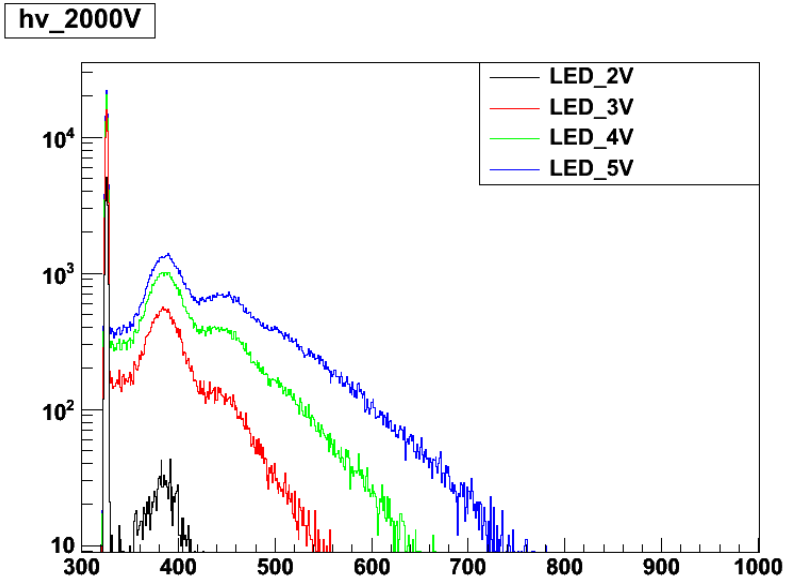


Similar to what HGC effort has found










Tunable Light Source
Spectral Products
Deuterium Lamp 200-400nm
Light source
Monochromator
Coupler
Bifurcated fiber
Slits

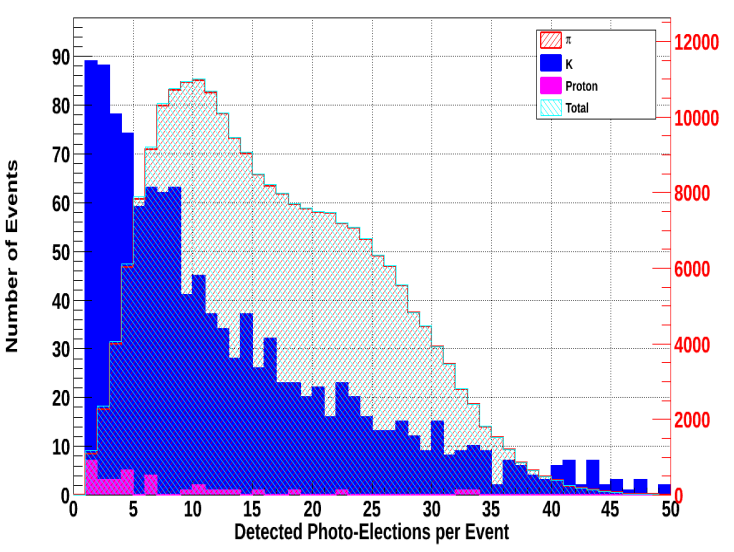
Hamamatsu R1584 PMT	Measured Gain ($x10^7$)	Manufacturer Reported Gain ($x10^7$)	Measured/ Reported	Peak Height/Width Ratio
LA0271	4.38±0.04	3.20	1.37±0.01	3.57
LA0272	5.57±0.05	3.60	1.55±0.01	3.69
LA0273	7.39±0.05	5.79	1.28±0.01	3.74
LA0274	2.26±0.03	0.97	2.33±0.03	3.57
Burle 8854 J0992499 94-43	**2.75±0.04**	**5.1 (catalog)**	**0.54±0.01**	**4.10**

-Manufacturer test sheet gains at 2000V (Hamamatsu catalog gain: $1.4x10^7$)

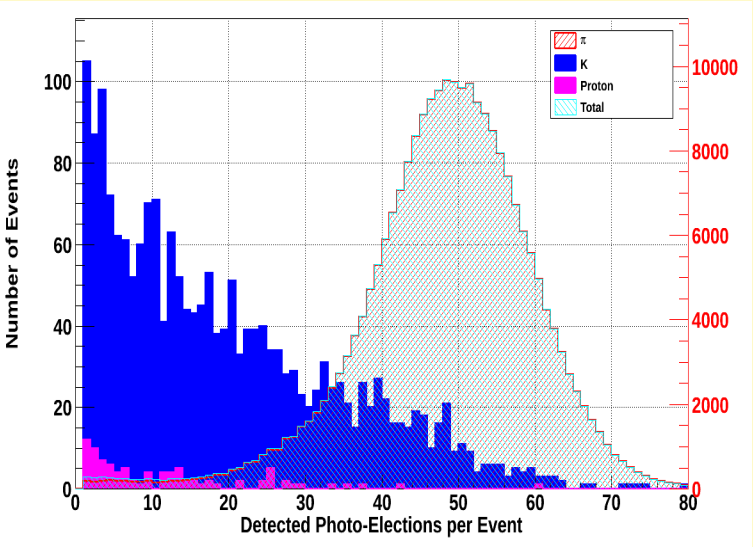
-Measured gains interpolated from values measured at 1950 V and 2050 V

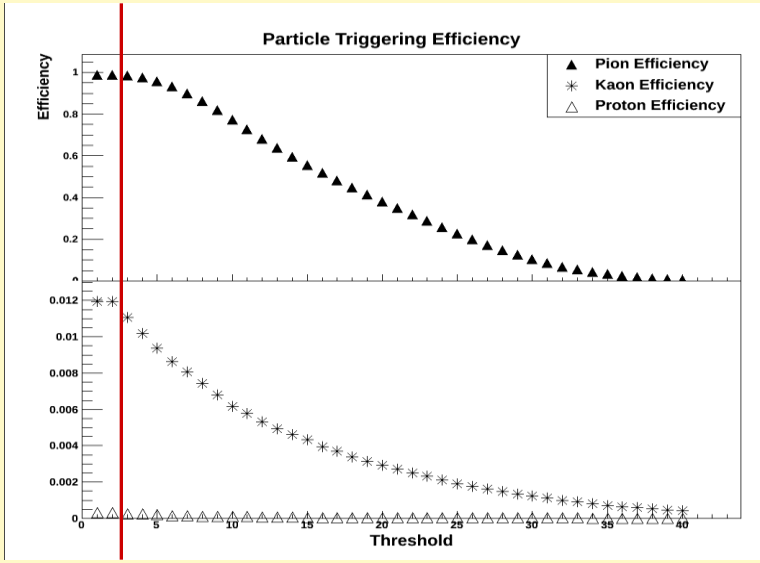
Expected Performance

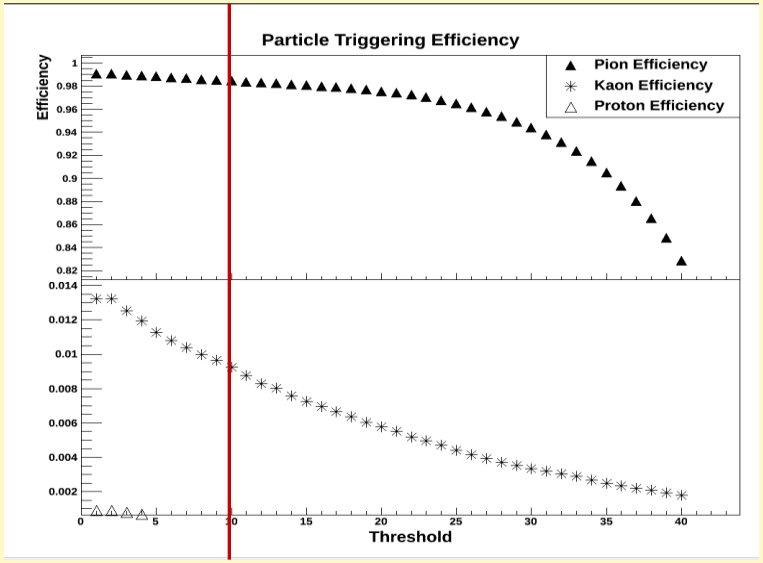
p_0=3 GeV/c



p_0=7 GeV/c







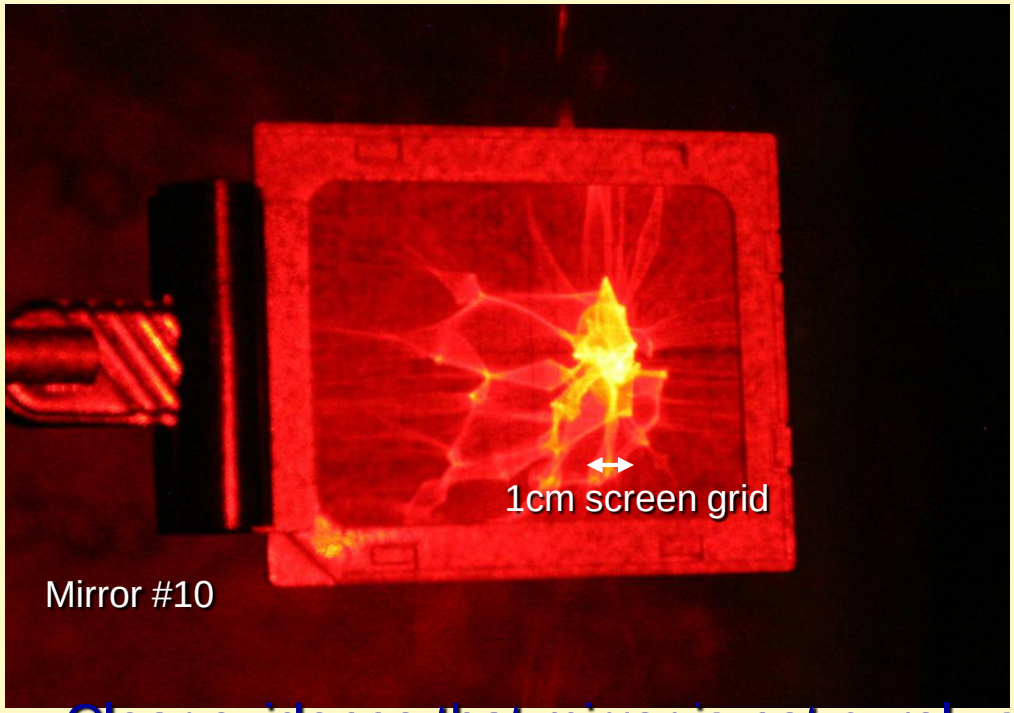
Uncertainty for Mirror Radius Measurement

- Uncertainty for each measurement with Farro arm:
  - dz = 0.16mm
- Uncertainty for Fitted radius:
  - dR = 2cm
- Uncertainty for Fitted *K:*
  - d*K* = 0.15

- Method: Mirror #10 and #13 were measured twice for the reproducibility check

Quality Check using Diffused Laser Beam

- **We diffused a laser beam using a concave lens so that full mirror was illuminated, and looked at light reflected from the uncoated mirror blank.**



- Lens equation

$$\frac{1}{f} = \frac{1}{S_{image}} - \frac{1}{S_{object}}$$

  yields f=55.5±0.5 cm
  - anticipated value: f=55.0 cm
- Most of the reflected light is focused to a spot of about 1 cm^2 area.

- **Clear evidence that mirror is not purely spherical (as expected)**
- **Difficult to interpret the reflected spot shape and tail in more detail since mirrors are uncoated and there is reflection from front and back surfaces.**
- **Will revisit this after some mirrors are aluminized.**

Dr. Garth Huber, Dept. of Physics, Univ. of Regina, Regina, SK S4S0A2, Canada.

NSERC Equipment Grant Budget *(Updated June 7/12)*

Item	Vendor	Budget (C$)	Funds Spent (C$)	Budget Variance (C$)
1 Mirrors				
Glass Mirror Blanks	Sinclair Glass	$8,747	$10,329.72	-$1,582.37
Carbon Fiber backing and stiffening brackets	UofR Mech. Shop	$5,539	$2,199.35	$3,339.85
Mounting Assemblies	UofR Mech. Shop	$7,033	?	?
Mirror Quality Tests	Dumur Industries	$500	$639.90	-$139.90
2 Photomultipliers				
PMTs, mu-Shields, Bases	Hamamatsu	$23,430 (5 PMTs)	$19,140.40 (4 PMTs)	$4,289.60
Quartz Windows & Adapters	Hardin Optical	$10,020	$14,250.43	-$4,230.43
Mounting Assemblies		$5,633	?	?
3 Pressure Vessel	HCI Precision Waterjets	$60,304	$74,260.16	-$14,525.16
4 Shipping & Misc		$7,596	$806.18	?
TOTAL		**$125,000**	**$121,626.14**	**-$12,852.91**

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