SHMS Heavy Gas Čerenkov August 2012 Update

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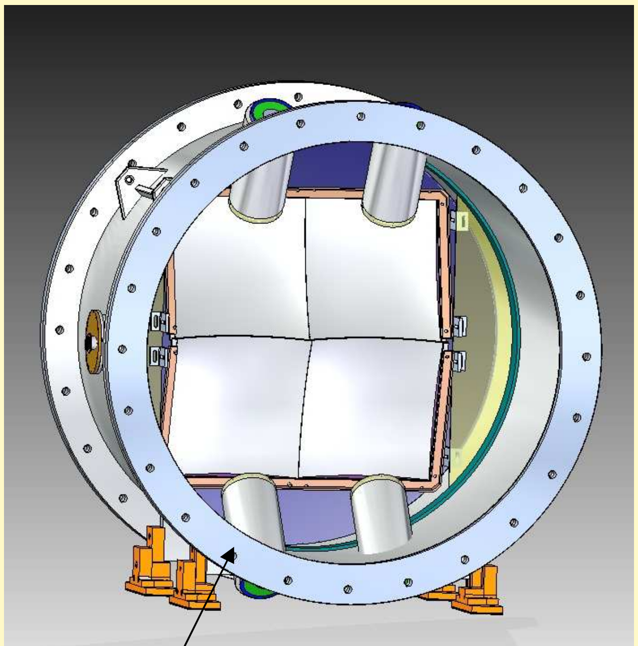
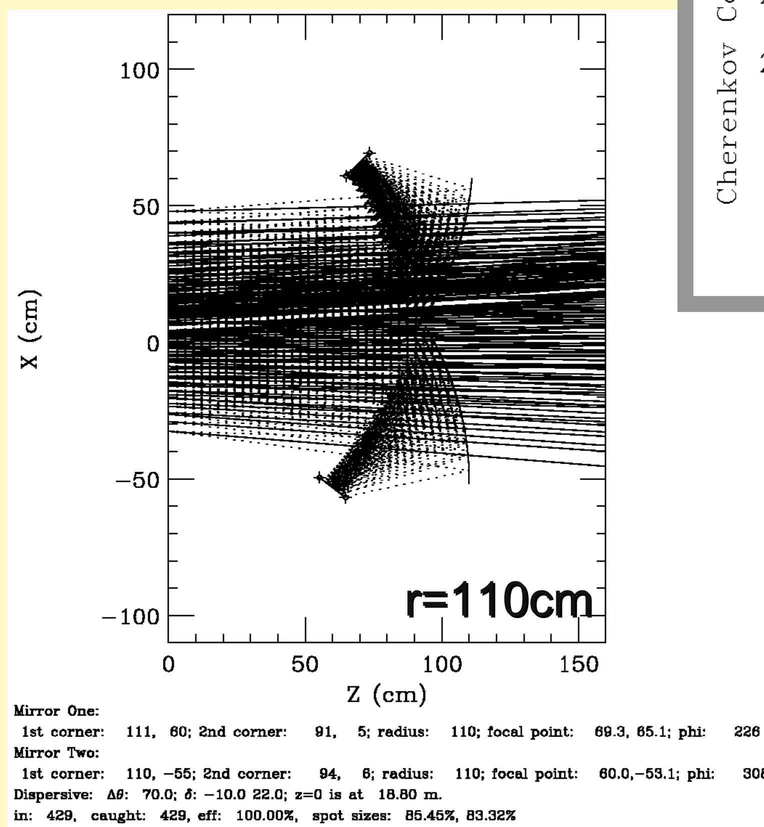
SHMS Detectors Working Group. August 27, 2012.

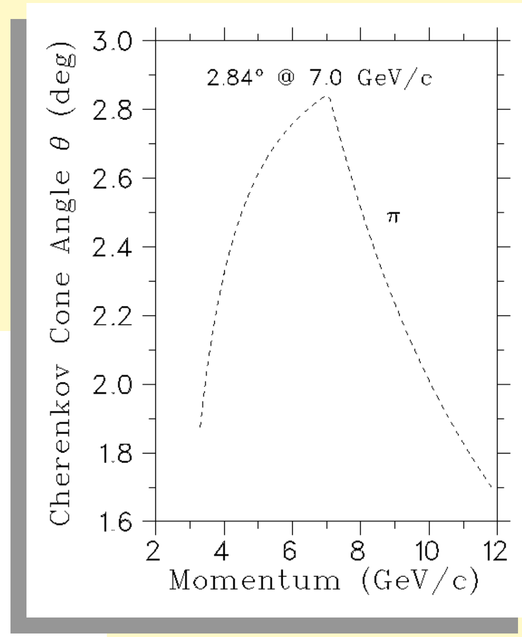
SHMS Heavy Gas Čerenkov Overview

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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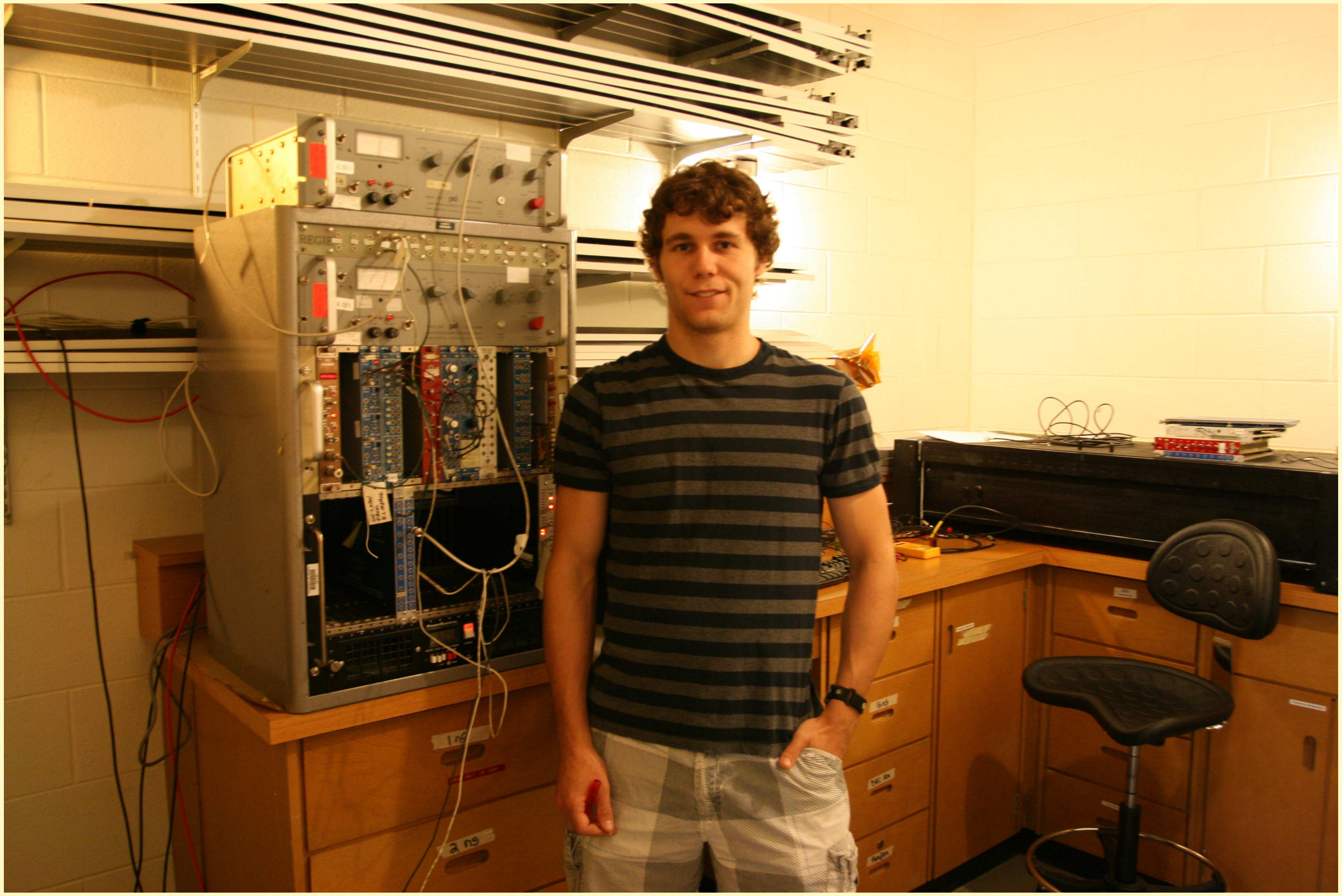
PMT Q/A Measurements

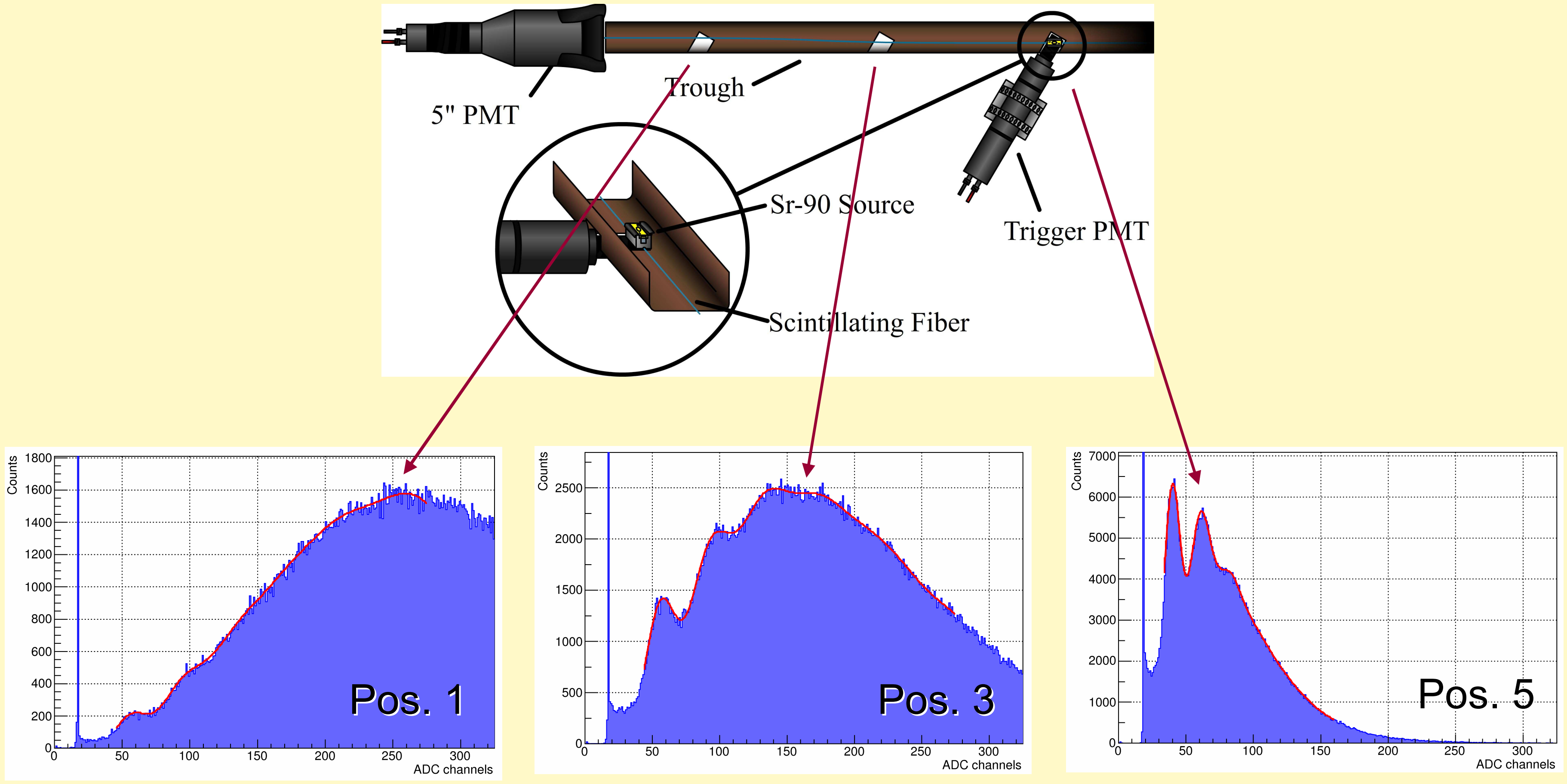


PMT gain tests formed most of the summer research project for Alex Fischer, NSERC Undergraduate Research Award recipient.

Method 1 – Gain measurements with optical fiber

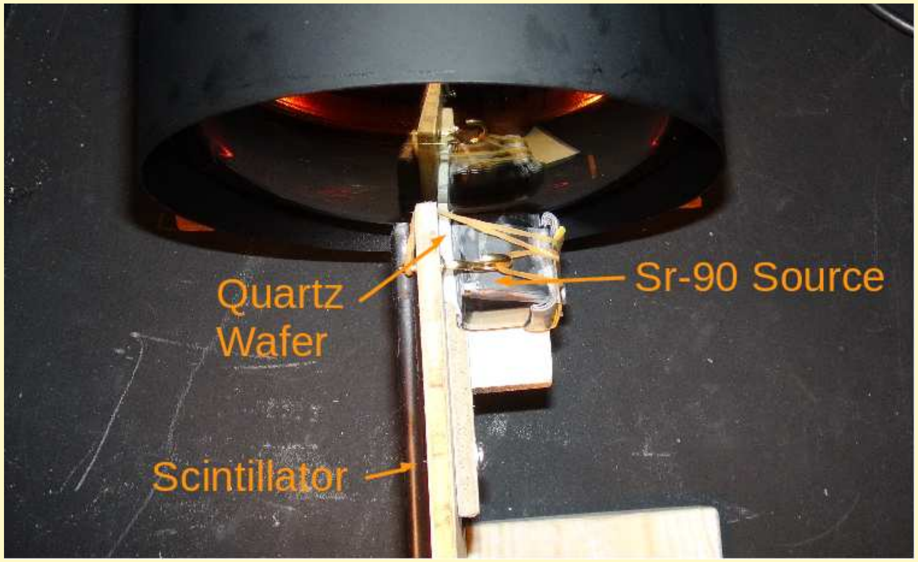
Set-up used for GlueX SiPM gain investigations adapted for PMT tests.

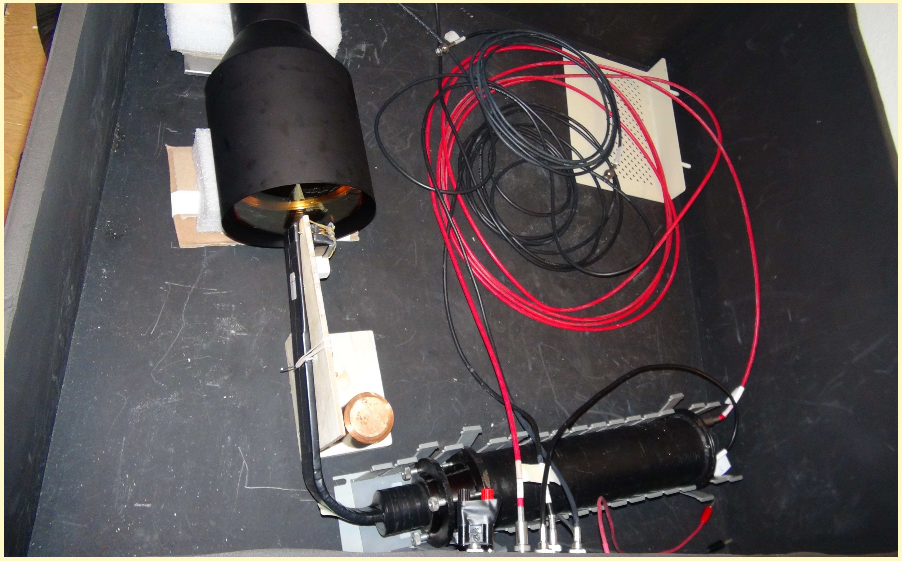
- Sr-90 β-source illuminates scintillating fiber, which illuminates small spot at center of PMT.
- Emitted light is primarily in the blue visible region.



Method 2 – Čerenkov light from β Source

- **Method used to overcome two limitations of the optical fiber tests:**
  - Light from optical fiber not representative of light distribution in HGC as it is dominantly in the blue-visible region.
  - Light collected is intense (many photoelectrons), limiting the maximum voltage that may be used.
- **β's from Sr-90 source traverse 2mm quartz wafer, producing Čerenkov radiation, and stop in thin scintillator, which forms trigger.**





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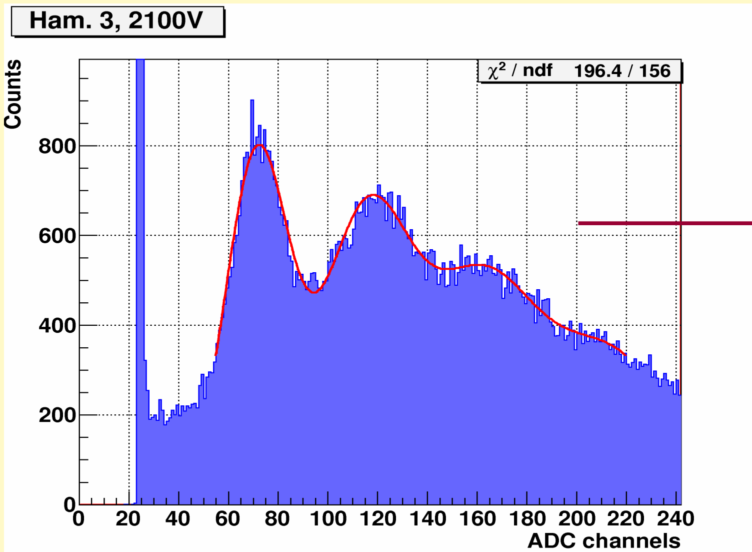
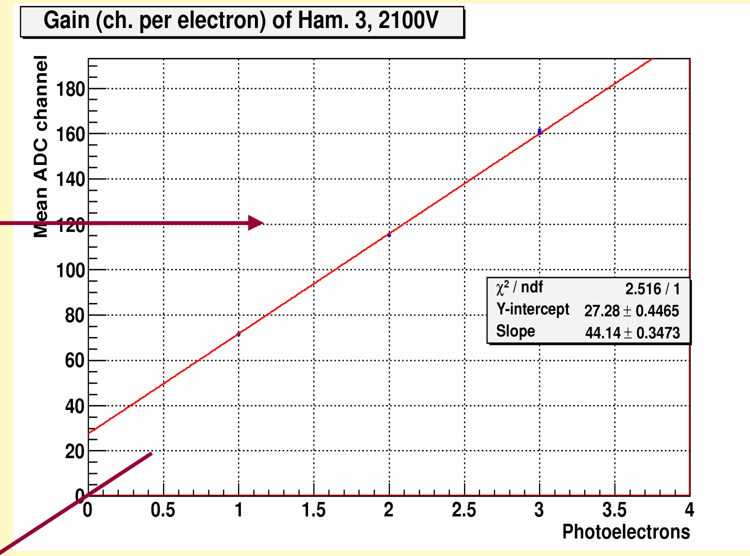
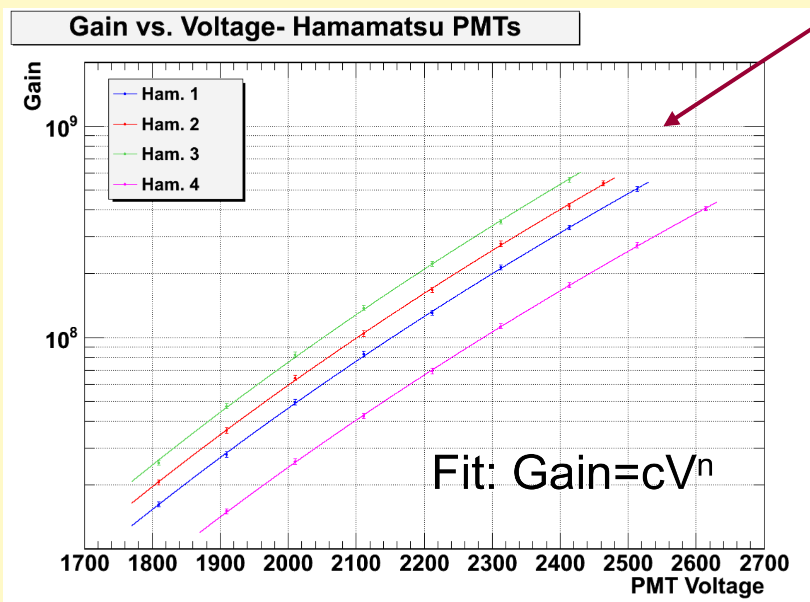
β-Čerenkov Test Results







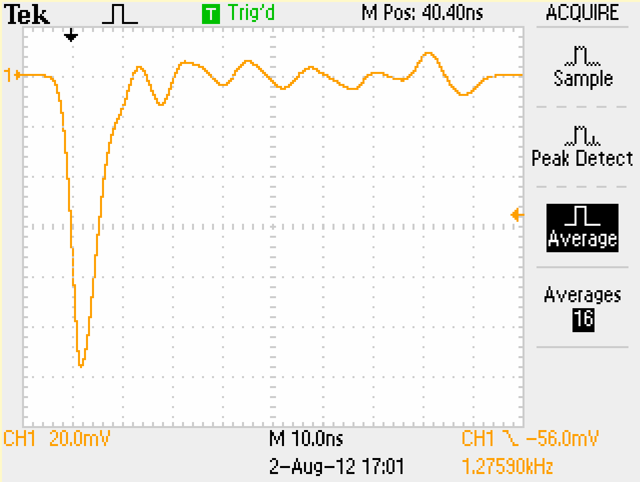
- Gains measured by β-Čerenkov method are 0-5% higher than those measured by optical-fiber method at same voltage, which is only slightly higher than ±2~3% systematic errors.
- Voltage exponent (n=10.5) very consistent for all Hamamatsu PMTs.

Hamamatsu R1584 PMT	Measured Gain β-Čerenkov ($x10^7$)	Manufacturer Reported Gain ($x10^7$)	Measured/ Reported	Peak Height/Width Ratio
LA0271	4.63	3.20	**1.45**	3.57
LA0272	5.94	3.60	**1.65**	3.69
LA0273	7.64	5.79	**1.32**	3.74
LA0274	2.43	0.97	**2.51**	3.57
Burle 8854 J0992499	2.99	5.1 (catalog)	**0.59**	4.10

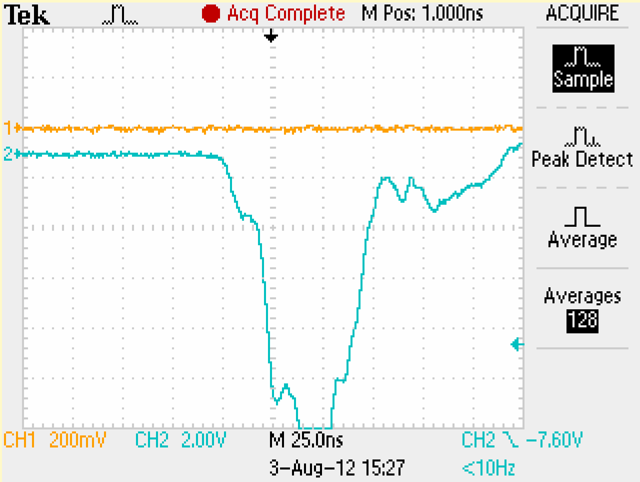
- Manufacturer test sheet gains at 2000V (Hamamatsu catalog gain: $1.4 x 10^7$)
- Measured gains taken as the fitted power function evaluated at 2000V.
- Measured gains exceed manufacturer test sheet by wide margins.
- Burle 8854 was found to have slightly higher resolution and lower gain than the Hamamatsu R1584, as expected.
- **Detailed results in HallC-doc-738-v1**

Issues requiring further investigation

- We observe a lot of ringing in the output signal from the Hamamatsu R1584's.

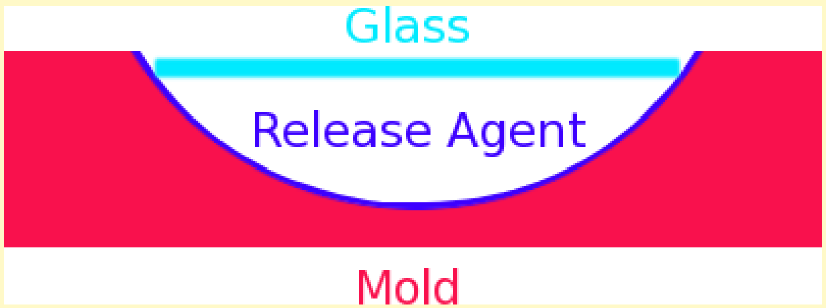


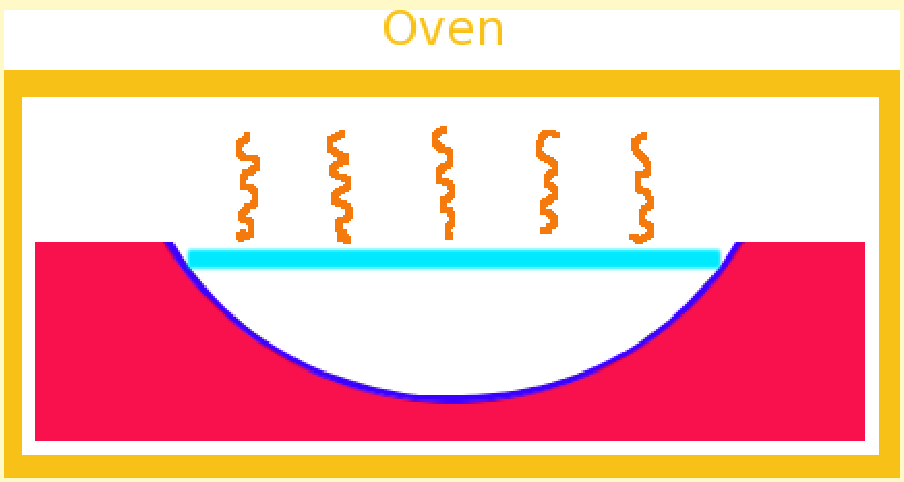
- Occasionally (1 per ~10sec) very large and long pulses are observed.
  - Possibly due to discharge between the PMT at –HV and the μ-shield at ground.
  - Either need to improve insulation between PMT and μ-shield, or use +HV.



Ham. 2 @ 2000V

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.**

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)

$\kappa =$ CONIC CONSTANT

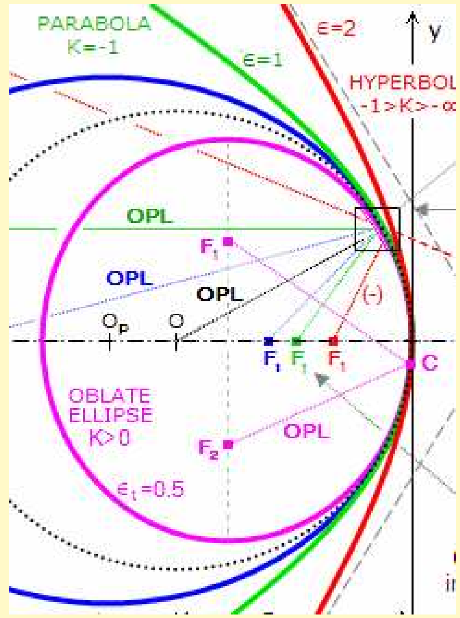
$= 0$ sphere

$= -1$ parabola

$0 < \kappa$ oblate elipsoid

$-1 < \kappa < 0$ prolate elipsoid

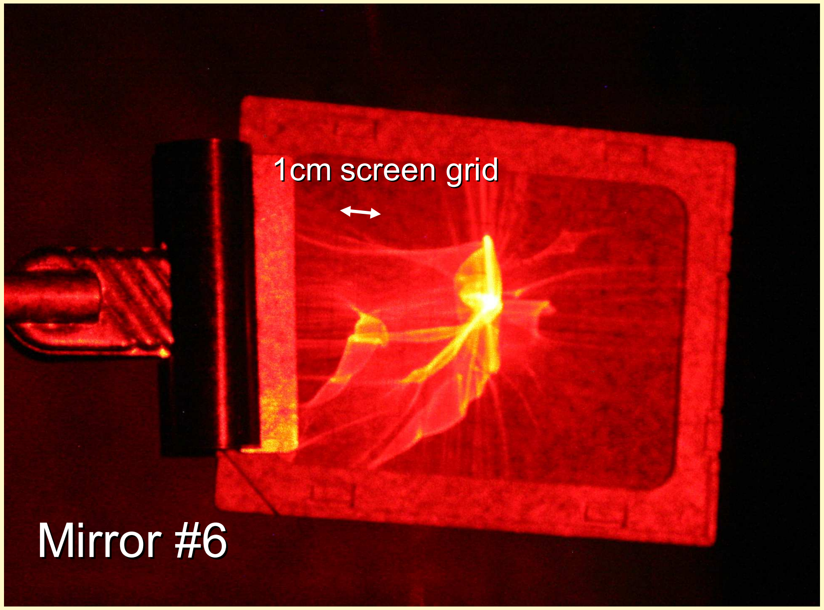
$\kappa < -1$ hyperboloid



- **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.**

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.

Detailed report at HallC-doc-716-v2.

Incorporate Oblate Mirror Shape in Geant4

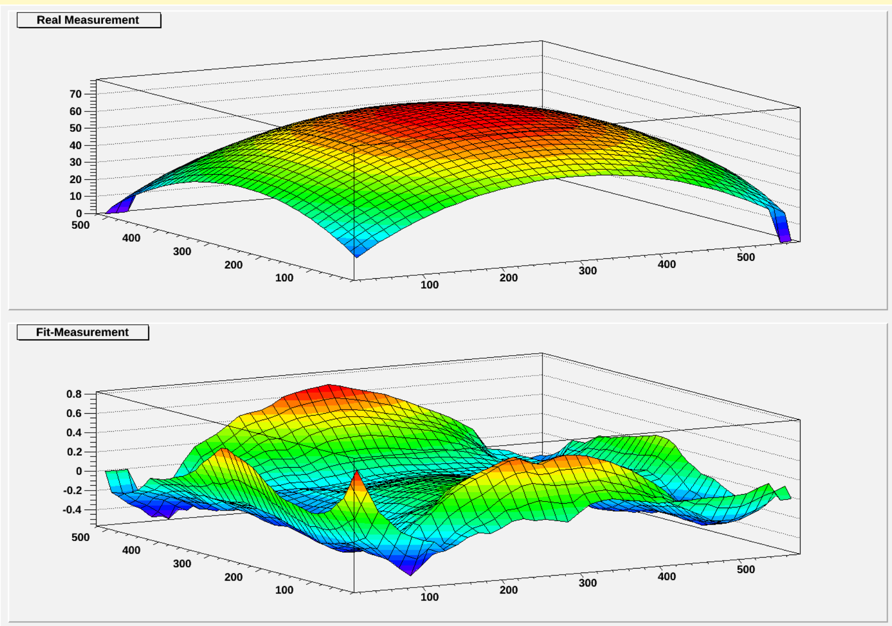
- Use General Ellipsoid quadratic surface construction.
  - Ellipsoid parameterization is different than conic section parameterization typically used in optics but provides an acceptable fit to mirror data.
- Use Mirror #6 parameters (neither best nor worst one):

```
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));
```

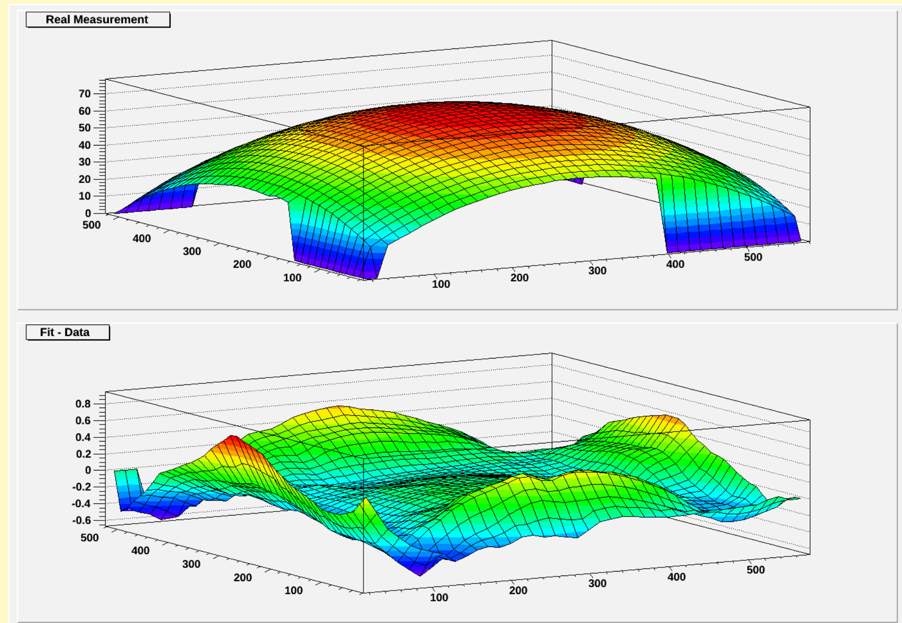
Mirror #6 curvature incorporated into Geant4

Mirror #6 is our 3rd-best mirror, expected to go into the detector.
Refit the curvature data with an ellipsoid:

Oblate conic fit



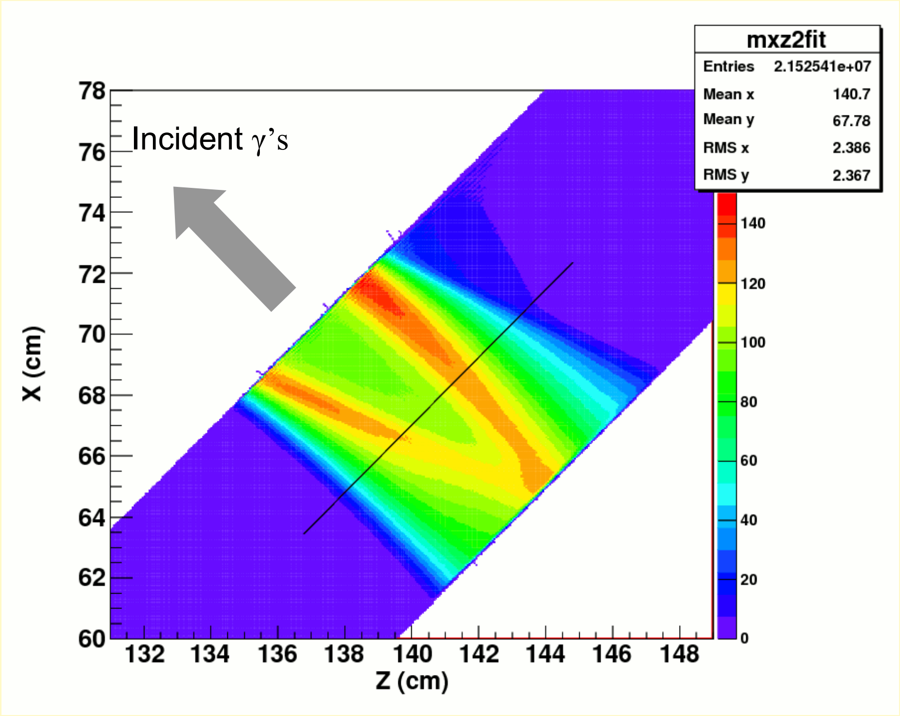
Ellipsoid fit

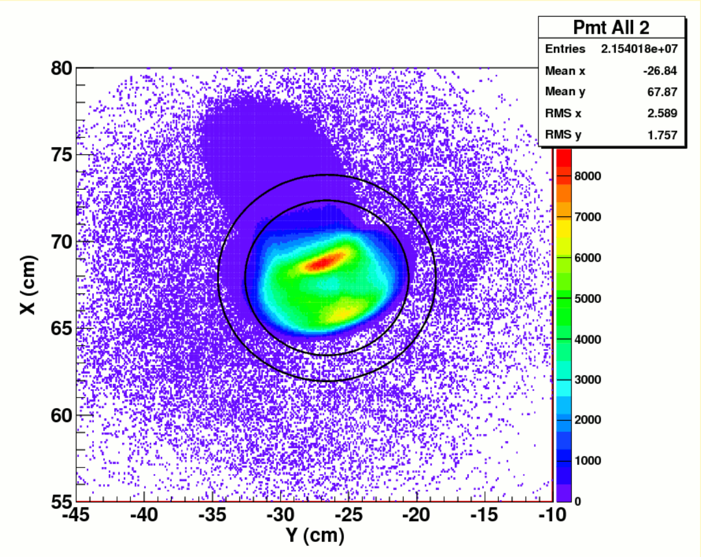


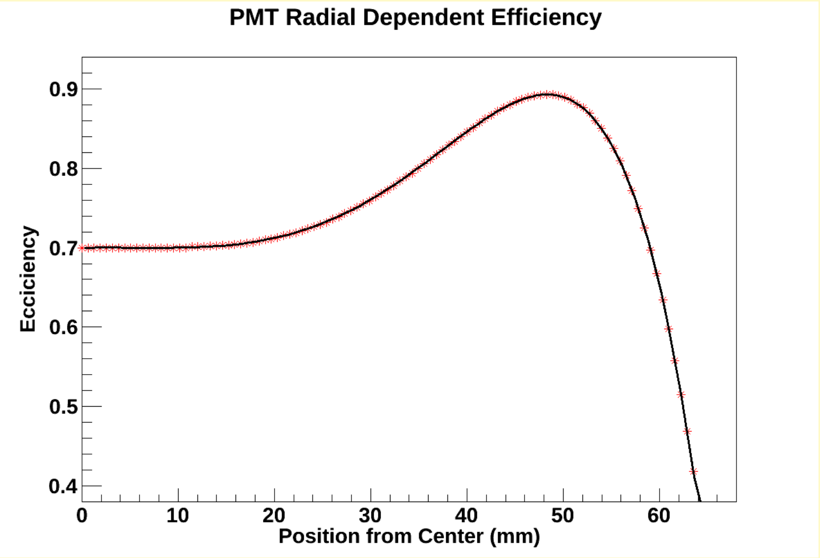
Deviations between data and fit somewhat smaller with ellipsoid function:

- In addition to being more convenient to model in Geant4,
- It also provides a more accurate representation of the mirror surface.

Detailed optimization of PMT position and angle





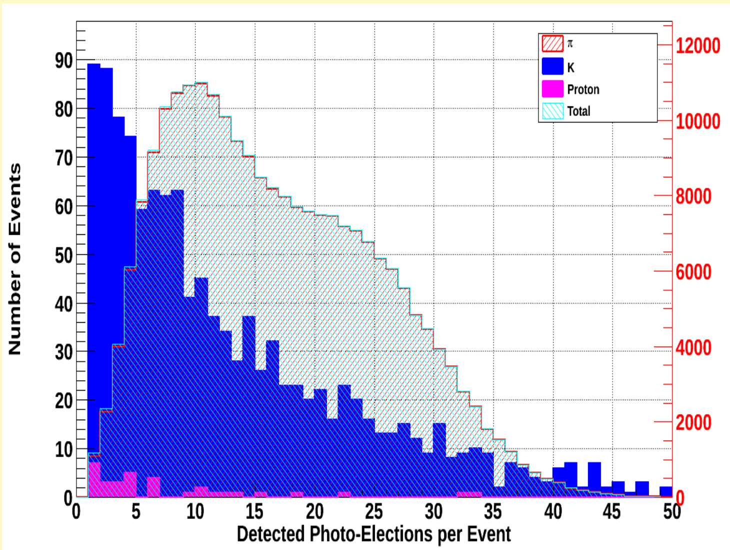


Simulations include:

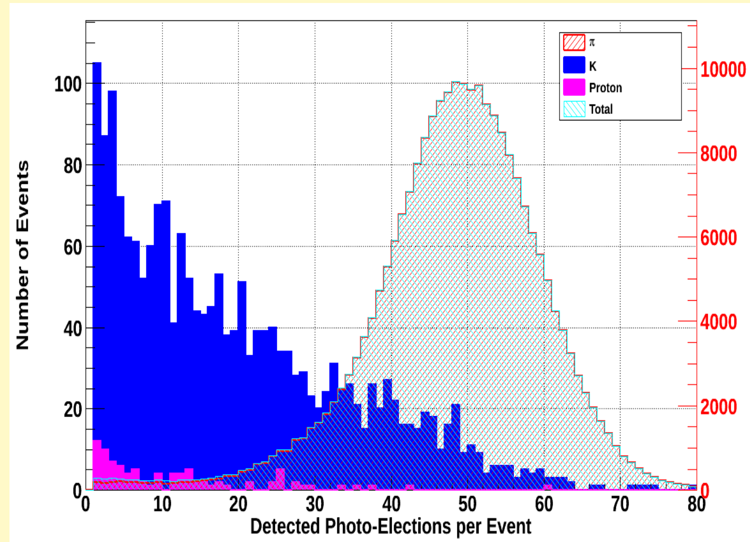
- Realistic oblate mirror shape.
- Position dependent PMT response.
- Reflectivity curve provided by vendor.

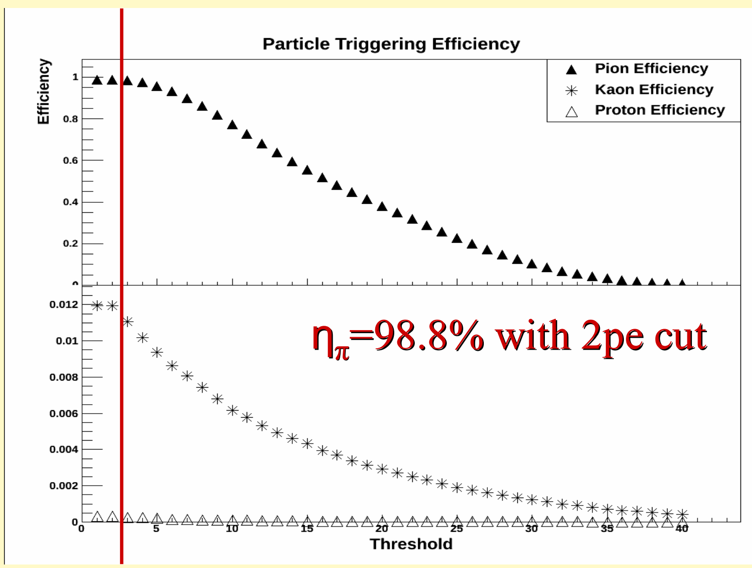
Predicted Performance for π^+, K^+, p

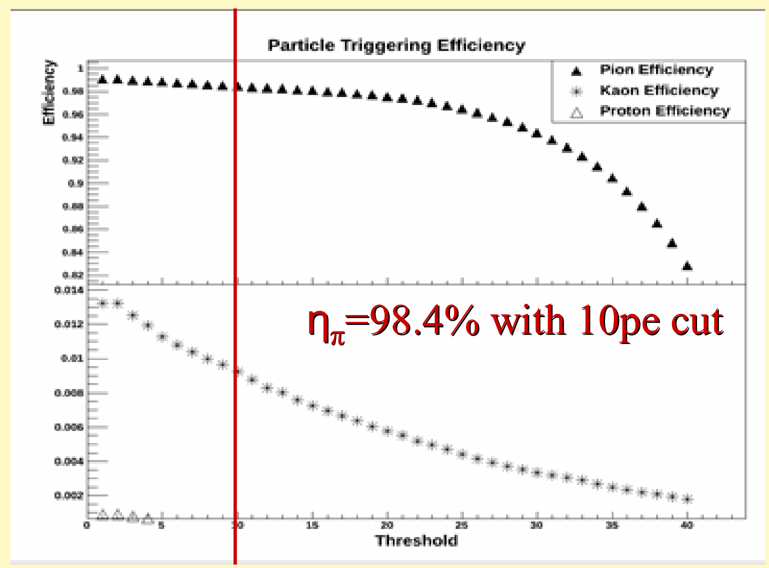
p_0=3 GeV/c



p_0=7 GeV/c







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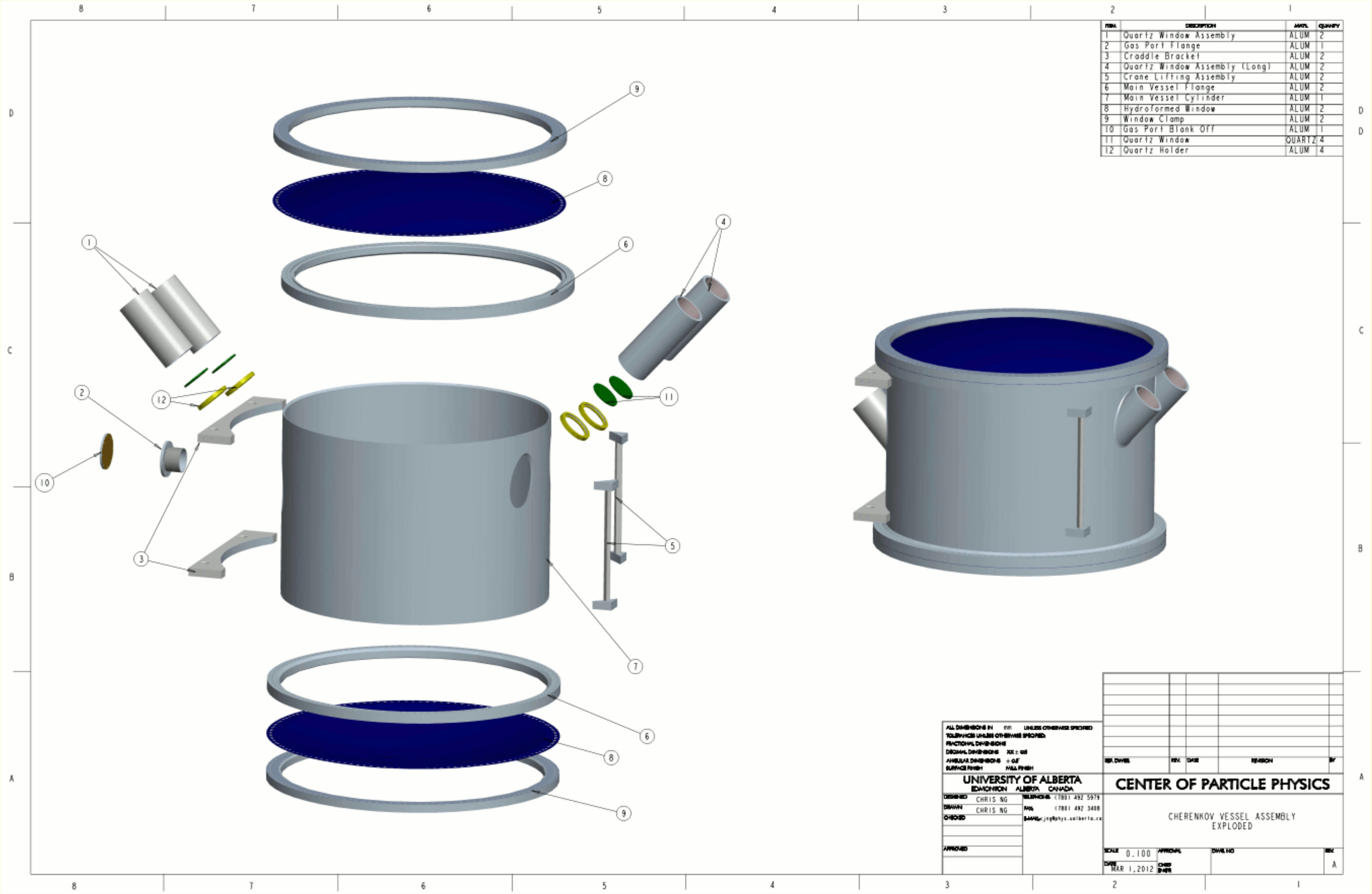
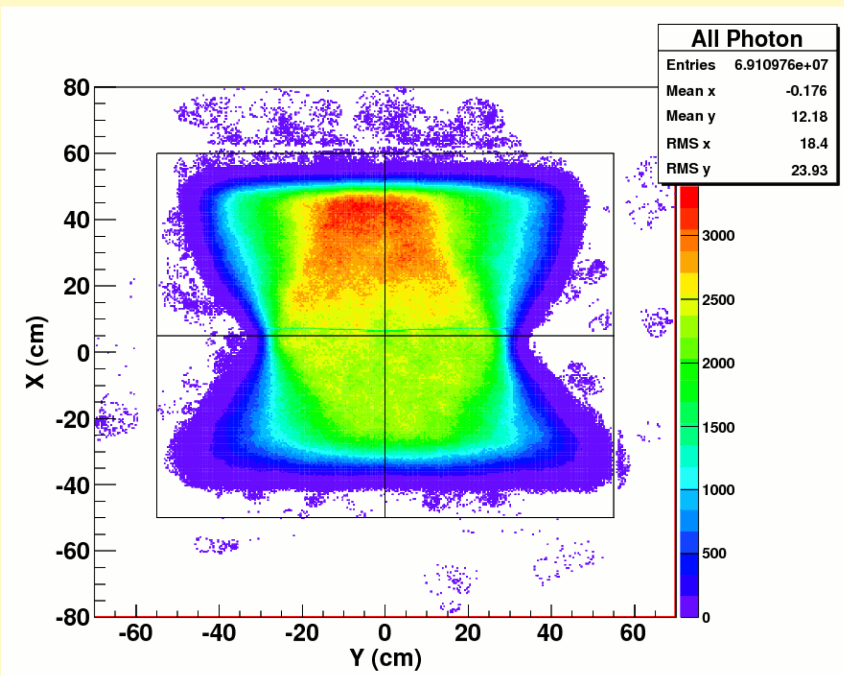
Engineering Review of Construction Drawings Completed

- Best bid received from HAI Precision Waterjets, Trenton, ON.
- Vessel delivery expected in mid-November.

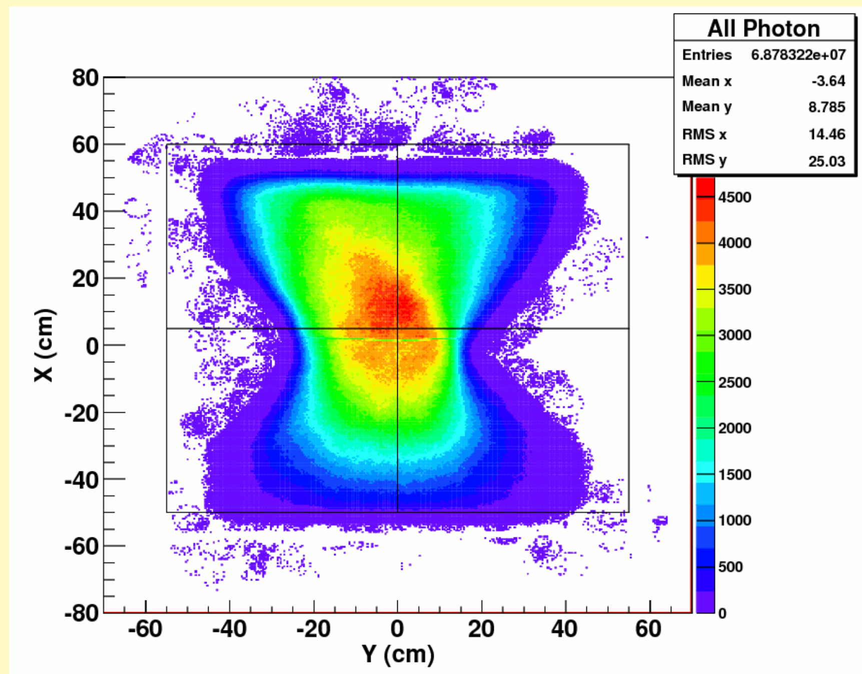


New SHMS Envelope Implications

- **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)

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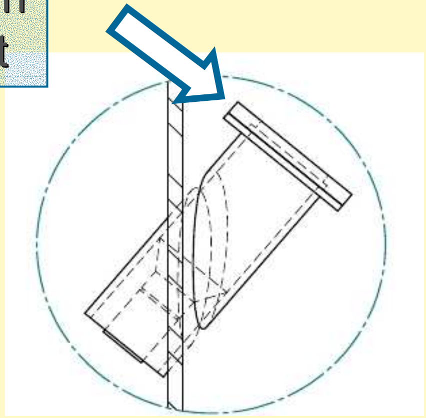
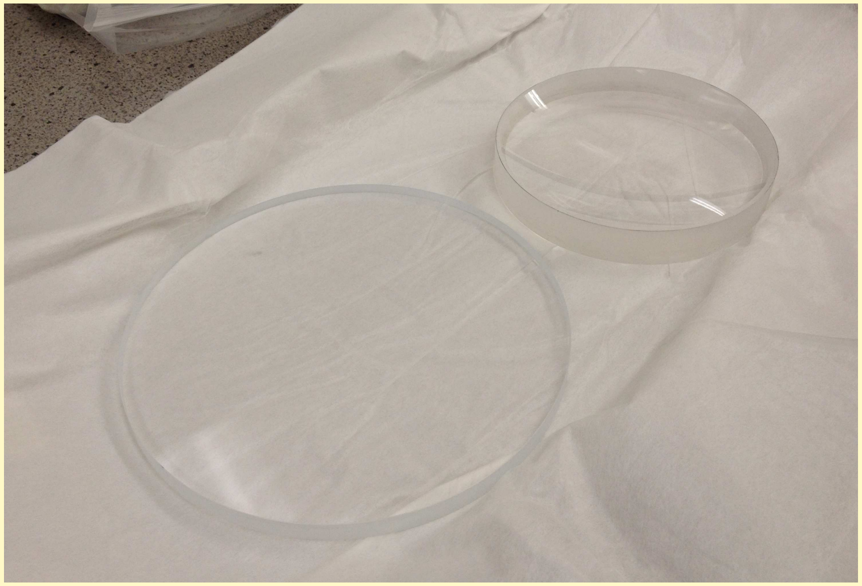
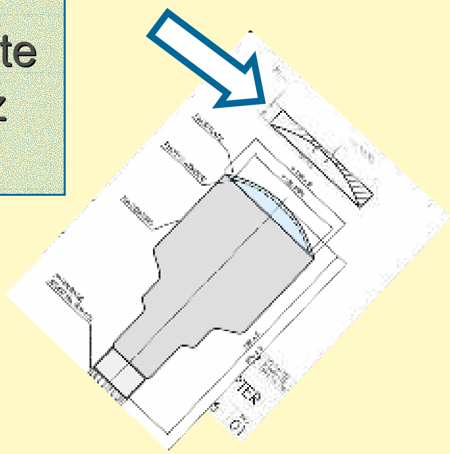
Quartz (Corning 7980) Windows and Adapters have arrived

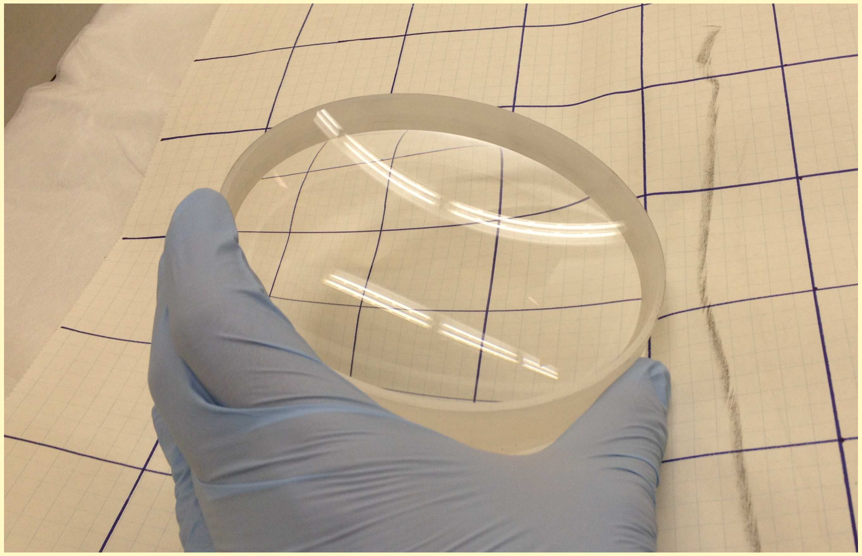
PMT views gas enclosure through a quartz viewport





An adapter is needed to mate PMT to quartz viewport.





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NSERC Equipment Grant Budget *(Updated Aug 22/12)*

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	$13,548.80	-$3,528.80
Mounting Assemblies		$5,633	?	?
3 Pressure Vessel	HCI Precision Waterjets / ASM	$60,304	$74,862.00	-$15,127.00
4 Shipping & Misc		$7,596	$3,404.50	$4,191.92
TOTAL		**$125,000**	**$124,121.35**	**-$8,556.90**