SHMS Heavy Gas Cherenkov Detector

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University of Regina

NSERC CRSNG

FRN: SAPIN-2016-00031
SAPEQ-390126-2010

Hall C Experimental Readiness Review. August 24, 2016.

SHMS Heavy Gas Cherenkov Overview

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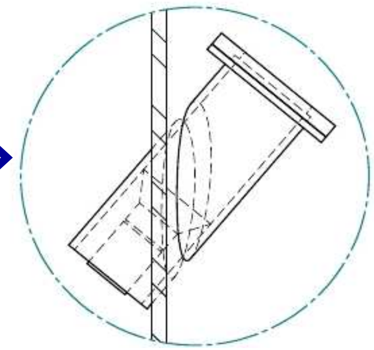
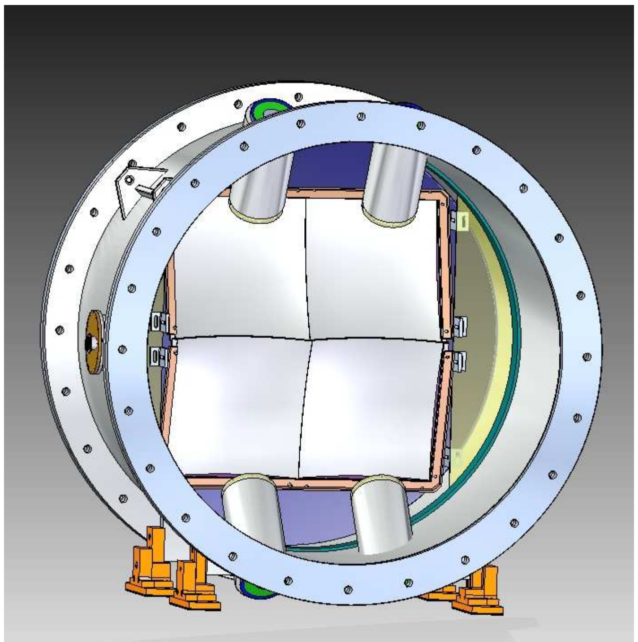
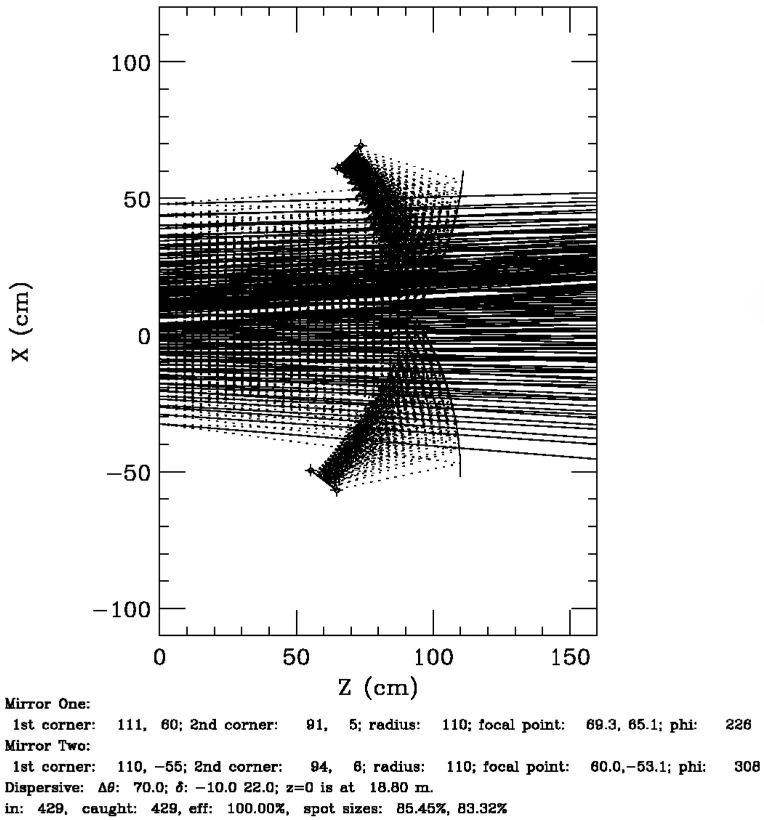
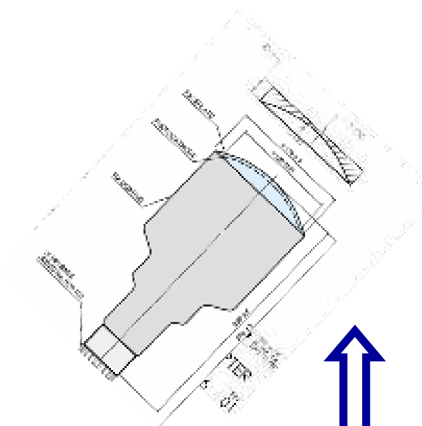
- Cylindrical aluminum vessel filled with C_4F_{10} @ $0.3<P<1.0$ atm for π /K separation.
- Alternately, can be filled with CO_2 for e/π separation

PMT views gas enclosure through a quartz viewport









An adapter is needed to mate PMT to quartz viewport. Coupled with RTV-615.

HGC Timeline / Studies Performed

- CD3 conceptual design review – Jan 2008
- Optics design using raytrace & Geant4 – 2008-10
- SHMS detector review – Aug 2009
- **3yr Equipment grant approved by NSERC – Apr 2010**
- Detailed CAD design, FEA calculations – 2010-11
- Optical studies of mirrors, determine oblateness – 2010-11
- **Hall C engineering review – Jan 2012**
- Measure UV reflectivity of aluminized mirrors – 2012
- PMT gain studies, discover ringing problem –– summer 2012
- Measure UV transmission through RTV – fall 2012
- Vacuum certification of vessel at HAI (Trenton, ON) – Jan 2013
- Optimize PMT coupling to quartz adapter – summer 2013
- Fix PMT ringing problem, notify Hamamatsu – summer 2013
- Complete fabrication, window hydroforming – Feb-June 2013
- Test assembly and mirror alignment in Regina – July 2013
- **Final assembly and alignment at JLab – Aug 2013**
- Test with cosmics in ESB – summer 2014
- **Install on SHMS – Apr 2015**

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PMT Tests with β-Čerenkov at Regina - 2012

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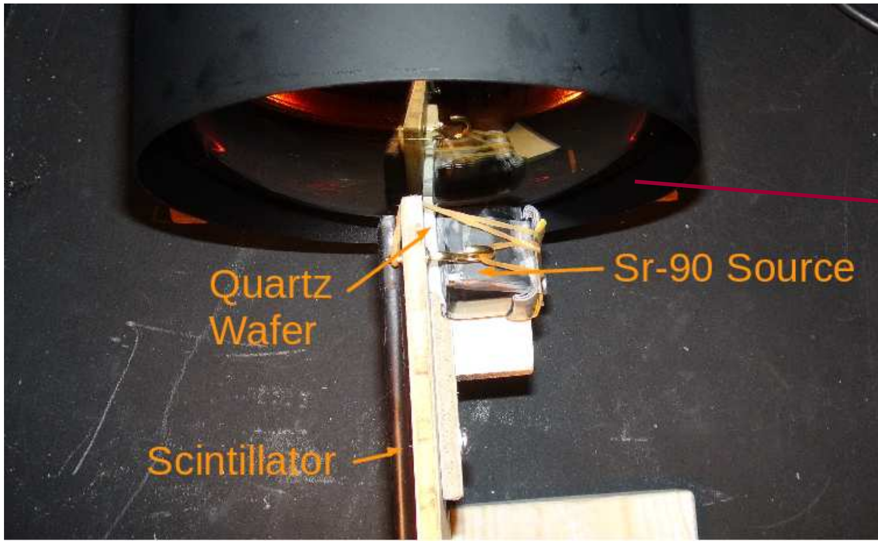
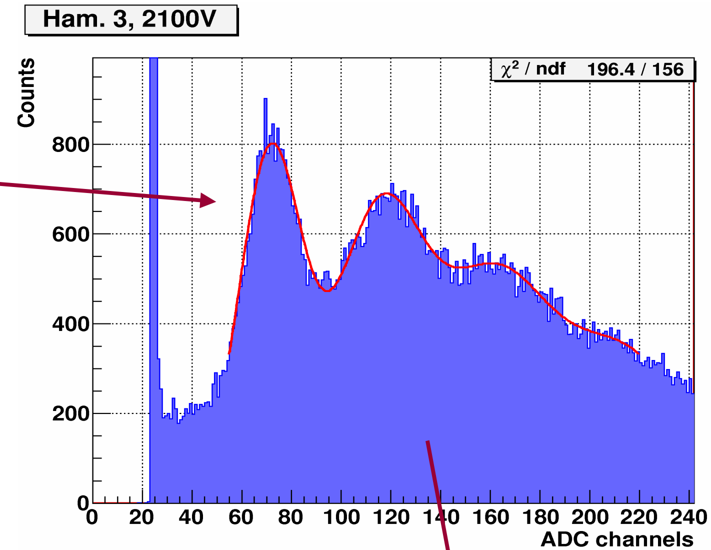
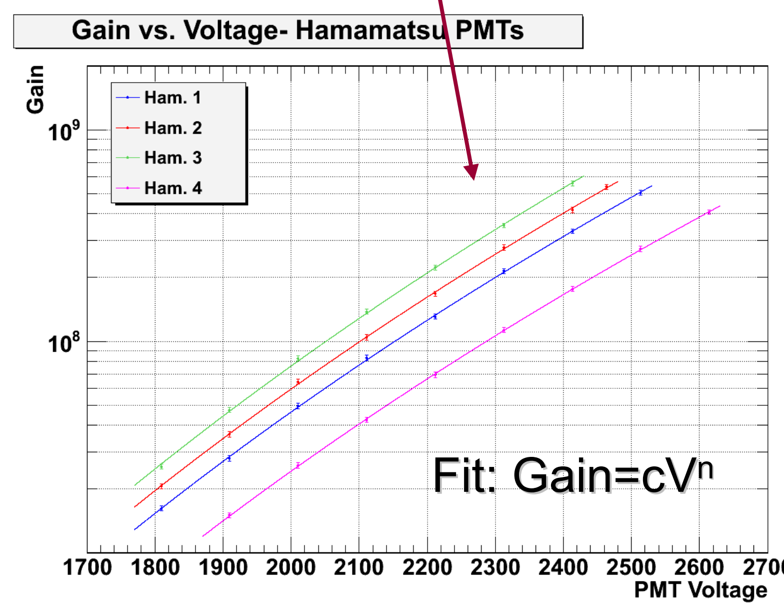




Hamamatsu R1584 PMT	Measure Gain ($x10^7$)	Manuf. Reported Gain @ 2000V	Meas. / Manuf.	Meas. n $\frac{G_1}{G_2}=\left(\frac{V_1}{V_2}\right)^n$
LA0271	4.63	3.20	1.45	11.20
LA0272	5.94	3.60	1.65	10.36
LA0273	7.64	5.79	1.32	11.30
LA0274	2.43	0.97	2.51	11.24



Detailed results in HallC-doc-738, 765

Mirror UV Reflectivity Tests at JLab - 2012

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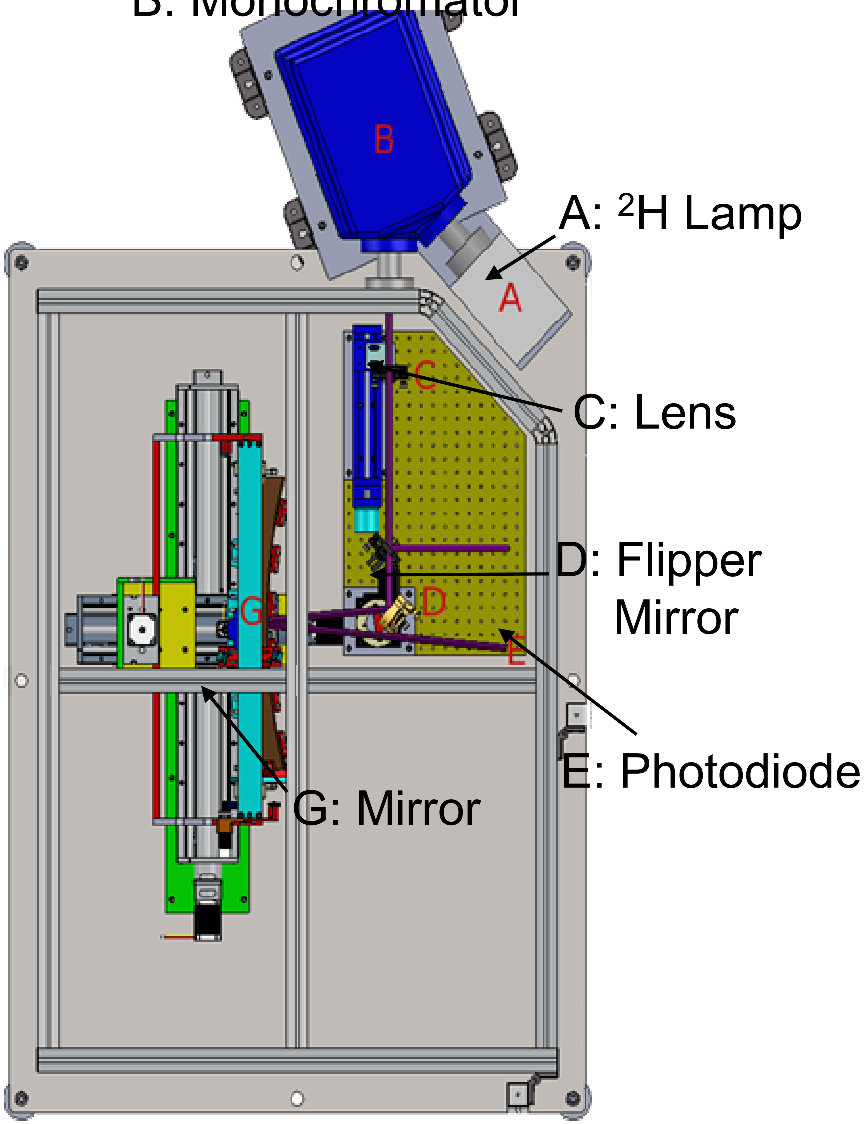
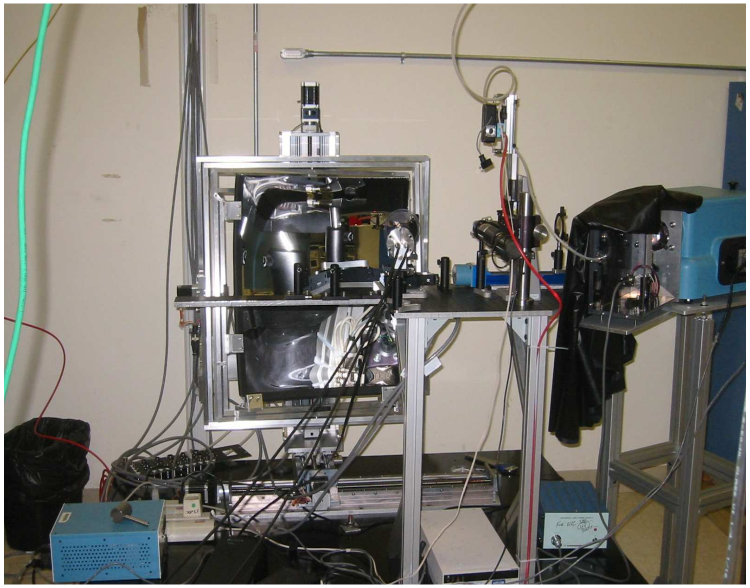
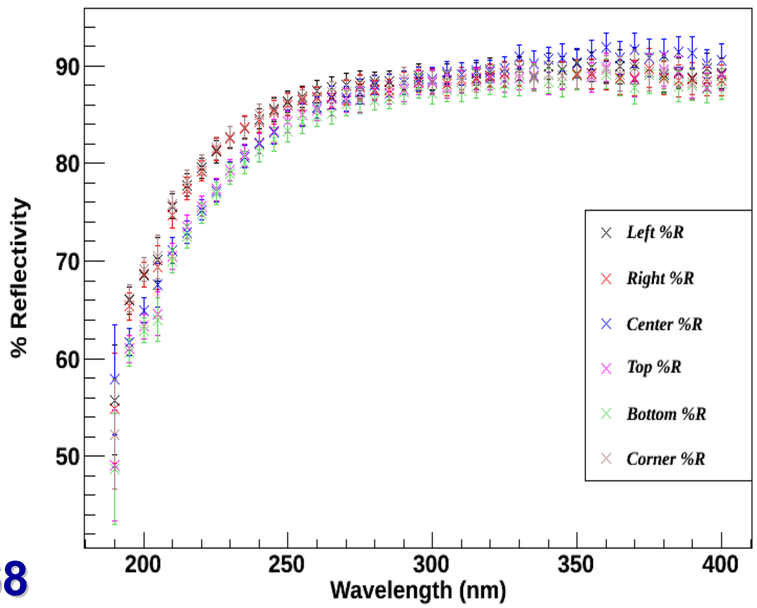




Real Mirror % Reflectivity



Detailed results in HallC-doc-735, 754, 768

Hydroforming and Test alignment at Regina - 2013

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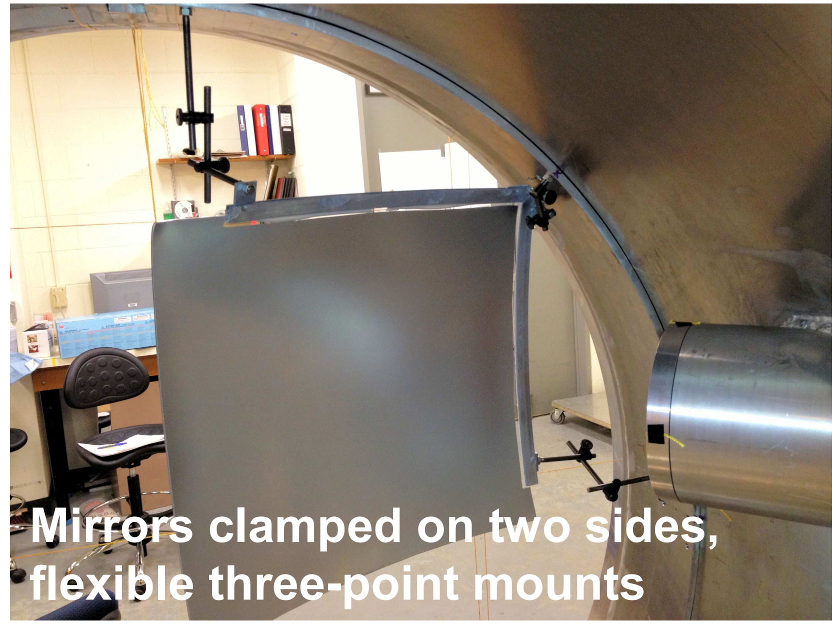
Hydroform AL 2024-T3
to JLab design spec



Mirrors clamped on two sides,
flexible three-point mounts

Initial mirror positions set to design
spec with measurement jig

Fine-tune mirror positions with
LED-light “Christmas tree”

Helium leak-check of Vessel at JLab - 2013

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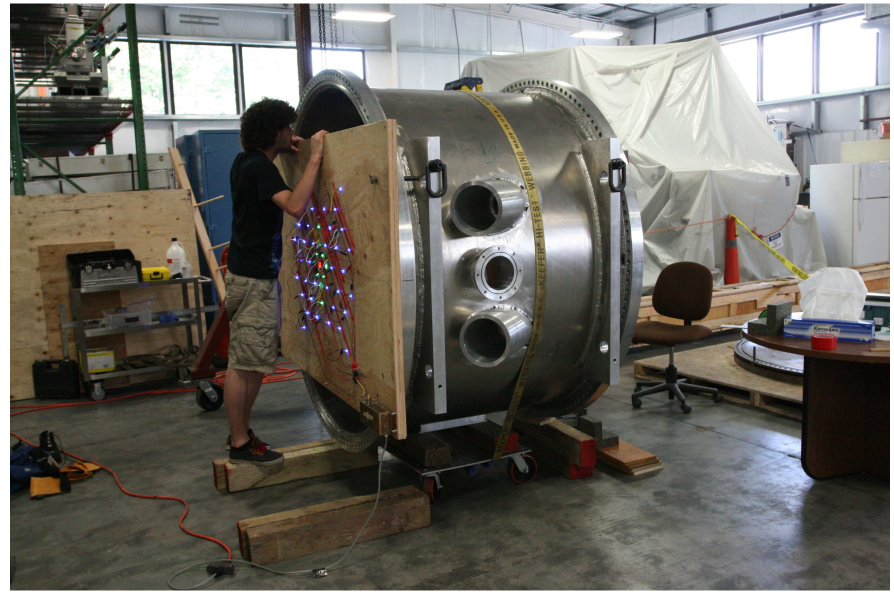
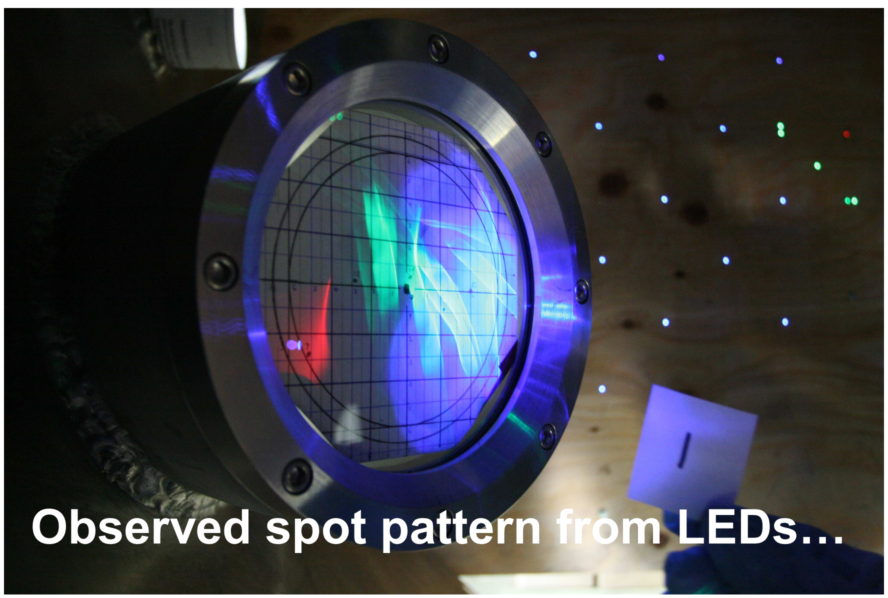
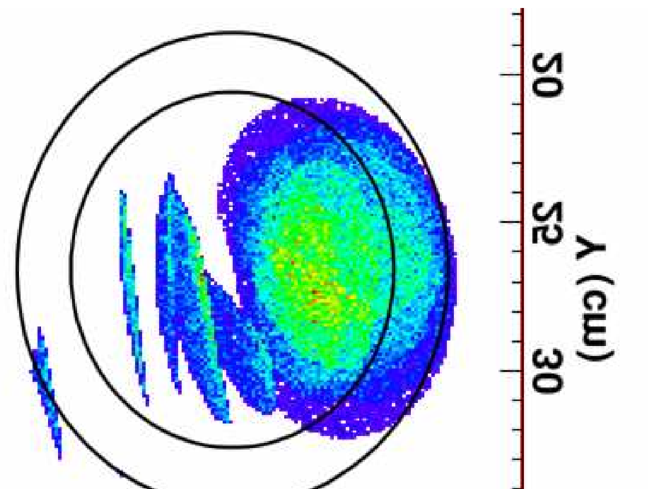
No leaks identified with He sniffer.
Evidence of AL outgassing overnight.

Mirror Assembly and Alignment at JLab - 2013





Observed spot pattern from LEDs…



Compared to GEANT4 simulation of "Christmas Tree"

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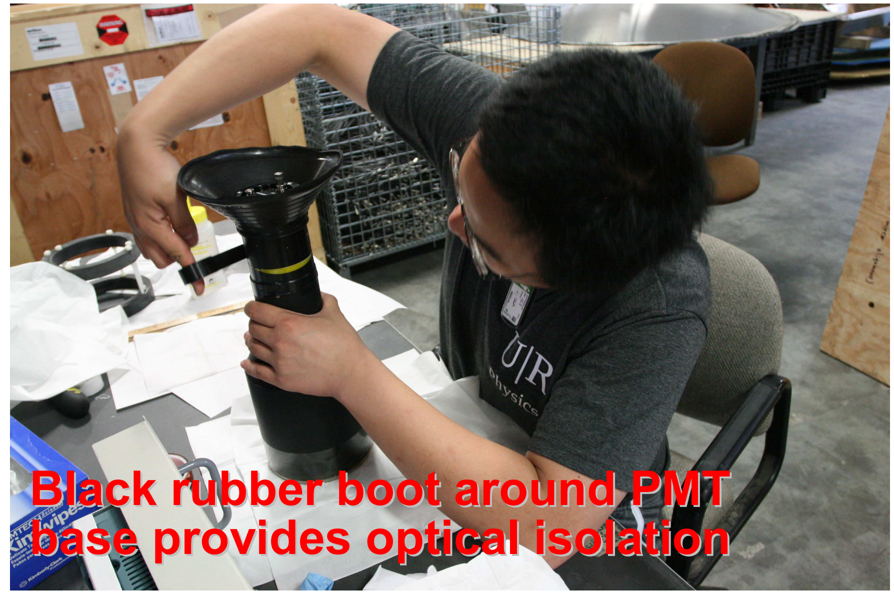
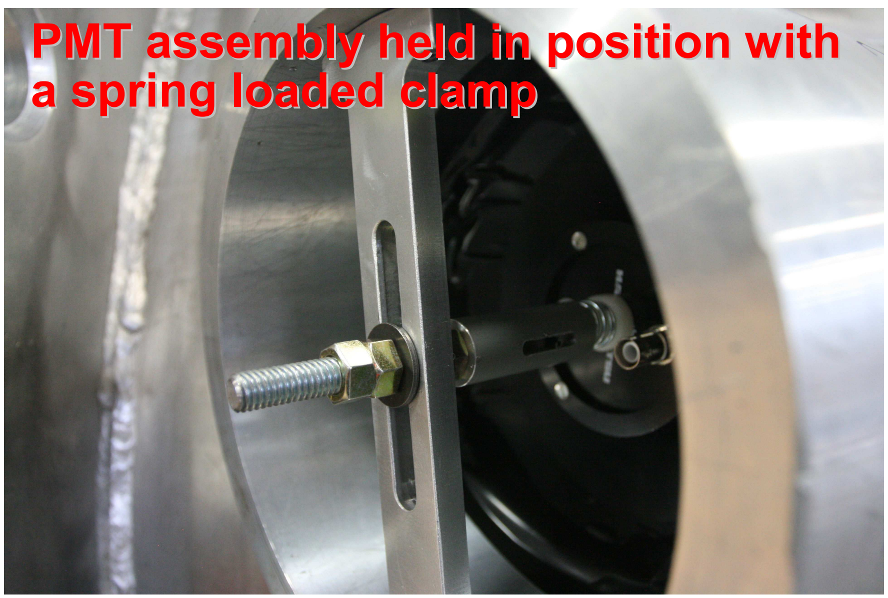
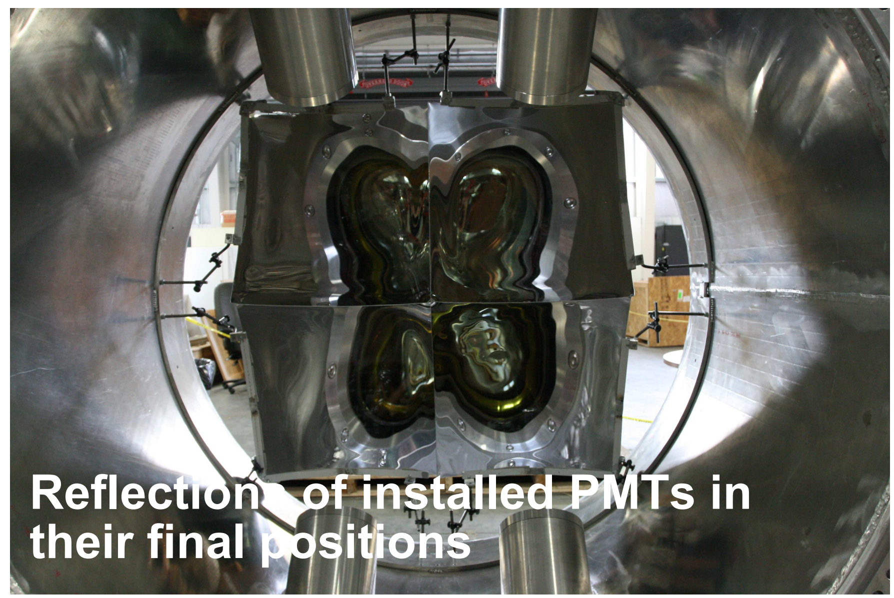
PMT and Quartz window Mating and Install - 2013







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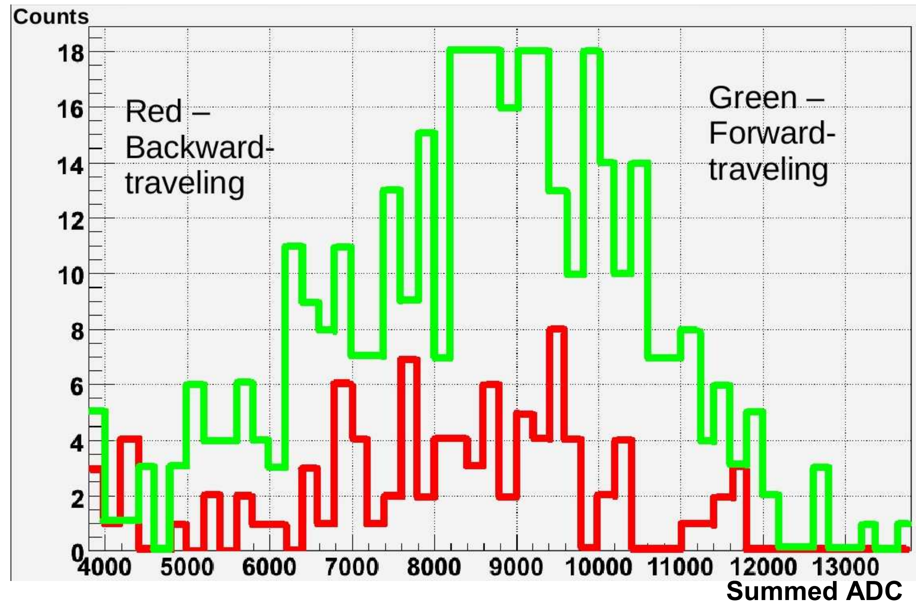
Cosmic Ray Tests in ESB - 2014

HGC cosmic test setup in ESB.
- Triggers only lower right PMT.
- Filled with 1 atm CO_2.



Although cosmic trigger rate was very low, we observe evidence of Čerenkov light produced by nearly-horizontal cosmics traversing HGC (green curve).
HGC PMT2 @ -2100V

Detailed results in HallC-doc-801

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Installation in Hall C – April 2015

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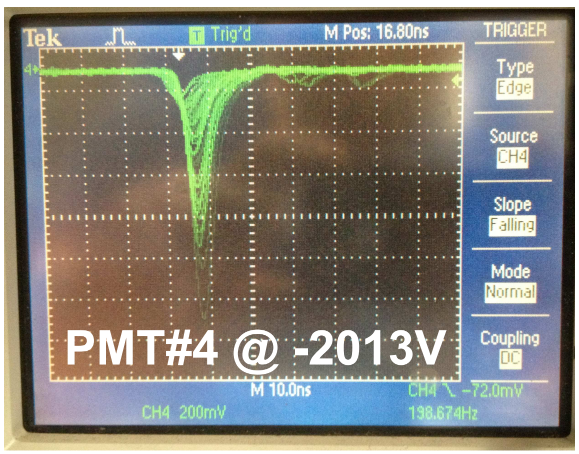


PMT Pos.	R1584 PMT	Meas. Gain ($x10^7$)	Gain scaling param. n	Calc. HV for $G=5x10^7$	Manuf. Anode Dark Current	Meas. Rate > 100mV (Hz)
1 (LL)	LA0274	2.43	11.24	-2132	90.0	80-100
2 (LR)	LA0272	5.94	10.36	-1967	210.0	300-350
3 (UL)	LA0273	7.64	11.30	-1926	120.0	50-55
4 (UR)	LA0271	4.63	11.20	-2013	130.0	120-130

More info in hclog # 3332718, 3333557

Cherenkov Calibration Experience

- We have experience analyzing and calibrating Cherenkov detector data.
- Ready to calibrate HGC with SHMS data!

HMS Aerogel Cerenkov Calibration for Fpi-2

Garth Huber (huberg@uregina.ca)
February 26, 2004

Abstract

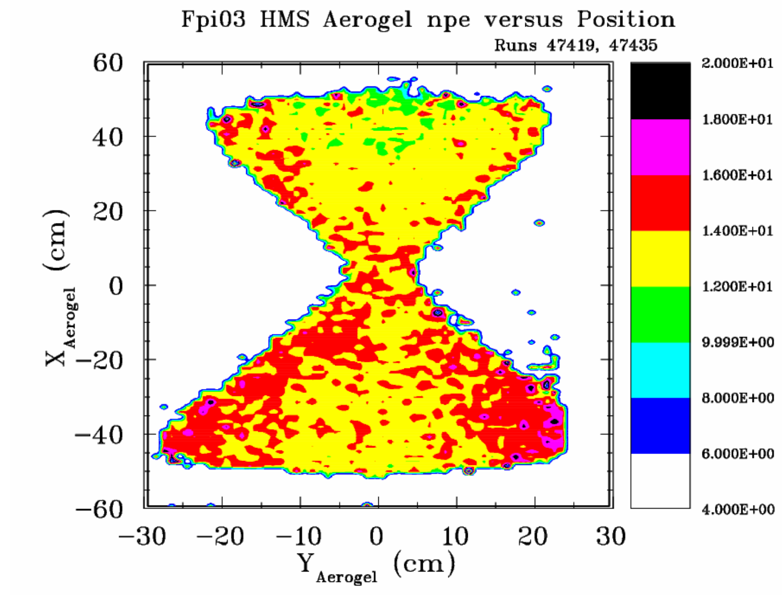
Details regarding the calibration of the HMS aerogel Cerenkov detector are presented.

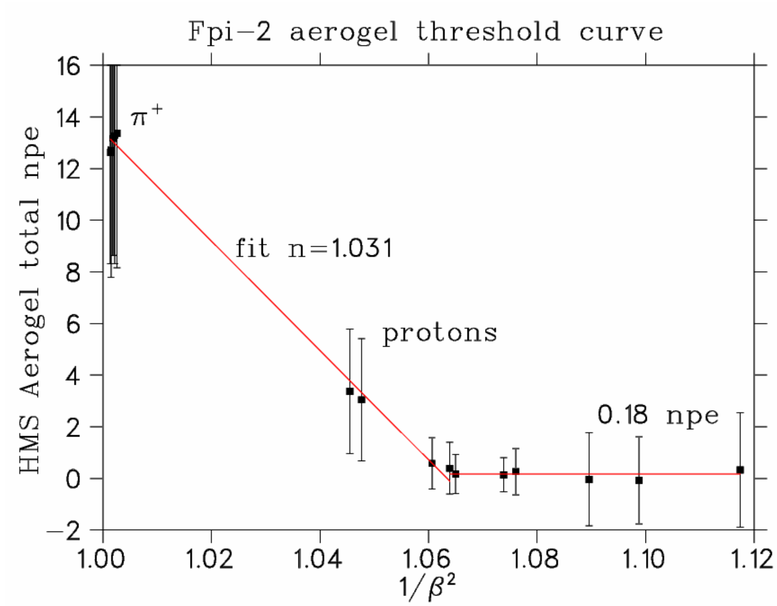
1 Calibration Method

The aerogel Cerenkov adcs were calibrated with a new kumac titled `haero_calib.kumac`. The main points of this calibration are as follows:

1. The calibration kumac makes use of the haero-npe-pmt histograms rather than the typically-used raw adc spectra. This is because the haero-npe-pmt histograms have had their pedestals subtracted, where the pedestals are determined from the 1000 pulser events at the start of every run. As shown in this report, this treatment of the pedestal yields a stable calibration, and so seems to be an appropriate way to proceed.
2. Because the pedestals are already subtracted, in order to calibrate the detector it is only necessary to determine the pmt gain parameters. These correspond to the adc values of the single photoelectron peaks, after pedestal subtraction.
3. As shown in Fig. 1, the 1 p.e. peak positions are determined by fitting a Gaussian to the top of the 1 p.e. peak. The region of channels for which the fit is determined is very restricted, in order to keep the fit value from being skewed by the non-Gaussian shape of the rest of the histogram.
4. A caution to future users of this kumac is that because of the use of the haero-npe-pmt histograms, the initial gain parameters stored in `haero.param`, used in the first replay of the data, must be consistent with those assumed in the `haero_calib.kumac`, so that the correct gain parameters can then be calculated from the haero-npe-pmt data. If these two sets of parameters are inconsistent, erroneous gain parameters will be output.

Detailed results in HallC-doc-802





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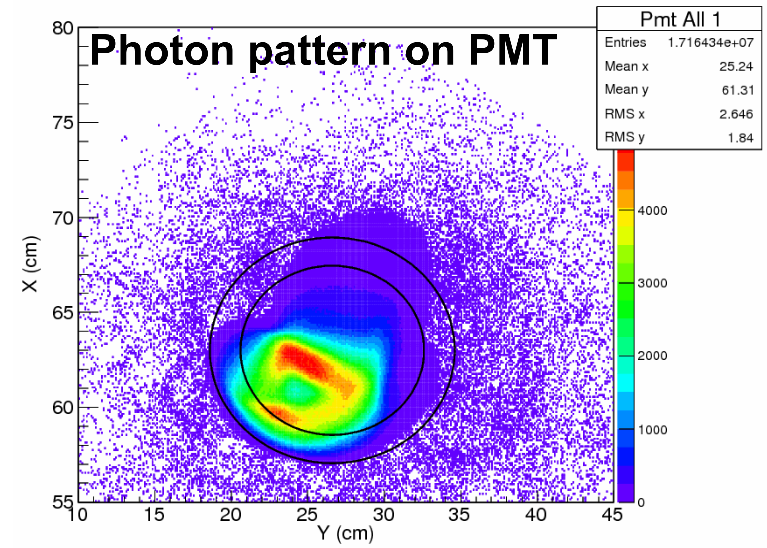
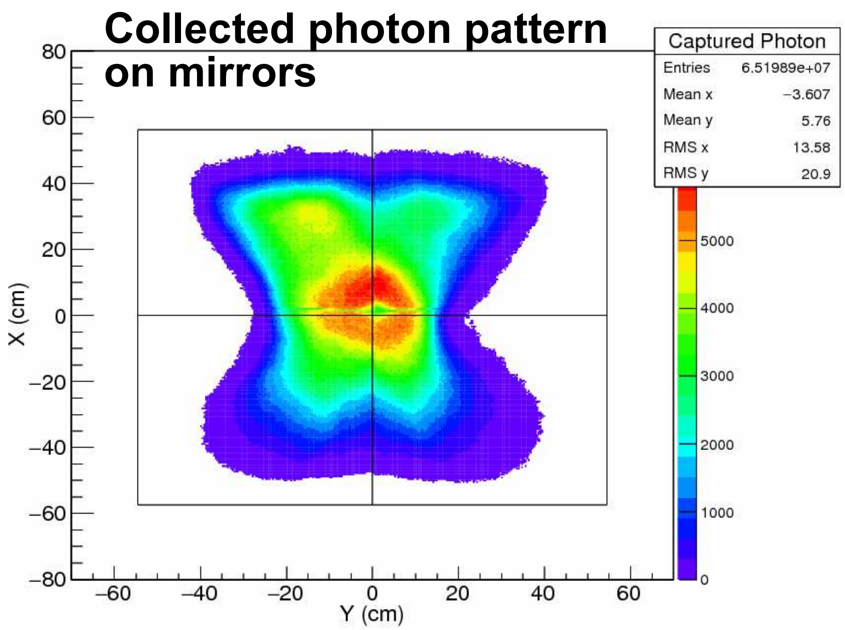
Optics Simulations - 7 GeV/c π @ 0.95 atm

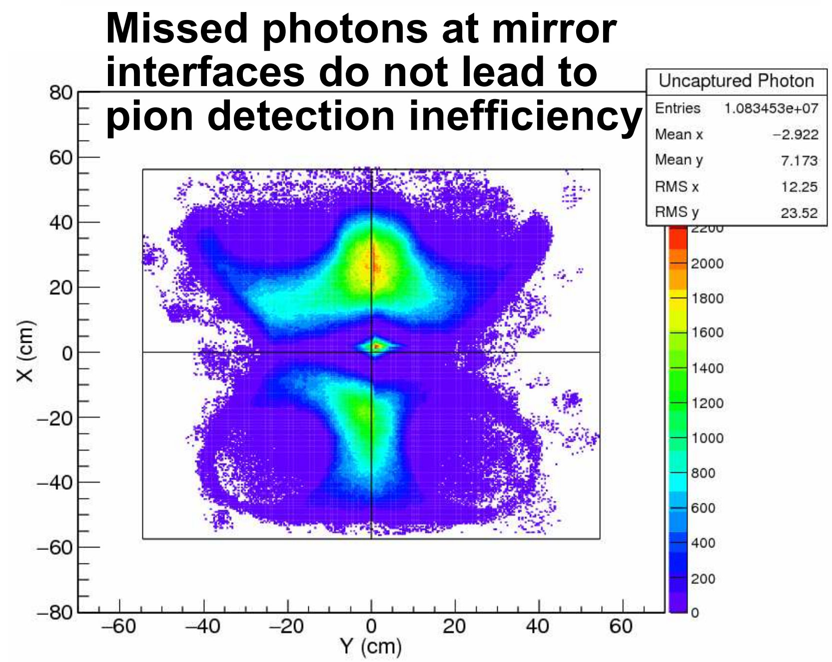
Cherenkov cone angle largest at 7 GeV/c (2.84°) → light hardest to focus.



GEANT4 Simulation includes:

- C_4F_{10} properties vs wavelength
- Measured 4 mirror oblateness
- Measured AL reflectivity vs wavelength
- Quartz adapter losses vs wavelength
- PMT efficiency vs wavelength





Details in JLAB-PHY-12-1697 (M.Sc. thesis)

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Projected Performance for $\pi^+:K^+:p$ = 5:3:2

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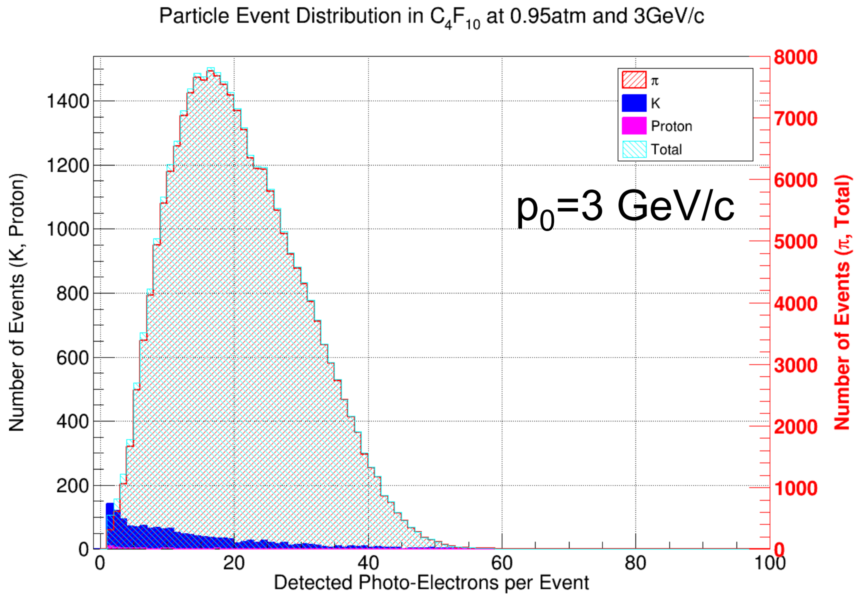
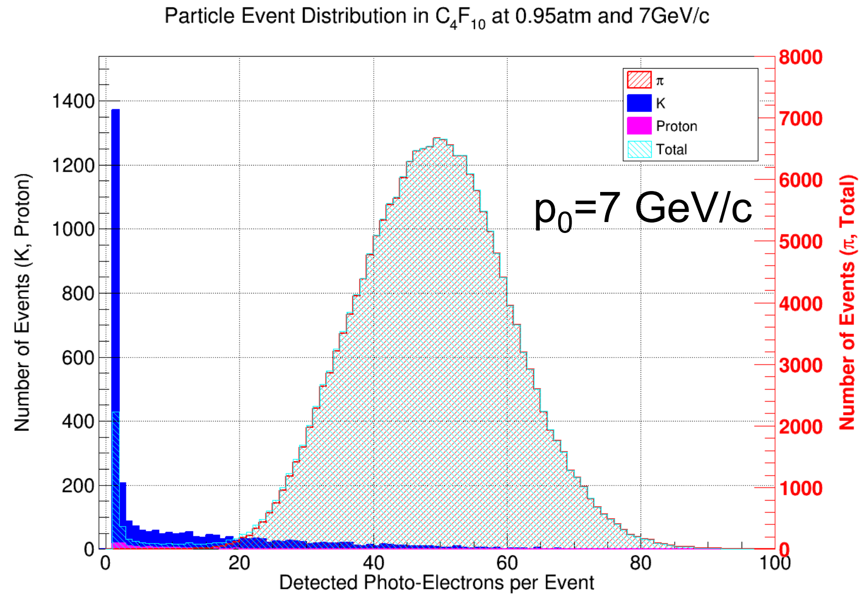
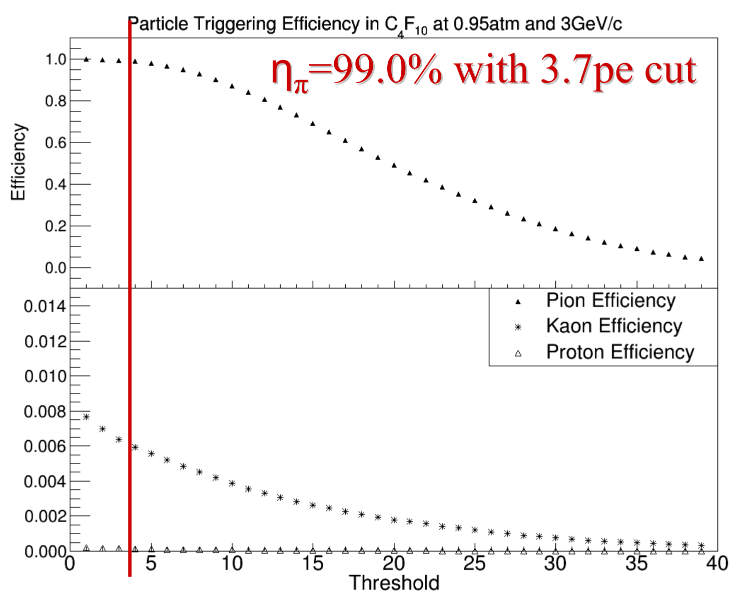
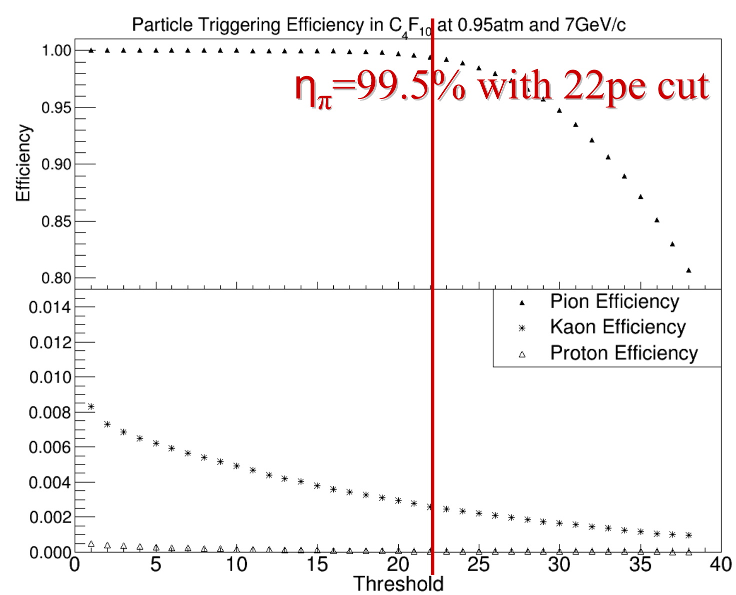




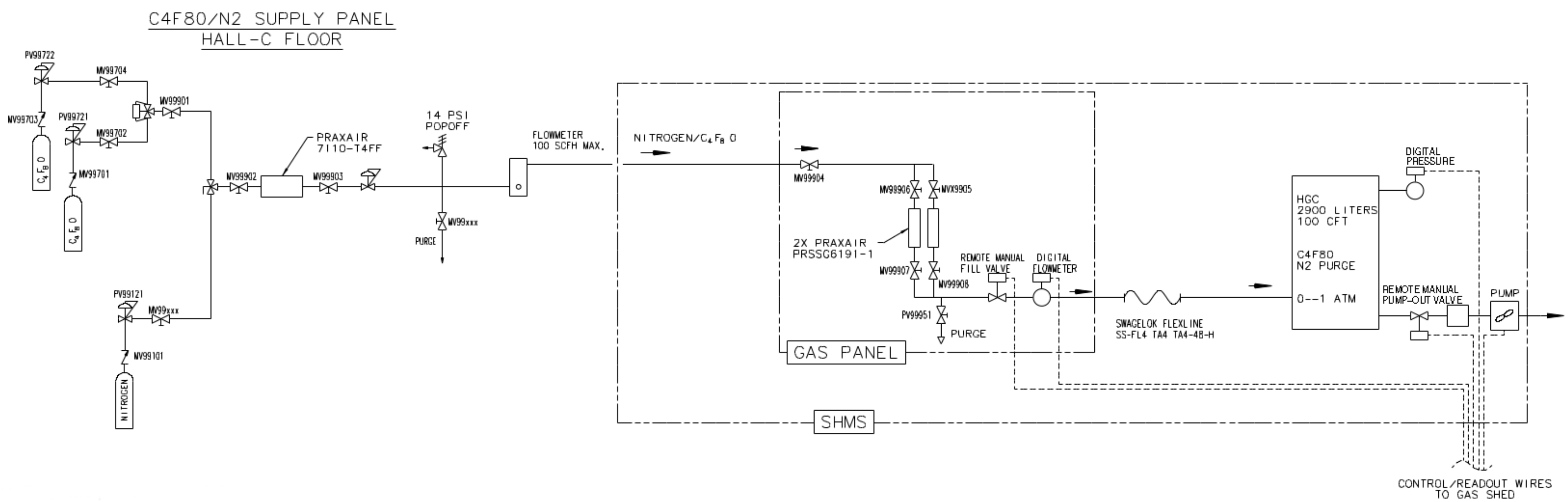




Detailed results in HallC-doc-803, 804

HGC Gas Handling System

- Gases: C_4F_8O, C_4F_{10}, CO_2.
- Pump and purge to clean out tank.
- Fill to desired pressure.
- Systems protected against overpressure with software interlocks and pop-off valves.
- Initial gas inventories on-site now.
- Gas bottles mounted on SHMS carriage at floor height.
  - Dual bottle manifold for primary gas.
- Pressures monitored & logged.



This information provided by Brad Sawatzky

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U.Regina Manpower

- **Garth Huber,** Faculty
  - Project leader.
- **Zafar Ahmed,** PDF
  - Helped write and test hcana, including portions needed for HGC analysis and efficiency calculations.
- **Wenliang Li,** Ph.D. student (graduating summer 2017)
  - Helped design, construct and align the HGC as part of his M.Sc. and Ph.D. studies.
- **Dilli Paudyal,** Ph.D. student (graduating summer 2017)
  - Available to help with shifts.
- **Samip Basnet,** Ph.D. student
  - Getting Hall C hardware experience this summer.
  - Experienced with SIMC and rate calculations.
- **Ryan Ambrose,** M.Sc. student
- **Rory Evans,** M.Sc. Student
  - Two new students to help with shifts and calibrations.
- **Matthew Strugari,** B.Sc. Student
  - Performed 2016 GEANT4 simulation studies.

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Backup Slides

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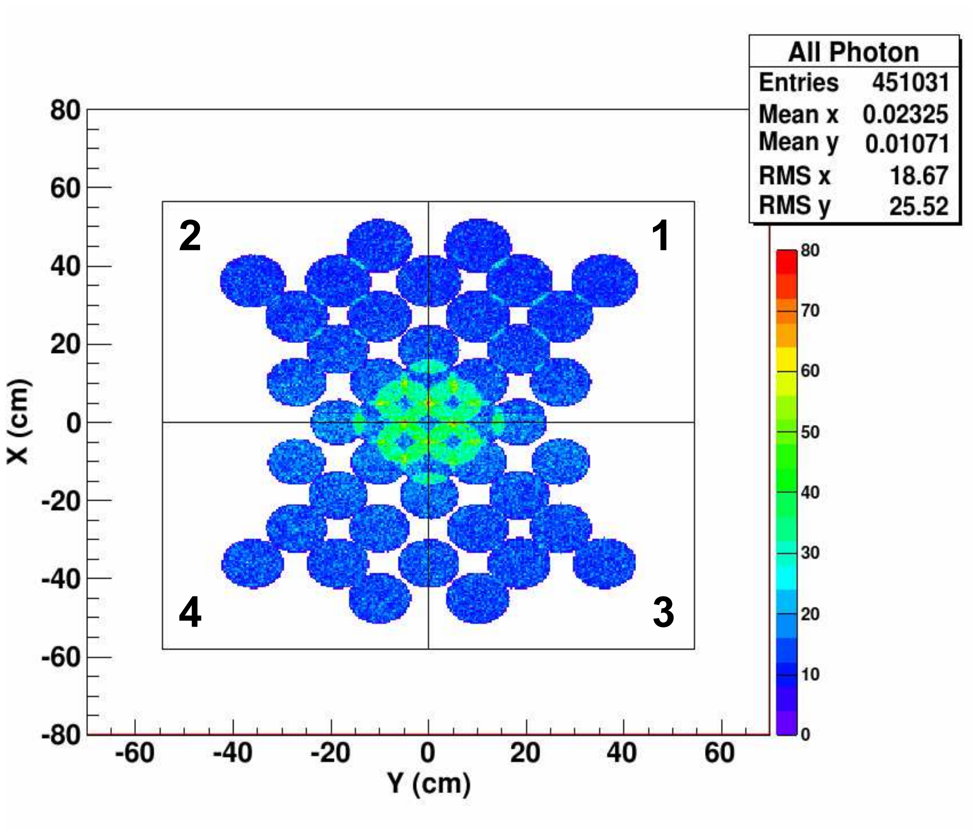
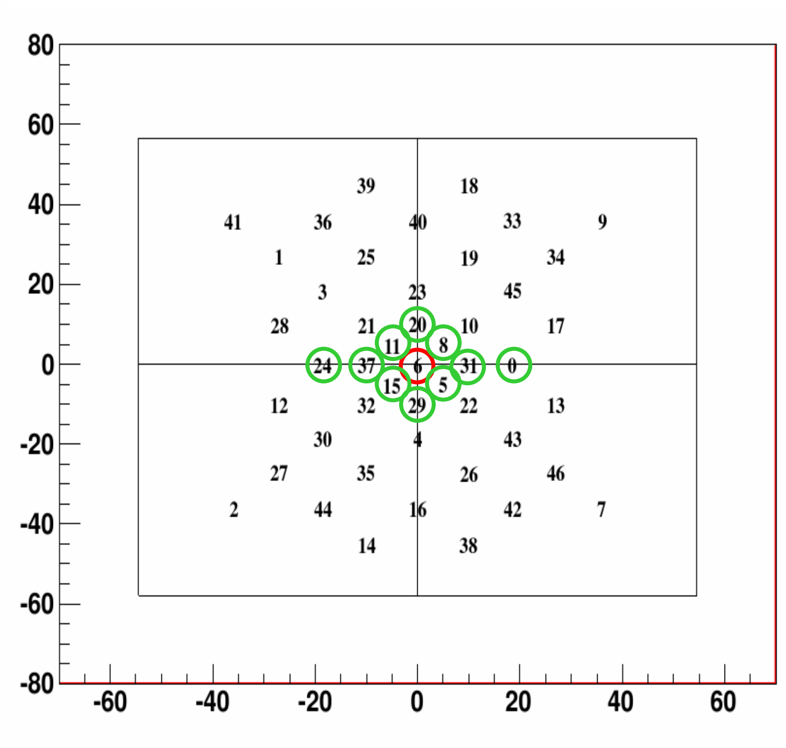
LED pattern replicates light pattern on mirrors





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How Slumped Mirror Blanks are Made

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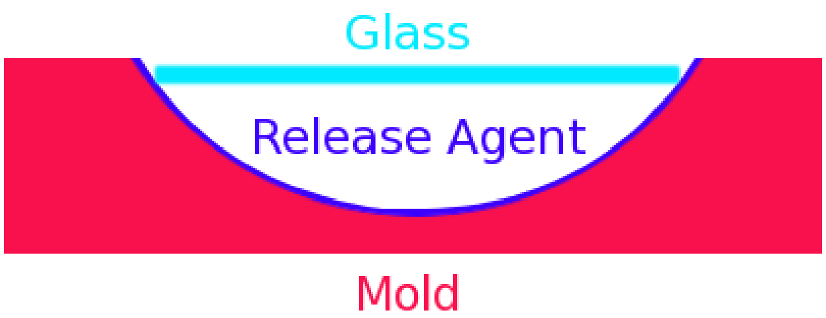

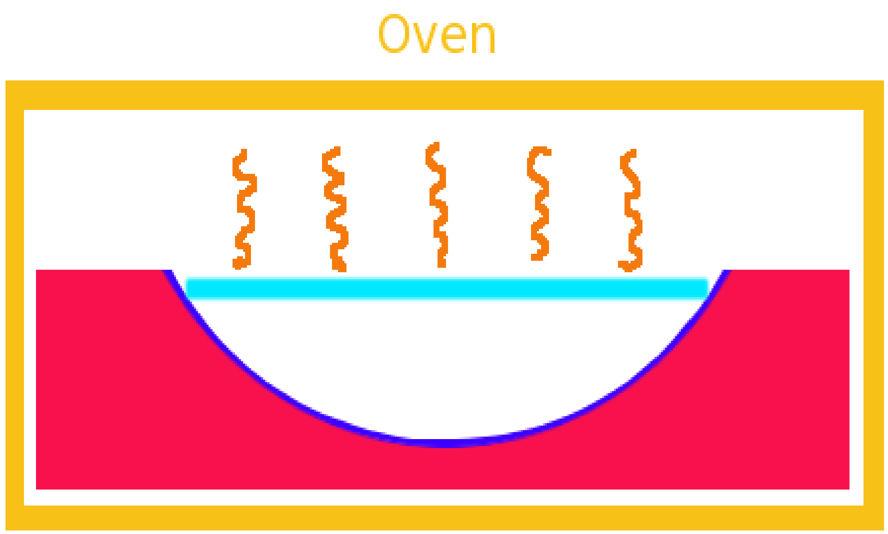

Stage 1:

- 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

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- **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

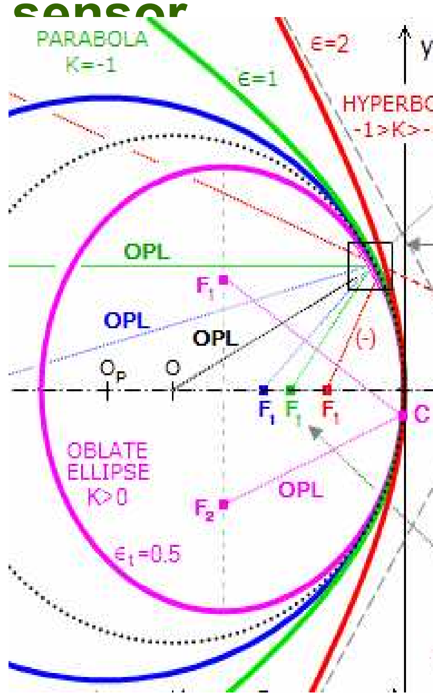
$= 0$ sphere

$= -1$ parabola

$0 < \kappa$ oblate elipsoid

$-1 < \kappa < 0$ prolate elipsoid

$\kappa < -1$ hyperboloid

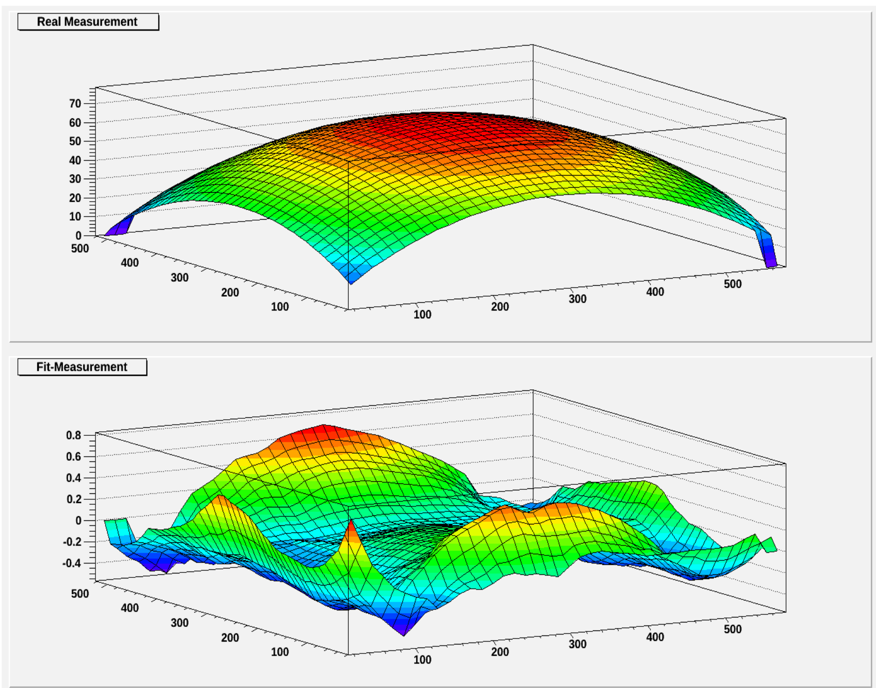


- **Nearly all mirrors displayed some degree of oblateness.**
  - Possibly due to contraction of glass during cooling after slumping.
- **The worst mirrors had varying curvature across their surface, due to various deformations.**

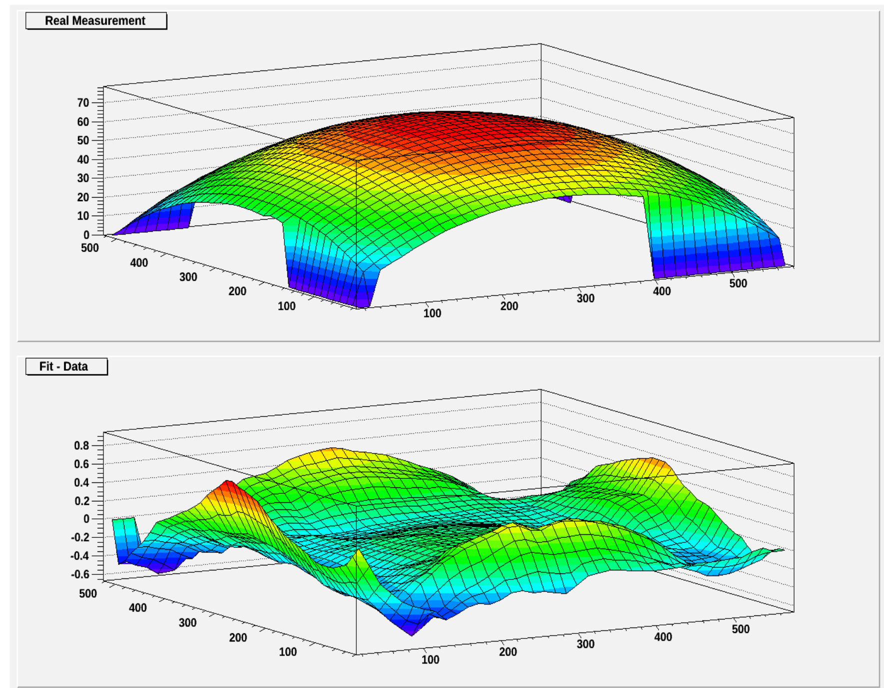
Mirror #6 curvature incorporated into Geant4

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.

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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));
```

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