

# SHMS Gas Čerenkov Detectors January 2010 Update

Garth Huber



UNIVERSITY OF  
REGINA

# Outline

- **Brief Overview.**
  - Noble Gas Čerenkov (U. Virginia)
  - Heavy Gas Čerenkov (U. Regina)
- **Heavy Gas Čerenkov detailed cost estimate for NSERC grant proposal.**
- **Preliminary FEA calculations of entrance window from University of Alberta.**
- **Geant4 3D Optics Simulations Update.**
- **DRAFT Heavy Gas Čerenkov Time Line.**

# Noble Gas Čerenkov : e/ $\pi$ separation

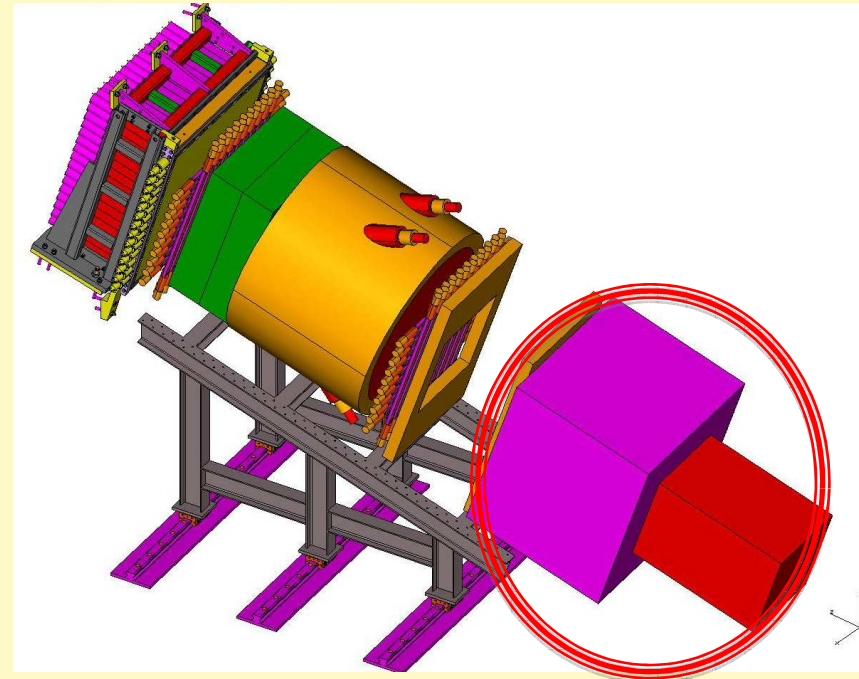
**e/  $\pi$  - separation requires**

$$1/\beta_{e,\min} < n < 1/\beta_{\pi,\max}$$

**$\pi$  threshold at 1 atm:**

- **Argon: ~5.5 GeV/c.**
- **Adding Neon: up to 11 GeV/c.**

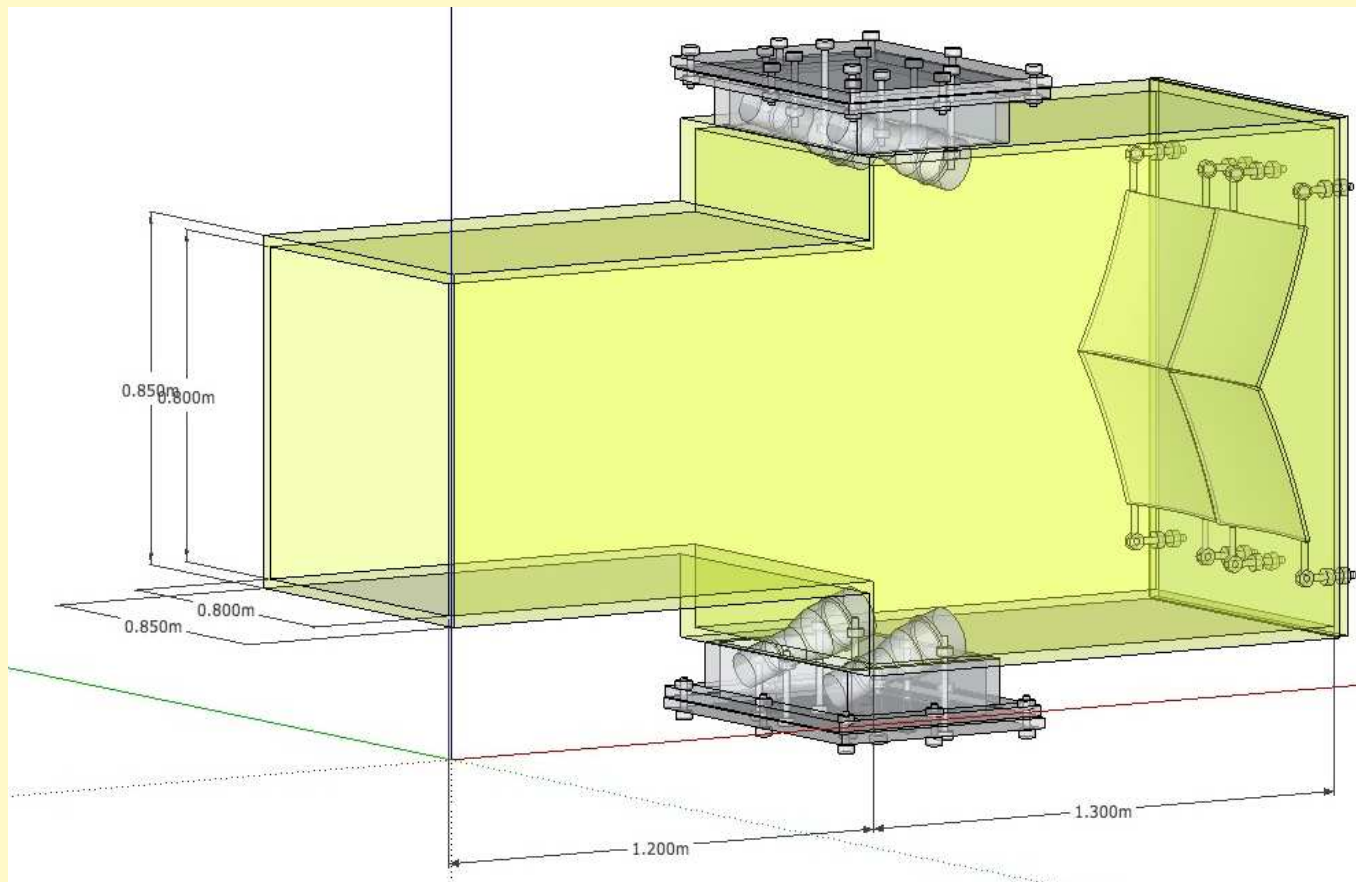
Gas	$Pr^\pi$ Threshold 6 GeV/c	$Pr^\pi$ Threshold 10 GeV/c	e <sup>-</sup> N <sub>p.e.</sub> relative Neon
Argon	0.95 atm	0.28 atm	4.3x
Nitrogen	0.99	0.29	4.5
Neon	4.04	1.20	1.0
Helium	7.73	2.30	0.53



Neon can be used over entire SHMS momentum range, but at cost of fewer photoelectrons at lower momentum, in comparison to Argon.

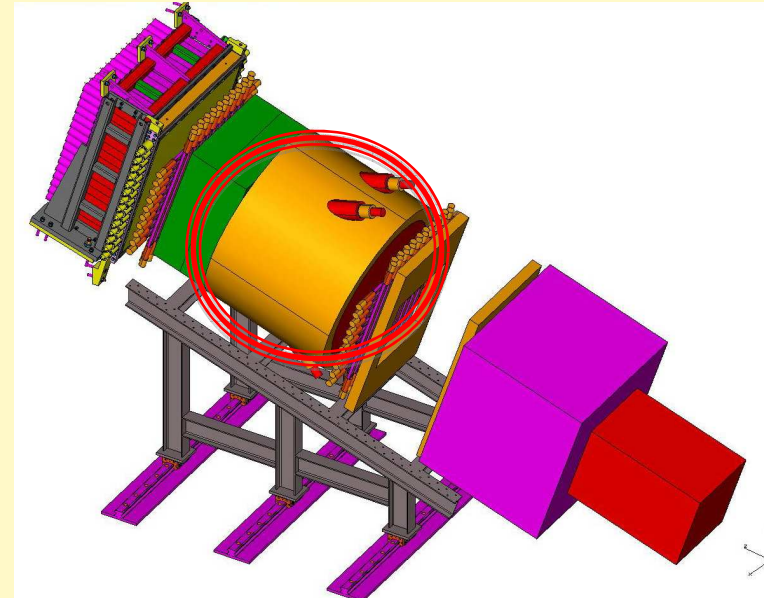
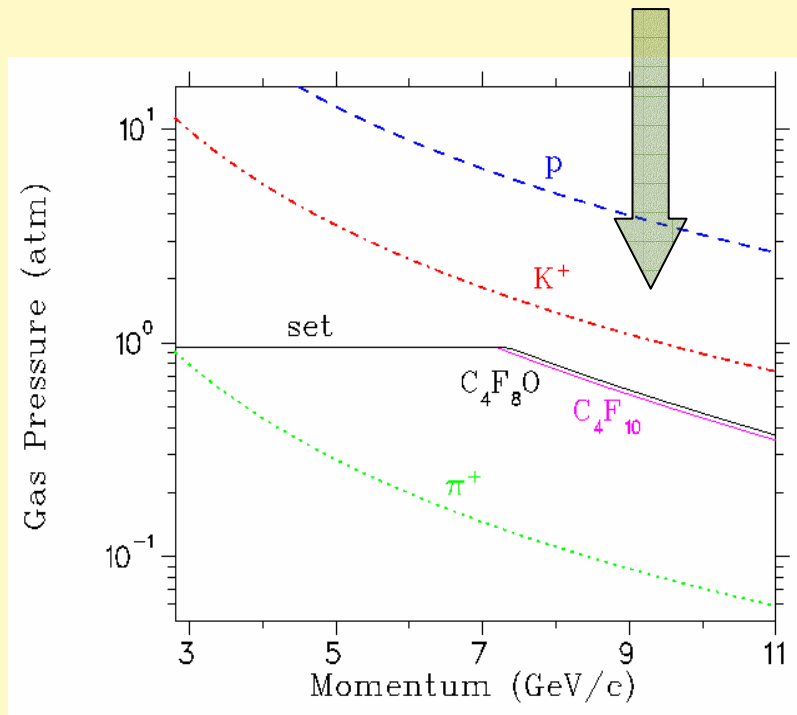
# Noble Gas Čerenkov Plan View

- 2.5 m long gas radiator in simple enclosure at 1 atm.
- Four mirrors --- each 75/2cm tall x 80/2cm wide.
- Four 5" PMTs at top and bottom (Hamamatsu R1584).



# Heavy Gas Čerenkov: $\pi/K$ separation for $P > 3.4$ GeV/c

To maintain good  $\pi/K$  separation, it is necessary to reduce the gas pressure above 7 GeV/c.

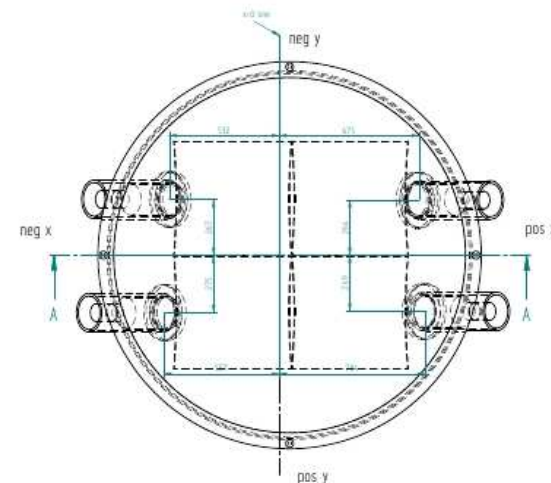
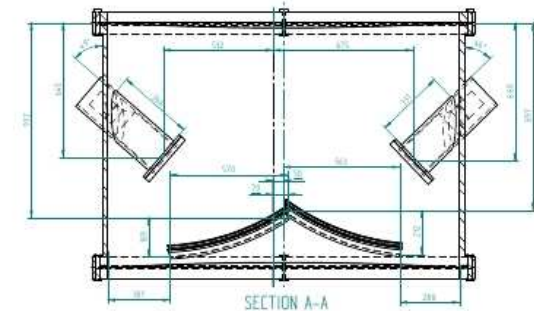


The lowest operating pressure of the detector is  $\sim 0.3$  atm.

To simplify the gas purification, it is intended to pump the detector to vacuum and then introduce the  $C_4F_8O$ .

# Pressure Vessel (PV)

- 1" thick 6061 aluminum alloy sheet rolled into a cylinder and welded.
- 4 tubular side ports house PMTs. Exterior surfaces are machined to ensure snug fit to mating holes milled in PV walls.
- **Design drawings were prepared to solicit budgetary quotations from 7 companies across Western Canada.**
- Quotations include a PV vacuum test but no design work.



## TWO BIDS SUBMITTED:

**Ross Machine Shop** C\$56,945  
 (Regina, also doing GlueX BCAL machining)

**EBCO Industries** C\$59,735  
 (Vancouver, used often by TRIUMF)

Preliminary design exchange meant only to show sizes and proportionality could not be considered drawing.

DIAGRAM IS IN TRANSPORT COORDINATES NOT ENGINEERING COORDINATES.

University of Regina	Name: Heavy Gas Cherenkov Detail Neg Y
Drawn by: Paul Sellas	Revision: A
Supervised by: Garth Huber	Date: Aug 13/2009

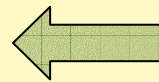
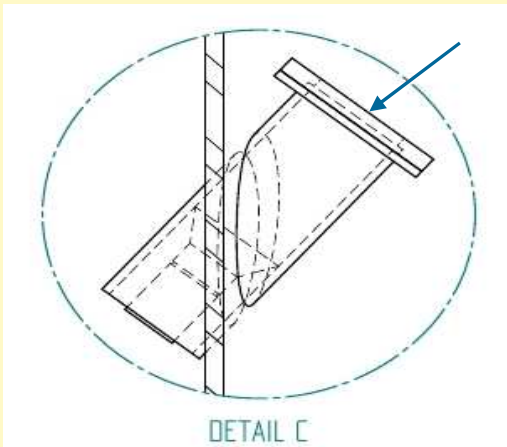
# PV Entrance and Exit Windows

- **Windows must not be excessively thick, as knock-on electrons produced by subthreshold particles traversing entrance window will lead to false signal in detector.**
- **Design assumes 1 mm thick high tensile strength 7075-T6 aluminum alloy plates which are clamped to the vessel end flanges in a manner similar to the HMS Gas Čerenkov detector.**
- **Windows will be hydroformed to a concave shape prior to mounting on the detector.**
  - **Expected to provide ~2x improvement in window strength.**



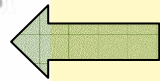
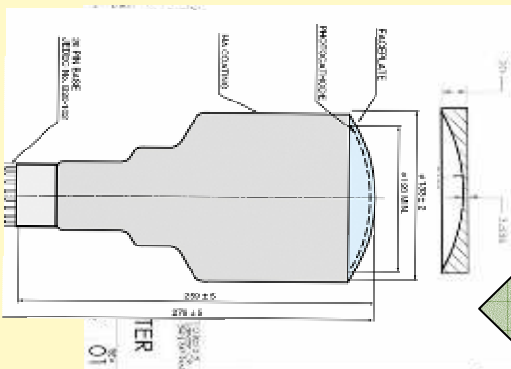
- **Vendor quotations include 3 windows.**
- **3<sup>rd</sup> window reserved for puncture test.**
- **Very few suppliers able to provide thin but large 7075 sheets.**
  - **Advanced Aerospace Metals (Crossville, TN)**

# PMTs, Quartz Windows, Adapters

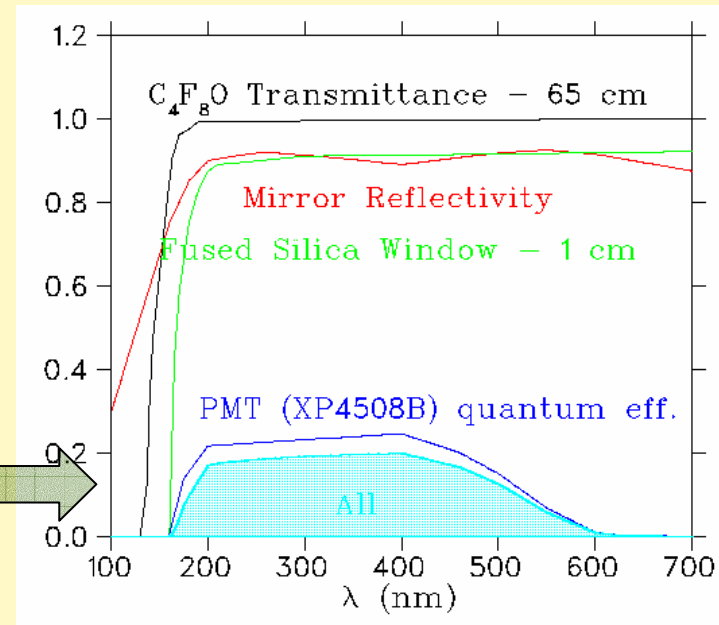


To isolate PMTs from mechanical stress due to varied pressures in detector, PMTs are mounted outside PV, viewing through Spectrosil 2000/2200 viewports.

**Require 5" PMTs with high gain and good UV sensitivity.**



50% of max. @185nm



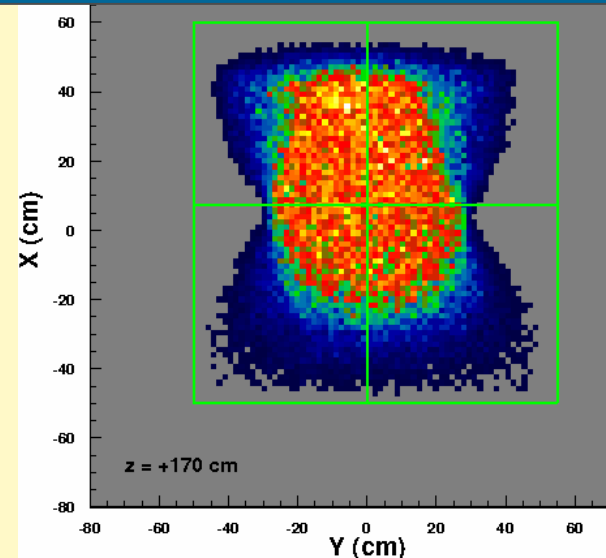
**Best Combination of Price & Performance:**  
 5 Hamamatsu R1584 PMT assy's C\$23,430  
 4 Windows+Adapters (Hardin Optical) C\$10,020



# Mirrors, Backing, Mounts

Four 55x60 cm<sup>2</sup> mirrors needed to span SHMS focal plane. →

- Mirrors must be thin (~3mm glass) to avoid knock-on electrons in Aerogel Čerenkov mounted downstream.
- Assembly to mount mirrors must also be outside beam envelope.
- Structural reinforcement design similar to carbon fiber epoxy backing on SOS Čerenkov. →



<b>10 Mirror Blanks (EuropTec USA)</b>	<b>C\$8,214</b>
<b>Carbon Fiber Backing</b>	<b>C\$5,539</b>
<b>Mirror Mounts to Vessel</b>	<b>C\$7,033</b>

# Mirror Aluminization

- **CERN has agreed to do aluminization, at cost of SFr2,000/mirror.**
- **Includes 200-600 nm reflectivity measurement of each mirror.**
- **Work to be carried out by CERN on a “best effort basis”.**
  - 6 month advance notice needed.
  - Evaporator time available in late 2010 & beginning 2011.
  - After this, it is difficult to project evaporator availability.
- **Need to determine whether it is better to apply carbon fiber backing before or after aluminization.**



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Geneva, October 19, 2009

## Quotation

### Application of Reflective Coatings on 5 Mirror Substrates

Approximate mirror dimensions: 60 cm x 55 cm. Spherical shape. Reflectivity to be optimized for Cherenkov applications.

Work performed by CERN:

- Optimization of coating parameters
- Process verification on sample mirrors
- Production coatings after acceptance of sample quality by client
- Witness samples for every coating
- Reflectivity measurements (200-600 nm) for every mirror

Cost per mirror: CHF 2,000.-  
Total Cost: CHF 10,000.-

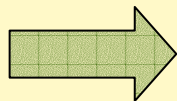
The cost does not include transport and packaging. The work is carried out on a best effort basis. No responsibility is assumed for accidental breakage of mirror substrates or delays in the production due to internal priority changes.

Group Leader

# Heavy Gas Čerenkov Cost Estimate

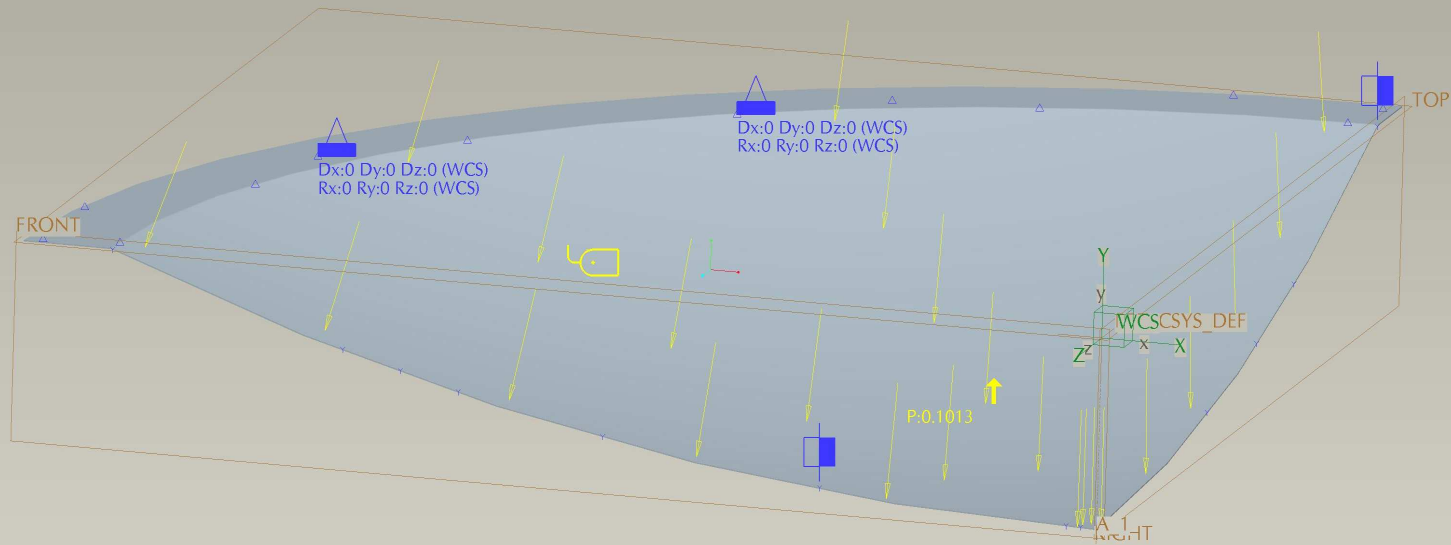
Item	Estimate (C\$)
Pressure Vessel	59,735
Window Hydroforming	569
Mirrors	7,000
Carbon Fiber Backing	5,539
Mirror Mounts	7,033
Mirror Aluminization	10,200
PMTs, mu-Shield, Bases	23,430
Convex Adapters	4,740
Spectrosil Windows	5,280
PMT Mounting Ass'y	5,280
Optical Alignment Jig	500
Valves & Fittings	2,239
Shipping	15,418
<b>TOTAL</b>	<b>C\$148,529</b>

Amount Requested  
from NSERC.  
Decision due April 1.



# FEA STUDY OF A HYDROFORMED ALUMINUM SHEET WINDOW FOR THE HEAVY GAS ČERENKOV DETECTOR

Jan Soukup  
University of Alberta



- Window thickness chosen to be 1mm.
- Window hydro-formed to be initially spherical with a center depth equal to a previously calculated maximum deflection of a flat window sheet.
- Two aluminum alloy materials analysed: Heat Treated 6061-T6 alloy and Cold 7075-T0 alloy
- Boundary conditions: The underside of the flat rim, but also the underside of the 5mm radius fillet on the original undeformed by stress sheet is fixed in all directions (as if glued).

# FEA Studies Performed

- **Window's large diameter/thickness ratio causes difficulty in handling boundary conditions at the rim.**
  - Can not yet model the contact elements that reflect support of the window sheet as it deforms and wraps around the radius of the rim.
- **Two FEA studies were performed:**
  1. Hydroformed window affixed rigidly along circumference, with sharp edge along flat support surface (rim).
  2. Support surface with R=5mm fillet and sheet fixed not only on flat part, but also on fillet between the flat and spherical parts of window.
- **Second study more realistic than first, but still not the actual situation.**
  - Expect sheet to actually find support on rim fillet up to the point where it departs the surface tangentially.
- **Highest stresses in both simulations are on the rim.**
  - Stresses due to shearing of the sharp edge of rim support where the unstressed hydroformed sheet leaves it tangentially.
  - But, under load the sheet bends sharply over the rim, so the stress is overestimated.
- **Critical stress, which should be in the middle of the window, is much lower.**

## FEA STUDY OF A HYDROFORMED 6061-T6 ALUMINUM SHEET WINDOW

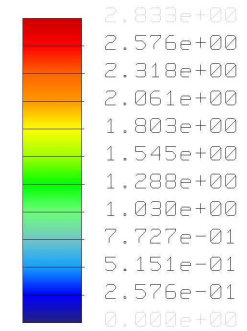
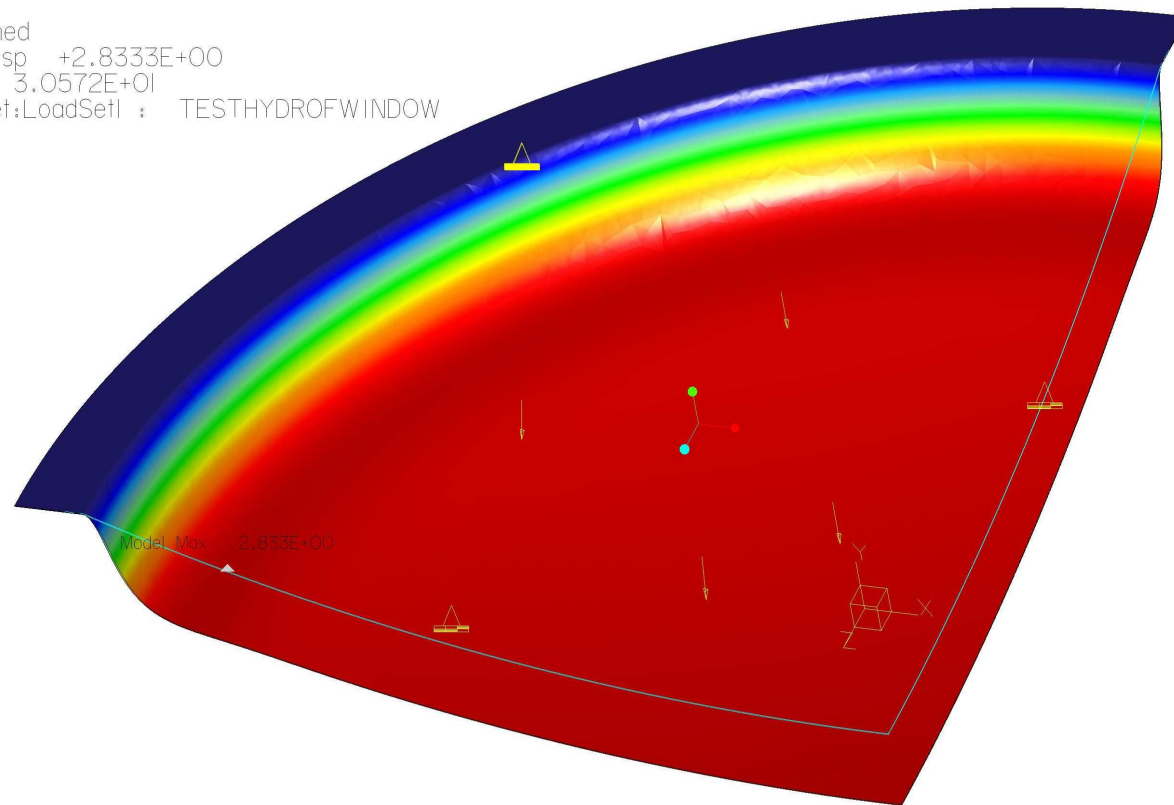
Displacement Mag (WCS)  
(mm)

Deformed

Max Disp +2.8333E+00

Scale 3.0572E+01

Loadset:LoadSet1 : TESTHYDROFWINDOW



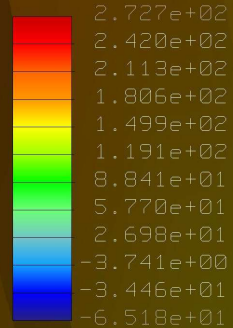
deformation of 6061 Al hydro window fixed also on edge rad

**Maximum additional window deflection = 2.83 mm (at center).**

# FEA STUDY OF A HYDROFORMED 6061-T6 ALUMINUM SHEET WINDOW

## Maximum Principal Stress (maximum tension stress).

Stress Max Prin (WCS)  
(N / mm<sup>2</sup>)  
Deformed  
Scale 3.0572E+01  
Loadset:LoadSet1 : TESTHYDROFWINDOW



Maximum tensile stress:  
272.7 MPa (on top of rim)

Compare to:  
Tensile Strength = 310 MPa  
Yield Strength = 255 MPa

Max Princ Str (max. tension stress) on edge 6061 Al hydro window

## FEA STUDY OF A HYDROFORMED 7075-T0 ALUMINUM SHEET WINDOW

### Added deformation to the hydro-formed shape

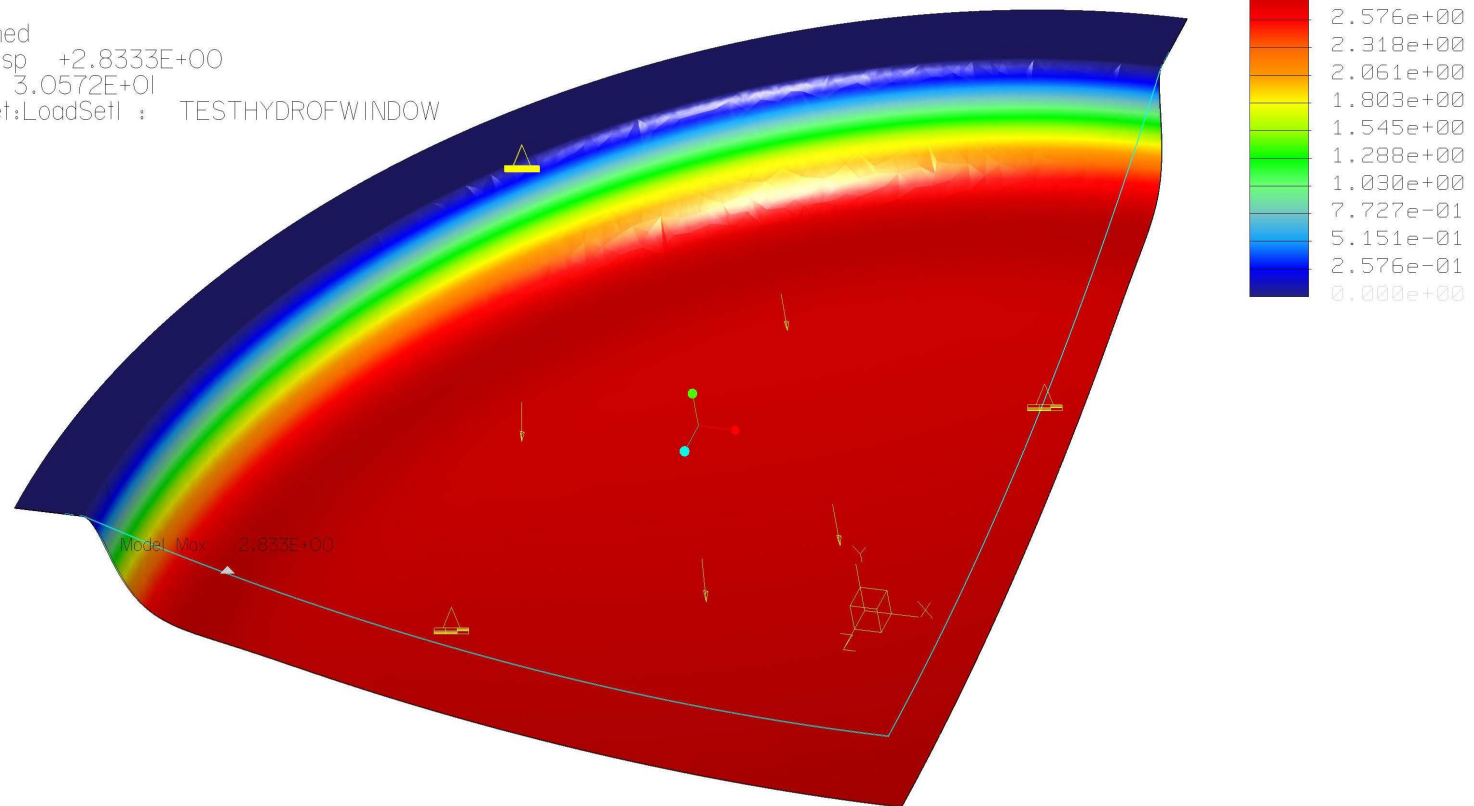
Displacement Mag (WCS)  
(mm)

Deformed

Max Disp +2.8333E+00

Scale 3.0572E+01

Loadset:LoadSet1 : TESTHYDROFWINDOW



deformation of 6061 Al hydro window fixed also on edge rad

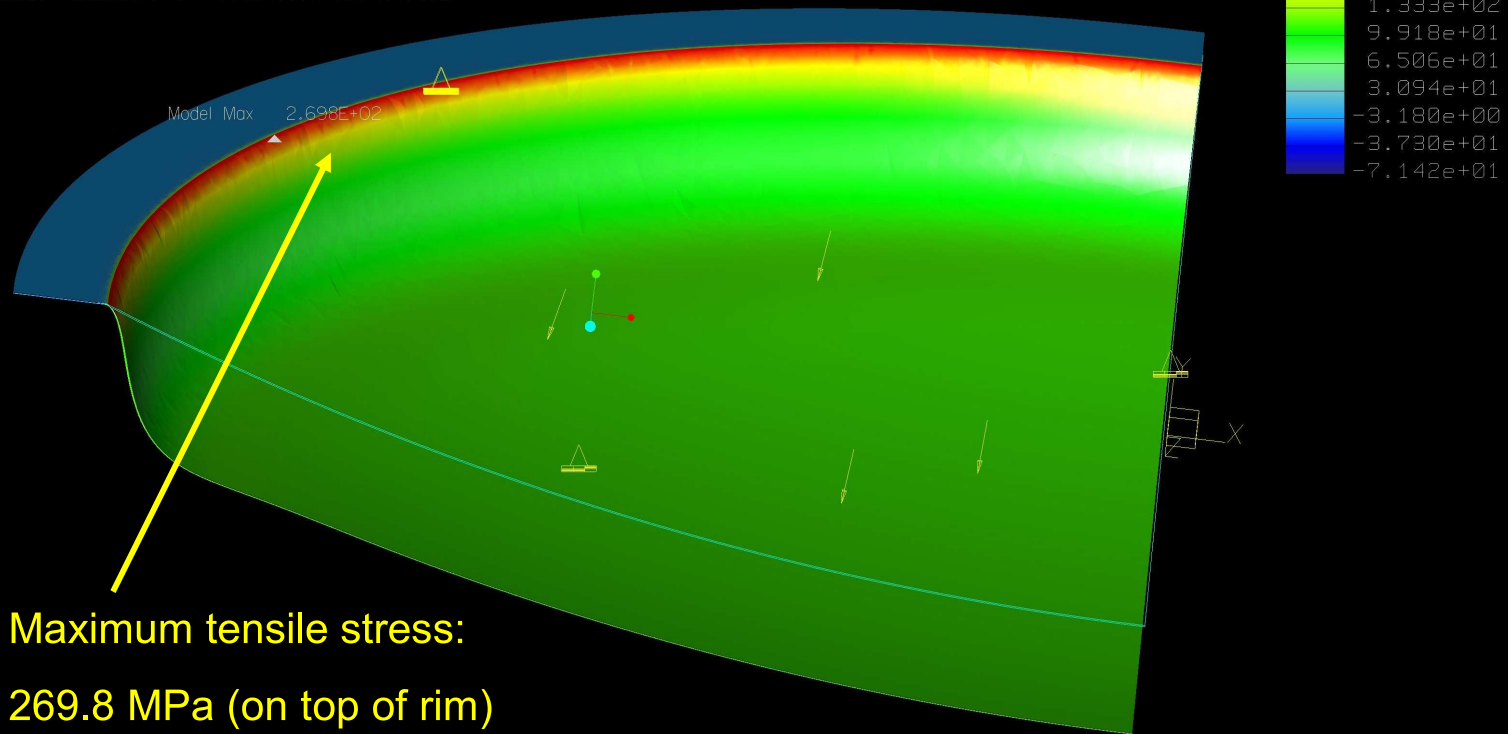
**Maximum additional window deflection = 2.61 mm (at center).**



# FEA STUDY OF A HYDROFORMED 7075-T0 ALUMINUM SHEET WINDOW

## Maximum Principal Stress (maximum tensile stress)

Stress Max Prin (WCS)  
(N / mm<sup>2</sup>)  
Deformed  
Scale: 3.3158E+01  
Loadset: LoadSet1 : TESTHYDROFWINDOW



**Maximum tensile stress:**  
**269.8 MPa (on top of rim)**

**Compare to:** Max Princ Str of a 1mm 7075-T0 Al Hydro window fixed also on edge rad.

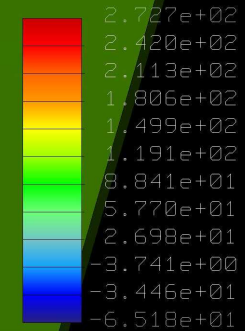
Tensile Strength = 220 MPa

Yield Strength = 95 MPa

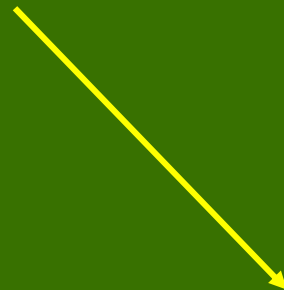
# FEA STUDY OF A HYDROFORMED 6061-T6 ALUMINUM SHEET WINDOW

## Maximum Principal Stress (maximum tension stress).

Stress Max Prin (WCS)  
(N / mm<sup>2</sup>)  
Deformed  
Scale 3.0572E+01  
Loadset:LoadSet1 : TESTHYDROFWINDOW



Maximum tensile stress in window center is low (<100 MPa)



Max Princ Str (max. tension stress) on edge 6061 Al hydro window

# FEA Conclusions & Issues

- Studies show trend to decreasing maximum stress, indicating that edge problem is only a technical one, associated with FEA simulation modeling.

ALLOY	Study #1 (Sharp Rim)	Study #2 (R=5 mm Rim)
Heat Treated 6061-T6	593 MPa	273 MPa
Cold 7075-T0	658 MPa	270 MPa

- Critical stress in middle of window is only 60-100 MPa.**

## QUESTIONS (Feedback needed):

- Is it necessary to use a heat treated material, or is 7075-T0 sufficiently strong?
- If so, can the hydro-forming proceed without first annealing the sheet and re-treat to T-6 afterward?

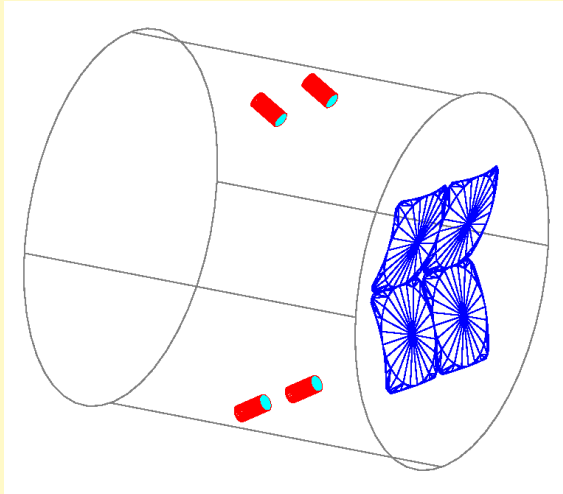
ALLOY	Cold (T0)	Heat Treated (T6)
<b>TENSILE STRENGTH</b>		
<b>6061</b>	115	310
<b>7075</b>	220	570
<b>YIELD STRENGTH</b>		
<b>6061</b>	48	255
<b>7075</b>	95	505

# Geant4 3D Optical Simulations

- **Emphasis of Geant4 studies is final optimization of mirror/PMT configuration, taking SHMS transverse plane effects into account.**
  - Simulations make use of 50,000 event SHMS white spectrum provided by Tanja Horn.
- **UVa and Regina collaborate closely on optical studies.**
  - **Geant4 framework by Vahe Mamyán.**
  - **Includes reflection of light from glass face of PMT.**
  - **Mirror reflectivity, PMT quantum efficiency, etc. taken into account to yield a predicted photoelectron distribution.**
  - **Donal Day has recently added for the variation in photoelectron yield due to lower electron collection efficiency at edges of Hamamatsu R1584 PMT.**

# Noble Gas Čerenkov Optical Studies

## Progress Report from Donal Day



**SIMULATION OF WORST CASE:**  
(discriminate between 11 GeV/c  $\pi$  & e  
with Neon @ 1atm)

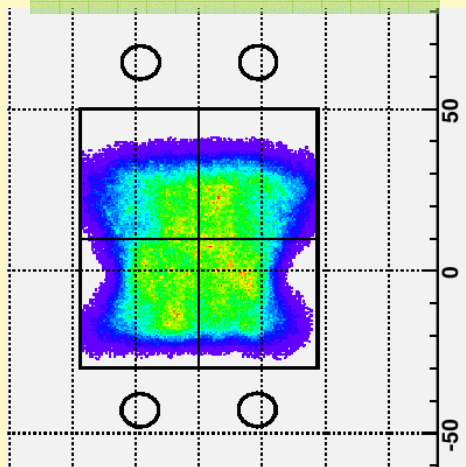
**50  $\gamma$ 's/electron strike PMT face.**

- Transmission through glass face (100%).
- PMT quantum efficiency (<20%>).
- PMT electron collection efficiency (50%).

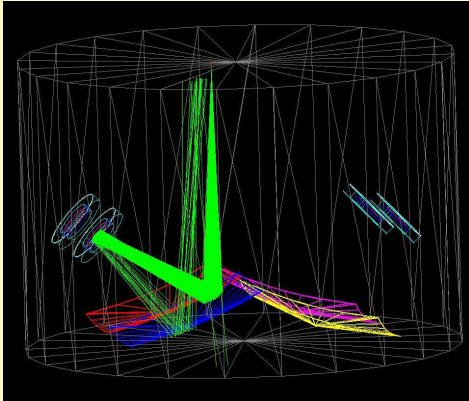
→ **Predict 5 photoelectrons detected.**

- **Wavelength shifter applied to surface of PMT should give  $\sim x2$  increase.**
- **Argon @ 1atm gives  $\sim 4x$  more  $\gamma$ .**

Mirror Hits to PMT



# Heavy Gas Čerenkov Optical Studies



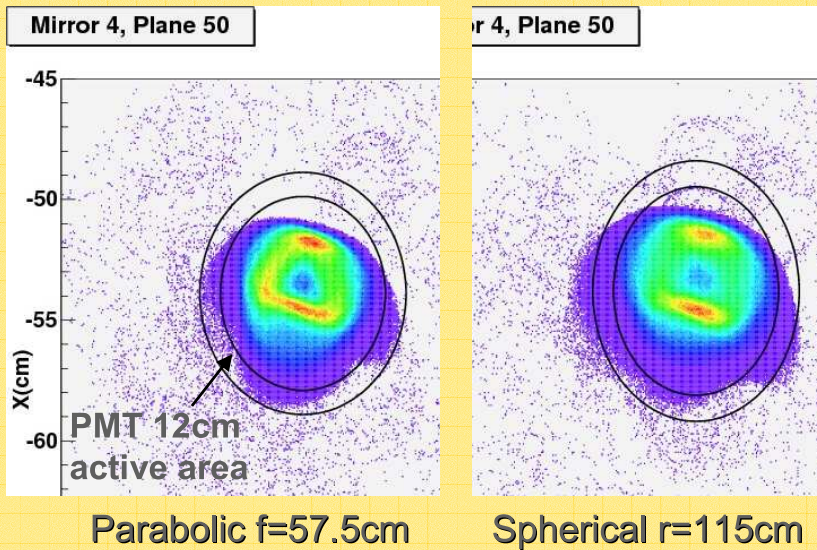
**$r=115\text{cm}$  Spherical Mirrors studied in 2009:**

~10% of  $\gamma$ 's reflect off quartz viewports and are lost.  
~97% of rest are focused onto efficient part of PMT.

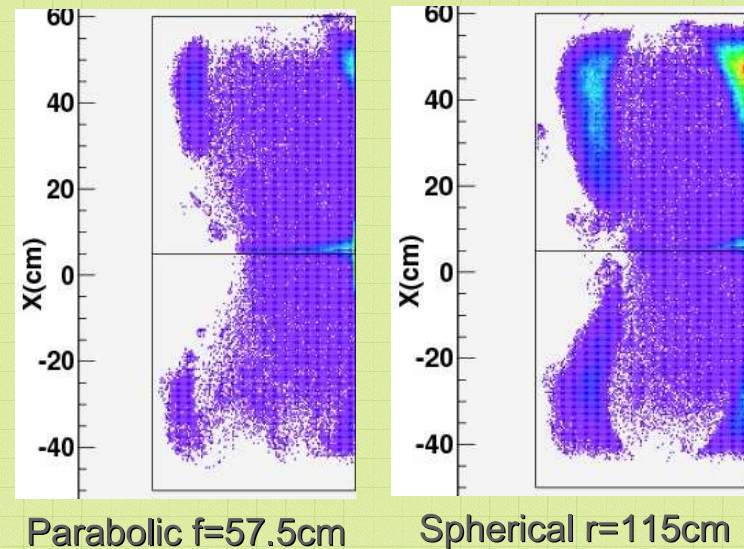
**Further studies planned for summer 2010:**

Do parabolic mirrors result in better light collection?

## 7 GeV/c Focusing onto PMT



## 7 GeV/c Mirror Hits missing PMT



# DRAFT Heavy Gas Čerenkov Time Line

- Time line is tight if money is delayed until FY12.
- Mirrors could be bottleneck if CERN aluminization facility busy.
- Time line assumes OK to apply backing before aluminization.

Activity Name	Owner	Start Date	Finish Date	% Complete	Fiscal Year												
					FY 08	FY 09	FY 10	FY 11	FY 12	FY 13	FY 14	FY 15					
115 HG Čerenkov (Regina)																	
116 1. Final Design Detail	U. Regina	5/1/12	6/11/12	0%													
117 2. Procurement		10/1/08	12/31/09	0%													
118 2.1 Pressure Vessel		10/20/11	6/29/12	0%													
119 2.1.1 Pressure Vessel Final Design Review	U. Regina	10/20/11	12/20/11	0%													
120 2.1.2 Pressure Vessel Procurement	U. Regina	1/5/12	4/30/12	0%													
121 2.2 PMTs, Bases, UV Glass Windows, Adapters	U. Regina	1/5/12	6/29/12	0%													
122 2.3 Mirrors	U. Regina	1/5/12	4/30/12	0%													
123 3. Fabrication																	
124 3.1 Mirrors		5/1/12	7/30/13	0%													
125 3.1.1 Mirror Optical Testing	U. Regina	5/1/12	6/29/12	0%													
126 3.1.2 Mirror Stiffening Brackets	U. Regina	7/2/12	9/28/12	0%													
127 3.1.3 Mirror Aluminization at CERN	U. Regina	10/1/12	6/28/13	0%													
128 3.1.4 Shipment of Mirrors to JLab	U. Regina	7/1/13	7/30/13	0%													
129 3.2 Mirror Mount Assemblies	U. Regina	10/1/12	4/30/13	0%													
130 3.3 PMT Mounting Assemblies	U. Regina	10/1/12	4/30/13	0%													
131 3.4 Pressure Vessel Window Hydroforming	U. Regina	5/1/12	6/29/12	0%													
132 3.5 Pressure Vessel Vacuum Tests	U. Regina	7/2/12	8/31/12	0%													
133 3.6 Shipment of Pressure Vessel to JLab	U. Regina	5/1/13	6/28/13	0%													
134 4. Installation at JLab		8/1/13	3/26/14	0%													
135 4.1 Assembly of Detector in Test Lab	U. Regina	8/1/13	8/30/13	0%													
136 4.2 Cosmic Tests	U. Regina	9/2/13	10/31/13	0%													
137 4.3 Install on SHMS	U. Regina	11/1/13	3/26/14	0%													
138 Calorimeter (Yerevan)...																	
143 Detectors Checkout (no beam)...		3/27/14	8/8/14	0%													
152 Commissioning (with beam)		1/1/15	5/28/15	0%													