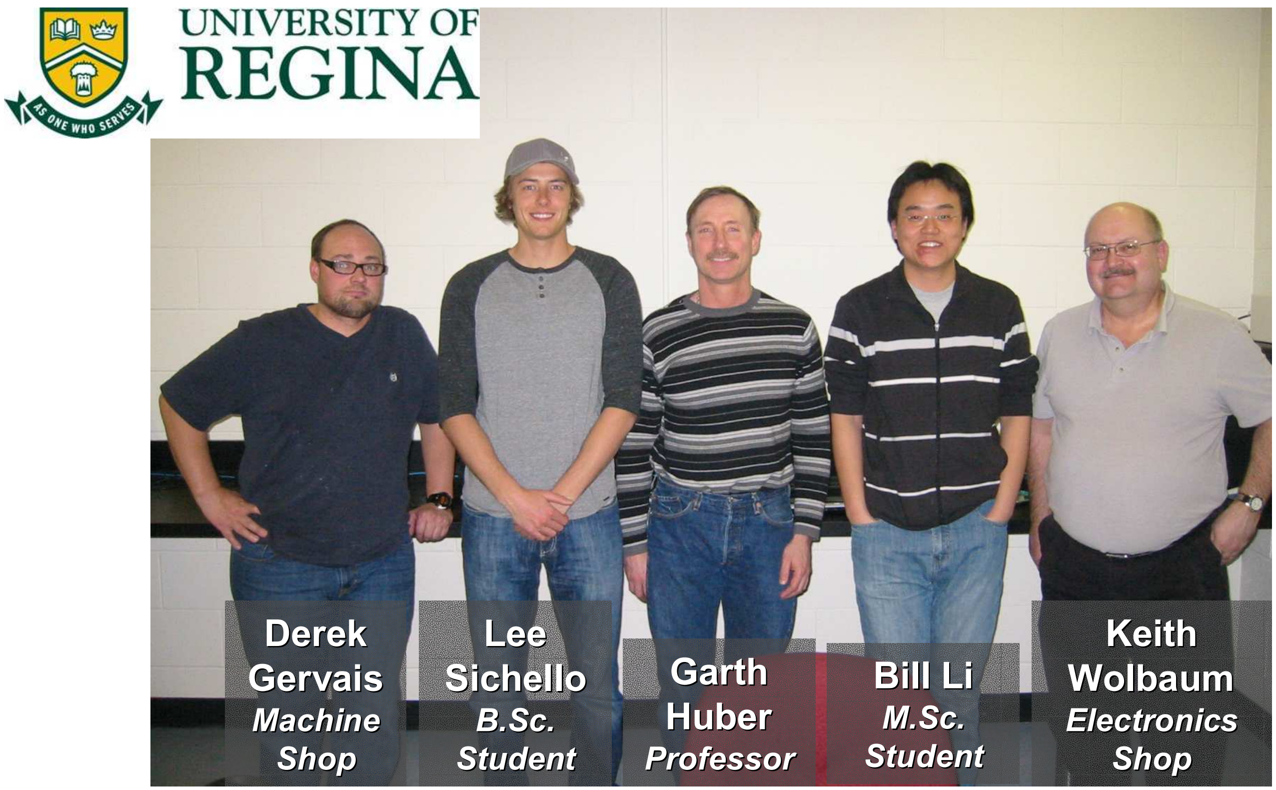
Heavy Gas Čerenkov Detector August 2011 Update

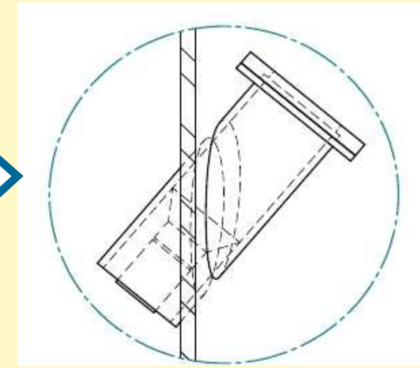


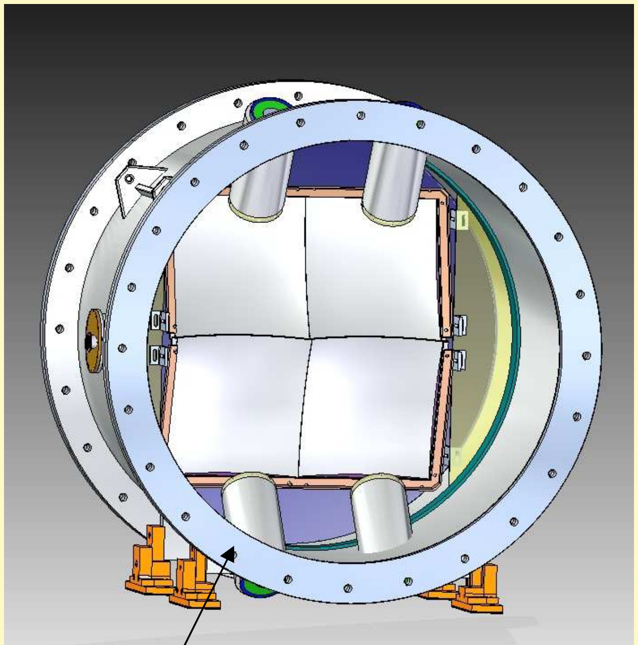
SHMS Detector Working Group Meeting. August 18, 2011.

Heavy Gas Čerenkov Overview

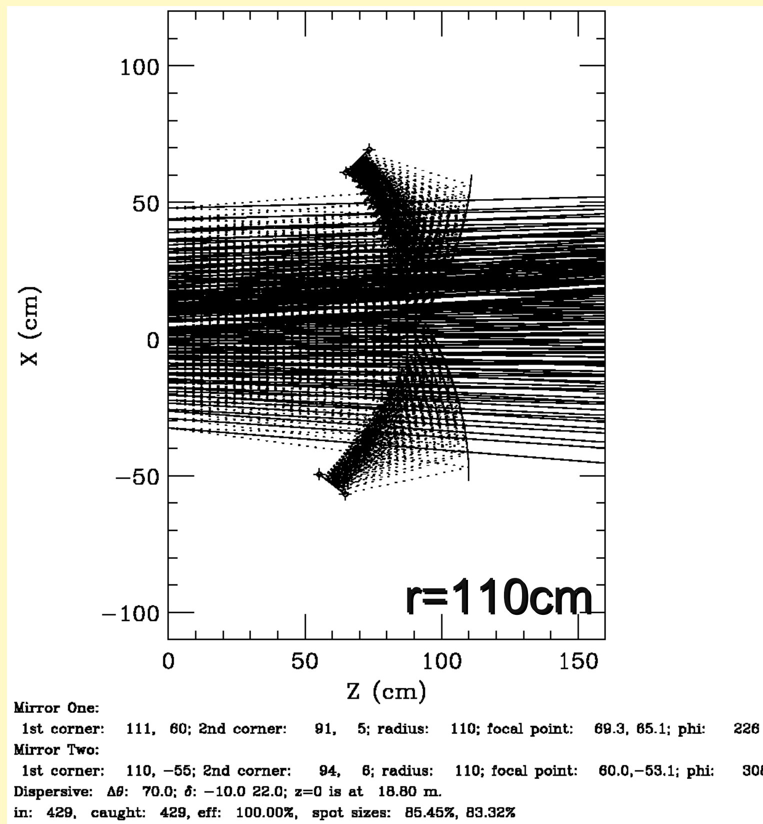
Cylindrical aluminum vessel filled with C_4F_8O @ 0.3<P<1.0 atm.

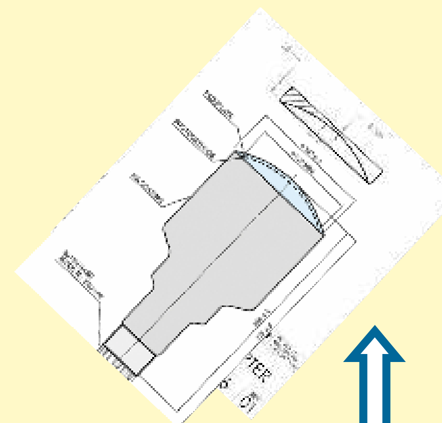
PMT views gas enclosure through a quartz viewport





170cm inner diameter.





An adapter is needed to mate PMT to quartz viewport.

Project Accomplishments since January update

DESIGN WORK:

- Carbon fiber mirror backing prototyping using test mirror from Sinclair Glass.
- Significant CAD work on mirror mounting frames and PMT holding sleeves.
- Refined mirror interleaving scheme and verification of performance improvement using Geant4.
- New proposal for entrance window clamp received from University of Alberta, including FEA calculations, July 11.

PROCUREMENT:

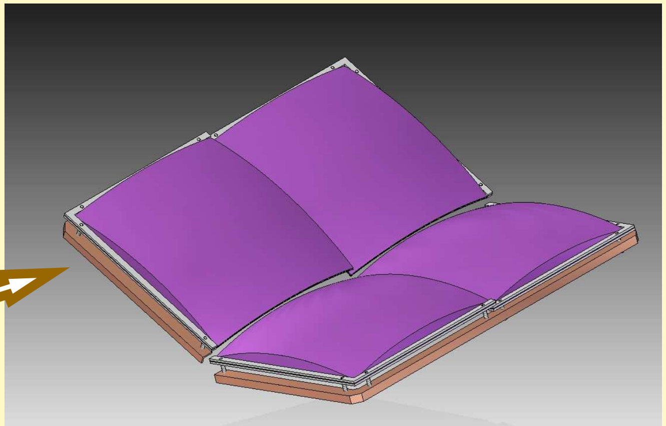
- 15 mirror blanks received from Sinclair Glass June 16.
  - Initial tests of mirror quality will be shown.
- 4 R1584 5" PMT, base and mu-shield kits received from Hamamatsu June 30.

Mirror Mounting Frames and Backing Supports

Revised Mirror Mounting Frame Design

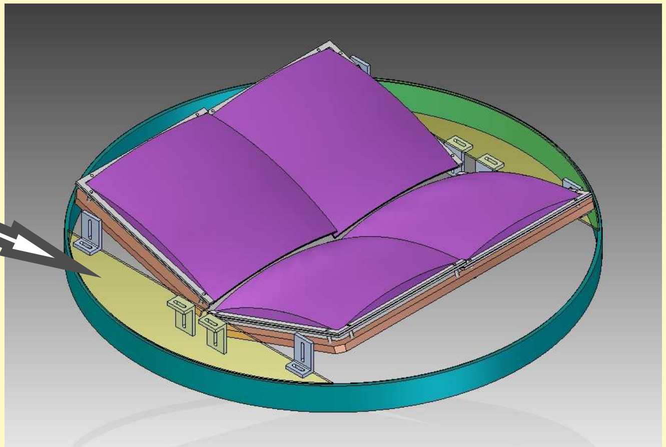
DESIGN CONSIDERATIONS:

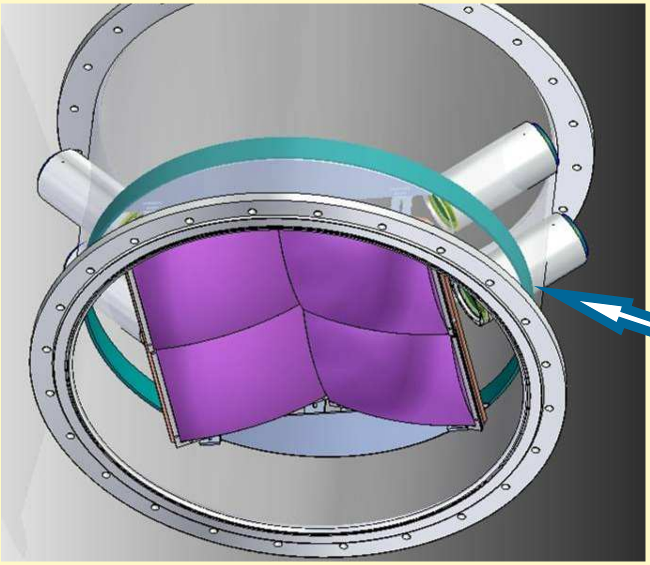
- Construction simplicity
- Maximum optics adjustability



Mirrors are attached along outer edges to two aluminum frames which run around perimeter.

Frames bolt onto two semi-circular plates, which are slotted for tilt angle adjustability.

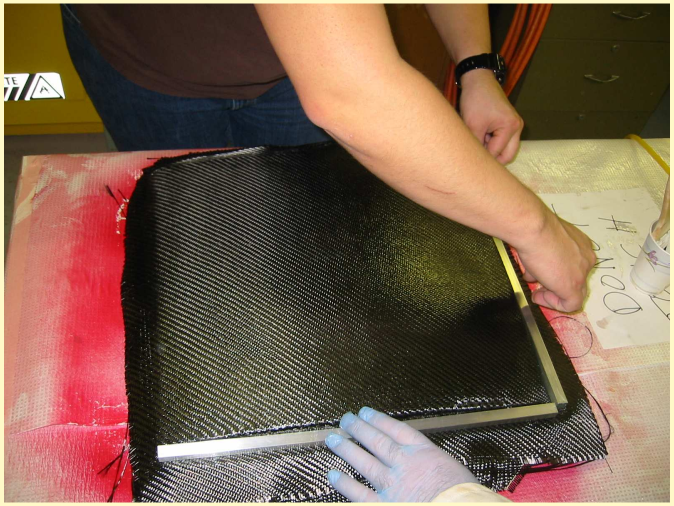




Semi-circular plates attach to a ring which is bolted to the interior of the vacuum vessel.

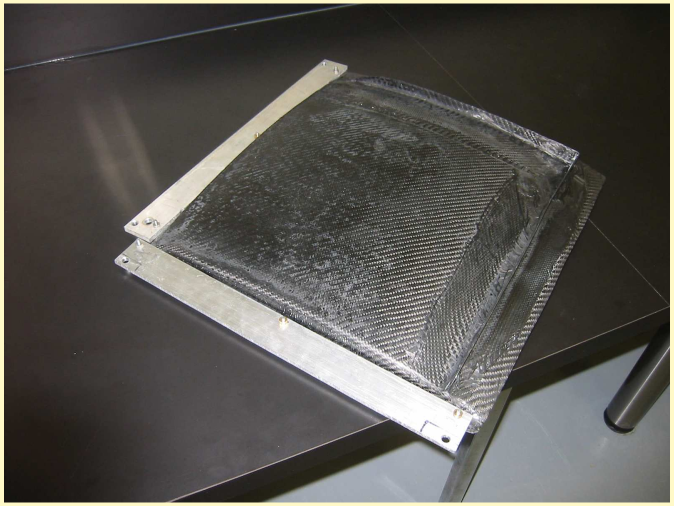
Prototype Carbon Fiber Mirror Backing

- A plaster cast of the test mirror was made. The cast was sealed with red lacquer paint and spread with a release agent.
- Three layers of carbon fiber were applied and brushed with epoxy.



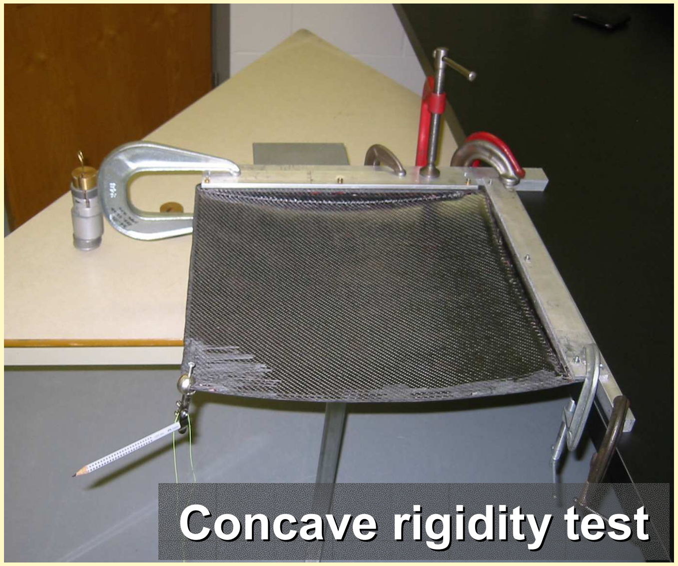
Along the two outer edges of the backing, extra carbon fiber was laid to form a tab for fastening purposes.

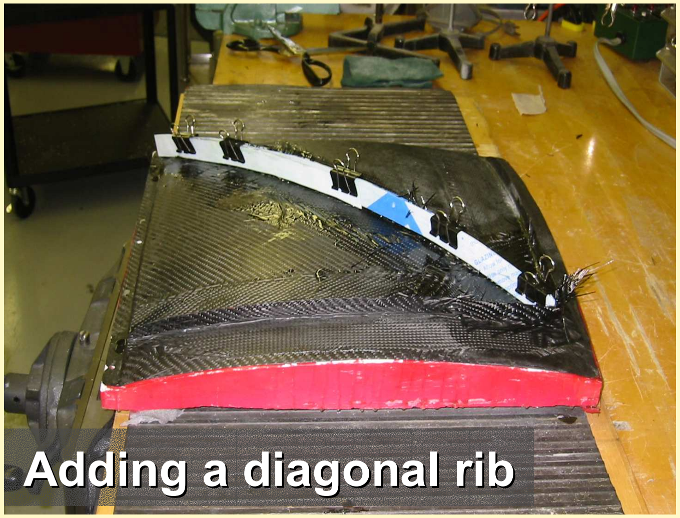
- After curing, the carbon fiber tabs are sandwiched between metal strips.
- Right angle ribs are added for rigidity.

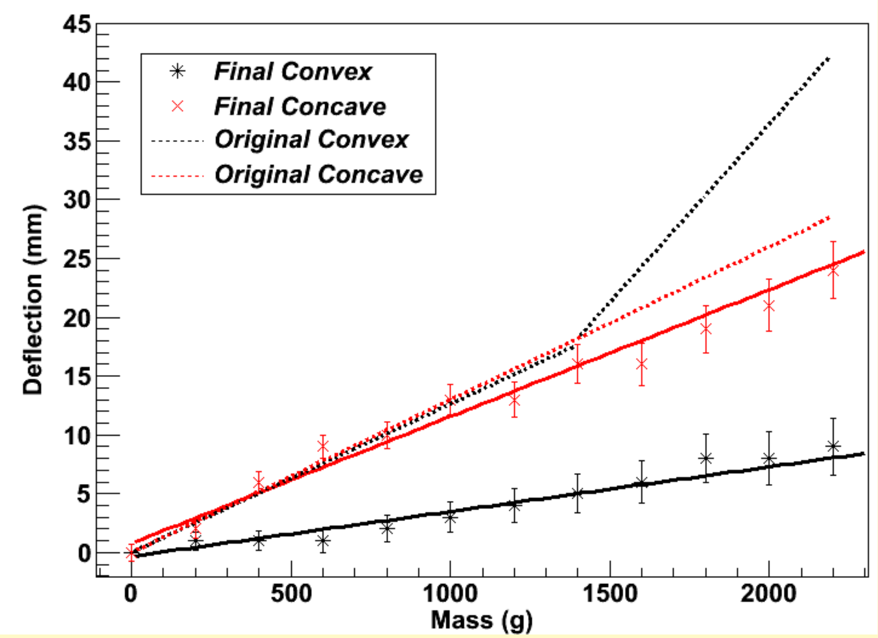


Mirror Backing Rigidity Tests

- To minimize material in the beam envelope, the corner in the center of the tank is unsupported and the mirror is clamped only along two outer edges.
- To guide our design choices, we tested the rigidity of the carbon fiber backing by hanging weights and measuring the deflection.


Concave rigidity test

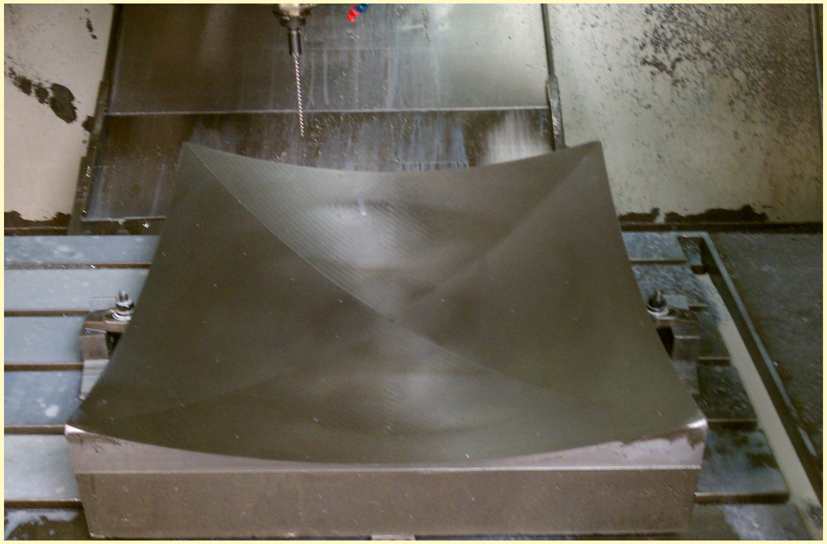

Adding a diagonal rib



Things Learned from the Prototyping

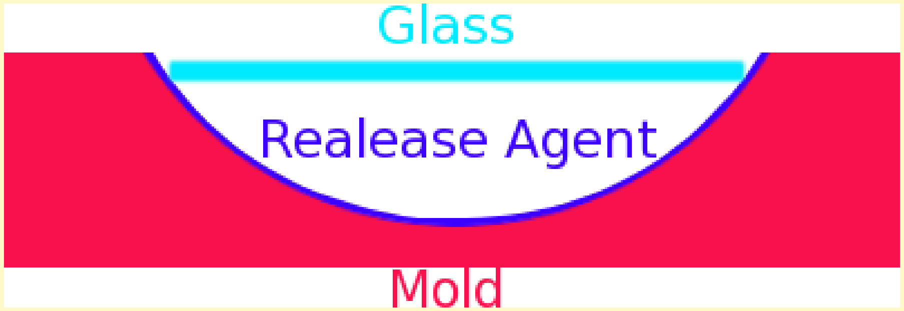
- **General concept seems okay, and fabrication of carbon fiber epoxy backing was easier than anticipated.**
- Plaster cast not sufficiently robust, searching for a better material.
  - Some cracking of plaster during curing.
  - Carbon fiber backing stuck partially to mold, despite use of release agent.
  - Would like one mold for the preparation of ~8 backings.

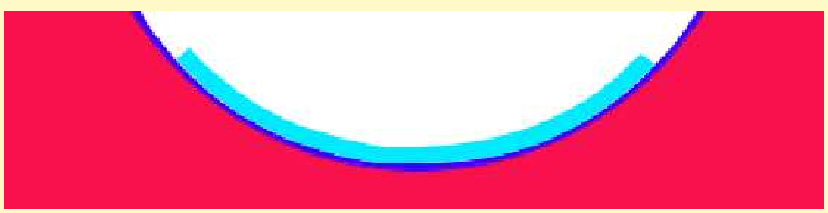
We arranged for the 800 lb glass slumping mold to be shipped from Indiana to Regina, so that it may be used for the forming of the carbon fiber backing.



Glass Mirror Blanks

Glass Slumping Procedure





Stage 1:

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

Stage 2:

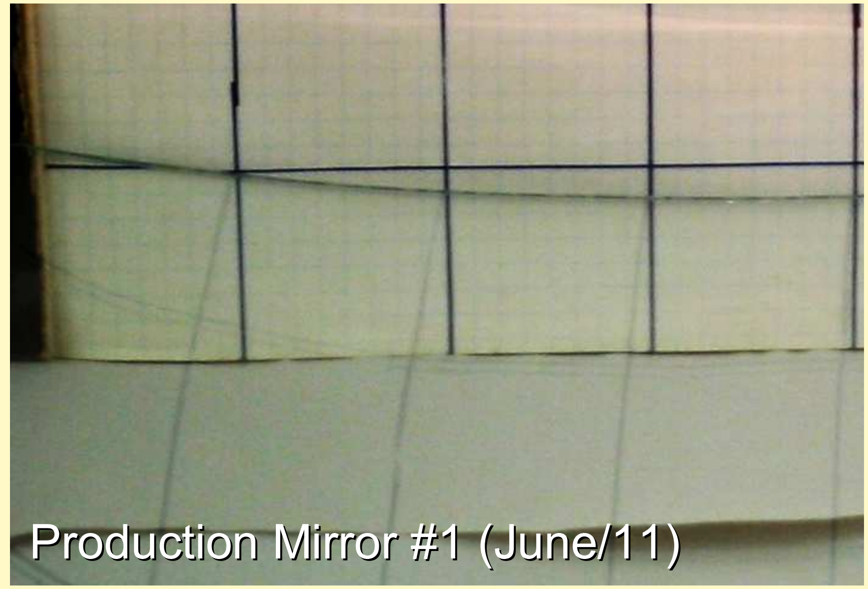
- Place mold into the oven.
- Glass slumps toward the mold.

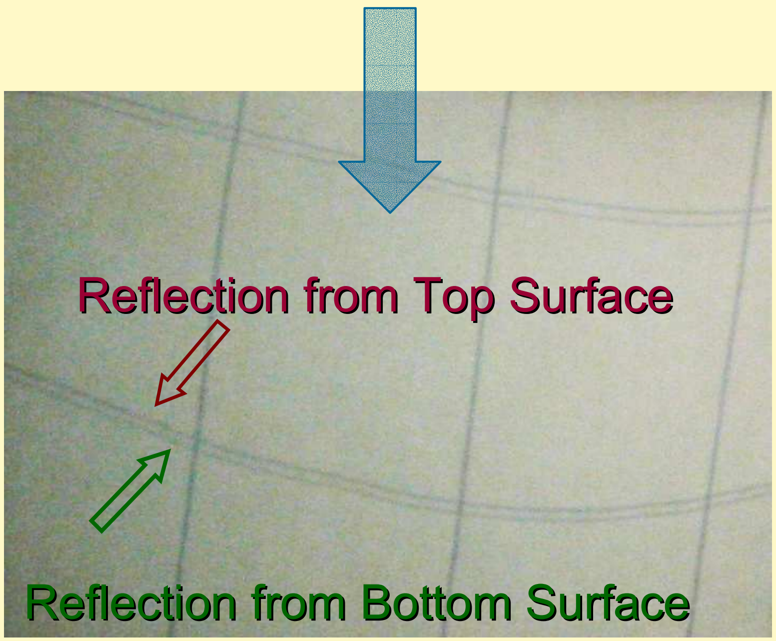
Important:

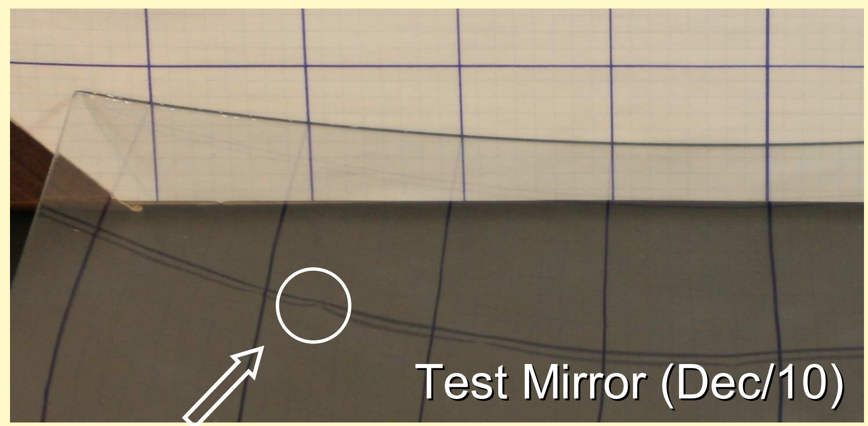
- **The glass is not slumped all the way to the mold.**
- **Front surface should have fewer imperfections than back surface.**
- **The mirror will be slightly non-spherical. If we are lucky, it will be closer to parabolic shape.**

Comparison of Production Mirror with Test Mirror

- Newly delivered mirrors have better surface quality than test mirror.
  - Reflection lines are parallel, no evidence of surface imperfections which plagued the test mirror.



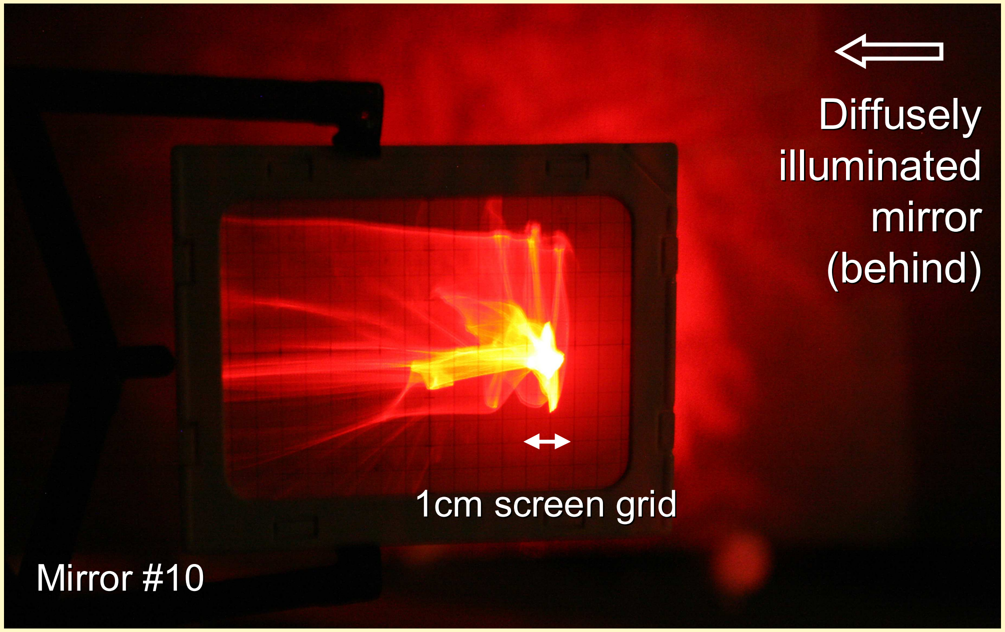




Deformity on back surface of test mirror slumped all the way to the mold

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.**

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

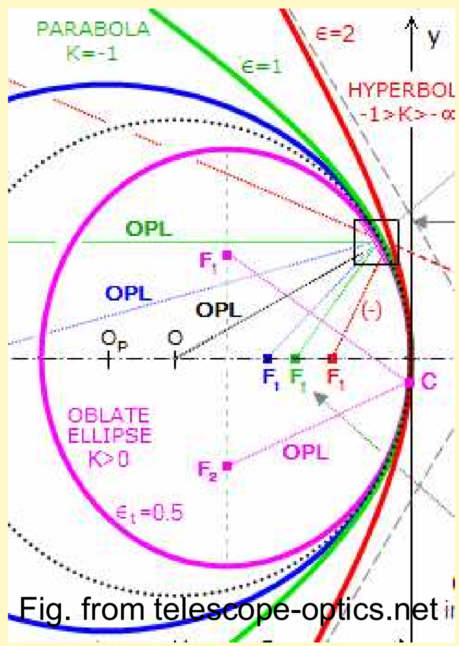
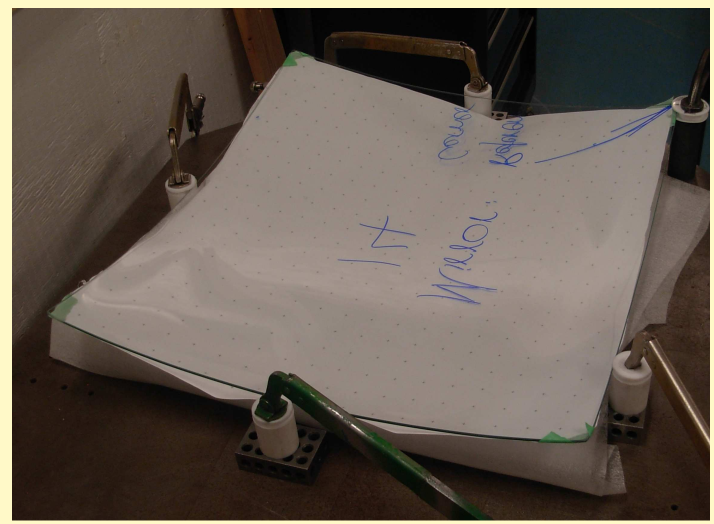
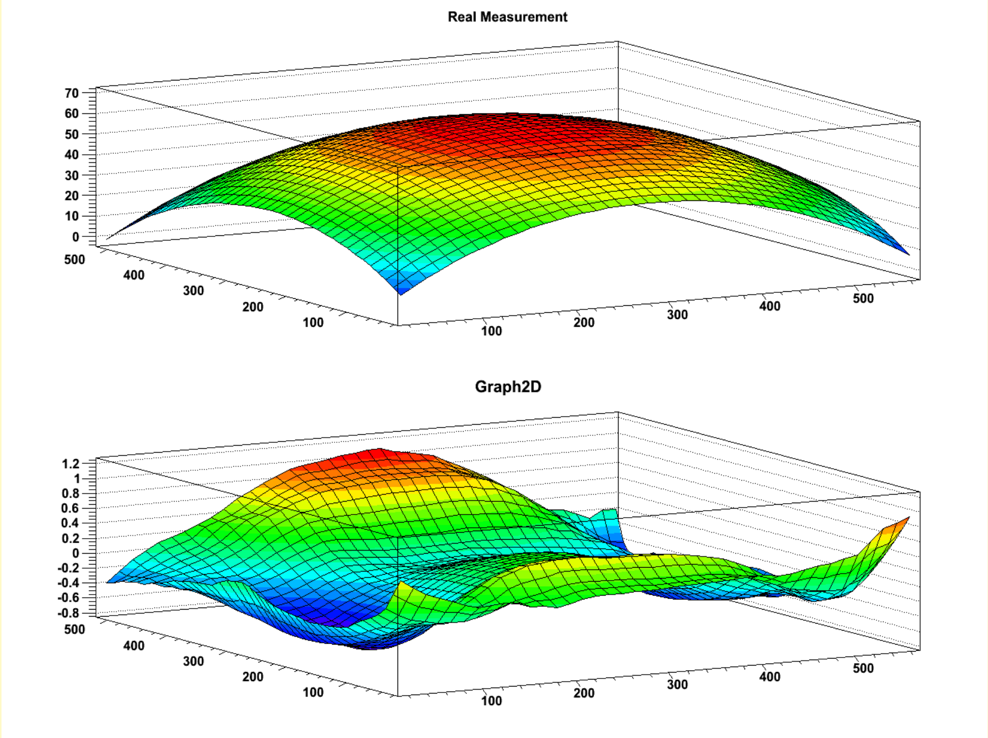


Fig. from telescope-optics.net



An Average Mirror (#15)

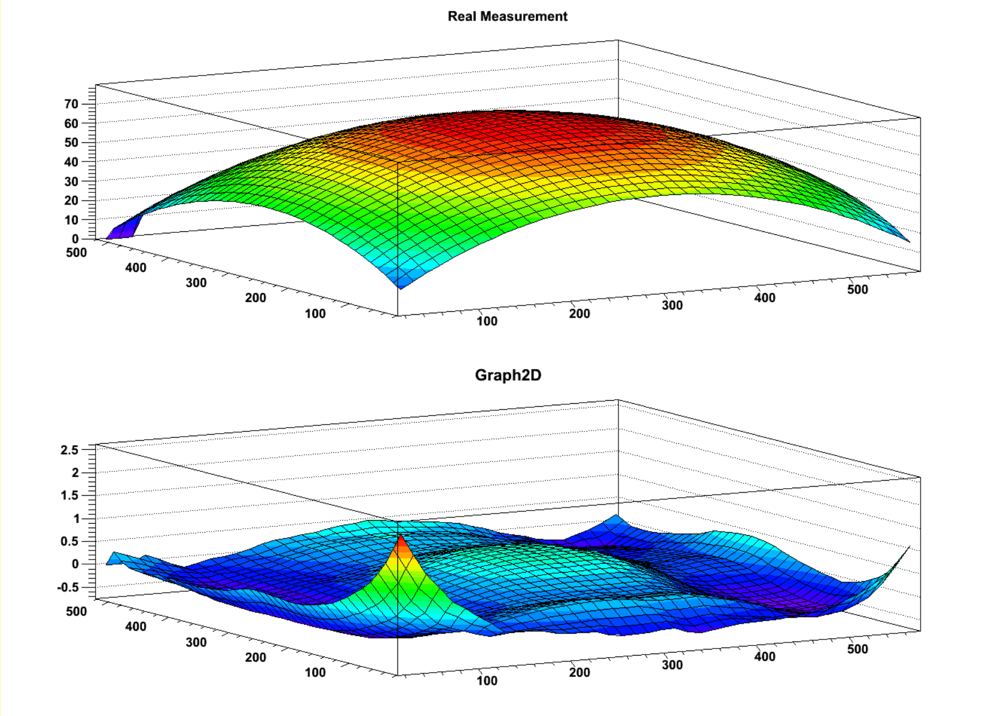
- Radius slightly larger than desired 110 cm but consistent.
- Typical curvature.
  - Slightly parabolic in center.
  - Oblate near outer perimeter, possibly due to contraction of glass during cooling after slump?



	Fit central 50% area	Fit central 75% area	Fit 90% area
Radius of Curvature at center	116.8 cm	114.3 cm	113.5 cm
Conic Constant	-0.19 (slightly parabolic)	-0.52 (slightly parabolic)	1.10 (oblate)

Probably our Best Mirror (#7)

- Mirror curvature consistently parabolic throughout.
- R slightly larger than desired 110cm, but consistent.

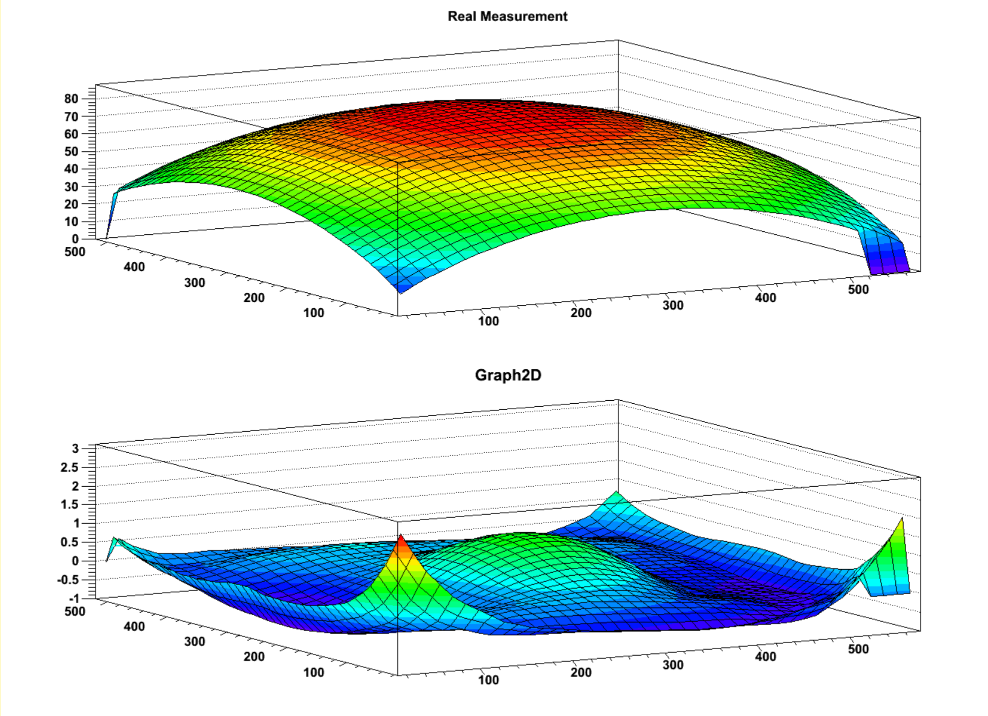


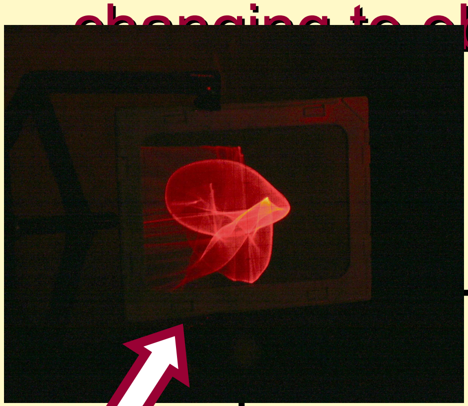
	Fit central 50% area	Fit central 75% area	Fit 90% area
Radius of Curvature at center	116.4 cm	113.8 cm	112.6 cm
Conic Constant	-0.26 (slightly parabolic)	-0.52 (slightly parabolic)	-0.55 (slightly parabolic)

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

Possibly our Worst Mirror (#4)

- Fit Radius of Curvature sensitive to % of mirror area included in fit.
- Inconsistent curvature, flatter near center, changing to oblate further





Confirmed by large, diffuse laser reflection.

	Fit central 50% area	Fit central 75% area	Fit 90% area
Radius of [illegible]ature at center	113.6 cm	124.5 cm	118.6 cm
[illegible]c Constant	-1.95 (hyperbolic)	+2.26 (oblate)	-0.34 (slightly parabolic)

Mirror Aluminization

- **Change of Plan:**
  - We can ship 2 mirrors for aluminization at Evaporated Coatings Inc. (Willow Grove, PA) once JLab has issued a Purchase Order.

Quantity	Description*	USD Price
1 lot of 1 - 2	600mm x 550mm x 3.2mm (nom) thick glass mirror blank with	$ 2125.00/lot
1 lot of 5 – 6	thin carbon fiber backing plate to be coated on the spherical surface	$ 3995.00/lot
1 lot of 9 -10	with ECI #801 UV-enhanced, first surface aluminum mirror coating	$ 5995.00/lot
	Optimized for Rmax@185 - 600nm for 0° AOI & for an air interface	
	Ambient (low) temperature processes will be utilized	
	R ≥ 88% @ 350-600nm; R ≥ 80% @ 250-350nm; 'Best Effort' R ≥ 80% @ 185-250nm	
	Curves supplied showing %R data from 200nm - 600nm,	
	with 'Best Effort' for 185-200nm data (due to noise/instrument limitations)	

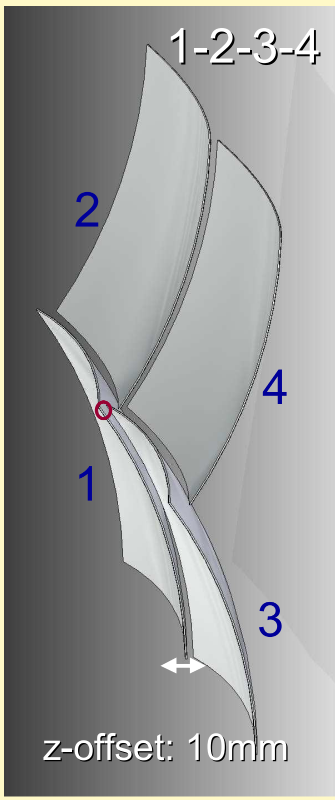
  - After aluminization they will be shipped to JLab, where the Detector Group will independently verify the UV reflectivity.
    - **Bill will come to JLab to help with the measurements.**
  - **If acceptable, then aluminize up to 6 additional mirrors for HGC, and all mirrors for NGC. Significantly cheaper than CERN.**
  - After aluminization, need to return mirrors to Regina for application of carbon fiber backing.

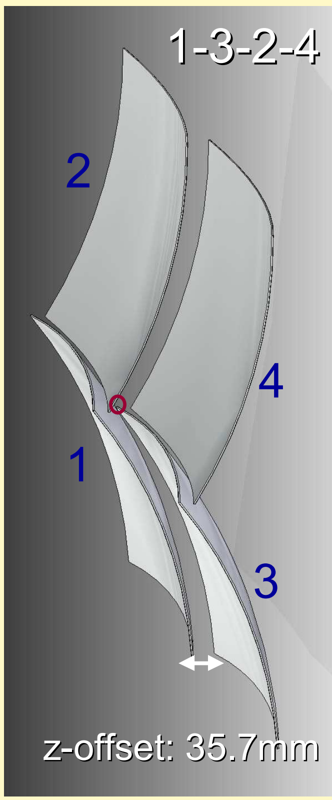
    Shipping costs also dramatically reduced vs. CERN.

Further Design Work

Mirror Placement Refinements

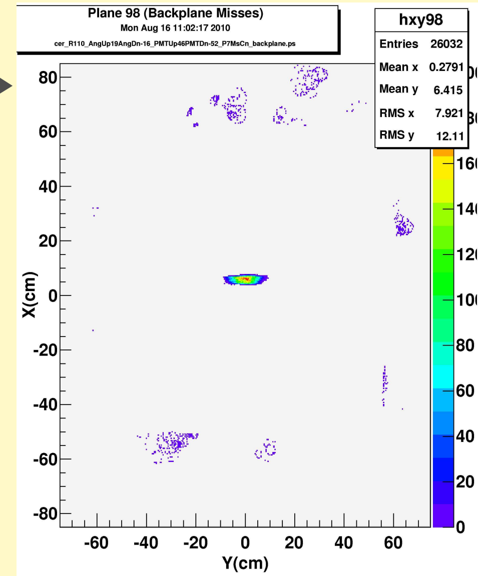
- Because the mirrors are curved, their interleaving is a little complicated.
- Want to avoid gaps while respecting 3/8" closest approach between mirrors.



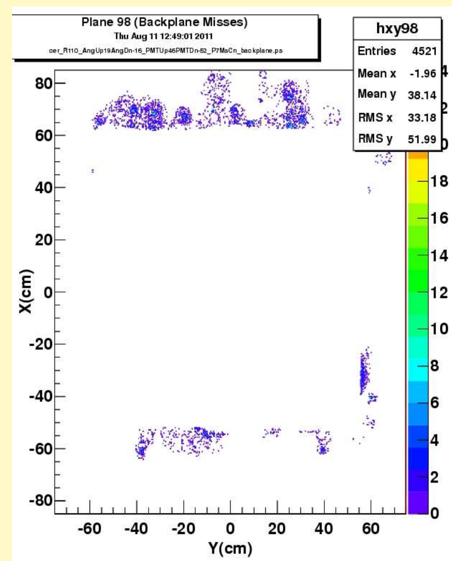


Aug 2010 Simulation:
- Spherical Mirror,r=110cm.
- 1-3-2-4 interleaving.
- Non-optimized gap.

Mirror misses: 26032 out of 14.4M γ's (0.2%)



- **CAD model used to optimize mirror clearances.**
- **Geant4 used to verify performance.**



Aug 2011 Simulation:
- 1-2-3-4 interleaving.
- Optimized gap.

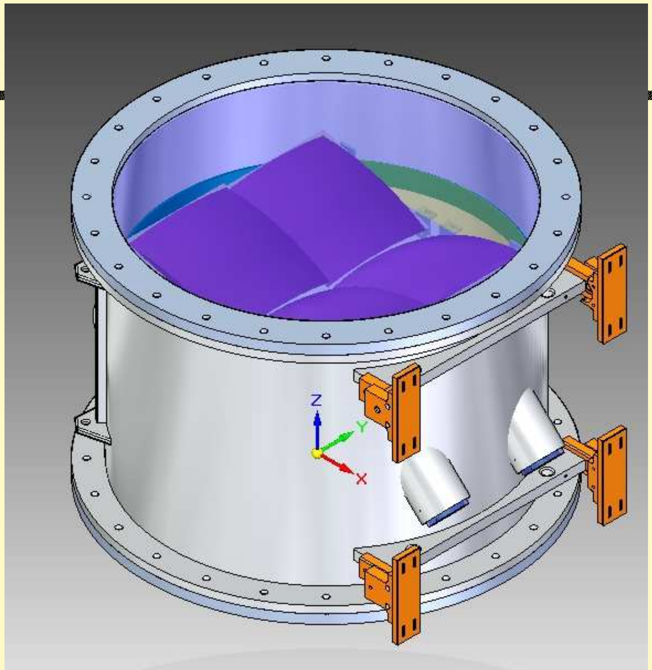
Mirror misses: 4521 out of 60.2M γ's (<0.01%)

Geant4 studies planned for next ~6 mo.

- **Now that we have precise mirror curvature data, we would like to refine the MC to more closely approximate actual mirror geometry.**
  - Does this affect the optimal positions and angles of PMT viewports?
- **Suggestions on how to include this in Geant 4 this eagerly welcomed!**
  - Incorporate Dumur sensor data as a Tesselated Solid?
  - Use fit conic formula as a Boundary Represented Solid?
- **If the studies indicate a change needed to PMT viewport positions, we would have to modify the vessel construction drawings.**
  - Could be done as late as April, 2012 without too much problem.
- **Suggestions also welcome on how to implement Donal Day's PMT position sensitivity measurements in SensitiveDetector analysis to produce more accurate simulated photoelectron distributions.**
- **Determine sensitivity to misalignments.**

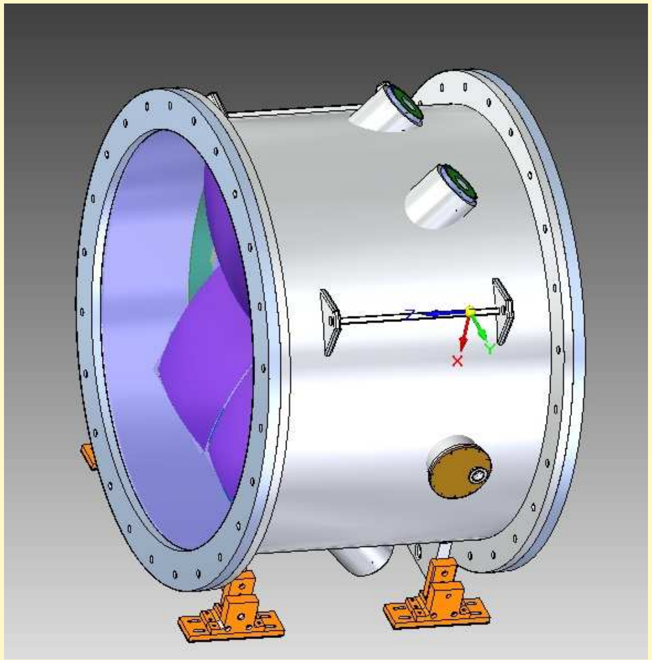
HGC Mounting Fixtures

- Foot design by Steve Furches (JLab) is more complex than we anticipated, but seems fine.
- We are expecting the pieces shaded in orange to be provided by JLab.



GAS SYSTEM INTERFACE:

- We propose a removable plate with a KF-50 fitting.
  - Removable plate allows alternate fittings or pressure gauges to easily be installed later.
- Unsure of best spot for plate.
  - Top, bottom, or beam left?



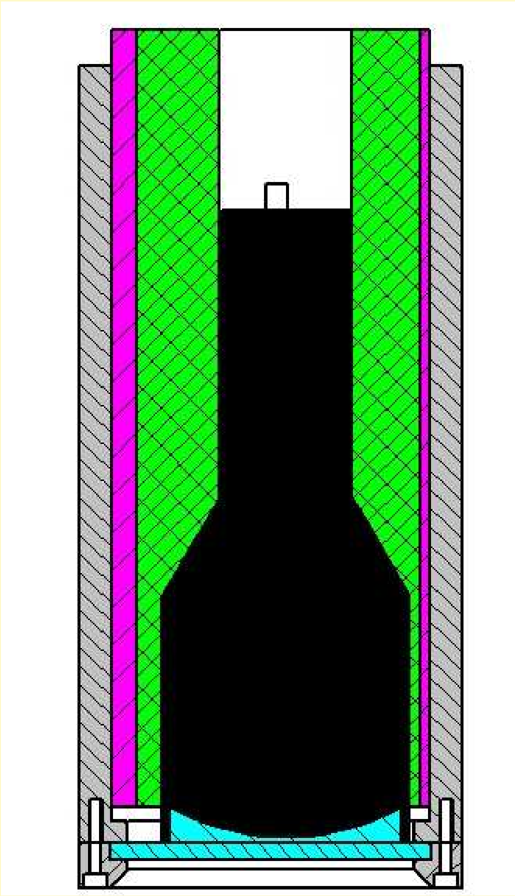
Revised PMT Mounting Brackets Design

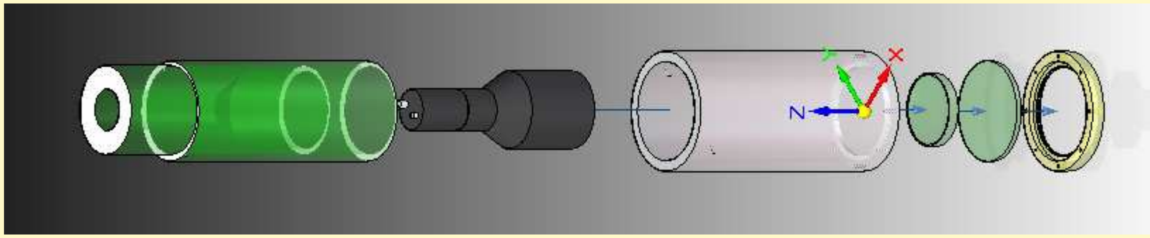
Design requirements:

- Need to mount PMT flush against quartz viewport.
- Want PMT position to be laterally adjustable against quartz viewport (~1cm).

A possible solution:

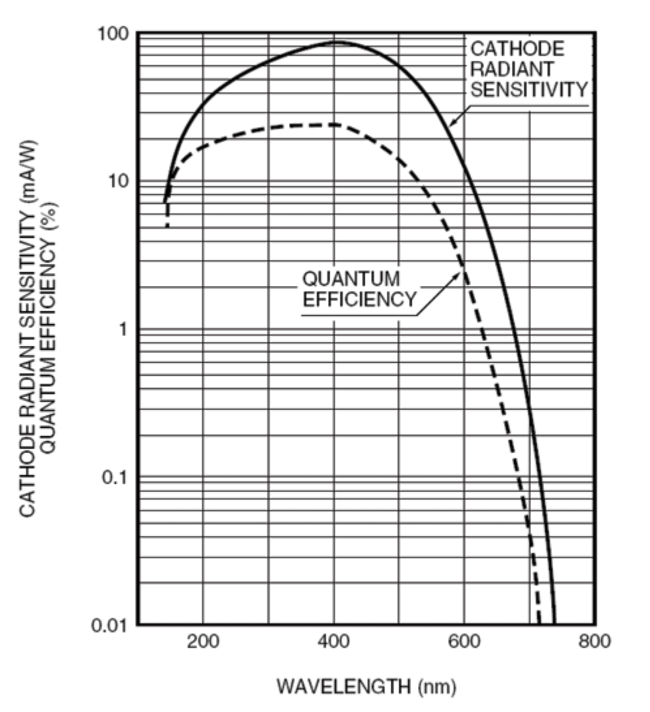
- Machine two nylon collars with offset holes to allow PMT adjustability.
- PMT + μshield rests inside collar.

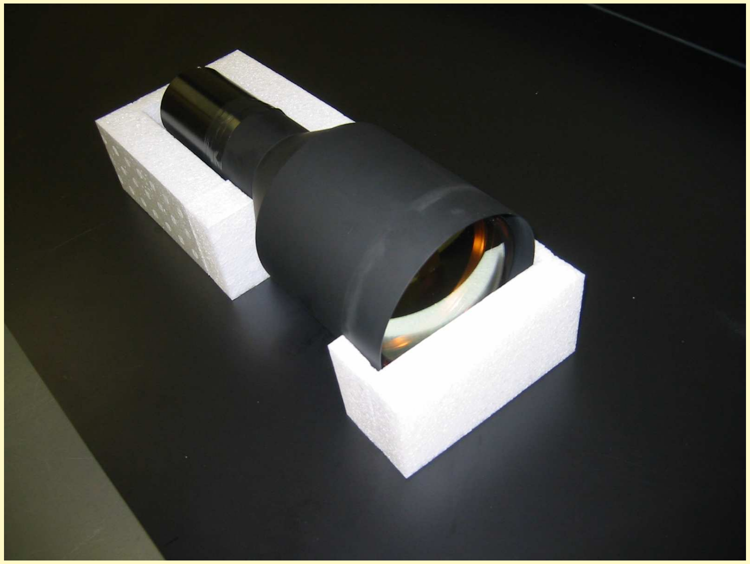




Hamamatsu H6528 kits have finally arrived

- **Japan earthquake caused some shipping delay.**
- Thermal stability and gain tests using Cerenkov light from cosmics in spare Q_{weak} quartz are planned for this fall-winter.

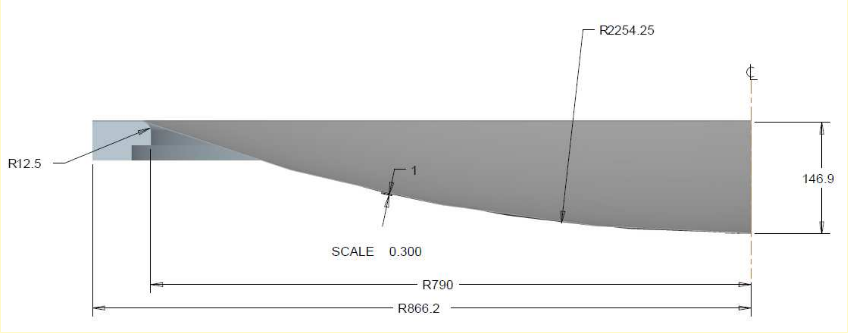




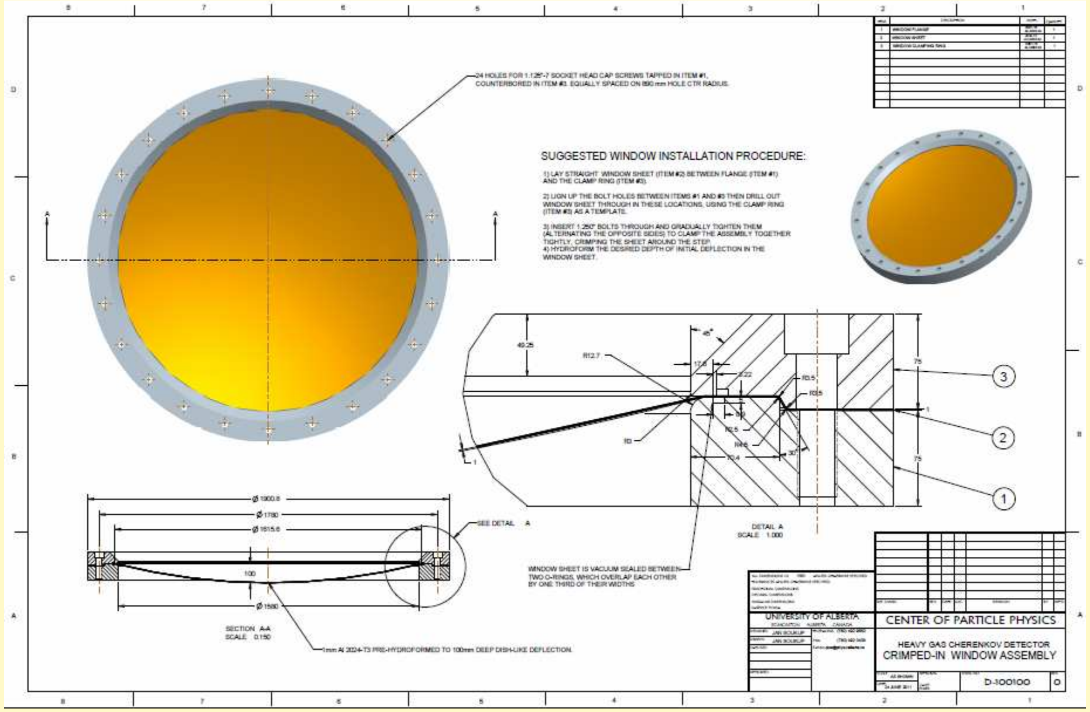
Possible Entrance Window Clamping Scheme

New entrance window FEA calculations by Jan Soukup, Detector Engineer @ University of Alberta.

- Calculations presented in Jan/11 assumed window rigidly glued along rim.
- 146.9mm hydroform depth seemed to conform to 2024-T3 aluminum material strength.

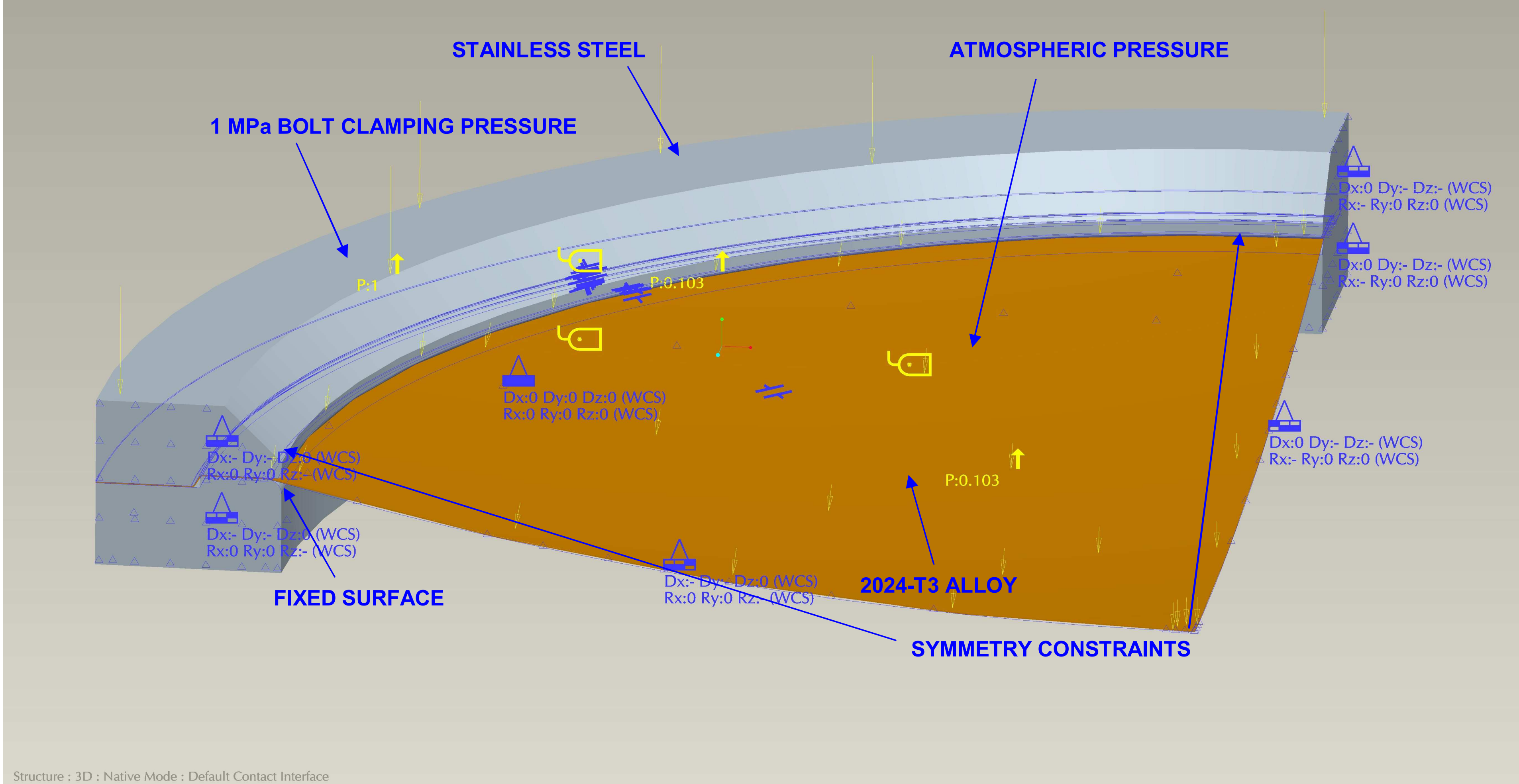


- New calculations assume a crimped window secured by 24 large bolts.
- Allows some slippage, which may reduce window stress, and possibly allow a smaller hydroform depth.

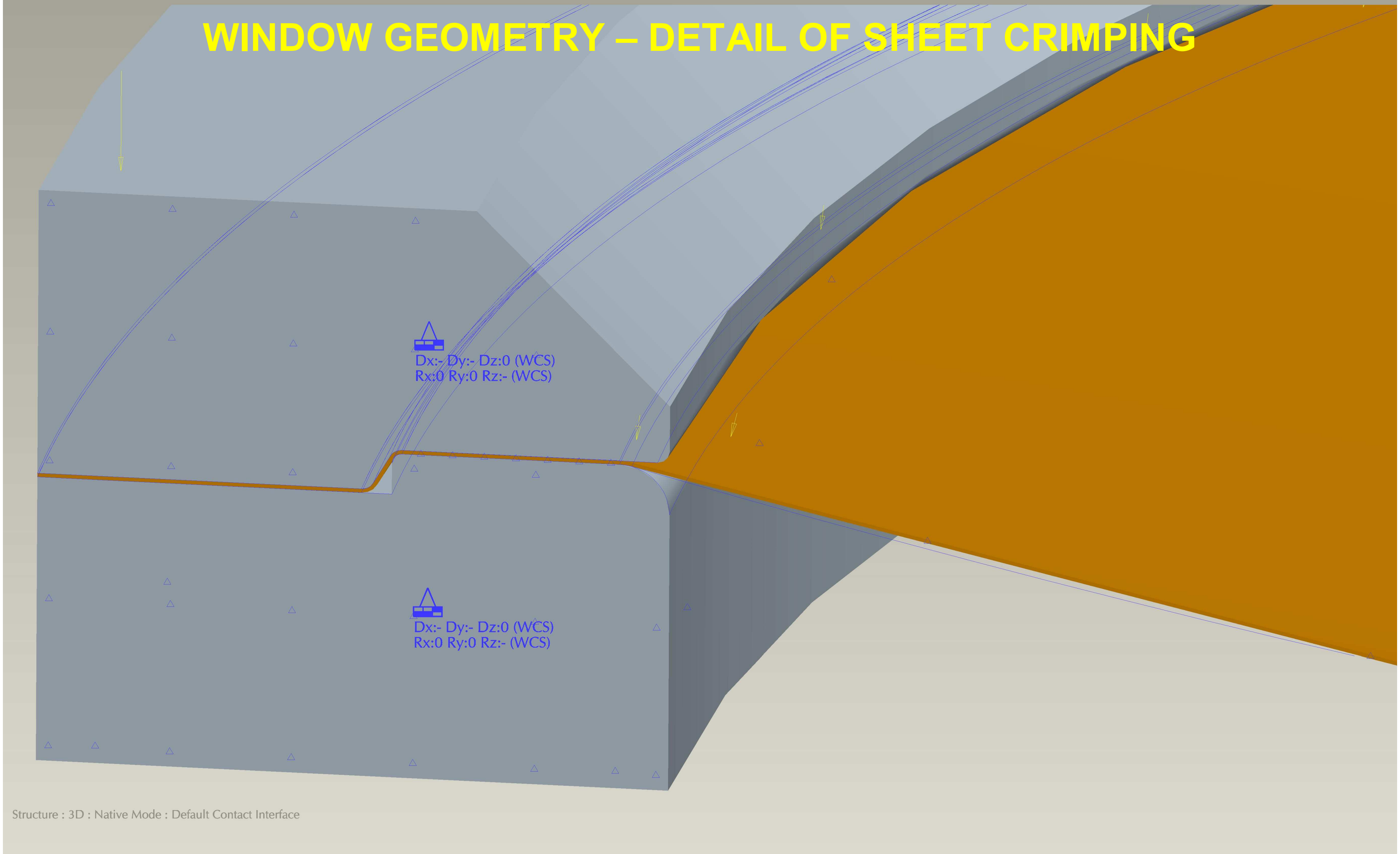


FEA STUDY OF A HYDROFORMED 2024-T3 ALUMINUM SHEET WINDOW

QUARTER-SYMMETRY FEA MODEL GEOMETRY

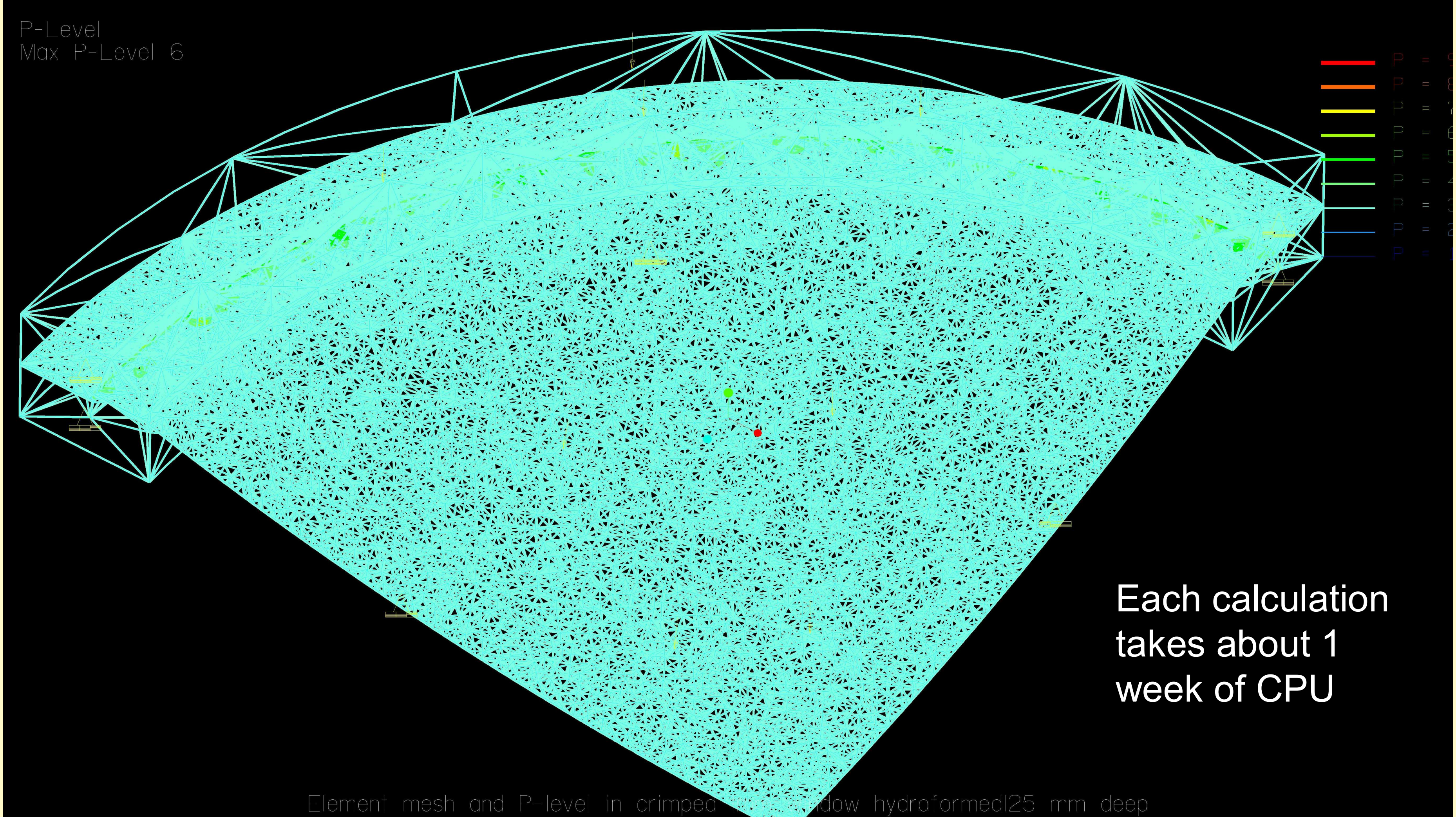


WINDOW GEOMETRY – DETAIL OF SHEET CRIMPING



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

FEA STUDY OF A CRIMPED 1mm THICK SHEET 2024-T3 ALUMINUM WINDOW PRE-HYDROFORMED TO A DISH DEPTH OF 125 mm.



Each calculation takes about 1 week of CPU

FEA MESH AND THE ELEMENT POLYNOMIAL ORDER

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

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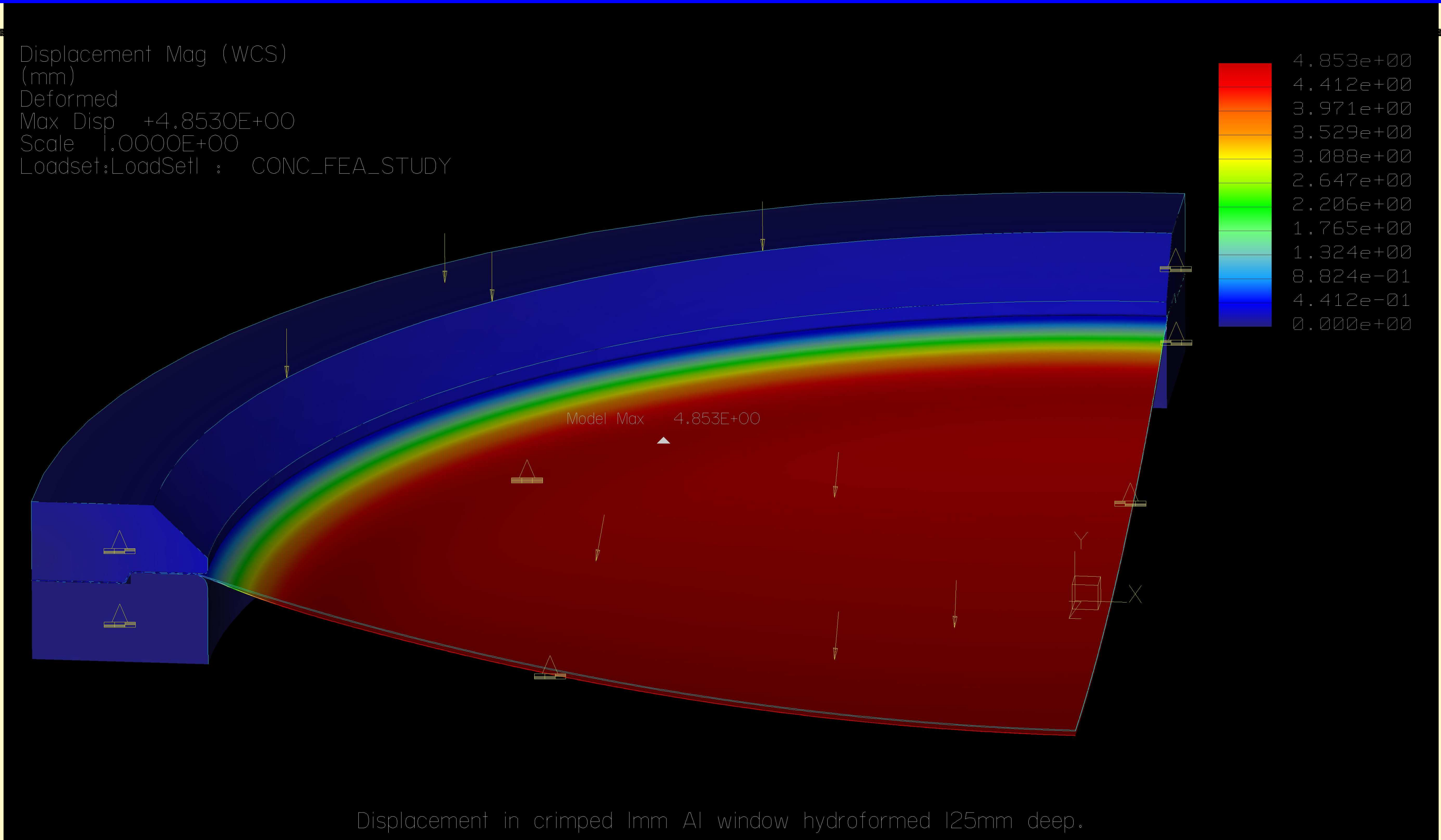
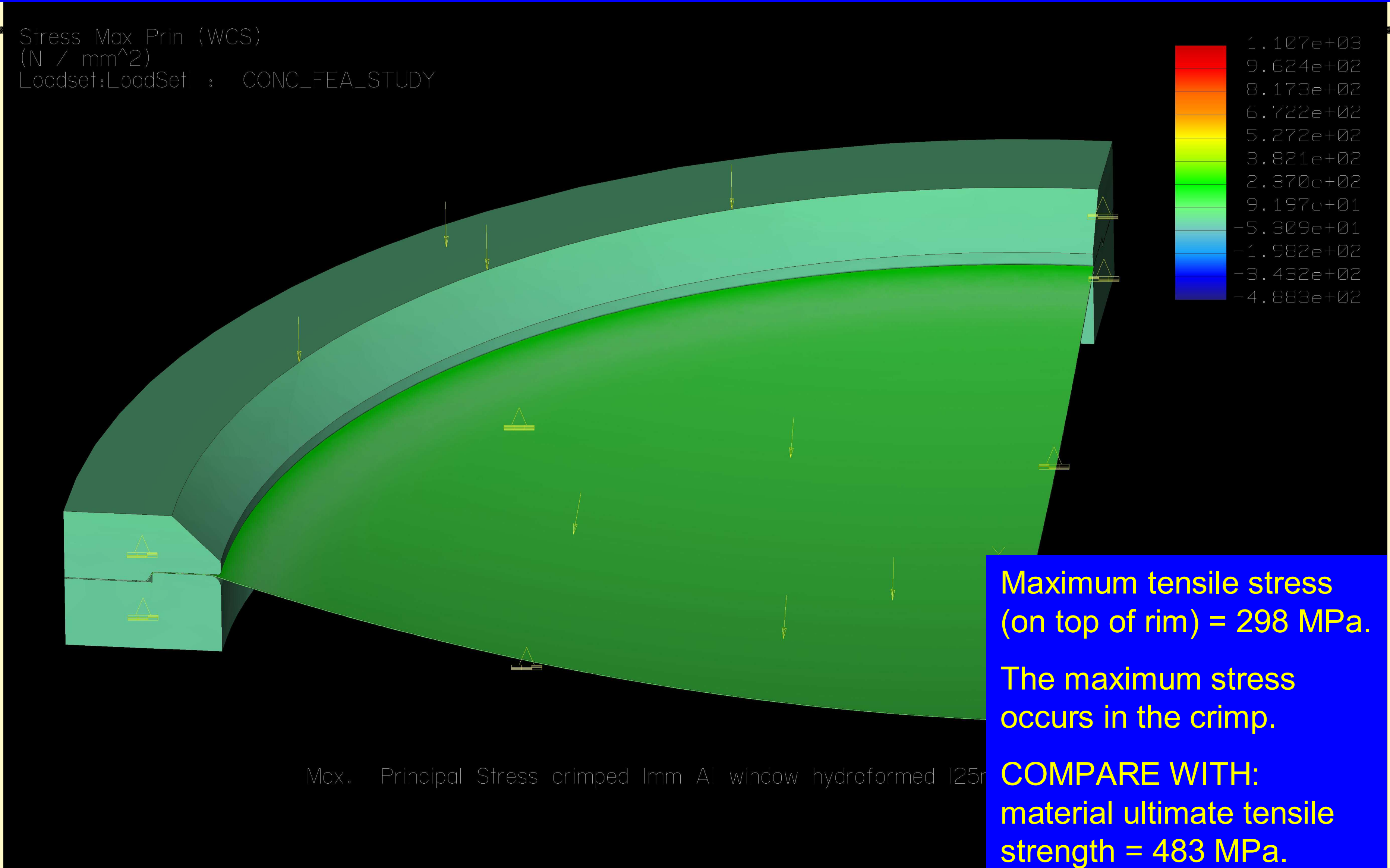


MAXIMUM DISPLACEMENT WITH FEA MESH

Maximum additional window deflection = 4.85mm

FEA STUDY OF A CRIMPED 1mm THICK SHEET 2024-T3 ALUMINUM WINDOW PRE-HYDROFORMED TO A DISH DEPTH OF 125 mm.



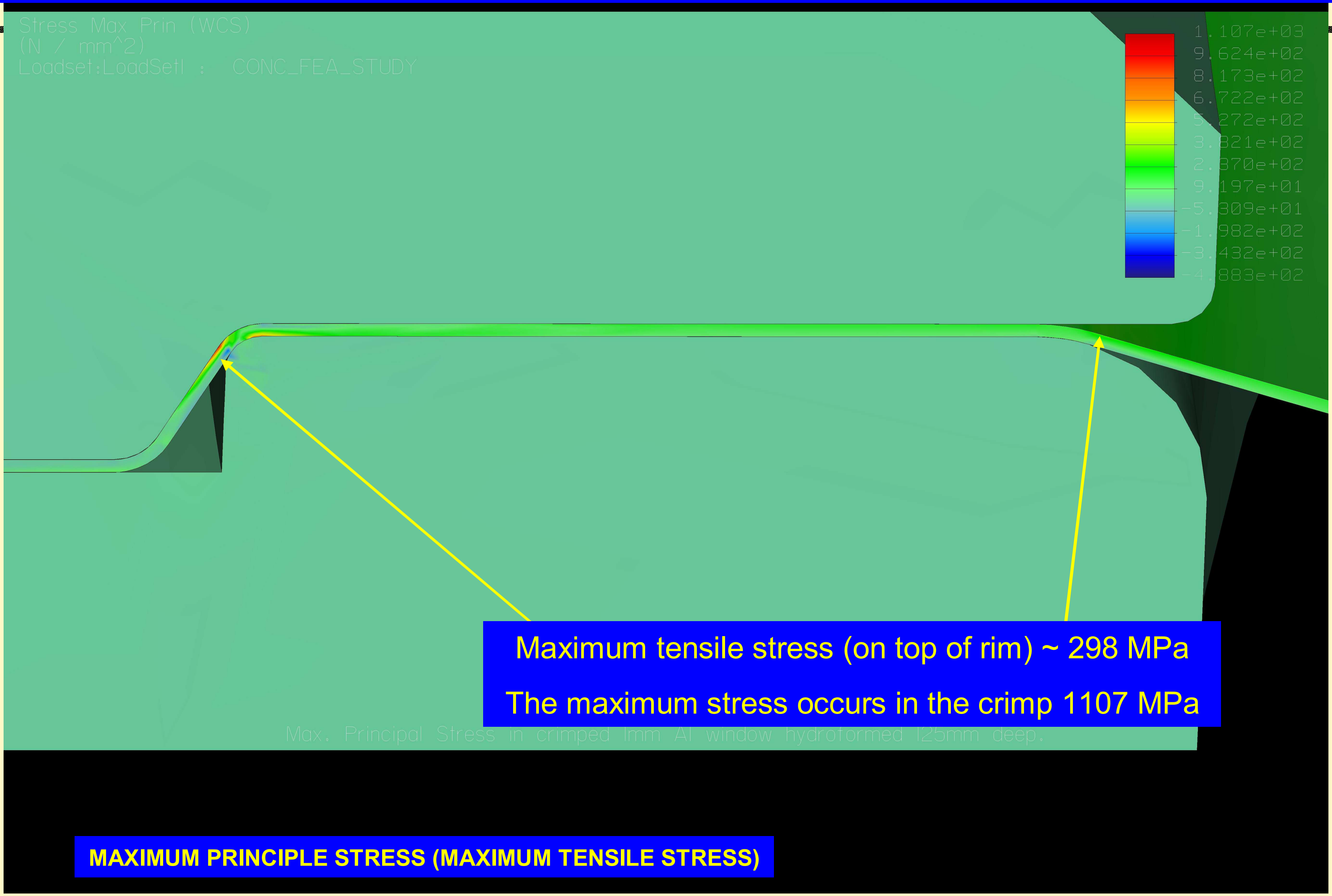
Maximum tensile stress (on top of rim) = 298 MPa.

The maximum stress occurs in the crimp.

COMPARE WITH: material ultimate tensile strength = 483 MPa.

MAXIMUM PRINCIPLE STRESS (MAXIMUM TENSILE STRESS)

FEA STUDY OF A CRIMPED 1mm THICK SHEET 2024-T3 ALUMINUM WINDOW PRE-HYDROFORMED TO A DISH DEPTH OF 125 mm.



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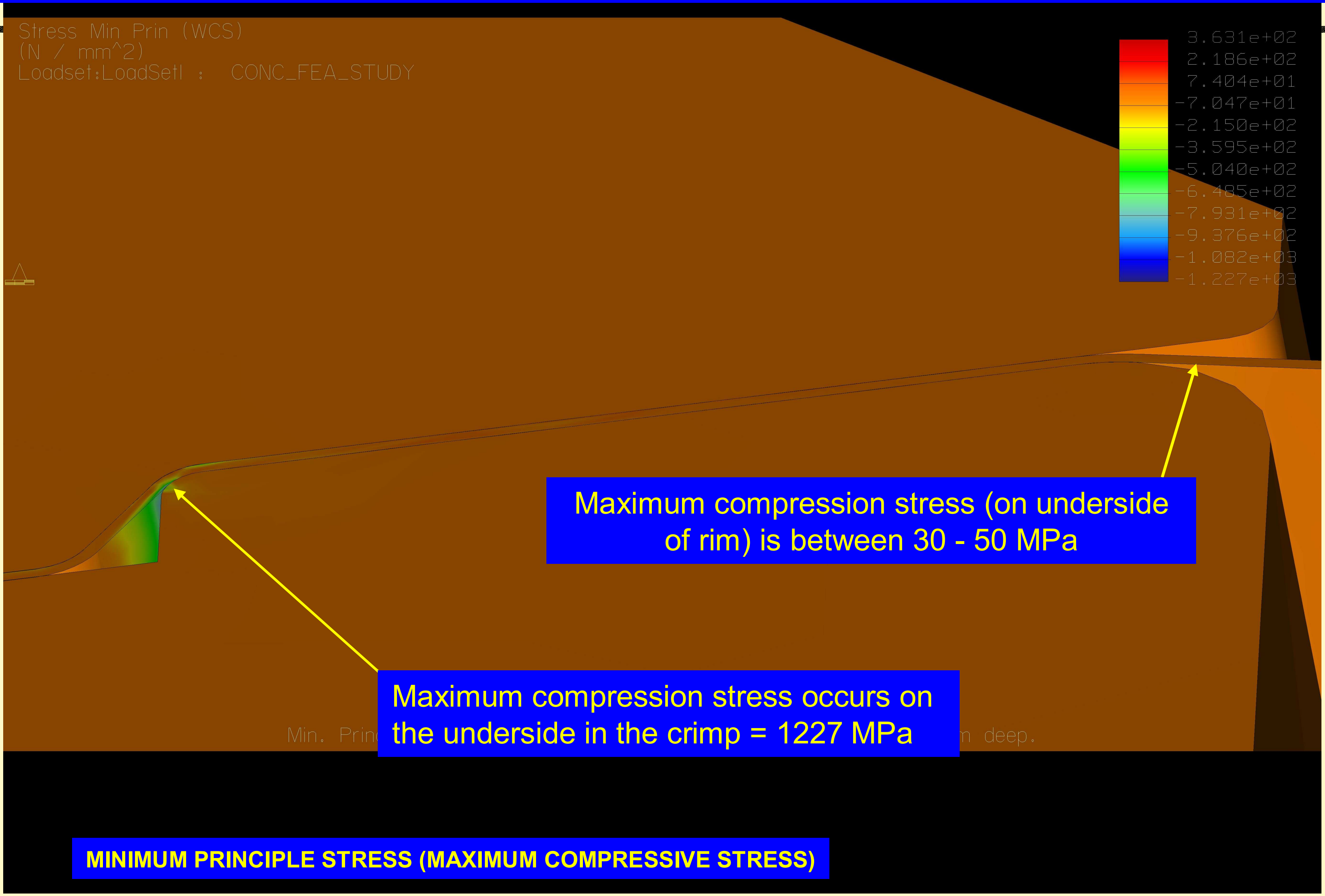
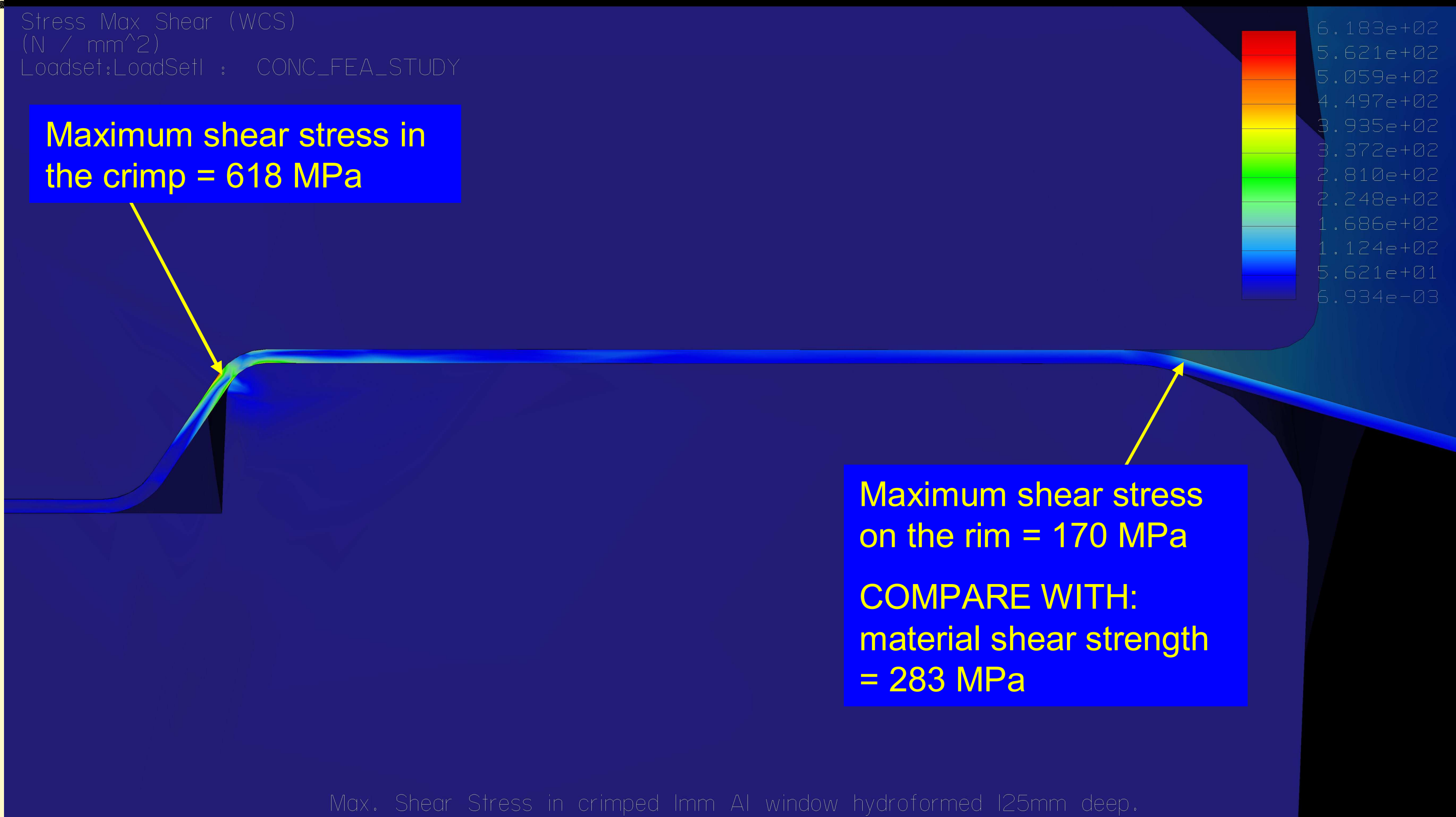
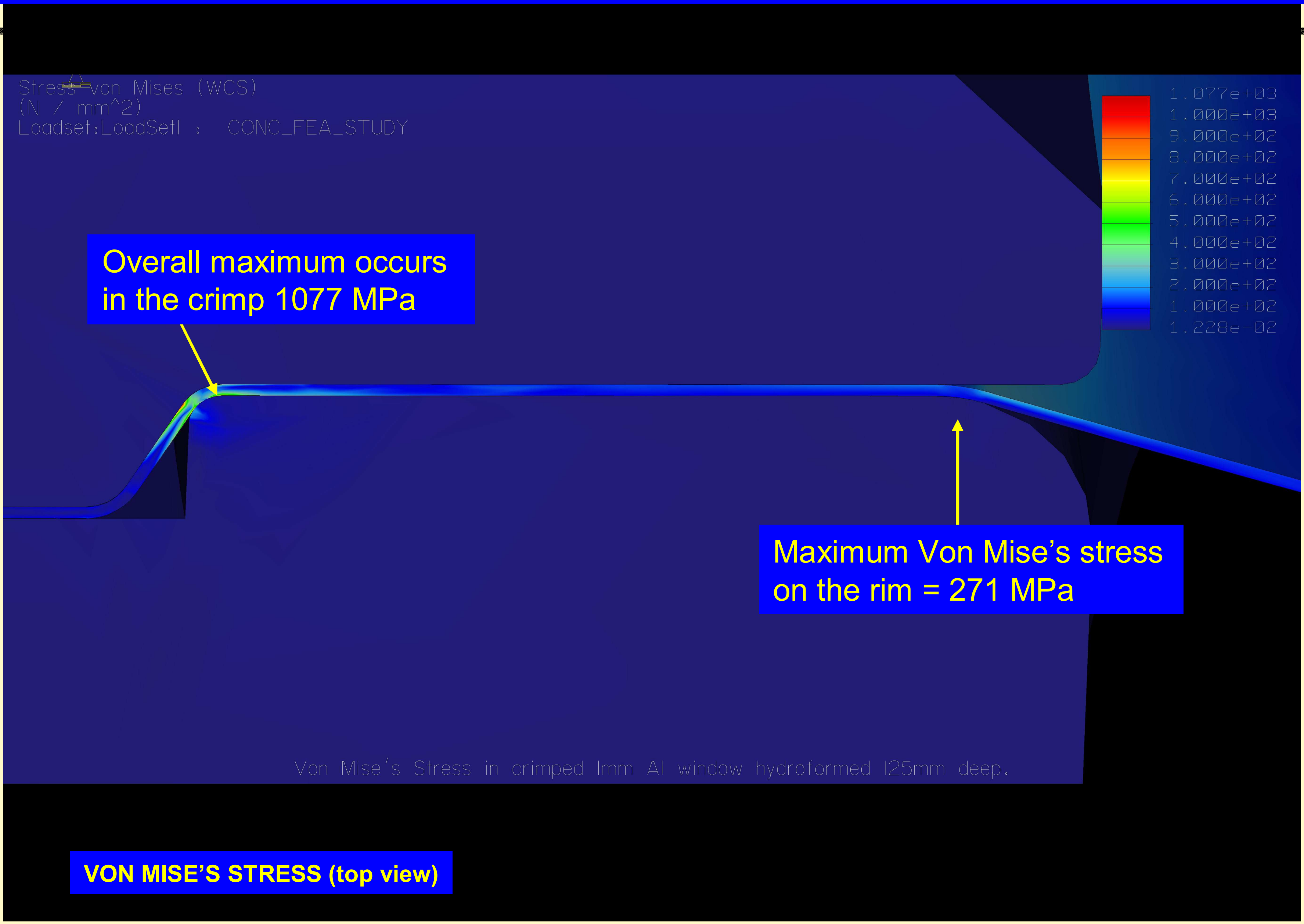


FEA STUDY OF A CRIMPED 1mm THICK SHEET 2024-T3 ALUMINUM WINDOW PRE-HYDROFORMED TO A DISH DEPTH OF 125 mm.



MAXIMUM SHEAR STRESS (detail)

FEA STUDY OF A CRIMPED 1mm THICK SHEET 2024-T3 ALUMINUM WINDOW PRE-HYDROFORMED TO A DISH DEPTH OF 125 mm.



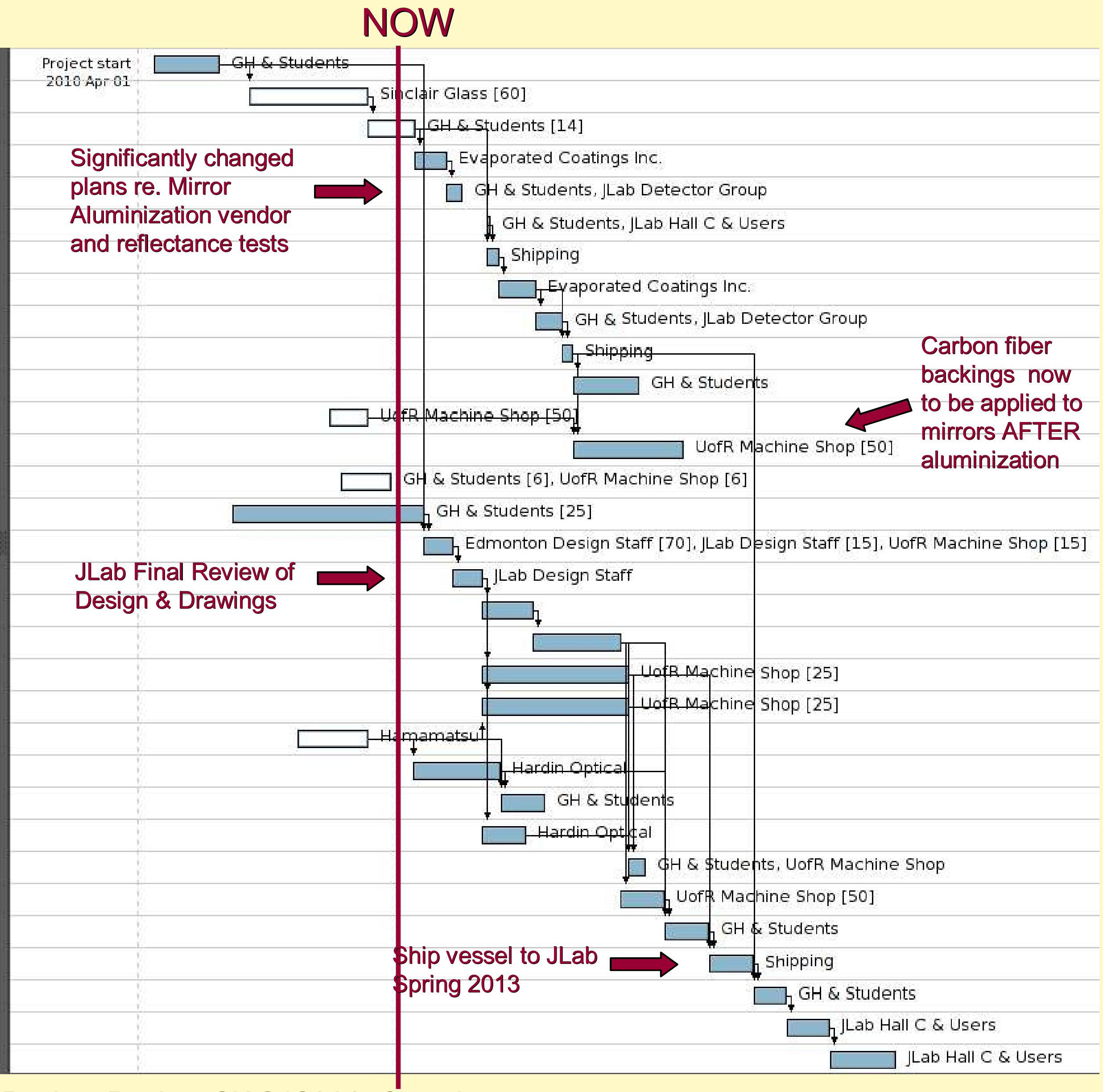
Window FEA Summary

	Crimped 100 mm hydroform	Crimped 125 mm hydroform	Glued 146.9 mm hydroform	2024-T3 aluminum ultimate strength
Additional Deflection	5.70 mm	4.85 mm	2.65 mm	
Max. Tensile Stress	396 MPa (top of rim)	298 MPa	271MPa	483 MPa
Max. Compressive Stress	281 MPa (underside of rim)	30-50 MPa	144 MPa	
Max. Shear Stress	284 MPa (on rim)	170 MPa	186 MPa	283 MPa
Max. Von Mise's Stress	492 MPa	271 MPa	324 MPa	

- **Need to discuss the necessity of the window crimp with Hall C engineering staff next week.**

Project Timeline Plans *(updated Aug 11/11)*

1	Finalize mirror selection via Geant4 Simulations
2	Mirror Procure
3	Mirror Optical Testing
4	Test Aluminization of 2 Mirrors
5	UV Reflectance Tests @ JLab
6	Aluminization Vendor Decision
7	Ship Mirrors from Regina to Alum. Vendor
8	Mirror Aluminization @ Vendor
9	More UV Reflectance Tests @ JLab
10	Ship Mirrors from JLab to Regina
11	Final Optical Tests of Aluminized Mirrors
12	Prototype Mirror Stiffening Brackets
13	Construct Mirror Stiffening Brackets
14	Design Mirror Mount Assemblies
15	Finalize PMT and Mirror Placement via Geant4 Simulations
16	Pressure Vessel Detailed Drawings
17	Pressure Vessel Final Design Review
18	Pressure Vessel Vendor Bids
19	Pressure Vessel Procure
20	Construct Mirror Mount Assemblies
21	Construct PMT Mount Assemblies
22	PMTs, mu-Shields, Bases Procure
23	PMT Adapters Procure
24	PMT, Base gain tests
25	Spectrosil Windows Procure
26	Optical Alignment Tests
27	Window Hydroforming
28	Pressure Vessel Vacuum Test
29	Ship Vessel & Parts from Regina to JLab
30	Assembly of Detector in Test Lab @ JLab
31	Cosmic Tests at JLab
32	Install on SHMS



Comment on Short-Term Schedule

- Waiting for final confirmation that the University of Alberta will make HGC construction drawings for us, based on our CAD model.
  - Drawings primarily for the vessel, entrance/exit window clamps, since the mirror and PMT support assemblies will be prototyped and built by the UofR Mech. Shop.
- Our readiness for the Final Design Review by JLab depends on the timeline (still uncertain) on getting the HGC construction drawings made.
  - Expecting the U of Alberta work schedule to be firmed up by Labor Day, with the actual work to proceed about a month later.
  - If the University of Alberta can not make the drawings, then I will need JLab to make them.
- Either way, hope the Design Review can be completed by year end, so that we can put the vessel to vendor bids in early 2012.

NSERC Equipment Grant Budget *(Updated Aug 10/11)*

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	
Mounting Assemblies	UofR Mech. Shop	$7,033		
Mirror Quality Tests	Dumur Industries	$500	$900.00	-$400.00
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		
Mounting Assemblies	Hardin Optical	$5,633		
3 Pressure Vessel		$56,501		
4 Shipping				
Shipping to/from Regina	Thomas Ahern	$7,596	$471.06	

My only reserve against other overexpenditures.

Will buy spare PMT later, if funds permit.