Heavy Gas Čerenkov Detector August 2010 Update

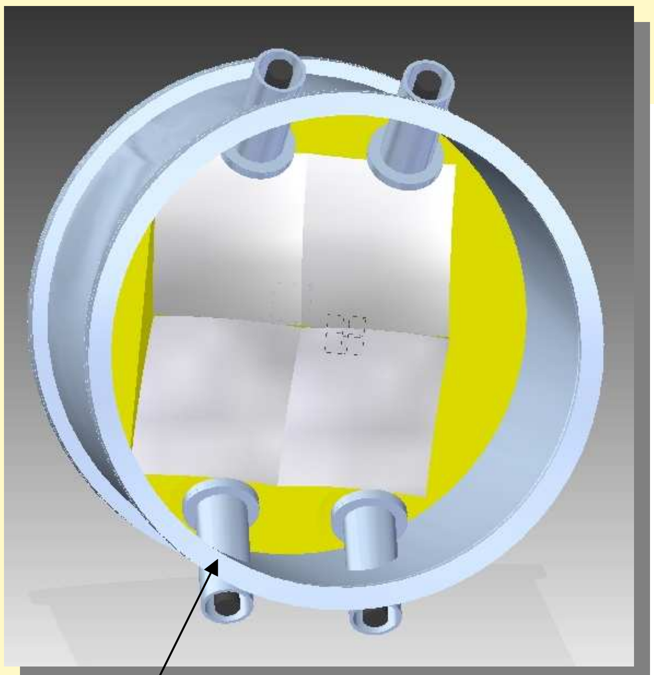
Garth Huber & Lee Sichello

UNIVERSITY OF REGINA

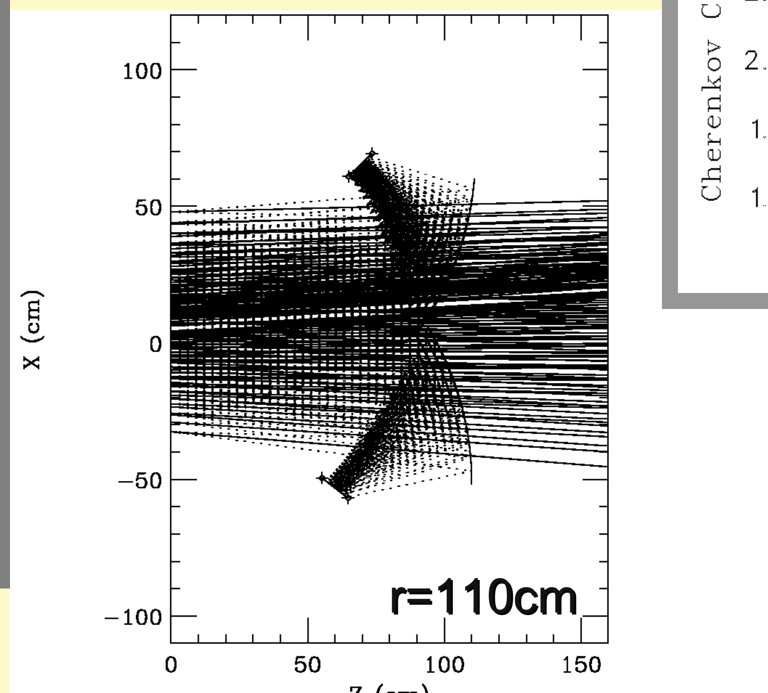
SHMS Detector Working Group Meeting. August 26, 2010.

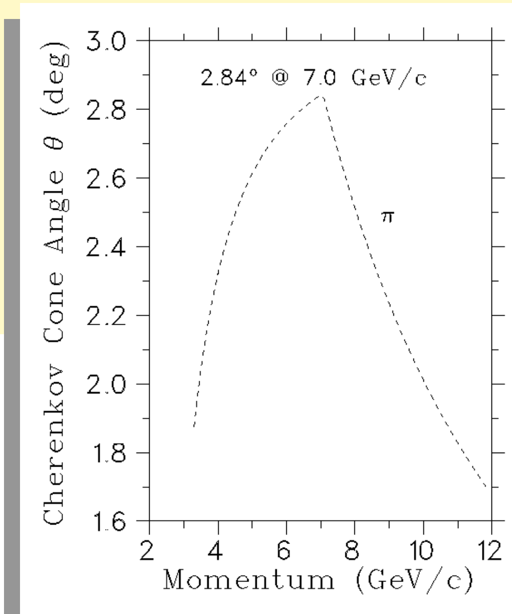
Heavy Gas Čerenkov Overview

Cylindrical aluminum vessel
similar to HMS Gas Čerenkov
(rated to 1 atm underpressure).



170cm inner diameter.





Hardest to collect all light at 7 GeV/c.

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

NSERC Funding Decision: March 31

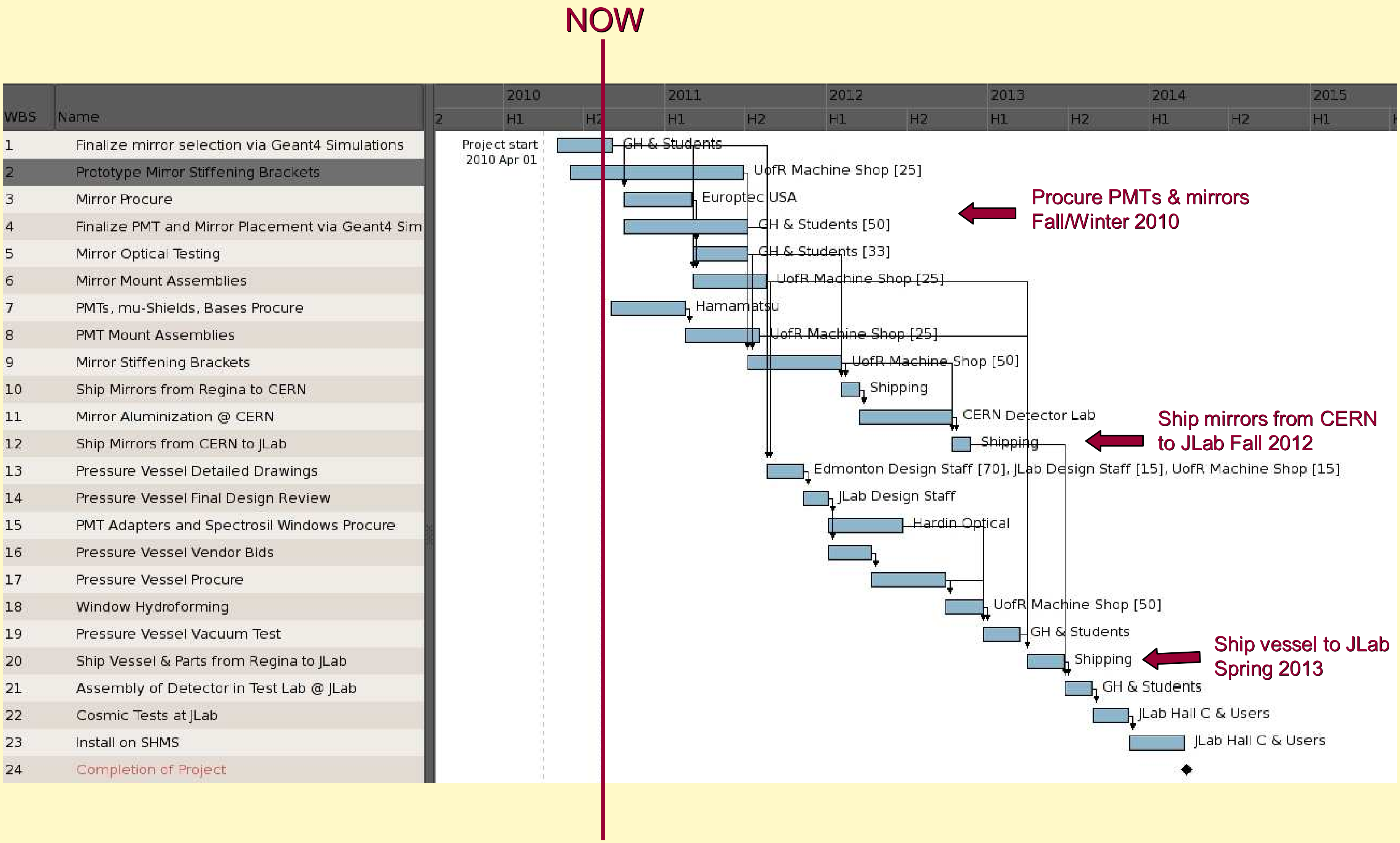
Research Tools & Instruments 1 Grant Application:

Requested Funds:		C$148,529
Awarded:	FY10 (April 1, 2010)	C$ 80,000
	FY11 (April 1, 2011)	C$ 45,000

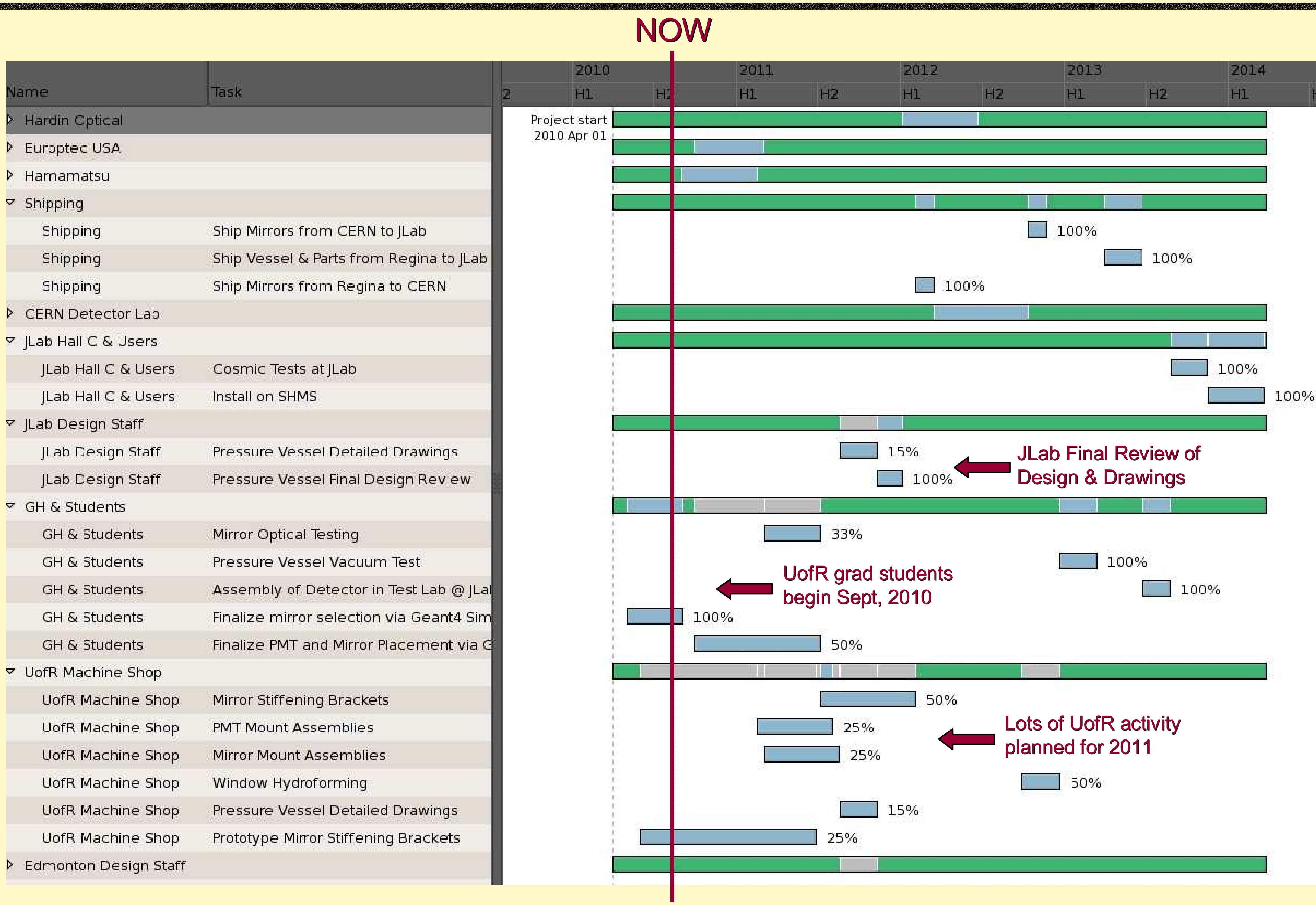
Subatomic Physics Evaluation Section (SPES) comments:

- *The SPES recognizes the applicants' merit and the strength of the research program this detector would support.*
- *Considering the budgetary pressure, the Section recommends funding at a level that is somewhat reduced with respect to that requested.*
- *Moreover, the Section acknowledges the timely need for initial funds but, given the SHMS schedule, recommends that approximately 1/3 of the amount be deferred to a second year.*
- *In seeking the necessary small economies, the Section encourages the applicants to refine the design of the vessel to possibly make use of in-house staff for finishing tasks and yield a higher response rate on a future request for quotes. The Section also suggests more economical shipping arrangements and aluminization processing.*

Project Timeline Plans *(updated Aug 11/10)*

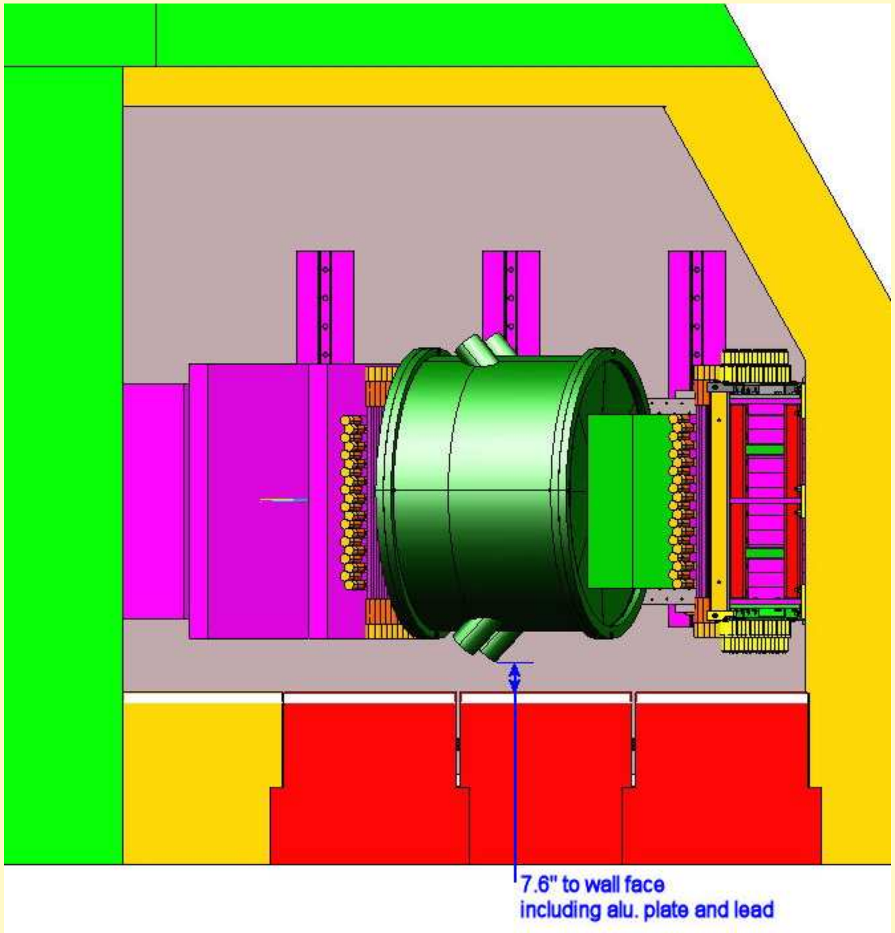


Resource Usage Plans *(updated Aug 11/10)*

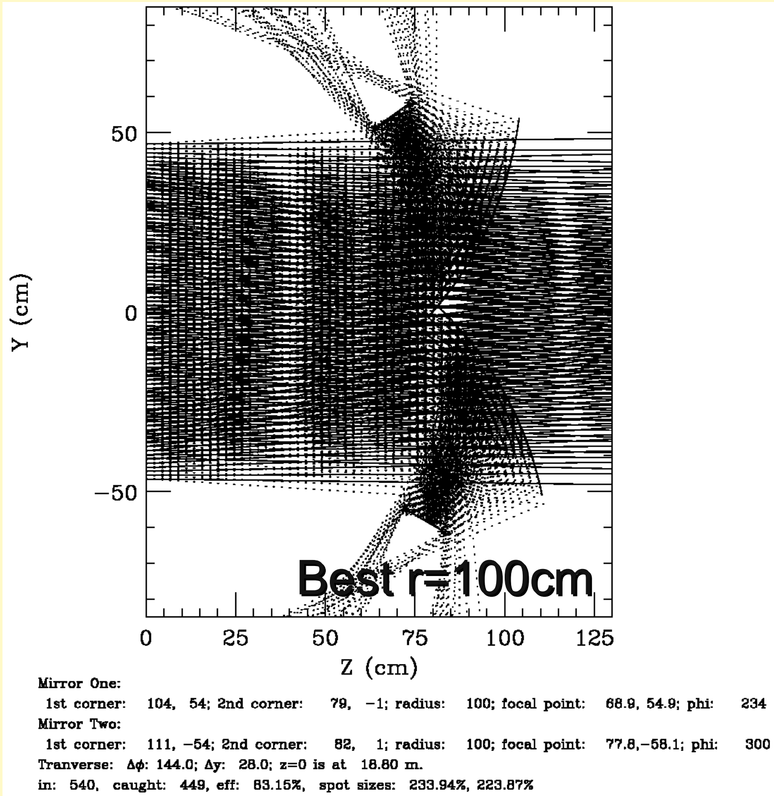


Transverse Configuration

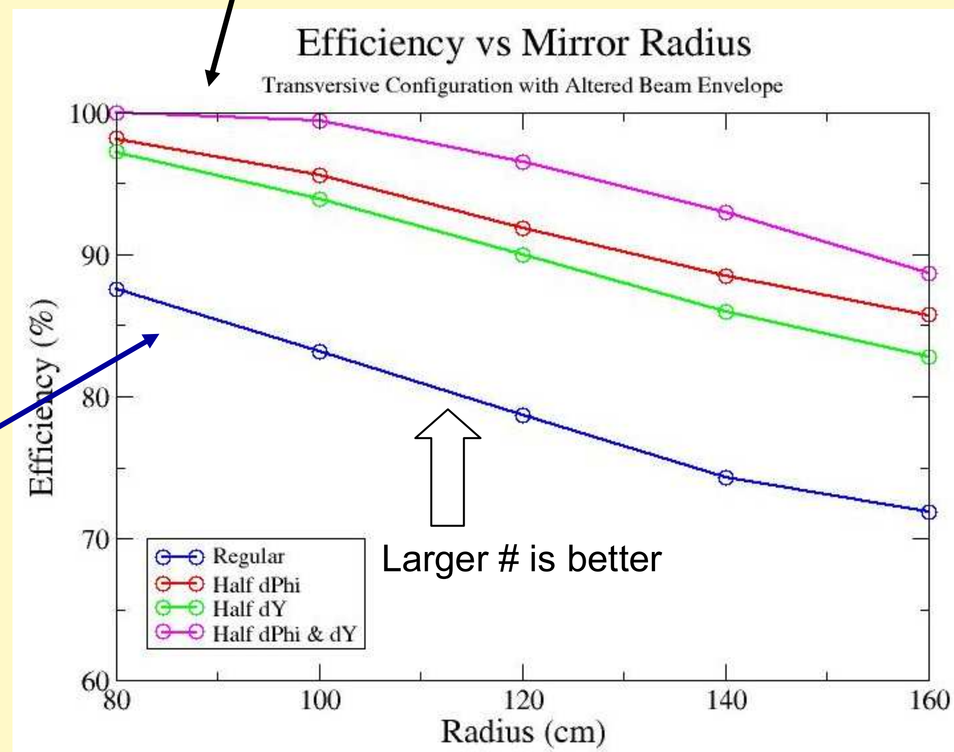
- Bert Metzger asked us to consider if HGČ PMTs can be mounted **Left-Right (transverse plane)** instead of **Top-Bottom (dispersive plane).**
  - If HGČ is simply rotated by 90º, there is 19cm clearance between the PMTs and the back wall.
- To see if this is advantageous, need an entirely new set of optics simulations.
  - Study was not in our plans for Summer 2010.
  - Study accommodated by deferring some planned studies until later this winter.



Transverse Configuration: 2D raytrace studies

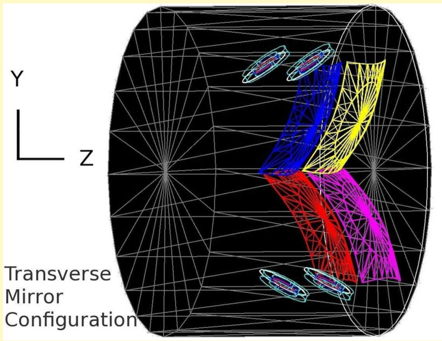


- Unable to collect 100% of Čerenkov light in all configurations studied.
- **Difficulty likely due to dispersion in transverse plane:**
  - → Reducing $\Delta\varphi/2$, $\Delta y/2$ results in improved performance.

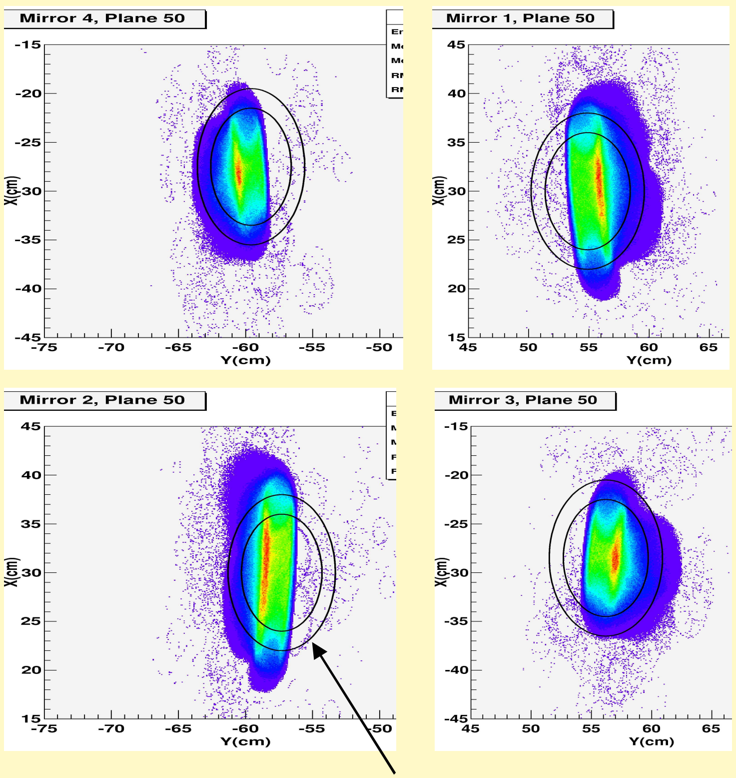


Best efficiency for r=80cm
- **But PMT interferes with beam envelope for r<100.**

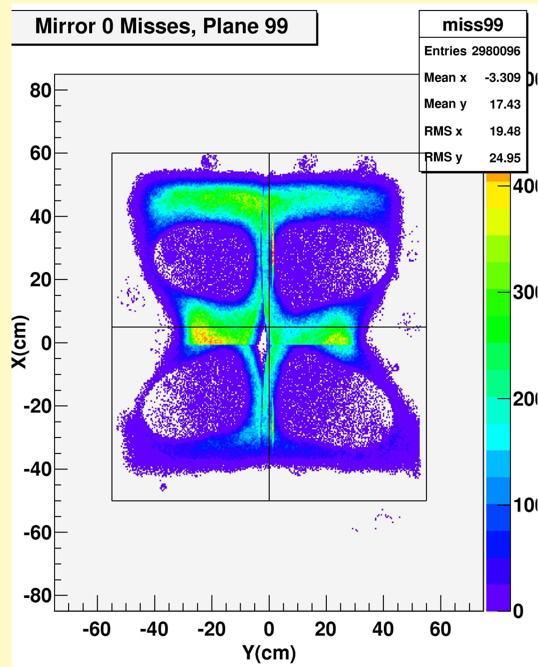
Transverse Configuration: 3D Geant4 studies



3D simulations confirm poor light collection found in 2D studies.



PMT 12cm active area



Mirror hit plot of light missing PMT.

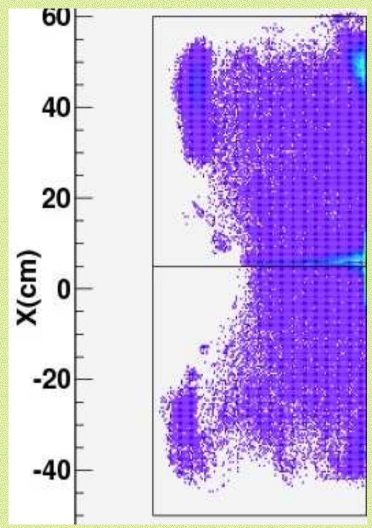
- 6 mirrors probably needed for good light collection efficiency in transverse configuration.

Mirror Curvature Studies

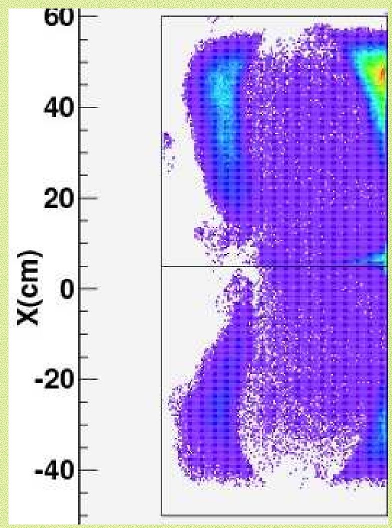
- Preliminary conclusions from Summer 2009 indicated slightly better performance with parabolic vs. spherical mirrors.

1. Mirror & PMT placements were not completely optimized in those studies.
2. With further optimization, will the spherical mirror performance approach that of parabolic?

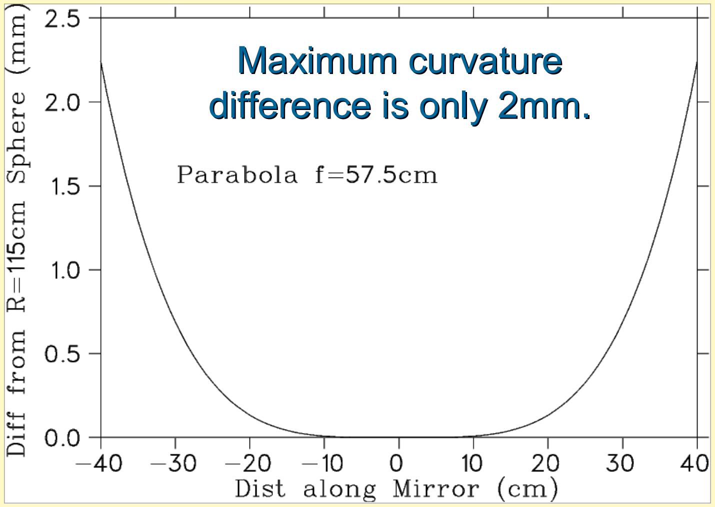
Mirror Hits missing PMT (Aug/09)



Parabolic f=57.5cm

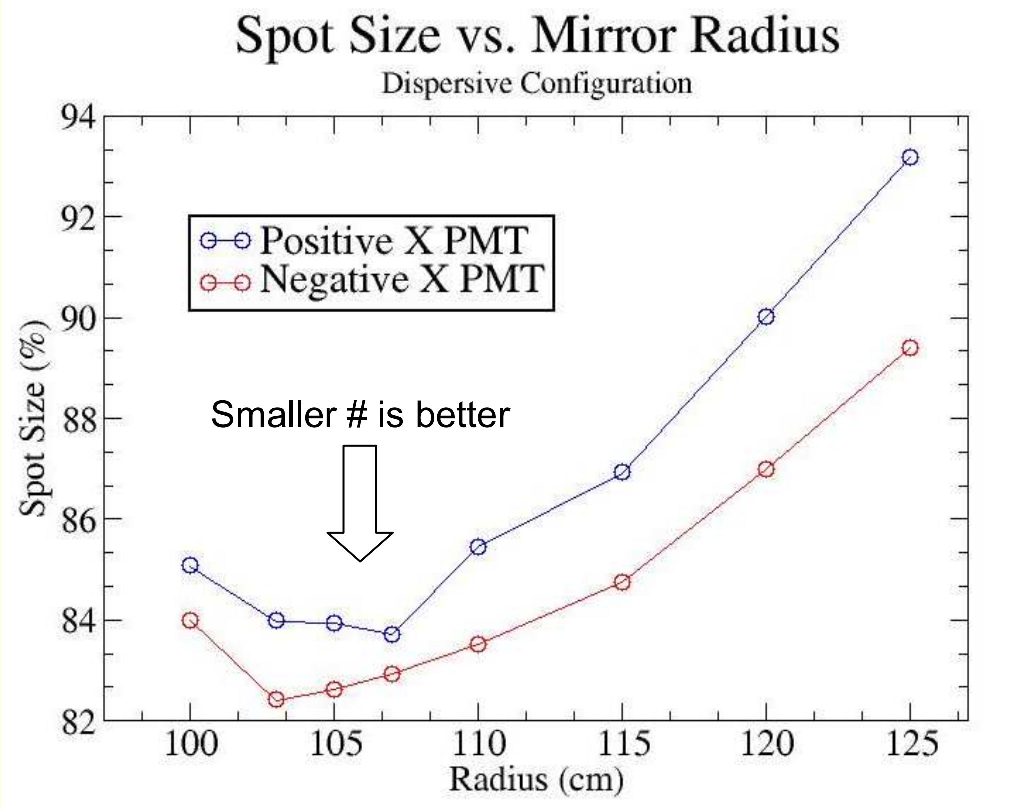


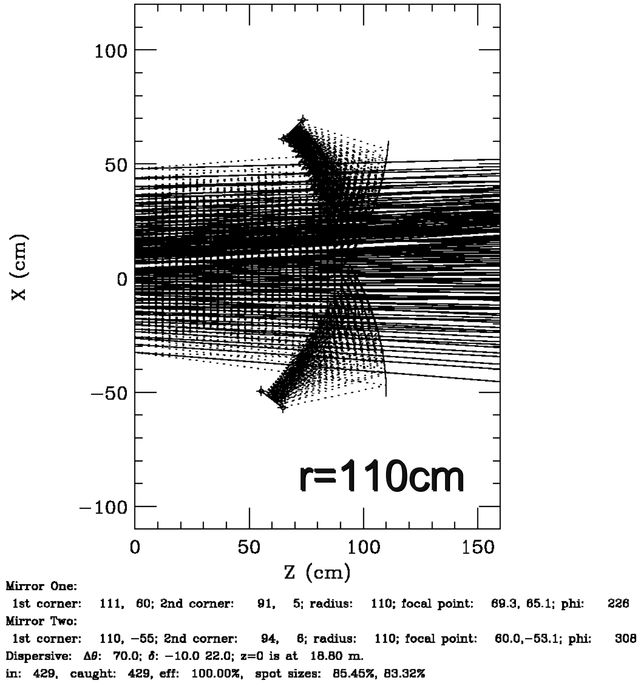
Spherical r=115cm



Spherical Mirrors: 2D raytrace studies

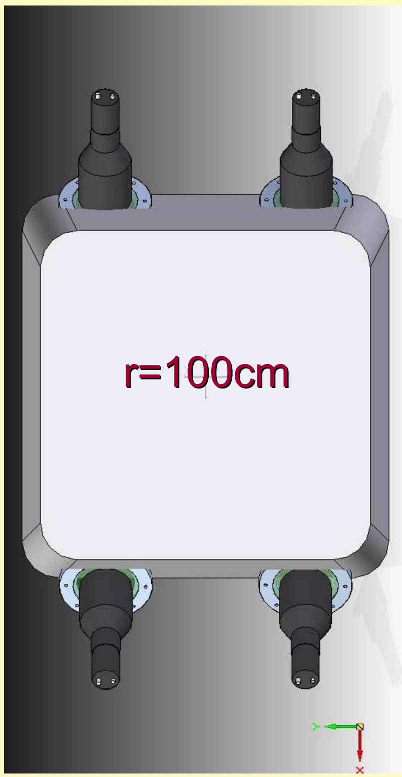
- Some improvements made to program to speed execution.
- Investigate finer grid of mirror radii, PMT and mirror positions compared to 2009.
- **Find better configurations with r=105-107cm vs. r=115cm previously.**

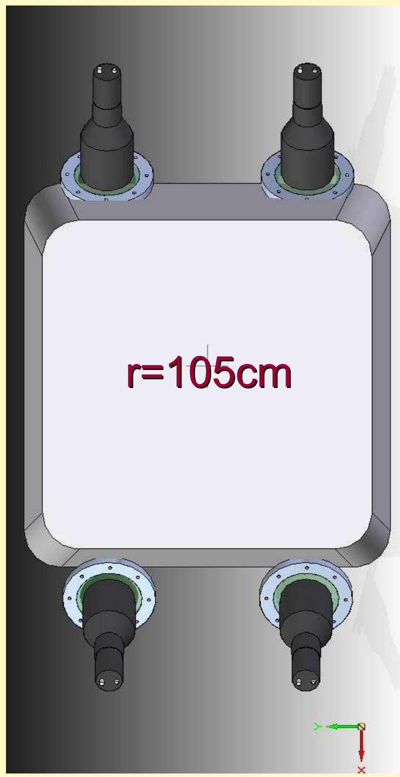


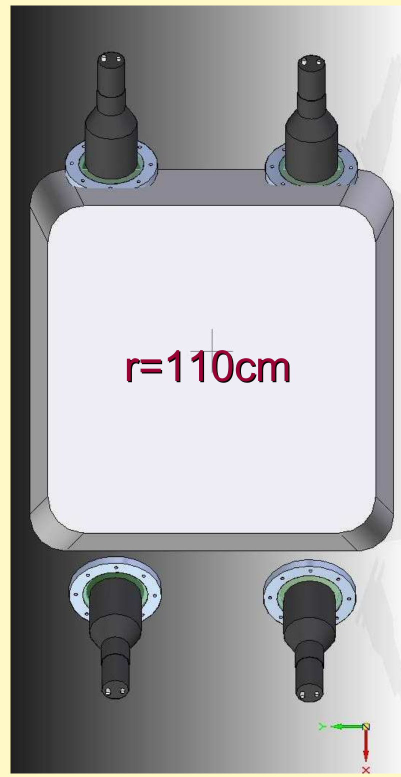


One constraint to keep in mind

- If the mirror focal length is too small, the PMT comes too close to the beam envelope and the flanges holding the quartz windows may block some particles.

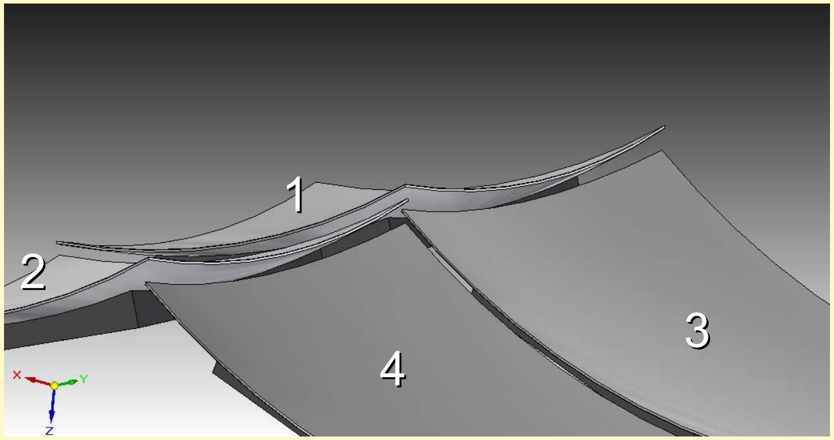




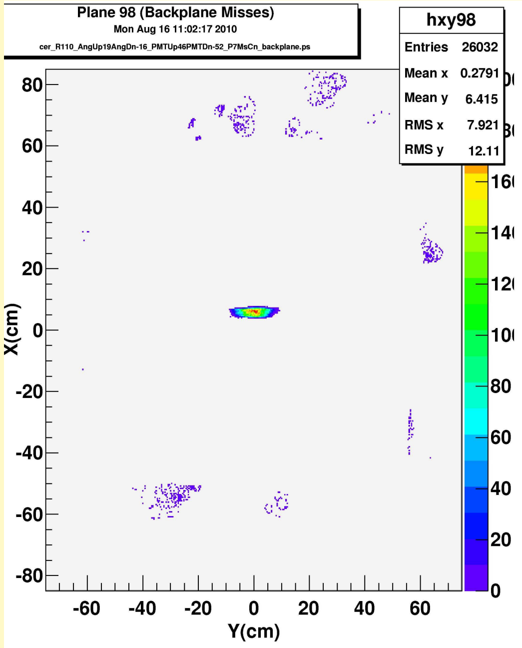


3D simulations: Mirror Interleaving

- Mirrors must be as close as possible without touching.
- Because the mirrors are curved, the interleaving is a little complicated.
- Required mirror spacing: 3cm.



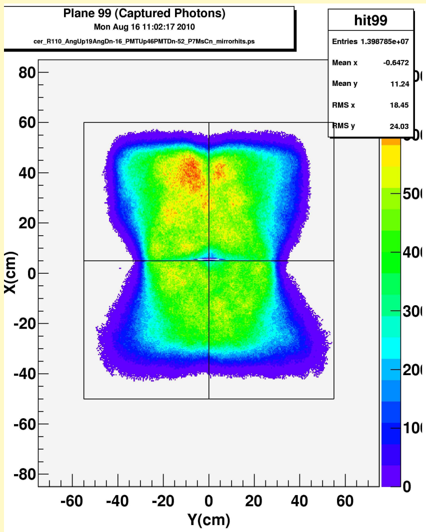
With extended light generation, some gaps are unavoidable.



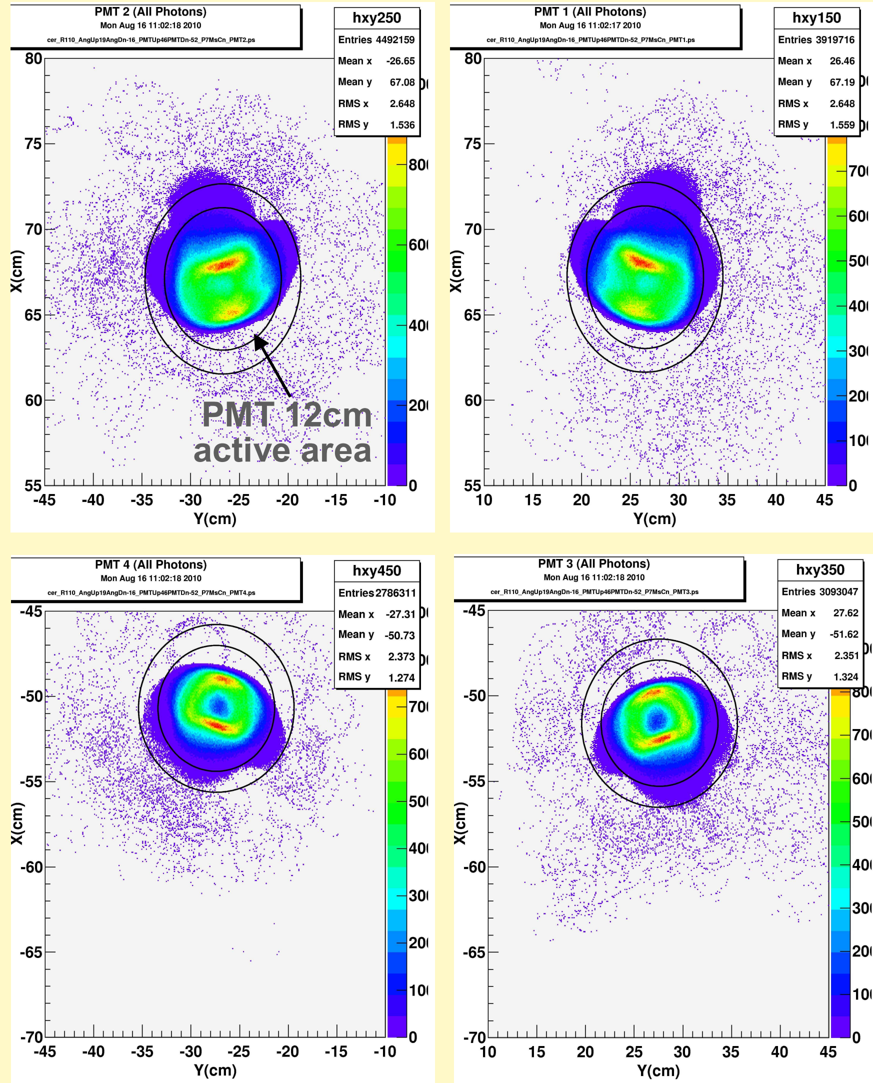
Spherical Mirror, r=110cm.

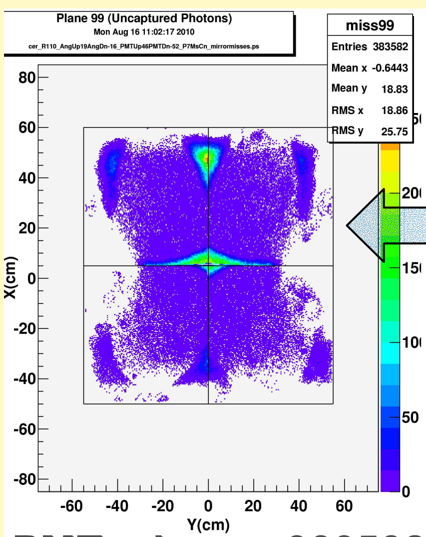
Mirror misses: 26032 out of 14.4M γ's (0.2%)

Spherical Mirrors: 3D Geant4 r=110cm



Choose r=110 instead of r=107 to allow extra clearance between quartz window flange and beam envelope.



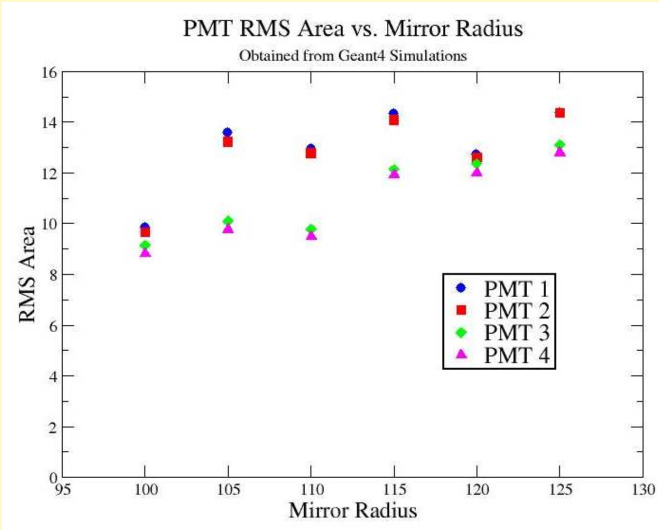


Aim is to reduce size of inefficient regions.

PMT misses: 383582 out of 14.4M γ's (2.7%)

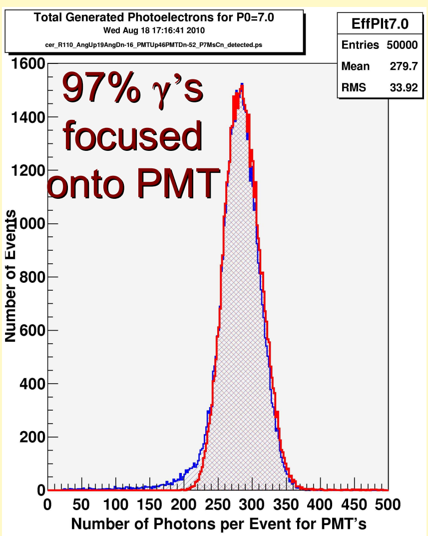
PMT positions re-optimized wrt raytrace positions:
#1: 3.0cm closer to mirror, #3: 3.1cm further.
Pairs1-2, 3-4 at equal angles, but offset by 3cm.

Spherical Mirrors: 3D Geant4 r=110cm

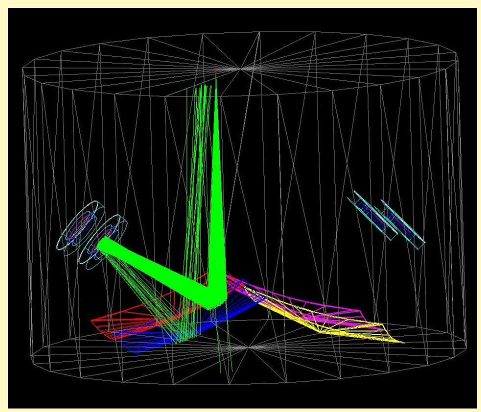


3D optics studies confirm better focusing of light onto PMTs with smaller r mirrors.

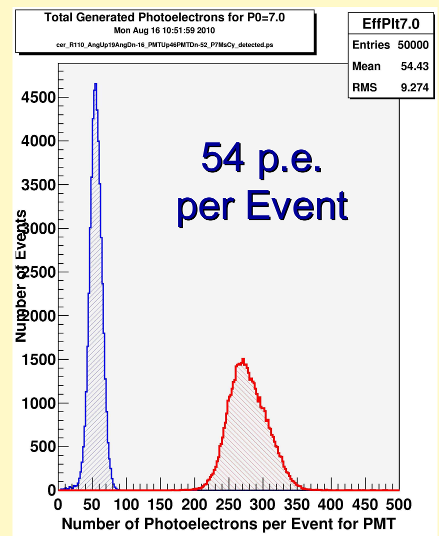
→ r<110cm mirrors might not allow sufficient clearance between beam envelope and quartz window flange.



γ's generated.
γ's collected.



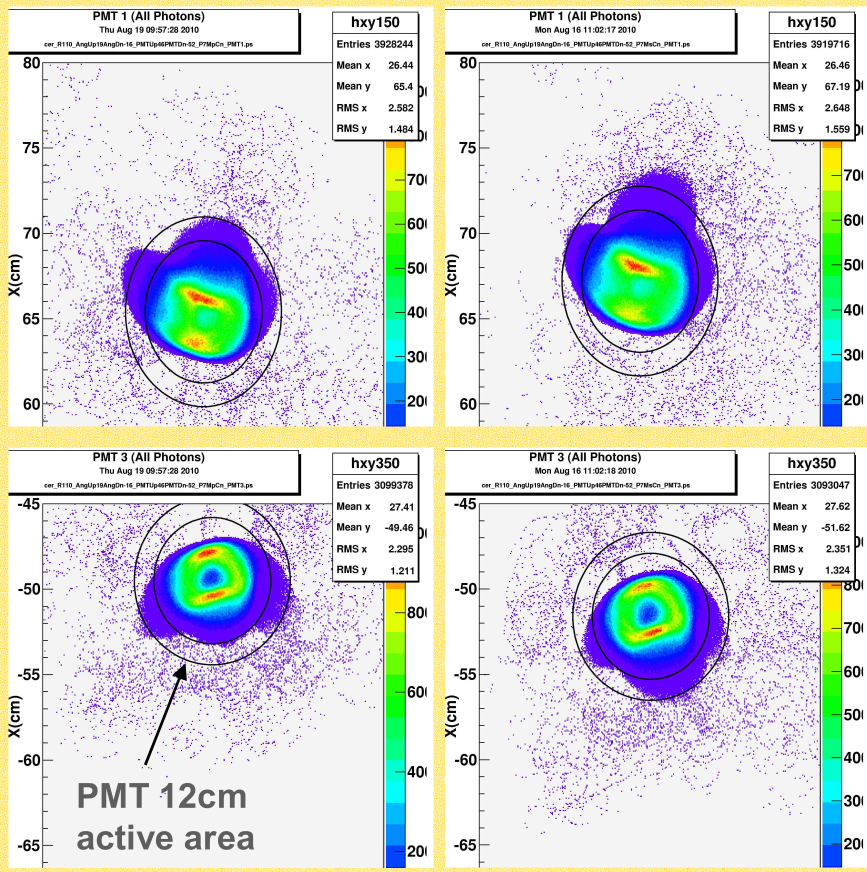
Number does not include ~10% γ's reflecting off quartz viewports.



Includes reflection and PMT quantum efficiency.

Spherical vs. Parabolic Mirrors: 7 GeV/c π^+

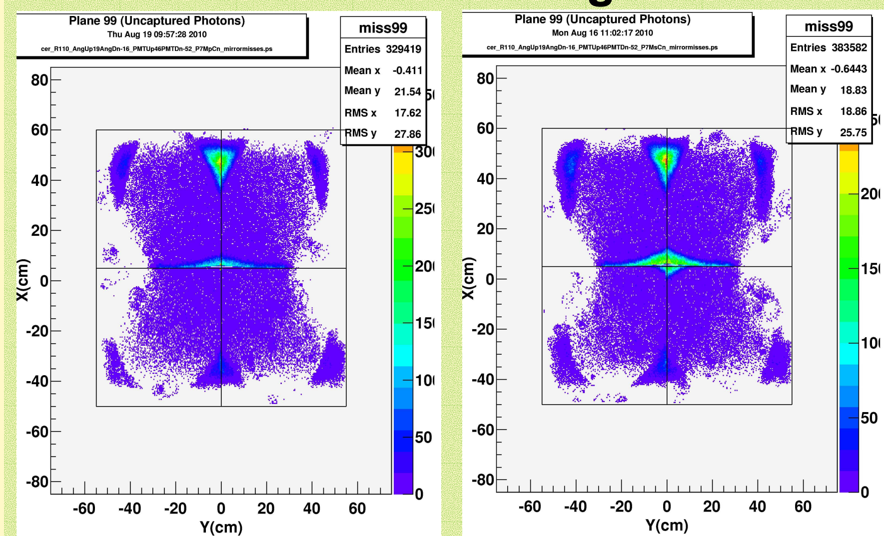
Focusing onto PMT



Parabolic f=55.0cm Spherical r=110cm

With our improved mirror & PMT configurations, the spherical mirror performance nearly approaches that of the parabolic mirrors.

Mirror Hits missing PMT



Parabolic f=55.0cm Spherical r=110cm

PMT positions for parabolic mirrors have been re-optimized compared to spherical mirror configuration. All are further from mirrors, #1: 2.8cm, #2: 2.8cm, #3: 3.9cm, #4: 2.6cm.

Plans for further Geant4 Study

- Bug checking and documenting:
  - Geant4 code is complex, still completing final bug checks.
- Implement Donal Day's PMT position sensitivity measurements in SensitiveDetector analysis to produce more accurate simulated photoelectron distributions.
  - This work only partially completed because of time needed for transverse configuration study.
- **Continue double-checks of optimized PMT-mirror locations and angles before finalizing vessel design:**
  - **Determine sensitivity to misalignments.**
  - **Once mirrors arrive, can refine MC to more closely approximate actual mirror geometry.**
  - **Need to be sure all engineering constraints in mirror mounts, beam envelope, etc. have been taken into account.**
- **Your feedback requested on proposed order this fall for 10 spherical r=110cm mirrors from EuropTec USA (Clarksburg, WV).**

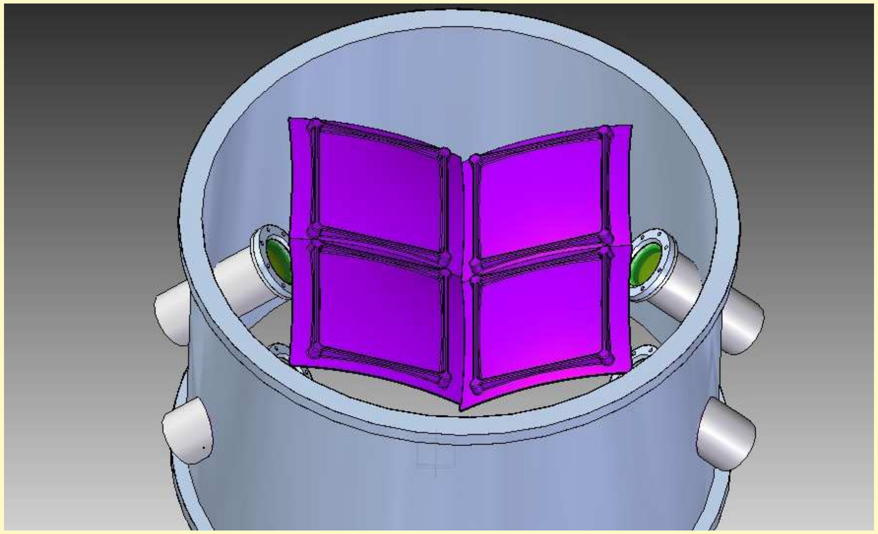
Mirror Backing Design Proposal

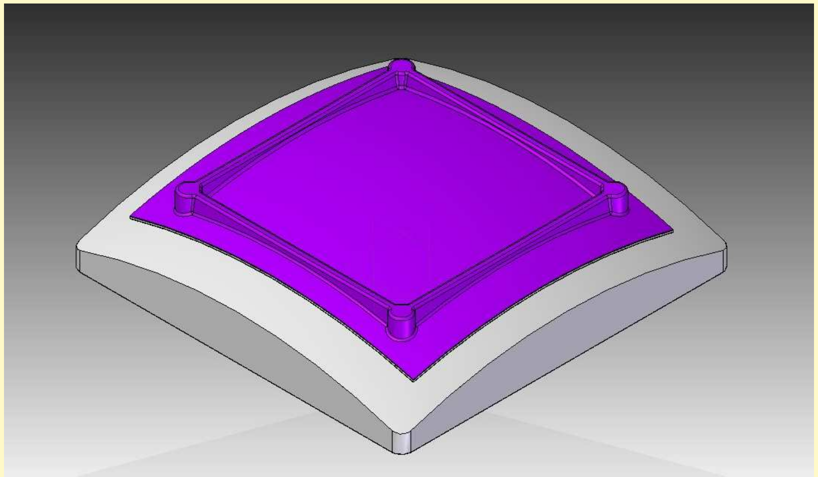
Design challenge:

- Mount 4 mirrors without dead spots due to clamps near center.

Reference design:

- SOS carbon fiber mirror backing with clamps on two outer sides.
- Mirror attachment fixtures to vessel yet to be designed.





Andre Braem (CERN Detector Lab):

- **It would be better to apply the carbon-fiber epoxy layer prior to the aluminization. A compact, fully polymerized and free of out-gassing holes back layer should not affect too much the reflectivity.**
- But a structure like honeycomb or based on rohacell foam or similar should be avoided since the out-gassing during the aluminization process could be excessive.
- **To stay on the safe side, I would suggest to aluminize and measure the reflectivity of a test sample before to launch the production of the new substrates.** I think a new composite structure might strongly affect the global shape and stability of the mirror (if the expansions of the different components do not perfectly match). This test sample could also be interesting to be measured in order to check the optical quality.

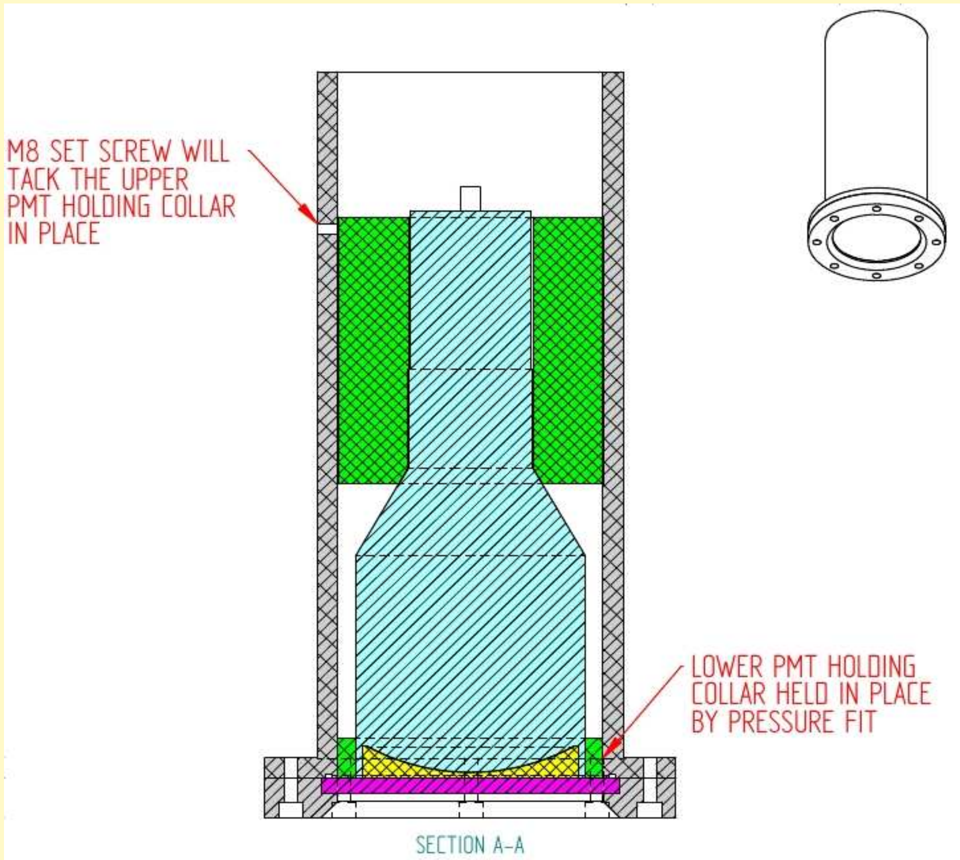
PMT Mounting Brackets Design Proposal

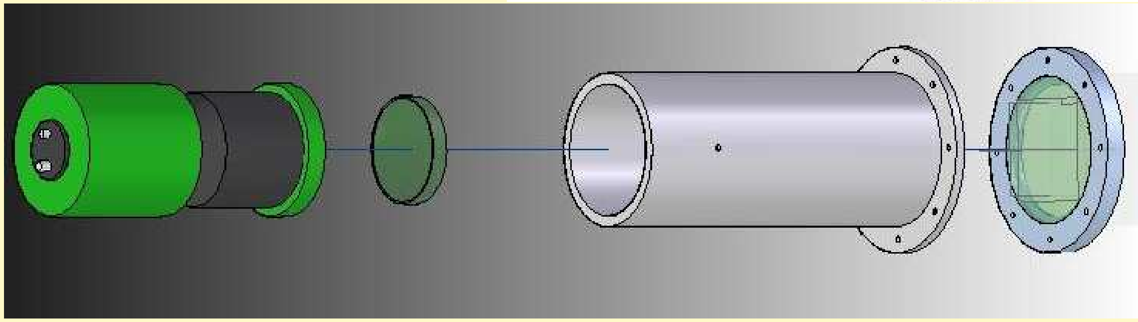
Design requirements:

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

A possible solution:

- Machine a series of (plastic?) collars with offset holes to allow PMT adjustability.
- PMT + μshield rests inside collar.

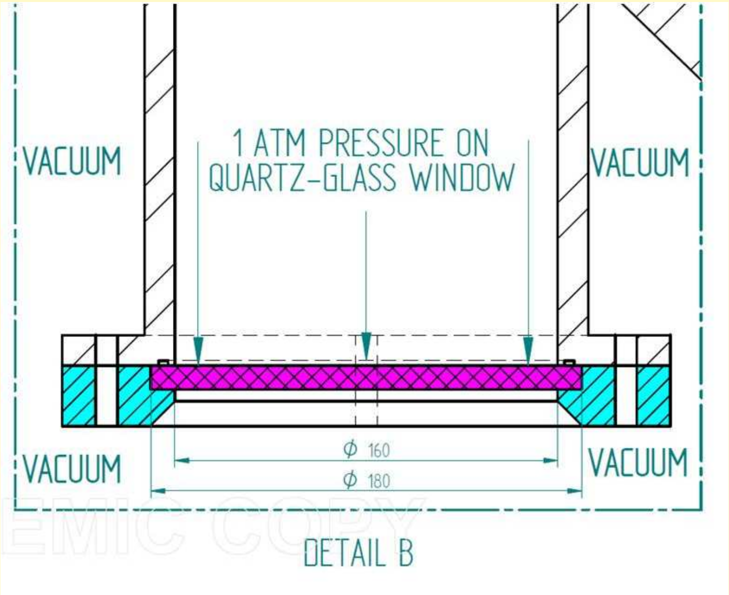




Dr. Garth Huber, Dept. of Physics, Univ. of Regina, Regina, SK S4S0A2, Canada.

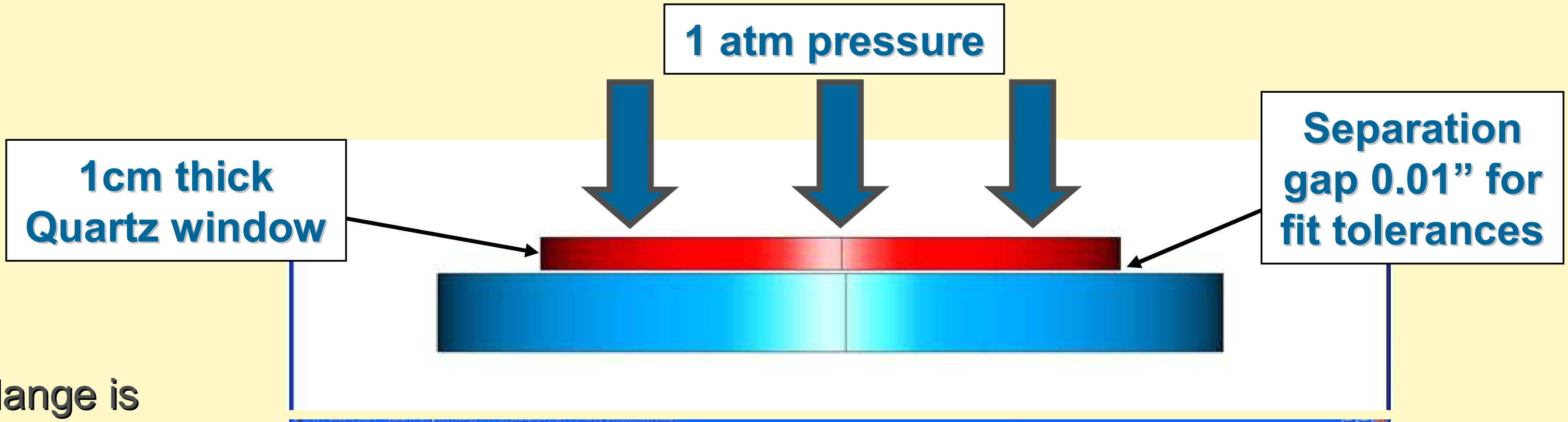
Quartz Window FEA Study

- In late June, we asked Steve Lassiter for a quick FEA study of the HGČ quartz windows.
- Needed to ensure our proposed flange design is sufficient to keep the quartz window from cracking under the applied 1atm pressure differential.
- A larger flange potentially affects the optics optimizations, since it requires additional clearance between the PMT and the beam envelope.



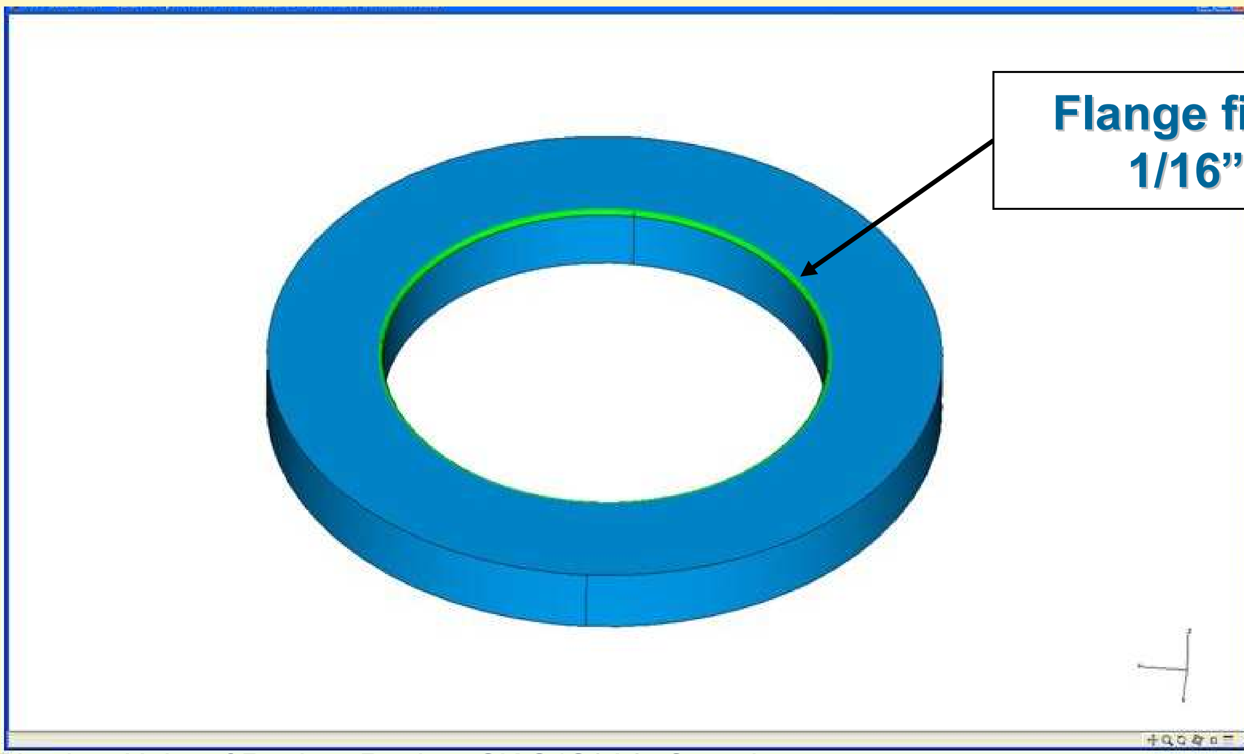
Assumed Properties Spectrosil 2000 Fused Quartz	
Modulus of Elasticity	10.7×10^6 psi
Poisson Ratio	0.170
Shear Modulus	4.5×10^6 psi
Compressive Strength	0.16×10^6 psi
Density	0.0798 lb/in^3

Modeled Configuration



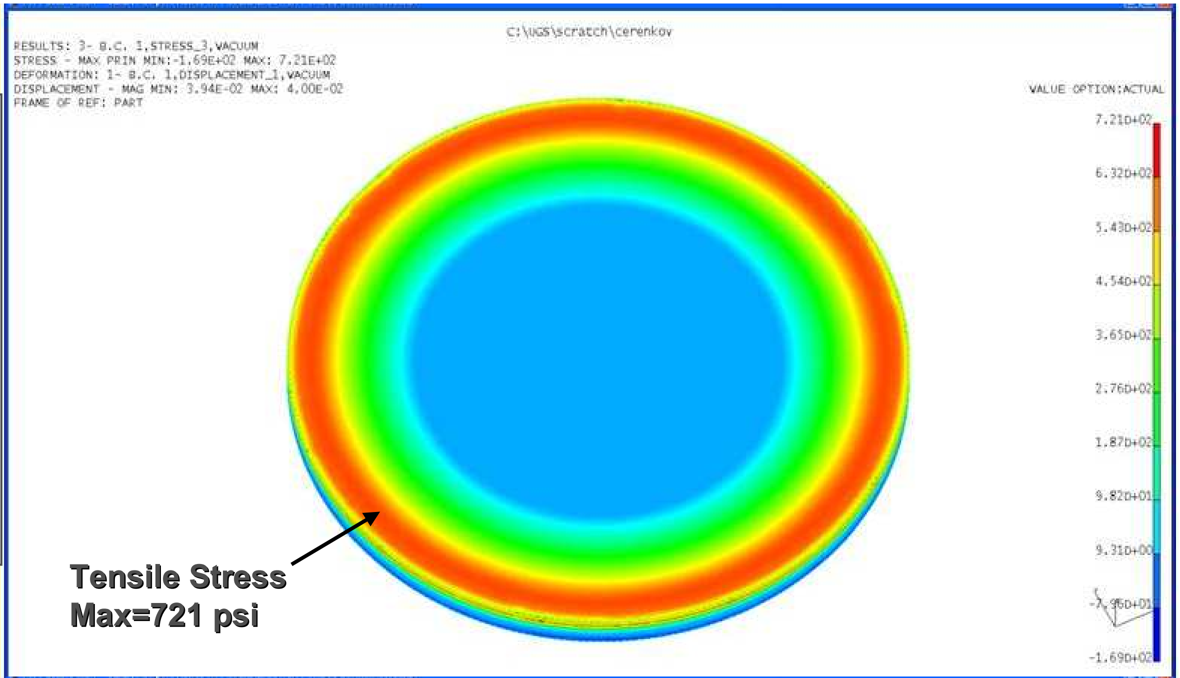
Flange is constrained not to move.

Quartz-glass allowed to move in the vertical direction and restrained from motion only along its edge.



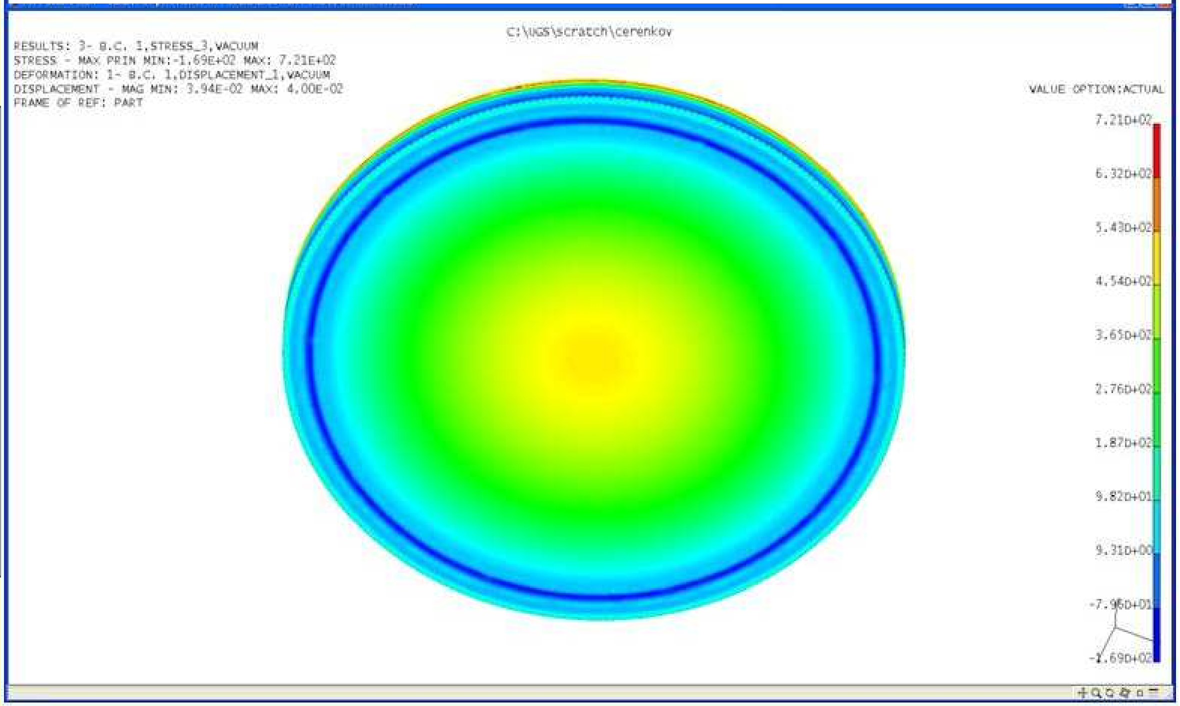
Maximum Principal Stress Top side.

Red = Tensile.
Blue = Compressive.

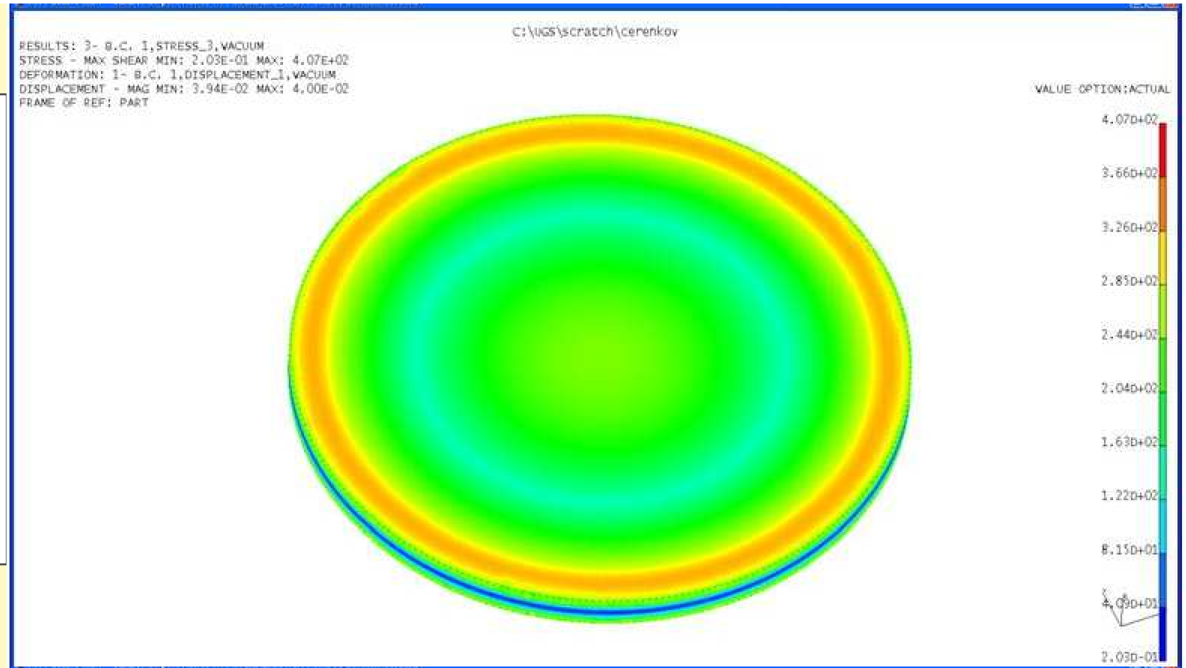


Maximum Principal Stress Bottom side.

Largest compressive stress along contact area with flange.

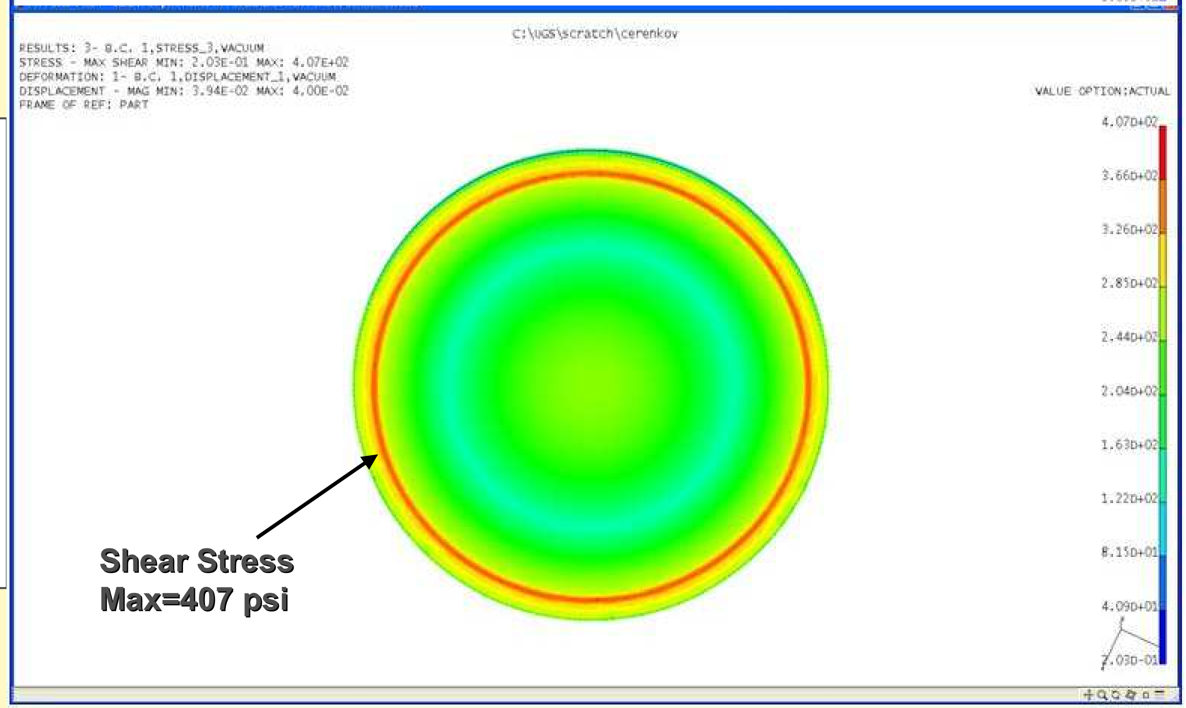


Shear Stress
Top side.

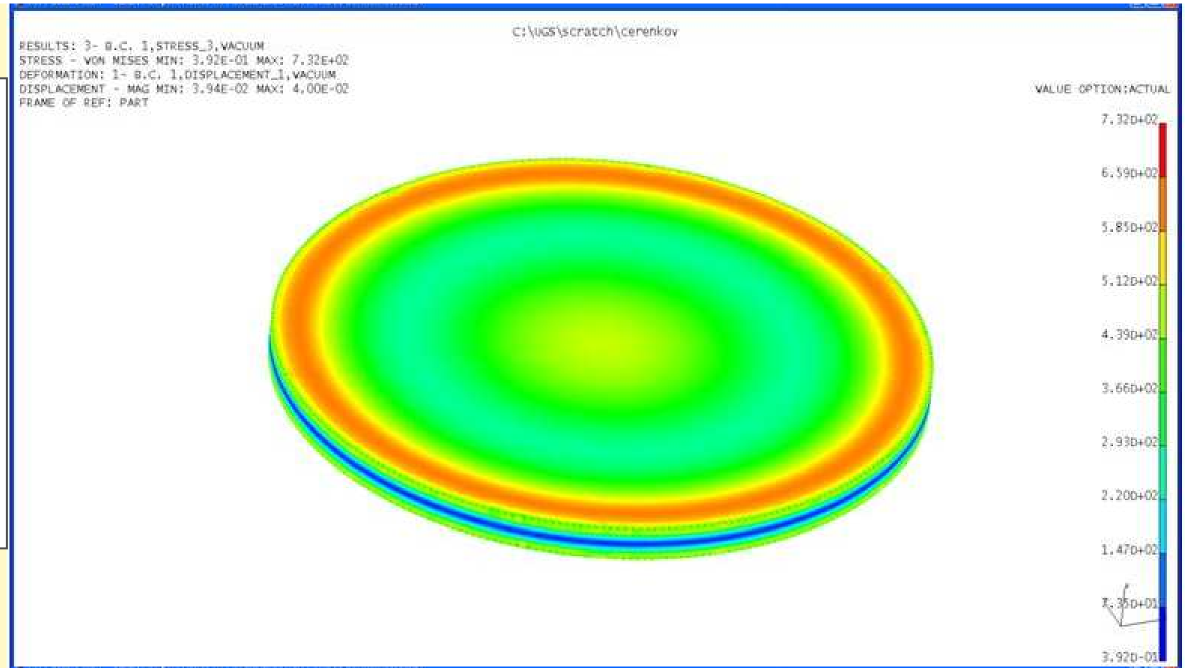


Shear Stress
Bottom side.

Highest shear stress along contact area with flange.

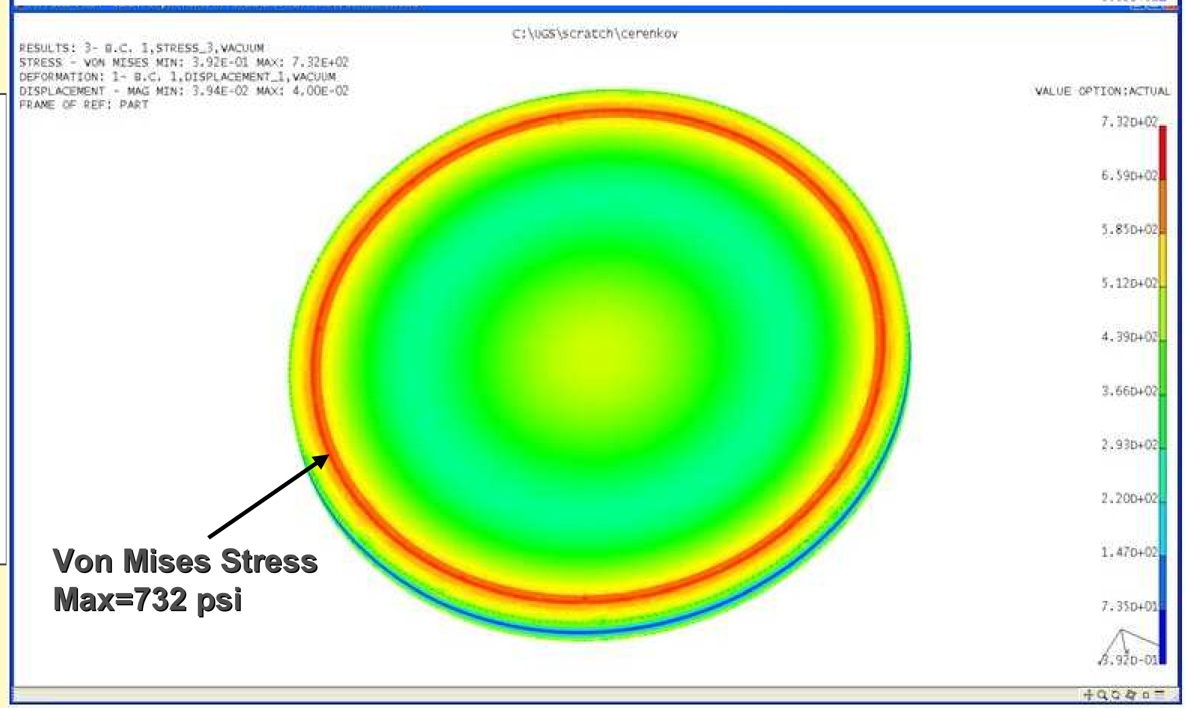


Von Mises Stress
Top side.



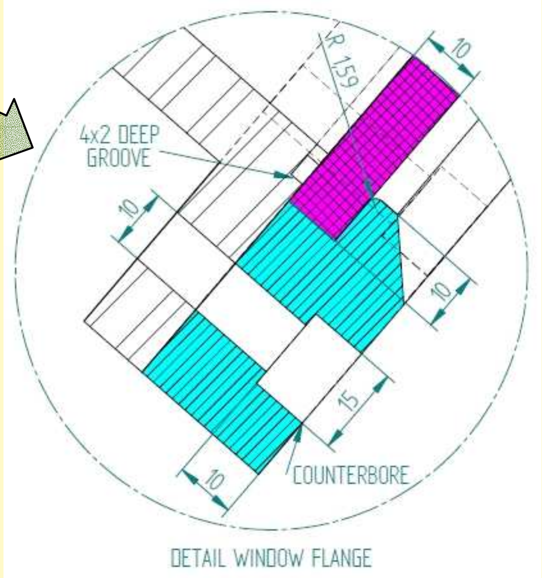
Von Mises Stress
Bottom side.

Highest VM stress along contact area with flange.



Conclusions from Steve Lassiter's FEA Study

- **Highest stresses (maximum principal and shear) occur along contact area of quartz window with bottom rim of flange.**
  - Suggest a fillet be machined into lip of window flange. FEA model used a fillet of 1/16", which is small and may warrant increasing.



- **Highest stresses small compared to reported Spectrosil 2000 properties.**

Maximum Stresses 1atm applied to quartz window	
Tensile	721 psi
Compressive	-169 psi
Shear	402 psi
Shear Modulus	**4.5×10^6 psi**
Compressive Strength	**0.16×10^6 psi**

- Not known at what stress levels hazing and cracking begin, but it is probably only a small fraction of the reported compressive strength.

Quartz window sitting on flange with loads and restraints as shown.