SoLID Heavy Gas Cherenkov Update

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for HGC group

SoLID Collaboration Meeting. Jan 10, 2019

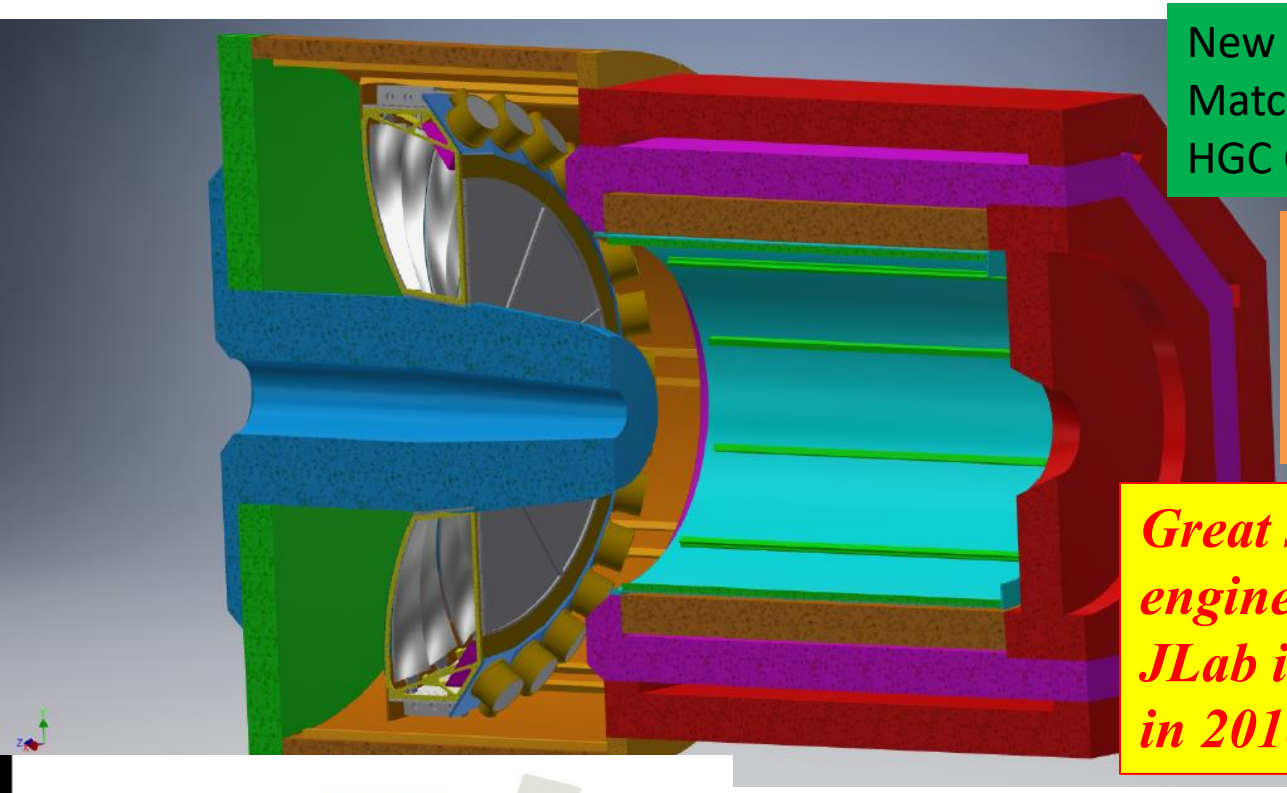
Duke UNIVERSITY

University of Regina

Overview

- Prototype design and window test
- Gas system
- Magnetic Shielding test
- Readout
- Cost overview

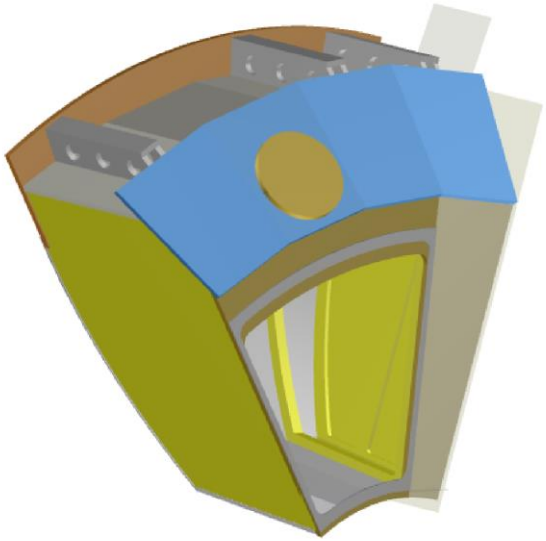
Design of whole detector and prototype of one sector

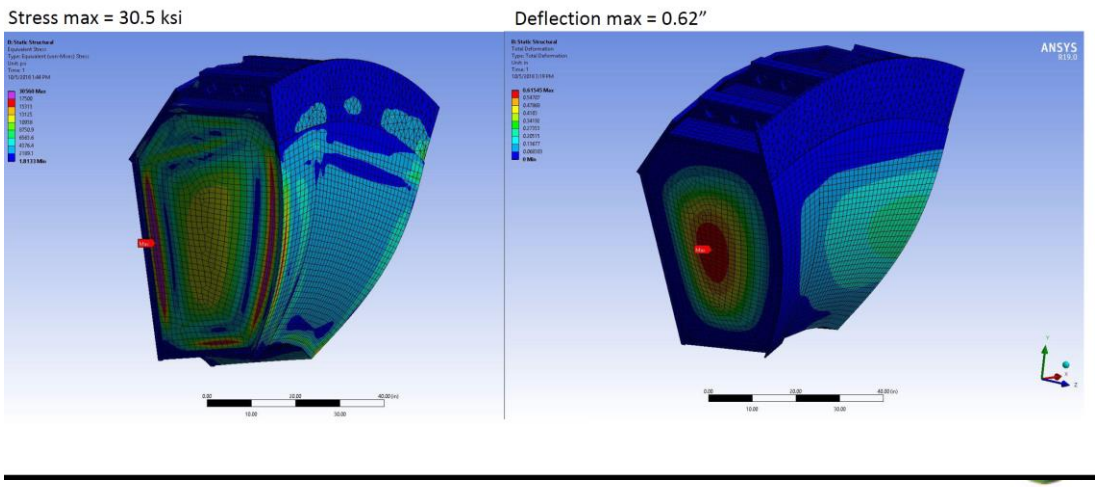


New Magnet CAD from Whit Seay
Matching Jay Benesch's field design
HGC CAD from Gary Swift @ Duke

To reach physics at 7deg, may need trim endcap nose from 7 to 6.8 deg, wait for other detector like LGC to confirm

Great support from Hall A engineering (Whit and Robin) JLab informal reviews were held in 2018/08 and 2018/10

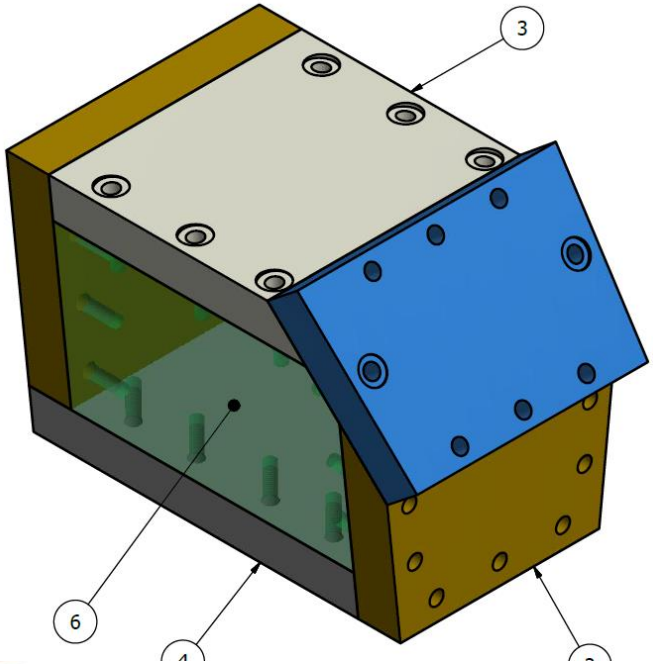


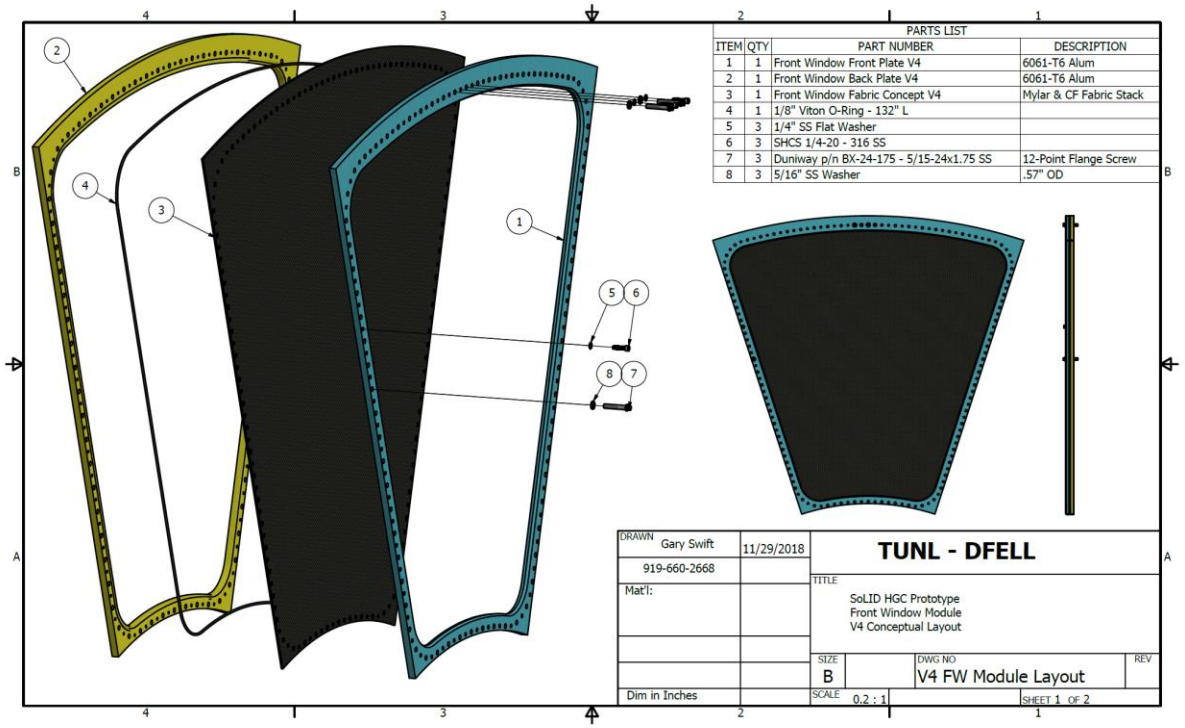


New window frame and small test box

Before doing the prototype

- Plan to built a small box to test machining and bounding technique
- Plan to built a new “self-hold” window frame which can be put on the prototype directly
- Test both for gas tightness





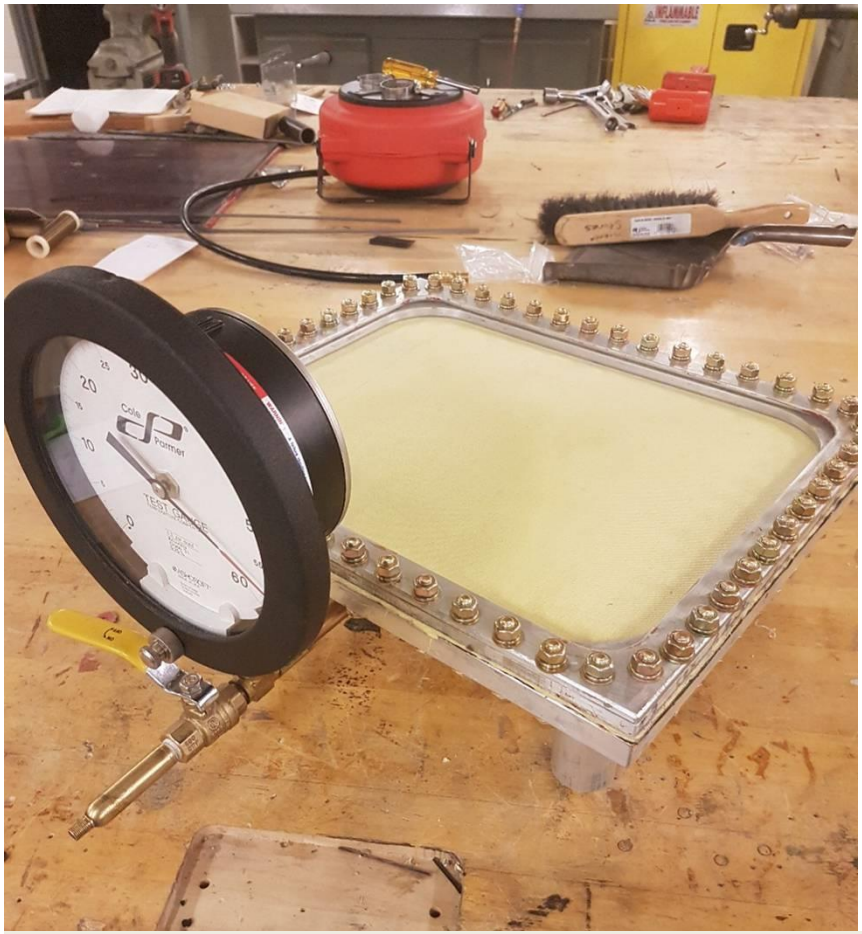
Still need support from Hall A engineering for guidance including stress analysis and safety

Plan to finish the full prototype by the end of 2019 at Regina

Window material (Mylar and Heavy Stock Flat Carbon Fiber Shell)

- Heavier stock carbon fiber fabric from Fiber Glast.
- Try flat window (no preformed bulge) to improve clearance and simplify fabrication.
- Flat window structurally stable at +4 atm where previous flat window (with lighter CF) failed.
- Significantly reduced creaking noises over previous tests.
- Maintaining pressure for over 6 months with only small pressure drop (possibly due to atmospheric pressure variations).

- Very promising results from the thicker Carbon Fiber.
- Waiting for completion of full size version with this technique.



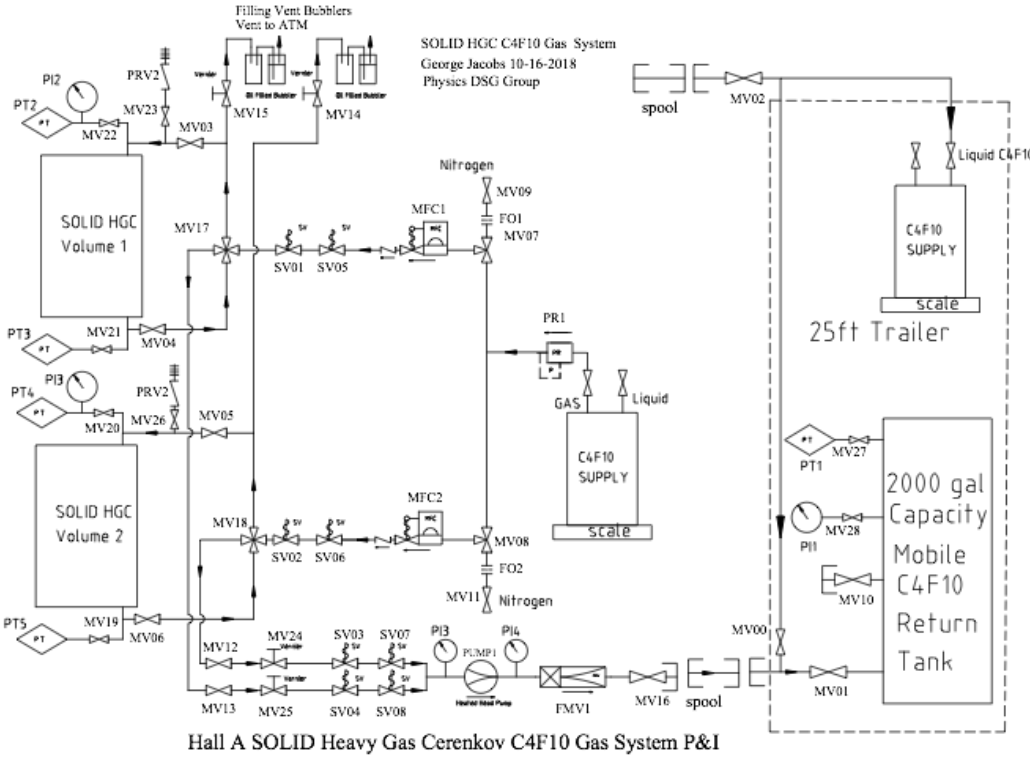
thickness: 0.075 - 0.09 inches or 0.19 - 0.23 cm
mass per unit area 3.57 kg/m2 = 0.357 g/cm2
density 1.6 - 1.9 g/cm3

Gas System

HGC gas system: The volume of the detector is 20 m3 filled with 300kg heavy gas (C4F10) at 1.5 atm (0.5 atm pressure difference)

A system similar to Hall B LTCC (~40 m3) gas system to allow C4F10 gas recovery

- Detector tank can not be vacuumed, so a “flushing” procedure with N2 will be used during filling
- Single fill requires 3 flushes (700 kg heavy gas) to reach ~95% purity, and most of 400kg of them can be recovered
- Sealed after the gas filling, with pressure monitoring

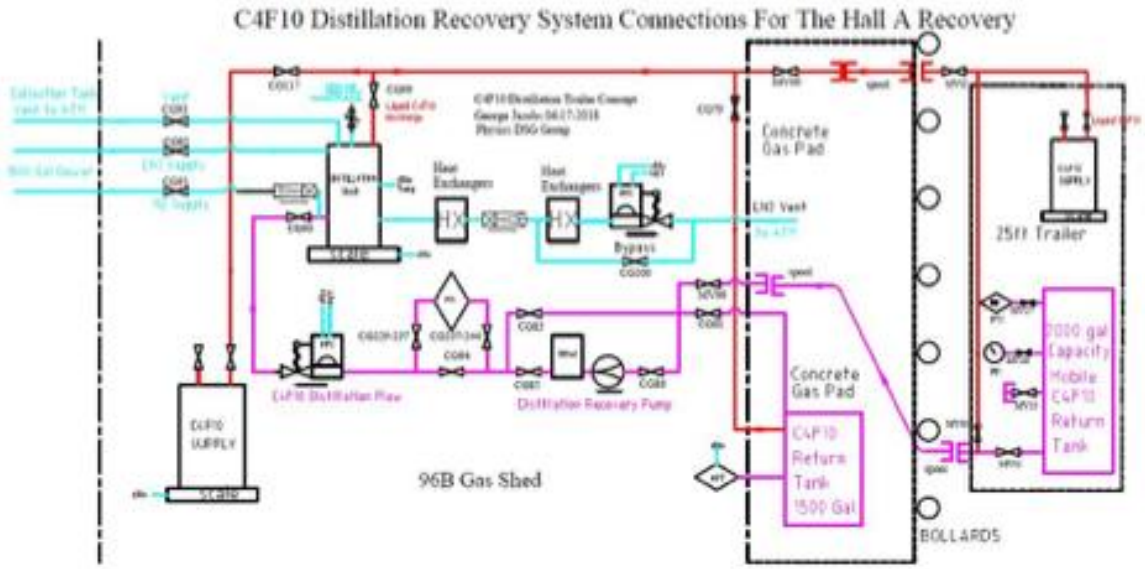


Hall A SOLID Heavy Gas Cerenkov C4F10 Gas System P&I

Gas system

Recovery and distillation

- Gas will be flushed out by nitrogen and collected by a large return tank as a buffer
- Run a heated gas line from Hall A to the gas shed 96B to share gas distillation unit with Hall B



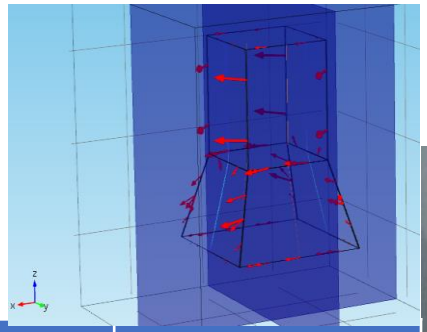
Cost estimation

- $100k and 0.5 FTE for gas line from Hall A to gas shed
  - (estimated by Robin Wine with record of the current line gas from Hall B to gas shed, adjusted for length and inflation)
- $100k and 0.5 FTE for everything else (tank,valve,pump,controller etc)
  - (estimated by George Jacob with Hall B experience)
- Total 200K and 1 FTE at JLab

Magnetic ShieldingTest

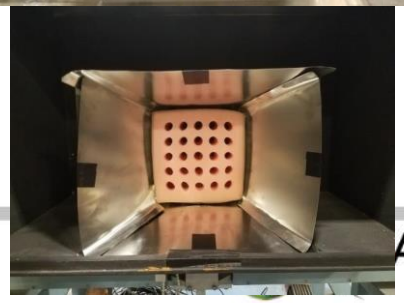
- test shielding performance of a single and double layer of 0.05" thick NETIC (steel) sheet in 90 G field of both direction

Sim show good agreement with test



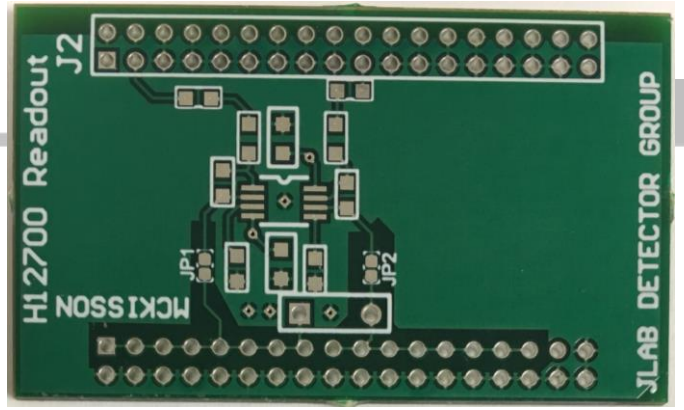
	Longitudinal (+/- 0.3 G)	Transverse (+/- 0.3 G)
Position 1	51.9 G 18.7 G	44.9 G 20.0 G
Position 2	41.8 G 14.8 G	37.1 G 15.0 G
Position 3	30.6 G 25.8 G	32.1 G 7.5 G

- 0.01" thick MuMetal foil is also added with minor effect so far.
- Will try two layer of 0.095" steel
- Work with vendor for next version

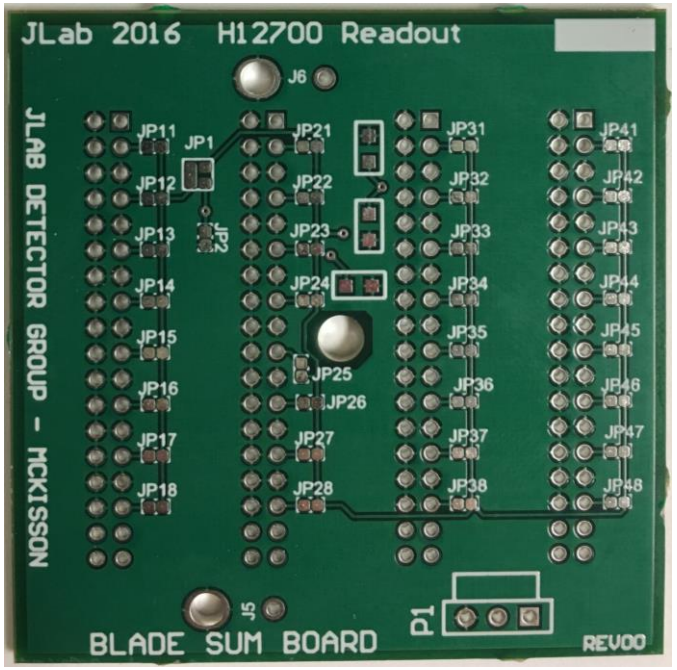


Readout

- Blade sum board designed by Jack McKisson of Jlab detector group could be our first choice of the readout system
  - Jack has finished some of the blade sum boards and we plan testing
  - Cost estimation ($160k total)
    - $100k for board and cable
    - $60 for mounting and cooling
- MAROC readout system can be considered as a possible upgrade option ($460k)



Blade board
(with three different sum configuration: 2, 4, 8 channels)



Sum board

SoLID HGC Budget

	supplier	quantity	Cost in pCDR 2014/07 (k$)	Cost 2018/08 (k$)	comment
Full Tank with thin window	Regina	10	300	771	Shipping included
Mirror base		30	290	400	13m2 total area
Mirror coating	SBU	30		10	mainly shipping cost
Reflecting cone	ECI	30		90	coated Lexan film attached to the inside of shielding
Magnetic Shielding	Amuneal/MSC	30	116	150	shape change from cone to trapezoid
PMT	Hamamatsu	480	1628	1440	Change from H8500-03 to H12700-03 (low dark current and high gain option available)
PMT WLS coating	Temple	480		144	Better QE at UV
Sum Readout	jlab	480		160	
gas	F2 Chemicals at UK		154	450	Assume C4F10 $300/kg, 300kg for entire volume of 20m3 at 1.5atm, 1500kg needed for initial test
Gas system	jlab		85	200	Sharing purifying unit with HallB, 100k for gas line from HallA to gas shed 96B, 100K for all other parts
test and installation equipment	Misc.			40	
Parts Total			2573	3855	
Labor requested (FTEs)			6.5	12.5	2.4 FTEs at jlab, 4.75 FTEs at Duke and 5.35 FTEs at Regina.
Labor contributed (FTEs)			1.5	1.5	1 FTEs at Duke and 0.5 FTEs at Regina

Parts in (k$)	Year1	Year2	Year3	Year4	Year5	total	tasks
Full Tank with thin window		250	250	271		771	design by Duke in Y1 and Y2, Built by Regina in Y2,Y3,Y4
Mirror base	67	133	200			400	Led by Temple, Duke helps with test
Mirror coating				10		10	Led by Temple/SBU, Duke helps with test
Reflecting cone			45	45		90	Duke
Magnetic Shielding		75	75			150	Duke
PMT	720	720				1440	Duke
PMT WLS coating		72	72			144	Temple
Sum Readout			80	80		160	Designed by Jlab, tested by Duke
gas	450					450	Duke
Gas system	100	100				200	Led by jlab, Duke and Regina help
test and installation equipment					40	40	Joint effort by jlab,Duke and Regina
Total	1337	1350	722	406	40	3855	

Labor (FTEs)	Year1	Year2	Year3	Year4	Year5	KPP	Total
Requested	0.2+0.2 Tech/Eng (jlab)	0.2+0.1 Tech/Eng (jlab)	0.3+0.1 Tech/Eng (jlab)	0.3+0.1 Tech/Eng (jlab)	0.4 Tech/Eng (jlab)	0.5 Tech/Eng (jlab)	2.4
	0.2 Technician (Regina)	0.7 Technician (Regina)	0.7 Technician (Regina)	0.7 Technician (Regina)	0.2 Technician (Regina)		2.5
	0.3 engineer (duke)	0.3 engineer (duke)	0.2 engineer (duke)	0.1 engineer (duke)	0.1 engineer (duke)		1
	0.2 Postdoc (Regina)	0.2 Postdoc (Regina)	0.2 Postdoc (Regina)	0.2 Postdoc (Regina)	0.2 Postdoc (Regina)	0.5 Postdoc (Regina)	1.5
	0.5 Postdoc (Duke)	0.5 Postdoc (Duke)	0.5 Postdoc (Duke)	0.5 Postdoc (Duke)	0.5 Postdoc (Duke)	0.5 Postdoc (Duke)	3
	0.1 graduate (Regina)	0.3 graduate (Regina)	0.3 graduate (Regina)	0.3 graduate (Regina)	0.1 graduate (Regina)	0.25 graduate (Regina)	1.35
	0.1 graduate (Duke)	0.1 graduate (Duke)	0.1 graduate (Duke)	0.1 graduate (Duke)	0.1 graduate (Duke)	0.25 graduate (Duke)	0.75
Total Requested	1.8	2.4	2.4	2.3	1.6	2	12.5
contributed	0.1 scientist (Regina)	0.1 scientist (Regina)	0.1 scientist (Regina)	0.1 scientist (Regina)	0.1 scientist (Regina)		0.5
	0.2 scientist (Duke)	0.2 scientist (Duke)	0.2 scientist (Duke)	0.2 scientist (Duke)	0.2 scientist (Duke)		1
Total contributed							1.5

backup

HGC optical system optimization

Elements

- Spherical mirror: determined by z1, z2 and radius r
- PMT: determined by tilt angle and distance d from PMT center to z2
- Reflective/shielding cone: shape, length, opening

Approach

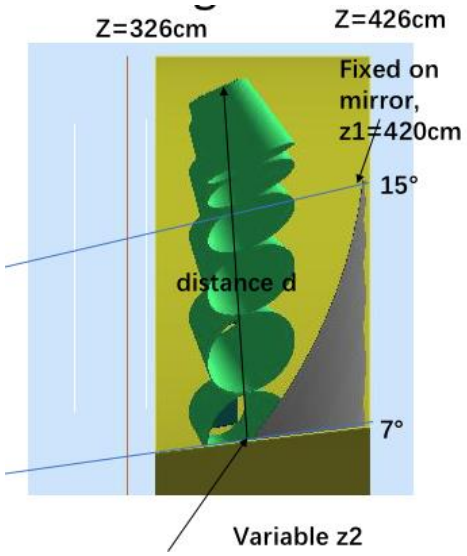
- z1=420cm is determined by boundary
- Try the radius r and variable z2 to set the mirror
- Then adjust the position of PMT and parameters of cones to collect photons effectively
- Very small region found when given r and z2 because we hope to collect all the photons
- Approximate feasible region of r and z2:

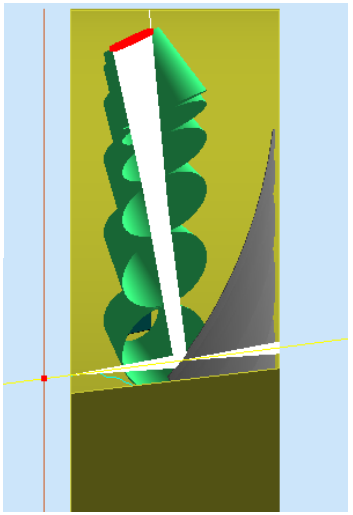
  z2=390cm r=210 to 250cm

  z2=380cm r=240 to 280cm

  z2=370cm r=280 to 300cm

  outside which we can't find a position for PMT to collect all the light





- Make light emitted by 7 degrees pions directly reflected to the center of PMT
- Large z2 and smaller r will give more gas length and more photons

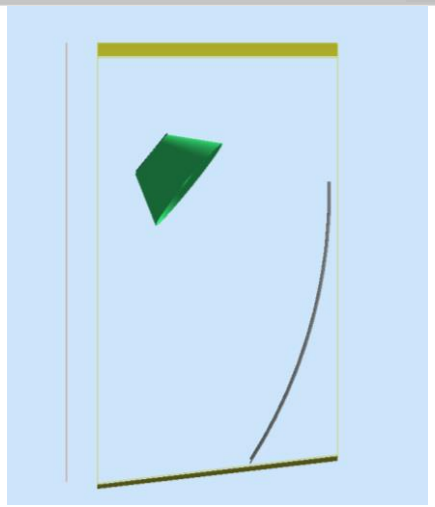
Mirror

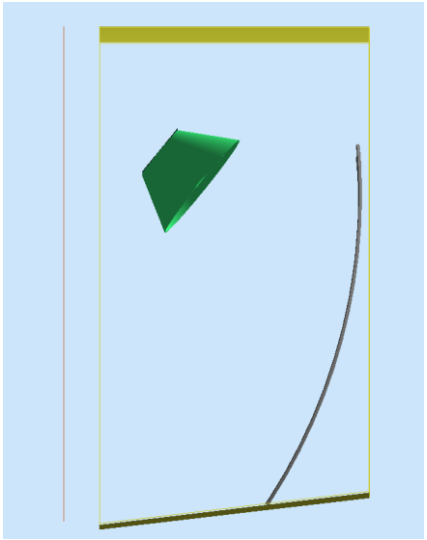
- 1. Cover more on small and large angles

  Change: cut by 7 and 15 degrees --> cut by 6.8 and 16 degrees

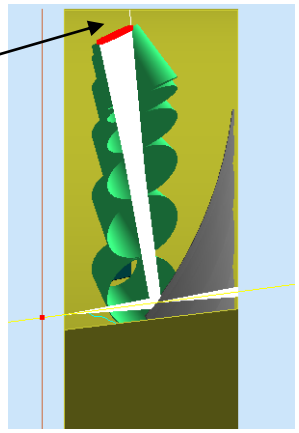
- 2. Adjust the position and radius to lengthen path distance for small angles

  Change: Make r smaller and z2 greater, currently r=210cm, z2=390cm

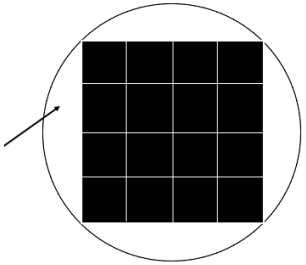


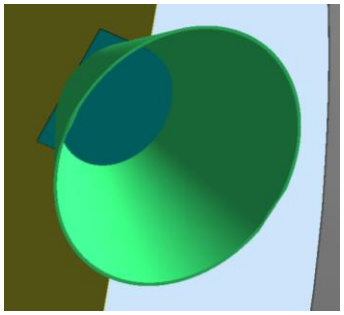


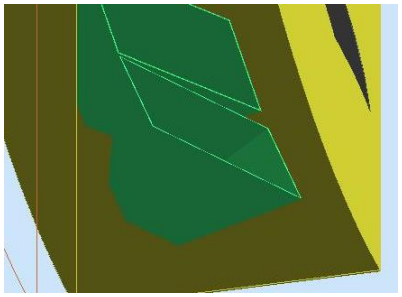
Reflective cone and shielding



- 1. No shielding behind PMT
  Change: leave enough room behind
- 2. Light loss at the gap between PMT and cone
  Change: Use smaller-end cone or pyramid-like cone
  We used the latter one when testing
  TBD by the test on the shielding effect

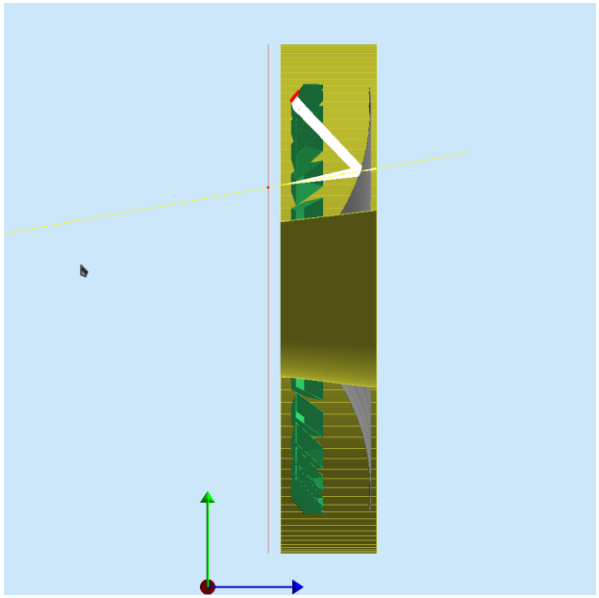




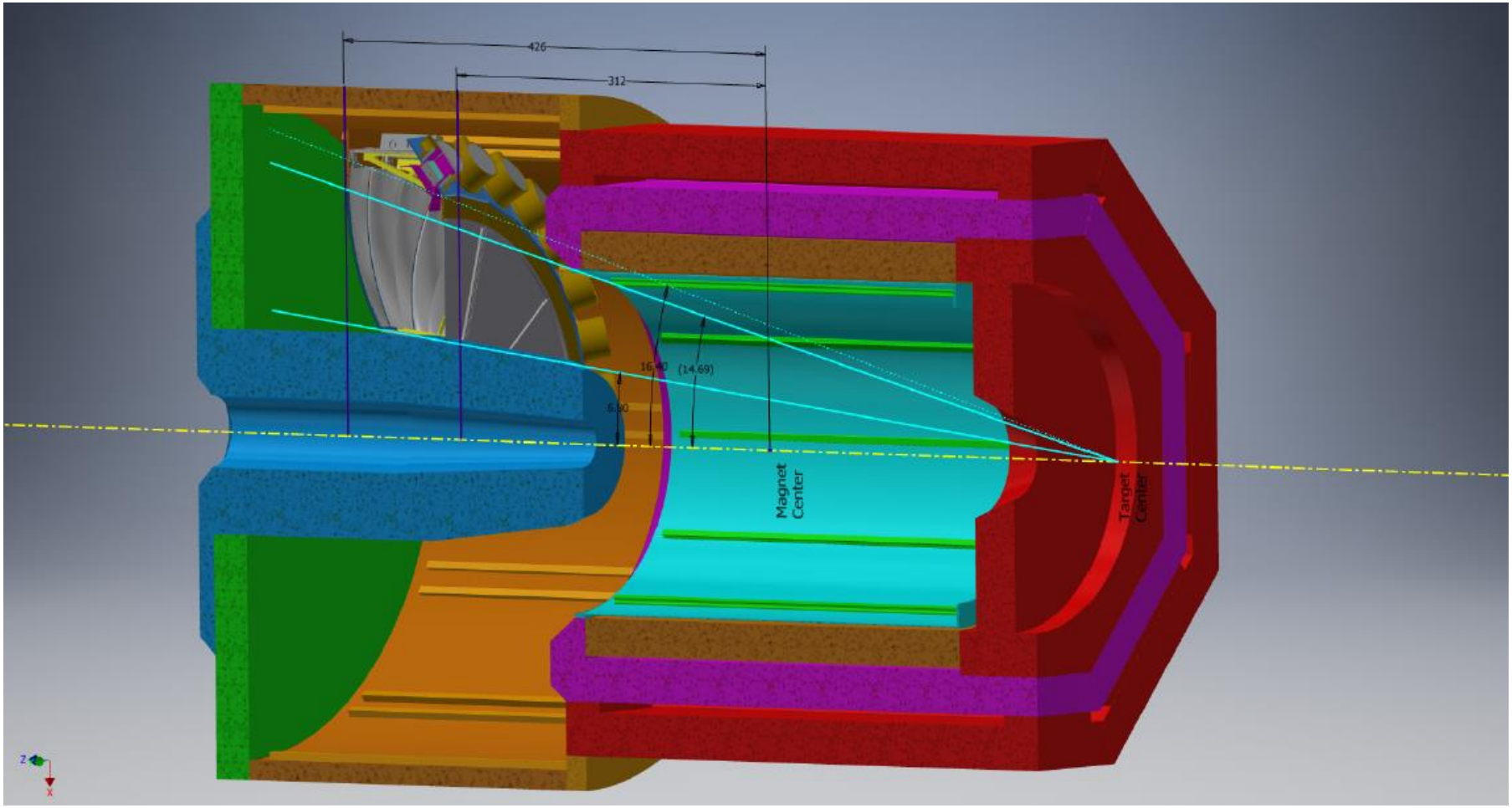


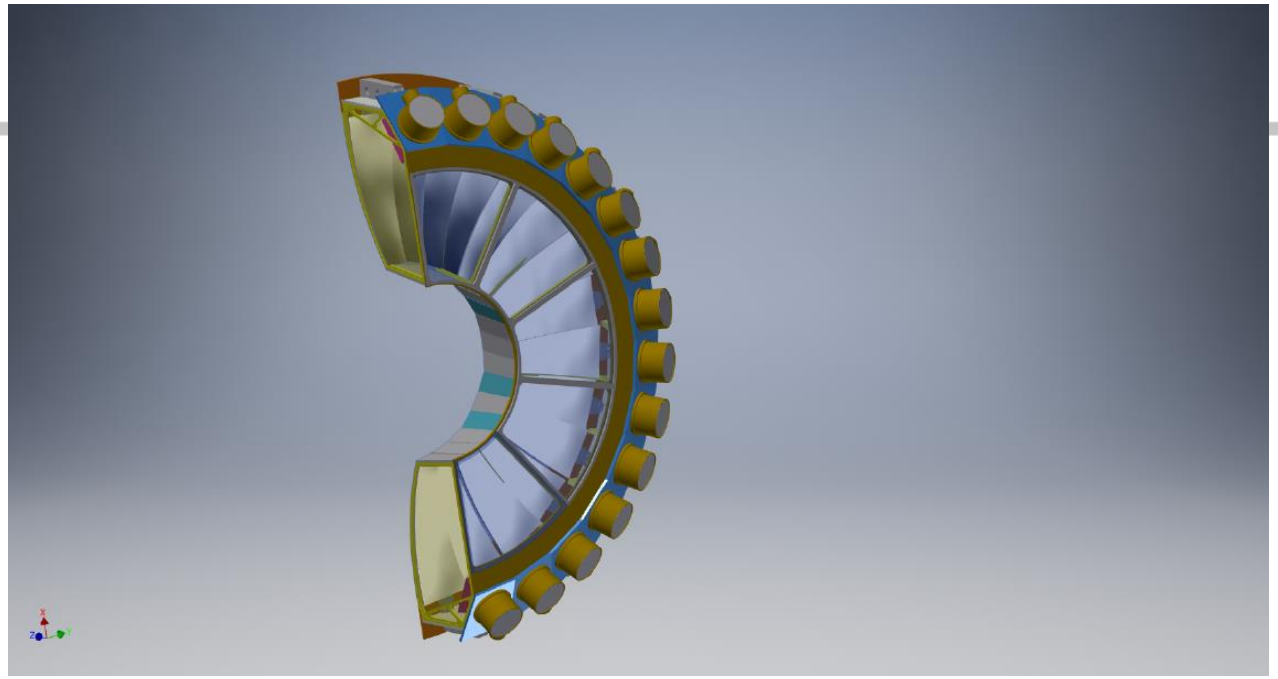
Configuration 2018_02_19_SVNr1361

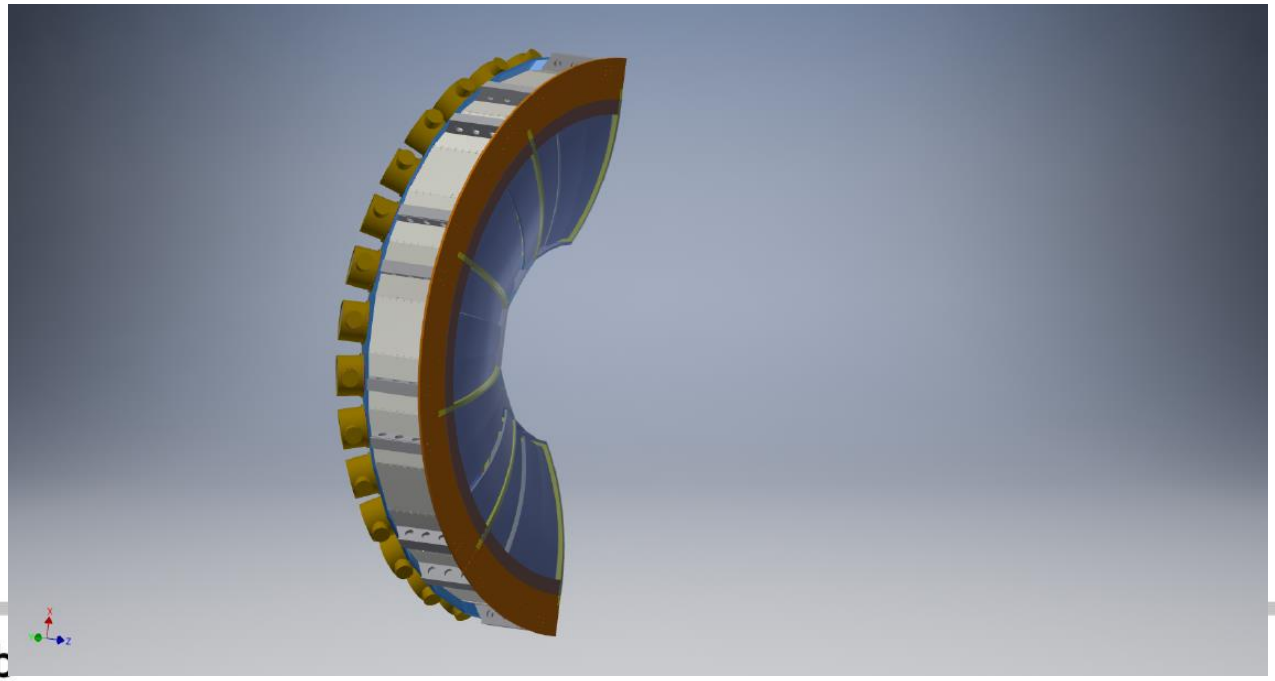
the sector at phi=0 deg

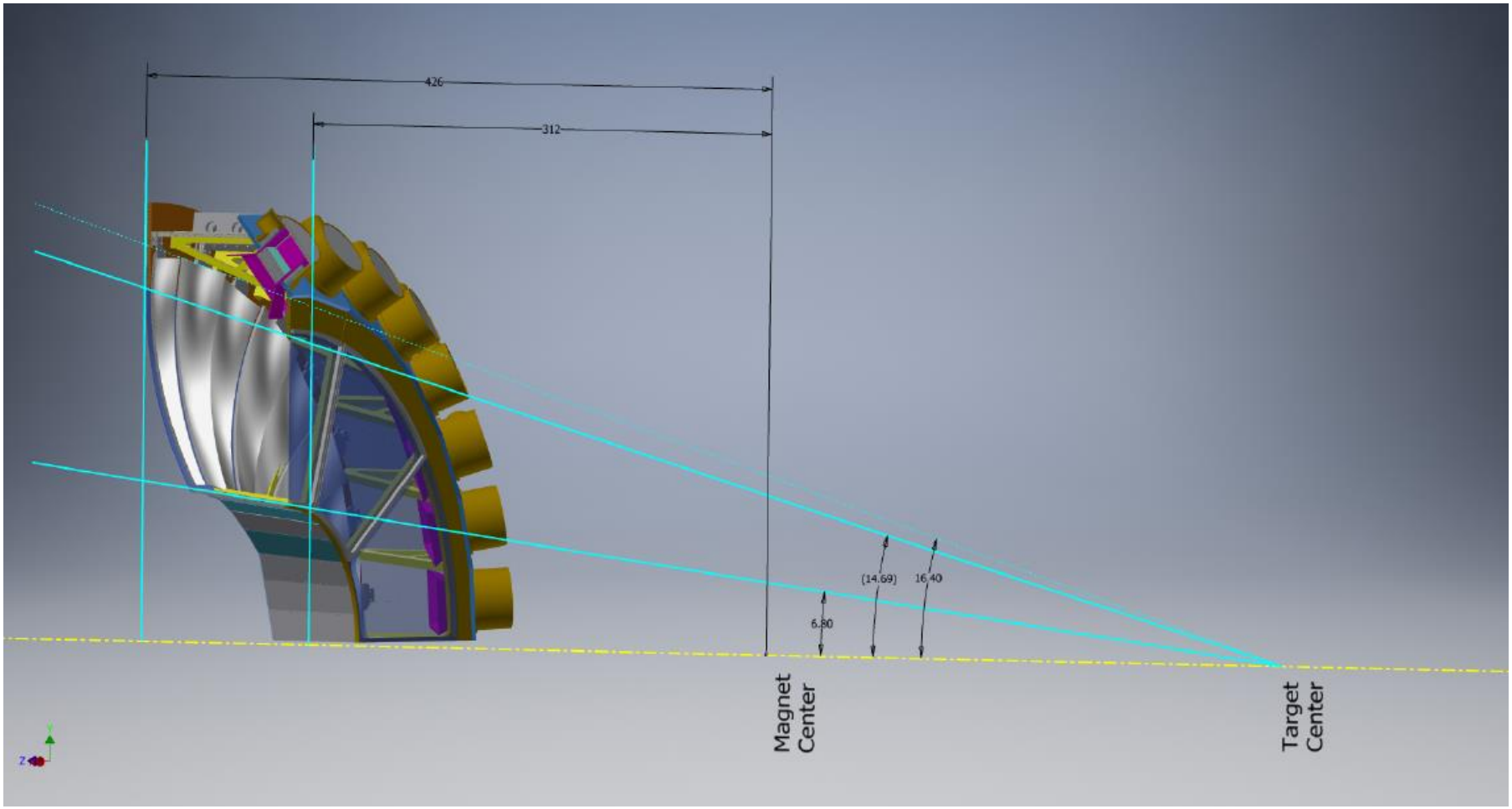


- Mirror: radius r=210cm, z2=390cm
  center: x=199.23cm, y=0cm, z=210.12cm
- PMT: distance d=135cm, tilt angle=39 degrees
  center: x=215.48cm, y=0cm, z=343.74cm
  width: 21.3cm
  four corners: x=223.76cm y=±10.65cm z=350.44cm
  x=207.20cm y=±10.65cm z=337.04cm
- Refelection: length=16.18cm, end 32cm*44.82cm
  x=222.71cm y=±16.00cm z=370.41cm
  x=187.88cm y=±16.00cm z=342.22cm


426
312
16.40
(14.69)
6.80
Magnet Center
Target Center

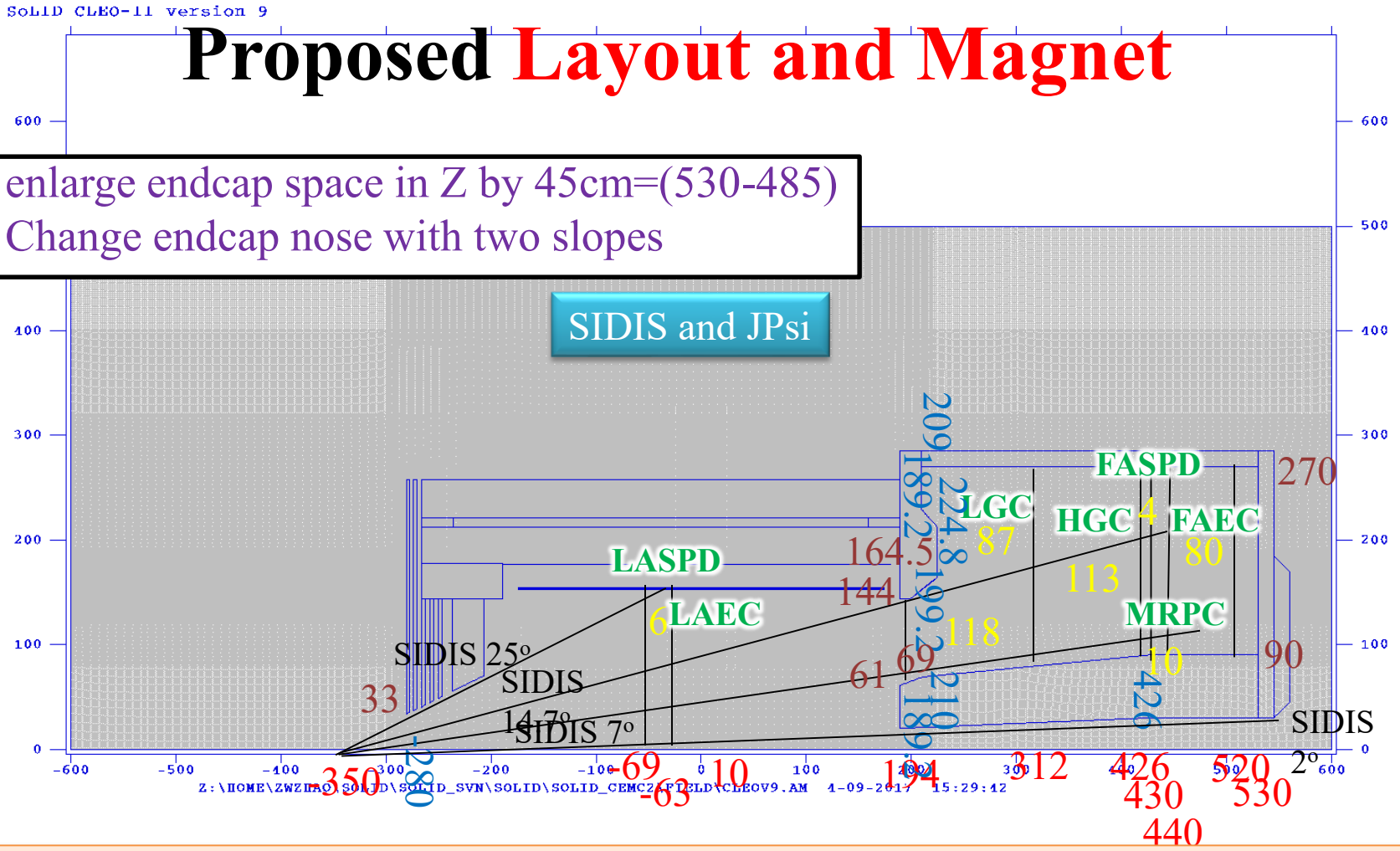





426
312
(14.69)
16.40
6.80
Magnet Center
Target Center

Proposed Layout and Magnet

enlarge endcap space in Z by 45cm=(530-485)
Change endcap nose with two slopes



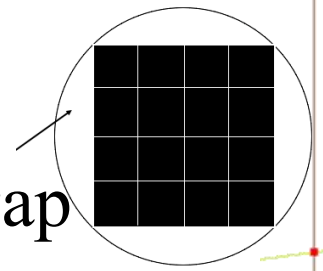
HGC change and condition:

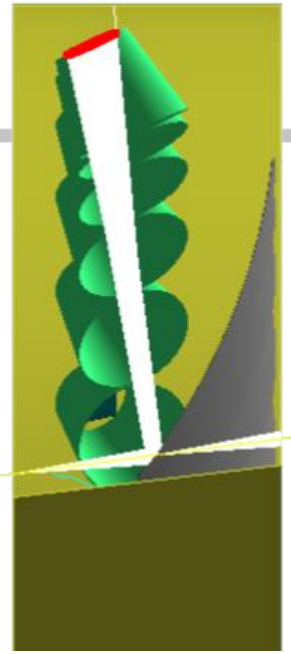
- move 20cm downstream, boundary Z=312-426cm
- assume front window at z=326cm and leave 14cm for window bulging and clearance
- cover more forward particle, 7 deg instead 8 deg from He3 target center at Z=-350cm
- cover large angle 14.7 deg at Z=-350cm, and optimize for full 40cm target
- Take field effect into account for both He3 and NH3 setup

Optical Design

Old design

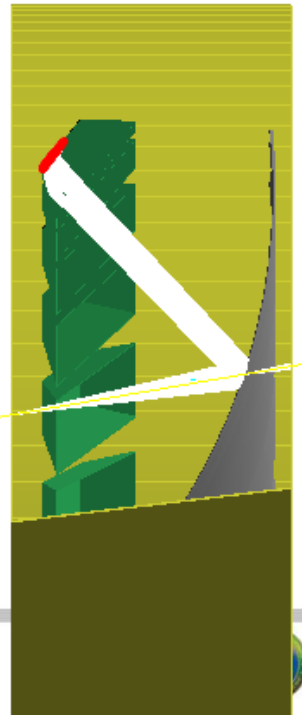
- No shielding behind PMT
- large light loss (20-30%) at the gap between PMT and cone





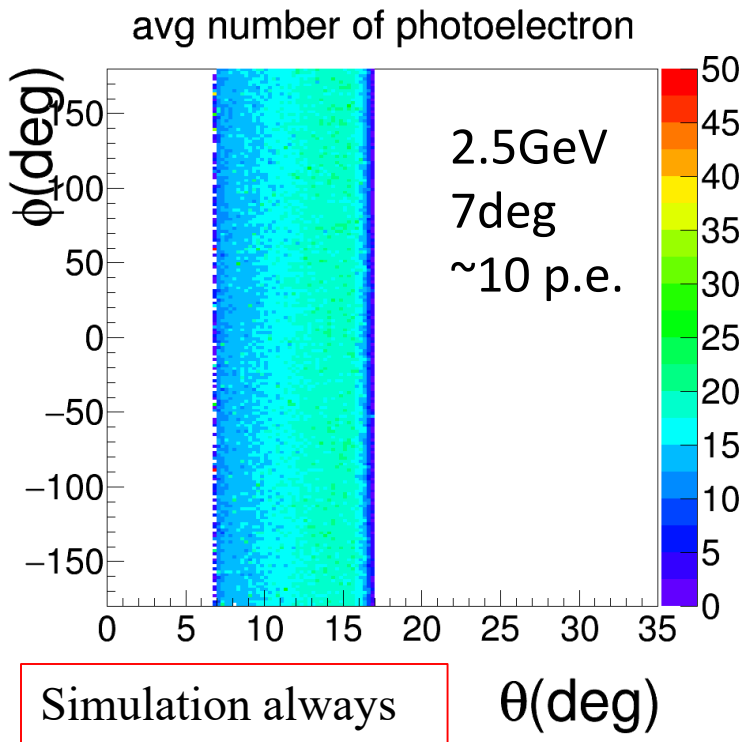
New design

- Room for shielding behind PMT
- Pyramid shape collects all lights
- Optimize for 7deg to have one bounce photons only
- Use as much as possible gas length with mirror inner edge at Z=390cm with 210cm radius
- Less gas volume, more room for tank mechanic structure

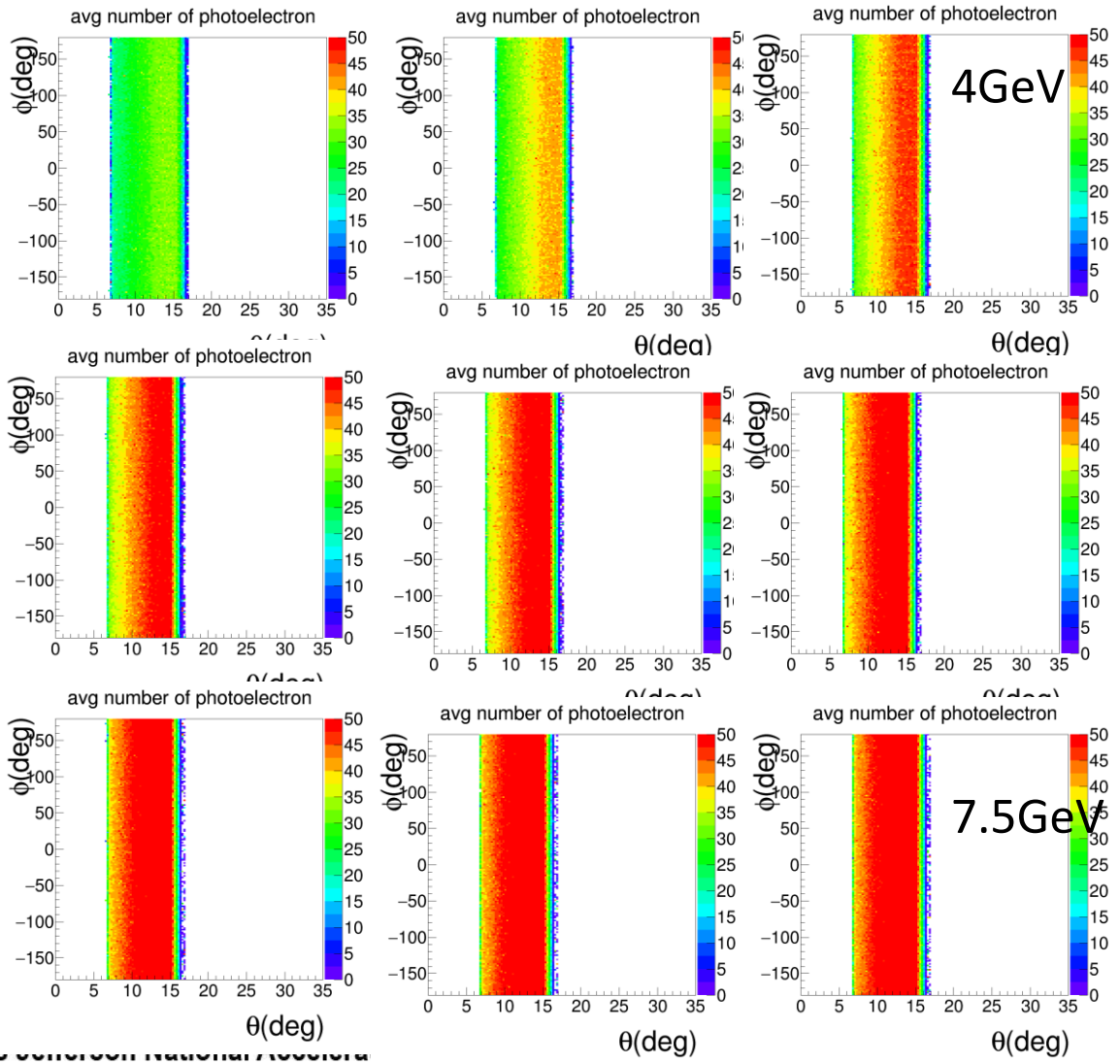


Bo Yu, visiting undergrad from Shandong U. China

SIDIS He3, 2.5-7.5GeV, pi-,Vz=-350cm, no field



Simulation always has a safety factor 2



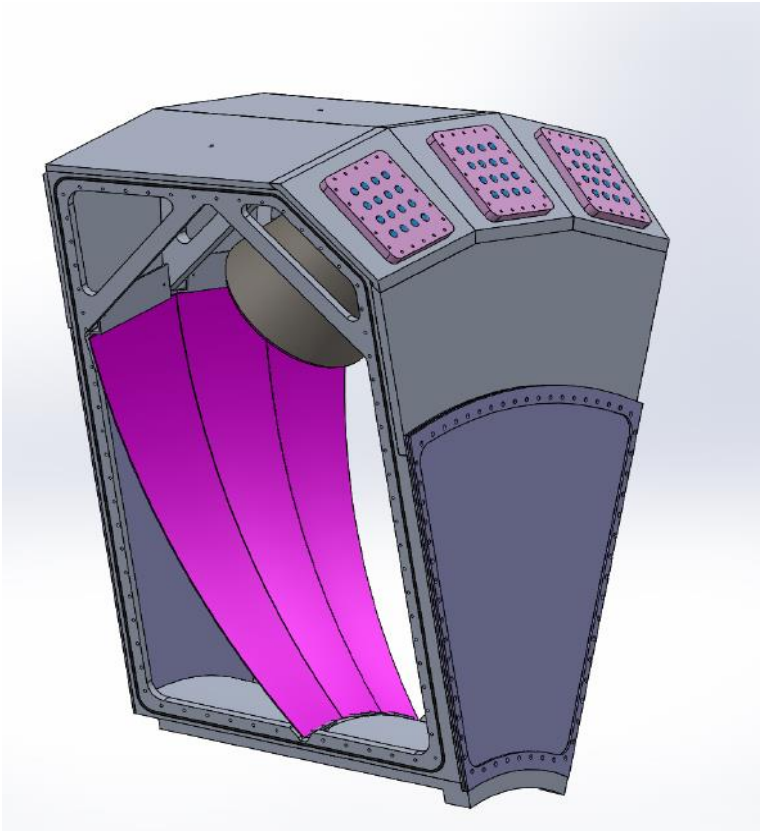
Work ongoing to study field effect

HGC Prototyping Update

C$100k grants allow the U.Regina group to construct one SoLID HGC module for testing.

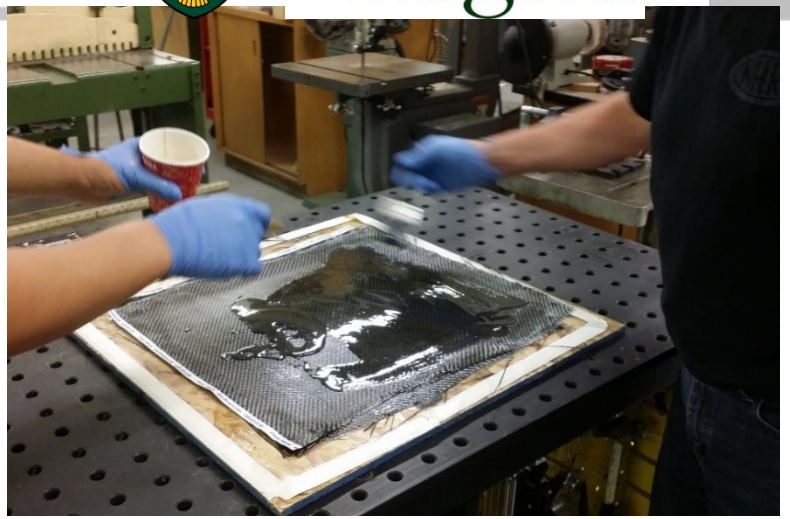
Questions to be addressed:

- Enclosure deformation at 1.5 atm operating pressure (investigate design and metal alloy options).
- Performance of the O-ring seals against adjacent units.
- Performance of thin entrance window in terms of light and gas tightness (test several options).



Conceptual design by Gary Swift, Duke U.

- Hard shell constructed with Fiber-Glast carbon- fiber and epoxy.
- Mylar inner window beneath shell is used to seal against O-ring.
- Kevlar from previous test placed on top as a safety measure, as protection against a catastrophic shell failure.

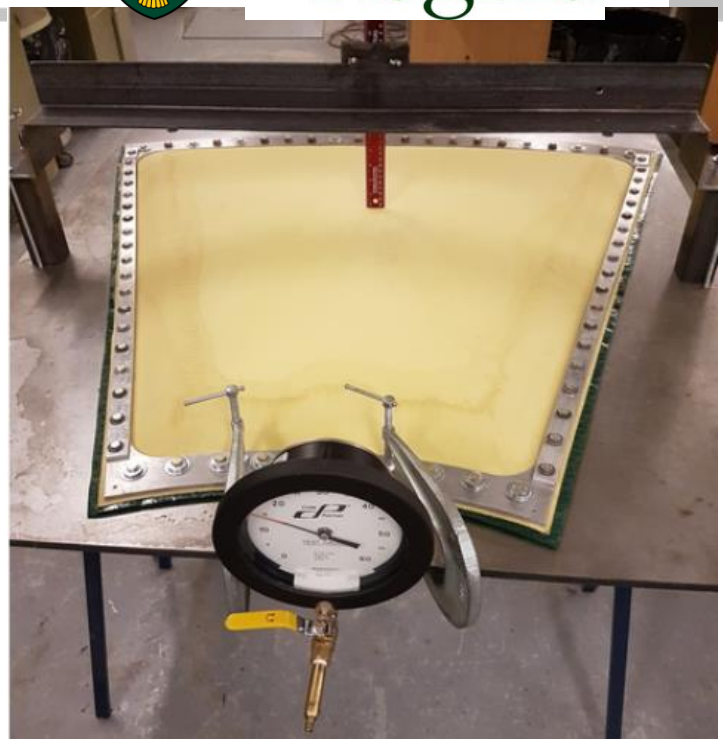


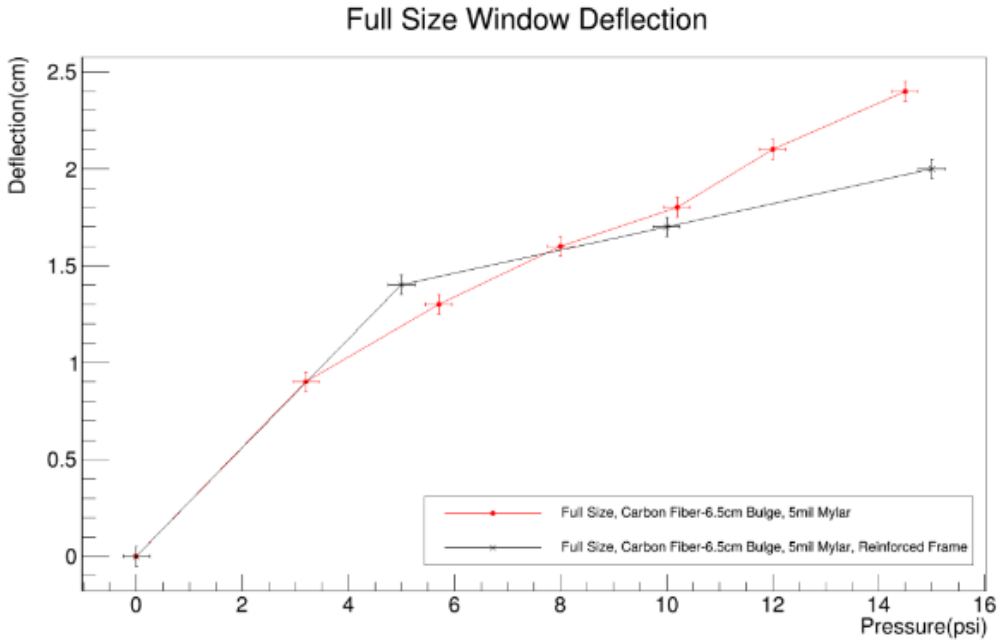
Above: Fabrication of carbon fiber shell with epoxy

Left: Foam mold for full size window shell

Full Size Carbon-Fiber Window

- Moderate success with full size CF shell:
  - Structurally stable at +1 atm
  - Failure in pressure seal due to previously identified frame issues
  - Alarming creaking noises from shell under stress while inflating; potential safety concern
  - Deflection only 2cm beyond constructed bulge at maximum pressure



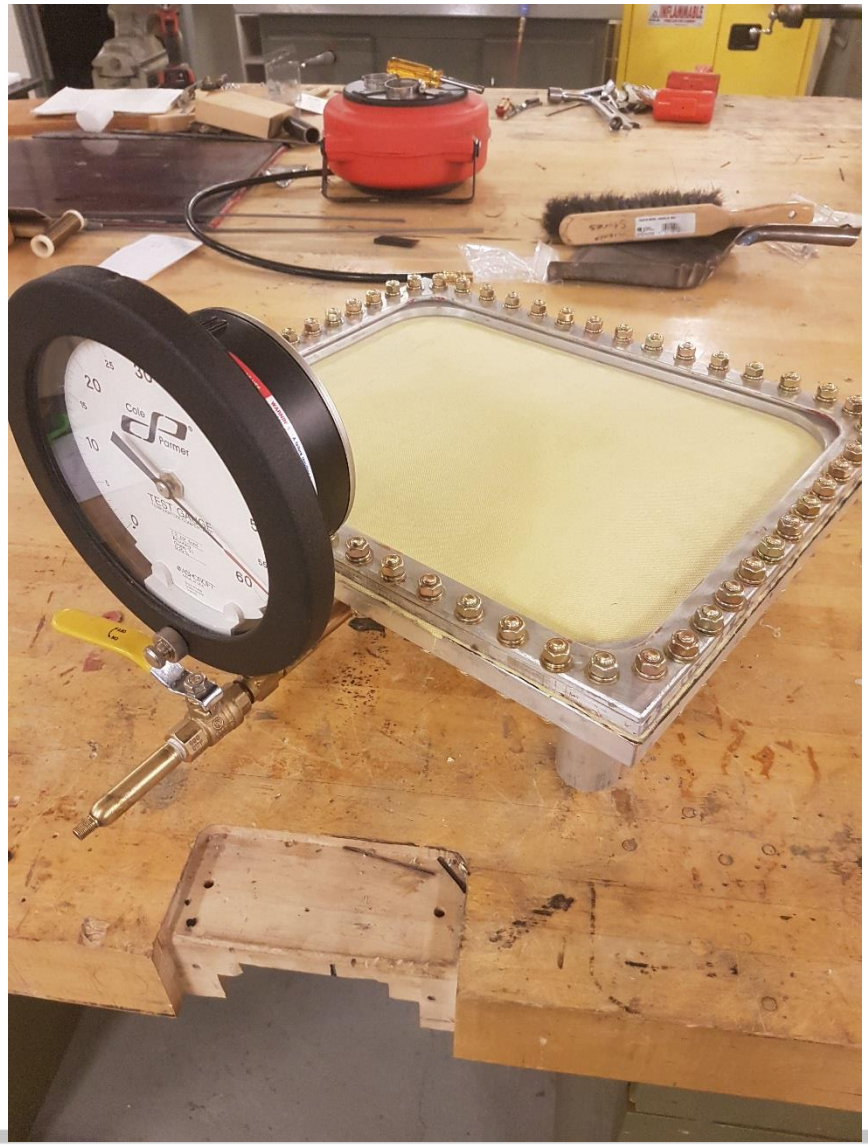


- New test frame following recent modifications forthcoming
- Replacement of O-ring with gasket being considered

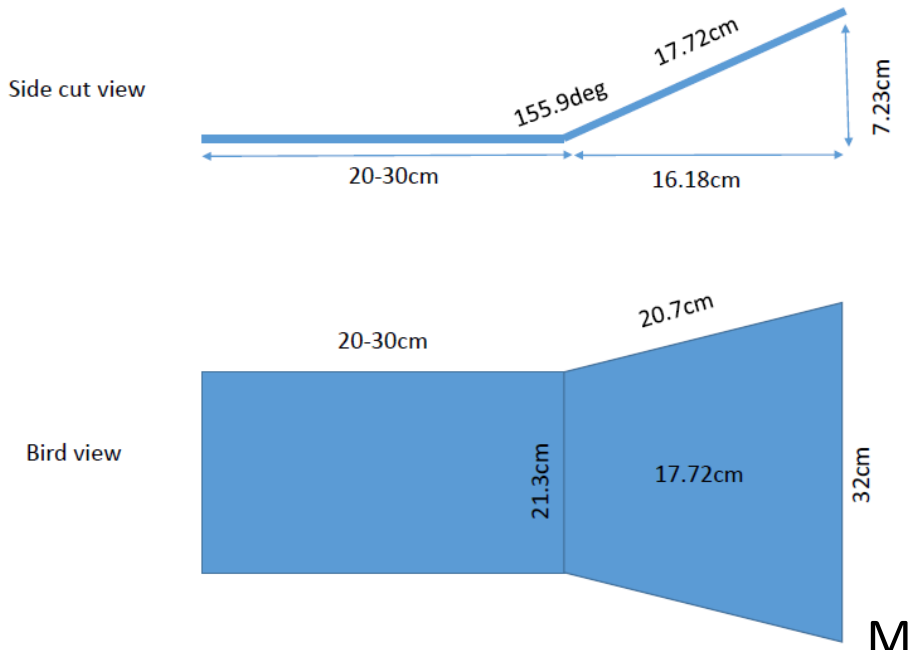
Heavier Stock Carbon Fiber

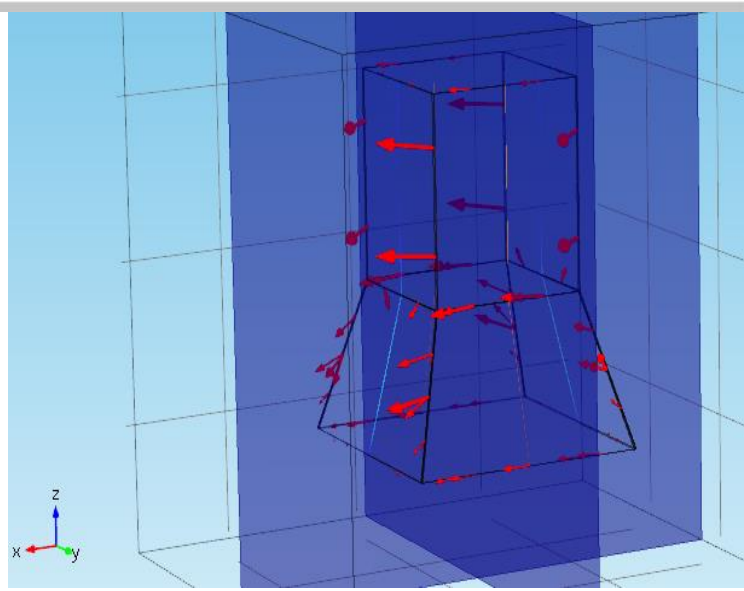
- Heavier stock carbon fiber fabric obtained from Fiber Glast
- Want to try flat window to improve clearance and simplify fabrication
- Flat window structurally stable at +4 atm where previous flat window (with lighter CF) failed
- Significantly reduced creaking noises over previous tests
- Maintaining pressure for 40 days and counting!

- Very promising results from the thicker Carbon Fiber
- Next test will be a full size version, possibly on whole new frame



Magnetic shielding





Simulation with COSMOL

Join 4 sides by welding and annealing

Use layers of low carbon steel and mumetal

Prototyping starts this summer

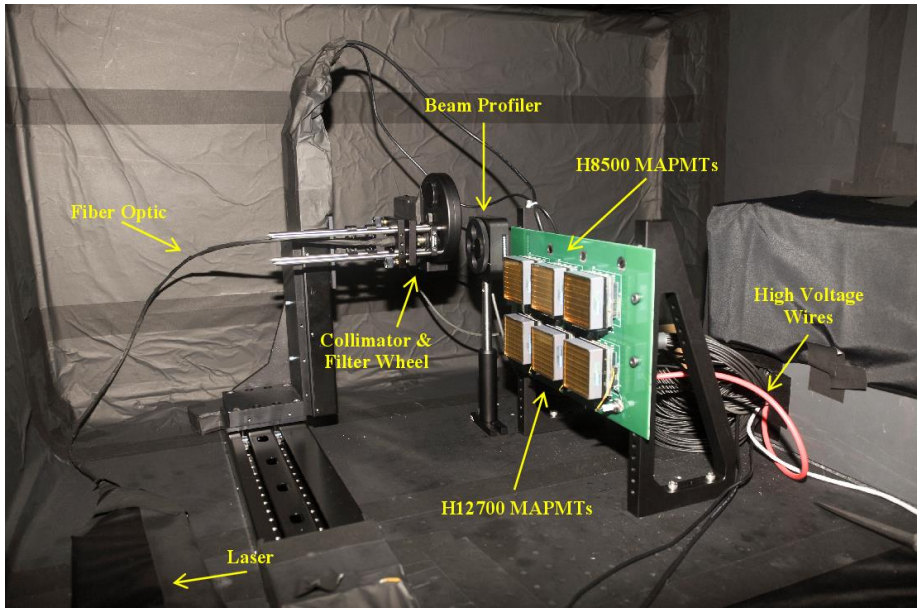
Drew Smith and Chao Gu

Material: Pure Iron
Permeability: 4000 - 10000
Thickness: 1mm - 2 mm
B outside : 100 G in trans or long
Shielding factor at PMT center: 10 -50
Gap at 4 sides affects trans more
endcap affect long

Wei Ji, grad
Tsinghua U China

Readout and DAQ

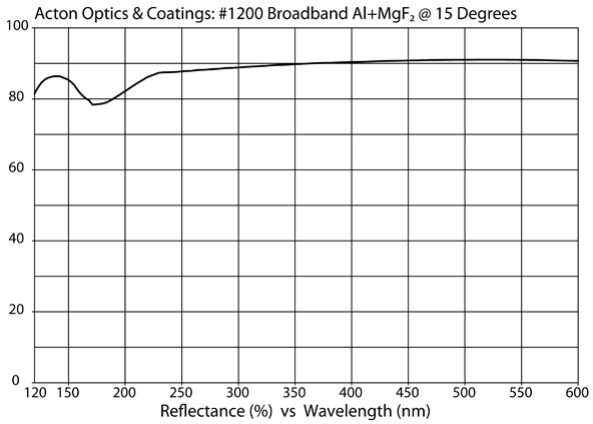
- MAROC readout system
  - Planning a high rate readout test with existing MAROC boards using the Hall B test platform with laser, starting this summer
  - Will purchase new readout board with MAROC chips and a total sum for H12700 PMT readout
  - The system will be used for the prototype telescopic Cherenkov and a high rate beam test will be performed in the future



Drew Smith and Chao Gu

Mirror coating update

- In April 2018, last piece of equipment, the rotating shaft + motor for rotating the mirror blank (frame) inside the evaporator was received
- installation of the equipment at least until August because of current work with sPHENIX
- will coat and test the small CFRP coupons first
- Plan to pursue the highest reflectivity down to 120 nm, and hope to match WLS-coated MAPMT at 160nm at least. will see how it goes once start coating



Klaus Dehmelt and Tom Hammick @ SBU