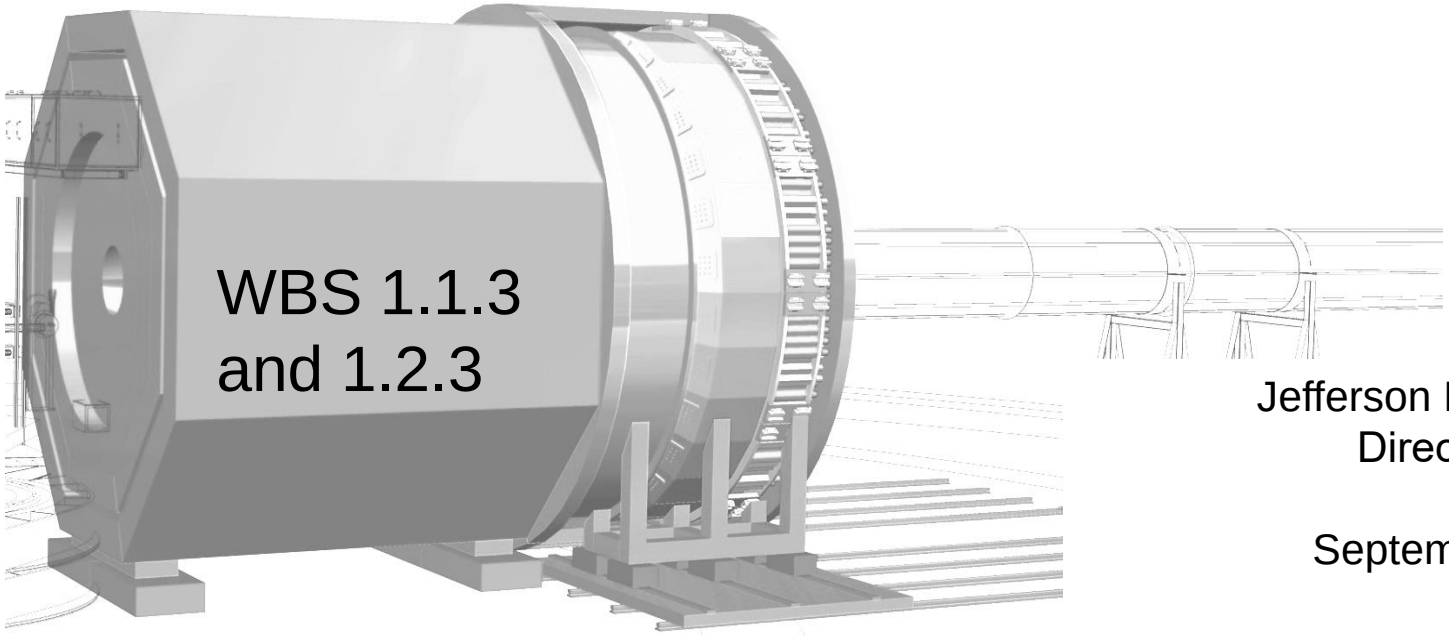
Heavy Gas Cerenkov



Jefferson Lab SoLID Project
Director's Review

September 9-11, 2019

Zhiwen Zhao

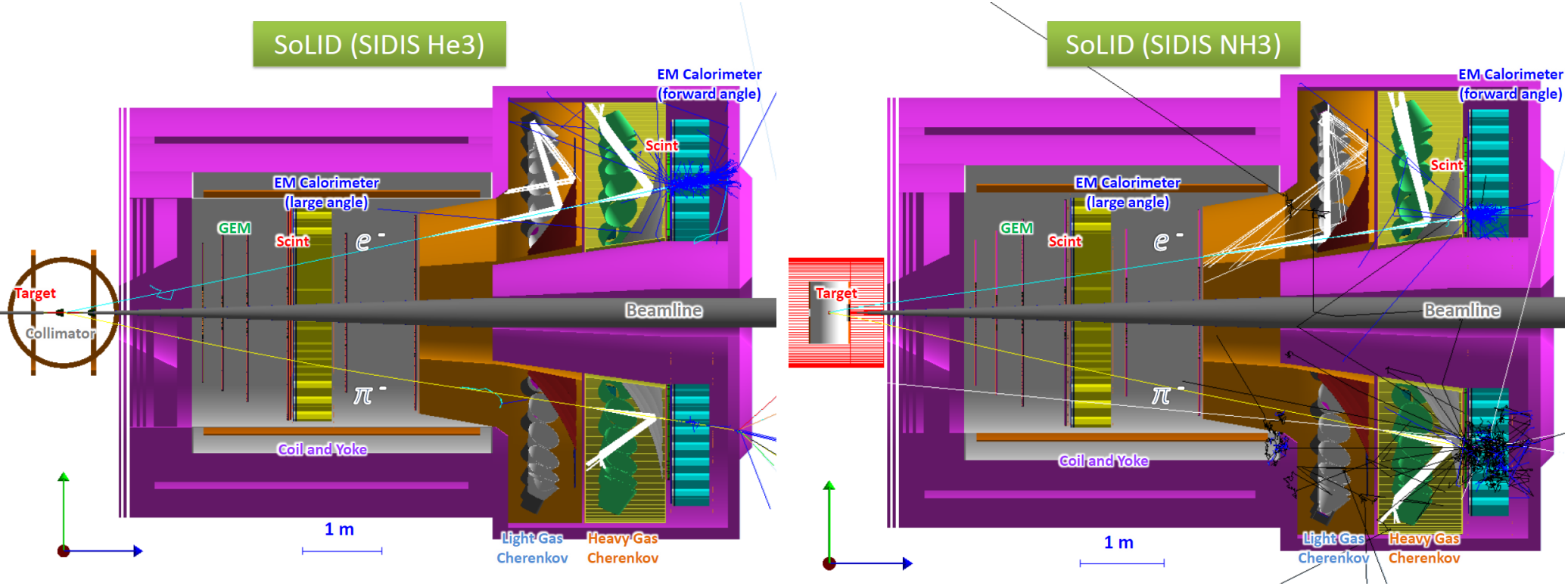
HGC group
Duke University

Outline

1. Requirement and Design
2. Technical Risks
3. Cost and Duration and basis
4. ESH&Q Considerations
5. Addressing Previous Director's Review Recommendations

HGC requirement

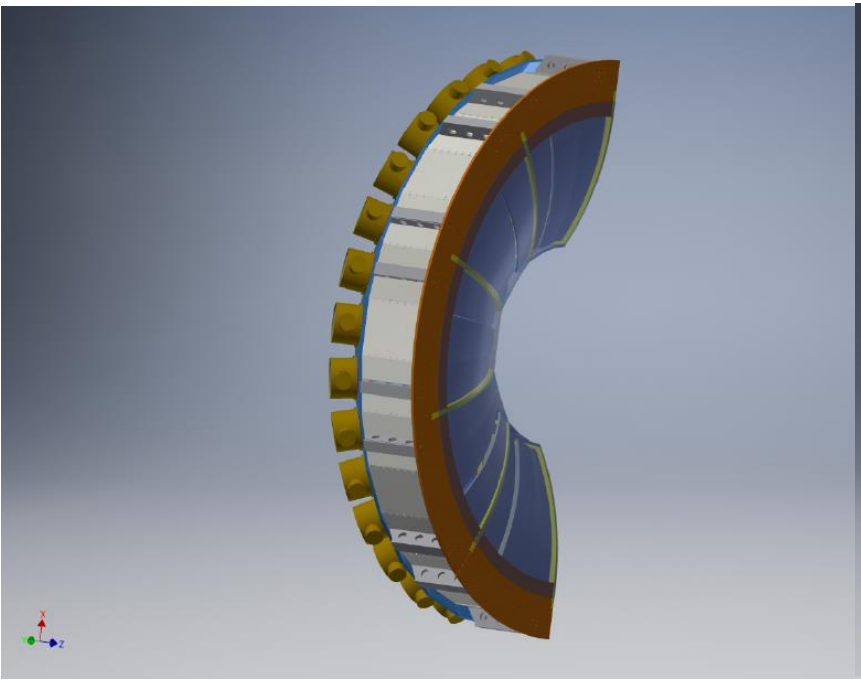
HGC is used to identify charged pions and reject charged kaons.
It is only used for SIDIS polarized ^{3}He and SIDIS polarized proton (NH_3) experiments.

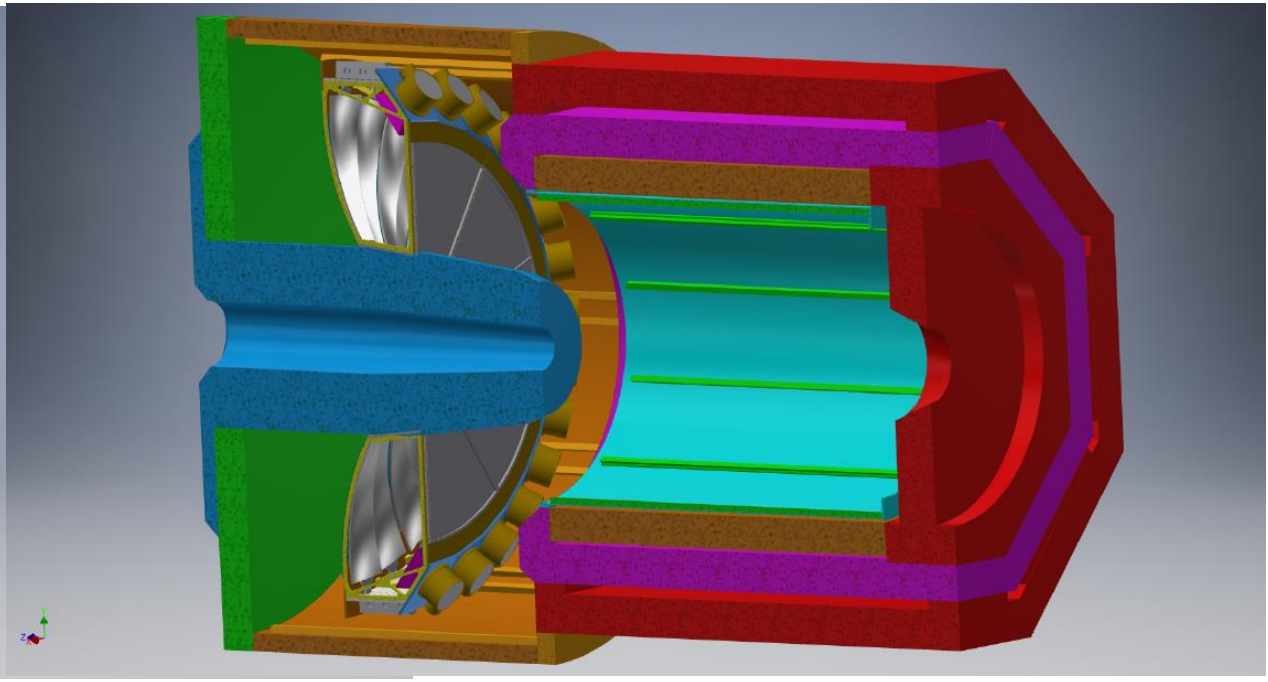


- ❑ Kinematic coverage: 2.5GeV < P < 7.5GeV, 8º < θ < 15º, full azimuthal angle
- ❑ π^+/π^- detection: efficiency >90% and Np.e. > 10
- ❑ K^+/K^- rejection: factor >10
- ❑ Space limit along beam direction: ~1m
- ❑ Magnetic field at photosensor location: ~100G

HGC design overview

- Radiator: ~1m long C_4F_8 gas at 1.7atm (abs) and 20^{o}C
- Sectors (30): each sector has 1 mirror, 1 photosensor array, 1 magnetic shielding cone and 1 reflection cone
- Super-sectors (10): each super-sector has 3 sectors sharing 1 front and 1 back window
- Mirrors (30): light weight, spherical shape, same type as LGC
- Magnetic shielding cones (30): layers of low carbon iron and mu-metal
- Reflection cones (30): reflection film attached to shielding cone
- Photosensors (480): 2” Multi-anode PMT (MaPMT) in 4x4 array with sum readout, same type as LGC

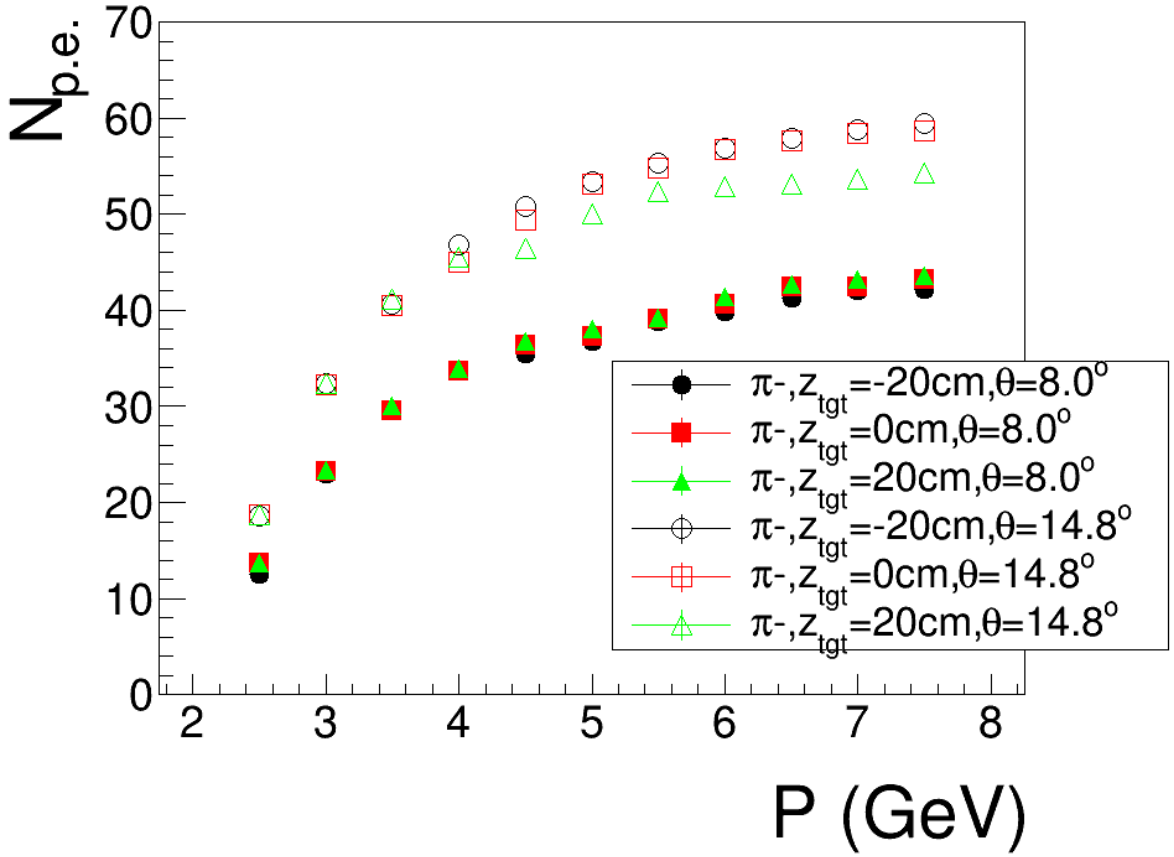


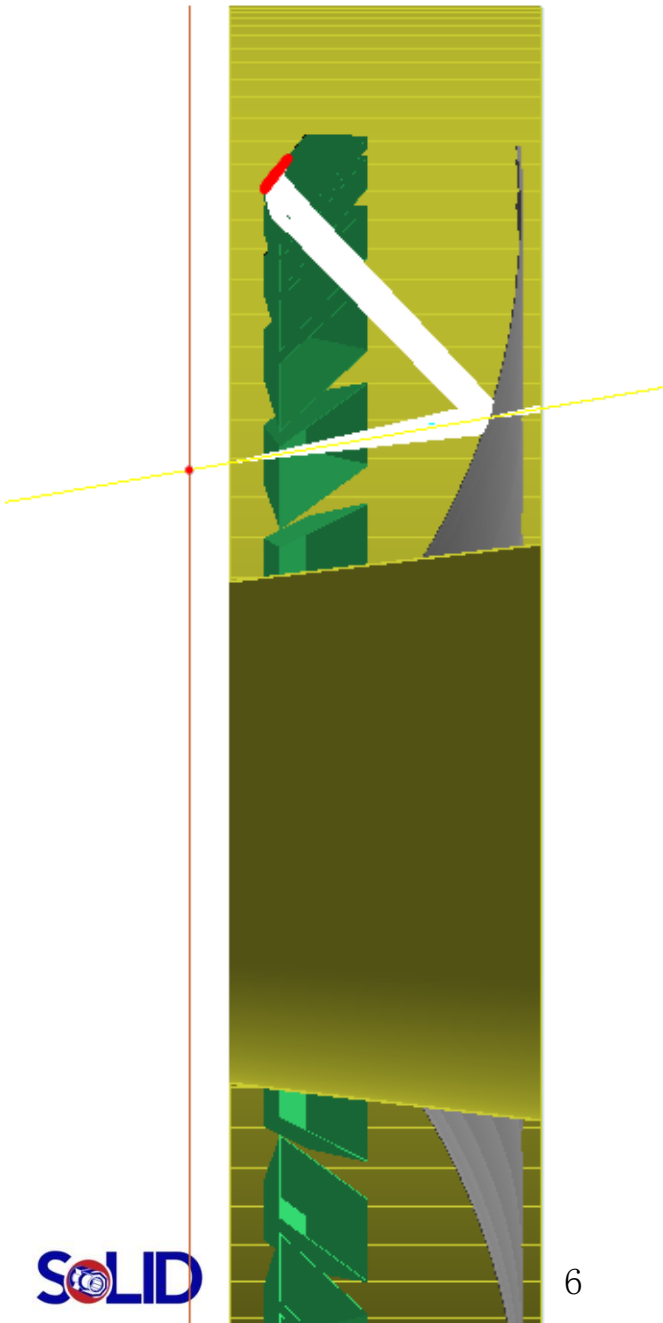


Simulation

- Use the standard “SoLID_GEMC” based on GEMC and Geant4
- Detector description includes wavelength dependent optical features (gas refraction index, light absorption in gas, mirror reflectivity, reflection cone reflectivity, and PMT quantum efficiency) with cutoff at 200nm
- ^{3}He target 40cm length is included
- Particle decay for a flight path ~7m is included
- Both HGC standalone simulation and SoLID overall simulation use the exact same detector description and signal processing

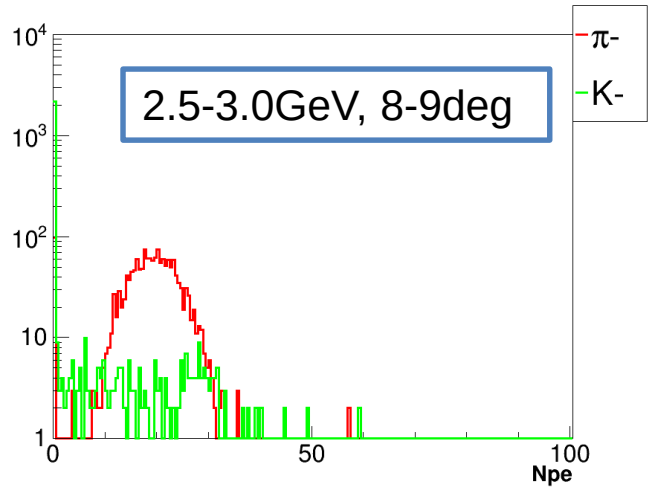
Number of photoelectrons

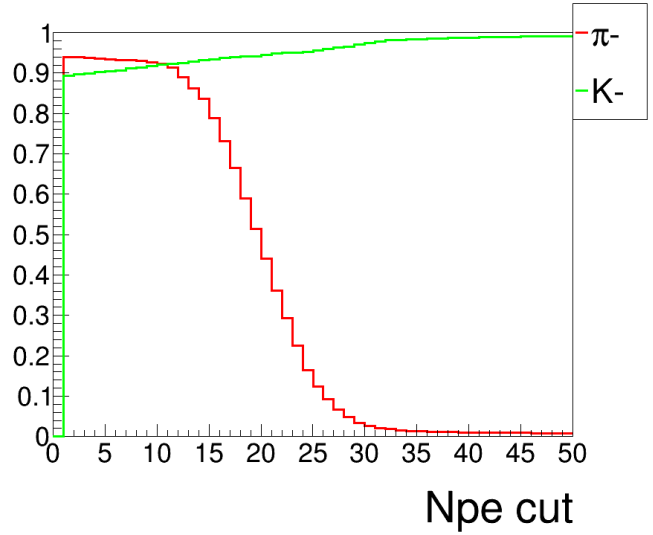


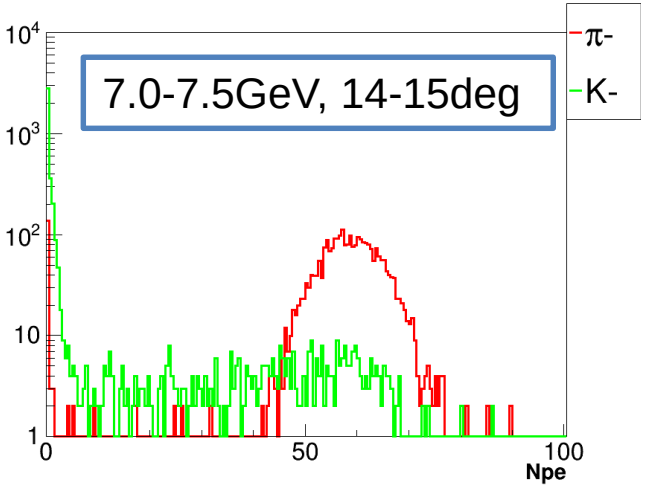


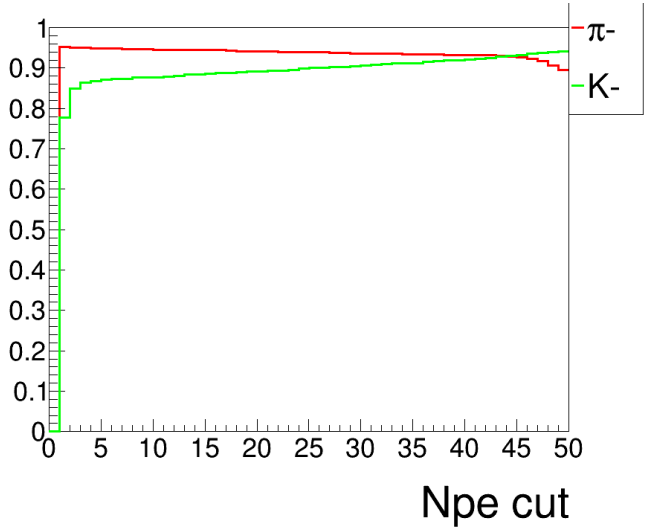
- Np.e. > 10, over full range of momentum, polar angle and target length

Pion efficiency and kaon rejection









eff. for pion
1-1/rej. for kaon

Np.e. cut can be adjusted to balance both requirements

More advanced likelihood method can be used

- π^+/π^- efficiency > 90% and K^+/K^- rejection >10, over full range of momentum and polar angle

Technical Risks

➢**Heavy Gas Cerenkov is a very common detector used at JLab and many other labs. - low risk**

➢Operating at 1.7 atm (abs) as a pressure system

- ❑Prototyping to verify mechanical structure and material to satisfy JLab ESH&Q requirement

➢Magnetic shielding of 10x10cm MaPMT array

- ❑Prototyping was conducted to validate the design

➢Choice of gas and its performance, availability and price

- ❑Beam test was carried out to verify the C_4F_8 performance. Survey of availability and price with vendors was conducted. Recycling gas system is planned.

➢There is “no show stopper”

UofR Prototype for pressure system

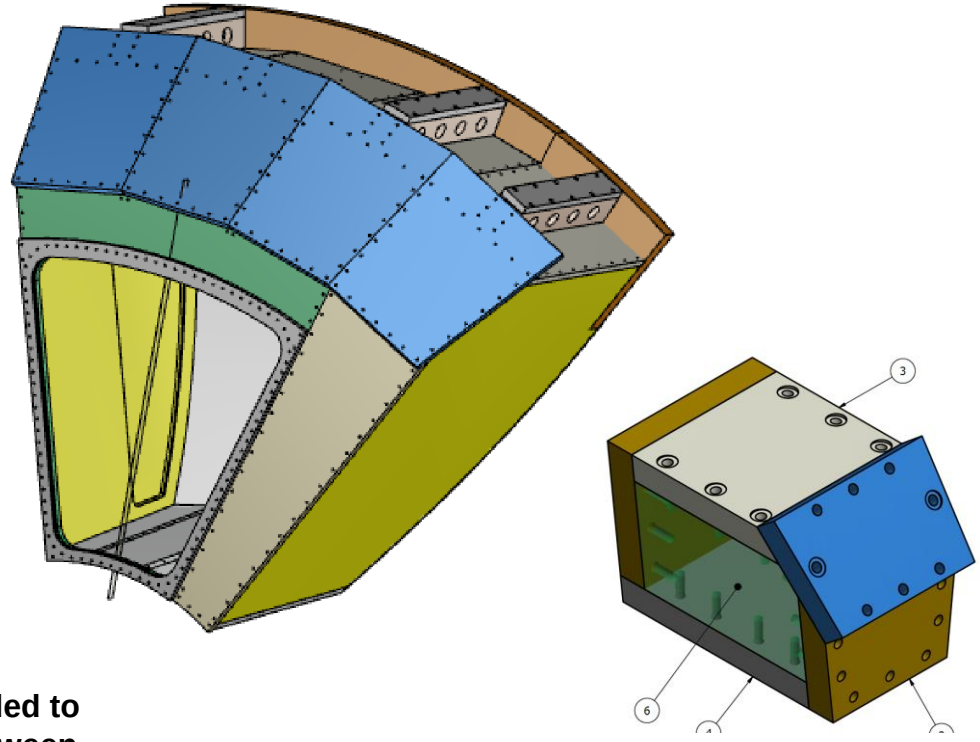
➢C$100k grant from Canada allowed University of Regina (UofR) group to construct a prototype of one SoLID HGC super-sector based on the design from Duke University for testing mechanic structure, materials and gas tightness

➢Design reviewed by JLab Hall A Design Authority to ensure the following ESH&Q guidelines for the pressure system are met

- ❑The thin window needs to be designed with the lesser of 90% yield or 50 Ultimate strength (Note: 50% Ult will govern for aluminum)
- ❑The thin window needs to be tested to 2X operational pressure to qualify design and material batch
- ❑The tank needs to be designed to a safety factor of 3 using engineering analysis
- ❑The tank needs to be pneumatically tested to a minimum of 1.15X operational pressure

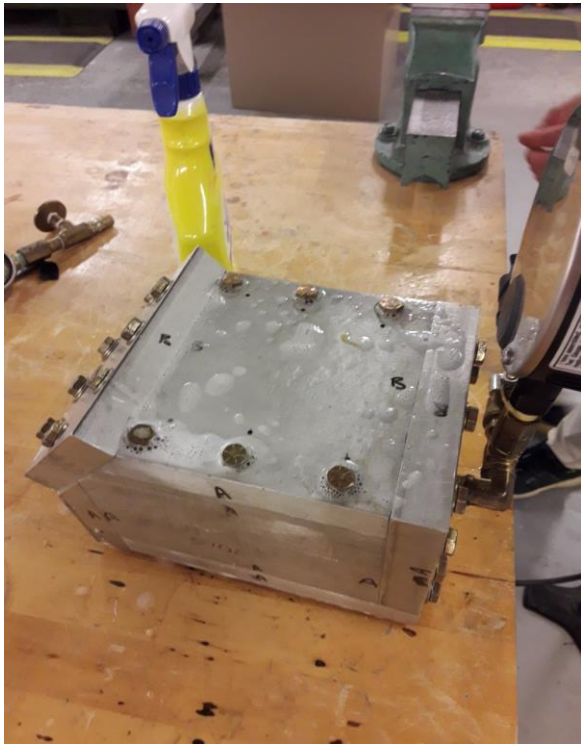
UofR Prototype (tank)

- Design is finished by Duke with a safety factor > 3
- UofR built a small box to test materials and assembly method and it was tested to 100psi/6.8atm with no leak detected
- The prototype tank will be built and tested with >1.15X operational pressure



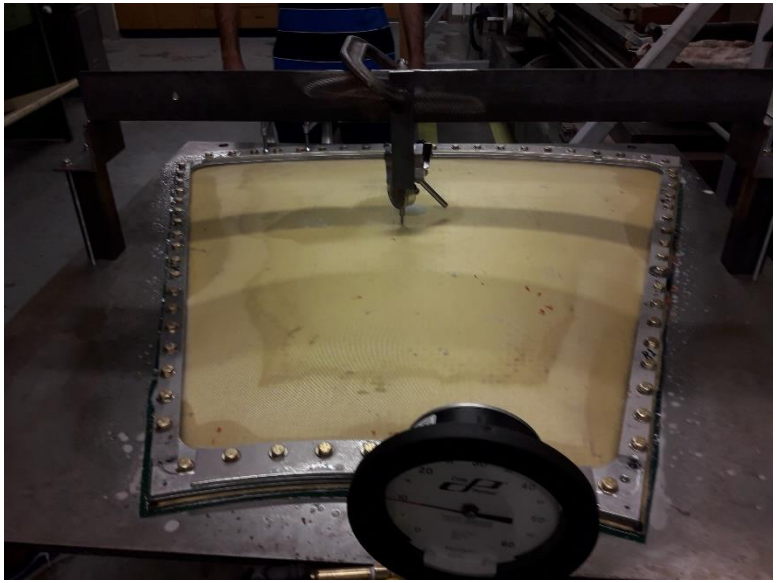
Prototype design

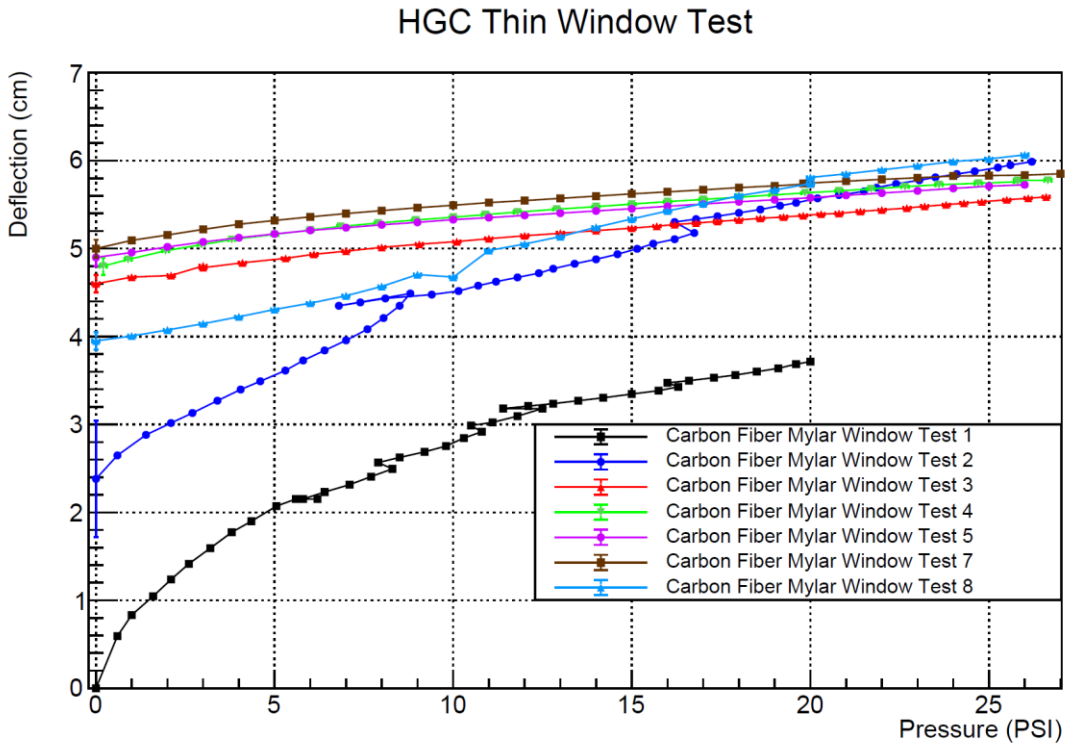
(front window not shown. extra section included to test connection between super-sectors)



UofR Prototype (front window)

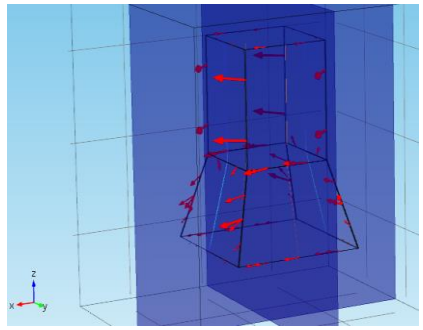
- A full size window made of layers of mylar(3mil)/carbon-fiber(90mil)/kevlar(12mil) was built and tested to 26.5psi/1.8atm relative (>2X operating pressure) multiple times.
- Window bulged only 6cm
- **Fabrication is reproducible**





Magnetic shielding prototype

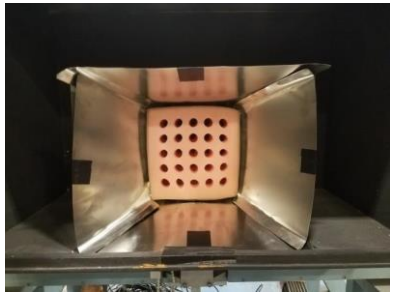
- Working with vendors to obtain materials for testing and specs of their magnetic property for field calculation
- tested shielding performance of two layers of 0.095" thick low carbon iron sheets in ~100 G field at longitudinal and transverse directions



at PMT array location	Longitudinal (+/- 0.3 G)	Transverse (+/- 0.3 G)
test	14.9 G	7.8 G
calculation	21G	5.6G

Field < 25G means MaPMT gain drop < 5%

Satisfy requirement

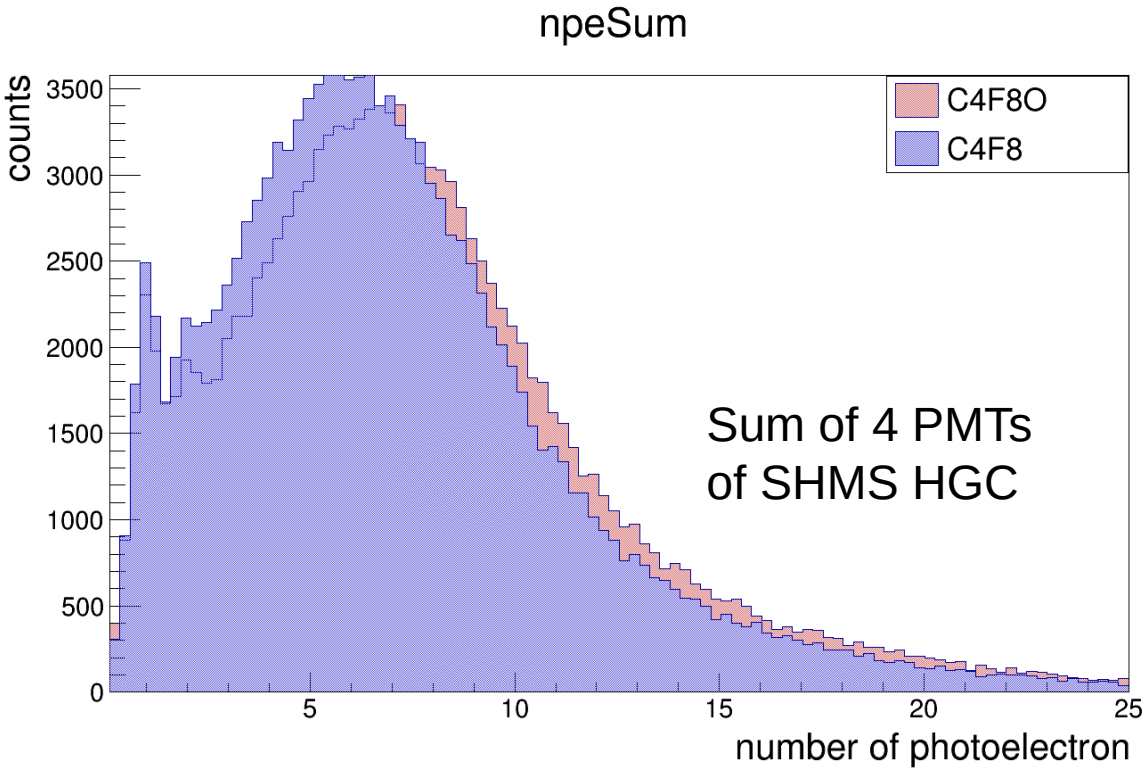


Gas

Choice of gas: C_4F_8

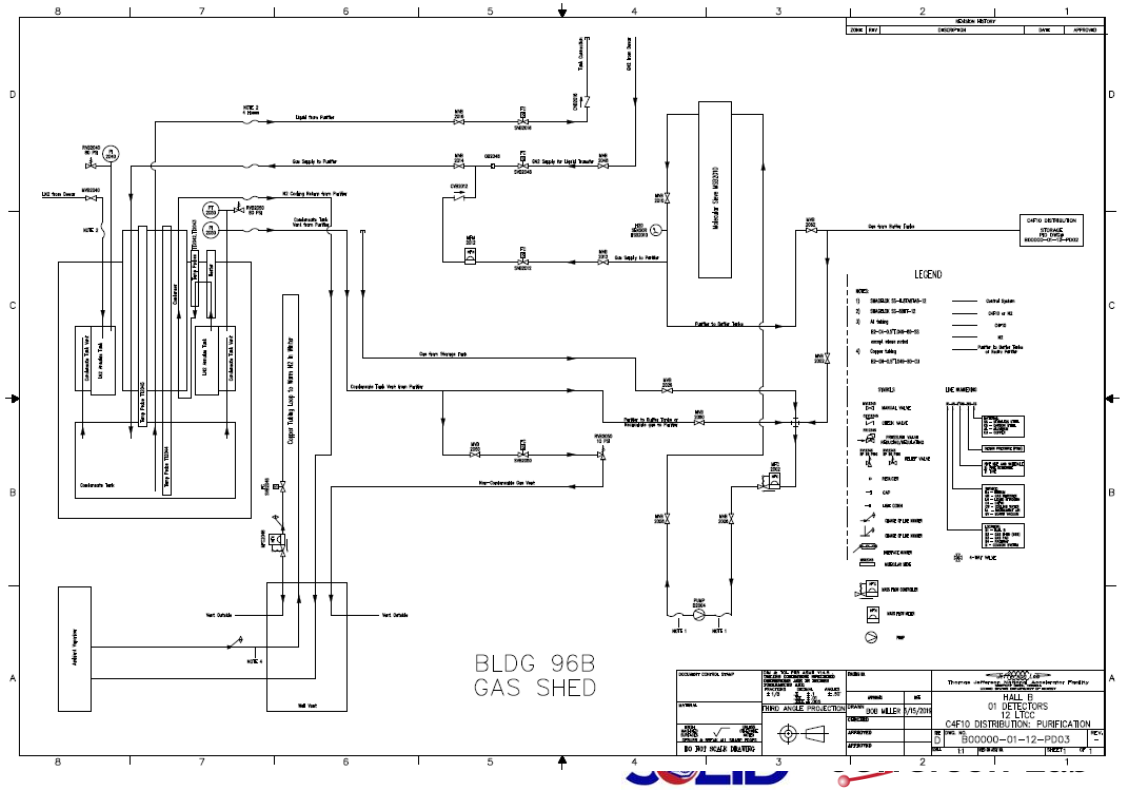
- Beam test has shown its performance very close to other common heavy gases used for Cerenkov detector
- OK to use according to ESH&Q “our sustainability goals require that we minimize releases, and track and report any occurrences”
- Widely available from many suppliers in bulk quantity
- Hall A GRINCH detector will use C_4F_8 next year

- Summer 2019, running HallC SHMS HGC with C_4F_8O and C_4F_8 for comparison (photon sensitivity down to 200nm including mirrors and PMTs)
- The results from two neighboring runs show average Np.e. ratio of C_4F_8/C_4F_8O is ~93%, proportional to the ratio of refraction index n-1 as expected
- higher pressure gives higher refraction index and higher photon yield. C_4F_8 at 1.7atm (abs) satisfies the physics requirement.



Gas system

- Fill-and-seal system without need for circulation during running
  - Extensive JLab experience with Hall B LTCC gas system
- Build new supply and return units with heated transfer lines
- Sharing purifying unit with LTCC gas system
  - It can work with both C_4F_8 and C_4F_{10}
  - >90% recovery efficiency estimated for C_4F_8 and tests planned
  - Both detectors only need to purify gas at recovery stage
  - Both return units have large buffer tanks to give flexibility
  - Cost saving for JLab



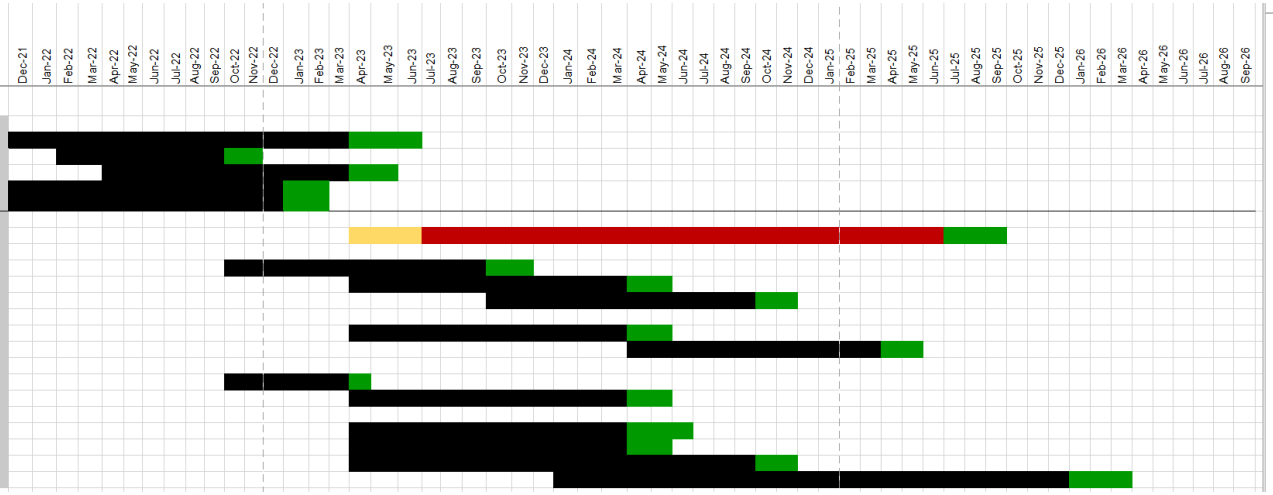
Cost and basis

WBS	Activity #	Activity Name	Costed Labor (PW)	Contrib Labor (PW)	Total Labor (PW)	Labor Cost (Direct $K) ($K)	Procurement Cost (Direct $K) ($K)	Total Cost (Direct $K) ($K)
1.1.3	**HGC**	**Heavy Gas Cherenkov (HGC)**	**80.00**	**13.00**	**93.00**	**$160.63**	**$0.00**	**$160.63**
1.1.3.1		Tank and front thin window	49.00	13.00	62.00			
1.1.3.2		Magnetic Shielding and reflection cone	5.00	0.00	5.00			
1.1.3.3		Gas System	13.00	0.00	13.00			
1.1.3.4		Sum Readout	13.00	0.00	13.00			
1.2.3	**HGC**	**Heavy Gas Cherenkov (HGC)**	**488.00**	**52.00**	**540.00**	**$785.00**	**$3,932.40**	**$4,717.40**
1.2.3.1		Tank and front thin window	189.00	13.00	202.00		$771.00	
1.2.3.2		**Mirrors**	**17.00**	**0.00**	**17.00**		**$599.40**	
1.2.3.2.1		Mirror Blanks			0.00		$400.00	
1.2.3.2.2		Mirror Coating			0.00		$170.00	
1.2.3.2.3		Mirror Assembly	17.00		17.00		$29.40	
1.2.3.3		**Magnetic Shielding and reflection cone**	**31.00**	**13.00**	**44.00**		**$240.00**	
1.2.3.3.1		Magnetic Shielding	22.00	9.00	31.00		$150.00	
1.2.3.3.2		Reflection cone	9.00	4.00	13.00		$90.00	
1.2.3.4		**PMTs and Coating**	**0.00**	**0.00**	**0.00**		**$1,622.00**	
1.2.3.4.1		PMTs			0.00		$1,440.00	
1.2.3.4.2		PMT coating			0.00		$182.00	
1.2.3.5		**Gas and Gas System**	**44.00**	**4.00**	**48.00**		**$460.00**	
1.2.3.5.1		Gas System	44.00	4.00	48.00		$300.00	
1.2.3.5.2		Gas for Testing, Commissioning and Initial Operation			0.00		$160.00	
1.2.3.6		Sum Readout	62.00	13.00	75.00		$200.00	
1.2.3.7		Testing and Installation	145.00	9.00	154.00		$40.00	

HGC components	Cost basis
Tank and front window	experience with SHMS HGC, prototype, quote
Mirror and coating	experience , quote, together with LGC
Magnetic shielding and reflection cone	experience , quote
PMT and WLS coating	experience , quote and test coating, together with LGC
Gas	experience , quote
Gas system	experience with CLAS12 LTCC gas system
Readout	experience ,quote, test board, together with LGC
Testing and installation	Experience with SHMS HGC and CLAS12 LTCC

Duration and basis

		black regular; green float; red critical; yellow long lead	total labor (PW)	Start Date	Finish Date	duration (WKS)	comments
3	1.1.3	**Heavy Gas Cherenkov (HGC)) design**	93.00	12/1/2021	3/31/2023		
4	1.1.3.1	Tank and front thin window	62.00	12/1/2021	3/31/2023	64	long lead item
5	1.1.3.2	Magnetic Shielding and reflection cone	5.00	2/1/2022	9/30/2022	10	integrated into tank
6	1.1.3.3	Gas System	13.00	4/1/2022	3/31/2023	26	jlab personnel
7	1.1.3.4	Sum Readout	13.00	12/1/2021	12/31/2022	26	electronic and mechanical design, integrated into shielding
8	1.2.3	**Heavy Gas Cherenkov (HGC) construction**	540.00	10/1/2022	12/31/2025		
9	1.2.3.1	Tank and front thin window	202.00	4/1/2023	6/30/2025	117	long lead item
10	1.2.3.2	**Mirrors**	17.00				
11	1.2.3.2.1	Mirror Blanks	0.00	10/1/2022	9/30/2023	52	similar to LGC
12	1.2.3.2.2	Mirror Coating	0.00	4/1/2023	3/31/2024	52	similar to LGC
13	1.2.3.2.3	Mirror Assembly	17.00	10/1/2023	9/30/2024	52	similar to LGC
14	1.2.3.3	**Magnetic Shielding and reflection cone**	44.00				
15	1.2.3.3.1	Magnetic Shielding	31.00	4/1/2023	3/31/2024	52	affects 1.2.3.3.2 and 1.2.3.6
16	1.2.3.3.2	Reflection cone	13.00	4/1/2024	3/31/2025	26	depends on 1.2.3.3.1
17	1.2.3.4	**PMTs and Coating**	0.00				
18	1.2.3.4.1	PMTs	0.00	10/1/2022	3/31/2023	26	similar to LGC
19	1.2.3.4.2	PMT coating	0.00	4/1/2023	3/31/2024	52	similar to LGC
20	1.2.3.5	**Gas and Gas System**	48.00				
21	1.2.3.5.1	Gas System	48.00	4/1/2023	3/31/2024	52	can float, jlab personnel
22	1.2.3.5.2	Gas for Testing, Commissioning and Initial Operatic	0.00	4/1/2023	3/31/2024	10	can float
23	1.2.3.6	Sum Readout	75.00	4/1/2023	9/30/2024	52	depends on 1.2.3.4 and 1.2.3.3.1
24	1.2.3.7	Testing and Installation	154.00	1/1/2024	12/31/2025	104	mainly depends on 1.2.3.1



- Tank and front thin window are long lead items
- Mirror and mirror coating, PMT and PMT coating, and readout electronics are coordinated with LGC

ESH&Q Considerations

- HGC hazards
  - As a pressure system, it needs to satisfy the requirements through its design and test. It's under supervision of Hall A Design Authority
  - Its gas needs to satisfy the requirements. It will be recovered for reuse and the quantity used will be monitored by the lab ESH&Q staff

- ESH&Q Considerations for HGC:
  - Conduct all work in accordance with JLAB's Integrated Safety Management (ISM) program.
  - All SoLID users will comply with all applicable training requirements of JLAB, Physics Division and Hall A.
  - Adhere to all Physics Division Oversight requirements such as internal reviews. One example is the Experiment Readiness Review (ERR).
  - Plan all work according to Physics Division work planning requirements.
  - See Ed Folts' ESH&Q presentation for more information

Address Recommendations from 2015 Director's Review

- HGC received no recommendation