SoLID Heavy Gas Cherenkov

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for HGC group

SoLID Collaboration Meeting. Aug 8, 2019







Overview

- Requirement
- Design
- Simulation and performance
- Prototype and R&D
- Summary





Requirement



SIDIS Heavy Gas Cherenkov (HGC)

- □ π^+/π^- detection: eff>90%, 2.5<P<7.5GeV, 8° < θ < 15°, full azimuthal
- \Box K⁺/K⁻ rejection: 10

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□ Space limit along beam direction: ~1m

□ Field at photonsensor: ~100G (TOSCA model)





Design

- Radiator: ~1m long C4F10 at 1.5atm or C4F8 at 1.7atm at 20°C
- 30 sectors: each sector has 1 mirror, 1 photonsensor array, 1 magnetic shielding and 1 reflection cone
- > 10 supersectors: each supersector has 3 sectors with 1 front and 1 back window
- > 30 Mirror: light weight, spherical, same as LGC mirror
- > 480 Photonsensor: 2" Multi-anode PMT (MaPMT) in 4x4 array
- > 30 magnetic shielding cone: layers of low carbon iron and mu-metal
- 30 reflection cone: reflection film attached to shielding cone



Simulation

- Simulation uses "SoLID_GEMC" based on GEMC and Geant4
 - Gas refraction index and absorption, mirror reflection, reflection cone, and PMT QE are all wavelength dependent (cut off at 200nm)
 - HGC standalone simulation and it as a part of SoLID overall simulation use the exact same detector description and response
 - He3 target length (40cm) and window collimator effects are included
 - Particle decay effect is included
 - Apply safety factor 0.5 on Np.e. from simulation







in preCDR

later





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Efficiency and Rejection

- Pion efficiency > 95% and kaon rejection > 10
- He3 target window collimator add acceptance effect and the combined efficiency and acceptance are ~82% on average and kaon rejection > 10
- Only result at the lowest P and smallest polar is shown, where there is the least Np.e.



Same number of particle for different particle species





- C\$100k grants from CFI & Fedoruk at Canada allow UofR to construct one SoLID HGC supersector (3 sectors with 1 front window) prototype for testing structure, materials and gas tightness
- JLab HallA engineering helped review to ensure the following ESH&Q guide lines for the pressure system
 - "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"





Prototype (tank)

- Design is finished by Duke and UofR is currently waiting for bid from contractors.
- UofR built a small box to test material and assembly method and it was leak tested to 100psi/6.8atm with no leaks detected









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Prototype (front window)

- A full size window of Mylar/carbon fiber/Kevlar is made
- Inflated the full size window to more than 2X operating pressure (26.5 psi or 1.8 atm relative)
- Window bulged after testing but has stabilized after inflating multiple times.
- Even at more than 2X operating pressure the deflection is only 6cm.
- > Fabrication is reproducible



MAPMT Field Test

- gain loss in the multiplication chain within magnetic field
- The loss is just a few percent if we can shield the field below 10G



S. Malace, B. Sawatzky, H. Gao

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Magnetic Shielding

- Working with vendors to obtain materials and their magnetic property
- Simulated and tested shielding performance of two layers of 0.095" thick low carbon iron sheet in 90 G field at both direction



	Longitudinal (+/- 0.3 G)	Transverse (+/- 0.3G)
Position 1	14.9 G	7.8 G
(sensor plance)	21 G	5.6 G
Position 2	6.7 G	6.0 G
	6.3 G	3.6 G
Position 3	15.0 G	2.4 G
	6.6 G	2.2 G

- Sim shows results similar to test
- Need to test homogeneity
- Working with vendor for next version, adding a mu-metal layer

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Sum Readout

- Jlab detector group helped design and build a preliminary sum board with 4 quad sum and 1 total sum
- Plan to test it during preRD

detector group test stand









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MAROC Readout

- Alternative/Upgrade readout solution with total sum and pixel information
- Based on CLAS12 RICH readout design
- Modify ASIC board and add a total sum board (design done by INFN Ferrara)
- Plan to make a few boards and test during preRD

MAROC test stand





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Reflection Cone Film

- Lexan film coated with Al and protection from company ECI
- used for CLAS12 LTCC mirror with good reflection shown below





Mirror Coating R&D at Stony Brook U

- Refurbish a chamber and coat mirror with reflection 200nm and below
- All parts are ready Summer 2019, working on installation
- Small carbon fiber coupons for mirror base are in hand
- VUV spectrometer at BNL will be used to measure reflecivity









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Gas and Gas System

➢ Gas: C4F10

- commonly used for other heavy gas Cerenkov/RICH detectors. Currently running large detectors are CLAS12 LTCC (30m³/300kg), COMPASS RICH-1 (80m³/800kg), comparing to SoLID HGC(20m³/300kg)
- It's OK to use with ESH&Q "our sustainability goals require that we minimize releases, and track and report any occurrences"
- Supplier F2-Chemical at UK plans to maintain the production capability and also produces it for medical use

Gas system:

- □ Fill-and-seal system without need for circulation during running
- □ A lot of experience with HallB LTCC gas system
- □ Have supply and return units with heated transfer lines
- □ Sharing purifying unit with LTCC gas system (>95% recovery eff.)
 - $\,\circ\,$ Both detectors only need to purify gas at recovery stage
 - Both return units have buffer tanks



Other Gas

- C4F8O is identical to C4F10 (n-1=.0014 at 405nm) in term of performance, but hard to find suppliers
- C4F8 (n-1=.0013 at 405nm) and C3F8 (n-1=.0011 at 405nm) are widely available with better price
- C4F8/C3F8 needs to be at 1.7atm/1.9atm for same performance of C4F10 at 1.5atm
- It's OK to use with ESH&Q
- GRINCH at HallA will use C4F8 as default
- Summer 2019, we ran HallC SHMS HGC with C4F8O and C4F8 for comparison
- Two neighboring runs shows peak Np.e. ratio of C4F8/C4F8O is 92%, directly proportional to n-1 as expected
- We may test C3F8 later
- HallB gas system can purify C4F8/C3F8 and tests for eff are planned







Cost Basis

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





Summary

- SoLID HGC design satisfies its requirement
- Various R&D are ongoing to mitigate any technical risk.
- Cost estimation is based on experience, quote and various ongoing R&D





backup





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C4F10 P-T

- "EPA has taken the approach with GHG compliance of placing most of the regulatory burden on the manufacturing side of things. In other words, if we are able to purchase C4F10 legally, this can be done without the requirement for obtaining any air permits at this time."
- "Our sustainability goals require that we minimize releases, and track and report any occurrences"



-- Scott Conley





Max signal particle efficiency at target for HGC with full setup

HGC standalone setup with only decay effect has pion eff ~0.99 and kaon rejection ~10 HGC full setup kaon rejection ~ 10 without much dependence on momentum, angle, collimator



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Decay rate in vacuum with 6.7m flight path (from target to hgc window in current endcap)

Mom (Gev)	1	2	3	4	5	6	7	8	9	10
pim	0.113	0.058	0.039	0.030	0.024	0.020	0.017	0.015	0.013	0.012
km	0.589	0.359	0.257	0.200	0.163	0.138	0.119	0.105	0.094	0.085



Window thickness test for hgc (NOT hgc_moved)

material	Win_front	gas	mirror	Win_back	2
HGC original	kevlar+mylar	C4F10 at 1.5atm	CFRP	Al	
HGC real	Kevlar+CF+myl ar	C4F10 at 1.5atm	CFRP	Al	
HGC CO2	Al	CO2 at 5atm	CFRP	Al	

Length in cm	Win_front	gas	mirror	Win_back	
HGC original	0.06	100	0.3	0.10	
HGC real	0.24	100	0.3	0.64	
HGC CO2	0.50	100	0.3	1.28	

Length in radiation length	Win_front	gas	mirror	Win_back	total
HGC original	0.002	0.033	0.011	0.011	0.057
HGC real	0.009	0.033	0.011	0.072	0.125
HGC CO2	0.056	0.025	0.011	0.144	0.206



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Back window study

 Type: Disklowment Uni: n SK/2019, 559:32 PM 0.05687

 0.05687

 0.04265

 0.02844

 0.01422

 0.Mm



- latest 1/4 inch thick back window concept
- displacement (<0.08") and safety factor for yield (>5) are studied with 15psi/1atm applied on Alum 2014-T4
- Alum 6061-T6 is good too with SF ~4
- Since the radius is so large we may be able to deform an accurately cut flat sheet, in place, during assembly.







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
- Iarge 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 Thomas Jefferson Mational Accelerator Facility





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

avg number of photoelectron



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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).

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Conceptual design by Gary Swift, Duke U.



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- 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

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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



Stress max = 30.5 ksi



Deflection max = 0.62"



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 "selfhold" 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

JSA

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.

University



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



Magnetic shielding



Join 4 sides by welding and annealing

Use layers of low carbon steel and mumetal

Prototyping starts this summer Drew Smith and Chao Gu



Simulation with COSMOL

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



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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



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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

Klaus Dehmelt and Tom Hammick @ SBU

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
100 Acton Optics & Coatings: #1200 Broadband Al+MgF, @ 15 Degrees



