Overview of SOLID Technical Updates

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Hall A/C collaboration meeting

Outlines

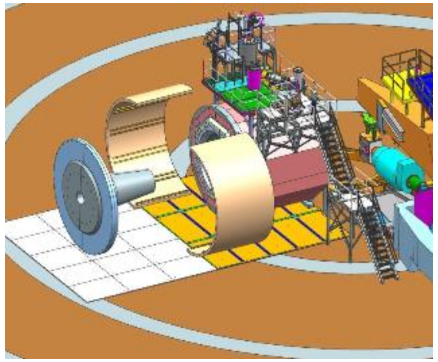
- Project Development
- Overview of the Status of All Systems
- The Path Forward for SoLID

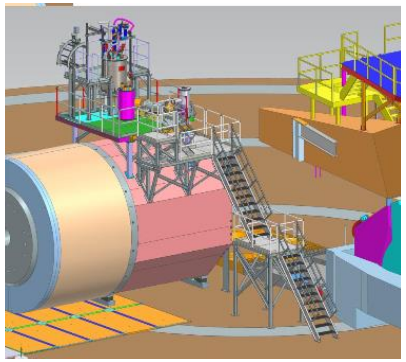
Project Development

- **2014:** pre-CDR submitted
- **Recommended twice in the Long Range Plan as a MIE project:** 2015, 2023 (recommendation #4)
- **Three rounds of Director's Reviews:** 2015, 2019, 2021
    - Submitted to DOE as MIE project in 2019
    - DOE Science Review in 2021: positive results
    - SoLID costs remain the same over the years other than the inflation
- **2024 Facility Review: ready to launch**
- **Pre-R&D activities since 2018 (funded by DOE and Jlab):**
    - R&D conducted on all detector systems
    - Two beam tests focused on the Cherenkov detector readout (2018, 2020)
    - Two beam tests with full set of prototype detectors under high rate (2022, 2026)

Solenoidal magnet

- The CLEO II magnet: 1.5 T central field, 2.9 m inner diameter, 3.5 m length
- All parts were moved to the test lab in 2019
- Phase I is complete
  - New Instrumentation and Control System complete and commissioned
  - New Cryo Control Reservoir complete and commissioned
  - Static tests complete
  - Low current (120 A) cold test complete in 2023
- Modifications of the downstream coil collar and return yoke are required for PVDIS to reach 35 deg. A new endcap that houses the forward detectors will be built





Targets

SIDIS:

- 40 cm Polarized He-3 target (used in A1n, GEn, similar requirements, 60% polarization)
- 3 cm Transversely polarized proton (NH3) target (a new magnet is purchased and tested, 70% polarization)

J/Psi:

- 15 cm Standard cryogenic liquid hydrogen target

In front of the magnet

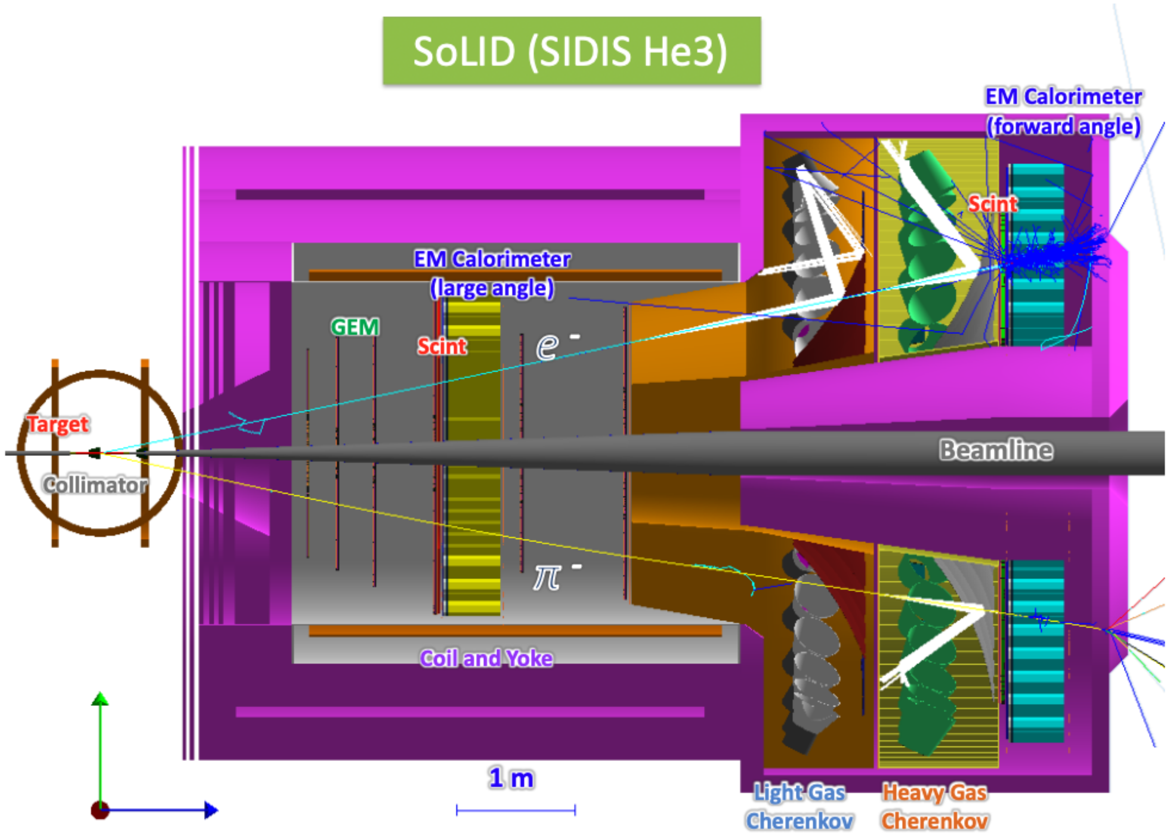
PVDIS:

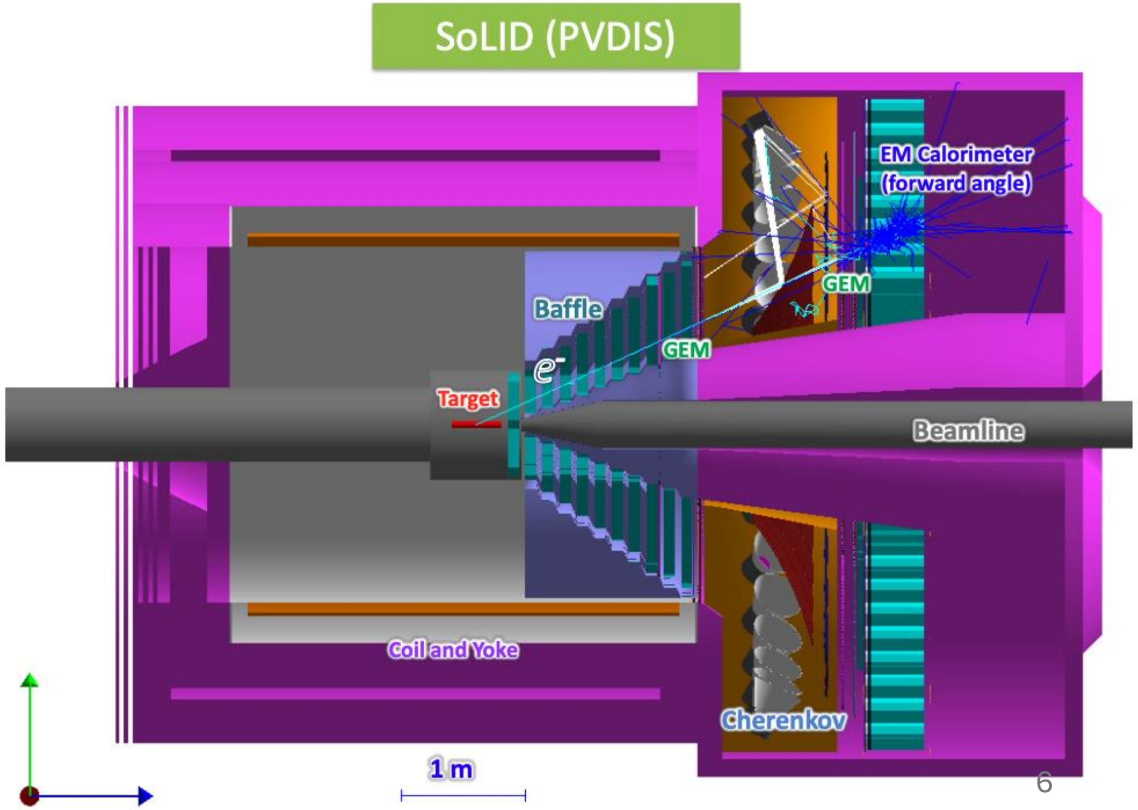
- 40 cm cryogenic liquid hydrogen/deuterium cell (less power than; MOLLER has 1.2 m LH2 target)

Inside the magnet

Detector Systems

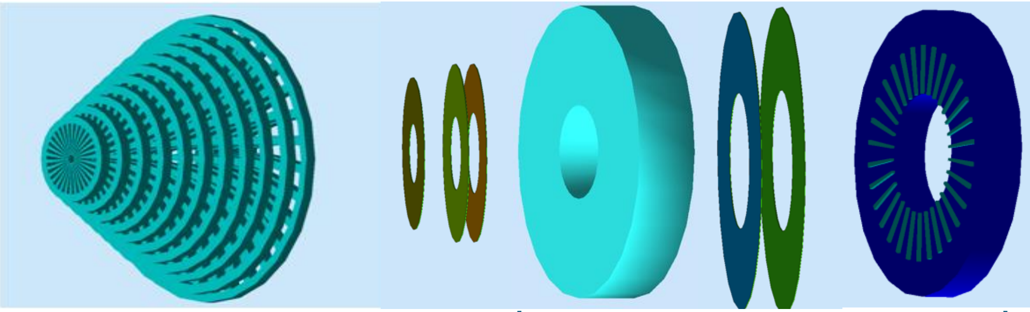
- Two main configurations: **SIDIS** (SIDIS He3, SIDIS NH3, J/Psi), **PVDIS**
- Polar angular coverage: SIDIS: 8 – 24 deg; PVDIS: 22-35 deg
- Momentum coverage: 0.6 – 7 GeV/c (~ 2% resolution)
- High luminosity 10^36 ~ 10^39 $cm^{-2}s^{-1}$
- High rate and high radiation tolerance, large cover area and costs are key factors in the detector design





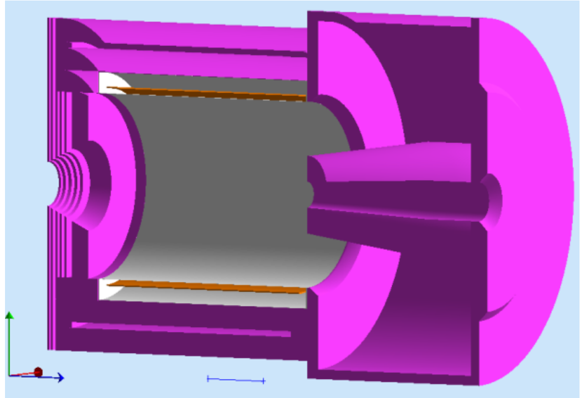
Detector Systems

PVDIS: Baffle 3xGEMS LGC 2xGEMs EC



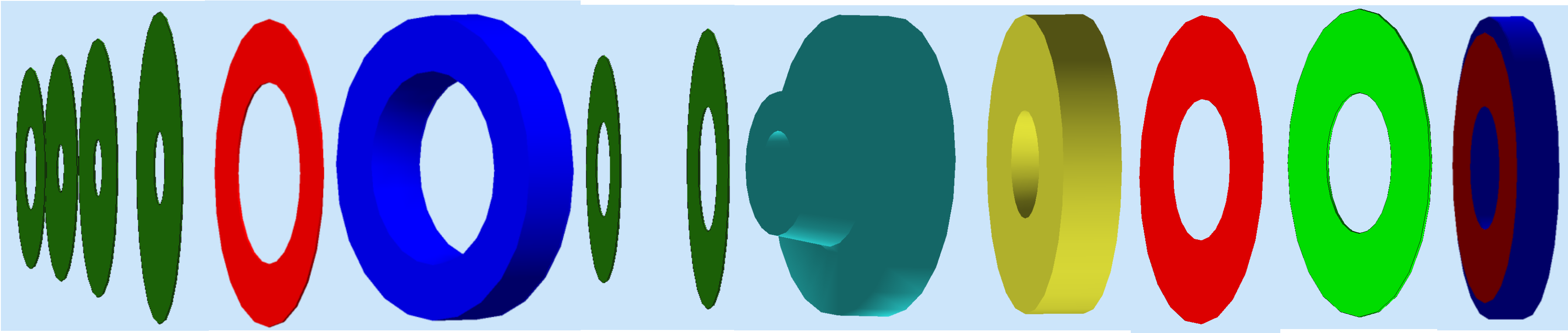
Inside Solenoid magnet EndCap

Uses full capability of JLab electronics



SIDIS&J/ψ:

4xGEMs LASPD LAEC 2xGEMs LGC HGC FASPD (MRPC) FAEC

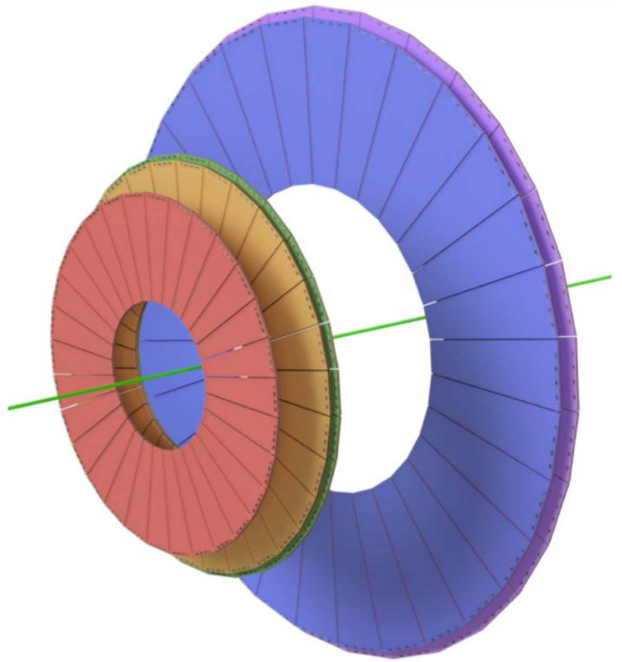


Inside Solenoid magnet EndCap

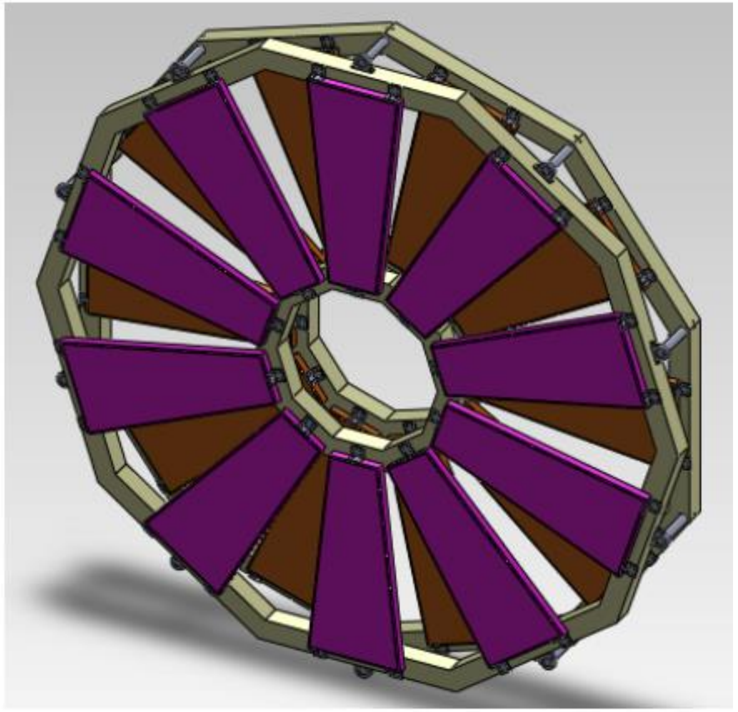
Pre-R&D items: LGC, HGC, ECAL, GEMs, DAQ, Magnet, MRPC

GEMs

- **PVDIS (5 GEM planes):** Baffles prevent the GEM sector joints from impacting acceptance; therefore, one GEM wheel per location is sufficient.
- **SIDIS (6 GEM planes):** Two overlapping GEM wheels are required at each location to provide full azimuthal coverage.



PVDIS: GEM planes at five locations



SIDIS: one GEM location

GEMs

- The trapezoid shape and active area are smaller than EIC GEM; UVA has been building prototypes for EIC R&D
- The highest hit rate is few hundred kHz/cm2, similar to the SBS-GEpV
- Valuable experience gained from SBS-GEpV for GEM performance under high luminosity:
  - GEM detector: GEM handles high occupancy (40%) well
    - High rates cause gain variations → UVa is investigating parallel power supplies and active dividers to maintain stable gain.
    - The biggest background is low energy photon converting to electrons → UVA is investigating on optimizing foils and detector structures to reduce the background.
  - Track reconstruction software:
    - High occupancy imposes huge challenge in track reconstruction
    - The MIP-like particle has smaller signal than the low energy electron
  - Readout electronics and DAQ:
    - At high rate, APV25 baseline drops causing signals out of reading range → shorten the strips would reduce the occupancy, hence increase the rate capability
    - APV-MPD readout limit trigger rate at 5 kHz due to MPD data bandwidth with 1.25 Gbps; → reduce number of APVs per MPD would help to increase the trigger rate and use a newly developed MPD with 10 Gbps link
    - APV requires trigger (not easy to convert to streaming readout)
    - APV is no longer in production

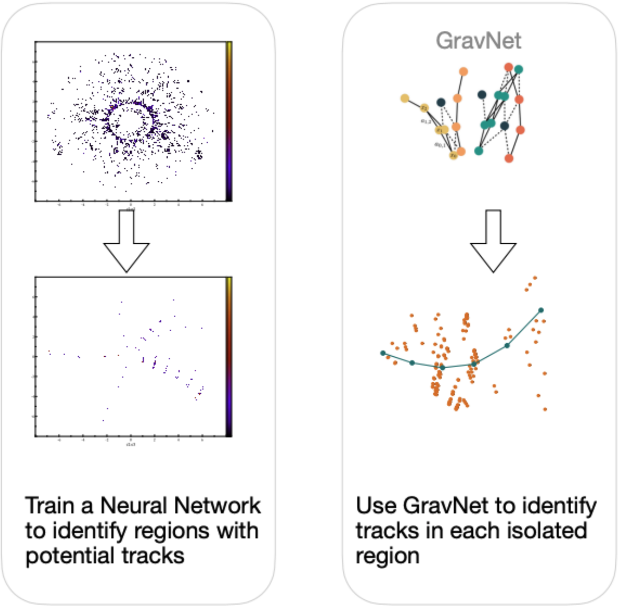
GEMs

Readout electronics:

- Instead of APV25, SoLID will use improved VMM3 as the front-end ASIC
  - Many buffers; radiation hard; Digital output; Excellent for high rates; trigger or continuous mode
- Prototype boards have been built and tested. One engineer in the FEDAQ group is working on this development.
- Potential new ASIC for high-luminosity experiments: a Genesis Mission proposal has been submitted.

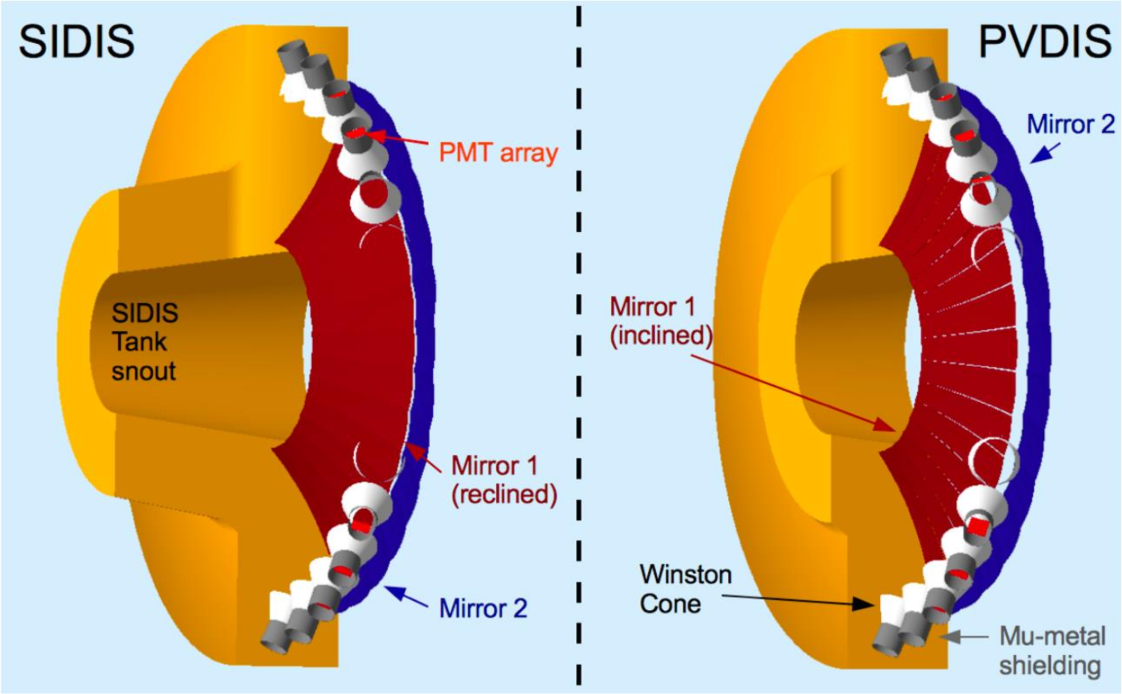
AI Tracking reconstruction:

- Use Graph Neutral Network on tracking finding and fitting
- Work with the data scientists from the Data Science Group;
- A Genesis Mission proposal has been submitted: develop AI track finding and fitting algorithm for both SBS GEPV and SoLID.

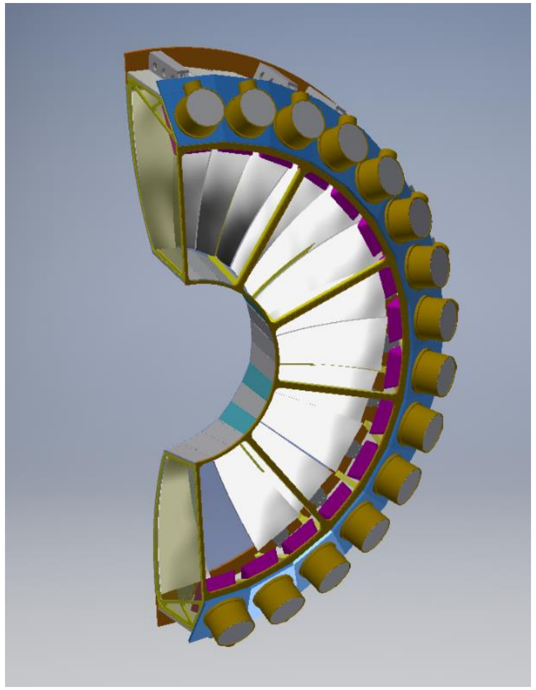


Light/Heavy Gas Cherenkov

- LGC and HGC have similar structures and readouts
- LGC are used in both PVDIS and SIDIS; HGC is used only in SIDIS
- For LGC, to accommodate different scattering angles,
  - SIDIS tank has an extra “snout” to increase the material length by 1m
  - Mirror 1 will be slightly inclined in PVDIS;



Light Gas Cherenkov



Half Heavy Gas Cherenkov

Light/Heavy Gas Cherenkov

Pre R&D actives:

- Mirror fabrications, reflections, mechanical mounting etc.
- Photosensor and readout: two beam tests (2018, 2020) to study two types of photosensors performance under high background rate
    - Baseline design: 64-pixel photosensors, arranged as 3×3 or 4×4 modules per sector.
    - **Hamamatsu H12700 MaPMTs** Good performance demonstrated. Require magnetic shielding.
    - **Pixelated LAPPDs** Better magnetic-field tolerance. Comparable Cherenkov detection performance demonstrated in 2020 beam test.
- In the beam tests, the Npe yield remains only half of the simulated value. Further investigation is ongoing (could be mirror degrade)
- Canada CFI funds got approved for the HGC manufacturing, agreement with Jlab waiting for DOE approval

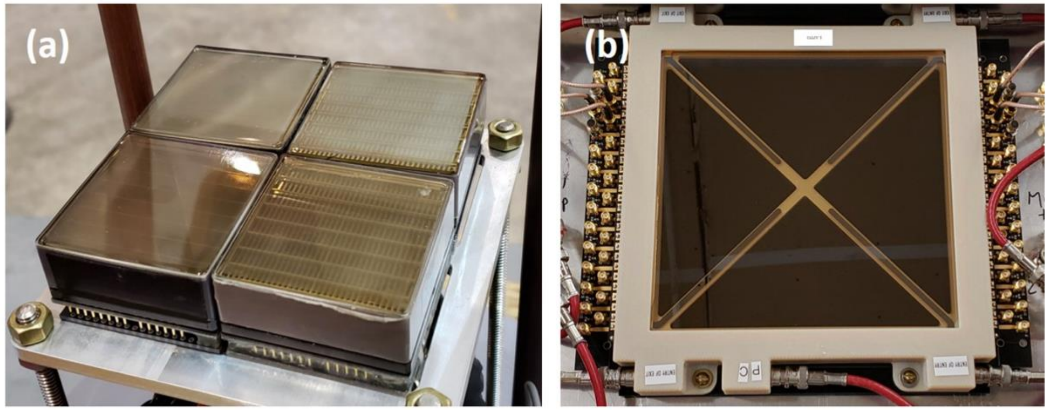
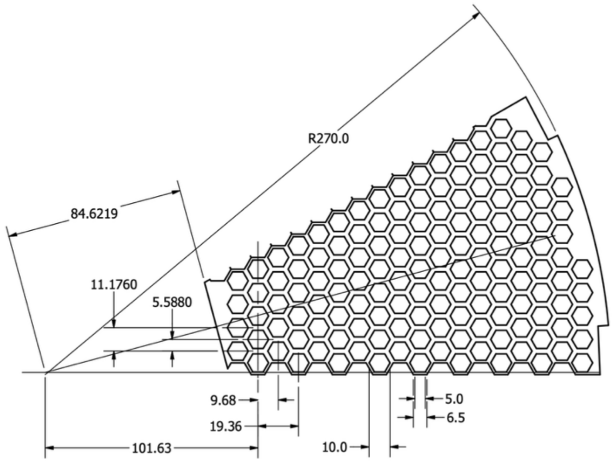
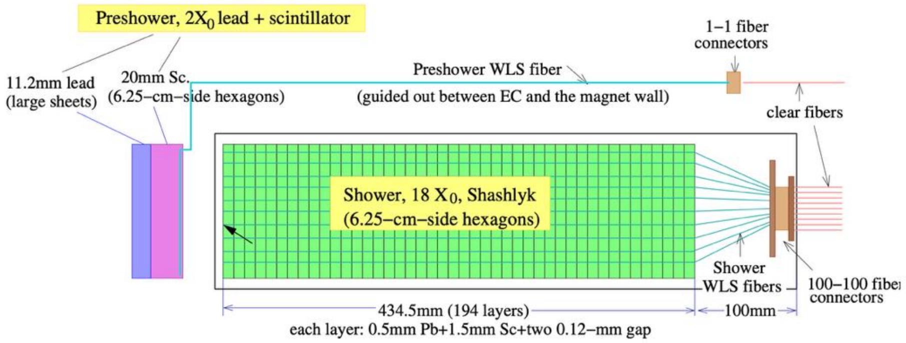


Figure 2. (a) 10×10 cm^2 p-terphenyl coated MaPMT array, and (b) 20×20 cm^2 LAPPD.

ECAL and LASPD

- PVDIS uses all modules in the forward angle (FAEC)
- SIDIS divides into forward angle (FAEC) and large angle (LAEC)

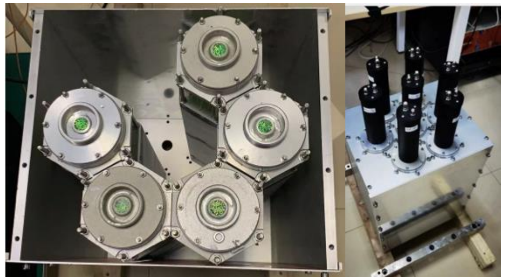




shashlyk design embedded with WLS fibers

Hexagon shape

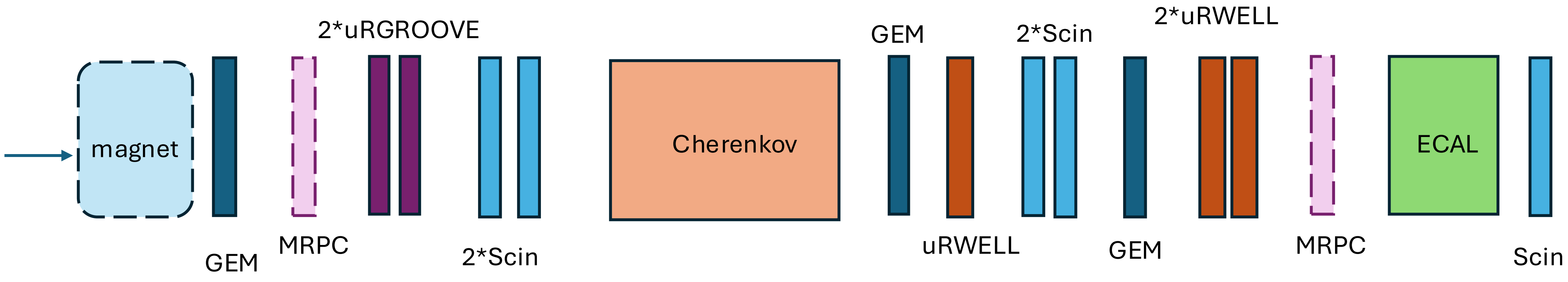
Seven modules →



Super module

- The ECAL module design and fabrication is finalized
- Good PID performance is demonstrated for ECAL and LASPD in the 2022 beam test
- Demonstrate ML PID on 2022 beam test data
- 2022 beam test shows PMT gain shift at high rate → PMT base design needs optimization
- Other to do:
  - MaPMT readout of Preshower testing
  - MCP-PMT readout of LASPD

2026 Beam Test



- Will have magnet to reduce the neutral background
- Key goal: assess the performance of tracking with GEMs, uRwell, uRGROOVE in high rate conditions;
- Detector installation at large angle is complete
- Next: trigger+detector commissioning, magnet installation
- Planning to take data at low angle (15 degrees) in August

SOLID Moving forward

- Current funding situation is complicated
  - DOE CD-0 approval is unlikely in the near term
- MOLLER CD Project is nearing completion
  - Experiment is expected to complete running before 2031
- SoLID aims to be installed in 2031
  - Detector construction and integration activities should begin soon
- Collaboration plans to pursue staged construction approach
  - Initially build the components required for one experiment
  - Funded primarily by Jefferson Lab; Will limit the cost to what Jlab can support
  - Progressively expand and enhance the detector
  - Iteratively secure additional funding opportunities

SOLID Moving forward

Experiments	PVDIS	SIDIS-^{3}He	SIDIS-Proton	J/ψ
Target Length	LH_2/LD_2 40 cm	^{3}He 40 cm	NH_3 3 cm	LH_2 15 cm
Target Polarization Target Spin Flip	N/A N/A	$\sim$60% $\leq$20 mins	$\sim$70% $\leq$4 hours	N/A N/A
GEM Tracking Chambers	5 chambers	6 chambers	6 chambers	6 chambers
SPD	N/A	Forward+Large angle	Forward+Large angle	Forward+Large angle
E&M Calorimeter	Forward angle	Forward + Large angle	Forward + Large angle	Forward + Large angle
Light Gas Cherenkov	1 m long	2 m long	2 m long	2 m long
Baffles	Yes	N/A	N/A	N/A
Heavy Gas Cherenkov	N/A	1 m long	1 m long	N/A
Beam Polarimetry	0.4% determination	$<$ 3%	$<$3%	N/A
Target Polarimetry	N/A	$\sim$ 3%	$\sim$ 3%	N/A
DAQ	Single trigger	Coincidence trigger	Coincidence trigger	Coincidence trigger

First experiment

- Need to reduce the cost to what Jlab can support
- The expected results would still be significantly better than existing and planned measurements.

Summary

- SoLID is ready to launch
- We welcome the community to join the SoLID effort. It could be the new standard equipment in Hall A

Table 6: Summary of Key Parameters for Approved Programs

Experiments	PVDIS	SIDIS-^{3}He	SIDIS-Proton	J/ψ
Reaction channel	$p(\vec{e},e')X$	$(e,e'\pi^{\pm})$	$(e,e'\pi^{\pm})$	$e+p\rightarrow e'+J/\Psi(e^-,e^+)+p$
Approved number of days	169	125	120	60
Target	LH_2/LD_2	^{3}He	NH_3	LH_2
Unpolarized luminosity ($cm^{-2}s^{-1}$)	$0.5\times10^{39}/1.3\times10^{39}$	$\sim 10^{37}$	$\sim 10^{36}$	$\sim 10^{37}$
Momentum coverage (GeV/c)	2.3-5.0	1.0-7.0	1.0-7.0	0.6-7.0
Momentum resolution	$\sim$2%	$\sim$2%	$\sim$3%	$\sim$2%
Polar angular coverage (degrees)	22-35	8-24	8-24	8-24
Polar angular resolution	1 mr	2 mr	3 mr	2 mr
Azimuthal angular resolution	-	6 mr	6 mr	6 mr
PID (e^-)	detection eff. $\geq$ 90% pion contam. $<$ 0.001	detection eff. $\geq$ 90% pion contam. $<$ 1%	detection eff. $\geq$ 90% pion contam. $<$ 1%	detection eff. $\geq$ 90% pion contam. $<$ 1%
PID ($\pi^{\pm}$)		detection eff. $\geq$ 90% kaon contam. $<$ 1%	detection eff. $\geq$ 90% kaon contam. $<$ 1%	
Trigger type	Single e^-	Coincidence $e^- + \pi^{\pm}$	Coincidence $e^- + \pi^{\pm}$	Triple coincidence $e^-e^-e^+$
Expected DAQ rates	<20 kHz $\times$ 30	<100 kHz	<100 kHz	<30 kHz
Backgrounds	Negative pions, photons	(e,$\pi^-\pi^{\pm}$) (e,e'$K^{\pm}$)	(e,$\pi^-\pi^{\pm}$) (e,e'$K^{\pm}$)	BH process Random coincidence
Major requirements	Radiation hardness 0.4% Polarimetry π^- contamination Q^2 calibration	Radiation hardness Detector resolution Kaon contamination DAQ	Shielding of *sheet-of-flame* Target spin flip Kaon contamination	Radiation hardness Detector resolution