LGC UPDATE

+ pre-R&D prototype update

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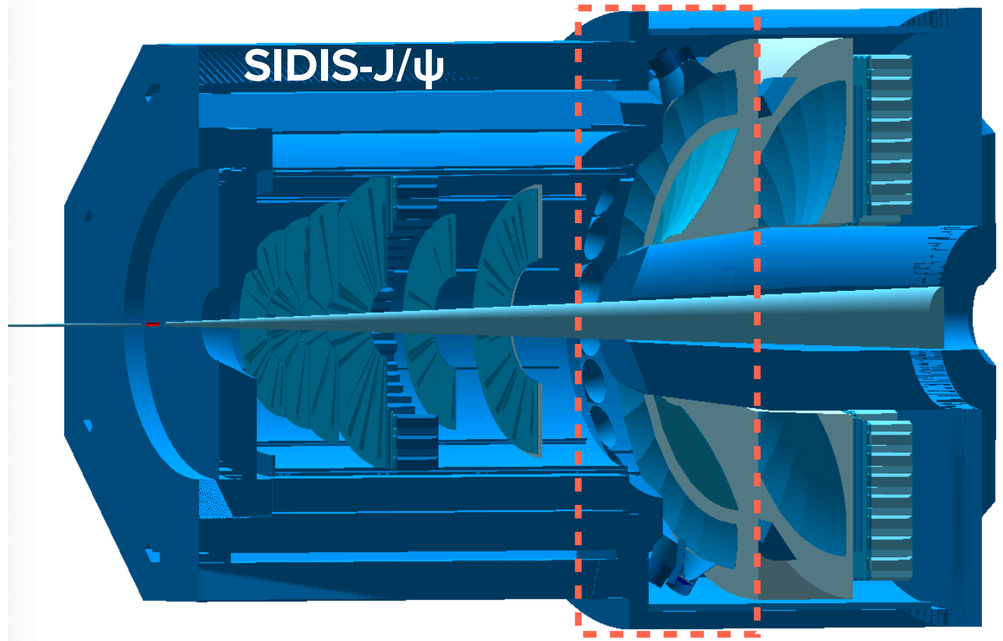
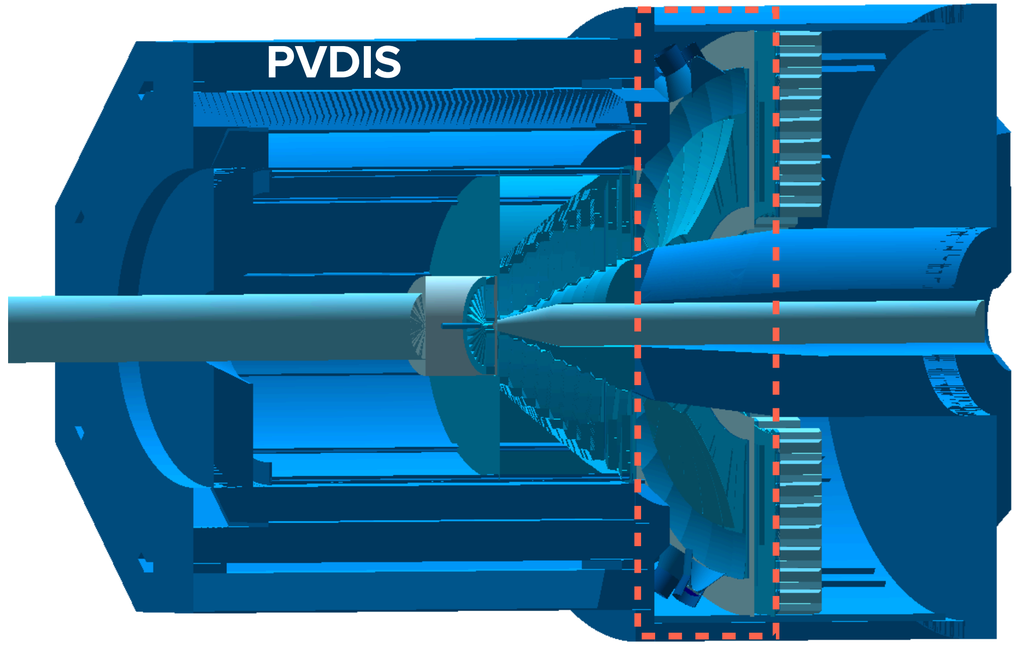
June 10th 2021

On behalf of ANL, NMSU, and Temple U

Simulation Update

- Simulation is in mostly stable state in GEMC.
  - Some optimization remains between newer mirror/PMT positions, and cone orientation and size.
  - Timing digitization will eventually need to be made more realistic: FADC channel conversion
  - Depending on path for future simulation, it may be better to wait rather than waste time converting from GEMC digitization to whatever is the future sim program.





Overview of general LGC responsibilities

- Three primary groups make up the LGC collaboration:
  - ANL will be involved in project management and general tank construction.
  - NMSU will concentrate on mirror design, development, and fabrication.
  - Temple U will concentrate on WLS coating of photosensors and electronics testing.

- Synergistic activities exist between the HGC group and LGC group:
  - Prototyping has already been a successful joint effort.
  - Electronics/photosensor design and testing, and mirror design and testing is shared between groups: expectation that final designs for electronics and mirrors will be very similar / shared between groups.

Some thoughts on mirror fabrication

- Design choice remains to use reflective coated lexan film for all mirrors/cones.
  - Eliminates the need for polished blanks ($$$).
    - Direct purchasing from ECI is current plan, but in-house coating (SBU) of Lexan is a possibility.
  - Lexan is fairly resistant to radiation etching, but a quantitative study of expected radiation exposure versus reflectivity is needed.
  - Injector molded CFRP purchased from an external vendor is the primary choice for "blanks".
    - Viability of 3D printed continuous carbon-fiber reinforced polymer to build mirrors will also be explored:
      - Benefits include more quality control, less expensive iteration on prototyping and design, and likely a more optimized design with respect to radiation length and cost.
  - "Gluing" of reflective film to selected blanks is non-trivial and will require prototyping and quality control in a clean room environment: Some experience exists with the refurbishing of the Hall-B LTCC mirrors.
- A fall-back plan of using flat mirror arrays still exists: would impact engineering complexity and total radiation length.

- Mirror quality control testing will be important: Will require measurements of
  - "spot size" of spherical mirrors
  - Total reflectivity down to UV

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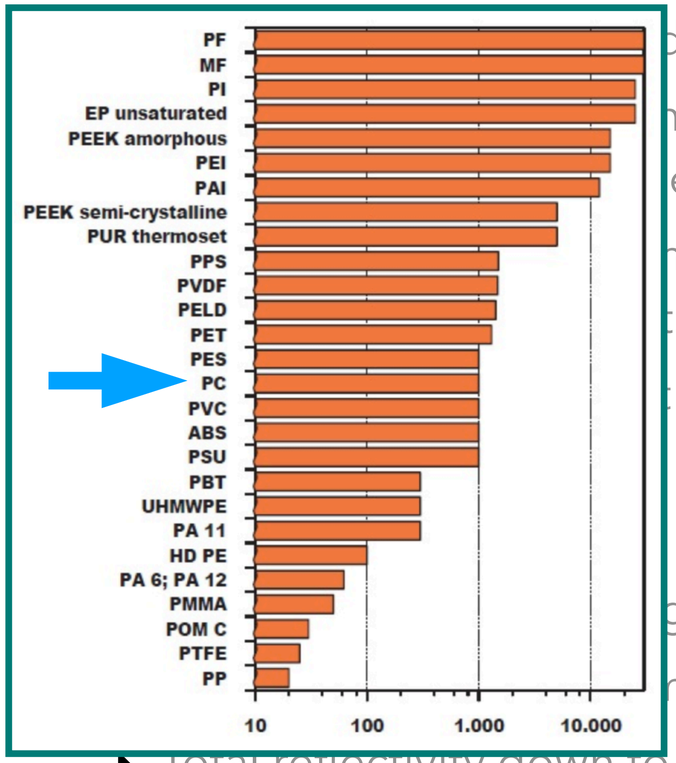

Modifications in polymeric properties due to different doses of gamma irradiation ranging from 10^1 Gy to 10^6 Gy: An account

Advances in Applied Science Research, 2013, 4(6):225-236

Table 2. Bulk etch rate (V_G) in µm/h for gamma-irradiated Polycarbonate detectors

Detector	Etching Temperature	No Dose	10^3 Gy		10^6 Gy	
			Pre	post	Pre	post
Makrofol-E	60^0C	0.73 ± .06	0.72 ± .06	0.78 ± .06	0.90 ± .06	1.03 ± .06
Lexan	60^0C	0.64 ± .03	0.59 ± .03	0.64 ± .03	0.73 ± .03	0.85 ± .03
Polycarbonate (transparent)	60^0C	0.62 ± .03	0.62 ± .03	0.63 ± .03	0.74 ± .03	0.73 ± .03
Polycarbonate (semitransparent)	60^0C	0.67 ± .03	0.66 ± .03	0.67 ± .03	0.84 ± .03	0.89 ± .03

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Stock photo of CCF printed device using MarkForged 3D printer

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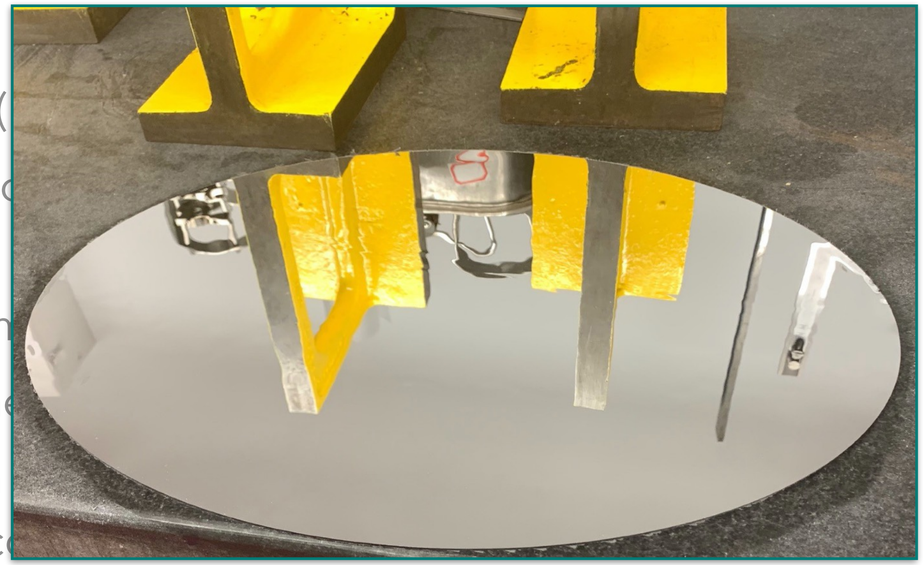

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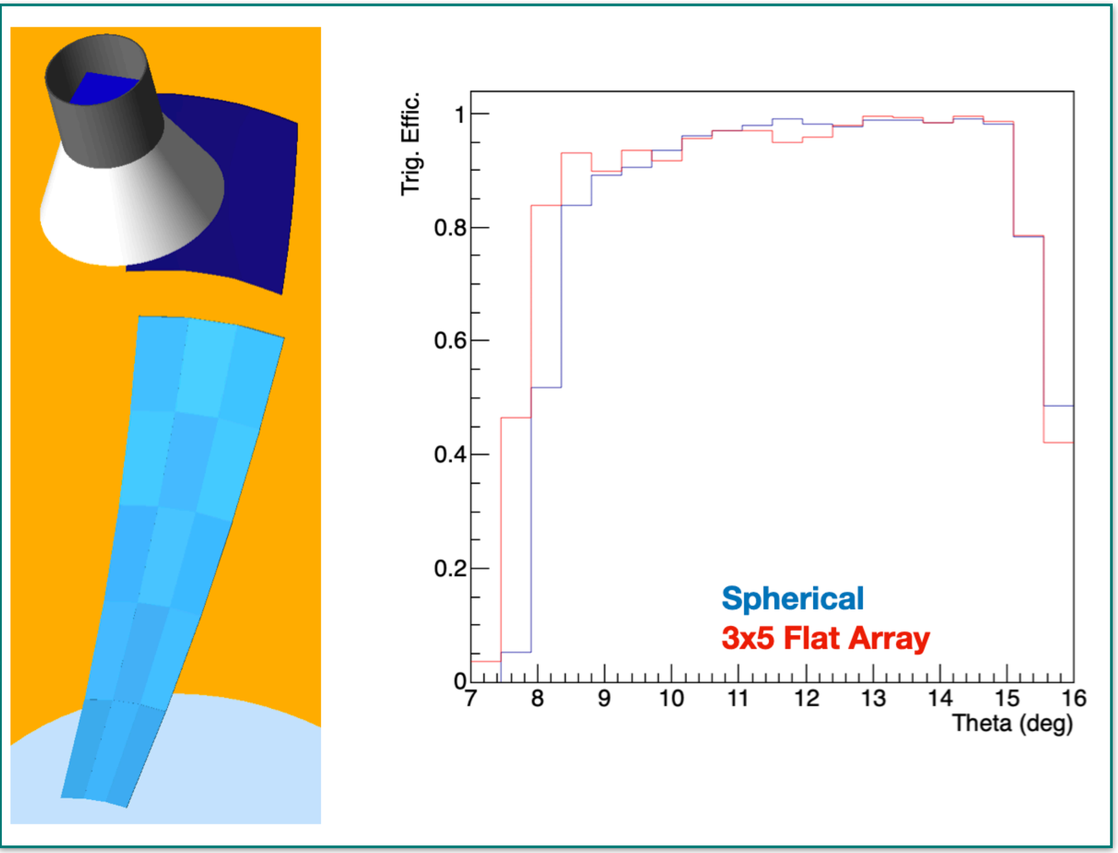

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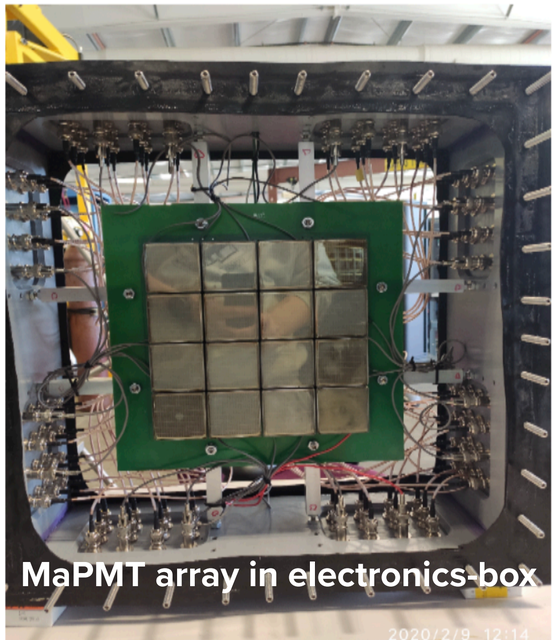
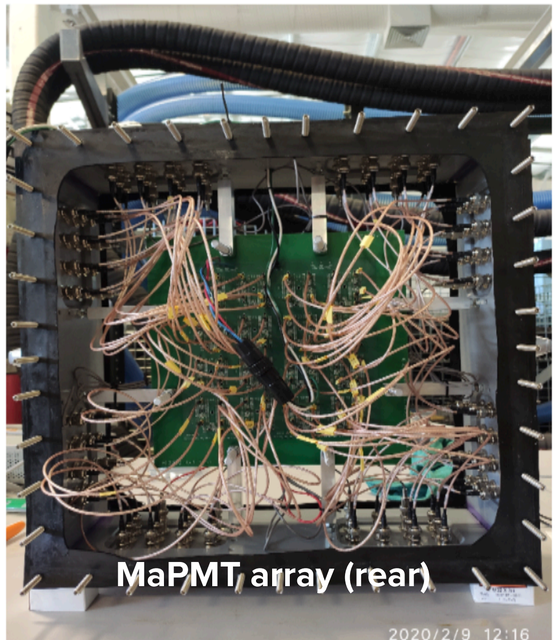
Some thoughts on tank construction

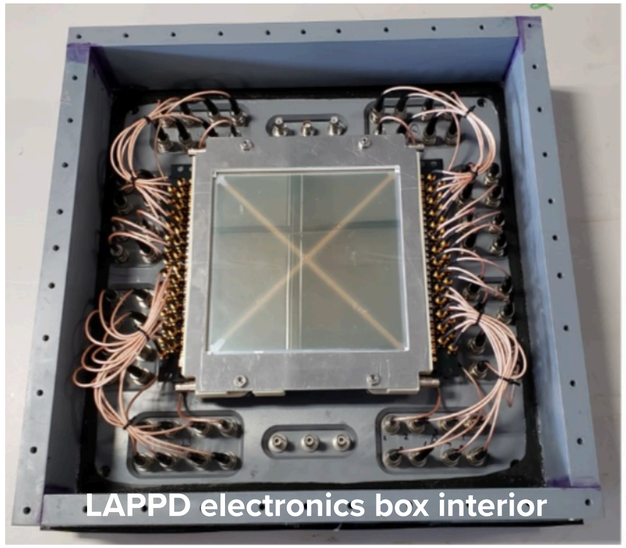
- Tank design will need some access to all photosensor arrays:
  - Non-trivial for arrays down near the floor.
  - Electronics and cabling space needs to be considered carefully
- Rotatable mirror systems will need a clever design to minimize material and precisely adjust rotation angle.
- A partial sector prototype (or something similar) will be needed to test/iterate design specifications.
- A good initial tank design exists (done at Temple) , but a next step design is currently underway at ANL.

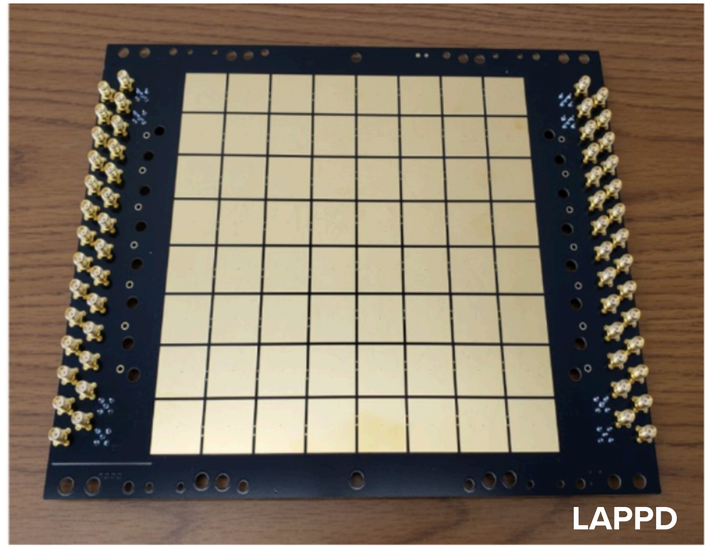
Some thoughts on photo-sensors / electronics

- Good progress was made on testing high rate analysis of MaPMT arrays and an LAPPD.
  - A simple summing board solution for the MaPMT array looks viable for SoLID production running.
    - A quadrant based division of each MaPMT will make a cleaner trigger. (See talk by Chao).
  - The LAPPD also looks promising as a possible alternative. An McpPMT could achieve similar effectiveness.
  - Additional background separation provided by pixel analysis could not be run parasitically (time constraints). Additional tests are currently being run on the bench. (See talk by Bishnu).


MaPMT array in electronics box


MaPMT array (rear)


LAPPD electronics box interior

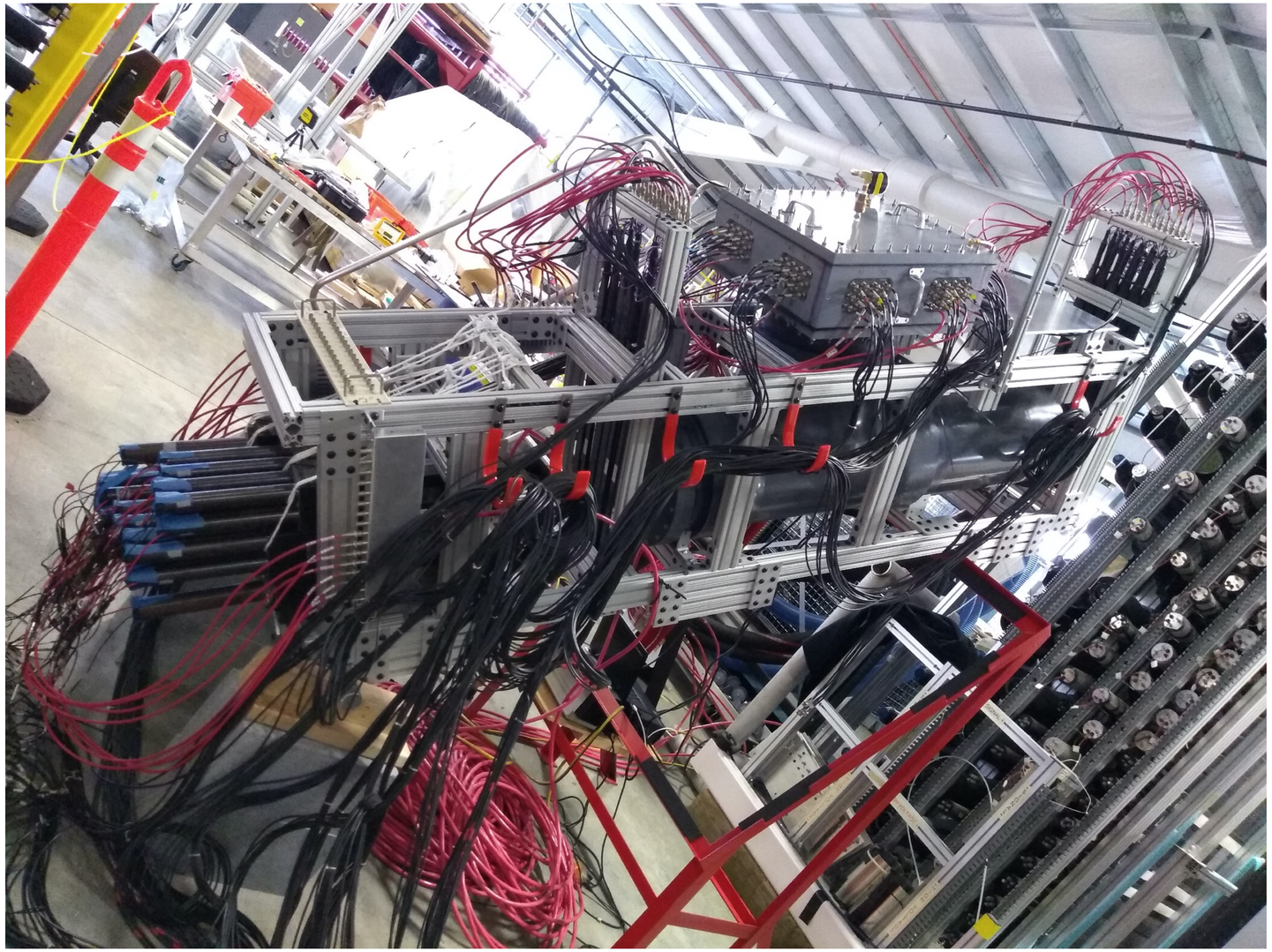

LAPPD

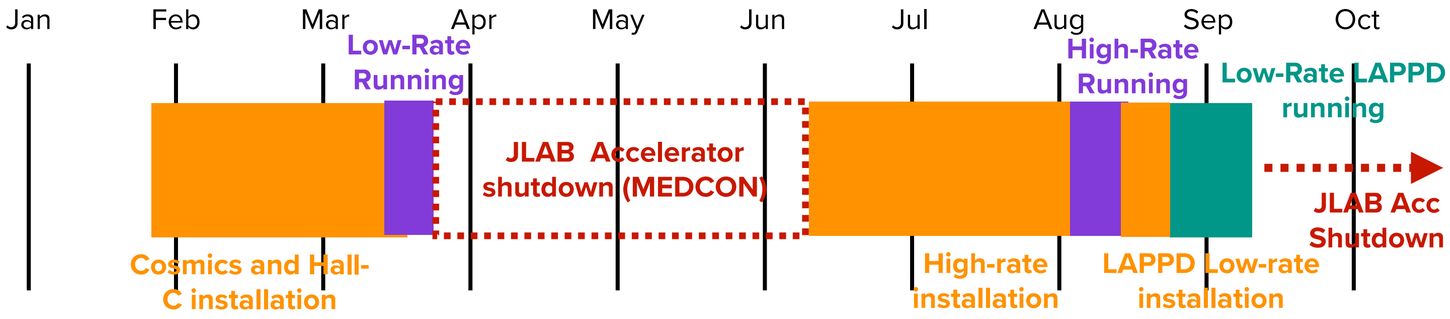
Summary of "R&D" needed along the way to final product

- Mirrors:
  - External fabrication of blanks to test final specs and rigidity over time.
  - Alternative blank 3D printer fabrication design, prototyping, and iteration.
  - Adhesion testing to minimize deformity of reflective film when attached to blanks.
  - Radiation hardness test of reflective film alone, and reflective film glued to blank material.
  - Lexan reflective coating tests, if we want to try to produce film "in-house"
  - Reflectivity tests of all mirrors (samples) down as far as feasible in wavelength.
- Electronics:
  - Summing board design to iterate from prototype results.
  - Alternative photosensor tests, including WLS tests.
  - If digitization on a per-pixel level is needed -> R&D for SoLID specific MAROC (or comparable) board development.
- Tank:
  - Prototype testing of critical design specifications, including structural integrity with minimized material in acceptance, and mirror mounting and rotation mechanisms.
  - Combined (electronics, mirrors, tank) prototype of 1 "sector" of the LGC.

Pre-R&D prototype cherenkov

- Transported to JLAB ESB in January 2020.
  - Scintillator planes, calorimeter blocks, and DAQ were added and the the entire device was cosmic tested.
- TCD set-up in Hall-C to collect parasitic data during "d2n" experimental running in March.
  - Low-rate data collected for MaPMT "simple" summing board.
- JLAB goes into shutdown end of March, testing postponed
  - TCD set-up for high rate testing.
- JLAB resumes operations in August, available parasitic opportunity is truncated.
  - High rate data collected for MaPMTs
  - Additional low-rate data collected for LAPPDs with CO2 and then C4F8 gas.





Pre-R&D prototype cherenkov goals

- Primary:
  - Understand the exact response of Hamamatsu H12700 MaPMTs, aligned in a square array, under high rate conditions to:
    - Best understand the realistic response of our proposed electronics
    - Determine the most efficient high-rate electron trigger configuration for in SoLID
    - Better match true response to Monte Carlo.
- Secondary:
  - Test alternate technologies:
    - WLS coated LAPPD
    - MAROC summing electronics (pixel+quad+sum readout)
  - Test components of Cherenkov detectors
    - Simple summing board design
    - Mirror fabrication (reflective lexan film + carbon fiber blanks)
    - C4F8 gas response and interaction with electronics under realistic conditions.
    - WLS coated MaPMT response with pixel/quadrant/sum logic.

Progress on prototype Cherenkov milestones

As of quarterly report 4 (Q4)

Milestone	Objectives	Expected Completion Date	Status
1	Construction and delivery of Cherenkov tank to Jefferson Lab.	Early January 2020	Complete (Q1)
2	Cosmic testing and installation into experimental hall.	Mid February 2020	Complete (Q1)
3	Collection and analysis of low and high rate data with electronic summing-board.	End of Year 2020 (+2 Month Contingency)	Collection complete (Q2), Analysis completed (Q4).
4	Collection and analysis of high rate data with MAROC electronics.	End of Year 2020 (+4 Month Contingency) **Extended to end of Summer 2021**	Moved to bench and nearing completion.

Additional analysis of LAPPD to be completed by end of Summer 2021

Summary

- Simulation is in a stable state.
  - Next steps will likely be implemented after newer simulation framework (if needed)
- Division of responsibilities is well defined within LGC group.
  - Many R&D studies will be needed along the way to a final product.
  - All efforts are being made by both LGC and HGC groups to form common solutions where overlaps exist (electronics, mirrors)
- The pre-R&D prototype analysis remains on schedule. See the next two talks for details.