SOLID LGC

Michael Paolone
Temple University

SoLID Collaboration Meeting 08/08/19

GOALS AND CHALLENGES

- Goal: To provide precision electron / pion separation in the kinematic regimes necessary for the SoLID J/Psi, SIDIS, and PVDIS programs.

- Challenges: Provide trigger level input in a 2π high luminosity environment while minimizing complexity and cost.

LGC contributors:

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Junqi Xi [1]

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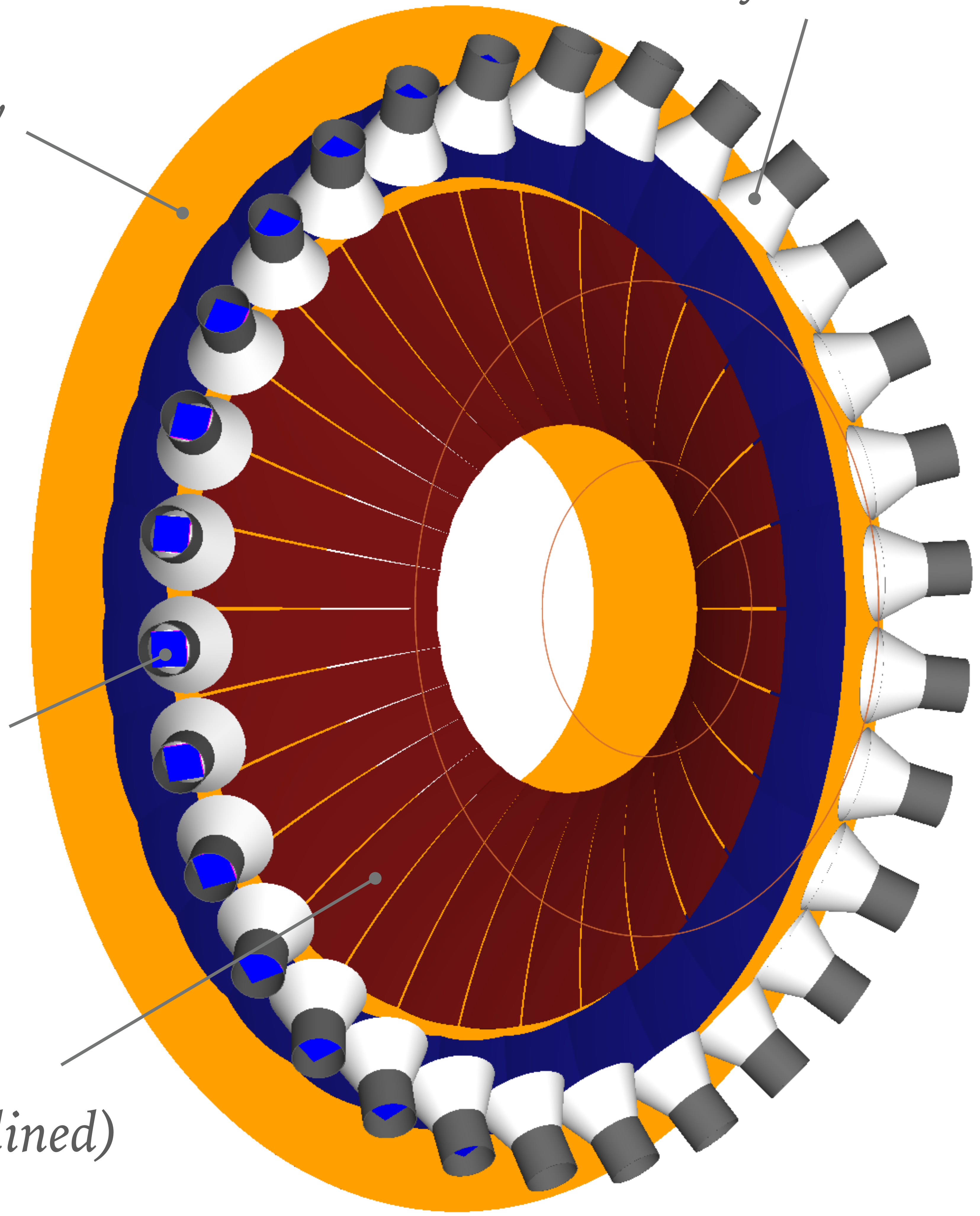
2) *Temple University*

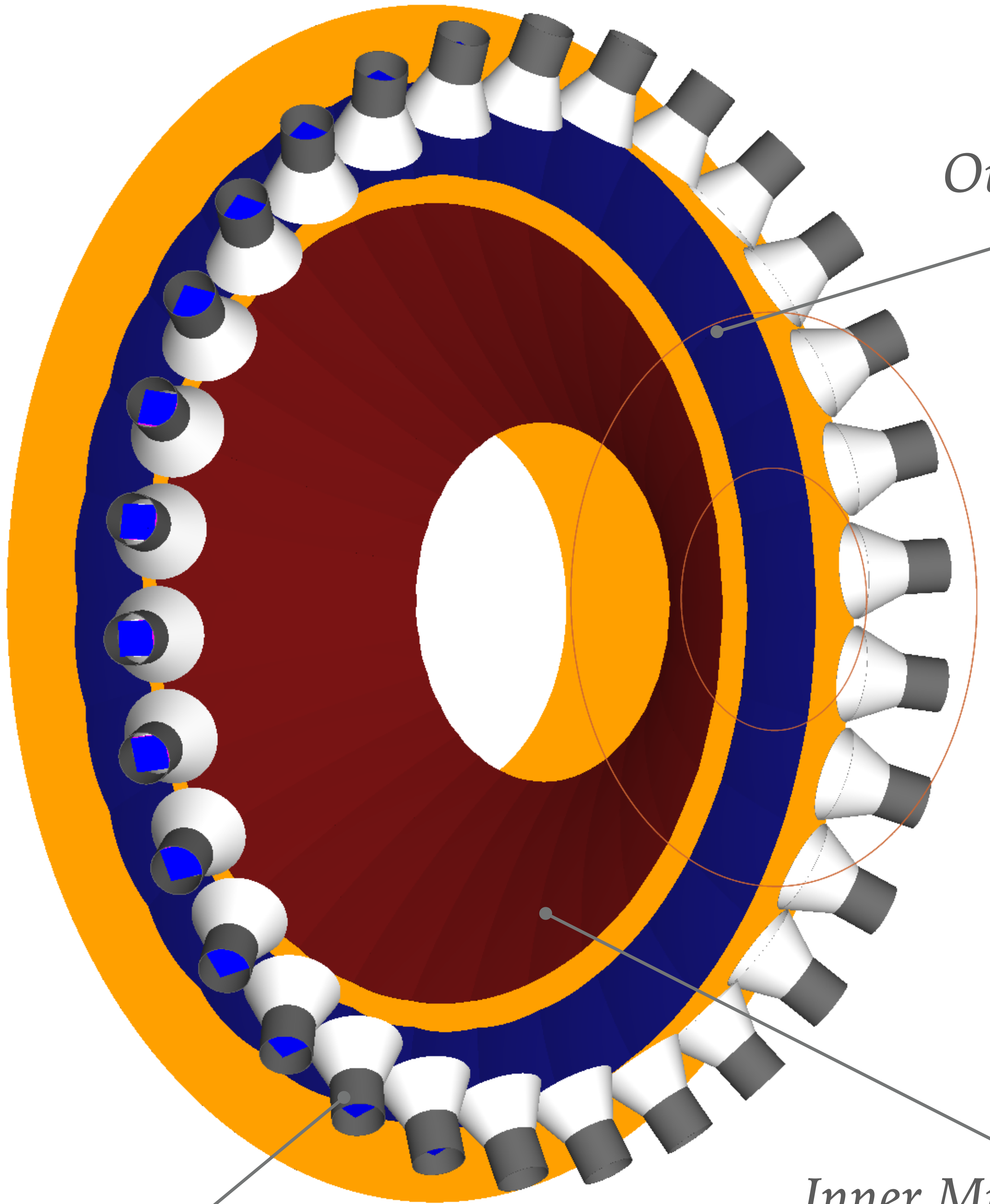
KINEMATICS / GEOMETRICS

	Momentum Acceptance (GeV/c)	Scattering Angle Acceptance (deg)	Target Z-Location (cm)	Special Constraints
J/Psi & SIDIS	1.0 to 7.0	8.0 to 15.0	-350.0	No Baffles
PVDIS	2.0 to 5.0	22.0 to 35.0	10.0	Baffles

- The primary physics configurations of the SoLID detector require quite different optical solutions.
- Creating a detector that can be adjusted to meet both configuration's requirements to maximize common component use has a significant cost advantage.

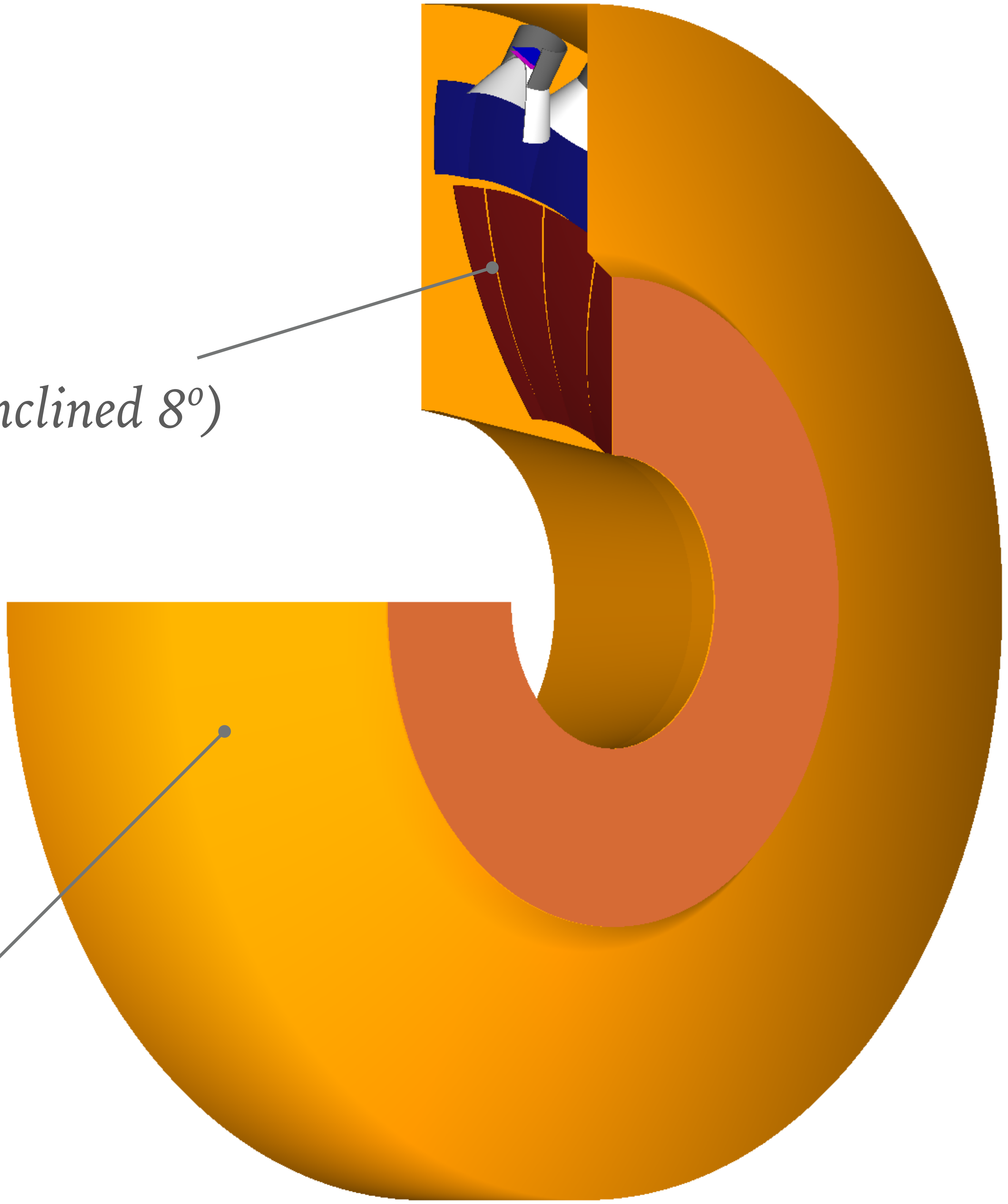
ADJUSTABLE CONFIGURATION



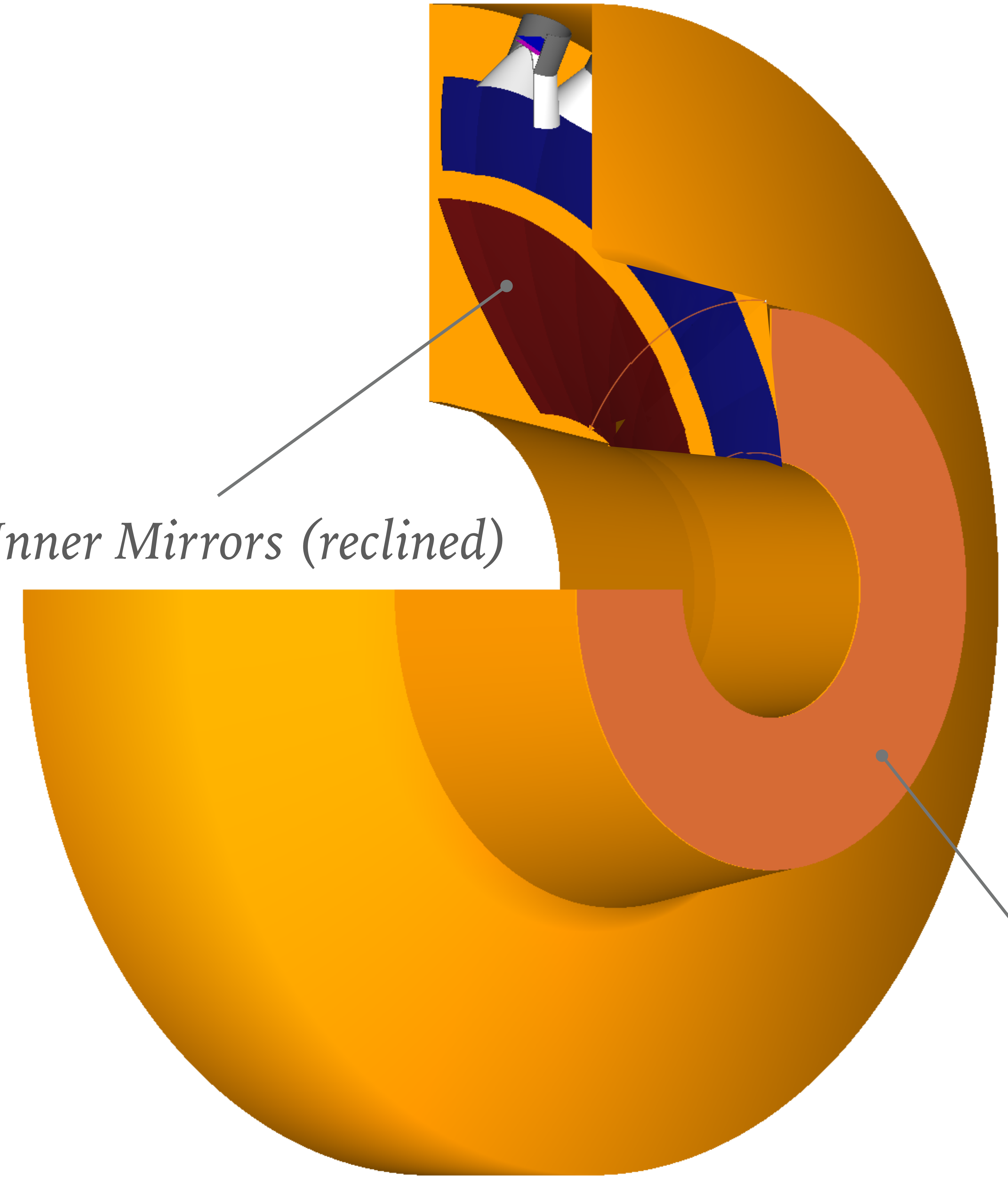


ADJUSTABLE CONFIGURATION

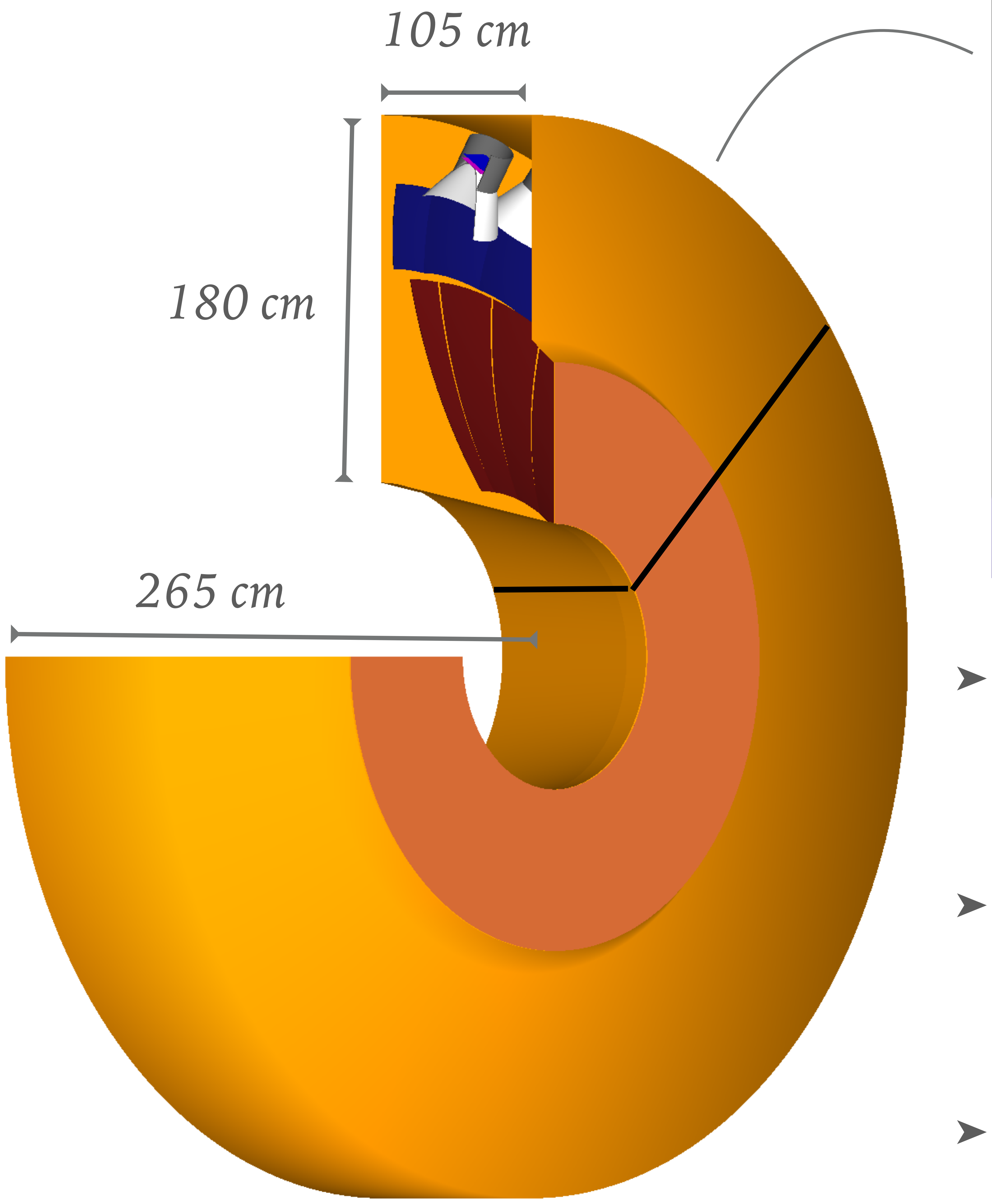
PVDIS

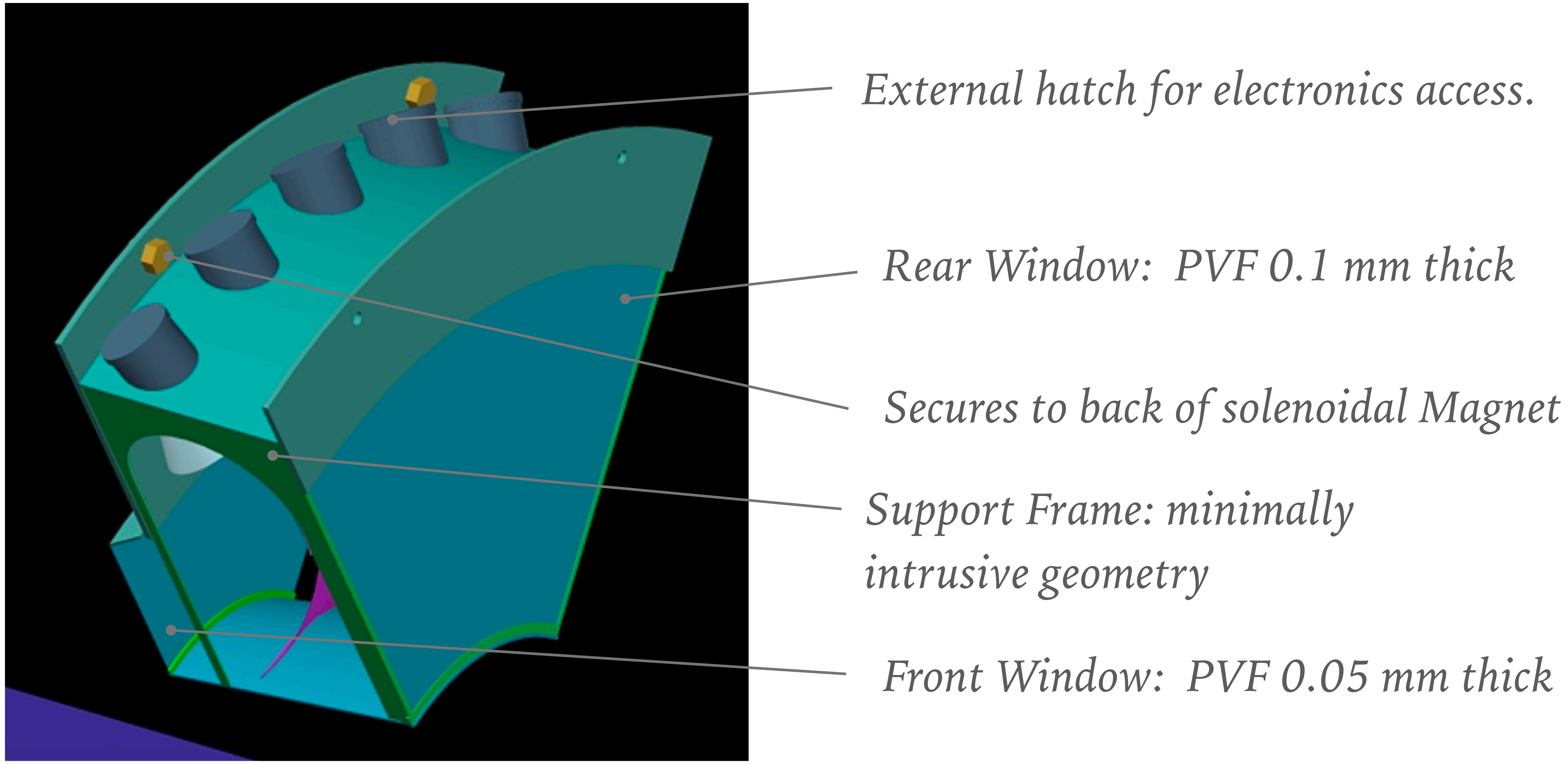


J/Psi & SIDIS



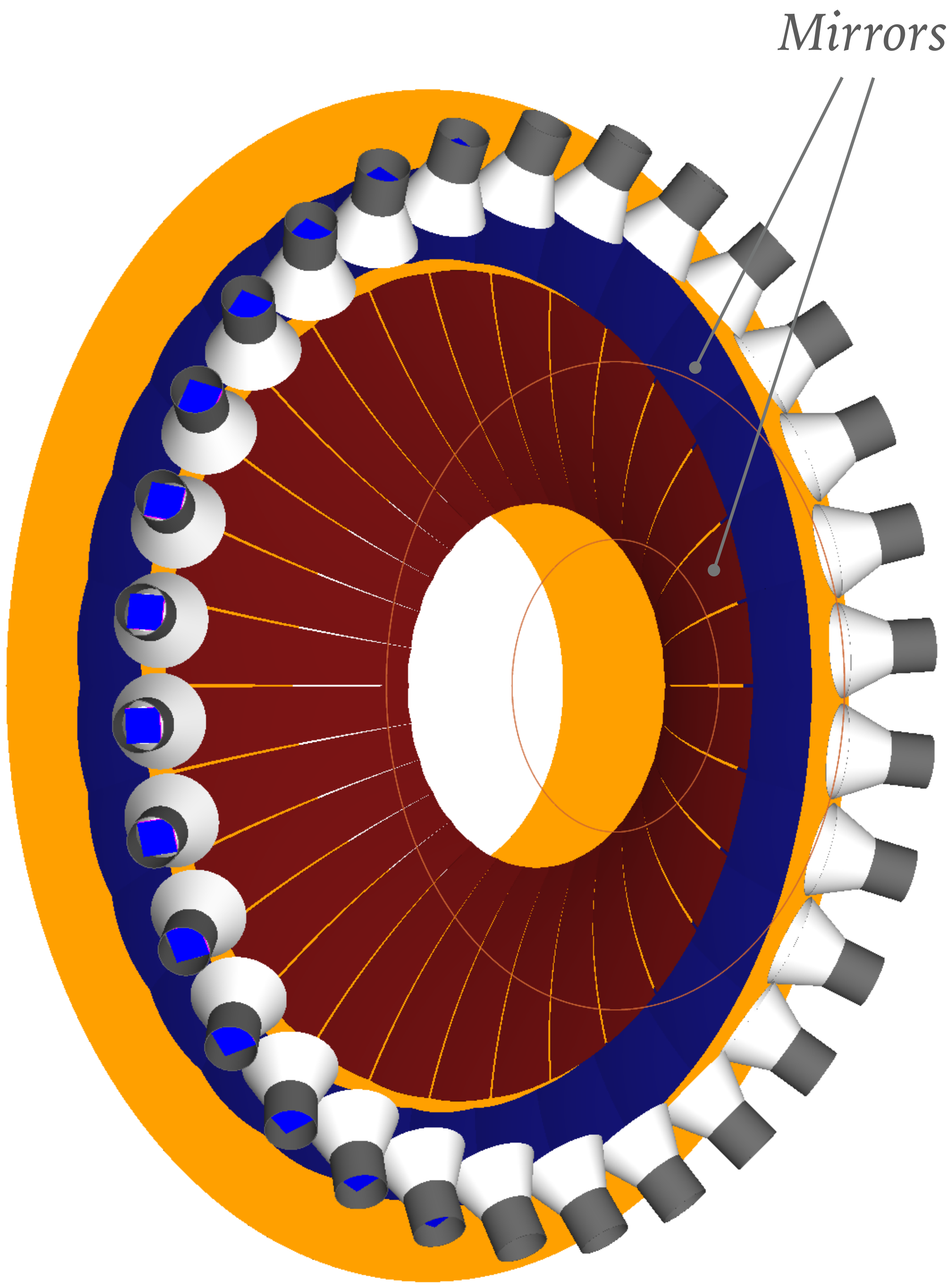
DETECTOR ANATOMY: TANK



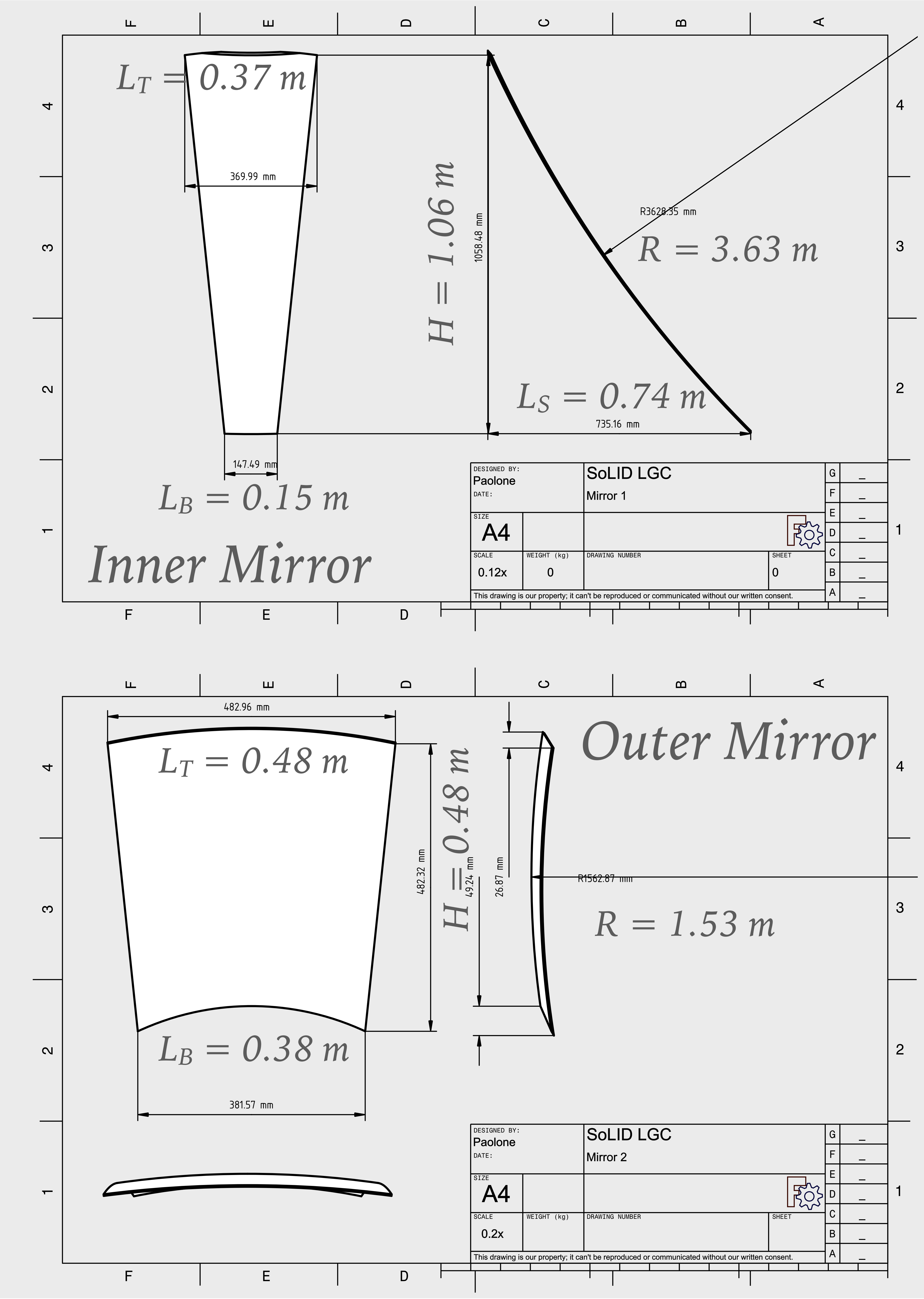


- The tank will be divided into 6 equal sections, each externally supported to the back of the solenoidal magnet housing, and internally supported by a minimally invasive frame. Each section will interlock to create a single gas vessel.
- The tank is designed to use CO^2 or N^2 at slightly over atmospheric pressure to maintain gas purity. "Pump and Dump" style-system, with automated pressure controls.
- Entrance and exit windows will be made from Polyvinyl Fluoride (PVF or Tedlar) which has 1.45 g/mm^3 density (low rad length).

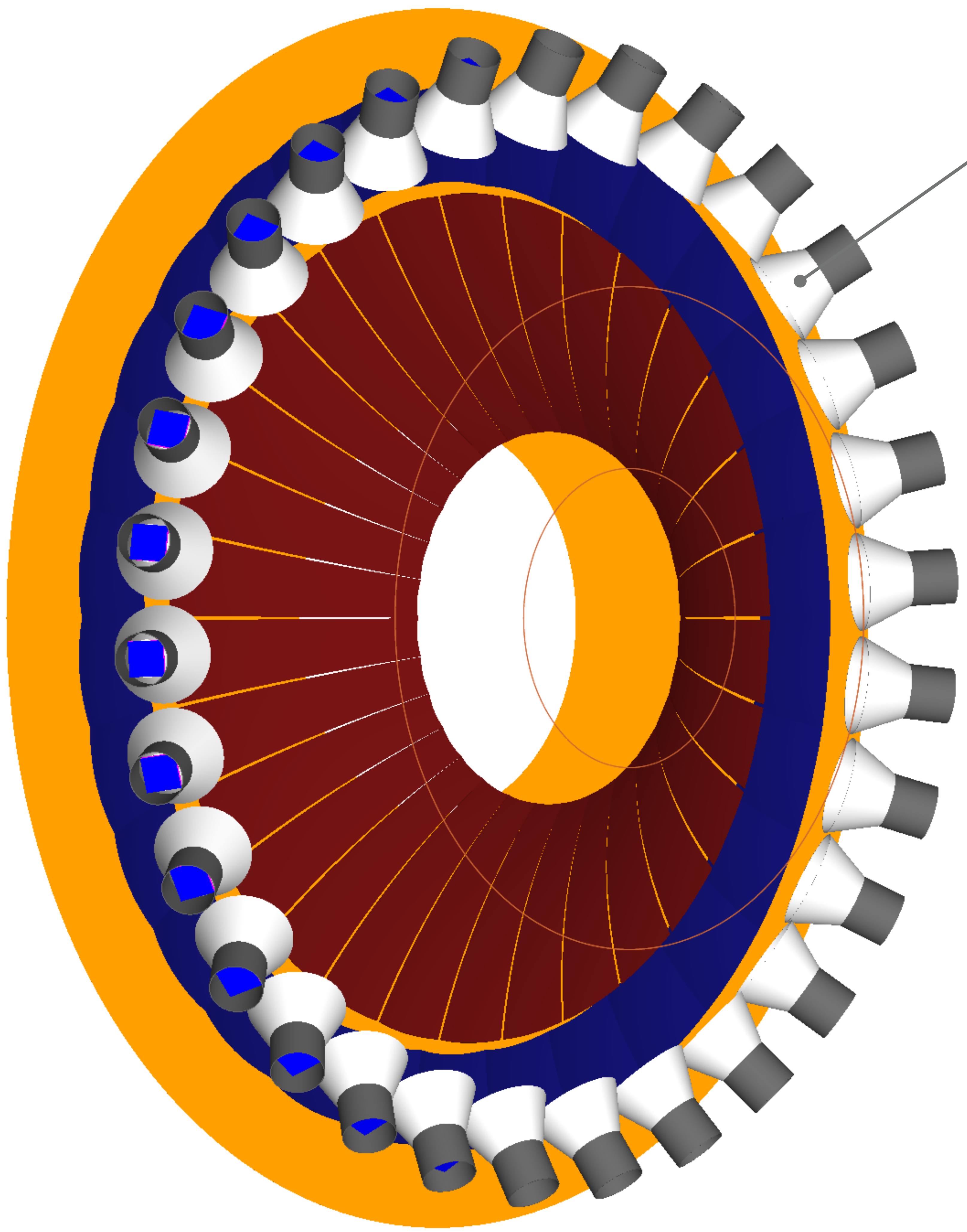
DETECTOR ANATOMY: MIRRORS

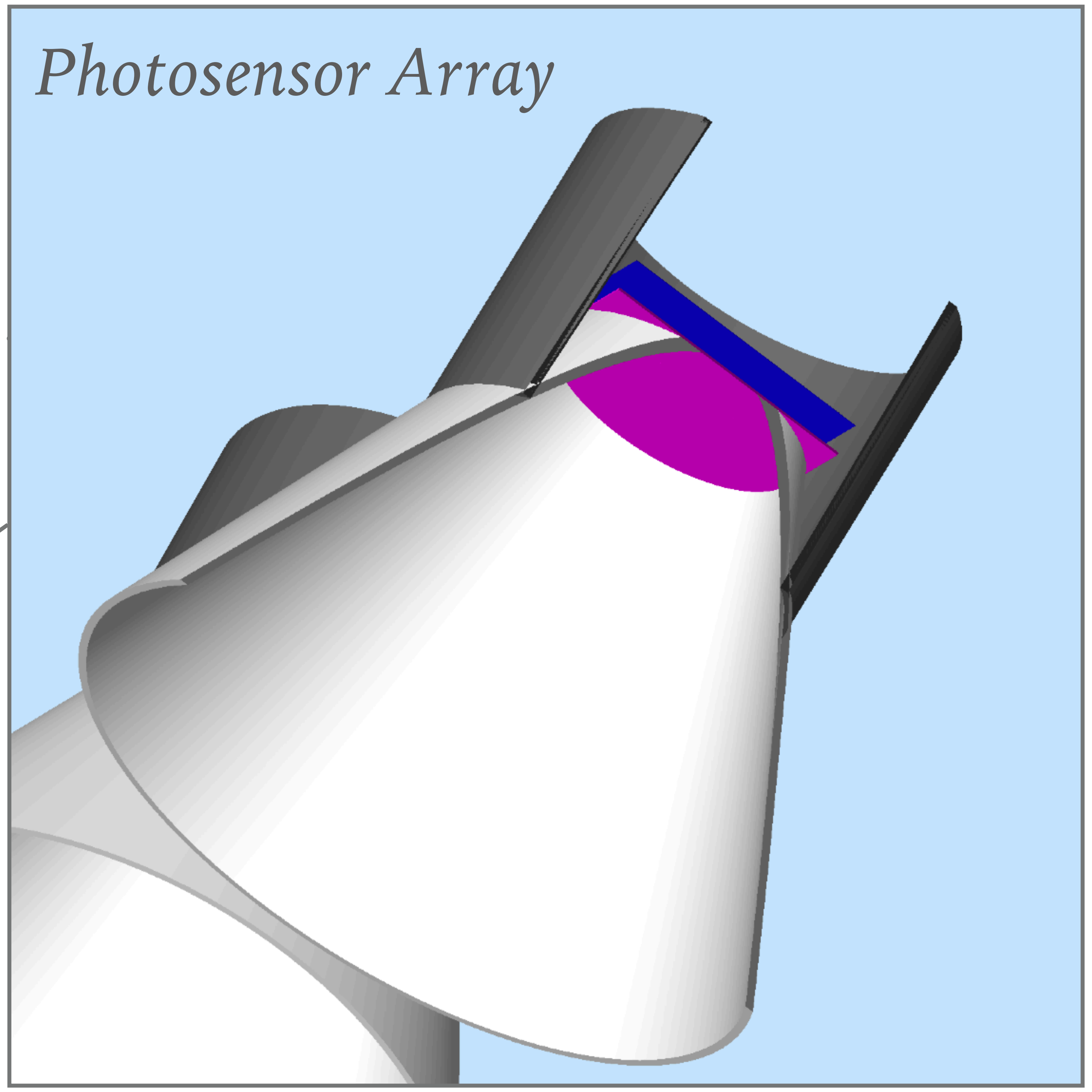


- Each sector consists of an inner and outer mirror. In the PVDIS configuration, both mirrors are in acceptance, where only the inner mirror is used for J/Psi & SIDIS.
- Each mirror is spherical in geometry and will be constructed from thin/lightweight carbon-fiber or fiberglass.
- The blanks themselves will not be polished to optical quality, but will be covered with Aluminum coated Lexan reflective film. (>85% reflectivity down to 200nm)



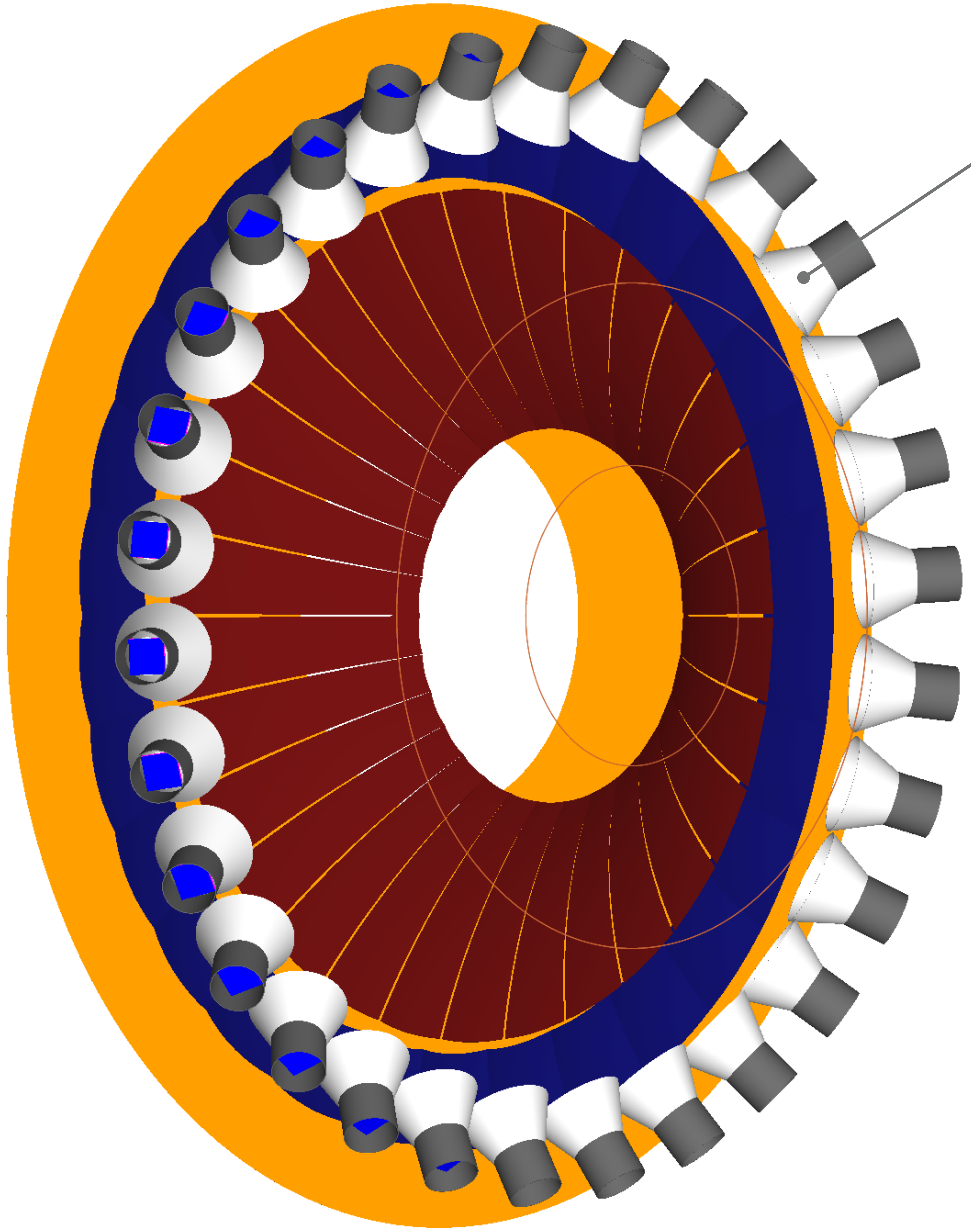
DETECTOR ANATOMY: PS ARRAY

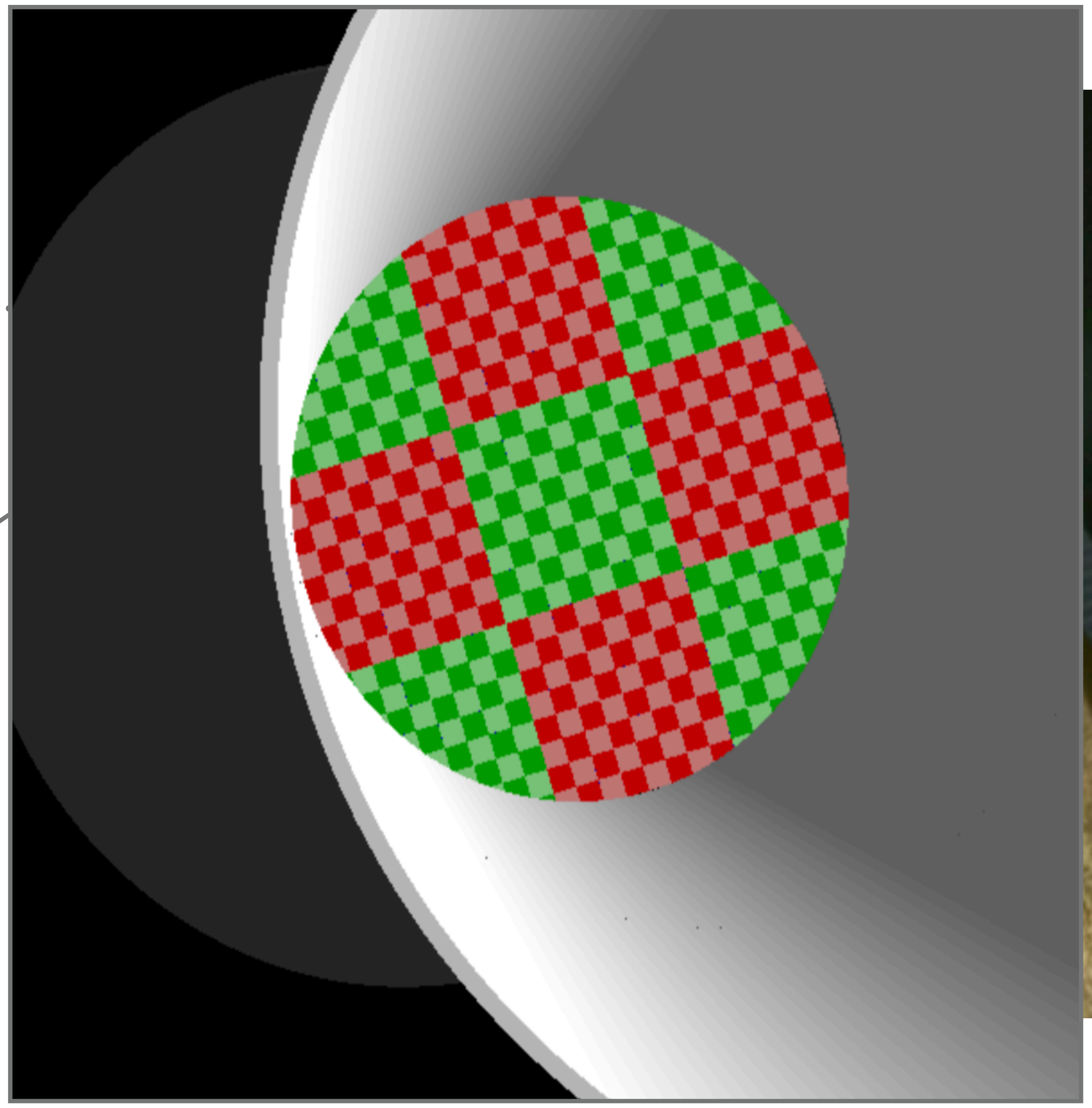


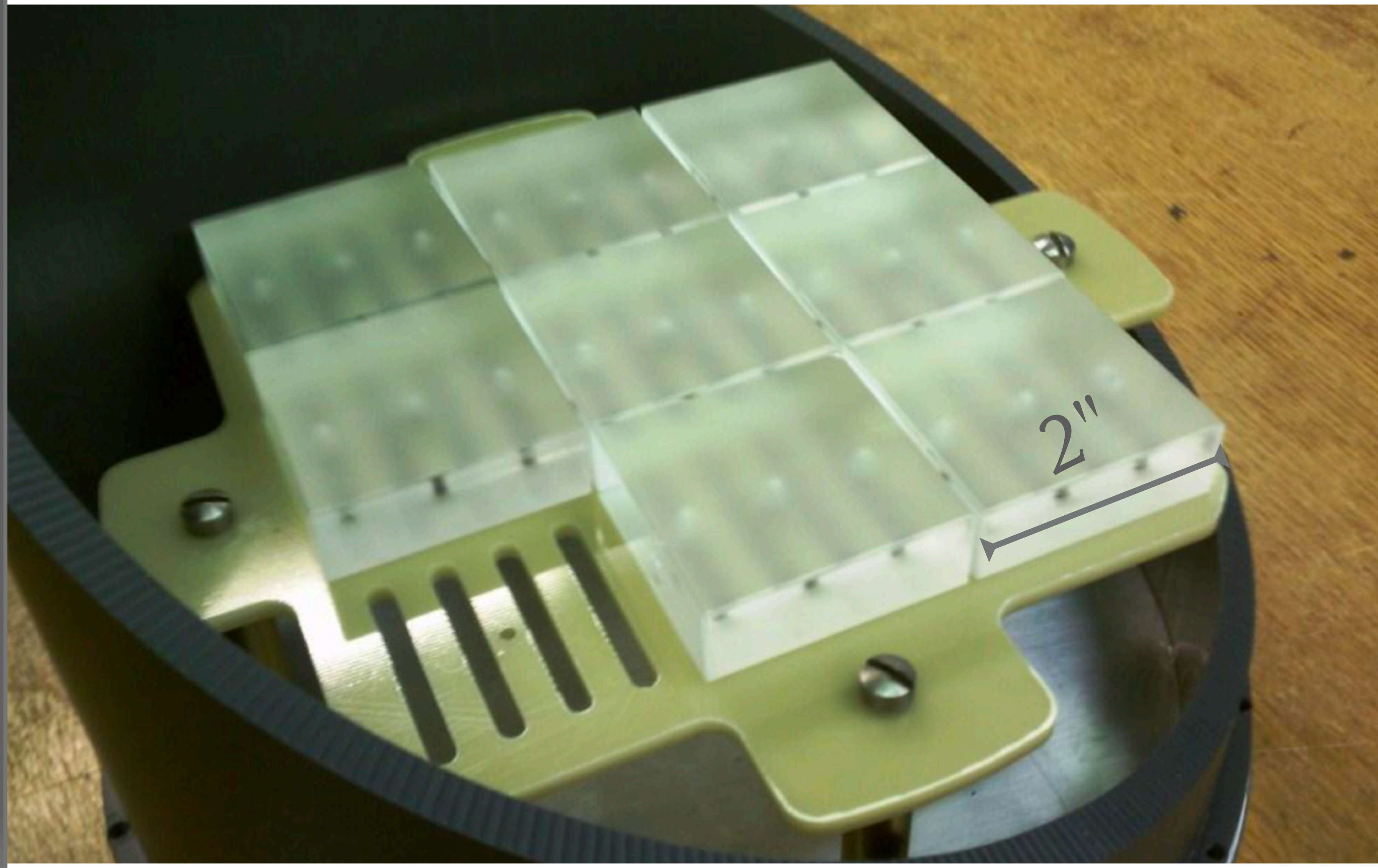


- Each sector houses a photosensor array.
  - 3x3 array of MaPMTs
  - Summing Electronics
  - Magnetic Shield
  - Reflective Cone

DETECTOR ANATOMY: PMTS

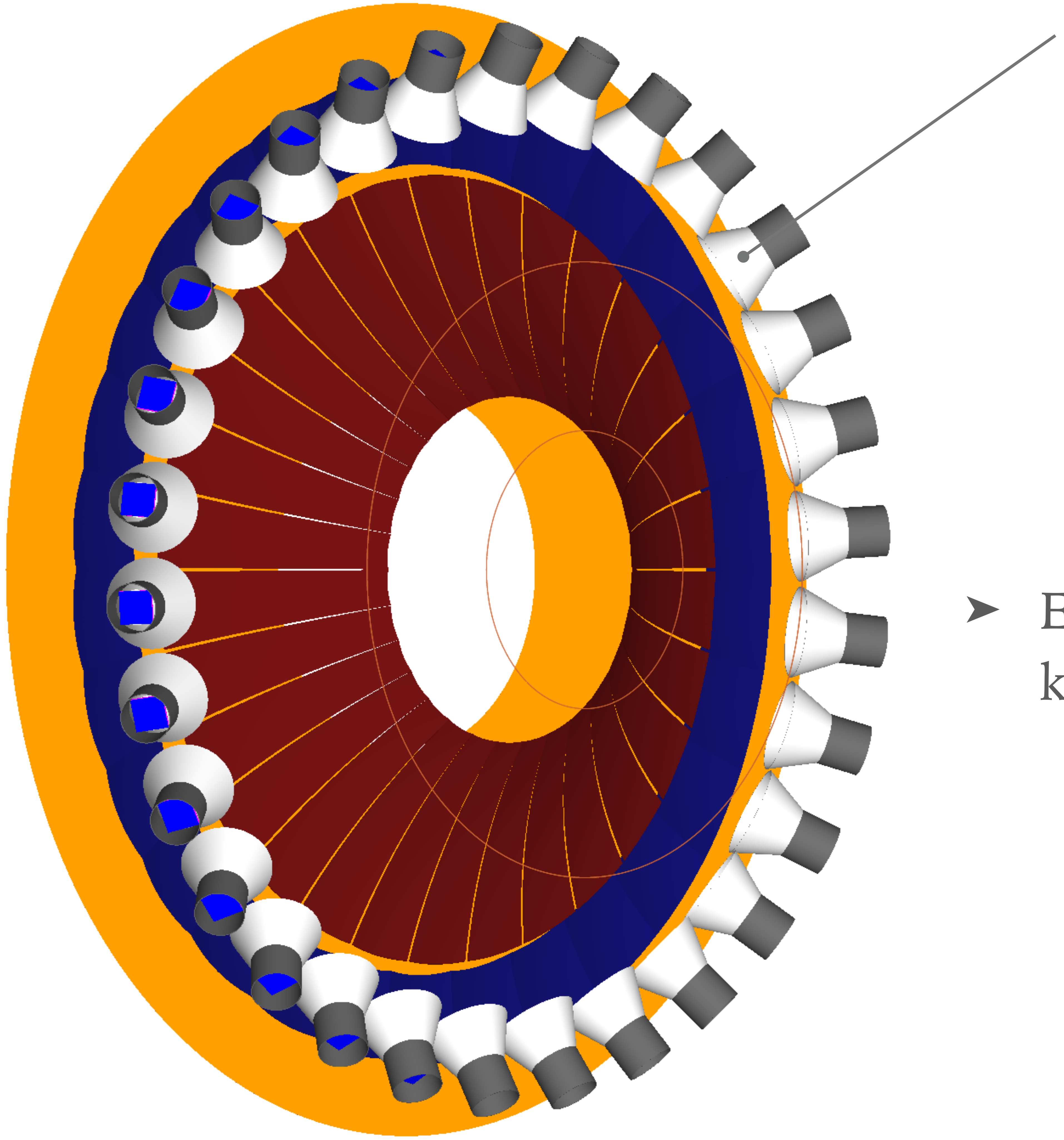


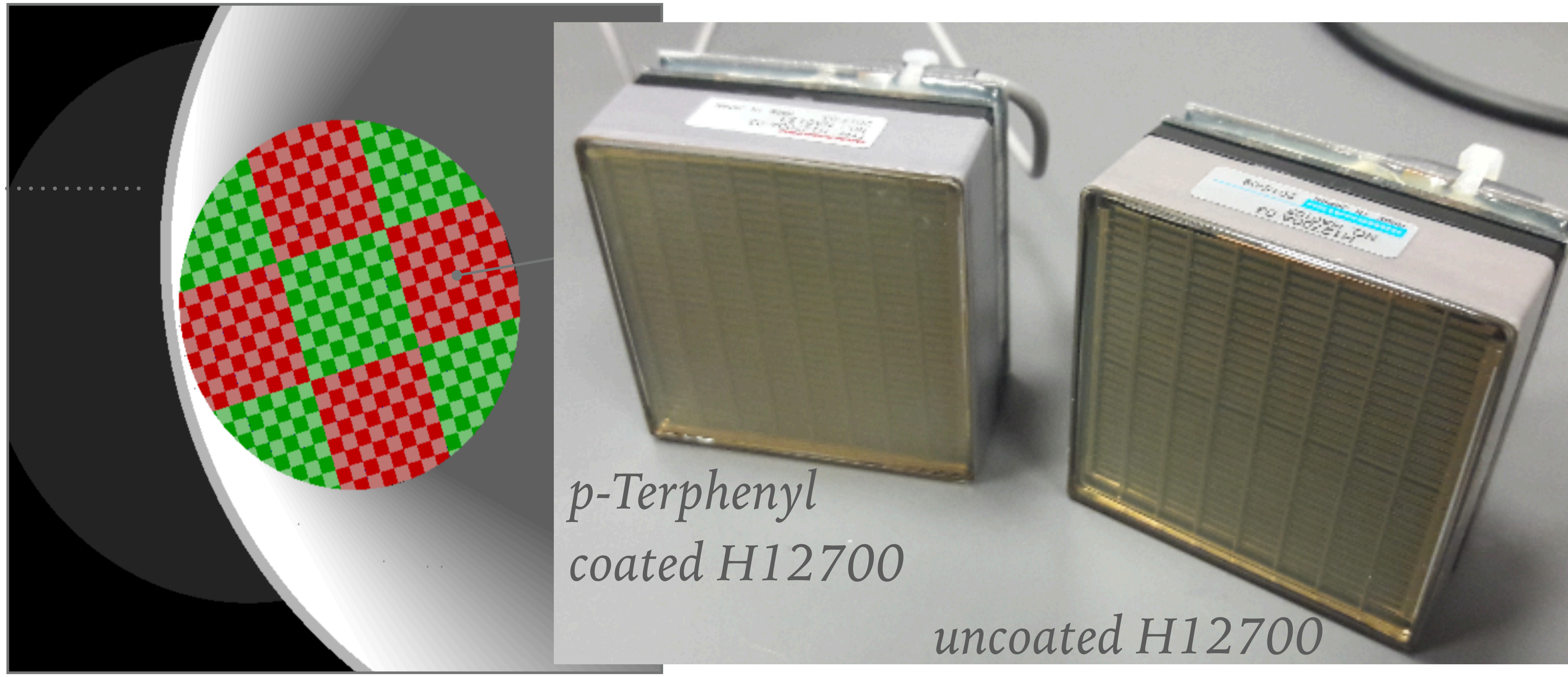




- Each PS array is designed to have a 3x3 tiled array of Hamamatsu H12700 MaPMTs. Each MaPMT has a 64 pixel readout.
    - All pixels which will be summed electronically into one signal for use at the trigger level. The summing board is being designed by the JLab detector group.
- The MaPMTs and summing electronics front board will connect to an aluminum support frame.

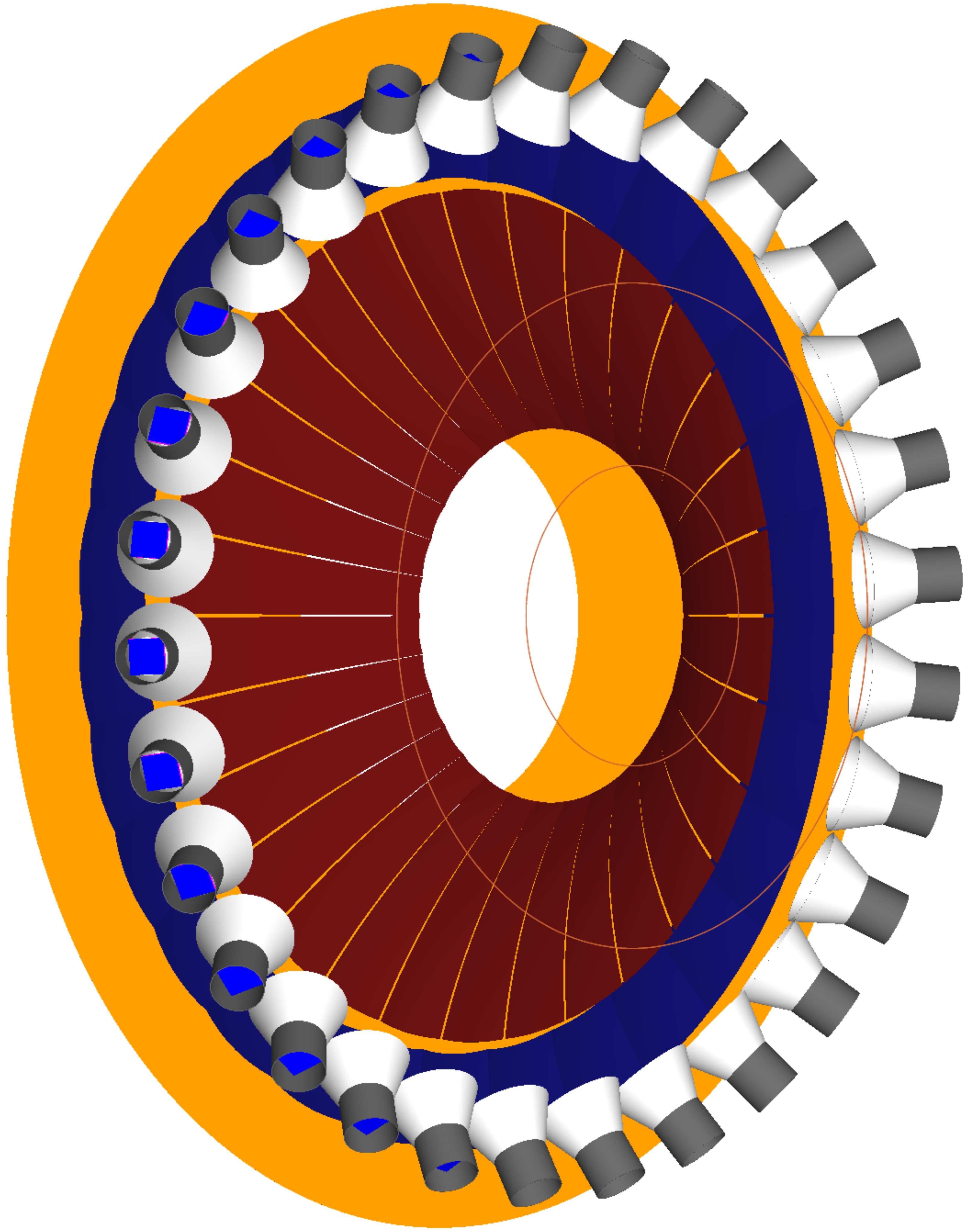
DETECTOR ANATOMY: PMTS

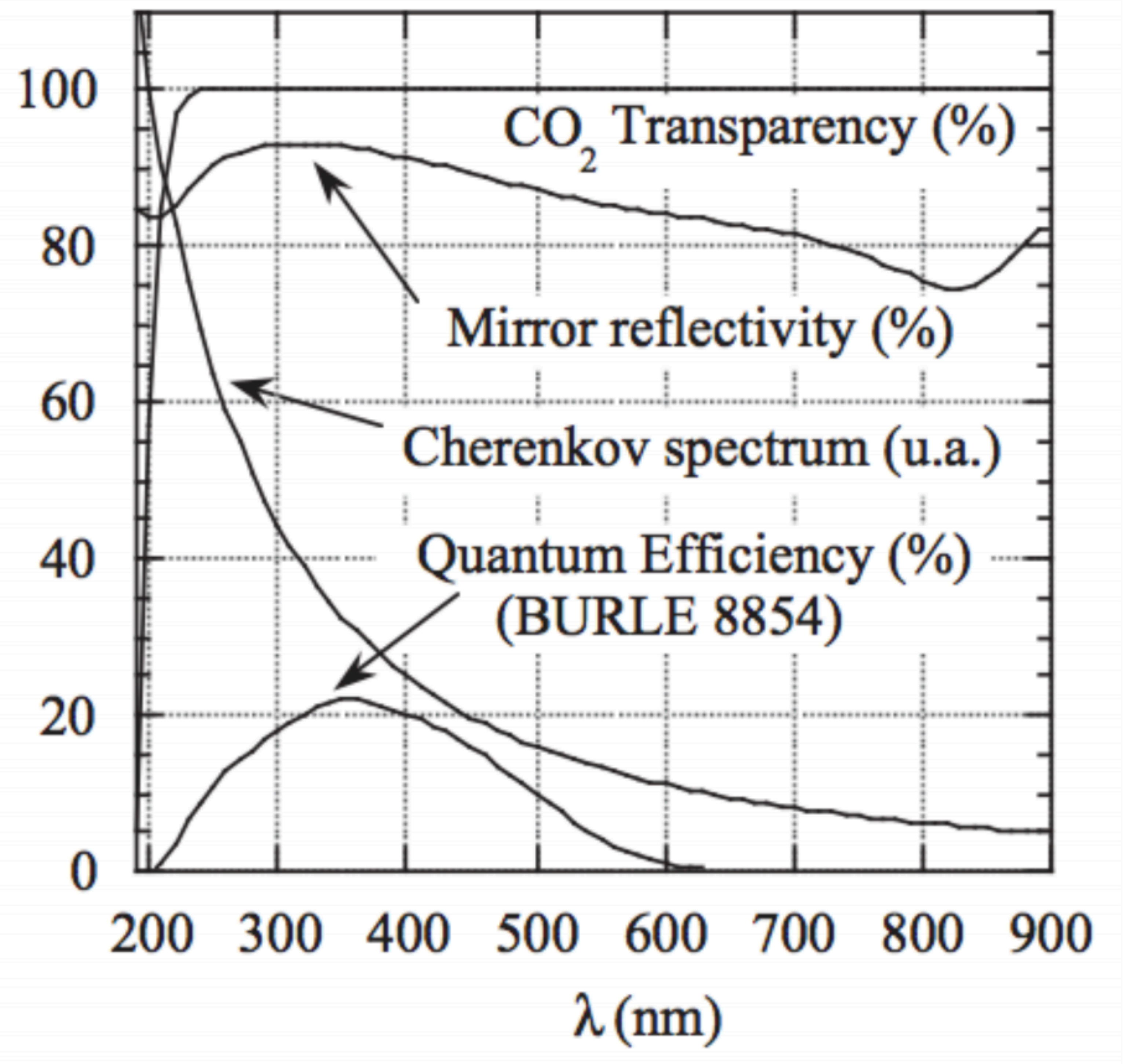


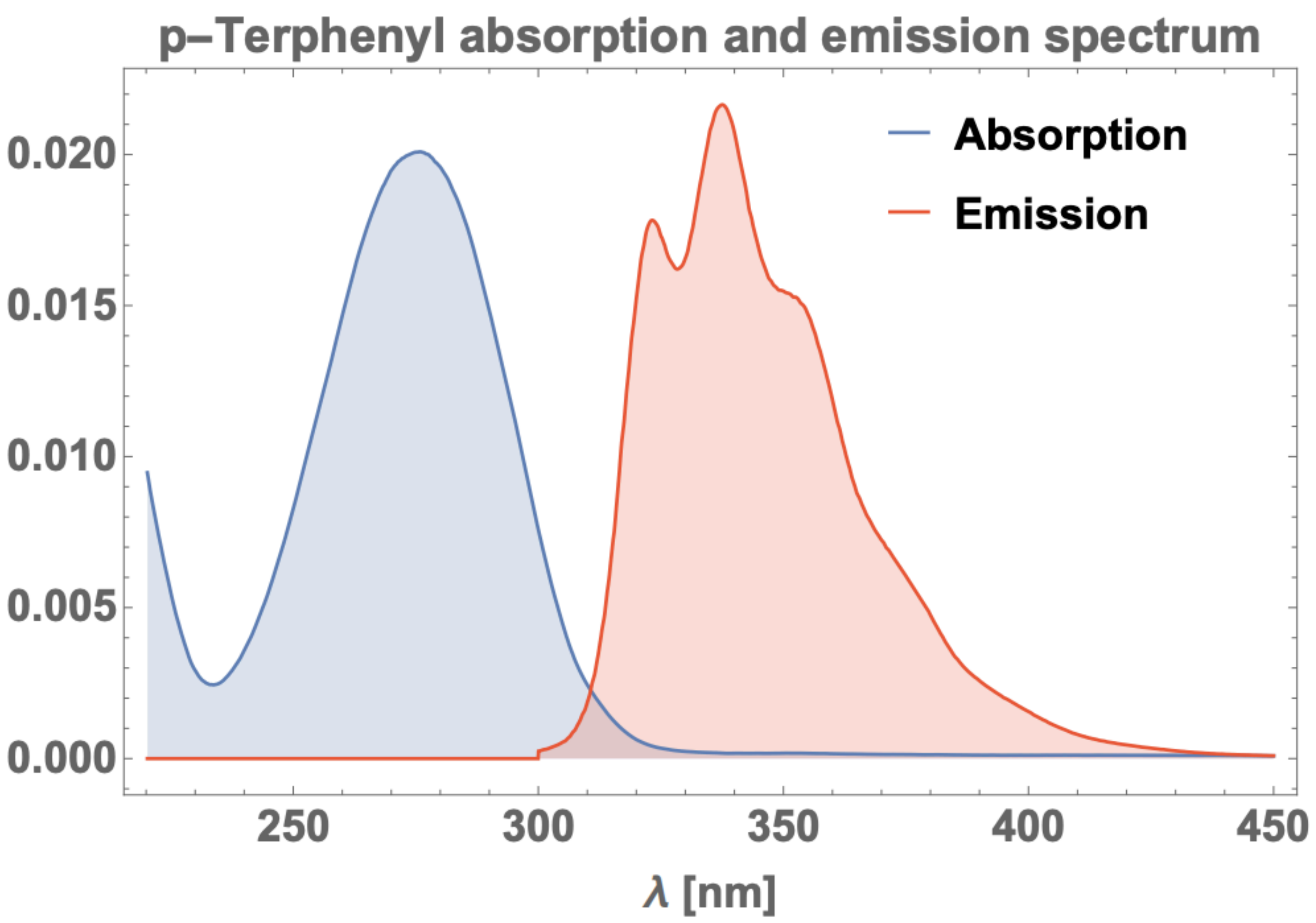


- Each MaPMT will be coated with a wave-length shifting substrate (WLS) known as p-Terphenyl.

DETECTOR ANATOMY: PMTS

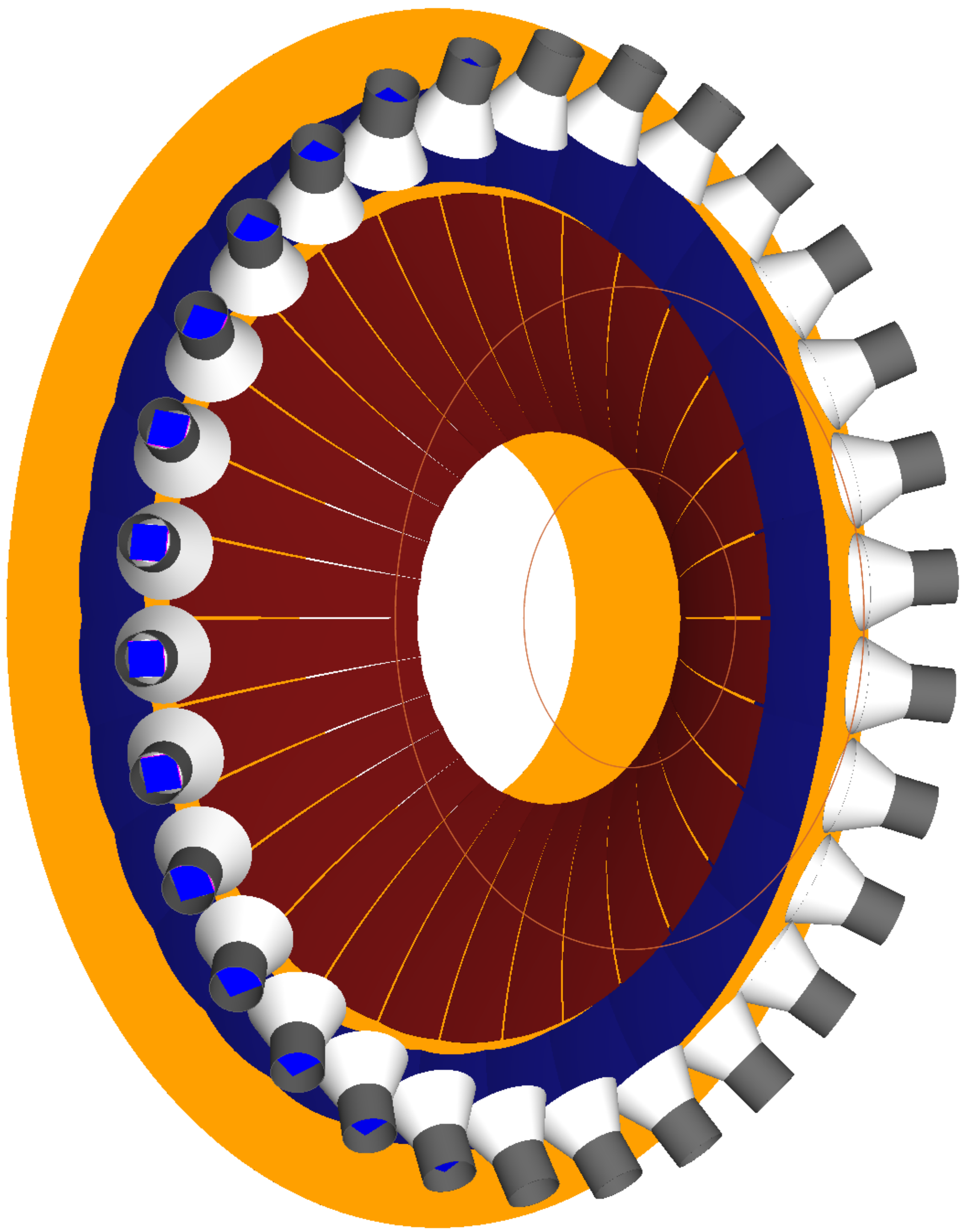


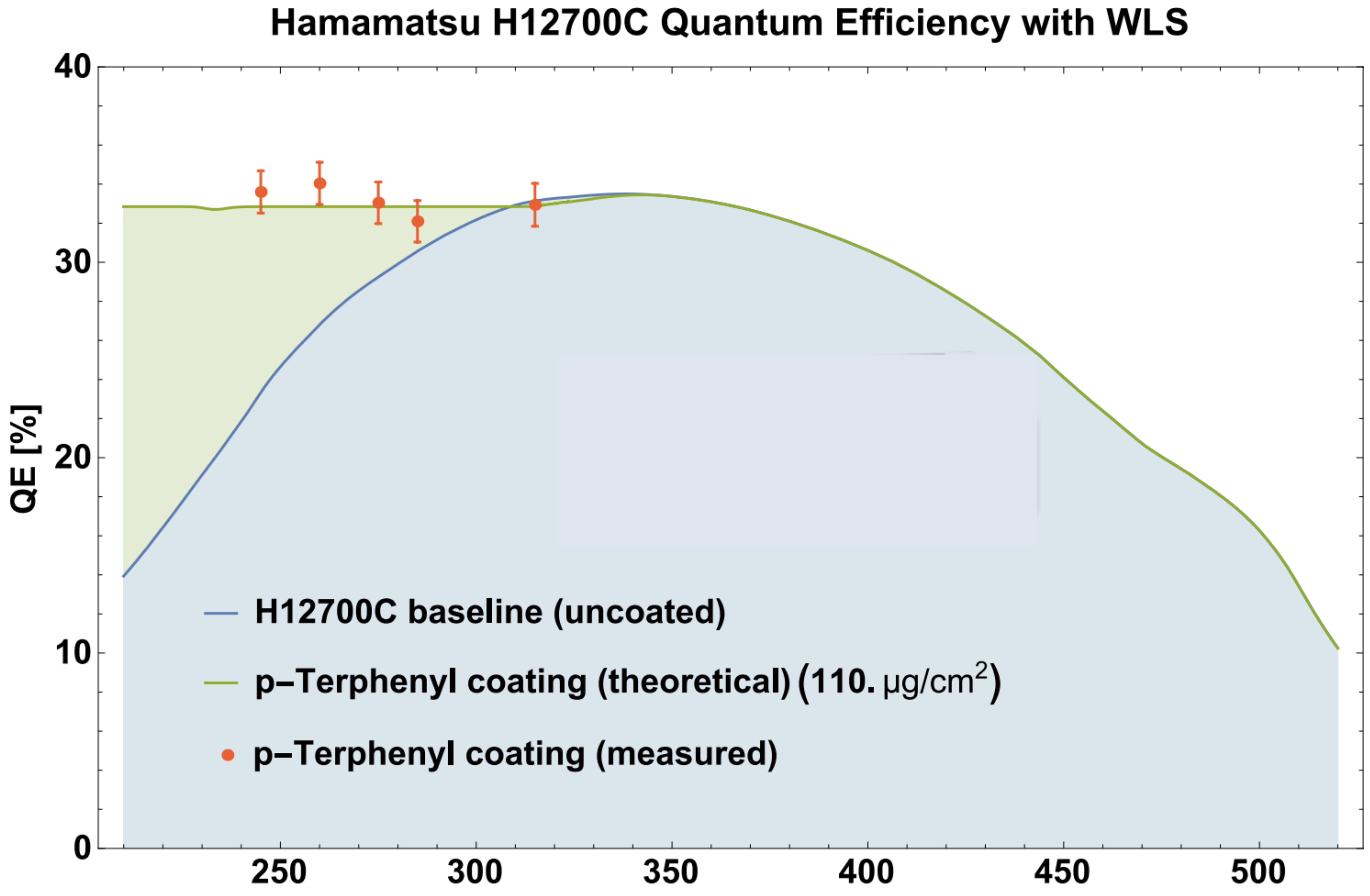




- Each MaPMT will be coated with a wave-length shifting substrate (WLS) known as p-Terphenyl.
  - The Cherenkov spectrum increases exponentially at low wavelength, but UV glass of PMTs limits the efficiency of detection.
  - p-Terphenyl absorbs low wavelengths and emits light in the peak detection region for the PMT.

DETECTOR ANATOMY: PMTS





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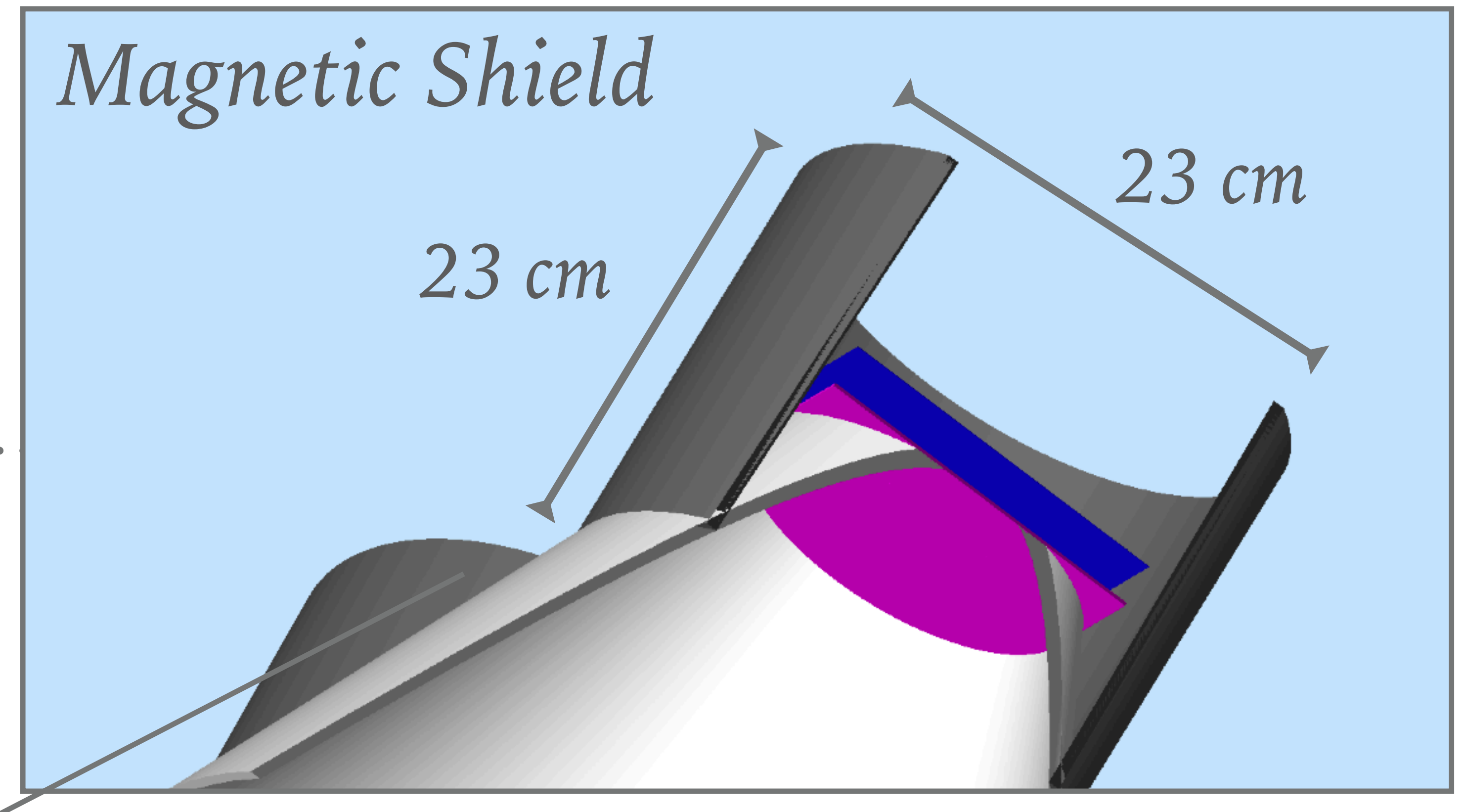
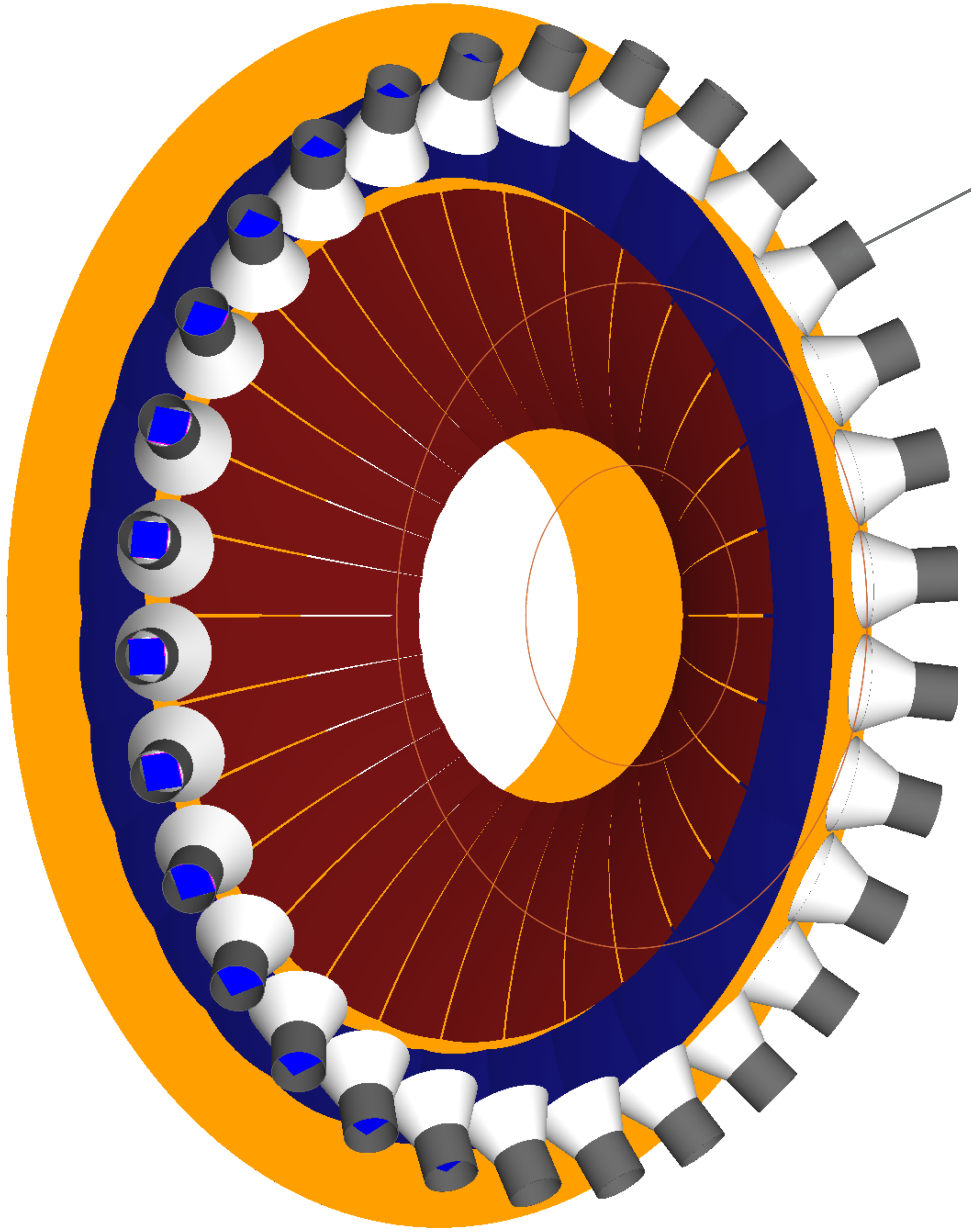
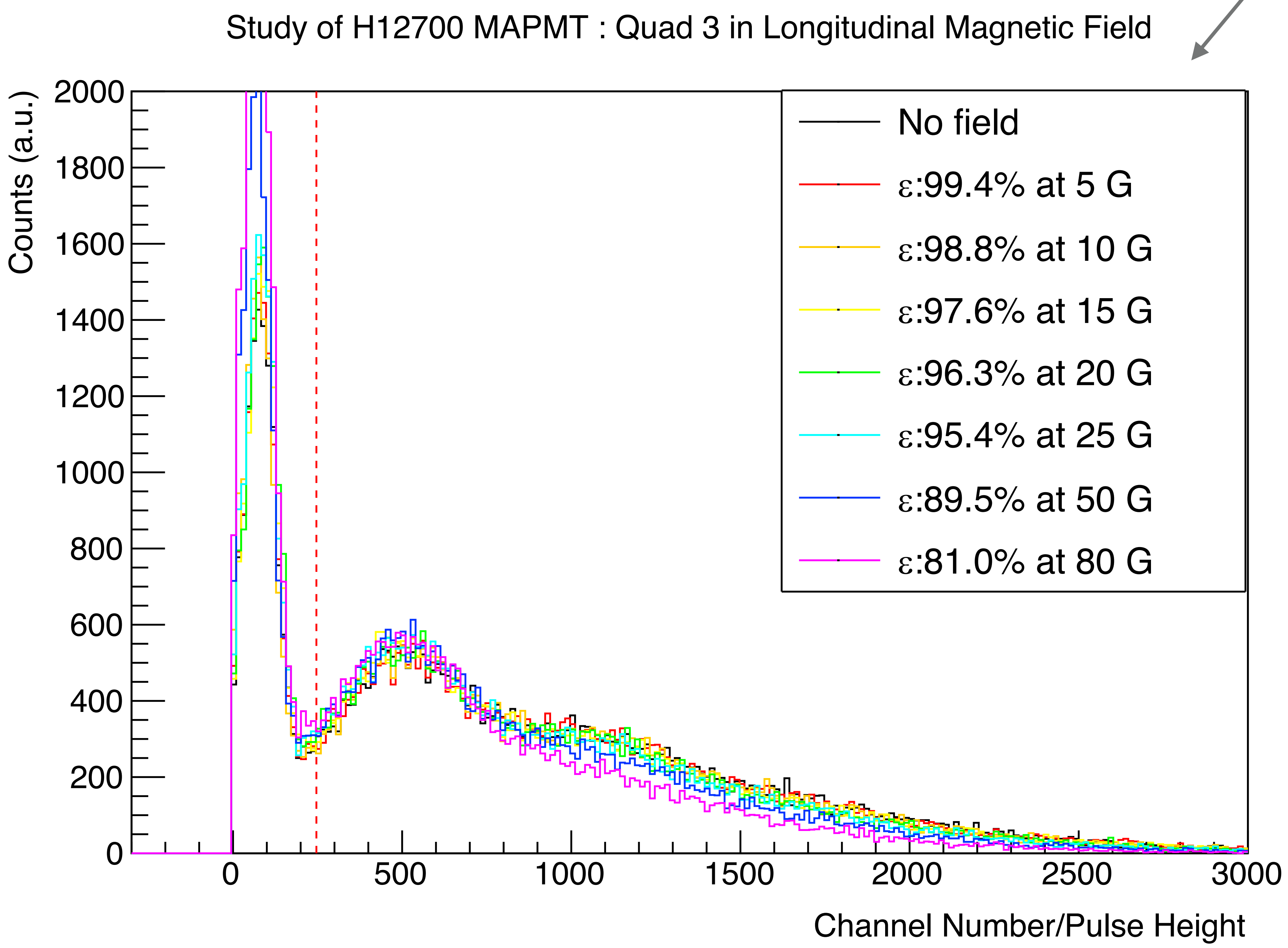
  - The Cherenkov spectrum increases exponentially at low wavelength, but UV glass of PMTs limits the efficiency of detection.
  - p-Terphenyl absorbs low wavelengths and emits light in the peak detection region for the PMT.
  - The result is an effective gain in Quantum Efficiency at low wavelength.

DETECTOR ANATOMY: MAGNETIC SHIELDS

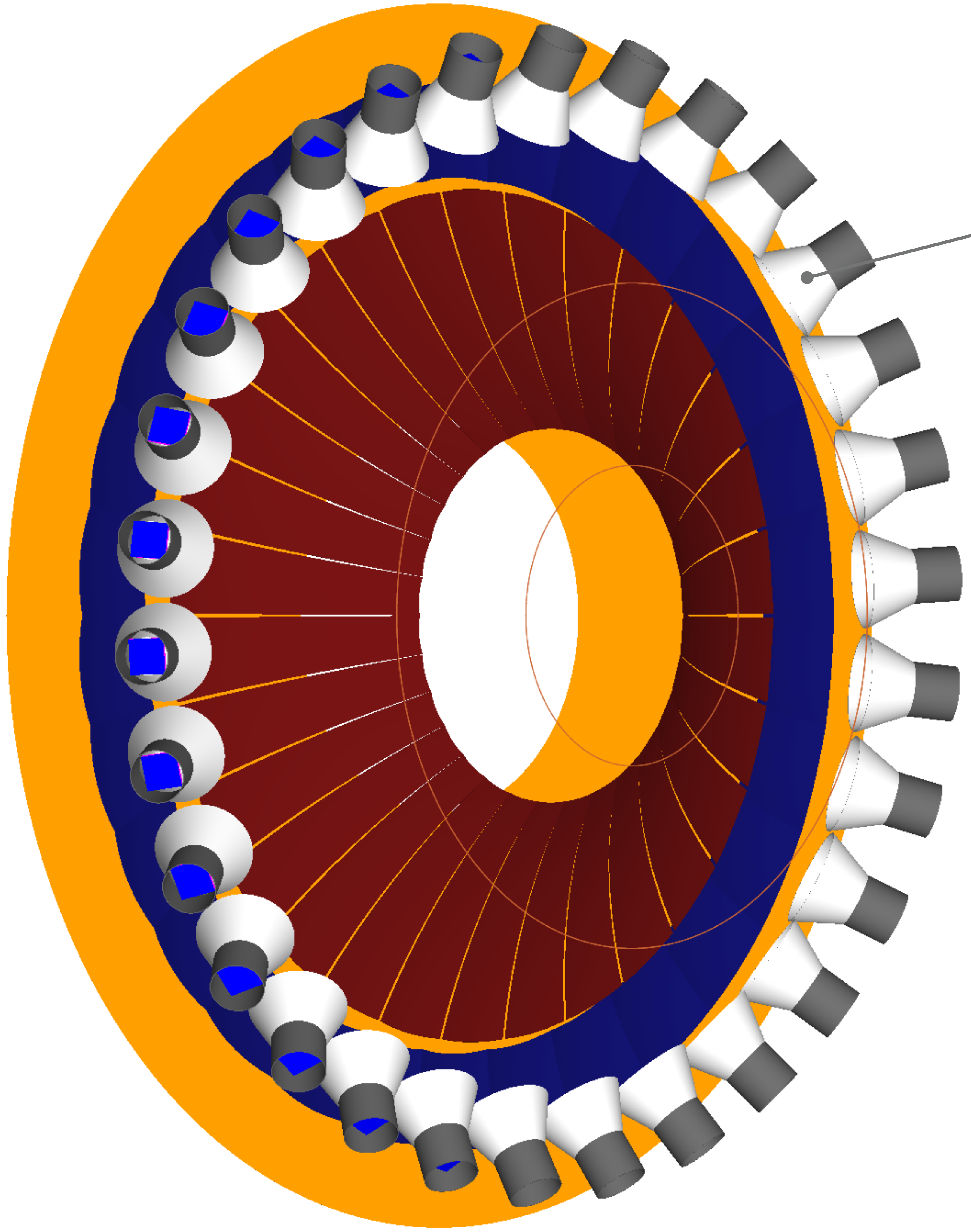


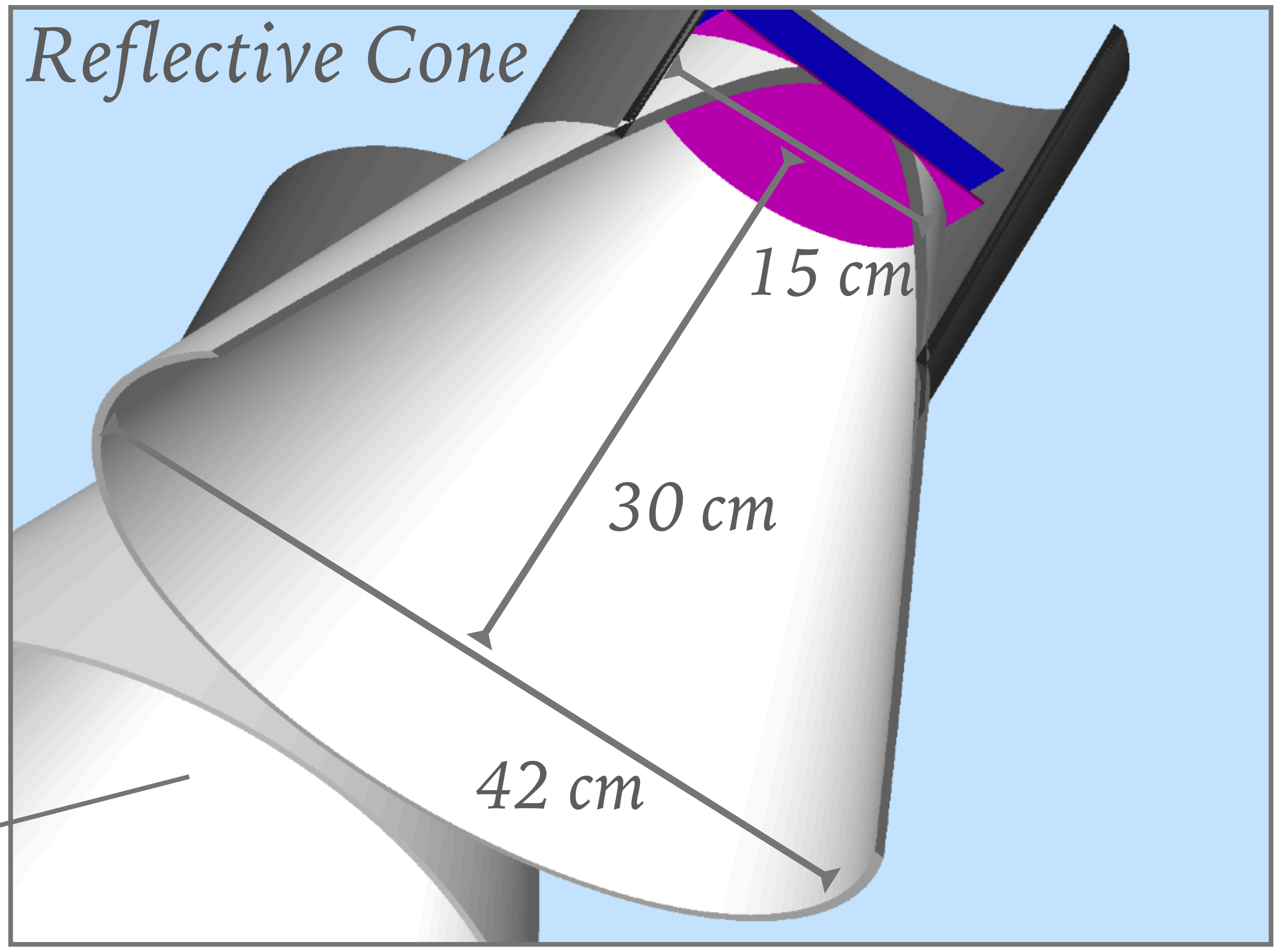




- Each PS array includes magnetic shielding to keep the total field below 50 G (10% loss on H12700).
  - Based on test results from Melanie Rehfuss at Temple University.
  - Expected field at PMTs is between 90 to 120 G (direction off axis of PMT face).
  - Each shield will be cylindrical in shape and consist of 0.08" thick mu-metal.
  - Resulting field below 50 G in any direction within PMT acceptance.

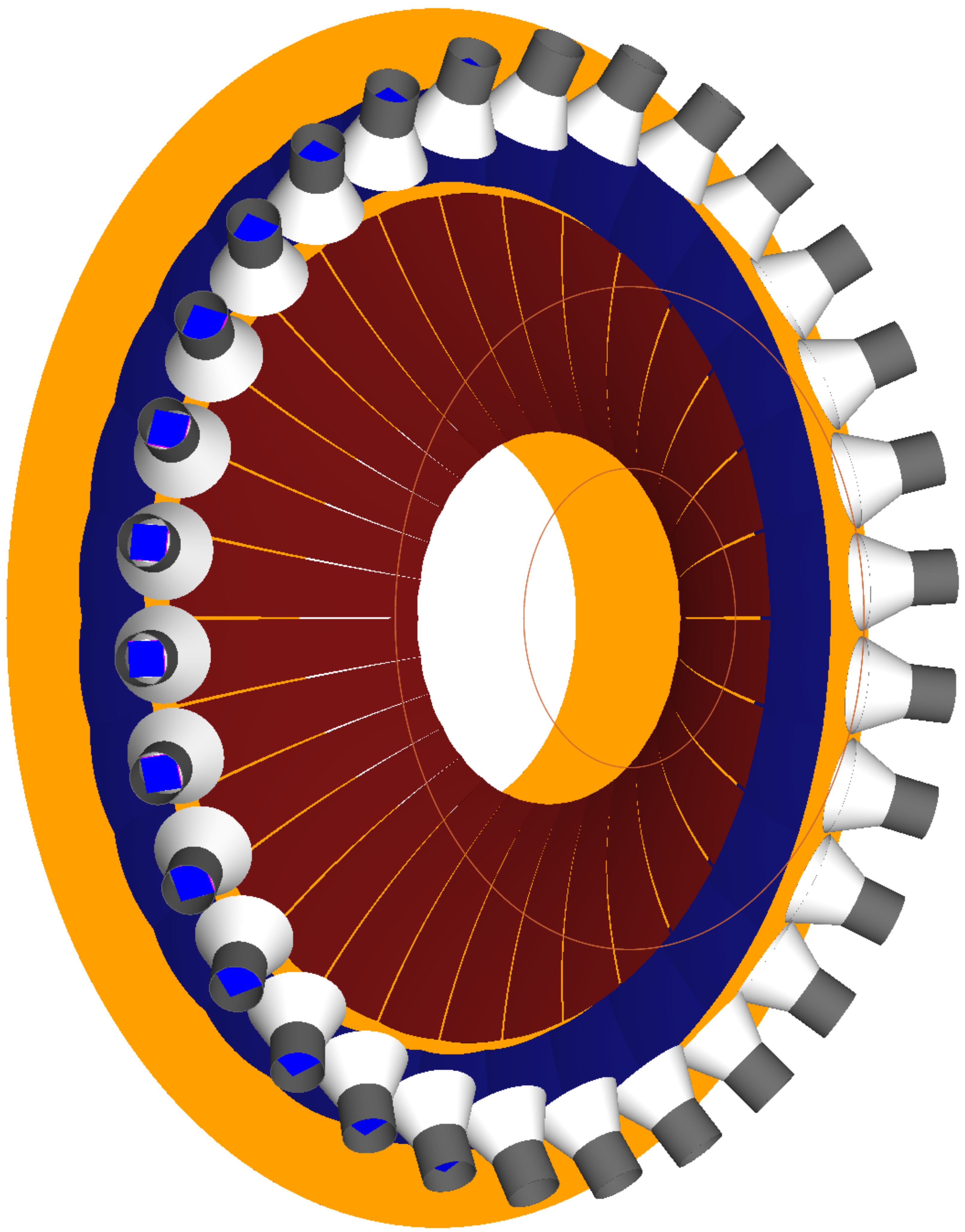
DETECTOR ANATOMY: REFLECTIVE CONES





- The reflective cones are needed to maintain uniform azimuthal acceptance, especially in the J/Psi SIDIS configuration.
  - The cones themselves are outside of acceptance and can be constructed from machined aluminum or glass.
  - Each cone inserts into the magnetic shield to sit flat against the MaPMT array. A circular acceptance onto a square array leaves some pixels unused.
  - The cones will be coated with Lexan reflective film in a similar fashion to the primary mirrors.

FUTURE OF PHOTOSENSORS

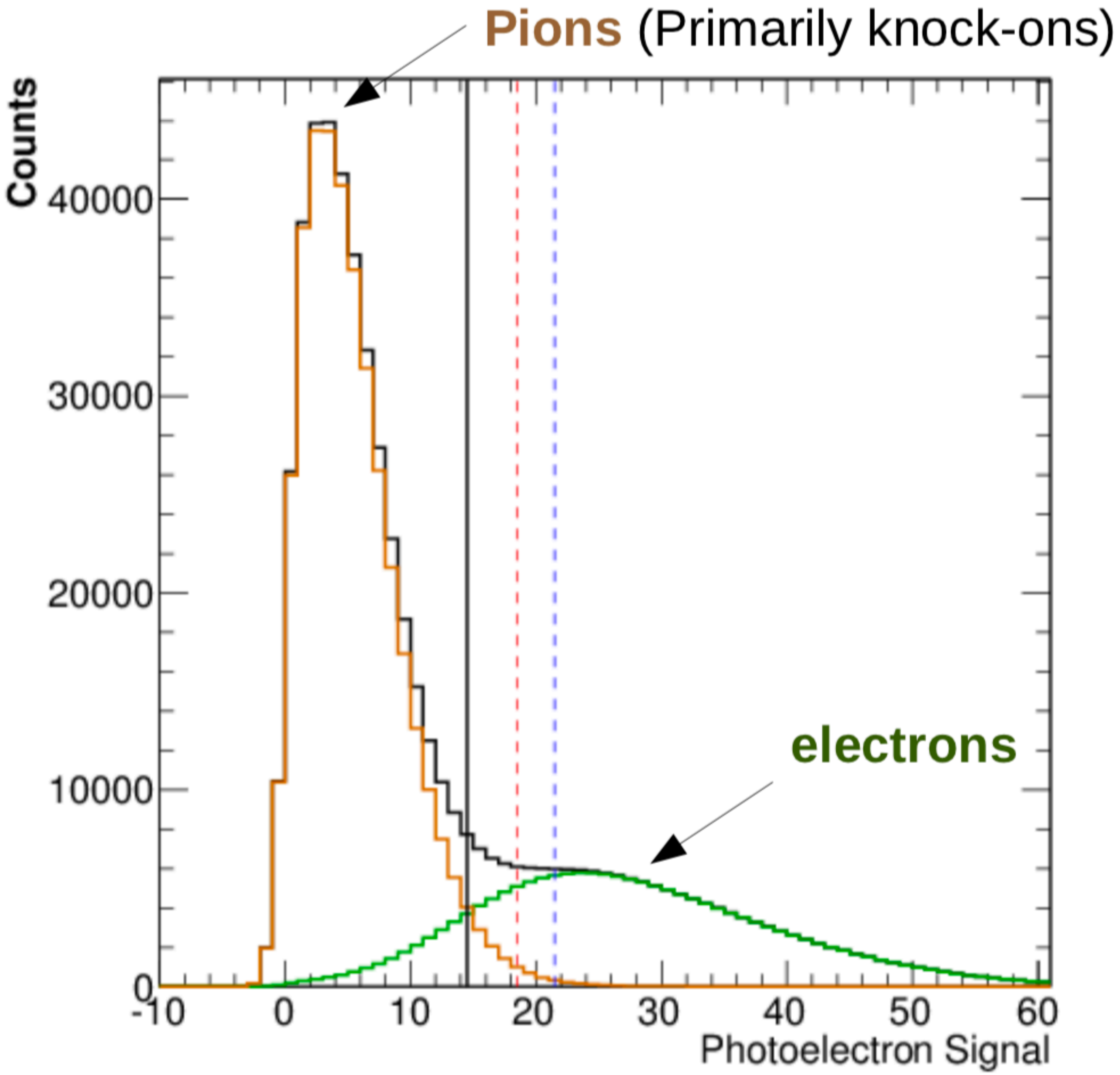


- Note about future technologies:
  - We currently are requesting H12700 MaPMTs because of their good quantum efficiency, relatively clean signal, reasonable response in magnetic fields, and ability to be tiled into larger arrays.
  - There are newer technologies on the horizon, including micro-channel photomultiplier tubes (McPMTs) and large area picosecond photosensor devices (LAPPDs).
    - Both of these technologies have the potential to be scalable to larger areas with little to no impact from magnetic fields.
      - This could effectively eliminate the need for magnetic shields and possibly the reflective cones in the LGC design.
    - Should these technologies be adequately established/tested and with costs comparable to an array of H12700s, they should be seriously considered as an alternative.

DETECTOR RESPONSE

- The total pi / e separation depends on the location of the photoelectron cut. Using a more restrictive cut can increase pion rejection but will also decrease electron collection efficiency.

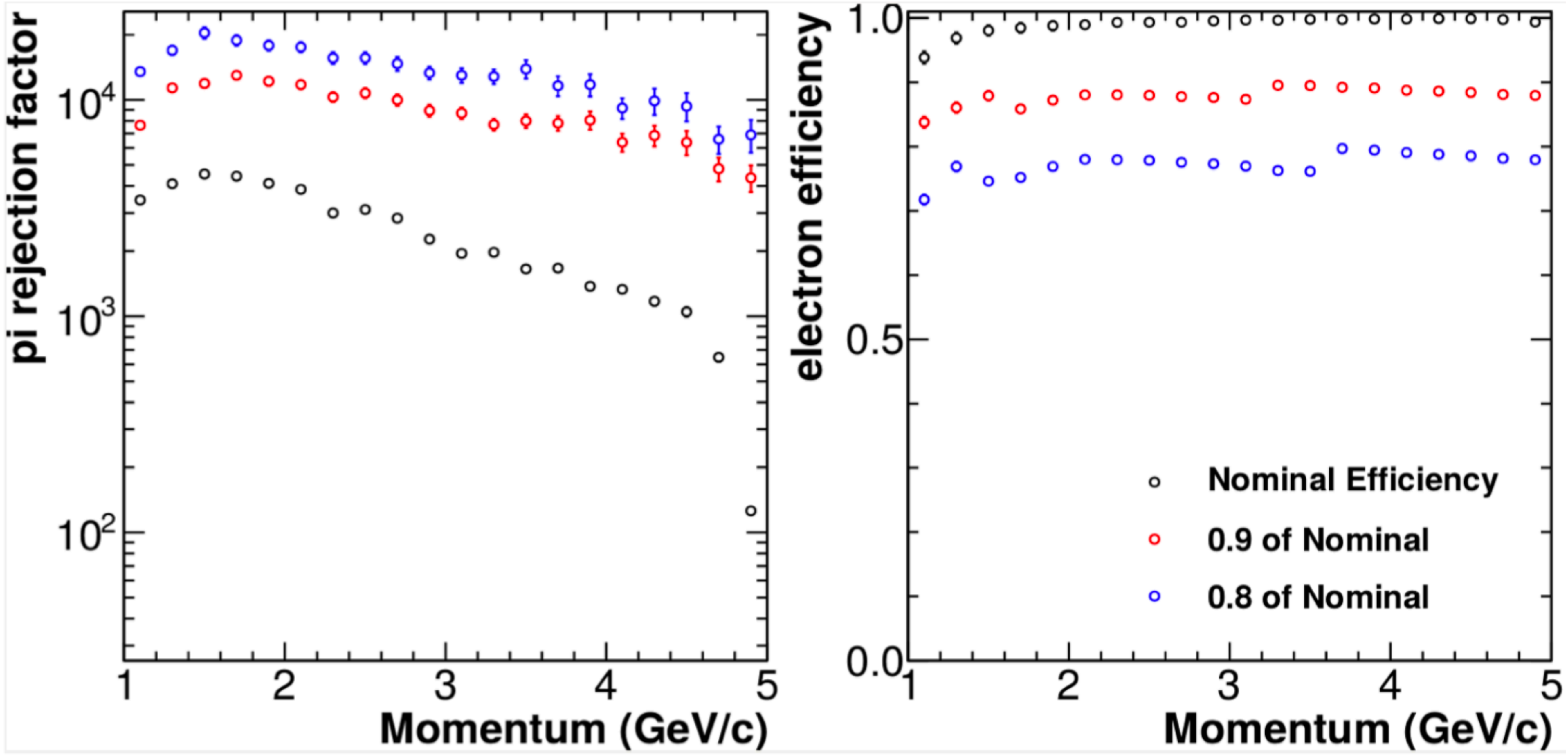
- Nominal Cut
- 0.9 of Nominal (10% eff decrease)
- 0.8 of Nominal (20% eff decrease)



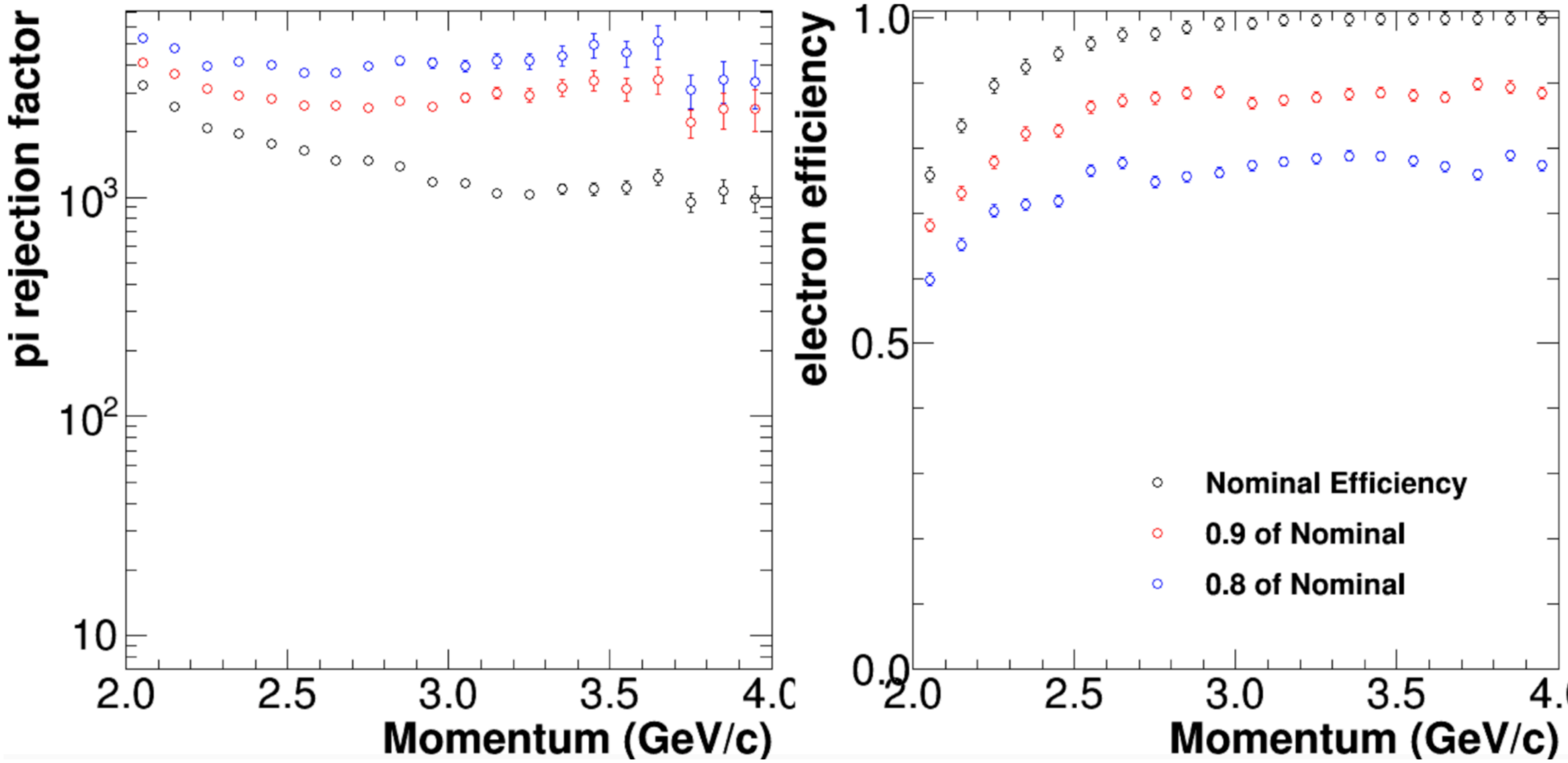
REJECTION / EFFICIENCIES

- With the proposed LGC design, pion rejection factors stay above 500:1 for all cuts for both configurations.

J/Psi SIDIS



PVDIS



BUDGET, ESTIMATES, AND RISKS

Activity Name	Costed Labor (PW)	Contrib Labor (PW)	Total Labor (PW)	Labor Cost ($K)	Procurement Cost ($K)	Total Cost ($K)
Light Gas Cherenkov (LGC)	**554.40**	**44.00**	**598.40**	**$1,408.18**	**$2,911.90**	**$4,320.08**
Tank and Support	**300.40**	**22.00**	**322.40**	**$763.02**	**$504.00**	**$1,267.02**
Gas System	44.00		44.00	$111.76	$63.00	$174.76
Windows/Frame/Support	124.40		124.40	$315.98	$441.00	$756.98
Integration/Assembly	132.00	22.00	154.00	$335.28		$335.28
Mirrors	**44.00**	**0.00**	**44.00**	**$111.76**	**$932.40**	**$1,044.16**
Mirror Blanks			0.00	$0.00	$630.00	$630.00
Mirror Coating			0.00	$0.00	$264.60	$264.60
Mirror Assembly	44.00		44.00	$111.76	$37.80	$149.56
Photosensor Detector Array	**66.00**	**0.00**	**66.00**	**$167.64**	**$1,425.10**	**$1,592.74**
Photosensors			0.00	$0.00	$1,020.60	$1,020.60
Photosensor Coating			0.00	$0.00	$102.10	$102.10
Summing Electronics			0.00	$0.00	$113.40	$113.40
Mu-metal Shielding			0.00	$0.00	$37.80	$37.80
Reflective Cones			0.00	$0.00	$113.40	$113.40
Array Assembly	66.00		66.00	$167.64	$37.80	$205.44
Transport , Travel and Testing	**144.00**	**22.00**	**166.00**	**$365.76**	**$50.40**	**$416.16**
Transport			0.00	$0.00	$25.20	$25.20
Travel			0.00	$0.00	$25.20	$25.20
Testing	144.00	22.00	166.00	$365.76		$365.76

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- Construction of the frame and support makes up the majority of the tank cost.
  - The frame and support requires precision alignment and mounting brackets for all 60 mirrors and 30 sensor arrays.
  - Estimates come from our engineer's experience with other Cherenkovs (the SANE Cherenkov used at Jefferson Lab).
  - The tank will be constructed in stages:
    - First a single section as a production prototype, with a partial neighboring section to test assembly and gas tightness.
    - After completing and testing the first section, the remaining 5 can be built in parallel.

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- The mirror blank estimates have evolved the most since the beginning of the project.
  - Initial quotes from Composite Mirror Applications (CMA) put mirror blank cost near $500k, but an apparent error in their quote calculations moved the total cost > $1.5M.
  - Latest quotes come from email correspondence with carbon-fiber manufacturers (Rockwest and ProTech Composites).
    - Cost difference ($1.5M to $500k) comes from NOT requiring optically polished mirror blanks. Since the Lexan film is optical-grade before coating, this reduces the requirements on the blanks. (These strips were used to refurbish the CLAS Cherenkov mirrors for the CLAS12 LTCC).
      - Costs now are driven by the geometrical tolerances of the design (<1%).
  - Back-up plan to pre-fabricated blanks relies on in-house construction of optical-grade fiberglass via methods used for Hall-A cherenkov mirrors (vendor quotes obtained).

BUDGET, ESTIMATES, AND RISKS

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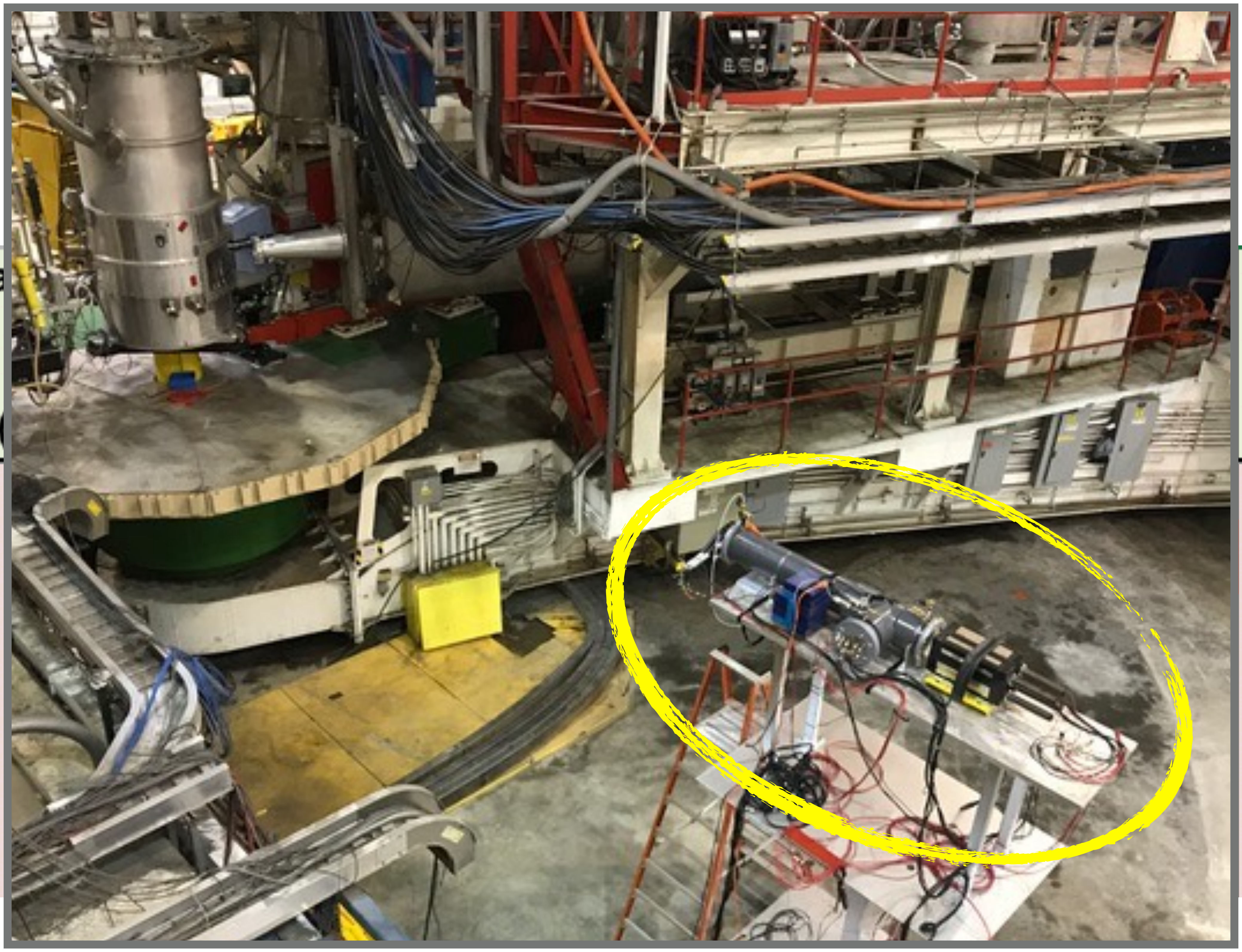
- Hamamatsu H12700 MaPMTs (270 @ $3k each [vendor quote]): The high luminosity of the PVDIS configuration combined with the baffle system creates a large (hundred of kHz to > 1 MHz) rate per PMT from simulation estimates.
    - Total trigger rate is reduced by requiring some coincidence logic inside the array (i.e. requiring 2+ PMTs in coincidence to fire with 2+ photoelectrons each).
    - Although the technical PMT / DAQ specifications claim to be adequate for our running conditions, tests are needed at high-rate to optimize efficiencies (detection/trigger).

BUDGET, ESTIMATES, AND RISKS

Activity Name	Costed Labor (PW)	Contrib Labor (PW)	Tota
Photosensor Detector Array	66.00	0.00	
Photosensors			
Photosensor Coating			
Summing Electronics			
Mu-metal Shielding			
Reflective Cones			
Array Assembly	66.00		



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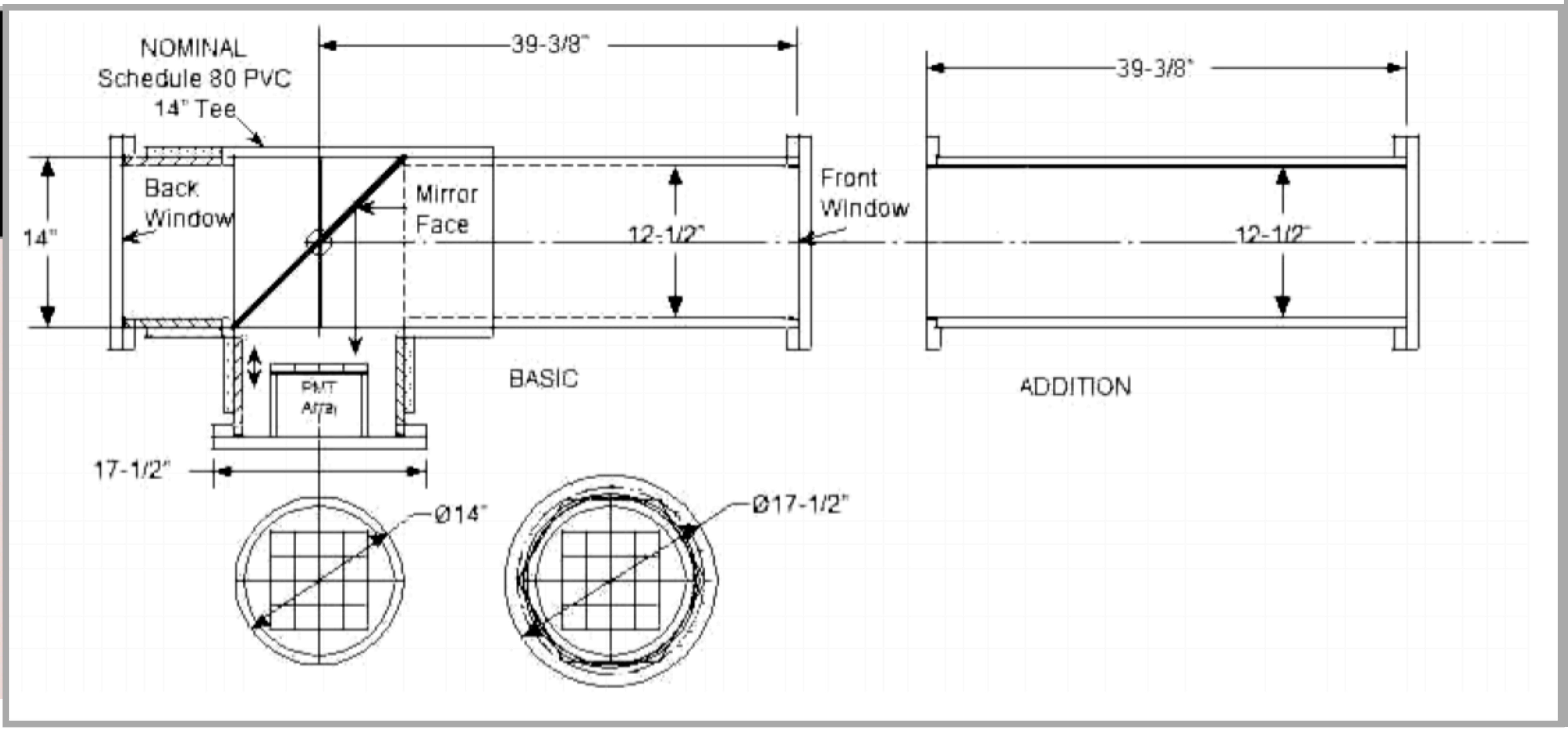
  - Total trigger rate is reduced by requiring some coincidence logic inside the array (i.e. requiring 2+ PMTs in coincidence to fire with 2+ photoelectrons each).
  - Although the technical PMT / DAQ specifications claim to be adequate for our running conditions, tests are needed at high-rate to optimize efficiencies (detection/trigger).
  - Initial studies are being preformed with a small prototype telescope Cherenkov (used parasitically in Hall-C).

BUDGET, ESTIMATES, AND RISKS



SoLID Pre-R&D Request

SoLID Collaboration

July 31, 2019

3 High Rate Test of MaPMT Arrays Using a Prototype Telescopic Cherenkov Device

3.1 Overview

Future Cherenkov detectors at facilities like the SoLID at JLab or EIC will rely on arrays of MaPMTs in high rate environments. It is essential to test the response of MaPMT arrays under high-rate with modern electronic readout systems and gain-enhancing WLS coating to help guide decisions in design and provide input for realistic simulations. A telescopic prototype Cherenkov detector will be constructed. The detector will use an array of 16 MaPMTs inside a tank constructed from industrial PVC piping. The prototype is designed to record signals from simple analog-summing as well as digital read-out electronics. The prototype will collect data parasitically at Jefferson Lab under high-rate conditions. Comparative analyses of N_2 and C_4F_{10} radiators, arrays with and without WLS coating, and read-out electronics will be performed. Magnetic shielding design will be studied. The results will be used to design efficient trigger logic and background-suppression algorithms, and help maximize efficiencies of future detectors.

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  - Total trigger rate is reduced by requiring some coincidence logic inside the array (i.e. requiring 2+ PMTs in coincidence to fire with 2+ photoelectrons each).
  - Although the technical PMT / DAQ specifications claim to be adequate for our running conditions, tests are needed at high-rate to optimize efficiencies (detection/trigger).
  - A pre-R&D proposal has been submitted for a new prototype Cherenkov that can run parasitically at Jefferson Lab.

CHARGES AND CONCLUSIONS SPECIFIC TO THE LGC

- 1) "Are the scientific and technical requirements clearly identified? Is the SoLID conceptual design sound, achievable and sufficiently defined to meet those requirements?"
  - The requirements for pion/electron identification are clear, and the LGC, as currently designed, can provide discrimination above the general requirement of 500:1 for all configurations.
- 2) "Is the risk assessment sufficiently mature for this stage, and are there appropriate plans in place to mitigate these risks?"
  - Risks have been studied concerning the construction and expected performance of the LGC. The detector as a whole relies on many tried and tested methods for Cherenkov detectors. The highest area of risk centers around high rates expected for the photosensors. Trigger logic design can help mitigate total rate. Steps have also been taken to investigate high rates with a new prototype Cherenkov, which is scheduled to finish before LGC designs are finalized.

CHARGES AND CONCLUSIONS SPECIFIC TO THE LGC

- 3) "Are the cost and schedule estimates appropriately developed for this stage of pre-project planning? Is the basis of the contingency estimate well-founded, and is there appropriate cost and schedule contingency included to address the identified risks?"
  - Although final designs have not been drafted yet, we have relied on lab and engineering experience building Cherenkovs (E142/E143 and E154/E155 at SLAC, and SANE used at Jefferson Lab), along with communication with scientists who've recently commissioned detectors (CLAS12 LTTC, CLAS12 RICH, Hall-A Cherenkov). Any discoveries made concerning high rates with the prototype Cherenkov which may impact design are not expected to significantly affect cost or time estimates.
- 4,5,6) No direct response needed by the LGC group (ES&H, off-project scope, no DR recommendations directly for the LGC).