Status and Plans of the Water Cherenkov Test Experiment (WCTE) Experiment

Mark Hartz
For the WCTE Collaboration

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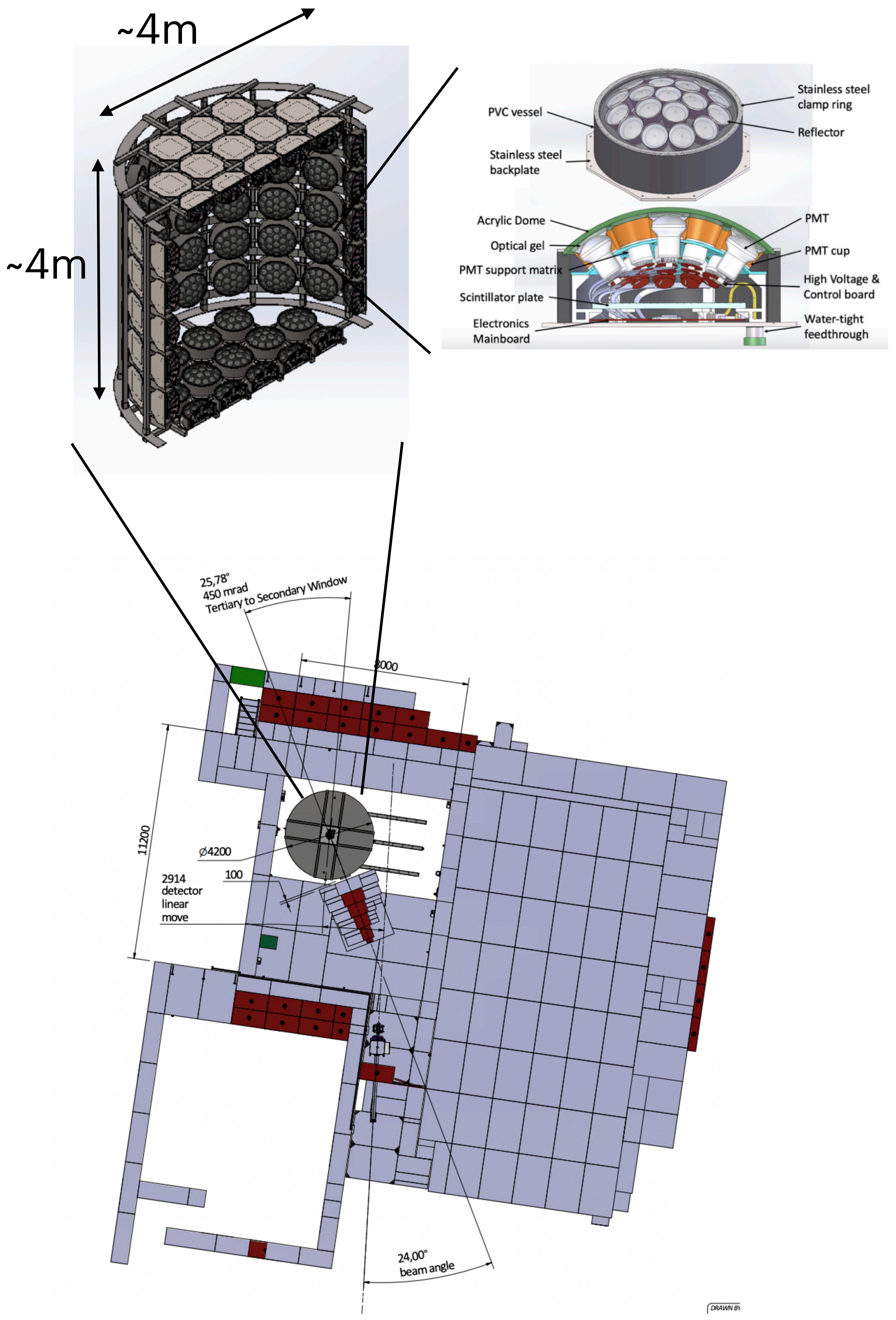
Reintroduction to the WCTE

- 50-ton scale water Cherenkov detector to study detector systems and important physical processes for neutrino experiments
- Study detector calibration and response with known particle fluxes of 0.2-1 GeV/c π, p, e, μ
- Operation in the T9 beam
- Nominal design includes moving detector that can receive direct secondary beam or tertiary particles produced by target just upstream of the detector
- Have received approval from the CERN Research Board in March 2022

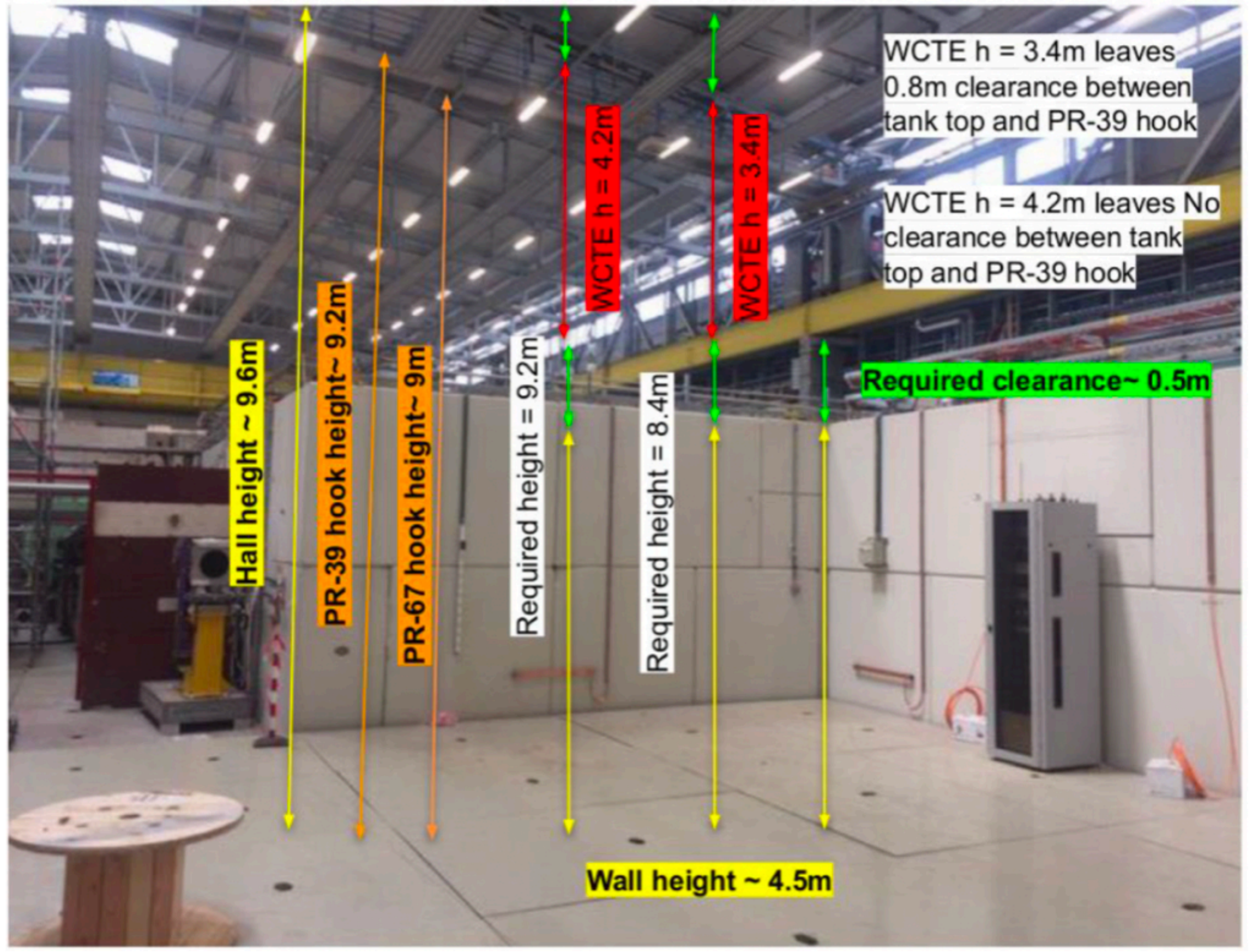


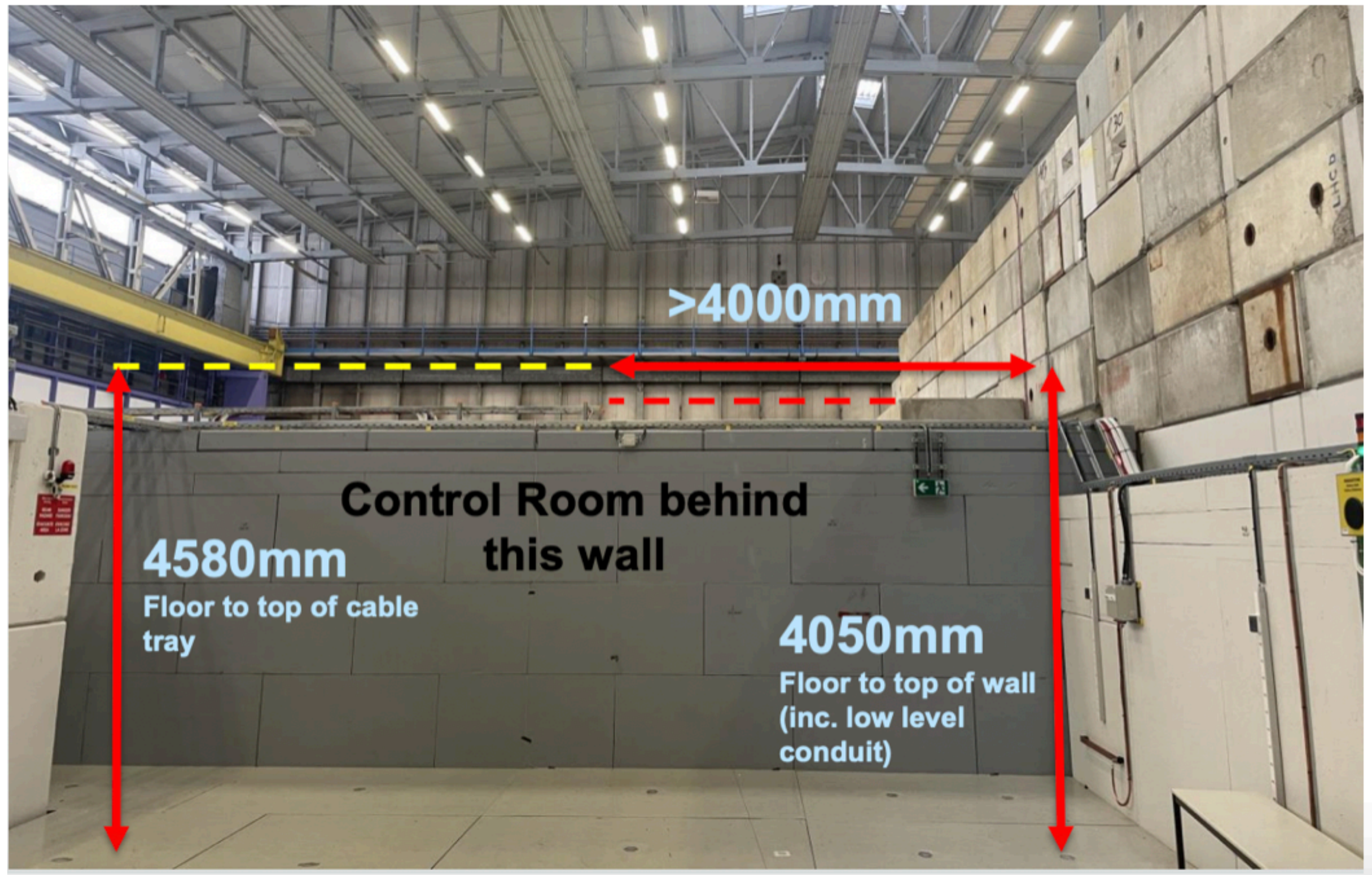
Topics Covered

- Detector dimensions and transport
- Development of the detector assembly procedure
- Beam configuration studies
- Detector development progress
- Schedule

Detector Dimensions Challenges

- WCTE detector will be lifted by crane into the T9 area
- Original height of 4.3 meters did not have enough clearance over the wall
  - Identified area (lower right) with extra 0.5 m of clearance, but not enough
  - Detector height must be reduced
- Detector diameter also needs to be reduced to <4 meters based on conversations with vendors about their capabilities to produce and transport tanks

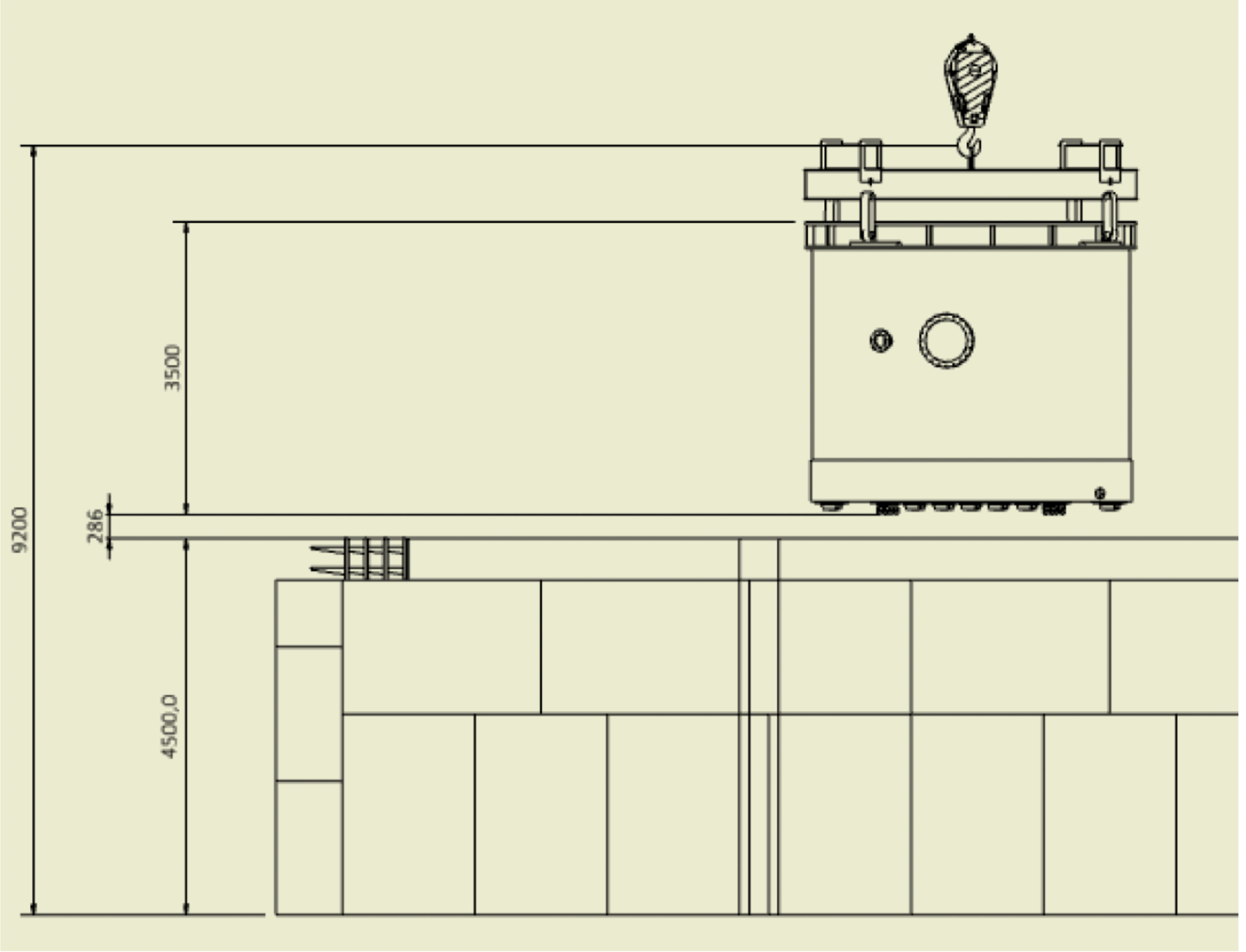




Detector Dimensions Change

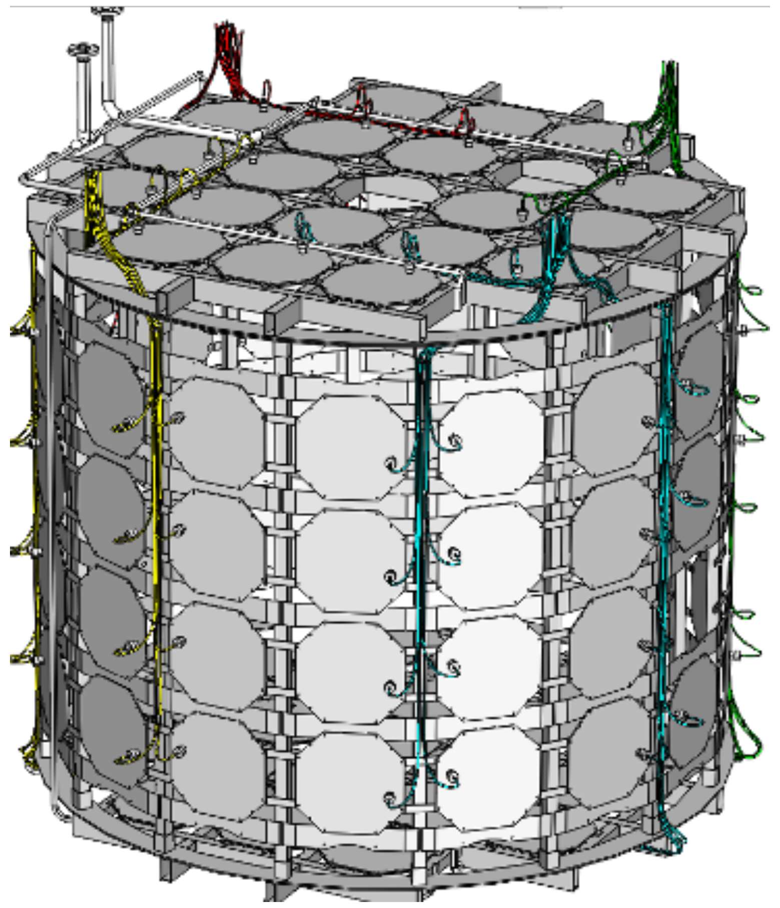
Config	Columns	Rows	Height (mm)	Diameter (mm)	ID height (mm)	ID diameter (mm)
Original	18	5	4320	4022	3539	3621
Reduced diam 1	18	5	4200	3800	3539	3439
Reduced diam 2 (16c-5r)	16	5	4200	3800	3539	3427
Reduced height and diam (16c-4r)	16	4	3400	3800	2739	3427

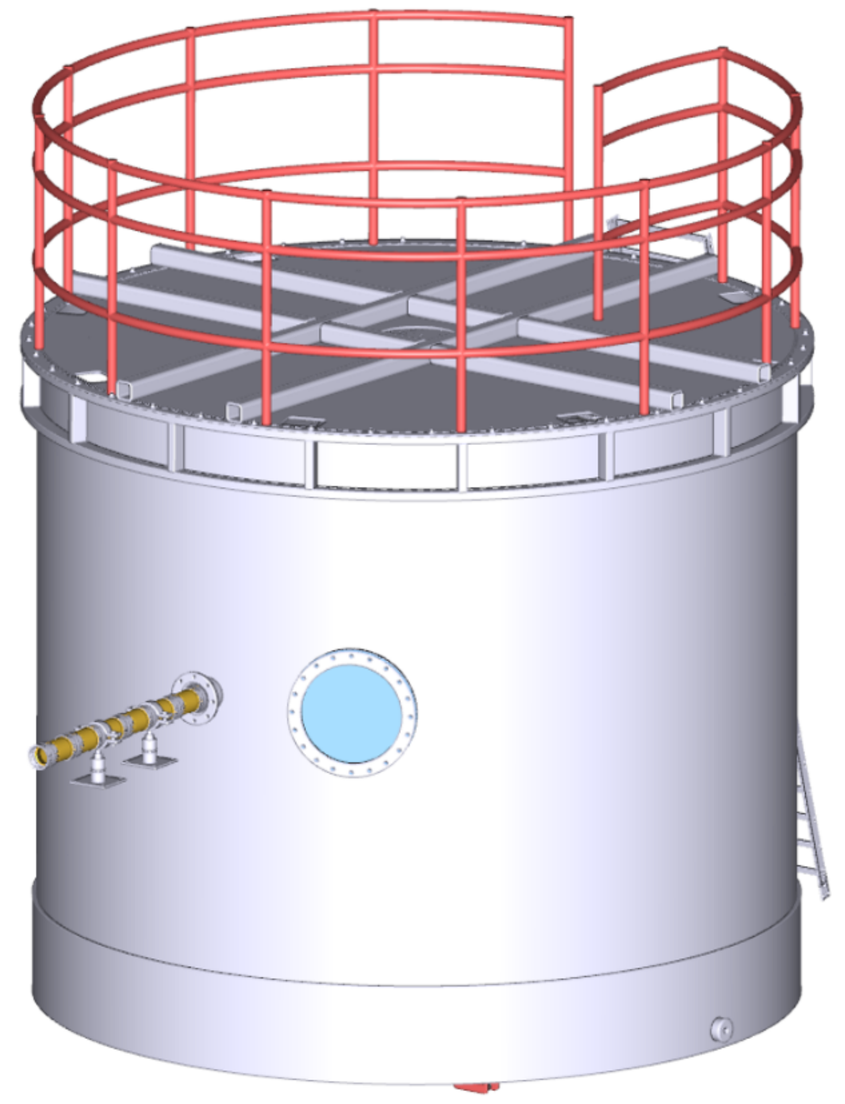
- Studied different detector configurations with reduced rows and columns of mPMTs
- Converged on reducing columns from 18 to 16 and reducing rows from 5 to 4
  - No significant degradation of reconstruction performance observed
- Even with reduction, care must be taken with design of lifting beam
  - In discussion with the Engineering Department Handling Engineering (EN-HE) group



Status of Tank and mPMT Structure

- In progress to finalize tank and mPMT support structure and integration of the rest of detector components:
- Tank design elements being finalized:
  - Integration with railing system
  - Final design of beam windows
  - Final design of the lid to integrate pipes, cables and CDS
- mPMT structure design elements being finalized :
  - Integration of water pipes
  - Cable routing
  - Mounting of photogrammetry cameras and lights
  - Mounting of mPMTs and black sheets
- Quotation from five Spanish companies interested in the project for the latest design of tank and mPMT-support structure
  - Manufacturing time of 3-4 months
  - Transport time of ~1 week

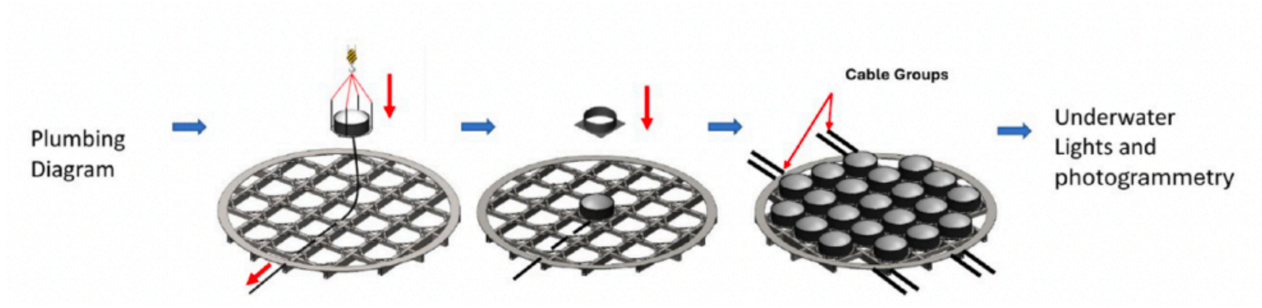


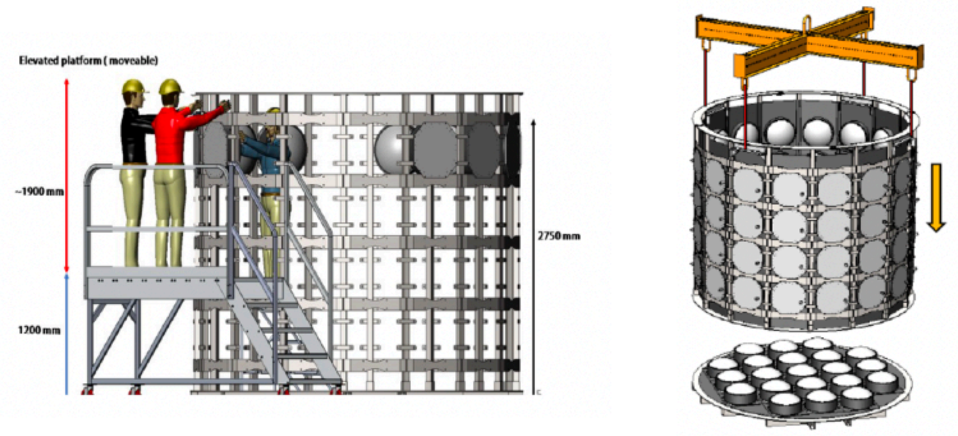


Detector Assembly Procedure

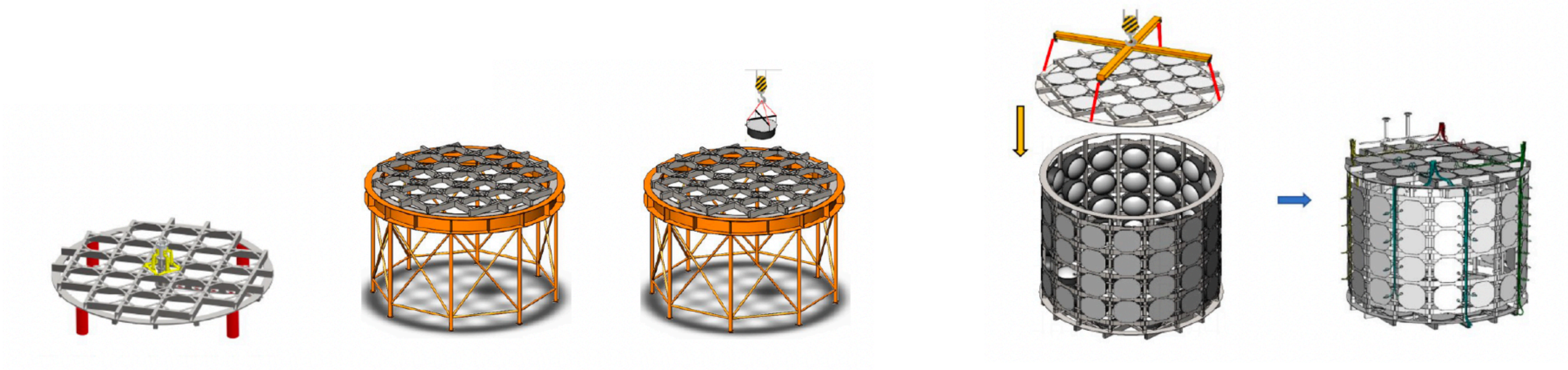
Barrel Installation

Bottom Endcap Installation



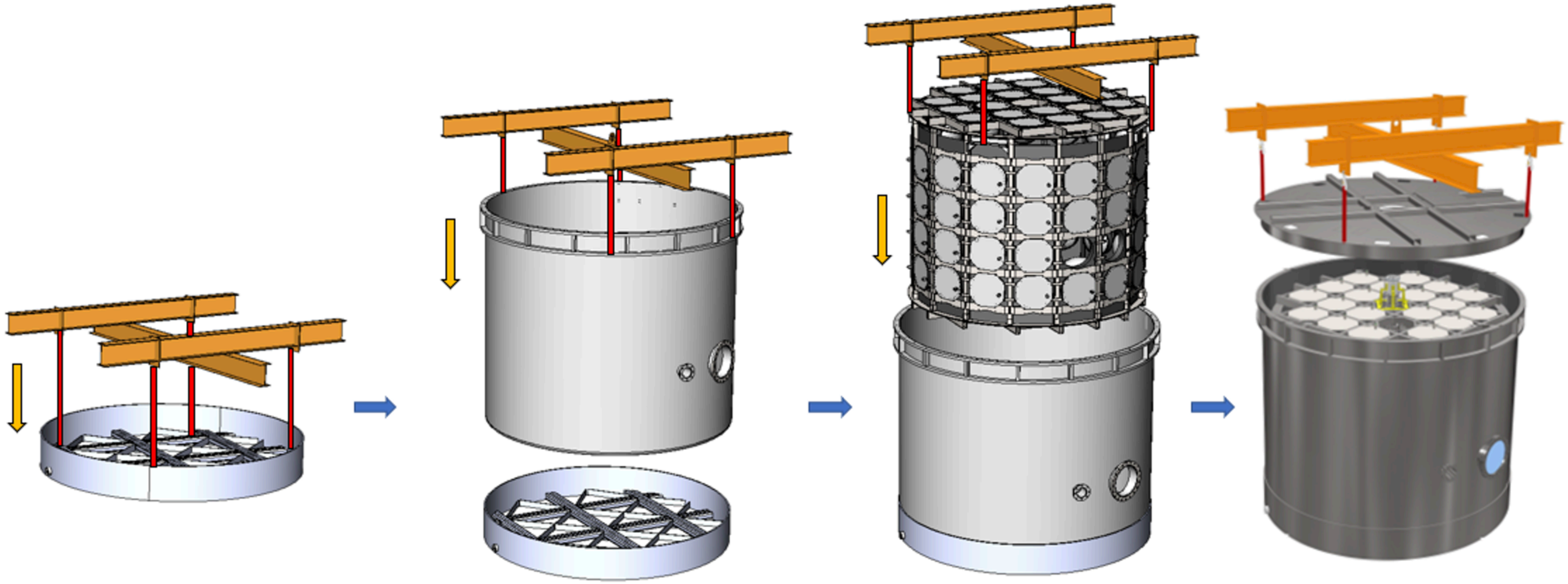


Top Endcap Installation



- Development of the detector assembly procedure is priority
- mPMTs will be installed on the bottom and top endcaps and barrel region of support structure separately
- We won’t use welding, but rather fasteners and braces to attach the barrel and endcaps
- We will need a raised platform for workers installing the top mPMTs on the barrel
- We will need a structure hold the top endcap during mPMT installation

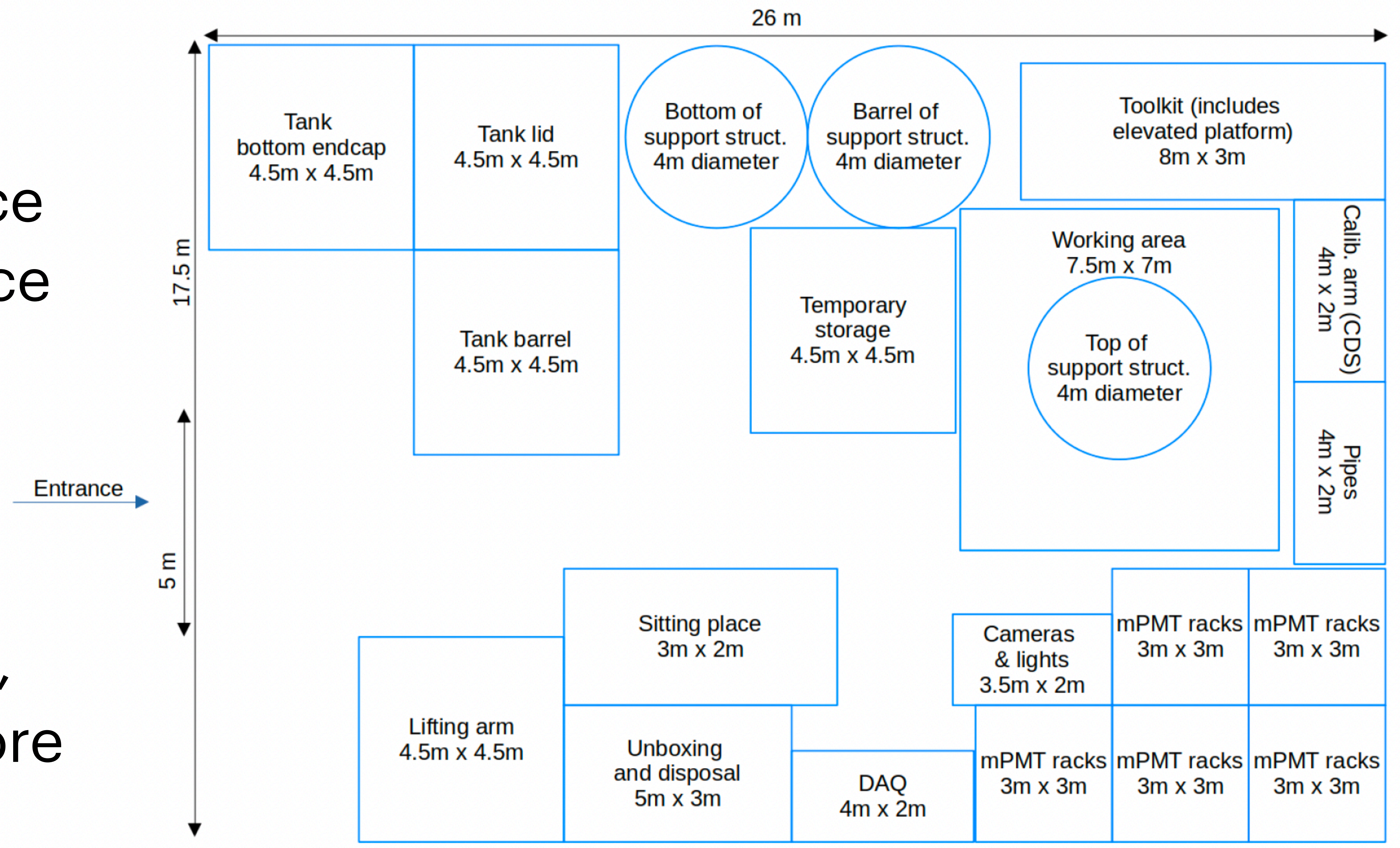
Detector Lifting



- The base structure, tank, populated support structure and lid will all be lifted into the experimental area separately
- The lifting points are being designed so that the same lifting beam can be used
- This requires transport of the populated support structure from the assembly to the experimental area while not yet installed in the tank

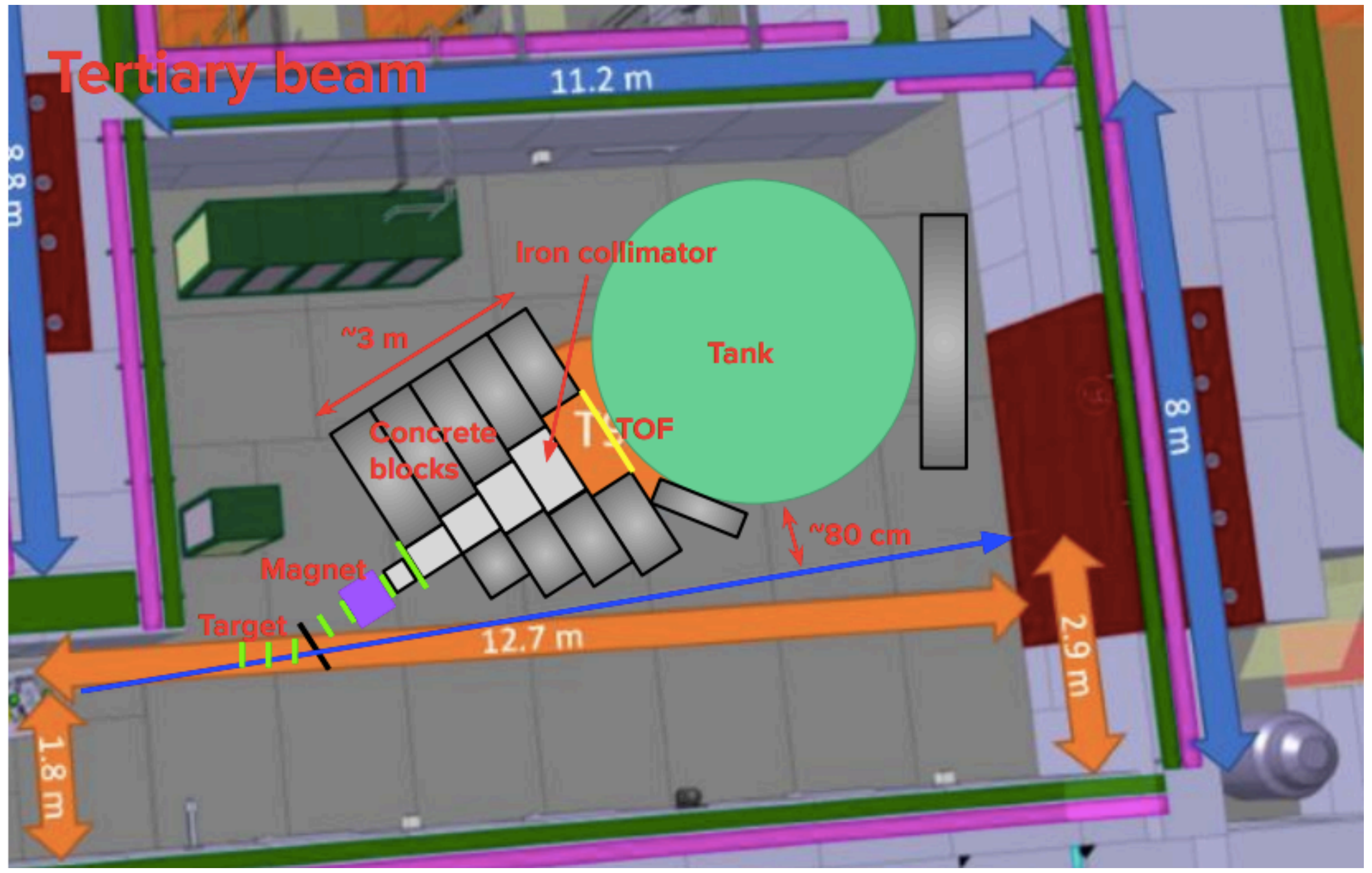
Assembly Area

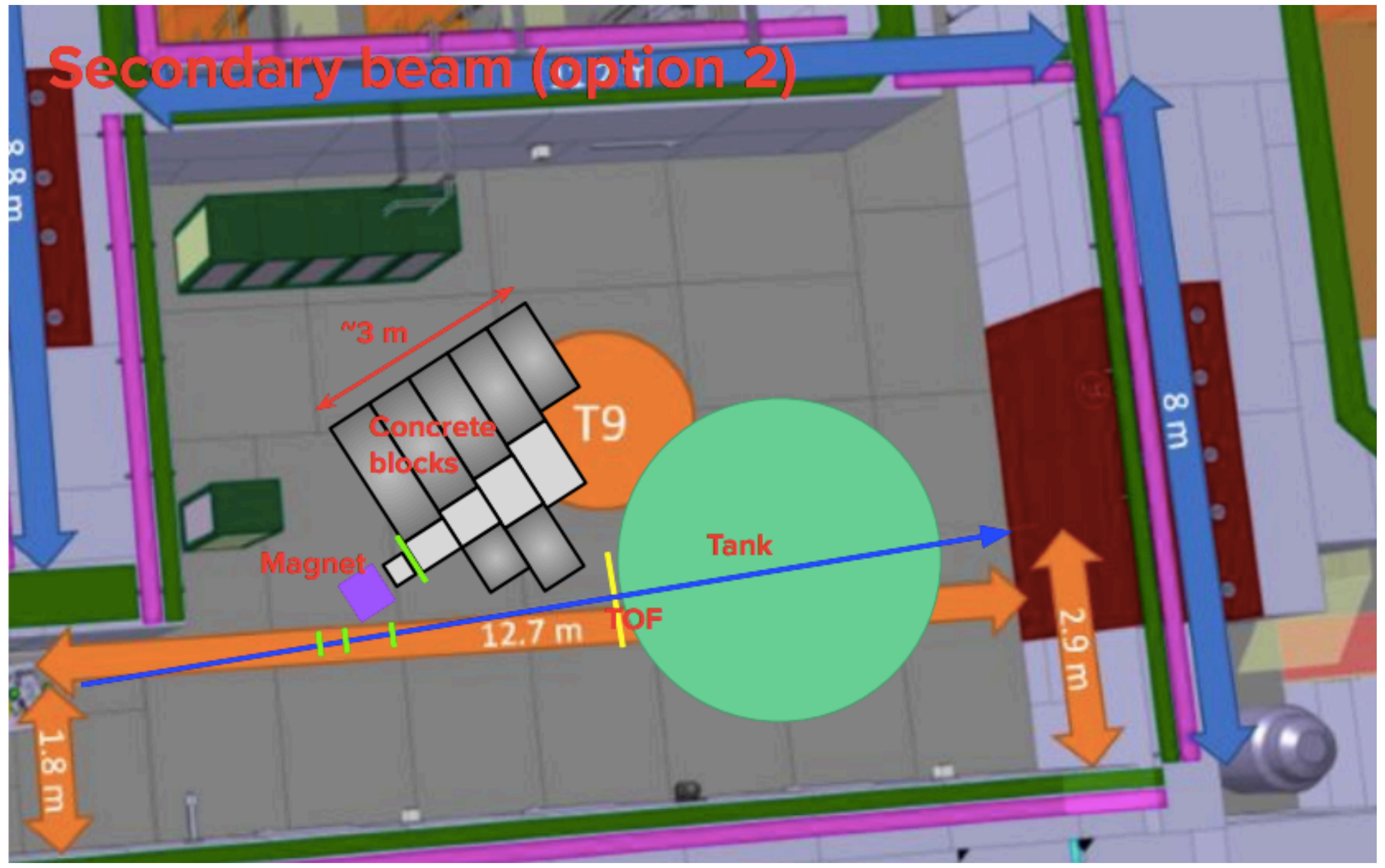
- We are updating our requirements for the assembly area
- Requirements have not changed too much since the proposal, but we likely need more floor space
  - Original proposal: 15 m × 15 m
  - Updated estimate: 17.5 m × 26 m
  - Accommodates separate storage of the tank, base structure, lid and support structure before transport
- We are preparing an assembly document that we will share with the EP-Space group



Experimental Beam Configurations

- Based on the capabilities of the pre-upgrade T9 beam, we designed the experiment with two configurations
- **Tertiary** - a tertiary production target ~3 m upstream of the detector with a spectrometer and collimator
  - Access particle momenta below 400 MeV/c
- **Secondary** - the detector sits directly in the secondary beam line
  - Best configuration for electron and muon fluxes
- Two configurations add complexity:
  - Two beam windows
  - Rail system to move detector
  - Spectrometer and collimator for tertiary configuration

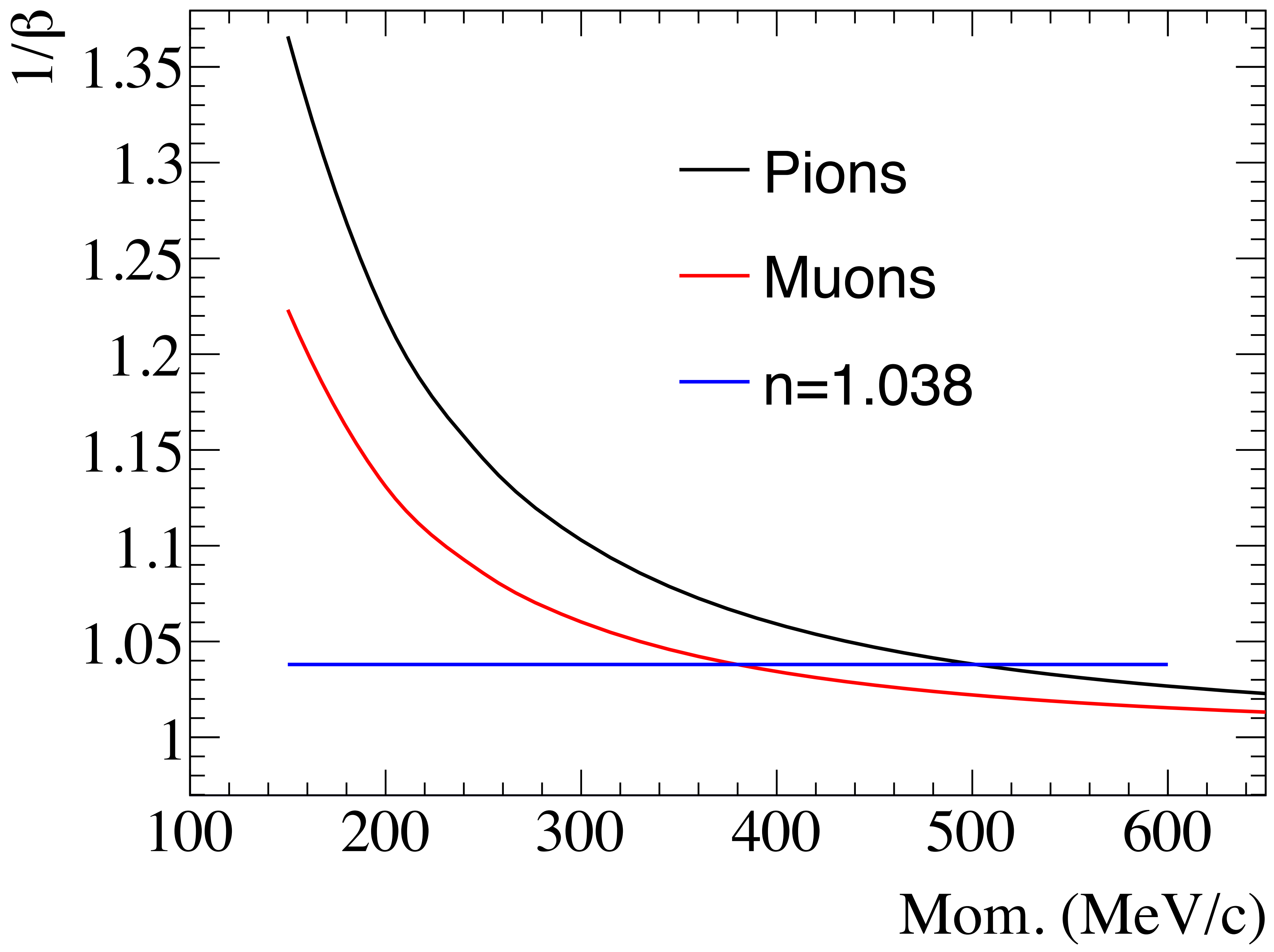




Low Momentum Secondary Beam

- At our December 2021 visit to CERN, we learned that low momentum operation for the T9 magnets below 200 MeV/c is possible
- This raised the question of whether low momentum particle fluxes in the secondary beam would be enough for WCTE
- If so, it would reduce the experimental complexity significantly and remove the need to move the detector
- Major concerns:
    - Are the non-electron components of the beam enough, particularly pions
    - Can we carry out particle identification, particularly between pions and muons well enough
        - Use combination of time-of-flight and aerogel Cherenkov threshold detectors (ACT)

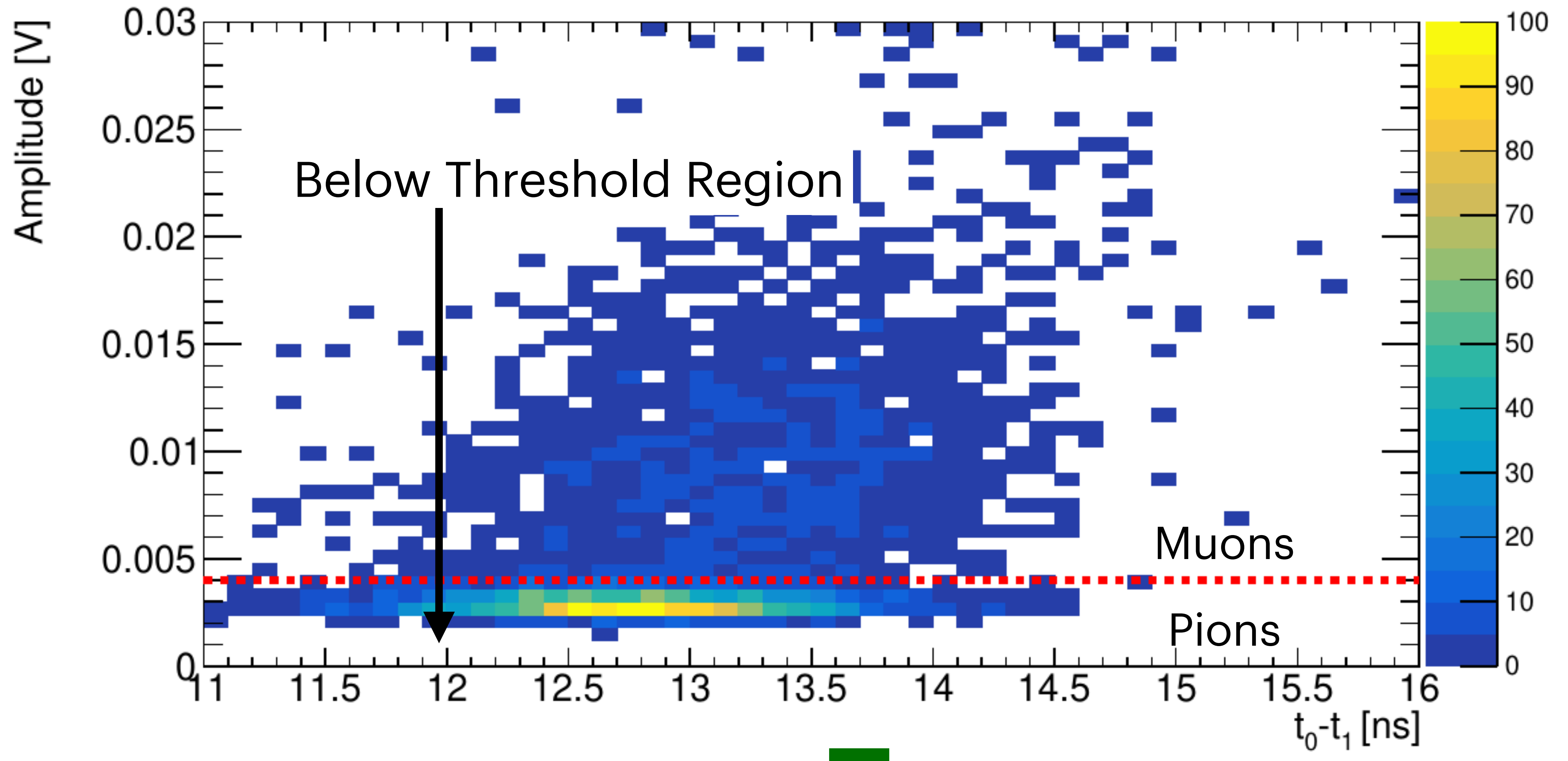
Beam Test in March

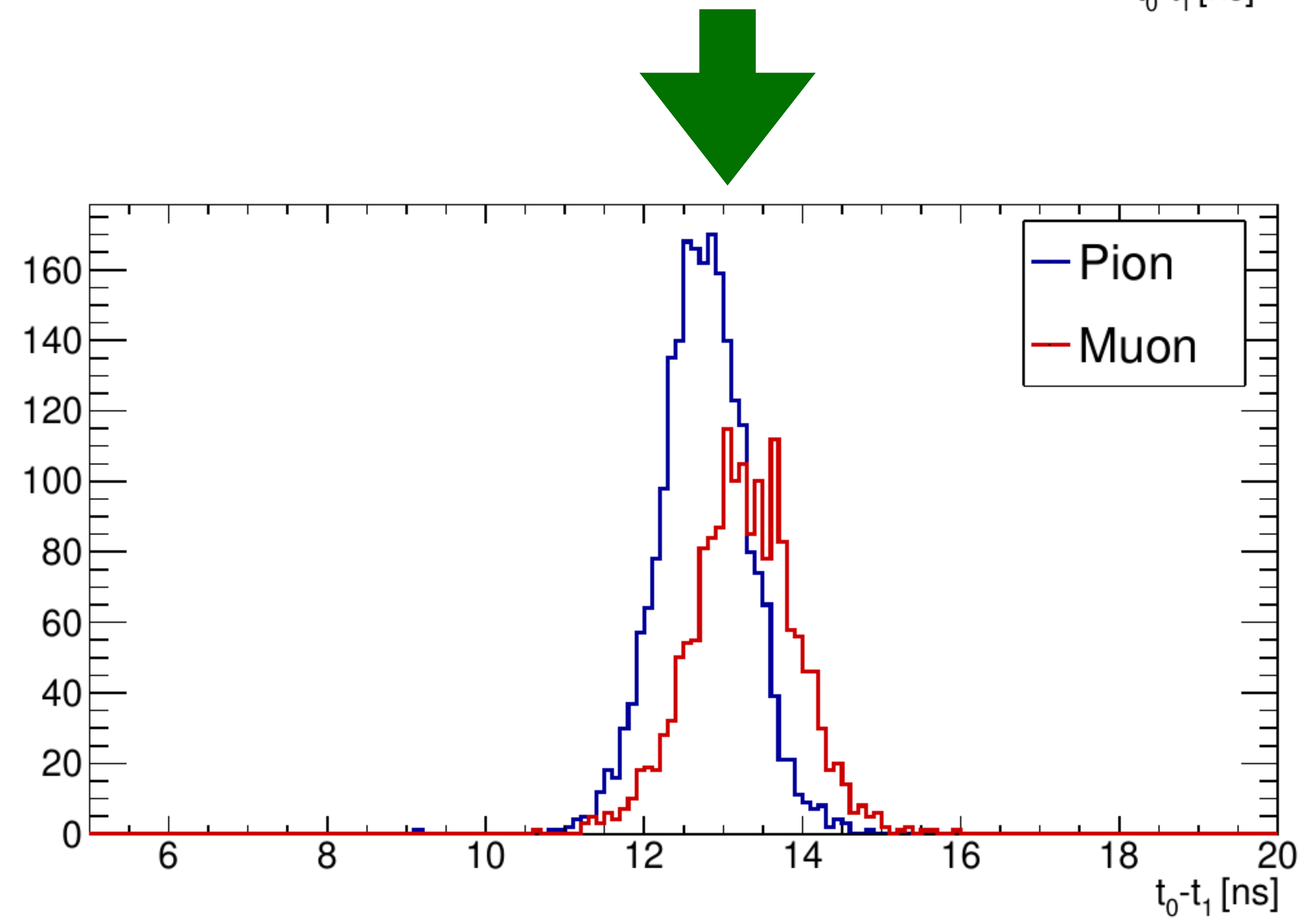


- We took low momentum data in the T9 beam line during the beam commissioning in March
- We used an ACT (above left) with n=1.038 to help study pion and muon fractions
  - Separation of pions and muons around 450 MeV/c (above right)
- We used the T9 scintillator detectors to measure TOF

Particle Identification Performance

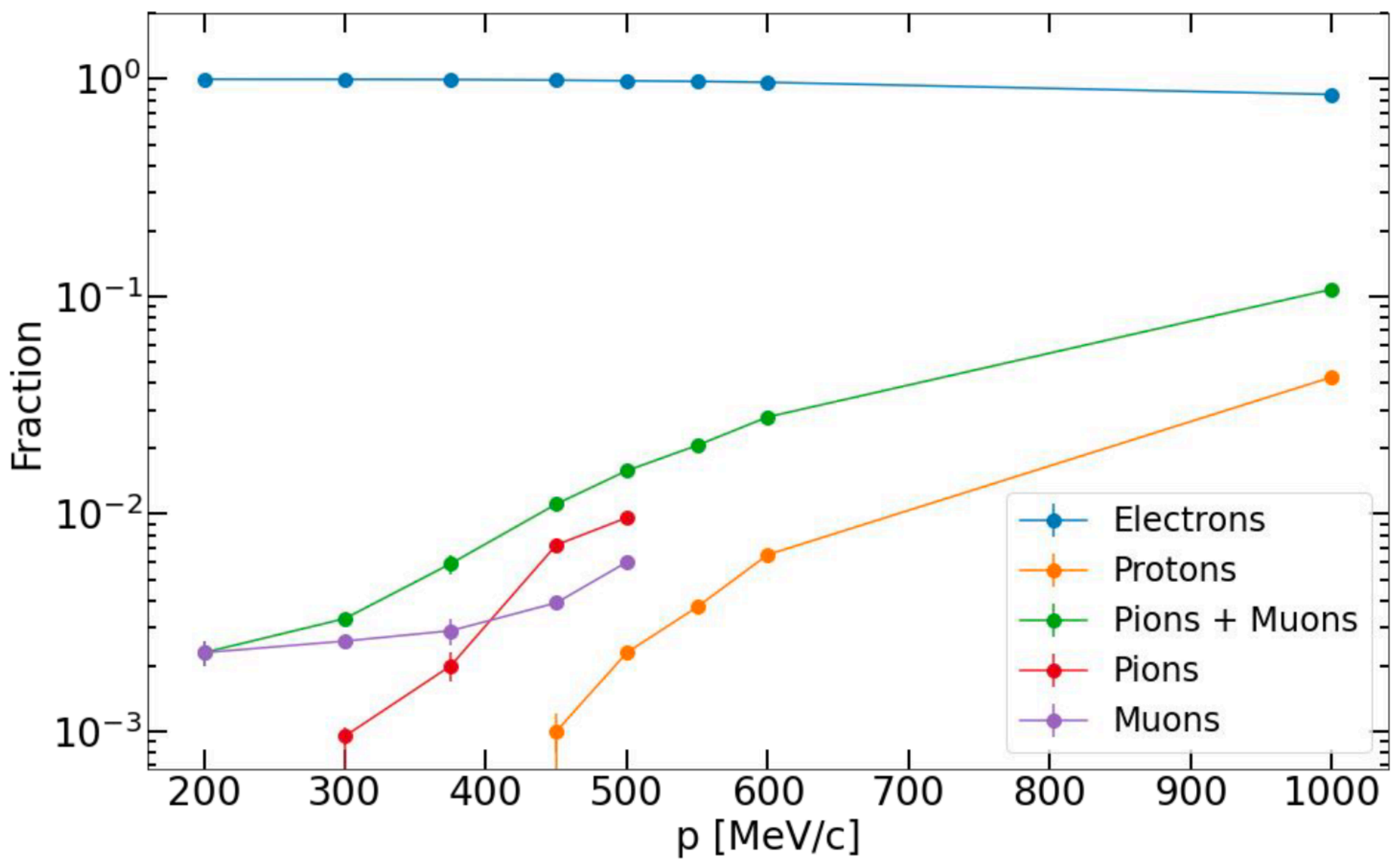
- We study the ACT monitor signal vs. The TOF measurement
- We see a correlation between the two
  - Below threshold particles have a TOF that is consistent with pions, while above threshold are consistent with muons
- PID performance will need to be improved for WCTE operation
  - Thicker aerogel and multiple PMT readout for ACT
  - Better timing resolution for TOF



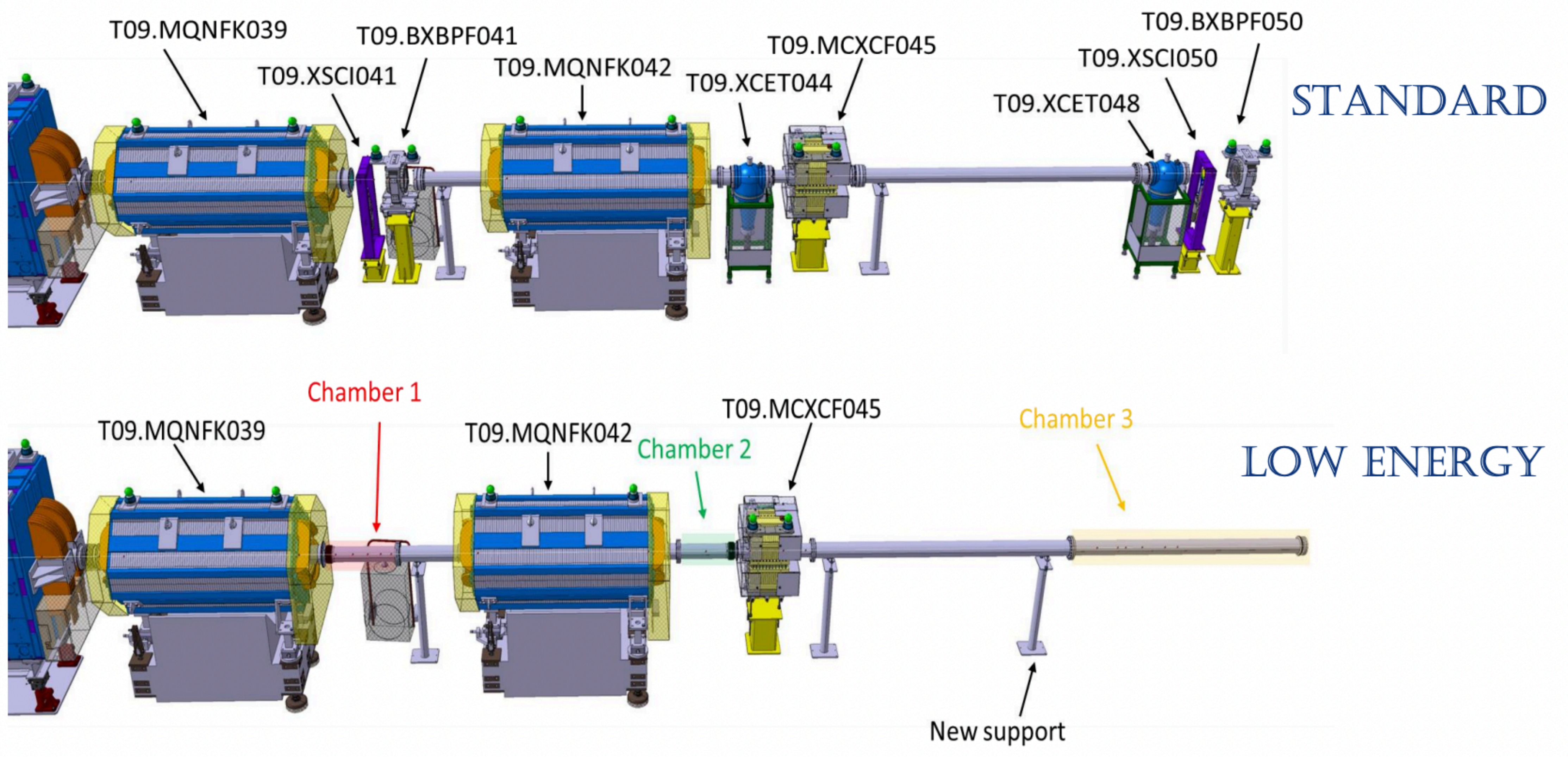


Beam Test Results

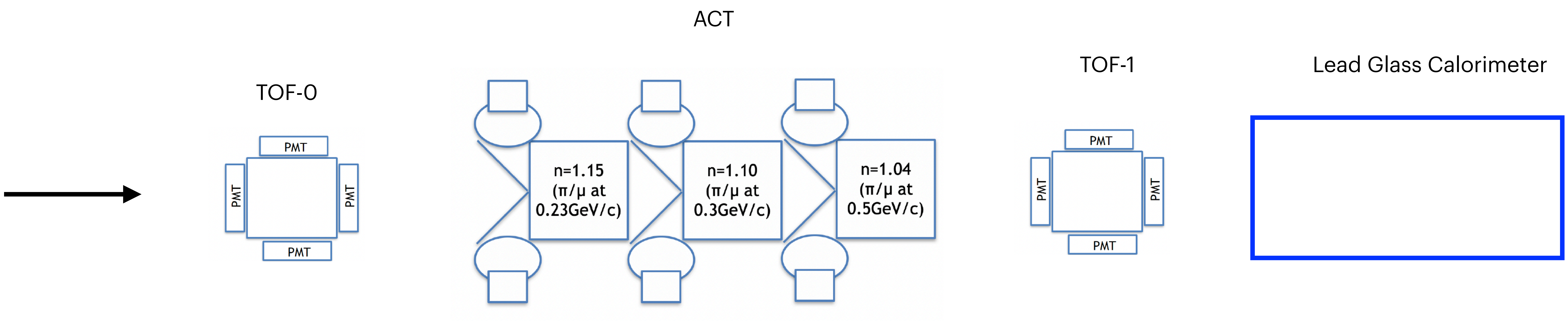
- Measured beam composition shows that electrons make up more than 99% of the beam below 450 MeV/c
- Simulation studies confirmed that there was too much material in the beam line for optimal low momentum operation in July
- This low momentum configuration is already designed into and available for the T9 beam line



https://edms.cern.ch/document/2370892



Beam Test in July



- We learned that the beam will be changed to low momentum configuration for the SHERPA beam time in July
- Beam is available on July 13-19, after SHERPA
- We are readying a simple beam measurement configuration with improved TOF detectors (readout from all sides) and two additional ACT detector

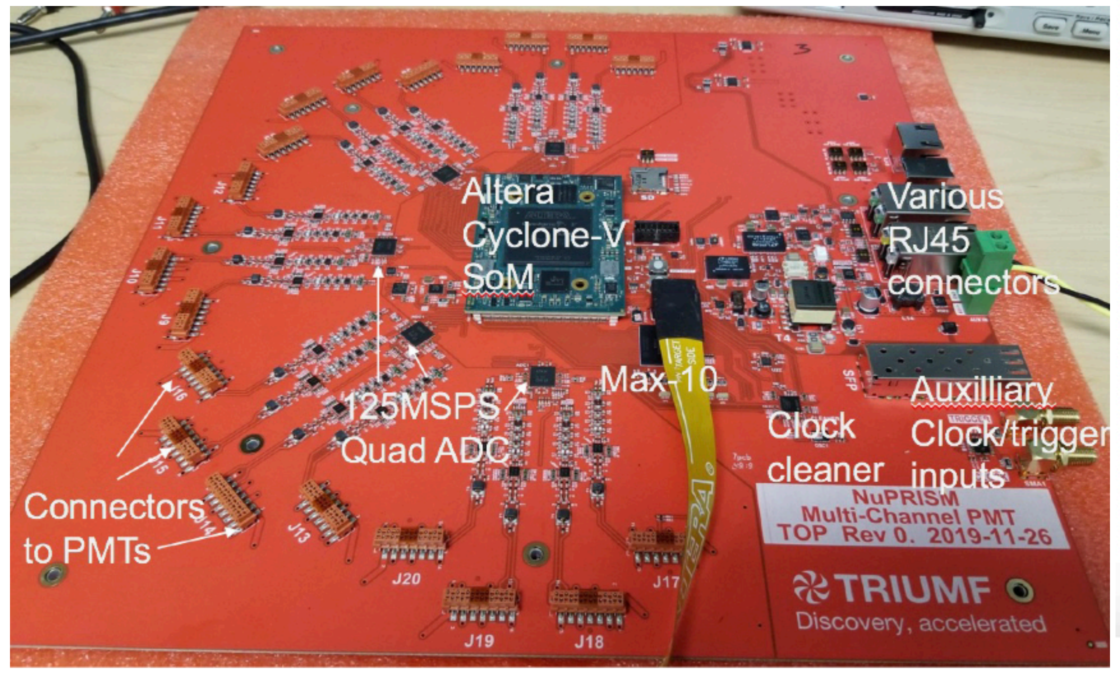
Environment & Safety

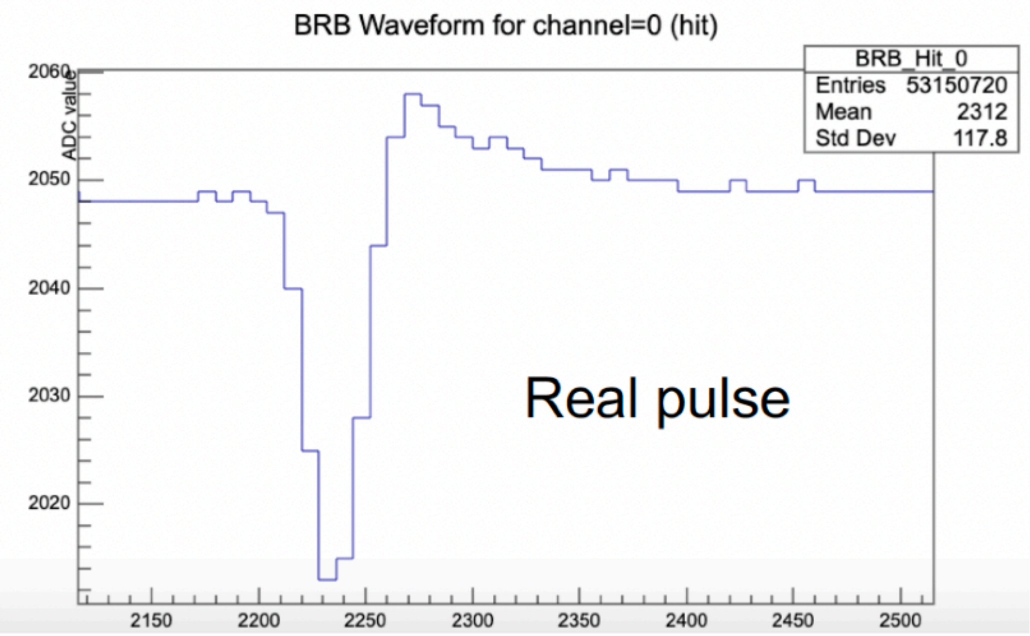
- We completed the Initial Safety Declaration and had the Launch Safety Discussion
- Safety contact for WCTE is Stefania Bordoni (University of Geneva)
- Outstanding issues that require further discussion
  - Disposal of the water after removal of the gadolinium sulfate leaving 0.14% sodium sulfate to be discussed with experts
  - Recapture of gas from the RPC time-of-flight detector to minimize the release of SF_6
- We are collecting the necessary information for the next stage of discussion on these topics
  - Working towards more detailed design of water system
  - Investigating the gas recovery capabilities in the East Hall

mPMT Update

- Functional electronics mainboard prototypes are produced and tested
- Progress to finalize design for pre-production prototype to be completed this summer
- Mechanical design is focused on methods of optical gel application applied before or after assembly
- Major delays encountered due to long lead times on procurement of components including electronics components and optical gel

Electronics main board





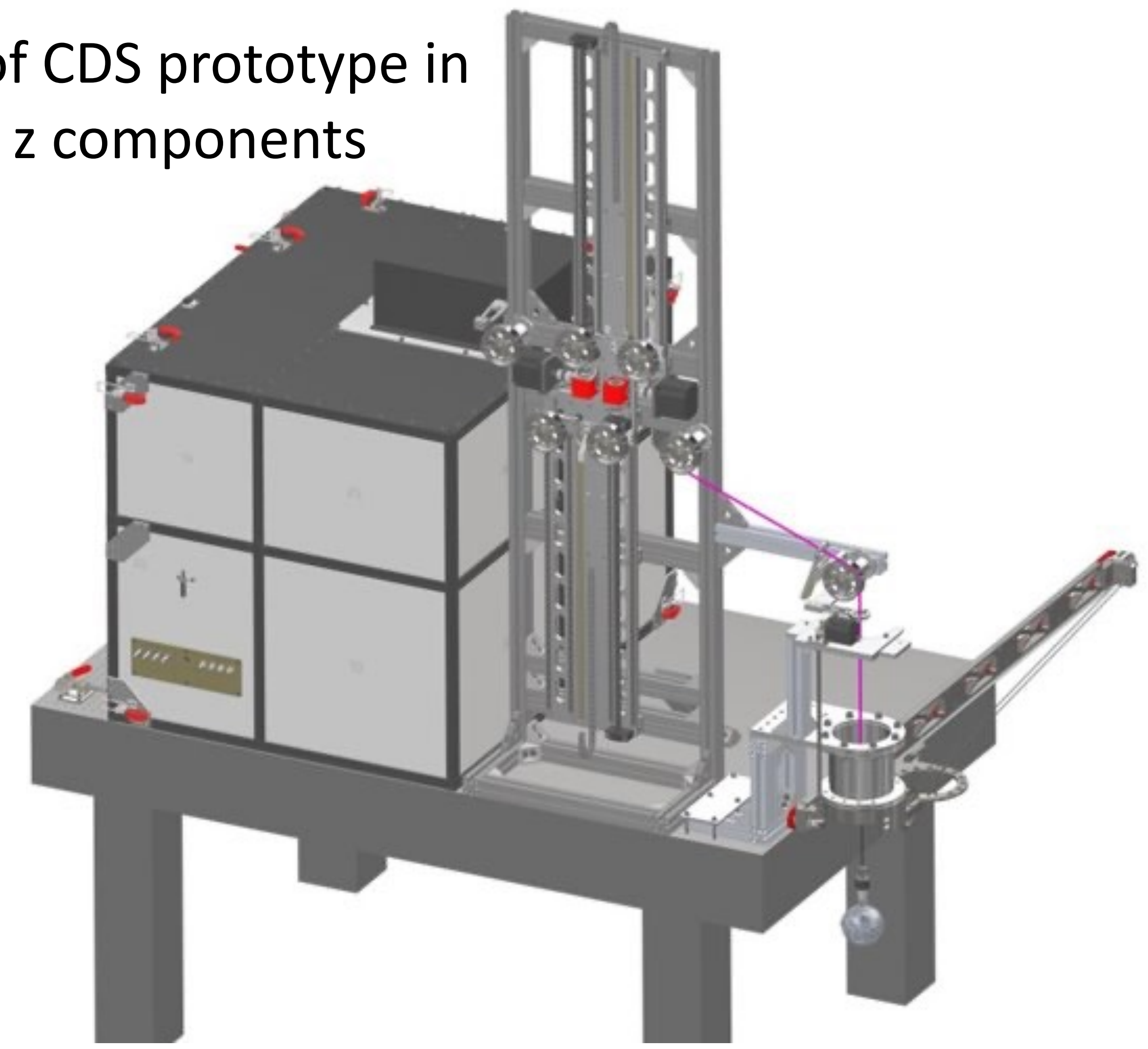
Ex-situ gel application prototype

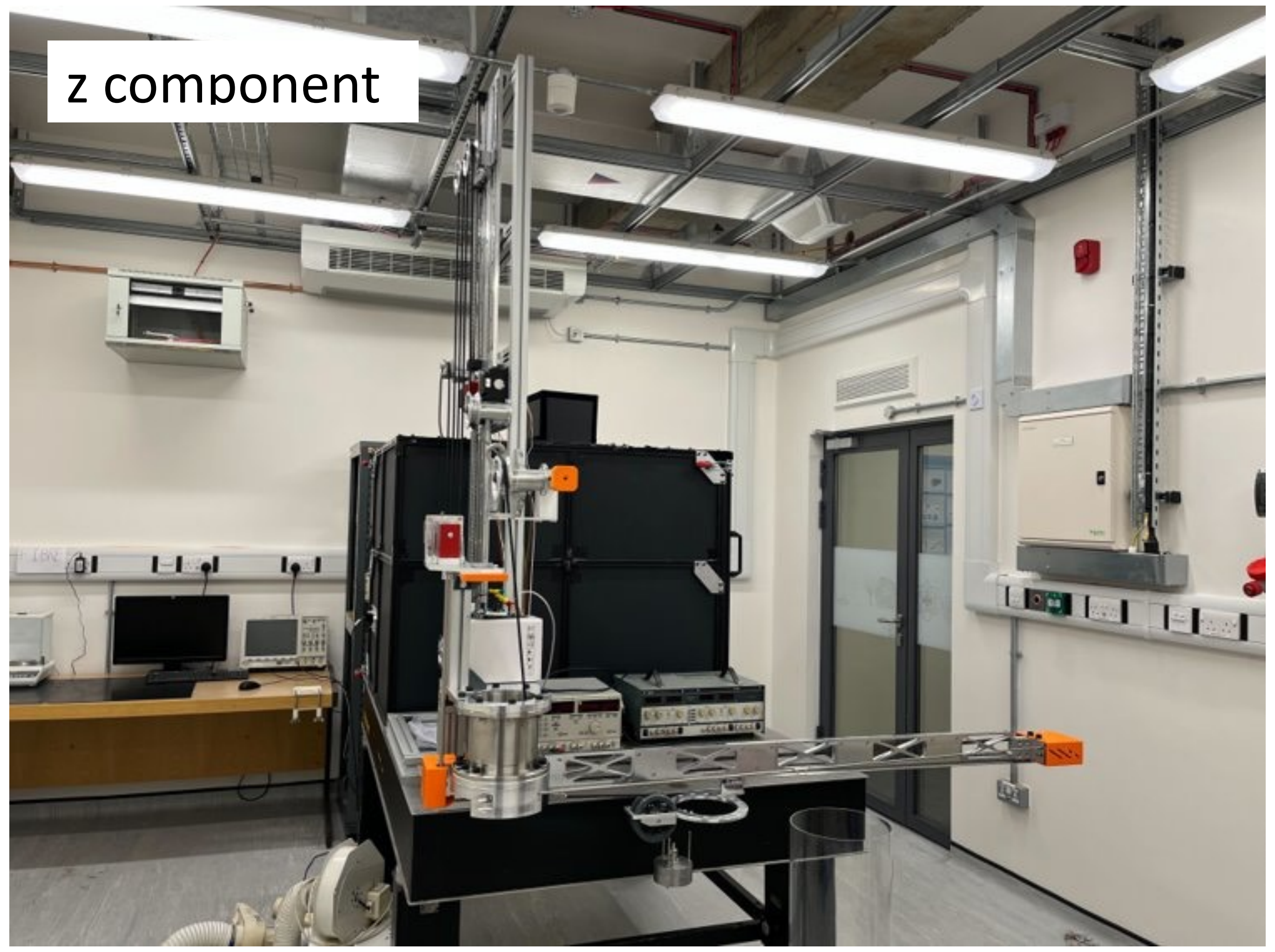
In-situ gel application prototype

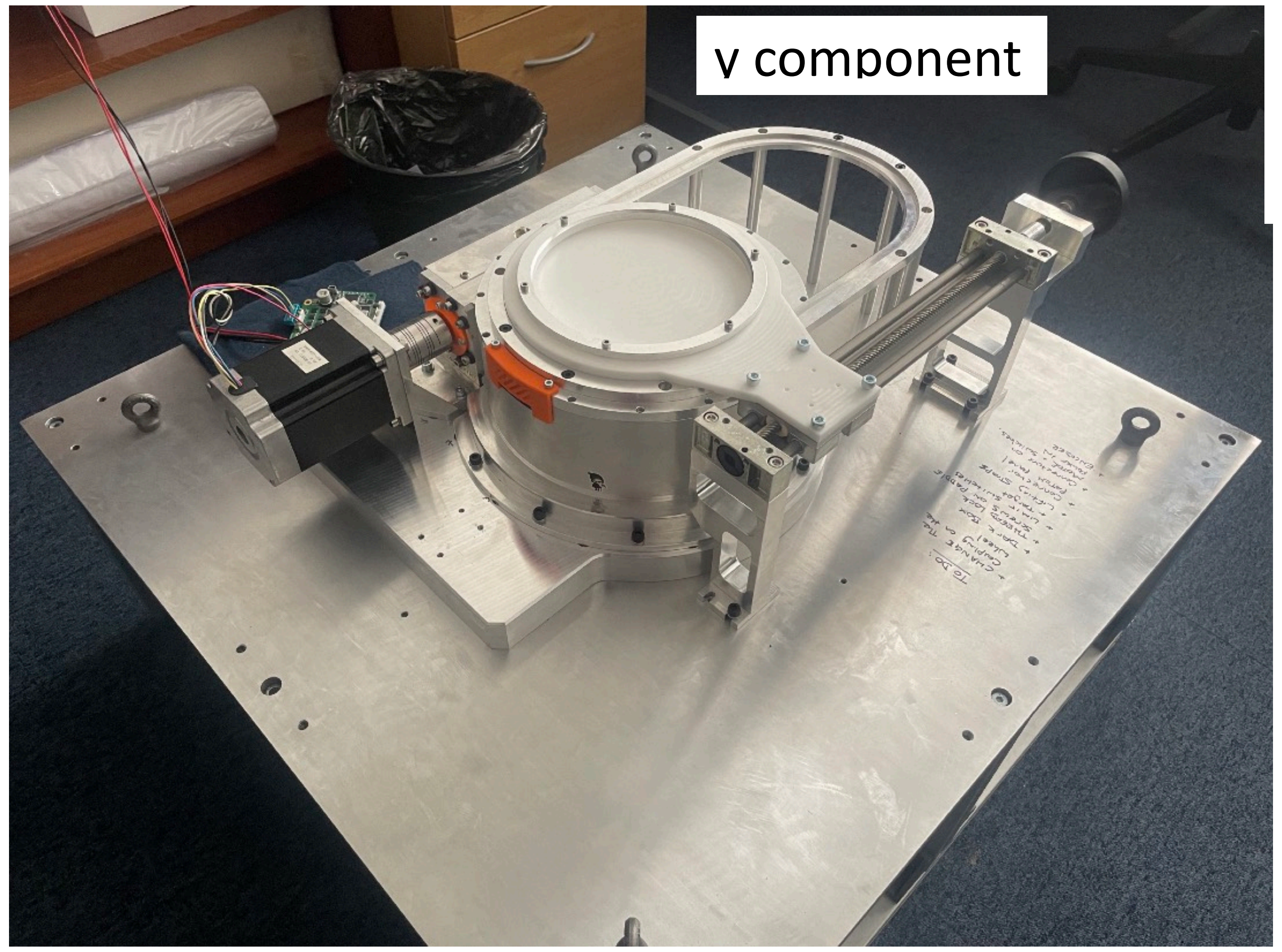
CDS Calibration System

- Prototype of the central deployment system (CDS) has been built and manufactured at Imperial college
- A light sealed unit has also been built and will be used to characterize and measure the uniformity of the laser diffuser ball
- Prototypes of the diffuser ball are currently being made
- A mock up of the shaft in the detector through which the calibration sources will be deployed has also been made to test the "drop of calibration sources into the detector"

Concept of CDS prototype in lab (x and z components shown)







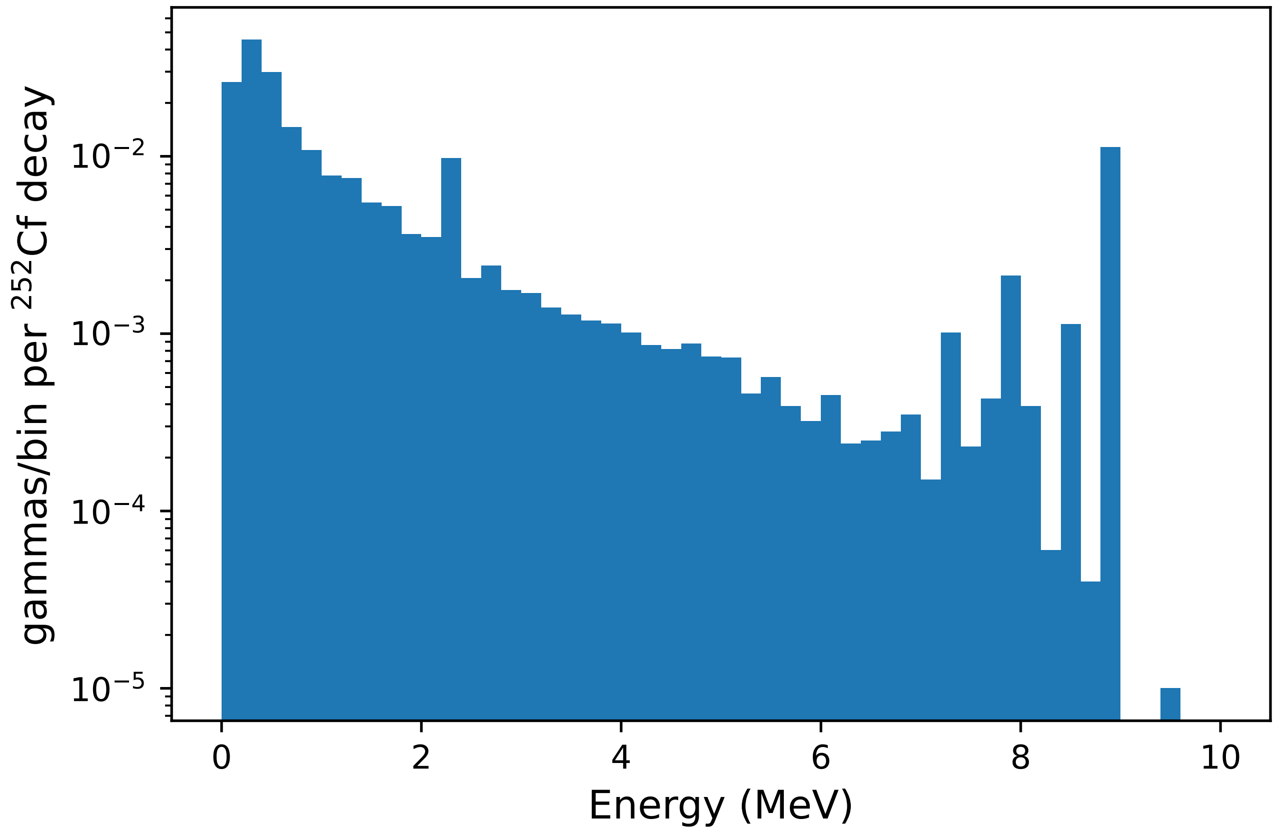
Prototype diffuser ball and preload mass
(not yet filled with optical gel)

Radioactive Calibration Sources

Gamma source - Ni/Cf

- Goal is an isotropic source of gamma rays leading to single photon events for PMT calibration
- WCTE source, similar to previous SK design: 13.5 cm diameter, NiO + polyethylene mixed with epoxy; ^{252}Cf source held by brass rod in center of sphere
- ^{252}Cf decay provides neutrons: Thermal neutron capture on nickel: ^{58}Ni(n,γ)^{59}Ni (~9 MeV in gamma energy)
- Currently preparing materials for prototype sphere to understand construction process

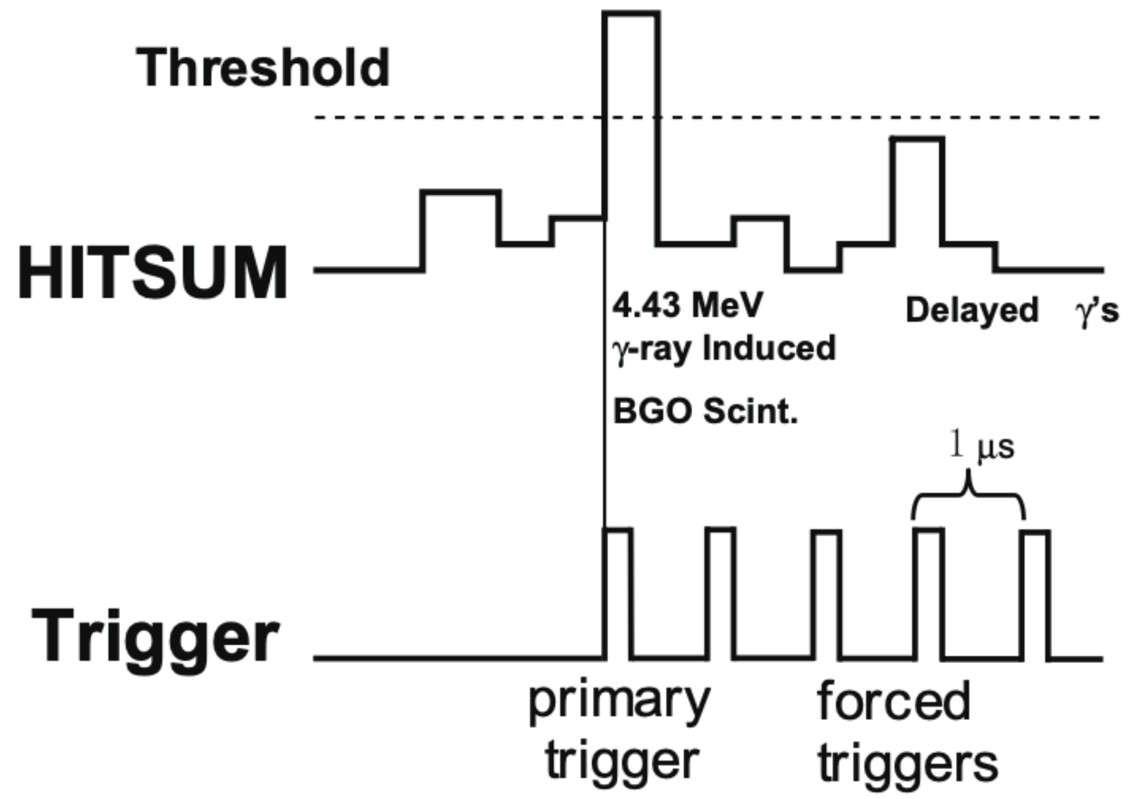
Nickel source used in SuperK (https://arxiv.org/abs/1307.0162)



Gamma ray spectrum from simulated (Geant4) NiCf source with diameter 13.5 cm between 0 - 10 MeV

Neutron source - Am/Be

- In SK: acrylic case containing BGO scintillators surrounding an AmBe neutron source
- Tagging (~4.4 MeV gamma emitted in coincidence with a large fraction of neutrons) may be done by PMTs
- Currently considering a similar source for WCTE (potentially a cylindrical crystal with AmBe source embedded)

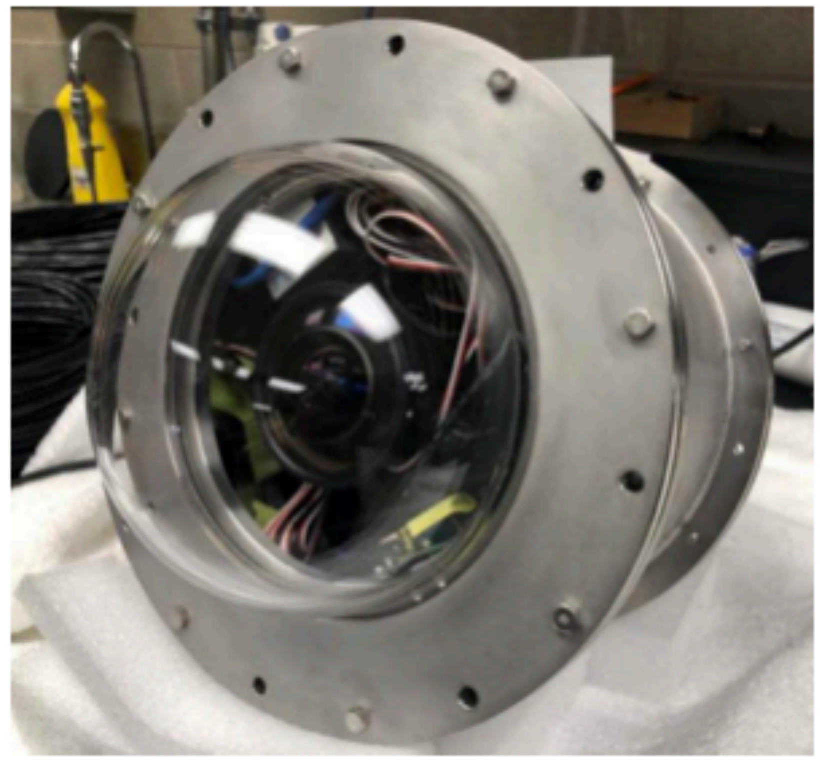


Tagging: trigger on sum of analog PMT signals within 200 ns, from H. Watanabe et al. Astropart. Phys. 31, 320 (2009).

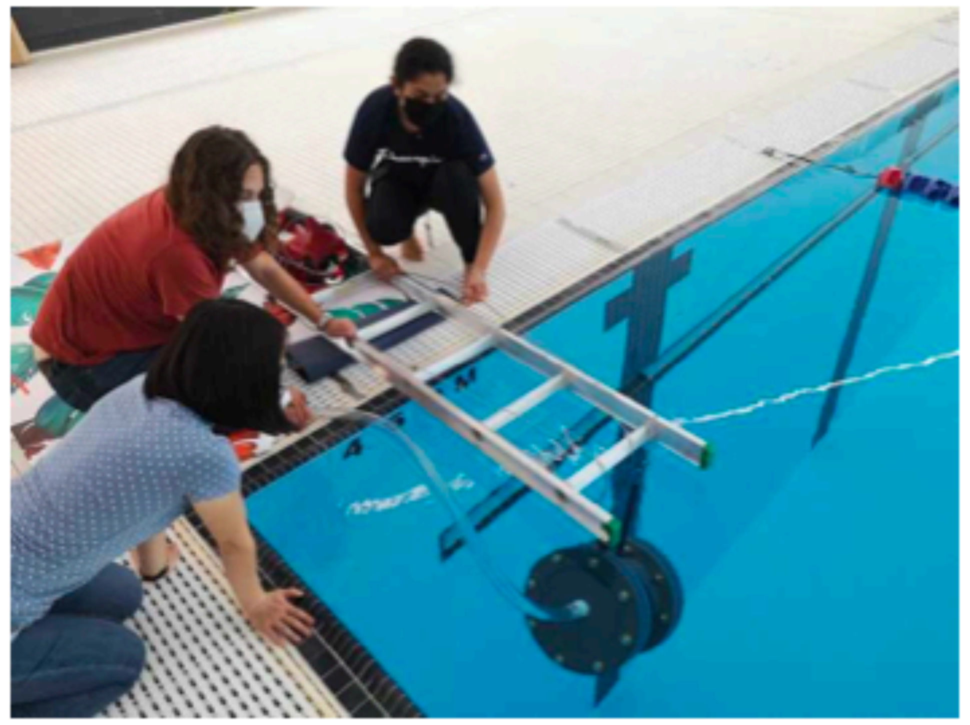
Photogrammetry System

- Use standard cameras and lenses with custom-built underwater vessels for fixed cameras
- Ongoing tests at the UBC pool to characterize the optics under water
- Tests of the vessel at necessary pressures for Hyper-K detector are planned
- Prototype readout system has been developed and being tested
- Photogrammetry simulation of detectors under development - choose the best location of cameras in detectors

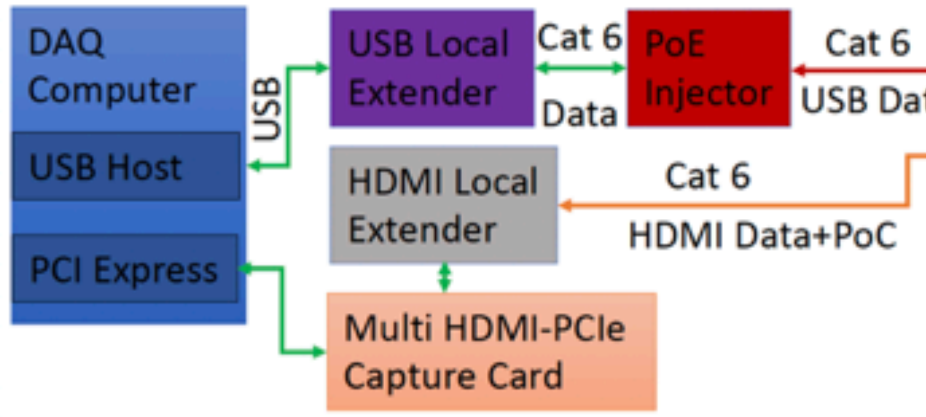
Prototype camera housing

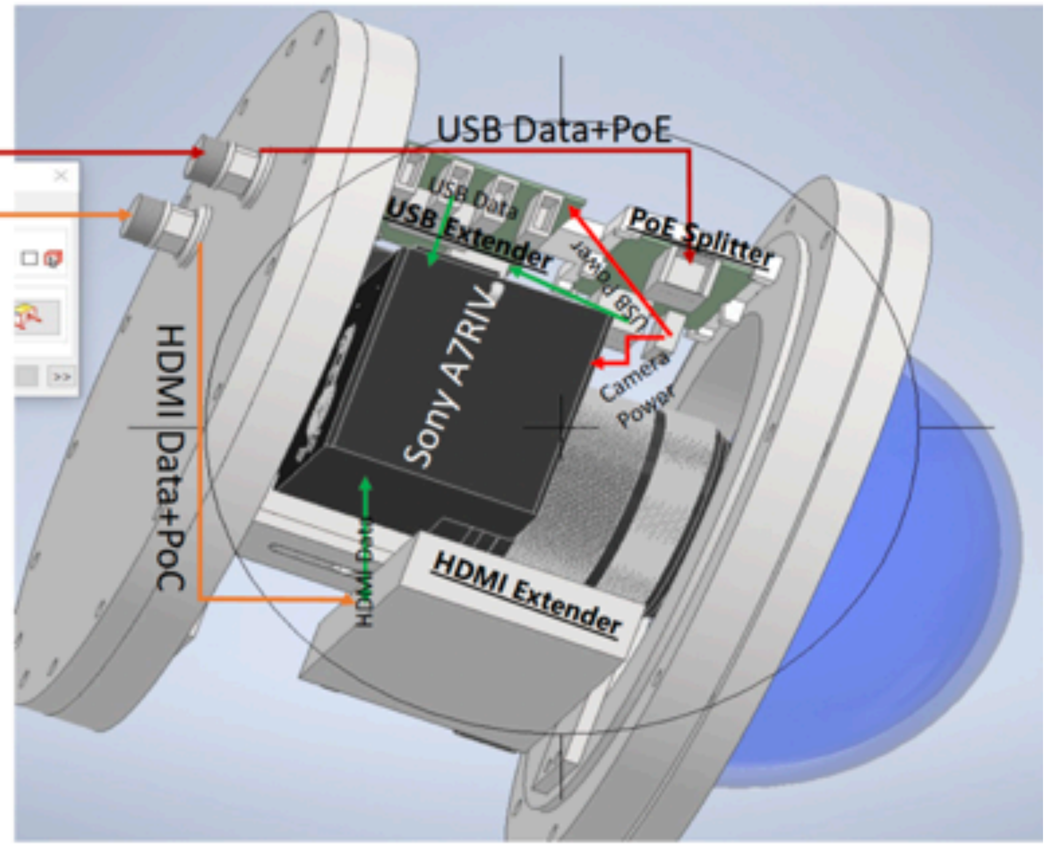


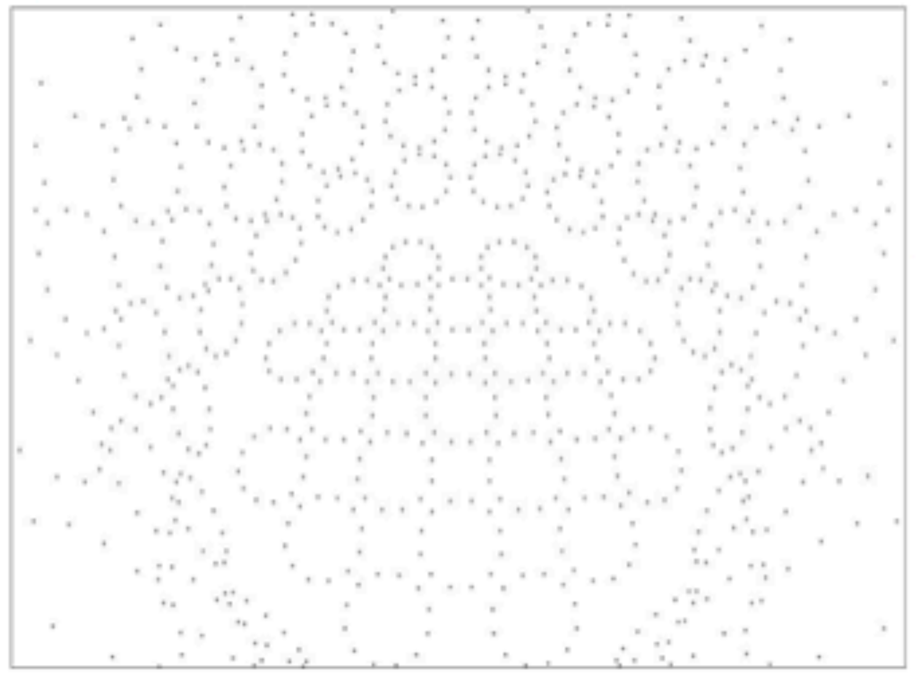
Measurements at UBC Pool



Camera readout (under development)



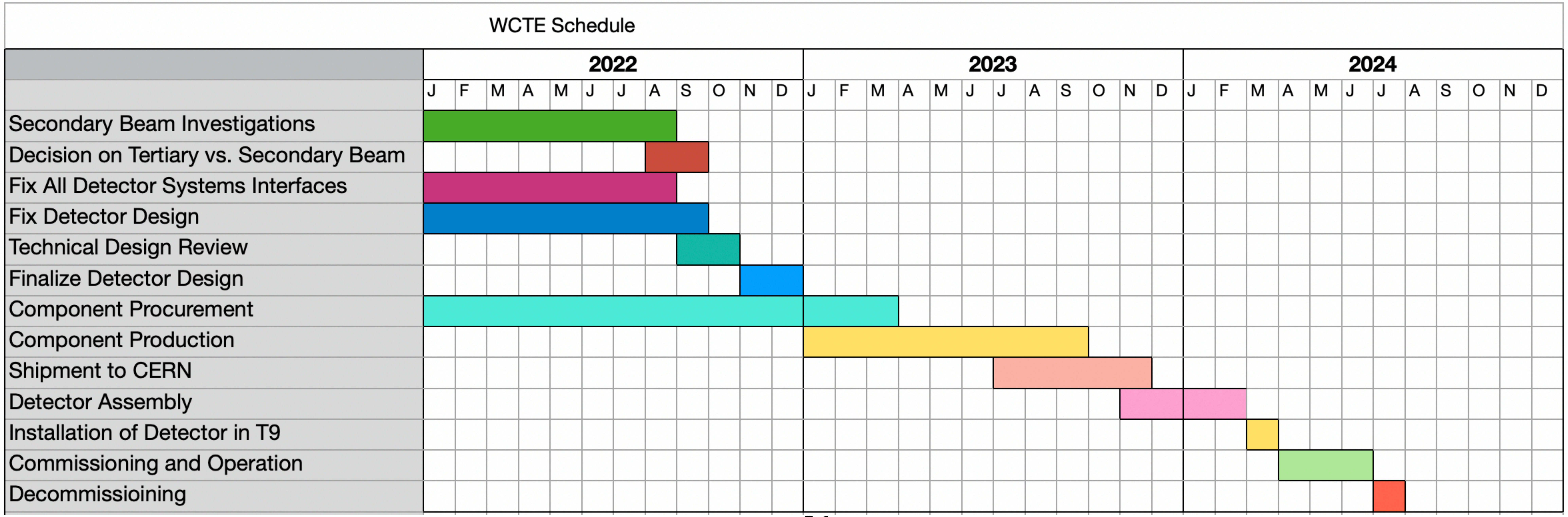




LED beacons from simulation

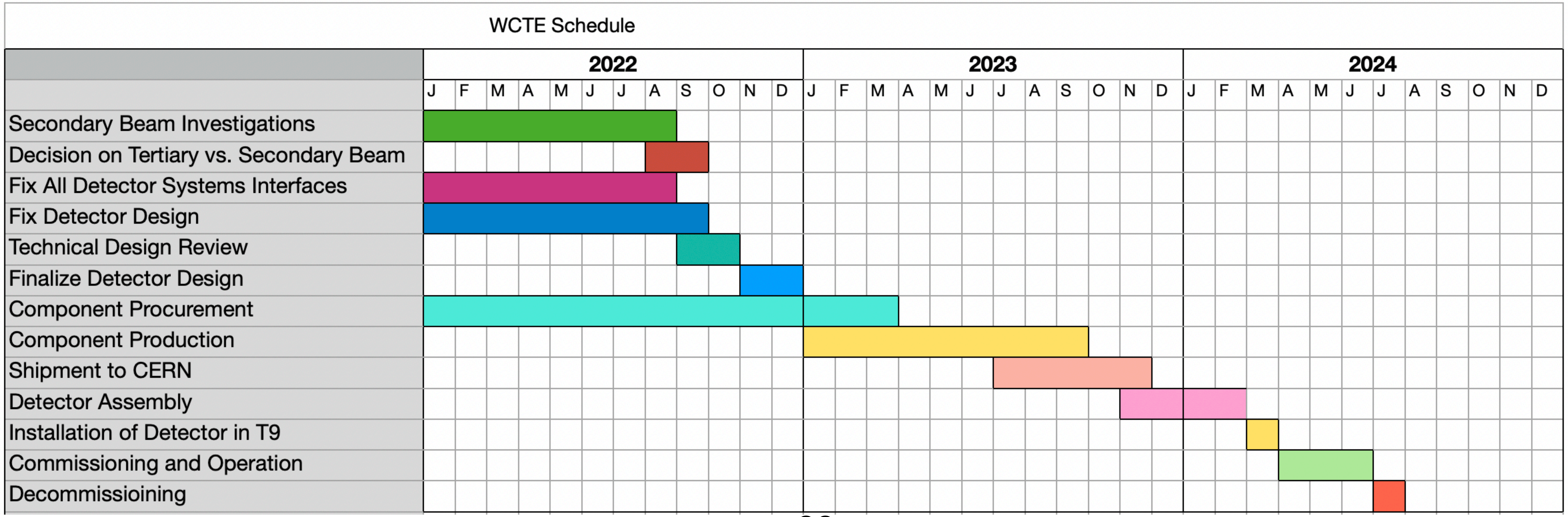
Schedule

- The schedule in the WCTE proposal assumed detector assembly starting in late 2022 and operation of the WCTE from the start of beam in 2023
- Based on the impact of COVID-19 on detector development and the impact of global supply chain shortages, we need to delay WCTE by 1 year
- We plan to start the detector assembly in November 2023 with the start of operation in April 2024



Schedule, Cont.

- Proceeding to a final detector design requires a decision about whether we operate in both secondary and tertiary configurations or just secondary
  - We aim to make a decision by the end of September 2022 based on the data collected in July
- We plan to have completed the detector design and released a technical design report by the end of 2022



Summary

- The WCTE collaboration is working hard toward finalizing the design of the experiment in 2022
- Significant progress on the development of detector systems with prototype production and testing for many systems
- Investigation of operation in secondary beam only is critical to complete the experiment's design
  - Aim to make a decision by September 2022
- The impact of COVID-19 and global supply shortages have caused delays
  - Propose 1-year delay for construction and operation of WCTE
  - Plan operation from April 2024