WCTE Collaboration Meeting Closeout

Mark Hartz

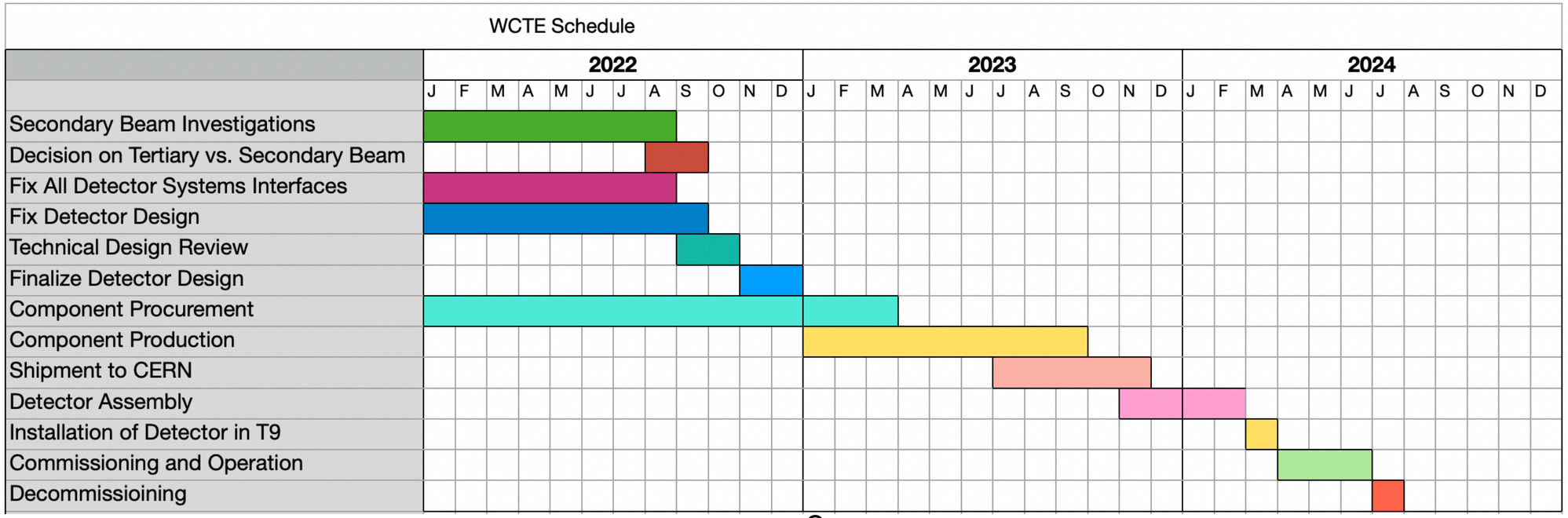
WCTE Collaboration Meeting, July 22, 2022

Meeting Closing

- Thanks to everyone for joining and contributing to the meeting
- It was a great opportunity for many people to finally meet in-person either for the first time or after a couple of years
- We identified a number of areas of critical work and important decision points that will be the focus in the coming months (more on following slides)
- With approval of the experiment, we are working towards completion of the MoU with CERN
    - Will follow up with country/institutional representatives in coming weeks
- The in-person/hybrid meeting at CERN appears to be a success.
    - Another meeting in November/December? Will send out poll.

Schedule

- We are aiming for WCTE construction in late 2023 and operation with the start of beam in 2024 (could be as early as February)
- To meet this schedule, we need to finalize the design by the end of 2022
- Activities in the coming months to answer major questions necessary to complete the design

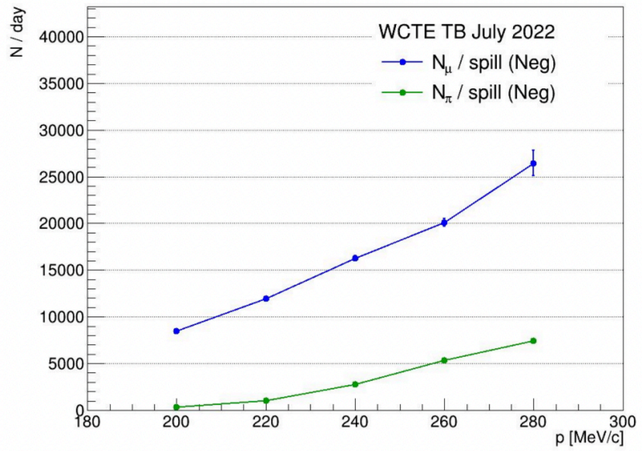


Beam Configuration Decision

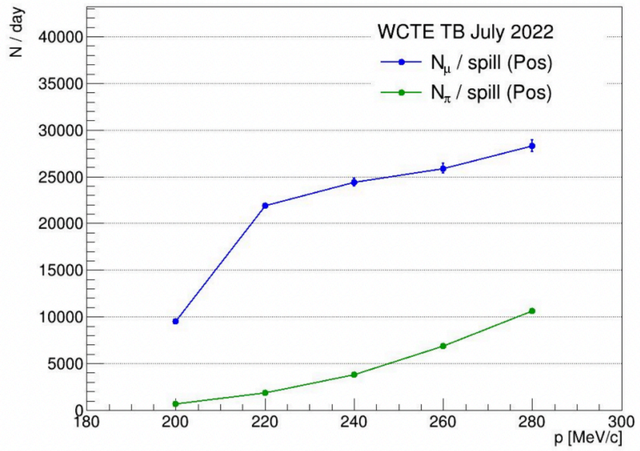
- Do we run in tertiary and secondary configurations, or only secondary?
- Preliminary data from beam measurements over that past couple of weeks are promising:

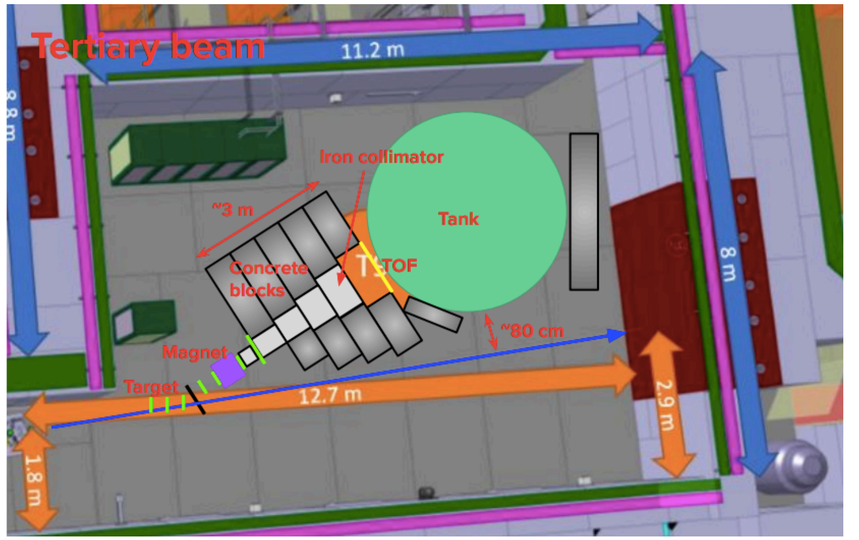
  - Assuming 40s between spills (conservative assumption, typically the rate is 2x).
  - @200MeV Neg: 400 π^- / day :: @220MeV Neg: 1000 π^- / day.
  - @200MeV Pos: 700 π^+ / day :: @220MeV Pos: 1800 π^+ / day.

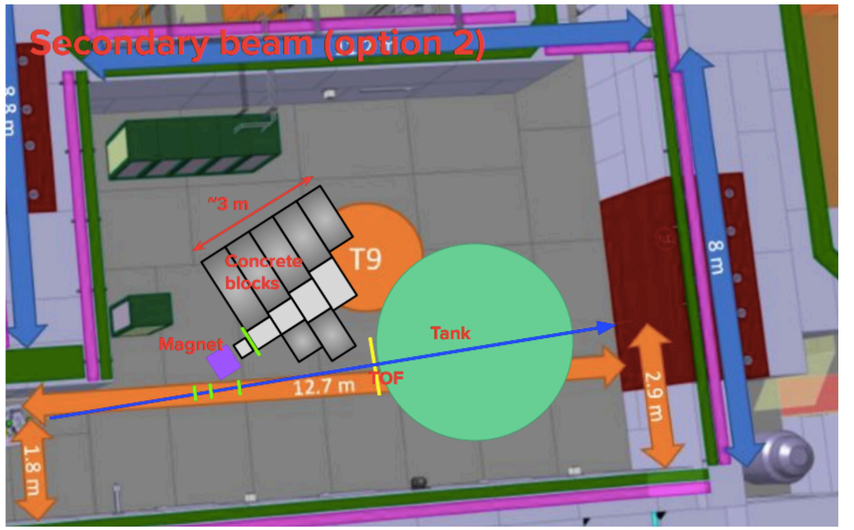
Negatively charged particles



Positively charged particles

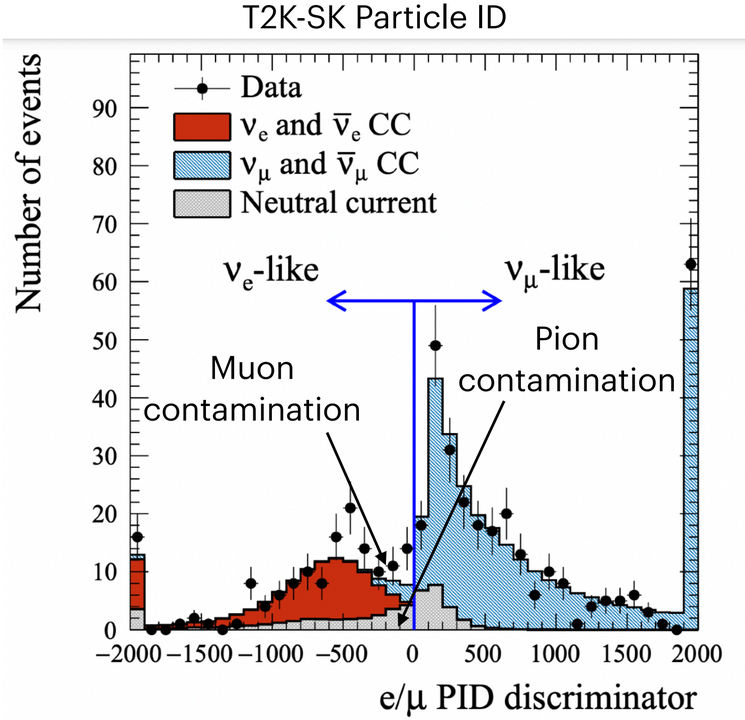


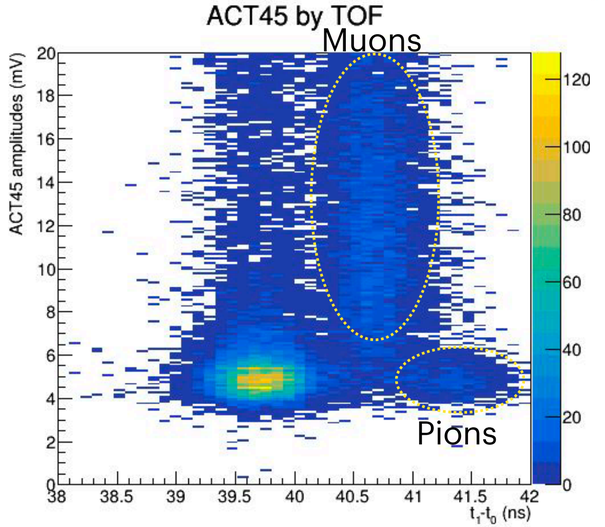




Beam Configuration Outstanding Questions

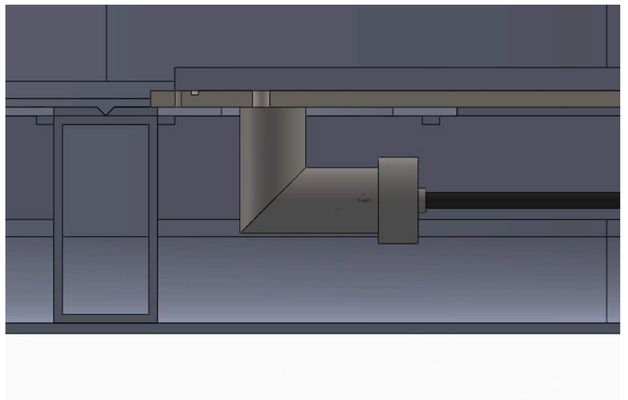
- Do we get enough pion, muon and proton events in a reasonable run time
  - Low momentum pions appear to be the limiting case
  - A couple thousand at each point may be sufficient
- Most strict purity requirements likely come from our plan to study particle identification
  - Electron fraction in our pion and muon samples should be less than rejection factor for pions and muons that we need to investigate
- Are beam rates low enough so that pile-up is managable
  - Requirements different for pure water (~10 us pile-up free window for Michel electron) and Gd loaded water (~100 us pile-up free window for neutron capture)

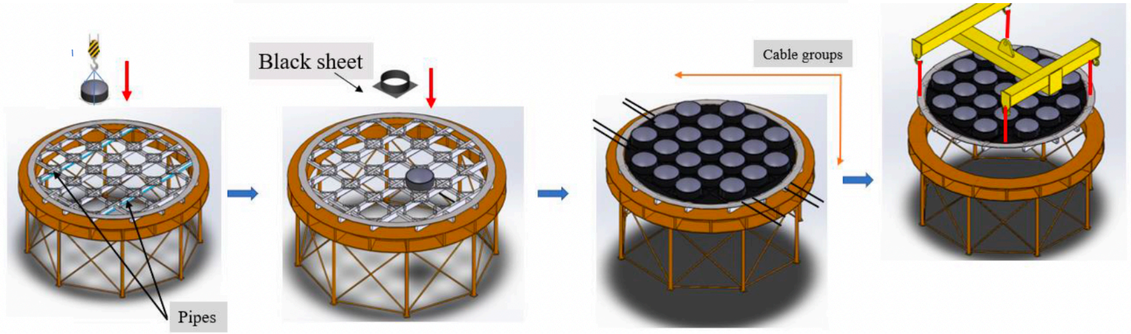


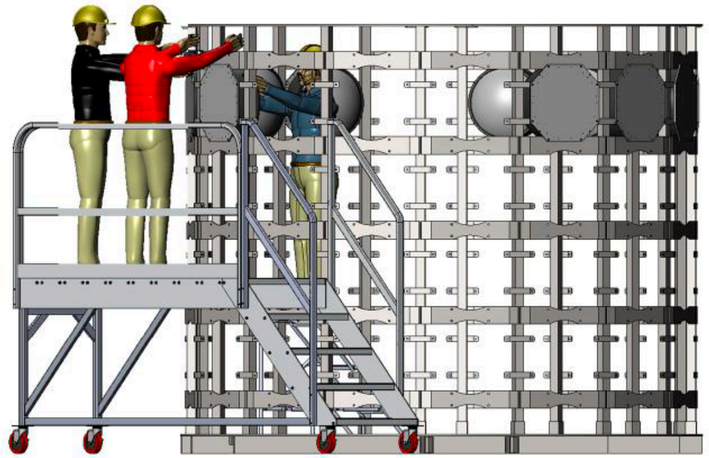


Detector Mechanical Design & Assembly

- Mechanical design issues include:
  - Clearance for cables appears to be ok, but requires mPMT feedthrough design change
  - Lifting points for all components compatible with H-beam spreader
  - Mounting of photogrammetry cameras and interference with blacksheet
- Assembly procedure development will continue:
  - Details of worker access need to be worked out
  - How blacksheet is installed must be decided
  - How do we test the detector operation in the assembly area?



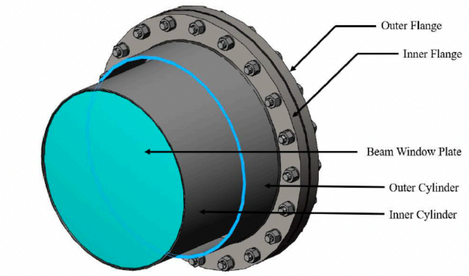


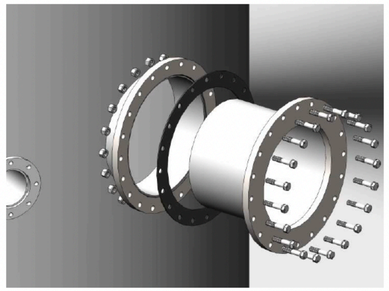


Beam Window

- Requirements for beam window(s) will depend on decision about secondary beam operation
- Design of tertiary beam window that extends to black sheet boundary
- For the secondary beam, do we need the extendable beam pipe?
- Detector is now 4 mPMT rows high. At which mPMT row is the window?
- Potential interf

Tertiary Beam Window





Secondary Extendable Beam Pipe

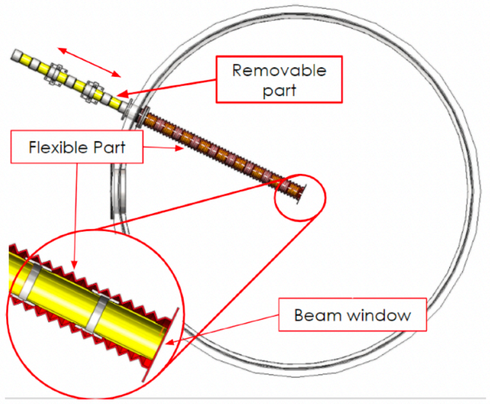
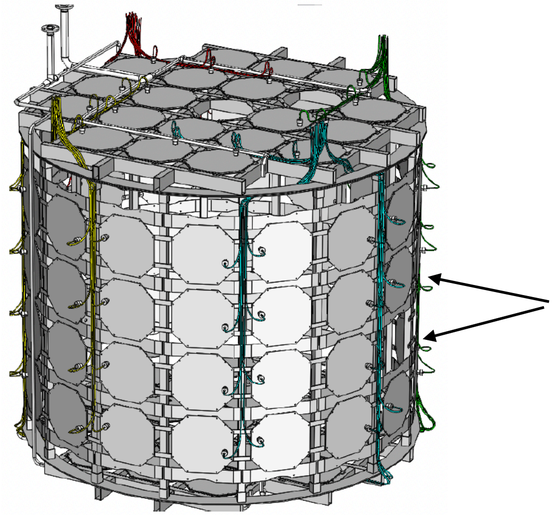


FIG. 36. Schematics of the extendable secondary beam window.



Vertical location?

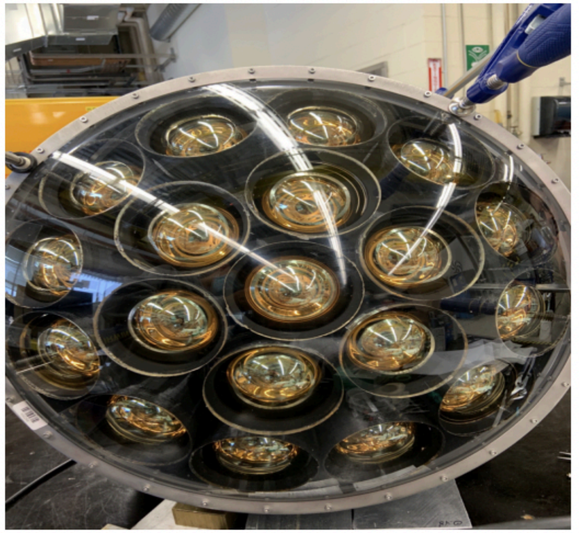
Water System

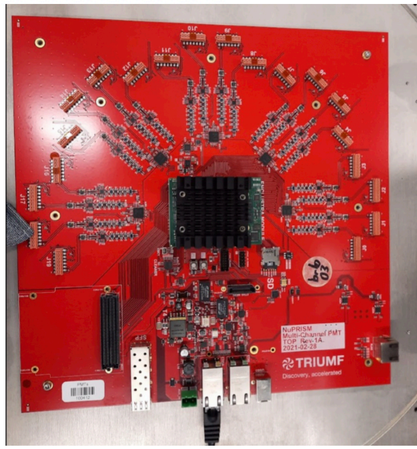
- Need to determine which systems are necessary for the WCTE system
  - Potential significant impact on cost of system
- Amount of chilling power needed should be determined
  - What will be the building temperature?
  - Can we insulate the tank?
- Dose water at inlets move calibration sources?
- Details and safety aspects of Gd loading and removal need to be developed
- Funding model for water system under development

Prototype water system being built for IPMU

mPMTs, Electronics & DAQ

- Development of mPMTs and electronics appears to be progressing well
- Major challenges in procurement of components on the timescale needed for WCTE assembly
- mPMT Assembly procedure needs to be further developed and refined to meet requirement of 3 mPMTs per week
- Details related to integration of Hyper-K mPMTs into WCTE should be worked out
- How much of the HK timing system do we need/ want for WCTE. Need GNSS components?





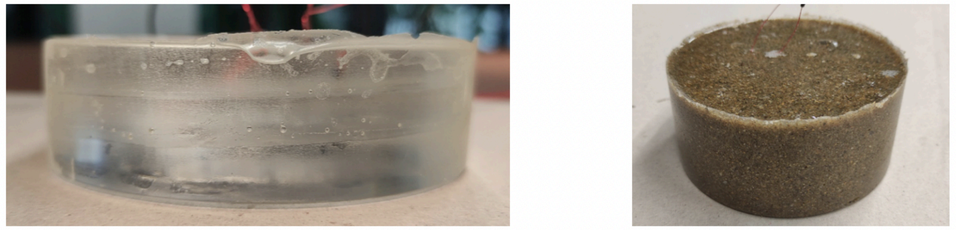
Installation in the mockup frame

Calibration

- Great progress on calibration system
- Consider if MoU with Super-K should be updated or is sufficient
- Tagging method for AmBe sources needs to be decided
- Should start talking to CERN safety group about handling and storage of radioactive sources
- mPMT assembly and testing/precalibration activities must be integrated (including electronics)

Prototyping and testing for CDS

Epoxy tests for NiCf source



Photogrammetry vessel test

Analysis & Software

- Significant progress, but still plenty to do. Contributions welcome!
- Biases in reconstructed distributions after tuning of fiTQun should be understood
- Study of PID distributions and pion samples for decision on secondary beam
- Update beam window simulation with designed window
- Follow up on vertical position of the beam window

Extra Slides

WCTE Structure

Collaboration Officers

Spokesperson: M. Hartz

CERN Liaison: M. Scott

Safety Officer: S. Bordoni

Technical Coordinator: TBD

Work Package Groups and Leaders

Beamline Systems: M. Pavin

Mechanical Systems: C. Garde, P. Fernandez

Water Systems: P. de Perio

mPMTs & Electronics: T. Lindner, M. Ziembicki

DAQ & Triggering: B. Richards

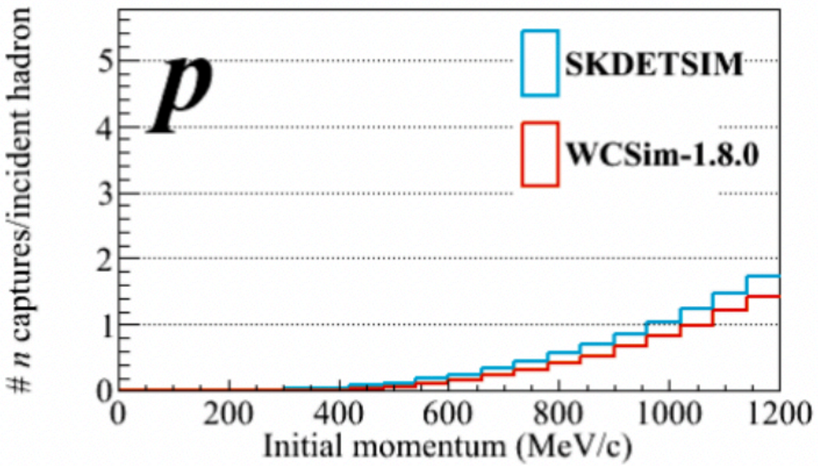
Calibration Systems: P. de Perio, M. Scott

Analysis and Software: L. Anthony

Please work with the relevant work package leaders on the development of the WCTE systems

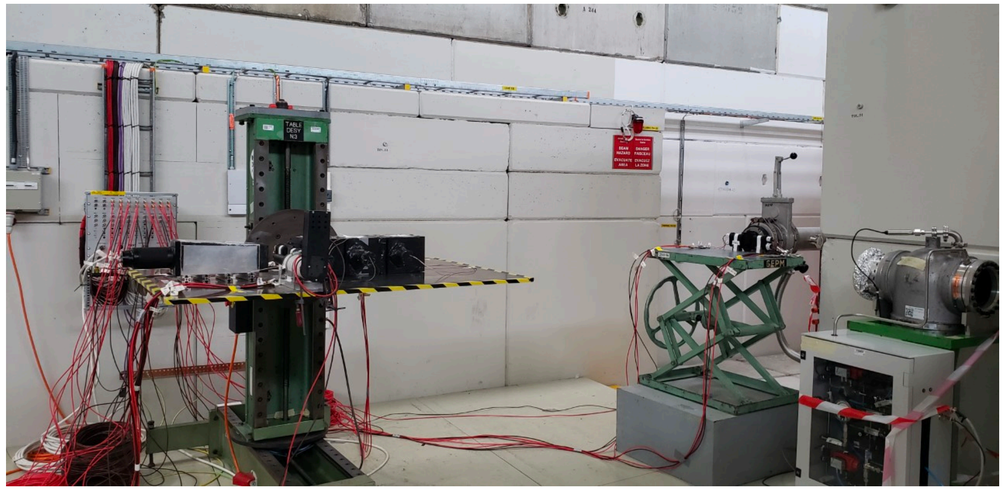
Analysis Questions for Beam Change

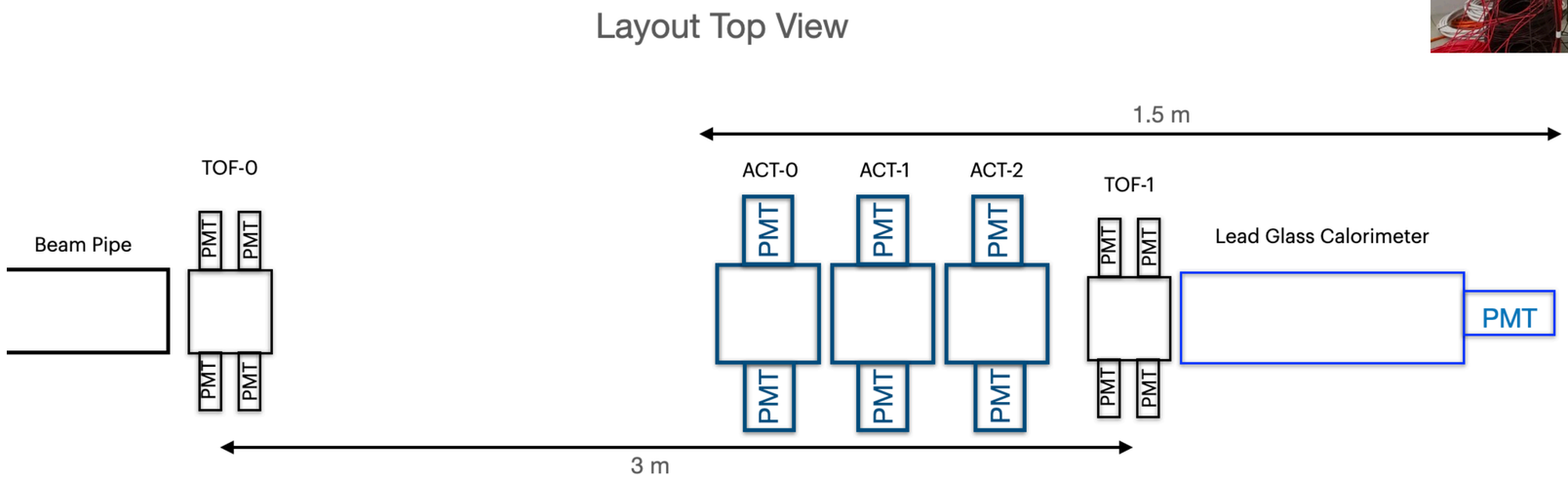
- What are the lowest proton and pion momenta at which we need to operate?
  - Protons above ~400 MeV/c for secondary neutron production?
  - Pions above ~200 MeV/c for $K \rightarrow \pi^{+}+\pi^{0}$ in proton decay channel?



- What level of purity is needed for each particle type?
  - Muons are rejected by factor of ~10^{3}-10^{4} for electron neutrino measurements
    - Less than 10^{-3} contamination of electrons in muon sample?
  - What pion purity is necessary to study pion misidentification as electrons?

Beam Studies

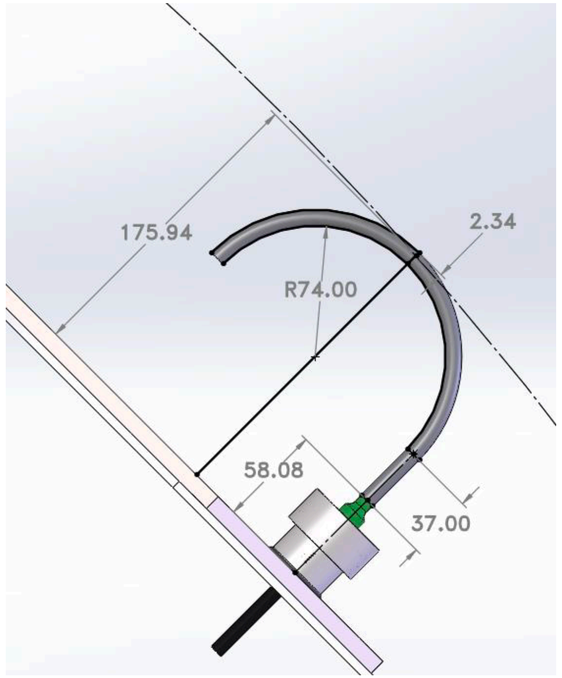


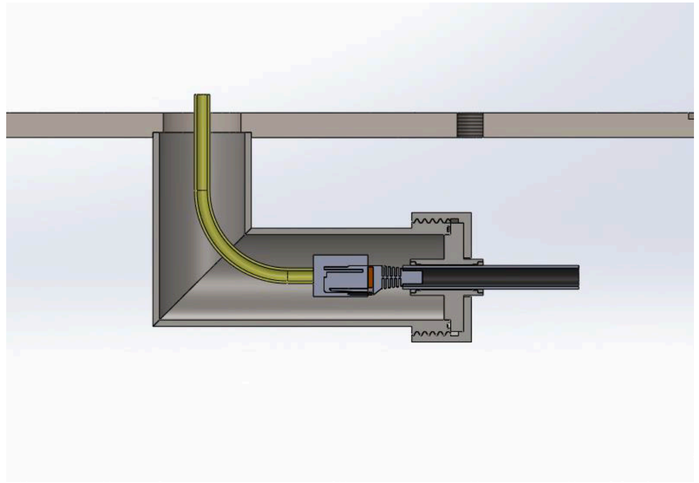


- For the past week, we have collected low momentum data with time-of-flight and aerogel Cherenkov threshold detectors to measure the beam composition
- Preliminary results in Thursday's session

Important Discussions - mPMT/Mechanical Integration

- Integration of the mPMTs with the mechanical structure should be finalized soon
- Major point of discussion is cabling, feedthrough and clearance for cables
  - Hope we can converge at this meeting
- How many Hyper-K style mPMTs will be installed in WCTE
  - Are these compatible with the mounting mechanism
- How will the black sheet be installed?





Important Discussions - Water System

- There are still a number of open questions and action items related to the water system
- What sub-systems (UV, ion exchange resins, micro/nano-filters, etc.) are necessary?
  - More in Patrick's talk
- Detailed design of gadolinium addition and removal systems must be developed and discussed with the safety group
- What chilling power is necessary?
- ...
- Funding scheme for water system is still being developed

Important Discussions - Integration

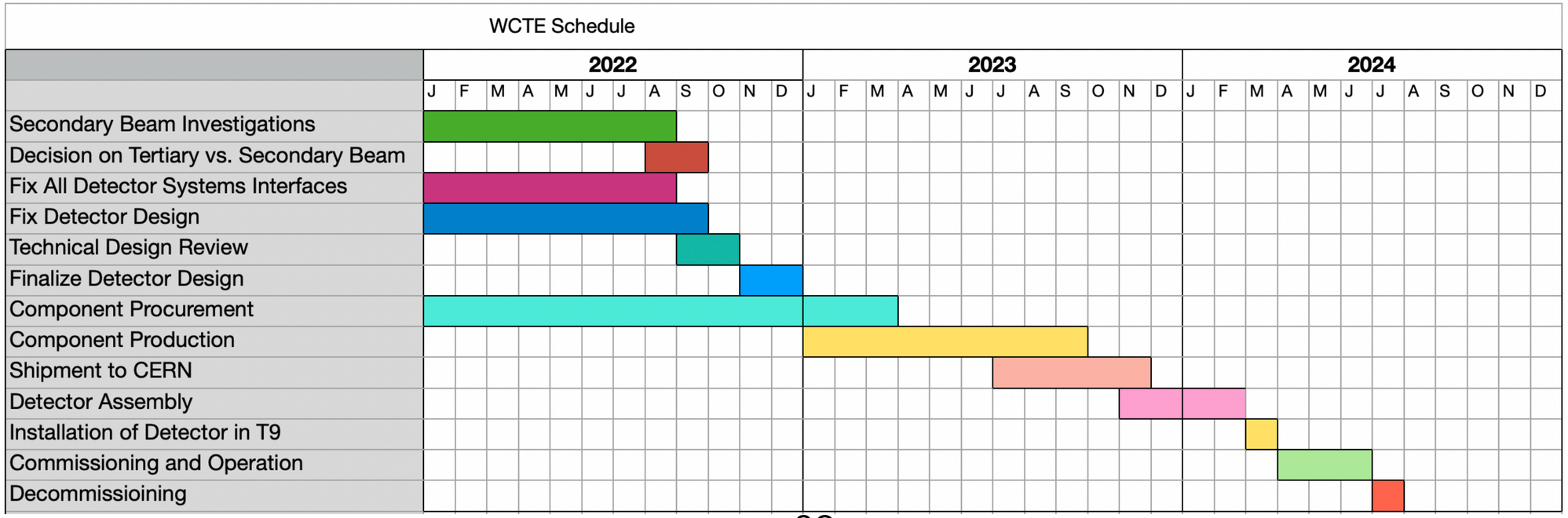
- Integration of systems should be discussed at this meeting with development of plans to converge
- Some important integration discussions:
  - All detectors and calibration with the DAQ and slow control
  - mPMT cabling and mounting with the support structure, tank and lid
  - Water system pipes with the support structure, tank and lid
  - Calibration sources with the CDS
  - ...

Missing Systems

- It is important for each work package group to identify any systems that don’t have a responsible group or don’t yet have funding
- Make sure that all details like cabling, connectors, consumables are considered
- Information of contributions must be collected for the MoU as well

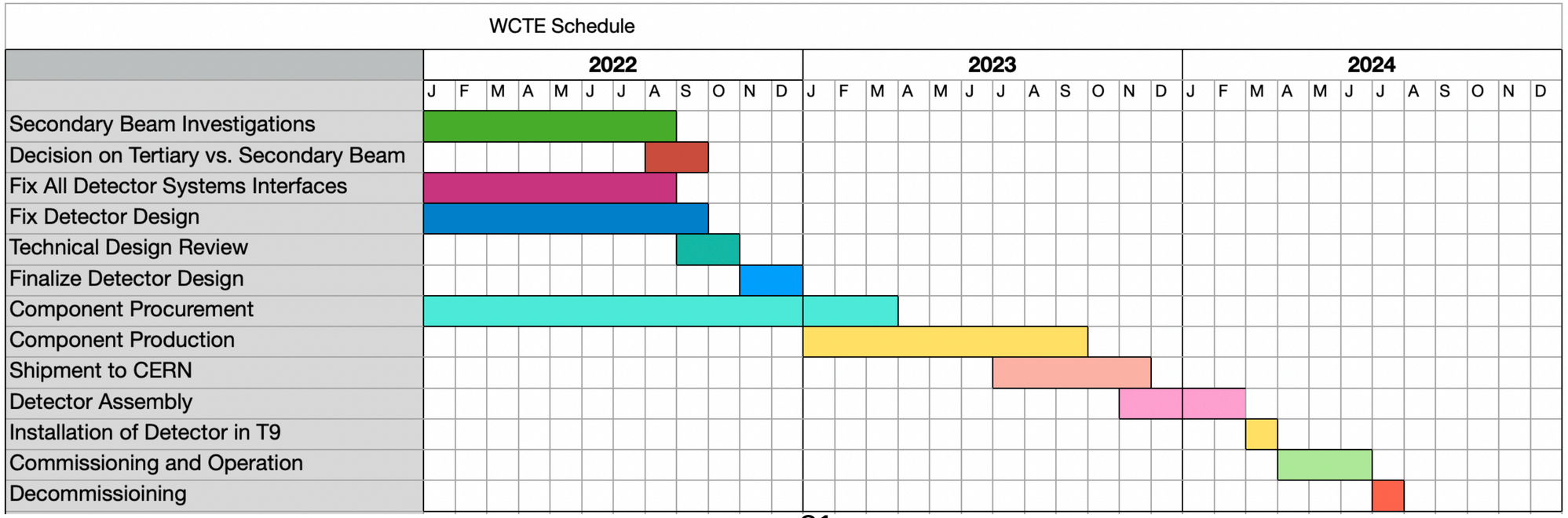
Schedule Discussion (2)

- We want WCTE to be the first experiment to run in 2024 so that we have time to install the detector in the experimental area and commission during the winter shutdown
- We heard that the winter shutdown in 2024 could be shorter and beam could start as early as February
  - Can we be ready?
  - We need a more detailed assembly, installation and commissioning plan



Schedule Discussion (3)

- In order to keep to the schedule, we should make import design decisions this year and fix the detector design
- Decision on secondary vs. secondary+tertiary beam by end of September
- Technical design document by the end of August with review and iteration by the end of October
- Finalize design in consultation with relevant CERN groups by the end of the year

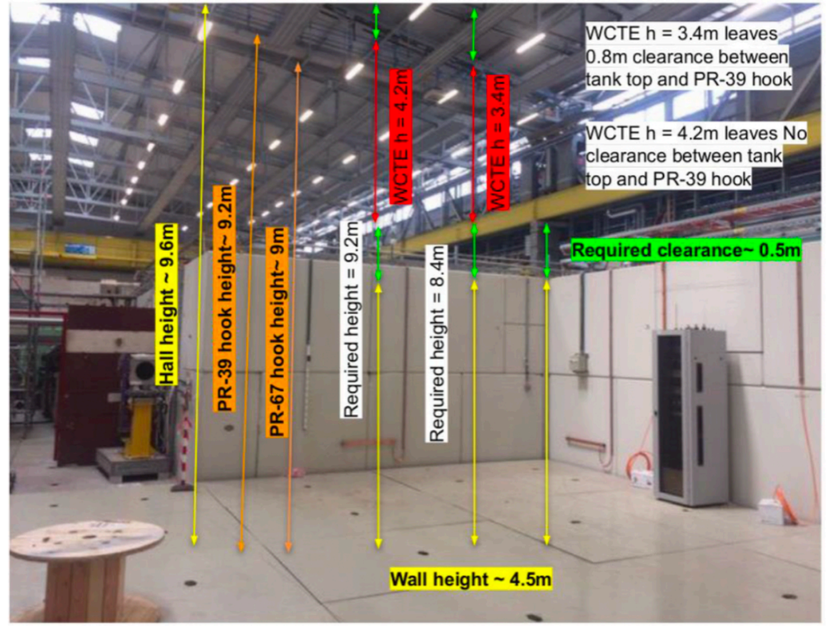


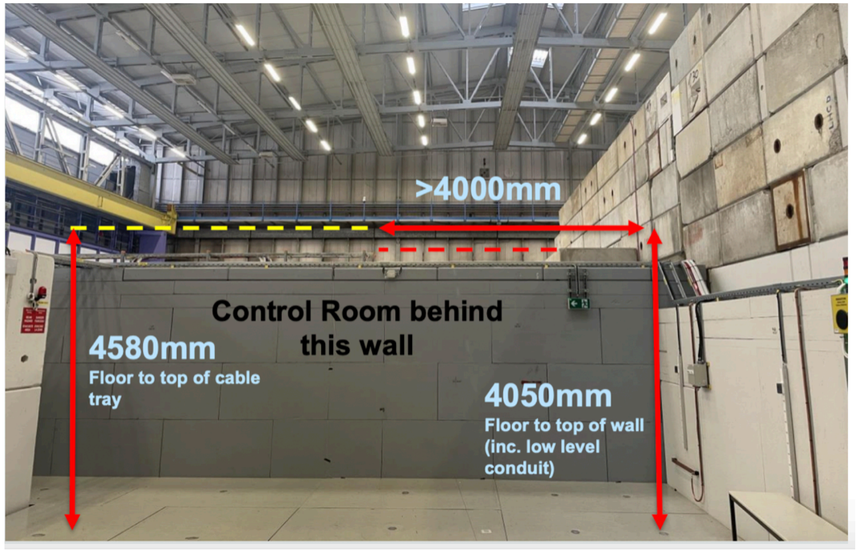
Summary

- WCTE has been approved by the CERN Research Board
- We now move to finalize the design of WCTE and move into the construction phase
- Operation of WCTE from start of beam time in 2024
- Many important aspects of design to finalize
  - Beam configuration
  - DAQ and synchronization of systems
  - Mechanical interface for components installed in the detector
  - …
- Let’s have a fun and productive meeting and work towards our goals

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

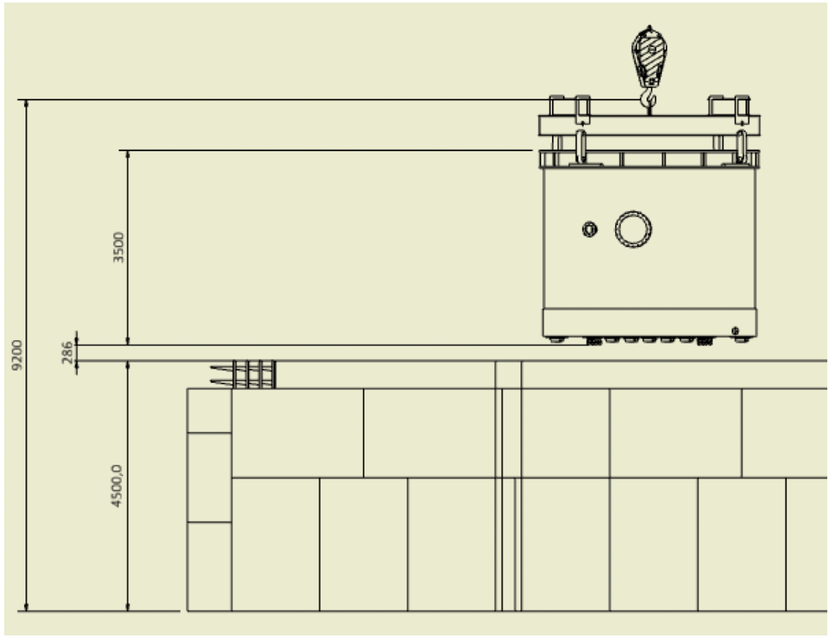




Detector Dimensions Change

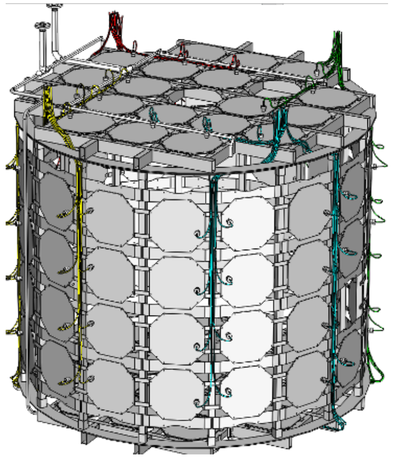
Config	Columns	Rows	Height (mm)	Diameter (mm)	ID height (mm)	ID diameter (mm)
Original	18	5	4320	4022	3539	3621
Reduced diam 1	18	5	4200	3800	3539	3439
Reduced diam 2 (16c-5r)	16	5	4200	3800	3539	3427
Reduced height and diam (16c-4r)	16	4	3400	3800	2739	3427

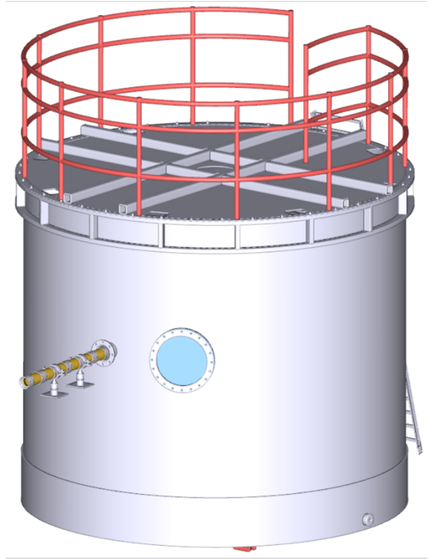
- Studied different detector configurations with reduced rows and columns of mPMTs
- Converged on reducing columns from 18 to 16 and reducing rows from 5 to 4
  - No significant degradation of reconstruction performance observed
- Even with reduction, care must be taken with design of lifting beam
 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



Status of Tank and mPMT Structure

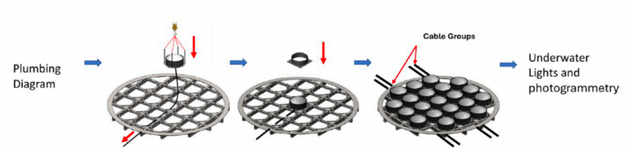
- In progress to finalize tank and mPMT support structure and integration of the rest of detector components:
- Tank design elements being finalized:
  - Integration with railing system
  - Final design of beam windows
  - Final design of the lid to integrate pipes, cables and CDS
- mPMT structure design 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



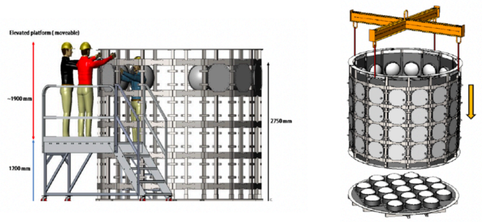


Detector Assembly Procedure

Bottom Endcap Installation



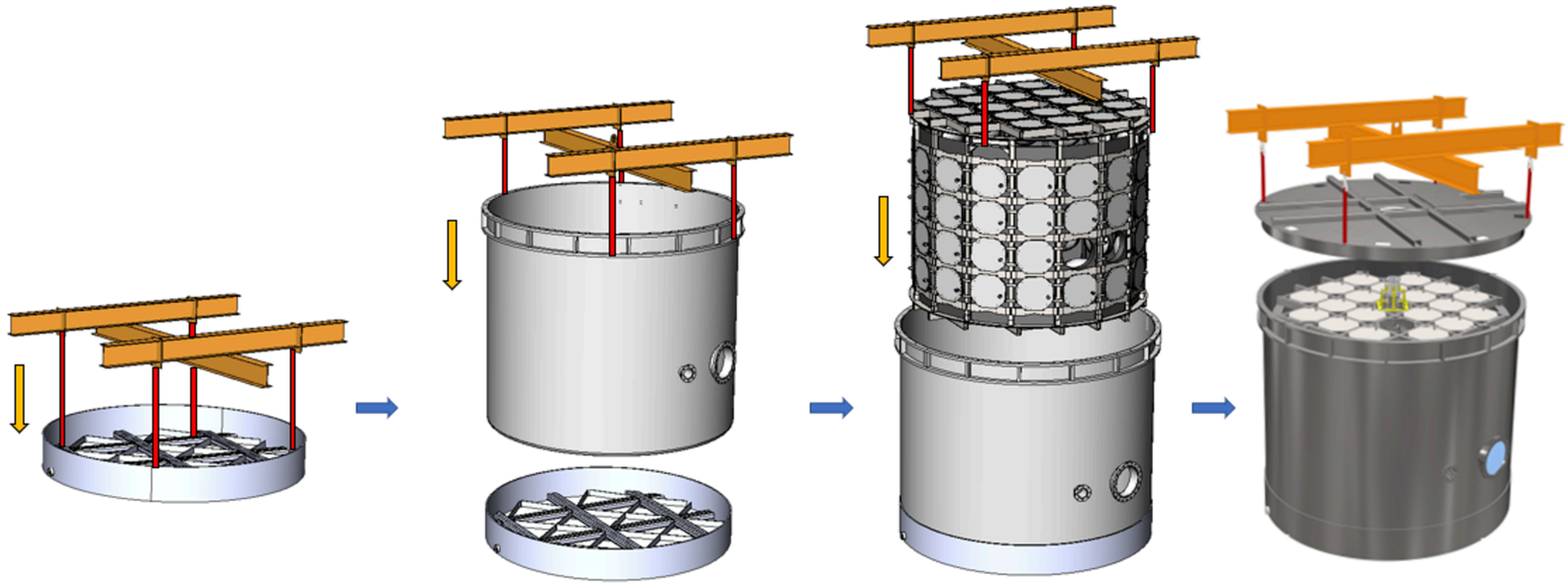
Barrel Installation



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

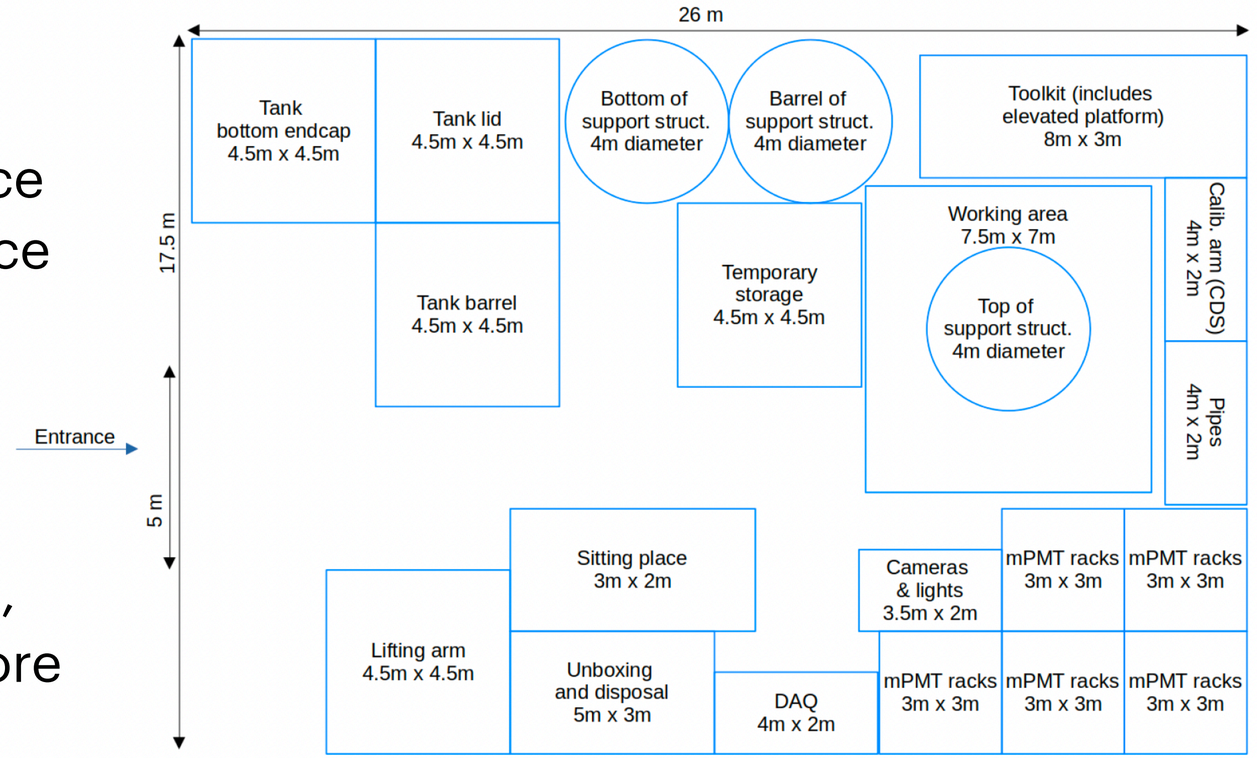
Detector Lifting



- 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

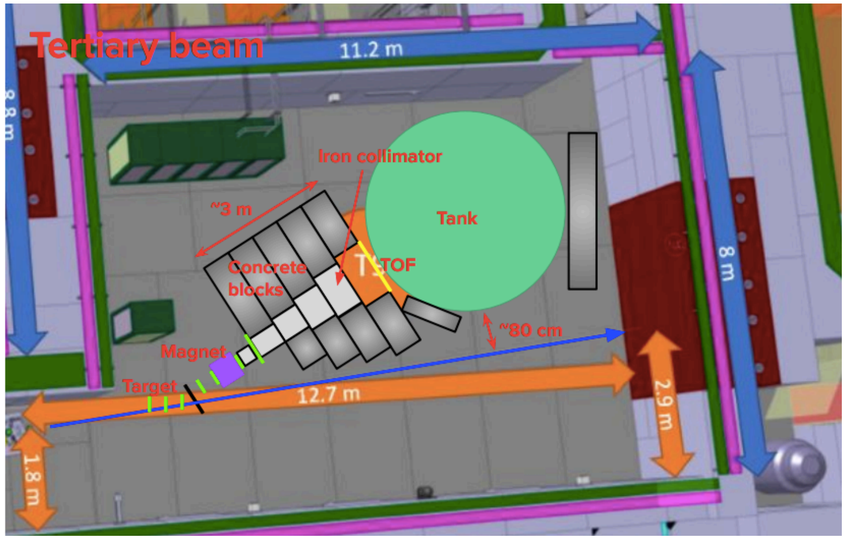
Assembly Area

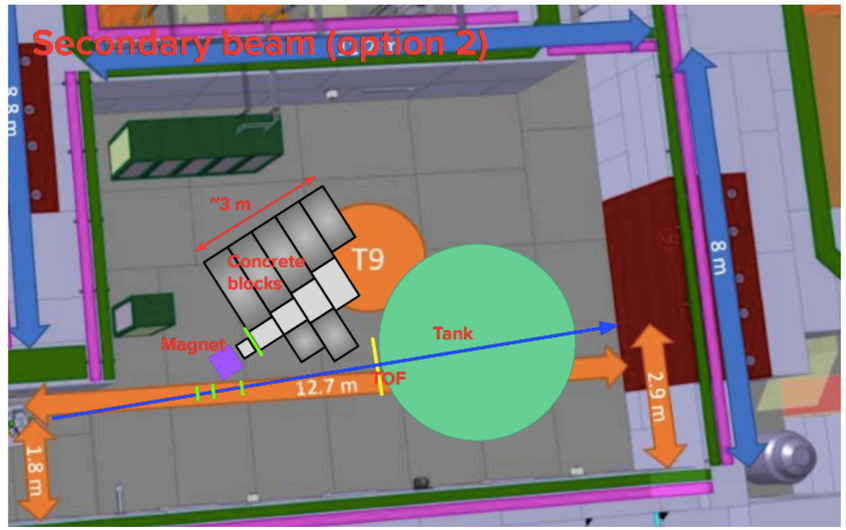
- We are updating our requirements for the assembly area
- Requirements have not changed too much since the proposal, but we likely need more floor space
  - Original proposal: 15 m × 15 m
  - Updated estimate: 17.5 m × 26 m
  - Accommodates separate storage of the tank, base structure, lid and support 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

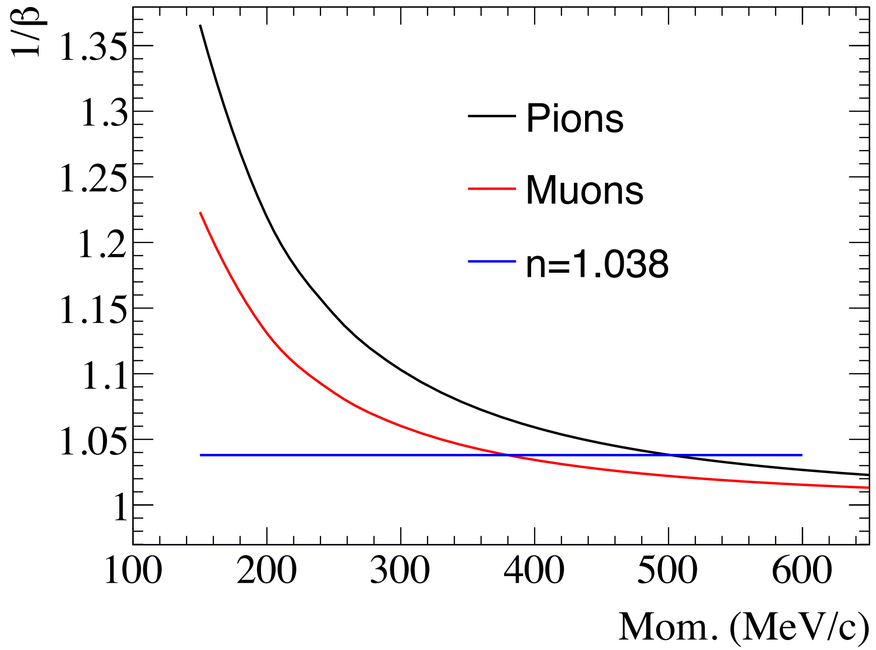




Low Momentum Secondary Beam

- 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)

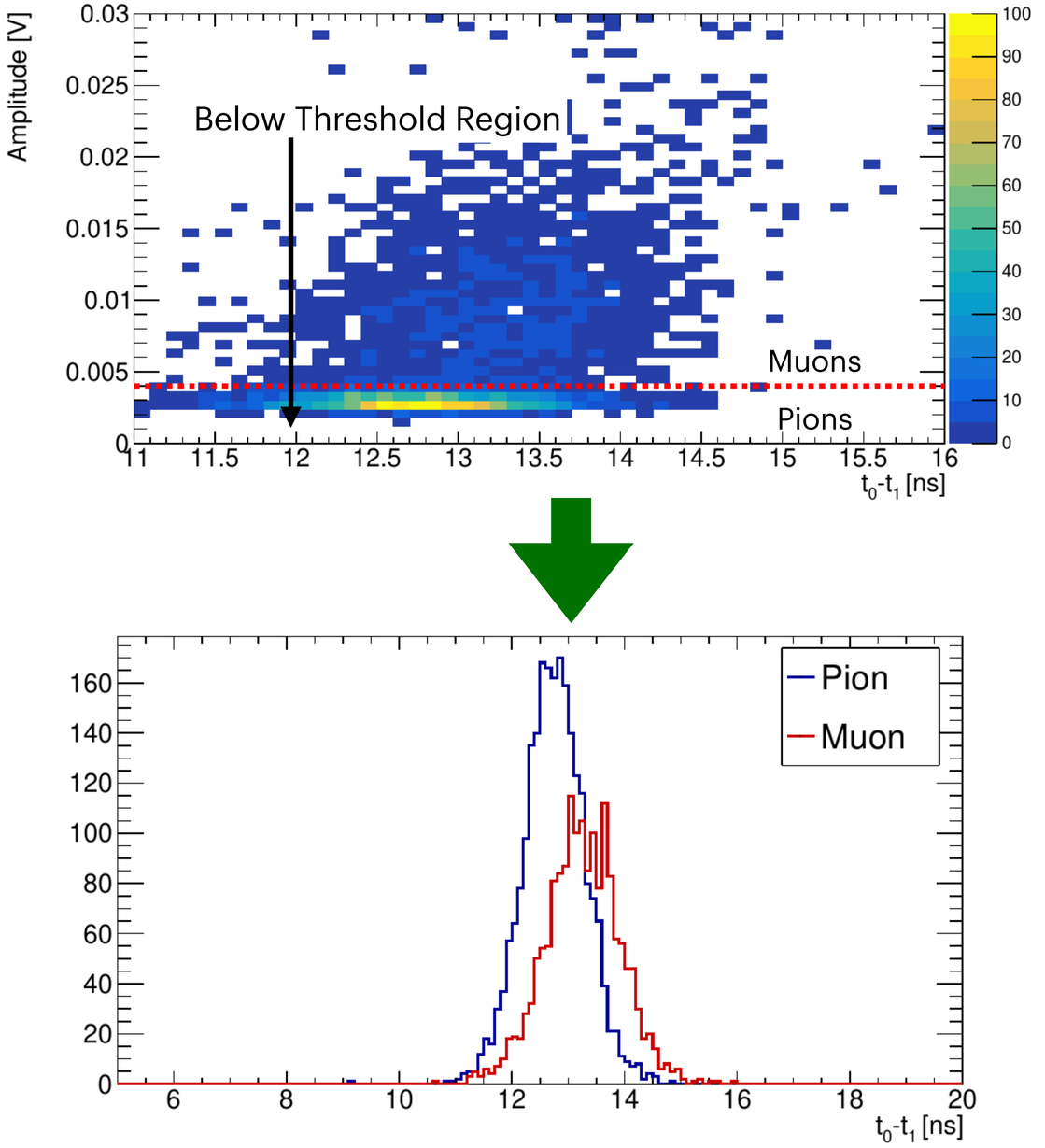
Beam Test in March



- 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

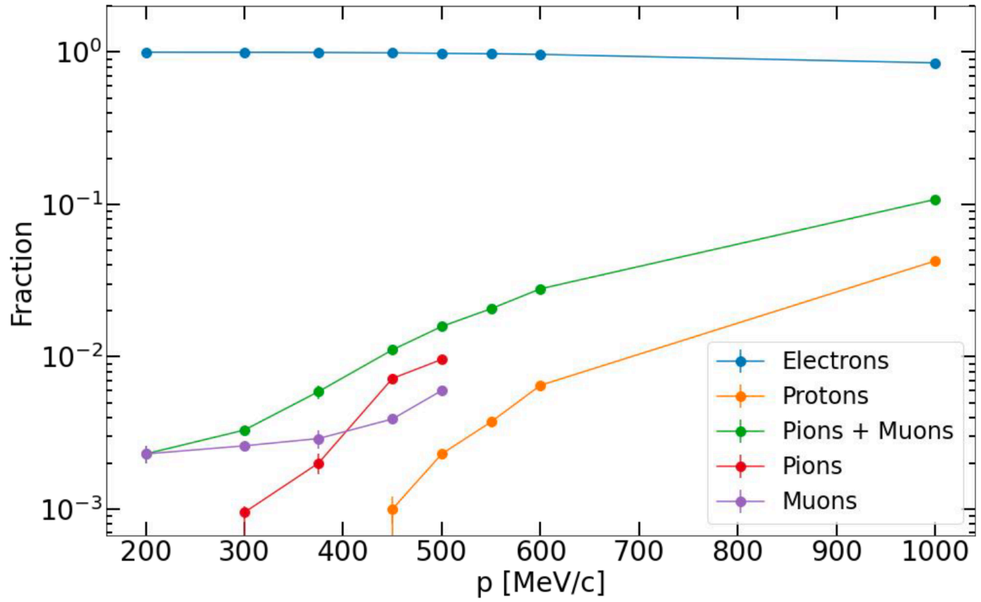
Particle Identification Performance

- 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

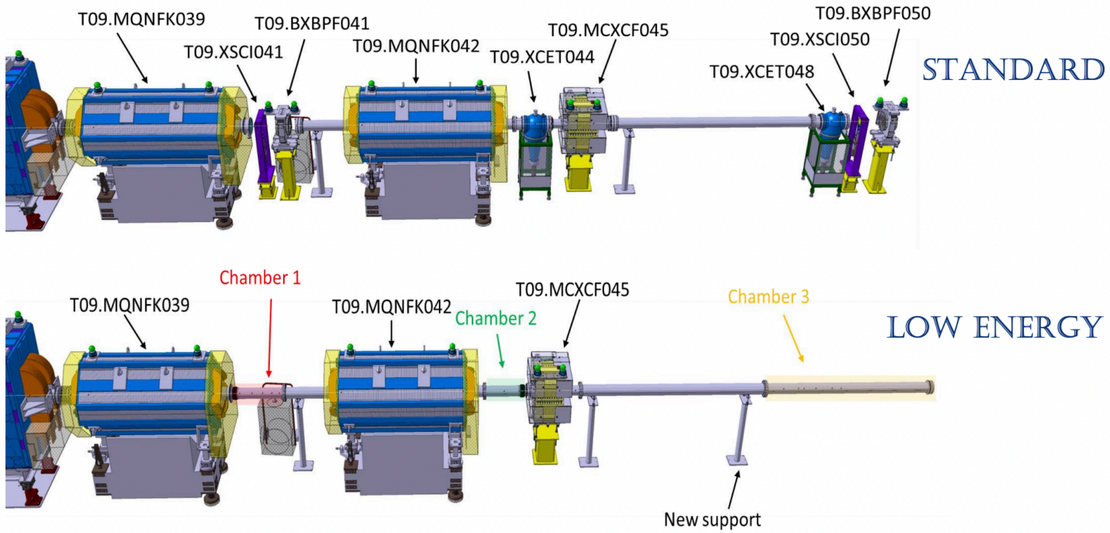


Beam Test Results

- 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



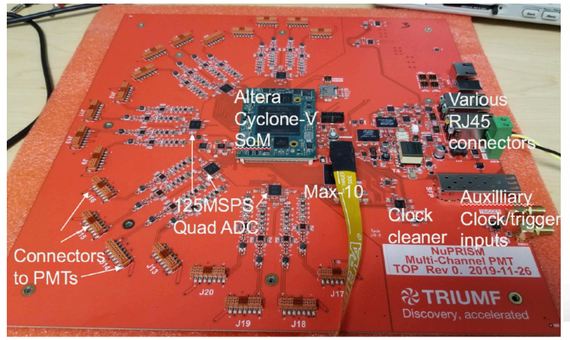
Environment & Safety

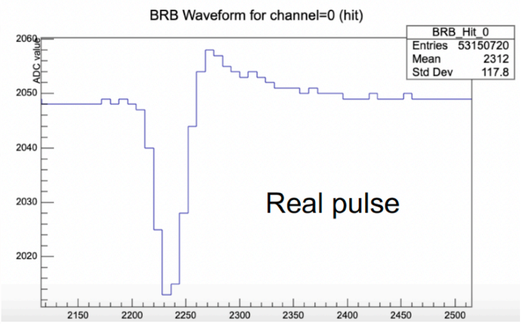
- We completed the Initial Safety Declaration and had the Launch Safety Discussion
- Safety contact for WCTE is Stefania Bordoni (University of Geneva)
- Outstanding issues that require further discussion
  - Disposal of the water after removal of the gadolinium sulfate leaving 0.14% sodium sulfate to 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





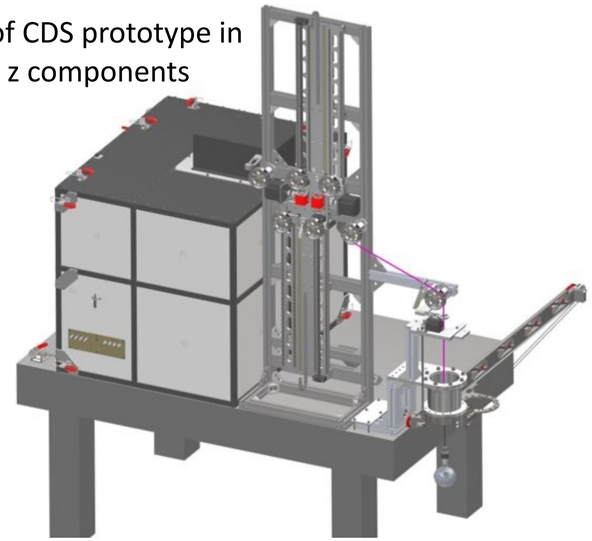
Ex-situ gel application prototype

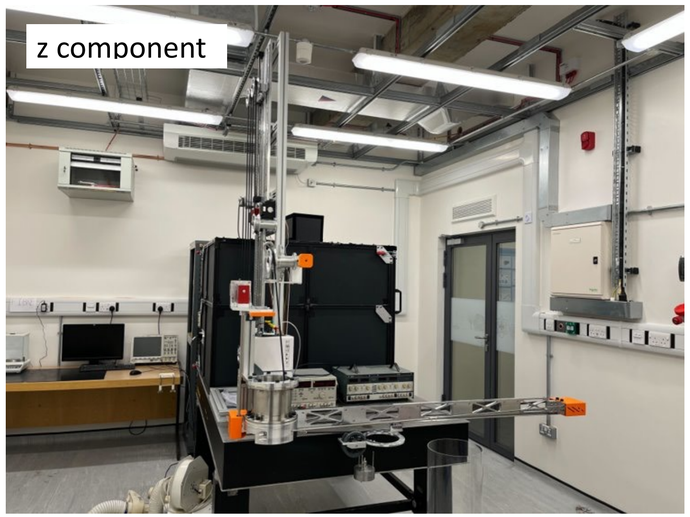
In-situ gel application prototype

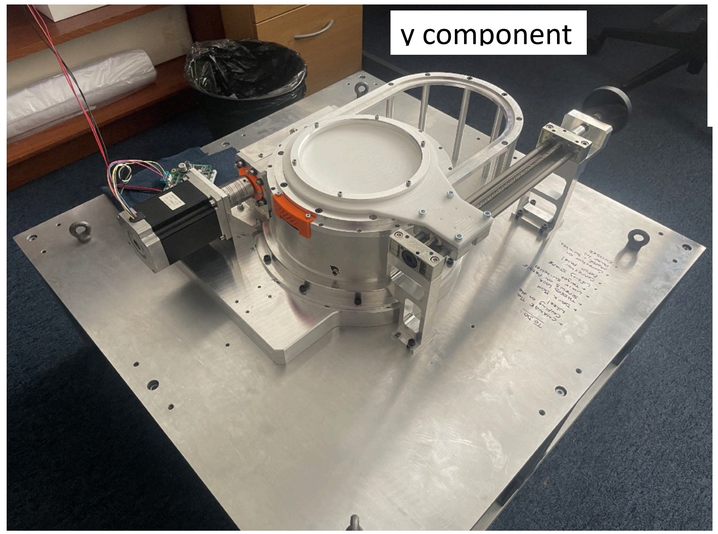
CDS Calibration System

- 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)







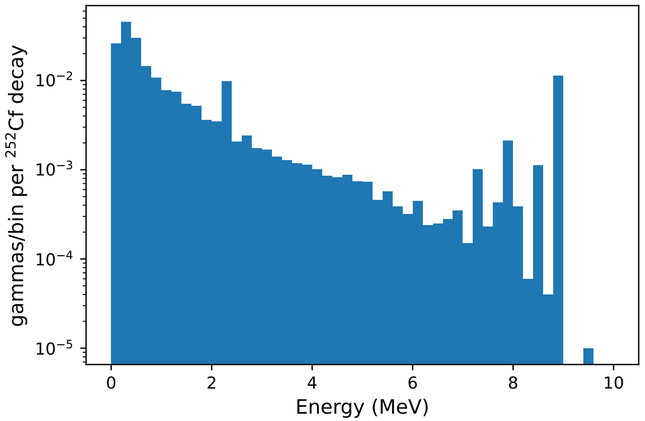
Prototype diffuser ball and preload mass
(not yet filled with optical gel)

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

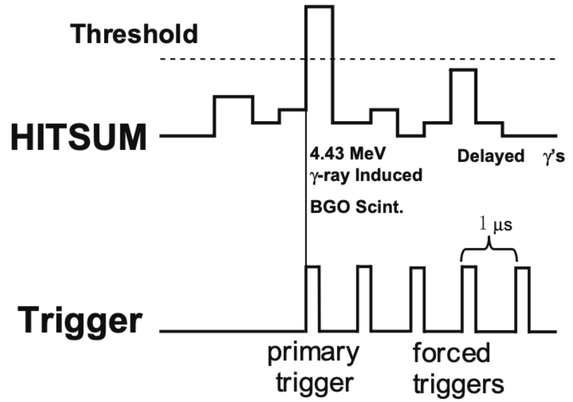
Nickel source used in SuperK (https://arxiv.org/abs/1307.0162)



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)

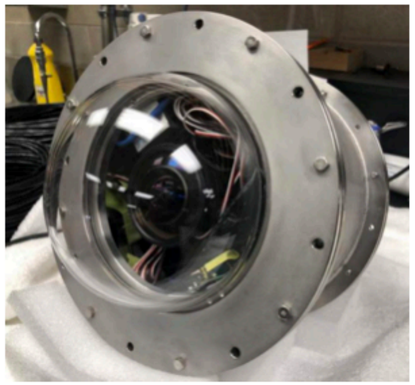


Tagging: trigger on sum of analog PMT signals within 200 ns, from H. Watanabe et al. Astropart. Phys. 31, 320 (2009).

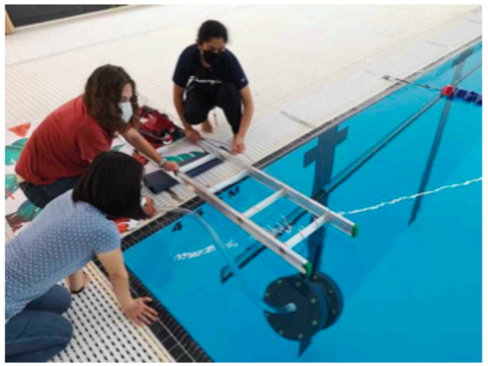
Photogrammetry System

- 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

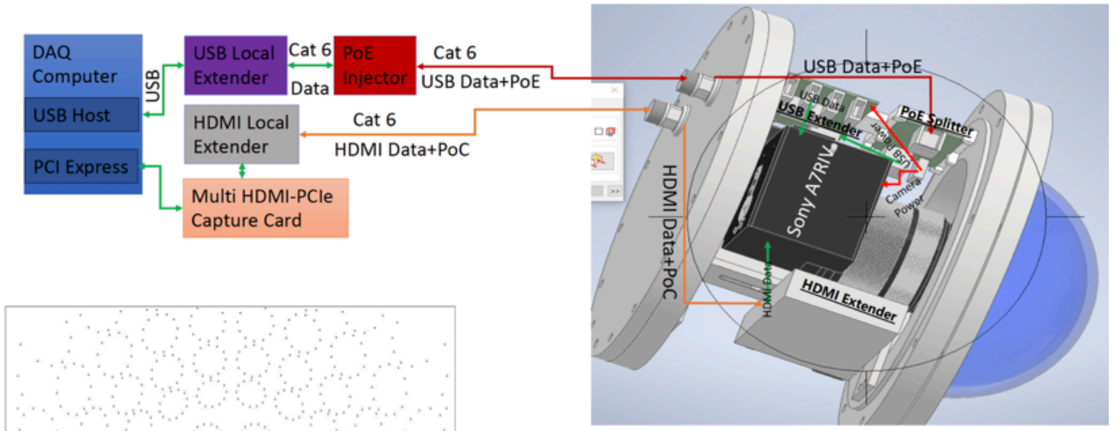
Prototype camera housing

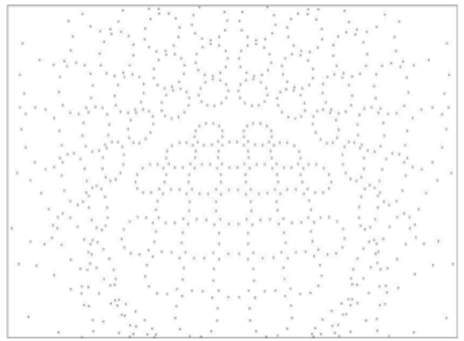


Measurements at UBC Pool



Camera readout (under development)





LED beacons from simulation