Water System Status

Patrick de Perio (for the Water Group)

WCTE Collaboration Meeting

July 19, 2022

KAVLI IPMU INSTITUTE FOR THE PHYSICS AND MATHEMATICS OF THE UNIVERSE

Introduction

- Water is one of the major components of the detector we need to control
- Aim to develop a minimal (cost & size) water purification system for WCTE and IWCD
- Largely based on successful techniques from Super-K
  - WCTE is smaller
    → Less stringent transparency requirements
  - However, larger surface area to volume ratio
    → More contaminants
  - And potentially higher temperature ~17°C
    → More bacteria

Water Cherenkov
Test Experiment (WCTE)

3.6m tall, 3.8m diameter

~100 mPMT modules

40 tonne

2 t/hr flow (1 day turnover)

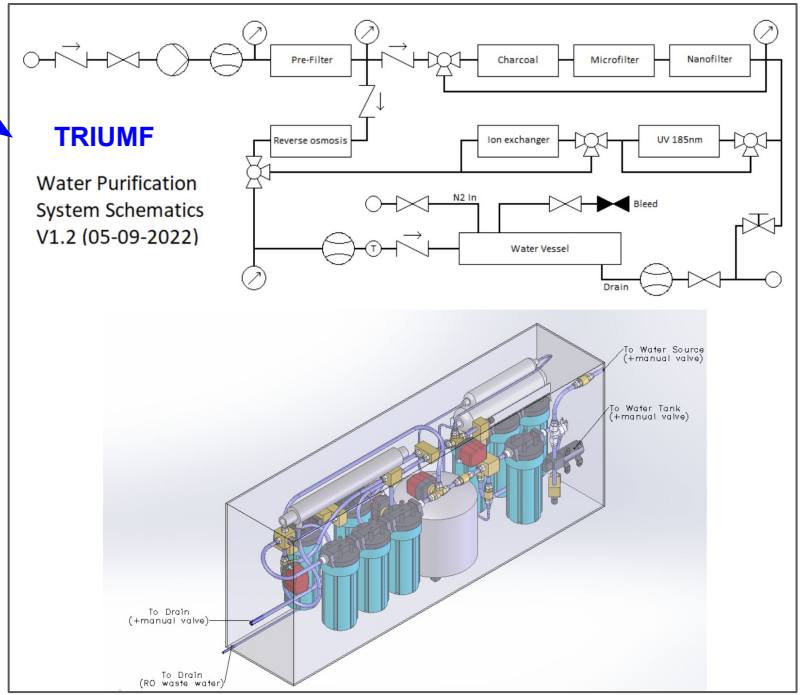
Candidate Detector Water Purification Systems

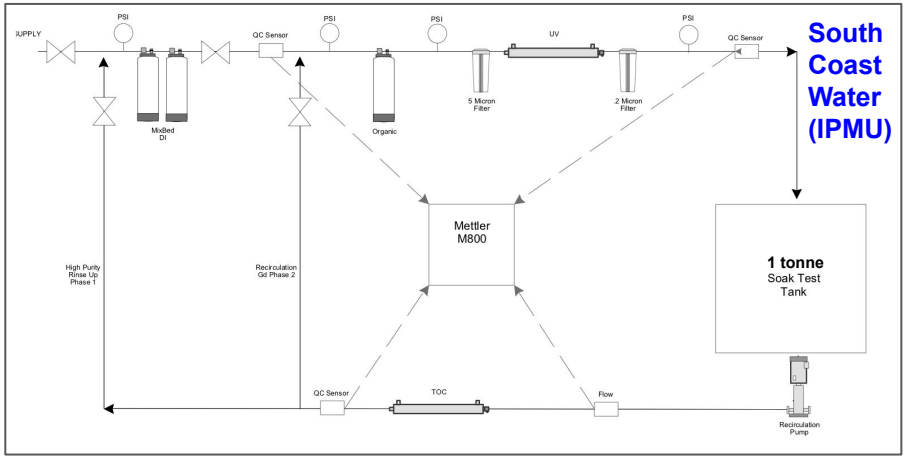
- Continuing consultations with two companies so far:
  1. **S**outh **C**oast **W**ater (USA) designing smaller (0.15 t/hr) R&D/soak-test system for IPMU/ICRR
  2. Taiyo Giken (Japan)

- Investigating cost reduction by building ourselves with individual components

- Plan to extend to WCTE (2 t/hr) based on what we learn

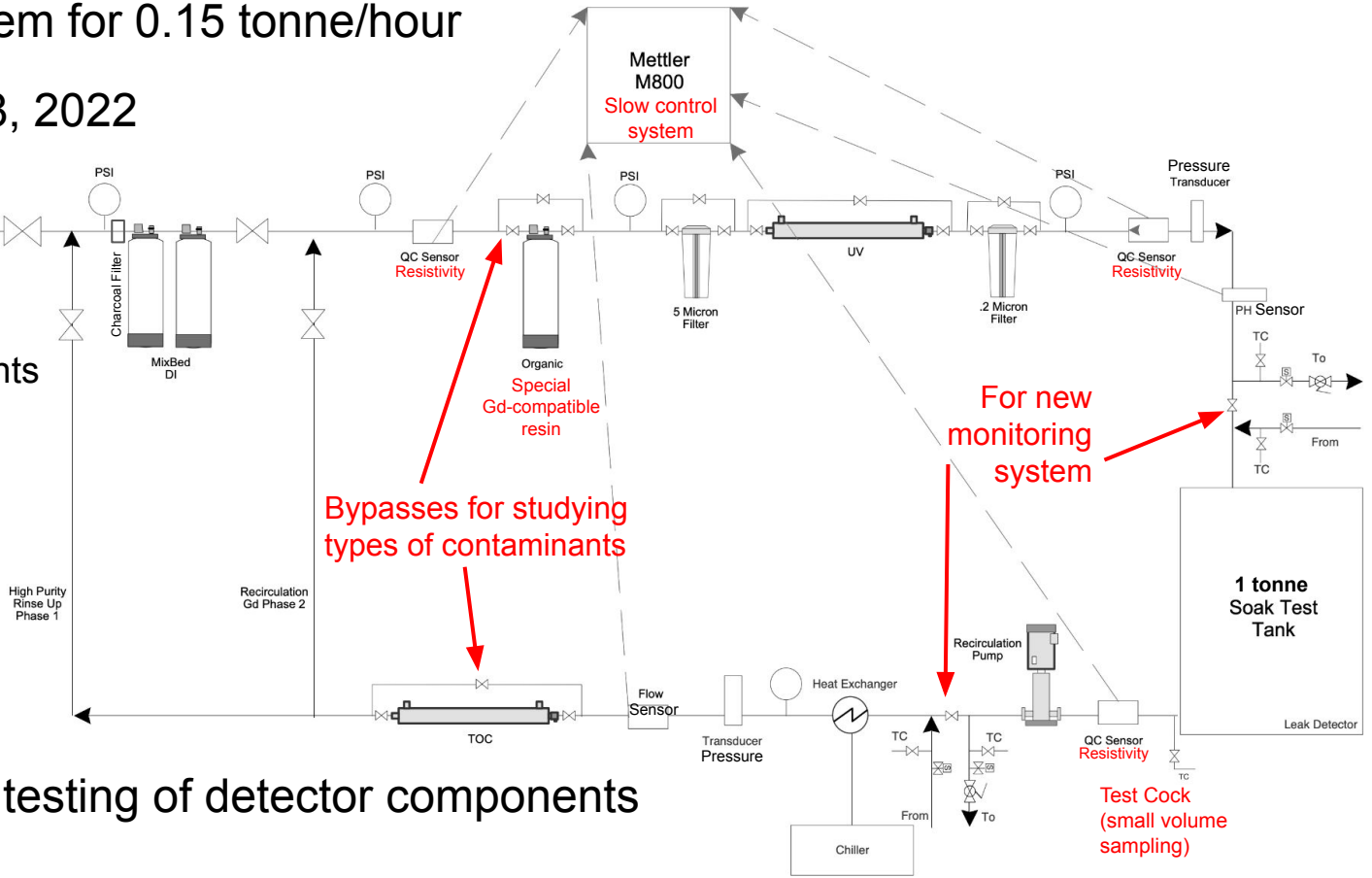
A. Konaka





SCW Company: IPMU Test Bench (Prototype) System

- Scaled down system for 0.15 tonne/hour
- Ordered on Feb. 8, 2022
  - Delivery delayed by 4 months to late July
  - Supply chain issues on various components
    - Still waiting on solenoid valves and controller
- Test purification components, new water monitoring system, and soak testing of detector components



SCW Company: IPMU Test Bench (Prototype) System

Photos of current assembly at SCW, preparing for shipment this week

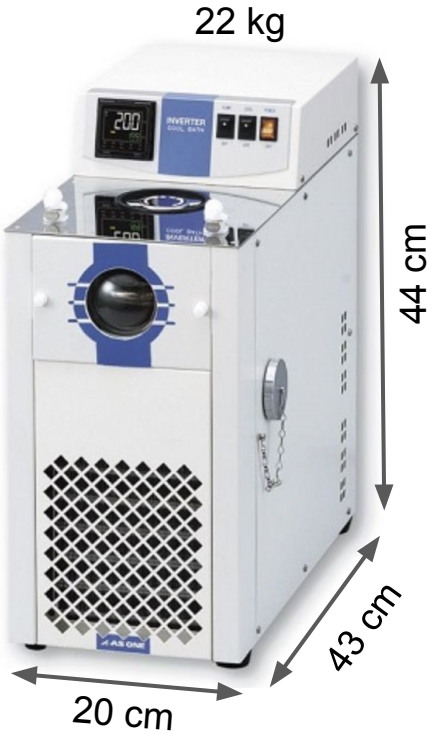
PVC piping would need to be replaced by non-halogen, non-phosphorous flame retardant plastic with CERN approval

- Polypropylene recommended by SCW

Test Cock (small volume sampling)

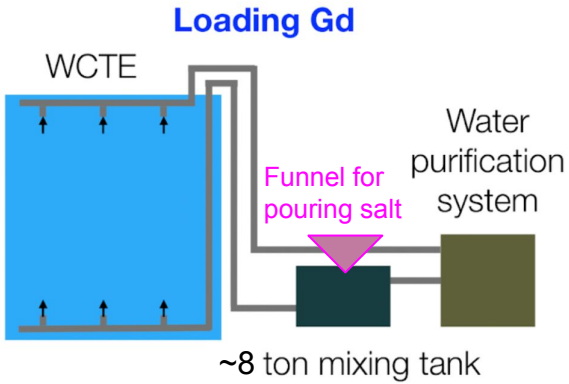
Water Temperature Control

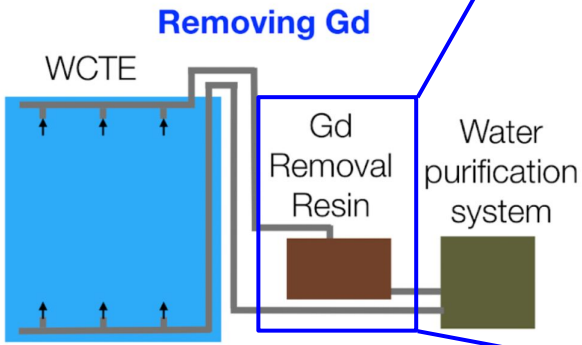
- Currently no AC in experimental area
  - Room temperature >25°C?
- ASONE LTCi-400A (Japan) approved by SCW as compatible
  - Delivered to IPMU and to be tested this summer
    - Cooling capacity: 400 W
    - Pump capacity: 4 L/min
    - Consumption: 850 W
    - Price: 3000 USD
- WCTE candidate: ASONE MTC-3000
  - Cooling capacity: 3 kW
    - mPMTs: 20W * 100 ~ 2 kW
  - Pump capacity: 2.4 t/hr
  - Consumption: 1600 W
  - Price: 5000 USD
- Insulation around the tank?

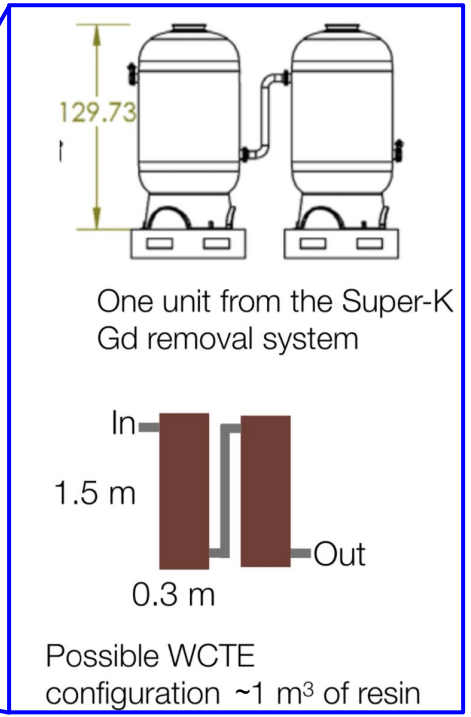


WCTE Gadolinium Systems

- Aiming for 0.2% mass $Gd_2(SO_4)_3 \cdot 8H_2O$ → 100 kg for 50 t water
- Would need ~60L of Gd-compatible water purification resin
  - In consultation with Super-K/EGADS regarding procurement of above two
- Loading/removal systems need technical design and procedure soon for CERN safety review
  - SCW also built the EGADS systems
    - Requires 600L of Na ResinTech (US) CG8 → 3k USD





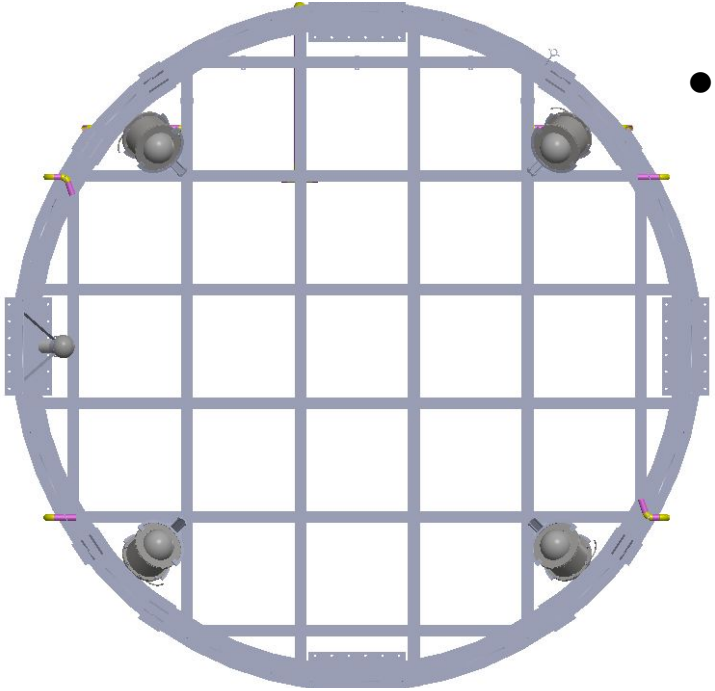


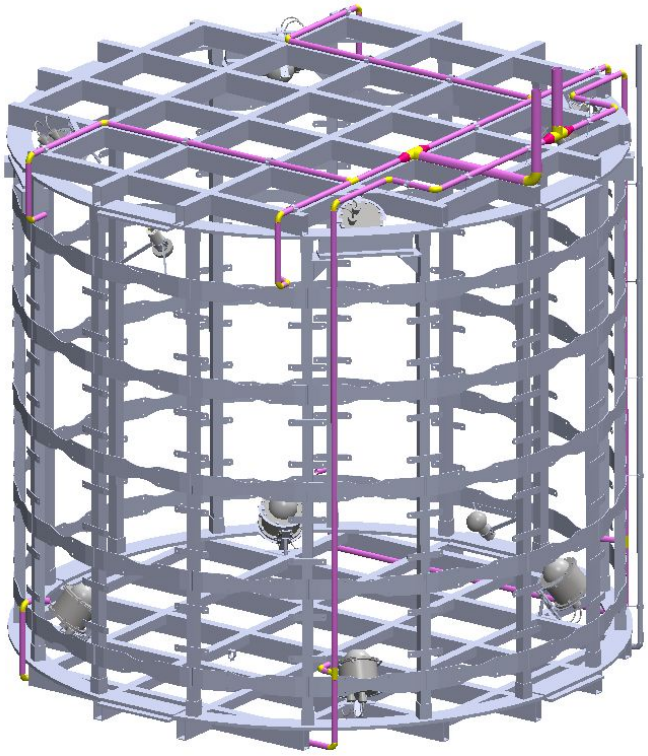
Scaling to WCTE

- After commissioning IPMU system, start working with SCW (and/or Japanese) company to design WCTE system
  - Scaling from 0.15 → 2 t/hr: pump, purification components, resin tanks, pump, chiller
    - Initial estimate = 210k USD
  - Can we get away with a less performant system for WCTE?
    - For example, SCW is now determining reduction in flow and filtration performance for a reduced budget of 100k USD

Water-Detector Interface: Plumbing

- Design by Spanish group (M.M. Slabu)
  - 5 cm diameter pipe for main lines → 2.5 cm for inlet/outlet
  - Material likely stainless steel ~30 m → 1000 USD
    - Plus flanges, orifice plates, mounting brackets, etc.

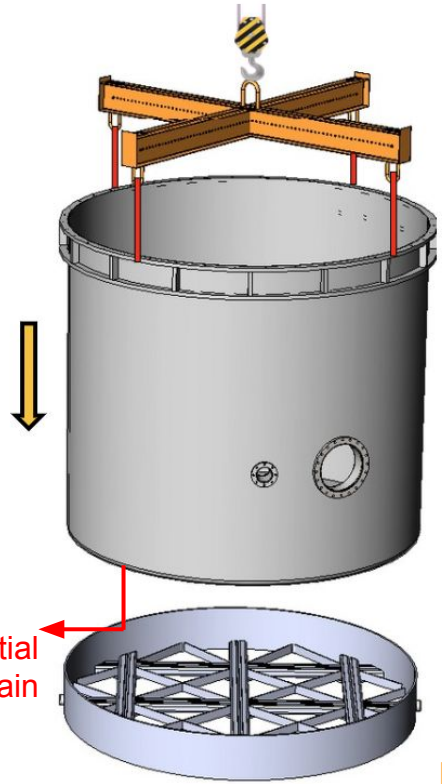


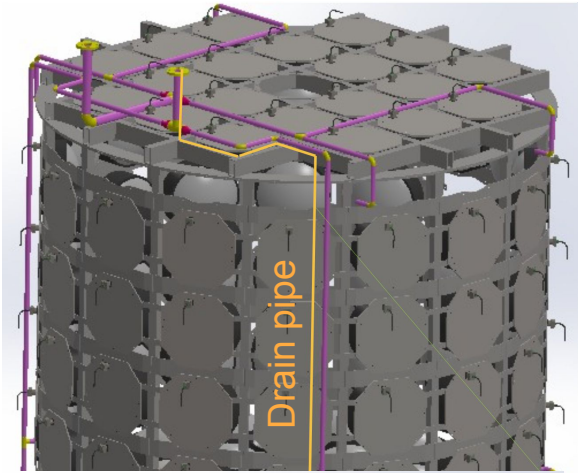


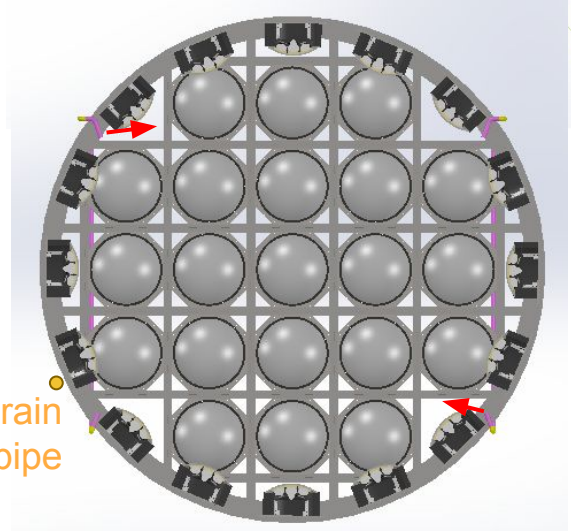
- Horizontal-facing inlet/outlets to avoid vertical turbulence
  - Face the same direction around the circumference to avoid colliding streams
- Assembly procedure design in progress

Water-Tank Interface: Drainage

- Interference with the base and movement system makes a simple drain at the bottom of the tank difficult
  - If the tank does not need to move, simple drain may be possible
- Nominally add another line (orange) for pumping water out to drain

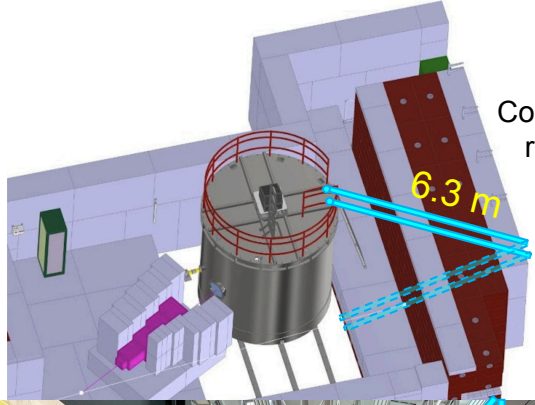


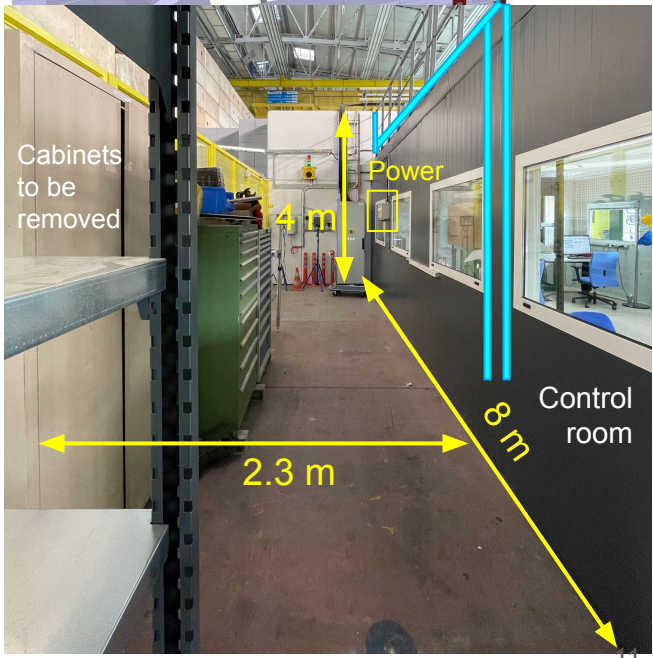




Water-CERN Facility Interface

- Following info to be determined at CERN this week
- Need more precise dimensions of available space, height of wall, distances to flanges on detector lid,
- Location of DI water source for initial filling
- Location of water drain
  - To optimize positioning of drain in tank
- Any disposal limitations on Gd or Na_2SO_4 concentration in the waste water?
  - <0.5 ppb Gd concentration was achieved in EGADS
  - Sodium sulfate is nominally 3xGd
    - Main component of laundry detergent, so probably fine?
- Power requirements to be determined after SCW design

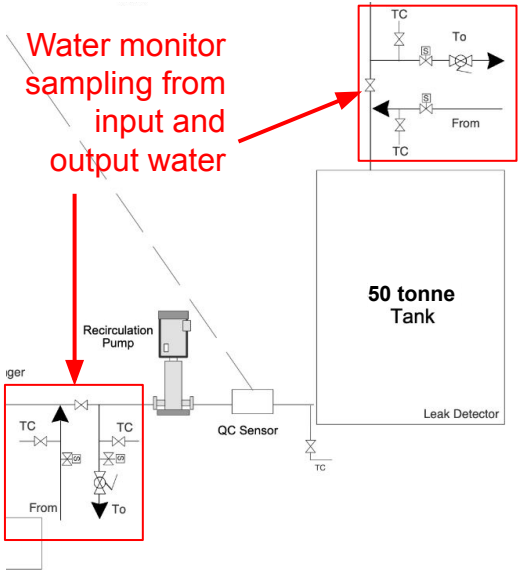


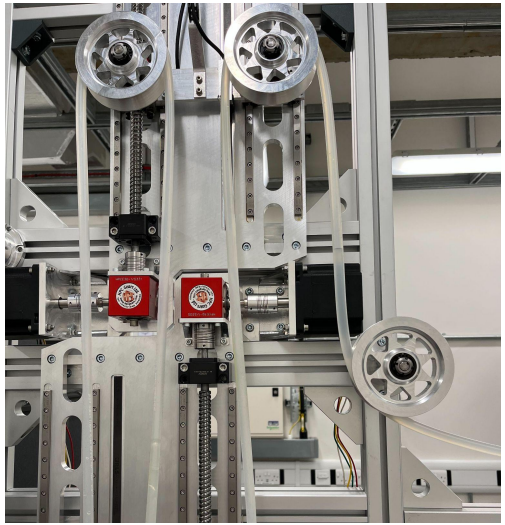


Water-Calibration Interface

Lauren Anthony (ICL)

1. Ports designed for sampling directly from circulation loop
2. Sampling from tube deployed via CDS to allow position dependent water quality measurements
    - Initial siphon testing with Tygon tubing through CDS successful
    - However, tube collapsed with vacuum pump (need slower pump and/or more rigid tube)





WCTE Budget Summary

- Currently 40k USD available between Sweden+Japan, must be spent this year
  - Applying for more funding in Japan, to be available April 2023
  - Additional contributions welcome

Component		**Estimated (kUSD)**	**Committed?**
Purification system (SCW)		100 - 210	Japan? + ?
	Chiller	5 - 10	
	Gd-compatible resin*	5	Japan?
Gd mixing tank (SCW)		?	
Gd-sulfate*		5 - 20	Japan?
Gd removal (SCW)		6	
	Na Resin	3	
Detector+Facility plumbing		2 - 3	

*Some minimum purchase required

Summary

- WCTE water system design and company consultations underway
  - Visiting CERN now to finalize some details, especially facility interfaces
  - Gd component consultations with Super-K
  - Progress on interface to calibration

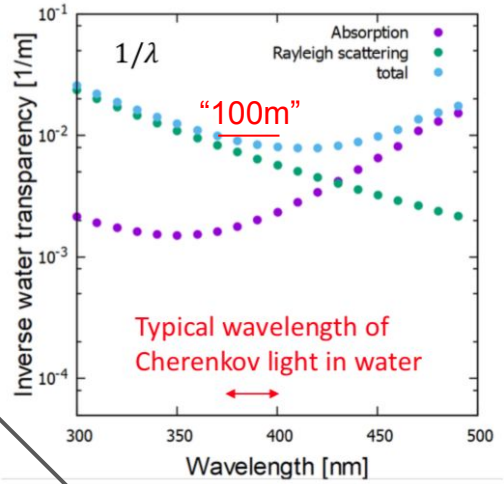
- WCTE should be able to perform with scaled down (smaller & cheaper) water system than Super-K
  - IPMU R&D test bench this summer to help answer this question
- Need responsible groups for cost/effort sharing of major components

Appendix

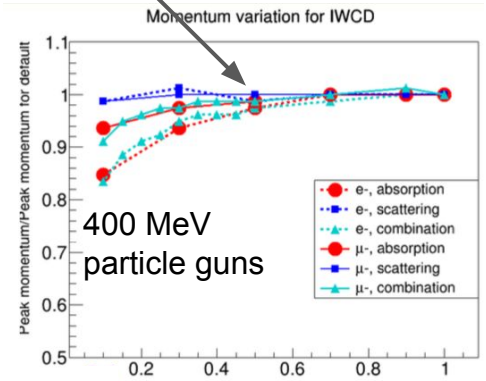
Water Transparency Requirement

- Check effect of increasing light scattering and absorption in detector simulation with e/μ particle gun
  - Super-K “100m” attenuation length model (right) assumed as nominal
  - Scale the curves by factor λ and check effect on e.g. reconstructed momentum
- Indication of performance degradation below “50m” att. length
  - Small, but correlated with all other reconstructed variables (PID, pos, dir)
    - Want to be able to make any impact negligible
  - Momentum can be corrected for *on average*, but water parameters degenerate with other detector parameters like PMT response
    - Want to minimize these degeneracies
- Aim for “50m” attenuation length capable purification system
  - Can always study worse cases by reducing flow
  - However, difficult to predict quantitatively since no well-understood water purification theory and largely dependent on actual materials immersed
- WCTE (IWCD) are 1/10 (1/4) smaller diameter than SK
  - Can probably get away with cheaper, smaller system

Yamauchi-san (TUS), WCTE



The default settings in WCSim



Scale factor for curves above

EGADS Example (https://arxiv.org/abs/1908.11532)

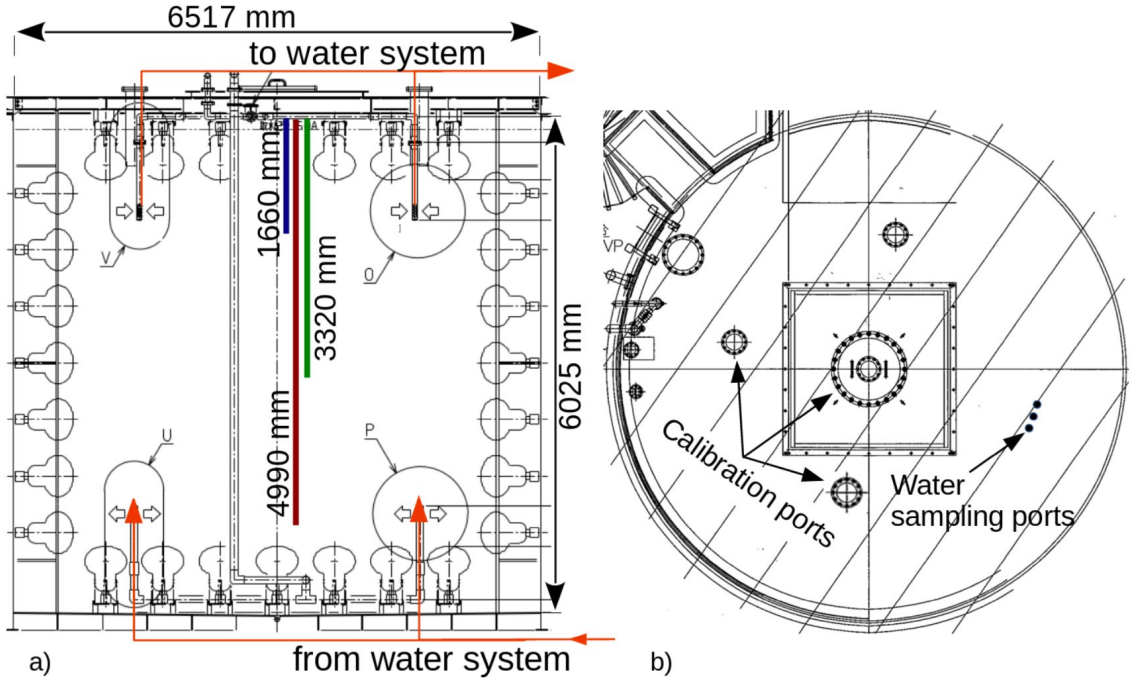


Figure 5: Left a) schematic view of the EGADS tank, its sampling ports (bottom, centre and top at 4990, 3320, and 1660 mm from the tank-top) and inflow and outflow from and to the water purification systems. Right b) top view of the EGADS tank with its calibration and water sampling ports.

Materials in Water

- Care about rate of impurities dissolving (elution) in water from all materials

- Surface area estimates:
  - Tank = 64m^2 = 23m^2 (endcaps) + 41m^2 (barrel)
  - Support structure = ?
  - 106 mPMTs = 74m^2 = [0.20m^2 (SS) + 0.27m^2 (PVC) + 0.23m^2 (acrylic)] x 106
  - ID Blacksheet = 27m^2