TRIUMF
University of Victoria
Canadian Association of Physicists
Association canadienne des physiciens et physiciennes
Hyper-K

Water Monitoring System for Water Cherenkov Detectors

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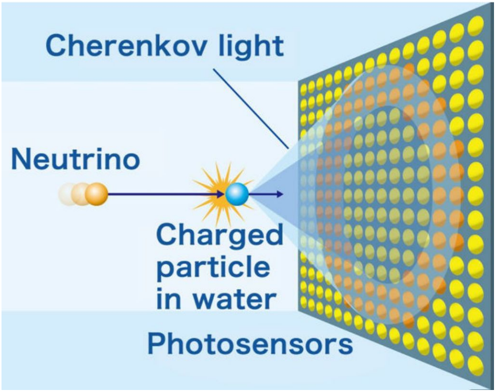
21 June 2023

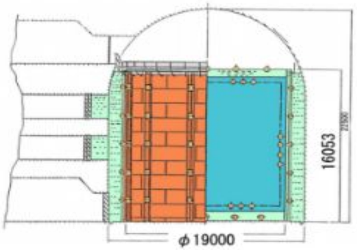
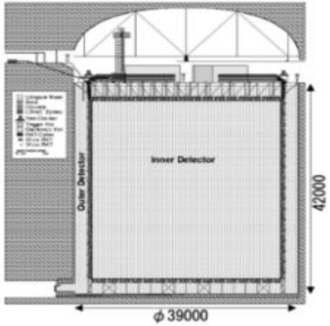
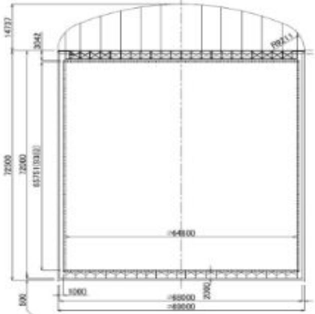
Discovery, accelerated

The Large Neutrino Detectors in Japan

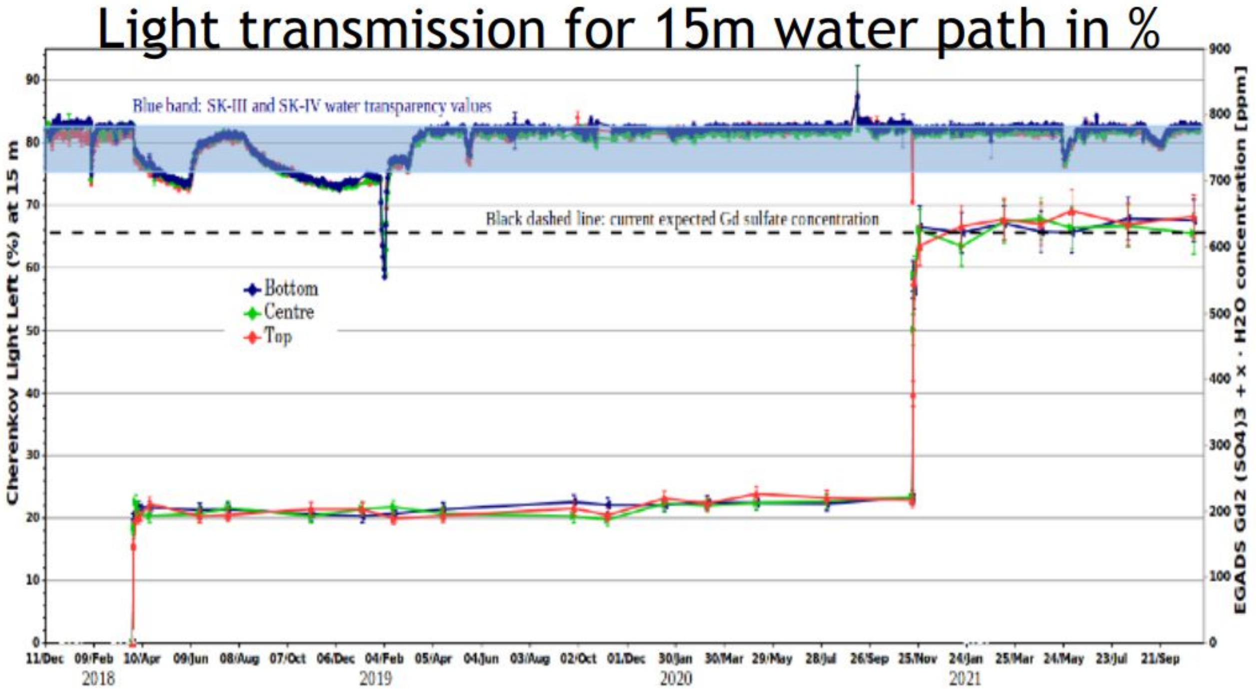


Cherenkov ring shows:

- ➢ Particle’s momentum
- ➢ particle type

Kamiokande	Super-Kamiokande	Hyper-Kamiokande
1983～1996	1996~Present	Aiming to start observation in 2027
		
Size		
19m diameter x 16m hight	39m diameter x 42m hight	68m diameter x 71m hight
Water mass (Fiducial mass)		
4500 ton※ (680~1040 ton) ※The waer mass in the tank(inner tank and, upper and bottom outer tank) is 3000 ton	50000 ton (22500 ton)	260000 ton (190000 ton)
Photomultiplier Tubes		
50cm diameter / 948	50cm diameter / 11146	50cm diameter / about 40000

Continuous Water Monitoring



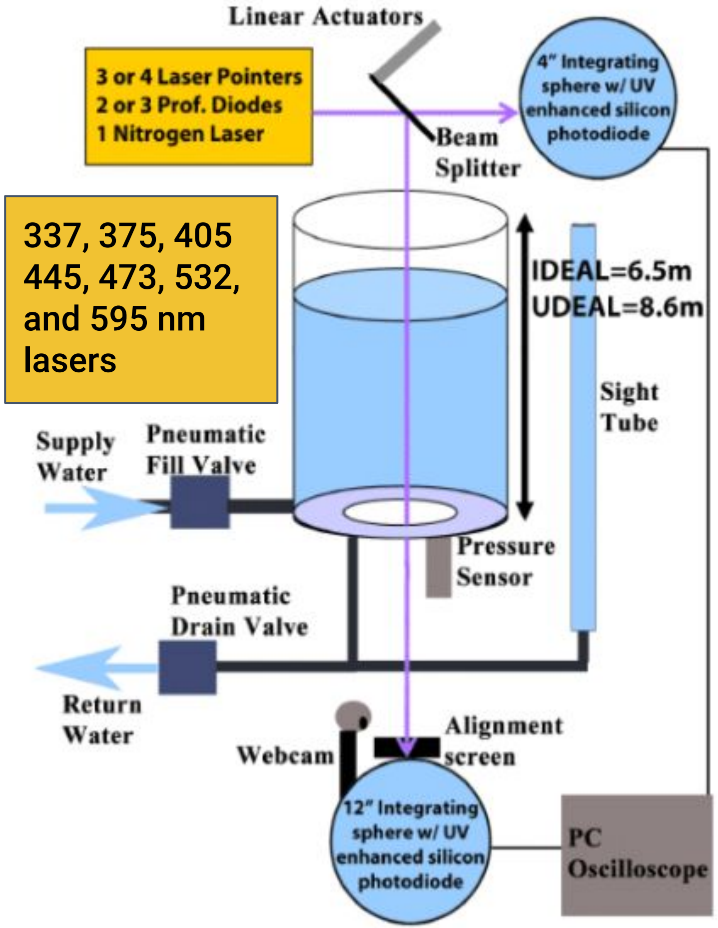
The continuous high-sensitivity optical water monitoring system for:

- ❑ HyperK
- ❑ WCTE in early 2024
- ❑ IWCD experiment in 2026
- ❑ Drinking water monitoring

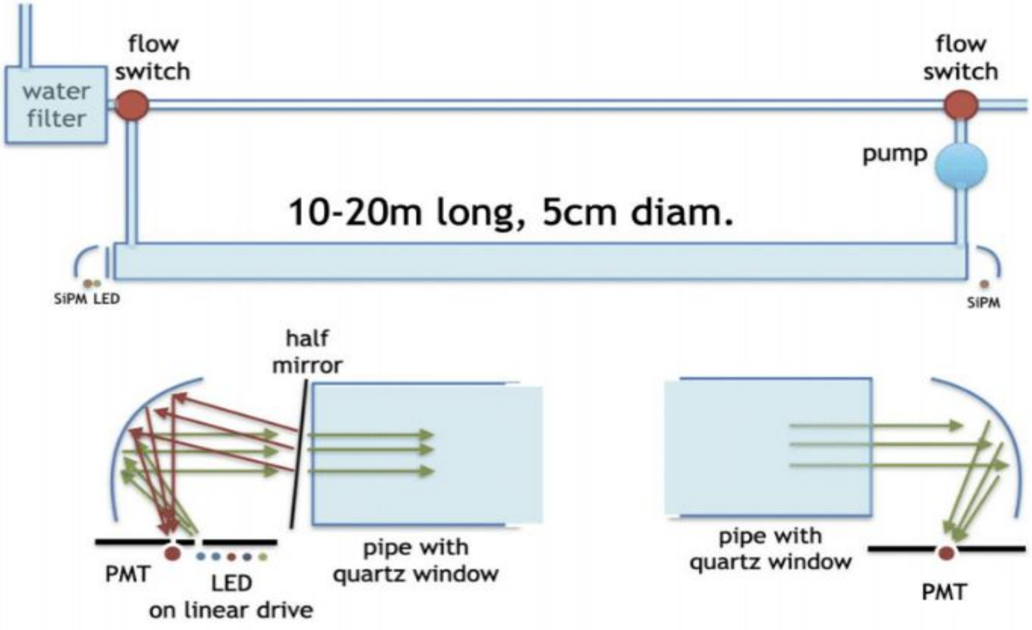
Importance of water quality:

- water transparency
- long Cherenkov light attenuation length

UDEAL System



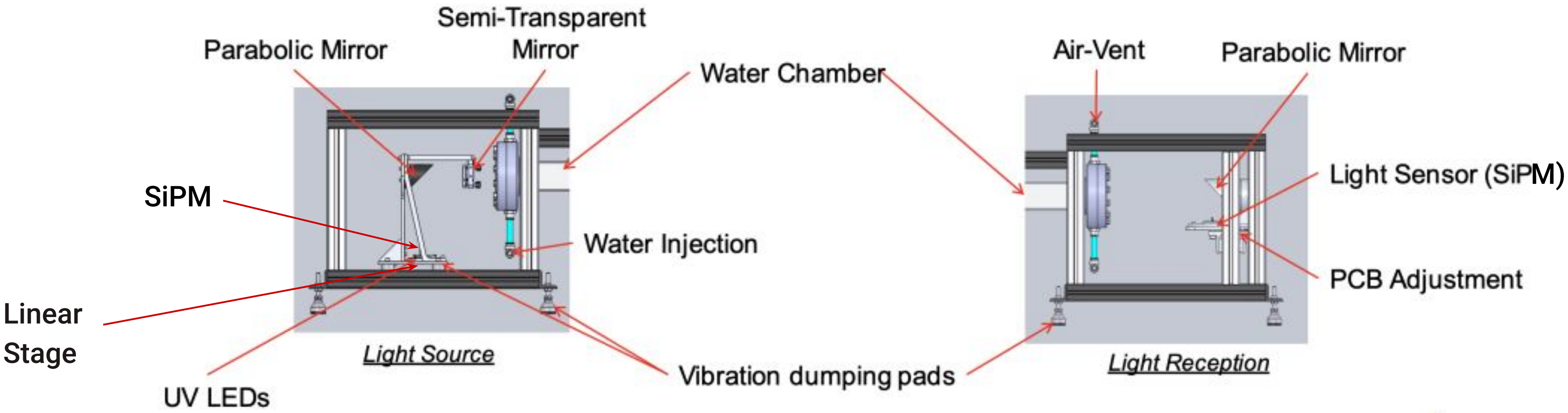
Schematics of Our Detector



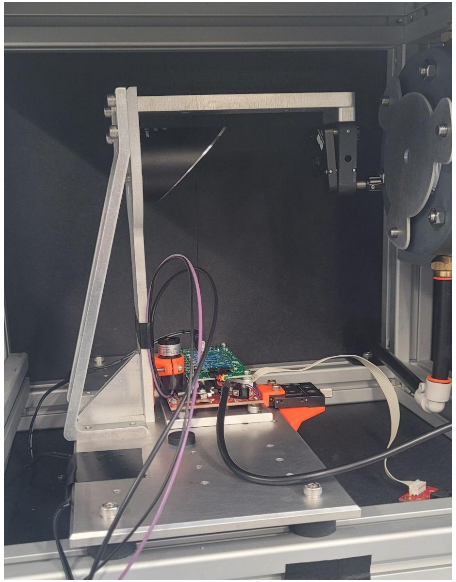
- Horizontal water pipe instead of vertical
- The water quality measured relative to ultra-pure water

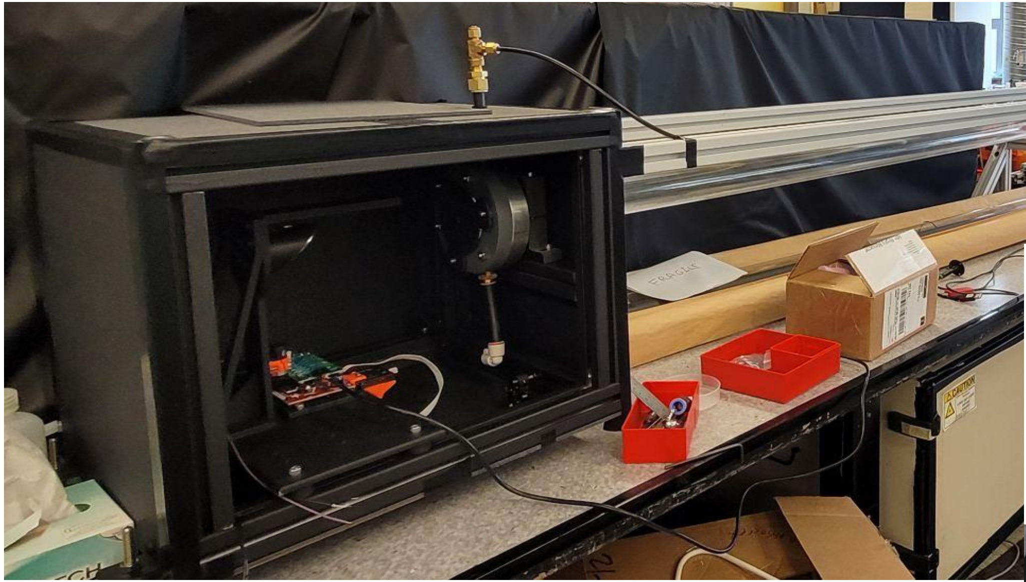
Mechanical Design

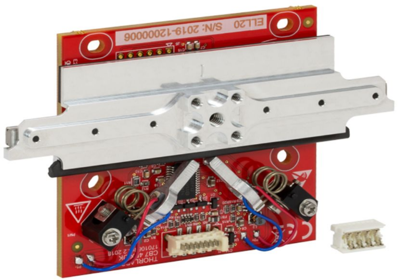
★ To cut costs, SiPMs will take the place of PMTs.

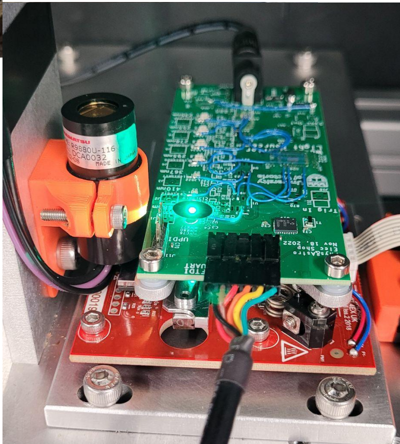


Prototype Detector





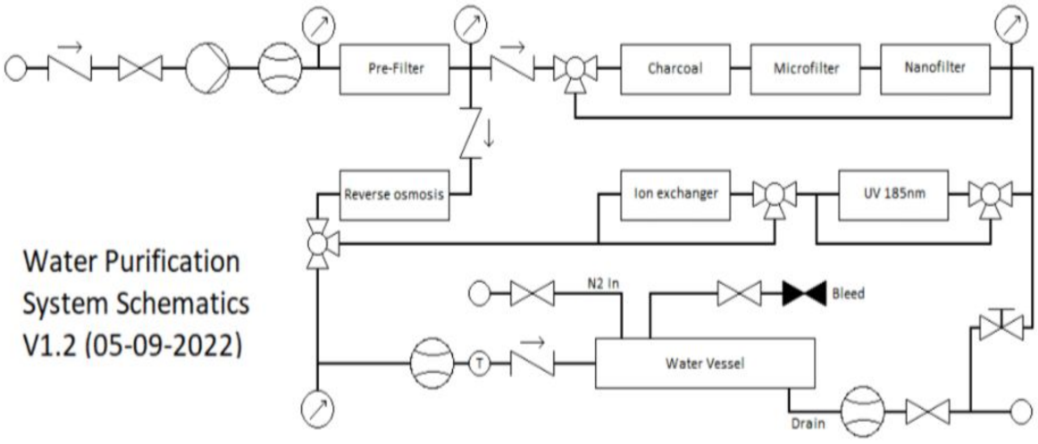


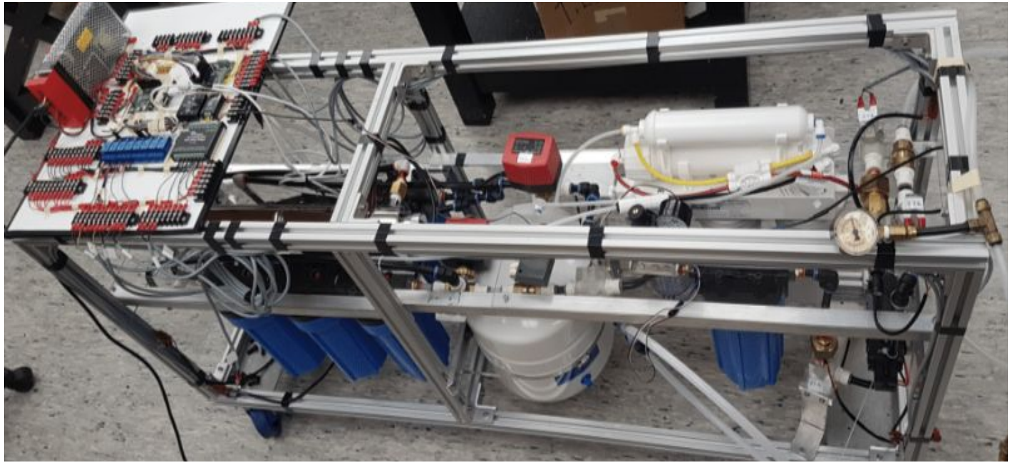


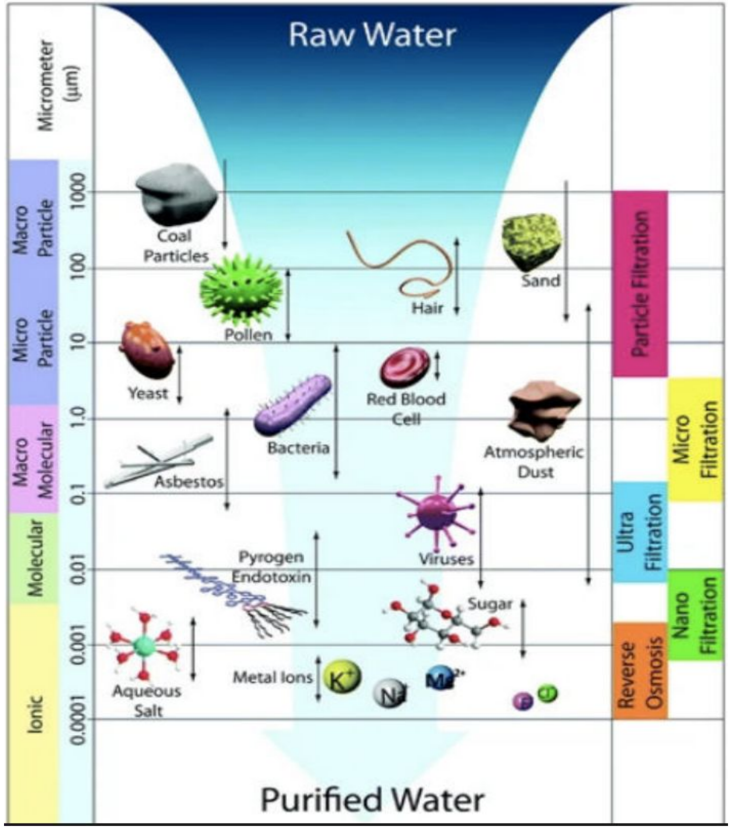
- ❖ Testing on this prototype, which was constructed by TRIUMF engineers, has already begun.

- ❖ One fixed parabolic mirror and one rotatable mirror. LED board on a 60 mm Linear Translation Stage with Resonant Piezoelectric Motors.

Water Filtration System

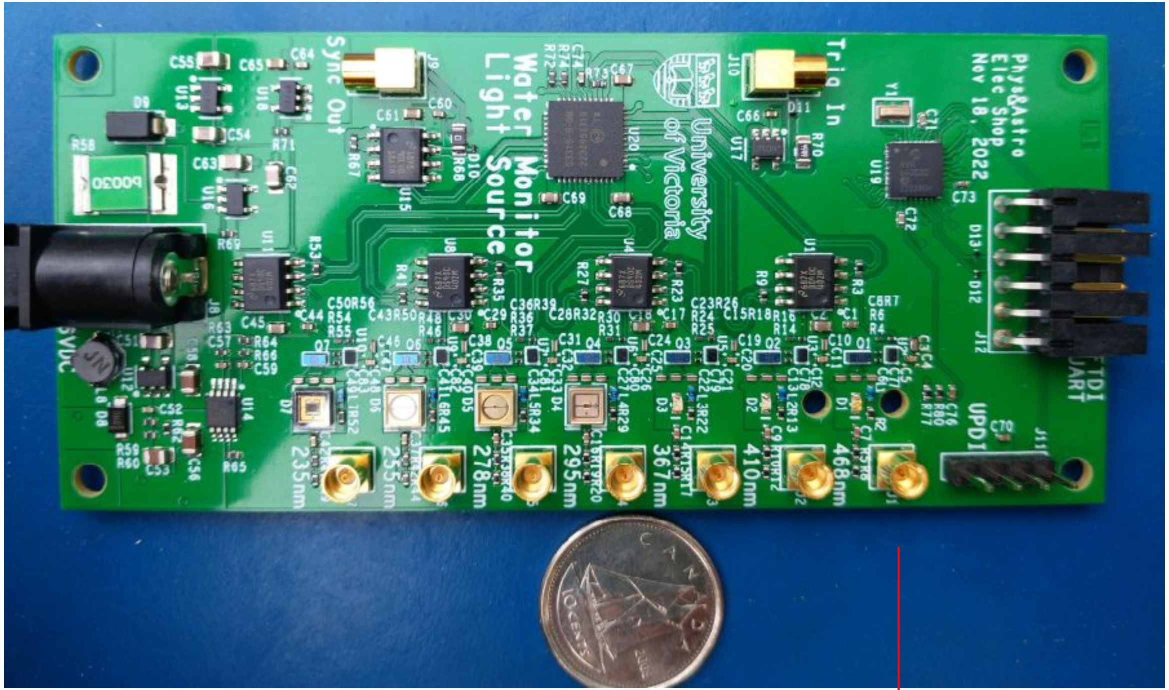


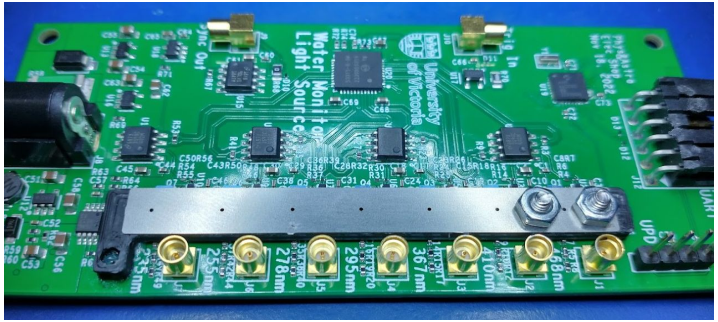


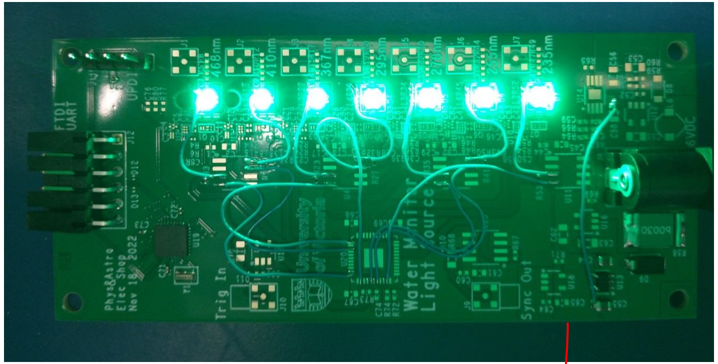


- ❏ ultra-pure (RO)
- ❏ particle filter (MF,NF)
- ❏ ion exchange resins
- ❏ UV steriliser (organic)

Water Monitor Light Source



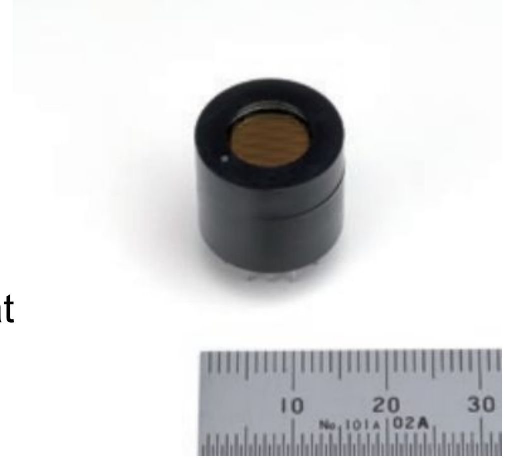


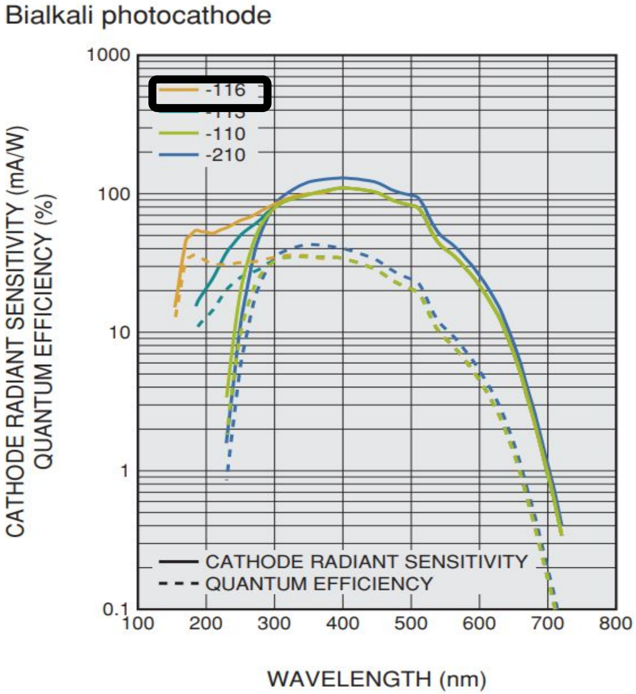


Nicolas Braam from UVic has built two fully populated boards & two partially populated boards, as well as another board with visible LEDs for alignment.

Light Detection

Two R9880U-116 PMTs with spectral response ranges of 160 nm to 700 nm at the source and reception sites





I. One PMT near the LEDs (the focal point of the first mirror) at the source site, collects reflected photons from the half-mirror.

II. The other PMT at the reception site detects the focused beam at the focal point of the second mirror.

➢ Hence, relative transmission is measured.

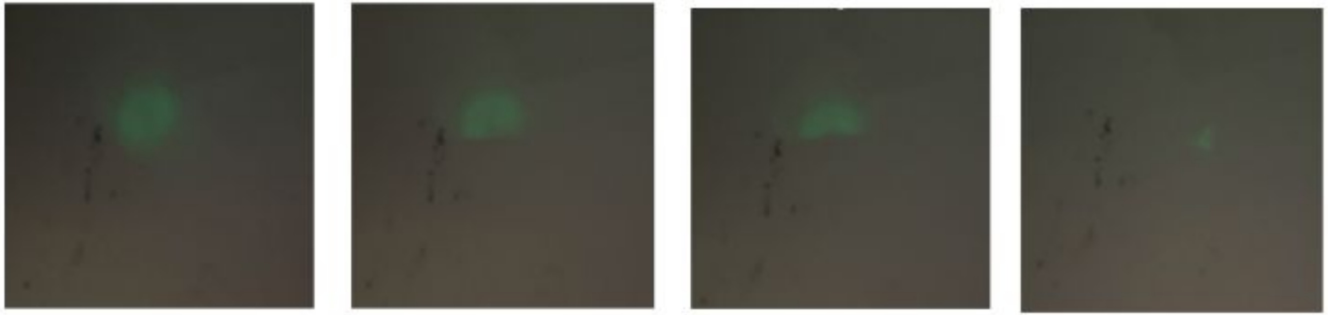
PRODUCT VARIATIONS

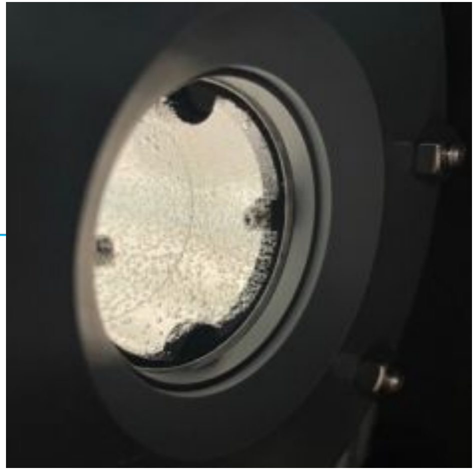
Type No.		-09	-116	-113	-110	-210	-04	-01	-20	Unit
Photocathode ①		Cs-Te	SBA			UBA	MA		ERMA	—
Spectral response	Range	160 to 320	160 to 700	185 to 700	230 to 700		185 to 870	230 to 870	230 to 920	nm
	Peak	240	400						630	nm
Window material		Quartz		UV	Borosilicate		UV	Borosilicate		—

NOTE: ① Photocathode materials
SBA: Super bialkali, UBA: Ultra bialkali, MA: Multialkali, ERMA: Extended red multialkali

Current Status

Observing how adding water to the pipe affects the image of the light spot on the receiving-end

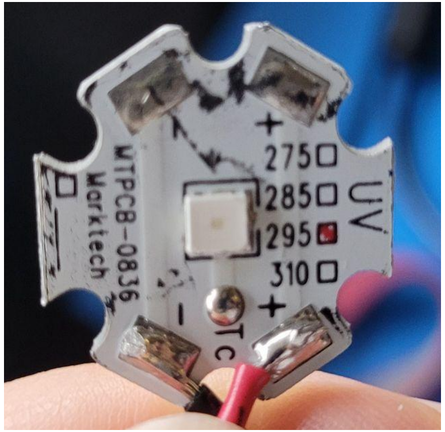


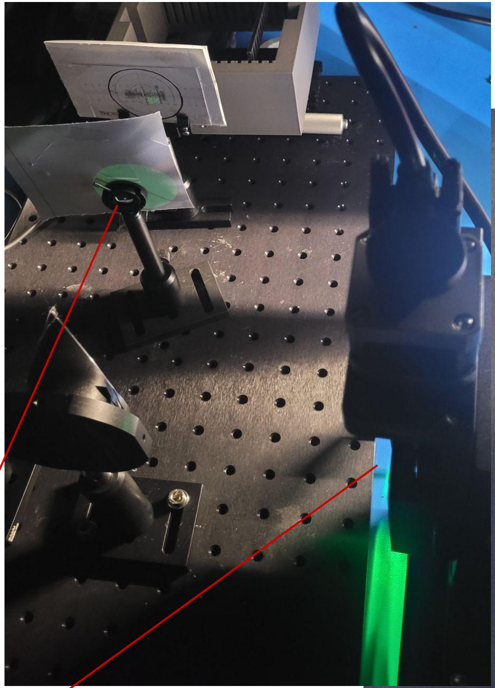


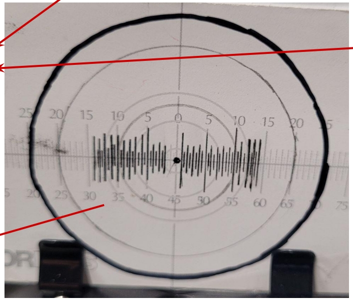
Bubbles on the inner surface and the quartz windows at two ends of the pipe

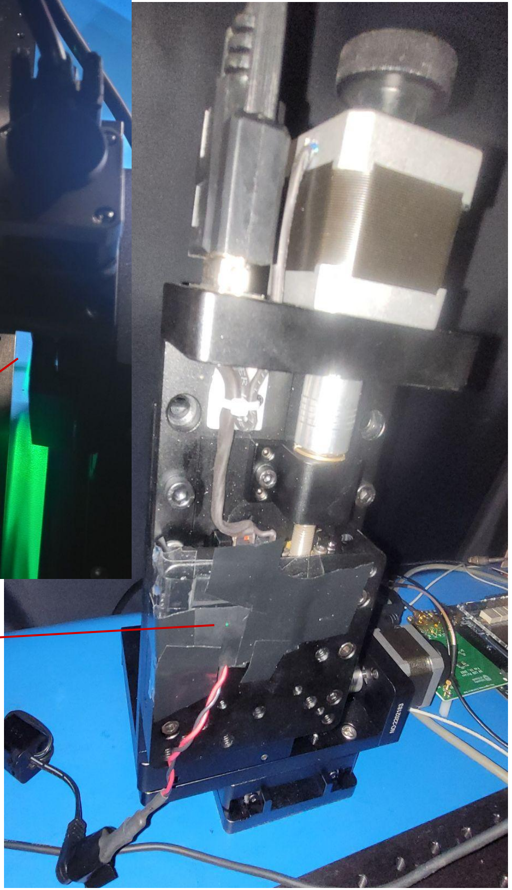
- ❖ Possible solution: degassing the water before entering the pipe or vacuuming the pipe

Optics Study for Alignment

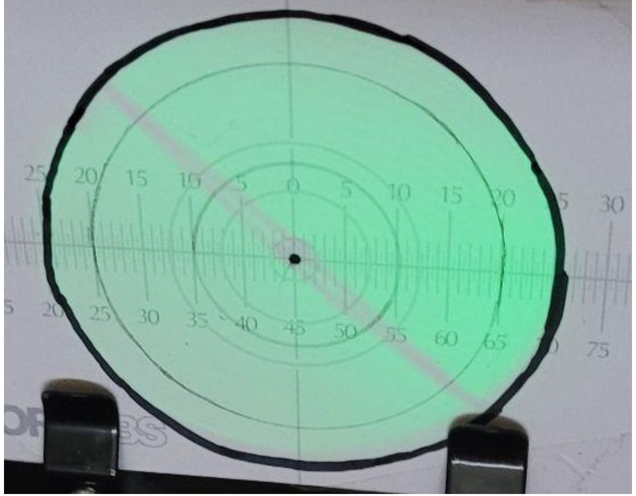


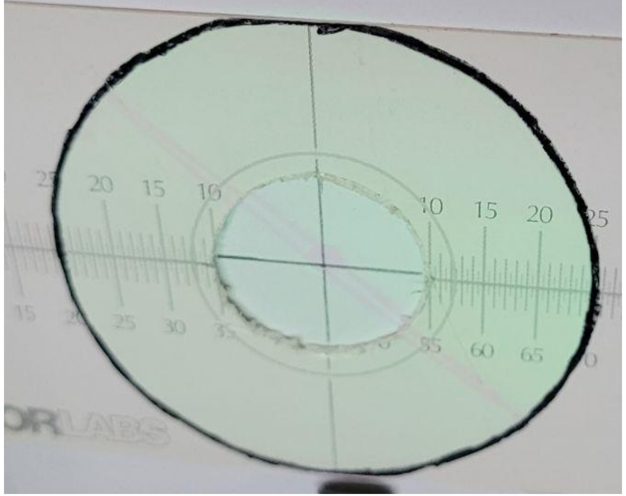






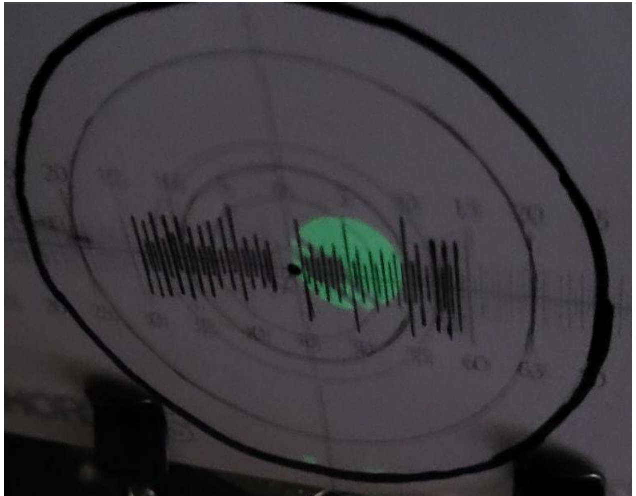
- ➔ An iris after the first mirror to reduce the beam diameter from 50.8 mm to 10 mm
- ➔ A bright LED on a motorized 3D stage with tape on it to make a point light source
- ➔ Screen once put 9 inches after the first mirror, and once put 54 inches away

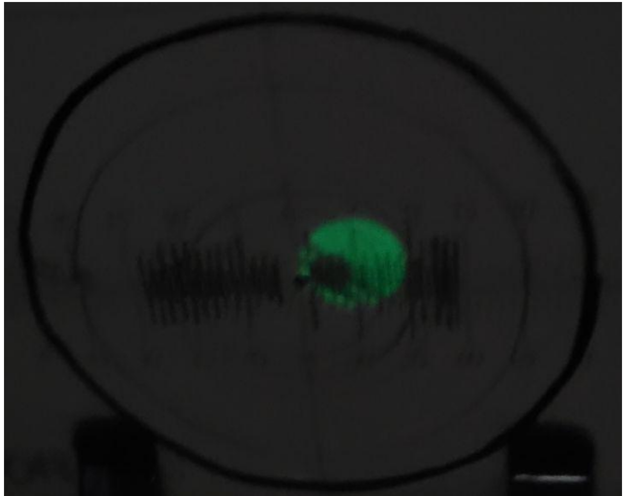




9 inches

54 inches





- ***Parallel beam within 0.5 mrad***
  - 0.1 mm displacement of the LED in X and Z directions corresponds to 1 mm displacement of the second image.
  - Approximately 0.4 mm displacement of the LED in the y direction(axis of the parabolic mirror) changes the second image’s size by 1 mm.
- *Achieved this alignment on the prototype as well.*

Moving the LED

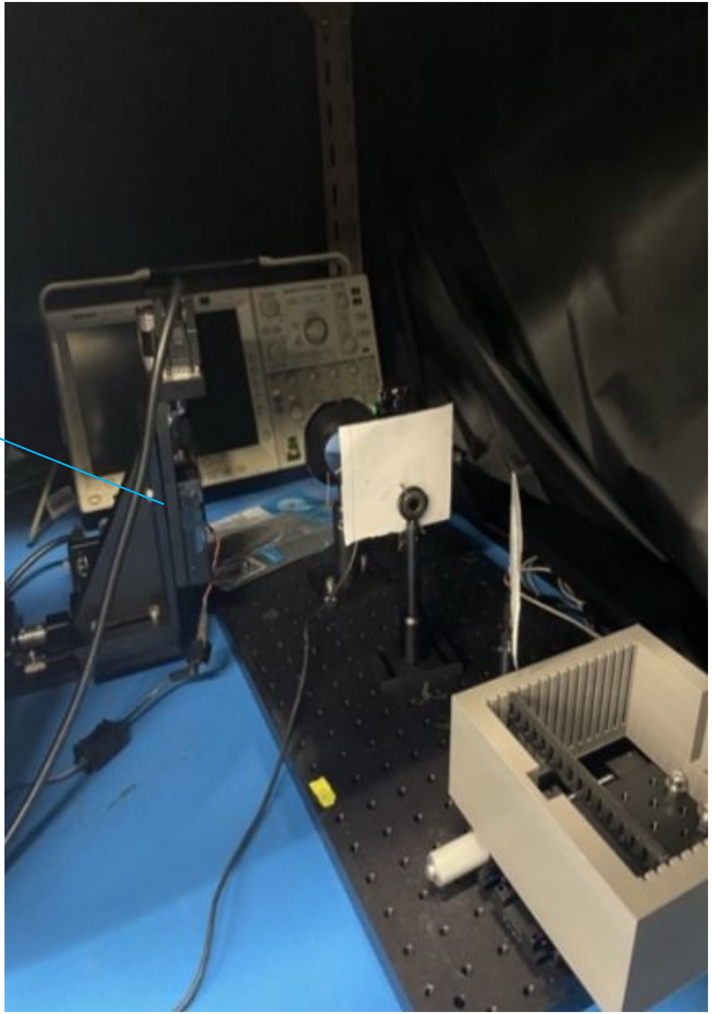
★ Goal: Study the effect of small displacements of the LED on the beam image

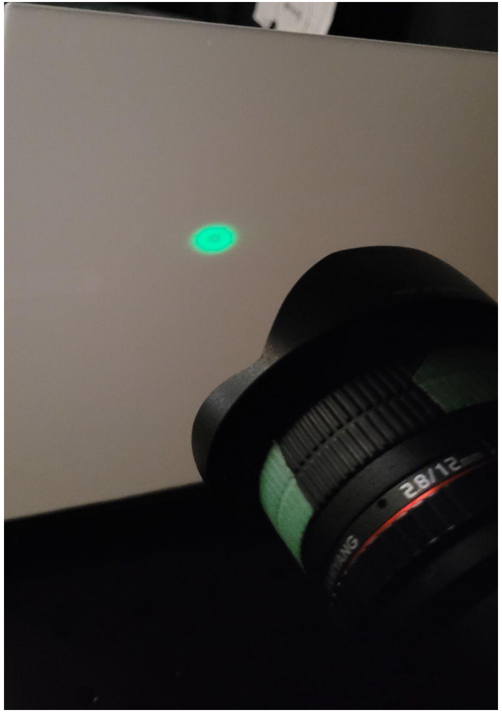
❖ The motorized stage moves the LED in small steps and scans a small volume

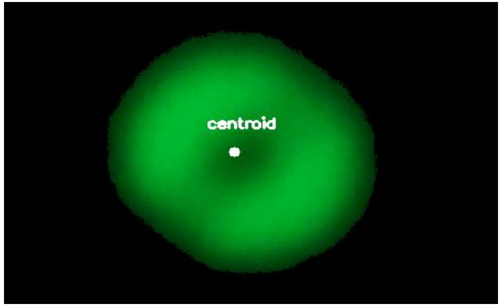
❖ A diffused glass is used as a screen about 1.5 m away from the mirror.

❖ The camera records the pictures.

❖ The analysis is in progress.



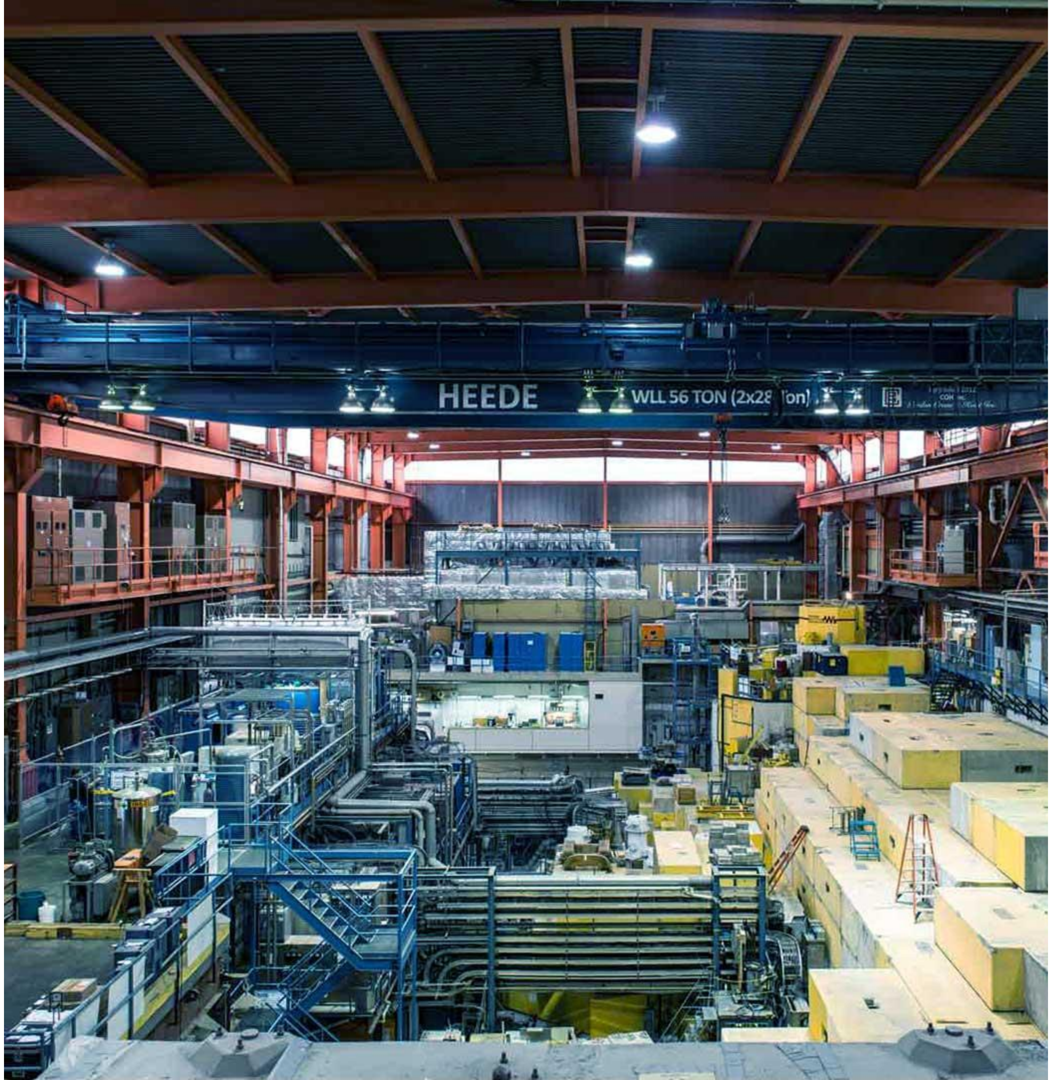




TRIUMF

Thank you.

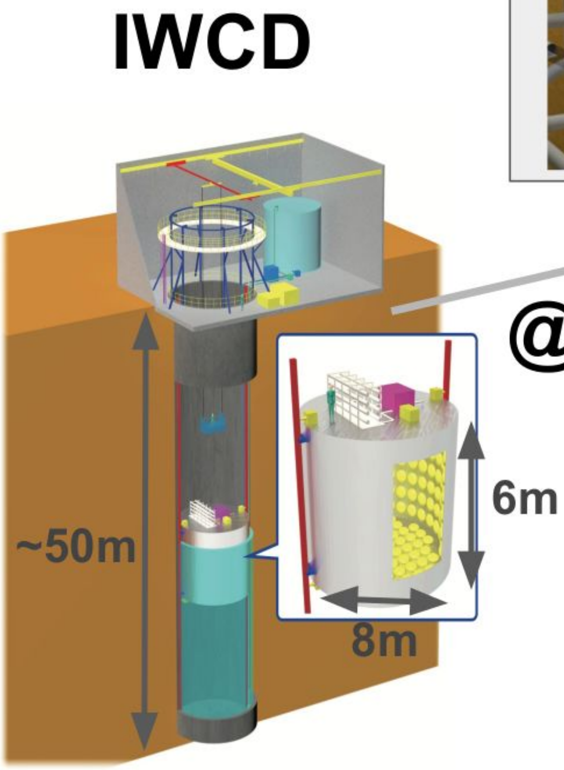
Questions or comments?



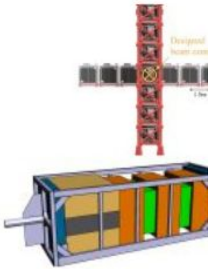
Discovery, accelerated

Additional Slides

The Intermediate Water Cherenkov Detector (IWCD)



Other near detectors @ 280m
- INGRID
- Upgraded ND280



@~1km

- Sub-kiloton scale water Cherenkov detector
- **Vertically movable** detector
- Gadolinium (**Gd**) **loading** option

Ryosuke Akutsu's slide

Water Cherenkov Test Experiment (WCTE)

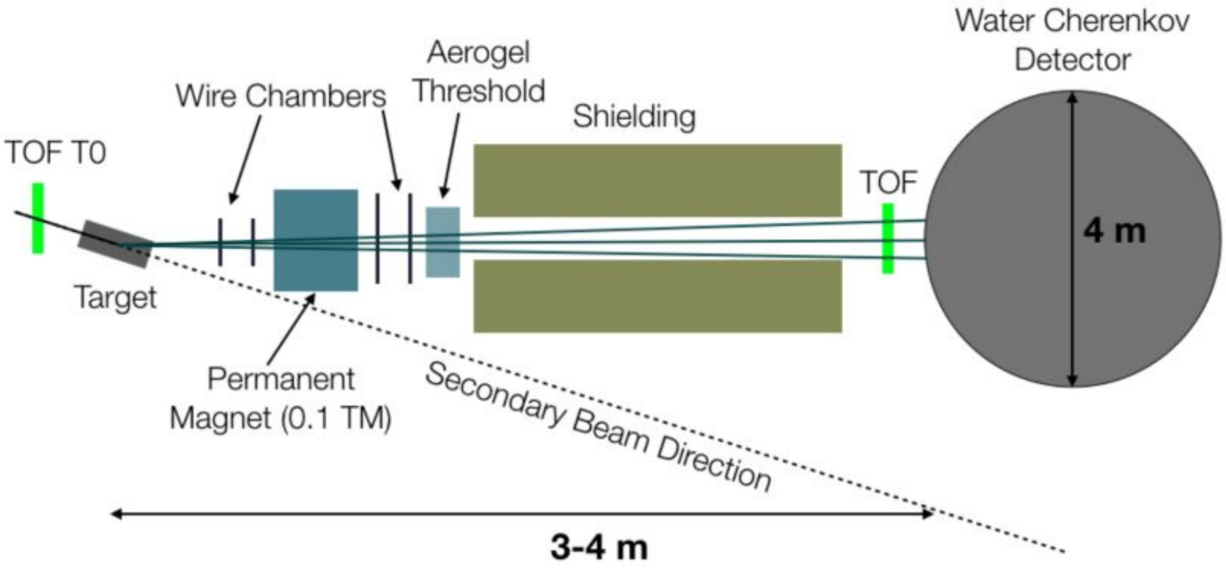
Goal: study detector systems and detector response to pions, muons, electrons and protons from 200 MeV/c up to 1000 MeV/c

~4m diameter,

~4m high

cylindrical water

Cherenkov detector

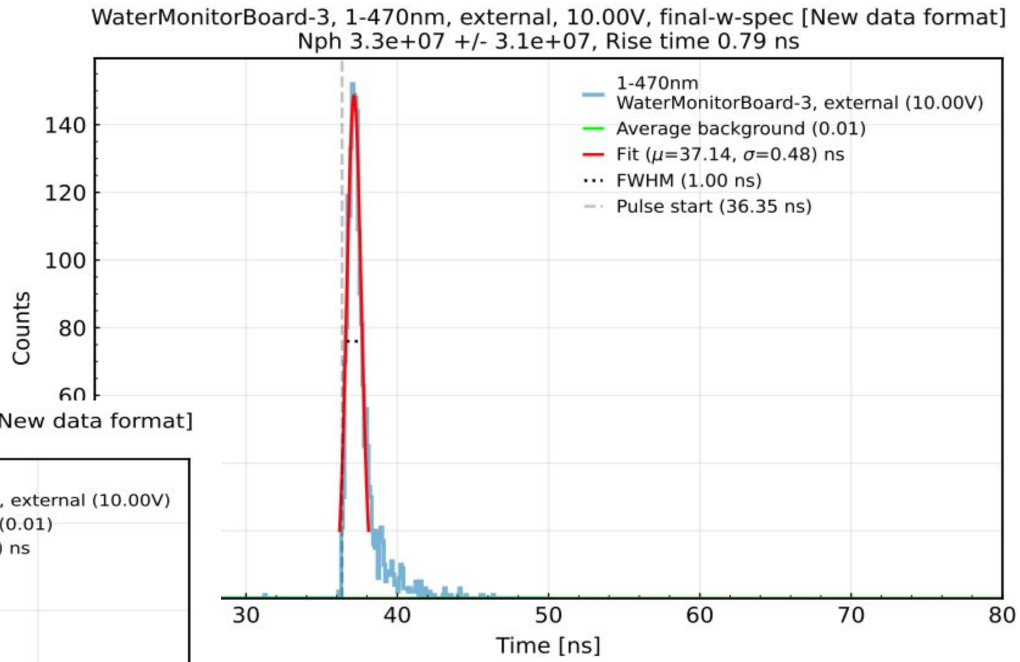


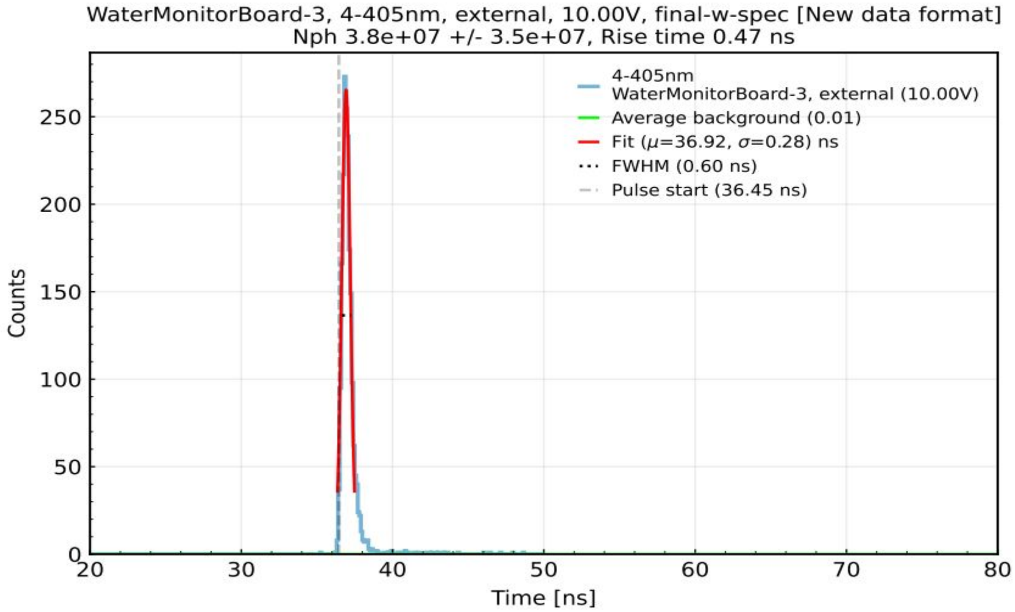
The Timing Spectrum

FWHM light profile at maximum output for 7 LED channels:

470nm - 0.9ns

405nm - 0.6ns





365nm - 0.5ns

295nm - 0.7ns

278nm - 0.5ns

255nm - 0.5ns

235nm - 0.6ns

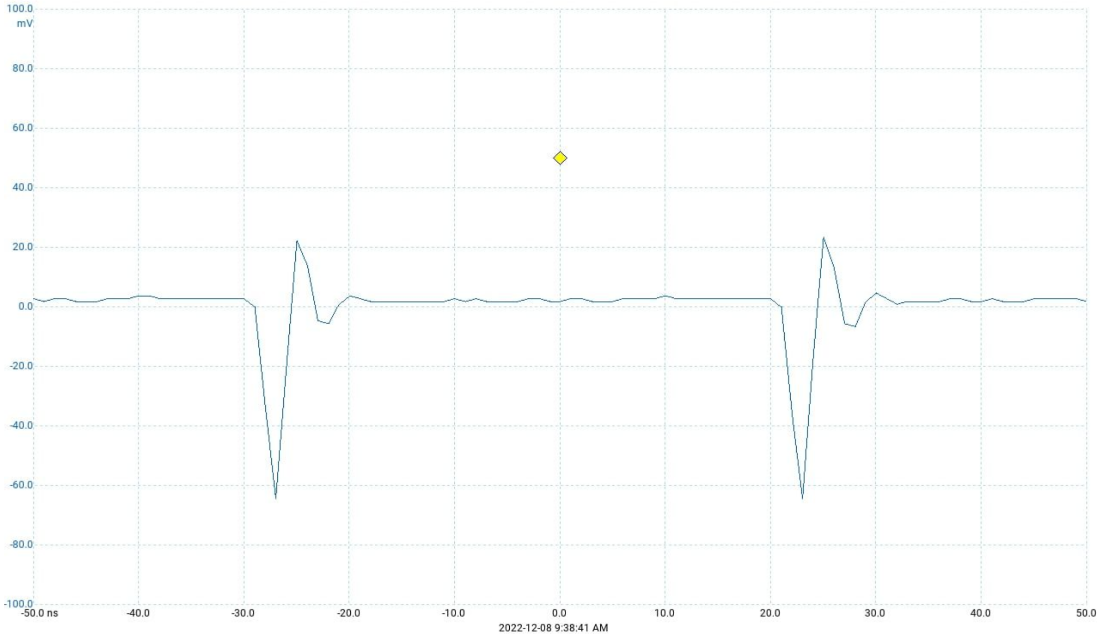
DAQ

PicoScope 3406D MSO is used:

- as an oscilloscope during operation

and

- for data acquisition.



Channel	Name	Span	Value	Min.	Max.	x	σ
A	Frequency	Whole trace	20 MHz	20 MHz	20.41 MHz	20.01 MHz	54.88 kHz
A	Cycle time	Whole trace	50 ns	49 ns	50 ns	49.98 ns	132.1 ps
A	Mean	Whole trace	213.8 μV	111.1 μV	307.2 μV	216.9 μV	37.18 μV
A	RMS	Whole trace	11.56 mV	11.51 mV	13.06 mV	11.64 mV	299 μV
A	RMS ripple	Whole trace	11.67 mV	11.62 mV	11.75 mV	11.67 mV	30.37 μV

Pico Technology www.picotech.com PicoScope 7 T&M Early Access Version 7.0.114.13320 JO352/0519 PS3406DMSO

MIDAS for controlling the overall system, including DAQ, high voltages and environmental monitors, and the selective water purification system