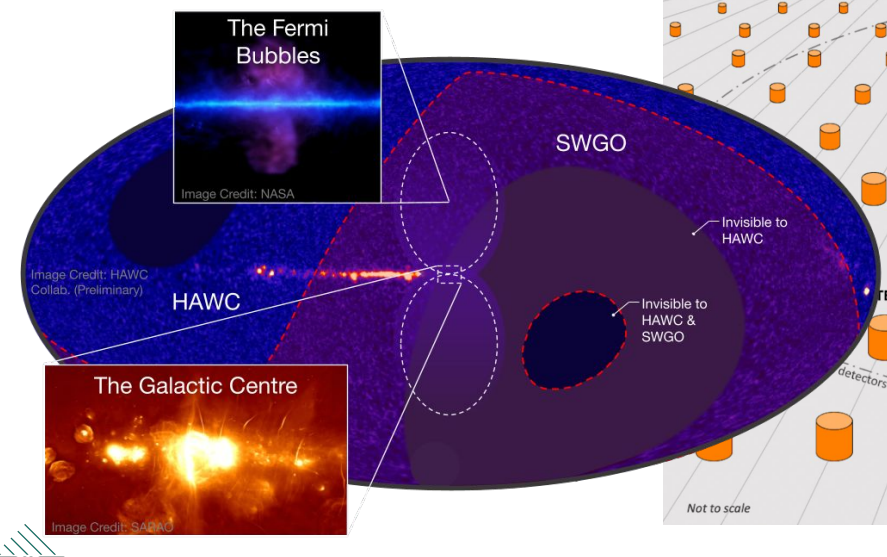
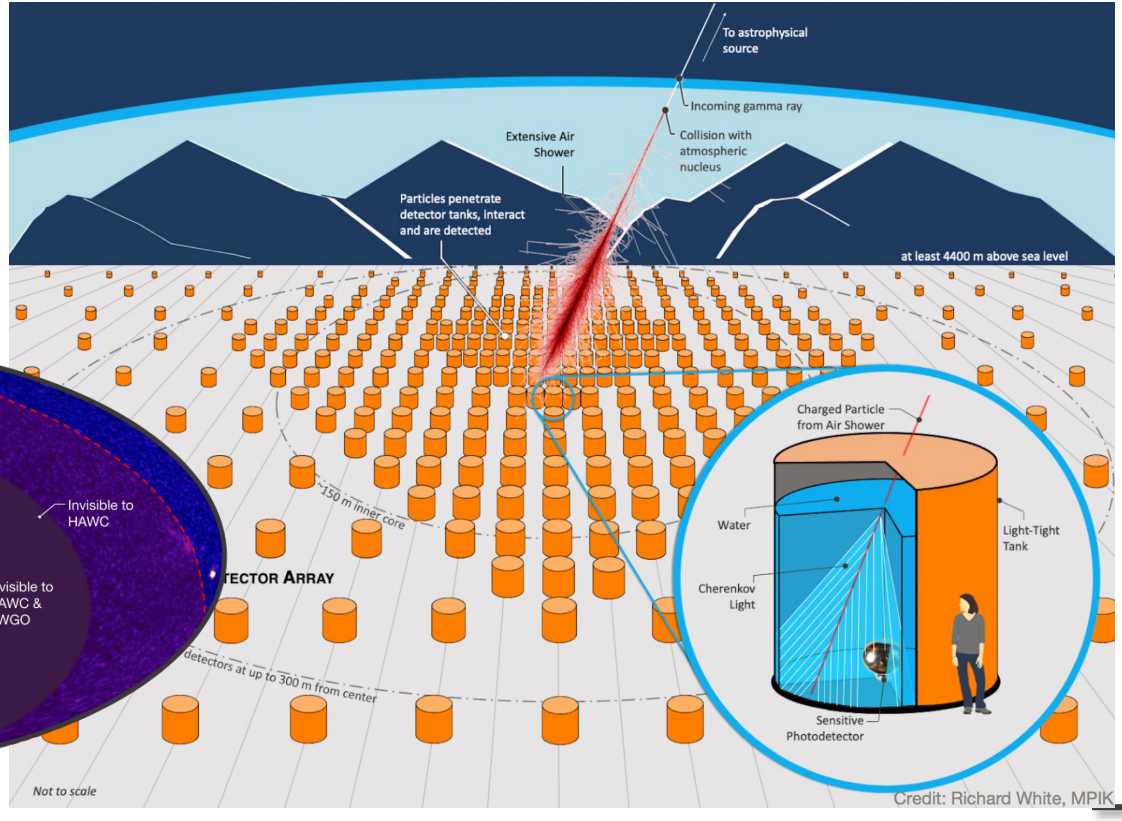
SWGO Unit Prototyping

11.06.2023
3rd GCOS Workshop
Hazal Goksu

SWGO
The Southern Wide-field Gamma-ray Observatory

- Next generation gamma-ray observatory
- Wide FoV
- 80% fill factor for central array
- 24/7 data taking.





Unit Detector Design

Cylindrical Tanks

- Steel tanks
- Rotomolded HDPE tanks

Bladders in Water

- In a natural lake
- In an artificial lake (Pond)

https://pos.sissa.it/395/714/

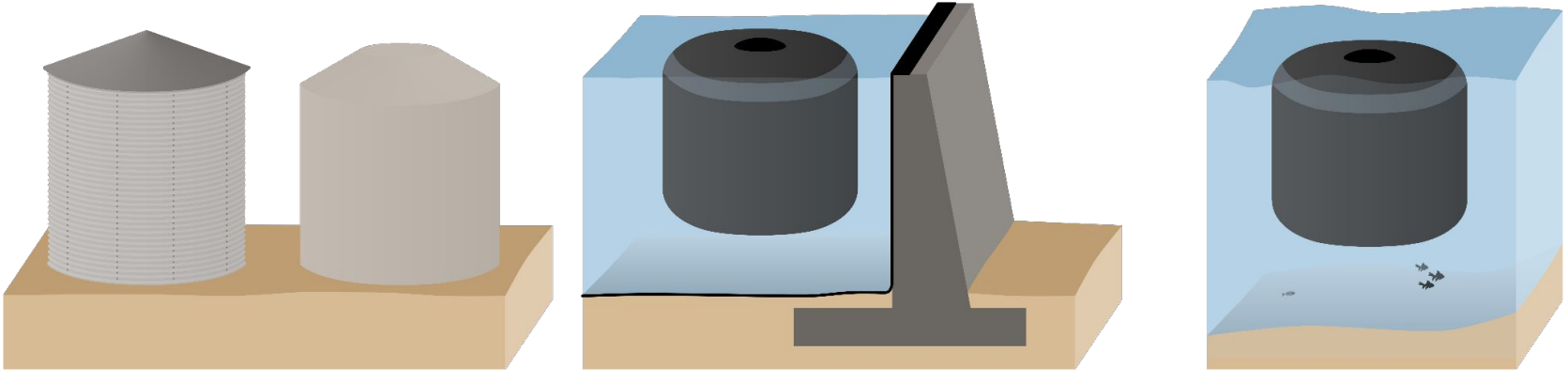
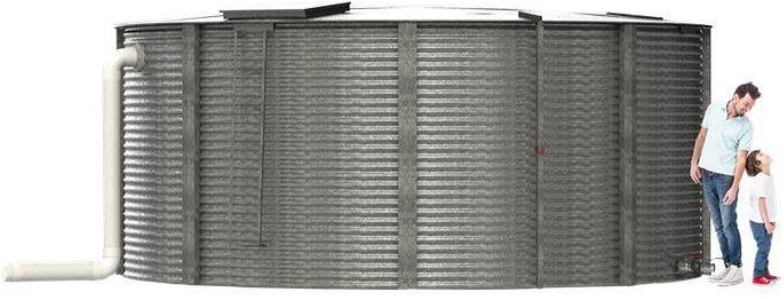


Image by Felix Werner

Tank Developments

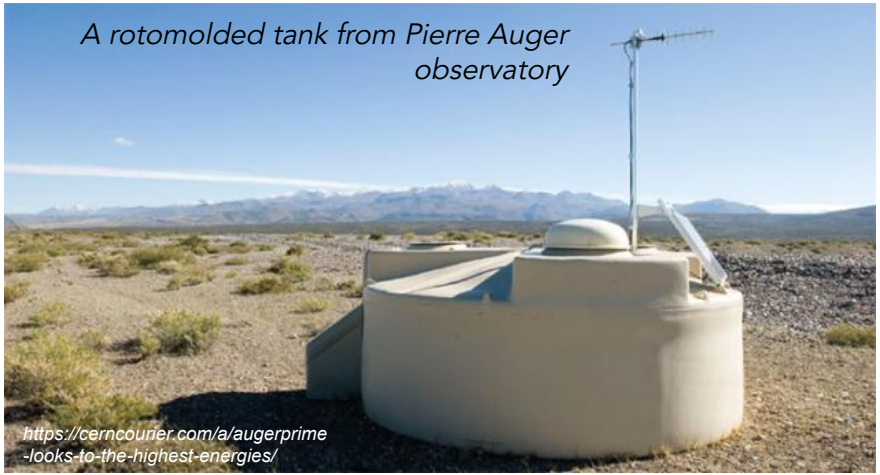
- Steel tanks from Aquamate
  - Includes bladders as well
- Easy to transport, assembly on site
- Recently built in Peru & HAWC site

https://www.aquamate.com.au/



Tank Developments

- Rotomolded tanks:
  - Similar to Auger Observatory
  - Company in Brazil
  - A candidate design made up of rotomolded tanks, single chamber [See PoS ICRC 2021, 707]



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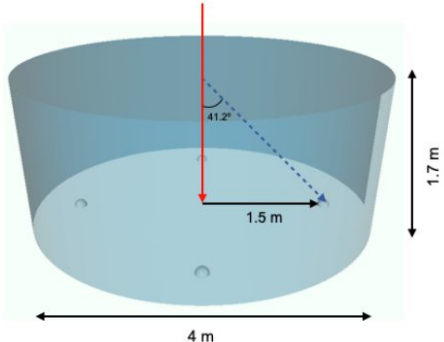
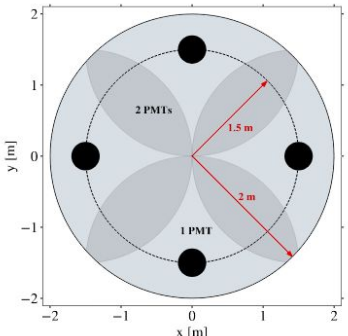




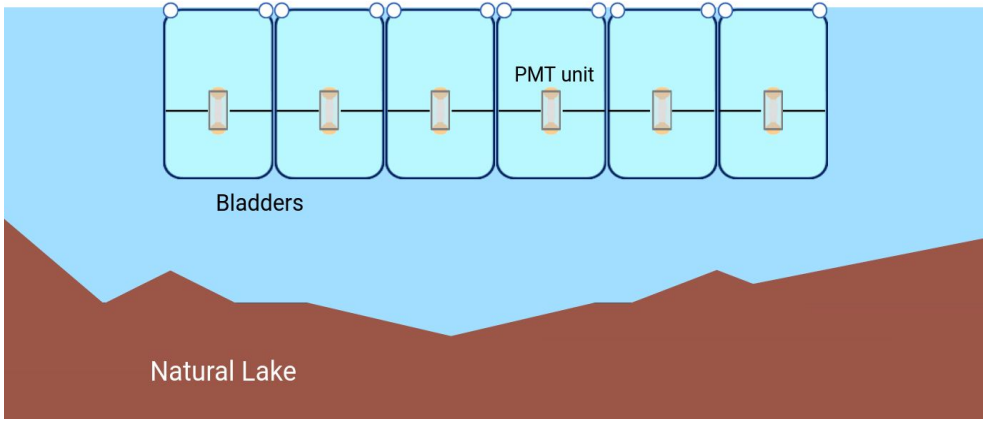
Lake Design

Advantages

- Cost reduction: No need for tanks
- Reduced constraints on unit dimensions
- Improved muon detection
- Flexible arrangement

Challenges

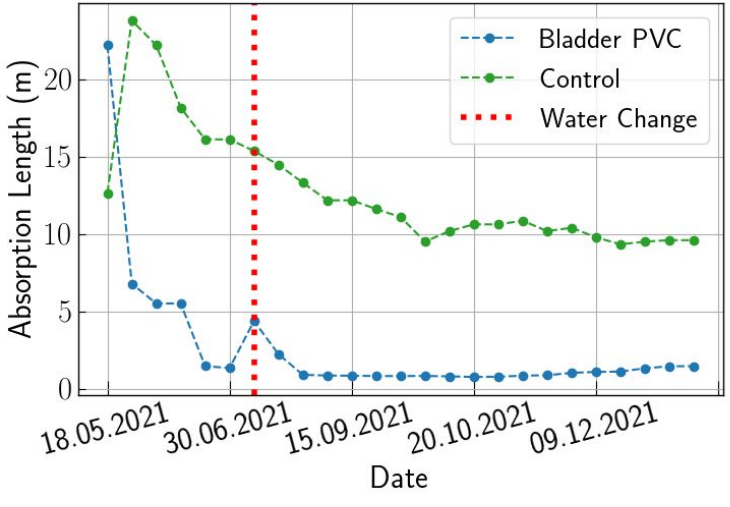
- New technology; experience
- Mechanical stability under water motion
- Continuous position calibration required

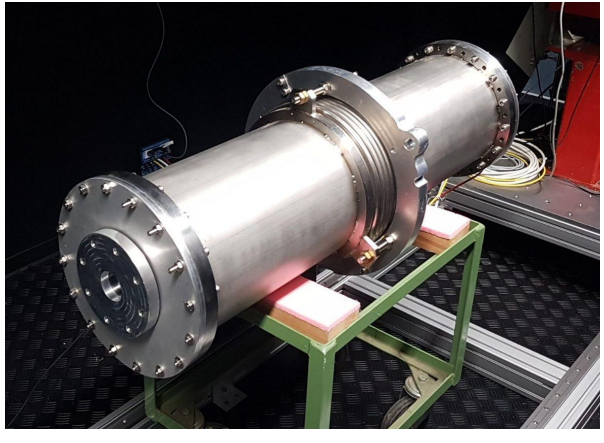


Bladders: Material Tests

- Light tightness
- No degradation of water inside bladder
- (Partially) Reflective inner layer
- Withstand wave motion
- Water tightness

- ➔ Light tightness tests
- ➔ Water degradation measurements
- ➔ Reflectivity tests
- ➔ Test in Sibinacocha (Peru) soon





MPIK Bladders

1. PVC Bladder
   - For Mechanical tests
2. Enviro Bladder
   - Aquamate
3. Geoflex Bladder
   - Aquamate
4. Our own material
   - *Advanced Films, LLC*
   - Made Auger & HAWC bladders

Aim to find a light-tight bladder that can be produced in mass


Enviro Bladder

Geoflex bladder

AQUAMATE LAYFIELD

Bladders: Manufacturing

- At MPIK
  - Tried hot air welding
    - Not water tight
  - Impulse sealer sent by Michael Schneider
    - Used it for "Umbrella"
- At Aquamate
  - Hot air welding
  - Using material from Layfield & later from Advanced Films, LLC

AQUAMATE
16 Drury Terrace
Tonsley SA 5042
ABN 76 084 835 905

Prototypes: Hot Air Welding

- Making our own bladders **at MPIK**

~ April 2020

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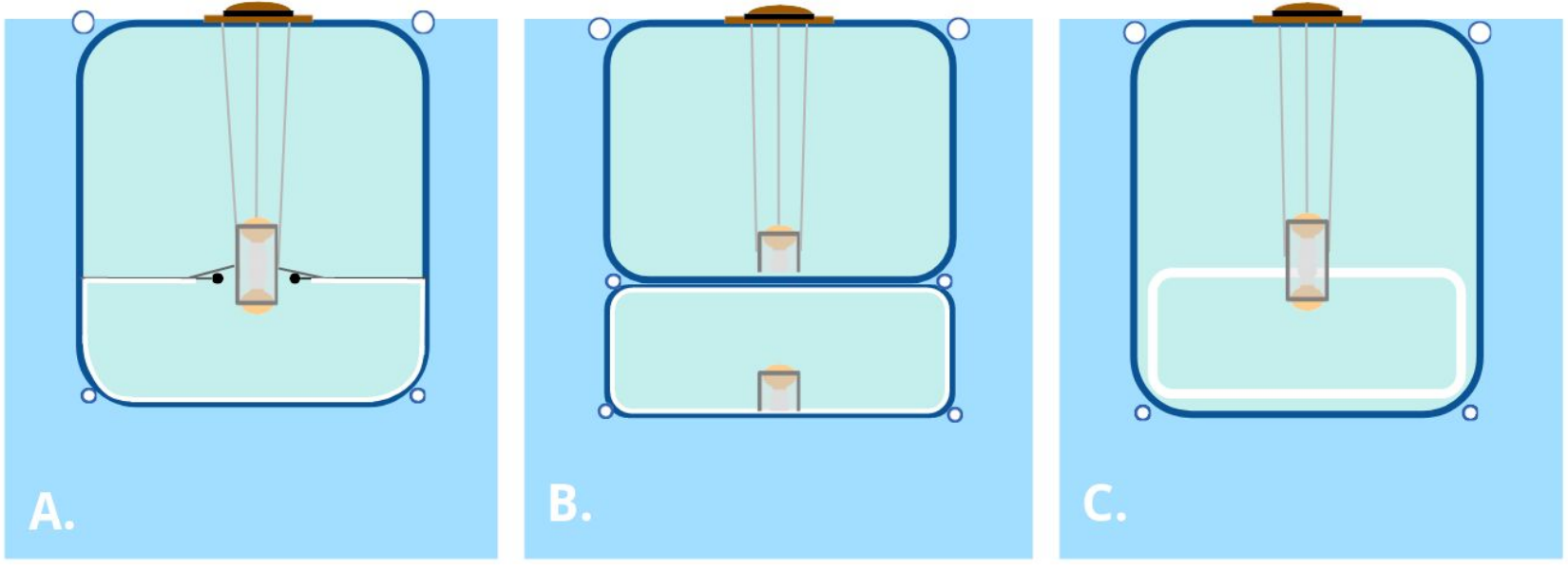
Towards a Double-Layered Bladder

- Lower Chamber Alternatives



Double Layered Bladder with a Membrane

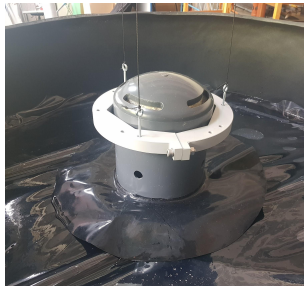
Two Separate Bladders connected in the Middle

A tyvek-only Bladder immersed in bigger Bladder

Towards a Double-Layered Bladder

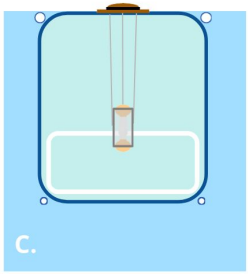
A. Membrane inside bladder
   - Advanced Films LLC & Aquamate are to make such bladders for us

Mechanical tests at MPIK with a membrane and mock double-PMT support

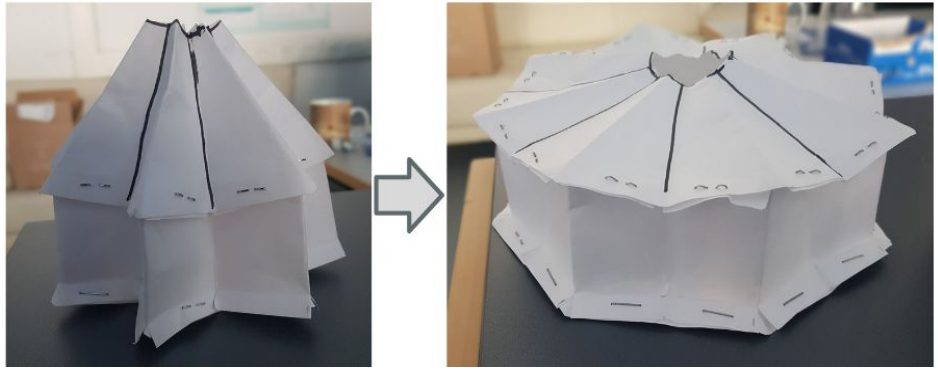


B. Two Separate Bladders
   - Tests with spot-gluing tyvek

C. Matryoshka



- No tyvek-lined/ laminated material available to us right now
- Matryoshka: A bladder made up only of tyvek
  - No need for water tightness
  - No need to laminate tyvek
  - Allows tests with a double cell bladder
- Keeps shape with umbrella mechanism

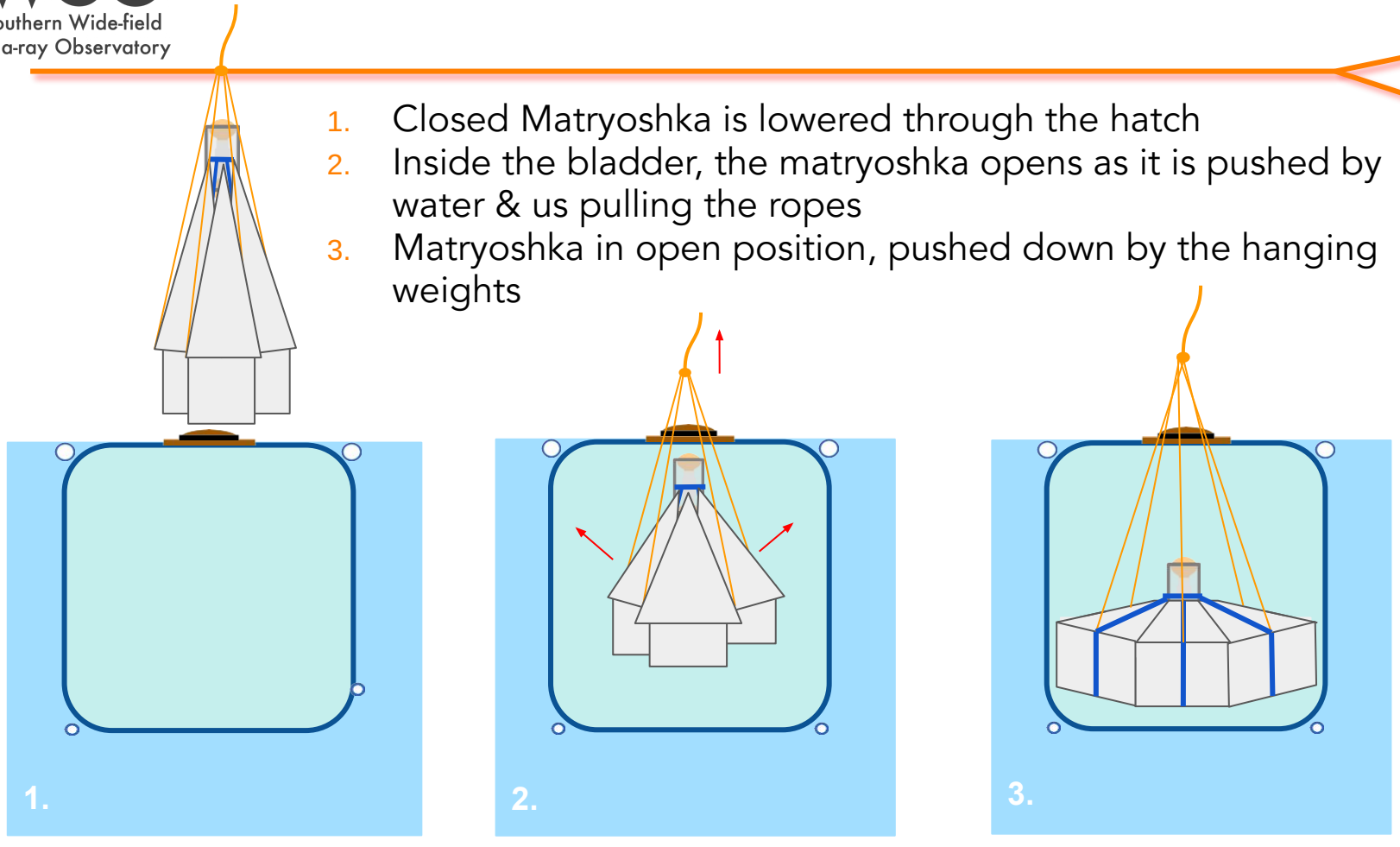


1:10 matryoshka model

Small scale prototype

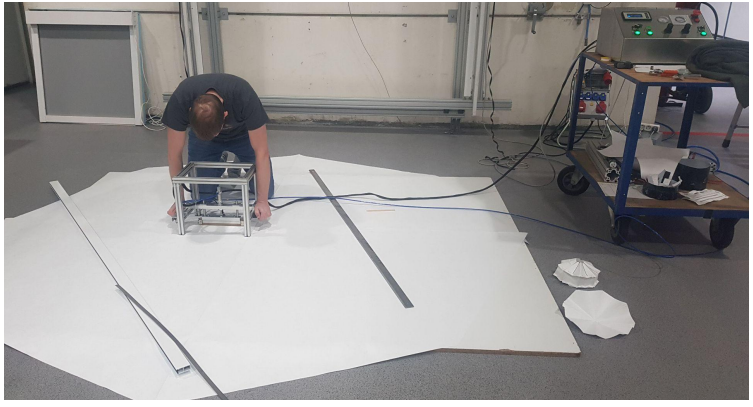
Umbrella Mechanism

1. Closed Matryoshka is lowered through the hatch
2. Inside the bladder, the matryoshka opens as it is pushed by water & us pulling the ropes
3. Matryoshka in open position, pushed down by the hanging weights



C. Matryoshka

Sealing the top



The Umbrella

Sealing the sides

Matryoshka Prototype

Passes through hatch

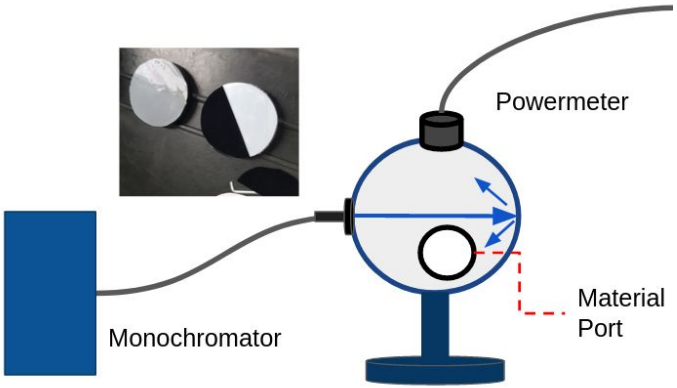
Opened by pulling the ropes

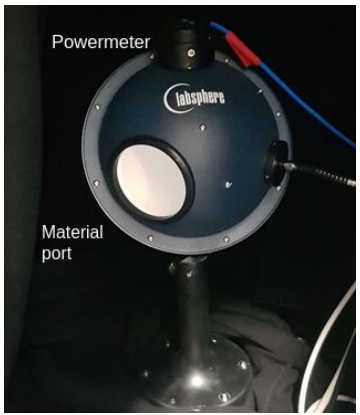
SWGO
The Southern Wide-field Gamma-ray Observatory

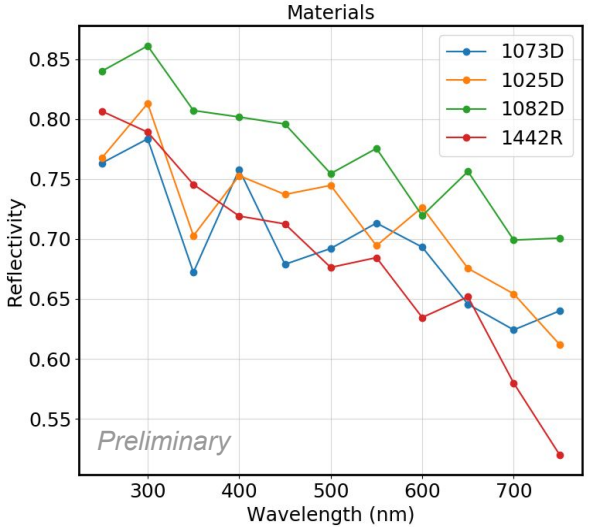
Backups

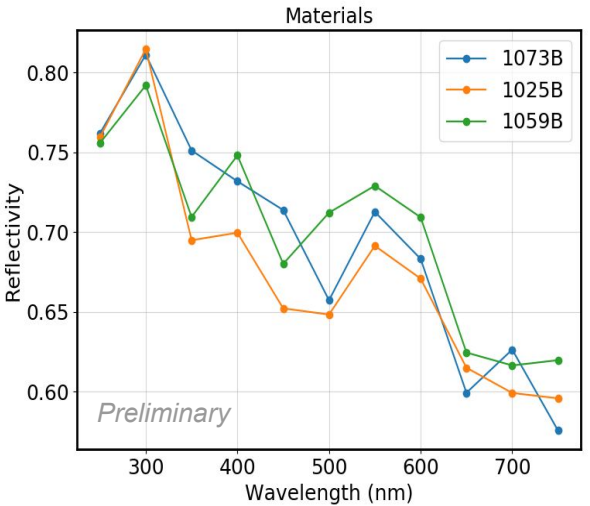
Material Tests: Reflectivity

- Testing different tyvek samples
  - Paper-like vs fabric-like
  - Treated vs untreated
- Integrating Sphere & Xenon lamp & monochromator



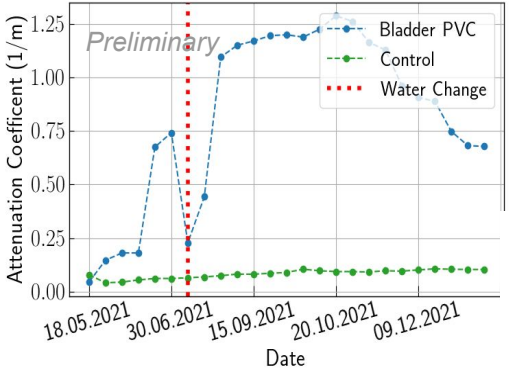


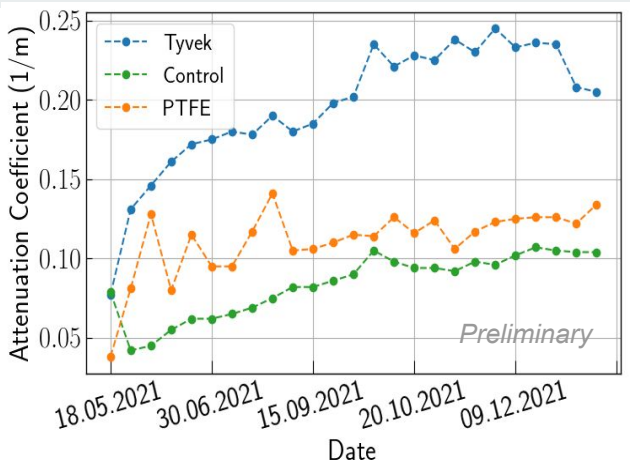




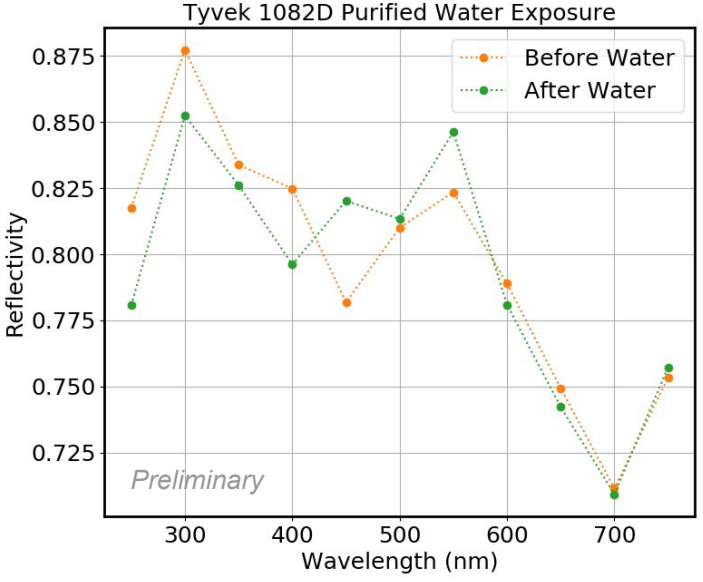
Material Tests: Water Quality

- Water transmission tests since March 2021
- C-star transmissometer with wavelength 410 nm & path length 25 cm
- Monitoring
  - Different bladder materials
  - Cables and shrinkable tubes
  - Screws
  - Reflective liners



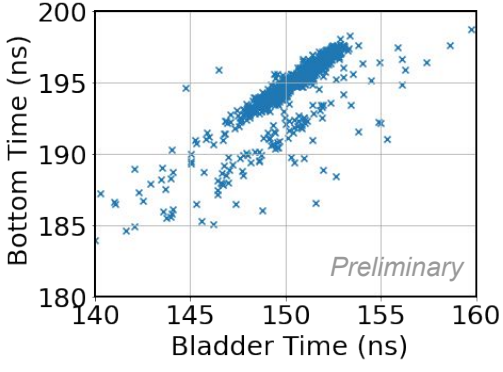


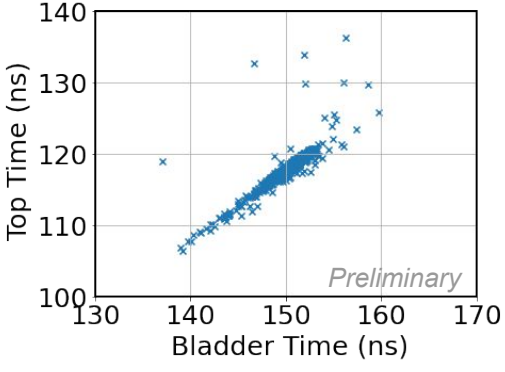
- Tyvek reflectivity change negligible after two years of water exposure

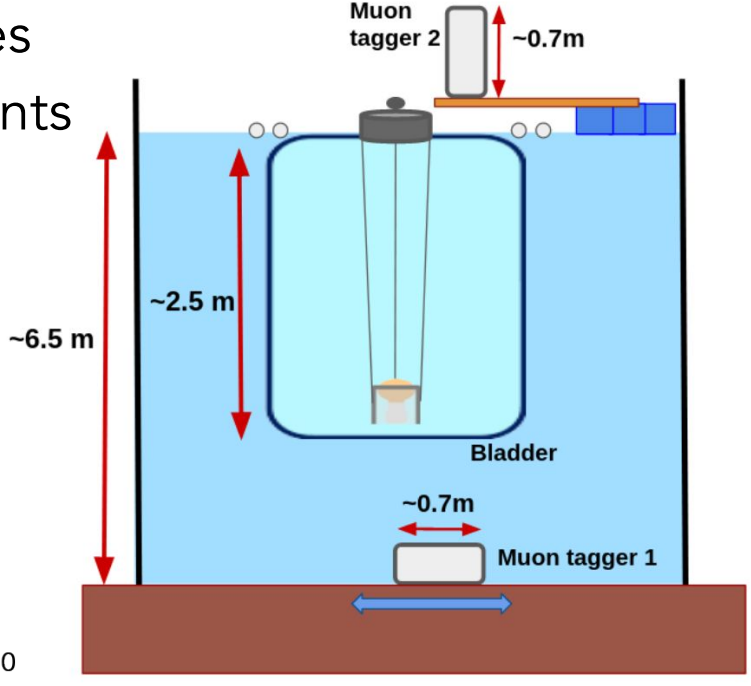


Experimental Verification

- Muon Taggers & PVC bladder studies
- Took 3-fold coincidence measurements
  - Single chamber bladder
  - Between two taggers

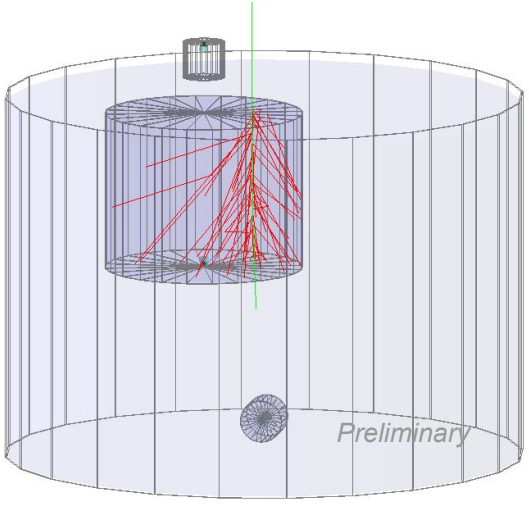






Experimental Verification

- Compare single unit simulations with experimental results
- 3-fold coincidence measurements → Done
  - Rates from simulations are within experimental results
- 4-fold coincidence measurements → Aquamate bladder + matryoshka



Pond Development

- No need to worry about waves & disrupting wild-life
- Bladder development same with natural lake plans
- Mini pond site & arrangements made in Peru
- Geomembrane can be used

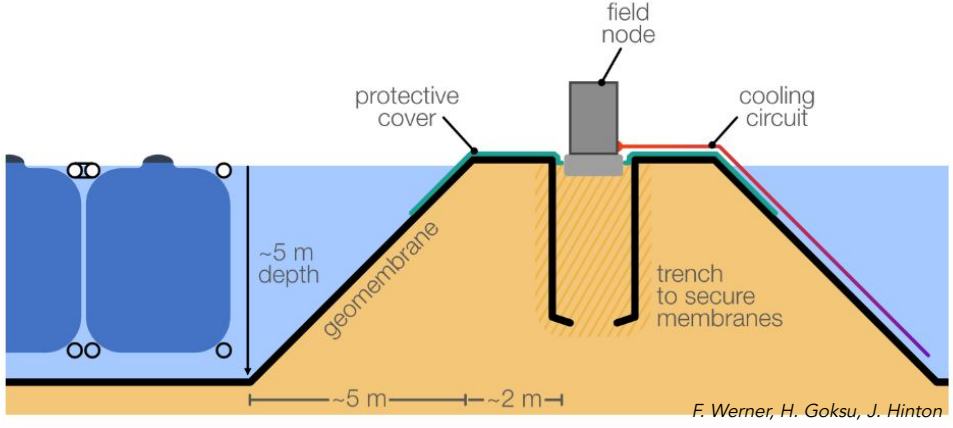
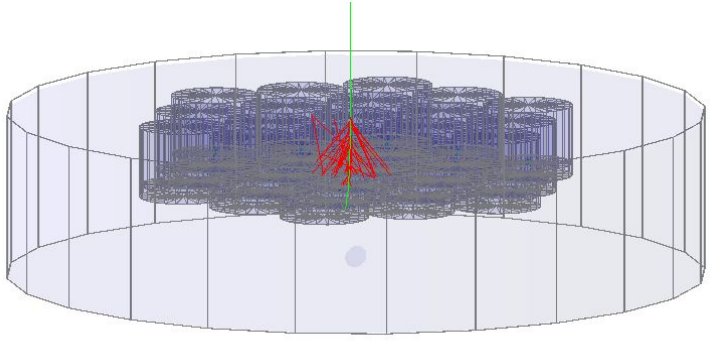
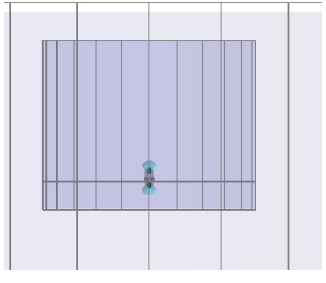


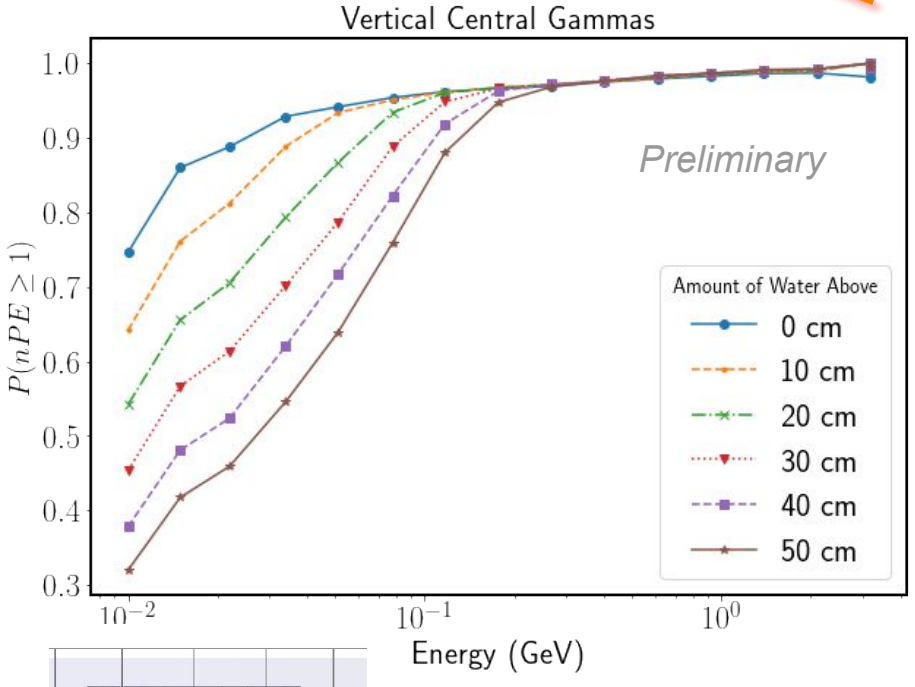
Fig. 2 Sketch of the cross-section of the pond edges.

Simulated Performance

- Bladders partially immersed in water
- Simulations to show effect of water volume above
- Overburden ~ lower altitude
- Small array of DLWCDs in a lake ~ ongoing shower simulations

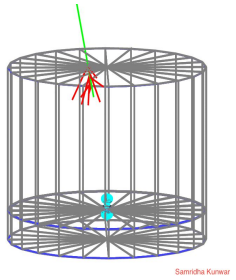






Double Layered Detector Unit

- Lower chamber for muon detection
- Result of [paper]():
  - Lower chamber: >0.5m
  - Upper chamber ~2.5m
  - Some reflective material
  - High fill-factor



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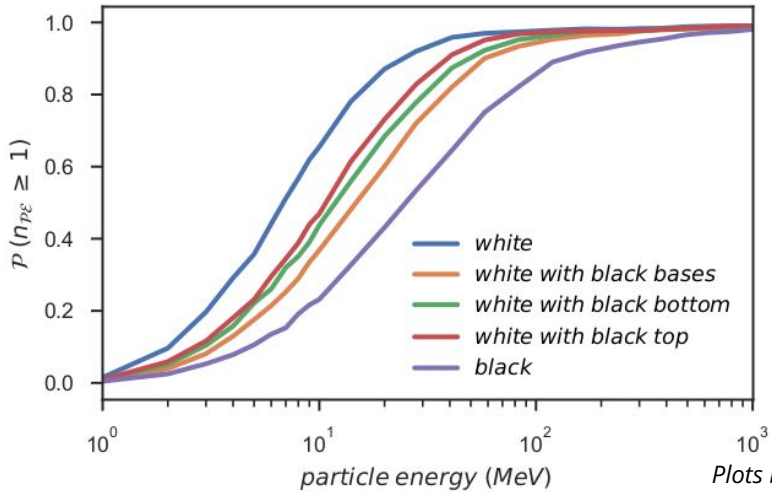
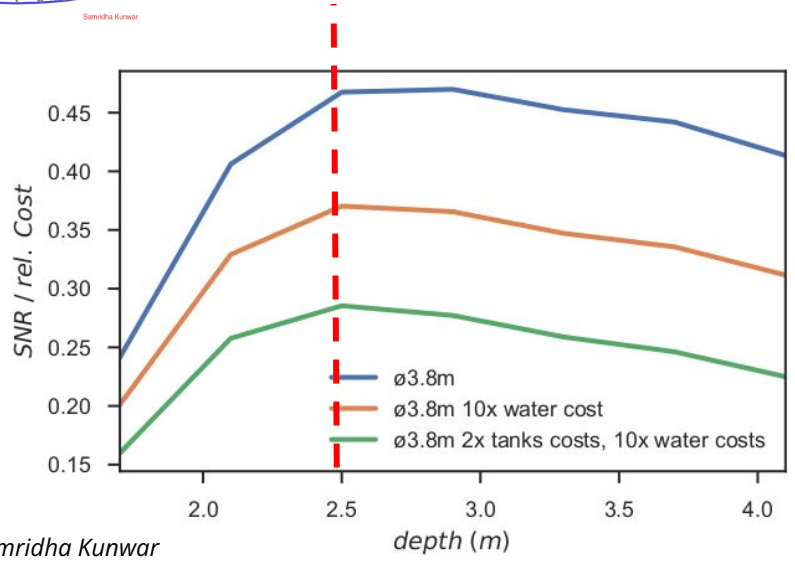
Volume 1050, May 2023, 168138

Full Length Article

A double-layered Water Cherenkov Detector array for Gamma-ray astronomy

Samridha Kunwar [a], Hazal Goksu [a], Jim Hinton [a], Harm Schoorlemmer [c], Andrew Smith [b], Werner Hofmann [a], Felix Werner [a]

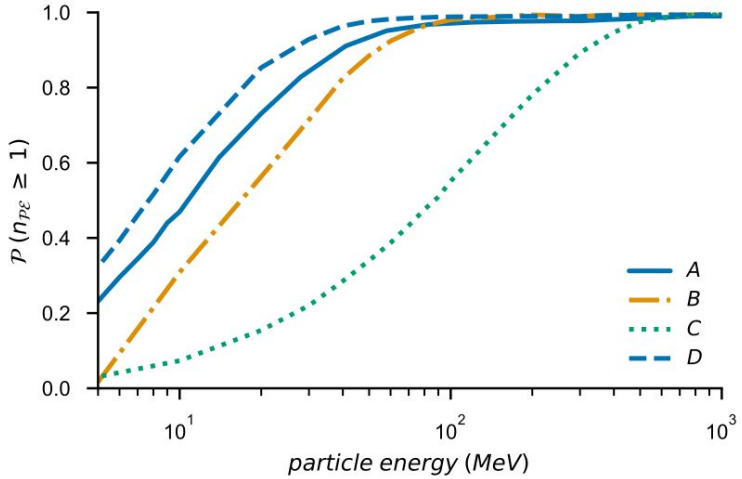


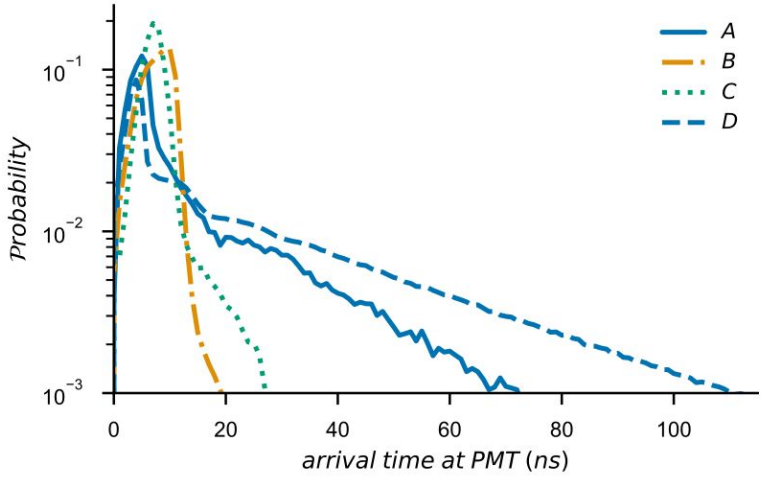


Plots by Samridha Kunwar

Comparison

A. **White DLWCD** (3.8 m diameter and 2.5 m depth)
   a. black top and an 8-inch PMT
B. A **HAWC-like** single-layered unit (7.3 m diameter and 4 m depth)
   a. black walls, central 10-inch PMT and three 8-inch PMTs
C. A **LHAASO-like** black unit (5 m × 5 m square, 4.5 m depth)
   a. open top and an 8-inch PMT
D. **White DLWCD** with alternative geometry (3.4 m diameter and 3.0 m depth)
   a. black top and an 8-inch PMT

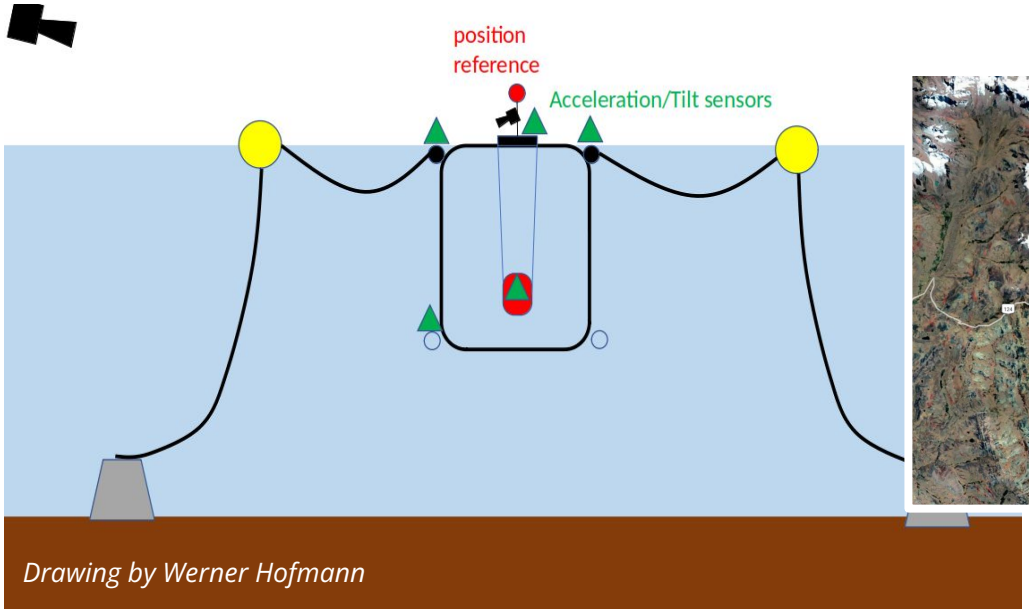




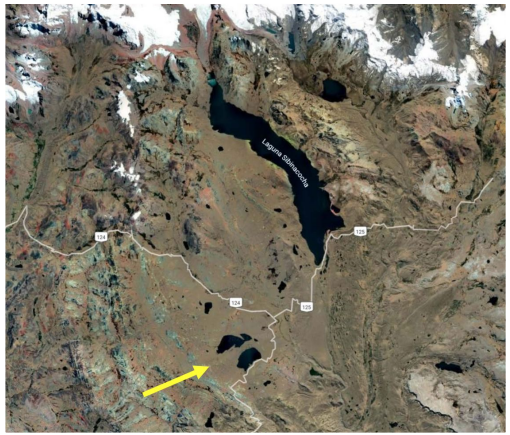
Aquamate Bladders

AQUAMATE
16 Drury Terrace
Tonsley SA 5042

- Already in test tank in Australia
- One bladder to be sent to **Peru, lake Sibinacocha,** for wave motion measurement & mechanical tests
- Accelerator built by students from Peru

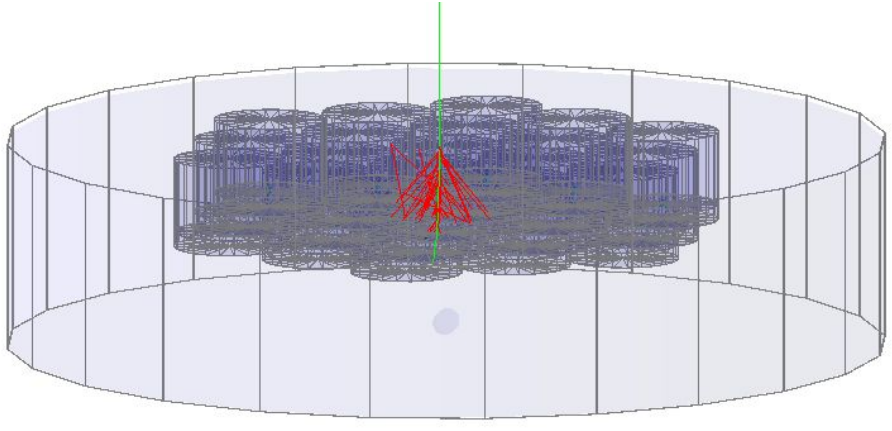


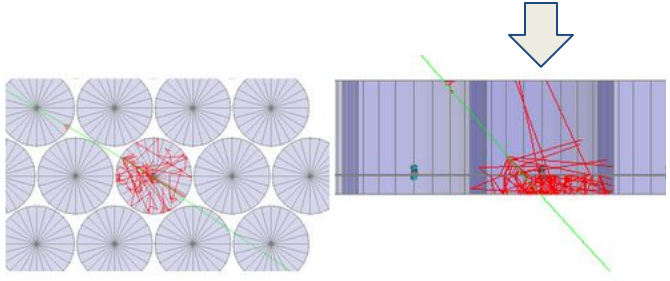
Drawing by Werner Hofmann



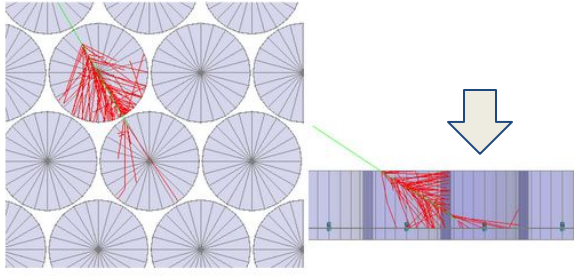
Simulated Performance

- Shielding of unit in water vs with other units only
  - Muon tagging purity
- Simulate candidate configurations in water





Sideways entry (poor shielding)

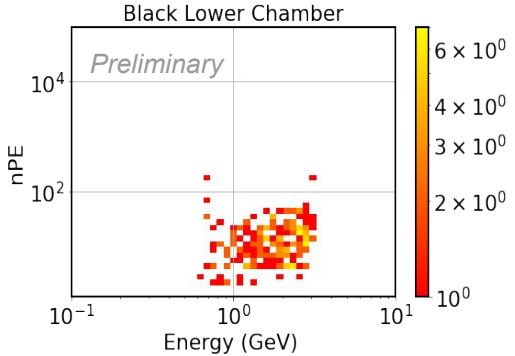


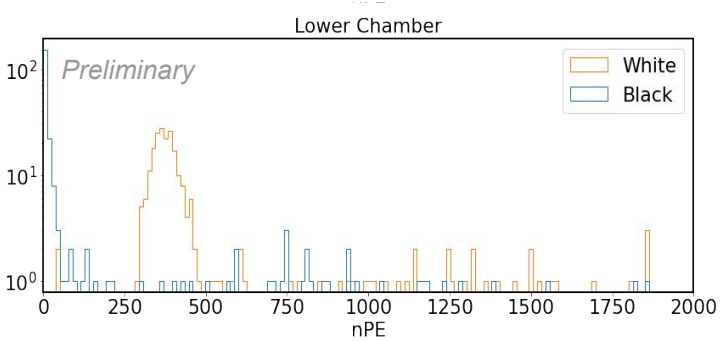
Shielding by adjacent bladder

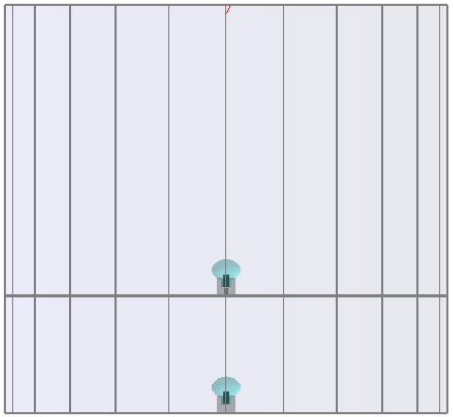
Black muon chamber

1 GeV muons

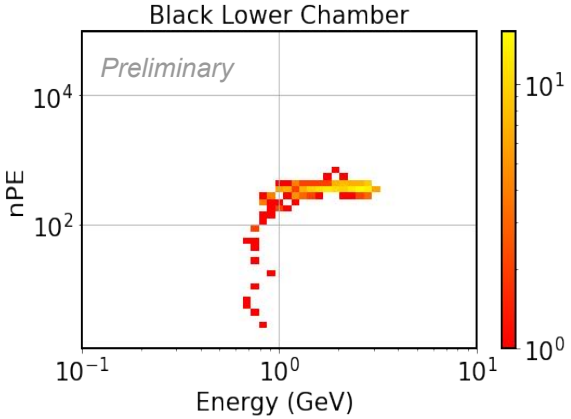
1m

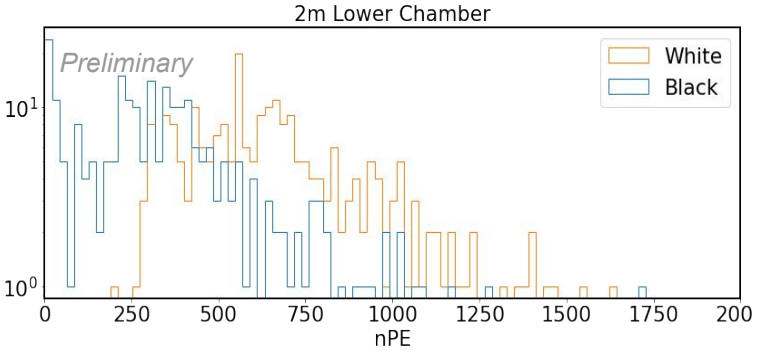


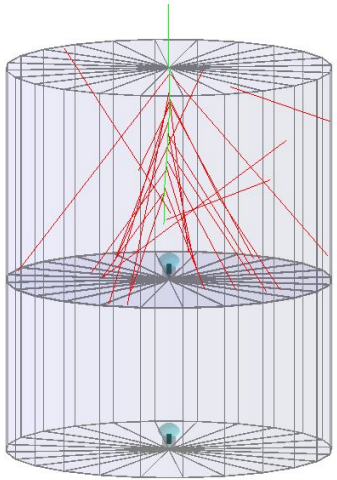




2m







Double-chamber WCD

- From the paper:
  - Lower chamber: >0.5m
  - Upper chamber ~2.5m
  - Some reflective material
  - High fill- factor

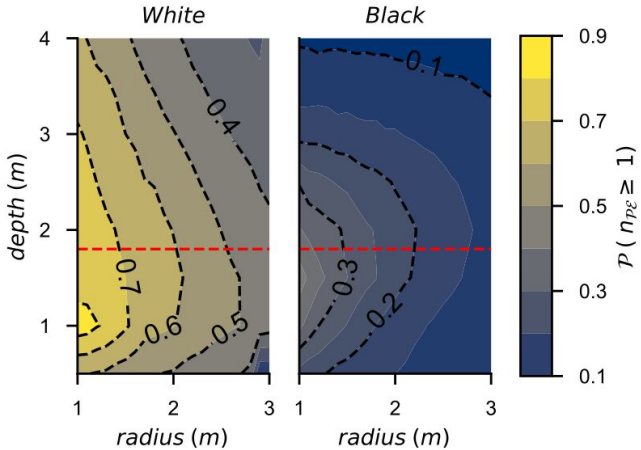
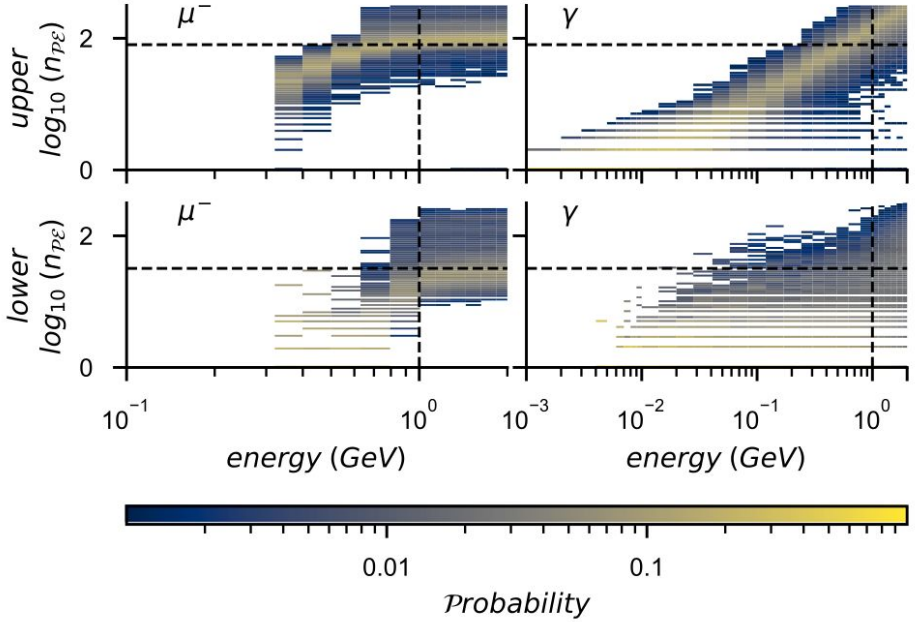


Fig. 2. Probability of detection of one or more photo-electrons as a function of upper chamber radius and depth, for vertical 10 MeV γ-rays injected across the top surface of the chamber, for a chamber with entirely white walls (left) and a chamber with entirely black walls (right). A dashed horizontal red line shows the depth corresponding to ≈5 radiation lengths. The reference design for SWGO has a radius of 1.91 m (3.8 m in diameter).



Samridha Kunwar