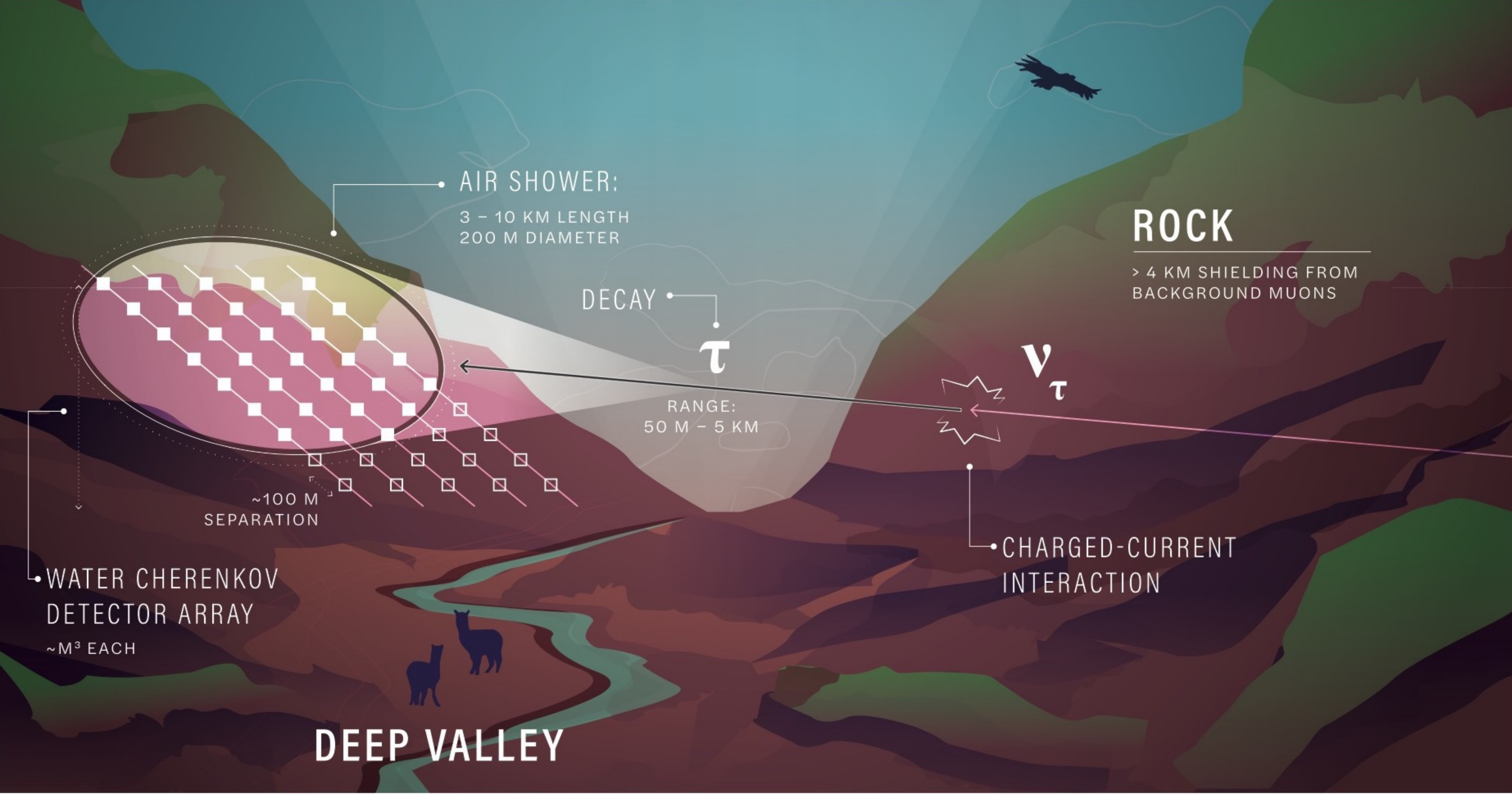
TAMBO Hardware Activities

Will Thompson

TAMBO Workshop

October 18th, 2022

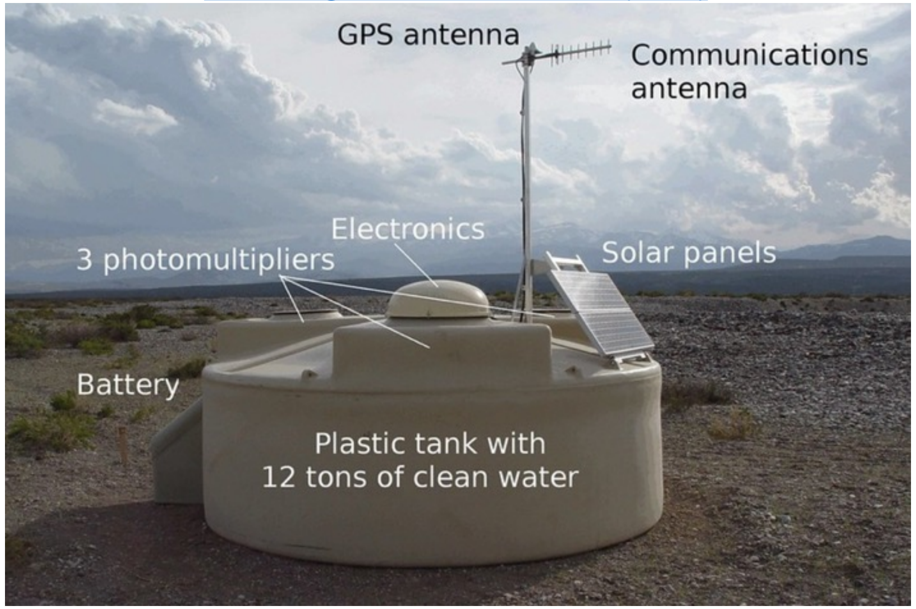


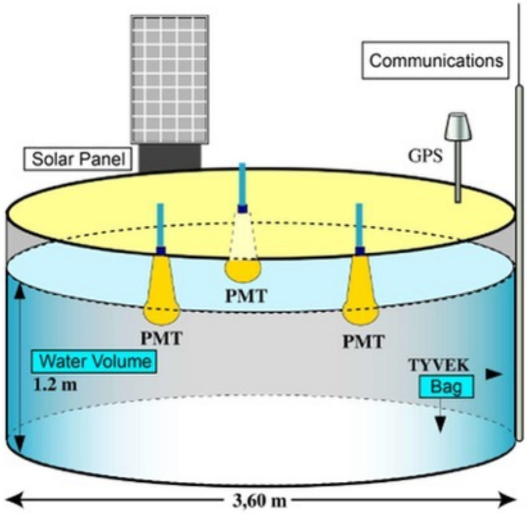
TAU AIR-SHOWER MOUNTAIN-BASED OBSERVATORY (TAMBO) · COLCA VALLEY, PERU

Water Cherenkov Tanks & TAMBO

- Baseline TAMBO design uses 1-tonne water Cherenkov tanks
  - Lots of experience in CR field
- Special considerations for TAMBO
  - Would be difficult to deploy giant tanks of water on side of world's 2nd deepest canyon
  - Need ~20k detectors… PMTs are expensive!
- Scintillator panels are one possible solution
  - Water Cherenkov detectors: ~$3,000, ~1000 kg
  - Plastic scintillator panels: ~$1,000, ~40 kg

Pierre Auger Collaboration, ICRC(2021)



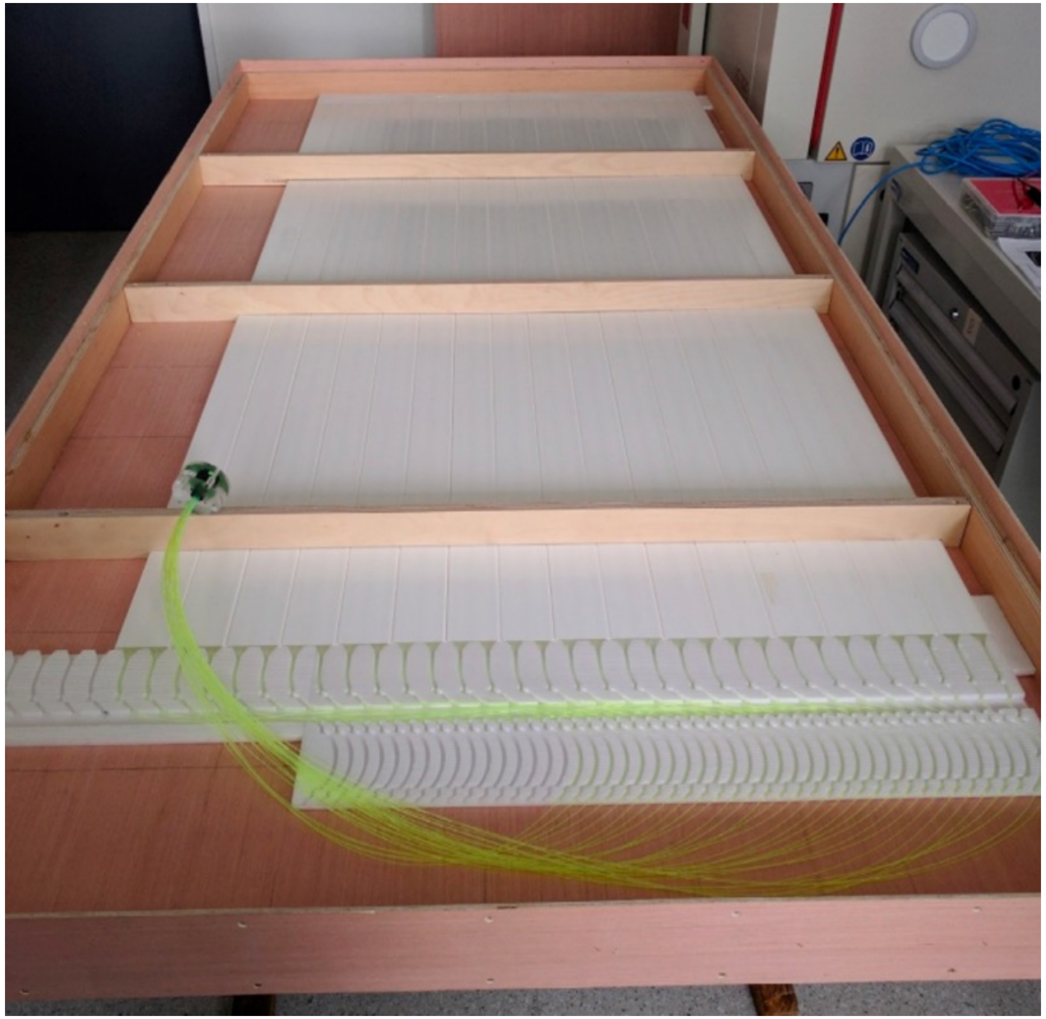


Scintillation Panel Overview

- Main goals:
  - Replace water with scintillator to reduce weight
  - Replace PMT with SiPM to reduce cost

- Challenges:
  - Coupling large-area panel (1.5 m^2) with small-area SiPM (36 mm^2)
  - Matching scintillator emittance (~400 nm) with SiPM acceptance (~500 nm)

- Baseline design: Scintillator “threaded” with wavelength-shifting optical fiber & mounted to SiPM



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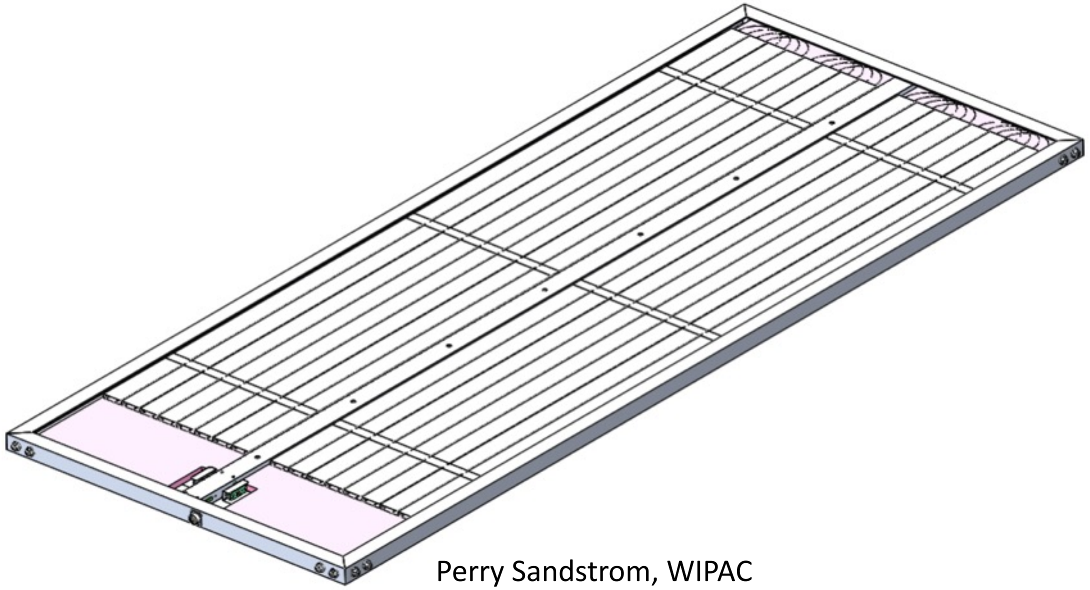
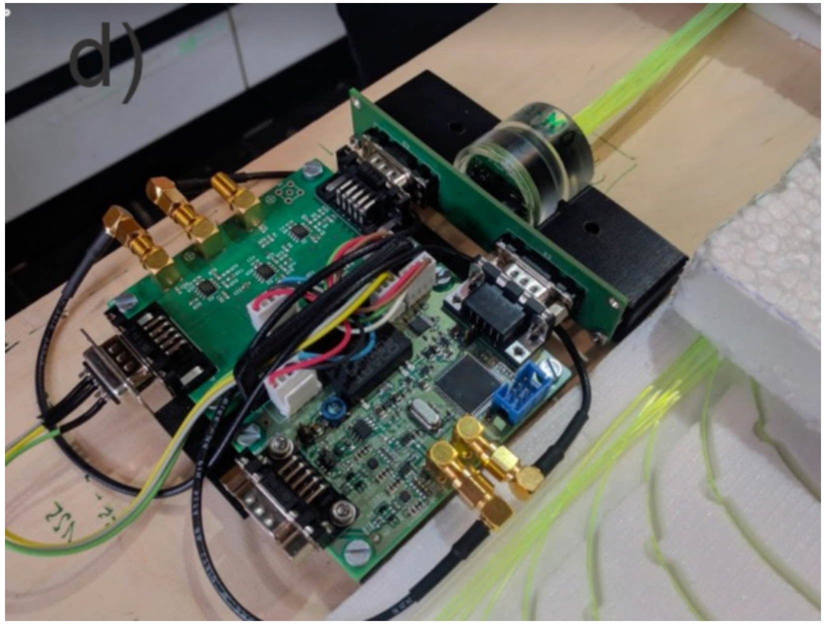
Baseline Detector Prototype



Perry Sandstrom, WIPAC



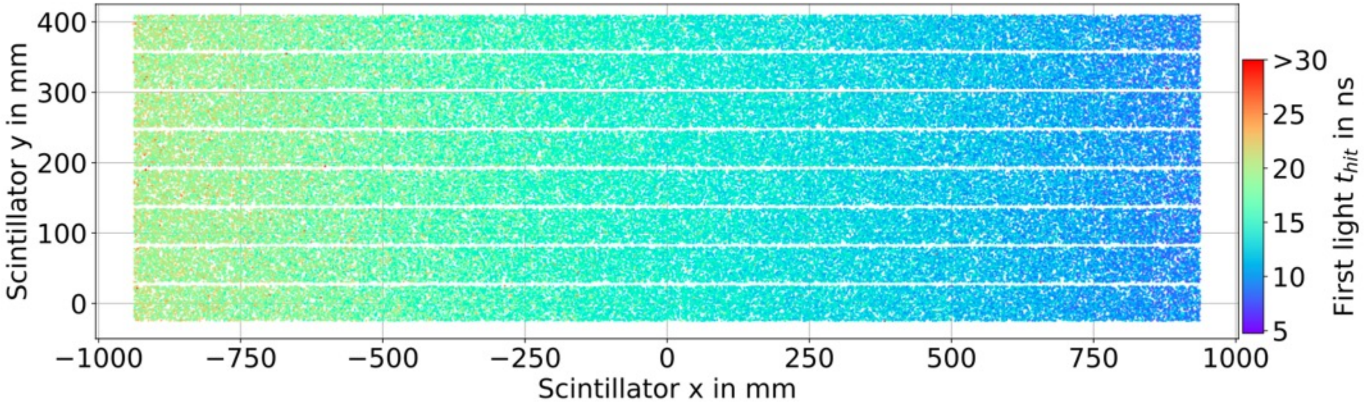
Thomas Huber PhD Thesis

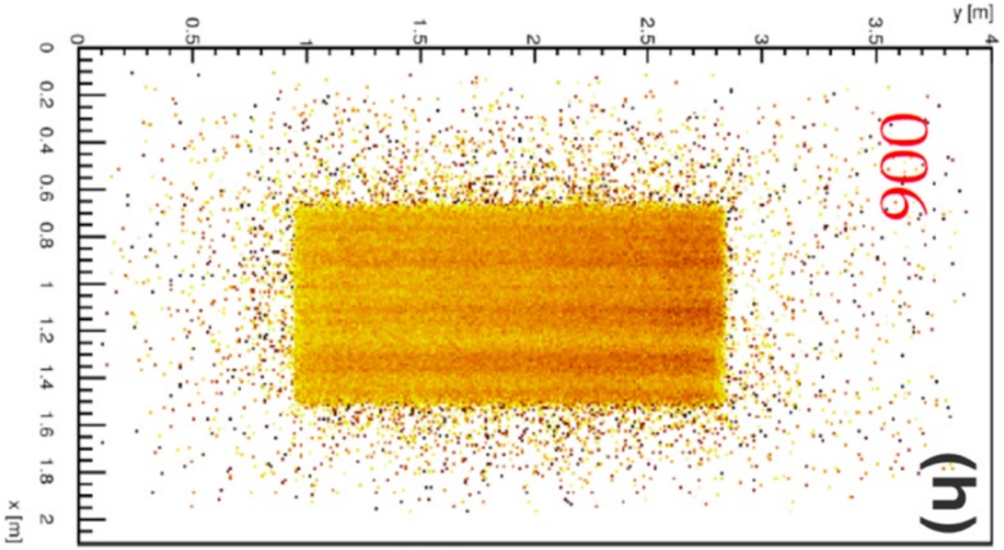
- Similar scintillation panels built by KIT and UW Madison for IceTop upgrade
  - Plan to use for baseline design; good for experience with this type of detector
  - Not at all optimized for TAMBO; also want to explore different panel designs

- Supplies for panels have just arrived at Harvard – starting to build this month!
  - Enough supplies from Madison to build ~10 panels with this design

Detector Characterization & New Designs

- Full TAMBO simulation will set minimum detector requirements, guiding design
- Requires characterization measurements of timing resolution, light-collection & uniformity, etc
  - Will indicate necessary improvements to detector design
- Working with PUCP to develop Geant4 simulation of scintillator panels to test proposed protypes
  - Only build promising designs
  - First simulation will be of baseline design; vet by comparing simulated and measured panel properties





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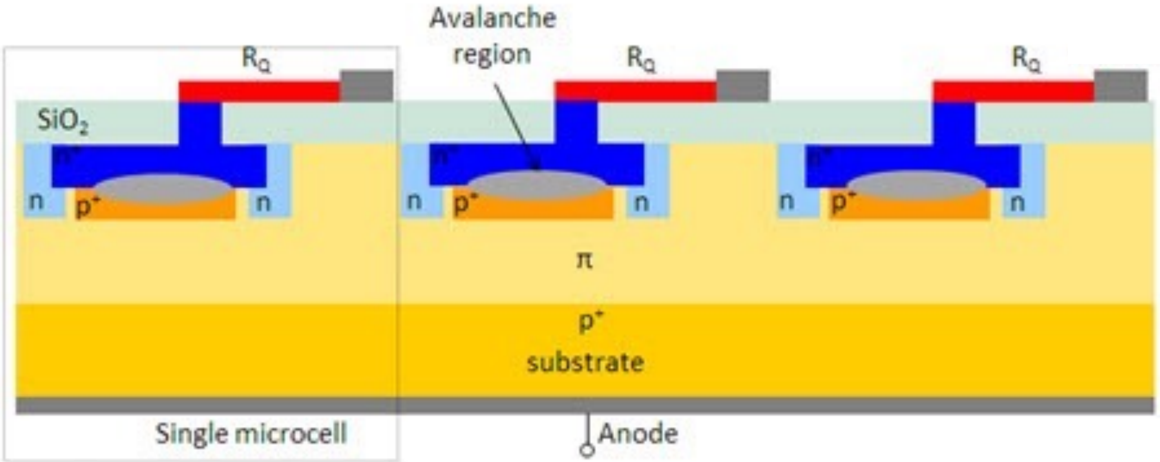
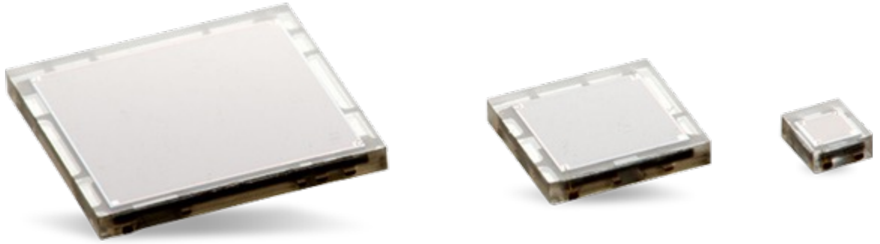
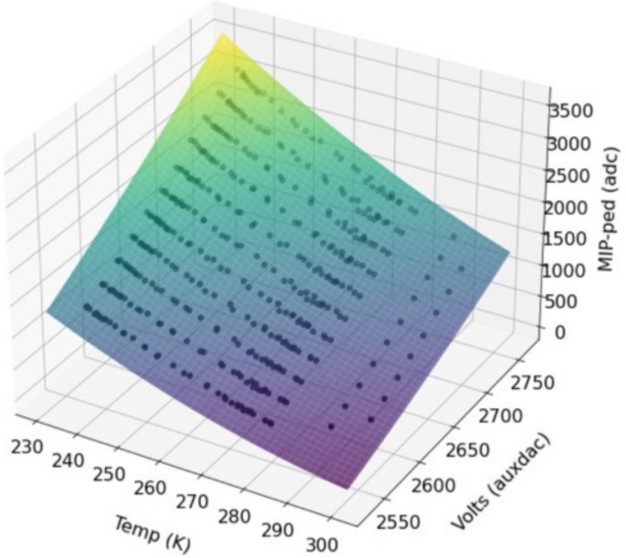
SiPM Considerations

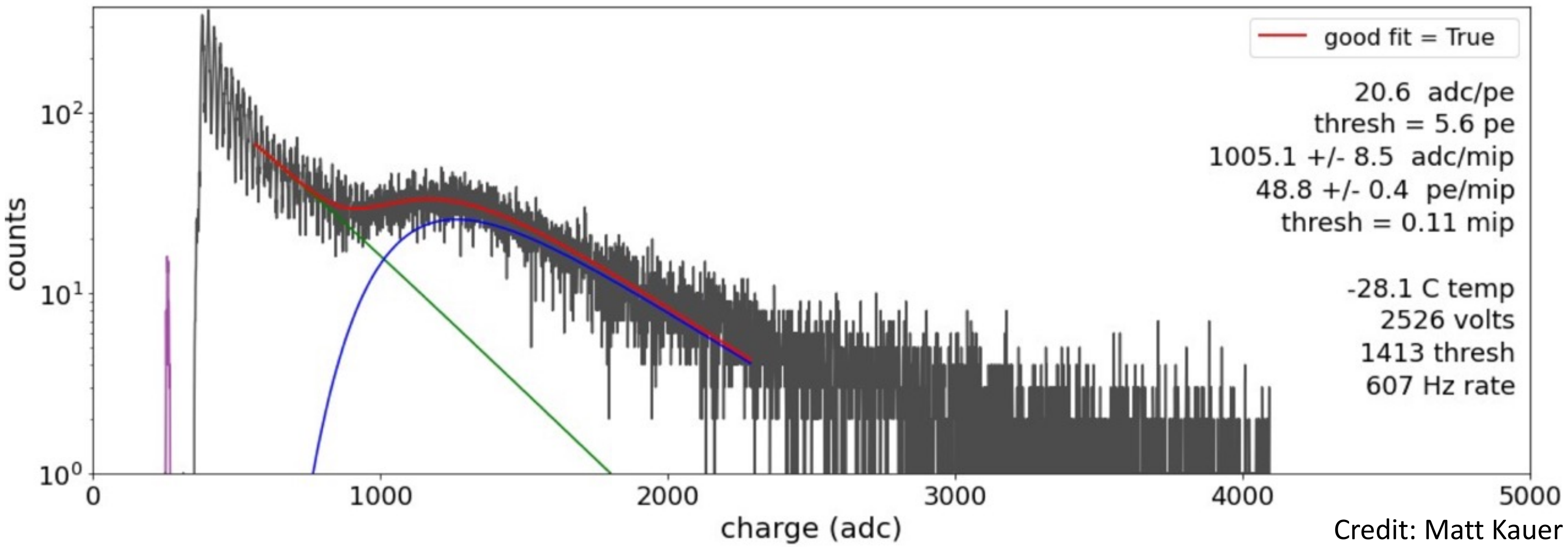
- Array of avalanche photodiodes used to detect light
  - R&D for many years finally becoming competitive with PMTs!
- Compared to PMTs:
  - Benefits: Inexpensive, lower operating voltage (~50 V), small time spread (~100 ps), rugged
  - Drawbacks: high dark rates, small sensitive areas (~36 mm^2), temperature-dependent gain
  - Neutral: comparable light sensitivity, peak sensitivity to green light





SiPM Characterization Measurements





Credit: Matt Kauer

- In addition to panel design, must also consider SiPM performance in canyon environment
- Main concern is temperature and its fluctuations
  - SiPM dark rate increases with temperature – determines minimum light yield from fibers
  - Compensate for temperature-induced gain changes by adjusting bias voltage in real-time
- Undergrad Tommaso Serafin developing testbench for these measurements

Deployment of Prototype Array

- Ultimate test of performance will be field deployment of small array in Colca Canyon

- Idea is to make measurements of CR air showers to demonstrate detector performance
  - Successful demonstration would be convincing for suitability of panels in TAMBO
  - Also tests panel robustness to canyon environment
  - Is there more interesting physics we can probe with a small array?

- Of course, field deployment opens whole new can of worms
  - On-board digitizers, panel communications & cabling, panel supports, field hub, on-site lab
  - Would be great to have help with these projects!

Scintillator Panel Development Goals

- Near-term projects:
  - Build panel(s) with baseline design
  - Derive physics impact of detector characteristics using full TAMBO simulation
  - Develop & perform panel characterization measurements
  - Perform SiPM characterization measurements
  - Create Geant4 simulation of panels
- Mid-term projects:
  - Develop new panel designs, including simulation & characterization
    - Fiber is big cost driver – can we reduce this?
- Long-term projects:
  - Lots of tech/engineering work need for demonstrator array
- Please contact us if you are interested in getting involved in this development!

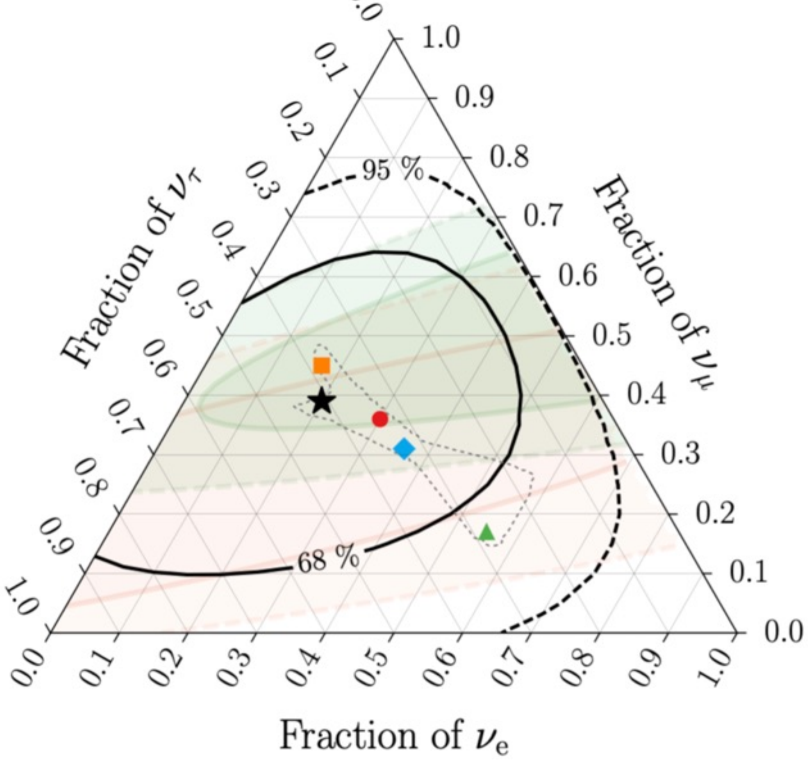
A Final Thought

- Interest in using panels in lieu of tanks motivated by fact that:
  - Panels appear to be cheaper than tanks
  - Panels should be easier to deploy
  - … but this is all based on tank designs not optimized for TAMBO
- Not much thought has been given to optimization of the water tank design
  - Would be excellent if another group could work on developing a water tank design optimized for TAMBO
  - Please reach out if interested!
- Of course, there’s more to it than cost and ease of deployment
  - Ex: impact of different geometries between panels & tanks
  - Am interested in hearing experts’ (your) ideas on this

Questions?

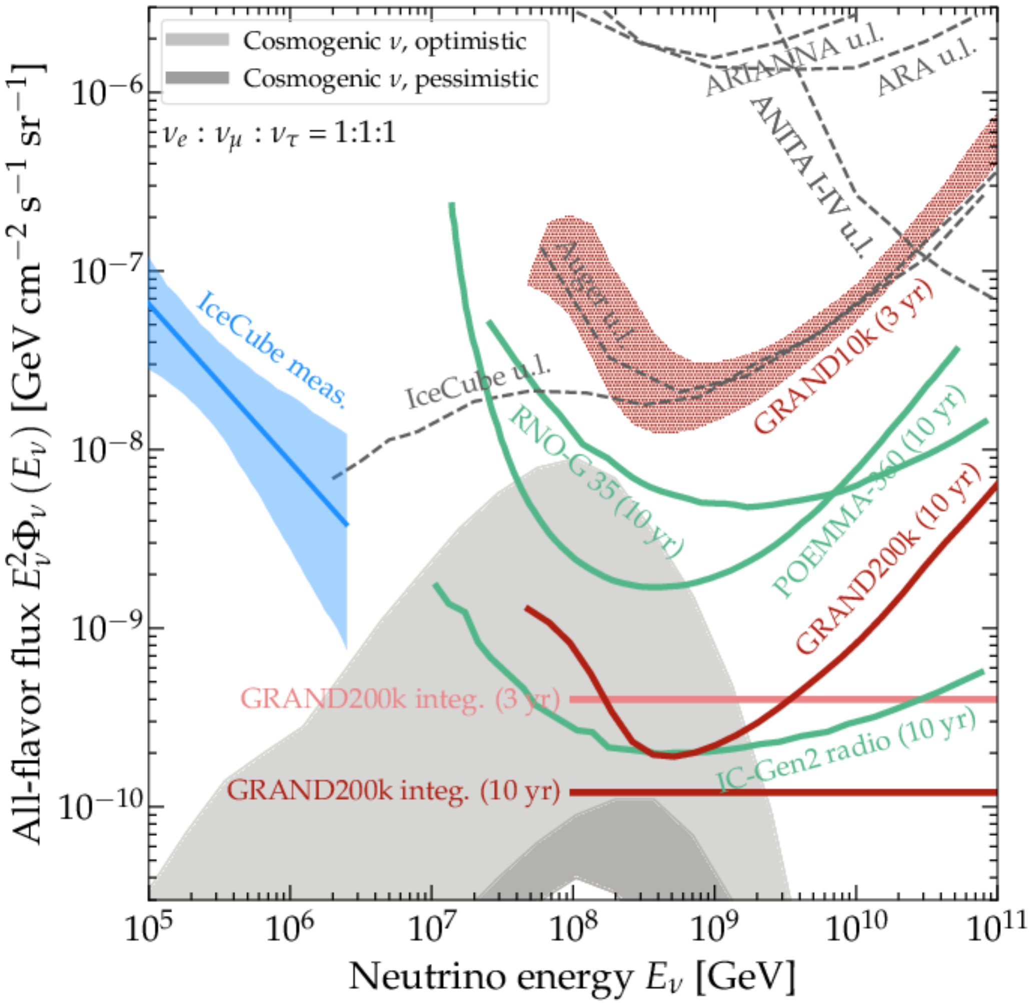
Importance of ν_τ

- ν_τ one of least studied SM particles
  - Difficult to produce because of high energies required
  - Difficult to detect because of τ properties, as in IceCube
- BSM searches using astrophysical flavor ratios limited by small number of ν_τ events identified
- ν_τ may allow observation of UHE objects at lower (PeV) energies
  - Argüelles *et al* arXiv:2203.13827



IceCube, arXiv:2011.03561

Bridging the High-Energy Gap



Grand Collaboration PoS (ICRC2017)

- Diffuse flux measured by IceCube up to ~1 PeV
- Next generation telescopes focus on measuring >10 PeV neutrinos
  - Leaves gap from 1-10 PeV
- TAMBO bridges gap & will:
  - Determine if astrophysical sources accelerate neutrinos above 10 PeV
  - Characterize 1-10 PeV neutrino sources