ALTO project:

Concept and Design Choices
for a
Wide-Field Southern VHE Gamma-Ray Observatory

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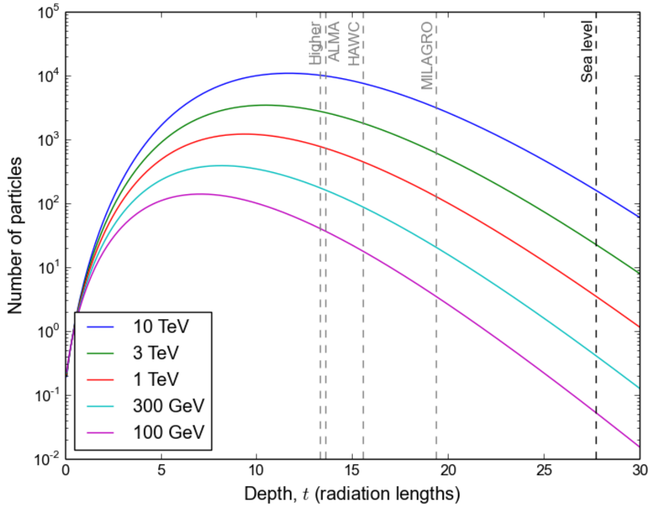
Linnæus University

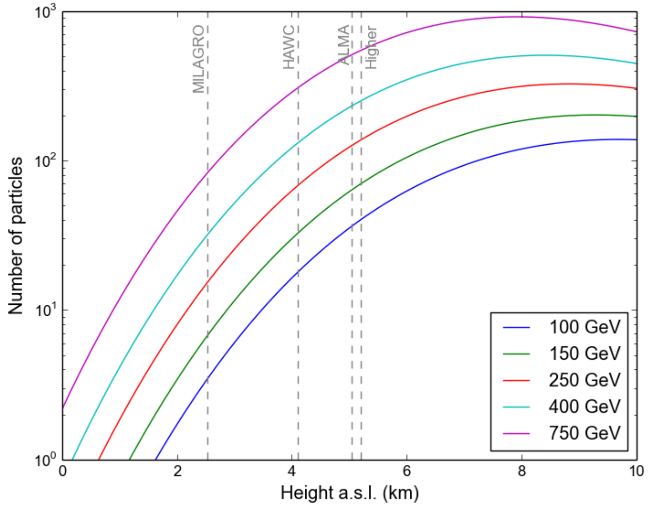
ALTO Key Design Characteristics

- Altitude (> ~5km):
  - For Physics goals, as a survey / alert instrument for transients
- Layout; Fine-grained array:
  - Smaller Water Cherenkov Detector (WCD) tanks than HAWC
  - Low dead-space
  - Improved angular resolution expected
- “Unit” design: Water Cherenkov tank + Muon-detector component
  - Liquid scintillator box (Scintillator Layer Detector, SLD)
  - Provides background rejection power
- Advanced electronics: NectarCam + White Rabbit
  - Trigger channel precisely time-stamped with “White Rabbit” system
  - Analogue memories + ADCs measure the waveform of the detector pulses
  - No cables from centre, only fibres

ALTO Altitude,
Physics Considerations

- Aim for ~5.1km or higher
- Physics Goals:
  - Transients … AGNs, GRBs, Grav. Waves…
  - Survey (esp. extragalactic)… Fermi Bubbles?





  - ⇧ in altitude HAWC → ALTO ⇒ x2 # particles
  - Or for same # particles, energy ⇩ by 40%

ALTO Altitude, Technical Considerations

- High altitude ⇒ difficult working & operating conditions, so care about
  - Install-ability,
  - Reliability,
  - Maintainability
- Site characteristics
  - Plateau: a flattish space with diameter ~160m
  - Access: a nearby road needed
  - Water: source of water not too distant
  - Infrastructure:
    - Power grid or access to Diesel
    - Network access (data transfer, remote operation /monitoring)
    - Lower altitude accommodation for local crew
  - National interest and funding in host country

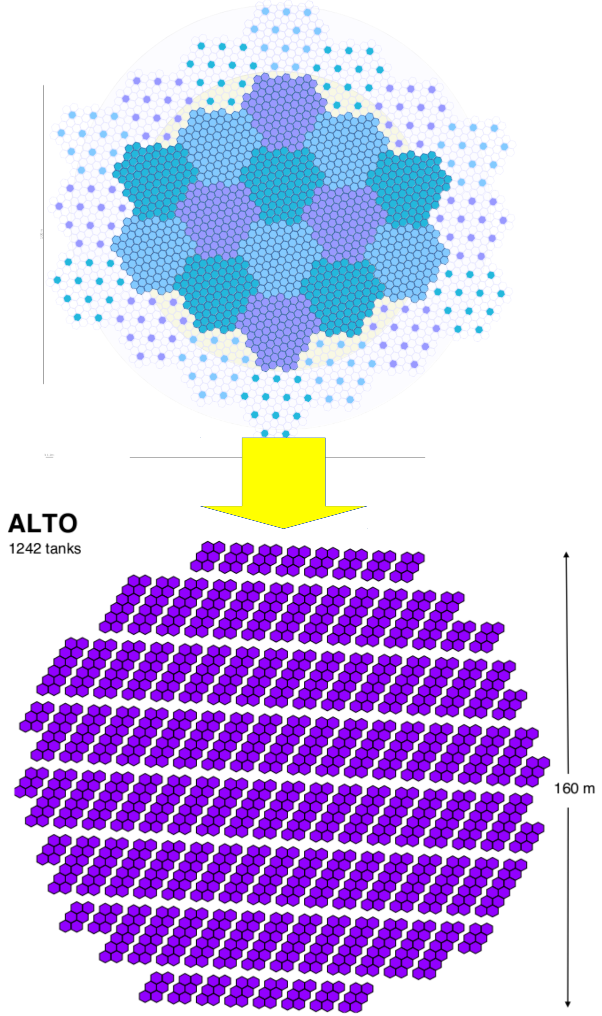
ALTO Site Candidates

- Search “by google-hand” along the Andes
  ⇒ best current candidates
  - 4.8km at LLAMA (possible QUBIC) site
  - ~5km near Chacaltaya
  - 5.1km at ALMA/ACT site, perhaps up to 5.4km!

ALMA/ACT Site Topology
(marker at 5.4km)

ALTO Layout Design Process: “The Simpler The Better”

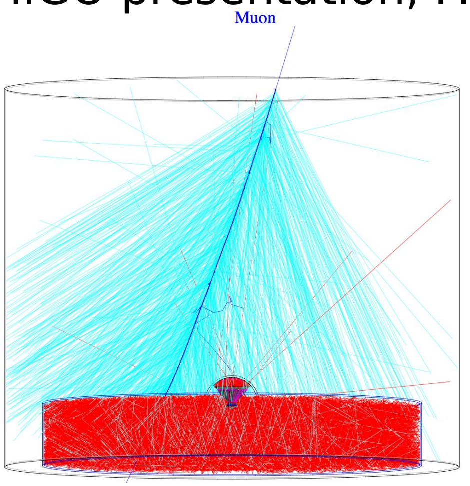
- Initial design
  - All units contiguous, accessed from above
  - Scintillator box sunk into WCD tank
  - Optical Module (OM) with PMT up/down for WCD/SLD
  - … probably unmaintainable



- Current design:
  - “Clusters” of 6 units
  - Scintillator boxes accessed from the sides
  - OM with single large PMT for WCD, separate smaller PMT for SLD
  - Access roads wide enough for truck, W-E

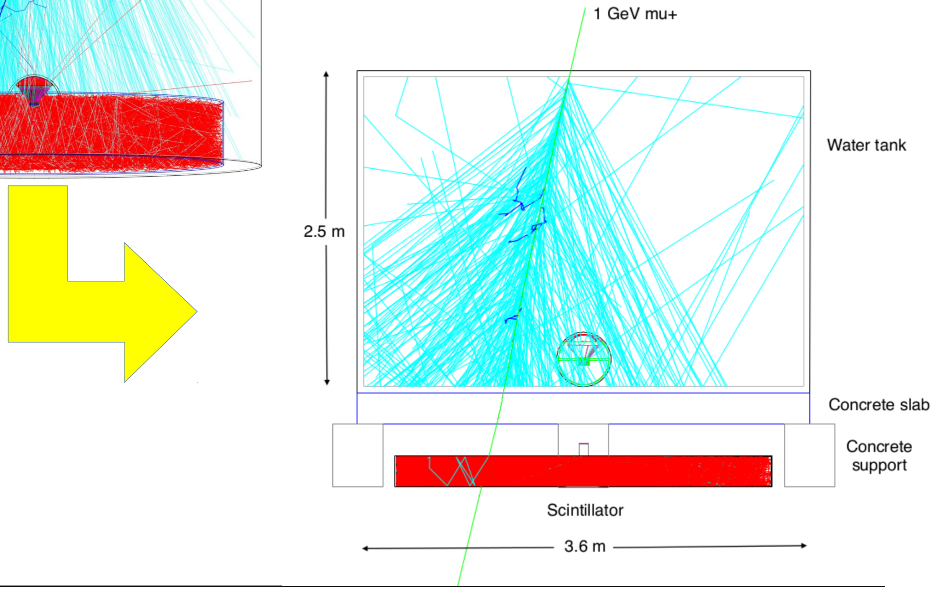
ALTO Unit
Design Process

- Given diameter, WCD height imposed by geometry of Cherenkov angle
- Assuming Antares OM (see AMIGO presentation, F. Schüssler, tomorrow)



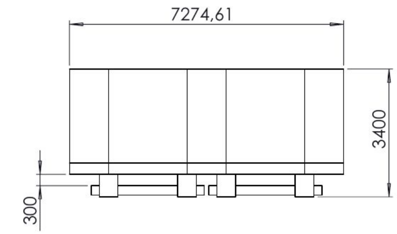
- Initial design
  - 1 central OM
    - Dismount Antares OM
    - Add 2nd smaller downwards PMT
  - ⇒ Too Complicated!!

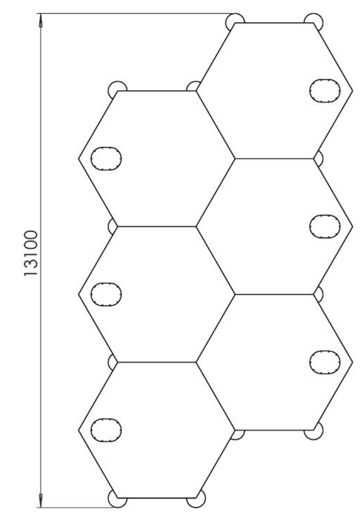
- Current design
  - Separate WCD and SLD
  - Keep Antares module intact!
  - Scintillator height lowered (from simulations)

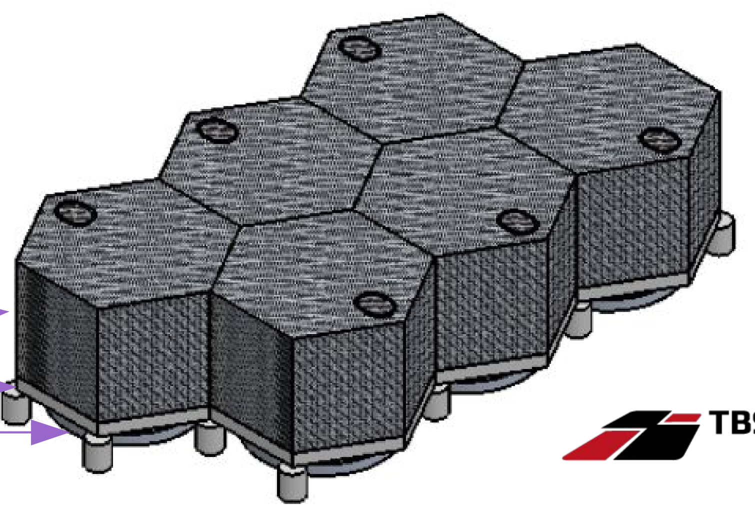


ALTO Cluster (6xUnits)

- Cluster = Group of 6 Units = 6 x (WCD + SLD)
  - WCDs on concrete "table" (1 pour for cluster)
  - SLDs below "table", on telescopic rails
- Each cluster to have common:
  - Electronics readout unit
  - Solar panel + battery (TBD)
  - Communication to central control by fibre only





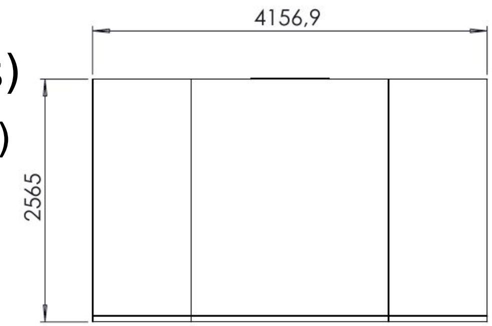


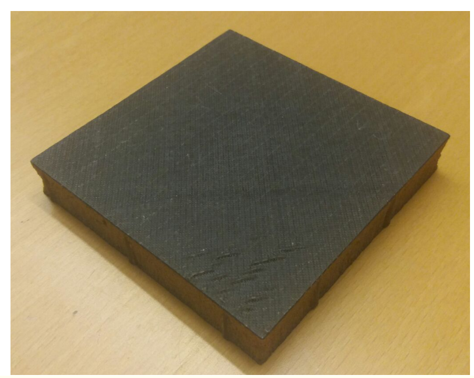
ALTO Cluster
- WCD tank
- Concrete table
- SLD box

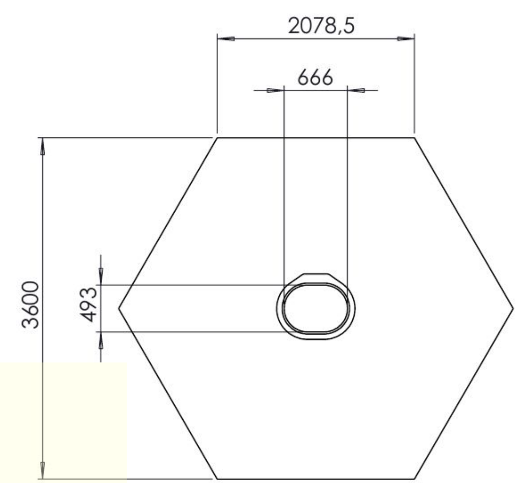
TBS

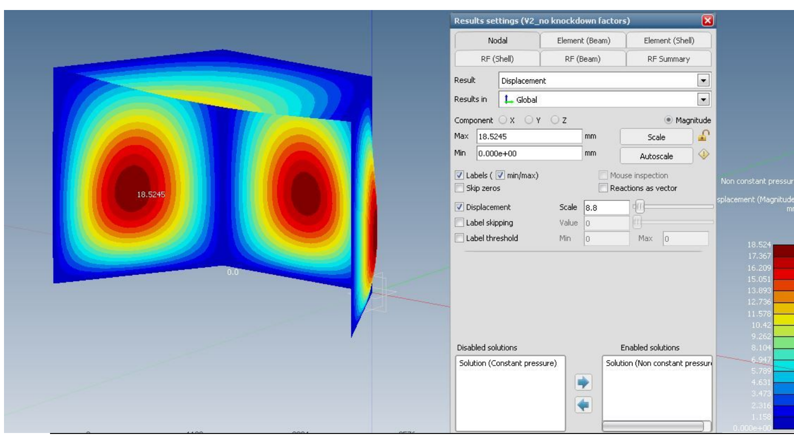
ALTO Unit Technical Details: WCD Tank

- WCD Tank: Carbon Fibre (TBS-Yard, Torsås… CF experts)
  - Strength to resist 28T water, but durable and light (<500kg)
  - Flat Pack (Ikea-type) for international transport
  - Glueing at lower altitude + UV-resistant paint applied
  - Transport by truck the final 10s of kms
  - Filling on-site from tanker trucks (via lower valve)





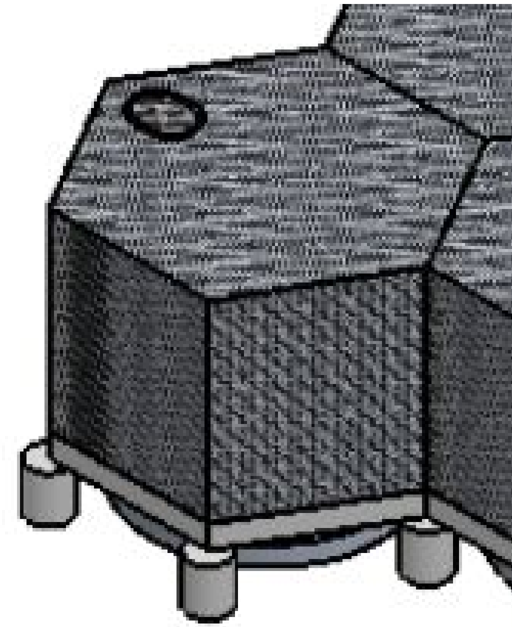




ALTO Tank
- Right: Views
- Above: Carbon Fibre sample
- Left: Strength calculations

ALTO Unit Technical Details: Table + SLD box

- Reinforced Concrete Table
  - 30cms is overkill for support, but...
  - Provides extra absorption of most $e^{\pm}$ in showers
- Aluminium SLD box
  - Shallow cylinder, 3m diameter, 25cm height
  - Central protrusion for PMT housing
  - Box on telescopic rails hanging from Table ⇒ Ease of access
  - MP5 company in partnership with TBS yard
- Filled with liquid scintillator
  (Collaboration with J-P Ernenwein):
  - Linear Alkyl Benzene (LAB) in which is diluted
  - 5 g/L PPO (Scintillation Grade: 2,5-Diphenyloxazole)
  - 0.02 g/L POPOP (1-4,bis-2-(5-Phenyloxazolyl)-benzene)
  - Non-toxic, stable liquid
  - Used for Antares surface array, SNOLAB, others...
- Plan to measure scintillator characteristics in lab (summer 2017)

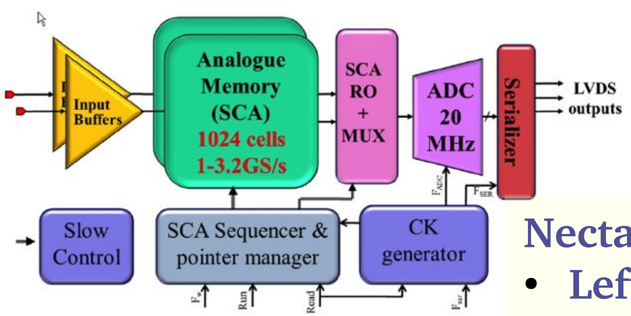


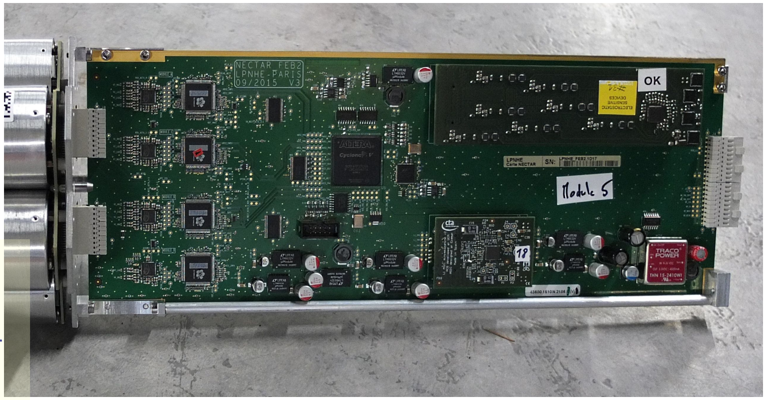
ALTO Unit
- WCD tank
- Concrete table
- SLD box

ALTO proposal for NectarCam electronics

- Use of NectarCam front-end module allows a low-cost, low power read-out close to the detectors
- Main specifications of NectarCam module (module = 7 PMTs)
  (adapted from J-F Glicenstein, Gamma2016)

– Analogue bandwidth	> 250 MHz (measured)
– Analogue memory depth	1024 cells (differential)
– Integration window	1-60 ns (cells @ 1 GHz)
– Sampling frequency	0.5-2 GHz (nominal 1 GHz)
– Dynamic range (<5% non linearity)	0.5-2000 photo-electrons (measured)
– Charge resolution	32% (single p.e.), 2 % (2000 p.e)
– Time resolution	<1 ns (>5 p.e)
– Dead time	1.93 – 6.52 us (for read-out of 16 – 64 samples)
– Dead time fraction	<3 % at 4.5 kHz trigger rate
– Power consumption (per module)	18.5 W





NectarCam
- **Left: Nectar ASIC operation**
- **Right: NectarCam board**

ALTO using NectarCam Electronics

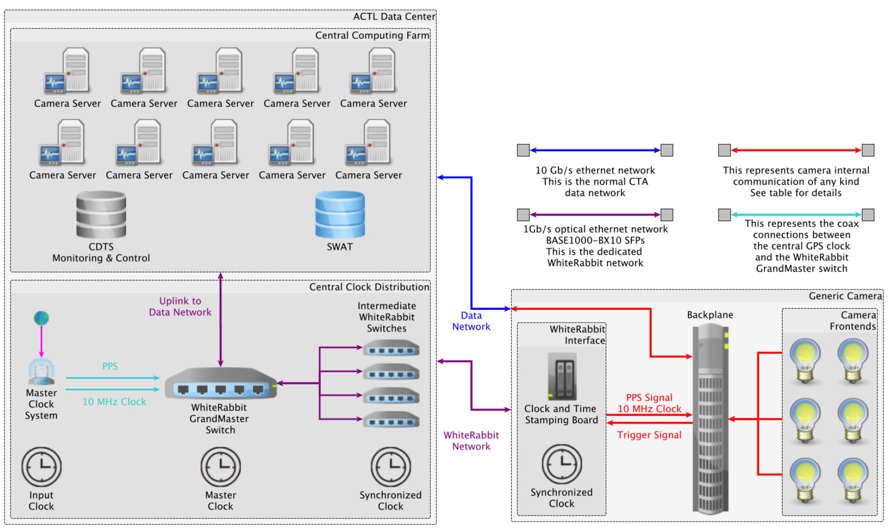
- Modification of NectarCam electronics
  - Nectar Analogue memory (depth 1024) stores waveform (high and low-gain channels)
  - Each WCD/SLD self-triggers at a few p.e. (in standard NectarCam Pixel-Trigger channel)
    - Writing to Analogue memory stops, readout begins in defined window
    - Trigger signal sent to White Rabbit node for time-stamping (see next)
  - FPGA can provide integrated charge, timing information (max. time, width at half-max or above threshold …)
  - Modify read-out to handle independent channel (Nectar ASIC) read-out?

- Design process will be driven by Simulations, initial tests
  - WCD Rate extrapolated from HAWC and others, expected < 20kHz
    - Use local coincidence of WCDs in cluster (L0) to lower rate, but affect on low-energy events?
    - Do we need GHz sampling? (note, Trigger time-stamping at ns is independent)
  - SLD rate extrapolated to be a few kHz (<2 kHz?)
    - Cannot do local coincidence of SLDs, since looking for isolated muons!
    - But certainly can use ≤ 0.5 GHz sampling rate for Scintillation channel
  - If rates turn out too high for acceptable performance → explore DREAM (dead-time free) analogue memory

ALTO Electronics
Trigger Time-stamping

- Trigger for each WCD and SLD time stamped by White-Rabbit node (1-2 per cluster)
- Each WR node has its dedicated WR fibre,
  to send time-stamps to central point through hierarchy of WR switches at centre
- Software Array Trigger identifies coincidences
- In parallel, data sent to central server over standard 10Gbps fibres
- If no coincidence, non-coincident data are eliminated
- Coincident data are saved and treated

- Similar to the CTA Time-Stamping and Software Trigger strategy



White Rabbit
- **Right: SPEC/TiCkS node**
- **Left: CTA trigger strategy**

ALTO Background Rejection

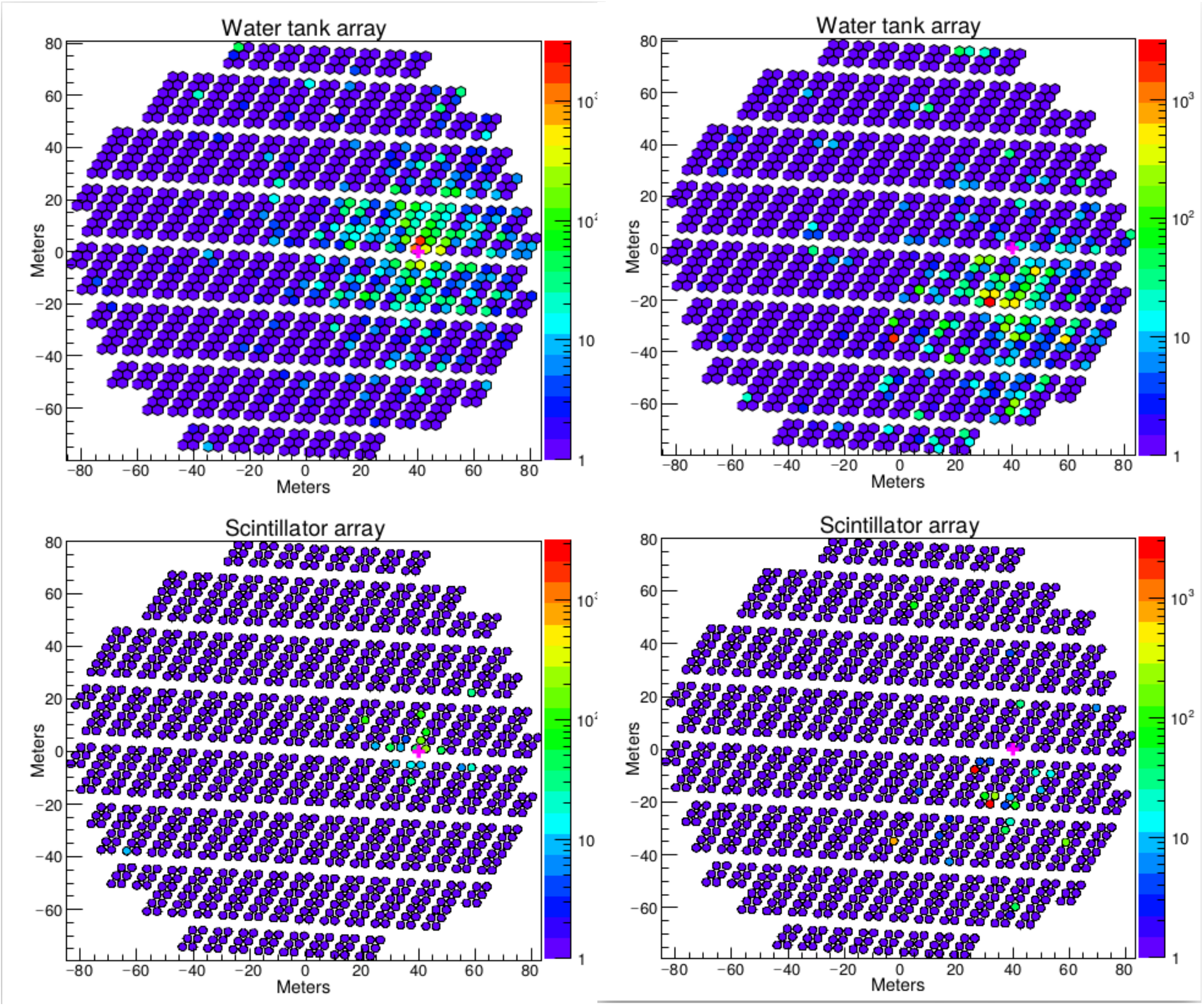
- Scintillator channel
  - $\Rightarrow$ rejection from muon multiplicity
- Fine grained array
  - Better fit of the Lateral Distribution Function (LDF)
    $\Rightarrow$ rejection from parameters determined from fit
  - Good angular resolution expected
    $\Rightarrow$ background rejection for point sources
- See example showers on next slide,
  and especially, next talk on ALTO Simulations, S. Thoudam

Gamma-ray and proton showers at same energy and core position

x,y 40, 0 m
E 1.5 TeV
Zen 12°

Gamma-ray

Proton



Gamma-ray and proton showers at same energy and core position

```
x,y  40, 0 m
E    1.5 TeV
Zen  12°
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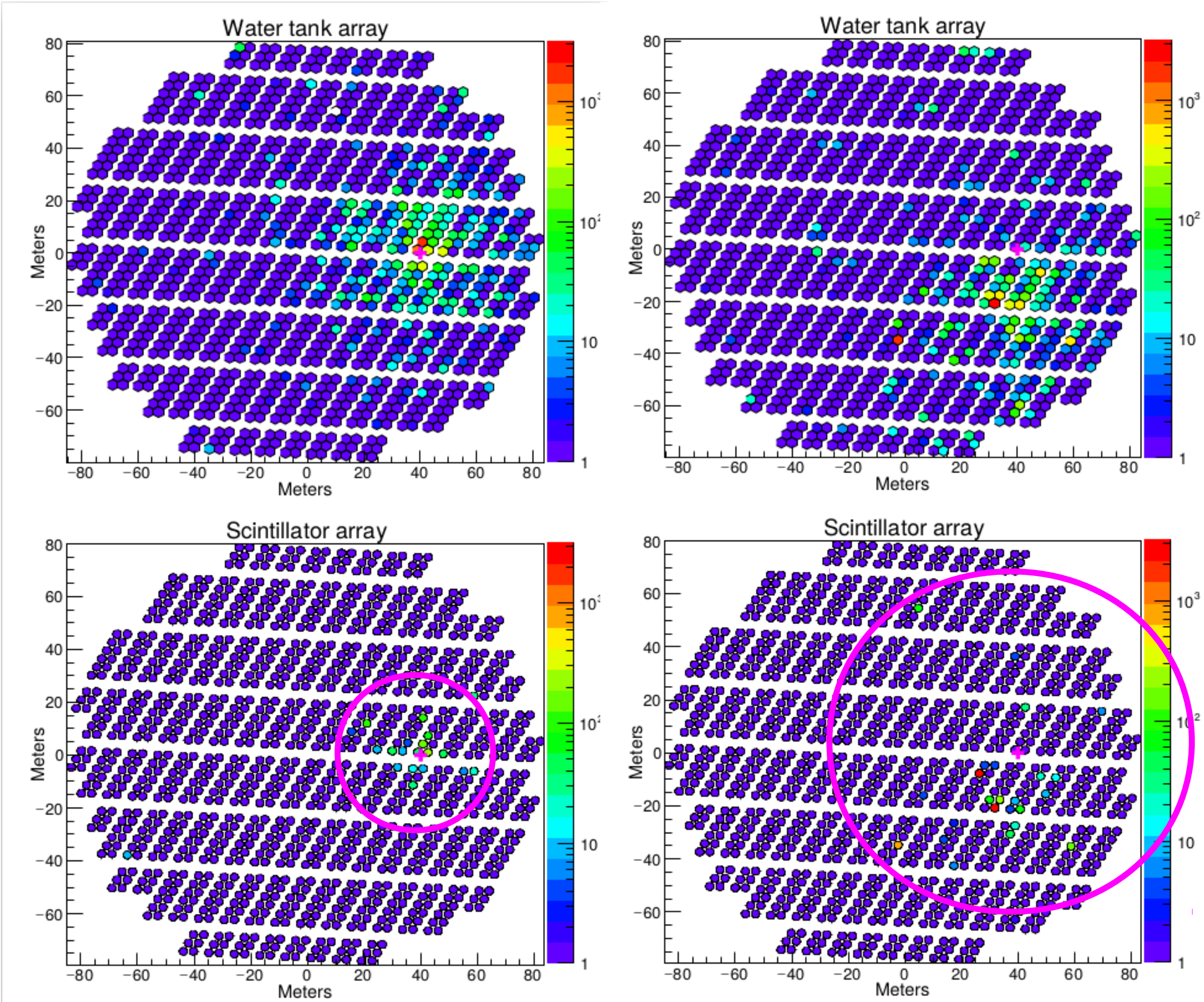
Gamma-ray

Proton



Scintillator signal from $e^{\pm}$ / γ's.

Concentrated, Correlated to core

Scintillator signal from $e^{\pm}$ / γ's & μ's.

Widely-Dispersed, Not well-correlated to core

ALTO Prototype Plans

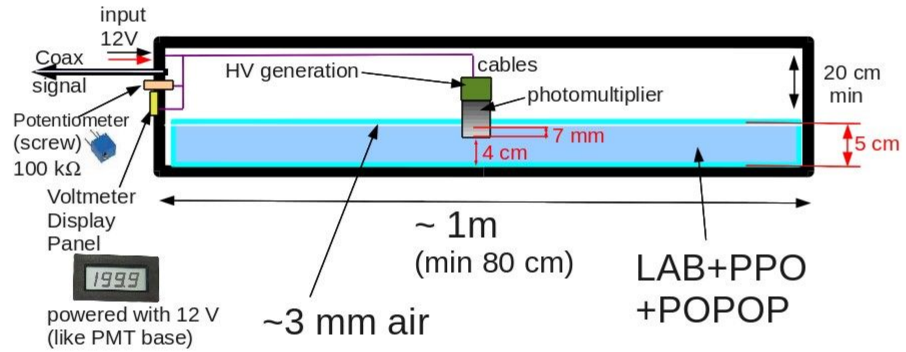
- Prototype with 1 unit, fully funded
  - To be installed at LnU
  - May pour concrete table for >=3 units ($\Rightarrow$ expand as funding allows)

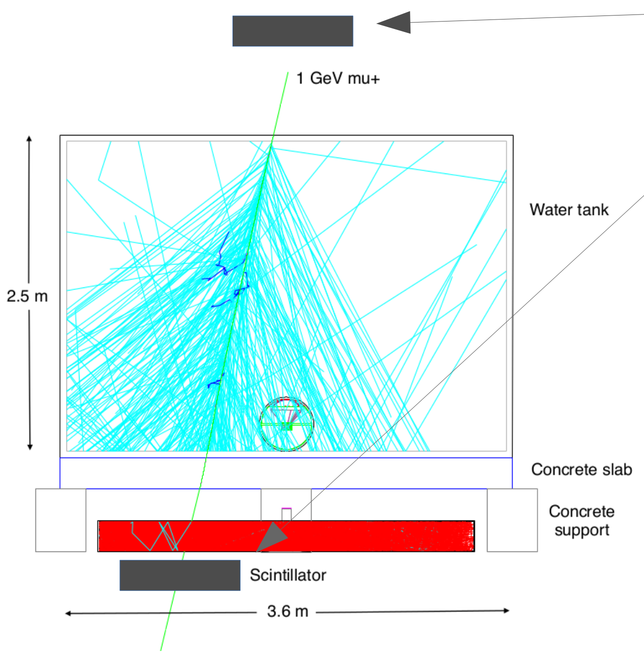
ALTO Prototype location
- Above: Arial view
- Below: South / North view

  - Will provide
    - rates (WCD/SLD) to be compared with simulations for LnU altitude
    - Test if NectarCam cluster electronics can be used ~ “as-is”
    - Installation experience

ALTO Prototype
Expected results

- Will test using “Muon boxes”
  from the Antares surface detector array (J-P Ernenwein)
- Can determine response to muons with ~ known trajectories,
  compare with simulations





Antares surface detector box
- Above: Schematic
- Right: Photo
- Left: Use for ALTO

ALTO Conclusions

- Design of ALTO is advancing
- Careful consideration of install-ability, reliability, and maintainability is influencing design
- Self-contained Electronics as close to detectors as possible
- Simulations are the next step to allow design decisions esp. for electronics, e.g.
  - Timing precision needed
  - Waveform precision and characteristics to save
  - Dynamic range needed
  - Coincidence strategy to be used
- Subsequent step is the prototyping of 1-3 units @ LnU
- Future step: Prototype installation on test site?