Monitoring the energetic Universe with the ALTO Observatory

http://alto-gamma-ray-observatory.org

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The ALTO project

- Project born in 2014 at Linnaeus University after a research grant from the Crafoord Foundation was received

- A Wide Field-of-View (~ 2 sr) gamma-ray observatory:

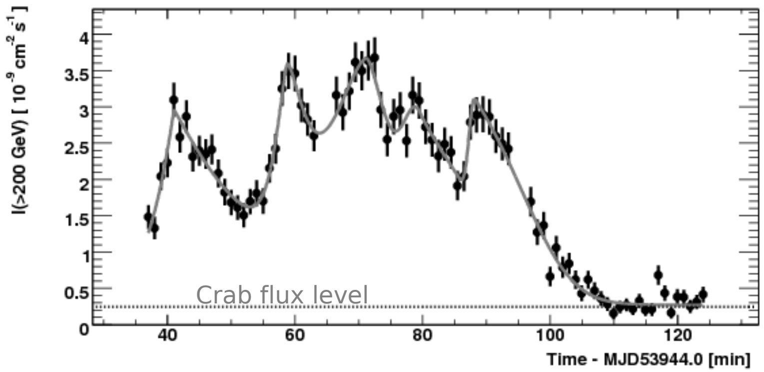
  - In the Southern hemisphere → Daily observations of Southern sources
  - At high altitude (> 5 km) → Low threshold E ≥ 200 GeV
  - Particle detectors → Observations may be done 24h per day
  - Hybrid detectors → Improved S/B discrimination
  - Excellent timing accuracy → Improved angular resolution (~ 0.1° at few TeV)
  - Modular design → Phased construction and easy maintenance
  - Simple to construct → Minimize human intervention at high-altitude
  - Long duration → Should operate for 30 years
  - “Open Observatory” → Distribute data to the community “à la Fermi-LAT”

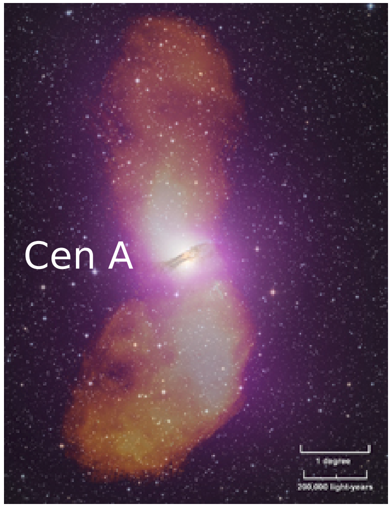
ALTO Science Goals

Daily monitoring of Southern targets:

- Transients and variable sources;
- Active Galactic Nuclei, Gamma-Ray Bursts (if spectra favourable), X-ray binaries;
- Galactic centre and central region;
- Alerts to other observatories;
- Multi-year light-curves;
- High-end of the sources' spectra;
- Search for PeVatrons;

H.E.S.S. PKS 2155-304 (blazar) flare





Study of extended sources:

Fermi Bubbles,
Vela SNR,
AGN radio lobes;

Credit: NASA/DOE/Fermi LAT Collaboration, Capella Observatory, and Ilana Feain, Tim Cornwell, and Ron Ekers (CSIRO/ATNF), R. Morganti (ASTRON), and N. Junkes (MPIfR)

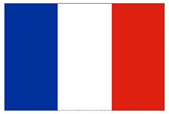
Other accessible goals:

- Search in past data if alerted to detections of:
  - gravitational waves or
  - neutrinos;
- Study of the cosmic-ray composition & anisotropy;
- Dark matter searches;
- EBL studies (if threshold low enough);
- Search for Lorentz invariance violation;
- Axion-like particles from distant AGNs.

Current Collaboration

Sweden

- Department of Physics and Electrical Engineering, Linnaeus University, Växjö
  - PI Yvonne Becherini
  - Post-doc Satyendra Thoudam
  - Two PhD students
- Industry: TBS Yard AB, Torsås
  - Industrial construction responsible Lars Tedehammar



France

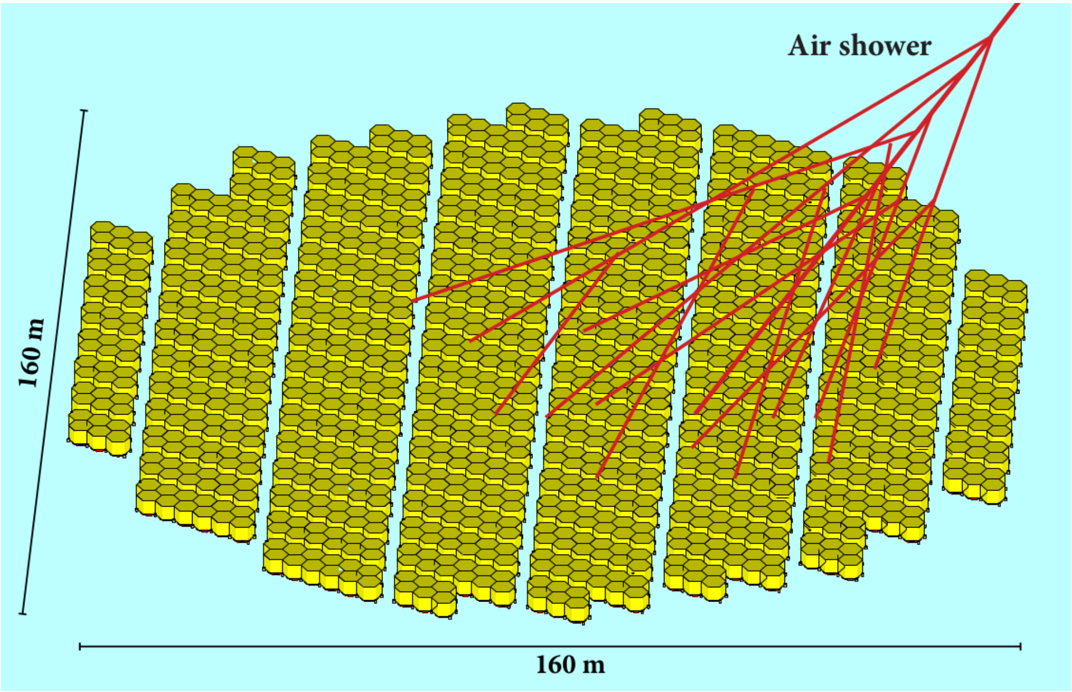
- APC Laboratory, IN2P3/CNRS, Paris
  - Michael Punch
  - Jean-Christophe Hamilton (discussions about the site)
- Aix-Marseille University
  - Jean-Pierre Ernenwein
- LAL/Orsay
  - Dominique Breton, Jihane Maalmi (work on WaveCatcher electronics)
- CEA/Saclay
  - Eric Delagnes (past discussions on electronics)

Discussions with other parties in Academia/Research Institutes:
the SGSO alliance

Key design characteristics of the full array

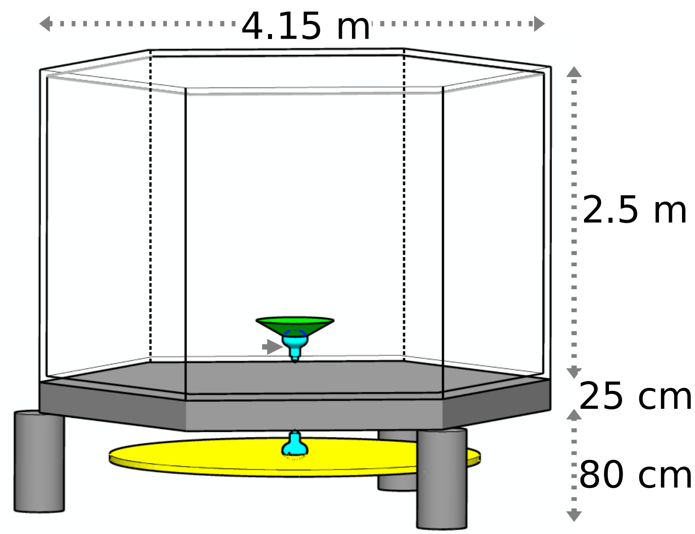
- Southern Hemisphere (Chile/Argentina)
- Altitude ~ 5 km a.s.l
- Energy range ≳ 200 GeV
- ~ 1200 detector units

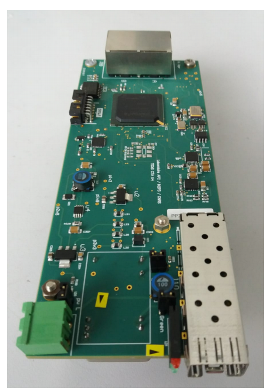
- Advanced electronics
  - Sub-ns timing
- Small-sized, closed-packed WCDs
- Low dead-space (“packing factor” ~70%)
- Scintillation detectors

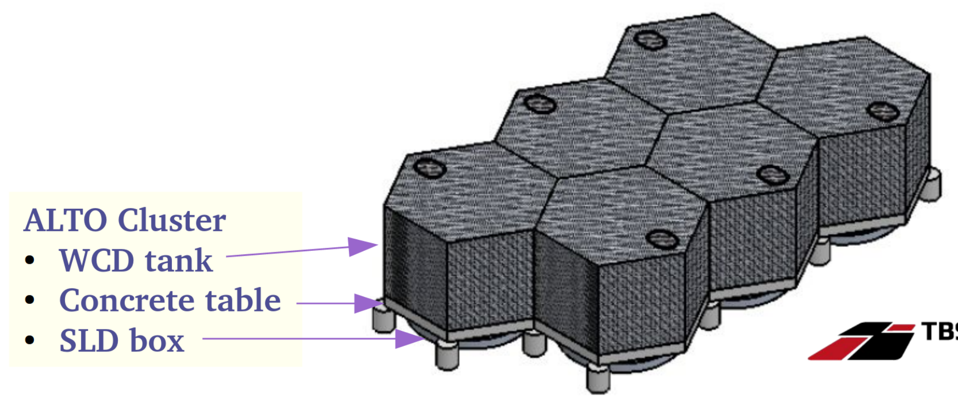


ALTO detection unit & cluster

- Water Cherenkov tank:
  contains one Hamamatsu super-bialkali 8’’ PMT;
- Muon-detector scintillator tank for background rejection:
  - Liquid scintillator box (Scintillator Layer Detector, SLD) with one 8’’ standard Hamamatsu PMT;
- Advanced electronics for 6-tank “cluster”,
  WaveCatcher + White Rabbit:
  - Trigger channel precisely time-stamped with “White Rabbit” system;
  - Analogue memories + ADCs measure the waveform of the detector pulses;
  - SBC (single board computer) for local control & acquisition
  - No cables from central DAQ room, only fibres.

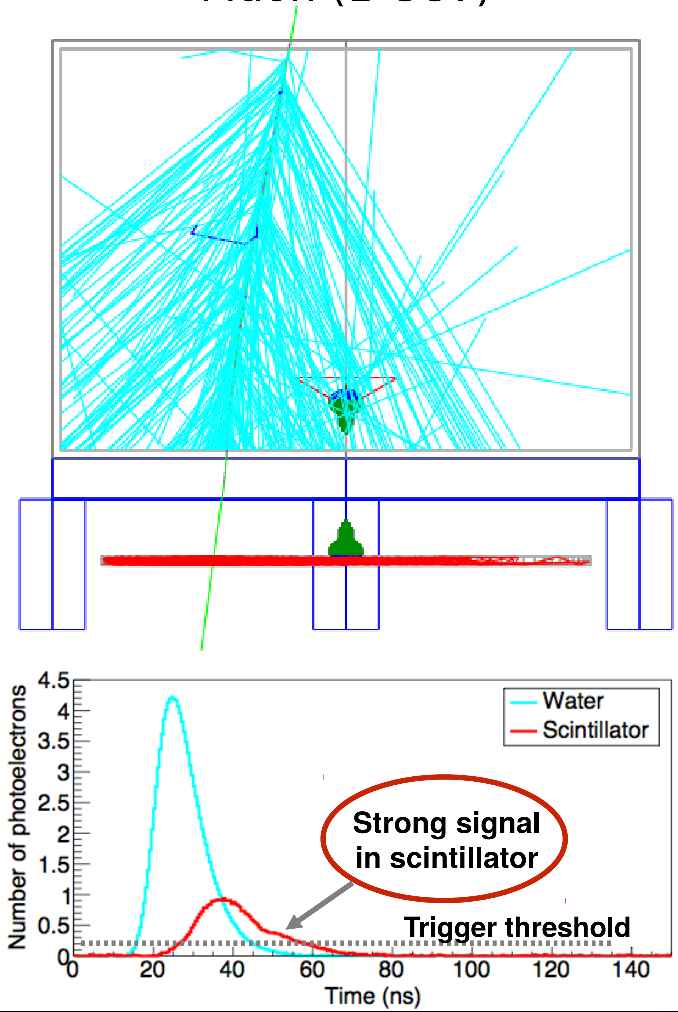




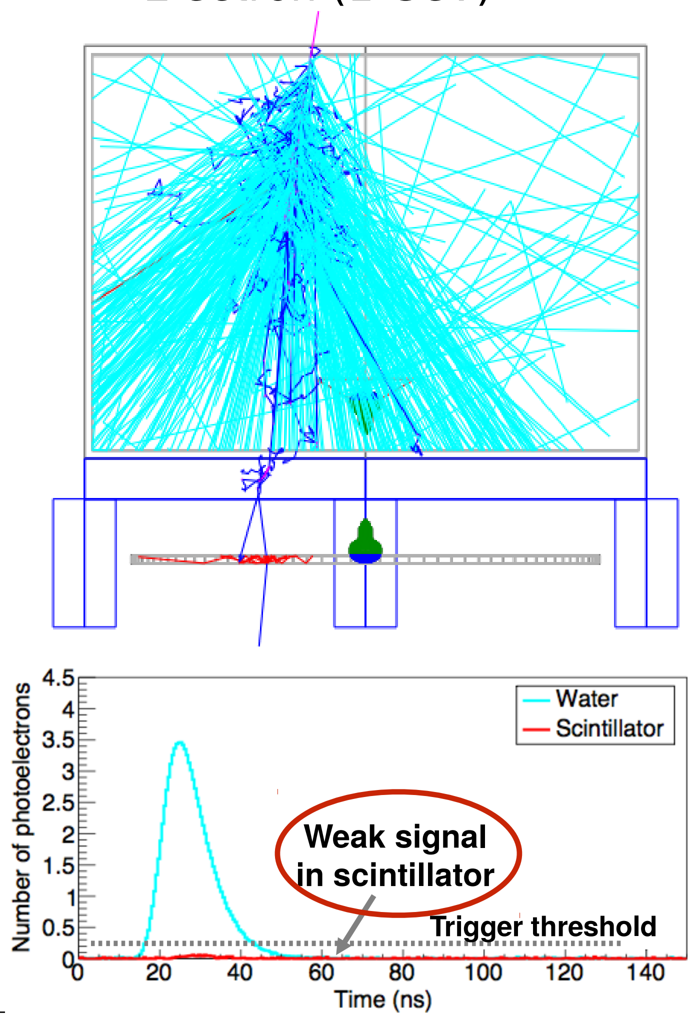


ALTO response to single particle

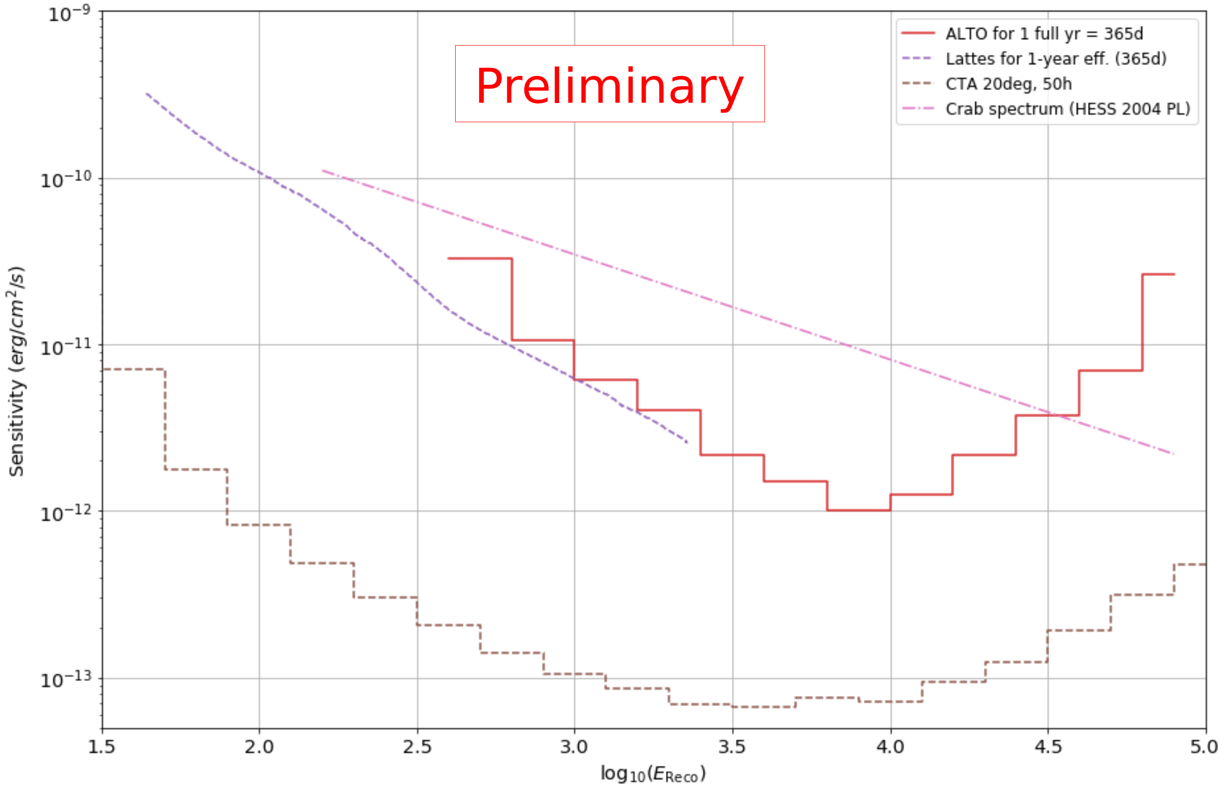
Muon (1 GeV)



Electron (1 GeV)



Sensitivity for 1 year live-time on a source 18° from Zenith



Further improvements overall expected now that the software chain is complete

ALTO prototype construction timeline in 2018

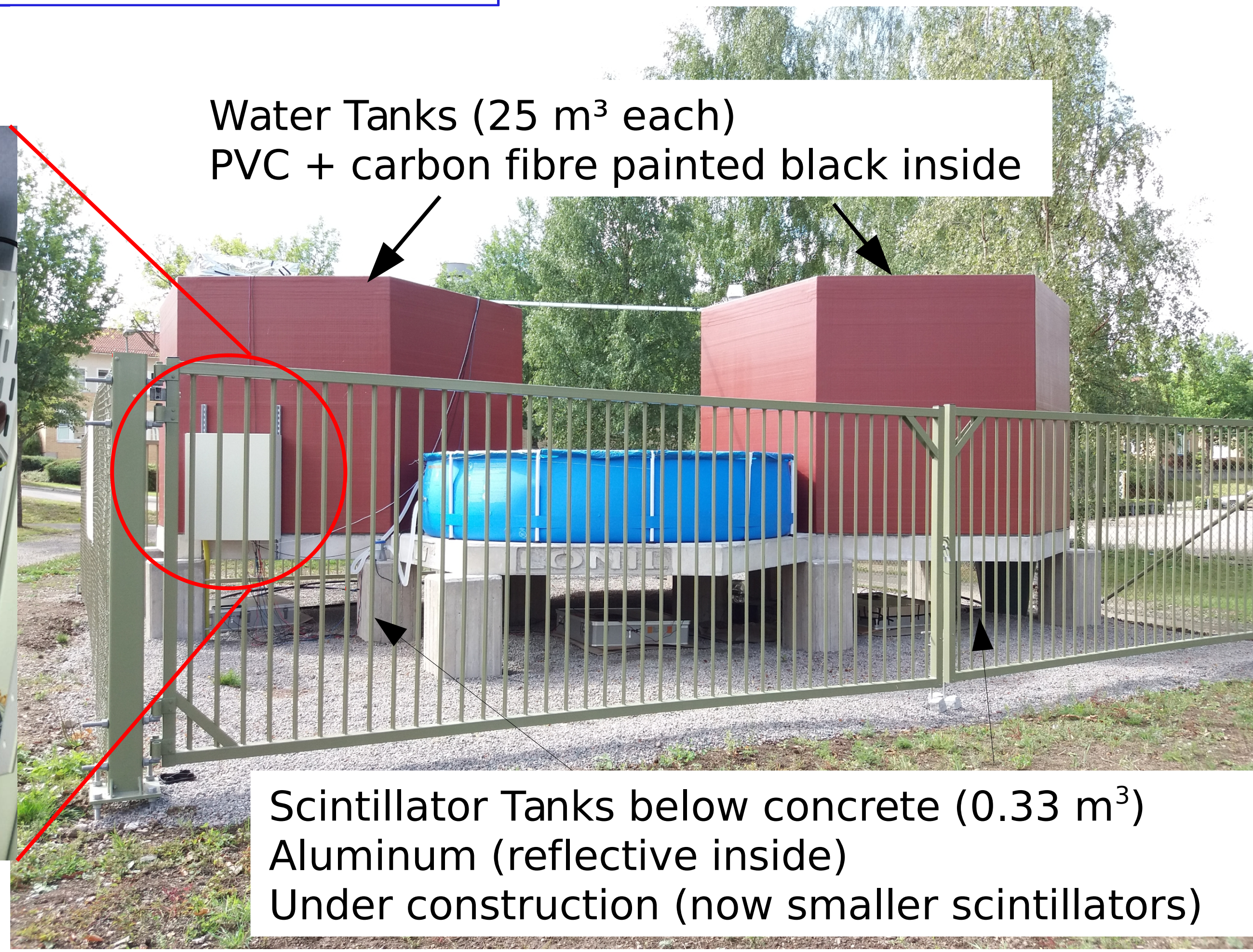
- Jan 8: Digging at the prototype site on LnU campus started
- Jan 26: Ground preparation and underground concrete base finished,
  columns construction well underway
- Jan 31: Concrete slab pouring
- Feb 27: Concrete structure ready, first water tank ready at TBS Yard
  (needed more carbon fibre for the second tank)
- Apr 7: Both water tanks ready, water resistance test
- Apr 18: Water tanks arrived at prototype site
- May 6: Photomultipliers installed in the water tanks
  and work on electronics and network ongoing
- May 8: First air-Cherenkov coincidence event between ALTO tanks with the full DAQ chain
- May 16: Filling of water Cherenkov tanks
- May 25: Data taking with ALTO water Cherenkov tanks started
- June 28: Added small plastic and liquid scintillators, waiting for the final ALTO scintillators
- Aug 7: Muon detectors production started
- Oct 7: Event display available
- Now: Waiting for muon detectors delivery!

Follow our Blog on the website alto-gamma-ray-observatory.org

ALTO Prototype array in Växjö

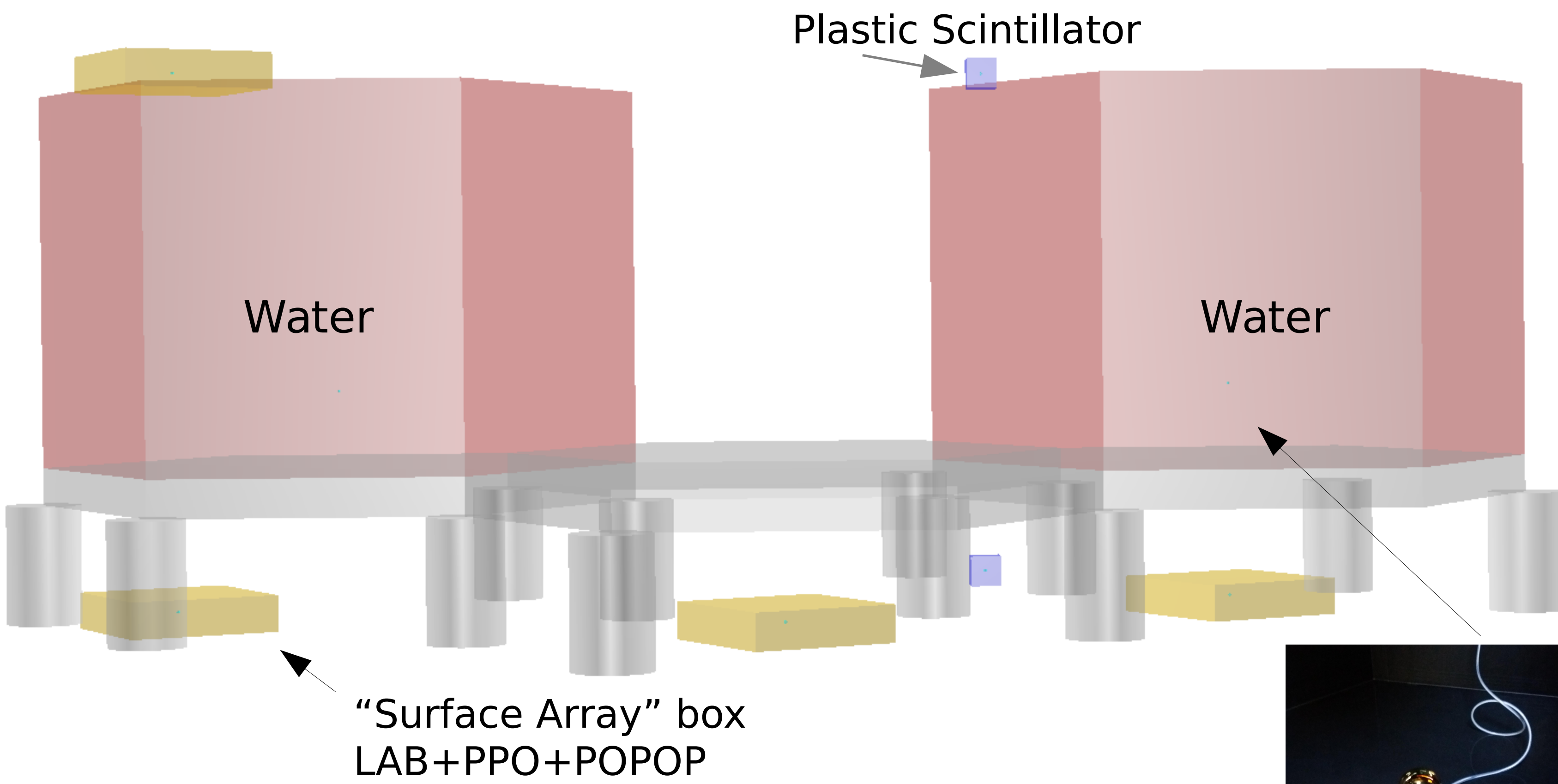
ALTO

On site electronics

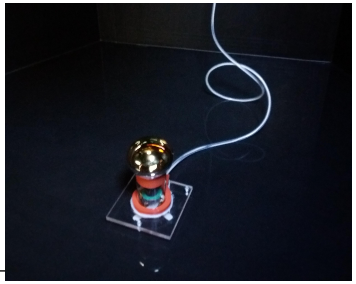


Control room

ALTO Prototype array in Växjö
Current configuration



Event Display



Current status of ALTO & lessons learned

- ALTO simulations and Analysis now quite mature
  - We have a complete and detailed simulation of a realizable detector
  - We have completed the full chain up to the sensitivity curves
    - Many parameters developed and tested
    - MVA - BDT machinery in place and working
    - Now, some time for optimizations based on full chain

- ALTO Prototype used to learn about
  - hardware configuration (number of samples in waveform, sampling period, thresholds, PMT gain, methods for WF integration at SBC level),
  - about self-calibration &
  - about behaviour of water/crown/PMT encapsulation.

Will be pursued with Scintillator tanks.

Project time-line & Next steps

ALTO

- 2018 - Validation of prototype design;
- 2020 - If prototyping phase successful:
  - Installation of one or more ALTO clusters at the final site in the Southern hemisphere (our choice: QUBIC/LLAMA site in Argentina);

2017 — Prototype construction

2018-2019 — Prototype validation and operation

2020 — Installation of one or more clusters at the final site for further validation

Full deployment

Conclusions

- ALTO is a new project, financially supported primarily by Linnaeus University and Swedish private Foundations for now;
- The project's aim:
  → to build a wide FoV VHE gamma-ray observatory with enhanced sensitivity with respect to current WCDA technology;
- Simple design:
  → limits costs of construction in full production phase; Prototype costs higher;
- Collaboration between Academia and Industry:
  → cost-effective solutions;
  → knowledge transfer benefiting both parties;
- Possible location of the observatory:
  → Argentina, near QUBIC/LLAMA;
- Aimed investment cost for full deployment
  → ~ 20M€ excluding salaries;
- Expansion of collaboration:
  → to cover costs, expertise in DAQ, design optimisation
- Status of the project with further information can be found at the website:
  → http://alto-gamma-ray-observatory.org/
- For enquiries about the project, please contact yvonne.becherini@lnu.se

Backups

ALTO site in South America

- Presence of water nearby is a key factor, to lower the costs
- In order to simplify and be quick, we are aiming for the installation of 2-3 full ALTO clusters behind the site of QUBIC/LLAMA in Argentina, at an altitude of 4850 m
- We should be in the back lobe of QUBIC in order not to disturb the QUBIC experiment data taking
- There might also be the possibility to share infrastructure, power, network, roads
- The 2-3 cluster installation will allow us
  - To further test the construction feasibility at high altitude
  - To acquire further experience on singles and coincidence rates
  - To build partnerships with local industries