Overview of the Planned Surface Enhancement of IceCube

Presented at the XIX International Workshop on Neutrino Telescopes

Roxanne Turcotte *for the IceCube Collaboration*, 24.02.2021

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European Research Council
Established by the European Commission

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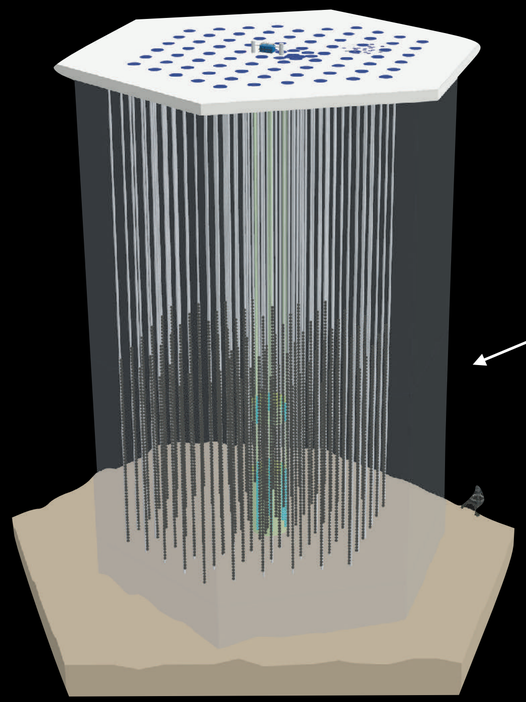
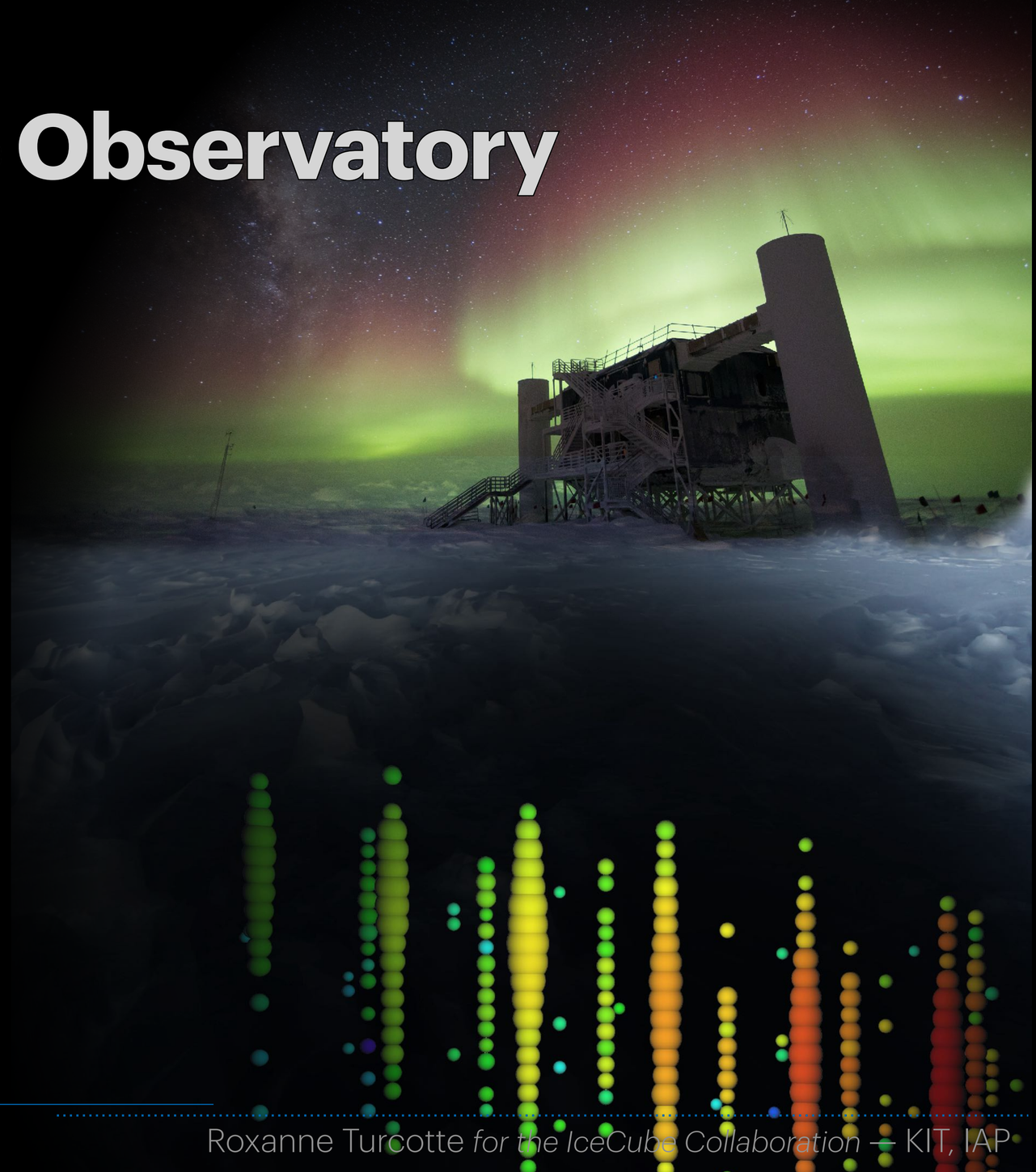
The IceCube Neutrino Observatory

In-ice neutrino detector

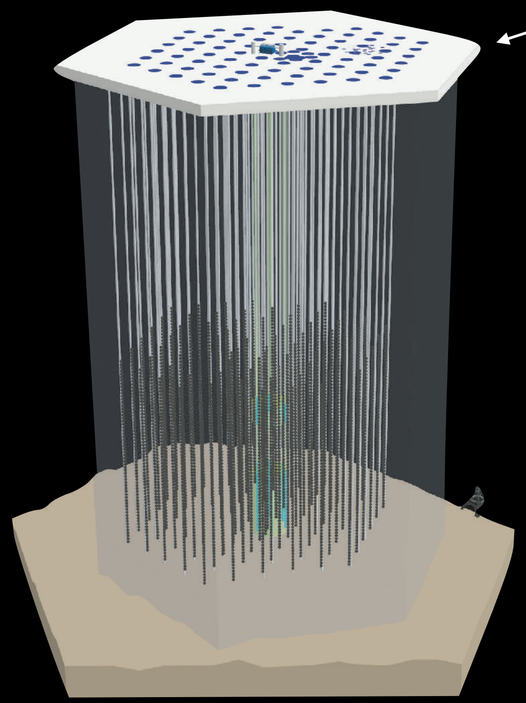


Neutrino detector



The IceCube Neutrino Observatory

Also a cosmic-ray detector !

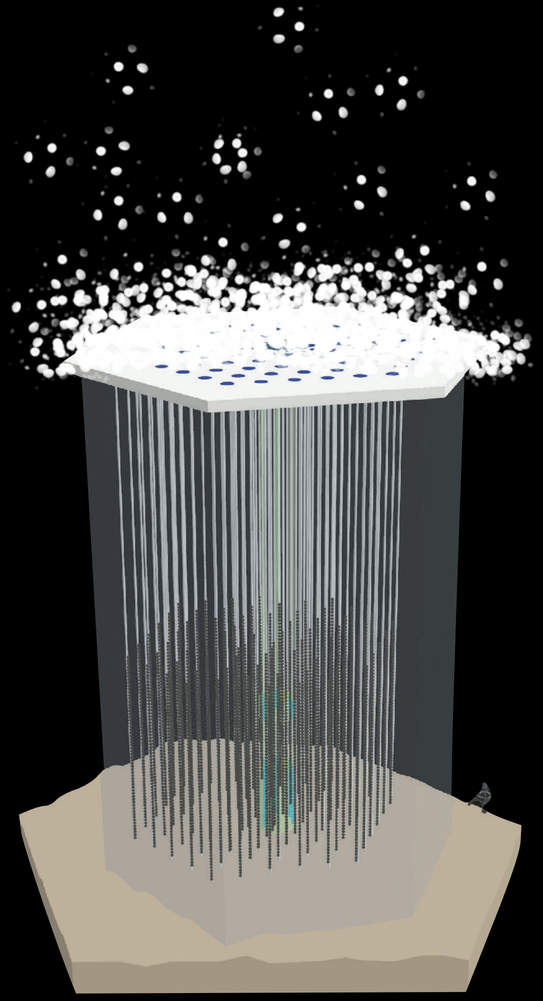


IceTop

- 162 ice Cherenkov tanks
- Atmospheric background veto
- Cosmic-ray detector

The IceCube Neutrino Observatory

Snow accumulated over the years...

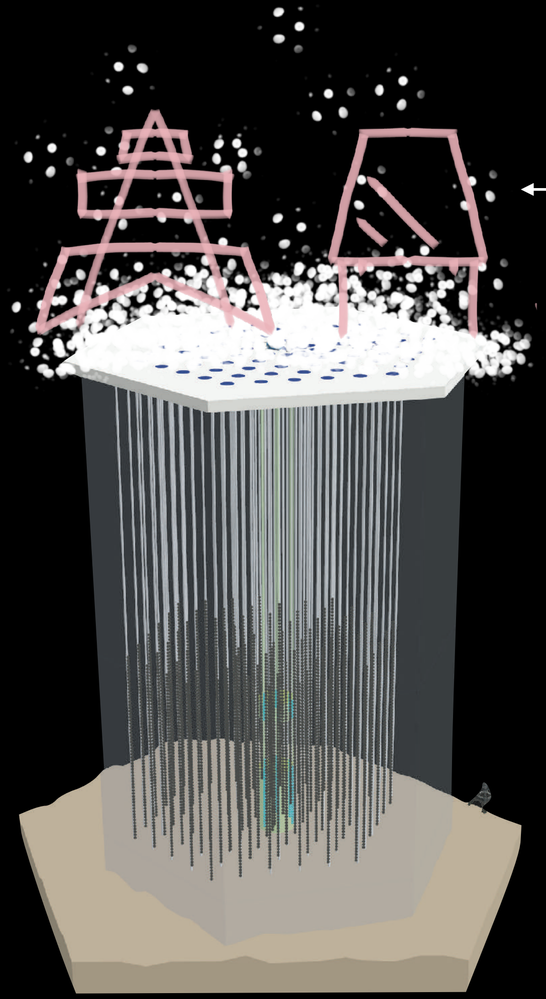


↑ Threshold

↓ Resolution

The IceCube Neutrino Observatory

Enhanced



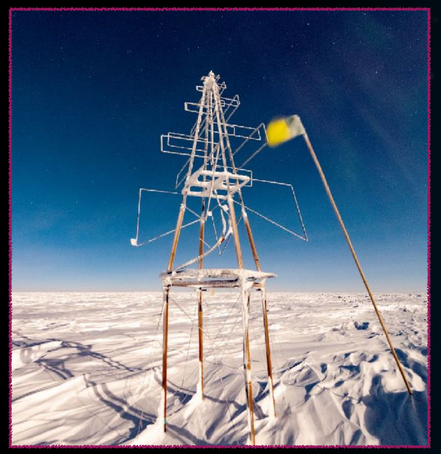
Enhanced surface array

- **Lowering** the detection **threshold**
- Improving the atmospheric muons **veto** for the in-ice detector
- Improving the understanding of the **atmospheric background**
- Increasing the **resolution** of **Xmax** and **energy** especially in the **second knee** region of the CR spectrum
- Improving **mass composition** reconstruction
- Sensitive to more **inclined showers**
- Possibly detect **PeV gamma-rays** from the Galactic centre

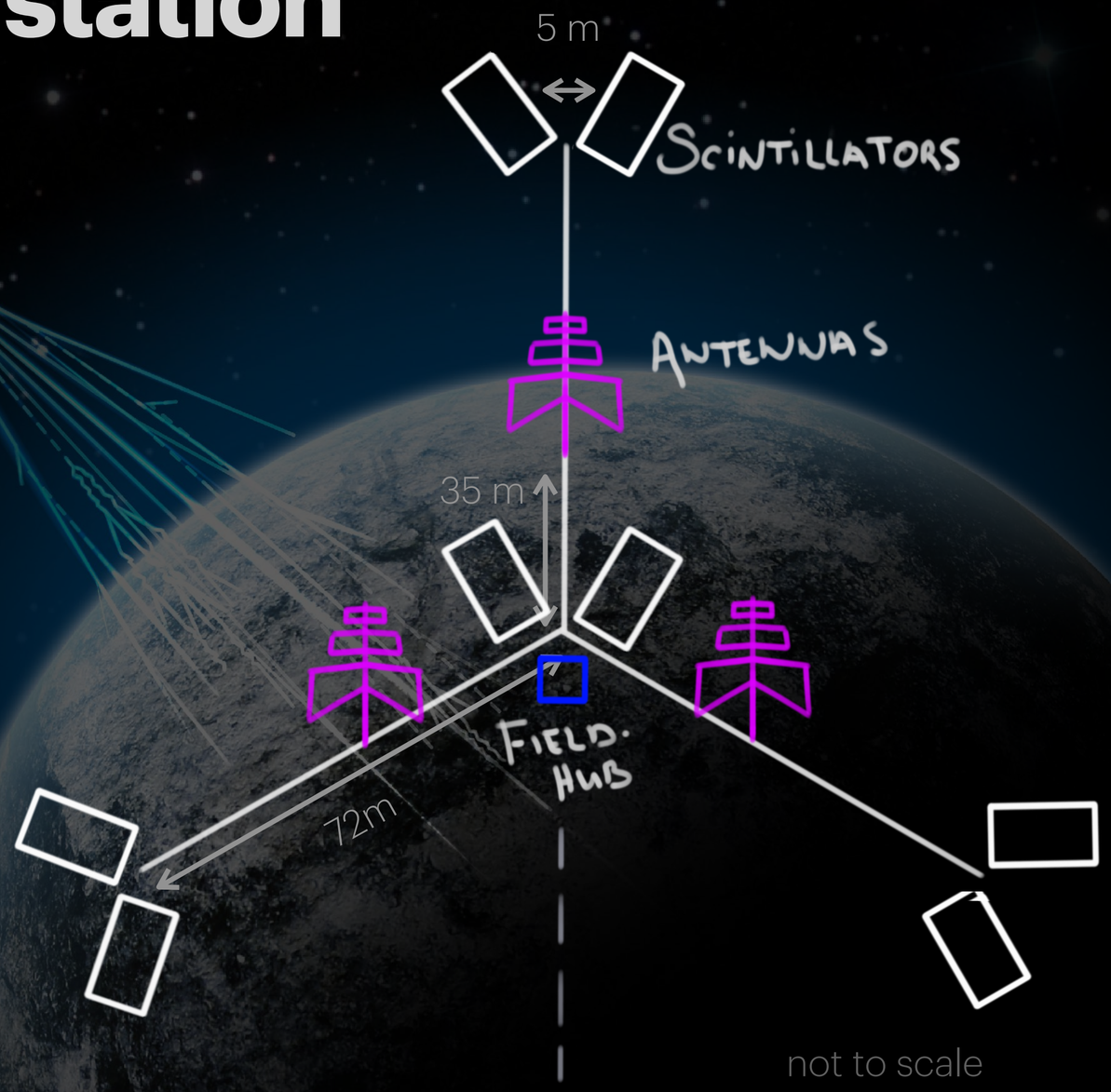
Planned layout of one station

8 scintillators and 3 antennas

- 8 scintillator panels
- 3 antennas
- 1 insulated FieldHub

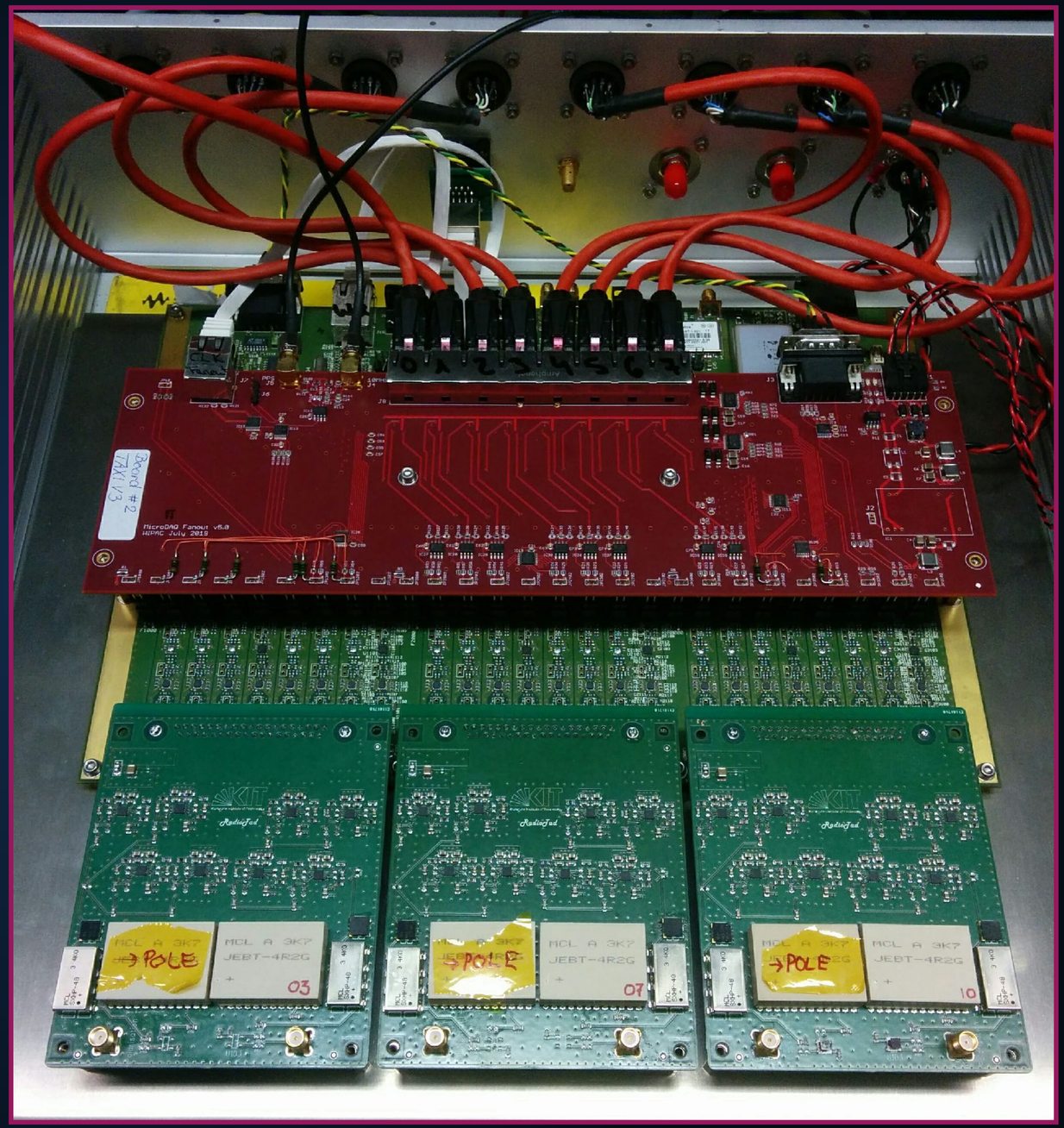


Both detector types are elevated and raisable !



Station

Inside the field-hub



Station

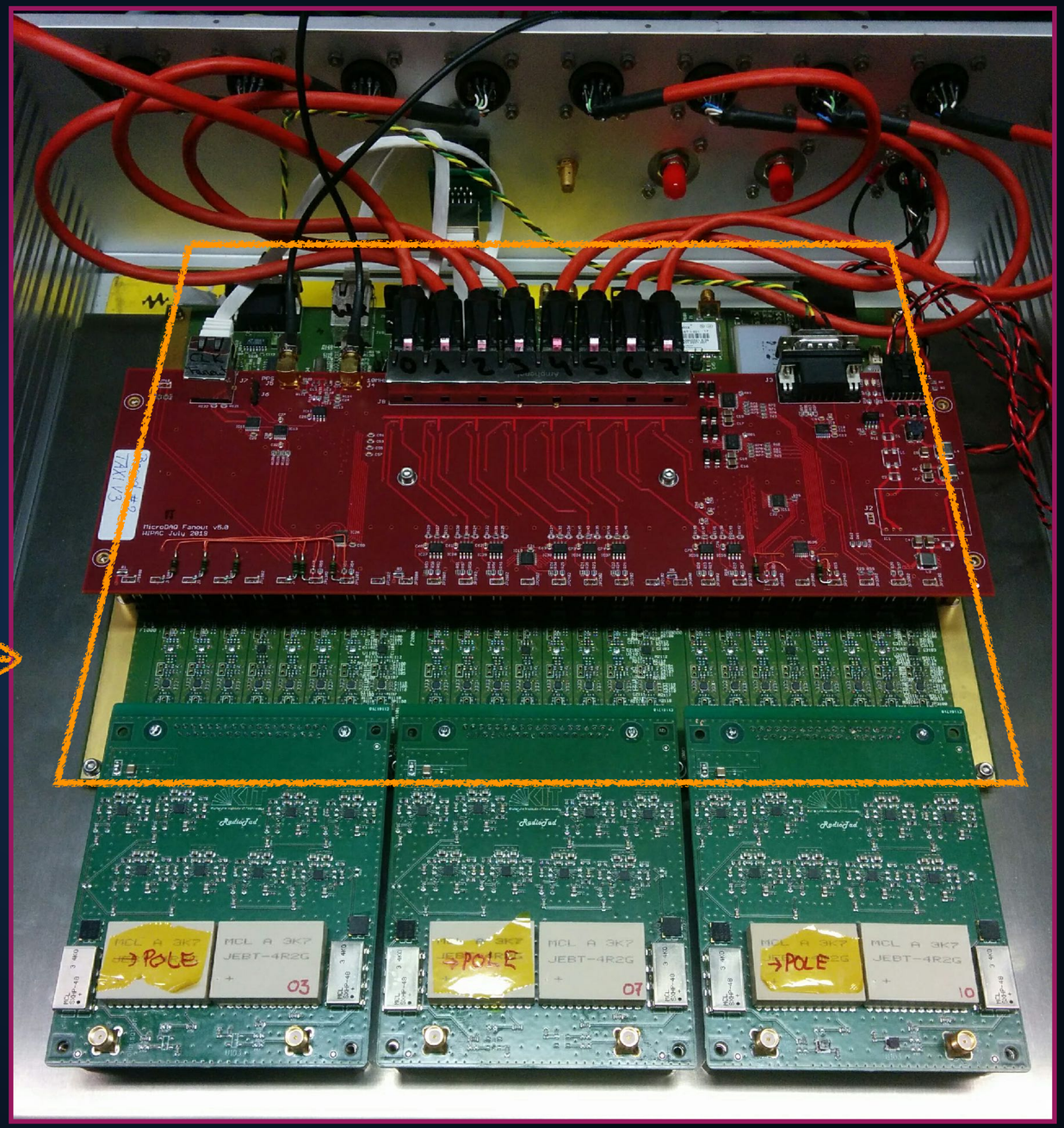
Inside the field-hub

Data Acquisition System (DAQ)

Transportable Array for eXtremely large area Instrumentation (TAXI)

FPGA

embedded on-board linux



Station

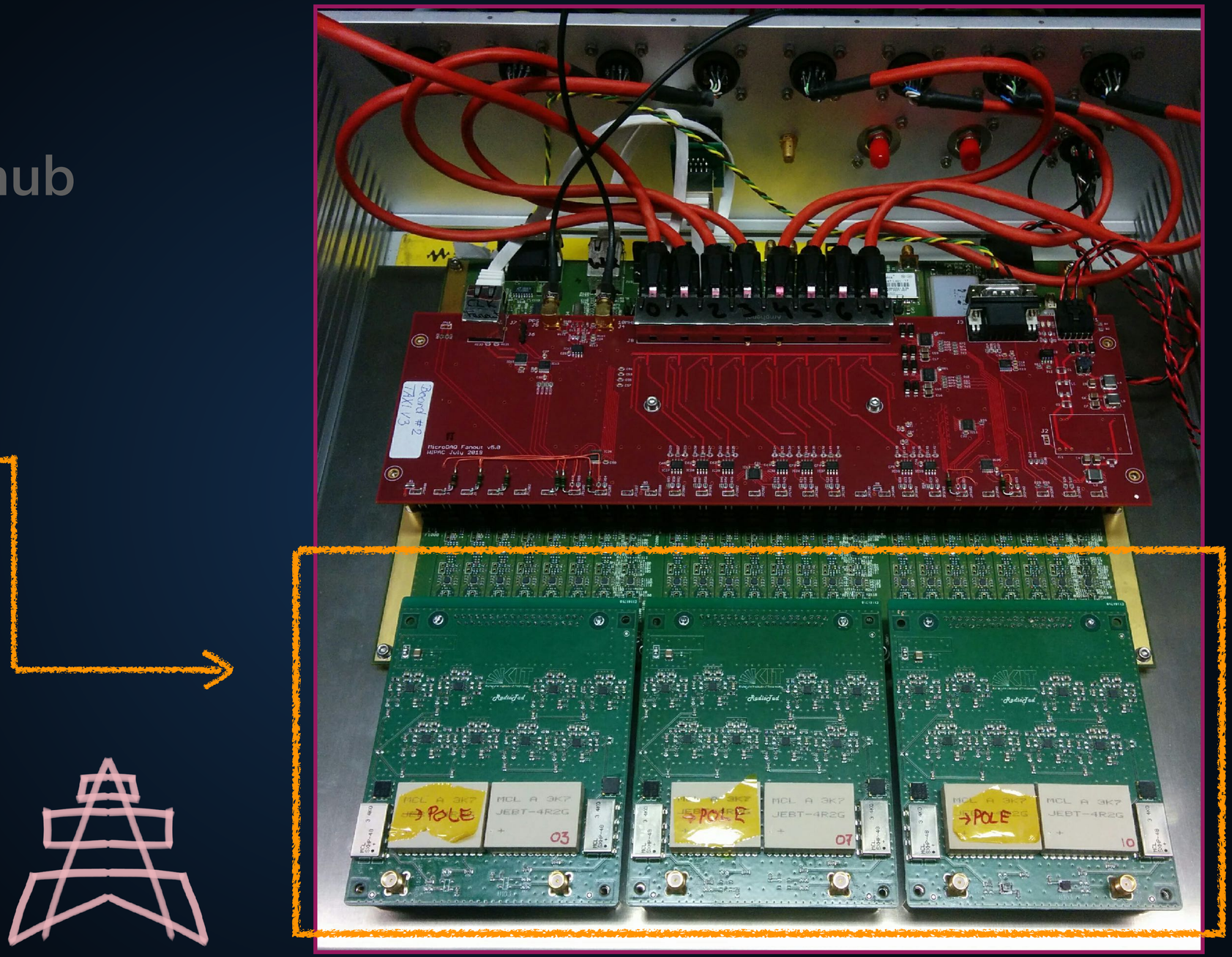
Inside the field-hub

Radio

LNA

RadioTad

DRS4



Station

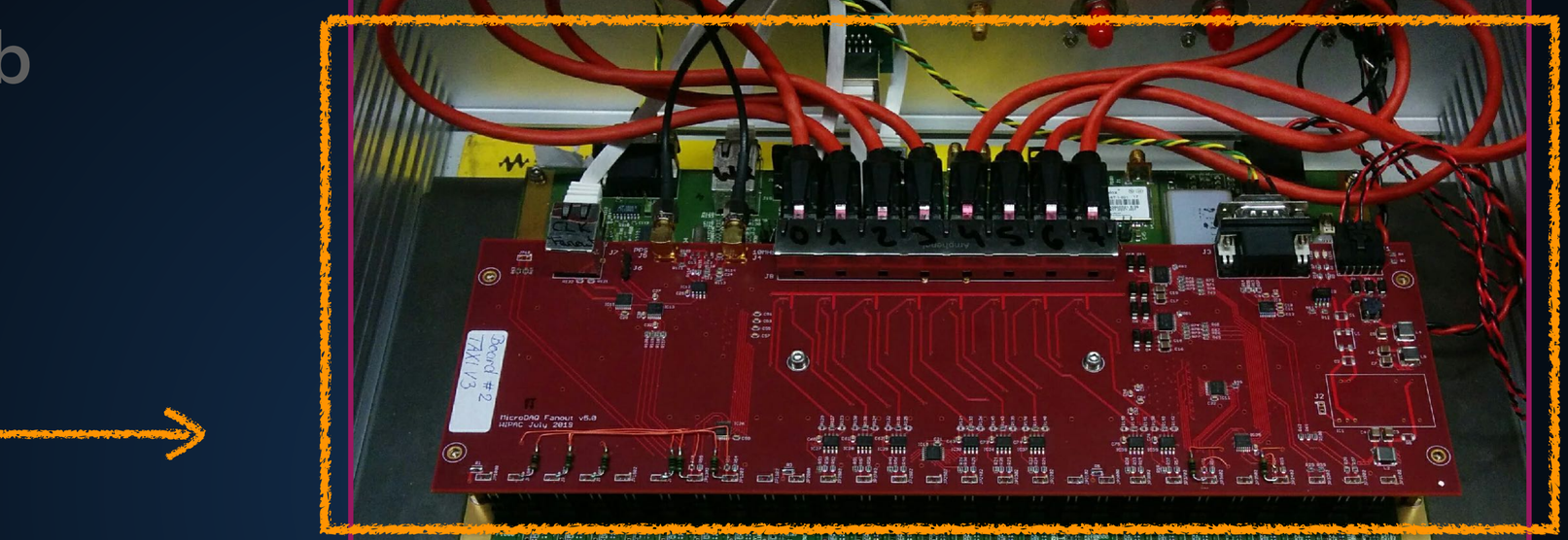
Inside the field-hub

Scintillators

Fanout board

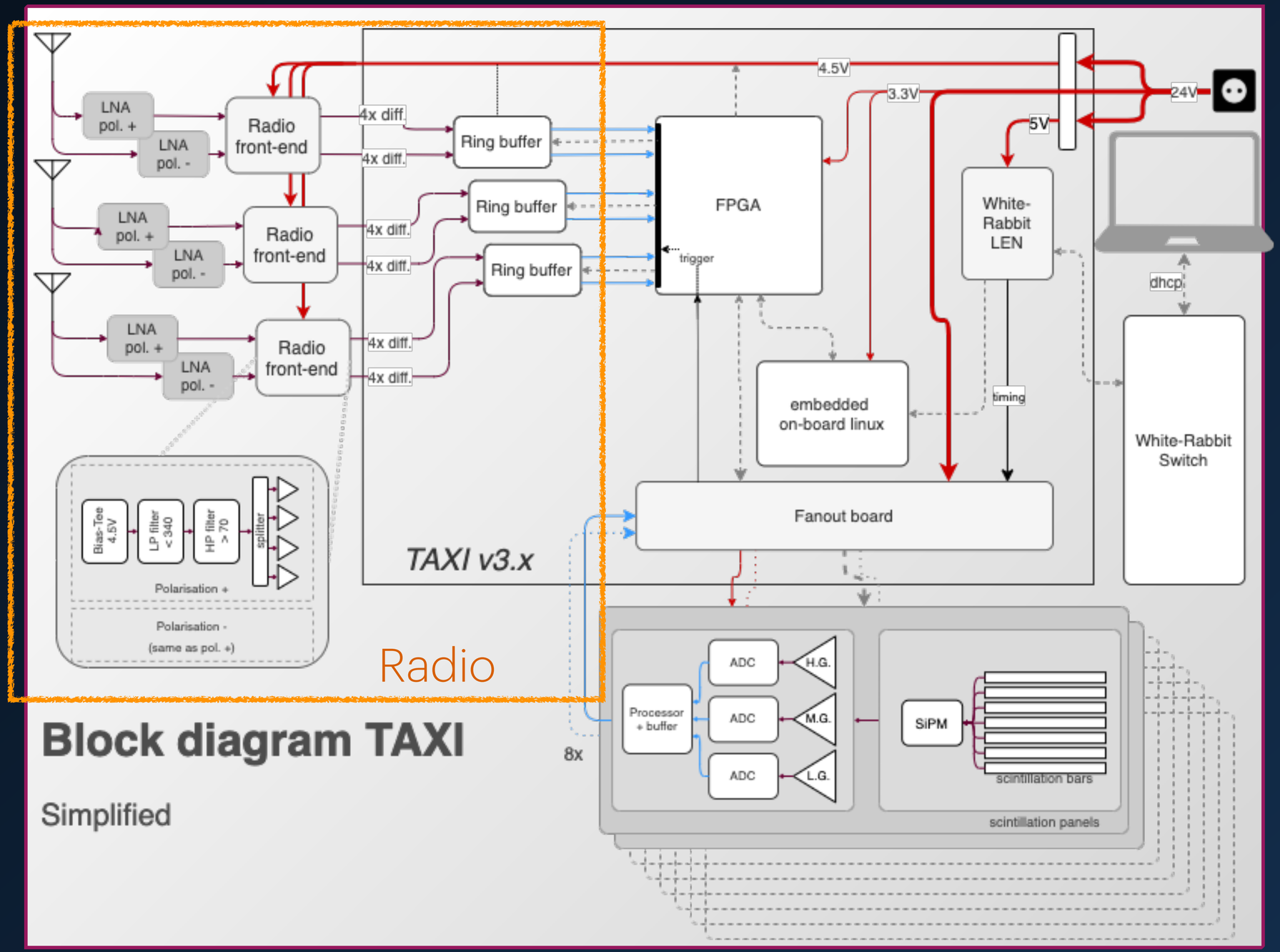
MicroDAQ

Cookie board



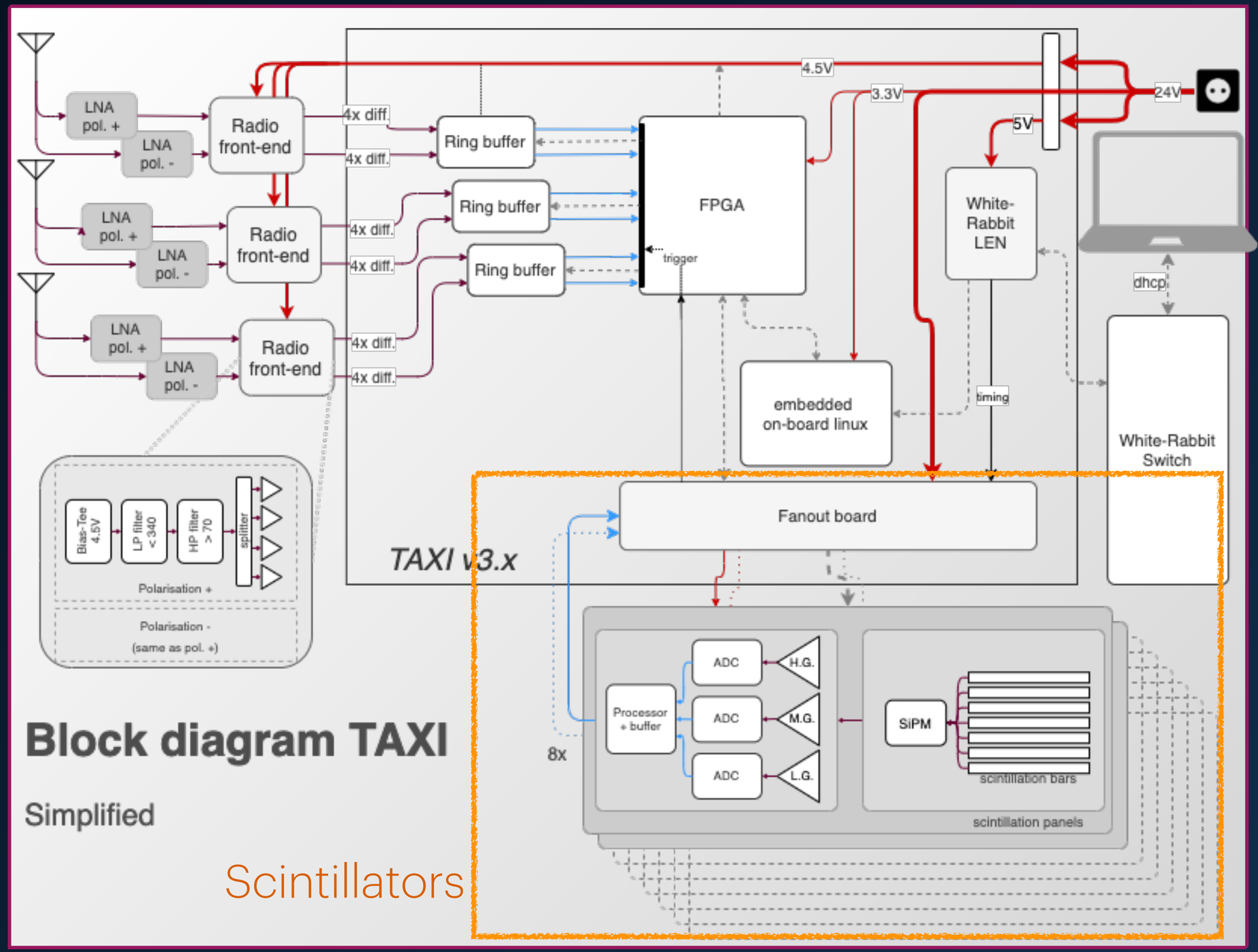
Station
Technical details

- ~45 dB gain
- 70-340 MHz bandwidth
- Ring buffer :
  - Records continuously
  - Read-out when triggered by the scintillators
  - Possibility of 4 µs, 2 µs and 1 µs traces
- LPDA antennas



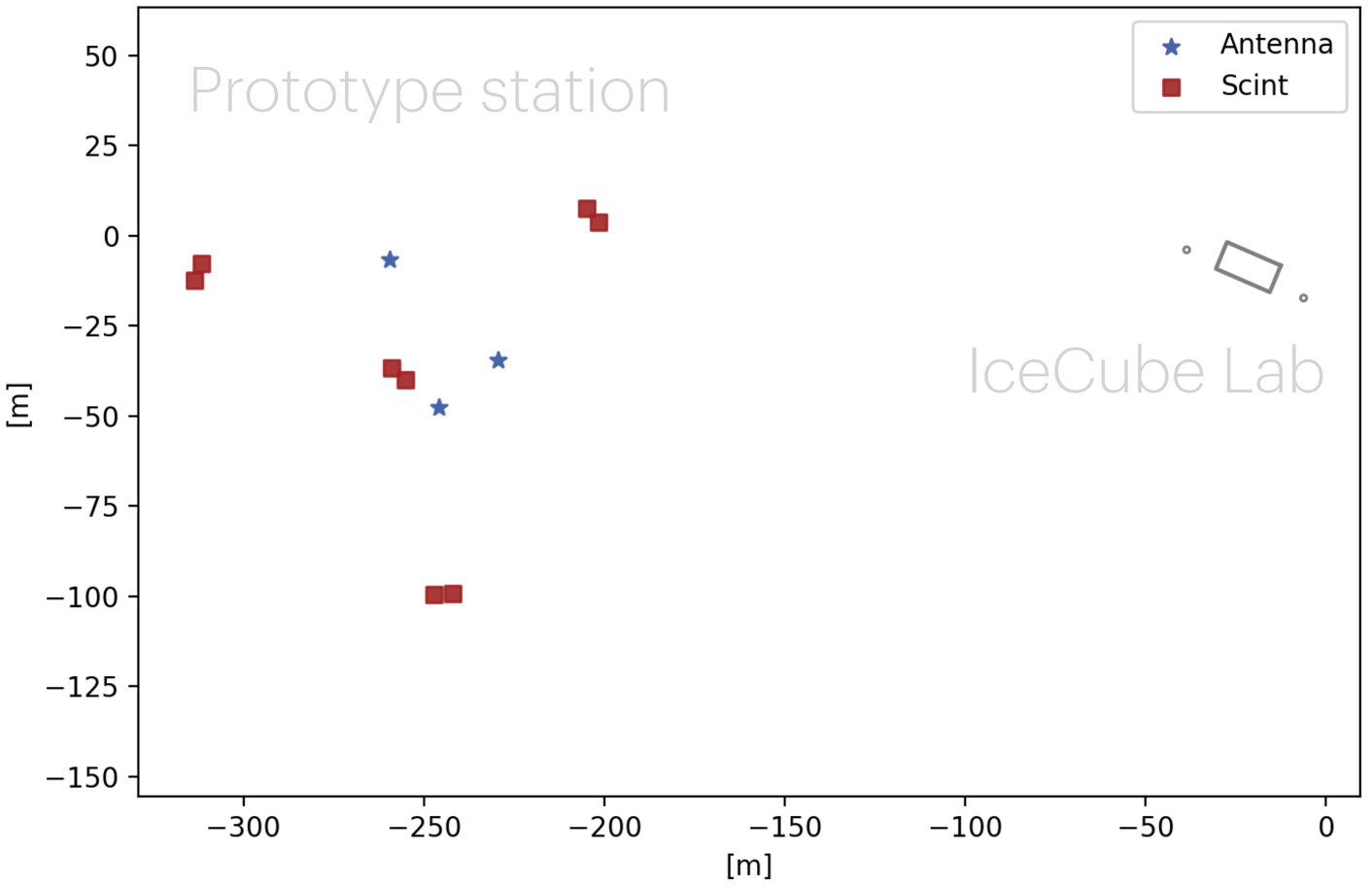
Station
Technical details

- Plastic scintillation bars
- Silicon photomultiplier
- 3 different gains
  - Low, medium, high
- Conversion to digital in the front-end
- Triggers the radio reading
- Temperature sensor



The prototype station

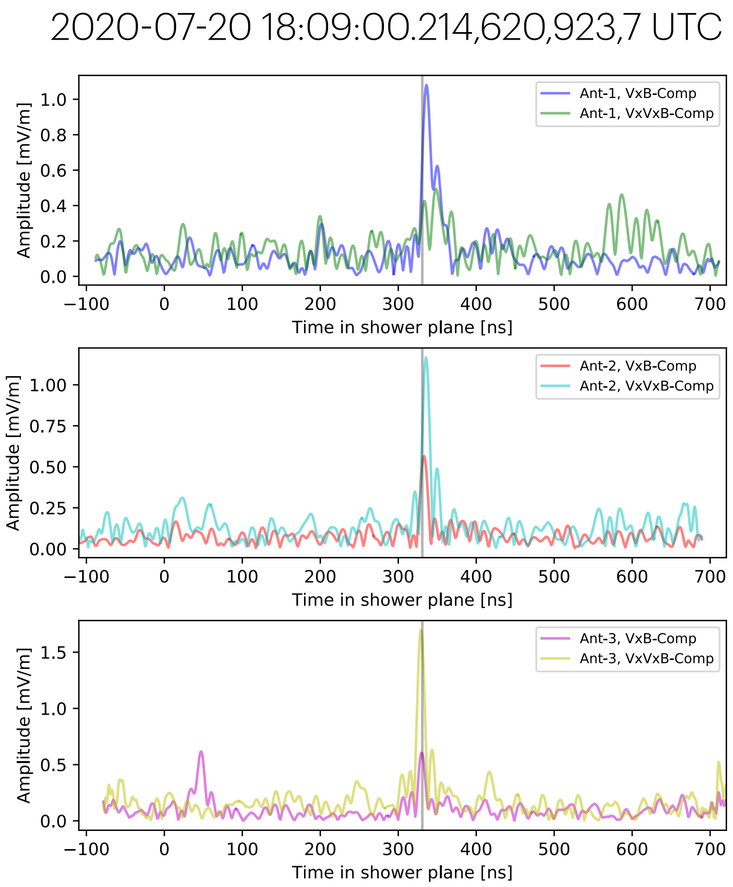
Deployed in January 2020



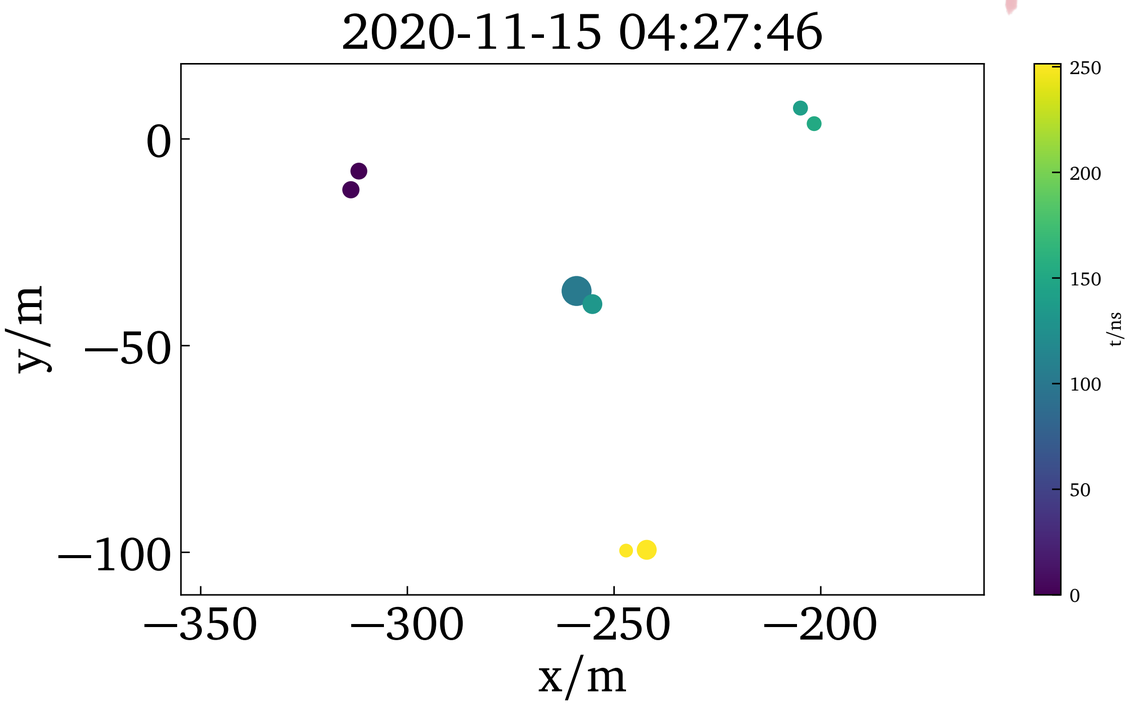
The prototype station

Air showers !

- We detected radio shower!
- We detected scint. shower!
- Stay tuned for more!



Plot by Alan Coleman

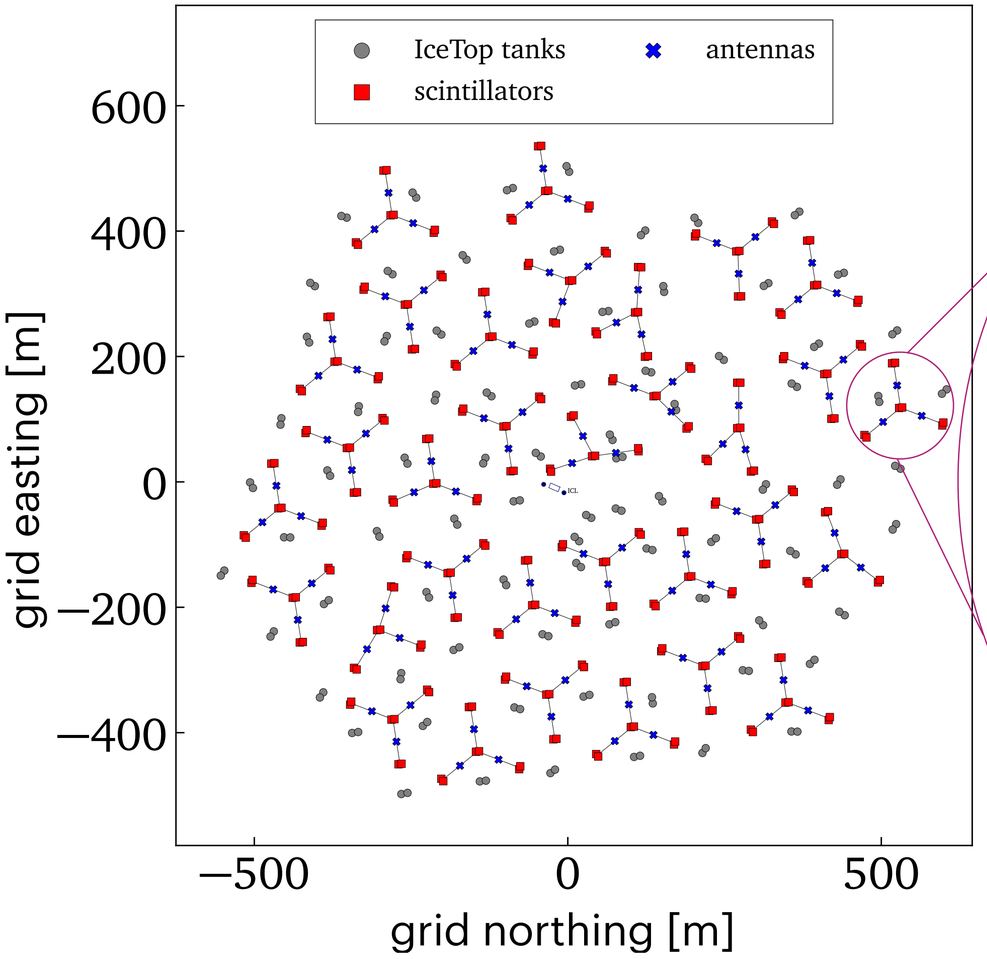


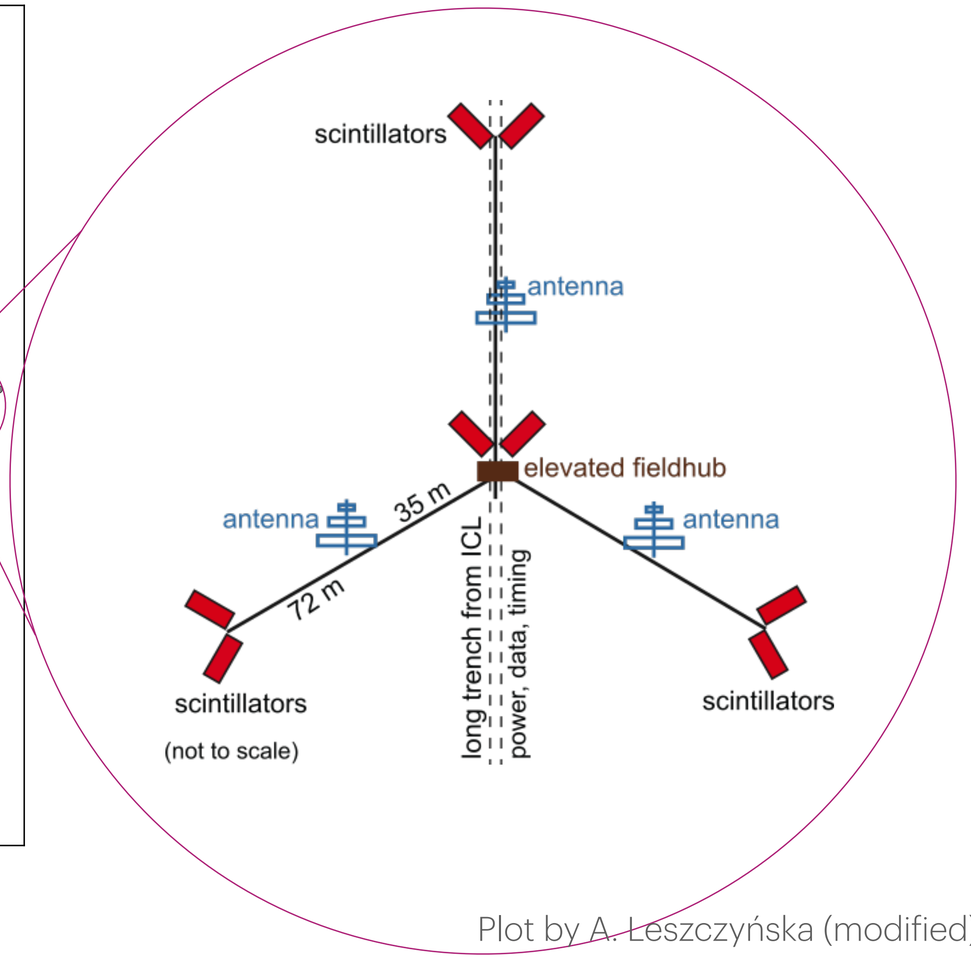
Plot by Marie Oehler

Deployment planning

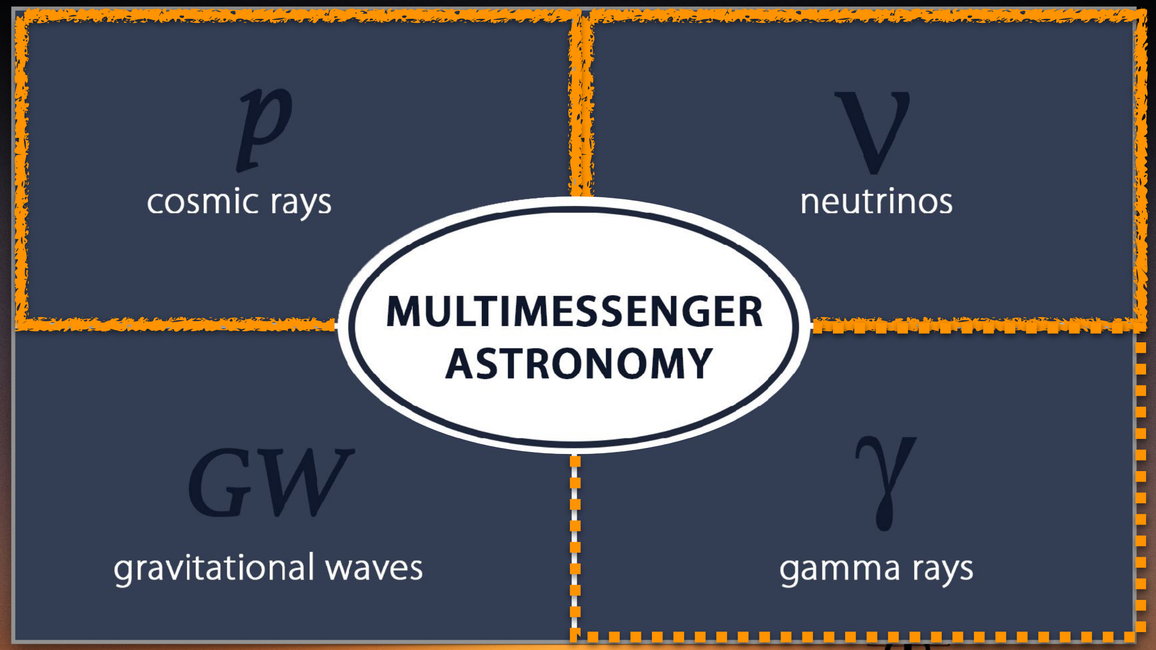
32 stations by 2026

- 256 scintillation panels
- 96 antennas





Plot by A. Leszczyńska (modified)



Conclusion

- IceCube -

A unique observatory in the multi-messenger era

Backup

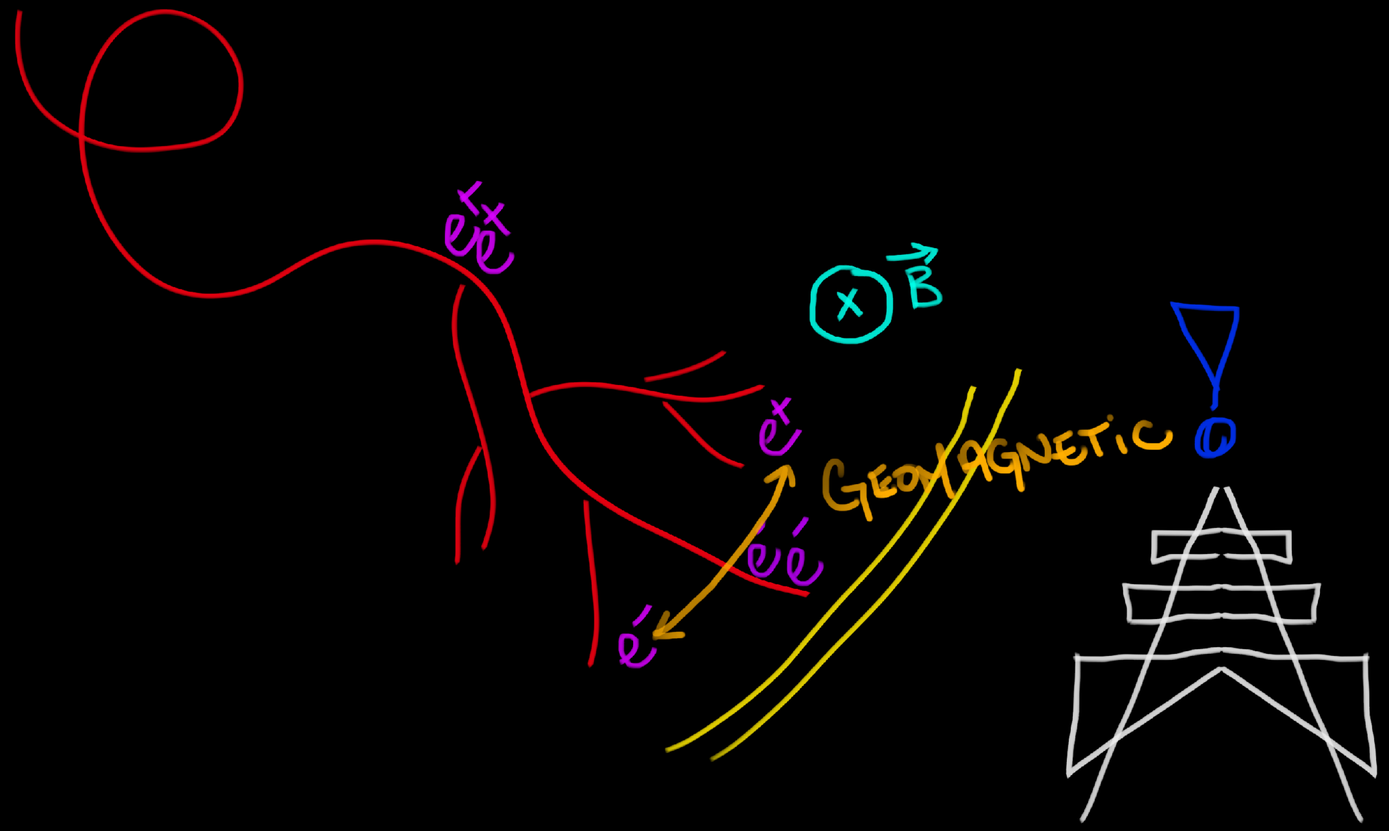
An enhanced surface array

Detection technique - Radio

- Radio sees the **electromagnetic** part of the shower
- Radio emission from:
  - **Geomagnetic** effect:

time varying current induced by the separation of electrons and positrons by the Earth's magnetic field

  - Askaryan effect

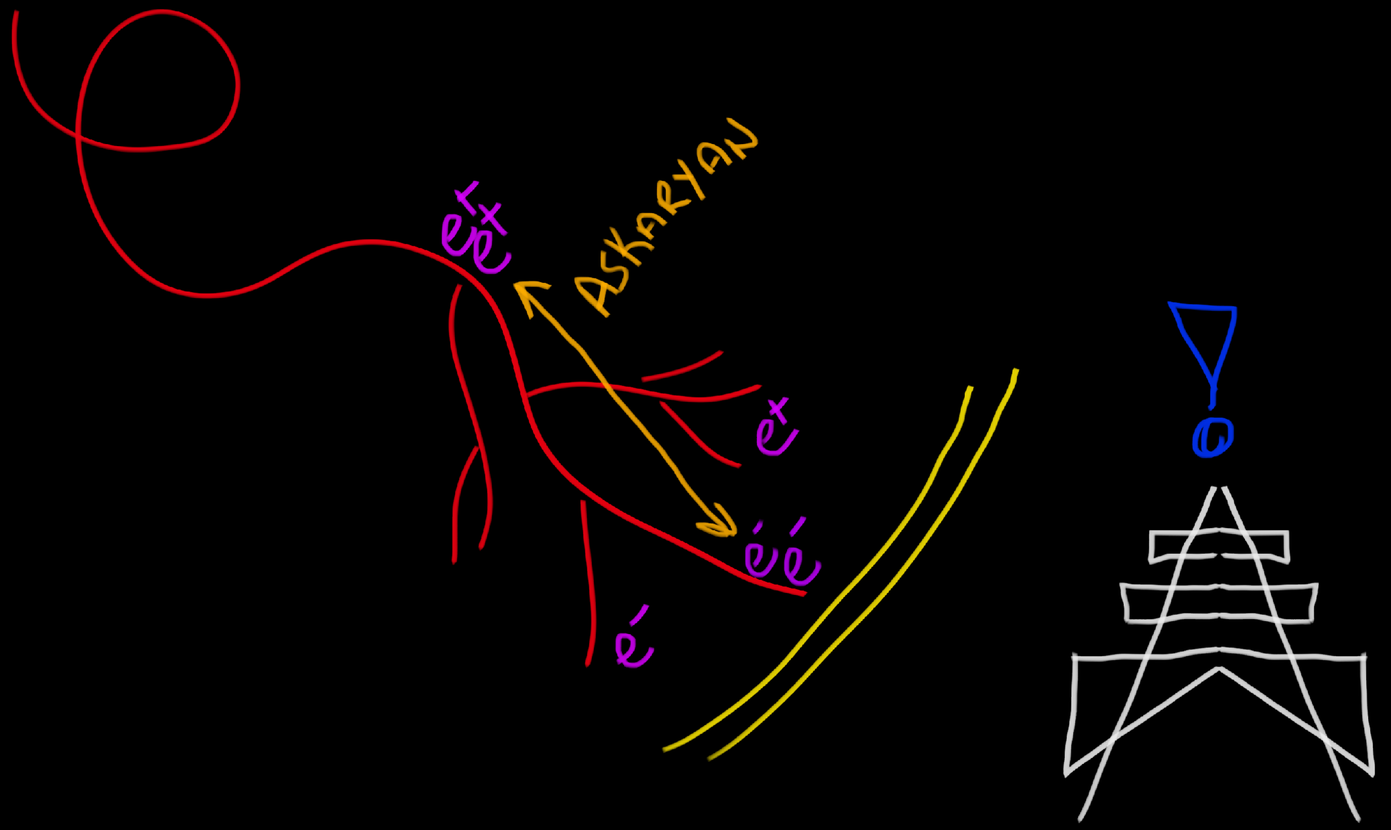


An enhanced surface array

Detection technique - Radio

- Radio sees the **electromagnetic** part of the shower
- Radio emission from:
  - Geomagnetic effect
  - **Askaryan** effect:

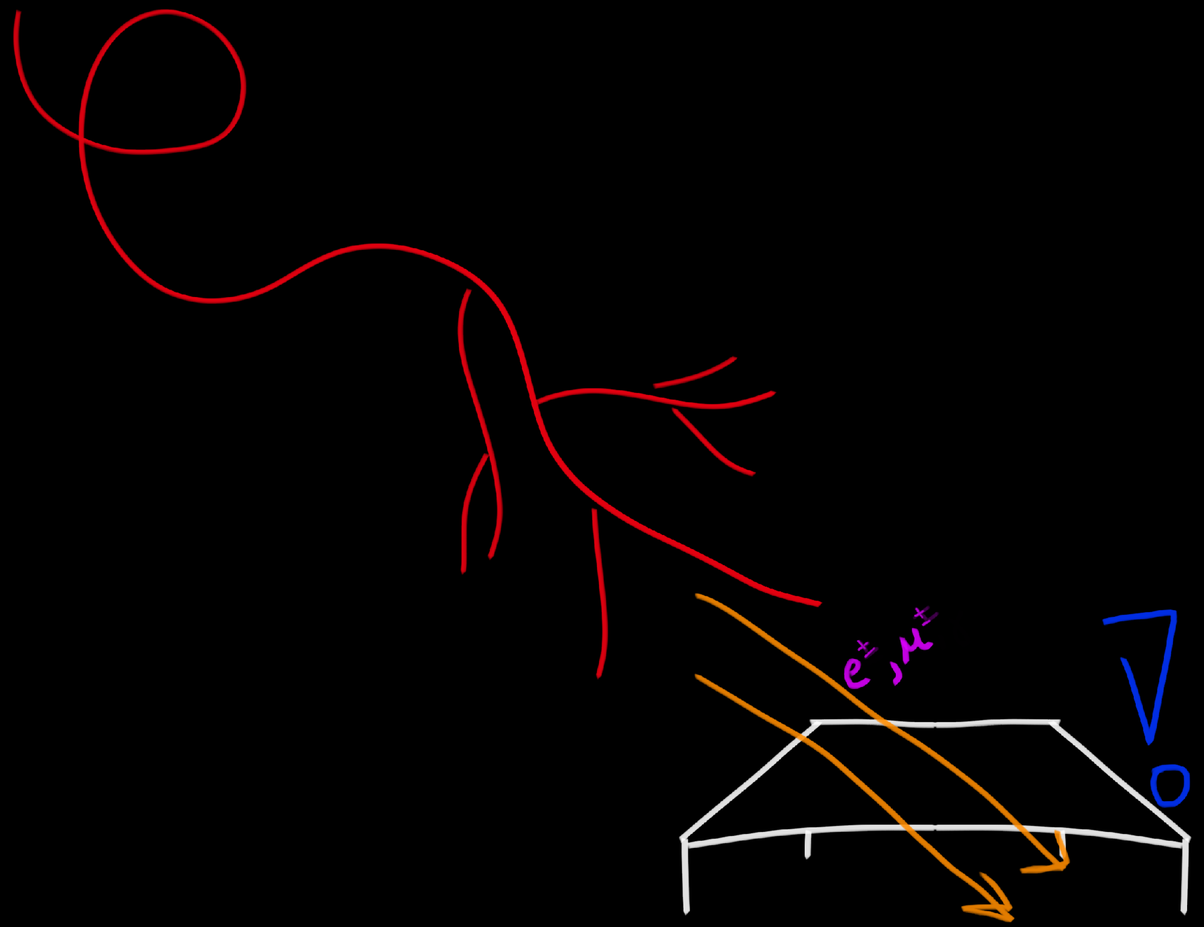
time varying net charge induced by the excess of electrons in the shower front.



An enhanced surface array

Detection technique - Scintillation panel

- Scintillation panels see **all the charged particles** of the shower
- Charged particles create scintillation photons in the panels which are then converted into a current by the silicon photomultiplier



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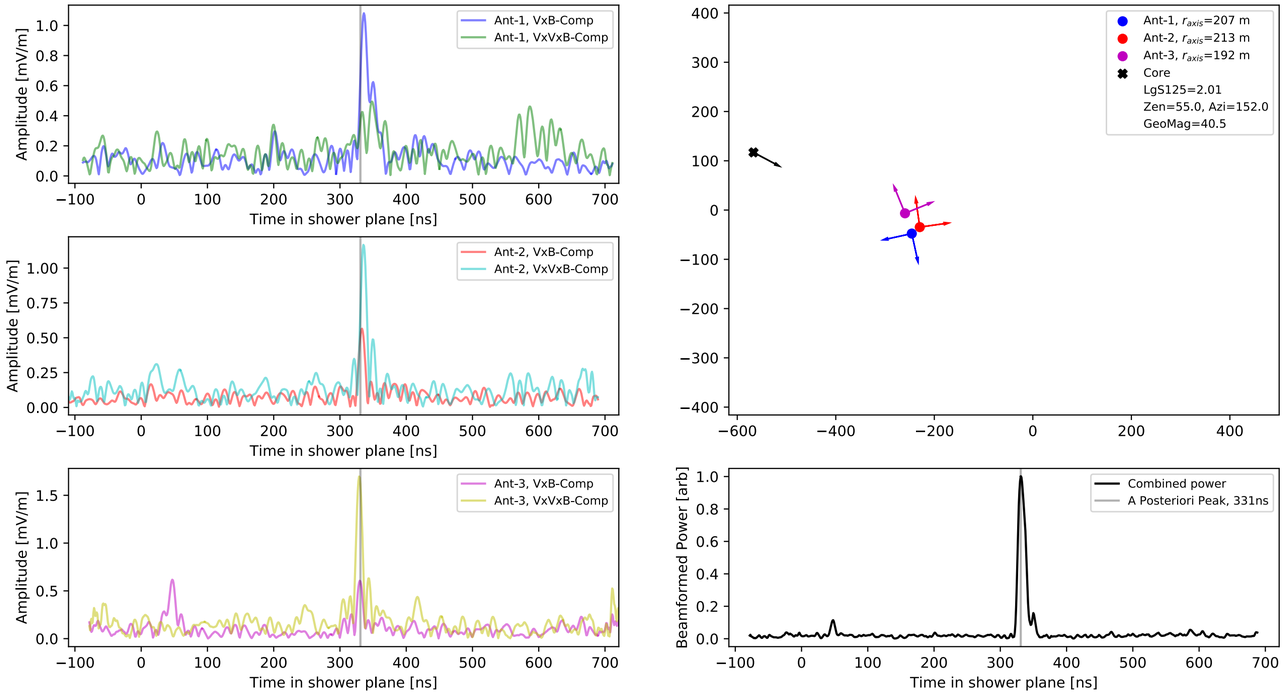
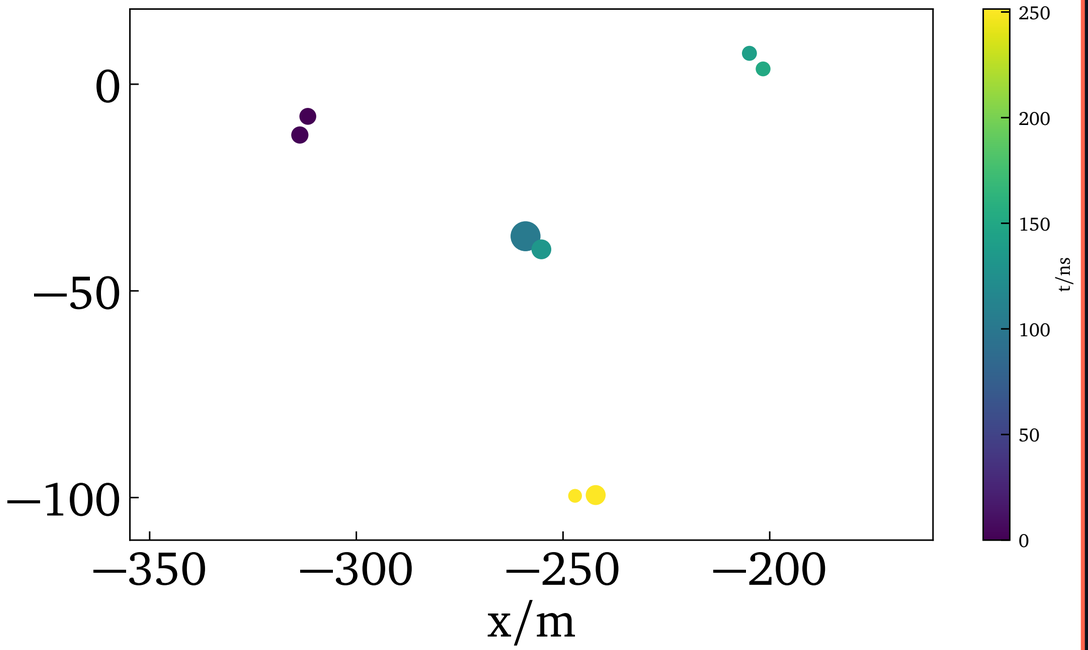
2020-07-20 18:09:00.214,620,923,7 UTC



Plot by Alan Coleman

2020-11-15 04:27:46



Plot by Marie Oehler