Towards a R&D station

for large area detectors in harsh environments

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HAP Workshop Advanced Technologies
24–25 January 2013 @ KIT

HELMHOLTZ ASSOCIATION

Alliance for Astroparticle Physics

DESY

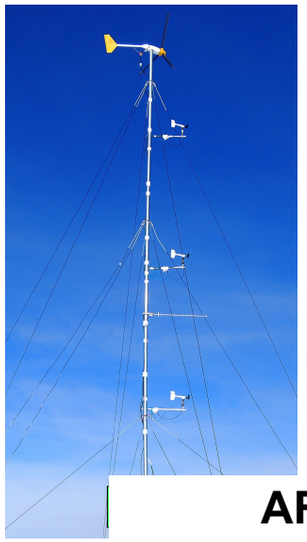
Outline

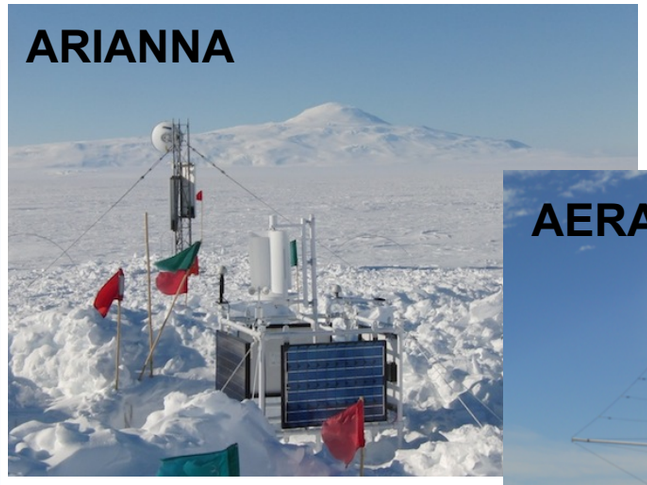
- The Concept
- Current Status
- Ideas for Future Use

The Concept

The Idea

- Common “feature” of many astroparticle projects at the highest energies:
  (UHECR, neutrinos, (non-imaging) gamma astronomy)
  - Small signal fluxes:
    - Large detection areas required
  - Very similar infrastructure:
    - capture of an analogue signal
    - trigger for distributed stations
    - communications
    - power distribution
    - clock distribution





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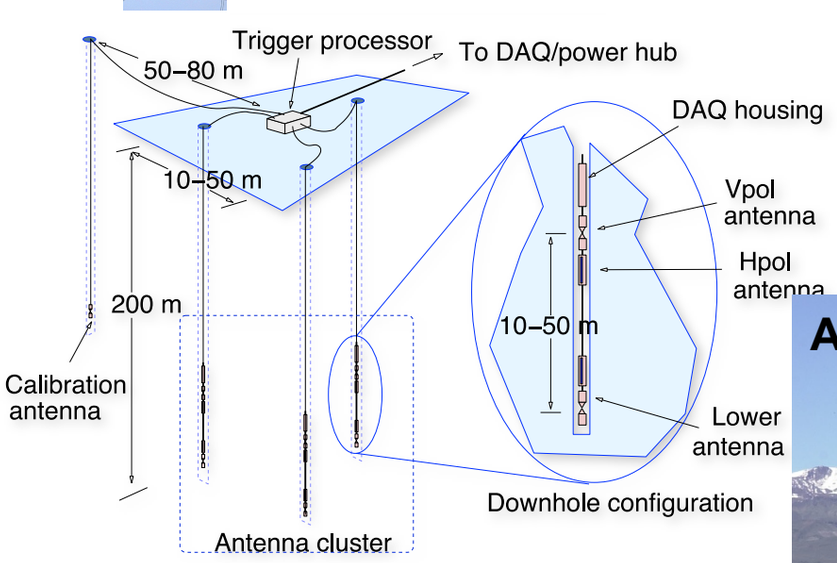
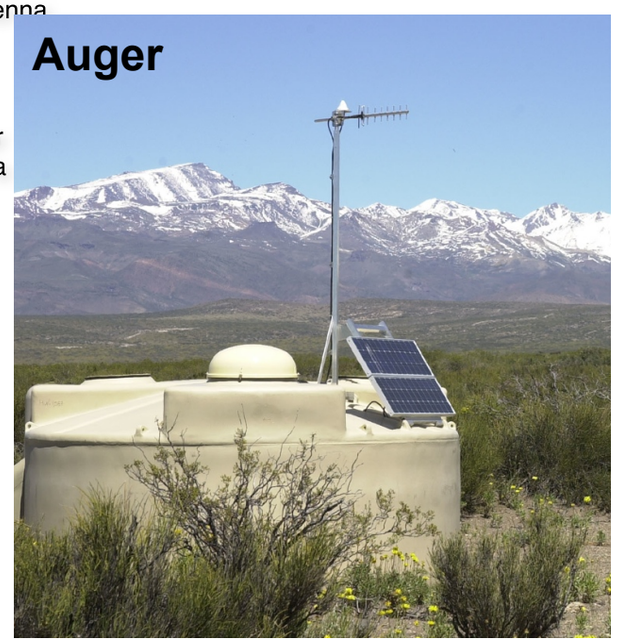




- **Development of a R&D system for testing different aspects of large are detectors**

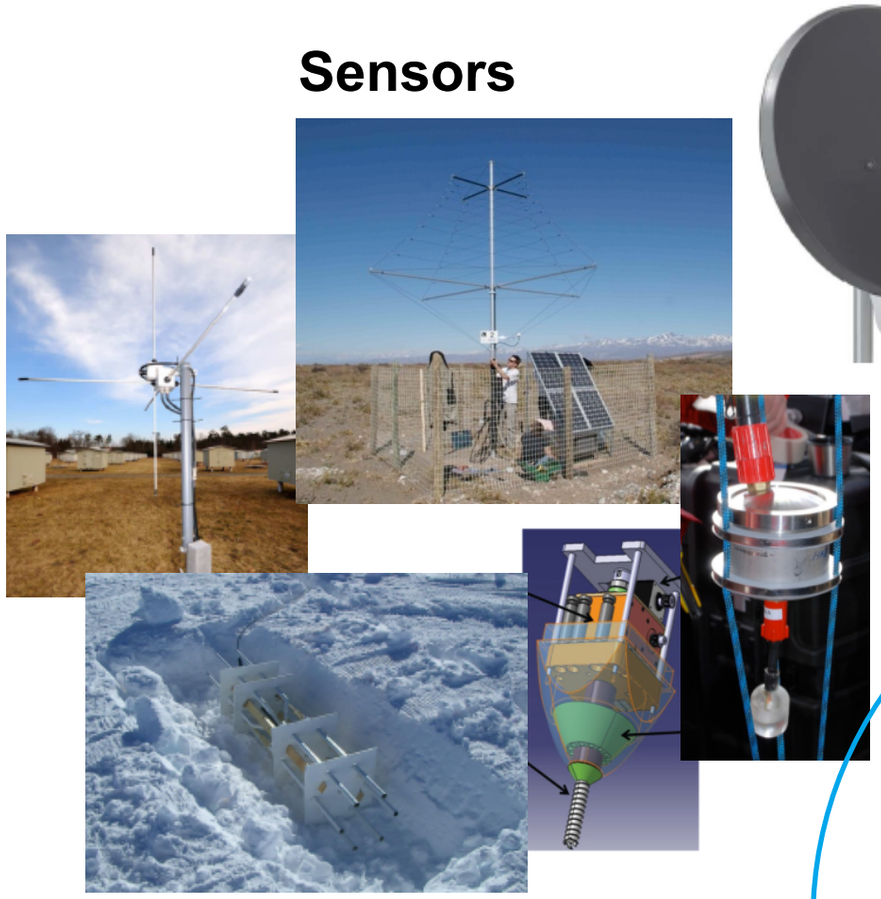
Input signals

- Air shower surface detector with PMTs (scintillators or water-Cherenkov)
  - (unipolar) PMT pulse (order of 10 ns)
- Radio air shower detection
  - Waveform ≤ 100 MHz
- Microwave air shower detection
  - (unipolar) pulse (order of 10 ns) after power detector
- Radio neutrino detection
  - (unipolar) pulse (order of 10 ns) after power detector
- Non-imaging Cherenkov telescopes
  - (unipolar) PMT pulse (order of 10 ns)
- Acoustic neutrino detection
  - Waveform ≤ 1 MHz

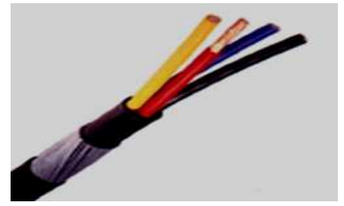
- **Very similar requirements:**
  single R&D station for different projects possible

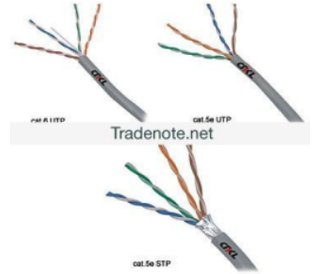
R&D station

Sensors

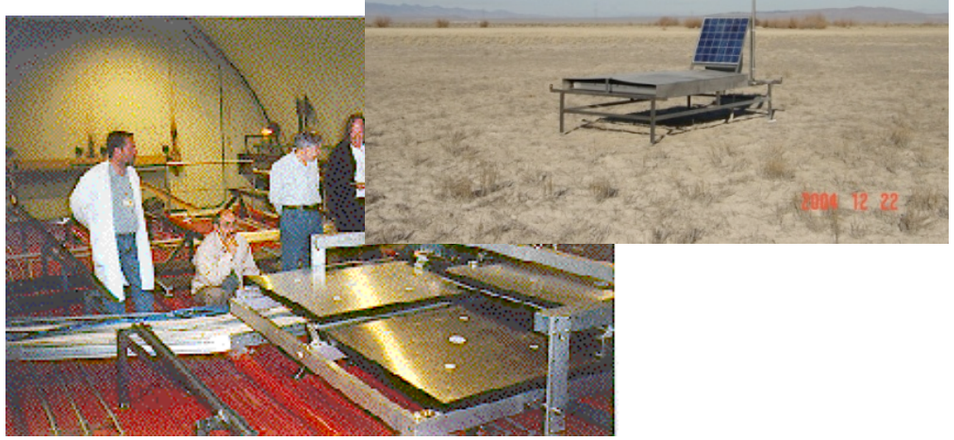


Communication





Reference Detector

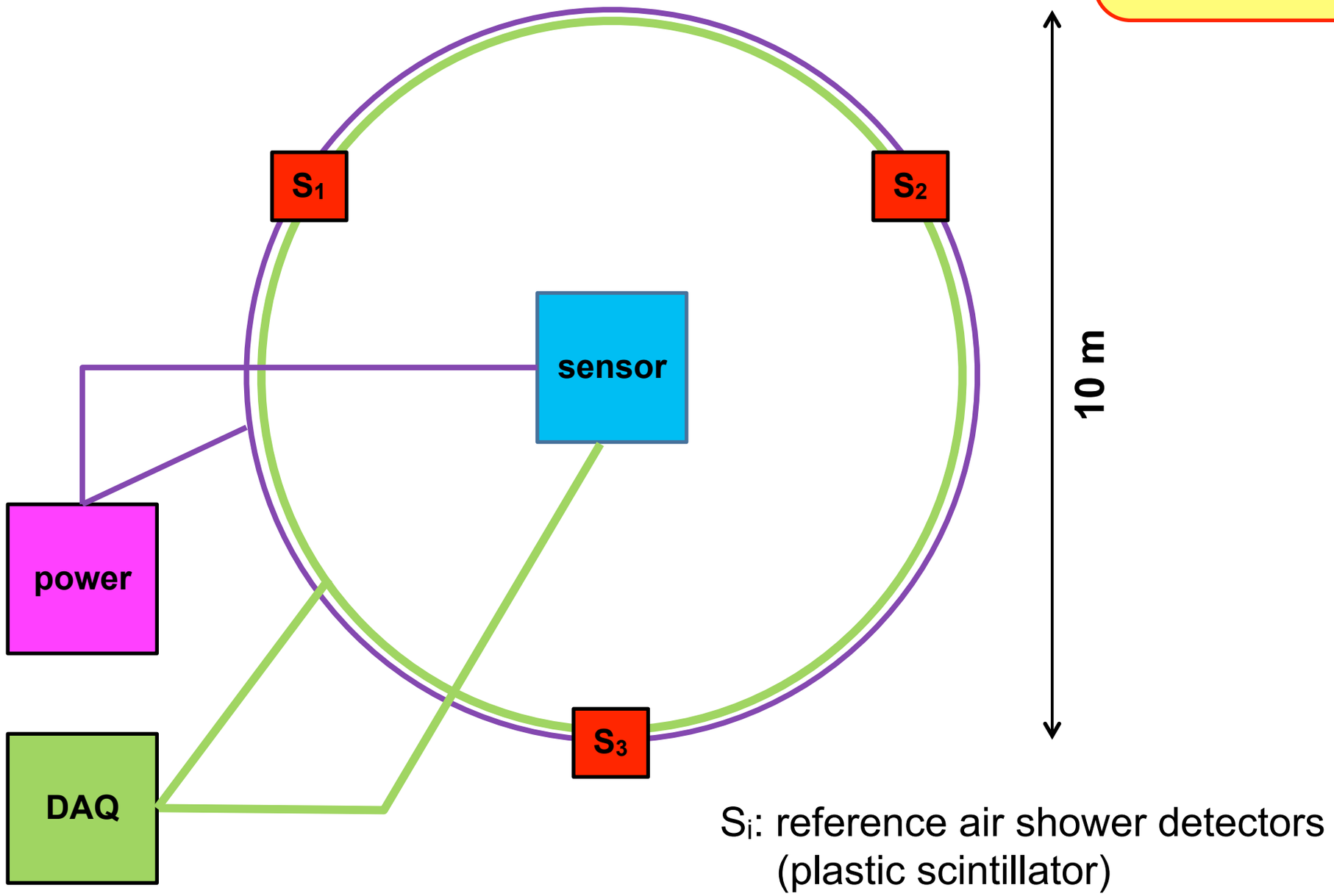


Power Source

First Step: Single Station

Sensor R&D

Idea: Use a simple reference air shower detector for trigger and coarse reconstruction



S_i: reference air shower detectors (plastic scintillator)

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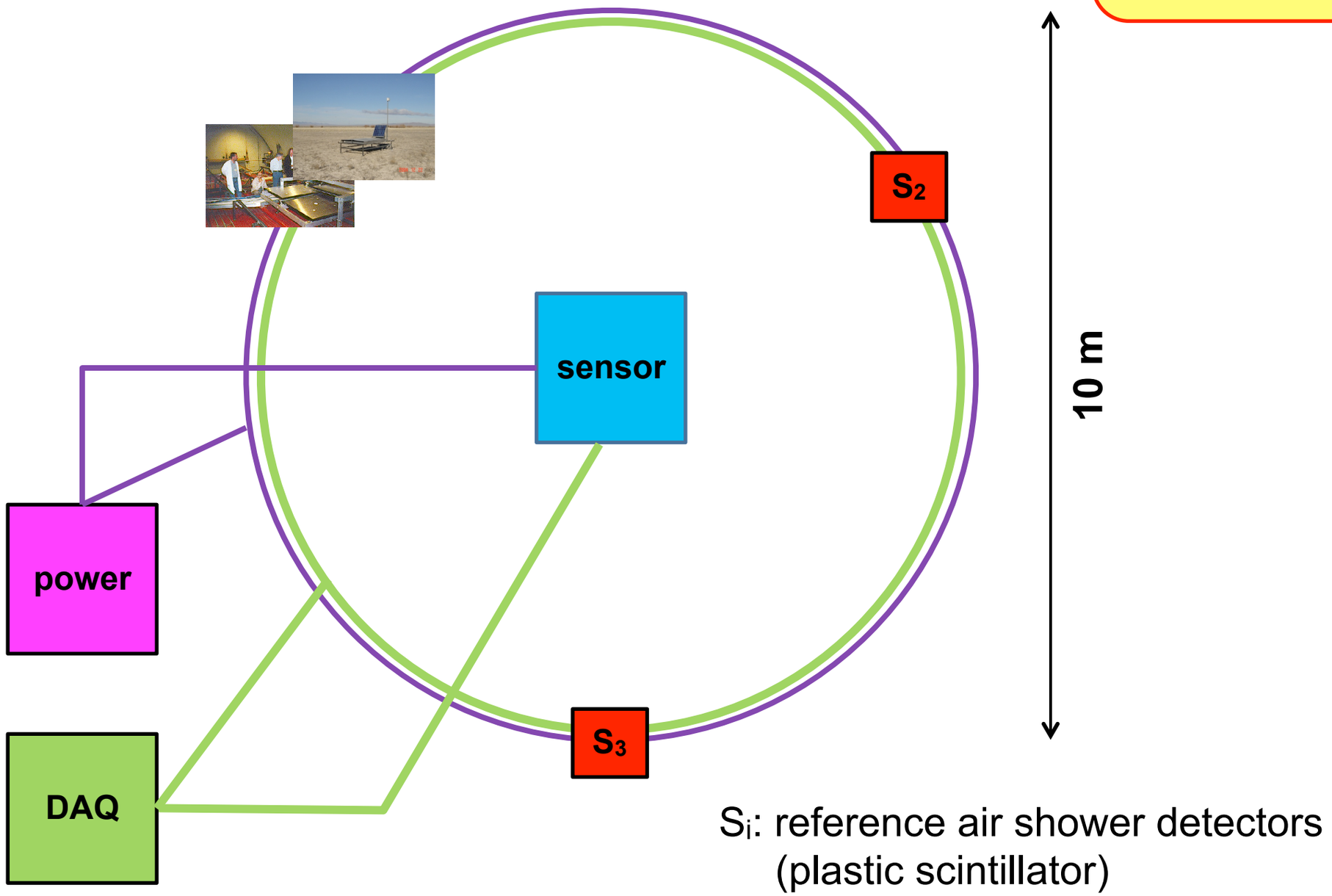

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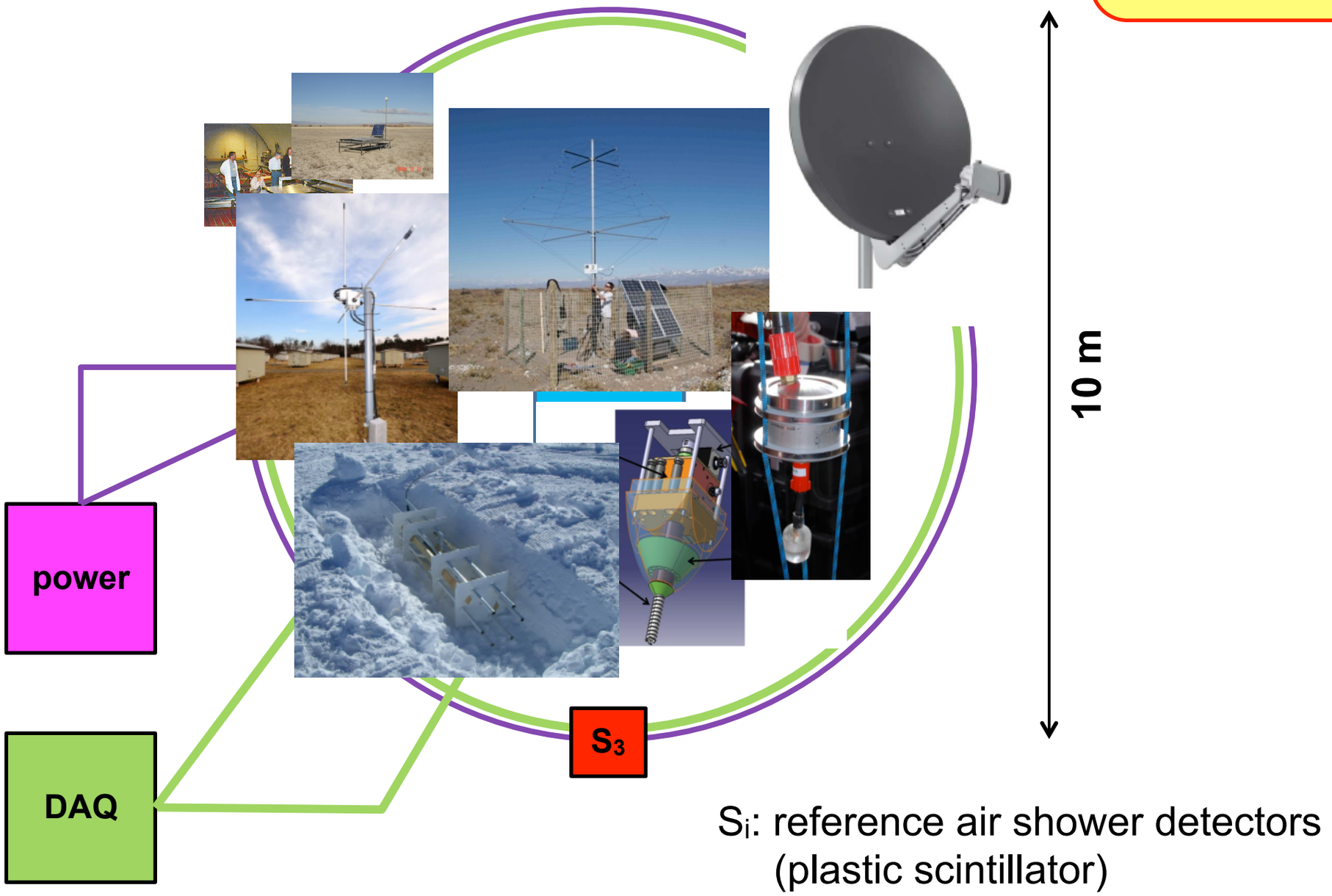

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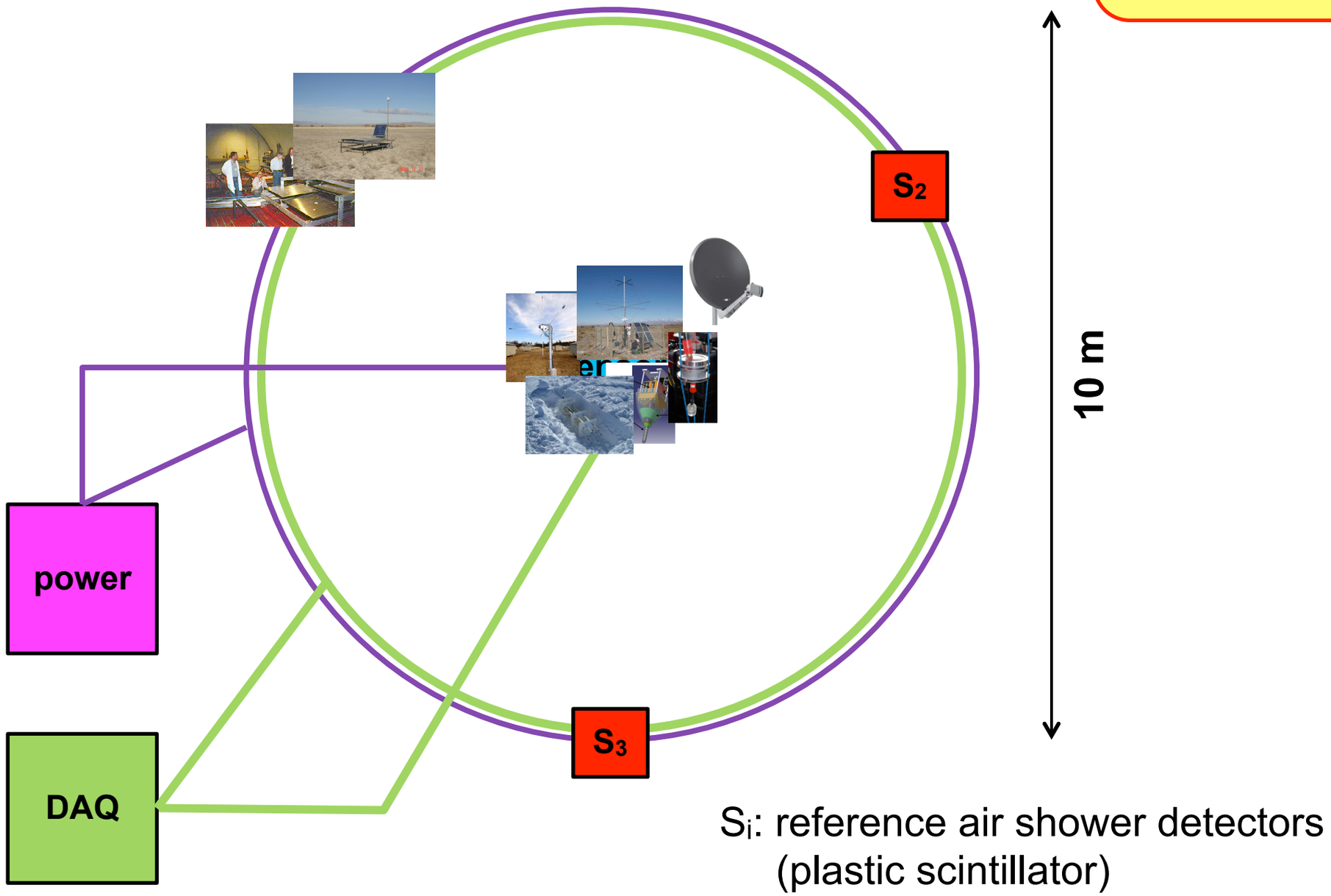
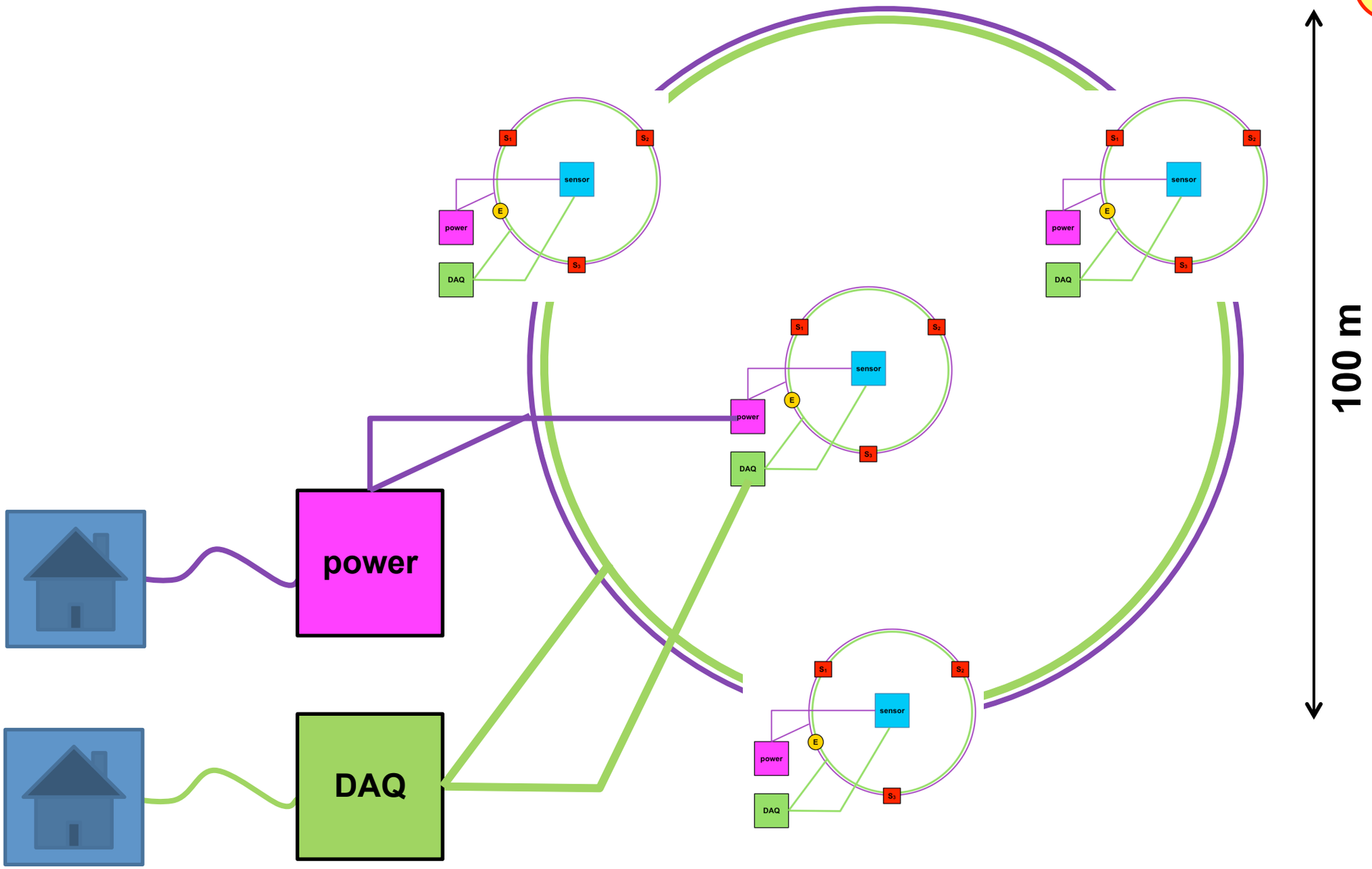


S_i: reference air shower detectors (plastic scintillator)

Second Step: Cluster (4 Stations)

Array R&D



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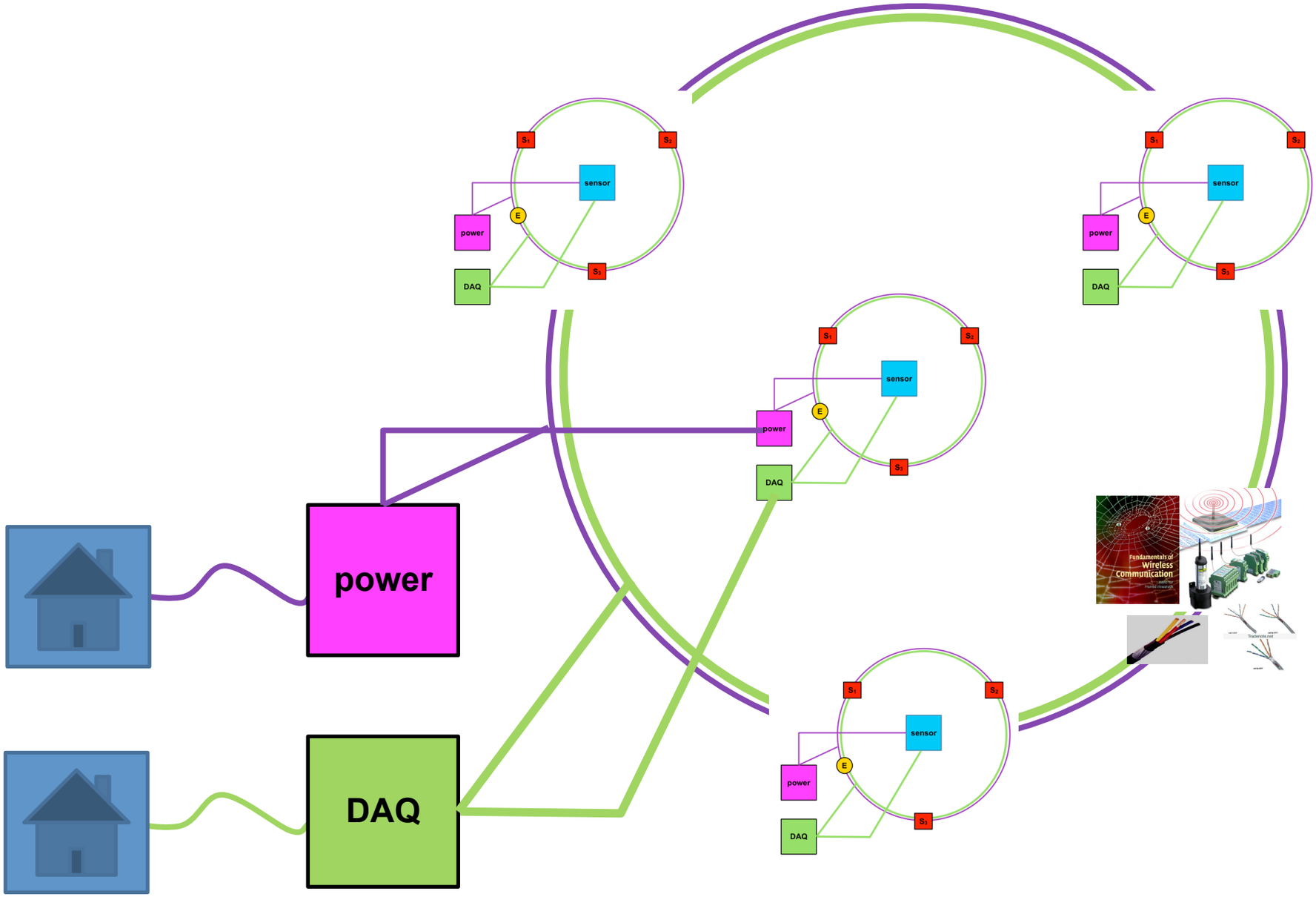

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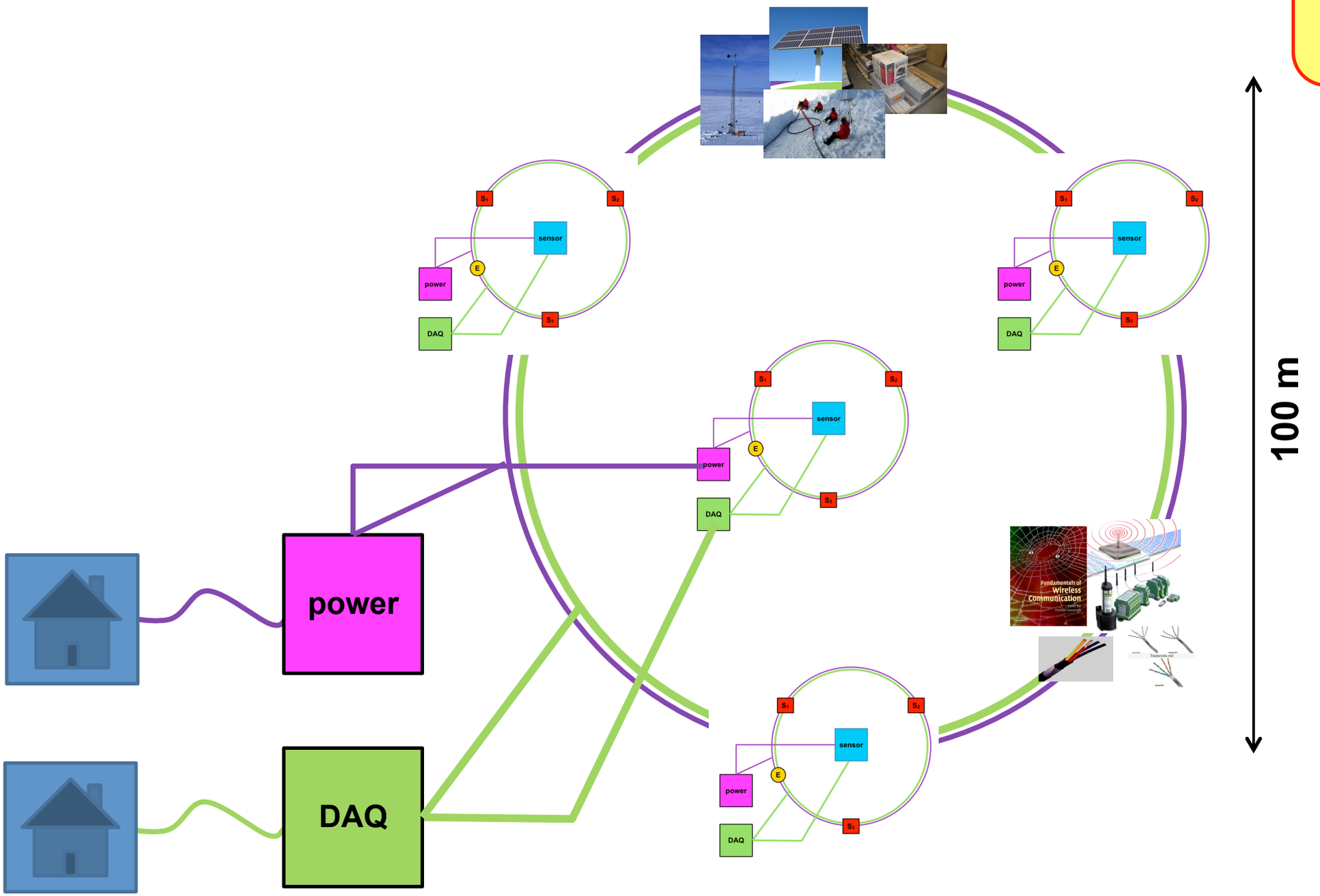

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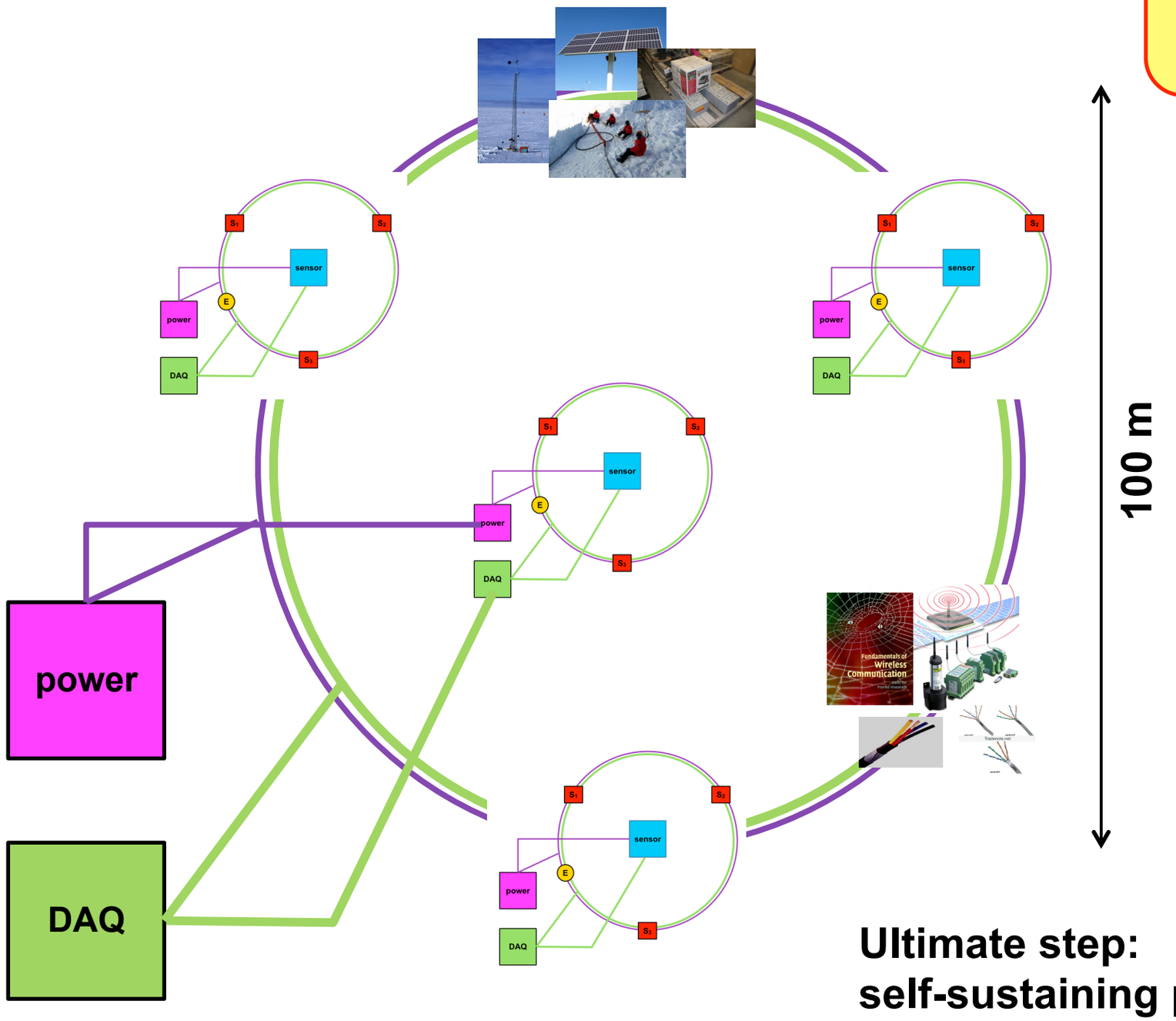

Ultimate step:
self-sustaining power and DAQ

Requirements

- Highly modular system that allows easy interchange of components
  - R&D for different system components in well defined environment
- Easy transport and setup: site studies for future projects
  - long term background measurement and monitoring
  - signal propagation studies (signal speed, attenuation, refraction, …)
- Operation at isolated sites
  - low power, self-sustained power supply
  - environmental range from Antarctica to hot climate
- Scalability

Synergy Within the Helmholtz Alliance

> during design and construction

- experience and components for hard- and software (Aachen, Bonn, DESY, …, KIT, …, Wuppertal, ….)

> during application

- possible examples: radio/hybrid detector in Antarctica, Auger ~~North~~ next, Tunka-Hiscore, Tunka-Rex

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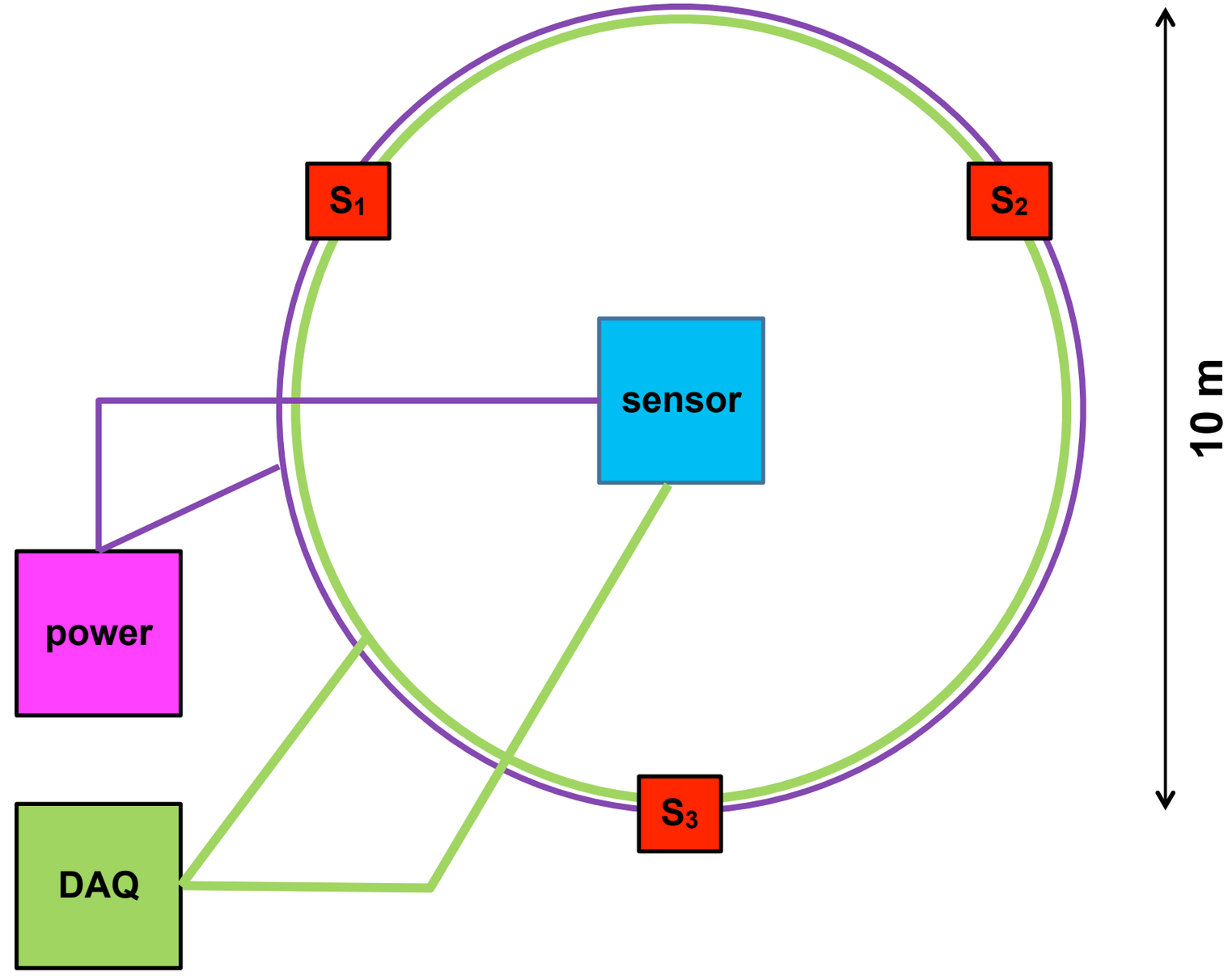
DESY

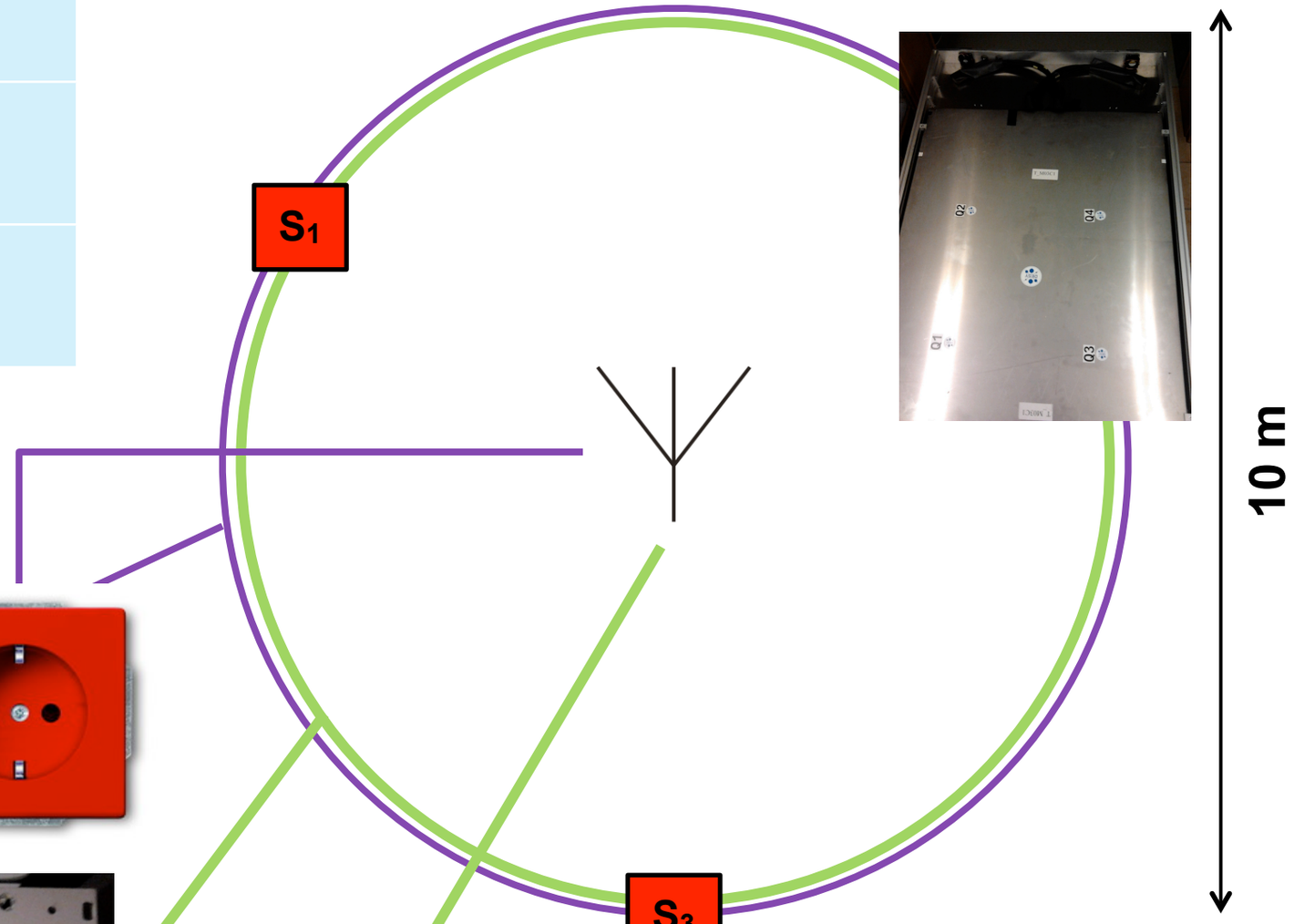
Current Status

Towards Single Station #1

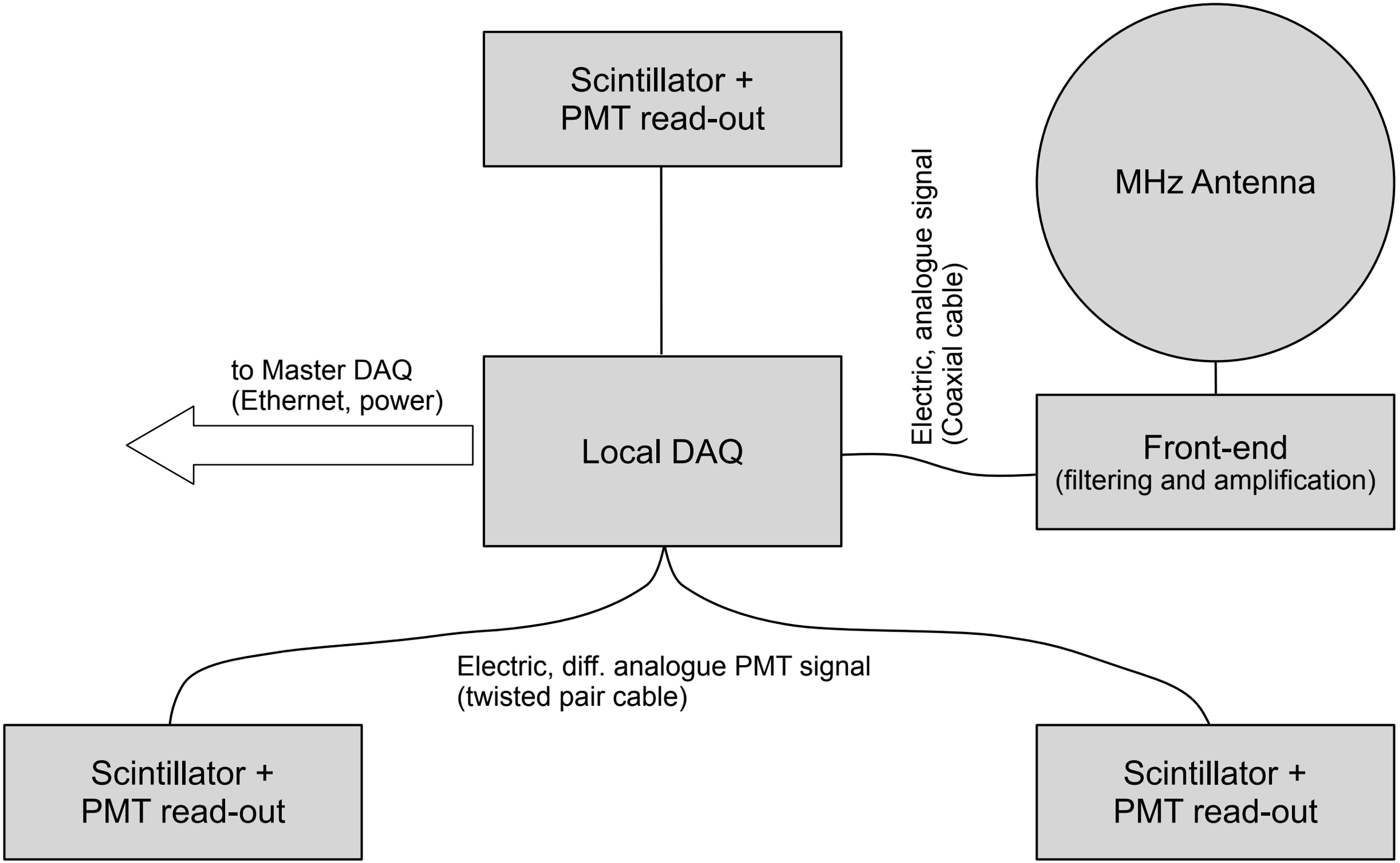


Towards Single Station #1

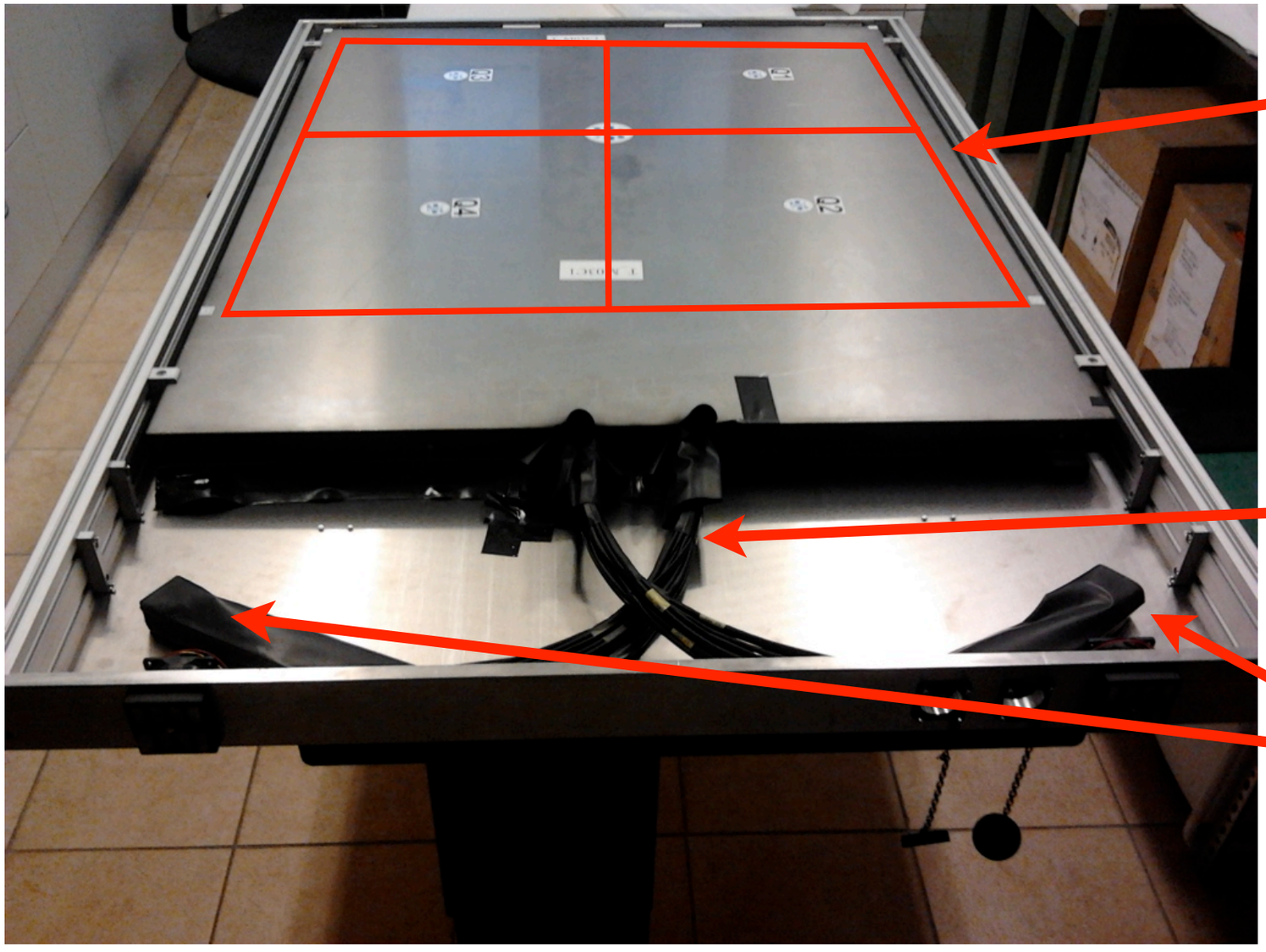
Sensor:	radio antenna (MHz air shower detection)
Ref. Detector:	plastic scintillator
DAQ:	based on AERA board
Power:	fully cabled



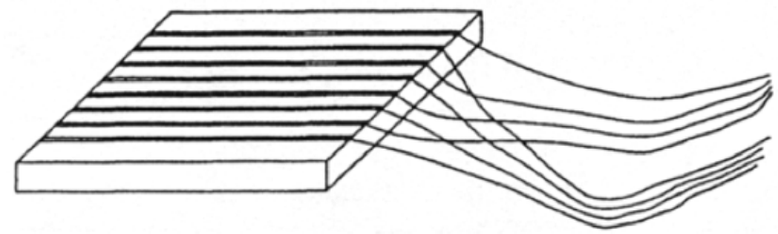
Local Station Overview



Scintillator Reference Detector



1 m^2 tiled plastic scintillator
4 tiles, 50 × 50 cm each

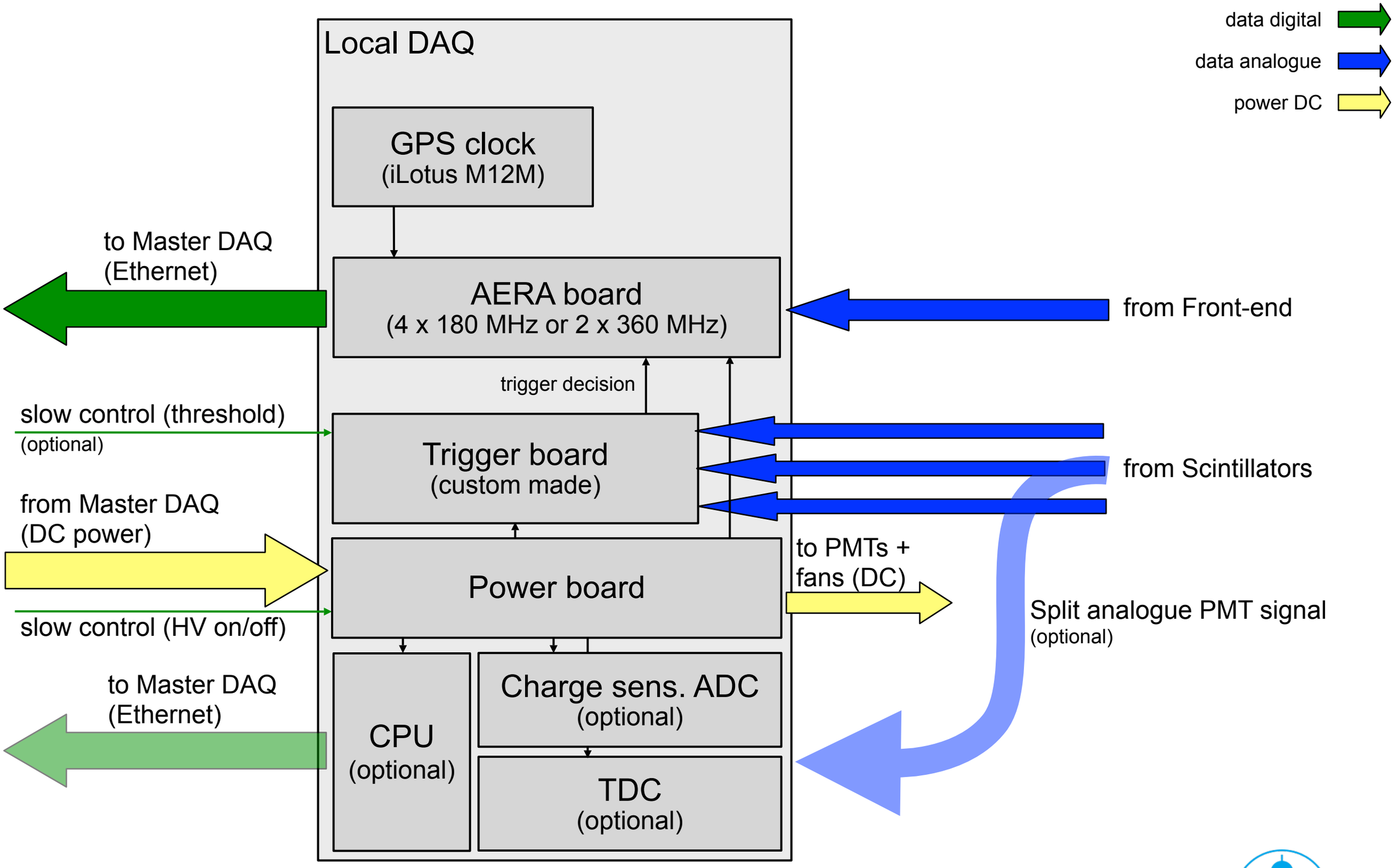


optical fibers
each tile read out by 2 sets of fibers

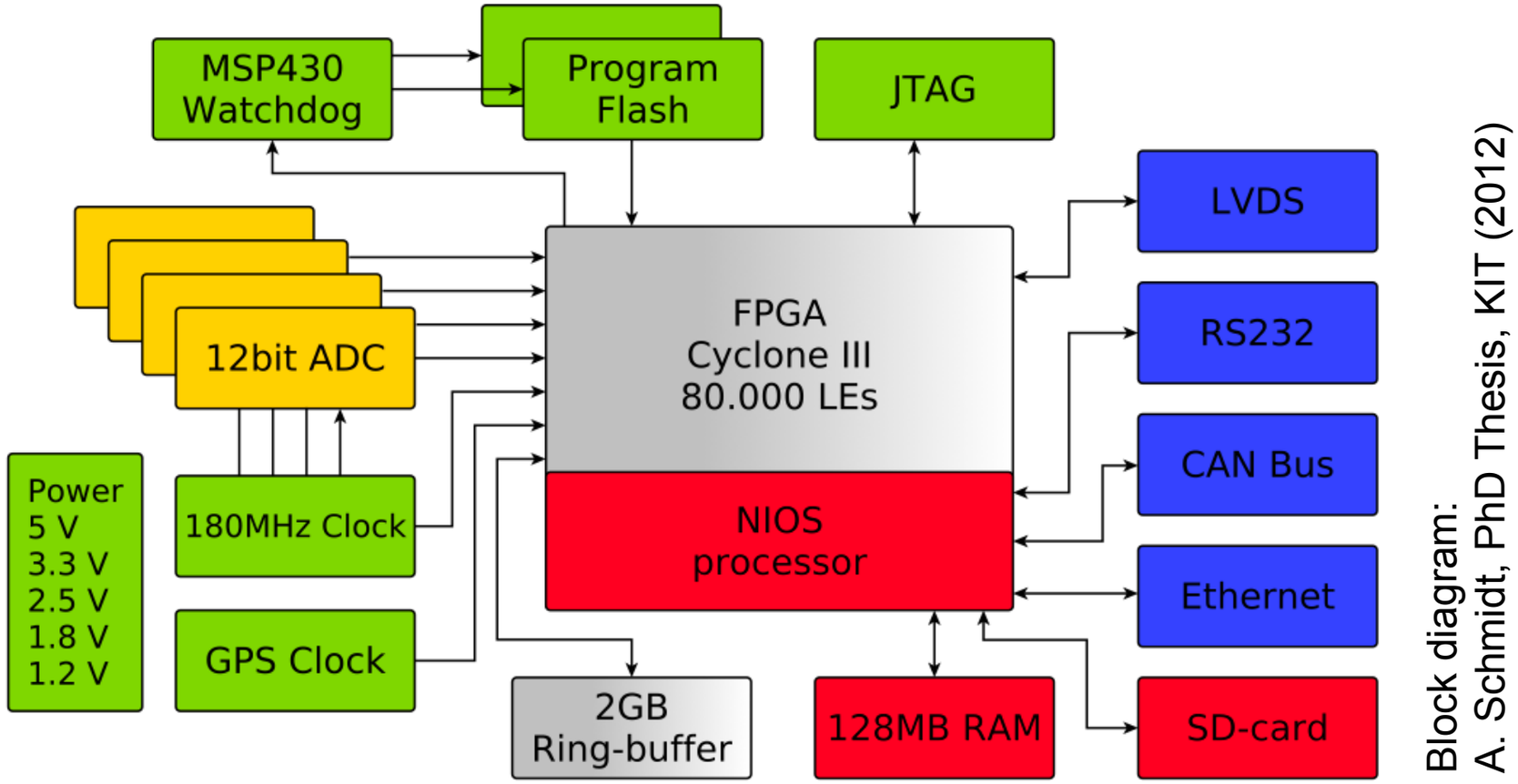
Hamamatsu R 5900-3-M4
2 × 2 multi-anode PMT

- Input: ± 12 V
- Output: analogue differential PMT signal (8 channels)

Local DAQ Overview



AERA Digitizer Board



Block diagram:
A. Schmidt, PhD Thesis, KIT (2012)

- Developed at KIT (IPE, IKP) for the Auger Engineering Radio Array (AERA)
- Four digitizers (180 MHz, 12 bit; can be interlaced to 2 × 360 MHz)
- deep ring buffer
- powerful FPGA for real-time signal processing
- possibility for external trigger (will be used for R&D station)

Local Air Shower DAQ

- Analogue sum of PMT signals from same scintillator tile (noise suppression)
- discrimination of sum signal (12 channels)
- trigger decision in FPGA
  - sent as external trigger to AERA board
- TDC and QDC for the 12 channels currently as VME modules
  - allows coarse estimate of air shower geometry
  - **will be implemented in trigger FPGA in next version**

Software

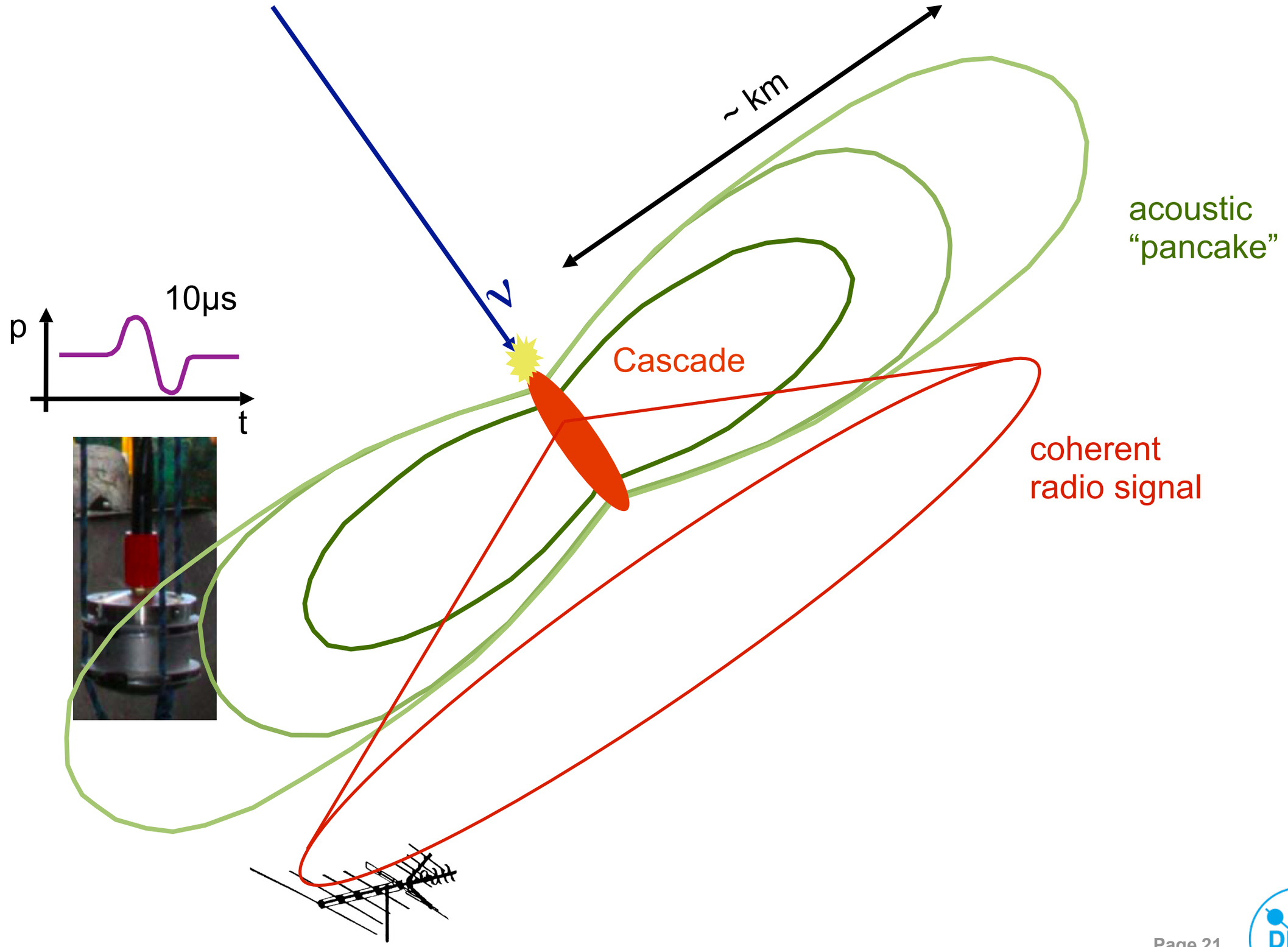
- C++ with heavy use of boost libraries
  - works on NIOS processor; performance to be studied
- Boost.Asio: asynchronous I/O via TCP/IP between different components
  - Master DAQ, Local air shower DAQ, AERA board
- Boost.Thread: POSIX threads
- Boost.Serialization: data storage
- Boost.Python: python bindings for analysis

Location and Timeline

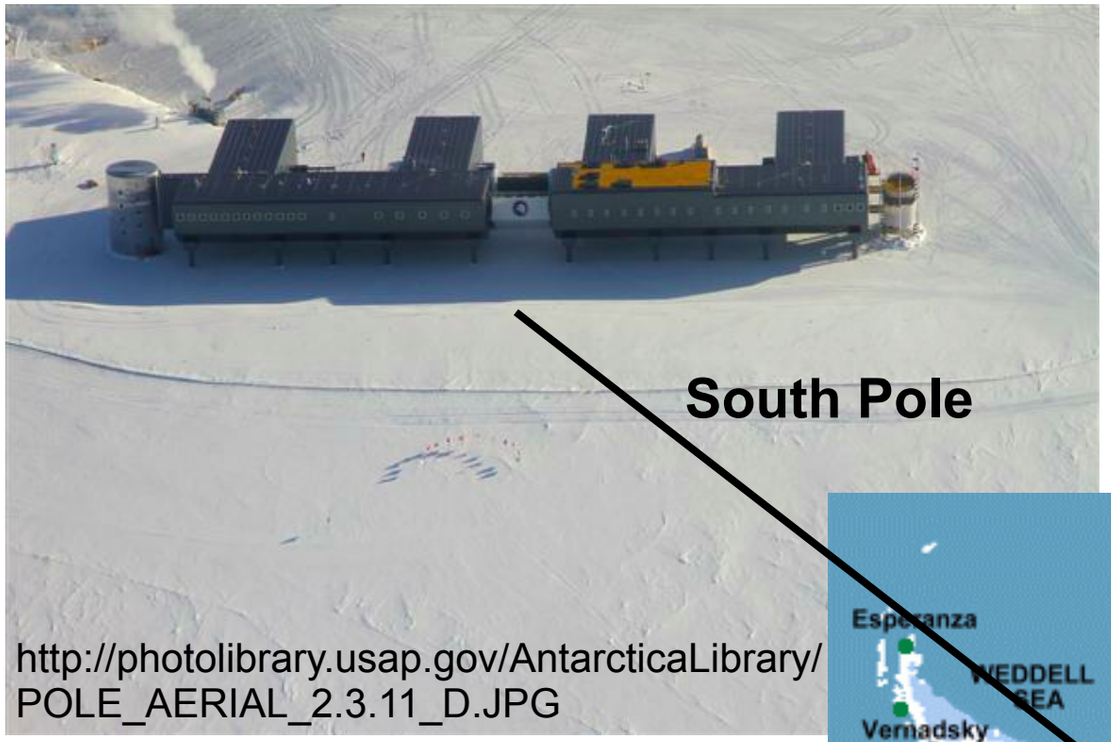
- Step 0:
  - station setup and operation
  - location: DESY in Zeuthen
    (station may later be used for education and outreach)
  - time: first half of 2013
- Step 1:
  - cluster setup and operation
  - location: convenient site near to DESY in Zeuthen
  - time: 2013 + first half of 2014
- Step 3:
  - ready for use in first field testing: > July 2014

Ideas for Future Use

Hybrid UHE Neutrino Detector

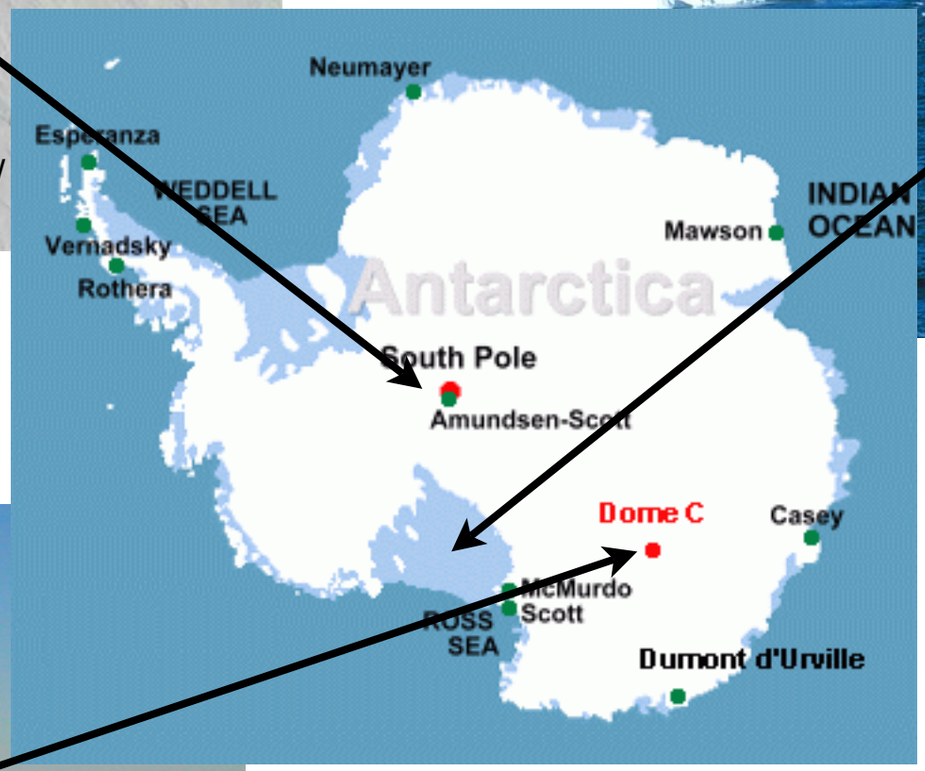


Possible Sites to Be Studied



South Pole

http://photolibrary.usap.gov/AntarcticaLibrary/POLE_AERIAL_2.3.11_D.JPG



http://www.phys.unsw.edu.au/nature/antarctica_map2.gif

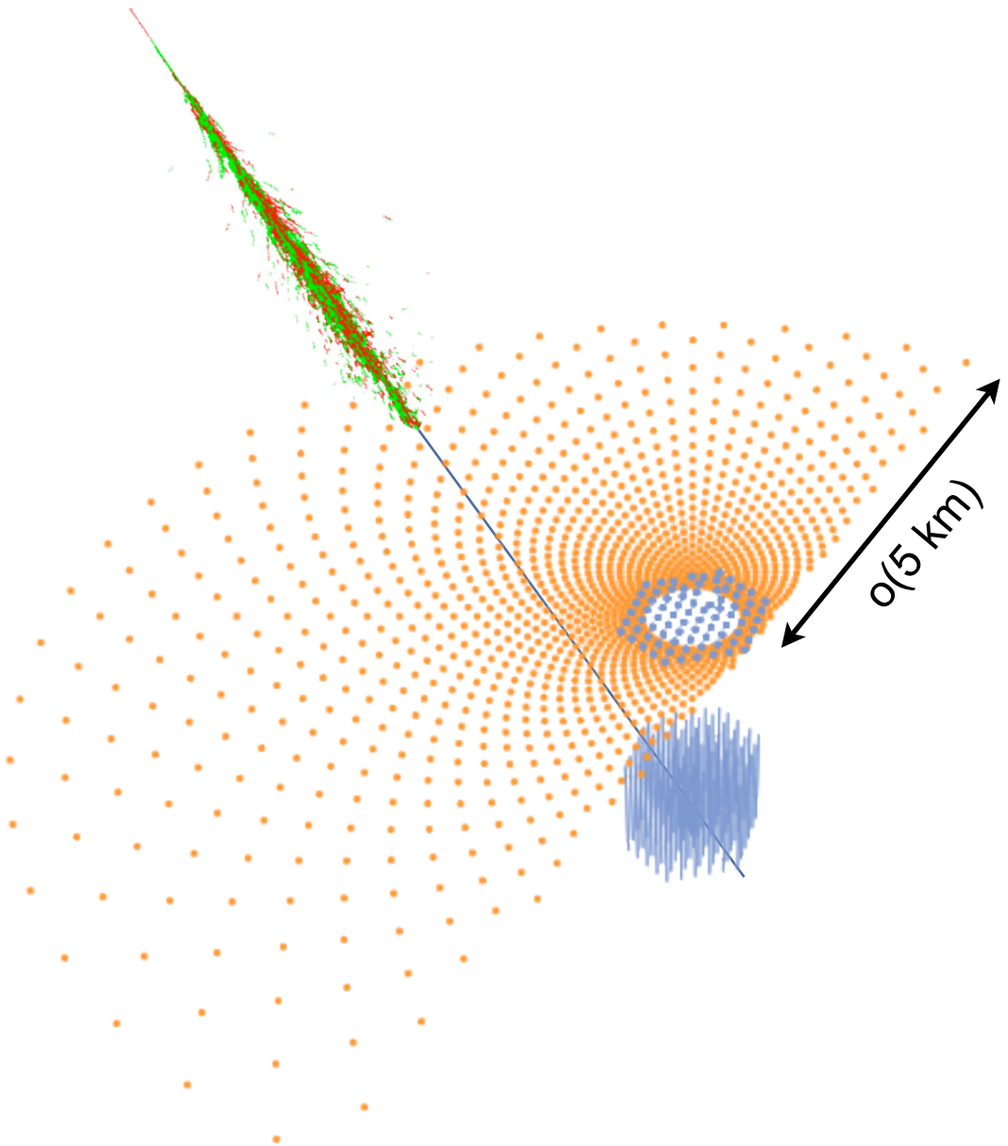
Ross Shelf

http://upload.wikimedia.org/wikipedia/commons/1/1a/Ross_Ice_Shelf_1997.jpg

Concordia Station

http://upload.wikimedia.org/wikipedia/commons/b/b7/ConcordiaFromTower.jpg

IceCube Surface Extensions



- Different extensions discussed within IceCube

- Radio air shower extension
  - the project formerly known as RASTA
  - simultaneous measurement of charged particles in IceTop, HE muons in deep detector and radio signal

- Surface air shower veto with simple ice-Cherenkov or scintillation detectors

Site Exploration Worldwide

Next generation UHECR detector array?

Summary and Conclusions

- All large area detectors in astroparticle physics face similar challenges
  - Signal capture
  - Distributed trigger
  - Clock synchronization
  - Power distribution and communication

- Development of a modular cluster for research & development on different aspects of arrays
  - Single station with external air shower trigger
    - test and calibration of sensors and read-out
  - Four station cluster
    - development and test of
      clock synchronization, trigger, communication, and power distribution
    - easily transportable: exploration of prospective sites of future detectors