Karlsruhe Institute of Technology

15th Pisa meeting on advanced detectors

The Scintillation Detectors and its DAQ of the IceCube Surface Array Enhancement

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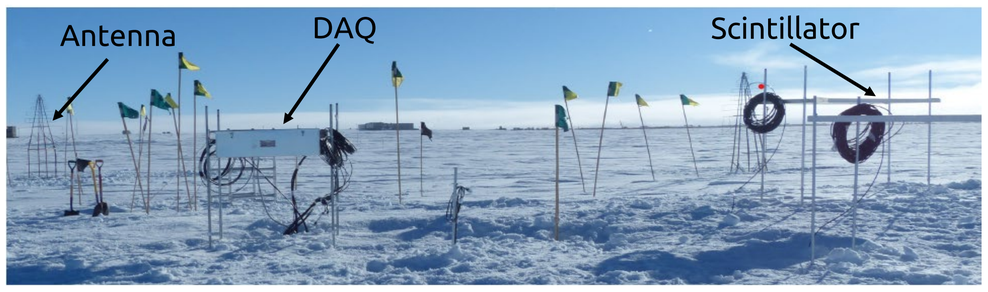
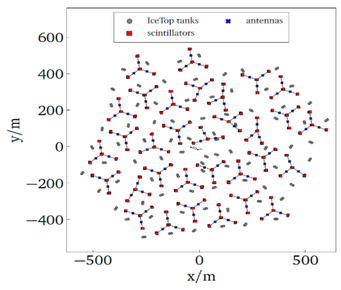
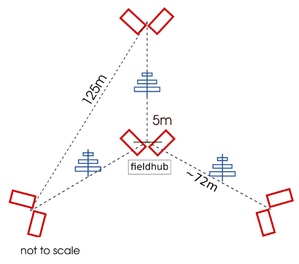
- Karlsruhe Institute for Technology (KIT), Institute for Astroparticle Physics (IAP)



First full prototype station deployed early 2020



Planned layout of the full surface array enhancement



Layout of one station of the surface array enhancement

Deployed scintillation detector

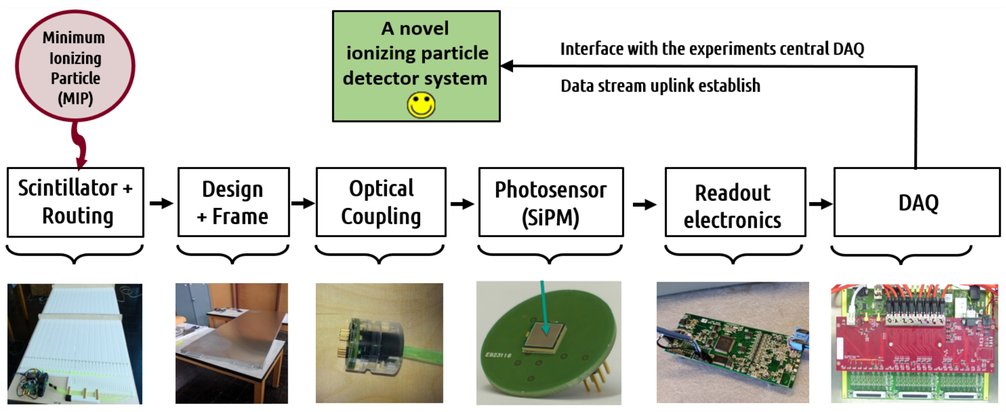
- The IceCube surface array, IceTop, is foreseen to be enhanced by a hybrid detector array. Each station of the IceCube surface array enhancement will include:

  - Eight Scintillation detectors,
  - Three Radio antennas and
  - One central data acquisition (DAQ)

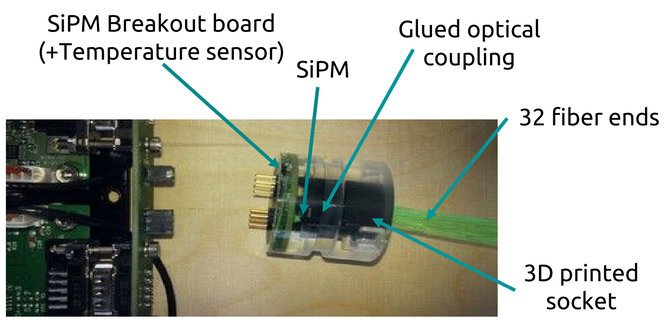
- It is planned to deploy 32 of these stations in coming years to
  - Lower the energy threshold for air shower detection capability,
  - Improve the veto capabilities for the in-ice neutrino detection,
  - Mitigate the effect of snow accumulation on the IceTop detectors,
  - be able to perform multi-component observations of air showers

- These improvements of the IceCube surface array enables among others to
  - Veto atmospheric neutrinos,
  - Investigate the energy spectra and composition of cosmic rays in a wide energy range,
  - validate hadronic interaction models

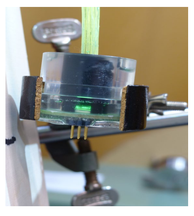
Scintillation Detectors



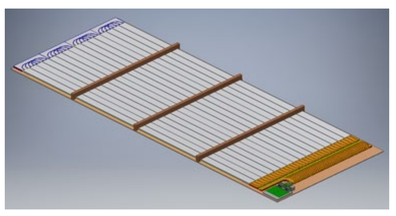
Detectors working principle



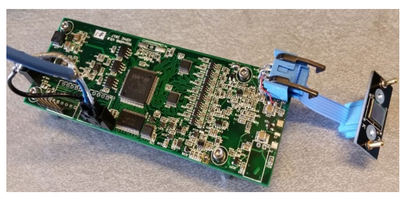
Photons → Electronic signal



Optical coupling



CAD of the detectors

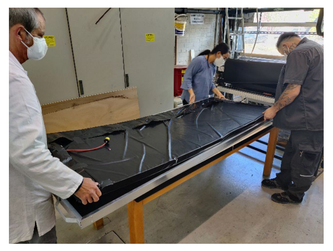


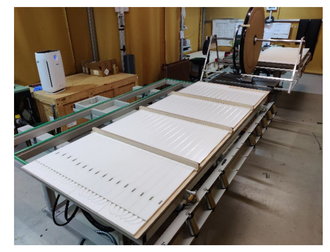
Integrated signal readout

- Transmission of the (signal integrated) charge deposit
- ARM Cortex M4 32-bit microcontroller
- Three 12-bit ADCs
- Temperature correction via gain adjustment

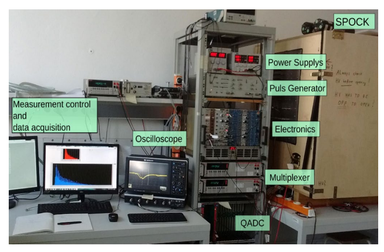
Production

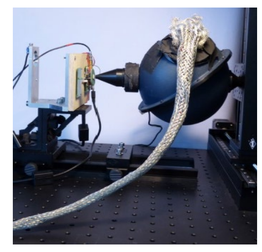
- Normalized production procedure to ensure stable light yield and detection efficiency.





- Test and calibration procedures to create uniformly performing detectors.

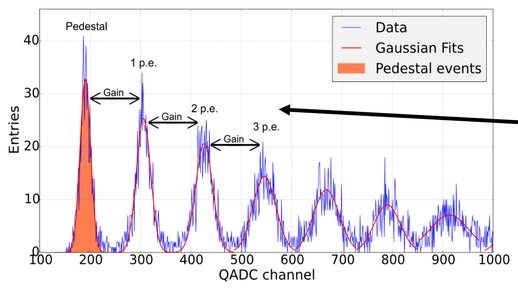




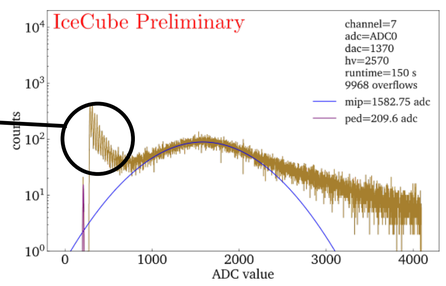
Single Photon Calibration Setup at KIT (SPOCK)

Detector calibration (pre-deployment and onsite) and air-shower detection and reconstruction

- Charge histograms:

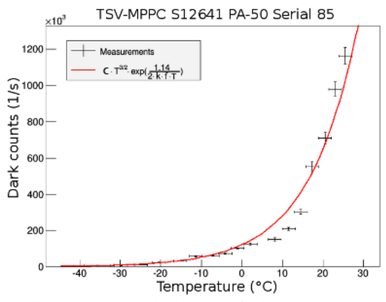


Single p.e. peaks of one SiPM

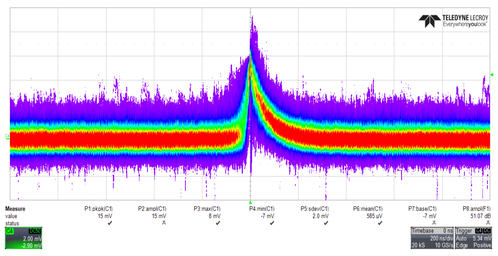


Charge histogram of one detector

- SiPM (Sensor characteristics):

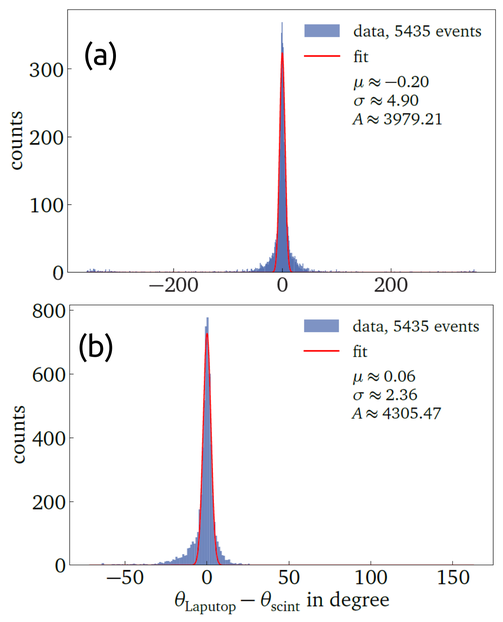


Exponential drop of the dark count rate of one SiPM at low temperatures



SiPM dark count peaks and electronical rippling noise calibration procedure of one SiPM and its breakout board

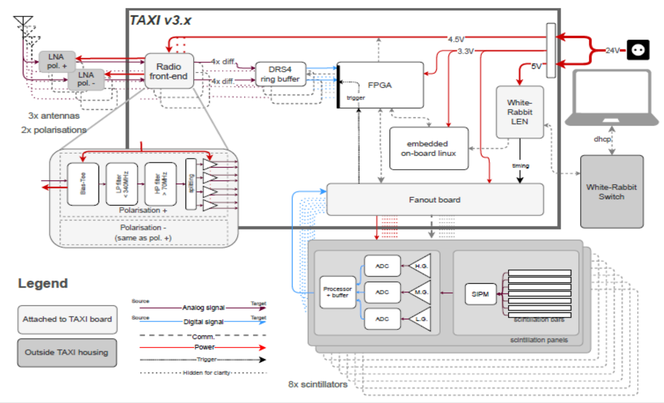
- Air-shower reconstruction:
  - For the reconstruction of high coincidence events, measured with the scintillation detectors of the prototype station, are used and compared with the reconstructed air-shower events with IceTop
  - The arrival direction difference between the azimuth **(a)** and zenith angles **(b)** are shown, reconstructed with the scintillators of the Prototype Station and the reconstruction of the event with the IceTop array



Data acquisition (DAQ) system: TAXI

- Specially developed DAQ (“TAXI”) for processing radio antenna traces and integrated scintillator signals

Consists of
- 3 DRS4 samplers with up to 5 GS/s
- SPARTAN FPGA for data processing
- Embedded linux system
- Nanosecond timing by a White Rabbit system



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