R&D and production of the scintillation detectors for the IceCube Surface Array Enhancement

Shefali *for the IceCube Collaboration*

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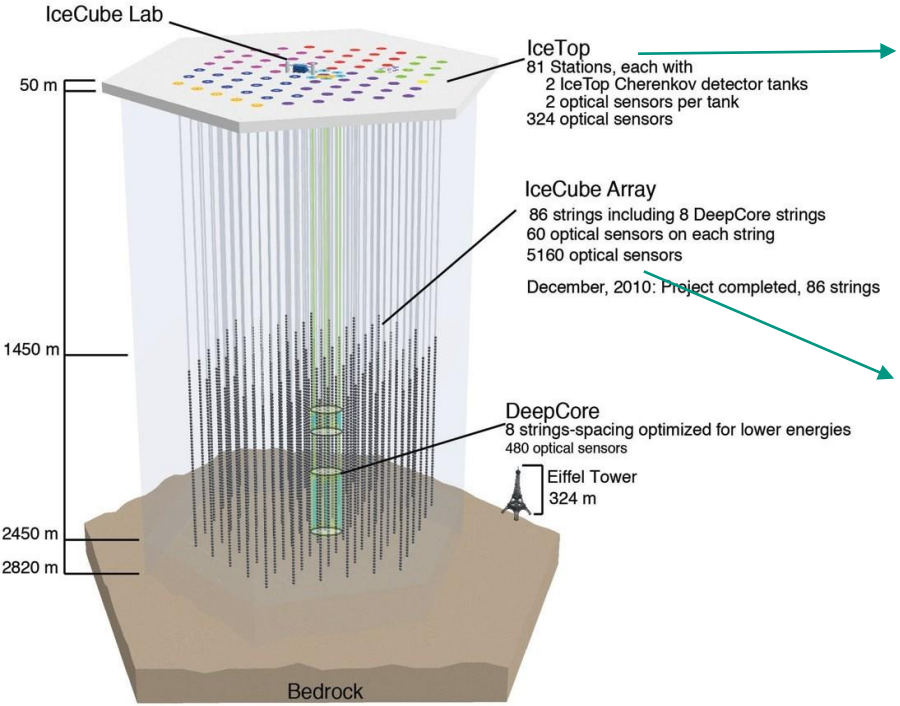
IceCube Neutrino Observatory



IceTop Cherenkov detectors

Digital Optical Modules (DOMs)

- DOMs detect Cherenkov radiation from neutrino interactions in ice
- IceTop: The surface instrumentation of IceCube
  - Veto and calibration for the In-Ice detector
  - Better understanding of the background from the atmospherics neutrinos and muons
  - Unique opportunity for cosmic ray physics
- Challenges:
  - Non-uniform snow accumulation on surface detectors→ Lower threshold and increased uncertainty

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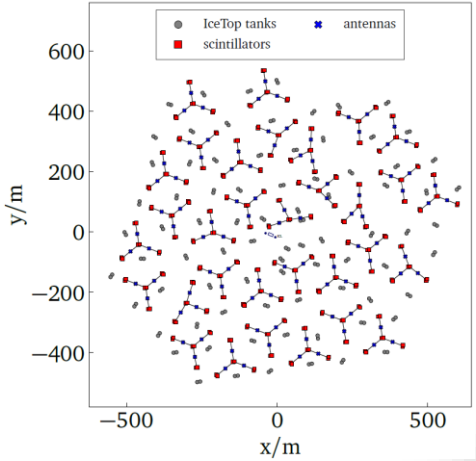
Surface Array Enhacement

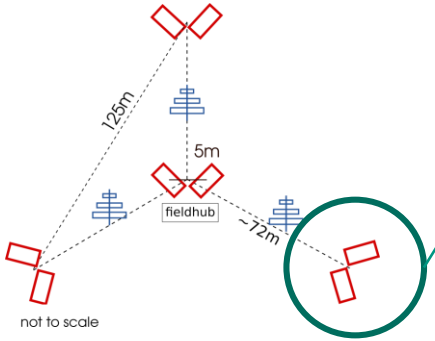
- IceTop surface array enhancement planned with 32 stations by 2026

- One Surface Array enhancement (SAE) station:
  - 3 radio antennas
  - 8 scintillation detectors
  - 1 central fieldhub DAQ

- Science Case:
  - Vetoing the atmospheric neutrinos to increase the in-ice astrophysical neutrino detection
  - Measuring the energy spectra and composition of cosmic rays in a wide range
  - Validation of hadronic interaction models

- This requires,
  - **Lower energy threshold** for air shower measurements
  - Mitigate the e**ffect of snow accumulation** on the IceTop detectors
  - **Multi-component observation** of air showers





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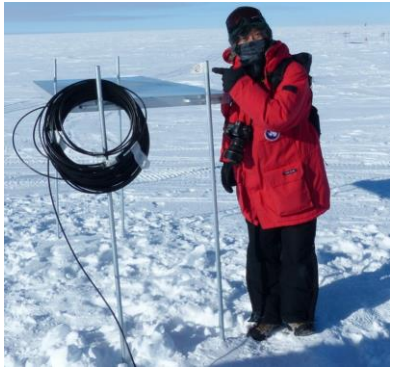
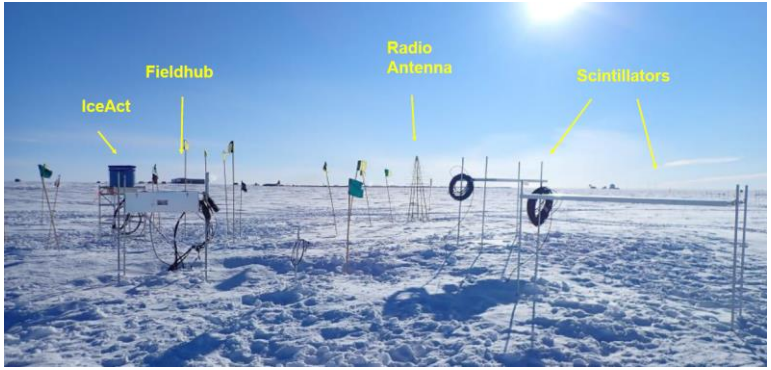
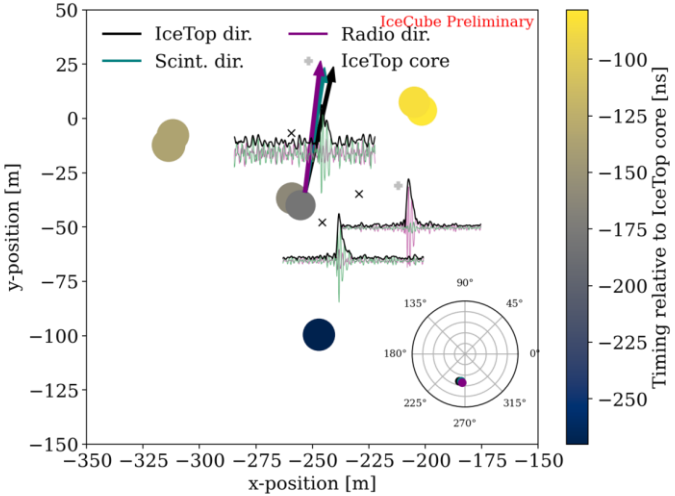
Prototype Station

- Complete prototype station since January 2020 at the pole
- Air shower reconstruction with the prototype station already achieved
- Individual data streams for reconstruction:
  - IceTop data
  - Radio data
  - Scintillator data
- >3 scintillator detections within 1µs : scintillator event
- Radio antennas triggered from >6 scintillator coincidences
- All three detectors recording event with 2µs considered a triple coincidence event and reconstruction achieved
- Combined reconstruction planned for the future array







https://arxiv.org/pdf/2107.08750.pdf

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Scintillation Panels

- **Components of a scintillation detector:**
  - 16 plastic scintillation bars made of polystyrene
  - Wavelength-shifting fibers routed through two holes in the scintillation bars and glued to the Silicon Photomultiplier (SiPM) using a PMMA coupler
  - A custom microDAQ board used to digitize and read out the SiPM signals
  - The detector inlay is the wrapped in a light tight foil and finally an aluminum casing
- **Working Principle:**
  - A minimum ionizing particle (MIP) traversing through the panel interacts with scintillation bars
  - Excitation and de-excitation of valence electrons produces photons
  - Photons are transferred by the fibers and converted into photoelectrons by an SiPM

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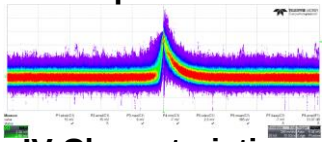
Production at KIT

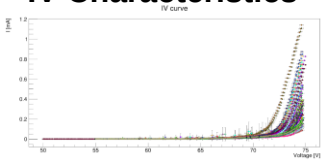
Karlsruher Institut für Technologie

Calibration of SiPMs and testing of DAQ

Dark spectrum

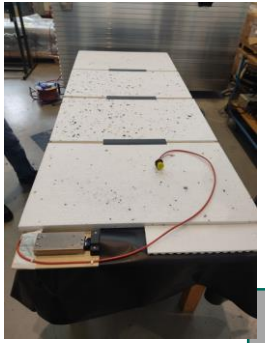


IV Characteristics

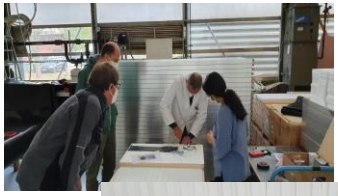


Freezer Tests

Detector Inlay assembly

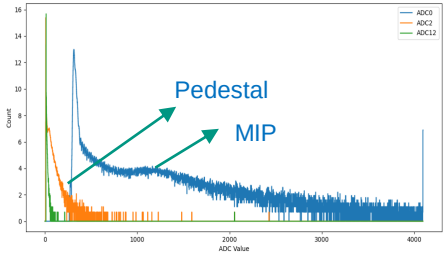


Light shielding and final steps

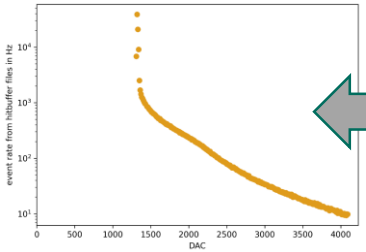


Calibration Measurements of full detector

Histogram (5 mins)



Threshold Scans



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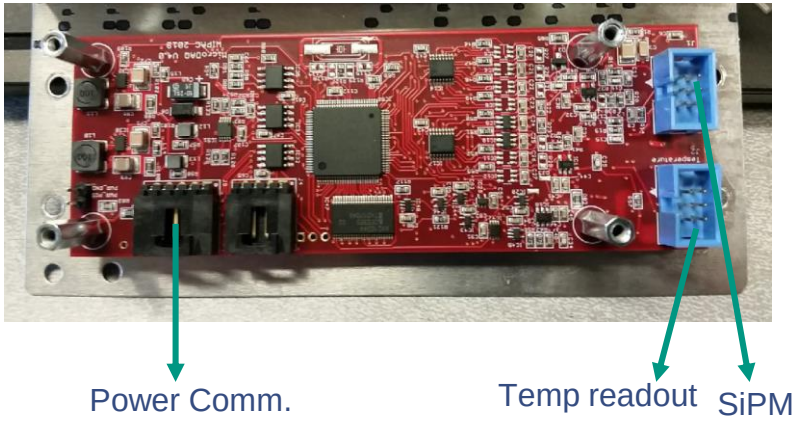
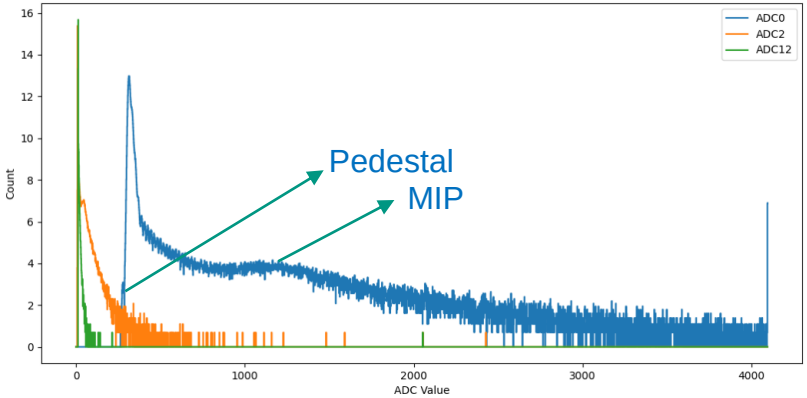
Data Acquisition of the detectors

- The event peaks recorded by SiPM are read out and digitized with MicroDAQ
- Temperature readout placed next to the SiPM
- 3 ADCs for 3 different gain channels are implemented
- 1Hz CPU triggers to capture pedestal
- Two measurement modes:
  - Hitbuffer Measurements : For each hit, timestamp, charge from each channel and CPU trigger is recorded
  - Histogram Measurements: charge of the hits saved as a histogram in the buffer of the microprocessor (Convenient for longer measurements)
  - Three gain levels to have a wide dynamic range
  - ADC12 = low gain, ADC2 = medium gain,

ADC0 = High gain





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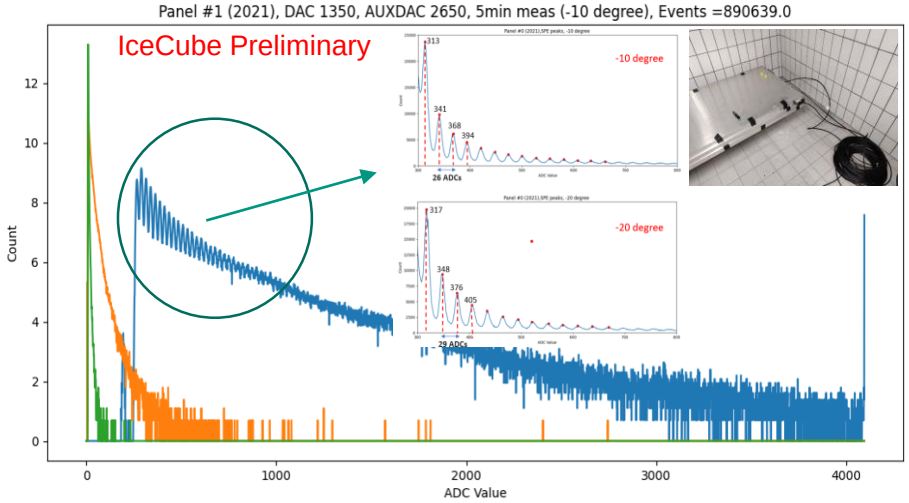
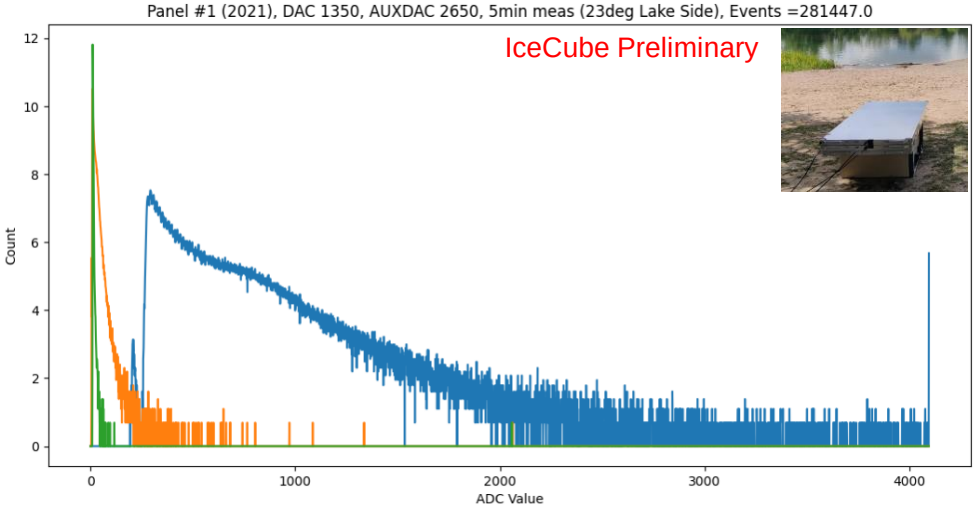
Performance tests in Karlsruhe

- Measurements performed at low temperatures in a freezing facility at -20 and -10 °C:
  - Finger spectra: Single photoelectron peaks
  - Higher gain at lower temperatures: with in the expected range, as measured from the Prototype station
- Lots of shielding and experimental setup in the campus
  - Remote measurements to achieve minimum RFI noise : Significant MIP peak visible





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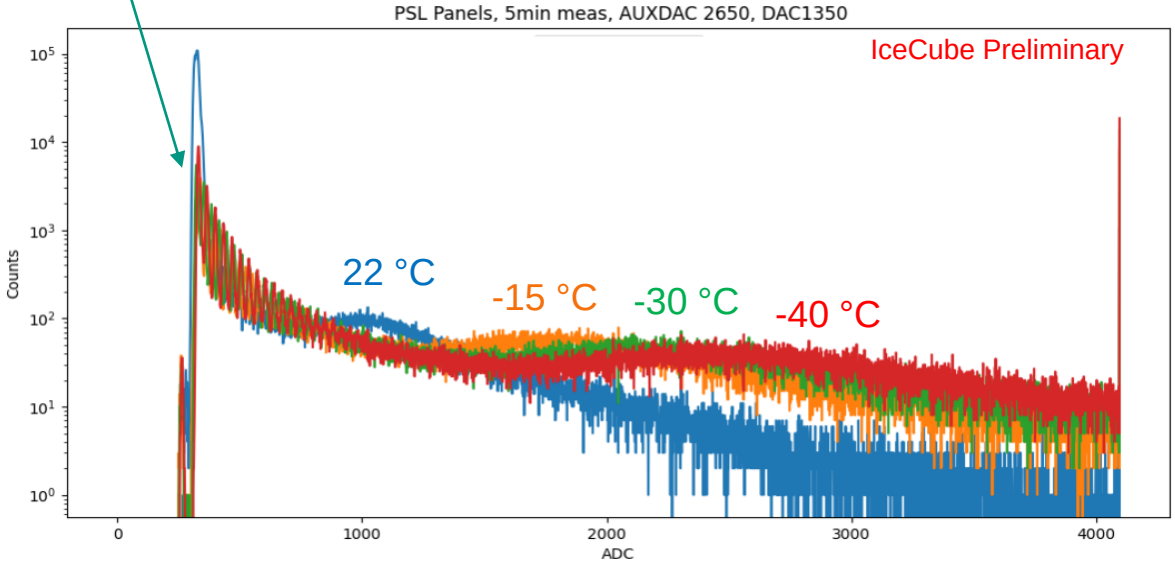
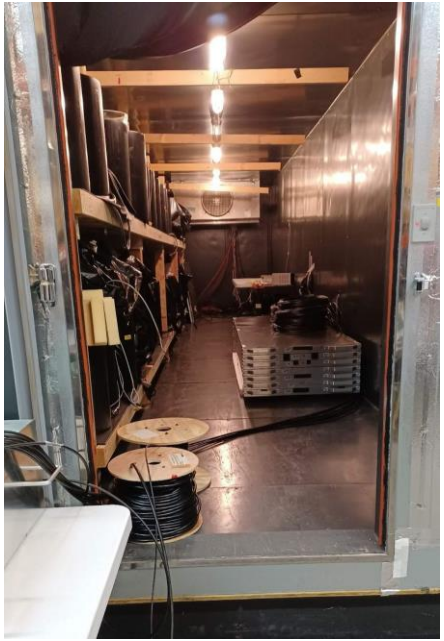
Remote Tests in Madison

- After production and functionality tests at KIT, 8 scintillation panels and a Field hub DAQ sent to IceCube headquarter (Madison)
- The system placed in a cooling chamber
- Remote measurements: Histogram measurements at : 22, -15, -30 and -40 °C (High gain results presented)
- Increase in gain with decrease in temp as expected
- Finger Spectra visible at negative temperatures





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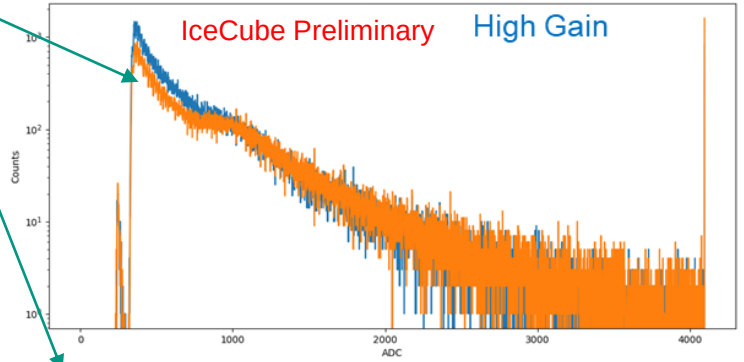
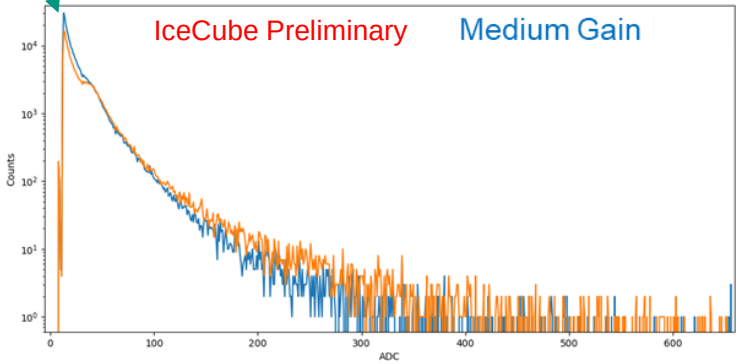
Barracks Measurements

- To shield from RFI, faraday cage like structure (metal container room: Barracks), used for final testing at KIT
- Furthermore, to shield from natural radioactivity, lead shielding setup for the panels constructed





Shielded
Non-Shielded

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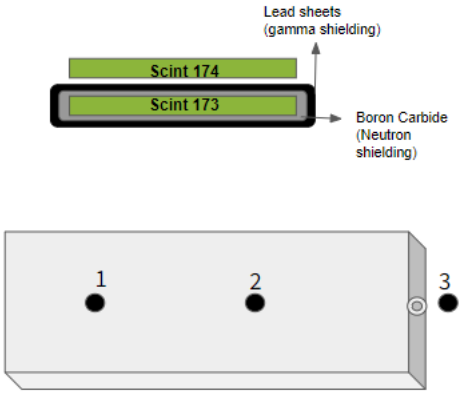
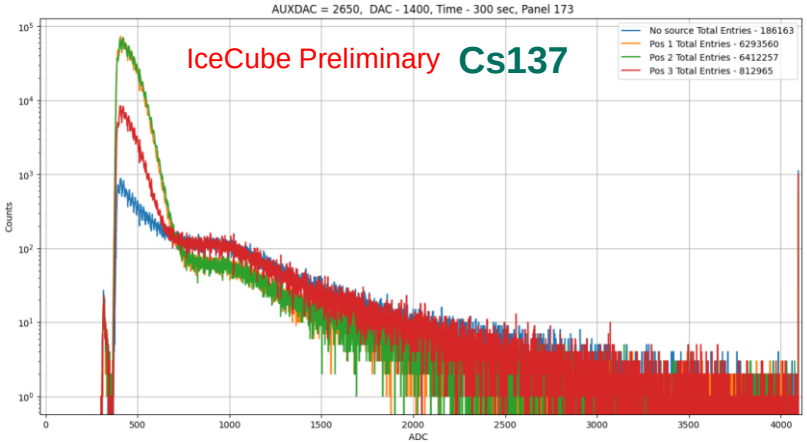
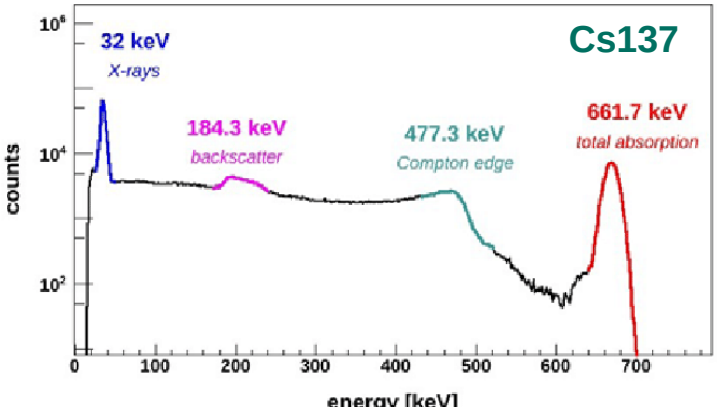
Energy Calibration of the detectors' ADC

- Radioactive sources used for the energy calibration of the Scintillation panels:
  - Gammas: Cs 137, and Na22
  - Neutrons: AmBe
- Energy calibration can be achieved by calculating the conversion factor for deposited energy from muons to gammas with existing simulations
- Coming soon!!







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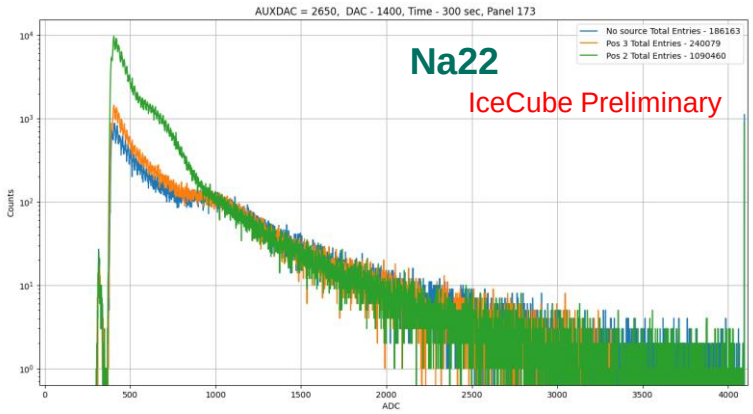

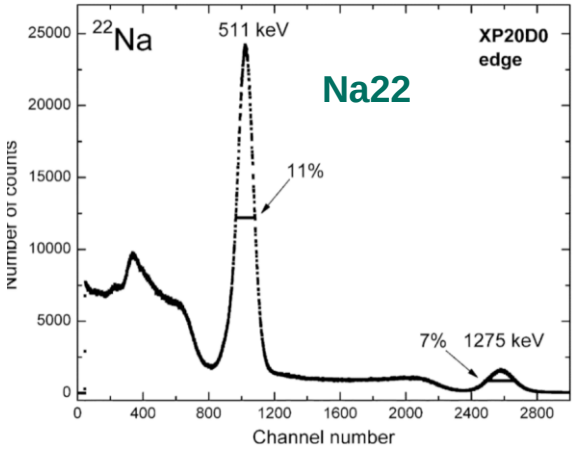

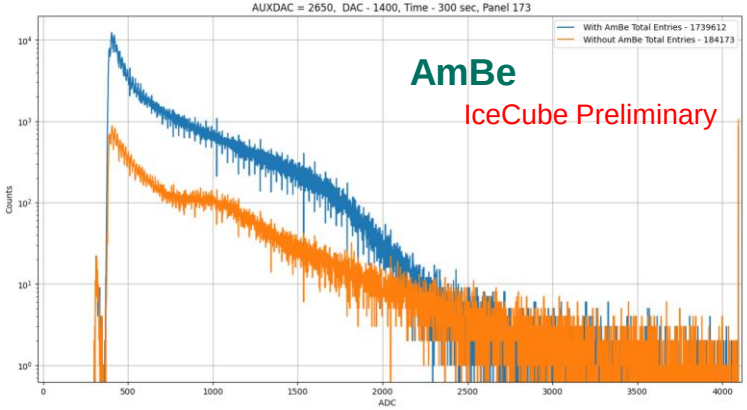

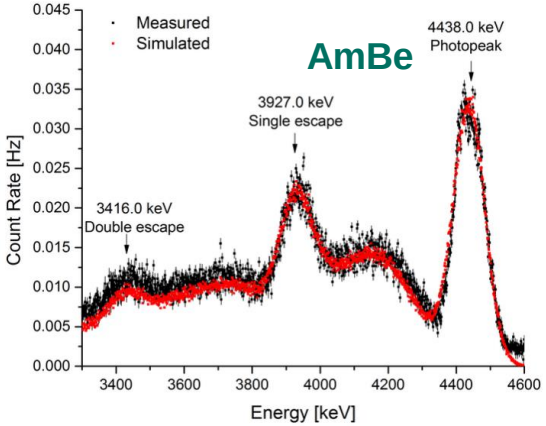

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Conclusion and Outlook

- The scintillators with updated readout electronics are functional and comparable to the prototype station
- The existing prototype scintillators will be replaced by the updated panels in Antarctic season 2022-23
- The deployment of more stations is planned for the upcoming Antarctic summers depending on the pandemic
- Series production of 4 complete stations and inlay for additional 5 stations is complete
- Setup for the functionality tests of the panels with the lead shielding at KIT is being used for calibration of detectors
- Energy calibration of the stations coming soon!

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