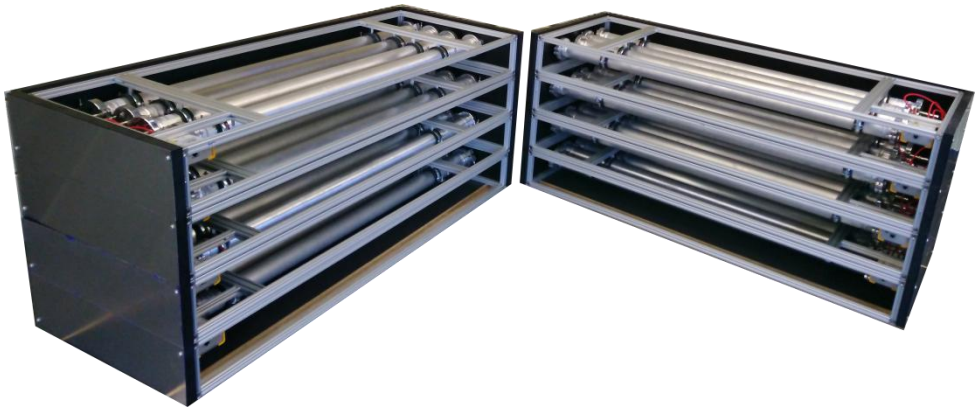
Boron-lined tubes and readout electronics for low count-rate environments

With Boron-10 converters replacing helium-3 the total sensitive detector area per instrument increased likewise due to the lower efficiency per layer. However, commonly used alloys for substrates contain a significant amount of radioisotopes which lead to an undesired background counting rate. For detector applications exposed to a low flux, like in our case measuring environmental neutrons generated by cosmic-ray particles, such can easily increase the error of the signal. The tubes we have developed feature B4C coatings of up to 0.2 m^2 on high-purity copper substrates. Furthermore the geometry and the pressure have been designed for a dE/dx suppression of unwanted contributions from gammas, electrons, muons and also heavy-isotope decays like from remains of radon. In combination with the form factor our pulse shaping electronics determines pulse length and height, which allows to discriminate against other particle species. The main goal of this development is to provide a detector system largely free of intrinsic background at considerably lower costs.



09.12.2020

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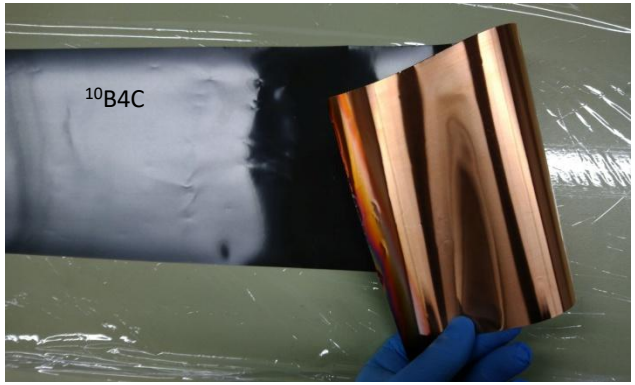
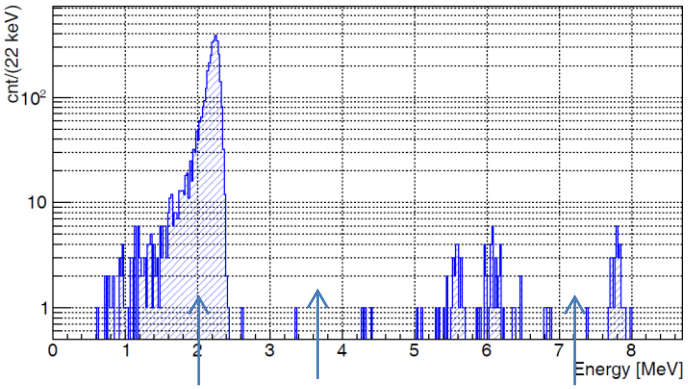
Background suppression and frontend electronics

Intrinsic background suppression



Measured sample of high purity copper foils

5 days
400 cm^2



Calibration Source

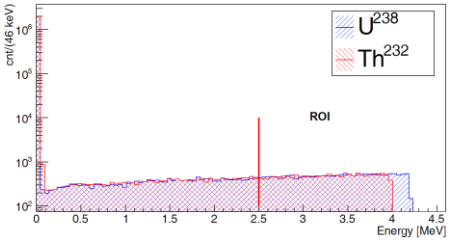
ROI

(1.05 +/- 0.1) /h/m^2
in 2.6-5.0 MeV

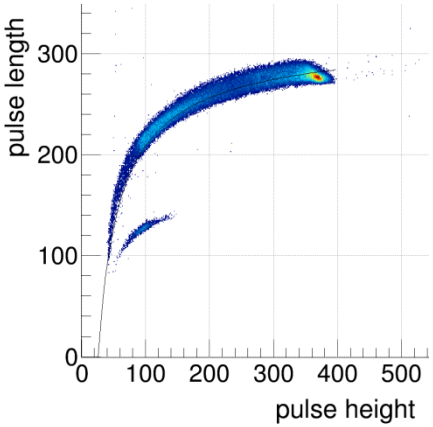
Rn-222
Traces

In collaboration with
Heinrich Wilsenach
IKTP, TU-Dresden

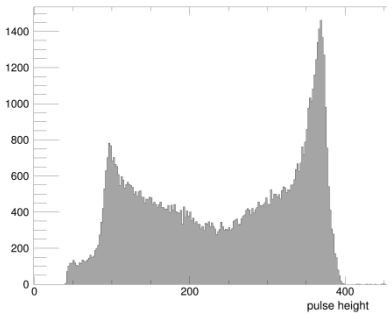
Simulated U+Th Spectra



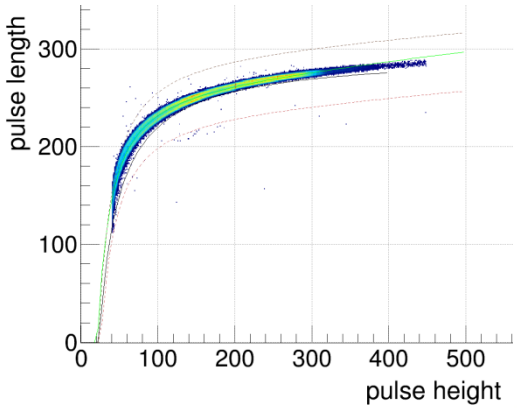
Helium tube (2“, 1.5 bar He-3)



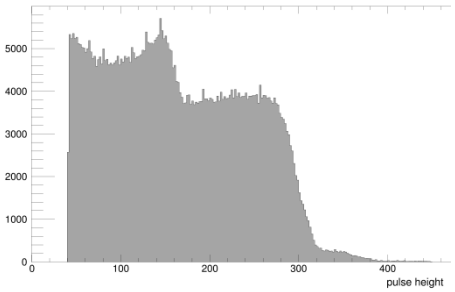
Pulse height projection



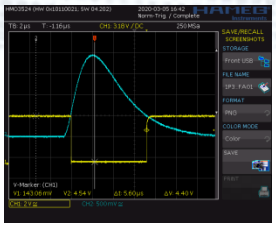
^{10}B4C tube tube (2“, 0.25 bar Ar:CO_2)

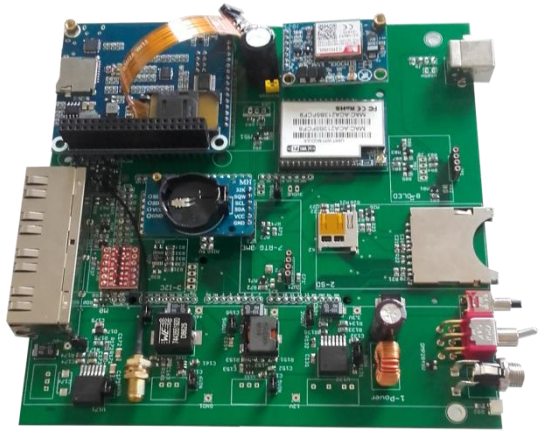


Pulse height projection



Electronics





High Voltage

HV - Module

DAC

Pulse Analyzer

DAC

Arduino Nano

Pulslength

Pulsheight

Integrator

Mainamplifier

Comparator

Detector

+-5V

Slow-Control & Data processing

Data transfer & control

Arduino Mega

SD Card

Wi-fi Module

Clock

+-5V

Power supply

Battery

DC-DC Converter

Designed to read out proportional tubes

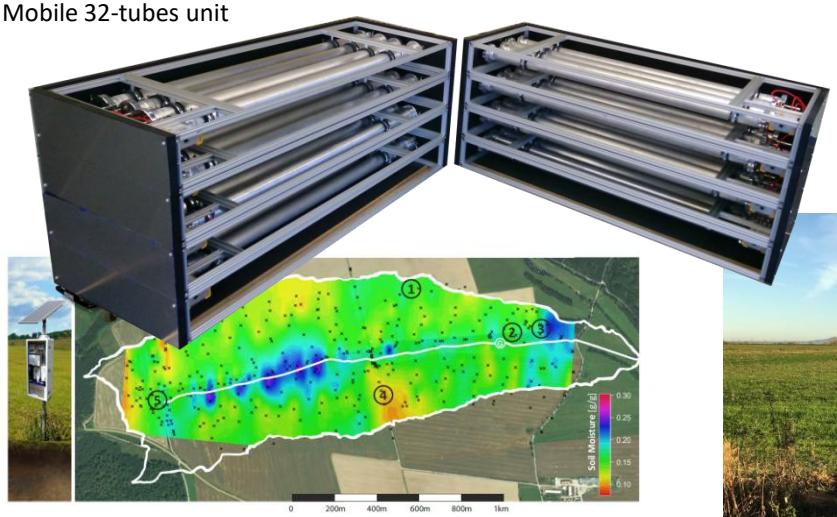
- Integrating Preamplifier + Main amplifier
- Comparator (Schmitt-Trigger)
- Arduino nano
  - Pulse length and height measurements via time over threshold and internal 10-bit ADC
  - Schmitt-Trigger threshold configuration via 12-bit DAC

- Comparator triggers nano's Input Capture Unit (ICU) if a pulse > a THL voltage
- The ICU measures the time for which the THL voltage is exceeded (Pulselength)
- The ICU also triggers the ADC which needs between 250 ns and 16mus to sample the Pulseheight

Application

Cosmic Ray Neutron Sensing (CRNS) is a technique to determine the soil water content on a scale up to ten hectares by measuring neutrons in the epithermal-to-fast range originating from cosmic radiation. The application of CRNS is especially of interest in the fields of climate modeling and agriculture.
This results into following requirements:
- **large detectors** due to the low count rate for neutrons outside the lab
- **high signal-to-noise ratio:** neutron events need to be separated reliably from background events
- **temperature stability:** the energy measurement should not drift with temperature
- due to the variety of environmental conditions the detector system should be **weather resistant**
- the whole detector system is powered by a solar panel to ensure a stand-alone operation over a long period. Thus, the readout electronics should have a **low power consumption.**

Mobile 32-tubes unit



soil moisture map of a reference field
in collaboration with Martin Schrön, UFZ Leipzig

Agriculture: Measurement of the field water capacity

Hydrological Modeling: COSMICSense field campaign in a deforested area