



# Radioactivity measurements using embedded processing

Aran Mol, INCAS<sup>3</sup>

# What is INCAS<sup>3</sup>?

- A private research institute
- Driven by industry and social demands
- Full development cycle from needs analyses to product
- Strong international academic and industrial network



# Example projects

Other examples:

SPRINT – Balance training for elderly people



More Wise – Mapping underground oil reservoirs

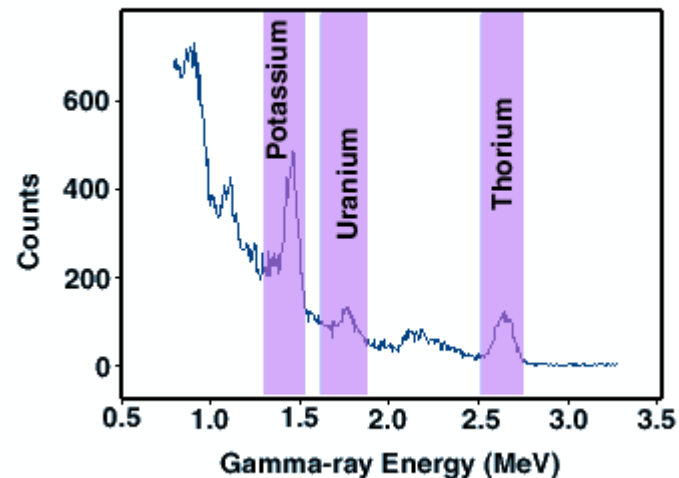
Panic detection – Automatic classification of sound events

ENSA/DROPS – Monitoring (natural) radioactivity



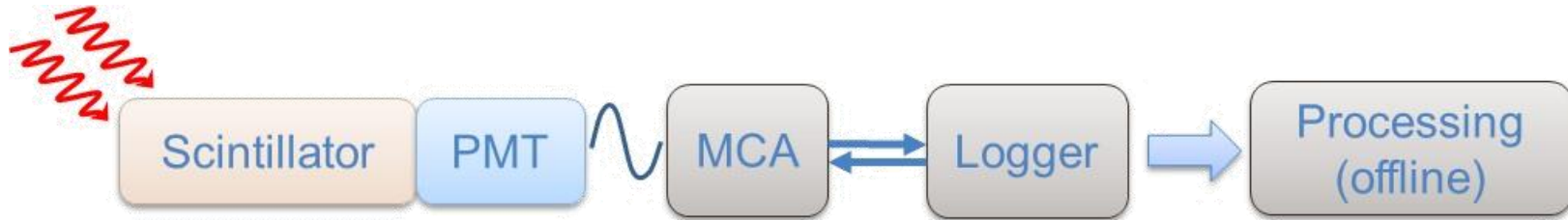
# Radiation detection

- Focus on low levels of (natural) radioactivity
- Many applications
  - Geophysics
  - Oil & Gas
  - Medical
  - Environmental
  - Security
  - ...



# Challenge = to “sensorize”

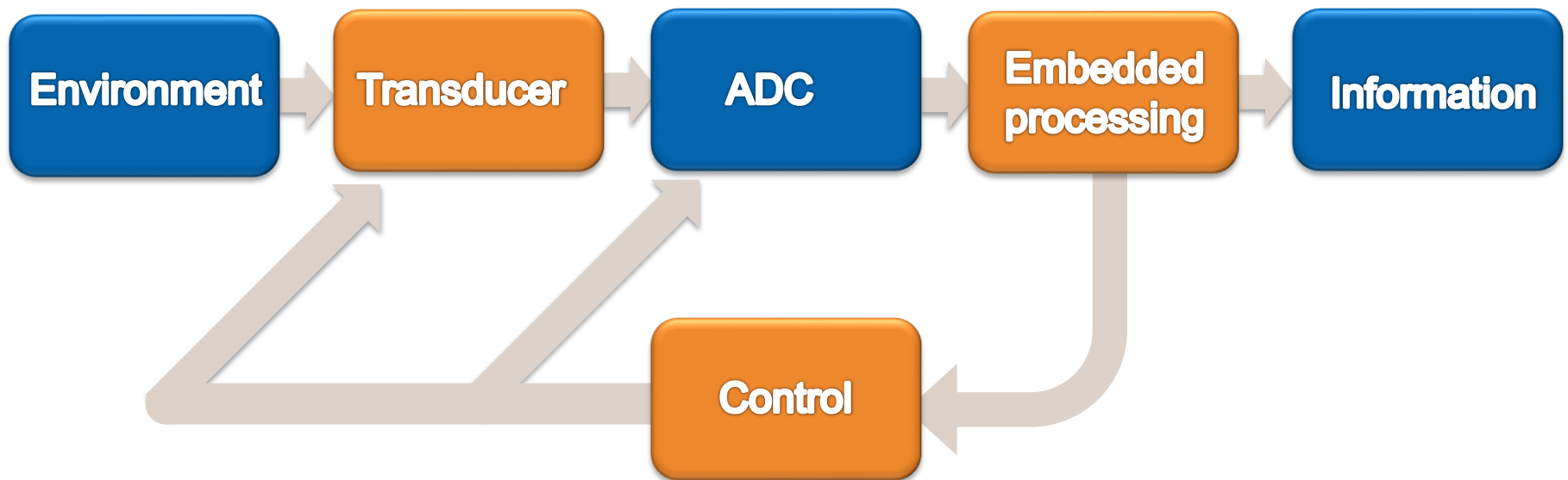
- Move “acquisition chain” to embedded solution



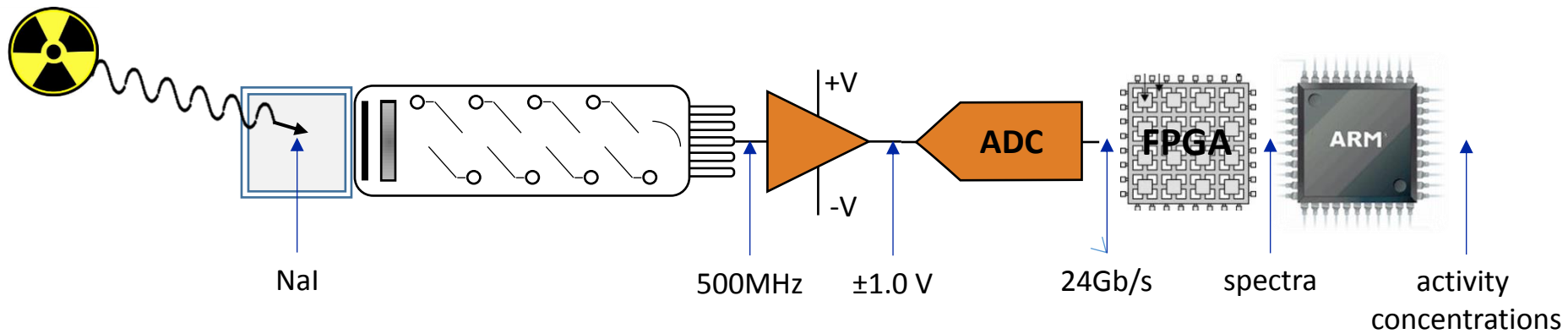
- In our case:
  - Embed detector drift feedback algorithms
  - Embed spectral processing algorithms
  - Embed data storage
  - Embed data visualization

# System philosophy

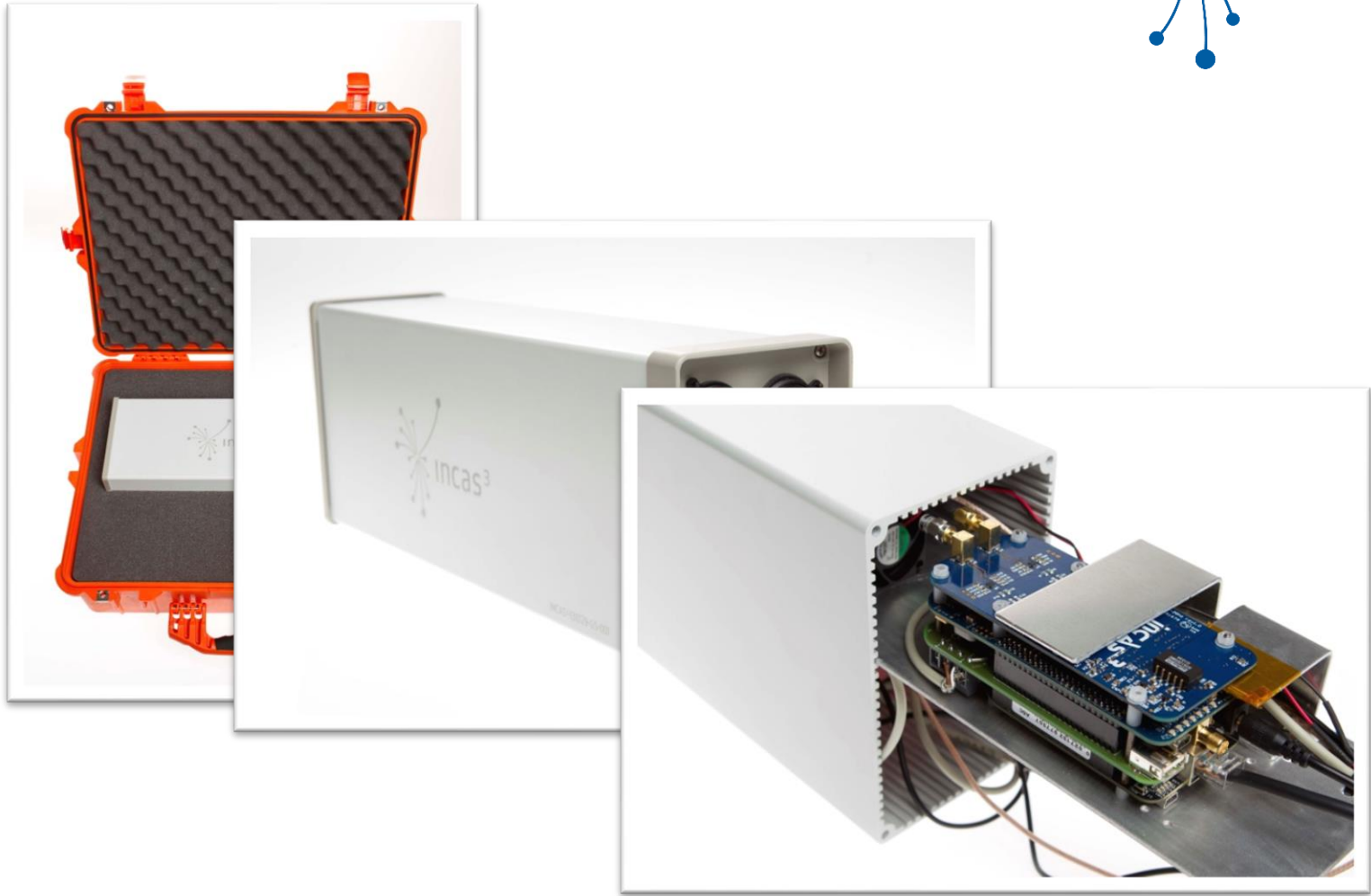
- Early digitization
- Local processing, self diagnostics, calibration



# Detector system



- Complex sensor
- Modular approach





# System overview

- Modules in stack
- 3 main boards
  - Fast ADC board
  - FPGA board
  - ARM board
- 1 for additional functionality
  - Additional DACs & ADCs
  - Connectivity
  - GPS



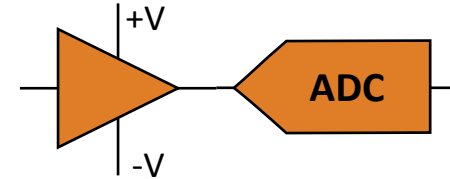
# ADC board

- Signal conditioning
  - Single-ended
  - Balanced
  - Amplification
- Digitization
  - 2 GHz; 12 bit; single channel

Analog signal

Register settings

Digital data

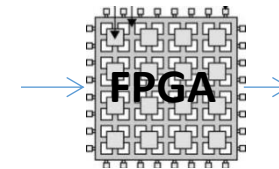


# FPGA board

- Event detection
- Event descriptor extraction
  - Energy
  - Time of detection
  - ...
- Performance parameters
  - Signal stability
  - Baseline tracking
  - Noise tracking
  - Pile-up rejection

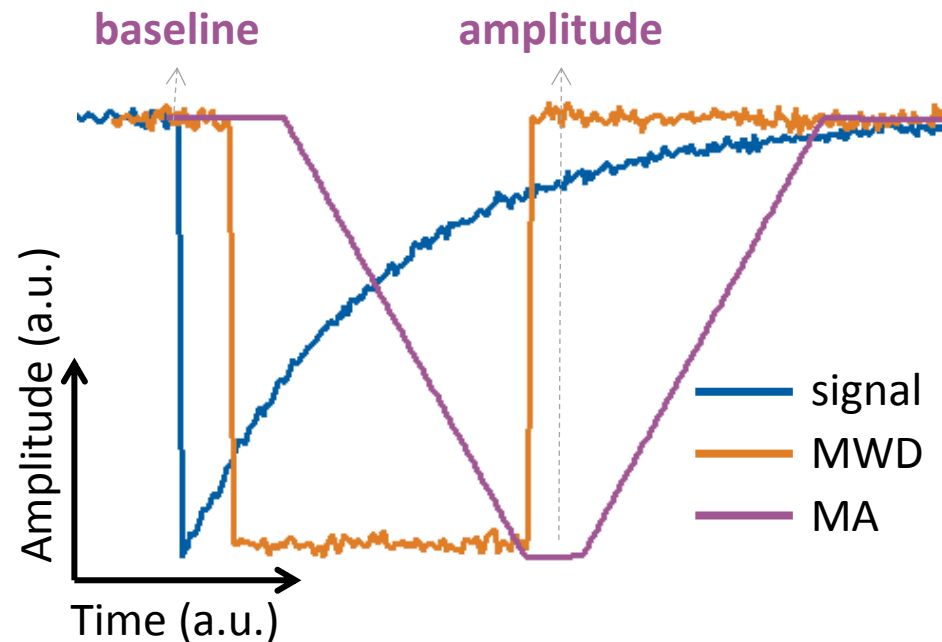
ADC data  
parameters

Spectra or  
raw data  
Register readout  
ADC settings  
Clock signals  
Power



# FPGA board - signal analysis

- Parameters set at runtime by user
- Dead time: 1.14  $\mu$ s (maximum)

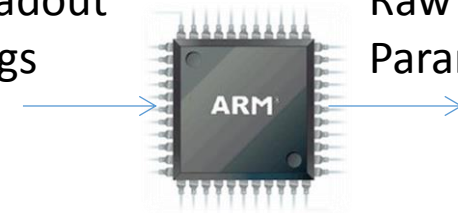


# ARM board

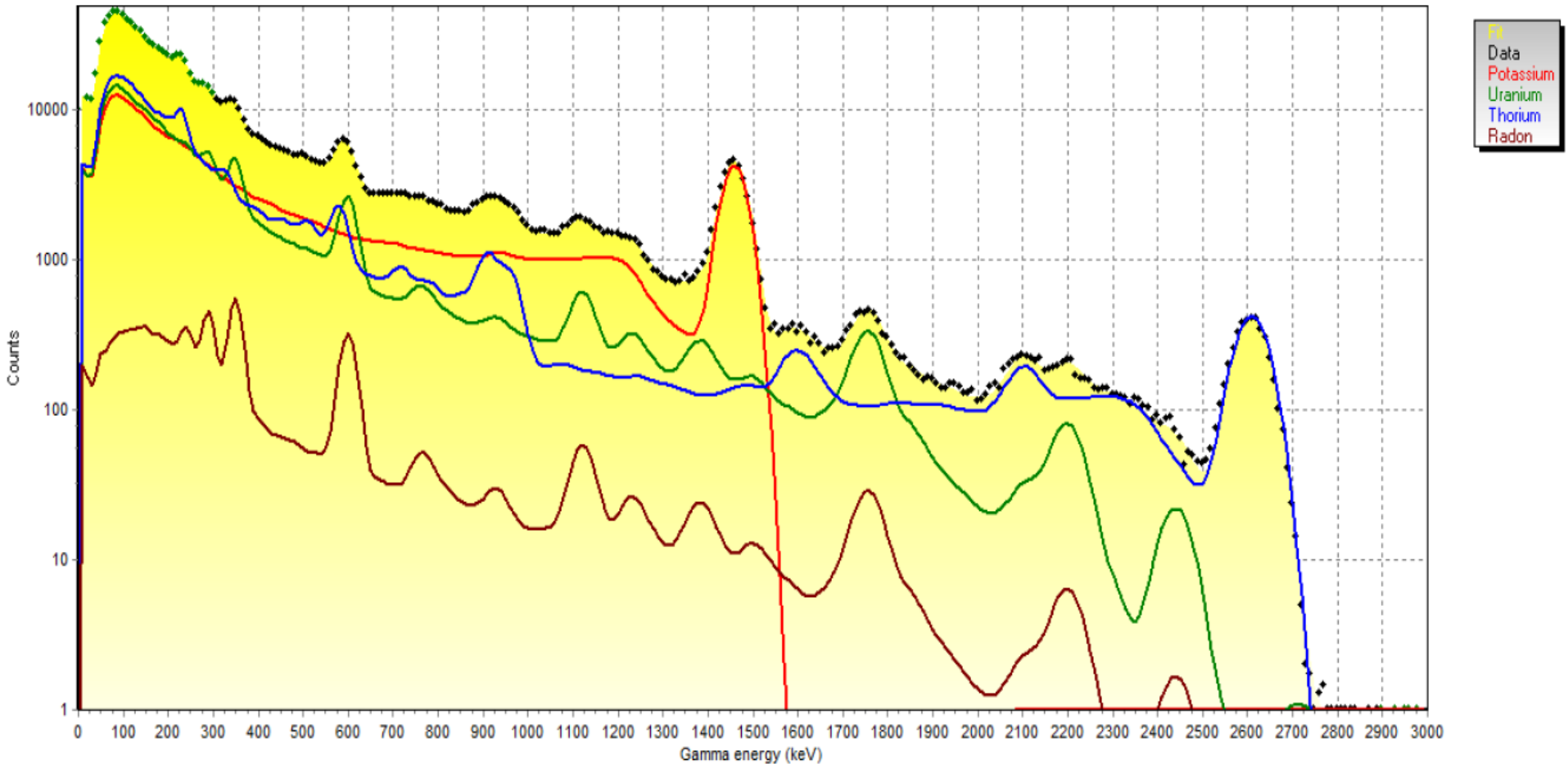
- Ethernet connection
- Temperature stabilization of spectrum
- Full spectrum analysis
- C++ code on Linux buildroot
- Interface server

Measured spectra  
& raw data  
HV readout  
Register readout  
User settings

Activities Analyzed spectra  
Raw data  
Parameters



# ARM board - FSA



# Full-Spectrum-Analysis

$$Wy = WAX$$

*Weight factors*

$$W = \frac{1}{\sqrt{XA}}$$

$$A = (yW) \cdot (XW)^T \cdot ((X^T W) \cdot (XW))^{-1}$$

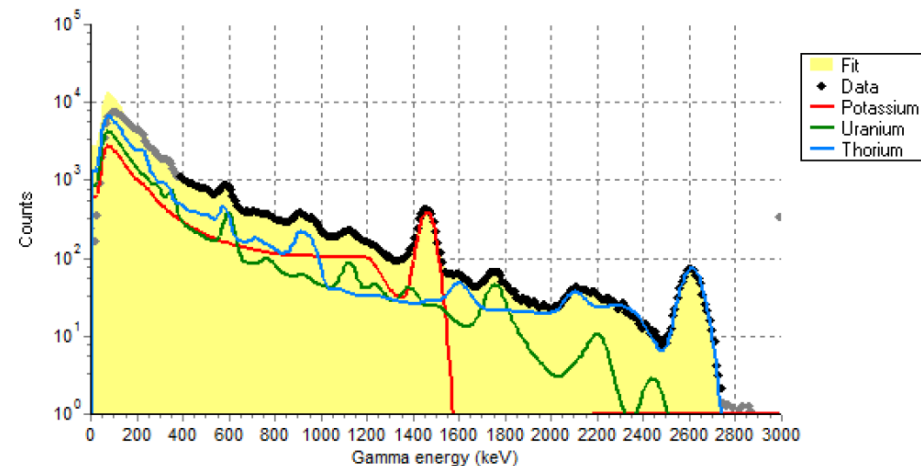
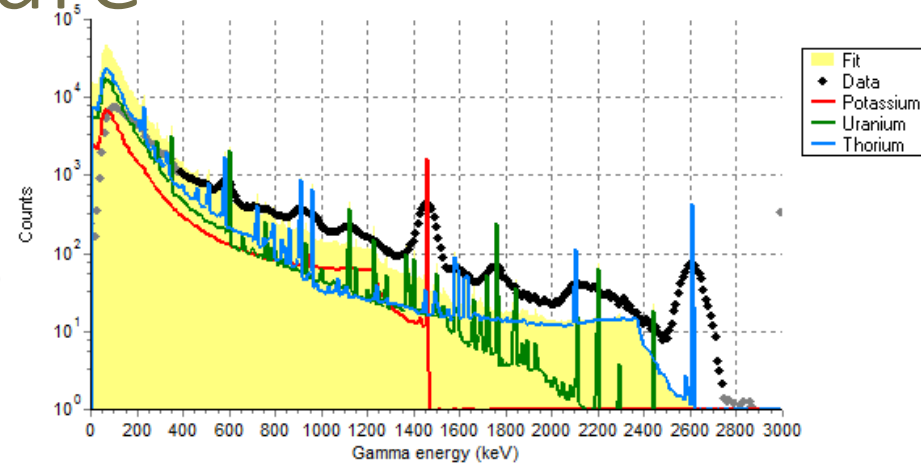
*Activity*

*Uncertainty*

$$u = \frac{1}{\sqrt{WX^T WX}}$$

# Calibration procedure

- Volume source: semi-infinite brick castle
- MCNPX simulations used to determine detector response
- With detector response known, standard spectra can be calculated for any isotope and geometry





# Precision

- Energy resolution of detector:  
7.0 % at 662 keV
- Very accurate activity estimations
- Very small nonlinear term

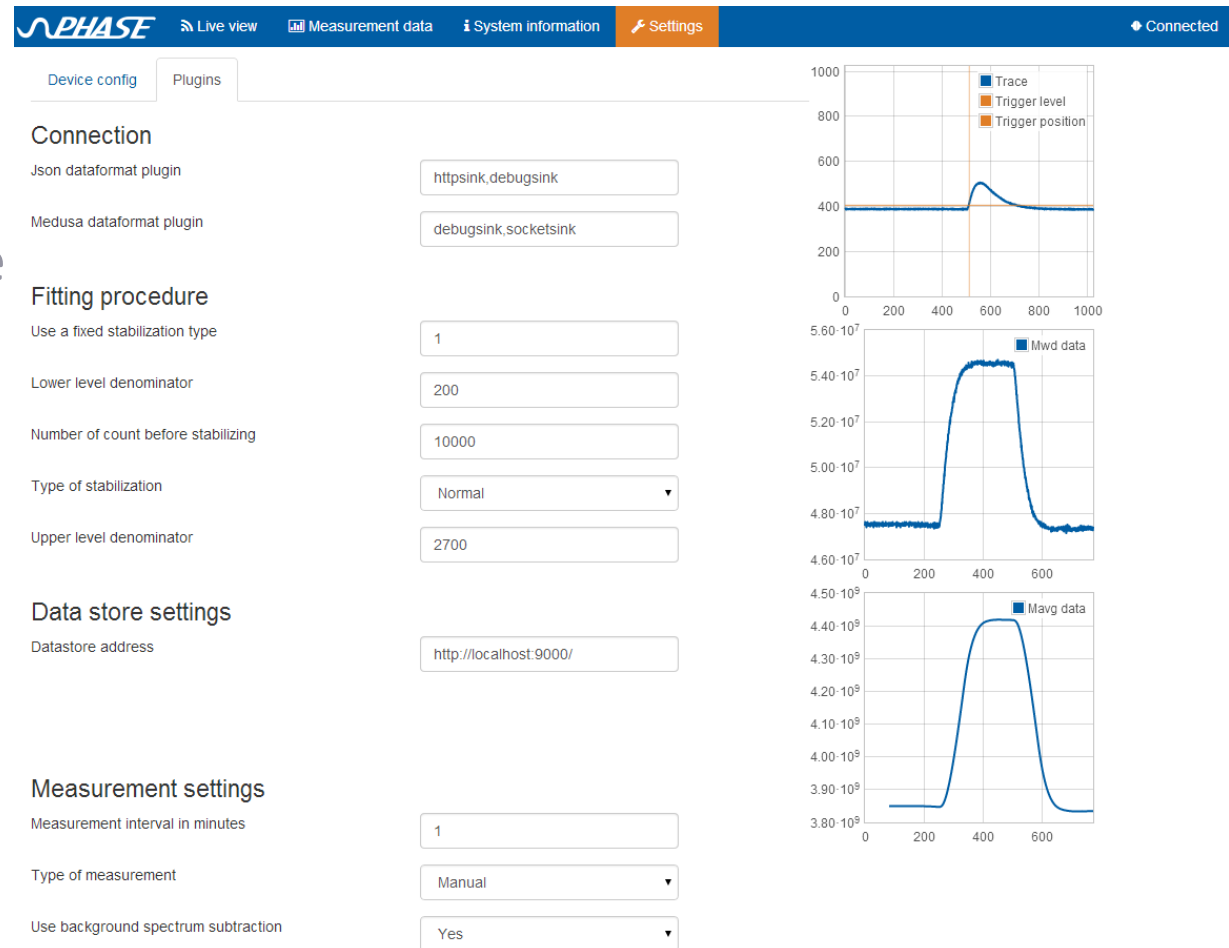
## Fact sheet

General information	
Tool ID	DROPS0001
Crystal type	NaI
Crystal dimensions	76 x 76 mm
Application	Open field
Calibration Setup	Stonehenge (4 $\pi$ semi-infinite homogeneous source of known activity and density)
Read-out	-
Calibration duration	Approximately 1 hour
Date of calibration	July 19th, 2013
Commissioned by	-

Calibration results	
Energy resolution @662 keV	7.0%
Quality of energy resolution	Excellent
Overall scaling factor	100%
Quality of scaling factor	Excellent
Quality of fit	98%
Energy scaling factors	$a_0$ : -2.00 $a_1$ : 0.675 $a_2$ : 0.000010
Overall spectra quality	Excellent
Overall quality of the tool	Excellent

# Interface

- Web server
  - Easily accessible
  - Easily changed
- Tabs:
  - Live view
  - Settings
  - Data storage
  - System lineage

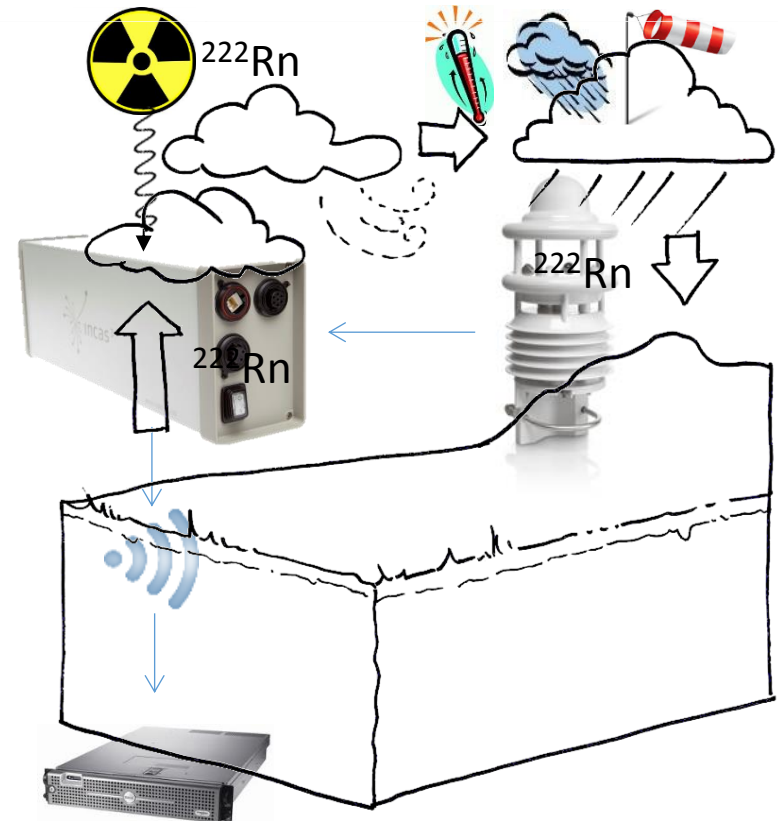


The screenshot shows the PHASE web interface with the following components:

- Navigation Bar:** PHASE logo, Live view, Measurement data, System information, Settings (active), Connected.
- Device config / Plugins:**
  - Connection:
    - Json dataformat plugin: httpsink, debugsink
    - Medusa dataformat plugin: debugsink, socketsink
  - Fitting procedure:
    - Use a fixed stabilization type: 1
    - Lower level denominator: 200
    - Number of count before stabilizing: 10000
    - Type of stabilization: Normal
    - Upper level denominator: 2700
  - Data store settings:
    - Datastore address: http://localhost:9000/
  - Measurement settings:
    - Measurement interval in minutes: 1
    - Type of measurement: Manual
    - Use background spectrum subtraction: Yes
- Data Plots:**
  - Top plot: Trace (blue line), Trigger level (orange vertical line), Trigger position (orange vertical line).
  - Middle plot: Mwd data (blue line).
  - Bottom plot: Mavg data (blue line).

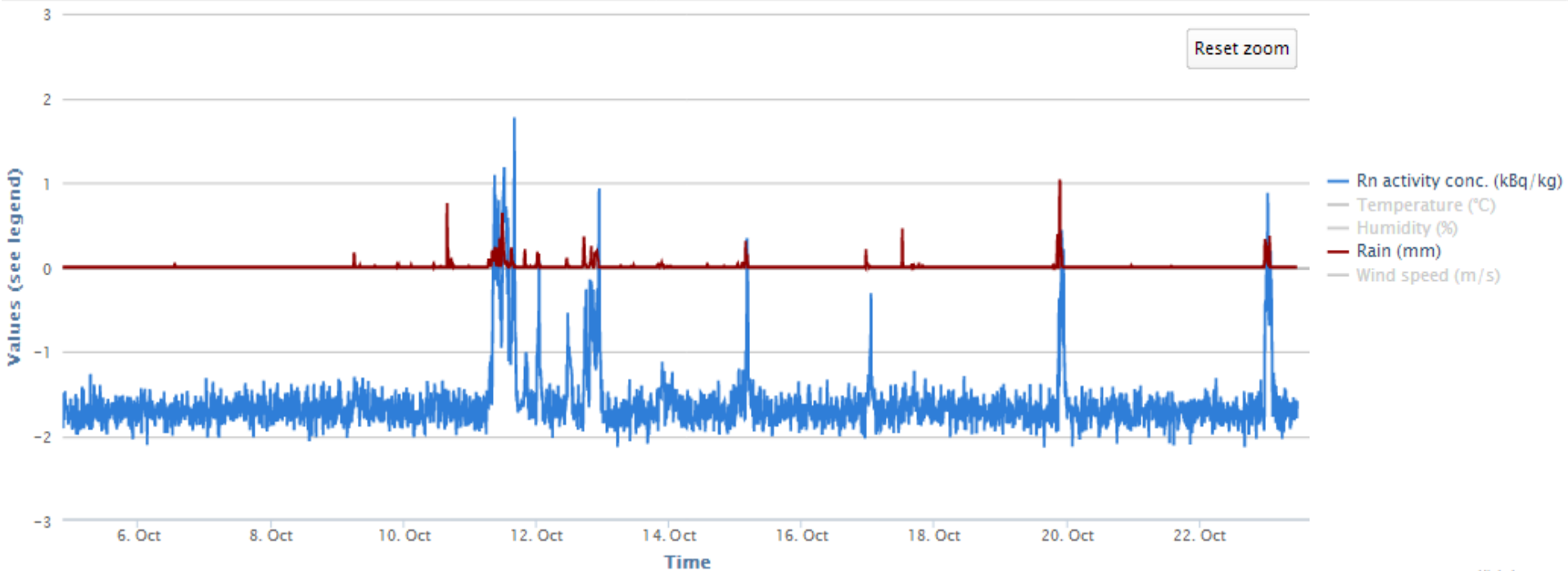
# DROPS project

- **D**ynamic **R**ain **O**bservation & **P**arametrization **S**ystem
- High-school collaboration project
- Study correlation between weather and radon activity



# DROPS results

- Continuous dataset from 22 July to 22 October



# Ongoing work...

- Continued development of detector electronics & scintillator signal processing
  - Testing & certification
    - Field testing Canada
    - Temperature and mechanical stability testing
  - Advanced real time analysis & control
    - Pile up correction
  - Pulse shape discrimination
    - Neutron detection
  - Improve fitting procedure

# Applications

- Environmental monitoring
  - Pilot: Uranium mining Canada
- Precision farming
  - Soil content in sugar beet harvesting
- Nuclear reactor monitoring
  - First tests expected this year

# Thank you

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*provincie* Drenthe



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