Particle Detectors with Arduino-based Frontend Electronics

Innovative Particle Detection

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an Open-Hardware platform
- low-cost electronics
- kHz signal processing
- for students or rapid prototyping

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With the Arduino open source electronics platform microcontrollers have become a comparably easy-to-use tool for rapid prototyping and implementing creative solutions. Their stability especially qualifies them to be used for slow control units. Yet, running at 16 MHz, the capabilities can be extended to data taking and signal analysis at decent rates. Such devices in combination with dedicated frontend electronics can offer low cost alternatives for student projects and independently operating small scale instrumentation. We present two projects, which cover as well the readout of **helium-3** and **boron-10 proportional counters** as of **scintillators** or wavelength shifting fibers with **Silicon Photomultipliers**.

The **nCatcher** combines commercially available analog electronics and the Arduino nano enabling pulse shape analysis for proportional counters. The frontend integrates and shapes pulses to microseconds in order to use the Arduino's signal analysis capabilities - time over threshold measurement and a 10-bit analog to digital converter. Combining these two parameters allows for effective discrimination between different radiation types by estimating the total deposited energy (E) of incoming radiation as well as the mean energy loss per distance (dE/dx). This makes the device suitable for low to medium rate environments, where a good signal to noise ratio is a crucial.

With the **SiPMTrigger** we have realized a small scale design for triggering or vetoing. It consists of a custom mixed signal frontend board featuring signal amplification, discrimination and a coincidence unit. An Arduino MEGA digitally adjusts the thresholds of both channels and measures the trigger rate up to 200 kHz.
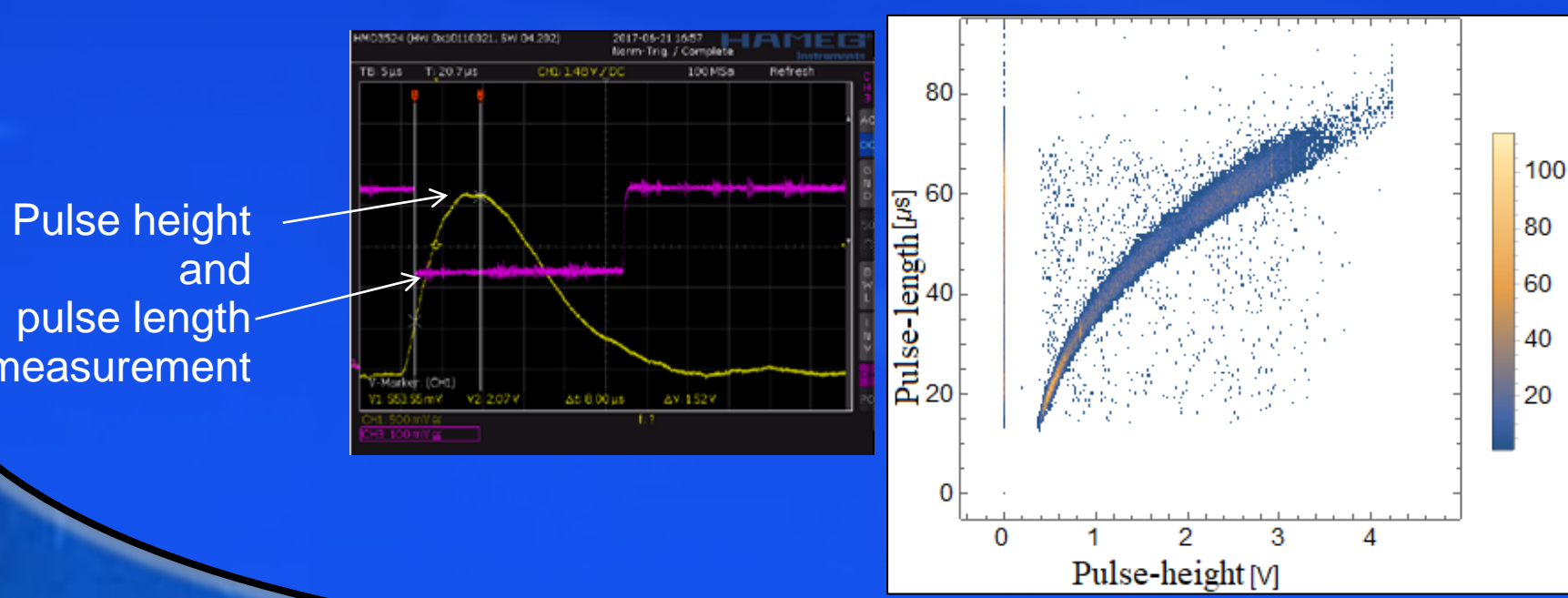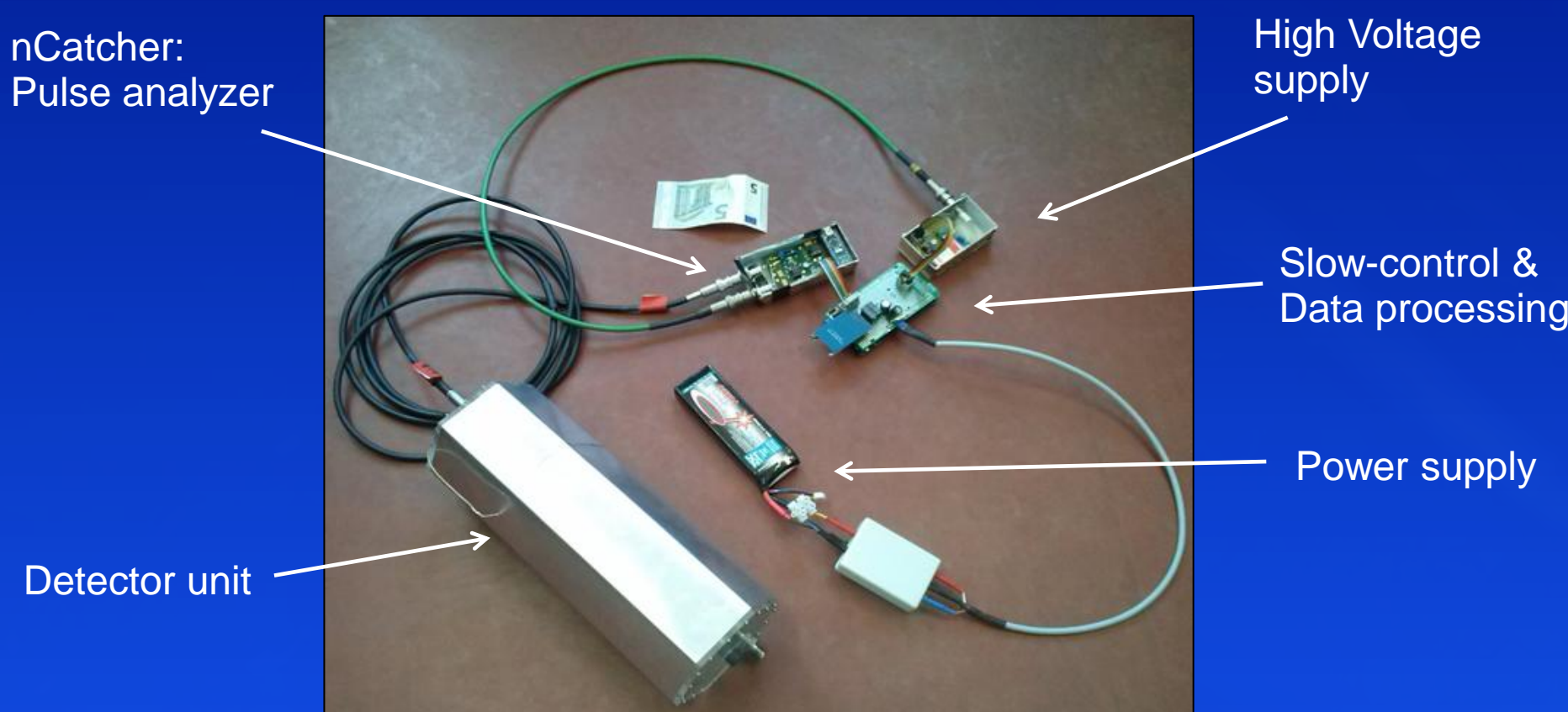
Proportional Counter

It's a Pulse Height Analyzer:

Designed to read out proportional chambers

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

It's a Single Channel Analyzer:

- 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 16 μs to sample the pulse height

nCatcher: Pulse analyzer

High Voltage supply

Slow-control & Data processing

Detector unit

Power supply

Pulse height and pulse length measurement

The Arduino Platform

	Arduino Uno	Arduino Mega	Arduino Nano
Microcontroller	ATmega328	ATmega2560	ATmega328
Flash Memory	32KB	256KB	32KB
Clock Speed	16MHz	16MHz	16 MHz
RAM	2KB	8KB	1KB
Price	15 €	19 €	6 €
Digital I/O Pins	14	54	14

Cost Calculation

Main Components:

PCB:	~ 20 €
PCB Components:	~ 15 €
Arduino Nano:	~ 10 €
Arduino MEGA:	~ 19 €
Arduino Box:	~ 10 €

Optional:

Coaxial Cable/Jacks:	~ 30 €
SD Card and RTC:	~ 25 €
DC-DC Converter:	~15€
High Voltage Unit:	~150 €

Cost Calculation

Main Components:

PCB:	~20 €
PCB Components:	~28 €
Arduino Nano:	~10 €
Arduino Box:	~10 €
SiPM (x2)	~80 €

Optional:

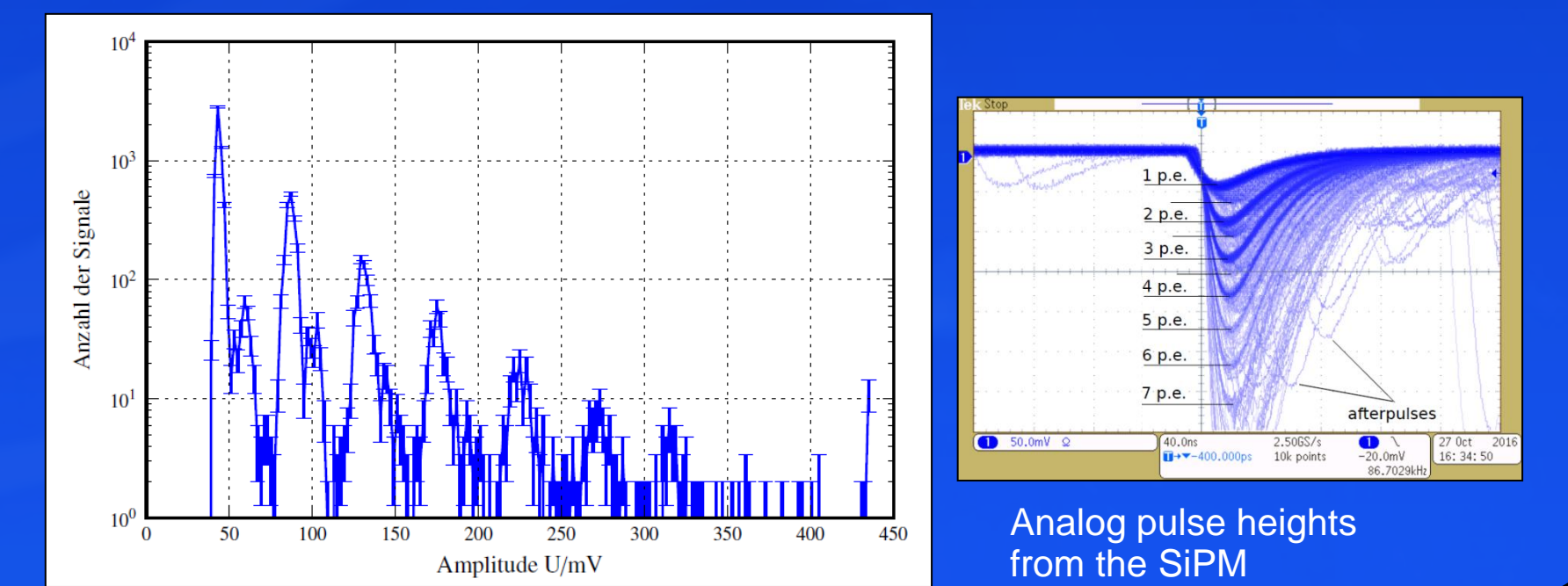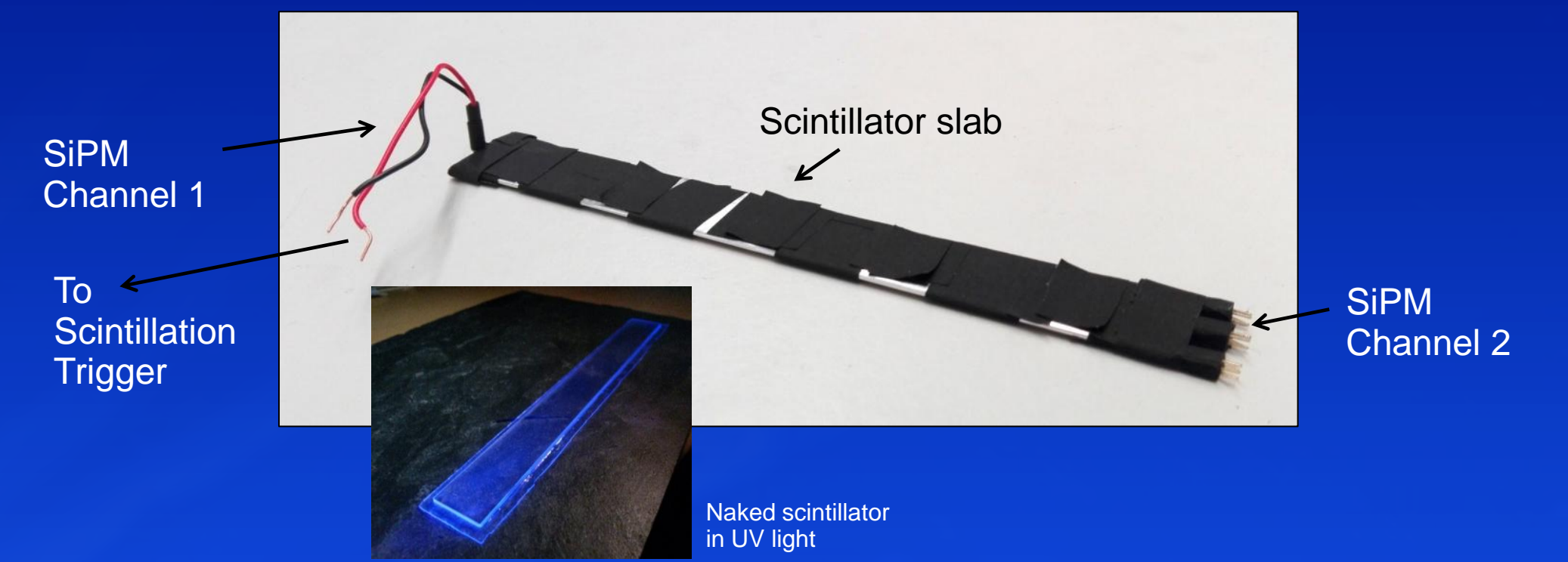|	
Coaxial Cable/Jacks:	~ 30 €
SD Card and RTC:	~ 25 €
DC-DC Converter:	~ 15 €
SiPM Voltage Unit:	~ 70 €
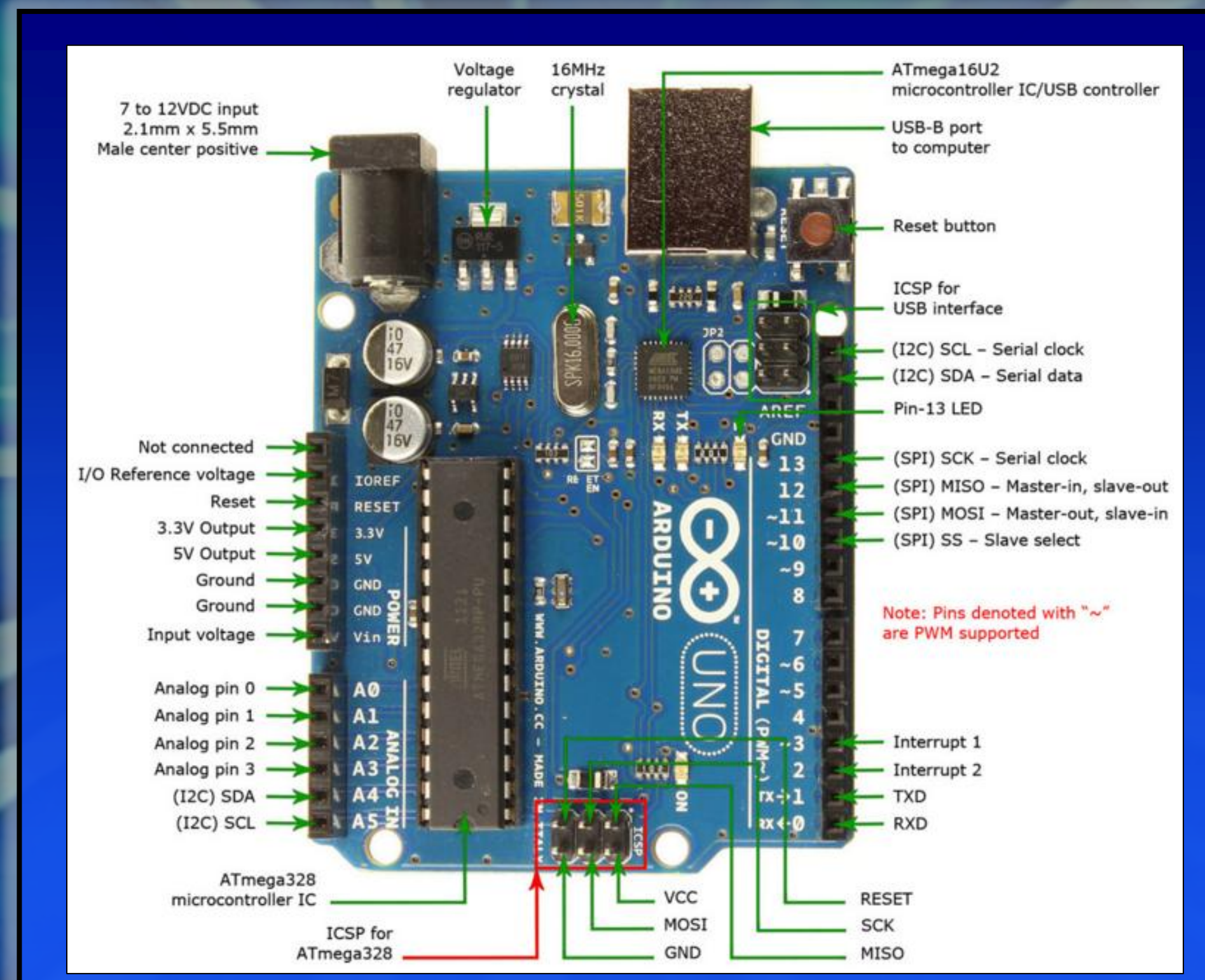
Scintillation Trigger

It's a Single Channel Analyzer:

Designed to read out Silicon Photomultipliers

- Preamplifier (x2)
- Digital Comparator (x2)
  Arduino MEGA for
  - threshold adjustment (both channels)
  - trigger rate measurement
  - fast trigger output (<15 ns)

It's a Coincidence Counter:

- Comparator triggers Arduino if pulse height > THL voltage
- a discrete logic gate provides the fast coincidence signal of both channels
- external coincidence for chaining
- The full coincidence pulse height spectrum can be obtained by a THL Scan

SiPM Channel 1
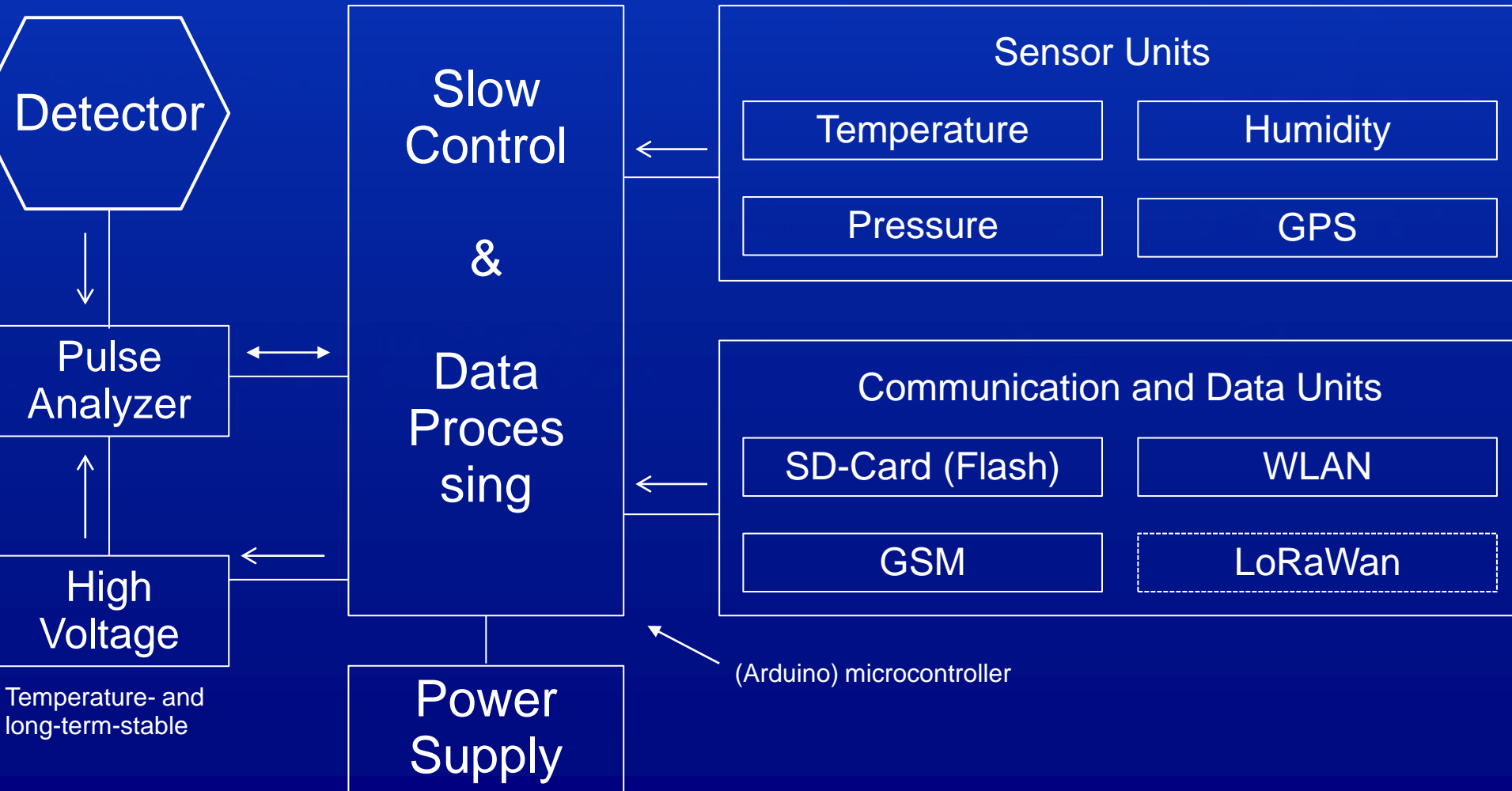
Scintillator slab

To Scintillation Trigger

SiPM Channel 2

Naked scintillator in UV light

Finger spectrum for pulse heights of n photoelectron counting events

Analog pulse heights from the SiPM

Electronics

Read-out unit (Pulse Analyzer)

Analog read-out and amplification via commercially available operational amplifiers
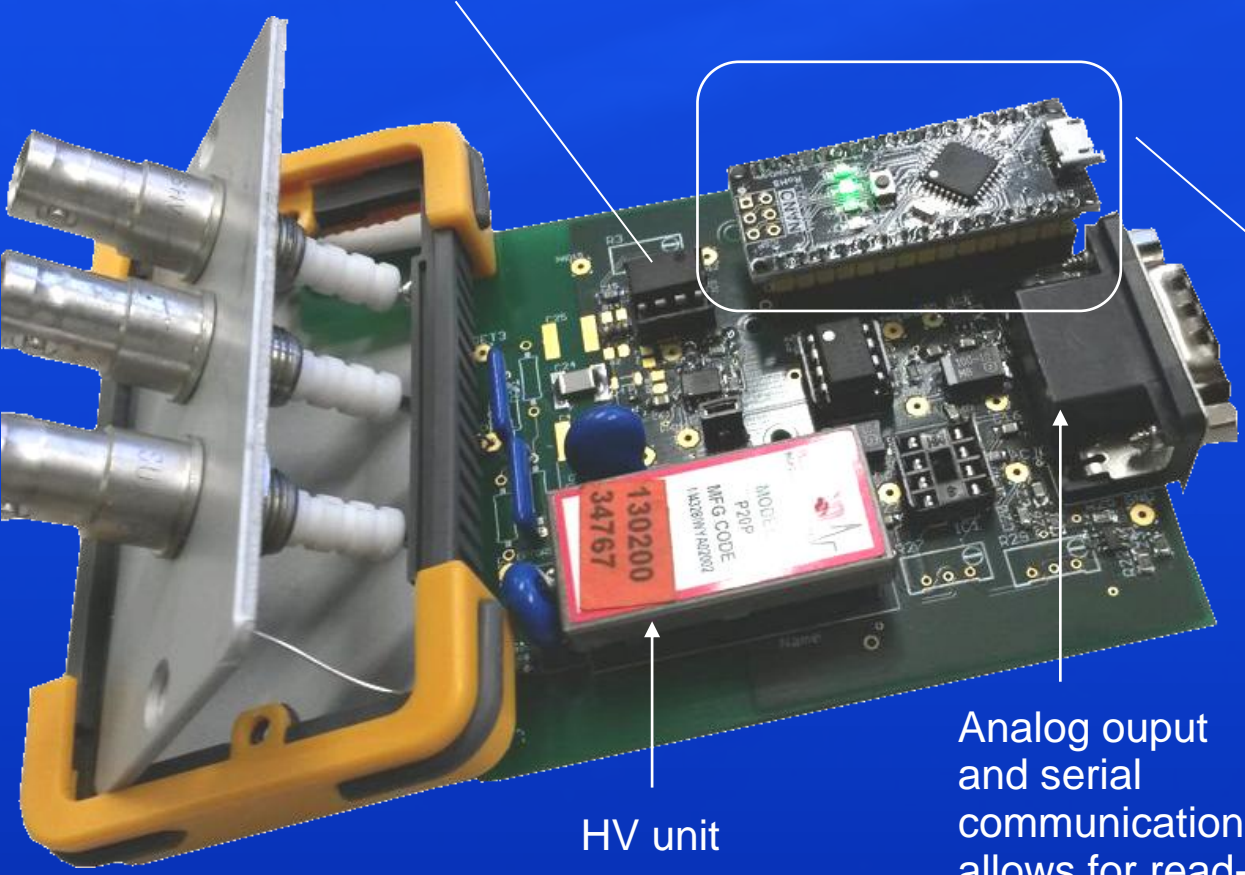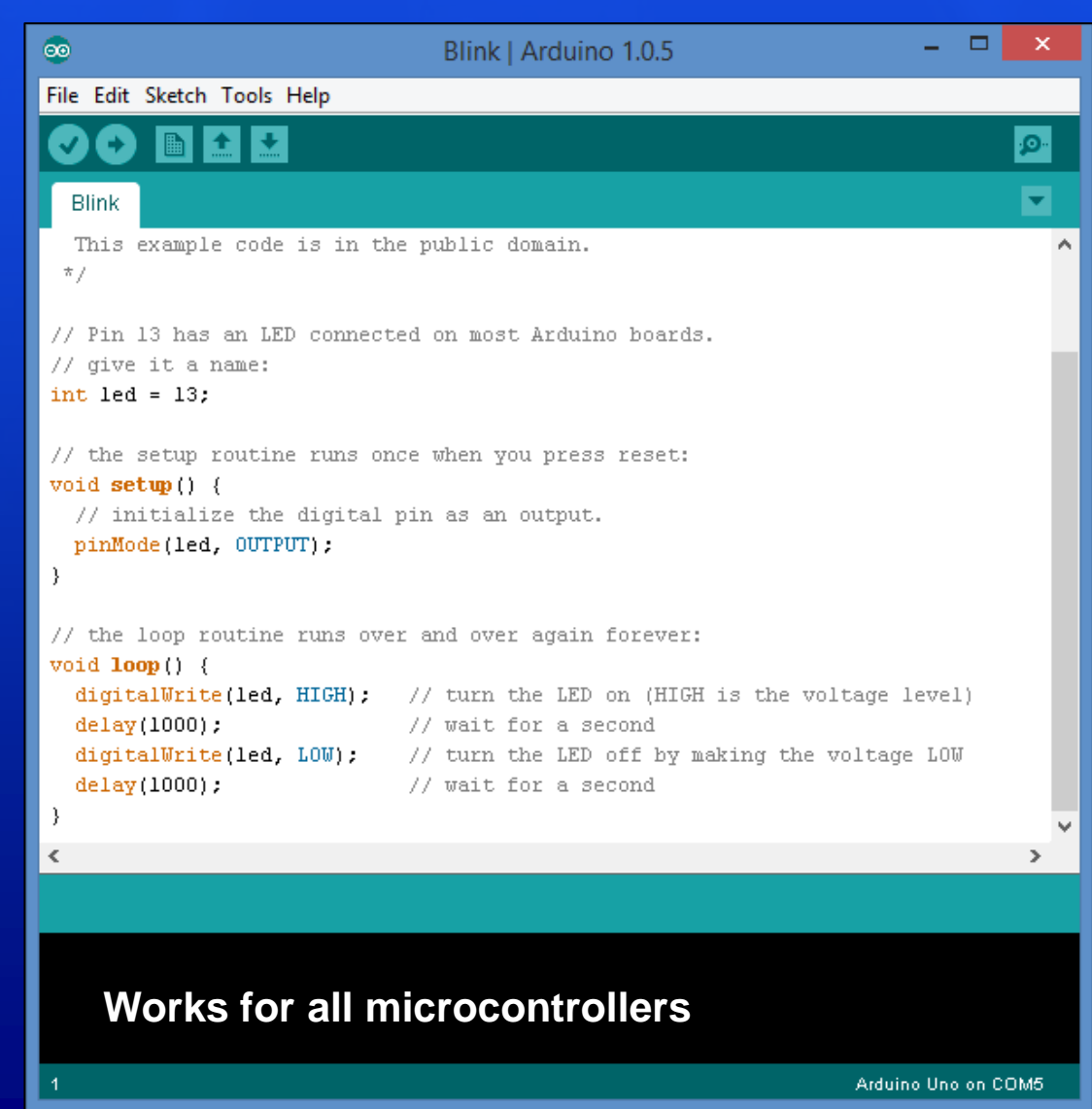
Arduino Nano
- ADC: pulse height measurement
- Time over threshold: pulse length measurement
- Communication with data loggers possible via I²C

HV unit

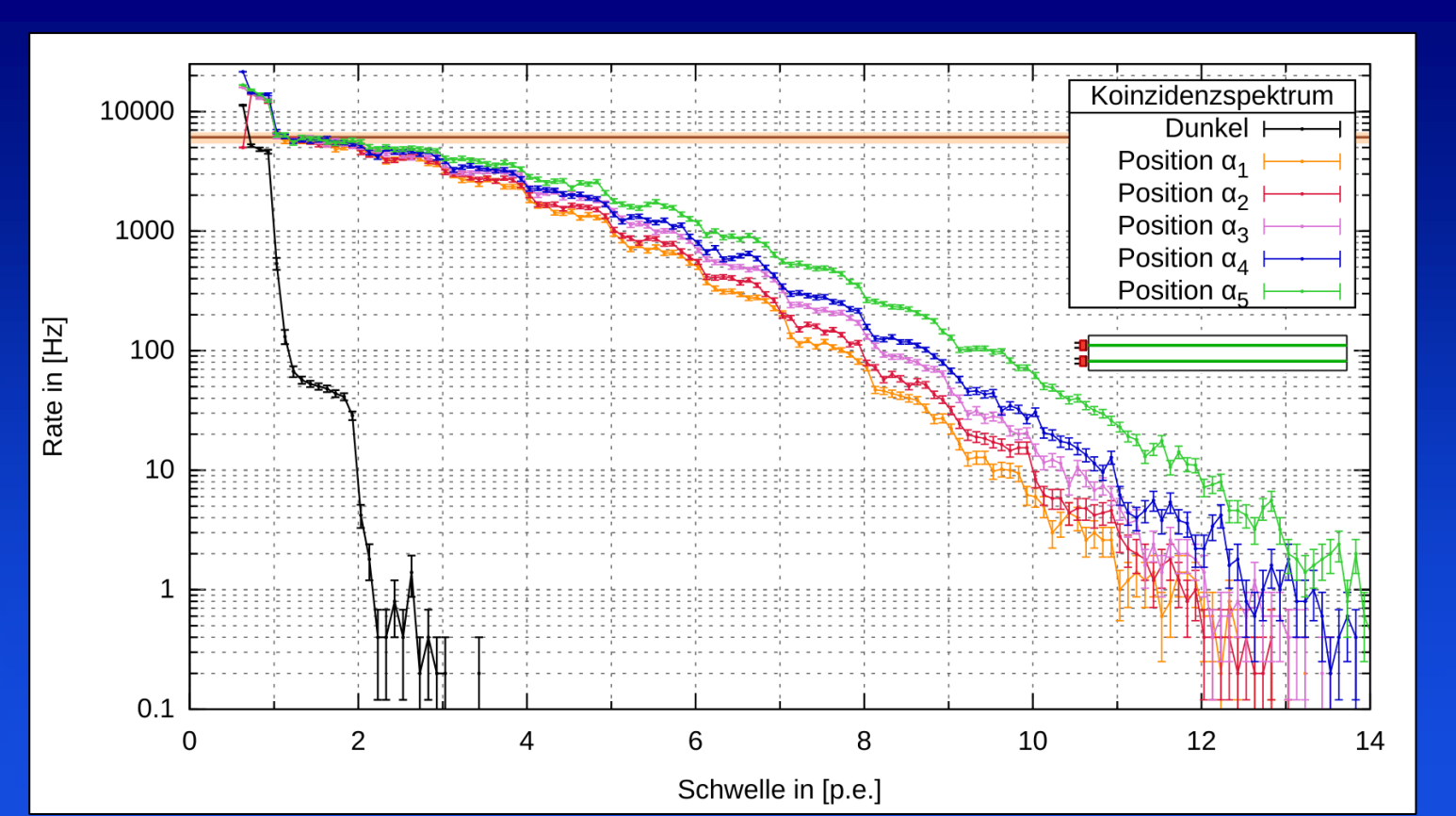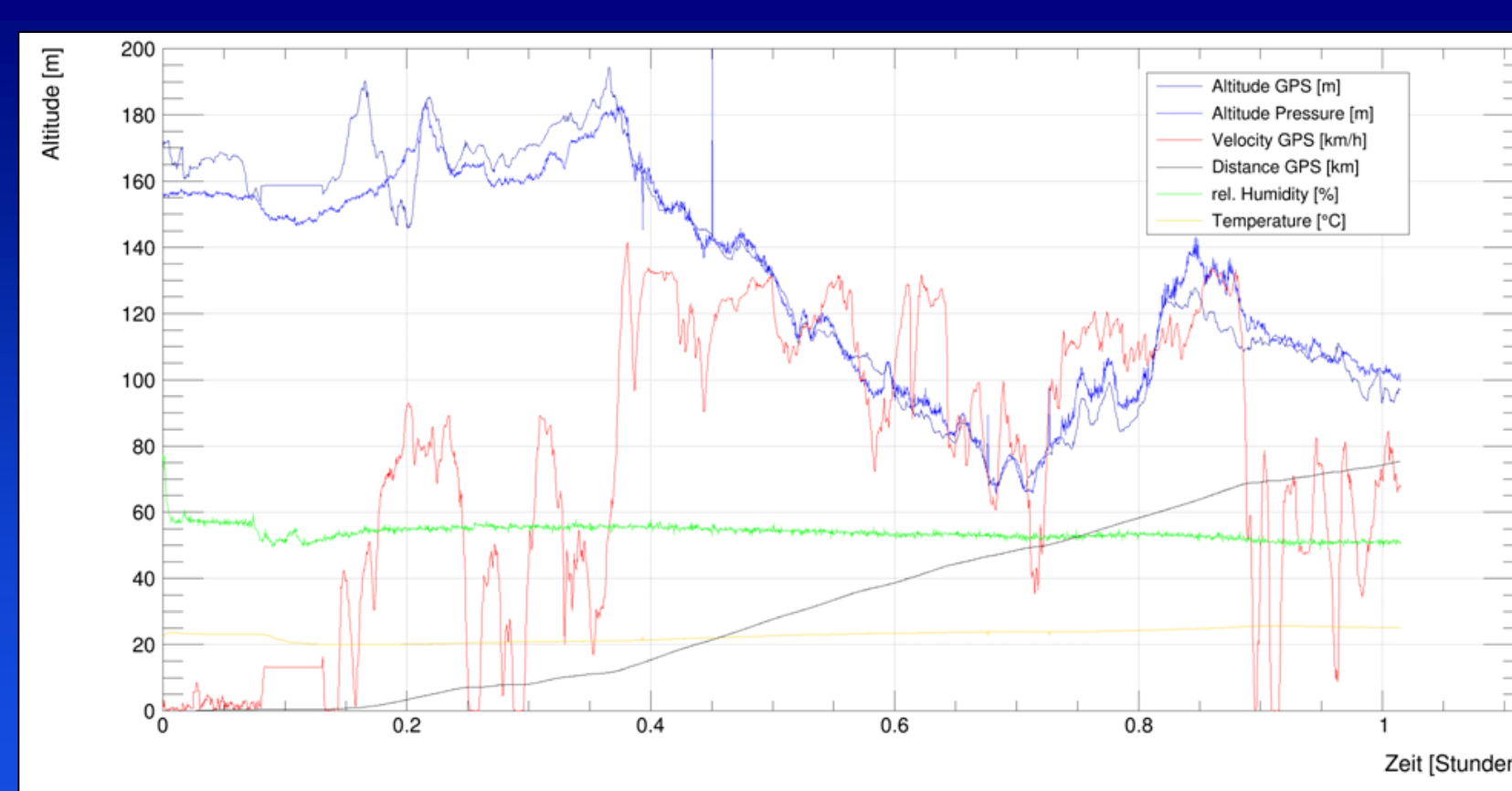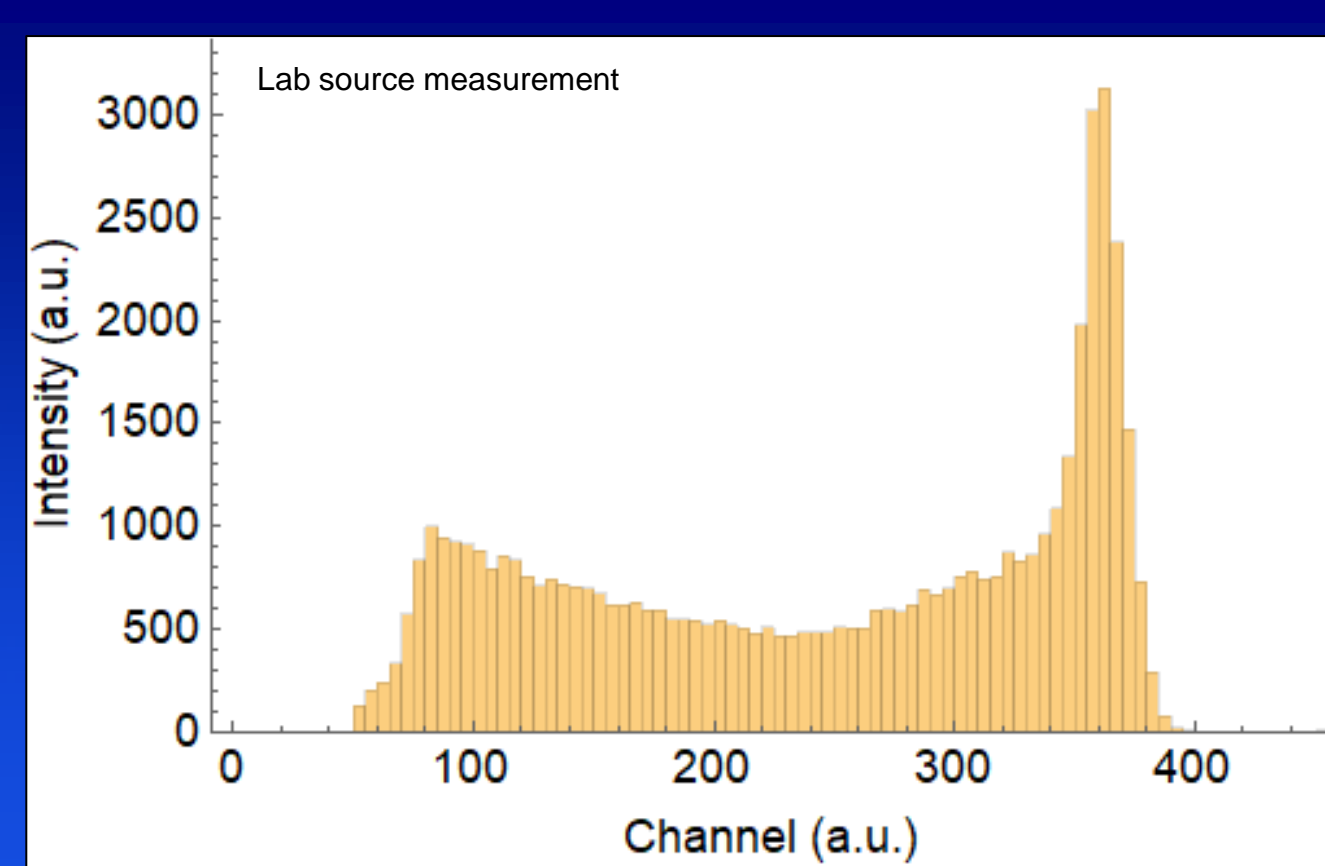Analog ouput and serial communication allows for read-out and control

Detector → Pulse Analyzer → High Voltage ← Power Supply

Slow Control & Data Processing

Sensor Units
Temperature	Humidity
Pressure	GPS

Communication and Data Units
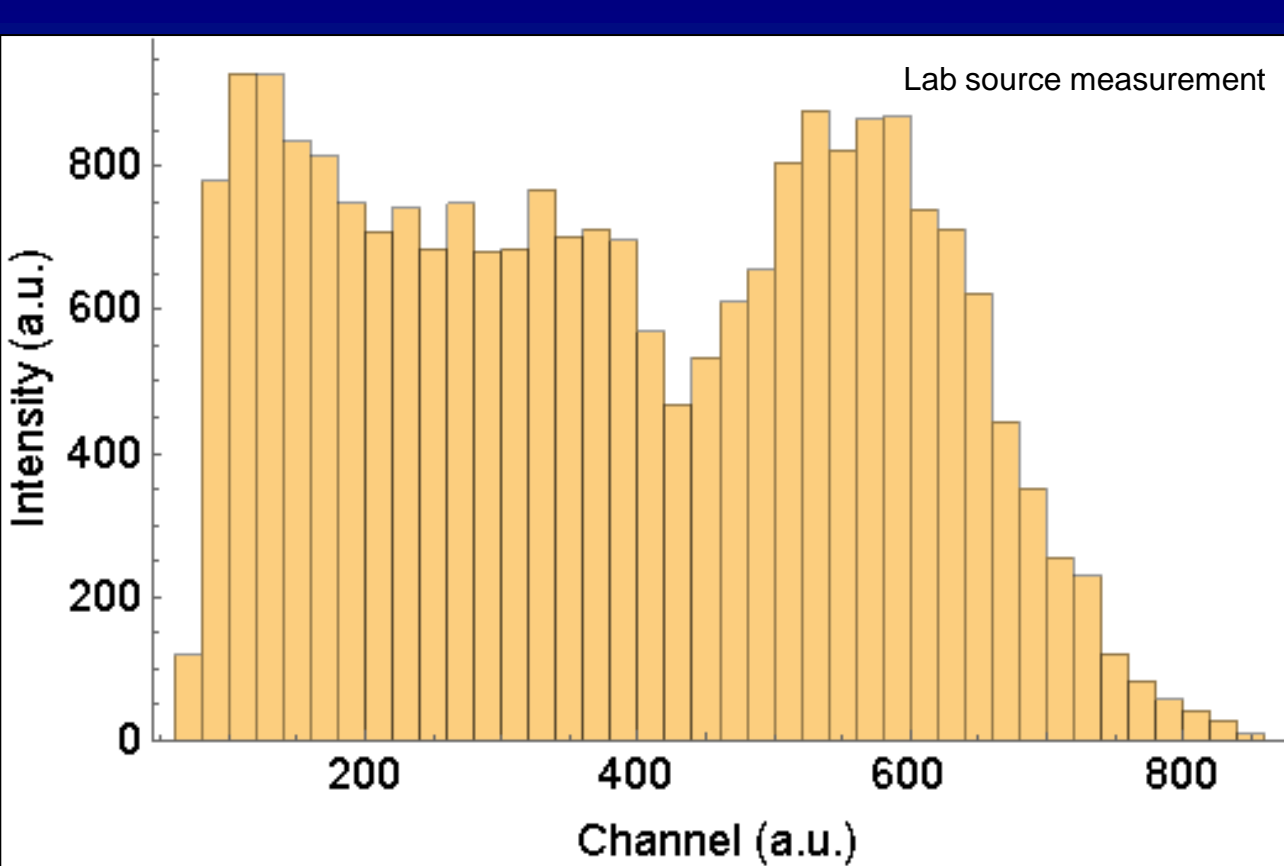| SD-Card (Flash)	WLAN
GSM	LoRaWan

(Arduino) microcontroller

Temperature- and long-term-stable

Arduino Studio

Usability for education: easy programming interface

```
// Pin 13 has an LED connected on most Arduino boards.
// give it a name:
int led = 13;

// the setup routine runs once when you press reset:
void setup() {
  // initialize the digital pin as an output.
  pinMode(led, OUTPUT);
}

// the loop routine runs over and over again forever:
void loop() {
  digitalWrite(led, HIGH);   // turn the LED on (HIGH is the voltage level)
  delay(1000);               // wait for a second
  digitalWrite(led, LOW);    // turn the LED off by making the voltage LOW
  delay(1000);               // wait for a second
}
```

Works for all microcontrollers

Electronics

Analog out

I2C Connector

Coincidence out & Comparator out

SiPM #1

SiPM #2

communication

Voltage supply

SiPM (HV) Input

SiPMTrigger board

Amplifier → Comparator → TTL → pulse width

threshold

SiPMs

Amplifier → Comparator → TTL → pulse width

WLS fibers Scintillator

thr.

dig. Potentiometer

Power supply

Microcontroller (Arduino)

SPI

SiPM Voltage supply

Data Taking Showcase

Lab source measurement

Pulse height spectrum of a 1-1.2 μm [10]B-coating

Lab source measurement

Pulse height spectrum of a 1.5 bar [3]He counter (Reuter Stokes)

Data logger for environmental variables like pressure, temperature, humidity or GPS coordinates

Koinzidenzspektrum
Dunkel
Position α_1
Position α_2
Position α_3
Position α_4
Position α_5

Pulse height spectrum of a wavelength shifting fibre + scintillator setup with an alpha source

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