JOHANNES GUTENBERG UNIVERSITÄT MAINZ

Self-Made Particle Detectors for High Schools and Universities

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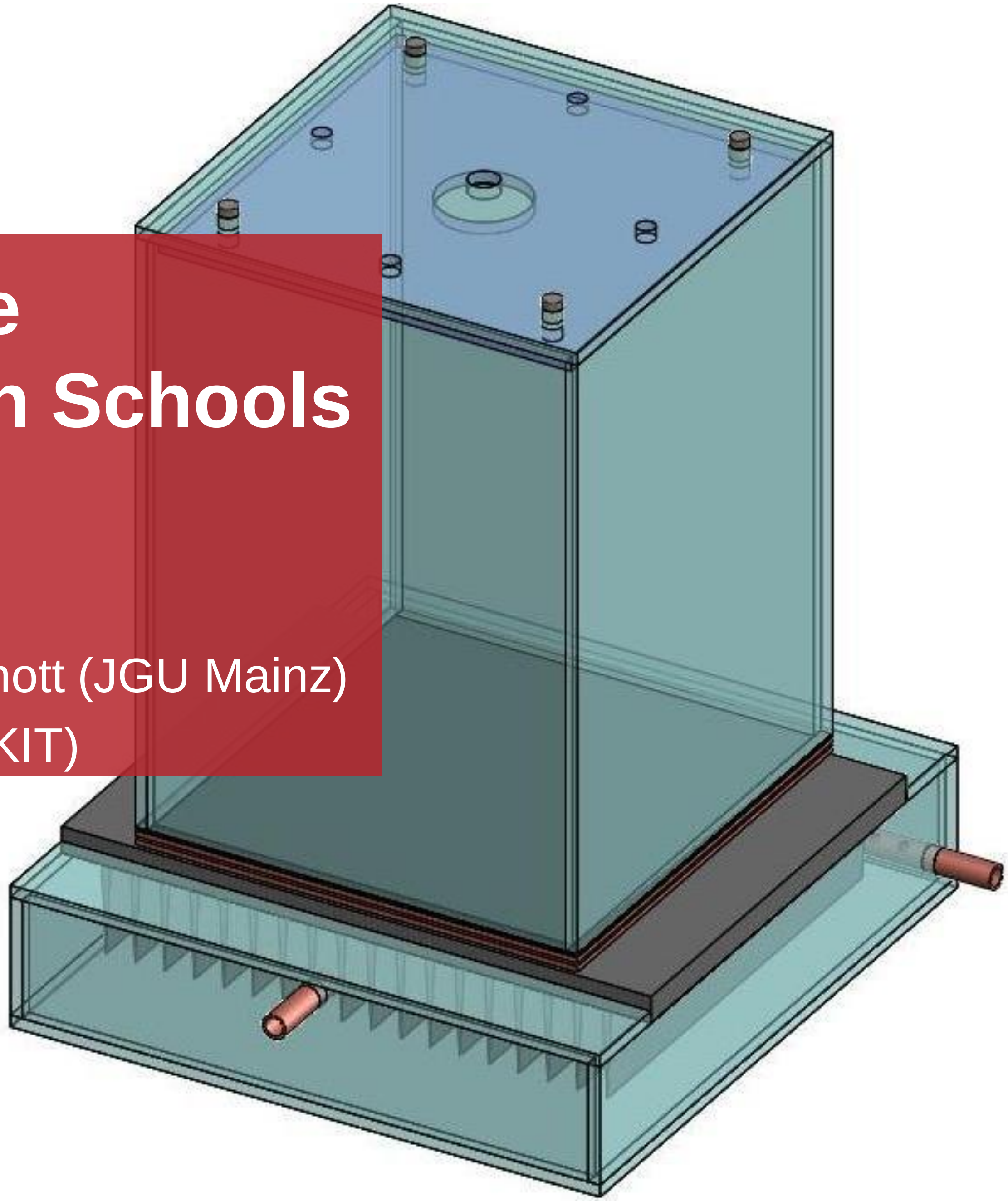

ACP 2018

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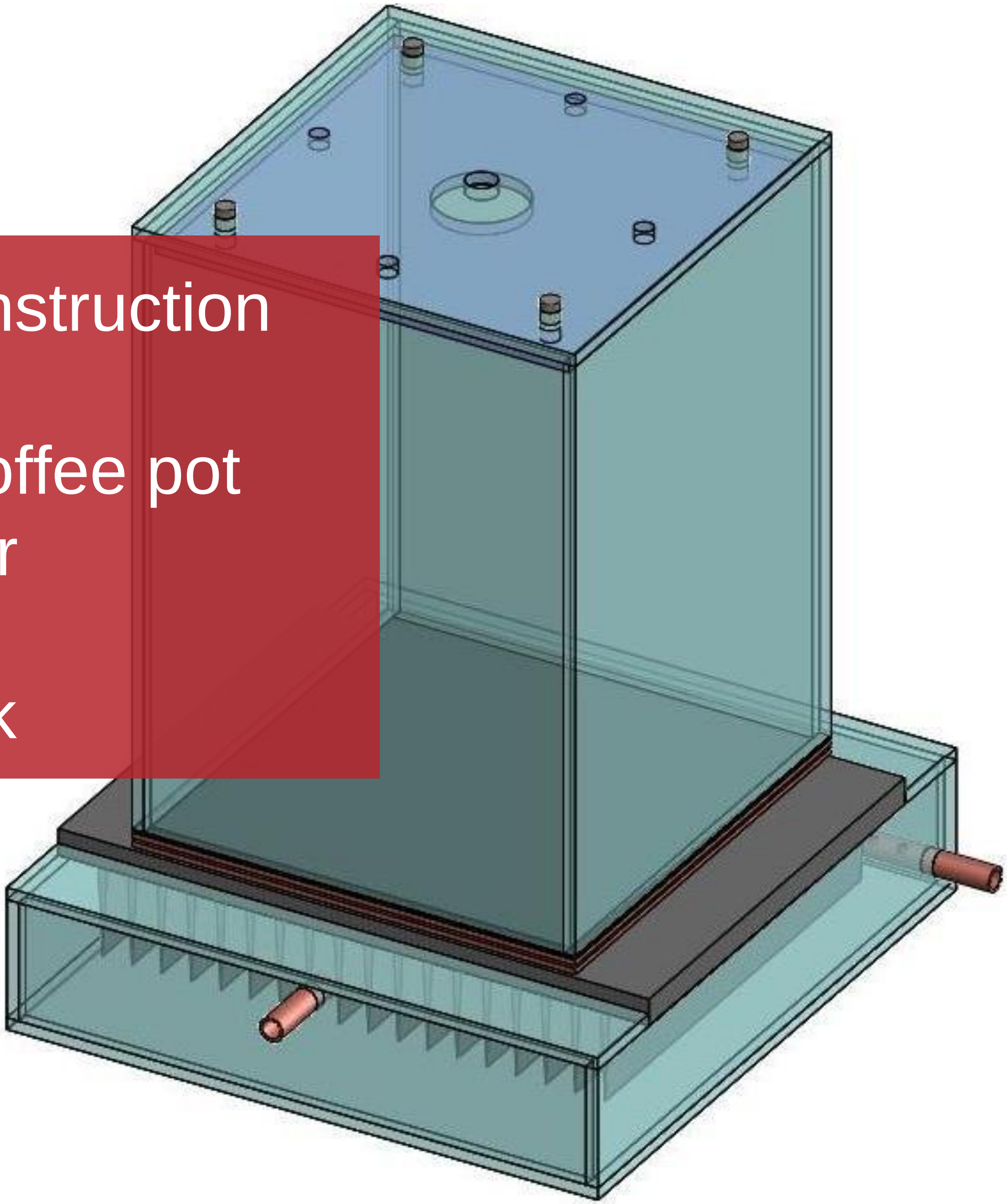
- Cloud chamber construction
- Kamiokanne – A coffee pot Cherenkov detector
- Readout framework

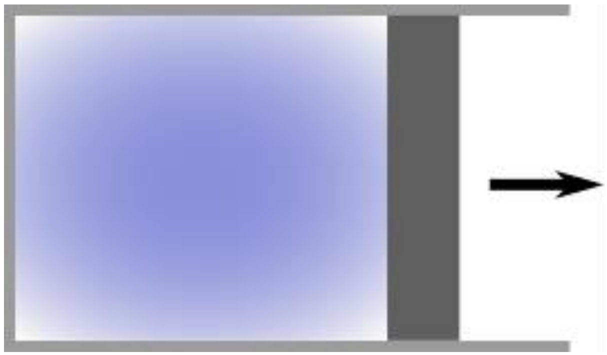


Cloud Chamber

Working principle

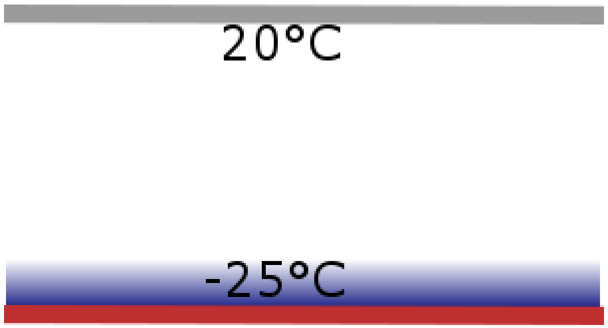
- Radiation ionizes a gas in an oversaturated condition
- Ions act as condensation nuclei for a cloud formation
  → chemtrails of airplanes

Expansion Cloud Chamber



- Oversaturation reached by volume expansion
- No continuous operation

Diffusion Cloud Chamber



- Oversaturation reached by temperature gradient
- Long and stable operation

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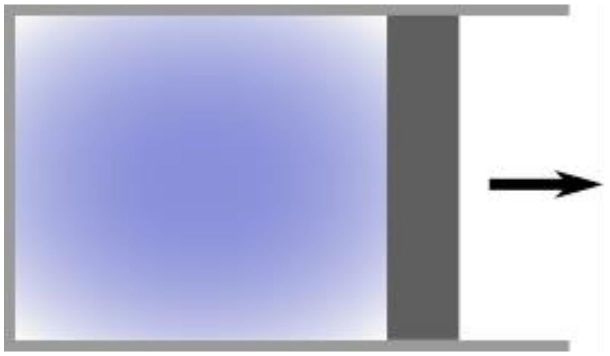

Diffusion Cloud Chamber

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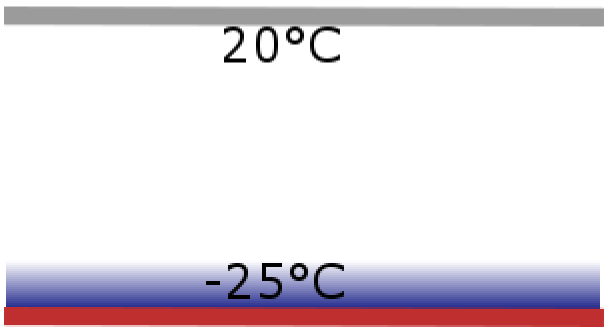
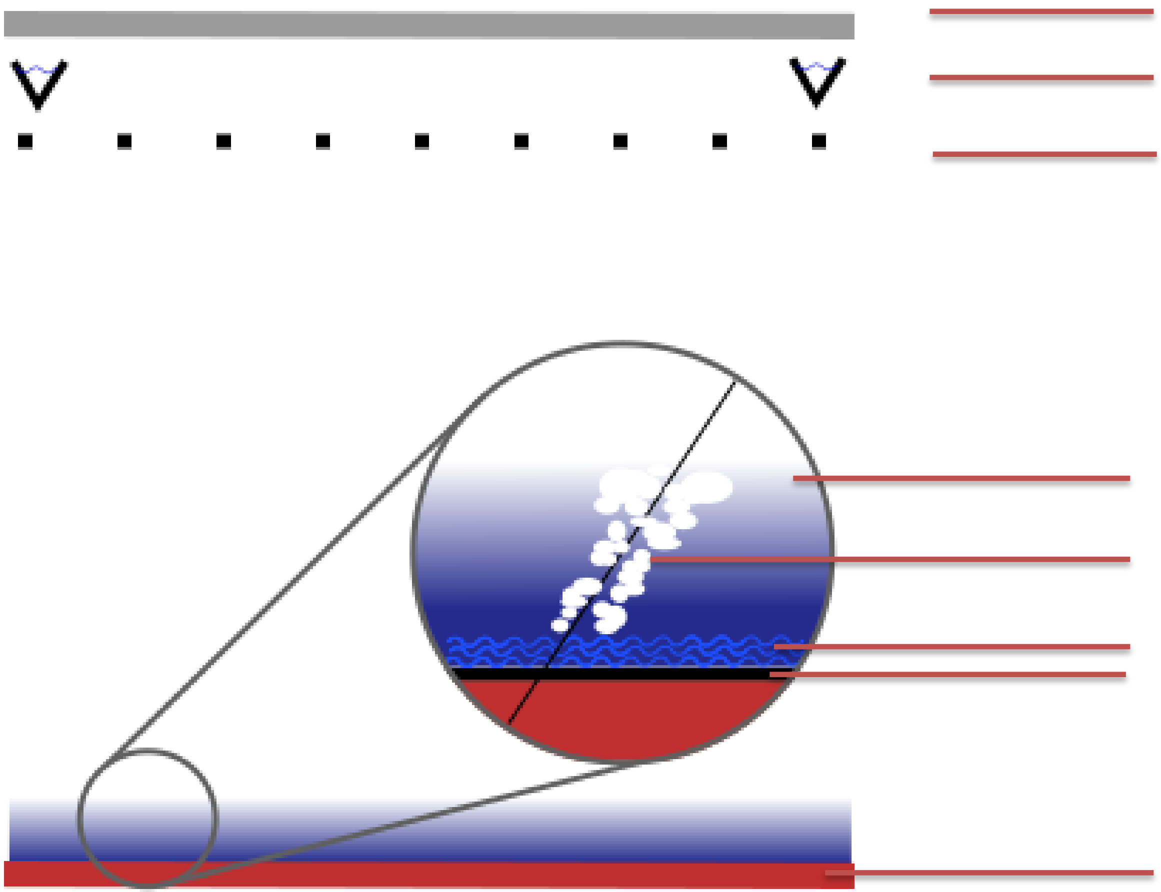


Diffusion Cloud Chamber



- Top (glass) cover
- Isopropanol reservoir
- HV for ion collection (not necessary)
- Oversaturated layer
- Droplet trace formation
- Liquid layer
- Black base plate for better contrast together with tangential light
- Cooling unit

$$\Delta T > 45°C$$

!!! **Thermal stable oversatured layer** !!!

→ uniform temperature distribution + tight enhousing

Cooling Technologies

Technology	Pro	Contra
Dry Ice Cooling	▪ Quick to build ▪ Little material effort	▪ Dry ice not easily available ▪ Limited operation time
Peltier Cooling	▪ Long operation time ▪ Peltier easy to buy and safe to handle	▪ Heat transfer from Peltier elements necessary
Refrigerating Compressor Cooling	▪ Long operation time	▪ Compressor technology has to be bought as is

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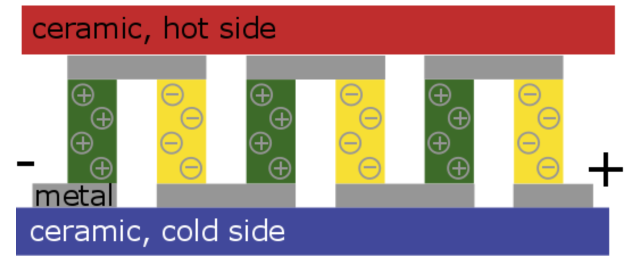
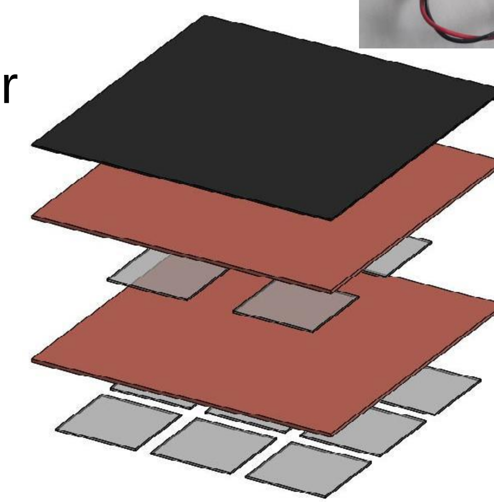
Peltier Characteristics

- Peltier under study (choosen by cost and easy purchase): TEC1-12706
- Size: $40 \cdot 40\ mm^2$



- Theoretical cooling capability: $\Delta T = 75$ K
- Measured cooling capability: $\Delta T = 43$ K
- Limited by heat transport from the downside
- → double layer of Peltier elements necessary for $\Delta T > 45\ K$ for cloud chamber operation
- $12\ V$ supply voltage for lower layer, $5\ V$ for upper layer
- Active area: $150 \cdot 150\ mm^2$ with in total 13 Peltier



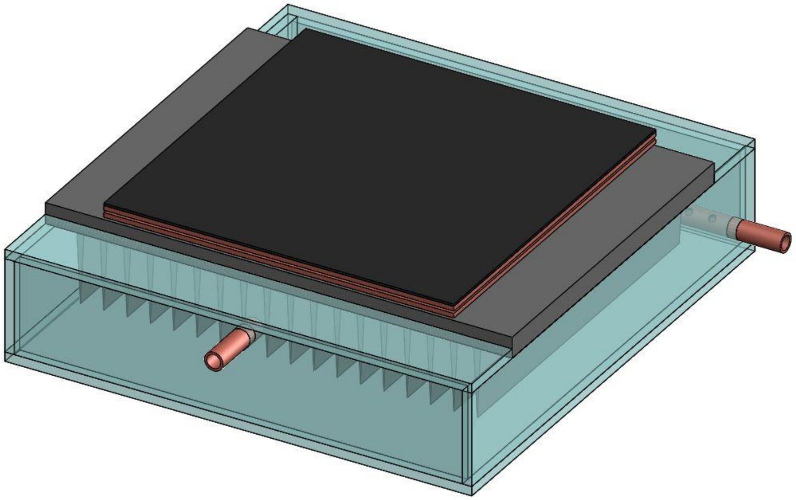
- Uniformity of the Peltier element: $\pm 3\ K$
- $2\ mm$ copper plates used to uniform temperature distribution
- Temperature coupling with generous spread thermal paste

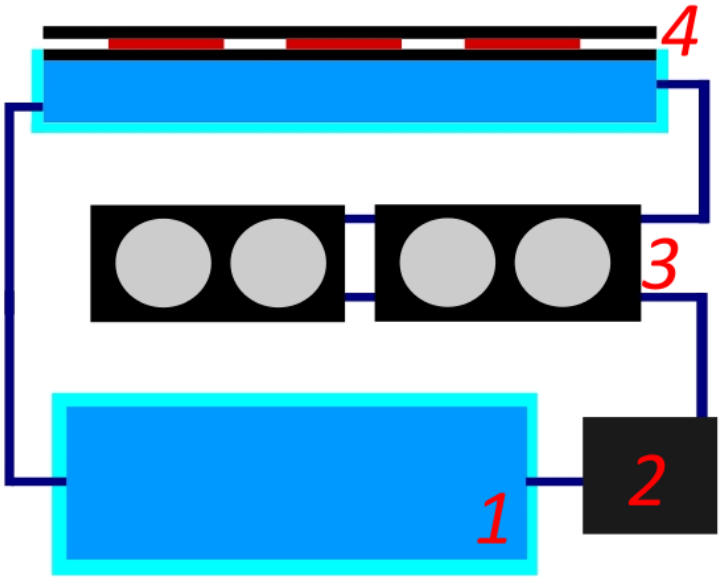
Cooling unit

- Heat transport from the downside of the Peltier sandwich by water cooling
- Couple Peltire to heat sink with cooling rib in water basin

- Water either continuously flushed to sink or cooling circuit
- Circuit be implemented with standard computer cooling supply

- Pump (2) transports water from big reservoir (1) through radiators (3) to the water basin under the Peltier elements (4)
- !!! Stable gluing of the basin needed since water is under pressure !!!

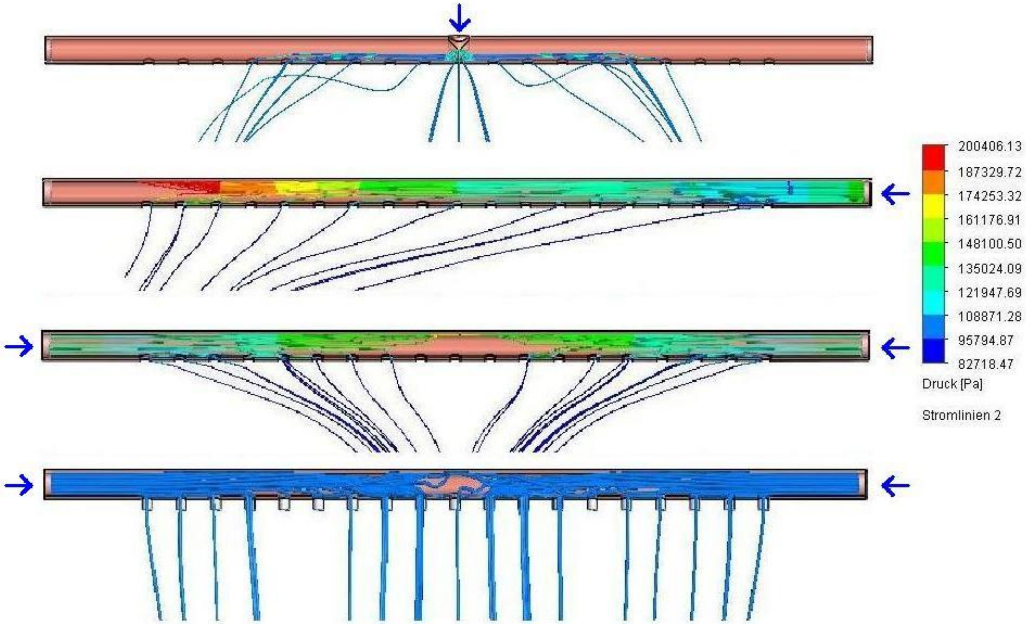


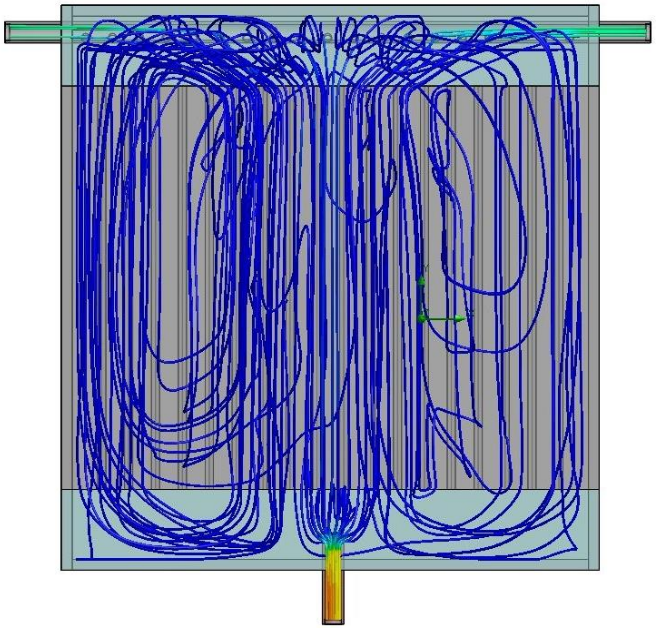


Heat sink studies

- Some physics fun during construction: Simulation of the water flow in the basin under the Peltier elements

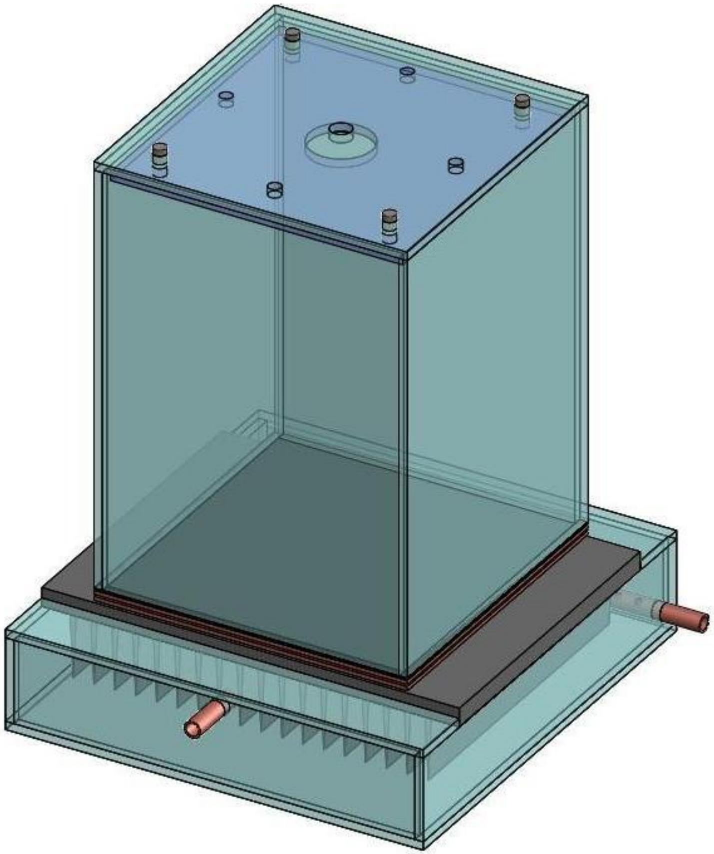
- Several studies like thermal calculations of the water cooling circuit or the air cooling of the power supplies, electrical power consumption or vapour formation make it more than a pure ‚mechanical' tasks



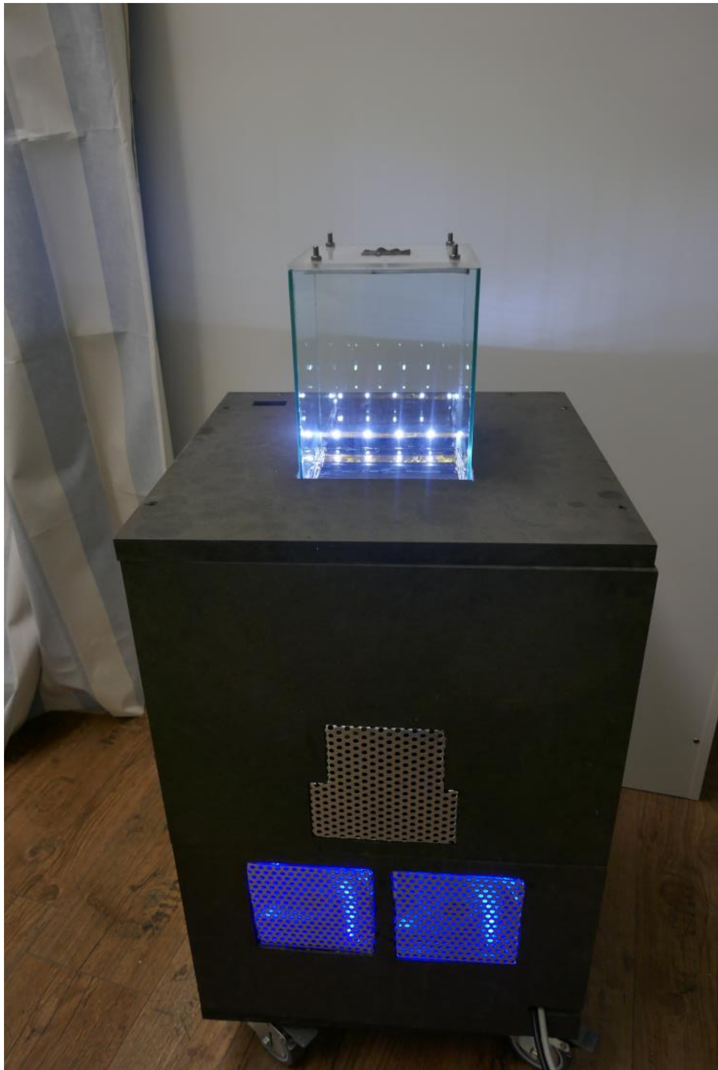


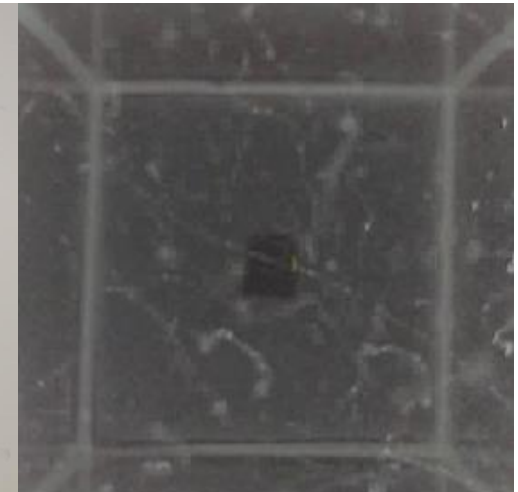
Total layout

- Isopropanol reservoir in a vlies tissue under the top cover
- Illumination with LED band around the cooling plate
- Powered by computer power supplies
  - Separate power supply for the Peltiers due to large consumption and to operate water cooling independently
- Whole setup hosted in moveable cabinet



Final Cloud chamber





Cost estimation

Peltier elements (10)	30 USD	Basic cloud chamber **165 USD**
Power supply	60 USD	
Copper plates (2)	40 USD	
Plexiglas for hood	10 USD	
Cooling rips	25 USD	
Thermal paste	20 USD	

Power supply	35 USD	Water cooling circuit 180 USD
Radiator (2)	90 USD	
Pump	45 USD	

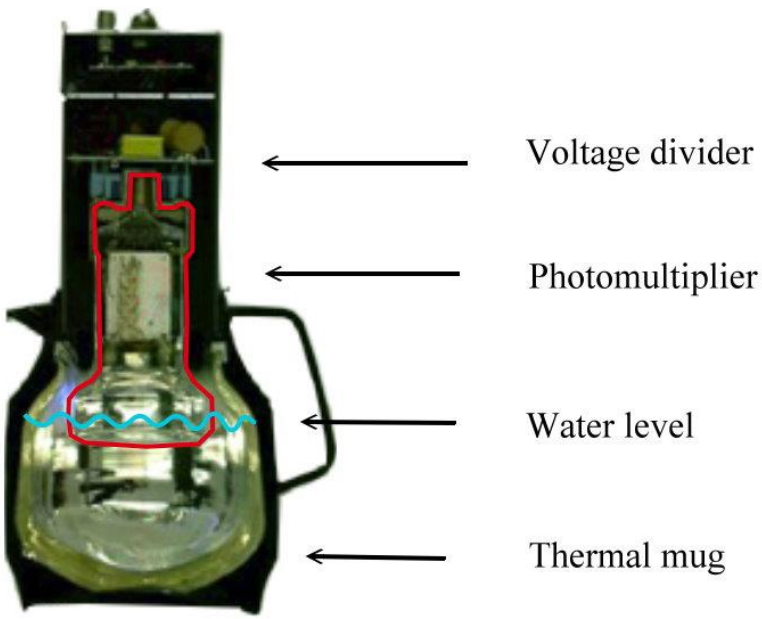
Kamiokanne

Kamiokanne detector

- Water Cherenkov detector in a coffee can (German: ‚Kanne‘)

- Photomultipier coupled to a water filled thermal can
- Traversing cosmic muons create Cherenkov light in the water

- Developed 1997 at JGU Mainz, until then in use for student courses and school outreach at several German universities



Measurements and Outlook

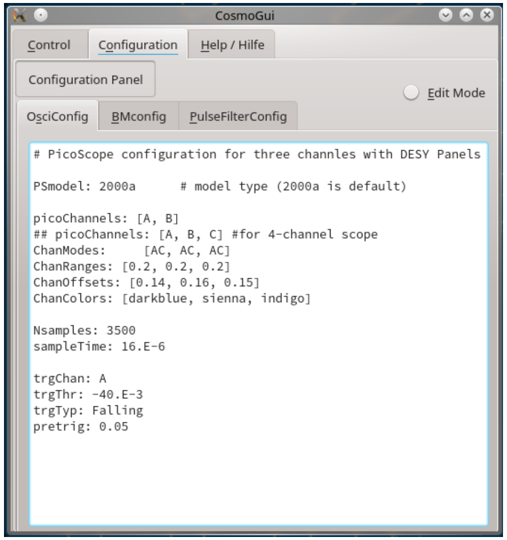
- Possible Measurements
  - Count rates at different heights and with different absorbers
  - Concept of dark count (can without water)
  - Signal / noise ratio estimation
  - Muon lifetime by with muons decaying in the water → double pulse
  - ….

- Outlook
  - HV needed for the PMT gives legal issues in the usage with school students
  - Readout with a PMT with integrated HV generation
  - Readout with a SiPM and light guiding fibers under development

Readout framework

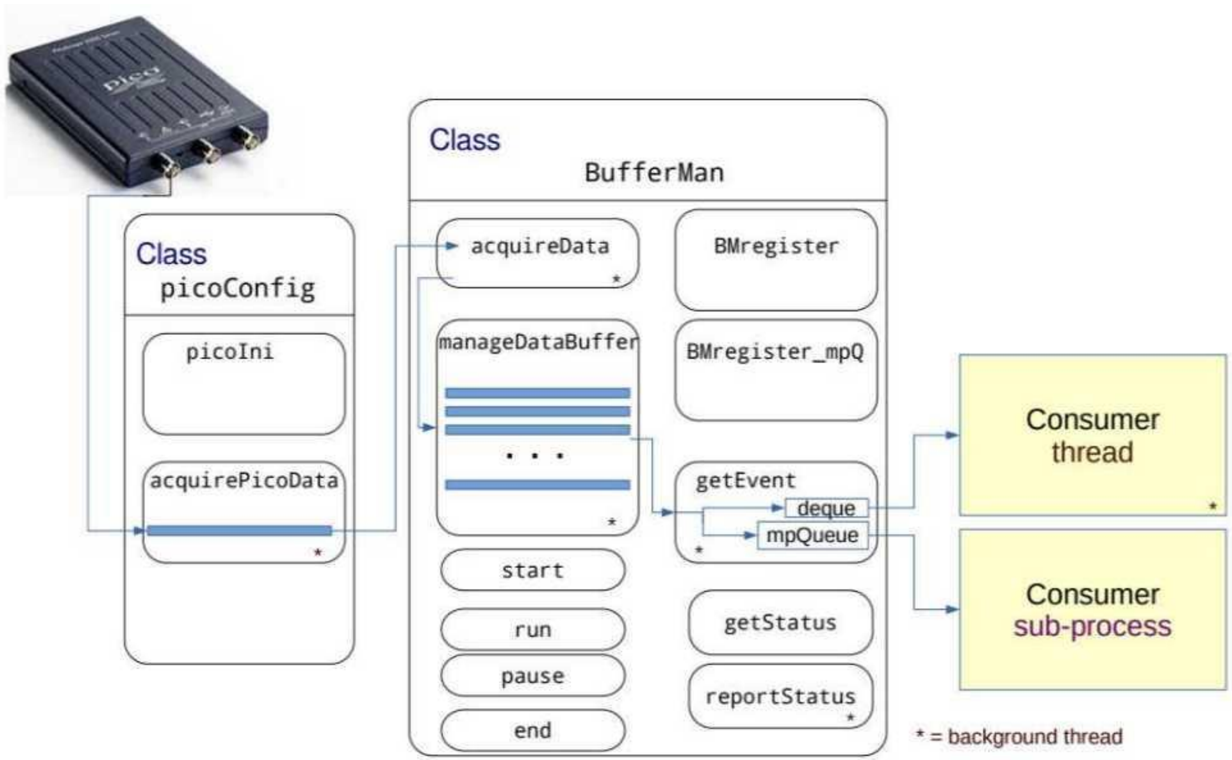
Concept

- Readout with an USB oscilloscope (PicoScope) and DAQ software at the computer (e.g. RaspberryPi)
- Implements the modern data taking approach with early stage digitization
- Concept of an oscilloscope is also well known to school students
  no „black box“ DAQ
- Small setup with ‚cheap‘ components
- Flexible through own readout program

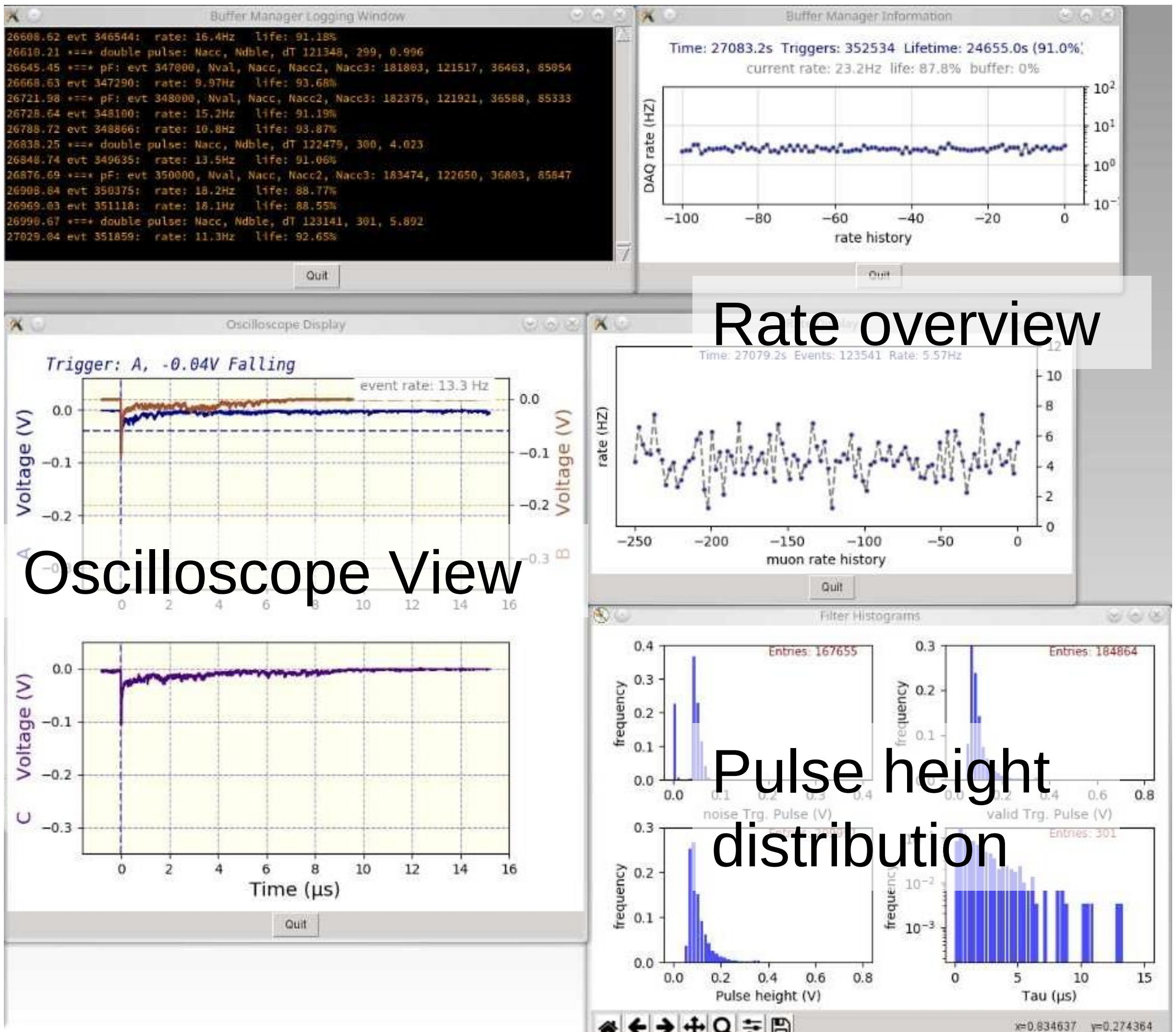


Code development

- Python framework developed by Günter Quast and Lars Vielsack (https://github.com/GuenterQuast)
- Implements a buffer manager and correlation function for trigger pulses with reference pulses
- Double pulse trigger possible

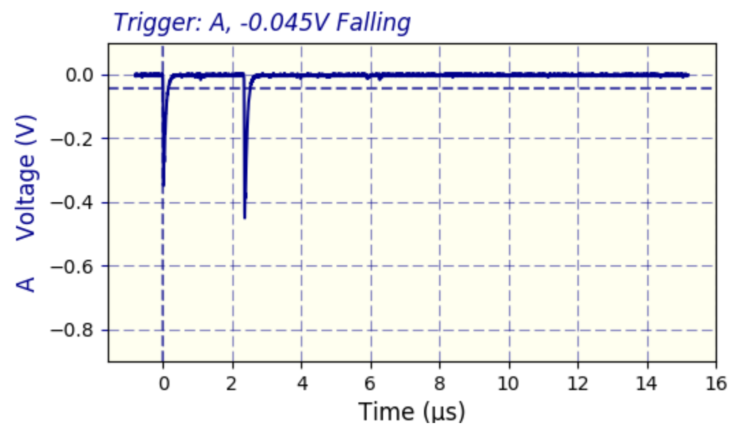


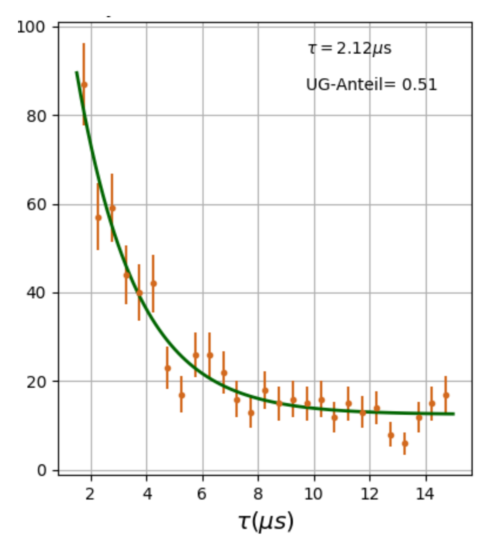
User interface

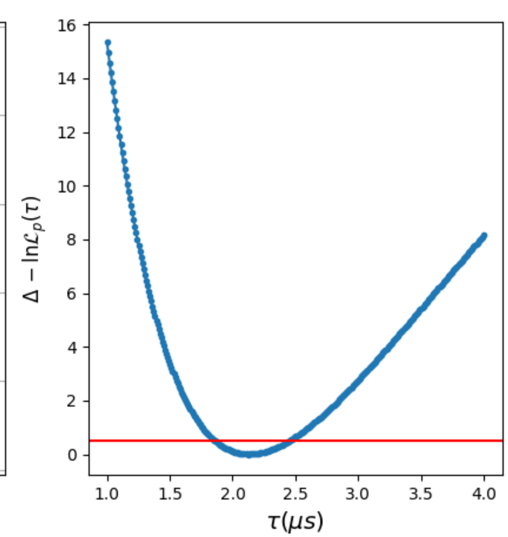


Example study

- Measurement of the muon life time with the Kamiokanne
- 20 days data taking
- $\tau = 2.1 \ \pm 0.3 \ \mu s$







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Summary

- Cloud chamber as a cheap self build particle detector
- Water Cherenkov detector Kamiokanne
- Custom python readout framework for USB oscilloscope