



David Mchedlishvili
(HEPI / SMART|EDM_lab, TSU)

Experimental Development for Medicine

GGSB 2026



Overview

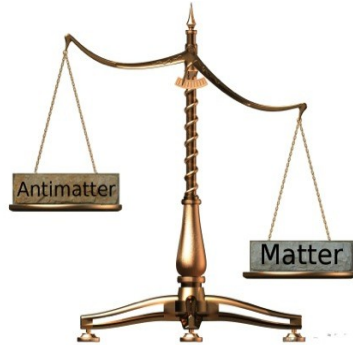
- Introduction
- Past and present objectives
- Instruments and methods
- Measurements at INM-5
- Observations and systematic effects
- Future plans

SMART|EDM_lab opening in 2016



Strong cooperation with JEDI collaboration

Science case: *Baryon asymmetry in the Universe*


$$\eta = \frac{N_B - N_{\bar{B}}}{N_\gamma} \approx \begin{cases} 10^{-10} & \text{(measured)} \\ 10^{-18} & \text{(SCM prediction)} \end{cases}$$

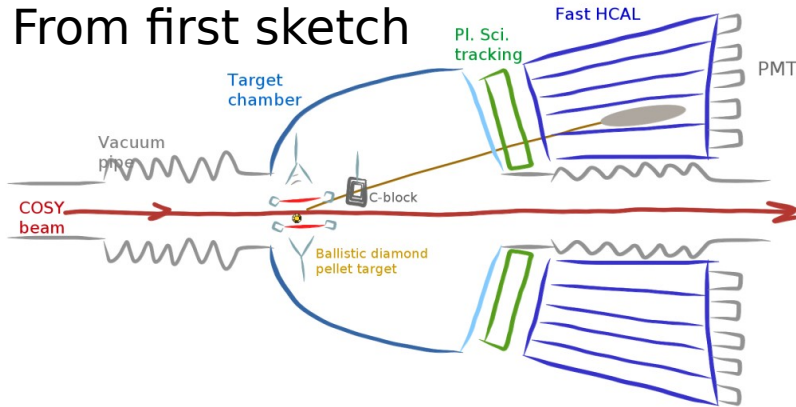
Answer may be hidden in CP symmetry.
EDMs?

Topics:

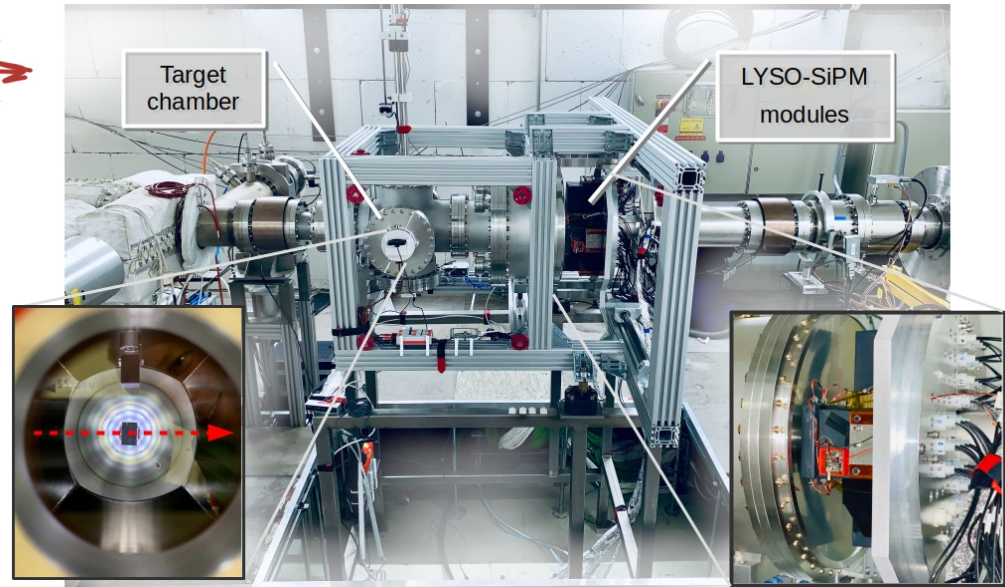
- Polarimeter detector assembly
- Multi-channel modular power supply
- DAQ and online monitoring software

JEDI Polarimeter (JePo)

From first sketch



To fully operational
detector system





Change of focus

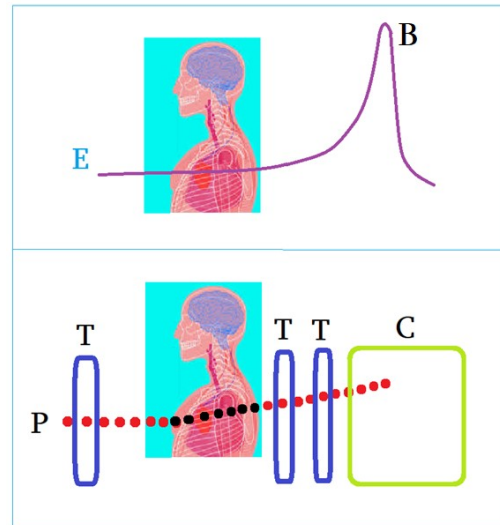
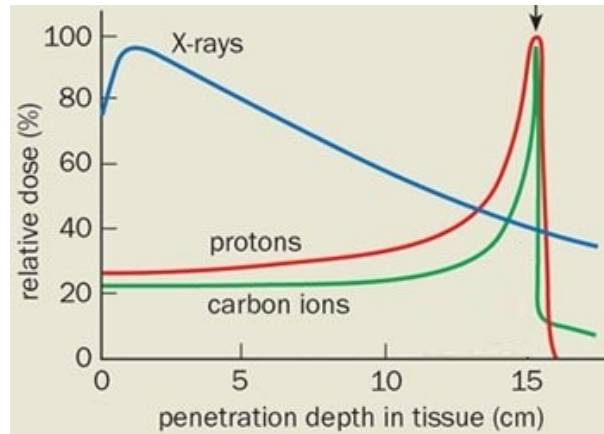
From **E**lectric **D**ipole **M**oments ...

... to **E**xperimental **D**evelopment for **M**edicine

SRNSFG STEM project

“Low-energy calorimeter for hadronic tomography. Creation and mathematical modeling of a test physical detector”

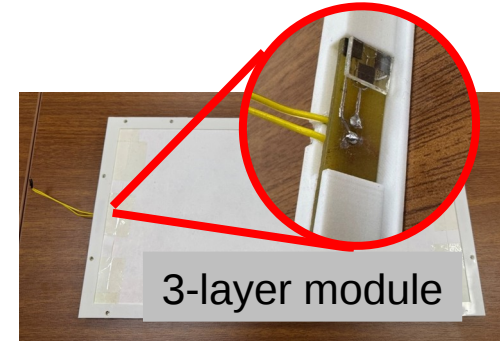
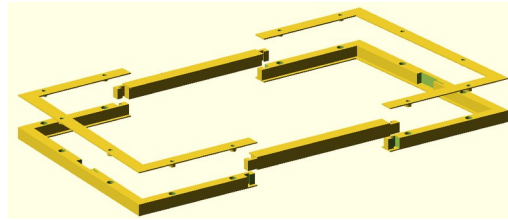
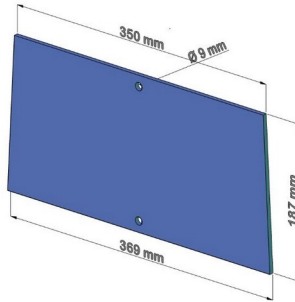
Bragg peak



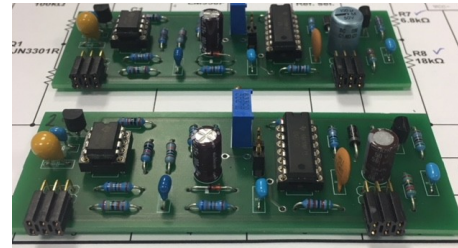
- Can be used to determine treatment maps;
- These maps can be adjusted in online mode, during the treatment irradiation;
- Optimizing and monitoring the treatment process, with minimal harm to the patient.

Recent developments

- SiPM-based modular calorimeter

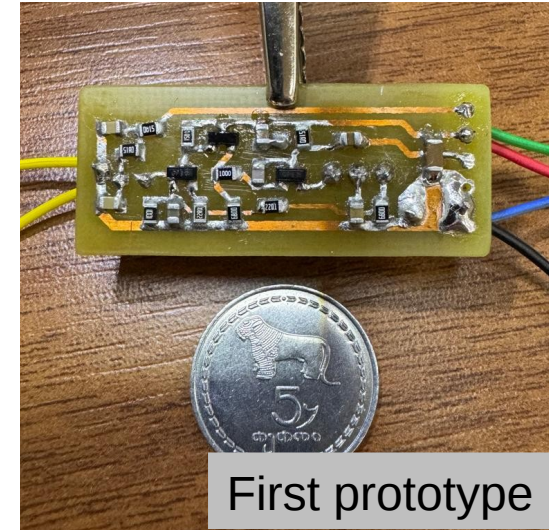
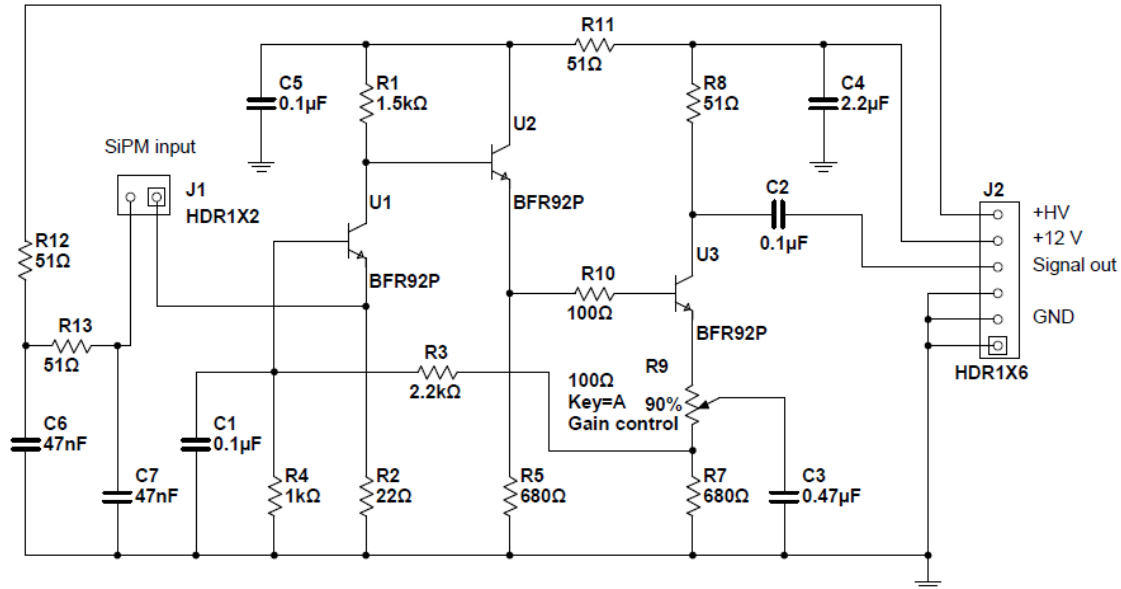


- Power supplies for low and high voltage SiPMs
(see talks by Salome Tvauri
and Nikoloz Khalichava)



Recent developments (continued)

- BJT-based preamplifier for fast SiPM signals (trans-impedance mode)

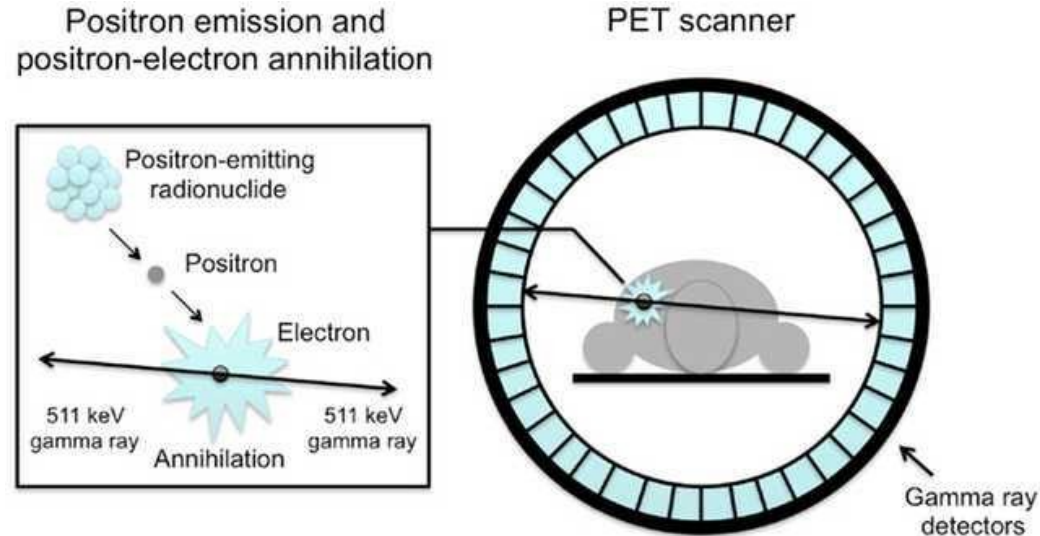


First prototype

Measured gain: 1.25 V/mA

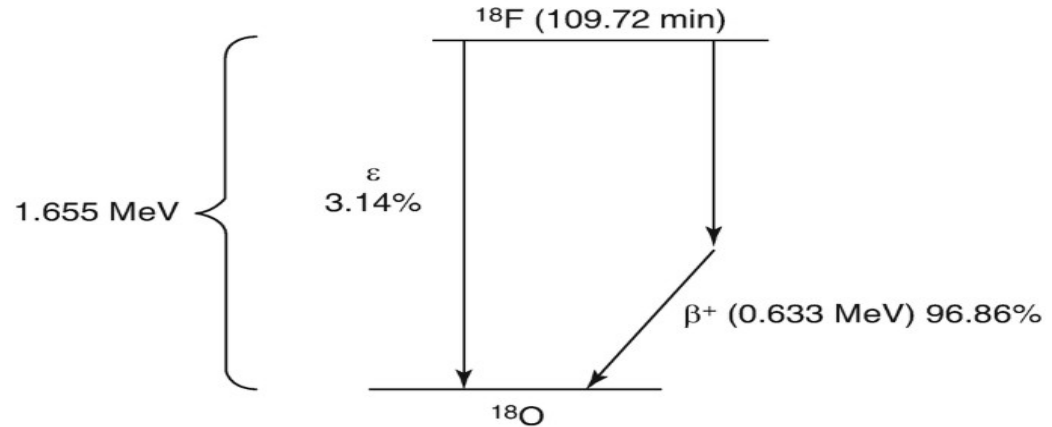
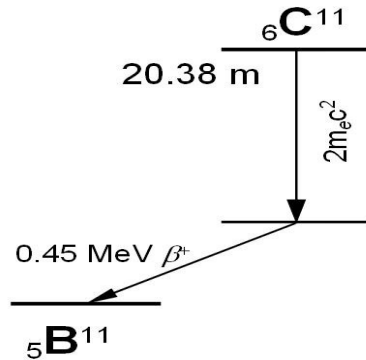
PET (Positron Emission Tomography)

- Small amount of radioactive substance (radiotracer) is injected in the patient's body;
- $e^+ + e^- \rightarrow \gamma + \gamma$ reaction measured by the detector;
- 3D image reconstruction visualizes metabolic processes.



Radiotracers

- Standard: ^{11}C ($T_{1/2}=20.4\text{min}$), ^{15}O ($T_{1/2}=2\text{min}$), ^{18}F ($T_{1/2}=1.83\text{h}$), ...;
- Non-standard: ^{45}Ti ($T_{1/2}=3.08\text{h}$), ^{73}Se ($T_{1/2}=7.15\text{h}$), ^{72}As ($T_{1/2}=26\text{h}$), ...



The main objective

Setup the experimental facility to measure β^+ decay rates of different radionuclides (^{45}Ti , ^{22}Na , ...) and/or study β^+ intensities

Related studies:

DE GRUYTER

Radiochim. Acta 2015; 103(6): 403–409

Sebastian Kuhn, Ingo Spahn, Bernhard Scholten, and Heinz H. Coenen*

Positron and γ -ray intensities in the decay of ^{45}Ti

DE GRUYTER

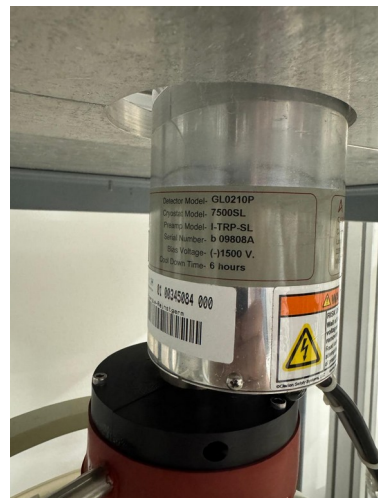
Radiochim. Acta 2025; 113(8): 601–609

Mazhar Hussain*, Lucas Mues genannt Koers, Ingo Spahn*, Stefan Spellerberg, Bernd Neumaier and Syed M. Qaim

Positron emission intensity in the decay of ^{72}As for use in PET studies

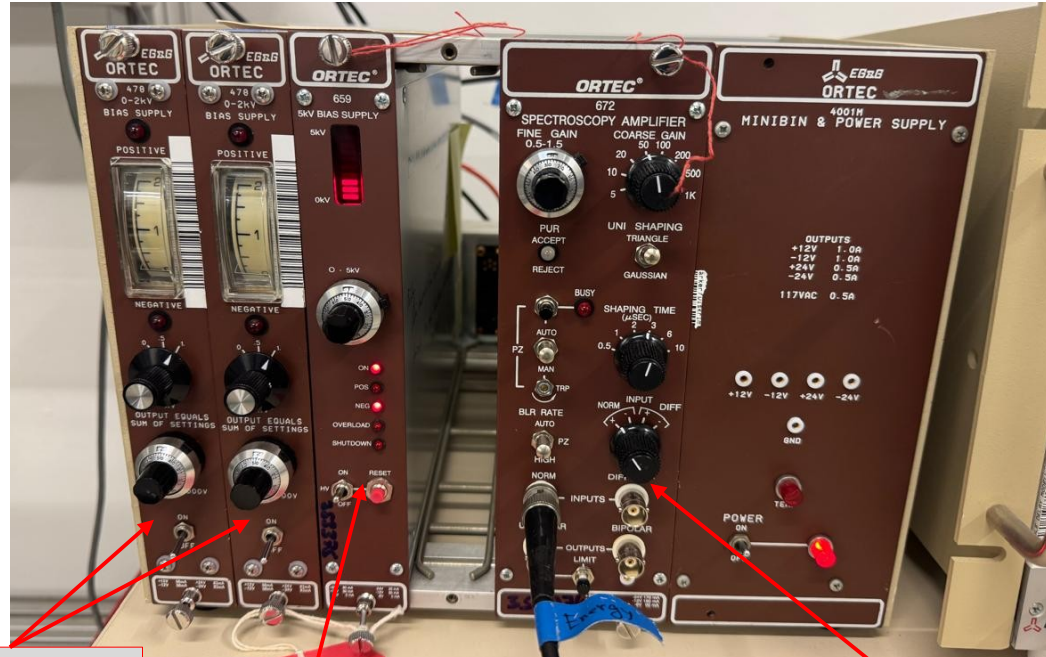
Detectors used

HPGe – Excellent energy resolution to check/control the impurities in samples. Mainly used for X-ray spectroscopy.



NaI(Tl)+PMT assembly – Excellent γ detection efficiency, good timing for employing γ - γ coincidence technique.

Electronics (*the old way*)

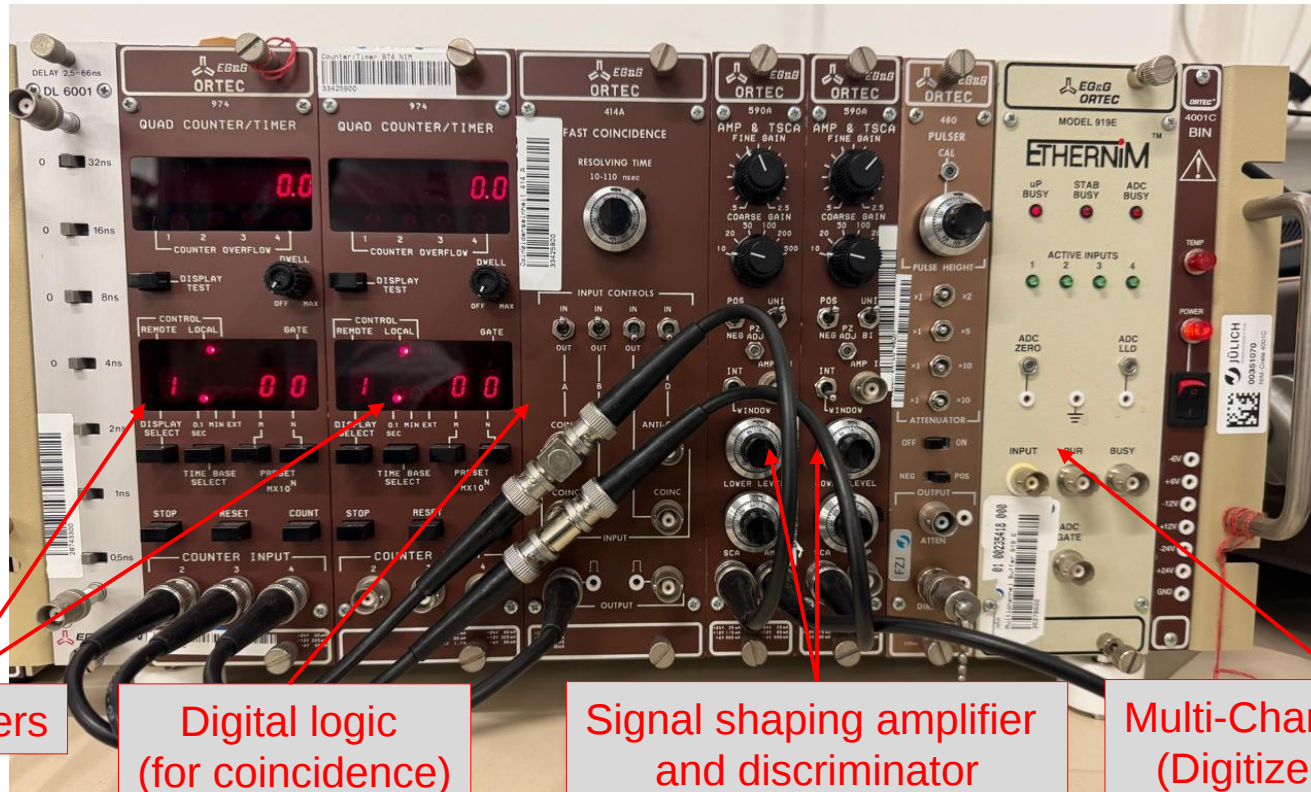


HV for PMTs

HV for HPGe

Signal shaping amplifier
for HPGe

Electronics (the old way)



Counters

Digital logic
(for coincidence)

Signal shaping amplifier
and discriminator

Multi-Channel analyser
(Digitizer, SAR type)

SADC vs SAR (successive approximation)

SAR: Measures only the peak amplitude in the signal. i.e. No shape, no integral (charge), bad timing. Conversion takes n steps for n -bit conversion (12 bit in our case, takes $\sim 15 \mu\text{s}$).

SADC: Samples signals. Acquires signal shapes. i.e. integral (charge), fast timing, conversion times in nanoseconds. Built-in hardware functions (like coincidence) for real time processing. Very flexible in configuration.

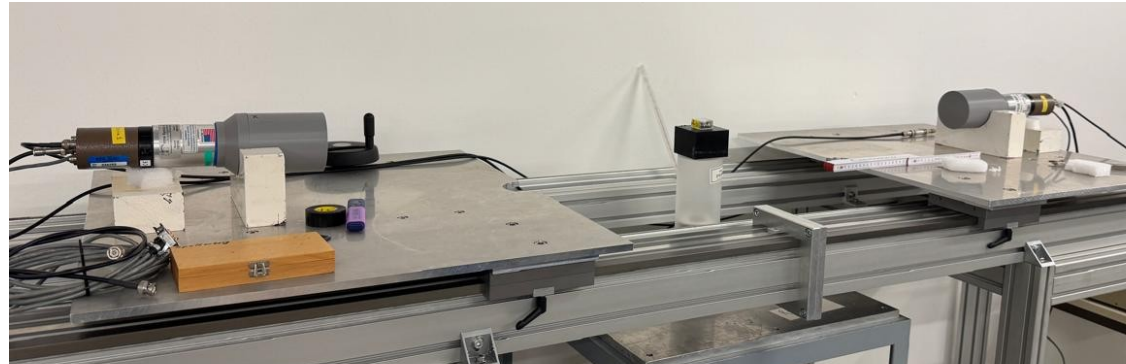
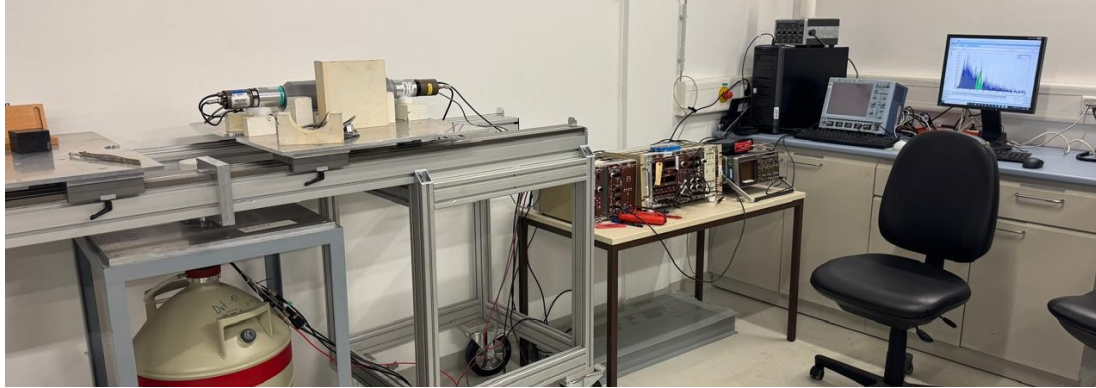
Better approach (*modern way*)



CAEN DT5720B (*provided by Dachi*):

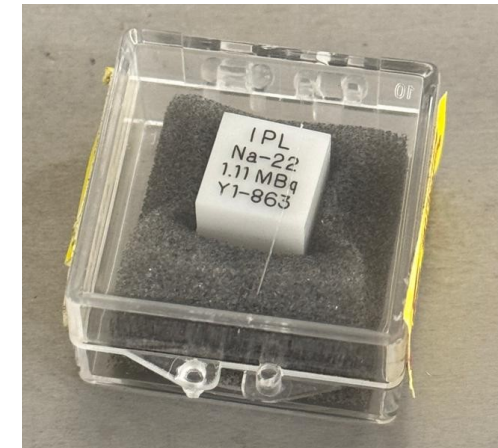
- Main: 4 ch, 12 bit, 250 MSPS (all channels converted in parallel)
- Inputs: 2 V_{pp} full scale
- Software: CoMPASS by CAEN (free)

Experimental setup

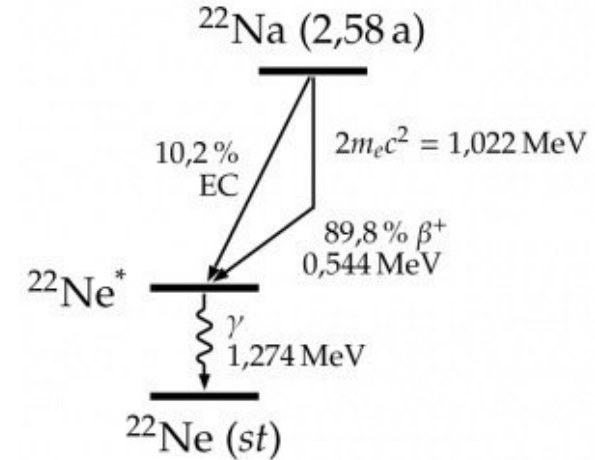
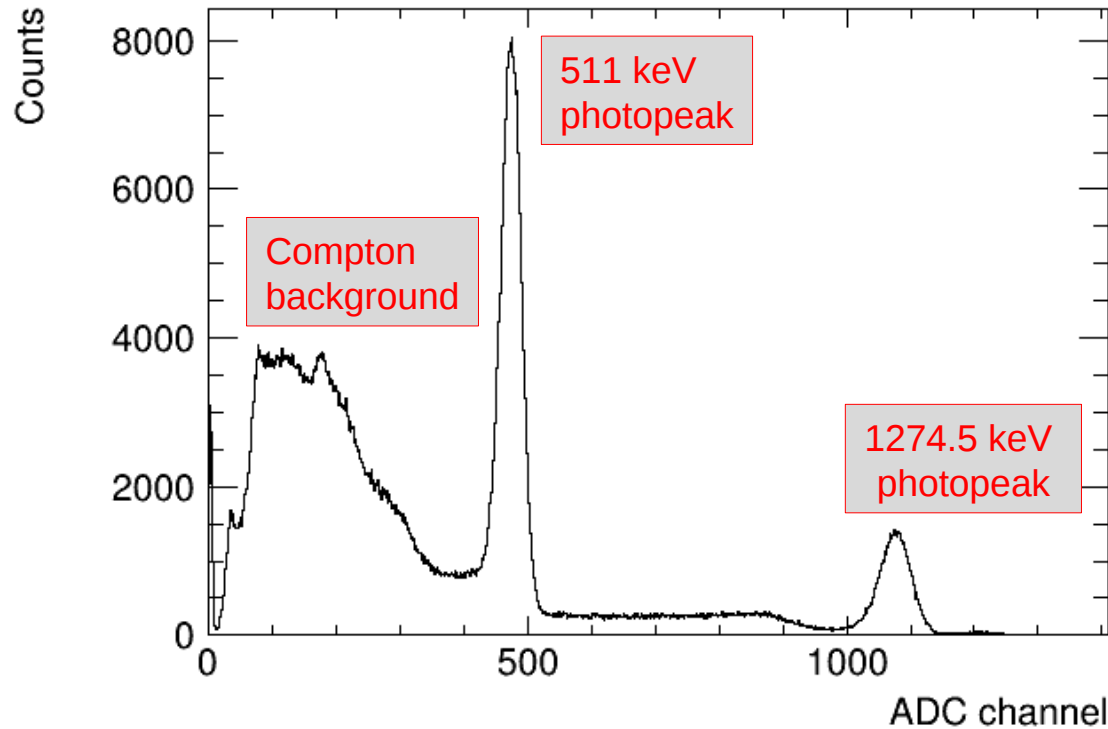


Measurements

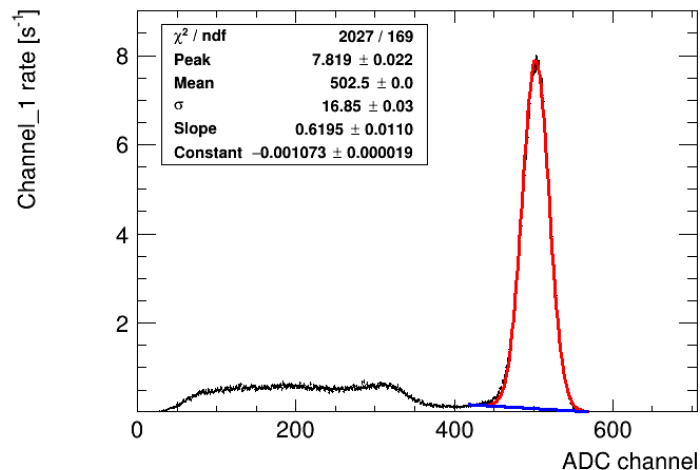
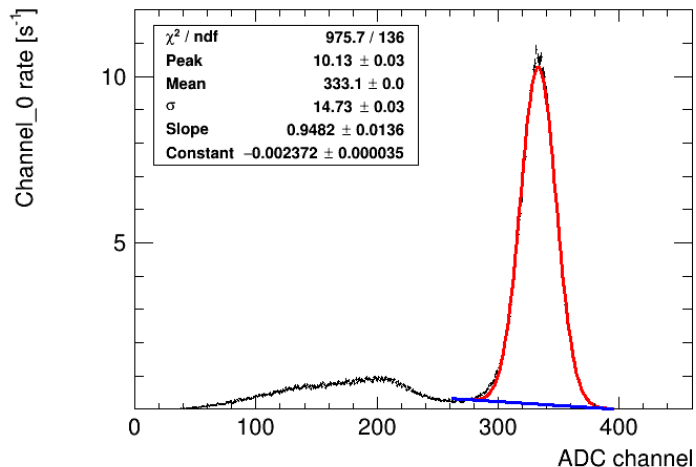
Radioactive sources used: ^{137}Cs , ^{60}Co , ^{22}Na , ^{18}F



^{22}Na spectrum



γ - γ coincidence with ^{22}Na



Recorded rate: 515 cps (full distributions taken)

Produced β^+ rate: 668 kcps

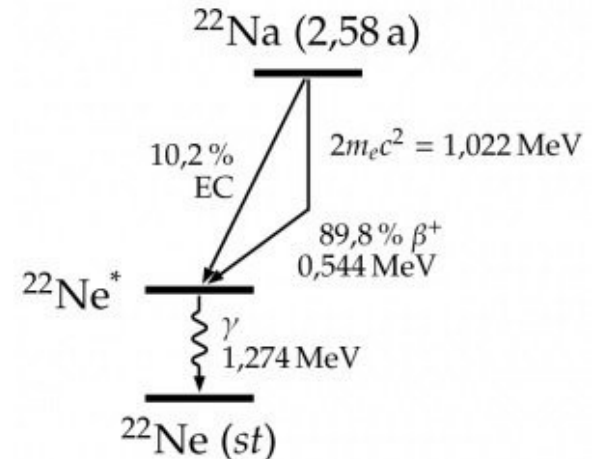
Total activity: 744 kBq

Documented activity of the source: 762.5 kBq (Provided by Ingo, 17.07.2026)

γ - γ coincidence with ^{22}Na

Correction factors:

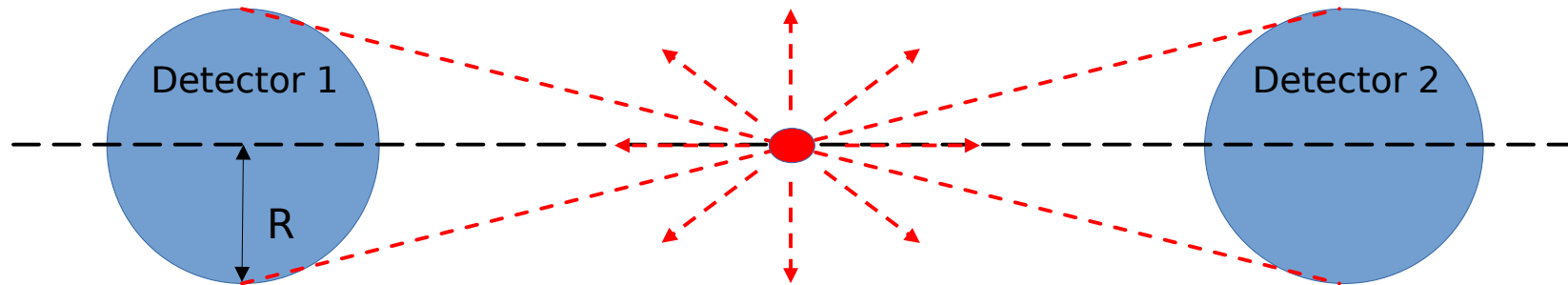
- Geometrical acceptance: 9.1×10^{-4} (*assuming point-like source and ideal source placement in the center*)
- Intrinsic γ -detection efficiency of NaI: $\cong 0.85$ (from literature)
- β^+ decay probability of ^{22}Na : 89.8% (from literature)



Geometrical acceptance

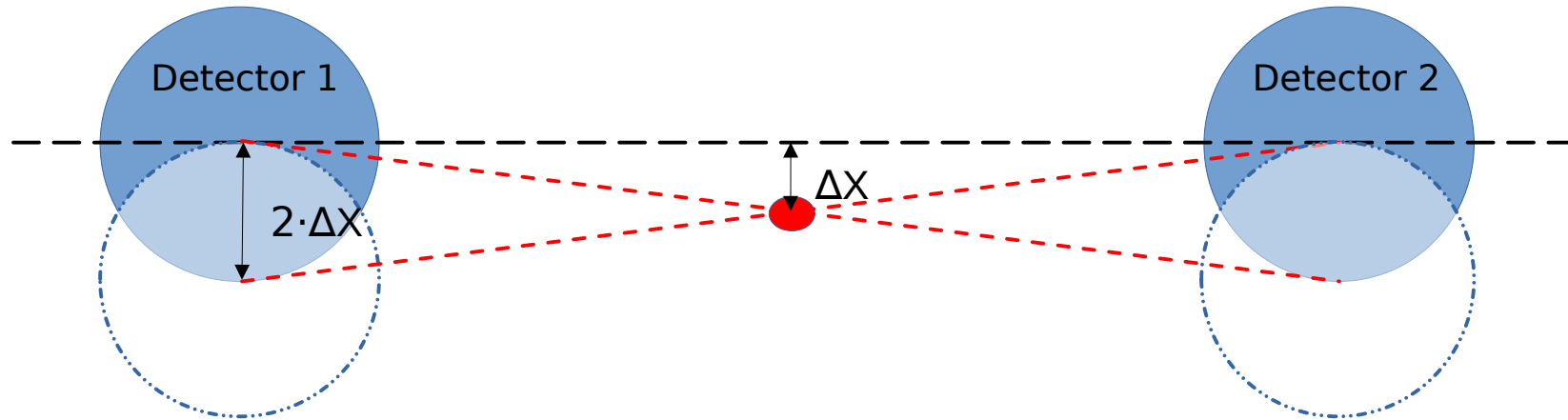
Only a small portion of produced gammas is covered by the detector

$$\varepsilon = \frac{R^2}{4 D^2}$$



Geometrical acceptance

- Only a small portion of produced gammas is covered;
- Any displacement of the source from the center strongly reduces acceptance



Intrinsic γ -detection efficiency of NaI

d: distance between source and the detector – 67 cm;

R: radius of the cylindrical detector – 4 cm

d/R: 16.75

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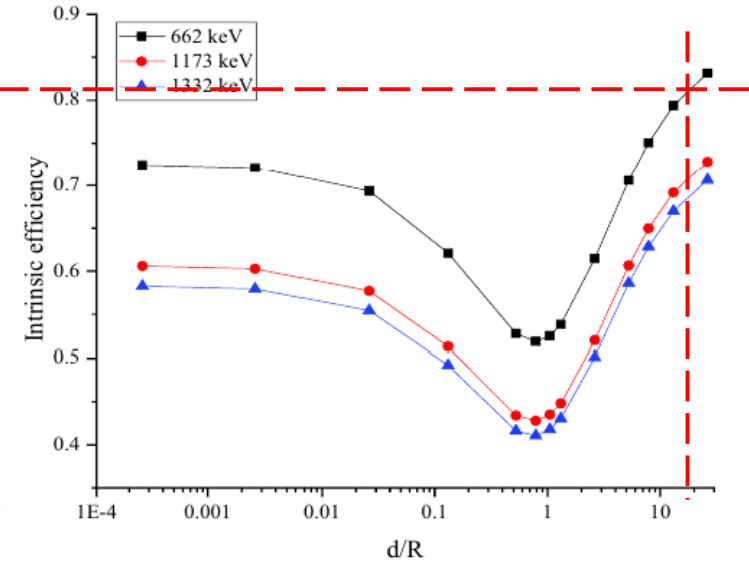
International Journal of
Science, Architecture, Technology and Environment

Calculation of Intrinsic and Absolute Efficiency of a NaI(Tl) Detector Using an Analytical Method

Pham Dang Quyet^{1*}, Trinh Thi Tu Anh², Pham Xuan Hai¹

09/08/2026

David Mchedlishvili

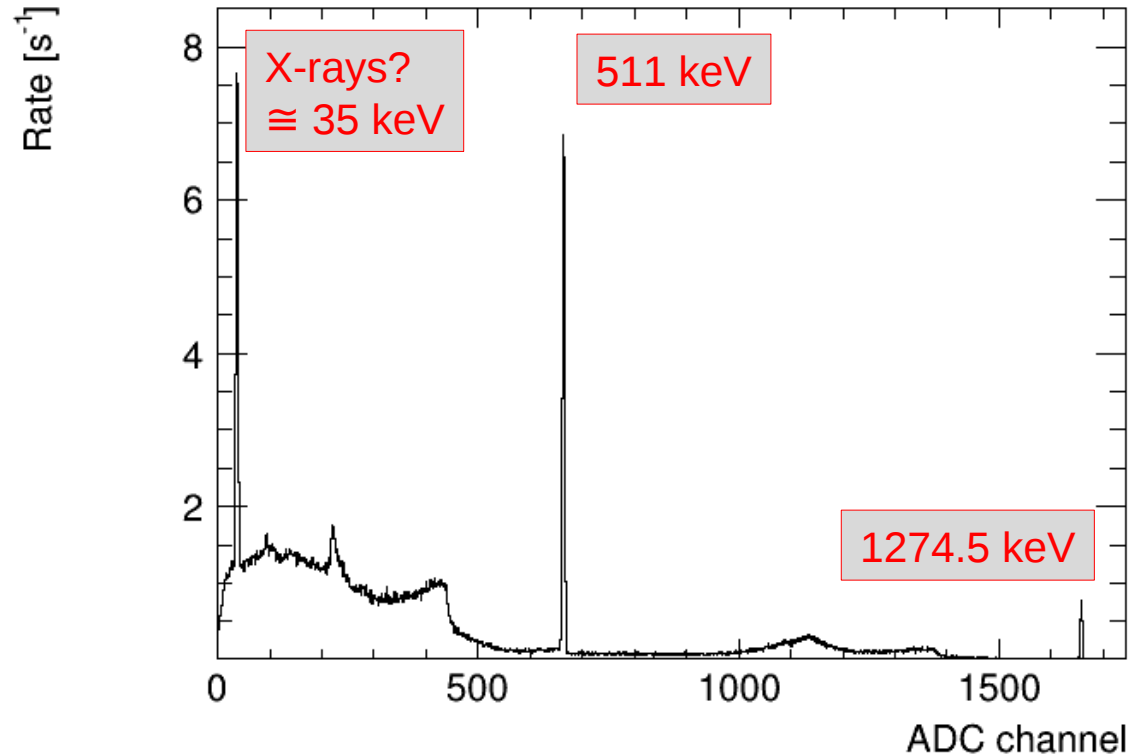


Calculations provided
for ^{137}Cs and ^{60}Co

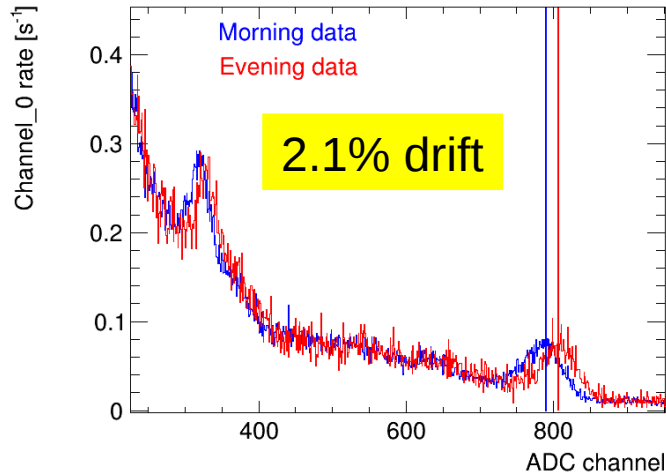
Systematic effects in γ - γ coincidence measurement

- ▶ DAQ deadtime: Negligible in our case.
- ▶ Pileups and rejected events: Must be a small number.
- ▶ Background from false coincidences: Negligible to small. Can be easily estimated using non- β^+ source.
- ▶ Geometrical acceptance: Major contributor. 5 mm shift in the transverse direction decreases the acceptance by 16%.
- ▶ Size and shape of the source: Can cause big uncertainties. Problematic to take into account.
- ▶ ...

HPGe spectrum (^{22}Na)

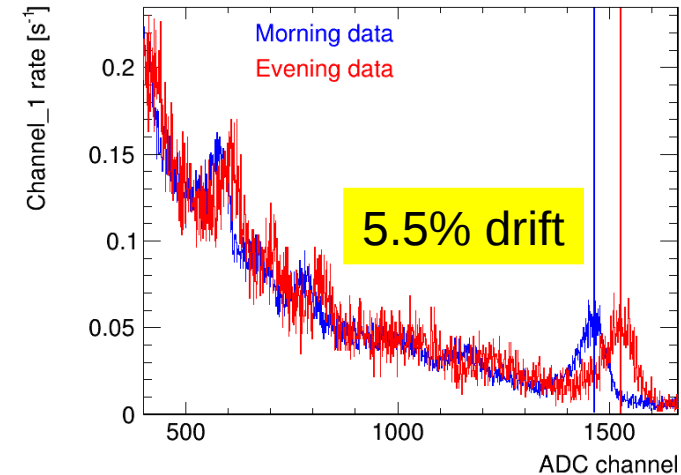


Background measurement

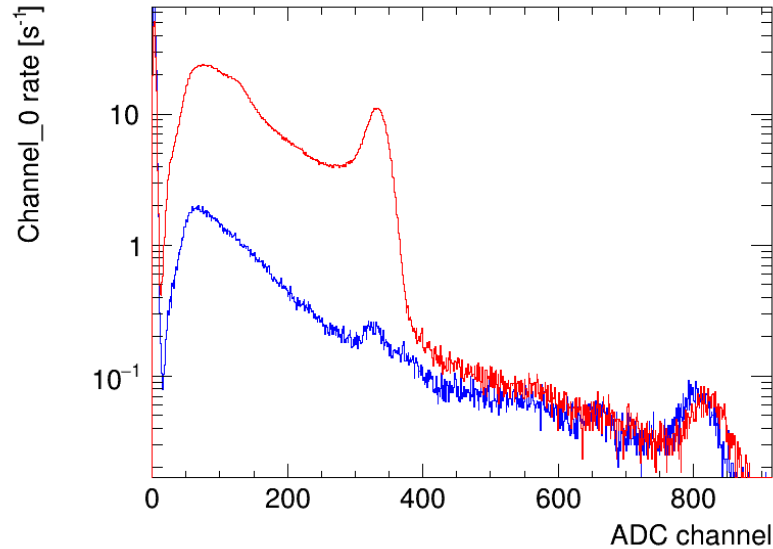


What causes the drift:

- HV?
- Temperature?
- ... More investigation needed



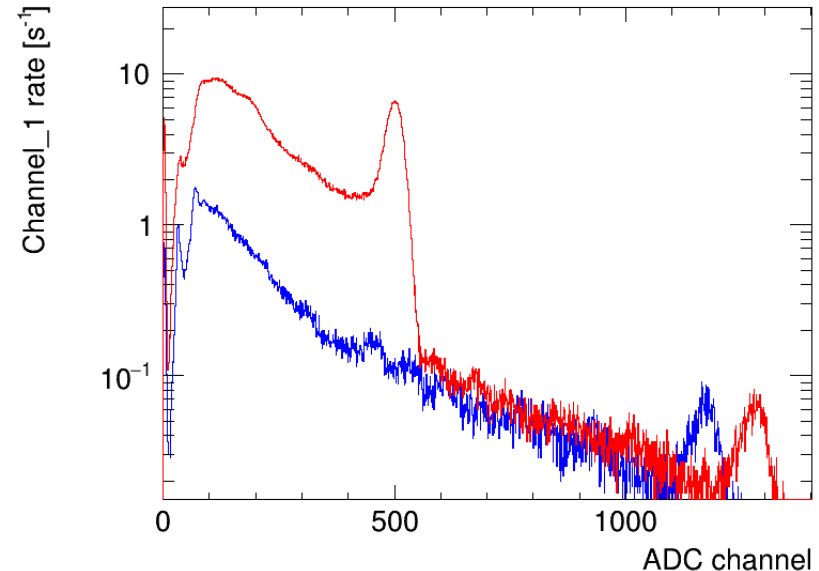
Pump effect on the background



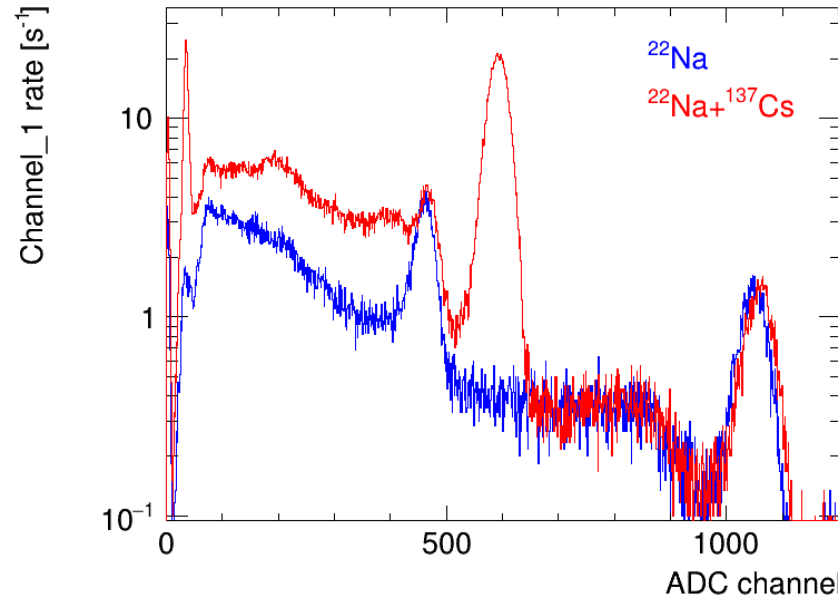
Normal background

Bg just after the pump operation (^{18}F , ^{11}C)

Something to keep in mind while
conducting experiments



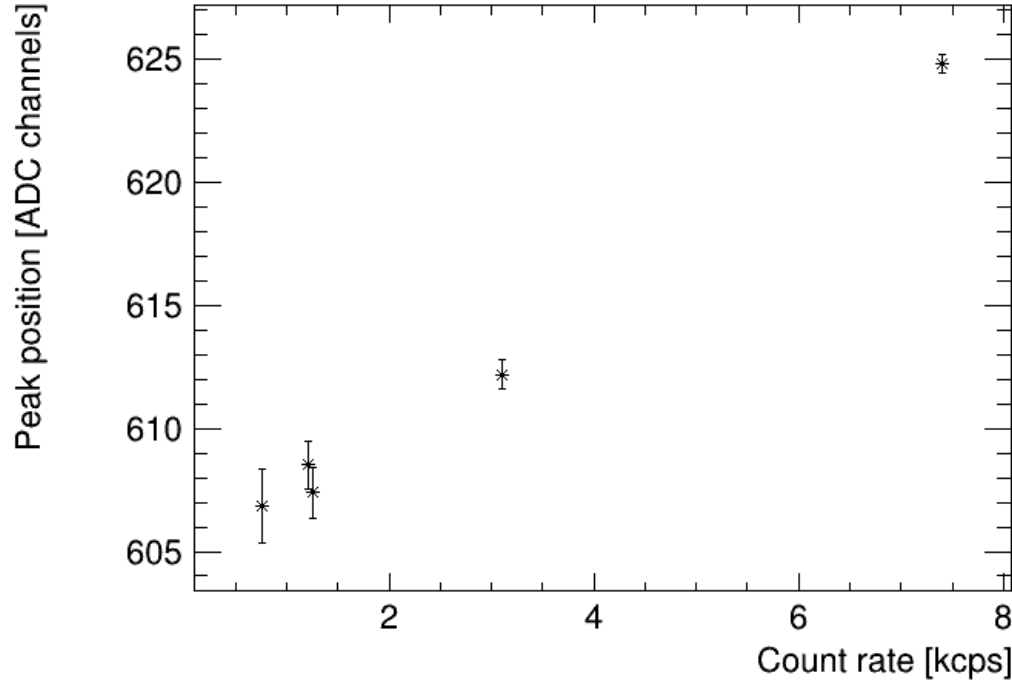
Gain vs rate



^{22}Na source placed in the middle;

^{137}Cs source is placed close to the gamma detector (ch1) to increase to total rate roughly by factor 3.

Gain vs rate

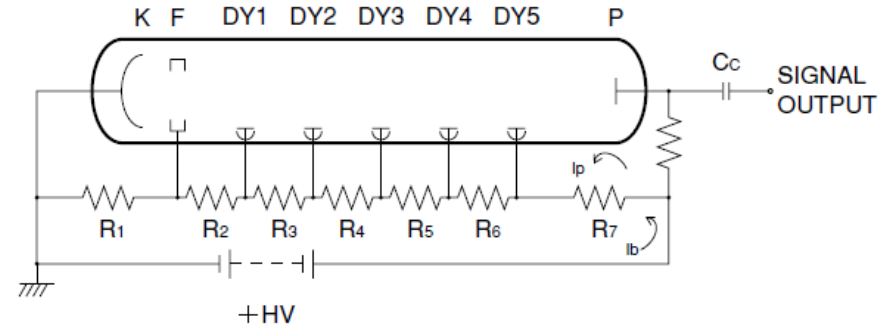


^{137}Cs source is placed at variable distances from the gamma detector (ch1) to change the detector counting rate

Gain vs rate

Effect from PMT HV divider?

- Highest electron current close to anode shunts R_7 resistance;
- Reduced voltage on R_7 increases voltage drop on the front part of the divider;
- Leading to the gain increase overall (known phenomena).



Divider Current: 0.8 mA

Estimated max. average anode current: $< 0.5 \mu\text{A}$ (0.06%)

We should not see the effect ...

Future plans

- ▶ There are lot more recorded data to analyse;
- ▶ Students needed (master? PhD?);
- ▶ Further investigate systematics;
- ▶ Taking some detector(s) to Georgia would be helpful;
- ▶ Conduct experiments in different conditions (rates, distances, using new electronics, ...);
- ▶ Try other β^+ sources.
- ▶ ...



Questions?



Thank you