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# Conventional Test-stands at MPI

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# Outline

→ **Introduction**
- two different kinds of test stand

→ **commercial detectors: REGe and XtRA**
- apparatus description
- results

→ **test stand for detector prototype: K1**
- apparatus description
- results

→ **Conclusions**

# Introduction:

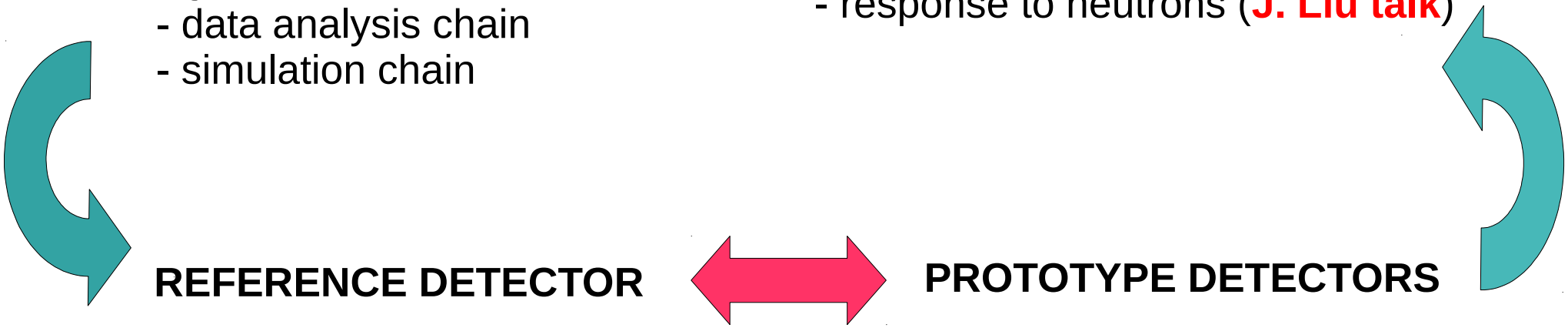
## Two different kinds of test stand

### 1) Commercial detectors: REGes and XtRa

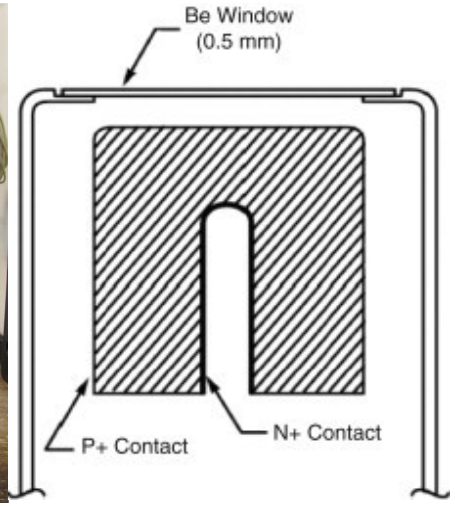
- **general tests**
  - background monitoring
  - material screening
- **equipment tests**
  - collimator test
- **analysis tests**
  - data analysis chain
  - simulation chain

### 2) Test facility: K1

- **characterize prototype detectors**
- **study all kinds of properties**
  - T dependence of pulse lengths
  - axes orientation
  - test of PSS and PSA
  - response to neutrons (**J. Liu talk**)

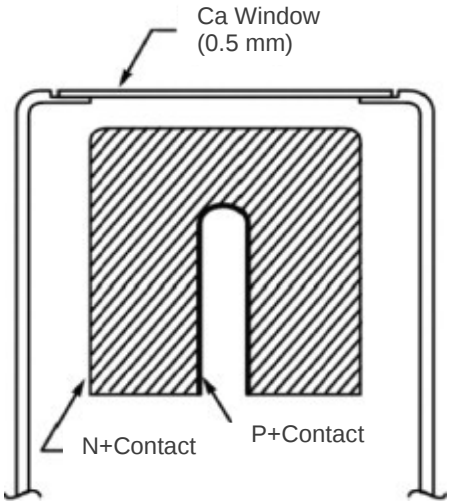


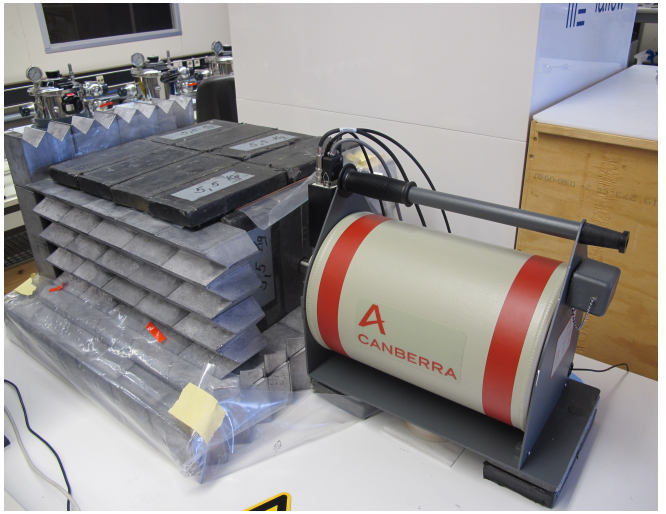
# REGe and XtRa: experimental setups


- **REGe** = **R**everse **E**lectrode Coaxial **Ge** detectors
- Mantle: **p-contact**, core: **n-contact**
- **Thin ion implanted contacts**
- Spectroscopy from **10 keV to >10 MeV**
- Excellent **Energy Resolution**

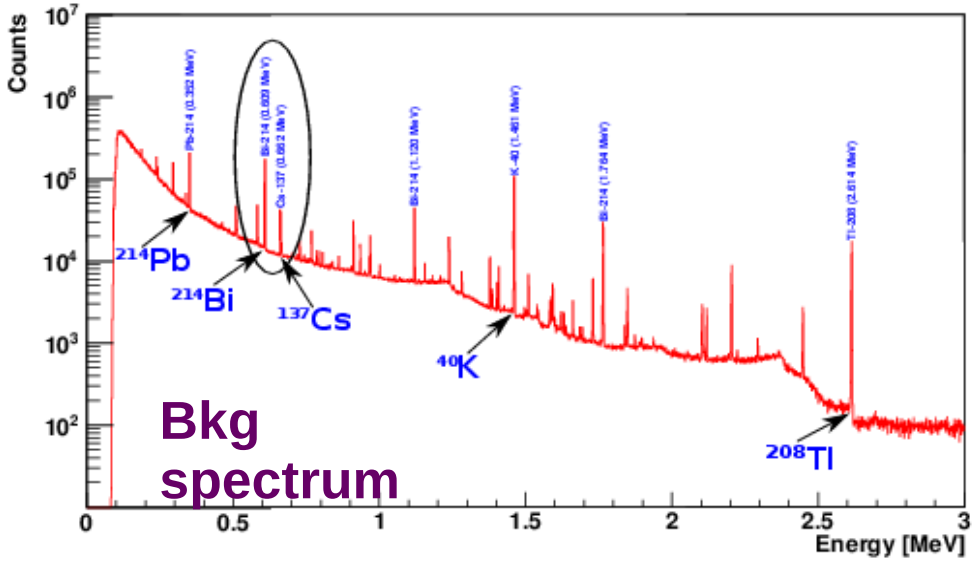
- **XtRa** = E**xte**nded **Ra**nge Coaxial Ge Detectors
- Mantle: **n-contact**, core: **p-contact**
- **Carbon** composite **cryostat window**
- Spectroscopy from **3 keV to >10 MeV**
- Excellent **Energy Resolution**
- **Lead castle** for **weak sources**



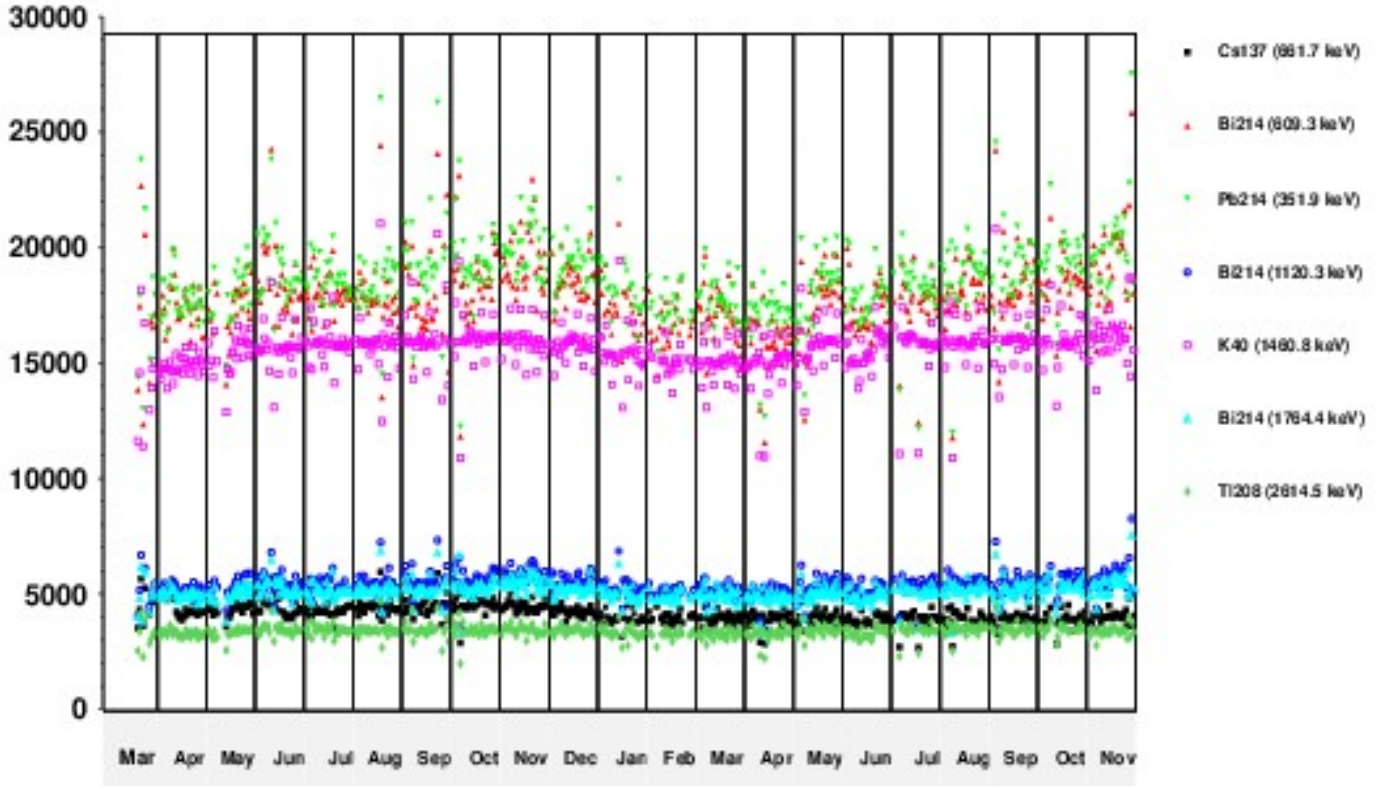
# REGe results: background monitoring

## Radioactive background monitoring since March, 23rd 2011 until now



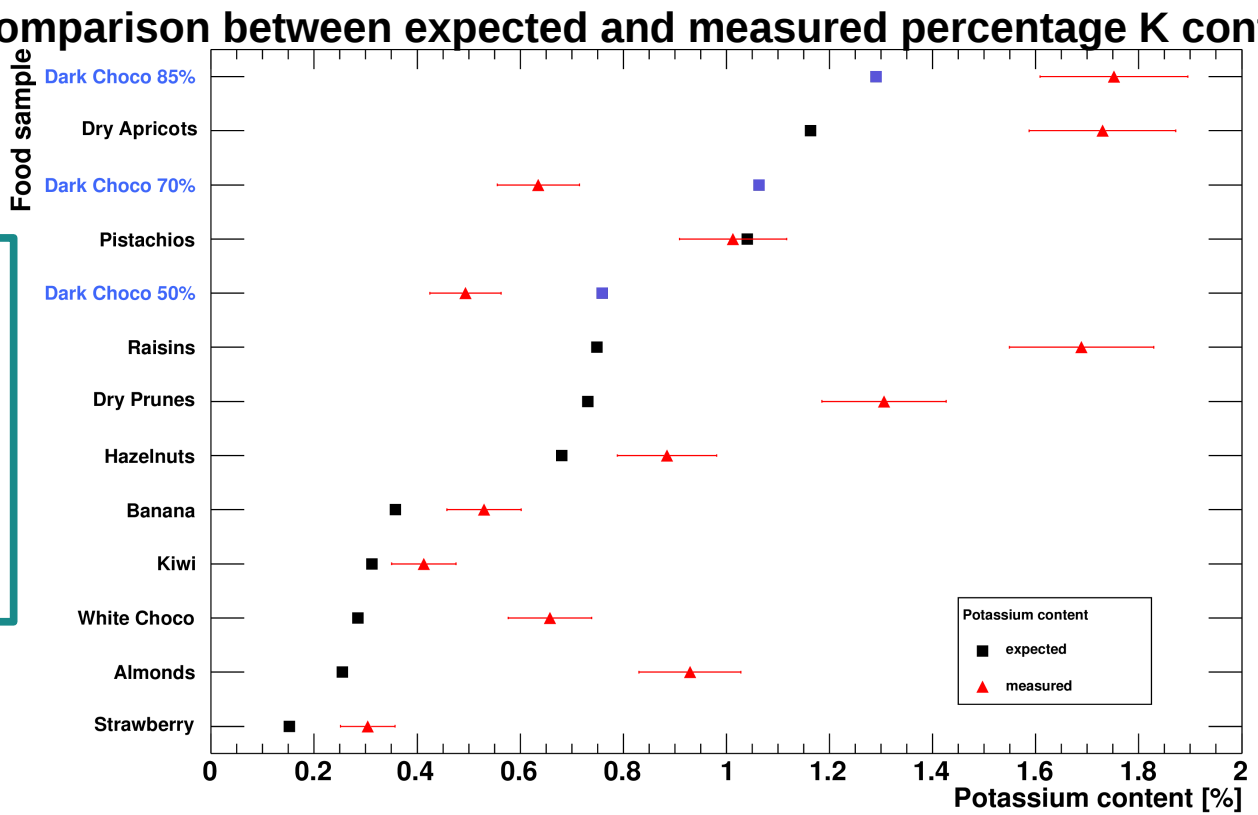

**Expectation:**
**Cs137** increase
**Bi214** be stable

**Evidence:**
**NO INCREASE**
**Periodic fluctuation on Bi214**

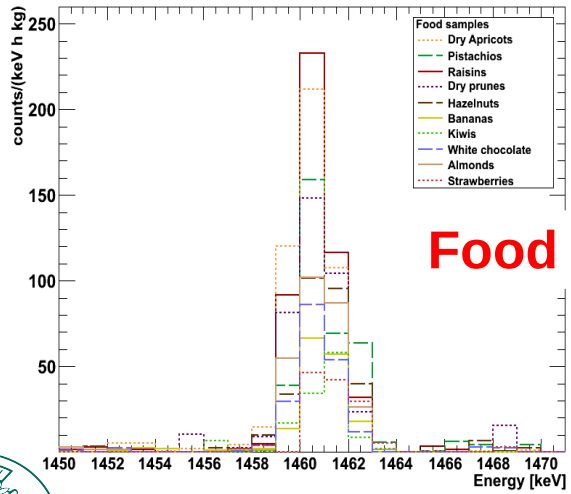


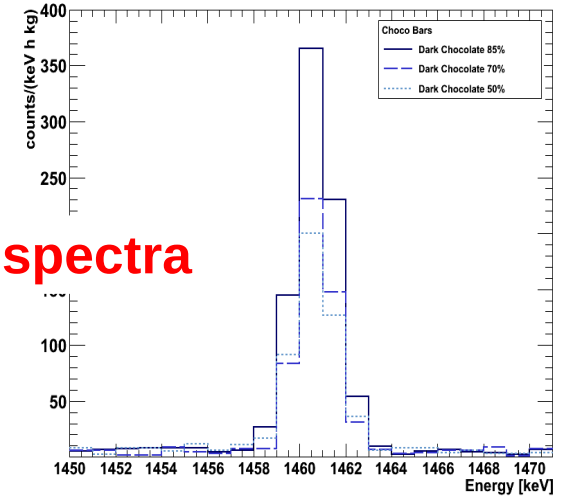
# XtRa results: screening tests (I)

- $^{40}$**K peak at 1460 keV**
- **energy spectra** from food samples
- detector **calibration** with KCl
- **Potassium content**




USDA National Nutrient Database for Std. Ref.,Release 17




**Food spectra**

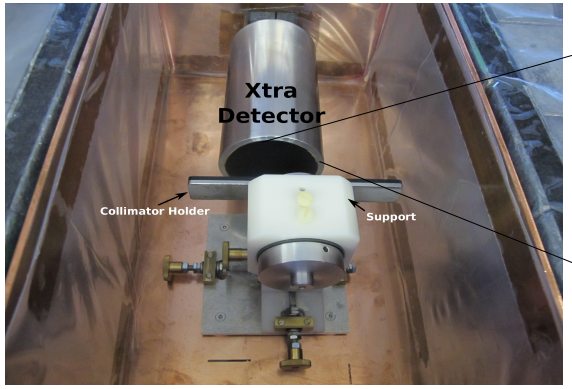
**Expectation:**
**K** in chocobars **proportional to cocoa percentage**

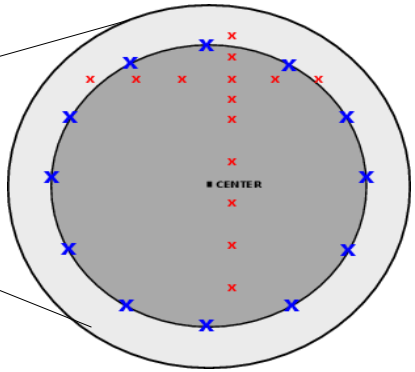
**Evidence:**
**NO PROPORTIONALITY**

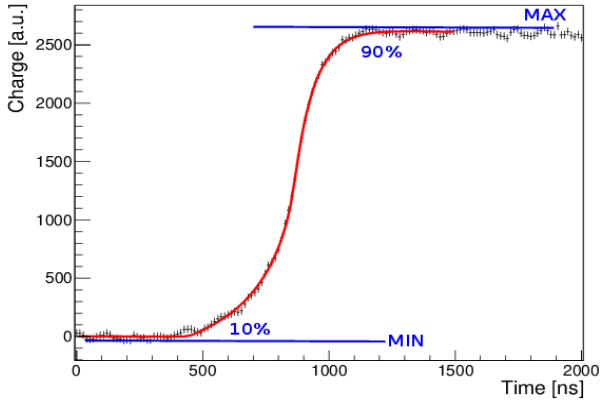
# XtRa results: equipment test (I)

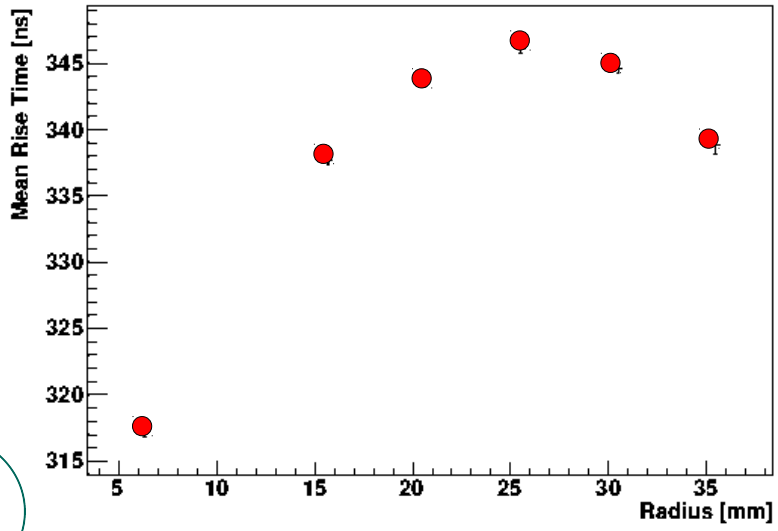
**Goals:** → **Test the collimator for GALATEA (S. Irlbeck talk)**
→ **Scan a commercial detector**

**Scanning XtRa** with:
- $^{152}$**Eu** → gamma source (v, h, c scan)
- $^{90}$**Sr** → beta source (h scan)



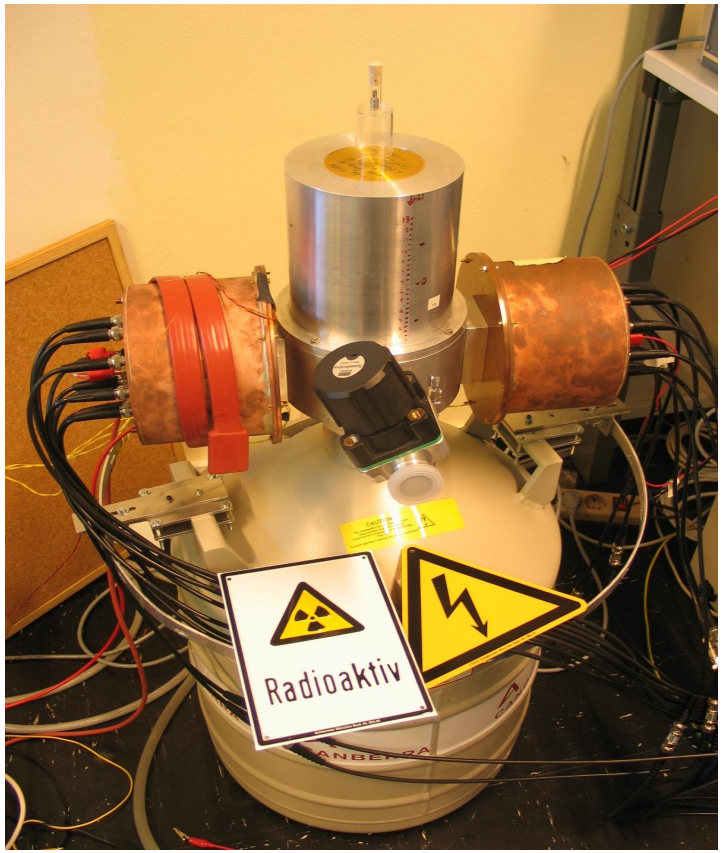

## Example:

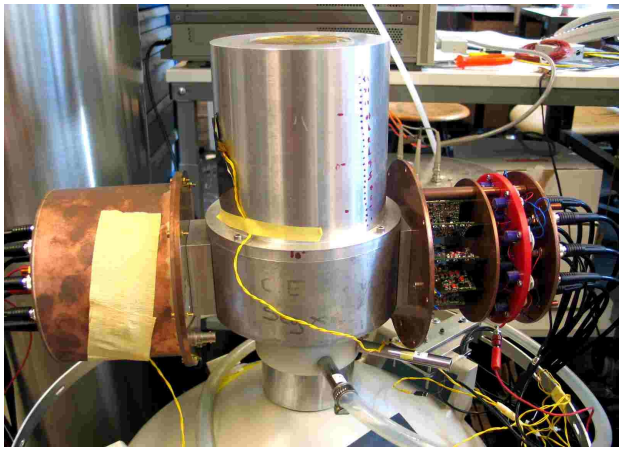
### $^{152}$Eu vertical scan
- pulses from the **122keV peak**
- two different methods to extract the rise time
  - **Min-Max method**
  - **Fitting method**

**RISE TIME DEPENDENT ON THE RADIUS**

**Closed ended coaxial geometry!**

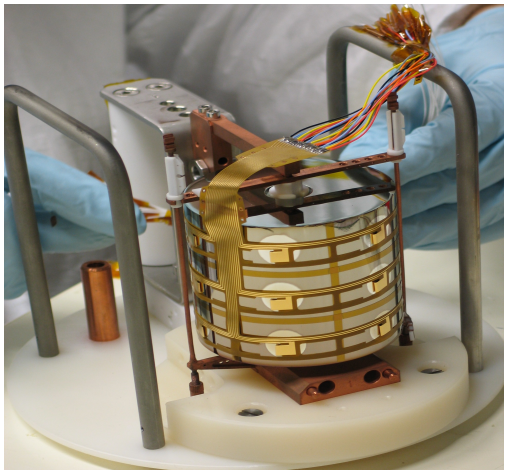
# K1: experimental setup



- Two-walled **aluminum vacuum can**
- Copper “ears” housing **pre-amplifier boards**

- **Cooling finger** to a standard **LN2 dewar**
- **Siegfried-II:** **18-fold** n-type detector High Purity



**Temperature of the detector increases with time**
- possible studies on **temperature-dependent parameters**

**Latest results**
**1)** Temperature dependence of pulse lengths **Eur. Phys. J. C 72 (2012) 1950**
**2)** Crystallographic axis determination **Eur. Phys. J. Appl. Phys. 56 (2011) 10104**

# K1 results: temperature dependence of pulse lengths (I)

## Theoretical model

→ the **velocity** of charge carriers depends on **mobility and electric field**

$$\mathbf{v}_{e/h}(\mathbf{x}) = \mu_{e/h}(\mathbf{x})\mathbf{E}(\mathbf{x}) \qquad \mu_e \propto T^{-\frac{3}{2}}$$

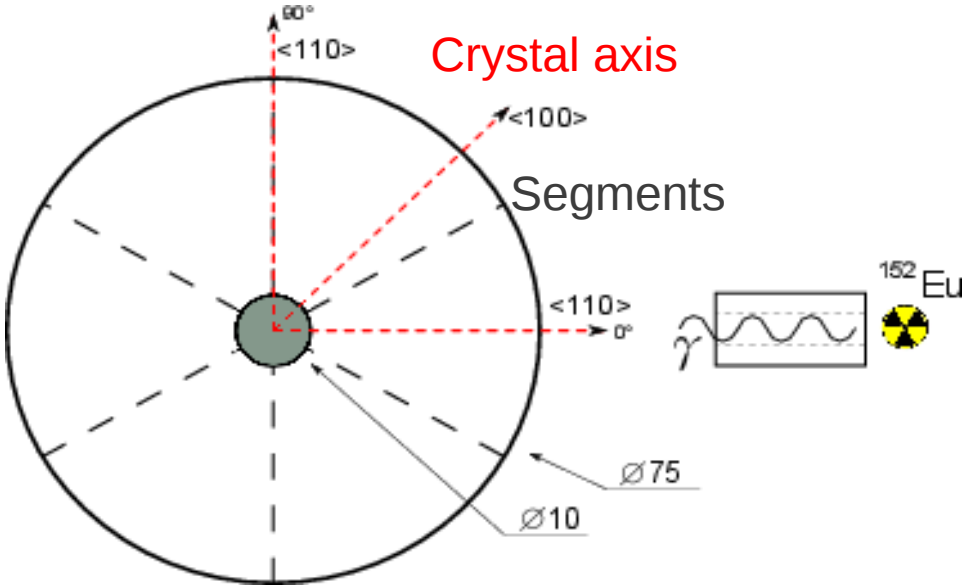
→ the **rise time** of the pulse should depend on the **TEMPERATURE**

$$t(r_1, T) = 0.63 \cdot T^{\frac{3}{2}} \ [ns]$$

**Pulses → rise time → temperature dependence**

## Data collection:

- measure along:
  - **<110> "slow" axis**
  - **<100> "fast" axis**
- use the **122keV** gamma line from **$^{152}$Eu**



# K1 results: temperature dependence of pulse lengths (II)

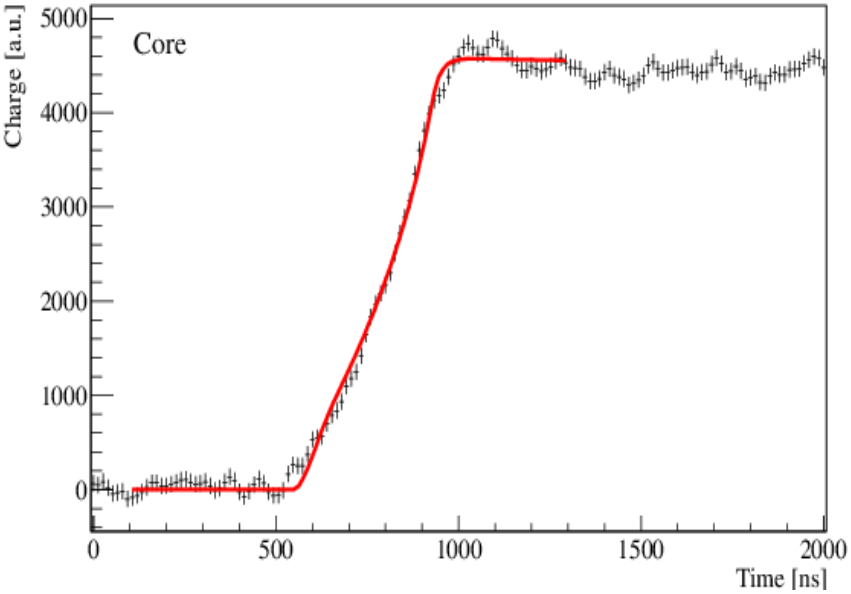
## Rise time extraction

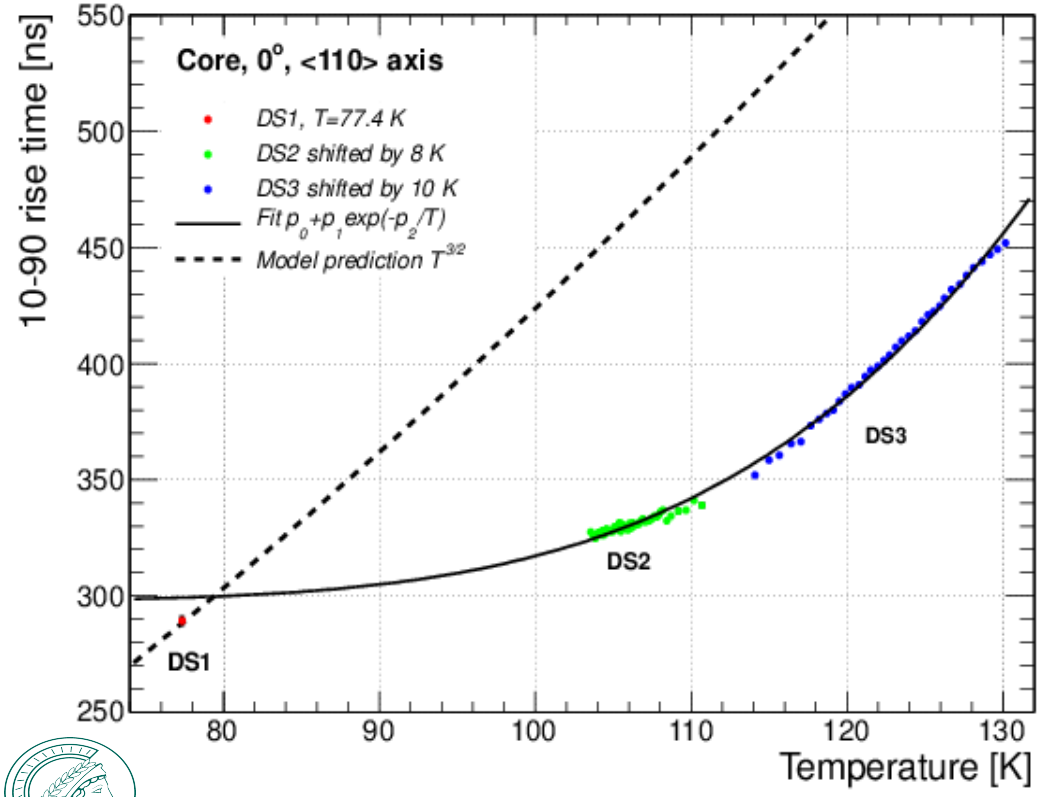
- **measured pulses fitted** with **simulated pulses to suppress influence of noise**

$$C^{c,s}_{meas}(t) = A^{c,s} \cdot C^{c,s}_{cim}\left(\frac{t^{c,s}_{scale}}{t^{c,s}_{scale} + t^{c,s}_{offset}}\right)$$

- from $\mathbf{t_{scale}}$ the **rise time** is evaluated as:

$$t_r^{meas:10-90} = \frac{t_r^{sim:10-90}}{t_{scale-mean}}$$




- Strong **T dependence** of **rise time**
- **T dependence** well described by a **Boltzmann-like ansatz**

**DECREASING EFFECTIVE MOBILITY**

- **The simple $T^{3/2}$ doesn't fit at all!!**

# K1 results: crystallographic axis determination (I)

**Two different methods were used:**

**A) Scan Method**

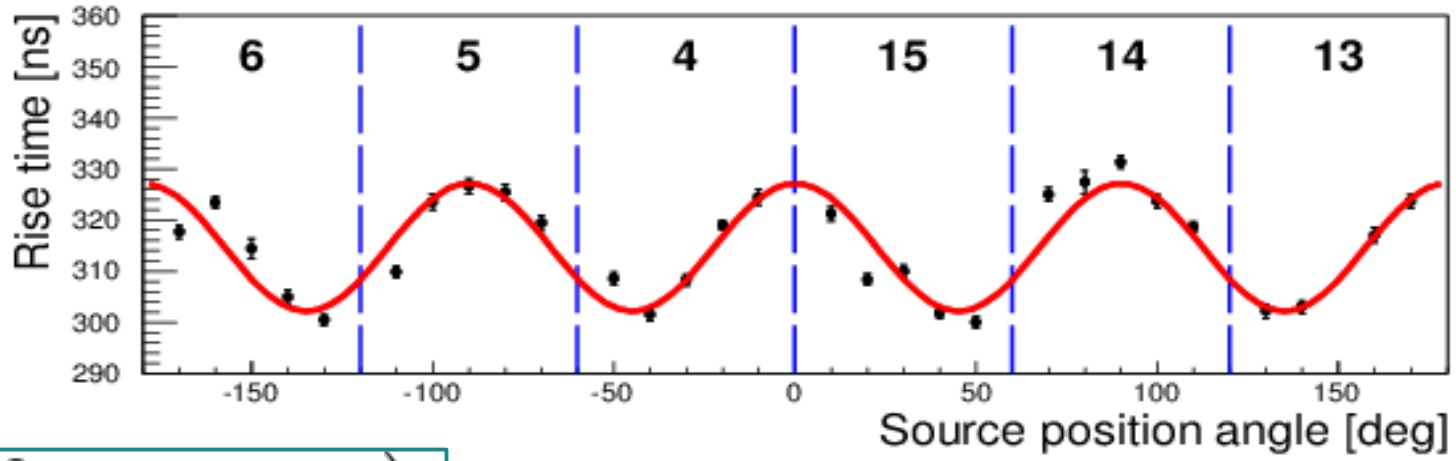
**B) Occupancy Method**

## A) Scan method

Velocity and trajectories depends on the relative angle of the source and the axis

→ **The rise time depends on the source azimuth angle!**

- $^{152}$Eu collimated
- 122 keV ɣ used
- 10° azimuth steps




$$t_r(\phi) = A + B \cdot sin\left(\frac{2\pi}{90}(\phi + \phi_{<110>})\right)$$

$$\phi_{<110>} = -0.2^\circ \pm 0.4^\circ(stat.) \pm 3.1^\circ(syst.)$$

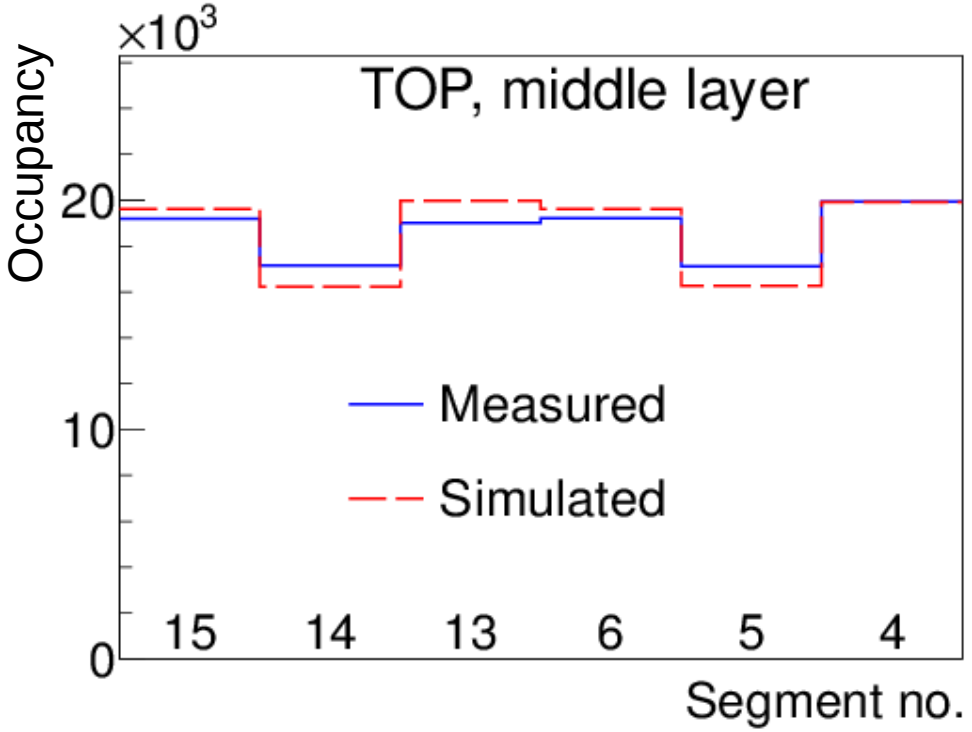
- can be used **even with not segmented detector**
- **data taking** is **time consuming**

***Something NEW!***

# K1 results: crystallographic axis determination (II)

## B) Occupancy Method

**Comparing measured occupancies with simulated occupancies where the axes orientation is one of the simulation parameters**




$$\phi^{Co,top}_{<110>} = -1.8^{\circ} \pm 1^{\circ}(stat.) \pm 6^{\circ}(syst.)$$

Use **high energy gammas** from **$^{60}$Co** or **$^{228}$Th**

- evaluate the **occupancies** from the **measured spectra** => $D_i$
- evaluate the **occupancies** from the **simulated spectra** => $Mc_i$
- minimize a **statistic test** to extract the **axes orientation**

$$\epsilon = \sum_{i=1}^{6} \frac{(D_i - MC_i)^2}{D_i^2}$$

# Conclusions

## Summary:

- **REGes:**
  - monitored the **radioactive background** since **Fukushima disaster**
- **XtRa:**
  - measured the **potassium content for 13 different food samples**
  - characterize the detector with **gamma** and **beta sources**

- **K1**:
  - **all our papers came out of this test stand**
  - studied **temperature dependence of pulse lengths**
  - determined **crystallographic axes orientation** with a **NEW method**

## Outlook:

- **K1** will be the first **test facility** for the **new Segmented BEGe prototype**
- a **good idea** would be to have a **second K1**

# Backup Slides

## Activity = number of decays per second

- from the **exponential decay law**: if we have initially $N_0$ radioisotopes

$$D(t) = N_0 - N(t) = N_0\left(1 - e^{-\frac{t}{\tau}}\right)$$

is the number of decays after a time t

- if we use the half life $t_{1/2}$ and expand in **Taylor series** we can obtain

$$e^{-\frac{t}{\tau}} = 1 - \frac{t}{\tau} = 1 - \frac{t \cdot ln2}{t_{\frac{1}{2}}}$$

- if we have a **certain mass of a radioactive isotope** $m_I$

$$A = \frac{D(t)}{t} = \left(\frac{m_I}{m_I^A} \cdot N_A\right) \cdot \frac{ln2}{t_{\frac{1}{2}}}$$

For a Potassium Chloride (KCl) sample :

- of mass $m_{KCl}$
- with a cenrtain amount of impurities $i_{tot}$ we will have:

$$m_{^{40}K} = m_{KCl} \cdot (1 - i_{tot}) \cdot m_K^{KCl} \cdot a_{^{40}K}$$

$$A_{1460} = 141.9\ Bq$$

## Activity = number of decays per second

Directly from the exponential decay law for $N_0$ radioisotopes:

$$A = \frac{D(t)}{t} = N_0 \cdot \frac{ln2}{t_{\frac{1}{2}}}$$

if we have some amount $m_I$ of radioisotope it will be:

$$A = \frac{D(t)}{t} = \left( \frac{m_I}{m_I^A} \cdot N_A \right) \cdot \frac{ln2}{t_{\frac{1}{2}}}$$

**Potassium Chloride calibration salt**

- **mass of the salt** sample
- **impurities**
- **mass of Potassium in KCl**
- **isotopic abundance** for $^{40}K$
- **atomic mass of $^{40}K$**

$$m_{^{40}K} = m_{KCl} \cdot (1 - i_{tot}) \cdot m_K^{KCl} \cdot a_{^{40}K}$$

$$A_{1460} = 141.9\ Bq$$

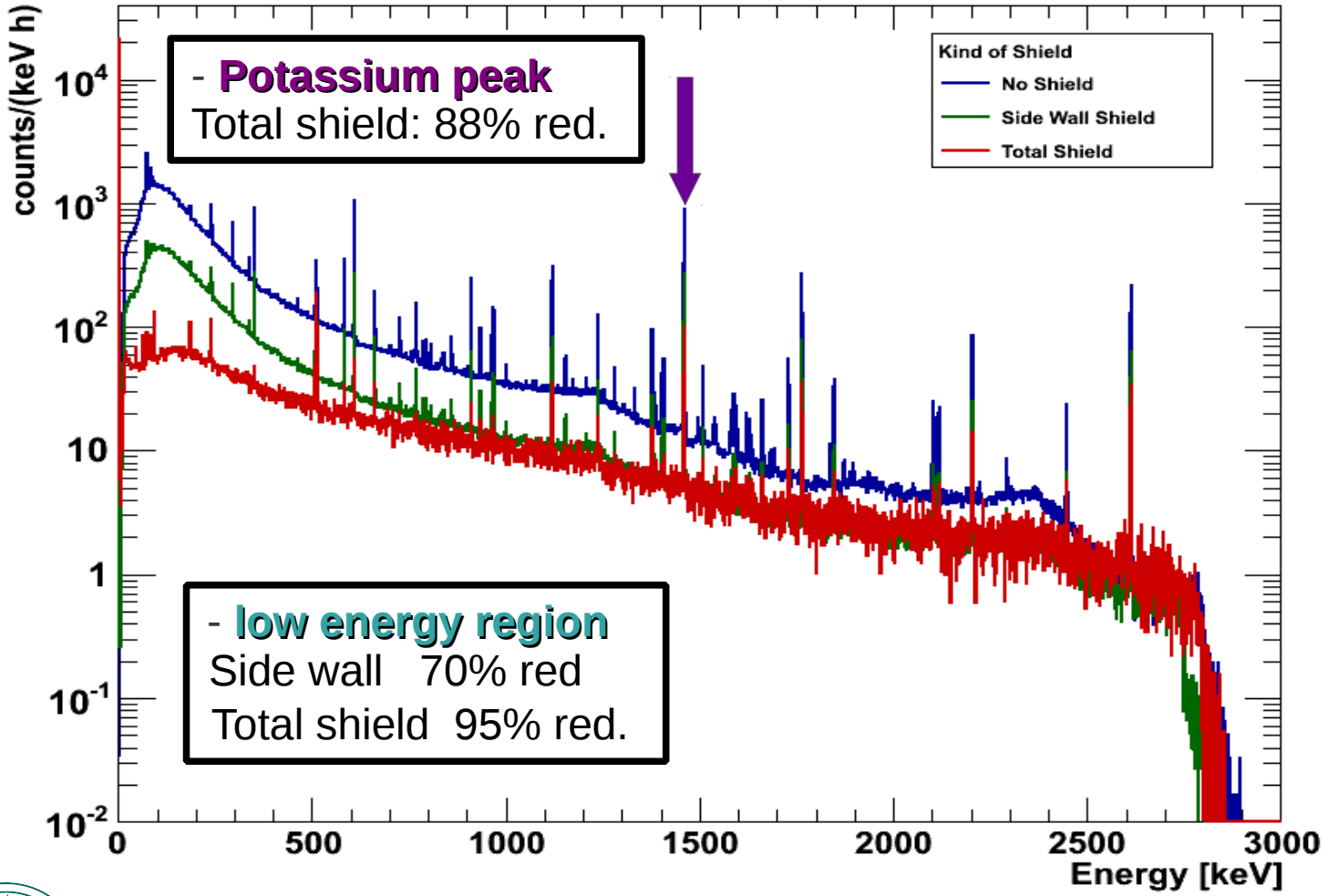
# Experimental Setup: Background reduction

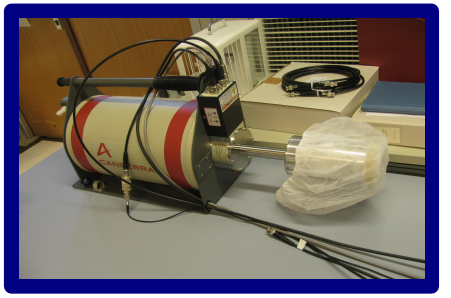
- **100 g of strawberry** => **153 mg of K => 0.018 mg** of $^{40}$K → **WEAK SOURCE**

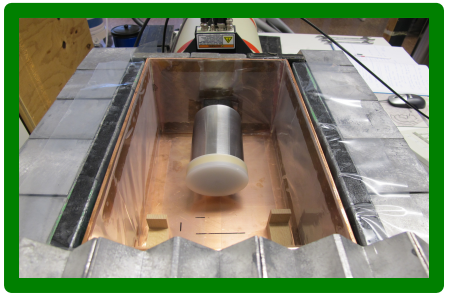
- from this weak source in 1 hour → **20 counts**
- from the bkg radiation in 1 hour → **1000 counts**

→ **SHIELD!!!**

**Natural radioactive background: reduction due to lead castle**





# Experimental Setup: Detector Calibration (I)

Calibrate the **detector response** with a **WELL KNOWN** quantity of K

**Known mass of K : Spectrum$_A$ = unknown mass of K : Spectrum$_B$**

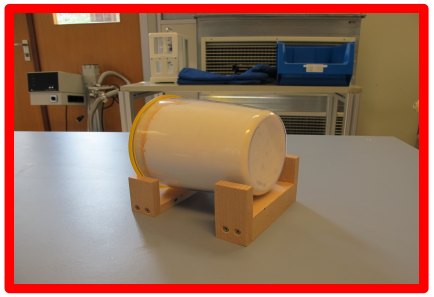
Define the **experimental settings**:

**1) position of the plastic container:**

- vertical
- horizontal

**2) relative distance between source and detector**

**MAXIMIZING THE GEOMETRICAL ACCEPTANCE, $a^g$**



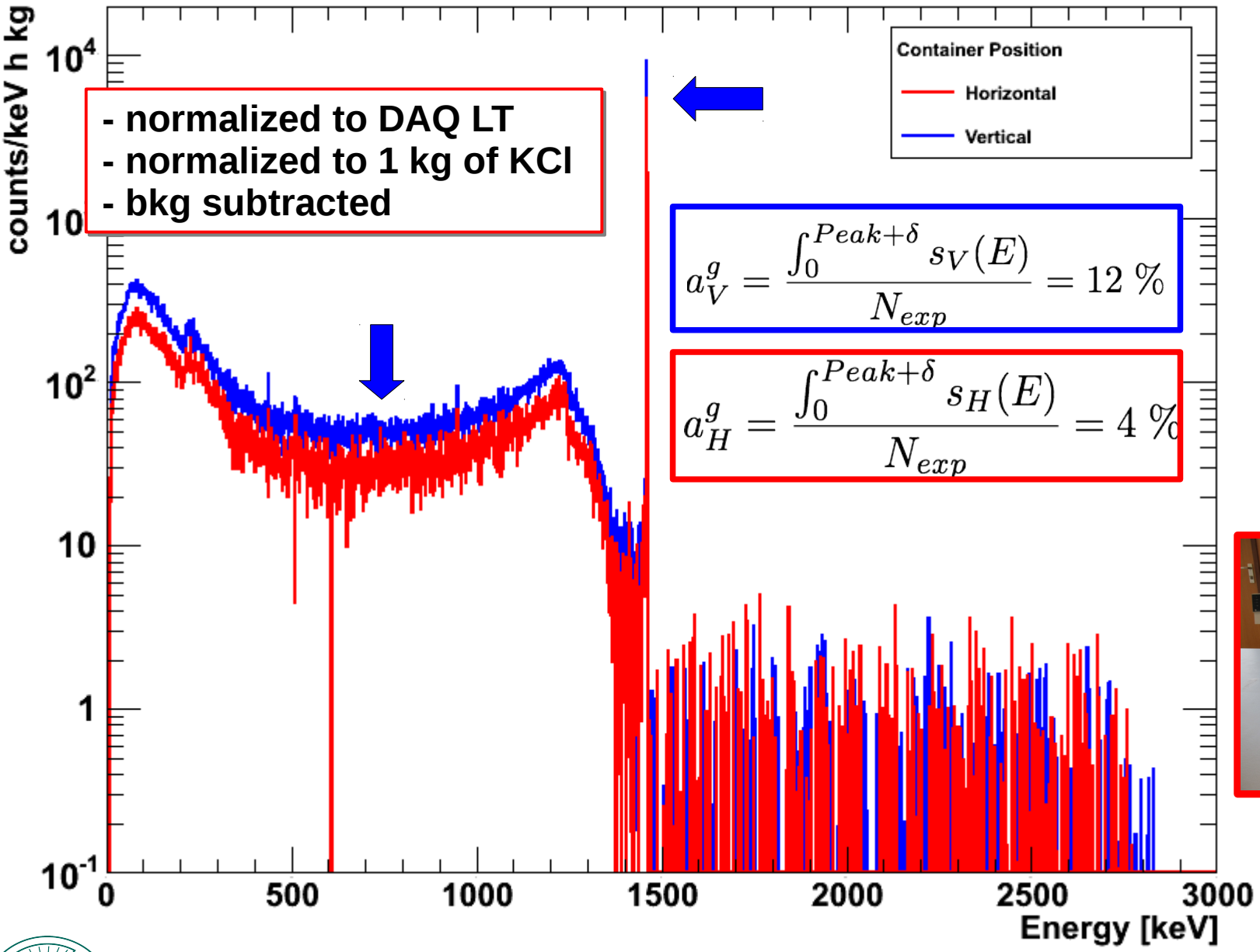
$$a^g = \frac{N_{measured}}{N_{emitted}}$$

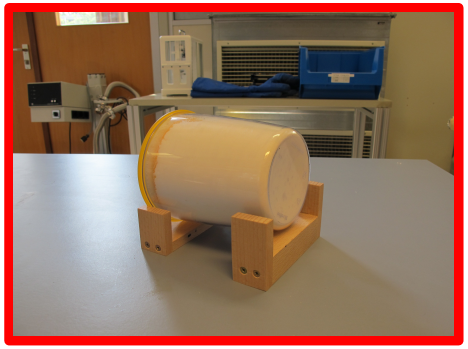
Where: $N_{measured}$ are obtained directly f**rom the measured spectrum**

$N_{emitted}$ can be **calculated from the activity** of the sample

# Experimental Setup: Detector Calibration (II)

## Potassium Chloride spectra in horizontal and vertical position



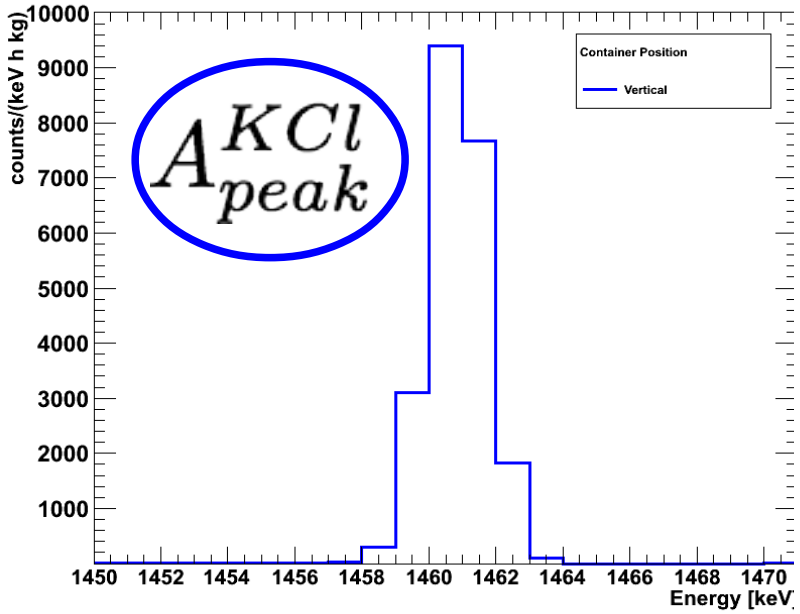



# Data Analysis: Food Spectra

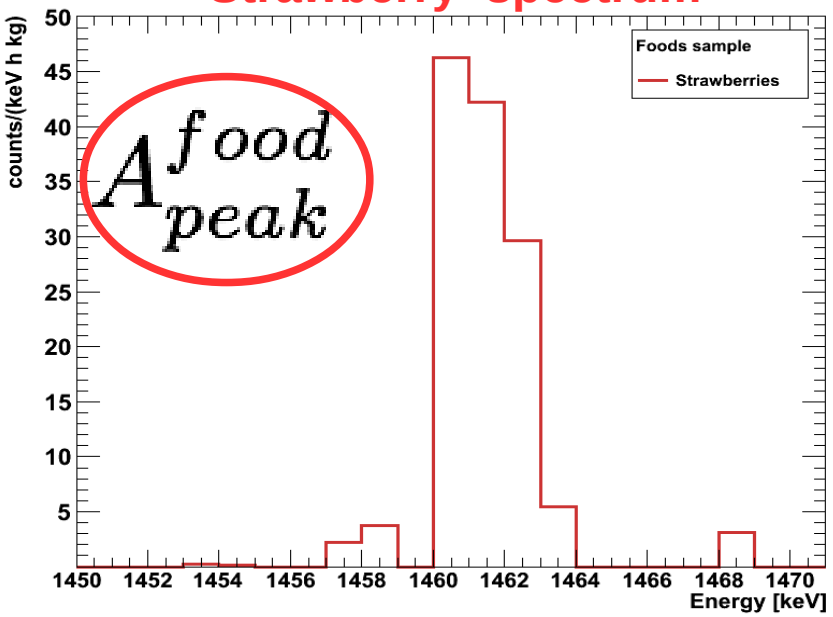
**ONCE CALIBRATED...**

**- from the spectra → extrapolate the potassium content**

**KCl spectrum**




**Strawberry spectrum**




**Known mass of K : Spectrum$_{KCl}$ = unknown mass of K : Spectrum$_{F}$**

$$m_K^{meas} = \frac{A_{peak}^{food}}{A_{peak}^{KCl}} \cdot m_K^{KCl} \quad \Rightarrow \quad K_{cont}^{meas} = \frac{m_K^{meas}}{m_{sample}^{meas}}$$

**To be compared to the expected Potassium content**

**USDA National Nutrient Database for Std. Ref., Release 17**