DPG-Frühjahrstagung
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Germanium Detectors and Natural Radioactivity in Food

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Outline

→ **Introduction**
- Natural Radioactivity in Food

→ **Experimental setup**
- Background Reduction
- Detector Calibration

→ **Data analysis**
- Food Spectra
- Potassium Content

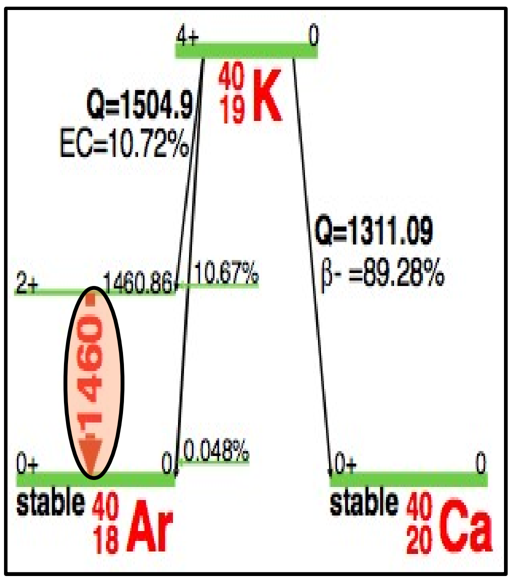
→ **Conclusions**

Introduction: natural radioactivity in food

- **Potassium** plays a central role in many **physiological processes**
- Every kind of food contains Potassium

What is the potassium content of different food sample?

- Potassium has a **radioactive isotope**: ^{40}K (i.a. 0.012%)



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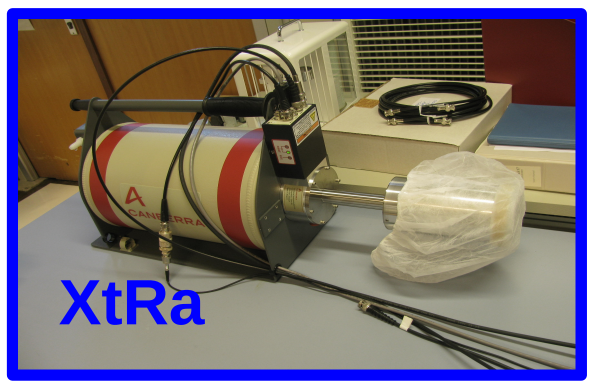
Use a Germanium Detector



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Counting Gammas from the 1460 peak

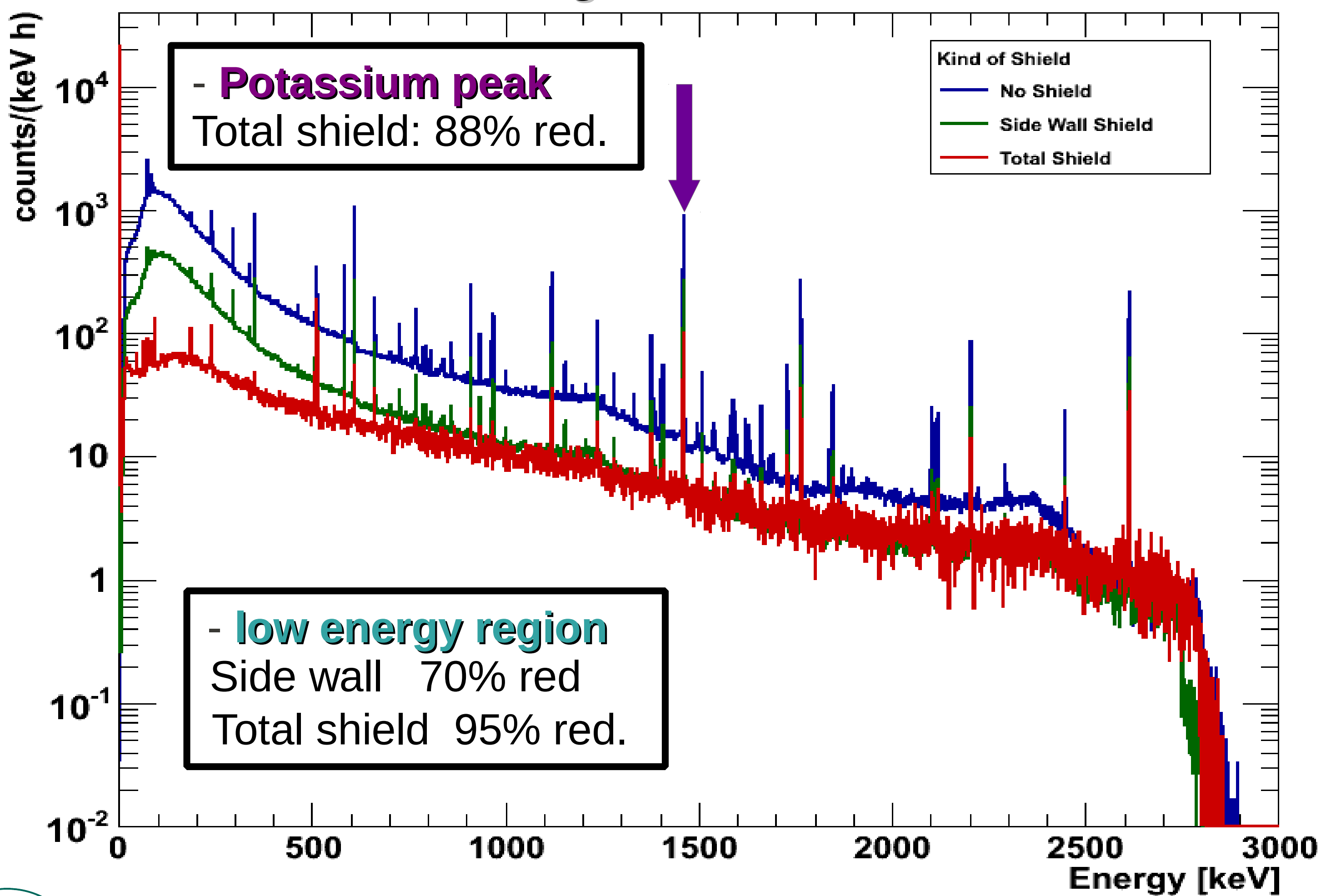
Experimental Setup: Background reduction

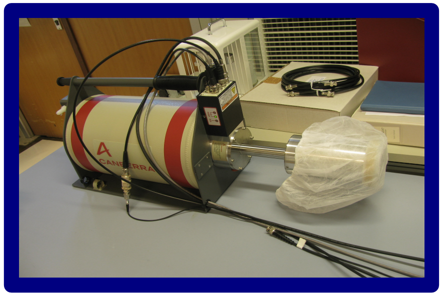
- **100 g of strawberry** => **153 mg of K => 0.018 mg** of ^{40}K → **WEAK SOURCE**

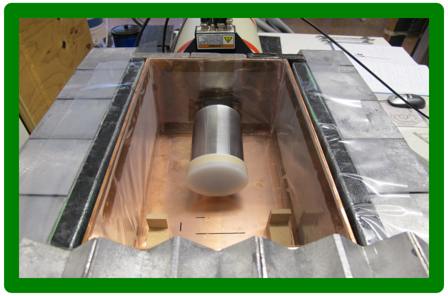
- from this weak source in 1 hour → **20 counts**
- from the bkg radiation in 1 hour → **1000 counts**

SHIELD!!!

Natural radioactive background: reduction due to lead castle







Experimental Setup: Detector Calibration (I)

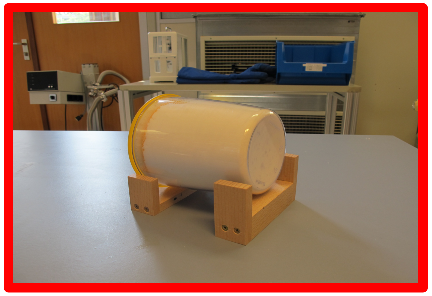
Calibrate the **detector response** with a **WELL KNOWN** quantity of K

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

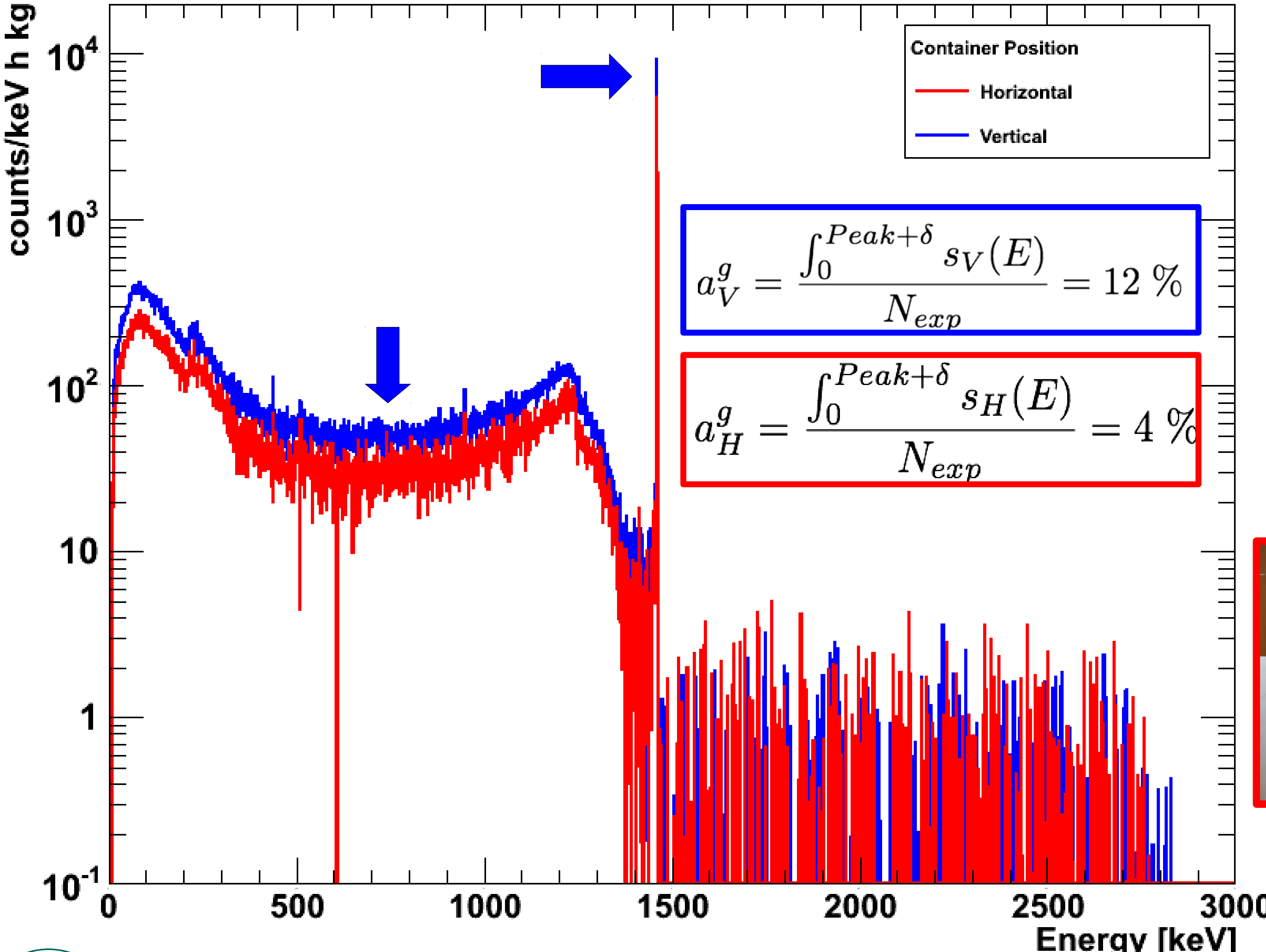
$$a^g = \frac{N_{measured}}{N_{emitted}}$$

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

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

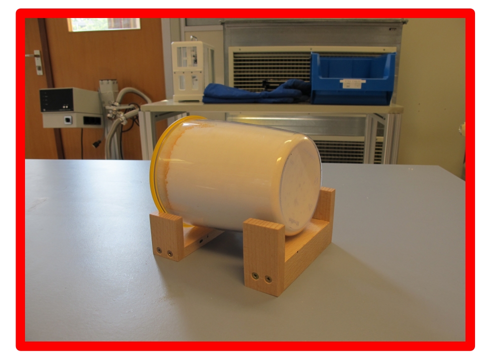
Experimental Setup: Detector Calibration (II)

Potassium Chloride spectra in horizontal and vertical position



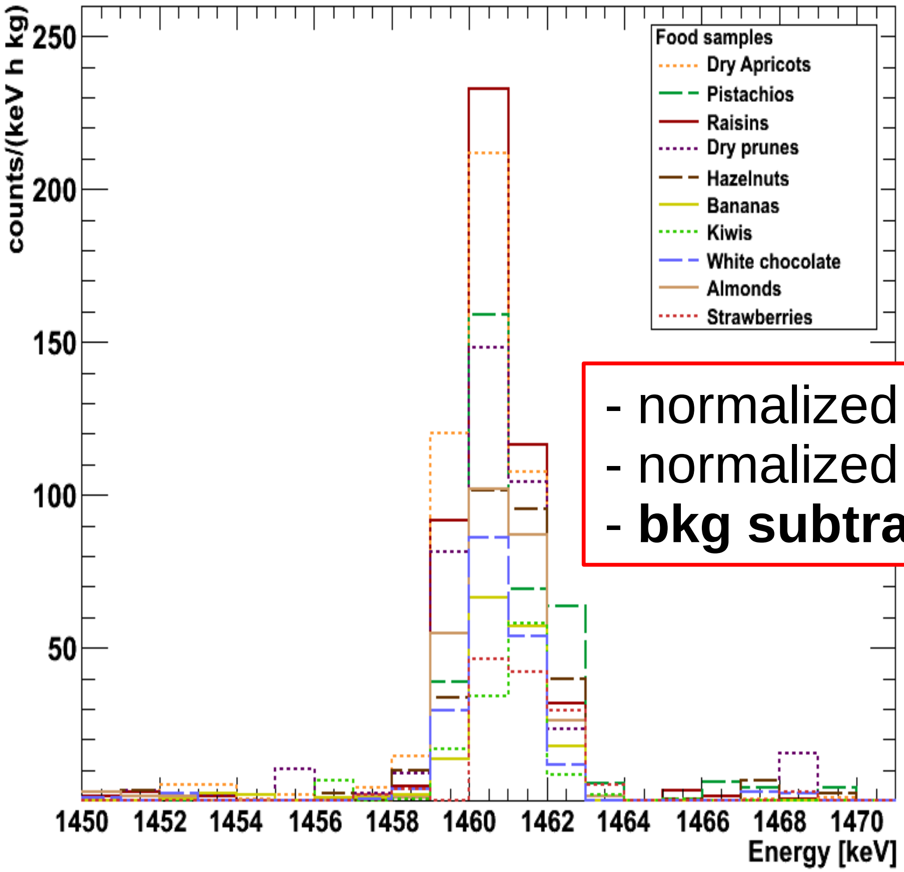
$$a_V^g = \frac{\int_0^{Peak+\delta} s_V(E)}{N_{exp}} = 12\ \%$$

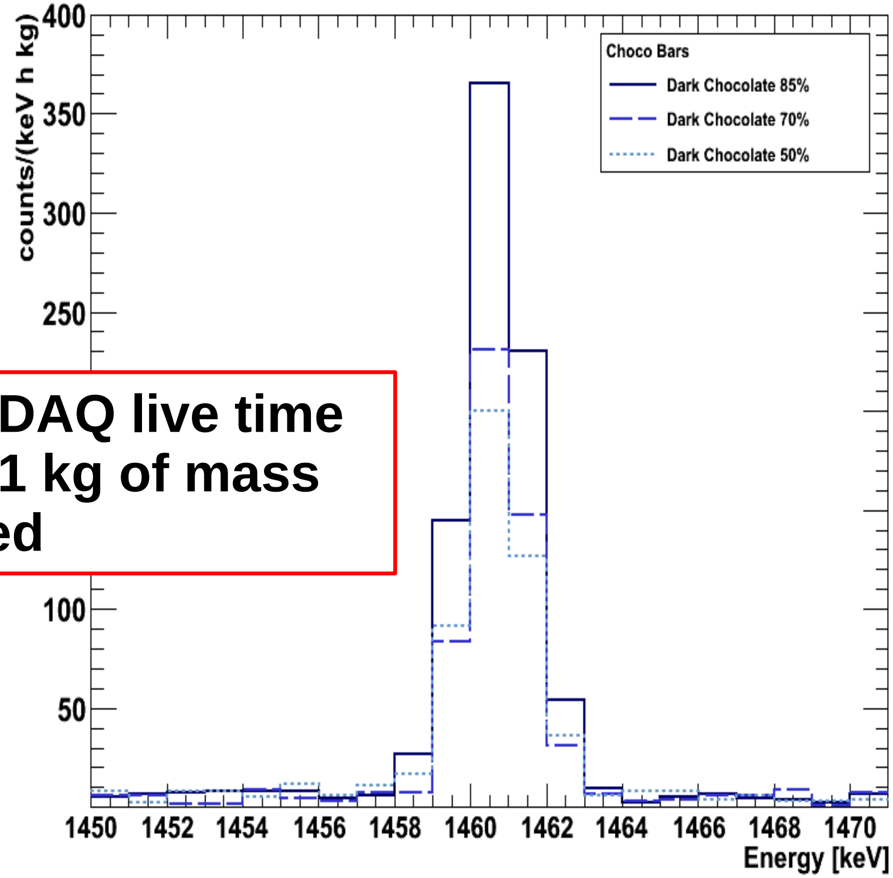
$$a_H^g = \frac{\int_0^{Peak+\delta} s_H(E)}{N_{exp}} = 4\ \%$$



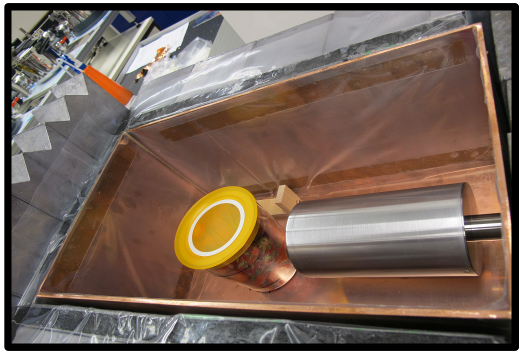
Data Analysis: Food Spectra

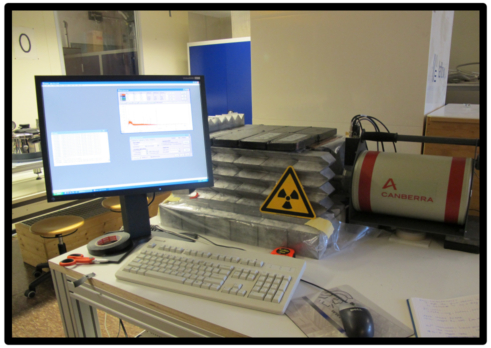
Food samples spectra: zoom on ^{40}K peak





- normalized to **DAQ live time**
- normalized to **1 kg of mass**
- **bkg subtracted**





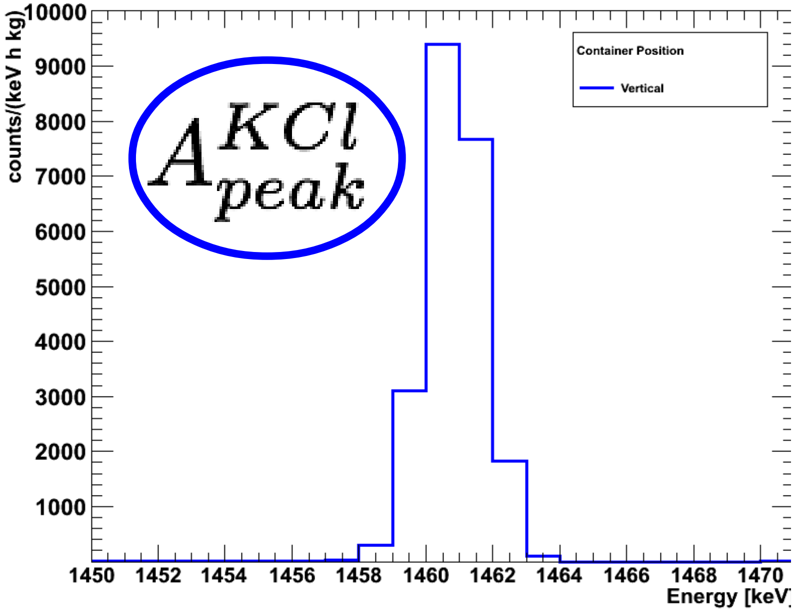
always the same experimental settings

Data Analysis: Food Spectra

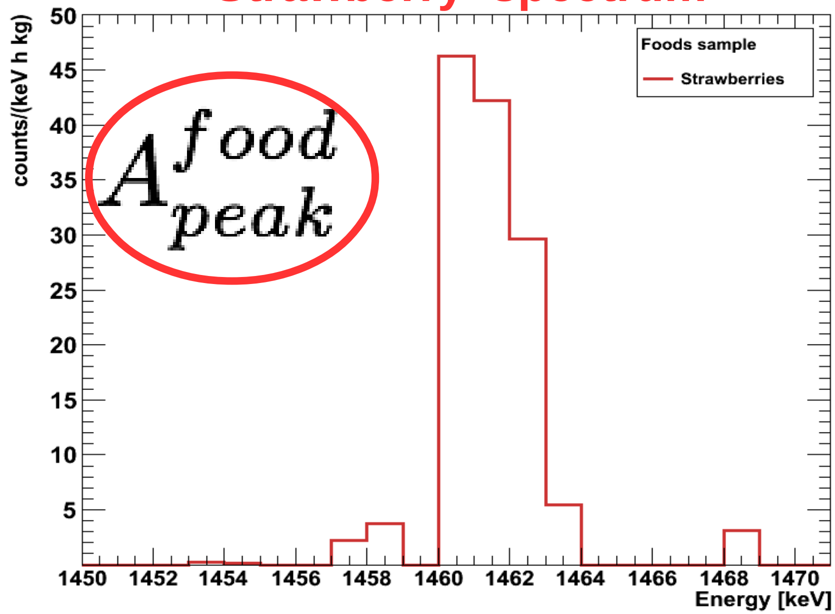
ONCE CALIBRATED...

- from the spectra → extrapolate the potassium content

KCl spectrum



Strawberry spectrum



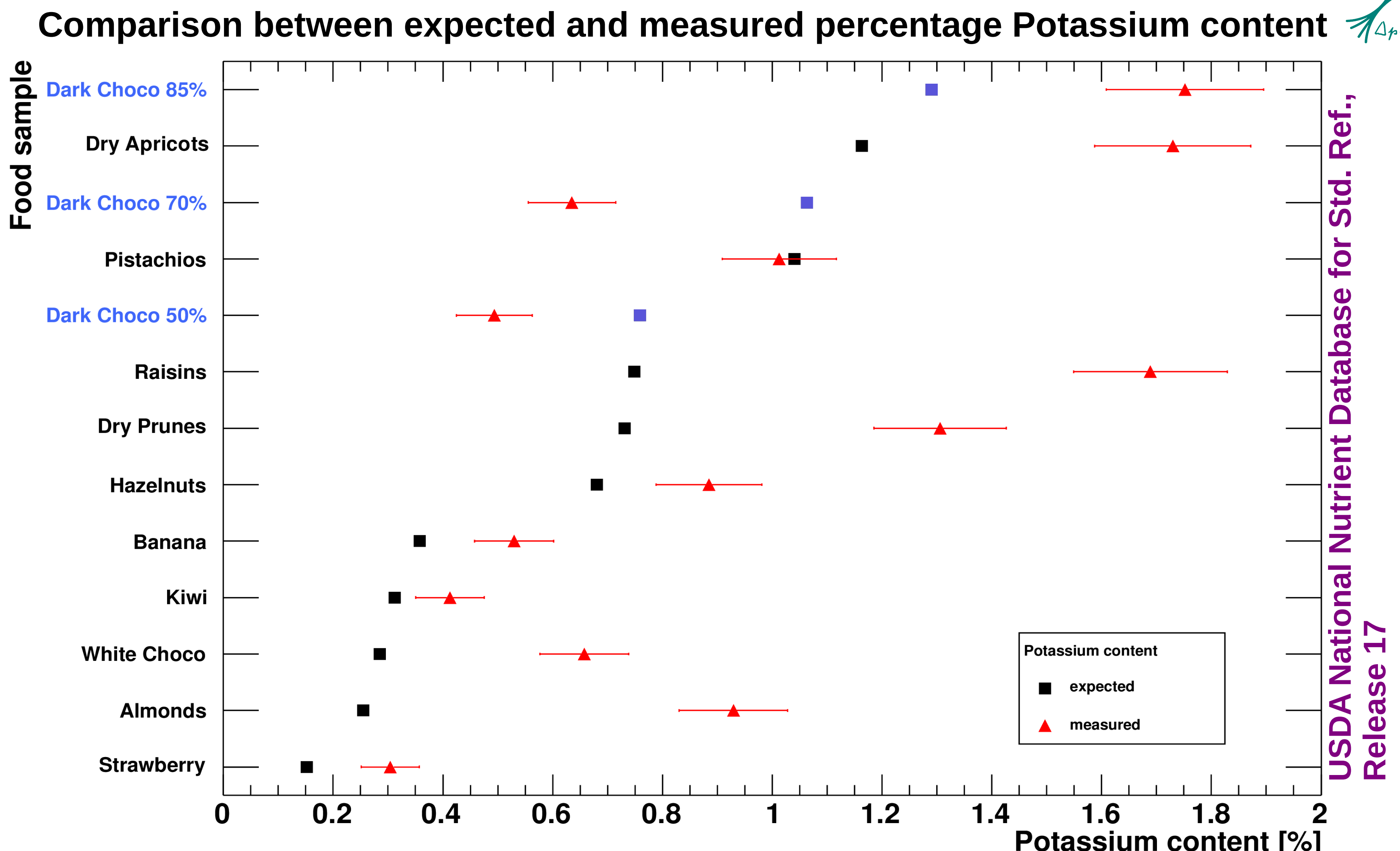
Known mass of K : Spectrum$_{KCl}$ = unknown mass of K : Spectrum$_F$

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

To be compared to the expected Potassium content

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

Data Analysis: Potassium Content



- **potassium content** in dark chocolate bars **not proportional** to **cocoa percentage**
- **deviation** from expected values
  - **different origin, production methods** of food samples

Conclusions

To summarize...

- built a shield with **high bkg reduction power**
- **good performances** of the detector with **weak sources** like strawberries
- measured **Potassium content** of **13** different food samples

- **Potassium** content in chocolate with different given cacao percentages is not proportional to the percentage

Outlook:

- further measurements will be done:
  - to **refine the method**
  - to check **chocolates**
  - to check **reproducibility for fruit**

Suggestion:

If you have cramps try raisins!!

Backup Slides

Data analysis

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:

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

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

Data analysis

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**

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

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

Data analysis

- with this experimental setup we can measure also **WEAK SOURCES**!
  → we can measure the **Potassium content** in different food sample

This are values that you can find in literature... but are they true??

Food	Potassium content in 1 pound [g]
Strawberry	0.76
Sugared almonds	1.27
White chocolate	1.43
kiwi	1.56
Banana	2.18
Hazelnuts	2.5
Dry Prunes	3.4
Raisins	3.74
Pistachios	5.125
Dry Apricots	9.25

Chocolate	Potassium content in 1 pound [g]
Dark Chocolate 50% cacao	3.81
Dark Chocolate 70% cacao	5.334
Dark Chocolate 85% cacao	6.477

We can do it but before...**we need to CALIBRATE the detector!**