Evaluation

January 14, 2026

[1]:
```
import numpy as np
import matplotlib.pyplot as plt
import pandas as pd
import yaml
from IPython.display import display, Math
from uncertainties import ufloat
```

1 Exercise 1: Calibration

The calibration data and a Gaussian fit are used to get the peak position and the calibration factor. The results are:
Peak position: 412.54
Energy calibration factor: 1.2387 keV/unit

This is used to process all further data.

2 Exercise 2: Parity violation

The processed data of the positive and the negative setting of the magnetic field is examined to determine wether parity is violated.

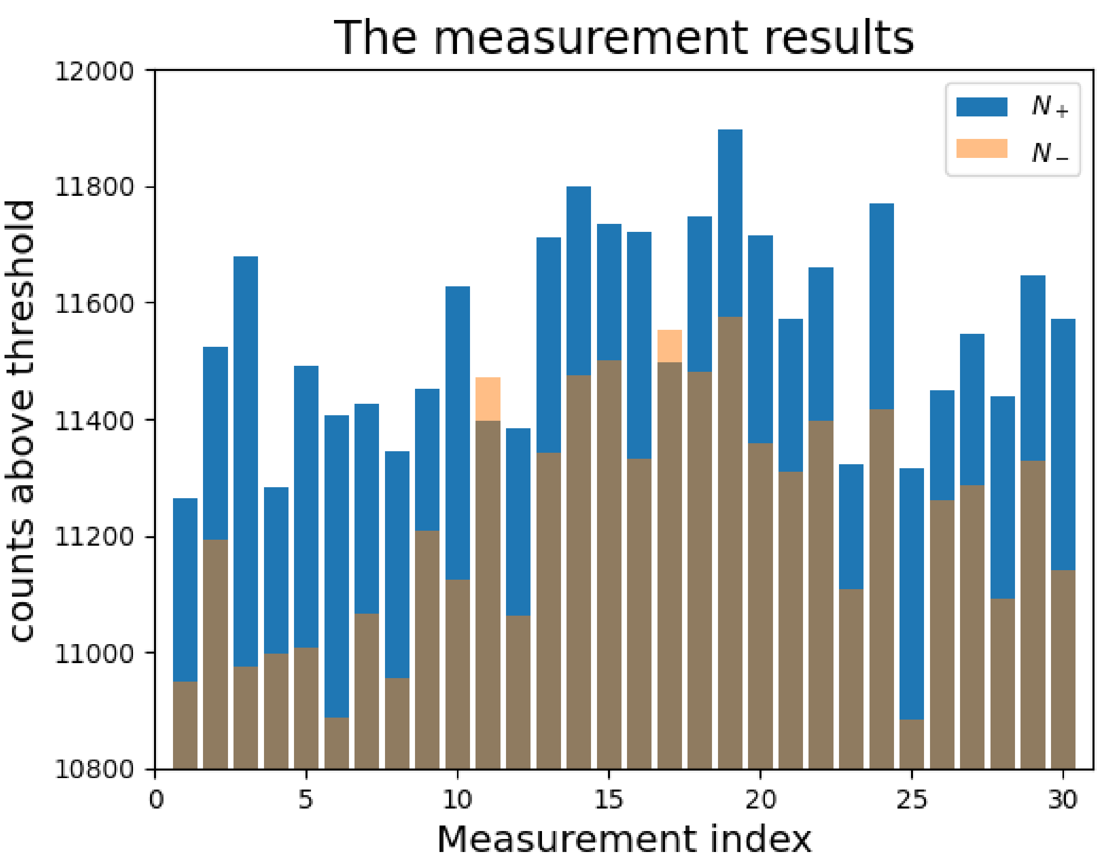
[2]:
```
# load the yaml file
with open('DataFolder/processed_files.yaml', 'r') as file:
    data = yaml.safe_load(file)['results_df']

# get the measurement values
val = [data[:][i]['Entries_Above_Threshold'] for i in range(len(data))]
val_p = val[:30] # positive field
val_m = val[30:] # negative field
sum_p = sum(val_p)
sum_m = sum(val_m)
p = ufloat(sum_p, np.sqrt(sum_p))
m = ufloat(sum_m, np.sqrt(sum_m))
```

[3]:
```
# plot the measurements
x = range(1, 31)
plt.bar(x, val_p, label = '$N_+$')
```

```
plt.bar(x, val_m, alpha = 0.5, label = '$N_-$')
plt.ylim((10800, 12000))
plt.xlim((0, 31))
plt.title('The measurement results', size = 'xx-large')
plt.xlabel('Measurement index', size = 'x-large')
plt.ylabel('counts above threshold', size = 'x-large')
plt.legend()
plt.show()

# show the results
display(Math(rf'\text{{The sum of the detection counts is:}}'))
display(Math(rf'\text{{positive: }} n_+ = {p.n:.0f} \pm {p.s:.0f} \text{{␣
↪entries above threshold}}'))
display(Math(rf'\text{{negative: }} n_- = {m.n:.0f} \pm {m.s:.0f} \text{{␣
↪entries above threshold}}'))
display(Math(rf'\text{{mean difference: }}  \bar n_+ - \bar n_- = {p.n - m.n}␣
↪\text{{ entries}}'))
```



The sum of the detection counts is:

positive: $n_+ = 346388 \pm 589$ entries above threshold

negative: $n_- = 336719 \pm 580$ entries above threshold

mean difference: $\bar{n}_+ - \bar{n}_- = 9669.0$ entries

Here the deviation is the square root of the values. $\Delta n = \sqrt{\bar{n}}$

The difference of the mean values is way larger than the deviation. That means it can be assumed that the parity is violated on β-decay.

2.1 2.1: Comparison of errors

To compare the errors of different estimations we use the value of the asymmetry $E = \frac{N_+ - N_-}{N_+ + N_-}$

Using Gaussian error propagation the error of E is calculated as follows

$$\Delta E = \sqrt{\left[\left(\frac{1}{N_+ + N_-} - \frac{N_+ - N_-}{(N_+ + N_-)^2}\right)\Delta N_+\right]^2 + \left[\left(-\frac{1}{N_+ + N_-} - \frac{N_+ - N_-}{(N_+ + N_-)^2}\right)\Delta N_-\right]^2}$$

$$\Delta E = \sqrt{\left(\frac{2N_-}{(N_+ + N_-)^2}\Delta N_+\right)^2 + \left(\frac{2N_+}{(N_+ + N_-)^2}\Delta N_-\right)^2}$$

One method uses the squareroot of the sums N_+ and N_-:
$\Delta N_\pm = \sqrt{\bar{N}_\pm}$

The other one estimates E for each pair of values N_+ and N_- with the statistical deviation $\sigma = \sqrt{\frac{\sum (E - \bar{E})^2}{N}}$ and the error of the mean $\frac{\sigma}{\sqrt{N}}$ where N is the number of pairs of values.

[4]:
```python
E1 = (p - m) / (p + m)
E2 = [(val_p[i] - val_m[i]) / (val_p[i] + val_m[i]) for i in range(30)]
E2 = ufloat(np.mean(E2), np.std(E2) / np.sqrt(30))

display(Math(rf'\text{{For the sum: }} E_{{Sum}} = {E1.n:.6f}\pm{E1.s:.6f}'))
display(Math(rf'\text{{For each pair of values: }} E_{{Pairs}} = {E2.n:.
↪6f}\pm{E2.s:.6f}'))
```

For the sum: $E_{Sum} = 0.014154 \pm 0.001210$

For each pair of values: $E_{Pairs} = 0.014184 \pm 0.001185$

So its almost the same. For this evaluation the values of the first method are used.

3 Exercise 3: Degree of Polarisation of γ

The polarisation P_C of the bremsstrahlung is determined using this formula:

$$E = \frac{N_+ - N_-}{N_+ + N_-} = f P_C \frac{\phi_C^-}{\phi_0}$$

$$\Rightarrow P_C = \frac{N_+ - N_-}{N_+ + N_-} \frac{\phi_0}{\phi_C^-} \frac{1}{f}$$

And the deviation:

$$\Delta P_C = \sqrt{\left(\frac{\phi_0}{\phi_C^-} \frac{1}{f} \Delta E\right)^2 + \left(E \frac{1}{f} \Delta \left(\frac{\phi_0}{\phi_C^-}\right)\right)^2 + \left(E \frac{\phi_0}{\phi_C^-} \frac{1}{f^2} \Delta f\right)^2}$$

Since no error for f is given it is assumed as 0. It follows:

$$\Delta P_C = \sqrt{\left(\frac{\phi_0}{\phi_C^-} \frac{1}{f} \Delta E\right)^2 + \left(E \frac{1}{f} \Delta \left(\frac{\phi_0}{\phi_C^-}\right)\right)^2}$$

With
$f = \frac{1}{13}$
$\frac{\phi_C^-}{\phi_0} = 0.52 \pm 0.05$

It follows:

[5]:
```
E = E1
phi_ratio = ufloat(0.52, 0.05)
f = 1 / 13

P_C = E / (phi_ratio * f)

display(Math(rf'P_C = {P_C.n:.3} \pm {P_C.s:.2}'))
```

$P_C = 0.354 \pm 0.046$

So the degree of polarisation is about $35\% - 36\%$ for the bremsstrahlung.

4 Exercise 4: Longitudinal Polarisation of e^-

Here the longitudinal polarisation is the same as the helicity of the electrons (→ blue book). The helicity is calculated as follows:

$$H = \frac{P_C}{L}$$

$$\Delta H = \sqrt{\left(\frac{1}{L} \Delta P_C\right)^2 + \left(\frac{P_C}{L^2} \Delta L\right)^2}$$

where L is the helicity transfer. It's value is taken from the $2.5MeV$ curve in figure 7.7 in the blue book (Note to Shivam: Could you link this to the figure in the protocol if it's included? Thank you)

To get the value the ratio of the Energies is needed.

$E_\gamma \geq 1MeV$ as this was the criterium in the first place.

$E_{e,max} = 2.28MeV$ (source: https://en.wikipedia.org/wiki/Yttrium-90, please add this to the references)

Only the kinetic energy is transferred. It follows: $E_{kin,max} = E_{e,max} - m_e c^2 = 2.28MeV - 0.51MeV = 1.77MeV$

That means the minimum of $\frac{E_\gamma}{E_{kin}}$ is $\frac{1}{1.77} = 0.56$.
It follows: $0.56 \leq L \leq 0.92$, $L = 0.74 \pm 0.18$.

So the longitudinal polarisation is:

[6]:
```
L = ufloat(0.74, 0.18)
H = P_C / L
display(Math(rf'H = {H.n:.3f} \pm {H.s:.3f}'))
```

$H = 0.478 \pm 0.132$