# gamma_spec

April 12, 2022

# 1 Gamma ray spectroscopy

## 1.1 Functions

[11]:
```
# %load ../setup.py
"""
Packages for plotting and other stuff
version: 1.0
author: Riasat
"""
# %matplotlib widget

# data loading
import pandas as pd

# data maipulation
import pwlf
import numpy as np
from scipy.interpolate import interp1d, UnivariateSpline
from scipy.signal import find_peaks

# plotting tools
import matplotlib.pyplot as plt

# extra tweaks
import warnings

warnings.filterwarnings("ignore")

# plot tweaks
plt.style.use("seaborn-poster")
pd.options.display.max_columns = None
pd.options.display.float_format = "{:.5f}".format

# function for extrapolation
def extrapolate1d(x, y):
    f = interp1d(x, y, kind="linear", fill_value="extrapolate")
    a = np.arange(0, x[len(x) - 1], 0.001)
```

```python
    b = f(a)
    return a, b


# function for interpolation
def interpolate1d(x, y):
    f = interp1d(x, y, kind="linear", fill_value="extrapolate")
    a = np.arange(x[0], x[len(x) - 1], 0.001)
    b = f(a)
    return a, b


# function for interpolation
def interpolate2d(x, y):
    f = interp1d(x, y, kind="quadratic", fill_value="extrapolate")
    a = np.arange(x[0], x[len(x) - 1], 0.001)
    b = f(a)
    return a, b


# function for interpolation
def interpolate3d(x, y):
    f = interp1d(x, y, kind="cubic", fill_value="extrapolate")
    a = np.arange(x[0], x[len(x) - 1], 0.001)
    b = f(a)
    return a, b


# funciton for polynomial fitting
def polfit(a, b, c):
    z = np.polyfit(a, b, c)
    f = np.poly1d(z)

    x = np.arange(a[0], a[len(a) - 1], 0.001)
    y = f(x)
    return x, y


# function for picewise linear fit
def picewise_linear_fit(x, y, segments):
    my_pwlf = pwlf.PiecewiseLinFit(x, y)  # fit my data
    res = my_pwlf.fit(segments)  # fit the data for n line segments
    # slopes = myPWLF.calc_slopes()  # calculate slopes

    # predict for the determined points
    xHat = np.linspace(min(x), max(x), num=10000)
    yHat = my_pwlf.predict(xHat)
```

```
    # calculate statistics
    # p = myPWLF.p_values(method="non-linear", step_size=1e-4)  # p-values
    # se = myPWLF.se  # standard errors
    return xHat, yHat
```

## 1.2 Data

[12]:
```
file_name = "data_gamma_spec.xlsx"
bg_count = 42

# calibration data
data_cesium_calib = pd.read_excel(file_name, sheet_name="cs calibration")
cs_channel_og = data_cesium_calib["cs_channel"]
cs_counts_og = data_cesium_calib["cs_counts"]
data_cobalt_calib = pd.read_excel(file_name, sheet_name="co calibration")
co_channel_og = data_cobalt_calib["co_channel"]
co_counts_og = data_cobalt_calib["co_counts"]
# distance data
data_dist = pd.read_excel(file_name, sheet_name="distance")
distance_og = data_dist["distance"]
dist_counts_og = data_dist["counts"]
net_dist_counts_og = dist_counts_og - bg_count
data_dist["net counts pm"] = net_dist_counts_og
print(f"{data_cesium_calib}, \n{data_cobalt_calib}, \n{data_dist}")
```

```
    cs_channel  cs_counts
0      5.00000       8512
1      6.00000       8952
2      7.00000       9812
3      8.00000      12027
4      9.00000      11115
5     10.00000       9377
6     11.00000       7925
7     12.00000       7210
8     14.00000       6104
9     15.00000       5885
10    16.00000       5894
11    17.00000       5848
12    18.00000       5462
13    19.00000       4688
14    20.00000       2737
15    21.00000       1831
16    22.00000       1201
17    23.00000       1101
18    24.00000       1360
19    25.00000       2974
```

```
20    26.00000      8208
21    26.20000      9083
22    26.40000     11059
23    26.60000     12327
24    26.80000     13203
25    27.00000     13885
26    27.20000     14113
27    27.40000     14106
28    27.60000     13374
29    27.80000     12504
30    28.00000     11745
31    28.20000     10116
32    28.40000      8893
33    28.60000      7113
34    28.80000      5914
35    29.00000      4769
36    30.00000      1307
37    31.00000       381
38    32.00000       229,
    co_channel  co_counts
0           40       1017
1           41        897
2           42        931
3           43        818
4           44        855
5           45        840
6           46       1049
7           47       1382
8           48       1556
9           49       1113
10          50        631
11          51        563
12          52        936
13          53       1326
14          54       1417
15          55        920
16          56        134,
    distance  counts  net counts pm
0          5    8843           8801
1          6    6777           6735
2          7    5426           5384
3          8    4430           4388
4          9    3870           3828
5         10    3201           3159
6         11    2656           2614
7         12    2360           2318
8         13    2110           2068
9         14    1818           1776
```

| | | | |
|---|---|---|---|
| 10 | 15 | 1638 | 1596 |
| 11 | 16 | 1462 | 1420 |
| 12 | 17 | 1299 | 1257 |
| 13 | 18 | 1205 | 1163 |
| 14 | 19 | 1129 | 1087 |
| 15 | 20 | 1006 | 964 |
| 16 | 21 | 950 | 908 |
| 17 | 22 | 833 | 791 |

### 1.3 Spectrum

[13]:
```
# cesium
channel_interpolated_cs, counts_interpolated_cs = interpolate3d(cs_channel_og,␣
↪cs_counts_og)
# cobalt
channel_interpolated_co, counts_interpolated_co = interpolate3d(co_channel_og,␣
↪co_counts_og)
# naming the elements
element_name = ["Cesium-137", "Cobalt-60", "Cobalt-60 Lower", "Cobalt-60␣
↪Higher"]
channel_interpolated = [channel_interpolated_cs, channel_interpolated_co]
counts_interpolated = [counts_interpolated_cs, counts_interpolated_co]
channel_original = [cs_channel_og, co_channel_og]
counts_original = [cs_counts_og, co_counts_og]
```

#### 1.3.1 Peak determination

[14]:
```
res_name = ["Cesium-137", "Cobalt-60 lower peak", "Cobalt-60 upper peak"]

for i in range(2):
    peak_id_max = find_peaks(counts_interpolated[i], height=np.
↪max(counts_interpolated[i]) - 500)
    heights = peak_id_max[1]["peak_heights"]
    pos = channel_interpolated[i][peak_id_max[0]]
    print(f"{element_name[i]}: \n\t channel = {pos} and peak = {heights}")


peak_counts = [14173.38421456, 1567.36215049, 1344.06124333]
peak_channel = [27.2, 48, 54]
known_energy = [0.662, 1.171, 1.332]
```

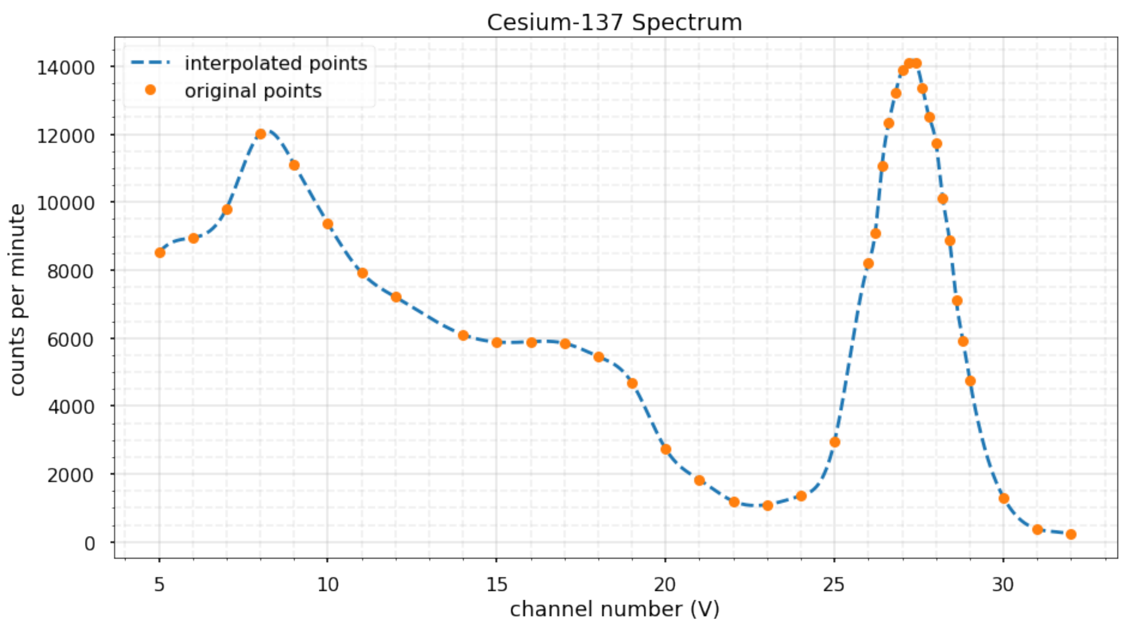
```
Cesium-137:
         channel = [27.315] and peak = [14173.38421456]
Cobalt-60:
         channel = [47.835 53.704] and peak = [1567.38499347 1445.49952008]
```

### 1.3.2 Cesium spectrum

[15]:
```python
plt.style.use("seaborn-poster")
plt.figure(figsize=(15, 8))

# plt.axvspan(vi[6], vi[7], alpha=0.2)
# for i in range(6, 8):
#     plt.annotate(f"{vi[i]:.2f}", xy=(vi[i]-0.5, 0), fontsize=14)
# plt.annotate(f"43029", xy=(24 + 0.5, 43029), fontsize=14)

plt.title(f"{element_name[0]} Spectrum")
plt.xlabel("channel number (V)")
plt.ylabel("counts per minute")
plt.plot(channel_interpolated_cs, counts_interpolated_cs, "--",␣
 ↪label="interpolated points")
plt.plot(cs_channel_og, cs_counts_og, "o", markersize=9, label="original␣
 ↪points")
plt.legend(loc="upper left")
plt.grid(alpha=0.3, which="major")
plt.minorticks_on()
plt.grid(alpha=0.2, which="minor", ls="--")
```



### 1.3.3 Cobalt-60 Spectrum

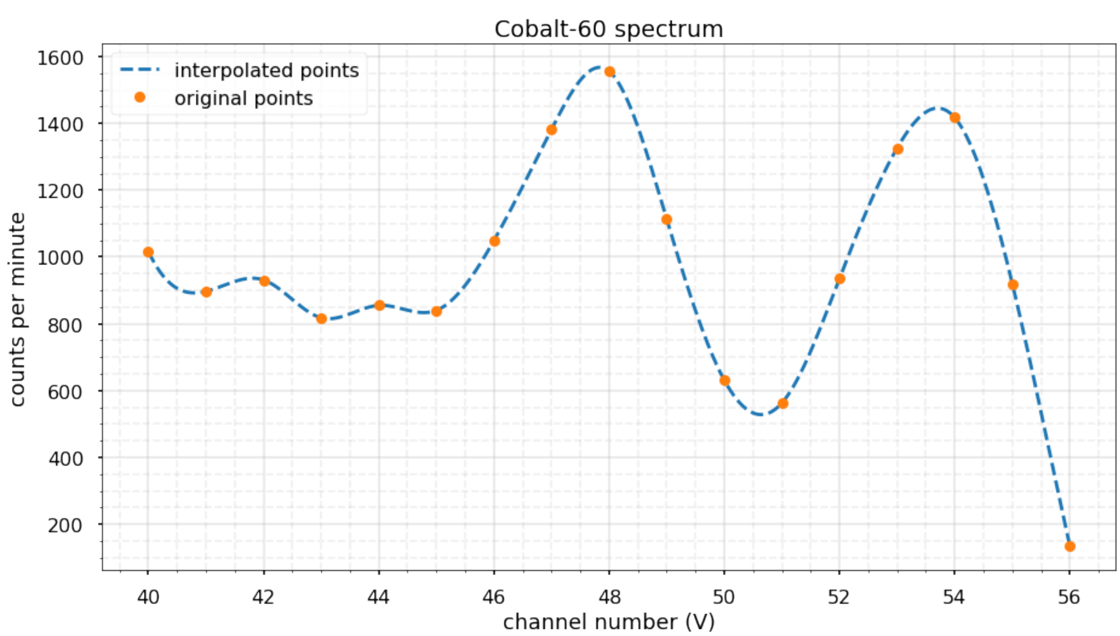
[16]:
```python
plt.style.use("seaborn-poster")
plt.figure(figsize=(15, 8))

# plt.axvspan(vi[2], vi[3], alpha=0.2)
# plt.axvspan(vi[4], vi[5], alpha=0.2)

# for i in range(2, 6):
#     plt.annotate(f"{vi[i]:.2f}", xy=(vi[i]-1, 300), fontsize=14)
# for i in range(1,3):
#     plt.annotate(f"{peak_counts[i]}", xy=(peak_channel[i] + 0.5,␣
↪peak_counts[i]), fontsize=14)

plt.title(f"{element_name[1]} spectrum")
plt.xlabel("channel number (V)")
plt.ylabel("counts per minute")
plt.plot(channel_interpolated_co, counts_interpolated_co, "--",␣
↪label="interpolated points")
plt.plot(co_channel_og, co_counts_og, "o", markersize=9, label="original␣
↪points")
plt.legend(loc="upper left")
plt.grid(alpha=0.3, which="major")
plt.minorticks_on()
plt.grid(alpha=0.2, which="minor", ls="--")

plt.show()
```



### 1.4 Calibration

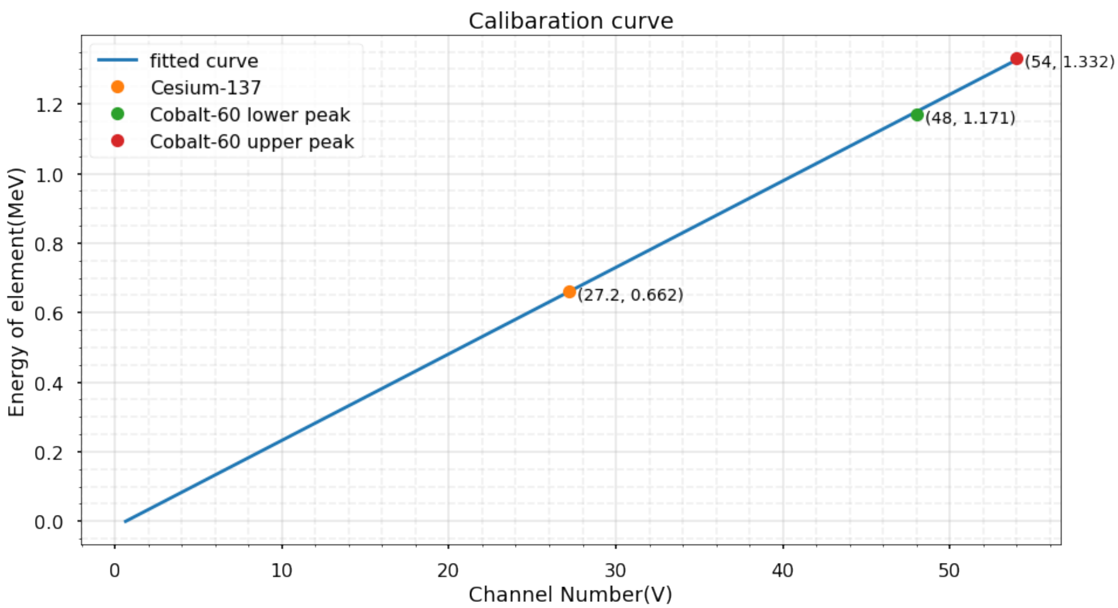
[17]:
```
# extrapolated points
peak_channel_fit, known_energy_fit = polfit(peak_channel, known_energy, 1)
cal_chan_ext, cal_eng_ext = extrapolate1d(peak_channel_fit, known_energy_fit)

ckt = [item for item in cal_eng_ext if item >= 0]

plt.style.use("seaborn-poster")
plt.figure(figsize=(15, 8))
plt.title(f"Calibaration curve")
plt.xlabel("Channel Number(V)")
plt.ylabel("Energy of element(MeV)")

# plt.plot(peak_channel, known_energy)

plt.plot(cal_chan_ext[634:], ckt, "-", label="fitted curve")
for i in range(len(res_name)):
    plt.plot(peak_channel[i], known_energy[i], "o", label=res_name[i])
    plt.annotate(f"({peak_channel[i]}, {known_energy[i]:.3f})",␣
 ↪xy=(peak_channel[i]+0.5,known_energy[i]-0.025), fontsize=14)
plt.legend(loc="upper left")
plt.grid(alpha=0.3, which="major")
plt.minorticks_on()
plt.grid(alpha=0.2, which="minor", ls="--")
plt.show()
```



[18]:

```
scatter_peaks = [8.26, 17.10]
cs_scatter_energy = np.interp(scatter_peaks, cal_chan_ext, cal_eng_ext)
print(f"\n Back-scattering peak: {cs_scatter_energy[0]:.3f} MeV\n Compton edge␣
 ↪peak energy: {cs_scatter_energy[1]:.3f} MeV")
```

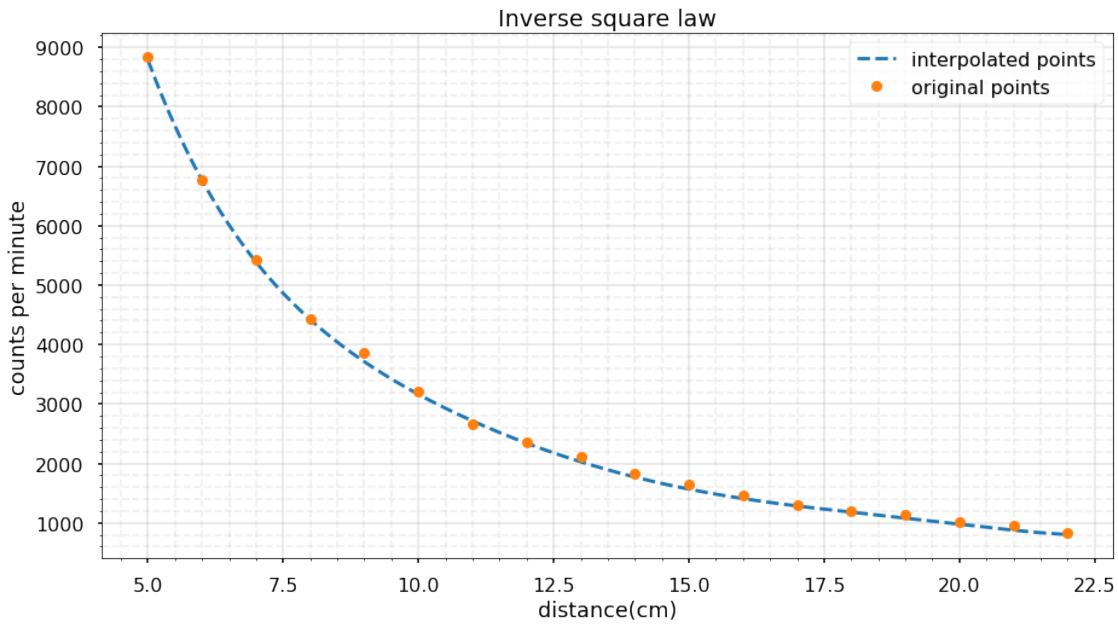
```
Back-scattering peak: 0.190 MeV
Compton edge peak energy: 0.409 MeV
```

[19]:

```
# converting counts per minute to per second
net_counts_ps = net_dist_counts_og/60
constant_k = net_counts_ps*distance_og*distance_og
data_dist["counts ps"] = net_counts_ps
data_dist["constant k"] = constant_k
dist_fitted, dist_counts_fitted = polfit(distance_og, net_dist_counts_og, 6)
plt.style.use("seaborn-poster")
plt.figure(figsize=(15, 8))

plt.title(f"Inverse square law")
plt.xlabel("distance(cm)")
plt.ylabel("counts per minute")
plt.plot(dist_fitted,dist_counts_fitted, "--", label="interpolated points")
plt.plot(distance_og,dist_counts_og, "o", markersize=9, label="original points")
plt.legend(loc="upper right")
plt.grid(alpha=0.3, which="major")
plt.minorticks_on()
plt.grid(alpha=0.2, which="minor", ls="--")

plt.show()
print(f"{data_dist}")
```




| | distance | counts | net counts pm | counts ps | constant k |
|---|---|---|---|---|---|
| 0 | 5 | 8843 | 8801 | 146.68333 | 3667.08333 |
| 1 | 6 | 6777 | 6735 | 112.25000 | 4041.00000 |
| 2 | 7 | 5426 | 5384 | 89.73333 | 4396.93333 |
| 3 | 8 | 4430 | 4388 | 73.13333 | 4680.53333 |
| 4 | 9 | 3870 | 3828 | 63.80000 | 5167.80000 |
| 5 | 10 | 3201 | 3159 | 52.65000 | 5265.00000 |
| 6 | 11 | 2656 | 2614 | 43.56667 | 5271.56667 |
| 7 | 12 | 2360 | 2318 | 38.63333 | 5563.20000 |
| 8 | 13 | 2110 | 2068 | 34.46667 | 5824.86667 |
| 9 | 14 | 1818 | 1776 | 29.60000 | 5801.60000 |
| 10 | 15 | 1638 | 1596 | 26.60000 | 5985.00000 |
| 11 | 16 | 1462 | 1420 | 23.66667 | 6058.66667 |
| 12 | 17 | 1299 | 1257 | 20.95000 | 6054.55000 |
| 13 | 18 | 1205 | 1163 | 19.38333 | 6280.20000 |
| 14 | 19 | 1129 | 1087 | 18.11667 | 6540.11667 |
| 15 | 20 | 1006 | 964 | 16.06667 | 6426.66667 |
| 16 | 21 | 950 | 908 | 15.13333 | 6673.80000 |
| 17 | 22 | 833 | 791 | 13.18333 | 6380.73333 |