surface_barrier

April 17, 2022

1 Surface Barrier

1.1 Functions

[56]:

```
# %load ../../setup.py
"""
Packages for plotting and other stuff
version: 5.0
author: Riasat
"""
# uncomment the below line to use interactive plots
# %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
from scipy import optimize

# 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):
```

```python
    f = interp1d(x, y, kind="linear", fill_value="extrapolate")
    a = np.arange(0, x[len(x) - 1], 0.001)
    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
```

```python
    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


# curve fit
def cur_fit(x, y):
    func = lambda t, a, c, d: a * np.log(t + c) + d
    popt, pcov = optimize.curve_fit(func, x, y)  # type: ignore
    xx = np.arange(x[0], x[len(x) - 1], 0.001)
    yy = func(xx, *popt)
    return xx, yy


def estimate_coef(x, y):
    # number of observations/points
    n = np.size(x)
    # mean of x and y vector
    m_x = np.sum(x)
    m_y = np.sum(y)
    # calculating cross-deviation and deviation about x
    SS_xy = np.sum(y * x)
    SS_xx = np.sum(x * x)
    deno = n * SS_xx - m_x * m_x
    # calculating regression coefficients
    b = (n * SS_xy - m_x * m_y) / deno
    a = (m_y * SS_xx - m_x * SS_xy) / deno

    return (a, b)
```

1.2 Data

[57]:
```python
file_name = "data_surface.xlsx"
res_name = ["Am-241", "Pu-239", "Cm-244"]
# calibration data
data_cesium_calib = pd.read_excel(file_name, sheet_name="calibration")
peak_channel = data_cesium_calib["calib_channel"]
known_energy = data_cesium_calib["calib_energy"]

data_am = pd.read_excel(file_name, sheet_name='thick')
left_air = data_am['left_air']
right_air = data_am['right_air']
left_vacc = data_am['left_vacc']
```

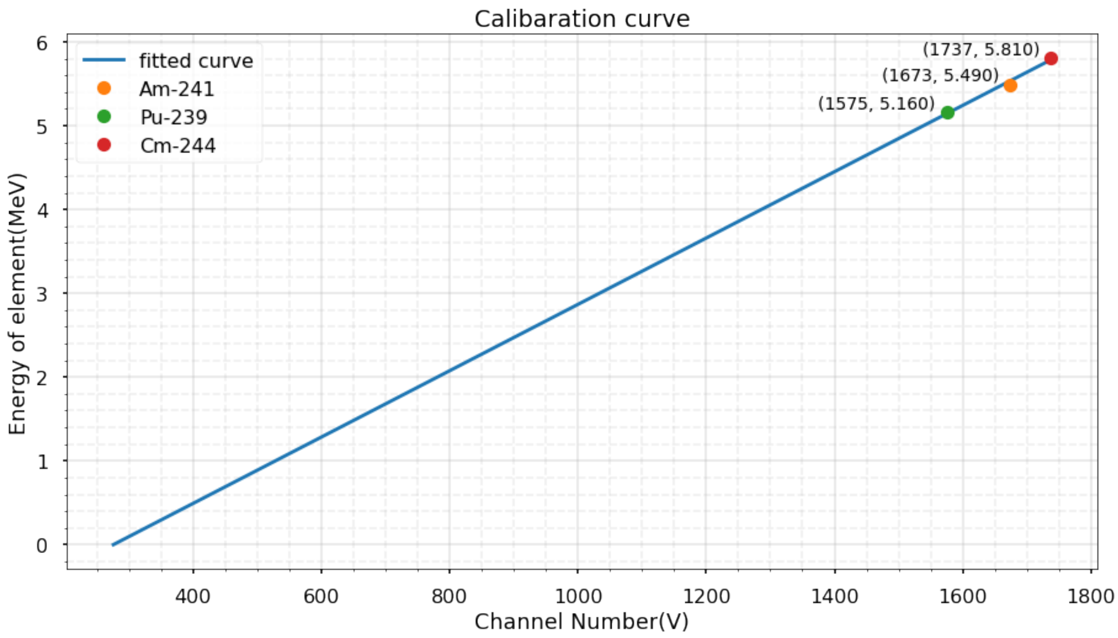
```
right_vacc = data_am['right_vacc']
vaccum_peak = data_am['vaccum_peak']
air_peak        = data_am['air_peak']
thickness = data_am['thickness']
print(data_cesium_calib)
```

```
   calib_channel  calib_energy
0           1673       5.49000
1           1575       5.16000
2           1737       5.81000
```

1.3 Calibration

[58]:

```
# 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(cal_chan_ext[275635:], 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]-200,known_energy[i]+0.05), 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()
```



1.4 FWHM

[59]:
```
# air energy from calibration curve
peak_energy_air = np.interp(air_peak, cal_chan_ext, cal_eng_ext)
peak_energy_vaccum = np.interp(vaccum_peak, cal_chan_ext, cal_eng_ext)

data_am['energy air'] = peak_energy_air
data_am['energy vaccum'] = peak_energy_vaccum

# print(data_am)
```

1.5 Thickness vs. energy

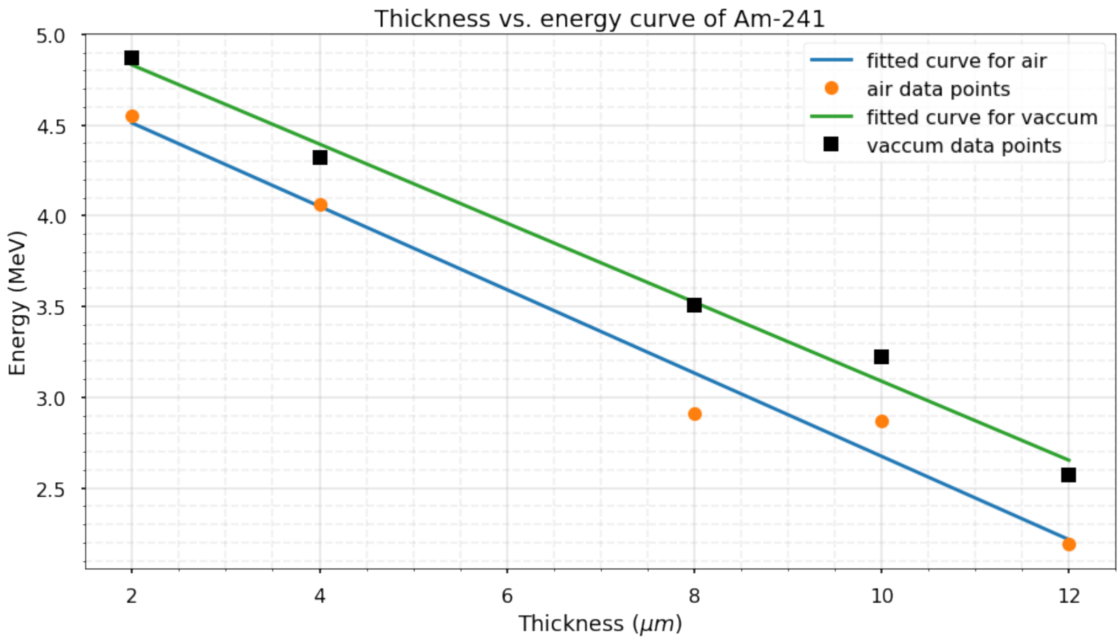
[60]:
```
# observations
xe = thickness
ye_air = peak_energy_air
ye_vac = peak_energy_vaccum

# estimating coefficients
be_air = estimate_coef(xe, ye_air)
be_vac = estimate_coef(xe, ye_vac)
print(
    f"Estimated coefficients (Air): \n a = {be_air[0]:.3f} \n b = {be_air[1]:.
↪3f} \
    \nEstimated coefficients (Vaccum): \n a = {be_vac[0]:.3f} \n b = {be_vac[1]:
↪.3f}"
```

```
)

# predicted response vector
ye_pred_air = be_air[0] + be_air[1] * xe
ye_pred_vac = be_vac[0] + be_vac[1] * xe
```

```
Estimated coefficients (Air):
 a = 4.970
 b = -0.230
Estimated coefficients (Vaccum):
 a = 5.266
 b = -0.218
```

[64]:

```
# thickness_fitted_air, peak_energy_air_fitted = polfit(thickness,␣
 ↪peak_energy_air, 1)
# thickness_fitted_vaccum , peak_energy_vaccum_fitted = polfit(thickness,␣
 ↪peak_energy_vaccum, 1)

plt.style.use("seaborn-poster")
plt.figure(figsize=(15, 8))
plt.title(f"Thickness vs. energy curve of Am-241")
plt.xlabel(r"Thickness ($\mu m$)")
plt.ylabel("Energy (MeV)")

plt.plot(xe, ye_pred_air, "-", label="fitted curve for air")
plt.plot(thickness, peak_energy_air, "o", label='air data points')
plt.plot(xe, ye_pred_vac, "-", label="fitted curve for vaccum")
plt.plot(thickness, peak_energy_vaccum, "ks", label='vaccum data 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()
```



1.6 Thickness vs. FWHM

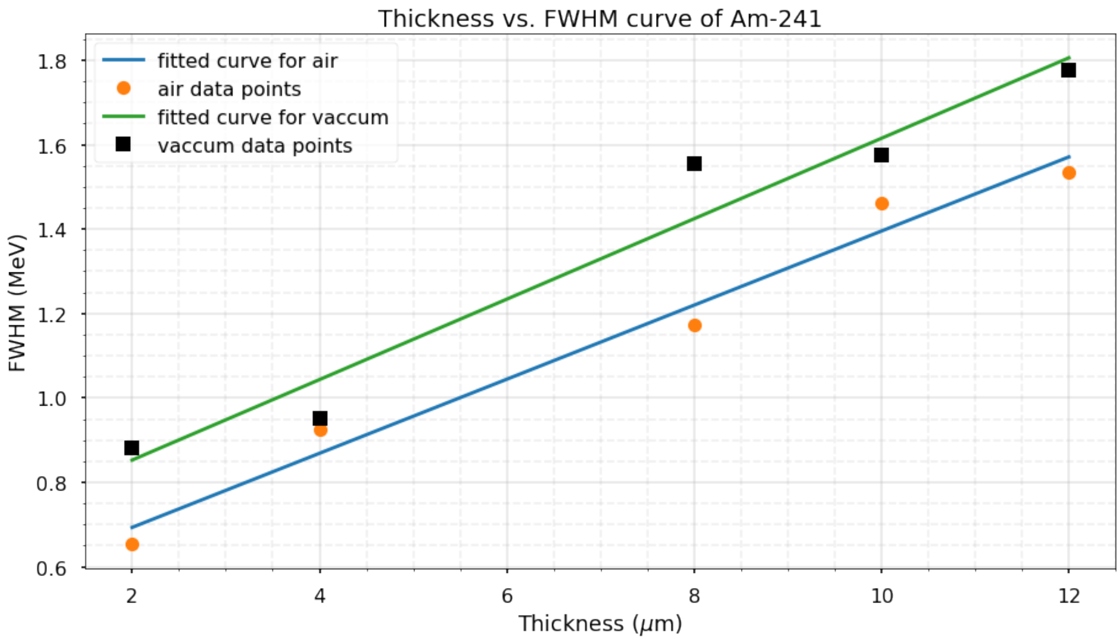
[62]:
```
left_air_energy = np.interp(left_air, cal_chan_ext, cal_eng_ext)
right_air_energy = np.interp(right_air, cal_chan_ext, cal_eng_ext)
fwhm_air_mev = abs(left_air_energy - right_air_energy)

left_vaccum_energy = np.interp(left_vacc, cal_chan_ext, cal_eng_ext)
right_vaccum_energy = np.interp(right_vacc, cal_chan_ext, cal_eng_ext)
fwhm_vaccum_mev = abs(left_vaccum_energy - right_vaccum_energy)

data_am['fwhm_air_mev'] = fwhm_air_mev
data_am['fwhm_vaccum_mev'] = fwhm_vaccum_mev
print(data_am)
```

```
   thickness  vaccum_peak  air_peak  left_vacc  right_vacc  left_air  \
0          2         1506      1425       1345        1568      1326
1          4         1367      1303       1206        1446      1138
2          8         1162      1011        862        1255       798
3         10         1090      1001        779        1177       724
4         12          925       829        575        1024       537

   right_air  energy air  energy vaccum  fwhm_air_mev  fwhm_vaccum_mev
0       1491     4.54981        4.87045       0.65316          0.88275
1       1372     4.06687        4.32022       0.92630          0.95005
2       1094     2.91098        3.50872       1.17173          1.55571
3       1093     2.87139        3.22370       1.46070          1.57550
```

```
4       925     2.19052        2.57054       1.53591          1.77739
```

[65]:
```
# observations
x = thickness
y_air = fwhm_air_mev
y_vac = fwhm_vaccum_mev

# estimating coefficients
b_air = estimate_coef(x, y_air)
b_vac = estimate_coef(x, y_vac)
print(
    f"Estimated coefficients (Air): \n a = {b_air[0]:.3f} \n b = {b_air[1]:.3f}␣
↪\
    \nEstimated coefficients (Vaccum): \n a = {b_vac[0]:.3f} \n b = {b_vac[1]:.
↪3f}"
)

# predicted response vector
y_pred_air = b_air[0] + b_air[1] * x
y_pred_vac = b_vac[0] + b_vac[1] * x

plt.style.use("seaborn-poster")
plt.figure(figsize=(15, 8))
plt.title(f"Thickness vs. FWHM curve of Am-241")
plt.xlabel(r"Thickness ($\mu$m)")
plt.ylabel("FWHM (MeV)")

plt.plot(x, y_pred_air, "-", label="fitted curve for air")
plt.plot(thickness, fwhm_air_mev, "o", label="air data points")
plt.plot(x, y_pred_vac, "-", label="fitted curve for vaccum")
plt.plot(thickness, fwhm_vaccum_mev, "ks", label="vaccum data 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()
```

```
Estimated coefficients (Air):
 a = 0.518
 b = 0.088
Estimated coefficients (Vaccum):
 a = 0.662
 b = 0.095
```


Thickness vs. FWHM curve of Am-241
fitted curve for air
air data points
fitted curve for vaccum
vaccum data points
FWHM (MeV)
Thickness (μm)
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2
4
6
8
10
12