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Week 1 Mar 1st — Mar 5th

Goals

This week we start our new experiment. γ ray Spectroscopy. The goals of this week is to understand the background about the gamma ray. Do the Literature review and discussion with professor and Classmate to better understand this topic. Also I want to know the application of gamma ray and what expect to learn from this experiment.

Introduction

Gamma-rays also know as gamma radiation. It is an electromagnetic radiation with a wavelength less than 10^{-12} meters. Generated by radioactive decay, lighting, nuclear explosions, supernova explosions, etc. Gamma Ray has strong penetrability and high energy. It primarily interact with matter through Photoelectric absorption, Compton scattering, and pair production. As energy increase. Interact happened from photoelectric absorption → Compton scattering → pair production.

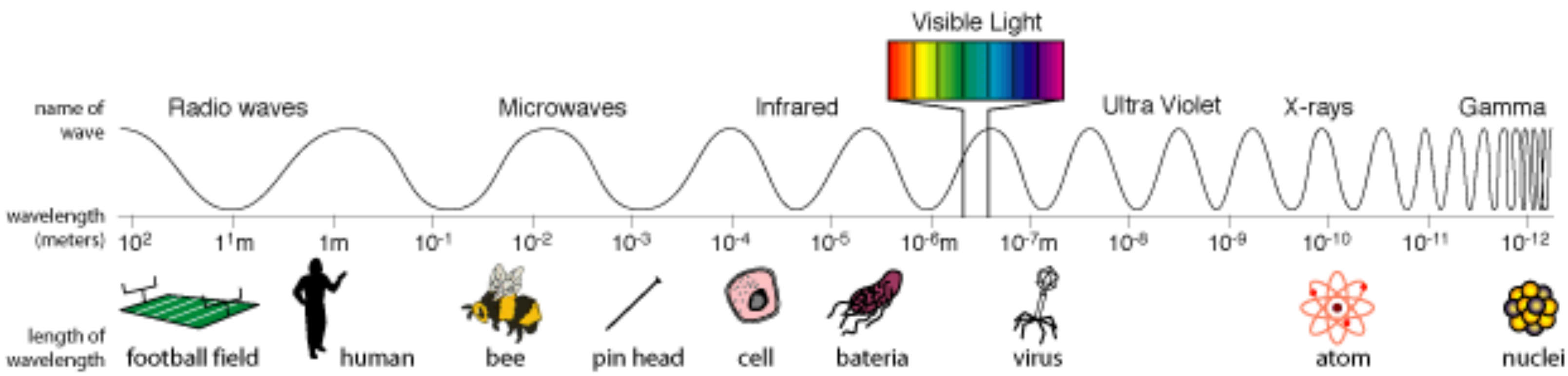
Literature Review

Gamma-Ray Spectroscopy Experiment Week 1 Literature Review

1. **What are gamma rays? When were they initially discovered? What are the sources of gamma rays?**

   Gamma-rays also known as gamma radiation or γ-ray. It is an electromagnetic radiation with a wavelength less than 10^-12 meters. The wavelength of gamma rays is smaller than the X-rays (10^-8-10^-12 meters).[1] Just like x-rays, gamma rays have strong penetrability (more than x-rays). The earliest discovery of gamma ray was from French chemist Paul Ulrich Villard (1860-1934) in 1900. When he was studying the radioactivity of radium. Today we believe that "On Earth, gamma waves are generated by nuclear explosions, lightning, and the less dramatic activity of radioactive decay. In the universe, such as neutron stars and pulsars, supernova explosions, and regions around black holes." [2]

2. **In general, what is the frequency (or energy) range of gamma ray? Could we see gamma**



   rays?

Credit: Christopher Auyeung **Source:** CK-12 Foundation

124830.18eV = 0.12MeV

The frequency of gamma rays is usually greater than 3×10^{19} Hz, and the energy is greater than 2×10^{-14} J, which is equivalent to 124,830.18 eV. So the energy of gamma rays is actually pretty high. Interesting thing is that the highest energy gamma ray that people have currently observed has reached 450 TeV (trillion electron volts) [3]. The largest accelerator LHC made by humans can only reach 1.18 TeV per beam.[4] Our naked eyes can't see it. Gamma-ray's wavelength is too small, tens of thousands times smaller than visible light

3. **Would the gamma rays emitted from different radioactive isotopes be the same? Why?**

   "All gamma rays emitted from a given isotope have the same energy, a characteristic that enables scientists to identify which gamma emitters are present in a sample." [5]

Gamma rays emmitted by different radioactive isotopes are different. The energy level will be different

4. **Do gamma rays have charge? How do they interact with matter? Describe three main interaction channels.**

Gamma rays does not have charge, they interact with matter in 3 main ways: Photoelectric effect, Compton effect, and Pair Production.
In photoelectric effect, entire energy converted to KE of a bound atomic electron. "photopeak".
In Compton effect, scatters from an electron. In collision, gamma ray gives up less than 100% of it's energy to KE of e. For gamma ray with energy greater than 1.02 MeV, possible to produce electron-positron pair. Annihilate to produce two more gamma ray 0.511 MeV.

5. **How can one detect gamma rays? Name at least two approaches.**

We could use scintillation detectors or semiconductor. In the lab we have sodium iodide (NaI) scintillator detector, and high-purity germanium (HPGe) semiconductor detector.

6. **How does one measure the energy of gamma rays?**

For NaI detector, it use photomultiplier tube (PMT) to detect light. For HPGe detector, gamma ray interaction produce electrons that are directly collected and amplified.

The detector will detect the intensity of the emitted gamma rays. And there are multiple channels. The higher energy ~~are~~ the higher channel will detect.

7. **How can one avoid unnecessary exposure to gamma rays that could be very harmful to human beings? Explain the concept of attenuation coefficient.**

If we might exposure to gamma ray, we should have a Gamma ray detector. Stay away from radiation items. Lead can play a great roll in protection of radiation.

8. **Name a few applications that have utilized the gamma rays.**

Gamma rays have penetrability and able to damage to the cells, and are used to sterilize medical supplies, etc. Gamma-ray radiotherapy. Discovery of stars and possible black holes.

Reference

[1] http://gsp.humboldt.edu/OLM/Courses/GSP_216_Online/lesson1 -2/spectrum.html

[2] https: //science.nasa.gov/ems/12_gammarays

[3] https://www.sciencemag.org/news/2019/07/highest-energy-light-ever-seen-traced-crab-nebula

[4] https://home.cern/science/accelerators/large-hadron-collider

[5] https://www.cdc.gov/nceh/radiation/isotopes.html#gamma

Here need more references.

Most reference are from internet and book NUCLEAR DECAY AND RADIOACTIVITY chapter 7 " Detecting Nuclear Radiations "

Summary

This week we did the literature review about "Gamma-Ray Spectroscopy" experiment. Learned background about gamma rays, have a general idea about what are we going to do in this experiment. We had a good discussion during the virtual lab meeting.

Week 2 Mar 8th — Mar 12th

Goals

Second week of gamma rays experiment. The goals for this week is read the text book chapter 7 Detecting Nuclear Radiations, watch the lab video. Be familiar with the lab equipment and finish the pre lab question.

Pre-Lab Questions.

1. Draw a cartoon of what happens from the instant of nuclear decay to the moment that your detector produces an output pulse.
2. Explain the logic of the electronics from detector to multi-channel analyzer (MCA).
3. What does the MCA do?
4. When measuring the attenuation coefficient of Al or Pb, it is not necessary to repeat the experiments with both detectors. On which detector should you focus?
5. What is the expected energy-dependence of the attenuation coefficients?
6. What is the most efficient way to determine the energy-dependence of the attenuation coefficients?
7. The NaI detector has inferior resolution to the HPGe detector. If a single spectral line is separated by more than the detector resolution from the next nearest line, what is the accuracy with which you can identify the position of the line? Is it given by the width of the detector response, or can it be identified more precisely?
8. Can your calibration change within a session or between sessions?

1\. γ decay, γ rays → Photo electric effect / Compton effect / Pair production → Detector

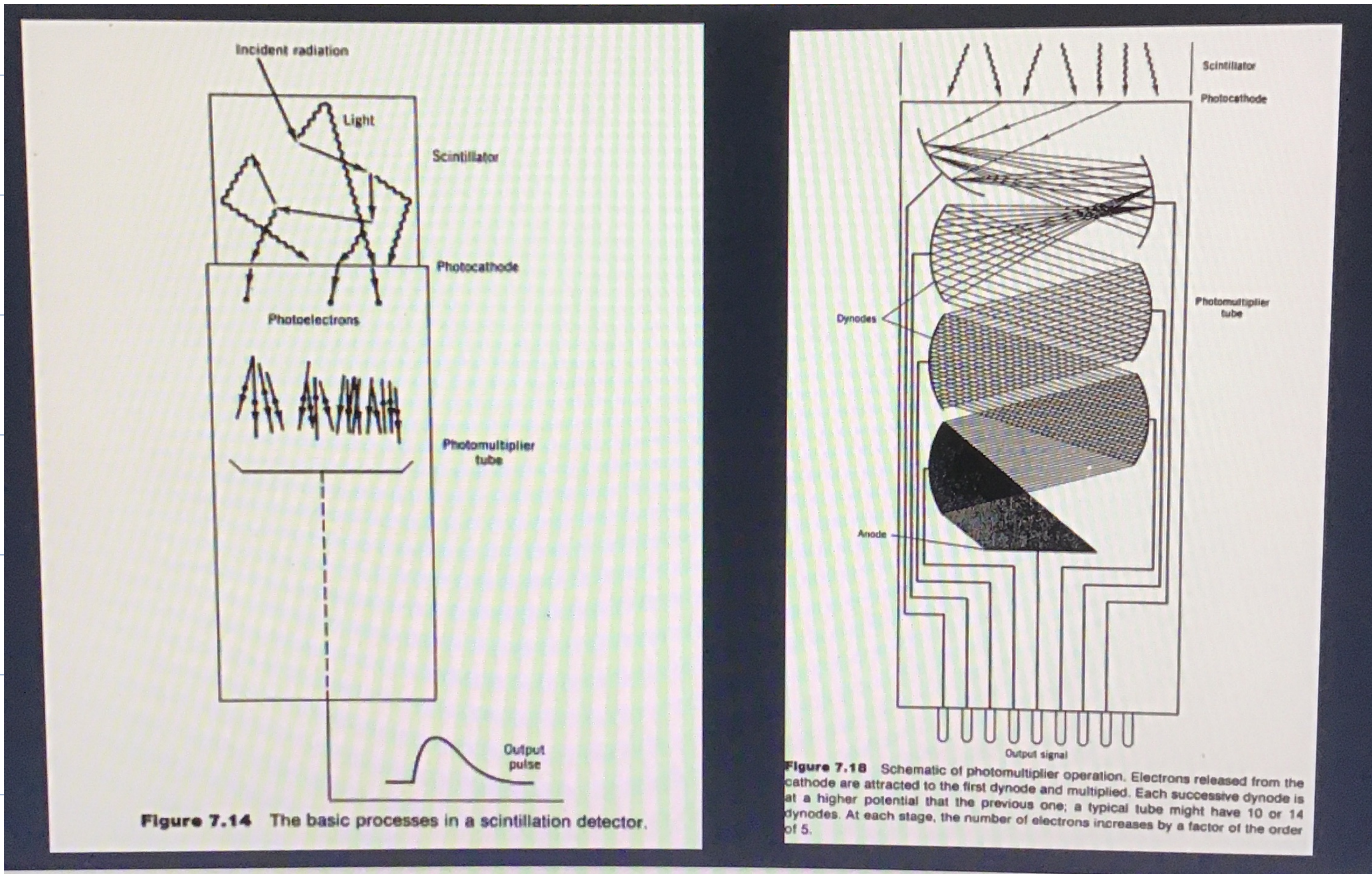


Figure 7.14 The basic processes in a scintillation detector.

Figure 7.18 Schematic of photomultiplier operation. Electrons released from the cathode are attracted to the first dynode and multiplied. Each successive dynode is at a higher potential that the previous one; a typical tube might have 10 or 14 dynodes. At each stage, the number of electrons increases by a factor of the order of 5.

① The radiation enter the detector ② emit light (visible or non visible)

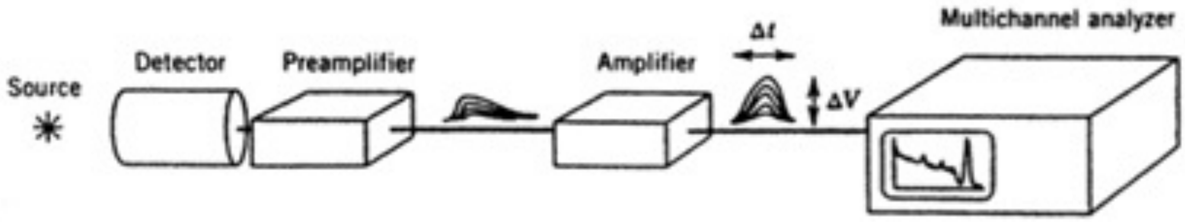
③ light strikes photosensitive surface and release photoelectron

④ electrons form output pulse.

2 A detector can measure the intensity within each channel. In semiconductor device, the detector requires a voltage to provide an electric field to collect the charge produced in the detector. In scintillator detectors

a bias voltage is needed for operation the photomultiplier tube.

3 MCA is multi-channel analyzer. Each channel can be measured at the same time, and can measure the pulse intensity within each channel.



4. When measuring the attenuation coefficient of Al or Pb we should focus on the HPGe-detector (high-purity germanium semiconductor detector)

HPGe has really good resolution, the peaks is clear and accurate. It is easy for us to calculate μ with the data from HPGe detector

5. $I = I_0 e^{-\mu t}$

I is the intensity (counts) I_0 is the initial counts. t is the distance.

6. The most efficient way to determine the energy-dependence of attenuation coefficients is to visulize the attenuation coefficients and the energy.

7. $\overline{n^2} = \sum_{n=0}^{\infty} (n^2 \times P(n))$

$$= \sum_{n=0}^{\infty} \left(n^2 \frac{\mu^n e^{-\mu}}{n!}\right) = \mu e^{-\mu} \sum_{n=0}^{\infty} \frac{n\mu^{n-1}}{(n-1)!} = \mu e^{-\mu}\left(\sum_{n=0}^{\infty} \frac{\mu^n}{n!} + \sum_{n=0}^{\infty} \frac{(n-1)\mu^{n-1}}{(n-1)!}\right)$$

$$= \mu e^{-\mu}(e^{\mu} + \mu e^{\mu})$$

$$= \mu + \mu^2$$

$$\sigma_n^2 = \mu + \mu^2 - \mu^2 = \mu$$

$$\sigma_n = \sqrt{\mu}$$

8 Calibration will not change within a session. But will change in different sessions. It is best to calibrate every time in a new session.

Summary

This week (week 2) we watched the lab video, see the NaI detector and HPGe detector. Have a better understanding about the experiment. Understand the equipments. Understand how does it work, what data will we get. What can we do with the data. We also studied how to determine the uncertainty.

Week 3 Mar 15th — Mar 19th

Goals

This week we are going to analyze the data collected by NaI detector and HPGe detector. Watch the lab video, visulize the data from different radioisotopes. Compare the out come from different detector. Establish a calibration equation to figure out the relationship between peak channel number and energy. Identify the unknow sample.

Introduction & Guide

Gamma Ray: Data from Week 3

Please find the "Gamma Ray on Week 3.zip" file for datasets to calibrate NaI and HPGe detectors. There are two columns in each csv file; the first column is channel number, and the second column is the signal intensity related to the pulse height collected. Please plot these data and present the following data analysis in your lab notebook.

A. Using the NaI detector, the gamma ray spectra of several radioactive isotopes were measured.

1) Please analyze the data measured from each radioactive isotope included in each csv file and determine the nature of the peaks by the corresponding channel number, which is proportional to the energy. Write down the the channel number of each peak.
2) Please check the literature on-line (by googling) to find out the corresponding energies (in eV) associated with the peaks from each radioactive isotope.
3) Make a table and establish a calibrate equation for the NaI detector output by plotting peak energy vs peak channel number.
4) Based on your own calibration curve, find out the peak energies of the data from an unknown sample ("unknown.csv") and determine what this unknown sample is.

B. Using the HPGe detector, the gamma ray spectra of Co60 and Cs137 were measured.

1) Please analyze the data measured from each radioactive isotope included in each csv file and determine the nature of the peaks by the corresponding channel number, which is proportional to the energy. Write down the channel number of each peak.
2) Please check the literature on-line (by googling) to find out the corresponding energies (in eV) associated with the peaks from each radioactive isotope.
3) Make a table and establish a calibration equation for the HPGe detector output by plotting peak energy vs peak channel number.

Used Python plot the data, x-axis will be the channel number and y-axis will be the counts of signals. Higher energy gamma rays will be detected by the later channel.

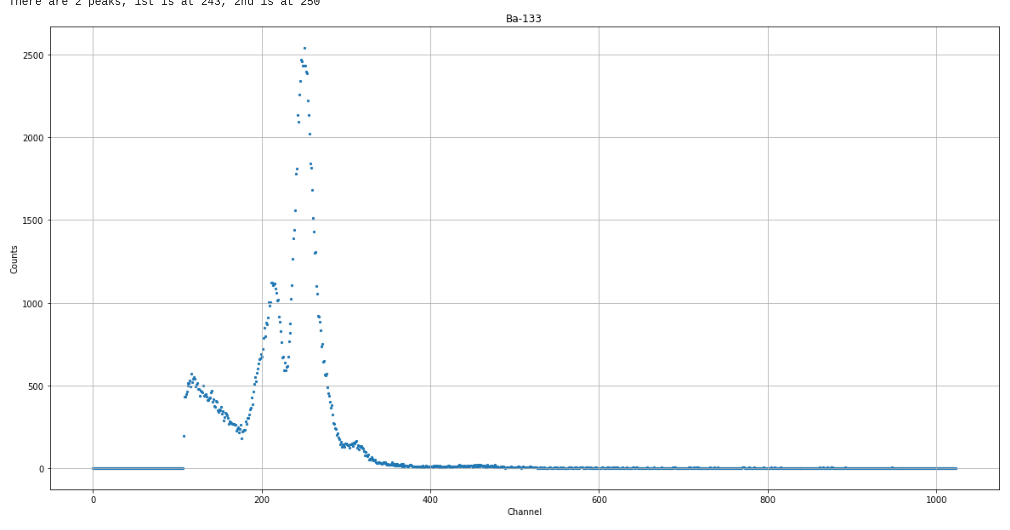
Data Analysis

NaI Detector

In [1]:
```
%matplotlib inline
import matplotlib.pyplot as plt
import numpy as np
```

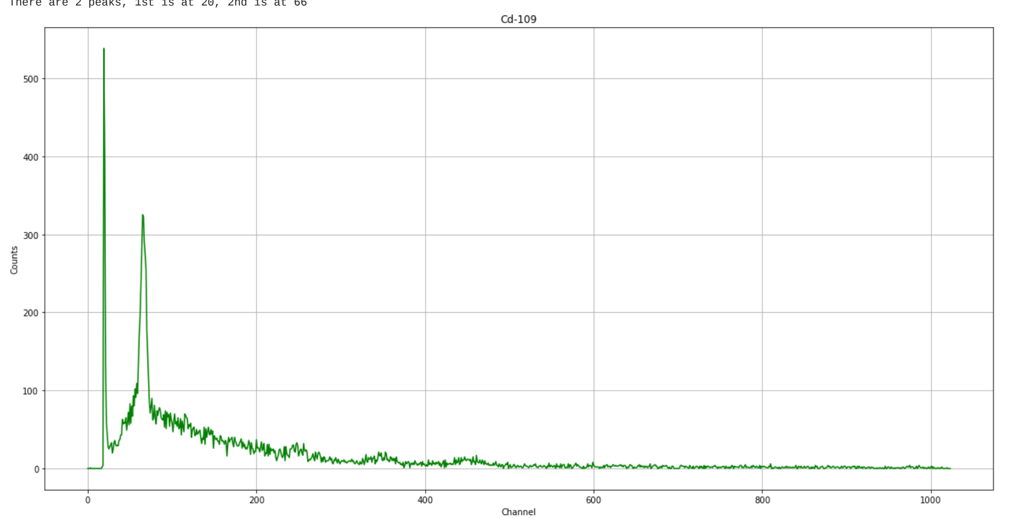
In [2]:
```
# Ba-133
Ba133_Channel,Ba133_Counts = np.loadtxt('ba-133.csv',skiprows = 22,delimiter = ',',usecols = (0,2),unpack = True)
plt.figure(figsize=(20,10))
plt.scatter(Ba133_Channel,Ba133_Counts,s = 5.0,alpha = 1.0)
plt.title("Ba-133")
plt.xlabel('Channel')
plt.ylabel('Counts')
plt.grid()
print('There are 2 peaks, 1st is at 243, 2nd is at 250')
```

```
There are 2 peaks, 1st is at 243, 2nd is at 250
```



In [3]:
```
# Cd-109
Cd109_Channel,Cd109_Counts = np.loadtxt('cd-109.csv',skiprows = 22,delimiter = ',',usecols = (0,2),unpack = True)
plt.figure(figsize=(20,10))
plt.plot(Cd109_Channel,Cd109_Counts,alpha = 1.0,c = 'g')
plt.title("Cd-109")
plt.xlabel('Channel')
plt.ylabel('Counts')
plt.grid()
print('There are 2 peaks, 1st is at 20, 2nd is at 66')
```

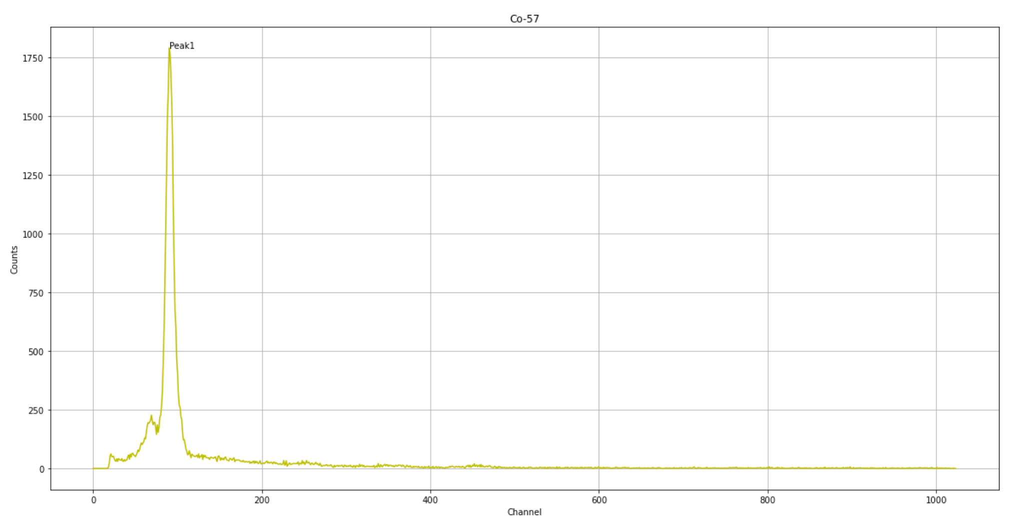
```
There are 2 peaks, 1st is at 20, 2nd is at 66
```



In [4]:
```
# Co-57
Co57_Channel,Co57_Counts = np.loadtxt('co-57.csv',skiprows = 22,delimiter = ',',usecols = (0,2),unpack = True)
plt.figure(figsize=(20,10))
plt.plot(Co57_Channel,Co57_Counts,c = 'y')
plt.title("Co-57")
plt.xlabel('Channel')
plt.ylabel('Counts')
plt.grid()
print('There are 1 big peak at channel 90')
k = Co57_Counts.argmax()
plt.text(Co57_Channel[k],Co57_Counts[k],'Peak1')
```

```
There are 1 big peak at channel 90
```

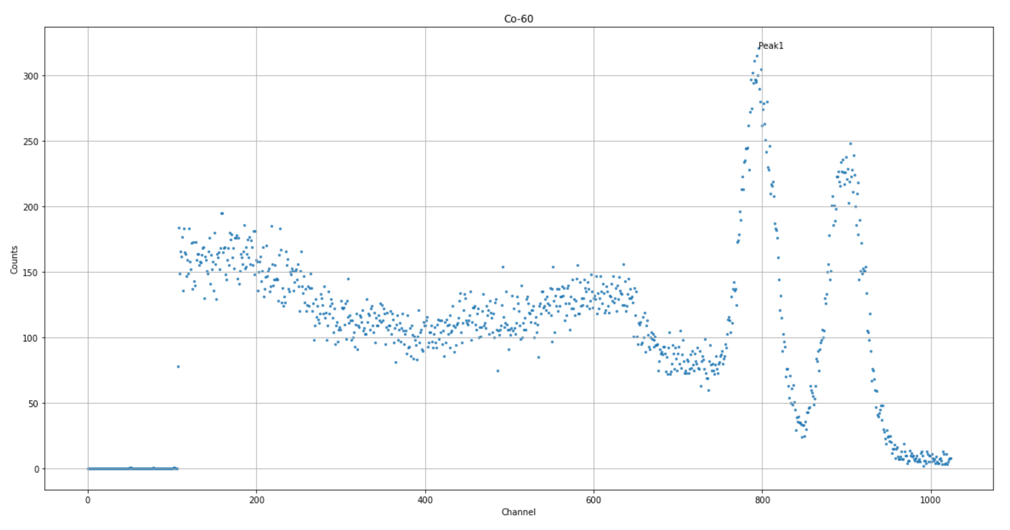
Out[4]:
```
Text(90.0, 1792.0, 'Peak1')
```



In [5]:
```
# Co-60
Co60_Channel,Co60_Counts = np.loadtxt('co-60.csv',skiprows = 22,delimiter = ',',usecols = (0,2),unpack = True)
plt.figure(figsize=(20,10))
plt.scatter(Co60_Channel,Co60_Counts,s=5.0,alpha=0.8)
plt.title("Co-60")
plt.xlabel('Channel')
plt.ylabel('Counts')
plt.grid()
print('There are 2 peaks at 796 and 900')
k = Co60_Counts.argmax()
plt.text(Co60_Channel[k],Co60_Counts[k],'Peak1')
```

```
There are 2 peaks at 796 and 900
```

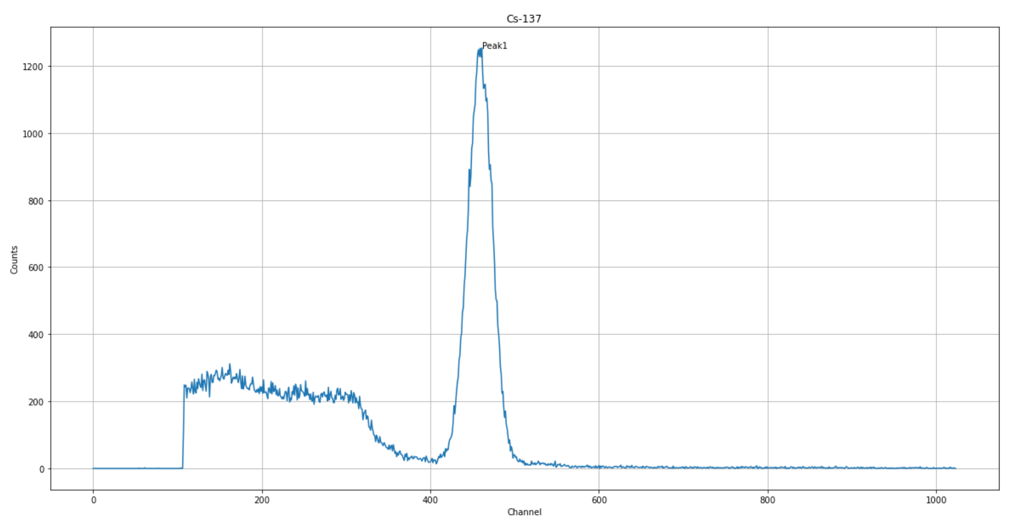
Out[5]:
```
Text(796.0, 321.0, 'Peak1')
```



In [6]:
```
# Cs-137
Cs137_Channel,Cs137_Counts = np.loadtxt('cs-137.csv',skiprows = 22,delimiter = ',',usecols = (0,2),unpack = True)
plt.figure(figsize=(20,10))
plt.plot(Cs137_Channel,Cs137_Counts)
plt.title("Cs-137")
plt.xlabel('Channel')
plt.ylabel('Counts')
plt.grid()
print('There are 1 big peak at 461')
k = Cs137_Counts.argmax()
plt.text(Cs137_Channel[k],Cs137_Counts[k],'Peak1')
```

```
There are 1 big peak at 461
```

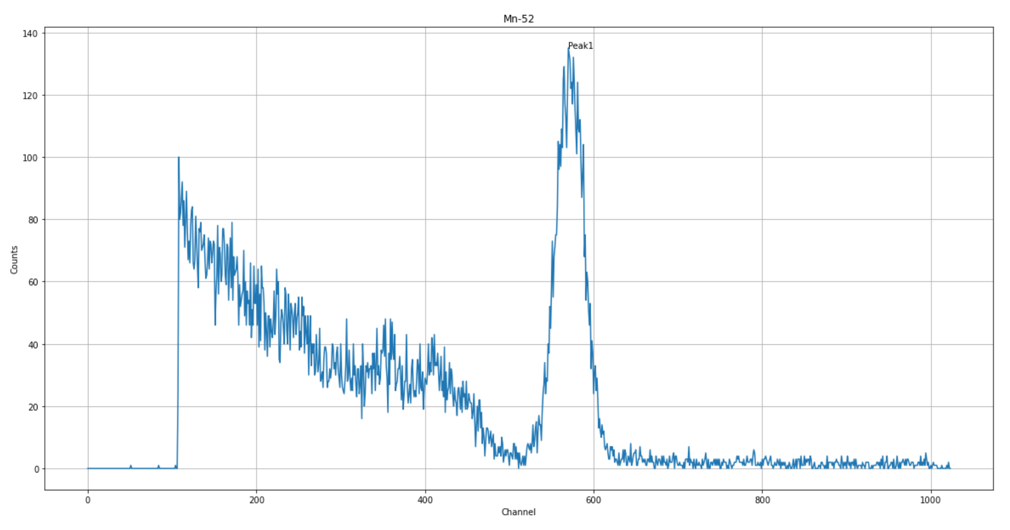
Out[6]:
```
Text(461.0, 1253.0, 'Peak1')
```



In [7]:
```
# Mn-52
Mn52_Channel,Mn52_Counts = np.loadtxt('mn-52.csv',skiprows = 22,delimiter = ',',usecols = (0,2),unpack = True)
plt.figure(figsize=(20,10))
plt.plot(Mn52_Channel,Mn52_Counts)
plt.title("Mn-52")
plt.xlabel('Channel')
plt.ylabel('Counts')
plt.grid()
print('There are 1 big peak at 570')
k = Mn52_Counts.argmax()
plt.text(Mn52_Channel[k],Mn52_Counts[k],'Peak1')
```

```
There are 1 big peak at 570
```

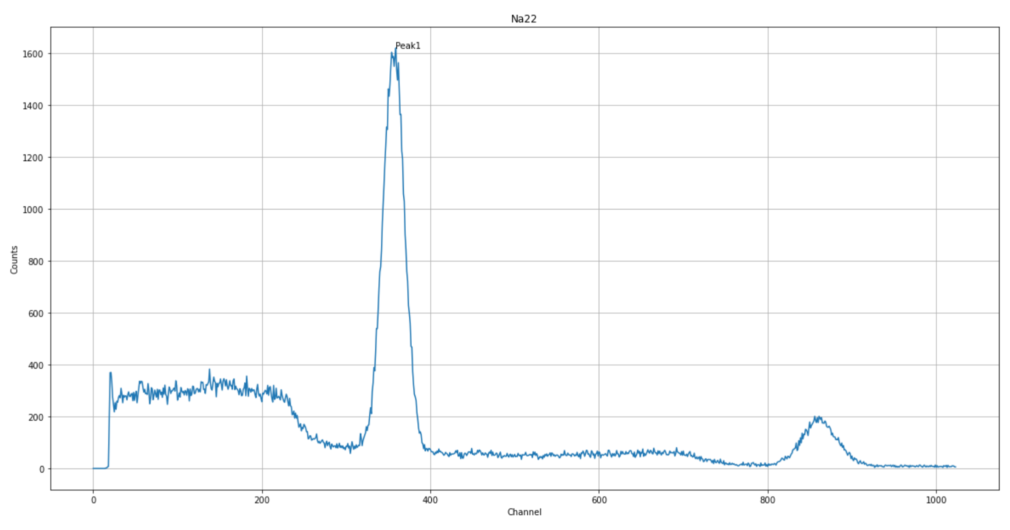
Out[7]:
```
Text(570.0, 135.0, 'Peak1')
```



In [8]:
```
# Na-22
Na22_Channel,Na22_Counts = np.loadtxt('na-22.csv',skiprows = 22,delimiter = ',',usecols = (0,2),unpack = True)
plt.figure(figsize=(20,10))
plt.plot(Na22_Channel,Na22_Counts)
plt.title("Na22")
plt.xlabel('Channel')
plt.ylabel('Counts')
plt.grid()
print('There are 2 peaks at 359 and 882')
k = Na22_Counts.argmax()
plt.text(Na22_Channel[k],Na22_Counts[k],'Peak1')
```

```
There are 2 peaks at 359 and 882
```

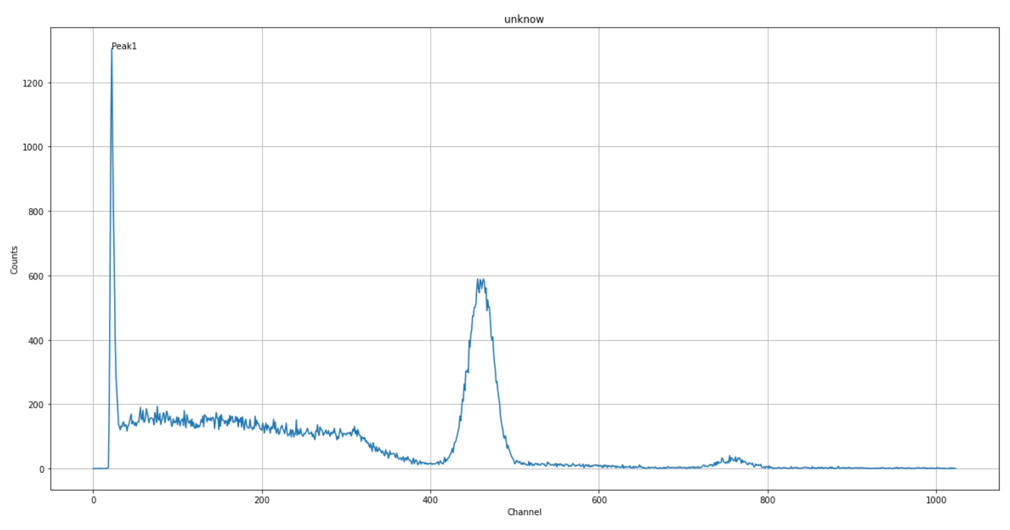
Out[8]:
```
Text(359.0, 1620.0, 'Peak1')
```



In [9]:
```
# unknown
unknown_Channel,unknown_Counts = np.loadtxt('unknown.csv',skiprows = 22,delimiter = ',',usecols = (0,2),unpack = True)
plt.figure(figsize=(20,10))
plt.plot(unknown_Channel,unknown_Counts)
plt.title("unknow")
plt.xlabel('Channel')
plt.ylabel('Counts')
plt.grid()
print('There are 3 peaks at 22 and 455 and around 735')
k = unknown_Counts.argmax()
plt.text(unknown_Channel[k],unknown_Counts[k],'Peak1')
```

```
There are 3 peaks at 22 and 455 and around 735
```

Out[9]:
```
Text(22.0, 1305.0, 'Peak1')
```



Ba133 243:303 251:356 ##channel_number:energy

Cd109 65:88.03

Co57 90:122.06

Co60 796:1.17164 900:1.33177

Cs137 461:0.6616 MeV

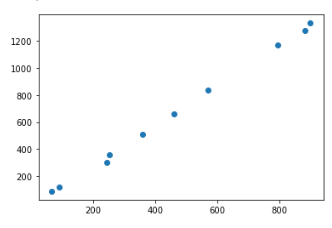
Mn52 570:834.84

Na22 359:511 882:1274.5 KeV

Peak Energy	88.03	122.06	303	356	511	661.6	834.84	1171.64	1274.5	1331.77
Peak Channel Number	65	90	243	251	359	461	570	796	882	900

In [10]:
```
channelN= np.array([65,90,243,251,359,461,570,796,882,900])
peakE = np.array([88.03,122.06,303,356,511,661.6,834.84,1171.64,1274.5,1331.77])
plt.scatter(channelN,peakE)
```

Out[10]:
```
<matplotlib.collections.PathCollection at 0x26097bb2190>
```

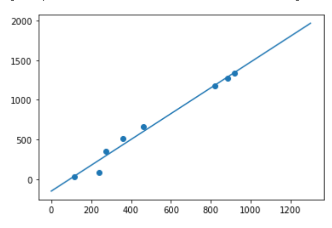


In [11]:
```
from scipy.optimize import curve_fit
def func(x, m, b):
    return m * x + b
curve_fit(func,channelN,peakE)
```

Out[11]:
```
(array([  1.49006016, -22.51677415]),
 array([[ 3.17995612e-04, -1.46818573e-01],
        [-1.46818573e-01,  9.61051831e+01]]))
```

In [94]:
```
x = np.linspace(0, 1300)
y = x * 1.62918265 - 151.94521852
plt.scatter(channelN,peakE)
plt.plot(x,y)
```

Out[94]:
```
[<matplotlib.lines.Line2D at 0x22fe340fa90>]
```



Energy = channel*1.49006016 - 22.51677415

For Unknown sample ther are two visible peaks one of then is at channel number 22, another is around 583. Thus we can calculate the gamma-ray energy should be around 797.868 KeV and 1086.2 KeV

65ZN Cs-134 Sb-125 Bi-207

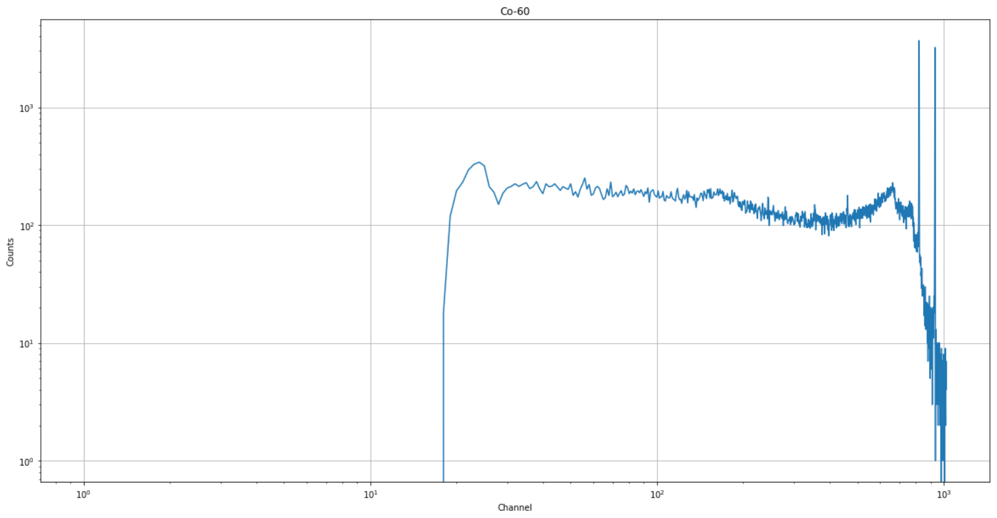
The unknown is actually two samples they are Cs137 and Zn65

the peak is at 661keV 1.115MeV

HPGe Detector

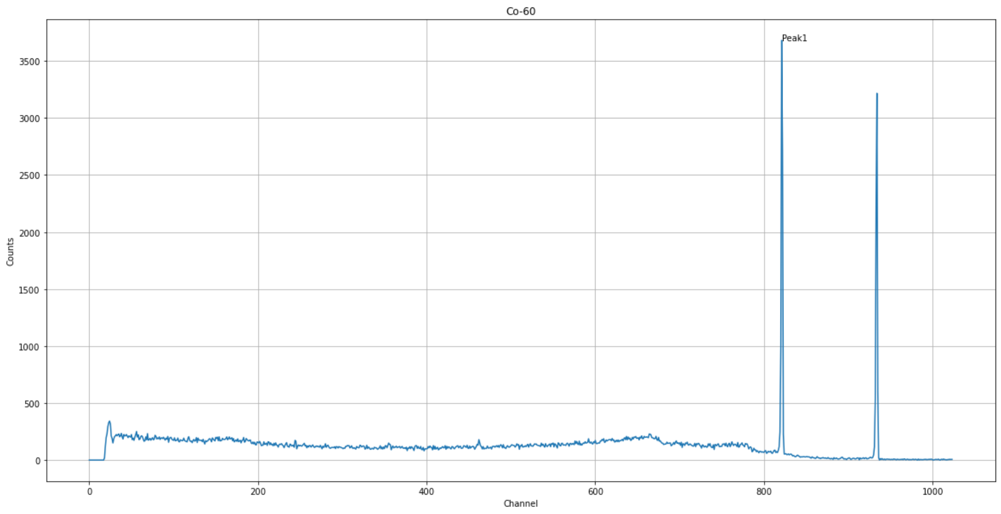
In [1]:
```
%matplotlib inline
import matplotlib.pyplot as plt
import numpy as np
from scipy.optimize import curve_fit
```

In [4]:
```
# Co-60
Co60_Channel,Co60_Counts = np.loadtxt('Co-60_hpge.csv',skiprows = 22,delimiter = ',',usecols = (0,2),unpack = True)
plt.figure(figsize=(20,10))
plt.loglog(Co60_Channel,Co60_Counts,alpha = 1.0)
plt.title("Co-60")
plt.xlabel('Channel')
plt.ylabel('Counts')
plt.grid()
```



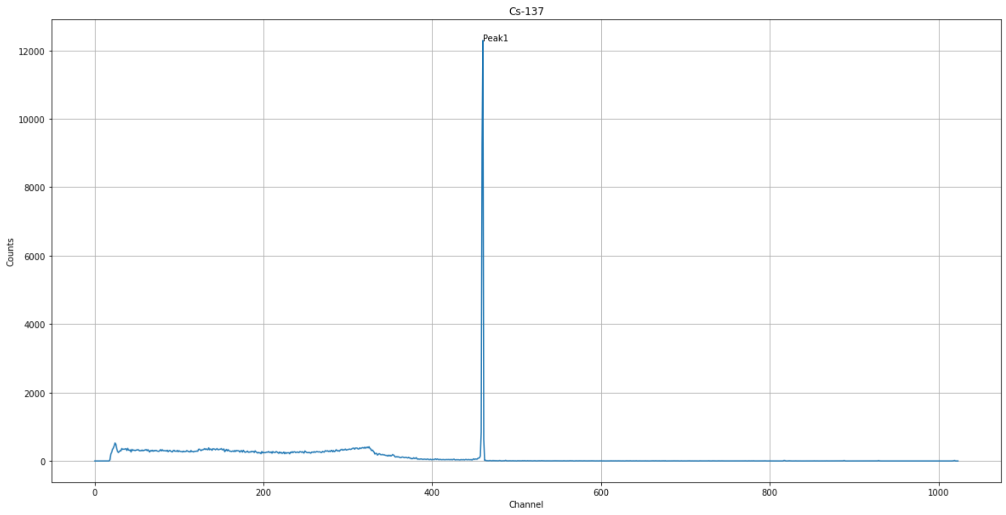
In [5]:
```
Co60_Channel,Co60_Counts = np.loadtxt('Co-60_hpge.csv',skiprows = 22,delimiter = ',',usecols = (0,2),unpack = True)
plt.figure(figsize=(20,10))
plt.plot(Co60_Channel,Co60_Counts,alpha = 1.0)
plt.title("Co-60")
plt.xlabel('Channel')
plt.ylabel('Counts')
plt.grid()
k = Co60_Counts.argmax()

print('Peak 1 is at',plt.text(Co60_Channel[k],Co60_Counts[k],'Peak1'),'Peak 2 is at 934')
```

```
Peak 1 is at Text(821.0, 3681.0, 'Peak1') Peak 2 is at 934
```



In [6]:
```
#cs-137_hpge.csv
Cs_Channel,Cs_Counts = np.loadtxt('cs-137_hpge.csv',skiprows = 22,delimiter = ',',usecols = (0,2),unpack = True)
plt.figure(figsize=(20,10))
plt.plot(Cs_Channel,Cs_Counts,alpha = 1.0)
plt.title("Cs-137")
plt.xlabel('Channel')
plt.ylabel('Counts')
plt.grid()
k = Cs_Counts.argmax()
plt.text(Cs_Channel[k],Cs_Counts[k],'Peak1')
```

Out[6]:
```
Text(460.0, 12290.0, 'Peak1')
```



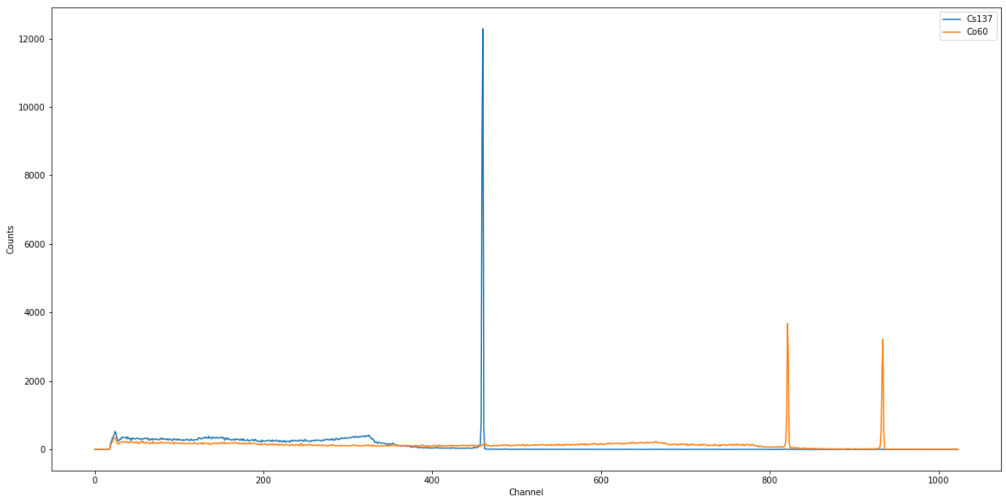
Peak Energy	661.66KeV	1173.24KeV	1332.50Kev
Peak Channel Number	460	821	934

In [10]:
```
peak_energy = np.array([661.66,1173.24,1332.50])
peak_channel_number = np.array([460,821,934])
def func(x, a, b):
    return a * x + b
curve_fit(func,peak_channel_number,peak_energy)
```

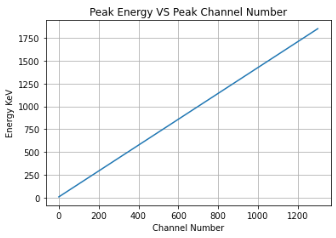
Out[10]:
```
(array([ 1.41572337, 10.52424694]),
 array([[ 2.21040694e-06, -1.63201724e-03],
        [-1.63201724e-03,  1.29529644e+00]]))
```

In [11]:
```
x = np.linspace(0, 1300)
y = x * 1.41572337 + 10.52424694
plt.figure(figsize=(20,10))
plt.plot(Cs_Channel,Cs_Counts,label='Cs137')
plt.plot(Co60_Channel,Co60_Counts,label='Co60')
plt.xlabel('Channel')
plt.ylabel('Counts')
plt.legend()
```

Out[11]:
```
<matplotlib.legend.Legend at 0x1edeadc8430>
```



In [12]:
```
plt.plot(x,y)
plt.title('Peak Energy VS Peak Channel Number')
plt.xlabel('Channel Number')
plt.ylabel('Energy KeV')
plt.grid()
```



Energy = Channel number x 1.41572337 + 10.52424694

Energy = channel number * 1.41572337 + 10.52424694

In [ ]:

Discussion

The NaI detector is simple and relable. But the drawback is that is NaI could obsorb water from the atmosphere which will destroy the crystal.

HPGe detector has really good resolution. But it require really low working temperature.

We could use Gaussian distribution to analyze peak. But there are too much work. The uncertainty in the peak position is reduced as more data are collected.

Summary.

From the NaI detector.

γ-ray energy = channel number $\times$ 1.49 − 22.51617

Unknow sample is Cs137 and Zn65

From HPGe detector.

γ-ray energy = channel number $\times$ 1.41572337 + 10.52424694

Week 4 Mar 22nd — Mar 26th

Goals

This week's goal is use HPGe detector measure Eu gamma ray. Then determine the energy of the peacks. Second part is to calculate the attenuation coefficient of Al and Pb. Watch lab video, keep reading the materials in D2L. Understand the attenuation coefficient.

Introduction

From last week we got Energy = channel number × 1.41572337 + 10.52424694. We could use this equation to calculate the related gamma ray energy of Eu152.

Attenuation coefficient is depends on the intensity and distance. It describ the fraction of attenuated incident photons in a monoenergetic beam per unit thickness of a material.

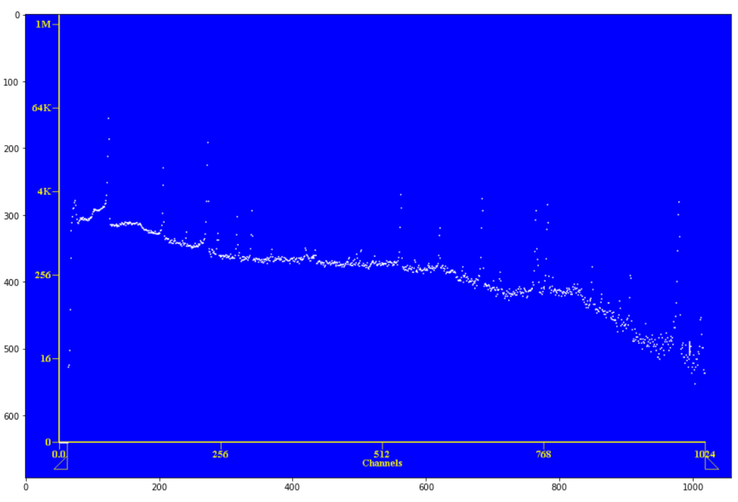
The equation is $\underset{\text{Intensity}}{\underset{\uparrow}{I}} = \underset{\text{initial inten.}}{\underset{\uparrow}{I_0}} e^{-\mu x}$ ← distance

μ : linear attenuation coefficient

Data Analysis

In [1]:
```python
%matplotlib inline
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
from scipy.optimize import curve_fit

import matplotlib.image as mpimg
plt.figure(figsize=(20,10))
img = mpimg.imread('Eu-spec.PNG')
plt.imshow(img)
```

Out[1]: <matplotlib.image.AxesImage at 0x16ca085e6a0>



In [2]:
```python
df = pd.read_excel('Eu-HPGe-detector.xlsx',skiprows = range(1, 3),usecols = 'A')
print(df)
```

```
    152-Eu
0       78
1      165
2      235
3      282
4      305
5      541
6      603
7      670
8      756
9      774
10     845
11     905
```

From Previous HPGe Lab we get

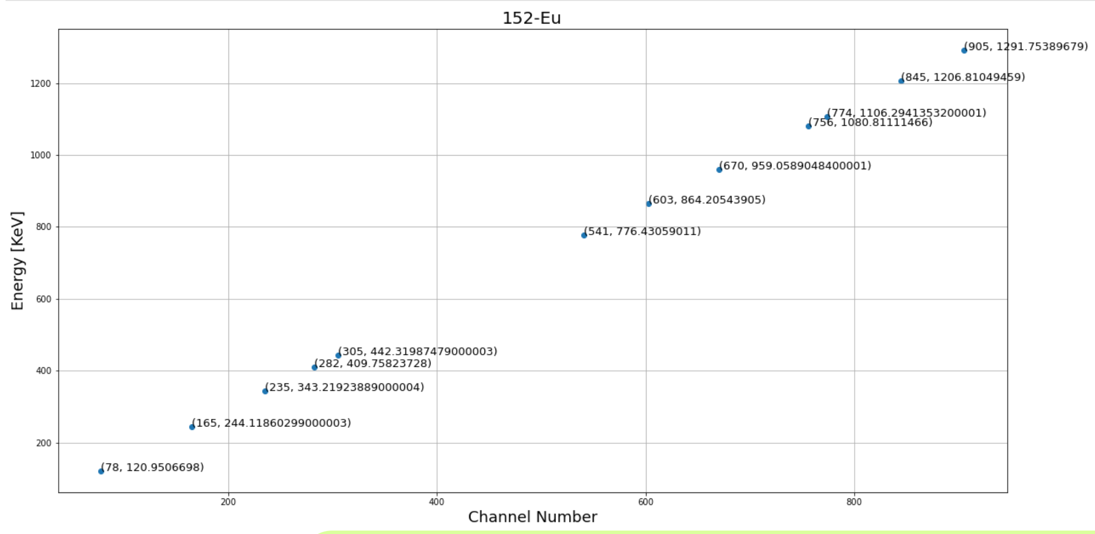
Peak Energy	661.66KeV	1173.24KeV	1332.50Kev
Peak Channel Number	460	821	934

And: Energy = channel number X 1.41572337 + 10.52424694

In [3]:
```python
def energy(x):
    Energy = x * 1.41572337 + 10.52424694
    return Energy

df['Energy'] = energy(df)
print(df)
```

```
    152-Eu       Energy
0       78   120.950670
1      165   244.118603
2      235   343.219239
3      282   409.758237
4      305   442.319875
5      541   776.430590
6      603   864.205439
7      670   959.058905
8      756  1080.811115
9      774  1106.294135
10     845  1206.810495
11     905  1291.753897
```

In [4]:
```python
plt.figure(figsize=(20,10))
plt.scatter(df['152-Eu'],df['Energy']) ### 152-Eu is the channel number

for xy in zip(df['152-Eu'],df['Energy']):
    plt.annotate('(%s, %s)' % xy, xy=xy, textcoords='data',fontsize=13) ### label the points

plt.title("152-Eu",fontsize=20)
plt.xlabel('Channel Number',fontsize=18)
plt.ylabel('Energy [KeV]',fontsize=18)
plt.grid()
```



Here are the gamma ray energy related with the channel number peaks.

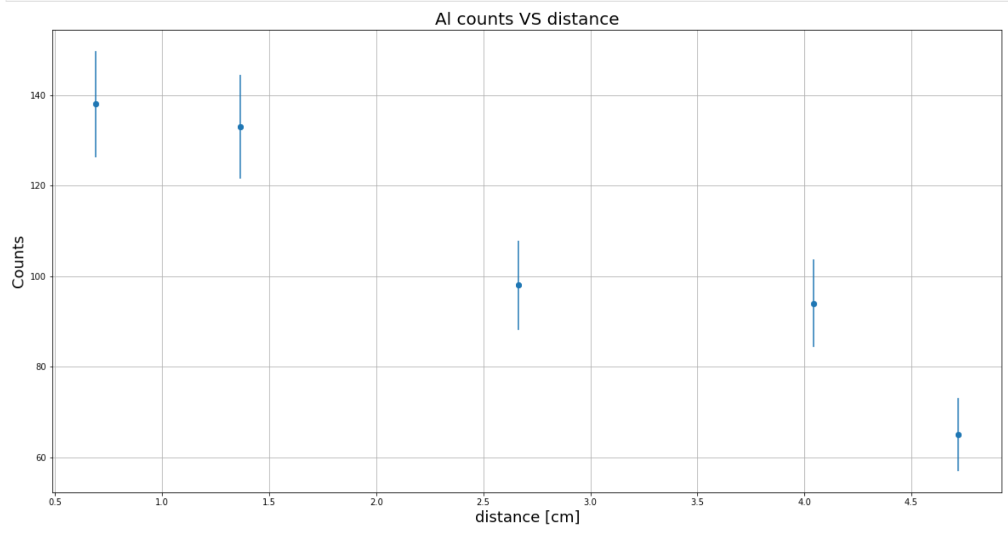
Peak Energy	120.95KeV	244.12KeV	343.22Kev	409.76KeV	442.32Kev	776.43KeV	864.21Kev	959.06KeV	1080.81KeV	1106.30Kev	1206.81KeV	1291.75Kev
Peak Channel Number	78	165	235	282	305	541	603	670	756	774	845	905

Determine the attenuation coefficients

In [6]:
```python
#Al
Al = pd.read_excel('Attenuation using NaI detector.xlsx',skiprows = range(1, 10)
                   ,usecols = 'A:C',skipfooter=10)
print(Al) ## 1 distance x 2 dx
```

```
   attentuation coefficients  Unnamed: 1  Unnamed: 2
0                        148       0.690       0.001
1                        143       1.366       0.001
2                        108       2.663       0.001
3                        104       4.044       0.001
4                         75       4.720       0.001
```

In [10]:
```python
I_Al = Al["attentuation coefficients"] -10  # Counts
X_Al = Al["Unnamed: 1"] # distance
Al_err = I_Al ** (1/2) # uncertainty
plt.figure(figsize=(20,10))
plt.scatter(X_Al,I_Al)
plt.errorbar(X_Al,I_Al,yerr=yerr,xerr=0.001,fmt="o") #counts ground is 10: dx is 0.001
plt.title("Al counts VS distance",fontsize=20)
plt.xlabel('distance [cm]',fontsize=18)
plt.ylabel('Counts',fontsize=18)
plt.grid()
```



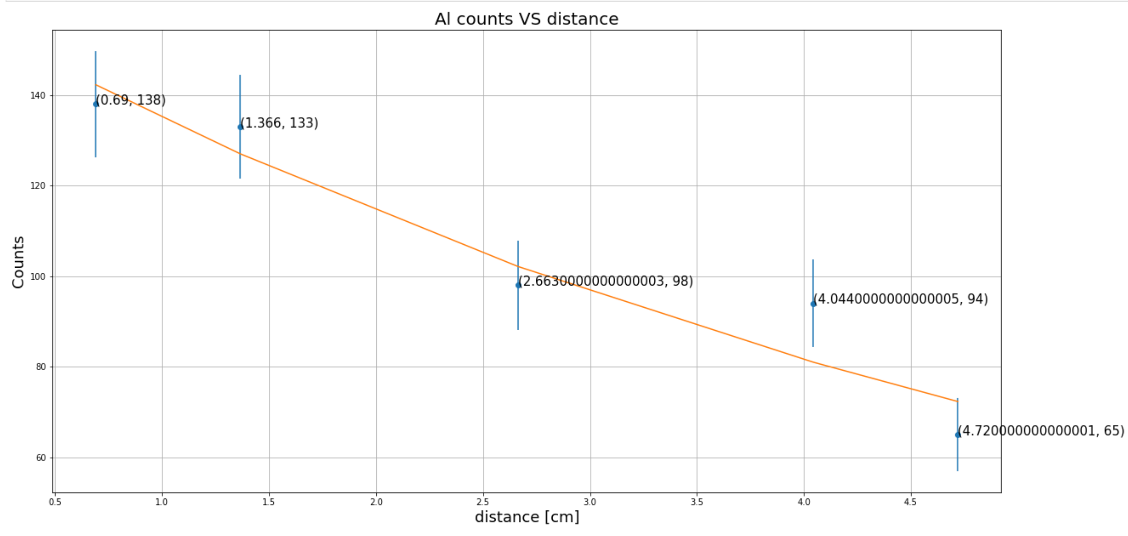
Intensity error is equal to $\sqrt{I}$

In [22]:
```python
def atten(x,I,err):
    Atten = curve_fit(lambda x, i0, u: i0 * np.exp(-u*x), x, I, sigma = err)
    print('I0 is',Atten[0][0],'Attenuation coefficient is',Atten[0][1],'cm^-1')
```

In [23]:
```python
atten(X_Al,I_Al,Al_err)
```

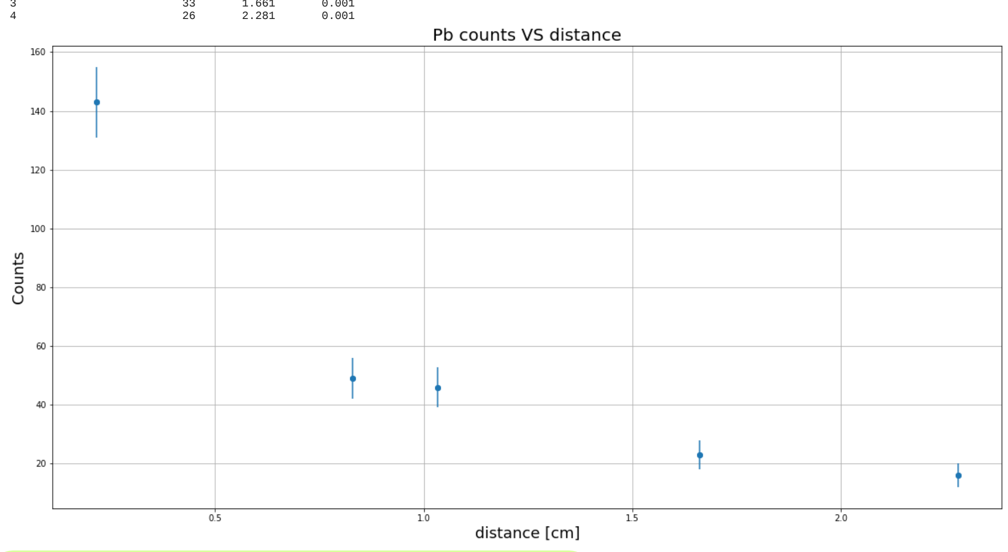
```
I0 is 159.76352240974037 Attenuation coefficient is 0.16791315342814608 cm^-1
```

In [17]:
```python
plt.figure(figsize=(20,10))
plt.errorbar(X_Al,I_Al,yerr=Al_err,xerr=0.001,fmt="o") #counts ground is 10: dx is 0.001
plt.plot(X_Al,159.76*np.exp(-0.1679*X_Al))
for xy in zip(X_Al,I_Al):
    plt.annotate('(%s, %s)' % xy, xy=xy, textcoords='data',fontsize=15)

plt.title("Al counts VS distance",fontsize=20)
plt.xlabel('distance [cm]',fontsize=18)
plt.ylabel('Counts',fontsize=18)
plt.grid()
```



In [19]:
```python
#Pb
Pb = pd.read_excel('Attenuation using NaI detector.xlsx',skiprows = range(1, 20)
                   ,usecols = 'A:C')
print(Pb)

IPb = Pb["attentuation coefficients"] -10
XPb = Pb["Unnamed: 1"]
Pb_err = IPb ** (1/2)
plt.figure(figsize=(20,10))
plt.scatter(XPb,IPb)
plt.errorbar(XPb,IPb,yerr=Pb_err,xerr=0.001,fmt="o") #counts ground is 10: dx is 0.001
plt.title("Pb counts VS distance",fontsize=20)
plt.xlabel('distance [cm]',fontsize=18)
plt.ylabel('Counts',fontsize=18)
plt.grid()
```

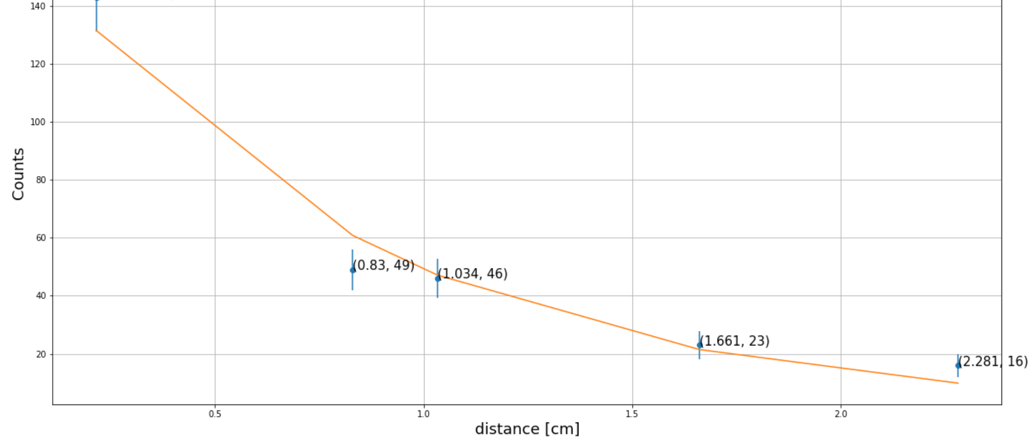
```
   attentuation coefficients  Unnamed: 1  Unnamed: 2
0                        153       0.215       0.001
1                         59       0.830       0.001
2                         56       1.034       0.001
3                         33       1.661       0.001
4                         26       2.281       0.001
```



In [24]:
```python
atten(XPb,IPb,Pb_err)
```

```
I0 is 172.28445663013812 Attenuation coefficient is 1.254596000806527 cm^-1
```

In [21]:
```python
plt.figure(figsize=(20,10))
plt.errorbar(XPb,IPb,yerr=Pb_err,xerr=0.001,fmt="o") #counts ground is 10: dx is 0.001
plt.plot(XPb,172.28445663*np.exp(-1.254596*XPb))

for xy in zip(XPb,IPb):
    plt.annotate('(%s, %s)' % xy, xy=xy, textcoords='data',fontsize=15)

plt.title("Pb counts VS distance",fontsize=20)
plt.xlabel('distance [cm]',fontsize=18)
plt.ylabel('Counts',fontsize=18)
plt.grid()
```



Discussion

HPGe detector has very good resolution. However, there are still some peaks doesn't show up in the visualization. To improve that we could decrease the background noise by cover the detector with Pb. And we could also increase the measure time so more signal could show on the peaks. Overall, the more data the better.

Summary

In this week's lab, we got an accurate gamma ray energy table for Eu152 thanks to HPGe detector.

We got attenuation coefficient for Al and Pb. They are 0.1679 cm^{-1} and 1.254596 cm^{-1}