analysis

January 8, 2024

[21]:
```
%matplotlib inline
import numpy as np
import matplotlib.pyplot as plt
import pandas as pd
from mpl_toolkits.mplot3d import Axes3D
import plotly.graph_objs as go
import seaborn as sns
from sklearn.cluster import KMeans
from sklearn.ensemble import IsolationForest
from scipy.stats import shapiro
from scipy.stats import sem, t
```

[3]:
```
file_path = 'muon_simulation_results.csv'
df = pd.read_csv(file_path)
df[['x', 'y', 'z']] = df['Position'].str.strip('[]').str.split(expand=True).
 ↪astype(float)
threshold = 1
df['Is_Cavity'] = (df['Energy_Loss'] < threshold) & (df['Energy_Loss'] != 0)
df= df[df['Energy_Loss'] != 0]
df.head()
```

[3]:

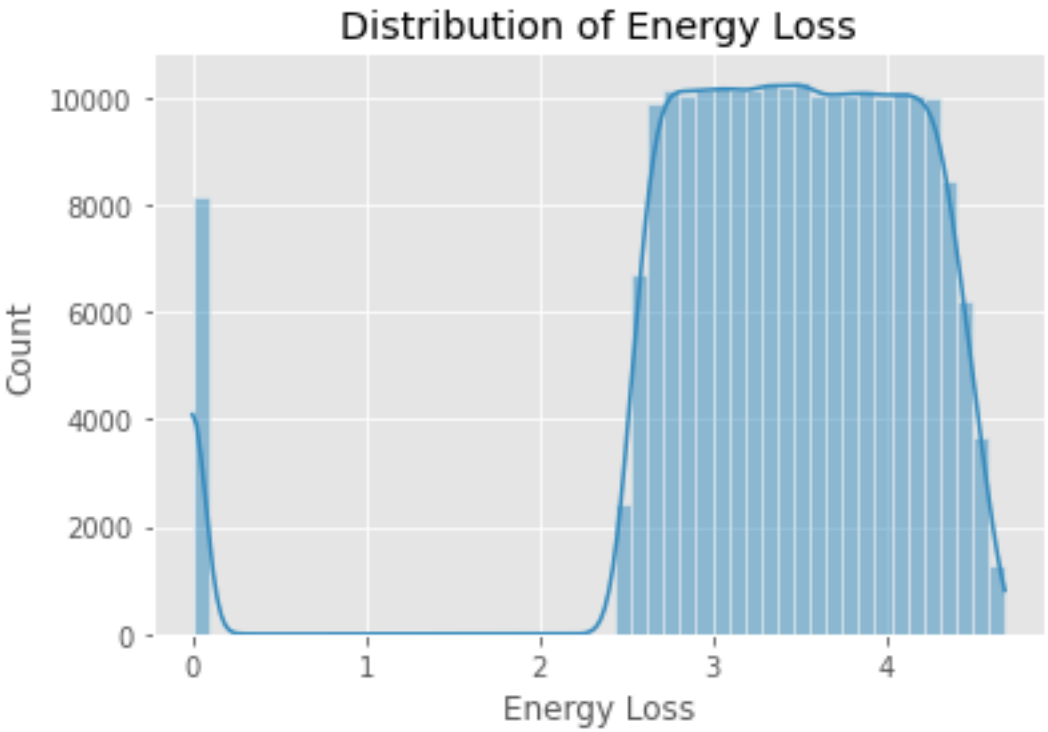
	Muon_ID	Position	Direction	Energy	Energy_Loss	Is_Absorbed	x	y	z	Is_Cavity
1	0	[157.75195142 203.93749687 31.43731061]	[-0.39390541 -0.84616522 0.35894701]	604.747462	2.593000	False	157.751951	203.937497	31.437311	False
2	0	[157.71256088 203.85288034 31.47320531]	[-0.43084303 -0.84417936 0.31896002]	601.880612	2.866850					
3	0	[157.66947658 203.76846241 31.50510131]	[-0.41077938 -0.86389257 0.29146169]	599.004357	2.876255					
4	0	[157.62839864 203.68207315 31.53424748]	[-0.44788913 -0.83151933 0.32858931]	595.834652	3.169705					
5	0	[157.58360973 203.59892122 31.56710641]	[-0.47346401 -0.82867732 0.29853934]	592.975050	2.859602					

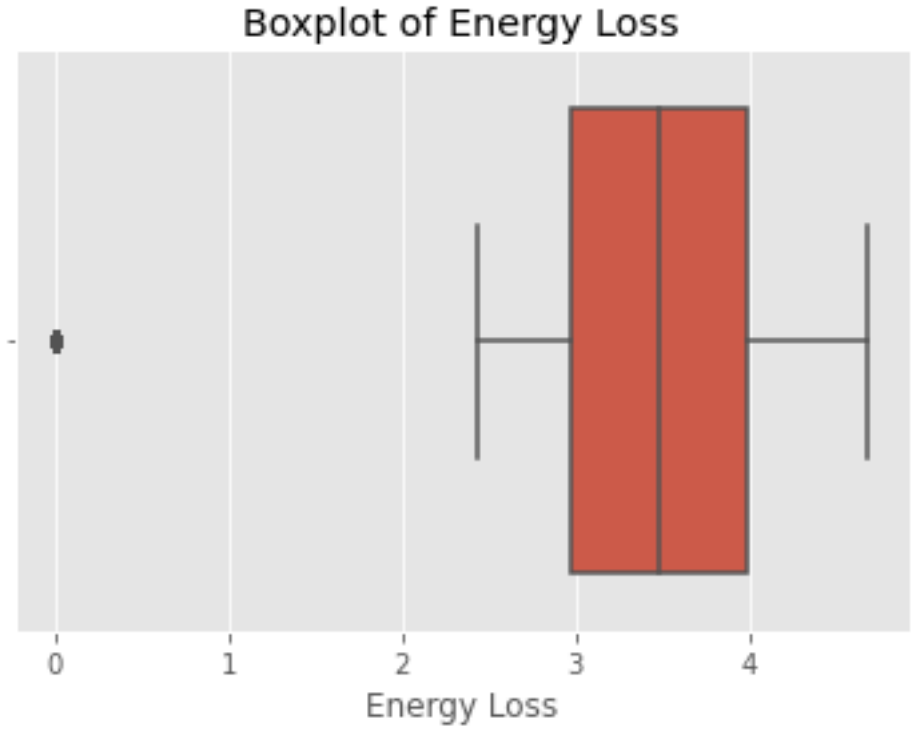
```
2        False  157.712561  203.852880  31.473205      False
3        False  157.669477  203.768462  31.505101      False
4        False  157.628399  203.682073  31.534247      False
5        False  157.583610  203.598921  31.567106      False
```

[4]:
```
energy_loss_stats = df['Energy_Loss'].describe()
print(energy_loss_stats)
```

```
count    218599.000000
mean          3.387053
std           0.869905
min           0.000012
25%           2.972947
50%           3.476681
75%           3.983219
max           4.685977
Name: Energy_Loss, dtype: float64
```

[34]:
```
plt.style.use('ggplot')
sns.histplot(df['Energy_Loss'], bins=50 , kde=True)
plt.xlabel('Energy Loss')
plt.ylabel('Count')
plt.title('Distribution of Energy Loss')
plt.show()
sns.boxplot(x=df['Energy_Loss'])
plt.title('Boxplot of Energy Loss')
plt.xlabel('Energy Loss')
plt.show()
```


Distribution of Energy Loss
Count
10000
8000
6000
4000
2000
0
0
1
2
3
4
Energy Loss


Boxplot of Energy Loss
0
1
2
3
4
Energy Loss

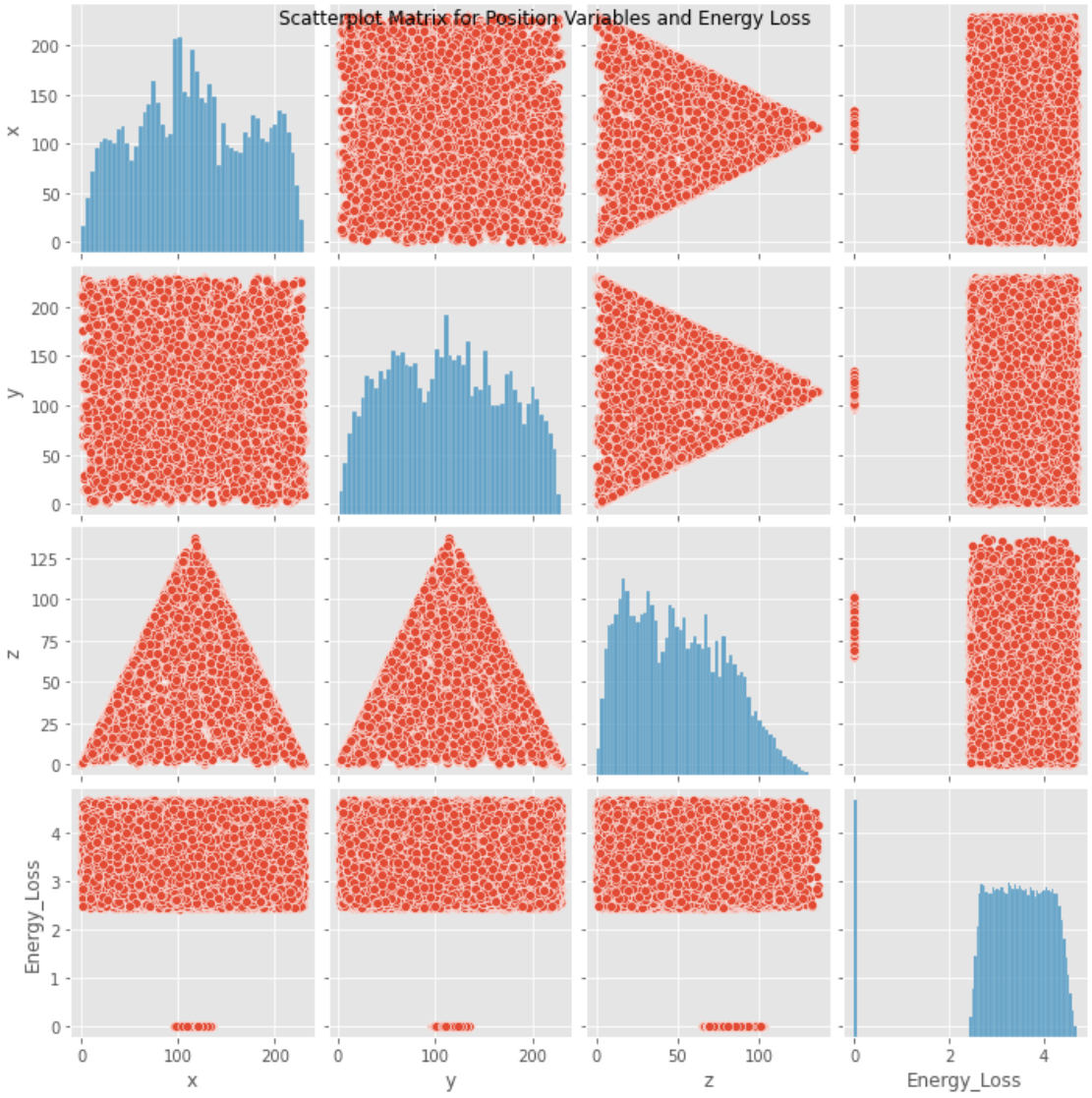
[35]:
```
shapiro_test = shapiro(df['Energy_Loss'].sample(800))
print(f"Shapiro-Wilk test:\nStatistics={shapiro_test[0]},␣
 ↪p-value={shapiro_test[1]}")
skewness = df['Energy_Loss'].skew()
kurtosis = df['Energy_Loss'].kurt()
print(f"Skewness: {skewness}")
print(f"Kurtosis: {kurtosis}")
correlation_matrix = df.drop(['Energy_Loss', 'Muon_ID', 'Is_Absorbed'], axis=1).
 ↪corrwith(df['Energy_Loss'])
print("\nCorrelation with Energy Loss:\n", correlation_matrix)
confidence = 0.95
data = df['Energy_Loss']

n = len(data)
mean = np.mean(data)
std_err = sem(data)
h = std_err * t.ppf((1 + confidence) / 2, n - 1)

confidence_interval = (mean - h, mean + h)
print(f"95% confidence interval for the mean of Energy Loss:␣
 ↪{confidence_interval}")
```

```
Shapiro-Wilk test:
Statistics=0.8070188760757446, p-value=7.94901554398927e-30
Skewness: -1.9993308216584464
Kurtosis: 5.948566955037791

Correlation with Energy Loss:
 Energy       0.098950
x             0.004754
y             0.001427
z            -0.179825
Is_Cavity    -0.765620
dtype: float64
95% confidence interval for the mean of Energy Loss: (3.3834066089285844,
3.3906999794306167)
```

[40]:
```
sns.pairplot(df.sample(80000), vars=['x', 'y', 'z', 'Energy_Loss'])
plt.suptitle('Scatterplot Matrix for Position Variables and Energy Loss')
plt.show()

confidence = 0.95
data = df['Energy_Loss']

n = len(data)
mean = np.mean(data)
std_err = sem(data)
```

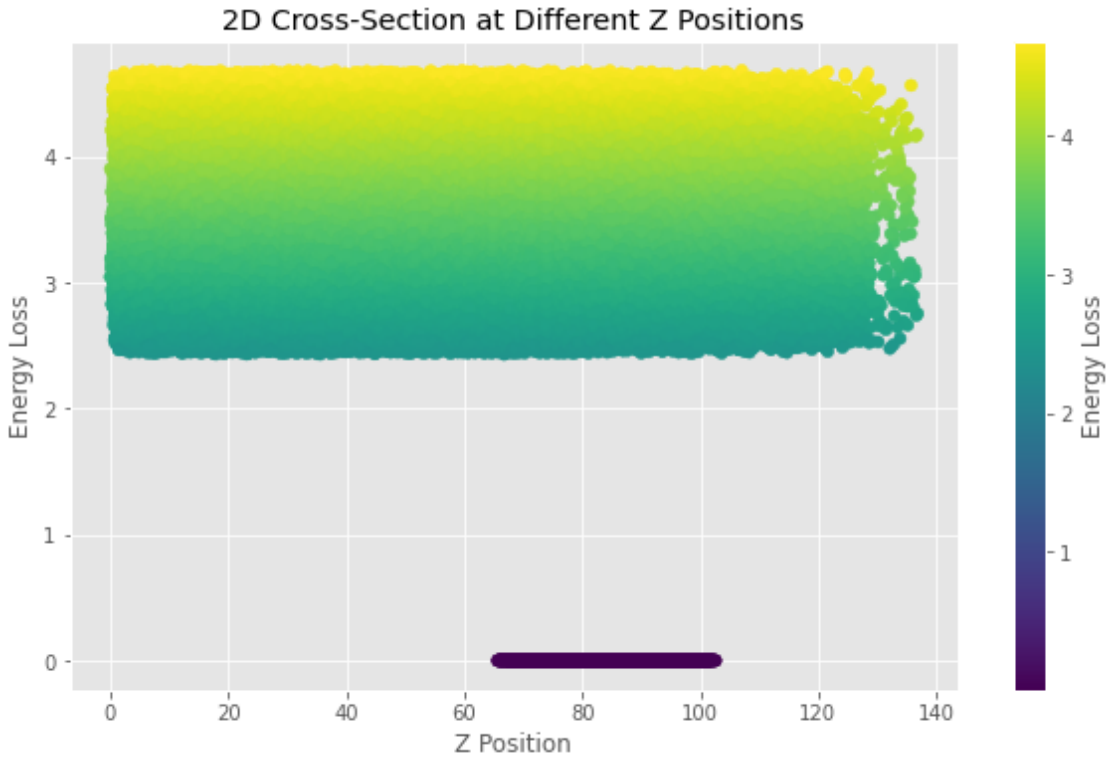
```
h = std_err * t.ppf((1 + confidence) / 2, n - 1)

confidence_interval = (mean - h, mean + h)
print(f"95% confidence interval for the mean of Energy Loss:␣
 ↪{confidence_interval}")
```

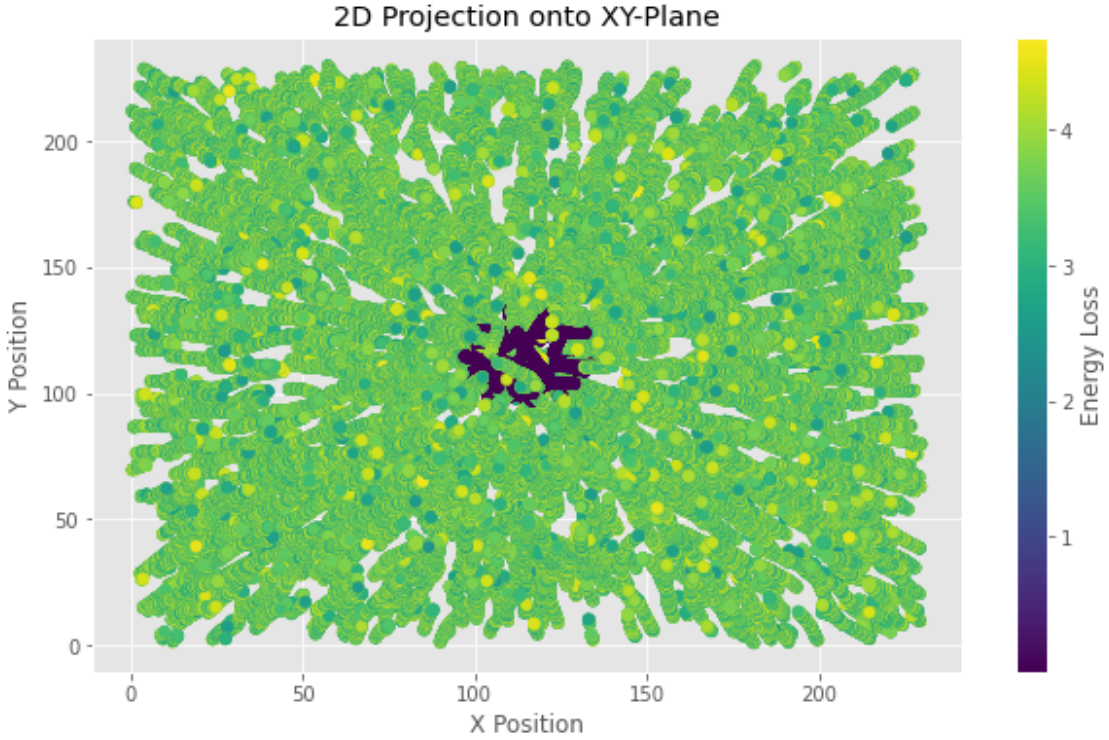
```
/opt/anaconda3/lib/python3.9/site-packages/seaborn/axisgrid.py:88: UserWarning:

The figure layout has changed to tight
```

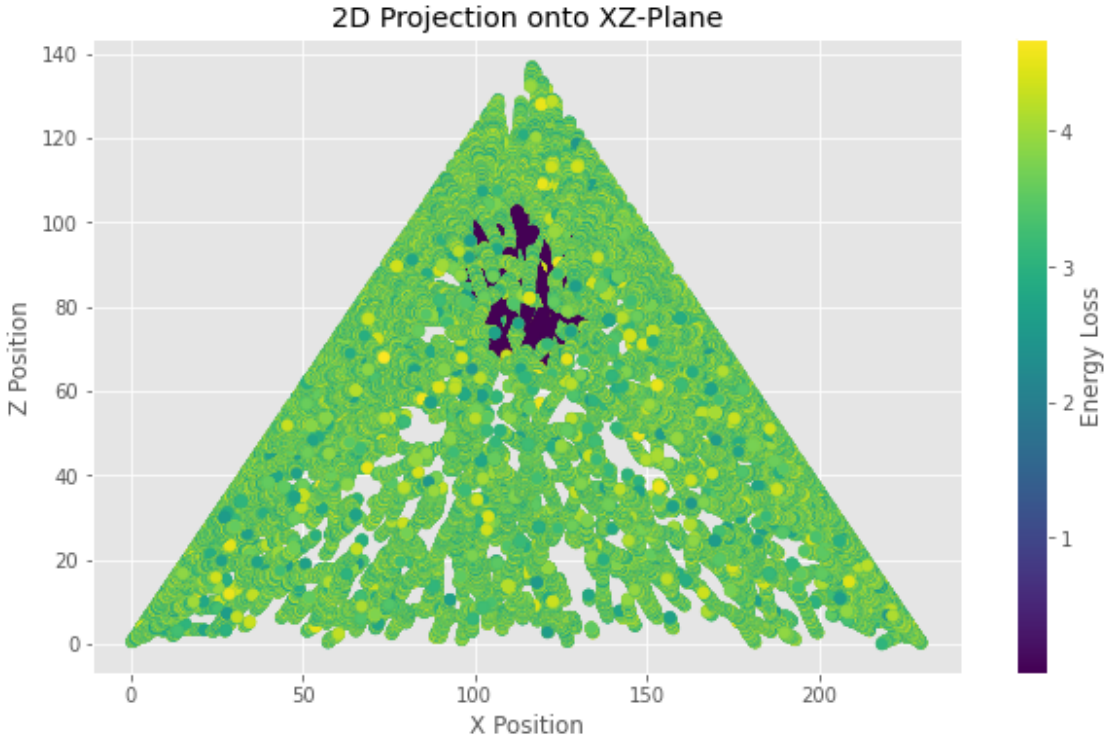


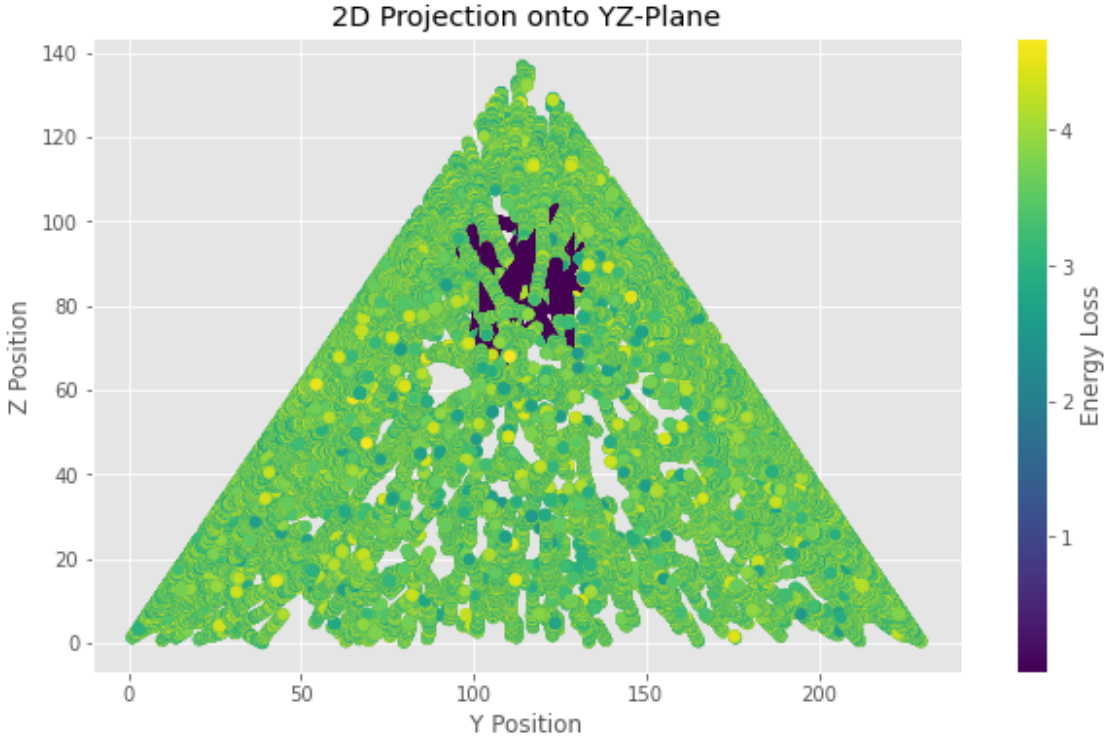

```
95% confidence interval for the mean of Energy Loss: (3.3834066089285844,
3.3906999794306167)
```

[37]:
```
plt.figure(figsize=(10, 6))
plt.scatter(df['z'], df['Energy_Loss'], c=df['Energy_Loss'], cmap='viridis')
plt.colorbar(label='Energy Loss')
plt.xlabel('Z Position')
plt.ylabel('Energy Loss')
plt.title('2D Cross-Section at Different Z Positions')
plt.grid(True)
plt.show()
plt.figure(figsize=(10, 6))
plt.scatter(df['x'], df['y'], c=df['Energy_Loss'], cmap='viridis')
plt.colorbar(label='Energy Loss')
plt.xlabel('X Position')
plt.ylabel('Y Position')
plt.title('2D Projection onto XY-Plane')
plt.grid(True)
plt.show()
plt.figure(figsize=(10, 6))
plt.scatter(df['x'], df['z'], c=df['Energy_Loss'], cmap='viridis')
plt.colorbar(label='Energy Loss')
plt.xlabel('X Position')
plt.ylabel('Z Position')
plt.title('2D Projection onto XZ-Plane')
plt.grid(True)
plt.show()
plt.figure(figsize=(10, 6))
plt.scatter(df['y'], df['z'], c=df['Energy_Loss'], cmap='viridis')
plt.colorbar(label='Energy Loss')
plt.xlabel('Y Position')
plt.ylabel('Z Position')
plt.title('2D Projection onto YZ-Plane')
plt.grid(True)
plt.show()
```


2D Cross-Section at Different Z Positions
Energy Loss
Z Position
0
20
40
60
80
100
120
140
0
1
2
3
4
Energy Loss
1
2
3
4

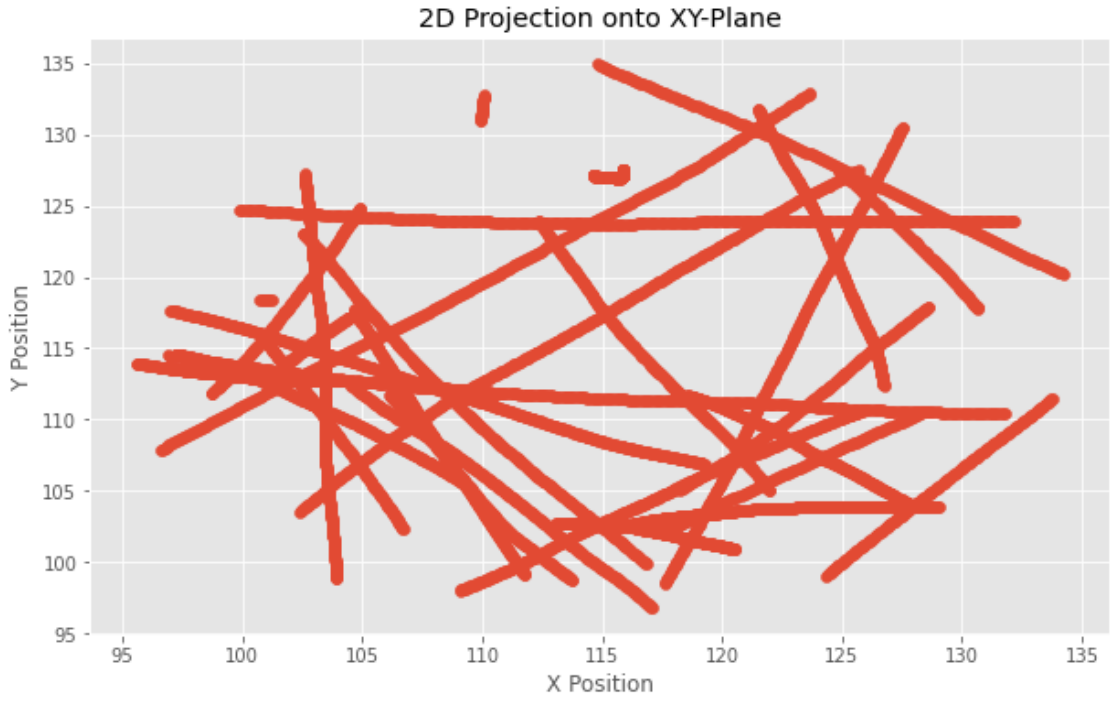

2D Projection onto XY-Plane
Y Position
X Position
0
50
100
150
200
0
50
100
150
200
Energy Loss
1
2
3
4

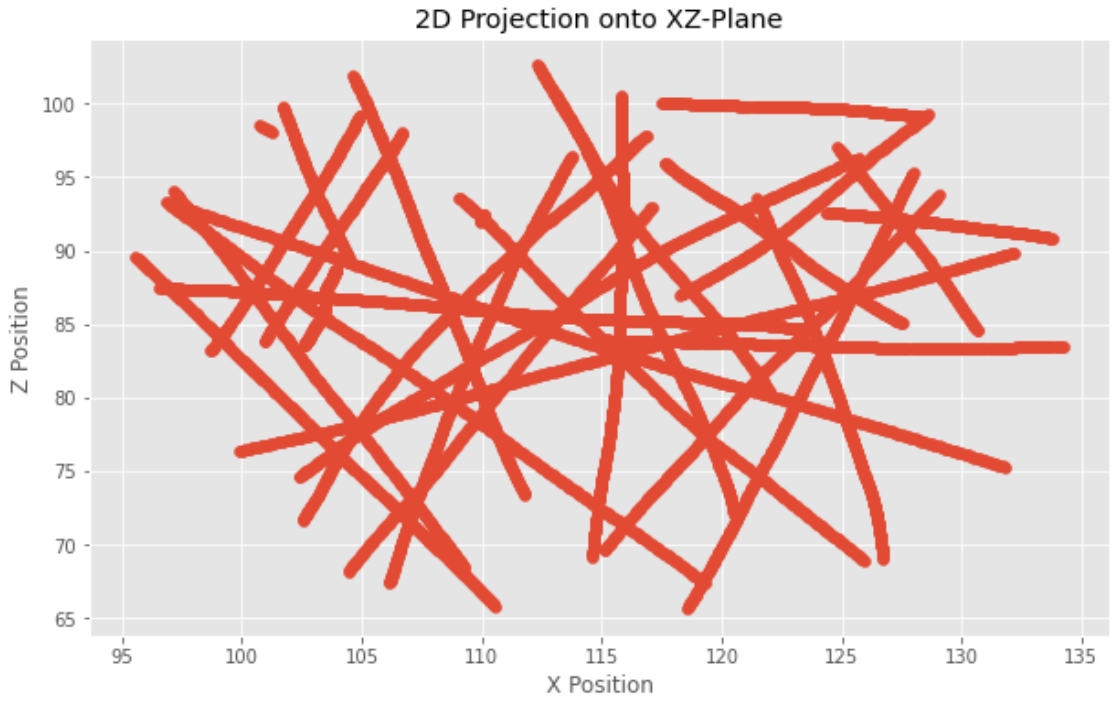

2D Projection onto XZ-Plane
Z Position
X Position
Energy Loss
0
20
40
60
80
100
120
140
0
50
100
150
200
1
2
3
4


2D Projection onto YZ-Plane
Z Position
Y Position
Energy Loss
0
20
40
60
80
100
120
140
0
50
100
150
200
1
2
3
4

[ ]:

[38]:
```
plt.figure(figsize=(10, 6))
pos = df[df['Is_Cavity'] == True]
plt.scatter(pos['x'], pos['y'])
plt.xlabel('X Position')
plt.ylabel('Y Position')
plt.title('2D Projection onto XY-Plane')
plt.grid(True)
plt.show()
plt.figure(figsize=(10, 6))
plt.scatter(pos['x'], pos['z'])
plt.xlabel('X Position')
plt.ylabel('Z Position')
plt.title('2D Projection onto XZ-Plane')
plt.grid(True)
plt.show()
```





[39]:
```
# do not run this cell
trace = go.Scatter3d(
    x=df['x'],
    y=df['y'],
    z=df['z'],
    mode='markers',
    marker=dict(
        size=5,
        color=df['Energy_Loss'],
        colorscale='Viridis',
        opacity=0.8
    )
)
layout = go.Layout(
    margin=dict(l=0, r=0, b=0, t=0)
)

fig = go.Figure(data=[trace], layout=layout)
fig.show()
```

[ ]:

[ ]:

[ ]: