AlkahestResultV4a

July 4, 2023

```
[ ]: import numpy as np
     import pandas as pd
     import seaborn as sns
     import matplotlib.pyplot as plt
     from sklearn.impute import SimpleImputer
     from sklearn.pipeline import Pipeline
     from sklearn.preprocessing import StandardScaler
     from sklearn.feature_selection import VarianceThreshold
     from stabl.preprocessing import LowInfoFilter
     from stabl.stabl import Stabl, save_stabl_results,plot_stabl_path,␣
      ↪plot_fdr_graph
     from stabl.visualization import boxplot_features
     from sklearn.base import clone
     from sklearn.linear_model import LogisticRegression,LogisticRegressionCV,␣
      ↪LinearRegression
     from sklearn.model_selection import LeaveOneOut,RepeatedStratifiedKFold
     from sklearn.metrics import roc_auc_score
```

This here provides the code that gets us the result of the best model on the V4a (normalized to V3) only unstim data.

The best model found was a Lasso model, with hyperparameters lambda_1 = 0.25. Reminder, the Lasso solves:

$$\text{argmin}_\beta \frac{1}{2n}\|y - X\beta\|_2^2 + \lambda_1\|\beta\|_1$$

We also use the usual preprocessing pipeline, with a variance threshold of 0.001 (i.e. features with lower variance are removed before fitting the model).

0.0.1 Step 1: Setup

We import the data and set up the preprocessing pipeline:

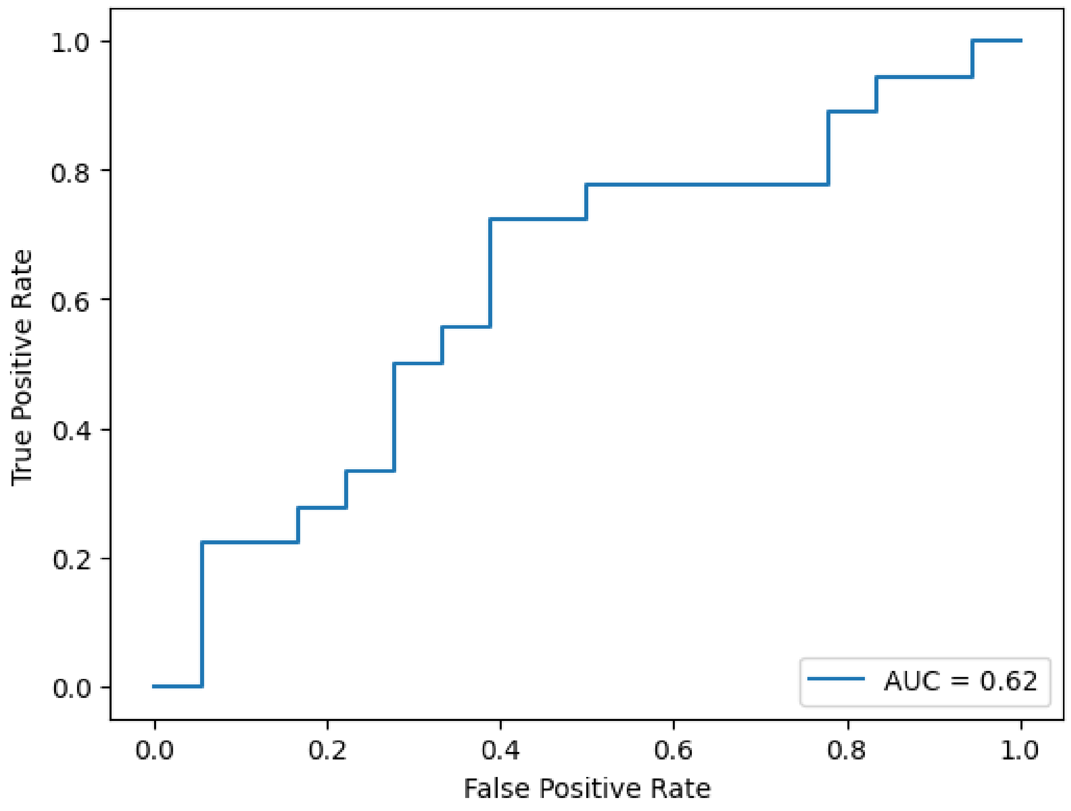
```
[ ]: dataV4a = pd.read_csv("./Data/Alkahest-V4a.csv",index_col=0)
     dataV4a = dataV4a.iloc[:,[x[-6:]  == "Unstim" for x in dataV4a.columns]]
     label = pd.read_csv("./Data/AlkahestLabel.csv",index_col=0).iloc[:,0]

     preprocessing = Pipeline(
             steps=[
                 ("variance", VarianceThreshold(0.001)),
                 ("lif", LowInfoFilter(0)),
                 ("impute", SimpleImputer(strategy="median")),
                 ("std", StandardScaler())
             ]
         )

     X = dataV4a.to_numpy()
     y = label.to_numpy()
```

0.0.2 Step 2: Cross-Validation

ow we calculate the ROC curve for the cross-validation predictions, using Leave-One-Out cross-validation. We obtain an AUC of 0.62 for the curve.

```
[ ]: from sklearn.metrics import roc_curve,RocCurveDisplay,auc



c =  0.25
model = LogisticRegression(penalty="l1", C=c, max_iter=int(1e8), solver="saga",␣
 ↪class_weight="balanced")
kf = LeaveOneOut()
all_probs=[]
for train, test in kf.split(X, y):
    Xtrain = pd.DataFrame(data=preprocessing.fit_transform(dataV4a.iloc[train,:
 ↪]),
                          index=dataV4a.index[train],
                          columns=preprocessing.get_feature_names_out()
                         ).to_numpy()
    Xtest = pd.DataFrame(data=preprocessing.transform(dataV4a.iloc[test,:]),
                          index=dataV4a.index[test],
                          columns=preprocessing.get_feature_names_out()
                         ).to_numpy()
    all_probs.append(model.fit(Xtrain, y[train]).predict_proba(Xtest)[:,1])
all_probs = np.array(all_probs).flatten()
fpr, tpr, thresholds = roc_curve(y, all_probs)
roc_auc = auc(fpr, tpr)
disp = RocCurveDisplay(fpr=fpr, tpr=tpr, roc_auc=roc_auc)
disp.plot()
```

```
[ ]: <sklearn.metrics._plot.roc_curve.RocCurveDisplay at 0x1614ed81410>
```



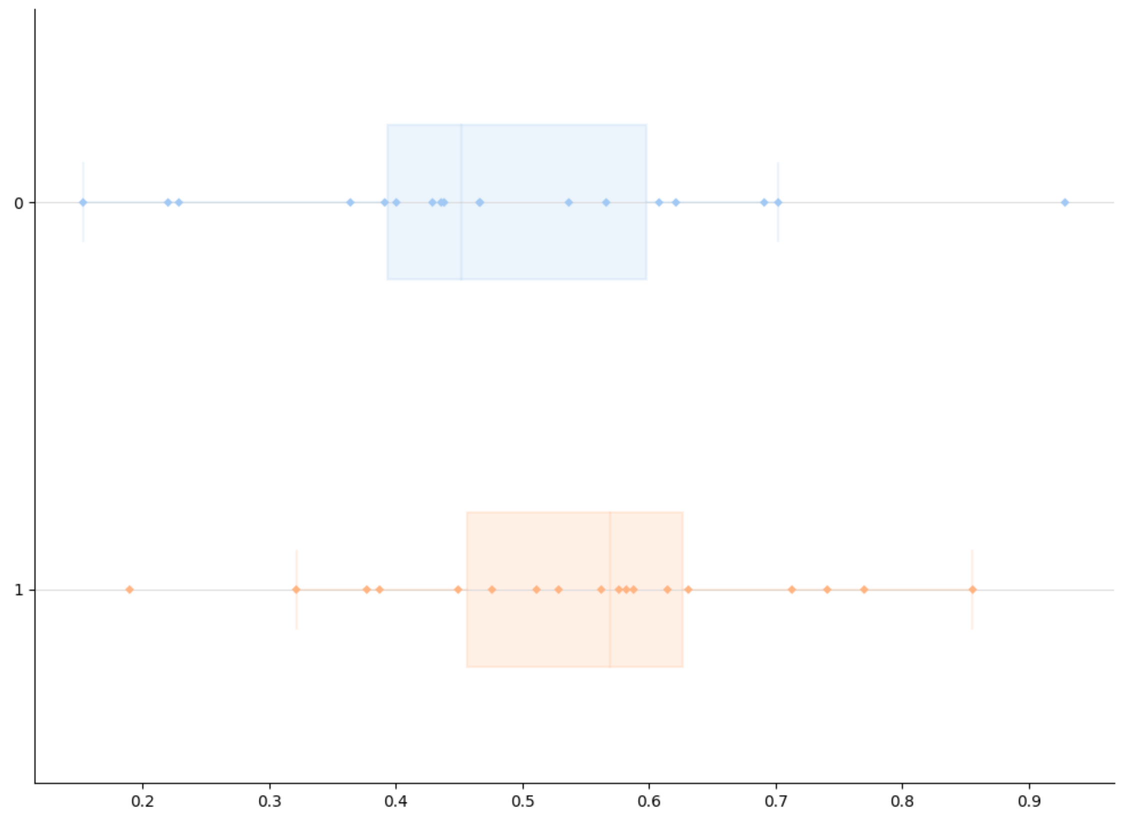
We then calculate the p-value of the same predictions, which is about 21.4%.

```
[ ]: from scipy.stats import mannwhitneyu

     utest1,upval1 = mannwhitneyu(all_probs[y == 1],all_probs[y == 0],method="exact")
     print( "p-value of the U-Test on the CV predictions : ",upval1)
```

```
p-value of the U-Test on the CV predictions :  0.21424980209385966
```

The spread of the predictions is in the next figure - 0 is placebo, 1 is Alkahest. The dots are the prediction values. Ideally we want the top line to have all dots at 0, and bottom line all at 1.

```
[ ]: import matplotlib.patches as pltp
     fig, ax = plt.subplots(1, 1, figsize=(10, 8))
     palette = ["#4D4F53", "#C41E3A"]
     sns.boxplot(data = [all_probs[y == 0],all_probs[y == 1]],
                 ax=ax,
                 showfliers=False,
                 palette="pastel",
                 boxprops=dict(alpha=.2),
                 whiskerprops=dict(alpha=.2),
                 width=.4,
                 orient="h",
                 saturation=1
             )
     sns.stripplot(data=[all_probs[y == 0],all_probs[y == 1]],
                 ax=ax,
                 palette="pastel",
                 jitter = False,
                 alpha=1,
                 size=4,
                 marker="D",orient="h"
             )
     box_patches = [patch for patch in ax.patches if type(patch) == pltp.PathPatch]

     num_patches = len(box_patches)
     lines_per_boxplot = len(ax.lines) // num_patches

     for i, patch in enumerate(box_patches):
         col = patch.get_facecolor()
         patch.set_edgecolor(col)
         patch.set_facecolor(col)

         for line in ax.lines[i * lines_per_boxplot: (i + 1) * lines_per_boxplot]:
             line.set_color(col)
             line.set_mfc(col)
             line.set_mec(col)

     ax.grid(which='major', color='#DDDDDD', linewidth=0.8, axis="y")

     ax.spines['top'].set_visible(False)
     ax.spines['right'].set_visible(False)



     fig.tight_layout()
     fig.subplots_adjust(top=0.9)
     ax.set_ylabel('')

     plt.show()
```



0.0.3 Step 3: We get the final model

We fit the model on all of the data.

```
[ ]: Xstd = pd.DataFrame(data=preprocessing.fit_transform(dataV4a),
                          index=dataV4a.index,
                          columns=preprocessing.get_feature_names_out()
                         )
     model.fit(Xstd.to_numpy(), y)
```

```
[ ]: LogisticRegression(C=0.25, class_weight='balanced', max_iter=100000000,
                        penalty='l1', solver='saga')
```

Then we look at which features get a non-zero coefficient, to get a similar understanding of which features were selected by the model.

```
[ ]: for i in Xstd.columns[np.where(model.coef_[0] != 0)]:
         print(i)
```

```
CD8Tem_pSTAT6_Unstim
Tregnaive_MAPKAPK2_Unstim
NK-Tcells_pSTAT6_Unstim
gdT_pSTAT6_Unstim
```

```
CD8Tcm_Frequency_Unstim
Th2_STAT5_Unstim
Tregmem_ERK_Unstim
Baso +++_STAT5_Unstim
Th1naive_MAPKAPK2_Unstim
```

```
[ ]: pd.DataFrame(data=all_probs,index=dataV4a.index,columns=["LOO CV predictions"]).
      ↪to_csv("./ResultsFinal/V4a/FinalLASSO_CV_predictions.csv")
```

Boxplots for these features are further down.

0.0.4 Part 2: Stability Selection

With a base estimator a Lasso model, we look at what features it selects:

```
[ ]: ss =Stabl(
         base_estimator=clone(model),
         lambda_name="C",
         lambda_grid=np.linspace(0.01, 3, 50),
         artificial_type=None,
         sample_fraction=0.5,
         replace= True,
         hard_threshold=0.3,
         n_bootstraps=2000,
         random_state=42
     )

     ss.fit(Xstd,y)
```

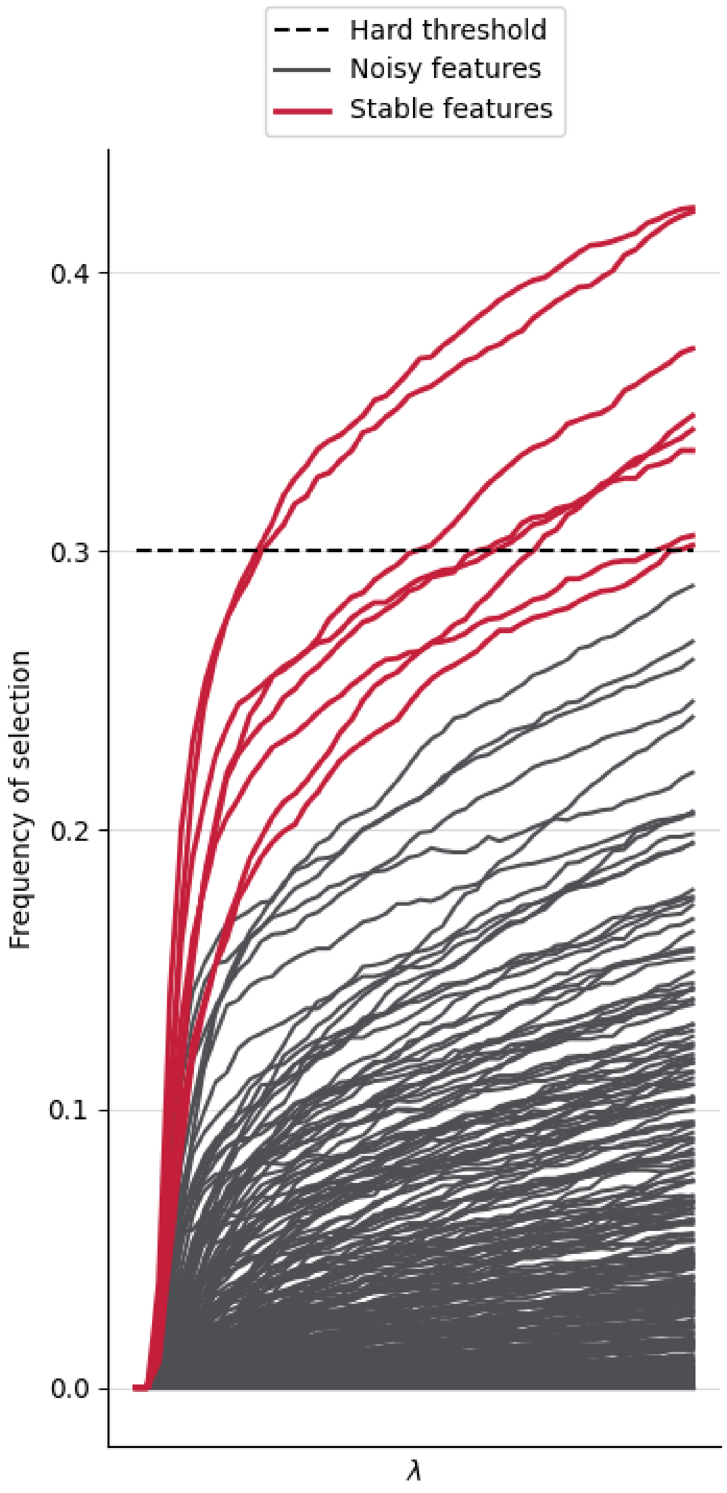
```
                                                            12<00:00,
46.97s/it]
```

```
[ ]: Stabl(artificial_type=None,
           base_estimator=LogisticRegression(C=0.25, class_weight='balanced',
                                             max_iter=100000000, penalty='l1',
                                             solver='saga'),
           hard_threshold=0.7,
           lambda_grid=array([0.01      , 0.07102041, 0.13204082, 0.19306122,
     0.25408163,
            0.31510204, 0.37612245, 0.43714286, 0.49816327, 0.55918367,
            0.62020408, 0.68122449, 0.7422449 , 0.80326531, 0.86428571,
            0.92530612, 0.98…
            1.23040816, 1.29142857, 1.35244898, 1.41346939, 1.4744898 ,
            1.5355102 , 1.59653061, 1.65755102, 1.71857143, 1.77959184,
            1.84061224, 1.90163265, 1.96265306, 2.02367347, 2.08469388,
            2.14571429, 2.20673469, 2.2677551 , 2.32877551, 2.38979592,
            2.45081633, 2.51183673, 2.57285714, 2.63387755, 2.69489796,
            2.75591837, 2.81693878, 2.87795918, 2.93897959, 3.        ]),
           n_bootstraps=2000, random_state=42, replace=True)
```

The stability path generated:

```
[ ]: plot_stabl_path(ss)
```

```
[ ]: (<Figure size 400x800 with 1 Axes>,
      <Axes: xlabel='$\\lambda$', ylabel='Frequency of selection'>)
```



The features selected:

```
[ ]: ss.get_feature_names_out()
```

```
[ ]: array(['CD8Tem_pSTAT6_Unstim', 'intMC_Frequency_Unstim',
            'Tregnaive_MAPKAPK2_Unstim', 'NK-Tcells_pSTAT6_Unstim',
            'gdT_pSTAT6_Unstim', 'CD8Tcm_Frequency_Unstim',
            'Th1naive_STAT3_Unstim', 'Baso +++_STAT5_Unstim'], dtype=object)
```

```
[ ]: save_stabl_results(ss,"./ResultsFinal/V4a/",dataV4a,y)
```

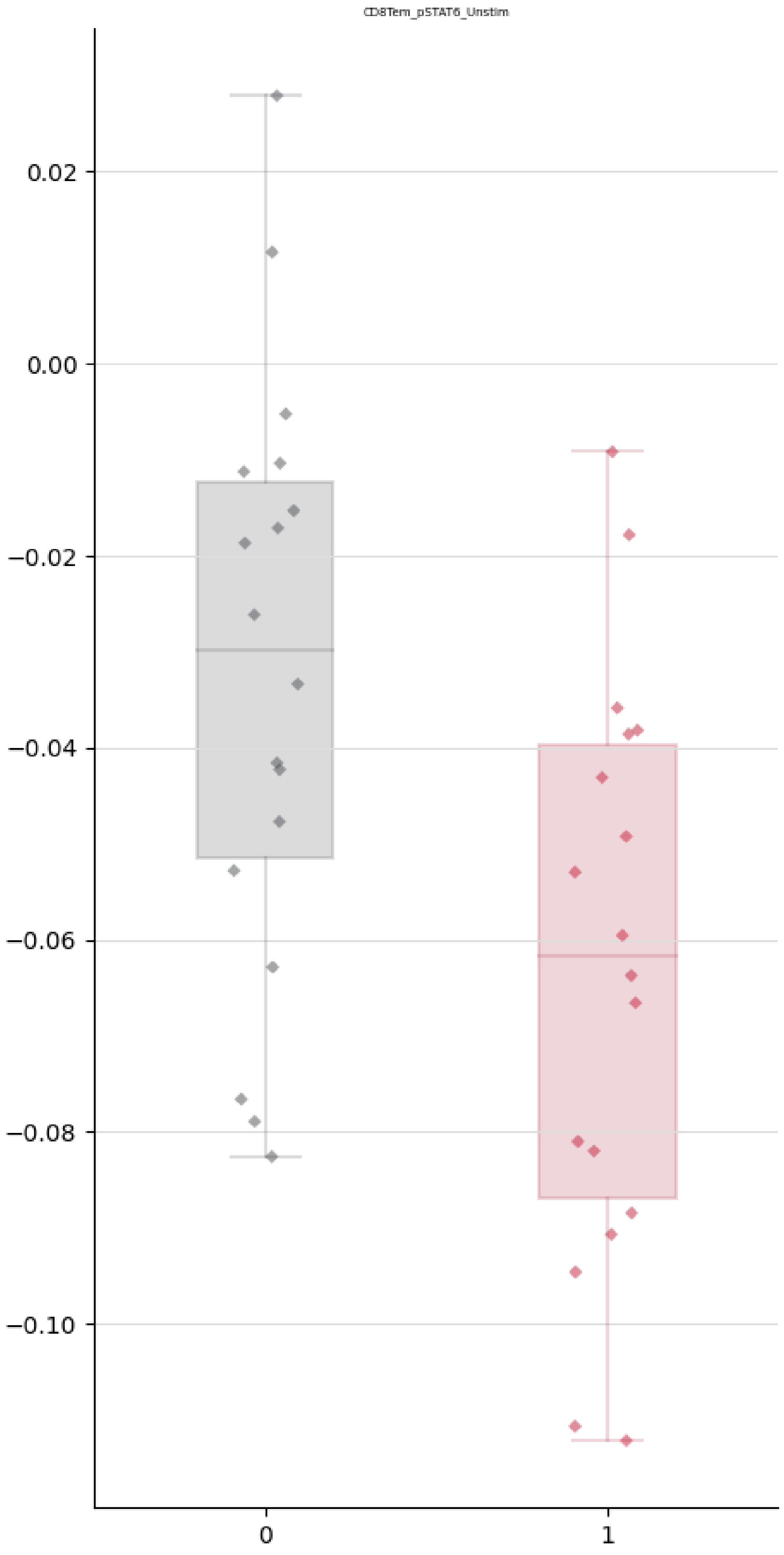
```
c:\Users\Max\AppData\Local\Programs\Python\Python311\Lib\site-
packages\stabl\visualization.py:260: FutureWarning: Passing `palette` without
assigning `hue` is deprecated.
  sns.stripplot(
c:\Users\Max\AppData\Local\Programs\Python\Python311\Lib\site-
packages\stabl\visualization.py:260: FutureWarning: Passing `palette` without
assigning `hue` is deprecated.
  sns.stripplot(
c:\Users\Max\AppData\Local\Programs\Python\Python311\Lib\site-
packages\stabl\visualization.py:260: FutureWarning: Passing `palette` without
assigning `hue` is deprecated.
  sns.stripplot(
c:\Users\Max\AppData\Local\Programs\Python\Python311\Lib\site-
packages\stabl\visualization.py:260: FutureWarning: Passing `palette` without
assigning `hue` is deprecated.
  sns.stripplot(
c:\Users\Max\AppData\Local\Programs\Python\Python311\Lib\site-
packages\stabl\visualization.py:260: FutureWarning: Passing `palette` without
assigning `hue` is deprecated.
  sns.stripplot(
c:\Users\Max\AppData\Local\Programs\Python\Python311\Lib\site-
packages\stabl\visualization.py:260: FutureWarning: Passing `palette` without
assigning `hue` is deprecated.
  sns.stripplot(
c:\Users\Max\AppData\Local\Programs\Python\Python311\Lib\site-
packages\stabl\visualization.py:260: FutureWarning: Passing `palette` without
assigning `hue` is deprecated.
  sns.stripplot(
c:\Users\Max\AppData\Local\Programs\Python\Python311\Lib\site-
packages\stabl\visualization.py:260: FutureWarning: Passing `palette` without
assigning `hue` is deprecated.
  sns.stripplot(
```

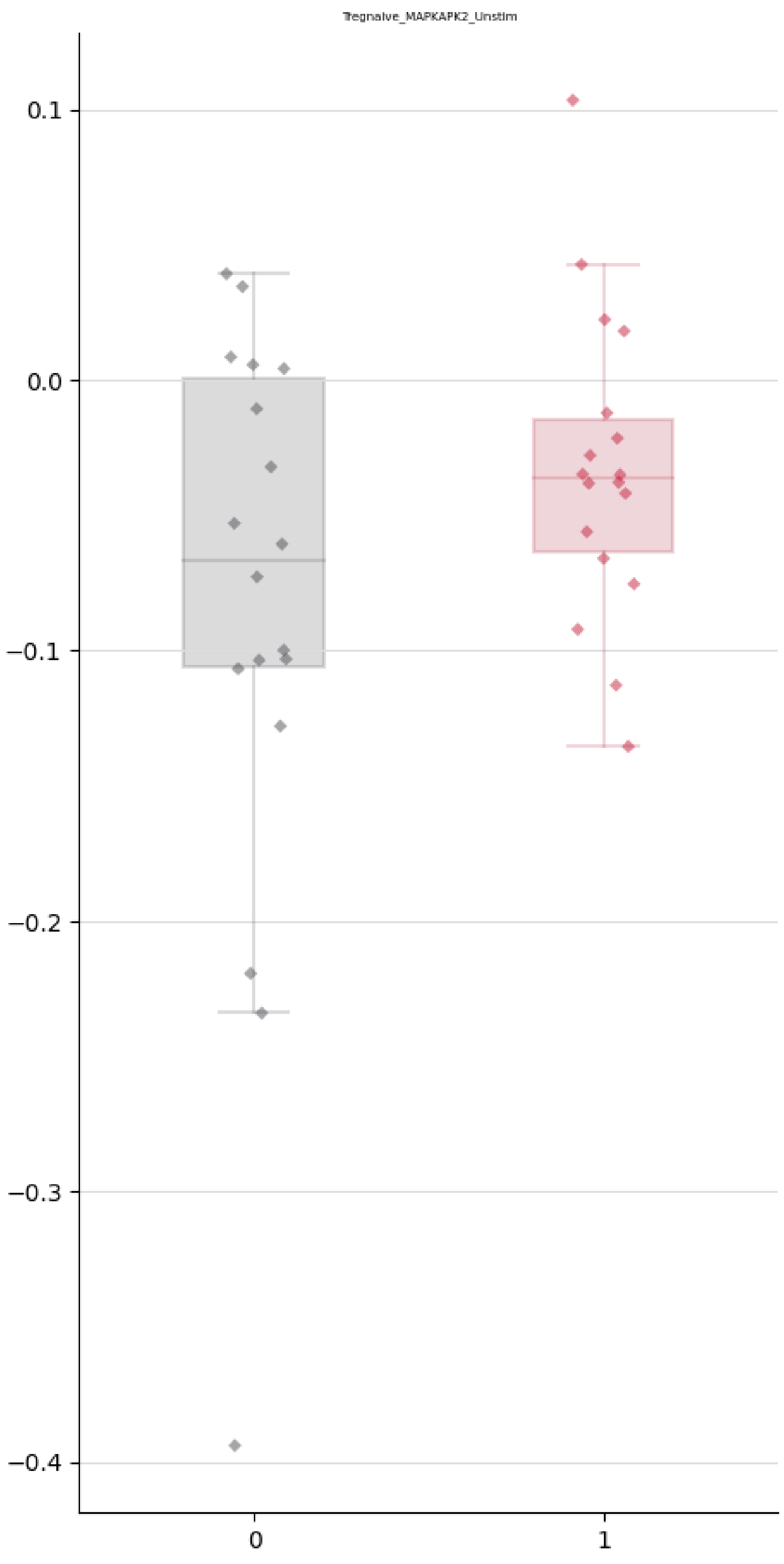
Here are the boxplots for these features.

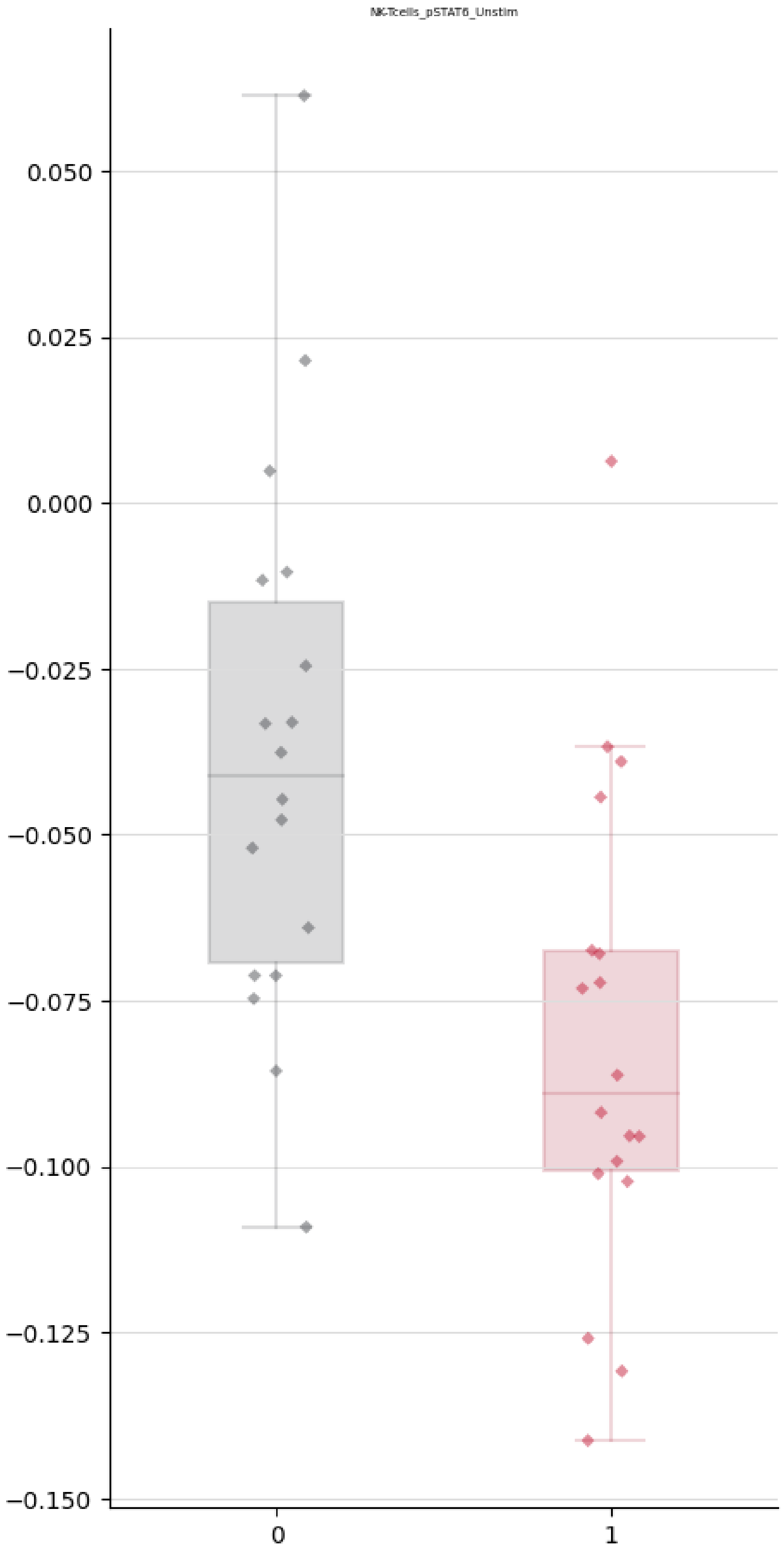
```
[ ]: boxplot_features(Xstd.columns[np.where(model.coef_[0] != 0)], dataV4a,y)
```

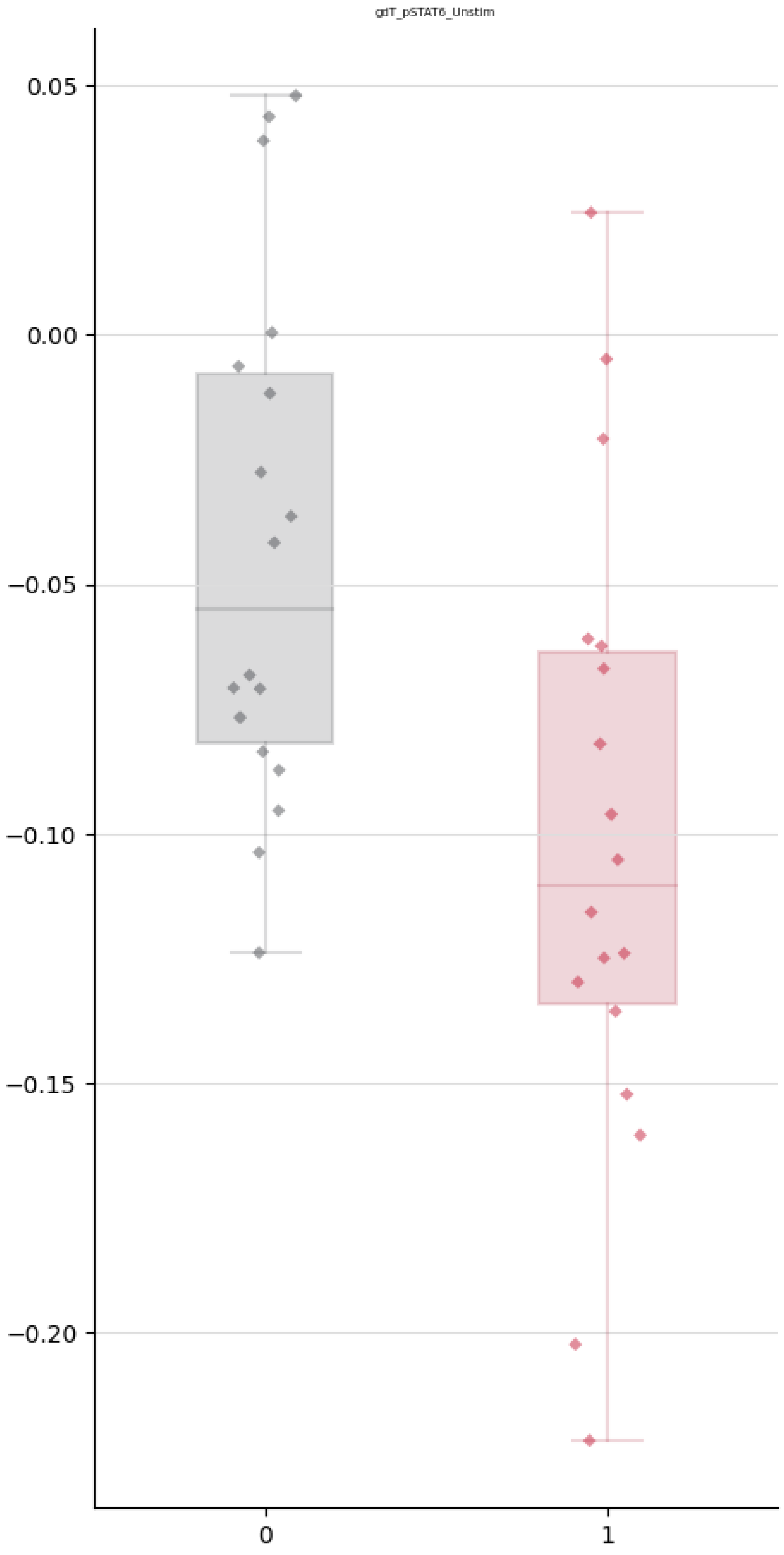
```
c:\Users\Max\AppData\Local\Programs\Python\Python311\Lib\site-
packages\stabl\visualization.py:260: FutureWarning: Passing `palette` without
assigning `hue` is deprecated.
```

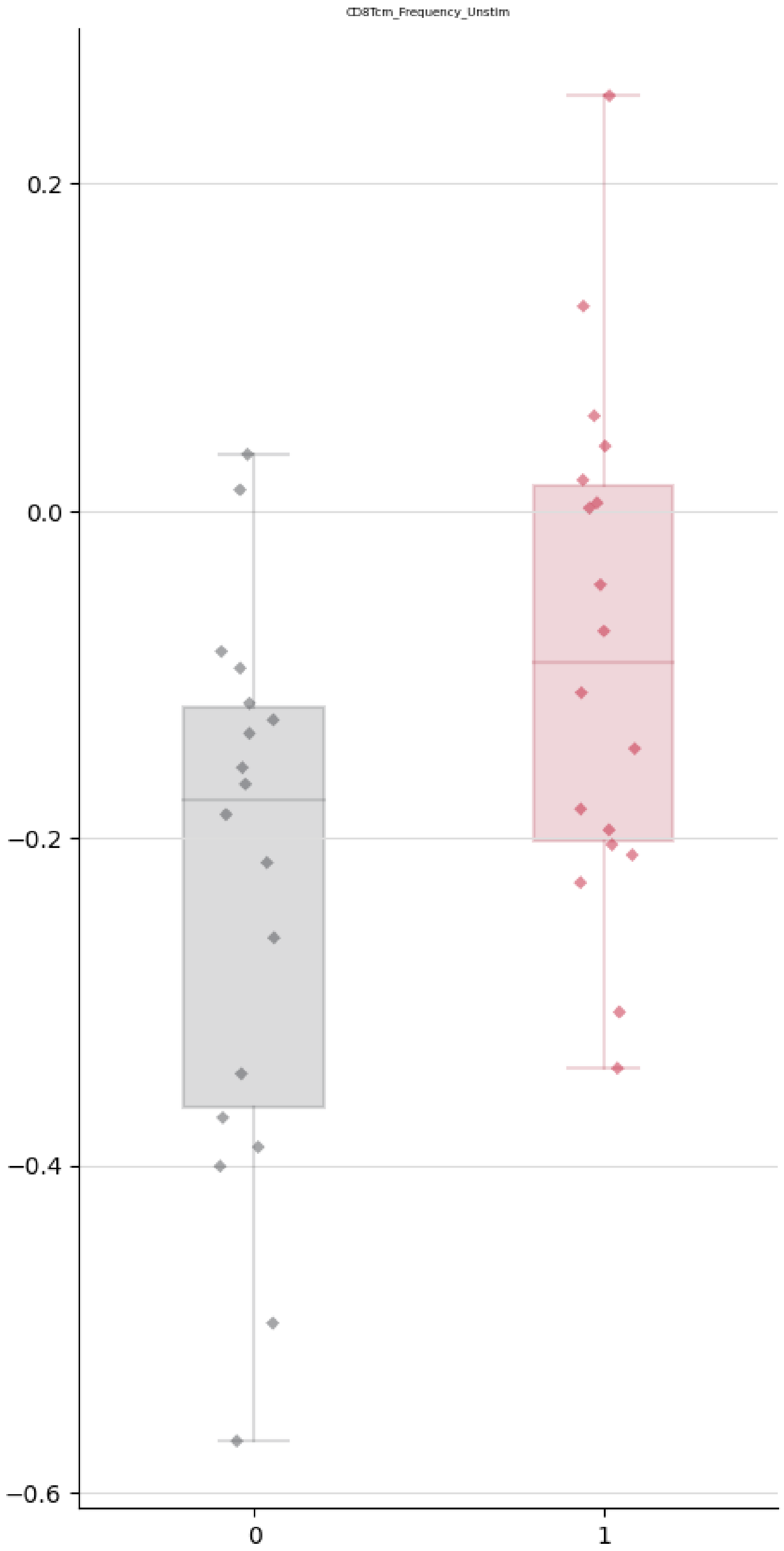
```
  sns.stripplot(
c:\Users\Max\AppData\Local\Programs\Python\Python311\Lib\site-
packages\stabl\visualization.py:260: FutureWarning: Passing `palette` without
assigning `hue` is deprecated.
  sns.stripplot(
c:\Users\Max\AppData\Local\Programs\Python\Python311\Lib\site-
packages\stabl\visualization.py:260: FutureWarning: Passing `palette` without
assigning `hue` is deprecated.
  sns.stripplot(
c:\Users\Max\AppData\Local\Programs\Python\Python311\Lib\site-
packages\stabl\visualization.py:260: FutureWarning: Passing `palette` without
assigning `hue` is deprecated.
  sns.stripplot(
c:\Users\Max\AppData\Local\Programs\Python\Python311\Lib\site-
packages\stabl\visualization.py:260: FutureWarning: Passing `palette` without
assigning `hue` is deprecated.
  sns.stripplot(
c:\Users\Max\AppData\Local\Programs\Python\Python311\Lib\site-
packages\stabl\visualization.py:260: FutureWarning: Passing `palette` without
assigning `hue` is deprecated.
  sns.stripplot(
c:\Users\Max\AppData\Local\Programs\Python\Python311\Lib\site-
packages\stabl\visualization.py:260: FutureWarning: Passing `palette` without
assigning `hue` is deprecated.
  sns.stripplot(
c:\Users\Max\AppData\Local\Programs\Python\Python311\Lib\site-
packages\stabl\visualization.py:260: FutureWarning: Passing `palette` without
assigning `hue` is deprecated.
  sns.stripplot(
c:\Users\Max\AppData\Local\Programs\Python\Python311\Lib\site-
packages\stabl\visualization.py:260: FutureWarning: Passing `palette` without
assigning `hue` is deprecated.
  sns.stripplot(
```

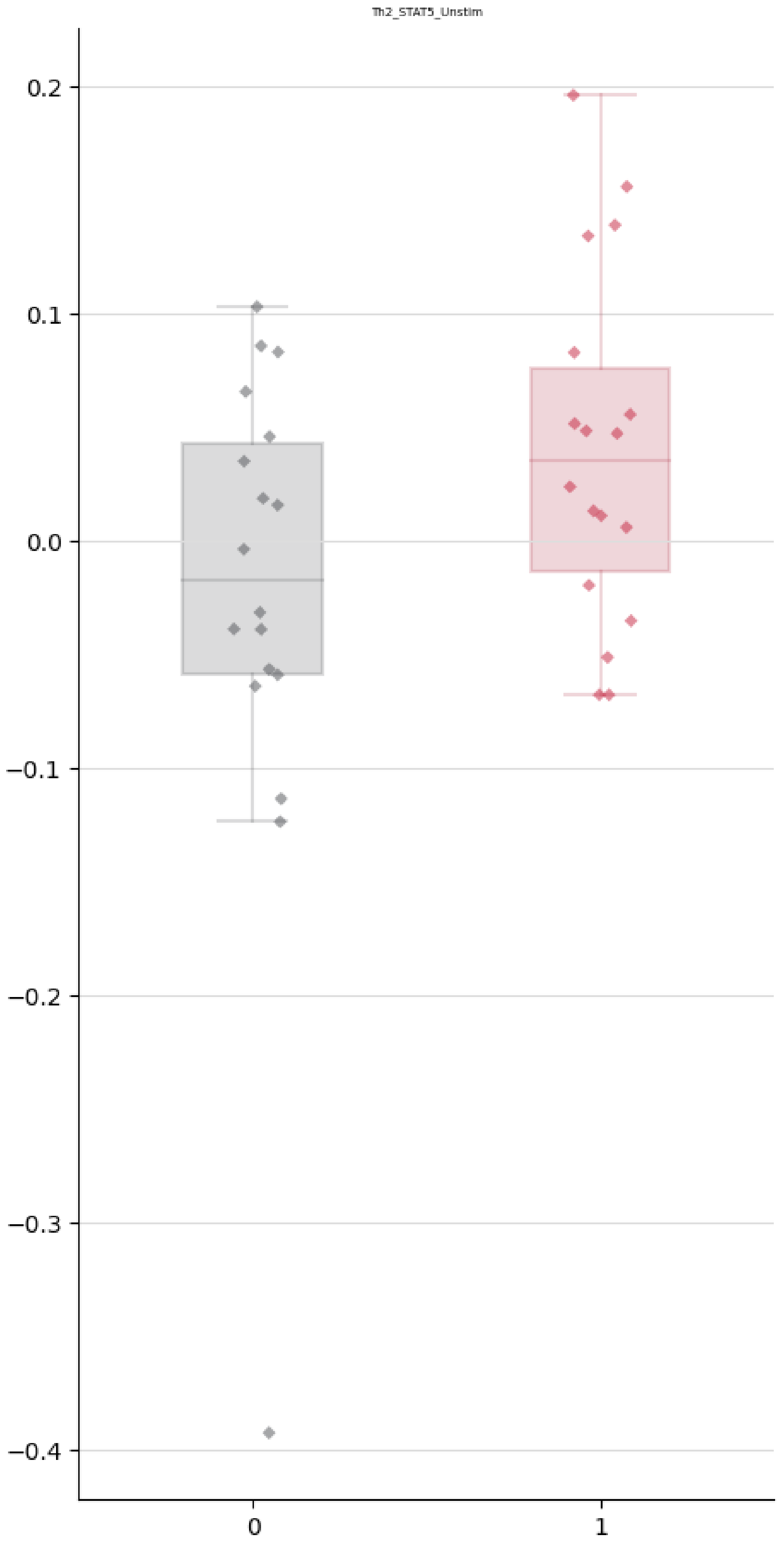

CD8Tem_pSTAT6_Unstim
0.02
0.00
−0.02
−0.04
−0.06
−0.08
−0.10
0
1

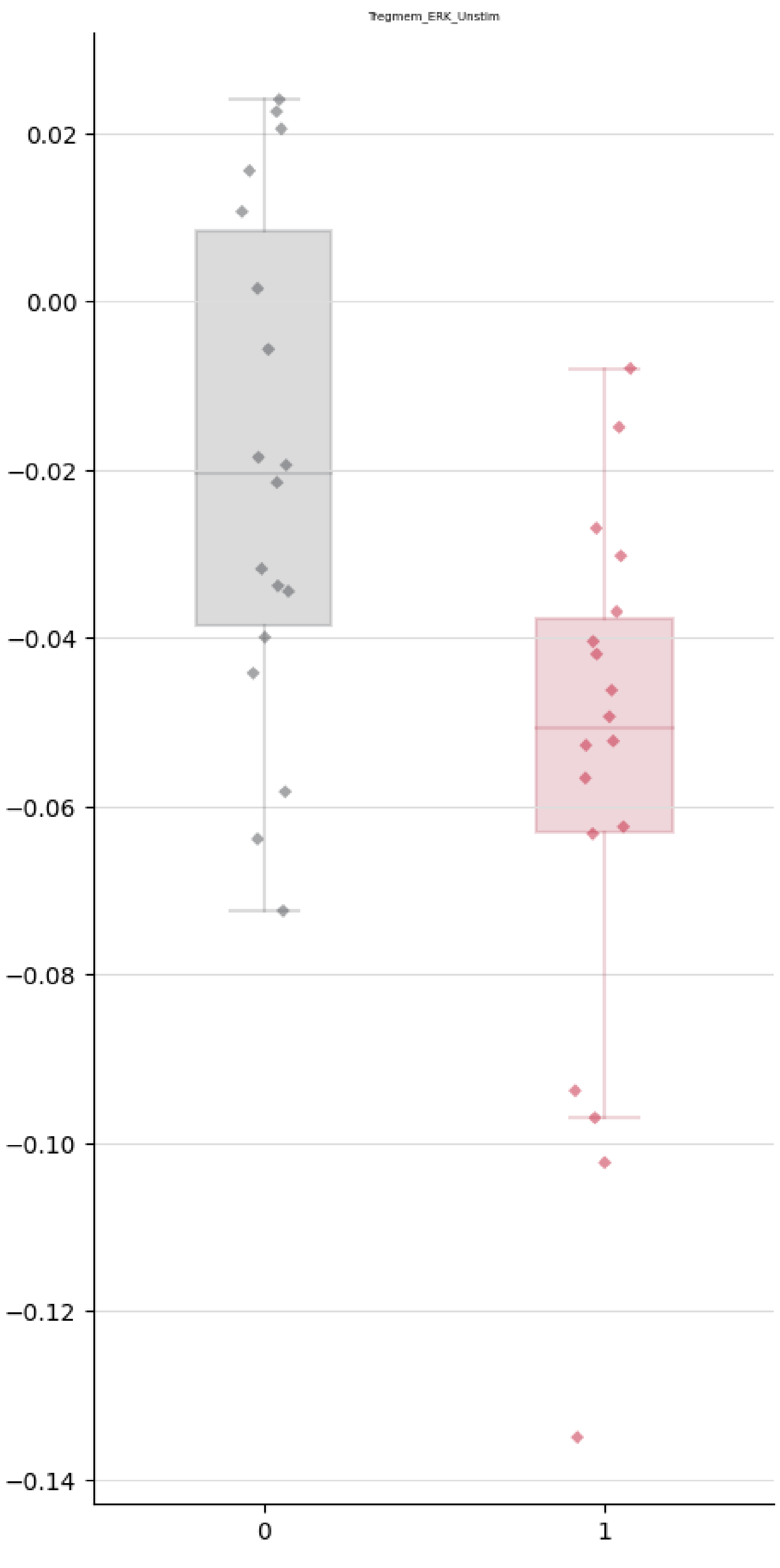

Tregnaive_MAPKAPK2_Unstim
0.1
0.0
−0.1
−0.2
−0.3
−0.4
0
1

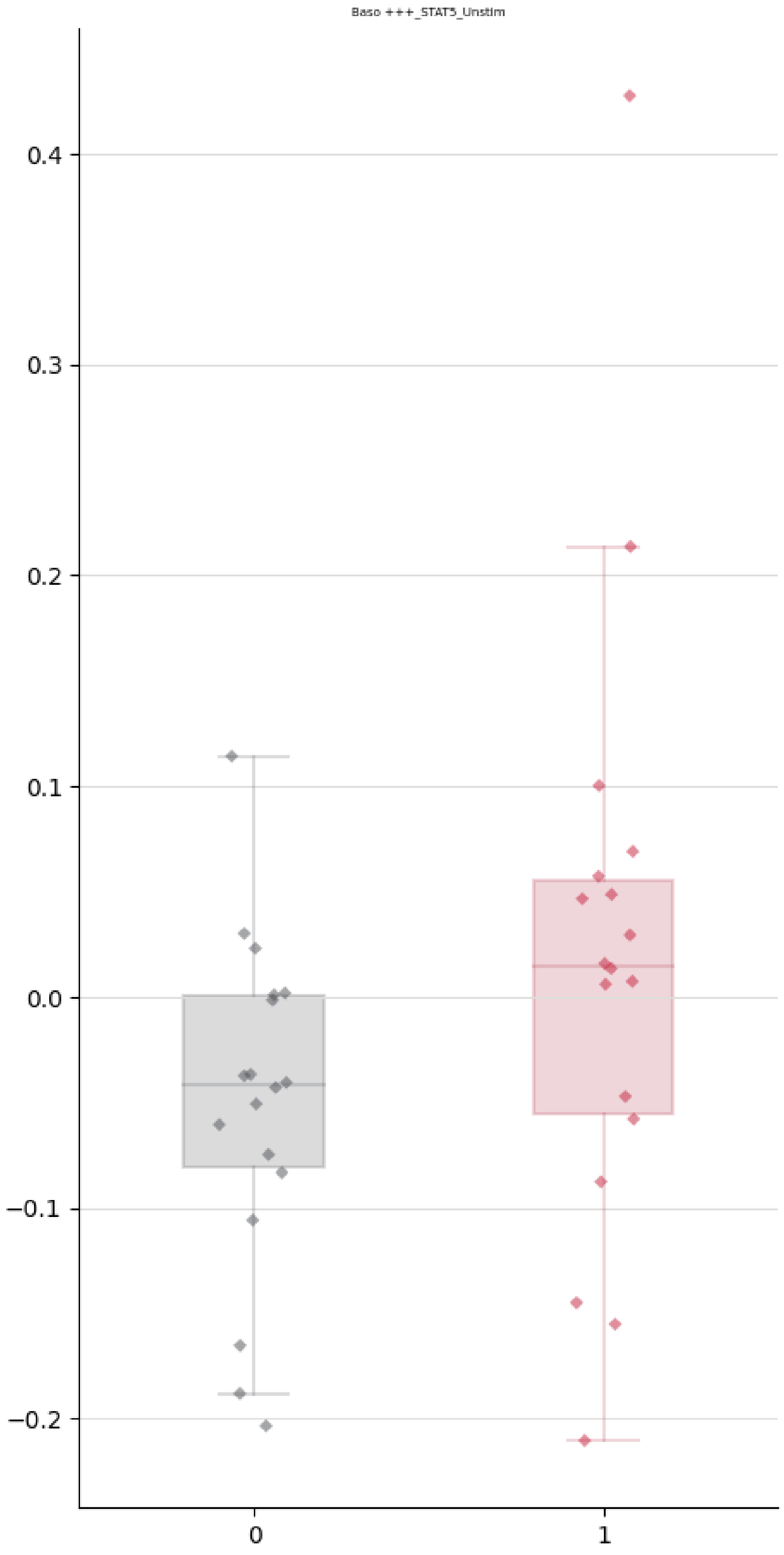

NKTcells_pSTAT6_Unstim
0.050
0.025
0.000
−0.025
−0.050
−0.075
−0.100
−0.125
−0.150
0
1

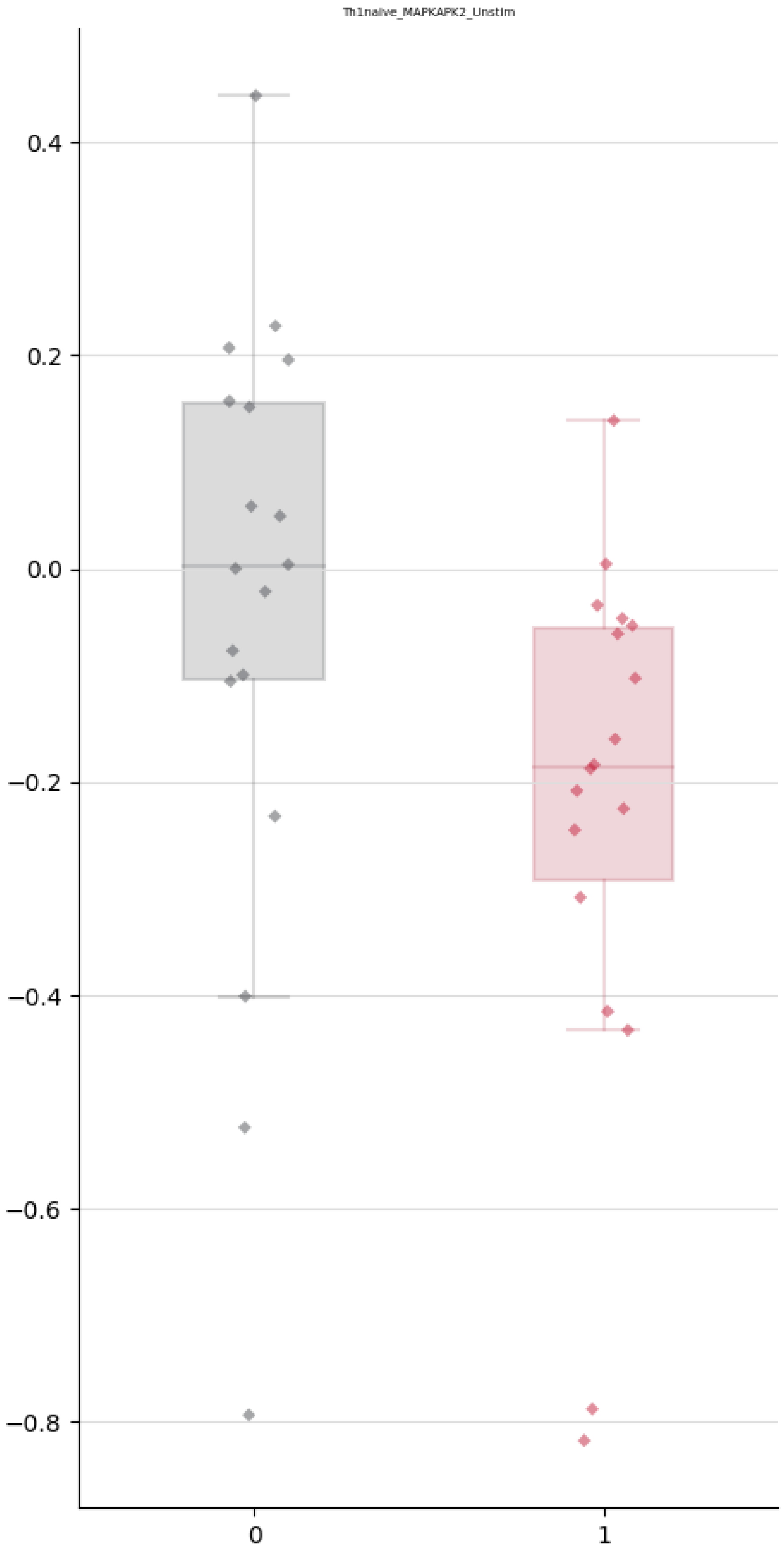

gdT_pSTAT6_Unstim
0.05
0.00
−0.05
−0.10
−0.15
−0.20
0
1


CD8Tcm_Frequency_Unstim
0.2
0.0
−0.2
−0.4
−0.6
0
1


Th2_STAT5_Unstim
0.2
0.1
0.0
−0.1
−0.2
−0.3
−0.4
0
1


Tregmem_ERK_Unstim
0.02
0.00
−0.02
−0.04
−0.06
−0.08
−0.10
−0.12
−0.14
0
1


Baso +++_STAT5_Unstim
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
0
1


Th1naive_MAPKAPK2_Unstim
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
0
1

[ ]:
```

```