Credit Card Fraud Detection (Classification)

In [1]:
```
import pandas as pd
import numpy as np
from sklearn.model_selection import train_test_split
import matplotlib.pyplot as plt
from imblearn.over_sampling import RandomOverSampler, SMOTE, ADASYN, BorderlineSMOTE
from imblearn.under_sampling import RandomUnderSampler, NearMiss
```

In [2]:
```
from sklearn.model_selection import cross_val_predict
from sklearn.preprocessing import StandardScaler
from sklearn.linear_model import LogisticRegression
from sklearn.metrics import precision_score, recall_score, f1_score, accuracy_score
from sklearn.metrics import precision_recall_curve, roc_curve, confusion_matrix, ConfusionMatrixDisplay
```

In [3]:
```
credit = pd.read_csv('creditcard.csv')
credit.head()
```

Out[3]:

	Time	V1	V2	V3	V4	V5	V6	V7	V8	V9	...	V21	V22	V23	V24	
0	0.0	-1.359807	-0.072781	2.536347	1.378155	-0.338321	0.462388	0.239599	0.098698	0.363787	...	-0.018307	0.277838	-0.110474	0.066928	0.
1	0.0	1.191857	0.266151	0.166480	0.448154	0.060018	-0.082361	-0.078803	0.085102	-0.255425	...	-0.225775	-0.638672	0.101288	-0.339846	0.
2	1.0	-1.358354	-1.340163	1.773209	0.379780	-0.503198	1.800499	0.791461	0.247676	-1.514654	...	0.247998	0.771679	0.909412	-0.689281	-0.
3	1.0	-0.966272	-0.185226	1.792993	-0.863291	-0.010309	1.247203	0.237609	0.377436	-1.387024	...	-0.108300	0.005274	-0.190321	-1.175575	0.
4	2.0	-1.158233	0.877737	1.548718	0.403034	-0.407193	0.095921	0.592941	-0.270533	0.817739	...	-0.009431	0.798278	-0.137458	0.141267	-0.

5 rows × 31 columns

In [4]:
```
credit.isna().sum()
```

Out[4]:
```
Time      0
V1        0
V2        0
V3        0
V4        0
V5        0
V6        0
V7        0
V8        0
V9        0
V10       0
V11       0
V12       0
V13       0
V14       0
V15       0
V16       0
V17       0
V18       0
V19       0
V20       0
V21       0
V22       0
V23       0
V24       0
V25       0
V26       0
V27       0
V28       0
Amount    0
Class     0
dtype: int64
```

In [5]:
```
credit['Class'].value_counts()
```

Out[5]:
```
0    284315
1       492
Name: Class, dtype: int64
```

In [6]:
```
X = credit.drop(['Class'], 1).to_numpy()
y = credit['Class'].to_numpy()
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.33, random_state=42)
```

```
C:\Users\Seneca\AppData\Local\Temp/ipykernel_18096/4172792951.py:1: FutureWarning: In a future version of pandas all arguments of
DataFrame.drop except for the argument 'labels' will be keyword-only
  X = credit.drop(['Class'], 1).to_numpy()
```

In [7]:
```
scaler = StandardScaler()
X_train_s = scaler.fit_transform(X_train)
X_test_s = scaler.fit_transform(X_test)
```

In [8]:
```
def run_sampler_batch(run_model, samplers = [], incROC = False):
    metrics = []
    conf_disps = []
    rocs = []

    # make sure there are samplers to run
    if(len(samplers) > 0):
        for sampler, name in samplers:
            # get samples

            X_train_re, y_train_re = sampler.fit_resample(X_train_s, y_train)

            # run model
            if(incROC):
                mets, conf_disp, roc = run_model(X_train_re, y_train_re, name)
                rocs.append(roc)
            else:
                mets, conf_disp = run_model(X_train_re, y_train_re, name)

            # store performance stats in lists
            metrics.append(mets)
            conf_disps.append(conf_disp)

    else: # run model with original scaled training data
        if(incROC):
            mets, conf_disp, roc = run_model(X_train_s, y_train, "No Sampling Method")
            rocs.append(roc)
        else:
            mets, conf_disp = run_model(X_train_s, y_train, "No Sampling Method")

        # store performance stats in lists
        metrics.append(mets)
        conf_disps.append(conf_disp)

    # return performance stats
    if(incROC):
        return metrics, conf_disps, rocs
    return metrics, conf_disps
```

In [9]:
```
def print_metrics(metrics):
    for item in metrics:
        print("******************************************")
        print(item["name"])
        print("Accuracy Score: ", item["accuracy"])
        print("Precision: ", item["precision"])
        print("Recall: ", item["recall"])
        print("F1: ", item["f1"])
        print()

def plot_conf_disps(conf_disps):
    for item in conf_disps:
        print(item["name"])
        item["disp"].plot()
        plt.show()

def plot_rocs(rocs):
    for item in rocs:
        plt.plot(item["fpr"], item["tpr"])
        plt.title(item["name"])
        plt.xlabel("False Positive Rate")
        plt.ylabel("True Positive Rate (Recall)")
        plt.show()
```

Logistic Regression

In [10]:
```
def run_log_reg(X_tr_nn, y_tr_nn, name):
    print("RUNNING LOGISTIC REGRESSION CLASSIFIER ON DATA: ", name)
    log_reg = LogisticRegression(solver='lbfgs', random_state=42, max_iter=1000)

    log_reg = log_reg.fit(X_tr_nn, y_tr_nn)

    y_pred = log_reg.predict(X_test_s)
    # y_pred = np.where(y_pred > 0.5, 1, 0)

    # get metrics to be printed later
    metrics_rf = {"name": name,
              "accuracy": accuracy_score(y_test, y_pred),
              "precision": precision_score(y_test, y_pred, zero_division=False),
              "recall": recall_score(y_test, y_pred),
              "f1": f1_score(y_test, y_pred),
             }

    # generate confusion matrix visualizations
```

```python
    conf_matrix = confusion_matrix(y_test, y_pred)
    conf_disp_rf = {"name": name,
                    "disp": ConfusionMatrixDisplay(conf_matrix)
                    }

    # get false and true positive rates to graph later

    y_scores = cross_val_predict(log_reg, X_test_s, y_test, cv=3, method="decision_function")
    fpr, tpr, thresholds_roc = roc_curve(y_test, y_scores)
    roc_rf = {"name": name,
              "fpr": fpr,
              "tpr": tpr
             }

    return metrics_rf, conf_disp_rf, roc_rf
```

Logistic regression without accounting for class imbalances

In [11]:
```python
metrics, conf_disps, rocs = run_sampler_batch(run_model=run_log_reg, incROC=True)
```

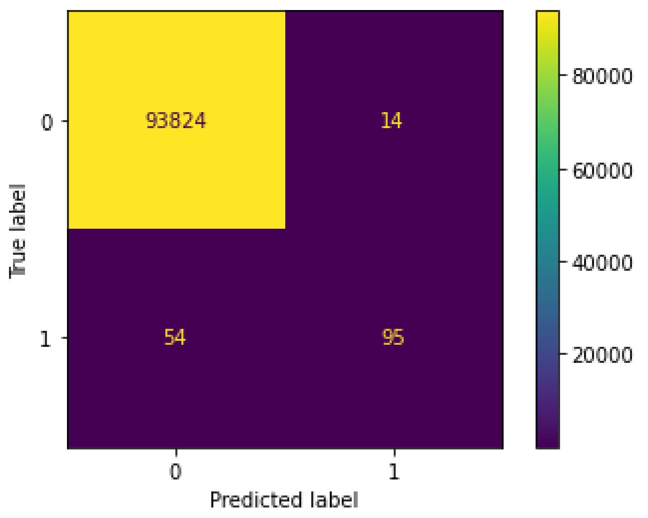
```
RUNNING LOGISTIC REGRESSION CLASSIFIER ON DATA:  No Sampling Method
```

In [12]:
```python
print_metrics(metrics)
```

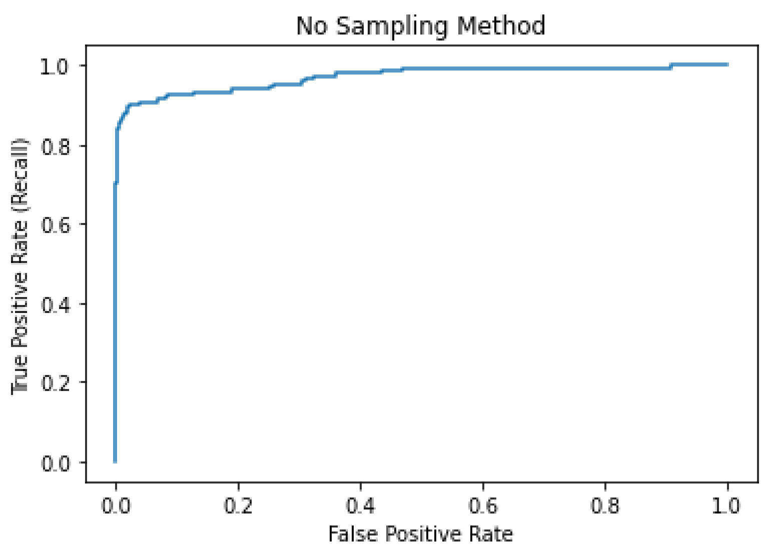
```
*****************************************
No Sampling Method
Accuracy Score:  0.9992764956855735
Precision:  0.8715596330275229
Recall:  0.6375838926174496
F1:  0.7364341085271318
```

In [13]:
```python
plot_conf_disps(conf_disps)
```

```
No Sampling Method
```



In [14]:
```python
plot_rocs(rocs)
```



Logistic Regression with Oversampling

In [15]:
```python
over_samplers = [[RandomOverSampler(random_state=42), "RandomOverSampler"],
                 [SMOTE(random_state=42), "SMOTE"],
                 [ADASYN(random_state=42), "ADASYN"],
                 [BorderlineSMOTE(random_state=42), "BorderLineSMOTE"]
                ]
```

In [16]:
```python
metrics, conf_disps, rocs = run_sampler_batch(run_model=run_log_reg, samplers=over_samplers, incROC=True)
```

```
RUNNING LOGISTIC REGRESSION CLASSIFIER ON DATA:  RandomOverSampler
RUNNING LOGISTIC REGRESSION CLASSIFIER ON DATA:  SMOTE
```

```
RUNNING LOGISTIC REGRESSION CLASSIFIER ON DATA:  ADASYN
RUNNING LOGISTIC REGRESSION CLASSIFIER ON DATA:  BorderLineSMOTE
```

In [17]:

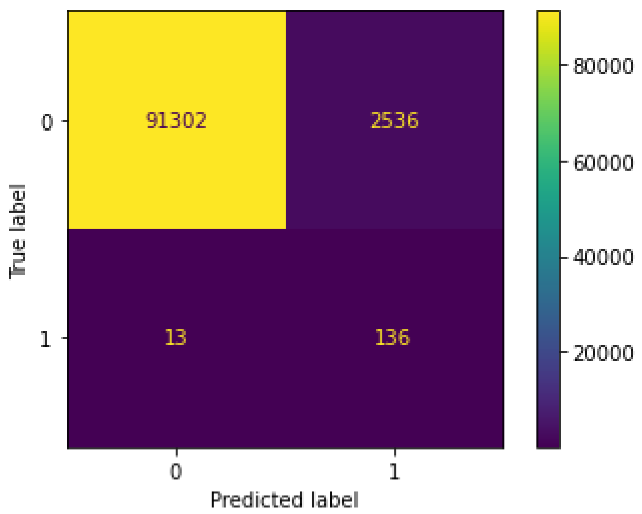
```python
print_metrics(metrics)
```

```
******************************************
RandomOverSampler
Accuracy Score:  0.9728792279783375
Precision:  0.05089820359281437
Recall:  0.912751677852349
F1:  0.09641970932293513

******************************************
SMOTE
Accuracy Score:  0.9721344441252514
Precision:  0.049927113702623906
Recall:  0.9194630872483222
F1:  0.0947113722779122

******************************************
ADASYN
Accuracy Score:  0.9053805313500803
Precision:  0.015621537779747396
Recall:  0.9463087248322147
F1:  0.030735694822888286

******************************************
BorderLineSMOTE
Accuracy Score:  0.9909774756083288
Precision:  0.13403141361256546
Recall:  0.8590604026845637
F1:  0.23188405797101452
```

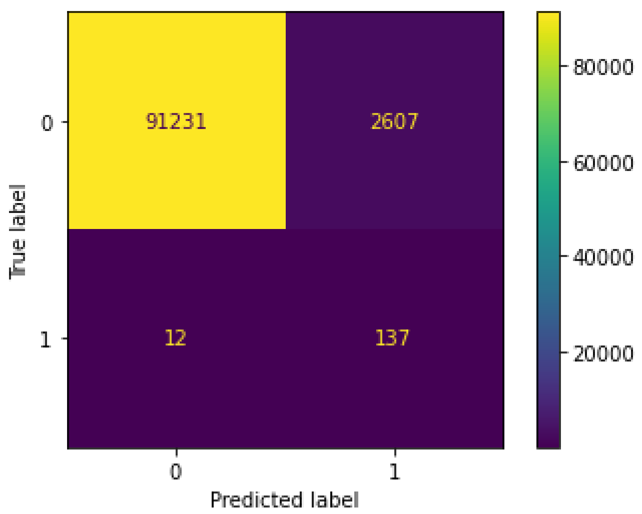
In [18]:

```python
plot_conf_disps(conf_disps)
```

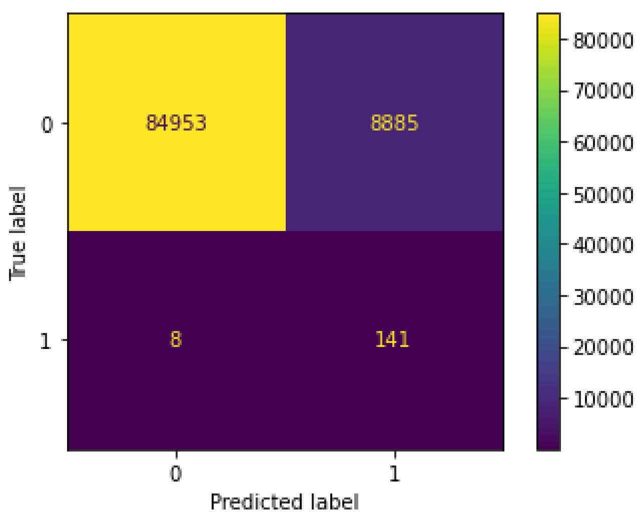
RandomOverSampler



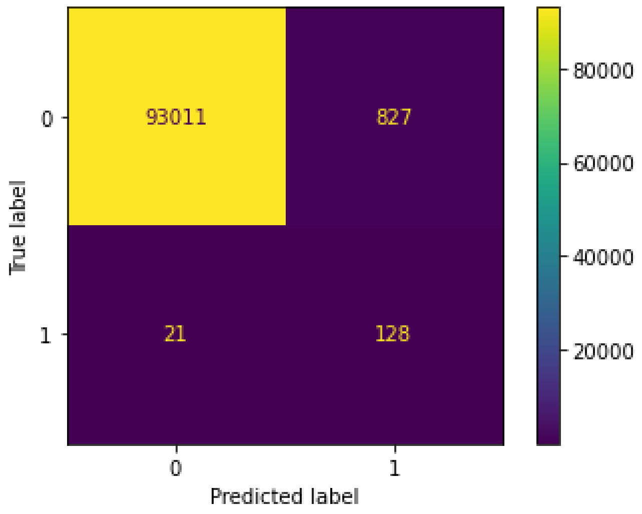
SMOTE



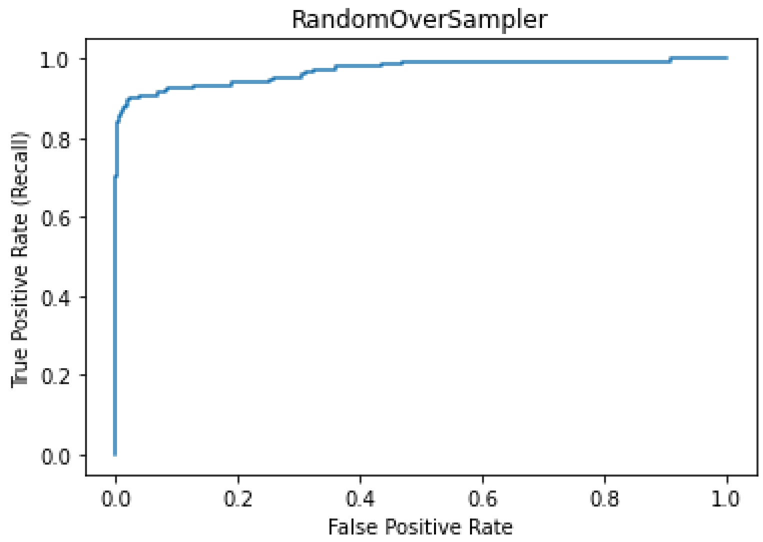
ADASYN

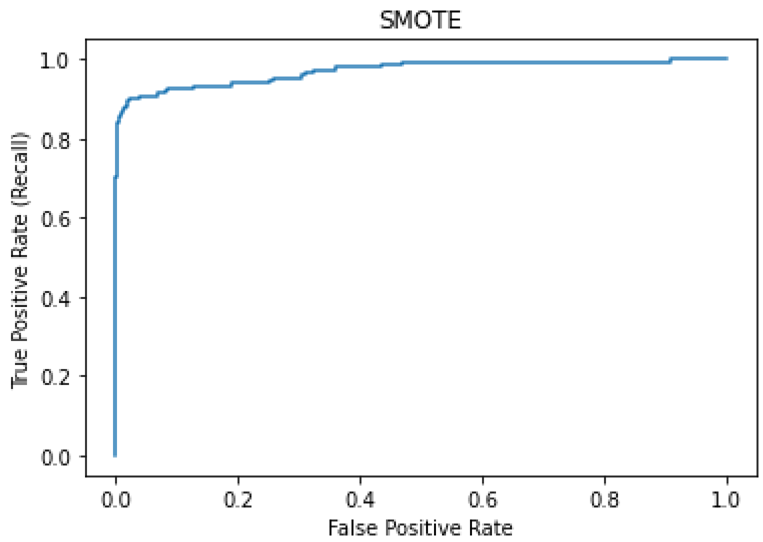


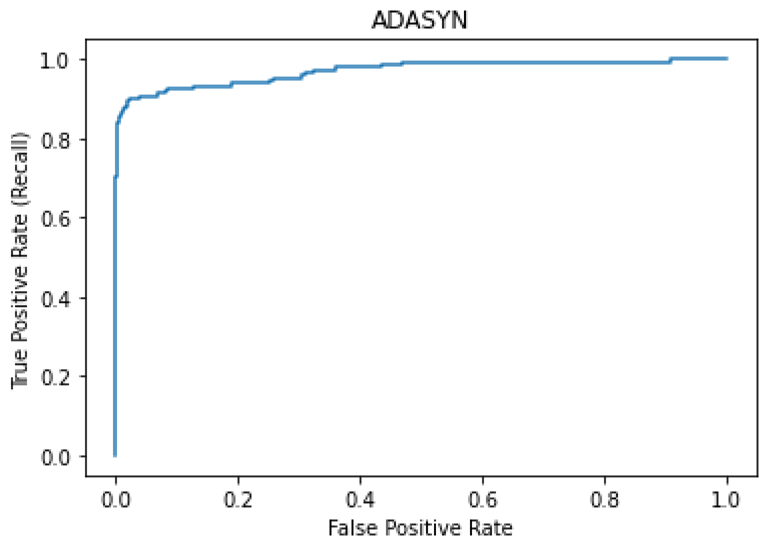
BorderLineSMOTE

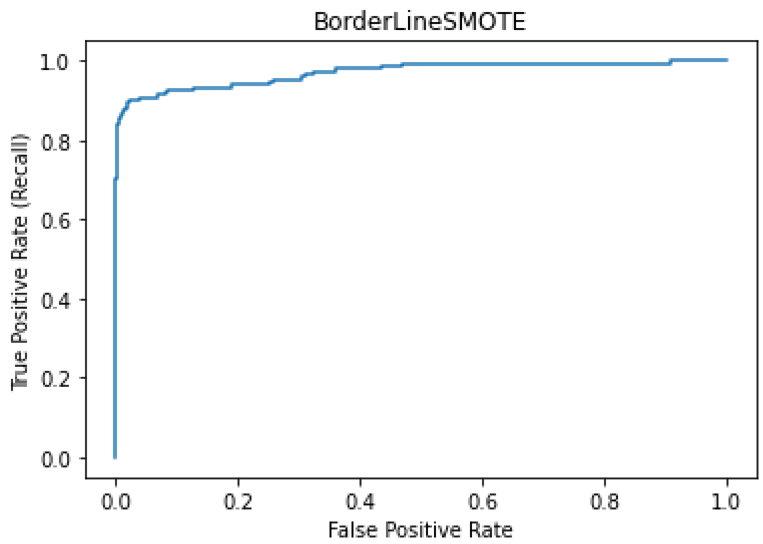


In [19]:
```
plot_rocs(rocs)
```









Logistic Regression with Undersampling

In [20]:
```
under_samplers = [[RandomUnderSampler(random_state=42), "RandomUnderSampler"],
                  [NearMiss(), "NearMiss"]
                 ]
```

In [21]:
```
metrics, conf_disps, rocs = run_sampler_batch(run_model=run_log_reg, samplers=under_samplers, incROC=True)
```

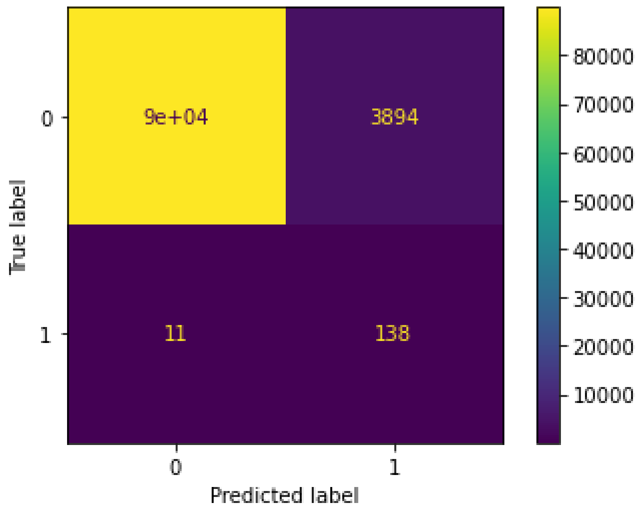
```
RUNNING LOGISTIC REGRESSION CLASSIFIER ON DATA:  RandomUnderSampler
RUNNING LOGISTIC REGRESSION CLASSIFIER ON DATA:  NearMiss
```

In [22]:
```
print_metrics(metrics)
```

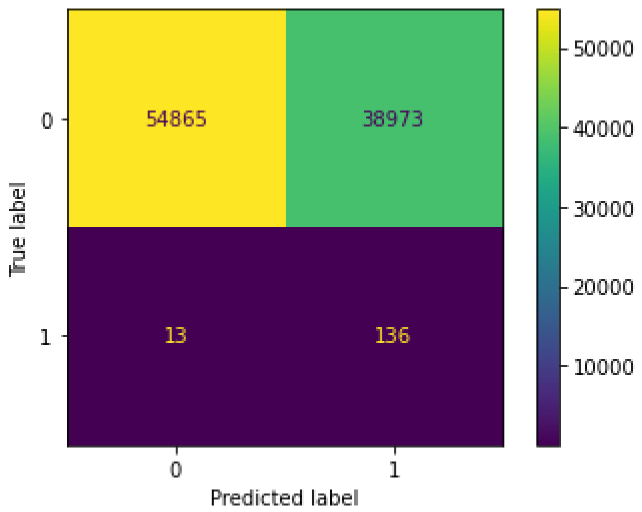
```
*****************************************
RandomUnderSampler
Accuracy Score:  0.9584517007671274
Precision:  0.03422619047619048
Recall:  0.9261744966442953
F1:  0.06601291557043769

*****************************************
NearMiss
Accuracy Score:  0.585197952908381
Precision:  0.0034774604311028153
Recall:  0.912751677852349
F1:  0.006928524122471852
```

In [23]:
```
plot_conf_disps(conf_disps)
```

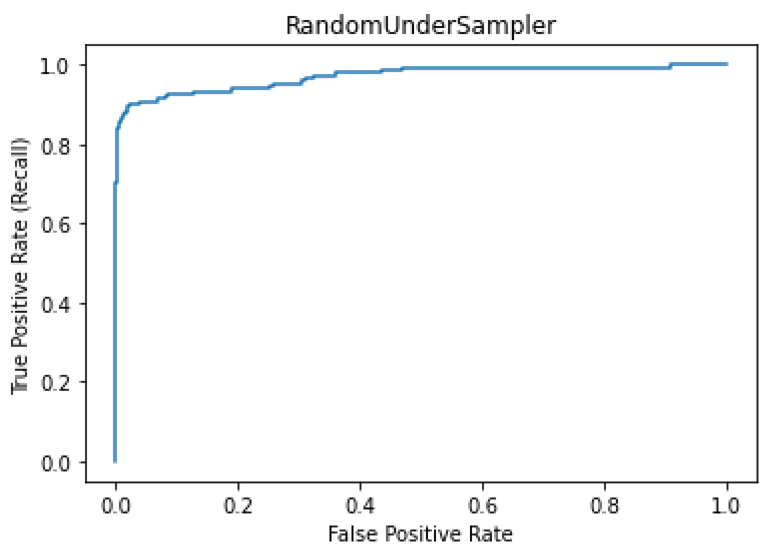
RandomUnderSampler

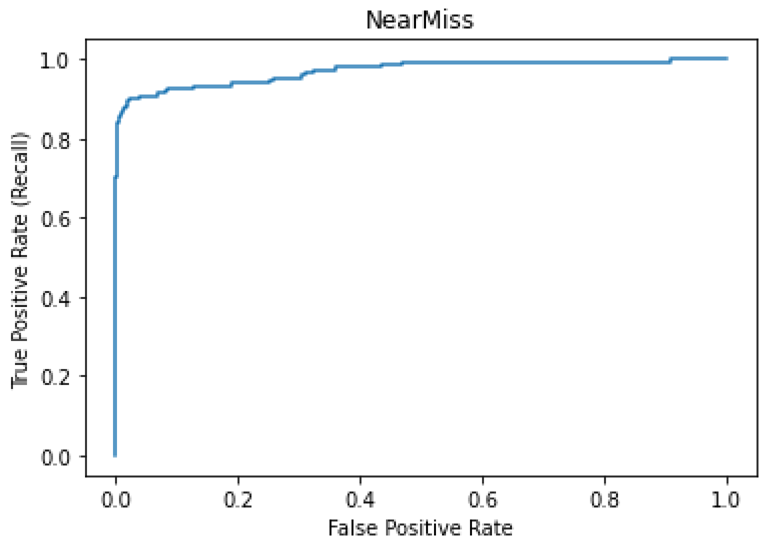


NearMiss



In [24]:
```
plot_rocs(rocs)
```





Neural Network

In [25]:
```
import keras
from keras.models import Sequential
from keras.layers import Dense
```

In [26]:
```
np.shape(X_train_s[0])
```

Out[26]:
```
(30,)
```

In [27]:
```
def run_nn(X_tr_nn, y_tr_nn, name):
    print("RUNNING NEURAL NETWORK ON DATA: ", name)
    classifier = Sequential()
    classifier.add(keras.layers.Dense(units=60, kernel_initializer='uniform', activation='tanh', input_dim=30))
    classifier.add(keras.layers.Dense(units=30, kernel_initializer='uniform', activation='tanh'))
    classifier.add(keras.layers.Dense(units=10, kernel_initializer='uniform', activation='tanh'))
    classifier.add(keras.layers.Dense(units=1, kernel_initializer='uniform', activation='sigmoid'))

    classifier.compile(optimizer='adam', loss='binary_crossentropy', metrics=['accuracy'])

    history = classifier.fit(X_tr_nn, y_tr_nn, epochs=20, batch_size=10)

    y_pred = classifier.predict(X_test_s)
    y_pred = np.where(y_pred > 0.5, 1, 0)

    # get metrics to be printed later
    metrics_nn = {"name": name,
               "accuracy": accuracy_score(y_test, y_pred),
               "precision": precision_score(y_test, y_pred, zero_division=False),
               "recall": recall_score(y_test, y_pred),
               "f1": f1_score(y_test, y_pred),
              }

    # generate confusion matrix visualizations
    conf_matrix = confusion_matrix(y_test, y_pred)
    conf_disp_nn = {"name": name,
                 "disp": ConfusionMatrixDisplay(conf_matrix)
                 }

    return metrics_nn, conf_disp_nn
```

Neural Network without accounting for class imbalance

In [28]:
```
metrics, conf_disps = run_sampler_batch(run_nn)
```

```
RUNNING NEURAL NETWORK ON DATA:  No Sampling Method
Epoch 1/20
19082/19082 [==============================] - 20s 1ms/step - loss: 0.0091 - accuracy: 0.9991
Epoch 2/20
19082/19082 [==============================] - 20s 1ms/step - loss: 0.0040 - accuracy: 0.9993
Epoch 3/20
19082/19082 [==============================] - 21s 1ms/step - loss: 0.0035 - accuracy: 0.9994
Epoch 4/20
19082/19082 [==============================] - 21s 1ms/step - loss: 0.0034 - accuracy: 0.9993
Epoch 5/20
19082/19082 [==============================] - 22s 1ms/step - loss: 0.0032 - accuracy: 0.9993
Epoch 6/20
19082/19082 [==============================] - 23s 1ms/step - loss: 0.0031 - accuracy: 0.9993
Epoch 7/20
19082/19082 [==============================] - 24s 1ms/step - loss: 0.0030 - accuracy: 0.9993
Epoch 8/20
19082/19082 [==============================] - 23s 1ms/step - loss: 0.0028 - accuracy: 0.9994
Epoch 9/20
19082/19082 [==============================] - 23s 1ms/step - loss: 0.0027 - accuracy: 0.9994
Epoch 10/20
19082/19082 [==============================] - 27s 1ms/step - loss: 0.0026 - accuracy: 0.9994
Epoch 11/20
19082/19082 [==============================] - 21s 1ms/step - loss: 0.0025 - accuracy: 0.9994
```

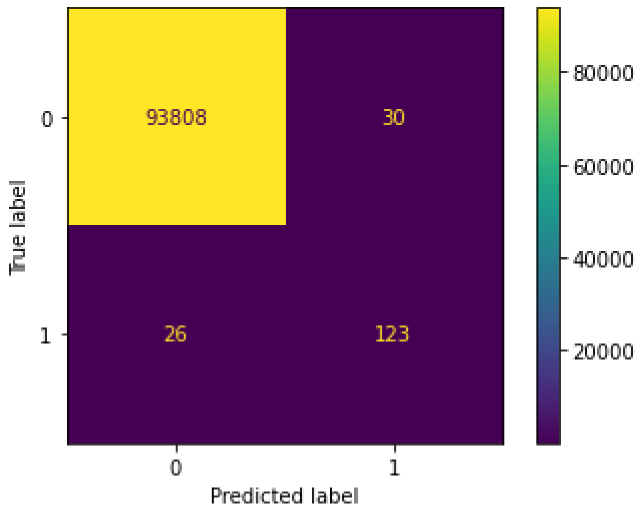
```
Epoch 12/20
19082/19082 [==============================] - 22s 1ms/step - loss: 0.0025 - accuracy: 0.9994
Epoch 13/20
19082/19082 [==============================] - 21s 1ms/step - loss: 0.0022 - accuracy: 0.9995
Epoch 14/20
19082/19082 [==============================] - 21s 1ms/step - loss: 0.0023 - accuracy: 0.9995
Epoch 15/20
19082/19082 [==============================] - 21s 1ms/step - loss: 0.0021 - accuracy: 0.9995
Epoch 16/20
19082/19082 [==============================] - 21s 1ms/step - loss: 0.0022 - accuracy: 0.9995
Epoch 17/20
19082/19082 [==============================] - 21s 1ms/step - loss: 0.0021 - accuracy: 0.9996
Epoch 18/20
19082/19082 [==============================] - 21s 1ms/step - loss: 0.0019 - accuracy: 0.9995
Epoch 19/20
19082/19082 [==============================] - 21s 1ms/step - loss: 0.0018 - accuracy: 0.9995
Epoch 20/20
19082/19082 [==============================] - 21s 1ms/step - loss: 0.0018 - accuracy: 0.9995
```

In [29]:
```
print_metrics(metrics)
```

```
*****************************************
No Sampling Method
Accuracy Score:  0.9994041729175311
Precision:  0.803921568627451
Recall:  0.825503355704698
F1:  0.8145695364238411
```

In [30]:
```
plot_conf_disps(conf_disps)
```

```
No Sampling Method
```



Neural Network with Oversampling

In [31]:
```
over_samplers = [[RandomOverSampler(random_state=42), "RandomOverSampler"],
                 [SMOTE(random_state=42), "SMOTE"],
                 [ADASYN(random_state=42), "ADASYN"],
                 [BorderlineSMOTE(random_state=42), "BorderLineSMOTE"]
                ]
```

In [32]:
```
metrics, conf_disps = run_sampler_batch(run_nn, over_samplers)
```

```
RUNNING NEURAL NETWORK ON DATA:  RandomOverSampler
Epoch 1/20
38096/38096 [==============================] - 52s 1ms/step - loss: 0.0476 - accuracy: 0.9835
Epoch 2/20
38096/38096 [==============================] - 57s 1ms/step - loss: 0.0080 - accuracy: 0.9978
Epoch 3/20
38096/38096 [==============================] - 49s 1ms/step - loss: 0.0051 - accuracy: 0.9987
Epoch 4/20
38096/38096 [==============================] - 42s 1ms/step - loss: 0.0037 - accuracy: 0.9992
Epoch 5/20
38096/38096 [==============================] - 42s 1ms/step - loss: 0.0030 - accuracy: 0.9994
Epoch 6/20
38096/38096 [==============================] - 43s 1ms/step - loss: 0.0027 - accuracy: 0.9995
Epoch 7/20
38096/38096 [==============================] - 44s 1ms/step - loss: 0.0027 - accuracy: 0.9995
Epoch 8/20
38096/38096 [==============================] - 44s 1ms/step - loss: 0.0021 - accuracy: 0.9996
Epoch 9/20
38096/38096 [==============================] - 45s 1ms/step - loss: 0.0020 - accuracy: 0.9996
Epoch 10/20
38096/38096 [==============================] - 45s 1ms/step - loss: 0.0018 - accuracy: 0.9997
Epoch 11/20
38096/38096 [==============================] - 44s 1ms/step - loss: 0.0017 - accuracy: 0.9997
Epoch 12/20
38096/38096 [==============================] - 42s 1ms/step - loss: 0.0016 - accuracy: 0.9997
Epoch 13/20
38096/38096 [==============================] - 42s 1ms/step - loss: 0.0018 - accuracy: 0.9997
Epoch 14/20
38096/38096 [==============================] - 43s 1ms/step - loss: 0.0015 - accuracy: 0.9997
```

```
Epoch 15/20
38096/38096 [==============================] - 44s 1ms/step - loss: 0.0014 - accuracy: 0.9997
Epoch 16/20
38096/38096 [==============================] - 45s 1ms/step - loss: 0.0014 - accuracy: 0.9998
Epoch 17/20
38096/38096 [==============================] - 45s 1ms/step - loss: 0.0015 - accuracy: 0.9997
Epoch 18/20
38096/38096 [==============================] - 45s 1ms/step - loss: 0.0015 - accuracy: 0.9997
Epoch 19/20
38096/38096 [==============================] - 45s 1ms/step - loss: 0.0014 - accuracy: 0.9997
Epoch 20/20
38096/38096 [==============================] - 47s 1ms/step - loss: 0.0017 - accuracy: 0.9997
RUNNING NEURAL NETWORK ON DATA:  SMOTE
Epoch 1/20
38096/38096 [==============================] - 45s 1ms/step - loss: 0.0507 - accuracy: 0.9819
Epoch 2/20
38096/38096 [==============================] - 45s 1ms/step - loss: 0.0109 - accuracy: 0.9968
Epoch 3/20
38096/38096 [==============================] - 44s 1ms/step - loss: 0.0067 - accuracy: 0.9981
Epoch 4/20
38096/38096 [==============================] - 45s 1ms/step - loss: 0.0048 - accuracy: 0.9988
Epoch 5/20
38096/38096 [==============================] - 44s 1ms/step - loss: 0.0038 - accuracy: 0.9990
Epoch 6/20
38096/38096 [==============================] - 45s 1ms/step - loss: 0.0032 - accuracy: 0.9992
Epoch 7/20
38096/38096 [==============================] - 44s 1ms/step - loss: 0.0030 - accuracy: 0.9993
Epoch 8/20
38096/38096 [==============================] - 45s 1ms/step - loss: 0.0024 - accuracy: 0.9994
Epoch 9/20
38096/38096 [==============================] - 45s 1ms/step - loss: 0.0021 - accuracy: 0.9995
Epoch 10/20
38096/38096 [==============================] - 44s 1ms/step - loss: 0.0020 - accuracy: 0.9995
Epoch 11/20
38096/38096 [==============================] - 42s 1ms/step - loss: 0.0020 - accuracy: 0.9995
Epoch 12/20
38096/38096 [==============================] - 42s 1ms/step - loss: 0.0017 - accuracy: 0.9996
Epoch 13/20
38096/38096 [==============================] - 41s 1ms/step - loss: 0.0015 - accuracy: 0.9996
Epoch 14/20
38096/38096 [==============================] - 41s 1ms/step - loss: 0.0015 - accuracy: 0.9997
Epoch 15/20
38096/38096 [==============================] - 41s 1ms/step - loss: 0.0015 - accuracy: 0.9996
Epoch 16/20
38096/38096 [==============================] - 42s 1ms/step - loss: 0.0013 - accuracy: 0.9997
Epoch 17/20
38096/38096 [==============================] - 42s 1ms/step - loss: 0.0013 - accuracy: 0.9997
Epoch 18/20
38096/38096 [==============================] - 42s 1ms/step - loss: 0.0012 - accuracy: 0.9997
Epoch 19/20
38096/38096 [==============================] - 41s 1ms/step - loss: 0.0013 - accuracy: 0.9997
Epoch 20/20
38096/38096 [==============================] - 40s 1ms/step - loss: 0.0012 - accuracy: 0.9997
RUNNING NEURAL NETWORK ON DATA:  ADASYN
Epoch 1/20
38096/38096 [==============================] - 39s 1ms/step - loss: 0.0588 - accuracy: 0.9797
Epoch 2/20
38096/38096 [==============================] - 42s 1ms/step - loss: 0.0099 - accuracy: 0.9975
Epoch 3/20
38096/38096 [==============================] - 42s 1ms/step - loss: 0.0066 - accuracy: 0.9984
Epoch 4/20
38096/38096 [==============================] - 40s 1ms/step - loss: 0.0052 - accuracy: 0.9988
Epoch 5/20
38096/38096 [==============================] - 41s 1ms/step - loss: 0.0041 - accuracy: 0.9991
Epoch 6/20
38096/38096 [==============================] - 41s 1ms/step - loss: 0.0031 - accuracy: 0.9993
Epoch 7/20
38096/38096 [==============================] - 40s 1ms/step - loss: 0.0030 - accuracy: 0.9994
Epoch 8/20
38096/38096 [==============================] - 40s 1ms/step - loss: 0.0027 - accuracy: 0.9995
Epoch 9/20
38096/38096 [==============================] - 40s 1ms/step - loss: 0.0022 - accuracy: 0.9995
Epoch 10/20
38096/38096 [==============================] - 39s 1ms/step - loss: 0.0021 - accuracy: 0.9995
Epoch 11/20
38096/38096 [==============================] - 38s 1ms/step - loss: 0.0020 - accuracy: 0.9996
Epoch 12/20
38096/38096 [==============================] - 38s 990us/step - loss: 0.0022 - accuracy: 0.9996
Epoch 13/20
38096/38096 [==============================] - 38s 995us/step - loss: 0.0018 - accuracy: 0.9996
Epoch 14/20
38096/38096 [==============================] - 45s 1ms/step - loss: 0.0016 - accuracy: 0.9997
Epoch 15/20
38096/38096 [==============================] - 47s 1ms/step - loss: 0.0016 - accuracy: 0.9997
Epoch 16/20
38096/38096 [==============================] - 48s 1ms/step - loss: 0.0016 - accuracy: 0.9997
Epoch 17/20
38096/38096 [==============================] - 46s 1ms/step - loss: 0.0016 - accuracy: 0.9997
Epoch 18/20
38096/38096 [==============================] - 46s 1ms/step - loss: 0.0017 - accuracy: 0.9997
Epoch 19/20
38096/38096 [==============================] - 47s 1ms/step - loss: 0.0016 - accuracy: 0.9997
```

```
Epoch 20/20
38096/38096 [==============================] - 48s 1ms/step - loss: 0.0015 - accuracy: 0.9997
RUNNING NEURAL NETWORK ON DATA:  BorderLineSMOTE
Epoch 1/20
38096/38096 [==============================] - 51s 1ms/step - loss: 0.0170 - accuracy: 0.9957
Epoch 2/20
38096/38096 [==============================] - 51s 1ms/step - loss: 0.0052 - accuracy: 0.9989
Epoch 3/20
38096/38096 [==============================] - 53s 1ms/step - loss: 0.0038 - accuracy: 0.9993
Epoch 4/20
38096/38096 [==============================] - 51s 1ms/step - loss: 0.0032 - accuracy: 0.9994
Epoch 5/20
38096/38096 [==============================] - 51s 1ms/step - loss: 0.0028 - accuracy: 0.9995
Epoch 6/20
38096/38096 [==============================] - 51s 1ms/step - loss: 0.0024 - accuracy: 0.9996
Epoch 7/20
38096/38096 [==============================] - 51s 1ms/step - loss: 0.0024 - accuracy: 0.9996
Epoch 8/20
38096/38096 [==============================] - 53s 1ms/step - loss: 0.0022 - accuracy: 0.9997
Epoch 9/20
38096/38096 [==============================] - 51s 1ms/step - loss: 0.0020 - accuracy: 0.9997
Epoch 10/20
38096/38096 [==============================] - 51s 1ms/step - loss: 0.0018 - accuracy: 0.9997
Epoch 11/20
38096/38096 [==============================] - 52s 1ms/step - loss: 0.0017 - accuracy: 0.9997
Epoch 12/20
38096/38096 [==============================] - 49s 1ms/step - loss: 0.0016 - accuracy: 0.9997
Epoch 13/20
38096/38096 [==============================] - 51s 1ms/step - loss: 0.0017 - accuracy: 0.9997
Epoch 14/20
38096/38096 [==============================] - 49s 1ms/step - loss: 0.0016 - accuracy: 0.9998
Epoch 15/20
38096/38096 [==============================] - 45s 1ms/step - loss: 0.0017 - accuracy: 0.9997
Epoch 16/20
38096/38096 [==============================] - 47s 1ms/step - loss: 0.0014 - accuracy: 0.9998
Epoch 17/20
38096/38096 [==============================] - 47s 1ms/step - loss: 0.0013 - accuracy: 0.9998
Epoch 18/20
38096/38096 [==============================] - 46s 1ms/step - loss: 0.0015 - accuracy: 0.9998
Epoch 19/20
38096/38096 [==============================] - 47s 1ms/step - loss: 0.0013 - accuracy: 0.9998
Epoch 20/20
38096/38096 [==============================] - 46s 1ms/step - loss: 0.0012 - accuracy: 0.9998
```

In [33]:

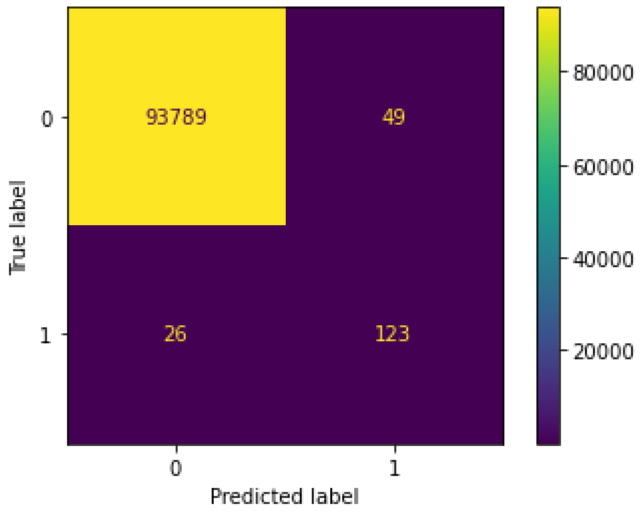
```
print_metrics(metrics)
```

```
*****************************************
RandomOverSampler
Accuracy Score:  0.9992020173002649
Precision:  0.7151162790697675
Recall:  0.825503355704698
F1:  0.7663551401869161

*****************************************
SMOTE
Accuracy Score:  0.9984572334471788
Precision:  0.5078740157480315
Recall:  0.8657718120805369
F1:  0.6401985111662531

*****************************************
ADASYN
Accuracy Score:  0.9989466628363497
Precision:  0.631578947368421
Recall:  0.8053691275167785
F1:  0.7079646017699115

*****************************************
BorderLineSMOTE
Accuracy Score:  0.9992764956855735
Precision:  0.7755102040816326
Recall:  0.7651006711409396
F1:  0.7702702702702703
```

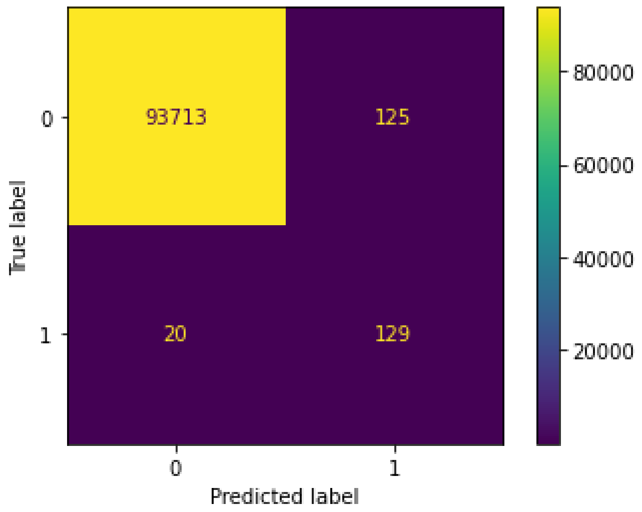
In [34]:

```
plot_conf_disps(conf_disps)
```

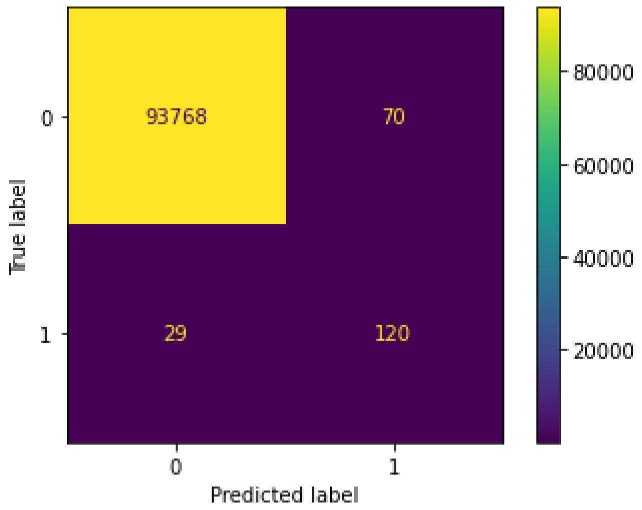
```
RandomOverSampler
```



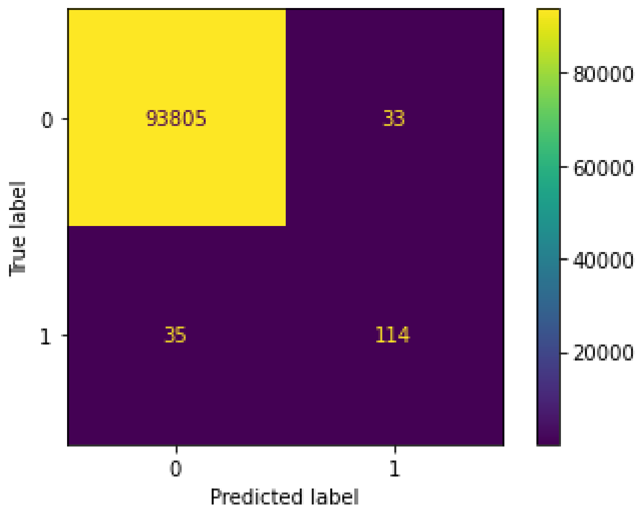
SMOTE



ADASYN



BorderLineSMOTE



Neural Network with Undersampling

In [35]:

```
under_samplers = [[RandomUnderSampler(random_state=42), "RandomUnderSampler"],
                  [NearMiss(), "NearMiss"]
                 ]
```

In [36]:

```
metrics, conf_disps = run_sampler_batch(run_nn, under_samplers)
```

```
RUNNING NEURAL NETWORK ON DATA:  RandomUnderSampler
Epoch 1/20
69/69 [==============================] - 0s 854us/step - loss: 0.5887 - accuracy: 0.8630
Epoch 2/20
69/69 [==============================] - 0s 1ms/step - loss: 0.3145 - accuracy: 0.9344
Epoch 3/20
69/69 [==============================] - 0s 1ms/step - loss: 0.2301 - accuracy: 0.9402
Epoch 4/20
69/69 [==============================] - 0s 1ms/step - loss: 0.1945 - accuracy: 0.9461
Epoch 5/20
69/69 [==============================] - 0s 1ms/step - loss: 0.1725 - accuracy: 0.9577
Epoch 6/20
69/69 [==============================] - 0s 1ms/step - loss: 0.1654 - accuracy: 0.9548
```

```
Epoch 7/20
69/69 [==============================] - 0s 1ms/step - loss: 0.1586 - accuracy: 0.9563
Epoch 8/20
69/69 [==============================] - 0s 1ms/step - loss: 0.1538 - accuracy: 0.9548
Epoch 9/20
69/69 [==============================] - 0s 1ms/step - loss: 0.1458 - accuracy: 0.9534
Epoch 10/20
69/69 [==============================] - 0s 1ms/step - loss: 0.1455 - accuracy: 0.9563
Epoch 11/20
69/69 [==============================] - 0s 1ms/step - loss: 0.1430 - accuracy: 0.9548
Epoch 12/20
69/69 [==============================] - 0s 1ms/step - loss: 0.1408 - accuracy: 0.9548
Epoch 13/20
69/69 [==============================] - 0s 1ms/step - loss: 0.1411 - accuracy: 0.9548
Epoch 14/20
69/69 [==============================] - 0s 2ms/step - loss: 0.1332 - accuracy: 0.9563
Epoch 15/20
69/69 [==============================] - 0s 2ms/step - loss: 0.1341 - accuracy: 0.9592
Epoch 16/20
69/69 [==============================] - 0s 2ms/step - loss: 0.1315 - accuracy: 0.9577
Epoch 17/20
69/69 [==============================] - 0s 1ms/step - loss: 0.1284 - accuracy: 0.9577
Epoch 18/20
69/69 [==============================] - 0s 2ms/step - loss: 0.1249 - accuracy: 0.9636
Epoch 19/20
69/69 [==============================] - 0s 2ms/step - loss: 0.1289 - accuracy: 0.9548
Epoch 20/20
69/69 [==============================] - 0s 2ms/step - loss: 0.1266 - accuracy: 0.9592
RUNNING NEURAL NETWORK ON DATA:  NearMiss
Epoch 1/20
69/69 [==============================] - 1s 968us/step - loss: 0.5603 - accuracy: 0.8717
Epoch 2/20
69/69 [==============================] - 0s 1ms/step - loss: 0.3267 - accuracy: 0.9227
Epoch 3/20
69/69 [==============================] - 0s 1ms/step - loss: 0.2194 - accuracy: 0.9577
Epoch 4/20
69/69 [==============================] - 0s 1ms/step - loss: 0.1703 - accuracy: 0.9636
Epoch 5/20
69/69 [==============================] - 0s 1ms/step - loss: 0.1475 - accuracy: 0.9679
Epoch 6/20
69/69 [==============================] - 0s 1ms/step - loss: 0.1270 - accuracy: 0.9708
Epoch 7/20
69/69 [==============================] - 0s 1ms/step - loss: 0.1239 - accuracy: 0.9752
Epoch 8/20
69/69 [==============================] - 0s 1ms/step - loss: 0.1099 - accuracy: 0.9767
Epoch 9/20
69/69 [==============================] - 0s 1ms/step - loss: 0.1073 - accuracy: 0.9767
Epoch 10/20
69/69 [==============================] - 0s 2ms/step - loss: 0.1085 - accuracy: 0.9738
Epoch 11/20
69/69 [==============================] - 0s 2ms/step - loss: 0.1109 - accuracy: 0.9723
Epoch 12/20
69/69 [==============================] - 0s 2ms/step - loss: 0.1048 - accuracy: 0.9738
Epoch 13/20
69/69 [==============================] - 0s 1ms/step - loss: 0.0956 - accuracy: 0.9796
Epoch 14/20
69/69 [==============================] - 0s 1ms/step - loss: 0.0994 - accuracy: 0.9767
Epoch 15/20
69/69 [==============================] - 0s 1ms/step - loss: 0.0968 - accuracy: 0.9767
Epoch 16/20
69/69 [==============================] - 0s 2ms/step - loss: 0.1016 - accuracy: 0.9767
Epoch 17/20
69/69 [==============================] - 0s 2ms/step - loss: 0.1079 - accuracy: 0.9694
Epoch 18/20
69/69 [==============================] - 0s 2ms/step - loss: 0.1004 - accuracy: 0.9752
Epoch 19/20
69/69 [==============================] - 0s 1ms/step - loss: 0.0944 - accuracy: 0.9781
Epoch 20/20
69/69 [==============================] - 0s 2ms/step - loss: 0.0944 - accuracy: 0.9781
```

In [37]:

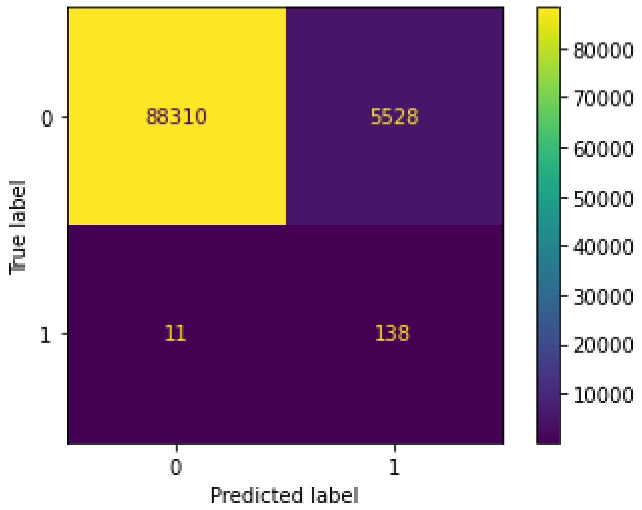
```
print_metrics(metrics)
```

```
*****************************************
RandomUnderSampler
Accuracy Score:  0.9410663176822327
Precision:  0.02435580656547829
Recall:  0.9261744966442953
F1:  0.047463456577815984

*****************************************
NearMiss
Accuracy Score:  0.5532254460723292
Precision:  0.003252920505271156
Recall:  0.9194630872483222
F1:  0.006482905477345322
```

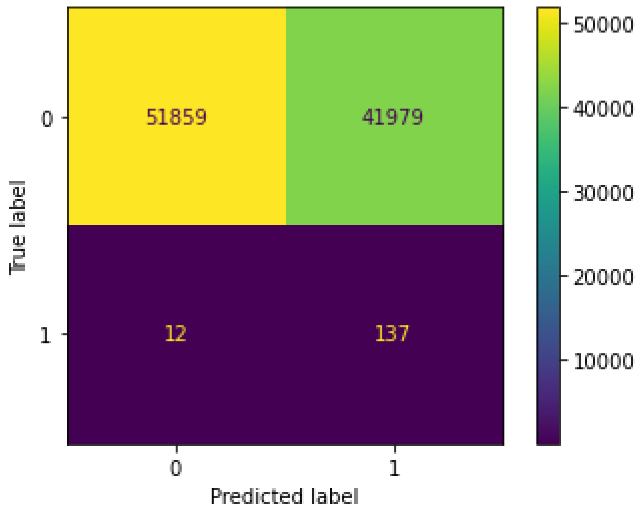
In [38]:

```
plot_conf_disps(conf_disps)
```

```
RandomUnderSampler
```



NearMiss



Random Forest Classifier

In [39]:

```
from sklearn.ensemble import RandomForestClassifier
```

In [40]:

```
def run_rfc(X_tr_nn, y_tr_nn, name):
    print("RUNNING RANDOM FOREST CLASSIFIER ON DATA: ", name)
    rfc = RandomForestClassifier(random_state=42)

    rfc.fit(X_tr_nn, y_tr_nn)

    y_pred = rfc.predict(X_test_s)
    # y_pred = np.where(y_pred > 0.5, 1, 0)

    # get metrics to be printed later
    metrics_rf = {"name": name,
                  "accuracy": accuracy_score(y_test, y_pred),
                  "precision": precision_score(y_test, y_pred, zero_division=False),
                  "recall": recall_score(y_test, y_pred),
                  "f1": f1_score(y_test, y_pred),
                 }

    # generate confusion matrix visualizations
    conf_matrix = confusion_matrix(y_test, y_pred)
    conf_disp_rf = {"name": name,
                    "disp": ConfusionMatrixDisplay(conf_matrix)
                   }

    # get false and true positive rates to graph later

    y_scores = cross_val_predict(rfc, X_test_s, y_test, cv=3)
    fpr, tpr, thresholds_roc = roc_curve(y_test, y_scores)
    roc_rf = {"name": name,
              "fpr": fpr,
              "tpr": tpr
             }

    return metrics_rf, conf_disp_rf, roc_rf
```

In [41]:

```
metrics, conf_disps, rocs = run_sampler_batch(run_model=run_rfc, incROC=True)
```

```
RUNNING RANDOM FOREST CLASSIFIER ON DATA:  No Sampling Method
```

In [42]:

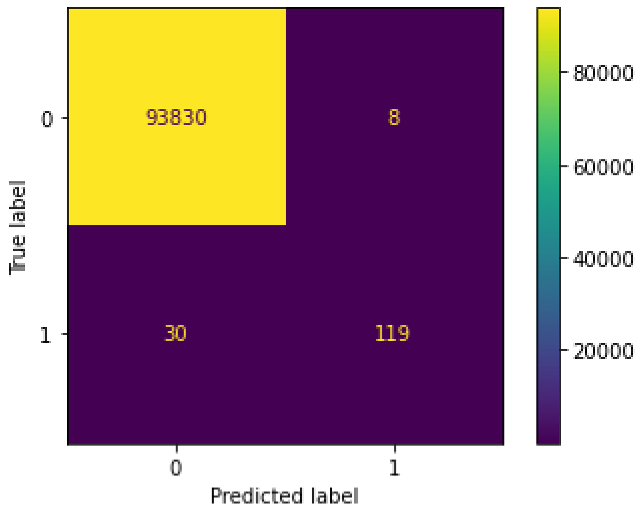
```
print_metrics(metrics)
```

```
*****************************************
No Sampling Method
Accuracy Score:  0.9995956887654676
Precision:  0.937007874015748
Recall:  0.7986577181208053
F1:  0.8623188405797101
```

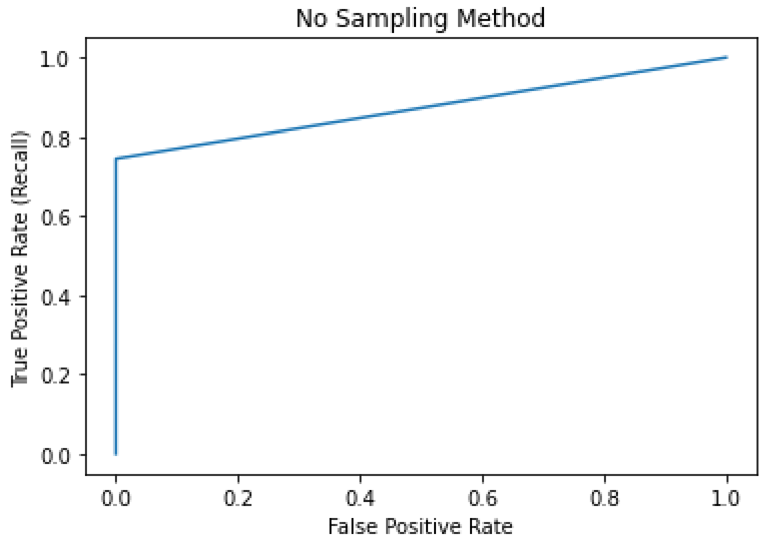
In [43]:

```
plot_conf_disps(conf_disps)
```

No Sampling Method



In [44]:
```
plot_rocs(rocs)
```



Random Forest Classifier with Oversampling

In [45]:
```
over_samplers = [[RandomOverSampler(random_state=42), "RandomOverSampler"],
                 [SMOTE(random_state=42), "SMOTE"],
                 [ADASYN(random_state=42), "ADASYN"],
                 [BorderlineSMOTE(random_state=42), "BorderLineSMOTE"]
                ]
```

In [46]:
```
metrics, conf_disps, rocs = run_sampler_batch(run_model=run_rfc, samplers=over_samplers, incROC=True)
```

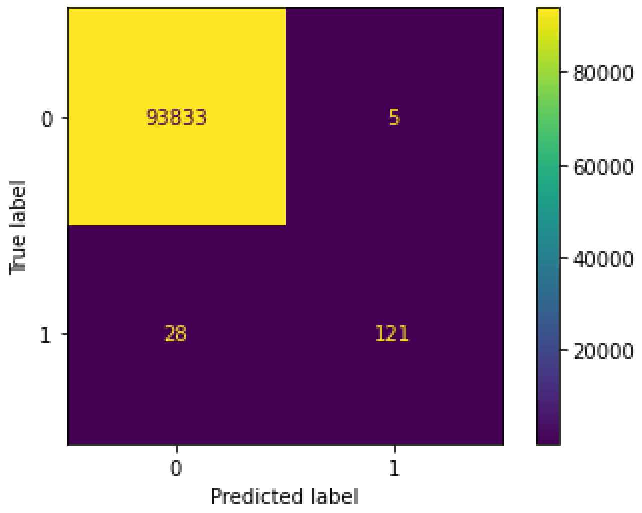
```
RUNNING RANDOM FOREST CLASSIFIER ON DATA:  RandomOverSampler
RUNNING RANDOM FOREST CLASSIFIER ON DATA:  SMOTE
RUNNING RANDOM FOREST CLASSIFIER ON DATA:  ADASYN
RUNNING RANDOM FOREST CLASSIFIER ON DATA:  BorderLineSMOTE
```

In [47]:
```
print_metrics(metrics)
```

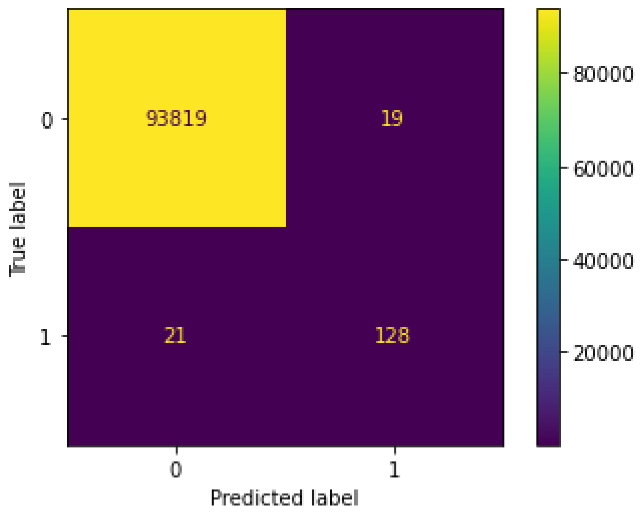
```
*******************************************
RandomOverSampler
Accuracy Score:  0.9996488876121166
Precision:  0.9603174603174603
Recall:  0.8120805369127517
F1:  0.8800000000000001

*******************************************
SMOTE
Accuracy Score:  0.999574409226808
Precision:  0.8707482993197279
Recall:  0.8590604026845637
F1:  0.8648648648648649

*******************************************
ADASYN
Accuracy Score:  0.9995105706108292
Precision:  0.8551724137931035
Recall:  0.8322147651006712
F1:  0.8435374149659864

*******************************************
BorderLineSMOTE
Accuracy Score:  0.9995956887654676
Precision:  0.9302325581395349
Recall:  0.8053691275167785
F1:  0.8633093525179855
```

In [48]:
```
plot_conf_disps(conf_disps)
```

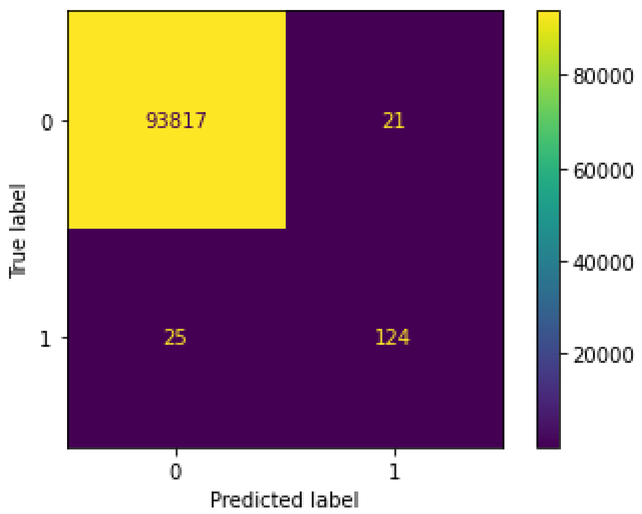
RandomOverSampler



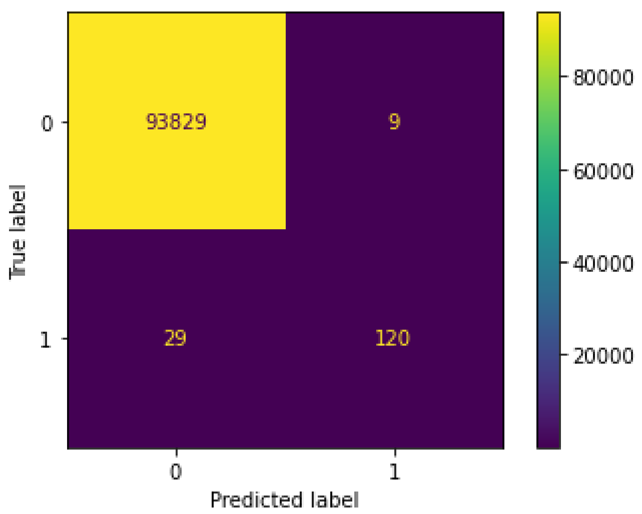
SMOTE



ADASYN



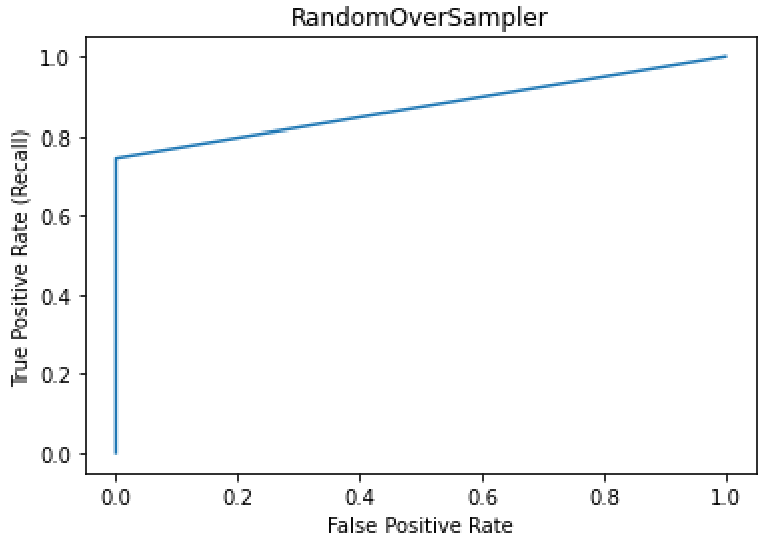
BorderLineSMOTE

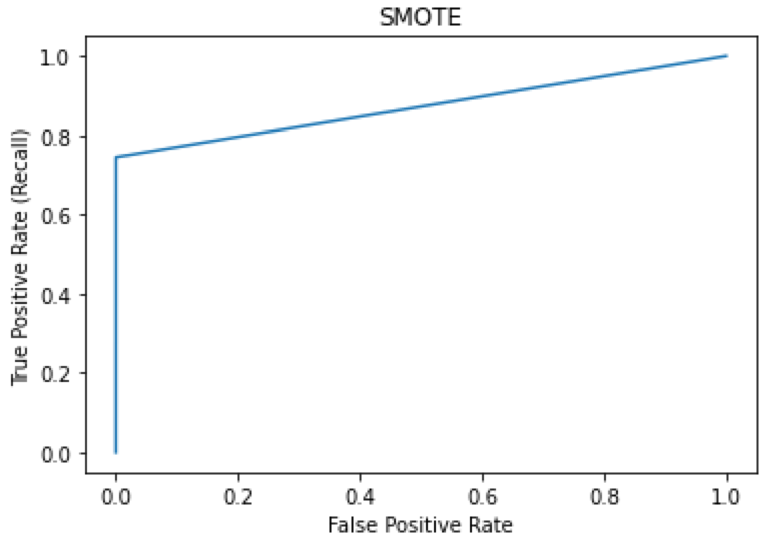


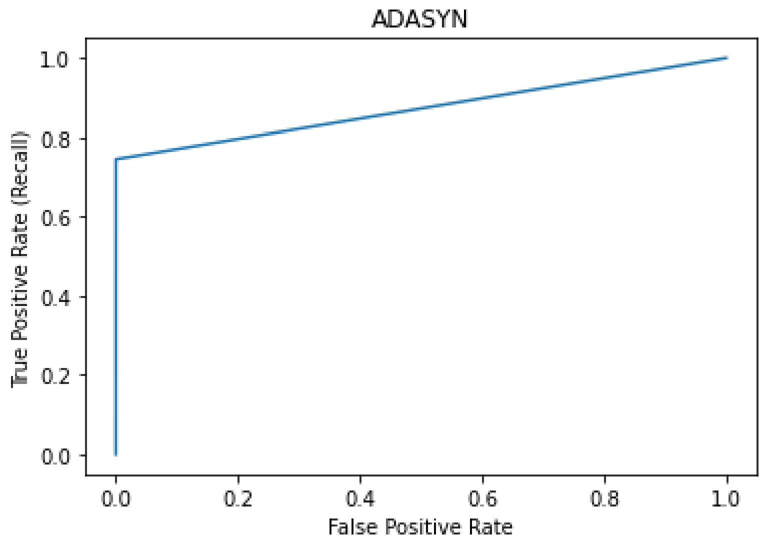
In [49]:

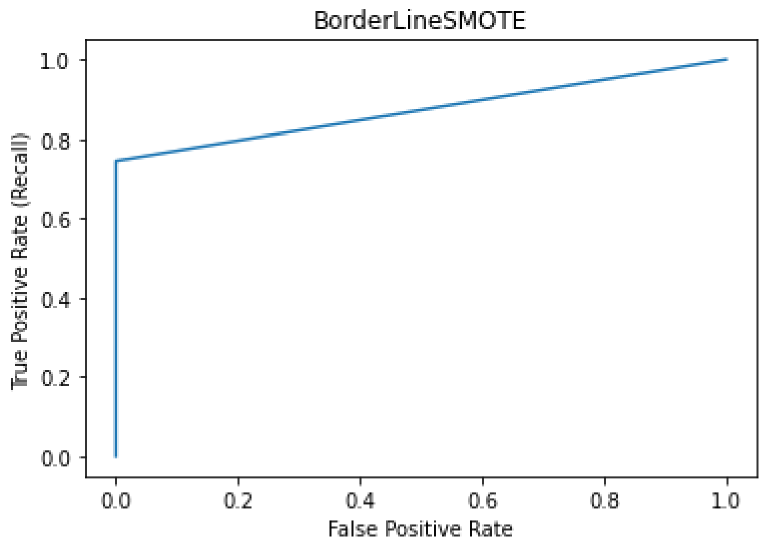
```
plot_rocs(rocs)
```

RandomOverSampler









Random Forest Classifier with Undersampling

In [50]:
```
under_samplers = [[RandomUnderSampler(random_state=42), "RandomUnderSampler"],
                  [NearMiss(), "NearMiss"]
                 ]
```

In [51]:
```
metrics, conf_disps, rocs = run_sampler_batch(run_model=run_rfc, samplers=under_samplers, incROC=True)
```

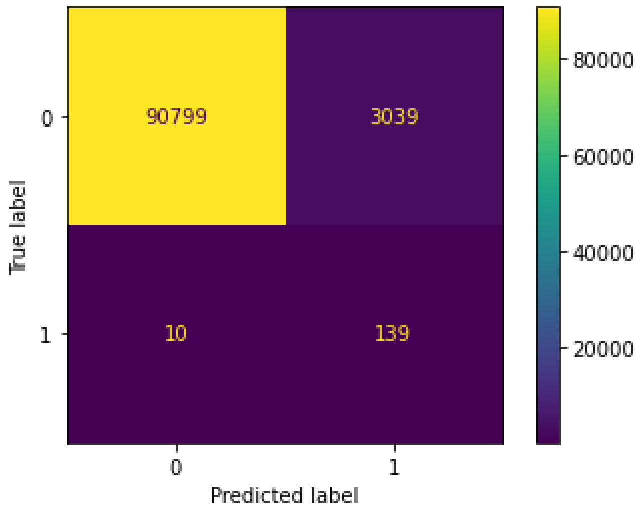
```
RUNNING RANDOM FOREST CLASSIFIER ON DATA:  RandomUnderSampler
RUNNING RANDOM FOREST CLASSIFIER ON DATA:  NearMiss
```

In [52]:
```
print_metrics(metrics)
```

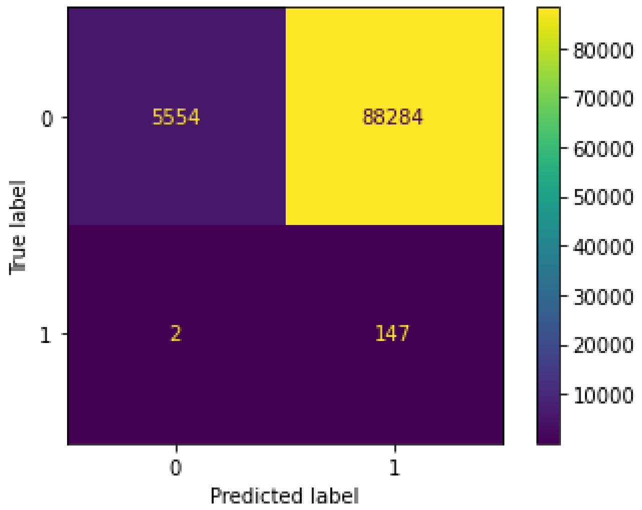
```
*****************************************
RandomUnderSampler
Accuracy Score:  0.967559343313437
Precision:  0.04373820012586532
Recall:  0.9328859060402684
F1:  0.08355876164712954

*****************************************
NearMiss
Accuracy Score:  0.0606573249491951
Precision:  0.0016623129897886488
Recall:  0.9865771812080537
F1:  0.0033190336419056223
```

In [53]:
```
plot_conf_disps(conf_disps)
```

```
RandomUnderSampler
```



NearMiss



In [54]:
```
plot_rocs(rocs)
```