[1]:
```
import h5py
import matplotlib.pyplot as plt
import numpy as np
import tensorflow.keras as K
from sklearn.model_selection import train_test_split
import pandas as pd
```

```
Intel MKL WARNING: Support of Intel(R) Streaming SIMD Extensions 4.2 (Intel(R)
SSE4.2) enabled only processors has been deprecated. Intel oneAPI Math Kernel
Library 2025.0 will require Intel(R) Advanced Vector Extensions (Intel(R) AVX)
instructions.
Intel MKL WARNING: Support of Intel(R) Streaming SIMD Extensions 4.2 (Intel(R)
SSE4.2) enabled only processors has been deprecated. Intel oneAPI Math Kernel
Library 2025.0 will require Intel(R) Advanced Vector Extensions (Intel(R) AVX)
instructions.

2024-04-17 15:29:47.130479: I tensorflow/core/platform/cpu_feature_guard.cc:182]
This TensorFlow binary is optimized to use available CPU instructions in
performance-critical operations.
To enable the following instructions: SSE4.1 SSE4.2, in other operations,
rebuild TensorFlow with the appropriate compiler flags.
```

[2]:
```
with h5py.File("info/data/output_signal.h5", "r") as file:
    signal_data = file["events"][:]

with h5py.File("info/data/output_bg.h5", "r") as file:
    bg_data = file["events"][:]
```

1 Loading the Data

[3]:
```
# storing signal and background data in panda DataFrame
signal = pd.DataFrame(signal_data)
background = pd.DataFrame(bg_data)

# concatenating the data frames to be part of one big set
df = pd.concat([signal, background])

# reseting the indicies
df = df.reset_index()

# creating the labels for the data sets i.e; signal = 1, background = 0 for␣
 ↪classification
labels = np.concatenate([np.ones(signal.shape[0]), np.zeros(background.
 ↪shape[0])])
labels = pd.DataFrame({'ttZ': labels})

# adding labels as a column at the end of the DataFrame
```

```
df = df.join(labels)

# shuffling the DataFrame
df_shuffled = df.sample(frac=1, random_state=42)  # 'random_state' for␣
↪reproducibility
df_shuffled.head()

# splitting the labels from the rest of the dataset
y = df_shuffled['ttZ']

# we can check the class distribution in the subset
print('ttZ events: {:.2f}%'.format(np.sum(y)/len(y) * 100))
print('WZ events: {:.2f}%'.format((1 - np.sum(y)/len(y)) * 100))
```

```
ttZ events: 68.65%
WZ events: 31.35%
```

2 Various Feature Lists

[4]:
```
# base input list suggested by the project
input_list = [ "H_T",
               "jet_1_pt",
               "jet_2_pt",
               "lep_1_pt",
               "lep_2_pt",
               "n_bjets",
               "jet_1_twb",
               "jet_2_twb",
               "bjet_1_pt"]

# best input list suggested by SRS
input_list_2 = ['jet_1_pt',
                'jet_3_pt',
                'jet_1_eta',
                'jet_3_eta',
                'jet_1_twb',
                'jet_2_twb',
                'jet_3_twb',
                'bjet_1_pt',
                'n_jets',
                'n_bjets',
                'n_leptons']

# smallest input list that still has an accuracy >80%, suggested by SRS
input_list_3 = ['jet_3_pt',
                'jet_1_twb',
                'jet_2_twb',
```

```
                'jet_3_twb',
                'bjet_1_pt',
                'n_jets',
                'n_bjets']

input_lists = [input_list, input_list_2, input_list_3]
```

3 Running Base Model for all Feature Lists

[5]:
```
fig, axs = plt.subplots(3, 3, figsize=(12, 16))

for i, feature_list in enumerate(input_lists):
    names = ['base list', 'SRS: best list', 'SRS: best smallest list']
    X = df_shuffled[feature_list]
    x_train, x_rem, y_train, y_rem = train_test_split(X, y, train_size=0.8)
    x_val, x_test, y_val, y_test = train_test_split(x_rem, y_rem, train_size=0.5)

    preprocessing_layer = K.layers.Normalization()
    preprocessing_layer.adapt(x_train)

    model = K.Sequential(
    [
        preprocessing_layer,
        K.layers.Dense(50, activation="relu", name="hidden1"),
        K.layers.Dense(25, activation="relu", name="hidden2"),
        K.layers.Dense(10, activation="relu", name="hidden3"),
        K.layers.Dense(1, activation="sigmoid", name="output"),
    ]
    )

    model.summary()

    model.compile(optimizer=K.optimizers.Adam(learning_rate=0.0002),
                  loss=K.losses.BinaryCrossentropy(),
                  metrics=[K.metrics.BinaryAccuracy()])

    fit_history = model.fit(
        x_train,
        y_train,
        batch_size=512,
        epochs=100,
        validation_data=(x_val, y_val),
        verbose = 0)


    print("Printing summary of the trained model:")
```

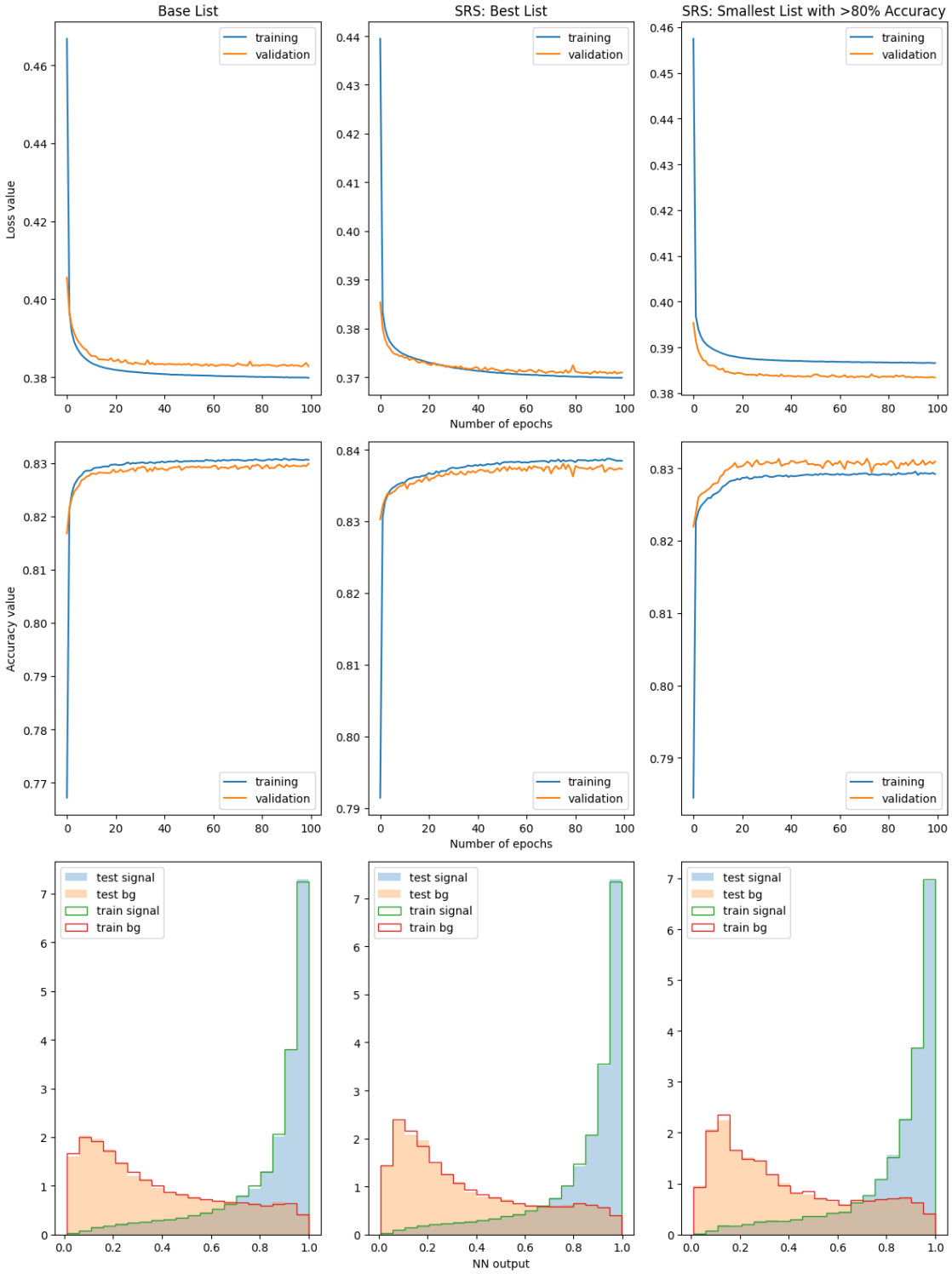
```
    print(model.summary())

    titles = ['Base List', 'SRS: Best List', 'SRS: Smallest List with >80%␣
↪Accuracy']

    axs[0, i].plot(fit_history.history["loss"], label="training")
    axs[0, i].plot(fit_history.history["val_loss"], label="validation")
    axs[0, i].legend()
    axs[0, i].set_title(titles[i])

    axs[1, i].plot(fit_history.history["binary_accuracy"], label="training")
    axs[1, i].plot(fit_history.history["val_binary_accuracy"],␣
↪label="validation")
    axs[1, i].legend()

    _, bins, _ = axs[2, i].hist(model.predict(x_test[y_test.astype(bool)]),␣
↪bins=20, alpha=0.3, density=True, label="test signal")
    axs[2, i].hist(model.predict(x_test[~y_test.astype(bool)]), bins=bins,␣
↪alpha=0.3, density=True, label="test bg")
    axs[2, i].hist(model.predict(x_train[y_train.astype(bool)]), bins=bins,␣
↪density=True, histtype="step", label="train signal")
    axs[2, i].hist(model.predict(x_train[~y_train.astype(bool)]), bins=bins,␣
↪density=True, histtype="step", label="train bg")
    axs[2, i].legend()

    if i == 0:
            axs[0, i].set_ylabel("Loss value")
            axs[1, i].set_ylabel("Accuracy value")

    elif i == 1:
        axs[0, i].set_xlabel("Number of epochs")
        axs[1, i].set_xlabel("Number of epochs")
        axs[2, i].set_xlabel("NN output")

fig.tight_layout()
plt.savefig("feat-comparison.pdf")
plt.show()
```

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 normalization (Normalizatio  (None, 9)                19
 n)

 hidden1 (Dense)             (None, 50)                500
```

```
 hidden2 (Dense)             (None, 25)                1275

 hidden3 (Dense)             (None, 10)                260

 output (Dense)              (None, 1)                 11

=================================================================
Total params: 2,065
Trainable params: 2,046
Non-trainable params: 19
_________________________________________________________________
Printing summary of the trained model:
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 normalization (Normalizatio  (None, 9)                19
 n)

 hidden1 (Dense)             (None, 50)                500

 hidden2 (Dense)             (None, 25)                1275

 hidden3 (Dense)             (None, 10)                260

 output (Dense)              (None, 1)                 11

=================================================================
Total params: 2,065
Trainable params: 2,046
Non-trainable params: 19
_________________________________________________________________
None
1595/1595 [==============================] - 1s 375us/step
723/723 [==============================] - 0s 375us/step
12723/12723 [==============================] - 5s 388us/step
5817/5817 [==============================] - 2s 380us/step
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 normalization_1 (Normalizat  (None, 11)               23
 ion)

 hidden1 (Dense)             (None, 50)                600

 hidden2 (Dense)             (None, 25)                1275
```

```
 hidden3 (Dense)             (None, 10)                260

 output (Dense)              (None, 1)                 11

=================================================================
Total params: 2,169
Trainable params: 2,146
Non-trainable params: 23
_________________________________________________________________
Printing summary of the trained model:
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 normalization_1 (Normalizat  (None, 11)               23
 ion)

 hidden1 (Dense)             (None, 50)                600

 hidden2 (Dense)             (None, 25)                1275

 hidden3 (Dense)             (None, 10)                260

 output (Dense)              (None, 1)                 11

=================================================================
Total params: 2,169
Trainable params: 2,146
Non-trainable params: 23
_________________________________________________________________
None
1587/1587 [==============================] - 1s 440us/step
731/731 [==============================] - 0s 397us/step
12725/12725 [==============================] - 5s 398us/step
5815/5815 [==============================] - 2s 383us/step
Model: "sequential_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 normalization_2 (Normalizat  (None, 7)                15
 ion)

 hidden1 (Dense)             (None, 50)                400

 hidden2 (Dense)             (None, 25)                1275

 hidden3 (Dense)             (None, 10)                260
```

```
 output (Dense)              (None, 1)                 11

=================================================================
Total params: 1,961
Trainable params: 1,946
Non-trainable params: 15
_________________________________________________________________
Printing summary of the trained model:
Model: "sequential_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 normalization_2 (Normalizat  (None, 7)                15
 ion)

 hidden1 (Dense)             (None, 50)                400

 hidden2 (Dense)             (None, 25)                1275

 hidden3 (Dense)             (None, 10)                260

 output (Dense)              (None, 1)                 11

=================================================================
Total params: 1,961
Trainable params: 1,946
Non-trainable params: 15
_________________________________________________________________
None
1589/1589 [==============================] - 1s 385us/step
729/729 [==============================] - 0s 382us/step
12724/12724 [==============================] - 6s 469us/step
5815/5815 [==============================] - 2s 384us/step
```


Base List
SRS: Best List
SRS: Smallest List with >80% Accuracy
training
validation
Loss value
Number of epochs
Accuracy value
test signal
test bg
train signal
train bg
NN output