

# Assignment 2 - Machine Learning

## Topics in Particle Physics and Astroparticles II

April 2022

**1.** This segment utilizes the first set of samples assigned to each one: Group 1 - Dark Photons  $\rightarrow \mu^\pm \mu^\mp$ ; Group 2 - Heavy Neutral Leptons  $\rightarrow \pi^\pm \mu^\mp$

1. Overlap the distributions of all the physical features, from both the signal and the background.
2. Select the three features that provide the biggest separation between distributions. Explain why you should not use the Invariant Mass.
3. Applying cuts on the selected features try to remove as much background events as possible while maintaining a selection efficiency of the signal above 95%.
4. Can you expect to obtain better results if you perform a Machine Learning analysis on the same data? Why or why not?
5. Select a maximum of 5 features to utilize in a Machine Learning analysis. Explain why you chose them.
6. Define and train a Neural Network with the selected features.
7. After applying the full set of data on the Neural Network, define a score threshold so that you have a selection efficiency of 95%. Present the selection efficiency of the background events. Compare it with the analysis from question 1.3.

**2.** This segment utilizes the second set of samples assigned to each one: Group 1 - Heavy Neutral Leptons  $\rightarrow \mu^\pm \mu^\mp \nu$ ; Group 2 - Heavy Neutral Leptons  $\rightarrow \rho^\pm \mu^\mp$  (recall that  $\rho$  mesons decay immediately according to  $\rho^\pm \rightarrow \pi^\pm \pi^0$ )

1. Overlap the distributions of all the physical features, from both the signal and the background.
2. If you perform a similar analysis to question 1.3 can you expect a bigger, smaller or similar background survival rate. Why?

3. Perform a Machine Learning analysis with the same features as in question 1.6. Show the background survival rate for a signal selection efficiency of 95%. Select a threshold that maintains the same rate of background survival as in question 1.7. Compare both results.

Materials to be handed in:

- report with answers to the questions above
- link to code / notebook used