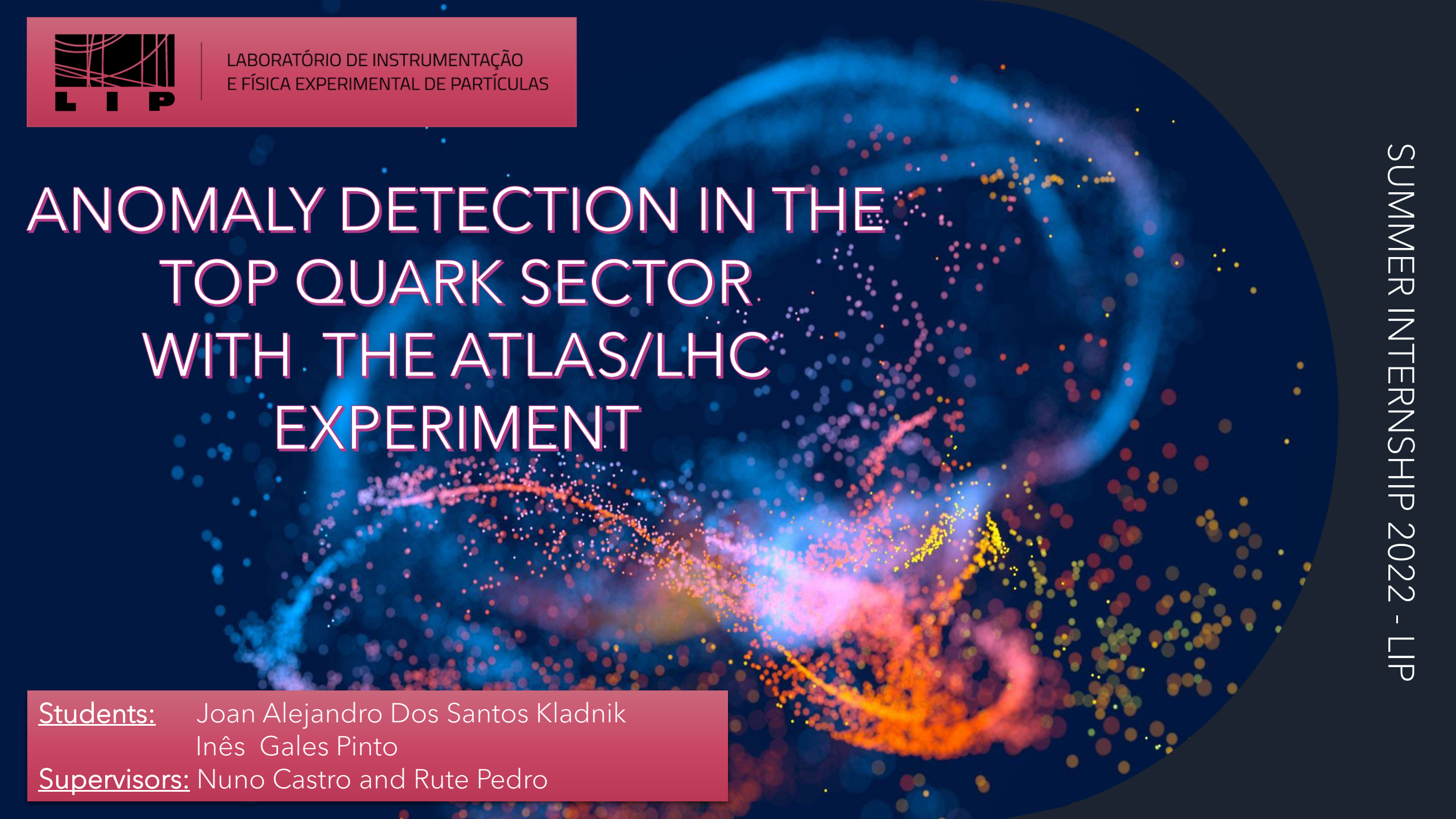


LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS

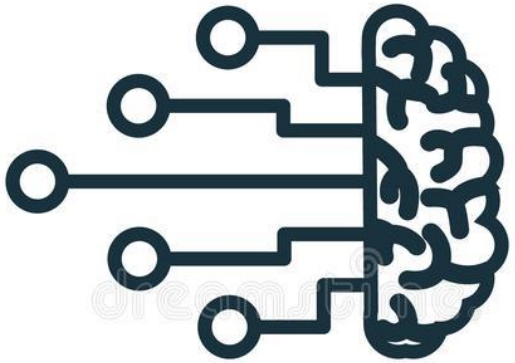
ANOMALY DETECTION IN THE TOP QUARK SECTOR WITH THE ATLAS/LHC EXPERIMENT

SUMMER INTERNSHIP 2022 - LIP

Students: Joan Alejandro Dos Santos Kladnik
Inês Gales Pinto
Supervisors: Nuno Castro and Rute Pedro

INTRODUCTION

- Trying to detect anomalies (Unknown events) at the particle collision events in ATLAS experiment ;
- Application of Machine Learning methods to detect anomalies (Deep learning);
- Construction of Neural Networks;
- Treatment of the Neural Networks outputs .

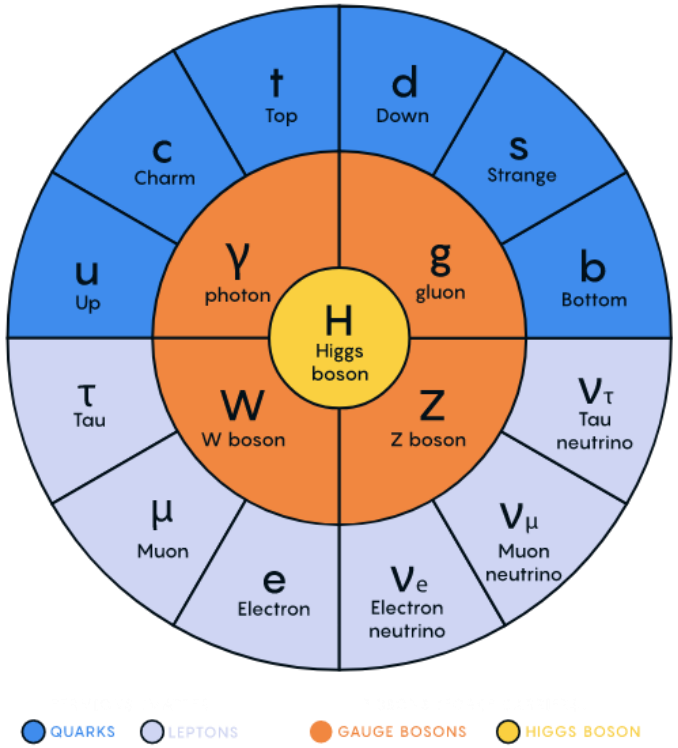


MACHINE LEARNING

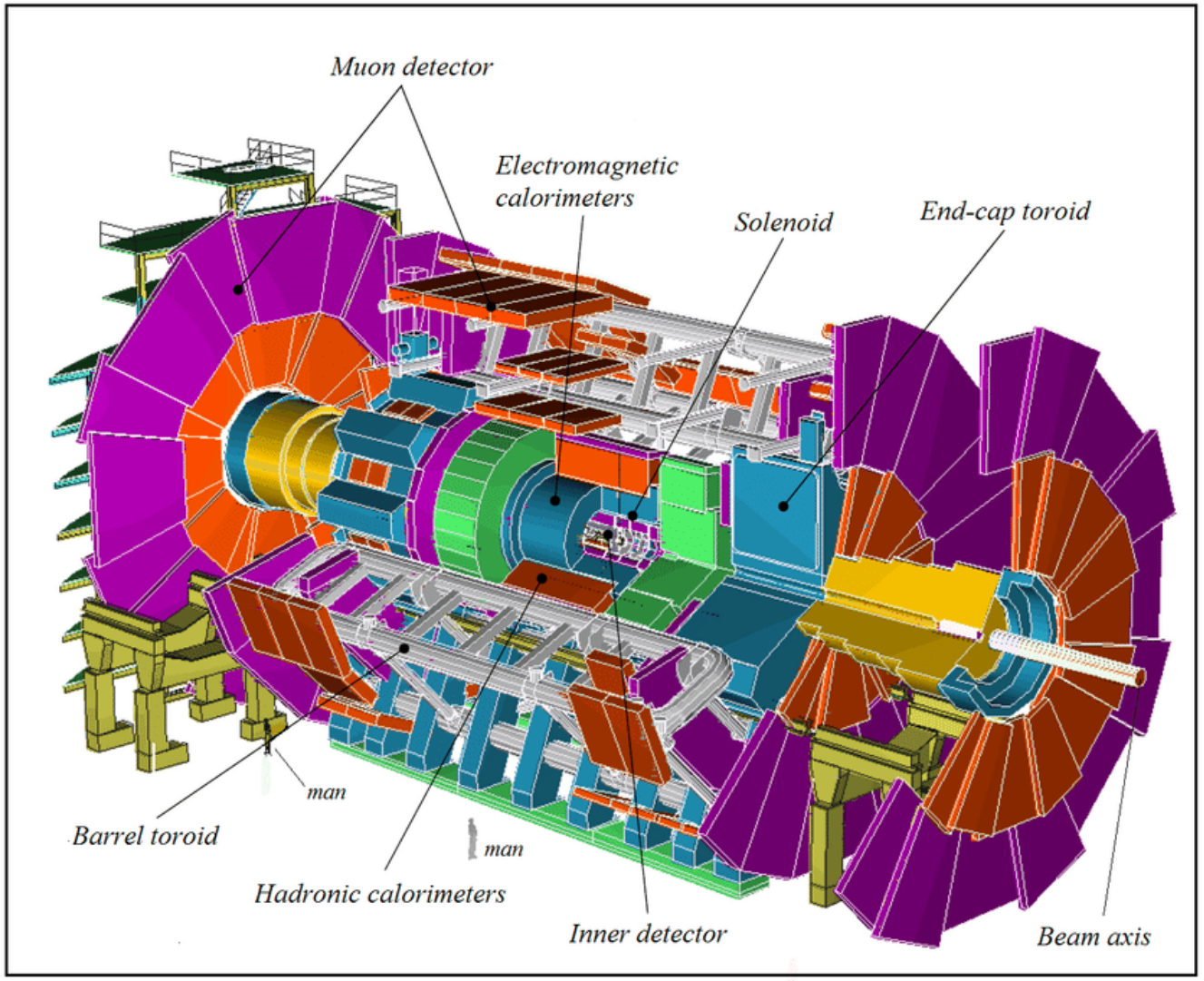
https://www.dreamstime.com/machine-learning-icon-outline-style-thin-line-creative-logo-graphic-design-more-image163107940

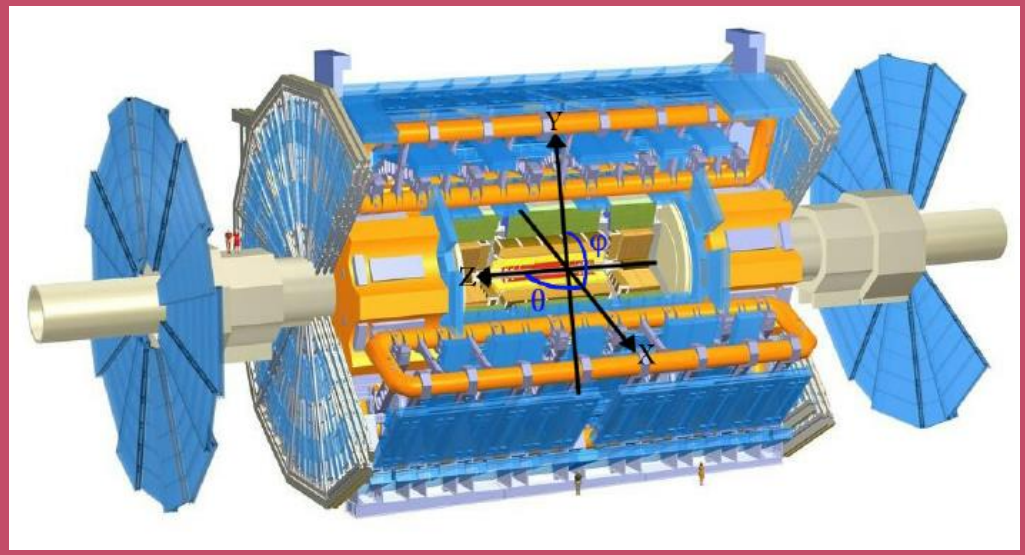
STANDARD MODEL AND ISSUES

✓ Incredibly successful and compatible with almost all experiment results.



- Unable to explain the existence the hypothesis of dark energy and dark matter;
- Neutrino mases is predicted to be zero (false);
- Does not include gravity...





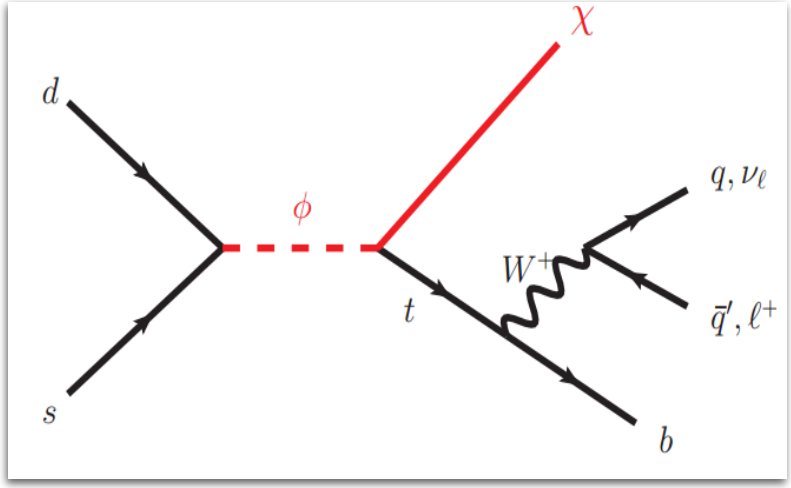
ATLAS EXPERIMENT

A Toroidal LHC apparatuS

- Detect Higgs Boson;
- Detect particles that could make up dark matter.

DATASET

- To train, validate and test the models, simulated events have been used (Geant4 Monte Carlo Simulations).



THE ATLAS COLLABORATION, Search for large missing transverse momentum in association with one top-quark in proton–proton collisions at s = $\sqrt{13}$TeV with the ATLAS detector. P.5.

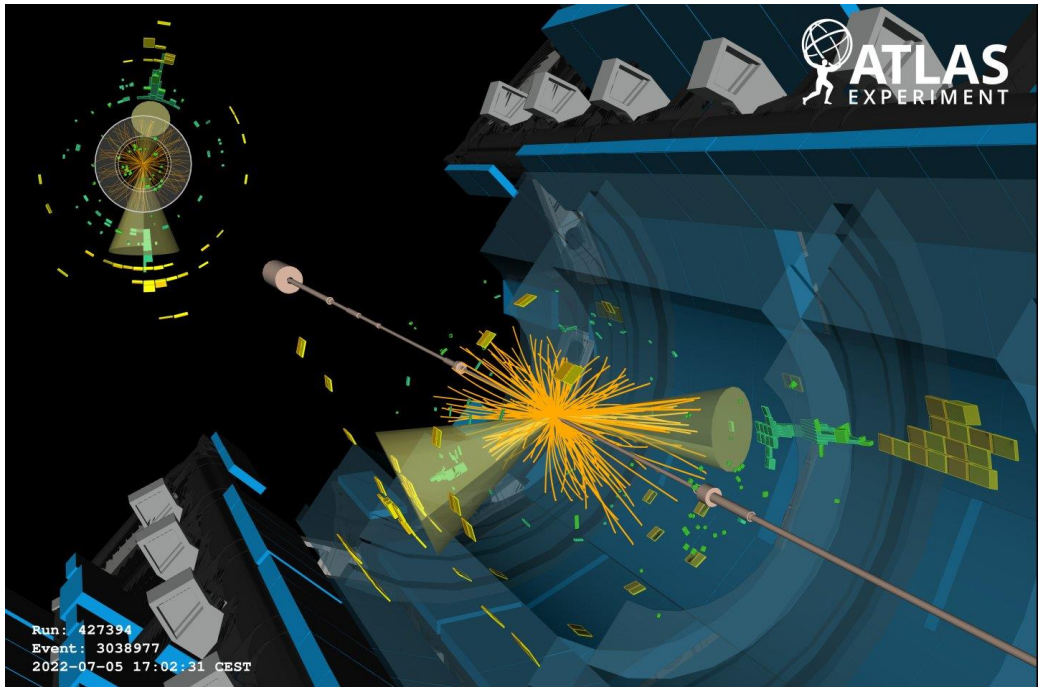


Image courtesy of ATLAS experiment at the European Organization for Nuclear Research (CERN)

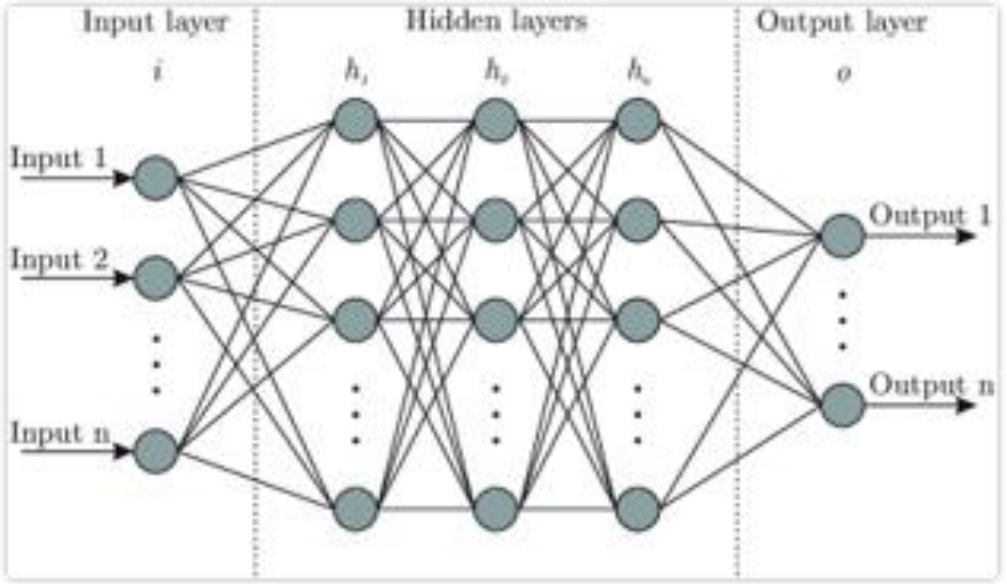
Features

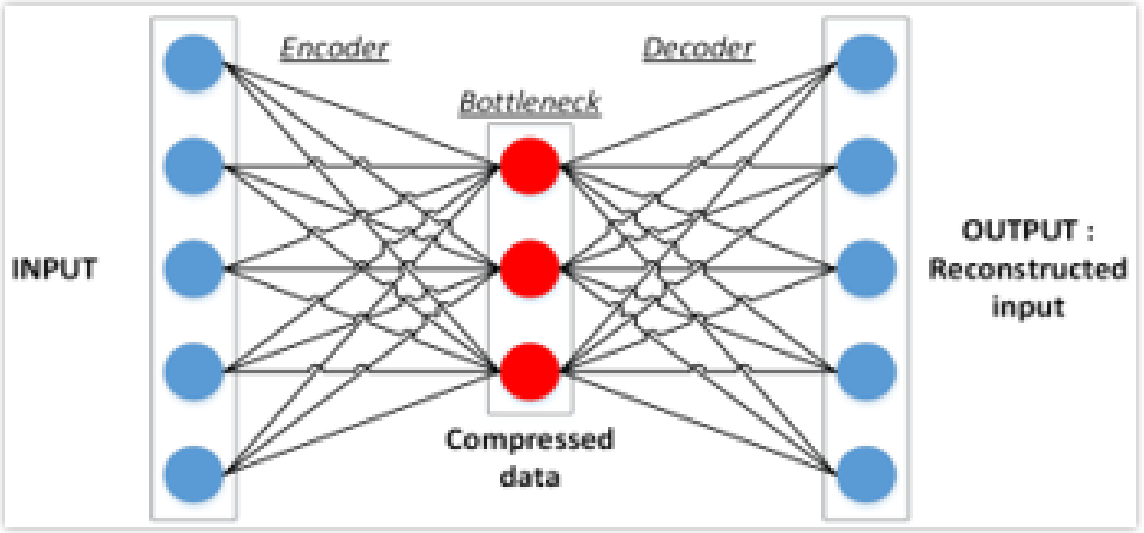
- N – multiplicity of jets
- MET – Missing Transverse Energy
- 4-momentum (p_x , p_y, p_z ,e)
- Ht – scalar sum of objects
- Delta – higher level variables

NEURAL NETWORKS

Supervised Learning

- Trainning with signal and background events;
- The aim of the Neural Network is to differentiate bkg-events and sig-events.



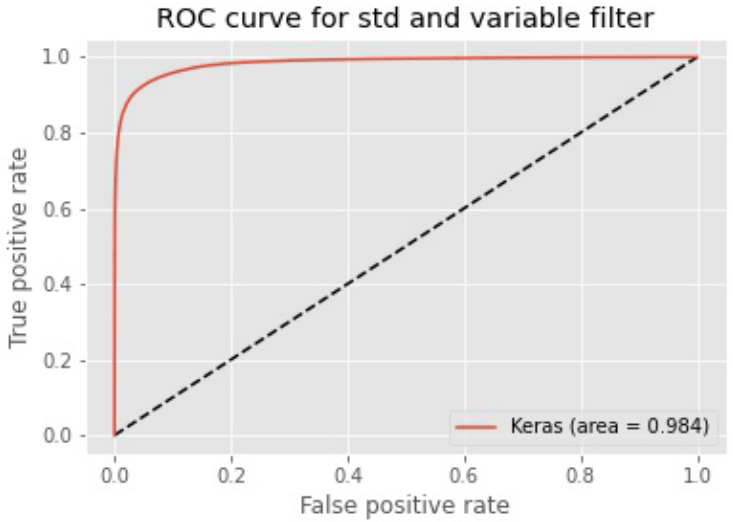


Semi-Supervised Learning

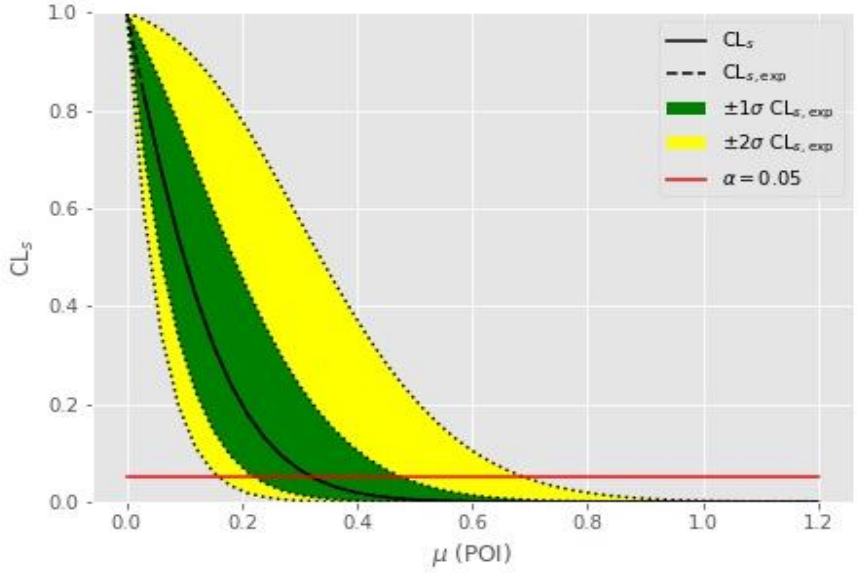
- Trainning only with background events;
- The Autoencoder (AE) is a neural network;
- Try to reconstruct events;
- A bad reconstruction could correspond to an anomaly

TOOLS FOR THE ANALISIS

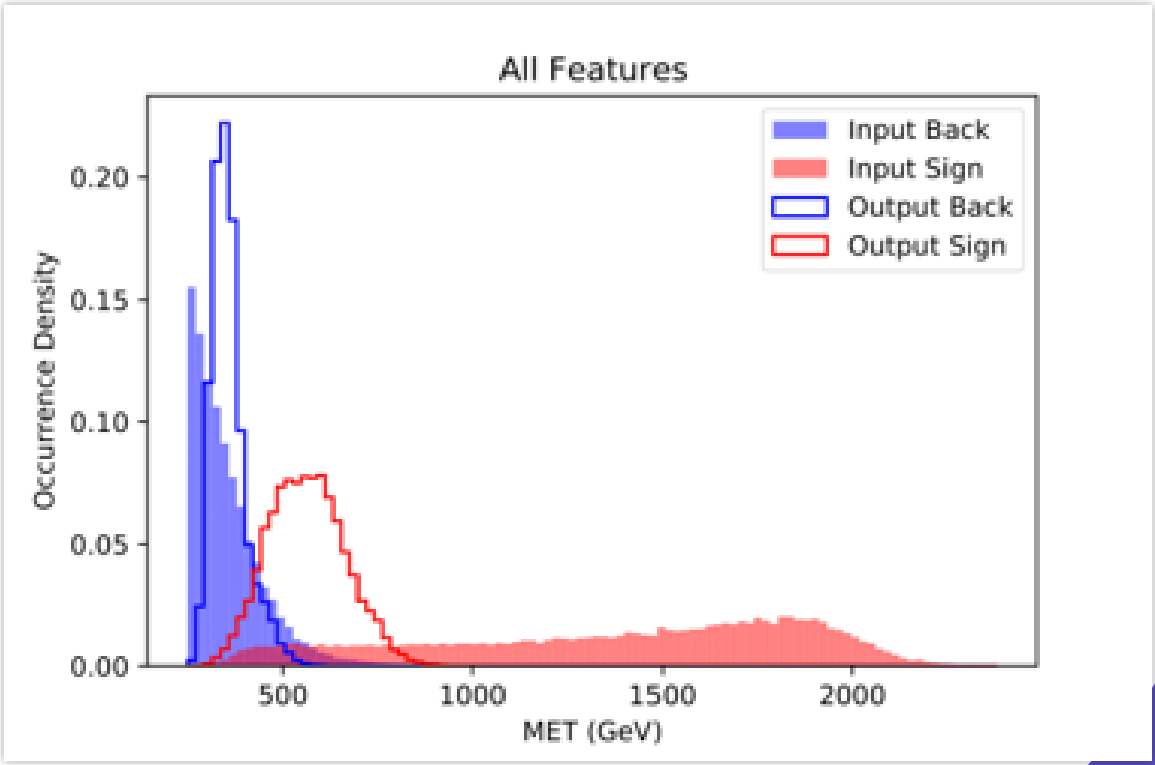
- ROC AUC (area under curve): Measure of the performance of classification of a binary classification system.



- CLs method: Is a statistical method used to define upper limits /exclusion limits on model parameters.



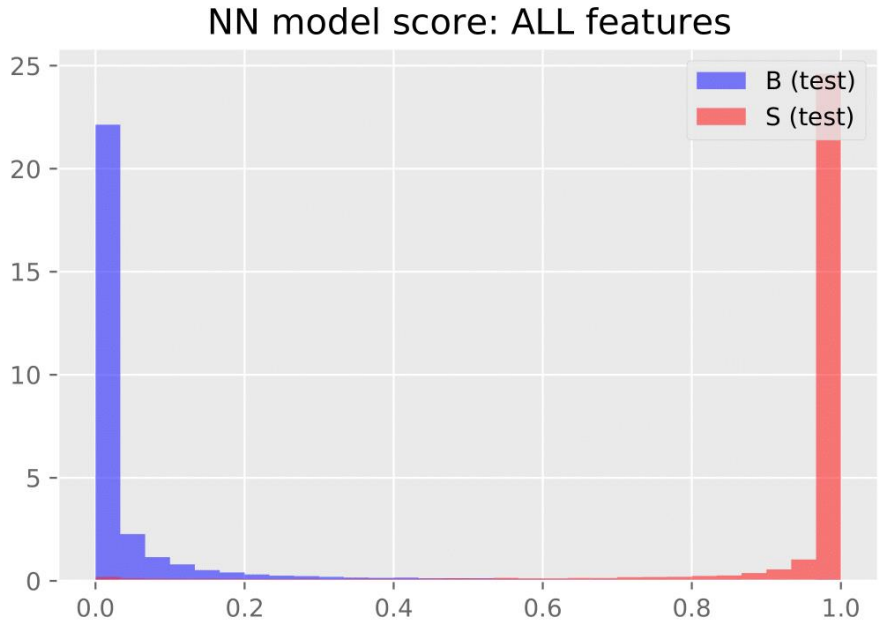
- Reconstruction Error: Used to detect anomalies, is the measure of the loss when the AE tries to reconstruct events.



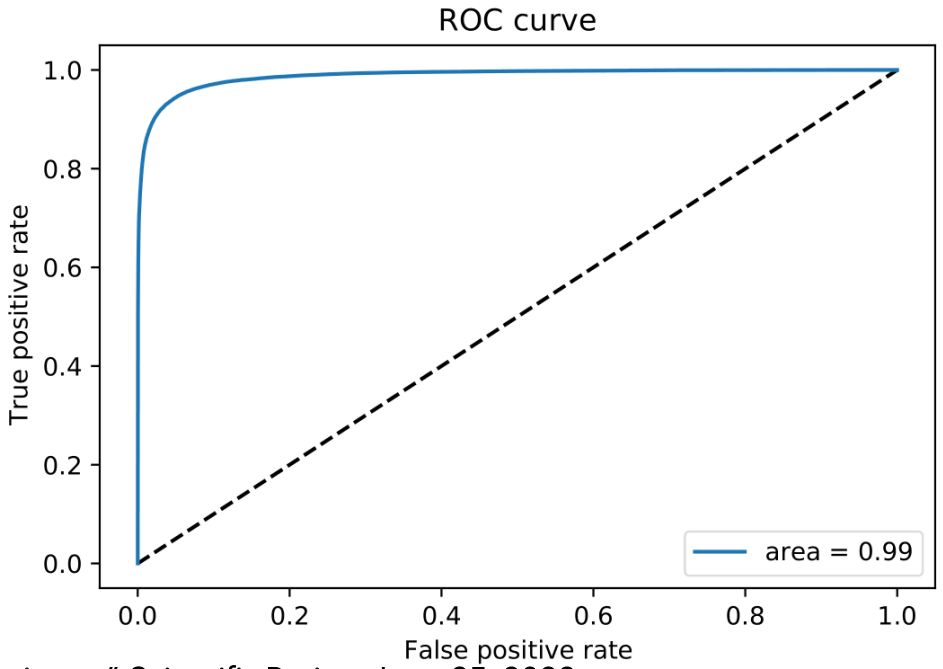
RESULTS – Deep Neural Network

DNN as a binary classification system:

➡ Event classification



➡ Performance of classification

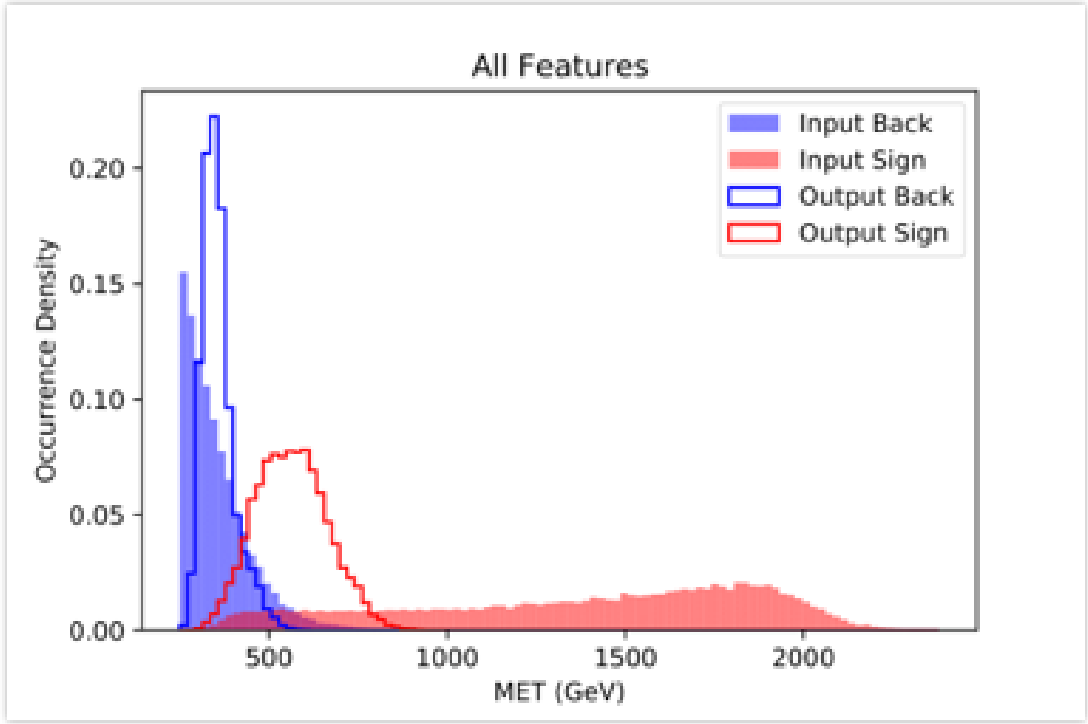


Inês Pinto . "Anomaly detection in the top quark sector with the ATLAS/LHC experiment". Scientific Project June 25, 2022.

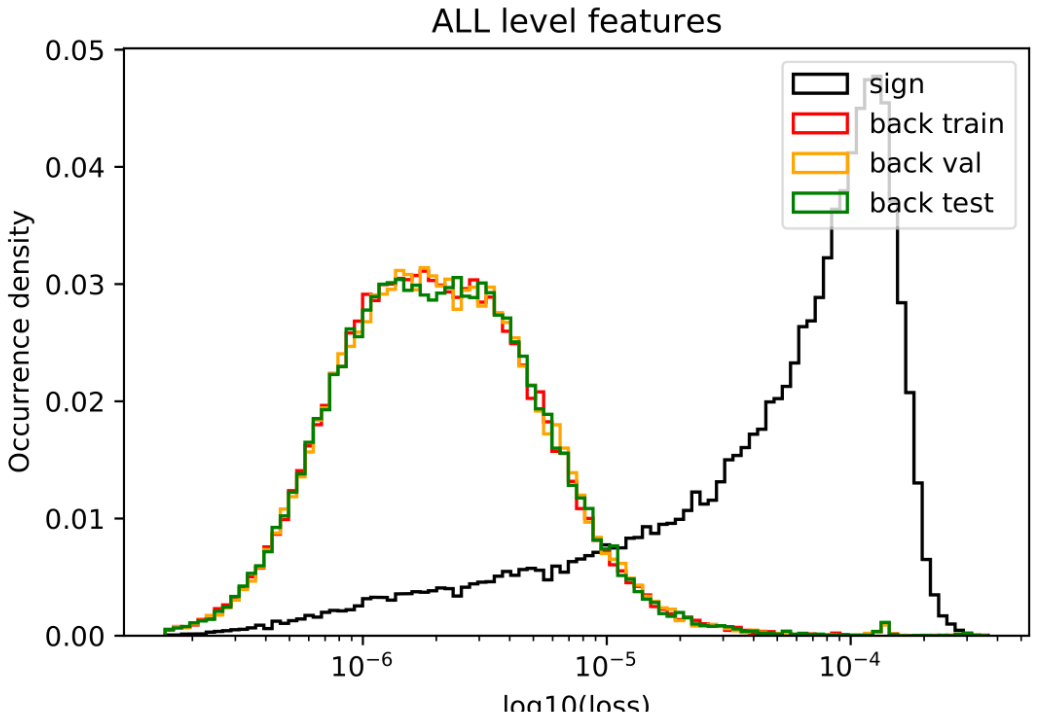
RESULTS - Autoencoder

DNN as a Autoencoder:

Events reconstruction
(Signal and Background)



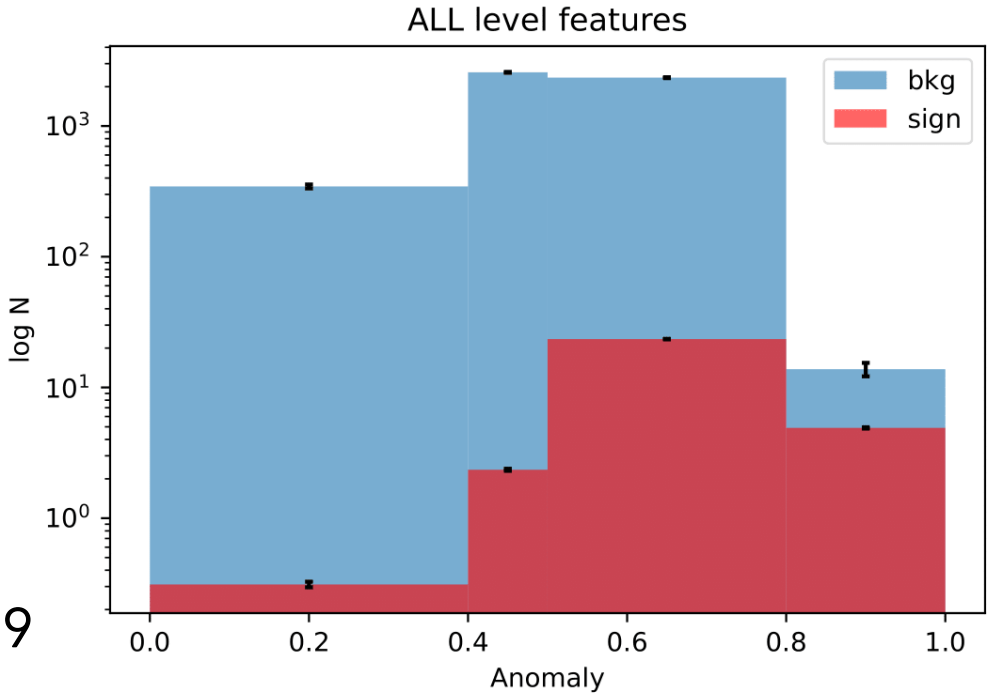
Loss Values for the
reconstructed events

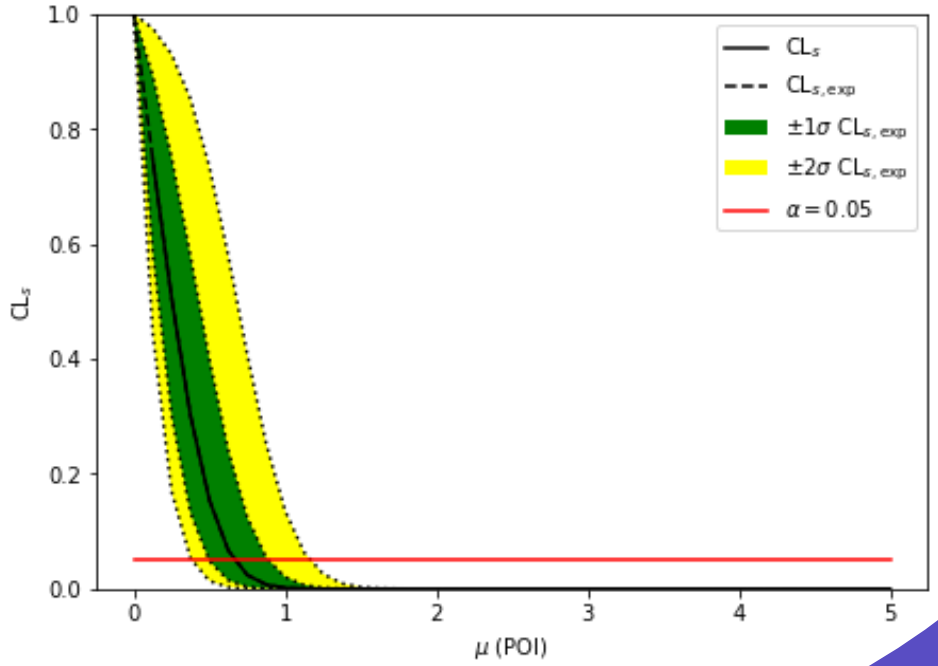


RESULTS

	AUC
NN	0.99
AE	0.96

	-1σ	μ	+1σ
NN	0.50	0.67	0.89
AE	0.55	0.78	1.15





Further Work

THANK YOU!
QUESTIONS?

https://www.newscientist.com/article/2267304-tom-gauld-has-a-heart-to-heart-with-dark-matter/