ATLAS EXPERIMENT

THE UNIVERSITY of EDINBURGH
School of Physics and Astronomy

Deep Learning & the Higgs Boson

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Deep Learning & the Higgs Boson

Classification with Fully Connected and Adversarial Networks.

- **Lecture1: The Higgs boson and event classification:**
  - Event classification with a fully connected neural network (NN) with Keras API.

- **Lecture2: Solving the background sculpting challenge:**
  - Event classification with adversarial neural network (ANN).
  - Hands-on knowledge of manipulating neural networks in Tensorflow.

- **Lecture3: Putting it all together:**
  - Compare ANN classification performance to the fully connected network.

Lecture3: Putting it all together

- **Hands-on: 40'**
  Compare fully connected and adversarial network classification performance.
- **Lecture2 survey discussion: 15'**
- **Lecture3 results discussion: 15'**
- **Wrap up: CERN open data & LHC AI challenges.**

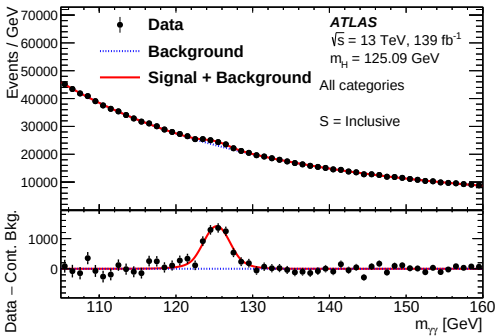
Reminder: Our Challenge

Classification: separate

- Signal with Higgs boson.
- Background with no Higgs boson.

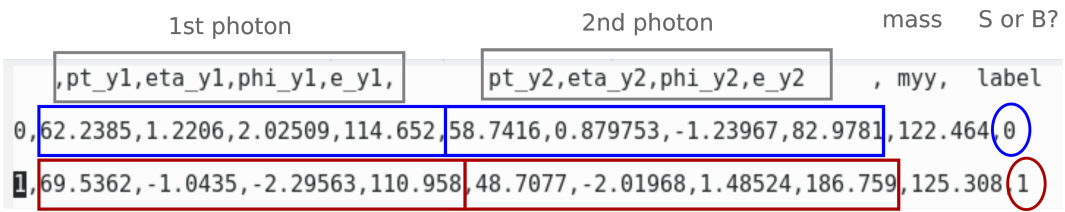
Approach:

- use synthetic data.
- Introduce no bumps in the $\mathrm{m}_{\gamma\gamma}$ distribution; these would hamper the background estimate.



Reminder: What is in the data?

- Momenta p are 4-dimensional (Lorentz) vectors.
- They are passed in cylindrical coordinates.



Lecture1: fully connected network

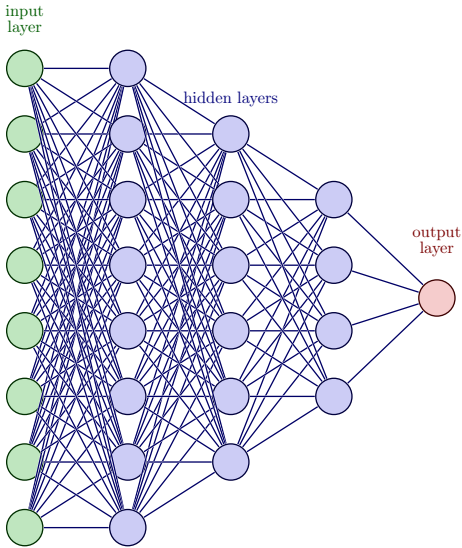
Fully connected deep neural network.

Inputs:

- Features x: photon 4-vectors.
- Labels y: signal (1) or background (0).

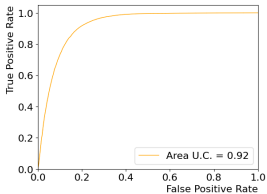
Output:

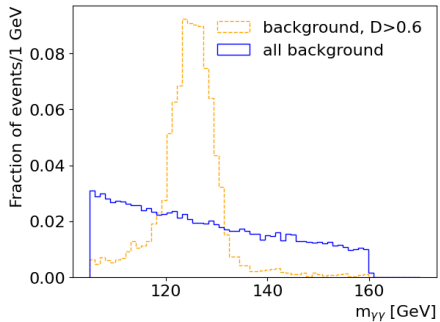
- discriminant: $z = p_{clf}(y|x, \theta_{clf})$.



Lecture1: Classification Results

Student 4



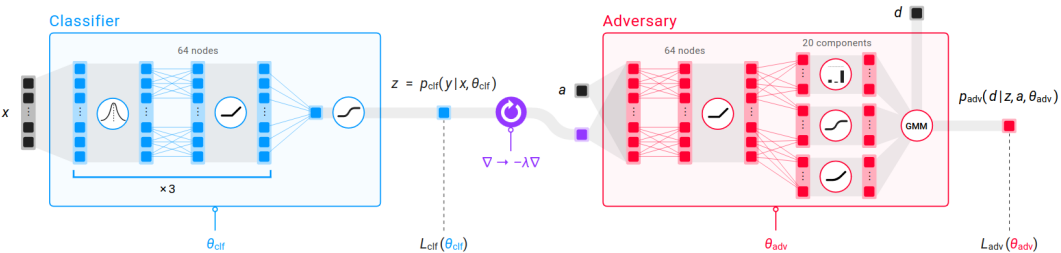


Lecture2: Adversarial Neural Network

- Both networks trained simultaneously with a loss:

$$L = L_{clf}(\theta_{clf}) - \lambda L_{adv}(\theta_{clf}, \theta_{adv})$$

- Classifier: tries to guess event label (y = signal or background).
- Adversary: tries to guess $d = \mathrm{m}_{\gamma\gamma}$.
- Trade-off controlled by parameter λ.



Hands-on work

Compare classification with fully connected and adversarial network.

- Classification performance, eg ROC curve.
- S and B myy distribution, for high discriminant scores (events likely to be S). Does ANN reduce bumps in the background $\mathrm{m}_{\gamma\gamma}$ spectrum?

Further suggestions:

- Any discriminant scores, for which ANN background $\mathrm{m}_{\gamma\gamma}$ is bumpy?
- Train/validation loss curves as expected?

Where is the data:

- (1) Yesterday: you ran code/final/ann_classification.ipynb over 200k events
- (2) 2M event runs: https://cern.ch/dl23solutions

The code/final/ann_helpers/ may be useful for the task.

- **Share results:** https://cern.ch/lec3results
- Reminder: github: https://cern.ch/dl23code

Survey Discussion

Wrap Up

Where is our data from: CERN

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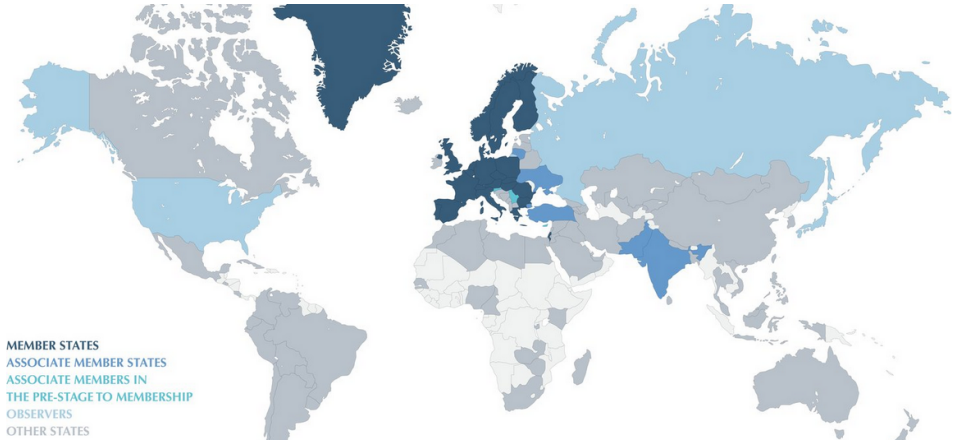
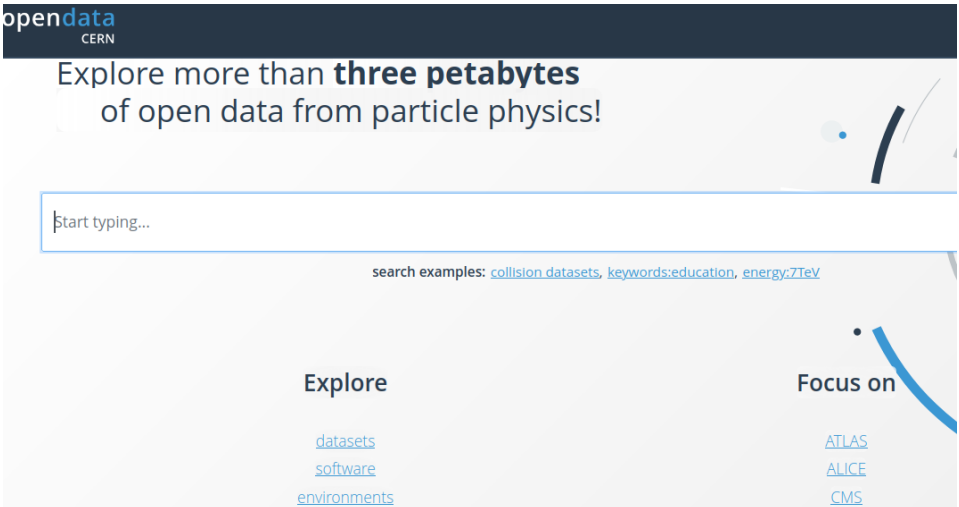


Large Hadron Collider at CERN

CERN OpenData



ATLAS $H \to \gamma\gamma$ dataset

DOI:10.7483/OPENDATA.ATLAS.B5BJ.3SGS

ML datasets

- LHC research involves complex detectors and 100-s of PB of data.
- ML is ubiquitous; data collection, analysis and simulation pipelines.
- Several CERN Open Data datasets target machine learning.
- Examples from the ATLAS collaboration:
  - Jet reconstruction training
  - Top Tagging
  - Generative Adversarial Network for detector simulation
  - Higgs Boson Machine Learning Challenge

Summary

In this tutorial you:

- (1) Wrote a fully connected network to classify Higgs boson events.
- (2) Assessed that this classification results in an undesired bias ($\mathrm{m}_{\gamma\gamma}$ distribution).
- (3) Learned about the **adversarial neural network technique**, and used it to remove this bias.

Hope what you've learned will be useful for your work.

Thank you and well done!