



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.**



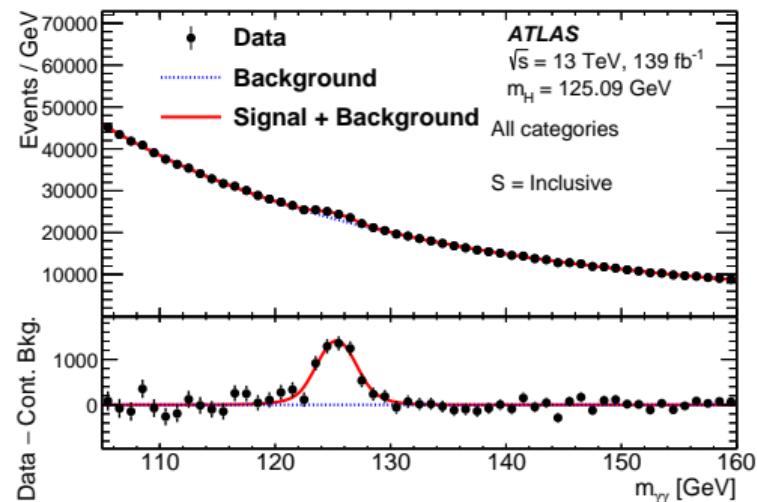
Reminder: Our Challenge

Classification: separate

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

Approach:

- use synthetic data.
- Introduce no bumps in the $m_{\gamma\gamma}$ 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.

1st photon	2nd photon	mass	S or B?
,pt_y1,eta_y1,phi_y1,e_y1,	pt_y2,eta_y2,phi_y2,e_y2	, myy,	label
0,62.2385,1.2206,2.02509,114.652,	58.7416,0.879753,-1.23967,82.9781,	122.464,	0

1,69.5362,-1.0435,-2.29563,110.958,	48.7077,-2.01968,1.48524,186.759,	125.308,	1
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Lecture1: fully connected network

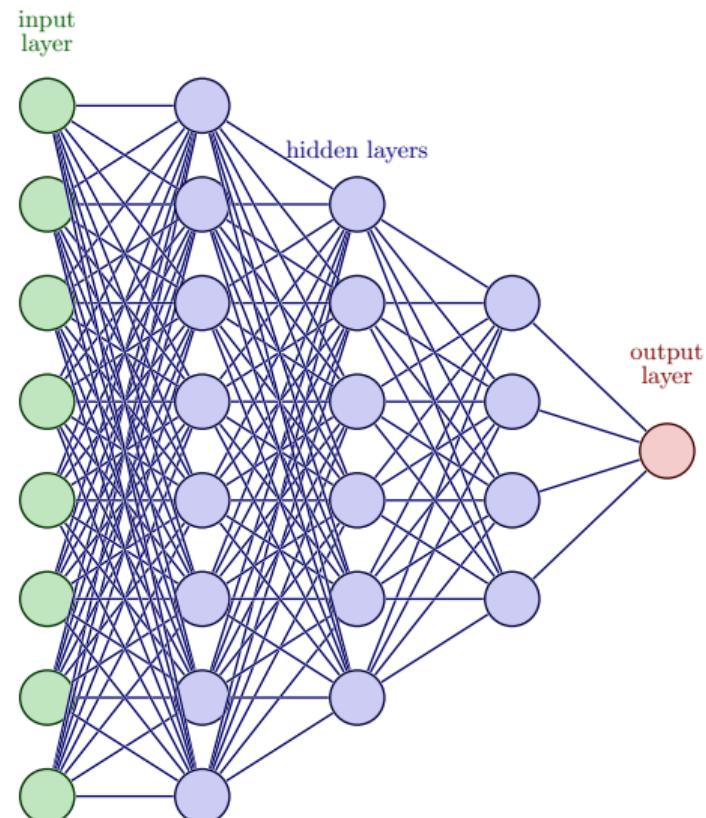
Fully connected deep neural network.

Inputs:

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

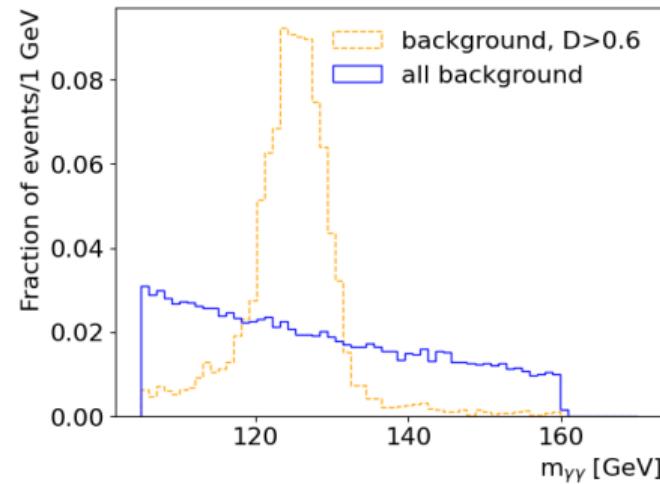
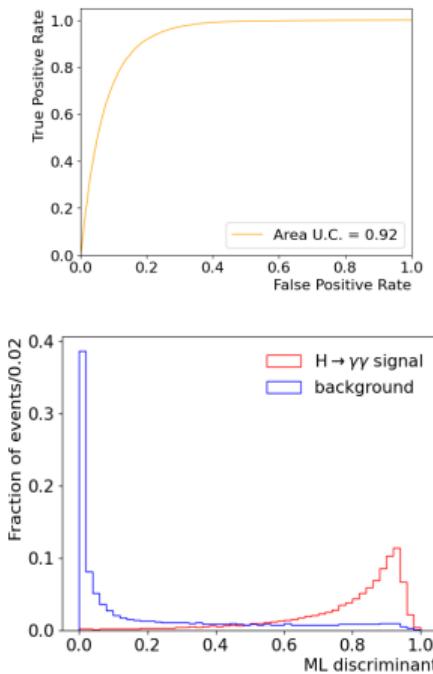
Output:

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



Lecture1: Classification Results

Student 4

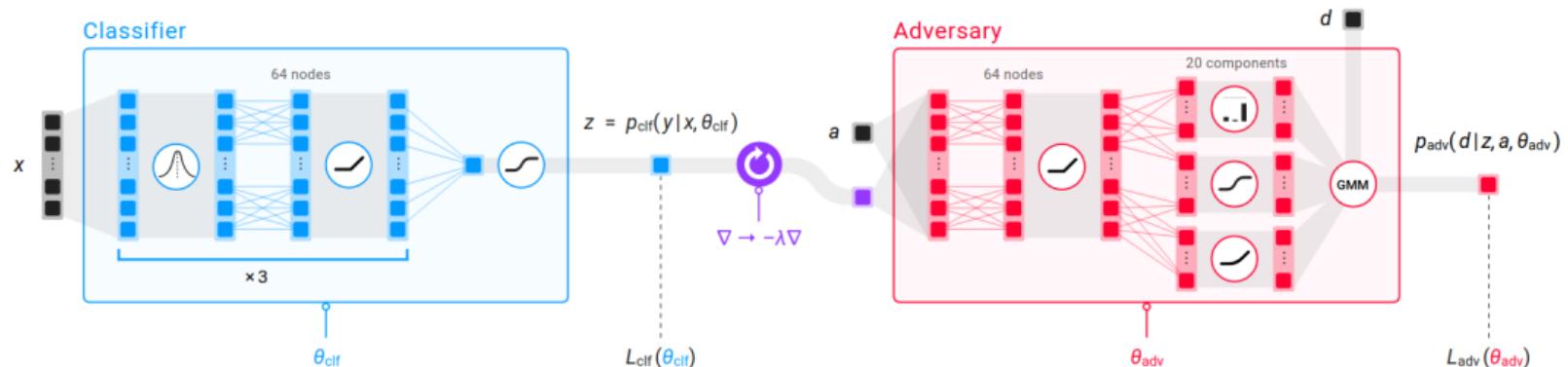


Lecture2: Adversarial Neural Network

- 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 $d = m_{\gamma\gamma}$.
- 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 $m_{\gamma\gamma}$ spectrum?

Further suggestions:

- Any discriminant scores, for which ANN background $m_{\gamma\gamma}$ 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

CERN: founded in September 1954: 12 European States

“Science for Peace”

Today: 23 Member States

~ 2500 staff

~ 1800 other paid personnel

~ 13000 scientific users

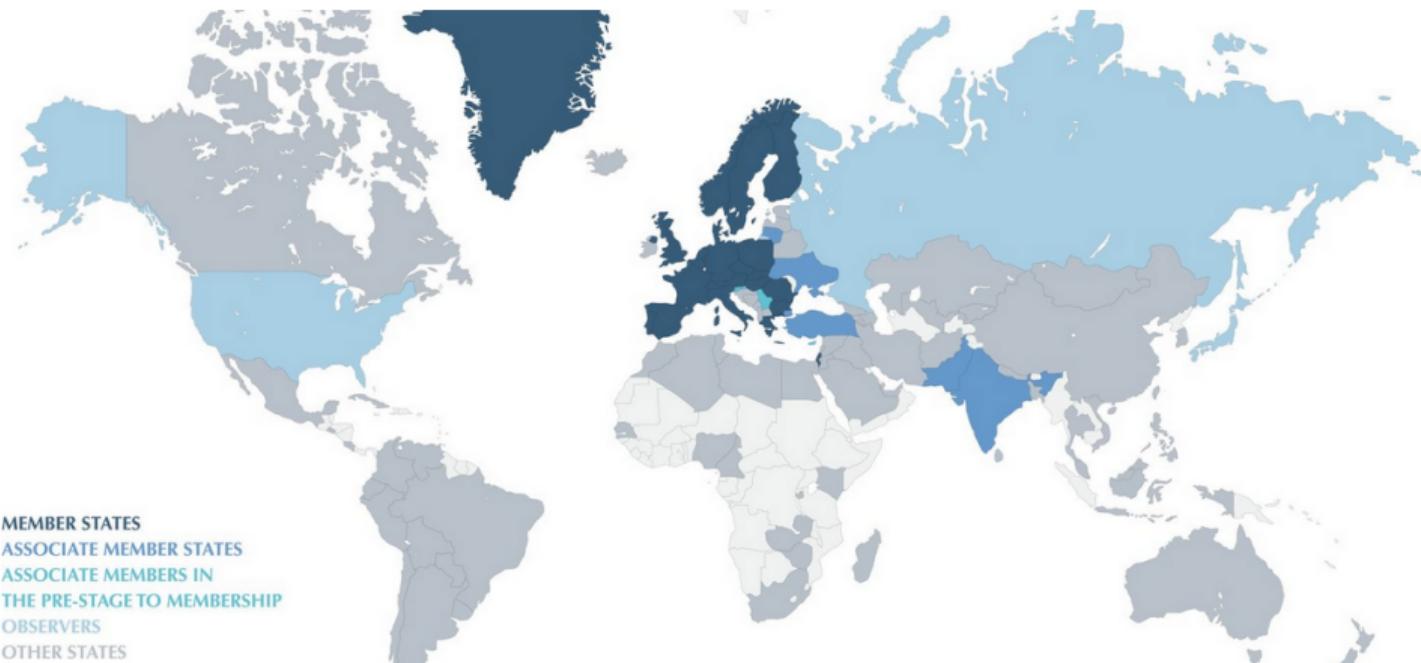


Member States: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Israel, Italy, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovak Republic, Spain, Sweden, Switzerland and United Kingdom

Associate Members in the Pre-Stage to Membership: Cyprus, Slovenia

Associate Member States: India, Lithuania, Pakistan, Turkey, Ukraine

Where is our data from: CERN



MEMBER STATES
ASSOCIATE MEMBER STATES
ASSOCIATE MEMBERS IN
THE PRE-STAGE TO MEMBERSHIP
OBSERVERS
OTHER STATES

Large Hadron Collider at CERN



CERN OpenData

opendata
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Explore more than **three petabytes**
of open data from particle physics!

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search examples: [collision datasets](#), [keywords:education](#), [energy:7TeV](#)

Explore

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Focus on

[ATLAS](#)

[ALICE](#)

[CMS](#)

ATLAS $H \rightarrow \gamma\gamma$ dataset

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

The screenshot shows a dark-themed web interface for the CERN Open Data Portal. At the top left is the "opendata CERN" logo. To its right is a search bar with the placeholder "Search" and a magnifying glass icon. On the far right are "Help" and other navigation links. Below the header, the main title is "ATLAS 13 TeV samples collection Gamma-Gamma, for 2020 Open Data release" by "ATLAS Collaboration". A citation section follows: "Cite as: ATLAS Collaboration (2020). ATLAS 13 TeV samples collection Gamma-Gamma, for 2020 Open Data release. CERN Open Data Portal. DOI:10.7483/OPENDATA.ATLAS.B5BJ.3SGS". Below this are category buttons: "Dataset" (highlighted in blue), "Derived", "ATLAS", "13TeV", and "CERN-LHC". A horizontal line separates this from the "Description" section. The "Description" section contains the following text: "The ATLAS Collaboration has released 10/fb of collision data at a centre-of-mass energy of 13 TeV from the 2016 data-taking period, intended solely for educational purposes, to the general public. This set of real data is accompanied by matching simulated samples of Standard Model processes and a selection of Beyond the Standard Model signals."

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 ($m_{\gamma\gamma}$ 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!

