ATLAS EXPERIMENT

THE UNIVERSITY of EDINBURGH
School of Physics and Astronomy

Deep Learning & the Higgs Boson

Dr. Liza Mijović

Deep Learning & the Higgs Boson

Classification with Fully Connected and Adversarial Networks.

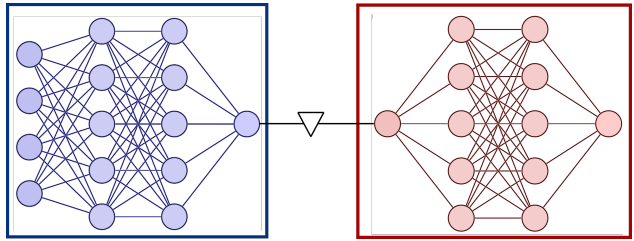
- **Lecture1: The Higgs boson and event classification:**
  - Event classification with a fully connected neural network (NN) with Keras API.

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

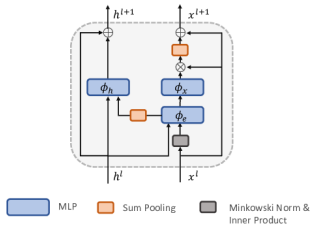
- **Lecture3: Putting it all together:**
  - Compare ANN classification performance to the fully connected network.

Why is this useful?

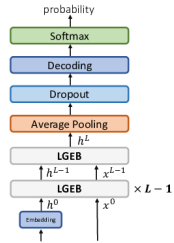
- Classification with Adversarial neural network: generic solution for removing bias.
- Good tool for your toolbox.



- Research at LHC: unique, big AI challenges.
- Bench-marking & collaboration.
- Image: LorentzNet, Microsoft.



Lorentz Group Equivariant Block (LGEB)



LorentzNet

Lecture Schedule

10:30-12:00	**Goldberger** - *Room M*	**Gleyzer** - *Room M*
	Mijovic - *Room A*	**Liang** - *Room A*
		Raj - *Room B*
	Lunch - Rooms HG	*Lunch - Rooms HG*
13:00-14:30	**Gallinari** - *Room M*	**Goldberger** - *Room M*
	Schultz - *Room A*	**Mijovic** - *Room A*
	Wei - *Room B*	
	Short break	*Short break*
14:45-16:15	**Gleyzer** - *Room M*	**Gallinari** - *Room M*
	Liang - *Room A*	**Schultz** - *Room A*
	Raj - *Room B*	**Wei** - *Room B*
	Coffee break - Rooms HG	*Coffee break - Rooms HG*
16:45-18:15	**Goldberger** - *Room M*	**Lampert** - *Room M*
	Mijovic - *Room A*	**Mahoney** - *Room A*

Room A:

- **Lecture1: Mon Morning**
- **Lecture2: Mon Evening**
- **Lecture3: Tue Afternoon**

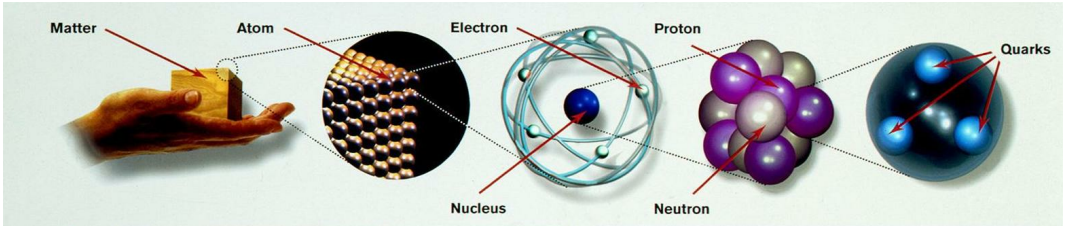
Please bring your laptop.

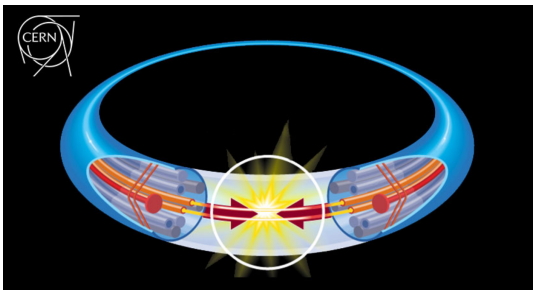
Lecture1:

Higgs boson & event classification:

event classification with a fully connected neural network (NN) with Keras API.

Fundamental Particles and Collisions

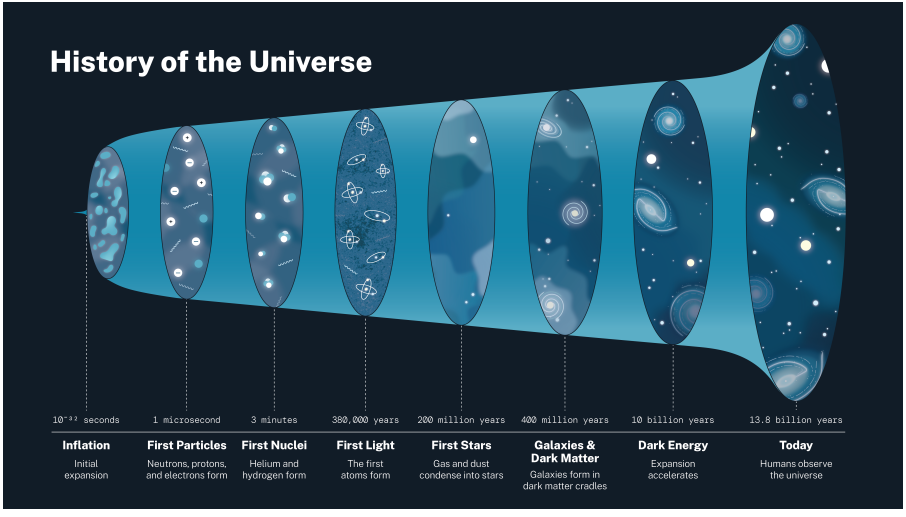




Large Hadron Collider (LHC):

- **Collide protons.**
- **New particles:** $\mathbf{E \sim mc^2}$**.**
- **Detector: snap-shot of collision.**

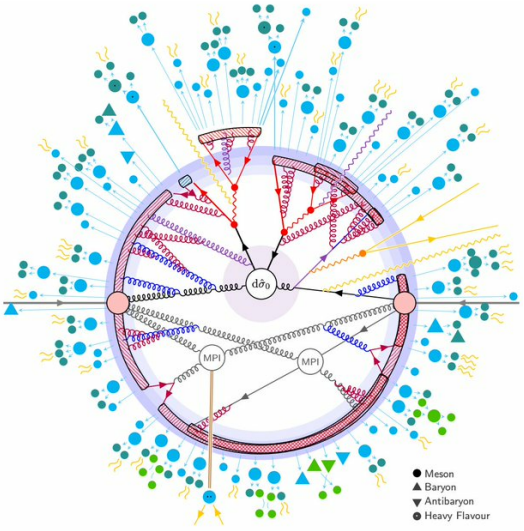
Why study particle collisions?



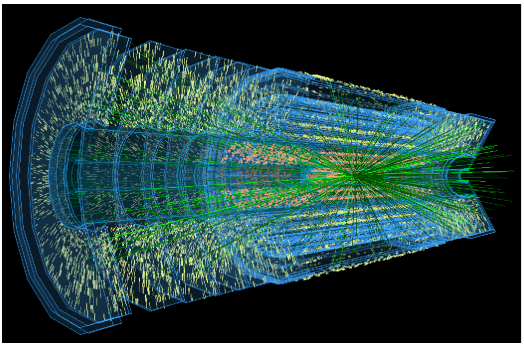
Cannot account for*: dark matter, cosmic inflation, matter/anti-matter asymmetry.

Image credit: NASA. *Additional observation we cannot account for are neutrino masses.

Challenge: Collisions are Complex

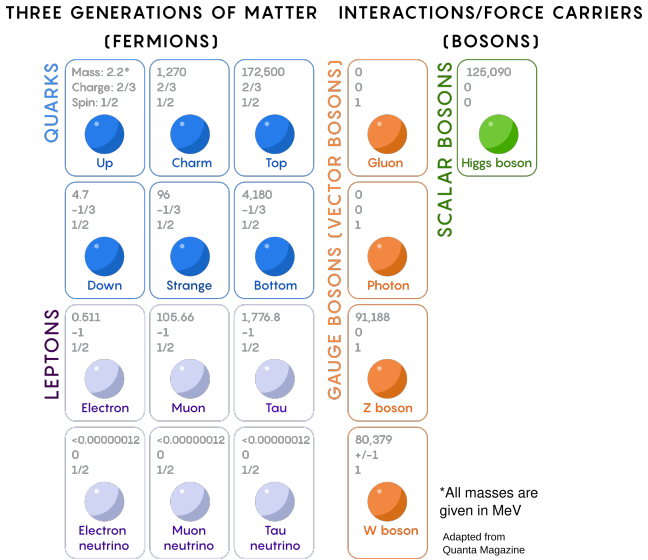


- $\sim$ 1000 particles / collision.
- Figure: inner-tracker.
- 5B channels.

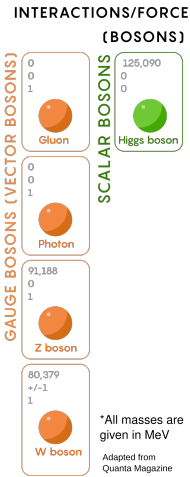


LHC Detectors

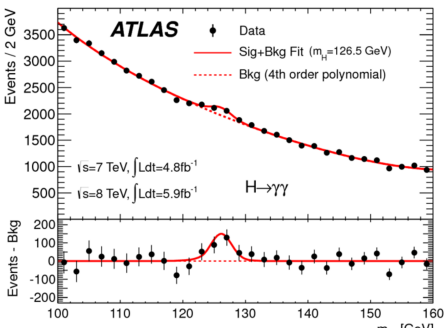
The Standard Model



The Higgs boson



- 1964: R. Brout, F. Englert, P. Higgs: W, Z masses.
- 2012: Higgs boson observation, ATLAS & CMS



- 2013: Nobel prize to F. Englert & P. Higgs

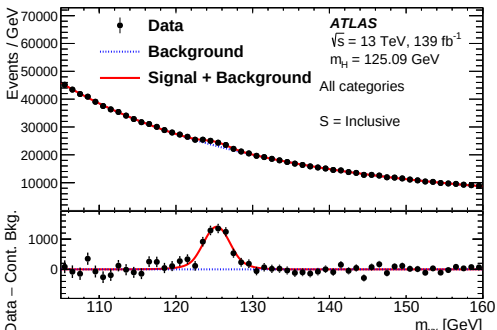
Our Challenge

Classification: separate

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

Approach:

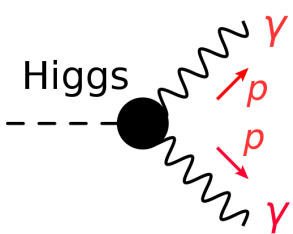
- use synthetic data.
- Introduce no bumps in the $\mathrm{m}_{\gamma\gamma}$ distribution; these would hamper the background estimate.
  $\Rightarrow$ evening lecture.



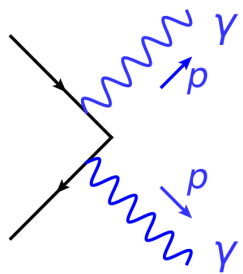
What is in the data?

Two photons (γ) per event, with momenta p.

Signal, label=1



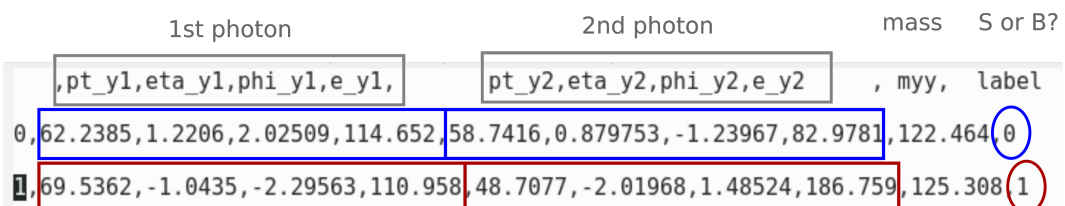
Background, label=0



What is in the data?

Momenta p have two catches:

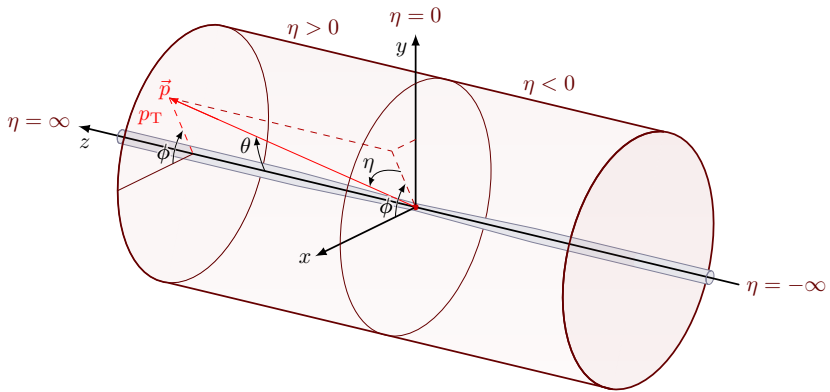
- (1) They are 4-dimensional (Lorentz) vectors.



What is in the data?

Momenta p have two catches:

- (2) They are passed in cylindrical coordinates.



Hands-on work

Let's get set up!

- Download the data: https://cern.ch/dl23data
- Set up the environment: https://cern.ch/dl23code

Let's do some classification!

Using data_200k.csv try to classify signal vs background.

- Use Keras & fully connected deep neural network.
- Use photon momenta as (8) input features.
- Do not use myy as input feature.

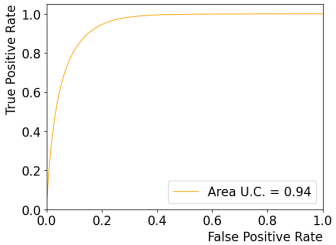
Let's share resuts:

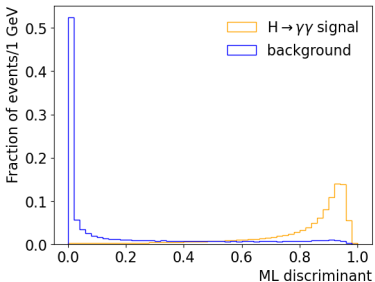
- https://cern.ch/dl23lect1
- Classification performance, eg ROC curve, accuracy etc.
- S and B myy distribution, for high discriminant scores (events likely to be S).

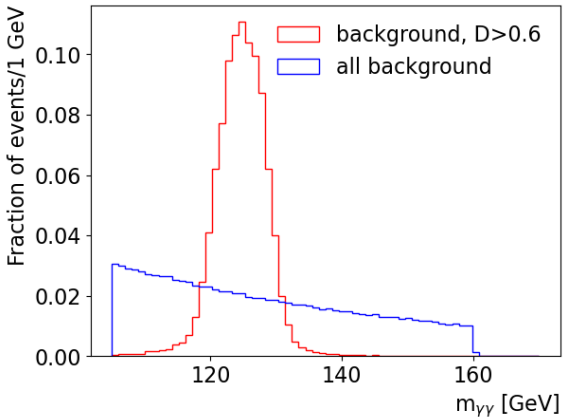
Any feedback? https://cern.ch/l1feed

Extra

Example


True Positive Rate
False Positive Rate
Area U.C. = 0.94


Fraction of events/1 GeV
ML discriminant
H→γγ signal
background


Fraction of events/1 GeV
background, D>0.6
all background
mγγ [GeV]