



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.



Lecture Schedule

10:30-12:00	Goldberger - Room M	Gleyzer - Room M
	Mijovic - Room A	Liang - Room A
		Raj - Room B
	<i>Lunch - Rooms HG</i>	<i>Lunch - Rooms HG</i>
13:00-14:30	Gallinari - Room M	Goldberger - Room M
	Schultz - Room A	Mijovic - Room A
	Wei - Room B	
	<i>Short break</i>	<i>Short break</i>
14:45-16:15	Gleyzer - Room M	Gallinari - Room M
	Liang - Room A	Schultz - Room A
	Raj - Room B	Wei - Room B
	<i>Coffee break - Rooms HG</i>	<i>Coffee break - Rooms HG</i>
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.

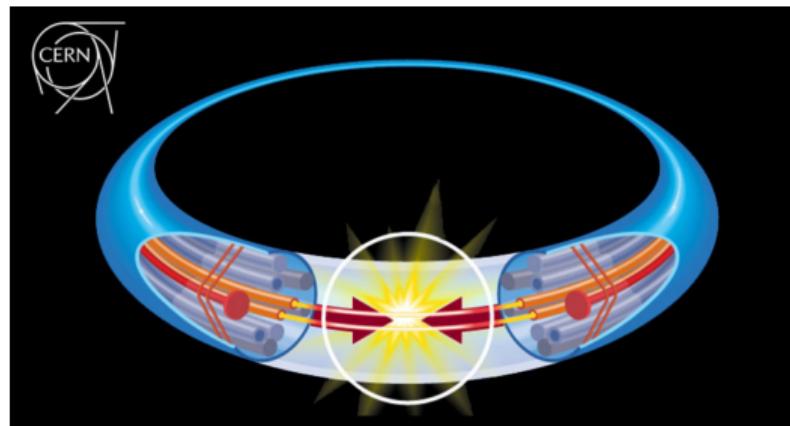
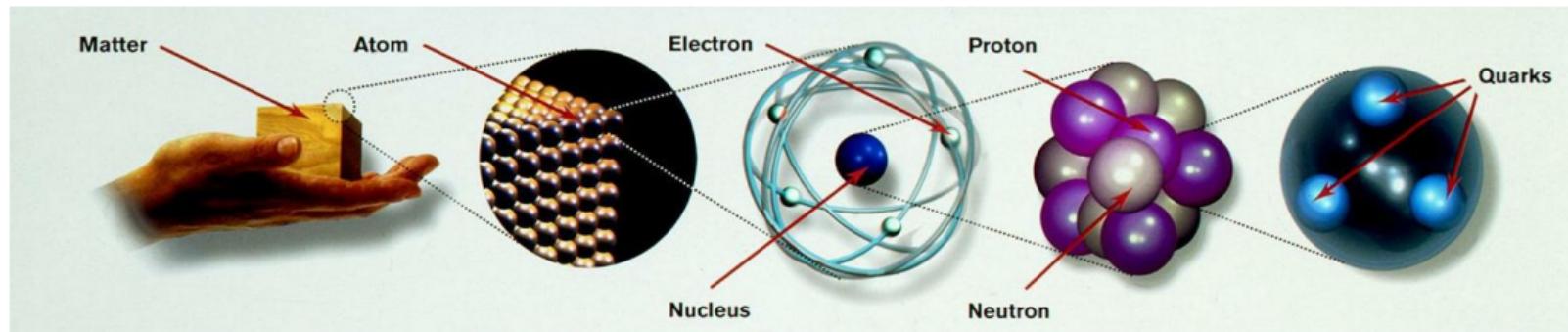
Lecture1:

Higgs boson & event classification:

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



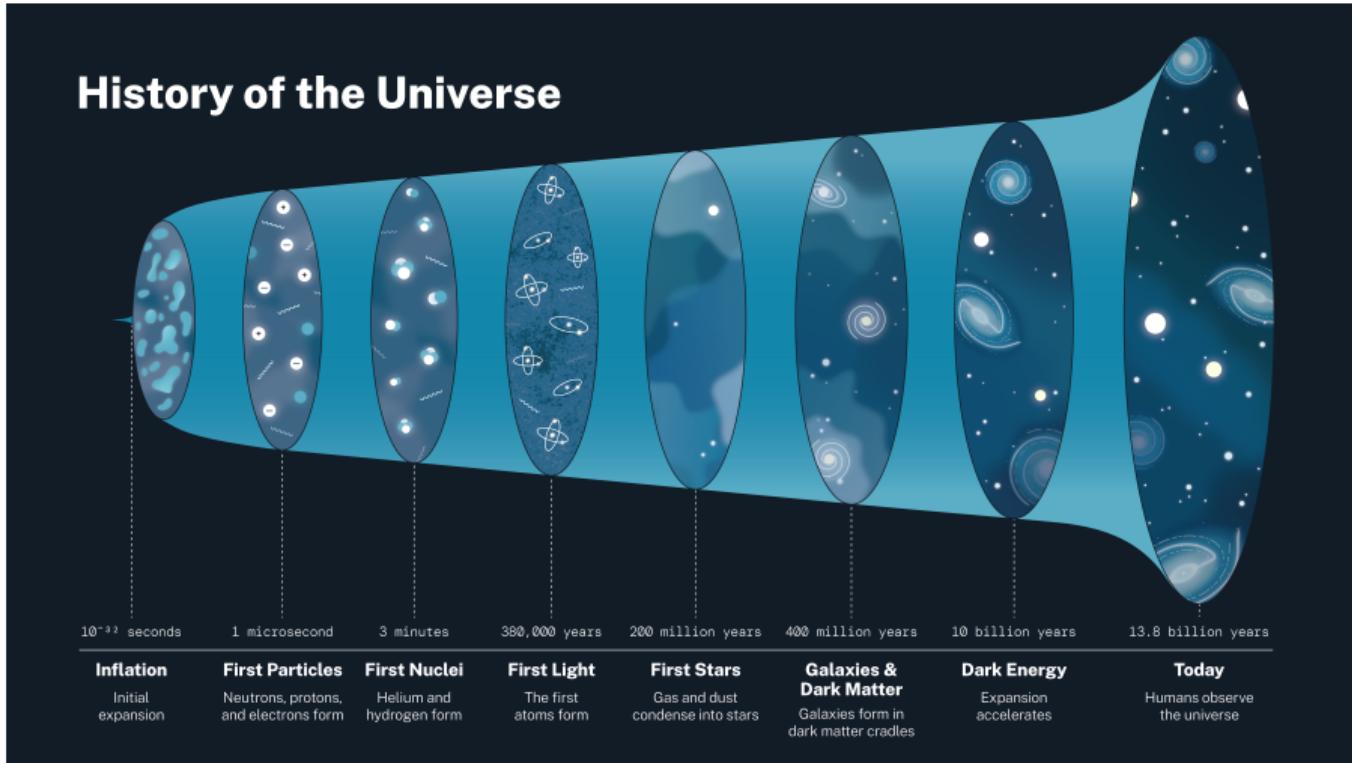
Fundamental Particles and Collisions



Large Hadron Collider (LHC):

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

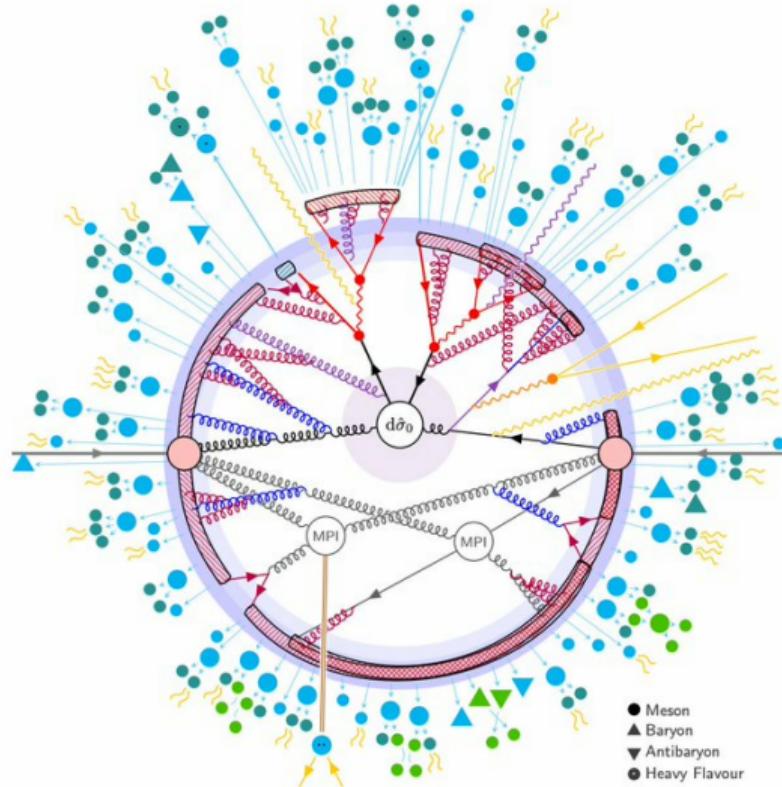
Why study particle collisions?



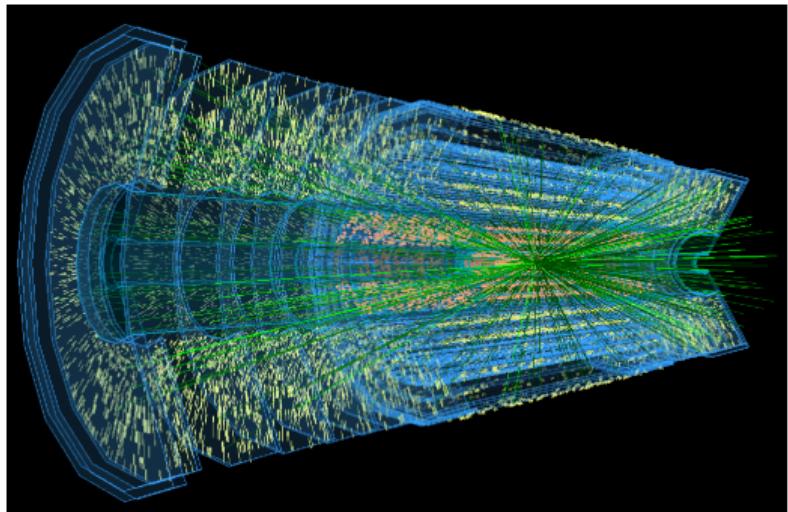
Cannot account for*: dark matter, cosmic inflation, matter/anti-matter asymmetry.

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

Challenge: Collisions are Complex



- ~ 1000 particles / collision.
- Figure: inner-tracker.
- 5B channels.



LHC Detectors



The Standard Model

THREE GENERATIONS OF MATTER INTERACTIONS/FORCE CARRIERS

(FERMIOS)			(BOSONS)		
QUARKS			SCALAR BOSONS		
Mass: 2.2* Charge: 2/3 Spin: 1/2			125,090 0 0		
Up  1,270 2/3 1/2			Gluon  0 0 1		
Down  4.7 -1/3 1/2			Higgs boson  0 0 1		
Charm  96 -1/3 1/2			Photon  0 0 1		
Top  172,500 2/3 1/2			Z boson  91,188 0 1		
Strange  4,180 -1/3 1/2			W boson  80,379 +/-1 1		
Bottom  0.511 -1 1/2			*All masses are given in MeV		
Electron  0.511 -1 1/2			Adapted from Quanta Magazine		
Muon  0.10566 -1 1/2					
Tau  0.17768 -1 1/2					
Electron neutrino  <0.00000012 0 1/2					
Muon neutrino  <0.00000012 0 1/2					
Tau neutrino  <0.00000012 0 1/2					

The Higgs boson

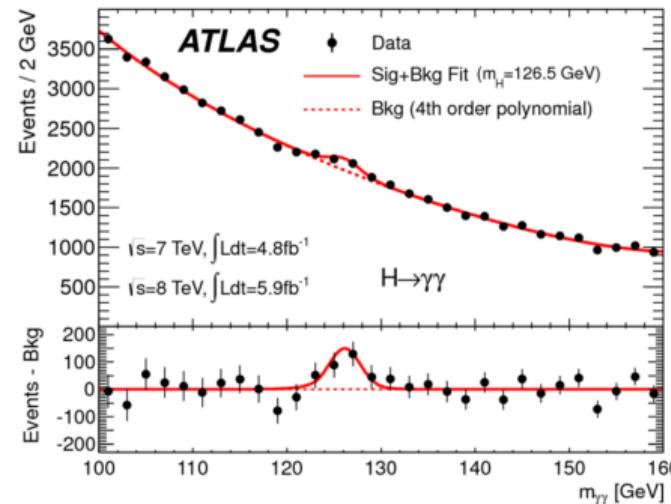
INTERACTIONS/FORCE CARRIERS (BOSONS)

SCALAR BOSONS	Events
Gluon	125,090
Higgs boson	0
GAUGE BOSONS (VECTOR BOSSONS)	
Photon	0
Z boson	91,188
W boson	80,379 +/- 1

*All masses are given in MeV

Adapted from Quanta Magazine

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



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