



International Masterclasses

ATLAS Z-Path Handbook

Introduction

Masterclass Ingredients

- Physicist
- Non-Physicist
- Real Data from an Experiment
- Tool to Visualise Data
- Method to Analyse Data
- Coffee

Goal of the ATLAS Z-Path Masterclass

- Identify collisions in ATLAS that are Z-boson candidates
- Calculate their invariant mass
- Plot them in a histogram, present, and compare

HYPATIA

<http://hypatia.iasa.gr/en/index.html> (or click on “ATLAS Z Path” in agenda)

HY.P.A.T.I.A
Hybrid Pupil's Analysis Tool for Interactions in ATLAS

Start HYPATIA 1 HYPATIA 2 HYPATIA 3 HYPATIA 4 Exercises Batch Help

Do you want to learn what happens when protons of the highest energy in the world collide with protons of the same energy?

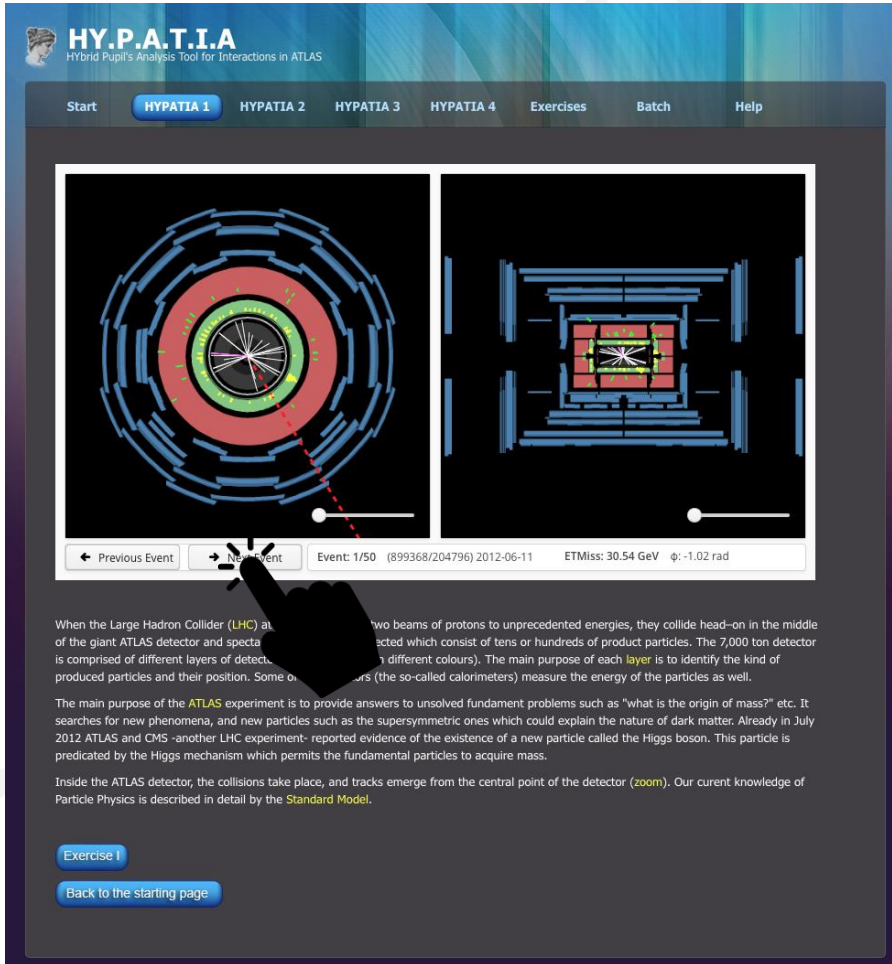
Do you want to learn how to identify tracks and distinguish electrons from muons?

Do you want to discover invisible particles? (Z^0 , 91 times heavier than the proton)?

Do you want to make histograms of the new particles and learn about their width (Heisenberg uncertainty principle)?

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Viewing Events



The screenshot shows the HYPATIA 1 web interface. At the top left is the logo and text "HY.P.A.T.I.A Hybrid Pupil's Analysis Tool for Interactions in ATLAS". Below this is a navigation bar with buttons for "Start", "HYPATIA 1", "HYPATIA 2", "HYPATIA 3", "HYPATIA 4", "Exercises", "Batch", and "Help". The main content area features two side-by-side detector views: a top-down view on the left and a side-view on the right. Below the views is a control bar with "Previous Event" and "Next Event" buttons, and a status bar showing "Event: 1/50 (899368/204796) 2012-06-11 ETMiss: 30.54 GeV ϕ : -1.02 rad". A hand cursor is pointing at the "Next Event" button. Below the interface is a text block explaining the LHC and ATLAS detector, followed by two buttons: "Exercise 1" and "Back to the starting page".

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Start HYPATIA 1 HYPATIA 2 HYPATIA 3 HYPATIA 4 Exercises Batch Help

← Previous Event → Next Event Event: 1/50 (899368/204796) 2012-06-11 ETMiss: 30.54 GeV ϕ : -1.02 rad

When the Large Hadron Collider (LHC) accelerates two beams of protons to unprecedented energies, they collide head-on in the middle of the giant ATLAS detector and spectra of particles are produced which consist of tens or hundreds of product particles. The 7,000 ton detector is comprised of different layers of detectors (coloured in different colours). The main purpose of each layer is to identify the kind of produced particles and their position. Some of the calorimeters (the so-called calorimeters) measure the energy of the particles as well.

The main purpose of the ATLAS experiment is to provide answers to unsolved fundamental problems such as "what is the origin of mass?" etc. It searches for new phenomena, and new particles such as the supersymmetric ones which could explain the nature of dark matter. Already in July 2012 ATLAS and CMS -another LHC experiment- reported evidence of the existence of a new particle called the Higgs boson. This particle is predicted by the Higgs mechanism which permits the fundamental particles to acquire mass.

Inside the ATLAS detector, the collisions take place, and tracks emerge from the central point of the detector (zoom). Our current knowledge of Particle Physics is described in detail by the [Standard Model](#).

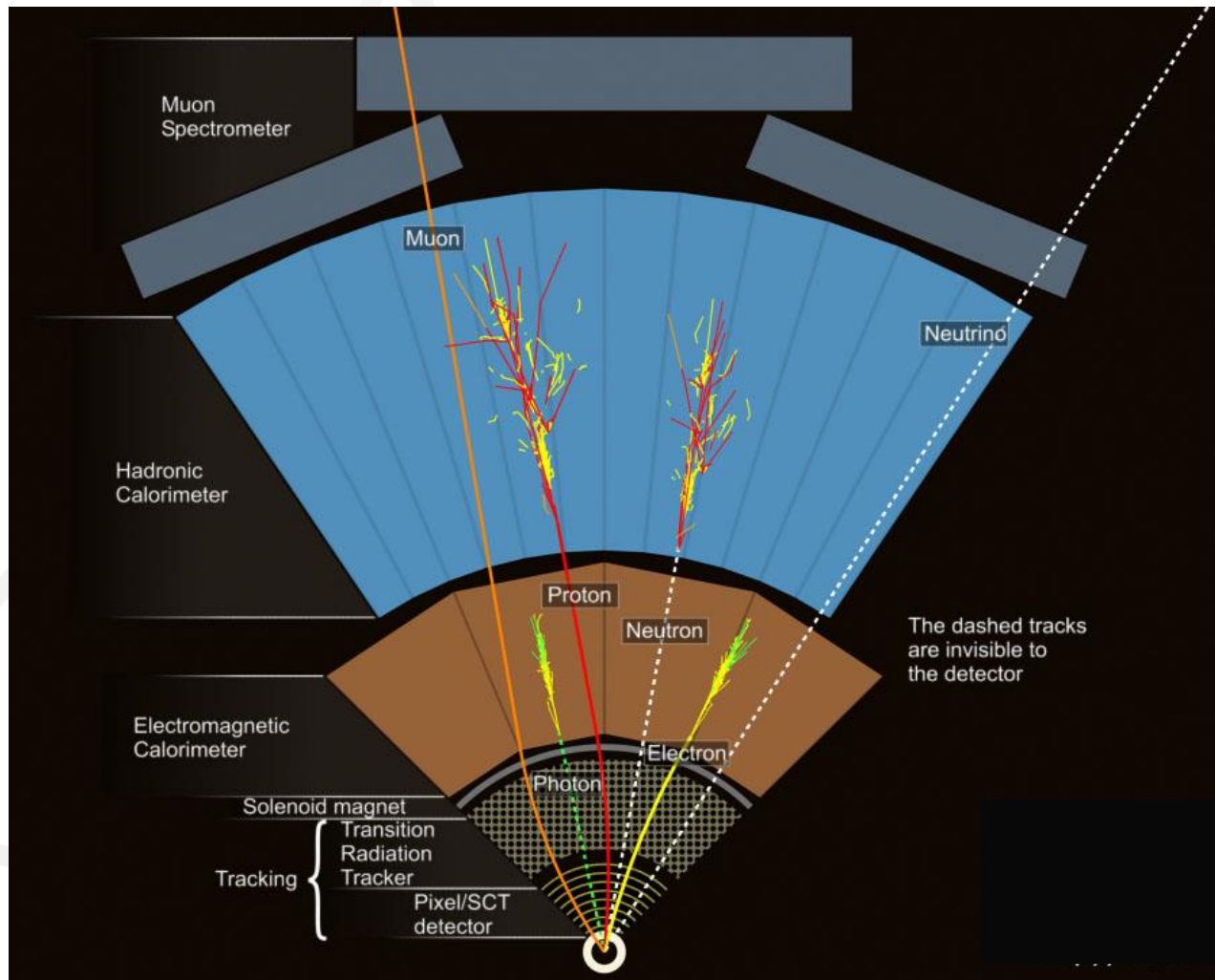
Exercise 1

Back to the starting page

HYPATIA 1

- Click through events
- Try zooming in/out
- What is missing E_T ?

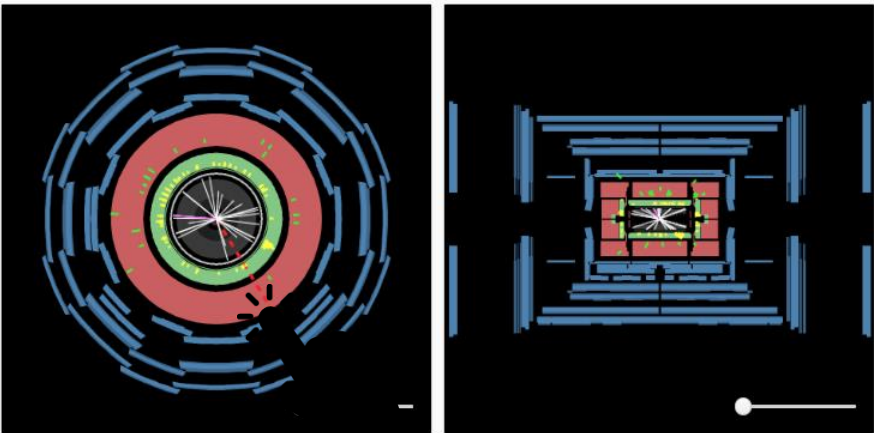
Particle ID in ATLAS



Particle Identification

HYPATIA
Hybrid Pupil's Analysis Tool for Interactions in ATLAS

Start HYPATIA 1 **HYPATIA 2** HYPATIA 3 HYPATIA 4 Exercises Batch Help



← Previous Event → Next Event Group_3A event001.xml ETMiss: 30.54 GeV ϕ : -1.02 rad

Track	+/-	p [GeV]	p_T [GeV]	ϕ [rad]	θ [rad]
Tracks_4	-	2.87	2.513	3.061	2.075
Tracks_6	+	5.542	5.486	0.124	1.428
Tracks_19	-	3.379	3.055	3.061	2.012
Tracks_21	-	5.047	3.104	1.73	2.479
Tracks_25	-	29.649	17.682	-0.471	-0.639
Tracks_27	+	54.452	35.956	-0.468	-0.721
Tracks_59	+	5.944	3.127	-2.682	-0.554
Tracks_71	-	4.142	2.591	-2.794	-2.466

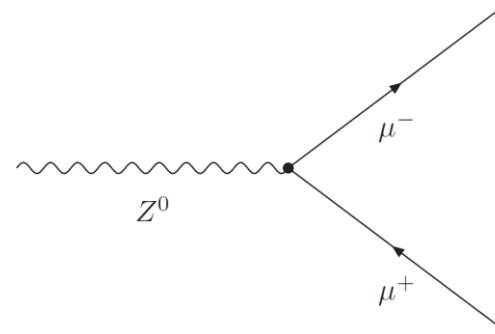
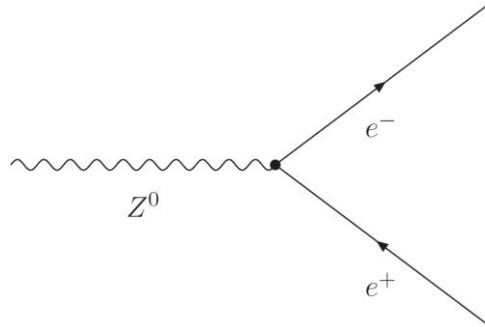
HYPATIA 2

- Click through events
- Identify particles:
 - electrons / positrons
 - muons (+/-)
 - missing E_T
- Note the variables:
 - p = momentum
 - p_T = transverse momentum
 - ϕ = azimuthal angle
 - Θ = polar angle

How to spot a Z boson

Z boson lifetime = 10^{-25} seconds

- We identify it by its decay products



Z boson mass = 91 GeV

- And by the mass reconstructed from the two leptons

$$m_X = \sqrt{2E_1 E_2 (1 - \cos\theta)}$$

Expect lepton momenta to be similar to the Z mass

Mass Reconstruction

HY.P.A.T.I.A
Hybrid Pupil's Analysis Tool for Interactions in ATLAS

Start HYPATIA 1 HYPATIA 2 **HYPATIA 3** HYPATIA 4 Exercises Batch Help

← Previous Event → Next Event + Insert Electron + Insert Muon - Delete Track

ETMiss: 30.54 GeV ϕ : -1.02 rad p_T 10 GeV event001.xml Start

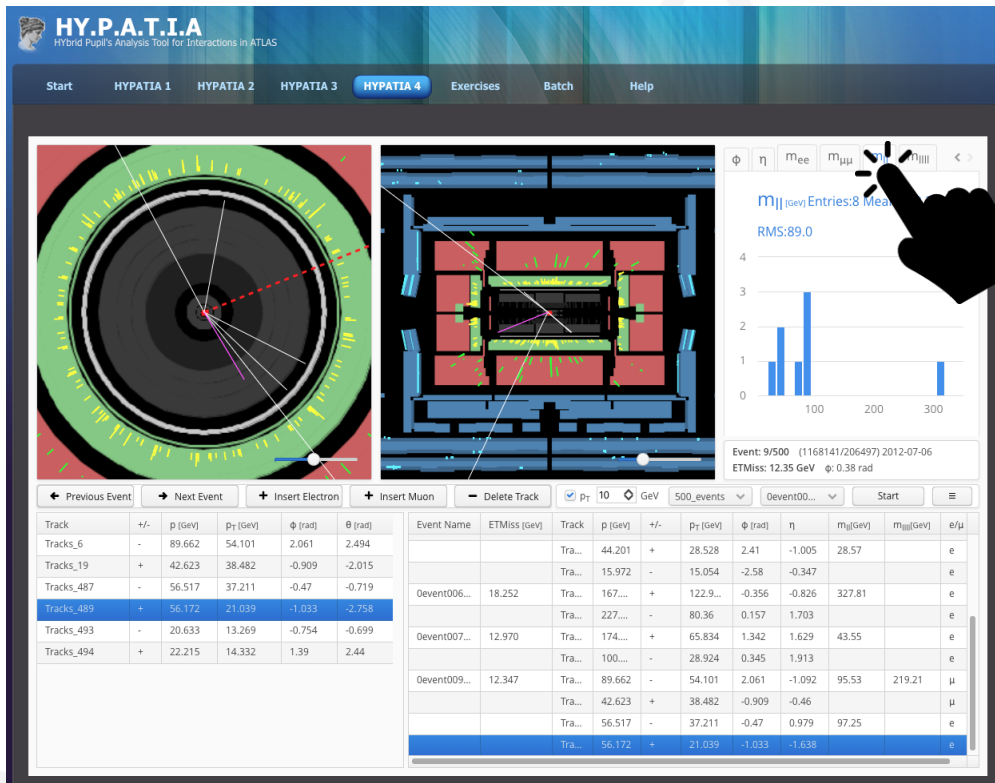
Track	p [GeV]	p_T [GeV]	ϕ [rad]	θ [rad]
Tracks_25	29.649	17.682	-0.471	-0.639
Tracks_27	54.452	35.956	-0.468	-0.721
Tracks_374	231.567	151.217	2.459	0.712
Tracks_375	268.225	132.885	1.915	2.623

Event Name	ETMiss [GeV]	Track	p [GeV]	+/-	p_T [GeV]	ϕ [rad]	η	m_{ll} [GeV]	m_{ll} [GeV]	e/ μ
event001.xml / Group_3A	30.543	Tracks_25	29.649	-	17.682	-0.471	1.106	103.01	537.87	e
		Tracks_374	231.567	+	151.217	2.459	0.99			e
		Tracks_27	54.452	+	35.956	-0.468	0.975	234.95		e
		Tracks_375	268.225	-	132.885	1.915	-1.328			e

HYPATIA 3

- Click through events
- Click on tracks
- Make a p_T cut
 - What happens to the low momentum tracks?
- Add particle pairs
 - What are the reconstructed masses?
 - Try different combinations

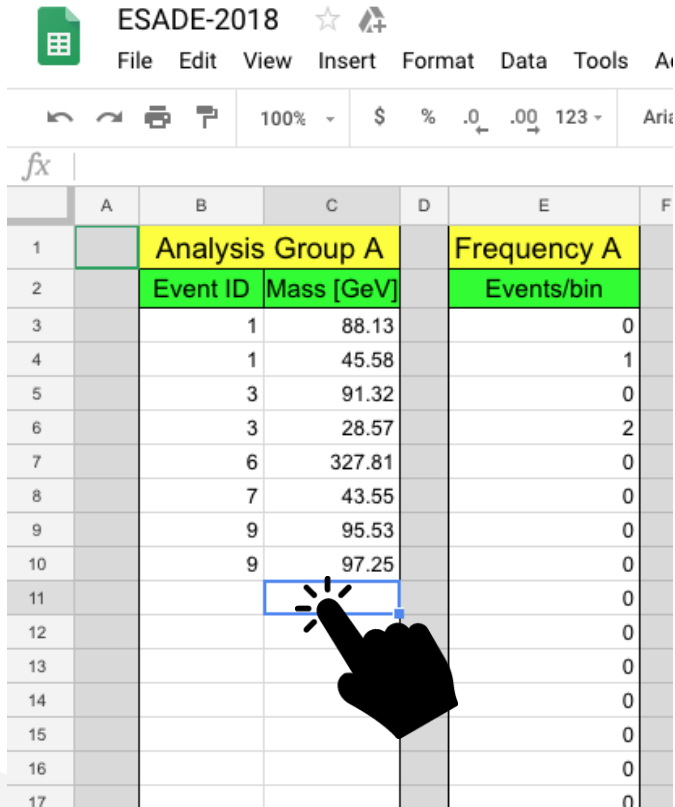
Data Analysis (Part I)



HYPATIA 4

- Select $m_{||}$ tab upper-right
- Apply p_T cut
- Select 500_events data
 - Group A starts at 0event001
 - Group B starts at 3event001
- Make a p_T cut
 - What happens to the low momentum tracks?
- Add particle pairs
 - Note reconstructed masses
 - See Next Slide

Data Analysis (Part II)



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	A	B	C	D	E	F
1		Analysis Group A			Frequency A	
2		Event ID	Mass [GeV]		Events/bin	
3		1	88.13		0	
4		1	45.58		1	
5		3	91.32		0	
6		3	28.57		2	
7		6	327.81		0	
8		7	43.55		0	
9		9	95.53		0	
10		9	97.25		0	
11					0	
12					0	
13					0	
14					0	
15					0	
16					0	
17					0	

Google Sheet

- Enter Event ID
 - Example: 6/500 (enter 6)
- Enter masses of pairs
- Gather Data
 - 150 events for each group
- Take screen captures of typical and interesting events
 - Typical = expected Z boson
 - Interesting = other
- Make mass histogram
 - From Google sheets

The Presentation

Introduction

- About the Experiment
- About the Search

Data Analysis

- Describe the Method
- Describe the Results
- Show typical and interesting event displays

Results

- Present Mass Histogram
- Point out any peculiarities (if any)
- Describe next steps