HYPATIA Tutorial

ATLAS Masterclass (27/04/2024)

Charlie Chen & Adrienne Scott (UVIC)

Overview of HEP Analyses

- Remember that most **H**igh-**E**nergy **P**hysics (**HEP)** analyses are "counting experiments": they count number of good physics objects that pass a certain set of cuts.
- We plot each of the variables (e.g. momentum, energy, mass, position, etc.) that we are interested in as histograms.

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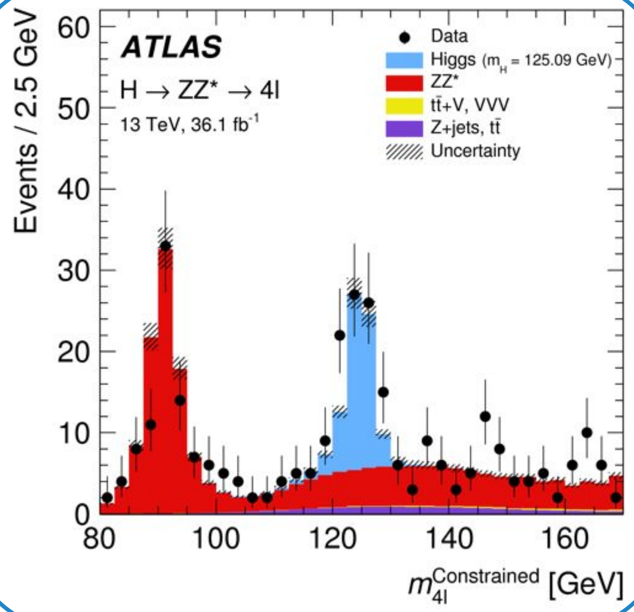

- Here we see an example of a Higgs boson analysis which plots the the combined mass of four particles (leptons)
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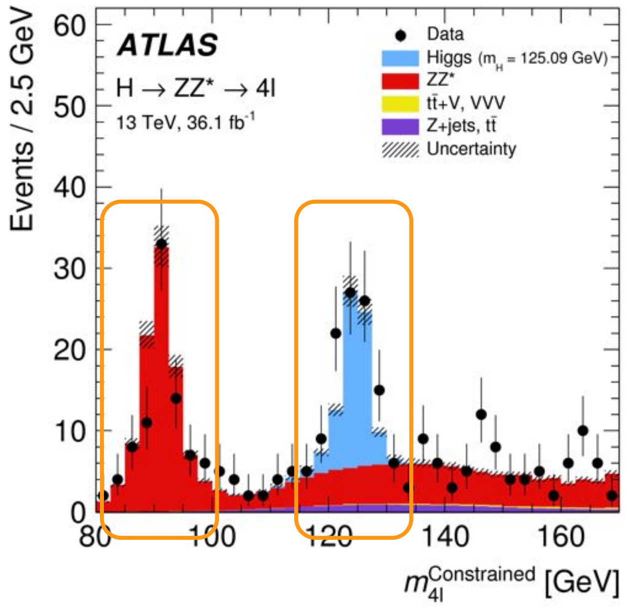

- Here we see an example of a Higgs boson analysis which plots the the combined mass of four particles (leptons) ⟶ Are there any distinct patterns that we can see?

- There are two distinct peaks in this histogram, implying that there we have successfully <u>reconstructed</u> two parent particles ⟶ Which standard model particles do these peaks correspond to?

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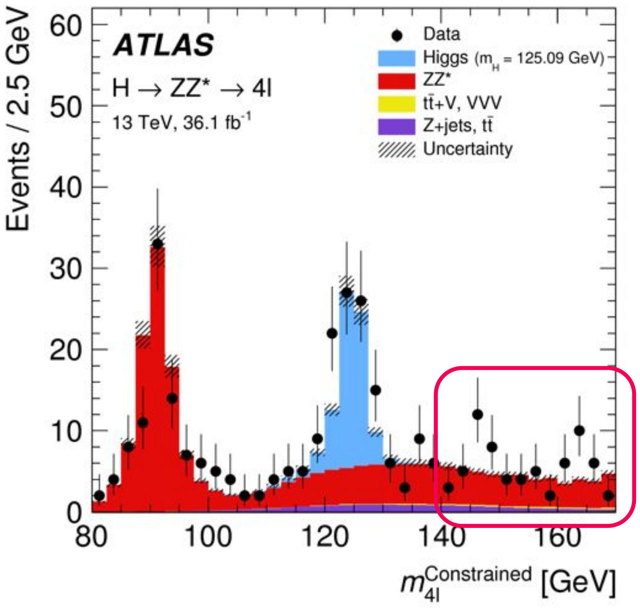


- Here we see an example of a Higgs boson analysis which plots the the combined mass of four particles (leptons) ⟶ Are there any distinct patterns that we can see?

- There are two distinct peaks in this histogram, implying that there we have successfully reconstructed two parent particles ⟶ Which standard model particles do these peaks correspond to?

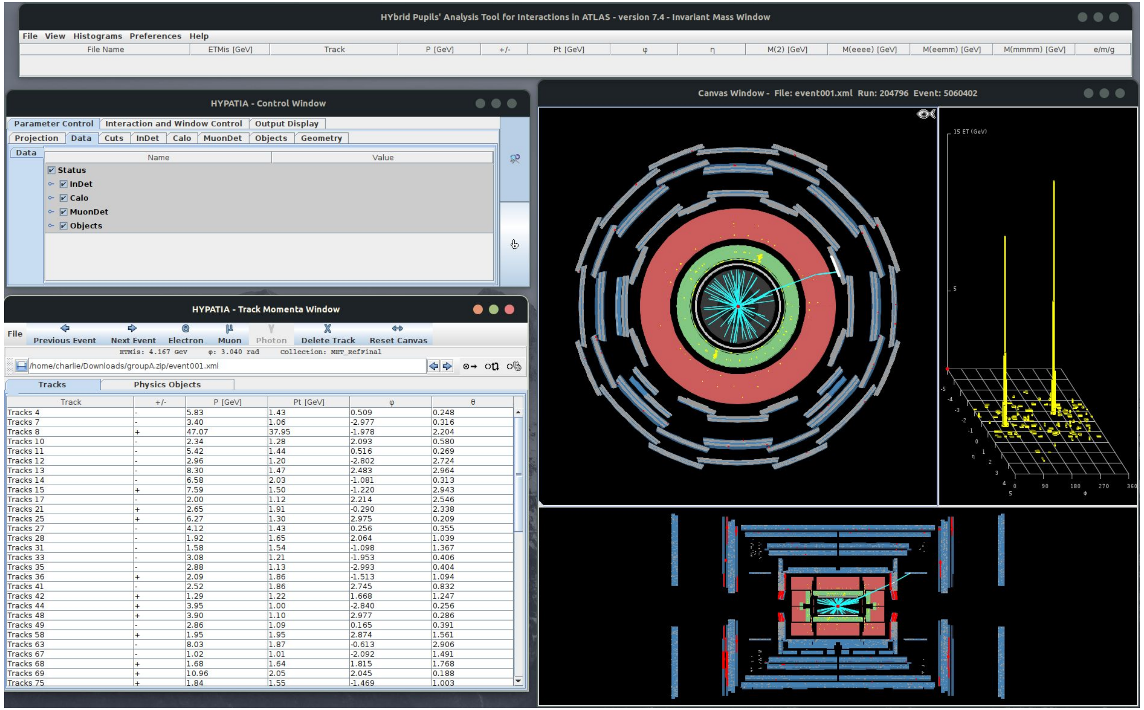
- There are other smaller peaks elsewhere in the histogram, do these correspond to any particles that we are aware of? Are 12 events enough to say that we've discovered a new particle?

Intro to HYPATIA

- We will try to perform a similar analysis using the analysis tool HYPATIA.

- This tool is a simplified version of the same tools that would be used in a standard ATLAS analysis and gives good consistent results.

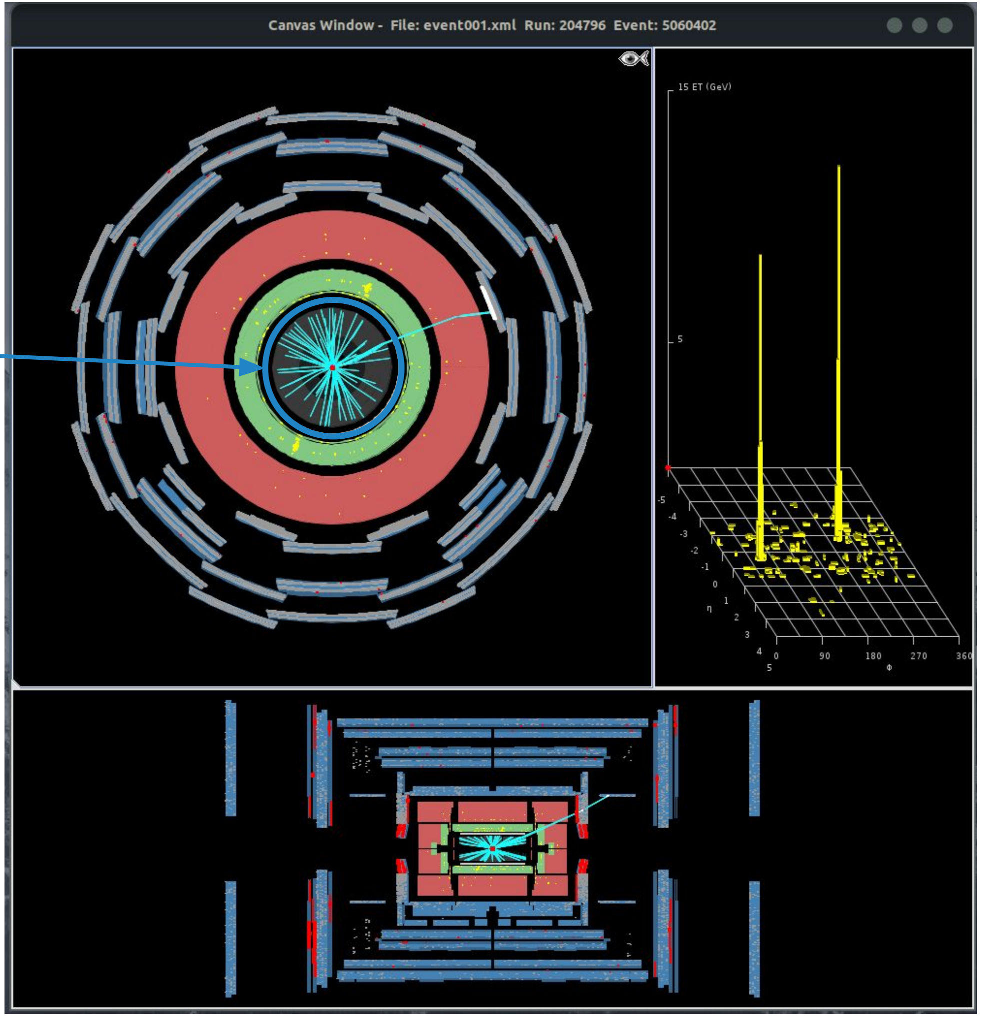
- When you open HYPATIA for the first time, you will see 4 separate windows. Let's go through each of these windows.



Main Detector

- This is the main detector window, which shows the main sub-detectors and the various tracks and energy deposits.

Inner detector: responsible for precise tracking of charged particles



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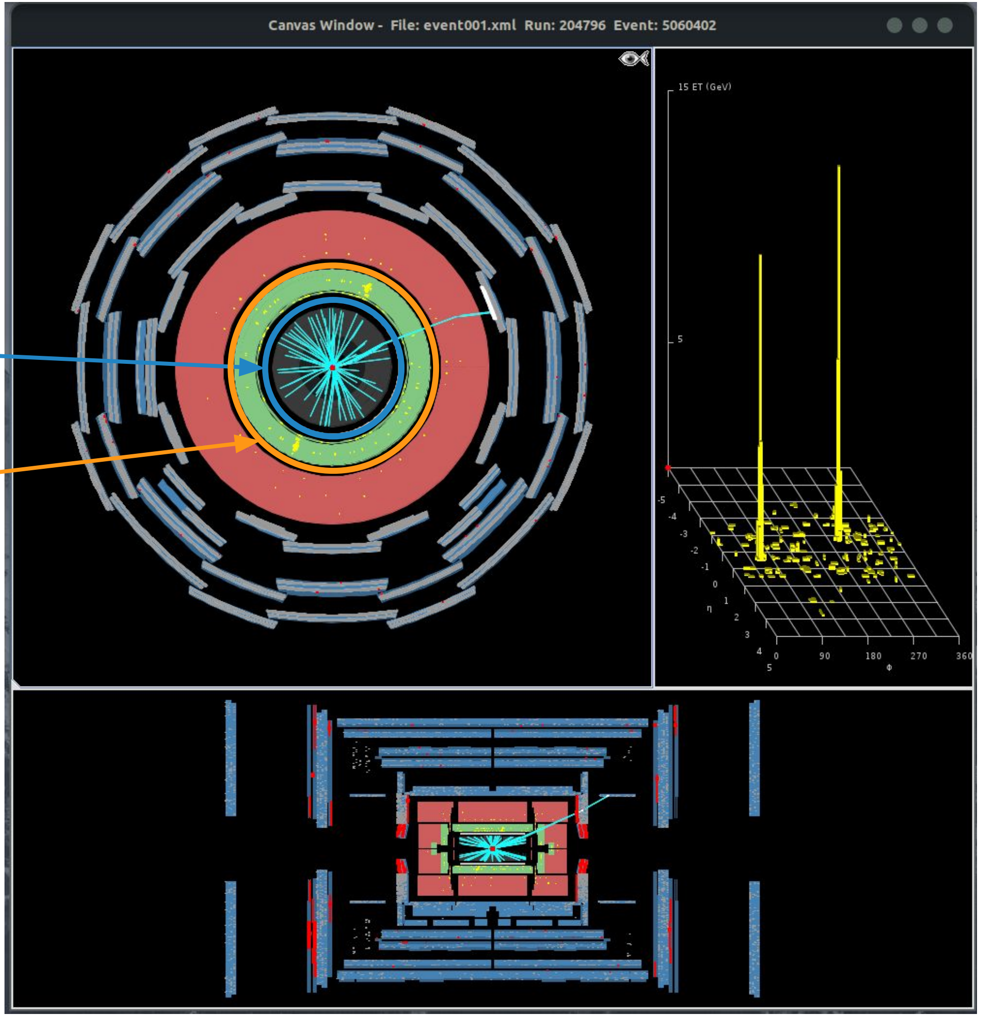

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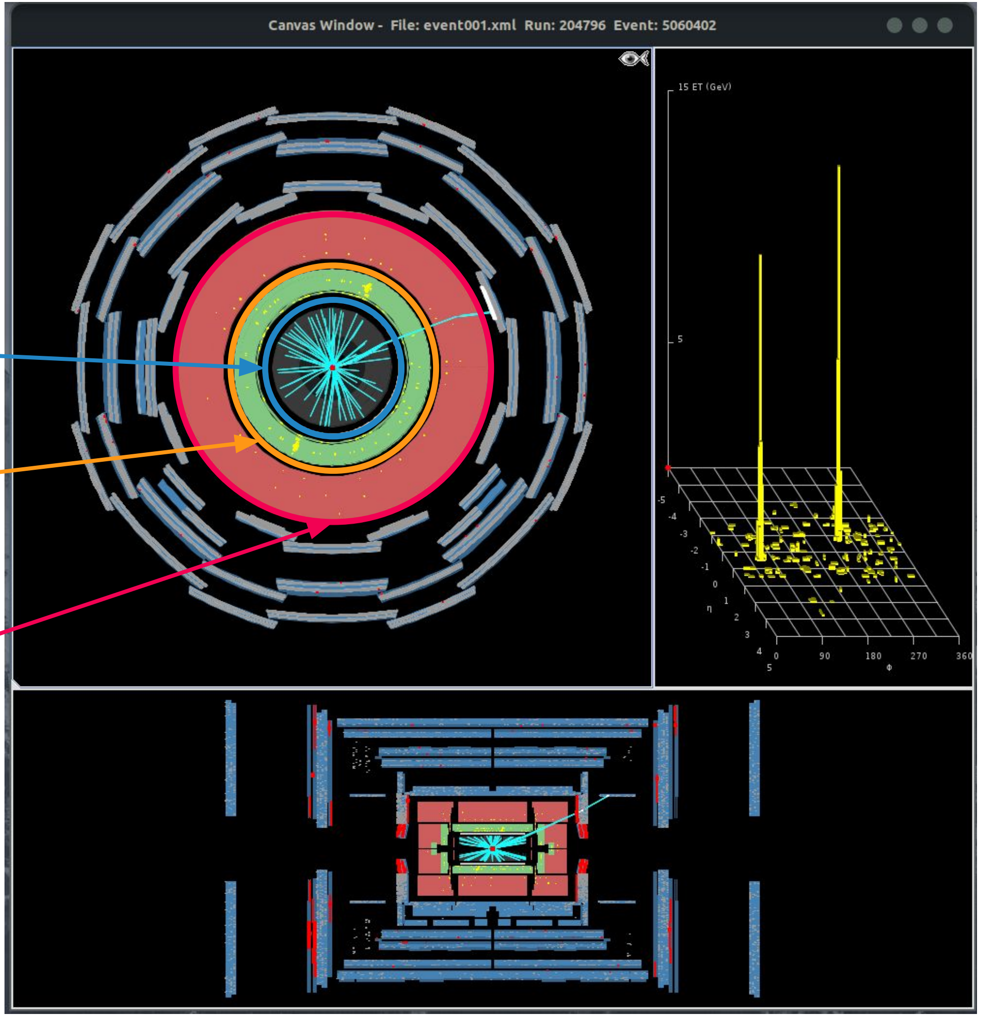
Hadronic calorimeter: energies of hadrons (i.e. particles that are made of quarks and gluons), and of quark and gluon 'jets'



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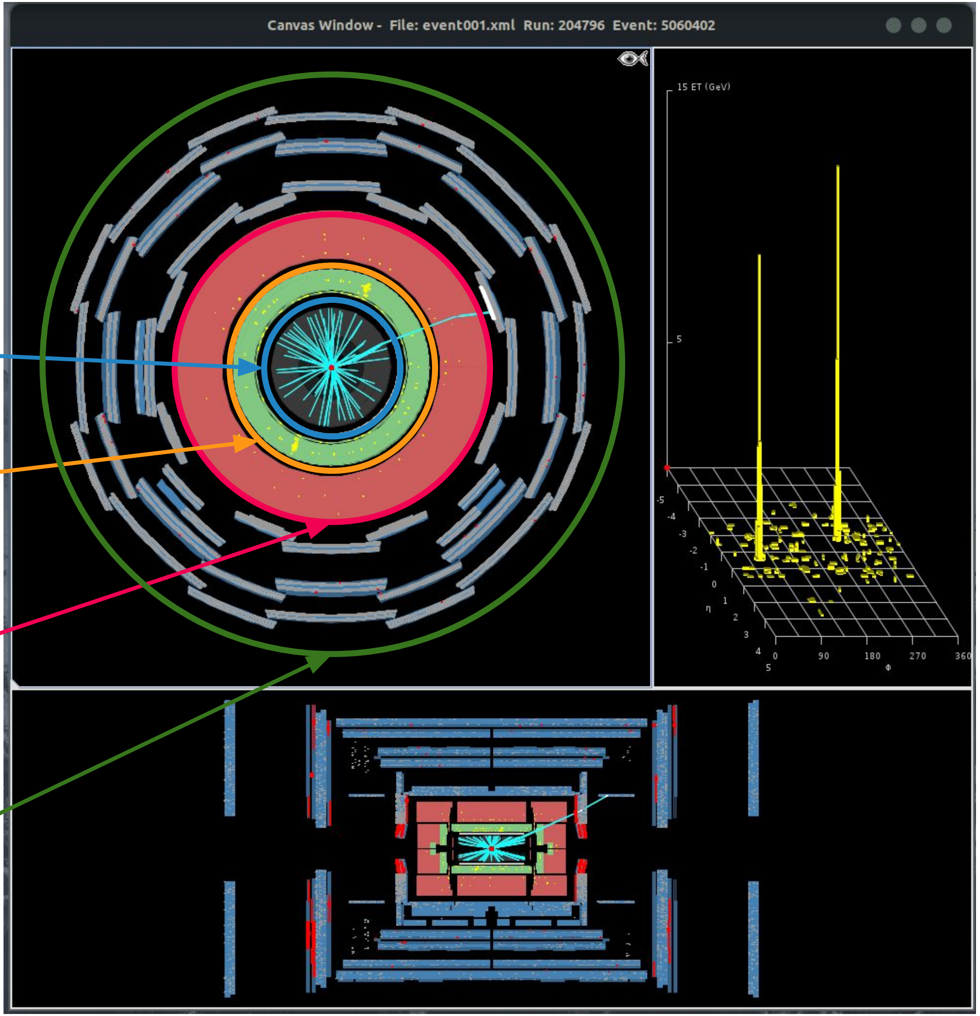
Muon spectrometer: measures passages of muons



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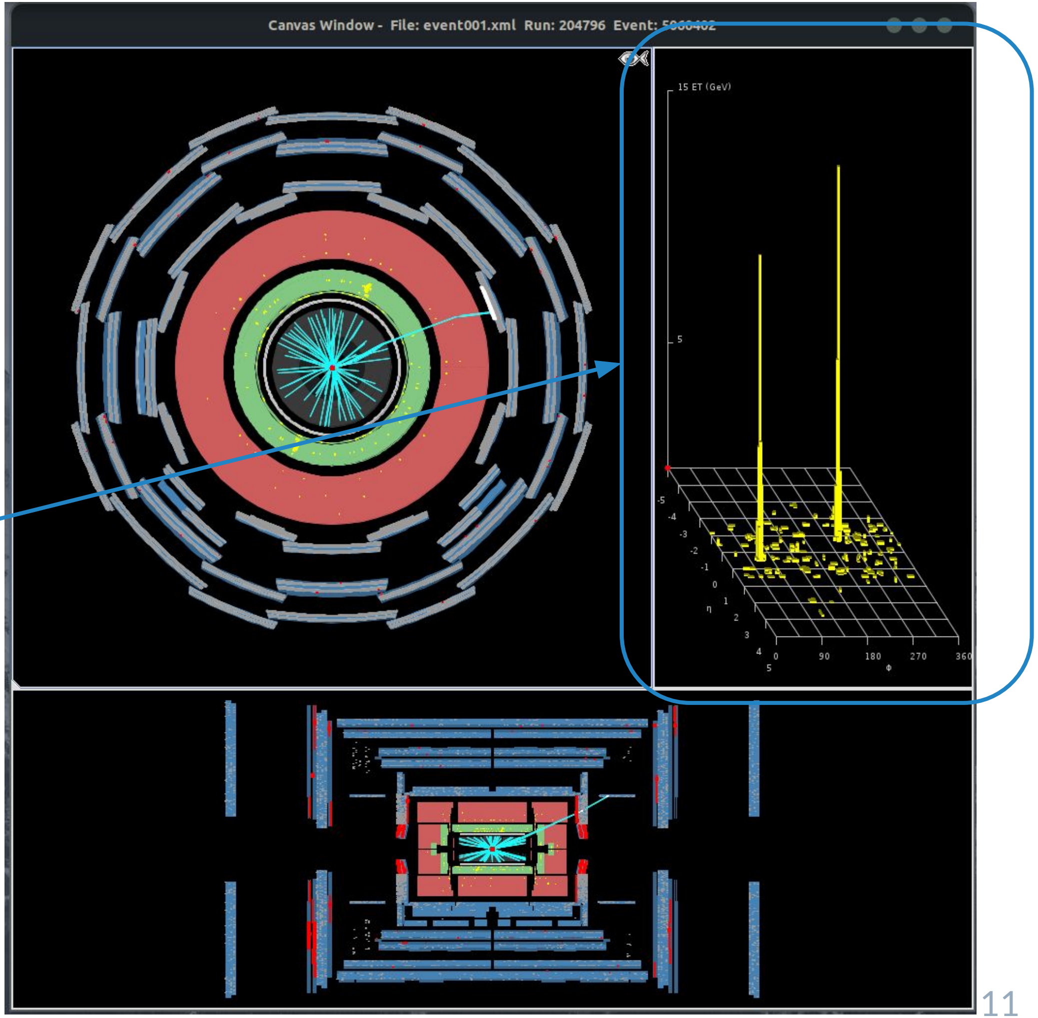
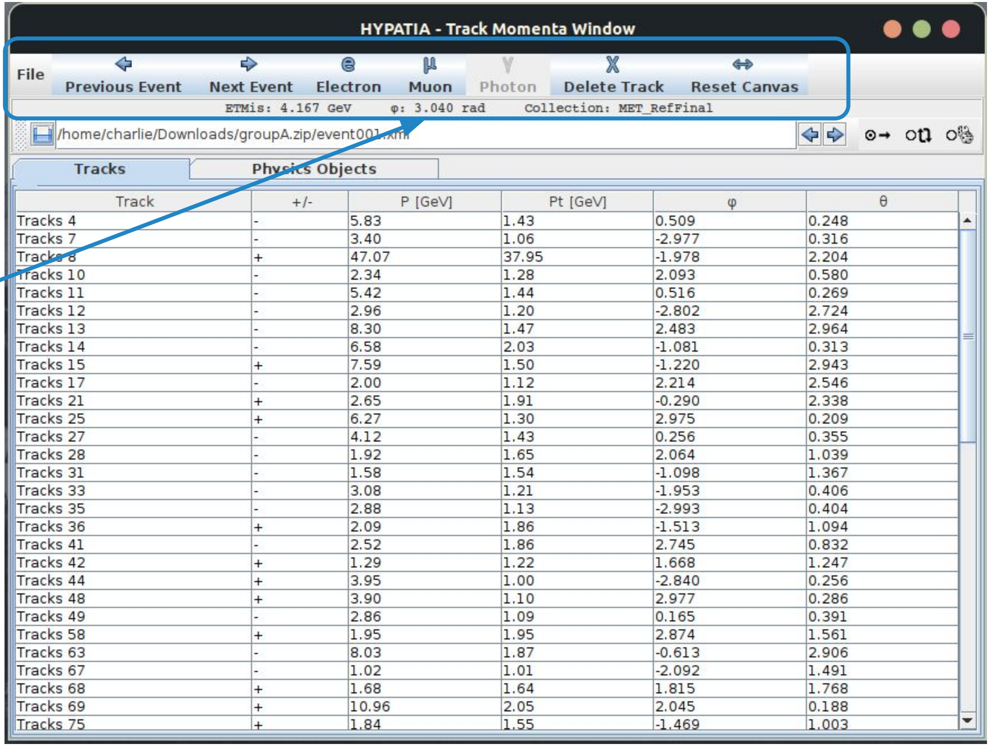


- This window shows where energy deposits occurred in the calorimeter.

Particle Measurements

- This is a complete list of tracks and physics objects that were recorded in the event.

We will use this interface to identify tracks/physics objects with electrons, muons and photons.



Track	+/-	P [GeV]	Pt [GeV]	φ	θ
Tracks 4	-	5.83	1.43	0.509	0.248
Tracks 7	-	3.40	1.06	-2.977	0.316
Tracks 8	+	47.07	37.95	-1.978	2.204
Tracks 10	-	2.34	1.28	2.093	0.580
Tracks 11	-	5.42	1.44	0.516	0.269
Tracks 12	-	2.96	1.20	-2.802	2.724
Tracks 13	-	8.30	1.47	2.483	2.964
Tracks 14	-	6.58	2.03	-1.081	0.313
Tracks 15	+	7.59	1.50	-1.220	2.943
Tracks 17	-	2.00	1.12	2.214	2.546
Tracks 21	+	2.65	1.91	-0.290	2.338
Tracks 25	+	6.27	1.30	2.975	0.209
Tracks 27	-	4.12	1.43	0.256	0.355
Tracks 28	-	1.92	1.65	2.064	1.039
Tracks 31	-	1.58	1.54	-1.098	1.367
Tracks 33	-	3.08	1.21	-1.953	0.406
Tracks 35	-	2.88	1.13	-2.993	0.404
Tracks 36	+	2.09	1.86	-1.513	1.094
Tracks 41	-	2.52	1.86	2.745	0.832
Tracks 42	+	1.29	1.22	1.668	1.247
Tracks 44	+	3.95	1.00	-2.840	0.256
Tracks 48	+	3.90	1.10	2.977	0.286
Tracks 49	-	2.86	1.09	0.165	0.391
Tracks 58	+	1.95	1.95	2.874	1.561
Tracks 63	-	8.03	1.87	-0.613	2.906
Tracks 67	-	1.02	1.01	-2.092	1.491
Tracks 68	+	1.68	1.64	1.815	1.768
Tracks 69	+	10.96	2.05	2.045	0.188
Tracks 75	+	1.84	1.55	-1.469	1.003

Particle Measurements

- This is a complete list of tracks and physics objects that were recorded in the event.

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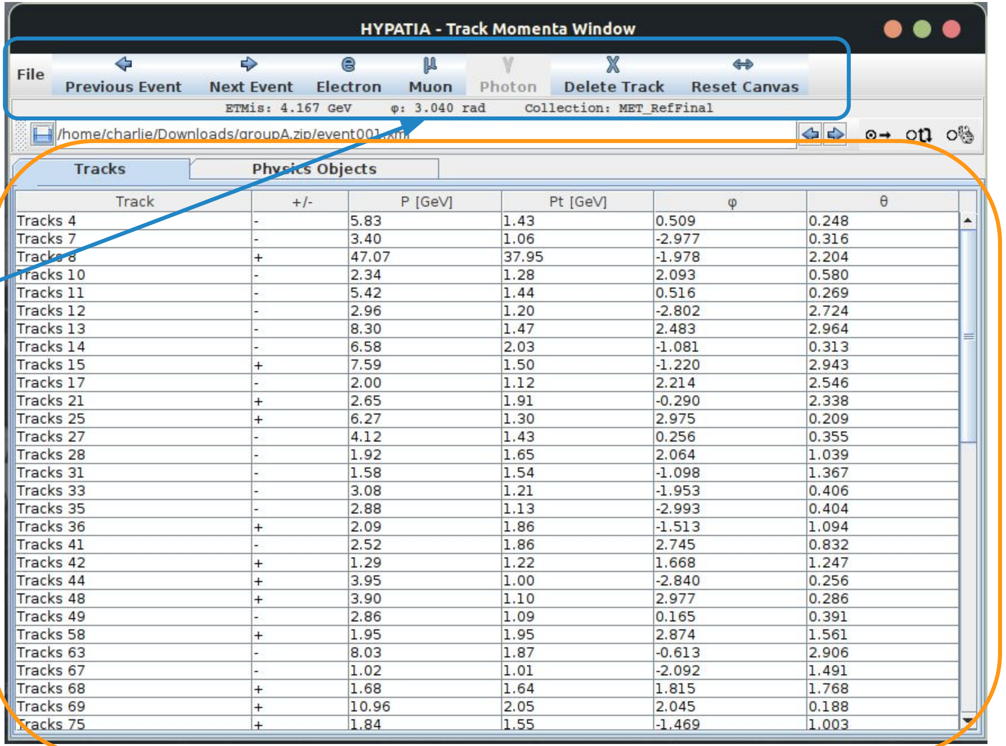
This is the full list of tracks and physics objects. There are alot of tracks, do we need all of these tracks? How do we determine which tracks to keep?



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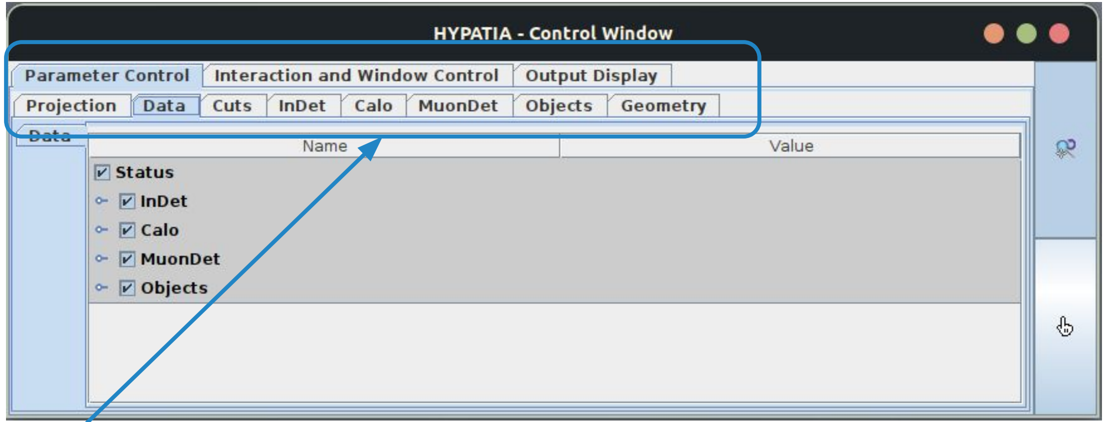
Control Window

- This window is where we will control which cuts we will apply to our tracks to determine which tracks we will keep for our analysis.



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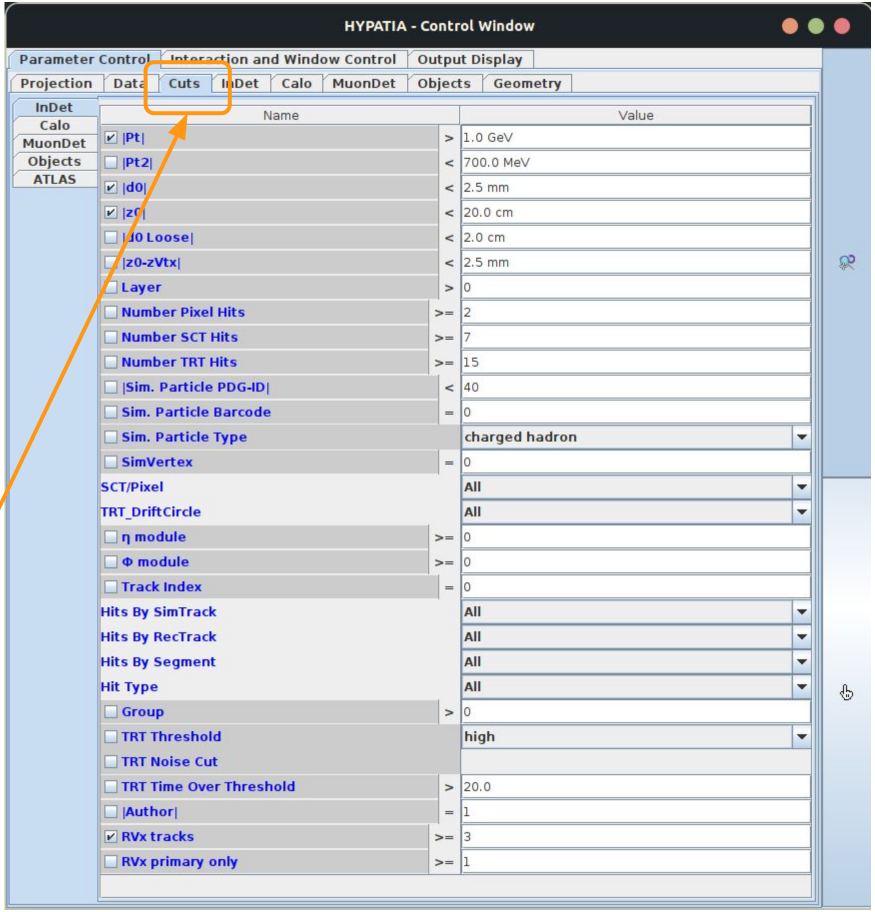
The cuts tab allows you to enter different requirements for your physics objects, we will use this (demo) to reduce the list of physics objects.



Invariant Mass

HYbrid Pupils' Analysis Tool for Interactions in ATLAS - version 7.4 - Invariant Mass Window

File View Histograms Preferences Help

File Name	ETMis [GeV]	Track	P [GeV]	+/-	Pt [GeV]	φ	η	M(2) [GeV]	M(eeee) [GeV]	M(eemm) [GeV]	M(mmmm) [GeV]	e/m/g
event001.xml	4.167	Tracks 173	36.6	-	32.6	1.132	0.491	122.275				e
		Tracks 239	827.4	+	311.6	0.983	1.632					e

- When we begin to assign tracks to particles, we will see them being populated in the invariant mass window.

Here, as an example, I've added two tracks which I've assigned to be electrons. HYPATIA then calculates the invariant mass of those two tracks.

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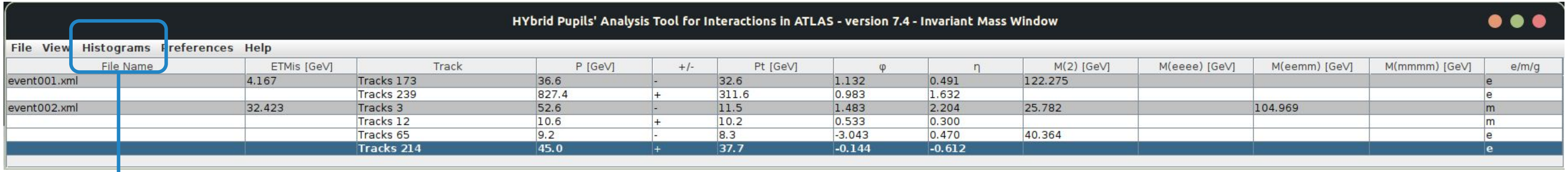
event002.xml	32.423	Tracks 3	52.6	-	11.5	1.483	2.204	25.782		104.969		m
		Tracks 12	10.6	+	10.2	0.533	0.300					m
		Tracks 65	9.2	-	8.3	-3.043	0.470	40.364				e
		Tracks 214	45.0	+	37.7	-0.144	-0.612					e

- As I go through more events and label tracks, the list begins to grow.

For the second event, I've added four tracks with 2 muons and 2 electrons.

Invariant Mass



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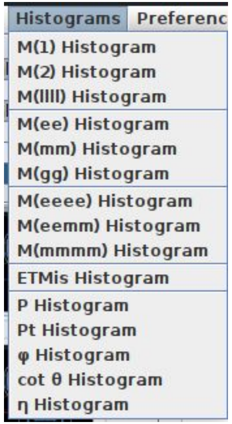
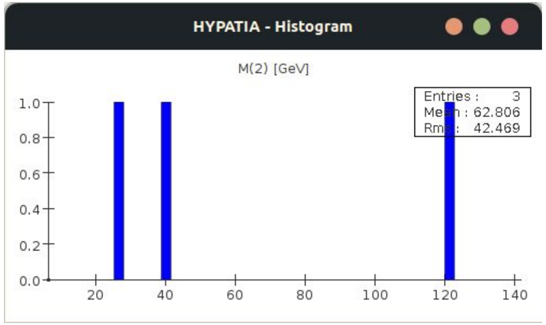
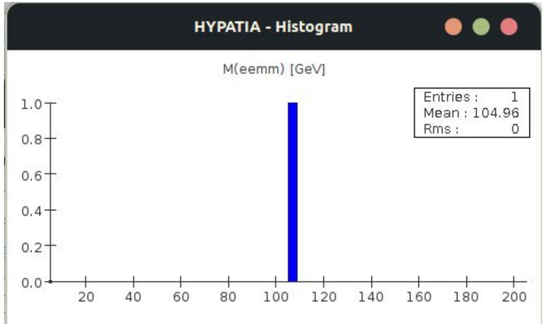


- After we've completed assigning tracks in all of the events, then HYPATIA will automatically plot histograms of the different invariant mass quantities.





More Data = Better Results

- As good scientists, we know that when we collect more data we get better results. At the end of the session we will compile everyone's data into a single histogram and see if we've accomplished our goal of finding a new particle!

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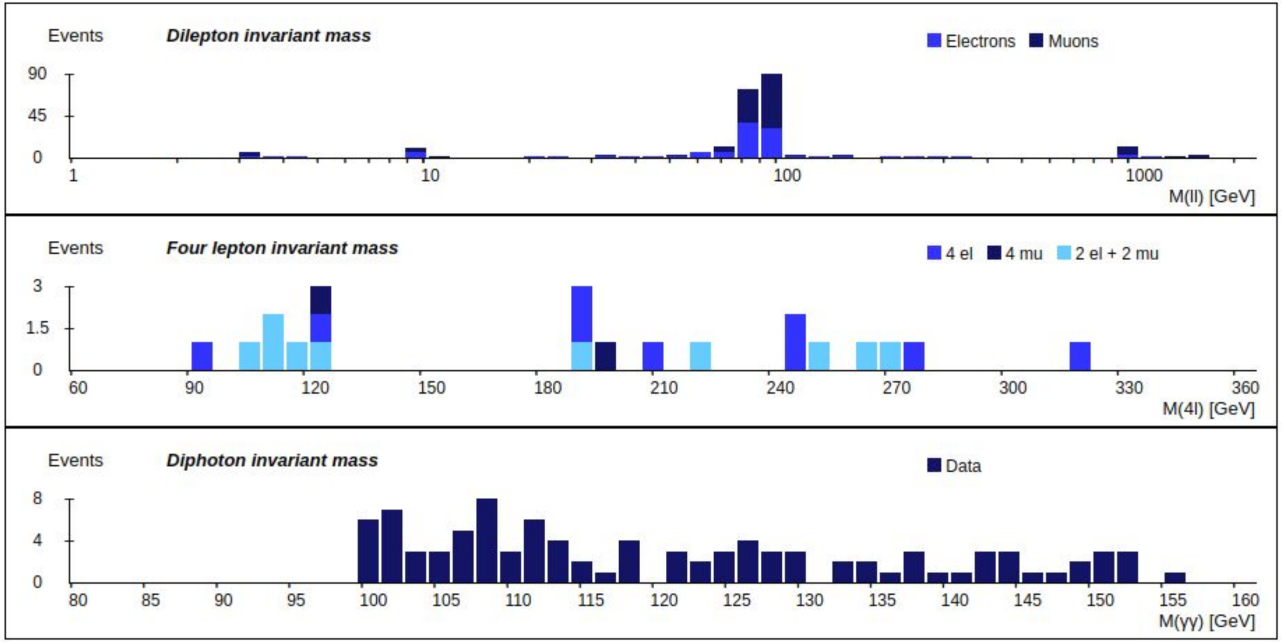

Plot type: ll+4l+γγ overview

Dilepton statistics

	Electrons			
Region	R1	R2	R3	R4
Events	6	9	67	4
Mean	3.20	10.11	89.77	994.22
Width	0.54	1.09	3.95	30.21

	Muons			
Region	R1	R2	R3	R4
Events	4	5	93	8
Mean	3.05	9.54	90.43	1,013.91
Width	0.08	0.52	3.20	28.34

Number of events

	Student distribution	Expected
ll	270	585
4l	25	40
γγ	98	270
Sum	393	895