Laboratory Exercise for 4th year Undergraduate Students specializing in Nuclear Physics

Overview

- **Real LHC** events
- Each week 2 teams (3 students each)
- 30 students total
- 1,5 hour introduction
- 3 hour exercise
- Report and questionnaire

Exercise Goals

- Familiarize students with the LHC and the ATLAS experiment
- Explain how particle detectors work
- Emphasize the different signatures of particles
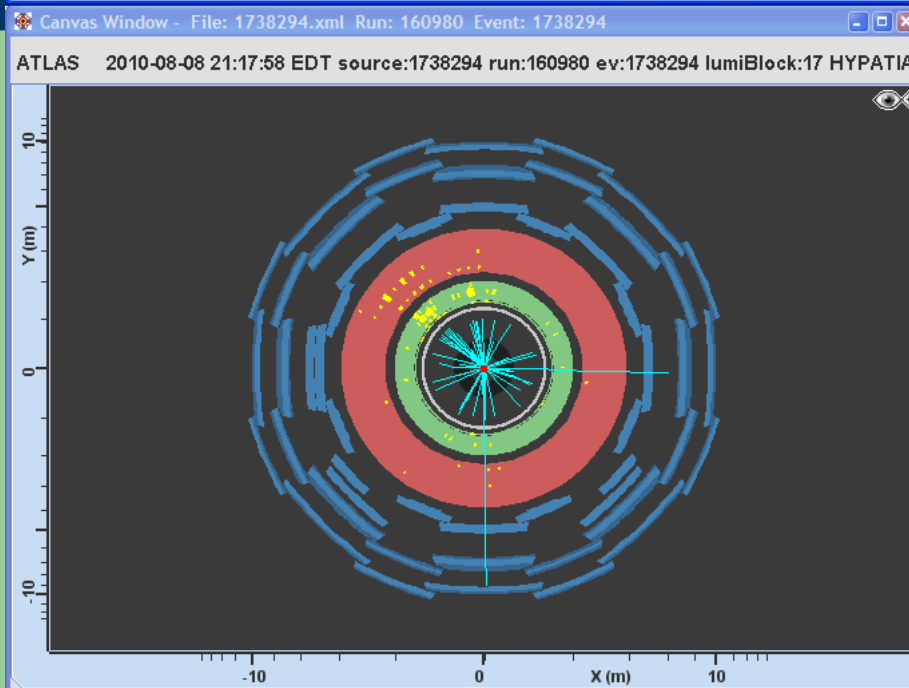- Demonstrate how a physicist analyses a real event

HYPATIA v.6 – Physics lab

- Special version for this exercise
- Only reconstructed inner detector tracks are shown in the tables
- Muon tracks are shown in the canvas
- Corresponding inner←→muon tracks are automatically selected
- Only inner detector tracks are used for invariant mass calculations

Hybrid pupils' analysis tool for interactions in ATLAS - version 6.0 - Invariant Mass Window

File   View   Histograms   Preferences   Help

File Name	ETMis [GeV]	Track	P [GeV]	+/-	Pt [GeV]	φ	η	M(lν) [GeV]	M(2l) [GeV]	M(4l) [GeV]
1380883.xml	6.919	TrackParticleCandidate 9	3.3	+	1.8	0.801	1.215	6.941	2.038	4.805
		TrackParticleCandidate 20	1.7	-	1.7	0.348	0.168	6.750		
		TrackParticleCandidate 37	9.1	-	4.1	0.556	1.449	10.598	0.584	
		TrackParticleCandidate 7	3.7	+	1.9	0.417	1.290	7.205		
124721.xml	3.407	TrackParticleCandidate 2	3.8	-	1.0	1.803	1.991	2.884	1.811	
		TrackParticleCandidate 6	9.4	-	1.8	-3.076	2.329	4.973		
		TrackParticleCandidate 22	2.1	-	1.9	1.850	-0.406	4.024		
10274950.xml	46.458	TrackParticleCandidate 12	1.1	-	1.0	-0.641	-0.427	8.185	25.485	
		TrackParticleCandidate 39	198.6	-	170.5	-2.539	0.567	177.967		
		TrackParticleCandidate 22	1.1	+	1.1	-2.325	-0.155	14.270		
18543843.xml	4.214	TrackParticleCandidate 3	1.4	+	1.0	0.519	-0.801	0.590	32.535	64.588
		TrackParticleCandidate 0	223.2	-	41.9	-1.492	2.357	24.225		
		TrackParticleCandidate 9	2.2	-	1.6	0.893	-0.850	0.237	2.621	
		TrackParticleCandidate 7	1.8	+	1.1	-2.044	-1.097	4.178		
30697814.xml	13.013	TrackParticleCandidate 6	1.4	-	1.3	2.730	-0.311	7.621	2.080	

Canvas Window - File: 1738294.xml Run: 160980 Event: 1738294

ATLAS   2010-08-08 21:17:58 EDT source:1738294 run:160980 ev:1738294 lumiBlock:17 HYPATIA

HYPATIA - Track Momenta Window

File   Previous Event   Next Event   Insert Track   Delete Track   Reset Canvas

ETMis: 25.223 GeV   φ: -0.646 rad   Collection: MET_RefFinal

D:\ASEC\Events\Physics Lab 2010\5\1738294.xml

Reconstructed

RecTracks

Track	+/-	P [GeV]	Pt [GeV]	φ	θ
TrackParticleCandidate 1	+	144.77	38.51	-0.026	2.872
TrackParticleCandidate 2	-	12.45	10.47	2.277	0.998
TrackParticleCandidate 3	+	19.94	16.97	2.514	2.124
TrackParticleCandidate 4	+	16.86	14.18	2.293	1.000
TrackParticleCandidate 6	+	6.97	5.88	2.423	1.003
TrackParticleCandidate 7	-	310.03	121.83	-1.565	2.738
TrackParticleCandidate 8	-	2.61	2.23	2.270	1.026
TrackParticleCandidate 10	+	13.45	11.05	1.756	2.177
TrackParticleCandidate 11	-	4.62	3.82	1.650	2.169
TrackParticleCandidate 12	+	2.63	1.66	1.773	2.460
TrackParticleCandidate 16	-	11.27	1.95	-0.147	2.968
TrackParticleCandidate 17	+	19.35	3.45	3.053	2.962
TrackParticleCandidate 19	-	6.00	5.51	-2.117	1.977
TrackParticleCandidate 21	-	4.93	1.01	2.372	2.934
TrackParticleCandidate 24	-	5.24	4.28	1.789	2.183
TrackParticleCandidate 25	+	5.36	4.67	2.520	1.059
TrackParticleCandidate 28	-	3.61	2.83	2.366	2.243
TrackParticleCandidate 31	-	1.84	1.60	2.665	1.047
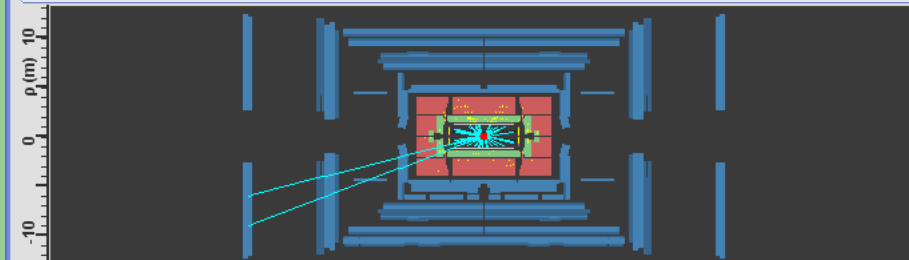
HYPATIA - Control Window

Parameter Control   Interaction and Window Control   Output Display

Projection   Data   Cuts   InDet   Calo   MuonDet   Objects   Geometry

Data

Name	Value
☑ Status	
☑ InDet	
☑ Calo	
☑ MuonDet	
☐ Objects	

Lab Notes

- 22-page instructions booklet (Greek or English)
- Introduction to the Standard Model
- Detailed description of the ATLAS experiment
- Exercise Description
- HYPATIA instructions

Exercise 1
Recognize electrons and muons

- See how different particles show up on the detectors
- Demonstrate the importance of different canvas views
- Explain differences between electrons and muons
- Familiarize students with HYPATIA
- Uses **simulated** events

Event number	Track number	Electron	Muon	p of track
...				
...				

Exercise 2

Recognize Z particle decays

- Learn to separate Z decays form background events (cosmics and dijets → muons)

| Event number	Z Decay type	P Track1	P Track2	Etmiss	Invariant mass

- More complex recognition procedure (Z→µ⁺µ⁻ isolated/non-isolated)
- Uses **real LHC** events (5 groups, 30 events each, 14 Z, 16 background)

Exercise 2
Recognize Z particle decays

- Explain ETmiss
- Introduce the concept of Invariant Mass and how to calculate it
- Highlight the importance of Histograms
- Calculate Z mass and width
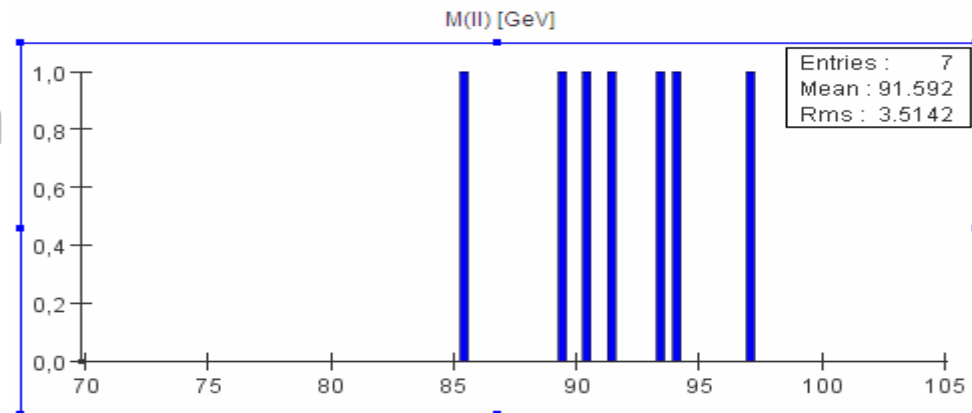
Exercise 3
Find the Higgs

- Discover the Higgs particle hidden among 9 background events
- Easy exercise
- Gives the sense of discovery
- Explain the importance of the Higgs Boson
- Uses **simulated** events

Report and Questionnaire

- Students need to write a report containing their results
- Questions on the results
- Explain deviation from theory
- Judge their understanding of the exercise
- Questionnaire about the quality and impressions from the exercise