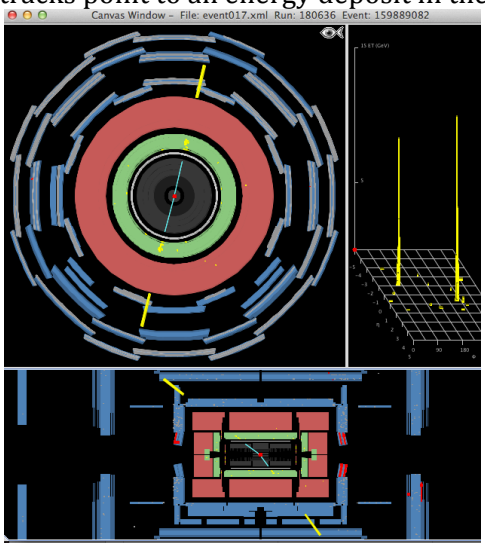
Z-Path 2013 – Event Displays

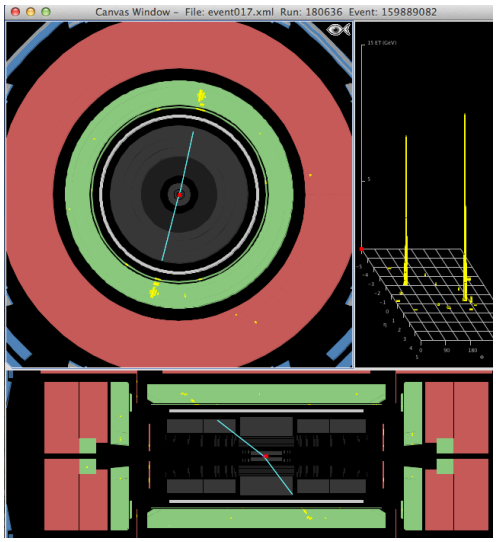
Examples of l^+l^-, $\gamma\gamma$ and 4-lepton events

1. e^+e^- – events

1.1. Event 1

Electrons usually have a calorimeter object and a corresponding charged track. The left figure shows both tracks and calorimeter objects. In the left figure it is clear that both tracks point to an energy deposit in the calorimeter.





Pt [GeV]	φ	η	M(2) [GeV]	M(4) [GeV]	e/m/g
32.2	1.344	-1.058	91.682		e
33.2	-1.816	0.682			e

HYPATIA – Track Momenta Window

Previous Event | Next Event | Electron | Muon | Photon | Delete Track | Reset Ca

ETMis: 12.267 GeV φ: -2.714 rad Collection: MET_RefFinal

events/group04.zip/event017.xml

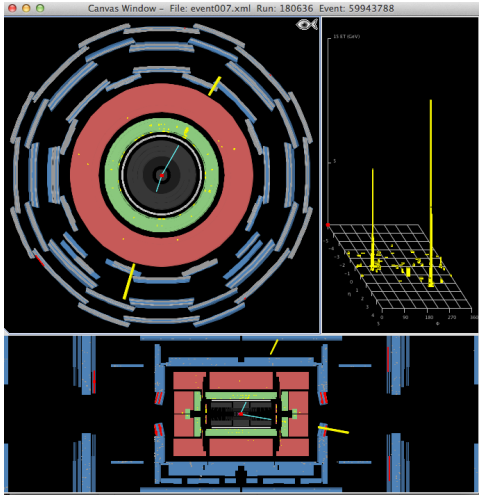
Tracks | Physics Objects

Track	+/-	P [GeV]	Pt [GeV]	φ	θ
Tracks 2	-	51.92	32.16	1.344	2.474
Tracks 34	+	41.21	33.18	-1.816	0.936

The 2-electrons are of opposite charge, have more than 30 GeV momentum, and stem from a Z boson decay: $M(e^+e^-)=91.7$ GeV

1.2. Event 2

Another event where a Z decays to a pair of e^+e^-.



The information about the calorimeter objects is reproduced below. The invariant mass is compatible with a Z boson M=88 GeV. One of tracks seems short; in fact it is emitted in the forward direction, as the z-view shows.

Pt [GeV]	φ	η	M(2) [GeV]	M(4) [GeV]	e/m/g
40.3	-1.867	2.436	88.041		e
20.9	1.035	0.470			e

HYPATIA – Track Momenta Window

Previous Event | Next Event | Electron | Muon | Photon | Delete Track | Reset Car

ETMis: 11.229 GeV φ: -2.391 rad Collection: MET_RefFinal

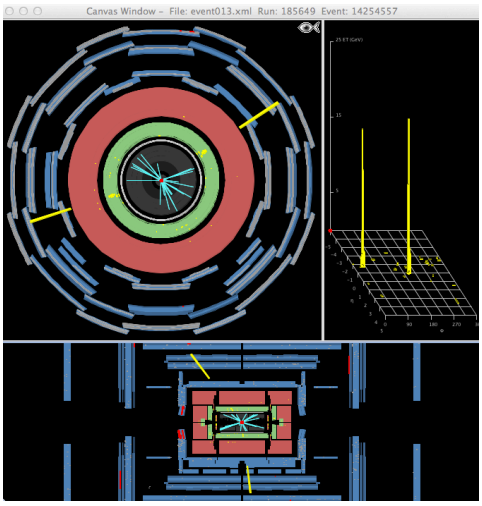
events/group04.zip/event007.xml

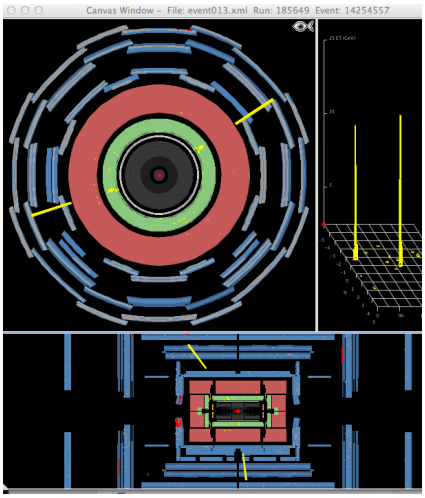
Tracks | Physics Objects

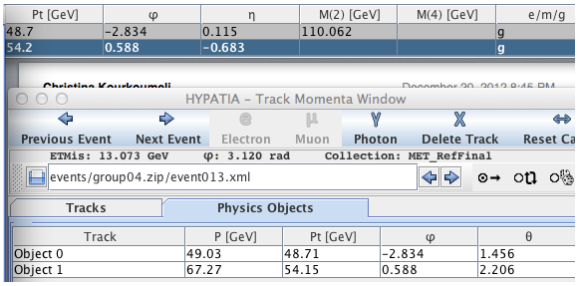
Track	P [GeV]	Pt [GeV]	φ	θ
Object 0	232.01	40.31	-1.867	0.175
Object 1	23.20	20.85	1.035	1.117

2. γγ events

2.1. Event 1

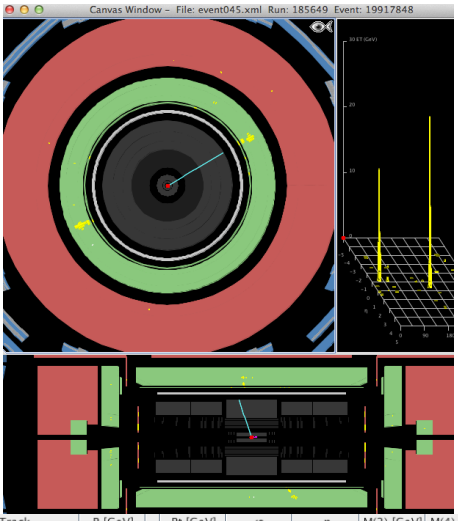


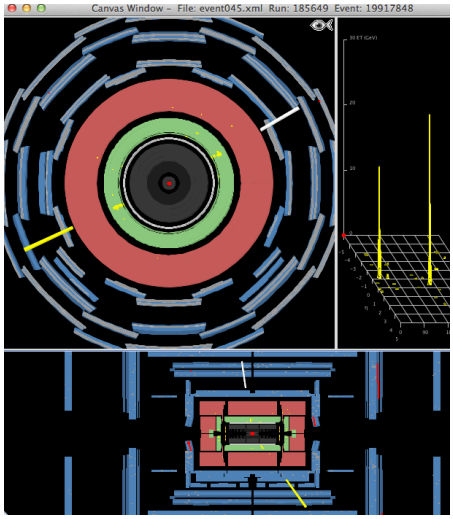


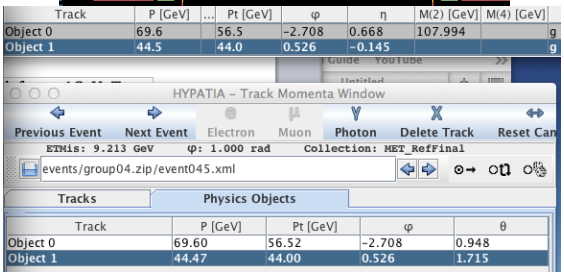


This event has 2 calorimeter objects clearly without tracks pointing to them (left figure). After a pT cut of 5 GeV all tracks disappear (right).
M(γγ)=110 GeV

2.2. Event 2

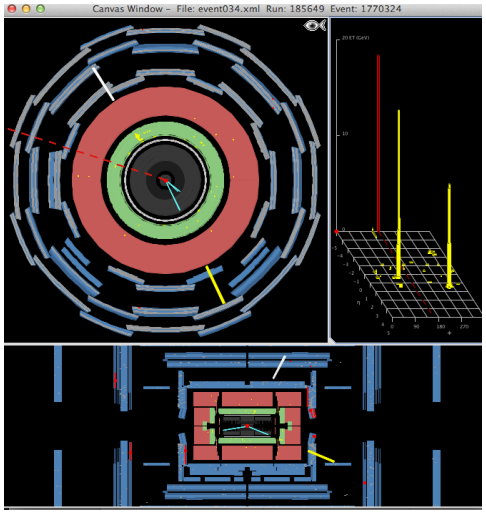






Another 2-photon event with 2 clear calorimeter objects: M(γγ)=108 GeV
After a pT cut of 5 GeV, one track remains, which however does not point to the cluster in the z-view. In fact, by requiring 2 pixel hits, the track disappears (right figure).

3. A “difficult” γγ event



Pt [GeV]	φ	η	M(2) [GeV]	M(4) [GeV]	e/m/g
25.3	-1.128	1.615	0.231	161.060	e
45.5	-1.121	1.616			e
45.7	-1.125	1.615	100.907		g
41.8	2.142	0.513			g

HYPATIA – Track Momenta Window

Previous Event | Next Event | Electron | Muon | Photon | Delete Track | Reset C

ETMis: 18.336 GeV φ: 2.826 rad Collection: MET_RefFinal

events/group04.zip/event034.xml

Tracks | Physics Objects

Track	P [GeV]	Pt [GeV]	φ	θ
Object 0	119.49	45.71	-1.125	0.393
Object 1	47.46	41.82	2.142	1.079

This event has 2 calorimeter clusters, one without any track pointing to it and one with a double track pointing to it (see zoom below). Assuming these are photons: M(γγ)=100.1GeV. Is this a 2-photon event? Study further!

Let’s look at the 4 double tracks.
The double track pointing to some calorimeter energy (with numbers 45-46, see below) have an invariant mass M(e^+e^-) =0.2GeV compatible with a converted photon! In fact this pair disappears when requiring at least 2 pixel hits (below right).

Track	P [GeV]	…	Pt [GeV]	φ	η	M(2) [GeV]	M(4) [GeV]	
Tracks 0	27.3	-	5.2	-0.697	-2.351	0.868	233.640	e
Tracks 9	52.6	-	8.9	-0.760	-2.462			e
Tracks 45	66.0	-	25.3	-1.128	1.615	0.231		e
Tracks 46	118.9	+	45.5	-1.121	1.616			e

HYPATIA – Track Momenta Window

Previous Event | Next Event | Electron | Muon | Photon | Delete Track | Reset Can

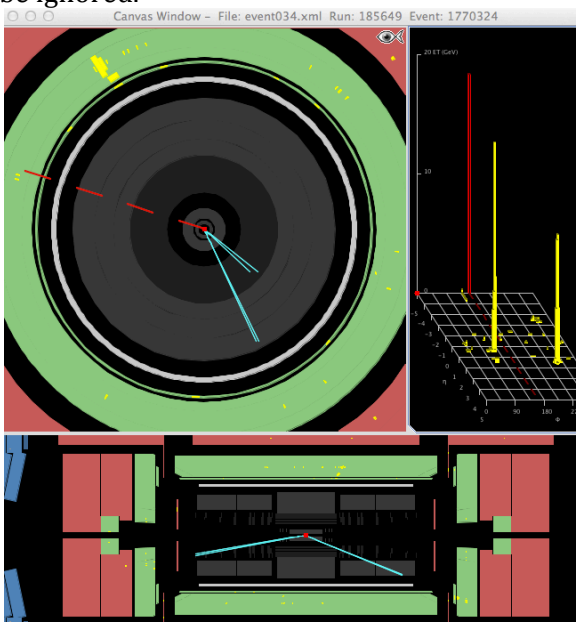
ETMis: 18.336 GeV φ: 2.826 rad Collection: MET_RefFinal

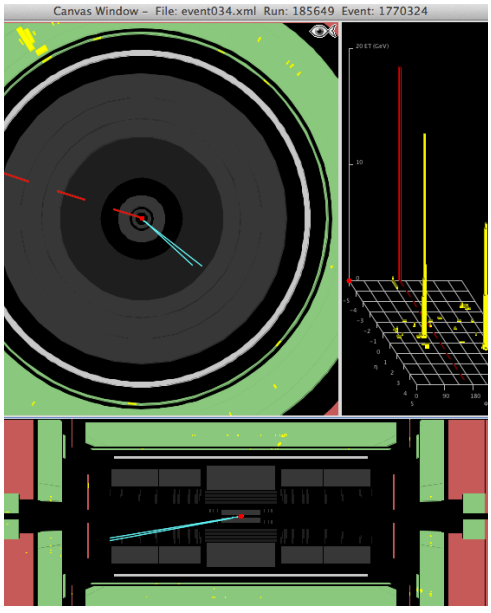
events/group04.zip/event034.xml

Tracks | Physics Objects

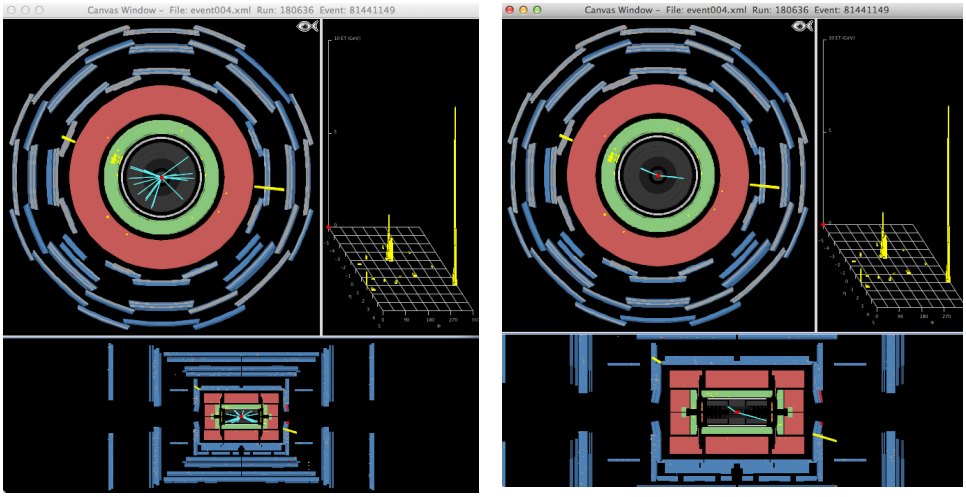
Track	+/-	P [GeV]	Pt [GeV]	φ	θ
Tracks 0	-	27.33	5.16	-0.697	2.952
Tracks 9	-	52.55	8.90	-0.760	2.971
Tracks 45	-	66.02	25.26	-1.128	0.393
Tracks 46	+	118.94	45.47	-1.121	0.392

What about the other pair remaining? It has no energy deposited in the calorimeter and both tracks have the same sign. These can be considered as random tracks and can therefore be ignored.

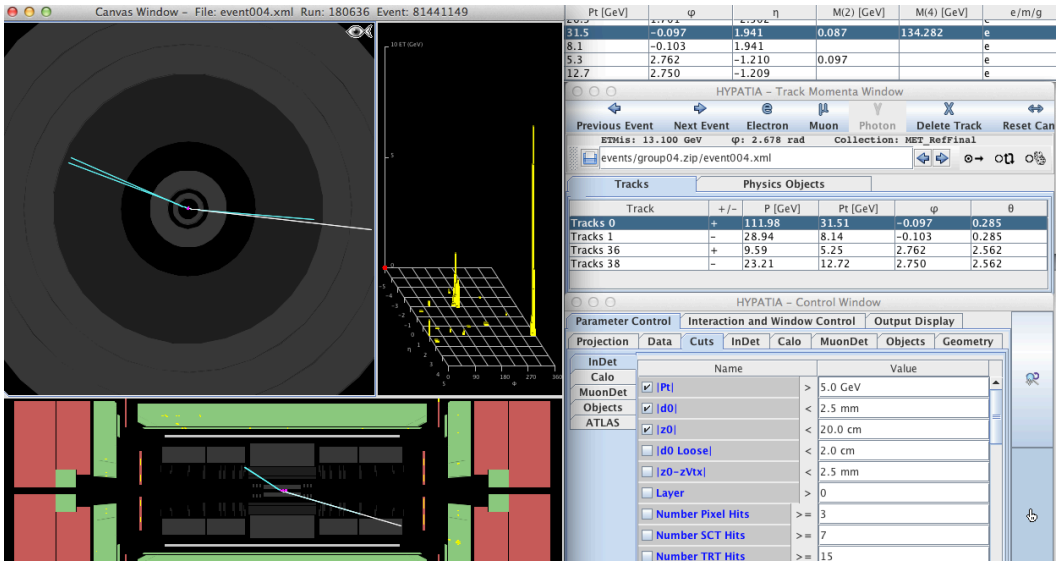


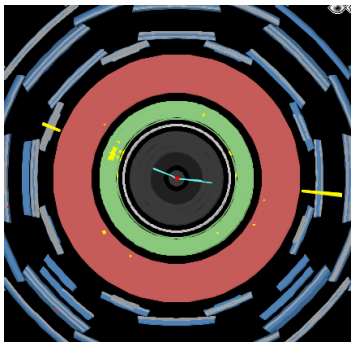


4. Is this event $\gamma\gamma$ or e^+e^-?



Left: pT>1GeV; Right pT>5 GeV. The zoom below reveals 2 pairs of e+e-. The left pair disappears if at least 2 pixel hits are required (see pictures at bottom of page). Each pair has an invariant mass of ~0.1 GeV, i.e. consistent with a photon conversion! We are in presence of 2-photons, both converted. The invariant mass of the 4 electrons is ~134 GeV.





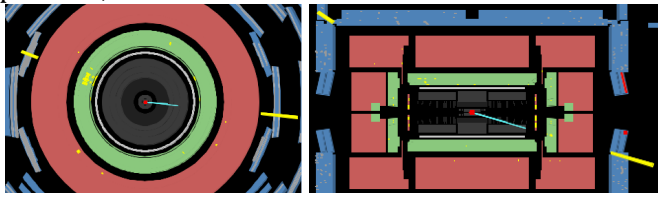
One pair of tracks is rejected by requiring 3 pixel hits.

Here is the calorimeter object information.

Tracks | Physics Objects

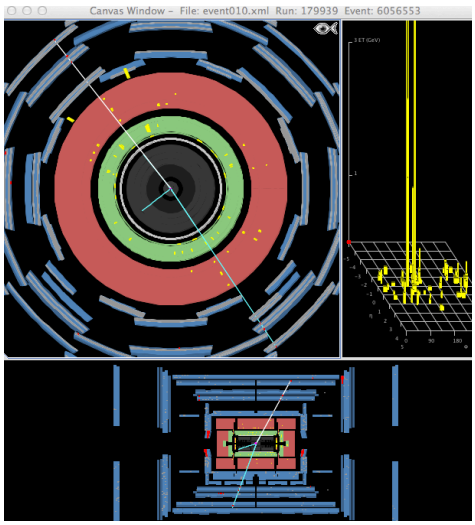
Track	P [GeV]	Pt [GeV]	φ	θ
Object 0	111.67	31.42	-0.099	0.285
Object 1	23.58	12.92	2.755	2.562

The conclusion is that the 2 objects correspond to 2 photons, which have converted and lead to 4 tracks.

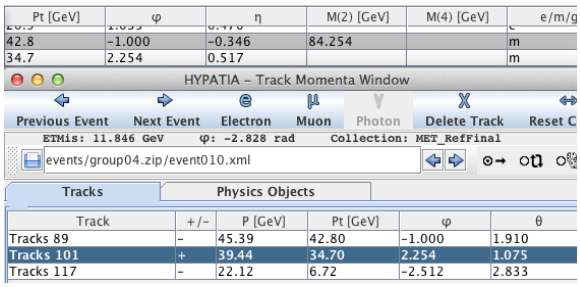


5. A $\mu^+\mu^-$ event

Muons are the easiest particles to recognise: hits in the muon spectrometer and in the inner detector, and at most very little activity in the calorimeter.

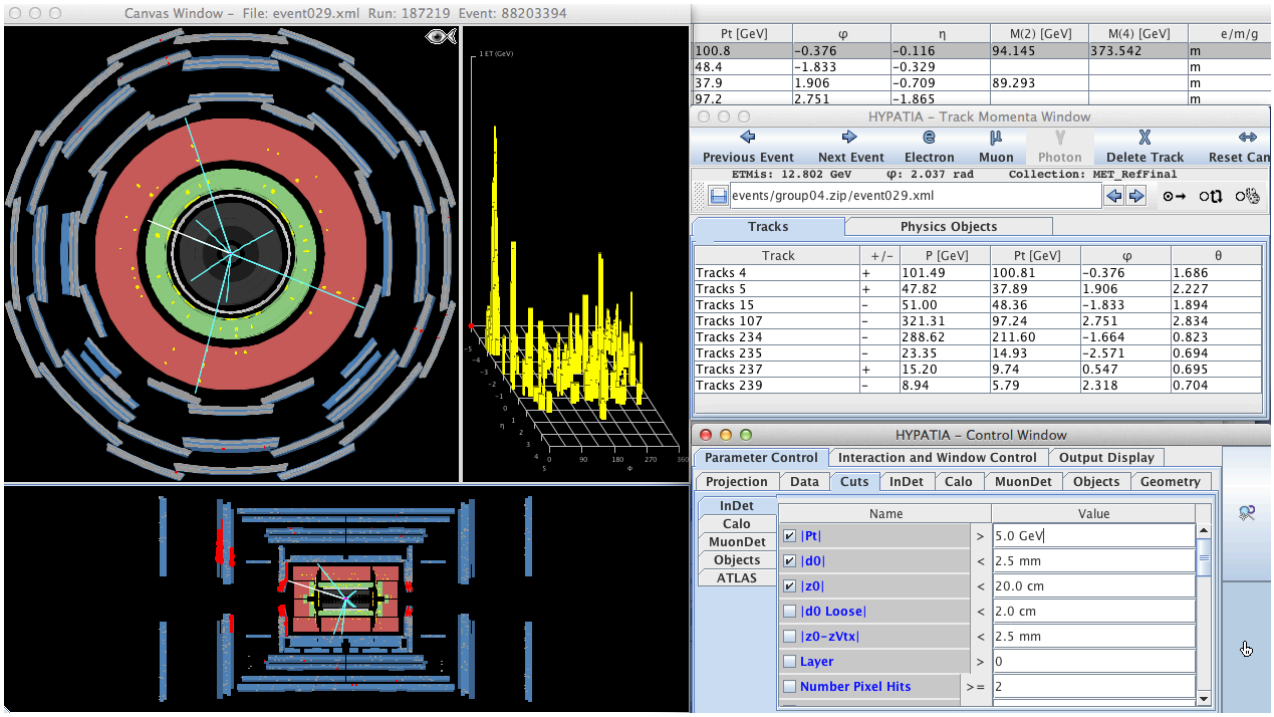


This is an example of di-muon event from Z decay. Two tracks (89 and 117 have opposite charge) with hits in the muon spectrometer (both views). M(μμ)=84.3 GeV.

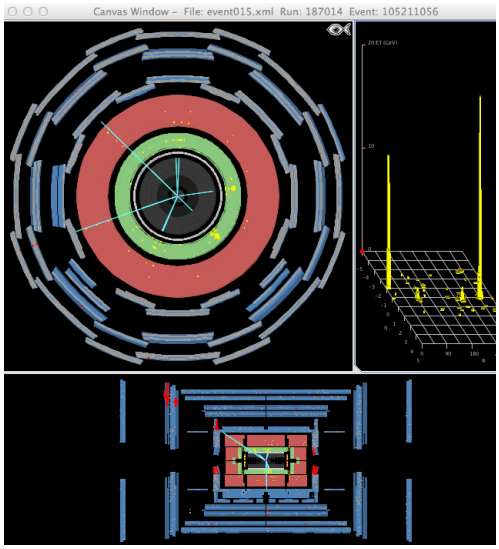


6. A 4-lepton event: $\mu^+\mu^-\mu^+\mu^-$

This interesting event has 4 clear muons, stemming from ZZ→μ⁺μ⁻μ⁺μ⁻ : M(μμ)=94.1 GeV and M(μμ)=89.3 GeV. M(μμμμ)=373.5 GeV. One of the muons has hits only visible in the z-view.



7. A 4-lepton event: $e^+e^-\mu^+\mu^-$



Another 4-lepton event stemming from $ZZ \rightarrow \mu^-\mu^+e^-e^+$ with $M(\mu\mu)=91.1$ GeV and $M(ee)=89.6$ GeV. There are 2 additional tracks, see further below.

Pt [GeV]	φ	η	M(2) [GeV]	M(4) [GeV]	e/m/
35.4	-2.835	0.027	91.056	291.010	m
84.1	2.378	-1.212			m
44.9	0.154	-0.968	89.645		e
75.3	-0.804	0.200			e

HYPATIA – Track Momenta Window

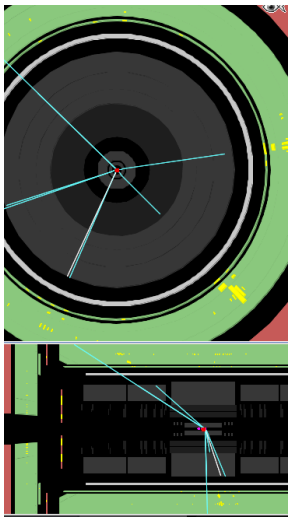
Previous Event | Next Event | Electron | Muon | Photon | Delete Track | Rese

ETMis: 8.258 GeV φ: 0.541 rad Collection: MET_RefFinal

events/group04.zip/event015.xml

Tracks | Physics Objects

Track	+/-	P [GeV]	Pt [GeV]	φ	θ
Tracks 4	+	12.48	11.87	-1.980	1.256
Tracks 6	+	153.74	84.09	2.378	2.563
Tracks 8	-	76.79	75.28	-0.804	1.372
Tracks 11	+	67.65	44.90	0.154	2.416
Tracks 31	-	10.10	9.30	-2.048	1.170
Tracks 72	-	35.46	35.44	-2.835	1.544



The 2 additional tracks (4 and31) with invariant mass $M_{ee}=1.2$ GeV stem from a converted photon. In most cases such tracks disappear when requiring 2 or 3 pixel hits. If not, just ignore them. In fact a higher p_T cut of 12 GeV (well justified) will get rid of them.

Pt [GeV]	φ	η	M(2) [GeV]	M(4) [GeV]	e/m/g
44.9	0.154	-0.968	89.645	122.631	e
75.3	-0.804	0.200			e
9.3	-2.048	0.411	1.203		e
11.9	-1.980	0.320			e

HYPATIA – Track Momenta Window

Previous Event | Next Event | Electron | Muon | Photon | Delete Track | Reset Can

ETMis: 8.258 GeV φ: 0.541 rad Collection: MET_RefFinal

events/group04.zip/event015.xml

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Tracks 6	+	153.74	84.09	2.378	2.563
Tracks 8	-	76.79	75.28	-0.804	1.372
Tracks 11	+	67.65	44.90	0.154	2.416
Tracks 31	-	10.10	9.30	-2.048	1.170
Tracks 72	-	35.46	35.44	-2.835	1.544