ZPATH – Note

Although the first master classes have worked rather well, we have noticed a few things that can be (i) improved and/or (ii) explained if they happen again:

- The students seem to find too many 4-leptons. There are only 1-3 events per 50 events and 34 in total!
- The students seem to misidentify electrons as photons. This leads to a peak on the di-photon invariant mass. This is a good indicator in itself and does not influence too much the rest of the di-photon distribution.
- Entering "di-photon" (objects) and e+e- tracks lead to an enhancement at the "4l" invariant mass.

In addition to the extra instructions for tutors and moderators – see below – we have now updated HYPATIA such that some of the background combinations some students seem to select are marked as "incompatible". Up to now only e-μ invariant masses were considered as incompatible. In order to help the students (who might forget some of the rules) we have now also declared as incompatible combinations with:
- same-sign track (l+l+, l-l-, l+l+l+l-, l-l+l-l-, and in general all combinations with non-zero electric charge)
- and l+l-γγ (these are no 4-lepton combinations)

We insist that if the Zpath instructions are followed the students won't enter those wrong combinations. In case they do, we ask the tutors and moderators to simply explain the origin of the observed enhancements at M_Z in γγ and $2M_Z$ in 4-leptons.
Here is an example of 3 events where we have "simulated" the various background combinations, most of which are now marked as incompatible.

Track	P [GeV]	+/-	Pt [GeV]	φ	η	M(2) [GeV]	M(4) [GeV]	e/m/g
Tracks 22	78.3	+	27.8	-1.048	-1.698	Incompatible	Incompatible	e
Tracks 128	40.0	+	19.5	1.374	-1.342			e
Tracks 155	501.5	+	204.7	1.409	1.545	Incompatible		e
Tracks 156	59.1	+	28.6	-1.206	-1.354			e
Object 0	296.6		100.1	-0.098	-1.750	116.681	Incompatible	g
Object 1	174.5		60.6	-1.792	-1.720			g
Tracks 105	14.2	+	8.4	2.714	-1.124	60.078		e
Tracks 110	297.4	-	100.3	-0.099	-1.750			e
Object 0	51.4		43.2	2.018	-0.608	90.868	Incompatible	g
Object 1	40.6		33.4	-1.366	0.643			g
Tracks 2	40.6	+	33.4	-1.366	0.643	90.869		e
Tracks 141	51.4	-	43.2	2.018	-0.608			e

1st event: selected 2 wrong-sign pairs; the 4l is also incompatible (charge=+4).
2nd event: selected 2 object and 2 opposite-sign charges; M("4l") is incompatible.
3rd event: in a clear Z→e+e- event, selected both objects and corresponding electron tracks; these would have given an enhancement at $2M_Z$; now made incompatible.

1. Important remarks for tutors

Students should not rush to finish all their 50 events: quality better than quantity
The students must follow strictly the following points:

1. Only enter pairs of oppositely charged tracks
    a. Only l+l- or l-l+. No l+l+ or l-l-.
    b. Don't enter l+l+l+l- or l-l-l-l+, … as 4-leptons
2. Do not forget to remove the e+e- tracks entered into the "Invariant Mass Window" in order to test photon conversions.
    a. To remove a track, click on it and click on "Delete Track" in the "Track momentum Window".
3. Do not enter further tracks as electrons (non-pointing or conversions) when physics objects are already entered as photons.
4. For electron track candidates, only enter the track information, not the physics objects in addition.

5. Tell the students that they only expect (1 to 3 max) 4-lepton events in their files.

   The following cuts may help the students to make good choices
6. In general use Pt cut of 5 GeV for tracks (to be efficient to 4-lepton events), and 10 GeV otherwise.
7. To improve the quality of tracks, enable the cuts on "Number of SCT hits" and "Number of Pixel hits".
   a. These cuts should be used as explained in the "instructions" sheet. However, we encourage the students to use them rather then entering blindly tracks, as they limit the number of wrong 4-leptons as well as reduce some of the conversions.
   b. The drawback is that one looses the control over such rejected tracks, leading to some electrons misidentified as photons. This is where a peak (or clustering of entries) around the Z-mass in the di-photon invariant mass is a good indicator!

2. Additional remarks for the moderators

We kindly ask the moderators to read the section above.
If the observations made persist, we ask them to briefly explain why the students might

- see a peak ~90 GeV in the di-photon invariant mass
- see an enhancement at ~180 GeV in the 4-lepton invariant mass
- have too many 4-lepton events than expected
- have entries outside the resonance regions in the di-lepton invariant mass