# Z-Path 2016 – Event Characterisation
# $l^+l^-$ , $\gamma\gamma$ and 4-lepton events

*The recommendations below will help students and tutors to go through the various final states with leptons or photons. This includes events easy to interpret, as well as some difficult ones. The tutors are asked to keep enough time for discussion at the end of the measurements, even if the students would not finish their assigned sample. Quality primes against quantity and some extra work dedicated to difficult (and very interesting) cases should be encouraged. It is also through such cases that students will learn a lot.*

## Briefly:

1. Set a minimum pT cut of 5 GeV
2. Study remaining tracks and/or physics objects and classify if compatible with muon, electron or photon.
3. Zoom in both views to distinguish between single and double tracks
4. Check whether the invariant mass of a double track is consistent with a converted photon
5. If needed, require at least 2 pixel and/or 7 SCT hits hits to make sure that single or double tracks stem from a primary vertex.
6. Check that your selected track come from the same vertex

## In more details:

**1. Set a $p_T$ cut of tracks in HYPATIA control window (cuts, InDet):**

1.1. A cut of 5 GeV is recommended in order not to miss some 4-lepton events.

1.2. You can increase the value to gain clarity in particularly crowded events.

**2. If tracks extend to the muon system (MS):**

2.1. Enter particles as muons if they have opposite electric charges

2.2. If no other pairs of leptons, proceed to the next event. If an additional pair of leptons is found (muons or electrons – see electron identification below) the event may contain 4 leptons and should be categorised correspondingly.

**3. To find electrons or photons, start either from "Tracks" or "Physics Objects" (HYPATIA – track momenta window)**

**3.1. Starting from "Tracks"**

3.1.1. Look for tracks in the inner detector pointing towards significant energy deposits in the electromagnetic calorimeter (ECAL)

3.1.2. A track might seem to point to a cluster in the side-view but not in the end-view (or vice versa), so **both views should be checked**

*3.1.3.* If 2 oppositely charged tracks are found that clearly point to one ECAL cluster each, **enter them as electrons**.

3.1.4. If 2 energy clusters are found in the ECAL without tracks pointing to them, go to "Physics Objects" and enter them as photons

**3.2. Starting from "Physics Objects"**

3.2.1. If at least 2 objects are found corresponding to significant ECAL energy deposits, these correspond most probably either to electrons or photons

3.2.2. Check tracks – **zoom to distinguish single and double (very close) tracks** – a track might seem to point to a cluster in the side-view but not in the end-view (or vice versa), so **both views should be checked** before classifying as electron/photon:

3.2.2.1. If 2 (single) oppositely charged tracks are found pointing to an ECAL cluster each, **enter them as electrons** (from the **"Tracks"** tab)

3.2.2.2. If no tracks are found pointing to the ECAL clusters, **enter the objects as photons** (from the **"Physics Objects"** tab)

**3.3. Converted photons lead to close, oppositely charged tracks with very small invariant mass**

3.3.1. 2 very close tracks pointing to one ECAL cluster may come from a converted photon ($\gamma \rightarrow e^+e^-$). To check this, enter the 2 tracks as electrons and read the resulting invariant mass.

3.3.1.1. In most cases M(ee) is very close to 0, such that you can go back to the "Physics Object" and enter the object as photon. **Remember to take the electrons out of the invariant mass table again**.

3.3.1.2. In some cases the tracks disappear when requiring at least 2 pixel hits and/or 7 SCT hits, see below, such that you are left with 2 isolated photons in the event.

4. **A Cut on "Number Pixel Hits" >=2** may help getting rid of a single track or a double track (from a converted photon) that do not come from a primary vertex (main interaction point)
5. **A cut on "Number SCT hits" >=7** may help having good, long tracks.
6. By zooming in on the side-view window, investigate if your selected tracks come from the same vertex (originate from the same place)**. If not; the two tracks can not come from the same heavy particle and thus are not the ones you are looking for.**