GET STARTED ON THE WEB WITH HYPATIA AND OPloT

You will now analyze up to 50 particle collisions (events) by using the visualization application HYPATIA.

From these collisions, you shall try to find the footprints from heavy neutral particles, like for instance the Z-boson or the Higgs boson.

All you need can be found at
http://atlas.physicsmasterclasses.org/en/zpath_measurement.htm (replace /en/ with your language)

This is:
1. The HYPATIA application and instructions
2. Your unique dataset - ask your tutor if you need help
3. The web plotting tool OPloT: http://cernmasterclass.uio.no/OPloT/
   - username: ippog
   - password: mc13

Do the following:
Go to the Z-Path: http://atlas.physicsmasterclasses.org/en/zpath_measurement.htm
1. Instructions of what to do can be found under the sub-menu items of **"Get to work"**:

   - Get to work→Data samples and tools
   - Get to work→Do it!
   - Get to work→Analyze your result (together with rest of students and tutors)

2. Find and download your data sample - follow instructions found at **"Data samples and tools"**.

   - To start HYPATIA
     - On a Windows or Mac:
       - Double-click the file Hypatia_7.4_Masterclass.jar
     - On Linux:
       - Right-click the file: HYPATIA_for_Linux.sh
       - Change the permissions to make it executable
       - Double-click the HYPATIA_for_Linux.sh file
   - Unzip data sample
   - Load events in HYPATIA with File→Read Events Locally - Navigate to your downloaded and unzipped data sample

3. If you need hints on how to use HYPATIA, and how to identify particles and events go to

   - How to use HYPATIA: Identifying Particles→Visualization with HYPATIA
   - How to identify particles: Identifying Particles→Particle footprint Visualization
   - How to identify events: Identifying Events→Visualization

4. After you are done analyzing your events, export the *Invariant Mass Table*

   - File→Export Invariant Masses
   - Place it in the default area, or on the Desktop. Remember where you put it!

5. Upload the file just produced (Invariant_Masses.txt) to OPloT

   - http://cernmasterclass.uio.no/OPloT/
   - Choose: Student → Year → Month → Date → Institute
   - Chose the correct group according to the description on OPloT
   - Upload your file Invariant_Masses.txt.

6. Congratulations - you have delivered your results!

Some recommendations how to tackle the detective work in HYPATIA
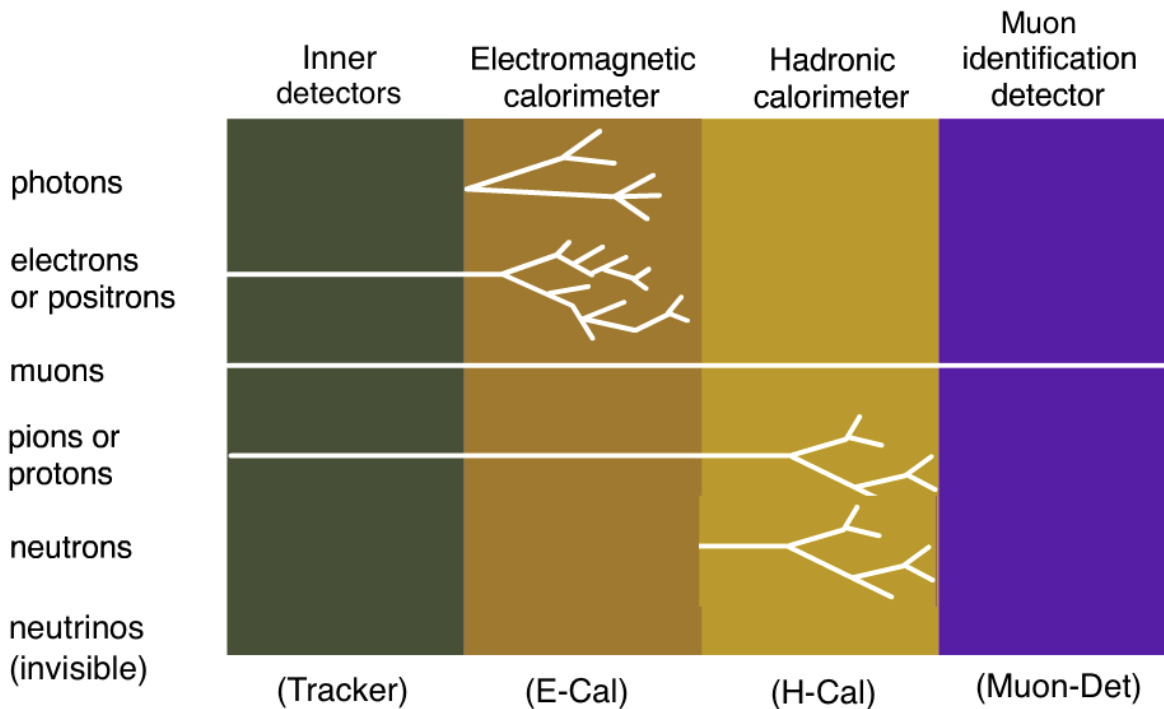
Briefly:
1. Set a minimum pT cut of 5 GeV
2. Study remaining tracks and/or physics objects and classify if compatible with muon, electron or photon.
3. Zoom in both views to distinguish between single and double tracks
4. Check whether the invariant mass of a double track is consistent with a converted 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:
- **Set a p_T cut of tracks in HYPATIA control window (cuts, InDet):**
  - A cut of 5 GeV is recommended in order not to miss some 4-lepton events.
  - You can increase the value to gain clarity in particularly crowded events.
- **If tracks extend to the muon system (MS):**
  - Enter particles as muons if they have opposite electric charges
  - 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.
- **To find electrons or photons, start either from "Tracks" or "Physics Objects" (HYPATIA – track momenta window)**
  - **Starting from "Tracks"**
    - Look for tracks in the inner detector pointing towards significant energy deposits in the electromagnetic calorimeter (ECAL)
    - 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**
    - If 2 oppositely charged tracks are found that clearly point to one ECAL cluster each, **enter them as electrons**.
    - If 2 energy clusters are found in the ECAL without tracks pointing to them, go to "Physics Objects" and enter them as photons
  - **Starting from "Physics Objects"**
    - If at least 2 objects are found corresponding to significant ECAL energy deposits, these correspond most probably either to electrons or photons
    - 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:
      - If 2 (single) oppositely charged tracks are found pointing to an ECAL cluster each, **enter them as electrons** (from the **"Tracks"** tab)
      - If no tracks are found pointing to the ECAL clusters, **enter the objects as photons** (from the **"Physics Objects"** tab)
  - **Converted photons lead to close, oppositely charged tracks with very small invariant mass**
    - 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.
      - 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**.
      - 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.
- **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)

- **A cut on "Number SCT hits" >=7** may help having good, long tracks.
- By zooming in on the z-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.**

	Inner detectors	Electromagnetic calorimeter	Hadronic calorimeter	Muon identification detector
photons				
electrons or positrons				
muons				
pions or protons				
neutrons				
neutrinos (invisible)				
	(Tracker)	(E-Cal)	(H-Cal)	(Muon-Det)

Electrons and photons:
- Leave energy-deposit in E-Cal
- Stop in E-Cal

Electron:
    Leaves a track in Tracker

Photon:
    Leaves **no** track in Tracker

Protons and neutrons:
- Leave energy deposit in H-Cal (and possibly a little in E-Cal)
- Stop in H-Cal

Proton:
Leaves track in Tracker

Neutron:
Leaves **no** track in Tracker

Muons:
- Leave track in Tracker
- Reach all the way out to the MuonDet
- Leave little energy deposit in E-Cal and H-Cal

Jets (not shown here):
- Are showers of particles, for instance a shower of neutrons, protons and other hadrons
- Leave many tracks in Tracker
- Leave energy-deposit in H-Cal (and possibly some in E-Cal)
- Stop in H-Cal

Neutrinos:
- Leave the whole detector without a trace
- Can only be inferred by the missing energy (ETMis) in the energy balance of the collision
- Indicated with red dashed line in HYPATIA

TYPICAL electron-positron event

- Energy deposits in electromagnetic calorimeters (E-Cal) (red circles)

- Tracks in the inner detector pointing towards the energy deposits

- One particle should be positive, the other negative

- NB! Remember to also investigate the longitudinal display, not just transverse as shown here!
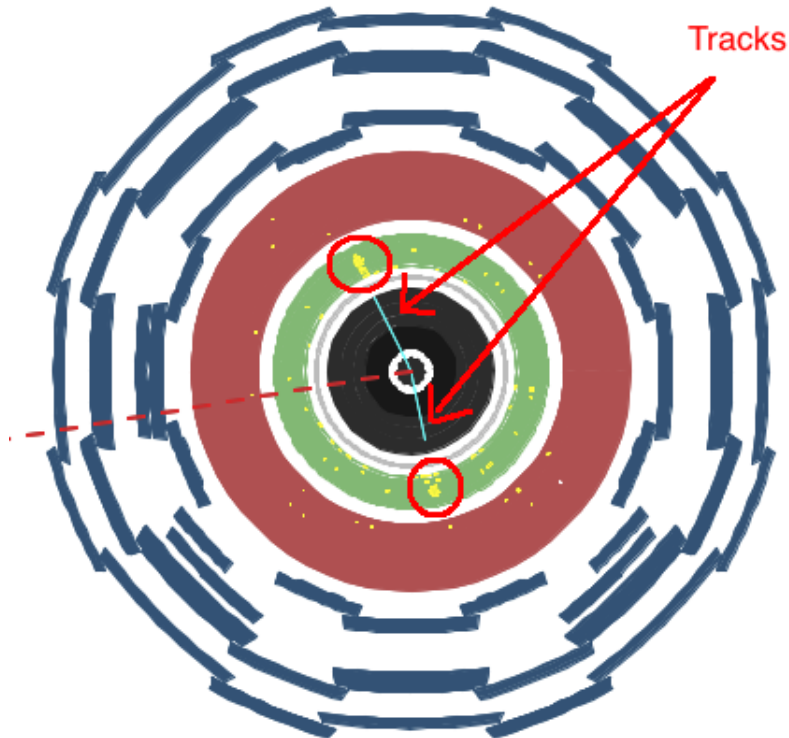

HYPATIA – Track Momenta Window

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

ETMis: 16.187 GeV   φ: -2.974 rad   Collection: MET_RefFinal

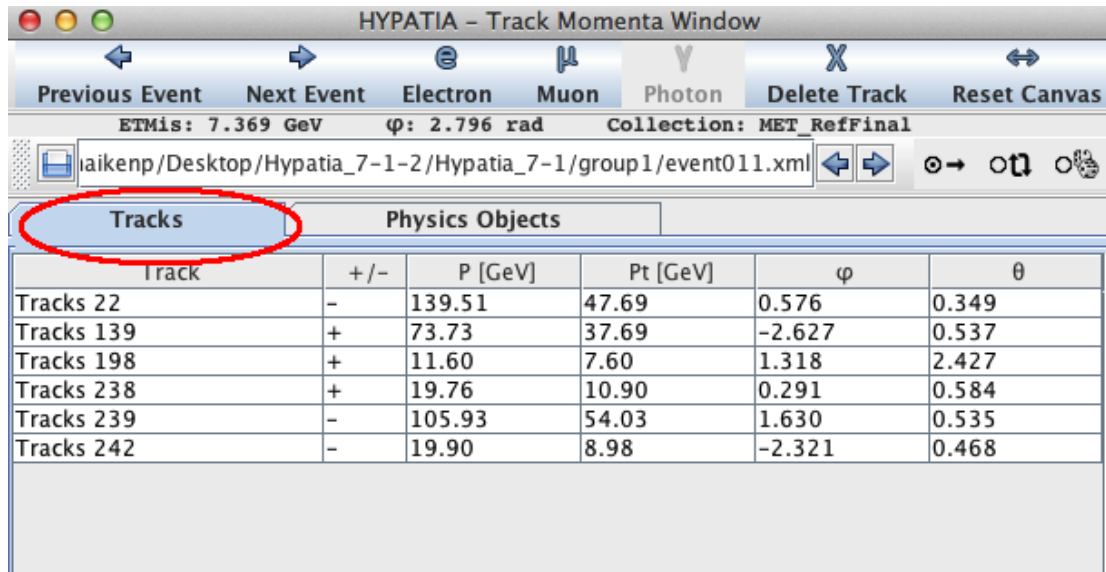aikenp/Desktop/Hypatia_7-1-2/Hypatia_7-1/group1/event013.xml

Tracks   Physics Objects

| Track	+/-	P [GeV]	Pt [GeV]	φ	θ
Tracks 2	+	40.57	33.41	-1.366	0.968
Tracks 141	-	51.42	43.19	2.018	2.144

Tracks

TYPICAL muon-antimuon event

- Tracks all the way through the detector and into muon detector

- One particle should be positive, the other negative

- NB! Remember to also investigate the longitudinal display, not just transverse as shown here!
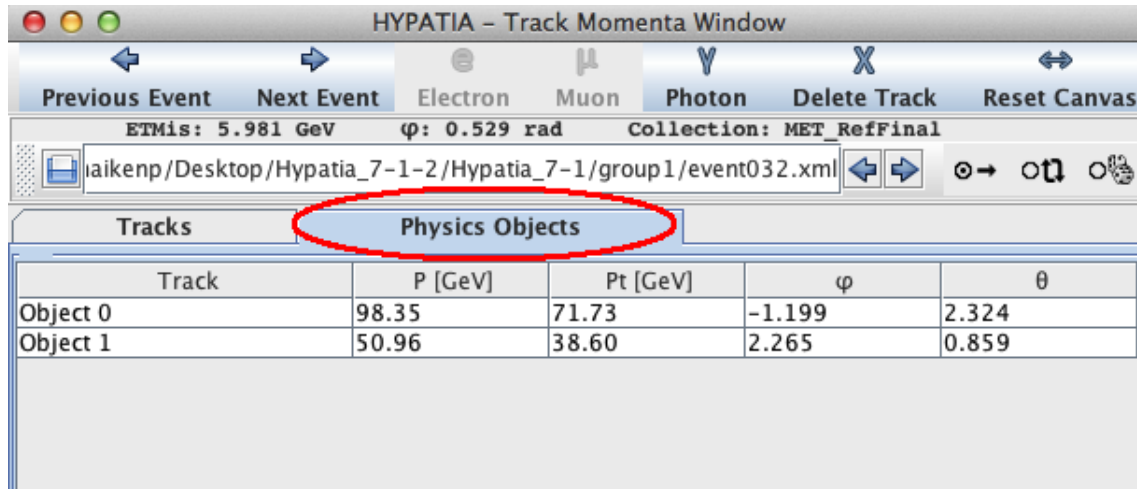

HYPATIA – Track Momenta Window

Previous Event   Next Event   Electron   Muon   Photon   Delete Track   Reset Canvas

ETMis: 7.369 GeV   φ: 2.796 rad   Collection: MET_RefFinal

aikenp/Desktop/Hypatia_7-1-2/Hypatia_7-1/group1/event011.xml

Tracks | Physics Objects

| Track	+/-	P [GeV]	Pt [GeV]	φ	θ
Tracks 22	-	139.51	47.69	0.576	0.349
Tracks 139	+	73.73	37.69	-2.627	0.537
Tracks 198	+	11.60	7.60	1.318	2.427
Tracks 238	+	19.76	10.90	0.291	0.584
Tracks 239	-	105.93	54.03	1.630	0.535
Tracks 242	-	19.90	8.98	-2.321	0.468

Long tracks through muon detector
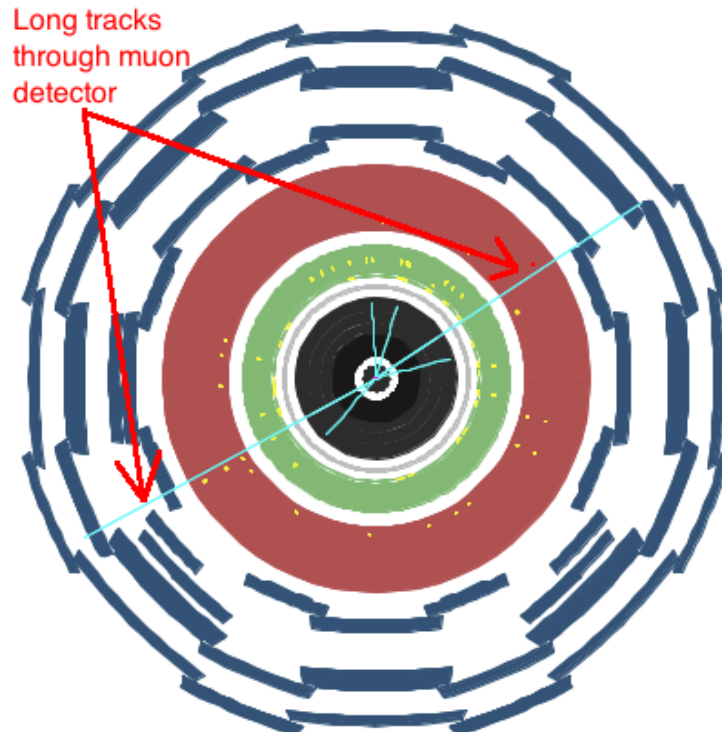
EXAMPLE of unconverted di-photon event

- Energy deposits in the electromagnetic calorimeter (red circles)

- Objects in the Physics Objects Tab, and marked with yellow "towers" (red arrows in figure to the right)

- No tracks in inner detector pointing towards the energy deposits

- NB! Remember to also investigate the longitudinal display, not just transverse as shown here!

NB! Photons can also be converted, and there will then be tracks in the inner detector. Needs your further analysis!
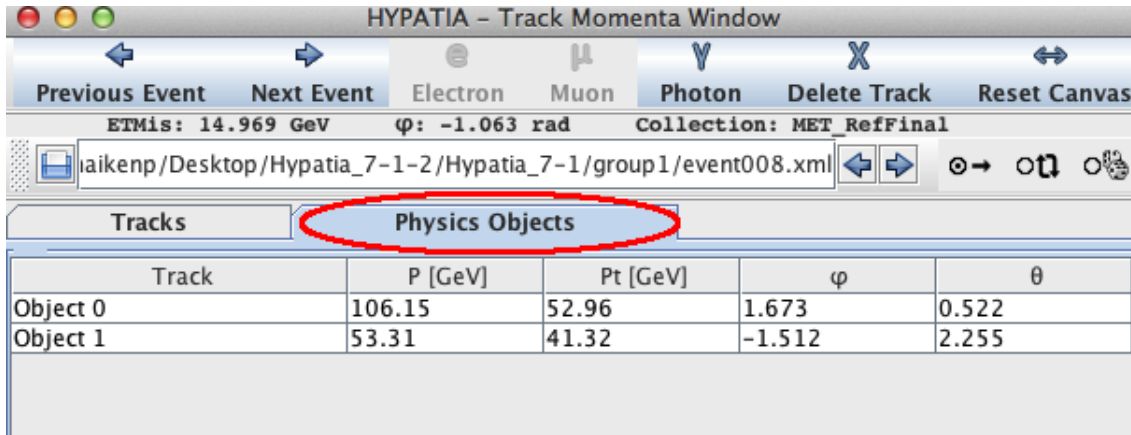

Track	P [GeV]	Pt [GeV]	φ	θ
Object 0	98.35	71.73	-1.199	2.324
Object 1	50.96	38.60	2.265	0.859

Physics Objects marked as Yellow towers
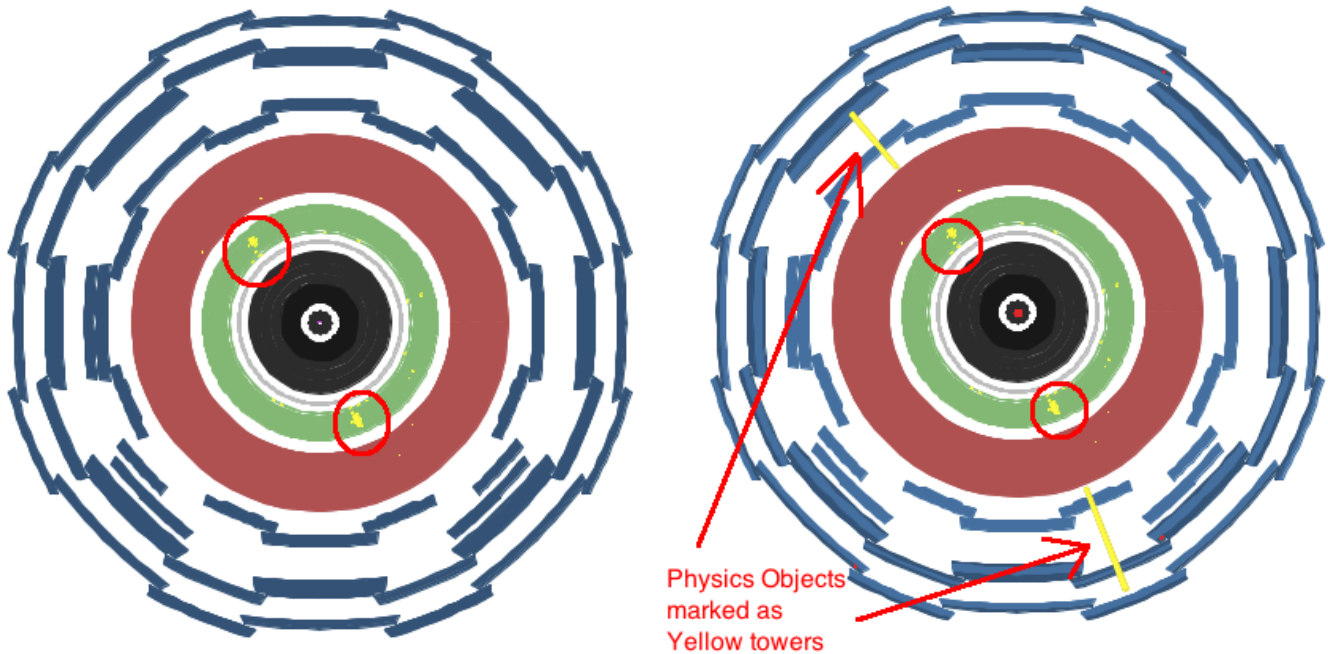
EXAMPLE of converted di-photon event

- Energy deposit in the electromagnetic calorimeter (red circles)

- Objects in the Physics Objects Tab, and marked with yellow "towers" (red arrows in figure to the right)

- Two tracks very close together pointing towards an energy deposit. If there is exactly one track pointing to each energy deposit, the event is most likely an electron-positron event!

- NB! Remember to also investigate the longitudinal display, not just transverse as shown here!