

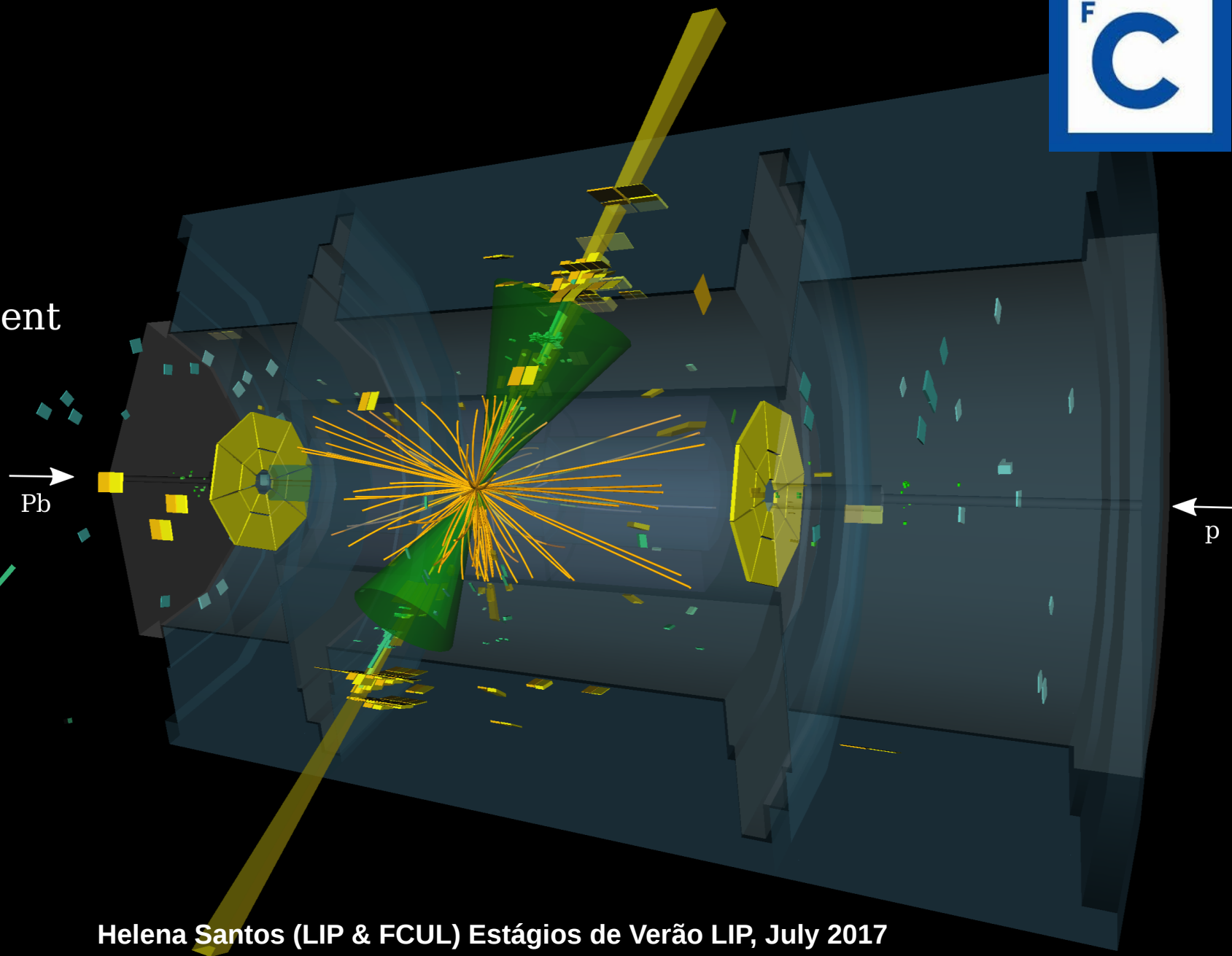


# HYPATIA Hands On



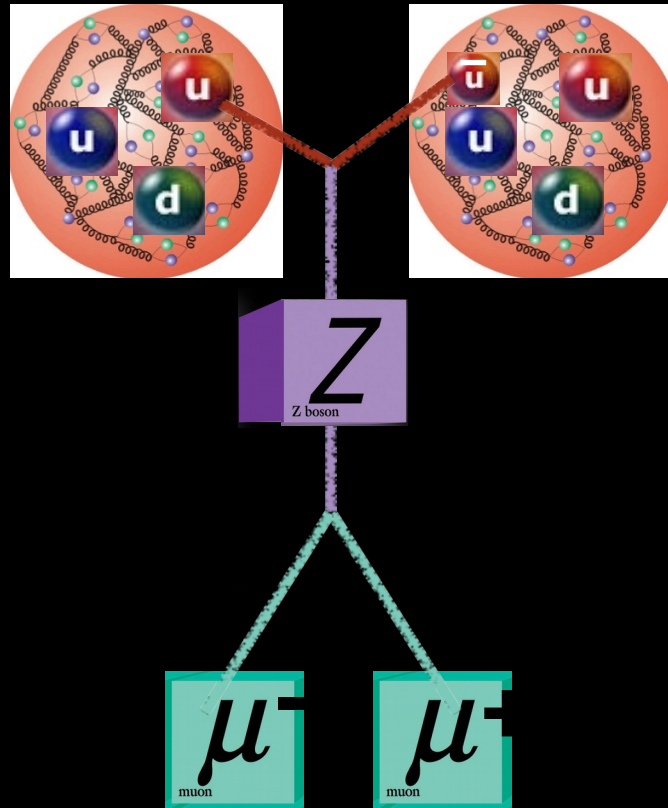
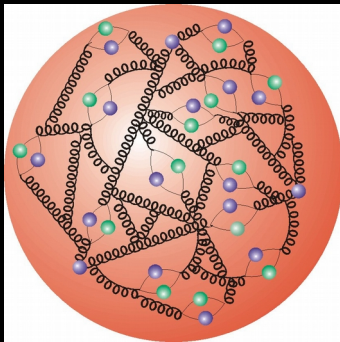
## Dijet p+Pb event

Run: 217946  
Event: 13617174  
Date: 2013-01-20



$$Z \rightarrow \mu^+ \mu^-$$

Na realidade, para além dos quarks  $uud$ , o protão é composto por um mar de quarks e glúões



|         |   |               |
|---------|---|---------------|
| $f$     | + | $\bar{f}$     |
| $2/3e$  |   | $(-1/3e)$     |
|         |   | $-2/3e(1/3e)$ |
| $Z$     |   |               |
| ↓       |   |               |
| $\mu^+$ | + | $\mu^-$       |
| $-1e$   |   | $1e$          |

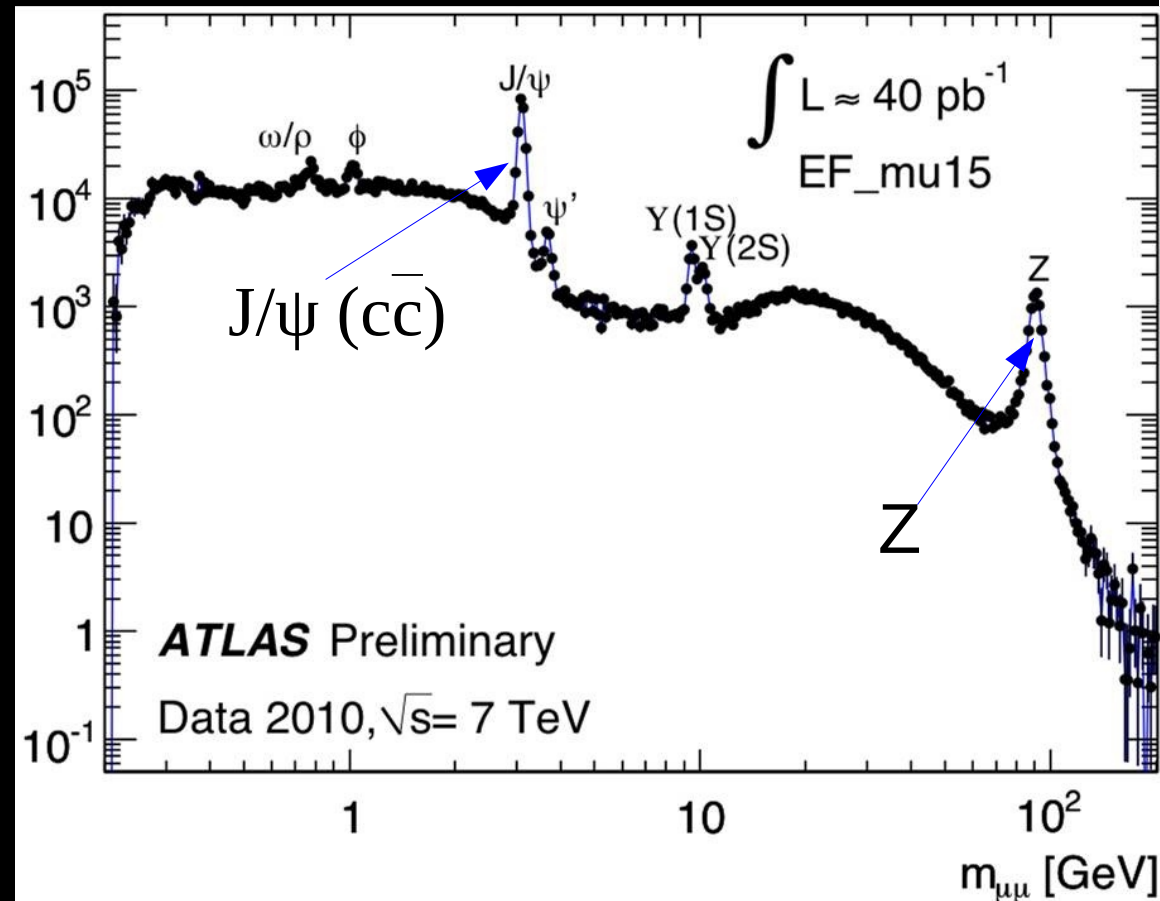
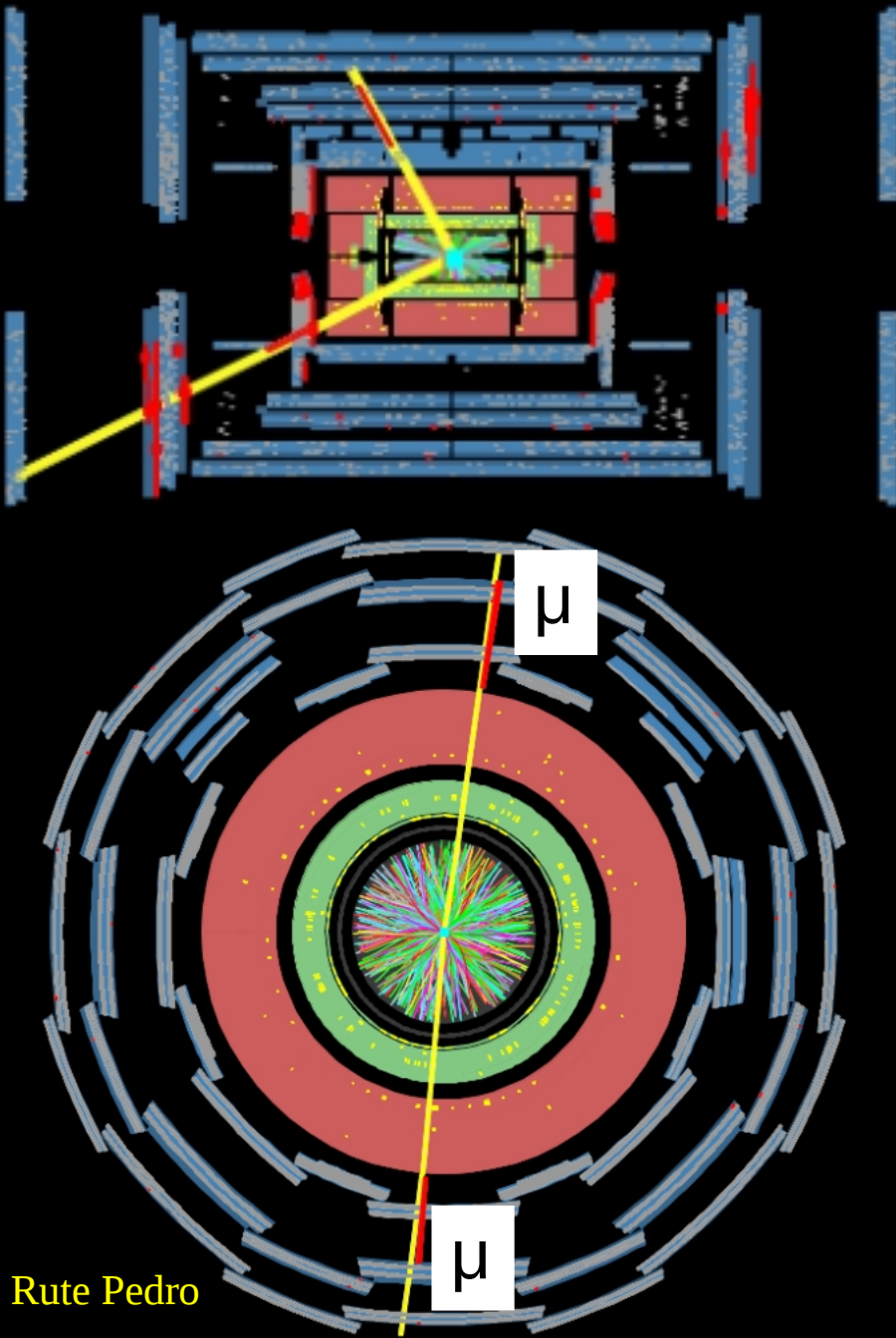
$$M^Z = \frac{\sqrt{2E_{\mu^-} E_{\mu^+} (1 - \cos \theta_{\mu^- \mu^+})}}{c^2}$$

O Z tem outros decaimentos:  $Z \rightarrow e^+ e^-$ ,  $\tau^+ \tau^-$ , par de quarks ou neutrinos. Na nossa actividade vamos considerar também o processo  $Z \rightarrow e^+ e^-$

$$Z \rightarrow \mu^+ \mu^-$$

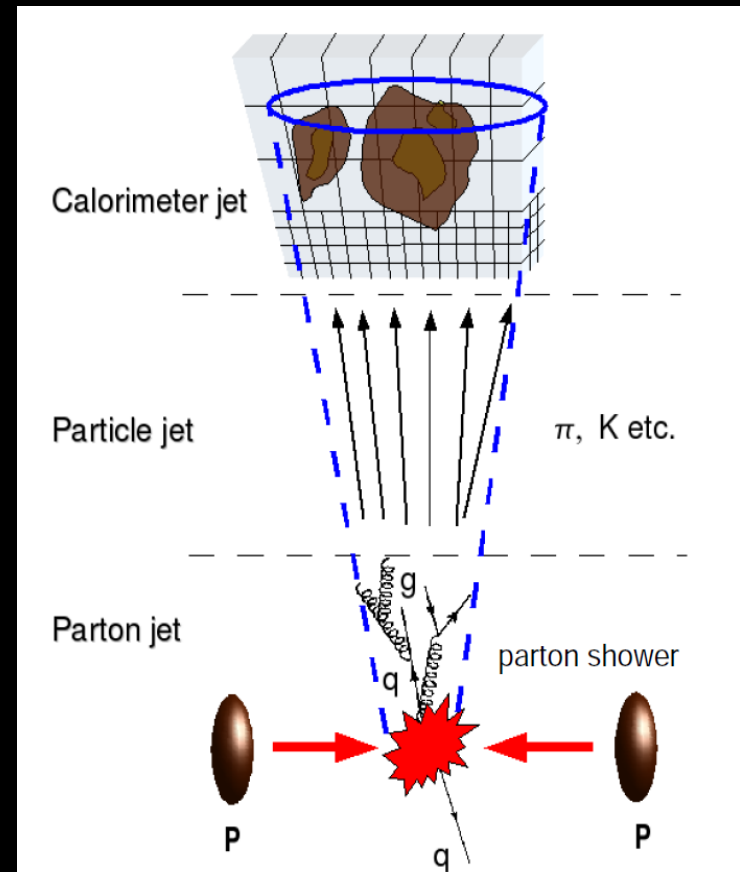
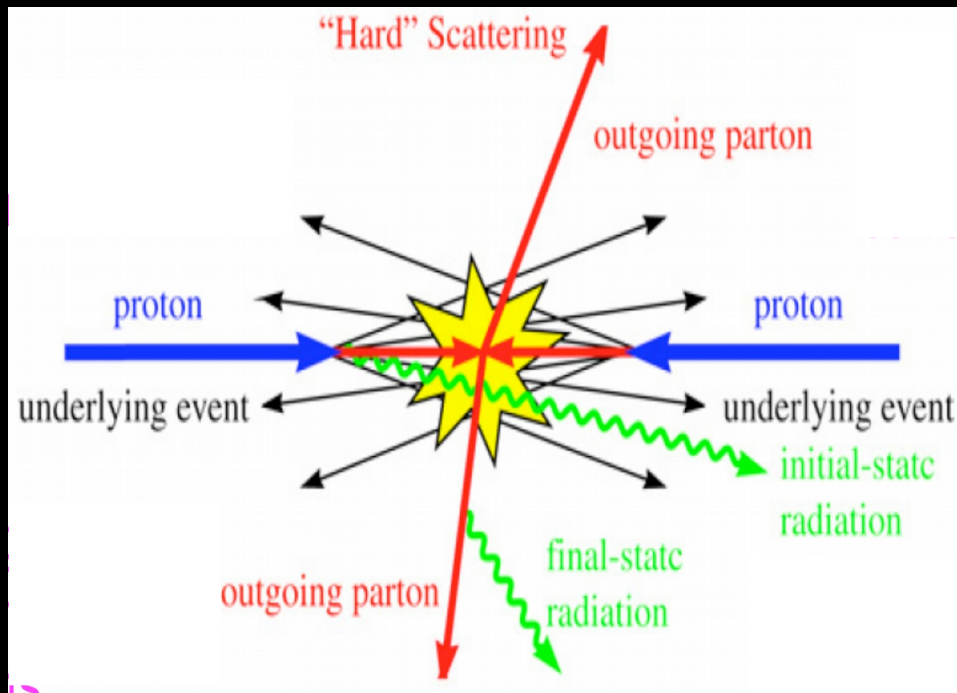
Depois de muitos eventos...

Espectro de massa invariante dos pares de muões

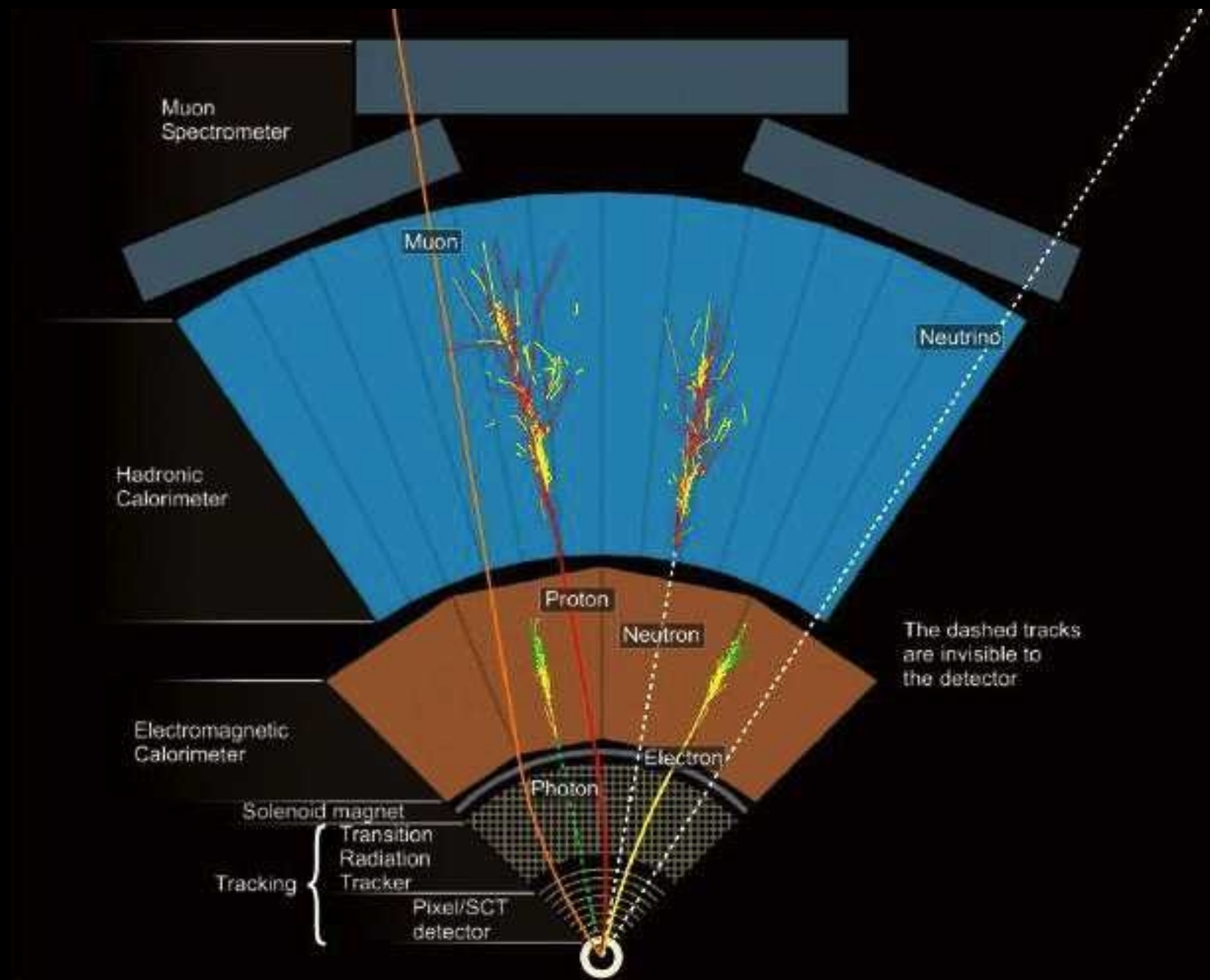


Na nossa actividade vamos considerar também o processo  $Z \rightarrow e^+ e^-$

# p+p collisions – the common picture



# Particle Detectors



# HYPATIA

- interactive event display of real data of collisions  
@  $\sqrt{s} = 8 \text{ TeV}$
- Event classification, histograming

user: idpasc17

passwd: WPL\*9999

`$java -jar Hypatia_7.4_Masterclass.jar`

# Events (Track Momenta Window):

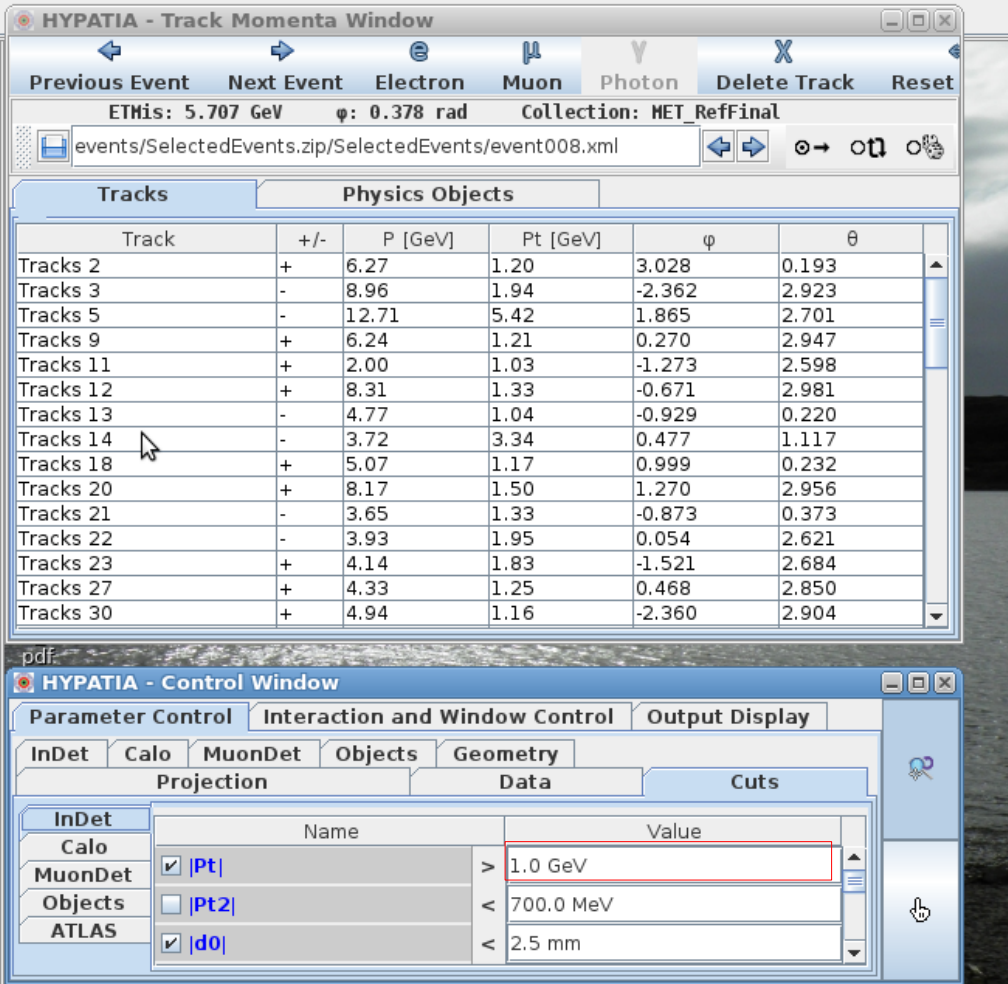
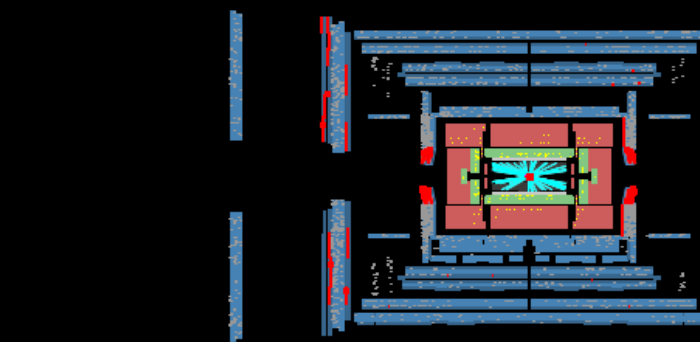
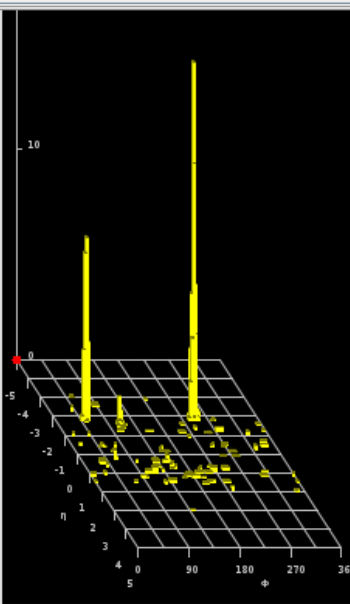
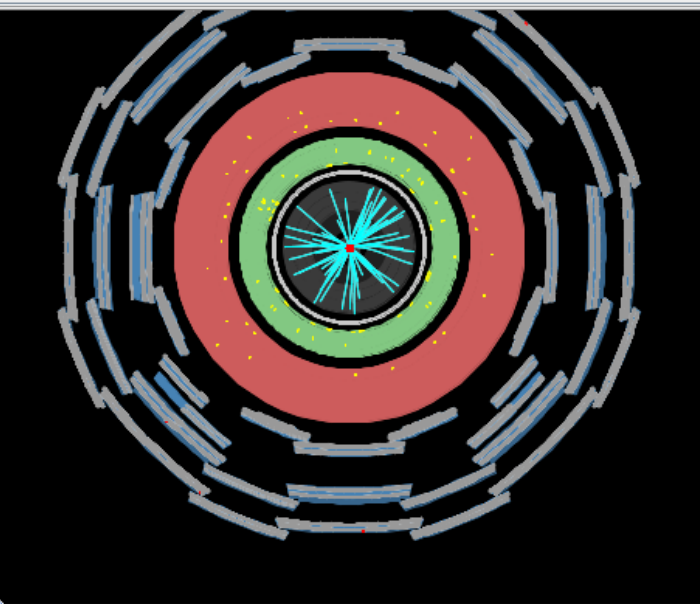
events/SelectedEvents.zip

Applications Places System

HYbrid Pupils' Analysis Tool for Interactions in ATLAS - version 7.4 - Invariant Mass Window

File View Histograms Preferences Help

File Name ETMis [GeV] Track P [GeV] +/- Pt [GeV]  $\phi$   $\eta$  M(2) [GeV] M(eeee) [GeV] M(eemm) [GeV] M(mmmm) [G... e/m/g



**HYPATIA - Track Momenta Window**

Previous Event Next Event Electron Muon Photon Delete Track Reset

ETMis: 5.707 GeV  $\phi$ : 0.378 rad Collection: MET\_RefFinal

events/SelectedEvents.zip/SelectedEvents/event008.xml

| Track     | +/- | P [GeV] | Pt [GeV] | $\phi$ | $\theta$ |
|-----------|-----|---------|----------|--------|----------|
| Tracks 2  | +   | 6.27    | 1.20     | 3.028  | 0.193    |
| Tracks 3  | -   | 8.96    | 1.94     | -2.362 | 2.923    |
| Tracks 5  | -   | 12.71   | 5.42     | 1.865  | 2.701    |
| Tracks 9  | +   | 6.24    | 1.21     | 0.270  | 2.947    |
| Tracks 11 | +   | 2.00    | 1.03     | -1.273 | 2.598    |
| Tracks 12 | +   | 8.31    | 1.33     | -0.671 | 2.981    |
| Tracks 13 | -   | 4.77    | 1.04     | -0.929 | 0.220    |
| Tracks 14 | -   | 3.72    | 3.34     | 0.477  | 1.117    |
| Tracks 18 | +   | 5.07    | 1.17     | 0.999  | 0.232    |
| Tracks 20 | +   | 8.17    | 1.50     | 1.270  | 2.956    |
| Tracks 21 | -   | 3.65    | 1.33     | -0.873 | 0.373    |
| Tracks 22 | -   | 3.93    | 1.95     | 0.054  | 2.621    |
| Tracks 23 | +   | 4.14    | 1.83     | -1.521 | 2.684    |
| Tracks 27 | +   | 4.33    | 1.25     | 0.468  | 2.850    |
| Tracks 30 | +   | 4.94    | 1.16     | -2.360 | 2.904    |

**HYPATIA - Control Window**

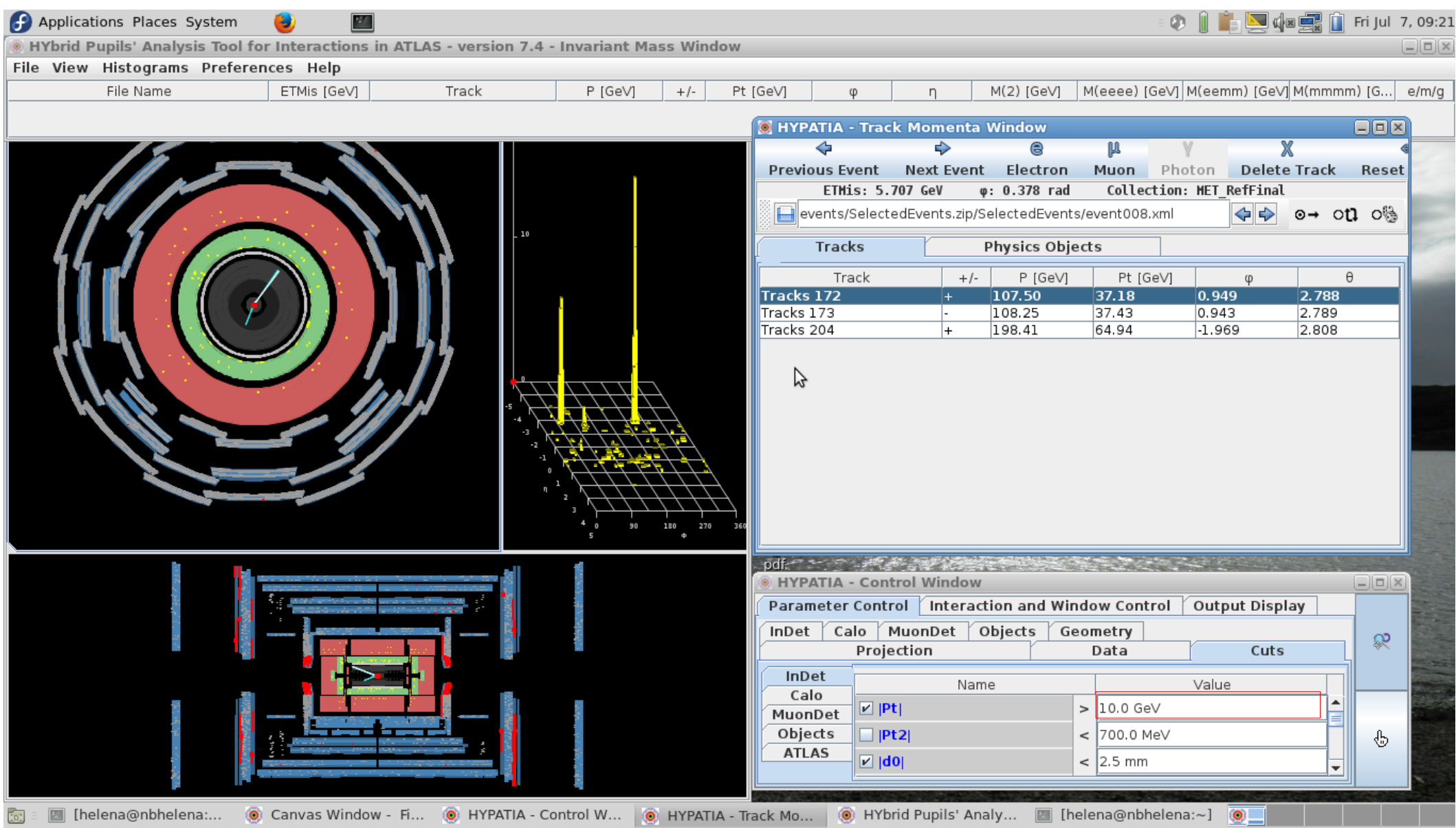
Parameter Control Interaction and Window Control Output Display

InDet Calo MuonDet Objects Geometry

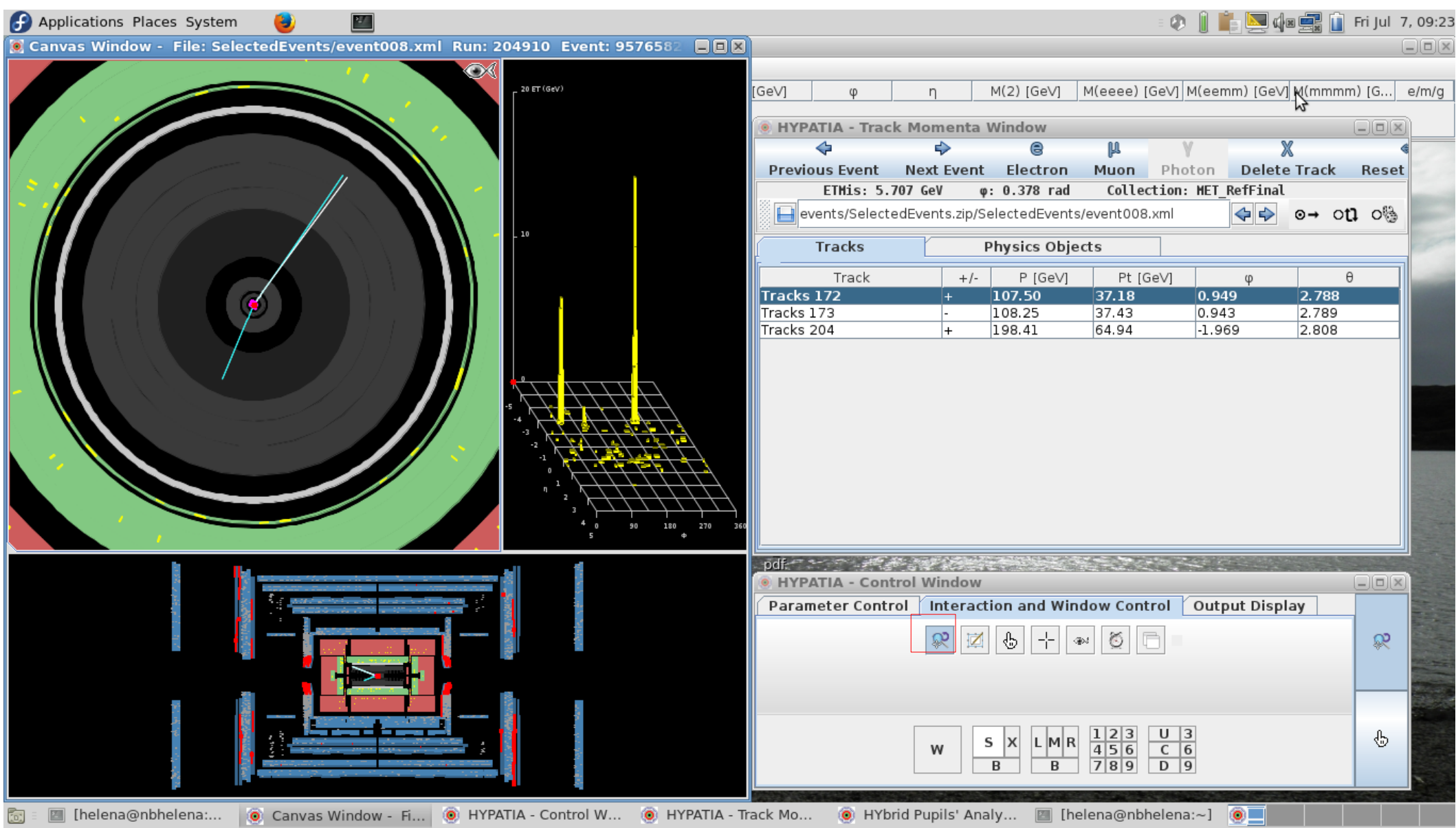
Projection Data Cuts

| Name                                    | Value       |
|-----------------------------------------|-------------|
| <input checked="" type="checkbox"/>  Pt | > 1.0 GeV   |
| <input type="checkbox"/>  Pt2           | < 700.0 MeV |
| <input checked="" type="checkbox"/>  d0 | < 2.5 mm    |

[helena@nbhelena:...] Canvas Window - Fi... HYPATIA - Control W... HYPATIA - Track Mo... HYbrid Pupils' Analy... [helena@nbhelena:~]



Cut at  $p_T > 10$  GeV is somewhat arbitrary but is useful at this step.

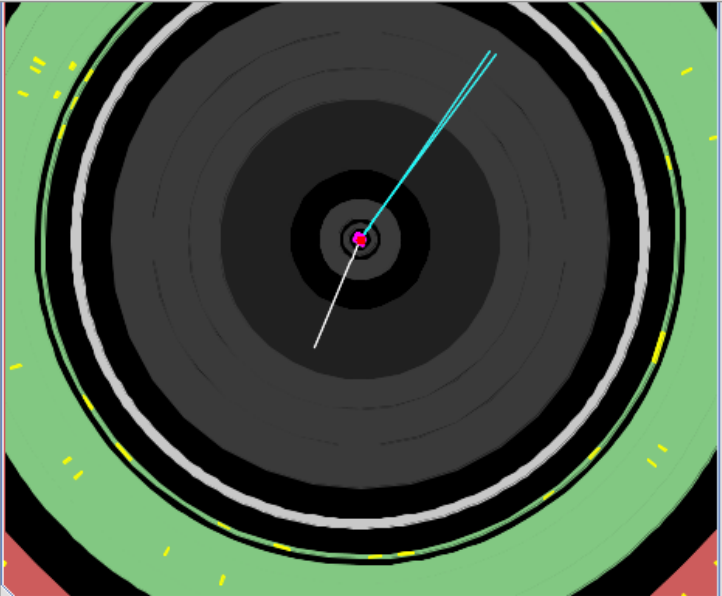
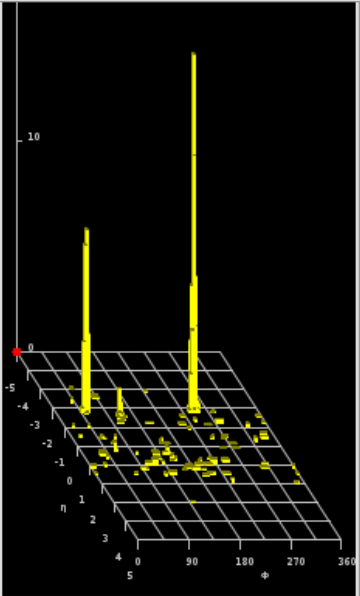
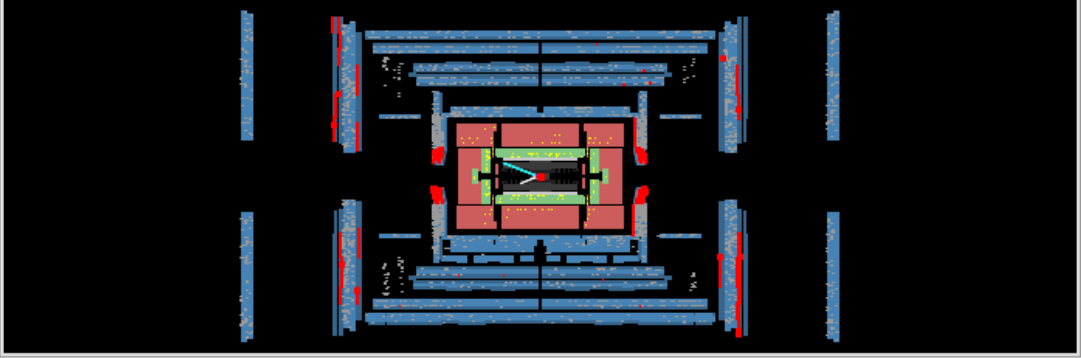


Applications Places System Fri Jul 7, 09:25

### HYbrid Pupils' Analysis Tool for Interactions in ATLAS - version 7.4 - Invariant Mass Window

File View Histograms Preferences Help

| File Name                   | ETMis [GeV] | Track      | P [GeV] | +/- | Pt [GeV] | $\phi$ | $\eta$ | M(2) [GeV] | M(eeee) [GeV] | M(eemm) [GeV] | M(mmmm) [G...] | e/m/g |
|-----------------------------|-------------|------------|---------|-----|----------|--------|--------|------------|---------------|---------------|----------------|-------|
| SelectedEvents/event008.xml | 5.707       | Tracks 173 | 108.2   | -   | 37.4     | 0.943  | -1.724 | 97.988     |               |               |                | e     |
|                             |             | Tracks 204 | 198.4   | +   | 64.9     | -1.969 | -1.782 |            |               |               |                | e     |

#### HYPATIA - Track Momenta Window

Previous Event Next Event Electron Muon Photon Delete Track Reset

ETMis: 5.707 GeV  $\phi$ : 0.378 rad Collection: MET\_RefFinal

events/SelectedEvents.zip/SelectedEvents/event008.xml

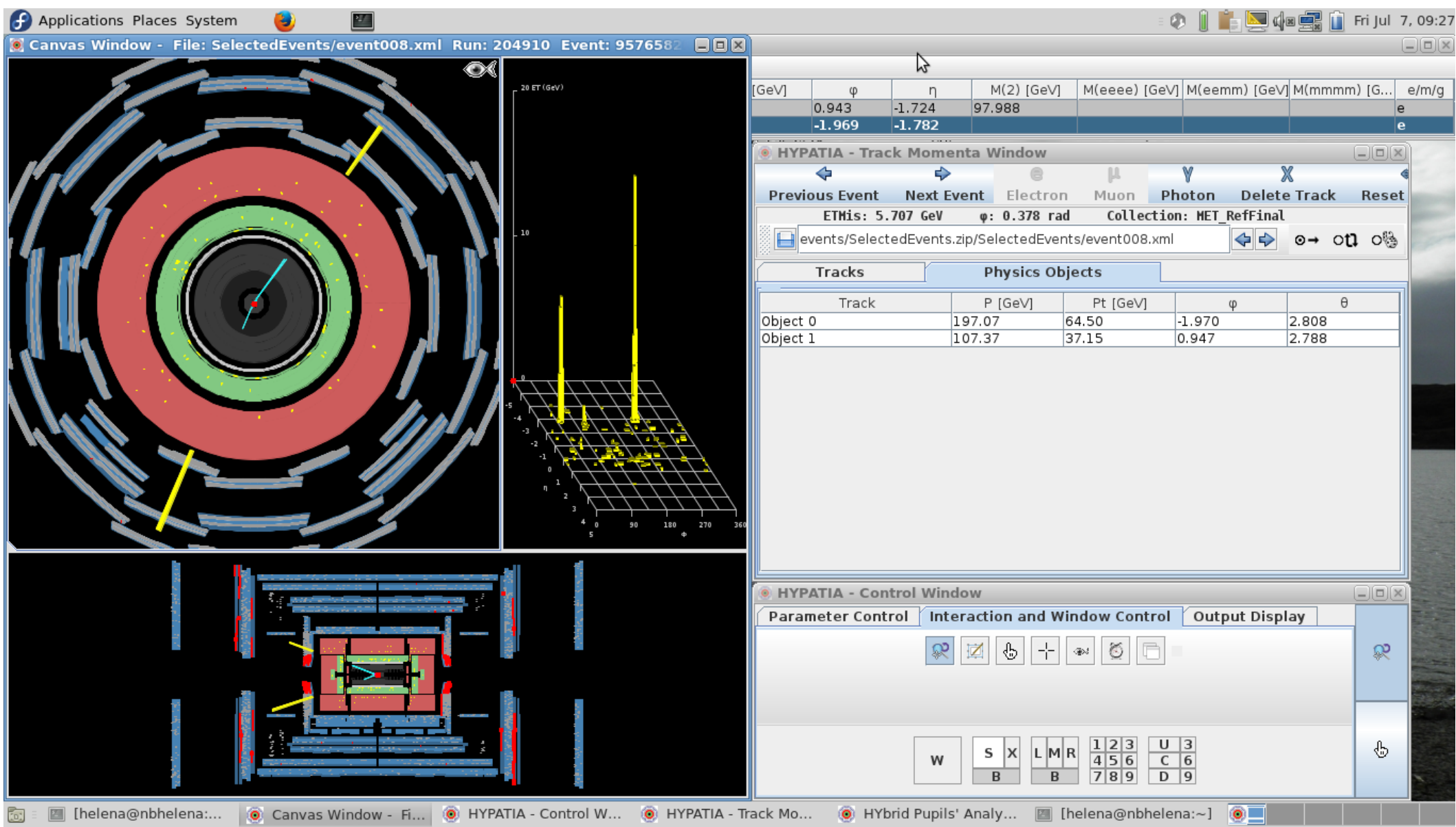
| Track      | +/- | P [GeV] | Pt [GeV] | $\phi$ | $\theta$ |
|------------|-----|---------|----------|--------|----------|
| Tracks 172 | +   | 107.50  | 37.18    | 0.949  | 2.788    |
| Tracks 173 | -   | 108.25  | 37.43    | 0.943  | 2.789    |
| Tracks 204 | +   | 198.41  | 64.94    | -1.969 | 2.808    |

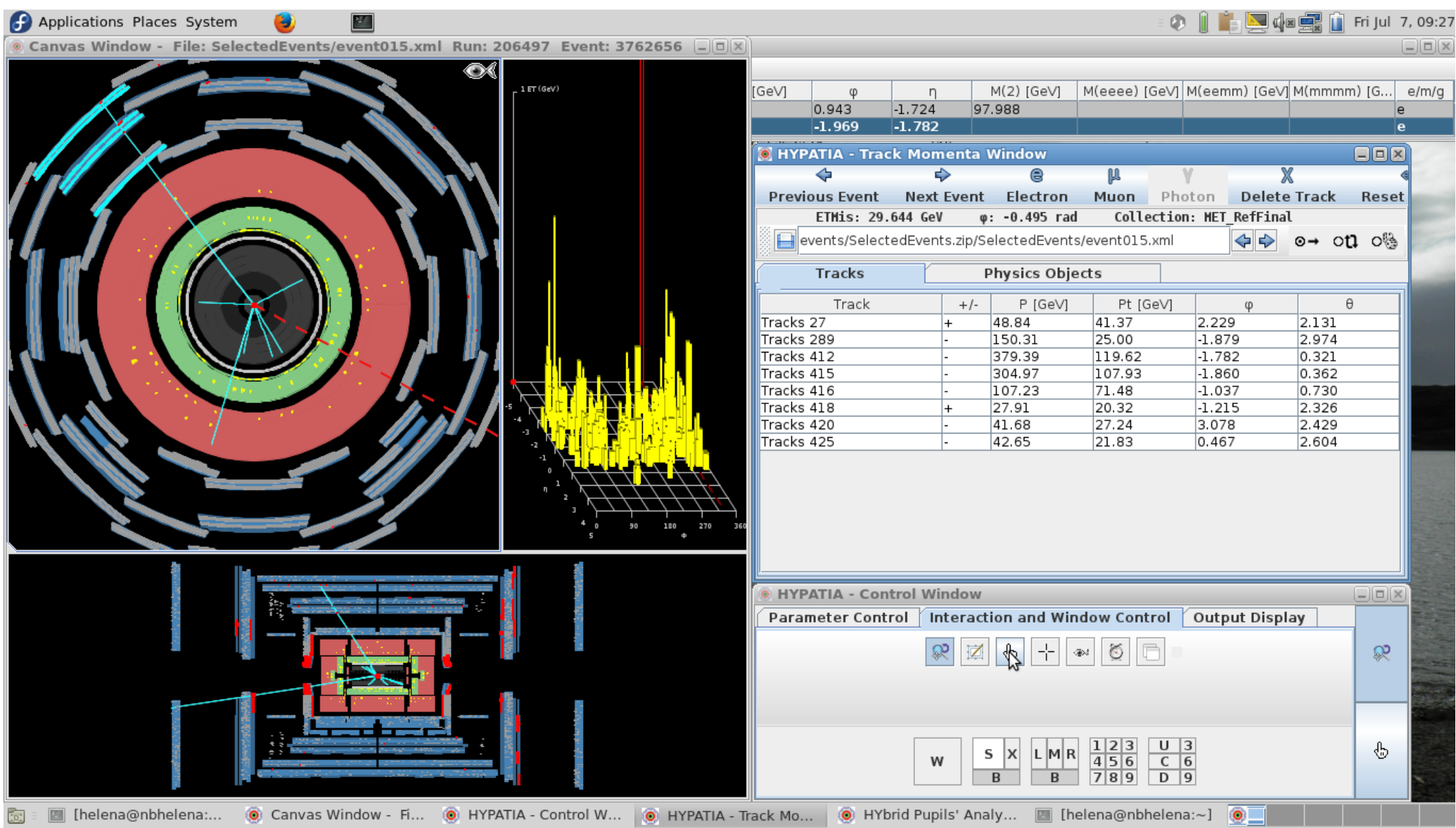
#### HYPATIA - Control Window

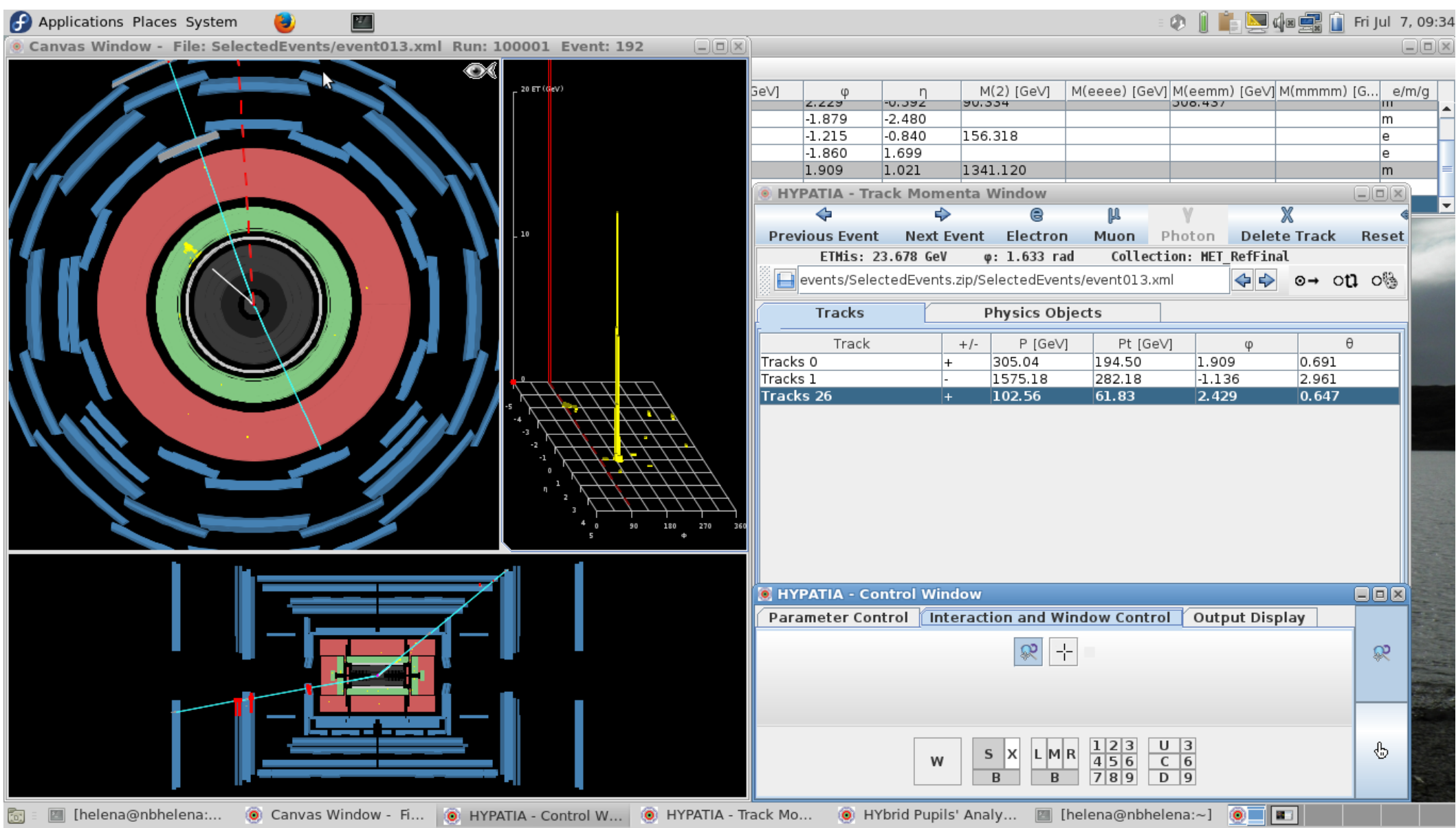
Parameter Control Interaction and Window Control Output Display

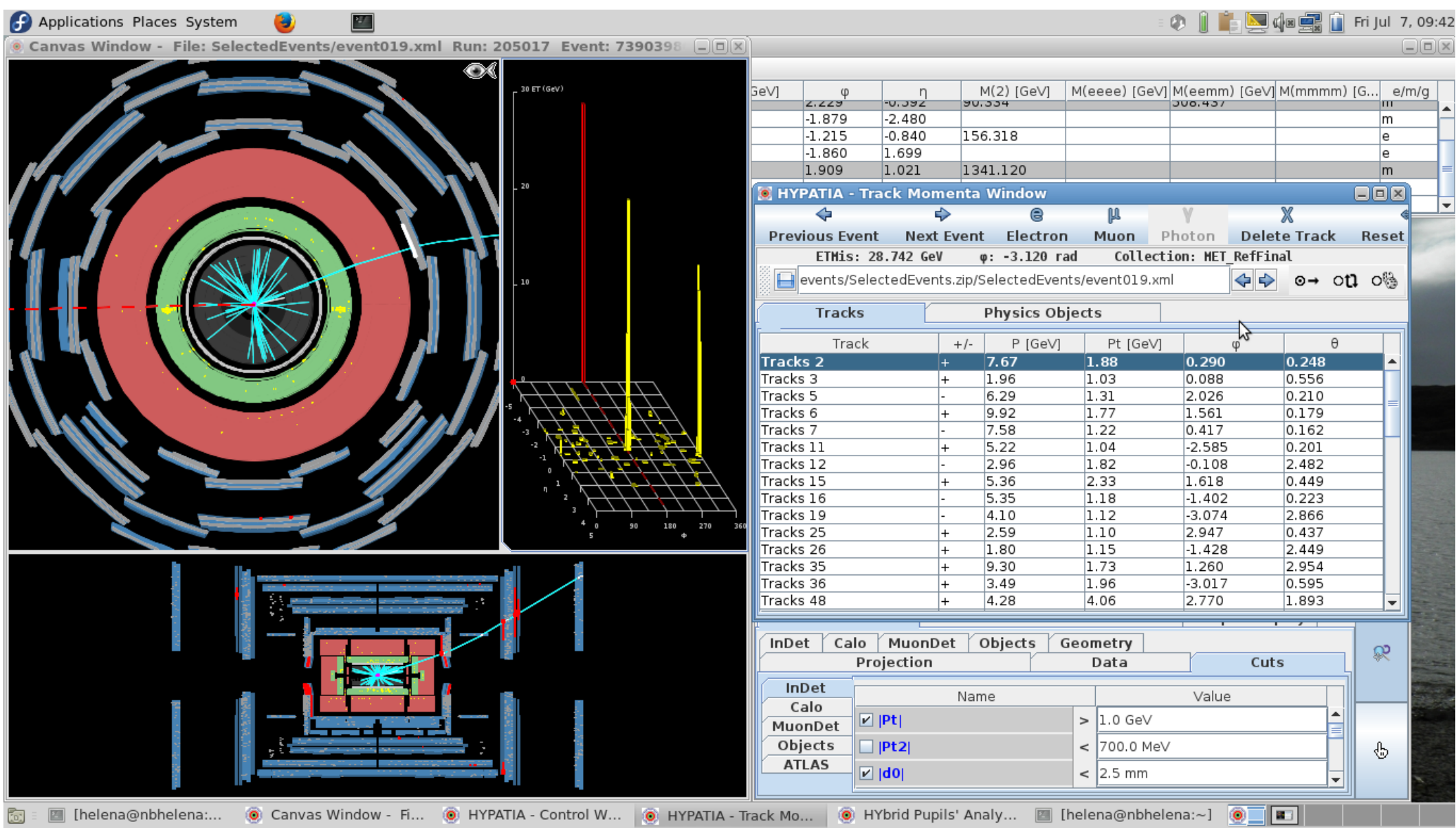
W S X L M R 1 2 3 U 3  
4 5 6 C 6  
7 8 9 D 9

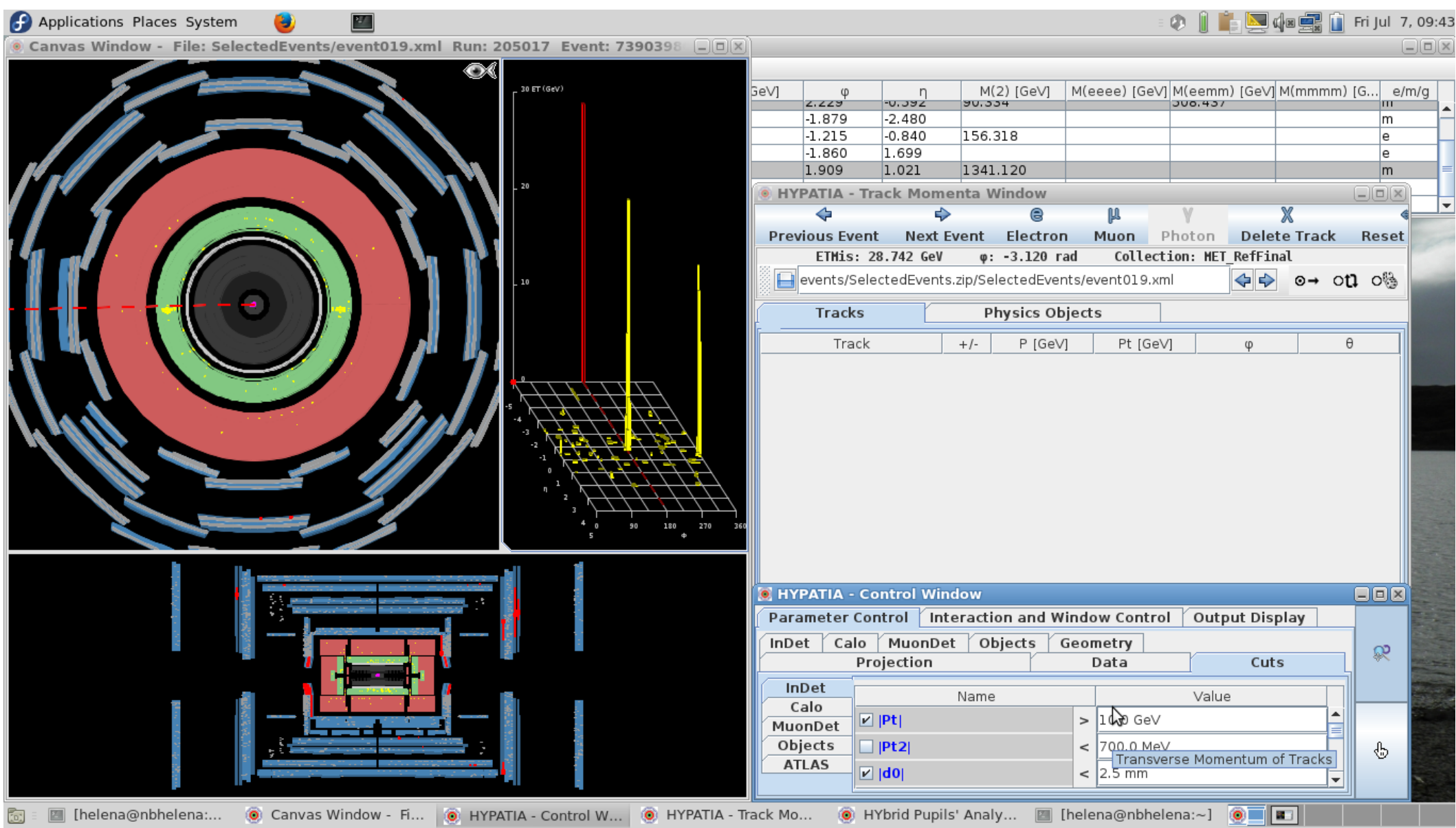
[helena@nbhelena:...] Canvas Window - Fi... HYPATIA - Control W... HYPATIA - Track Mo... HYbrid Pupils' Analy... [helena@nbhelena:~]

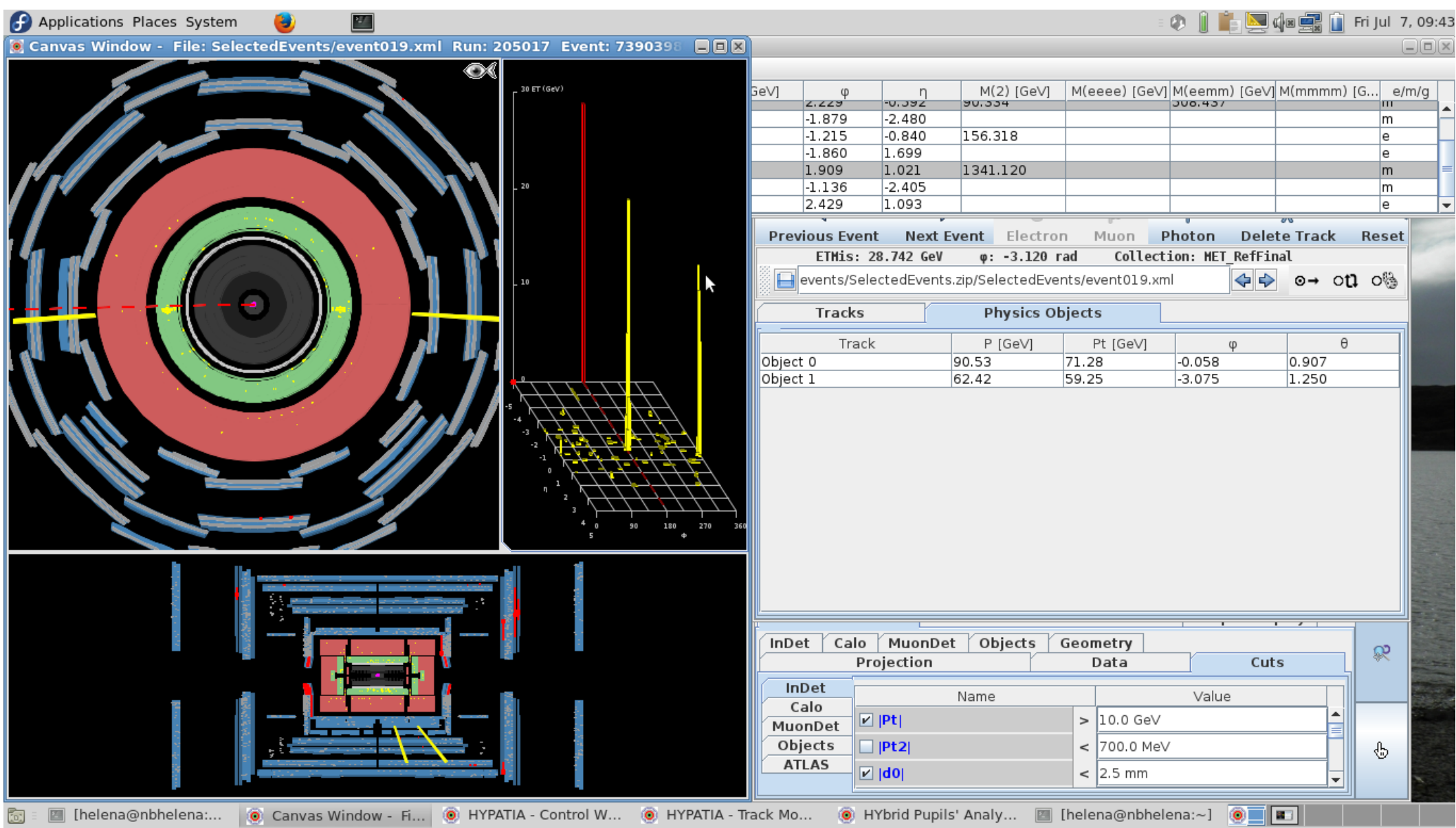












Applications Places System Fri Jul 7, 09:44

### HYbrid Pupils' Analysis Tool for Interactions in ATLAS - version 7.4 - Invariant Mass Window

File View Histograms Preferences Help

| File Name                   | ETMis [GeV] | Track    | P [GeV] | +/- | Pt [GeV] | $\phi$ | $\eta$ | M(2) [GeV] | M(eeee) [GeV] | M(eemm) [GeV] | M(mmmm) [G...] | e/m/g |
|-----------------------------|-------------|----------|---------|-----|----------|--------|--------|------------|---------------|---------------|----------------|-------|
| SelectedEvents/event019.xml | 28.742      | Object 0 | 90.5    |     | 71.3     | -0.058 | 0.719  | 132.243    |               |               |                | g     |
|                             |             | Object 1 | 62.4    |     | 59.2     | -3.075 | 0.326  |            |               |               |                | g     |

#### HYPATIA - Track Momenta Window

Previous Event Next Event Electron Muon Photon Delete Track Reset

ETMis: 28.742 GeV  $\phi$ : -3.120 rad Collection: MET\_Reffinal

events/SelectedEvents.zip/SelectedEvents/event019.xml

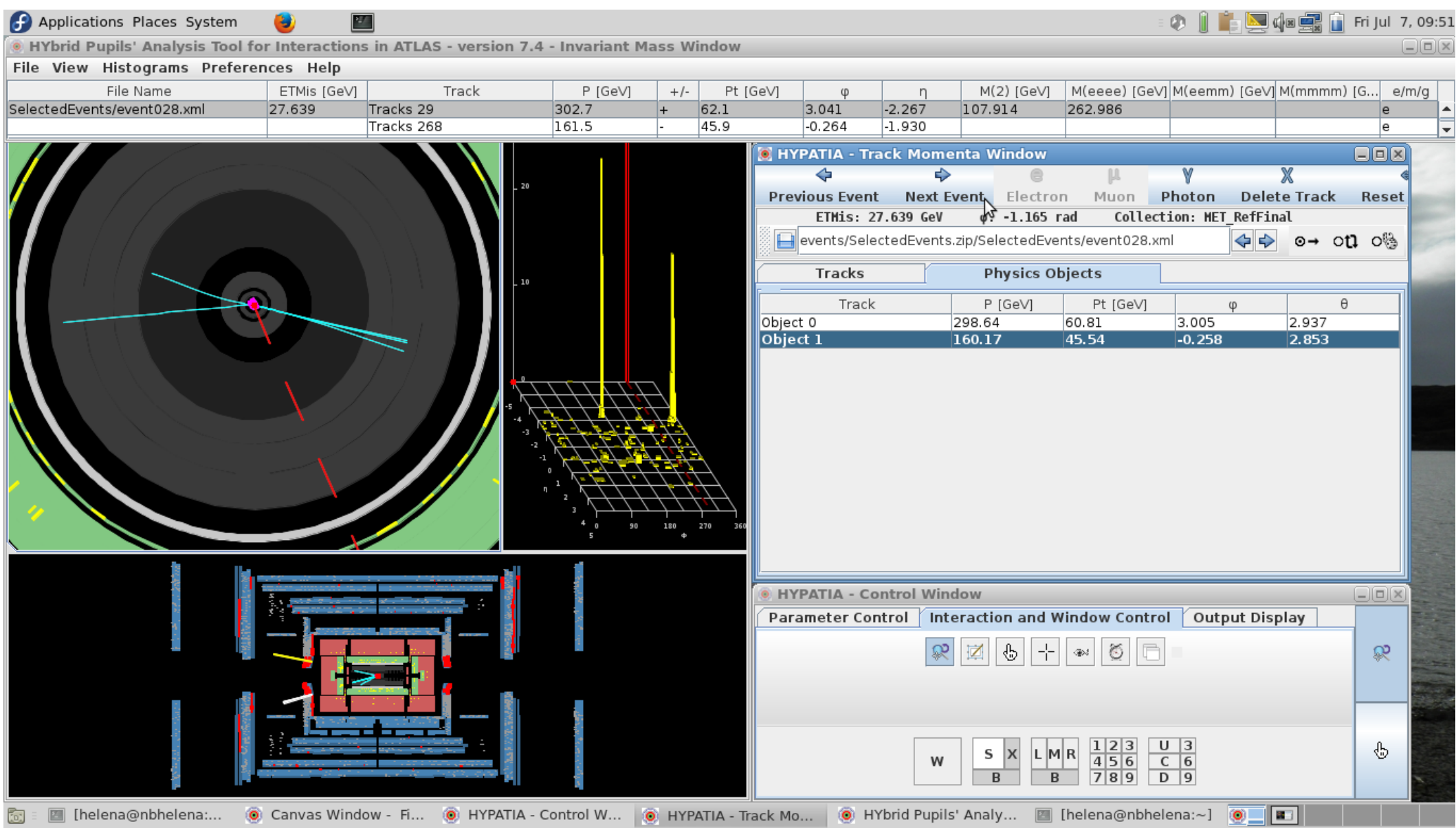
| Track    | P [GeV] | Pt [GeV] | $\phi$ | $\theta$ |
|----------|---------|----------|--------|----------|
| Object 0 | 90.53   | 71.28    | -0.058 | 0.907    |
| Object 1 | 62.42   | 59.25    | -3.075 | 1.250    |

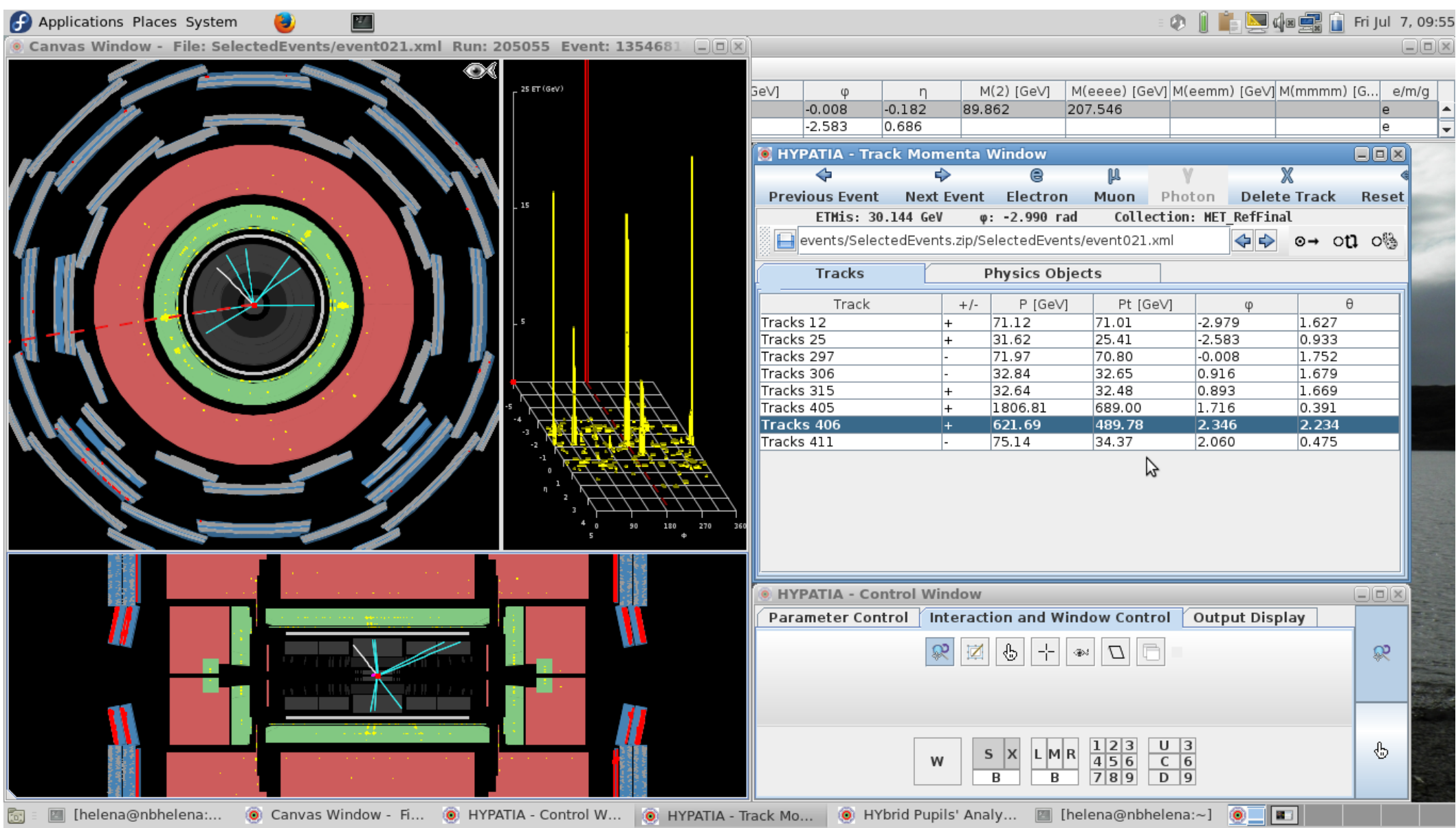
InDet Calo MuonDet Objects Geometry

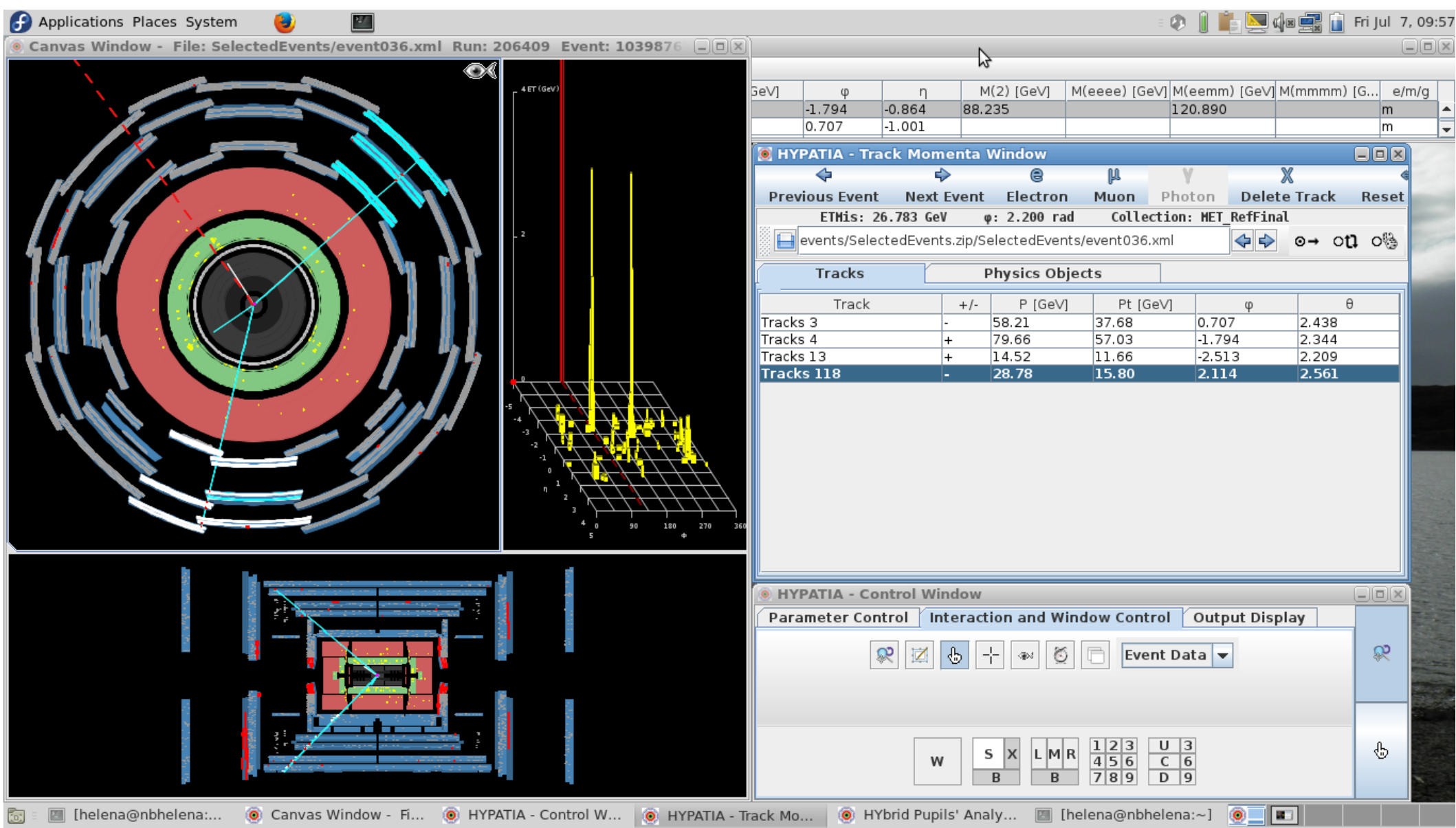
Projection Data Cuts

|         | Name                                    | Value       |
|---------|-----------------------------------------|-------------|
| InDet   |                                         |             |
| Calo    | <input checked="" type="checkbox"/>  Pt | > 10.0 GeV  |
| MuonDet | <input type="checkbox"/>  Pt2           | < 700.0 MeV |
| Objects |                                         |             |
| ATLAS   | <input checked="" type="checkbox"/>  d0 | < 2.5 mm    |

[helena@nbhelena:~] Canvas Window - Fi... HYPATIA - Control W... HYPATIA - Track Mo... HYbrid Pupils' Analy... [helena@nbhelena:~]







## Part II

[http://atlas.physicsmasterclasses.org/pt/zpath\\_exercise2.htm](http://atlas.physicsmasterclasses.org/pt/zpath_exercise2.htm)

**Events (Track Momenta Window):**

**events/Events2\_Z.zip**

**$p_T$  cut > 5 GeV**

Backup

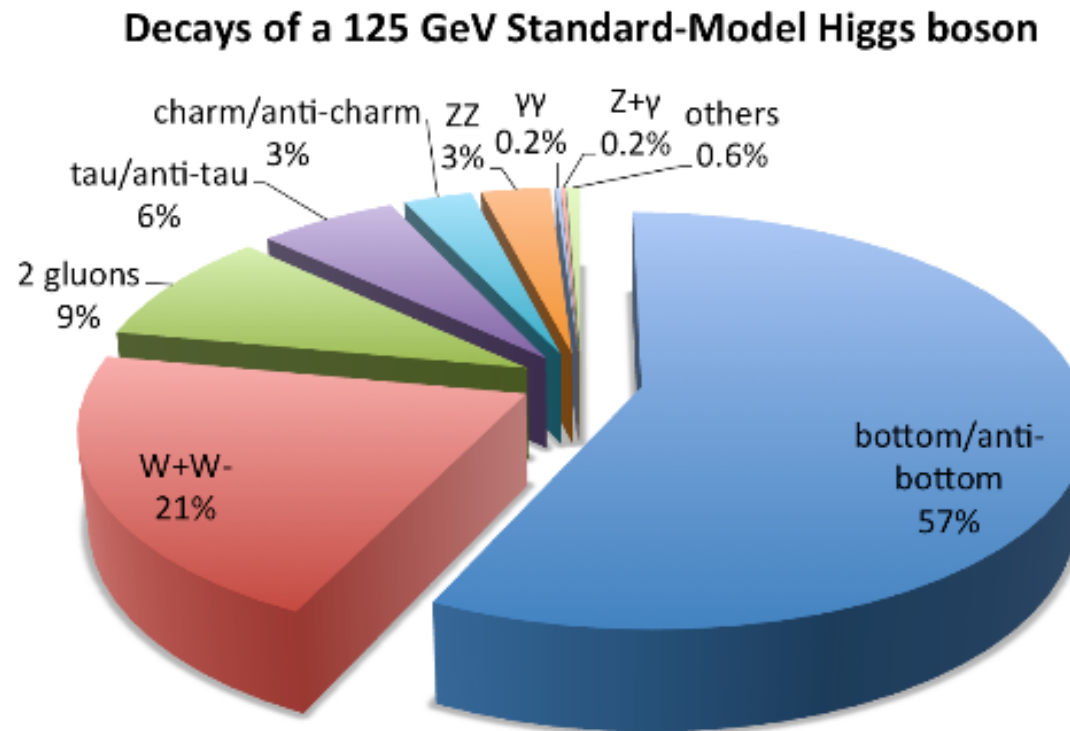
# Z boson properties

The Z boson (as well as  $W^+$  and  $W^-$  bosons) mediate the weak interaction. While the W bosons are responsible for some types of radioactive decay (those transforming a neutron in a proton and vice-versa), the Z boson plays an important role in the neutrino interactions.

- The Z boson is heavy – its mass is  $91.2 \text{ GeV}/c^2$  – and its life is very short: half-life of  $3 \times 10^{-25} \text{ s}$
- The Z boson is neutral  $\rightarrow$  the sum of electric charge of its decay products is zero. Z Decays through:
  - Quark-antiquark pair (70%)  $\rightarrow$  identified by jets in the calorimeter;
  - Neutrino-antineutrino pair (20%). Neutrinos cross the detector untouched. This decay mode may be identified if missing transverse momentum (MET) is high.
  - Lepton-antilepton pair (10%). The three lepton types (electron, muon, tau) are equally probable.

# Higgs boson

The Standard Model does not predict the mass of the Higgs boson, instead, for a given mass, predicts the production rates in p+p collisions at the LHC and the decay probabilities in other particles. For a mass of  $125 \text{ GeV}/c^2$  the SM predicts:



# p+p collisions – the common picture

