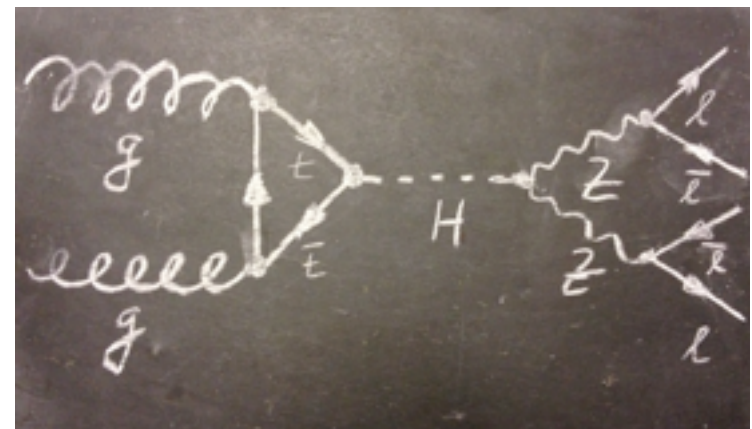
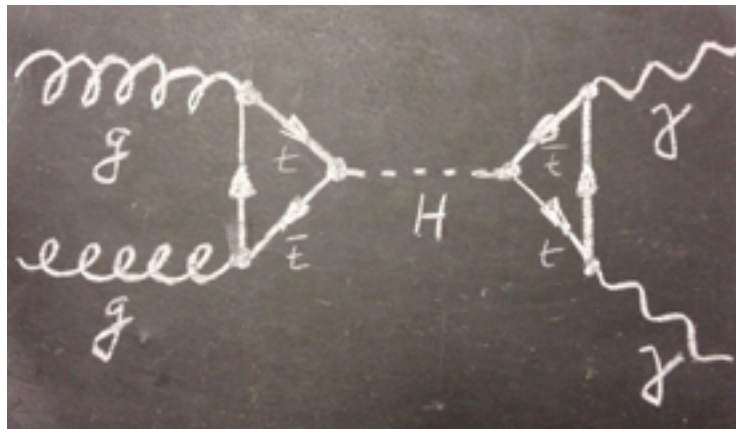
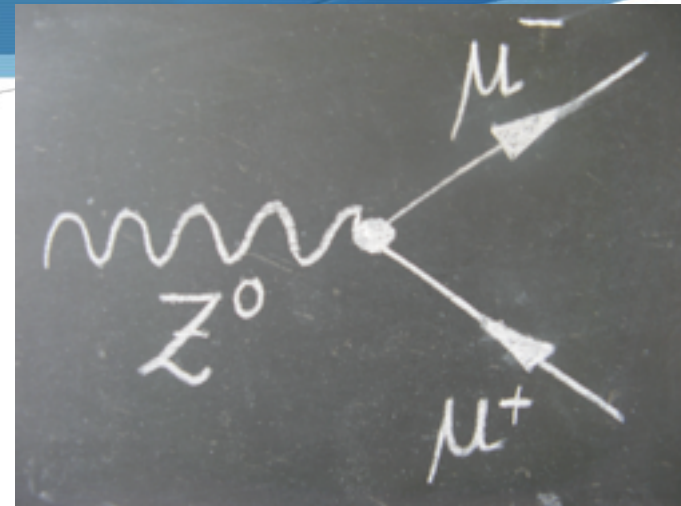
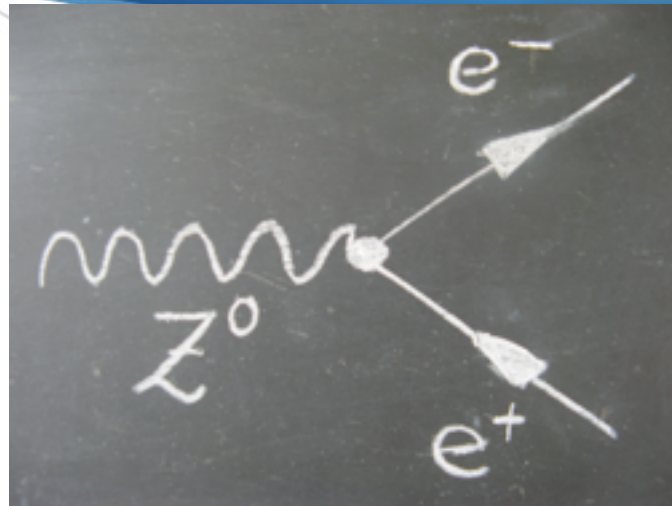




End now?



What we will look for



Invariant mass

- ◆ In special relativity (you certainly know $E=mc^2$), using energy and momentum conservation, a relativistic invariant, called the invariant mass appears.
- ◆ If a particle decays, the invariant mass of the decay products (calculated in any referential) is the mass of the initial particle.
- ◆ We will calculate (the software will do it in fact) the e^+e^- , $\mu^+\mu^-$, $\gamma\gamma$, $e^+e^-e^+e^-$, $e^+e^-\mu^+\mu^-$ or $\mu^+\mu^-\mu^+\mu^-$ invariant mass of our different candidates.

Beyond $E = mc^2$

In the more complete version of Einstein's formula $E = \sqrt{(\vec{p} \cdot c)^2 + (m_0 \cdot c^2)^2}$, E is the energy of the particle, p its the momentum and m_0 its the mass of the particle when at rest. It so happens that this definition of mass is conserved in Nature and is called "Invariant Mass". Shuffling the formula we get:

$$m_0 = \sqrt{\left(\frac{E}{c^2}\right)^2 - \left(\frac{\vec{p}}{c}\right)^2}$$

In the case of $Z \rightarrow e^+e^-$

In the case of a Z boson decaying to an electron (e^-) positron (e^+) pair the sum of energies and momenta of the electron and positron lead to the mass of the Z boson in the following way:

$$m_0^{(Z)} = \sqrt{\left(\frac{(E_{e^-} + E_{e^+})}{c^2}\right)^2 - \left(\frac{\vec{p}_{e^-} + \vec{p}_{e^+}}{c}\right)^2}$$

About histograms

3 2 3 7 1 7 1 1 7 5 9 3 6 2 0 1 1 5 6 10 3 6 10 1 1 1 5 6 10

6 9 0 1 5 3 5 9 3 9 5 7 1 3 3 10 7 1 3 3 10 10 10 7 1 0 8 4

8 1 1 0 6 10 4 1 5 9 9 4 1 0 2 8 7 8 0

3 8 9 10 7 10 5 4 9 7 10 6 3 7 7 0

3 6 4 8 1 4 8 5 4 7 4 9 3 3 0 8

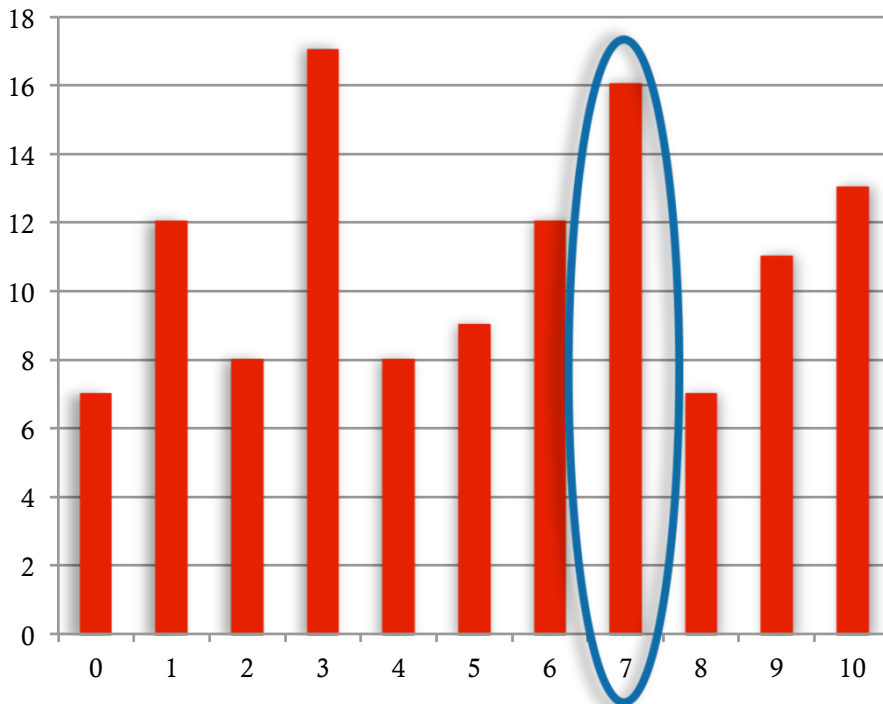
2 1 4 2 1 2 9 6 7 0 8

- ✓ Numbers between 0 and 10
- ✓ Distribution of occurrences

Value	Number of occurrences
0	7
1	12
2	8
3	17
4	8
5	9
6	12
7	16
8	7
9	11
10	13

About histograms

The table can be represented as a graph:

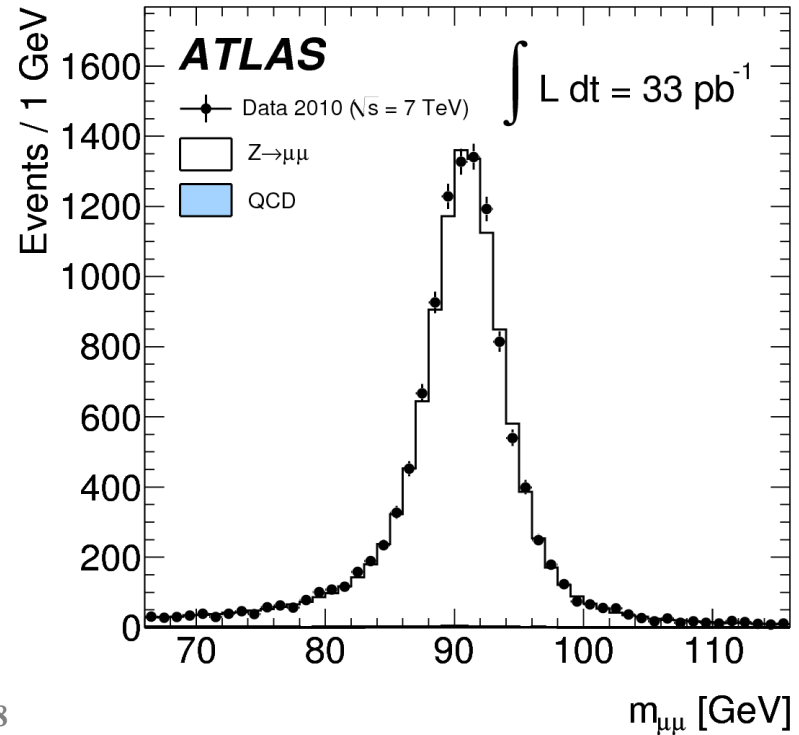
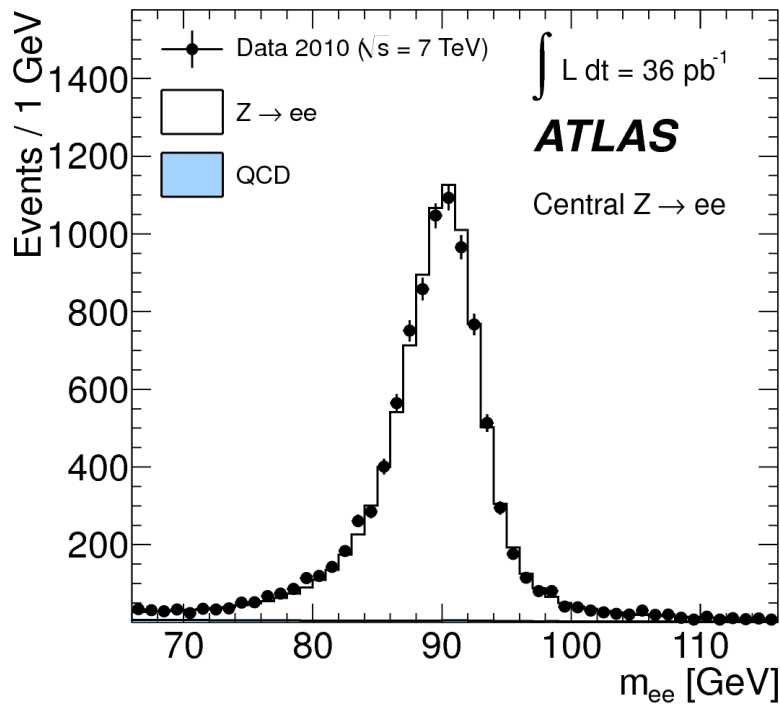
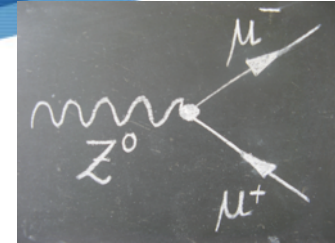
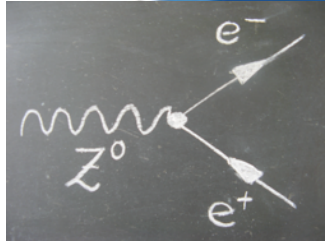


Each bar represents the number of occurrences of a given value.

This one tells you that the value 7 appeared 16 times.

This type of graph is an **histogram.**

Examples from ATLAS



Cuts we will use

- ◆ We will only considered tracks with sufficient transverse momentum: $p_T \geq 5 \text{ GeV}/c$
- ◆ Selected tracks should come from the same primary vertex (same proton-proton interaction): **check it zooming in on the side-view window**
- ◆ **If** you have difficulties on a given event, you may use **Pixel Hits ≥ 2** (tracks more likely to come from a primary vertex) and/or **SCT Hits ≥ 7** (good quality tracks); do no forget to remove those cuts moving to the next event