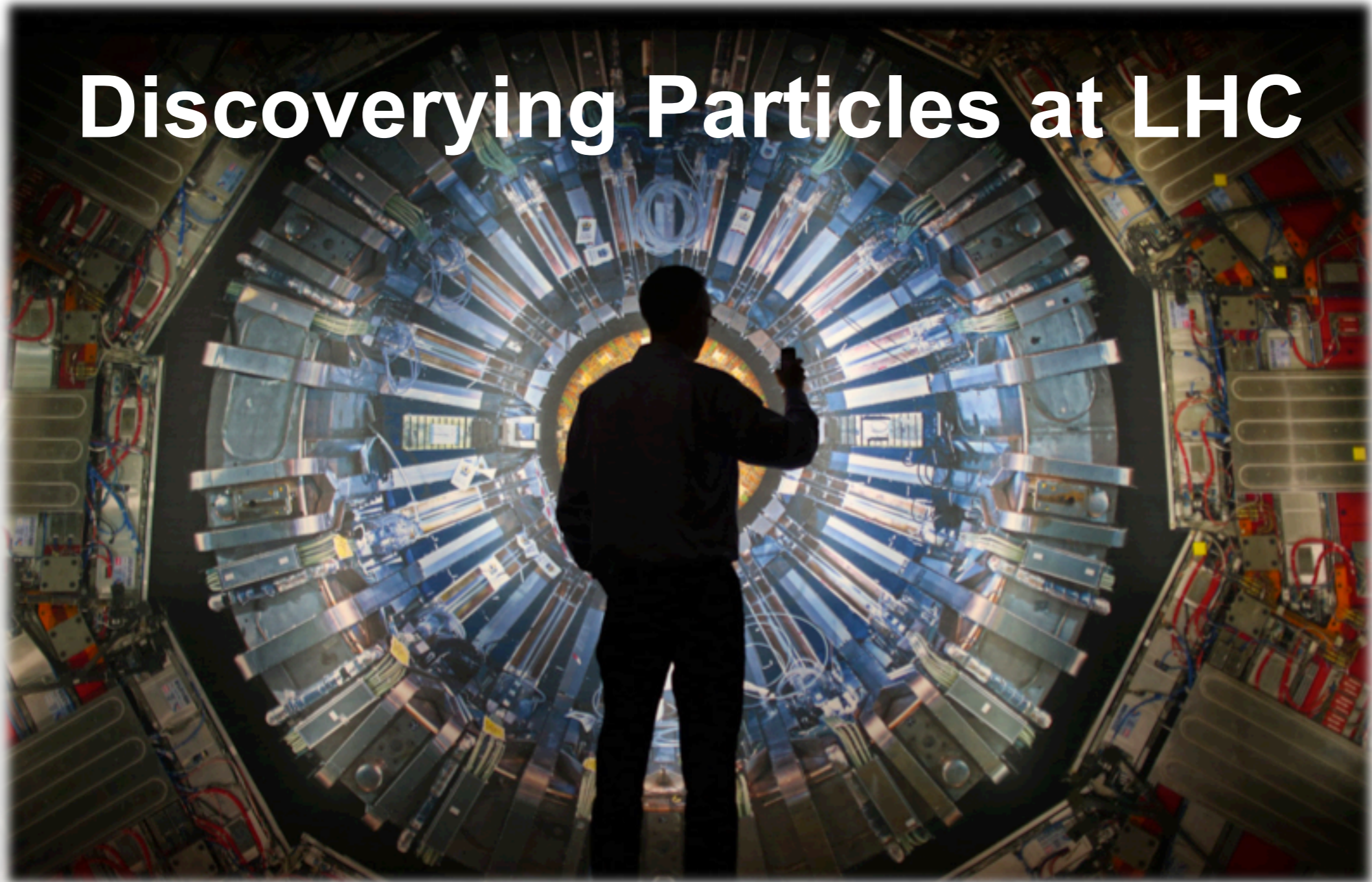


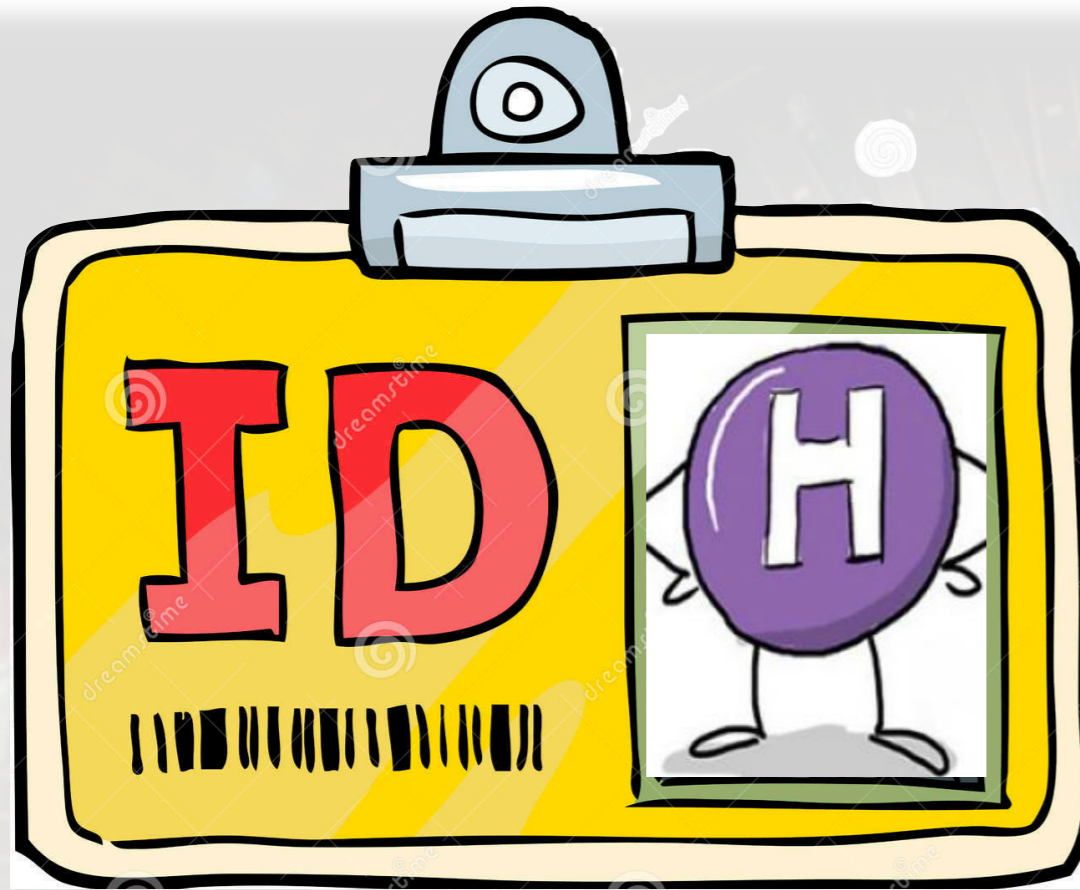
Discovering Particles at LHC



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PARTICLE IDENTIKIT



- The properties that describe univocally a particle are:

#1: Charge

#2: Spin

#3: Mass

Mass = Amount of matter (Newton 1687)

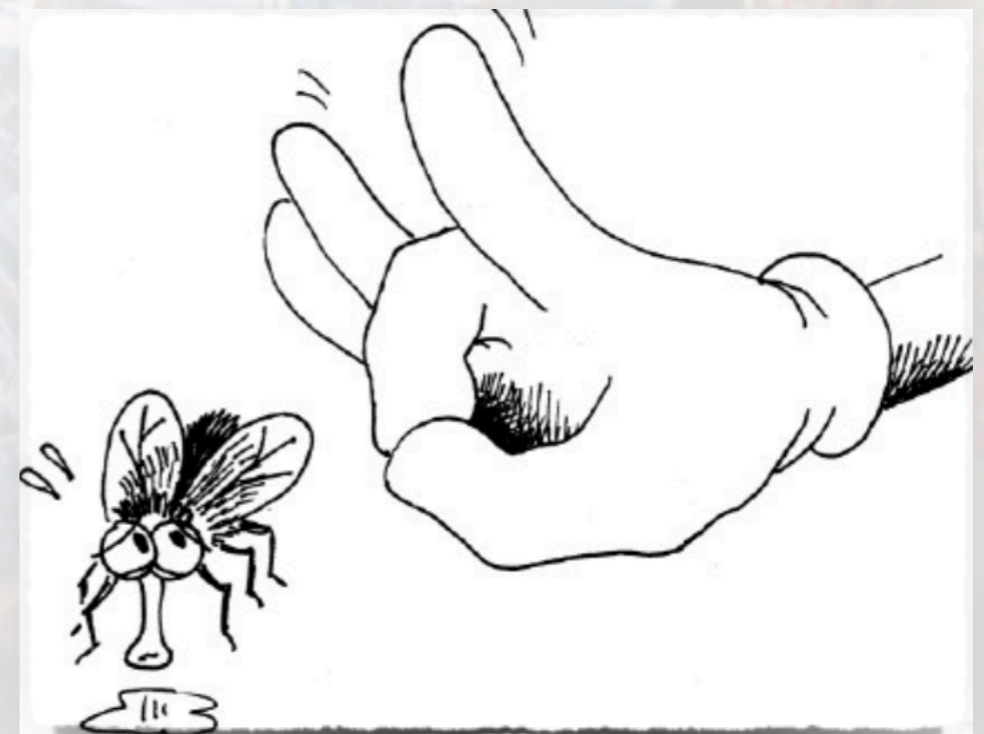
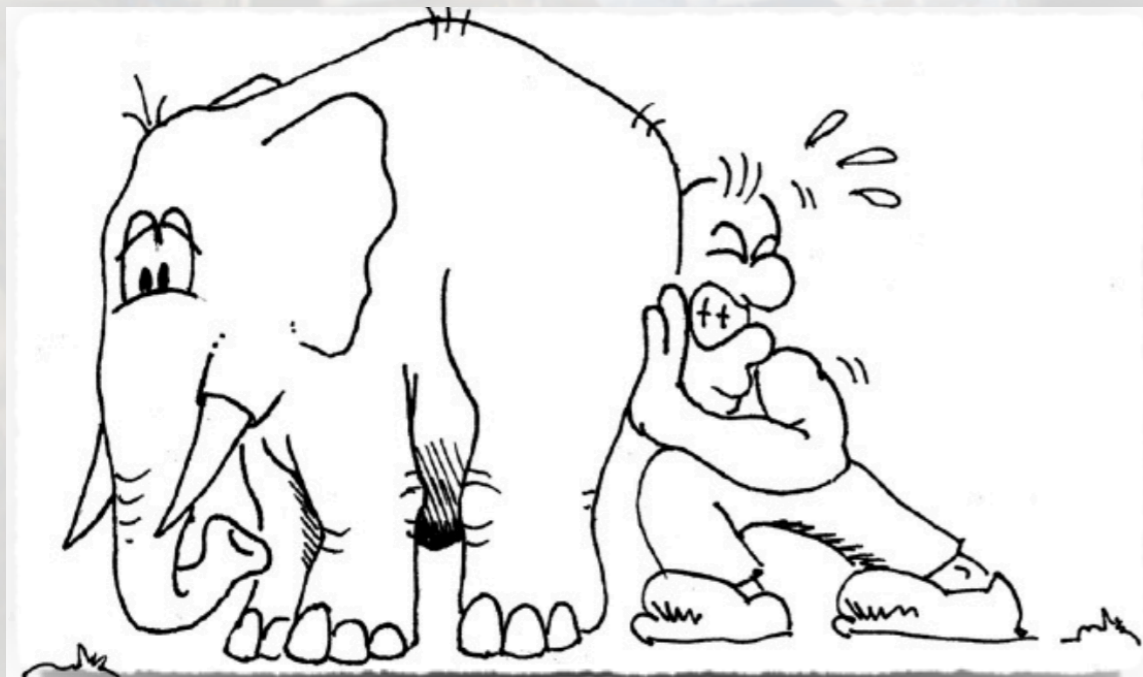


Mass = Amount of energy (Einstein 1905)



FORCES AND INTERACTIONS

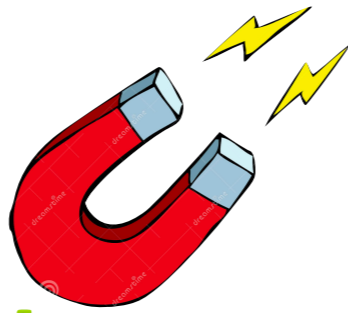
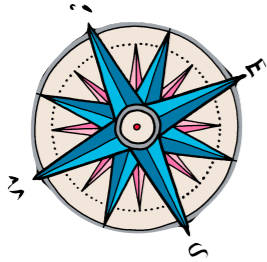
- The particles, and matter in general, **interact thanks to what we call forces**
- When we apply a force to an object, we **change its status of motion**
- **The lower the mass the easier to change is motion**



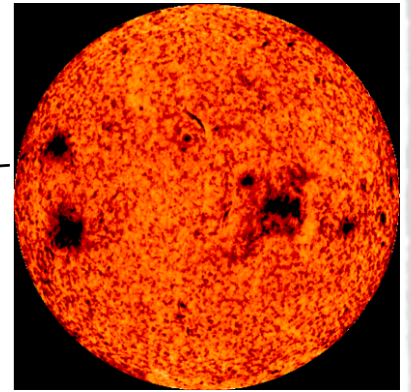
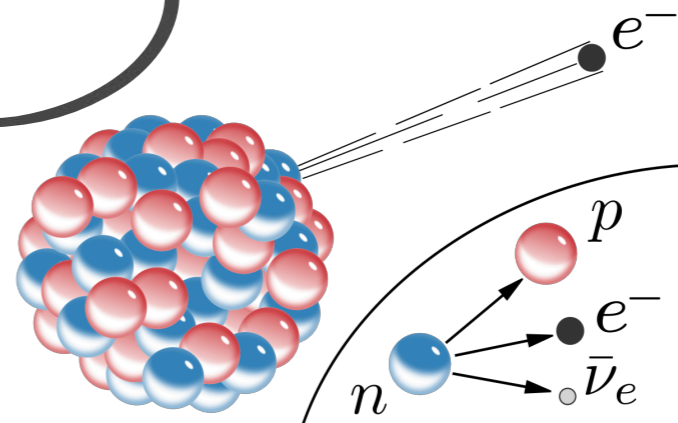
FANTASTIC FOUR



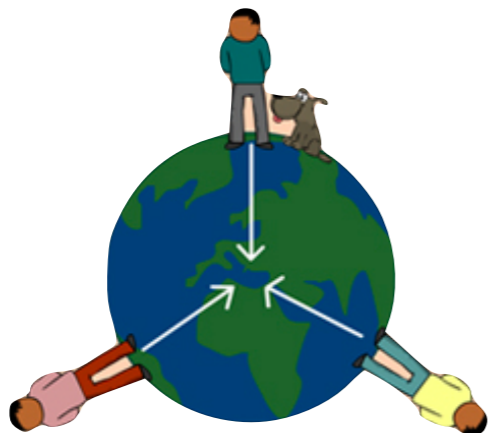
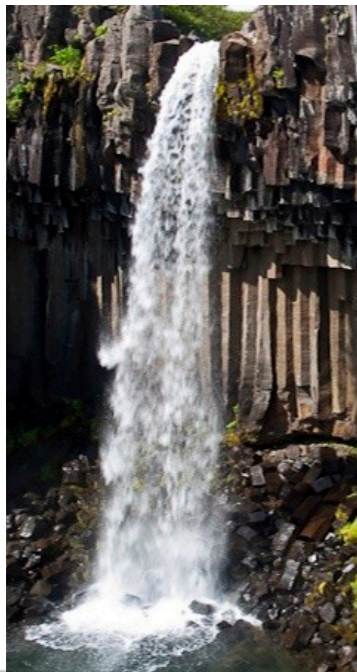
ELECTROMAGNETIC ($I=1$)



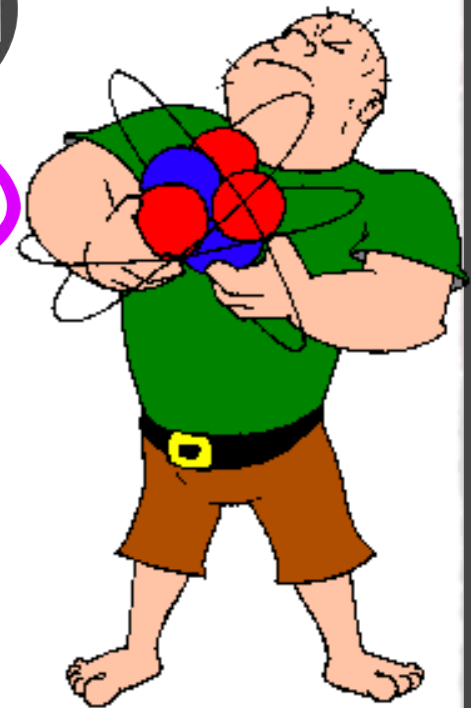
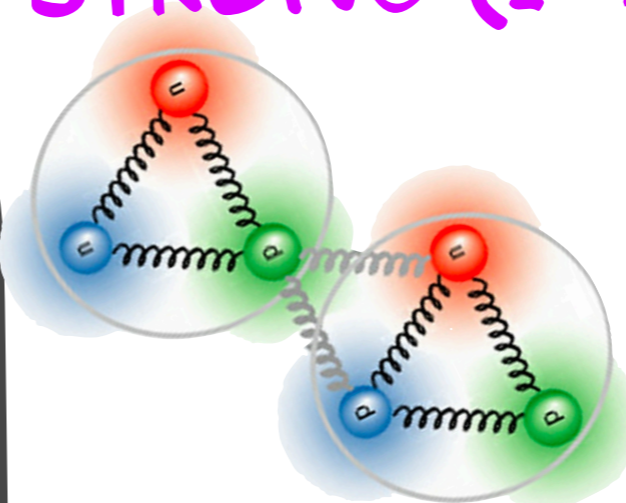
WEAK ($I=10^{-3}$)



GRAVITATIONAL ($I=10^{-36}$)

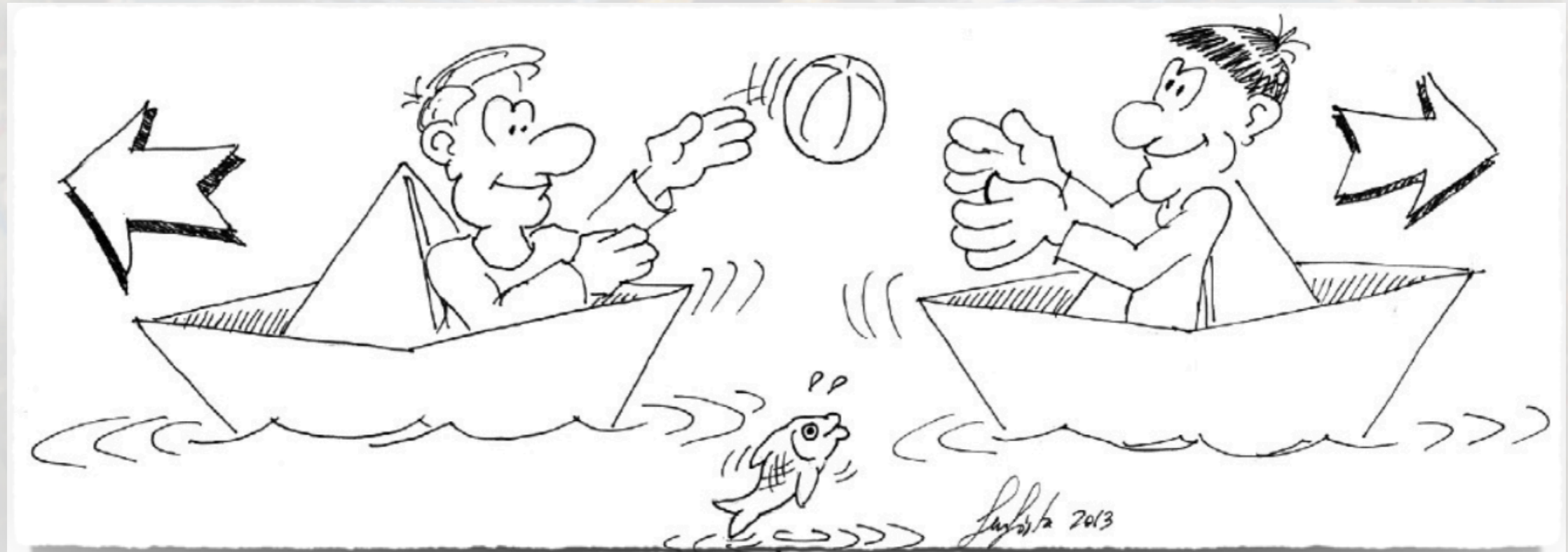


STRONG ($I=100$)



FORCES AS EXCHANGE OF PARTICLES

- Interactions which affect matter particles are due to an **exchange of force carrier particles**
- These particles are **like basketballs tossed between matter particles**

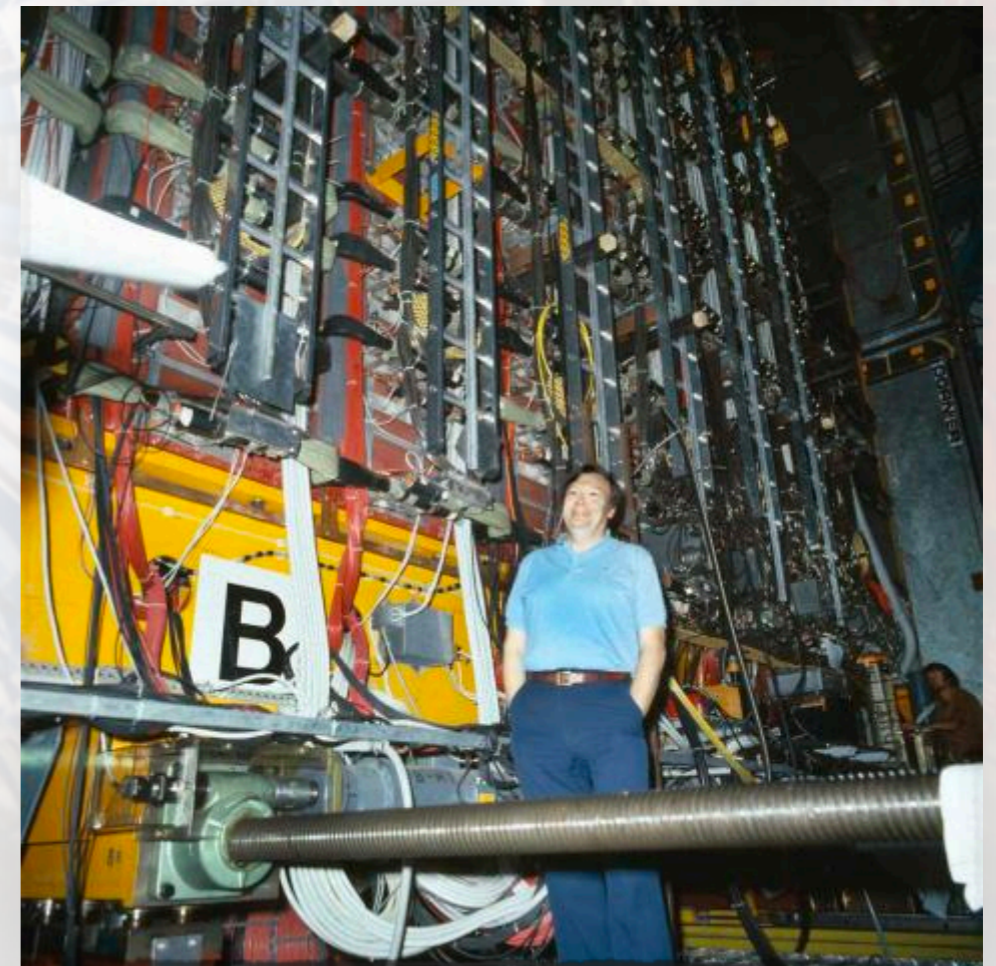


THE W AND Z BOSONS

→ W AND Z BOSONS ARE THE PARTICLES MEDIATOR OF THE WEAK FORCE

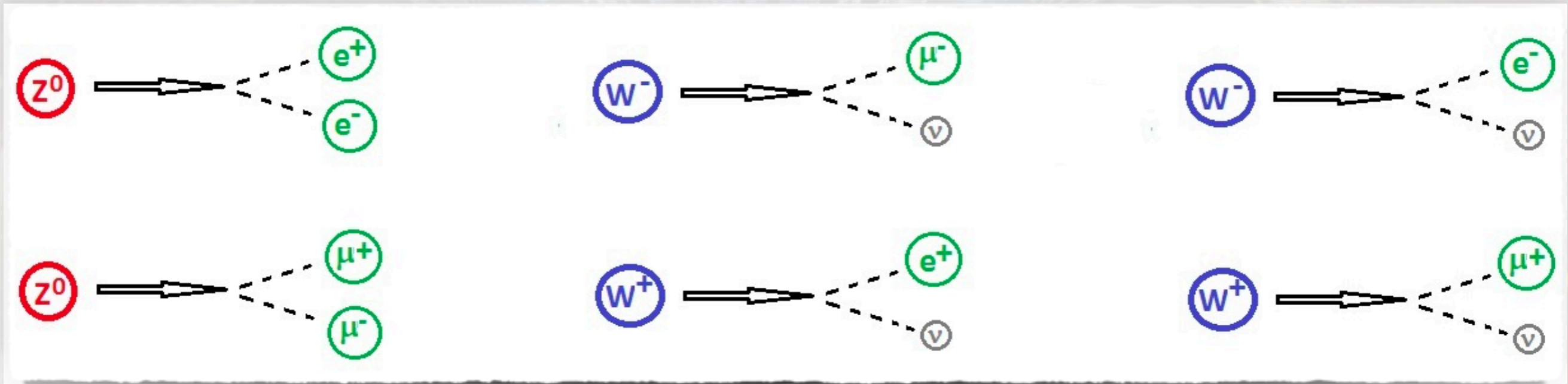
- They have been **predicted in the 1960`s** to explain the “beta” decays observed well before by Fermi.

- Theory predicted **W and Z masses around 100 GeV** and physicists at CERN built in early 1980`s the first most powerful collider able to reach such high energies: the SpPpS



DISCOVERY OF A NEW PARTICLE

- The **Z and W bosons** produced at LHC do not live long, but **decay immediately to other elementary particles that can be measured by the CMS and ATLAS detectors**



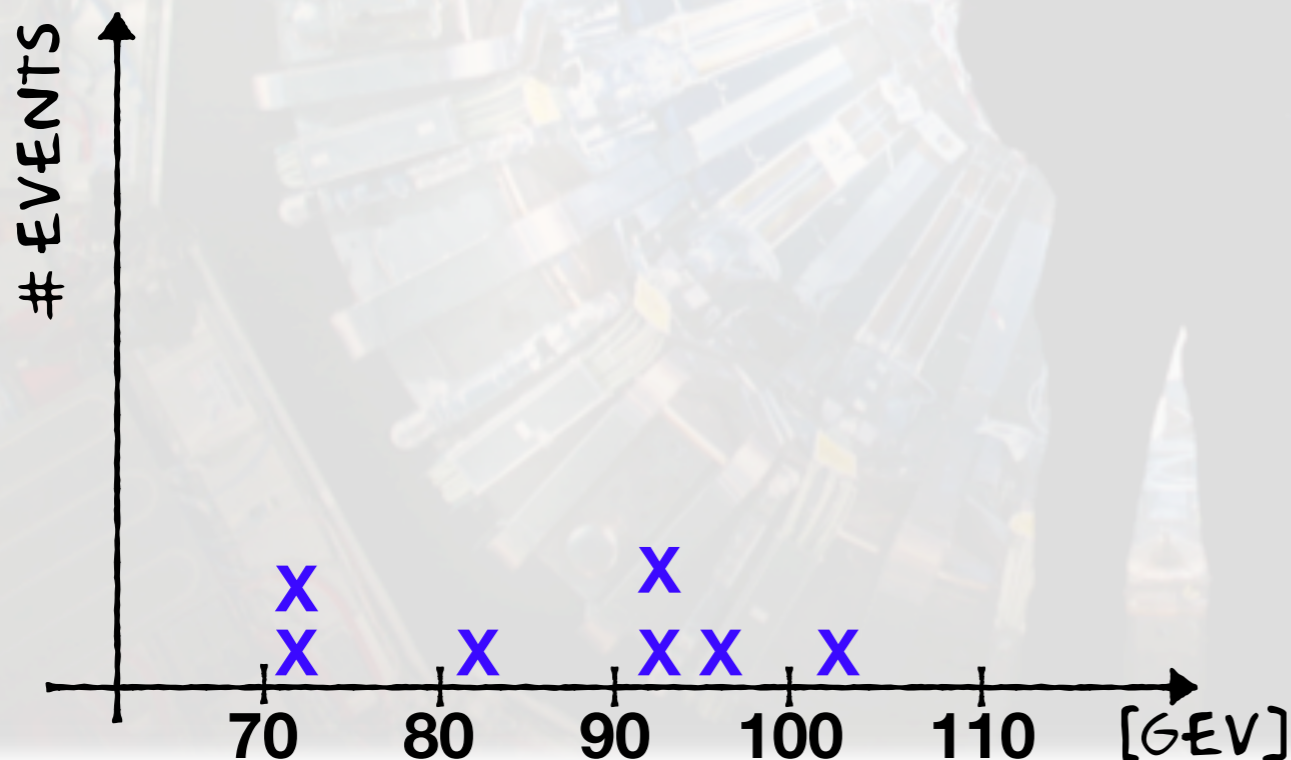
- So when in an LHC collision we produce a Z or W particle, **what we detect in the our experiments are only electrons and muons!**

THE Z BOSON MASS RECONSTRUCTION

- Measuring the **energies** and the **direction of production** of the two electrons or muons, we can compute the mass of the particle that have produced them in its decays:

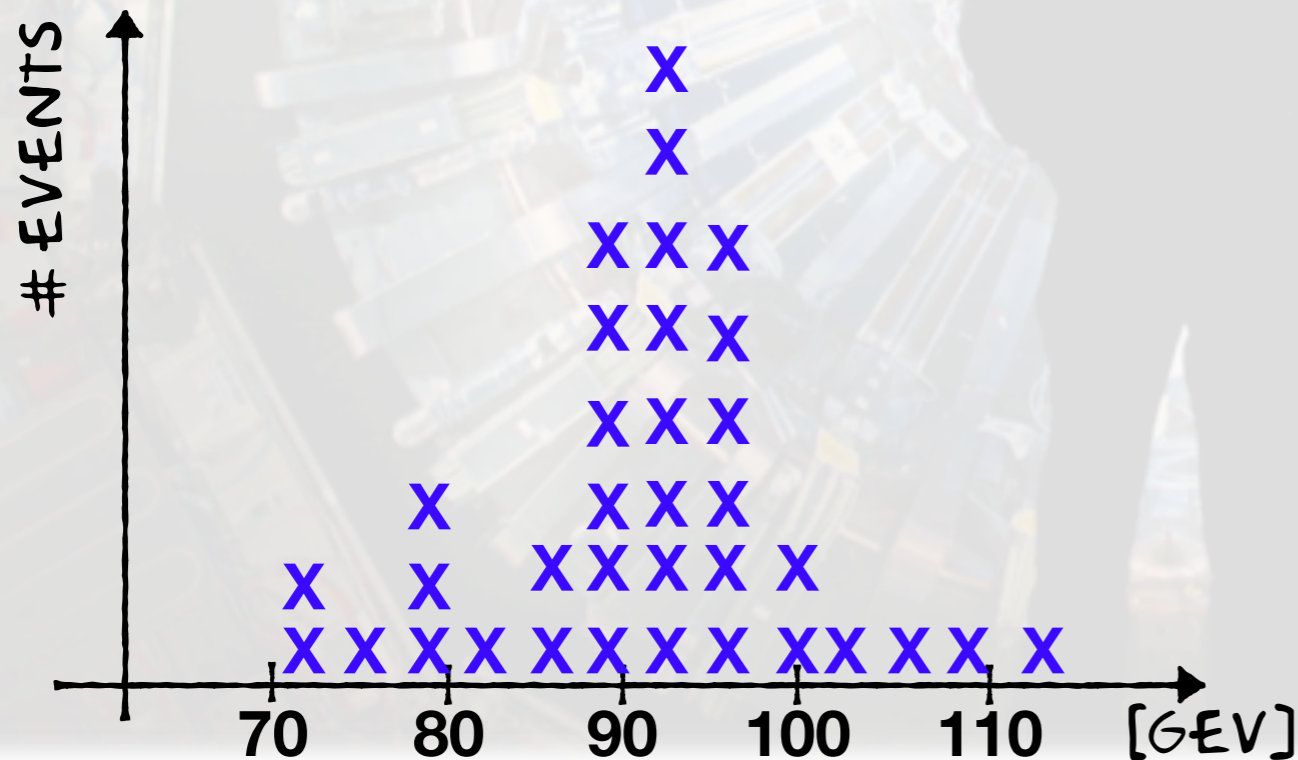
$$m_X = \sqrt{2E_1E_2(1 - \cos\theta)}$$

- In each **event** where we have two electrons/or muons we compute the Z mass with this formula and we fill an histogram of events:



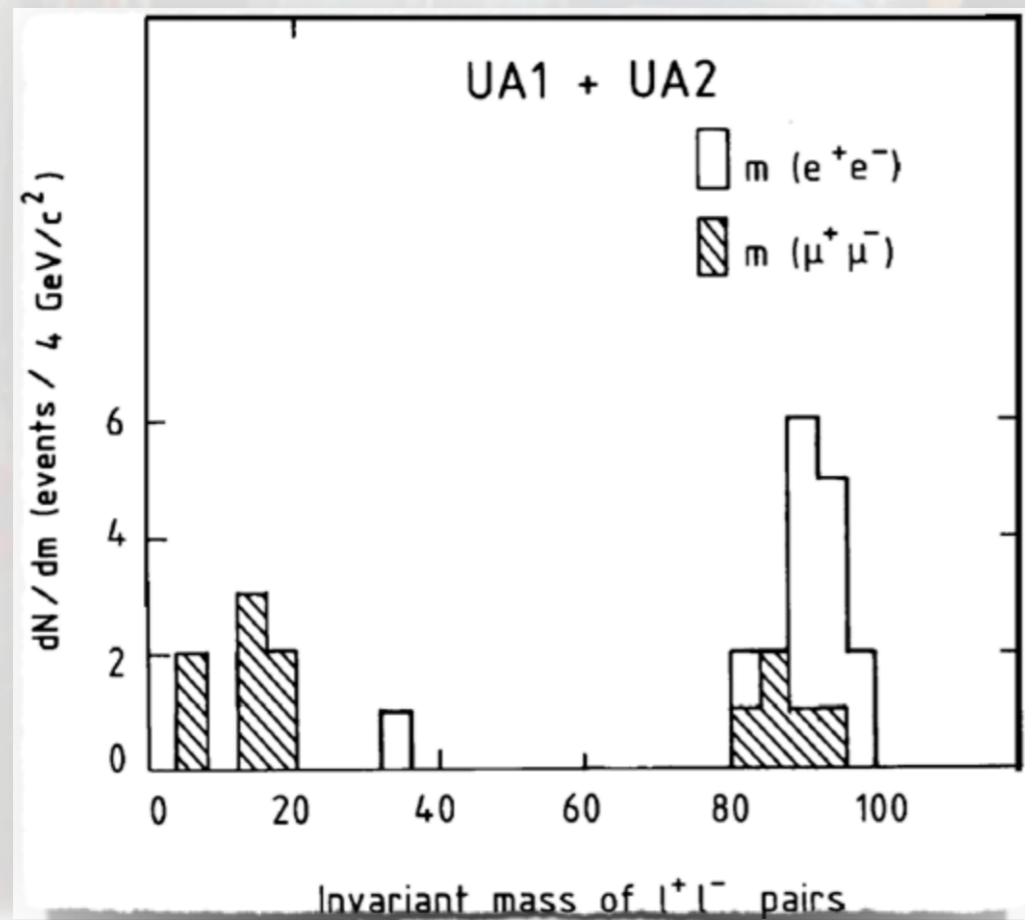
THE Z BOSON MASS RECONSTRUCTION

- A PEAK OF EVENTS WILL APPEAR CLOSE TO THE TRUE VALUE OF THE MASS OF THE Z BOSON IF THE Z EXISTS
- IF THE "EXCESS" OF EVENTS IS SIGNIFICANTLY BIG., WE DISCOVERED A NEW PARTICLE"



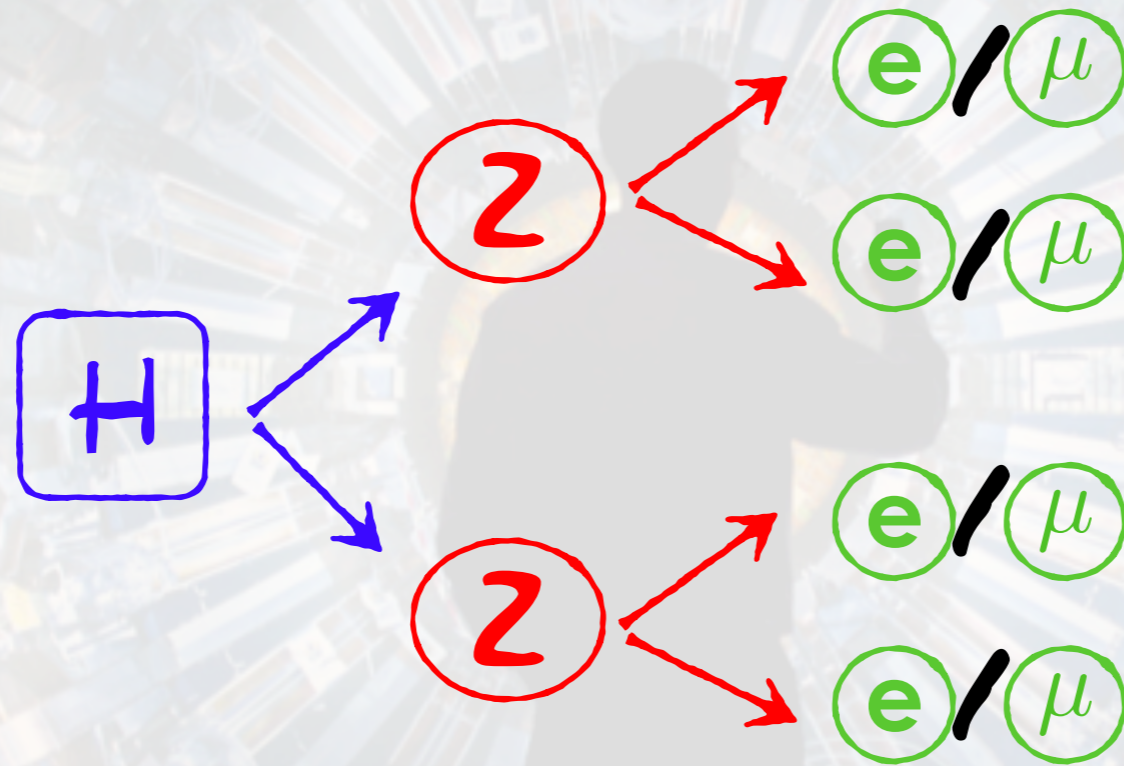
THE Z BOSON MASS RECONSTRUCTION

- A PEAK OF EVENTS WILL APPEAR CLOSE TO THE TRUE VALUE OF THE MASS OF THE Z BOSON IF THE Z EXISTS
- IF THE "EXCESS" OF EVENTS IS SIGNIFICANTLY BIG.. WE DISCOVERED A NEW PARTICLE"
- IN 1983 THE UA1 AND UA2 EXPERIMENTS AT CERN: DISCOVERY OF THE W AND Z BOSON



HOW WE USE THE Z BOSON TO DISCOVER THE HIGGS

- The discovery of the Z boson opened the opportunity to “use” the recently discovered particle for the quest of the Higgs boson:

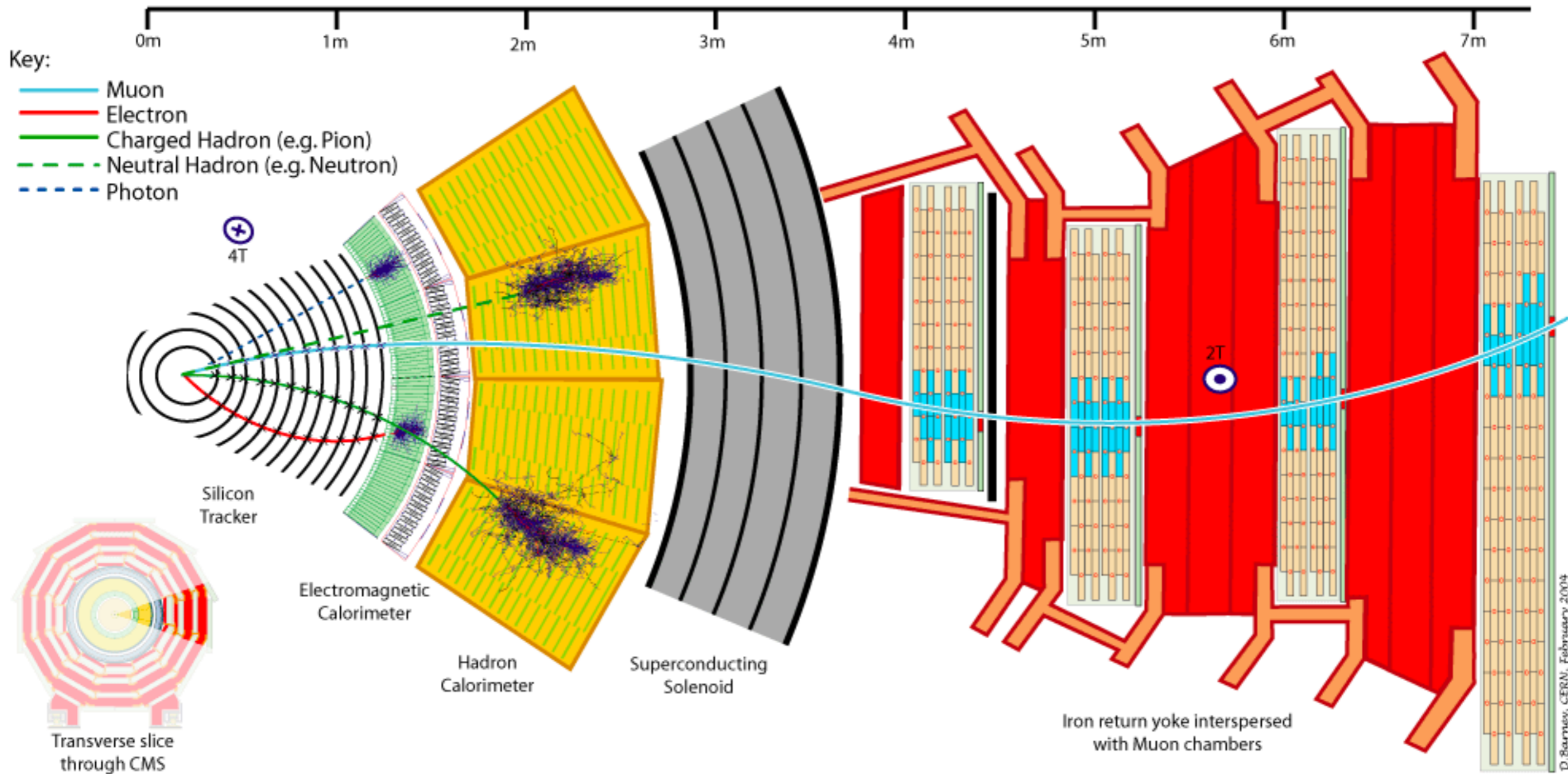


- Either decays of the **Z** to **electrons or muons** are considered

NOW IT'S YOUR TURN!!

- **Today we will look at the REAL DATA collected by CMS and ATLAS at LHC and we will try to “RE-DISCOVER” the Z and the W bosons.**
- **We will learn how to work in team in data analysis and how to present our own results like in a major physics conference!**

REMINDER: ELECTRON AND MUON



MANY RESONANCES AROUND!!

