



HIGGS BOSON RECONSTRUCTION

4th School on High Energy Physics

Prepared by

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Cairo university*

What is out there?

What is out there?

How did we get here?

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What is the world made of?

What is out there?

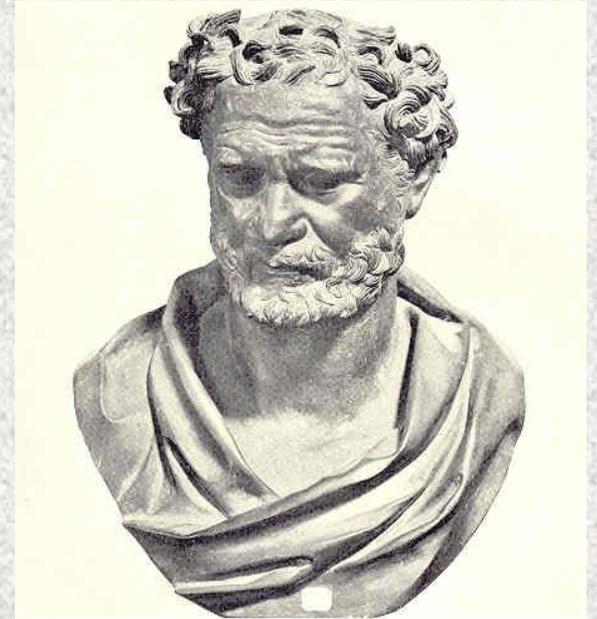
How did we get here?

What is the world made of?

What is the building block of matter?

more than 2400 years ago

The first attempts in describing the building block of matter was by the the Greek philosopher **Democrituse** (460-370 bc).
It leads him to conclude that:
the building block of matter called (atom)



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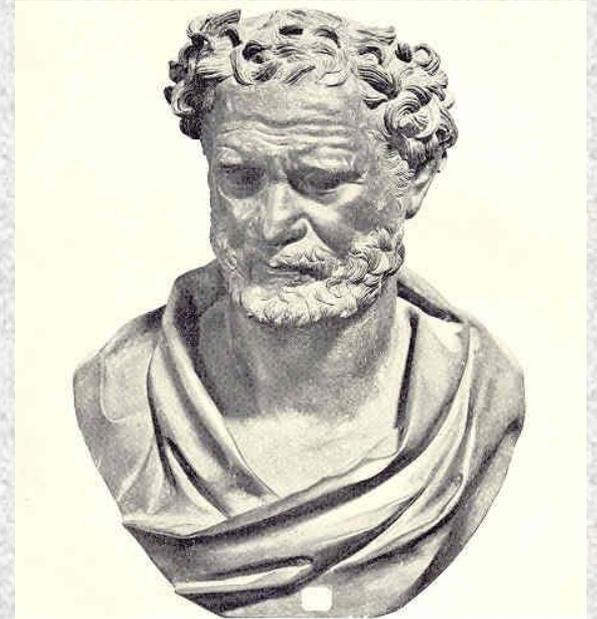
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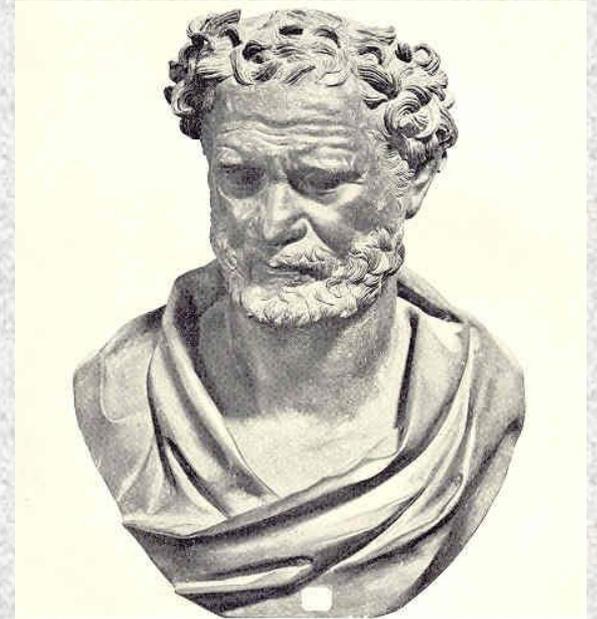
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3. all made of the same material



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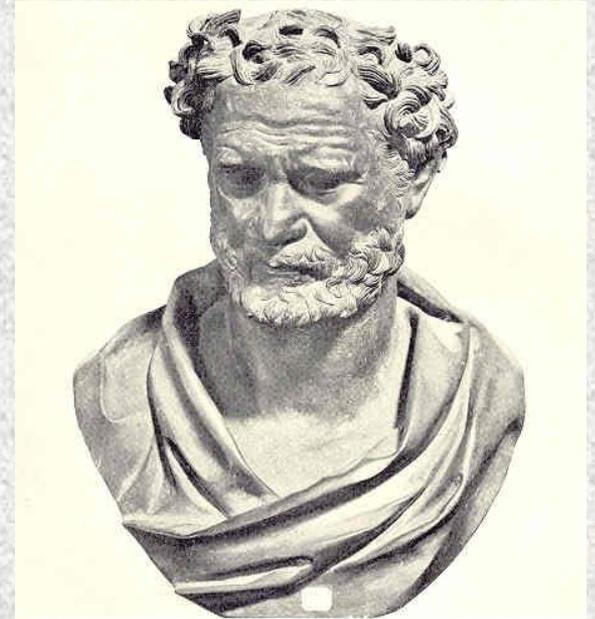
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4. different in shapes and sizes
5. infinite in number



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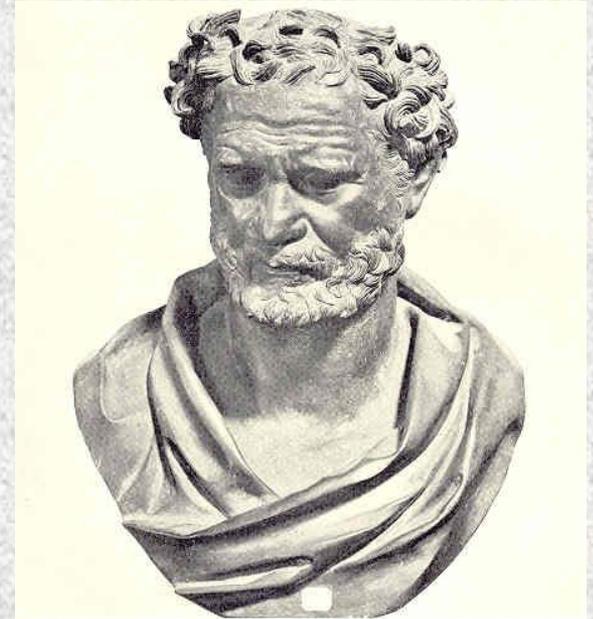
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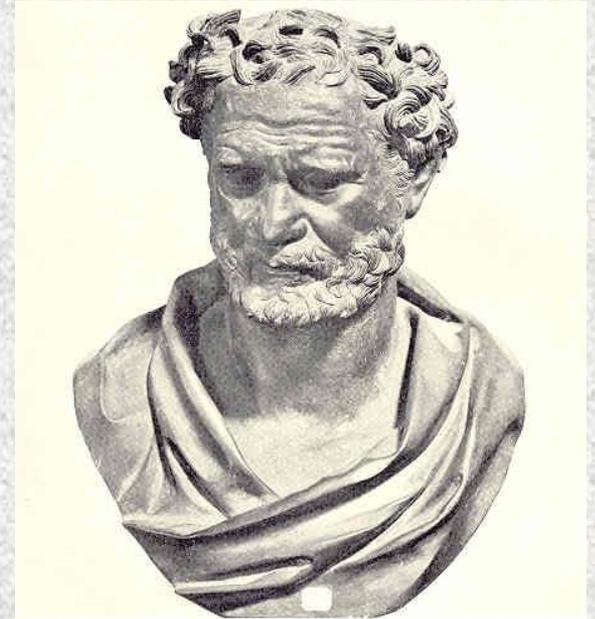
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Democrituse said

“ I think I finally understand atoms ”

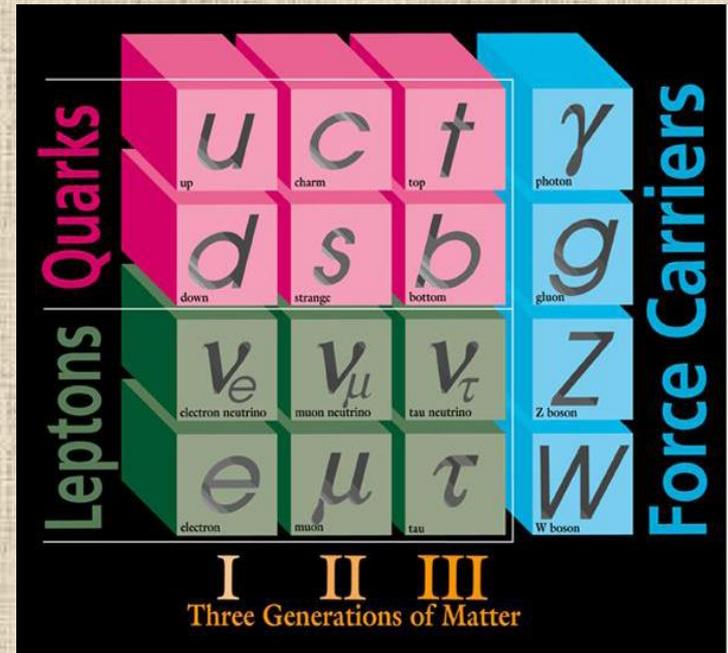
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a mathematical model combines theory and experiment to describe and explains all observed elementary particles and its interactions discovered in the universe.

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12 basic building blocks
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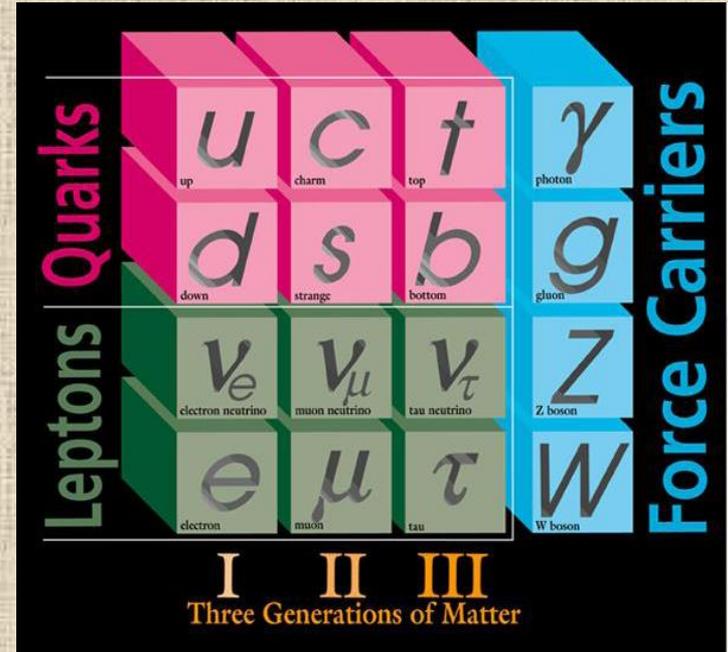
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6 leptons



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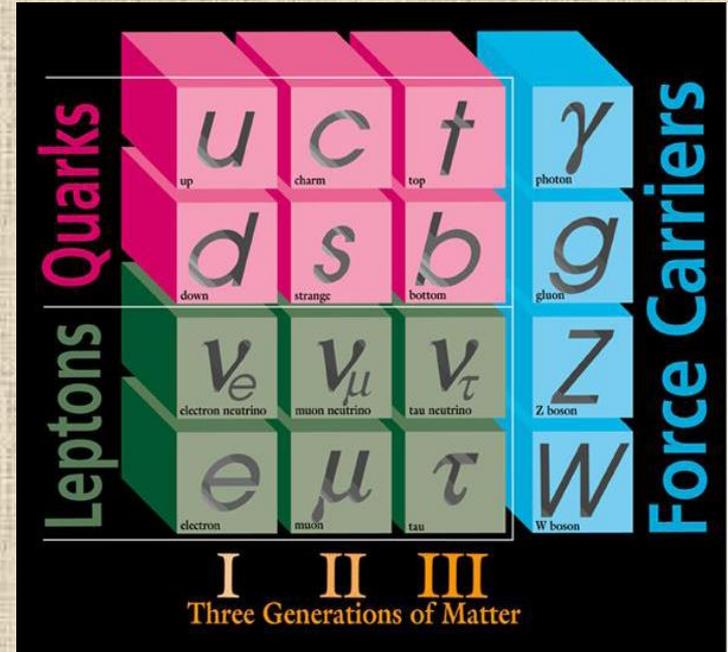
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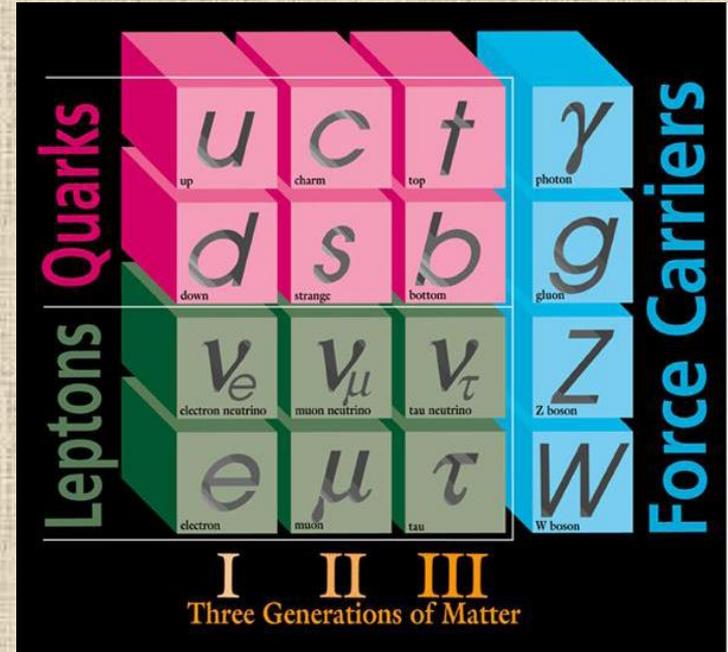
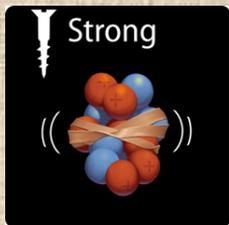
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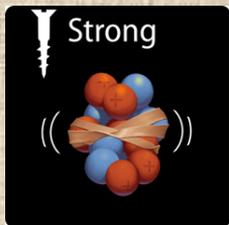
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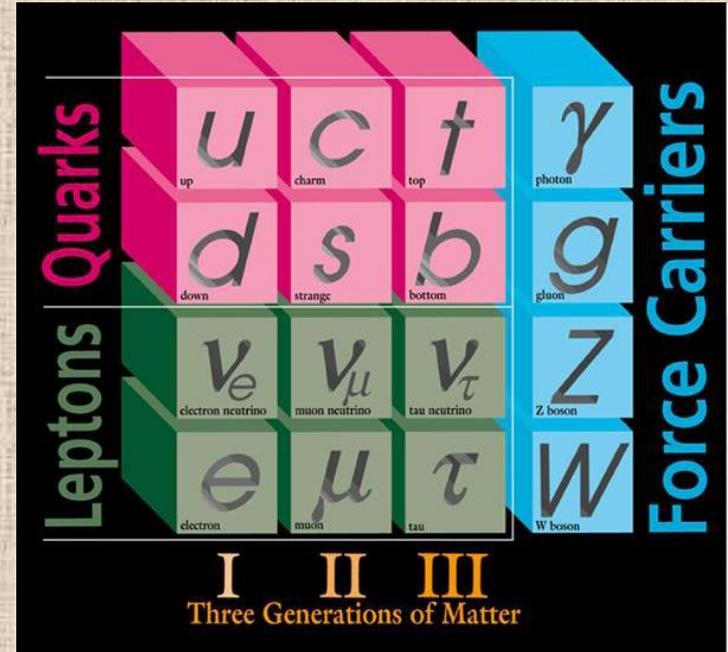
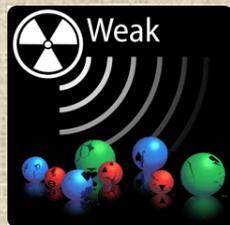
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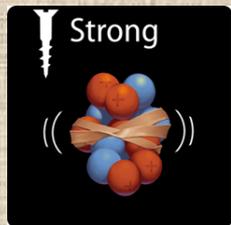
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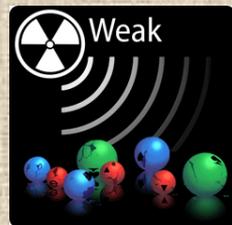
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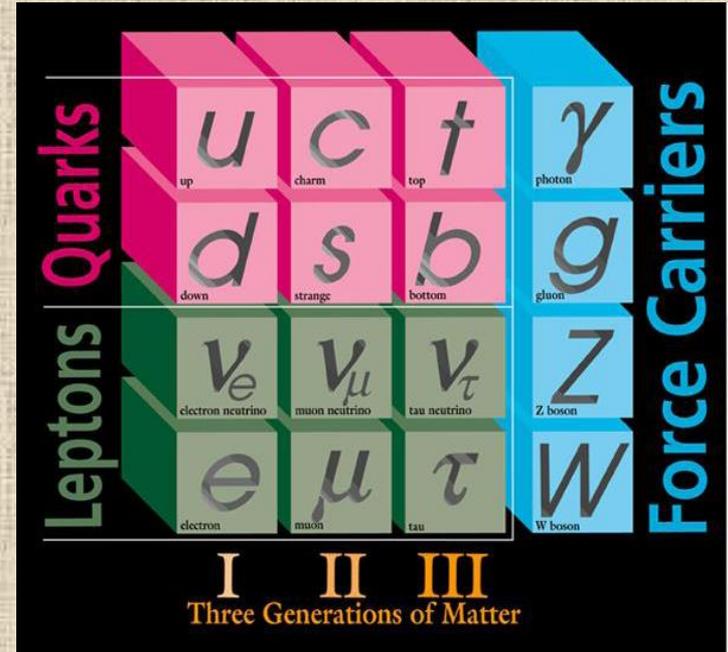
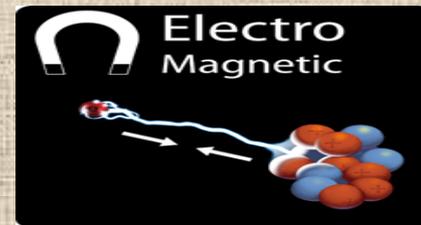
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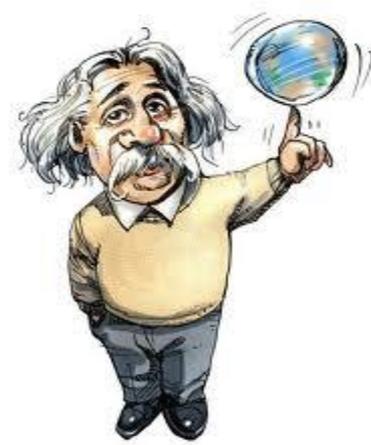


Electromagnetic



So far so good, but....

*... Is this the time for every physicist to say
"I think I finally understand atoms"*

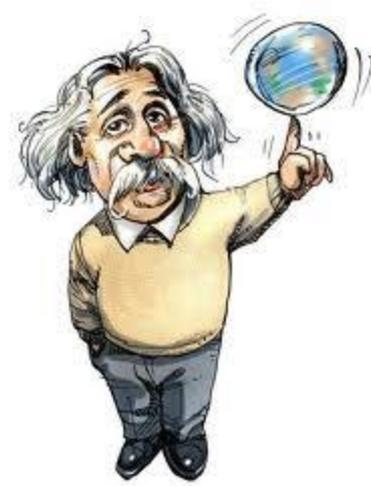


There are also some Questions that couldn't be solved!!!

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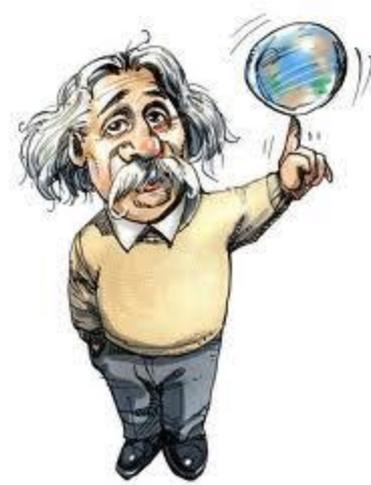
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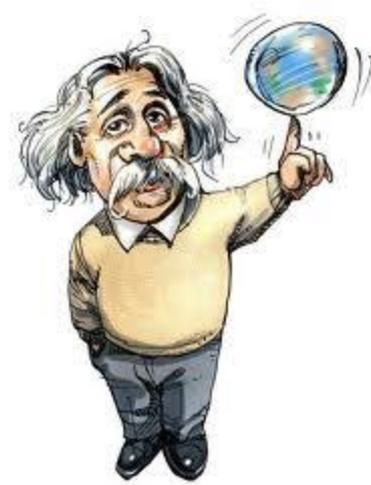
1. what is dark matter?

2. what happened to the missing antimatter?

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1. what is dark matter?
2. what happened to the missing antimatter?
3. The existence Super symmetric Particles!
4. Why are there *three* generations of *quarks* and *leptons*?

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- 2. what happened to the missing antimatter?*
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- 4. Why are there **three** generations of **quarks** and **leptons**?*
- 5. How does gravity fit into all of this?*

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There are also some Questions that couldn't be solved!!!

1. *what is dark matter?*
2. *what happened to the missing antimatter?*
3. *The existence Super symmetric Particles!*
4. *Why are there **three** generations of **quarks** and **leptons**?*
5. *How does gravity fit into all of this?*
and finally

6. ***what gives the particles **MASS**?***

the unsolved Mysteries of the standard model

Mass problem

why a particle has a certain mass?

*why is the photon **massless** and the W particle **massive**?*

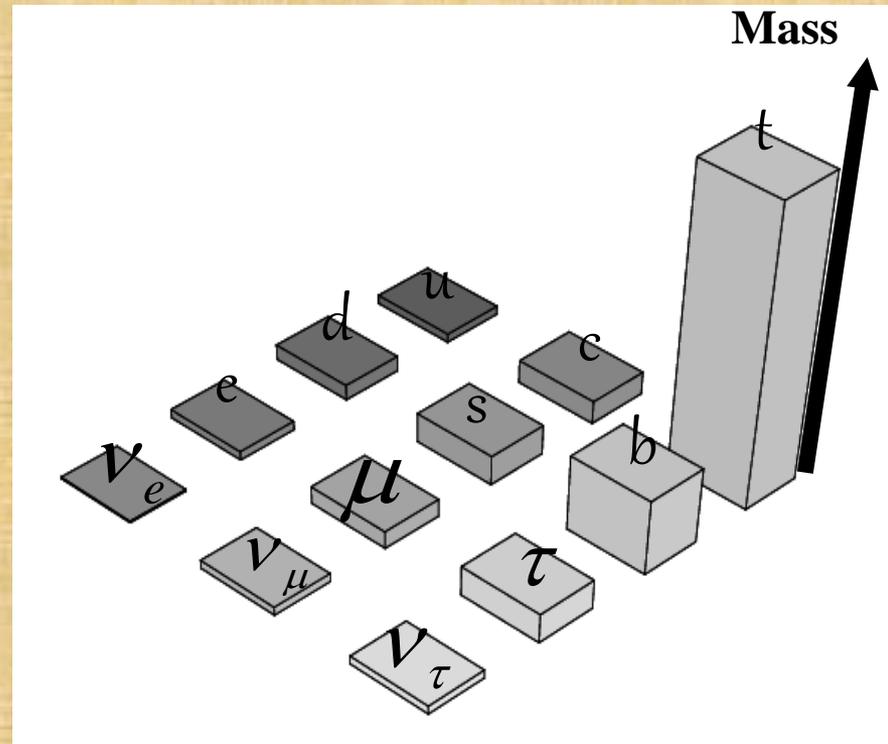
The standard model couldn't explained that !!

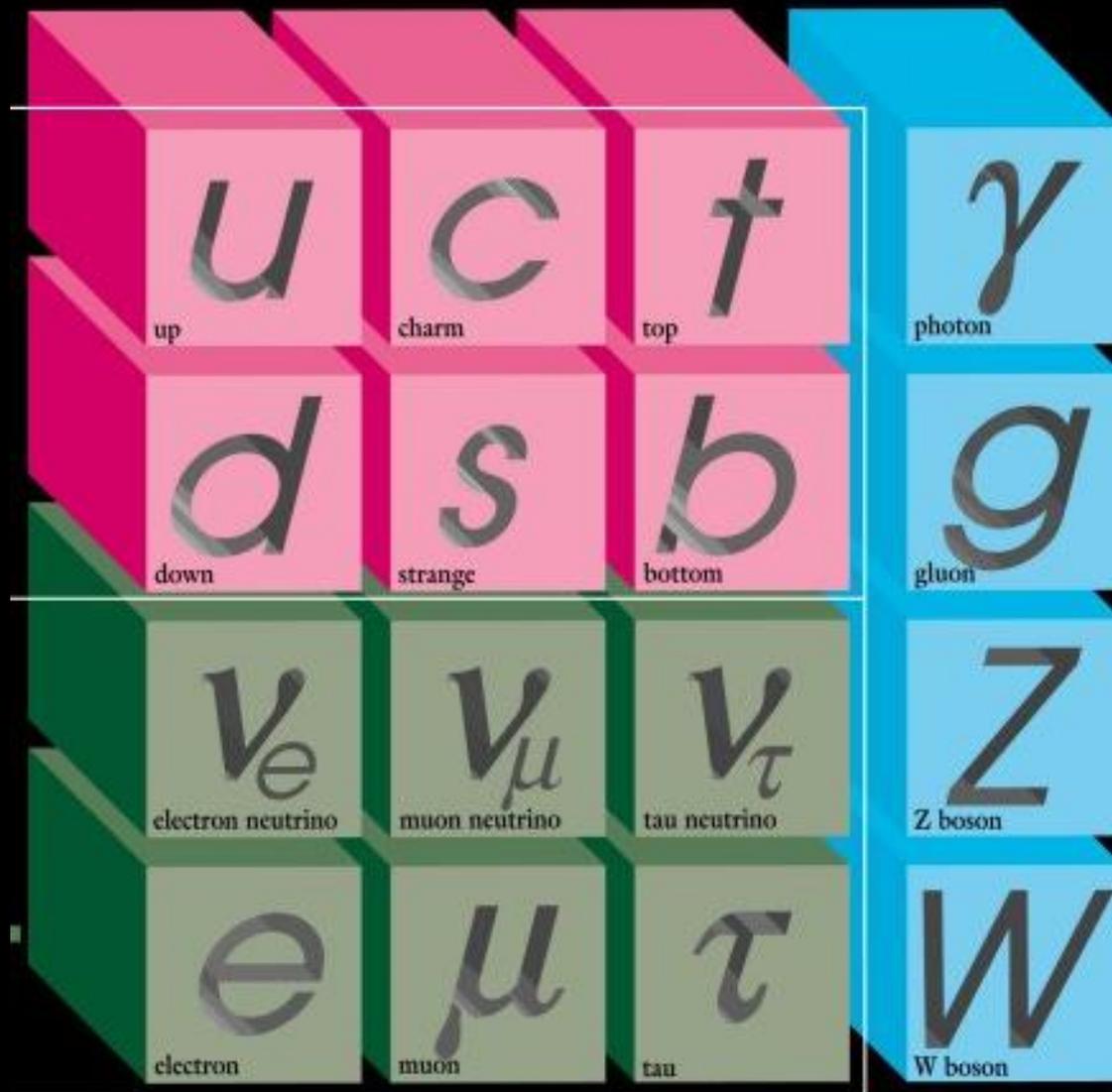
*Physicists have theorized the existence of a field
which interacts with other particles to give them mass*

the field

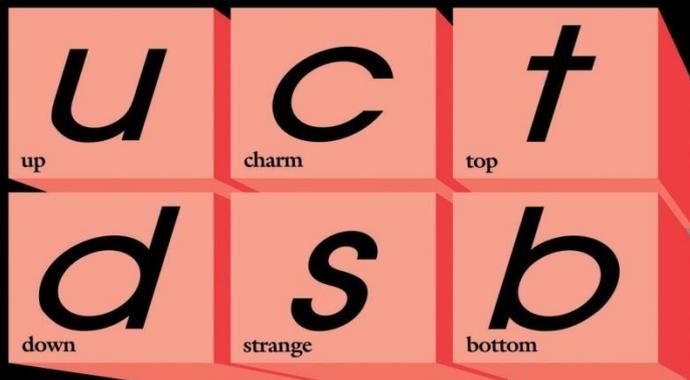
*called (**the Higgs field**)*

*The Higgs field requires a particle
called (**Higgs boson**)*

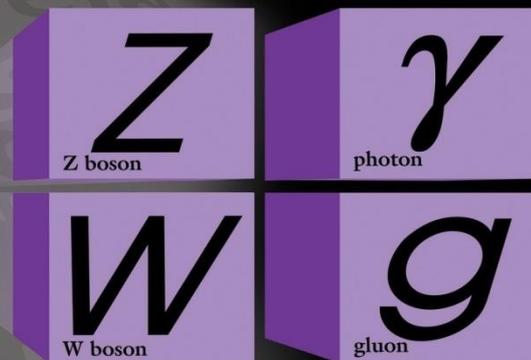




Quarks



Forces



Leptons

How the Higgs mechanism Works?

Suppose

(1) A Lot of physicists chat quietly in a fairly crowded room.



(2) A famous scientist enters the room causing a disturbance in the field



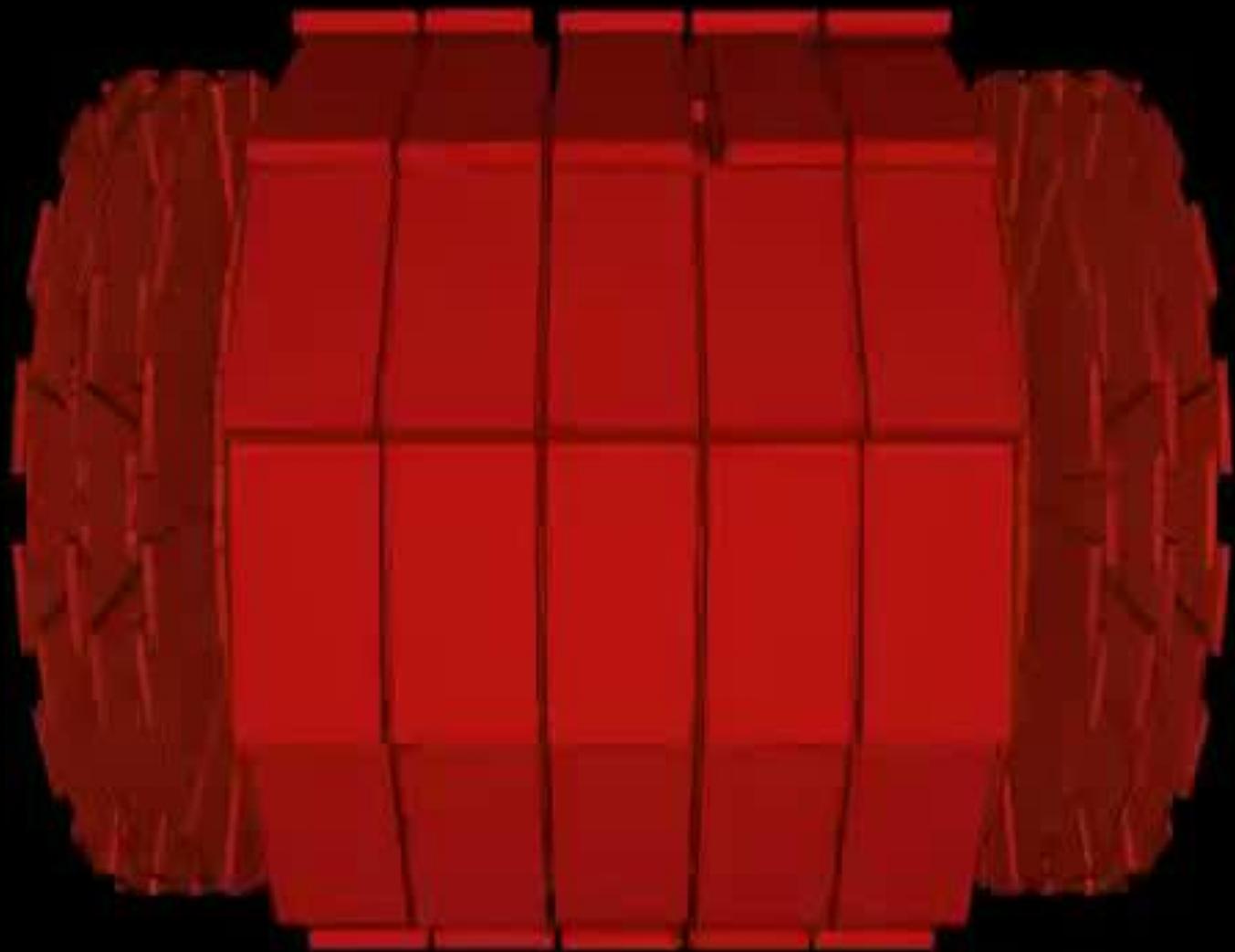
(3) Followers cluster and surround Einstein as this group of people forms a *“massive object”*.



How the Higgs mechanism Works? (continued)

- The Higgs Mechanism operates in a way similar to the case of the famous scientist in the crowded room.
- Particles that normally would have mass (e.g. Fermions, weak force carriers) move through the Higgs field interacting with Higgs particles.
- Through this interaction or disturbance particles may acquire mass. **Heavier** particles interact **more** with the Higgs field taking on **more mass**.
- Those particles that normally **do not** have mass, **do not** interact with the Higgs field, and therefore **do not** acquire mass.





the problem is

the Higgs particle has

no spin

no electric charge

no color charge

very unstable (1.6×10^{-22} s)

so it couldn't be detected directly since

(a) there are several different ways it can decay

(b) there are other collisions among those trillions that produce similar signatures.

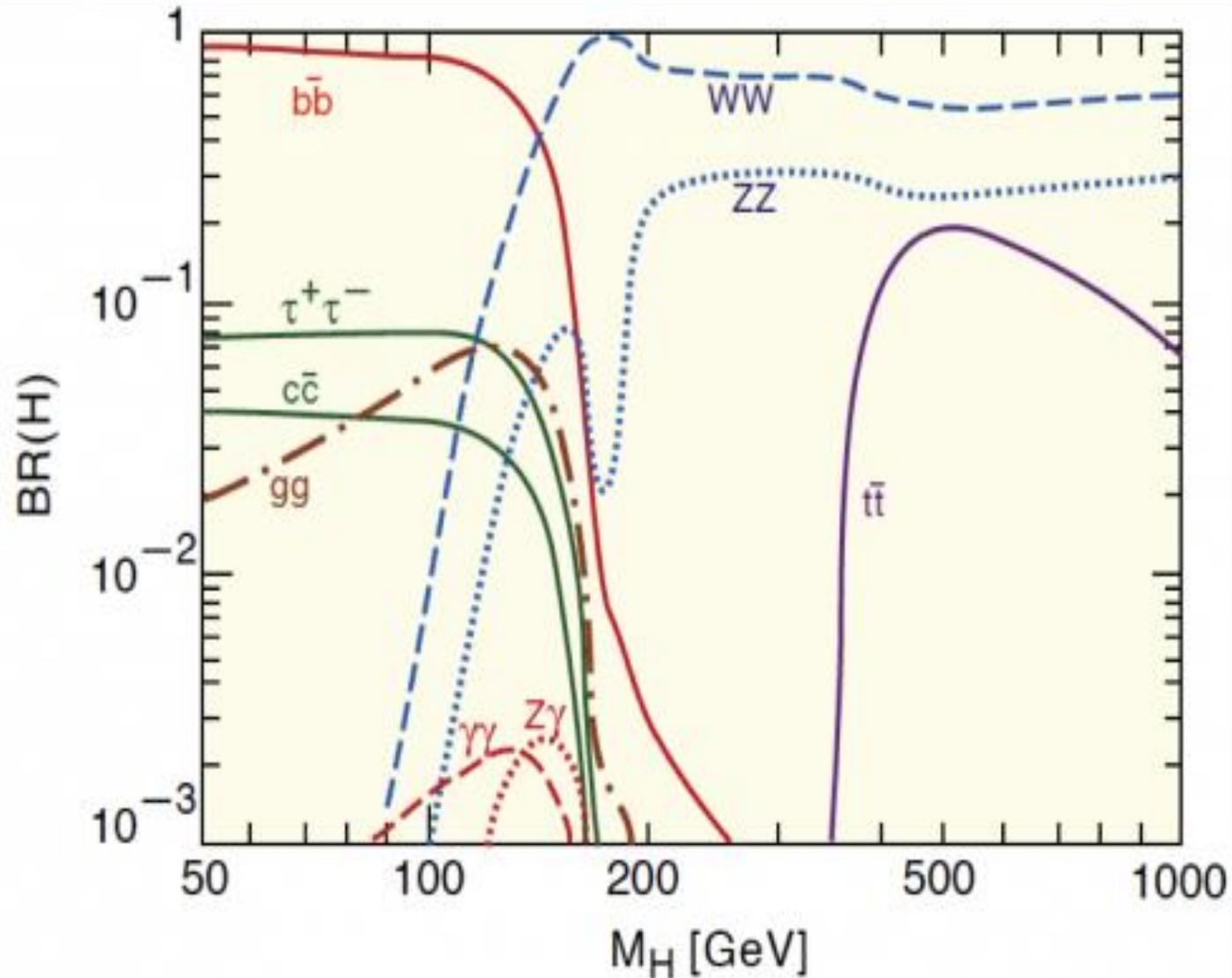
Unfortunately

The yield of Higgs particles in Relativistic Heavy Ion Collisions is very low (~ 21 events in 10^9 events)!!

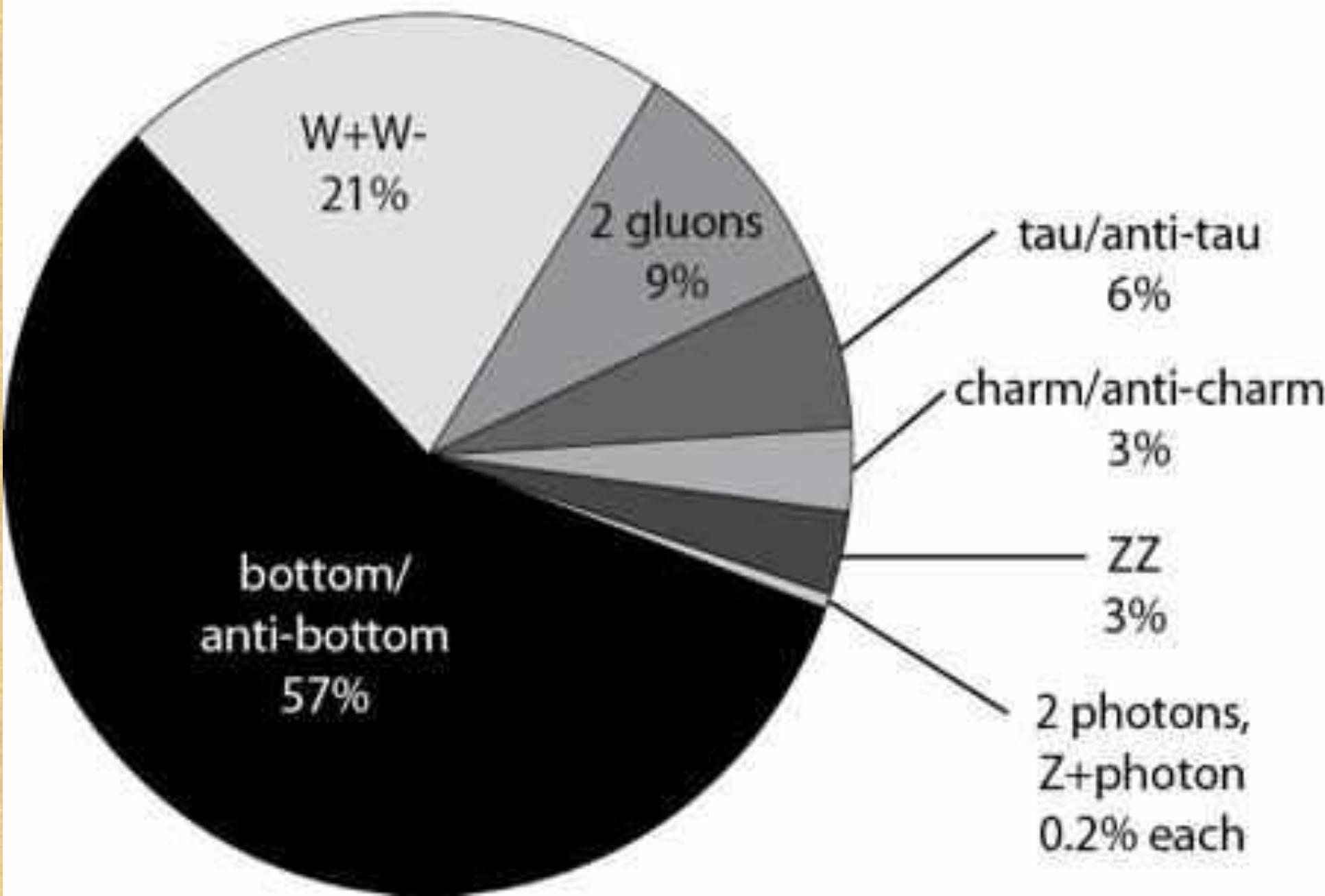


Discovery of Higgs Bosons

the observation of the Higgs boson in July 2012 indicates that the mass of the Higgs boson is 125.3 ± 0.6 GeV,



Decays of a 125 GeV Standard-Model Higgs boson



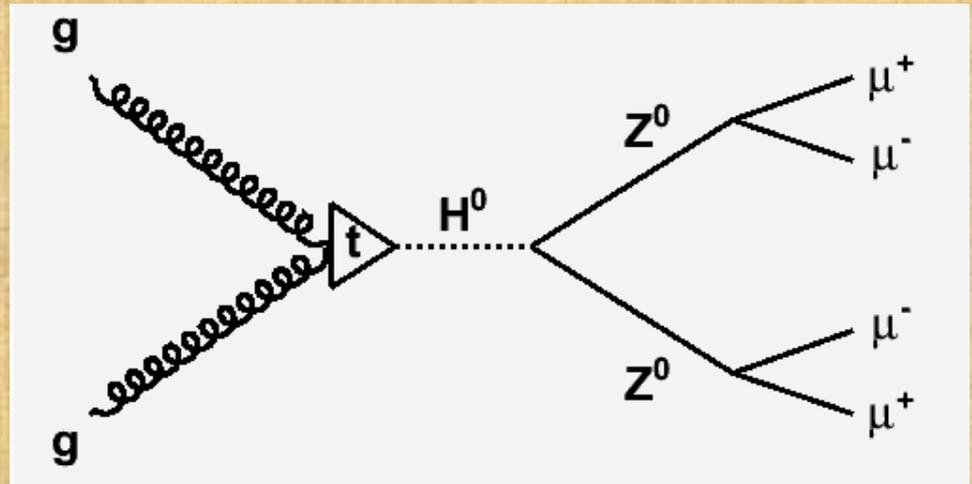
HIGGS BOSON RECONSTRUCTION

THROUGH ALGORITHM DEVELOPMENT AND ANALYSIS

1. *Using the last published data in Cern about the mass of Higgs boson*
2. *Using a MontCarlo technique (i.e. Pythia 8.1)*
3. *Making a data analysis using (i.e. .Root 5.3)*

We can reconstruct the Higgs boson from one of its decay channels.

$$h^0 \rightarrow Z^0 + Z^0 \rightarrow 2\mu^+ + 2\mu^-$$



My algorithm has to

- 1. find all the muons and anti muons first*
- 2. reconstruct the Z boson masses 91.1876 GEV*
- 3. Reconstructing the Higgs boson of 125.3 GEV from its Z daughters.*

By the help of

A Brief Introduction to PYTHIA 8.1

PYTHIA 6.4
Physics and Manual

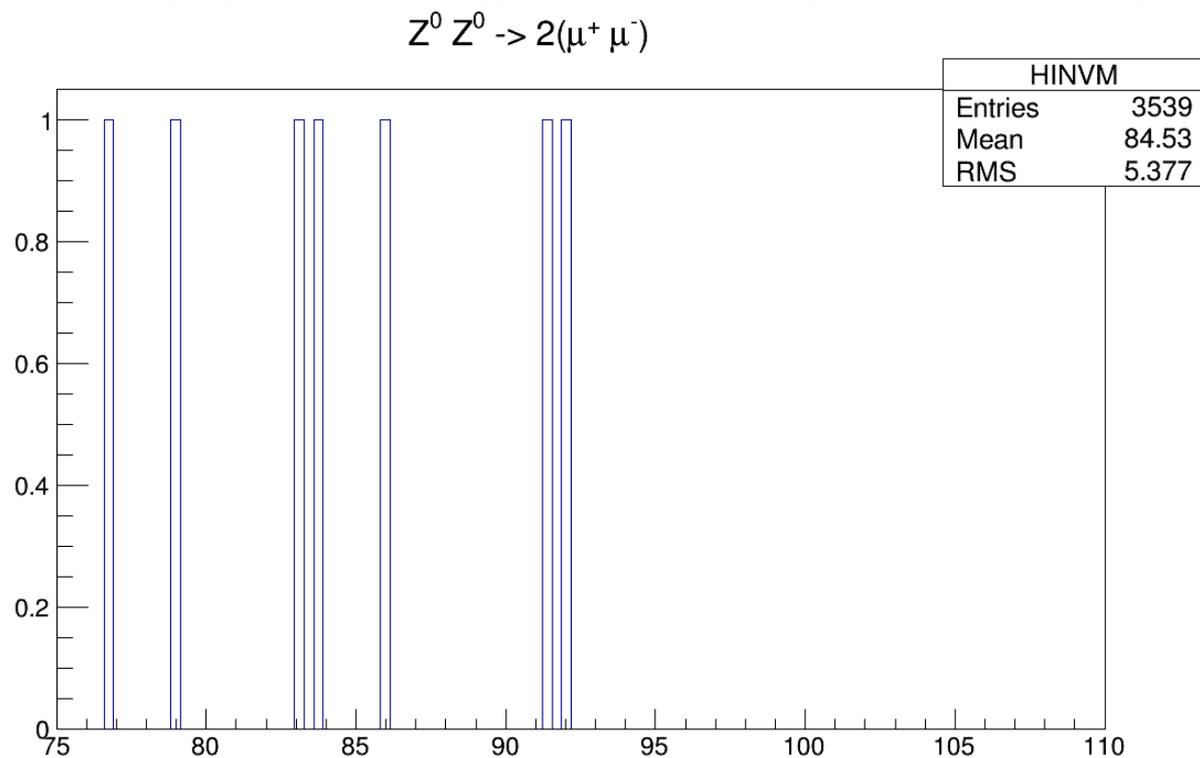
- 1. Torbjörn Sjöstrand ^{a,b,1}, Stephen Mrenna ^c, Peter Skands ^{a,c}*
- 2. using the classes that offer the four Lorentz vector*
- 3. opening the decay channels for Higgs and Z*
- 4. tabulating the data so that I can link the daughter and parent for each decay channel*

```

for(Int_t kk1 =0; kk1 < muonp; kk1++)
  for(Int_t kk2=0; kk2 < muonm; kk2++){
    pz0 = muonspm[0][kk1].p + muonspm[1][kk2].p;
    z02muon[z0count].muonplus = muonspm[0][kk1];
    z02muon[z0count].muonminus = muonspm[1][kk2];
    z0count++;
    muonspm[0][kk1].p.SetPxPyPzE(0.0,0.0,0.0,0.0);
    muonspm[1][kk2].p.SetPxPyPzE(0.0,0.0,0.0,0.0);

    }//for(Int_t kk2=0; kk2 < muonm; kk2++)

```



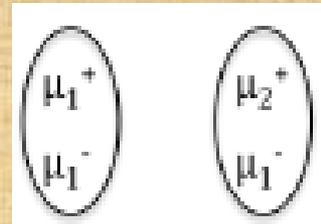
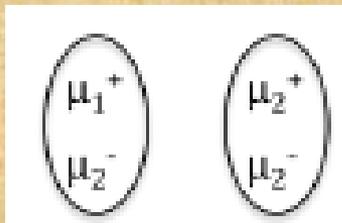
After some investigations , I found the problem

All this time I was constructing all possible muon pairs into Z instead of choosing the best possible pairs(with opposite charge)

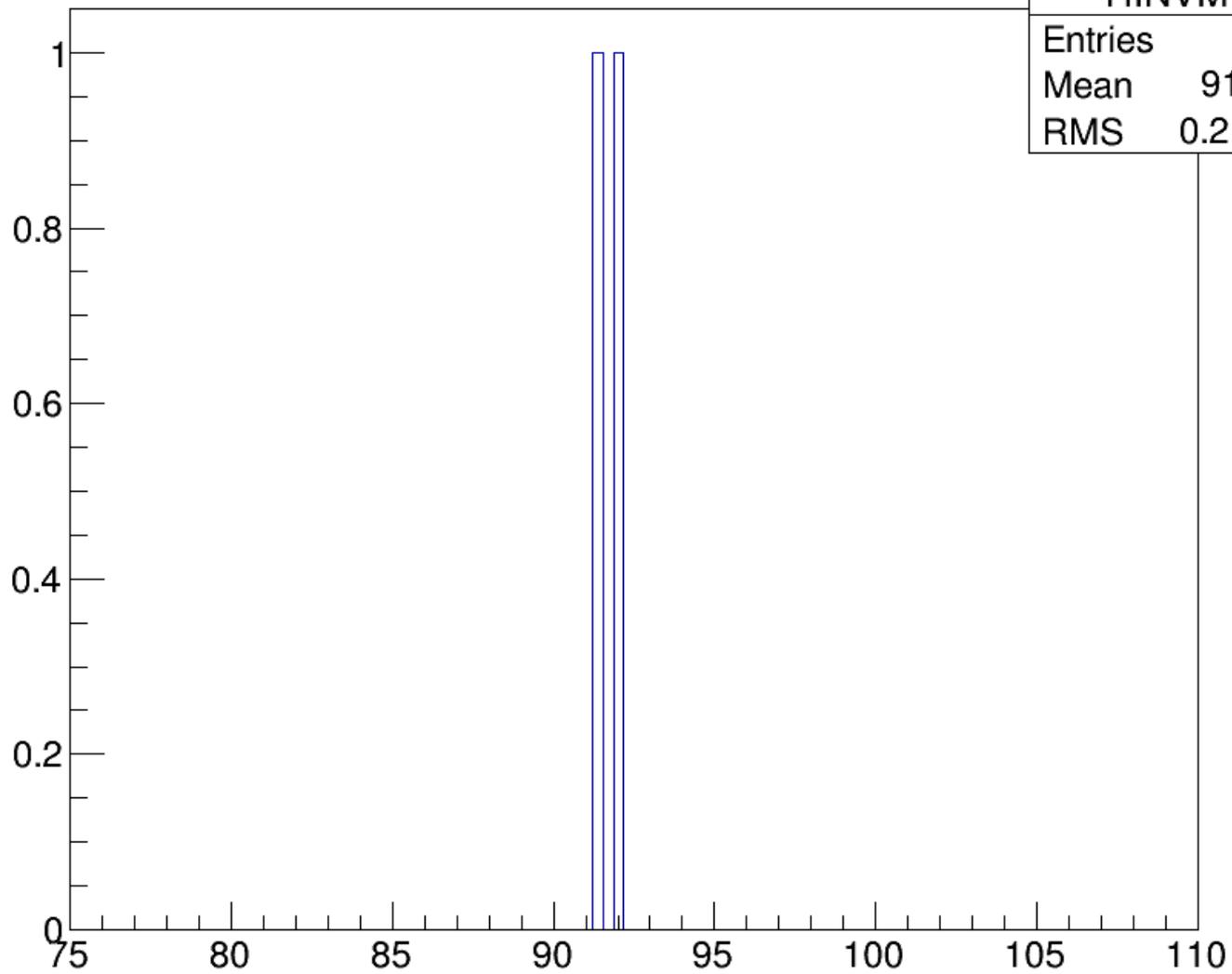
Solution

I made lots of combinations between muons so that I can find a special pairs with

1. opposite signs
2. total masses add up to 91.1876 GEV



Higgs $\rightarrow Z^0 Z^0 \rightarrow 2(\mu^+ \mu^-)$ Invariant Mass



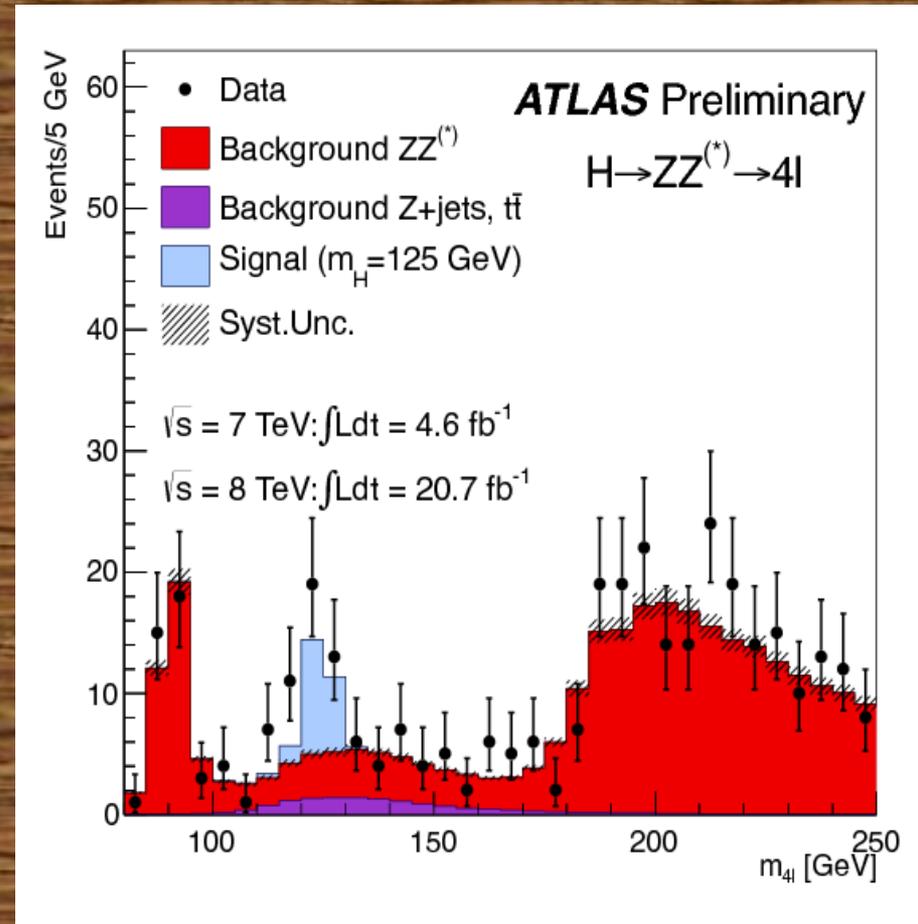
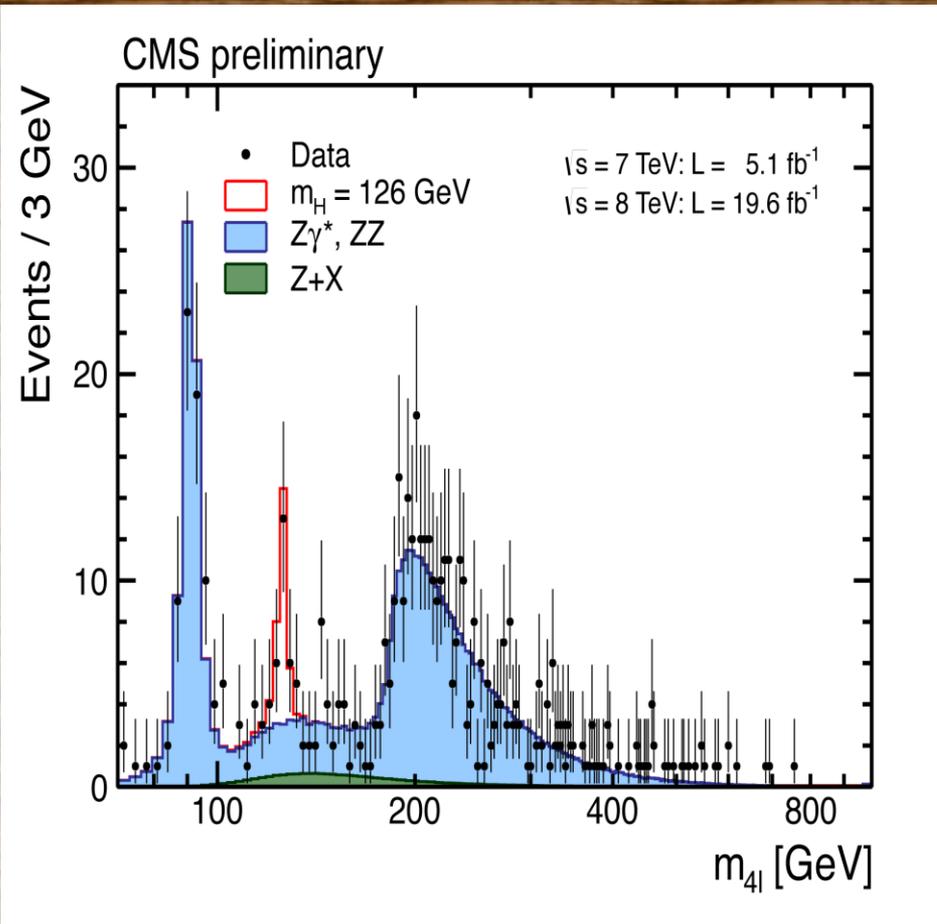
What is the next step

1. *I have to repeat the same mechanism in order to reconstruct the Higgs 'parents of the Z candidates then applying any kind of specific analysis on it*

```
for(Int_t kk1 =0; kk1 < z0count; kk1++)
  for(Int_t kk2=0; kk2 < z0count; kk2++){
    pH0 = z02muon[kk1].muonplus.p + z02muon[kk1].muonminus.p +
          z02muon[kk2].muonplus.p + z02muon[kk2].muonminus.p;
    eta=TMath::Abs(pH0.Eta());
    Bool_t true1=(eta<2.7&&eta>2.5);
    //Bool_t true1=(pz0.M())>=90);
    if(true1){
      HINVM->Fill(pH0.M());
      }// if(true1)
  }//for(Int_t kk2=0; kk2 < muonm; kk2++)
```

2. *I have to apply the same Idea with different kind of leptons (I.e. $2\mu^- 2\mu^+$, $2e^- 2e^+$ and $4e^-$)*

3. *I have to improve my code by including some Geometric cuts so that the data could reflect the real experimental one*



Conclusion

on the past two months , I believe that I have learned a lot not only as an academic education by attending schools , conferences and reading books.

But also the practical work increases my knowledge on C++ programming language and offers me a great learning of Pythia and linux shell

but I think that I have to read more about the usage of root 5.3 and Expand my limited experience in Pythia and other Montecarlo techniques

just to claims that

“I finally understand atoms “

References

1. R. Oerter (2006). The Theory of Almost Everything: The Standard Model, the Unsung Triumph of Modern Physics (Kindle ed.). [Penguin Group](#). p. 2. [ISBN 0-13-236678-9](#).
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3. http://en.wikipedia.org/wiki/Higgs_mechanism
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- 7-D. Griths, Introduction to Elementary Particles ("John Wiley & Sons, Inc.", 1987).

Thank you

