

# Origin of mass

Bedangadas Mohanty  
National Institute of  
Science Education and  
Research, Odisha, India



Buxi Jagabandhu  
Memorial Lecture  
BJB College,  
Bhubaneswar

24<sup>th</sup> January 2024

# My tributes to Shri Buxi Jagabandhu Bidyadhar Bhramarabara Ray Mohapatra



- Born around 1773 in Rorunga, near Puri. His ancestors were the commander in chief or Bakshi of the Khordha army.
- Led the Paika Rebellion in 1817 to revolt the land revenue policy of the British.
- Freedom fighter of India.

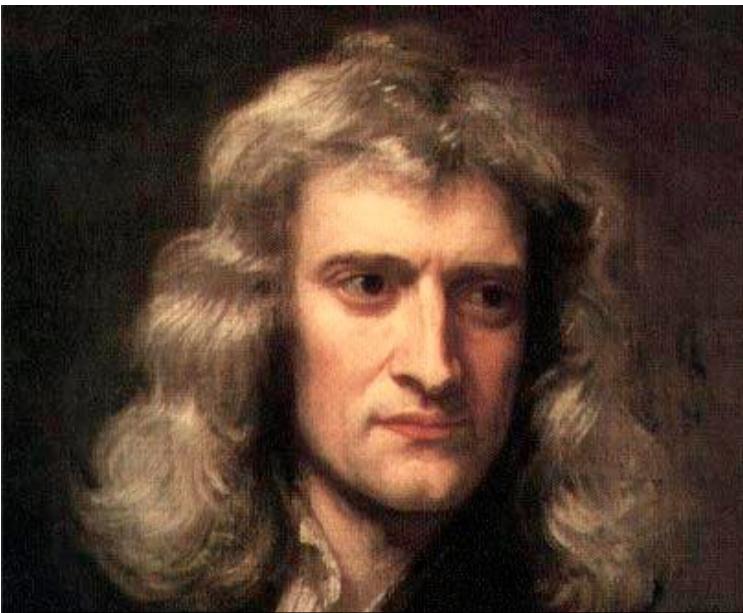
Fortunate to be asked to give a talk on a memorial lecture named after him and in a college (1957) named after him.

What is mass

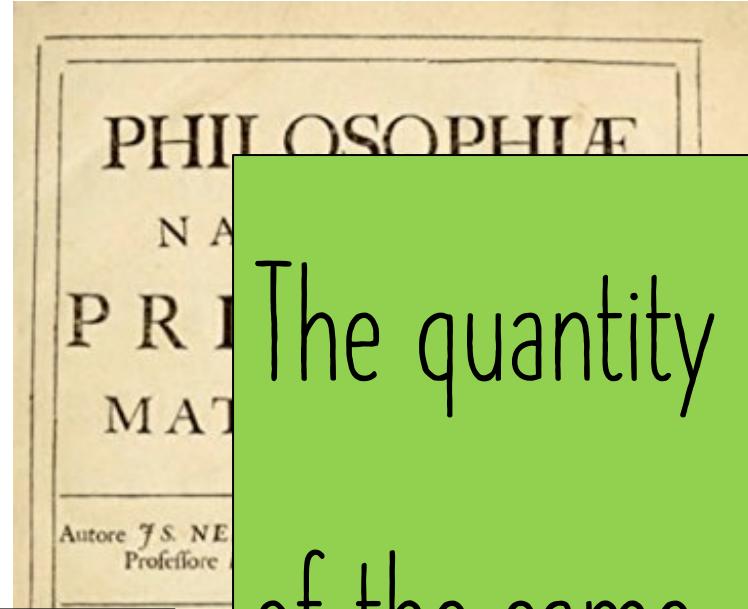
---

# According to Newton

---



Mass is a fundamental quantity -  
Same in earth, moon, jupiter .....  
Weight is different



MATHEMATICAL PRINCIPLES

The quantity of matter is the measure  
of the same, arising from its density  
and bulk conjointly.

# Elephant versus Ant

---



Which has more mass and why ?



Mass = Sum of mass of all building blocks ?

What are our  
building blocks

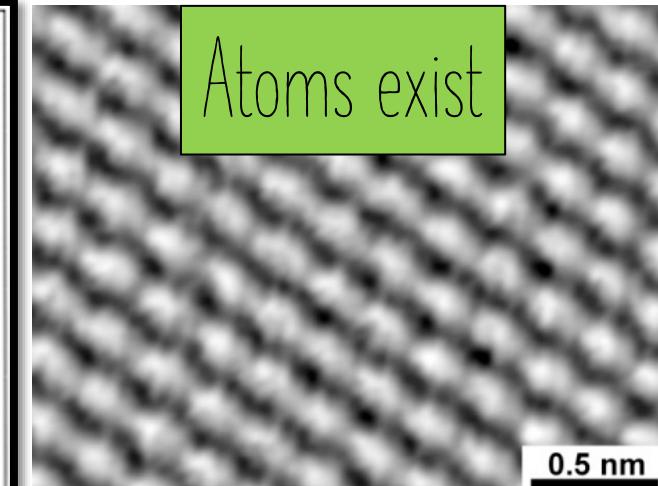
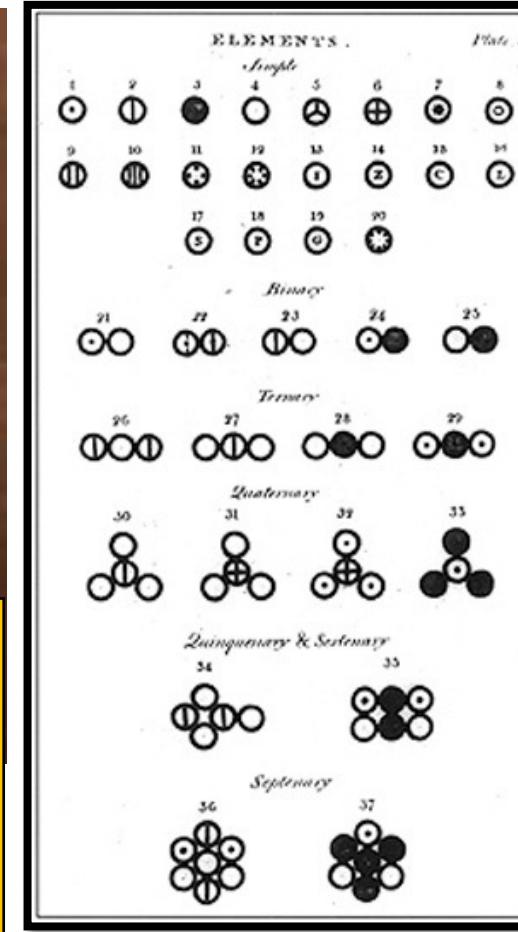
---

# Building blocks – Atoms ?

John Dalton



Greek ἄτομος/átomos, α-τέμνω,  
which means uncuttable, something that cannot be  
divided further.



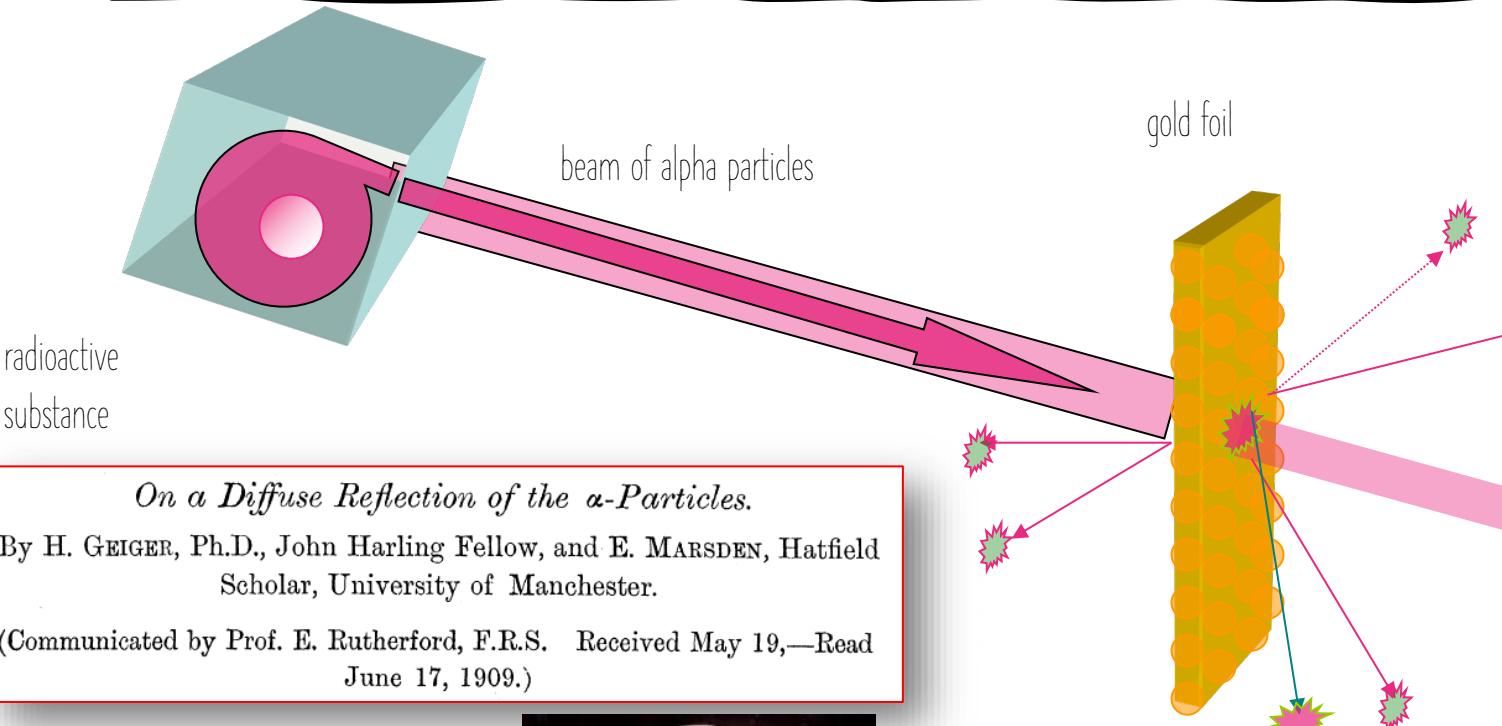
Atoms exist



TEM

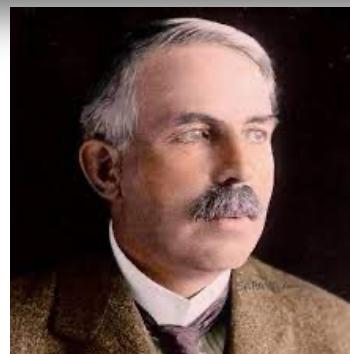
# Building blocks – proton, neutron, electron

8/32



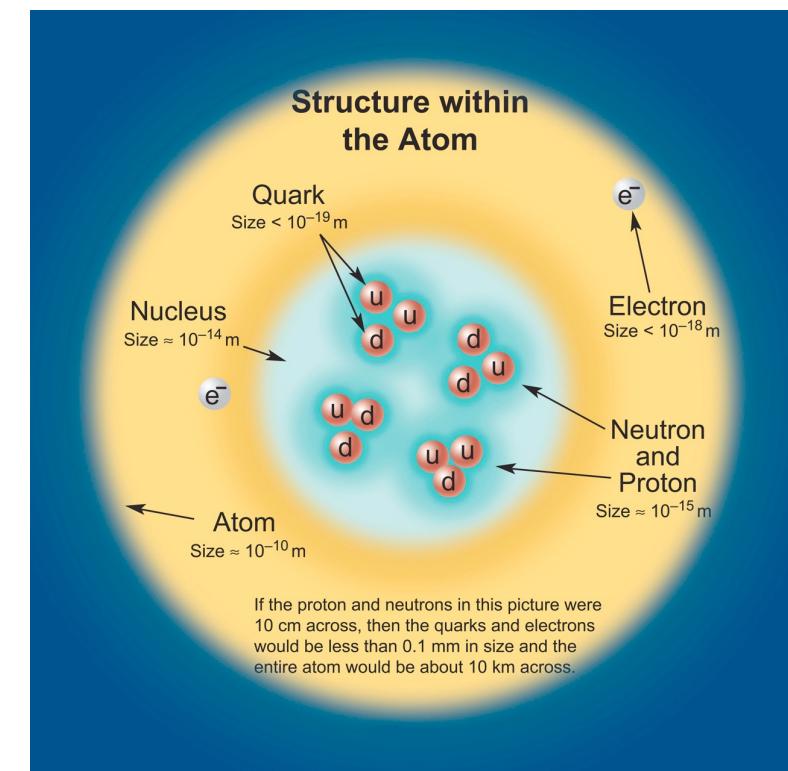
*On a Diffuse Reflection of the  $\alpha$ -Particles.*  
By H. GEIGER, Ph.D., John Harling Fellow, and E. MARSDEN, Hatfield Scholar, University of Manchester.  
(Communicated by Prof. E. Rutherford, F.R.S. Received May 19,—Read June 17, 1909.)

Marsden was an undergraduate student



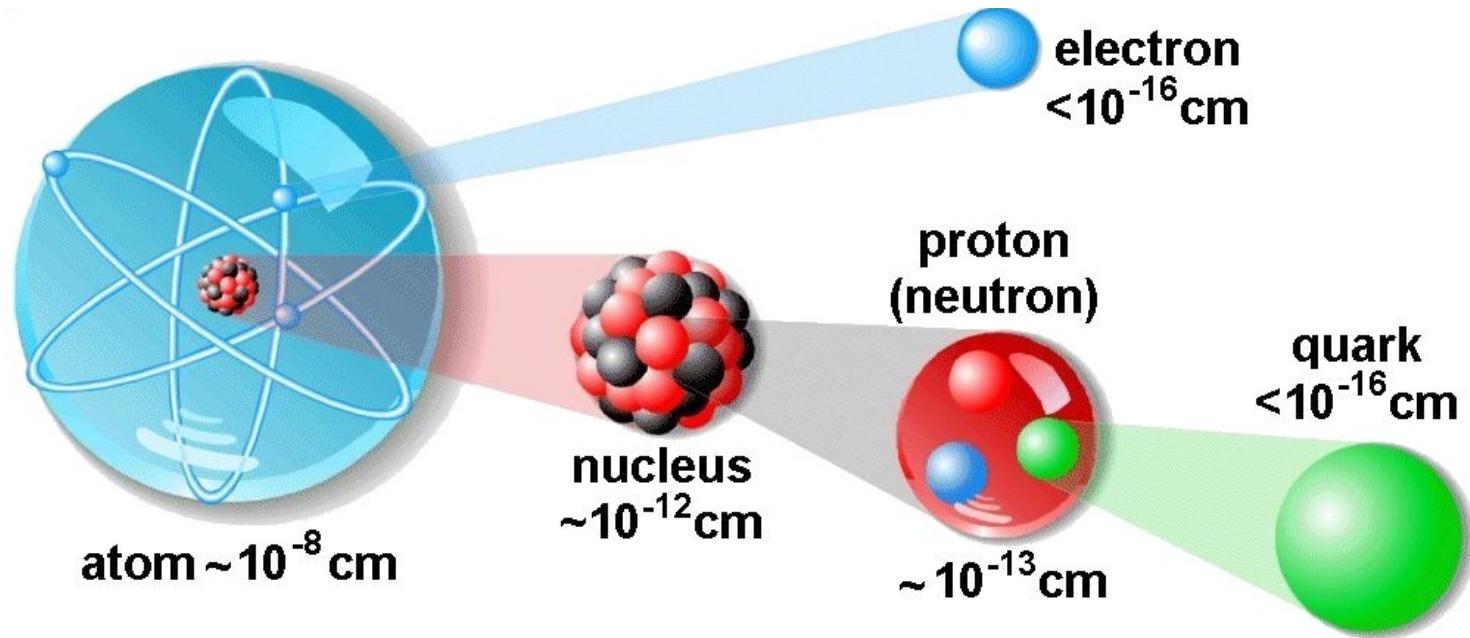
Rutherford

1908 Nobel Prize in Chemistry.  
Albert Einstein called him a 'second Newton'



# Building blocks: Quarks and electrons

---



Louis de Broglie

$$\lambda = h/p$$

$$f = E/h$$

1929 Nobel Prize in physics for his discovery of the wave nature of electrons

In 1952 the first Kalinga Prize was awarded to him by UNESCO for popularization of science

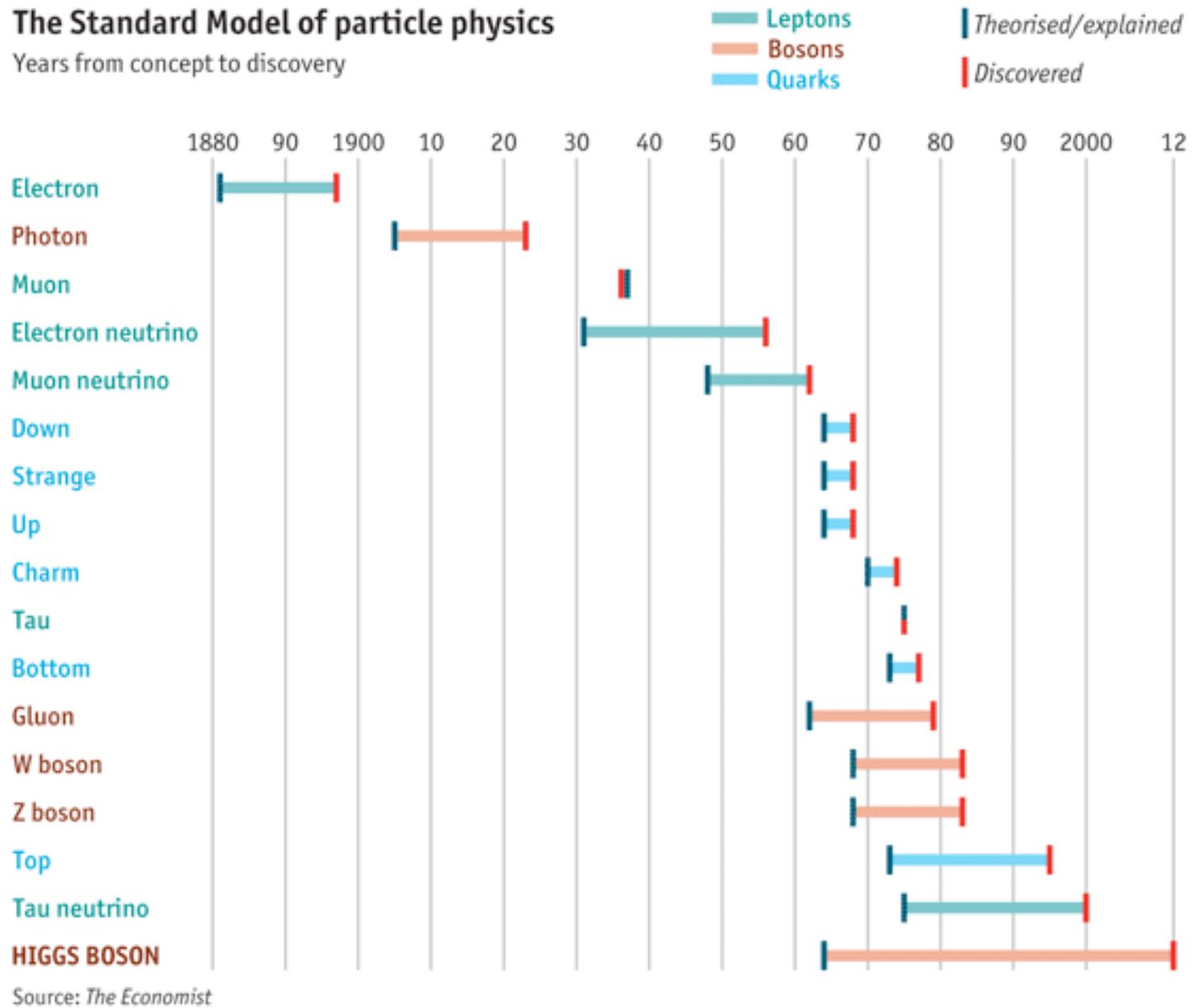
# Fundamental building blocks of visible matter

We are made of electron, quarks and gluons

Origin of Mass

## The Standard Model of particle physics

Years from concept to discovery



# Mass of electron and why worry about it ?

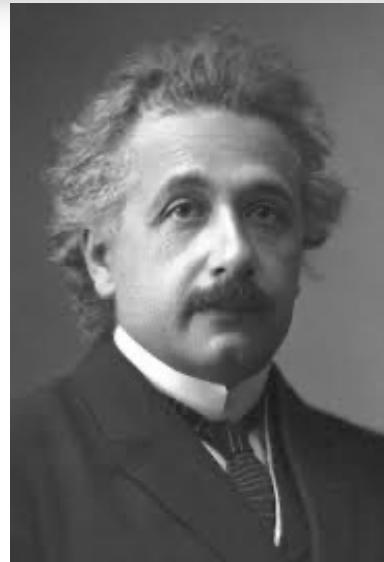
# What will happen if electron mass is zero ?

12/32

If equal to Zero

$$E = mc^2 = \frac{m_0 c}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Electron will move with speed of light



1921 Nobel Prize in Physics  
"for his services to theoretical physics, and especially for his discovery of the law of the photoelectric effect"

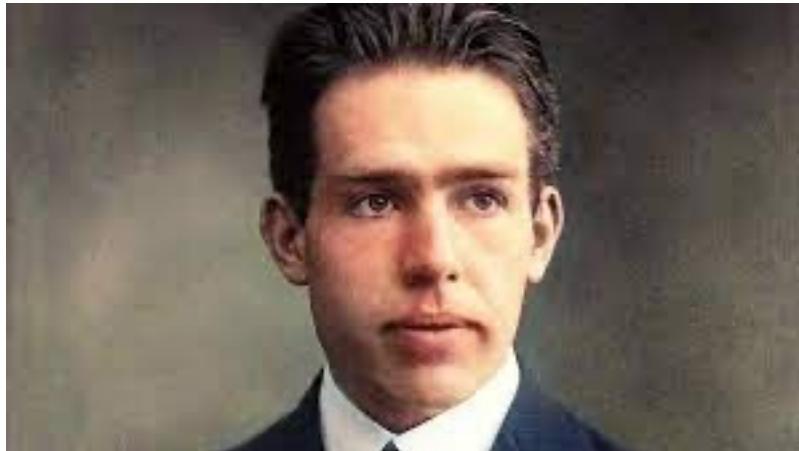
No atoms  
No Molecules  
No Compounds  
No Life  
We won't's exist

# What happens if electron mass a bit higher or a bit lower ?

13/32

## Expression of Bohr radius

$$r_n = 4\pi\epsilon_0 \frac{n^2 h^2}{m e^2}$$



Nobel Prize for 1922 for structure of atom



World will no  
longer be same

# Role of mass in nature/physics

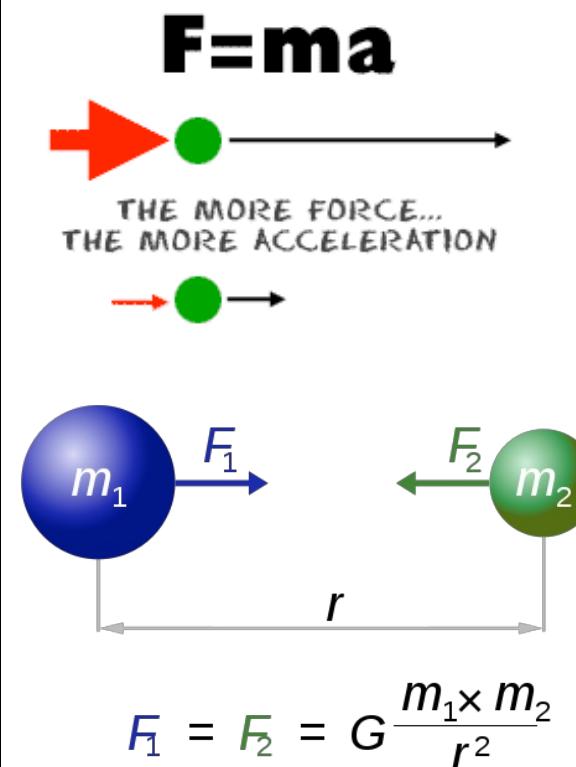
Newton:

Weight proportional to Mass

Einstein:

Energy related to Mass

Neither explained origin of Mass



$$T = 2\pi \sqrt{\frac{m}{k}}$$

$$E_K = \frac{1}{2}mv^2$$

$E_K$  = Kinetic Energy  
 $m$  = Mass  
 $v$  = velocity

# Origin of mass ?

How did electron get its mass ?

# Mass is generated by interactions

16/32

Anderson-Brout-Englert-Guralnik-Hagen-Higgs-Kibble - Boson



# Idea documented in journals

1964

## BROKEN SYMMETRY AND THE MASS OF GAUGE VECTOR MESONS\*

F. Englert and R. Brout

Faculté des Sciences, Université Libre de Bruxelles, Bruxelles, Belgium  
 (Received 26 June 1964)

VOLUME 13, NUMBER 16

PHYSICAL REVIEW LETTERS

19 OCTOBER 1964

## BROKEN SYMMETRIES AND THE MASSES OF GAUGE BOSONS

Peter W. Higgs

Tait Institute of Mathematical Physics, University of Edinburgh, Edinburgh, Scotland  
 (Received 31 August 1964)

## GLOBAL CONSERVATION LAWS AND MASSLESS PARTICLES\*

G. S. Guralnik, † C. R. Hagen, ‡ and T. W. B. Kibble

Department of Physics, Imperial College, London, England  
 (Received 12 October 1964)

*"When the time is ripe for certain things, these things appear in different places in the manner of violets coming to light in early spring." - Farkas Bolyai*

# Higgs field and mass

"Light" means All Electromagnetic Waves

Gamma Rays, X-rays,  
Ultraviolet light  
Visible Light  
Infrared Light,  
Microwaves, Radio Waves



Higgs Field  
Exists Everywhere

Higgs Field

May Be Zero ~~✓~~

May Not Be Zero

Higgs  
Waves

Higgs Particle

# How mass is generated?

Cost to build LHC: \$4.75 billion

Professor David J Miller of the Physics and Astronomy Department at University College London- bottle of Veuve Cliquot 1985 by Mr Waldegrave (UK Minister)

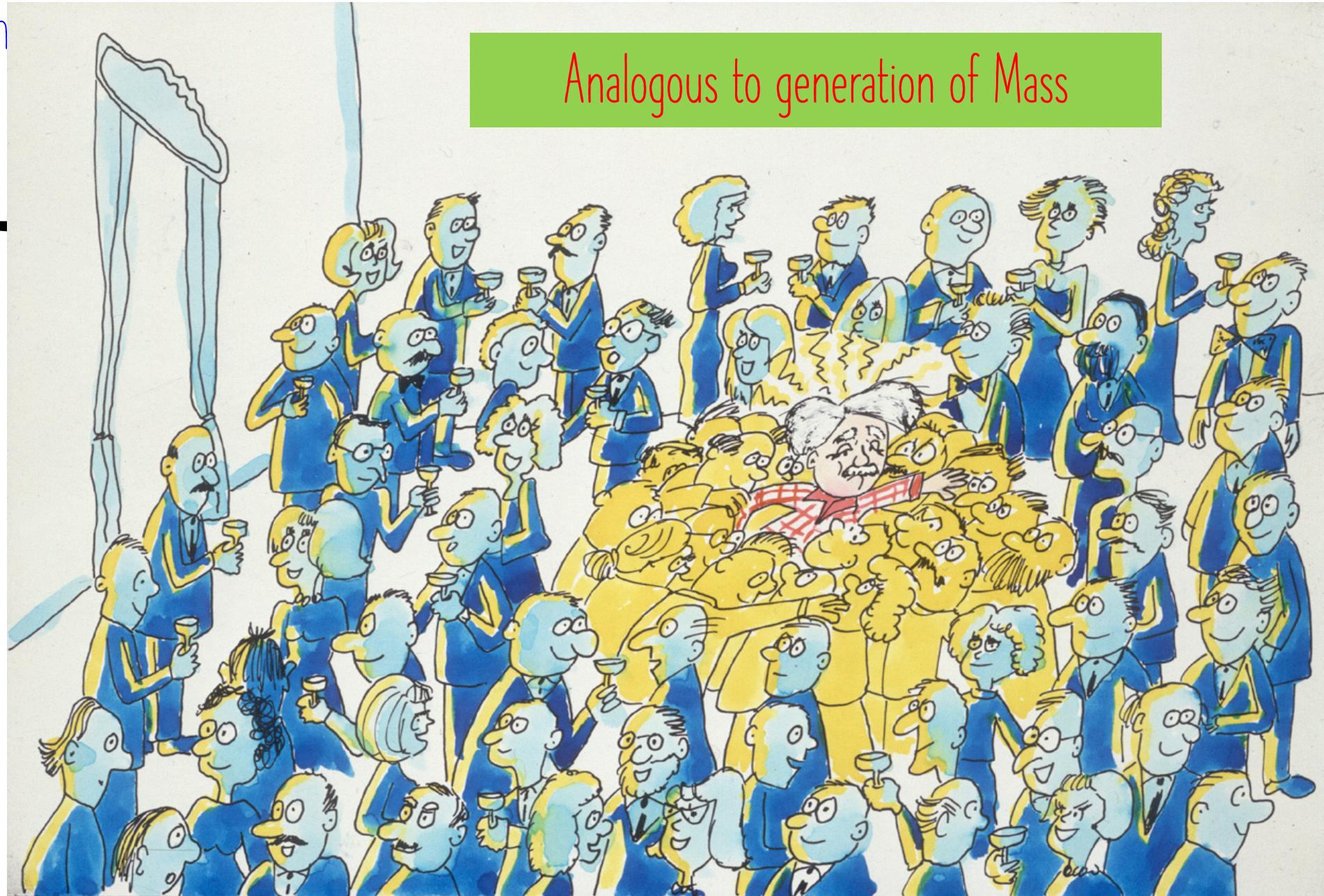
Imagine a room  
full of political  
activists

---

The Prime  
Minister  
walks in

He is  
surrounded  
by a cluster  
of people

Analogous to generation of Mass

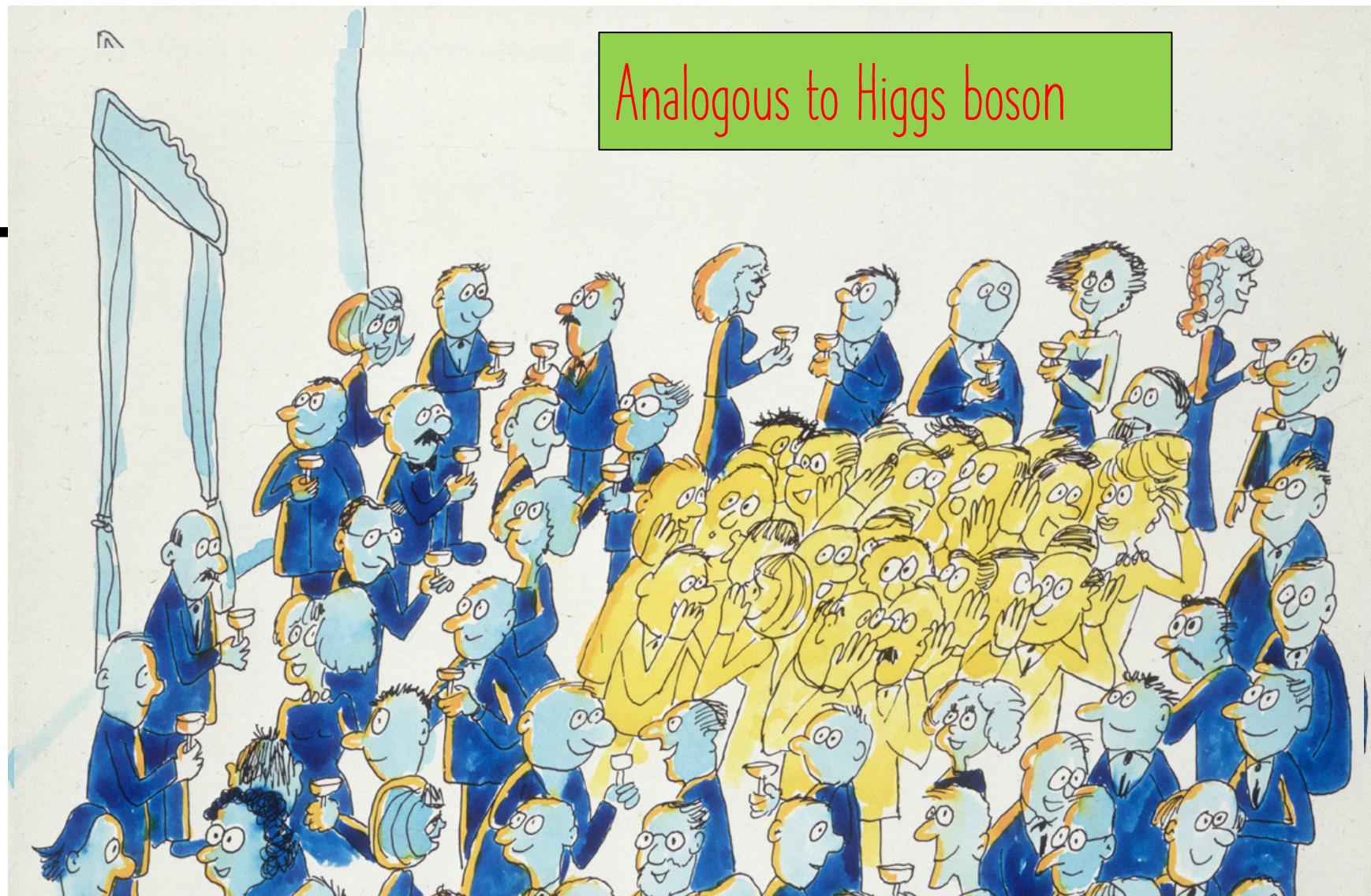


Imagine the same room again

An interesting rumour is introduced

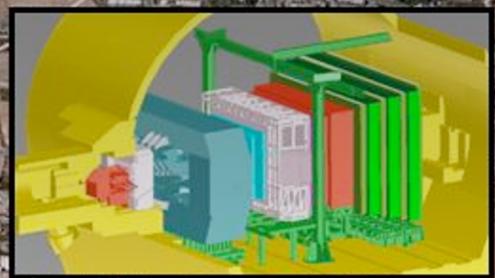
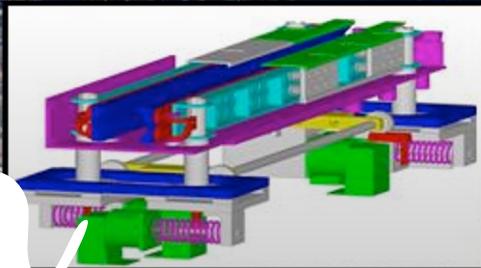
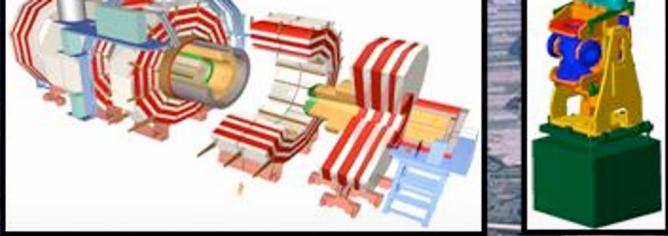
Soon we have a cluster of people discussing it

Analogous to Higgs boson

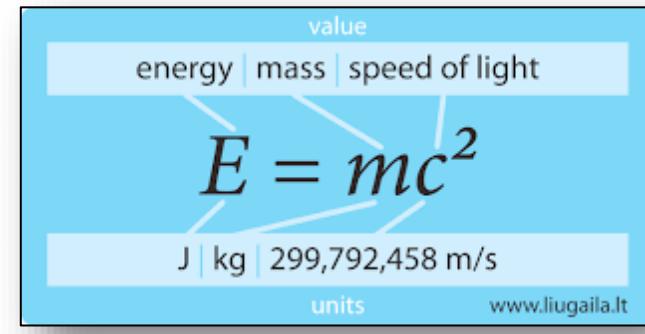


Discover Higgs Boson → Higgs field exists → electron gets mass by interaction with field

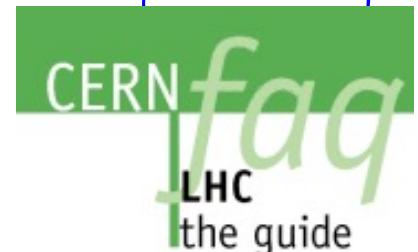
# Large Hadron Collider



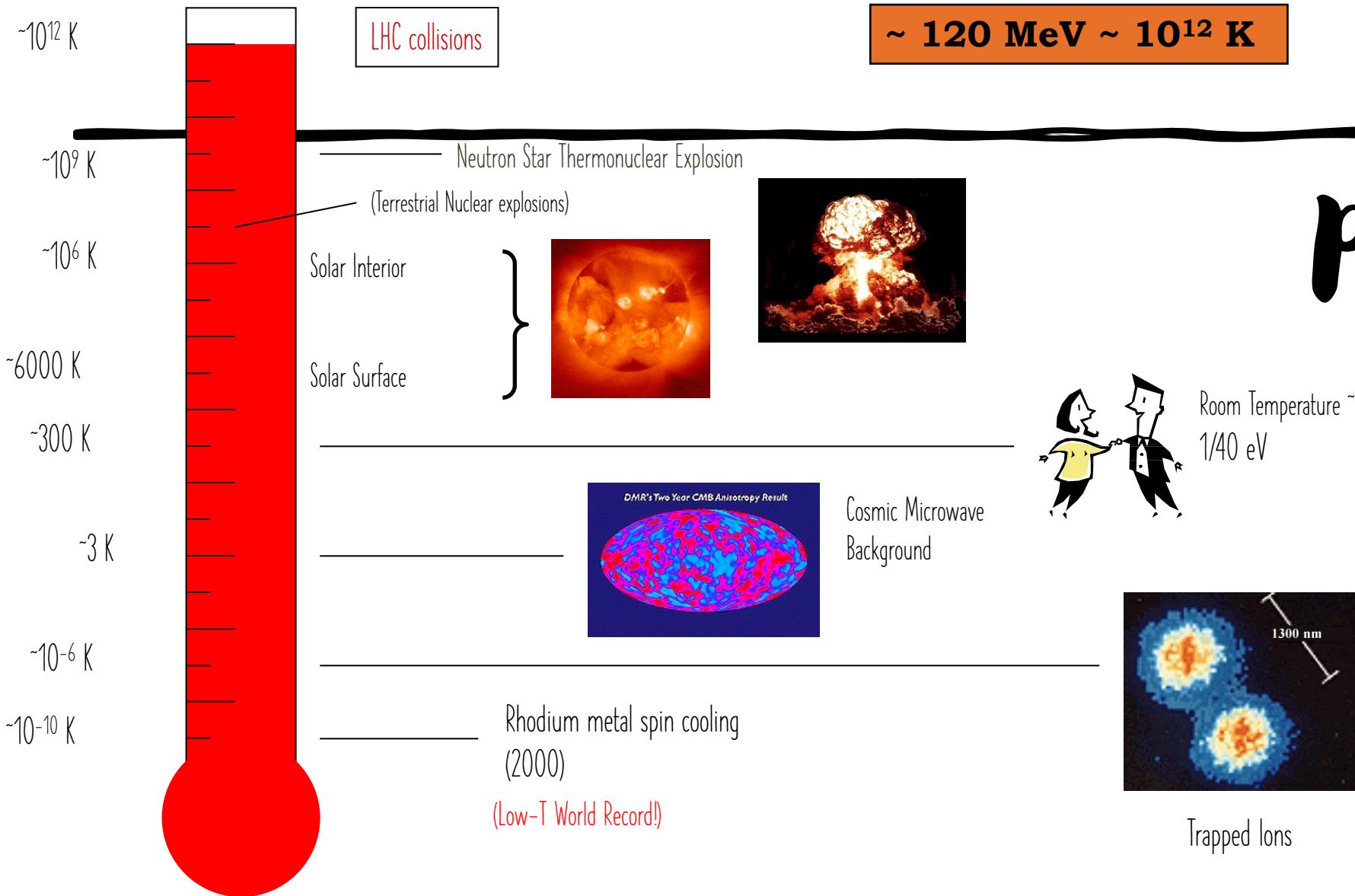
# Large Hadron Collider



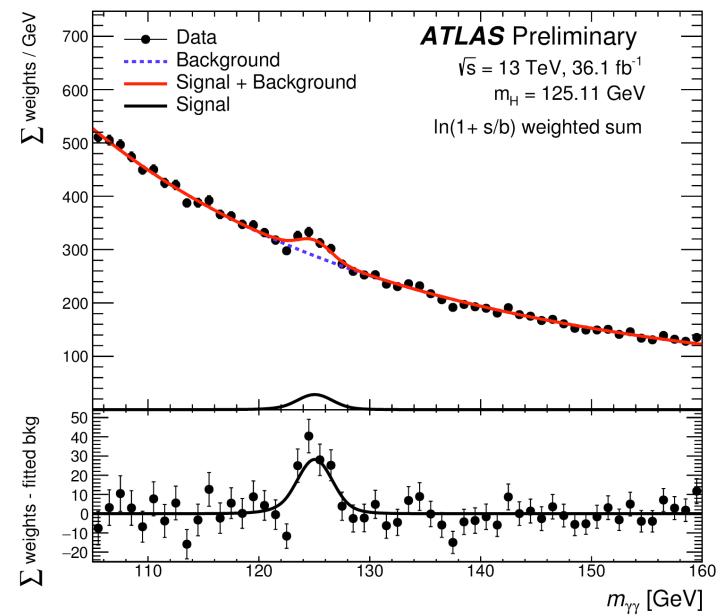
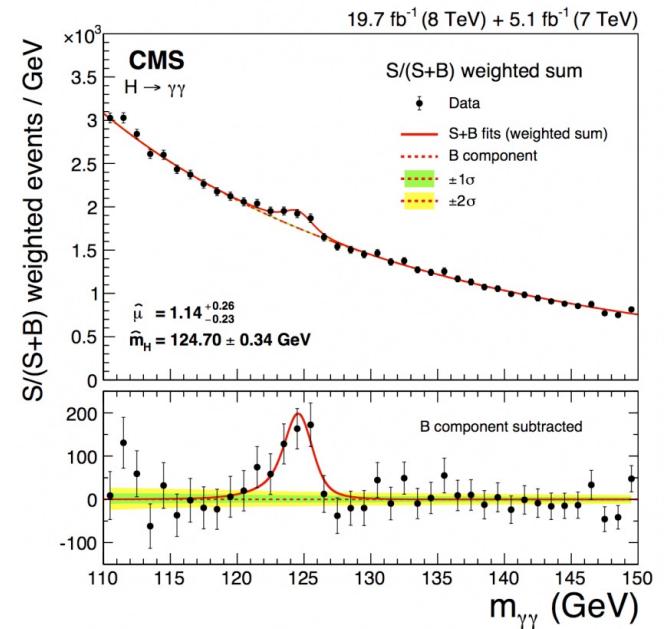
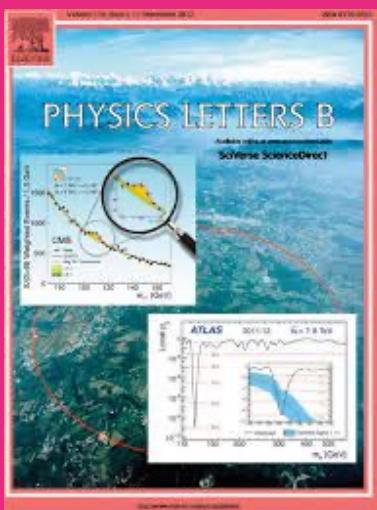
- ❖ Largest particle accelerator: Circumference is 26.659 Km.
- ❖ Worlds Coldest place: 9300 magnets at -271.3°C (1.9 K) - Colder than outer space
- ❖ Worlds Loneliest place: Internal pressure  $10^{-13}$  atm. 10 times less than the pressure on moon
- ❖ Fastest Race track: Trillions of protons race 11245 times a second with speed 99.9999991% speed of light
- ❖ Maximum energy 7 TeV (Tera electron volt)
- ❖ 600 Million collisions per second
- ❖ Produces matter with temperature more than 100,000 times the temperature of Sun
- ❖ Data recorded will fill around 100,000 dual layer DVDs every year



# Hottest matter produced



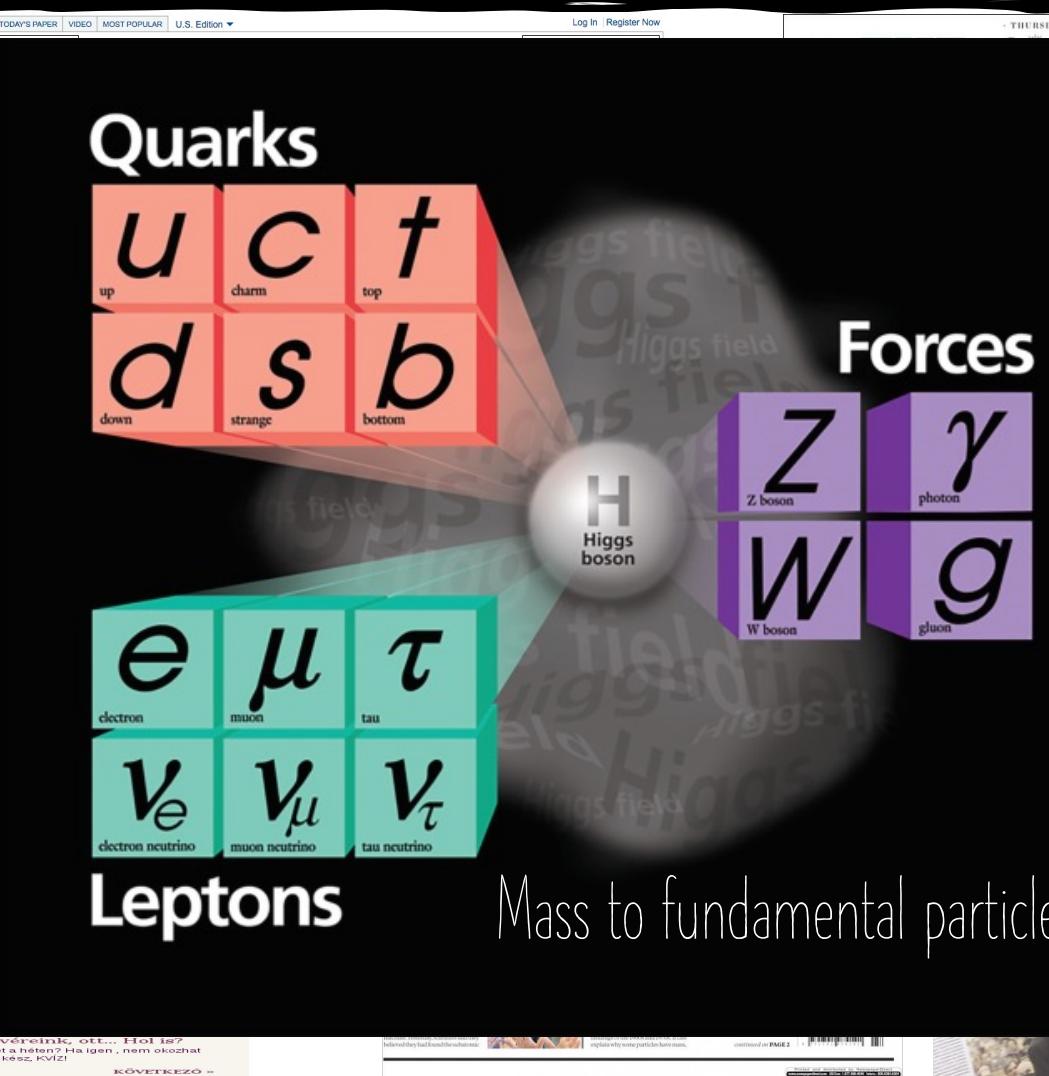
# Higgs boson discovery – 4th July 2012



A high-resolution satellite image of Earth, showing the planet's curvature. The image captures various cloud formations and the outlines of continents. The colors range from deep blues in the oceans to greens and browns on the landmasses.

[www.spaceandintelligence.com](http://www.spaceandintelligence.com)

# Worldwide media attention



# Nobel Prize in Physics 2013

Peter W. Higgs



2013: Origin of mass



François Englert



"for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider"

## The Standard Model

	Fermions			Bosons
Quarks	$u$ up	$c$ charm	$t$ top	$\gamma$ photon
	$d$ down	$s$ strange	$b$ bottom	$Z$ Z boson
Leptons	$\nu_e$ electron neutrino	$\nu_\mu$ muon neutrino	$\nu_\tau$ tau neutrino	$W$ W boson
	$e$ electron	$\mu$ muon	$\tau$ tau	$g$ gluon
				$H$ Higgs* boson

Source: American Association for the Advancement of Science; *The Economist*

\*Confirmation just announced

Fundamental constituents of the visible Universe

"I do not know what I may appear to the world; but myself I seem to have been only like a boy playing on the Sea shore and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me." - Attributed to Sir Isaac Newton (1642 - 1727)

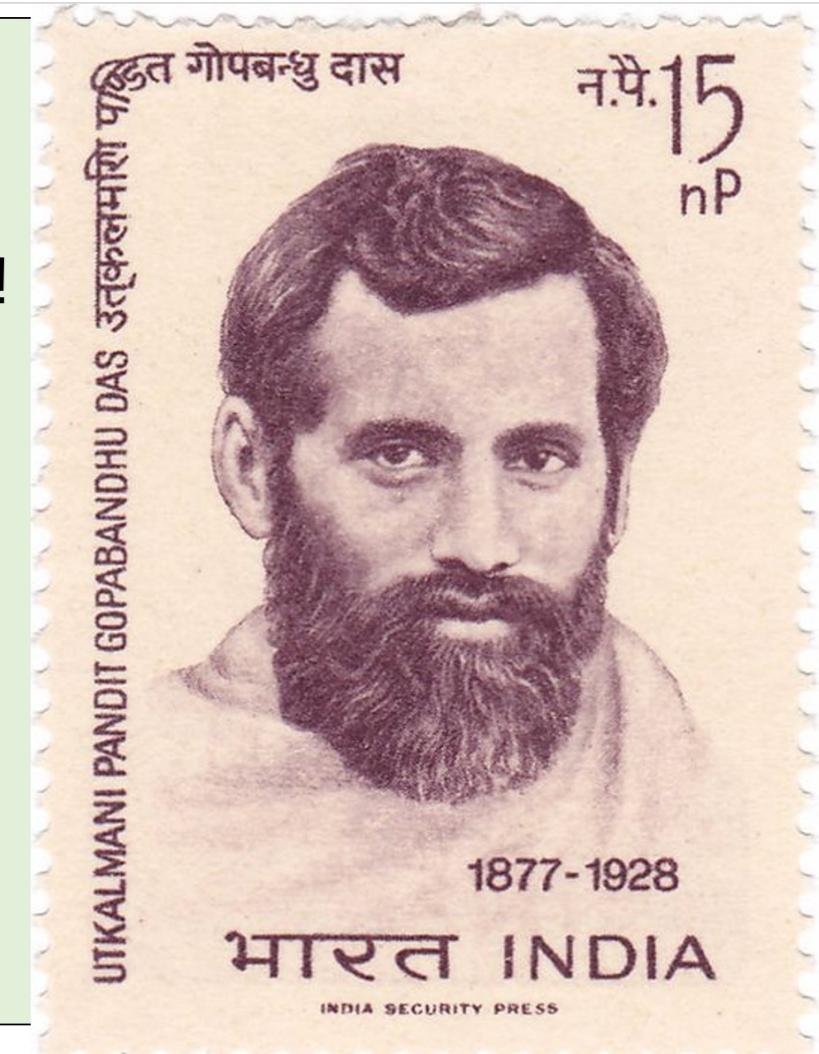


# Few words for the students

Science  
makes things  
humbling



ମାନବ ଜୀବନ ନୁହଁଇ କେବଳ ବର୍ଷ ମାସ ଦିନ ଦଣ୍ଡ !  
(Human life is not of years,  
months, days and hours,)  
କର୍ମେ ଜୀବନର କର୍ମ ଏକ ତାର ଜୀବନର ମାନଦଣ୍ଡ !!  
(Man lives on his action, the only  
measuring rod of life)  
କାପୁରୁଷ ପରି ମରିବା ଜଗତେ, ନୁହଁ ନର-ପଉରୁଷ  
(It is not in the world to die like a  
coward, but to be a man)  
ପରହିତ ସାଧୁ ମରେ ଯେ ମହୀରେ, ସେହି ଏକା  
ସୁପୁରୁଷ ।  
(The one who dies doing good for  
others, he alone is the good man)



*Prof. C. V.Raman: 1930 Nobel Prize "for his work on the scattering of light and for the discovery of the effect named after him"*

*“Youth is the most glorious time of all. I have said elsewhere that most of the great discoveries in Science have been made by young people. It is not the experience or wisdom that old age brings, but the freshness of outlook, the indomitable desire to achieve, which is the characteristic of youth, that makes discoveries possible. It is this that makes life worthwhile. If only you realise this and realise that here I am, I am still young, let me see what I can do, that all discoveries become possible.”*

*Thank you*

