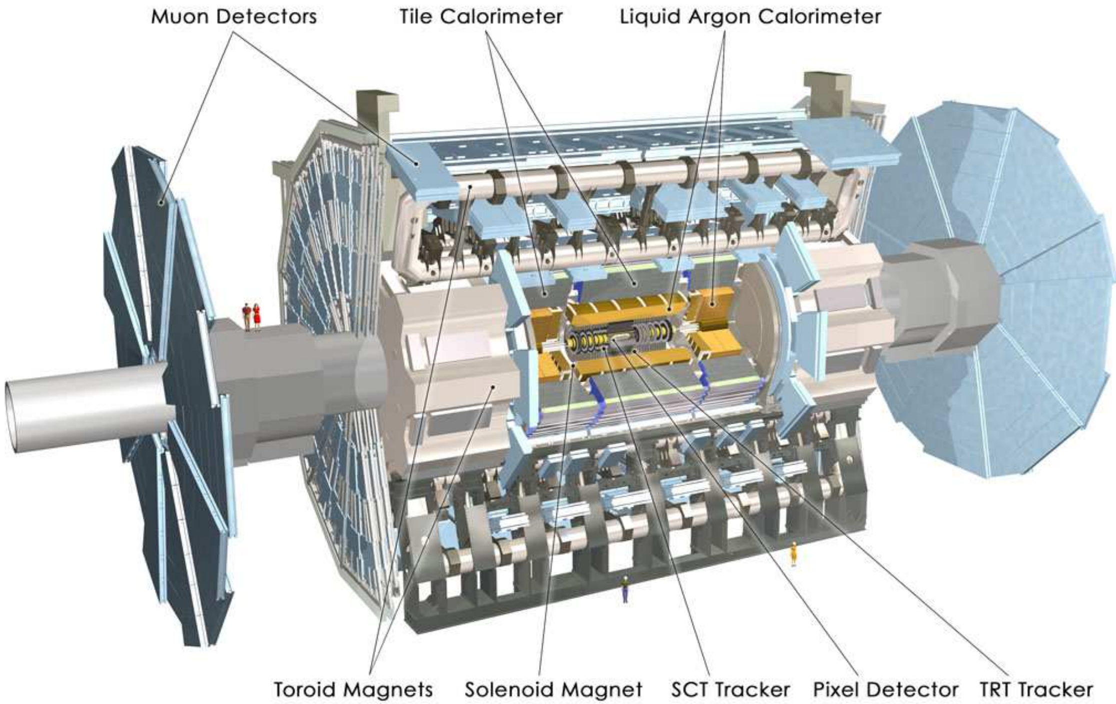
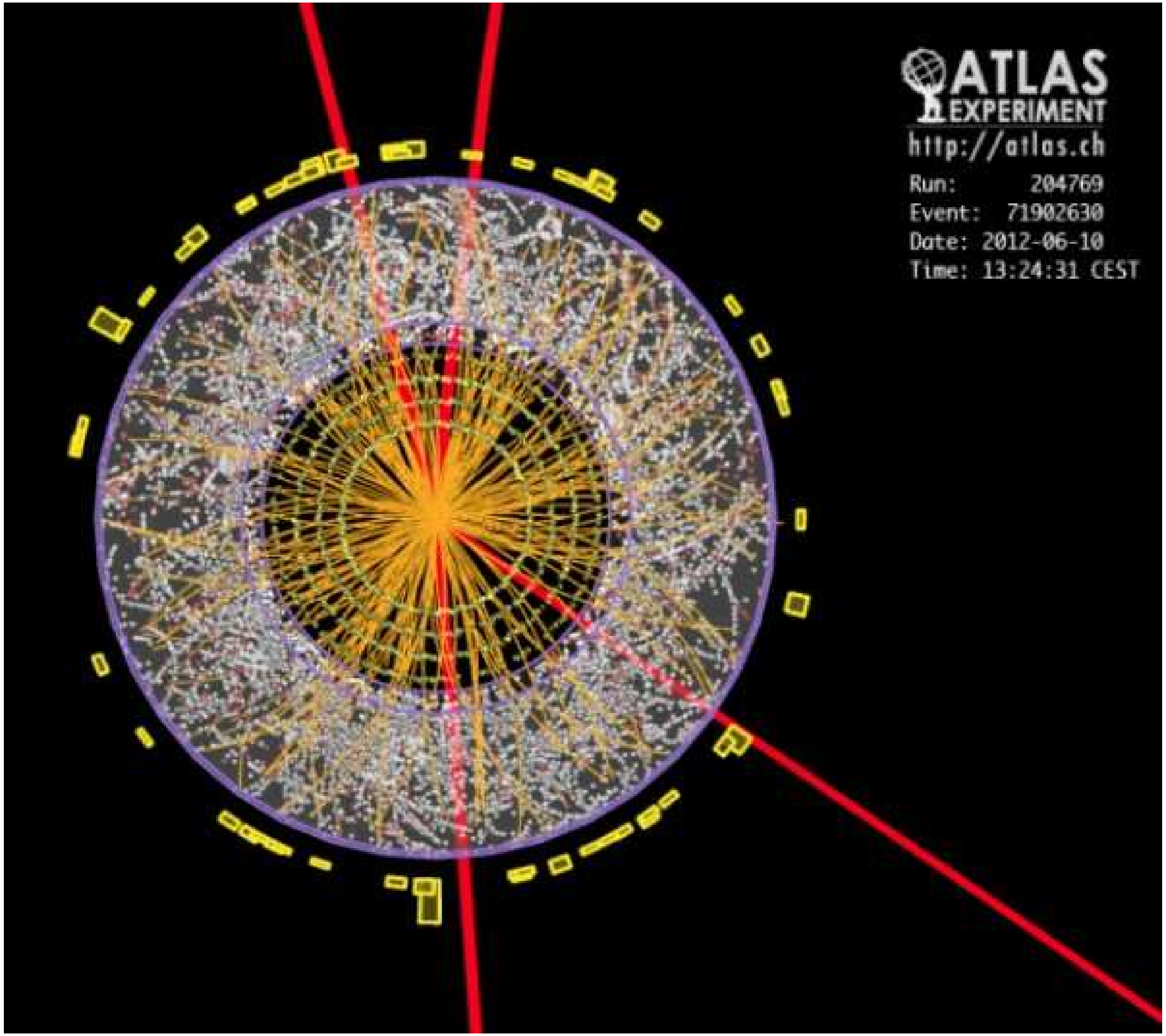
Large Hadron Collider (LHC) and origin of mass in the Universe

Michael Lublinsky

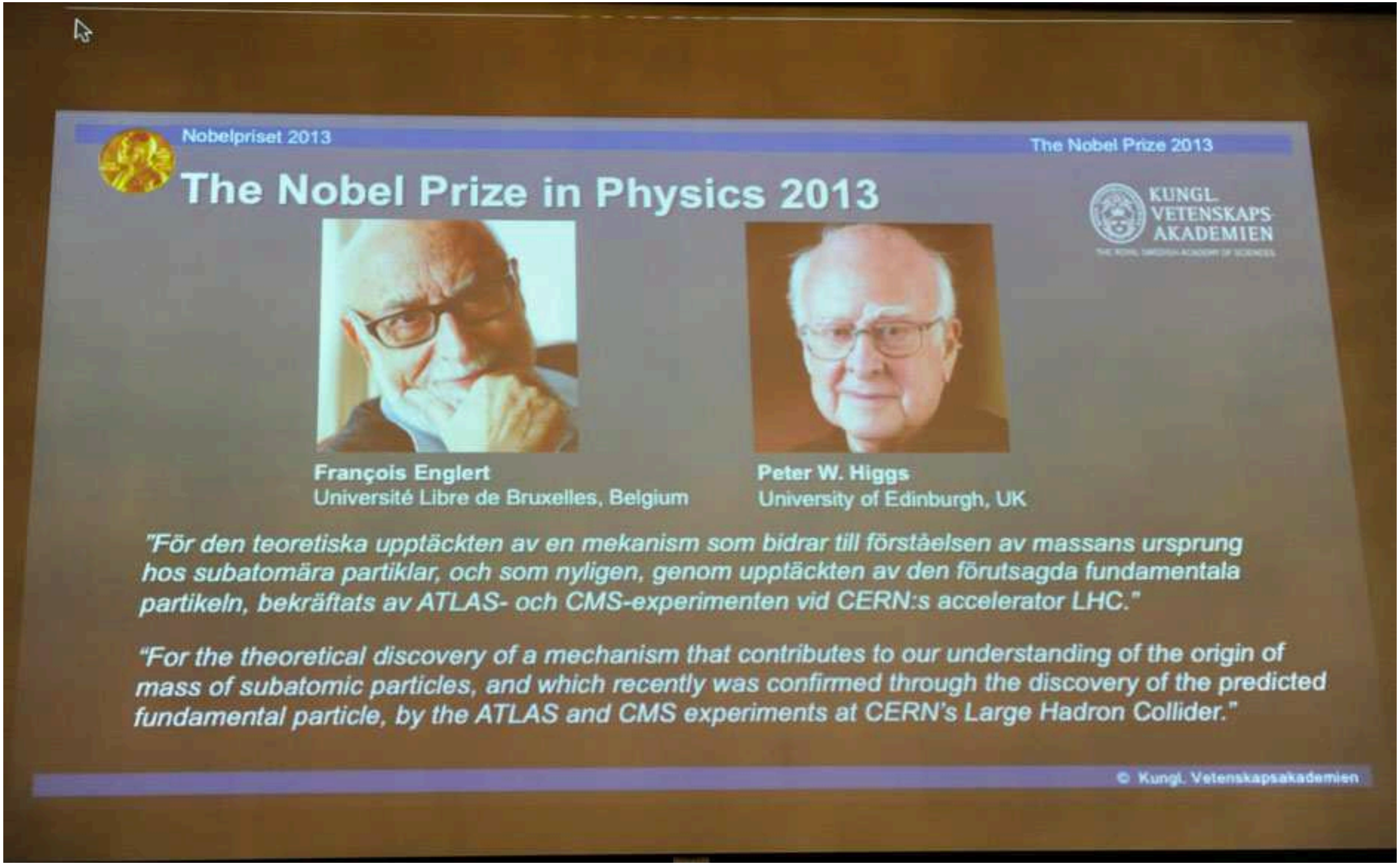
Physics Department

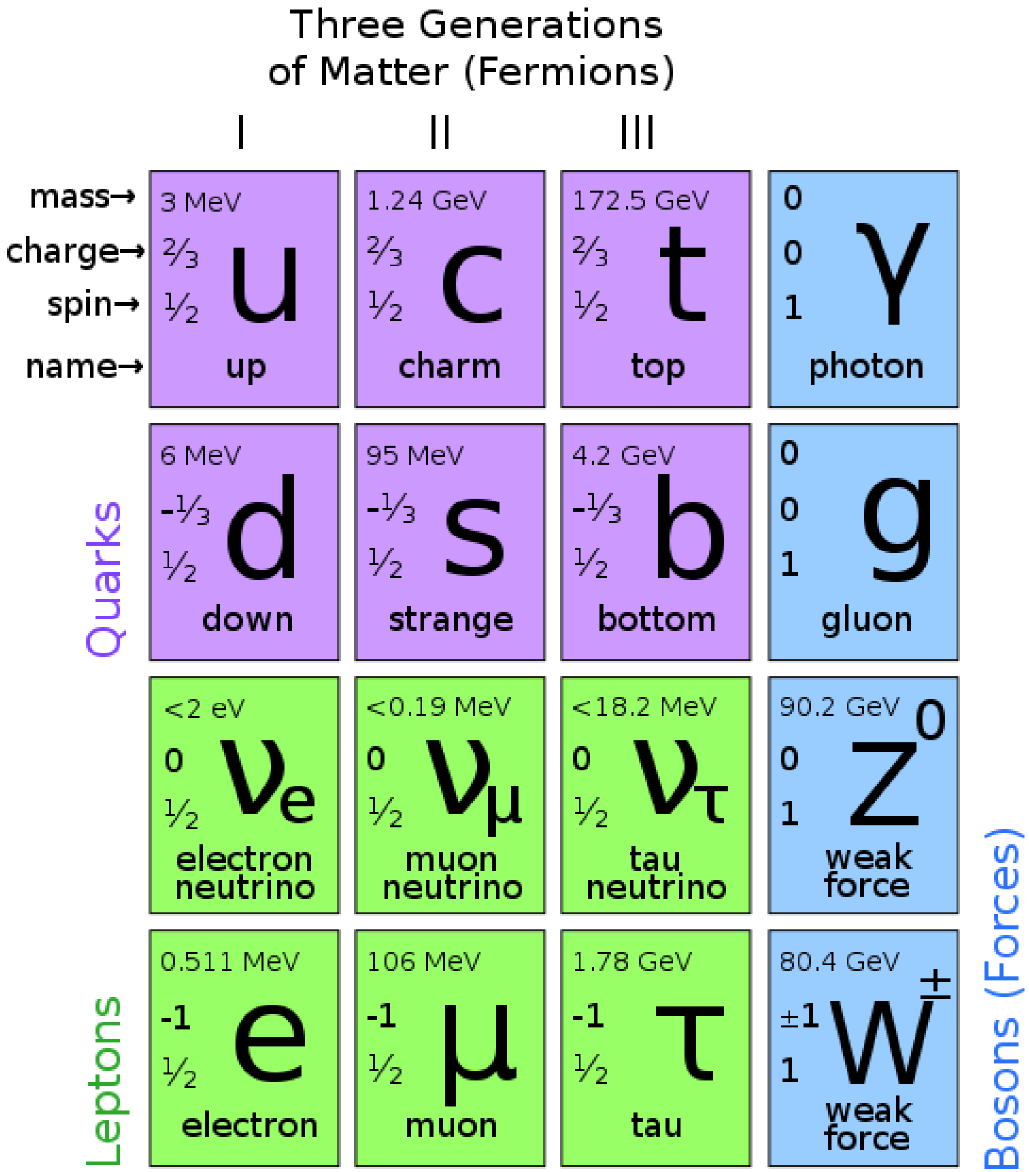

ALICE
CMS
ATLAS
LHCb

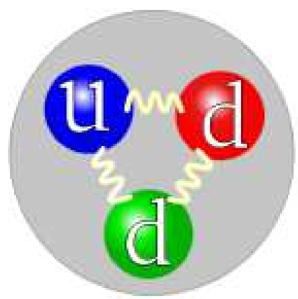

Muon Detectors
Tile Calorimeter
Liquid Argon Calorimeter
Toroid Magnets
Solenoid Magnet
SCT Tracker
Pixel Detector
TRT Tracker



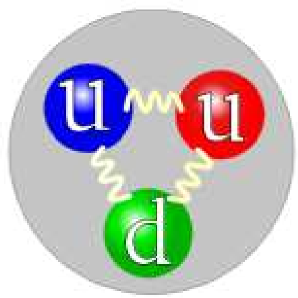
$\mathbf{H} \rightarrow \mu + \mu + \mu + \mu$ $\qquad\qquad$ $\mathbf{M(H) \simeq 125\ GeV \simeq 125\, m_{proton}}$


Nobelpriset 2013
The Nobel Prize 2013
The Nobel Prize in Physics 2013
KUNGL. VETENSKAPS AKADEMIEN
François Englert
Université Libre de Bruxelles, Belgium
Peter W. Higgs
University of Edinburgh, UK
"För den teoretiska upptäckten av en mekanism som bidrar till förståelsen av massans ursprung hos subatomära partiklar, och som nyligen, genom upptäckten av den förutsagda fundamentala partikeln, bekräftats av ATLAS- och CMS-experimenten vid CERN:s accelerator LHC."
"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."
© Kungl. Vetenskapsakademien

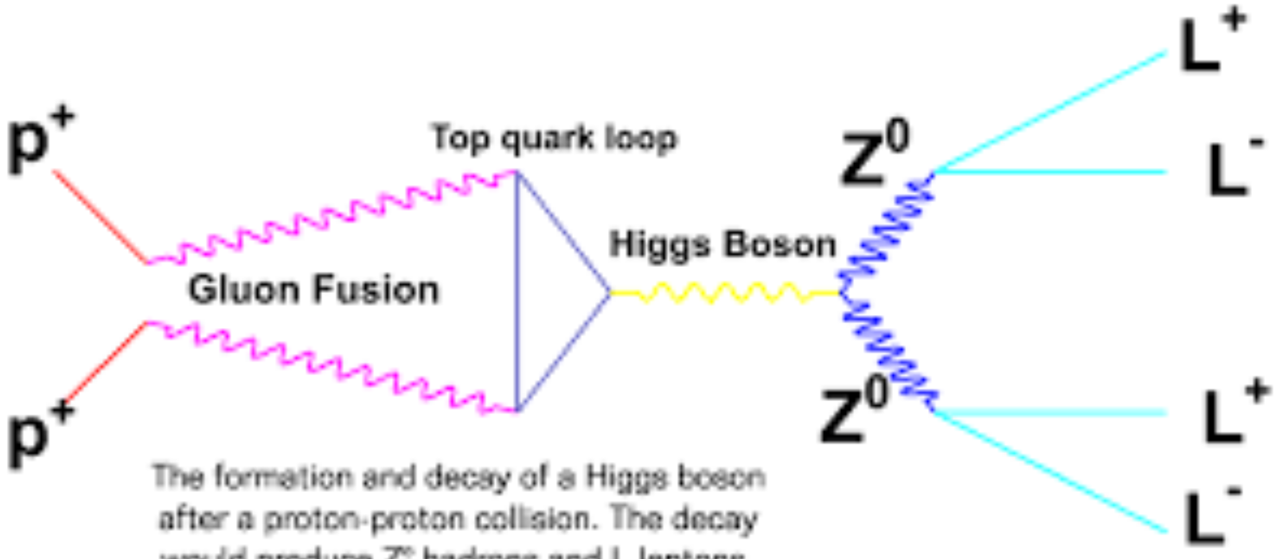




NEUTRON
Quark structure



PROTON
Quark structure



The formation and decay of a Higgs boson after a proton-proton collision. The decay would produce Z^0 hadrons and L leptons.

Higgs field. The result of this interaction is that all matter particles propagate in space slower than light. In other words, the interaction with the Higgs field modifies the dispersion relation between energy and momentum of the particles

$$\mathbf{E^2 - p^2c^2 > 0}$$

While it might sound like a type of friction, it is not. Friction causes a freely moving particle to slow down. Higgs medium makes freely moving particles to move with a constant velocity smaller than speed of light

Simple analogy:

Dispersion of light: $\omega = c\,k$; $E = \hbar\omega = c\,\hbar\,k = c\,p$

Dispersion of light in electromagnetic plasma:

$\omega^2 = \omega_{pl}^2 + c^2\,k^2$; $E = \sqrt{c^2\,p^2 + \omega_{pl}^2\,\hbar^2}$, Photon gets mass.

The Higgs particle discovered by the LHC is a fluctuation, or a wave in this medium. It is by itself "slowed" by the medium and hence massive.

The Higgs field is responsible for the masses of elementary particles (quarks and leptons).

The mass of 3 quarks making up protons and neutrons is

$$3 \times 5 \; MeV \; \simeq 15 \, MeV$$

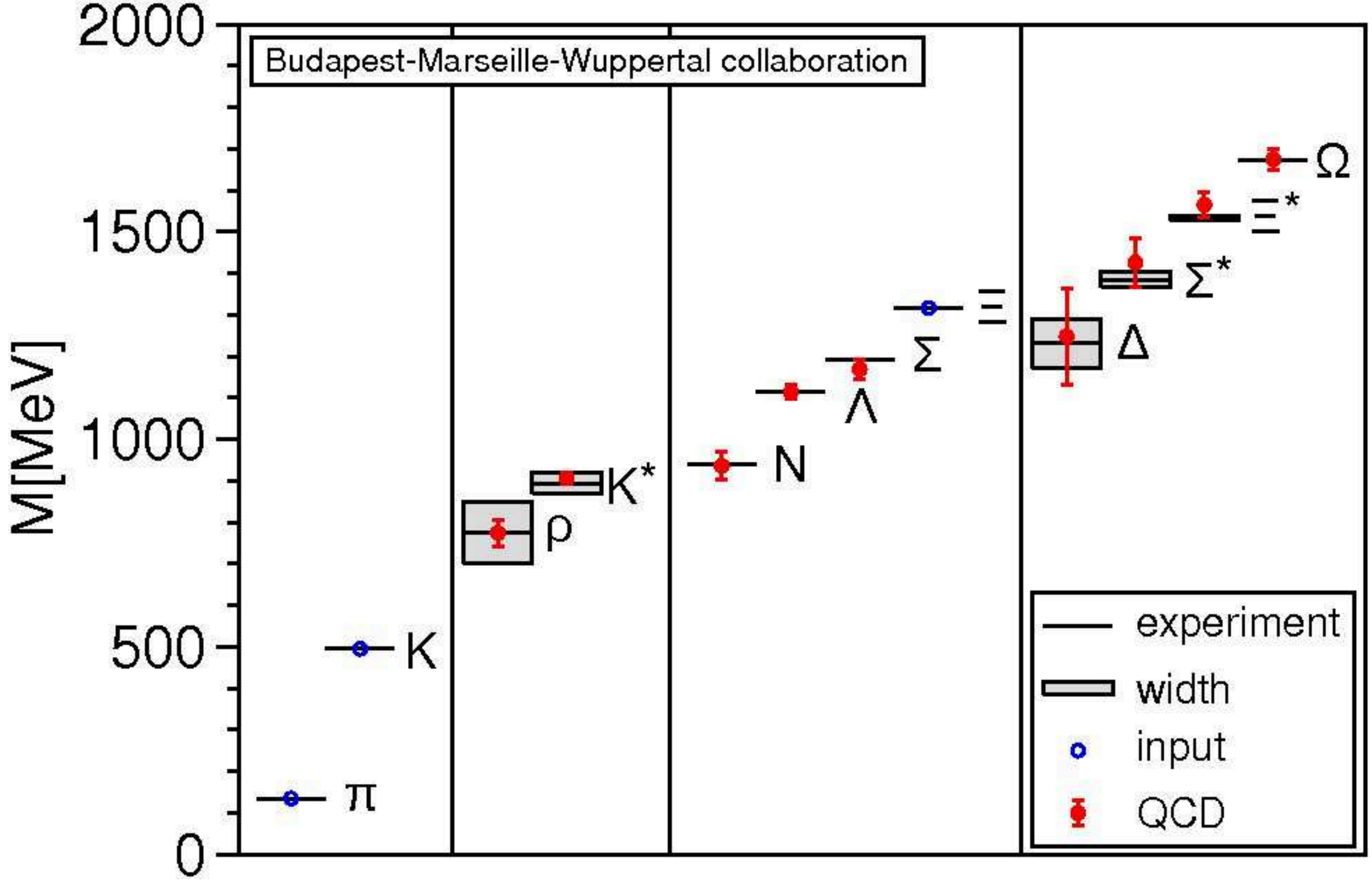
The mass of proton or neutron is

$$\mathbf{M_{proton/neutron} \; \simeq \; 1000 \, MeV}$$

So, in fact, Higgs is responsible for 1% of visible mass only!
Moreover, mass formation in the Universe does not need Higgs at all!

Where the rest of the mass is coming from?

The binding energy. The force that binds quarks together is called the Strong or Nuclear Force. The theory that describes Strong interactions is called Quantum Chromo-Dynamics (QCD) and it is a non-linear version of Quantum Electro-Dynamics.

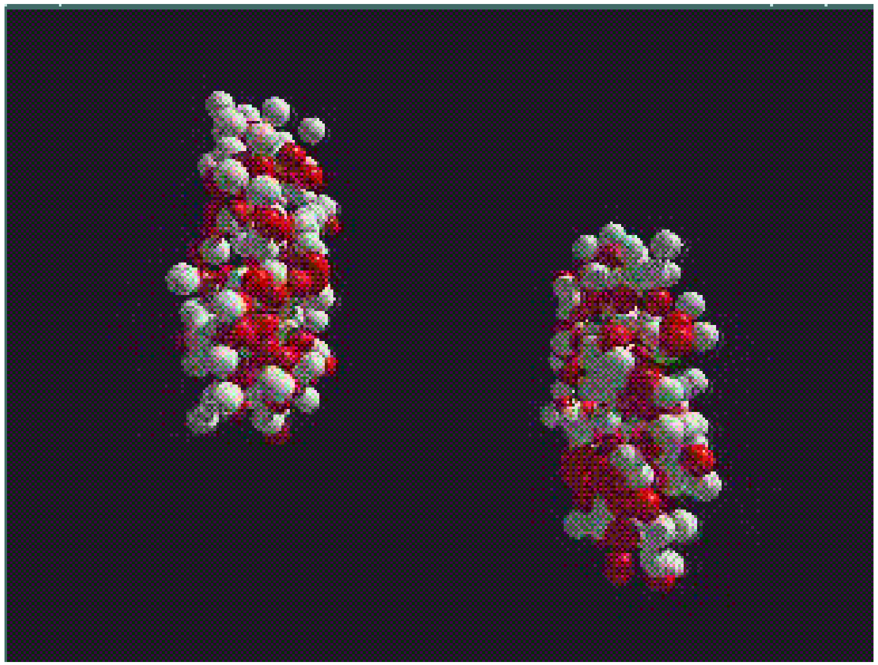


Budapest-Marseille-Wuppertal collaboration
M[MeV]
2000
1500
1000
500
0
π
K
ρ
K*
N
Λ
Σ
Ξ
Δ
Σ*
Ξ*
Ω
experiment
width
input
QCD

Quarks were free just after the Big Bang, when the Universe was over 10 trillion degrees hot. The hot "soup" of quarks (and gluons) in the early Universe is called Quark Gluon Plasma (QGP).

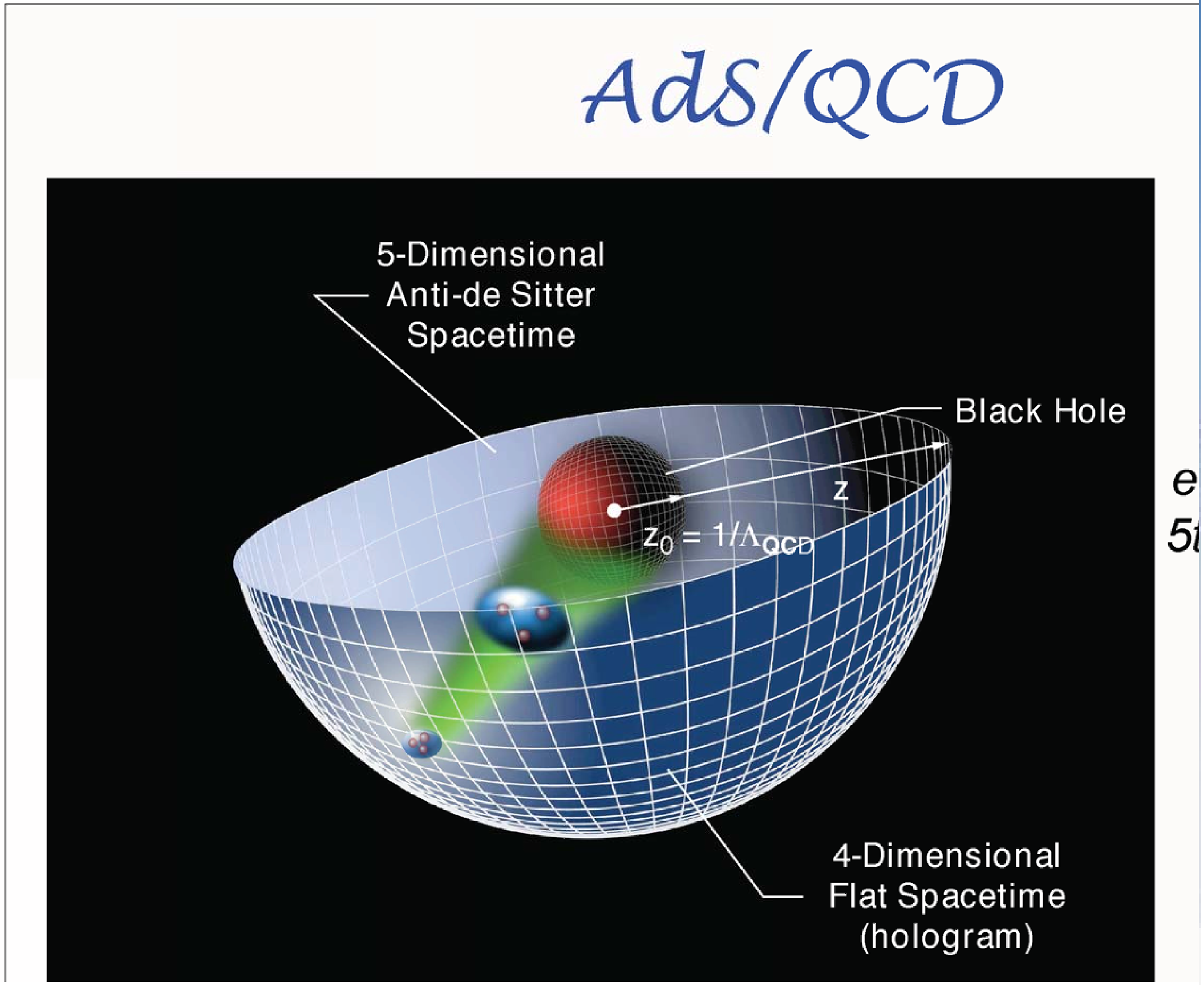
Quarks were forced into hadrons when the Universe cooled, a few seconds after the Big Bang.

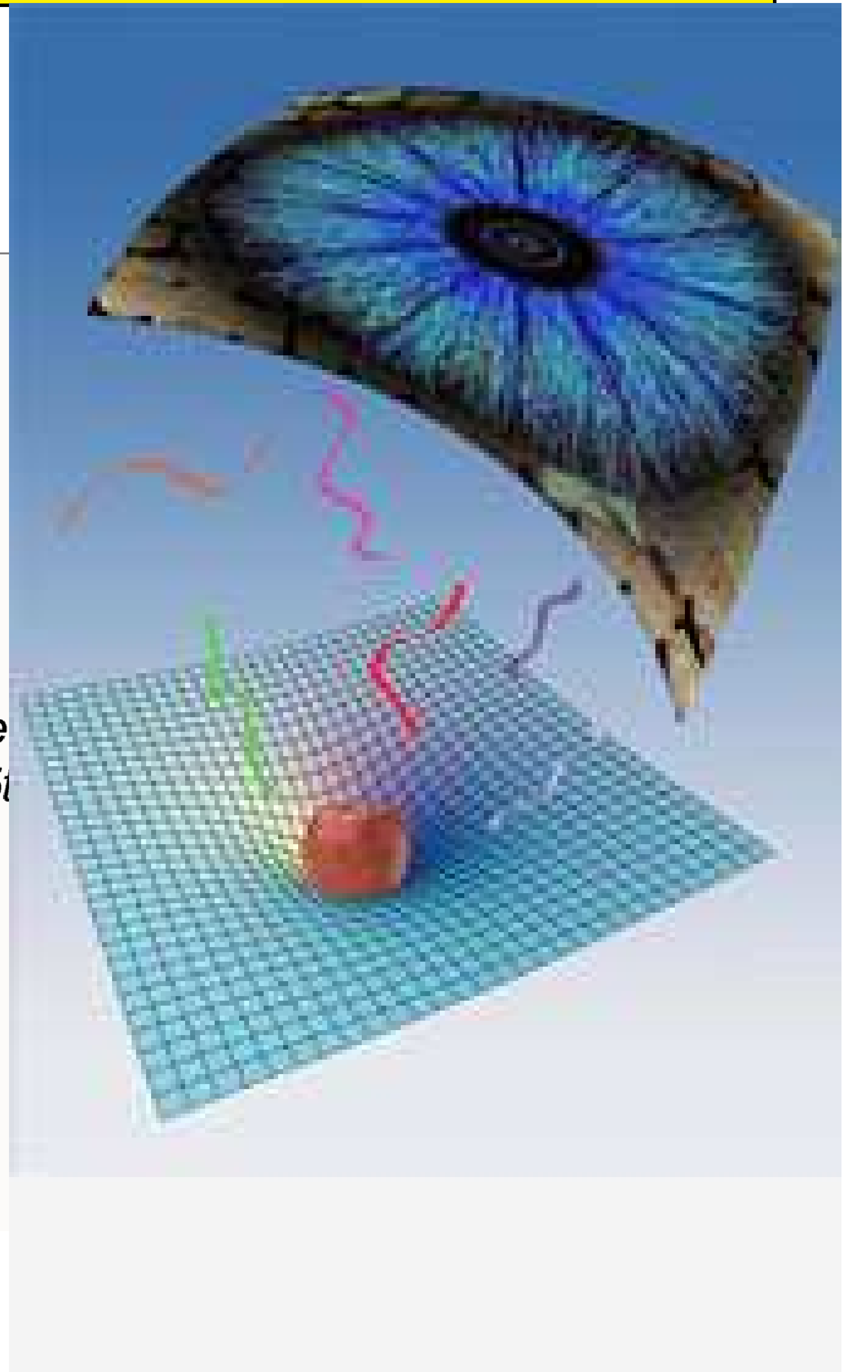
Heavy Ion collisions at the LHC recreate the conditions fraction of a second after the Big Bang

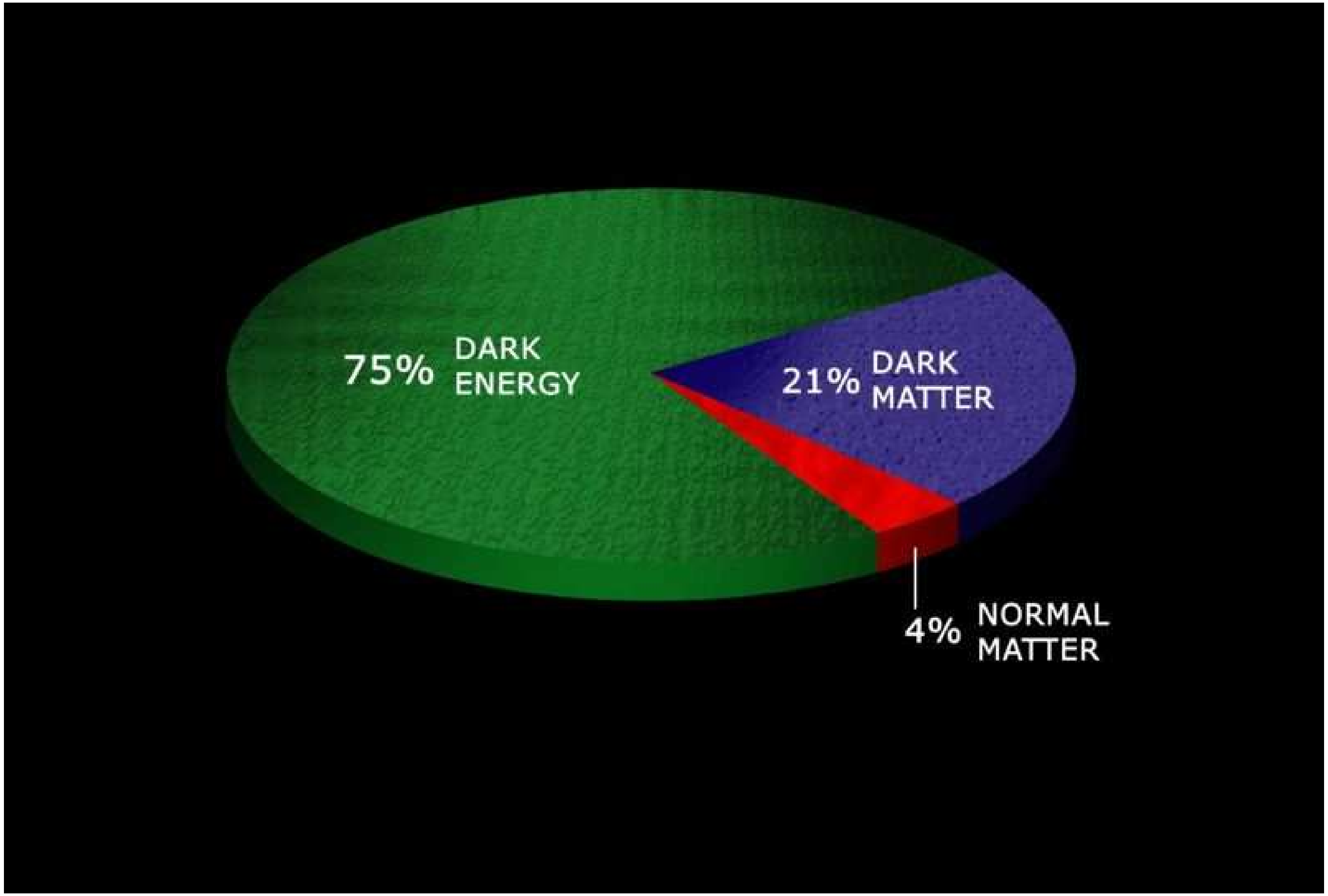


Heavy Ion Collisions as viewed from the extra dimension

Heavy Ion collision is a hologram of 5-D Black Hole.







Higgs is responsible for only 1% of mass of normal luminous matter

To understand dark matter, LHC is searching for exotic particles that has not been listed above