A Universe of particles

...a particle in the universe

International Particle
Physics Outreach Group

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preamble:

Why study physics?!

A Problem:

A Solution ?

Not quite…

Oops!... Now what?

Ok, let’s check this…

It seems to have worked well...

$\boxed{a\,P > A\,f}$

Message:

Physics has a crucial role on day-to-day activities!

OUR Universe!

~~**Why?!**~~

~~Universe!~~

What?

How?


Universe!
This is NOT our universe!
We are NOT seeing all that exists out there!

(the Higgs field exists EVERYwhere!

if we would see the Higgs field, this would be an image of our Universe)

Universe!

So, what do we “see” in our Universe?

Universe!

Stars (including black holes), Galaxies? 10%

Interstellar/intergalactic gas and dust? 84%

of which…

Hydrogen	74%
Helium	25%
Lithium	<1%
Beryllium	trace elements

(*Gas and dust only visible in wavelengths different than those of visible light*)

What else?!

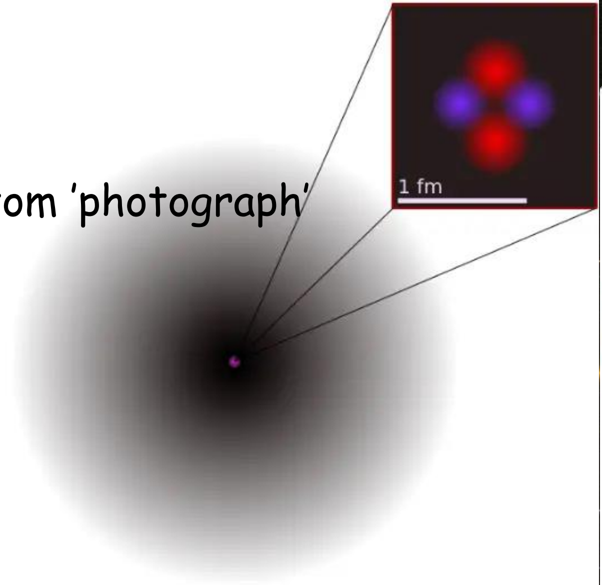
Neutrinos? 6%

But... this is only the part of matter known to us!

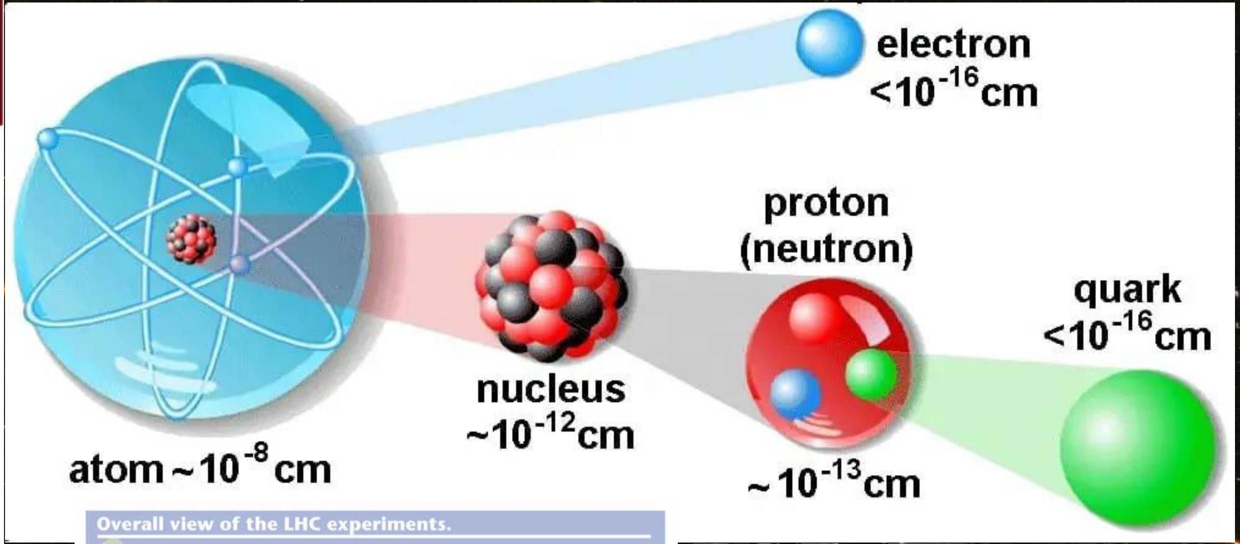

THIS? We don’t know!
We know nothing!
We really don’t know anything!
(DARK ENERGY)
68,5%
DARK MATTER
26,5%
DARK MATTER
Normal matter
5%

Not to s
Inkcubeko Youth and Science Centre
EXIT
0,
10 nm
0,00001 mm

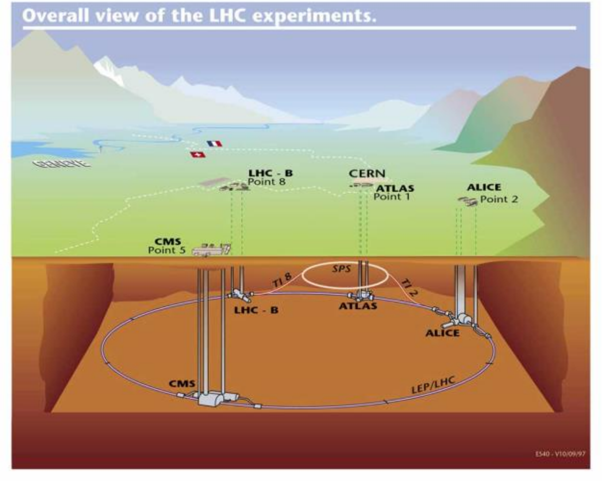
Atom 'photograph'



1 Å = 100,000 fm = 10^{-10} m = 10^{-8}cm



AFM = Atomic Force Microscope



Elementary particles:

1 GeV/c^2 = 1.78 x 10^{-27} kg ≈ m(proton) = 0,938 GeV/c^2

p={uud}
n={udd}

FERMIONS matter constituents spin = 1/2, 3/2, 5/2, ...

	Leptons spin =1/2			Quarks spin =1/2			
	Flavor	Mass GeV/c^2	Electric charge	Flavor	Approx. Mass GeV/c^2	Electric charge	
1956	ν_e electron neutrino	$(0-2)\times 10^{-9}$	0	u up	0.002	2/3	1964
1897	e electron	0.000511	–1	d down	0.005	–1/3	1964
1962	ν_μ muon neutrino	$(0.009-2)\times 10^{-9}$	0	c charm	1.3	2/3	1974
1937	μ muon	0.106	–1	s strange	0.1	–1/3	1964
2001	ν_τ tau neutrino	$(0.05-2)\times 10^{-9}$	0	t top	173	2/3	1995
1975	τ tau	1.777	–1	b bottom	4.2	–1/3	1977

And what about their interactions?

Properties of the Interactions

The strengths of the interactions (forces) are shown relative to the strength of the electromagnetic force for two u quarks separated by the specified distances.

Property	Gravitational Interaction	Weak Interaction (Electroweak)	Electromagnetic Interaction	Strong Interaction
Acts on:	Mass – Energy	Flavor	Electric Charge	Color Charge
Particles experiencing:	All	Quarks, Leptons	Electrically Charged	Quarks, Gluons
Particles mediating:	Graviton (not yet observed)	W^+ W^- Z^0	γ (photon)	Gluons
Strength at 10^{-18} m	10^{-41}	0.8	1	25
Strength at 3×10^{-17} m	10^{-41}	10^{-4}	1	60

Gravity (weight)	Weak Force (Radioactivity (β))	Electromagnetism (Electricity, magnets, light)	Strong Force (Cohesion of atomic nuclei)

+Higgs boson

- Gravity out of the Standard Model
- Particles of zero mass: range infinite
- Very short range: very massive particle!

but note:…many interactions incomprehensible! (Human relations, for ex.)

Interactions: exchange of particles!

BOSONS

force carriers
spin = 0, 1, 2, …

Unified Electroweak spin = 1

	Name	Mass GeV/c^2	Electric charge
1900	γ photon	0	0
1983	W^-	80.39	–1
1983	W^+ W bosons	80.39	+1
1983	Z Z boson	91.188	0

Strong (color) spin = 1

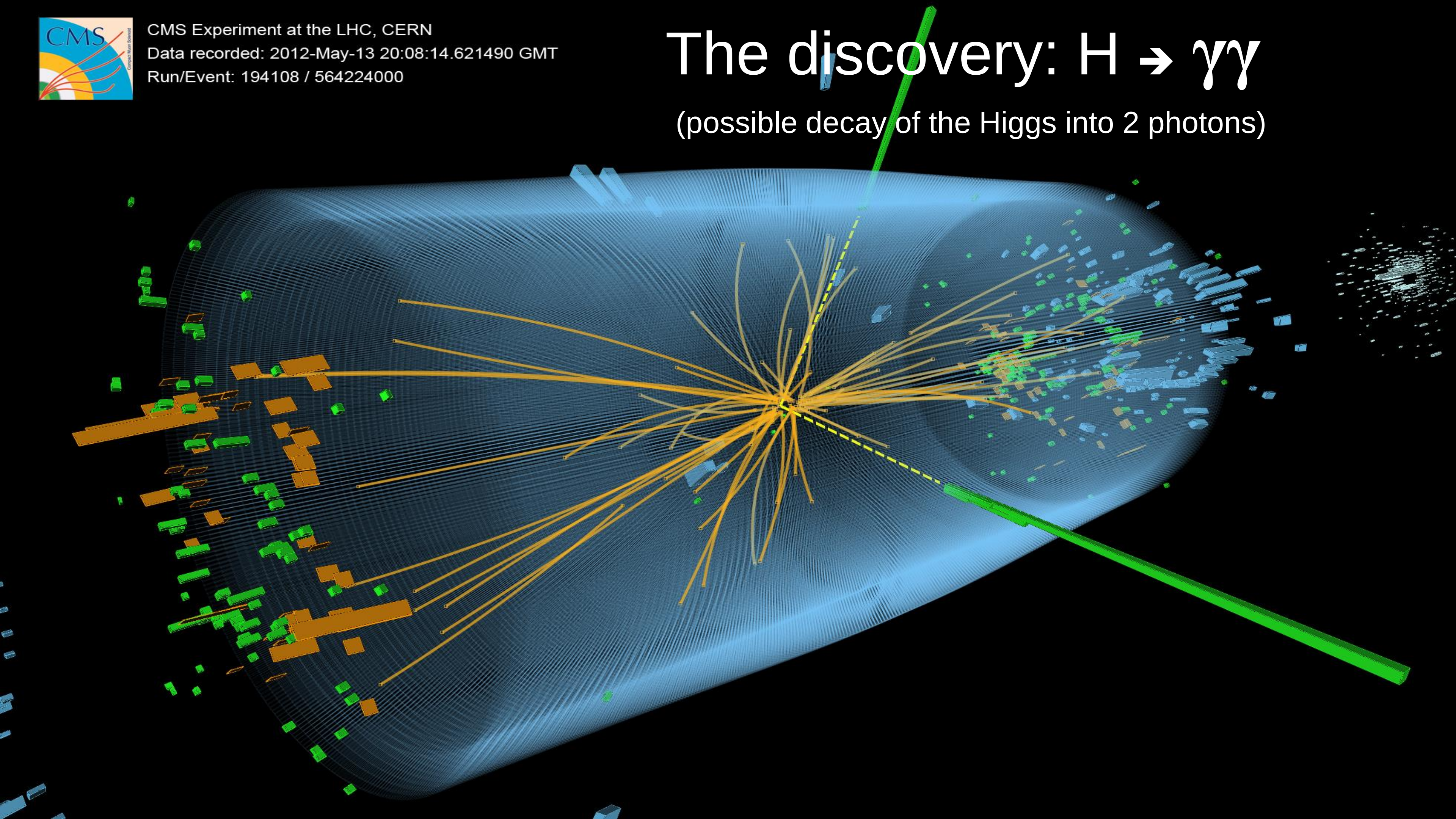
Name	Mass GeV/c^2	Electric charge	
g gluon	0	0	1979

Higgs Boson spin = 0

Name	Mass GeV/c^2	Electric charge	
H Higgs	126	0	2012

The discovery: H $\rightarrow \gamma\gamma$

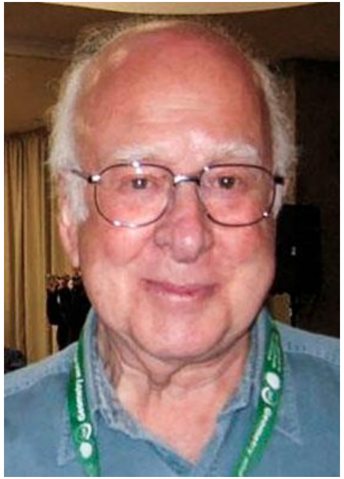
(possible decay of the Higgs into 2 photons)



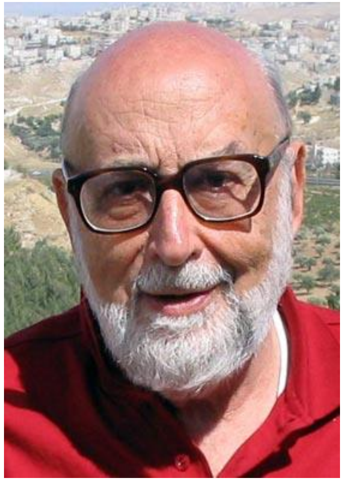
The Higgs field and the Higgs boson

Discovery of the Higgs boson...
...recognized with the Nobel Prize 2013:

Peter Higgs, english, born in 1929, Univ. of Edinburgh



François Englert, belgium, born 1932, U. Libre de Bruxelles



*"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**"*

It’s a collaborative effort!

BusinessWeek

VIEWPOINT May 20, 2009, 11:57AM EST

CERN's Collaborative Management Model

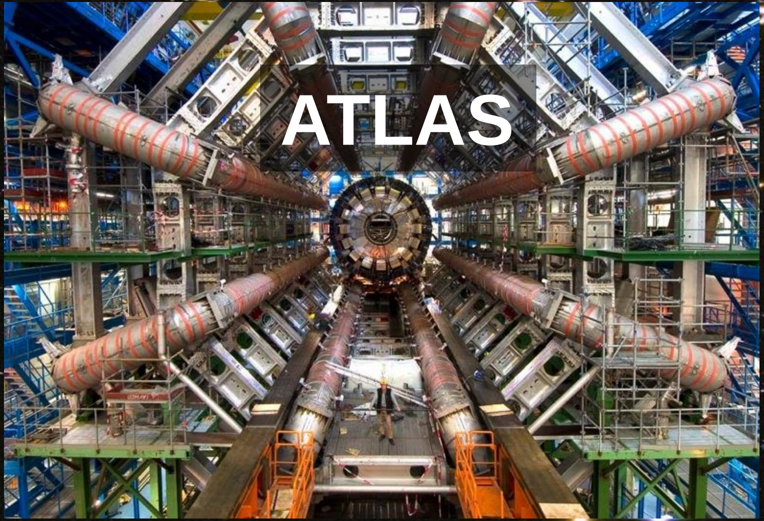
Business leaders could learn valuable leadership lessons from the collaborative management style at the Large Hadron Collider at CERN

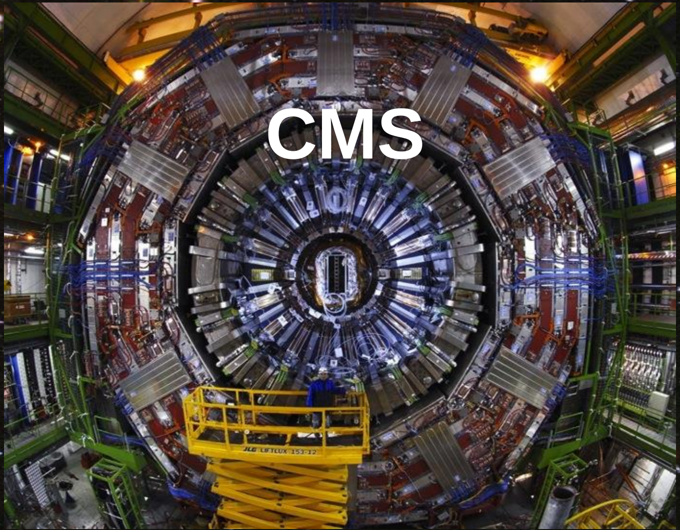
By Krisztina Holly

As a business leader, imagine trying to manage more than 7,000 scientists from 85 countries around the world—with their own languages, cultures, and expertise—on a 20-year collaboration to create the most complex system ever built.

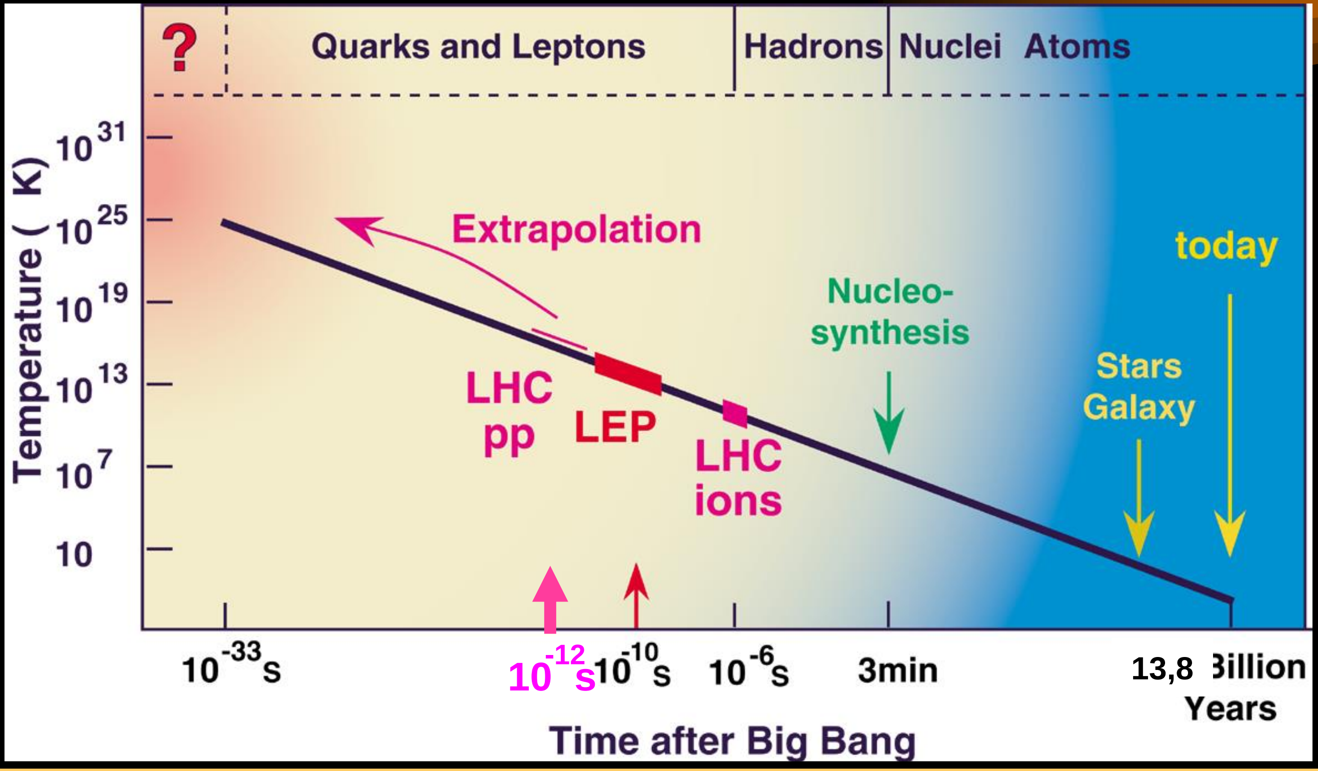
How do scientists work

and in very large experiments and international collaborations:

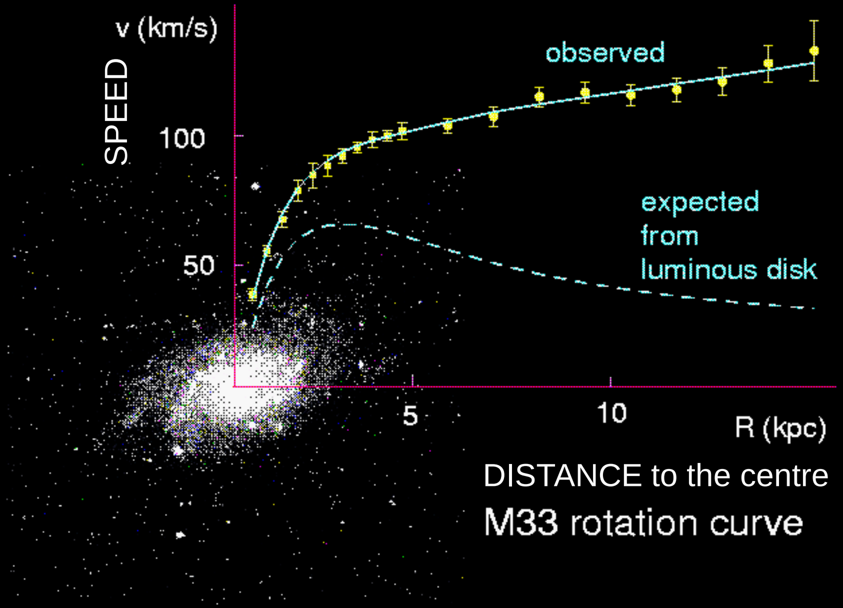


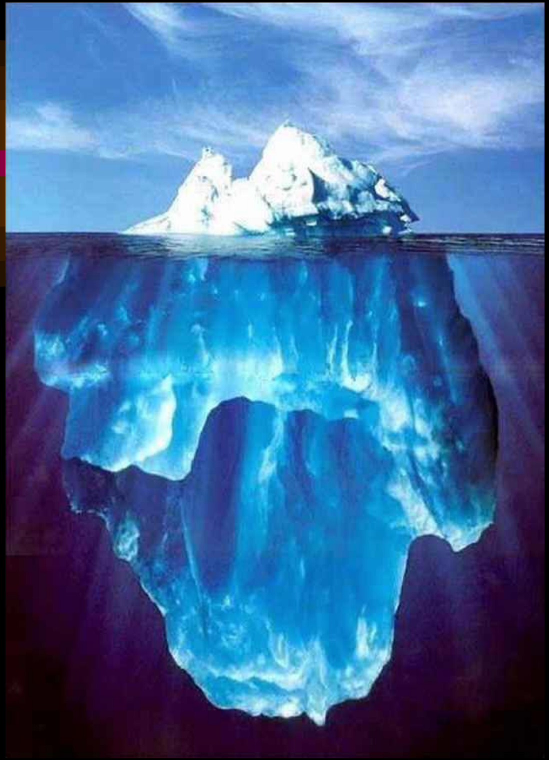


Back to the beginning of the Universe...



The Dark Matter evidence





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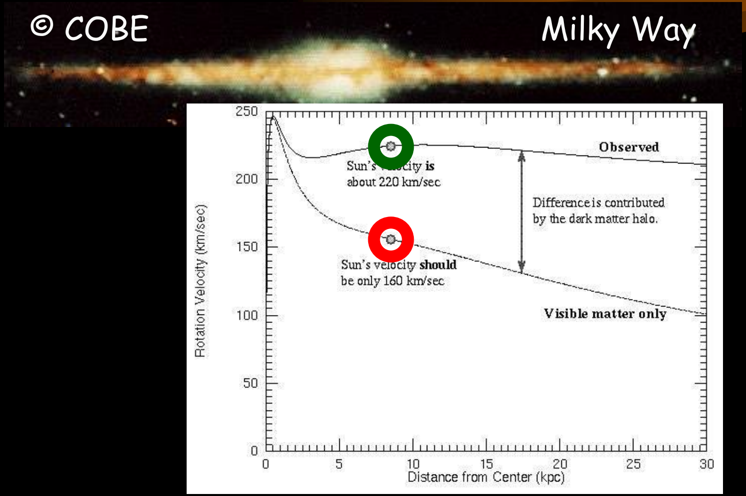
Largest fraction of matter does not shine! What can it be?!

Dark matter even in our galaxy!

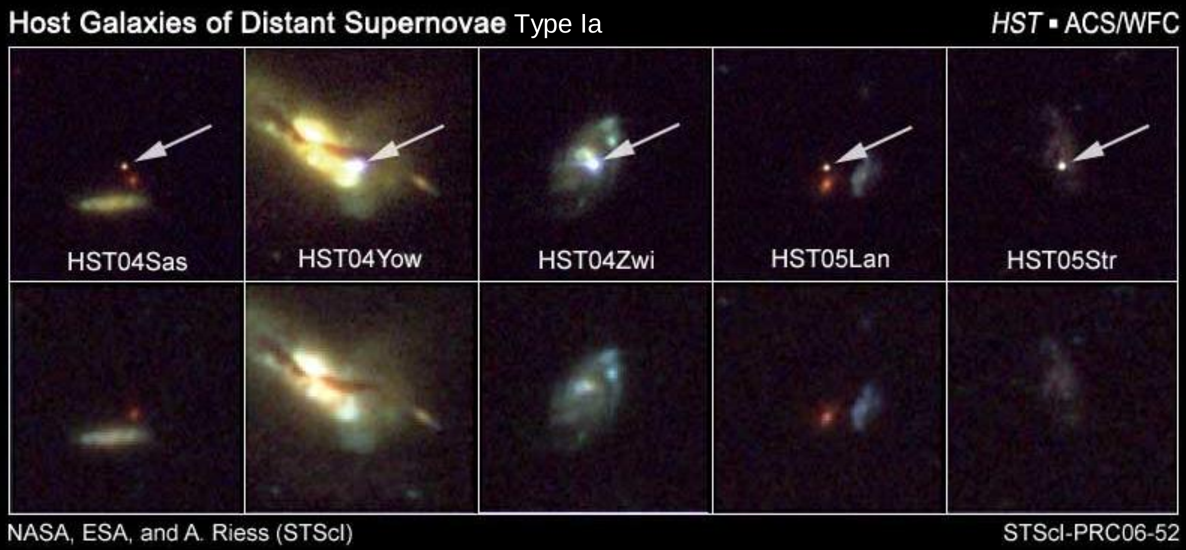


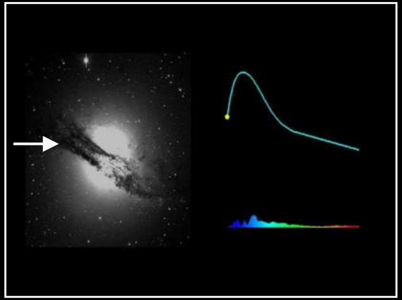
- Spread in the galaxy, not aggregated (not black holes)
- No form of matter known!

The problem of the expansion of the Universe

- Scientists studied distant supernova to measure the evolution of the expansion rate of the Universe (and won the Nobel Prize 2011).

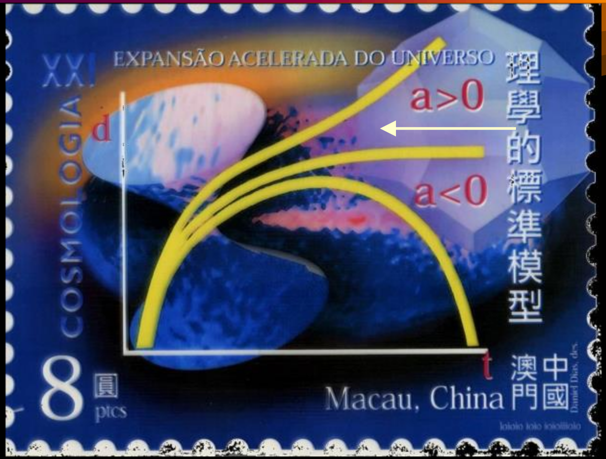
  They wanted to know if the rate decreased slowly or quickly (to a big crunch).





Oops…it is NOT diminishing!

- The expansion of the Universe is accelerating!!!

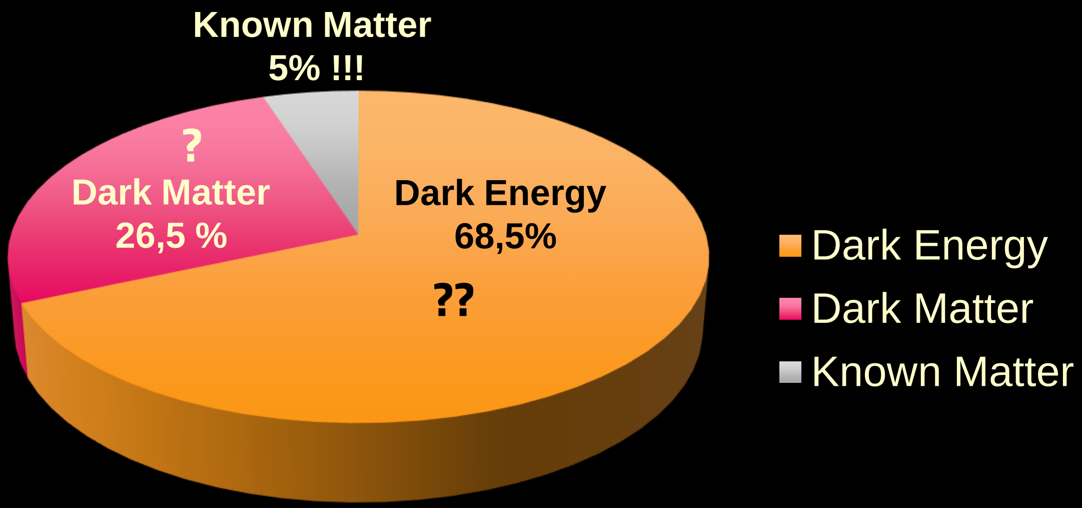


- *Something* is overcoming gravity

- Scientists call it ‘Dark Energy ’

What is the Universe made of ?

Universe

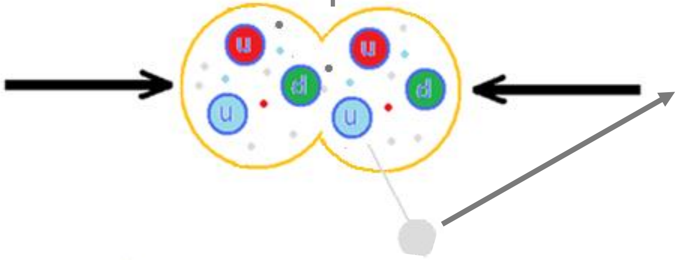


(Stamp from Macau)

...and why is it so *nice* to life ?!

Invariant mass of particle pairs

- Particle “X” that decay into two particles
- Events with two particles of defined properties are chosen, and the quantity **m(X)** is computed from the energy-momentum of the chosen particles



$$E_X = m_X c^2 \Rightarrow E_X^2 = m_X^2 c^4 + c^2 p_X^2$$

$$m_X^2 = (E_X^2 - c^2 p_X^2)/c^2 \qquad E_X ?\, p_X ?$$

$$E_X = E_1 + E_2 \,,\, p_X \text{ from } p_1 + p_2$$

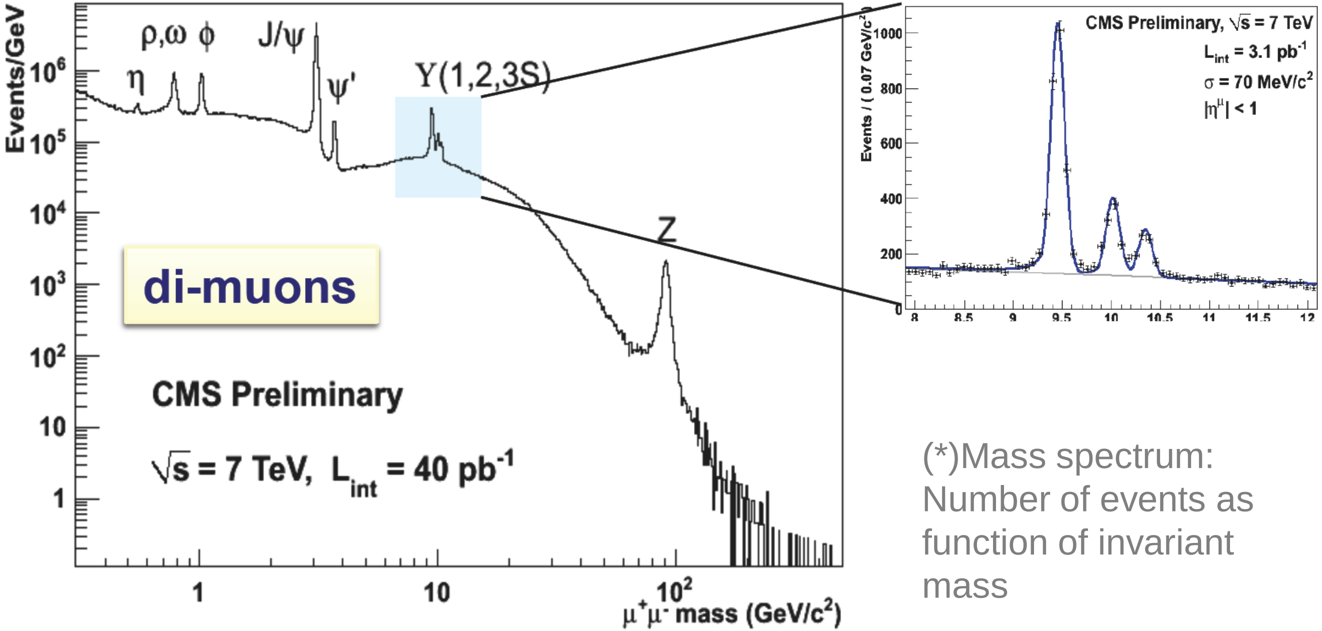
$$m_X^2 \cong 2 E_1 E_2 (1 - f(\theta))/c^4$$

The **tool** for today:

Mass spectrum(*) of muon pairs ("di-muons")

- Events with two oppositely charged muons
- Search for X particles that decay into two muons

...and build a distribution of mass values m(X)

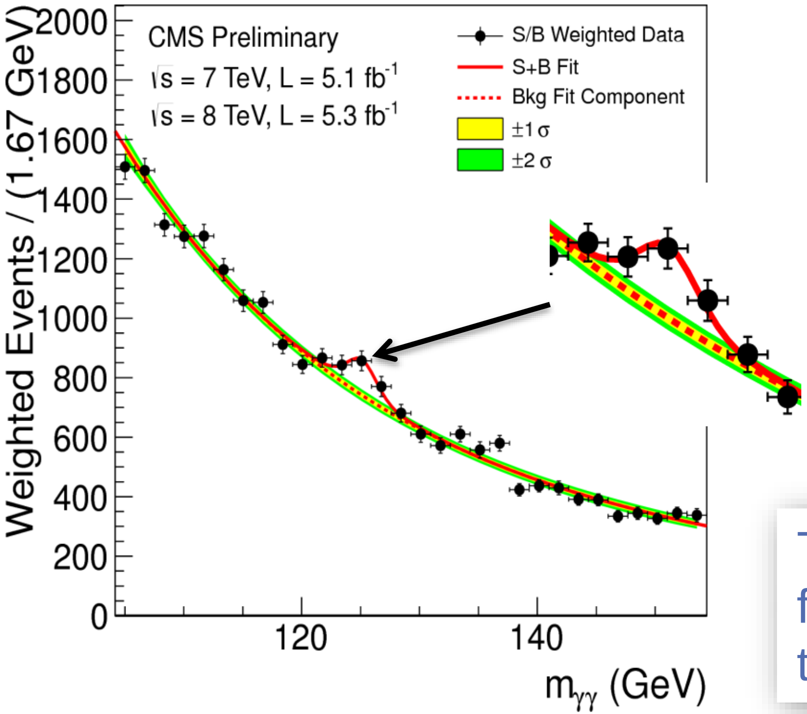


(*)Mass spectrum: Number of events as function of invariant mass

Results from the search for $X \rightarrow \gamma\gamma$:

Invariant mass distribution of 2 photons, m($\gamma\gamma$)

Results from CMS Collaboration

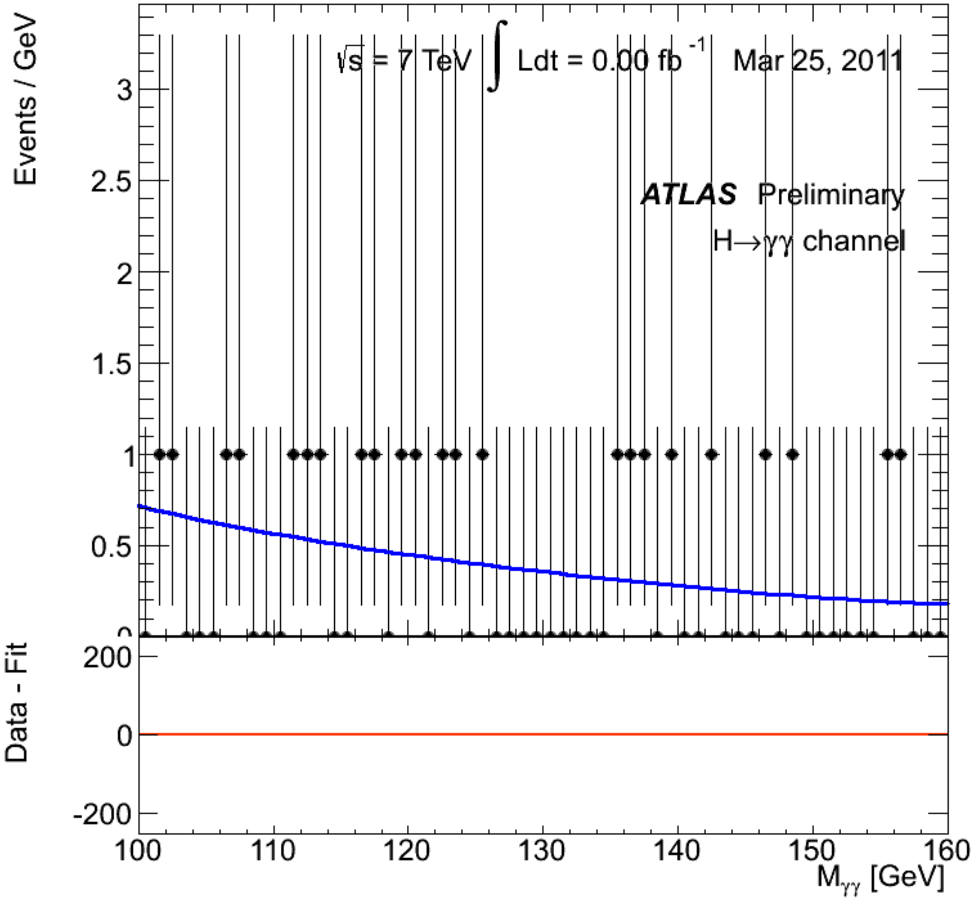


In the invariant mass distribution for $\gamma\gamma$, there is an excess of events incompatible with background for masses ~125 GeV/c^2.

The observation of this new state into 2 photons implies that the **new particle is a boson**, and that **cannot be a particle with "spin 1"**.

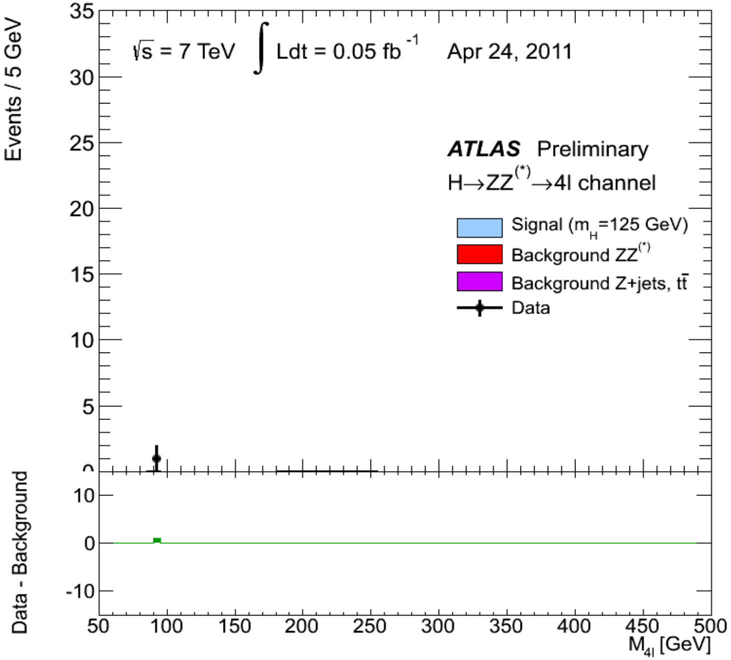
There is no other fundamental particle with these properties!

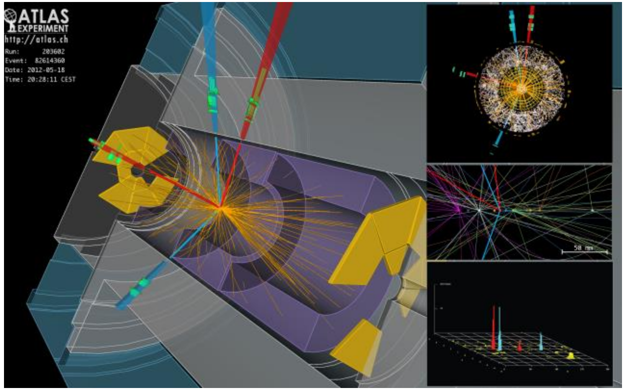
2012: Discovery of the Higgs boson also in ATLAS: $X \rightarrow \gamma\gamma$



Results from $X \to ZZ^* \to l_1^+ l_1^- l_2^+ l_2^- (4l)$:

Invariant mass distribution for 4 leptons, $M(4l)$





(*two electron[–positron] pairs, or two muon[-antimuon] pairs, or a pair of electrons and a pair of muons*).

$X =$ the Higgs boson

Thank you for your patience

Albert Einstein [P.N.1921]: (With knowledge...)

"We can look to the Universe as if there were no miracles.
But we can also look to the Universe as if everything is a miracle!"