The smallest pieces of our universe

Sourabh Dube

25th September, 2016

Science =

Regular person asks “WHY?”

Answer: “blah blah blah”

RP: “oh great!”

Science =

Regular person asks "WHY?"

Answer: "blah blah blah"

RP: "oh great!"

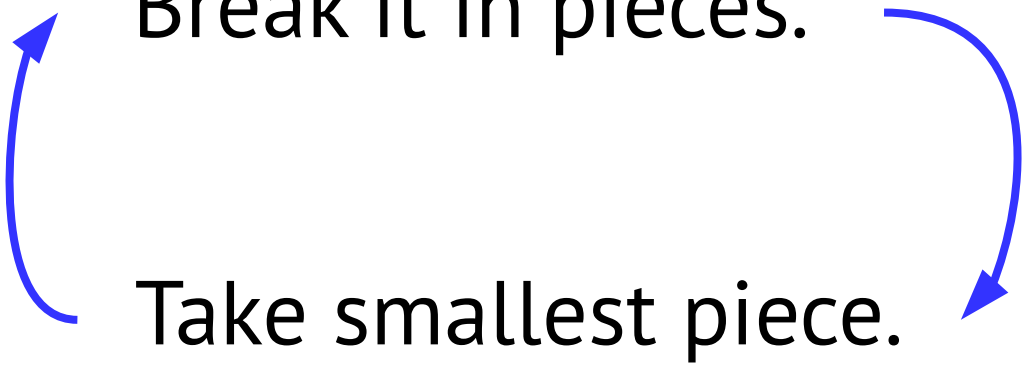
Science lover : "WHY?"

Answer: "blah blah blah"

SL: "oh great! And HOW?"

What are the smallest pieces?

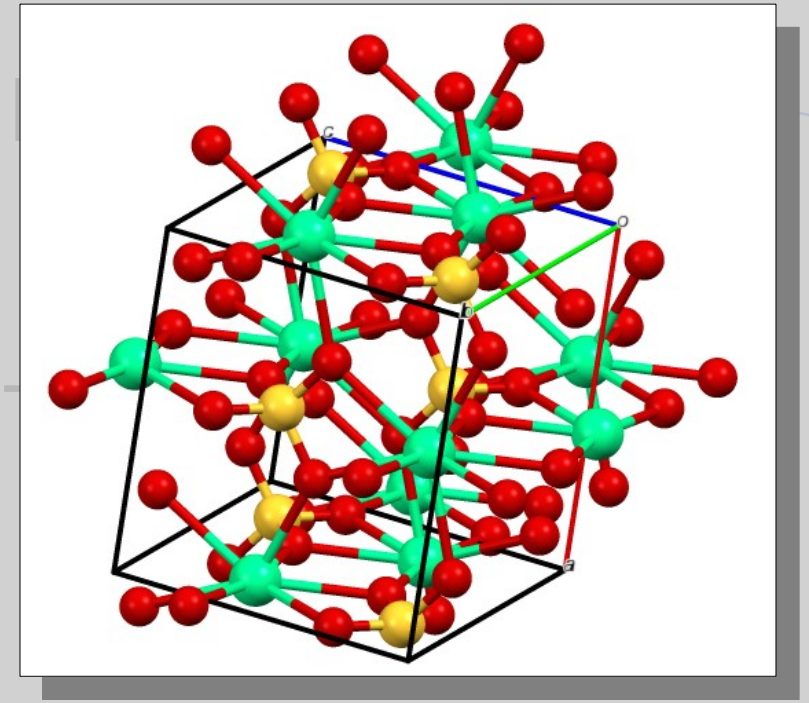
Take a piece of chalk.



What are the smallest pieces?

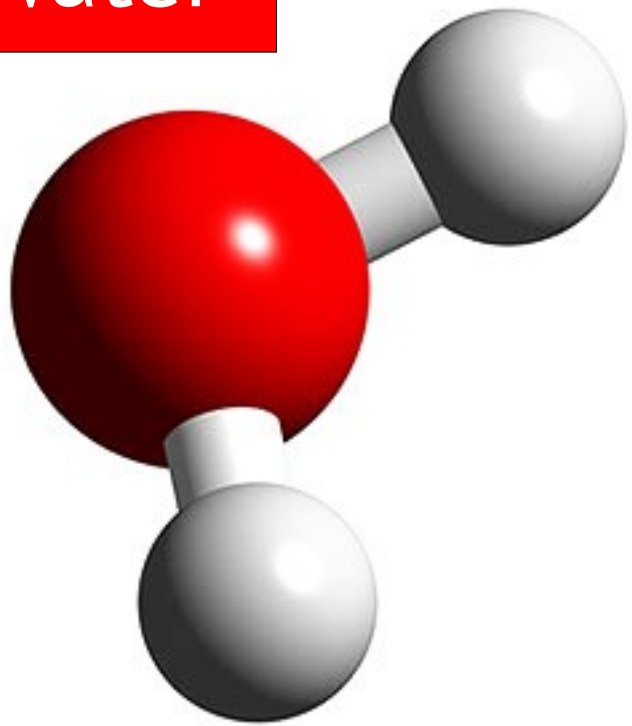
Take a piece of chalk.

Gypsum.

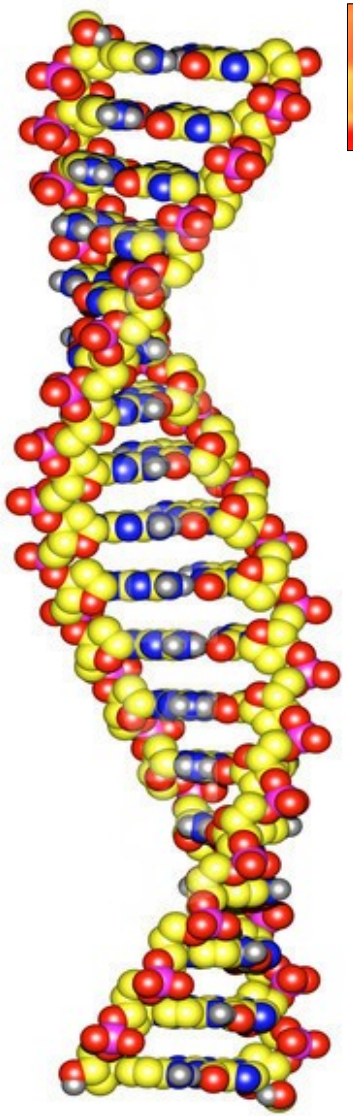


Molecules make up everything (?)

Water



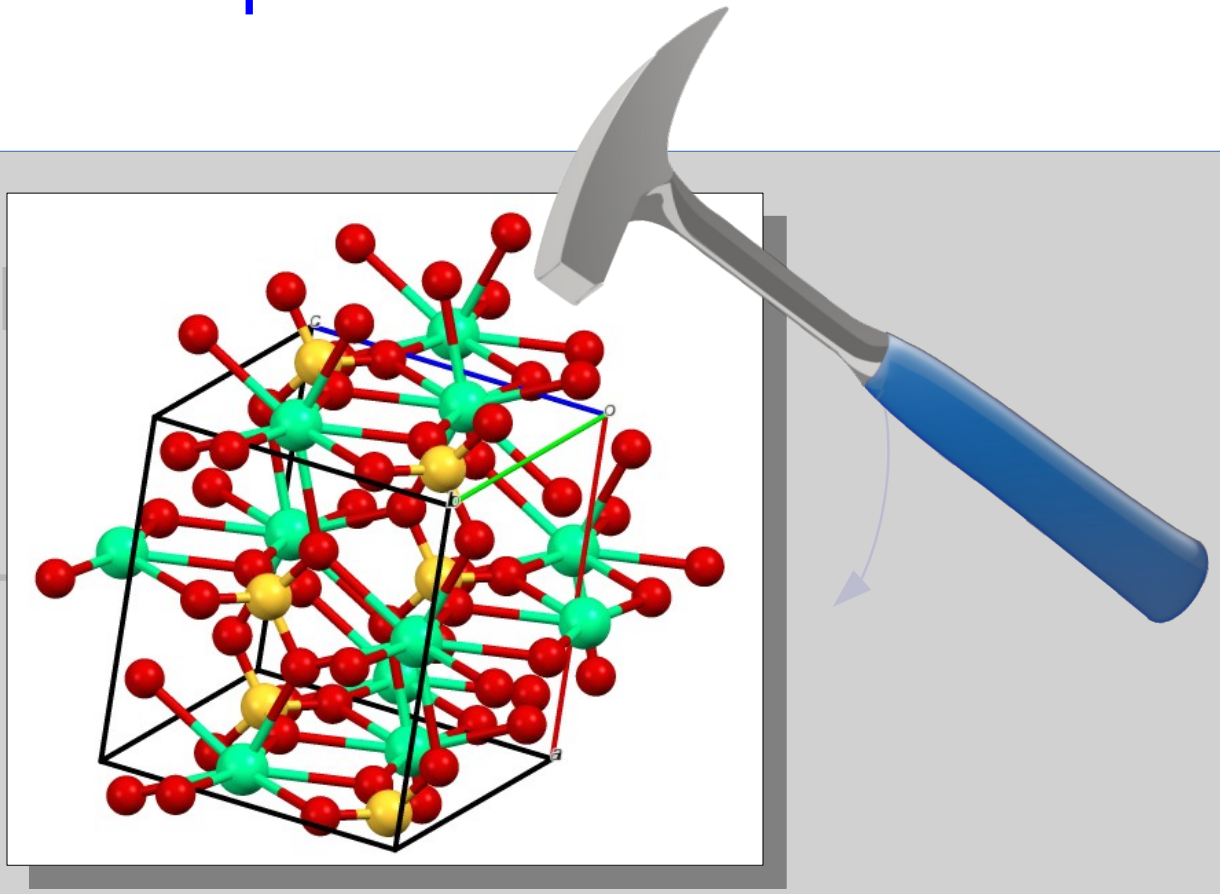
DNA



What are the smallest pieces?

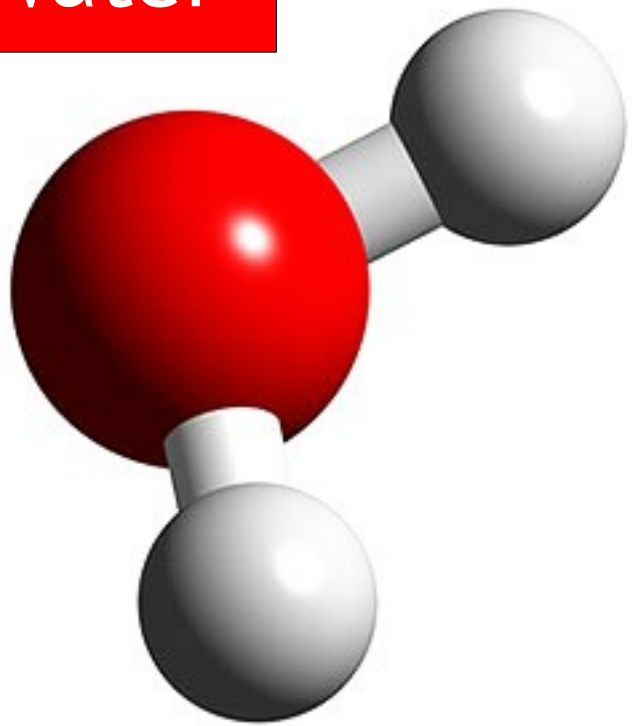
Take a piece of chalk.

Gypsum.
Calcium
Sulphur
Oxygen
Hydrogen

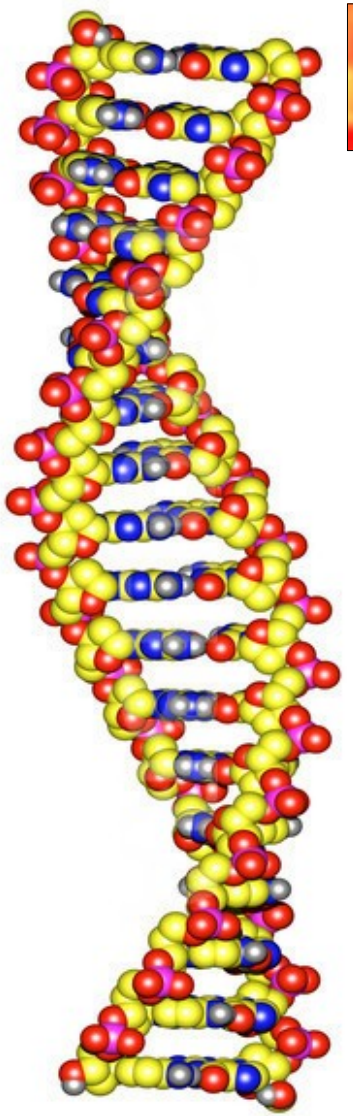


Molecules broken into atoms

Water



Oxygen



DNA

C
H
O
N
P

Indistinguishability of atoms

Each atom of oxygen is *exactly identical* to every other atom of oxygen.

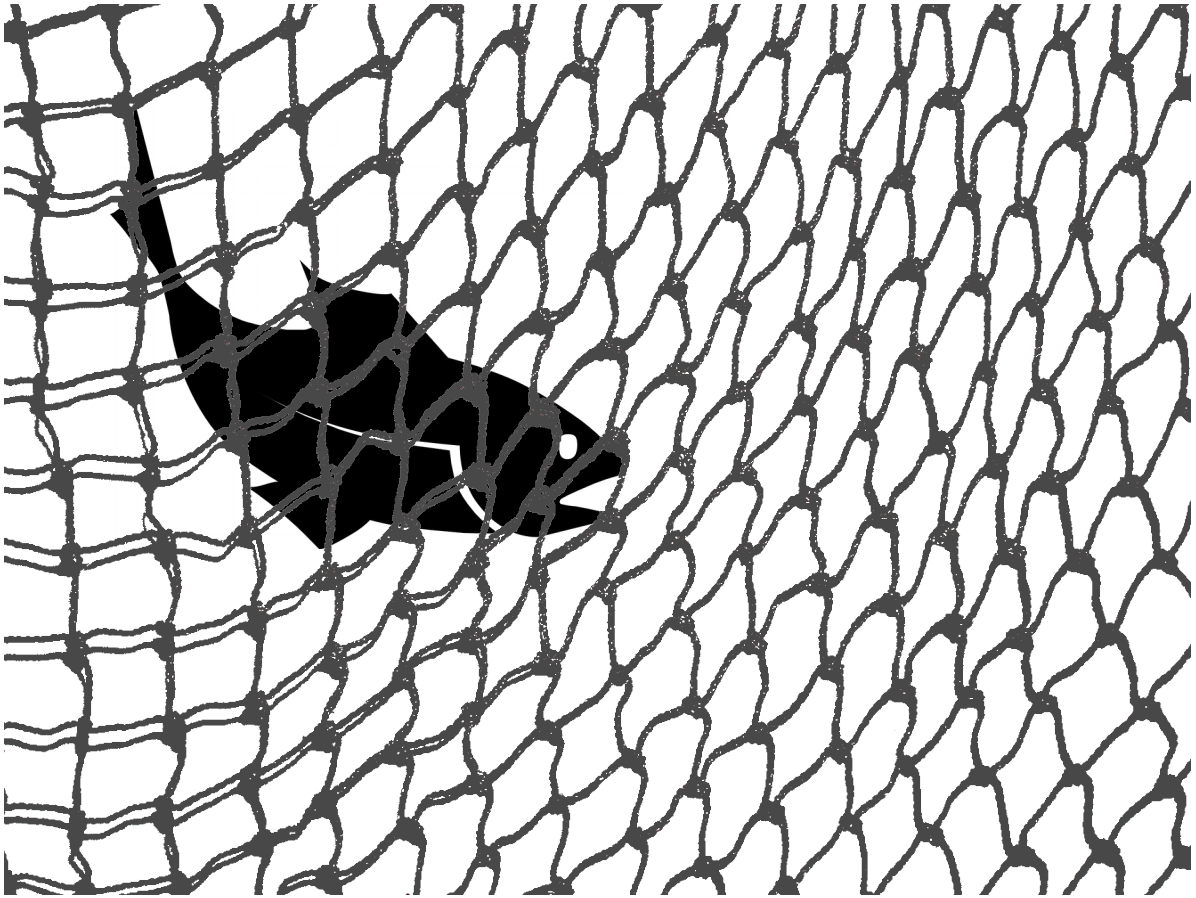
Thus one water molecule is exactly the same as any other water molecule.

Too small to see...

But what if object is smaller than wavelength of light?

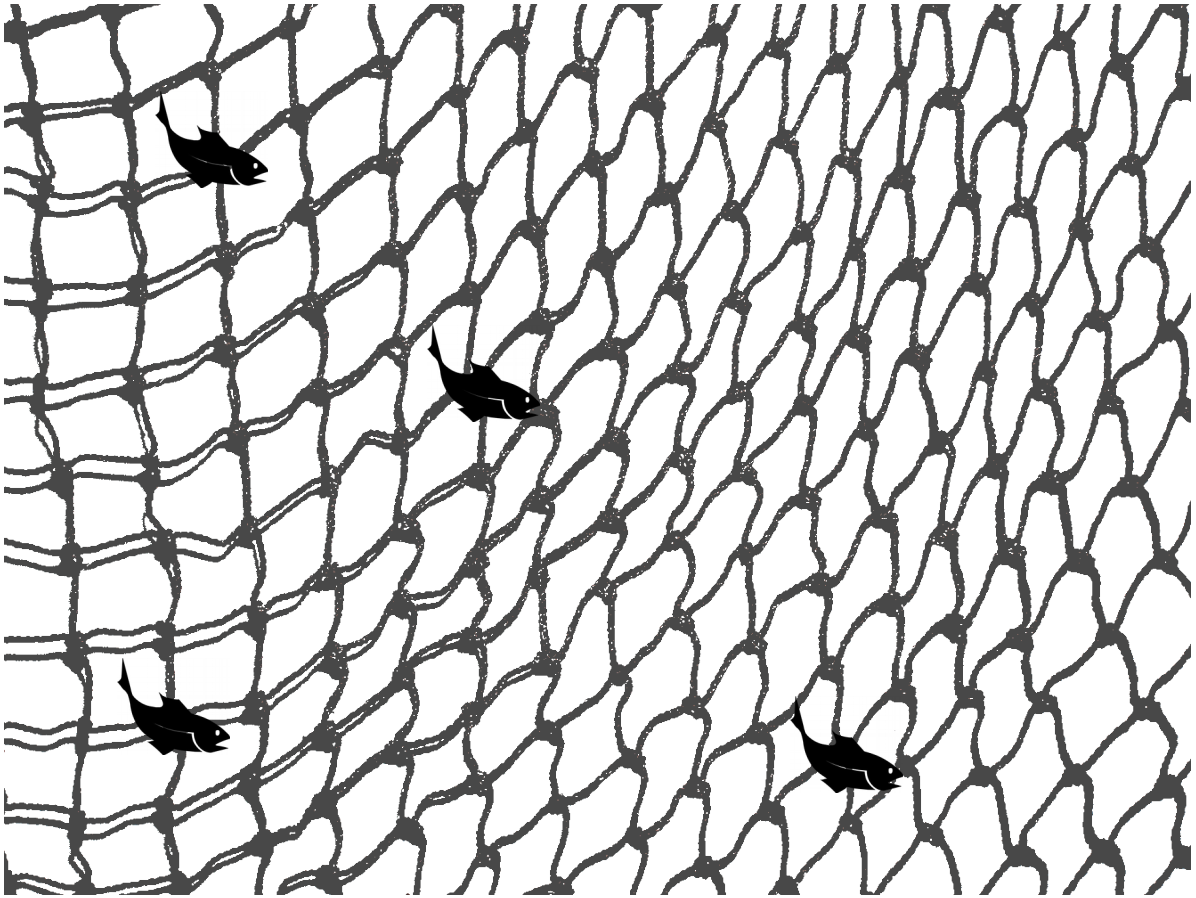
Too small to see...

Objects larger than wavelength can be seen

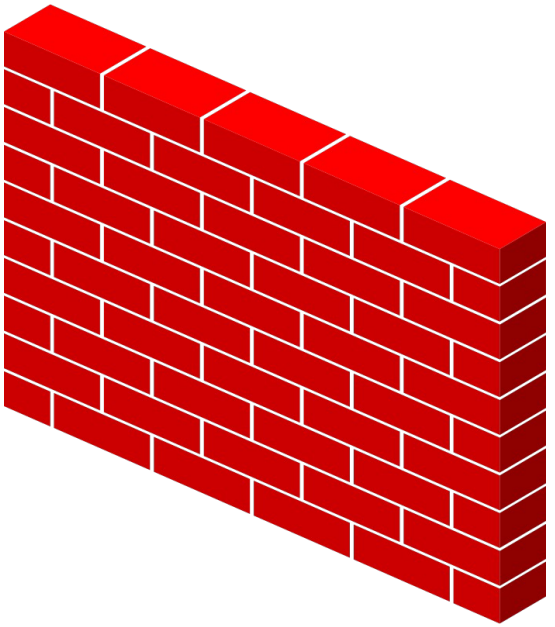


Too small to see…

Objects smaller than wavelength need to be “seen”



Too small to see...

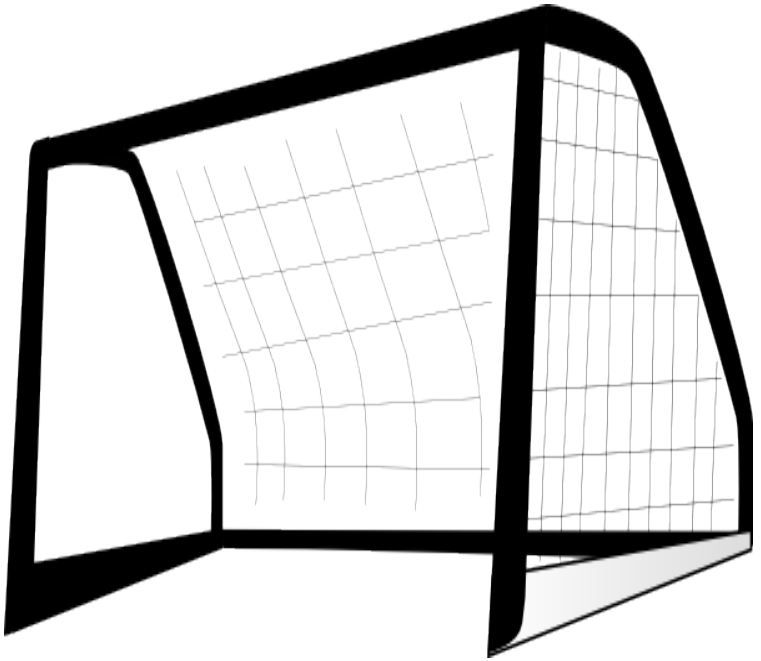


Too small to see...

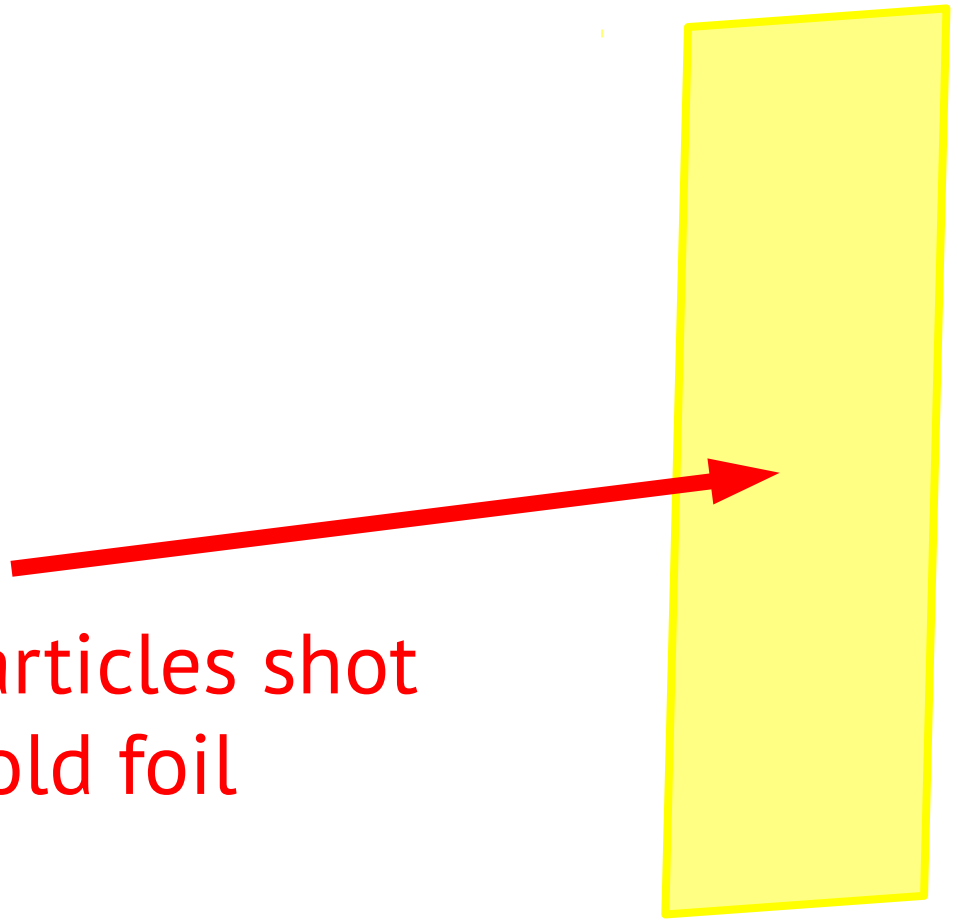
What if the wall is invisible?

Too small to see...

Too small to see...



Rutherford's gold foil experiment

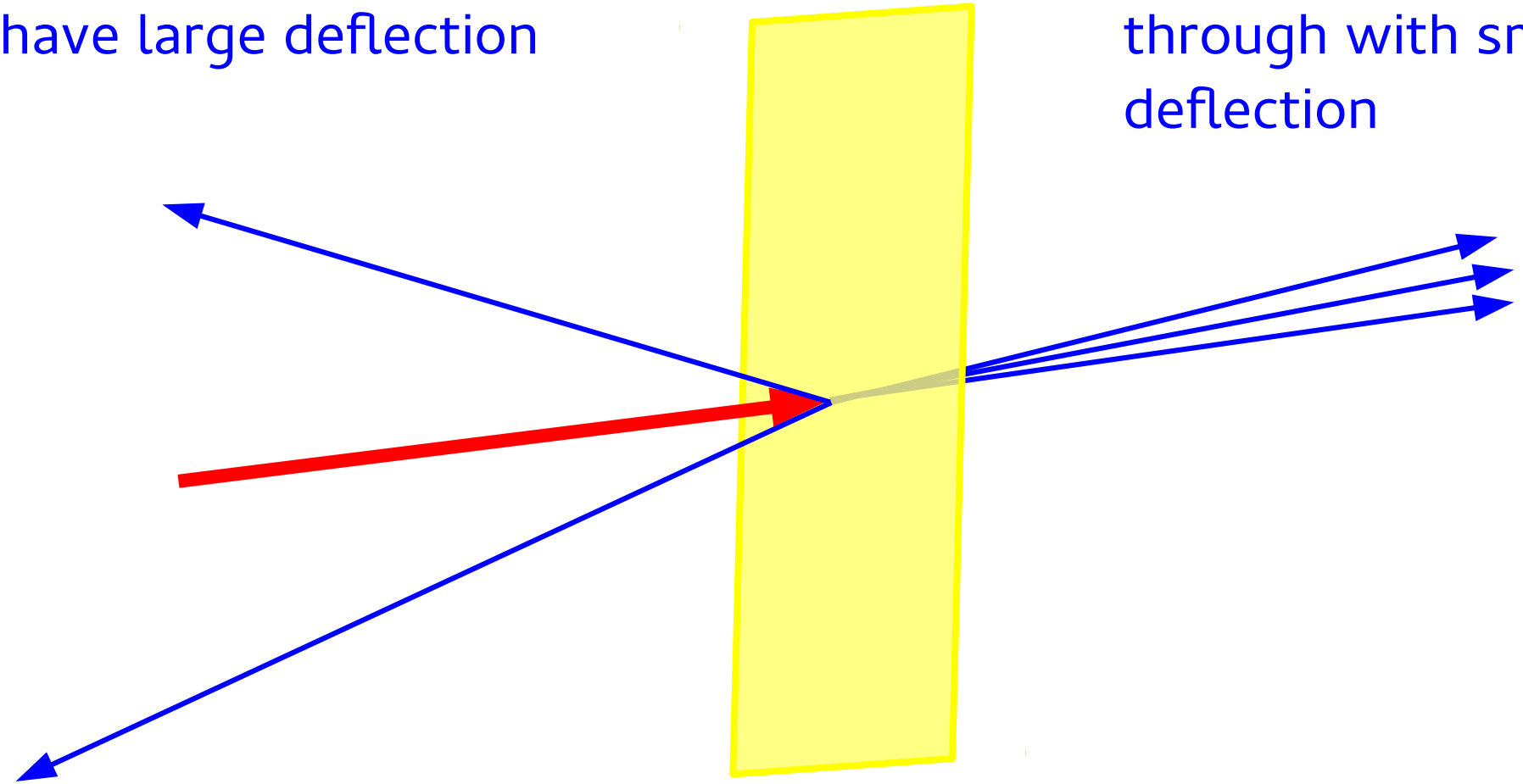


α-Particles shot
at gold foil

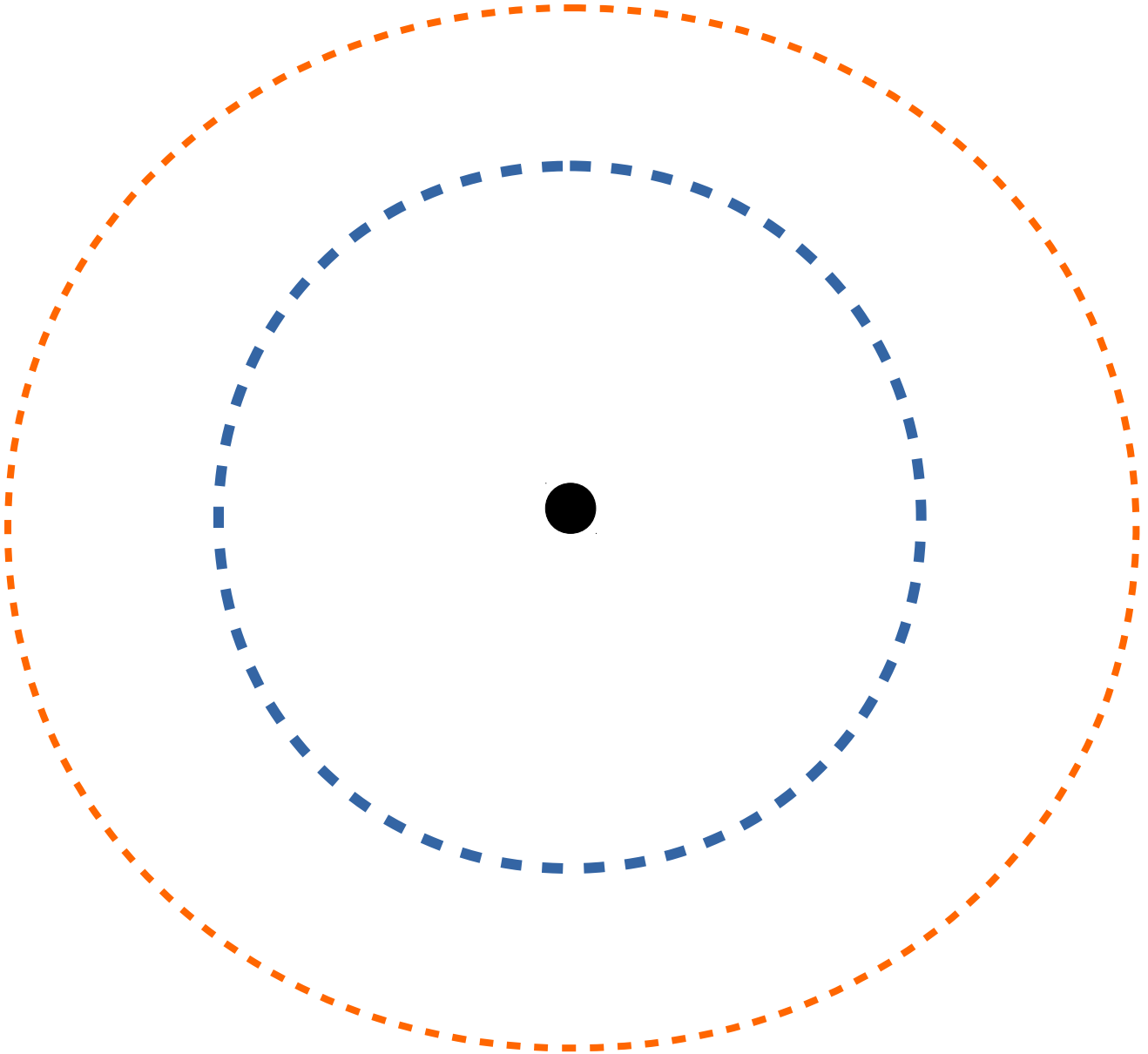
Rutherford's gold foil experiment

Some α-Particles have large deflection

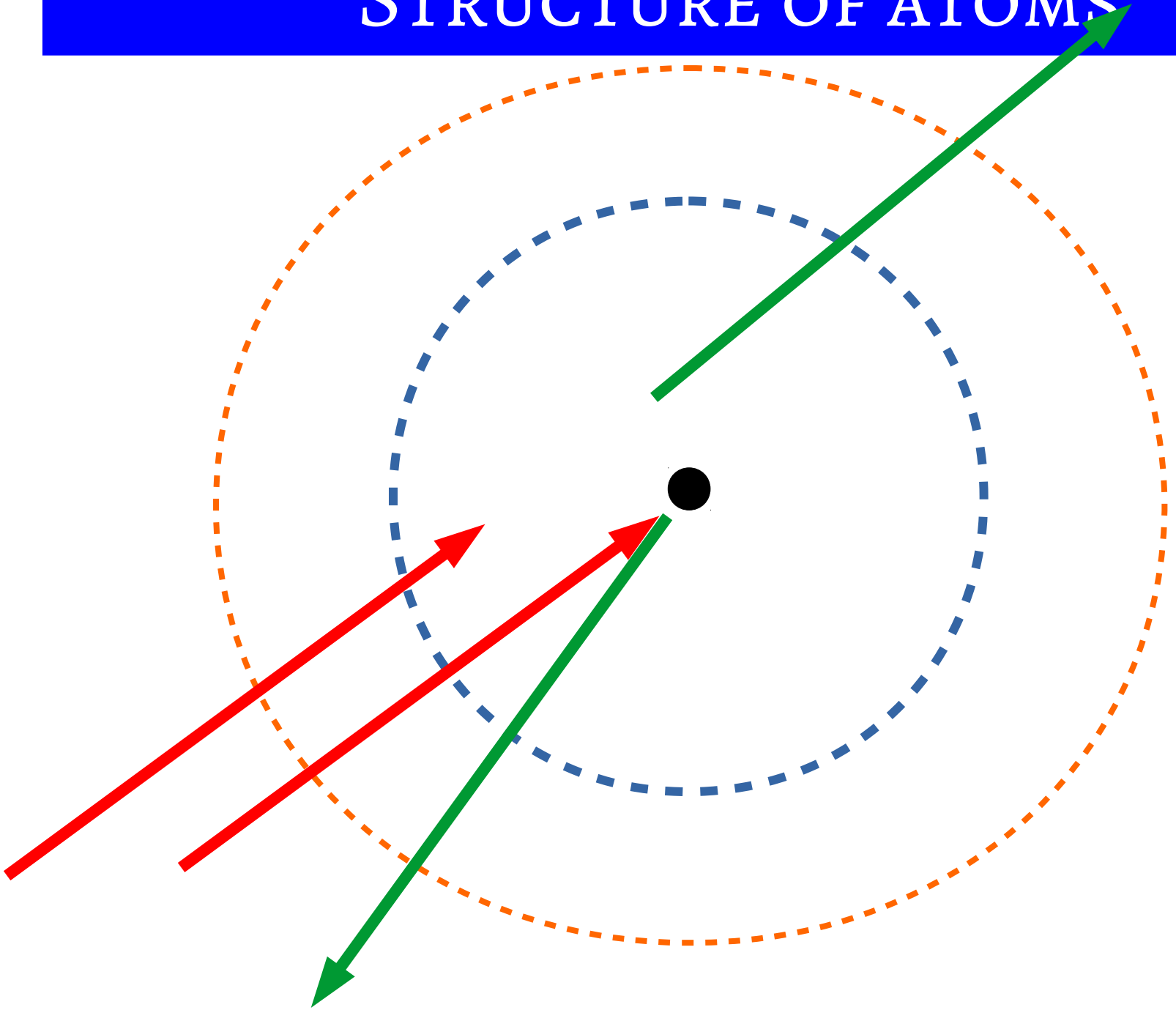
Most α-Particles go through with small deflection



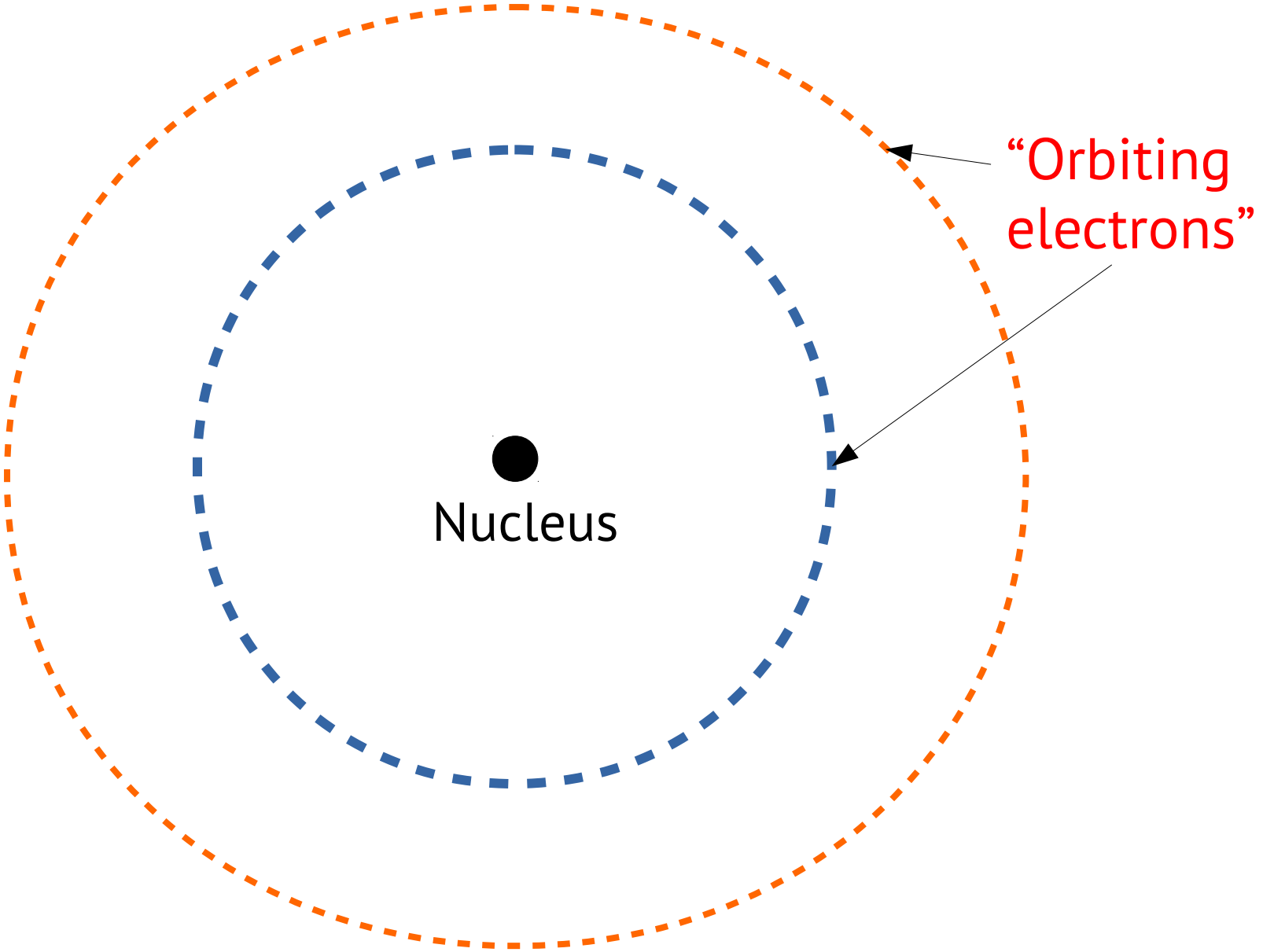
Structure of atoms



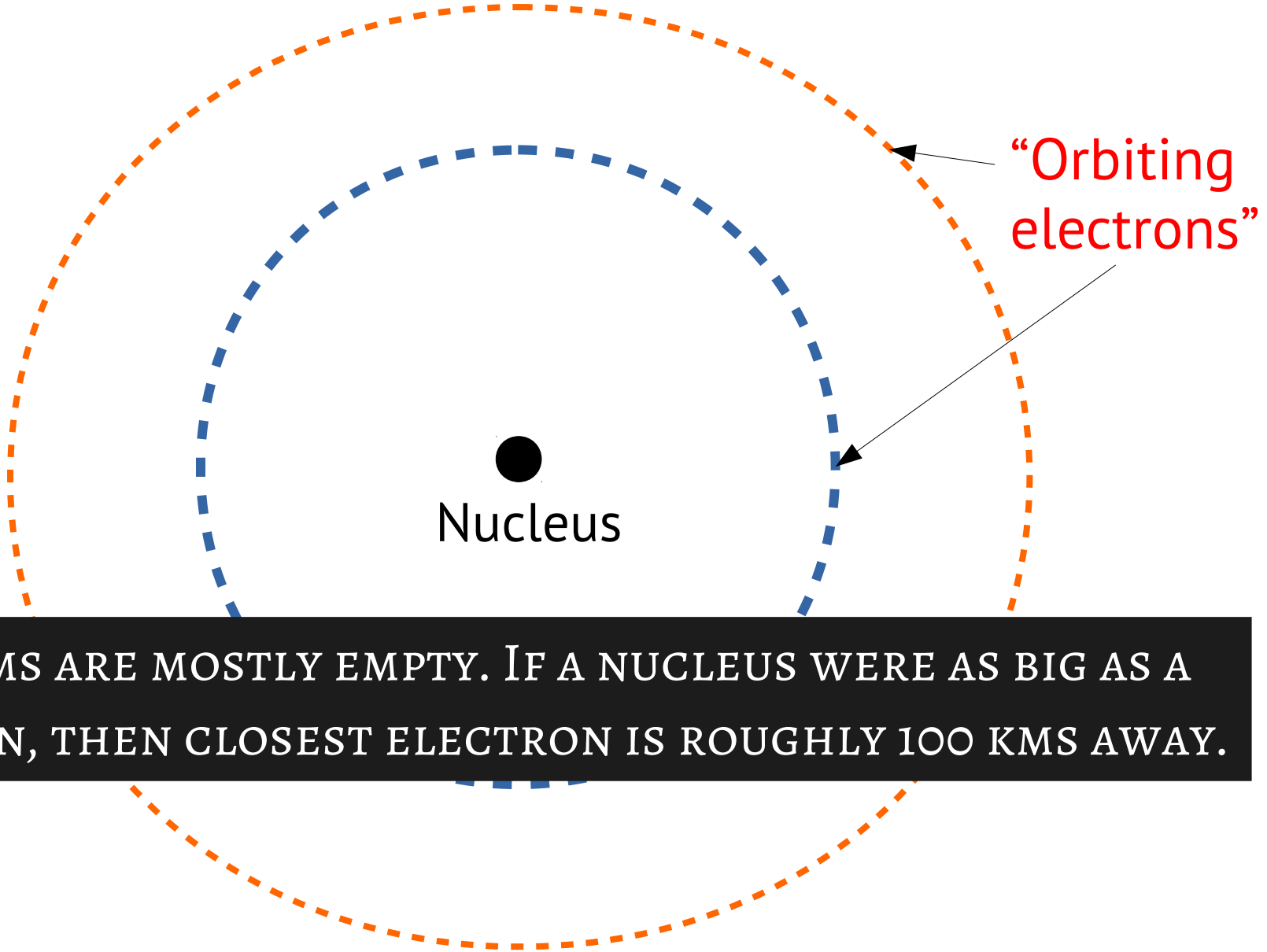
Structure of atoms



Structure of atoms

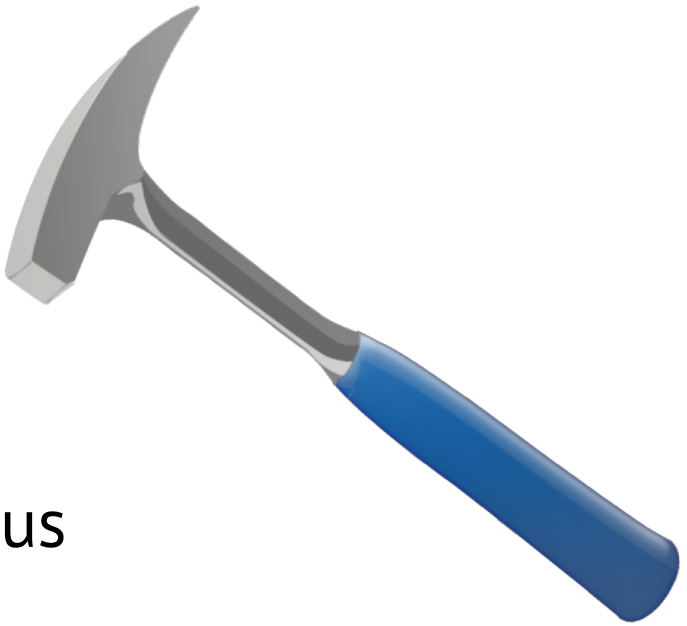


Structure of atoms



Atoms are mostly empty. If a nucleus were as big as a person, then closest electron is roughly 100 kms away.

Next step?



Nucleus

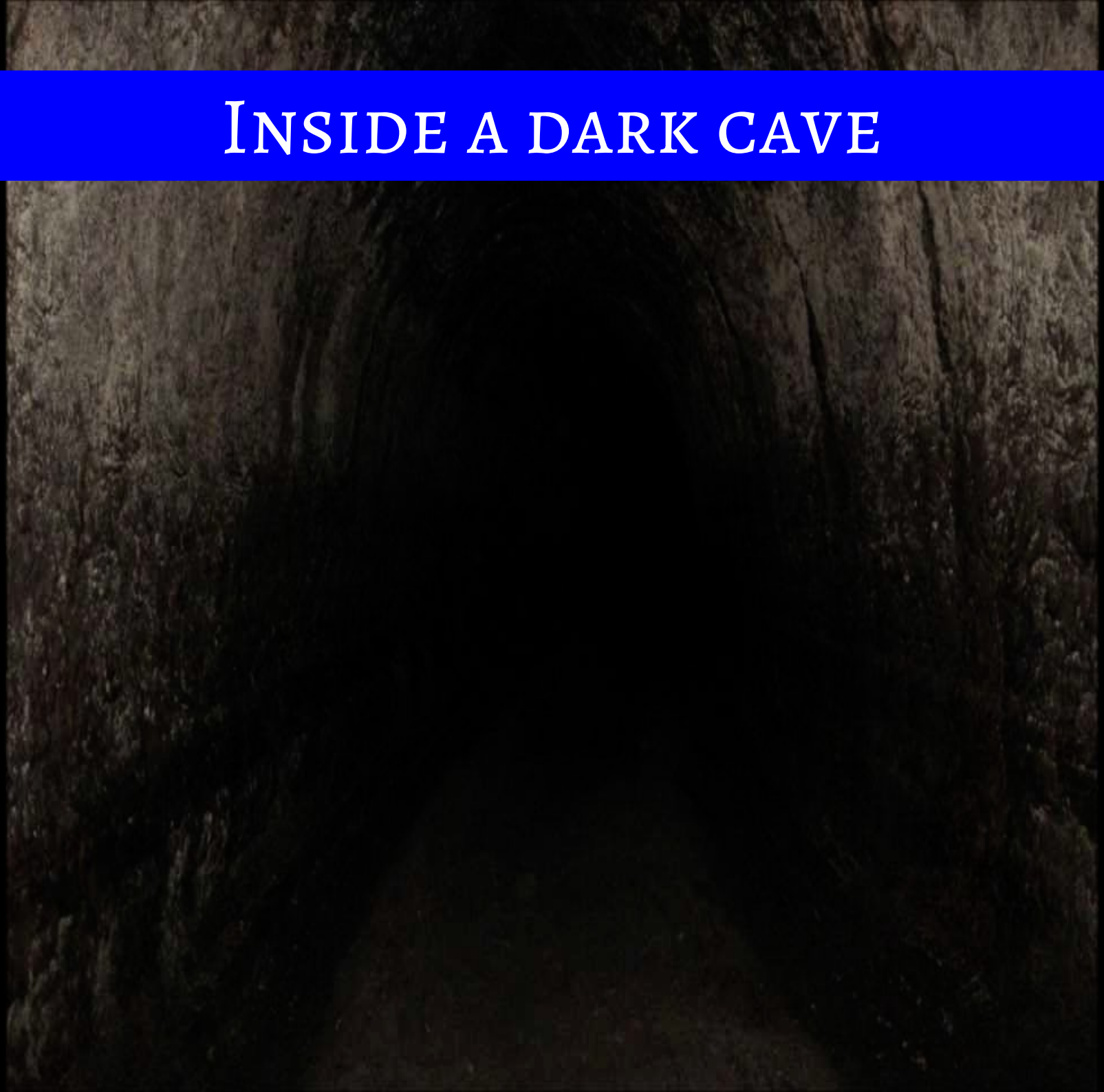
Need for 'high' energy

A nucleus is very small.

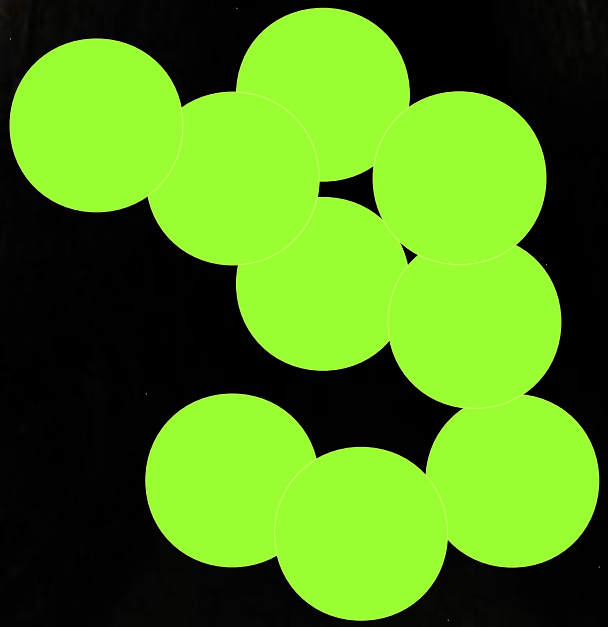
To be able to 'look' inside it, we need a *small* object of *high* energy.

Let me explain with an example.

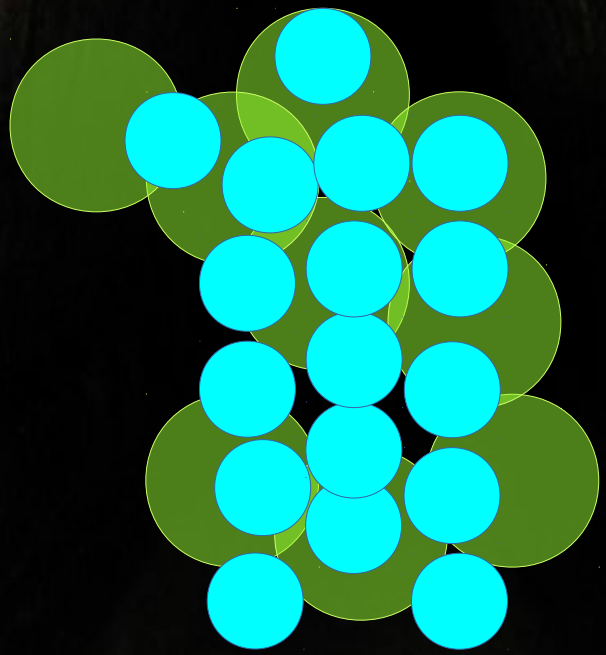
Inside a dark cave



Inside a dark cave



Inside a dark cave



Inside a dark cave

Size and Energy

Size we can look at, is inversely proportional to momentum

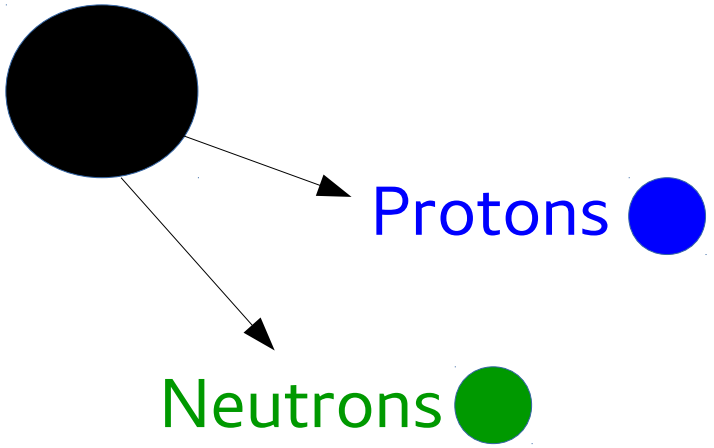
If

Length

Then

Energy

So what's in a nucleus?



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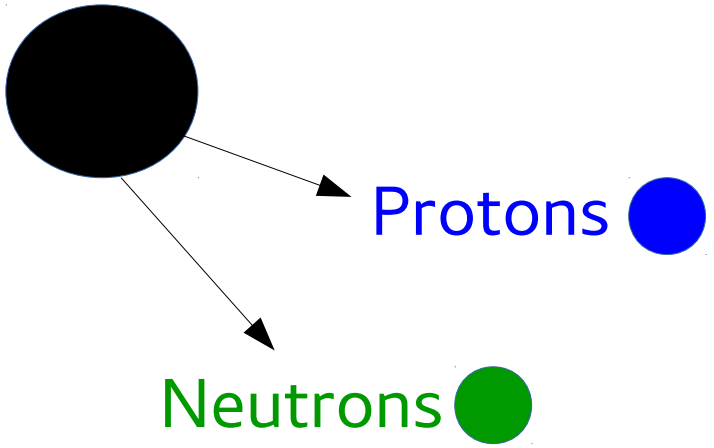
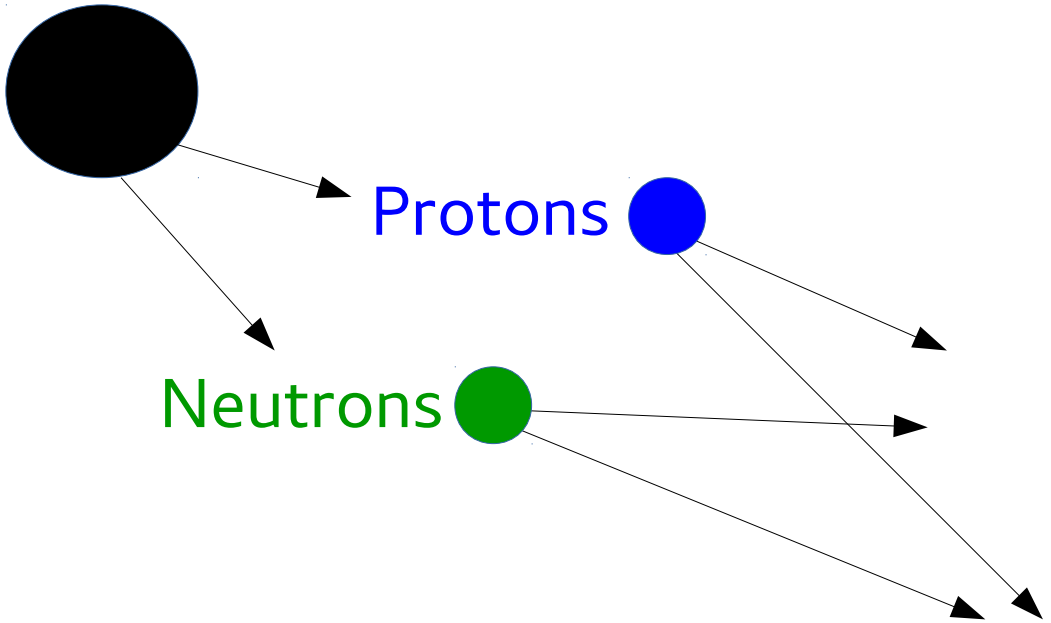


Deep Inelastic Scattering experiments with electrons

So what's in a proton/neutron?



QUARKS

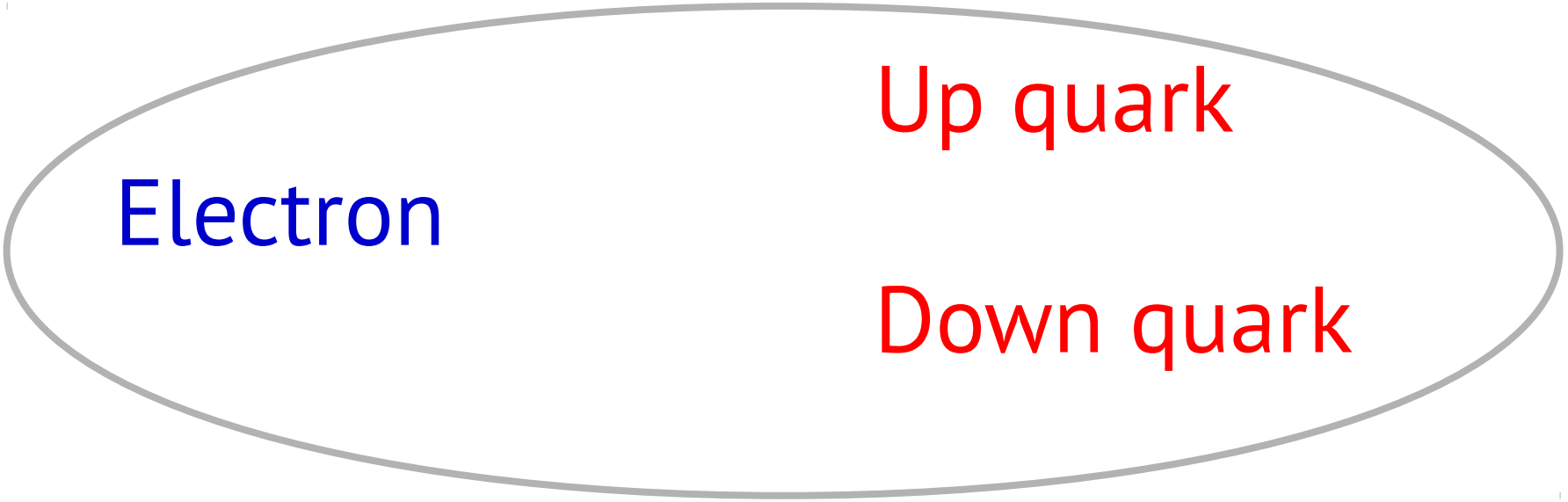
Up quark

Down quark

Proton = uud

Neutron = udd

The smallest pieces of our universe



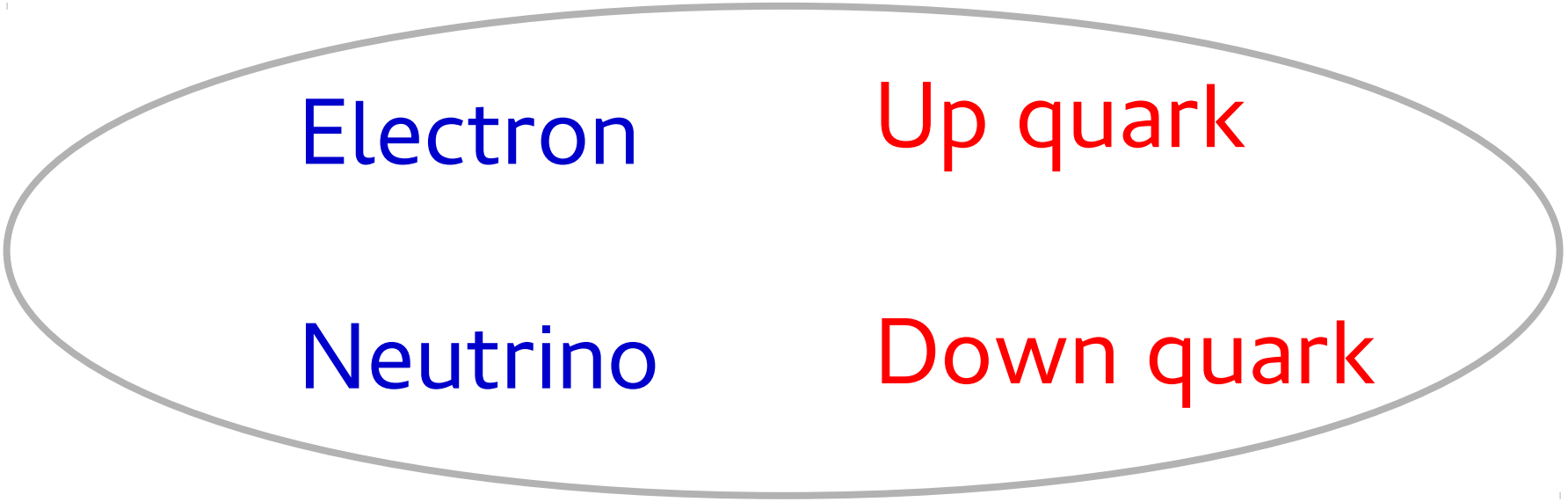
The smallest pieces of our universe

Up quark

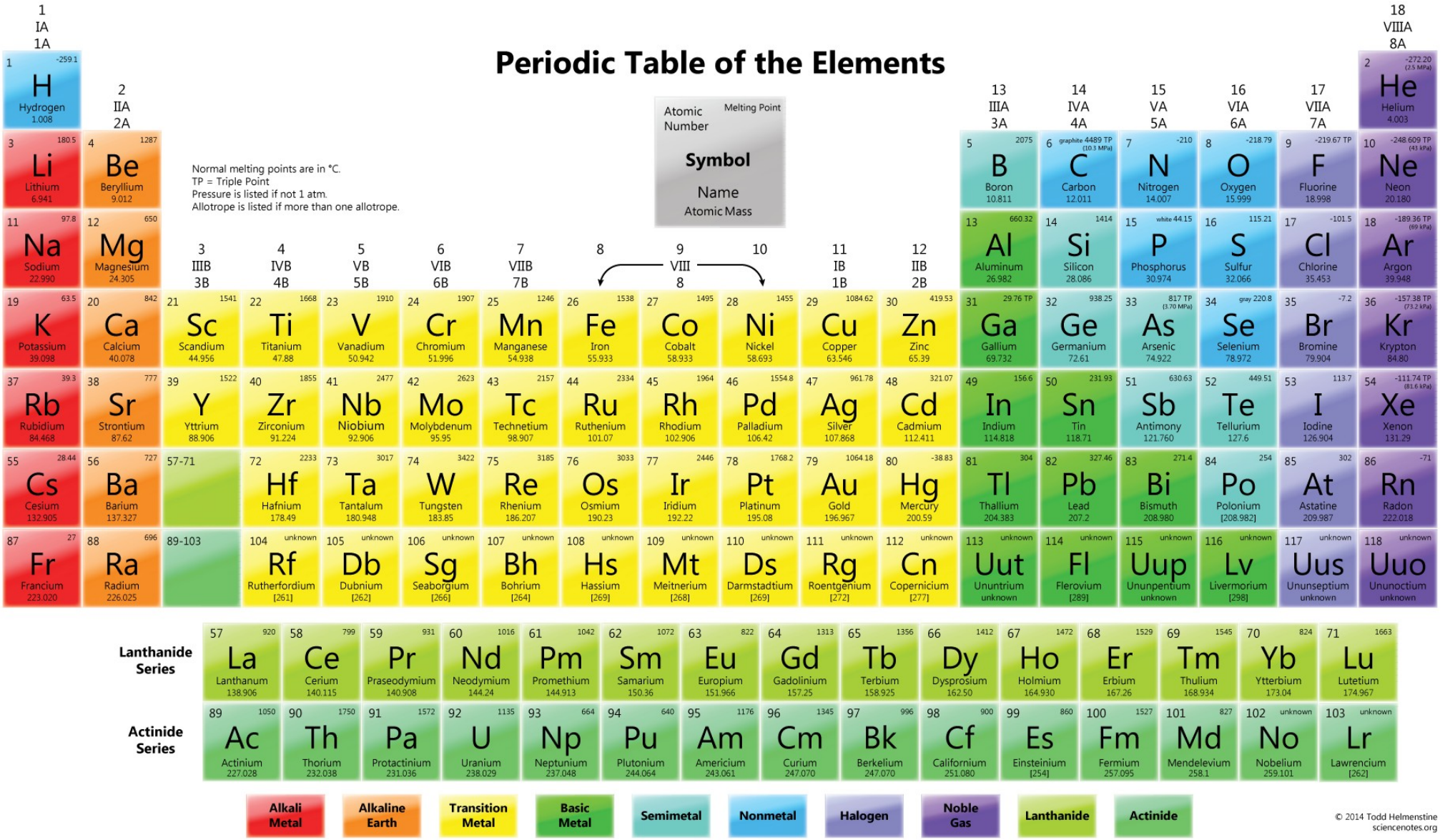
Electron

Down quark

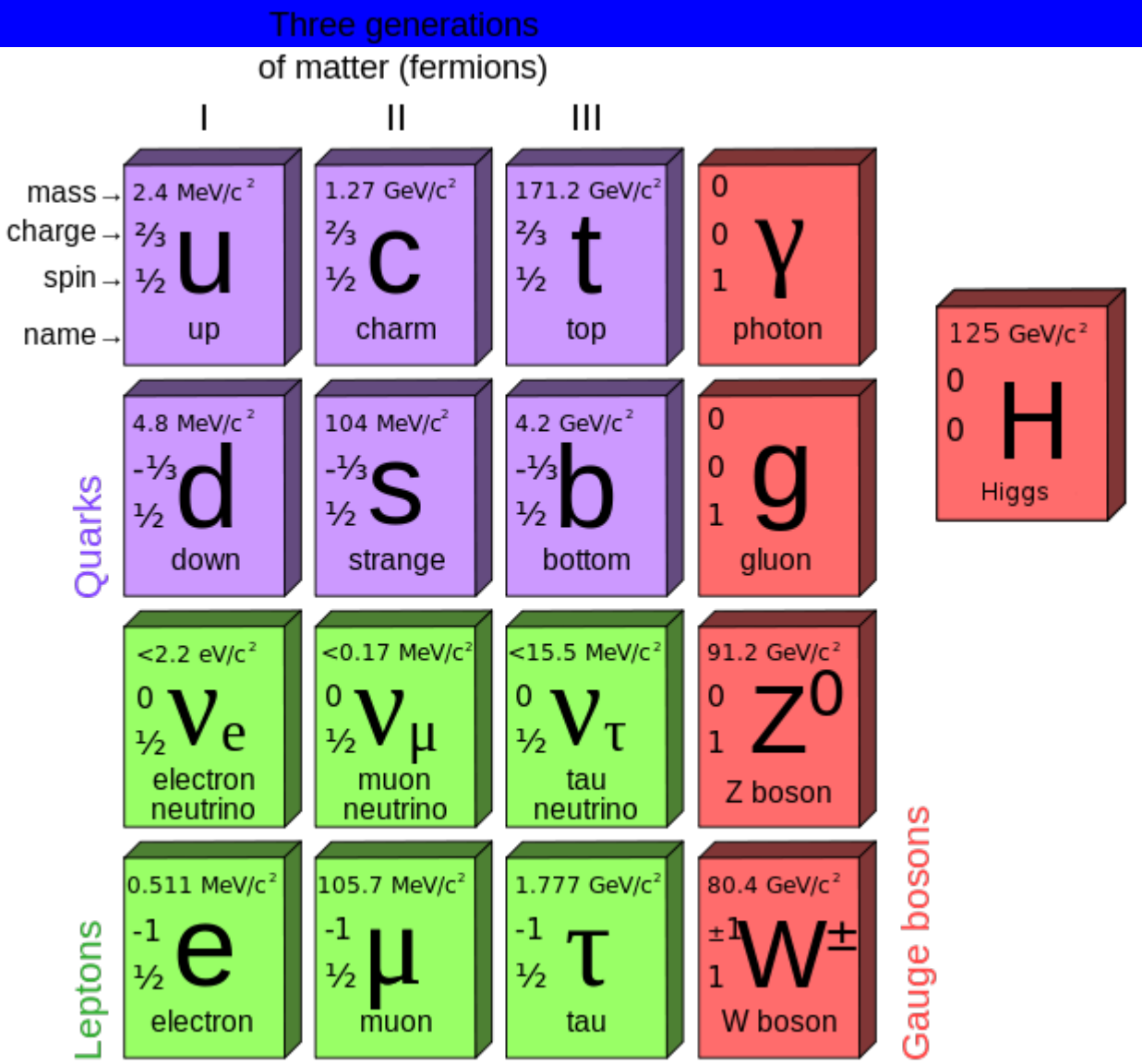
The smallest pieces of our universe



Periodic Table of Elements

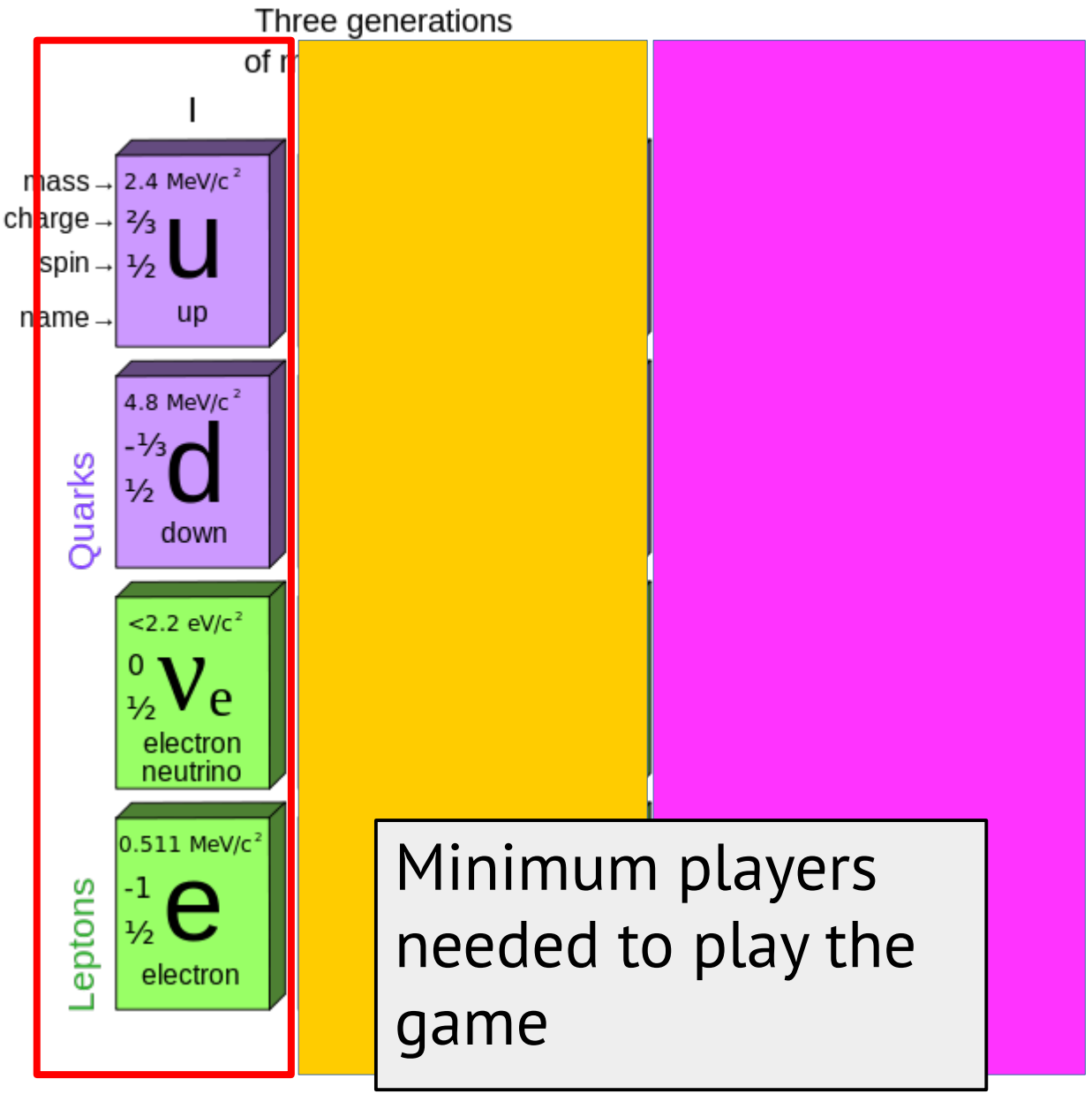


Standard Model of Particle Physics



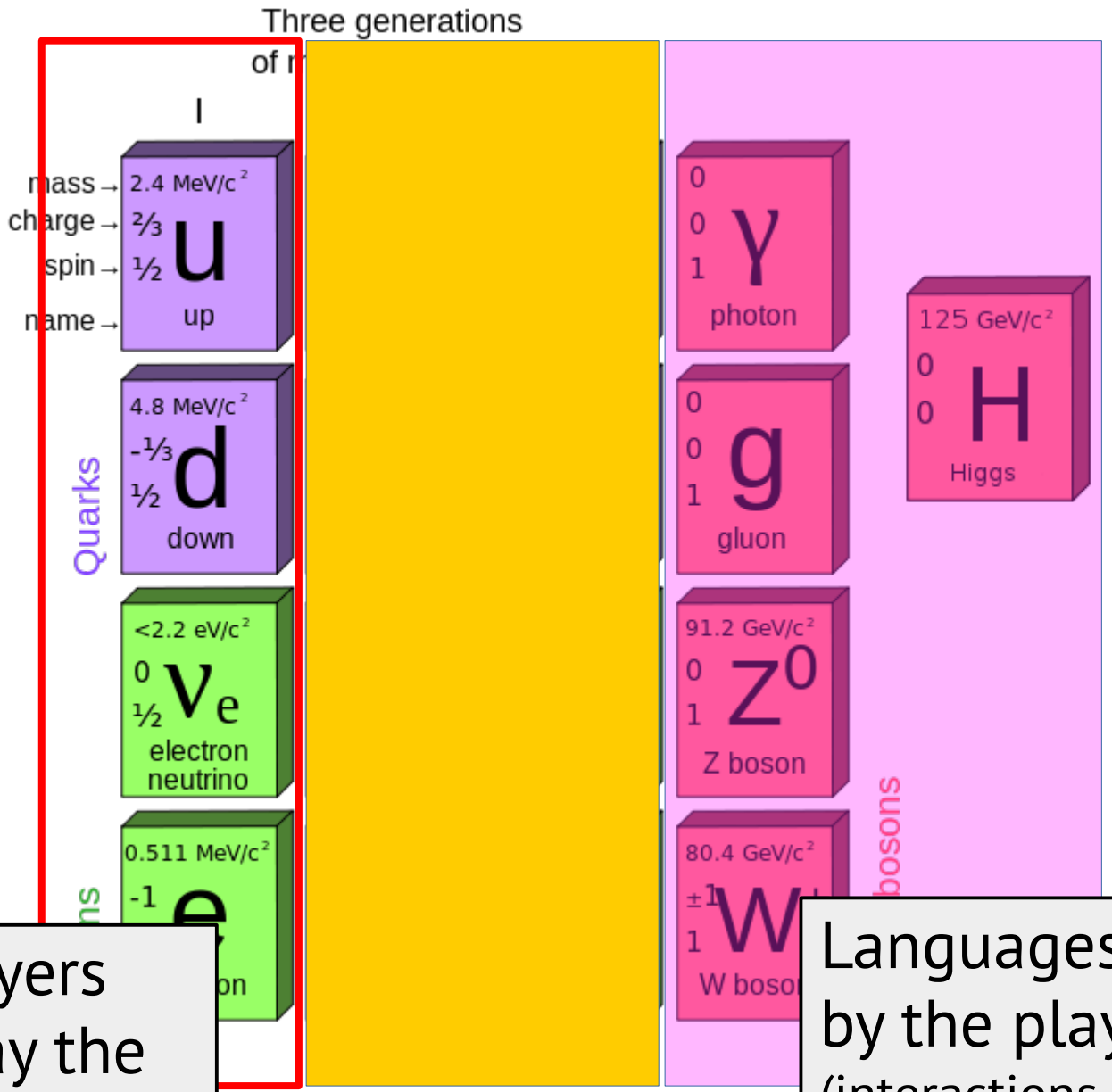
Periodic Table of Particles

SM EXPLAINED...



Minimum players needed to play the game

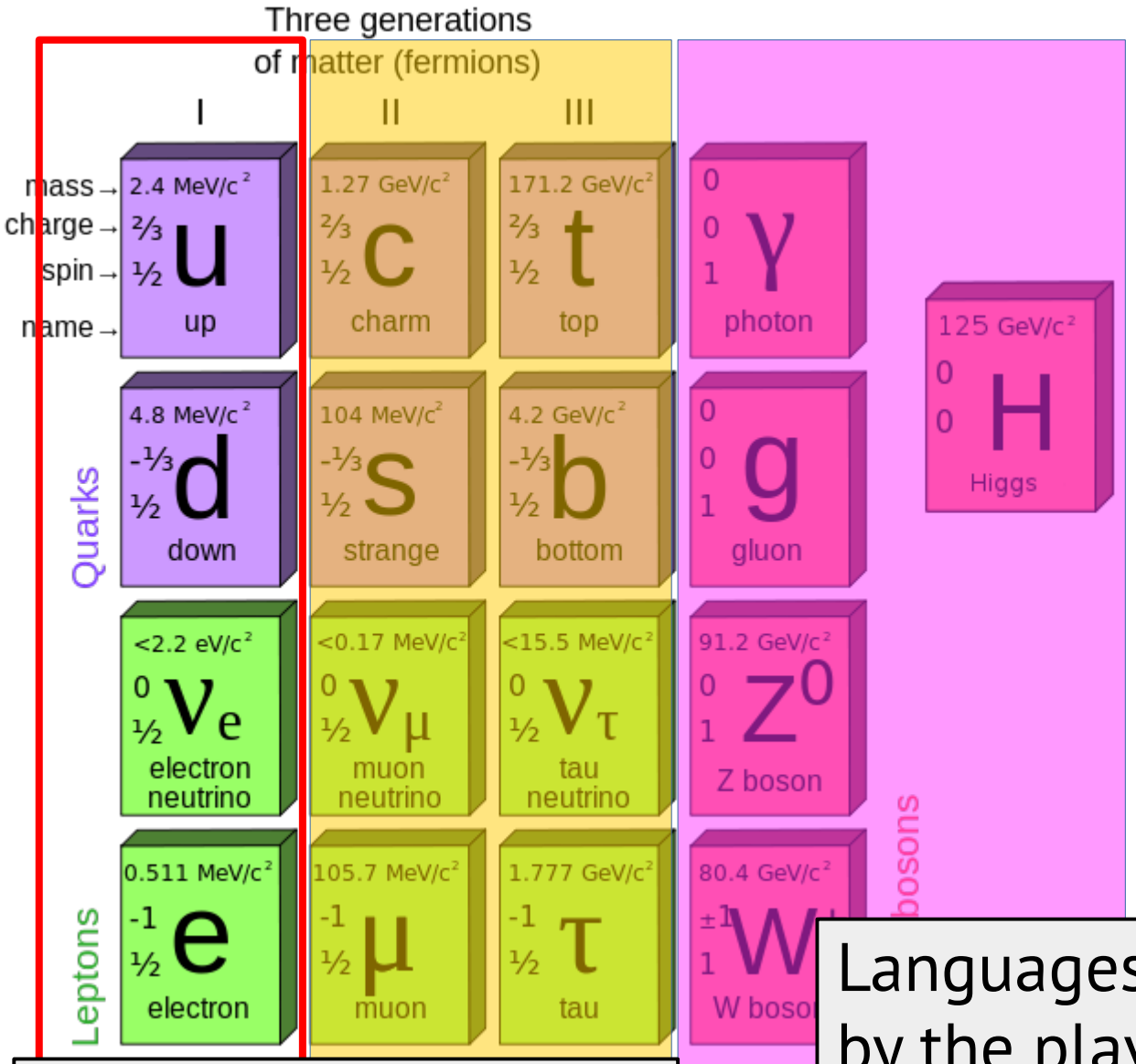
SM EXPLAINED...



Minimum players needed to play the game (Matter)

Languages spoken by the players (interactions between matter)

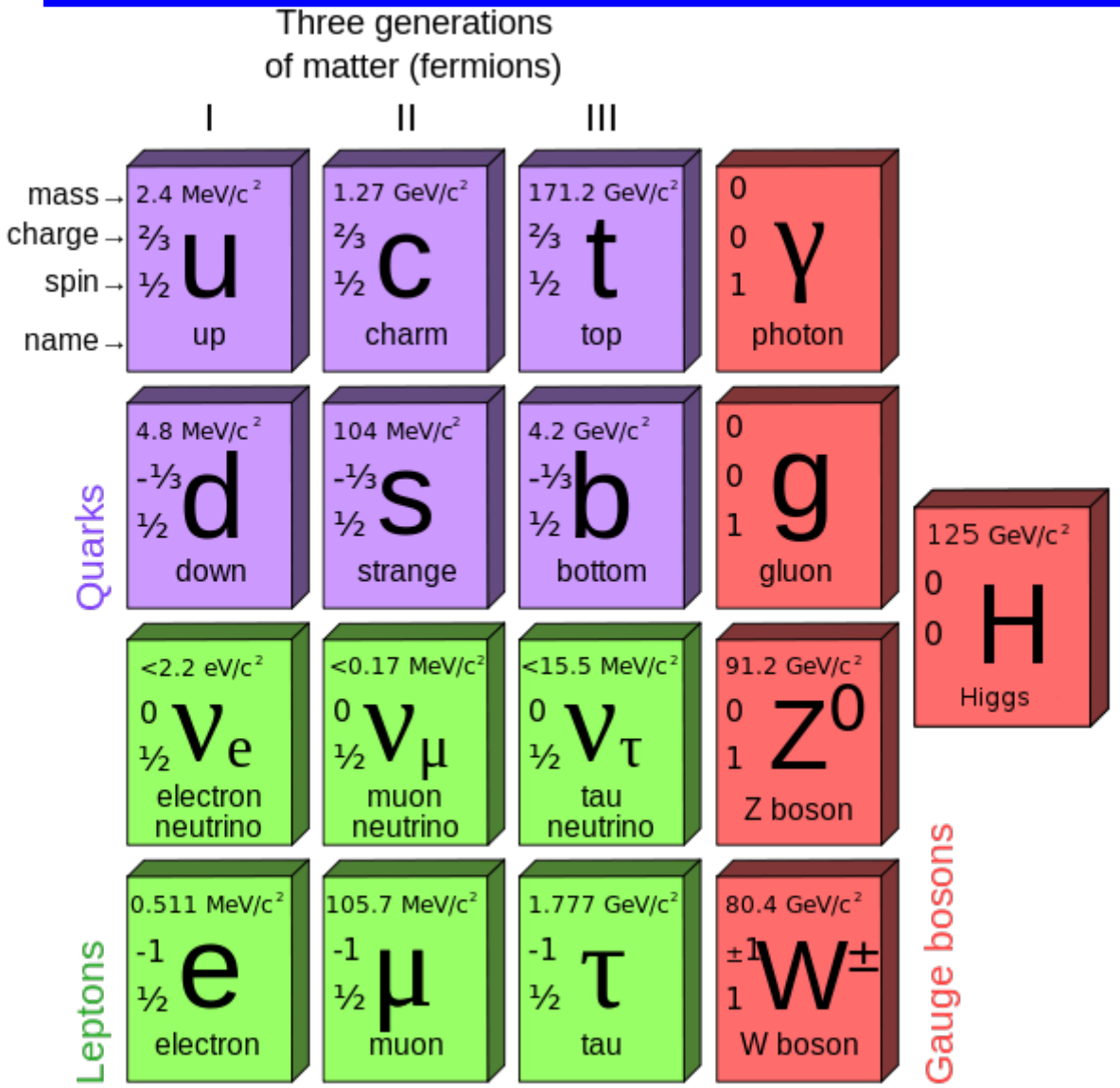
SM EXPLAINED...



More players (Matter)

Languages spoken by the players (interactions between matter)

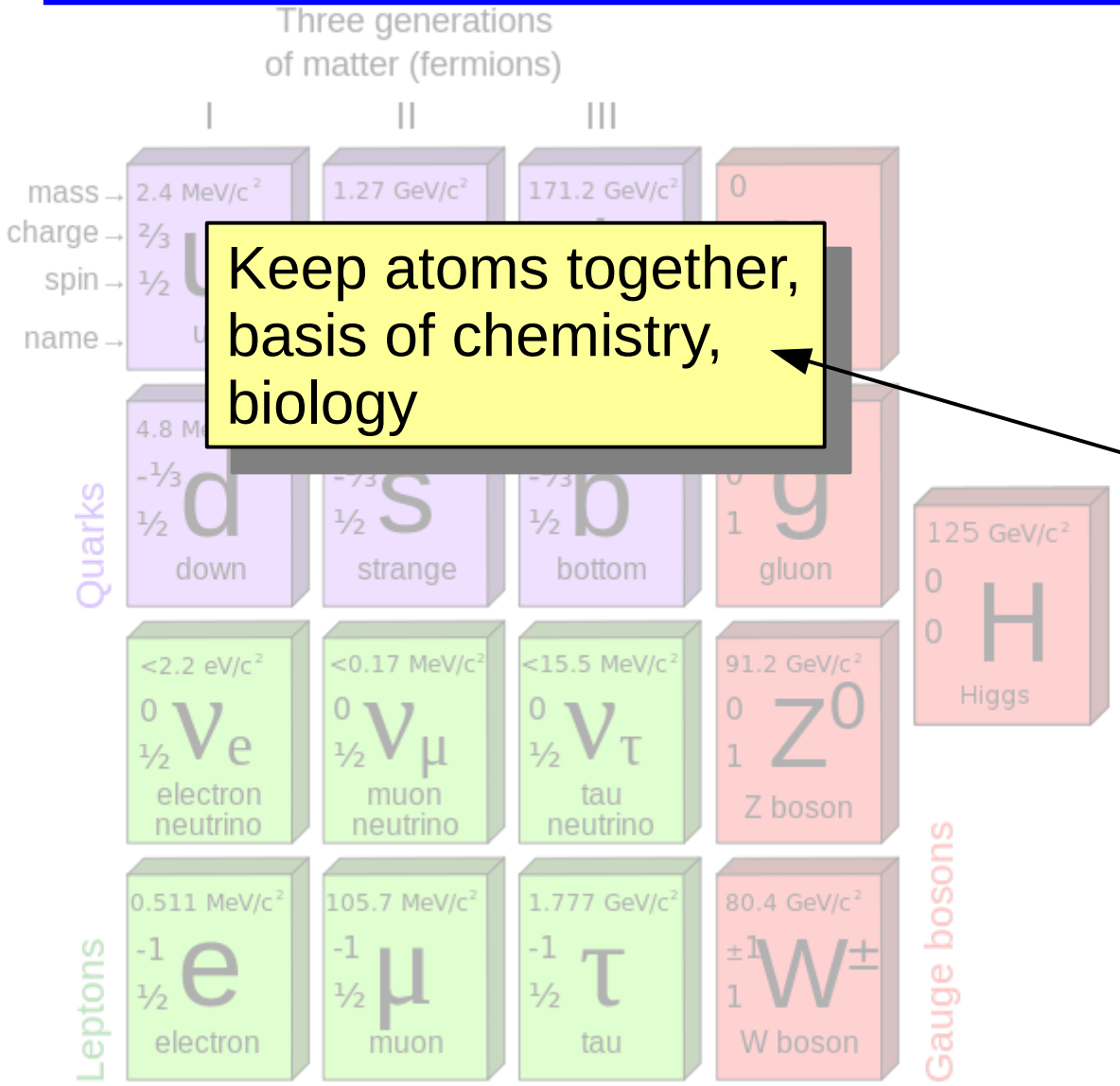
Standard Model of Particle Physics



Particles speak these 'languages'

- Electromagnetic interaction
- Strong interaction
- Weak interaction
- 'Higgs' interaction

Standard Model of Particle Physics



Keep atoms together, basis of chemistry, biology

Particles speak these 'languages'

- Electromagnetic interaction
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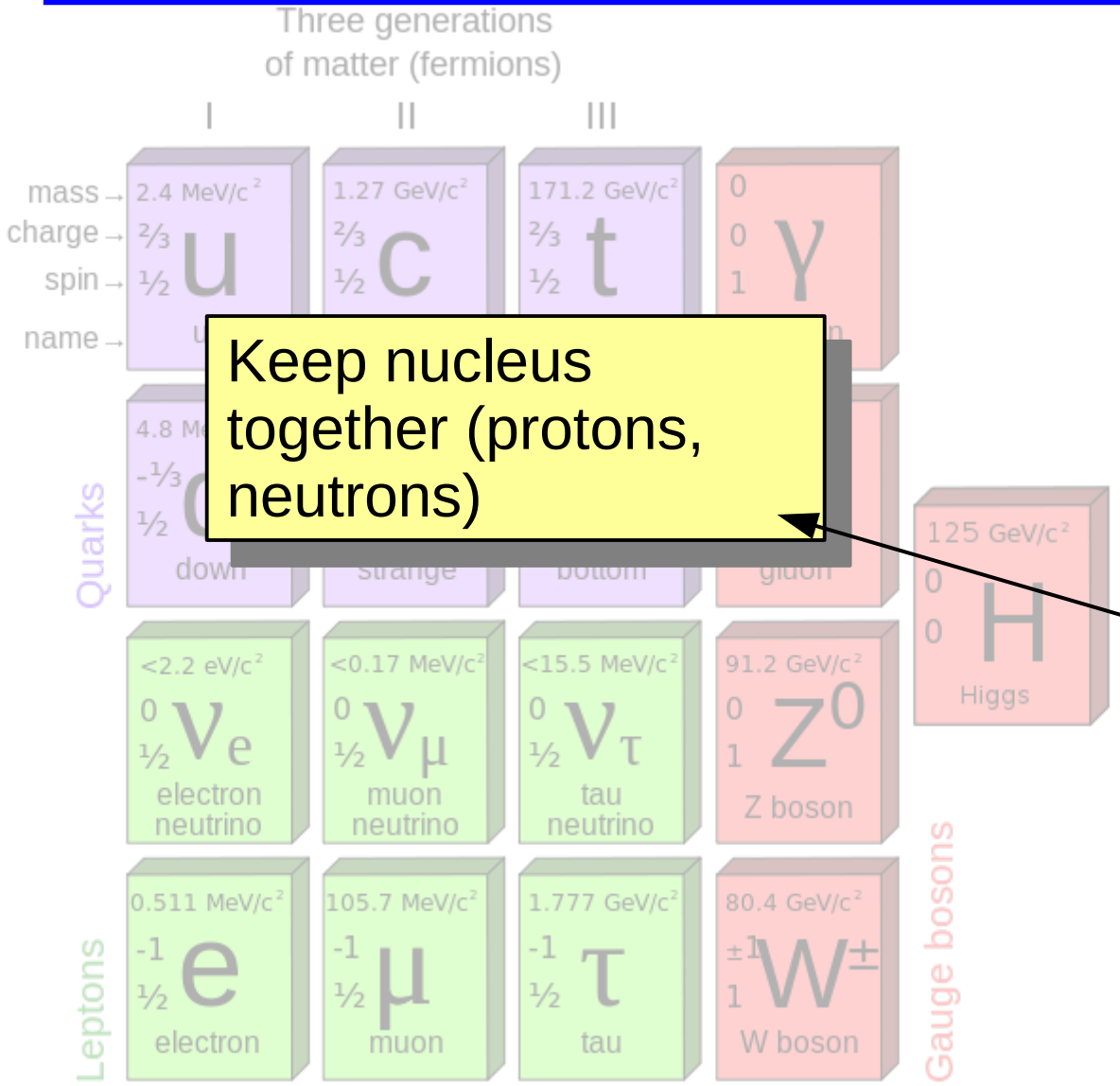
Standard Model of Particle Physics

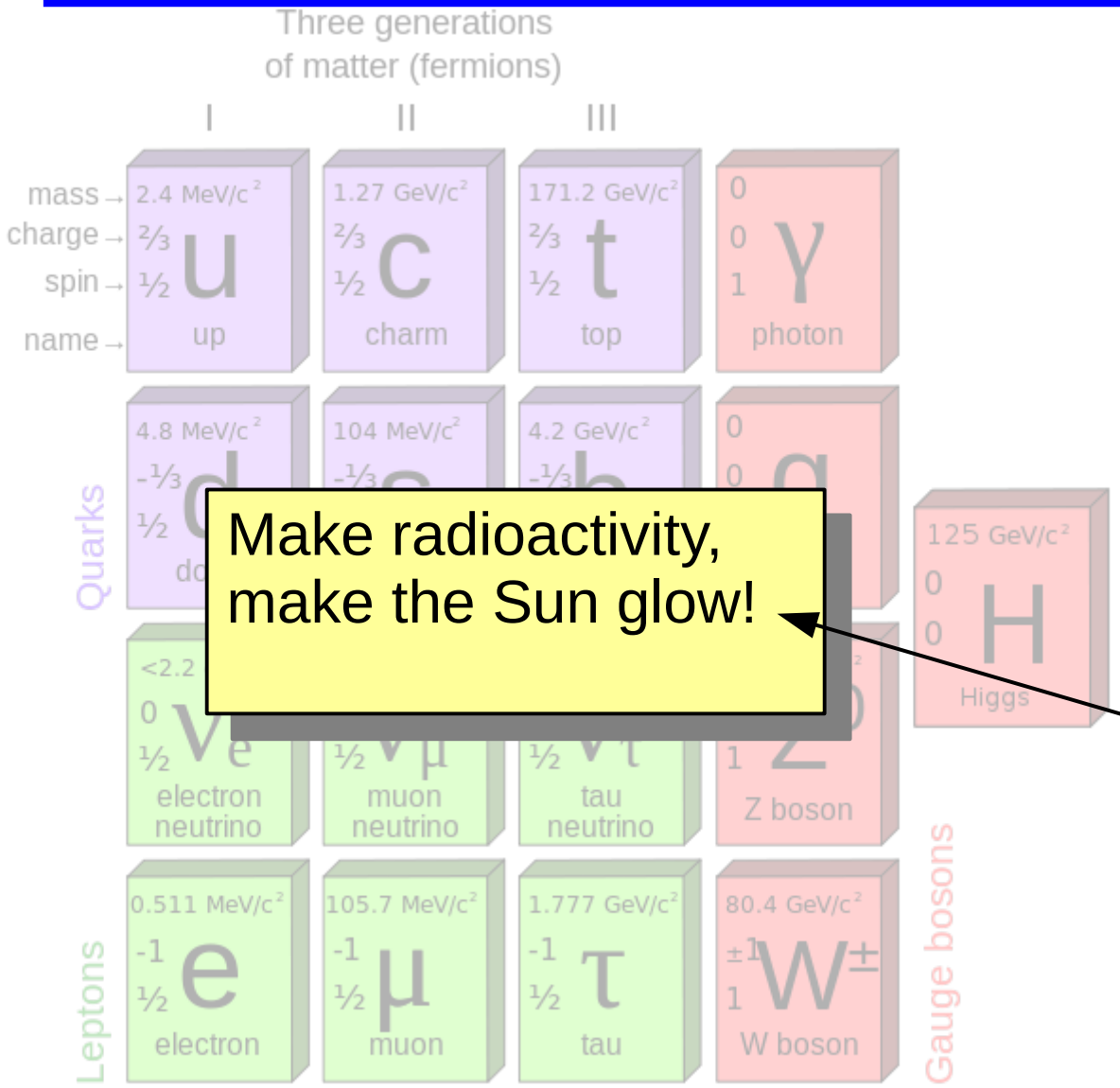


Keep nucleus together (protons, neutrons)

Particles speak these 'languages'

- Electromagnetic interaction
- Strong interaction
- Weak interaction
- 'Higgs' interaction

Standard Model of Particle Physics

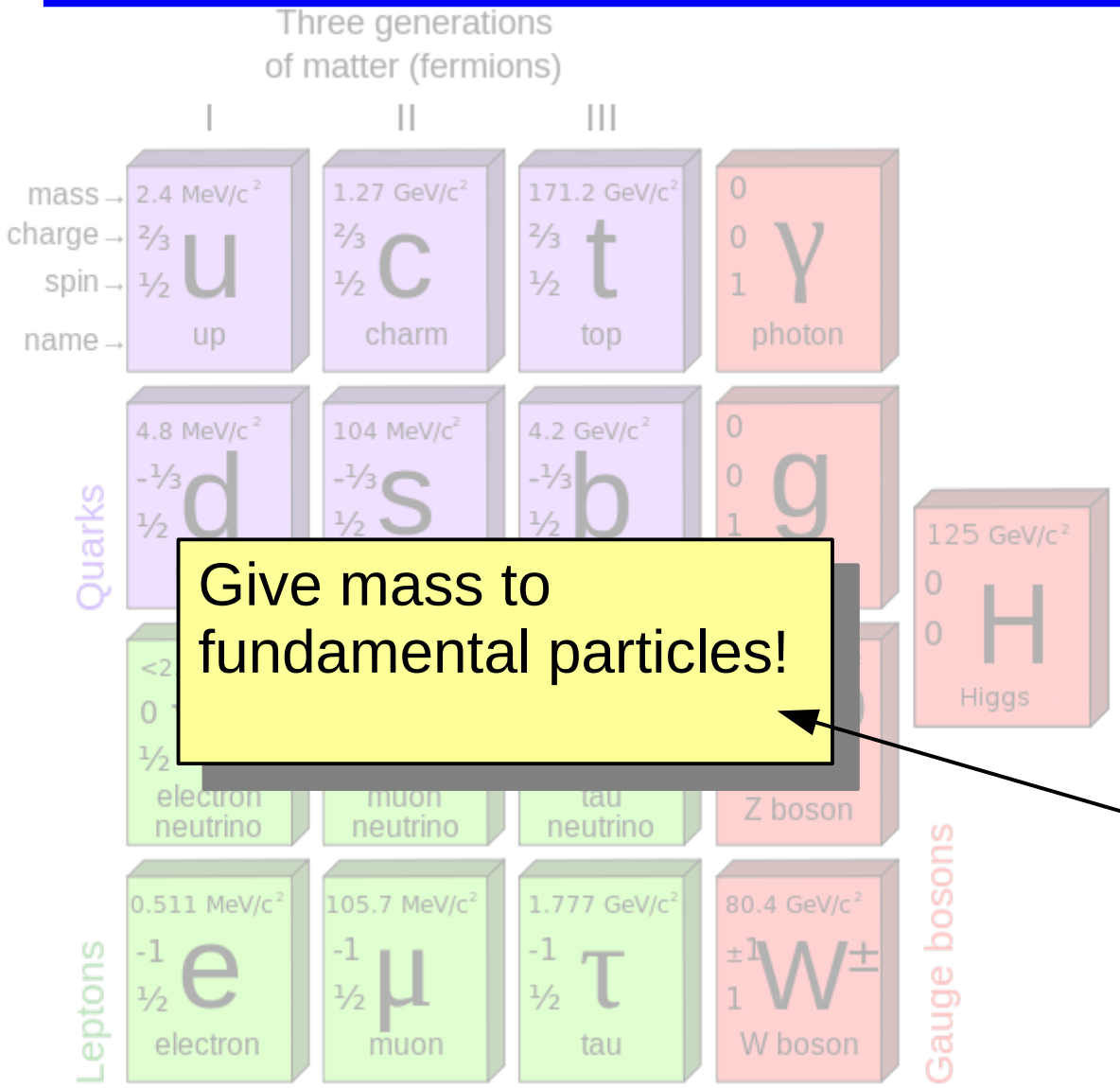


Make radioactivity, make the Sun glow!

Particles speak these 'languages'

- Electromagnetic interaction
- Strong interaction
- Weak interaction
- 'Higgs' interaction

Standard Model of Particle Physics

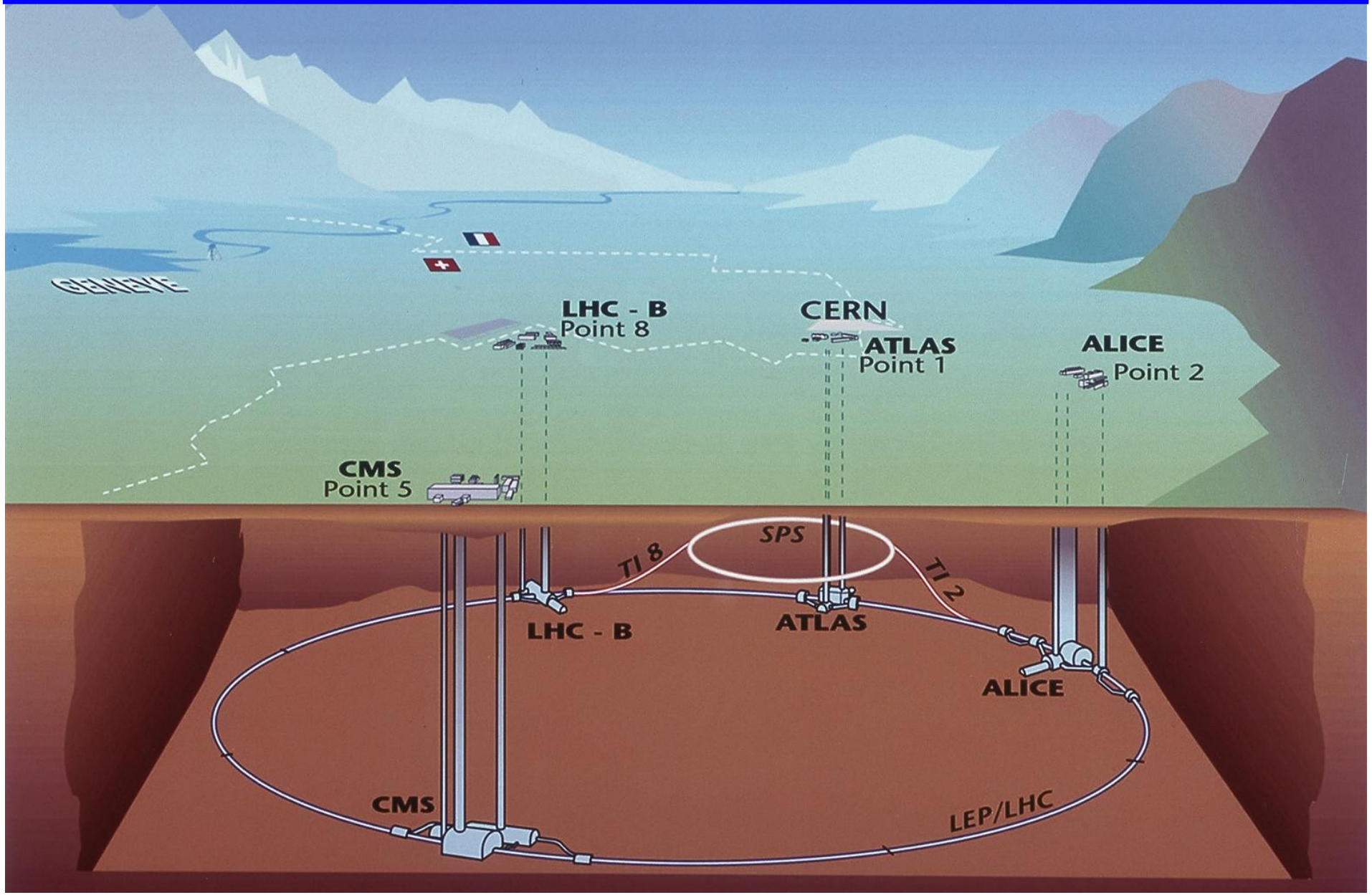


Give mass to fundamental particles!

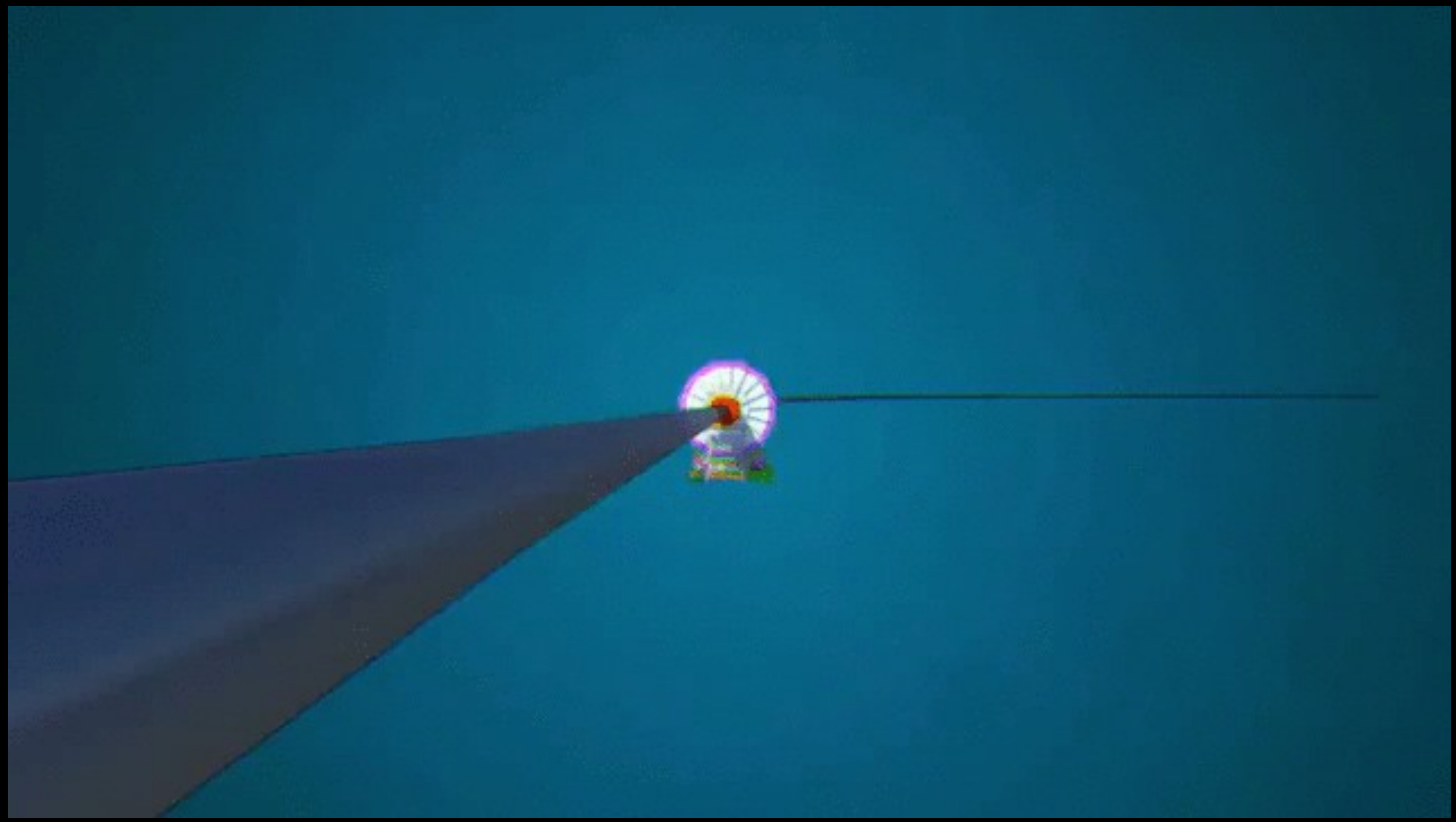
Particles speak these 'languages'

- Electromagnetic interaction
- Strong interaction
- Weak interaction
- 'Higgs' interaction

LHC: Large hadron collider

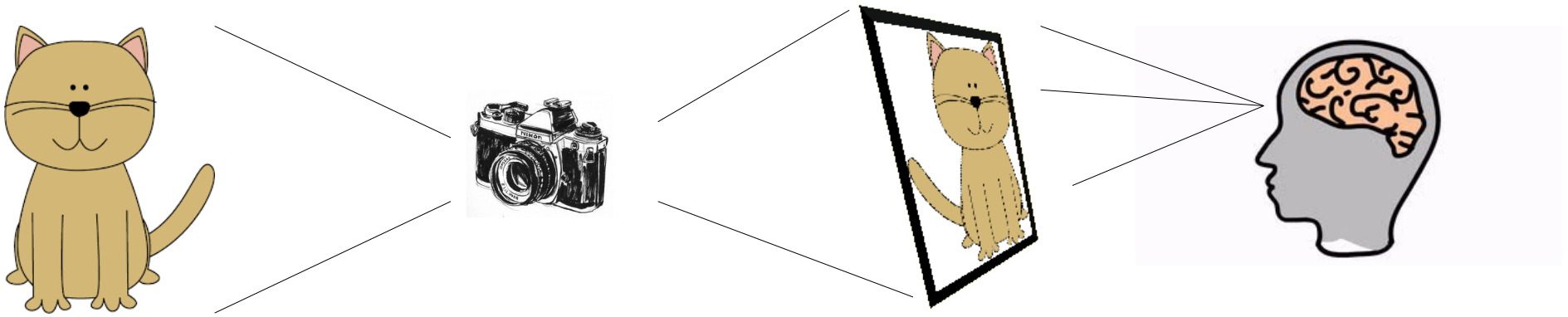


CMS DETECTOR



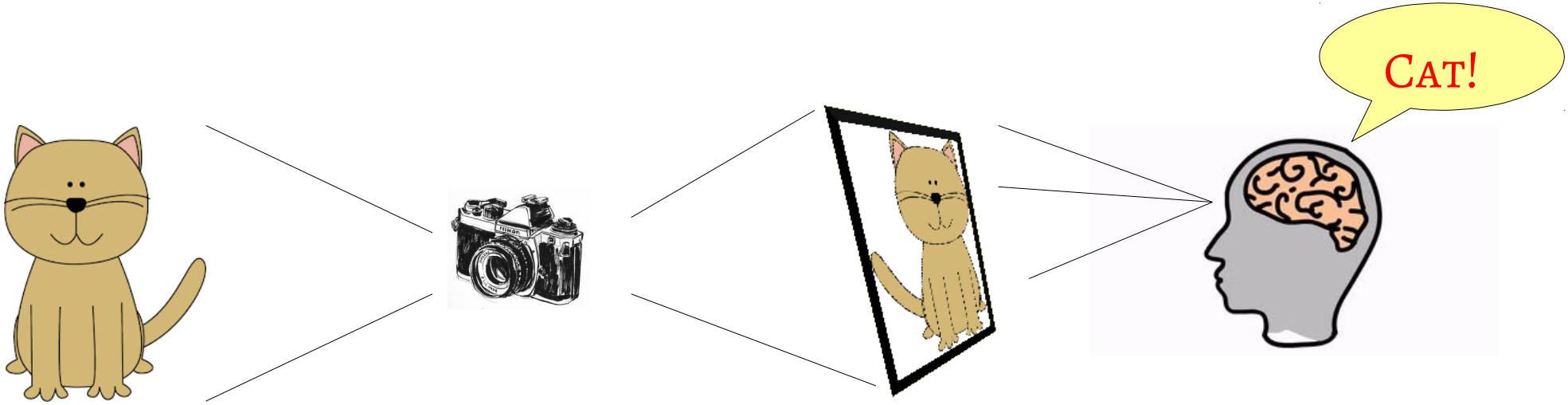
CMS is a giant camera

Reconstruction



Object Detector Data collected Data analyzed

Reconstruction

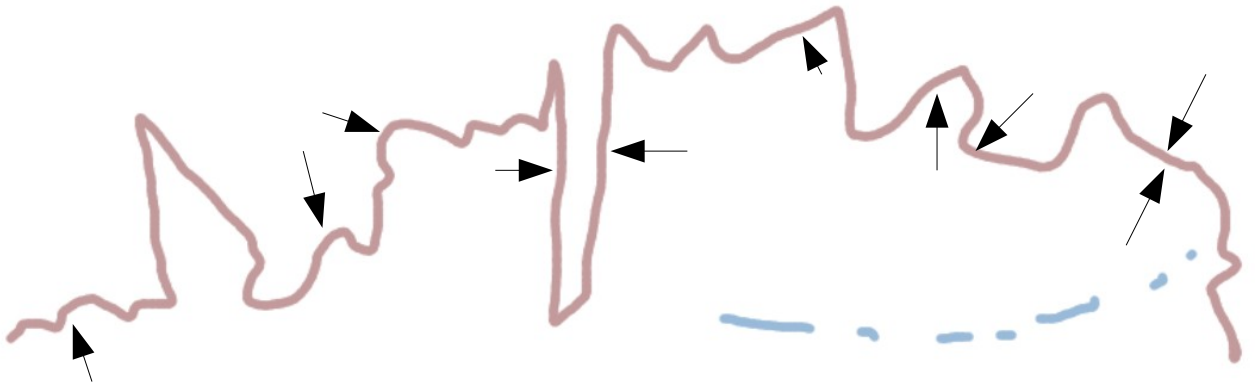


Object Detector Data collected Data analyzed

Nature of research

A non-researcher's view...

Nature of research



The Edges of
Human Knowledge

A researcher's view...

Why I like science?

- Objective Proof
  (does not depend on specific person)
- Cause and effect (reproducible)
- Why? And How?

IISER Pune CMS group

...along with summer students