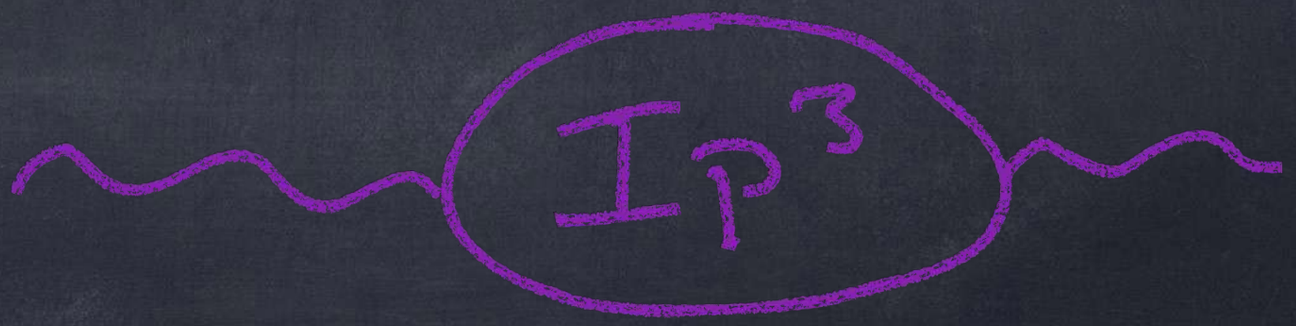
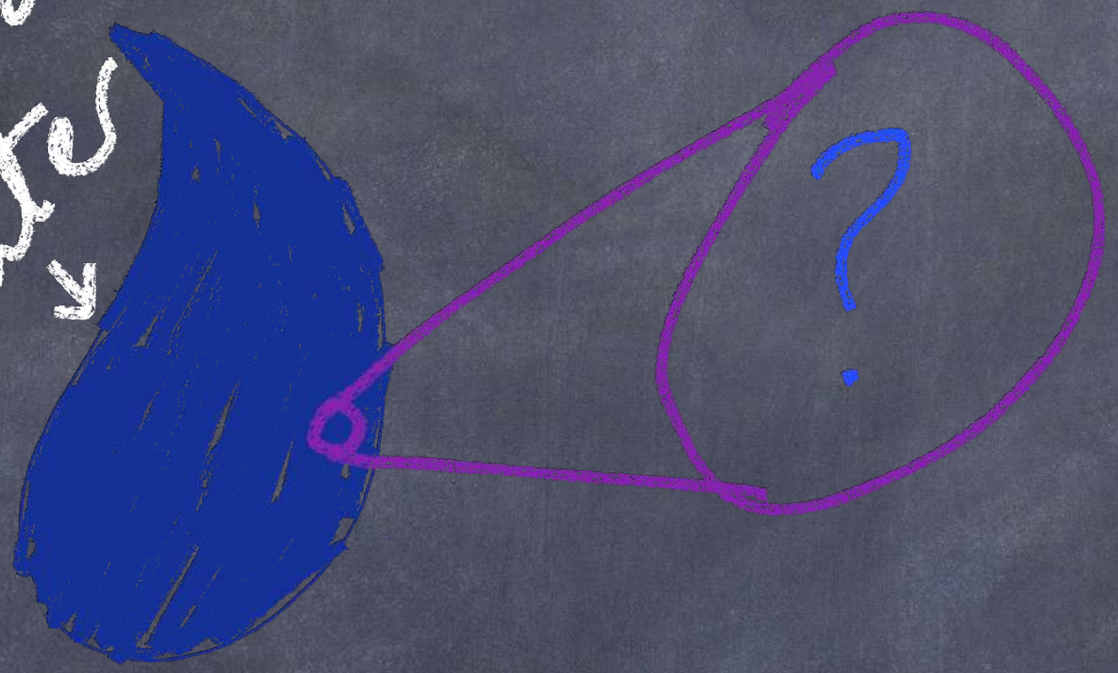
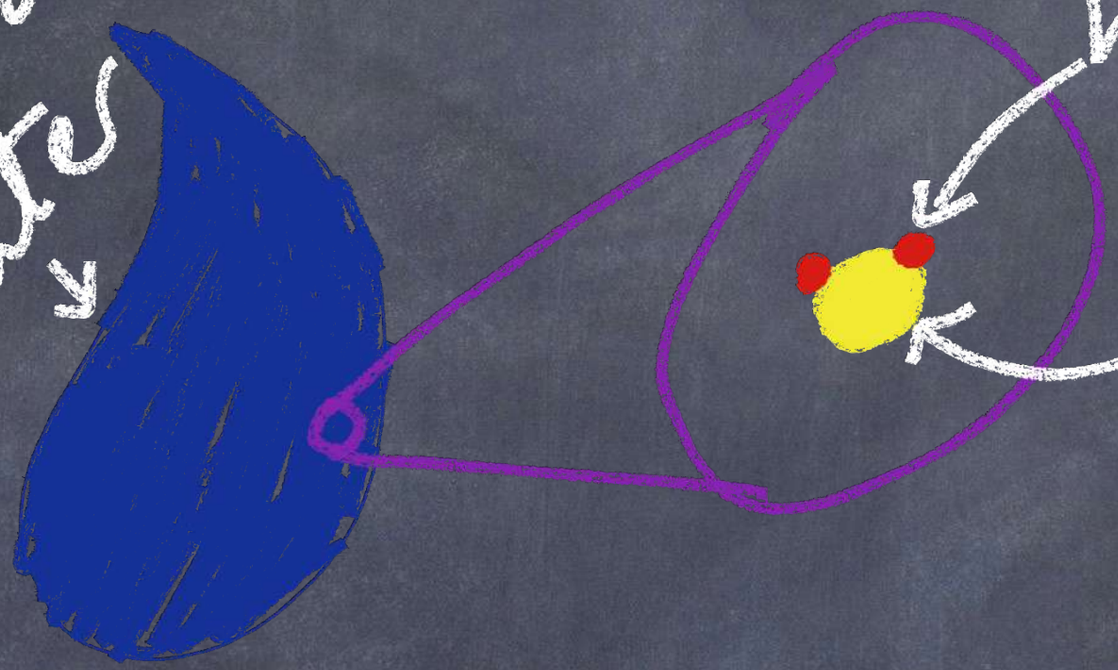
Modelling the Invisible



drop of water



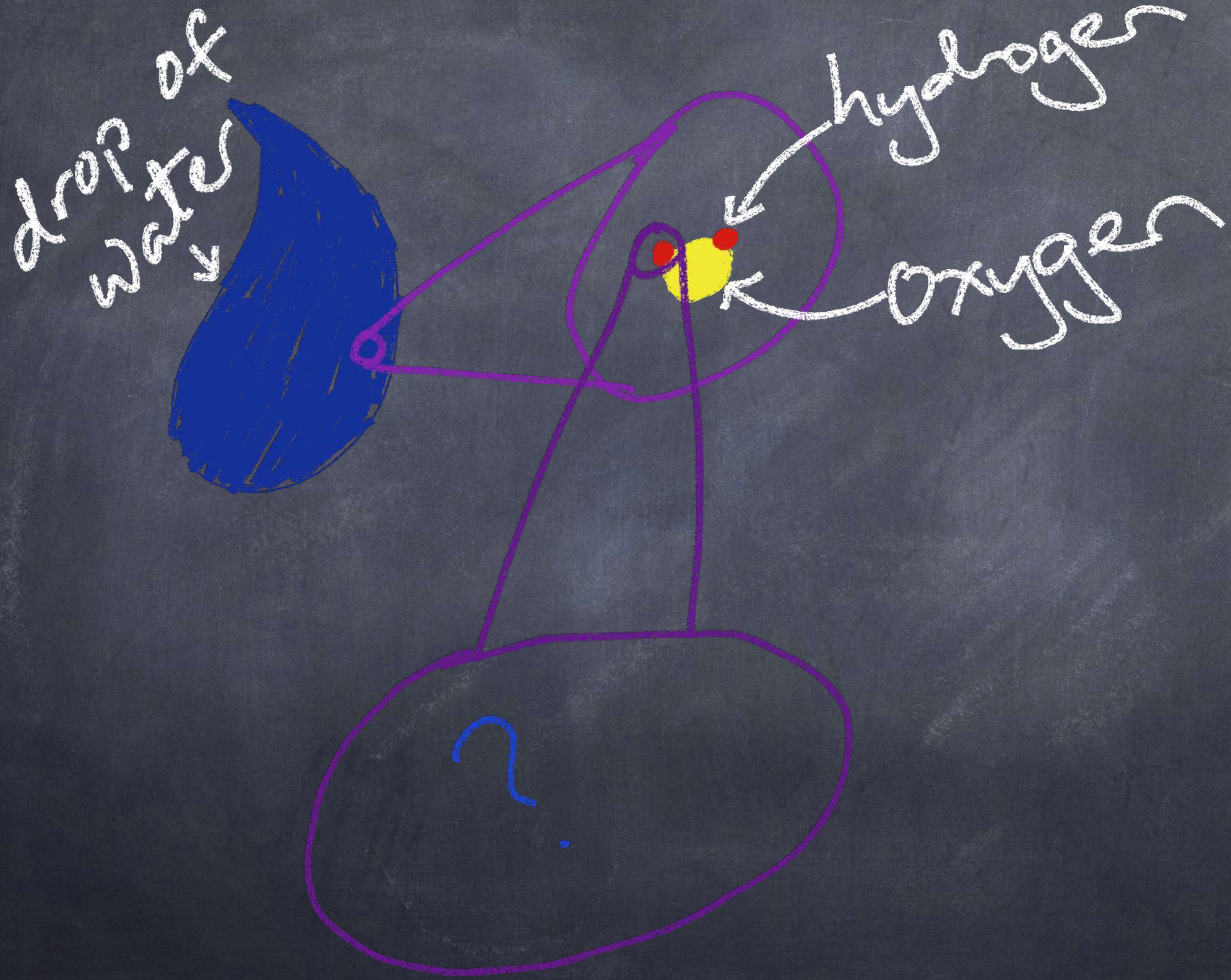
drop of water

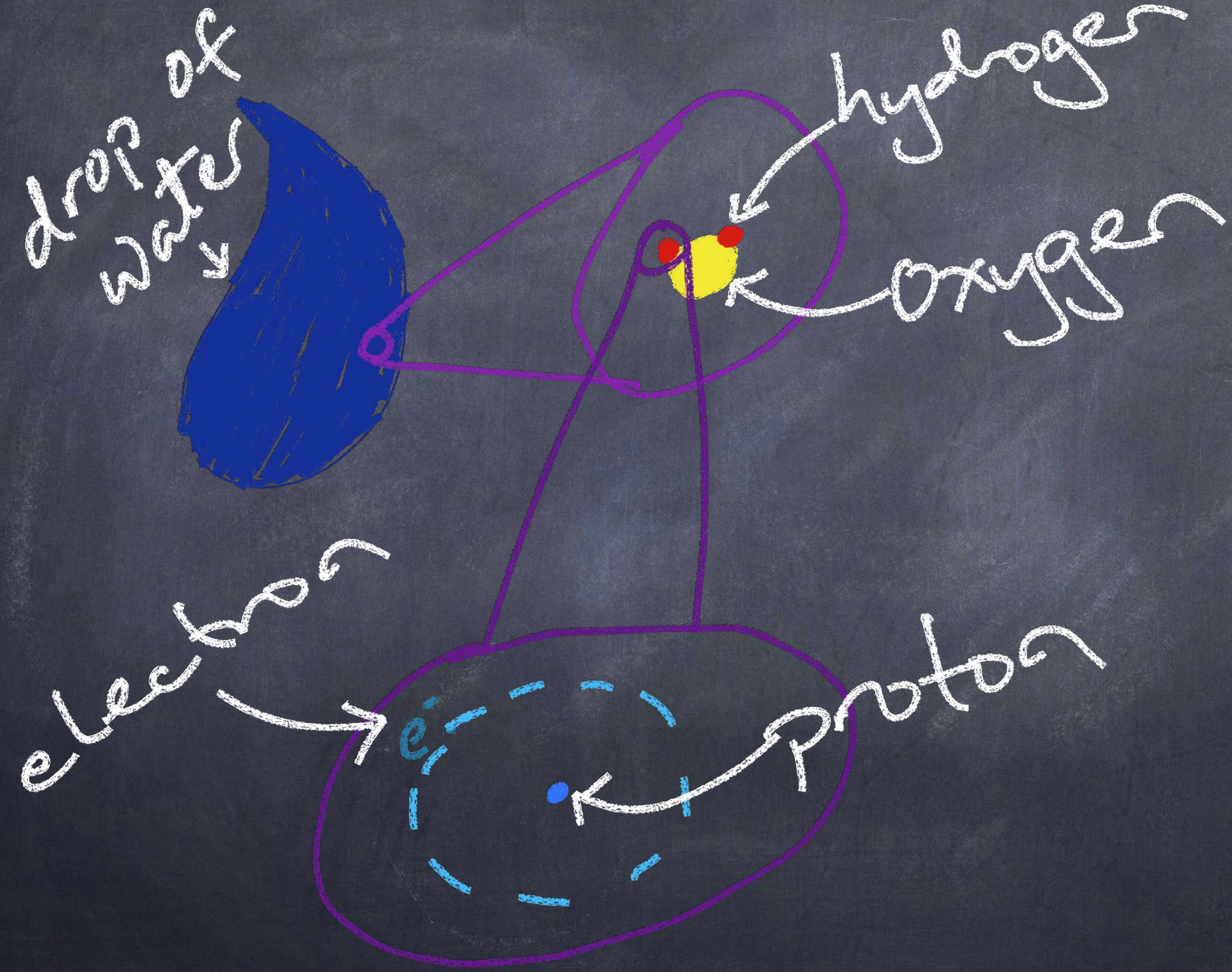


hydrogen

oxygen

H_2O : molecule of water


drop of water
hydroger
oxyger
?


drop of water
hydrogen
oxygen
electron
proton

drop of water

hydrogen

oxygen

electron

e

proton

neutron

What about the electron?

What about the electron?

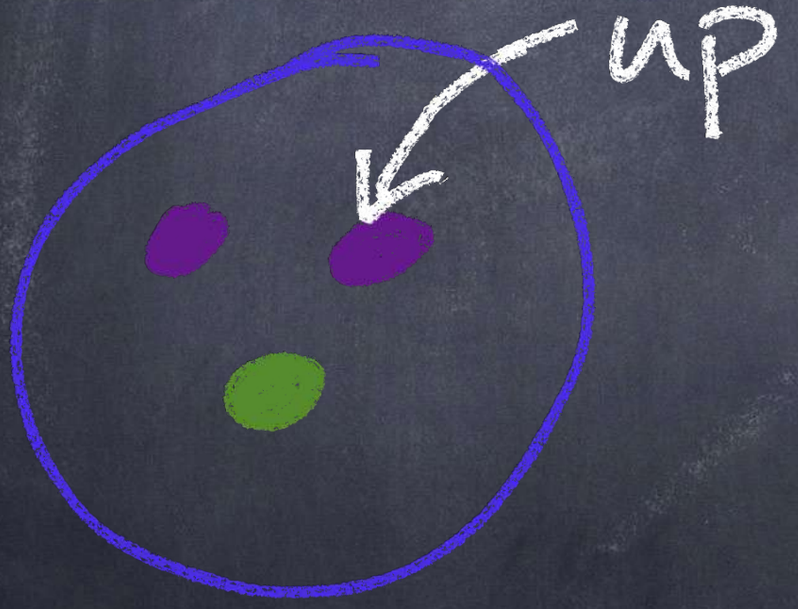
we can't break it apart!

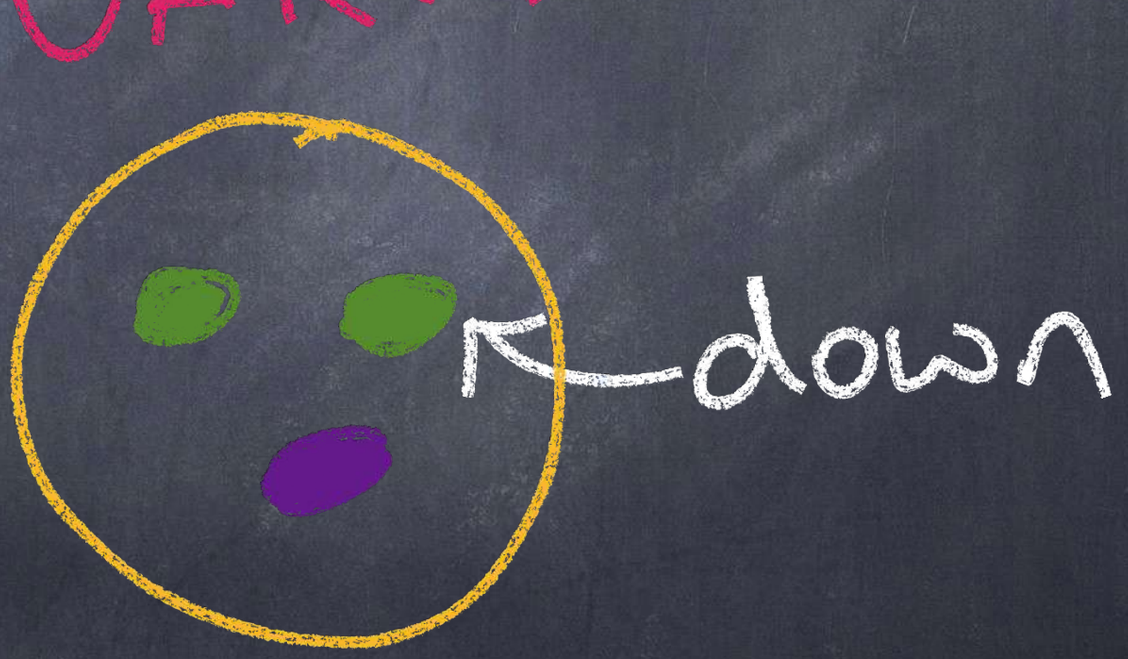
↑electron

Protons and neutrons?

Protons and neutrons?

QUARKS!





Particles ("stuff")?

Forces ("interactions")?

Particles ("stuff")? ✓

Forces (interactions)?

Gravity

+

electromagnetism

weak force

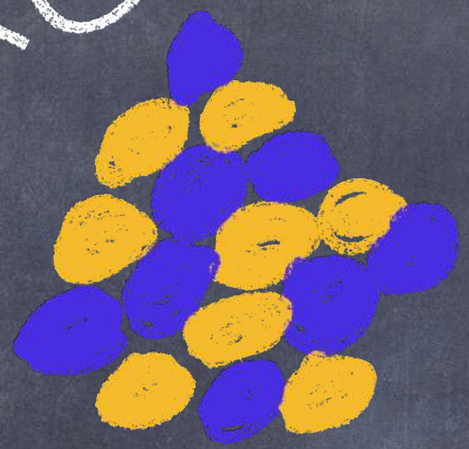
neutron

electron

proton

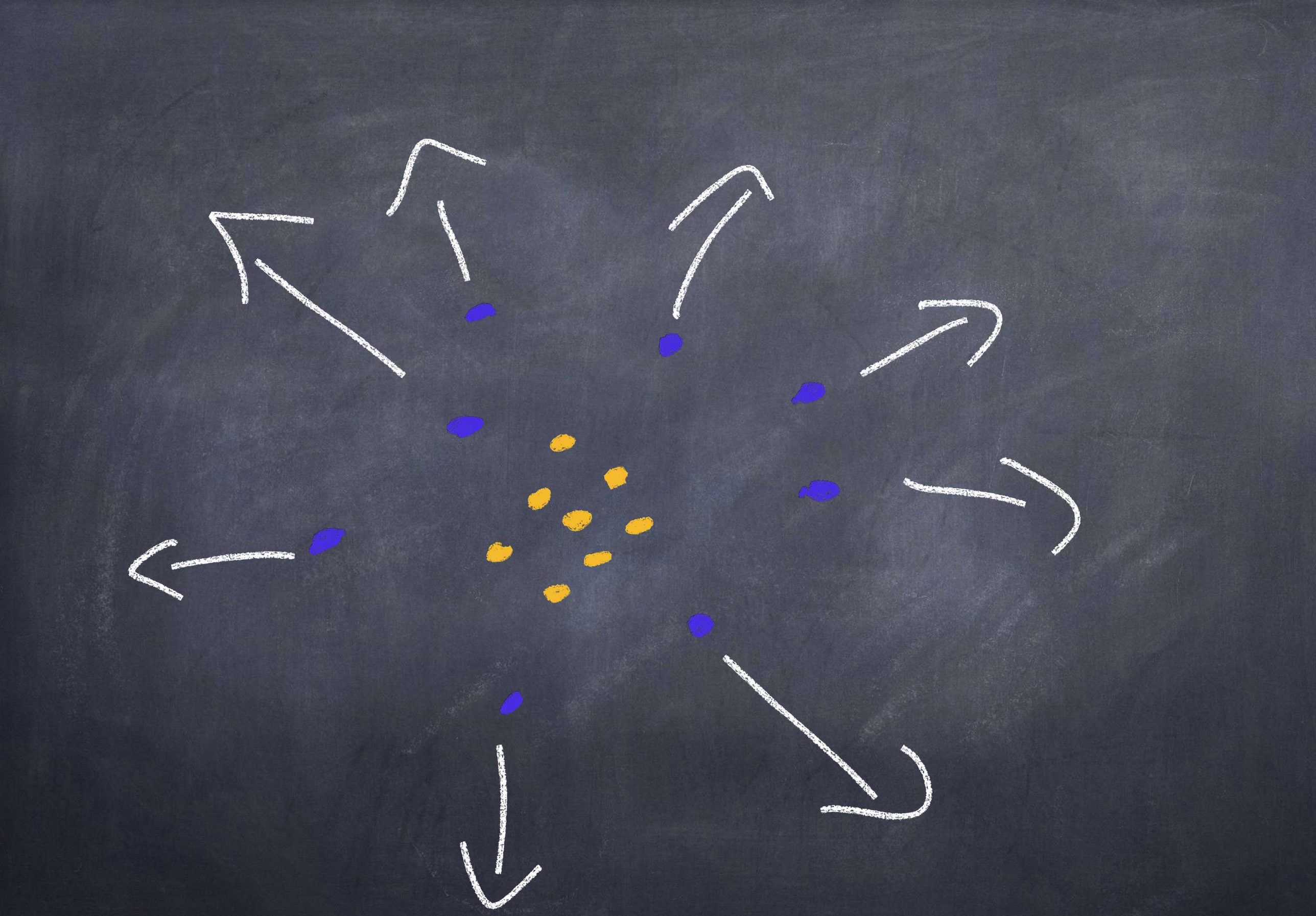
neutrino

Oxygen nucleus:



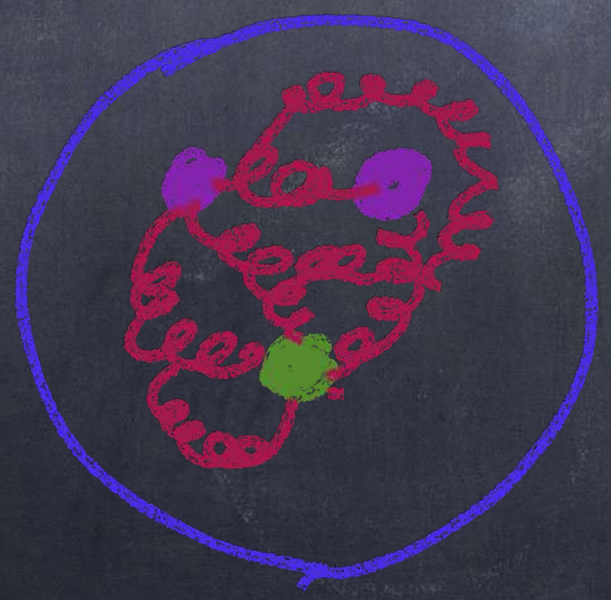
proton: positive

neutron: neutral



Enter the strong force!

Proton:



Standard Model

u	c	t
d	s	b

e	μ	τ
ν_e	ν_μ	ν_τ

g	H
γ	
W	
Z	

Standard Model

$$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} + i \bar{\psi} \not{D} \psi$$

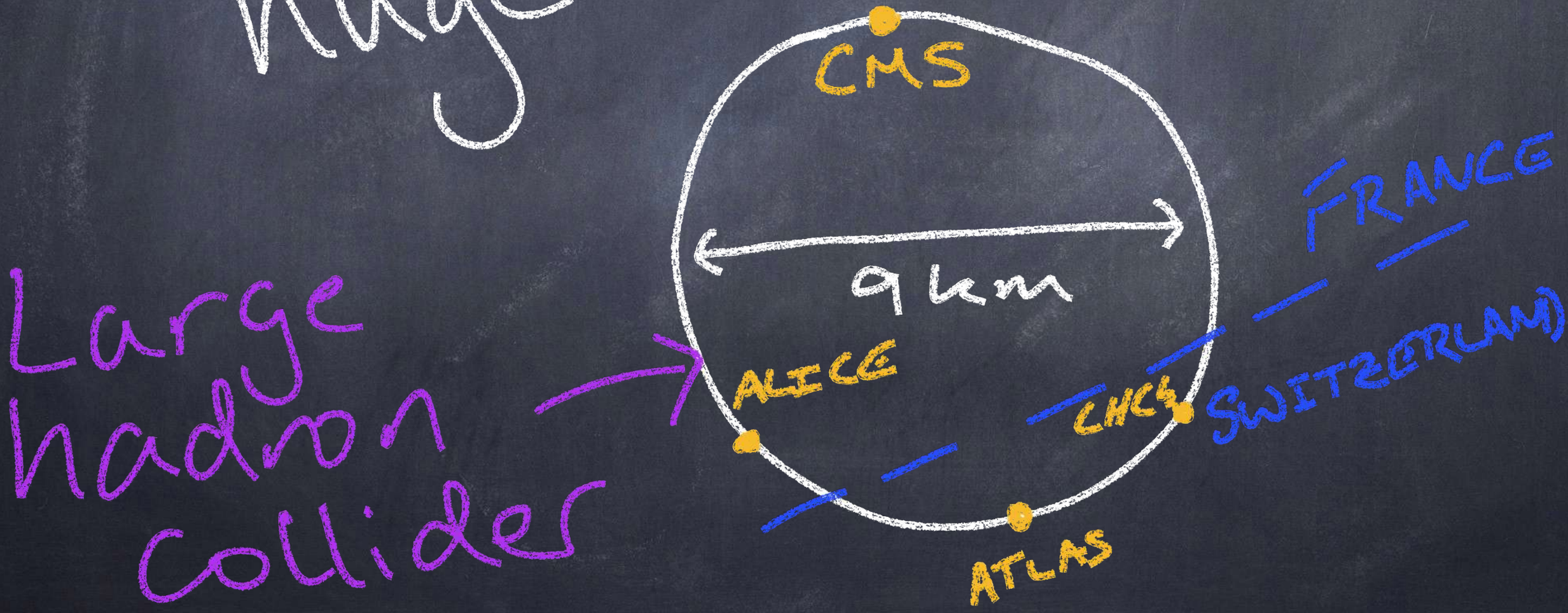
$$+ D_\mu \underline{\Phi}^\dagger D^\mu \underline{\Phi} - V(\underline{\Phi})$$

$$+ \bar{\psi}_L \hat{Y} \underline{\Phi} \psi_R + h.c.$$

How do we study small things?

What if they are even smaller?

We build a huge tunnel!

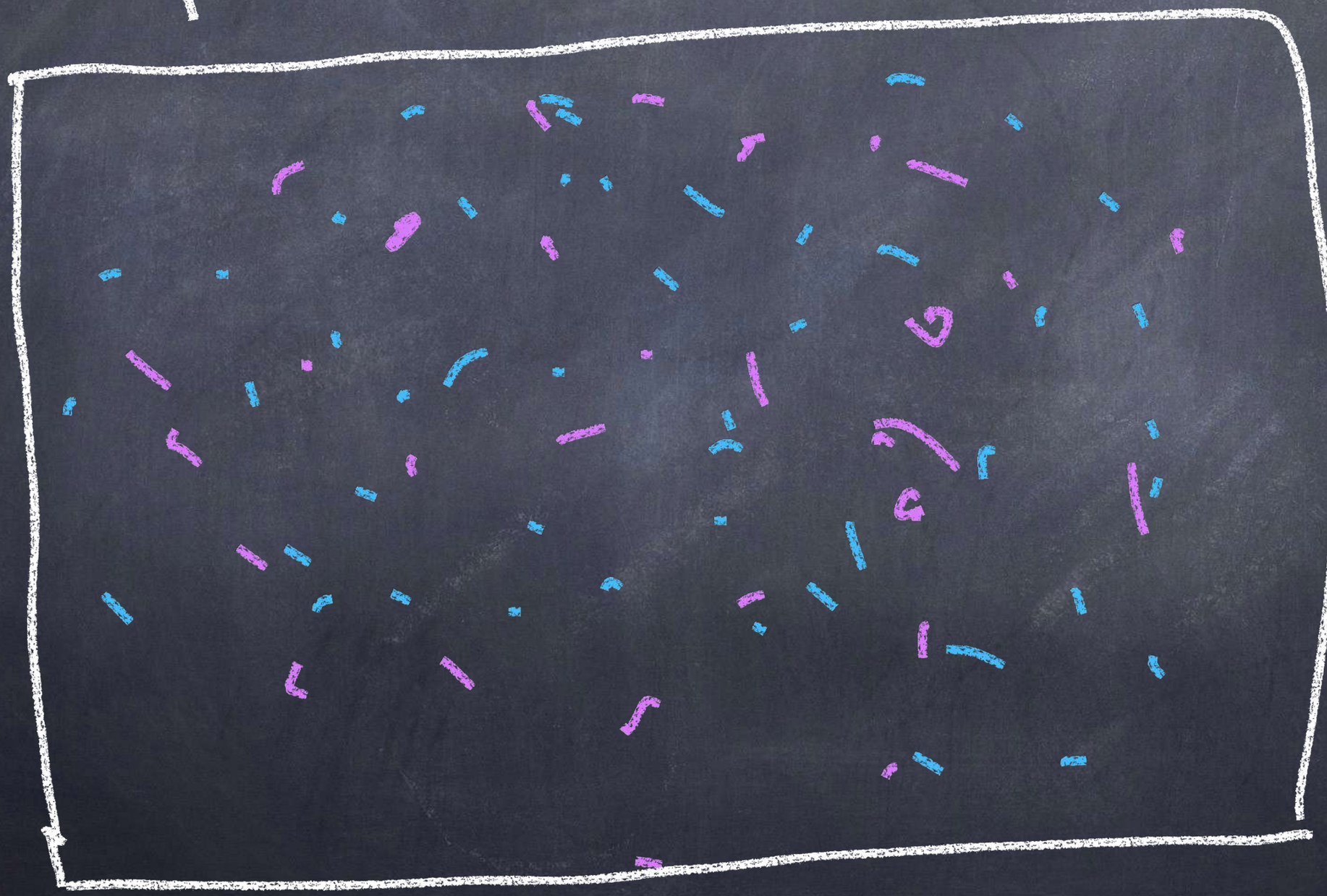


Then we collide particles in it

Then we collide particles in it

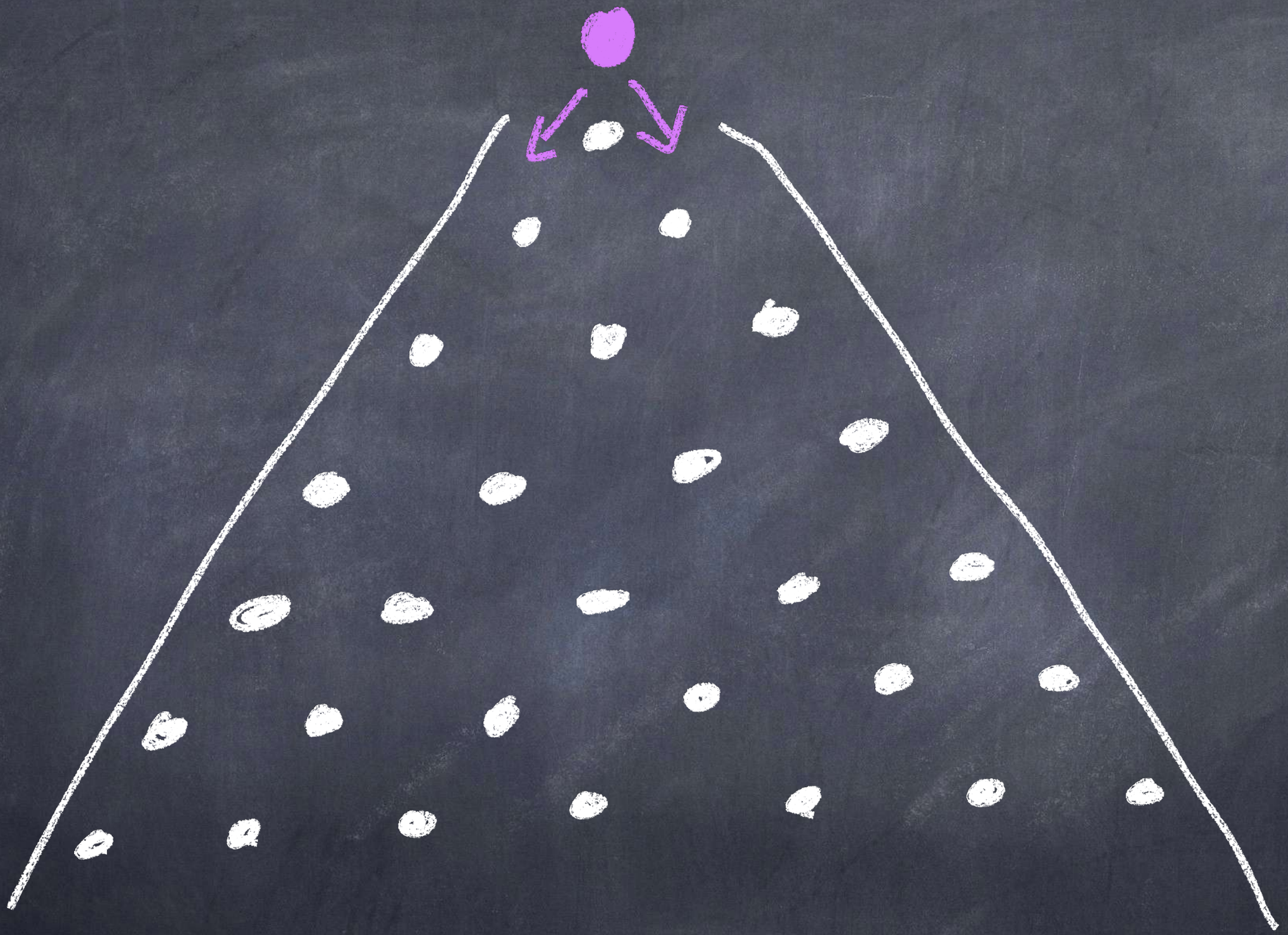
Then we collide particles in it

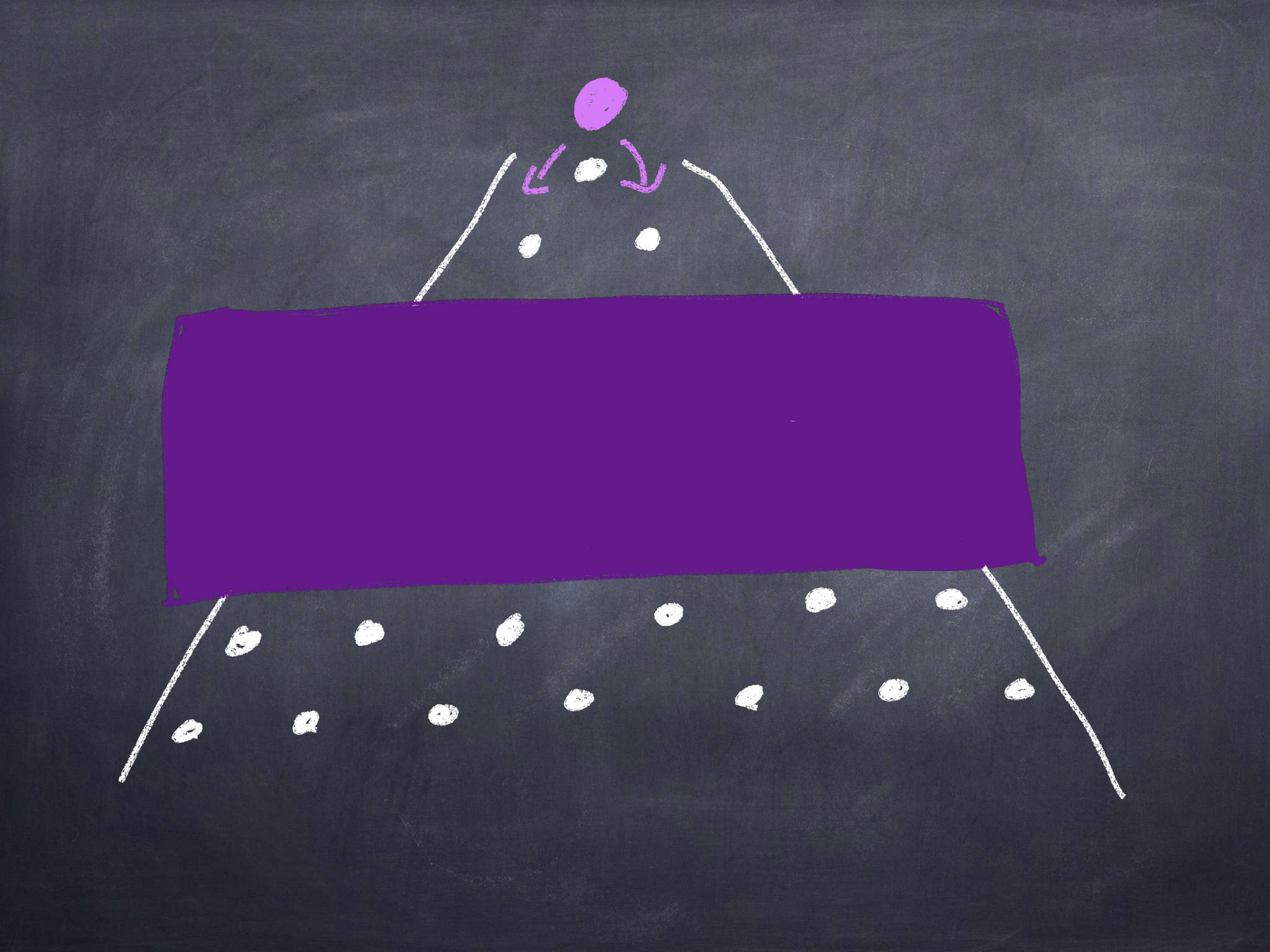
Then we collide particles in it



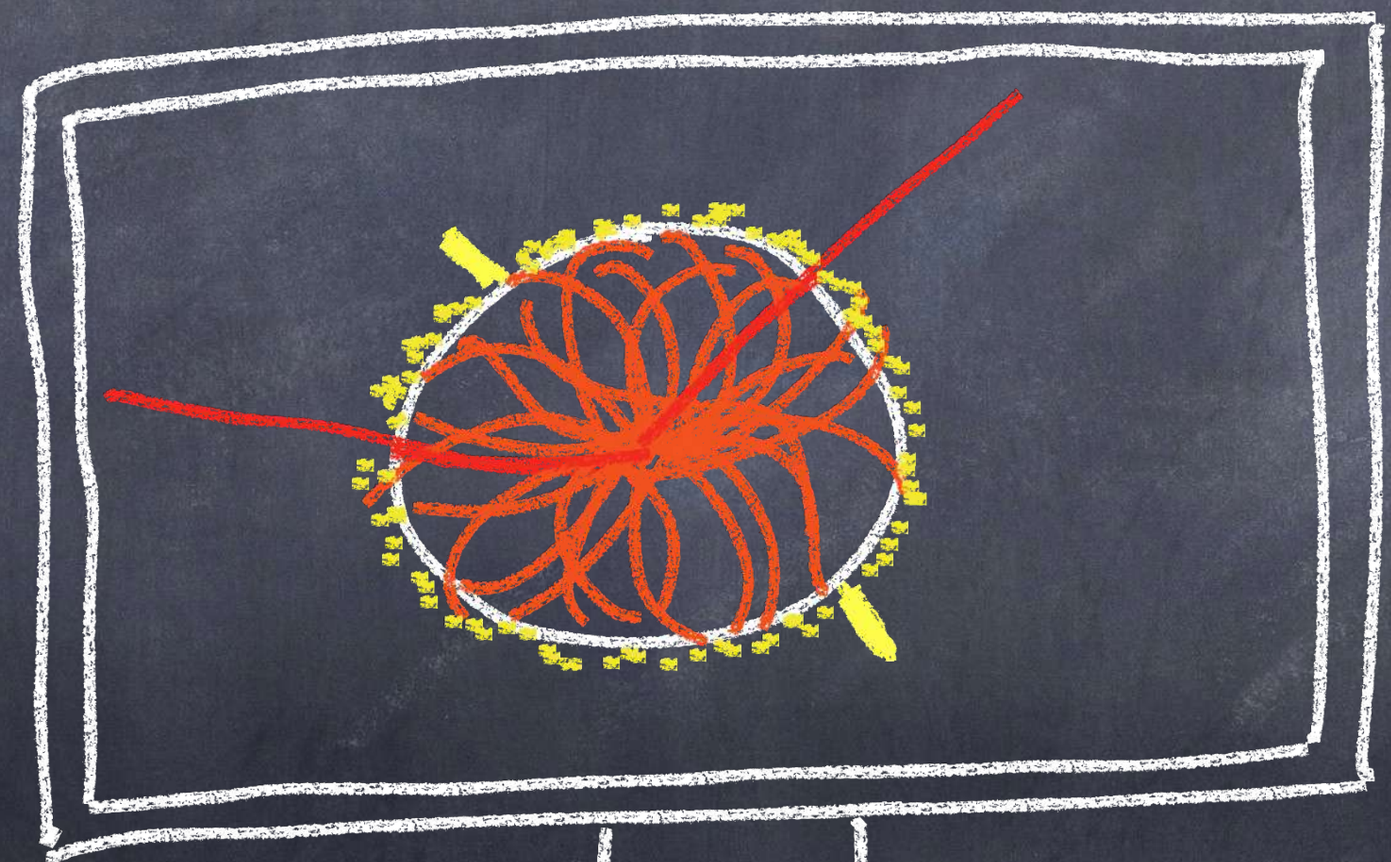
But how do we know what happens if we can't see the particles?

not just a particle physics problem...





Computer simulations!



Is this

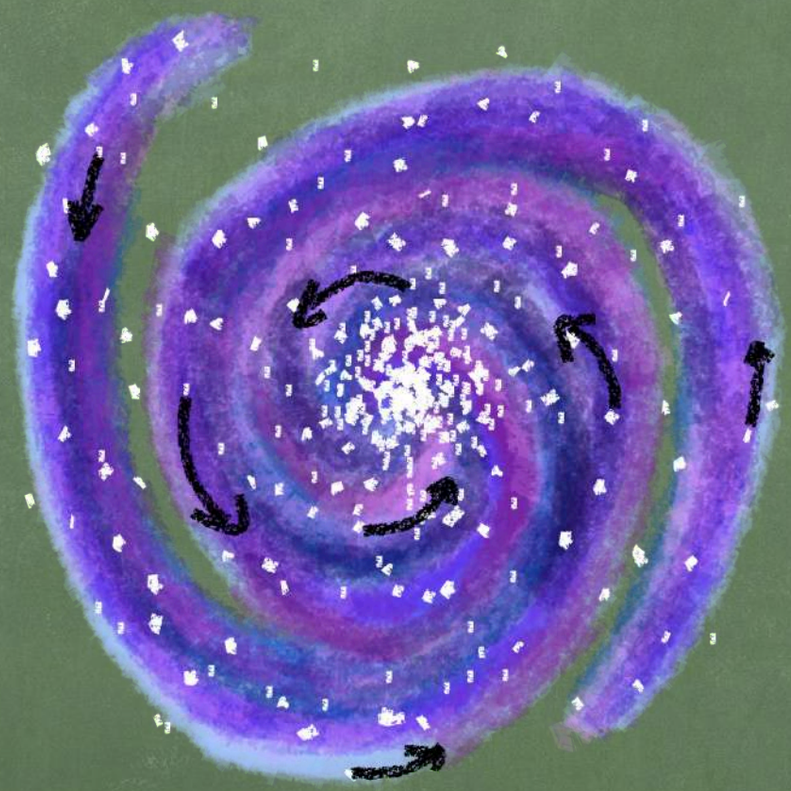
everything?

normal matter

dark matter

Can you
see the wind?

Can you
see the wind?



So what is dark matter?

So what is dark matter?

We don't know!

Fin