Antimatter at CERN

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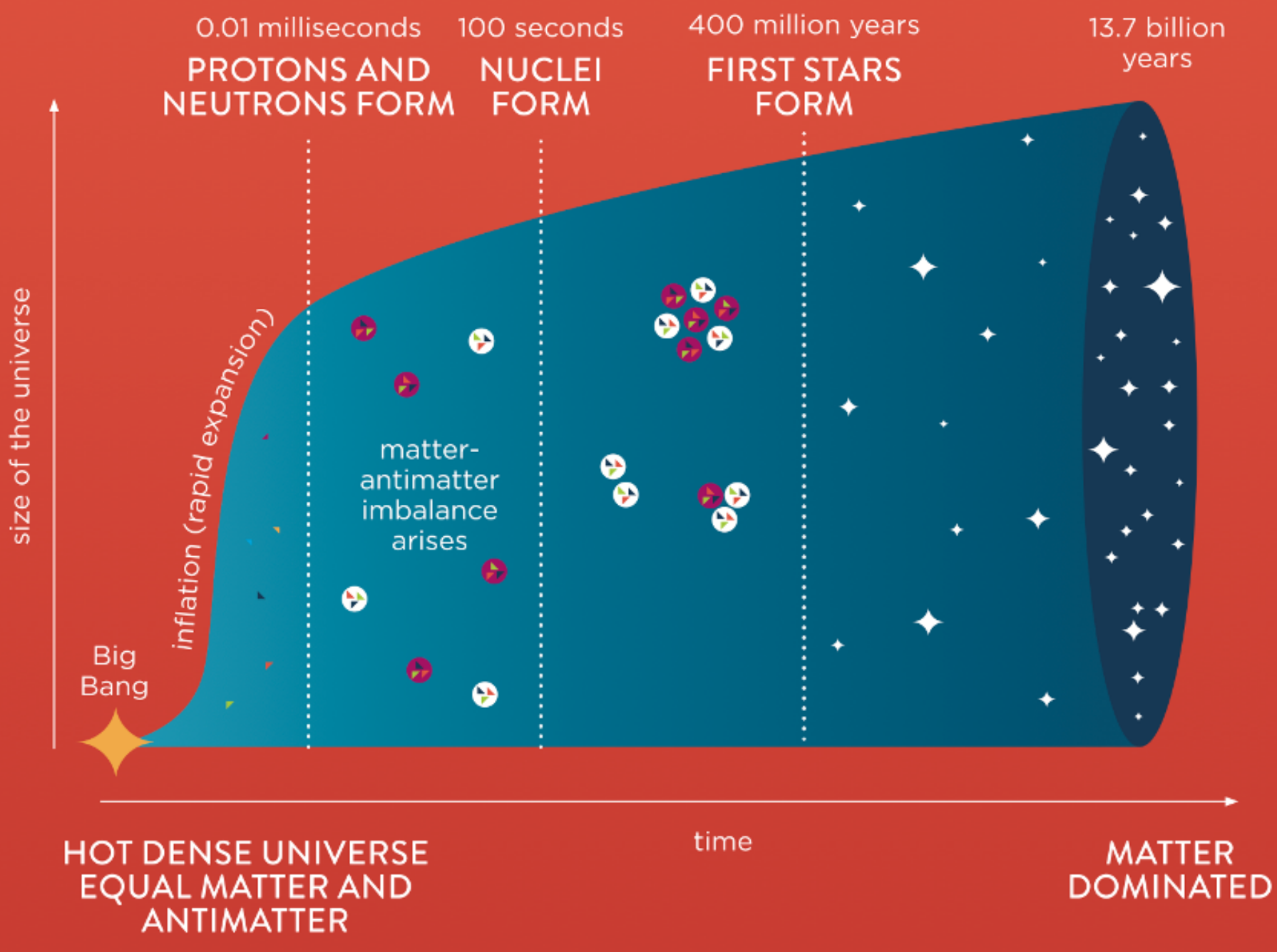
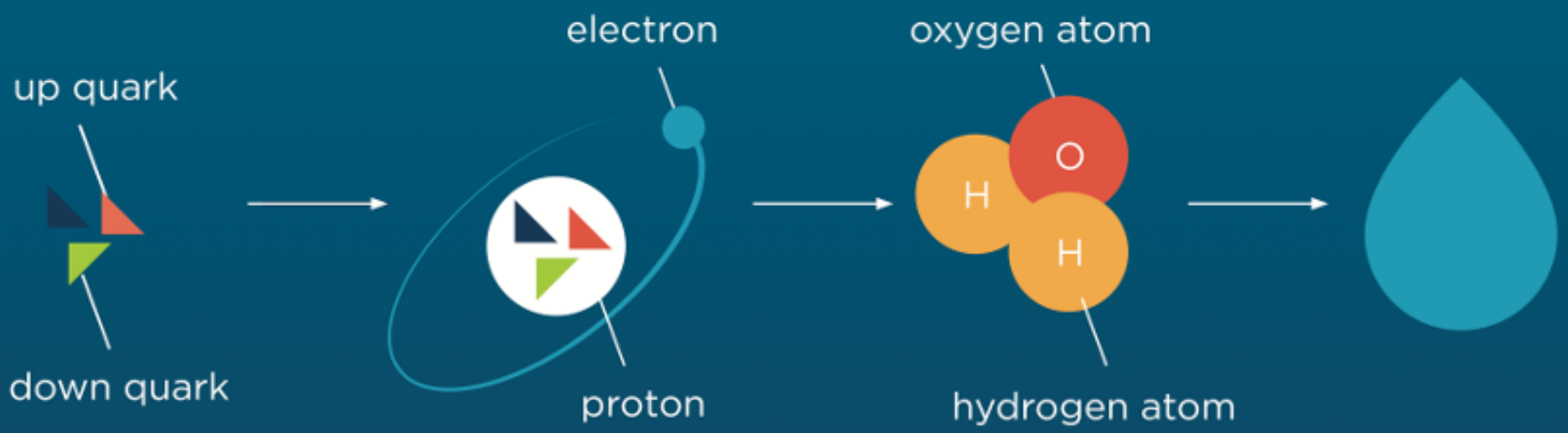
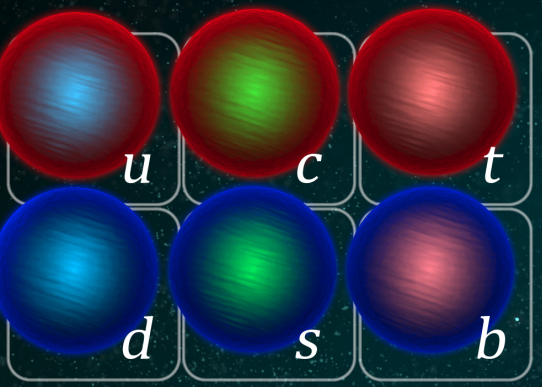
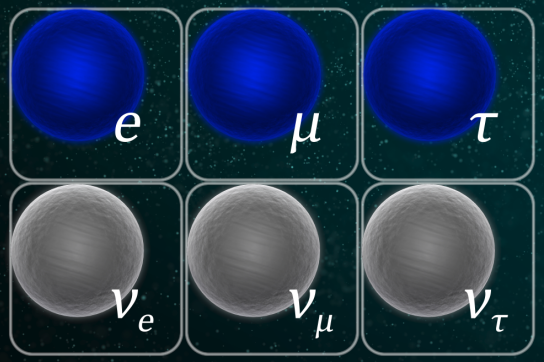

0.01 milliseconds
PROTONS AND NEUTRONS FORM
100 seconds
NUCLEI FORM
400 million years
FIRST STARS FORM
13.7 billion years
size of the universe
inflation (rapid expansion)
matter-antimatter imbalance arises
Big Bang
time
HOT DENSE UNIVERSE EQUAL MATTER AND ANTIMATTER
MATTER DOMINATED



QUARKS	HYDROGEN ATOM	WATER MOLECULE (H_2O)	WATER DROPLET
$< 10^{-18}$ m	10^{-15} m	10^{-10} m	10^{-2} m



Quarks

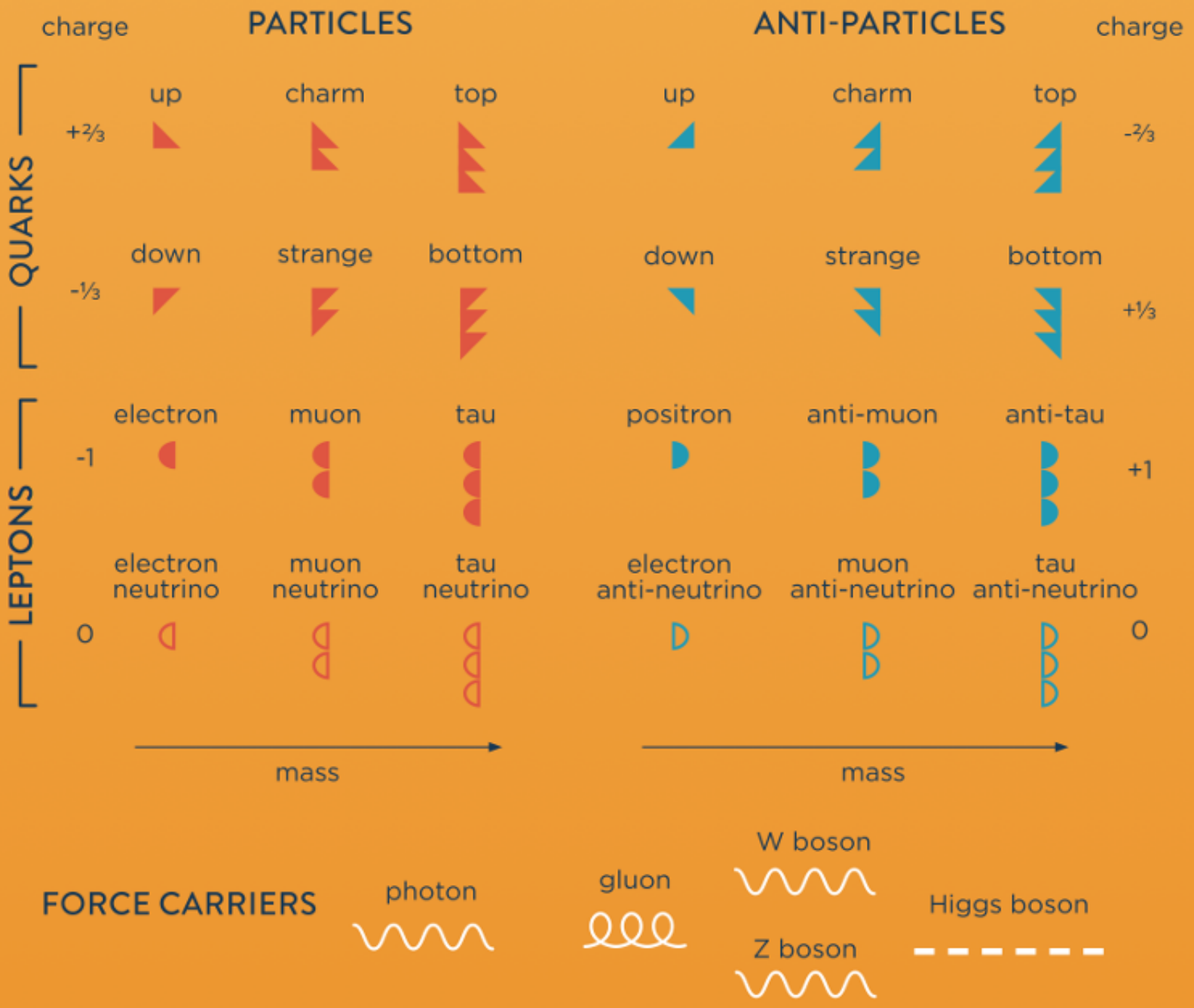


Leptons

Higgs boson

Forces

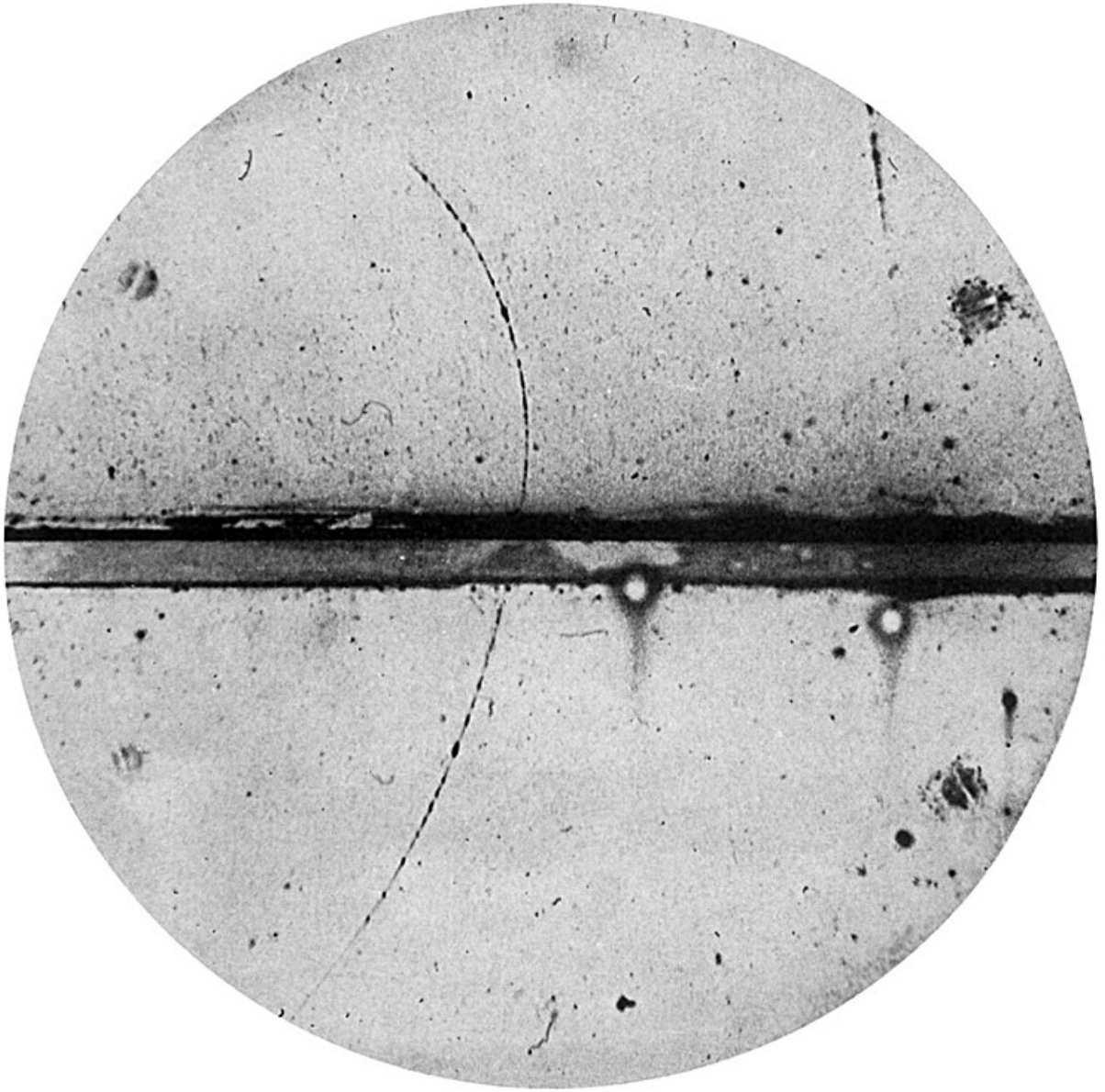
ACCELERATING SCIENCE


charge
PARTICLES
ANTI-PARTICLES
charge
QUARKS
LEPTONS
up
charm
top
+⅔
-⅔
down
strange
bottom
-⅓
+⅓
electron
muon
tau
positron
anti-muon
anti-tau
-1
+1
electron neutrino
muon neutrino
tau neutrino
electron anti-neutrino
muon anti-neutrino
tau anti-neutrino
0
0
mass
mass
FORCE CARRIERS
photon
gluon
W boson
Z boson
Higgs boson

Dirac, 1928...

$$(i\gamma \cdot \partial - m)\psi = 0$$

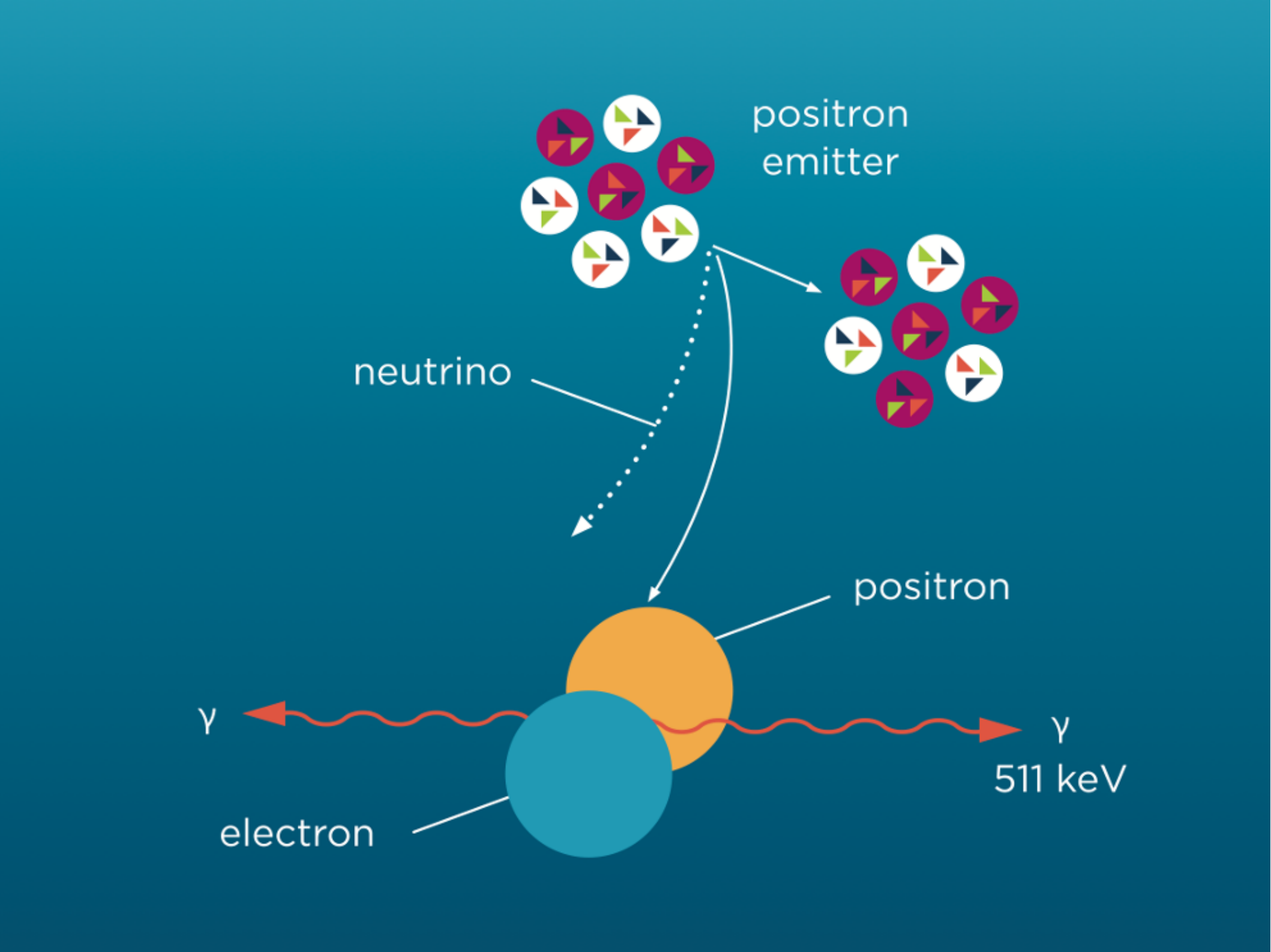
Anderson, 1932...

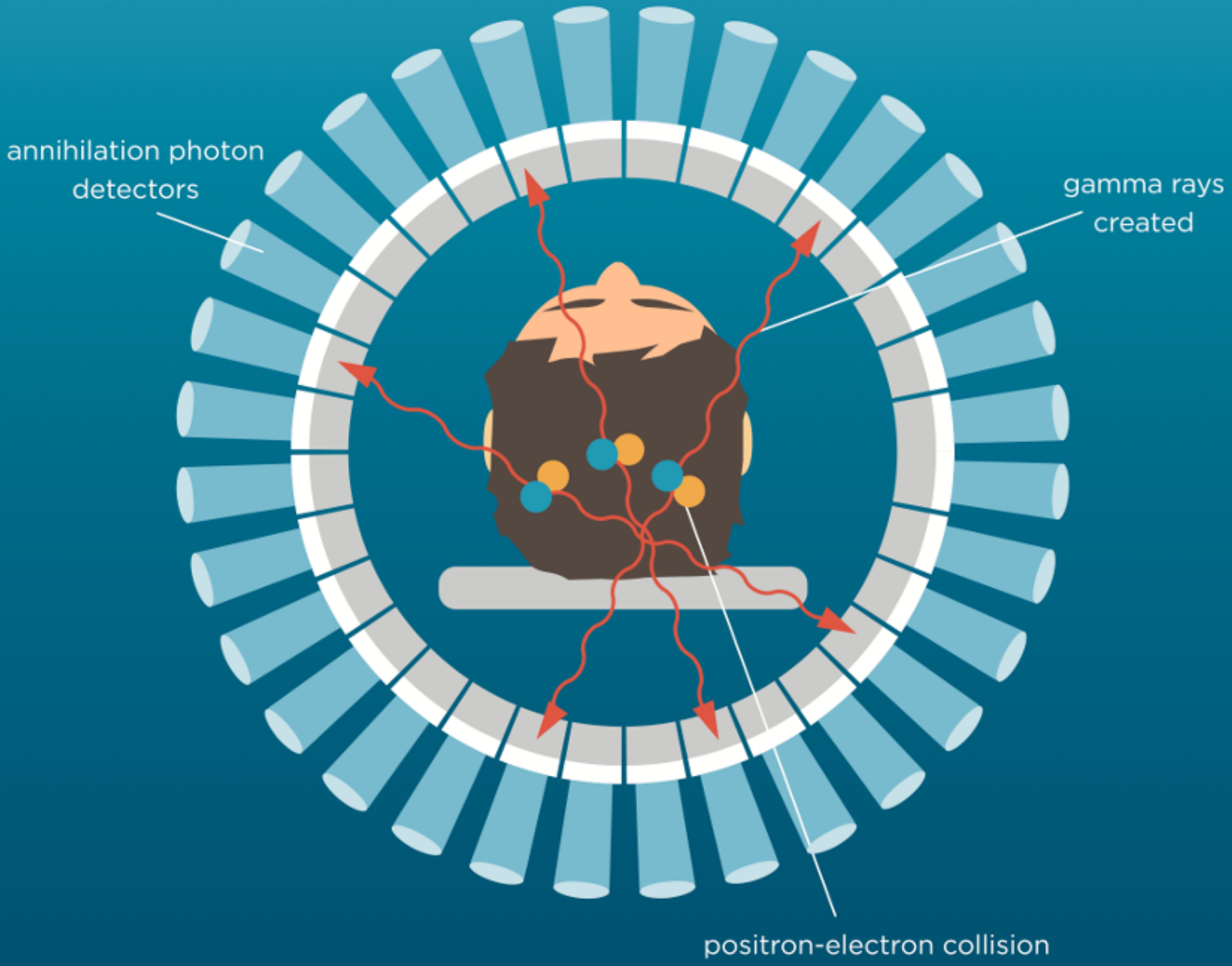


I think that the discovery of antimatter was perhaps the biggest jump of all the big jumps in physics in our century.

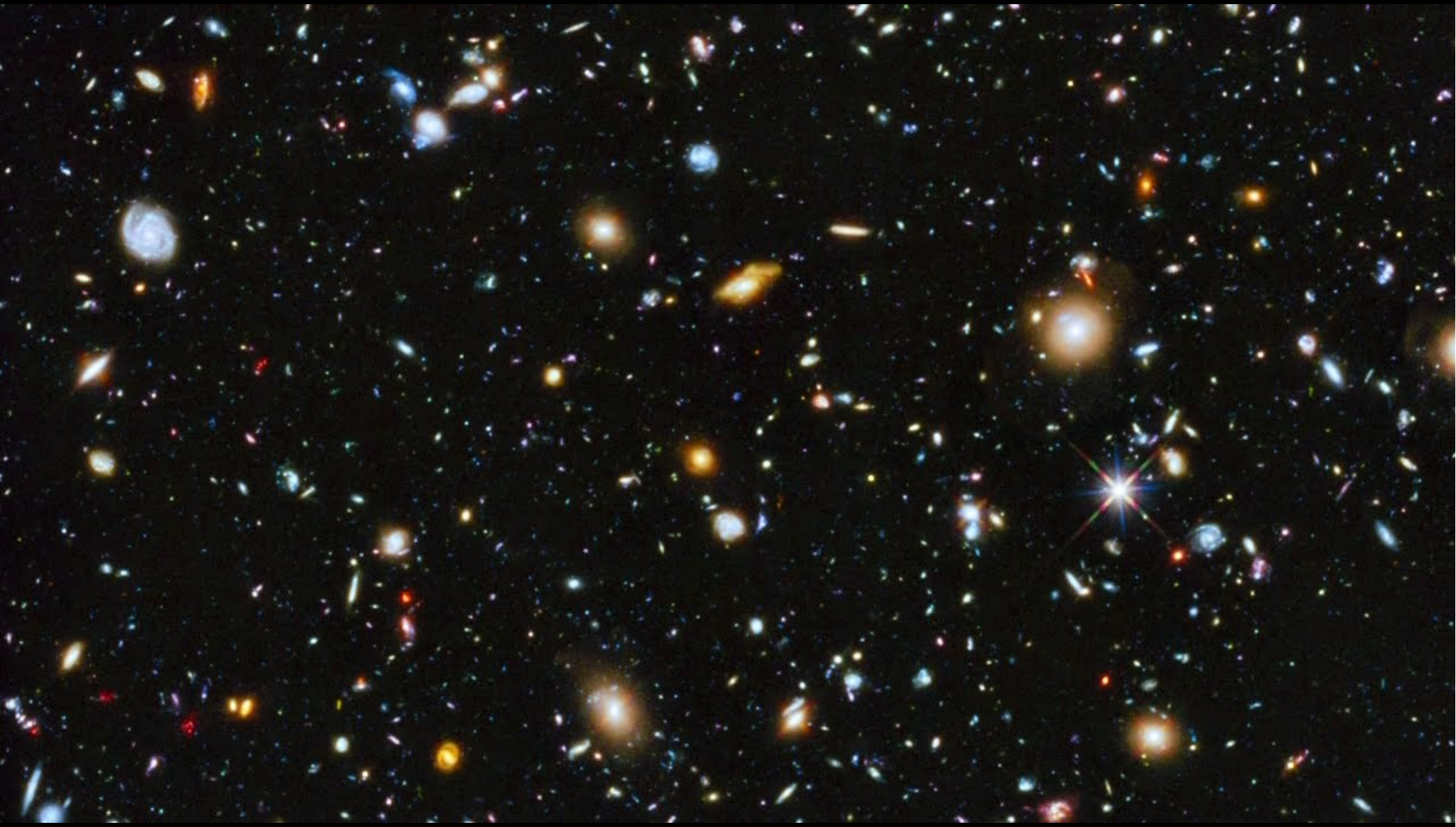
— Werner Heisenberg —

AZ QUOTES


positron
emitter
neutrino
positron
γ
γ
511 keV
electron

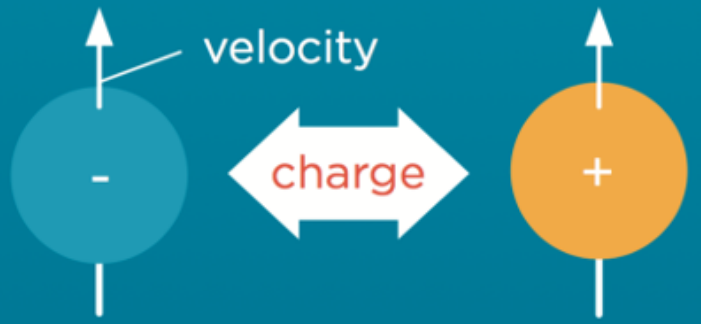

annihilation photon detectors
gamma rays created
positron-electron collision

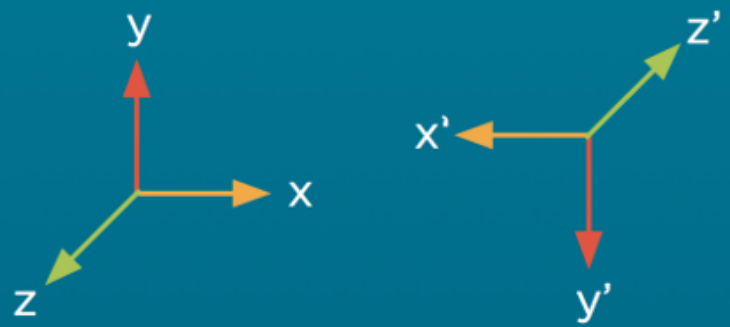
Why don’t we see antimatter?



C
CHARGE

Charge conjugation swaps positive and negative charges





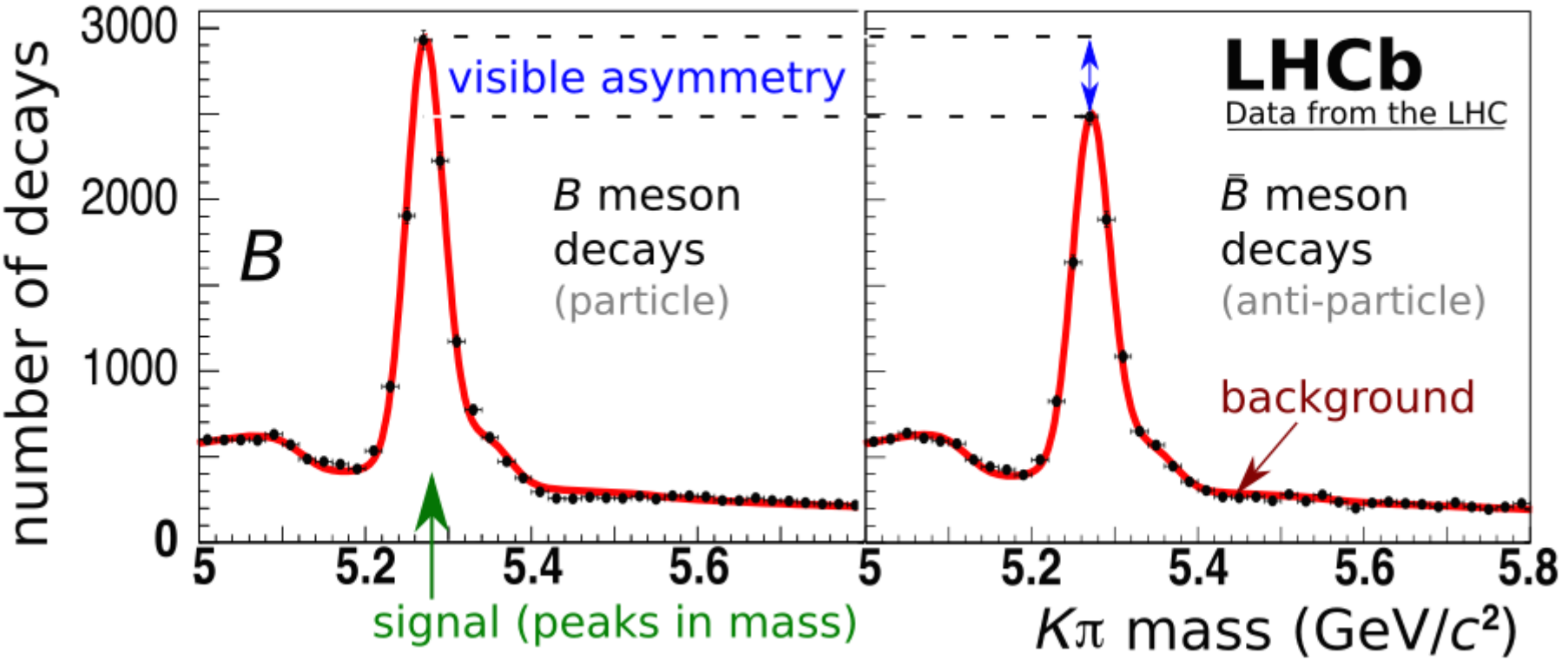
Parity reversal swaps up and down, left and right, forwards and backwards

P
PARITY

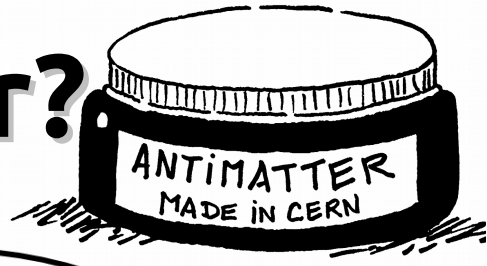
T
TIME

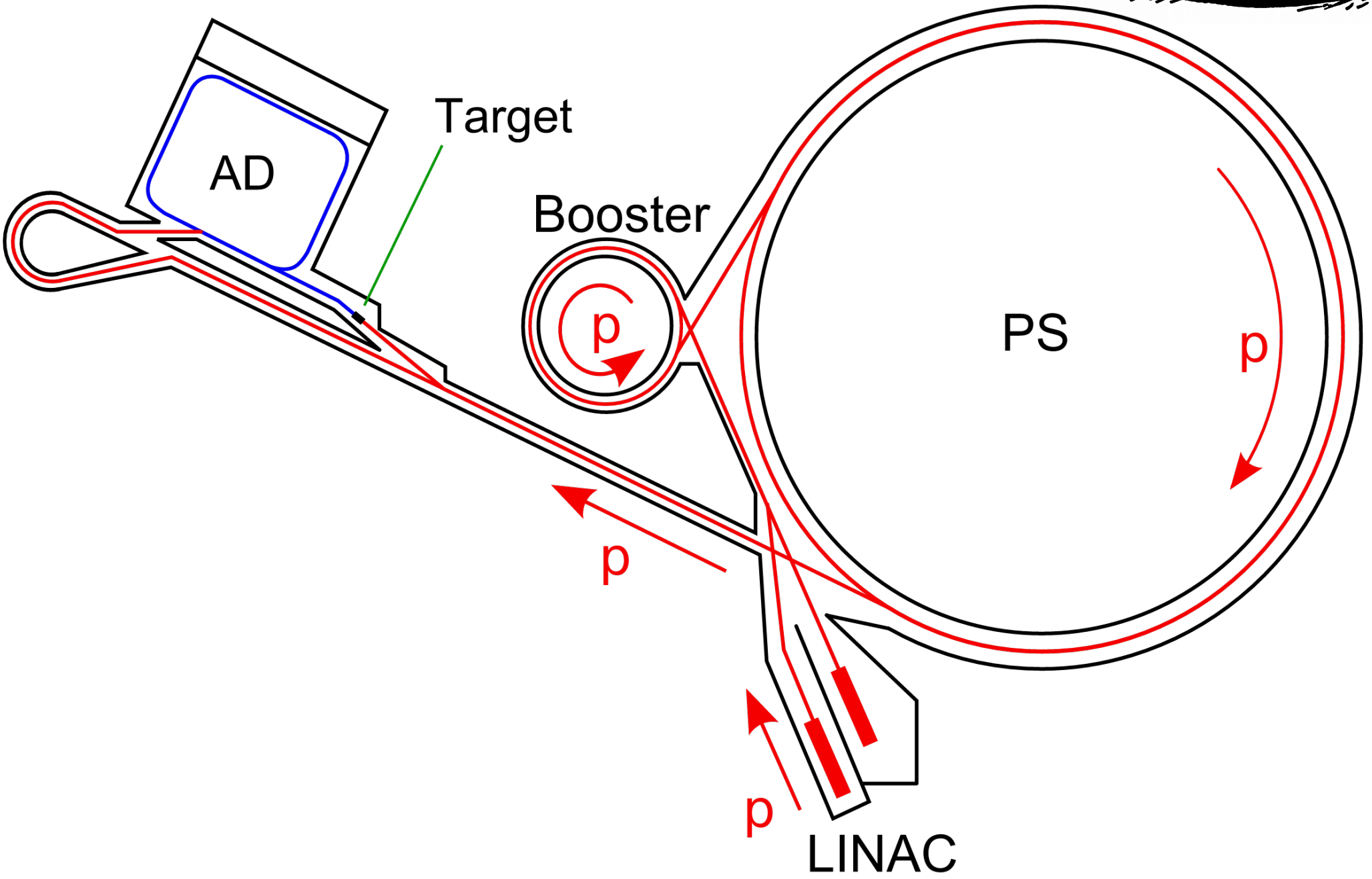
Time reversal swaps past and future

We have some clues… but not enough

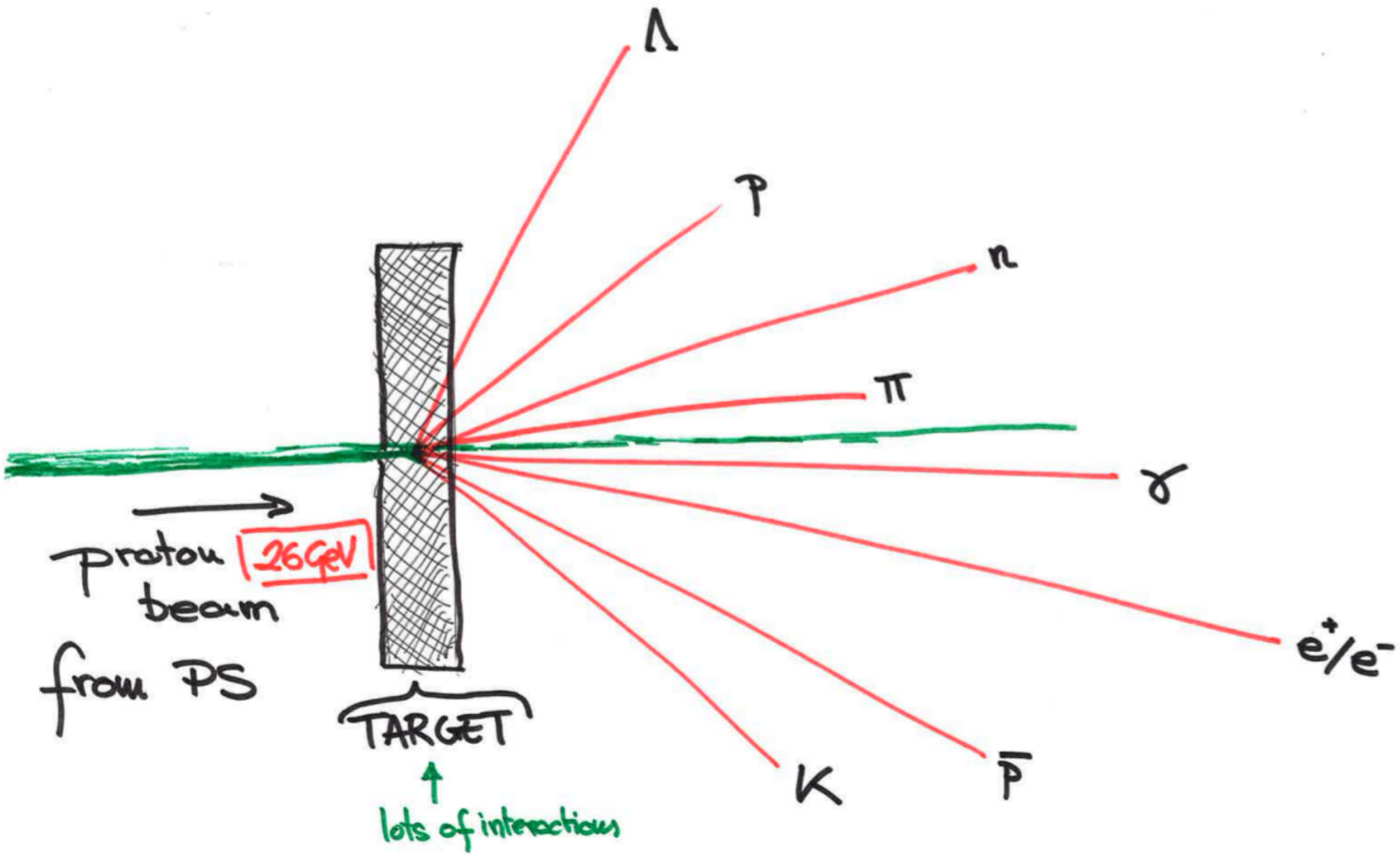


How do we create antimatter?

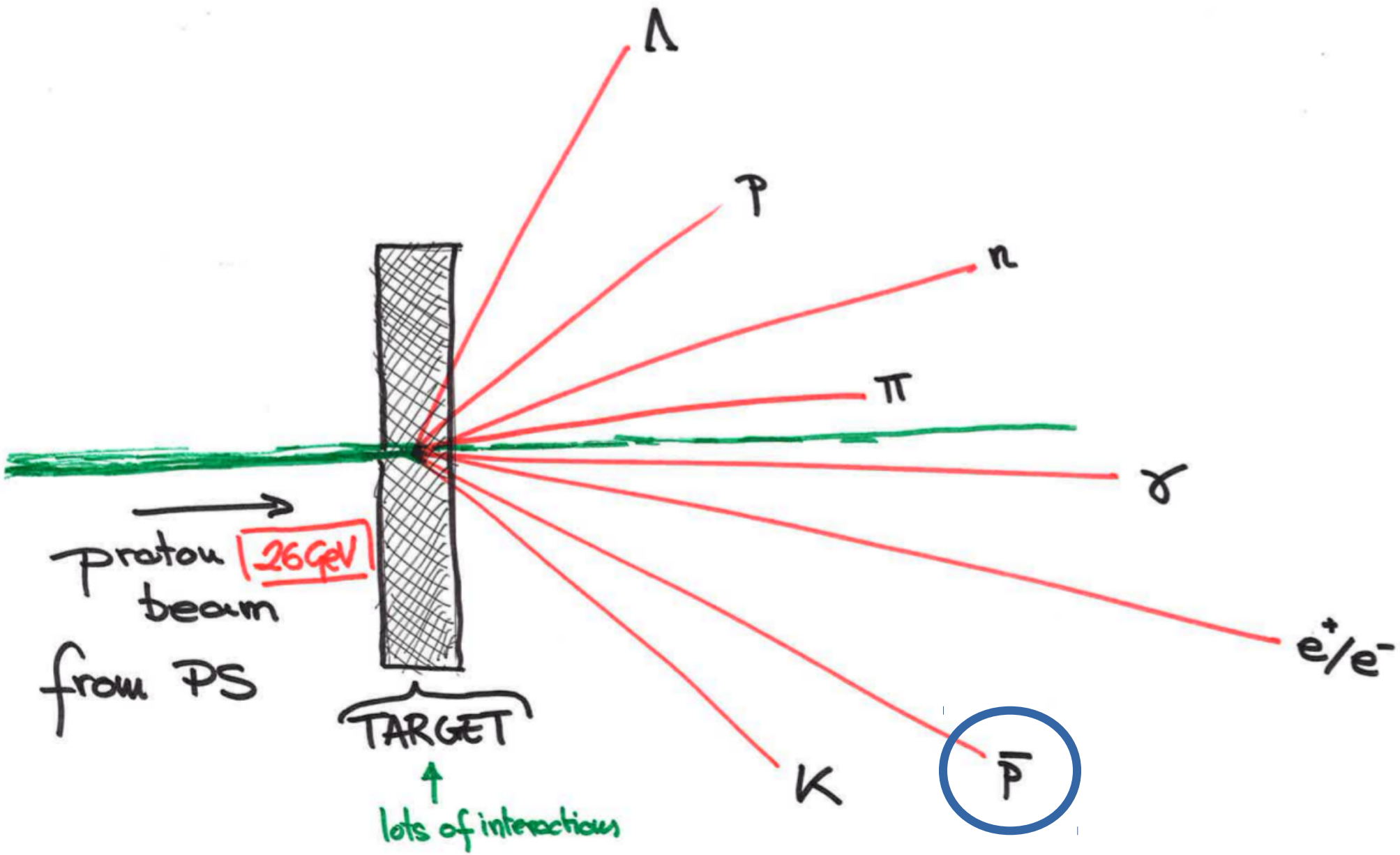




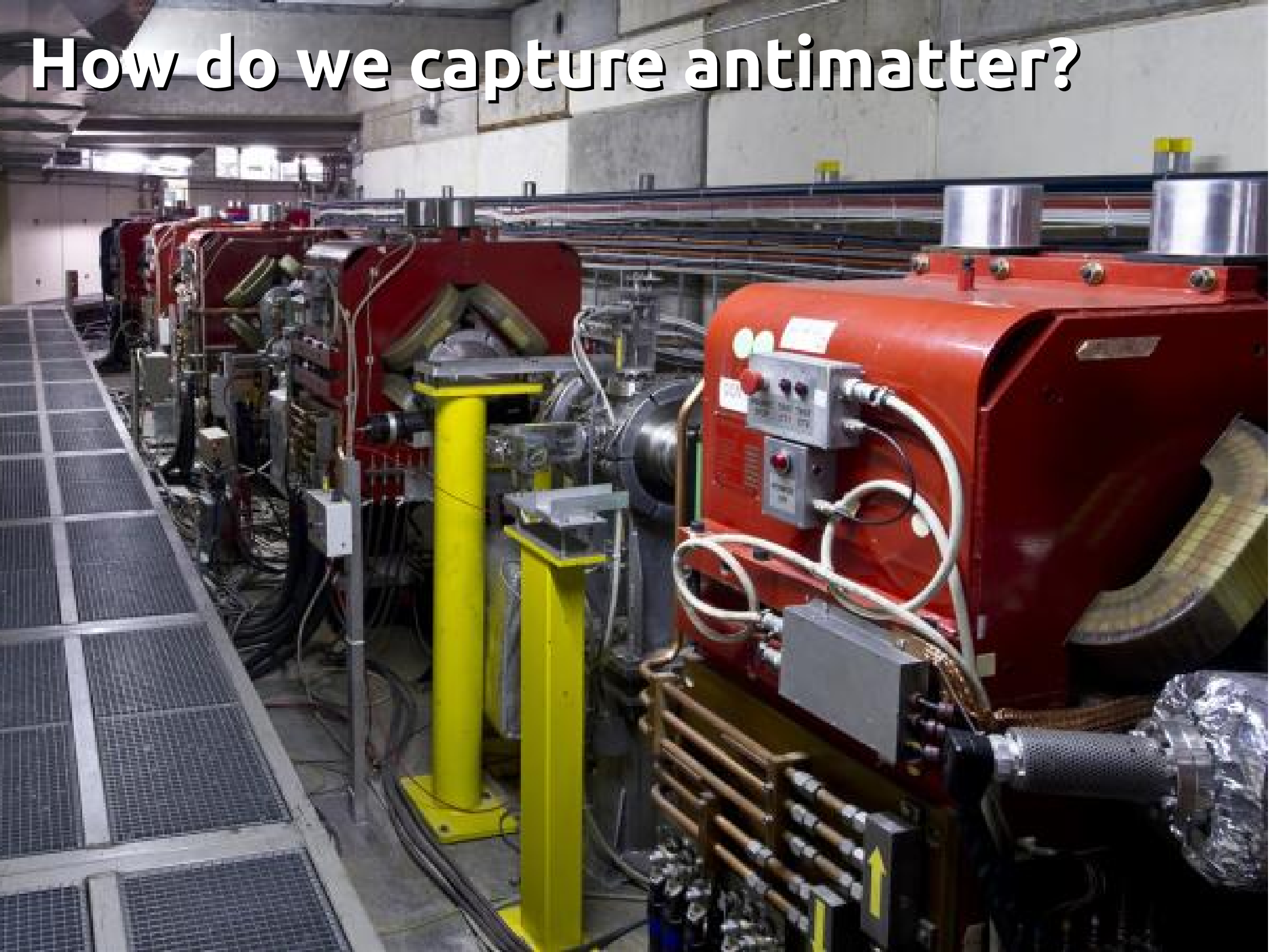
How do we create antimatter?



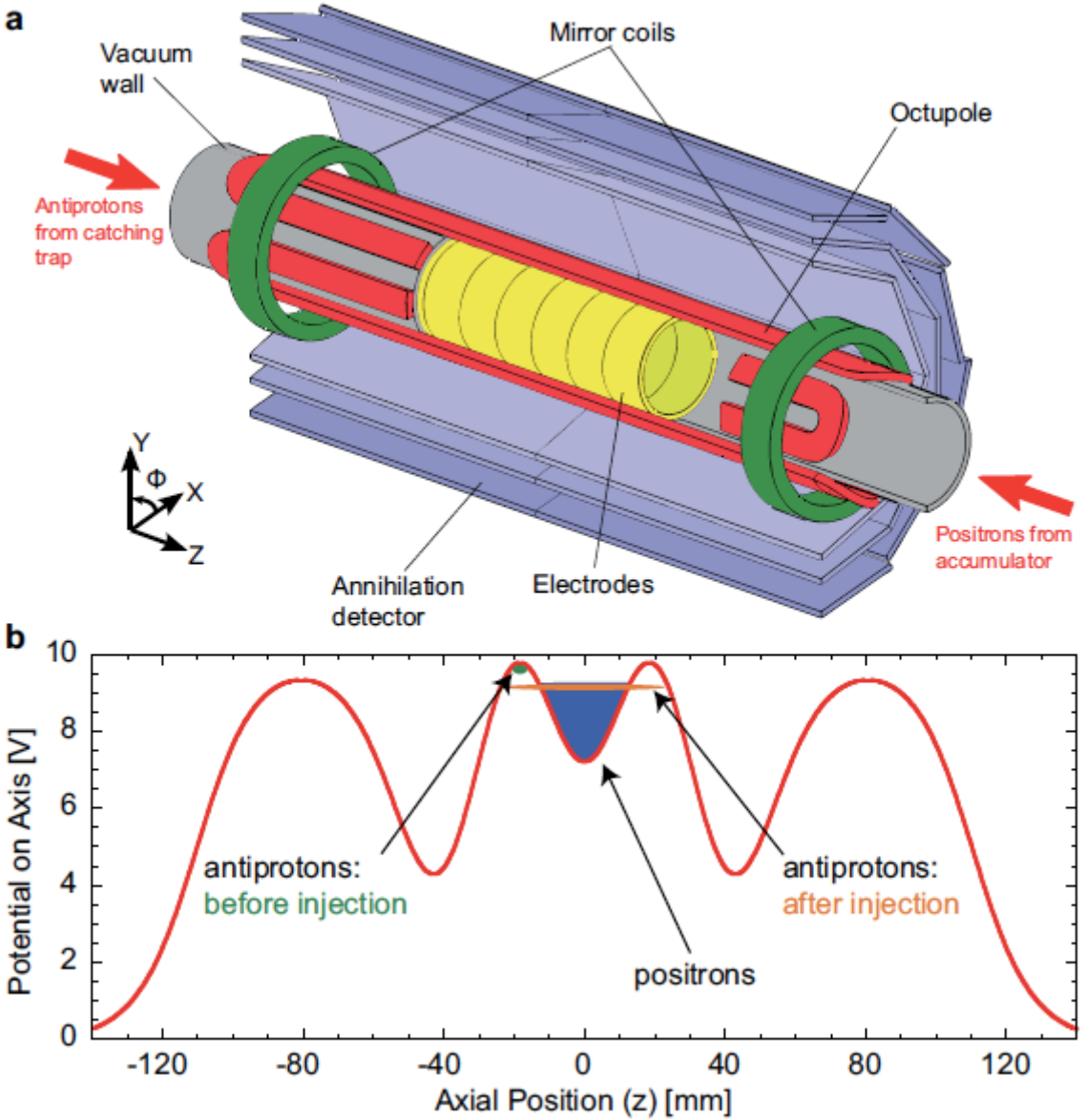
How do we create antimatter?



How do we capture antimatter?

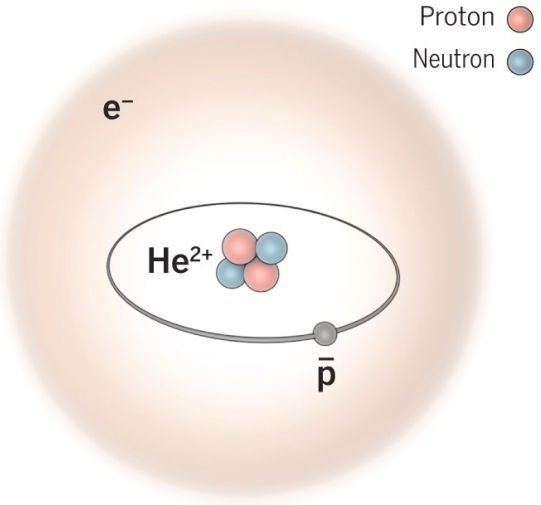


How do we store antimatter?

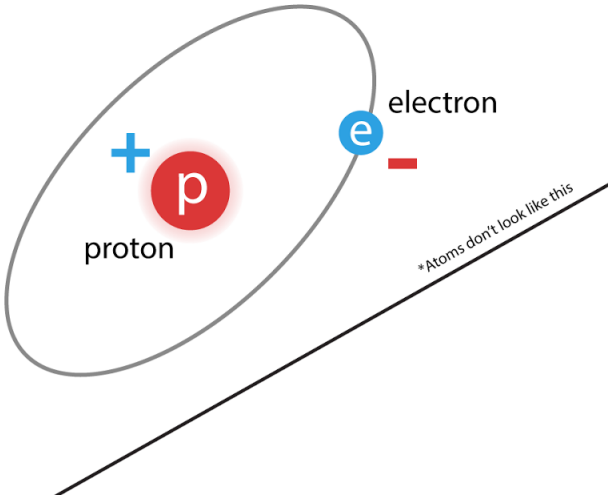


The experiments

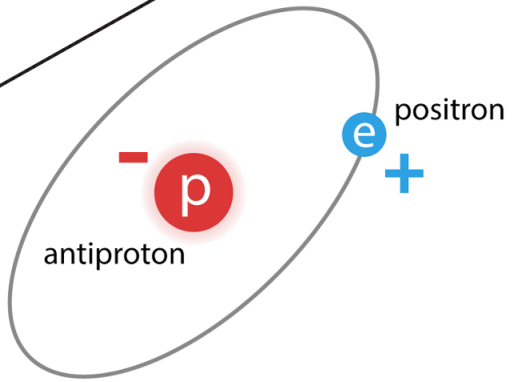
ASACUSA



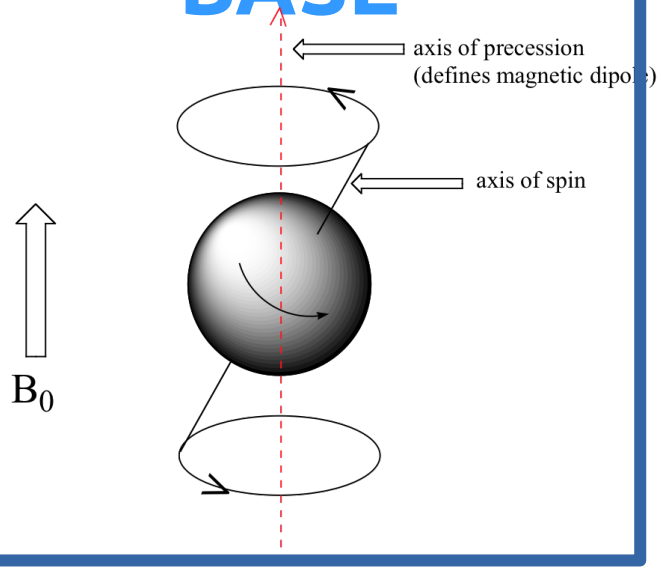
ATRAP



ALPHA

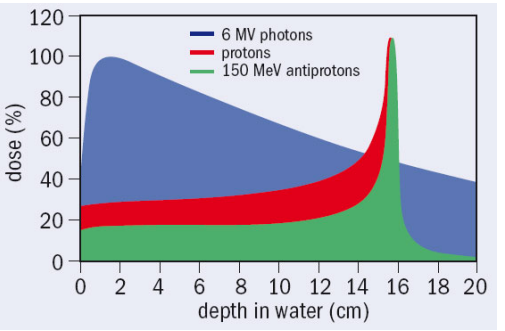


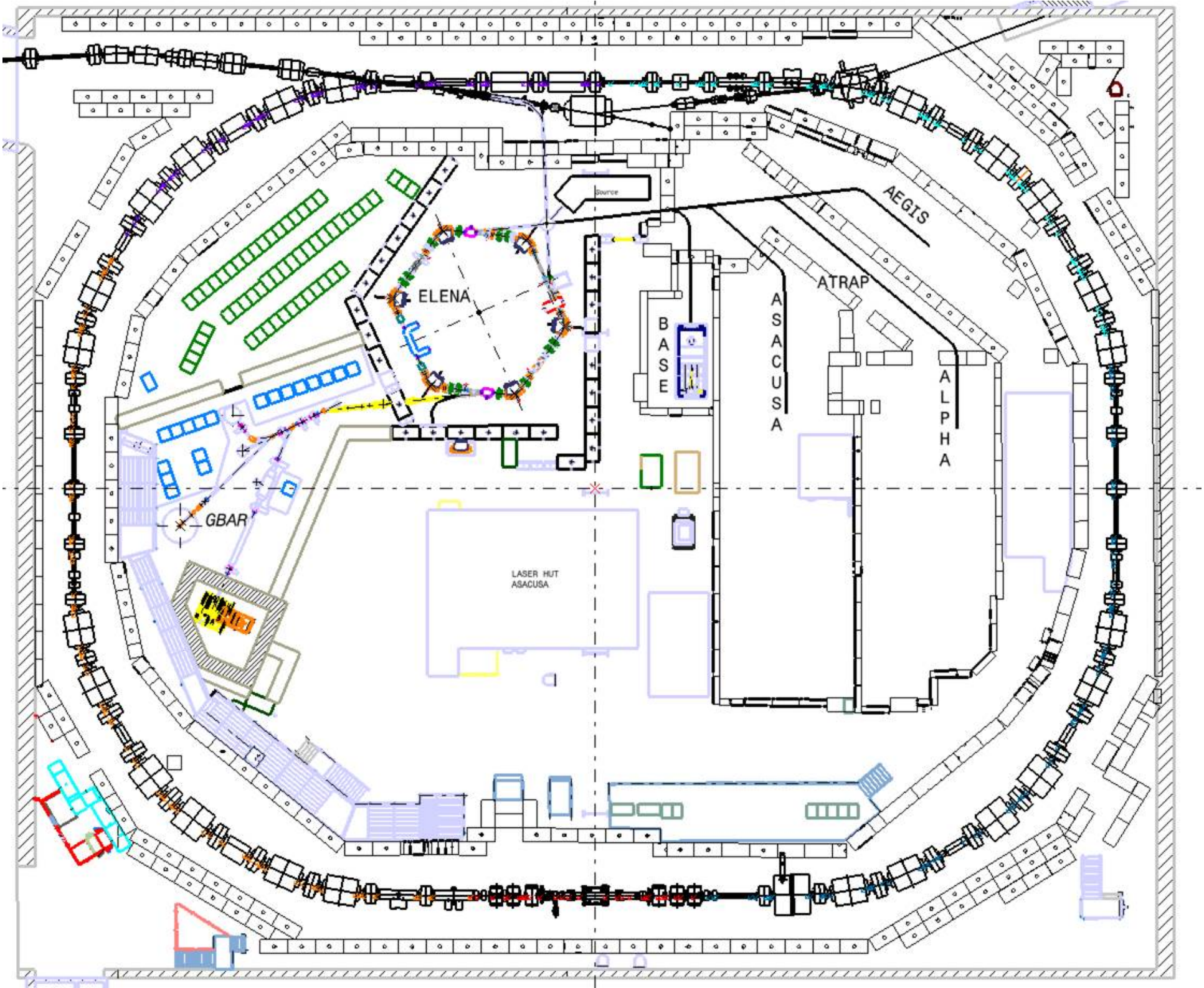
BASE



AEgIS/GBAR

ACE




AEGIS
ELENA
ATRAP
BASE
ASACUSA
ALPHA
GBAR
LASER HUT
ASACUSA

What are we going to see next?

Low Energy Ion Ring