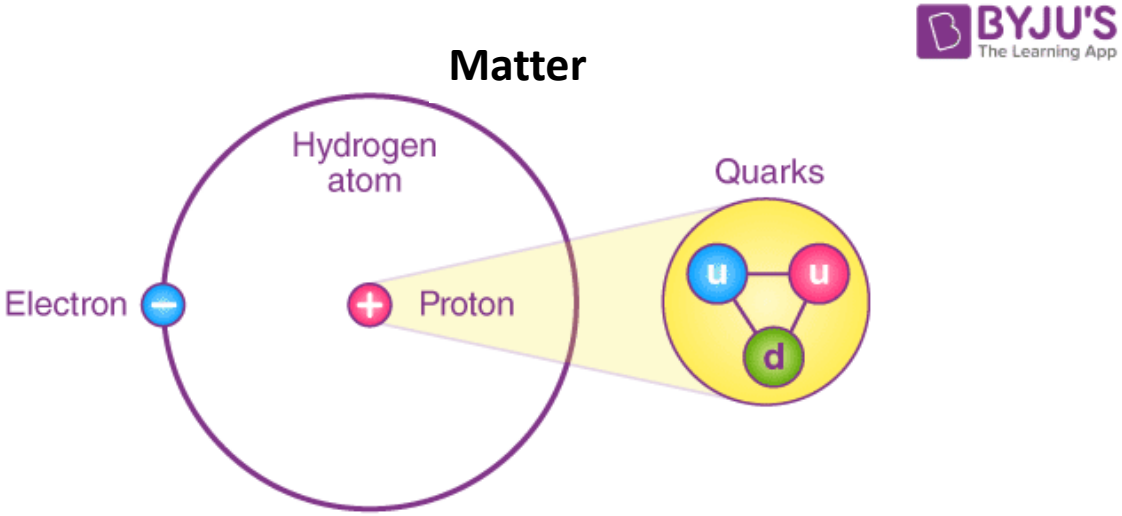
The ESSnuSB Project

Can neutrinos explain the matter–antimatter Mystery?

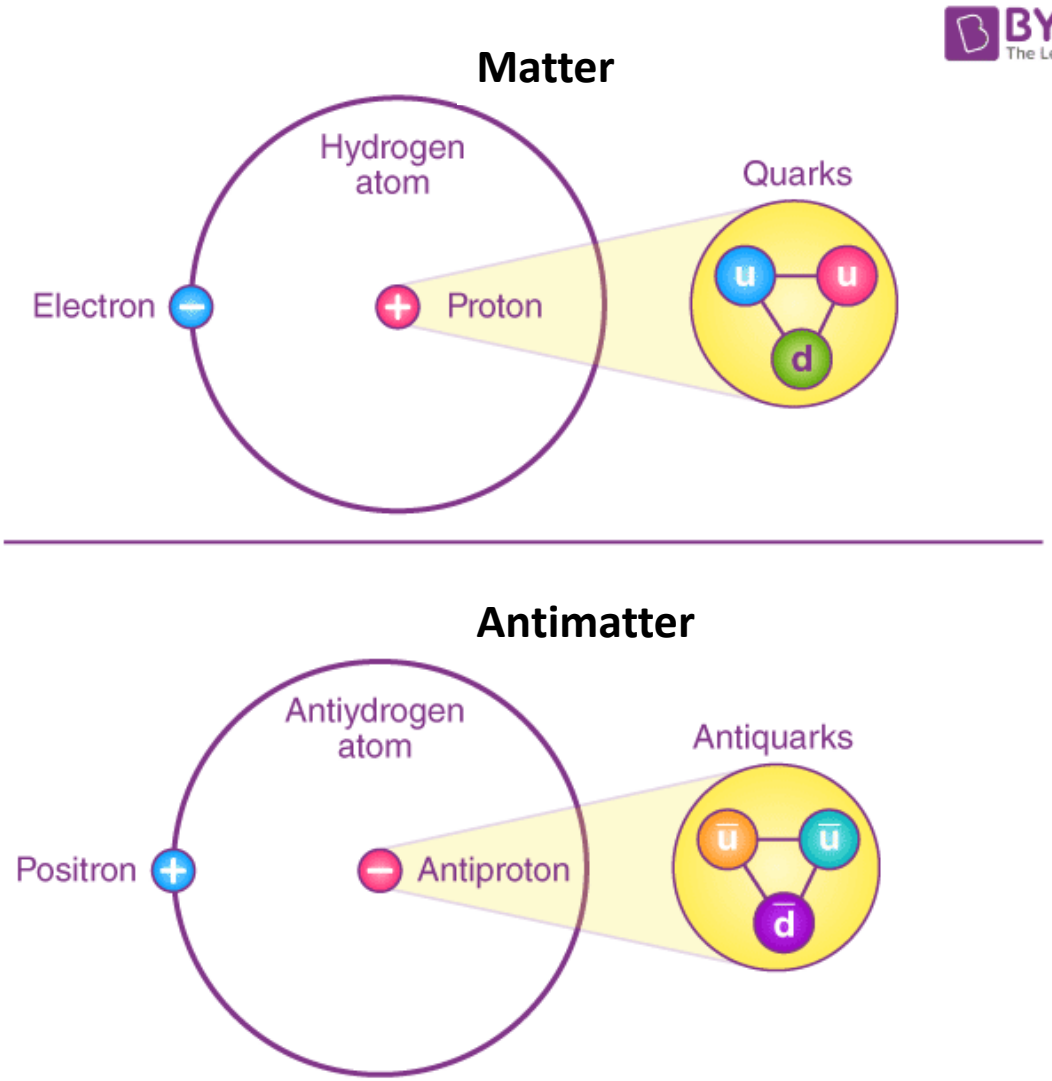
Co-funded by the European Union

P. Christiansen
(Lund University)

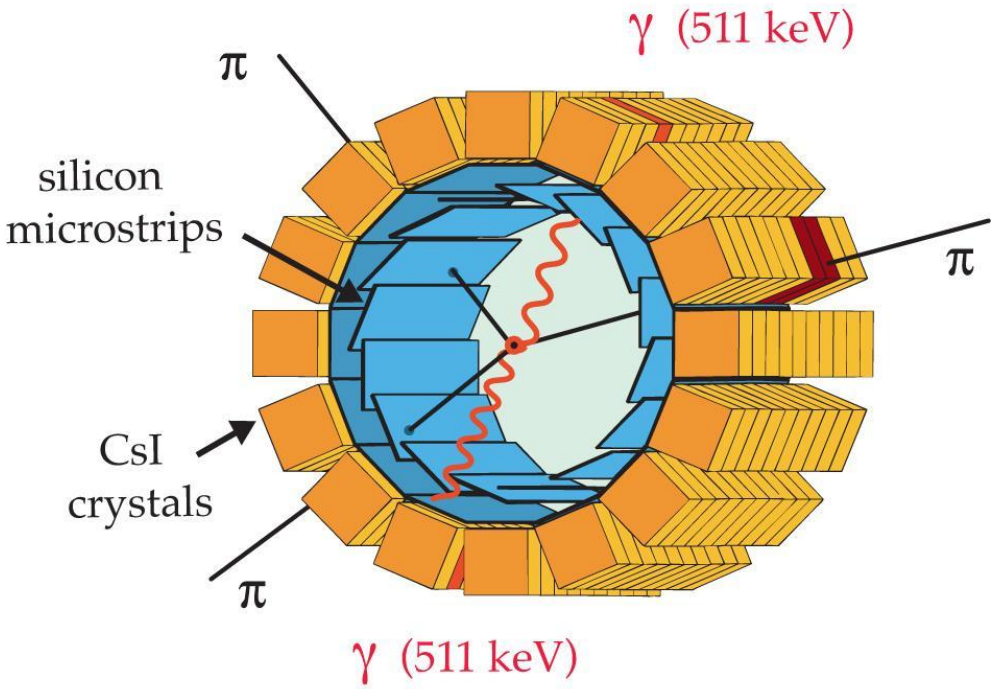
What is matter and antimatter?



What is matter and antimatter?



What happen when matter and antimatter meets?

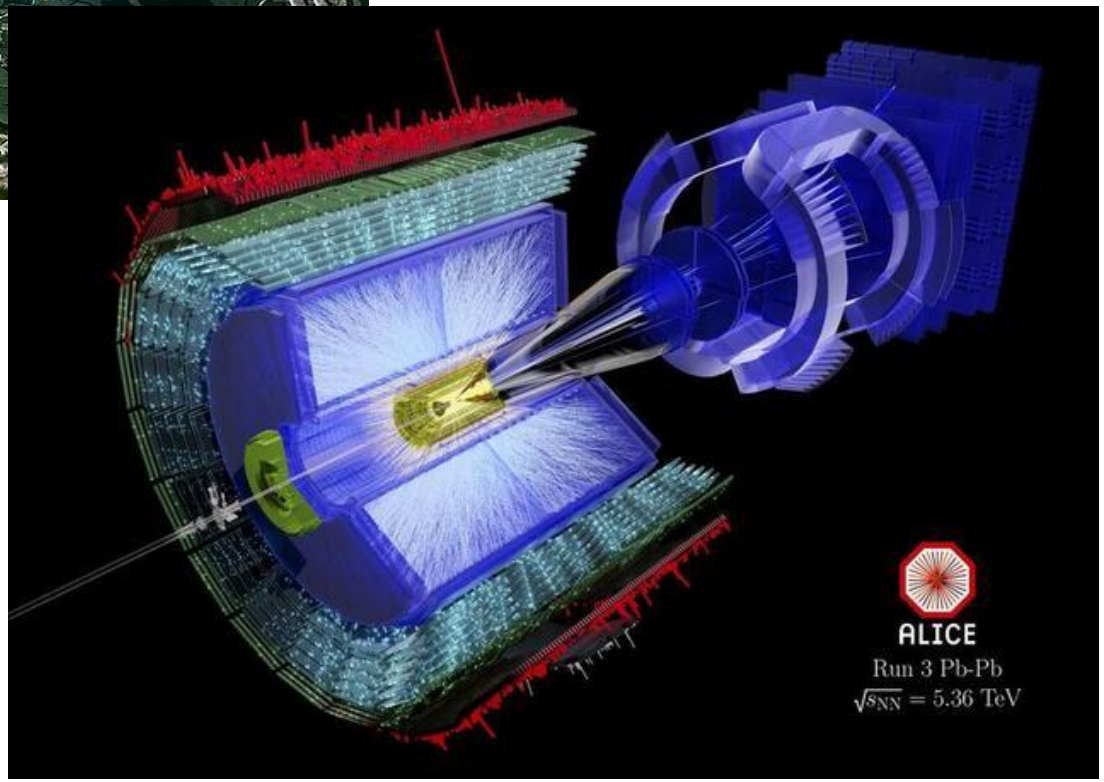


- Electron + positron → 2 photons (γ)
  - Distinct energy since $E = mc^2$
- Proton + antiproton → 3+ pions

We can look for 511 keV photons in the Universe

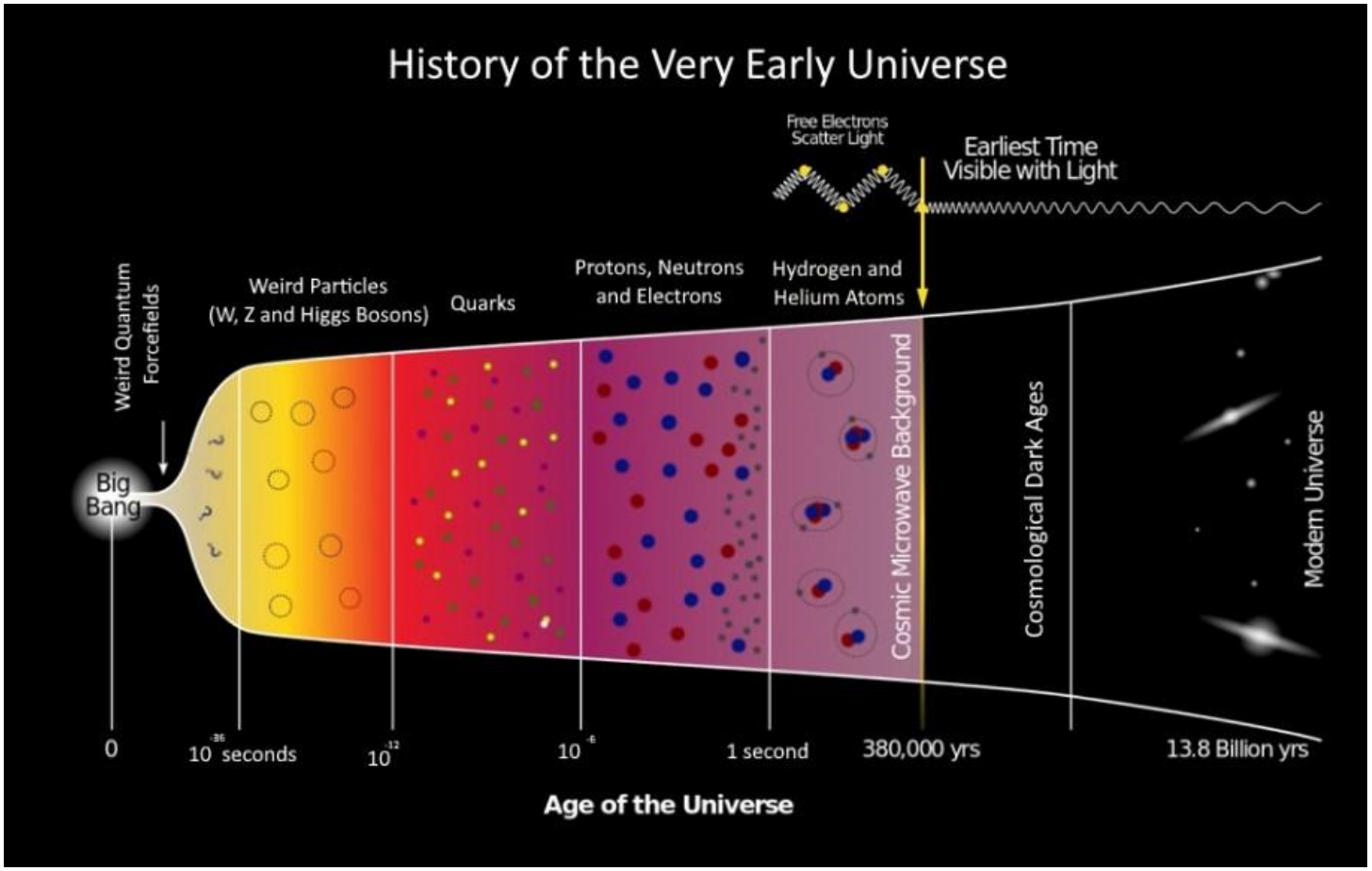
- We do not observe them
  → Our Universe is almost 100% matter!

Puzzle: experiments create equal number of particles and antiparticles



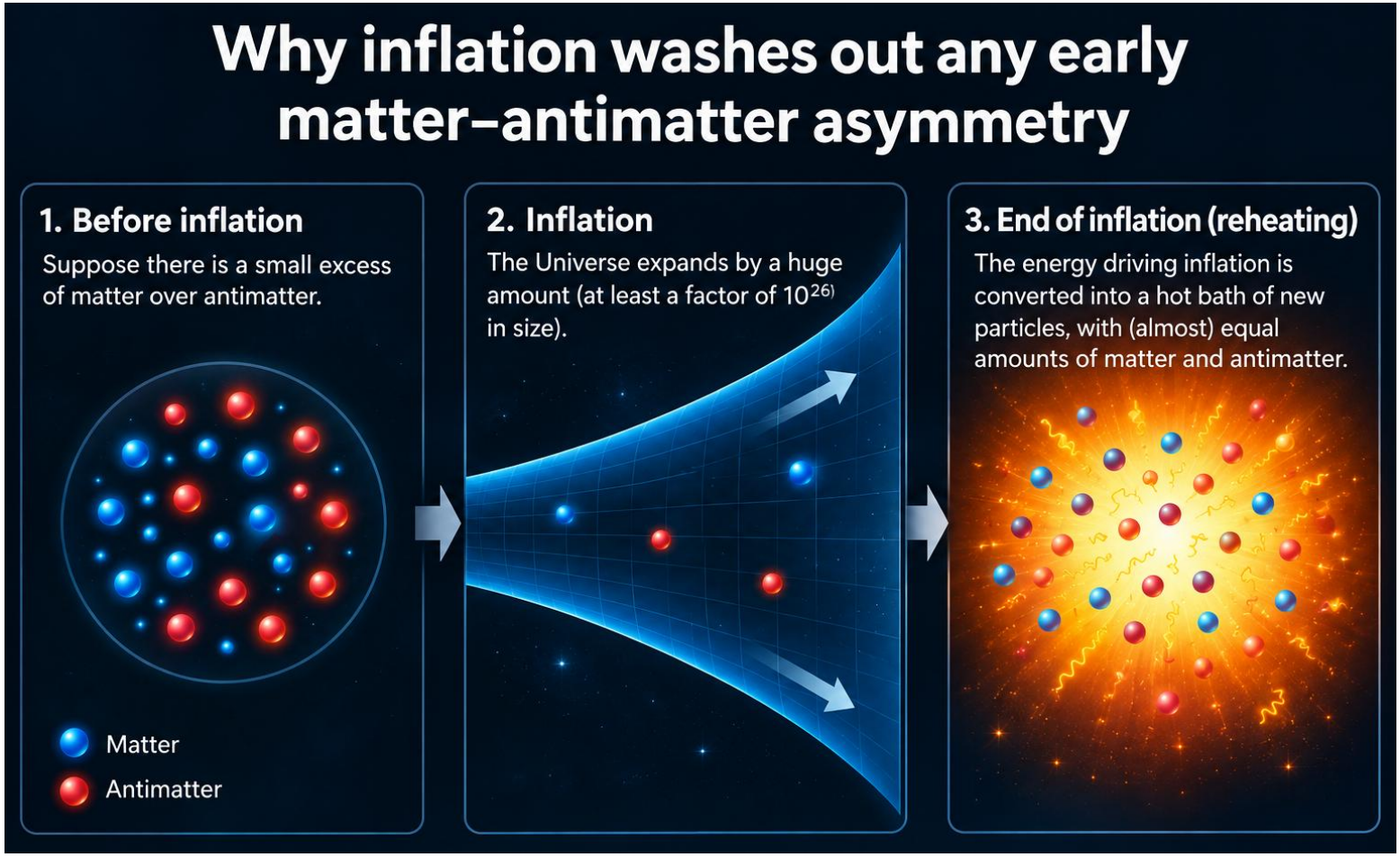
- In collisions we convert energy (E) into (anti)particles (m)
  - Particles and antiparticles are always created in pairs!

Could the Universe be made with more matter than antimatter?



- We know that the matter-antimatter asymmetry must be there before 10^{-6} second after Big Bang

Could the Universe be made with more matter than antimatter?



- And created after inflation

  → We are looking for new physics!

What is needed for the new physics?

Sakharov criteria

Three conditions must be fulfilled to create a matter–antimatter asymmetry in the Universe.

1 Baryon or lepton number violation

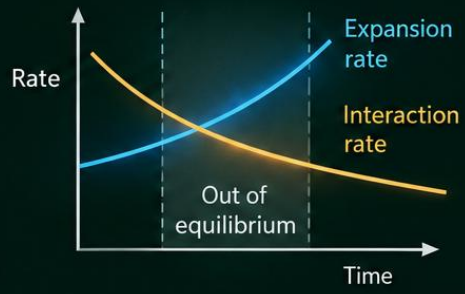
The laws of physics must allow processes that change the number of baryons (protons and neutrons) or leptons (such as electrons and neutrinos).

2 C and CP violation

Matter and antimatter must behave differently. The laws of physics must distinguish between particles and antiparticles (violation of charge conjugation symmetry C and the combined symmetry CP).

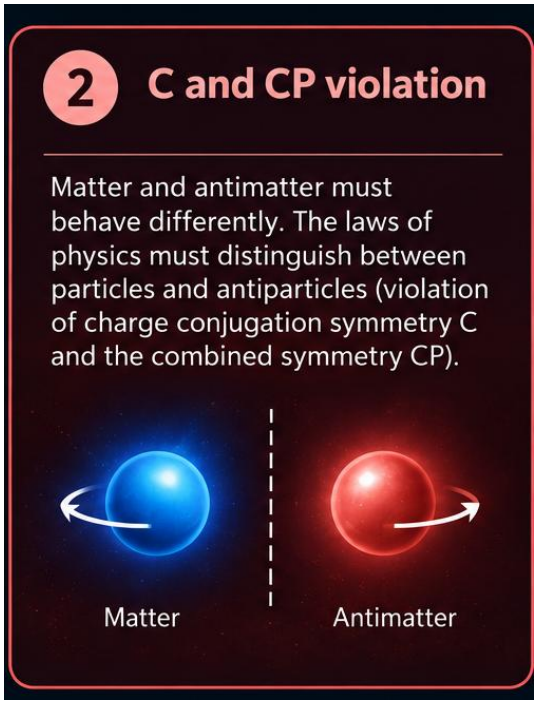
3 Departure from thermal equilibrium

The Universe must go through a period where it is not in thermal equilibrium, so that the created asymmetry is not immediately washed out by reverse processes.



If all three conditions are satisfied,
the Universe can naturally end up with more matter than antimatter.

What is ESSnuSB looking for?



- Neutrinos are the only **known** fundamental that could possibly explain the matter-antimatter asymmetry
  - All others are ruled out!
- ESSnuSB will **if funded** search for differences between matter (neutrinos) and antimatter (antineutrinos)

What are neutrinos?

- Very weakly interacting neutral particles
  - About 100 trillion (100.000.000.000.000) neutrinos pass through your body every second.
    - Still one would have to wait about 100 years for a neutrino to interact in a detector the size of a person.