Intrinsic parity

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The Intrinsic Parity of Elementary Particles

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The limitations to the concept of parity of quantum-mechanical states and, in particular, of intrinsic parity of elementary particles are discussed. These limitations are shown to follow from "superselection rules," i.e., from restrictions on the nature and scope of possible measurements. The existence of such superselection rules is proved for the case of spinor fields; it is also conjectured that a superselection rule operates between states of different total charge.

- Parity is a multiplicative quantum number $\mathcal{P}_{12} = \mathcal{P}_1 \mathcal{P}_2 (-1)^{L_{12}}$
- Quarks have intrinsic parity +1
- The lighter baryons (qqq) have positive intrinsic parity. What about light antibaryons?
- What about mesons?

In 1954, Chinowsky and Steinberger demonstrated that the pion has negative parity (is a pseudoscalar particle)

Charge conjugation

$\mathcal{C}$ - interchanges particles & antiparticles

It reverses all the internal quantum numbers such as charge, lepton number, baryon number, and strangeness. It does not affect mass, energy, momentum or spin.

$$\mathcal{C}|\psi\rangle = |\bar{\psi}\rangle \qquad \mathcal{C}^2 = 1$$

What are the eigenstates of charge conjugation?

$$\mathcal{C}|\psi\rangle = \eta_C|\psi\rangle \Rightarrow \eta_C = \pm 1$$

C-parity or charge parity

⇒ photon, neutral pion…
What about positronium, neutrino?

- Maxwell equations are invariant under $\mathcal{C}$
- $\mathcal{C}$ reverses the electric field
- Photon has charge parity η_C=-1

$$\pi_0 \to \gamma + \gamma \Rightarrow \eta_C(\pi_0) = 1$$

- Is the following decay possible?

$$\pi_0 \to \gamma + \gamma + \gamma$$

http://pdg.lbl.gov/2014/tables/contents_tables.html

Other Symmetries

$\mathcal{CP}$ - violated in K^0 decay (1964 Cronin & Fitch experiment)

$$K_2^0 \to \pi^+ + \pi^-$$

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EVIDENCE FOR THE 2π DECAY OF THE K_2^0 MESON*†

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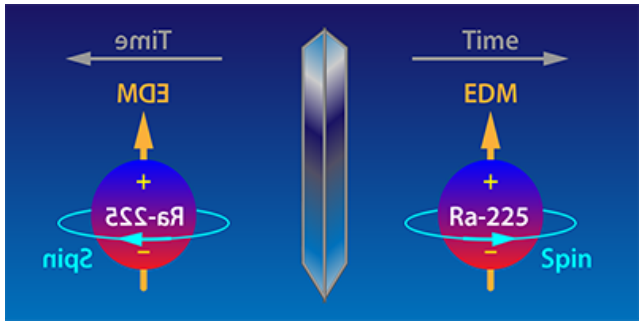
$\mathcal{CPT}$ - follows from relativistic invariance

The CPT theorem appeared for the first time in the work of Julian Schwinger in 1951 to prove the connection between spin and statistics. In 1954, Lüders and Pauli derived more explicit proofs. At about the same time, and independently, this theorem was also proved by John Stewart Bell. These proofs are based on the principle of Lorentz invariance and the principle of locality in the interaction of quantum fields.

Since $\mathcal{CP}$ is violated, $\mathcal{T}$ has to be violated as well!

Since CP is violated, T has to be violated as well!



Atomic/neutron electric dipole moment: The violation of CP-symmetry is responsible for the fact that the Universe is dominated by matter over anti-matter

http://physics.aps.org/synopsis-for/10.1103/PhysRevLett.114.233002

- Closely spaced parity doublet gives rise to enhanced electric dipole moment
- Large intrinsic Schiff moment
  - ^{199}Hg (Seattle, 1980's – present)
  - ^{225}Ra (ANL, KVI)
    Parker et al. 2015, d<5x10^{-22} e cm
  - ^{223}Rn at TRIUMF (E929)
  - FRIB
    - Widest search for octupole deformations
    - ^{238}U beam, beam dump recovery: ^{225}Ra: 6x10^{9}/s
    - ^{232}Th beam: ^{225}Ra: 5x10^{10}/s, ^{223}Rn: 1x10^{9}/s
    - 10^{12}/s with ISOL target FRIB upgrade

Neutron EDM searches

An international team of physicists has developed a shielding that dampens low frequency magnetic fields more than a million-fold. Using this mechanism, they have created a space that boasts the weakest magnetic field of our solar system.

http://phys.org/news/2015-05-shield-physics-standard.html
http://physicsworld.com/cws/article/news/2015/may/20/extraordinary-magnetic-shield-could-reveal-neutrons-electric-dipole-moment

HW: Using information from PDG.lbl.gov and nndc.bnl.gov determine whether the following decays/reactions are allowed by fundamental symmetries:

α. $\pi^0 \longrightarrow \gamma\gamma\gamma$
b. $e^+ + e^- \longrightarrow \gamma$
c. Gamma decay of excited state of ^{40}Ca at 3353 keV
d. Decay of meson $\eta \longrightarrow \pi^0 + \gamma$
e. Decay of meson $\eta \longrightarrow \pi^0 + \pi^-$