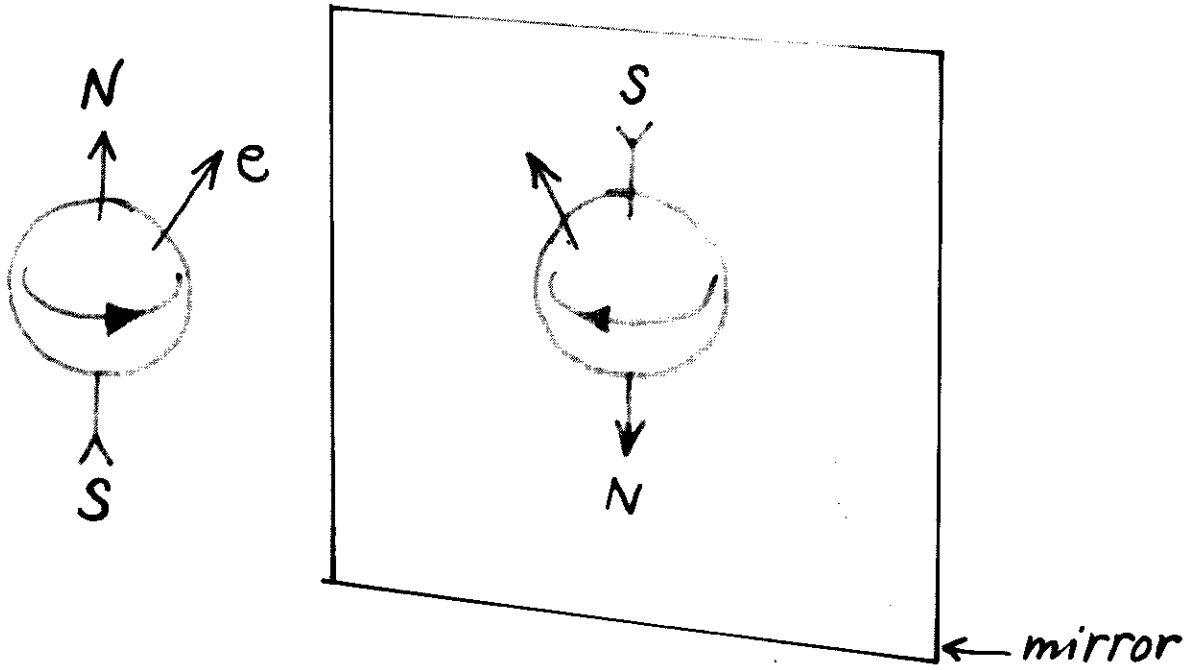
Fundamental experimental shock

^{60}Co emits electron "to the north"



Q: Is there a preferential direction of the electrons w.r.t. ^{60}Co spin?

A: Yes!

$\Rightarrow$ (unknown?) law of physics in mirror world is not the same as that in "our" world

$\Rightarrow$ Physics <u>not</u> invariant under P (neither under T)

Levi-Civita symbol

$\varepsilon_{\mu\nu\rho\sigma}$ totally antisymmetric, $\varepsilon_{0123} = +1$

- $g_{\mu\nu} x_1^{\mu} x_2^{\nu}$ invariant under R, B, P, T
- $\varepsilon_{\mu\nu\rho\sigma} x_1^{\mu} x_2^{\nu} x_3^{\rho} x_4^{\sigma}$ invariant under R, B
  flips sign under P, T

Example 2 : Hadron structure

- Postulate: quarks come in 3 colours

  quark $q = q^a = \begin{pmatrix} r \\ g \\ b \end{pmatrix}$ antiquark $\bar{q}_a = (\bar{r}, \bar{g}, \bar{b})$

  q.m. wavefunction → complex

  ⇒ quark colours form complex 3-dim space

- Copernican principle: physics should be invariant under different s.c. in this space

  ⇒ 3×3 complex rotation matrices: SU(3) ($\leftarrow \Lambda^\mu{}_\nu$)

  $$q^a \to q'^a = M^a{}_b q^b$$
  $$\bar{q}_a \to \bar{q'}_a = \bar{q}_b (M^\dagger)^b{}_a$$

- Invariant objects ("white")

  $\delta_a{}^b \; q^a \bar{q}_b$ mesons

  $\varepsilon_{abc} \; q^a q^b q^c$ baryons

  $\varepsilon^{abc} \; \bar{q}_a \bar{q}_b \bar{q}_c$ anti-baryons

  } indeed, the only found so far....

Symmetries ⇒ Conservation laws

Example: translation invariance of particle interactions

"propagator from x to y" $f(y;x) = \int dk\, e^{iky} \tilde{f}(k;x)$ Fourier transform

3 particles interact with strength $\lambda(y)$ at point y
this is described by

$$\int dy\, f_1(y;x_1) f_2(y;x_2) f_3(y;x_3)\, \lambda(y)$$

$$= \int \tilde{f}_1(k_1;x_1) \tilde{f}_2(k_2;x_2) \tilde{f}_3(k_3;x_3) * \underbrace{\int dy\, \lambda(y)\, e^{i(k_1+k_2+k_3)y}}$$

$\lambda(y) = \lambda = \text{constant}$

$$2\pi\, \lambda\, \delta(k_1+k_2+k_3)$$

Translation invariance of interaction

⇕

Momentum conserved in interaction

Examples

Symmetry	Conserved quantity
space translation	momentum
time translation	energy
space Rotation	angular momentum
Rotation in 3-dim colour space	colour
Rotation in 1-dim "complex phase" space	e.m. charge
Rotation in 2-dim (up, down) space (isospin)	weak charge

not exact

WARNING

Existence of a symmetry has to be determined by experiment!