

# Симетрии, инвариантность и законы за запазване

# Съдържание

- Симетрии и **инвариантност**
  - дискретни и непрекъснати преобразувания (на симетрия)
- **Непрекъснати** преобразувания (на симетрия)
  - **адитивни** закони за запазване
- **Дискретни** преобразувания (на симетрия)
  - **мултипликативни** закони за запазване (четности)

# Симетрии и инвариантност

- Ако са напълно известни законите на движение (т.е. уравненията на движение), тогава се изследват отделно симетриите на законите за запазване. Те следва да са инвариантни при уравненията на движение (първото не е такова!

- Теорема на Е. Ньотер: На всяко непрекъснато преобразуване на пространствените координатите, което оставя действието инвариантно, съответстват  $s$  динамични закони (комбинации от полни производни).



и свят (т.е. когато се разглеждат системи и частици, които са в покой в отнoсително движение).

трично преобразуване на координатите и време (скалярно и векторно),

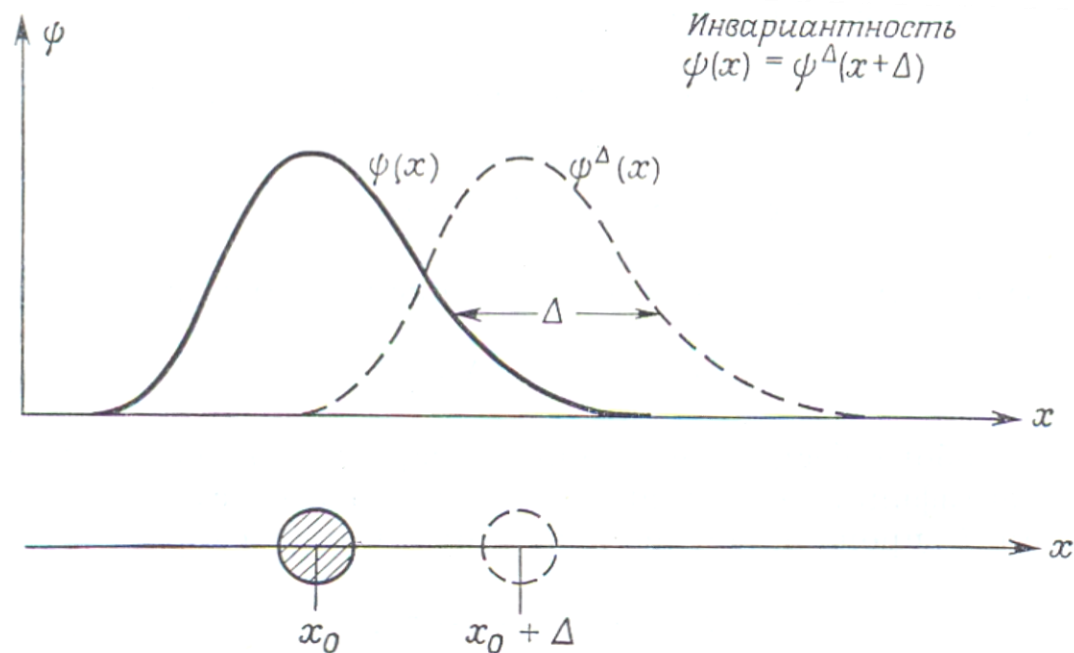
Amalie Emmy Noether

Born 23 March 1882, Erlangen, Bavaria, Germany

Died 14 April 1935, (aged 53)

Bryn Mawr, Pennsylvania, USA

# Пример с трансляция по оста X



# Пространствени непрекъснати преобразувания на симетрия

- трансляция в пространството и времето  $\rightarrow$  закон за запазване на енергията и импулса (хомогенност на пространство-времето);
- ротация спрямо произволна ос  $\rightarrow$  закон за запазване на пълния момент на импулса (изотропност на пространството)

# Вътрешни непрекъснати преобразувания на симетрия

- глобални калибровъчни преобразувания
  - закони за запазване на:
    - електрическият заряд;
    - барионния заряд (брой кварки – брой антикварки);
    - лептонните числа (поотделно?)

# Дискретни (пространствени) преобразувания на симетрия

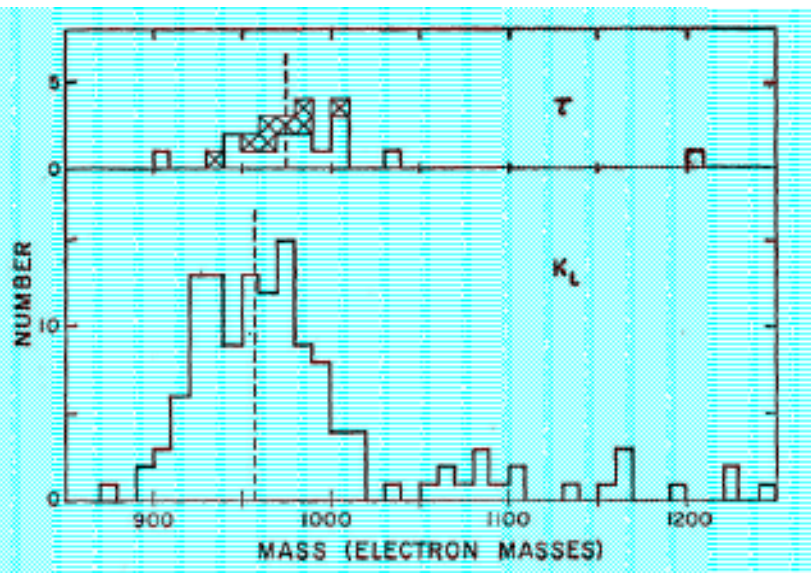
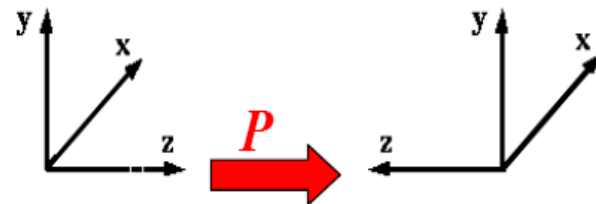
- Отражение на пространствените оси: *P-преобразувание*
- Обръщане на знака на времето: *T-преобразувание*
- Замяна “частици $\leftrightarrow$ античастици”: *C-преобразувание*



# P-симетрия

## загадката $\Theta - \tau$

- наблюдавани са два различни разпада:  
 $\theta^+ \rightarrow \pi^+ \pi^0$  (S-състояние:  $L=0, P=+1$ )  
 $\tau^+ \rightarrow \pi^+ \pi^+ \pi^-$  (S-състояние:  $L=0, P=-1$ )
- масите и сеченията за раждане са много близки (едни и същи)  
(6 GeV Bevatron, Brookhaven in 1954)



**Идея:** (предложена от T.D. Lee и C.N. Yang, 1956)

**(Пространствената) четност не се запазва в слабите взаимодействия!**

**Природата различава ляво и дясно!**



# (Пространствена) четност и закон за запазване на четността

$$\vec{r} \rightarrow -\vec{r} \quad \begin{pmatrix} x \rightarrow -x \\ y \rightarrow -y \\ z \rightarrow -z \end{pmatrix} \quad \begin{pmatrix} r \rightarrow r \\ \theta \rightarrow \pi - \theta \\ \phi \rightarrow \pi + \phi \end{pmatrix} \quad v(\vec{r}) = v(-\vec{r}) \quad |\psi(\vec{r})|^2 = |\psi(-\vec{r})|^2$$

$$P\psi(\vec{r}) = \pi\psi(-\vec{r}) \quad P^2\psi(\vec{r}) = \pi^2\psi(\vec{r}) \quad \pi = \pm$$

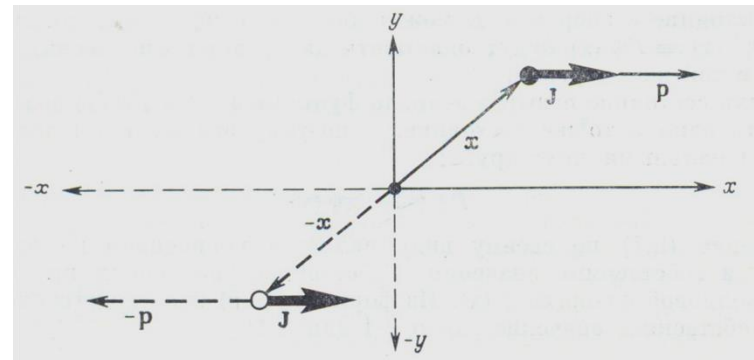
## Вектори

$$P[\vec{V}] = -\vec{V} \quad \vec{r}, \vec{v}, \vec{p}, \vec{F}, \vec{E}$$

## Псевдовектори

$$P[\vec{V}] = \vec{V} \quad \vec{L} = \vec{r} \times \vec{p}, \vec{B}$$

Четността се запазва при силното и електромагнитното взаимодействия!

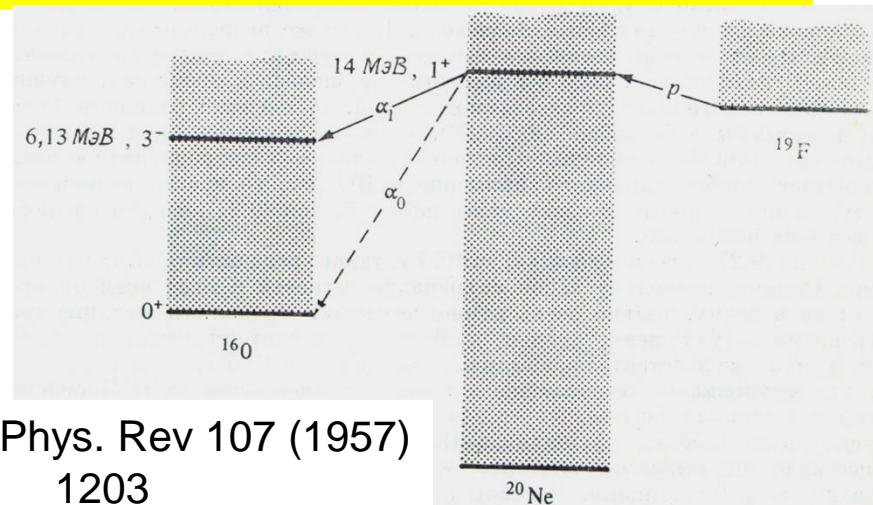


# Проверка на запазването на четността при ядрени преходи

$$V_{\text{nuclear}} = V_{\text{strong}} + V_{\text{weak}}$$

$$\psi_{\text{nuclear}} = \psi^{(\pi)} + F \psi^{(-\pi)}$$

$$\langle \hat{M} \rangle \propto \langle \hat{M} \rangle^{(\pi)} + F^2 \langle \hat{M} \rangle^{(-\pi)}$$



N. Tanner, Phys. Rev 107 (1957)

1203

$$F^2 < 4 \times 10^{-8}$$

- $\gamma$ -разпад на поляризирани ядрени състояния
- забранени ядрени преходи (разпади) -  $\alpha$  разпад  $2^- \rightarrow 0^+$

$$^{16}\text{O}(2^-) \rightarrow ^{12}\text{C}(0^+), \tau = 7 \times 10^{-7} \text{ s}$$

Neubeck et al., Phys. Rev C **10** (1974) 320

Ако преходът беше разрешен,  
то при  $Q = 1.7 \text{ MeV}$   $\tau \sim 2 \times 10^{-21} \text{ s}$ ,  
т.е.  $F^2 \sim 10^{-14}$

$$F \approx 10^{-7}$$

# Експеримент на С. С. Wu

LETTERS TO THE EDITOR

1413

The branching ratio of the two modes of decay of  $\text{Fm}^{253}$ , i.e.,  $E.C./\alpha$ , was found to be about 8.5—which gives  $\sim 89.5\%$  decay by electron capture and  $\sim 10.5\%$  by alpha emission. It was not possible to measure the cross section for the  $\text{CF}^{252}(\alpha,3n)\text{Fm}^{253}$  reaction because  $\text{Fm}^{253}$  could also be produced from other californium isotopes in the target.

A previous publication<sup>1</sup> on a possible  $\beta$  decay of the  $\text{Fm}^{253}$  gave the values of  $6.85 \pm 0.05$  MeV for the alpha-particle energy, and a half-life  $> 10^4$  years.

It is a pleasure to thank the crew of the cyclotron for their extremely careful and efficient operation of the machine during the bombardment. I wish to thank Professor Glenn T. Seaborg for his continued interest.

\* On leave from the Israel Atomic Energy Commission, Weizmann Institute of Science, Rehovoth, Israel.

<sup>1</sup> Thompson, Ghiorso, Harvey, and Choppin, *Phys. Rev.* **93**, 908 (1954).

<sup>2</sup> Harvey, Chetham-Strode, Ghiorso, Choppin, and Thompson, *Phys. Rev.* **104**, 1315 (1956).

<sup>3</sup> Thompson, Harvey, Choppin, and Seaborg, *J. Am. Chem. Soc.* **76**, 6229 (1954); Choppin, Harvey, and Thompson, *J. Inorg. and Nuclear Chem.* **2**, 66 (1956).

<sup>4</sup> Friedman, Gindler, Barnes, Sjöblom, and Fields, *Phys. Rev.* **102**, 585 (1956).

C.S.Wu et al., *Phys. Rev.* **105**  
(1957) 1413

come. The beta-particle counter should be placed *inside* the demagnetization cryostat, and the radioactive nuclei must be located in a *thin surface* layer and polarized. The schematic diagram of the cryostat is shown in Fig. 1.

To detect beta particles, a thin anthracene crystal 2 in. in diameter  $\times$  1 in. thick is located inside the

condition, the  $\text{Cs}^{137}$  conversion line (662 keV) still retains a resolution of 17%. The stability of the beta counter was carefully checked for any magnetic or temperature effects and none were found. To measure the amount of polarization of  $\text{Co}^{60}$ , two additional NaI gamma scintillation counters were installed, one in the equatorial plane and one near the polar position. The observed gamma-ray anisotropy was used as a measure of polarization, and, effectively, temperature. The bulk susceptibility was also monitored but this is of secondary significance due to surface heating effects, and the gamma-ray anisotropy alone provides a reliable measure of nuclear polarization. Specimens were made by taking good single crystals of cerium magnesium nitrate and growing on the upper surface only an additional crystalline layer containing  $\text{Co}^{60}$ . One might point out here that since the allowed beta decay of  $\text{Co}^{60}$  involves a change of spin of

## Experimental Test of Parity Conservation in Beta Decay\*

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AND

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*National Bureau of Standards, Washington, D. C.*

(Received January 15, 1957)

IN a recent paper<sup>1</sup> on the question of parity in weak interactions, Lee and Yang critically surveyed the experimental information concerning this question and reached the conclusion that there is no existing evidence either to support or to refute parity conservation in weak interactions. They proposed a number of experiments on beta decays and hyperon and meson decays which would provide the necessary evidence for parity conservation or nonconservation. In beta decay, one could measure the angular distribution of the electrons coming from beta decays of polarized nuclei. If an asymmetry in the distribution between  $\theta$  and  $180^\circ - \theta$  (where  $\theta$  is the angle between the orientation of the parent nuclei and the momentum of the electrons) is observed, it provides unequivocal proof that parity is not conserved in beta decay. This asymmetry effect has been observed in the case of oriented  $\text{Co}^{60}$ .

It has been known for some time that  $\text{Co}^{60}$  nuclei can be polarized by the Rose-Gorter method in cerium magnesium (cobalt) nitrate, and the degree of polarization detected by measuring the anisotropy of the succeeding gamma rays.<sup>2</sup> To apply this technique to the present problem, two major difficulties had to be over-

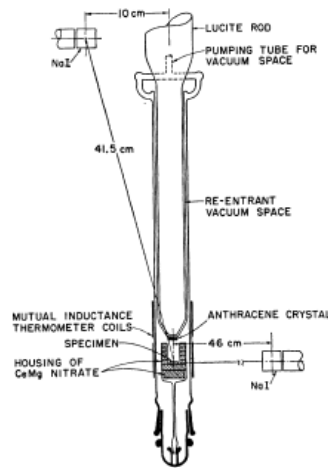


FIG. 1. Schematic drawing of the lower part of the cryostat.



Chien-Shiung Wu

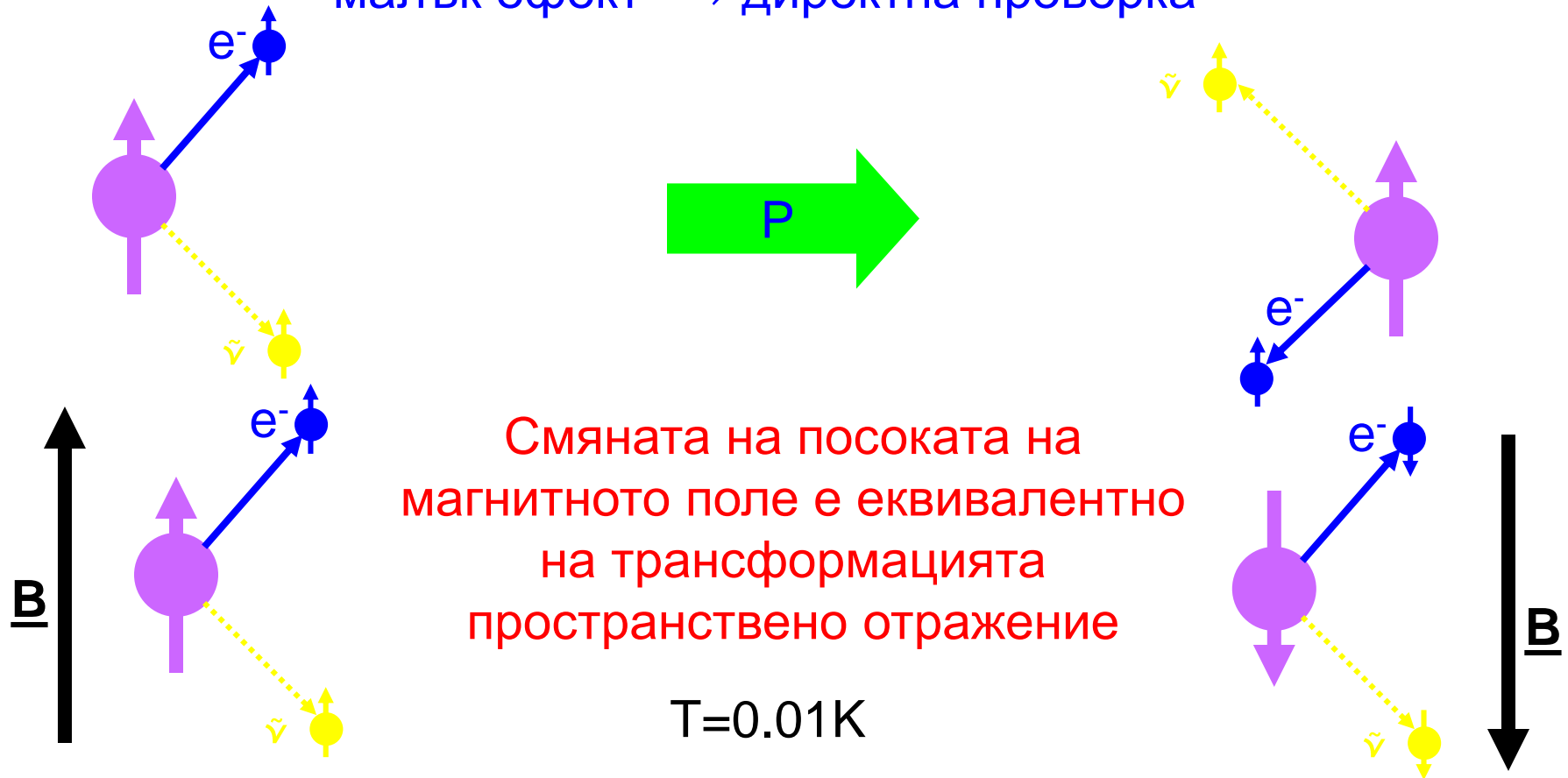
Born: May 31, 1912, Shanghai, China

Died: February 16, 1997 (aged 84)

New York City

# Експеримент на С. С. Wu

малък ефект  $\rightarrow$  директна проверка



Четността се запазва

$$N_{e^-}(\uparrow I) = N_{e^-}(\downarrow I)$$

Четността не се запазва

$$N_{e^-}(\uparrow I) \neq N_{e^-}(\downarrow I)$$

# Эксперимент на С. С. Wu

~70% эффект

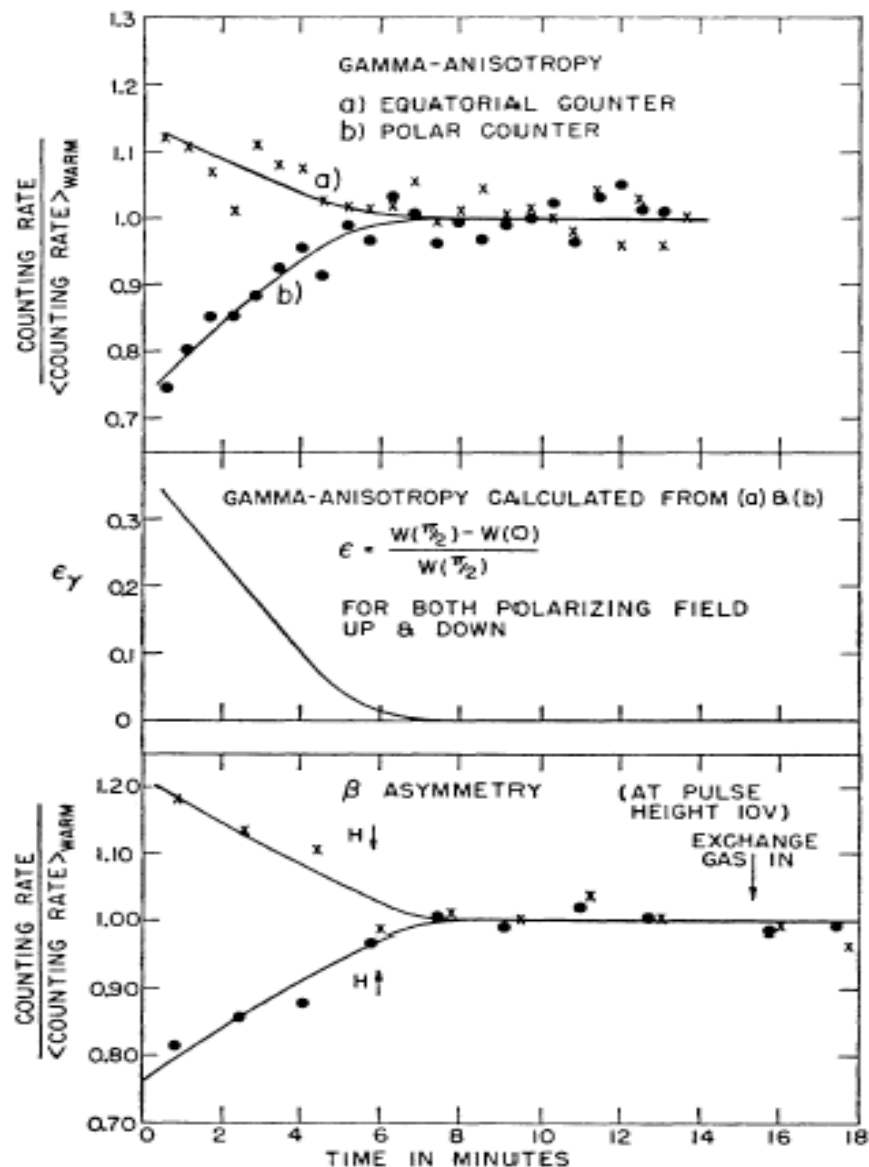
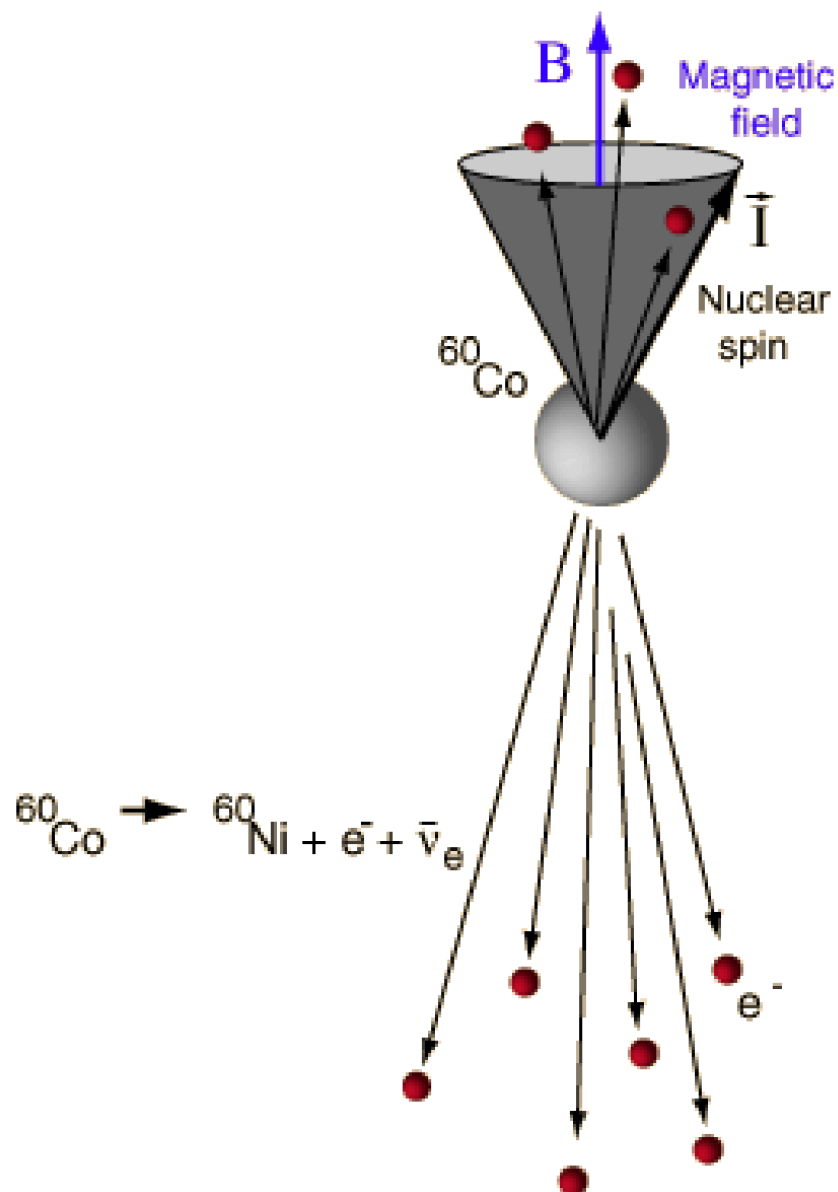
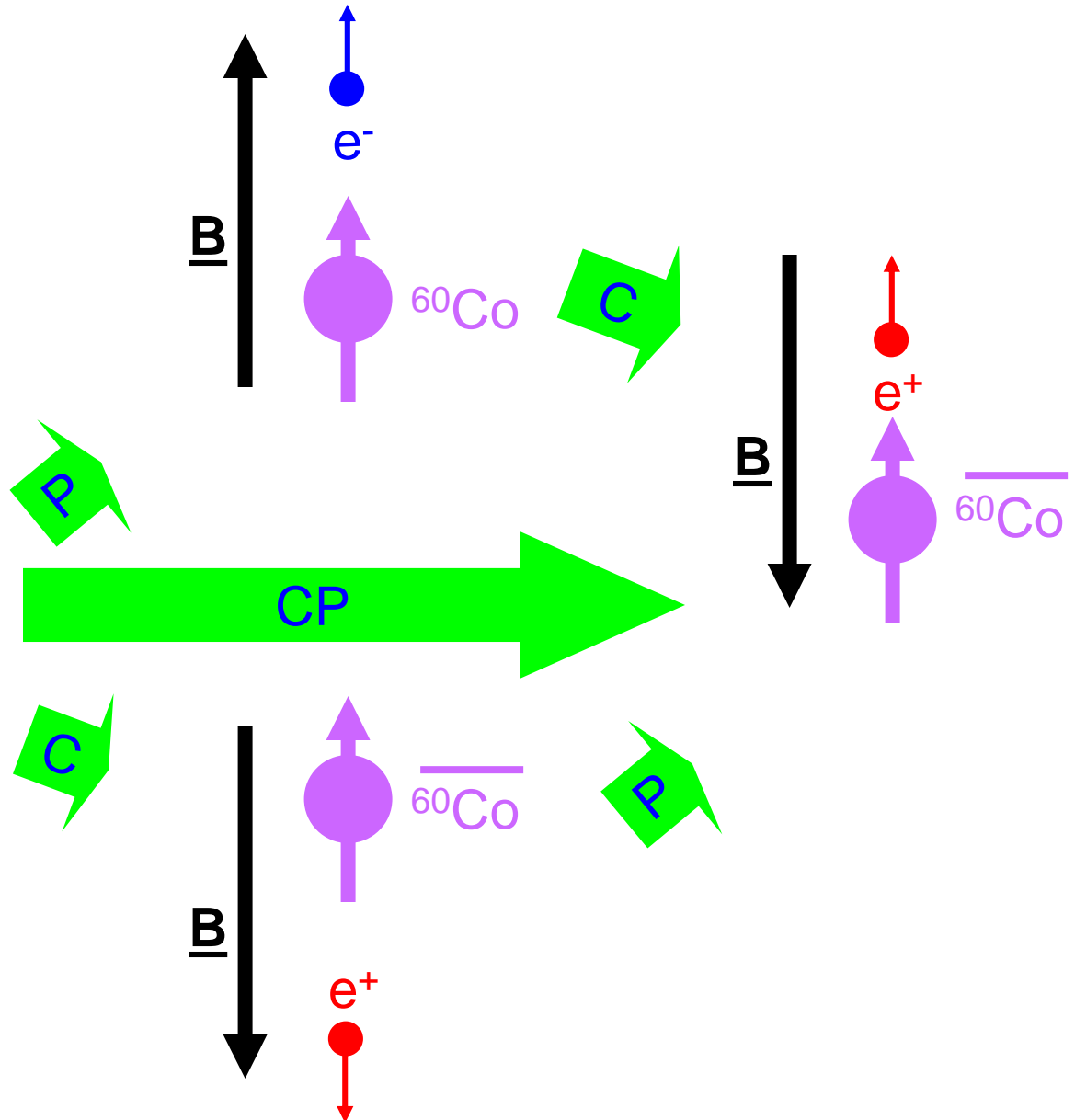
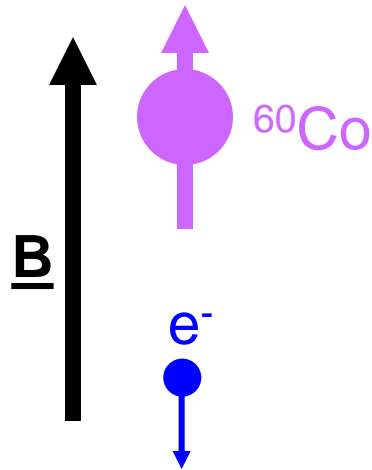
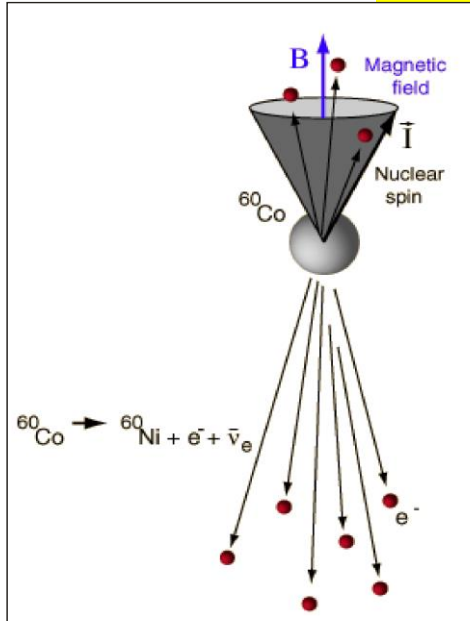


FIG. 2. Gamma anisotropy and beta asymmetry for polarizing field pointing up and pointing down.

# CP-симетрия



# СРТ-теорема

- Всяка Лоренц-инвариантна локална квантова теория на полето с ермитов хамилтониан е СРТ инвариантна
- Следствие: масите, времената на живот и спиновете на частиците и античастиците са равни

$$m_{\bar{K}^0} - m_{K^0} \approx \frac{2(m_{K_L^0} - m_{K_S^0}) |\eta| (\frac{2}{3}\phi_{+-} + \frac{1}{3}\phi_{00} - \phi_{\text{SW}})}{\sin \phi_{\text{SW}}}$$

$$|(m_{\bar{K}^0} - m_{K^0})/m_{K^0}| \leq 0.8 \times 10^{-18}$$