E AV.

Clase # 3

28/07/2025

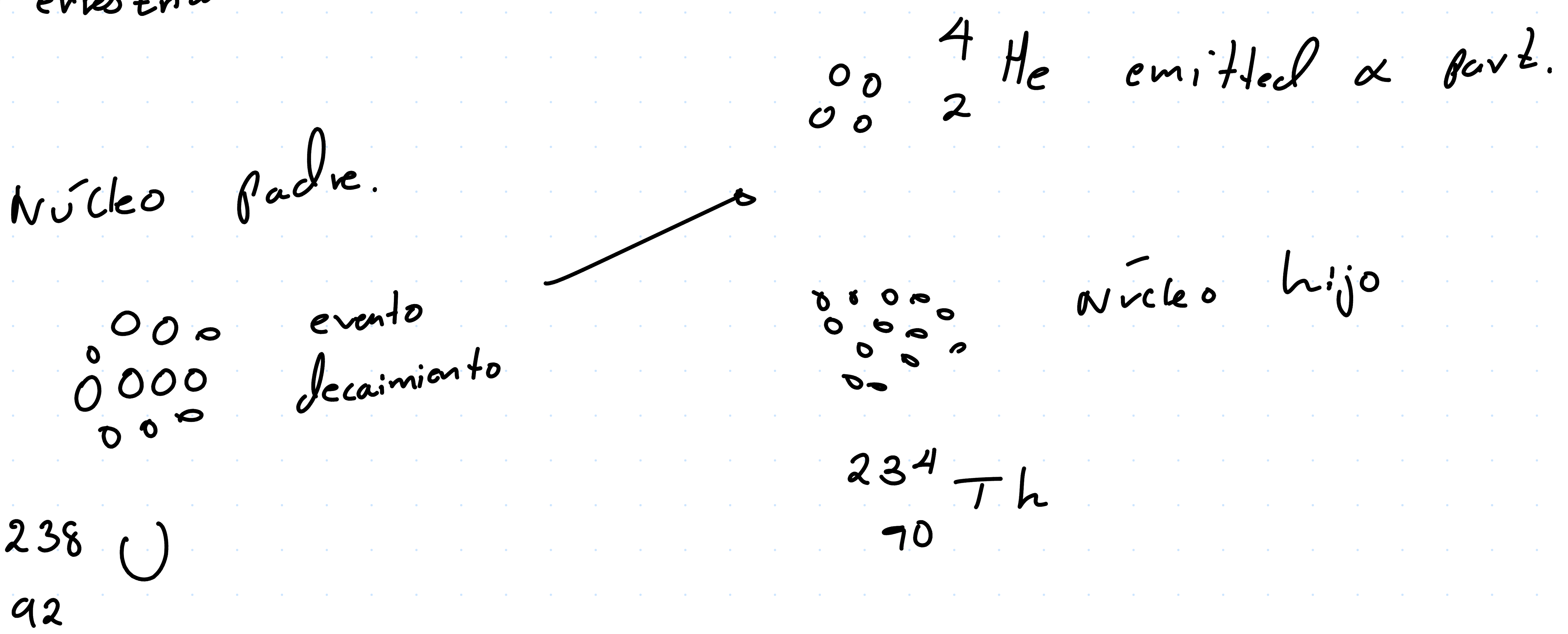
Topics in elementary particle physics.

ΛCDM

Materia bariónica : e^-, p, neutrones

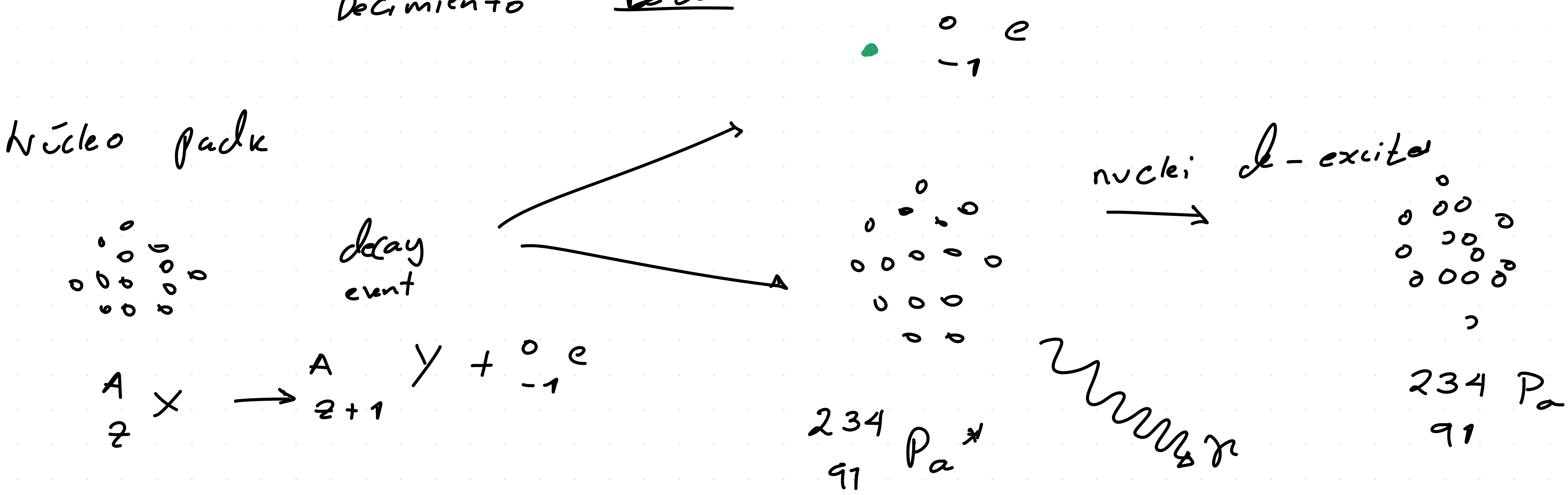
Early history (1899- 1907)

Terrestrial radioactivity (α, β, γ decays)



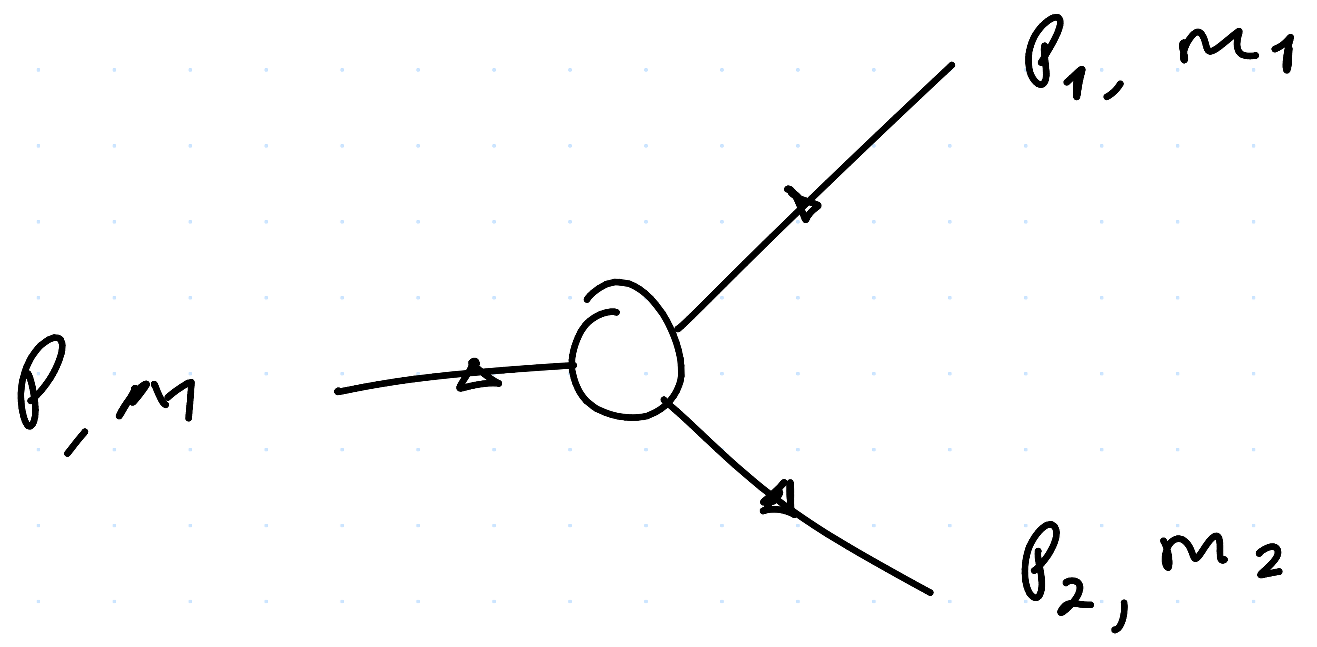
$$^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\alpha$$

Decimiento **Beta**



$$^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e$$

- Rutherford & Royds.



Two body decay

$0 \to 1+2$ decay in the rest frame of 0.

4-momenta are related by

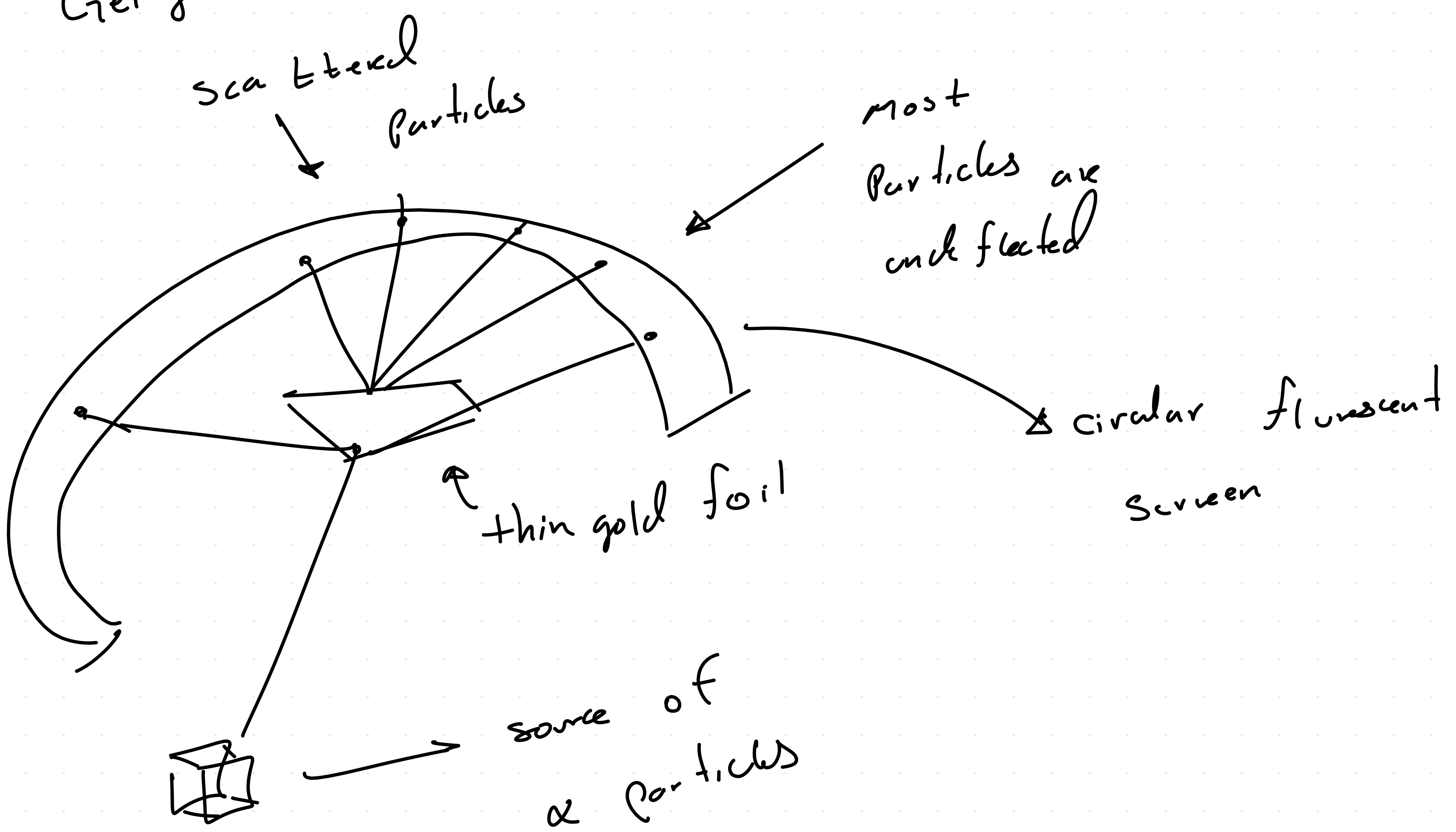
$p = p_1 + p_2$, $P = (M, 0) \Rightarrow p_2 = P - p$ and:

$$p_2^2 = (P - p_1)^2 = P^2 - 2P \cdot p_1 + p_1^2,$$

$$m_2^2 = M^2 - 2ME_1 + m_1^2 \Rightarrow E_1 = \frac{M^2 + m_1^2 - m_2^2}{2M}$$

Rutherford scattering

Geiger - Marsden Experiment (1908 - 1913)



Cosmic rays (1912)

- Hess (1912): Ionization rates at increasing height not explained cosmic-ray air showers

- Primaries: protons and alpha particles (~99%), heavier nuclei (~1%), ...

- Secondaries: ...

Matter Creation

(Mass-energy equivalence).

Antimatter (1932)

- Dirac (1928-1931, N.P.P. 1933): negative-energy solution of Quantum-Relativistic eq. for e^- = "anti-electron" (e^+) or positron.

- Anderson (1932, N.P.P. 1936):

  observed trail 10x longer than expected for

Cloud Chamber

- cloud chamber: device with supersaturated water-vapor (or/and alcohol)

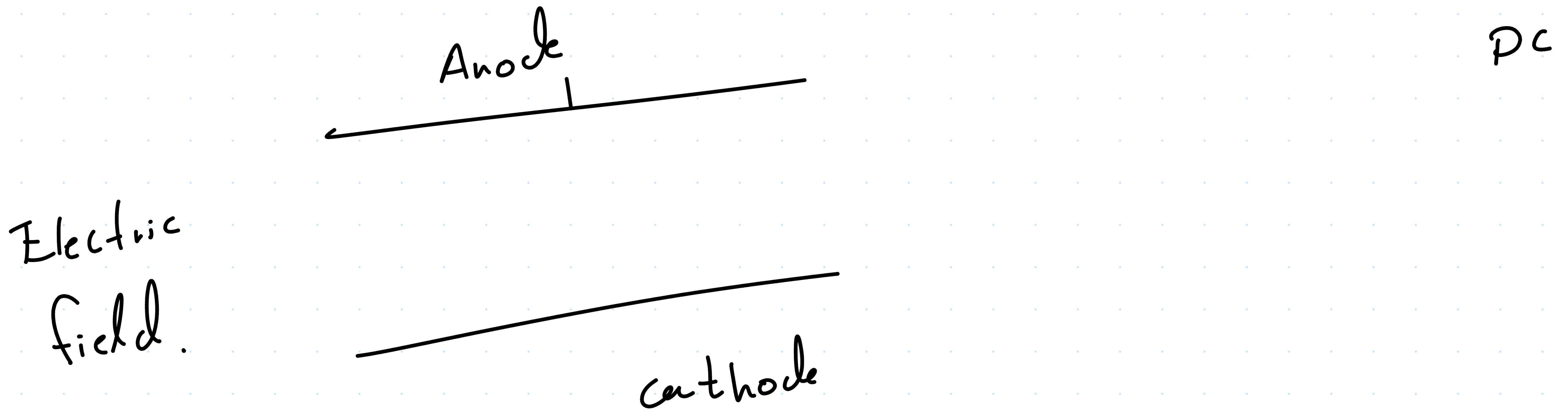
Neutron (1931 - 1935)

- Proton: Discovered by Rutherford. (1917-1919)

- Neutron Proposed (1920) by Rutherford to explain atomic mass (eg. of He), as a p-e^- system(!).

- Bothe (N.P.P. 1954) & Becker (1931, Fig.)

Ionization chamber



The photon

- Planck (1900, N.P.P. 1918): assumed $E_{EM} = nh\nu$ to fit black body rad. (UV catastrophe) spectrum.

- Einstein (1905, N.P.P. 1921): in photoelectric effect (PE), maximum E_e is independent of intensity of light.

- Millikan (1916, N.P.P. 1923): Experimental confirmation of Einstein's equation.

- Compton (1923, N.P.P. 1927, $\Delta_\lambda = h(1-\cos\theta/m_e c)$: measures inelastic scattering of light by free.

Light - electron interaction theory

- Born, Heisenberg, Jordan, (1925, N.P.P. 1954, -, 1532) and Dirac (1927): theory of the EM-field and its interaction with matter; introduces photon creation and annihilation operators.

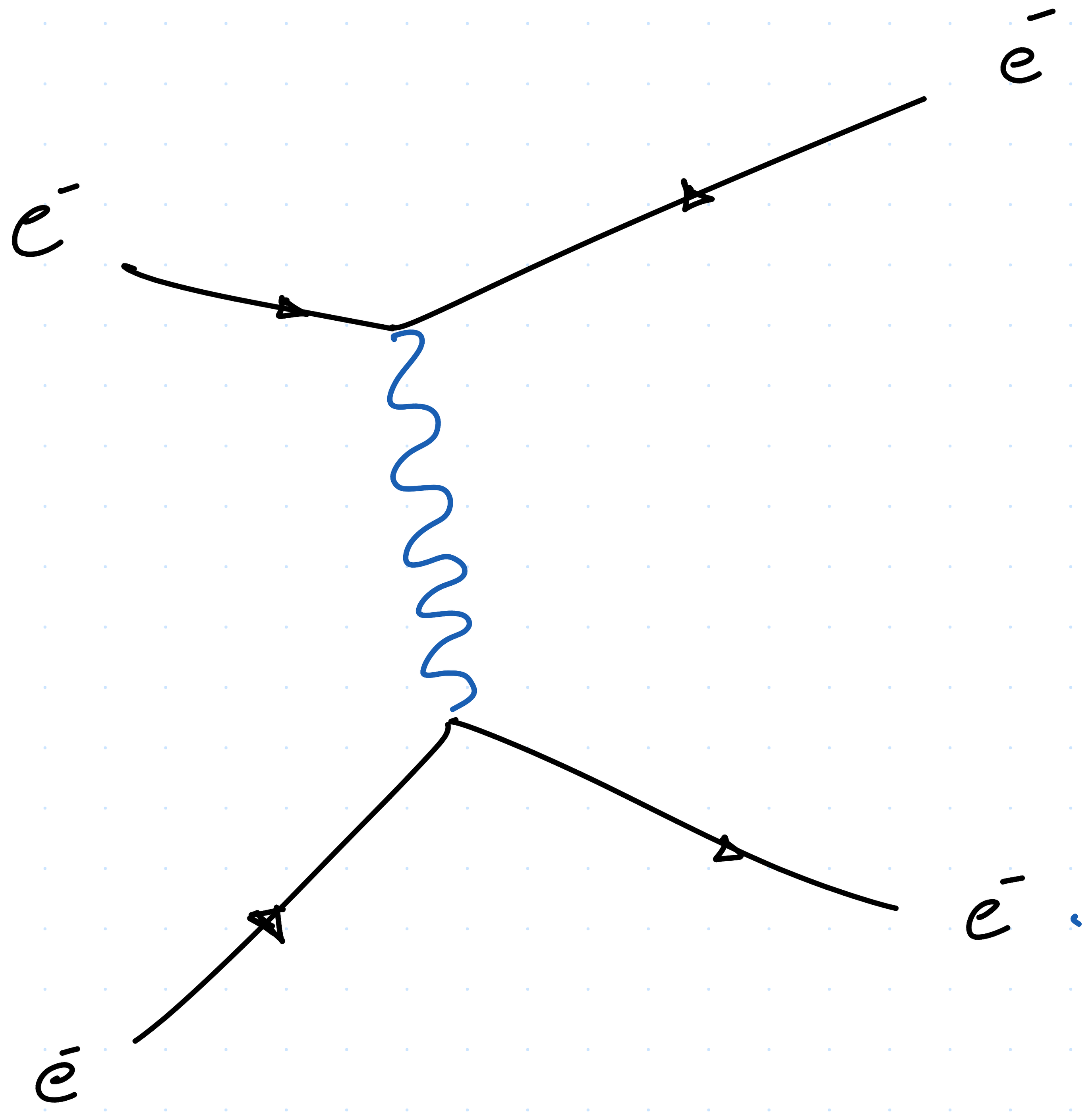
- Quantum electrodynamics (QED) fully developed by Feynman, Schwinger & Tomonaga (N.PP. 1965) by using Quantum Field theory (QFT):

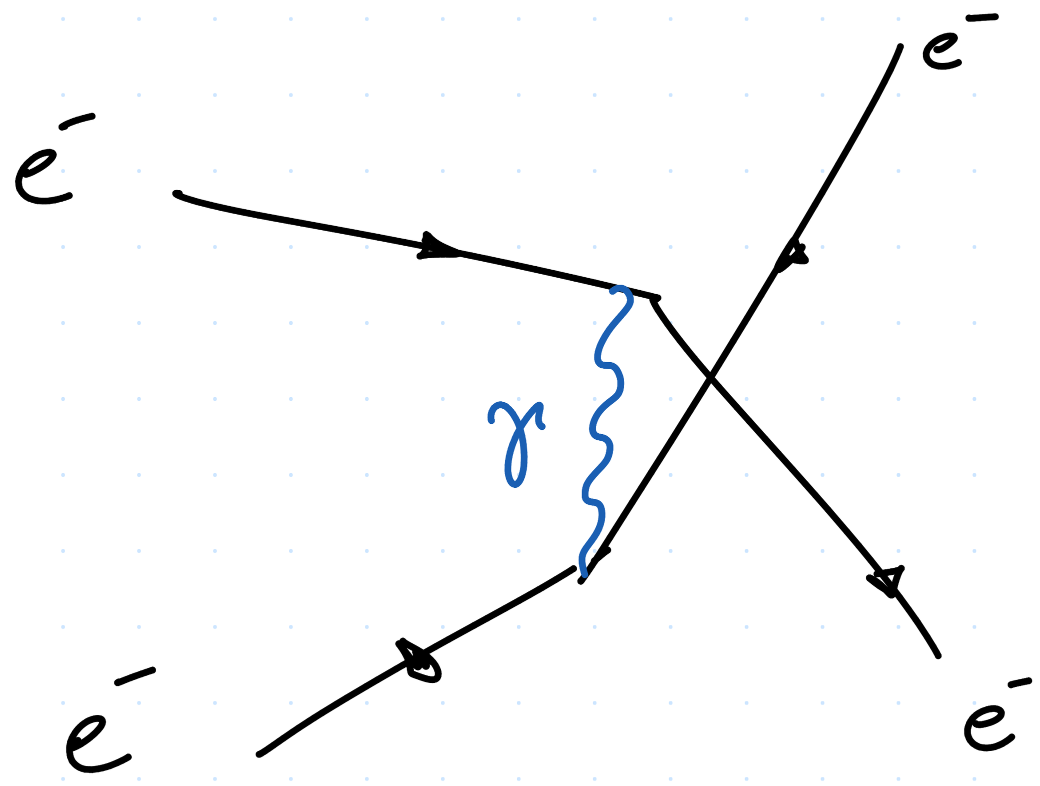
- Tool to unify QM and special relativity.

Feynman diagrams (1948)

$e^- - e^-$ coulomb scattering

(Møller)





$e^- - e^+$ coulomb scattering

(Babha).

What holds the nucleus together?

“A new force, stronger than the EM, is needed explain the short.

Yukawa meson

- Interaction btw 2 fermions ($p-p$, $n-n$, $p-n$) through ...

Potential

$$V(r) = \frac{-g^2}{(2\pi)^3} \int e^{ik\cdot r} \frac{4\pi}{k^2+m^2} d^3k = -g^2 \frac{e^{-mr}}{r}$$

$$(\Box + m^2) G(x,x') = \delta^4(x-x')$$

— o — o — o Muon (1936) — o — o — o —

- First observed by P. Kunze (1932), "discovered" by C.D. Anderson & S. Neddermeyer (1936) and confirmed by J.C. Street & E.C. Stevenson (1937).

Pion meson (1947)

Mass deduced from grain density

$\frac{m_\pi}{m_\mu} \approx 1.3$ $\quad E_\mu$ deduced from (secondary) cosmic rays reaching ground level.

- Can a muon produced in the atmosphere (~ 8000 m) reach earth considering it has a proper life time of $T_\mu = 2.2 \times 10^{-6}$ s ?