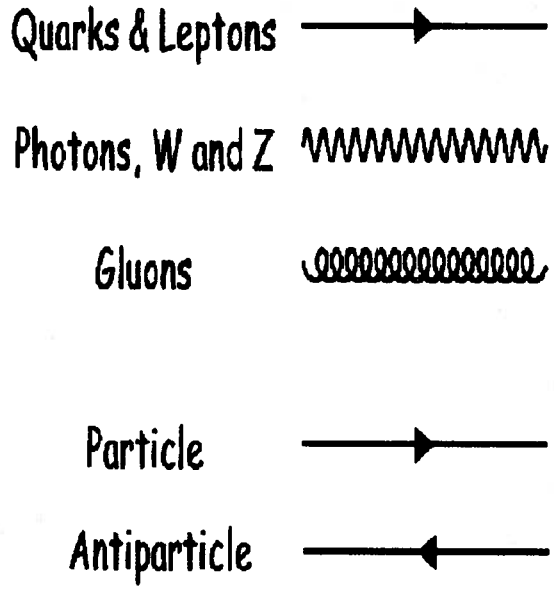
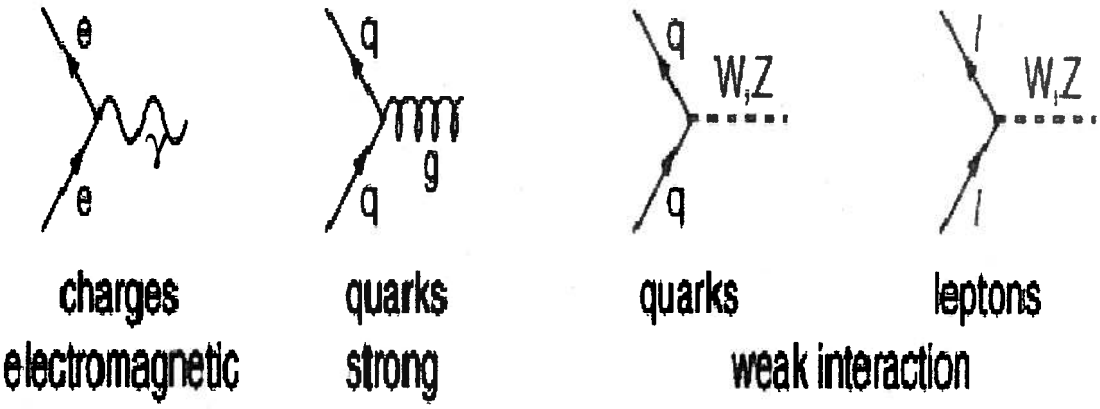
Particle Interactions & Feynman Diagrams

- Feynman diagrams are fantastic tools for graphically representing particle interaction processes and for performing calculations
- The interactions occur by the emission and absorption of gauge bosons at the "vertices"

Conventional Representations



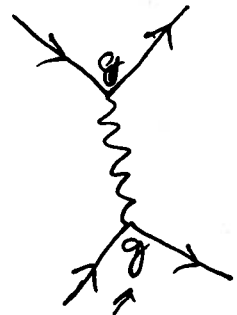


Note alternate convention for W,Z

Standard Model Interactions & Vertices

- Forces are mediated by the exchange of spin-1 gauge bosons

Force	Mediator	m(GeV)
EM(QED)	Photon γ	0
Weak	$W^{\pm}, Z$	80/91
Strong(QCD)	Gluons g (8)	0

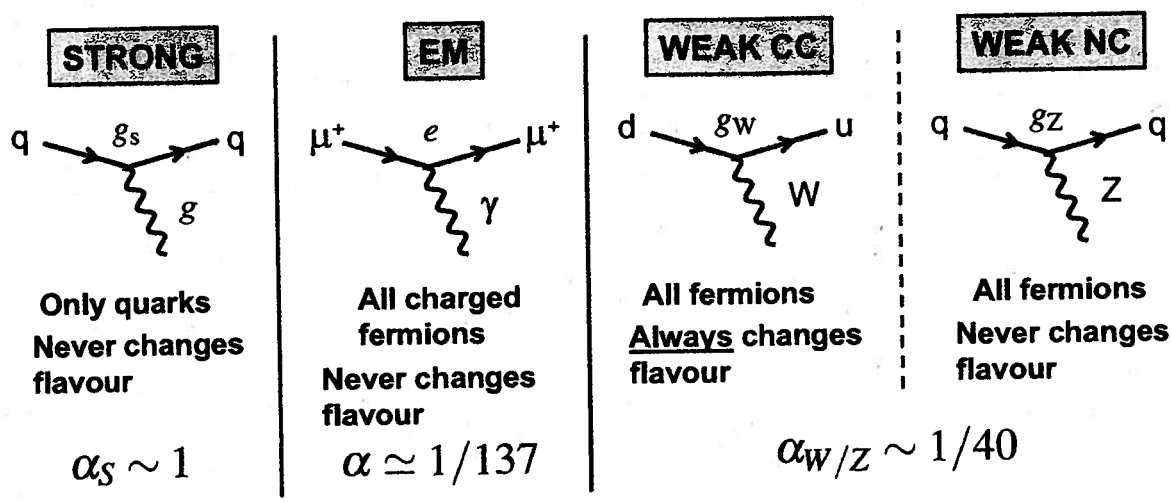


- The interaction strength or coupling is given by "charge" g

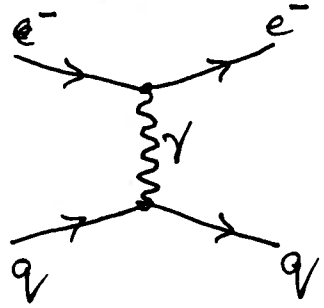
In QED, $g_{em} = e = \sqrt{4\pi\alpha\epsilon_0\hbar c}$ α is dimensionless

In Natural units, $g = \sqrt{4\pi\alpha}$

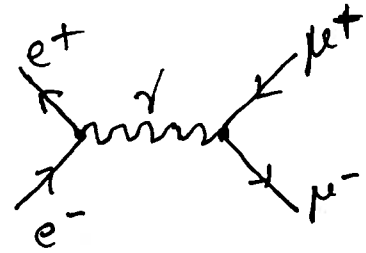
- Interaction of gauge bosons with fermions is described by the SM vertices

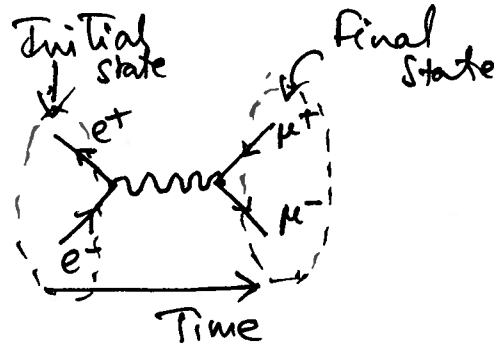


eq scattering



e^+e^- Annihilation



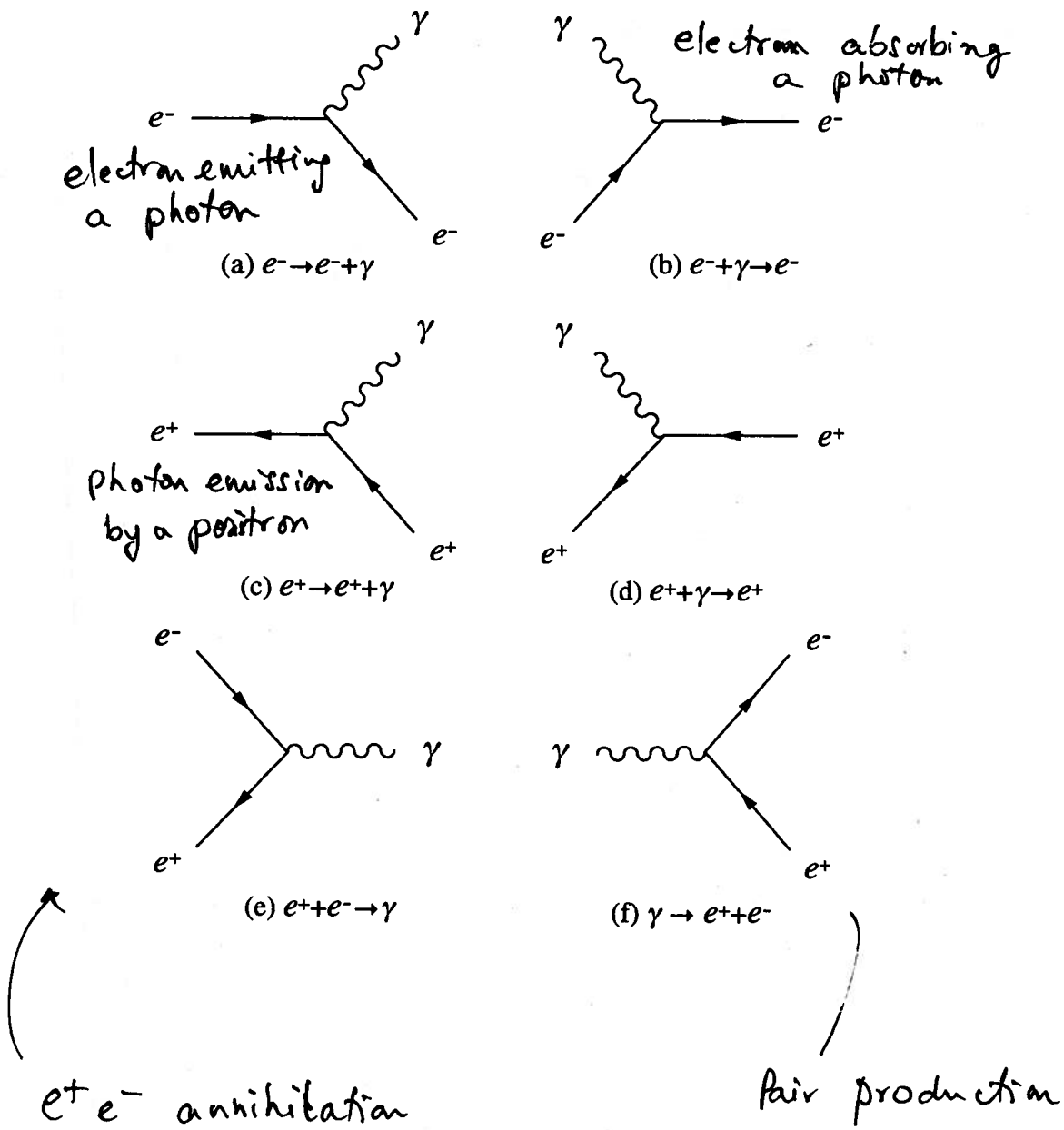


- Time flows from left to right
- Antiparticle is shown with an arrow going backwards in time
- Left hand side of the diagram represents the initial state. Right hand side represents the final state.
- Energy, momentum, angular momentum, charge, etc. are conserved at each vertex.
- The intermediate state is a "<u>virtual</u>" process

Virtual process need not conserve energy. The process happens in a very short time such that

$$\Delta E \cdot \Delta t \sim \hbar$$

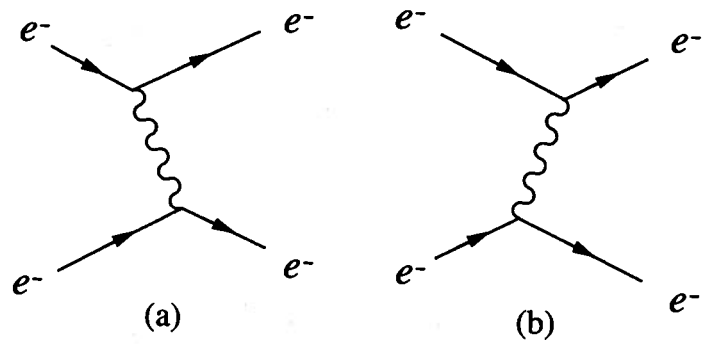
QED Processes / Vertices



e^+e^- annihilation

Pair production

Diagrams for e-e Scattering

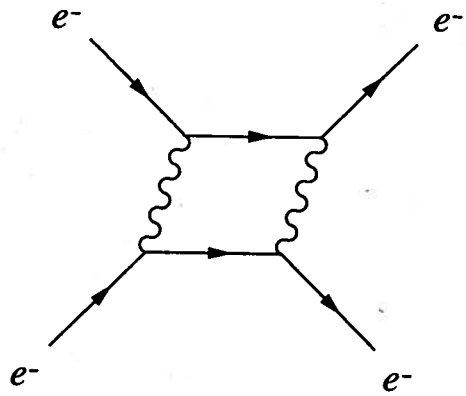


Lowest order

Amp $\sim \alpha^2$

Figure 1.7 Single-photon exchange contributions to electron–electron scattering. Time as usual runs from left to right.

Time-ordered diagrams. Both diagrams contribute. It is not possible to decide which electron emits the photon first!



Amp. $\sim \alpha^4$

Figure 1.8 A contribution to electron–electron scattering from two-photon exchange.

One can have n-photon exchanges with order α^{2n}.

But, normally higher order photon exchanges can be neglected.

Some other Processes

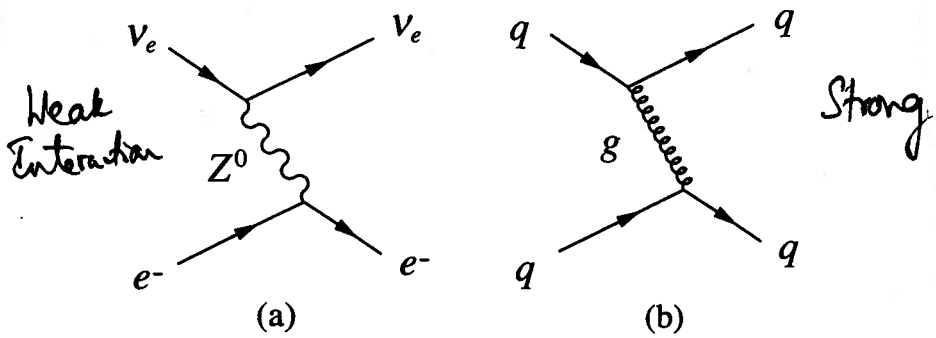


Figure 1.12 (a) Contributions of (a) Z^0 exchange to the elastic weak scattering reaction $e^- + \nu_e \rightarrow e^- + \nu_e$ and (b) the gluon exchange contribution to the strong interaction $q + q \rightarrow q + q$.

Weak Decay of n

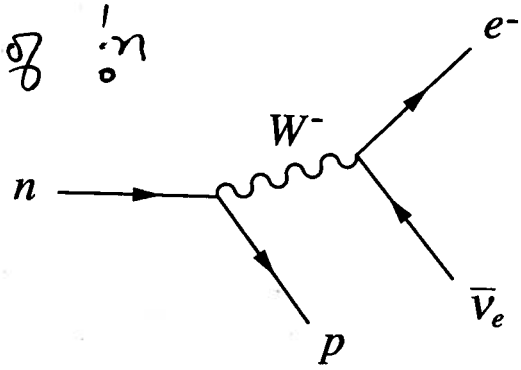
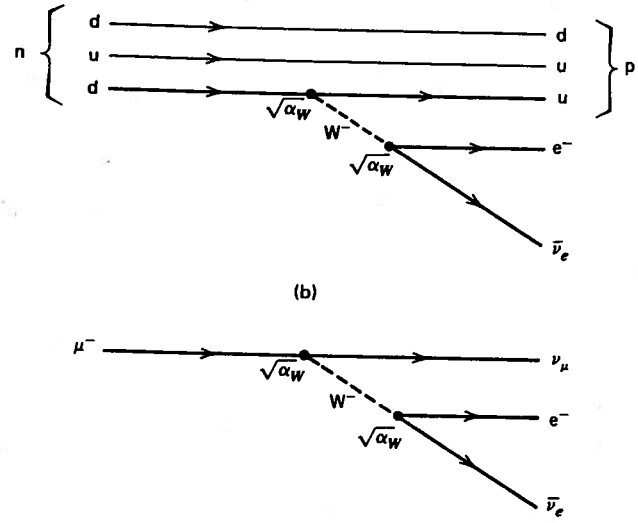


Figure 1.13 The decay $n \rightarrow p + e^- + \bar{\nu}_e$ via an intermediate W meson.

Actual SM process for neutron decay



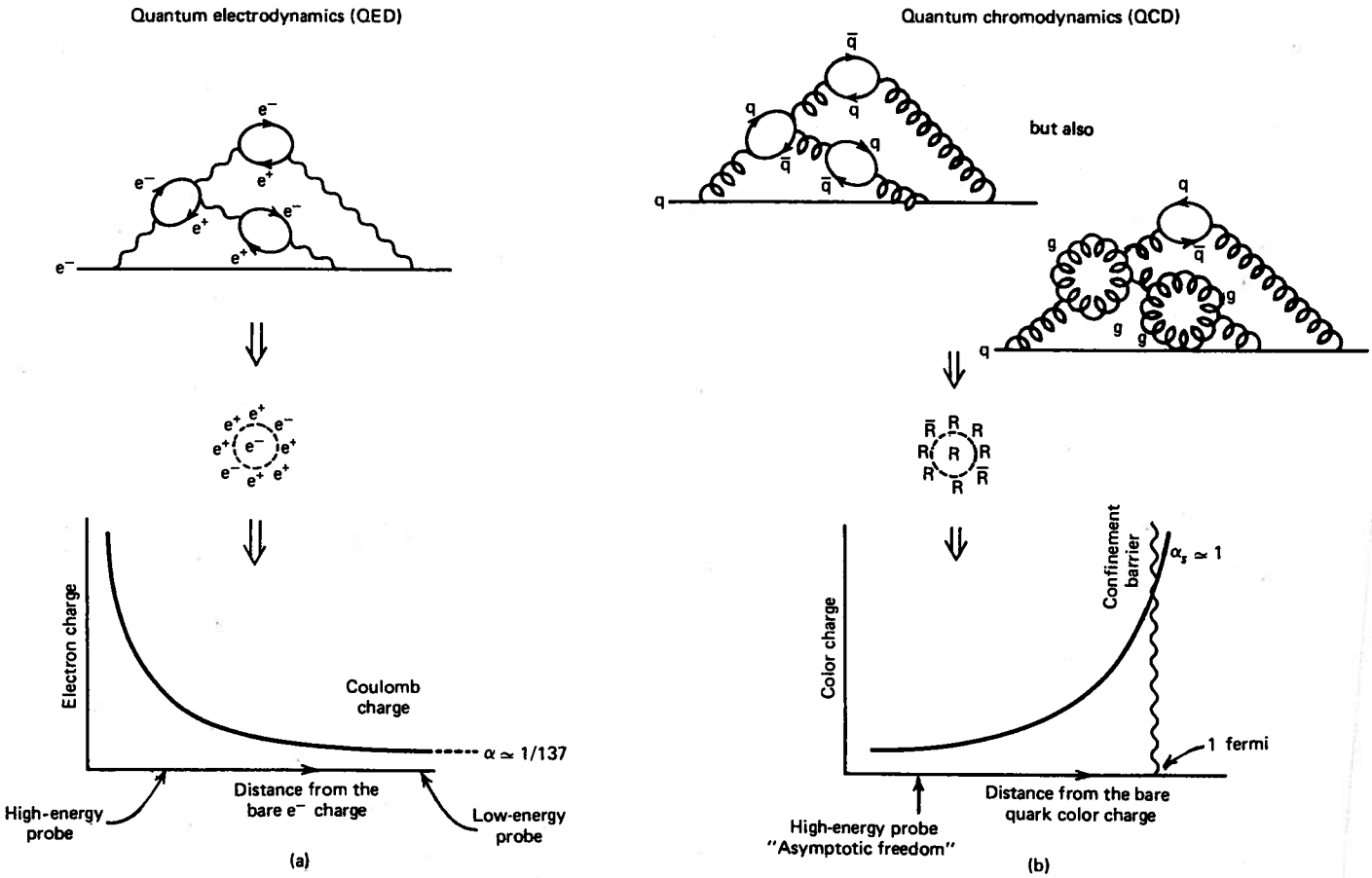
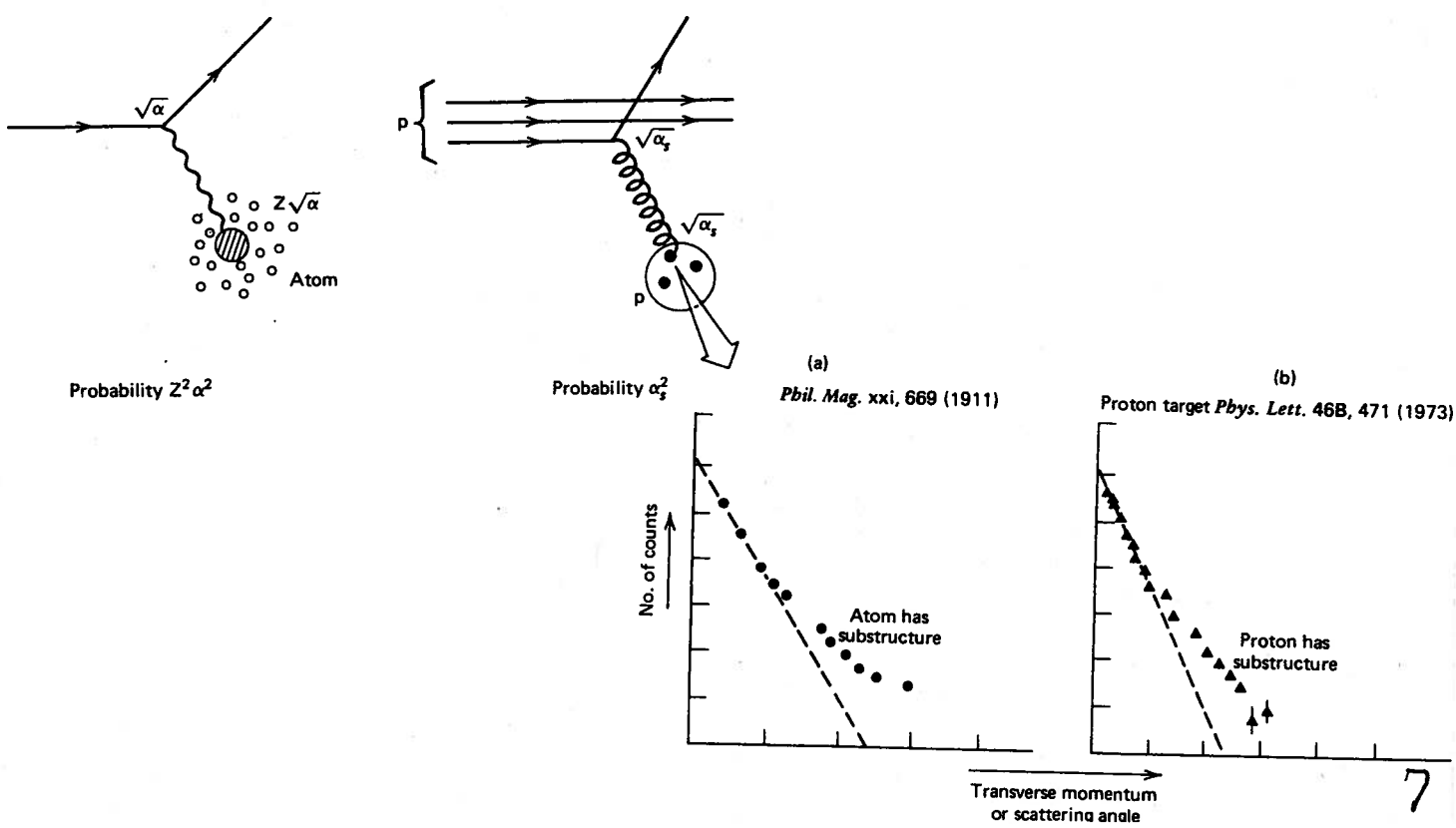



Fig. 1.5 Screening of the (a) electric and (b) color charge in quantum field theory.