First LHC School
Lecture#1

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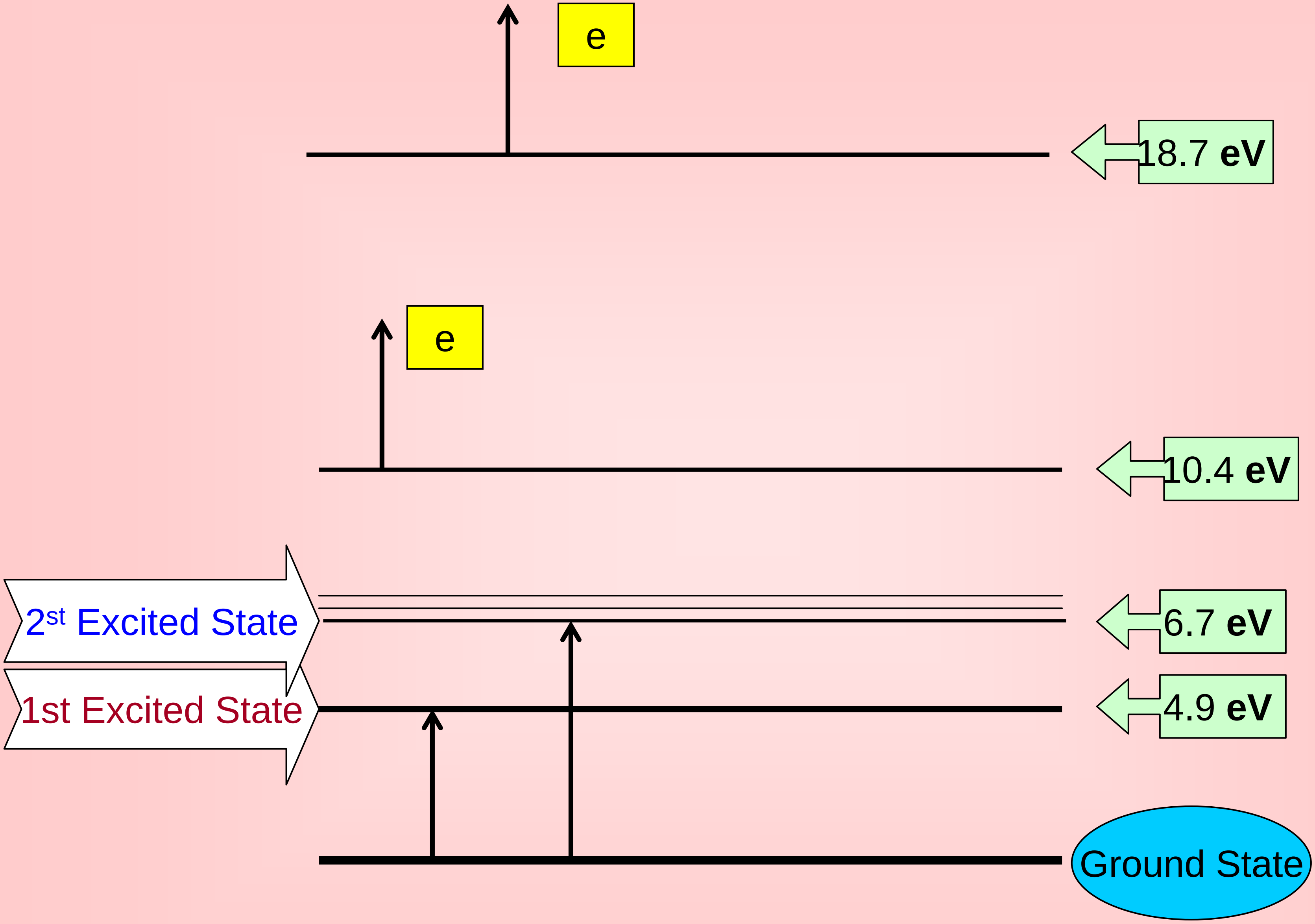


e

18.7 eV

e

10.4 eV

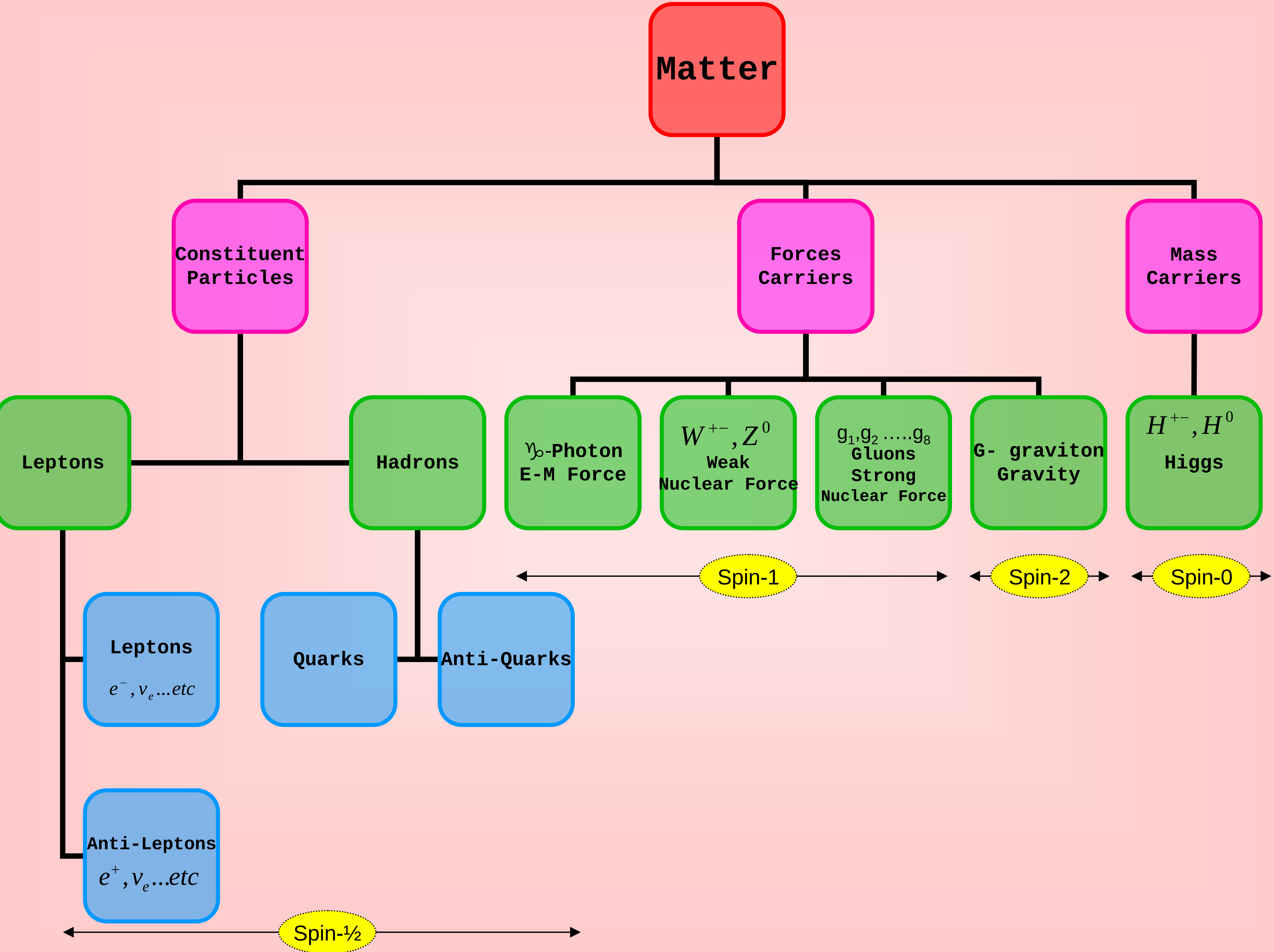
2st Excited State

6.7 eV

1st Excited State

4.9 eV

Ground State



Matter

Constituent Particles

Forces Carriers

Mass Carriers

Leptons

Hadrons

♑-Photon E-M Force

W^{+-}, Z^{0} **Weak Nuclear Force**

$g_1, g_2 \ldots g_8$ **Gluons Strong Nuclear Force**

G- graviton Gravity

H^{+-}, H^{0} **Higgs**

Spin-1

Spin-2

Spin-0

Leptons $e^{-}, v_{e} \ldots etc$

Quarks

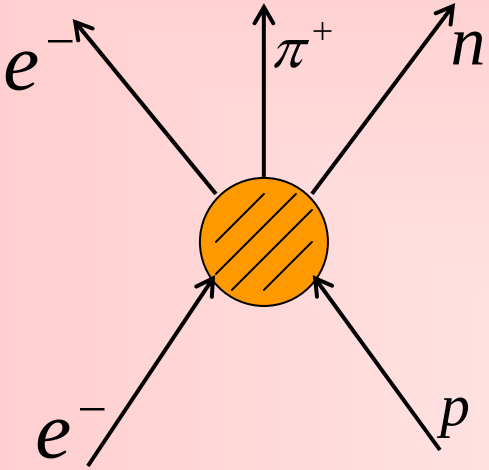
Anti-Quarks

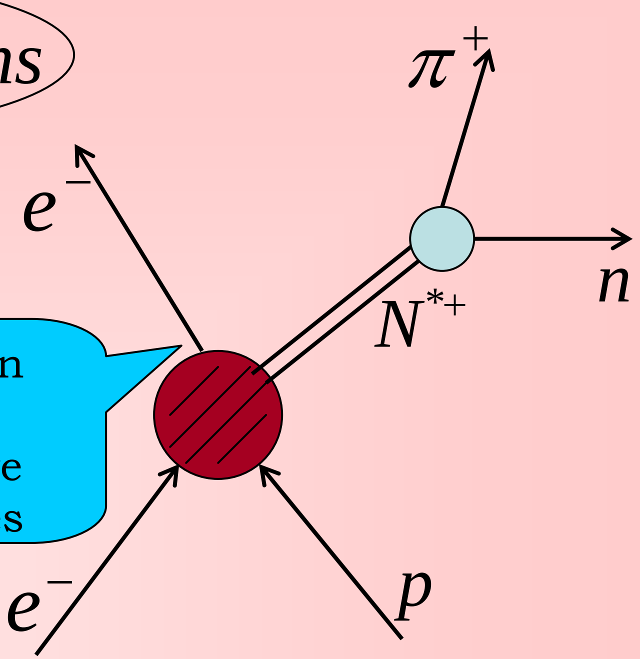
Anti-Leptons $e^{+}, v_{e} \ldots etc$

Spin-½

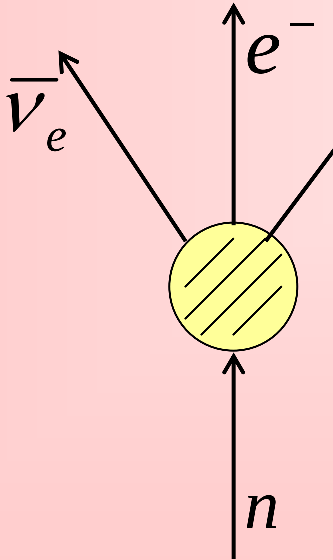
Particle Reactions

$$e^- + p \rightarrow e^- + n + \pi^+$$

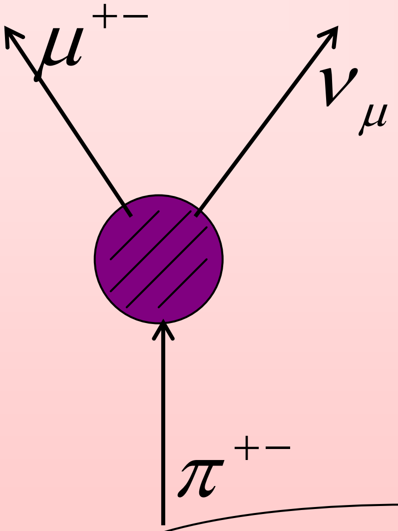


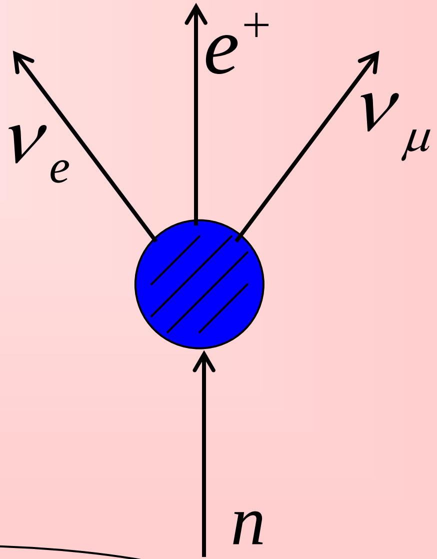


This Reaction shows that Nucleus have excited states

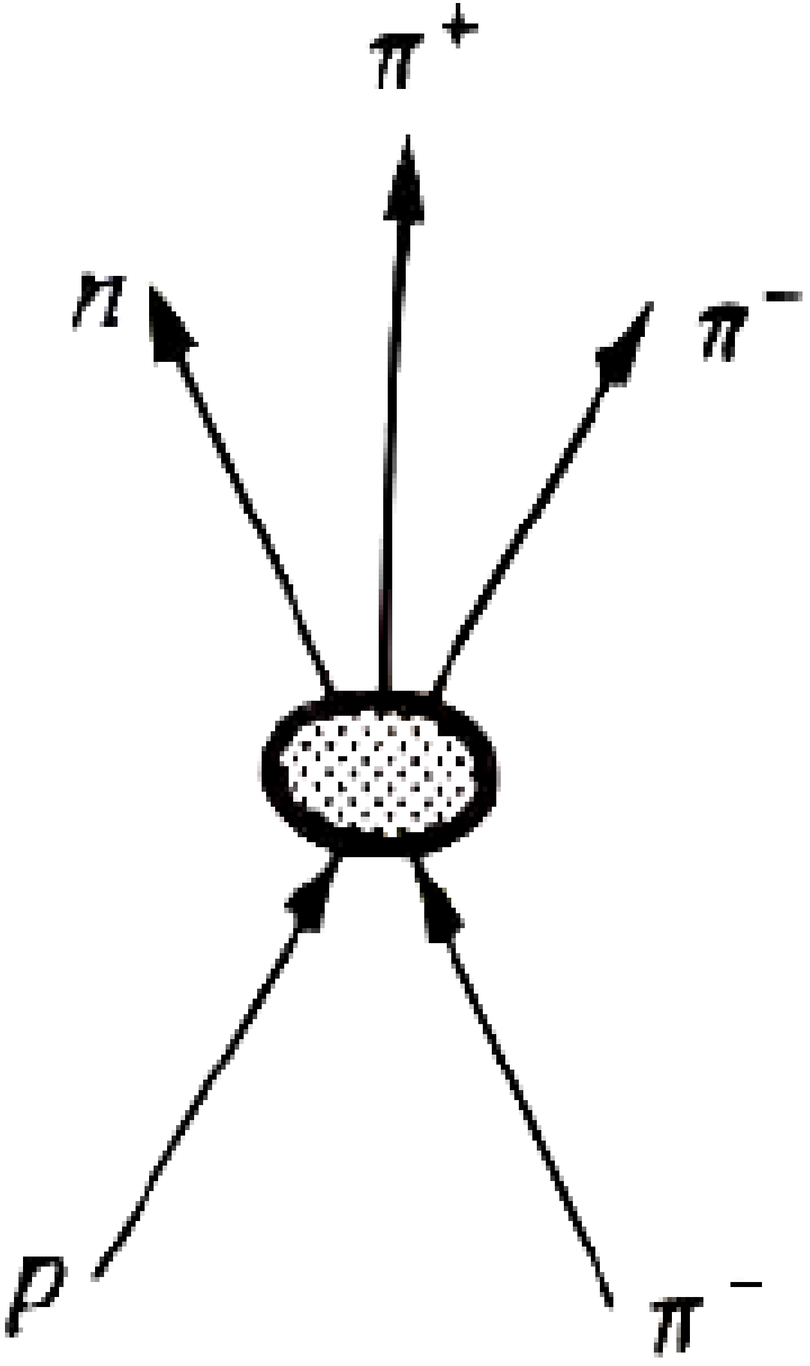


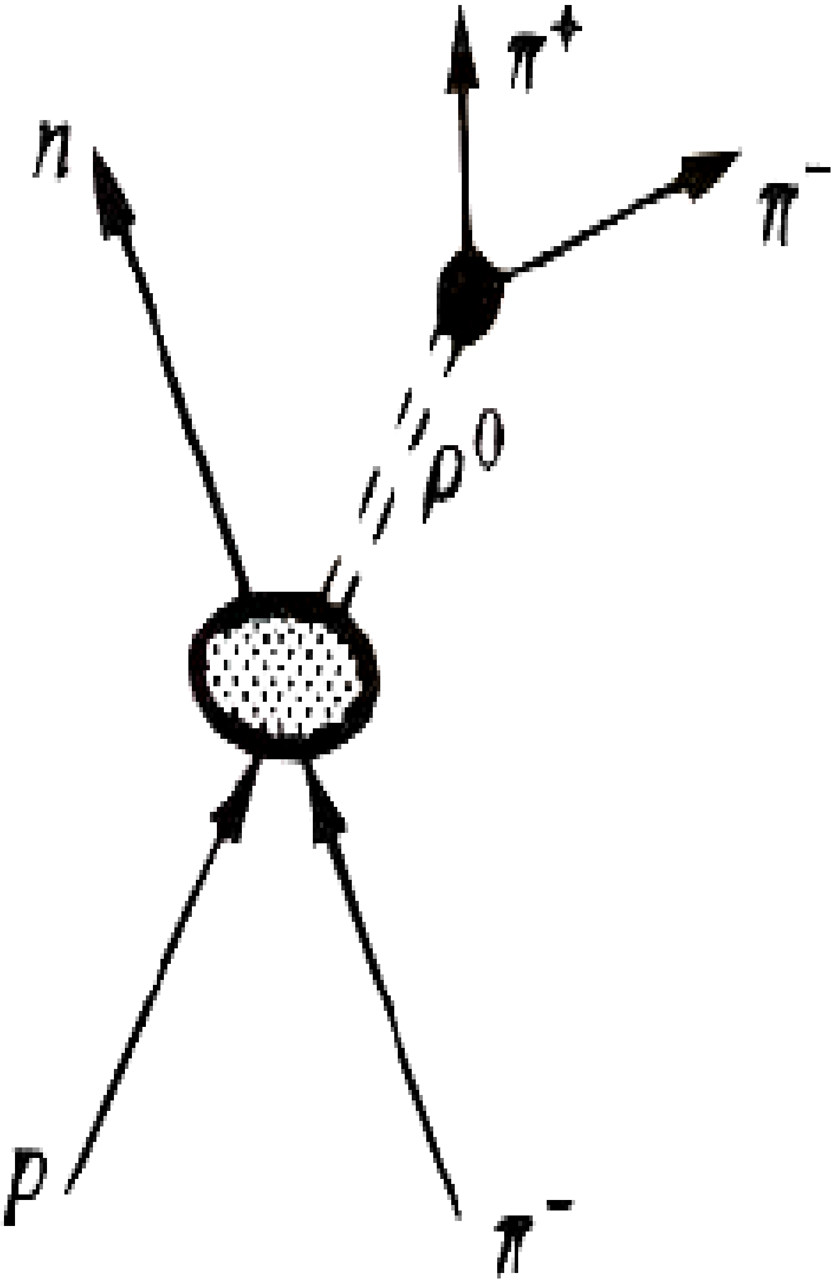
$$n \rightarrow p + e^- + \nu_e$$





Scattering Processes


π^+
n
π^-
p
π^-


π^+
n
π^-
ρ^0
p
π^-

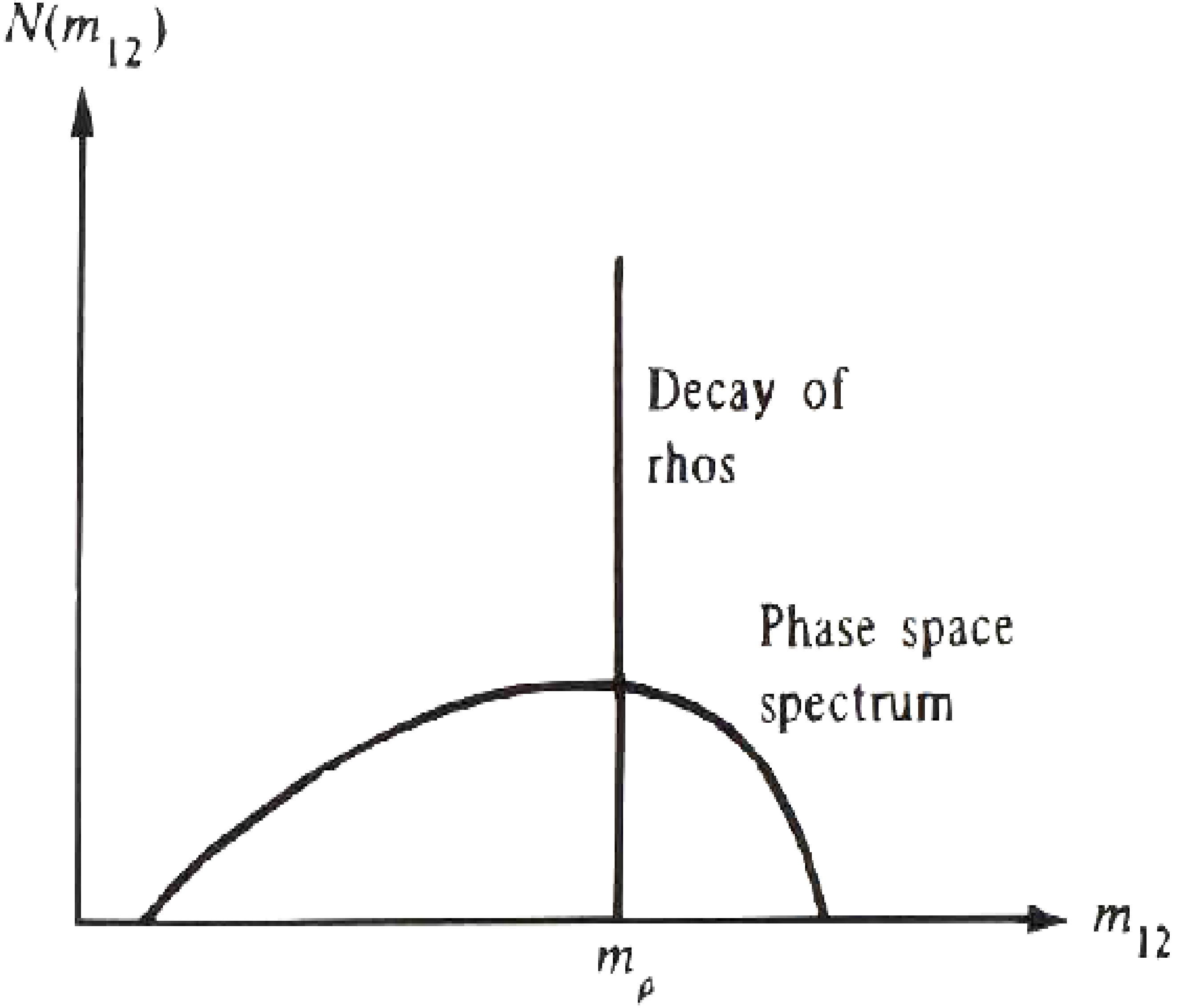


Figure 5.11: Invariant mass spectrum if pion pairs are produced independently (phase space) or if they result from the decay of a rho of small decay width.

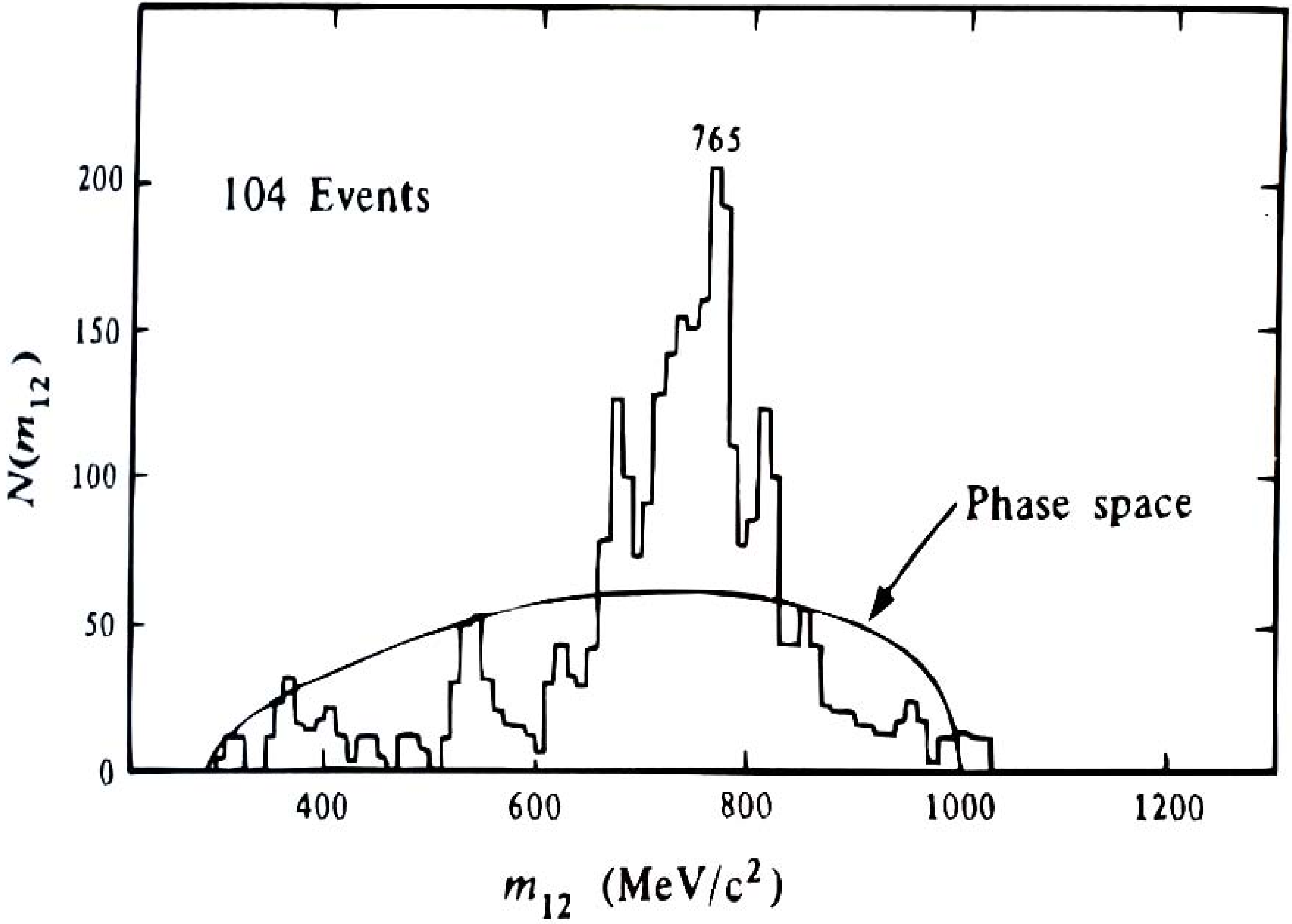


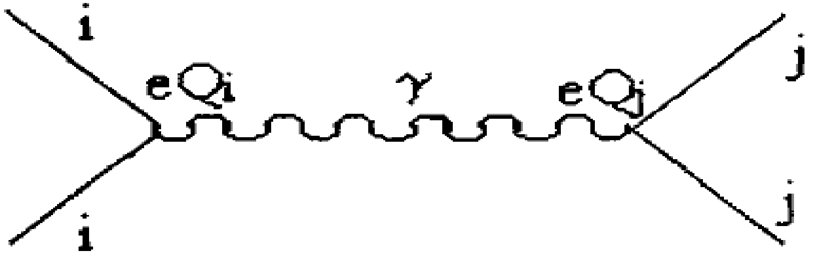
Figure 5.12: Invariant mass spectrum of the two pions produced in the reaction $p\pi^- \rightarrow n\pi^+\pi^-$. [After A. R. Erwin, R. March, W. D. Walker, and E. West, *Phys. Rev. Lett.* **6**, 628 (1961).]

Electromagnetic Force Between 2 Electrically Charged Particles

We deal with electrically neutral atoms.

Mediator of the electromagnetic force is electrically neutral massless spin 1 photon, the quantum of the electromagnetic field.

Exchange of photon gives the electric potential:



$V_{ij}^e = \frac{e^2}{4\pi}\frac{Q_iQ_j}{r}, r = |\mathbf{r}_i - \mathbf{r}_j|$

For an electron and proton

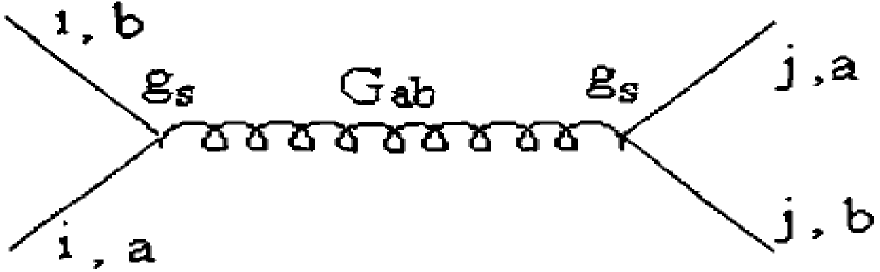
$V_{ij} = -\frac{\alpha}{r}, \alpha = \frac{e^2}{4\pi}$

Strong Color Force Between 2 Quarks

We deal with color singlet systems i.e. hadrons.

Mediators are eight massless spin 1 color carrying gauge vector bosons, called gluons.

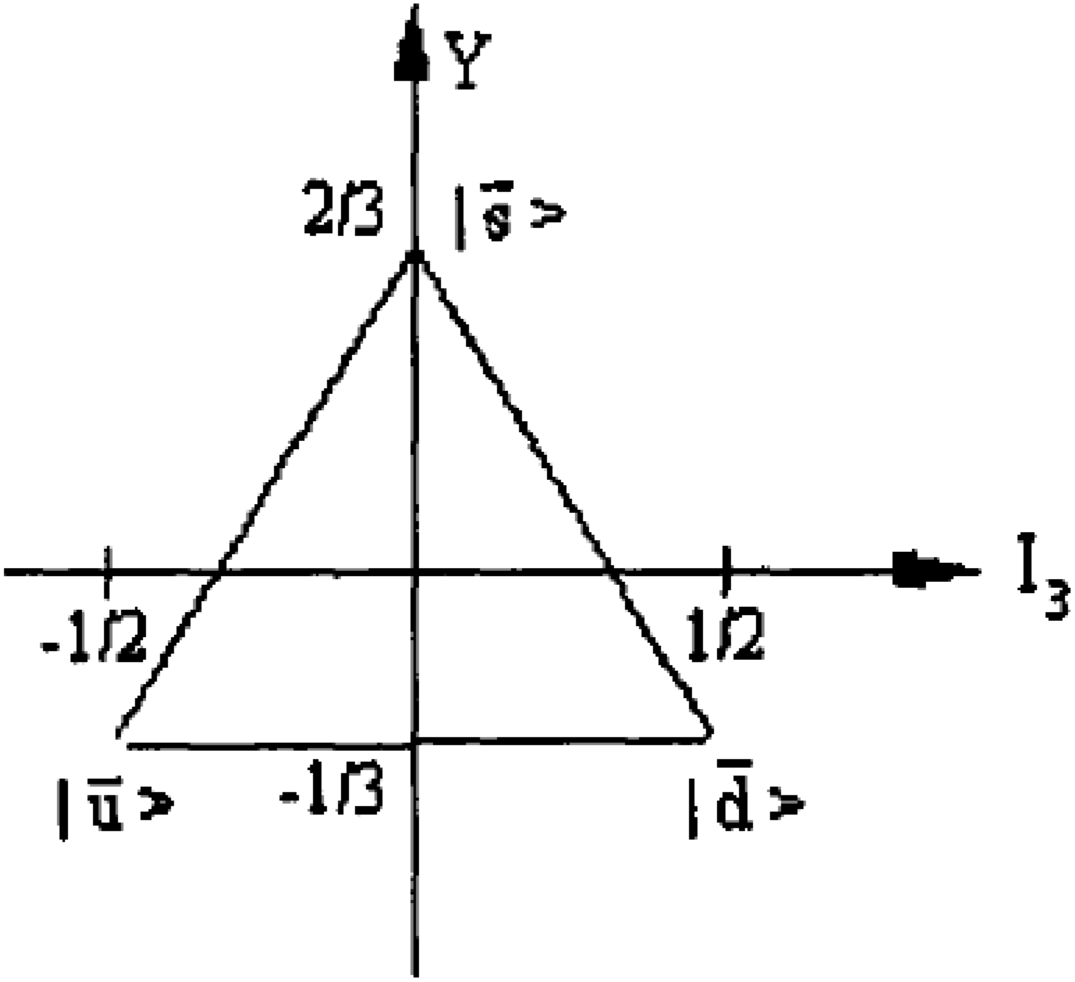
Exchange of gluons gives the color electric potential:

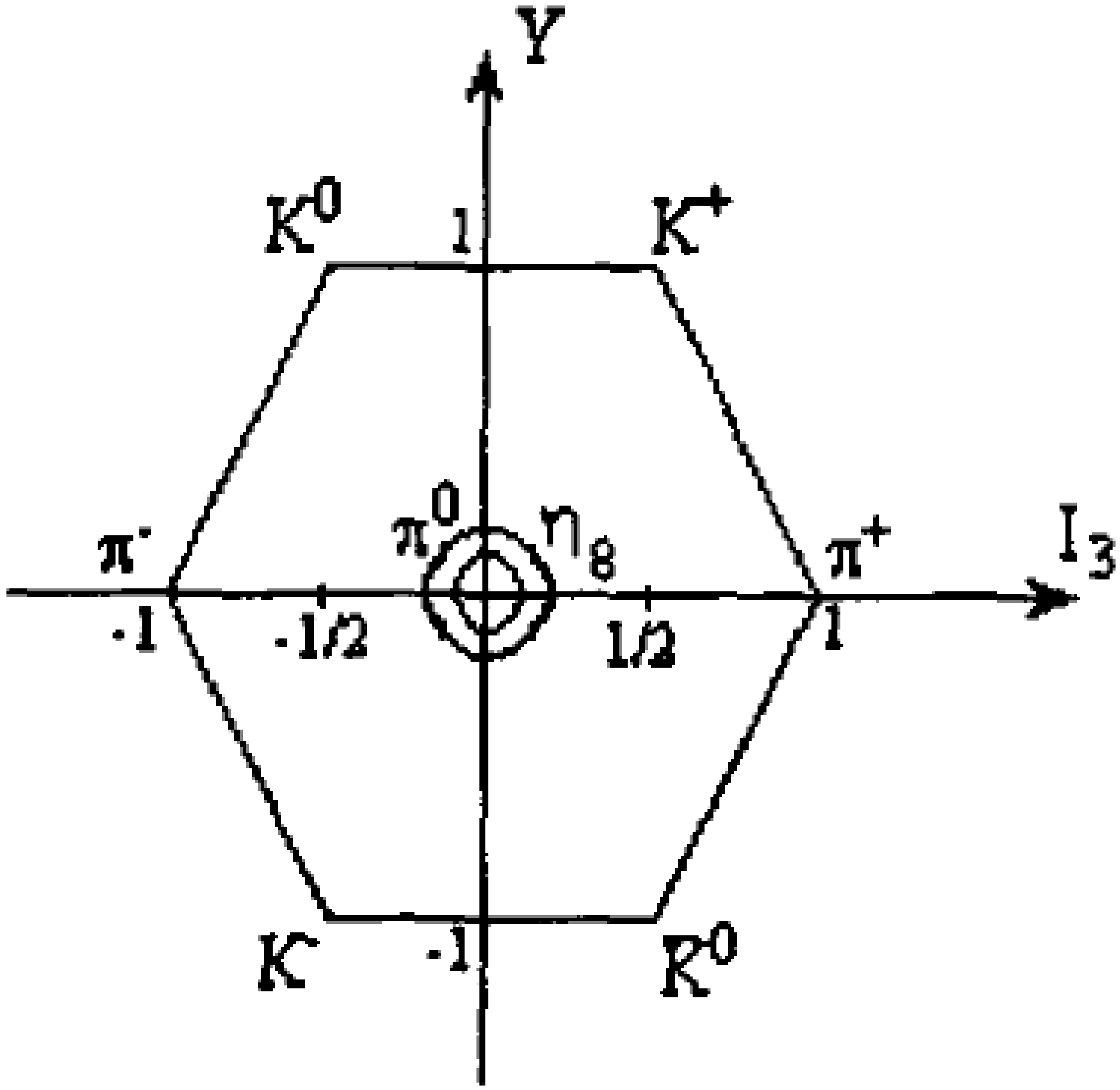


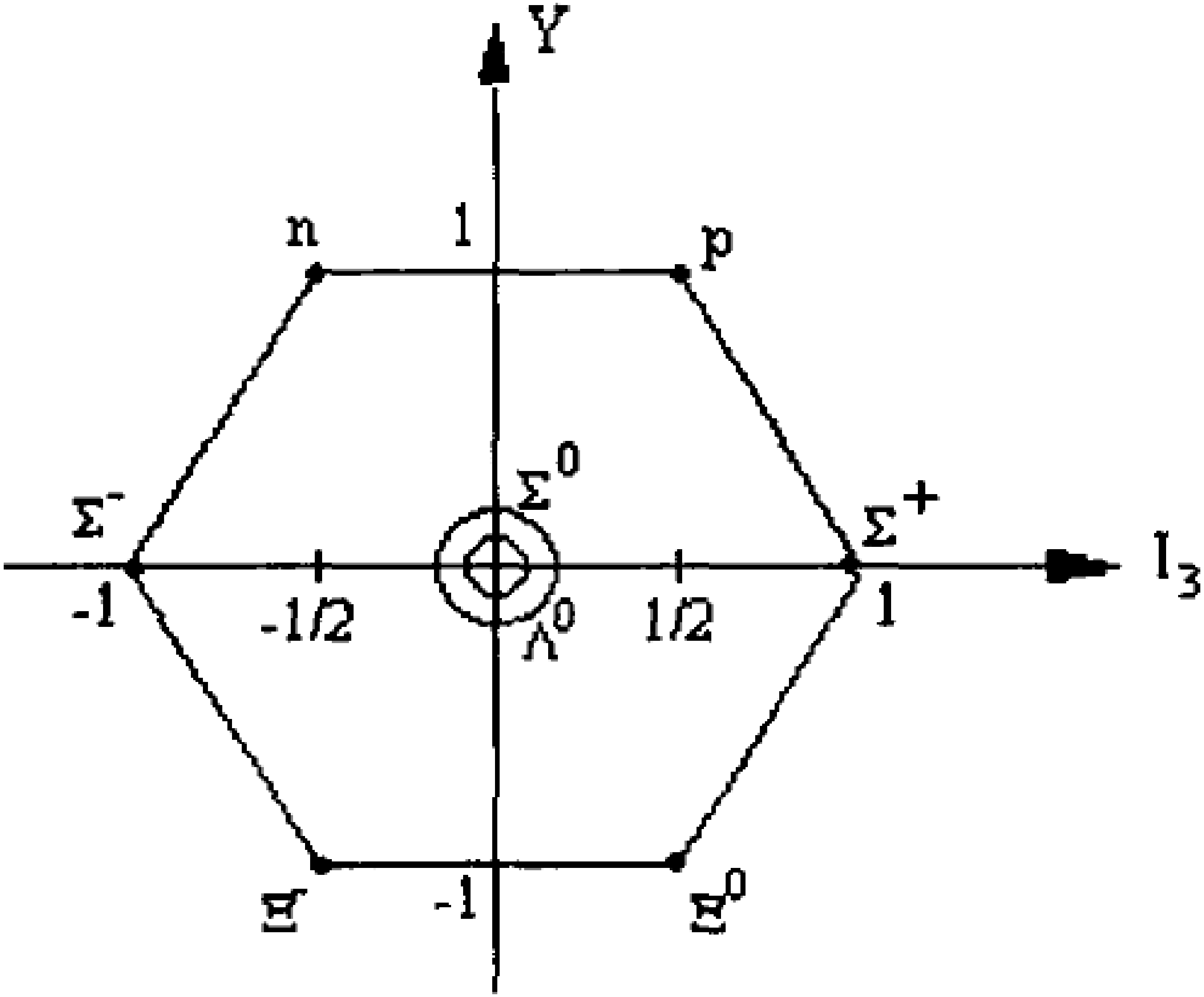
$V_{ij}^{q\bar{q}} = -\frac{4}{3}\alpha_s\frac{1}{r}, \alpha_s = \frac{g_s^2}{4\pi}$, for $\bar{q}q$ color singlet system (mesons) while for qqq color singlet system (baryons).

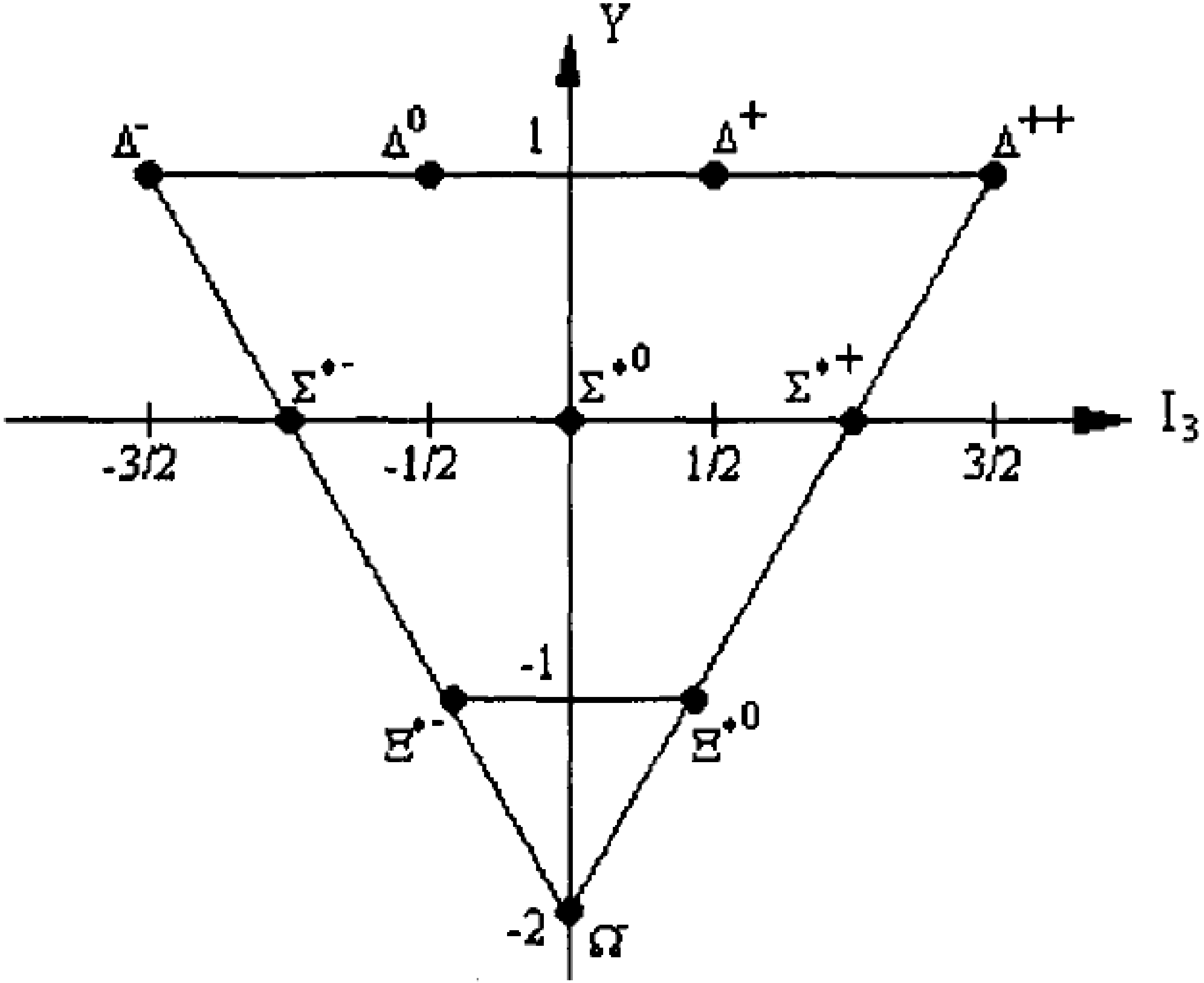
$V_{ij}^{qq} = -\frac{2}{3}\alpha_s\frac{1}{r}$

This attractive potential is responsible for the binding of atoms.	Note the very important fact that in both cases, we get an attractive potential. Without color, V_{ij}^{qq} would have been repulsive.
The theory here is called quantum electrodynamics (QED).	The theory here is called quantum chromodynamics (QCD).
Due to quantum (radiative) corrections, $\alpha\left(\sqrt{Q^2}\right)$ increases with increasing momentum transfer Q^2, for example $\alpha\left(m_e\right) \approx \frac{1}{137}$, $\alpha\left(m_W\right) \approx \frac{1}{128}$	Due to quantum (radiative) corrections, $\alpha\left(\sqrt{Q^2}\right)$decreases with increasing Q^2 [this is brought about by the self interaction of gluons (cf. Table 1)], for example $\alpha\left(m_\tau\right) \approx 0.35$, $\alpha_s\left(m_\Upsilon \simeq 10 \text{ GeV}\right) \approx 0.16$, $\alpha_s\left(m_Z\right) \approx 0.125$. That the effective coupling constant decreases at short distances is called the asymptotic freedom property of QCD.

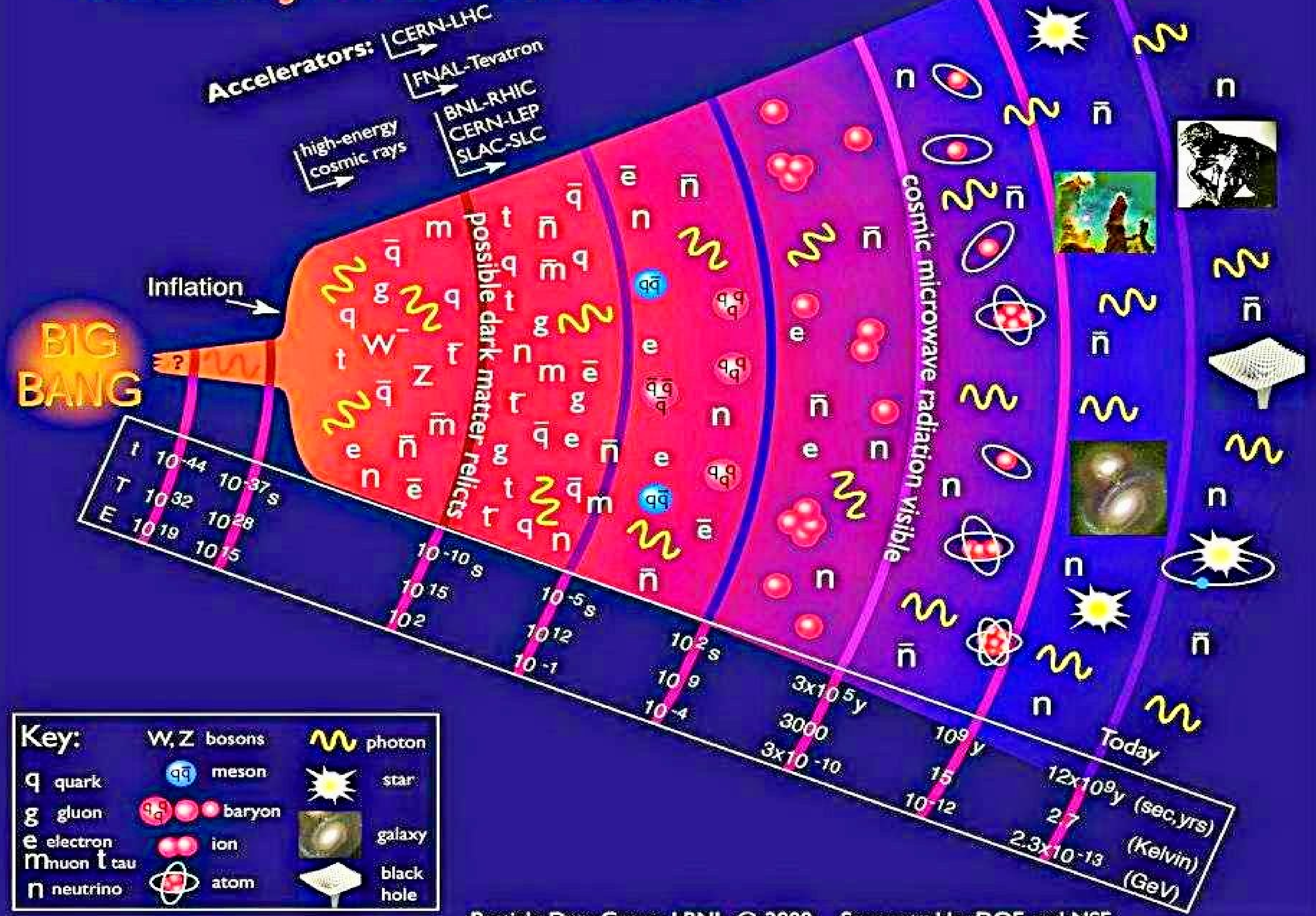

Y
2/3
$|\bar{s}>$
I_3
-1/2
1/2
$|\bar{u}>$
-1/3
$|\bar{d}>$


Y
K^0
1
K^+
π^0
η_8
π^-
π^+
I_3
-1
-1/2
1/2
1
K^-
-1
$\bar{K}^0$


Y
n
1
p
Σ⁰
Σ⁻
Σ⁺
I₃
-1
-1/2
Λ⁰
1/2
1
Ξ⁻
-1
Ξ⁰


Y
I₃
1
-1
-2
-3/2
-1/2
1/2
3/2
Δ⁻
Δ⁰
Δ⁺
Δ⁺⁺
Σ*⁻
Σ*⁰
Σ*⁺
Ξ*⁻
Ξ*⁰
Ω⁻

History of the Universe



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