Introduction of Particle Physics

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Collapsar

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1.1 Elementary Particle Kinematic and Dynamics

1.1.1 Scale

- $$\left.\begin{aligned} Atom &: \sim 10^{-8}\text{cm} \\ Nucleon &: \sim 10^{-12}\text{cm} \\ Proton &: 0.8\times 10^{-14}\text{cm} \end{aligned}\right\} \textbf{Structure}$$

- $$Electron :< 10^{-16}\text{cm} \leftarrow \textbf{point particle}$$

1.1.2 Units

Natural units:

$$\hbar = c = 1 \Leftarrow \begin{Bmatrix} \hbar = 6.58211\times 10^{-15}\text{Gev}\cdot\text{Sec} \\ c = 3\times 10^{10}\text{cm/Sec} \end{Bmatrix} \Rightarrow \begin{array}{l} 1\text{Gev} = (6.6\times 10^{-25}\text{Sec})^{-1} \approx 1.52\times 10^{24}\text{Sec}^{-1} \\ 1\text{Gev}^{-1} \approx 6.6\times 10^{-25}\text{s} \\ 1\text{Sec} = 3\times 10^{10}\text{cm} \end{array}$$

Dimension:

Dimension		**Type**	
M^0	velocity	angular momentum	
M^1	mass	energy	momentum
M^{-1}	length	time	
M^{-2}		cross section	

$$\begin{aligned} m_e = m_e c = m_e c^2 &\approx \frac{1}{2}\text{MeV} \\ &= \frac{1}{\hbar/m_e c} \approx (4\times 10^{-11}\text{cm})^{-1} \\ &= \frac{1}{\hbar/m_e c^2} \approx (1.3\times 10^{-21}\text{Sec})^{-1} \end{aligned}$$

Physical constants

$$\begin{aligned} &G_F{}^{①} = 1.16637(2)\times 10^{-5}\text{GeV}^{-2} \\ &M_{pl}{}^{②} = G_N^{-1/2} = M_{pl} = 1.2\times 10^{19}\text{GeV} \\ &M_W = 80.41 \pm 0.10\text{GeV} \\ &M_Z = 91.187 \pm 0.007\text{GeV} \\ &M_e = 0.51099906(15)\text{MeV} \\ &M_p{}^{③} = 938.2723(3)\text{MeV} \end{aligned}$$

① *Fermi constant*

② *Planck mass*

③ *proton mass*

1.1.3 Kinematics

Mass

$$E = \frac{m}{\sqrt{1-v^2}}, \mathbf{p} = \frac{m\mathbf{v}}{\sqrt{1-v^2}} \Rightarrow E^2 - \mathbf{p}^2 = m^2, \tag{1.1.1}$$

here E is energy ,**P** is momentum,**v** is velocity,and m is rest mass.

Experiment unstable particle

Probability density is given by

$$\boxed{\rho(M) = \frac{\Gamma}{2\pi\left[(M-m)^2 + \frac{\Gamma^2}{4}\right]}} \tag{1.1.2}$$

Fig. 1.1.1 shows Breit-Wigner distribution,where m is the mass, Γ is the width.

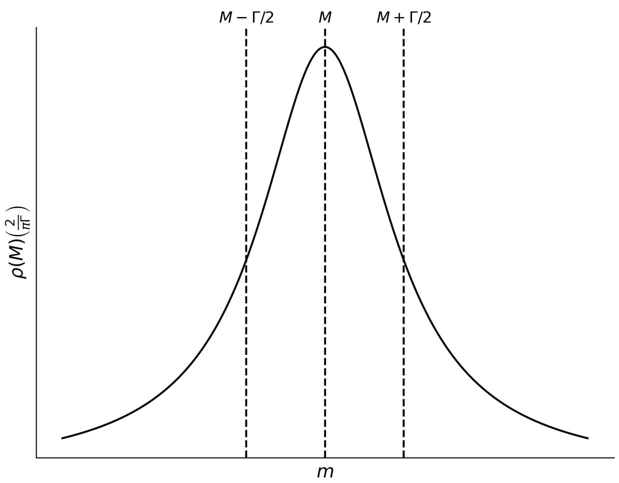

Figure 1.1.1. Breit-Wigner distribution

Lifetime,unstable particles——most of particles are unstable.

$$t \to t + \mathrm{d}t, N \to N - \mathrm{d}N$$
$$\mathrm{d}N = -\tau^{-1}N(t)\mathrm{d}t \Rightarrow N(t) = N(0)e^{-\frac{t}{\tau}},$$

here τ is lifetime and $\boxed{\tau = \frac{1}{\Gamma}}$.

Proof. $\square$

Some common particles have the following masses,

- photon: $\tau_\gamma = \infty$
- electron: $\tau > 2 \times 10^{23}$yr
- muon: $\tau = 2.19703(4) \times 10^{-6}$ s
- $\pi^\pm : \tau = 26029(23) \times 10^{-8}$ s
- $\pi^0 : \tau = (84 \pm 06) \times 10^{-17}$ s
- N : $\tau = (896 \pm 10)$s
- Proton: $\tau > 10^{32} y_r$

electric charge