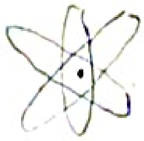
Nuclear & Particle Physics

Length Scales



Atom

$\sim 1\,\mathring{A} = 10^{-10}\,m$

Nucleus

$\sim 10F = 10^{-14}\,m$

proton

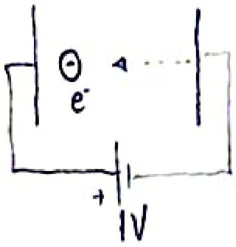
$\sim 1F = 10^{-15}\,m$

quark $\quad \bar{e}$

$\leqslant 10^{-18}\,m$

(currently, point particles)

Energy Scales



Considering two conductors connected to a 1V battery, the energy gained by one $\bar{e}$ taken from anode (+ve plate) and placed to cathode is $1eV$.

high potential for $\bar{e}$s

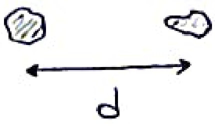
Atomic/Molecular/Solid State Physics $\sim$ eV

Nuclear Physics : keV

Particle Physics : MeV – GeV – TeV $\to \infty$

So, this realm of subatomic physics is also called the high energy physics. We need higher and higher energy accelerators, colliders to probe into smaller and smaller particles. Why?

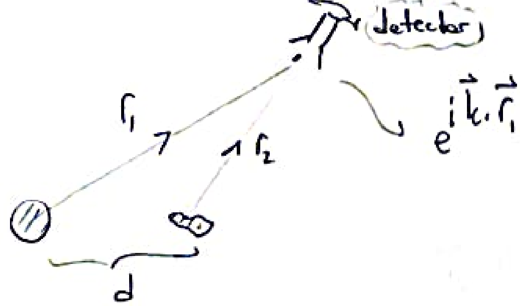
Consider two pieces separated by a distance d



If you send a wave (EM or matter wave $\overset{\nearrow}{e^{-/+}}$) of a wave length $\lambda \gg d$

then looking at the scattered wave, you cannot get a clue whether the scatterer is a single piece or multipieces.

However, if you decrease the wavelength to $\lambda \simeq d$, then by scanning over the solid $\measuredangle$ $d\Omega$, you will get an interference pattern



$$e^{i\vec{k}\cdot\vec{r}_1} + e^{i\vec{k}\cdot\vec{r}_2} = e^{i\vec{k}\cdot\vec{r}_1}\left[1 + e^{i\vec{k}\cdot(\vec{r}_2-\vec{r}_1)}\right]$$

$$\frac{2\pi}{\lambda}, \quad |\vec{r}_2-\vec{r}_1| \simeq d$$

$$\theta = |\vec{k}\cdot(\vec{r}_2-\vec{r}_1)| \simeq 2\pi\,\frac{d}{\lambda}$$

Note that when $\lambda \gg d$, the phase difference is so tiny.

But when $\lambda \simeq d$ we can easily resolve from the resulting pattern that there actually two pieces separated by d.

Recall that $E = h\nu = hck = 2\pi\, hc/\lambda$; so as $\lambda \to 0$, $E \to \infty$

<u>Lesson Learned:</u> Sending a higher energy probe (e^-, e^+, γ) we can resolve finer details in the "target".