PROTON - PROTON AND NEUTRON -NEUTRON INTERACTIONS

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- Important difference between the scattering of identical nucleons (proton-proton and neutron-neutron scattering) and the scattering of different nucleons (neutron-proton scattering) is the identical projectile and target nucleons must be described by a ***common wave function***

- ***Only singlet spin states can thus contribute to the scattering -*** The antisymmetric spin wave function, correspond to a total combined spin of 0; that is, the spin orientations must be different

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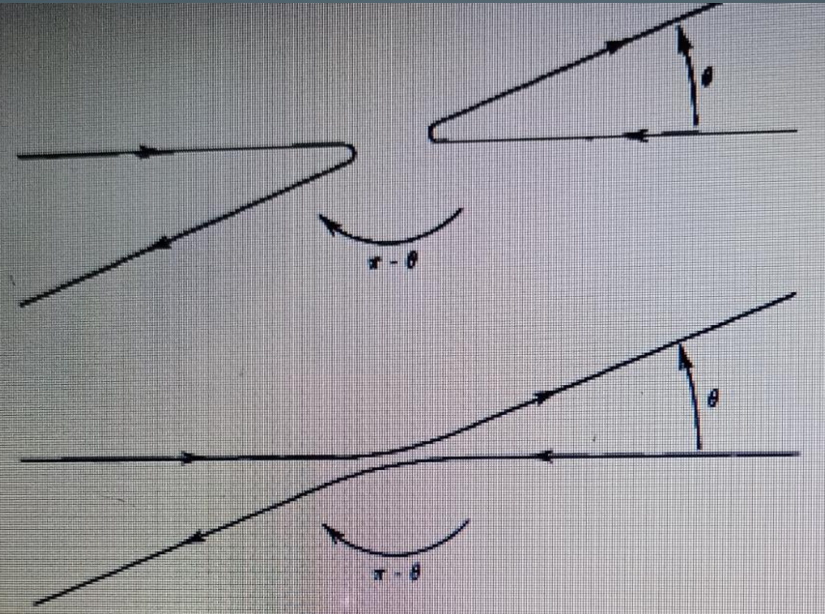

Figure 4.8 Scattering of identical particles in the center-of-mass system. One particle emerges at the angle θ and the other at $\pi - \theta$; because the particles are identical, there is no way to tell which particle emerges at which angle, and therefore we cannot distinguish the two cases shown.

- There is no experimental way to distinguish the two situations in the figure

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- When we square the scattered wave function to calculate the cross section, there will be a term proportional to the interference between the parts of the wave function that give scattering at Θ and at □-Θ. This interference is a purely quantum effect that has no classical analog.

PROTON – PROTON SCATTERING

- wave function must describe both Coulomb and nuclear scattering, and there will be an additional Coulomb-nuclear interference term in the cross section.
- The differential cross section is

$$\frac{d\sigma}{d\Omega} = \left(\frac{e^2}{4\pi\epsilon_0}\right)^2 \frac{1}{4T^2}\left\{\frac{1}{\sin^4(\theta/2)} + \frac{1}{\cos^4(\theta/2)} - \frac{\cos\left[\eta \ln \tan^2(\theta/2)\right]}{\sin^2(\theta/2)\cos^2(\theta/2)} - \frac{2}{\eta}(\sin\delta_0)\left(\frac{\cos\left[\delta_0 + \eta \ln \sin^2(\theta/2)\right]}{\sin^2(\theta/2)} + \frac{\cos\left[\delta_0 + \eta \ln \cos^2(\theta/2)\right]}{\cos^2(\theta/2)}\right) + \frac{4}{\eta^2}\sin^2\delta_0\right\} \quad (4.43)$$

PROTON – PROTON SCATTERING

- T is the laboratory kinetic energy of the incident proton (assuming the target proton to be at rest)
- Θ is the scattering angle in the center-of-mass system
- δ_0 the *l*= 0 phase shift for pure nuclear scattering.
- a is the fine-structure constant
- Since the two protons are identical, we cannot tell the case in which the incident proton comes out at Θ and the target proton at □-Θ (in the center-of-mass system) from the case Θ.
- scattering cross section must include a characteristic Coulomb (Rutherford) term sin^-4(□-Θ)/2 = cos^-4(Θ /2).

This term describes the interference between Coulomb scattering at □-Θ and at Θ.

PROTON – PROTON SCATTERING

- values for the proton-proton scattering length and effective range

$$a = -7.82 \pm 0.01 \text{ fm}$$

$$r_0 = -2.79 \pm 0.02 \text{ fm}$$

- The scattering length, which measures the strength of the interaction, includes Coulomb as well as nuclear effects and thus cannot be compared directly with the corresponding np value.