A toy model for simulating α particle emissions in p + 11B reactions at K_p =10 MeV via Monte Carlo method

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We present a toy model for simulating α particle emissions in p+11B reactions at K_p = 10 MeV via Monte Carlo method. Incident proton is accelerated along the z-axes by an oscillating electric field of frequency ω, and its momentum is randomly generated at the moment of the collision. After collision, we get an α particle, emitted in z-direction, and an excited 8Be nucleus at rest, which breaks down in two α particles emitted in opposite direction. Pseudorandom number generator Mersenne twister engine algorithm is employed to randomly spawn the emisson angles of α particles.

PACS numbers:

I. MODEL DESCRIPTION

Incident proton is accelerated along the z-axes by an oscillating electric field of frequency ω:

$$E_z = E_0 cos(\omega t + \phi). \tag{1}$$

From Newton's third law we get proton momentum:

$$F_z = eE_0 cos(\omega t + \phi) = \frac{dp_z}{dt}, \tag{2}$$

$$p_z = \frac{eE_0}{\omega} sin(\omega t + \phi) = p_{z,max} sin(\omega t + \phi), \tag{3}$$

where $p_{z,max} = \sqrt{2M_pK_p}$. Then $\omega t + \phi$ angle is randomly spawned at the time of the collision via the pseudorandom number generator: Mersenne twister engine algorithm. Incident proton collides with a 11B nucleus at rest to produce a 8Be excited nucleus at rest and an α particle moving in the same direction as incident proton. Thus, the polar angle θ_1 at which this α particle is emitted is constrained to two values: 0 and π, depending on if incident proton is moving forward or backward, respectively.

Later on, 8Be excited nucleus breaks down in two α particles moving in opposite direction. The angles θ_2 and θ_3 at which these two α particles are emitted are randonly spawned. Because of momentum conservation law, angle θ_3 is constrained to

$$\theta_3 = \pi - \theta_2, \tag{4}$$

so, actually, we just have to randomly generate θ_2 angle. Similarly, the azimuthal angles are related by the following relation:

$$\phi_3 = \pi + \phi_2. \tag{5}$$

Thus, in spherical coordinates the momentum of emitted $\alpha 1$ and $\alpha 2$ particles are

$$\boldsymbol{p_{\alpha 2}} = p_{\alpha 2} \left(sin(\theta_2) cos(\phi_2), sin(\theta_2) sin(\phi_2), cos(\theta_2) \right), \tag{6}$$

$$\boldsymbol{p_{\alpha 3}} = -p_{\alpha 2} \left(sin(\theta_2) cos(\phi_2), sin(\theta_2) sin(\phi_2), cos(\theta_2) \right), \tag{7}$$

where $p_{\alpha 2}$ is obtained from the energy conservation law,

$$M_p + \frac{p_p^2}{2M_p} + M_{11B} = M_{8Be}^* + M_\alpha + \frac{p_{\alpha 1}^2}{2M_\alpha}, \tag{8}$$

$$M_{8Be}^* = M_\alpha + \frac{p_{\alpha 2}^2}{2M_\alpha} + M_\alpha + \frac{p_{\alpha 3}^2}{2M_\alpha}, \tag{9}$$

$$M_p + \frac{p_p^2}{2M_p} + M_{11B} = 3M_\alpha + \frac{p_{\alpha 1}^2}{2M_\alpha} + \frac{p_{\alpha 2}^2}{2M_\alpha} + \frac{p_{\alpha 3}^2}{2M_\alpha}, \tag{10}$$

$$p_{\alpha 1}^2 + p_{\alpha 2}^2 + p_{\alpha 3}^2 = 2M_\alpha \left(M_p + \frac{p_p^2}{2M_p} + M_{11B} - 3M_\alpha \right), \tag{11}$$

Because of $p_{\alpha 2} = p_{\alpha 3}$,

$$p_{\alpha 1}^2 + 2p_{\alpha 2}^2 = 2M_\alpha \left(M_p + \frac{p_p^2}{2M_p} + M_{11B} - 3M_\alpha \right) = x. \tag{12}$$

$$p_{\alpha 2}^2 = (x - p_{\alpha 1}^2)/2. \tag{13}$$

So, we just have to randomly generate $p_{\alpha 1}$, constrained to the interval [0,x].

In Fig. 3 is illustrated the collision betwen p and 11B nucleus, and its subsequent decay products.

II. RESULTS

We present the angular and the energy distributions of emitted α particles.

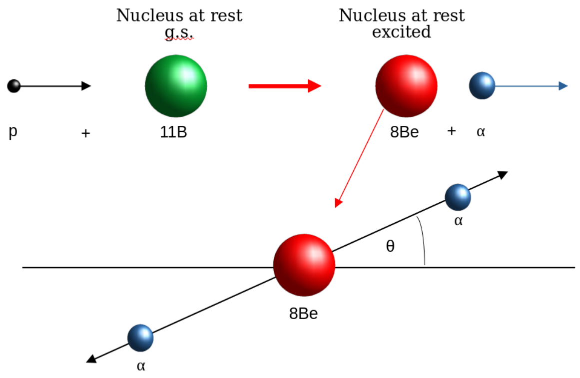

FIG. 1: (color online) Reaction scheme.

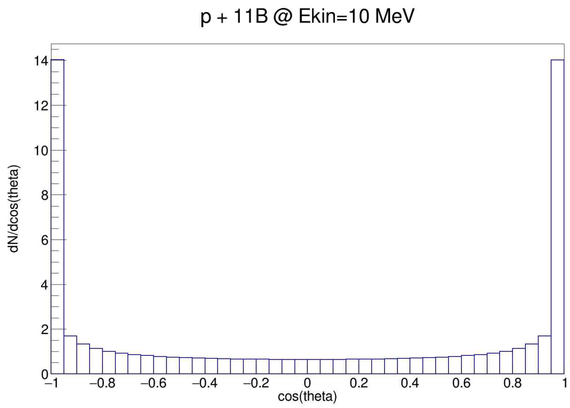

FIG. 2: (color online) Reaction scheme.

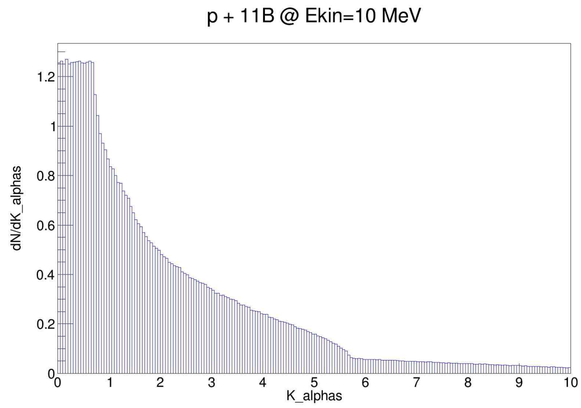

FIG. 3: (color online) Reaction scheme.

A. Angular distribution of emitted α particles

B. Energy distribution of emitted α particles

III. REFERENCES

Appendix I