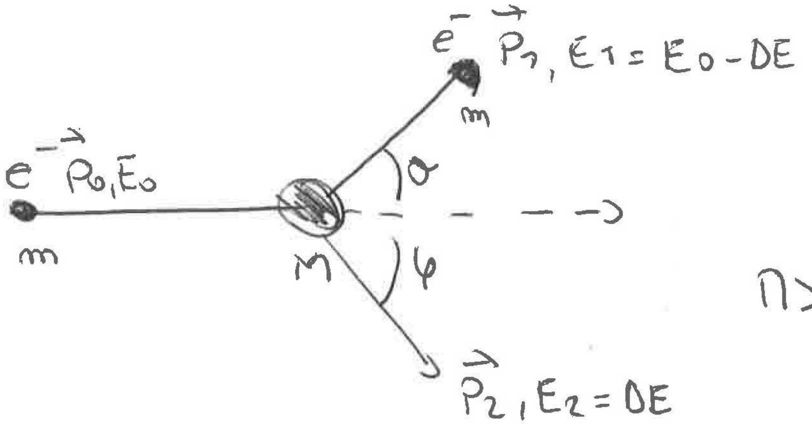

$M \gg m$.

$$\vec{P}_0 = \vec{P}_1 + \vec{P}_2$$

$$\begin{pmatrix} P_0 \\ 0 \end{pmatrix} = \begin{pmatrix} P_1 \cos\theta \\ P_1 \sin\theta \end{pmatrix} + \begin{pmatrix} P_2 \cos\varphi \\ -P_2 \sin\varphi \end{pmatrix}$$

$$\begin{cases} P_0 = P_1 \cos\theta + P_2 \cos\varphi \\ 0 = P_1 \sin\theta - P_2 \sin\varphi \end{cases}$$

$$\begin{cases} P_0 = P_1 \cos\theta + P_2 \cos\varphi \\ P_1 \sin\theta = P_2 \sin\varphi \end{cases}$$

Pour eliminer $\cos\varphi$ on élève au carré

$$\begin{cases} P_0^2 = (P_1 \cos\theta + P_2 \cos\varphi)^2 = P_1^2 \cos^2\theta + P_2^2 \cos^2\varphi + 2 P_1 P_2 \cos\theta \cos\varphi \\ P_1^2 \sin^2\theta = P_2^2 \sin^2\varphi \end{cases}$$

on Somme :

$$P_0^2 + P_1^2 \sin^2\theta = P_2^2 \sin^2\varphi + P_1^2 \cos^2\theta + P_2^2 \cos^2\varphi + 2 P_1 P_2 \cos\theta \cos\varphi$$

$$P_0^2 + P_1^2 \sin^2\theta = P_2^2 + P_1^2 \cos^2\theta + 2 P_1 P_2 \cos\theta \cos\varphi$$

on substitue $P_2 \cos\varphi$ par $P_0 - P_1 \cos\theta$

$$P_0^2 + P_1^2 \sin^2\theta = P_2^2 + P_1^2 \cos^2\theta + 2 P_1 \cos\theta (P_0 - P_1 \cos\theta)$$

$$P_0^2 + P_1^2 \sin^2\theta = P_2^2 + P_1^2 \cos^2\theta + 2 P_0 P_1 \cos\theta - 2 P_1^2 \cos^2\theta$$

$$P_0^2 + P_1^2 \sin^2\theta = P_2^2 - P_1^2 \cos^2\theta + 2 P_0 P_1 \cos\theta$$

on s'intéresse au produit $P_0 P_1$

$$P_0^2 = 2mE_0 \quad \text{et} \quad P_1^2 = 2m(E_0 - \Delta E) \quad \text{et} \quad P_2^2 = 2M\Delta E$$

$$P_0 = \sqrt{2mE_0} \quad \text{et} \quad P_1 = \sqrt{2m(E_0 - \Delta E)} \quad \text{et} \quad P_2 = \sqrt{2M\Delta E}$$

$$P_0 P_1 = \sqrt{2mE_0}\,\sqrt{2m(E_0 - \Delta E)} = \sqrt{2mE_0\, 2m(E_0 - \Delta E)}$$

$$P_0 P_1 = \sqrt{4m^2 E_0 (E_0 - \Delta E)} = \sqrt{4m^2 (E_0^2 - E_0 \Delta E)}$$

Comme $E_0 \Delta E \ll E_0^2$ alors : $E_0^2 - E_0 \Delta E \simeq E_0^2$

$$P_0 P_1 = \sqrt{4m^2 E_0^2} = 2mE_0$$

on a donc :

$$P_0^2 + P_1^2 \sin^2\theta = P_2^2 - P_1^2 \cos^2\theta + 4mE_0 \cos\theta$$

$$P_0^2 = P_2^2 - P_1^2 (\sin^2\theta + \cos^2\theta) + 4mE_0 \cos\theta$$

$$P_0^2 = P_2^2 - P_1^2 + 4mE_0 \cos\theta$$

$$2mE_0 = 2M\Delta E - 2m(E_0 - \Delta E) + 4mE_0 \cos\theta$$

$$2mE_0 = 2M\Delta E - 2mE_0 + 2m\Delta E + 4mE_0 \cos\theta$$

$$2m E_0 + 2m E_0 - 4m E_0 \cos\theta = 2n \Delta E + 2m \Delta E$$

$$4 m E_0 (1 - \cos\theta) = 2\Delta E (m + n)$$

$$2 \Delta E (m + n) = 4m E_0 (1 - \cos\theta)$$

$$\frac{2\Delta E}{E_0} = \frac{4m}{m+n} (1 - \cos\theta)$$

$$\frac{\Delta E}{E_0} = \frac{2 m}{m+n} (1 - \cos\theta)$$ comme $1 - \cos\theta = 2\sin^2(\theta/2)$

$$\frac{\Delta E}{E_0} = \frac{2m}{m+n} 2\sin^2(\theta/2)$$

$$\frac{\Delta E}{E_0} = \frac{4m}{m+n} \sin^2(\theta/2)$$