e^- $\longrightarrow$ $\longleftarrow$ e^+ $\qquad m_e = 0.511$ MeV

$E_- = 600$ MeV $\qquad E_+ = ?$

$$e^+e^- \to \varphi \to K^+K^- \quad \leftarrow$$

$m(\varphi) = 1019.5$ MeV

$m(K^+) = m(K^-) = 494$ MeV

(a) $E_+ = ?$

$$e^+e^- \to \varphi \to K^+K^-$$

(A) (B) (C)

$$\sqrt{s}\Big|_B = \sqrt{E_\varphi^2 - p_\varphi^2} = m_\varphi$$

$$\sqrt{s}\Big|_A = \sqrt{s}\Big|_B = \sqrt{s}\Big|_C = m_\varphi$$

$$\sqrt{s}\Big|_A = \sqrt{(E_+ + E_-)^2 - |\vec{p}_+ + \vec{p}_-|^2} =$$

$$= \sqrt{E_+^2 + E_-^2 + 2E_+E_- - p_+^2 - p_-^2 - 2\vec{p}_+\cdot\vec{p}_-}$$

$$= \sqrt{m_e^2 + m_e^2 + 2E_+E_- + 2P_+P_-}$$

$\vartheta_{\Delta\vartheta = 180°}$

$E \gg m_e$ $\quad E = p \quad \Rightarrow \vec{P}_+ \cdot \vec{P}_- = -P_+P_-$

$E_- = 600\ \text{MeV} \gg 0.511\ \text{MeV}$

$$\Rightarrow \sqrt{s} \simeq \sqrt{2E_+E_- + 2E_+E_-} = \sqrt{4E_+E_-} \overset{!}{=} m_\varphi$$

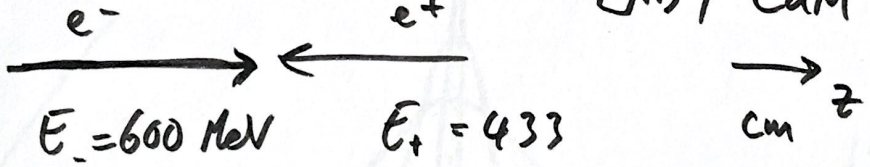
$$\Rightarrow 4E_+E_- = m_\varphi^2$$

$$\Rightarrow E_+ = \frac{m_\varphi^2}{4E_-} = \frac{1019.5^2}{4 \cdot 600} = 433\ \text{MeV}$$

$\gg m_e$

ok

(5) $\beta\gamma$ della φ = ?



$$P_{TOT} = P_{cm} = (E_{TOT}, \vec{P}_{TOT}) = (E_+ + E_-, \vec{P}_+ + \vec{P}_-)$$

$$\simeq (E_+ + E_-, E_- - E_+)$$

$$= (1033\ \text{MeV}, 167\ \text{MeV})$$

$\parallel \hat{z}$

$$P_{tot} = P_\varphi$$

$$\beta_\varphi = \frac{|\vec{P}_{tot}|}{E_{tot}} = \frac{E_- - E_+}{E_- + E_+} = \frac{167}{1033} = 0.162$$

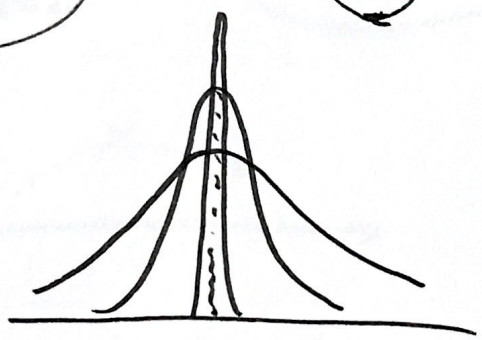
$$\gamma_\varphi = \frac{E_{tot}}{M_\varphi} = 1.013$$

$$\Rightarrow (\beta\gamma)_\varphi = 0.164$$

(c) distance media percorsa dalla φ nel CAS

$$\Gamma_\varphi = 4.3 \text{ MeV}$$

$\Gamma = \frac{\hbar}{\tau}$ $\quad X \rightarrow$ s.f.

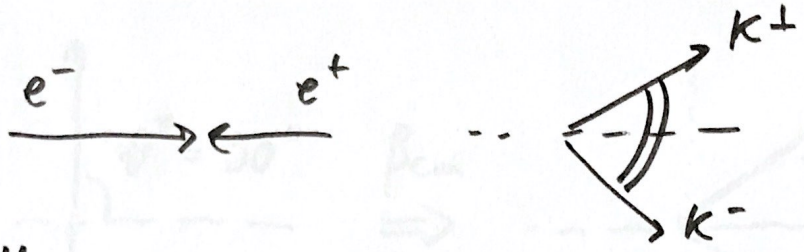


197 MeV fm

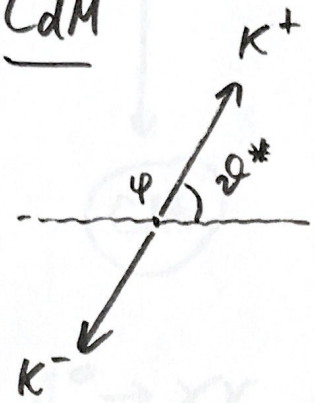
$$\tau = \frac{\hbar}{\Gamma} \rightarrow c\tau = \frac{(\hbar c)}{\Gamma} = \frac{197}{4.3} = 45.8 \text{ fm}$$

$$d = \beta\gamma c\tau = 0.164 \cdot 45.8 \text{ fm} = 7.5 \text{ fm}$$

(d)



CdM



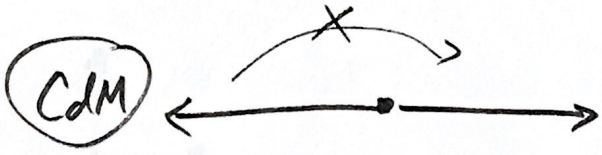
$$\Rightarrow E^*(K^+) = E^*(K^-) = \frac{m_\varphi}{2} = 510\ \text{MeV}$$

$$\Rightarrow p^*(K^+) = p^*(K^-) = \sqrt{E^{*2} - m_K^2} = 127\ \text{MeV}$$

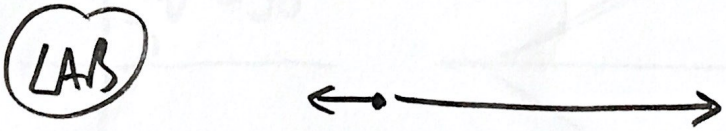
$$\beta^* = \frac{p^*}{E^*} = 0.25$$

$$\beta_{cm} = 0.162$$

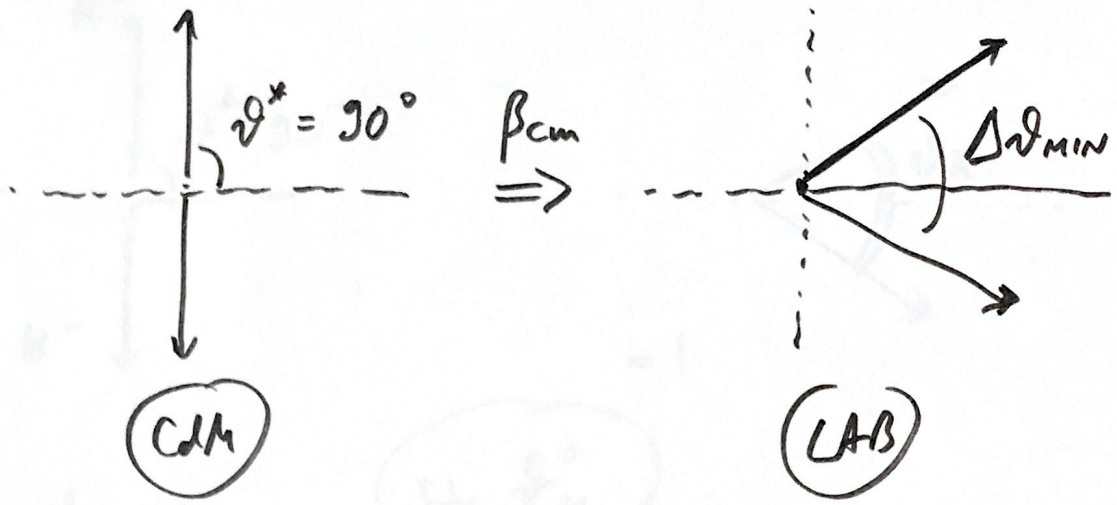
$$\beta_{cm} < \beta^*$$



$\Rightarrow \beta_{cm}$



$$\Rightarrow \Delta\vartheta_{MAX} = 180°$$



$\pi^0 \to \gamma\gamma$

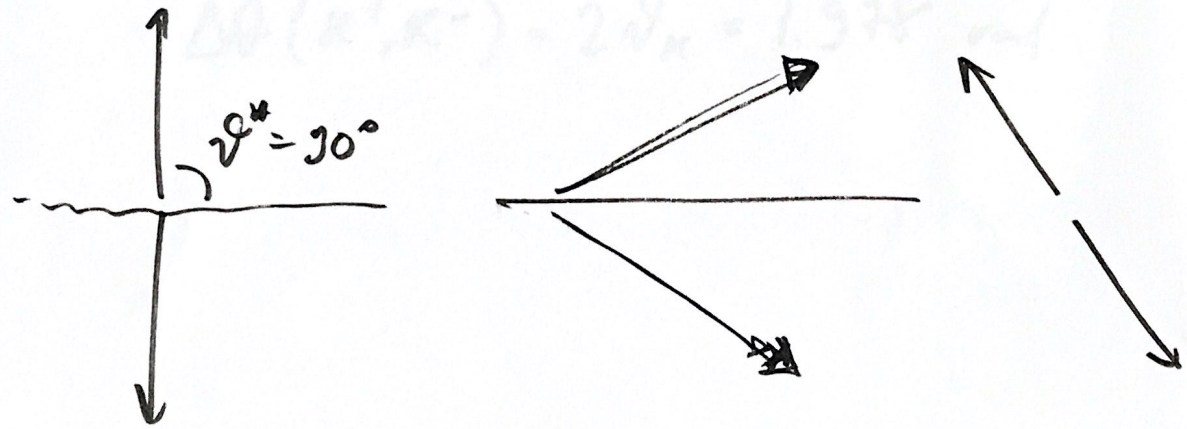
$(E_1E_2 - P_1P_2\cos\alpha)$

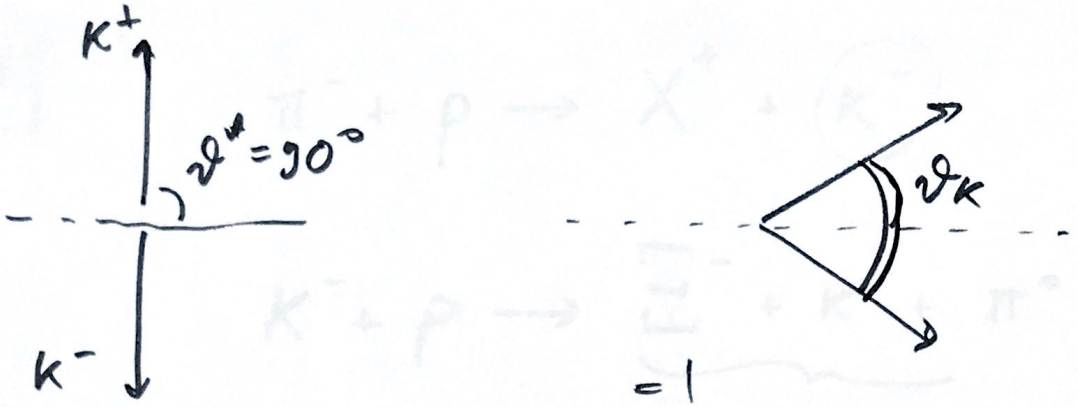
$$\sqrt{s} = m_{\pi^0} = \sqrt{2E_1E_2(1-\cos\alpha)}$$

$(m_\gamma = 0)$

$$E_2 = E_\pi - E_1$$

Si avrà angolo MINIMO quando $E_1 = E_2 = \frac{E_\pi}{2}$





$$= 1$$

$$\tan \vartheta_K = \frac{\sin \vartheta_K^*}{\gamma_\varphi \left(\beta_\varphi / \beta_K^* + \cos \vartheta^* \right)} =$$

$$\cos \vartheta^* = 0$$

$$= \frac{1}{\gamma_\varphi \beta_\varphi / \beta_K^*} = 1.521$$

$$\Rightarrow \vartheta_K = 0.989 \text{ rad}$$

$$\Delta\vartheta(K^+, K^-) = 2\vartheta_K = 1.978 \text{ rad}$$

EX

$$\pi^- + p \rightarrow X^+ + K^-$$

$$K^- + p \rightarrow \Xi^- + K^+ + \pi^0$$

(a) T_{soglia} del K^-

$m(p) = 938$ MeV $m(X^+) = 1400$ MeV

$m(\pi^\pm) = 140$ MeV $m(\pi^0) = 135$ MeV

$m(K^\pm) = 494$ MeV $m(\Xi^-) = 1530$ MeV

$$T_{soglia} = \frac{\left(m(\Xi) + m(K^+) + m(\pi^0)\right)^2 - \left(m(K^+) + m(p)\right)^2}{2m(p)} =$$

$$= 1392 \text{ MeV}$$

$$E_{soglia} = T_{soglia} + m_K = 1886 \text{ MeV}$$

$$P_{soglia} = \sqrt{E_{soglia}^2 - m_K^2} = 1820 \text{ MeV}$$

$$\pi^- + p \longrightarrow X^+ + K^-$$

(π: $E = p$)

$$P_\pi + P_p = P_X + P_K$$

$P_\pi = (E_\pi, \vec{P}_\pi) = (E_\pi, \vec{E}_\pi)$ incognita

$P_p = (m_p, \vec{0})$ fisso, noto

$P_K = (E_{soglia}, \vec{P}_{soglia})$ fisso, noto

$P_X = (E_X, \vec{P}_X)$ boh, non importa

$$s = (P_\pi + P_p)^2 = (P_X + P_K)^2 =$$

$$= P_X^2 + P_K^2 + 2 P_X P_K =$$

$$= m_X^2 + m_K^2 + 2E_X E_K - 2\vec{P}_X \cdot \vec{P}_K$$

$$= m_X^2 + m_K^2 + 2E_X E_K - 2 P_X P_K \cos\vartheta_{XK}$$

$$p_\pi + p_p = p_x + p_K \qquad p_{tot} = \text{cost.}$$

$$p_\pi + p_p - p_K = p_x$$

$$(p_\pi + p_p - p_K)^2 = p_x^2 = m_x^2$$

$$p_\pi^2 + p_p^2 + p_K^2 + 2p_\pi p_p - 2p_\pi p_K - 2p_p p_K = m_x^2$$

$$\| \qquad \| \qquad \|$$

$$m_\pi^2 \quad m_p^2 \quad m_K^2$$

$$\circledast\ p_\pi p_p = (E_\pi E_p - \vec{p}_\pi \cdot \vec{p}_p) = E_\pi m_p - \vec{p}_\pi \cdot \vec{0} = E_\pi m_p$$

$$\circledast\ p_p p_K = E_K m_p$$

$$\Rightarrow p = (E, \vec{p}) \qquad p^2 = E^2 - |\vec{p}|^2 = m^2$$

$$\circledast\ p_\pi p_K = E_\pi E_K - p_\pi p_K \cos\vartheta_{\pi K} =$$

$$= E_\pi E_K - E_\pi p_K \cos\vartheta_{\pi K}$$

$$\Rightarrow m_\pi^2 + m_p^2 + m_K^2 + 2E_\pi m_p - 2E_\pi E_K + 2E_\pi p_K \cos\vartheta_{\pi K} +$$

$$- 2E_K m_p = m_x^2$$

$$E_\pi = \frac{2E_K m_p - m_\pi^2 - m_p^2 - m_K^2 + m_X^2}{2\left(m_p - E_K + p_K \cos\vartheta_{\pi K}\right)}$$

$E_\pi = E_\pi(\vartheta_{\pi K})$

$\cos\vartheta_{\pi K} = 1$

$$E_\pi^{min} = \frac{2E_K m_p - m_\pi^2 - m_p^2 - m_K^2 + m_X^2}{2(m_p - E_K + p_K)} = 2497 \text{ MeV}$$

$\vartheta_{\pi K} = 0$