higher hadron physics Ex. 7 Julian Bergmann

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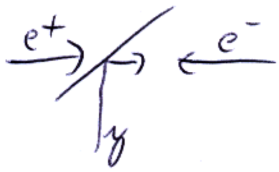

Compton scattering for a resting electron:

$$E_\gamma' = \frac{E_\gamma}{1+\frac{E_\gamma}{m_e c^2}(1-\cos(\phi))} \quad , \phi \overset{!}{=} 180^\circ$$

τ : $m_\tau = 1776{,}8\,\text{MeV} = E_{CMS,e^-}$

e^{+-} : $m_e = 511\,\text{keV}$

To scatter against resting electrons, we transfer the photons in the electrons center of mass system:

$$L_x = \begin{pmatrix} \gamma & +\gamma\beta & 0 & 0 \\ +\gamma\beta & \gamma & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad , \quad \beta = \frac{p}{E} = \frac{\sqrt{E_{CMS}^2 - m_e^2}}{E_{CMS}} = 0{,}9999999586$$

$$\gamma = \frac{1}{\sqrt{1-\beta^2}} = 3477{,}1112032$$

$$q_\gamma = \left(\frac{h}{\lambda}c, \frac{h}{\lambda}, 0, 0\right)^T, \quad \frac{h}{\lambda} = \frac{4{,}1356675\cdot 10^{-15}\,\text{eV}\cdot\text{s}}{10{,}59\cdot 10^{-6}\,\text{m}} = 3{,}90526\cdot 10^{-10}\,\text{eV}\frac{s}{m}$$

$$= 0{,}117077\,\frac{\text{eV}}{c}$$

$$L_x q_\gamma = (\underbrace{1{,}68354\cdot 10^{-5}\,\text{eV}}_{E_\gamma}, 1{,}68354\cdot 10^{-5}\,\frac{\text{eV}}{c}, 0, 0)^T$$

$$E_\gamma' = \frac{1{,}68354\cdot 10^{-5}\,\text{eV}}{1+\frac{1{,}68354\cdot 10^{-5}\,\text{eV}}{511\,\text{keV}}\cdot 2} = \boxed{811.589\,\text{eV}}$$

$(E_\gamma = 1{,}68353723211111)$

To get the real Energy, we need to leave the CMS_{e^-} again:

$$L_x' = \begin{pmatrix} \gamma & -\gamma\beta & 0 & 0 \\ -\gamma\beta & \gamma & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad , \quad L_x' \cdot (E_\gamma', -E_\gamma', 0, 0)^T$$

$$= (\underbrace{\boxed{5.64396\cdot 10^{6}\,\text{eV}}}_{\frac{h}{\lambda'}} = E_{\gamma',lab}, \;''\tfrac{\text{eV}}{c}'', 0, 0)^T$$

$$\frac{h}{\lambda} = 0{,}11707666905530\,84\,\text{eV}$$

$$\cancel{\Rightarrow \Delta E_{lab,\gamma} = -2{,}02699\cdot 10^{-10}\,\text{eV}}$$

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$$\Gamma(D^+ \to e^+ \nu_e) = f_D^2 |V_{cd}|^2 \frac{G_F^2}{8\pi} m_D m_e^2 \left(1 - \frac{m_e^2}{m_D^2}\right)^2$$

$f_D = 206{,}7$ MeV decay constant

$|V_{cd}| = 0{,}2252$ CKM-Matrix element

$G_F = 1{,}16637 \cdot 10^{-11} \frac{1}{\mathrm{MeV}^2}$

$m_D = 1869{,}62$ MeV

$m_e = 511$ keV

$m_\mu = 105{,}658$ MeV

$m_\tau = 1776{,}82$ MeV

$$\Gamma(D^+ \to e^+ \nu_e) = (206{,}7\,\mathrm{MeV})^2 \cdot (0{,}2252)^2 \cdot \frac{\left(1{,}16637 \cdot 10^{-11} \frac{1}{\mathrm{MeV}^2}\right)^2}{8\pi} \cdot (1869{,}62\,\mathrm{MeV}) \cdot (511\,\mathrm{keV})^2 \cdot \left(1 - \frac{(511\,\mathrm{keV})^2}{(1869{,}62\,\mathrm{MeV})^2}\right)^2$$

$$= 5{,}7259 \cdot 10^{-18}\,\mathrm{MeV}$$

$$\Gamma(D^+ \to \mu^+ \nu_\mu) = 2{,}4324 \cdot 10^{-13}\,\mathrm{MeV}$$

$$\Gamma(D^+ \to \tau^+ \nu_\tau) = 6{,}488 \cdot 10^{-13}\,\mathrm{MeV}$$

$$\frac{\Gamma(D^+ \to e^+ \nu_e)}{\Gamma(D^+ \to \mu^+ \nu_\mu,\ D^+ \to \tau^+ \nu_\tau,\ D^+ \to e^+ \nu_e)} = 6{,}4188 \cdot 10^{-6}$$

$$\frac{\Gamma(D^+ \to \mu^+ \nu_\mu)}{\Gamma(D^+ \to e^+ \nu_e,\ D \to \tau^+ \nu_\tau,\ D \to \mu^+ \nu_\mu)} = 0{,}27267$$

$$\frac{\Gamma(D^+ \to \tau^+ \nu_\tau)}{\Gamma(D^+ \to e^+ \nu_e,\ D \to \mu^+ \nu_\mu,\ D \to \tau^+ \nu_\tau)} = 0{,}72732$$

Important here is the helicity supression.
Here it leads to increased decay widths despite phase space.
As D^+ has $J=0$, the antileptons have to be left handed for angular momentum conservation.
However, to interact weakly, the anti leptons have to be right handed which is done by the right handed particle fraction proportional to $1-\beta$.
This again is increasing with the mass which leads to the observation of the decay widths and frations above.