Hadron Spectroscopy: Final Report

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$D_1 \to D^*\pi(1^+ \to 1^-0^-)$

$$A_H = \sqrt{\frac{2J_1+1}{4\pi}} A_{\lambda_2\lambda_3} D^{s_1^*}_{m_1\lambda_2-\lambda_3}(\theta,\phi)$$

$$A_{\lambda_2\lambda_3} \approx |\mathbf{p}|^L, A_{10} = +A_{-10}, A_{00} = +A_{00}$$

$$A_{m'm} = \eta_{D_1}\eta_{D^*}\eta_\pi(-1)^{S_{D_1}-s_{D^*}-s_\pi}A_{-m'm}$$

(where parity conservation is applied.)

In this scenario, $J_1 = 1$, $m_1 = 1$, $\lambda_3 = 0$, we can choose λ_2 from -1 to 1. The orbital angular momentum of final states L is then zero.

$$A_H = \begin{cases} \frac{1}{2}\sqrt{\frac{3}{\pi}}e^{i\phi}\cos^2\left(\frac{\theta}{2}\right), \lambda_2 = 1 \\ \sqrt{\frac{3}{2\pi}}\sin\left(\frac{\theta}{2}\right)\cos\left(\frac{\theta}{2}\right), \lambda_2 = 0 \\ \frac{1}{2}\sqrt{\frac{3}{\pi}}e^{-i\phi}\sin^2\left(\frac{\theta}{2}\right), \lambda_2 = -1 \end{cases}$$

The differential cross section is then the square of A_H.

$$\frac{\mathrm{d}\Gamma_{110}}{\mathrm{d}\theta} = \frac{3\left|\cos\left(\frac{\theta}{2}\right)\right|^4}{4\pi},$$

$$\frac{\mathrm{d}\Gamma_{100}}{\mathrm{d}\theta} = \frac{3\left|\cos\left(\frac{\theta}{2}\right)\sin\left(\frac{\theta}{2}\right)\right|^2}{2\pi},$$

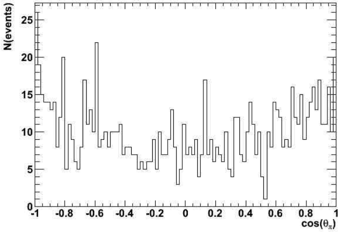
$$\frac{\mathrm{d}\Gamma_{1-10}}{\mathrm{d}\theta} = \frac{3\left|\sin\left(\frac{\theta}{2}\right)\right|^4}{4\pi}$$

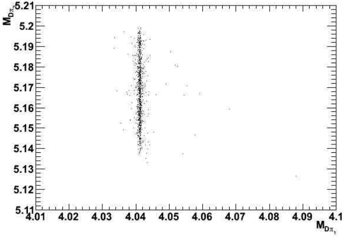
$D_1 \to D^*\pi_2 \to (D\pi_1)\pi_2$ with another decay $D^* \to D\pi(1^- \to 0^-0^-)$

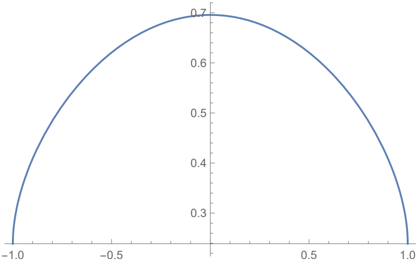
$$A_{H1} = \sqrt{\frac{2J_1+1}{4\pi}\frac{2J_2+1}{4\pi}}\sum_{\lambda_2} A_{\lambda_2\lambda_3} B_{\lambda_4\lambda_5} D^{s_1^*}_{m_1\lambda_2-\lambda_3}(\theta,\phi) D^{s_2^*}_{\lambda_2\lambda_4-\lambda_5}(\theta',\phi')$$

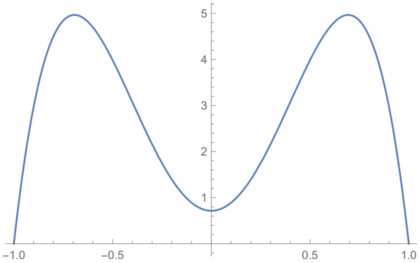
Thus obtain:

$$\frac{\mathrm{d}\Gamma}{\mathrm{d}\theta} = \frac{9\left|p\sin\left(\frac{\theta}{2}\right)\sqrt{2}\cos^3\left(\frac{\theta}{2}\right) - \sqrt{2}p\sin^3\left(\frac{\theta}{2}\right)\cos\left(\frac{\theta}{2}\right) + bp\cos(\theta)\sin\left(\frac{\theta}{2}\right)\sqrt{2}\cos\left(\frac{\theta}{2}\right)\right|^2}{16\pi^2}$$






0.7
0.6
0.5
0.4
0.3
−1.0
−0.5
0.5
1.0


5
4
3
2
1
−1.0
−0.5
0.5
1.0

Landau-Yang Theorem

For any vector particles,we can always write the field operator as a single vector field.

$$A_\mu(x) = \int \frac{\mathrm{d}^3 k}{(2\pi)^3} \frac{1}{\sqrt{2|\mathbf{k}|}} \sum_\lambda (a_\mathbf{k}^\lambda \epsilon_\mu^\lambda(k) e^{-ik\cdot x} + a_\mathbf{k}^{\lambda\dagger} \epsilon_\mu^{\lambda *}(k) e^{ik\cdot x})$$

Then the feynman rules can be easily derived. The amplitude of $vector \to \gamma\gamma$ is

$$i\mathcal{M} = \epsilon_1^{*\mu}(p_1)\epsilon_2^{*\nu}(p_2)\epsilon^\alpha(p)\Gamma_{\mu\nu\sigma}$$

since it must obey Lorentz-invariant

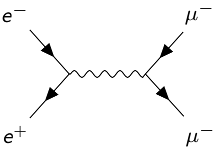
$$= (\epsilon_1 \cdot \epsilon_2)(a_1 \epsilon \cdot p_1 + a_2 \epsilon \cdot p_2) + a_3(\epsilon_1 \cdot \epsilon)(\epsilon_2 \cdot p_1) + a_4(\epsilon_2 \cdot \epsilon)(\epsilon_1 \cdot p_2)$$

final states symmetry (identical), $a_1 = a_2$, first term vanishes. And $\epsilon_2 \cdot p_1 = \epsilon_1 \cdot p_2 = 0$

$$= 0$$

R value: $e^+e^- \to hadron$

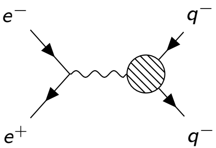
Provide $s \ll m_\mu$,



$$\left| \cdots \right|^2 = \frac{4e^4}{s}(1+\cos\theta)$$

Weak processes supressed when $s \ll m_Z$.

The contribution of EM process is obvious:



$$\propto -i\eta_e e Q_f \gamma^\mu$$