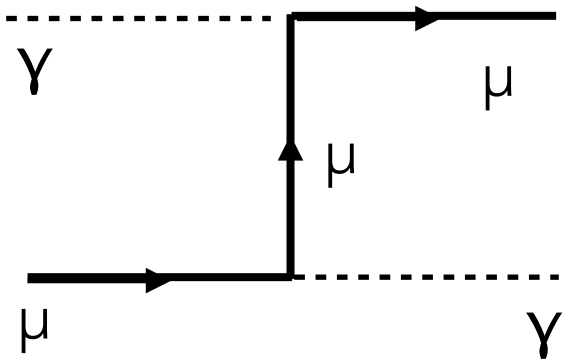
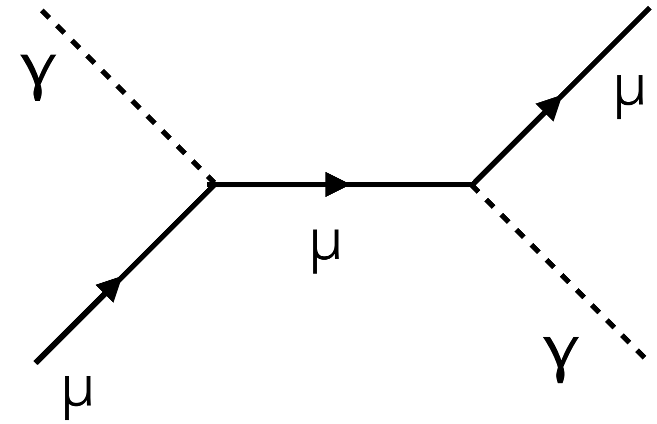
MIDTERM SOLUTION

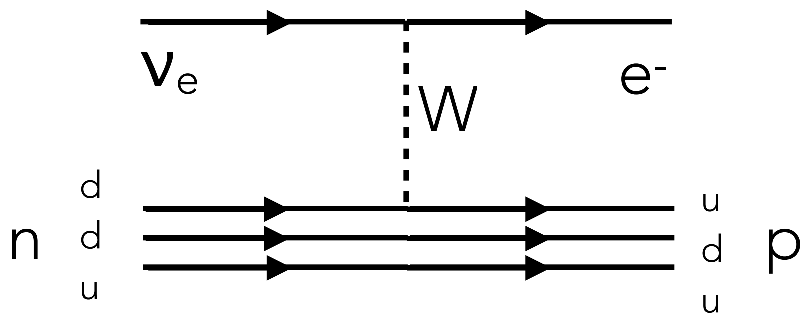
FEYNMAN DIAGRAMS

- $\gamma + \mu^- \rightarrow \gamma + \mu^-$

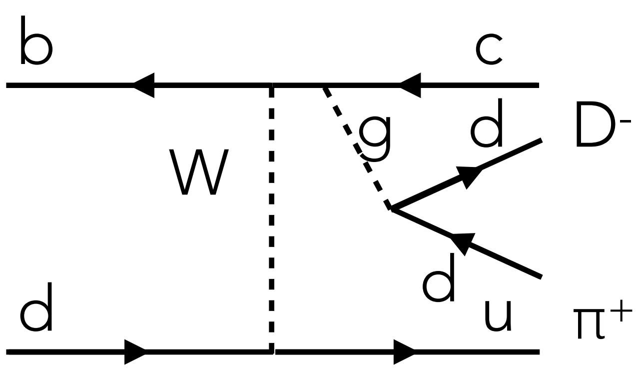




- $\nu_e + n \rightarrow e^- + p$



- $B^0 \rightarrow D^- + \pi^+$



DECAY OF THE Δ RESONANCE

- 1.) With "1" labeling the Δ, and 2,3 the outgoing particles

$$p_1 = p_2 + p_3 \qquad (p_1 - p_2)^2 = p_3^2 \qquad m_1^2 + m_2^2 - 2p_1 \cdot p_2 = m_3^2 \qquad p_1 = (m_1, \mathbf{0})$$

$$m_1^2 + m_2^2 - 2m_1 E_2 = m_3^2 \qquad E_2 = \frac{m_1^2 + m_2^2 - m_3^2}{2m_1} \qquad p_2 = (E_2, \mathbf{p}_2)$$

$$|\mathbf{p}_2|^2 = E_2^2 - m_2^2 = \left(\frac{m_1^2 + m_2^2 - m_3^2}{2m_1}\right)^2 - m_2^2$$

- with a bit of work, we could get (not needed):

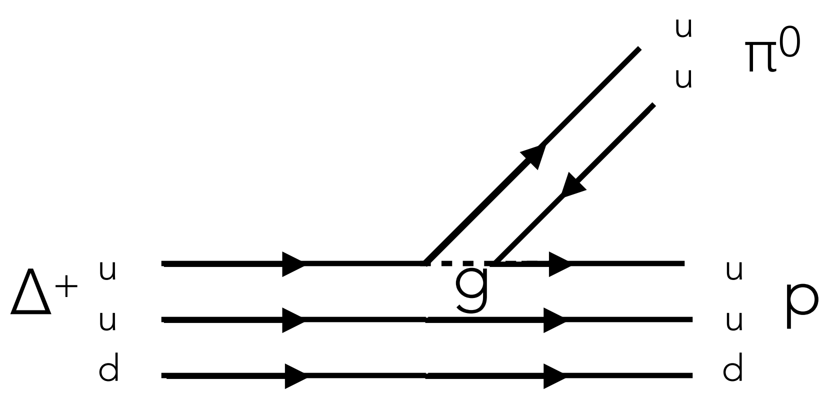
$$|\mathbf{p}_2| = \frac{1}{2m_a}\sqrt{[m_1^2 - (m_2 + m_3)^2]\,[m_1^2 - (m_2 - m_3)^2]}$$

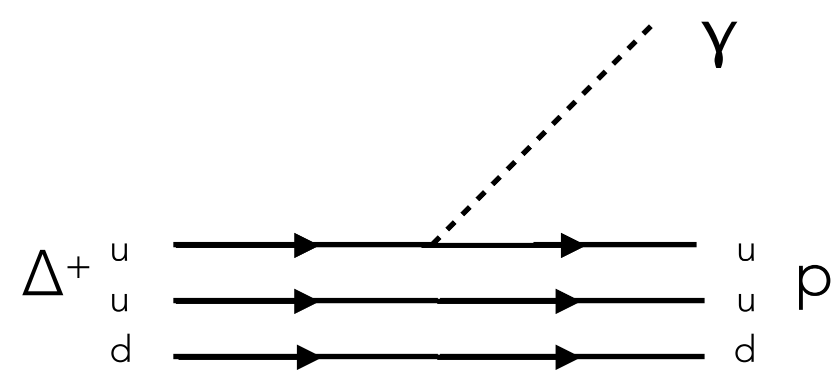
- plugging in numbers (m_1 = 1232, m_2 = 938, m_3 = 135,0)
    - $\Delta \rightarrow p + \pi^0$: 230 MeV/c
    - $\Delta \rightarrow p + \gamma$: 259 MeV/c
- 3.) If we take ratios of the decay rates, most things (M, $32\pi^2$, angular integration) cancel and we are left with:

$$\frac{|\mathcal{M}_{\Delta\to p+\gamma}|^2}{|\mathcal{M}_{\Delta\to p+\pi^0}|^2} = \frac{\Gamma_{\Delta\to p+\gamma}}{\Gamma_{\Delta\to p+\pi^0}}\frac{|\mathbf{p}^*_{\pi^0}|}{|\mathbf{p}^*_{\gamma}|} \qquad \frac{|\mathcal{M}_{\Delta\to p+\gamma}|^2}{|\mathcal{M}_{\Delta\to p+\pi^0}|^2} = \frac{\Gamma_{\Delta\to p+\gamma}}{\Gamma_{\Delta\to p+\pi^0}}\frac{|\mathbf{p}^*_{\pi^0}|}{|\mathbf{p}^*_{\gamma}|} = \frac{0.006}{0.994} \times \frac{230}{259} =\sim 5 \times 10^{-3}$$

DECAY OF THE Δ RESONANCE

- 2.)





- 4.) The $\Delta \rightarrow p + \gamma$ mode is mediated by the electromagnetic interaction, while the $\Delta \rightarrow p + \pi^0$ is mediated by the strong interaction. The relative decay rates show that the strong interaction is $O(10^2)$ times stronger in this case, despite the phase space favoring the electromagnetic decay slightly.

PHASE SPACE IN SCATTERING

- 1) Combination of the flux factor resulting from the relative velocity between the incoming particles, and the factors of energy from the Lorentz Invariant phase space factors for these particles.
- 2) The integral over the Lorentz invariant phase space of the outgoing particles
- 3) This is the matrix element, resulting from the Golden Rule, which states that the rate is a product of phase space factors and matrix element
- 4) Enforces 4-momentum conservation in the integral over the phase space.