Blatt 8

David
Lars

KET

1)

a) $s+t+u = (p_1+p_2)^2 + (p_1-p_3)^2 + (p_1-p_4)^2$ ✓

$= (p_1+p_2)^2 + (p_4-p_2)^2 + (p_3-p_2)^2$

$= p_1^2 + p_2^2 + p_3^2 + p_4^2 + 2p_2^2 + 2p_1p_2 - 2p_2p_4 - 2p_2p_3$ ✓

$= m_1^2 + m_2^2 + m_3^2 + m_4^2 + 2p_2^2 + 2p_1p_2 - 2p_2p_4 - 2p_2p_3$ ✓

$\Rightarrow 2p_2^2 \overset{!}{=} 2p_2p_4 + 2p_2p_3 - 2p_1p_2$

$p_2^2 = p_2(p_4+p_3-p_1) = p_2^2$ ✓ (✓)

$\Rightarrow s+t+u = \sum_{i=1}^{4} m_i^2$ ✓

2P

b) ✓

$s = p_1^2 + 2p_1p_2 + p_2^2 = p_1^2 + 2(E_1E_2 - \vec{p}_1\vec{p}_2) + p_2^2$ $\quad \left(p_i = \begin{pmatrix} E_i^0 \\ \vec{p}_i \end{pmatrix} \right)$

$p_1^2 = E_1^2 - \vec{p}_1^{\,2} \Rightarrow \vec{p}_1^{\,2} = E_1^2 - p_1^2 \overset{!}{=} -\vec{p}_1\vec{p}_2$

$s = p_1^2 + 2(E_1E_2 + E_1^2 - p_1^2) + p_2^2$

$p_2^2 = E_2^2 - \vec{p}_2^{\,2} \Rightarrow E_2 = \sqrt{p_2^2 + E_1^2 - p_1^2}$

$s = p_1^2 + p_2^2 + 2(E_1\sqrt{p_2^2+E_1^2-p_1^2} + E_1^2 - p_1^2)$

$s + p_1^2 - p_2^2 - 2E_1^2 = 2E_1\sqrt{p_2^2+E_1^2-p_1^2}$

$(s+p_1^2-p_2^2)^2 - 4E_1(s+p_1^2-p_2^2) + 4E_1^2 = 4E_1^2(p_2^2+E_1^2-p_1^2)$

$(s+p_1^2-p_2^2)^2 = 4E_1^2[(s+p_1^2-p_2^2) + (p_2^2-p_1^2)] = 4E_1^2 s$

$\Rightarrow E_1^2 = \frac{(s+p_1^2-p_2^2)^2}{4s}$ ← in massen? (✓) 1,5/2P

$4s$? $4\sqrt{s}$? $4s$?

c) $E_{ges,sp} = E_{1sp} + E_{2sp}$ $\quad s = (p_1+p_2)^2 = (E_{1sp}+E_{2sp})$ ← warum gilt das?

$\Rightarrow E_{ges,sp} = \sqrt{s}$ ✓ $s = 3$? 1P

d) Elast. Streuung: $m_1 = m_3 \quad m_2 = m_4$

~~$s = (p_1+p_2)^2 = (E_{1sp}+E_{2sp})$~~

$t = (p_1-p_3)^2 = -(\vec{p}_1-\vec{p}_3)^2 = -\vec{p}_1^{\,2} - \vec{p}_3^{\,2} + 2\vec{p}_1\vec{p}_3$?? ??

$= -2|p|^2(1-\cos\theta)$ ✓ 0,5P

$\Rightarrow \cos\theta = 1 + \frac{t}{2|p|^2}$

war nicht gefragt

für u, s?

e)

Schwellenergie: $E_s = 2(m_t - m_p) = 2(173 - 0,938)$ GeV

$= 344,124$ GeV $\quad$ 0P

5P

b)

$$S = (p_1 + p_2)^2 = (E_1 + E_2)^2$$
$$\text{SP}: \vec{p}_1 = -\vec{p}_2 = \vec{p}$$

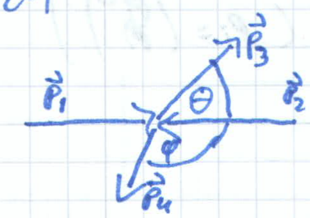
I) $E_2 = \sqrt{s} - E_1$

II) $E_2 = \sqrt{m_2^2 + \vec{p}_2^{\,2}} = \sqrt{m_2^2 + E_1^2 - m_1^2}$

$\Rightarrow s - 2\sqrt{s}E_1 + E_1^2 = m_2 + E_1^2 - m_1^2$

$\Rightarrow E_1 = \dfrac{s + m_1^2 - m_2^2}{2\sqrt{s}}$

d)



$\vec{p}_1 = -\vec{p}_2 \Rightarrow \vec{p}_1 = -\vec{p}_2 \Rightarrow |\vec{p}_1| = |\vec{p}_2| \to E_1 = E_2$

$s = (p_1 + p_2)^2 = \begin{pmatrix} E_1 + E \\ \vec{p}_1 + \vec{p}_2 \end{pmatrix}^2 = (E_1 + E_2)^2 = 4E_1^2 = 4(m^2 + p^2)$

$t = \ldots = -2|\vec{p}|^2(1 - \cos\Theta)$

$u = -2|\vec{p}| = (1 + \cos\Theta)$

e)

$S = (p_1 + p_2)^2 \stackrel{!}{=} (2m_t)$

$\left(\begin{pmatrix} E \\ \vec{p} \end{pmatrix} + \begin{pmatrix} m_p \\ 0 \end{pmatrix}\right)^2 = (E + m_p)^2 - \vec{p}^{\,2} = 4m_t^2$

$\Rightarrow E = \dfrac{2m_t}{m_p} - m_p \simeq 60\,\text{TeV}$

2a) Ruhesystem: $\vec{p}_Z = \vec{0}$, $\vec{p}_+ = -\vec{p}_-$ → $|\vec{p}_+| = |\vec{p}_-| = p_\tau$

$$\Rightarrow \begin{pmatrix} m_Z \\ \vec{0} \end{pmatrix} = \begin{pmatrix} E_+ + E_- \\ \vec{p}_+ - \vec{p}_+ \end{pmatrix} \quad |\ (\ )^2$$

$E_+ = E_- = E_\tau$: Die Energie wird gleichmäßig verteilt, da sie dieselbe Masse $m_+ = m_- = m_\tau$ besitzen

$E^2 = p^2 + m^2$

$$m_Z^2 = (E_+ + E_-)^2 = E_+^2 + E_-^2 + 2E_+E_-$$
$$= 4E_\tau^2 = 4(p_\tau^2 + m_\tau^2)$$

$$\Leftrightarrow \quad p_\tau = \frac{1}{2}\sqrt{m_Z^2 - 4m_\tau^2} = 45{,}559 \text{ GeV}$$

2P

b) $|\vec{p}_Z| \neq 0$

Beide im Winkel $\Theta/2$ → Energie gleichvert. Impulse gleich groß (Im Betrag)

$\vec{p}_+ + \vec{p}_- = \vec{p}_Z$;

$(|\vec{p}_+| + |\vec{p}_-|)\cos(\Theta/2) = |\vec{p}_Z|$

$\Leftrightarrow \quad 2p_\tau \cos(\Theta/2) = p_Z$

$\Leftrightarrow \quad p_\tau = \dfrac{p_Z}{2\cos(\Theta/2)}$

$$\begin{pmatrix} E_Z \\ \vec{p}_Z \end{pmatrix} = \begin{pmatrix} 2E_\tau \\ \vec{p}_+ + \vec{p}_- \end{pmatrix} \quad |\ (\ )^2$$

?

$$E_Z^2 - p_Z^2 = 4E_\tau^2 - |\vec{p}_+|^2 \quad |\vec{p}_-|^2 - 2\vec{p}_+\vec{p}_-$$

$\vec{p}_+\vec{p}_- = |\vec{p}_+||\vec{p}_-|\cos\Theta = p_\tau^2 \cos\Theta$

$$\Leftrightarrow \quad m_Z^2 = 2p_\tau^2 + 4m_\tau^2 - 2p_\tau^2\cos\Theta$$

$$\Leftrightarrow \quad +m_Z^2 = \frac{p_Z^2}{2\cos^2(\Theta/2)} + 4m_\tau^2 - \frac{p_Z^2\cos\Theta}{2\cos^2(\Theta/2)} \quad |\cdot(\cos\Theta+1)$$

$2\cos^2(\Theta/2) = \cos\Theta + 1$

$$\Leftrightarrow \quad m_Z^2 - 4m_\tau^2 - p_Z^2 = \cos\Theta(4m_\tau^2 - m_Z^2 - p_Z^2)$$

$$\Leftrightarrow \quad \Theta = \arccos\left(-\frac{m_Z^2 - 4m_\tau^2 - p_Z^2}{m_Z^2 - 4m_\tau^2 + p_Z^2}\right)$$

$|\vec{p}_Z| = 0$ GeV $\Theta = 180°$

$|\vec{p}_Z| = 100$ GeV $\Theta = 84{,}679°$

$|\vec{p}_Z| = 1$ TeV $\Theta = 10{,}413°$

5P

c) Die Z-Masse 92,187 GeV ist viel kleiner als die von $t\bar{t}$ 344,88 GeV. → Ein Zerfall eines ruhenden Z^0 in $t\bar{t}$ ist nicht möglich.

und wie wäre das bei einem beschleunigten?

1P

Σ 8P

⇒ 8P + 5P = 13P