E214 questions

April 28, 2018

1 Section 7.2.2

Question A

$$Z^0 \rightarrow e^+ e^- \tag{1}$$

$$p_{Z^0} = \begin{bmatrix} m_{Z^0} \\ \vec{0} \end{bmatrix} = \begin{bmatrix} E_e \\ \vec{p} \end{bmatrix} + \begin{bmatrix} E_e \\ -\vec{p} \end{bmatrix} \tag{2}$$

$$m_{Z^0} = 2\sqrt{p^2 + m_e^2} \tag{3}$$

$$m_{Z^0} = 91.2\,\mathrm{GeV}/c^2, \quad m_e = 511\,\mathrm{GeV}/c^2 \tag{4}$$

$$p = \sqrt{\frac{m_{Z^0}^2}{4} - m_e^2} = 45.6\,\mathrm{GeV}/c \tag{5}$$

Question B

$$E_{CMS} = 5\,\mathrm{GeV} \Rightarrow s = (p_{\tau^+} + p_{\tau^-})^2 = \begin{bmatrix} 2E_\tau \\ \vec{0} \end{bmatrix}^2 = 4E_\tau^2 = E_{CMS}^2 \tag{6}$$

$$p_\tau^2 = E_\tau^2 - m_{tau}^2 = \left(\frac{25}{4} - 1.78^2\right)\mathrm{GeV}^2/c^2 \tag{7}$$

$$p = 1.755\,\mathrm{GeV}/c \tag{8}$$

2 Section 7.4.1

First question: ptw.

We are looking at $W \rightarrow e\nu$ processes. We can use the missing transverse momentum (`ptmis_x, ptmis_y`), which we assign to the neutrino. As we know the electron transverse momentum: `el_px, el_py, el_pt`, the W-boson transverse momentum is determined by momentum conservation.

Fitting.

Also see Barlow pp. 58-60 (4.11-12): the standard deviation squared of a function $f(x, y)$ is given by

$$\sigma_f^2 = \left(\frac{df}{dx}\right)^2 \sigma_x^2 + \left(\frac{df}{dy}\right)^2 \sigma_y^2 + 2\frac{df}{dx}\frac{df}{dy}\mathrm{cov}(x, y) \tag{9}$$

Minimize correlation: no clue. Correlation is maximal if the variables are linearly dependent (± 1), 0 if they are statistically independent.

3 Section 7.5.1

Minimum invariant 4-lepton mass

At threshold: $m_{Z^0} = 2m_l$; the minimum 4-lepton invariant mass is acquired when both Z^0's are stationary (CMS frame),and equal to $2m_{Z^0}$.

Lepton mass distribution

See manual p. 41, also Thomson 17.19; there is a Z^0 peak and a Higgs-boson peak. One example for the background at the Higgs-peak is the $t \to bW^+$ decay.

Ideal/real detector.

Ideal: there would be no missing transverse momentum. In real detectors, there are energy losses not detected due to inactive detector elements, imperfect calibration (?).

Four leptons in $t\bar{t}$ event.

Might be manual p. 46 Figure 6.2?

Bins.

The error for bin entries is (counting statistics) $\sqrt{100} = 10$. Finding a bin with 130 entries (or more): $\sigma = 10 \to 3\sigma$ is what we are looking for. The probability of higher than 130 or lower than 70 is $1 - 3\sigma = 1 - 0.9973$, so the requested probability for 1 bin is $(1 - 3\sigma)/2$. The probability that at least one of the bins has more than 130 counts:

$$P = 1 - \left(1 - \frac{1 - 0.9973}{2}\right)^{200} = 1 - 0.7532 = 0.2368. \tag{10}$$