Polarizations

We define the polarization vectors for a W^+, in its CM, where $p_V = (M; 0, 0, 0)$, as:

$$\epsilon(\pm) = \epsilon_{R/L} = -\frac{1}{\sqrt{2}}(0; \pm 1, i, 0) \qquad \epsilon(0) = \frac{1}{M}(0; 0, 0, M) \tag{1}$$

which guarantees:

$$\epsilon_i \cdot \epsilon_j^* = -\delta_{ij}, \qquad p_V \cdot \epsilon_i = 0 \tag{2}$$

Boosting along $\hat{z}$ leaves $\epsilon(\pm)$ unchanged and gives:

$$\epsilon(0, p_z) = 1/M(p_z; 0, 0, E), \qquad p_V = (E; 0, 0, p_z) \tag{3}$$

We then get the general expression rotating the vectors by an angle θ around $\hat{y}$ and then by an angle ϕ around $\hat{z}$, obtaining

$$p_V = (E; p\sin\theta\cos\phi, p\sin\theta\sin\phi, p\cos\theta) \tag{4}$$

$$\epsilon(\pm, \vec{p}) = \frac{1}{\sqrt{2}}(0; \mp\cos\theta\cos\phi + i\sin\phi, \mp\cos\theta\sin\phi - i\cos\phi, \pm\sin\theta) \tag{5}$$

$$\epsilon(0, \vec{p}) = \frac{1}{M}(p; E\sin\theta\cos\phi, E\sin\theta\sin\phi, E\cos\theta) \tag{6}$$

This concides with the polarizations by Hagiwara and Zeppenfeld, who however, do not specify the charge of the vector.

For a W^-, $\epsilon(+) \leftrightarrow \epsilon(-)$ ($\epsilon_R \leftrightarrow \epsilon_L$), that is $\epsilon \leftrightarrow \epsilon^*$.