$$D_\mu \langle H \rangle = \Big(ig \underbrace{T^A W^A_\mu} + ig' g_Y B_\mu \Big) \frac{v}{\sqrt{2}} \begin{pmatrix} 0 \\ 1 \end{pmatrix}$$

$$T^A W^A = \frac{1}{2} \begin{pmatrix} W^3 & W^1 - iW^2 \\ W^1 + iW^2 & -W^3 \end{pmatrix}$$

$g_Y[H] = \frac{1}{2}$

$$= i \frac{1}{2} \begin{pmatrix} gW^3 + g'B & g(W^1 - iW^2) \\ g(W^1 + iW^2) & g'B - gW^3 \end{pmatrix} \frac{v}{\sqrt{2}} \begin{pmatrix} 0 \\ 1 \end{pmatrix}$$

$$= \frac{iv}{2\sqrt{2}} \begin{pmatrix} g(W^1 - iW^2) \\ g'B - gW^3 \end{pmatrix}$$

How to define normalized fields

ASSUME $W^{1,2,3}$, B ARE NORMALIZED

→ can think of them as UNIT VECTORS in field-space, eg $|W^i\rangle$, $|B\rangle$

OR $\underbrace{\vec{e}_{W^1}, \vec{e}_{W^2}, \vec{e}_{W^3}, \vec{e}_{W^4}}_{\text{ORTHONORMAL}}$

THEN: $|W^1 - iW^2|^2 = |W^1|^2 + |W^2|^2 = 2$

SO NORMALIZE: $\boxed{W^+ \equiv \frac{1}{\sqrt{2}} (W^1 - iW^2)}$

SIMILARLY: $-(g'B - gW^3)$

overall minus sign is a convention; does not affect normalization

$$\left| -(g'B - gW^3) \right|^2 = (g')^2 |B|^2 + g^2 |W^3|^2$$

$$= \boxed{(g')^2 + g^2 \equiv g_Z^2}$$

DEFINITION for CONVENIENCE

So the PROPERLY NORMALIZED State is

$$\boxed{Z_+ = \frac{-g'B + gW^3}{g_Z}}$$

NOW RETURN TO $D_\mu \langle H \rangle = \frac{iv}{2\sqrt{2}} \begin{pmatrix} g(W^1 - iW^2) \\ g'B - gW^3 \end{pmatrix}$

$$= \frac{iv}{2\sqrt{2}} \begin{pmatrix} g\sqrt{2}\, W^+ \\ -g_Z Z \end{pmatrix}$$

$$|D_\mu \langle H \rangle|^2 = \frac{v^2}{4}\left(|gW^+|^2 + \left|\frac{g_Z}{\sqrt{2}} Z\right|^2 \right)$$

$$= \Big(\underbrace{\frac{gv}{2}}_{M_W^2}\Big)^2 W^+W^- + \frac{1}{2}\Big(\underbrace{\frac{g_Z v}{2}}_{M_Z^2}\Big)^2 Z^2$$

factor of 1/2 is appropriate for particle that is its own antiparticle, like Z

$(W^+)^\dagger = W^-$

$W^\pm$ is <u>NOT</u> its own antiparticle, so <u>no</u> factor of 1/2