1) General HZZ and HZγ couplings

Consider effective HZV interaction Lagrangian (Hagiwara, Stong '94)

$$\mathcal{L}_{eff} = (1+a_Z)\frac{g_Z m_Z}{2} H Z_\mu Z^\mu + \frac{g_Z}{m_Z}\sum_{V=Z,\gamma}\Big[b_V H Z_{\mu\nu} V^{\mu\nu}$$
$$+ c_V (\partial_\mu H Z_\nu - \partial_\nu H Z_\mu) V^{\mu\nu} + \tilde{b}_V H Z_{\mu\nu}\tilde{V}^{\mu\nu}\Big]$$

- $V_{\mu\nu} = \partial_\mu V_\nu - \partial_\nu V_\mu$, $\tilde{V}_{\mu\nu} = \epsilon_{\mu\nu\alpha\beta} V^{\alpha\beta}$
- scalar components neglected, i.e. $\partial_\mu Z^\mu = \partial_\mu V^\mu = 0$
- operators w/ $d > 5$ neglected
- 7 couplings : $\underbrace{a_Z, b_Z, c_Z, b_\gamma, c_\gamma}_{\text{CP even}}, \underbrace{\tilde{b}_Z, \tilde{b}_\gamma}_{\text{CP odd}}$

Derive $H Z_\alpha V_\beta$ vertex

$$\Gamma^V_{\alpha\beta}(q, p_Z) = g_Z m_Z \Big[h_1^V(s)\, g_{\alpha\beta} + \frac{h_2^V(s)}{m_Z^2} q_\alpha p_{Z\beta} + \frac{h_3^V(s)}{m_Z^2}\epsilon_{\alpha\beta\mu\nu} q^\mu p_Z^\nu \Big]$$

- only 6 form factors ↝ 1 comb. of coupl. cannot be meas.

$$h_1^Z(s) = (1+a_Z) + 2c_Z\frac{s+m_Z^2}{m_Z^2} + 2(b_Z - c_Z)\frac{s+m_Z^2-m_H^2}{m_Z^2}$$

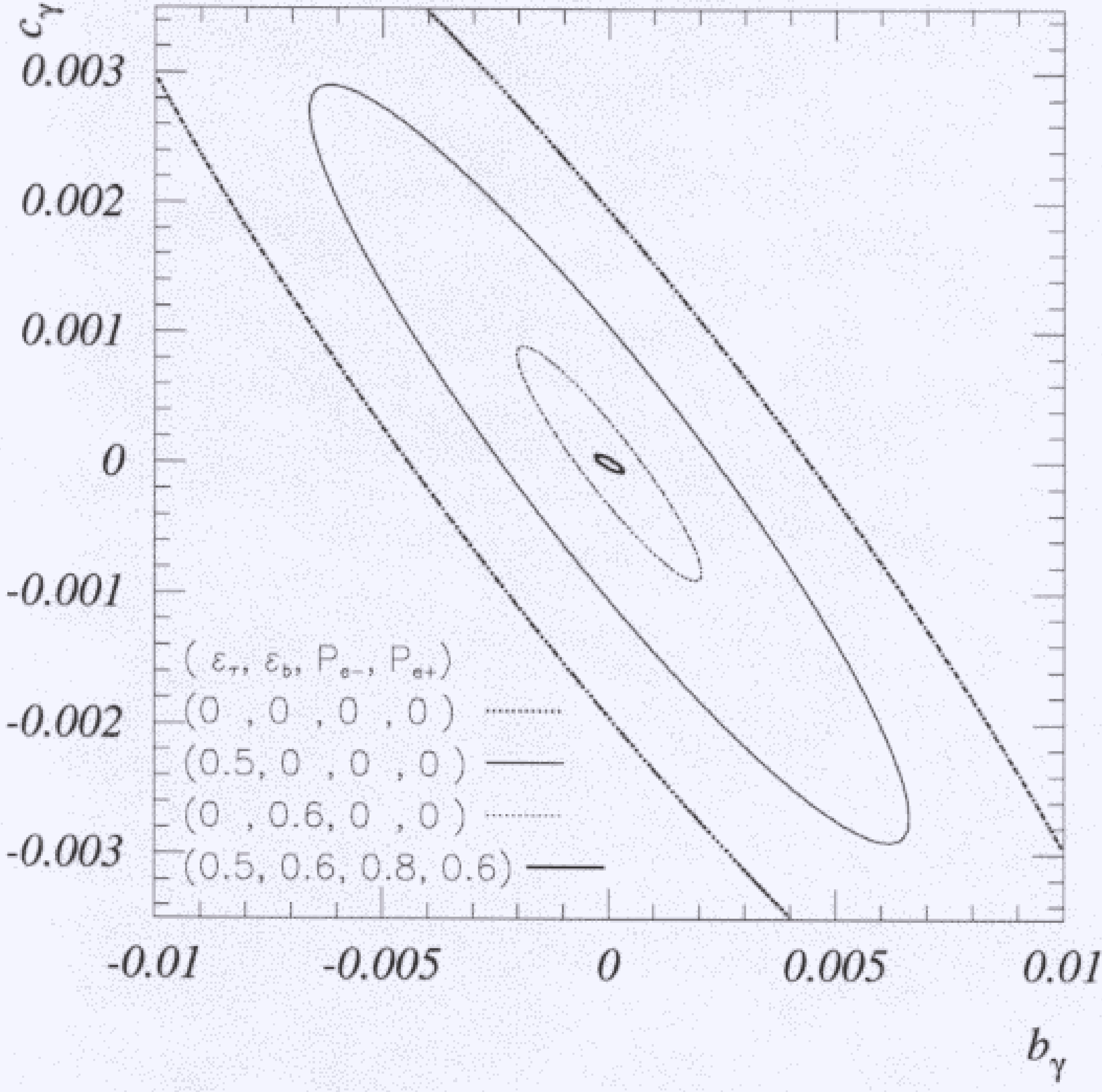
$$h_2^Z(s) = -4(b_Z - c_Z)$$

$$h_3^Z(s) = -4\tilde{b}_Z$$

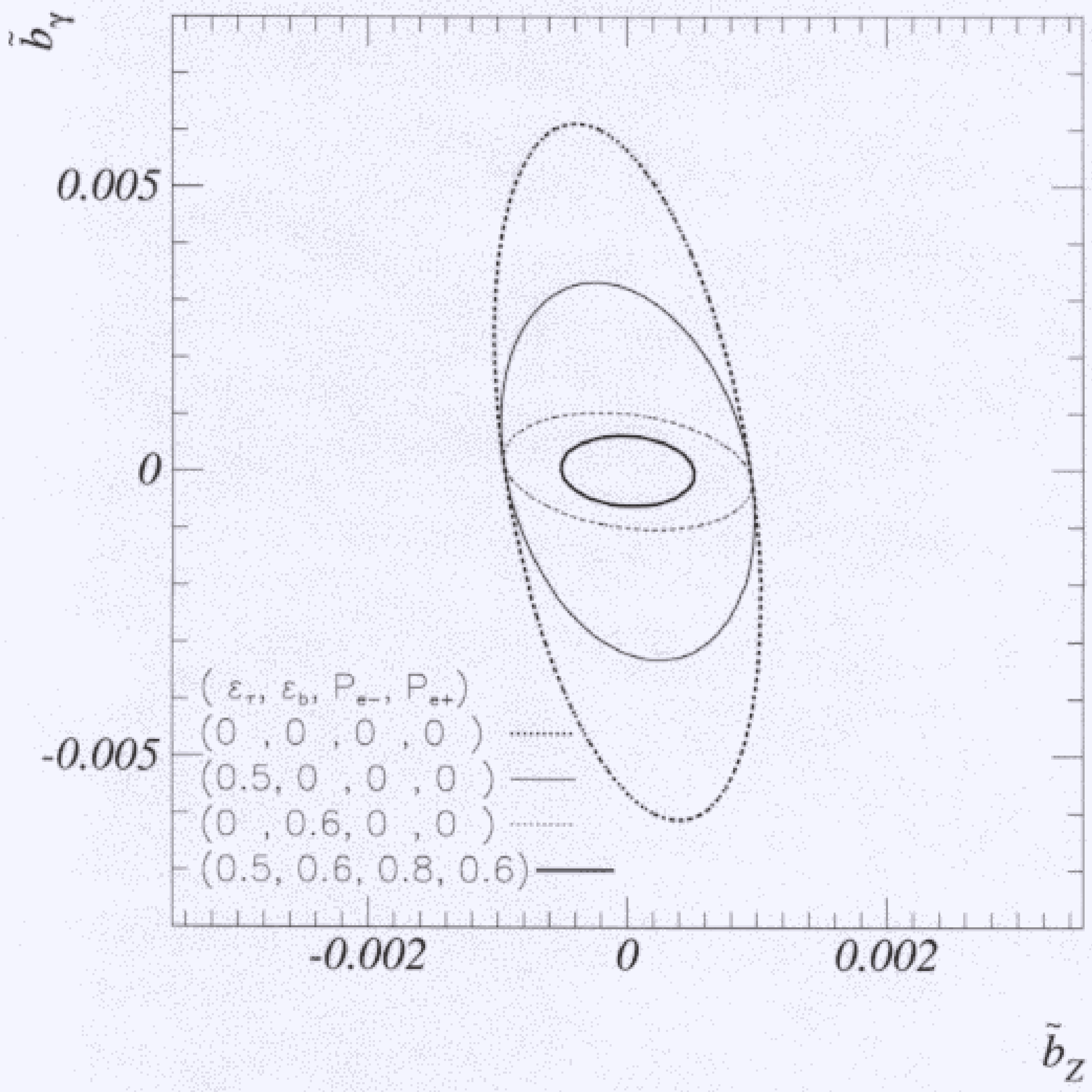
$$h_1^\gamma(s) = 2c_\gamma\frac{s}{m_Z^2} + (b_\gamma - c_\gamma)\frac{s+m_Z^2-m_H^2}{m_Z^2}$$

$$h_2^\gamma(s) = -2(b_\gamma - c_\gamma)$$

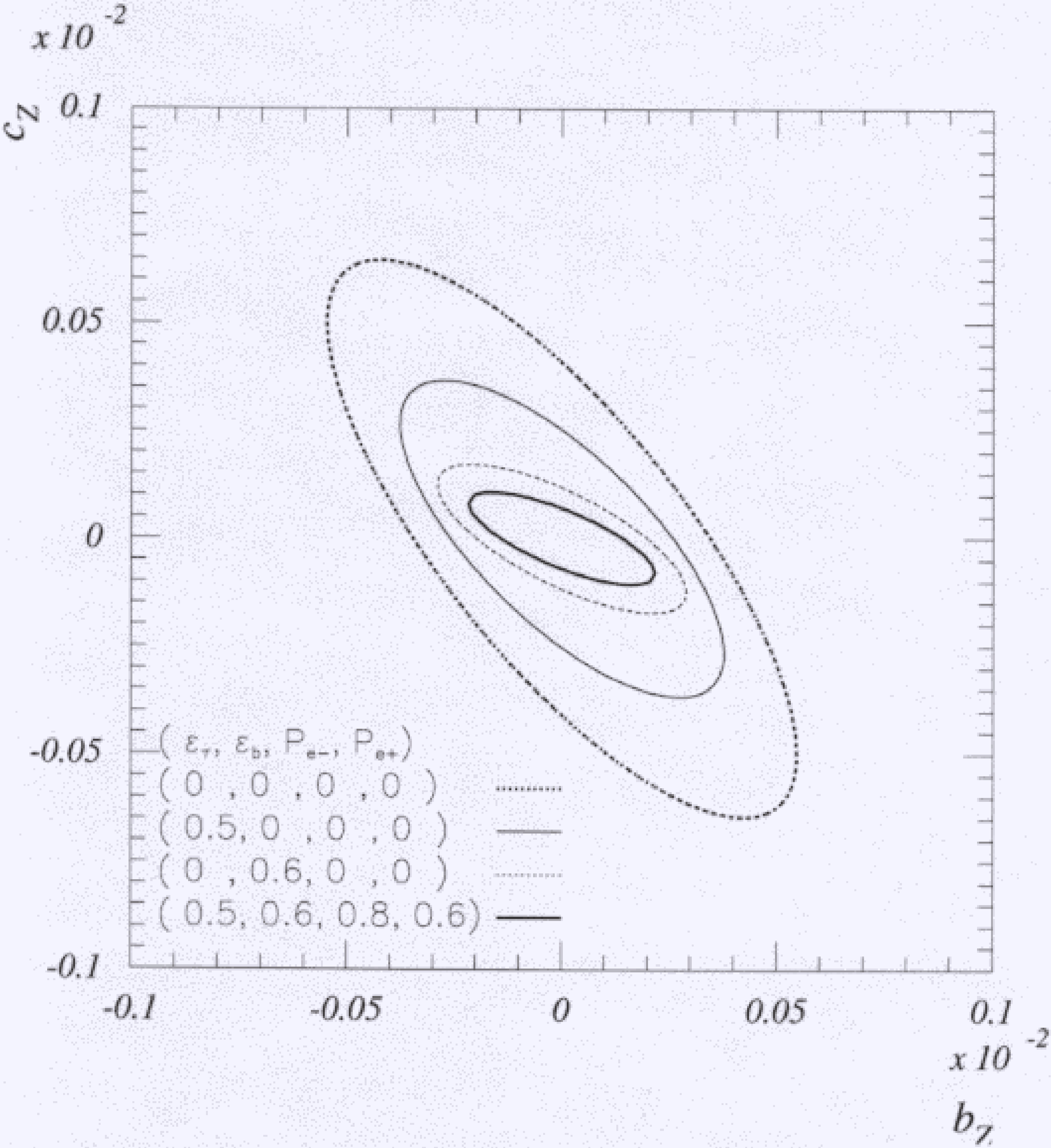
$$h_3^\gamma(s) = -2\tilde{b}_\gamma$$



c_γ
0.003
0.002
0.001
0
-0.001
-0.002
-0.003
-0.01
-0.005
0
0.005
0.01
b_γ
(ε_τ, ε_b, P_{e-}, P_{e+})
(0 , 0 , 0 , 0)
(0.5, 0 , 0 , 0)
(0 , 0.6, 0 , 0)
(0.5, 0.6, 0.8, 0.6)



$\tilde{b}_\gamma$
0.005
0
-0.005
-0.002
0
0.002
$\tilde{b}_Z$
(ε_τ, ε_b, P_{e-}, P_{e+})
(0 , 0 , 0 , 0)
(0.5, 0 , 0 , 0)
(0 , 0.6, 0 , 0)
(0.5, 0.6, 0.8, 0.6)



x 10 -2
c_Z
0.1
0.05
0
-0.05
-0.1
(ε_τ, ε_b, P_e-, P_e+)
(0 , 0 , 0 , 0)
(0.5, 0 , 0 , 0)
(0 , 0.6, 0 , 0)
(0.5, 0.6, 0.8, 0.6)
-0.1
-0.05
0
0.05
0.1
x 10 -2
b_Z