Top quark mass measurement near threshold at CEPC

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Theoretical cross section calculation

The top pair total cross section

$$\sigma(e^+e^- \to t\bar{t} + X) = \sigma_0 \cdot (R^\upsilon + R^a),$$

where $\sigma_0 = 4\pi\alpha^2/3s$, $s = q^2 = (E + 2m_t)^2$. Using optical theory,

$$\text{Vector } R^\upsilon = [(e_t - \frac{q^2\upsilon_e\upsilon_t}{q^2 - m_Z^2})^2 + (\frac{q^2}{q^2 - m_Z^2})^2 \cdot a_e^2\upsilon_e^2]\mathcal{I}m(\Pi^\upsilon(q^2)),$$

$$\text{Axial-vector } R^a = (\frac{q^2}{q^2 - m_Z^2})^2(\upsilon_e^2 + a_e^2)a_t^2\mathcal{I}m(\Pi^a(q^2)),$$

$$\text{Coupling factors } \upsilon_f = \frac{T_3^f - 2e_f sin^2\theta_w}{2sin\theta_w cos\theta_w}, \quad a_f = \frac{T_3^f}{2sin\theta_w cos\theta_w},$$

$$\text{Vacuum polarizations } \Pi_{\mu\nu}^X = i\int d^4xe^{iq\cdot x}\langle 0|Tj_\mu^X(x)j_\nu^X(0)|0\rangle$$

$$= (q_\mu q_\nu - q^2 g_{\mu\nu})\Pi^X(q^2) + q_\mu q_\nu \Pi_L^X(q^2),$$

Theoretical cross section calculation

$$R^{\upsilon} = [(e_t - \frac{q^2 \upsilon_e \upsilon_t}{q^2 - m_Z^2})^2 + (\frac{q^2}{q^2 - m_Z^2})^2 \cdot a_e^2 \upsilon_e^2] \frac{N_c}{2m_t^2} \cdot c_v [c_v - \frac{E}{m_t}(c_v + \frac{d_v}{3})] \mathcal{I}m\{G^S(E)\}, \quad (1)$$

$$R^a = (\frac{q^2}{q^2 - m_Z^2})^2 (\upsilon_e^2 + a_e^2) a_t^2 \cdot \frac{N_c c_a^2}{2m_t^4} \frac{d-2}{d-1} \mathcal{I}m\{G^P(E)\}.$$

S & P-wave Green functions:

$$G^S(E) = \frac{i}{2N_c(d-1)} \int d^4 x e^{iEx^0} \langle 0 | T(\chi^\dagger \sigma_k \psi)(x)(\psi^\dagger \sigma_k \chi)(0) | 0 \rangle,$$
$$G^P(E) = \frac{i}{2N_c} \int d^4 x e^{iEx^0} \langle 0 | T(\chi^\dagger i D_k \psi)(x)(\psi^\dagger i D_k \chi)(0) | 0 \rangle, \quad (2)$$

Theoretical cross section calculation

In (p)NRQCD perturbation theory, the expansion for the Green function $G^S(q^0)$ takes

$$G^X(E) = G_0^X(E) + \sum_{i=1}^{n} \delta_i G^X(E), \tag{3}$$

where $G_0^X(E) = G_0^X(0, 0; E)$ is the zero-point Green function in coordinate space, which can be derived by solving the non-relativistic Schrödinger equation in spherical coordinate

$$\left[-\frac{1}{m_t}\left(\frac{d^2}{dr^2} + \frac{2}{r}\frac{d}{dr}\right) - \frac{C_F \alpha_s}{r} - E\right] G_0(\mathbf{r}, \mathbf{r}^{'}; E) = \frac{1}{4\pi r^2}\delta(\mathbf{r} - \mathbf{r}^{'}), \tag{4}$$

$\delta_i G^X(E)$(i = 1, 2, 3, ...) is the high order corrections. Finally, the total theoretical cross section can been calculated by the QQbar_Threshold code.

(M. Beneke, Y. Kiyo, A. Maier, and J. Piclum, Comput. Phys. Commun. 209, 96 (2016), arXiv:1605.03010)

(Optional 1S mass by SM_tt_threshold in *Whizard*.)