Galactic center gamma-ray excess in the dark technicolor model

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the dark technicolor model

- Classical scaleinvariance: no tree level mass terms.
- Hidden (SM-singlet) sector with fermions and a confining gauge group.
- Messenger scalar, singlet under all gauge groups, couples to the hidden fermions and to the SM Higgs.
- Confinement in hidden sector $\rightarrow$ messenger vev $\rightarrow$ Higgs vev.

Lagrangian

$$
\begin{aligned}
\mathcal{L} \;=\; & |D_\mu H|^2 + |\partial_\mu S|^2 - \frac{1}{4} F^{a\mu\nu} F^a_{\mu\nu} + \sum_{i=1}^{N_f} \bar{Q}_i i \not{D} Q_i \\
& -\lambda_h |H|^4 - \frac{1}{4}\lambda_S |S|^4 + \lambda_{Sh} |S|^2 |H|^2 \\
& -\Big(\sum_{i=1}^{N_f} y_{Q_i} S \bar{Q}_i (1 + a_i \gamma^5) Q_i + \mathrm{h.c.}\Big) + \mathcal{L}_{\mathrm{SM,m_H=0}},
\end{aligned}
$$

$$
m_\pi^2 \approx m_Q \frac{\Lambda_{\mathrm{TC}}^3}{f_\pi^2}
$$

masses, vevs and mixing angle

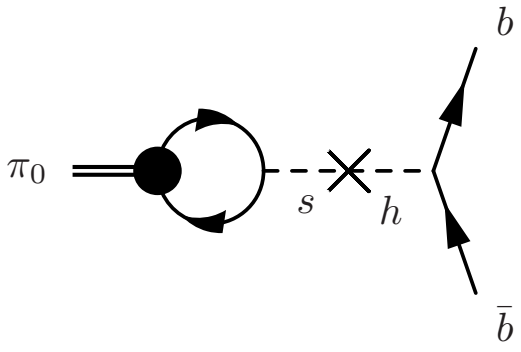
$$v_S = \left(\frac{y_Q \lambda_h}{\lambda_S \lambda_h - \lambda_{Sh}^2}\right)^{\frac{1}{3}} \Lambda_{\mathrm{TC}}, \qquad v_{EW} = \sqrt{\frac{\lambda_{Sh}}{\lambda_h}} v_S$$

$$\mathcal{M} = \begin{pmatrix} 3\lambda_S - \frac{\lambda_{Sh}^2}{\lambda_h} & -2\sqrt{\frac{\lambda_{Sh}^3}{\lambda_h}} \\ -2\sqrt{\frac{\lambda_{Sh}^3}{\lambda_h}} & 2\lambda_{Sh} \end{pmatrix} v_S^2,$$

$$m_h = \sqrt{2\lambda_h} v_{EW}, \qquad m_S = \sqrt{3\lambda_S - \frac{\lambda_{Sh}^2}{\lambda_h}} v_S,$$

$$\tan(2\theta_{Sh}) = \frac{4\lambda_{Sh}^{\frac{3}{2}}}{\sqrt{\lambda_h}\left(\lambda_{Sh}\left(2 - \frac{\lambda_{Sh}}{\lambda_h}\right) - 3\lambda_S\right)}.$$

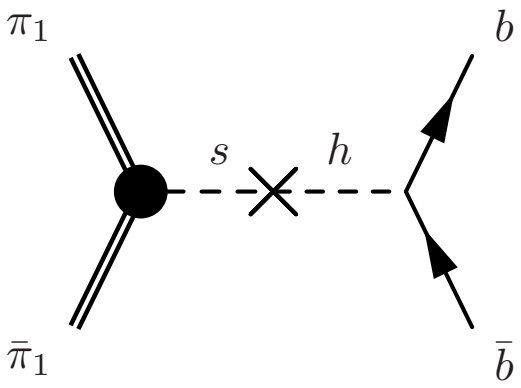
self scattering and decay



$$\Gamma(\pi_0 \to b\bar{b}) = \frac{C_\pi^4 a^2 y_Q^2 \sin^2\theta_{Sh} m_b^2 m_\pi}{8\pi v_{EW}^2 (m_\pi^2 - m_{\min}^2)^2} \left(1 - \frac{4m_b^2}{m_\pi^2}\right)^{\frac{3}{2}}$$

$$\langle \sigma v \rangle \approx \frac{9m_\pi^2}{16\pi^{\frac{3}{2}} f_\pi^4 \sqrt{x}}$$

freeze-out



$$\langle \sigma v \rangle = \frac{C_\pi^2 y_Q^2 \sin^2\theta_{Sh} m_b^2}{4\pi v_{EW}^2 (4m_\pi^2 - m_{\min}^2)^2} \left(1 - \frac{m_b^2}{m_\pi^2}\right)^{\frac{3}{2}}$$

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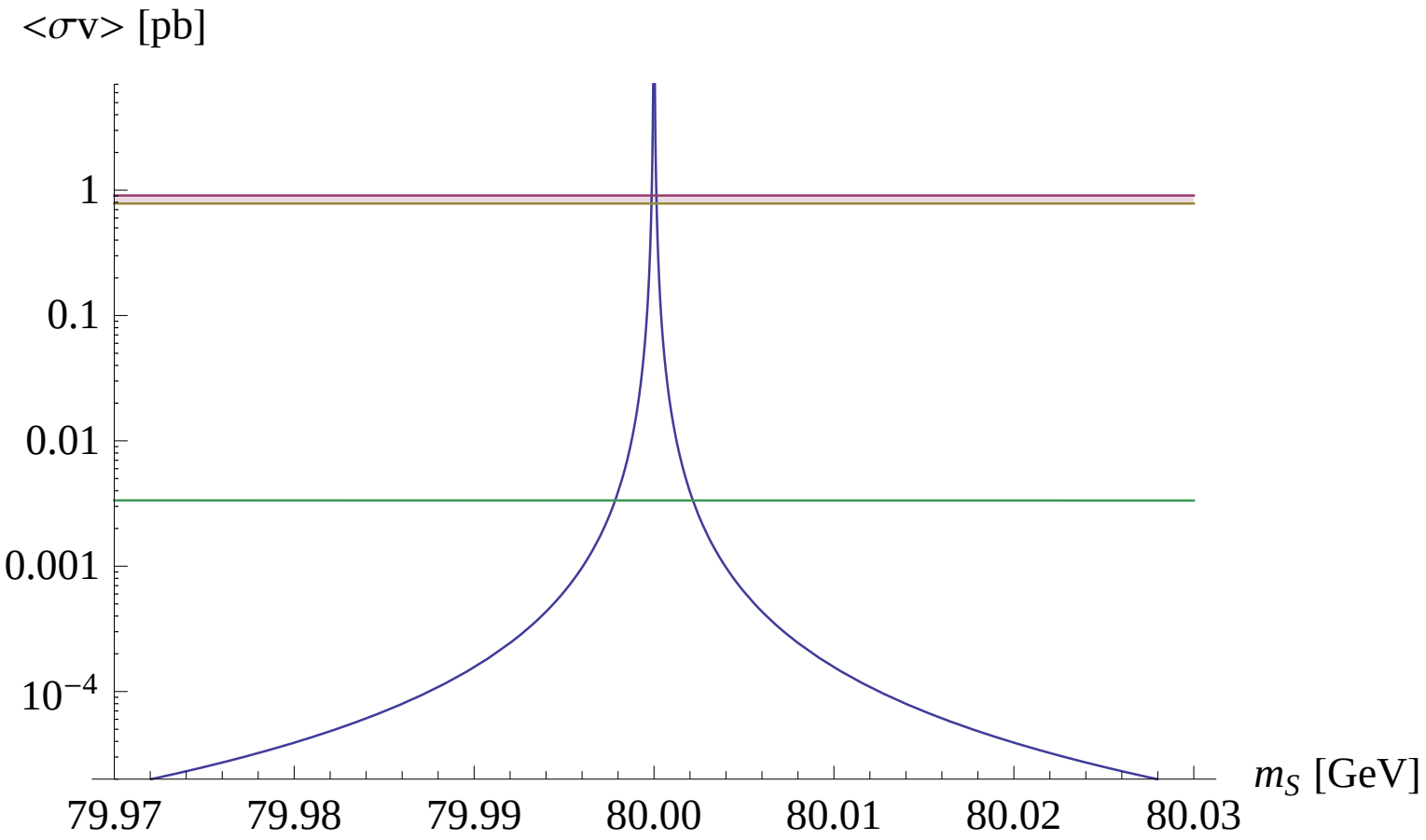


$$\lambda_{Sh} = 5 \times 10^{-4}, C_\pi = f_\pi = \Lambda_{\mathrm{TC}}/(4\pi)$$

freeze-in

$$\sigma(hh \to \pi\pi) = \frac{9 m_H^4 \sin^2\theta_{Sh} y_Q^2 C_\pi^2}{8\pi v_{EW}^2 s (s - m_{\min}^2)^2} \sqrt{\frac{s - 4m_\pi^2}{s - 4m_H^2}},$$

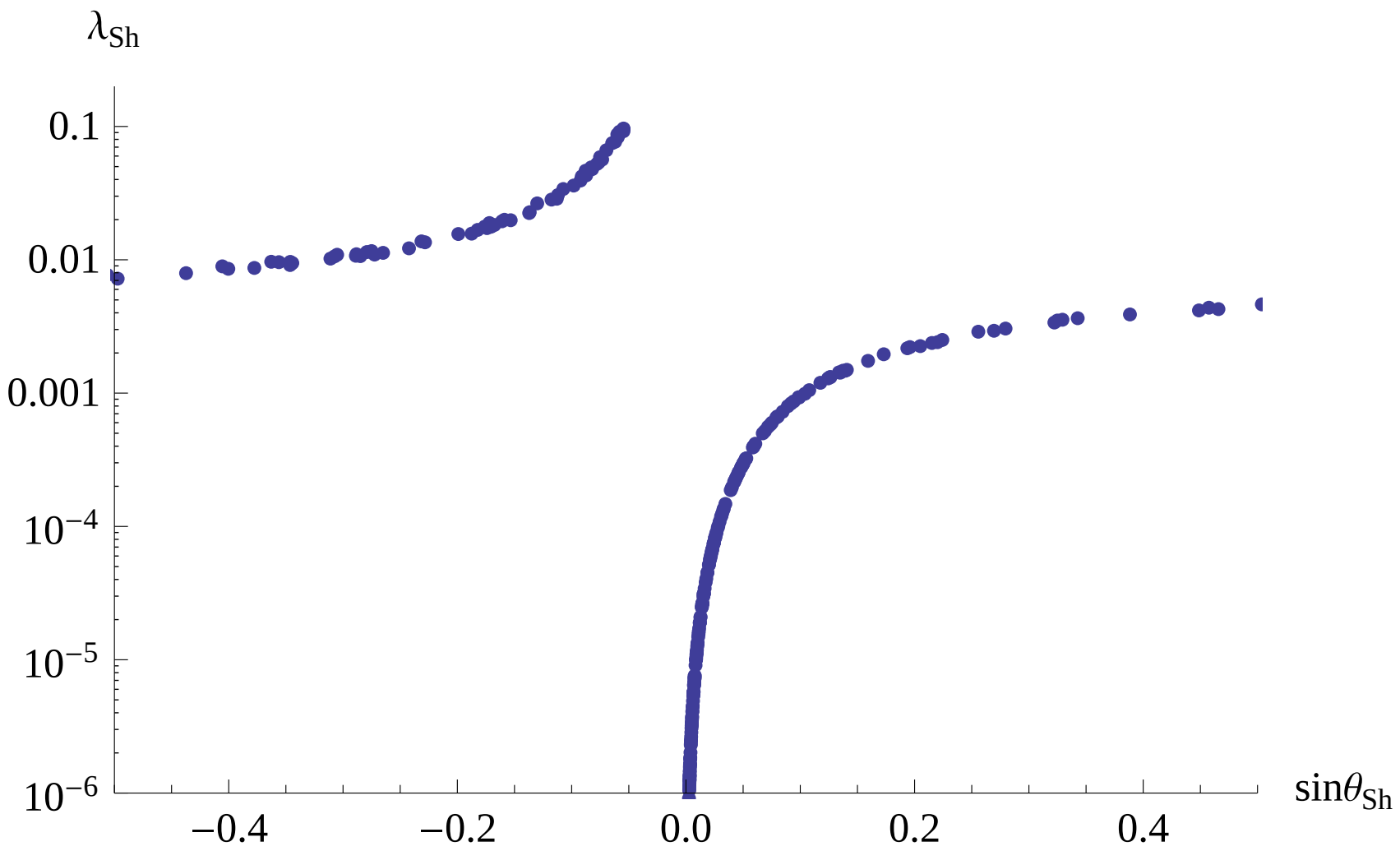
$$\sigma(VV \to \pi\pi) = \frac{\sin^2\theta_{Sh} y_Q^2 C_\pi^2}{72\pi v_{EW}^2 s (s - m_{\min}^2)^2} \sqrt{\frac{s - 4m_\pi^2}{s - 4m_V^2}} \times (s^2 - 4sm_V^2 + 12m_V^4),$$

$$Y = c \frac{\gamma}{sH}\bigg|_{T=m_\pi},$$

$$\gamma(ab \to cd) = \frac{T}{64\pi^4} \int_{s_{\min}}^{\infty} ds \sqrt{s} \hat{\sigma}(s) K_1\left(\frac{\sqrt{s}}{T}\right),$$

$$\hat{\sigma}(ab \to cd) = \frac{g_a g_b}{c_{ab}} \frac{2((s - m_a^2 - m_b^2)^2 - 4m_a^2 m_b^2)}{s} \sigma.$$

freeze-in



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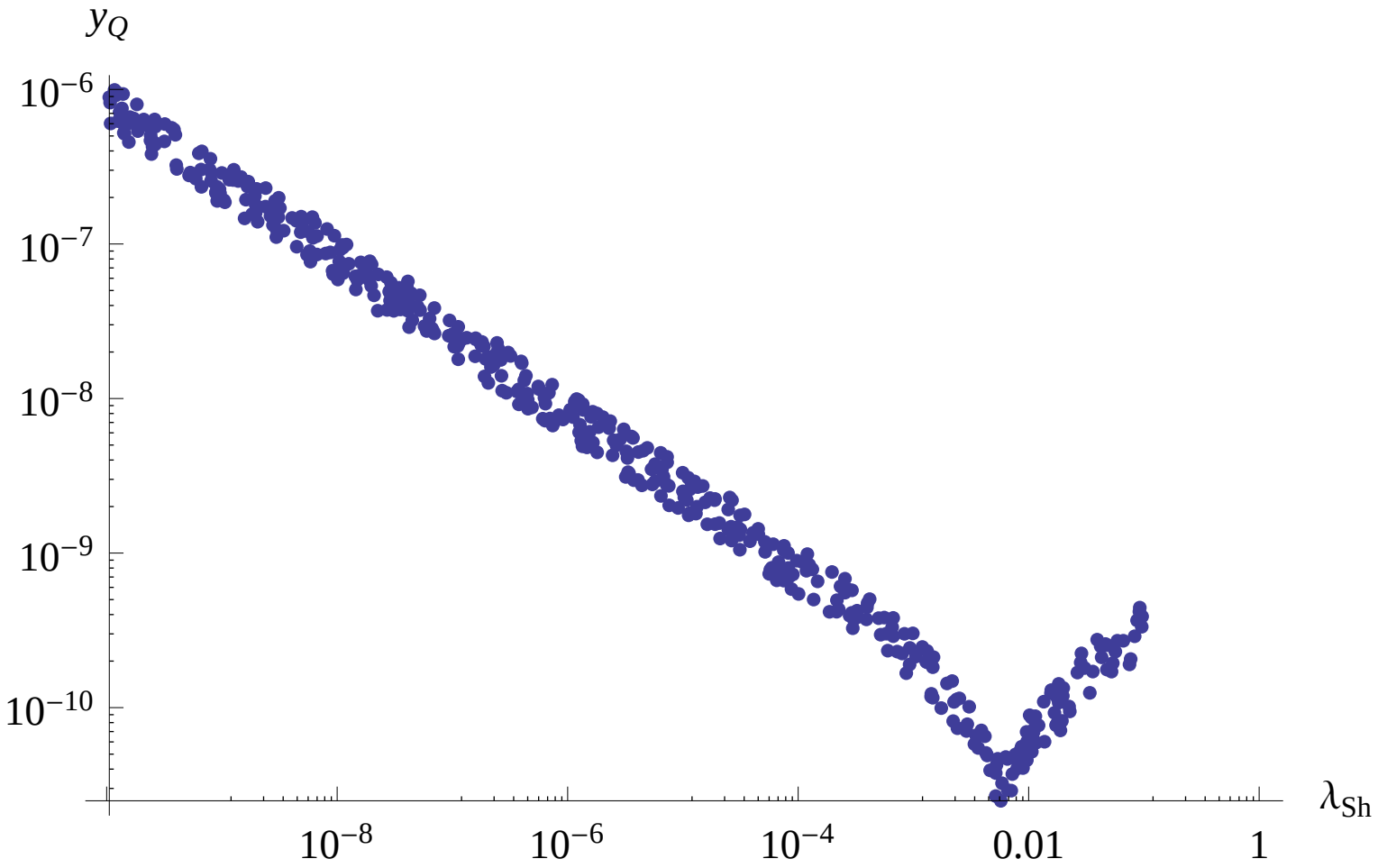

$$y_Q \approx 2.4 \times 10^{-11} \sqrt{\frac{\lambda_h}{\lambda_{Sh}}}$$

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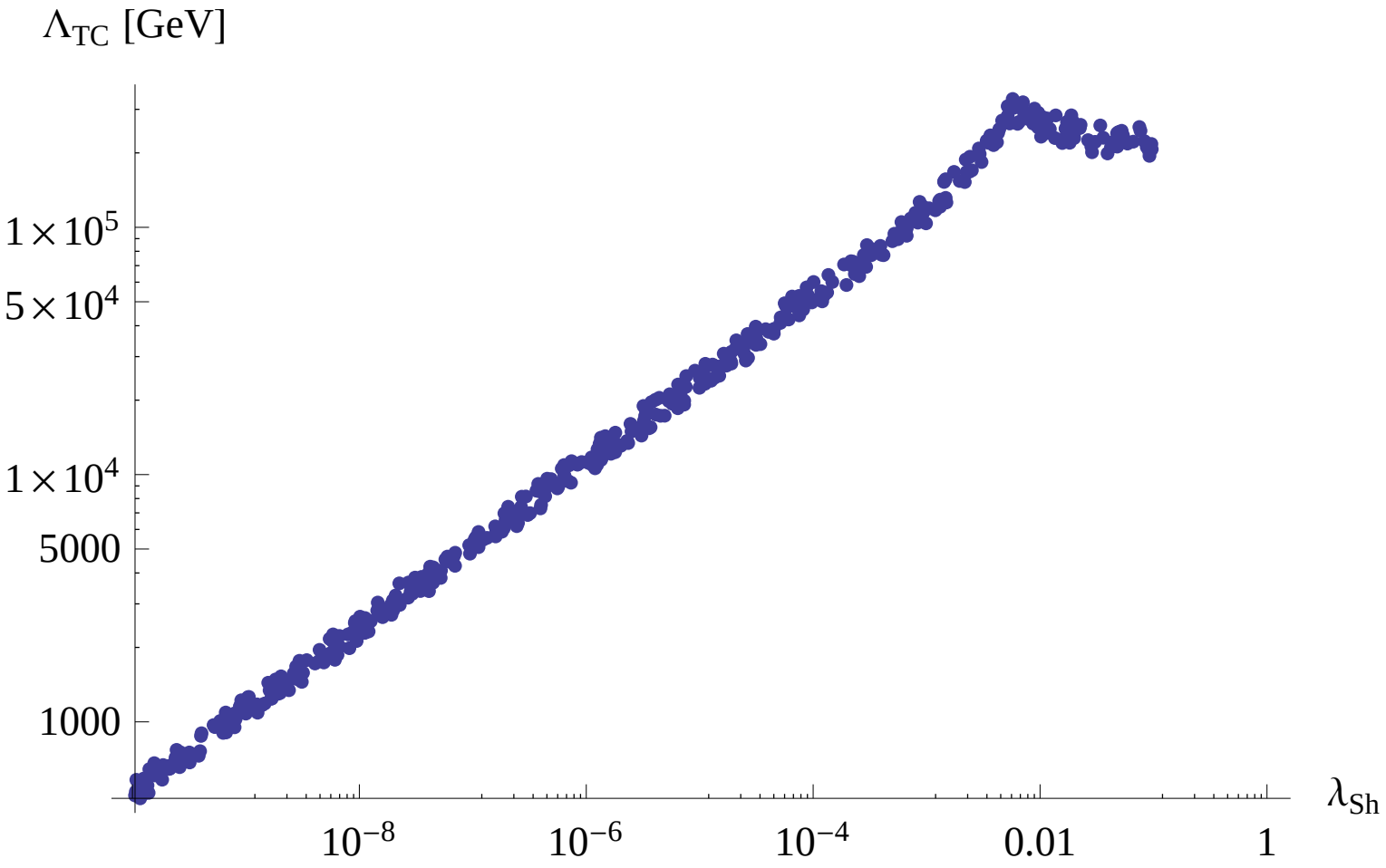
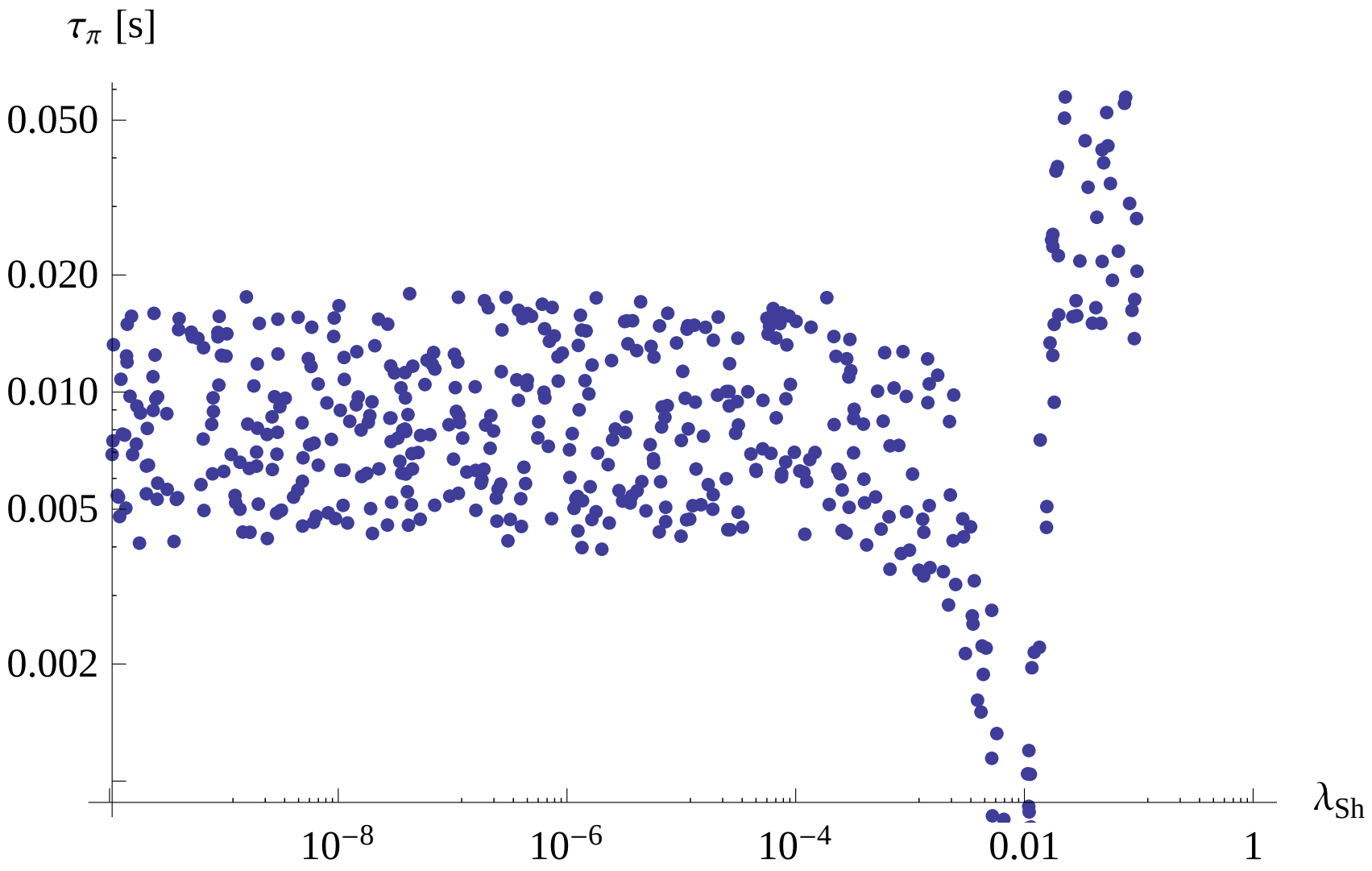


$$\Lambda_{\rm TC} \approx 1.1 \times 10^6 {\rm GeV} \lambda_{Sh}^{\frac{1}{3}}$$

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