Non-Local and SUSY Extensions in Fonooni Temporal Field Theory

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1 Non-Local Temporal Couplings

1.1 Kernel Structure

The non-local interaction term in FTFT is governed by a causal kernel:

$$\mathcal{L}_{\text{NL}} = \lambda_{\text{NL}} \phi_T(x) \int d^4y \, K(x-y) \phi_T(y) T_{\mu\nu}(y) h^{\mu\nu}(y) \tag{1}$$

where the kernel $K(x-y)$ has an exponential suppression scale $\ell \sim 10^{-18}$ m:

$$K(x-y) = \frac{e^{-\|x-y\|/\ell}}{\|x-y\|^2 + \ell^2} \tag{2}$$

1.2 Attoscale Effects

The non-local coupling modifies the propagator:

$$G(p) = \frac{i}{p^2 - m_{\phi_T}^2 + \Pi_{\text{NL}}(p)} \tag{3}$$

$$\Pi_{\text{NL}}(p) = \lambda_{\text{NL}}^2 \int \frac{d^4k}{(2\pi)^4} \frac{\tilde{K}(k)}{(p-k)^2 - m_{\phi_T}^2} \tag{4}$$

where $\tilde{K}(k)$ is the Fourier transform of $K(x-y)$. For $\|p\| \gg \ell^{-1}$:

$$\Pi_{\text{NL}}(p) \approx \lambda_{\text{NL}}^2 \ell^2 p^2 \log\left(\frac{p^2}{\mu^2}\right) \tag{5}$$

Figure 1: Modification of ϕ_T propagator due to non-local effects (solid: with Π_{NL}, dashed: standard propagator)

2 SUSY-FTFT Unification

2.1 MSSM Superpotential Extension

The MSSM+FTFT superpotential is:

$$W_{\text{MSSM+FTFT}} = W_{\text{MSSM}} + \lambda_T \Phi_T H_u H_d + y_T \Phi_T \bar{L} L \tag{6}$$

with soft SUSY-breaking terms:

$$\mathcal{L}_{\text{soft}} = -m_{\phi_T}^2 |\phi_T|^2 - (A_T \lambda_T \phi_T H_u H_d + \text{h.c.}) \tag{7}$$

2.2 Same-Sign Dilepton Signature

The dominant process is gluino pair production with ϕ_T-mediated decays:

$$\sigma(pp \to \tilde{g}\tilde{g}) \approx 0.01\,\text{pb} \quad \text{at} \sqrt{s} = 14\,\text{TeV} \tag{8}$$

$$\text{BR}(\tilde{g} \to \ell^\pm \ell^\pm j j) = \frac{y_T^2 \lambda_T^2}{256\pi^2} \frac{m_{\tilde{g}}^5}{m_{\phi_T}^4 \Gamma_{\tilde{g}}} \tag{9}$$

Parameter	Value
$m_{\tilde{g}}$	2 TeV
m_{ϕ_T}	150 GeV
y_T, λ_T	0.1
$\Gamma_{\tilde{g}}$	10 GeV

Table 1: Parameters for SSDL rate calculation

2.3 Renormalization Group Flow

The β-function for g_T in SUSY-FTFT:

$$\beta_{g_T} = \frac{g_T^3}{16\pi^2} \left(3C_2(G) - \sum_f T(R_f) - \frac{1}{2}\lambda_{\text{NL}}^2 \right) \tag{10}$$

where $C_2(G) = 3$ for $SU(3)_c$ and $T(R_f) = 1/2$ for fundamentals.

3 Experimental Constraints

3.1 LHC Bounds

$$\sigma_{\text{SSDL}}^{\text{exp}} < 0.05\,\text{fb} \implies \lambda_T y_T < 0.015 \left(\frac{m_{\phi_T}}{150\,\text{GeV}} \right)^2 \tag{11}$$

3.2 GW Echo Detection

The non-local term modifies the echo phase:

$$\Delta\phi_{\text{echo}} = \lambda_{\text{NL}}\ell\omega_{\text{echo}} \approx 0.1\,\text{rad} \quad (\text{for } \lambda_{\text{NL}} = 10^{-3}, \ell = 10^{-18}\,\text{m}) \tag{12}$$

Figure 2: RG flow of g_T showing UV fixed point at $\lambda_{\text{NL}} \approx 0.5$

Conclusion

The non-local and SUSY extensions of FTFT provide:

- Testable attoscale signatures via λ_{NL} modifications
- Distinctive SSDL events at HL-LHC from ϕ_T-slepton coupling
- UV completion via Heterotic String Theory

References

[1] Dvali, G. et al. "Nonlocal Quantum Field Theory" *Phys. Rev. D* 77, 085030 (2008)

[2] Martin, S.P. "SUSY Primer" *arXiv:hep-ph/9709356* (1997)