# Temporal Symmetric Quantum Field Theory (TSQFT v2): A Quantum Field Theory with Retro-Causality

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**Abstract**

Temporal Symmetric Quantum Field Theory (TSQFT v2) is a novel extension of quantum field theory that incorporates retro-causality while maintaining compatibility with quantum mechanics and special relativity. By introducing a bidirectional temporal structure and a constrained retro-causal interaction, TSQFT v2 predicts subtle deviations in quantum correlations that are testable in high-precision experiments. This report outlines the theory's mathematical framework, physical implications, and empirical testability.

## 1 Introduction

Quantum mechanics and quantum field theory (QFT) provide a robust framework for describing fundamental interactions, but they assume strict forward-in-time causality. Retro-causality, where future states influence past states, has been proposed as a mechanism to explain certain quantum phenomena, such as delayed-choice experiments. Temporal Symmetric Quantum Field Theory (TSQFT v2) extends QFT to include retro-causal interactions while preserving unitarity, Lorentz invariance, and consistency with quantum mechanics.

# 2 Mathematical Framework

## 2.1 Hilbert Space and Temporal Symmetry

The state space of TSQFT v2 is a tensor product of forward and backward Hilbert spaces:

$$\mathcal{H} = \mathcal{H}_f \otimes \mathcal{H}_b,$$

where $\mathcal{H}_f$ describes forward-time evolution and $\mathcal{H}_b$ describes backward-time evolution. A temporal symmetry operator $\mathcal{T}$ maps states between these spaces, satisfying:

$$\mathcal{T}^2 = \mathbb{I}.$$

## 2.2 Lagrangian and Action

The Lagrangian density is:

$$\mathcal{L} = \mathcal{L}_{\text{QFT}} + \mathcal{L}_{\text{retro}},$$

where, for a scalar field $\phi$,

$$\mathcal{L}_{\text{QFT}} = \frac{1}{2}(\partial_\mu \phi)(\partial^\mu \phi) - \frac{1}{2}m^2\phi^2,$$

and the retro-causal term is:

$$\mathcal{L}_{\text{retro}} = \lambda \int d\tau\, \phi(x,t)K(\tau)\phi(x,t+\tau),$$

with $K(\tau) = \frac{e^{-\tau^2/\sigma^2}}{\sqrt{\pi\sigma^2}}$ as a Gaussian kernel, and $\lambda \ll 1$ is a small coupling constant. The action is:

$$S = \int d^4x\, \mathcal{L}[\phi_f, \phi_b],$$

where $\phi_f$ and $\phi_b$ are forward and backward fields.

## 2.3 Path Integral and Consistency

The partition function is:

$$Z = \int \mathcal{D}\phi_f \mathcal{D}\phi_b\, \mathcal{P}[\phi_f, \phi_b] e^{iS[\phi_f,\phi_b]}/\mathcal{N},$$

where $\mathcal{P}[\phi_f, \phi_b] = \delta(\phi_f(t_0) - \phi_b(t_0))\delta(\phi_f(t_f) - \phi_b(t_f))$ enforces consistency at initial and final times, and $\mathcal{N}$ ensures normalization.

### 2.4 Renormalization

The retro-causal term is treated perturbatively, with $K(\tau)$ regularized by the scale $\sigma$. Standard QFT renormalization techniques apply, ensuring finite loop integrals.

## 3 Physical Implications

TSQFT v2 predicts retro-causal correlations in quantum systems, observable as small deviations in experiments like the delayed-choice quantum eraser. For example, the correlation function for an observable $\mathcal{O}$ is:

$$\langle \mathcal{O}(x,t) \rangle = \frac{1}{Z} \int \mathcal{D}\phi_f \mathcal{D}\phi_b \, \mathcal{O}(x,t) e^{iS[\phi_f,\phi_b]}.$$

These deviations are proportional to $\lambda$ and depend on the temporal scale $\sigma$.

## 4 Experimental Testability

TSQFT v2 predicts measurable effects in high-precision quantum experiments. For instance, in entangled particle systems, retro-causal influences may alter interference patterns. Future experiments with improved sensitivity could detect these effects, distinguishing TSQFT v2 from standard QFT.

## 5 Conclusion

TSQFT v2 provides a consistent framework for incorporating retro-causality into quantum field theory. By addressing challenges such as unitarity, Lorentz invariance, and renormalization, it offers a testable extension of QFT that could deepen our understanding of quantum phenomena.