Particle Interactions and the Structure of Information

1 Introduction

This paper explores the relationship between particle interactions and information creation. The premise is that each fundamental interaction in particle physics is not just an exchange of energy and momentum but also an instantiation of new information. This leads to a framework where information is treated as a conserved and quantifiable entity within physical processes.

2 Collisions as Information Creation

Each particle collision generates information by altering quantum states and redistributing energy. We define the state of a system at time t as:

$$S(t) = \{p_i, E_{ij}\} \tag{1}$$

where p_i represents the quantum states of particles and E_{ij} the interaction energies. A transition from state $S(t)$ to $S(t+1)$ can be described as:

$$S(t+1) = \hat{T}S(t) \tag{2}$$

where $\hat{T}$ is the transformation operator governing interaction outcomes.

3 Information Representation in Particle Interactions

To quantify information, we introduce an information function:

$$I(t) = \sum_i \log(p_i) + \sum_j \log(E_{ij}) \tag{3}$$

which measures the descriptive complexity of the system. The change in information over time, constrained by conservation laws, is given by:

$$\Delta I = I(t+1) - I(t) \leq kE \tag{4}$$

where E is the total interaction energy and k a proportionality constant.

4 The Role of Observation

An interaction is instantiated only upon observation, drawing a connection to quantum measurement. We formalize observation as an operator $\hat{O}$ acting on the system state:

$$\hat{O}S(t) = (V(t), E'(t)) \tag{5}$$

where $E'(t) \subseteq E(t)$ are the observed interactions. The act of measurement collapses possible outcomes into a realized state, structuring information within the FL Field.

5 FL Field as a Framework for Physical Laws

The FL Field provides a meta-theoretical structure in which physical laws emerge as constrained instantiations. We define FL as a category where:

- **Objects:** Lawful interactions (e.g., QED, QCD, Standard Model components).
- **Morphisms:** Proofs or transitions—describing how one set of laws transforms into another.

This categorical structure allows for a unification of interactions under a single informational paradigm.

6 Quantum Constraints on Information Propagation

The propagation of information follows constraints analogous to physical limits:

$$c_F = \text{max velocity of information propagation} \tag{6}$$

$$\mathcal{Q}_F = \mathcal{I}_0 \cdot \tau_0 \tag{7}$$

where $\mathcal{I}_0$ is the fundamental unit of information and τ_0 the smallest measurable time step.

7 Conclusion

Particle interactions are not merely energy exchanges but also processes of information transformation. The FL Field offers a framework where physical laws, quantum constraints, and information-theoretic principles are unified. Future work includes extending this to higher-order emergent structures and potential applications in computational models of physics.