Infinite Derivative Field Theory:
Stability, Asymptotic Safety, Trnas-Planckian Scattering, Dark Matter, Inflation & LHC

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- L. Buoninfante, , **A. Ghoshal**, , A. Mazumdar, S.Kumar, A.Koshelev, G.Lambiase, N.Okada, A.Tokareva, D.Villaba

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1709.09222
1812.02314
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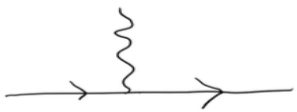
Motivation for Infinite-derivative Non-local QFT

- Prediction from string field theories: strings are non-local objects with associated non-local scale M_{NL}.
- UV completion of SM without introducing any new particles: no quadratic divergence of Higgs mass, vacuum stability, no Landau poles & no ghost.
- Trustable quantum theory upto infinite energy.
- Cosmology: Viable Higgs Inflation, Predictable DM mass & relic density.
- Neutrinos: Stable Heavy Neutrinos.
- *An Example:* Non-local QED:

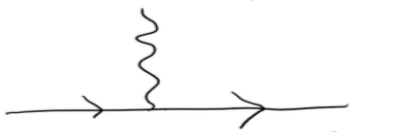
$$\mathcal{L} = -\frac{1}{4} F^{\mu\nu} e^{-\frac{\partial^2}{M^2}} F_{\mu\nu} + i\bar{\psi} e^{-\left(\frac{\partial^2 - g^2 A^2}{M^2}\right)} \gamma^\mu (\partial_\mu + igA_\mu)\psi$$

Local Vertices:



$$V_L = -ig\gamma^\mu$$

Non Local Vertices(1st order):

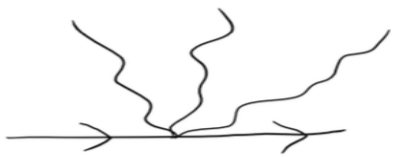


$$V_{NL}^{(1)} = -ig\gamma^\mu \left(\frac{p^2}{M^2}\right)$$

External momenta!

$$V_{NL}^{(1)} = -ig^2 \eta_{\alpha\beta} \left(\frac{\gamma^\mu p_\mu}{M^2}\right)$$

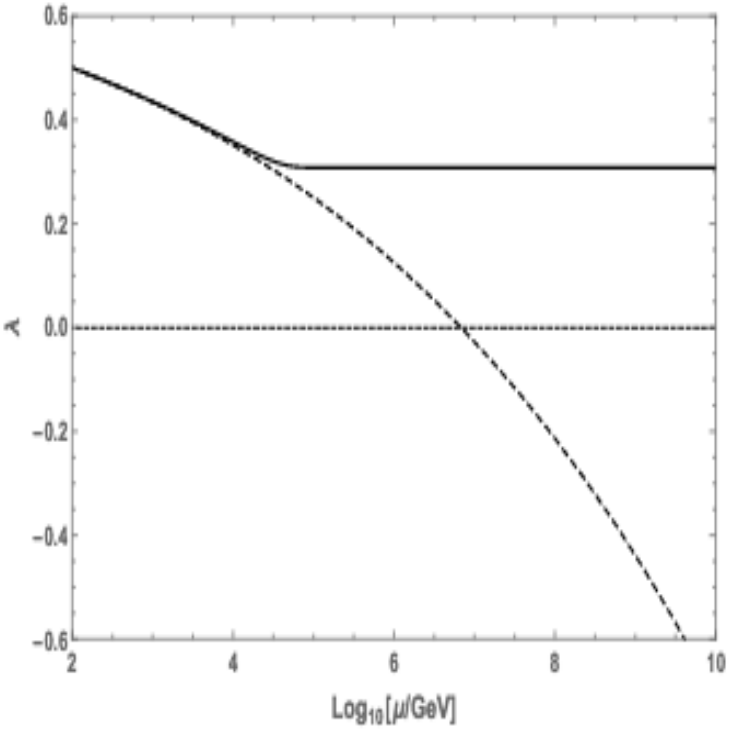
External momenta!

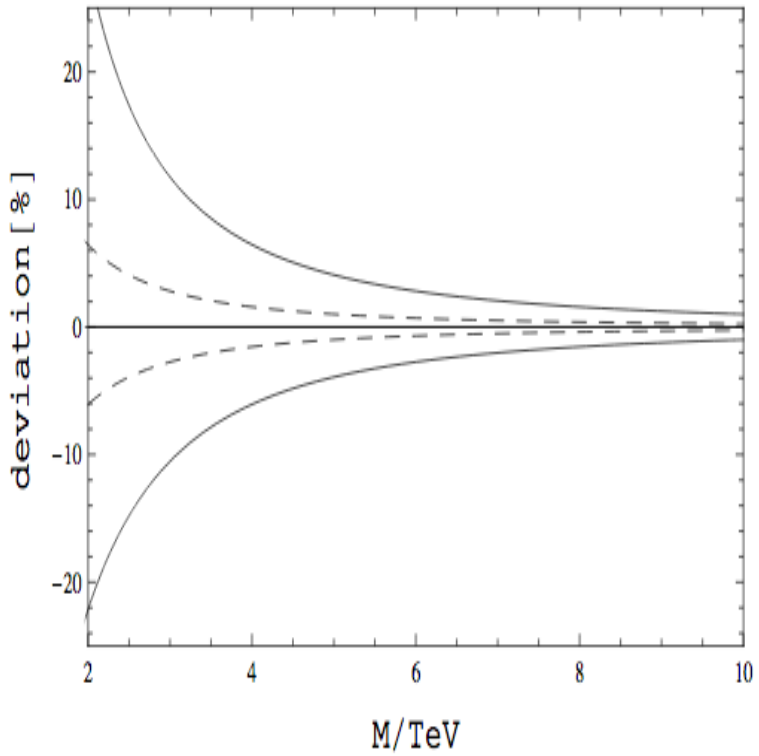


$$V_{NL}^{(1)} = -ig^3 \eta_{\alpha\beta} \left(\frac{\gamma^\mu}{M^2}\right)$$

Non-local contributions disappear in the $M \to \infty$ limit. Reduces to standard QFT.

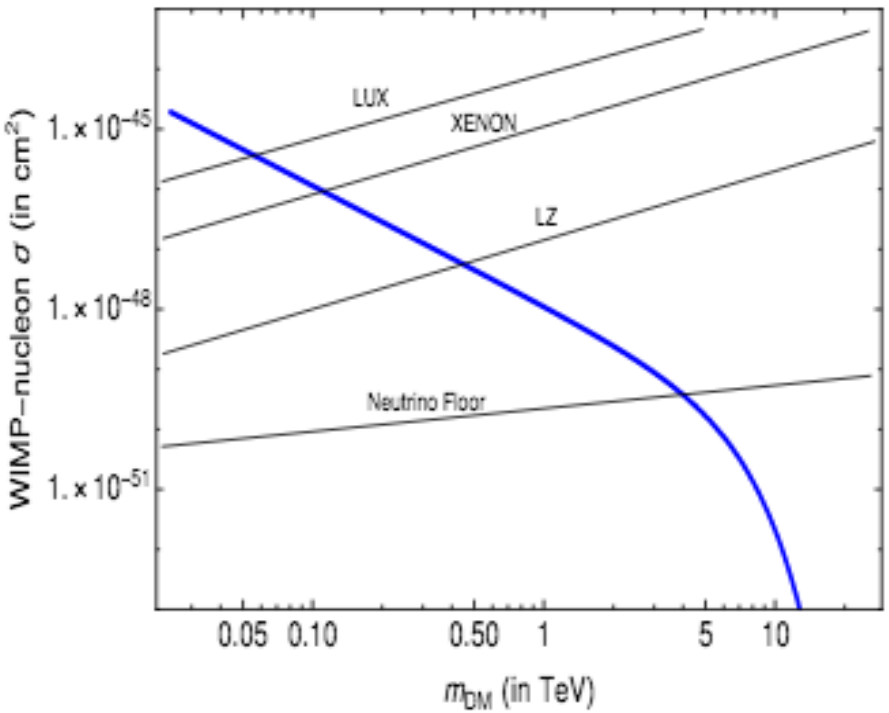
- $\beta-$ functions vanish in the $\mu > M$ limit.
- No quadratic mass divergence.
- Quartic running stops. $\mu = M$ is UV fixed point. Higgs vacuum remain stable.
- Conformal Invariance.
- Asymptotic Safety: theory valid upto infinite energy beyond Planck scale.
- LHC Signature:





- LHC constrains $M > O(TeV)$ currently.

- N-particle scattering gives scale transmutation; non-locality scales as $M_{eff} \sim \frac{M}{\sqrt{N}}$.
- Trans-planckian processes reduces to super sub-planckian processes.
- Dark matter relic determined by M.
- Direct Detection of Dark Matter experiments probe M upto O(30 TeV).
- Rescue some models of DM ruled out by direct detection.



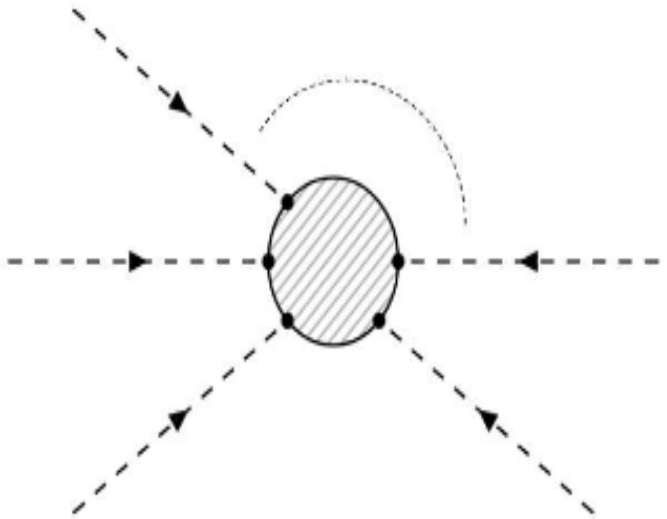


Figure: Effective non-local region.

- Higgs Inflation is self-healing: unitarize & conformal.