### INTRODUCTION

The Nonlinear Sigma Model with values in a coset space $G/H$ arises whenever a symmetry group $G$ is spontaneously broken to a subgroup $H$. In a minimal realization of the Standard Model, the LQSM geometry describes the dynamics of the Goldstone bosons responsible for the electroweak symmetry breaking of $SU(2) 	imes U(1)$ to $U(1)$.

- We consider the possibility that the theory is renormalizable in a nonperturbative sense, namely at a nontrivial ultraviolet (UV) Fixed Point (FP) of the Renormalization Group (RG) flow [1,2].
- A FP is defined by the requirement that the beta functions of the dimensionless couplings have a zero $\beta_0 = 0$.

A quantum field theory is said to be Asymptotically Safe (AS) if it has a FP with a finite number of UV-attractive directions. Observables quantities such as decay rates and cross sections can be expressed as functions of the couplings and if the couplings are finite, also the observable quantities will be finite. The good UV limit is obtained by requiring that out theory lies on a renormalization group trajectory for which all couplings remain finite when the energy goes to infinity.

- If the FP has a finite number of attractive directions, then the set of all points belonging to these trajectories is a non-renormalization surface called the "UV-critical surface". In an asymptotically safe theory we would have to perform experiments at some given energy scale $k_0$ in order to pin down completely our position in theory space. Everything else could then be computed, at least in principle, and would constitute genuine predictions that could be verified experimentally.

- The main tool used for study the scale dependence of our theory is the Exact Renormalization Group Equation (ERGE) [3]:

$$ \frac{d}{dk} \Gamma_{\beta_0} = \frac{1}{\pi} \text{Tr} \left( \frac{d}{dk} \left[ \Gamma_{\beta_0} \right] \right) \frac{k}{\beta_0} \frac{d}{dk} \Gamma_{\beta_0}. $$

This equation applies to the Effective Average Action $\Gamma_{\beta_0}$, which is a generalization of the standard effective action, obtained by implementing an infrared (IR) cutoff $\Lambda$ in its functional definition. The ERGE is well defined both in the IR and UV and we can thus forget about regularization.

### THE ELECTROWEAK MODEL

We consider a Nonlinear Sigma Model where the Goldstone bosons are coupled to the electroweak gauge bosons. We use a geometrical description where the Goldstone bosons are coordinates $\varphi^a(x)$ of a field $\Pi(x)$, taking values in $SU(2) \times U(1)$ - $SU(2)$.

- The lowest order terms in the Euclidean action are:

$$ \Gamma_{(1)} = \frac{1}{2} \int d^4x \left( \frac{1}{2} \partial_{\mu} \varphi^a(x) \partial^\mu \varphi^a(x) - \lambda^2 \varphi^a(x) \varphi^a(x) \right), $$

where $\varphi^a(x)$ are the Goldstone boson fields, $\lambda$ is the dimensionless gauge coupling and $\lambda^2$ is the mass dimension of the Goldstone bosons.

- In the limit $\lambda \rightarrow 0$ we have:

$$ \Gamma_{(2)} = \frac{1}{12} \int d^4x \left( \lambda^2 \varphi^a(x) \varphi^b(x) \varphi^c(x) \varphi^d(x) \right). $$

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### RESULTS

The running of the gauge couplings is very slow and for our purposes a good approximation to treat them as constants. Setting $g_0 = 0.65$ and $g = 0.25$ we find two physically acceptable UV FPs:

- **FP1**: 1 UV-attractive direction
  - $\beta_0 = -0.000935 \Lambda_0 = -0.001255$

- **FP2**: 2 UV-attractive directions
  - $\beta_0 = -0.000935 \Lambda_0 = -0.001530$

Oblique parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>$\beta_0$</td>
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</tr>
<tr>
<td>$\Lambda_0$</td>
<td>-0.001255</td>
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Goldstone boson scattering amplitude

In previous calculations of the RG flow of the LQSM we have kept the full field dependence of the effective action but expanded to second order in momenta. By contrast in order to compute the scattering amplitude of two Goldstone bosons to two Goldstone bosons we need terms of fourth order in the field, but we have to retain the full momentum dependence. We use the running of the Goldstone coupling to solve iteratively the functional equation (1) in order to obtain the full quantum effective action $\Gamma_{\beta_0}$. This procedure eliminates all divergences and produces a formula for the improved four-point amplitude, which has a much better high energy behavior with respect to the usual leading perturbative result.

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### REFERENCES