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Higher Order Renormalisation in Scalar Effective Field Theory

A study of the conformal basis

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Scalar Effective Field Theory

$$\mathcal{L} = \frac{1}{2}\partial_\mu\phi\partial^\mu\phi - \frac{g}{4!}\phi^4 + \sum_{n>4}\frac{1}{\Lambda^{n-4}}\mathcal{L}^{(n)}$$

with $\mathcal{L}^{(n)} = \sum_i c_i^{(n)}\mathcal{O}_i^{(n)}$: the operator basis

μ-dependence → anomalous dimensions (**AD**):

$$\frac{d\, c_i^{(n)}}{d\log\mu} = \gamma_{ij}^{(n)}c_j^{(n)} + \sum_{\substack{n_1+n_2\\=n+4}}\gamma_{ijk}^{(n_1 n_2)}c_j^{(n_1)}c_k^{(n_2)} + \dots$$

obtained through renormalisation

The Conformal Basis

A mathematically singled out basis spanned by all operators annihilated by the generator of special conformal transformations :

$$K_\mu = \sum_i^N\left(2\frac{d}{dp_i^\mu} + 2p_i^\nu\frac{d}{dp_i^\nu}\frac{d}{dp_i^\mu} - p_{i\mu}\frac{d}{dp_i^\nu}\frac{d}{dp_{i\nu}}\right)$$

The phase space integral defines an inner product on Feynman rules, which separates the physical from the non-physical operators :

$$\langle\mathcal{O},\ \mathcal{O}'\rangle = \left[\prod_{i=1}^{N}\int d^4p_i\ \delta^+(p_i^2)\right]\delta(P_{\text{tot}} - \Sigma_i p_i)\ \mathcal{O}\cdot\mathcal{O}'$$

Q: How do these characteristics affect physical quantities?

$$\langle\mathcal{O}^{(N)}_{conf},\ P^\mu_{\text{tot}}\,\mathcal{O}^{(N)}_\mu\rangle = 0\ ,\quad \langle\mathcal{O}^{(N)}_{conf},\ \partial^2\phi\,\mathcal{O}^{(N-1)}\rangle = 0$$

AD γ are basis-dependent → probe the properties of the conformal basis

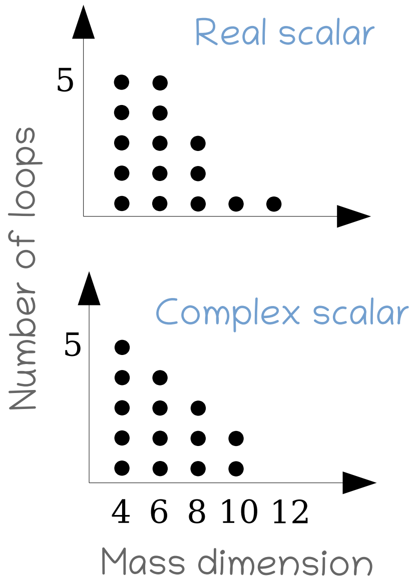
The R*-operation

R* recursively subtracts UV and IR subdivergences from 1PI diagrams at all loops

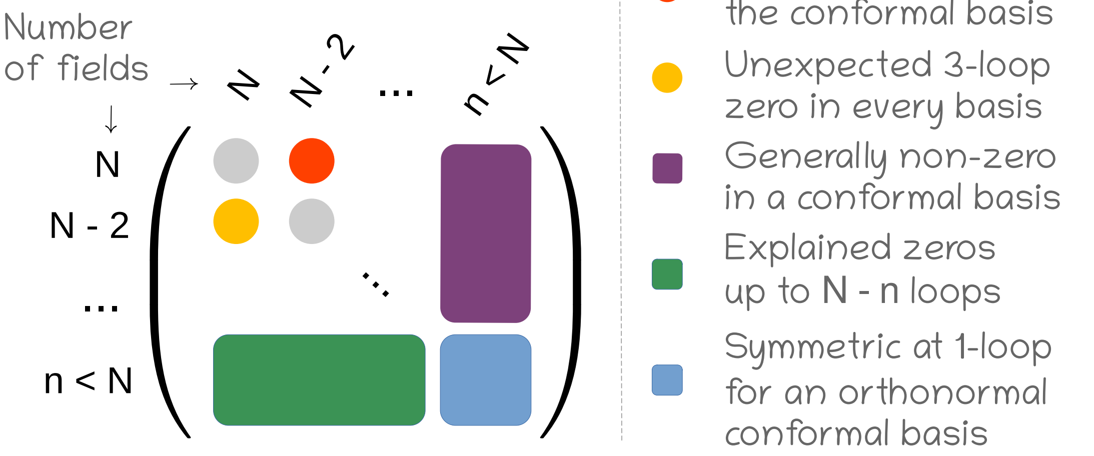
First application in EFT - useful properties:

- Renormalising off-shell Green's functions does not require non-physical counterterms
- Allows for Taylor expanding the integrand and "Infrared rearrangement", i.e. reorganising the momentum flow to simplify the calculation of diagrams with many external lines and high superficial degree of divergence

Scope of calculation:



Results:



General anomalous dimension matrix γ at mass dimension N

There exists a (non-conformal) basis that diagonalises γ at 1-loop