Two-loop renormalisation of non-Abelian gauge theories in 4D Implicit Regularisation

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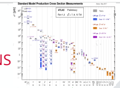
MOTIVATIONS



The data collected at the LHC does not indicate significant deviations from the predictions of the Standard Model (SM).

Taking into account that precision observables can be predicted already at 2 and 3 loops, it is evident the necessity to develop stringent tests of self-consistency of the SM.

Among the different proposals, the development of new regularisation schemes proves to be a viable alternative.

In this scenario, we pursued 2-loop corrections in non-abelian theories using Implicit Regularisation (IREG).

We compute the 2-loop β-function of pure Yang-Mills and QCD using the background field method and IREG.

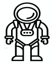
Traditional Regularisation Schemes — Dimensional regularisation (DReg) and dimensional reduction (DRED)

d-dimensions

4-dimensions

$1/\epsilon^n$ UV-div

Non-dimensional scheme — Implicit Regularisation.



4-dimensions

$$I_{log}(\Lambda^2) \equiv \int_k \frac{1}{(k^2-\Lambda^2)^2}$$ UV-div

Basic Divergent Integral

$\int_k = \int \frac{d^4k}{(2\pi)^4}$

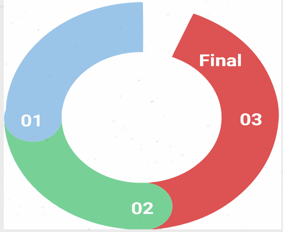
01. Objetives

Understand how to wisely remove UV-div (ultraviolet divergences) when they arise at 2-loop order for non-abelian gauge theories with IREG.

02. Methodology

FeynArts&FormCalc
We create the topologies and the amplitudes.
We do the contractions.

Regularisation
We make the simplifications and reductions for the integral.



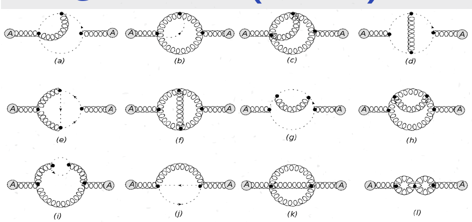
Integral Evaluation
According to the regularisation method used.

β-function

03. The Background Field Method

$$Z_g = Z_A^{(-1/2)}$$

We only need the 2-point functions as the abelian theories!



2-loop correction to the 2-point function of the BF A for pure Yang-Mills.

04. Results

$$\beta = -g_R\left[\beta_0\left(\frac{\tilde{g}_R}{4\pi}\right)^2 + \beta_1\left(\frac{\tilde{g}_R}{4\pi}\right)^4\right]$$

β-function YM

$$\beta|_{\mathrm{DS}} = -g_R\left[\frac{11}{3}C_A\left(\frac{\tilde{g}_R}{4\pi}\right)^2 + \frac{34}{3}C_A^2\left(\frac{\tilde{g}_R}{4\pi}\right)^4\right]$$

$$\beta|_{\mathrm{IREG}} = -g_R\left[\frac{11}{3}C_A\left(\frac{\tilde{g}_R}{4\pi}\right)^2 + \frac{34}{3}C_A^2\left(\frac{\tilde{g}_R}{4\pi}\right)^4\right]$$

β-function QCD

$$\beta_0|_{\mathrm{IREG}} = 11 - \frac{2}{3}n_f;\quad \beta_0|_{\mathrm{CDR}} = 11 - \frac{2}{3}n_f;$$

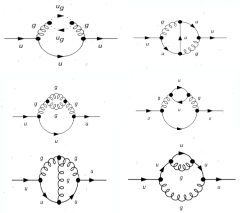
$$\beta_1|_{\mathrm{IREG}} = 102 - \frac{38}{3}n_f;\quad \beta_1|_{\mathrm{CDR}} = 102 - \frac{38}{3}n_f$$

UV-div part with IREG comply with non-abelian gauge invariance.

Intermediate comparison between schemes is not meaningful.

05. Perspectives

To complete the 2-loop project with IREG, we are performing the calculation of the 2-loop *quark mass anomalous dimension* in QCD within a mass-independent regularisation scheme.



$$\gamma_m^{IREG}\left(\Lambda^2\right) = 2\frac{\Lambda^2}{m^{IREG}}\frac{\partial m^{IREG}}{\partial\Lambda^2}$$

$$= -\beta^{IREG}\left(\Lambda^2\right)\frac{\partial \ln Z_m^{IREG}}{\partial g^{IREG}}$$

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