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Numerical Regularization for 4-loop Self-Energy Feynman Diagrams

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In recent work we computed 4-loop integrals for self-energy diagrams with 11 massive internal lines. Presently we perform numerical integration and regularization for diagrams with 8 to 11 lines, while considering massive and massless cases. For dimensional regularization, a sequence of integrals is computed depending on a parameter (ε) that is incorporated via the space-time dimension, and approaches zero. We consider diagrams where the leading term in the expansion is in $1/\varepsilon^2$ or in $1/\varepsilon$ or finite. The numerical integration methods include non-adaptive, double exponential integration, and Quasi-Monte Carlo approximations with embedded lattice rules implemented in CUDA C for acceleration on GPU, as well as adaptive integration layered over MPI. The leading term coefficient of $1/\varepsilon^2$ or $1/\varepsilon$ in the integral expansion is obtained via linear or nonlinear extrapolation as epsilon tends to zero.

Significance

We present new numerical approximations for 4-loop integrals, which are compared with results in the literature including (Baikov and Chetyrkin 2010) and (Smirnov and Tentyukov 2010). This work is part of our project on the numerical evaluation of loop integrals and expansions presented in, e.g., (de Doncker et al. 2018, 2019, 2020) and (de Doncker and Yuasa 2021). It stands out that our computations are fully numerical, based on automatic integration and numerical extrapolation for convergence acceleration. For automatic integration, the user is not required to specify characteristics of the integrand function - except for the function definition itself. The packages pySecDec (Borowka et al. 2018) and Forcer (Ruijl, Ueda and Vermaseren 2020) incorporate symbolic computations.

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