EW Sudakov logarithms and their implementation in OpenLoops

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Introduction

- EW Sudakov logarithms

$$L(s) = \frac{\alpha}{4\pi} \log^2 \frac{s}{M^2}, \qquad l(s) = \frac{\alpha}{4\pi} \log \frac{s}{M^2} \tag{1}$$

- They dominate over the other finite corrections at high energies ($E \gg M_{\mathrm{W}}$)
- At $E = 0.5 - 1\mathrm{TeV}$ they bring corrections which can amount to $\sim 10\%$ (or even more)
- In the high-energy limit, for not mass-suppressed processes, EW Sudakov logs factorize like

$$\delta\mathcal{M}^{\varphi_{i_1}\cdots\varphi_{i_n}} = \sum_{k=1}^{n} \sum_{\varphi'_k} \mathcal{M}_0^{\varphi_{i_1}\cdots\varphi_{i'_k}\cdots\varphi_{i_n}} \delta_{\varphi_{i'_k}\varphi_{i_k}} \tag{2}$$

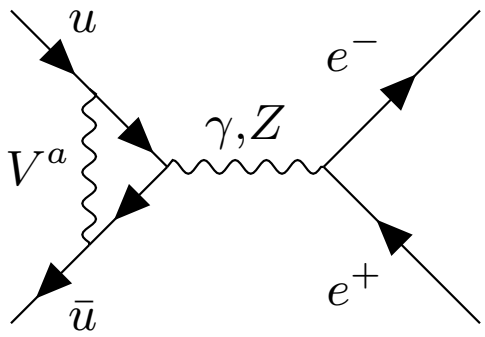
- References: `hep-ph/0010201v3` and `hep-ph/0104127`

Implementation in OpenLoops: why

- NLO EW corrections have been almost fully automated nowadays
- However, keep in mind:
  - Even if automated, one-loop computations can be very complicated, in particular for high multiplicity processes (already at NNLO/two-loop different techniques are required)
  - At high energies the full NLO EW is provided only by the Sudakov logarithms, which factorize
- Purpose of the implementation: find a way to compute these corrections relying on tree computations rather than loop ones
- This would simplify a lot all computations, speeding up the simulations

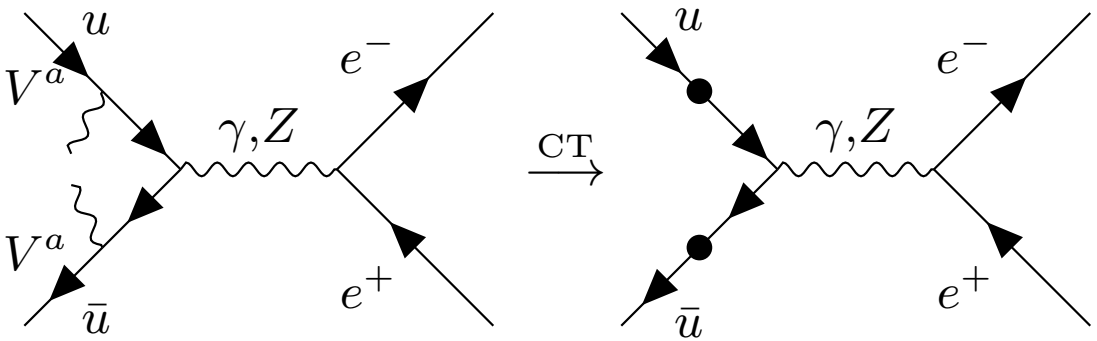
Implementation in OpenLoops: how

- Example: consider the 1-loop correction to $u\bar{u} \to e^+e^-$



(3)

- The idea is to cut the virtual propagator and replace it with two (pseudo) CT



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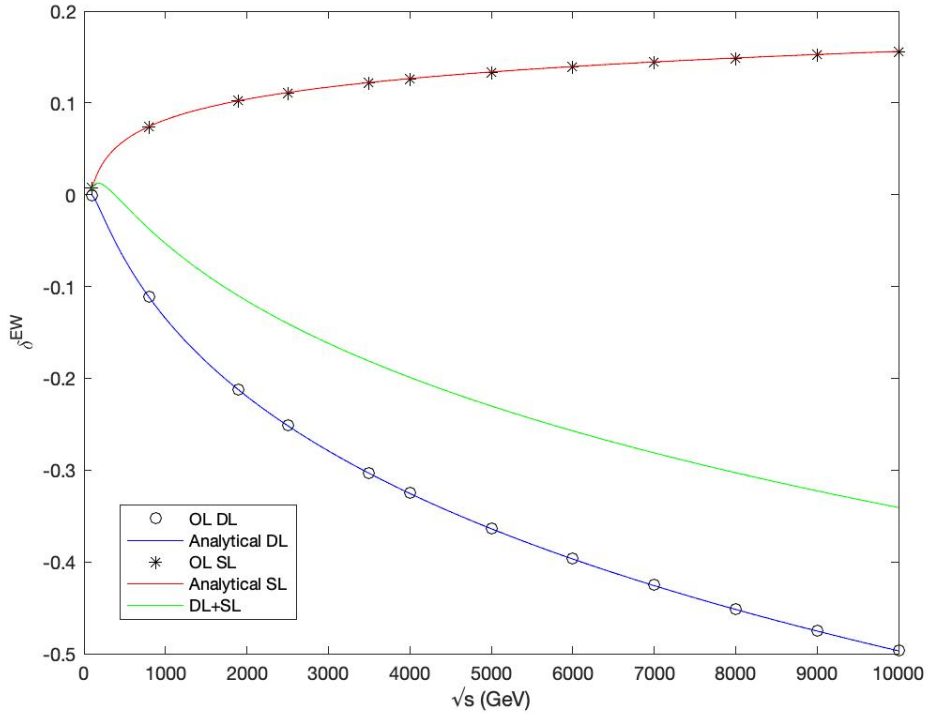
Implementation in OpenLoops: how

- Definition of a new model with the usual Feynman rules except for the CT ones

$$\text{e.g. } V^a = A \qquad \overset{f}{\longrightarrow}\!\bullet\!\overset{f}{\longrightarrow} = ieI_f^A \log \text{EWA} \tag{5}$$

- The insertion of CTs will result in the Born amplitude times a factor which will contain the proper logarithmic structure (for the previous diagram $\mathcal{M} \sim e^2 I_u^A I_{\bar{u}}^A \text{logEWA}^2 \times \mathcal{M}_0$)



What's next

- Future steps:
  - Conclude the SL contribution
  - Include external massive fermions
  - Generalize the procedure for external scalar/gauge bosons
  - Extend the implementation at NNLO