Two-loop five-point massless QCD amplitudes within the IBP approach

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Amplitudes 2018 School, UC Davis
12th June 2018

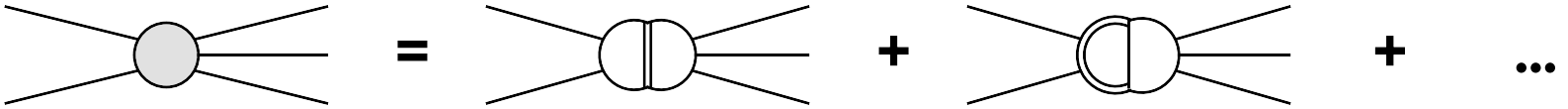
work performed with M. A. Lim and A. Mitov

Introduction

- Precise calculations of scattering amplitudes in gauge theories (such as QCD) require the evaluation of multi-loop integrals
- Multi-loop integrals are often evaluated using integration-by-parts (IBP) identities
- We introduce a new strategy for solving IBP identities and, as an example, apply it to the QCD scattering amplitude $q\bar{q} \to q'\bar{q}'g$ at 2 loops

Integration-by-parts (IBP) identities

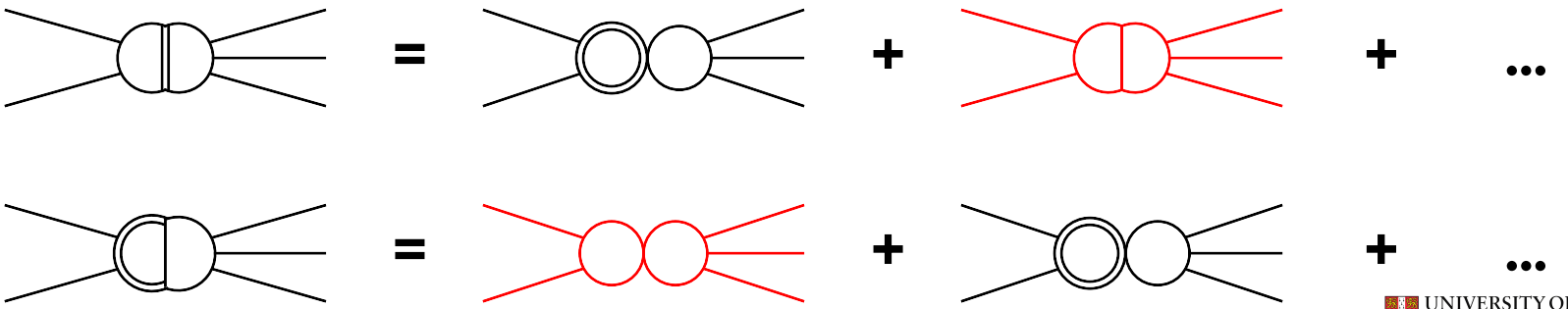
- Generic amplitude is a sum of Feynman integrals



- Integration-by-parts (IBP) identities:

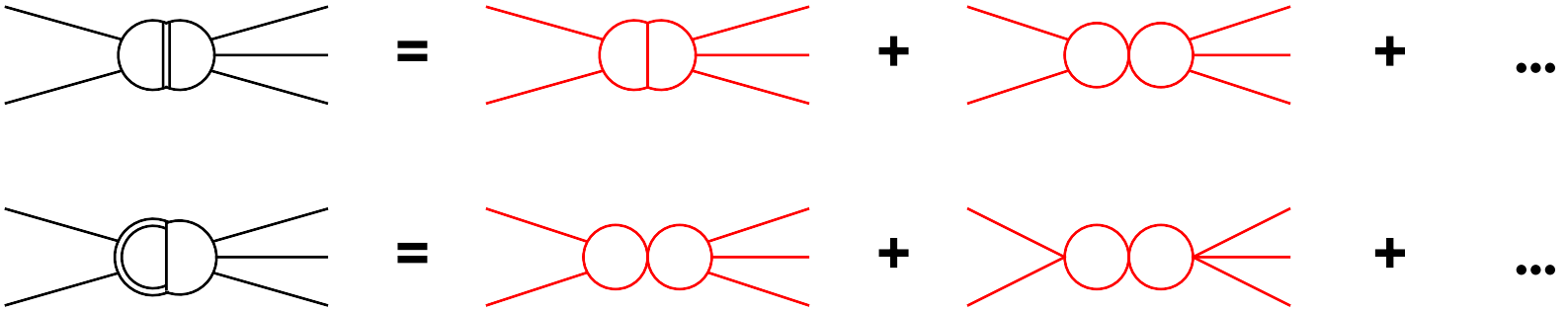
$$\int d^d k_1 \dots d^d k_N \frac{d}{dk_i^\mu} \left(\frac{1}{\Pi_1^{n_1} \dots \Pi_P^{n_P}} \right) = 0,$$

- Hence, many linear relations between integrals

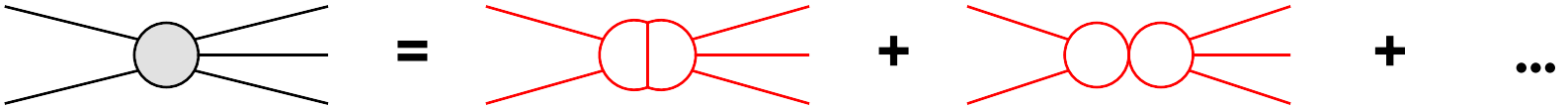


Integration-by-parts (IBP) identities (continued)

- Solve this system of equations to express all integrals in terms of a *small* basis of master integrals.



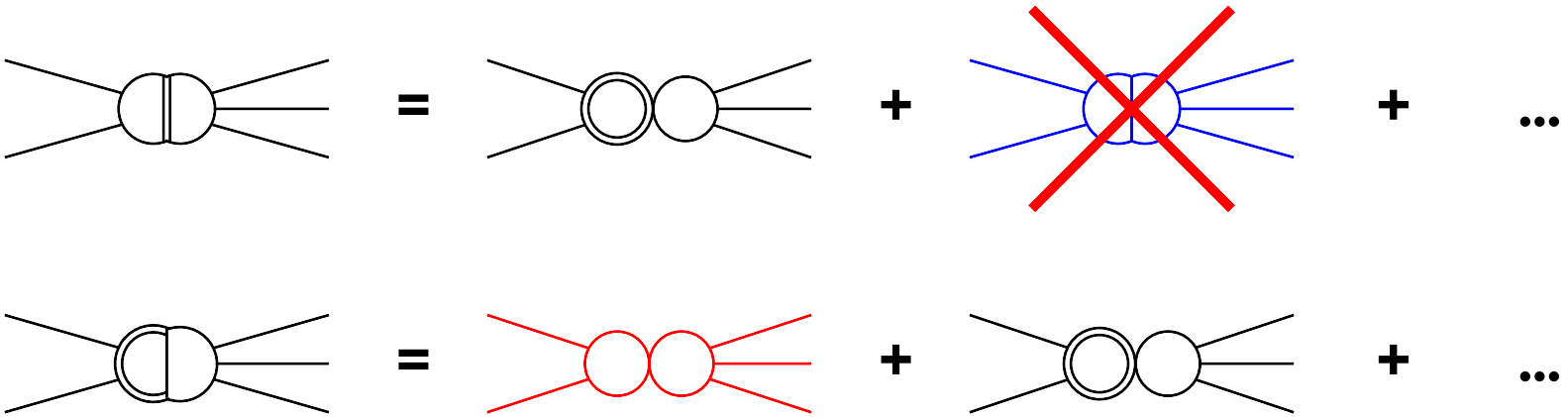
- Can hence write original amplitude in terms of master integrals



- Note: the solution to the IBP system is also used to evaluate the master integrals themselves

Our strategy

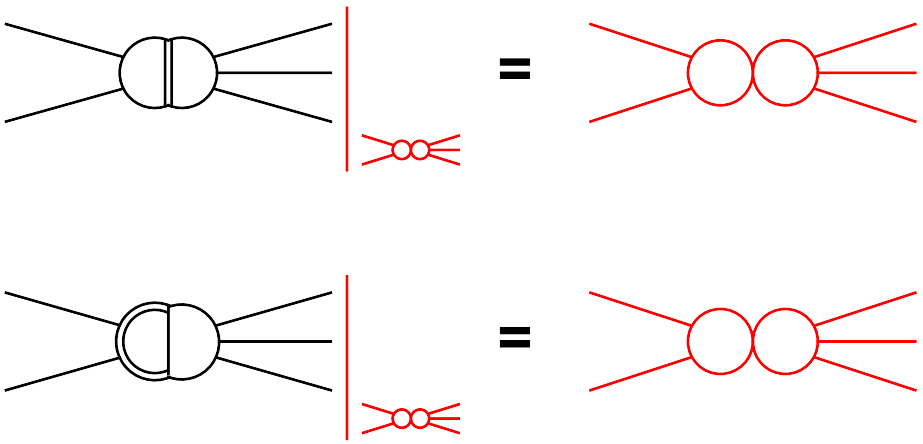
- Derive projections of the IBP equations onto a single master integral by setting all other master integrals to be zero



- This simplifies the IBP equations because many non-master integrals only project onto a subset of the master integrals

Our strategy (continued)

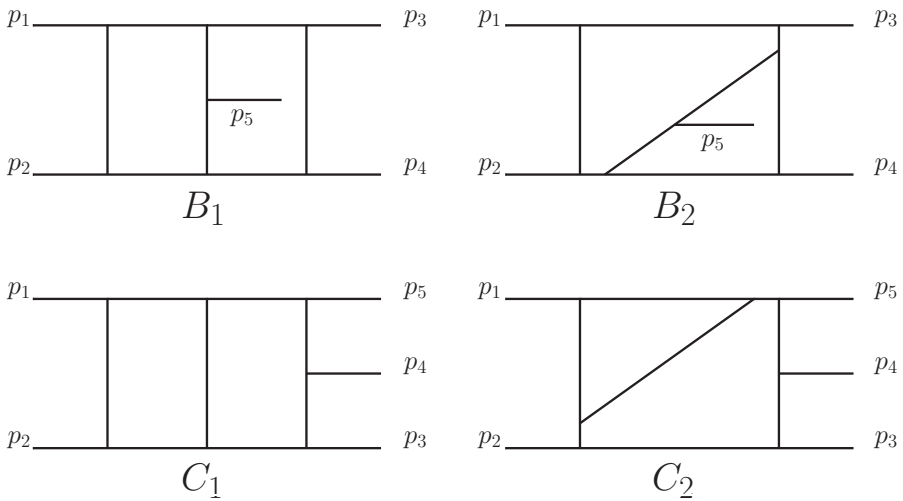
- By solving these simplified equations, one obtains the projections of all integrals onto a single master integral



- The full solution to the original IBP equations is obtained by repeating for each of the other master integrals and summing the solutions

Results

- We have implemented our strategy in a private code and applied it to the QCD amplitude for $q\bar{q} \to q'\bar{q}'g$ at 2 loops
- Most complicated 2-loop 5-point topologies:



Conclusions

- Proposed a new strategy for solving the IBP identities
- Derived analytic expressions for all integral coefficients needed to construct any planar 2-loop 5-point massless QCD amplitude with quarks and/or gluons

Future work:

- Fast numerical evaluation of results for use in collider phenomenology
- Compute reduction for non-planar topologies

Further reading – see our paper:

`hep-ph/1805.09182`

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