Expansion by Regions for precision Higgs physics

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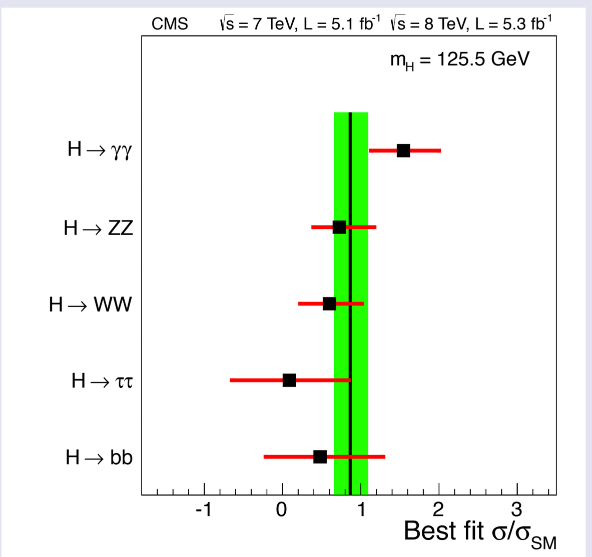
The need for precision calculations

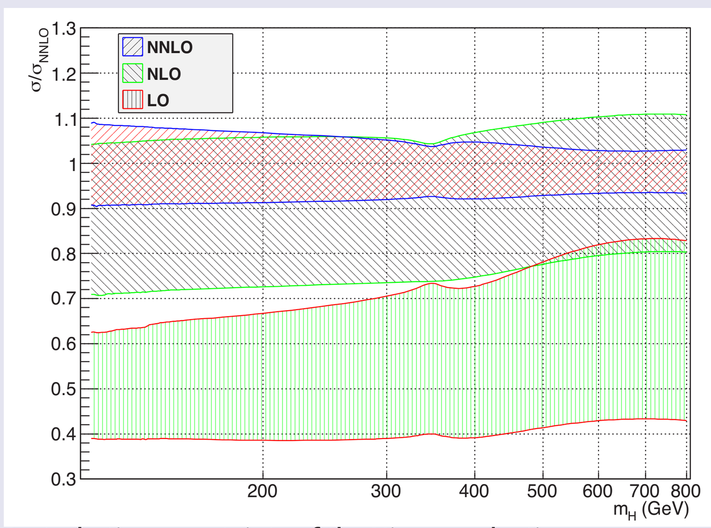
With the recent discovery of a Higgs-like boson, precision measurements of its properties will become the priority of future experiments.
The determination of the Higgs coupling properties is of paramount importance for our understanding of the standard model and possible BSM physics.



LHC results of the deviation of the Higgs branching ratios w.r.t. the Standard Model. arXiv:1207.7235

The potential tensions between the different decay widths of the Higgs have led to a proposal of a plethora of different new physics models. To be able to discriminate amongst them, high-precision predictions are required.

Calculations at NNNLO in QCD are necessary to ensure the perturbative stability and precision of observables in the Higgs sector.

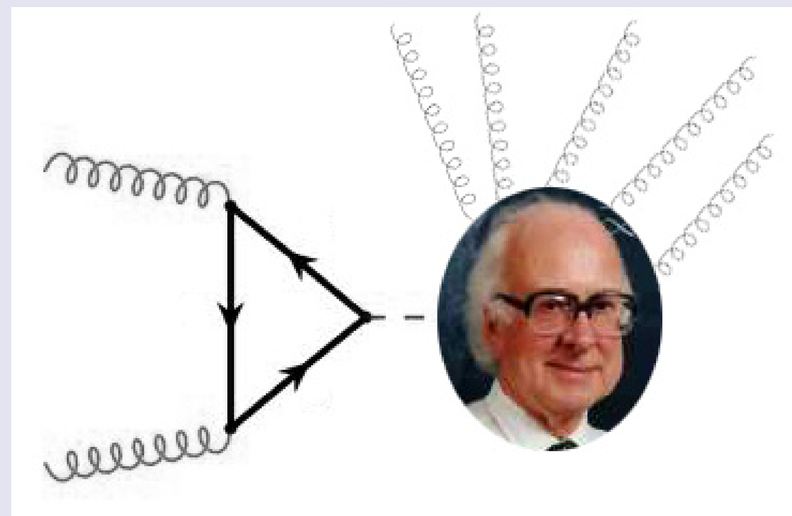


Perturbative uncertainty of the Higgs production cross-section in gluon fusion at LO, NLO and NNLO. arXiv:1202.3638v1

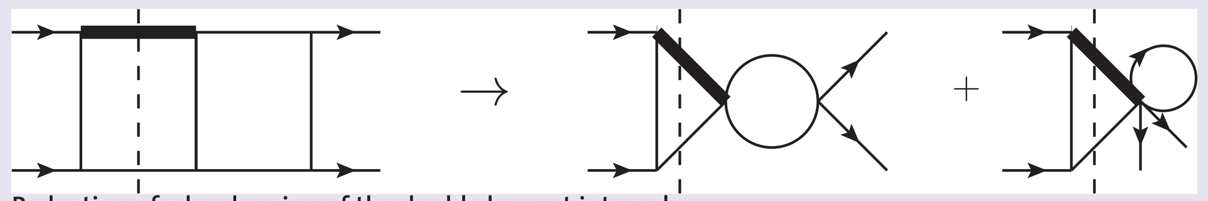
One ingredient of such formidable calculations is the determination of soft-collinear limits of NNLO calculations. These limits determine the boundary conditions of the systems of differential equations used to calculate the NNNLO master-integrals.
Furthermore they appear as FKS-subtraction terms in the cancellation of infrared divergences between real and virtual contributions.

Expansion by Regions

At the LHC ultra-hard gluons collide with enough energy to yield the massive Higgs boson. The mass of the Higgs takes up most of the available momentum, such that any other particles produced in the process can only carry a tiny fraction of the total momentum.
It seems natural to arrange calculations in such a way that this hierarchy of momenta is respected.



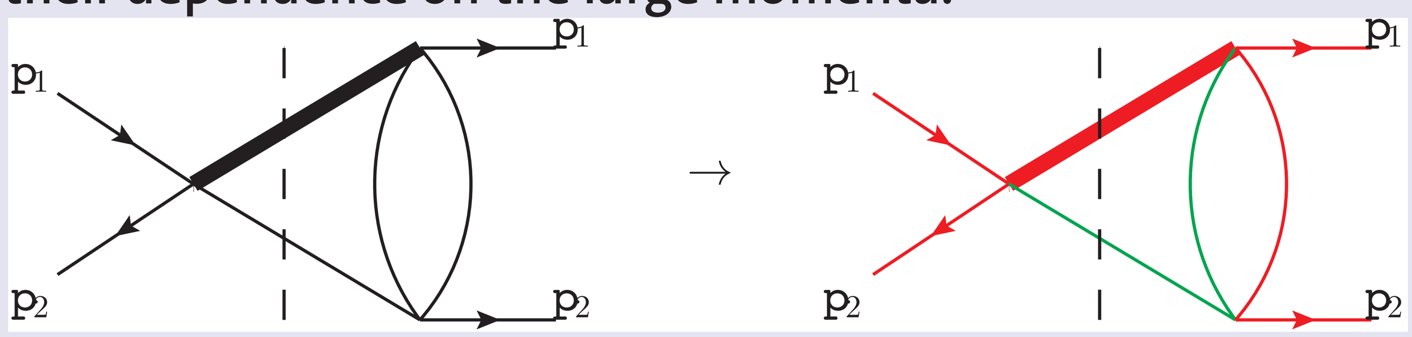
We make use of the fact that the dominant scale is the Higgs mass by expanding the diagram around it. This is part of a well known technique called method of regions. Complicated loop integrands are expanded, which significantly reduces their complexity.



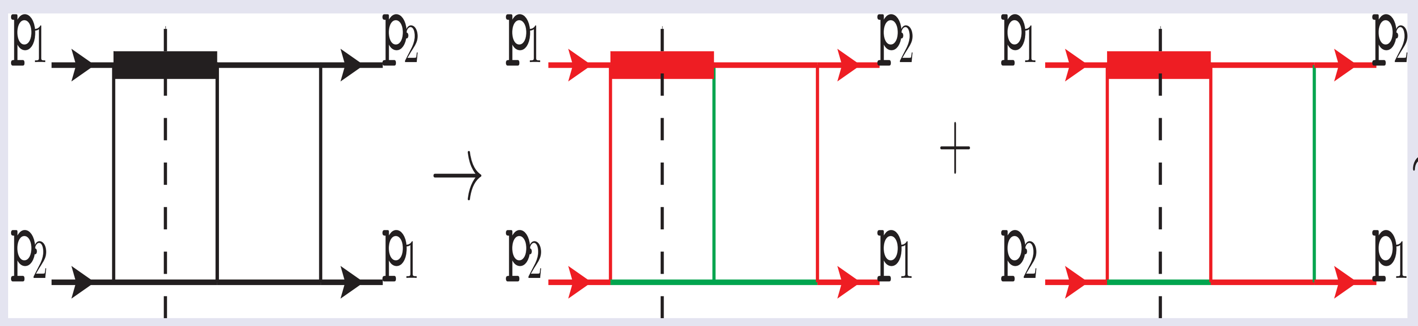
Reduction of a hard region of the double box cut integral.

The leading term of such an expansion corresponds to taking the limit of the integrand. Using this approach we were able to easily calculate the limits of soft-gluon radiation contributions to the Higgs production.
The limits of these real-virtual integrals are an essential part of NNLO calculations.

Below is a pictorial example of two integrals that we computed using our method and their dependence on the large momenta.



$$\sim s^{-3-2\epsilon}\left(1-\frac{m_h^2}{s}\right)^{-1-3\epsilon}$$



$$\sim s^{-2\epsilon}\left(1-\frac{m_h^2}{s}\right)^{1-3\epsilon}$$

The red propagators carry contributions from external momenta, while the green propagators only carry loop momentum. The wide line marks the massive Higgs propagator.

Conclusions

- Expand multiloop integrals around physical scales
- Leading terms of expansion by regions correspond to calculating the limit of the full integrand
- Expanded integrand is significantly simpler than the original integrand
- Easy method for calculating the limits of multiloop diagrams

References

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Acknowledgements

Many thanks to Babis Anastasiou and Claude Duhr. This work is supported by the ERC Starting Grant for the project “IterQCD”.

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