HiggsTools Mid-Term Review - ESR 10

Giulio Falcioni

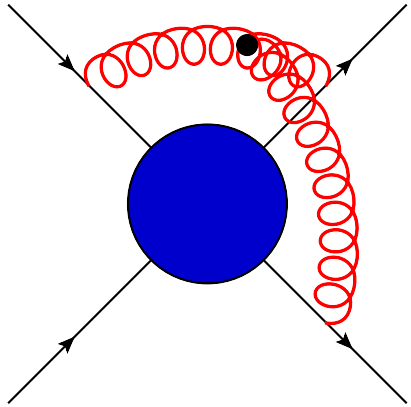
Desy (Zeuthen)

My background

My interests are focused on quantum field theory and particle physics.

- Master thesis (Università di Firenze, 2005-2011):
  study of the unitarity properties of an S matrix for gravitational scattering in the transplanckian regime.

- PhD work (Università di Torino, 2012-2015): the infrared structure of gauge theory scattering amplitudes. Long-distance (infrared) features of gauge theory amplitudes are universal and, besides giving insights on the structure of the theory, they are crucial for phenomenological applications (*e.g.* resummation, subtractions algorithms).



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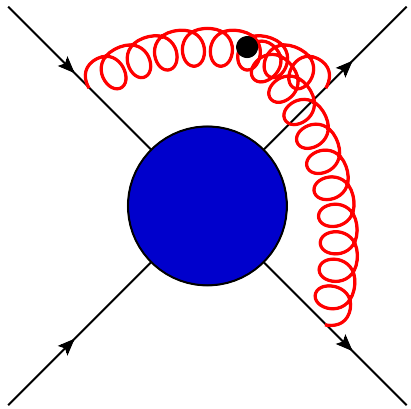
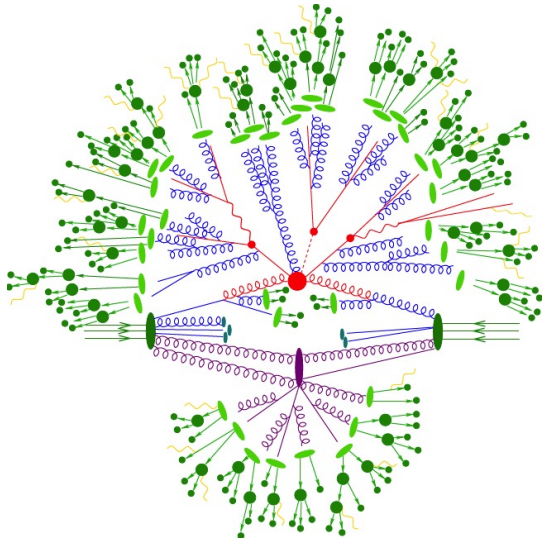


higgstools

The Higgstools project

- QCD plays a key role in experiments at colliders.

My project is focused on the effects of heavy quarks in Higgs physics. The aim is to increase the precision on α_s and PDFs.



An hadronic collision from Krauss's lectures.

- Task 3.3: improve the Parton Distribution Functions and their uncertainties
  - M3.3.3: improve PDFs using LHC data.
  - M3.3.4: consistent fit of PDFs at NNLO.
- Task 2.1: improve predictions for Standard Model(SM)-like Higgs scenarios
  - M2.1.2: better control on theoretical uncertainties for SM-like Higgs

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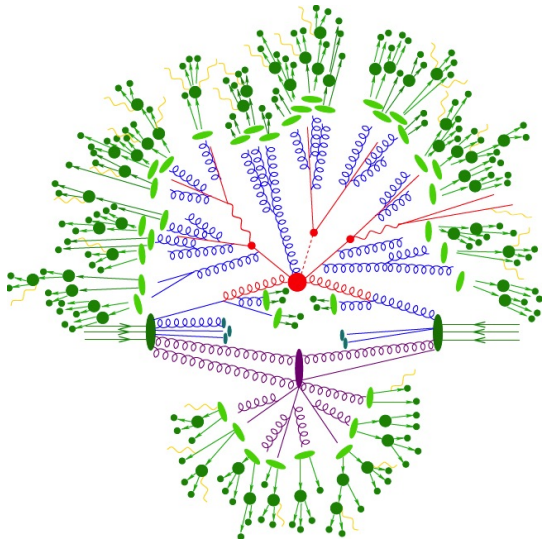

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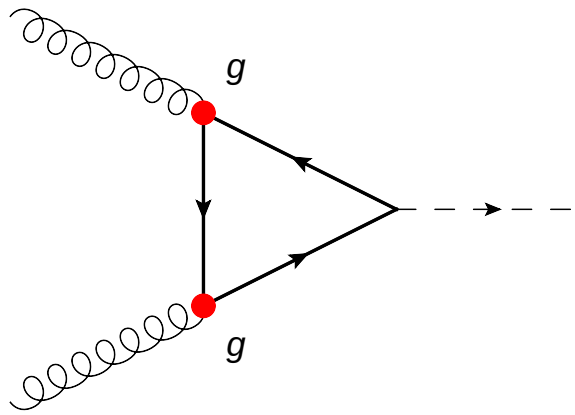
The Higgstools project

QCD and Higgs The QCD coupling constant α_s is a crucial parameter of the SM:

- The cross section for Higgs production already at LO is proportional to the square of the strong coupling constant $\alpha_s^2 = \left(\frac{g^2}{4\pi}\right)^2$.
- Sensitivity to the gluon PDF $\propto \mathcal{G}^2(x, \mu^2)$.
- Key step towards precision Higgs physics!



A better control on α_s, including quark mass effects at NNLO,

- improves PDFs fits (M3.3.3-M3.3.4),
- reduces theoretical uncertainties (M2.1.2).

PDFs and α_s provide the largest uncertainties to Higgs production.

First results: research and publications

These are the first results I obtained since March

PhD awarded I completed my thesis, titled *The infrared structure of gauge theory scattering amplitudes* and successfully defended it on the 18th of March. I gave two talks about the topics of my PhD: one in my node and one in the first Annual meeting in Freiburg.

New research project started in April 2015, regarding power corrections to DIS sum rules. This work is almost complete, a publication will appear soon.

First results: training

I could participate to the training events organized by the network

First young researcher meeting team working and cooperation in the network.

HT Annual Meeting plenary talks by senior scientists of the network and ESRs.

HT Annual school formal lecture courses on advanced topics in particle physics.

HT Journal club I attended to the ESR journal club sessions and gave a talk.

In addition, I could take part to the activities of my node

LHC physics seminar I am the coordinator of a cycle of meetings of PhDs and postdocs, focused on the discussion of the latest papers or of selected topics in high energy physics.

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German course Languages are important tools in the researcher's life.

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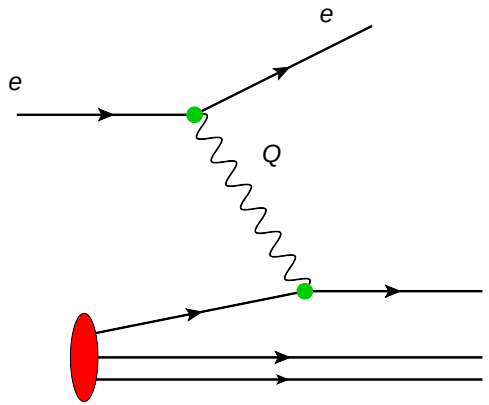
Few technical details

Heavy quark effects and α_s

Deep inelastic scattering (DIS) is a clean environment to study α_s.
Non-singlet sum rules are free from the gluonic contribution, which has the largest uncertainties. One example:

- Polarized Bjorken sum rule

$$\int_0^1 dx \left[g_1^{ep}(x) - g_1^{en}(x) \right] = \left| \frac{g_A}{g_V} \right| \frac{C_{BjP}(\alpha_s(Q^2))}{3},$$



The function C_{BjP} was computed up to $\mathcal{O}(\alpha_s^4)$ for n_f massless quark (Baikov, Chetyrkin and Kuhn, PRL 104 (2010) 132004)

$$C_{BjP}(\alpha_s) = 1 - \frac{\alpha_s}{\pi} + \left(-4.583 + \frac{n_f}{3}\right)\frac{\alpha_s^2}{\pi^2} + \left(-41.44 + 7.607 n_f - 0.1775 n_f^2\right)\frac{\alpha_s^3}{\pi^3}$$
$$+ \left[(-479.4 + 123.5 n_f - 7.697 n_f^2 + 0.1037 n_f^3)|_{\mathrm{NS}} + (4.074 - 0.2469 n_f)|_{\mathrm{SI}}\right]\frac{\alpha_s^4}{\pi^4}$$

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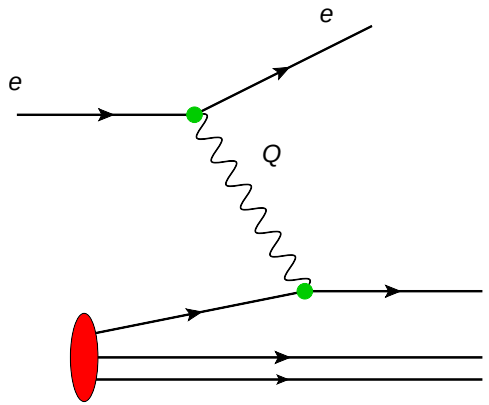

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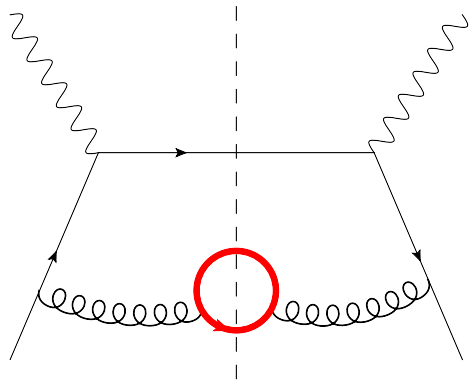
Few technical details

Heavy flavour contributions

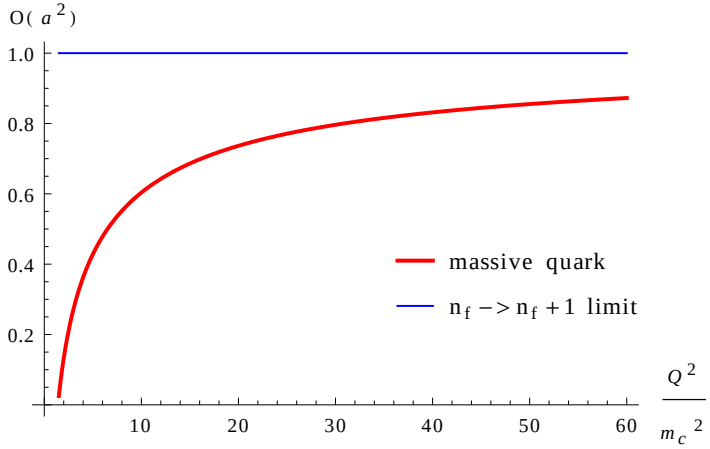
- Heavy flavours enter in NNLO QCD correction. Potentially important at $Q^2 \simeq m_H^2$.



One of the contributions of a heavy quark.

- Together with my supervisor Prof. Blümlein, we computed two more sum rules and four double-differential distributions relevant for experiments.

- The sum rule has a smooth transition to one more massless flavour $n_f \to n_f + 1$ at high energy $Q^2 \gg m_H^2$.



Quark mass effects on C_{BjP}.

Possible issues and solutions

Possible issues

- Calculations can become difficult: in the previous example we needed the real part of a two-loop diargam with massive propagators. Direct computation in these cases is voluminous.

Solutions

- Loop-integration techniques have been developing since the early days of quantum field theory and impressive progress has been done in recent years.
  For example, our two-loop problem became straightforward by applying cutting techniques and dispersion integrals.

Outlook on the project

Future developments

- The COMPASS experiment at CERN would like to analyze its data with our new results.
- We are currently providing an evolution code, including all information of our new results and others in the literature in a common publication presenting a world data analysis on the NS polarized PDFs and α_s.
- The project will be continued to three-loop heavy quark effects not available yet for some quantities relevant in LHC physics. The next part of the project is very challenging and will require training in state-of-art techniques in 3-loop integration.

Outlook on the project

Networking

Collaboration at different levels in the network is a crucial ingredient to tackle challenging projects:

Working group of ESRs on top physics topics just started!

Planned Secondment at Durham will start in November 2016 (months 35-36).

Net-work in progress!

Extracted from commons.wikimedia.org: Weaver ants, Rose Thumboor.

Outlook on my career

I would like to stay in research and keep working in particle physics, a field which still has many open questions to be settled at future experiments.

Time constraints are quite tight, but manageable: I have to apply soon for a postdoc position starting in 2017.

Thank you