HiggsTools Mid-Term Review - ESR 3

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ESR 3: Juan Manuel Cruz-Martinez

- Degree in Physics at the University of Seville (2009-13).
- Master in Advanced Physics (Theoretical Physics speciality) at the University of Valencia (2013-14).
- Master Thesis: Study of the charge asymmetry on top quark pair production via an axigluon.
- PhD studies at Durham University (2014 - ongoing).

Physics degree

PhD studies

Master on Particle Physics

WP 2 - Predictions and simulations of signal and background

Task 2.1 - Improved predictions for Standard Model-like Higgs scenarios

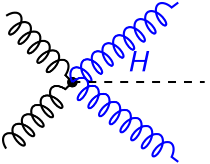
- The main focus of this project is the creation of a general purpose parton level Monte Carlo for Higgs production processes.
- Derivation and numerical implementation of IR subtraction terms for NNLO Higgs processes using the Antenna subtraction method.

Currently progressing on milestones 2.1.1 and a 2.1.2:

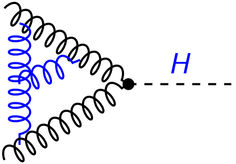
- Specialised code for SM-like scenario:
  - H production in gluon fusion.
  - VBF Higgs production (H + 2j).
- Improve control of theoretical uncertainties for the SM Higgs boson:
  - NNLO predictions.

Benchmarking process: H + 0j (M 2.1.1)

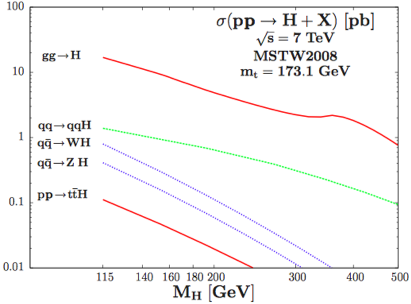
- Important Benchmarking process for LHC: very well known.
- It allows us to compare & validate our program up to a high level of precision.



Double Real diagram



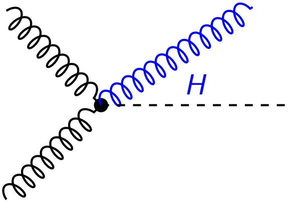
Double Virtual diagram



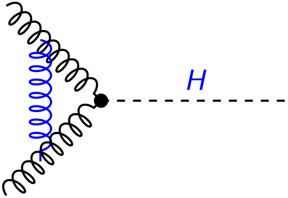
Cross section for Higgs production at LHC for different channels.

Control of divergences: the Antenna Subtraction Method

Higher order calculations present divergences. This means the numerical calculation breaks. We need to control said divergences in order to predict physical results.



A_3^0(g,g,g)



A_2^1(g,g)

$$d\sigma_{NLO}^{R} = d\Phi_3 \left(A_3^0 - F_3^0 A_2^0 \right) \qquad d\sigma_{NLO}^{V} = d\Phi_2 \left(A_2^1 + \mathcal{F}_3^0 A_2^0 \right)$$

where $\mathcal{F}_3^0 = \int d\Phi_3' \left(F_3^0 d\Phi_2 \right)$.

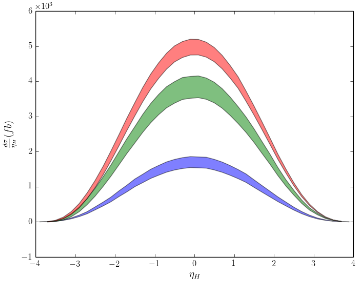
KLN Theorem: $d\sigma_{NLO}^{R} + d\sigma_{NLO}^{V} = \text{finite}$

Benchmarking process: H + 0j (M 2.1.1)

We test our prescription by comparing it to other tools in the market:
For $\mu_R = 80$ GeV
and using the MSTW2008
pdf set we get the following result:

$$\sigma = 18394 \pm 4 \text{ fb}$$

Where:



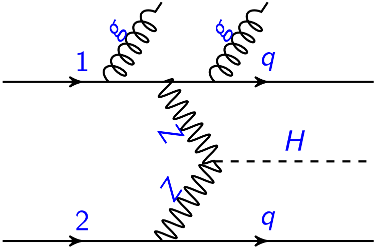
Rapidity distribution for LO/NLO/NNLO

$$\sigma_{fehipro} = 18389 \pm 11 \text{ fb}$$

$$\sigma_{hnnlo} = 18376 \pm 20 \text{ fb}$$

$$\sigma_{ggHiggs} = 18393 \pm 1 \text{ fb}$$

Currently: VBF Higgs production @ NNLO (M 2.1.1 & M 2.1.2)



Double real emission diagram for VBF Higgs production

Second only to Higgs production via gluon fusion, this is a very important process for LHC phenomenology:

- The contribution of this process was believed to be very small at NNLO.
- Recent study in the DIS approximation shows a considerable contribution, which motivates a complete NNLO calculation.

Optimisation

Higher order calculations require many mathematical and computational tools like the aforementioned Antenna Subtraction Method.

- Optimisation of the method: can better antennae be constructed?
- Automatisation of the method. We would like to have a fully automatic NNLO prescription.
- Optimisation of the phase space generator: a better phase space generator would allows us to improve our control over the calculation.
- Optimisation of the code for better performance and efficiency.

Computing time

Next-to-next-to Leading Order calculations are very expensive cputime-wise. Luckily, there are strategies that help us with this issue:

- The use of multithreading allows us to divide the program on multiple jobs.
- The use of the UK GRID gives us access to a wide network of CPUs all over the UK. Calculations that could take up to months in a Desktop computers can be reduced to just weeks or even days by using the GRID.
- Maximise efficiency by optimisation of the different programs and libraries we use.

Beyond the PhD: Shell Secondment

I will do my private secondment in Shell, at Rotterdam from May to August next year (months 29 to 31), focused on code optimisation.

Thanks to this opportunity I will be able to gain work experience in the private sector and work with state of the art tools used in industry.

I expect the different tools and techniques used during the secondment to be also useful towards the PhD studies.

Career outlook

Physics, and particularly particle physics, is a field in which international collaboration and crosstalk between experimentalist and theorist are highly encouraged.

Higgstools provides
an excellent environment for both aspects:
an international network that includes both experimentalist and theorist all across Europe.

The training and experience on management, outreach and experience in the industry sector will also be a positive contribution to our training as researchers.

Career outlook

The Institute for Particle Physics Phenomenology (IPPP) is a leading and vibrant international centre for research in particle physics phenomenology: the bridge between theory and experiment.

Within the Higgstools Network a secondment in Zurich is also planned. As Durham, Zurich is also internationally regarded as an important centre for research on high energy physics.

A PhD from Durham Universities within the Higgstools Network will undoubtedly boost a future career on academia.

Continuum training

A PhD is a continuum training towards academic excellence. These are some of the tools, techniques and events attended during this first year.

- Learning and familiarization with computational tools: Fortran, Form, MCFM, Madgraph.
- Networking: First Young Researchers Meeting
- Conferences: First Higgstools Annual Meeting, H+J Workshop, Young Theorist Forum
- Summer school: HiggsTools Annual School 2015

Career outlook: Summary

- The eventual release of a multipurpose NNLO Monte Carlo integrator for Higgs processes.
- Collaboration with different groups and universities (secondment in Zurich).
- A 3-months private secondment in Shell.
- Collaboration with experimentalists and gathering experience outside the PhD Project (organisation & management of conferences and workshops, YTF 2015, ttH phenomenology in the next Young Researcher Meeting)

Thanks!