Hello!

Thanks!

Welcome!

1-loop Electroweak correction in BSM:
current status and future plan

Fawzi’s talk on our SLOOPS project

Shankha's talk on our recent paper

The Motivation

We are facing the fact that: SM is not the ultimate theory!

- Gravity not included
- Neutrino masses not included
- Dark Matter not included
- Discrepancy shown in measurements (expect)

……

We are in TIME of BSM!!!

The Motivation

On the other hand, experimental measurements require all theoretical calculations up to at least percent Level, not only at colliders, like LHC etc, but also for Dark matter searches in cosmic/astrophysics.

Therefore, we need precisions upto 1-loop QCD or even 2-loop QCD level. While in the later case, 1-loop EW corrections are comparible.

Moreover, for BSM physics precision, 1-loop EW corrections are especially important and even comparible to 1-loop QCD corrections already in some typically scenarios.

The Motivation

Now, we can find that

the technical developments regarding
one-loop amplitudes are slowed down.

The automation efforts are shifted to two-loop amplitudes.

It is time to identify and root out

shortcomings and inconveniences of the existing tools,
especially those for 1-loop EW correction for BSM.

In the following, I will summarize
the features that we need for such tools.

The Features

We need a tool that is possible to:

1). create, and import any BSM models up to full 1-loop level
2). renormalization counter-terms generated automatically
3). renormalization schemes can be selected before/during the run-time
4). complex-mass scheme is avaible for on-shell/off-shell unstable particles
5). possible to handle a variety of final states
6). possible to handle more mass scales
7). IR subtraction can be done automatically for massless as well as massive cases
8). annihilation processes should be avaible
9). numerical stability should be obtained
10). cpu-time should be acceptable
11). memory not that intensive
12). possible to interface to generate observables, like both cross section and relic density.

The Stories

Considering these features we have already told some stories

--SLOOPS [F.B., etc.]

Features → SM-1loop, MSSM-1loop, NMSSM-1loop, SESM-1loop, IDM-1loop, ..., Complex-mass, Six-point function, Segmentation-method, DD-method →

- SM-1loop
- MSSM-1loop
- NMSSM-1loop
- SESM-1loop
- IDM-1loop
- ......
- Complex-mass
- Six-point function
- Segmentation-method
- DD-method

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The Stories

Among these stories, the things we still need are:

1). need more BSM models, like GM,EFT,etc.
2). only 2→2 processes are fully tested.
but 2→3 processes are not totally well tested.
3). complex-mass in avaiable, but not in application yet.
4). we use Phase Space Splicing, thus IR subtraction not automatically.
5). with FeynArts+Mathematica(Form),
2→4/5/6 processes are not recommend.
6). numerical stability only partly solved, still need improving,
expecially how to "automize"

The tools

Anyway, in order to organize a tool that can do these things,
we need 3 key phases, or say, design elements:

1. The first major design element is: the models and the possibility to import physics models, not only for SM but also BSM or even effective field theory applications up to full 1-loop QCD and EW level.

2. The second design element is: the element generators to compute one-loop QCD and EW amplitudes for any elementary processes.

3. The third element: which are also the key programs, are the libraries for the computation Of 1-loop integrals.

The tools - import models

In the market we have two free choices.

-The first one is LanHEP with the output in FeynArts Format:

The reason we choose and keep this choice is the following:

1). many BSM models are already created and checked.

2). all the CTs can be automatically obtained.

3). different renormalization schemes can be selected.

4). a general renormalization R_xi gauge is applied and can be used to verify the correctness of the calculation, the gauge invariance, and even the numerical stability of loop predictions.

-The second is FeynRules with the output in the UFO format.

The CTs can be generated at the same time. A special set of feynman rules called the rational terms should be obtained separately.

-The third one is REPT1L: not public

The tools

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The tools – generators

In the market we have the following choices:

-FeynArts/FormCalc[Thomas Hahn]:

FeynArts existeds as a diagram generator, and Mathematica(FORM) generate the specific source code. In this case, the weakness is obvious: For multiplicity processes, for example, $2 \to 5/6$ in SM or even $2 \to 4$ in BSM, the generation is extremely slow and memory may not enough.

-Grace (loop not public) [J. Fujimoto, etc.]

-Gosam[Mauro Chiesa, etc.]:

Use Qgraf program plus python extension to generate the diagrams followed by the generation of fortran code.

The tools - generators

In the market we have the following choices:

-MadLOOP: EW, NLO

-Recola[A.Denner, etc.]: Model generator not release.

-OpenLOOPs1[F.Buccioni, etc.]

-OpenLOOPs2: no interface needed between the process specific code and the generic code, but generator private, mainly for the purpose of NNLO QCD.

-NGluon/Helac-1loop/Blackhat: QCD

The tools

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The tools - reduction

In the market, we have the choice as follows:

-LoopTools[T.Hahn]: which is the one we use.

We also have some imporived versions:

-LT+segmentations

-LT+seg.+DD-methods: we split the PS into diff. regions depending on the different kinematics. But don't have the "rescue system", not automatic and only rely on"hard cuts". Enough for 2→2, but not for higher.

-LT+Quard.Precision (too slow)

-LT+semi-QP 2→3 possible, while anniliation (v→0) still too slow

-collier[A.Denner,etc.]: 2→4/5/6, NNLO, OK？？？

-Ninja[Tizano Peraro]: 2→2/3 quick. How about 2→4/5？？？

The tools - reduction

In the market, we have the choice as follows:

-cuttools[G.Ossola, etc.]: does not dispose of any mechanism to avoid instabilities in DP ? ? ?

-samurai[P.Mastrolia]:

-Golem95[T.Binoth,J.P.Guillet,etc]: classical tensor reduction methods

PJFRY[J.Fleischer,etc.]:

ONELoop[A.V.Hemeren]:

LoopTools

-On-the-fly[F.Buccioni,etc.]: Seg.+OPP+hydri-QP system, should connect to the generator which not public

The summary

Import the model (QCD,EW,SM,BSM,EFT-loop)	Matrix element generator	reduction
LanHEP (FeynArts Format, Full-CTs)	FormCalc (+2PPS/MadDipole)	LT LT + Seg. LT + DD + Seg. (hard cuts) LT + Quard. Precision (QP) LT + semi-QP
	GoSam (+SHERPA/MadDipole)	Ninja Samurai Golem95 PJFRY Oneloop
ReynRules (UFO Format, CTs+R-terms)	OpenLOOPs1 (+MadDipole)	Collier Cuttools Cuttools + QP
Recolar's Renor. Procedore Tools at 1-Loop (PEPT1L Format, Full-CTs)	Recola (+SHERPA)	collier
	OpenLOOPs2 (+SHERPA)	On-the-fly Seg.+OPP+hybra-QP

The future

1. Ninja can be added easily.

2. SHERPA should be added / or SubDipole method.

3. Complex-mass scheme should be applied and tested.

4. To cross check, collier system replace LTs ???

5. if 2→4 or hgiher, shift to OPENLoops1/GOSAM ???

Hello!

Thank

CPTGA[Centre de Physique Théorique de Grenoble-Alpes]

to give the chance!

Fawzi to help organize!

Welcome!