Les Houches
Physics @ TeV Colliders 2015
BSM session: Tools & MC

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Les Houches

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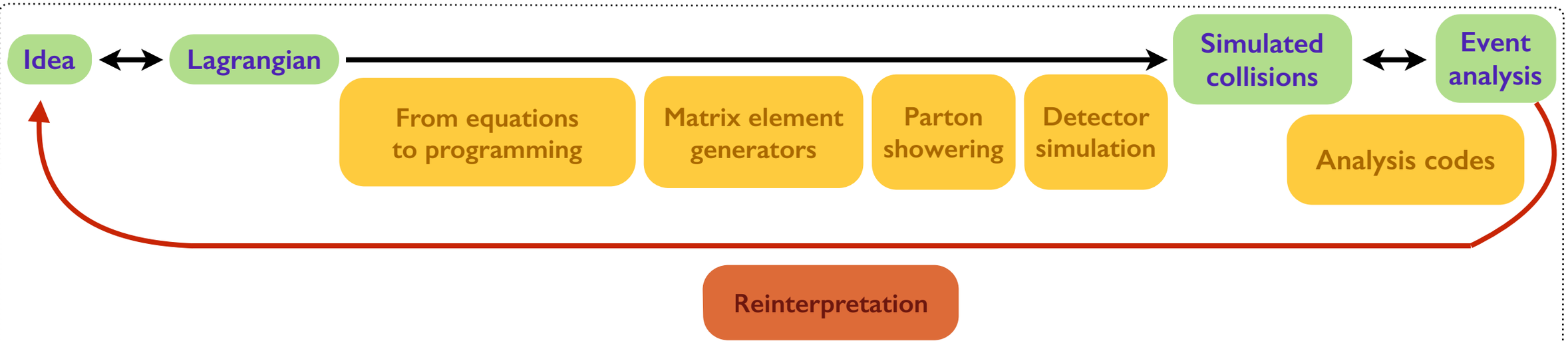
Beyond the Standard Model tools for collider physics

✦ A comprehensive approach to Monte Carlo simulations has been built over the last decades



✦ Past efforts mainly focusing on communication

- ✤ Connecting theory and matrix element generators: computer programs and SLHA (spectrum)
- ✤ Connecting matrix element generators to parton showering algorithms (LHE)
- ✤ Connecting data to theory: recasting / reinterpretation

The menu of the last 10 days

✦ What has been worked on in this Les Houches BSM tools session

- ✤ From theory to Monte Carlo tools: extension of the SLHA
- ✤ Automatic matrix element generators: QCD NLO calculations for new physics
- ✤ Detector simulation: development of a super-fastsim concept
- ✤ Reinterpretation: presentation of LHC searches to be used by theorists
- ✤ Physics examples: see the other presentations (sorry, this is tools only 😝)

✦ In this presentation:

1. Physics models on which we have focused & the SLHA extension
2. NLO corrections for new physics
3. A very fast detector simulator
4. The `LHAAD'
5. More tools & summary of the summary

SLHA / New physics models

✦ Extensions and discussions on existing accords

✤ SLHA extension: including cross section information

```
XSECTION SQRTS PDG_CODE1 PDG_CODE2 NF PDG_CODE3 ....
  SCALE_SCHEME QCD_ORDER EW_ORDER KAPPA_F KAPPA_R  PDF_ID VALUE CODE VERSION
```

★ Cross section calculator players to be contacted for commenting the proposal

★ Finalization ~~expected~~ mandatory for the proceedings

✦ Interests of the BSM and Higgs groups: definition of the models to implement

✤ Implementations of new (or extensions of) model in the simulation / calculation tools

★ Higgs effective field theory (developments in aMC@NLO & HIGLU)

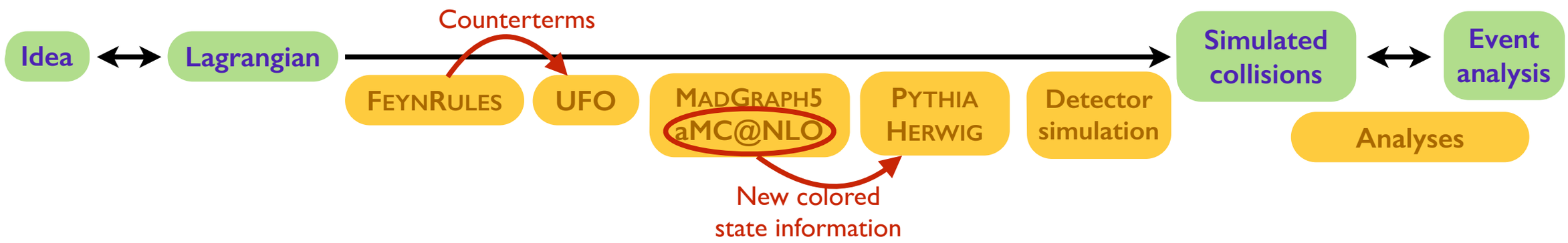
★ Loop-induced (N)MSSM Higgs process

★ Minimal and next-to-minimal dark matter simplified models (see the DM@LHC group)

★ Vector like quarks

Automated NLO calculations with MadGraph5_aMC@NLO

✦ Automatic NLO QCD calculations with aMC@NLO: the `*how to?*' for new physics



✦ How does it work?

- ✤ FeynRules is linked to the NLOCT module
  - ★ Calculation of UV and R_2 counterterms with the help of FeynArts / FormCalc
  - ★ Export of the information to the UFO
- ✤ Matching to parton showers
  - ★ Monte Carlo counterterms associated with the new colored states are included
  - ★ Restrictions on the parton showers (Pythia8, Herwig++)

The NLO BSM model library is mostly empty:
many extensions started during this LH

NLO corrections for Higgs effective field theories (1/2)

✦ Higgs effective field theories

✤ QCD corrections: series expansion both in the strong coupling and the effective scale

$$\sigma \approx 1 + O(\alpha_s) + O(1/\Lambda^2) + O(\alpha_s/\Lambda^2)$$

↓ SM@LO ↓ SM@NLO ↓ EFT@LO ↓ EFT@NLO

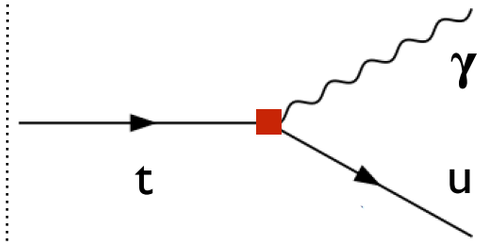
✤ EW corrections: treatment of the large Sudakov logs

✤ Efforts have been put in the implementation of both QCD and EW NLO effects

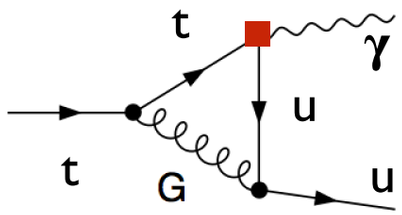
✦ Issue: operator mixings

✤ The structure of a given operators can be generated from another operator

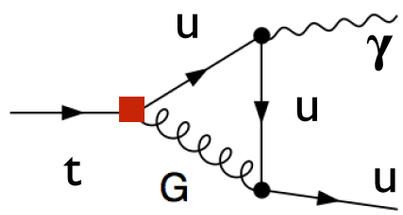
★ Example: gtu (NLO QCD) corrections to the γtu operator



EFT@LO



EFT@NLO



EFT@NLO

✤ Care is needed when dealing with a subset of operators (for divergence cancellations)

NLO corrections for Higgs effective field theories (2/2)

✦ Automatic NLO QCD corrections: simplifications with five operators

[Degrande, BF, Mawatari, Mimasu, Sanz]

$$\mathcal{L} = \mathcal{L}_{\rm SM} + \frac{i\bar{c}_W}{g\Lambda^2}\left[\Phi^\dagger T_{2k} \overleftrightarrow{D}^\mu \Phi\right] D^\nu W^k_{\mu\nu} + \frac{i\bar{c}_{HW}}{\Lambda^2}\left[D^\mu \Phi^\dagger T_{2k} D^\nu \Phi\right] W^k_{\mu\nu}$$
$$+ \frac{i\bar{c}_B}{g'\Lambda^2}\left[\Phi^\dagger \overleftrightarrow{D}^\mu \Phi\right] \partial^\nu B_{\mu\nu} + \frac{i\bar{c}_{HB}}{\Lambda^2}\left[D^\mu \Phi^\dagger D^\nu \Phi\right] B_{\mu\nu} + \frac{\bar{c}_\gamma}{\Lambda^2}\left[\Phi^\dagger\Phi - \frac{1}{2}v^2\right] B^{\mu\nu} B_{\mu\nu}$$

- ✤ Validation achieved (comparison with MCFM)

✦ NNLO inclusive σ: the $G\mu\nu\, G^{\mu\nu}\, |\Phi|^2$ operator is now included in HIGLU [Spira *et al.*]

✦ Monte-Carlo-based physics studies on-going (see the Higgs summary talk)

- ✤ VH production
- ✤ di-Higgs production
- ✤ VBF Higgs production

aMC@NLO model spread among the participants

✦ Extension to other operators (e.g., CP-odd ones)

✦ Basis issues? ➢ not relevant anymore [BF, Mawatari, Mimasu, Riva, Sanz]

- ✤ The ROSETTA framework is being finalized
- ✤ Any choice among the Higgs, the SILH and the Warsaw bases is fine
- ✤ Interface to eHDECAY, Monte Carlo tools, fitting tools, *etc.*

✦ Treatment of the electroweak corrections [Spira *et al.*]

- ✤ A document is in preparation: focus on the case where large scales are involved

QCD NLO corrections for vector-like quark production

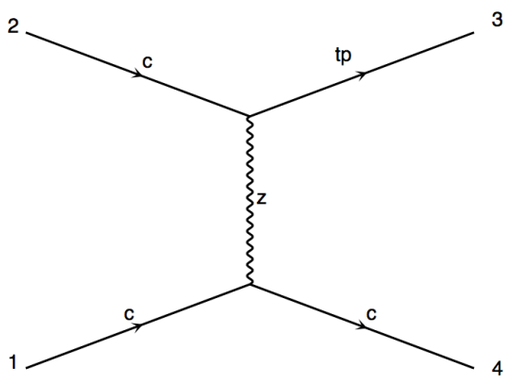
✦ Vector-like quarks (on-going validation)

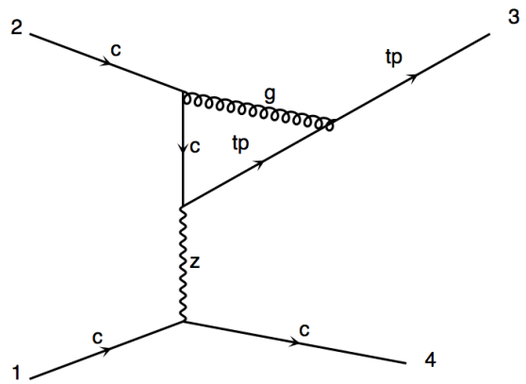
[Cacciapaglia, Deandrea, BF]

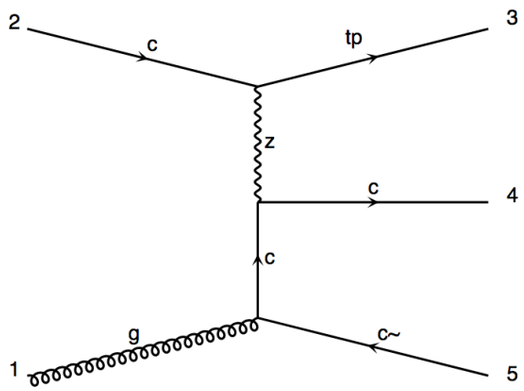
- ✤ Extension of the leading order parameterization initiated in 2013
- ✤ Focus on NLO QCD corrections

$$\mathcal{L} = \kappa_T \left\{ \sqrt{\frac{\zeta_i \xi_W^T}{\Gamma_W^0}} \frac{g}{\sqrt{2}} \left[\bar{T}_{L/R} W_\mu^+ \gamma^\mu d_{L/R}^i \right] + \sqrt{\frac{\zeta_i \xi_Z^T}{\Gamma_Z^0}} \frac{g}{2c_W} \left[\bar{T}_{L/R} Z_\mu \gamma^\mu u_{L/R}^i \right] - \sqrt{\frac{\zeta_i \xi_H^T}{\Gamma_H^0}} \frac{M}{v} \left[\bar{T}_{R/L} H u_{L/R}^i \right] \right\}$$
$$+ \kappa_B \left\{ \sqrt{\frac{\zeta_i \xi_W^B}{\Gamma_W^0}} \frac{g}{\sqrt{2}} \left[\bar{B}_{L/R} W_\mu^- \gamma^\mu u_{L/R}^i \right] + \sqrt{\frac{\zeta_i \xi_Z^B}{\Gamma_Z^0}} \frac{g}{2c_W} \left[\bar{B}_{L/R} Z_\mu \gamma^\mu d_{L/R}^i \right] - \sqrt{\frac{\zeta_i \xi_H^B}{\Gamma_H^0}} \frac{M}{v} \left[\bar{B}_{R/L} H d_{L/R}^i \right] \right\}$$
$$+ \kappa_X \left\{ \sqrt{\frac{\zeta_i}{\Gamma_W^0}} \frac{g}{\sqrt{2}} \left[\bar{X}_{L/R} W_\mu^+ \gamma^\mu u_{L/R}^i \right] \right\} + \kappa_Y \left\{ \sqrt{\frac{\zeta_i}{\Gamma_W^0}} \frac{g}{\sqrt{2}} \left[\bar{Y}_{L/R} W_\mu^- \gamma^\mu d_{L/R}^i \right] \right\} + h.c..$$

✦ To-be-initiated physics study: single vector like quark production







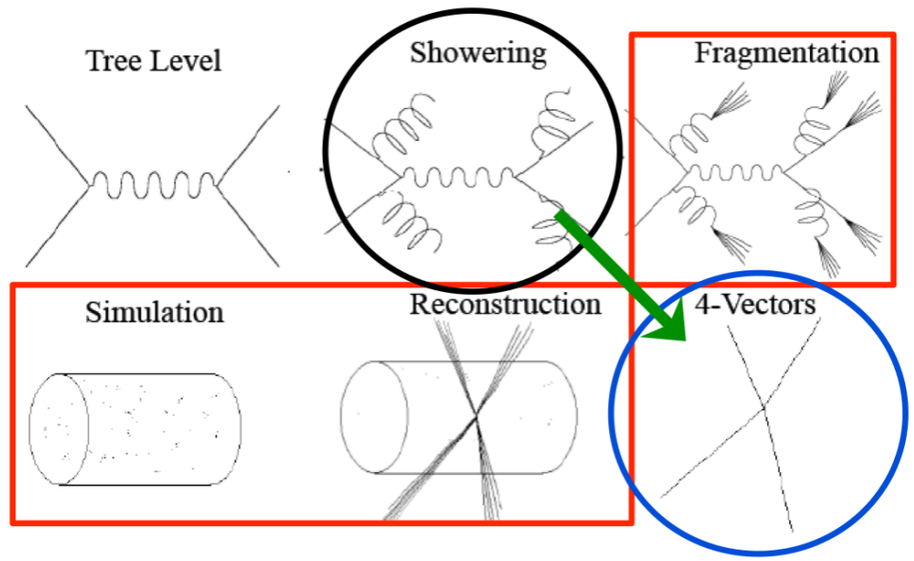
- ✤ How is the LHC sensitive to this channel?
- ✤ Properties of the produced jets?

FALCON: a very fast detector simulator

[Prosper, Sekmen *et al.*]

✦ Detector simulation is time consuming

- ✤ Could we get rid of it?
- ✤ Mapping of partonic-level to reconstructed-level events (transfer functions)
- ✤ Maps are designed by using (would-be) fullsim events from Delphes



✦ First try for making the idea concrete has been initiated

- ✤ Making the DELPHES output humain readable (LHE-like)
- ✤ Using the TURTLE program as a reader of that file, using the binary partitioning method
- ✤ Build the code constructing the maps
  - ★ Jet algorithm to be applied on the parton-level objects?
  - ★ DeltaR method?
- ✤ Provide a code returning a list of reconstructed objects from a partonic event
- ✤ Beta version and tests on the feasibility to be achieved for the proceedings

LHC analysis reinterpretations

✦ Growing interest by the theory community to reinterpret LHC results

- ✤ Testing more theories than those picked in the experimental papers
- ✤ Anyone not in a collaboration must be able to understand what has been done in an analysis
- ✤ Many tools are already available on the market (but with a limited set of analyses implemented)
- ✤ LHC legacy: the analyses and the results ➢ make the best out of them

Why a Les Houches Accord on Analysis Description?

✦ Picking up an experimental publication
- ✤ Reading
- ✤ Understanding

✅ **Relatively easy**

✦ Writing the analysis code in the tool internal language

✅ **Relatively easy**

✦ Getting the information missing from the publication for a proper validation
- ✤ Efficiencies (trigger, electrons, muons, b-tagging, JES, *etc.*)
  - ★ Including p_T and/or η dependence
  - ★ Accurate information
- ✤ Detailed cutflows for some well-defined benchmark scenarios
  - ★ Exact definition of the benchmarks (SLHA spectra)
  - ★ Event generation information (cards, tunes, LHE files if possible)
- ✤ Expected number of events in each region and cross sections
- ✤ Digitized histograms (e.g., on HEPDATA)

⚠ **Essential**
✗ **Often difficult!**

✦ Comparing tools and real life

LHAAD: Les Houches Accord on Analysis Description

[The session 2 tools working group]

✦ Development of a way to provide the information on the analysis in a readily form

- ✤ The analysis is described following a text format
  - ★ Two similar options so far (to be merged in one for the proceedings)
  - ★ Blocks for object definitions, functions and methods, selections, region definitions
  - ★ Regions are defined from a combination of cut blocks
- ✤ Validation: detailed cutflows for specific benchmarks must be provided in the description
- ✤ Must be endorsed by the experimental collaborations
  - ★ Small amount of work to make the analysis useable by the TH community
- ✤ Finalization of the recommendations to be achieved for the proceedings

✦ Presentation of results for specific new physics scenario

- ✤ Structure for the cutflows, the errors, *etc.*
- ✤ Information on how to (or not to) combine signal regions / analyses

The summary of the summary

✦ New physics theory implementations in the Monte Carlo tools

- ✤ NLO-QCD is not yet a standard, but this may happen soon
- ✤ Several model implementations have been initiated (aim: Monte Carlo studies)
- ✤ Specific treatment of the EFTs

✦ Communication between tools

- ✤ SLHA: extension to include cross section information
- ✤ LHAAD: design a mean to encapsulate efficiently the description of an experimental analysis

✦ Development of a novel detector simulation framework (FALCON)

- ✤ Starting from parton-level events and mapping to fully reconstructed events

✦ But also…

- ✤ Tutorials: aMC@NLO, CheckMate, MadAnalysis 5, Pythia 8, *president* card game, *etc.*
- ✤ Spectrum generator: issues on the Higgs mass calculations
- ✤ Many drinks …

Thanks!

Thanks to the organizers
for the great time!!!