Recent activities in the UGR/IFIC node

Roberto Pittau
(University of Granada, Spain)

HIGGSTOOLS ANNUAL MEETING

TORINO, May 15 2017

- I will cover the theory part of the **node** activities

Contributors:

F. del Aguila, **J. A. Aguilar-Saavedra**, *A. M. Donati*, **S. Heinemeyer**, **J. I. Illana**, *B. Page*, **M. Perez-Victoria**, **R. P.**, **J. Santiago**,
L. Ametller, C. Anastasiou, J. Bernabeu, J. de Blas, A. Carmona, M. Chala, J. C. Criado, C. Degrande, P. Drechsel, C. Escobar, L. Galeta, S. Khathibi, A. Lazopoulos, J. M. Lizana, V. A. Mitsou, J. Mueller, A. Segarra, C. Schappacher, P. Talavera, R. Vega-Morales, G. Weiglein

Topics:

1. Four dimensional Regularization/Renormalization techniques
2. Renormalization of CFT correlation functions
3. Top-down model-independent approach to new physics
4. High-precision calculations in the (N)MSSM
5. New observables for precision measurements at the LHC run2
6. Flavor changing Higgs decays in Little Higgs models

- The experimental aspects will be presented by J. Fuster in the 2^{nd} part of the talk: **J. A. Fuster**, **D. Melini (ESR)**

FDR

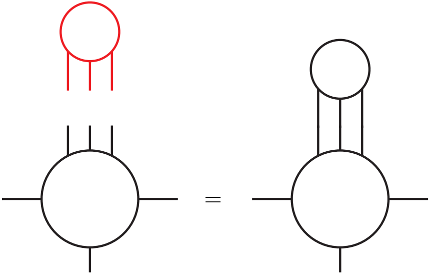
- FDR renormalization: $\mathcal{L} = \mathcal{L}$ in 4 dimensions **at all orders**
- To be compared with "Canonical" renormalization

$$\mathcal{L} = \mathcal{L}_0 + \underbrace{\sum_{\ell=1}^{N} \alpha^\ell \Delta\mathcal{L}^{(\ell)}}_{\text{CTs up to the } N^{th} \text{ perturbative order}} + \mathcal{O}(\alpha^{N+1})$$

- **NUMDEN** cancellation is essential to ensure gauge cancellations ⇒ **Gauge Invariance**

$$\underbrace{\int [d^4q_1]\cdots[d^4q_\ell]}_{\Uparrow\ \textbf{FDR integral}} \frac{\not{\bar{D}}_i}{\bar{D}_0 \cdots \not{\bar{D}}_i \cdots \bar{D}_k} = \int [d^4q_1]\cdots[d^4q_\ell] \frac{1}{\bar{D}_0 \cdots \bar{D}_k}$$

- As well as **SUBINTEGRATION** consistency, which ensures **Unitarity**



The **FDR** *solution to this problem allows one to fix the* "naive" *FDH scheme without introducing evanescent couplings*

Papers

1. FDR and UV divergences *(Gauge Invariance, no Cts)*

   R.P., JHEP 1211 (2012) 151
   Alice M. Donati and R.P., JHEP 1304 (2013) 167
   R.P., Fortsch.Phys. 63 (2015) 601-608

2. QCD up to two loops in FDR *(Translation rules with DReg)*

   Ben Page and R.P., JHEP 1511 (2015) 183

3. IR infinities in FDR *(Local subtraction scheme at 1 loop)*

   R.P., Eur. Phys. J. C (2014) 74:2686
   Alice M. Donati and R.P., Eur. Phys. J. C (2014) 74:2864

4. Comparisons with other schemes *(To d or not to d: Recent developments and comparisons of regularization schemes)*

   C. Gnendiger *et al.*, arXiv:1705.01827

Renormalization of composite operators and exact renormalization group

- The correlation functions of composite operators contain additional divergences
- Renormalization requires:
  - Non-local divs: Define renormalized operators (linear, with mixing)
  - Local & semi-local divs: non-linear counterterms

Lizana, Pérez-Victoria, arXiv:1702.07773

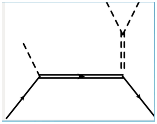
- Complete geometric formulation:
  - renormalized ops → vector fields
  - counterterms → connection
- Precise relation with exact renormalization group
- Mass-independent schemes ↔ normal coordinates in theory space

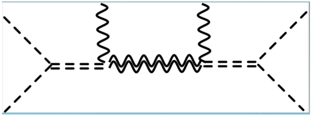
Top-down model-independent approach to new physics

- EFT offers a (bottom-up) model independent parametrization of NP effects in the presence of a mass gap: map experimental observables to Wilson Coefficients.
- In order to do physics with that info we need a top-down approach: NP model matching to the SM EFT.
- At tree level the complete classification of NP effects to L6 is almost finished New quarks (Aguila, Perez-Victoria, Santiago '00); New leptons (Aguila, Blas, Perez-Victoria '08); New vectors (Aguila, Blas, Perez-Victoria '10); New scalars: (Blas, Chala, Perez-Victoria, Santiago '15);

  Mixed contributions: Blas, Criado, Perez-Victoria, Santiago (hep-ph/1705xxx)

- Dimensionful couplings lead to contributions from particles with different spins $S^3, V^\mu D_\mu S, V^\mu V'_\mu S$





Top-down model-independent approach to new physics

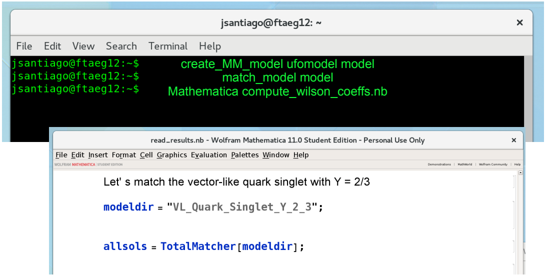
- EFT offers a (bottom-up) model independent parametrization of NP effects in the presence of a mass gap: map experimental observables to Wilson Coefficients.
- In order to do physics with that info we need a top-down approach: NP model matching to the SM EFT.
- At tree level the complete classification of NP effects to L6 is almost finished New quarks (Aguila, Perez-Victoria, Santiago '00); New leptons (Aguila, Blas, Perez-Victoria '08); New vectors (Aguila, Blas, Perez-Victoria '10); New scalars: (Blas, Chala, Perez-Victoria, Santiago '15);

  Mixed contributions: Blas, Criado, Perez-Victoria, Santiago (hep-ph/1705xxx)

- Dimensionful couplings lead to contributions from particles with different spins $S^3, V^\mu D_\mu S, V^\mu V'_\mu S$
- Once completed, the full tree-level dimension 6 UV/IR dictionary will be available (complete classification of the contribution from arbitrary new physics).

Top-down model-independent approach to new physics

- One-loop effects can be important. Some degree of automation is needed.
- MatchMaker: Automated tree-level and one-loop matching calculations   Anastasiou, Carmona, Lazopoulos, Santiago (to appear)
- Written in python, uses QGRAF, FORM, MATHEMATICA
- Features of current version:
  - Matching to SMEFT straight-forward (3 commands)



Top-down model-independent approach to new physics

- One-loop effects can be important. Some degree of automation is needed.
- MatchMaker: Automated tree-level and one-loop matching calculations   Anastasiou, Carmona, Lazopoulos, Santiago (to appear)
- Written in python, uses QGRAF, FORM, MATHEMATICA
- Features of current version:
  - Matching to SMEFT straight-forward
  - Off-shell matching with full kinematic structure (redundancies = non-trivial cross-checks)
  - Basis-independent results (includes redundant and evanescent operators)

Contribution I: [P. Drechsel, L. Galeta, S.H., G. Weiglein '16]

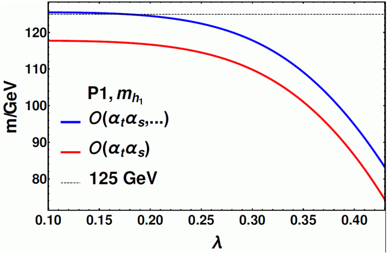
New high-precision calculation of NMSSM Higgs boson masses

Calculation based on:

– full one-loop
  (with improved renormalization)
– two-loop (taken from MSSM)
– log resummation
  (taken from MSSM)

red: m_{h_1} at 1L + 2L $\mathcal{O}(\alpha_t \alpha_s)$
blue: m_{h_1} at 1L + 2L + log resum.

⇒ all contributions needed for precise prediction



→ example parameter point
  λ: NMSSM trilinear coupling

⇒ currently implented into FeynHiggs

Contribution II:

[S.H., C. Schappacher '17]

New full one-loop chargino/neutralino production cross sections

$e^+e^- \to \tilde{\chi}_c^{\pm}\tilde{\chi}_{c'}^{\mp}, \tilde{\chi}_n^0\tilde{\chi}_{n'}^0$

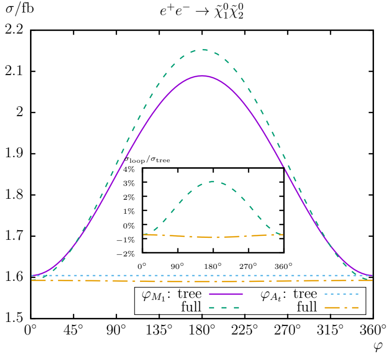
- full one-loop
- soft/hard radiation
- complex phases allowed

Example:

- strong phase dependence for M_1 (M_1: $U(1)$ SUSY-breaking par.)
- weak phase dependence for A_t (A_t: Higgs-scalar top coupl.)

⇒ large one-loop corrections

⇒ strong phase dependence



New observables for precision measurements at the LHC Run 2

- Description of the eight Z boson spin observables and collider applications for new physics searches.

  J. A. Aguilar-Saavedra, J. Bernabéu, V.A. Mitsou, A. Segarra, "*The Z boson spin observables as messengers of new physics*" Eur. Phys. J. C 77 (2017) 234

- t-channel single top polarisation: effect of four-fermion operators.

  J. A. Aguilar-Saavedra, C. Degrande, S. Khathibi, "*Single top polarisation as a window to new physics*" Phys. Lett. B 769 (2017) 498

- Description of the fully differential top decay distribution and its connection to new physics in the tbW interaction.

  J. A. Aguilar-Saavedra, J. Boudreau, C. Escobar, J. Mueller, "*The fully differential top decay distribution*" Eur. Phys. J. C 77 (2017) 200

HiggsTools (**PITN-GA-2012-316704)**

Flavor changing Higgs decays in Little Higgs models

UGR:

Francisco del Águila

José Ignacio Illana

José Santiago

Roberto Vega-Morales

UPC:

Lluis Ametller

Pere Talavera

V. Khachatryan et al. [CMS Collaboration], ``Search for lepton flavour violating decays of the Higgs boson to eτ and eμ in proton–proton collisions at √s=8 TeV'',
Phys. Lett. B 763 (2016) 472
doi:10.1016/j.physletb.2016.09.062
[arXiv:1607.03561 [hep-ex]]

B (H → eτ) < 0.69% and
B (H → eμ) < 0.035% at 95% CL

F. del Aguila (UGR)

$H \to \tau\mu$ is not any more over the SM prediction, but were initial indications of a large such branching ratio in disagreement with the SM. Thus, although this flavor changing Higgs decay is probably not tree level (too large), it may be much larger than in the SM (where is non-zero only due to the small neutrino masses and hence, no foreseen ever to be observable at any collider) and eventually observable.

At the LHC branching ratios of the order of 10^{-6} could be eventually reach and hence, enhanced one-loop corrections could be also eventually observed. With this aim **we are calculating these decays in the Little Higgs model with T-parity**. In this model the new particles can be relatively light due to the discrete Z_2 symmetry distinguishing SM from new T-odd particles, which have to be produced always in pairs. By the same reason their contributions to flavor changing Higgs decays are one-loop suppressed, but they can be enhanced to the experimental reach.

Previous calculations are certainly incomplete and infinite, against some claims. We do find large and finite one-loop lepton flavor Higgs decay amplitudes (in preparation).

F. del Aguila (UGR)