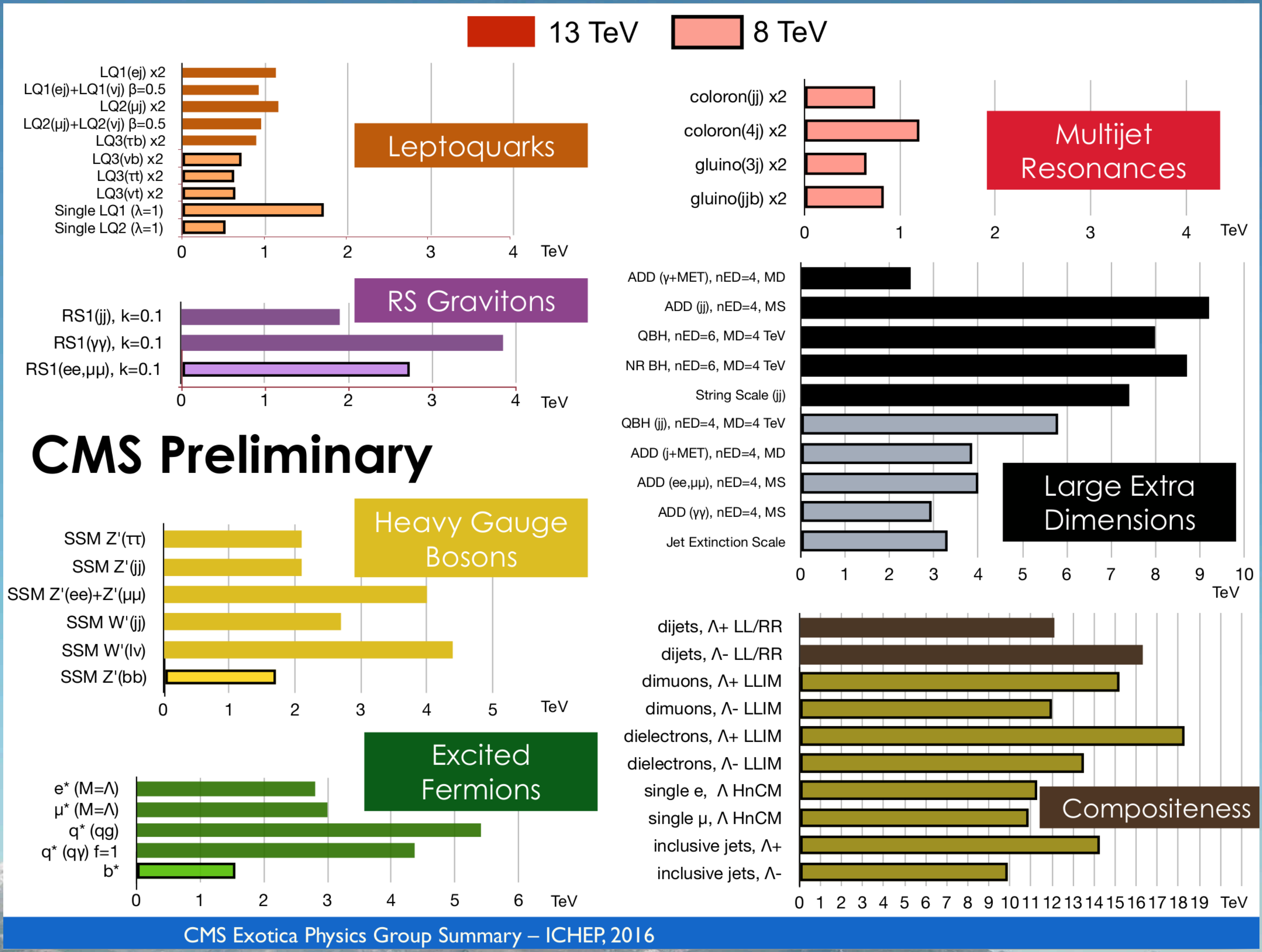
Moriond EW 2017
Monday, March 20, 2017

One-loop Effective Lagrangian after Matching

José Santiago

Based on: C. Anastasiou, A. Carmona, A. Lazopoulos, J.S. (to appear)

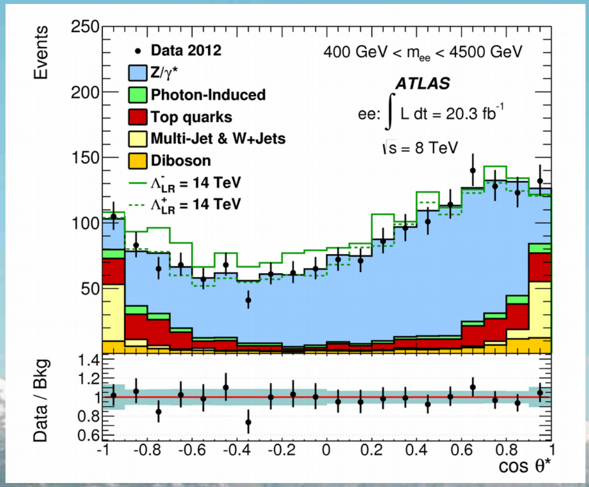
After the discovery of the Higgs, the LHC has turned into New Physics search mode



Given the absence (so far) of direct evidence of NP and the huge number of different searches, what is the best strategy to use these data?

Effective theories:

- General description of new physics with minimal theoretical input (in the presence of a mass gap)
- Map experimental (pseudo) observables to Wilson coefficients



$$\mathcal{L}_6 = \alpha_{lq}^{(1)} (\bar{l}\gamma^\mu l)(\bar{q}\gamma_\mu q) + \ldots$$

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- Global fit: use this map to encode all experimental information in constraints on Wilson coefficients

Ciuchini, Franco, Mishima, Silvestrini ('13); Blas, Chala, J.S. ('13, '15); Pomarol, Riva ('14); Falkowski, Riva ('15); Buckley, Englert, Ferrando, Miller, Moore, Russell, White ('15); Berthier, Trott (‘15), Blas, Ciuchini, Franco, Mishima, Pierini, Reina, Silvestrini (‘16), ...

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Effective theories:

- General description of new physics with minimal theoretical input (in the presence of a mass gap)
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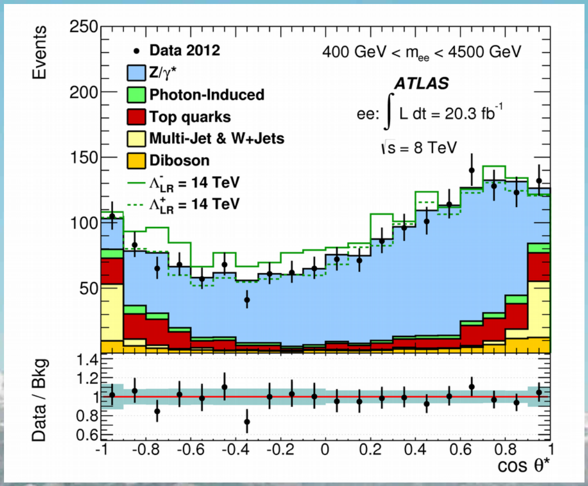
- Global fit: use this map to encode all experimental information in constraints on Wilson coefficients
- In order to extract information on NP we need to compute the Wilson coefficients in NP models: matching

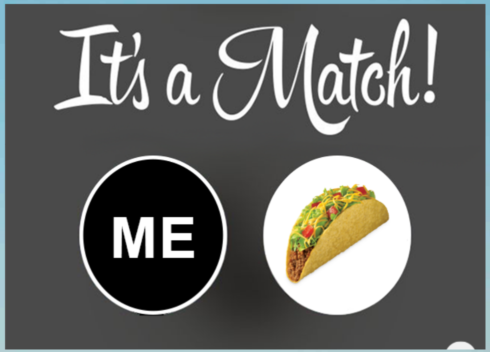
Matching a model to an EFT: compute the Wilson coefficients in that particular model (map UV model parameters to Wilson coefficients)

- Provides a dictionary between experimental observables and NP models

$$\mathcal{L}_{NP} = \mathcal{L}_{SM} + \bar{\Psi}(i\not{D} - M)\Psi - \lambda'\bar{\Psi}\phi\psi + \ldots$$

$$\mathcal{L}_{eff} = \mathcal{L}_{SM} + \sum_i \alpha_i \mathcal{O}_i$$





Matching a model to an EFT: compute the Wilson coefficients in that particular model (map UV model parameters to Wilson coefficients)

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- Can be (in principle) performed at an arbitrary order in the loop and operator dimension expansions
- At tree level (and dim 6) the dictionary is almost complete: tree-level, dimension 6 new physics effects have been completelly classified and computed

New quarks: Aguila, Perez-Victoria, J.S. (‘00);
New leptons: Aguila, Blas, Perez-Victoria (‘08),
New vectors: Aguila, Blas, Perez-Victoria (‘10);
New scalars: Blas, Chala, Perez-Victoria, J.S (‘15);
Mixed contributions: Blas, Criado, Perez-Victoria, J.S. (to appear)

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- At tree level (and dim 6) the dictionary is almost complete: tree-level, dimension 6 new physics effects have been completelly classified and computed
- Some effects (or some models) only appear at the loop level:
  - Number of possibilities increase dramatically
  - Automation needed: Match Maker

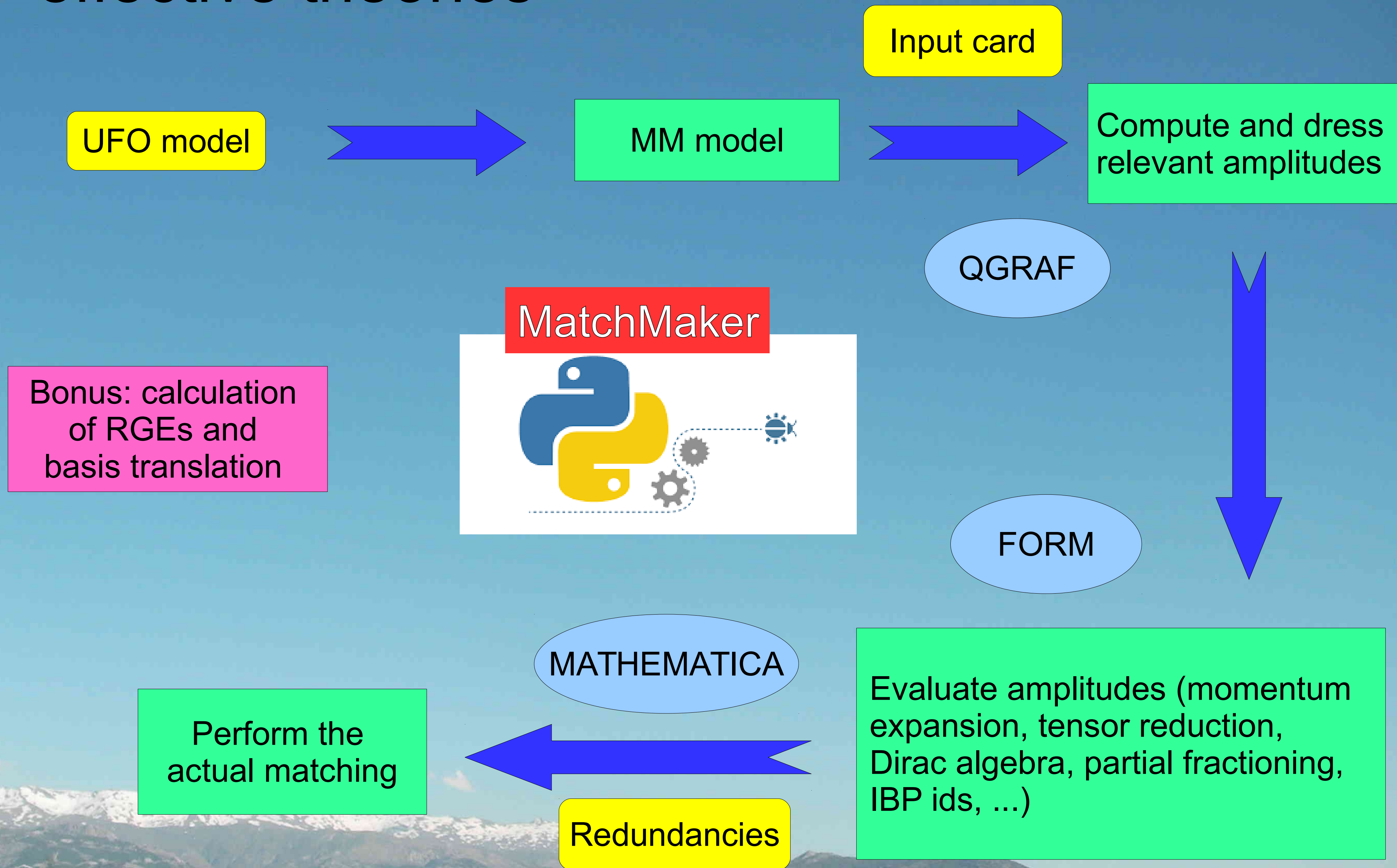
    Anastasiou, Carmona, Lazopoulos, J.S. (to appear)

MatchMaker: automated matching in effective theories

Anastasiou, Carmona, Lazopoulos, J.S.

- Automated tool to perform tree-level and one-loop matching of arbitrary theories into arbitrary effective Lagrangians
- Written in python (easy to install via pip, cross-platform). Uses well tested tools (QGRAF, FORM, Mathematica)
- Flexible (from full matching to specific operators), fully automated and general
- Off-shell matching with (initially) massless particles in the effective theory (e.g. unbroken phase of the SM)

MatchMaker: automated matching in effective theories



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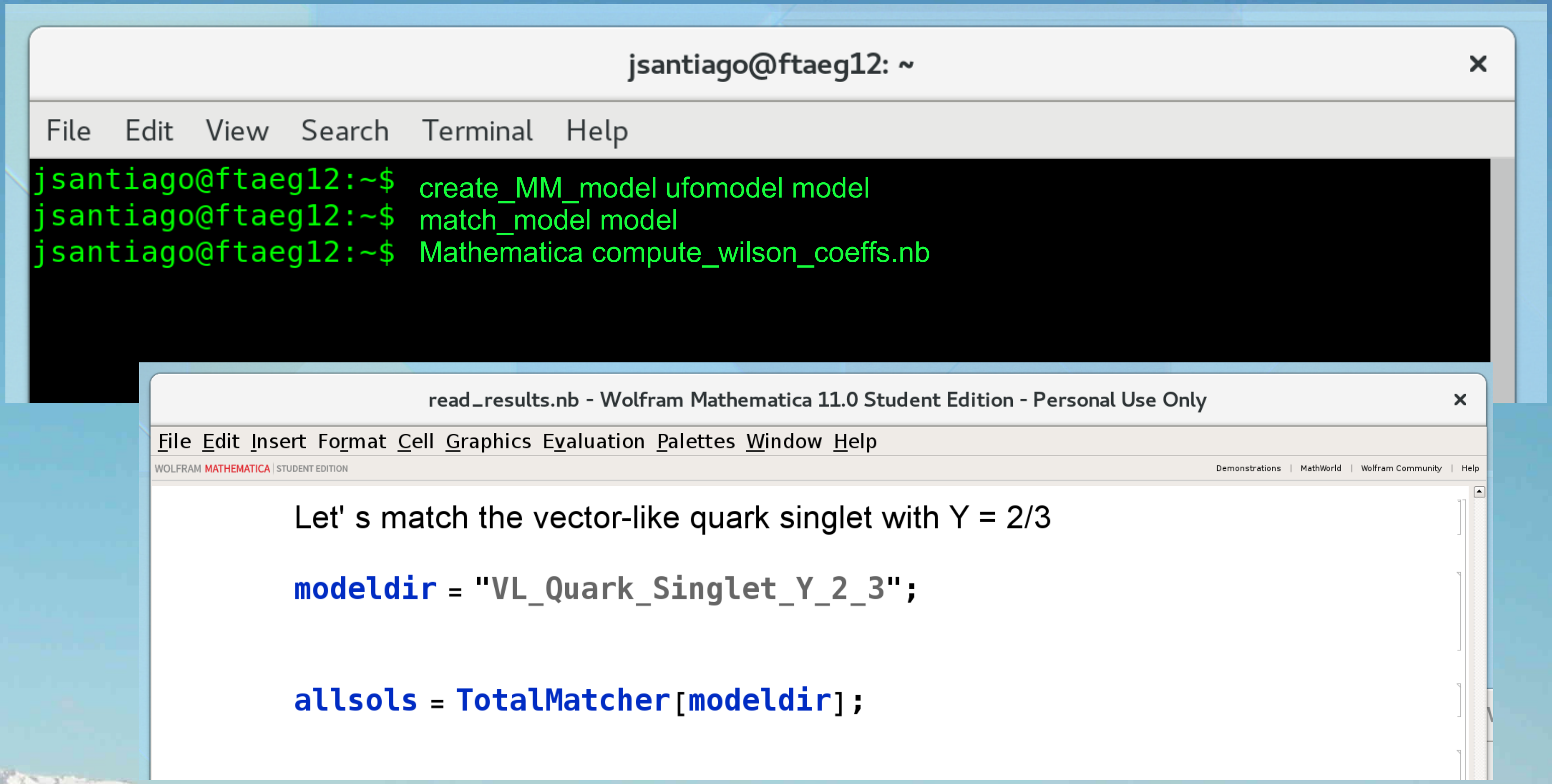
- Features of current version:
  - Matching to SMEFT fully automated



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MatchMaker: automated matching in effective theories

Anastasiou, Carmona, Lazopoulos, J.S.

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In[103]:=

```
Simplify[allsols[[3, 3]] /. mu → MHT /. onlytop0 /. onlytop1 /. onlymixingwithtop]
```

Out[103]=

$$\Big\{\text{alpha01} \to \frac{\text{lamprime3 lamprime3bar Nc}\,(-\text{lamprime3 lamprime3bar} + \text{ytop ytopbar})}{32\,\text{MHT}^2\,\pi^2},$$

$$\text{alpha010} \to -\frac{\text{g1 gw lamprime3 lamprime3bar Nc}}{192\,\text{MHT}^2\,\pi^2},\ \text{alpha012} \to -\frac{i\,\text{gs}^3}{2880\,\text{MHT}^2\,\pi^2},\ \text{alpha014} \to 0,$$

$$\text{alpha02} \to \frac{\text{lamprime3 lamprime3bar Nc}\,(-2\,\text{lamprime3 lamprime3bar} + 9\,\text{ytop ytopbar})}{96\,\text{MHT}^2\,\pi^2},$$

$$\text{alpha04} \to \frac{\text{gs}^2\,\text{lamprime3 lamprime3bar dd}[\text{a97}, \text{a99}]}{96\,\text{MHT}^2\,\pi^2\,\text{dd}[\text{i97}, \text{i99}]},\ \text{alpha06} \to \frac{\text{gw}^2\,\text{lamprime3 lamprime3bar Nc}}{384\,\text{MHT}^2\,\pi^2},$$

$$\text{alpha08} \to \frac{5\,\text{g1}^2\,\text{lamprime3 lamprime3bar Nc}}{3456\,\text{MHT}^2\,\pi^2},\ \text{alphaR1} \to \frac{\text{lamprime3 lamprime3bar Nc}\,(\text{lamprime3 lamprime3bar} - \text{ytop ytopbar})}{32\,\text{MHT}^2\,\pi^2},$$

$$\text{alphaR1bar} \to \frac{\text{lamprime3 lamprime3bar Nc}\,(\text{lamprime3 lamprime3bar} - \text{ytop ytopbar})}{32\,\text{MHT}^2\,\pi^2},$$

$$\text{alphaR2} \to \frac{\text{lamprime3 lamprime3bar Nc}}{48\,\text{MHT}^2\,\pi^2},\ \text{alphaR3} \to -\frac{7\,\text{g1 lamprime3 lamprime3bar Nc}}{576\,\text{MHT}^2\,\pi^2},$$

$$\text{alphaR4} \to \frac{5\,\text{gw lamprime3 lamprime3bar Nc}}{576\,\text{MHT}^2\,\pi^2},\ \text{alphaR5} \to -\frac{\text{gs}^2}{240\,\text{MHT}^2\,\pi^2},\ \text{alphaR6} \to 0,\ \text{alphaR7} \to -\frac{\text{g1}^2\,\text{Nc}}{270\,\text{MHT}^2\,\pi^2}\Big\}$$

200%

MatchMaker: automated matching in effective theories

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]:=

```
finalrule0[[1]]
finalrule0[[1]] /. Simplify[allsols[[3, 3]] /. mu → MHT /. onlytop0 /. onlytop1 /. onlymixingwithtop]
```

33]=

$$\text{al01} \to \text{alpha01} - 2\,\text{alphaR3}\,\text{g1} + \text{alphaR7}\,\text{g1}^2$$

34]=

$$\text{al01} \to -\frac{\text{g1}^4\,\text{Nc}}{270\,\text{MHT}^2\,\pi^2} + \frac{7\,\text{g1}^2\,\text{lamprime3}\,\text{lamprime3bar}\,\text{Nc}}{288\,\text{MHT}^2\,\pi^2} + \frac{\text{lamprime3}\,\text{lamprime3bar}\,\text{Nc}\,(-\text{lamprime3}\,\text{lamprime3bar} + \text{ytop}\,\text{ytopbar})}{32\,\text{MHT}^2\,\pi^2}$$

$$\mathcal{O}_1 = |\phi^\dagger D_\mu \phi|^2$$

MatchMaker: automated matching in effective theories

Anastasiou, Carmona, Lazopoulos, J.S.

- Features of current version:
  - Matching to SMEFT fully automated
  - Basis-independent results: generate all redundant and evanescent operators. A specific basis is chosen by the user via external file (default Warsaw basis)
- Cross-checks
  - Complete off-shell kinematic structure matched
  - Gauge invariance
  - Comparison with known results
  - Cancellation of IR divergencies

- Summary:
  - Effective Lagrangians allow us to encode relevant experimental information in a concise, efficient, unbiased way
  - The translation of this experimental information to NP models requires matching
  - Tree-level dictionary (Exp. Observables ↔ NP models) soon to be completed
  - Matchmaker: General, fully automated and flexible code to match arbitrary models to arbitrary effective Lagrangians at tree and one-loop levels
  - The ultimate goal is to use the code to classify and compute the complete one-loop dictionary between UV completions and the SM effective Lagrangian


Thank you!