

Moriond EW 2017
Monday, March 20, 2017

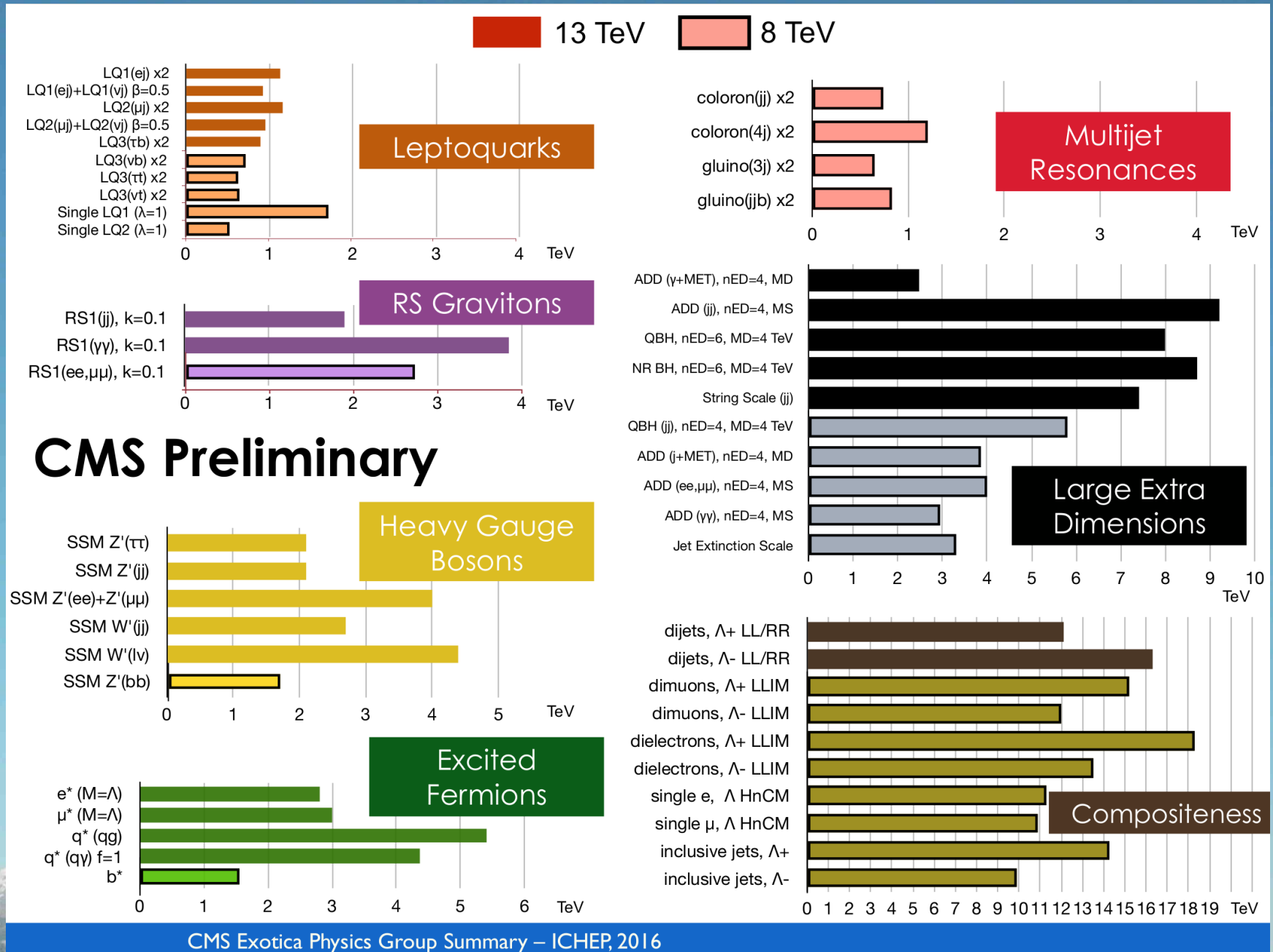
One-loop Effective Lagrangian after Matching

José Santiago



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

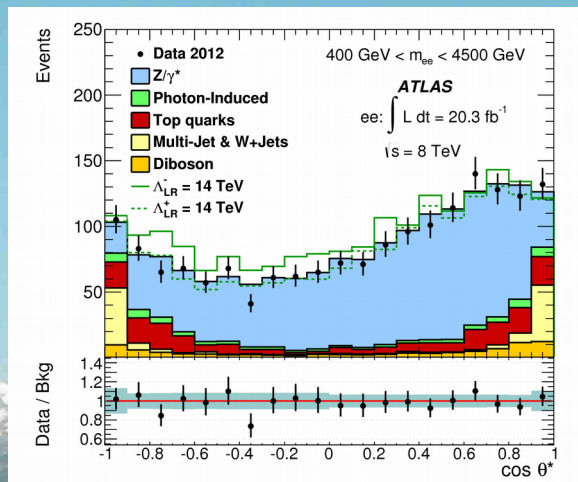
After the discovery of the Higgs, the LHC has turned into New Physics search mode



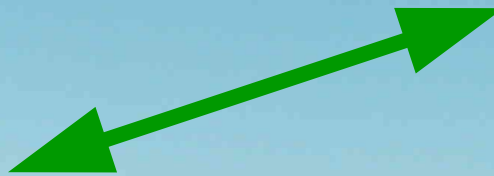
Given the absence (so far) of direct evidence of NP and the huge number of different searches, what is the best strategy to use these data?

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



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



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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), ...

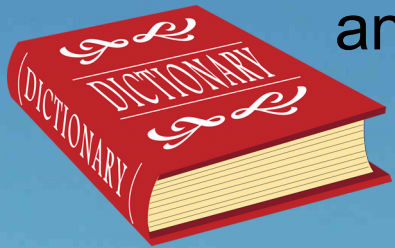
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Effective theories:

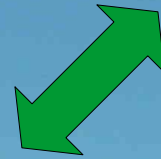
- General description of new physics with minimal theoretical input (in the presence of a mass gap)
- Map experimental (pseudo) observables to Wilson coefficients
- Global fit: use this map to encode all experimental information in constraints on Wilson coefficients
- In order to extract information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

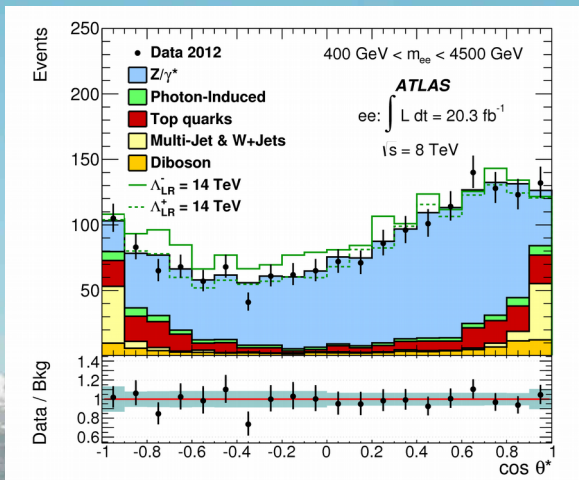
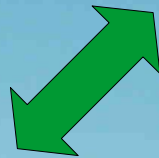
- Provides a dictionary between experimental observables and NP models



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



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



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

- Provides a dictionary between experimental observables and NP models
- 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 completely 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)

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

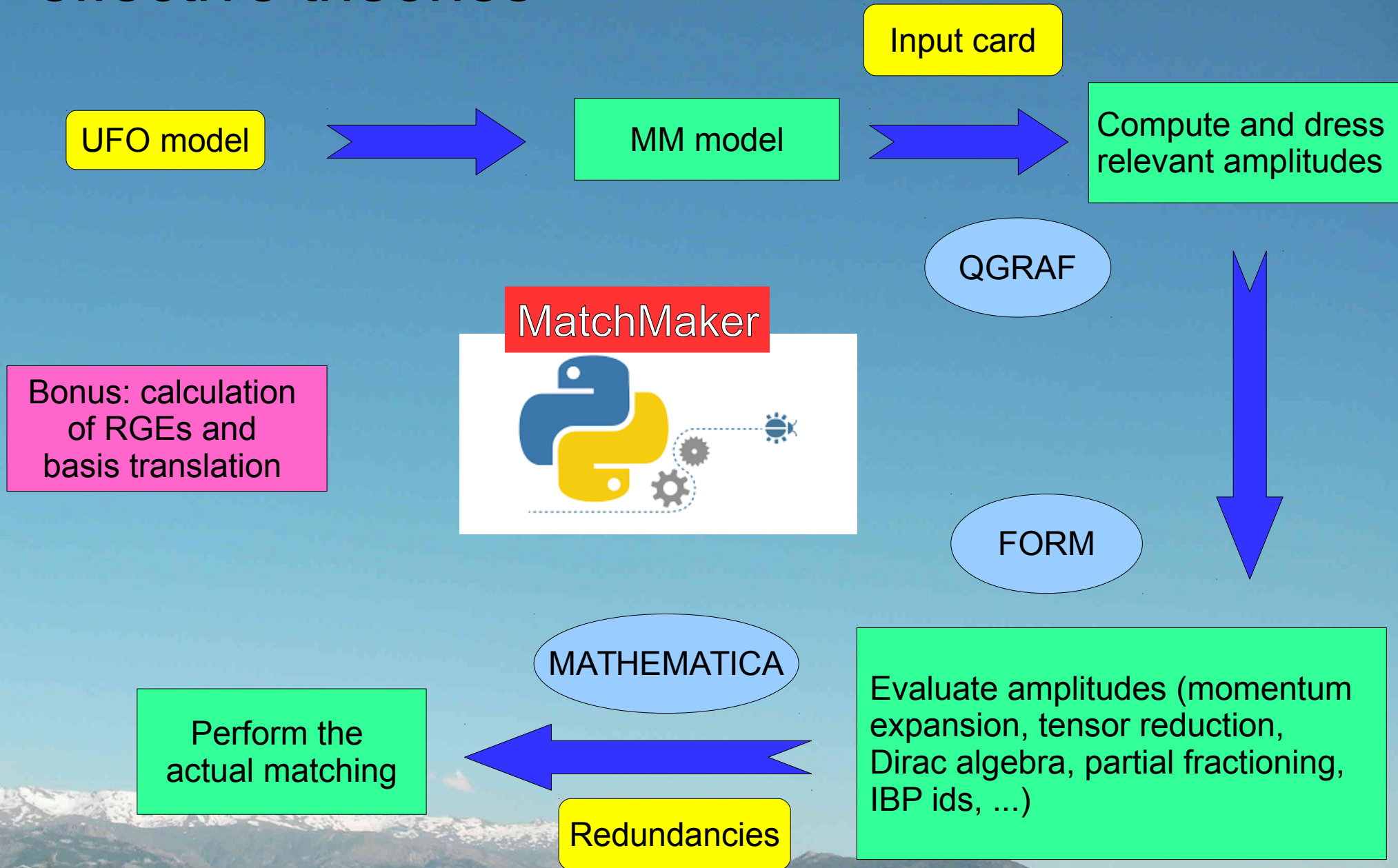
- Provides a dictionary between experimental observables and NP models
- Can be (in principle) performed at an arbitrary order in the loop and operator dimension expansions
- At tree level (and dim 6) the dictionary is almost complete: tree-level, dimension 6 new physics effects have been completely 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)

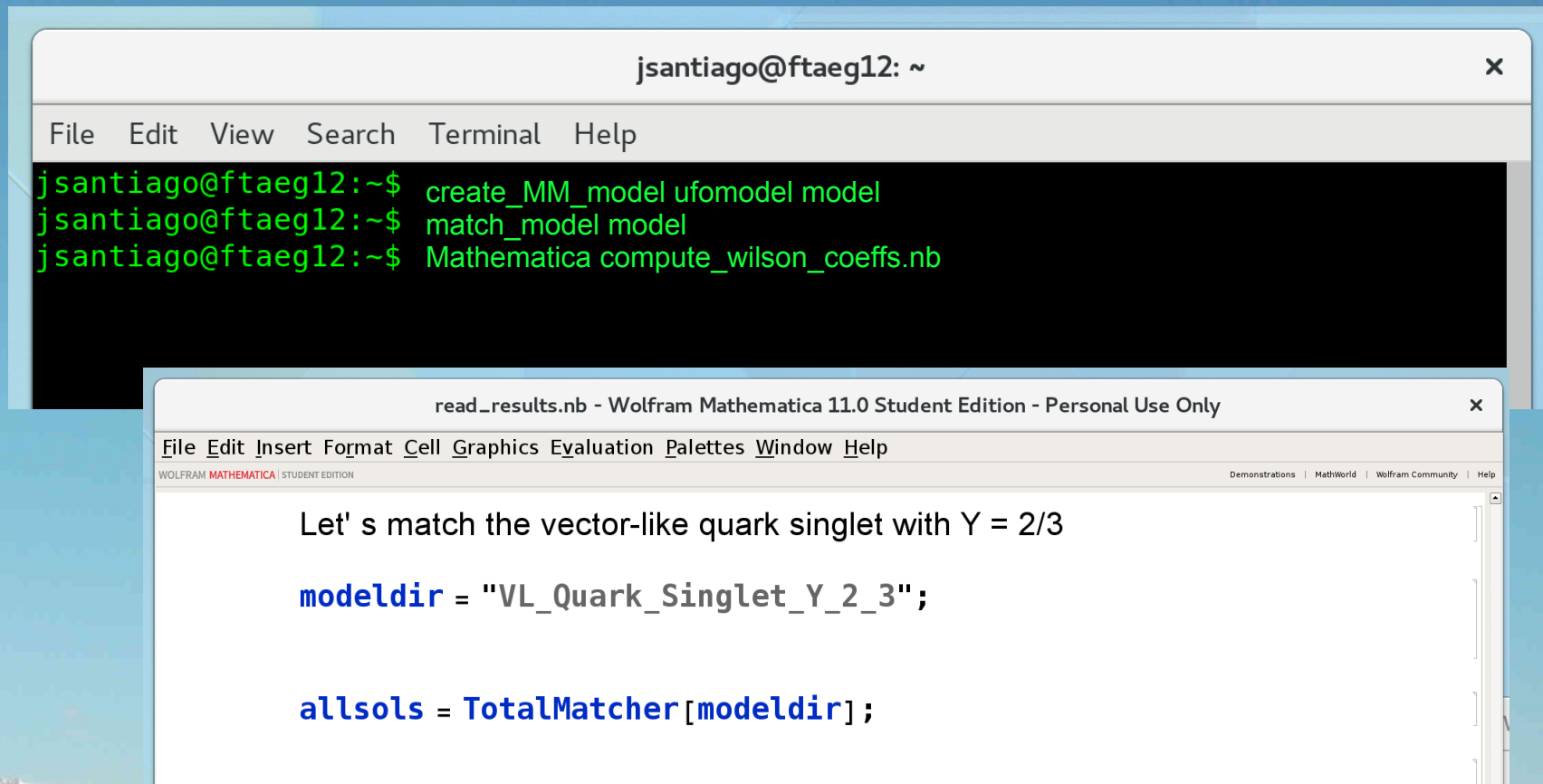
MatchMaker: automated matching in effective theories



MatchMaker: automated matching in effective theories

Anastasiou, Carmona, Lazopoulos, J.S.

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



The image shows two overlapping windows. The top window is a terminal window titled 'jsantiago@ftaeg12: ~'. It contains three lines of green text representing shell commands: 'create_MM_model ufomodel model', 'match_model model', and 'Mathematica compute_wilson_coeffs.nb'. The bottom window is a Mathematica notebook titled 'read_results.nb - Wolfram Mathematica 11.0 Student Edition - Personal Use Only'. The notebook content includes a text instruction 'Let' s match the vector-like quark singlet with $Y = 2/3$ ' followed by two lines of Mathematica code: 'modeldir = "VL_Quark_Singlet_Y_2_3";' and 'allsols = TotalMatcher[modeldir];'.

```
jsantiago@ftaeg12: ~  
File Edit View Search Terminal Help  
jsantiago@ftaeg12:~$ create_MM_model ufomodel model  
jsantiago@ftaeg12:~$ match_model model  
jsantiago@ftaeg12:~$ Mathematica compute_wilson_coeffs.nb
```

```
read_results.nb - Wolfram Mathematica 11.0 Student Edition - Personal Use Only  
File Edit Insert Format Cell Graphics Evaluation Palettes Window Help  
WOLFRAM MATHEMATICA | STUDENT EDITION  
Demonstrations | MathWorld | Wolfram Community | Help  
Let' s match the vector-like quark singlet with  $Y = 2/3$   
modeldir = "VL_Quark_Singlet_Y_2_3";  
allsols = TotalMatcher[modeldir];
```


MatchMaker: automated matching in effective theories

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- 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)



MatchMaker: automated matching in effective theories

Anastasiou, Carmona, Lazopoulos, J.S.

read_results.nb - Wolfram Mathematica 11.0 Student Edition - Personal Use Only

File Edit Insert Format Cell Graphics Evaluation Palettes Window Help

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Demonstrations | MathWorld | Wolfram Community | Help

In[103]:=

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

Out[103]=

$$\left\{ \begin{array}{l} \alpha_{01} \rightarrow \frac{\lambda_{\text{prime3}} \lambda_{\text{prime3bar}} N_c (-\lambda_{\text{prime3}} \lambda_{\text{prime3bar}} + y_{\text{top}} y_{\text{topbar}})}{32 M H T^2 \pi^2}, \\ \alpha_{010} \rightarrow -\frac{g_1 g_w \lambda_{\text{prime3}} \lambda_{\text{prime3bar}} N_c}{192 M H T^2 \pi^2}, \alpha_{012} \rightarrow -\frac{i g_s^3}{2880 M H T^2 \pi^2}, \alpha_{014} \rightarrow 0, \\ \alpha_{02} \rightarrow \frac{\lambda_{\text{prime3}} \lambda_{\text{prime3bar}} N_c (-2 \lambda_{\text{prime3}} \lambda_{\text{prime3bar}} + 9 y_{\text{top}} y_{\text{topbar}})}{96 M H T^2 \pi^2}, \\ \alpha_{04} \rightarrow \frac{g_s^2 \lambda_{\text{prime3}} \lambda_{\text{prime3bar}} \text{dd}[a_{97}, a_{99}]}{96 M H T^2 \pi^2 \text{dd}[i_{97}, i_{99}]}, \alpha_{06} \rightarrow \frac{g_w^2 \lambda_{\text{prime3}} \lambda_{\text{prime3bar}} N_c}{384 M H T^2 \pi^2}, \\ \alpha_{08} \rightarrow \frac{5 g_1^2 \lambda_{\text{prime3}} \lambda_{\text{prime3bar}} N_c}{3456 M H T^2 \pi^2}, \alpha_{R1} \rightarrow \frac{\lambda_{\text{prime3}} \lambda_{\text{prime3bar}} N_c (\lambda_{\text{prime3}} \lambda_{\text{prime3bar}} - y_{\text{top}} y_{\text{topbar}})}{32 M H T^2 \pi^2}, \\ \alpha_{R1\text{bar}} \rightarrow \frac{\lambda_{\text{prime3}} \lambda_{\text{prime3bar}} N_c (\lambda_{\text{prime3}} \lambda_{\text{prime3bar}} - y_{\text{top}} y_{\text{topbar}})}{32 M H T^2 \pi^2}, \\ \alpha_{R2} \rightarrow \frac{\lambda_{\text{prime3}} \lambda_{\text{prime3bar}} N_c}{48 M H T^2 \pi^2}, \alpha_{R3} \rightarrow -\frac{7 g_1 \lambda_{\text{prime3}} \lambda_{\text{prime3bar}} N_c}{576 M H T^2 \pi^2}, \\ \alpha_{R4} \rightarrow \frac{5 g_w \lambda_{\text{prime3}} \lambda_{\text{prime3bar}} N_c}{576 M H T^2 \pi^2}, \alpha_{R5} \rightarrow -\frac{g_s^2}{240 M H T^2 \pi^2}, \alpha_{R6} \rightarrow 0, \alpha_{R7} \rightarrow -\frac{g_1^2 N_c}{270 M H T^2 \pi^2} \end{array} \right\}$$

200%

MatchMaker: automated matching in effective theories

Anastasiou, Carmona, Lazopoulos, J.S.

]:=

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

33]=

```
al01 -> alpha01 - 2 alphaR3 g1 + alphaR7 g1^2
```

34]=

```
al01 -> -\frac{g1^4 Nc}{270 MHT^2 \pi^2} + \frac{7 g1^2 lamprime3 lamprime3bar Nc}{288 MHT^2 \pi^2} + \frac{lamprime3 lamprime3bar Nc (-lamprime3 lamprime3bar + ytop ytopbar)}{32 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 \longleftrightarrow 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



A wide-angle photograph of a snowy mountain slope. The foreground and middle ground are covered in snow, marked with numerous ski tracks that create a complex, wavy pattern. The snow appears bright white under the clear, deep blue sky. In the upper right, the top of the mountain is visible, with some sparse evergreen trees and a small wooden structure, possibly a ski lift station. The overall scene is bright and clear, suggesting a sunny day in winter.

Thank you!