Rosetta: Mapping general HEFT via the Higgs Basis to Monte Carlo

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Higgs cross section working group meeting
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University of Sussex

Foreword

- Announcement/advertisement of a MC tool for HEFT
  - Model implementation for event generation
  - + Basis translation tool
  - For use by experimental and theoretical community
- HXSWG: forum for discussion
- We would like to present our idea
  - Comments/suggestions/criticisms/advice/…
  - Wishlist?
  - People interested in contributing
- Work in progress (only a few weeks old!)
- Feel free to get in touch

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Status

- In anticipation of LHC13 data…
- Higgs EFT in a generally realised spontaneous breaking of EW symmetry looks to be an important framework to have in place
- Along with a proposal on how to parametrise deviations from SM expectations, tools are needed to generate signal
  - For use by both experimentalists & theorists
- General enough in scope to meet needs of both communities by linking to:
  - Dimension 6 bases/UV completions
  - Pseudo-observables (relating to interactions of mass eigenstates)

Higgs Basis

- Higgs Basis
  - Provides a bridge between needs of theorists and experimentalists
- Divide operator basis into classes based on observables that are constrained by measurements of different precision
  - LEP1, precision EW observables measured at Z pole (~0.1%)
  - LEP2, off peak line shapes, TGCs (~1%)
  - LHC, Higgs signal strengths (~10%)

[Massó, Sanz: 1211.1320]
[Gupta, Pomarol, Riva: 1405.0181]
…

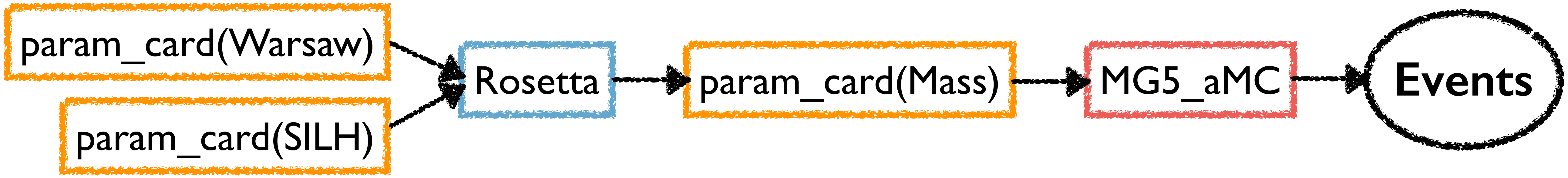
- Isolates current measurements of Higgs properties to a subset of relevant operators
  - Encode SU(2)xU(1) invariance by requiring certain relations between coefficients
  - Translate to other dim 6 bases such as Warsaw, SILH

Mass Basis

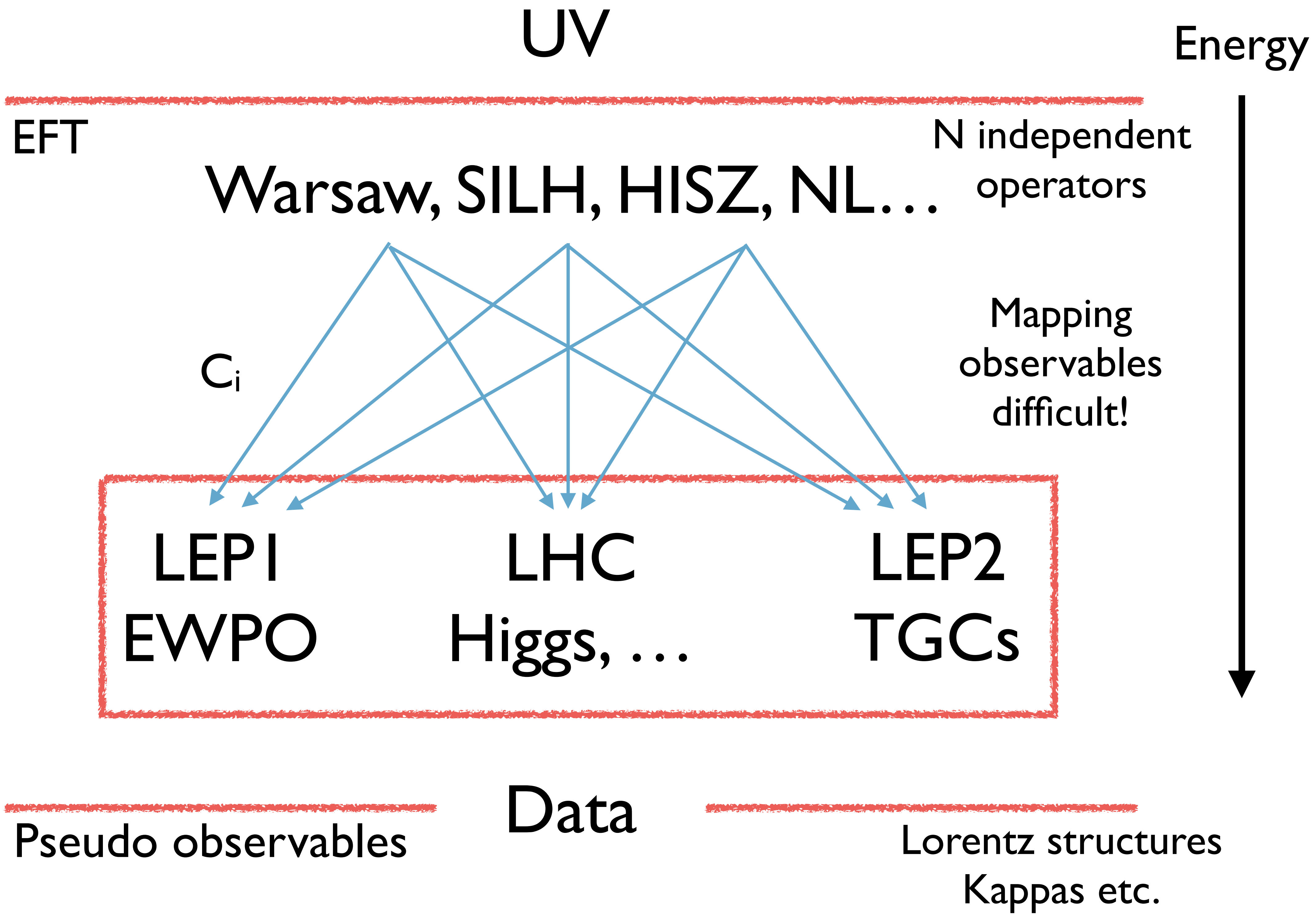
- HXSWG is working on a proposal to experimental collaborations using this basis
  - We have started working a tool to implement this in a MC-friendly way
- Our current idea:
  - Use the set of operators characterised by the Higgs Basis
  - Have a FeynRules/UFO implementation of these operators
  - Provide the possibility of multiple input formats in terms of coefficients of your favourite basis
- Aims to put all dim 6 bases on the same footing
  - Develop an additional 'translation' layer between the user defined coefficients in a given basis to a general implementation in terms of the 'redundant' Higgs Basis: Mass Basis

Mass Basis

- We will not assume any a-priori relationships between any of the coefficients (redundancy)
  - Allow theory users to encode the relations implicitly by calculating the values of the Mass Basis coefficients in terms of their chosen basis i.e. Warsaw (see mapping to dim 6 in proposal draft)
  - Experimentalists can simply pick the input format and generate signal
- Complete in terms of mass eigenstate interactions
- Rosetta: One tool serves all
  - Input/Output: LHA-style parameter card in an implemented model



HEFT Cartoon



UV

Energy

EFT

Warsaw, SILH, HISZ, NL…

N independent operators

C_i

Mapping observables difficult!

LEP1
EWPO

LHC
Higgs, …

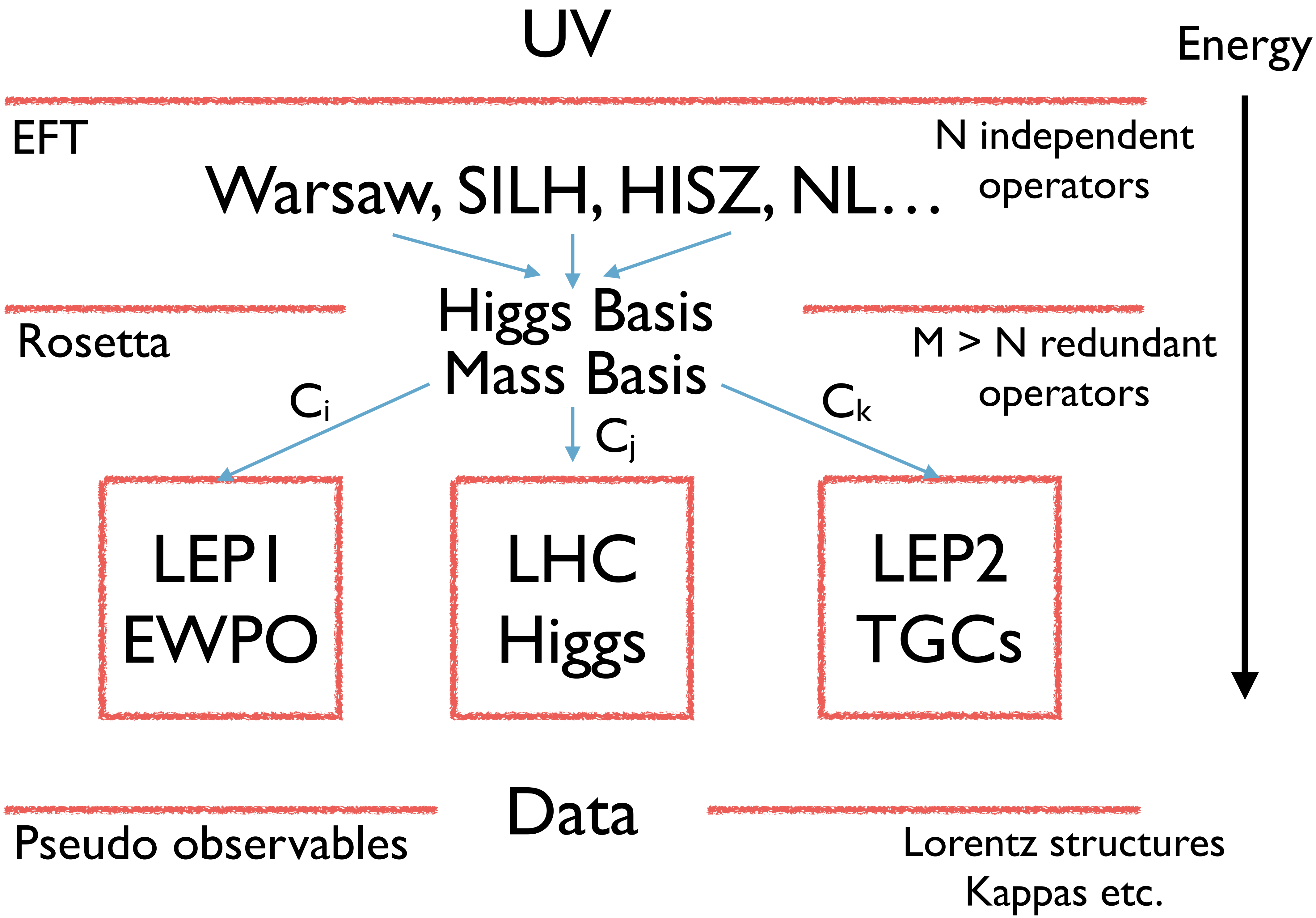
LEP2
TGCs

Data

Pseudo observables

Lorentz structures
Kappas etc.

HEFT Cartoon



UV

Energy

EFT

N independent operators

Warsaw, SILH, HISZ, NL…

Higgs Basis

Mass Basis

Rosetta

M > N redundant operators

C_i

C_j

C_k

LEP1 EWPO

LHC Higgs

LEP2 TGCs

Data

Pseudo observables

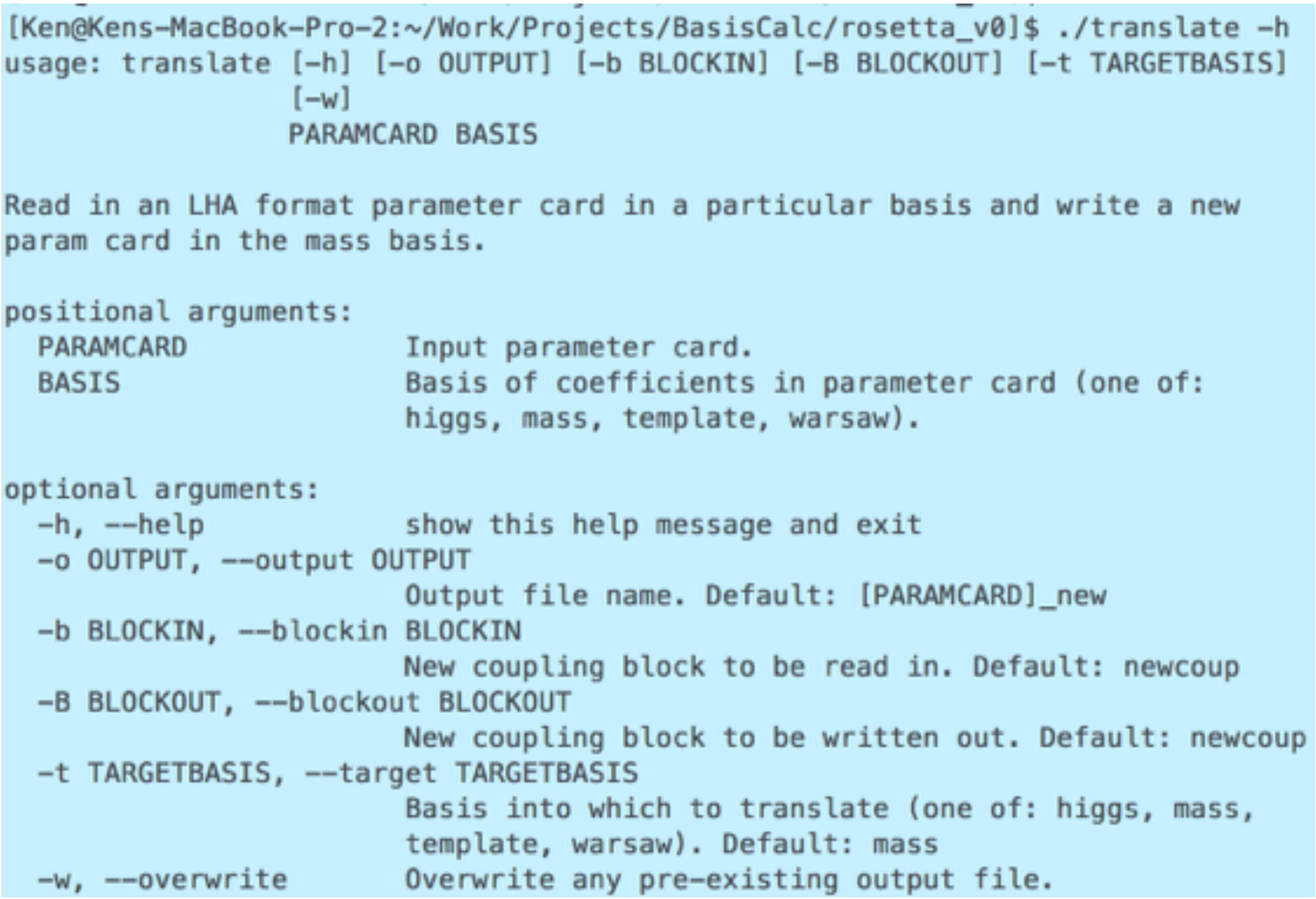
Lorentz structures
Kappas etc.

Rosetta

- Tries to avoid duplicating efforts
  - Implementing a translation should be less effort than implementing a full model
  - Some independent MC implementations needed for validation
- Simplify usage for non experts
  - ‘Community reviewed’ implemenations of EFT frameworks
  - Facilitate doing pheno and connecting to experiment
- Modular, user-implemented translations
  - Calculate dependent parameters, field/coupling redefinitions
  - Impose any further restrictions i.e. flavour structure/universality, custodial symmetry
  - Makes extensive theory user input/testing possible

Usage

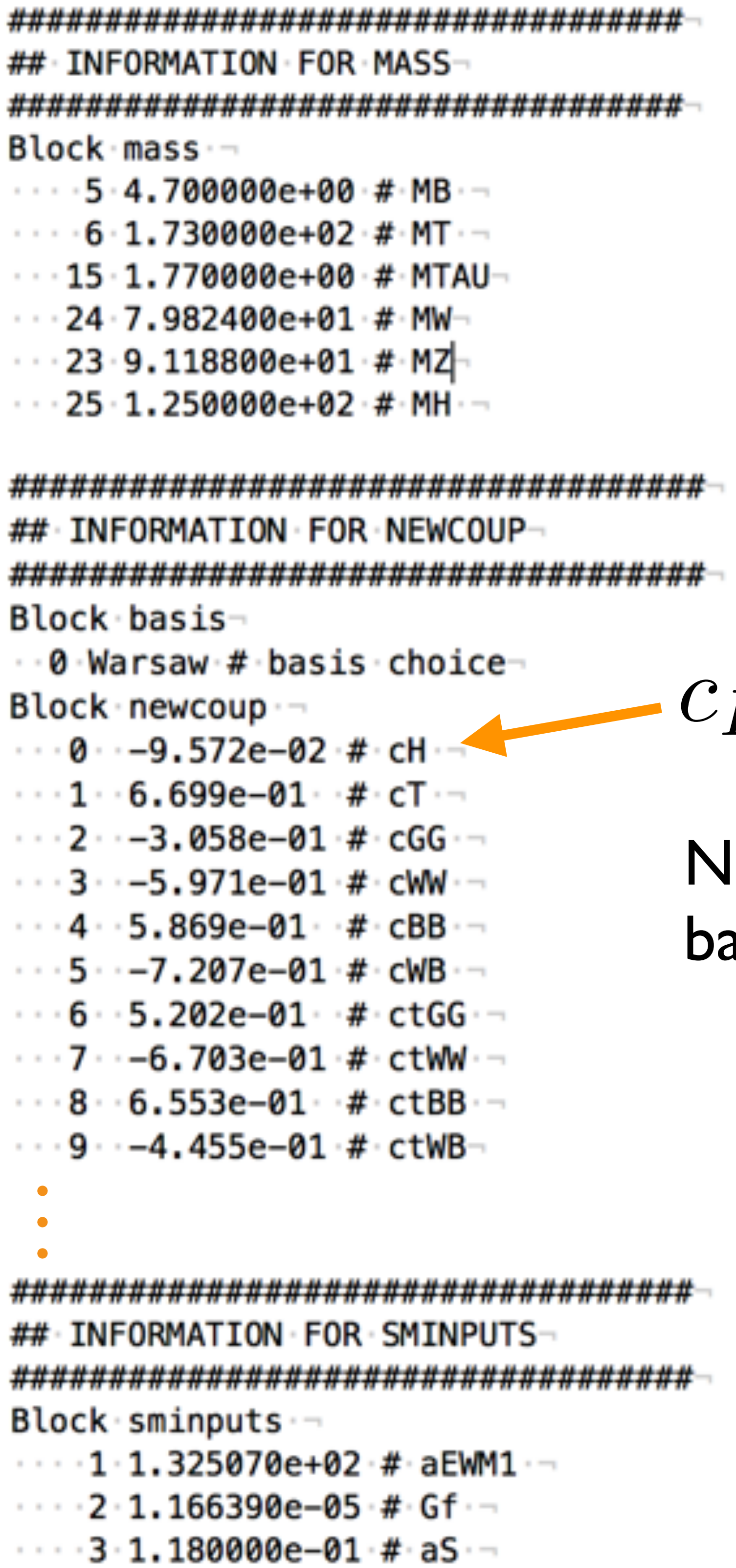
- Rosetta will ship with the Mass Basis FeynRules/UFO
  - Can also be used as a stand-alone program
- `./translate` : LHA card in → LHA card out



```
[Ken@Kens-MacBook-Pro-2:~/Work/Projects/BasisCalc/rosetta_v0]$ ./translate -h
usage: translate [-h] [-o OUTPUT] [-b BLOCKIN] [-B BLOCKOUT] [-t TARGETBASIS]
                 [-w]
                 PARAMCARD BASIS

Read in an LHA format parameter card in a particular basis and write a new
param card in the mass basis.

positional arguments:
  PARAMCARD             Input parameter card.
  BASIS                 Basis of coefficients in parameter card (one of:
                        higgs, mass, template, warsaw).

optional arguments:
  -h, --help            show this help message and exit
  -o OUTPUT, --output OUTPUT
                        Output file name. Default: [PARAMCARD]_new
  -b BLOCKIN, --blockin BLOCKIN
                        New coupling block to be read in. Default: newcoup
  -B BLOCKOUT, --blockout BLOCKOUT
                        New coupling block to be written out. Default: newcoup
  -t TARGETBASIS, --target TARGETBASIS
                        Basis into which to translate (one of: higgs, mass,
                        template, warsaw). Default: mass
  -w, --overwrite       Overwrite any pre-existing output file.
```

Example: input

param_card_WarsawBasis.dat



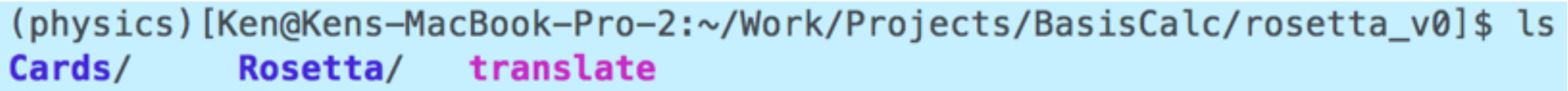
```
#####################################
## INFORMATION FOR MASS
#####################################
Block mass
    5 4.700000e+00 # MB
    6 1.730000e+02 # MT
   15 1.770000e+00 # MTAU
   24 7.982400e+01 # MW
   23 9.118800e+01 # MZ
   25 1.250000e+02 # MH

#####################################
## INFORMATION FOR NEWCOUP
#####################################
Block basis
  0 Warsaw # basis choice
Block newcoup
    0  -9.572e-02 # cH
    1  6.699e-01  # cT
    2  -3.058e-01 # cGG
    3  -5.971e-01 # cWW
    4  5.869e-01  # cBB
    5  -7.207e-01 # cWB
    6  5.202e-01  # ctGG
    7  -6.703e-01 # ctWW
    8  6.553e-01  # ctBB
    9  -4.455e-01 # ctWB
 ⋮

#####################################
## INFORMATION FOR SMINPUTS
#####################################
Block sminputs
    1 1.325070e+02 # aEWM1
    2 1.166390e-05 # Gf
    3 1.180000e-01 # aS
```

EFT input

$c_H\,,\ c_T\,,\ c_{GG}\,,\ \tilde{c}_{GG}\,,\ \ldots$

Names declared in basis implementation

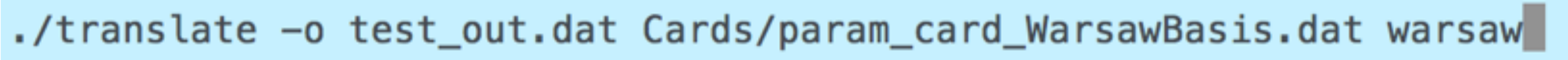
Example: translate



```
(physics)[Ken@Kens-MacBook-Pro-2:~/Work/Projects/BasisCalc/rosetta_v0]$ ls
Cards/      Rosetta/    translate
```

Python package

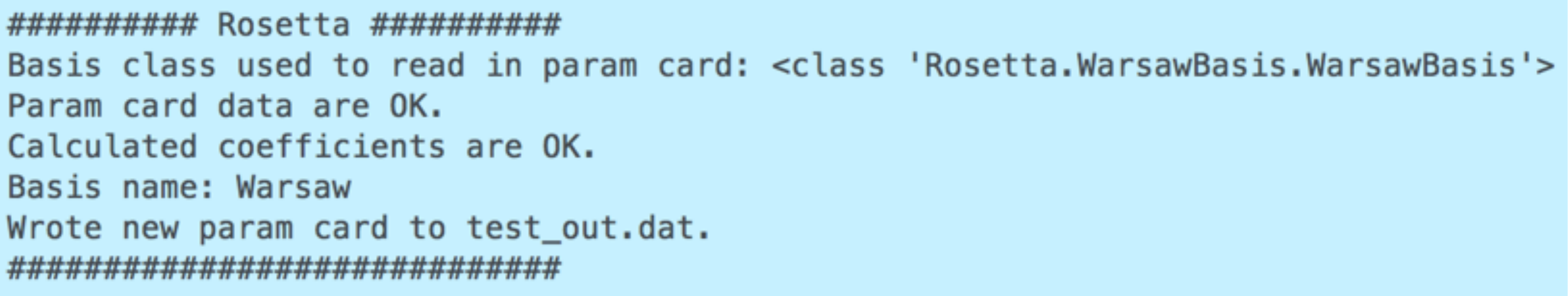
Command line script



```
./translate -o test_out.dat Cards/param_card_WarsawBasis.dat warsaw
```

Output

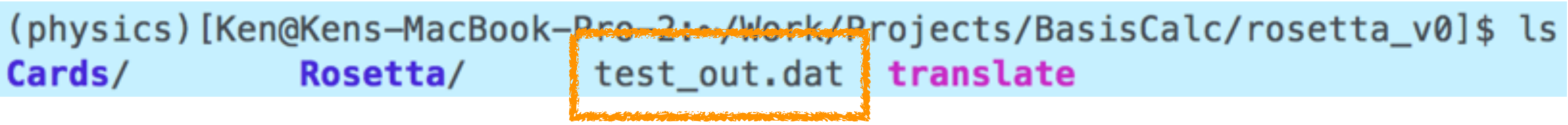
Basis name



```
########## Rosetta ##########
Basis class used to read in param card: <class 'Rosetta.WarsawBasis.WarsawBasis'>
Param card data are OK.
Calculated coefficients are OK.
Basis name: Warsaw
Wrote new param card to test_out.dat.
##############################
```

Some info/sanity checks:

Are all required inputs declared?
Are all dependent coefficients calculated?



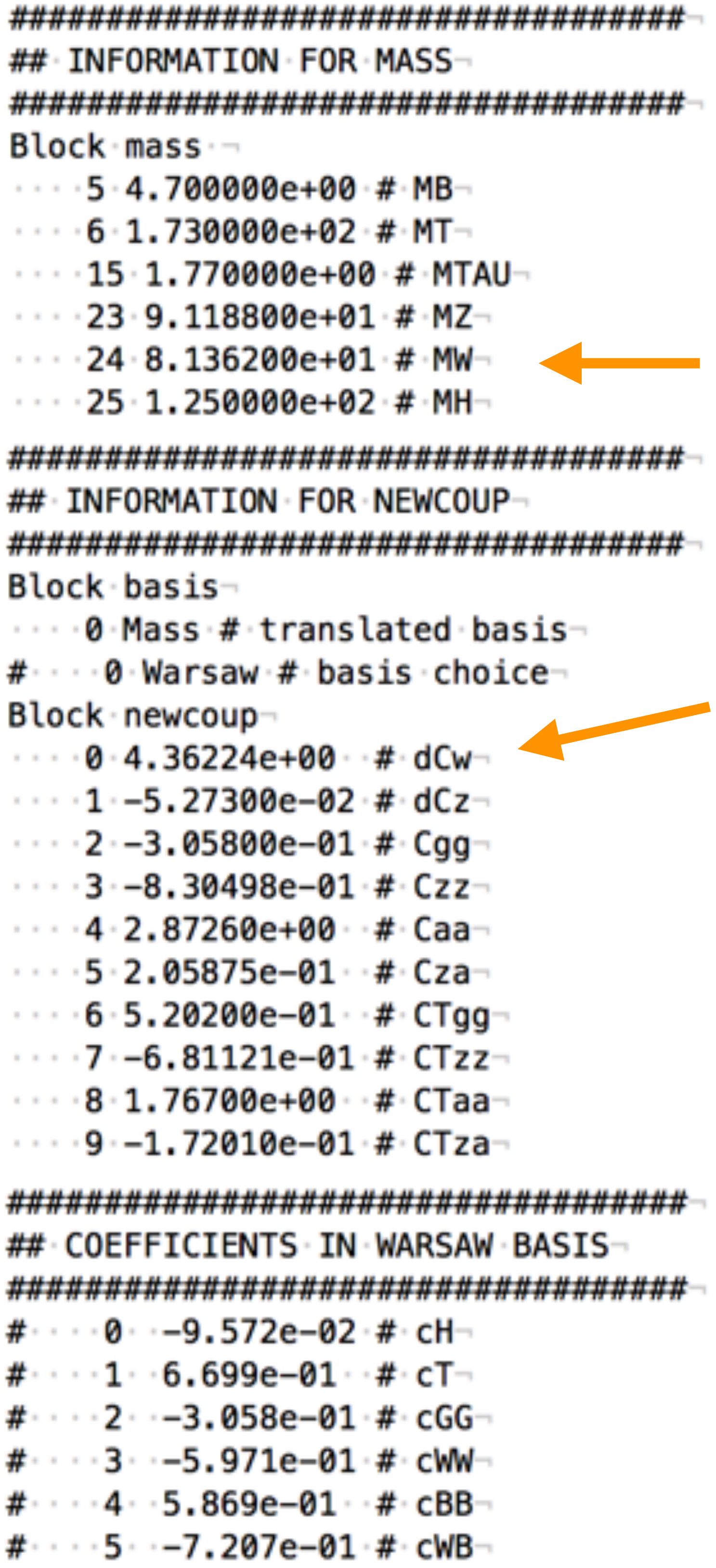
```
(physics)[Ken@Kens-MacBook-Pro-2:~/Work/Projects/BasisCalc/rosetta_v0]$ ls
Cards/         Rosetta/       test_out.dat  translate
```

Example: output

test_output.dat

Fit for use by the FeynRules/UFO implementation

Applies eqns. (4.5) - (4.15) in proposal draft



```
####################################
## INFORMATION FOR MASS
####################################
Block mass
    5 4.700000e+00 # MB
    6 1.730000e+02 # MT
    15 1.770000e+00 # MTAU
    23 9.118800e+01 # MZ
    24 8.136200e+01 # MW
    25 1.250000e+02 # MH
####################################
## INFORMATION FOR NEWCOUP
####################################
Block basis
    0 Mass # translated basis
#    0 Warsaw # basis choice
Block newcoup
    0 4.36224e+00  # dCw
    1 -5.27300e-02 # dCz
    2 -3.05800e-01 # Cgg
    3 -8.30498e-01 # Czz
    4 2.87260e+00  # Caa
    5 2.05875e-01  # Cza
    6 5.20200e-01  # CTgg
    7 -6.81121e-01 # CTzz
    8 1.76700e+00  # CTaa
    9 -1.72010e-01 # CTza
####################################
## COEFFICIENTS IN WARSAW BASIS
####################################
#    0  -9.572e-02 # cH
#    1  6.699e-01  # cT
#    2  -3.058e-01 # cGG
#    3  -5.971e-01 # cWW
#    4  5.869e-01  # cBB
#    5  -7.207e-01 # cWB
```

New W mass: $M_W + \delta m$

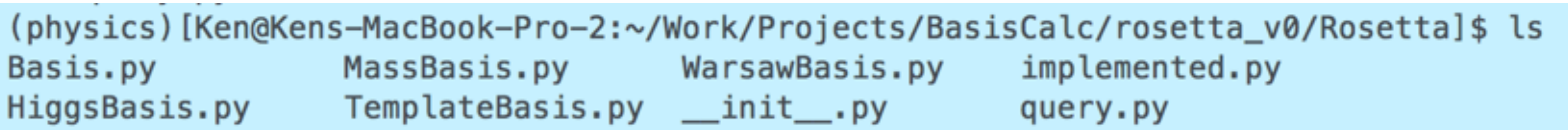
EFT output

$\delta c_z, \, \delta c_z, \, c_{gg}, \, \tilde{c}_{gg}, \, \ldots$

Names declared in Mass Basis implementation

Retains old input

Usage: implementing



```
(physics)[Ken@Kens-MacBook-Pro-2:~/Work/Projects/BasisCalc/rosetta_v0/Rosetta]$ ls
Basis.py           MassBasis.py       WarsawBasis.py     implemented.py
HiggsBasis.py      TemplateBasis.py   __init__.py        query.py
```

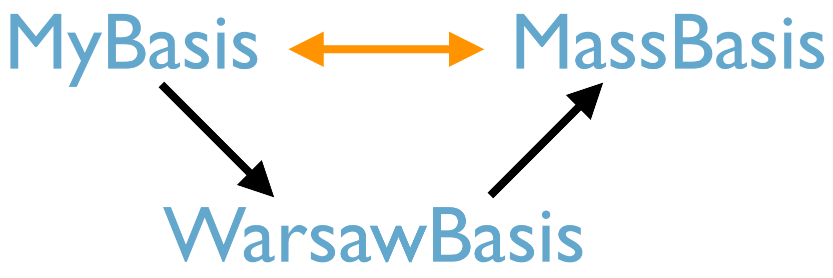
```
+ MyBasis.py
```

- Users can add their own basis to the module
- Requires a little bit of python
    - Declare independent [and dependent] coefficients
    - Declare required inputs (masses, EW parameters…)
    - Implement required functions:

        `translate()` [and `calculate_dependent()`]
    - Map coefficients to Mass Basis
- See Backup slides for more details on structure

Usage: implementing

- Existing implementation of Higgs Basis can be used to perform a few cross checks of output
  - Assuming MyBasis comes from a dim 6 linear SU(2)xU(1) realisation
  - Output of translation to Mass Basis → Input for Higgs Basis
  - Compare values dependent parameters



- Multi-step translation also possible
  - e.g. I already have a translation from my basis to Warsaw Basis
  - Implement those instead & use preexisting Warsaw Basis implementation to take me to the Mass Basis
  - One can even 'close the triangle' for additional consistency checks

More translation

- There is in principle no restriction to the direction of translation
  - Going ‘sideways’ between bases
- Going ‘up’ from mass basis
  - The LHC may give us constraints in terms of coefficients relating to pseudo-observables
  - Closer to Mass Basis rather than generic dim 6
  - The possibility of translating back to dim 6 bases may make the interpretation of constraints more efficient
- Optional choice of independent/dependent parameters
  - Users may want to have some freedom over this i.e. taking Cww as input rather than derived for studying WH associated production

In progress

$$\mathcal{L}_{\text{Higgs Basis}} = \boxed{\mathcal{L}^{\text{SM}} + \mathcal{L}^{(1)}_{\text{ewpt}} + \mathcal{L}^{(2)}_{\text{ewpt}} + \mathcal{L}_{\text{hff}} + \mathcal{L}^{(1)}_{\text{hvv}} + \mathcal{L}^{(2)}_{\text{hvv}} + \mathcal{L}_{hvff}} + \mathcal{L}_{\text{other}}$$

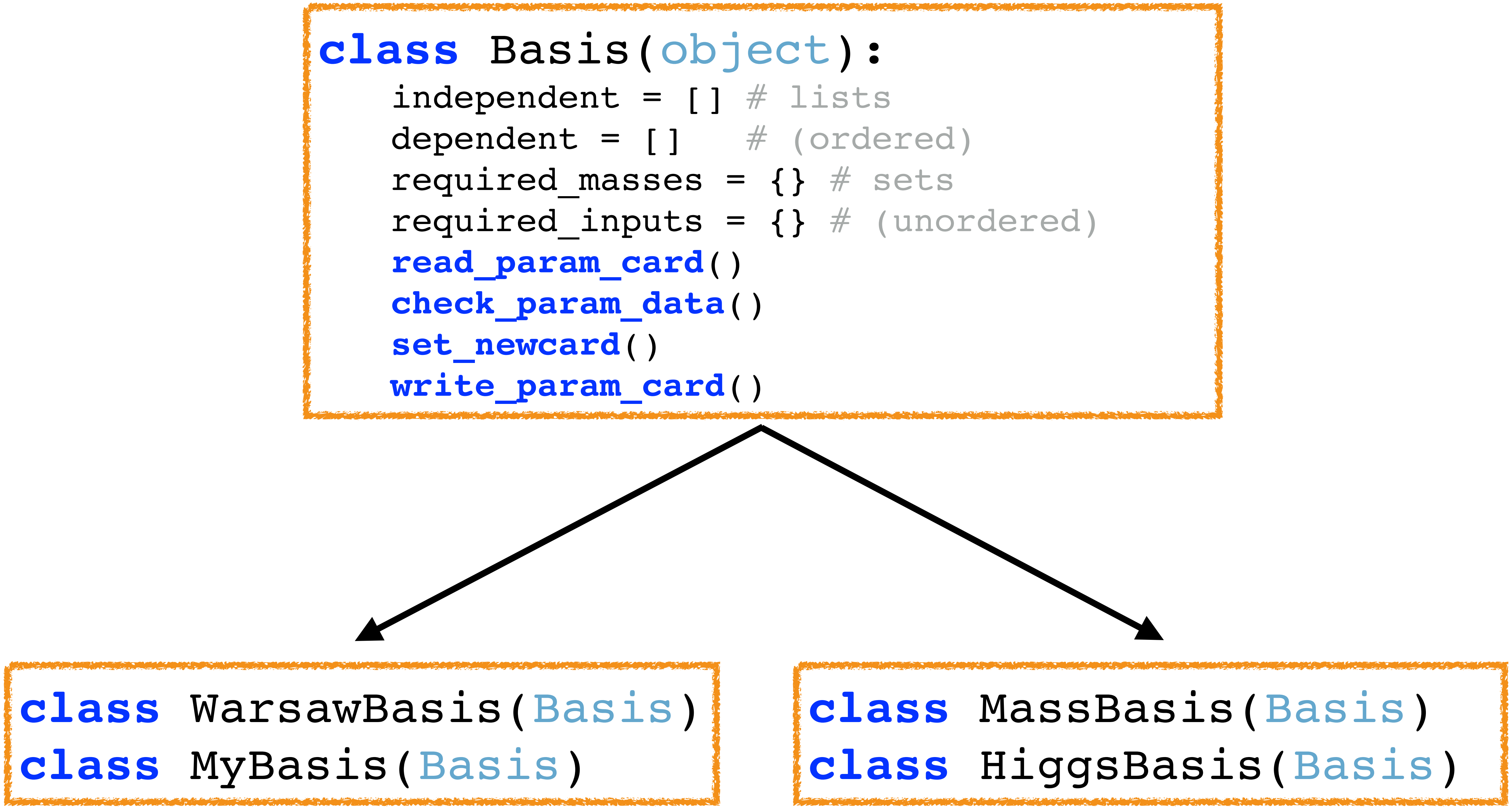
- Working on the model implementation derived from HC model (Maltoni et al.)
  - The full set of operators in the Higgs Basis proposal including ‘L_{other}’ is large
  - So far have restricted ourselves to the content of the draft version circulated at the last meeting
  - At validation stage for this subset of operators
- Already have at least one dim 6 implementation for validation, HEL model (Alloul et al.)
- Basic version of the Rosetta using info in proposal
  - Higgs Basis: calculation of dependent parameters
  - Warsaw Basis: translation to the Mass Basis

NLO?

- Once we have a complete LO framework
  - Possible to upgrade to NLO in QCD/EW
  - Add counterterms with help from a dim 6 SU(2)xU(1) invariant implementation (NLOCT…)
  - Upgrade Rosetta to modify counterterms in UFO
- Future work

Thank you

Base class



```
class Basis(object):
    independent = [] # lists
    dependent = []   # (ordered)
    required_masses = {} # sets
    required_inputs = {} # (unordered)
    read_param_card()
    check_param_data()
    set_newcard()
    write_param_card()
```

```
class WarsawBasis(Basis)
class MyBasis(Basis)
```

```
class MassBasis(Basis)
class HiggsBasis(Basis)
```

Base methods

```
class Basis(object)

self.par_dict = OrderedDict()
self.coeffs = namedtuple()
…
read_param_card() # fills these
self.par_dict, self.coeffs, self.input, self.masses, self.name, self.card
check_param_data() # check consistency
self.par_dict ↔ (self.independent, self.dependent, self.required_masses,
self.required_inputs)
set_newcard()
self.newcard = self.card ← self.newpar, self.newmasses
write_param_card()
```

Basic methods & members are under the hood, inherited by child basis classes

HiggsBasis

```
class HiggsBasis(Basis)

independent = [‘dCw’,‘dCz’,‘Czz’,‘Cgg’,…]
dependent   = [‘Cww’,‘CTww’,‘CLzu11’,‘CRWq23’,…]
required_masses = {1,2,3,4,5,6,11,12,13,14,15,16} # PIDs
required_inputs = {‘aEWM1’,‘MZ’,‘Gf’}
calculate_dependent():
self.dependent ← self.independent # eqns. (3.7), (3.9), (3.11) in draft
translate():
    NotImplemented
```

Basis & relations described in proposal draft:
Can be used as partial cross check for user implemented linear dimension 6 bases

MassBasis

```
class MassBasis(Basis)

independent = HiggsBasis.independent+HiggsBasis.dependent
calculate_dependent():
   NotImplemented
translate():
   NotImplemented
```

‘Container’ class for target coefficients:
User implemented `translate()` method in
MyBasis can create one of these instances to fill

MyBasis

```
class MyBasis(Basis)

independent = [‘A’,’B’,’C’,…] # My coefficients
dependent   = [‘D’,’E’,‘F’,…]
required_masses = {1,2,3,4,5,…} # PIDs
required_inputs = {‘aEWM1’,’MZ’,‘Gf’,…}
calculate_dependent():
self.dependent ← self.independent
translate():
M = MassBasis().coeffs._asdict() # Empty MassBasis instance
M[‘Czz’] = self.coeffs.A         # Fill
M[‘dCz’] = self.coeffs.as_dict()[’B’]
M[‘dM’] = self.par_dict[’C’]
…
self.newpar = M
useful_function():
   # Anything you like (providing it doesn’t override exiting functions)
```