HyperIso : A general BSM calculator for flavour observables

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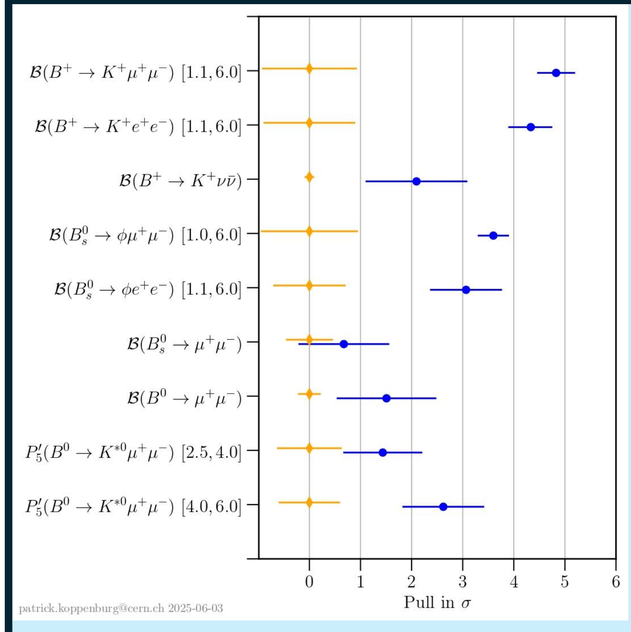
Motivation



(Non) perturbative QCD calculations

+

Calculations in each UV theories

+

Wilson coefficient matching

=

Need for automation

The main goal of HyperIso is to provide a new, open-access framework to calculate flavour observables in arbitrary BSM models (with heavy new particles, above EW scale), using the MARTY software [2].

Another key feature of HyperIso is its user-friendliness. It offers multiple interfaces, including C++, Python, terminal and a Graphical User Interface (GUI) to perform computation for any model.

SuperIso

SuperIso [1] allows the computation of flavour observables (rare decays, FCNC, etc.) in the SM and some BSM extensions (THDM, MSSM, NMSSM). The workflow includes Wilson coefficient calculation (in the WET) up to NNLO, Observable calculation (using lattice QCD inputs for non-perturbative QCD) and χ^2 estimation between experimental data and theoretical uncertainties.

By doing random, grid-based or directed scans over model parameters, one can constrain SUSY or THDM model using latest experimental data.

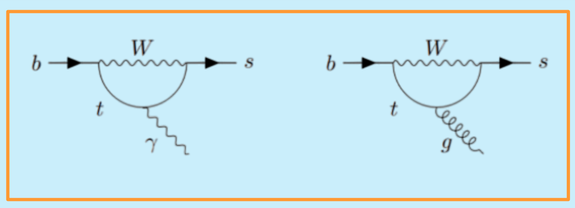
Despite its success, SuperIso focuses on SUSY models, and its architecture is unsuited for fully model-independent generalization.

Weak Effective Theory

Weak effective theory allows for easier calculations below the EW scale and decouple the calculation from the UV theory and the running for the coefficients, making this last part model independent. SM contributions for these coefficients are known to NNLL and for other models like THDM or MSSM, the coefficients have been calculated up to NNLO. For new models, one need first to match these coefficient by performing calculation in the UV theory.

$$L_{(B)SM} \to H_{\text{eff}}(b \to sX) = -\frac{4G_F}{\sqrt{2}} V_{tb}V_{ts}^* \sum_{i=1}^{10} C_i(\mu) O_i(\mu)$$

UV theory



m_t

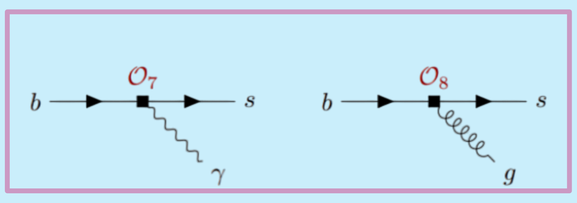
C_i M_W

RGE on Wilson coefficients !

B physics scales

m_b
m_c
Λ_{QCD}

Weak Effective Theory



QCD running

$$C_i^{eff}(\mu) = C_i^{(0)eff}(\mu) + \frac{\alpha_s(\mu)}{4\pi} C_i^{(1)eff}(\mu) + \mathcal{O}(\alpha_s^2(\mu))$$

References

[1] F. Mahmoudi, SuperIso v3.0: A program for calculating flavor physics observables in 2HDM and supersymmetry, 2009
[2] G. Uhlrich, F. Mahmoudi, A. Arbey, MARTY – Modern Artificial Theoretical physicist: A C++ framework automating symbolic calculations Beyond the Standard Model, 2020
[3] Patrick Koppenburg, Flavour (non-)Anomalies, 2025

Generic BSM phenomenology

Built-in or MARTY

Model selection

HYPER ISO

Random
Grid
Directed
(Multinest...)

Parameter generation

Wilson coefficients calculation

N^2LO/L from literature

Observable calculation

QCD Factorization
...

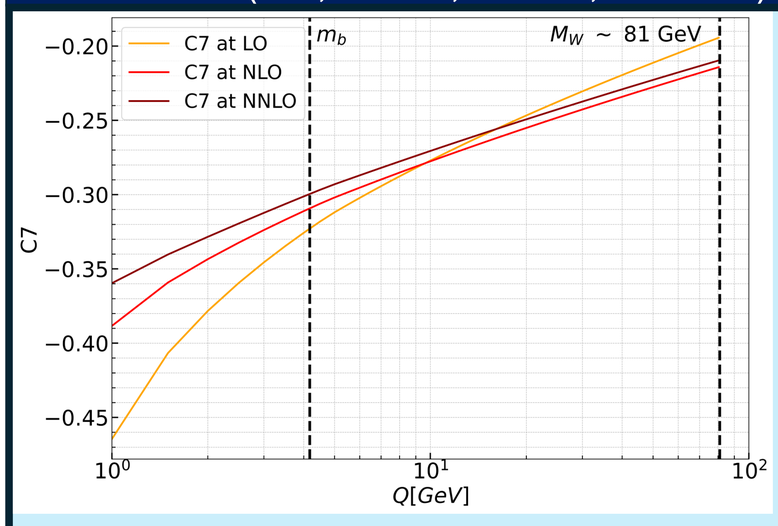
Associated χ^2

Check against exp. values accounting for theo. uncertainties

Constraints

MARTY ⇒ Calculations in any generic BSM scenario

Precision Physics
(SM, THDM, MSSM, NMSSM)



SM C7 Wilson Coefficient as a function of the running scale

In models such as the Standard Model, THDM, or SUSY-like frameworks, HyperIso can perform calculations up to NNLO, making it a highly precise tool for flavour observable predictions.

The code has been optimized for performance through CPU-level enhancements and matrix-level optimizations, significantly accelerating large-scale parameter scans.

These improvements make HyperIso particularly suited for high-statistics studies and global fits in flavour physics.

MARTY Workflow

C++ MARTY

Model building

Symmetries, breaking patterns
Field content
→ Lagrangian

Analytical QFT calculations

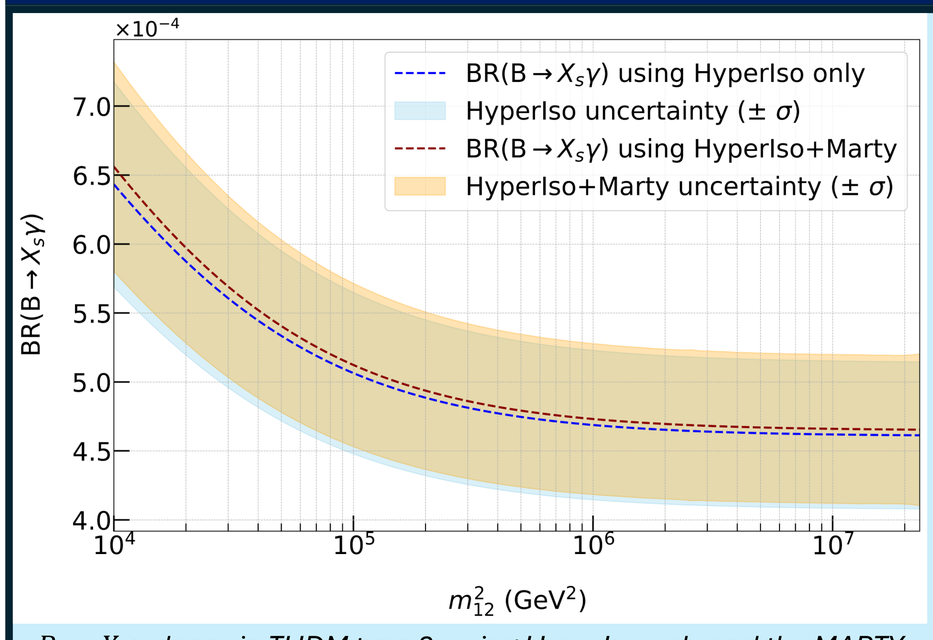
Scattering amplitudes
Decay widths
Wilson coefficients

Numerical library generation

Numerical phase space integration

- Adding new gauge symmetry
  → new gauge bosons
- Adding new Higgs fields
  → for massive gauge bosons
- Adding new charges to SM fermions
  → Anomalies cancelation
- Adding new fermions
  → HNL, Dark Matter, Vector like fermions, etc.
- Adding new fine-tuned interactions

HyperIso + MARTY workflow example



$B \to X_s\gamma$ decay in THDM type 2, using HyperIso only and the MARTY interface. m_{12} is the real Higgs mixing term in the THDM

Thanks to the MARTY interface, **HyperIso** can reproduce **SuperIso**'s Leading Order calculations in models such as the THDM or SUSY-like frameworks.

In addition, HyperIso can now extend the computation of Wilson coefficients at Leading Order in many BSM models, making it a very powerful tool for flavour phenomenology.

A new benchmark study on BSM models is currently in progress to demonstrate HyperIso's potential on scenarios unexplored by SuperIso.