Upgrading numerical tools for BSM exploration
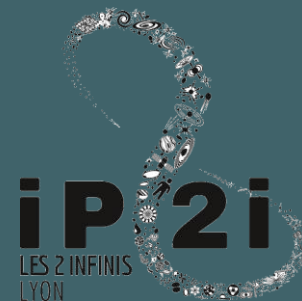
Niels Fardeau
October 7 2024

3rd Mini Workshop

Standard model…

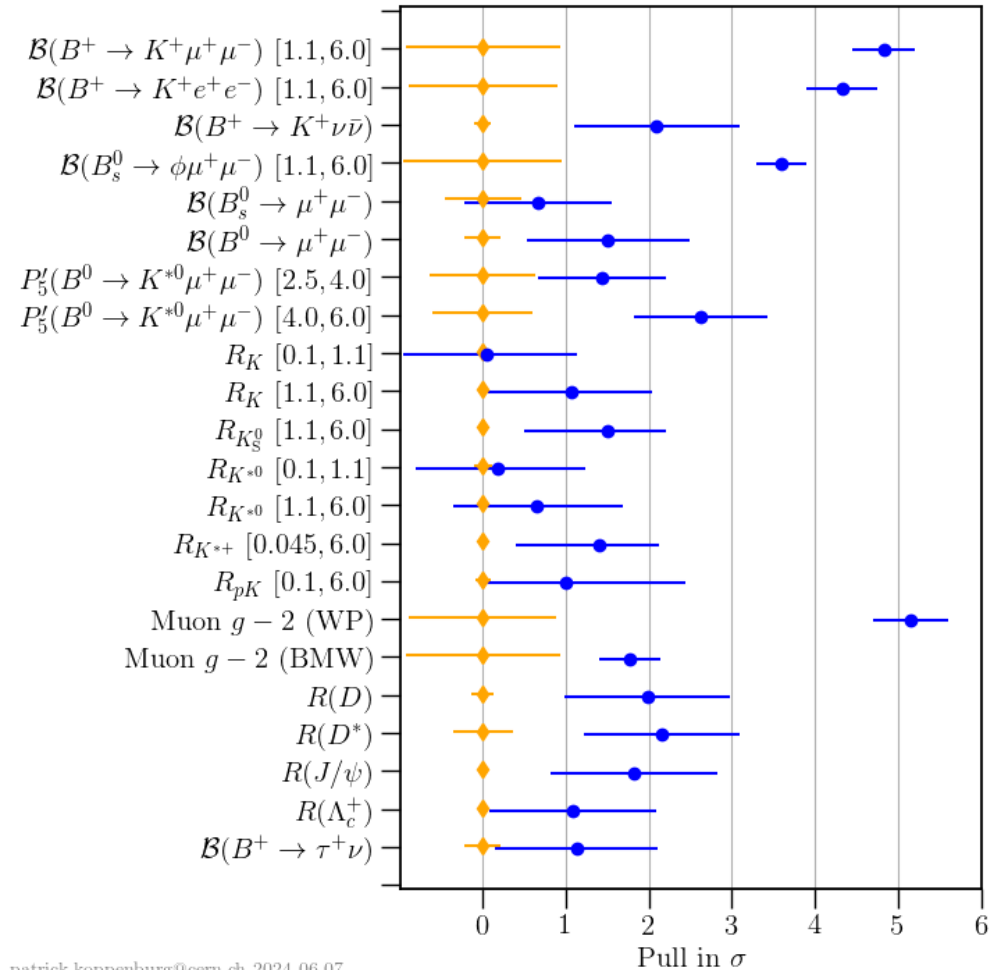**Standard Model of Elementary Particles**
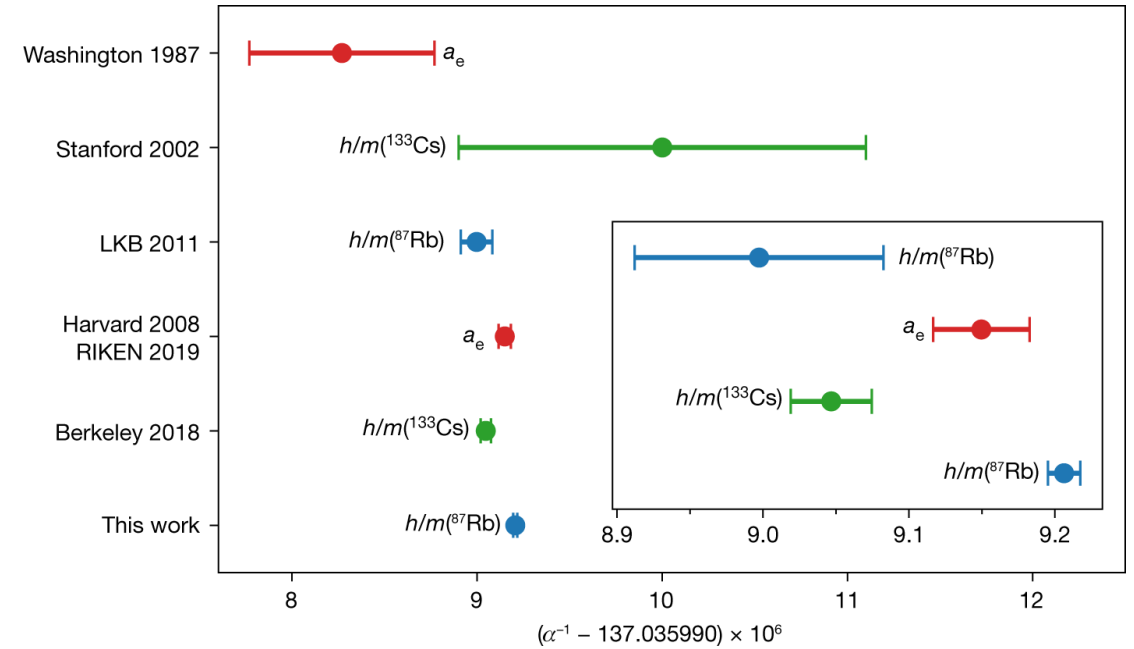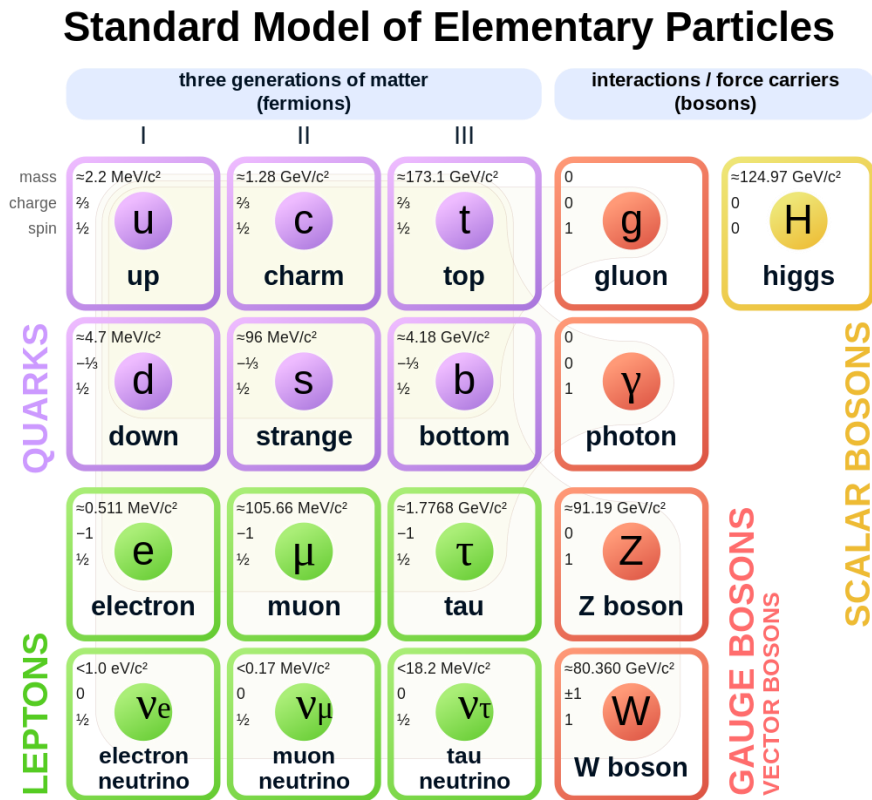
Morel et al. (2020) – Determination of the fine structure constant with an accuracy of 81 parts per trillion

… and its limits

The SM does not answer some important questions !
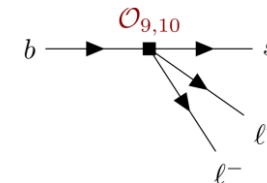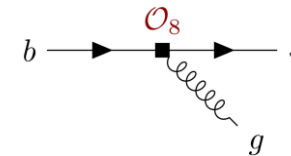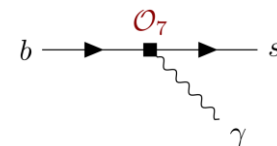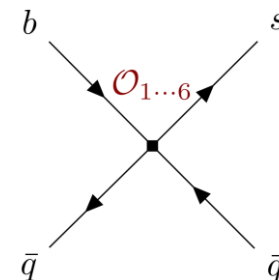
Need for BSM Physics

Patrick Koppenburg (2024) – Flavor anomalies

Calculations in flavor physics

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

For each BSM model

Calculation in full theory → Wilson coefficients C_i at $\mu \sim M_W$ → Running with RGE to $\mu \sim m_b$ → Observables

Calculation in effective theory
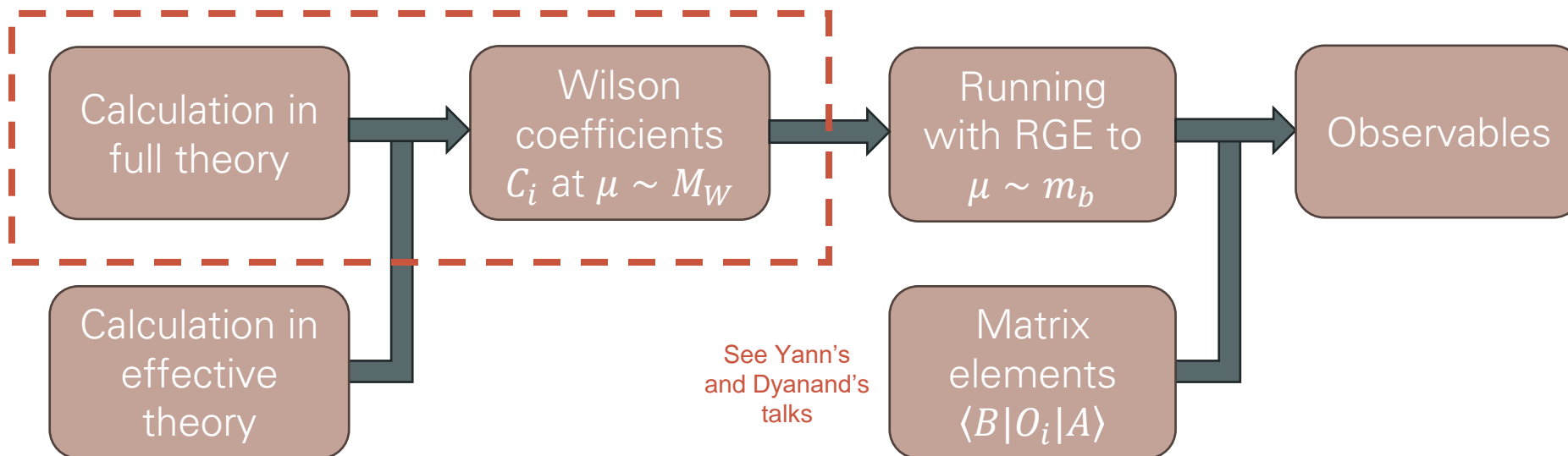
See Yann's and Dyanand's talks

Matrix elements $\langle B|O_i|A\rangle$

Need for automated calculations !

MARTY

Model building → Analytical QFT calculations → Numerical library generation → Numerical phase space integration **NEW**

Model building
Symmetries, breaking patterns
Field content
→ Lagrangian

Analytical QFT calculations
Scattering amplitudes
Decay widths
Wilson coefficients

SuperIso

SM
THDM
SUSY

Model choice

SuperIso

Random
Grid
Directed
(Multinest…)

Parameter generation

Wilson coefficient calculation

N²LO/L expressions
from literature

Observable calculation

QCD Factorisation
…

Associated χ^2

Check against exp. values
accounting for theo.
uncertainties

Constraints

HyperIso

C++ redesign of SuperIso (C99). Workflow diagram unchanged.

Upgrades :
- Modern C++ features
- Clear software architecture
- Various optimizations
- Reproduces SuperIso's behavior for the calculation of Wilson Coefficients (in SM, THDM and SUSY) and observables (WIP)
- Greater flexibility to add new observables and in model choice

Objectifs :
- « Direct » MARTY integration (see next slide)
- Extension of statistical calculations to generic nuisance distributions / likelihoods
- Simplified user interface (Python binding, GUI ?)
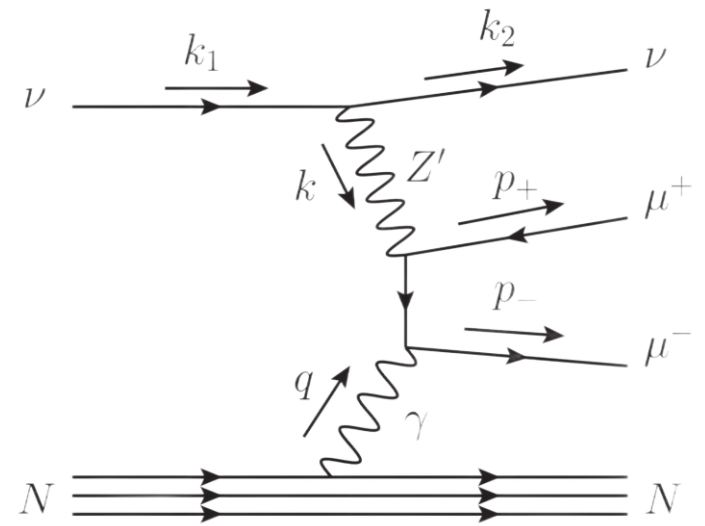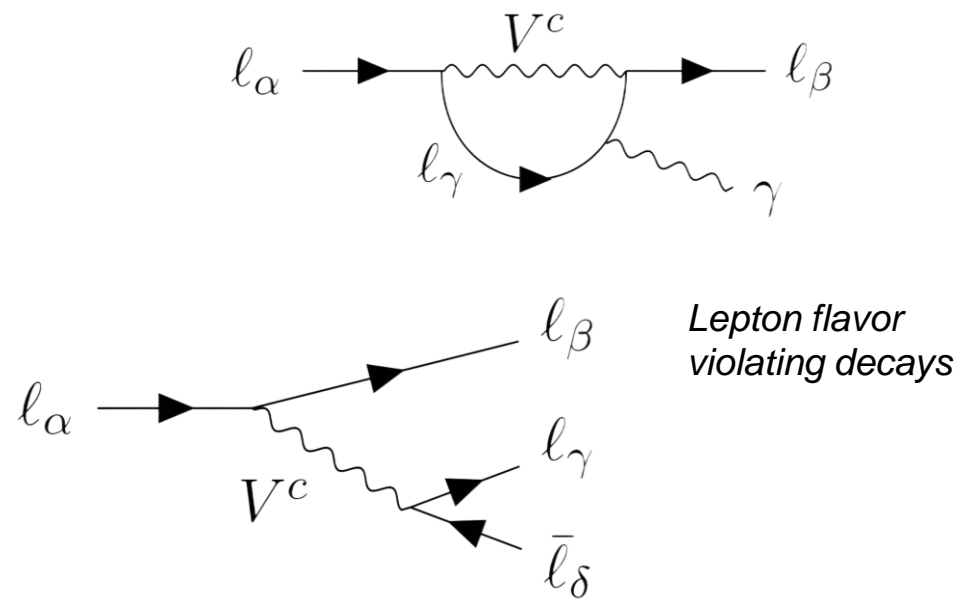
HyperIso – MARTY
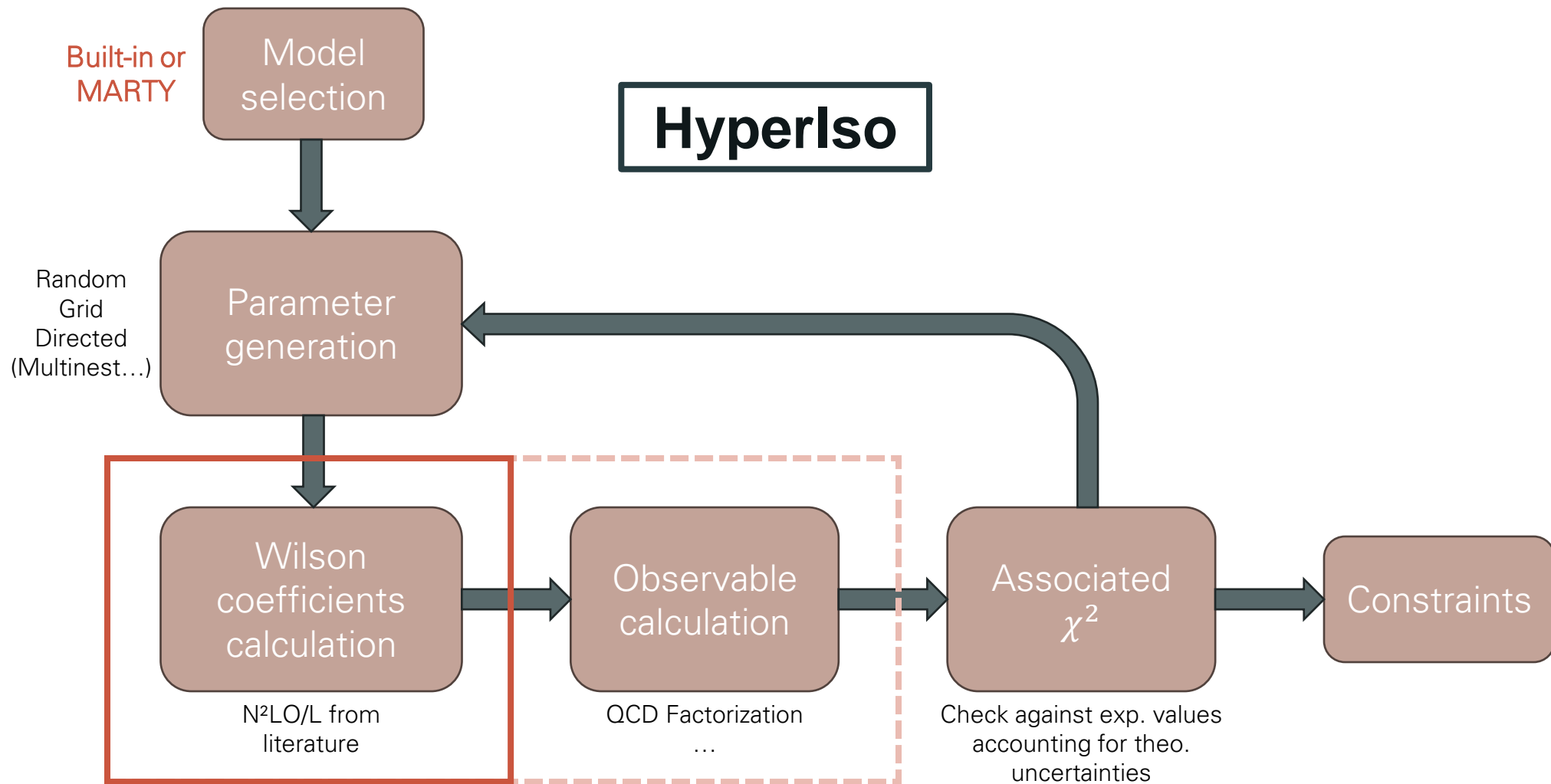
MARTY and the $SU(2)_\ell$ model

Darmé, Deandrea, Mahmoudi (2023) – Gauge $SU(2)_f$ flavor transfers [hep-ph:2307.09595]

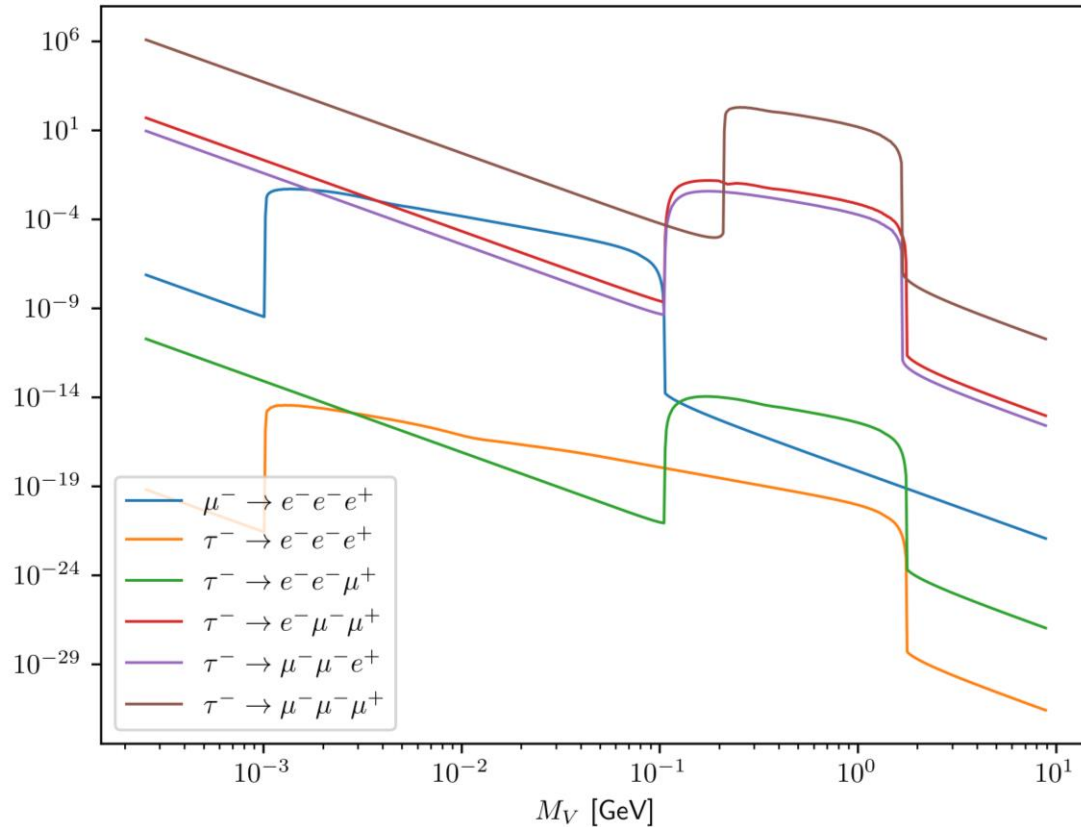Add a SU(2) gauged flavor symmetry between second and third generations of leptons.
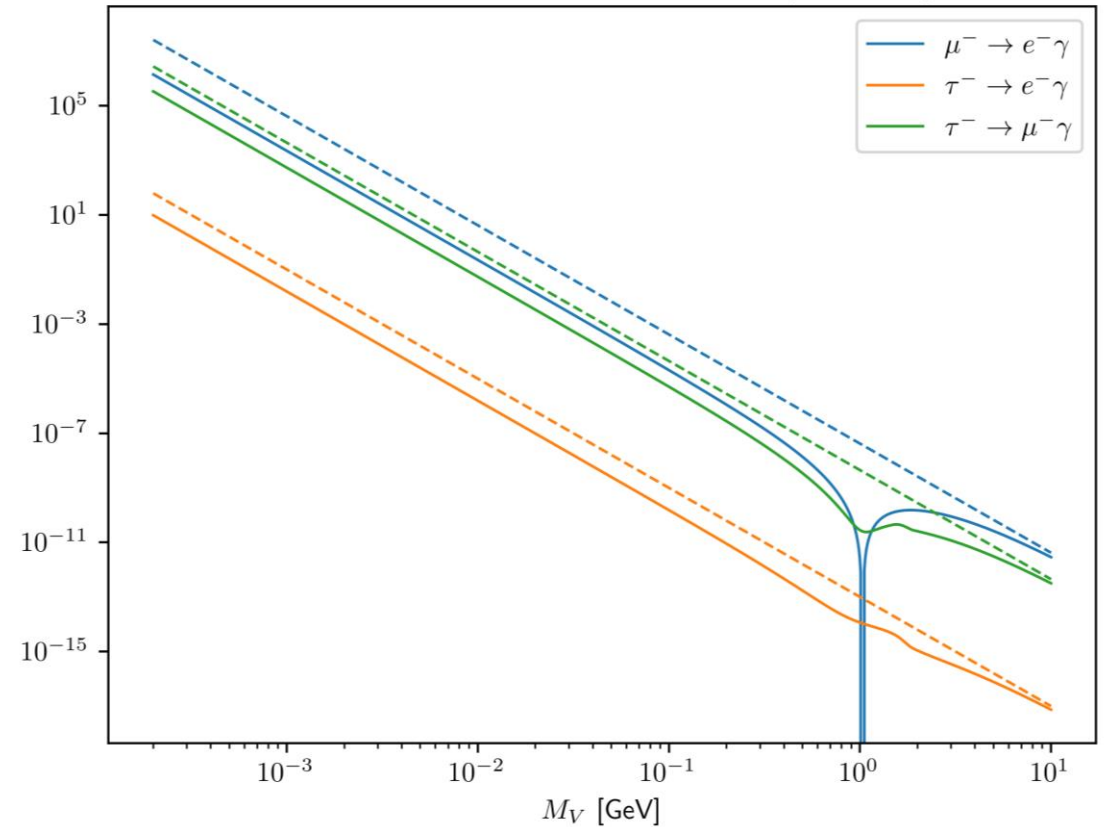
Constraints ?

Lepton flavor violating decays

Neutrino trident production [hep-ph:1406.2332]

MARTY and the $SU(2)_\ell$ model

LFV leptonic decays branching ratios (solid: LH + RH, dashed: LH only).
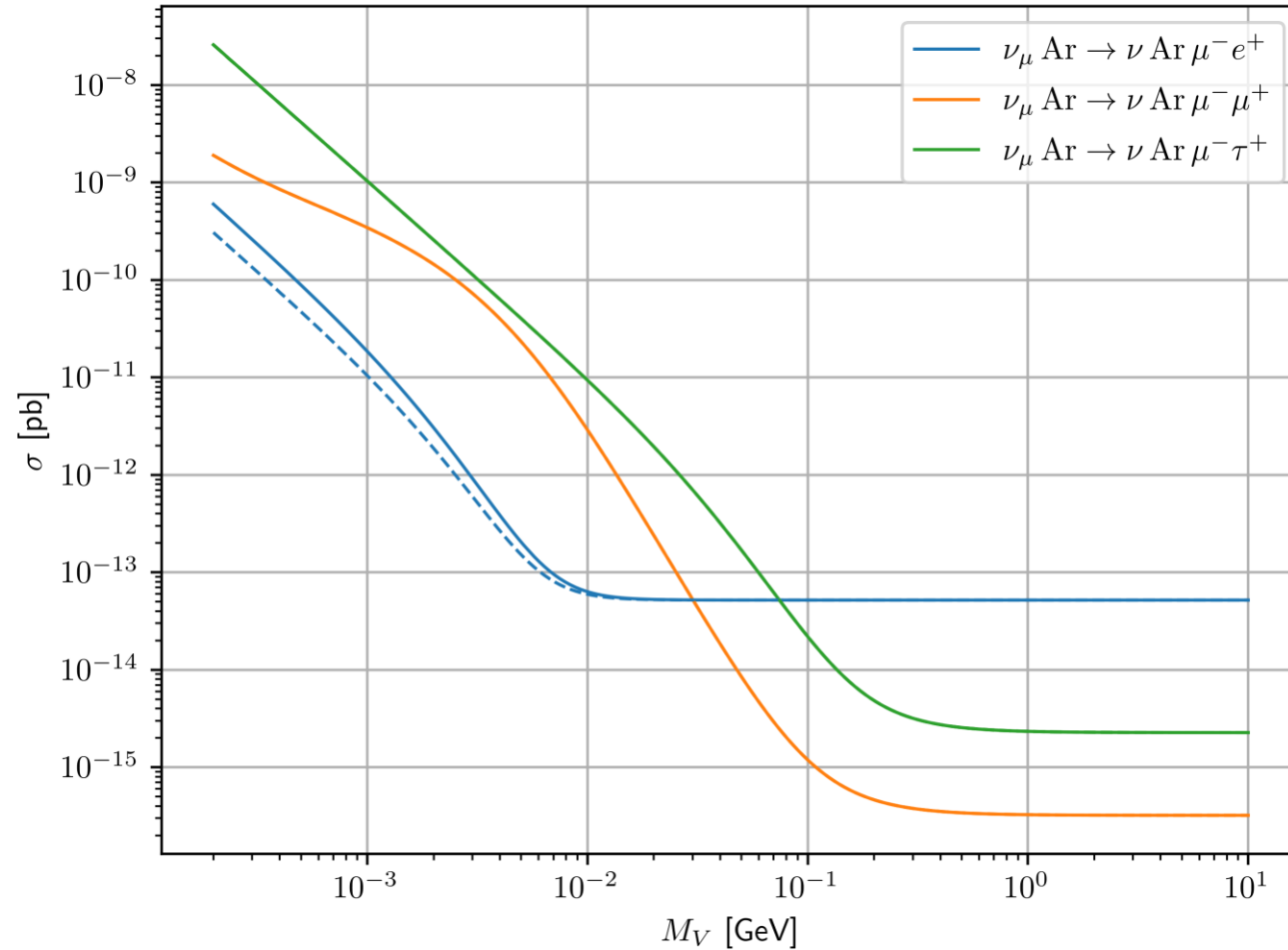
LFV Radiative decays branching ratios (LH + RH).

MARTY and the $SU(2)_\ell$ model

Neutrino trident production cross-sections (solid: LH + RH, dashed: LH only).

Thanks