RA2

Going Global

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Image designed by Tobias Blesgen

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New Physics

Most general Lagrangian density for $b \to c\ell\bar{\nu}_\ell$

$$\mathcal{L} = \frac{4G_F}{\sqrt{2}} V_{cb}\, c_{XY} \left(\bar{c}\,\Gamma_X\, b\right)\left(\bar{\ell}\,\Gamma_Y\,\nu\right),$$

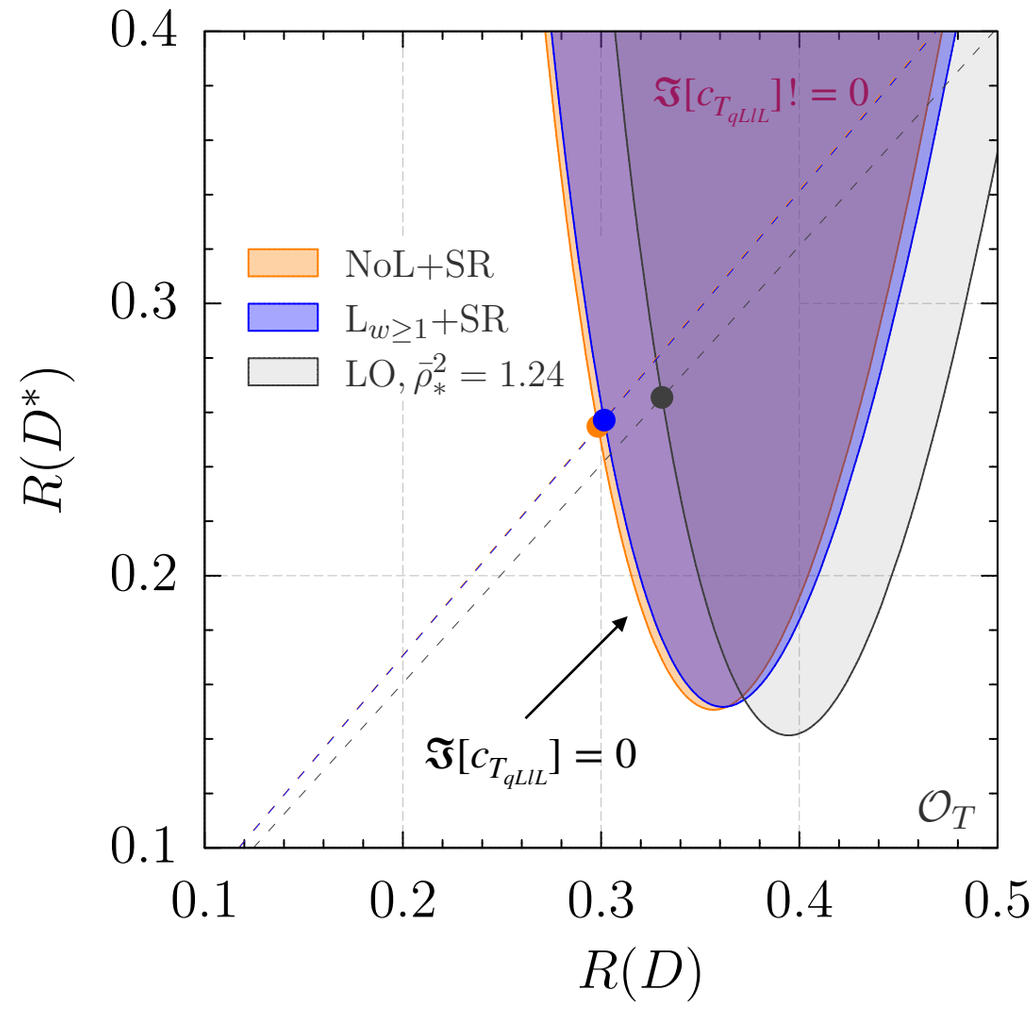
→ **10 NP** four-Fermi operators

→ **10 (complex)** Wilson coefficients = 20 dof

Current	Wilson Coefficient, c_{XY}	Operator
SM	1	$[\bar{c}\gamma^\mu P_L b]\,[\bar{\ell}\gamma_\mu P_L \nu]$
Vector	V_{qLlL}	$[\bar{c}\gamma^\mu P_L b]\,[\bar{\ell}\gamma_\mu P_L \nu]$
	V_{qRlL}	$[\bar{c}\gamma^\mu P_R b]\,[\bar{\ell}\gamma_\mu P_L \nu]$
	V_{qLlR}	$[\bar{c}\gamma^\mu P_L b]\,[\bar{\ell}\gamma_\mu P_R \nu]$
	V_{qRlR}	$[\bar{c}\gamma^\mu P_R b]\,[\bar{\ell}\gamma_\mu P_R \nu]$
Scalar	S_{qLlL}	$[\bar{c} P_L b]\,[\bar{\ell} P_L \nu]$
	S_{qRlL}	$[\bar{c} P_R b]\,[\bar{\ell} P_L \nu]$
	S_{qLlR}	$[\bar{c} P_L b]\,[\bar{\ell} P_R \nu]$
	S_{qRlR}	$[\bar{c} P_R b]\,[\bar{\ell} P_R \nu]$
Tensor	T_{qLlL}	$[\bar{c}\sigma^{\mu\nu} P_L b]\,[\bar{\ell}\sigma_{\mu\nu} P_L \nu]$
	T_{qRlR}	$[\bar{c}\sigma^{\mu\nu} P_R b]\,[\bar{\ell}\sigma_{\mu\nu} P_R \nu]$

Example for tensor (T_{qLlL}) NP + SM

Various values for $c_{T_{qLlL}}$ projected onto $R(D^{(*)})$



FB, Z. Ligeti, M. Papucci, D. Robinson
[Phys. Rev. D 95, 115008 (2017), arXiv:1703.05330]

HAMMER — a tool to correct $H_b \to H_c \tau \bar{\nu}$ to arbitrary NP

Challenge: Produce MC for each NP working point

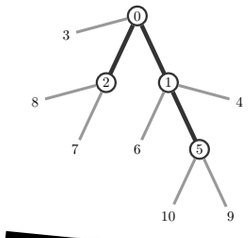
- **Need** a **MC generator** that incorporates **all NP effects** and **modern form factors** (e.g. EvtGen does not)

- **Very expensive**; MC statistics is already one of the largest systematic uncertainties on these measurements

HAMMER offers a solution to these problems

Helicity Amplitude Module for Matrix Element Reweighting

$$r_I = \frac{d\Gamma_I^{\text{new}}/d\mathcal{PS}}{d\Gamma_I^{\text{old}}/d\mathcal{PS}},$$



To correct angular distributions one needs to do this for all D* and τ decay products

SM or Phase-space MC can be corrected to NP or FFs via ratio of event weights

encode hadronic form factors

tensor that encodes amplitudes of given process

$$\sum_{\alpha,i,\beta,j} c_\alpha c_\beta^\dagger F_i F_j^\dagger W_{\alpha i \beta j},$$

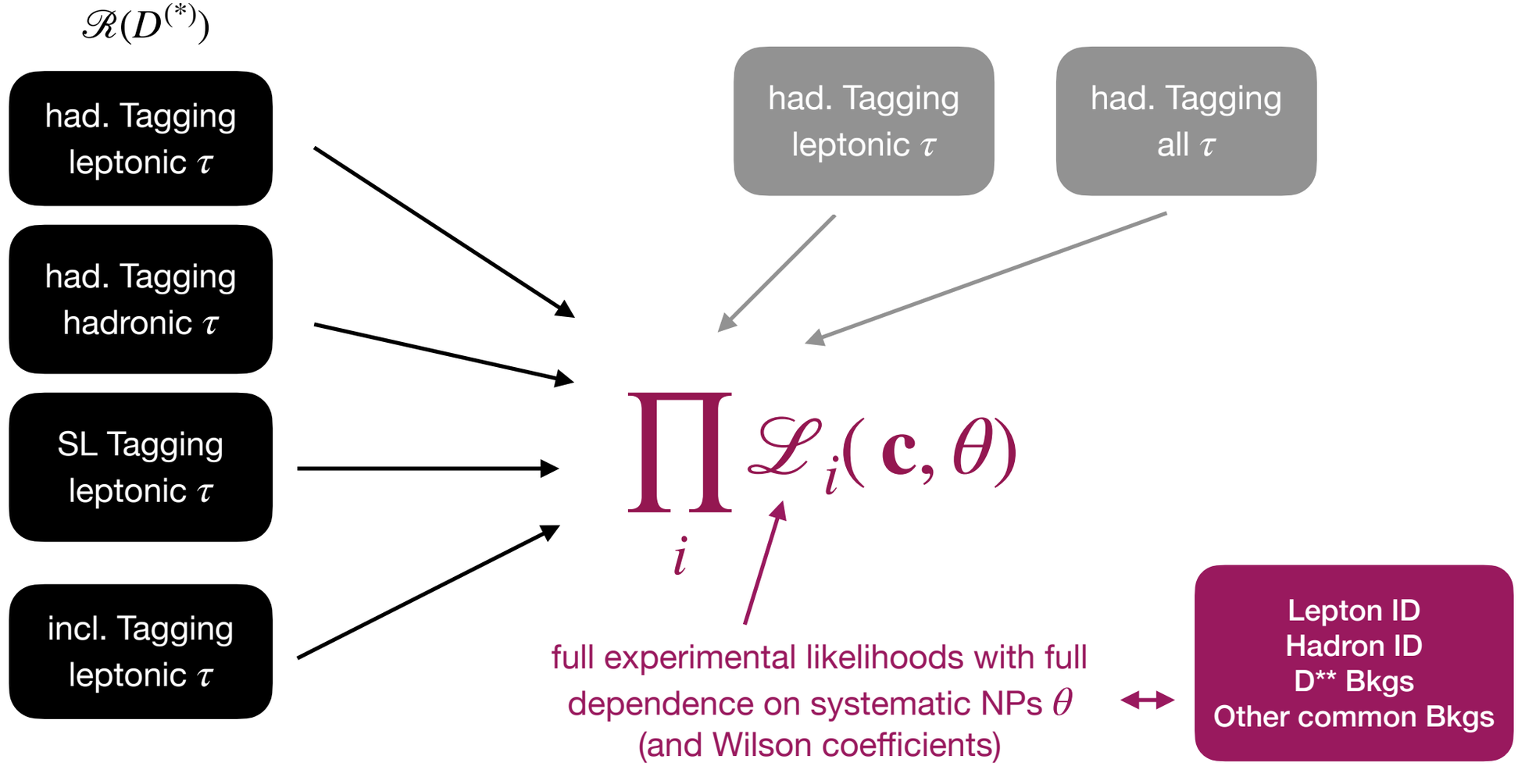
sum independent of Wilson coefficients c_α
→ can exploit this to create **fast predictions**

https://hammer.physics.lbl.gov/

The work program

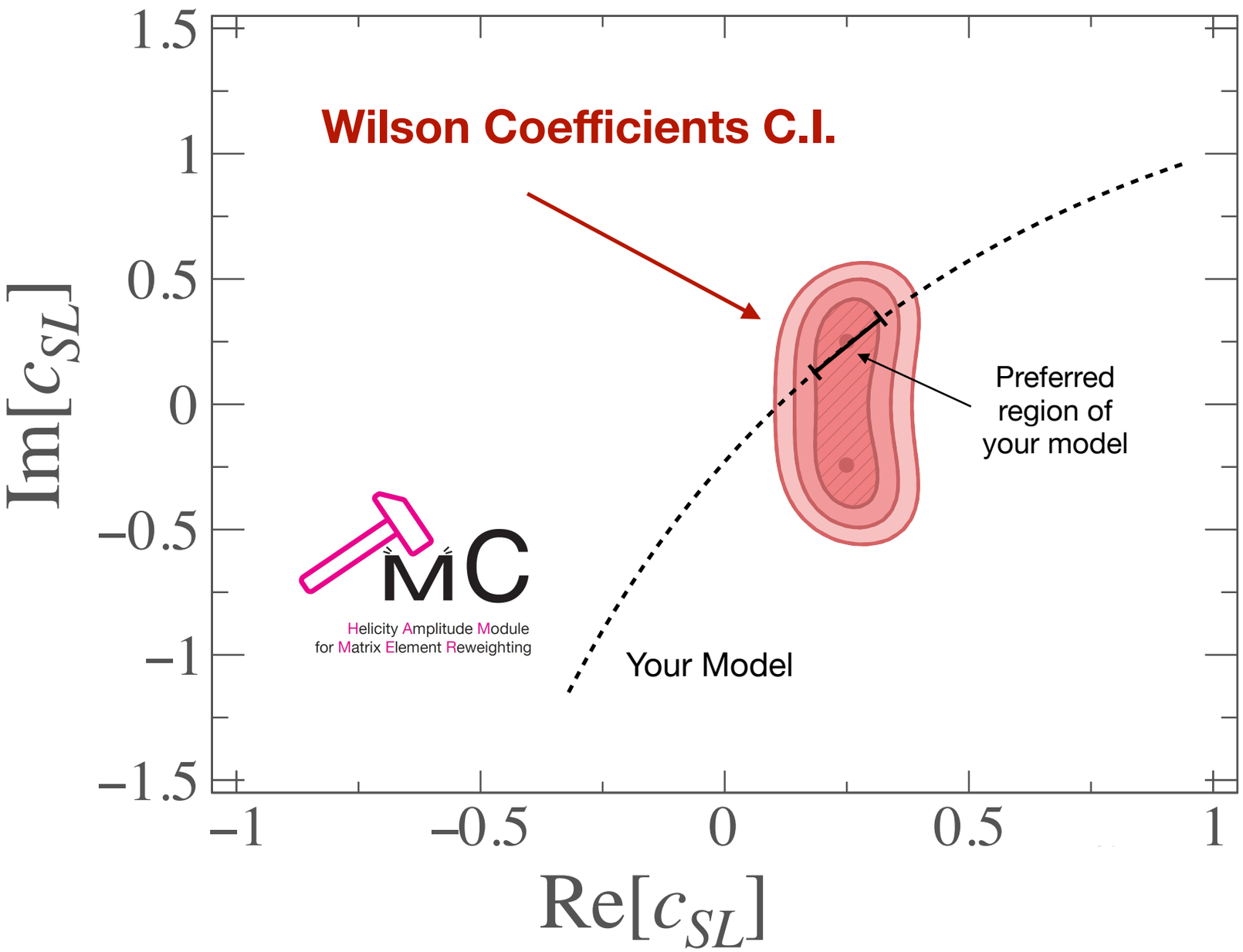
1. Use HAMMER to directly fit for Wilson coefficients $\mathbf{c}$ using experimental spectra, ideally combining the statistical power of several channels and observables

e.g. Belle II can access to several orthogonal measurements and properties



2. Provide theorists with **direct limits on Wilson** coefficients, that **incorporate all experimental effects** on *kinematic shape* changes and *efficiency x acceptance*

FB, S. Duell, Z. Ligeti, M. Papucci, D. Robinson
Eur. Phys. J. C (2020) **80**: 883 [arXiv:2002:00020]



With the profile likelihood contour or C.I. contours you can directly fit your model to all our data

Belle II + LHCb

+

$\mathcal{R}(D^{(*)})$

had. Tagging leptonic τ

had. Tagging hadronic τ

SL Tagging leptonic τ

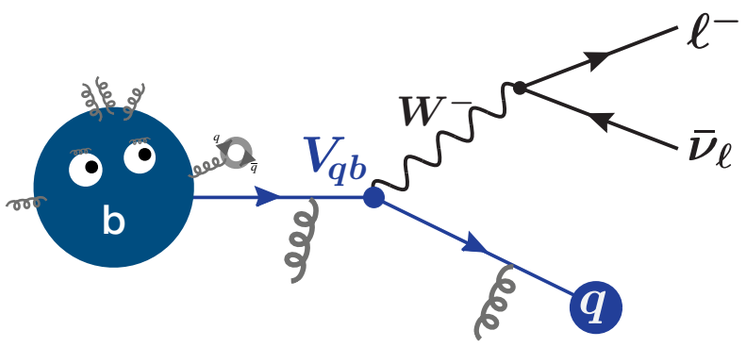
incl. Tagging leptonic τ

$\mathcal{R}(X_{(c)})$

had. Tagging leptonic τ

$\mathcal{R}(\pi/\rho/\omega)$

had. Tagging all τ



$\mathcal{R}(D^{(*)})$

leptonic τ

hadronic τ

$\mathcal{R}(J/\psi)$

leptonic τ

hadronic τ

$\mathcal{R}(\Lambda_c)$

leptonic τ

hadronic τ

$\mathcal{R}(D_s^{(*)})$

leptonic τ

hadronic τ

Create a **truly global** fit for $b \to c\tau\bar{\nu}_\tau$
(or $b \to q\tau\bar{\nu}_\tau$) that avoids biases & SM priors

Drawback: FFs are convolved with measured Wilson Coefficient
→ we should provide the entire framework to allow future updates →


SciPost Physics Submission

Working Draft

Publishing statistical models: Getting the most out of particle physics experiments

Kyle Cranmer, Sabine Kraml, Harrison B. Prosper (editors), Philip Bechtle, Florian U. Bernlochner, Itay M. Bloch, Enzo Canonero, Marcin Chrzaszcz, Andrea Coccaro, Glen Cowan, Matthew Feickert, Nahuel Ferreiro Iachellini, Andrew Fowlie, Lukas Heinrich, Alexander Held, Thomas Kuhr, Anders Kvellestad, Maeve Madigan, Farvah Mahmoudi, Knut Dundas Morå, Mark S. Neubauer, Maurizio Pierini, Juan Rojo, Sezen Sekmen, Luca Silvestrini, Veronica Sanz, Giordon Stark, Riccardo Torre, Robert Thorne, Wolfgang Waltenberger, Nicholas Wardle, Jonas Wittbrodt

Sensitivity study on combined analysis of beyond the Standard Model contributions in $B^0 \to D^{*-}\tau^+\nu_\tau$ decay

Johannes Albrecht, Florian Bernlochner, Marco Colonna, Lorenz Gärtner, Abhijit Mathad, Biljana Mitreska, Markus Prim