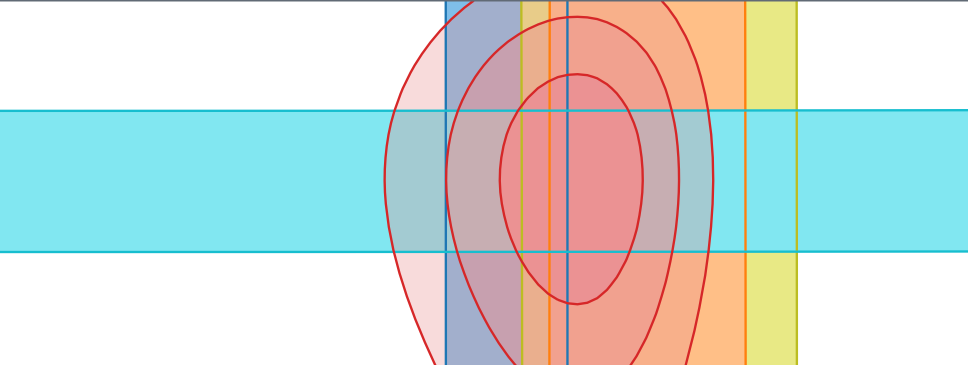
14th Conference on the Intersections of Particle and Nuclear Physics (CIPANP 2022), Lake Buena Vista, August 30, 2022

Indirect searches for new physics and the global SMEFT likelihood

Peter Stangl AEC & ITP University of Bern

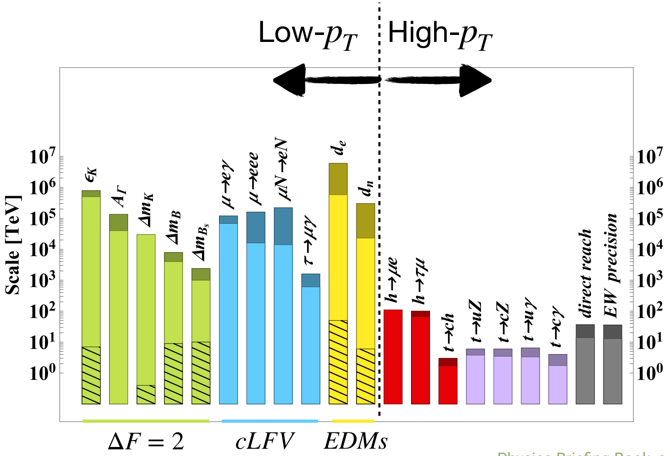


Indirect searches for new physics

Indirect searches for new physics

See also talk by Wolfgang Altmannshofer

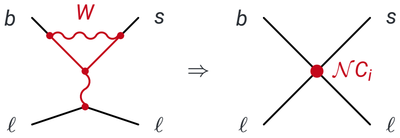
Precision measurements at **low energy** can indirectly probe scales far above the reach of direct searches



Physics Briefing Book, arXiv:1910.11775
annotations from Admir Greljo @ ICHEP 2022

Example: $b \to s\ell\ell$

- Effective $b \to s\ell\ell$ interaction in the Standard Model

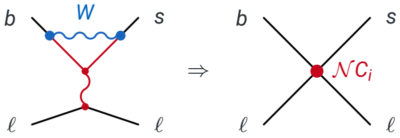


$$\mathcal{H}_{\text{eff}}^{bs\ell\ell} \supset -\mathcal{N} \sum_i C_i\, O_i$$

$$\mathcal{N} = \frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \frac{e^2}{16\pi^2} \approx (34\ \text{TeV})^{-2}$$

Example: $b \to s\ell\ell$

- Effective $b \to s\ell\ell$ interaction in the Standard Model

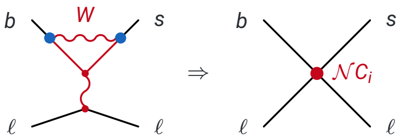


$$\mathcal{H}_{\text{eff}}^{bs\ell\ell} \supset -\mathcal{N} \sum_i C_i\, O_i$$

$$\mathcal{N} = \frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \frac{e^2}{16\pi^2} \approx (34\ \text{TeV})^{-2}$$

Example: $b \to s\ell\ell$

- Effective $b \to s\ell\ell$ interaction in the Standard Model

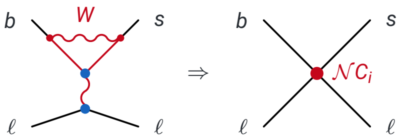


$$\mathcal{H}_{\text{eff}}^{bs\ell\ell} \supset -\mathcal{N} \sum_i C_i \, O_i$$

$$\mathcal{N} = \frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \frac{e^2}{16\pi^2} \approx (34\ \text{TeV})^{-2}$$

Example: $b \to s\ell\ell$

- Effective $b \to s\ell\ell$ interaction in the Standard Model

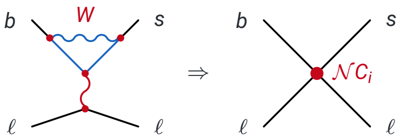


$$\mathcal{H}_{\text{eff}}^{bs\ell\ell} \supset -\mathcal{N} \sum_i C_i\, O_i$$

$$\mathcal{N} = \frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \frac{e^2}{16\pi^2} \approx (34\ \text{TeV})^{-2}$$

Example: $b \to s\ell\ell$

- Effective $b \to s\ell\ell$ interaction in the Standard Model

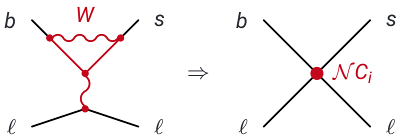


$$\mathcal{H}_{\text{eff}}^{bs\ell\ell} \supset -\mathcal{N} \sum_i C_i \, O_i$$

$$\mathcal{N} = \frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \frac{e^2}{16\pi^2} \approx (34 \text{ TeV})^{-2}$$

Example: $b \to s\ell\ell$

- Effective $b \to s\ell\ell$ interaction in the Standard Model

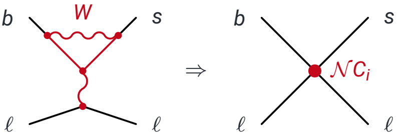


$$\mathcal{H}_{\text{eff}}^{bs\ell\ell} \supset -\mathcal{N} \sum_i C_i\, O_i$$

$$\mathcal{N} = \frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \frac{e^2}{16\pi^2} \approx (34\ \text{TeV})^{-2}$$

Example: $b \to s\ell\ell$

- Effective $b \to s\ell\ell$ interaction in the Standard Model



$$\mathcal{H}_{\text{eff}}^{bs\ell\ell} \supset -\mathcal{N} \sum_i C_i\, O_i$$

$$\mathcal{N} = \frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \frac{e^2}{16\pi^2} \approx (34\ \text{TeV})^{-2}$$

- Effective Hamiltonian at scale m_b:

$$\mathcal{H}_{\text{eff}}^{bs\ell\ell} = -\mathcal{N}\left(C_7^{bs} O_7^{bs} + C_7^{\prime bs} O_7^{\prime bs} + \sum_\ell \sum_{i=9,10,S,P} \left(C_i^{bs\ell\ell} O_i^{bs\ell\ell} + C_i^{\prime bs\ell\ell} O_i^{\prime bs\ell\ell} \right) \right) + \text{h.c.}$$

$$O_9^{(\prime)bs\ell\ell} = (\bar{s}\gamma_\mu P_{L(R)} b)(\bar{\ell}\gamma^\mu \ell)\,, \qquad C_9^{\text{SM}} \approx -4.1$$

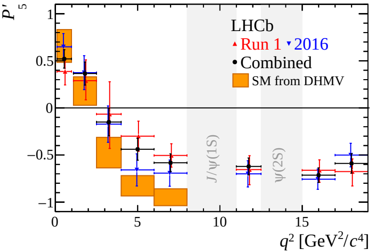
$$O_{10}^{(\prime)bs\ell\ell} = (\bar{s}\gamma_\mu P_{L(R)} b)(\bar{\ell}\gamma^\mu \gamma_5 \ell)\,, \qquad C_{10}^{\text{SM}} \approx +4.2$$

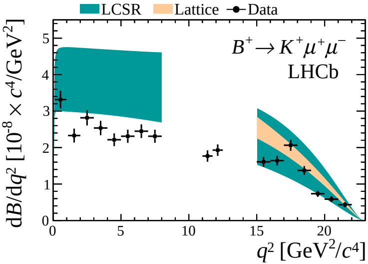
$$O_7^{(\prime)bs} = \frac{m_b}{e} (\bar{s}\sigma_{\mu\nu} P_{R(L)} b)\, F^{\mu\nu}\,, \qquad C_7^{\text{SM}} \approx -0.3$$

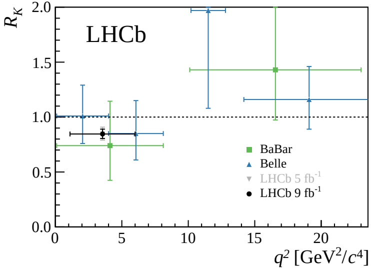
$$O_S^{(\prime)bs\ell\ell} = m_b (\bar{s} P_{R(L)} b)(\bar{\ell}\ell)\,,$$

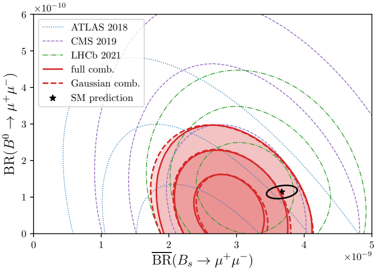
$$O_P^{(\prime)bs\ell\ell} = m_b (\bar{s} P_{R(L)} b)(\bar{\ell}\gamma_5 \ell)\,.$$

The $b \to s\ell\ell$ anomalies



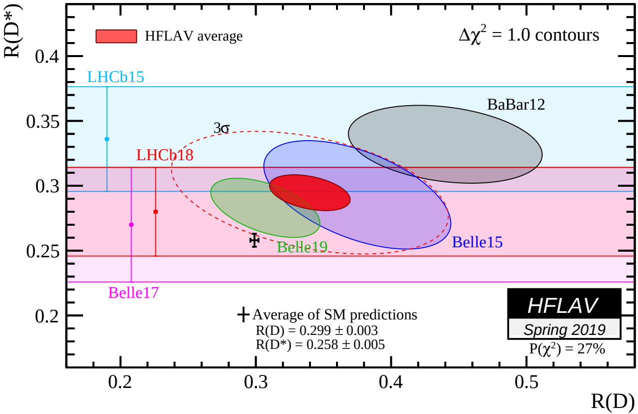






LHCb: arXiv:2003.04831, arXiv:2012.13241, arXiv:1403.8044, arXiv:1506.08777, arXiv:1606.04731, arXiv:2105.14007, arXiv:1705.05802, arXiv:2103.11769, arXiv:2108.09283, arXiv:2108.09284
ATLAS: arXiv:1812.03017, CMS: arXiv:1910.12127, Altmannshofer, PS: arXiv:2103.13370

The $b \to c\ell\nu$ anomalies



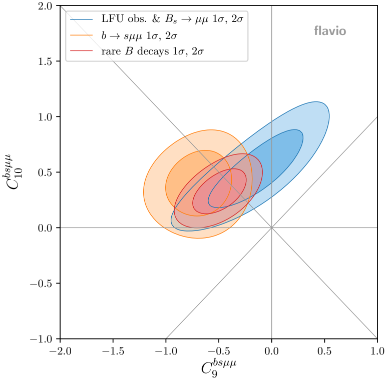
HFLAV, hflav.web.cern.ch
BaBar, arXiv:1205.5442, arXiv:1303.0571
LHCb, arXiv:1506.08614, arXiv:1708.08856
Belle, arXiv:1507.03233, arXiv:1607.07923, arXiv:1612.00529, arXiv:1904.08794

EFT fits in weak effective theory (WET)

For more details on $b \to s\ell\ell$ fits, see talk by Marco Fedele

$b \to s\ell\ell$

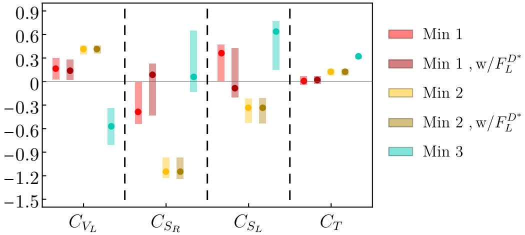
$$O_9^{bs\ell\ell} = (\bar{s}\gamma_\mu P_{L(R)} b)(\bar{\ell}\gamma^\mu \ell)$$
$$O_{10}^{bs\ell\ell} = (\bar{s}\gamma_\mu P_{L(R)} b)(\bar{\ell}\gamma^\mu \gamma_5 \ell)$$



Altmannshofer, PS, arXiv:2103.13370

$b \to c\ell\nu$

$$O_{V_L} = (\bar{c}\gamma_\mu P_L b)(\bar{\tau}\gamma^\mu P_L \nu_\tau)\,,$$
$$O_{S_R} = (\bar{c}P_R b)(\bar{\tau}P_L \nu_\tau)\,,$$
$$O_{S_L} = (\bar{c}P_L b)(\bar{\tau}P_L \nu_\tau)\,,$$
$$O_T = (\bar{c}\sigma_{\mu\nu}P_L b)(\bar{\tau}\sigma^{\mu\nu}P_L \nu_\tau)\,.$$



Murgui, Peñuelas, Jung, Pich, arXiv:1904.09311

Lessons learned from the Flavor Anomalies

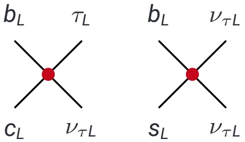
Model building - lessons learned

- Model explaining $R_{D^{(*)}}$ using $b_L \to c_L \tau_L \nu_{\tau L}$

$$b_L \to c_L \tau_L \nu_{\tau L} \xrightarrow{\text{SU(2)}_L} b_L \to s_L \nu_{\mu L} \nu_{\tau L}$$

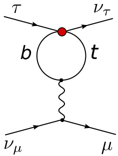
  Constrained by $B \to K \nu \bar{\nu}$ searches

  Buras, Girrbach-Noe, Niehoff, Straub, arXiv:1409.4557



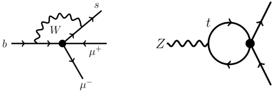
- Model explaining $R_{D^{(*)}}$ and $R_{K^{(*)}}$ using mostly 3rd gen. couplings
  Modifies LFU in τ and Z decays, strongly constrained

  Feruglio, Paradisi, Pattori, arXiv:1705.00929



- Model explaining $b \to s\mu\mu$ using $tt\mu\mu$ interaction
  Modifies $Z \to \mu\mu$, constrained by LEP

  Camargo-Molina, Celis, Faroughy, arXiv:1805.04917



What one would have to do

- Compute **all relevant observables** $\vec{\mathcal{O}}$ (flavour, EWPO, ...) in terms of Lagrangian parameters $\vec{\xi}$

$$\mathcal{L}_{\text{NP}}(\vec{\xi}) \to \vec{\mathcal{O}}(\vec{\xi})$$

- Take into account loop / RGE effects

$$\mathcal{L}_{\text{NP}}(\vec{\xi}) \xrightarrow{\Lambda_{\text{NP}} \to \Lambda_{\text{IR}}} \vec{\mathcal{O}}(\vec{\xi})$$

- Compare to experiment

$$\vec{\mathcal{O}}(\vec{\xi}) \to \underbrace{L_{\text{exp}}(\vec{\mathcal{O}}(\vec{\xi}))}_{\text{Likelihood}}$$

Tedious to do this for each model...

SMEFT approach

- Assuming $\Lambda_{\rm NP} \gg v$, NP effects in flavour, EWPO, Higgs, top,...can be expressed in terms of Standard Model Effective Field Theory (SMEFT) Wilson coefficients

$$\mathcal{L}_{\rm SMEFT} = \mathcal{L}_{\rm SM} + \sum_{n>4} \sum_{i} \frac{C_i}{\Lambda_{\rm NP}^{n-4}} O_i$$

Buchmuller, Wyler, Nucl. Phys. B 268 (1986) 621
Grzadkowski, Iskrzynski, Misiak, Rosiek, arXiv:1008.4884

- Powerful tool to connect model-building to phenomenology without need to recompute hundreds of observables in each model
  - Model building and matching:

$$\mathcal{L}_{\rm NP}(\vec{\xi}) \to \vec{C}(\vec{\xi}) \;\; @ \;\; \Lambda_{\rm NP}$$

  - *Model-independent* pheno:

$$\vec{C} \xrightarrow{\Lambda_{\rm NP} \to \Lambda_{\rm IR}} \vec{\mathcal{O}}(\vec{C}) \to L_{\rm exp}(\vec{\mathcal{O}}(\vec{C}))$$

  - **SMEFT likelihood** $L_{\rm exp}(\vec{C})$ can tremendously simplify analyses of NP models

The global SMEFT likelihood

The global SMEFT likelihood

- Several likelihood functions have been considered in the context of EFT fits

$$L(\vec{C}) = L_{\text{EW + Higgs}}(\vec{C}_{\text{EW + Higgs}}) \times \dots$$
$$L(\vec{C}) = L_{\text{top physics}}(\vec{C}_{\text{top physics}}) \times \dots$$
$$L(\vec{C}) = L_{B\text{ physics}}(\vec{C}_{B\text{ physics}}) \times \dots$$
$$L(\vec{C}) = L_{\text{LFV}}(\vec{C}_{\text{LFV}}) \times \dots$$

cf. eg. Falkowski, Mimouni, arXiv:1511.07434
Falkowski, González-Alonso, Mimouni, arXiv:1706.03783
Ellis, Murphy, Sanz, You, arXiv:1803.03252
Biekötter, Corbett, Plehn, arXiv:1812.07587
Hartland et al., arXiv:1901.05965
Ellis, Madigan, Mimasu, Sanz, You, arXiv:2012.02779
...

- But these likelihood functions should **not be considered separately** since RG (loop) effects mix different sectors and UV models match to several sectors

- We need to consider the **global SMEFT likelihood**

Basis for implementation

- Computing hundreds of relevant flavour observables properly accounting for theory uncertainties
  - **flavio** `https://flav-io.github.io` Straub, arXiv:1810.08132
  - Already used in $\mathcal{O}(100)$ papers since 2016

- Representing and exchanging thousands of Wilson coefficient values, different EFTs, possibly different bases
  - **Wilson coefficient exchange format (WCxf)** `https://wcxf.github.io/`
    Aebischer et al., arXiv:1712.05298

- RG evolution above and below the EW scale, matching from SMEFT to the weak effective theory (WET)
  - **wilson** `https://wilson-eft.github.io` Aebischer, Kumar, Straub, arXiv:1804.05033

based on
SMEFT RGE: Alonso, Jenkins, Manohar, Trott, arXiv:1308.2627, arXiv:1310.4838, arXiv:1312.2014
(ported from DsixTools: Celis, Fuentes-Martin, Vicente, Virto, arXiv:1704.04504)
SMEFT$\longrightarrow$ WET matching: Jenkins, Manohar, Stoffer, arXiv:1709.04486
WET RGE: Jenkins, Manohar, Stoffer, arXiv:1711.05270

Implementing the global SMEFT likelihood

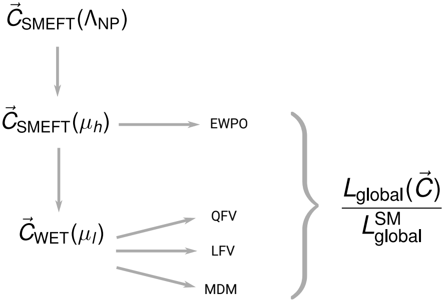
- Based on these tools, we have started building the **SME**FT **L**ike**LI**hood
  - **smelli** `https://github.com/smelli/smelli`

Aebischer, Kumar, PS, Straub, arXiv:1810.07698

- $L(\vec{C}) \approx \prod_i L^i_{\text{exp}}(\vec{O}_{\text{th}}(\vec{C},\vec{\theta}_0)) \times \tilde{L}_{\text{exp}}(\vec{O}_{\text{th}}(\vec{C},\vec{\theta}_0))$

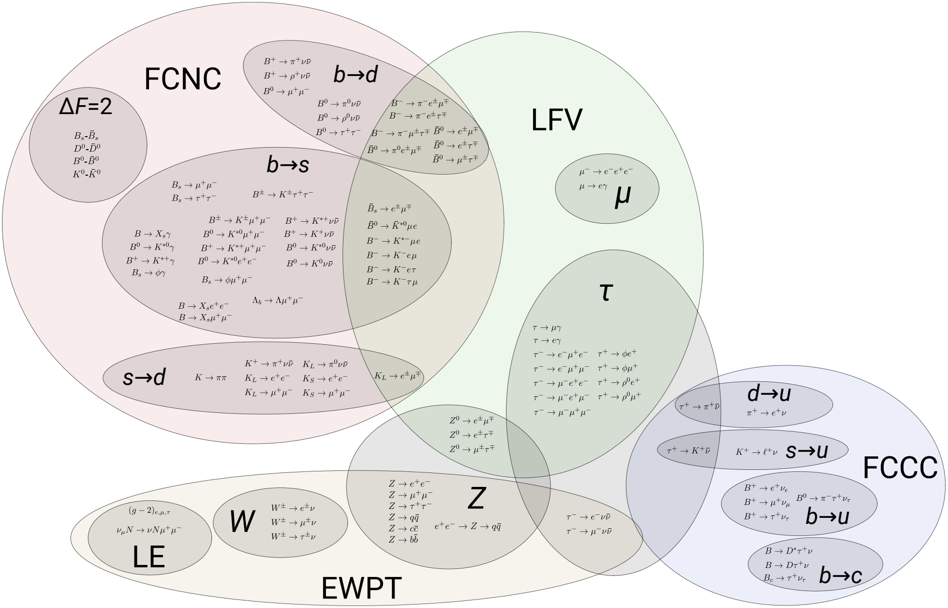
where

- $\vec{C}$ WET or SMEFT Wilson coefficients
- $\vec{\theta}_0$ fixed nuisance parameters
- $\vec{O}_{\text{th}}(\vec{C},\vec{\theta}_0)$ observable predictions
- $L^i_{\text{exp}}(\vec{O})$ experimental likelihood from measurement i for observables $\vec{O}$
- $\tilde{L}_{\text{exp}}(\vec{O})$ modified exp. likelihood: $-2\ln\tilde{L}_{\text{exp}}(\vec{O}) = \vec{D}^T(\Sigma_{\text{exp}}+\Sigma_{\text{th}})^{-1}\vec{D}$, with $\vec{D} = \vec{O} - \vec{O}_{\text{exp}}$ and covariance matrices $\Sigma_{\text{exp,th}}$ (Gaussian approx.)



smelli v1.1.1: Flavor + EWPT

Aebischer, Kumar, PS, Straub, arXiv:1810.07698



`smelli v2.0`: Higgs and beta decays, $K \to \pi\ell\nu$, $e^+e^- \to W^+W^-$

- **New observables**
  - **Higgs physics**: signal strengths for various decay ($h \to \gamma\gamma$, $Z\gamma$, ZZ, WW, bb, cc, $\tau\tau$, $\mu\mu$) and production (gg, VBF, Zh, Wh, $t\bar{t}h$) channels Falkowski, Straub, arXiv:1911.07866
  - **Beta decays**: lifetime and correlation coefficients of neutron beta decay, superallowed nuclear beta decays based on Gonzalez-Alonso, Naviliat-Cuncic, Severijns, arXiv:1803.08732
  - $\boldsymbol{K \to \pi\ell\nu}$: total branching ratios of $K^+ \to \pi^0\ell^+\nu$, $K_{L,S} \to \pi^\pm\ell^\mp\nu$ ($\ell = e, \mu$), and $K^+ \to \pi^0\mu^+\nu$ effective scalar form factor $\ln C$ and tensor coupling R_T
  - $\boldsymbol{e^+e^- \to W^+W^-}$: total and differential cross sections for $e^+e^- \to W^+W^-$ pair production measured in LEP-2
- Proper treatment of the **CKM matrix in SMEFT**
  based on Descotes-Genon, Falkowski, Fedele, González-Alonso, Virto, arXiv:1812.08163
  - **CKM input scheme** using 4 observables to fix 4 CKM parameters:
    - $R_{K\pi} = \Gamma(K^+ \to \mu^+\nu)/\Gamma(\pi^+ \to \mu^+\nu)$ (mostly fixing V_{us})
    - $BR(B^+ \to \tau\nu)$ (fixing V_{ub})
    - $BR(B \to X_c e\nu)$ (fixing V_{cb})
    - $\Delta M_d/\Delta M_s$ (mostly fixing CKM phase δ)
  - Determine **effective CKM** matrix in presence of SMEFT operators

New developments related to `smelli`

- **New numerical methods** developed for $b \to s\ell^+\ell^-$ analyses

  Altmannshofer, PS, arXiv:2103.13370

  - numerical efficient implementation of **NP dependence of theory covariance matrix**
  - **computational speed increased** by orders of magnitude through numerical improvements ($\mathcal{O}$(s) $\to$ $\mathcal{O}$(ms) per parameter point)

    $\to$ makes `smelli` suitable for parameter scans of NP models and EFT fits with many parameters
  - will be implemented for all observables in `smelli`

- Neutral and charged current **Drell-Yan tails** ($pp \to \ell^+\ell^-$, $pp \to \ell\nu$ for $\ell = e, \mu$)

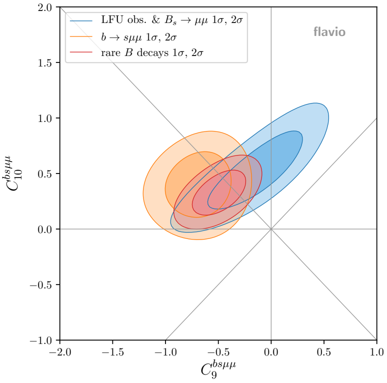
  Greljo, Šalko, Smolkovič, PS, work in progress

  - sensitivity to **all semi-leptonic four-fermion operators** with **all quark flavor combinations** of *u*, *d*, *s*, *c*, *b* (from parton distributions)
  - **complimentary to flavor physics** constraints
  - will be implemented in `smelli`

Applications of `smelli`

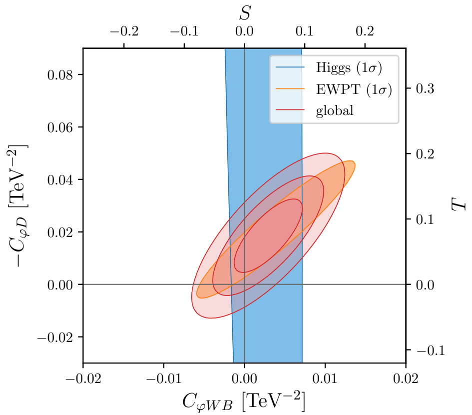
Bottom-Up approach: EFT fits

Global $b \to s\ell\ell$ fits



Altmannshofer, PS, arXiv:2103.13370

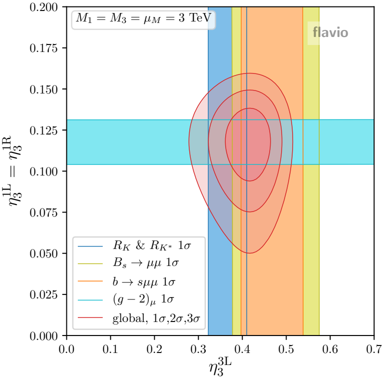
Higgs + EW fit



Falkowski, Straub, arXiv:1911.07866

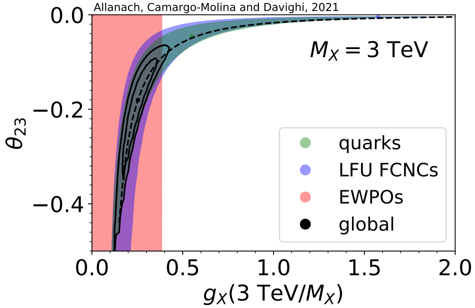
Top-Down approach: Analyses of NP models

$S_1 + S_3$ scalar leptoquarks
matched to SMEFT at 1 loop



Greljo, PS, Thomsen, arXiv:2103.13991
(matching: Gherardi, Marzocca, Venturini, arXiv:2003.12525)

Z' model from gauged $U(1)_X$
matched to SMEFT at tree level



Allanach, Camargo-Molina, Davighi, arXiv:2103.12056

Conclusion

Conclusions

- Lessons learned from Flavor Anomalies
  - Models that **explain anomalies** generically predict **effects in other observables**
  - Important to consider **numerous indirect bounds** and **loop effects**
- Python package **smelli** based on **flavio** implements a **Global SMEFT likelihood** currenlty containing
  - FCNC flavor observables ($b \to s$, $b \to d$, $s \to d$, and meson mixing)
  - FCCC flavor observables ($b \to c$, $b \to u$, $s \to u$, $d \to u$)
  - LFV observables (μ, τ, Z, B-meson, and Kaon decays)
  - EWPT (W and Z pole observables, τ decays, $(g-2)_{e,\mu,\tau}$)
  - Higgs physics (signal strengths)
  - Beta decays (neutron and superallowed nuclear beta decays)
- `smelli` will be extended soon
  - New numerical methods to **improve accuracy** and **computational speed**
  - Implementation of **Drell-Yan tails**
- **Truly global likelihood** is work in progress
  - Open-source development (contributions welcome!)
    `https://github.com/smelli/smelli`
    `https://github.com/flav-io/flavio`

Backup slides

Using smelli

Installing `smelli`

- Prerequisite: working installtion of **Python** version **3.7** or above
- Installation from the command line:

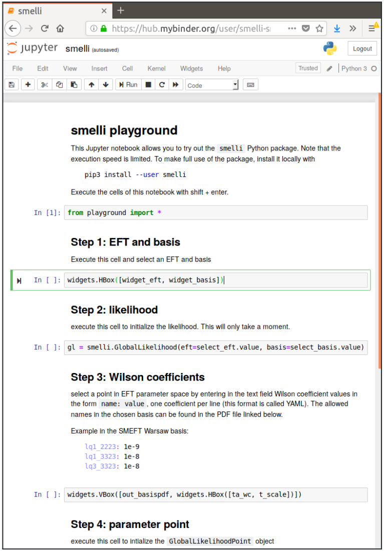
```
python3 -m pip install smelli --user

```

  - downloads `smelli` with all dependencies from Python package archive (PyPI)
  - installs it in user's home directory (no need to be root)

Using `smelli`

As any Python package, **smelli** can be used

- as library imported from other scripts
- directly in the command line interpreter
- in an interactive session
  $\rightarrow$ we recommend the **Jupyter notebook**



smelli tutorial in a Jupyter notebook at
`https://github.com/peterstangl/smelli-talk`

Using `smelli`

- Step 1:
  Import package and initalize `GlobalLikelihood` class

```
import smelli
gl = smelli.GlobalLikelihood()

```

possible arguments are

- `eft='WET'` to use Wilson coefficients in weak effective theory (no EWPOs) (default: `eft='SMEFT'`)
- `basis='...'` to select different WCxf basis (default: `basis='Warsaw'` for SMEFT, `basis='flavio'` for WET)

Using `smelli`

- Step 2:
  Select point in Wilson coefficient space using `parameter_point` method
- Three possible input formats:
  - Python dictionary with Wilson coefficient name/value pair and input scale

```
glp = gl.parameter_point({'lq1_2223': 1e-8}, scale=1000)
```

fixes Wilson coefficient $[C_{lq}^{(1)}]_{2223}$ to 10^{-8} GeV^{-2} at scale 1 TeV

  - WCxf data file in YAML or JSON format (specified by file path)

```
glp = gl.parameter_point('my_wc.yaml')
```

  - instance of class `wilson.Wilson` from `wilson` package

```
glp = gl.parameter_point(wilson_instance)
```

Using `smelli`

- Step 3:
  Get results from `GlobalLikelihoodPoint` instance `glp` defined in step 2
- The most important methods are:

```
glp.log_likelihood_global()

```

returns $\Delta \log L = \log\left(\frac{L_{\text{global}}(\vec{C})}{L_{\text{global}}^{\text{SM}}}\right)$

```
glp.log_likelihood_dict()

```

returns Python dictionary with contributions to $\Delta \log L$ from different sets of observables (EWPOs, charged current LFU, neutral current LFU,...)

```
glp.obstable()

```

returns table listing individual observables with their experimental and theoretical central values and uncertainties

Using `smelli`

```
glp = gl.parameter_point({}, scale=1000)
glp.obstable(min_pull='2.35')

```

returns observables with highest pull in Standard Model (no Wilson coefficient set)

Observable	Prediction	Measurement	Pull
$\langle \frac{d\overline{\text{BR}}}{dq^2} \rangle (B_s \to \phi\mu^+\mu^-)^{[1.0,6.0]}$	$(5.37 \pm 0.65) \times 10^{-8}\ \frac{1}{\text{GeV}^2}$	$(2.57 \pm 0.37) \times 10^{-8}\ \frac{1}{\text{GeV}^2}$	3.8σ
a_μ	$(1.1659182 \pm 0.0000004) \times 10^{-3}$	$(1.1659209 \pm 0.0000006) \times 10^{-3}$	3.5σ
$\langle P_5' \rangle (B^0 \to K^{*0}\mu^+\mu^-)^{[4,6]}$	-0.756 ± 0.074	-0.21 ± 0.15	3.3σ
$R_{\tau\ell}(B \to D^*\ell^+\nu)$	0.248	0.306 ± 0.018	3.3σ
$\langle A_{\text{FB}}^{\ell h} \rangle (\Lambda_b \to \Lambda\mu^+\mu^-)^{[15,20]}$	0.1400 ± 0.0075	0.250 ± 0.041	2.6σ
$\langle R_{\mu e} \rangle (B^\pm \to K^\pm\ell^+\ell^-)^{[1.0,6.0]}$	1.000	0.745 ± 0.098	2.6σ
ϵ'/ϵ	$(-0.3 \pm 6.0) \times 10^{-4}$	$(1.66 \pm 0.23) \times 10^{-3}$	2.6σ
$\text{BR}(W^\pm \to \tau^\pm\nu)$	0.1084	0.1138 ± 0.0021	2.6σ
$\langle R_{\mu e} \rangle (B^0 \to K^{*0}\ell^+\ell^-)^{[1.1,6.0]}$	1.00	0.68 ± 0.12	2.5σ
$R_{\tau\ell}(B \to D\ell^+\nu)$	0.281	0.406 ± 0.050	2.5σ
$\langle \frac{d\overline{\text{BR}}}{dq^2} \rangle (B^\pm \to K^\pm\mu^+\mu^-)^{[15.0,22.0]}$	$(1.56 \pm 0.12) \times 10^{-8}\ \frac{1}{\text{GeV}^2}$	$(1.210 \pm 0.072) \times 10^{-8}\ \frac{1}{\text{GeV}^2}$	2.5σ
$A_{\text{FB}}^{0,b}$	10.31×10^{-2}	$(9.92 \pm 0.16) \times 10^{-2}$	2.4σ
$\langle \frac{d\overline{\text{BR}}}{dq^2} \rangle (B^0 \to K^0\mu^+\mu^-)^{[15.0,22.0]}$	$(1.44 \pm 0.11) \times 10^{-8}\ \frac{1}{\text{GeV}^2}$	$(9.6 \pm 1.6) \times 10^{-9}\ \frac{1}{\text{GeV}^2}$	2.4σ
$\langle R_{\mu e} \rangle (B^0 \to K^{*0}\ell^+\ell^-)^{[0.045,1.1]}$	0.93	0.65 ± 0.12	2.4σ