Likelihood test case – EFT

from Cornelius' thesis

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Minutes

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Inputs (Cornelius)

The EFTfitter likelihood reads (eq. (5.9) Cornelius' thesis)

$$\mathcal{L}(x,\lambda) = \ln(p(x|\lambda)) = -\frac{1}{2}\sum_i \sum_j [x - Uy(\lambda)]_i \, M_{ij}^{-1} \, [x - Uy(\lambda)]_j \tag{1}$$

where

- Free parameters of the model λ – *Wilson coefficients*
  - $\lambda = (\bar{C}_{uB},\ \bar{C}_{uG},\ \bar{C}_{uW})$ – Meaningful range $-1 < \bar{C}_\alpha < 1$
- Observables $y = y(\lambda)$

$$\begin{aligned}\mathcal{O}_i(\bar{C}_{uB}, \bar{C}_{uG}, \bar{C}_{uW}) = p_0^{(i)} + p^{(i)}_{\bar{C}_{uB}} \bar{C}_{uB} + p^{(i)}_{\bar{C}_{uG}} \bar{C}_{uG} + p^{(i)}_{\bar{C}_{uW}} \bar{C}_{uW} + p^{(i)}_{\bar{C}_{uB}\bar{C}_{uG}} \bar{C}_{uB}\bar{C}_{uG} + p^{(i)}_{\bar{C}_{uB}\bar{C}_{uW}} \bar{C}_{uB}\bar{C}_{uW} \\ + p^{(i)}_{\bar{C}_{uG}\bar{C}_{uW}} \bar{C}_{uG}\bar{C}_{uW} + p^{(i)}_{\bar{C}^2_{uB}} \bar{C}^2_{uB} + p^{(i)}_{\bar{C}^2_{uG}} \bar{C}^2_{uG} + p^{(i)}_{\bar{C}^2_{uW}} \bar{C}^2_{uW}\end{aligned} \tag{2}$$

- Measurements x – *measured values (from ATLAS and HFLAV group)*
  - $\mathrm{BR}(\bar{B} \to X_s\gamma)\ :\ x_{\mathrm{BR}} = 332 \cdot 10^{-6}$
  - $\sigma^{\mathrm{fid}}(t\bar{t}\gamma \to 1l)\ :\ x_{\sigma_{1l}} = 521.0$ fb
  - $\sigma^{\mathrm{fid}}(t\bar{t}\gamma \to 2l)\ :\ x_{\sigma_{2l}} = 69.0$ fb

The EFTfitter likelihood reads (eq. (5.9) Cornelius' thesis)

$$\mathcal{L}(x,\lambda) = \ln(p(x|\lambda)) = -\frac{1}{2}\sum_i \sum_j [x - Uy(\lambda)]_i \, M_{ij}^{-1} \, [x - Uy(\lambda)]_j$$

where

- Covariance matrix M_{ij} – *simplifying assumption of uncorrelated measurements*

$$M = \begin{pmatrix} 7.54 \cdot 10^{-10} & 0 & 0 \\ 0 & 11565.0 & 0 \\ 0 & 0 & 106.0 \end{pmatrix}, \quad \text{yielding } M_{ij} = M_{ii}\delta(i-j) \tag{3}$$

- U is the matrix with elements being

$$U_{i\alpha} = \begin{cases} 1 & \text{if } x_i \text{ is a measurement of } y_\alpha \\ 0 & \text{else.} \end{cases} \tag{4}$$

so that "for $i = \mathrm{BR}$",

$$[x - Uy(\lambda)]_{\mathrm{BR}} = x_{\mathrm{BR}} - \mathcal{O}_{\mathrm{BR}}(\bar{C}_{uB}, \bar{C}_{uG}, \bar{C}_{uW}) \tag{5}$$

Putting the pieces together – Full simplified likelihood, uncorrelated measurements

- With the assumption of uncorrelated measurements,

$$\begin{aligned} \mathcal{L}(x,\lambda) &= -\frac{1}{2}\sum_i\sum_j \left[x - Uy(\lambda)\right]_i M_{ii}^{-1}\delta(i-j)\left[x - Uy(\lambda)\right]_j \\ &= -\frac{1}{2}\sum_i \left[x - Uy(\lambda)\right]_i M_{ii}^{-1}\left[x - Uy(\lambda)\right]_i \,. \end{aligned} \tag{6}$$

- Along with the "selection matrix U" (5),

$$\mathcal{L}(x,\lambda) = -\frac{1}{2}\sum_{i\in\{\mathrm{BR},\sigma_{1l},\sigma_{2l}\}} M_{ii}^{-1}\left(x_i - \mathcal{O}_i(\bar{C}_{uB},\bar{C}_{uG},\bar{C}_{uW})\right)^2 . \tag{7}$$

Sampler used – Discrete PDMP

Discrete PDMP used :

- Easier to implement for the first checks : only the energy needed
- Not working perfectly $\rightarrow$ questions at the end

Not a lot of statistics : only one simulation each time because questions regarding the first results

First check : Dependence of the observables on the SMFET coefficients

Recall $(i \in \{\mathrm{BR}, s1l, s2l\})$

$$\mathcal{O}_i(\bar{C}_{uB}, \bar{C}_{uG}, \bar{C}_{uW}) = p_0^{(i)} + p^{(i)}_{\bar{C}_{uB}}\bar{C}_{uB} + p^{(i)}_{\bar{C}_{uG}}\bar{C}_{uG} + p^{(i)}_{\bar{C}_{uW}}\bar{C}_{uW} + p^{(i)}_{\bar{C}_{uB}\bar{C}_{uG}}\bar{C}_{uB}\bar{C}_{uG} + p^{(i)}_{\bar{C}_{uB}\bar{C}_{uW}}\bar{C}_{uB}\bar{C}_{uW}$$
$$+ p^{(i)}_{\bar{C}_{uG}\bar{C}_{uW}}\bar{C}_{uG}\bar{C}_{uW} + p^{(i)}_{\bar{C}^2_{uB}}\bar{C}^2_{uB} + p^{(i)}_{\bar{C}^2_{uG}}\bar{C}^2_{uG} + p^{(i)}_{\bar{C}^2_{uW}}\bar{C}^2_{uW}$$

Plot of

$$O_{\mathrm{BR}}(\bar{C}_{uB}, 0, 0), O_{\mathrm{BR}}(0, \bar{C}_{uG}, 0), O_{\mathrm{BR}}(0, 0, \bar{C}_{uW}),$$
$$O_{\mathrm{s1l}}(\bar{C}_{uB}, 0, 0), O_{\mathrm{s1l}}(0, \bar{C}_{uG}, 0), O_{\mathrm{s1l}}(0, 0, \bar{C}_{uW}),$$
$$O_{\mathrm{s2l}}(\bar{C}_{uB}, 0, 0), O_{\mathrm{s2l}}(0, \bar{C}_{uG}, 0), O_{\mathrm{s2l}}(0, 0, \bar{C}_{uW}),$$

for $\bar{C}_\alpha \in [\![-1, 1]\!]$ and comparison with Figures 6 and 7 from SMEFT paper.

Some disagreements with $s1l$ observable

First check : Dependence of the observables on the SMFET coefficients

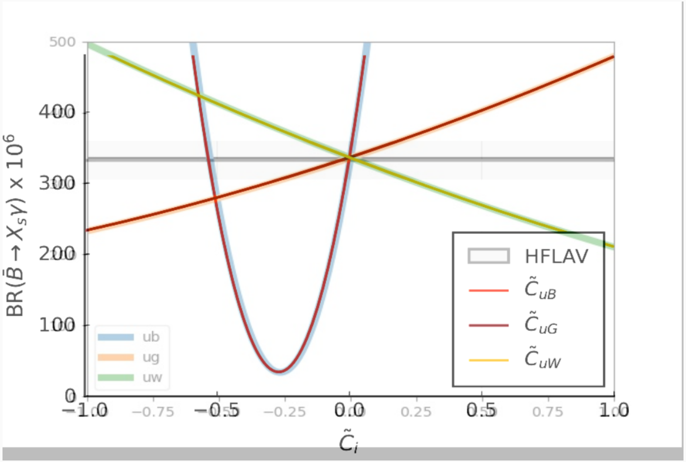


Figure 7 from paper

First check : Dependence of the observables on the SMFET coefficients

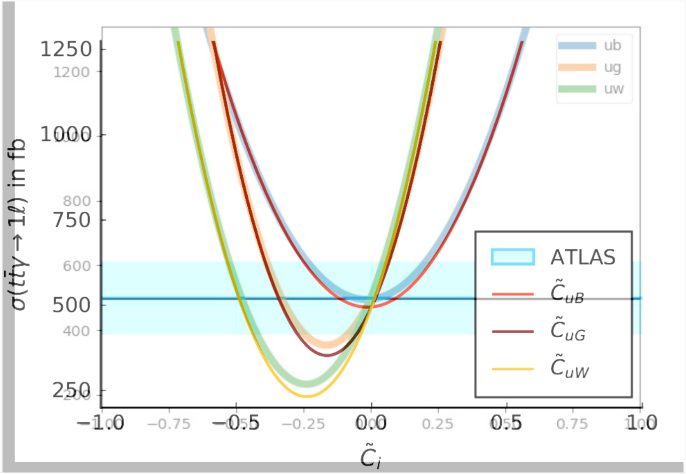


Figure 6 from paper

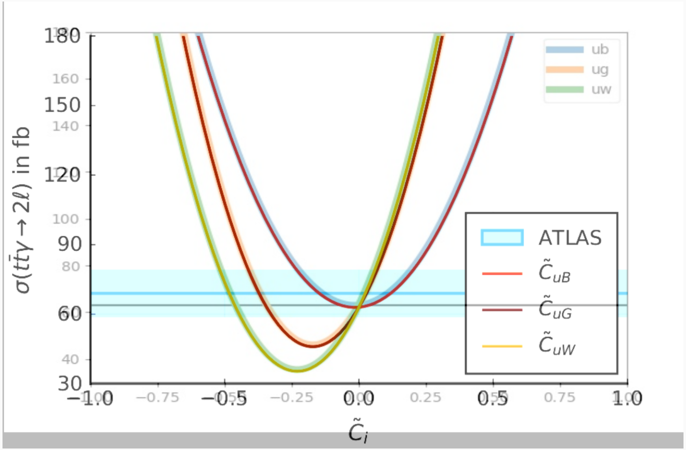


Figure 6 from paper

Second check : Sampling one SMEFT coefficient onto one observables

Recall

$$\mathcal{L}(x,\lambda) = -\frac{1}{2} \sum_{i\in\{\mathrm{BR},\sigma_{1l},\sigma_{2l}\}} M_{ii}^{-1} \left(x_i - \mathcal{O}_i(\bar{C}_{uB}, \bar{C}_{uG}, \bar{C}_{uW})\right)^2 .$$

Sampling of

$$-\mathcal{L}_{\mathrm{BR}}(\bar{C}_{uB},0,0) = \frac{M_{\mathrm{BR}}^{-1}}{2}(x_{\mathrm{BR}} - O_{\mathrm{BR}}(\bar{C}_{uB},0,0)),\ -\mathcal{L}_{\mathrm{ttl}}(\bar{C}_{uB},0,0) = \sum_{i\in\{\mathrm{s1l},\ \mathrm{s2l}\}} \frac{M_{\mathrm{ii}}^{-1}}{2}(x_{\mathrm{i}} - O_{\mathrm{i}}(\bar{C}_{uB},0,0)),$$

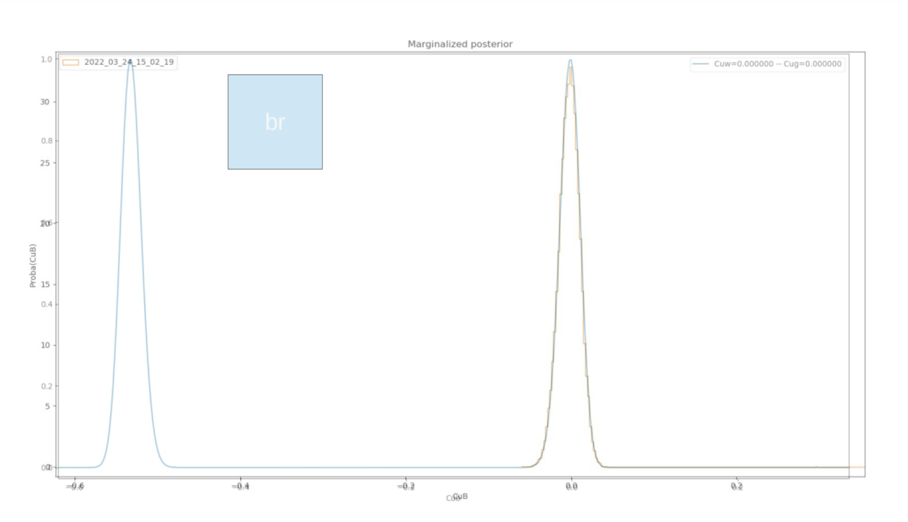
$$-\mathcal{L}_{\mathrm{BR}}(0,\bar{C}_{uG},0),\ -\mathcal{L}_{\mathrm{ttl}}(0,\bar{C}_{uG},0).$$

Comparison with plots for $\bar{C}_\alpha \in [\![-1,1]\!]$.

Apparent agreement between the plots

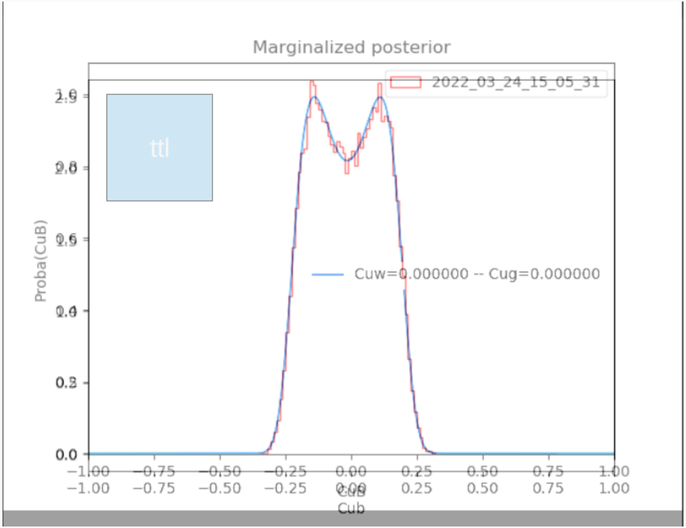
As mentioned previously, only one peak catched for $-\mathcal{L}_{\mathrm{BR}}(\bar{C}_{uB},0,0)$

Second check : Sampling one SMEFT coefficient onto one observables – CuB



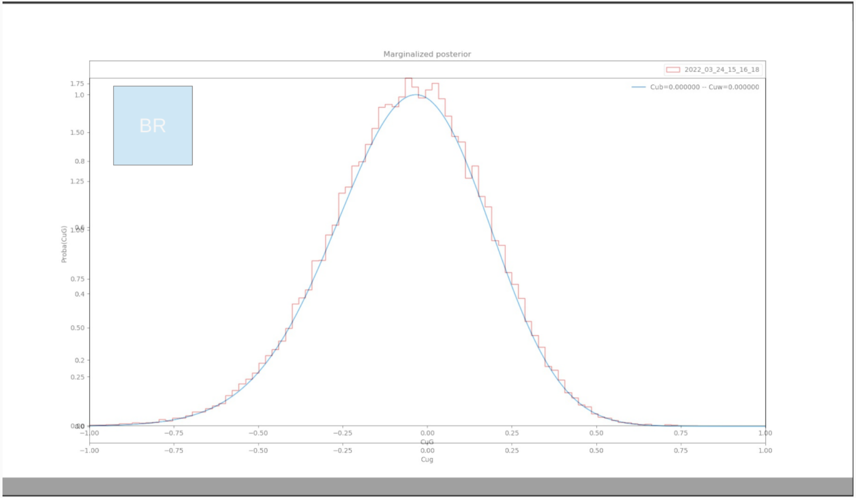
$$\text{CuG} = 0, \ \text{CuW} = 0$$

Second check : Sampling one SMEFT coefficient onto one observables – CuB



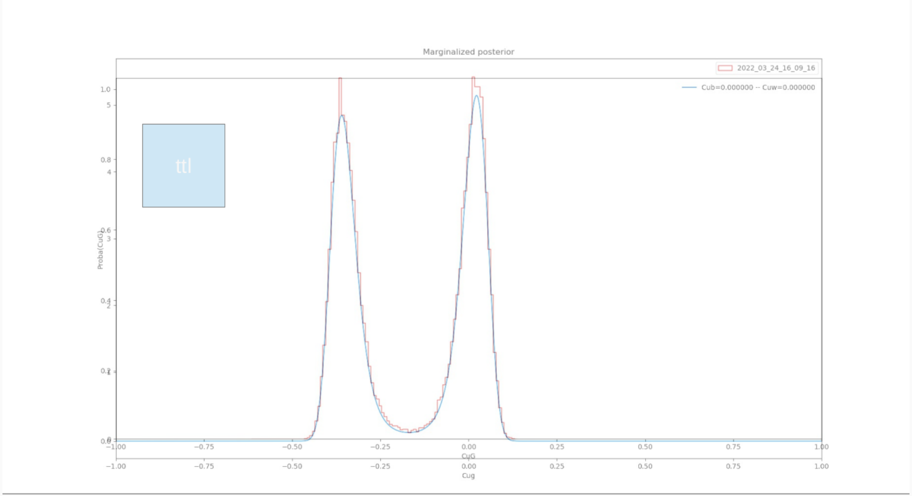
CuG = 0, CuW = 0

Second check : Sampling one SMEFT coefficient onto one observables – CuG



$CuB = 0, CuW = 0$

Second check : Sampling one SMEFT coefficient onto one observables – CuG



$CuB = 0,\ CuW = 0$

Third check : Sampling the SMEFT coefficients onto one observable

Recall

$$\mathcal{L}(x,\lambda) = -\frac{1}{2}\sum_{i\in\{\mathrm{BR},\sigma_{1l},\sigma_{2l}\}} M_{ii}^{-1}\left(x_i - \mathcal{O}_i(\bar{C}_{uB},\bar{C}_{uG},\bar{C}_{uW})\right)^2.$$

Sampling of

$$-\mathcal{L}_{\mathrm{BR}}(\bar{C}_{uB},\bar{C}_{uG},\bar{C}_{uW}) = \frac{M_{\mathrm{BR}}^{-1}}{2}(x_{\mathrm{BR}} - O_{\mathrm{BR}}(\bar{C}_{uB},\bar{C}_{uG},\bar{C}_{uW})) \text{ and}$$

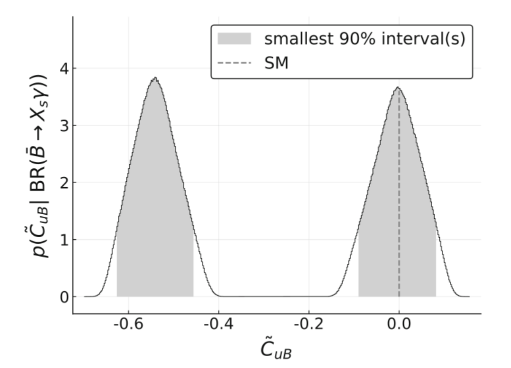
$$-\mathcal{L}_{\mathrm{ttl}}(\bar{C}_{uB},\bar{C}_{uG},\bar{C}_{uW}) = \sum_{i\in\{\mathrm{s1l,\ s2l}} \frac{M_{\mathrm{ii}}^{-1}}{2}(x_{\mathrm{i}} - O_{\mathrm{i}}(\bar{C}_{uB},\bar{C}_{uG},\bar{C}_{uW})),$$

Comparison with figures 8 and 9 from the EFT paper for $\bar{C}_\alpha \in [\![-1,1]\!]$ (not taking the 90%).

Some agreement between the plots for Figure 9

No agreement at all for Figure 8

Third check : Sampling the SMEFT coefficient onto one observables – CuB marginal



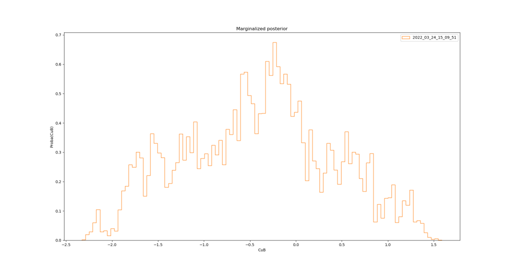


Figure 8 EFT paper

Third check : Sampling the SMEFT coefficient onto one observables – CuB marginal

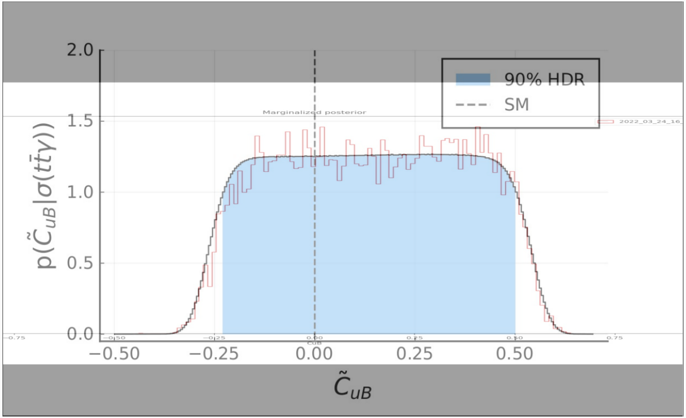


Figure 9 EFT paper

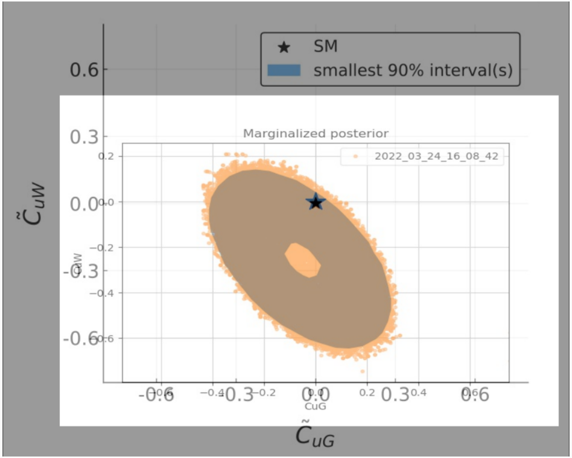


Figure 9 EFT paper

Fourth check : Sampling the SMEFT coefficients onto the observables

Recall

$$\mathcal{L}(x,\lambda) = -\frac{1}{2} \sum_{i \in \{\mathrm{BR}, \sigma_{1l}, \sigma_{2l}\}} M_{ii}^{-1} \left(x_i - \mathcal{O}_i(\bar{C}_{uB}, \bar{C}_{uG}, \bar{C}_{uW})\right)^2 .$$

Sampling of

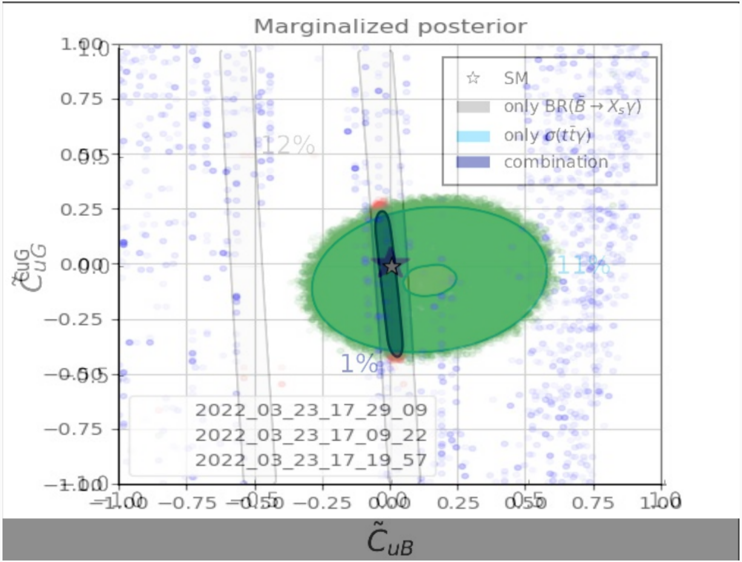
$$-\mathcal{L}(\bar{C}_{uB}, \bar{C}_{uG}, \bar{C}_{uW})$$

Comparison with figure 10 from the EFT paper (not taking the 90%).

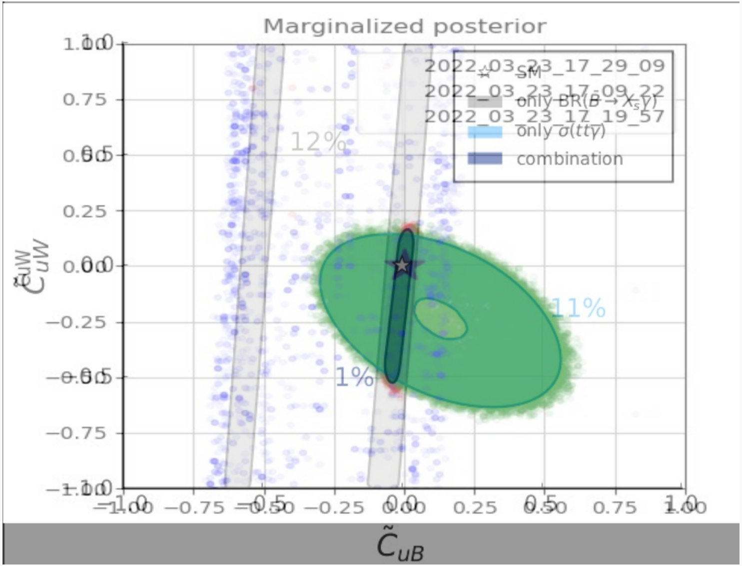
Some agreement between the plots for Figure 10

No agreement for only BR measurement between $\bar{C}_{uB}$ and $\bar{C}_{uG}$

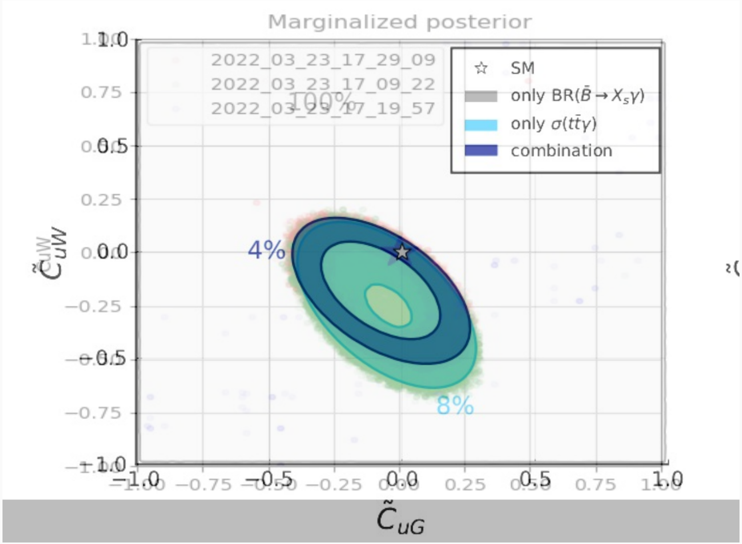
Third check : Sampling the SMEFT coefficient onto the observables



Third check : Sampling the SMEFT coefficient onto the observables



Third check : Sampling the SMEFT coefficient onto the observables

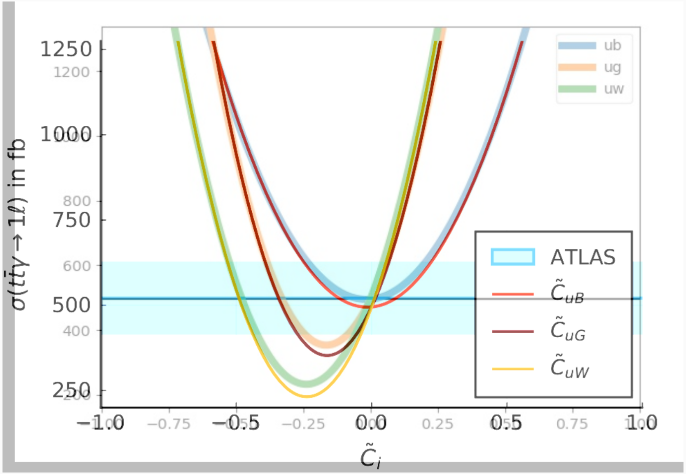


Main questions (if not already asked !)

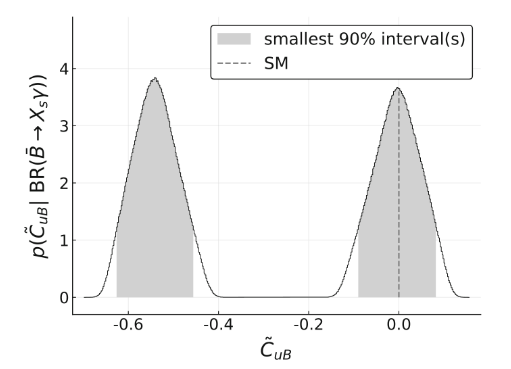
1. Disagreement between Figure 6 and my plots for the $\sigma(t\bar{t}\gamma \to 1l)$ observable
2. Strong disagreement Figure 8 between $p(\bar{C}_{uB}|\mathrm{BR}(\bar{B} \to X_s\gamma))$: BR should constrain $\bar{C}_{uB}$ but not $\bar{C}_{uG}$ nor $\bar{C}_{uW}$ (from paper), not what I observe
3. Strong disagreement Figure 10 between $p(\bar{C}_{uB}|\mathrm{BR}(\bar{B} \to X_s\gamma))$ against $p(\bar{C}_{uG}|\mathrm{BR}(\bar{B} \to X_s\gamma))$, see plots

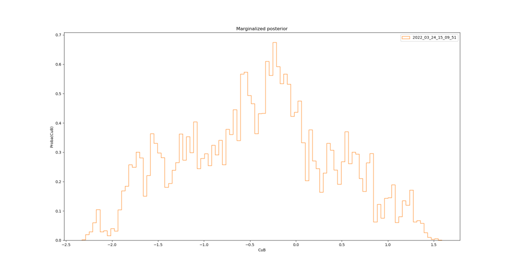
$\Longrightarrow$ Could I get data files used for the production of the plots in the EFT paper ?

1) Disagreement Figure 6



2) Strong disagreement Figure 8





3) Strong disagreement Figure 10