SMEFT activities in CmF RA3

10th June 2026
Christian Grefe

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Outline

- The goal is to identify and connect activities within the CmF research groups that are related to SMEFT interpretations and global fits

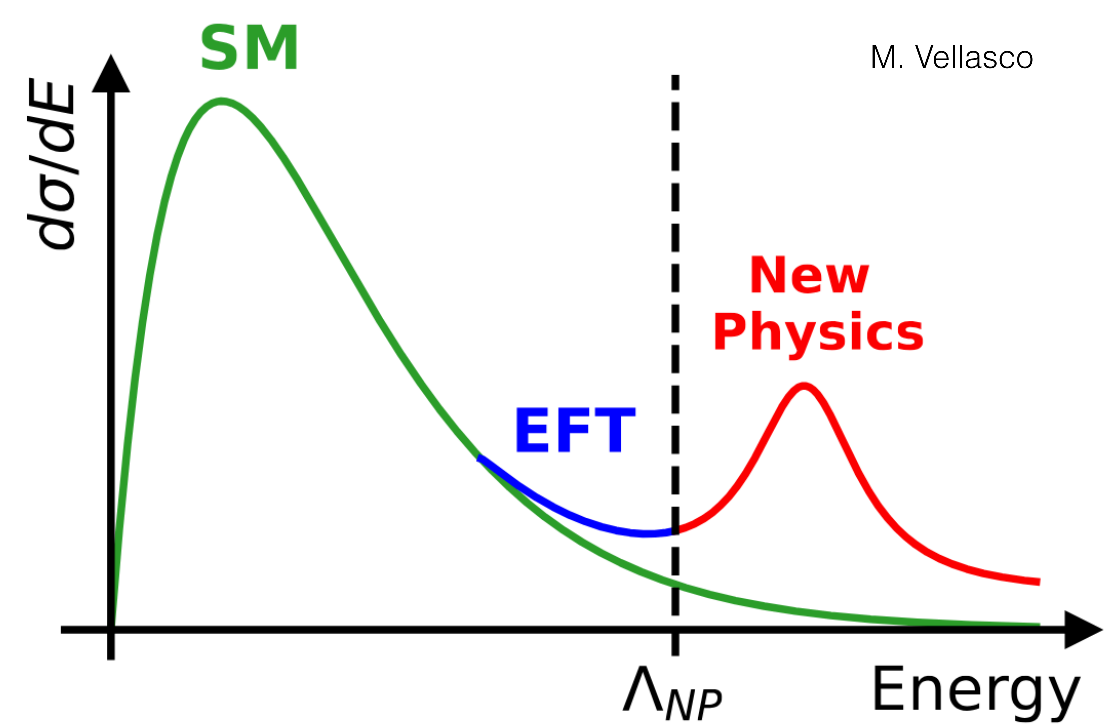
- Where are possible **synergies**? How do we combine our measurements at **different experiments**, final states and energy scales

- Can we use **common software tools** and build up **common expertise**?

- Includes feedback that I received (can be incomplete)

Effective Field Theories

- Assume that new physics is directly observable only at a much higher energy scale (Λ_{NP}).
- New physics will modify observable couplings through loop contributions.
- Parametrise modifications to the SM as an effective model valid at $E \ll \Lambda_{\mathrm{NP}}$
- SMEFT introduces ~2.5k additional operators at $\mathcal{O}^{(6)}$



Wilson coefficients

$$\mathcal{L}_{\mathrm{SMEFT}} = \mathcal{L}_{\mathrm{SM}}^{(4)} + \frac{1}{\Lambda_{\mathrm{NP}}} \sum_k C_k^{(5)} \boxed{O_k^{(5)}} + \frac{1}{\Lambda_{\mathrm{NP}}^2} \sum_k C_k^{(6)} \boxed{O_k^{(6)}} + \mathcal{O}\left(\frac{1}{\Lambda_{\mathrm{NP}}^3}\right)$$

Operators

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Effective Field Theories

$$\mathcal{L}_{\mathrm{SMEFT}} = \mathcal{L}_{\mathrm{SM}}^{(4)} + \frac{1}{\Lambda_{\mathrm{NP}}} \sum_k C_k^{(5)} \boxed{O_k^{(5)}} + \frac{1}{\Lambda_{\mathrm{NP}}^2} \sum_k C_k^{(6)} \boxed{O_k^{(6)}} + \mathcal{O}\left(\frac{1}{\Lambda_{\mathrm{NP}}^3}\right)$$

- These are not actually valid / UV complete theories (non renormalisable)
- Allows to combine information from different measurements that are sensitive to similar couplings in a consistent way
  - There can be cancellations so all operators should be considered
- Observed deviations need to be mapped to a UV complete theory
  - Cut-off at $\mathcal{O}^{(6)}$ is driven by practical considerations, $\mathcal{O}^{(8)}$ can certainly be relevant depending on the size of the WC

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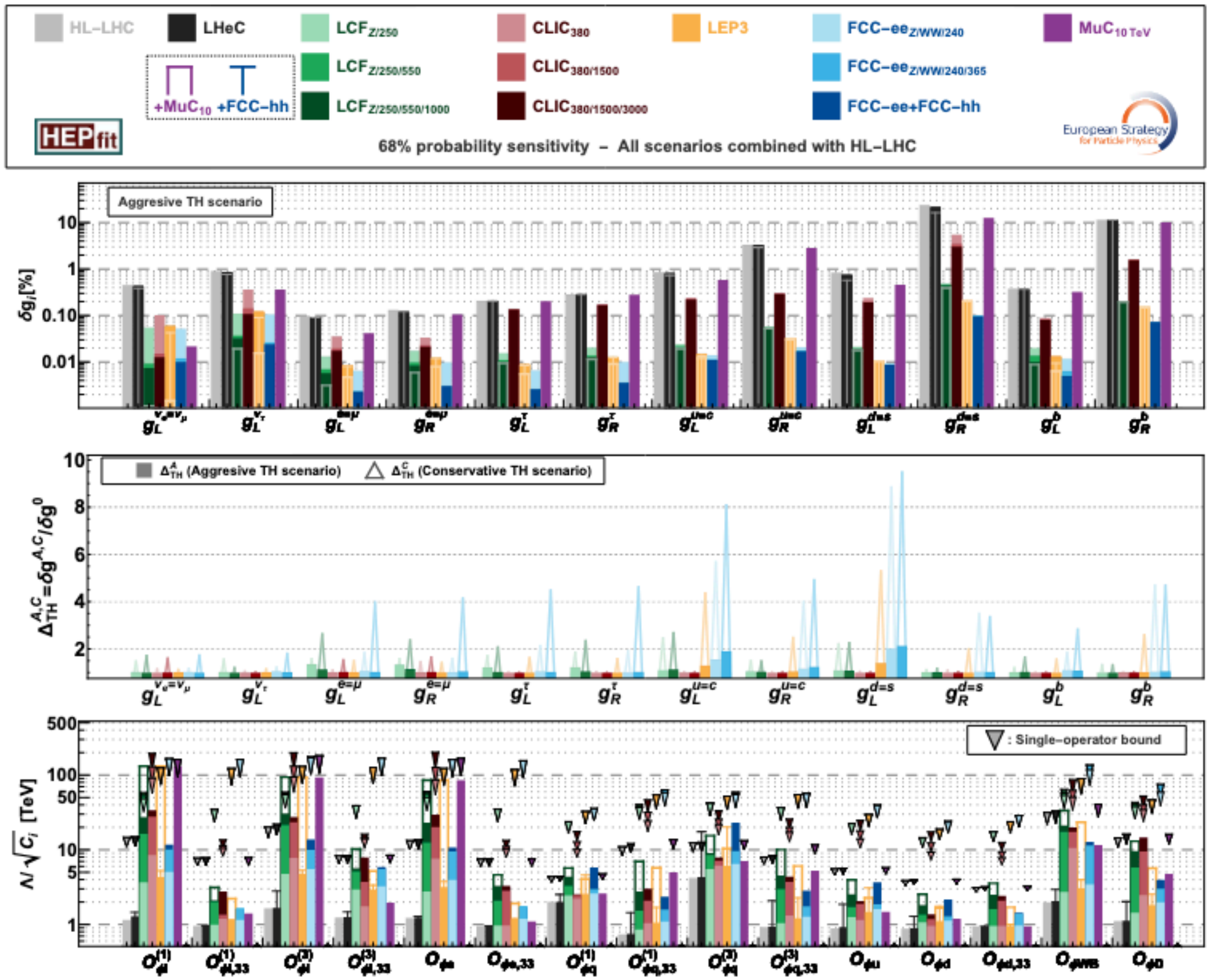
Future Collider Potential

- SMEFT fit in the electroweak sector from the physics briefing book of the 2026 European Strategy: arXiv:2511.03883. 124 Wilson coefficients (no CP violation, U(2) flavour assumption).



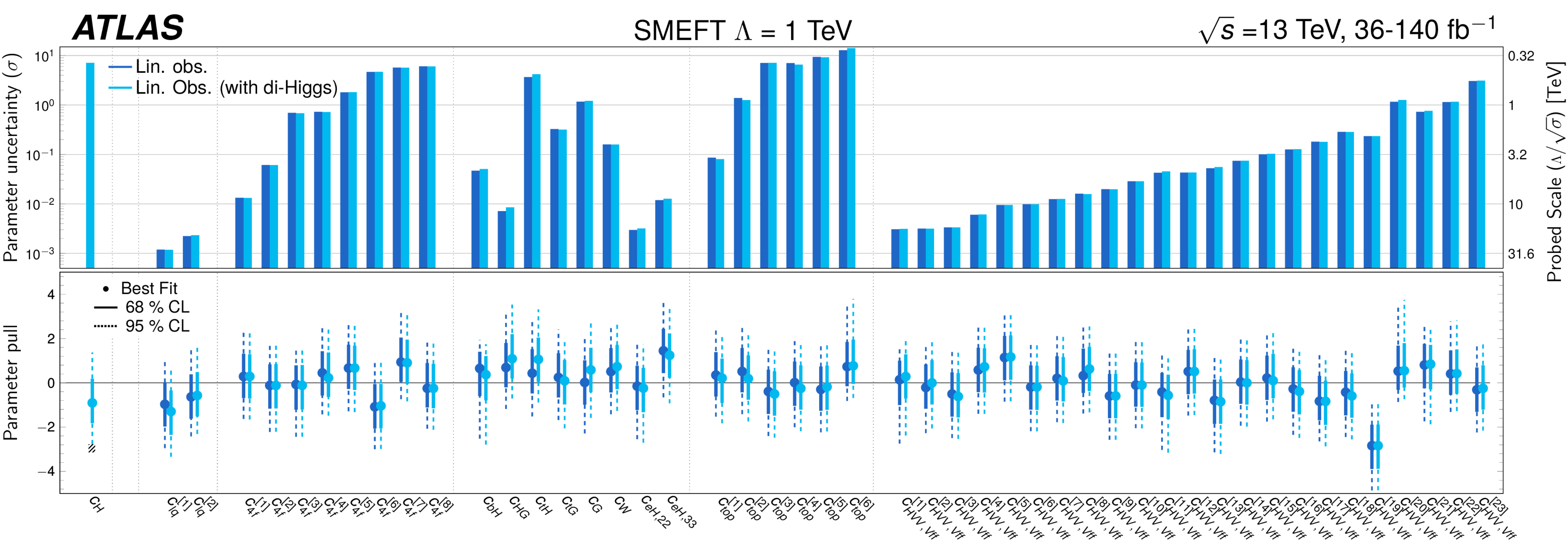
Uses HEPfit

Experiment specific efforts

- ATLAS recently published a large dim6 EFT fit, covering Higgs, Top and Electroweak operators (48 Wilson coefficients in the Warsaw basis). Includes LEP, SLD constraints.

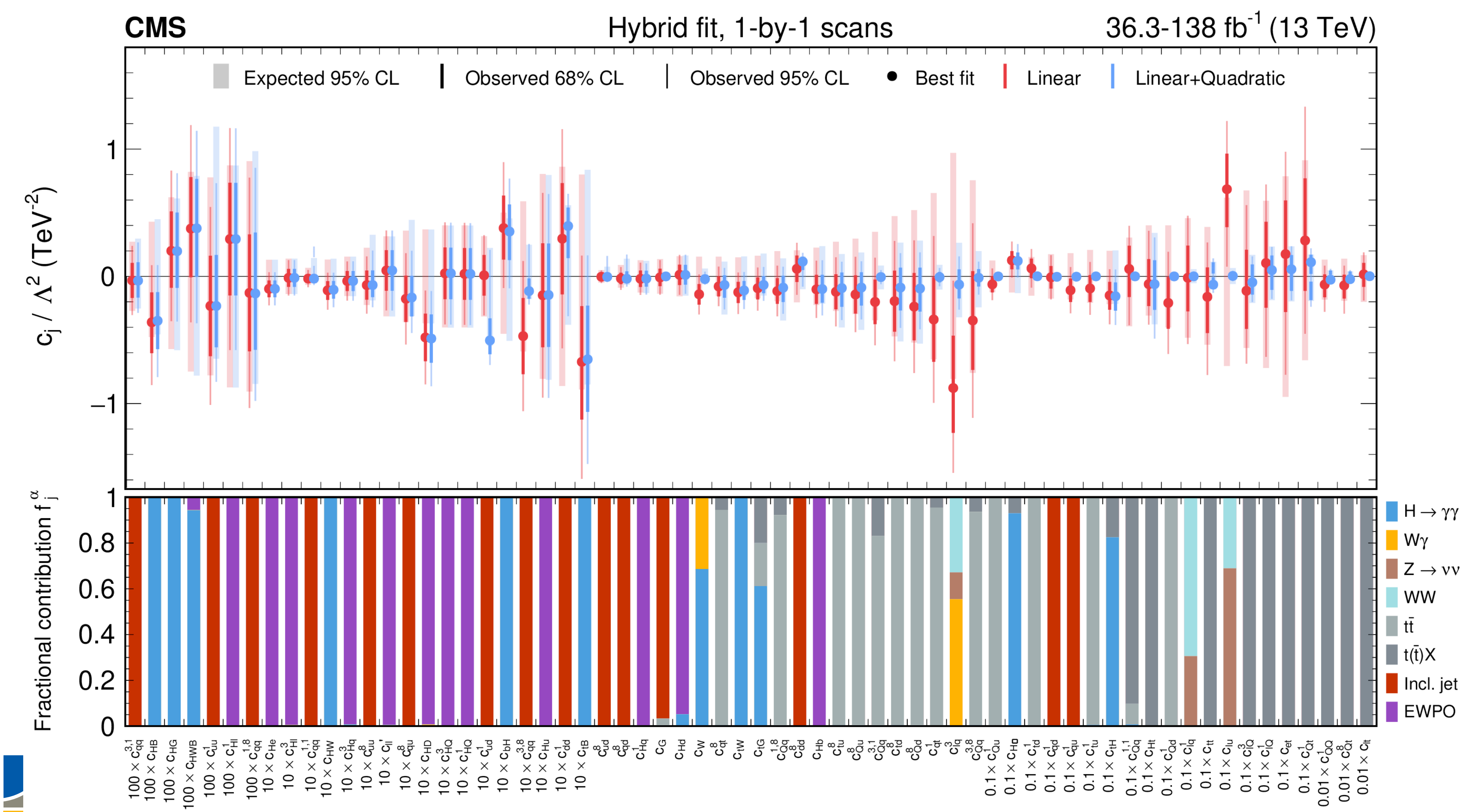
- arXiv:2604.21670

Uses ATLAS SW: EFTrexFitter

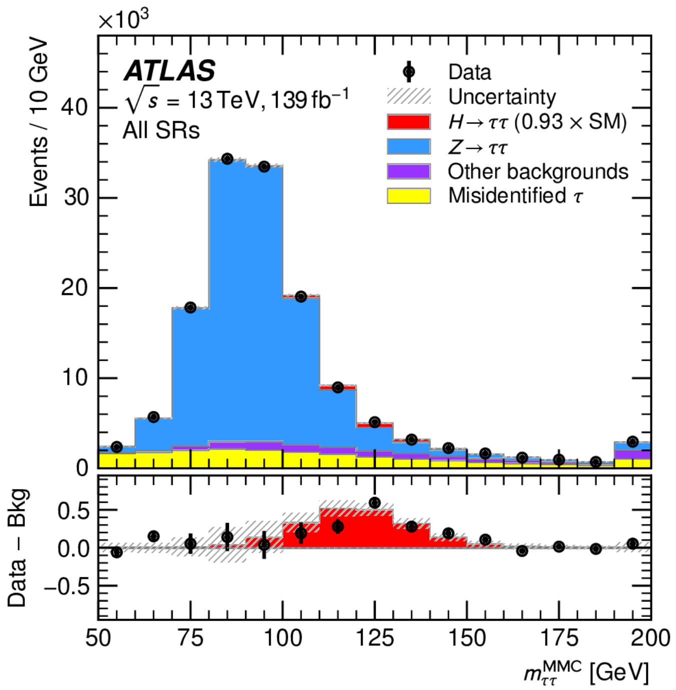


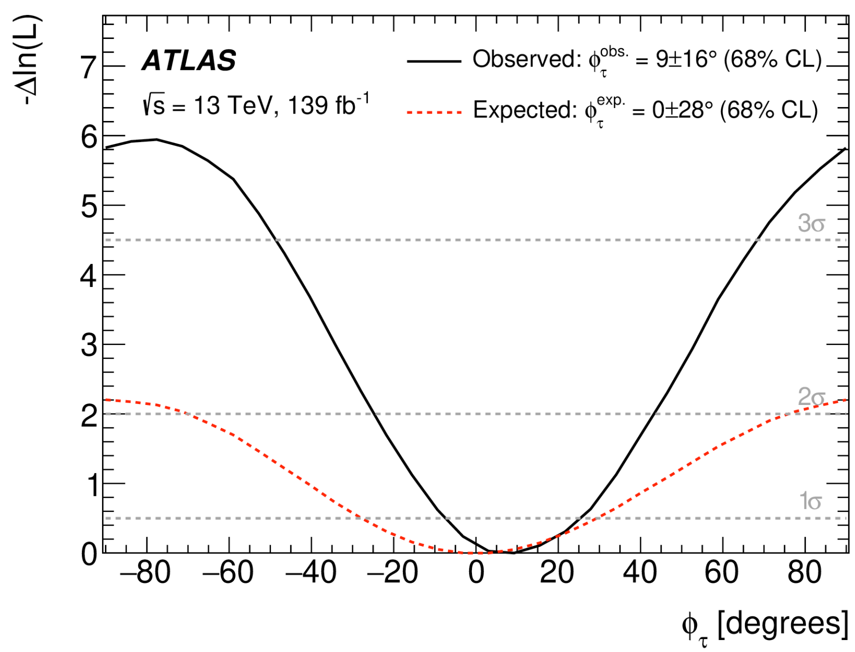
Experiment specific efforts

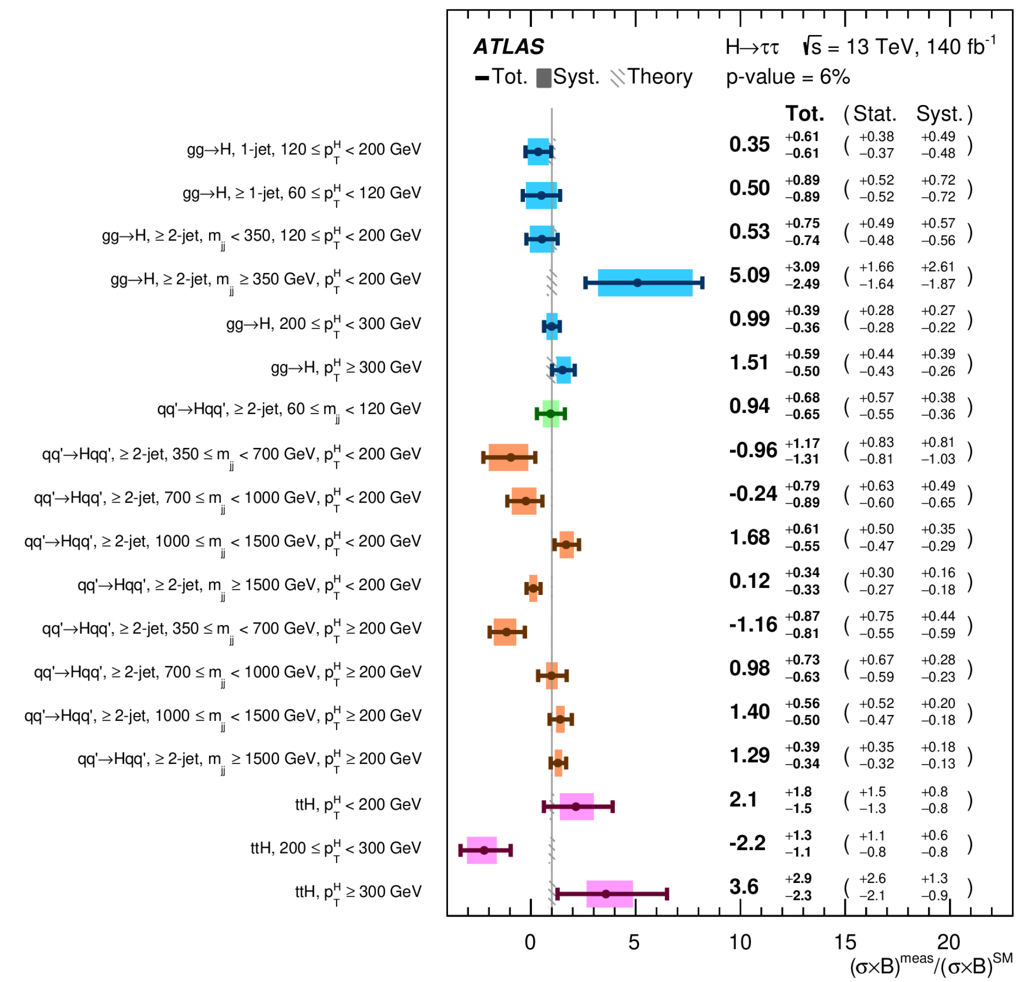
- Similar to the ATLAS result constraining 64 individual Wilson coefficients and 42 linear combinations. arXiv:2504.02958



Higgs boson properties with τ leptons







- Long experience in precision measurements in the $H \to \tau\tau$ final state. Differential cross section measurements using STXS framework (input to ATLAS EFT fit)

- Differential measurements of CP-sensitive observables give access to CP-violating operators

- See also arXiv:2201.08269, arXiv:2407.16320, arXiv:2212.05833

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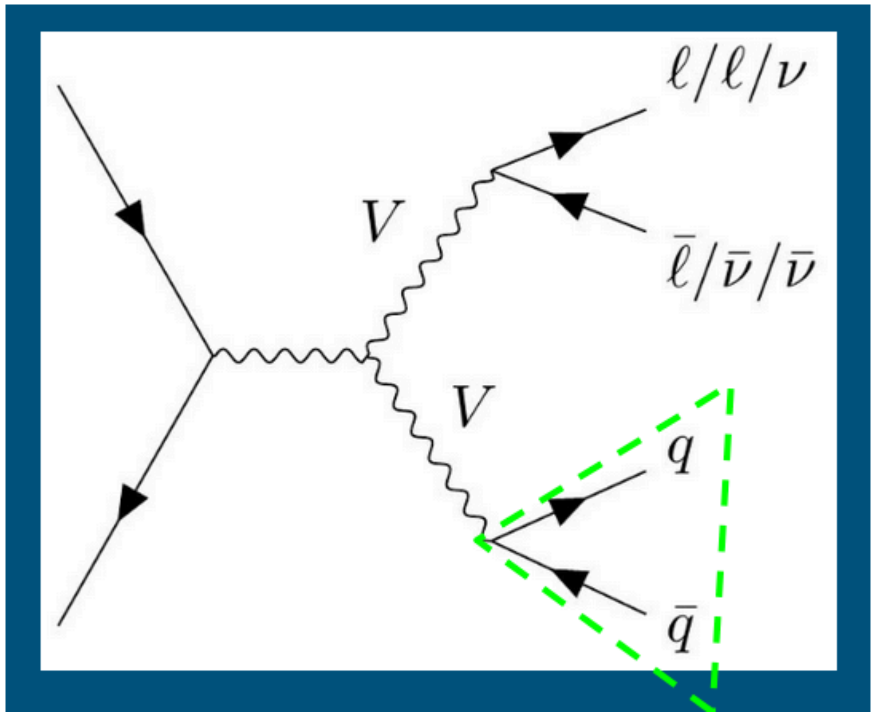
Bechtle, Desch, Grefe, et al. (Bonn)

Top quark precision measurements at ATLAS

- Planned measurements of top quark events in ATLAS
  - Differential measurements of spin correlations in $t\bar{t}$ events
  - Cross section measurements in top+X topologies
- These measurements are directly sensitive to multiple top quark operators in the SMEFT Lagrangian

Diez Pardos et al. (Siegen)

c_W in semi-leptonic VV production at ATLAS



Current ATLAS limits using fully leptonic channel

	Expected [TeV $^{-2}$]		Observed [TeV $^{-2}$]	
	95% CL (lin.)	95% CL (lin.+quad.)	95% CL (lin.)	95% CL (lin.+quad.)
c_W/Λ^2	[-0.668, 0.733]	[-0.103, 0.095]	[-1.150, 0.181]	[-0.093, 0.079]
c_{HWB}/Λ^2	[-0.326, 0.412]	[-0.326, 0.413]	[-0.470, 1.440]	[-0.458, 1.520]
c_{HD}/Λ^2	[-8.107, 9.096]	[-4.494, 3.976]	[-18.0, 1.7]	[-5.840, 1.680]
$c_{Hq}^{(1)}/\Lambda^2$	[-1.994, 2.122]	[-2.923, 1.615]	[-0.367, 3.980]	[-0.503, 2.550]
$c_{Hq}^{(3)}/\Lambda^2$	[-0.097, 0.106]	[-0.145, 0.074]	[-0.146, 0.0275]	[-0.165, 0.015]

https://arxiv.org/pdf/2507.03500

- Measurement of VV cross section directly sensitive to c_W

- Semi-leptonic channel benefits from much higher statistics due to higher branching ratio. Requires reconstruction of the boosted qq system

Preliminary (blinded) limits

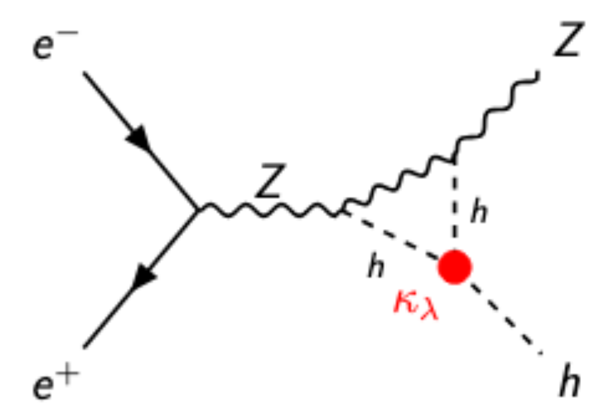
Channel	cW (linear)	cW (linear+quadratic)
0-lepton	$0.00^{+1.13}_{-1.51}$	$0.00^{+0.08}_{-0.07}$
1-lepton	$-0.08^{+0.94}_{-2.54}$	$0.02^{+0.04}_{-0.08}$
2-lepton	$0.00^{+1.81}_{-1.83}$	$0.01^{+0.18}_{-0.19}$
combined	$-0.08^{+0.59}_{-0.93}$	$0.02^{+0.04}_{-0.07}$

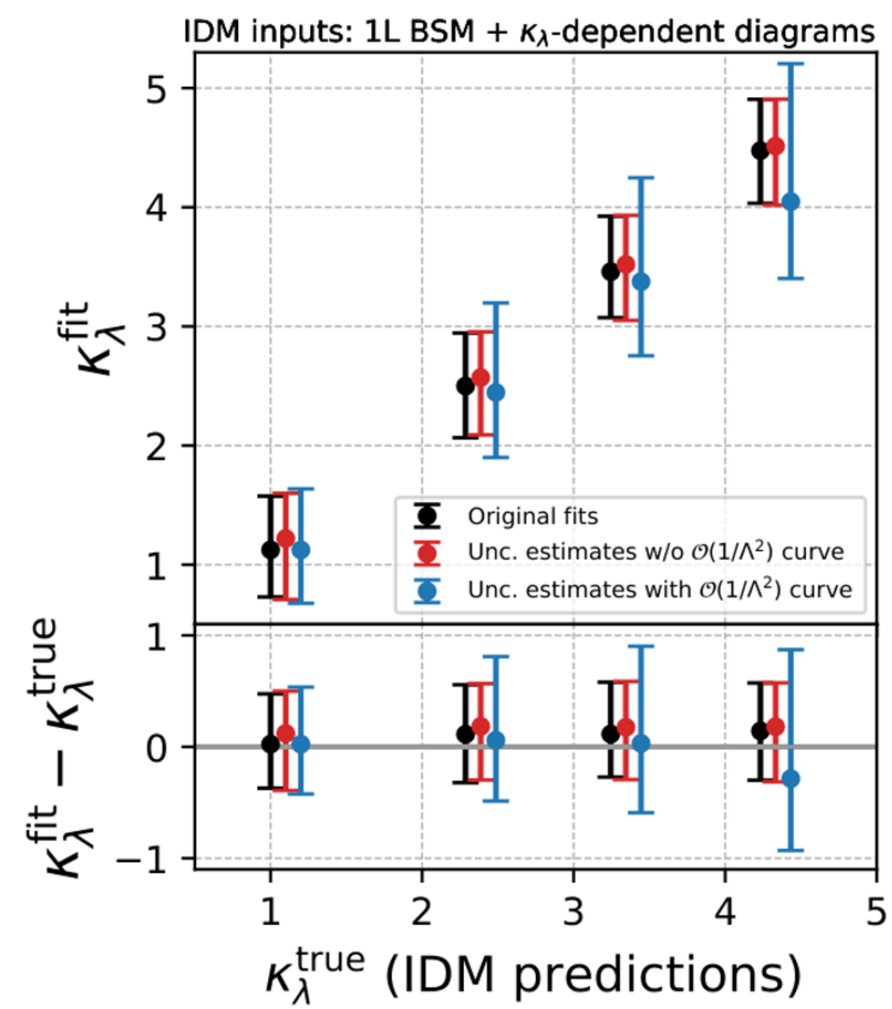
κ_{Λ_3} at FCCee

- Understanding the shape of the Higgs potential (κ_{Λ_3}) is a key goal of the future e^+e^- collider, but FCCee has no access to di-Higgs production. It is sensitive to loop corrections to single Higgs boson production.

- Future collider projections are parametrised using SMEFT fits (European Strategy), which necessarily make assumptions about Λ_{NP} and the included order of Wilson coefficients.

- Use Inert Doublet Model as a benchmark to quantify the additional uncertainty from matching the true model to SMEFT.





See also arXiv:2512.02111

Bechtle, Desch, Grefe, Vellasco (Bonn)

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Flavor sensitive operators at Belle2 & LHCb (RA2)

- Flavor sensitive operators are typically expressed in Weak Effective Theories (WET) - important to make the connection to SMEFT within CmF

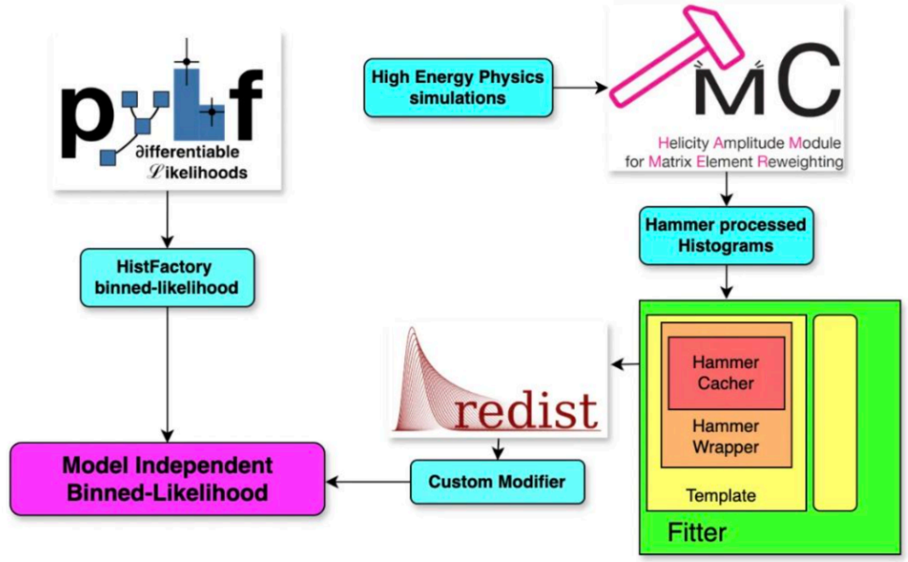
- Recent example from WET constraints extracted from $B^+ \to K^+ \nu\nu$ (Phys. Rev. D 112, 092016)

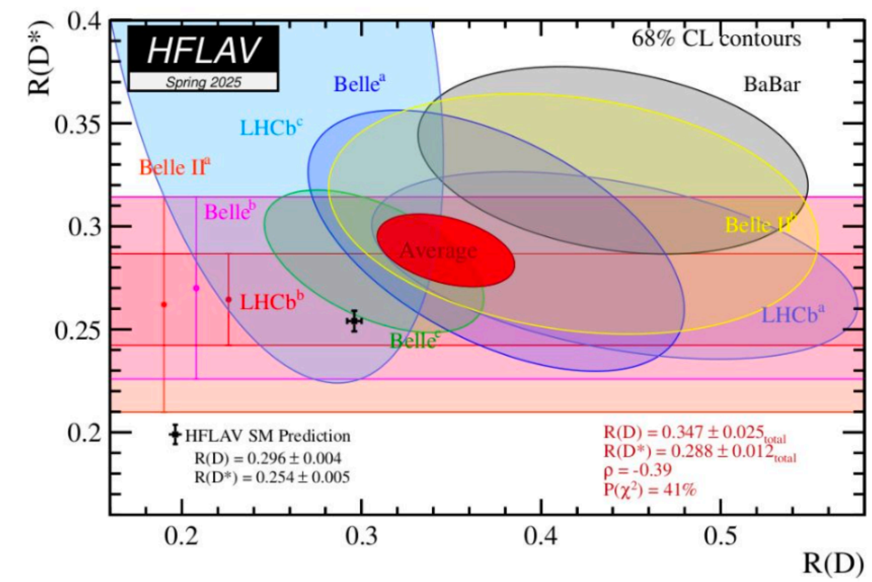
- Investigate flavour anomalies like

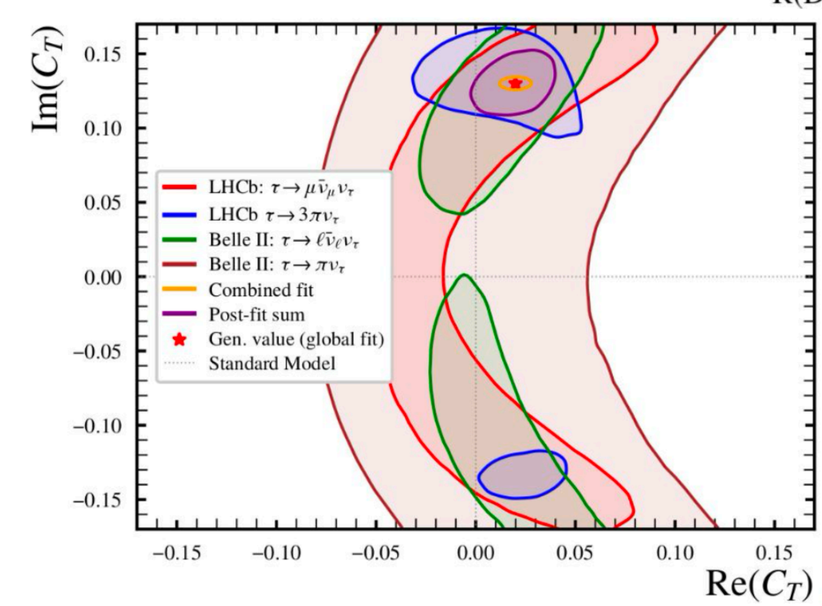
$$R(D^*) = \frac{B(B_0 \to D^{+*} \tau^- \bar{\nu}_\tau)}{B(B_0 \to D^{+*} \mu^- \bar{\nu}_\mu)}$$

- Hammer (arXiv:2002.00020) allows to reweigh MC without having to re-simulate samples - necessary for some analyses like $b \to c\tau\nu$

- Combination of LHCb and Belle II data for ultimate precision







Albrecht, Bernlochner, Stefkova, et al. (Bonn & Dortmund)

Framework to include all relevant measurements

- Plan to develop a framework to investigate the sensitivity of observables on Wilson coefficients in global fits.
    - Develop tool to store and manage EFT models, their free parameters, and the relevant observables and measurements.
    - Provide observable parametrisation and calculate their derivates, as well as statistical tools and goodness of fit evaluation

Towards a "global" EFT fit

- Constraints from flavour physics and high energy observables need to be combined in a global EFT to fully leverage our current knowledge

- Currently investigating jelli/smelli as framework

    - smelli (SMEFT Likelihood): calculates a global likelihood given values for SMEFT Wilson coefficients. Builds upon:

        - flavio: a general observable calculator, contains a large database of measurements (flavour physics focussed)

        - wilson: uses the renormalization group equations to connect Wilson Coefs. between the WET and the SMEFT

    - jelli is the latest version based on JAX: Just-In-Time (JIT) compilation, automatic differentiation. Extremely performant.

- Need to make assumptions about flavour structure when extrapolating to high energy observables

Bechtle, Desch, Grefe, Vellasco (Bonn)