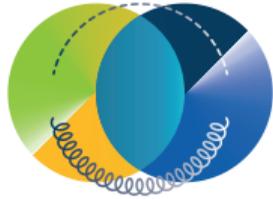# RA3 Contributions in Higgs Physics from Klaus, Christian and myself
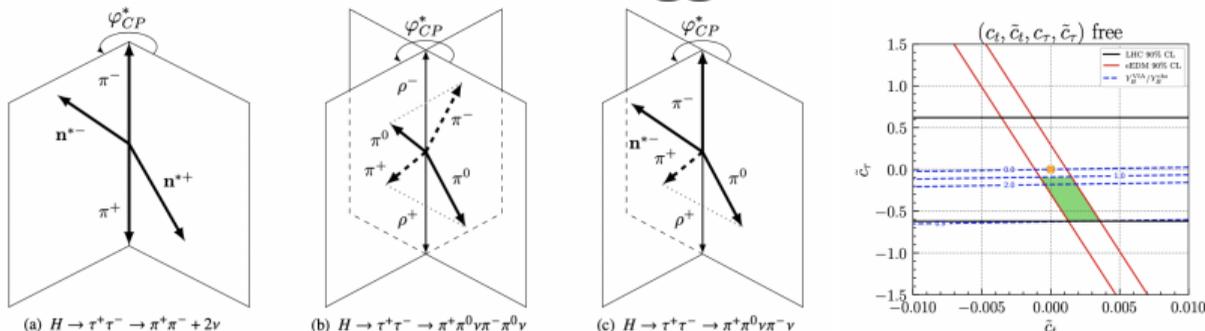
Philip Bechtle

Philip Bechtle

color meets flavor

07. October 2025

125 GeV Higgs *CP*

(a) $H \to \tau^+\tau^- \to \pi^+\pi^- + 2\nu$ (b) $H \to \tau^+\tau^- \to \pi^+\pi^0\nu\pi^-\pi^0\nu$ (c) $H \to \tau^+\tau^- \to \pi^+\pi^0\nu\pi^-\nu$

▶ **What we do anyway:** Test *CP* properties in the τ-Yukawa coupling of the 125 GeV Higgs boson (shape-only, mostly model independent) `https://arxiv.org/abs/2212.05833` *Eur.Phys.J.C 83 (2023) 563*

▶ **What we should/could do:** More global interpretations in the direction of H. Bahl et al., "Constraining the $\mathcal{CP}$ structure of Higgs-fermion couplings with a global LHC fit, the electron EDM and baryogenesis", `https://arxiv.org/abs/2202.11753`

▶ *Co-operations:* Theory, and with other CP measurements in top, ttH, extra Higgs, CPV in RA2

▶ Gaol: Co-operate within CmF and eventually with Dynaverse for HEFT and explicit model interpretations with only pure CP odd obseravables and with also CP even observables like rates (CPV 2HDM), ...

125 GeV Higgs *CP* with ML

- ▶ **What we started to do without real funding anyway:** 125 GeV Higgs CP in the $H\tau\tau$ coupling with ML
- ▶ **What we should/could do:** More work in the directions of H. Bahl et al., "$\mathcal{CP}$ Analysis with symbolic regression" `https://arxiv.org/abs/2507.05858`
- ▶ *Co-operations:* as above, but now mainly with TA2 – foundational models, global event interpretations with ML, ...
- ▶ Gaol: Co-operate within CmF, co-ordinated by TA2, to develop ML-based global event interpretation

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125 GeV Higgs: $H \to \tau\mu$

- ▶ **What we do from time to time anyway:** searches for LFV Higgs decays as re-interpretation of $H \to \tau\tau$ XS×BR measurement, e.g. `https://arxiv.org/abs/1907.06131`
- ▶ **What we should/could do:** fully exploit lifetime information in muonic tau decays. Then of course common interpretatioons with RA2
- ▶ *Co-operations:* Theory and RA2
- ▶ **Gaol: Co-operate within CmF, especially with RA2, and come up with interesting high scale model (or HEFT?)**

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Search for additional light neutral Higgs bosons
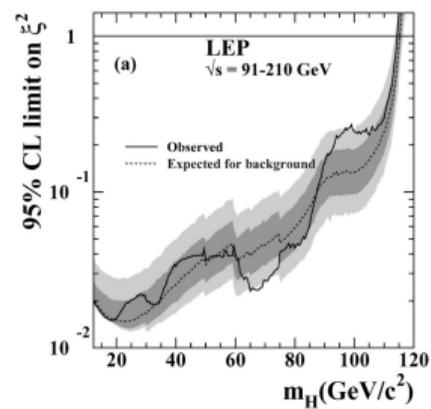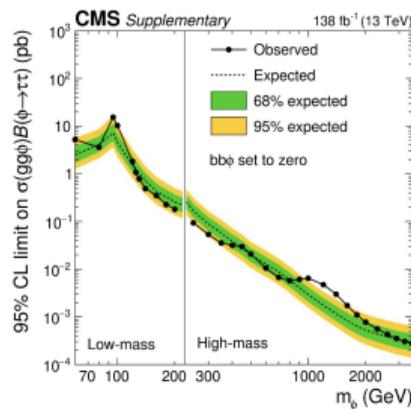
- ▶ What we do anyway: searches for additional scalar resonances
- ▶ What we should/could do: fully exploit spin information, assuming CP-even / CP-odd BSM scalars. Then of course common interpretatioons with RA2
- ▶ *Co-operations:* Theory, RA2, TA2 for ML
- ▶ Gaol: Co-operate within CmF, especially with RA2, and come up with interesting high scale model and perform the definite global interpretation

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Tentative Proposals for Research Groups within CmF RA3/RA2/TA2 based on the above, and with many of us

- ▶ Research Group "Explicit Anomalies at low and high scales"
    - ▶ Extended Higgs sectors High-Scale Models ((CPV) 2HDM, etc)
    - ▶ Global fit from the B to the t scale
- ▶ Research Group "CPV from the B to Baryogenesis"
    - ▶ CPV in Higgs, top, ttH, ...
    - ▶ Global fit of HEP + cosmological data
    - ▶ with Dynaverse?
- ▶ Research Group "New event interpretations with ML"
    - ▶ New ways of searching particles?
    - ▶ New ways of measuring CPV
- ▶ Research Group "From Flavor to Higgs at Future Colliders"
    - ▶ Not in the proposal
    - ▶ But a major topic over the next years
    - ▶ any future e^+e^- collider will be a tremendous flavor machine
    - ▶ Physics and global interpretations from 10 to 250 GeV

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Other

- ▶ High Scale versus SMEFT models – will fit into other activities anyway (Murillo)
- ▶ Physics studies and interpretations at Future Colliders (Christian)
- ▶ SM-like and resonant di-Higgs in 4τ
- ▶ The phenomenology of the inability to measure entanglement vs. non-entanglement, or non-locality, at current collider experiments

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