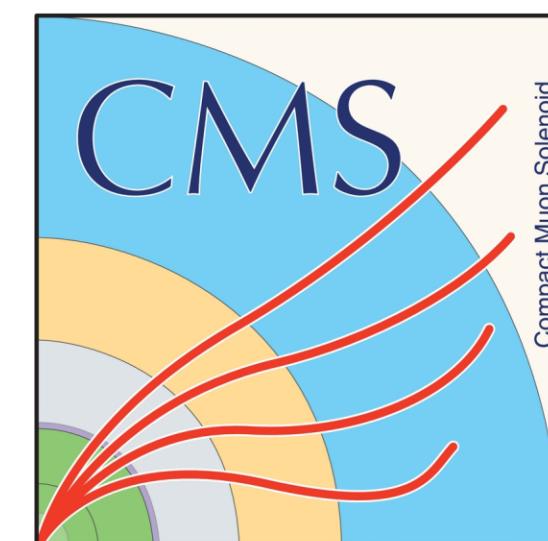




The Higgs through the looking glass.

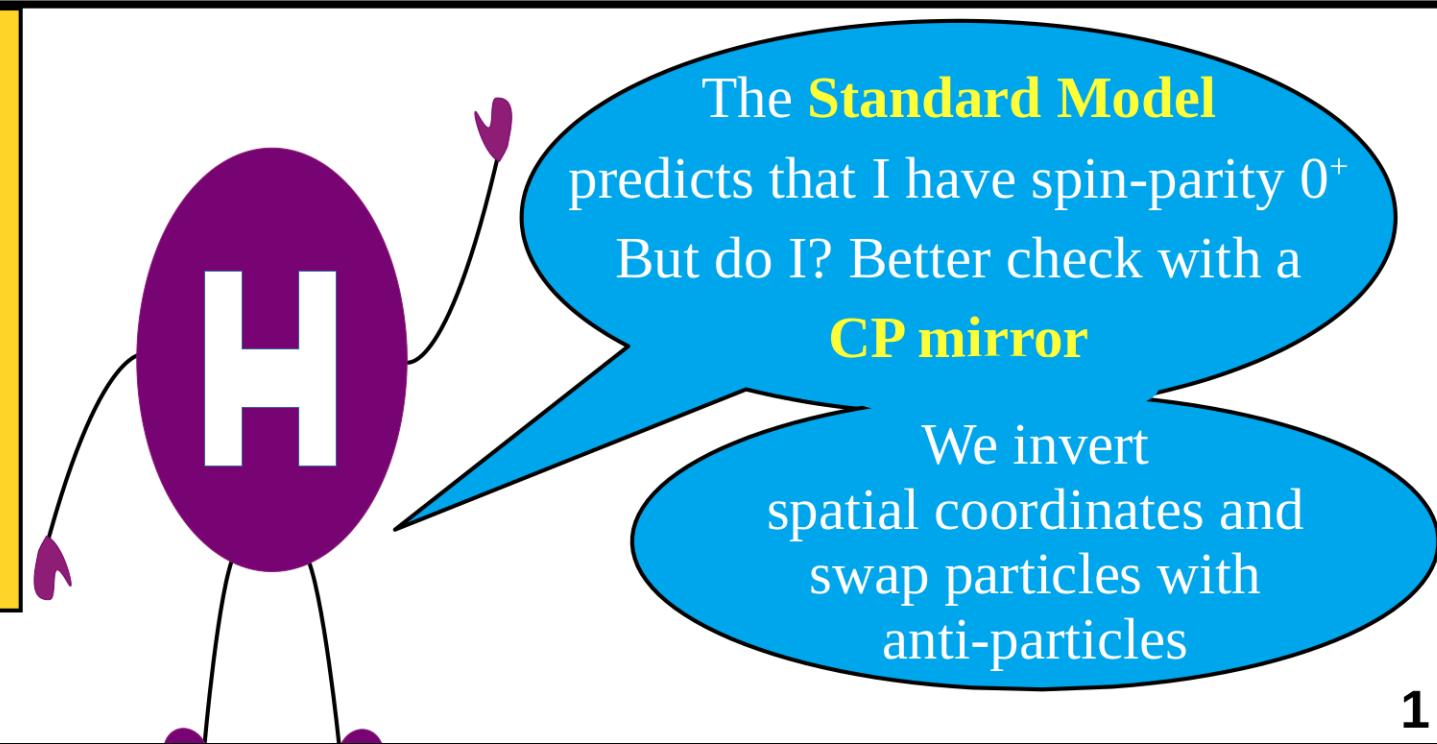
Measurement of the CP structure of the Yukawa interaction in Higgs boson decays to τ leptons in CMS

Andrea Cardini (DESY) on behalf of the CMS collaboration



CP-violation in the Higgs couplings can occur in:

- HVV couplings
- Yukawa coupling:
 - Production via $t\bar{t}H$ and ggH
 - Decays into τ leptons

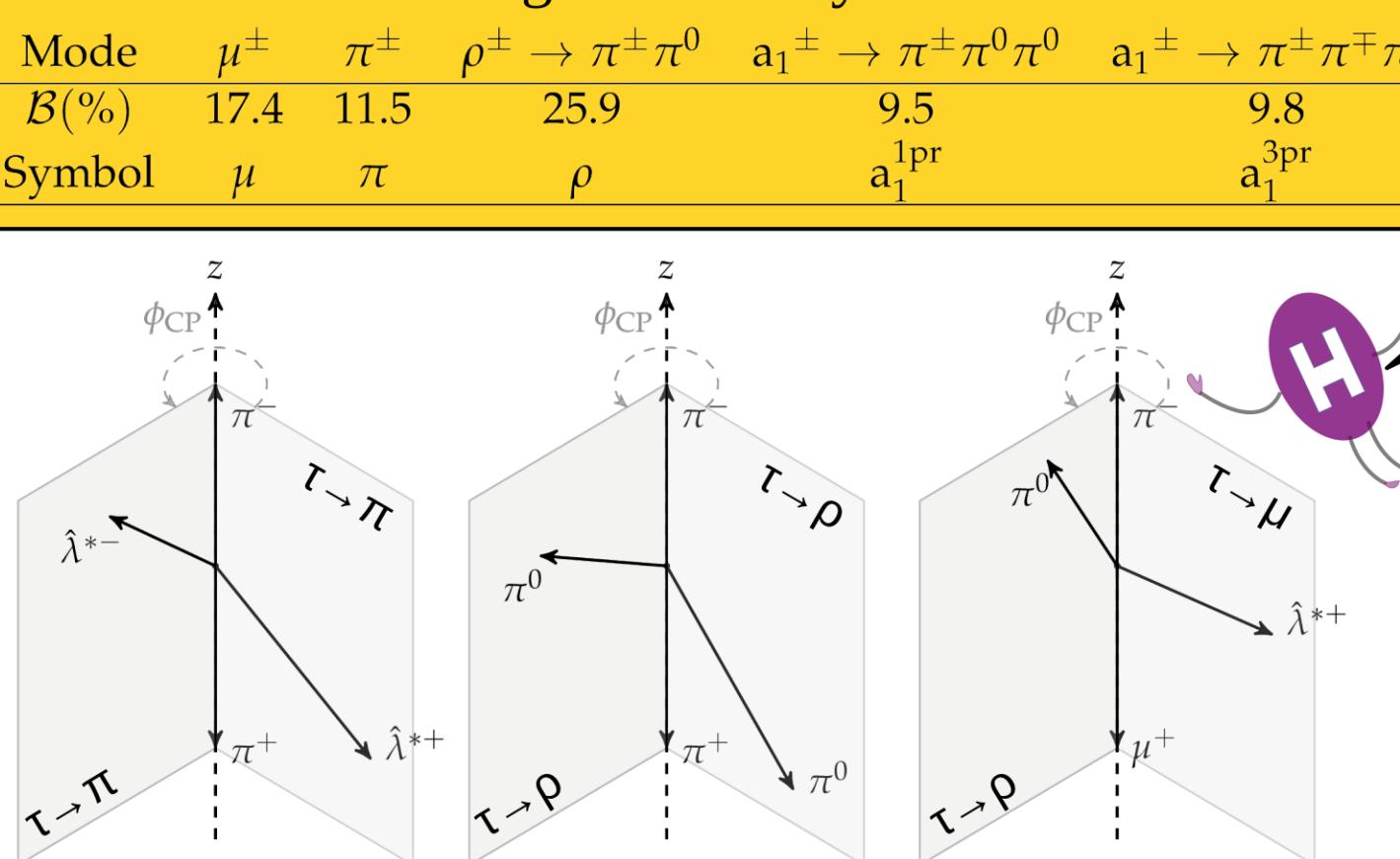


The Standard Model predicts that I have spin-parity 0^+ . But do I? Better check with a CP mirror

We invert spatial coordinates and swap particles with anti-particles

1

Investigated τ decay channels



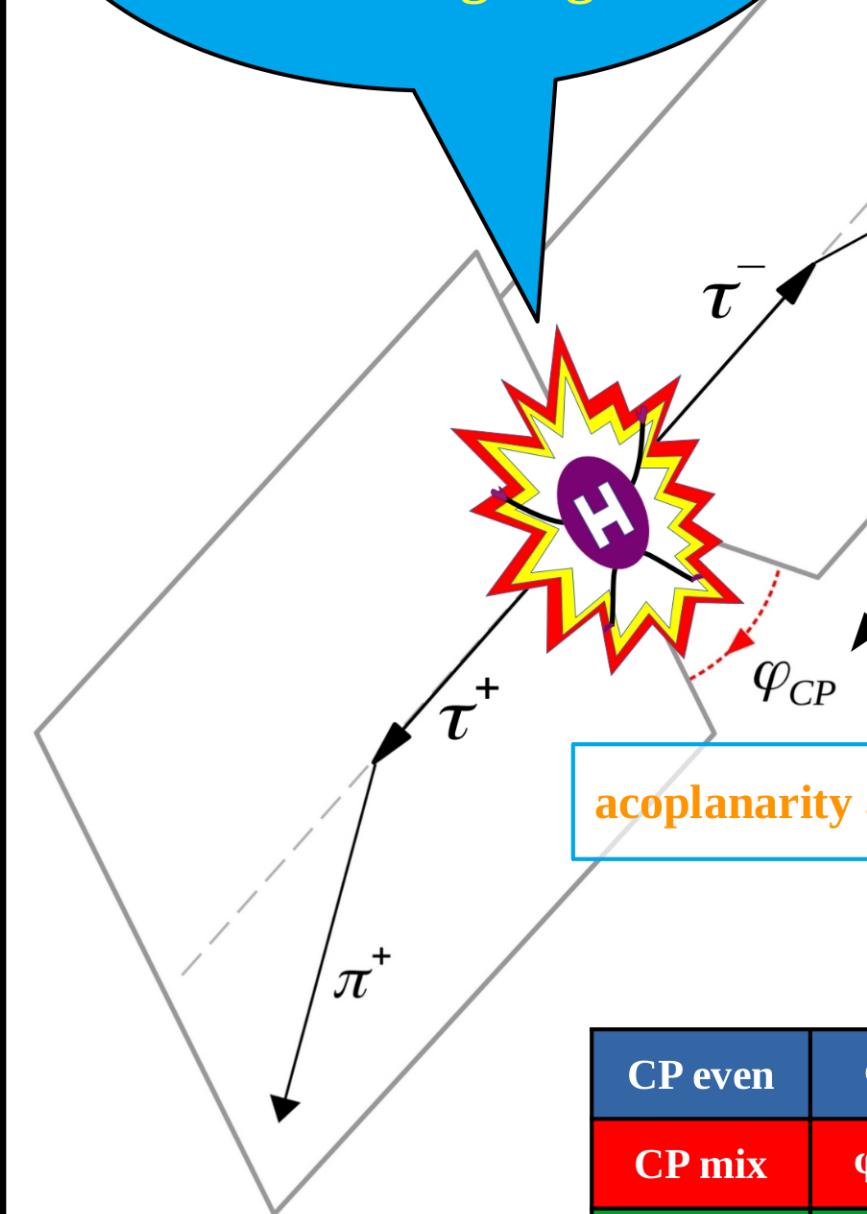
Decay planes are reconstructed with the τ decay products momenta

Impact parameters are used if only one charged particle is present

The τ_h are identified with the DeepTau NN-based ID² MVA-based identification of the decay modes³

3

If I decay to τ leptons the angle between the decay planes depends on the CP mixing angle



The cross-section of the $H \rightarrow \tau\tau$ process has a sinusoidal shape

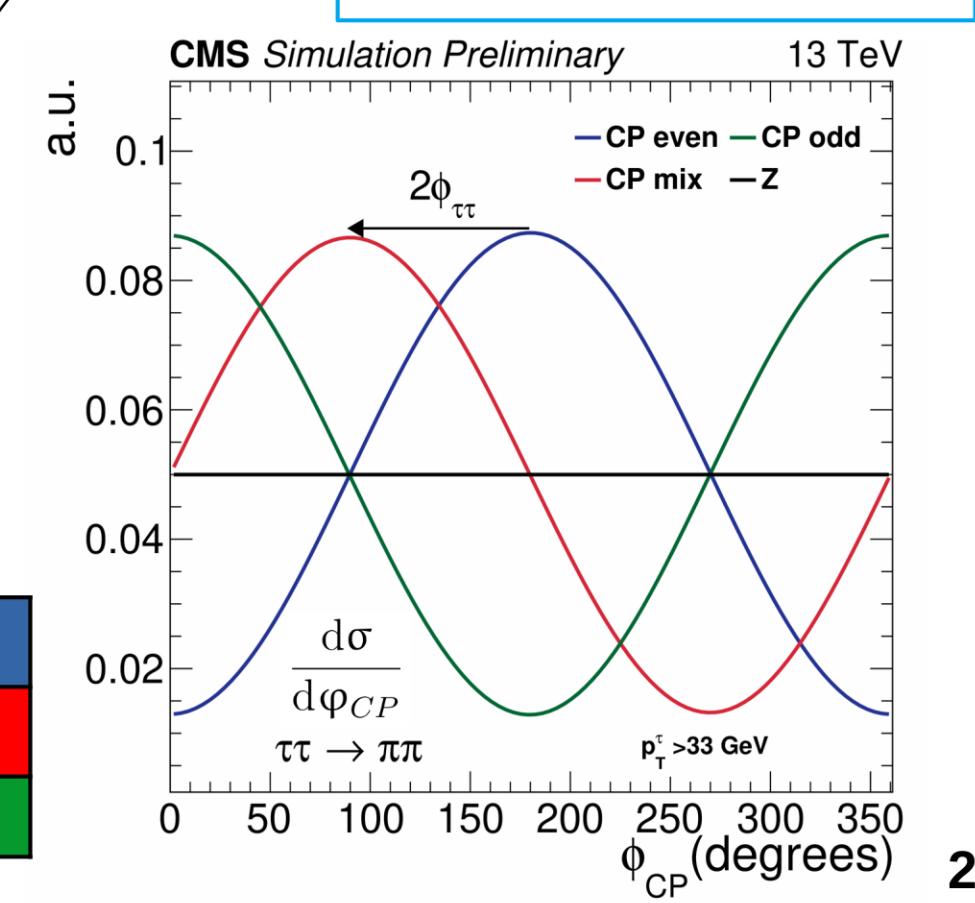
$$\frac{d\sigma}{d\phi_{CP}} \propto \text{const} - \cos(\phi_{CP} - 2\phi_{\tau\tau})$$

CP mixing angle

$$\mathcal{L}_{Y,\tau} = -\frac{m_\tau}{v} \bar{\tau} (\kappa_\tau + i\gamma^5 \tilde{\kappa}_\tau) H \tau$$

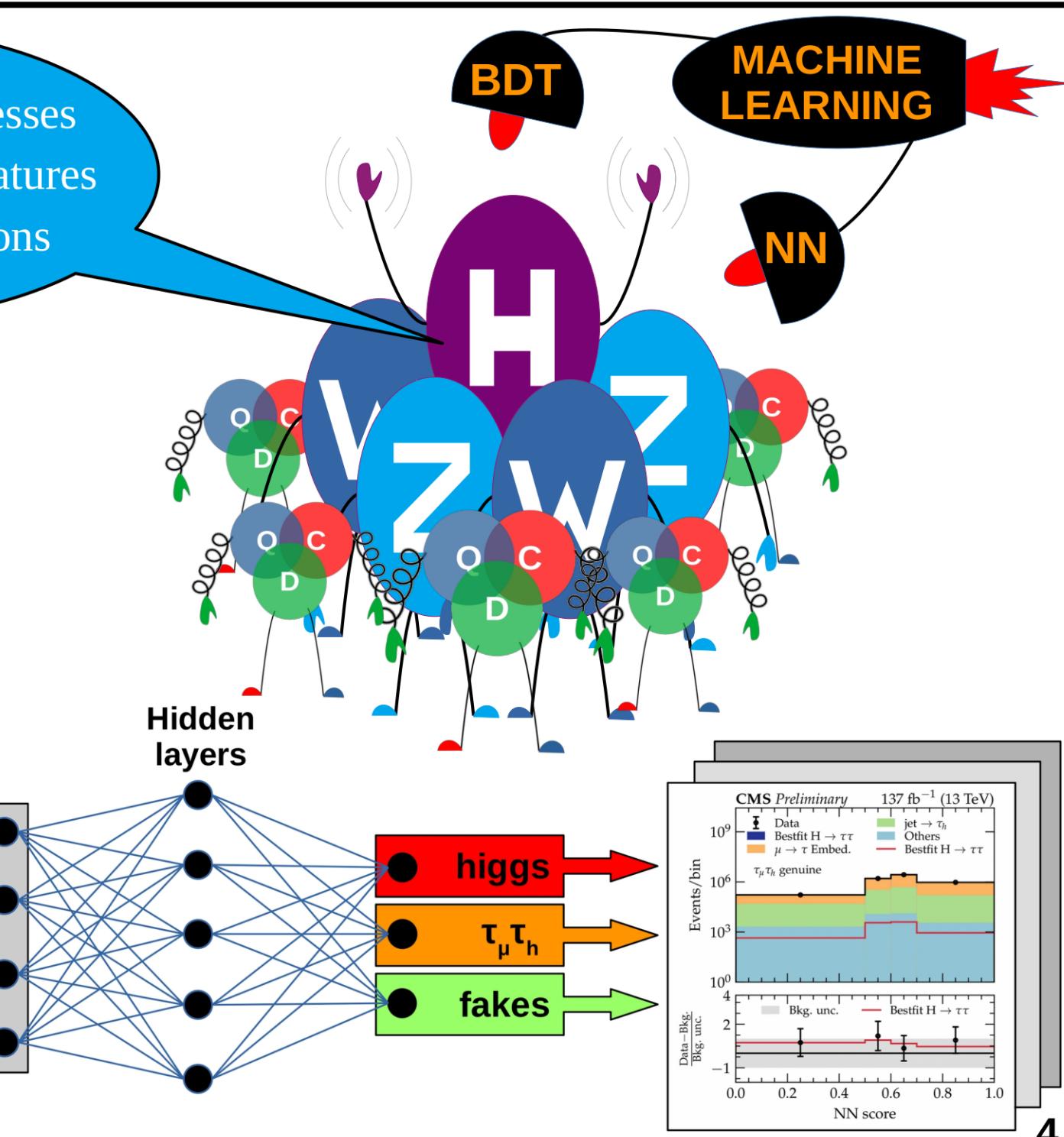
$$\kappa_\tau = \sqrt{\mu^{\tau\tau}} \cos(\phi_{\tau\tau})$$

$$\tilde{\kappa}_\tau = \sqrt{\mu^{\tau\tau}} \sin(\phi_{\tau\tau})$$



At the LHC many processes can produce similar signatures to my decays to τ leptons

BDT and neural network can help in identifying me

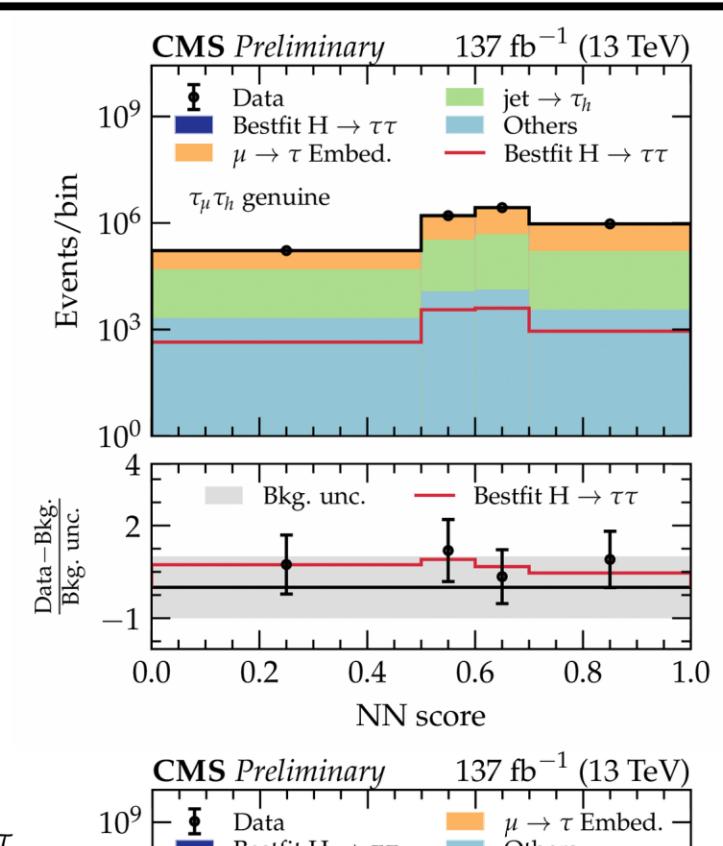


Machine learning tools¹ can be used to identify the Higgs decays from dominant backgrounds:

- Genuine di-tau production
- Lepton/jets faking τ_h

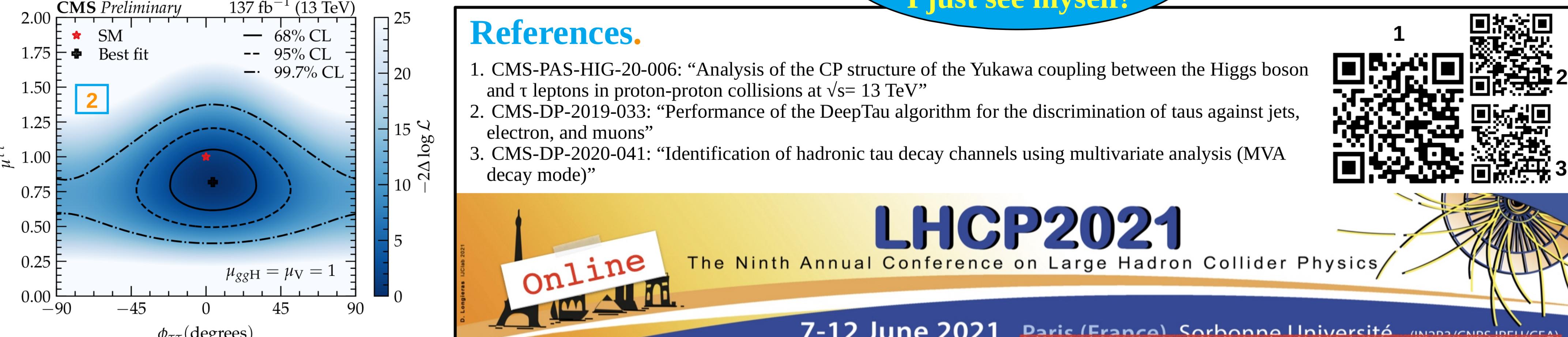
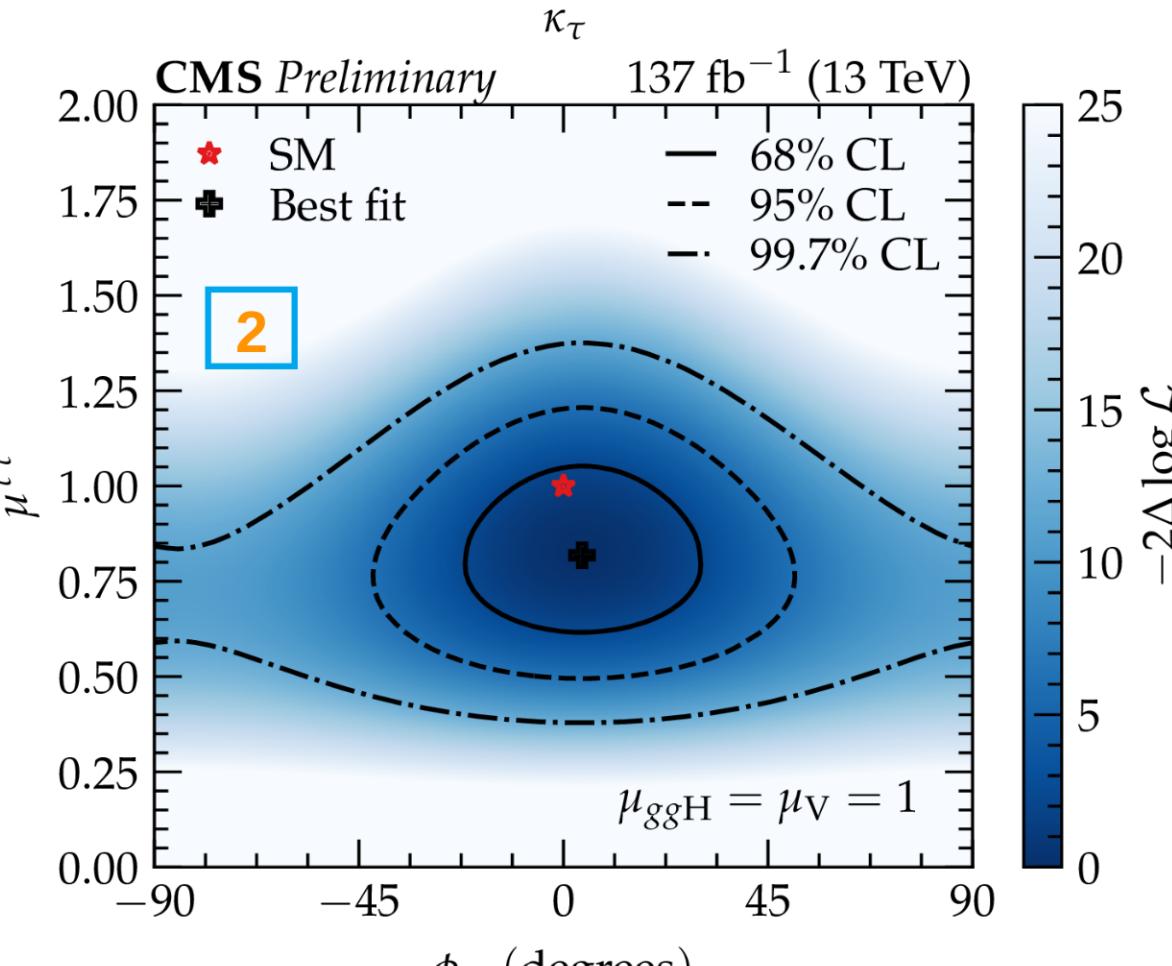
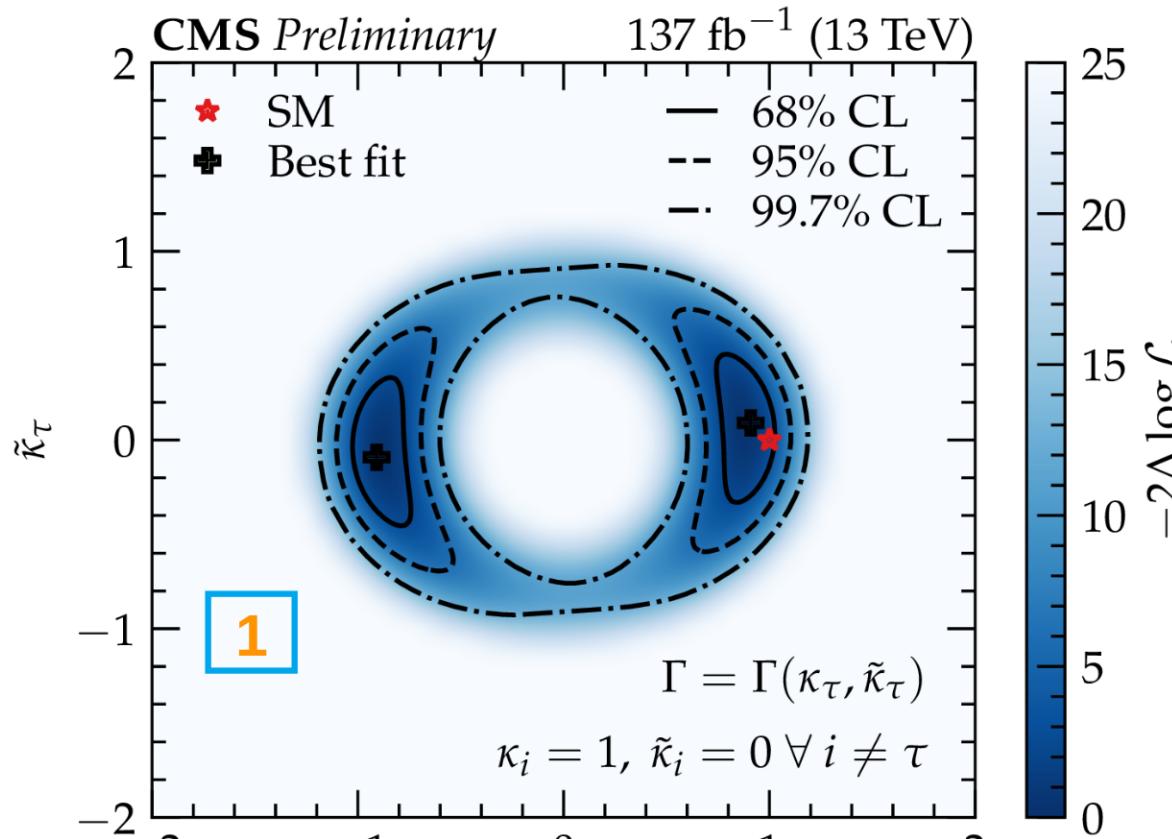
Simultaneous fit of signal and background models to data for:

- 3 years of data-taking: full Run 2
- Genuine $\tau_\mu \tau_h$ / $\tau_h \tau_h$ categories
- Leptons/jets faking τ_h backgrounds
- Signal category split by τ decay channel



Likelihood profiled¹ wrt:

1. Yukawa couplings
2. CP mixing angle+signal strength
3. CP mixing angle



References.

1. CMS-PAS-HIG-20-006: "Analysis of the CP structure of the Yukawa coupling between the Higgs boson and τ leptons in proton-proton collisions at $\sqrt{s} = 13$ TeV"
2. CMS-DP-2019-033: "Performance of the DeepTau algorithm for the discrimination of taus against jets, electron, and muons"
3. CMS-DP-2020-041: "Identification of hadronic tau decay channels using multivariate analysis (MVA decay mode)"

LHCP2021

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