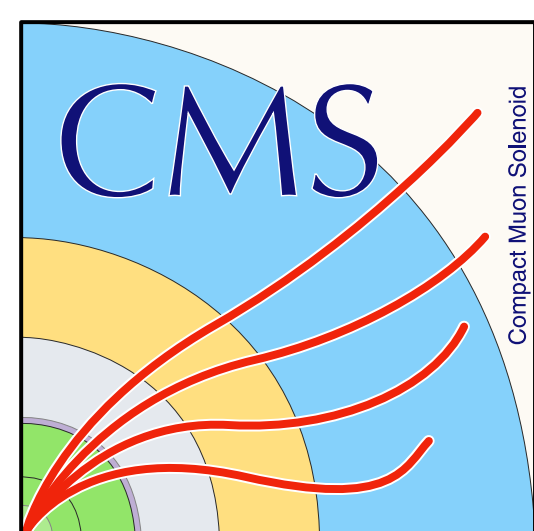


CP Structure of the Higgs-Tau Yukawa Coupling and CMS Phase II Outer Tracker Upgrade



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¹Deutsches Elektronen-Synchrotron DESY

Probing Higgs CP nature

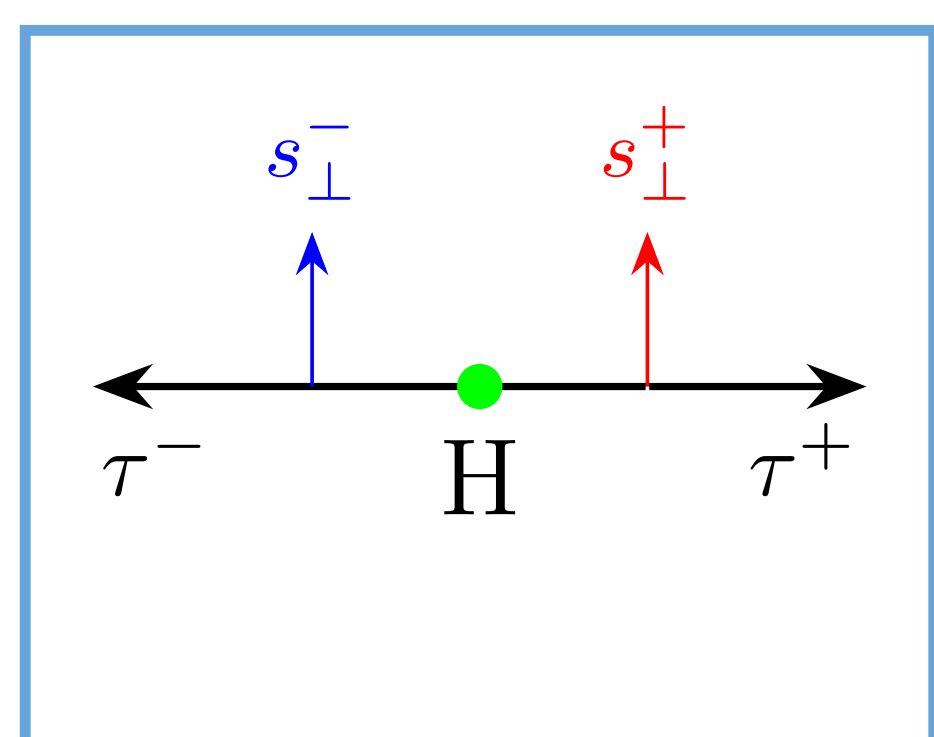
The Standard Model H-boson is **CP-even**, while **CP-odd** admixture is still allowed, so the Yukawa part of Standard model Lagrangian is:

$$\mathcal{L}_Y = \frac{m_\tau}{\nu} (\tilde{\kappa}_\tau \bar{\tau} \tau + \tilde{\tilde{\kappa}}_\tau \bar{\tau} i \gamma_5 \tau) H.$$

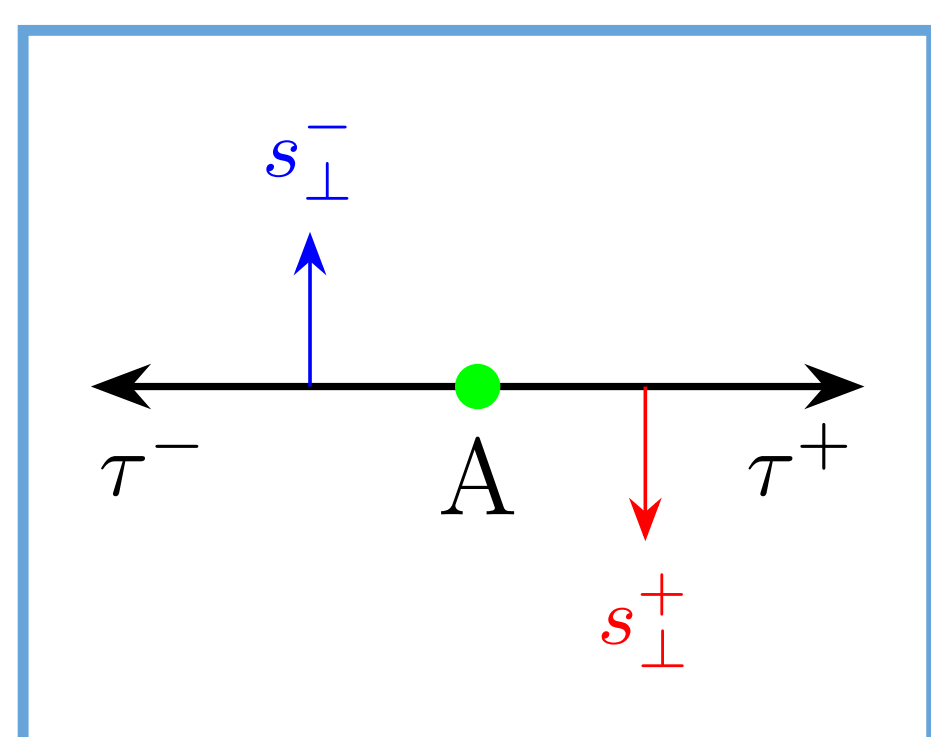
The ratio between **CP-odd** and **CP-even** coupling constants define CP-mixing angle:

$$\tan \alpha^{H\tau\tau} = \tilde{\tilde{\kappa}}_\tau / \tilde{\kappa}_\tau.$$

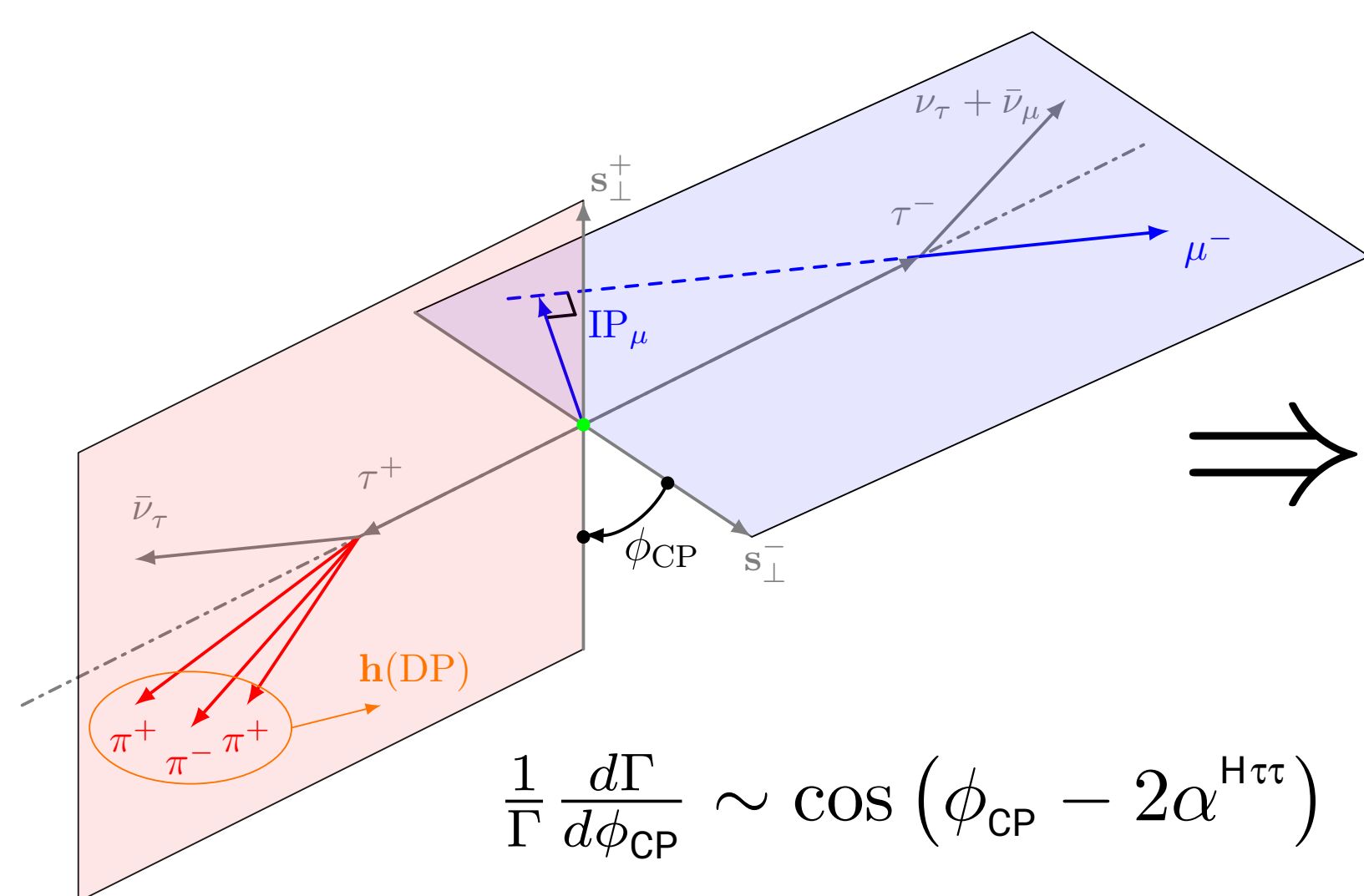
Experimentally at the LHC $\alpha^{H\tau\tau}$ can be accessed through **spin correlations** of the tau leptons.



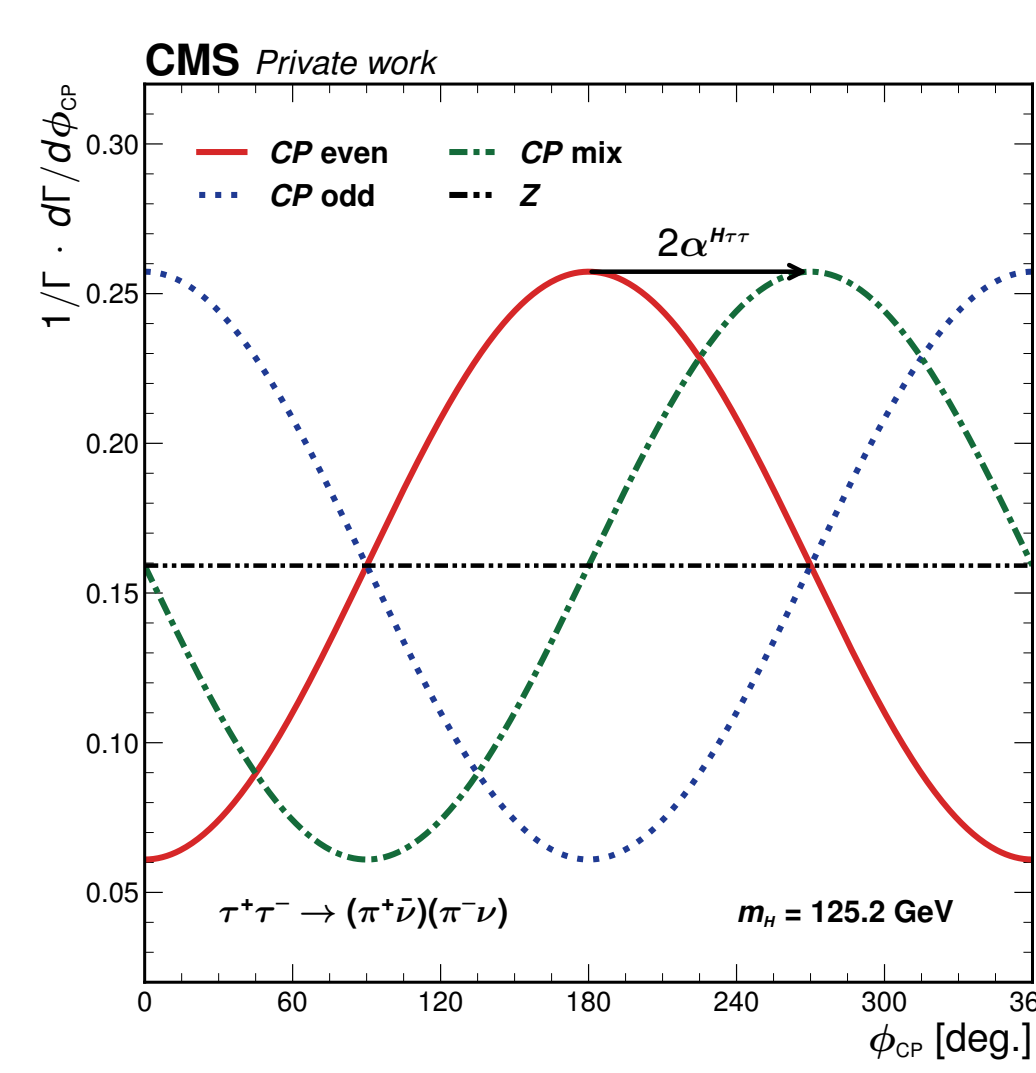
CP-even Higgs $\Rightarrow \alpha^{H\tau\tau} = 0^\circ$.



CP-odd Higgs $\Rightarrow \alpha^{H\tau\tau} = 90^\circ$.



Definition of the ϕ_{CP} angle using tau decay planes.



ϕ_{CP} distributions for different CP scenarios.

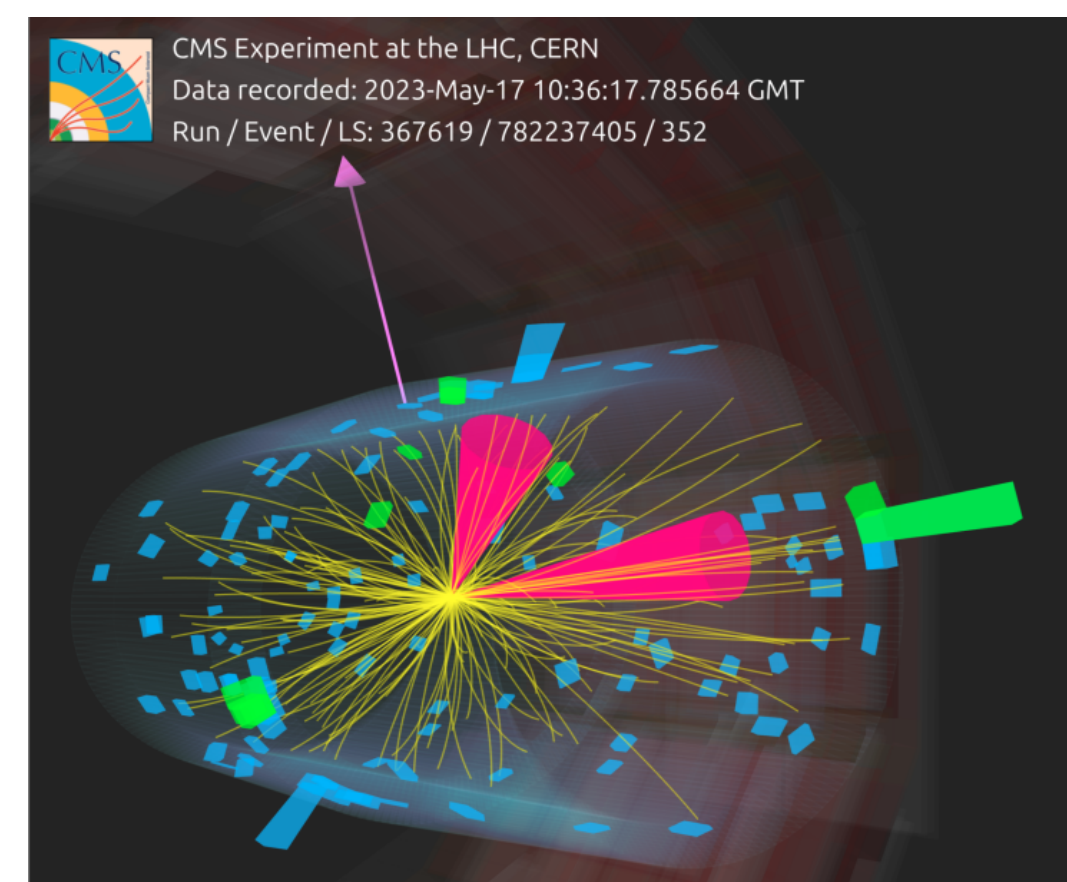
Tau decay products give the access to the tau spin correlations through the **polarimetric vector**:

$$d\Gamma[\tau \rightarrow X \nu_\tau] \sim 1 + \mathbf{h}(X) \cdot \mathbf{s}.$$

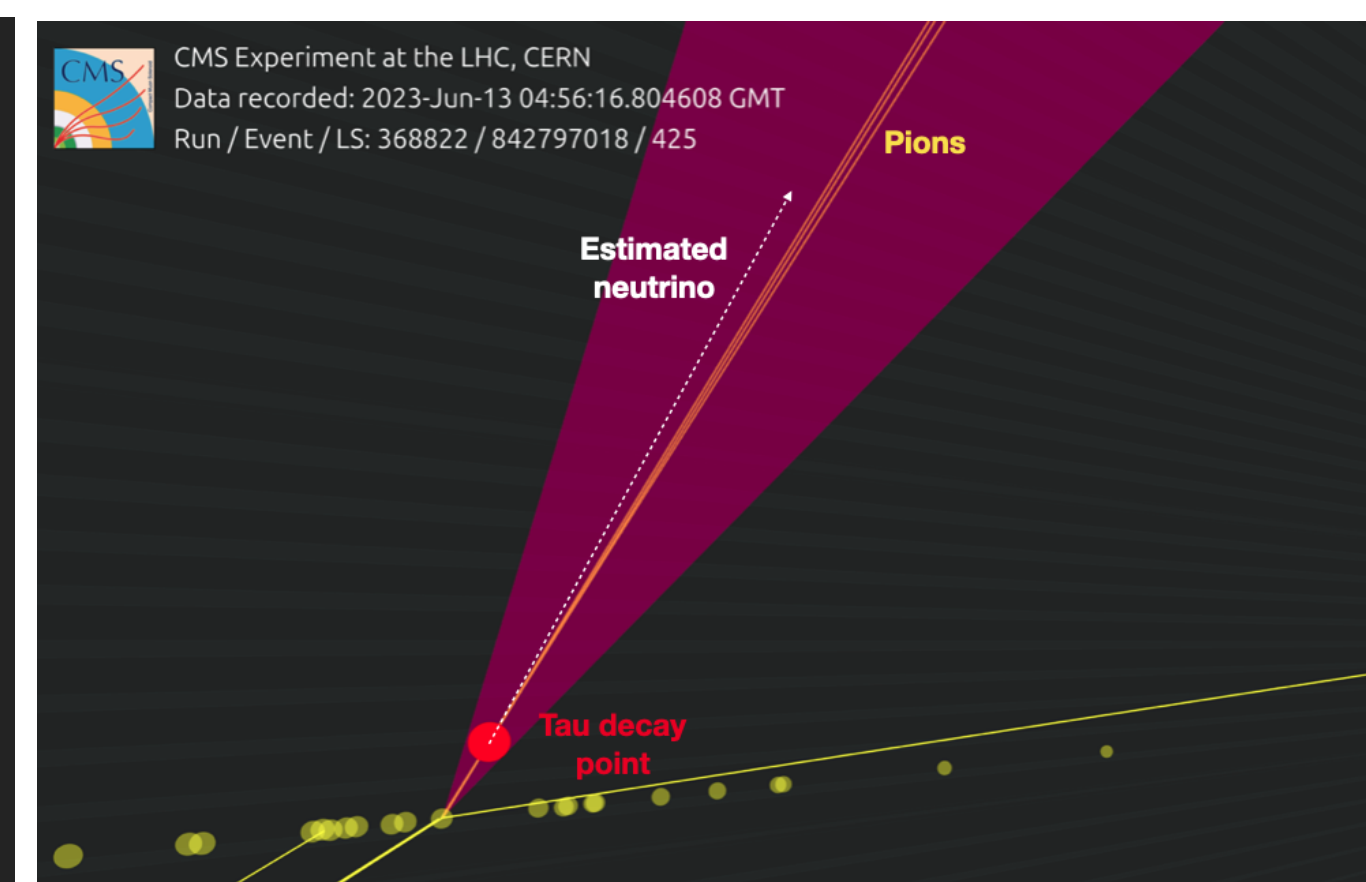
H $\rightarrow \tau\tau$ CP analysis at CMS

The analysis is performed using 62.4 fb⁻¹ of 13.6 TeV Run 3 data (2022–23) in the $\mu\tau_h$, $e\tau_h$, and $\tau_h\tau_h$ channels, with a fit to ϕ_{CP} in bins of a multiclass BDT score.

Event reconstruction

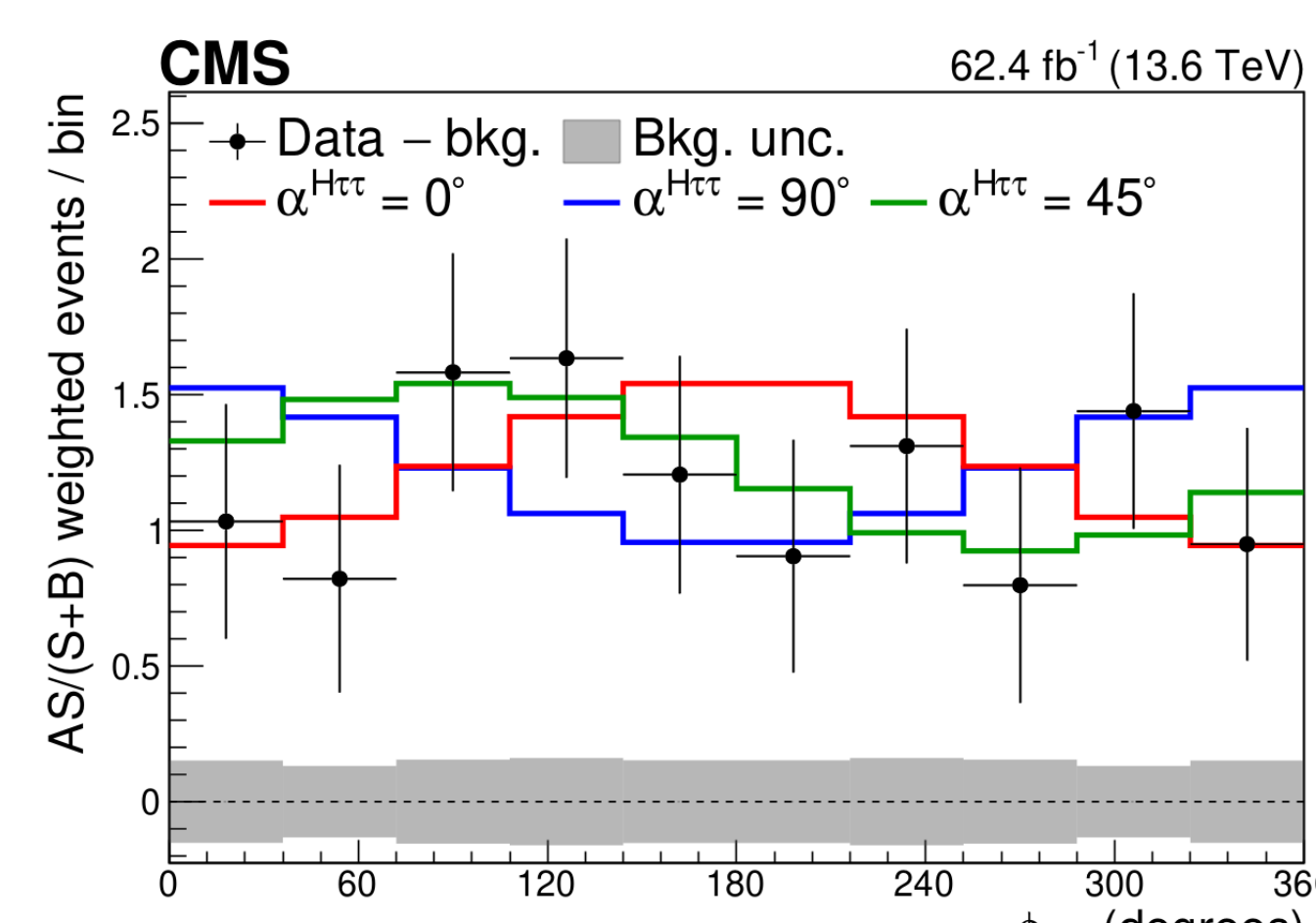


Candidate event for H $\rightarrow \tau\tau$ decay recorded by CMS.

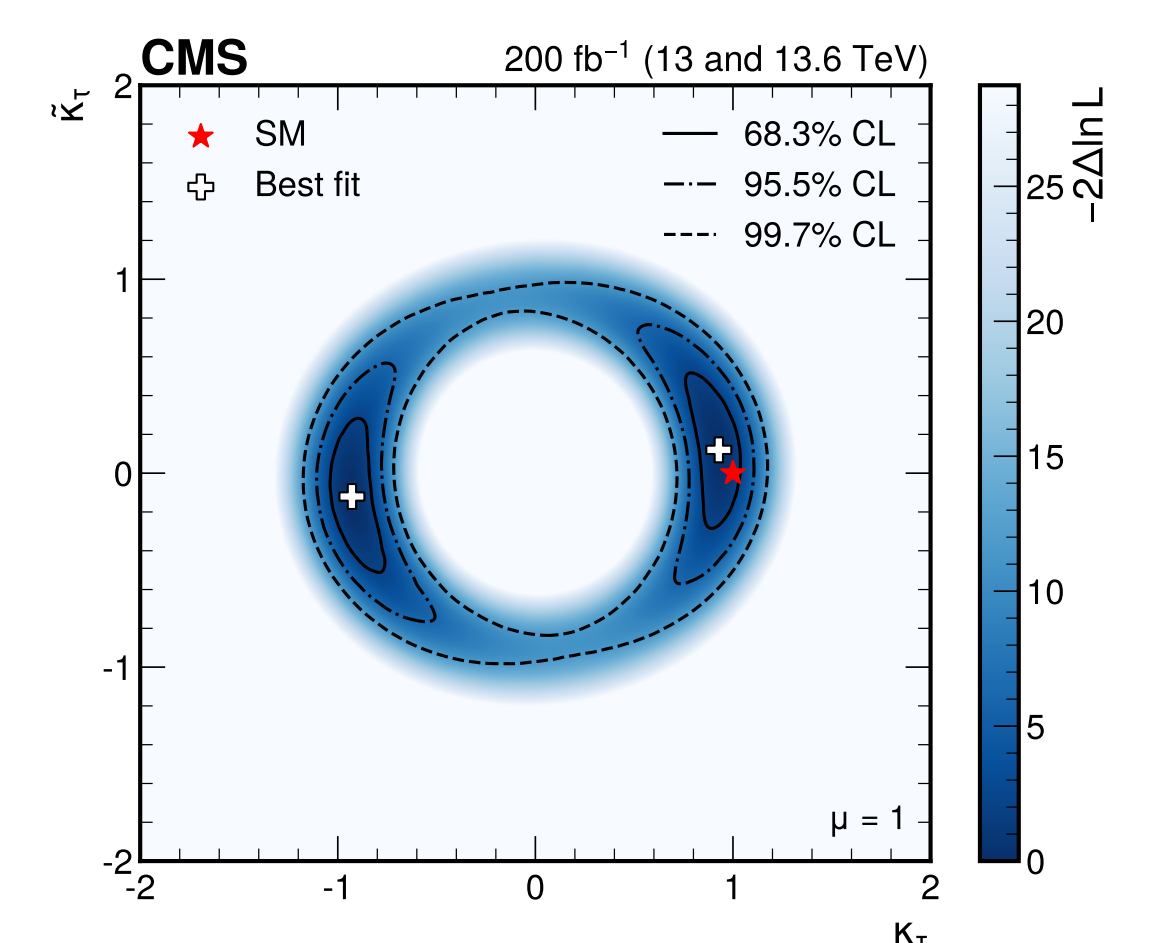


Decay of tau lepton illustrating the tau decay point, where the three pion trajectories originate from.

Results



ϕ_{CP} angle distributions for the Run 3 data (top) and Run 2 + Run 3 combined (bottom).

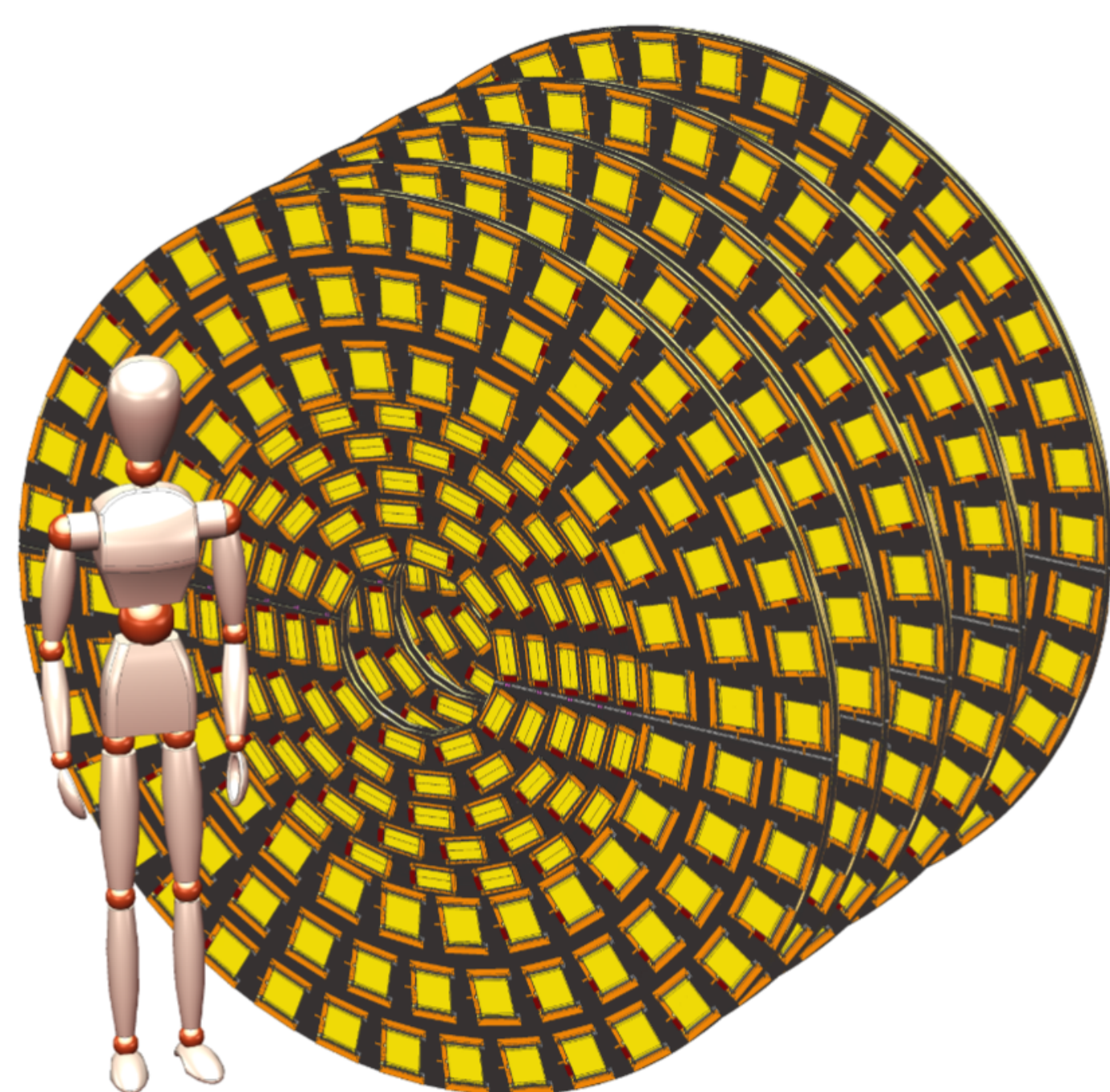
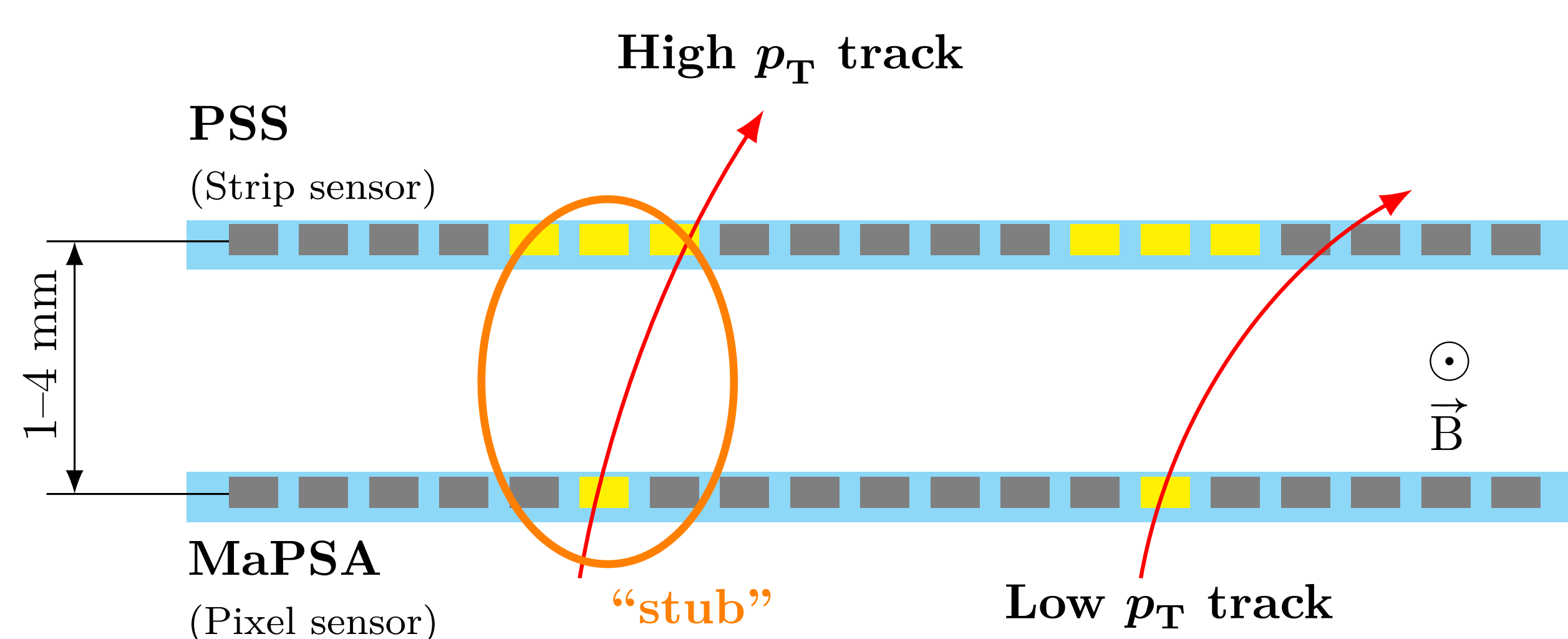
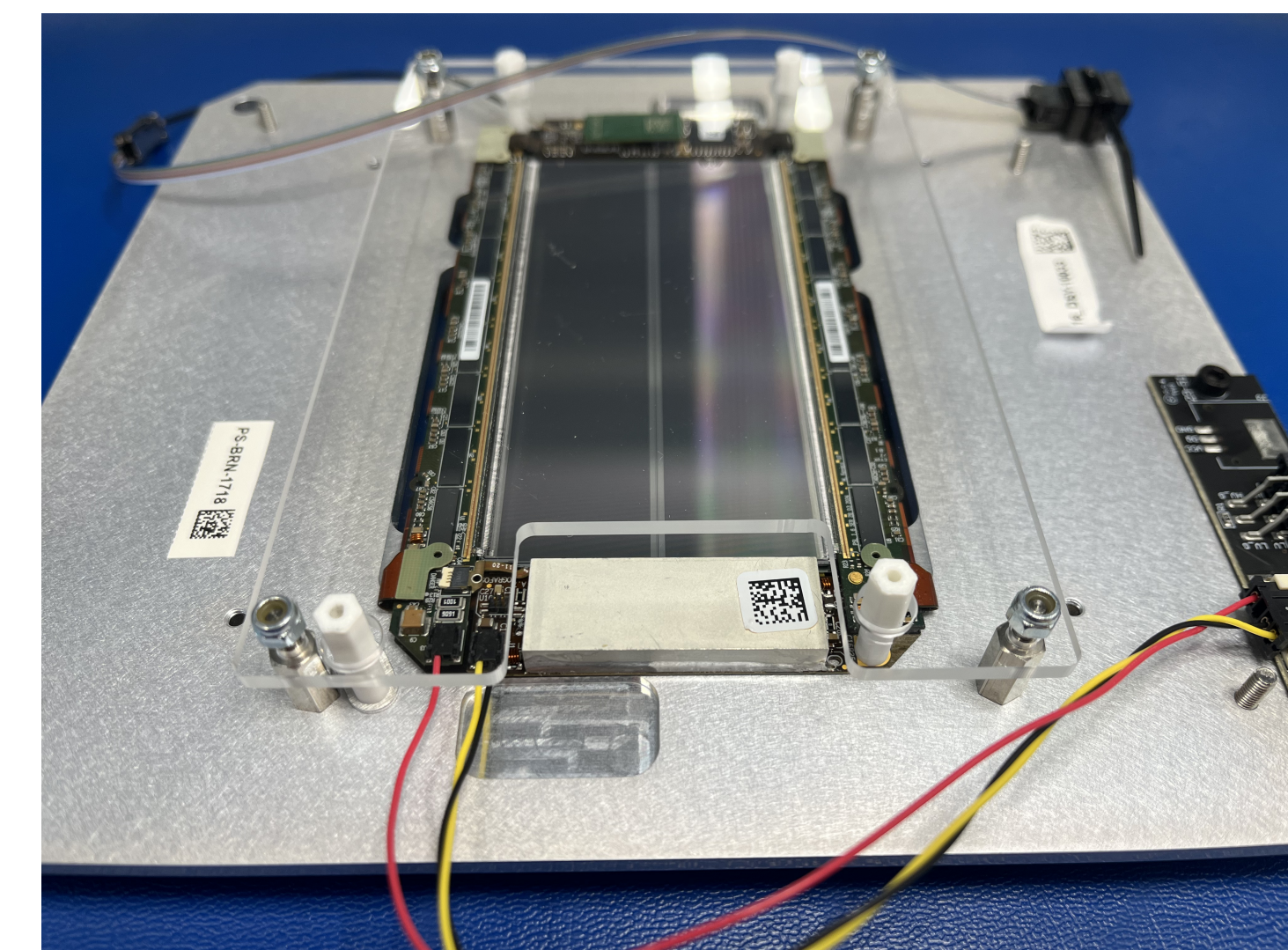


Observed scan of $-2 \Delta \ln L$ for the CP-odd $\tilde{\kappa}_\tau$ coupling against the CP-even (κ_τ) coupling for Run 2 + Run 3 combined.

- ⊗ Observed $\alpha^{H\tau\tau} = (36^{+33}_{-30})^\circ$, expected $(0 \pm 19)^\circ$
- ⊗ Expected exclusion of pure CP-odd: 2.8σ with 62.4 fb⁻¹, vs 2.6σ for Run 2 with more than twice the data
- ⊗ Run 2 + Run 3 combined: $\alpha^{H\tau\tau} = (7 \pm 16)^\circ$, expected $(0 \pm 14)^\circ$

This is the most precise CMS result on Higgs-tau Yukawa coupling measurement and the best expected precision of any experiment.

Phase II Upgrade of the CMS Outer Tracker at DESY



Status and Activities:

- ⊗ Automated assembly of PS modules happening at maximum throughput
- ⊗ The first batch of full modules with new bPOL_fx1 ASIC was assembled
- ⊗ All half-disks arrived to DESY, successfully passed all QC tests, and ready for the modules integration
- ⊗ First integration exercise at DESY successfully completed!

