Higgs searches in $t\bar{t}\phi$ production at the LHC

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Why we **care**

New scalars, both light and heavy, **predicted by several SM extensions**. **Dedicated searches** for these scalars must be prepared and improved.

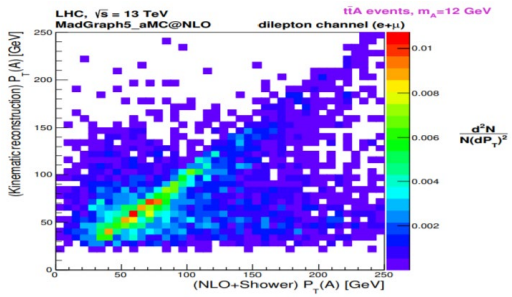
Discovered Higgs is **not a pure pseudoscalar,** but **mixed CP-states** are still possible. Additional **CP-violation**, needed to explain **matter-antimatter asymmetry.**

Higgs CP nature is of utmost importance. Can be directly probed in **scalars production alongside top-quarks**. $H \to \gamma\gamma$ in $pp \to t\bar{t}H$, **upper limit for CP-mixing angle of 43º.**

What we **did**

Studied sensitivity to **new scalars (ϕ) with generic couplings** to top quarks in **$t\bar{t}\phi$**, **$\phi \to b\bar{b}$** (in the dileptonic channel). Mass region: **12-500 GeV**.

$$\mathcal{L} = \kappa_t y_t \bar{t}(\cos\alpha + i\gamma_5 \sin\alpha)t\phi = y_t \bar{t}(\kappa + i\tilde{\kappa}\gamma_5)t\phi$$



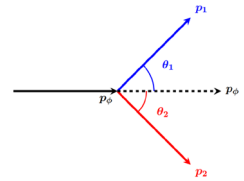
Selection cuts: at least 2 charged leptons and 4 jets with $p_T \geq 20$ GeV, $|\eta| \leq 2.5$, $|m_{l^+l^-} - m_Z| > 10$ GeV and 3 b-tagged jets.

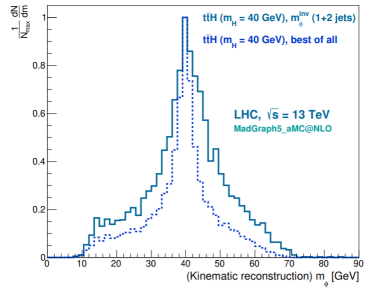
Reconstruction: boosted decision trees to match b-jets and charged leptons + kinematic fit to reconstruct neutrinos. **Backgrounds:** $t\bar{t}$ + 3 jets, $t\bar{t}V$ + jets, single top, V + jets, VV + jets (V = W, Z), $t\bar{t}b\bar{b}$ and $t\bar{t}H^{SM}$.

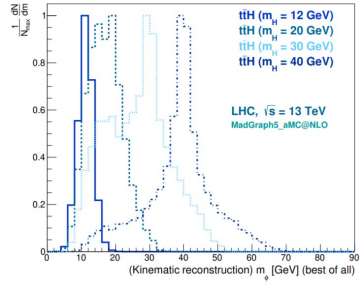
What we **found**

Low mass regime (12-40 GeV), jets from ϕ decay overlap. Previous analysis lose sensitivity. **New Higgs reconstruction method** (best of all) allows to explore this regime and **improves Higgs mass resolution by factor of two.**

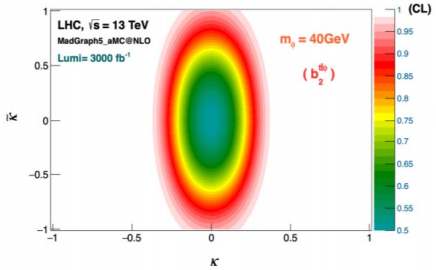
$$m_\phi^{(1)} = p_1 \sqrt{2\frac{\sin\theta_1}{\sin\theta_2}\left(1 - \cos(\theta_1 + \theta_2)\right)}$$

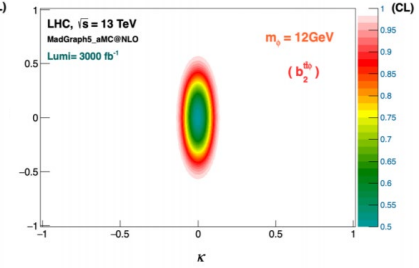






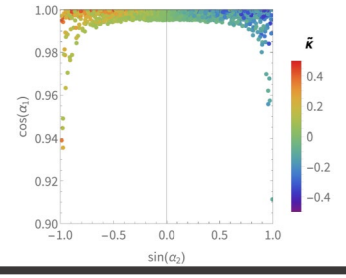
Confidence levels (CLs) for the **exclusion of the SM with a new Higgs boson ϕ, assuming the SM** hypothesis. For $m_\phi > 200$ GeV, CP-searches require the inclusion of additional channels.

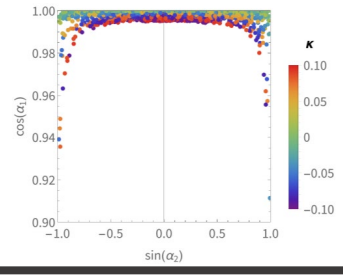


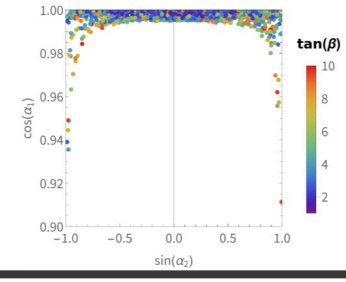


$L = 3000\,\text{fb}^{-1}$		Exclusion Limits from $b_2^{t\bar{t}\phi}$ (68% CL)	(95% CL)
$m_\phi = 12$ GeV	$\kappa \in$	[-0.05, +0.05]	[-0.11, +0.11]
	$\tilde{\kappa} \in$	[-0.26, +0.26]	[-0.50, +0.50]
$m_\phi = 20$ GeV	$\kappa \in$	[-0.07, +0.07]	[-0.13, +0.13]
	$\tilde{\kappa} \in$	[-0.26, +0.26]	[-0.49, +0.49]
$m_\phi = 30$ GeV	$\kappa \in$	[-0.07, +0.07]	[-0.14, +0.14]
	$\tilde{\kappa} \in$	[-0.26, +0.20]	[-0.50, +0.50]
$m_\phi = 40$ GeV	$\kappa \in$	[-0.17, +0.17]	[-0.32, +0.32]
	$\tilde{\kappa} \in$	[-0.53, +0.53]	[-1.00, +1.00]

Benchmark model: **complex two-Higgs-doublet model (C2HDM)**. Limits for κ and κ̃ constrain parameter space of C2HDM: $\cos\alpha_1 \approx 1$, but **CP-violating angle α_2 remains unconstrained.**







Acknowledgments

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