





Searches for Higgs exotic decays and additional (pseudo)scalars at CMS $% \left(\mathcal{M}_{n}^{2}\right) =0$

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Focus here on exotic Higgs decays with pseudoscalar, $H \rightarrow aa$, as well as direct searches for new (pseudo)scalars in CMS.

Lots of analyses could be covered in this talk \implies a personal choice is made:

- $H \rightarrow aa \rightarrow \gamma \gamma \gamma \gamma \gamma$ search with full Run 2 data CMS-PAS-HIG-21-003 (NEW)
- $H \rightarrow aa \rightarrow \mu\mu bb$ search with 2016 Run 2 data CMS-HIG-18-011, PLB 795 (2019) 398
- $H \rightarrow aa \rightarrow \mu\mu\tau\tau$ search in boosted regime with 2016 Run 2 data CMS-HIG-18-024, JHEP 08 (2020) 139
- Low-mass $h \to \gamma \gamma$ search with 2016 Run 2 data CMS-HIG-17-013, PLB 793 (2019) 320

Other, high mass, searches for additional Higgs bosons at CMS covered in Mariarosaria D'Alfonso's talk.

But there are lots of exciting analyses that you should look at ($H \rightarrow aa \rightarrow 4\mu$, $H \rightarrow aa \rightarrow \mu\mu\tau\tau$, $H \rightarrow aa \rightarrow 4\tau$, ...) following this link

Exotic decays $H \rightarrow aa$

Introduction to $H \rightarrow aa$ decays in CMS

Exotic decay of H to light pseudoscalars predicted by many BDM theories



Search for various final states in CMS: • $H \rightarrow aa \rightarrow bbbb$

- $H \rightarrow aa \rightarrow \mu\mu bb$
- $H \rightarrow aa \rightarrow \tau \tau \tau \tau$
- H
 ightarrow aa ightarrow bb au au

- H
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- $H \rightarrow aa \rightarrow \mu\mu\mu\mu$
- $H \rightarrow aa \rightarrow \gamma \gamma \gamma \gamma \gamma$ (Full Run 2 data)

$H \rightarrow aa \rightarrow \gamma \gamma \gamma \gamma \gamma$ search with full Run 2 data (NEW)

Exotic decay of the Higgs into a BSM pseudoscalar a decaying into 2 γ



Model independent analysis focus on final state with fully resolved photons \Longrightarrow

- * Both photon pairs have wide opening angle
- * photons reconstructed separately
- * $m_a \in [15, 60]$ GeV.

Interesting because:

- Coupling of a to fermions can lower $BR(a \rightarrow \gamma \gamma)$, but low background in 4 γ FS ($\gamma\gamma$ +jets, γ +jets and multijets)
- In some models, a may only decay into photons

Search for light pseudoscalars with $\geq 3\gamma$ events performed by ATLAS for Run 1 (EPJC 76 (2016) 210); first CMS search presented here.



See the poster by Tanvi Wamorkar for more details on this analysis

BDT

- Used to distinguish signal from $\gamma\gamma\gamma\gamma$ background
- Exploits the identification and kinematic information of γ and a candidates
- Data driven description of background obtained by mixing photons between events (only used for training)
- Output is uniform and sensitive to full m_a range thanks to interpolation of signal and using m_a^{hyp} as input
- BDT score is evaluated separately for each m_a



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Categorization

- * Events are categorized according to the MVA output score
- * Selection on BDT score optimized by maximizing a given fom over all possible categories in region 115 < $m_{\gamma\gamma\gamma\gamma\gamma} < 135 \text{ GeV}$
- * Only 1 category based on BDT output for each *m*_a



Signal parametrization

Signal model built from MC for each nominal m_a value:

- Modelled using double sided crystal ball function
- Scaled to expected number of events



Background parametrization

Bkg model built from data with the 3 years merged for each nominal m_a value:

- * Choice of background using Envelope method
- * Variety of functions considered: Bernstein polynomial, Exponential, Laurent, Power Law
- * Treats the choice of background pdf as a discrete nuisance parameter

Signal and Background parametrization (NEW)

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Exclusion limits (NEW)

Results

Set model independent limits (95 % CL) on $\sigma(pp \to H)BR(H \to aa)BR(a \to \gamma\gamma)^2$ with unbinned maximum-likelihood fits for each m_a hypothesis :



Observed limits are in agreement with the expected limits and within two standard deviations of expected limit.

The limits are the best provided in this channel. Analysis statistically limited.

$H \rightarrow aa \rightarrow \mu\mu bb$ search with 2016 Run 2 data

Strategy

- * a
 ightarrow bb has a large BR
- * Focusing on $m_a \in [20, 62.5]$ GeV
- * Uses 2016 data PLB 795 (2019) 398
- * Uses double muon trigger paths
- * Exclusive categorization based on the b-tagging to improve sensitivity
- * Signal parametrized by Voigtian function + Crystal Ball
- * Background modelled on data via the envelope method





Results

- * Observed limits are in agreement with the expected limits
- better sensitivity is achieved (between 1.4 and 1.8) using improved analysis techniques in Run II

$H \rightarrow aa \rightarrow \mu\mu\tau\tau$ search in boosted regime with 2016 Run 2 data

Strategy

- For $m_a < 2 \, m_b, \, BR(a
 ightarrow au au)$ dominates
- Uses $\tau_h \tau_\mu$ final state
- Focusing on $m_a \in [3.6, 21]$ GeV
- Uses 2016 data JHEP 08 (2020) 139
- H can be $m_H = 125$ GeV or $m_H = 300$ GeV



- Uses a simultaneous fit between three regions depending on isolation variables
- Signal parametrized by a sum of Voigtian function for m_{μμ} and Double-sided Gaussian for m_{μμττ}



Results



Low-mass $\textbf{h} \rightarrow \gamma \gamma$ search

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* Analysis \sim close to the standard $H \rightarrow \gamma \gamma$ measurement analysis but with extra differences : modelling of Drell-Yan $Z \rightarrow ee$ component near 90 GeV and low-mass triggers.

* Latest public results are with 2016 data 10.1016/j.physletb.2019.03.064:



* No significant excess observed with respect to expectations; one local excess of 2.8 sigma at m_H =95.3 GeV.

Full Run 2 results in progress. 13/14

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• Some selected Higgs boson exotic decays into pseudoscalars as well as a direct scalar search in CMS have been presented here

• Presented the $H\to aa\to\gamma\gamma\gamma\gamma\gamma$ new search (CMS-PAS-HIG-21-003) that just became public

• Showed a selection of other interesting analyses

• Stay tuned for the full Run 2 data results !

Thanks for your attention !

Backup