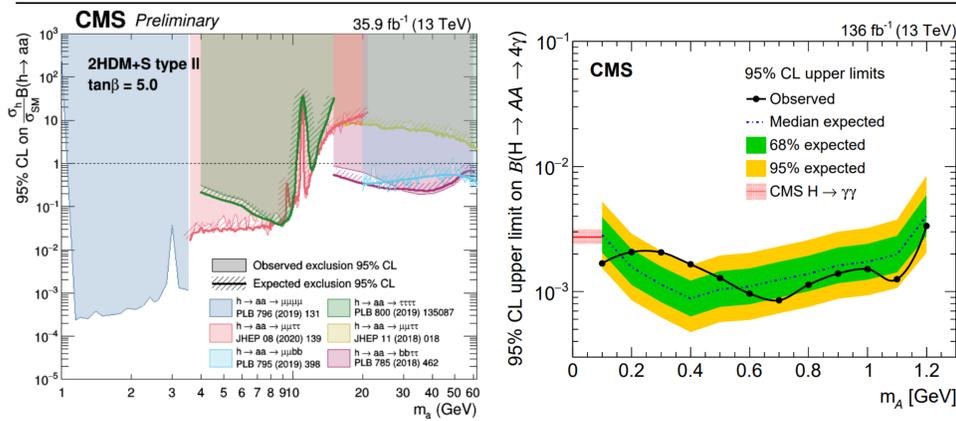# Search for light neutral bosons pair-produced in the Higgs boson decays in the four-electron final state in proton-proton collisions at $\sqrt{S}$ = 13 TeV

Yipin Wang (Peking University) on behalf of the CMS Collaboration

Motivation

Physics

- Most CMS searches target Higgs decays to ALPs with masses of tens of GeV
- The lightest ALP probed so far, via the diphoton channel, is $\mathcal{O}(100\ \mathrm{MeV})$

Technical (Reference: JHEP05(2021)138)

- Tens-of-MeV ALPs can decay within the tracker ($\beta\gamma c\tau_a \approx 1.65$ cm)
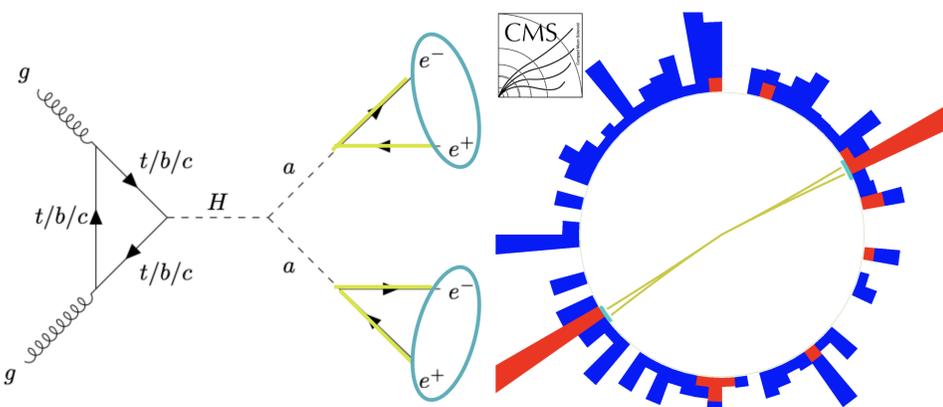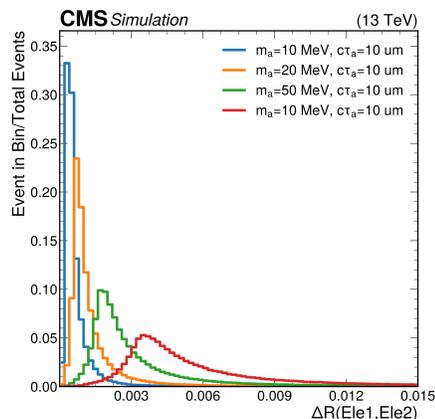- The e^+e^- pair from ALPs decay can be spatially resolved, enabling reconstruction

For tens-of-MeV ALPs, the only kinematically allowed SM final states are e^+e^- and $\gamma\gamma$. Photon channel reaches $\sim$100 MeV, while electron channel can probe lower masses due to superior tracker resolution

Signal

Search for $H \to aa \to 4e$:

Sample Setting

- Run2 (138 fb^{-1}, $\sqrt{S}$=13TeV)
- Higgs production: Gluon fusion
- m_a: 10, 20, 50, 100MeV
- $c\tau_a$: 1, 3, 10, 30, 100, 500um

Signal Signature

- Electron pair from ALP decay: $\Delta R < 0.015$
- Tracks of electron pair resolved, but ECAL SuperCluster merged
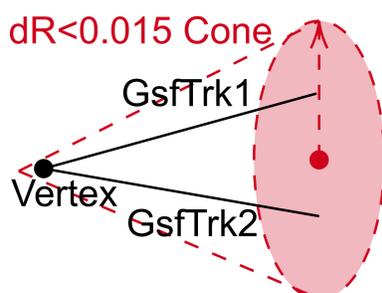
Selection

1. Merged Electron Pair Reconstruction

- $N_{miss\ hits}^{trk} < 2$, $p_T^{trk} > 5$ GeV, $p_T^{SC} > 25$ GeV
- 2 trks: $\Delta R(SC, trk) < 0.015$, $\frac{|p_T^{SC} - Sum(p_T^{trk})|}{p_T^{SC}} < 0.7$
- Vertex(2 trks): $\chi^2 < 5$

2. Merge Electron Pair Identification

- Iso Variables(Trk, ECAL, HCAL) Cuts
- Boosted Decision Tree(BDT) Selection
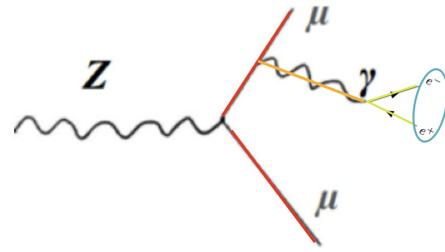
3. Reconstruct m_H from top-2 p_T selected MEPs

Overall signal efficiency after all three selection steps: $\sim$5%

Calibration

Tag and Probe to Calibrate MEP ID

- Process: $Z \to \mu\mu\gamma$
- Tag: Muon pair $\to$ providing pure phase space
- Probe: Converted FSR photon as MEP
- Pass Criteria: The MEP pass the ID requirements

Calibration Scale Factors

- Efficiency = N_{pass}/N_{probe}; SF = $\epsilon^{Data}/\epsilon^{MC}$
- Uncertainties: Statistical(Below table) + 10%(Systematic) + 5%(Kinematics)

Era	2016preVFP	2016postVFP	2017	2018
SFs	1.28 ± 0.40	1.10 ± 0.26	0.99 ± 0.14	1.04 ± 0.15

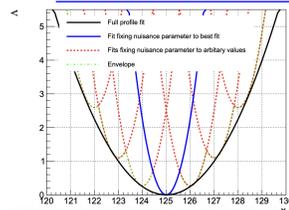Calibration yields Scale Factors close to 1, verifying the MEP ID

Modeling

Resonance Modeling

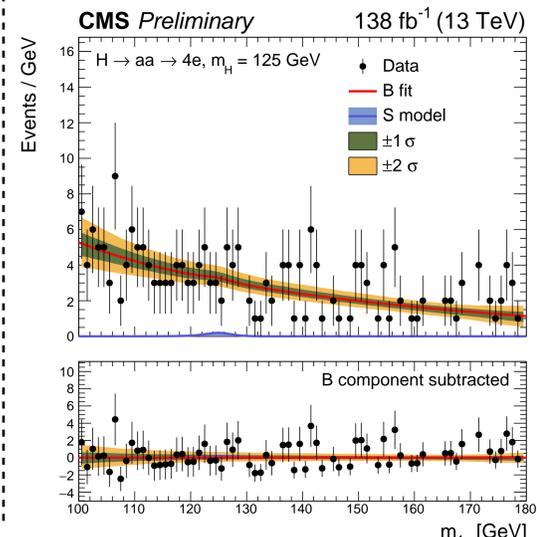| Sample	$\sigma(ggH)\times BR$/fb	Efficiency
ggH$\to aa \to 4e$	0.5(Nominal)	$\sim$5%
ggH$\to \gamma\gamma$	110	4.4×10^{-5}
ggH$\to ee\gamma$	3.93	5.4×10^{-4}

- Function: DCB+Gaussian or 5-Gaussian

Non-Resonance Modeling

- Build model with data in sideband
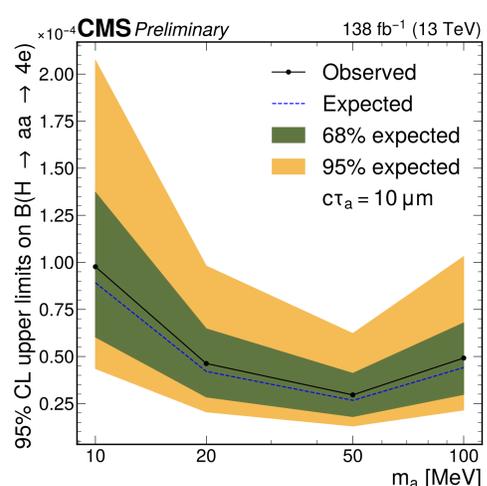- Function: bern, exp, pow, lau
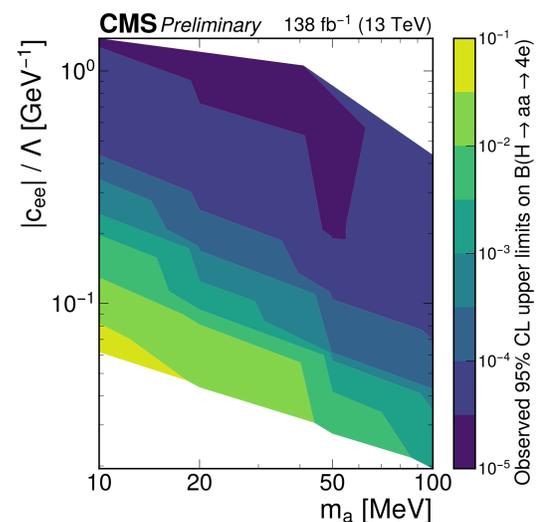- Envelope: JINST10(2015)P04015

S+B Post-fit Plot:

Results

Translation: $\frac{C_{ee}}{\Lambda} = \sqrt{\frac{8\pi}{\tau_a m_e^2 m_a \sqrt{1 - \frac{4m_e^2}{m_a^2}}}}$ (Reference: PRL.119,031802(2017))

10um ALPs Limits

Results Interpretation

First CMS Limits on tens-of-MeV ALPs:

- No excess beyond SM found, Limits reach $\mathcal{O}(10^{-5})$
- New constraints on the theoretical couplings governing ALPs

Future:

Future LHC data and CMS detector upgrades, together with advanced analysis techniques, will enhance searches for rare Higgs decays and extend CMS's reach into light, weakly-coupled sectors beyond the Standard Model