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BRANCHING RATIOS OF H1,2,3->MuMu IN THE BROKEN-PHASE N2HDM

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The discovery of the Higgs boson marked a triumph of the Standard Model, yet fundamental questions remain unanswered: what triggers the electroweak symmetry breaking, why does the Higgs have its observed mass, and are there additional scalar fields? These questions drive the search for an extended Higgs sector where the Next-to-Two-Higgs-Doublet Model (N2HDM) stands as a particularly compelling framework [1]. The N2HDM extends the Standard Model with two Higgs doublets and a real singlet, yielding three CP-even neutral scalars H1 H2 H3, and featuring four distinct Yukawa types (Type 1, Type 2, Type X/Lepton-Specific, Type Y/Flipped) through a softly-broken Z2 symmetry.

While LHC measurements have tightly constrained the properties of the SM-like Higgs (identified as H1) [2], the heavier states H2 and H3 remain largely unexplored. Their decays to di-muon pairs offer a particularly clean experimental signature and sensitive probe of Yukawa couplings, especially in lepton-specific scenarios. We presented the comprehensive analysis of H1 H2 H3 to muon pair branching ratios across all four N2HDM types using constraints from the latest global Higgs data fits.

Using best-fit parameters from a recent global 2analysis of LHC Higgs data and constructing a representative benchmark point for additional Higgs masses [1], we compute BR(H1,2,3+-) across all four Yukawa types. For the SM-like Higgs boson H1 (identified with the 125 GeV resonance), we find branching ratios remarkably consistent with Standard Model predictions:

Type 1: 1.9110-4
Type 2: 1.9210-4
Type X: 2.0510-4
Type Y: 2.1810-4

The calculation respects the unified parameter space of the N2HDM, where all three CP-even Higgs bosons originate from diagonalizing the same 33 mass matrix determined by fundamental parameters 1 8 m1,22 s tan and mixing angles 1 2 3. While the parameters are common, phenomenological constraints differ: H1 is tightly constrained to be SM-like by LHC measurements, while H2 and H3 face only direct search limits, allowing their masses (30-1500 GeV) and couplings greater freedom. For the additional Higgs bosons H2 and H3, we adopt a benchmark with masses mH2=600GeV and mH3=800GeV, total widths tot(H2)=20GeV and tot(H3)=30GeV, and effective couplings taken as midpoints of allowed ranges from global fits. The resulting branching ratios reveal striking type-dependent patterns spanning seven orders of magnitude.

These results exhibit clear patterns reflecting the Yukawa structure of each type:

1. Type 1 and Type Y show consistently small branching ratios (⊠10-7) for H2,3, as muon couplings are tied to up-type quark couplings that remain SM-like under constraints.
2. Type 2 displays enhanced branching ratios (10-6) for both H2 and H3, since muon couplings here are proportional to down-type quark couplings, which can be significantly enhanced while satisfying constraints.

3, Type X (Lepton-Specific) yields the largest H2 branching ratio (4.0310-6), reflecting the possibility of order-of-magnitude enhancements in lepton couplings in this scenario. The H3 value is more moderate due to different mixing patterns.

1. Binjonaid Maien. Confronting the Broken Phase of the N2HDM with Higgs Data. Particles, 8, (2025)
2. ATLAS Collaboration. Evidence for the Dimuon Decay of the Higgs Boson in pp Collisions with the ATLAS Detector. Phys. Rev. Lett. 135, v.135, (2025)

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