

# Short Term Scientific Mission (STSM) Scientific Report

## Models with extended scalar sectors at current and future LHC runs

This report is submitted for approval by the STSM applicant to the STSM coordinator.

Action number: CA15108

STSM Title: Models with extended scalar sectors at current and future LHC runs

STSM start and end date: 10.3.2019 - 30.3.2019

Grantee name: Tania Robens

## 1 Purpose of the STSM

After the discovery of the Higgs boson, is it natural to examine possible extensions of the scalar sector of the Standard Model (SM) of particle physics. The addition of new scalars to the SM allows for interesting new signatures at colliders, as well as a possible interplay with astroparticle physics.

During the STSM, we started to work on a project that discusses an extension of the SM scalar sector by two real scalars. This model exhibits various additional features that are interesting both from a collider and an astrophysical perspective.

The main purpose of the STSM was to initialize a close collaboration between the grantee and Dr. T. Stefaniak, as well as J. Wittbrodt, a PhD student, who are located at the host. The applicants have extensive experience in the setup and investigation of models with extended scalar sectors (see e.g. [A1, 1, 2, A2, A3, A4, A5, A6, 3, A7, A8, A9, 4]). Furthermore, the applicant, together with the senior collaborator at the host institute, is the subconvener on the chapter of the HL-LHC Higgs CERN Yellow Report [A10] on invisible Higgs decays and theoretical interpretation, an ideal prerequisite for the investigation of such models.

## 2 Description of the work carried out during the STSM

During the STSM, the grantee and her collaborators at the host discussed the strategy to investigate the above model, taking all current experimental and theoretical constraints into account. In more detail

- we agreed on the minimal setup we want to investigate, including specific symmetries that are imposed on the model;
- we then compared the goals of our study with the current state-of-the-art. Our setup has so far not been discussed in the literature
- we identified free model parameters as well as constraints which need to be applied in order to correctly investigate the models' parameter space.
- a scan was set up, build on the code presented in [5, 6, 7, 8].

- Especially in the light of the Higgs Cross Section working group call for Run II benchmarks [9, 10], we identified production and decay channels that might be of interest to the LHC experiments.
- We ran first scans in the light of these signatures, to identify interesting regions in the models' parameter space.
- We also extended the precision calculation of the W-boson mass presented in [A2] to account for the additional particle content of the model.

Furthermore, the grantee was able to profit from the Kickoff-meeting of the Excellence Cluster "Quantum Universe" [11], as well as various discussions with experimental colleagues from the CMS and FLC group at DESY regarding new physics searches at current and future colliders, and fruitful interaction with senior staff members and visitors of the DESY theory group.

### 3 Description of the main results obtained

The main result of the STSM is an agreement on the research strategy to investigate the model with two real scalars, imposing a specific additional symmetry. In the end of the STSM period, we had a working code for the case of three unstable scalars within our model taking all theoretical and experimental constraints into account<sup>1</sup>. We identified interesting regions in parameter space for the benchmark call of the Higgs Cross Section Working Group and started to further investigate these regions to render optimal benchmark planes within this model. We agreed on further steps for the project.

### 4 Future collaborations

The STSM served as an initialization of the project discussed above, where further collaboration, including mutual visits between the grantee and the host, is envisaged. This includes possible visits in the framework of further STSMs or the Quantum Universe excellence cluster, as well as the Pier program [16] at the University of Hamburg. Furthermore, the grantee currently applies for a 4-year Research Project of the Croatian Science Foundation [17], where the senior collaborator from DESY is tailored to participate as an external associate.

### 5 Foreseen publications

We esteem this project to lead to at least two journal publications as well as various community effort contributions. The results of the project will furthermore be presented at international workshops and conferences, additionally leading to conference proceeding contributions. A direct first outcome is a manuscript describing benchmark planes that has been submitted to the Higgs Cross Section Working Group.

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<sup>1</sup>We are using the publicly available tools `HiggsBounds` [12, 13, 14, 2, 15] and `HiggsSignals` [1] to compare with null-results from experimental searches as well as LHC signal strength measurements for the 125 GeV scalar.

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