ScannerS — Parameter Scans in Extended Higgs Sectors

Jonas Wittbrodt

22.10.20

Lund University, Theoretical Particle Physics

Parameter Scans

A parameter scan finds a set of allowed parameter points within a given model.

- + look at one parameter point at a time, straightforward to use
- + re-check points and see the effects of individual constraints
- + no need to find a best fit point
- - no global statements about the model
- - no meaningful interpretation of point densitiesensities

ScannerS [Mühlleitner et al. 2007.02985] performs such parameter scans in a number of models with extended Higgs sectors.

`https://www.gitlab.com/jonaswittbrodt/ScannerS`

Constraints in ScannerS

ScannerS implements experimental results and theoretical constraints as binary (allowed/not allowed) constraints.

Severities:

1. apply: only keep parameter points that pass this constraint
2. ignore: calculate the constraint, store it's result, but keep all parameter points
3. skip: don't perform any calculations related to the constraint

A model in ScannerS can implement any constraints that make sense for it.

Theoretical Constraints

All models in ScannerS implement the following *tree-level* theoretical constraints:

Perturbative Unitarity

- (semi-)analytic conditions in the high-energy limit
- Mathematica code to derive these constraints is included
- generally puts upper bounds on the values of the quartic couplings

Boundedness from Below

- analytic conditions
- generally puts lower bounds on the quartic couplings

Oblique Parameters

The oblique parameters S, T, and U are a parametrization of BSM contributions to EW observables.

1. calculation of S, T, and U in generic scalar extensions [Grimus et al. 0802.4353]
2. comparison to GFitter fit results [Haller et al. 1803.01853]

Especially the T parameter is very restrictive and typically forces at least one neutral scalar to be close in mass to each charged scalar.

Flavour Constraints

Most (pure) scalar extensions mainly impact flavour observables through the charged Higgs.

ScannerS generalizes the 2HDM flavour fit results [Haller et al. 1803.01853]. These are simple bounds in the $m_{H^\pm}$–$\tan\beta$ parameter plane.

Higgs Searches and Higgs Measurements

HiggsBounds [Bechtle et al. 2006.06007] is used to check against exclusion bounds from Higgs searches.

HiggsSignals [Bechtle et al. 1403.1582] is used to calculate a χ^2 from the Higgs measurements. ScannerS cuts on

$$\Delta\chi^2 = \chi^2 - \chi^2_{\text{SM}} < 6.18$$

Predictions are obtained either from HDECAY or one of its variants or by rescaling the SM-Higgs cxns and BRs that are tabulated in HiggsBounds.

EDMs

In models with CP-violation, the EDM of the electron is an important constraint.

1. calculation using [Abe et al. 1311.4704] (needs to be updated to [Altmannshofer et al. 2009.01258])
2. comparison to the ACME bound [ACME].

This constraint is extremely important in CP-violating models. The neutral EDM is probably also important, but the required QCD running would need to be implemented.

Dark Matter Constraints

In models with DM candidates, the corresponding constraints need to be tested as well.

1. link to MicrOMEGAs [Bélanger et al. `1801.03509`] to calculate relic density and DD cxn
2. require the relic density to not oversaturate the measurement [Planck `1807.06209`]
3. check the DD cxn against the Xenon1t results [XENON `1805.12562`]

Additional Constraints?

Straightforward to implement based on the existing ones. Usually the complicated part is not the constraint itself, but getting the corresponding model prediction.

See also the contribution guide in the git repo.

Models in ScannerS

- singlet extensions
  - CxSM (broken phase and dark phase)
  - TRSM (broken phase)
- 2HDM
  - R2HDM
  - C2HDM
- N2HDM
  - all four phases (broken, dark singlet, dark doublet, fully dark)
- CPVDM

Input Parameters

ScannerS tests a lot of points that are immediately excluded by some constraint.

⇒ the generation of the parameter point's properties from the input parameters needs to befast

Analytic relations between the input parameters (e.g. masses, mixing angles) and the other model parameters (e.g. λ_i) are implemented.

Additional Models?

1. derive the parameter transformations and implement them in the code
2. derive and implement unitarity constraints
3. implement boundedness constraintsif available
4. enable the EW precision, flavor constraints
5. obtain a prediction for Higgs Pheno
6. pass input to HiggsBounds for the Higgs Pheno constraint
7. if DM: implement the model in MO and provide the required input from ScannerS
8. if CP-violating: check if the 2HDM calculation generalizes, enable the constraint

See also the contribution guide in the git repo.