# Observable spectrum in the weak sector of the SM

## Lattice analysis of the SU(2) scalar-fermion-gauge system

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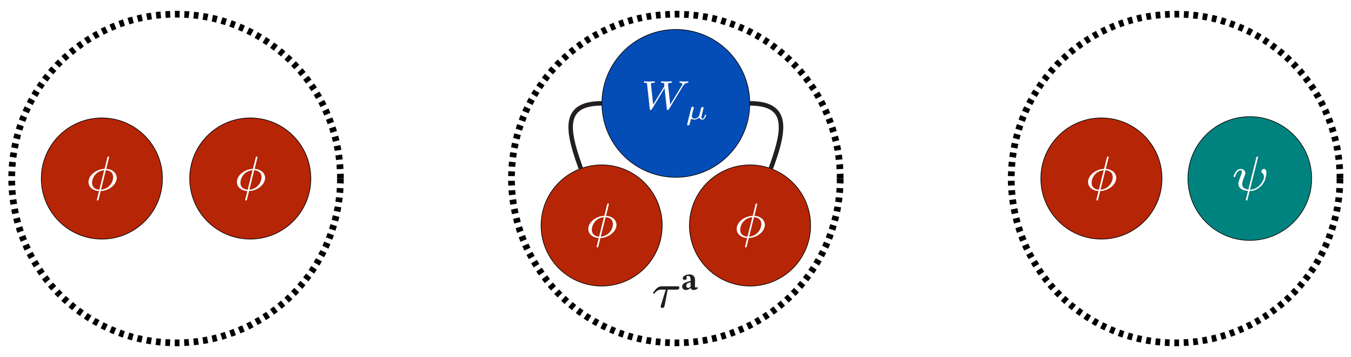
### Motivation

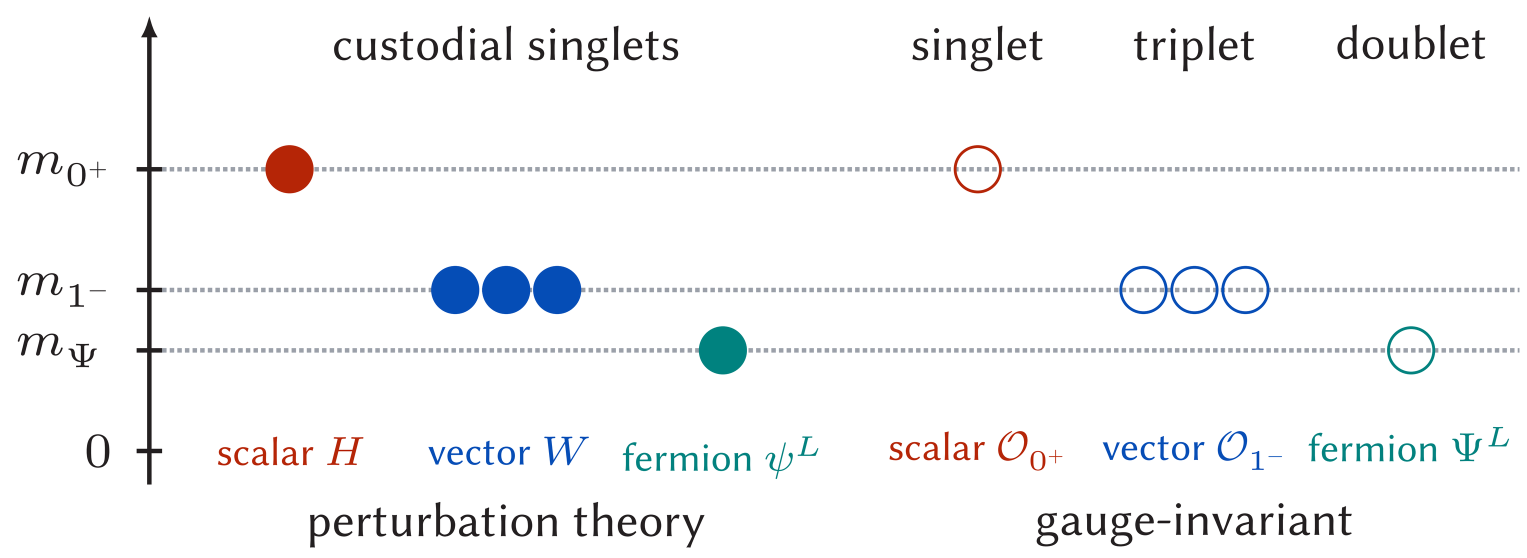
- In the standard approach to Higgs physics, the gauge symmetry is 'spontaneously broken'. Gauge fixing is performed and perturbation theory (PT) is used to calculate 'observable' quantities.
- This approach comes with conceptual problems.[1]
  - A gauge symmetry can never be spontaneously broken.
  - The gauge condition cannot be uniquely satisfied beyond PT.
  - This construction is gauge-dependent.
- Why does the standard approach still succeed in reproducing the physical spectrum of the weak SM?

### Gauge-invariant approach & FMS prediction

- Physical states must be described by gauge-invariant objects, i.e., bound states with the same global quantum numbers as the elementary fields.[1]




- The Fröhlich-Morchio-Strocchi (FMS) mechanism predicts a one-to-one mapping between gauge-dependent and gauge-invariant states.[2,3]
- This is supported by lattice calculations.[5,6]




### Lattice setup

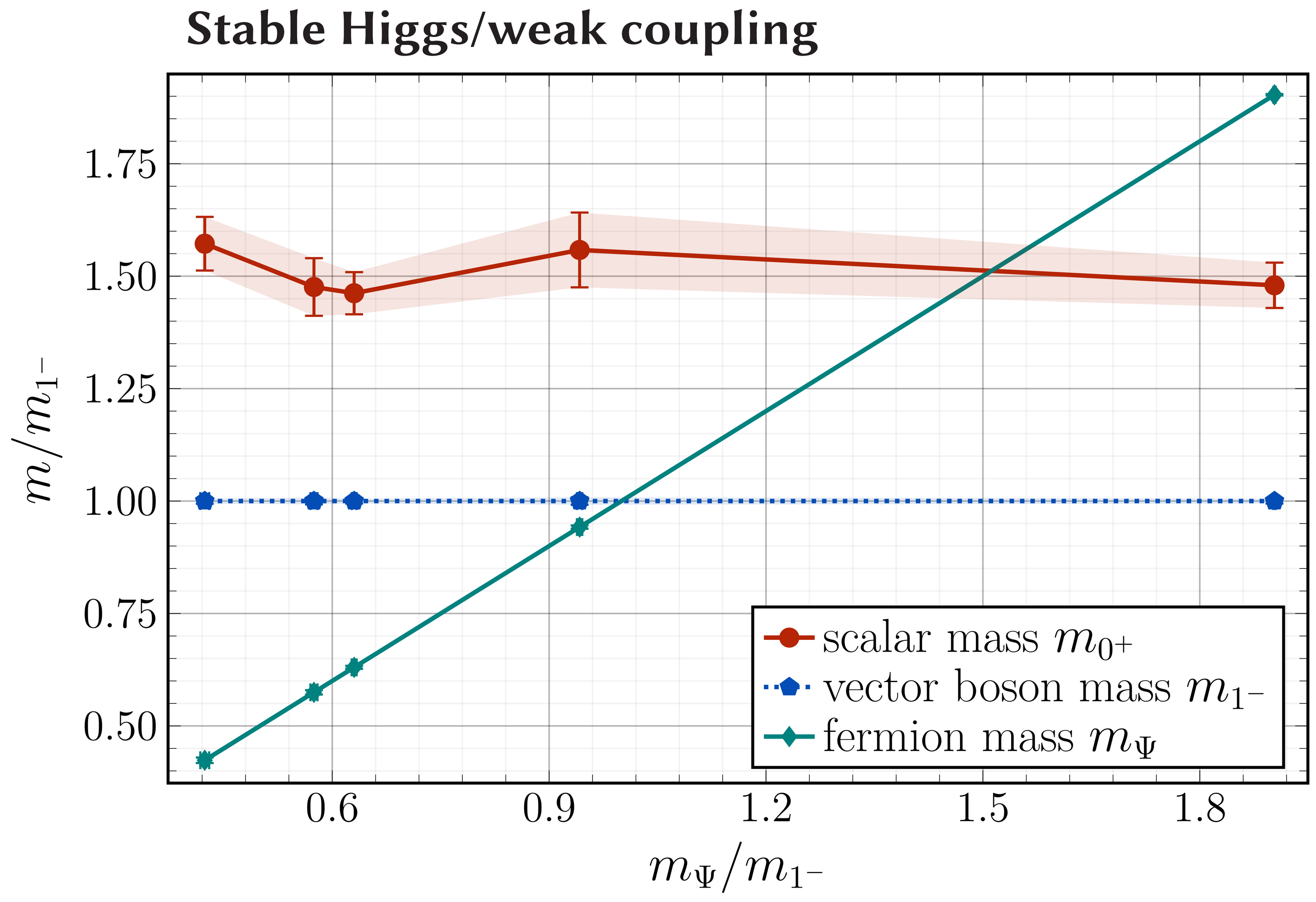
- The chiral nature of the weak gauge theory poses conceptual problems. Thus, we use vectorial leptons.
- For first simulations, we assume vanishing Yukawa couplings and two degenerate generations of leptons.
- We utilize the publicly available HiRep code.[7]

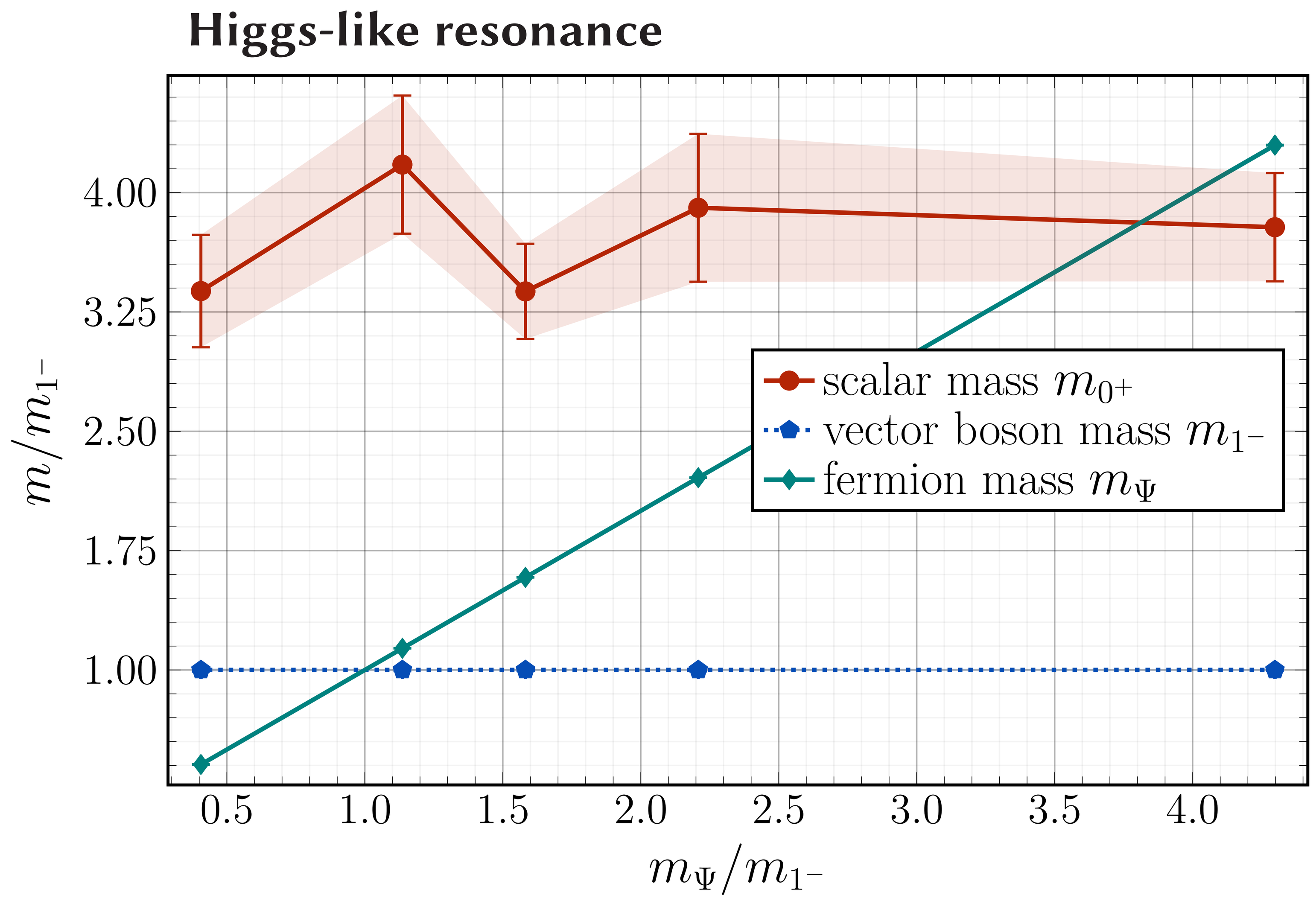
### References

[1] Maas, Prog. Part. Nucl. Phys. 106 (2019), 1712.04721
[2] Fröhlich, Morchio, Strocchi, Phys. Lett. B97 (1980)
[3] Fröhlich, Morchio, Strocchi, Nucl. Phys. B190 (1981)
[4] Dudal *et al.*, Eur. Phys. J. C 81 (2020), 2008.07813
[5] Maas, Mufti, JHEP 1404 (2014), 1312.4873
[6] Afferrante *et al.*, SciPost Phys. 10 (2021), 2011.02301
[7] Debbio, Patella, Pica, Phys. Rev. D 81 (2010), 0805.2058

### Preliminary results

- For our first exploration of the theory, we introduce fermions to the gauge-scalar subsystem.
- This is done for multiple parameter sets from pure gauge-scalar lattice simulations.




### First conclusions

- The gauge-scalar dynamics persist and the system can be fully controlled by the fermion mass.
- This appears to be a generic feature of the system in the Higgs-like domain.
- We have found a good proxy theory to describe the weak sector of the SM via lattice calculations.

### Outlook: scattering analysis

- We aim to identify qualitative differences between the perturbative and gauge-invariant approach via lepton scattering.
- From first results, we are able to identify simulation points for exploring various decay channels.

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