Gauge-invariant weak physics at zero and finite temperature

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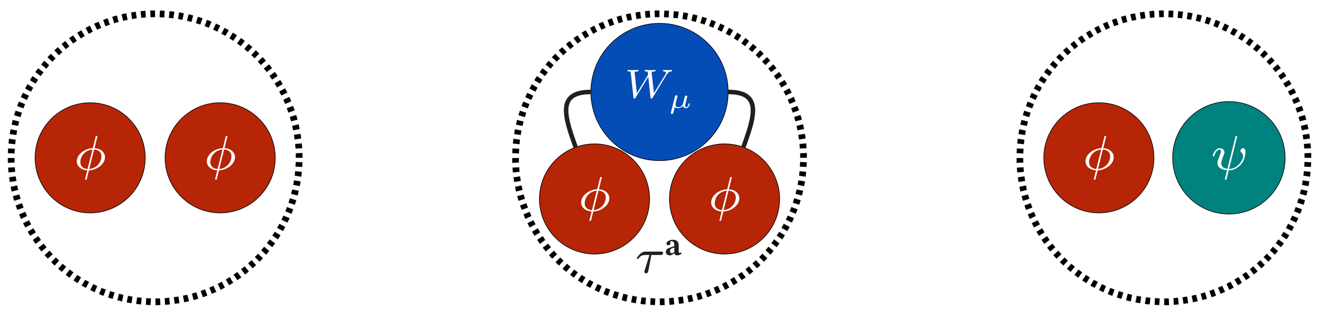
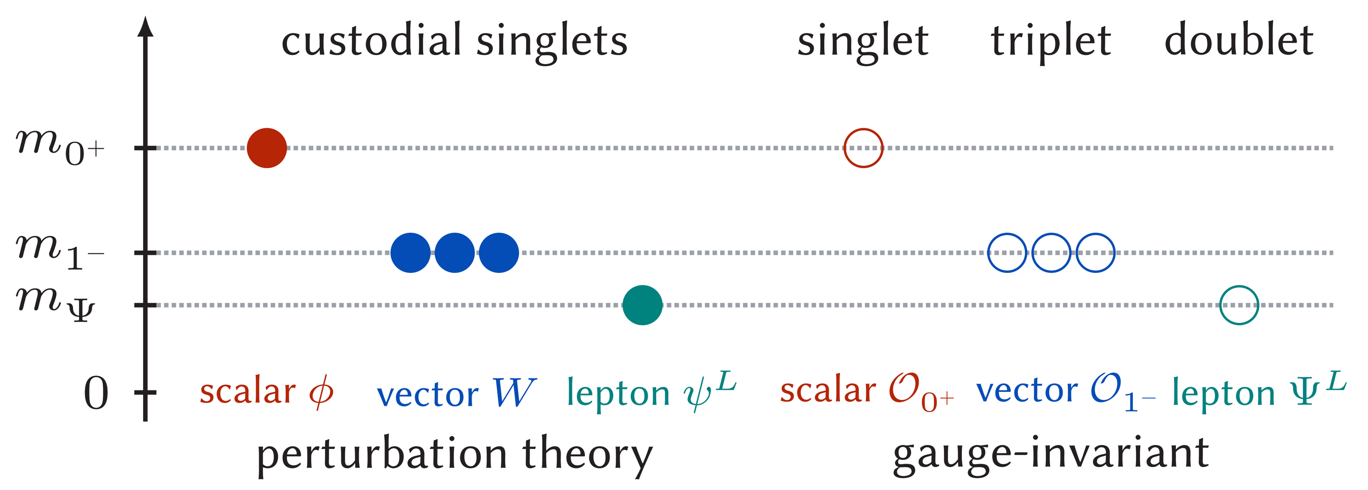
Higgs physics & FMS mechanism

- In the standard perturbative approach to Higgs physics, the gauge symmetry is 'spontaneously broken' and asymptotic states are described by elementary fields. This poses conceptual problems that cannot be addressed in a perturbative approach.[1]
- To avoid these issues, 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 and explains why the perturbative approach works.[2,3] This is supported by lattice calculations.[4,5]

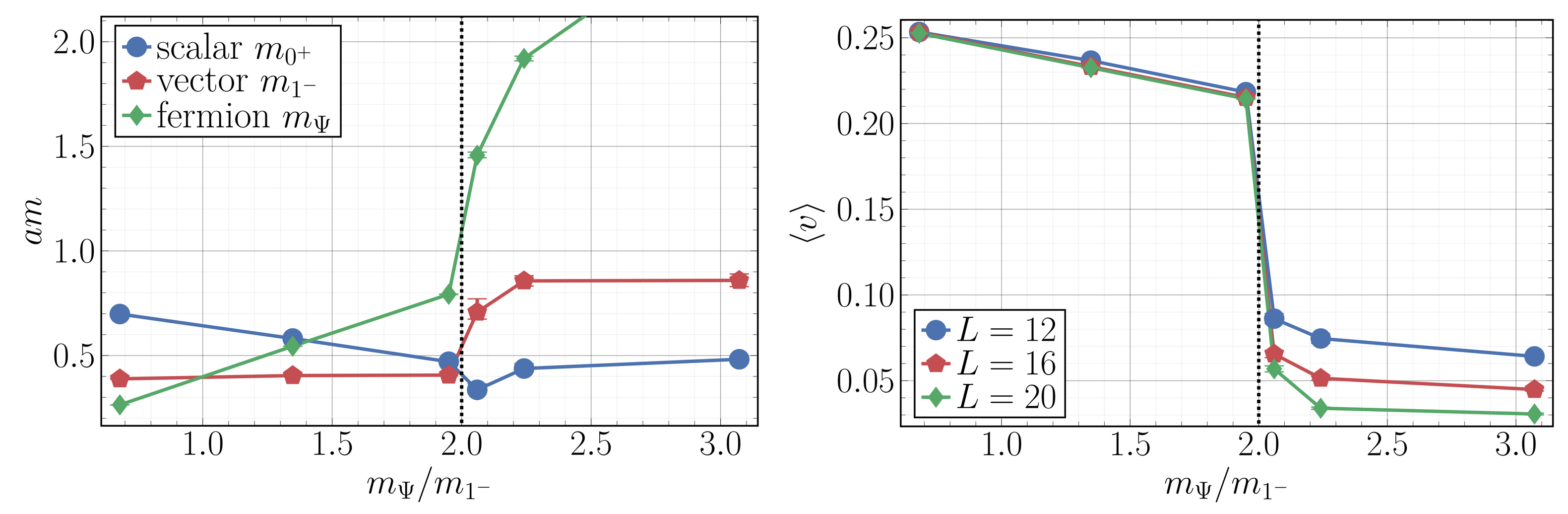


Lattice setup & simulation details

- The chiral nature of the weak gauge theory poses conceptual problems. Therefore, we simulate an SU(2) gauge-scalar theory with vectorial leptons.
- For first simulations, we assume vanishing Yukawa couplings and two degenerate generations of dynamical Wilson fermions.
- We utilize the publicly available HiRep code.[6,7]

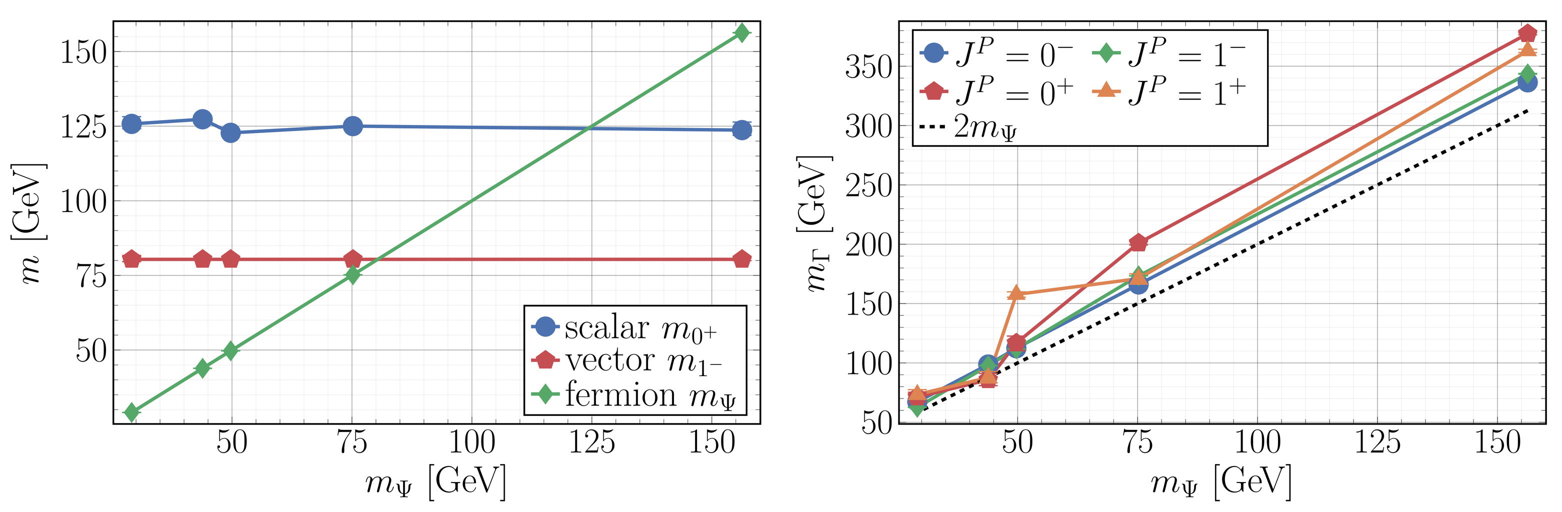
Light fermions trigger the Higgs effect

- Simulations starting in the QCD-like domain show changes in the mass hierarchy around $m_\Psi = 2m_{1^-}$.
- The vacuum expectation value clearly shows a transition into the Higgs-like domain for smaller fermion masses.



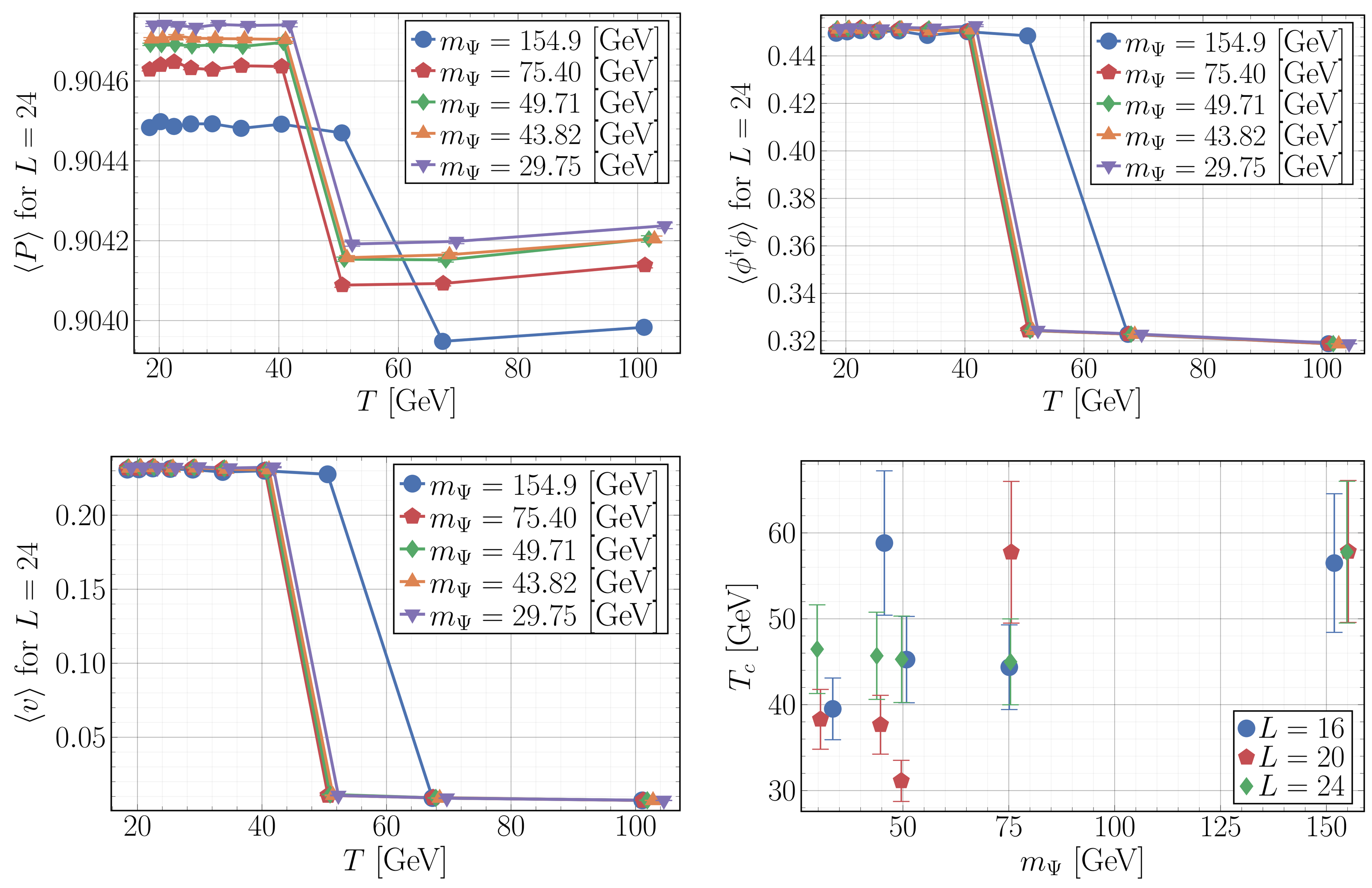
Fermion mass as a control parameter

- Lattice simulations in the Higgs-like domain show that the system can be fully controlled by varying the fermion mass without changing the overall dynamics of the gauge-scalar subsystem.
- The physical fermion exhibits a significant mass defect for small m_Ψ. This is consistent with the FMS description and cannot be reproduced via perturbative calculations.
- All leptonium masses lie above the $2m_\Psi$ threshold and are consistent with scattering states of two physical leptons.



Fermions insufficient for baryogenesis

- Finite-temperature effects in weak physics are of interest as they may provide insight into early universe phase transitions and the origin of matter-antimatter asymmetry.
- Investigations of the gauge-scalar system show no phase transition sufficient to explain this asymmetry.[8,9] Can the introduction of dynamical fermions change this?
- For different fermion masses, we find the same behavior in various gauge-independent thermodynamic quantities. The gauge-dependent vacuum expectation value also shows the same transition for all fermion masses.



- Within the current systematic uncertainties, we find no qualitative differences in the transition type across different fermion masses. Introducing fermions only slightly shifts the transition temperature T_c.
- From this, we conclude that the introduction of fermions does not produce a phase transition strong enough for baryogenesis.

References

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