UNIVERSITY OF HELSINKI
FACULTY OF SCIENCE

HELSINKI INSTITUTE OF PHYSICS

Non-perturbative study of Electroweak Phase Transition in BSM models

Tuomas V.I. Tenkanen

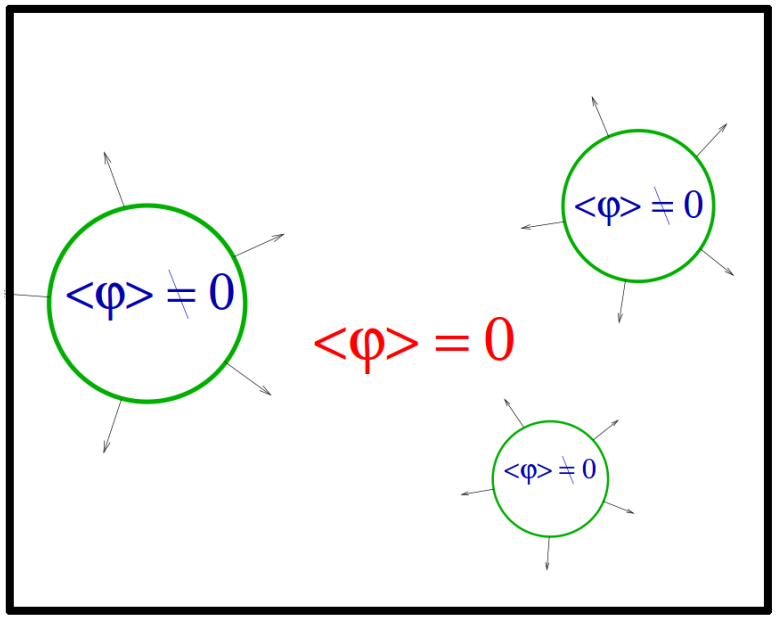
In collaboration with:
T. Brauner, A. Tranberg, A. Vuorinen and D. J. Weir (SM+real singlet: DR)
J. Kozaczuk and D. J. Weir (SM+real singlet: numerical analysis)
J. O. Anderssen, T. Gorda, L. Niemi, A. Tranberg, A. Vuorinen and D. J. Weir (2HDM)
L. Niemi, H. H. Patel, M. Ramsey-Musolf and D. J. Weir (SM+real triplet)

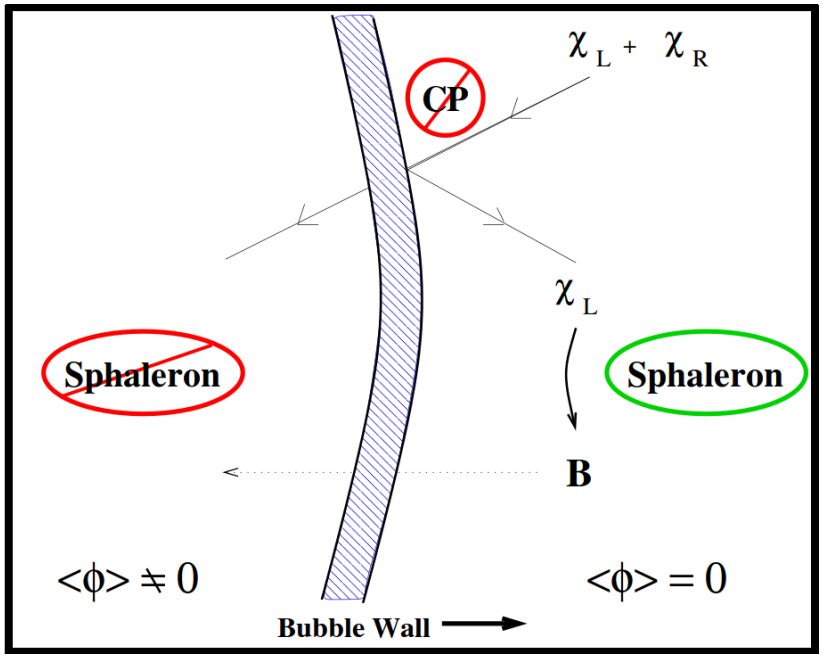
University of Helsinki and Helsinki Institute of Physics

Particle Physics Day 2017, Helsinki
20.10.2017

E-mail: tuomas.tenkanen@helsinki.fi

EW phase transition and baryogenesis



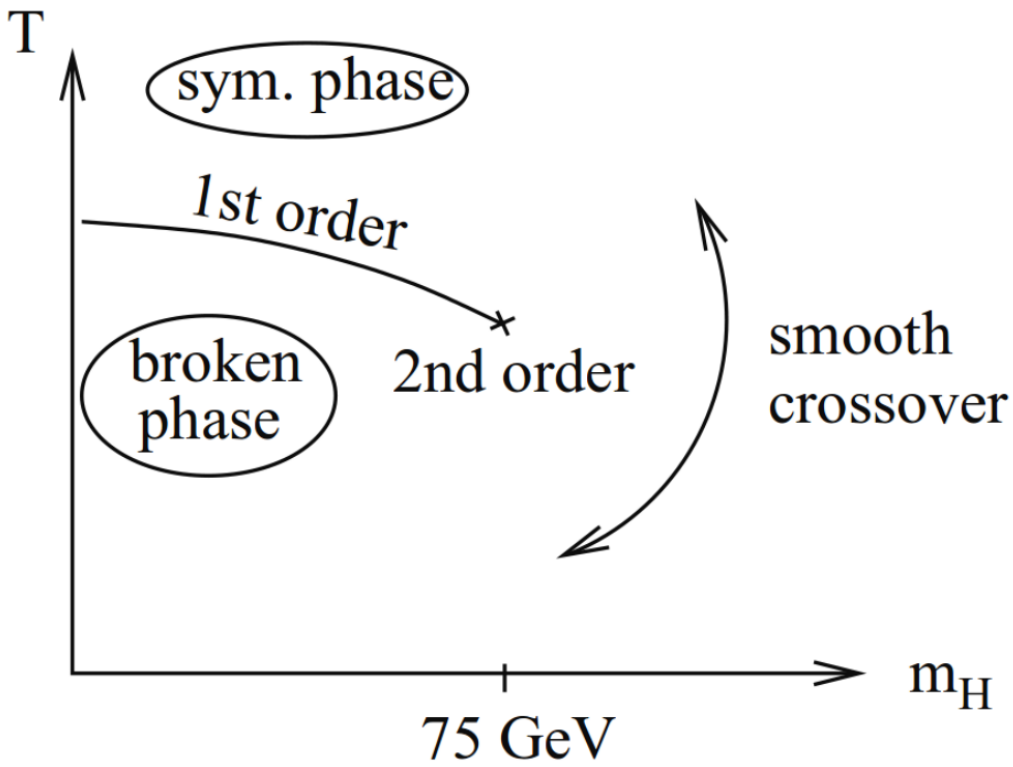


Morrisey *et al.*

- In nutshell: 1st order transition → bubble nucleation → CP-violation → sphalerons → baryon-antibaryon asymmetry

EW baryogenesis fails in the SM

- However, with observed $m_H = 125$ GeV, EW phase transition in the SM is not of first order, but a smooth crossover instead.[1]



J. M. Cline

- Also: CP violation in the SM is too weak at relevant temperatures.

[2] Kajantie et.al. (1996)

EW baryogenesis in BSM models

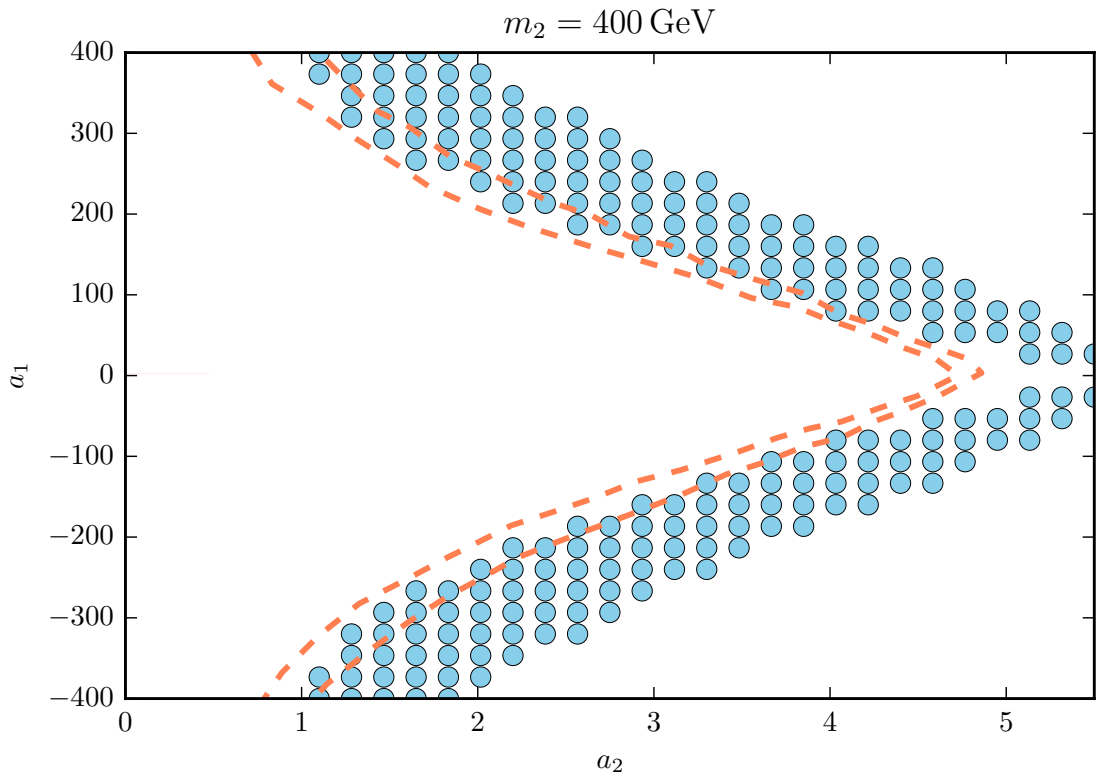
- BSM models with modified scalar sector could offer viable setup for EW baryogenesis: Strong 1st order phase transitition? Sufficient amount of CP-violation?
- SM+real singlet (non-Z_2): "Toy model", no extra CP-violation, no stable dark matter.
- Two-Higgs-doublet model (2HDM): More CP-violation, but also more strict collider constraints.
- SM+real triplet: 2-step phase transition, gives more freedom to avoid constraints and also rich features due to more complicated symmetry breaking pattern.

Non-perturbative analysis

- For EW baryogenesis, the most relevant features of phase transition are: character (1st, 2nd order or crossover), T_c, sphaleron transition rate and bubble nucleation rate.
- Usually studied perturbatively in terms of finite T effective potential.
- Non-perturbative lattice simulations are the most robust way to compute these quantities.
- Lattice simulations are most conveniently performed in effective 3d theory, which is obtained from the full 4d theory by using the method of dimensional reduction.

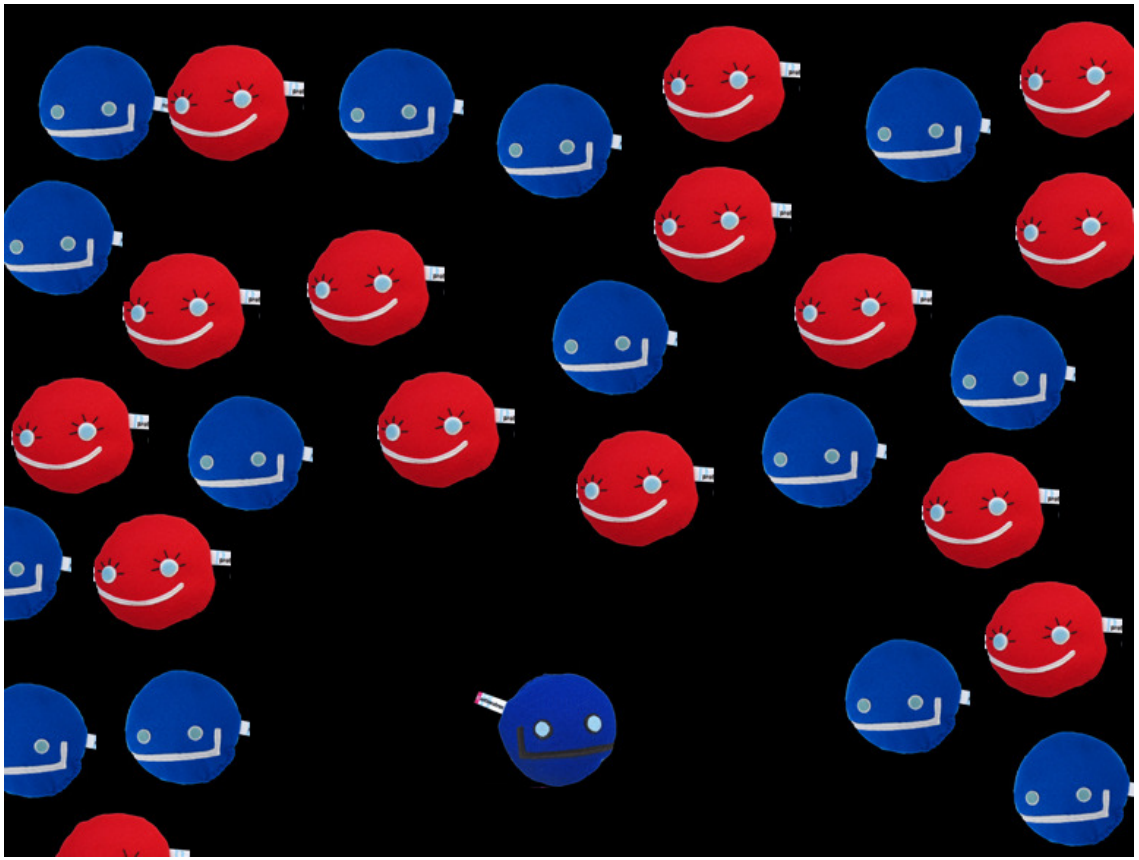
Perturbative (dots) vs. non-perturbative (dashed)

- SM + real singlet:



- Phenomenological consequences? Gravitational wave signal?

Work on progress!



- We don't know yet...

Summary

- EW baryogenesis might explain baryon asymmetry, if some BSM physics can cause enough C and CP violations and strong 1st order phase transition.
- Lattice simulations can be used to study EW phase transition in BSM models. Effective 3-d theory is derived by using finite T dimensional reduction.
- Coming soon: actual results...