Bound state spectrum of theories with a Brout-Englert-Higgs effect

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& L. Egger, A. Maas
arXiv:1701.02881

& A. Maas, P. Törek
arXiv:1709.07477, arXiv:1710.01941

666. WE-Heraeus-Seminar
From correlation functions to QCD phenomenology
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Carl Zeiss Stiftung

Gauge invariance

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- Weak interaction?

Ambiguities beyond perturbation theory

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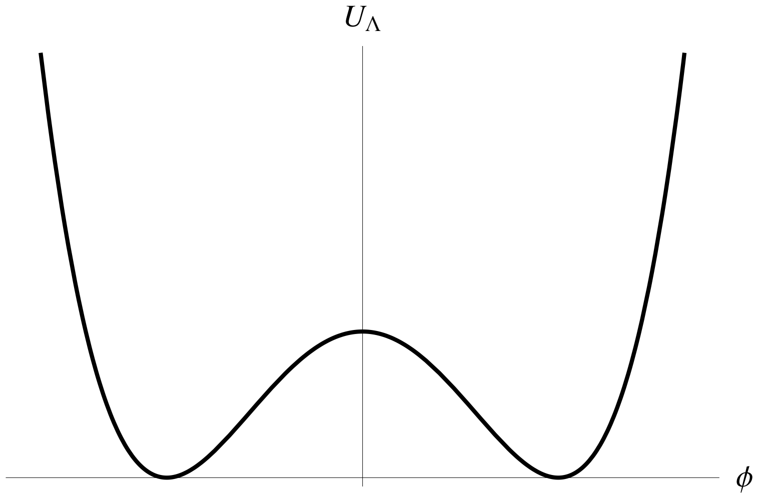

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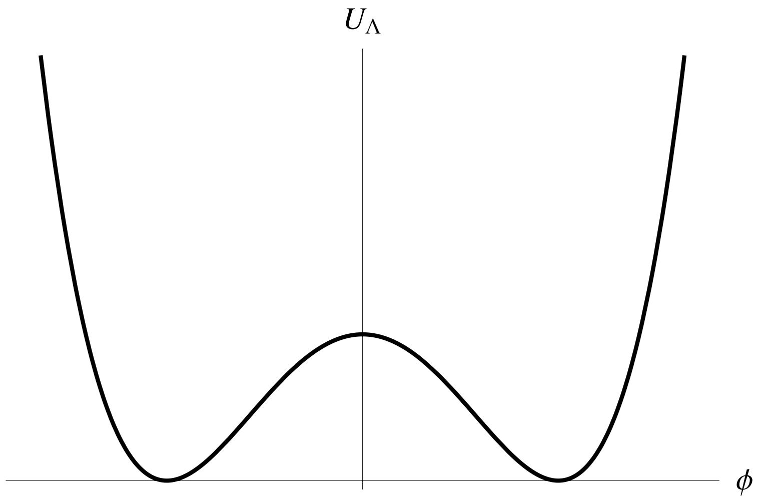

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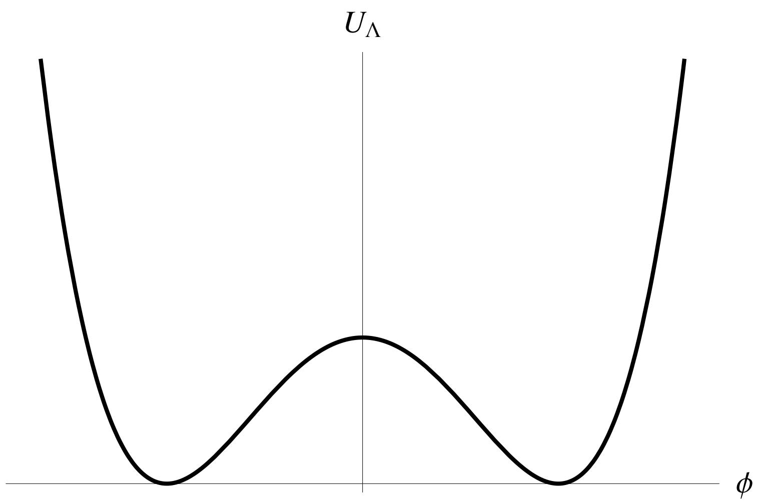

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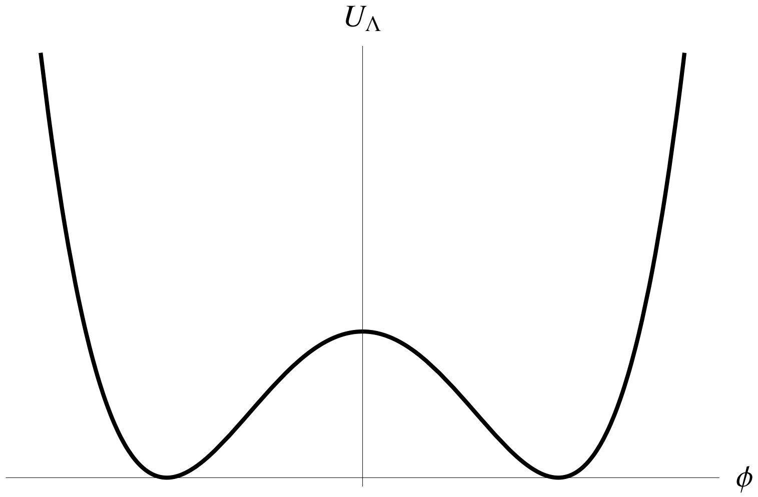

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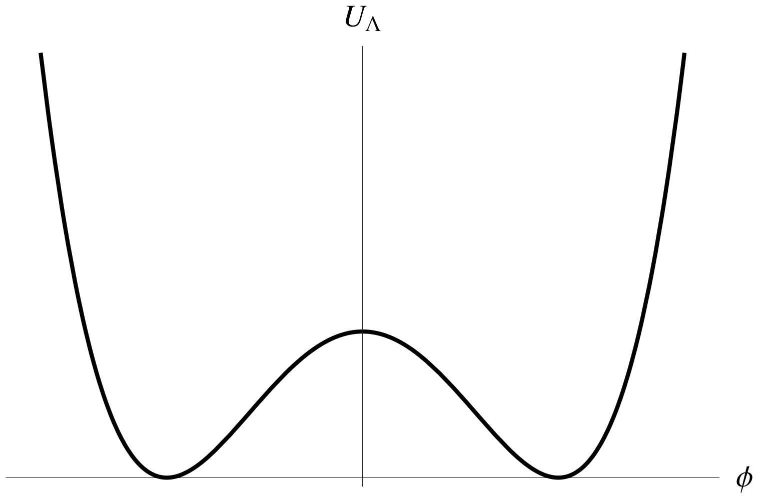

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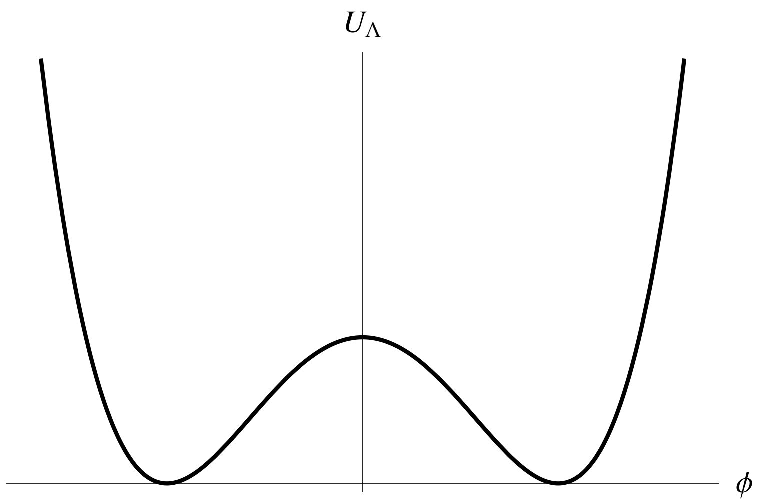

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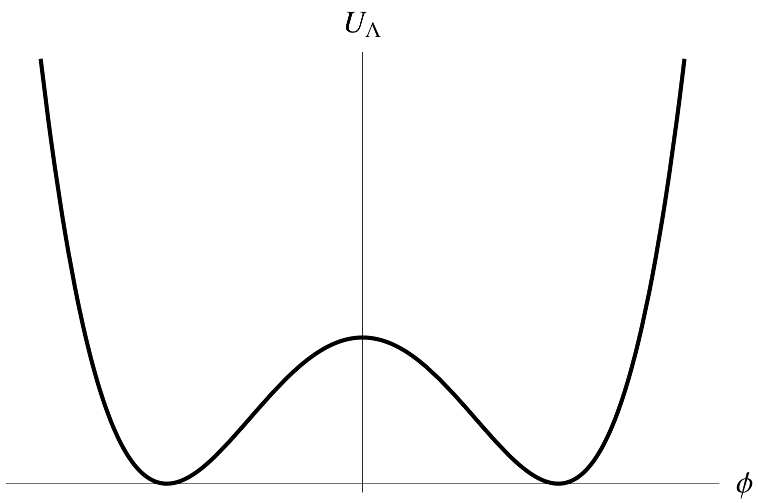

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Fröhlich et al '80, '81

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$$\langle \mathcal{O}(x)\mathcal{O}(y)\rangle = v^2 \langle h(x)h(y)\rangle_{\text{tl}} + \langle h(x)h(y)\rangle_{\text{tl}}^2 + O(g^2, \lambda)$$

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- Confirmed on the lattice for SU(2)-Higgs theory Maas '12

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$$\mathcal{L} = -\frac{1}{4} W^i_{\mu\nu} W^{i\mu\nu} + (D_\mu \phi)^\dagger D^\mu \phi - U(\phi^\dagger \phi)$$

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$$\mathcal{L} = \mathrm{Tr}[\partial_\mu X^\dagger \partial^\mu X] - U(\mathrm{Tr} X^\dagger X)$$

$$\text{where} \quad X = (\tilde{\phi} \;\; \phi) = \begin{pmatrix} \phi_2^* & \phi_1 \\ -\phi_1^* & \phi_2 \end{pmatrix} = \begin{pmatrix} v & 0 \\ 0 & v \end{pmatrix} + O(\varphi)$$

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- Mapping of local to global multiplets

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Egger,Maas,RS'17

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- Not true for all mesons, e.g., pions $\pi^+ : \ \bar{\mathcal{O}}_2^{ud} \mathcal{O}_1^{ud} (\sim \bar{d}u)$

Beyond the standard model

Maas, Törek '16,
Maas, RS, Törek '17

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Maas, Törek '16,
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- SU(N) gauge theory + Higgs in fundamental representation
- Local and global symmetry group do not match for N > 2: SU(N) vs U(1)

J^P	Field	Mass	Degeneracy	Operator	Mass	Degeneracy
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	$\tilde{A}_i^\mu$	m_A	$2(N-1)$	$O_{\pm 1}$	$(N-1)m_\mathrm{A}$	$1/\bar{1}$
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- Nonperturbative check for N=3

Beyond the standard model - SU(5) GUT

Maas, RS, Törek ’17

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$$\mathrm{SU(5)} \xrightarrow{\langle\Sigma\rangle\sim w} \mathrm{SU(3)xSU(2)xU(1)} \xrightarrow{\langle\phi\rangle\sim v} \mathrm{SU(3)xU(1)} \qquad w \gg v$$

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J^P	Field	Mass	Degeneracy	Operator	Mass	Degeneracy
0^+	h	m_h	1			
	φ^a	$\sim w$	6			
	σ_i	$\sim w$	8			
	$\tilde{\sigma}_i$	$\sim w$	3			
	$\bar{\sigma}_i$	$\sim w$	1			
1^-						

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	$\bar{\sigma}_i$	$\sim w$	1			
1^-	A^μ	0	1			
	$W^{\pm\mu}$	m_W	$1/\bar{1}$			
	Z^μ	m_Z	1			
	X^μ	$\sim w$	6			
	Y^μ	$\sim w$	6			

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1^-	A^μ	0	1			
	$W^{\pm\mu}$	m_W	$1/\bar{1}$			
	Z^μ	m_Z	1			
	X^μ	$\sim w$	6			
	Y^μ	$\sim w$	6			

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	φ^a	$\sim w$	6	O_{0-}	m_h	1
	σ_i	$\sim w$	8	$O_{\pm 1,+}$	$\sim w$	$1/\bar{1}$
	$\tilde{\sigma}_i$	$\sim w$	3	$O_{\pm 1,-}$	$\sim w$	$1/\bar{1}$
	$\bar{\sigma}_i$	$\sim w$	1			
1^-	A^μ	0	1			
	$W^{\pm\mu}$	m_W	$1/\bar{1}$			
	Z^μ	m_Z	1			
	X^μ	$\sim w$	6			
	Y^μ	$\sim w$	6			

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	$\tilde{\sigma}_i$	$\sim w$	3	$O_{\pm 1,-}$	$\sim w$	$1/\bar{1}$
	$\bar{\sigma}_i$	$\sim w$	1			
1^-	A^μ	0	1	O_{0+}	0	1
	$W^{\pm\mu}$	m_W	$1/\bar{1}$	O_{0-}	0	1
	Z^μ	m_Z	1	$O_{\pm 1,+}$	$\sim w$	$1/\bar{1}$
	X^μ	$\sim w$	6	$O_{\pm 1,+}$	$\sim w$	$1/\bar{1}$
	Y^μ	$\sim w$	6			

Summary

- Observable spectrum must be gauge invariant
- Non-Abelian gauge theory: composite operator
- FMS mechanism provides a mapping of the local to the global multiplets
- Same results in leading order for the standard model
- BSM model building may be affected
- Verification requieres non-perturbative methods