

# Nikhef An Effective Pathway to the New Standard Model



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Focus Session FM02: Journeys through the zeptouniverse: particle physics and the quest for a new standard model

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#### **Towards a New Standard Model**

**Standard Model of particle physics**: hugely succesful, but leaves many foundational questions unanswered

*Quarks & Leptons: Matter particles* 

Proton:



Mediators of fundamental interactions

#### **Origin of particle masses?**

particle masses are free parameters in the SM, to be measured from data

$$m_{\text{top-quark}} \simeq m_{\text{electron}}$$
?

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**Unexplained**, huge differences in the patterns of particle masses and couplings!

 $m_{\rm top-quark} \simeq 10^6 \times m_{\rm electron}$ 



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see also Keri's talk

#### What is Dark Matter?





er?

# 82% Dark Matter

#### **Towards a New Standard Model**

**Standard Model of particle physics**: hugely succesful, but leaves many foundational questions unanswered

Origin of the particle masses? Where is all the missing Antimatter?





see also Elisabetta's talk

requires new particles and interactions beyond the Standard Model!











Why Effective Theories?

describe physics exclusively in terms of the **degrees of freedom** and **dynamics** relevant at every length (energy) scale, and **integrate out** everything else



DoF: atoms

 $\Delta x \simeq 10^{-9} \text{ m}$ 

*Quantum Mechanics* 











#### **The Standard Model as an Effective Theory**

Assemble a New Standard Model from the **bottom up!** 



rich variety of signals!

constrain all SMEFT interactions from a global dataset

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## Matching



**Full Theory**  $\phi(m_{\phi}), \Phi(M_{\Phi})$  $\mathscr{L}_{int} = \lambda_3 \phi^2 \Phi$ 

 $\phi + \phi \rightarrow \Phi \rightarrow \phi + \phi$ 

Effective Theory

 $E \simeq M_{\Phi} \gg m_{\phi}$ 

$$\begin{split} \phi \ (m_\phi) \\ \mathcal{L}_{\text{int}} \supset c_4(\lambda, M_\Phi) \phi^4 \end{split}$$

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Low-energy parameters sensitive to ultraviolet dynamics!

#### **Constraints from low-energy data**

- Effective Theories can constrain New Physics in global analyses of processes from very high (above top quark mass) to very low energies (below proton mass)
- Correlate persistent anomalies in the low-energy (B-meson) sector with high-energy data non-universal lepton interactions?



SMEFiT: framework for data interpretation in terms of Effective Theories (Hartland et al 19)

#### What can EFTs do for me?

Crucial information to assemble the New Standard Model of particle physics

Marked increase in the potential to discover new particles and interactions

addressing the foundational questions left unanswered by the SM!



#### **Toward a global EFT analysis**

Combine data from Higgs, top quark, and diboson production at the LHC



A global interpretation of particle physics measurements is by construction the **most powerful indirect probe** of new UV dynamics

#### **Toward a global EFT analysis**



#### An Effective Pathway to the New Standard Model

Exciting times for high-energy physics as we enter a precision, data-driven era!

#### unique opportunity: 90% of LHC data yet to come!

Effective Theories represent a paradigm shift guiding the field towards new discoveries



#### The ultimate goals:

- First global analysis of the New
  Standard Model interactions
- Enormous increase in discovery
  potential of new particles
- Pinpoint most promising directions
  for experimental searches

#### Stay tuned for news from the high energy frontier!