Insights in New Physics through Di-Higgs Production and Precision Phenomenology

Felix Egle
18.11.2024

HELMHOLTZ

DESY.

Emmy Noether-Programm

DFG Deutsche Forschungsgemeinschaft

About Me

- 1997-2015 grown up in *Emerkingen* (`https://de.wikipedia.org/wiki/Emerkingen`)

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- 2024- .. PostDoc at DESY

About Me

Hobbys

- Piano
- Basketball
- Cooking and Baking
- Running (half marathon 2025?)
- Movies (Anyone up for movie nights? Sneak previews?)

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Two Truths One Lie

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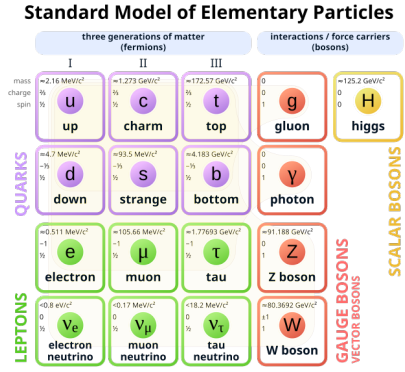
The Standard Model and New Physics

The Standard Model (SM)

> Currently well established theory in particle physics



[Wikimedia Commons]

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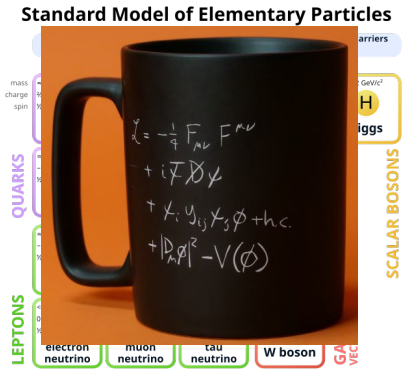

[visit.cern]

The Standard Model and New Physics

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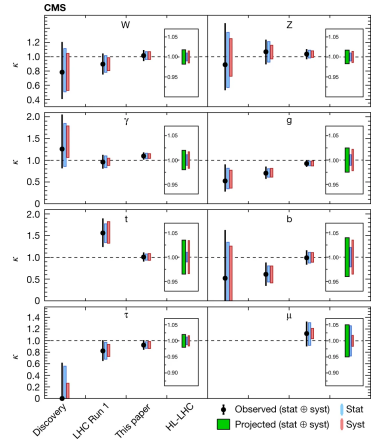
- Tight experimental limits and increasing sensitivity $\Rightarrow$ need precise theory calculations and predictions, **precision phenomenology**



[CMS Collaboration, Nature, 2022]

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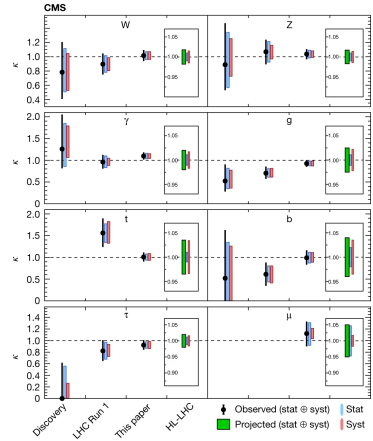

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The Standard Model and New Physics

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- Tight experimental limits and increasing sensitivity ⇒ need precise theory calculations and predictions, **precision phenomenology**
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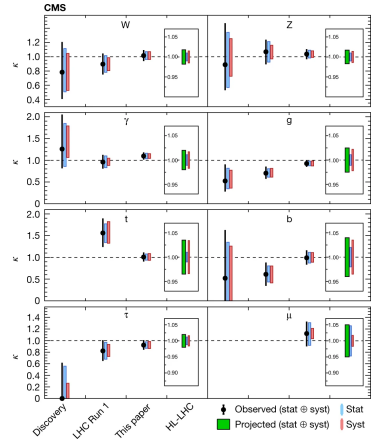
Shortcomings of the SM

- Experimentally: dark matter (DM), matter-antimatter asymmetry, ...
- Theoretically: neutrino masses, hierarchy problem, dynamical explanation of the Higgs mechanism, ...

We know that the SM is not the full story.



[CMS Collaboration, Nature, 2022]

My PhD Thesis

Projects contained in my Thesis

- Project I: Electroweak Corrections to Higgs Decays in the Complex Singlet Extension of the Standard Model [Egle, Mühlleitner, et al. 2022, 2023]
- Project II: Higgs Pair Production in a Realization of a Composite 2HDM [De Curtis, Delle Rose, Egle, et al. 2024]
- Project III: Supersymmetric Particle Decays in the Complex Next-to-Minimal Supersymmetric Extension of the Standard Model and Phenomenology [Egle, Gabelmann, et al. in preparation]

Project I

The Complex Singlet Extension of the SM (**CxSM**)

- **CxSM**: SM + additional singlet $\mathbb{S}$
- Simple extension of the SM with a DM candidate

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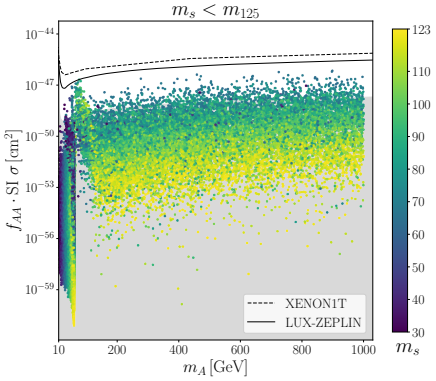
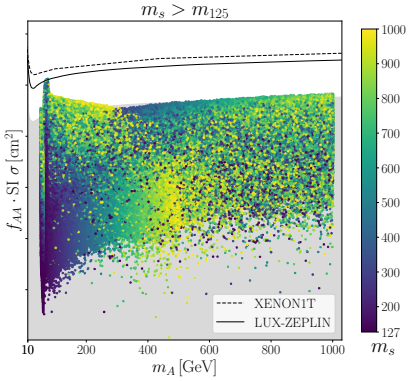
Goals

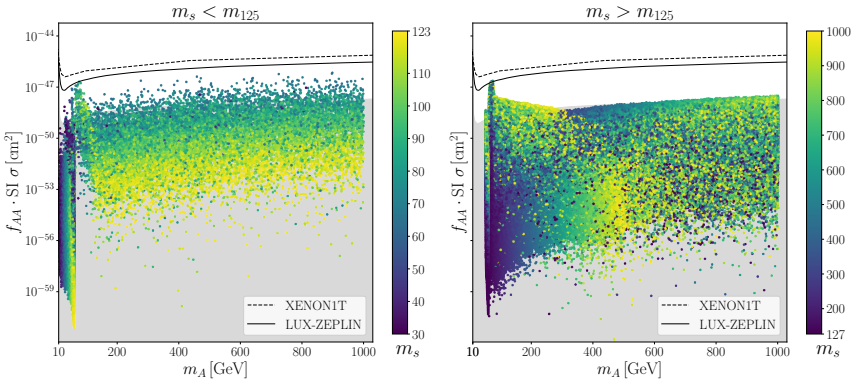
- Analyze allowed parameter ranges
- Calculate next-to-leading-order (NLO) electroweak (EW) corrections to Higgs decays and discuss their impact on the parameter space





Notation

- $f_{AA} \cdot \mathrm{SI}\,\sigma$: effective spin-independent DM nucleon scattering cross section



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Remarks

> Only a few points excluded by current experiments [Aprile et al. 2018; Aalbers et al. 2023]

> Many points below neutrino floor ⇒ **need complementary searches at colliders and precise theory predictions**

Project II

Composite Higgs Models

- Alternative approach to explain the Higgs mechanism / electroweak symmetry breaking
- Higgs is **not** elementary, but a **composite** pseudo Nambu Goldstone boson (SM analogy: pions)
- Solution to the hierarchy problem

Illustration by Sandbox Studio, Chicago

Project II

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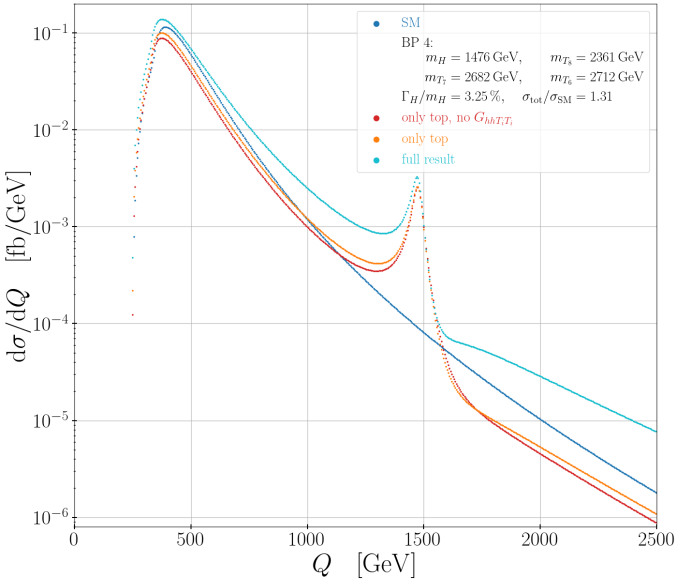
Higgs Pair Production

- Measurement of the trilinear Higgs coupling $\Rightarrow$ further insight into the Higgs potential
- Goal: Investigation of the impact of the composite sector on Higgs pair production

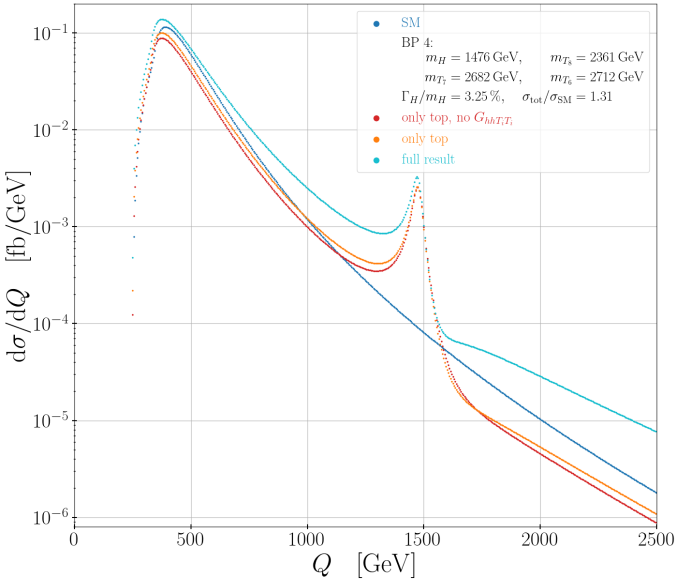
Illustration by Sandbox Studio, Chicago



Differential Distributions

> BP4 parameters:

f	750 GeV
$\lambda_{hhh}/\lambda_{\text{SM}}$	0.899
$\lambda_{Hhh}/\lambda_{\text{SM}}$	-2.576
$g_{htt}/g_{htt,\text{SM}}$	0.856
$g_{Htt}/g_{htt,\text{SM}}$	-0.864
G_{hhtt}	$-6.1 \times 10^{-5}\,1/\text{GeV}$



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Remarks

> Resonance visible at $m_H = 1476\,\text{GeV}$

> Red line: 2HDM without composite sector

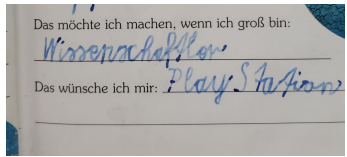
> Interference effects between **resonance**, **heavy quark contribution** and **effective quartic coupling**

Project III

Goals of the Project

- Calculate the supersymmetric particle decays in the (Complex) next-to-minimal supersymmetric extenison of the Standard Model (NMSSM)
- Update the code `SDECAY` [Mühlleitner, Djouadi, and Mambrini 2005] from the MSSM to the NMSSM
- Link the code to `NMSSMCALC` [Baglio et al. 2014]
- Do parameter scans, analyze phenomenology

Conclusion


Das möchte ich machen, wenn ich groß bin:
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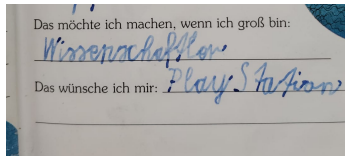
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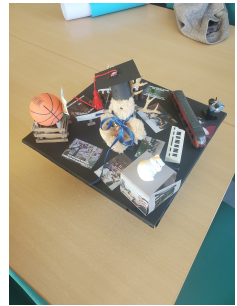

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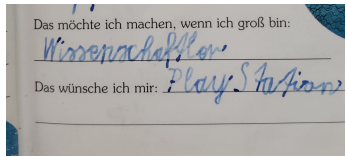

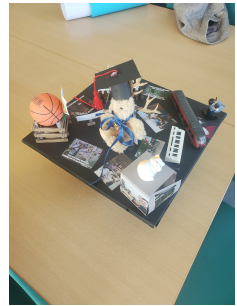

Thank you for your attention!

Questions?

Literature I

- Tumasyan, Armen et al. (2022). “A portrait of the Higgs boson by the CMS experiment ten years after the discovery”. In: Nature 607.7917, pp. 60–68. DOI: 10.1038/s41586-022-04892-x. arXiv: 2207.00043 [hep-ex].
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- — (2023). “Electroweak corrections to Higgs boson decays in a Complex Singlet extension of the SM and their phenomenological impact”. In: JHEP 11, p. 116. DOI: 10.1007/JHEP11(2023)116. arXiv: 2306.04127 [hep-ph].
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Literature II

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