

Probing new physics in the Higgs boson potential

Me and my life beyond BSM physics

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Theory Group – Phenomenology

DESY Theory Fellows Meeting, November 18, 2024

First part: me

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Who am I?

What I like

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What I like

Playing videogames

- The Legend of Zelda, Pokemon, Blasphemous, Spiritfarer, ...



Playing Super Smash Bros.

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Listening to music, going to concerts and festivals

- Lady Gaga, Chappell Roan, Tove Lo, Sufjan Stevens, Zahara ...



In a Dua Lipa concert

Who am I?

What I like

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- The Legend of Zelda, Pokemon, Blasphemous, Spiritfarer, ...



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In a Dua Lipa concert

Watching movies and series

- Fleabag, The Bridges of Madison County, Little Miss Sunshine, Six Feet Under, Aquí no hay quien viva ...



I also like sleeping

Who am I?

The people along
the road ❤️❤️❤️



Early stages: Jaén

1996 - 2013



Jaén

1996 - 2013



Jaén Cathedral



Olive
oil



Castle of Santa Catalina



See of olive trees

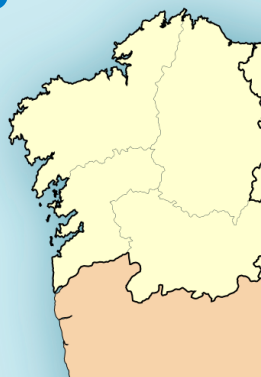
Bachelor's degree: Granada

2013 - 2017



Bachelor's degree

2013 - 2017



UNIVERSIDAD
DE GRANADA



Master's Degree & PhD Thesis: Madrid

2017 - 2023



Master's Degree & PhD Thesis

2017 - 2023



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Teórica
UAM-CSIC



Master's Degree & PhD Thesis

2017 - 2023

PhD supervisors: **María José Herrero + Sven Heinemeyer**

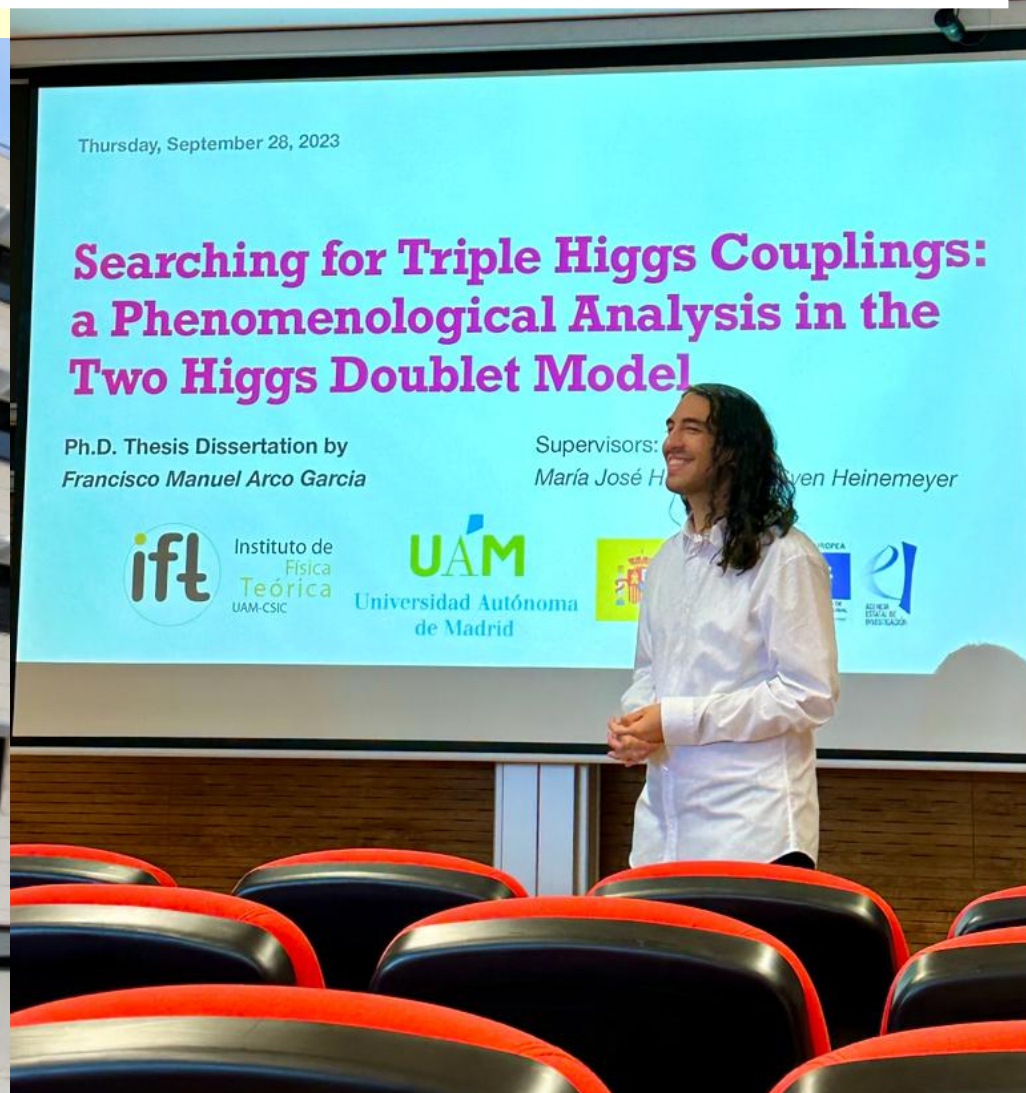


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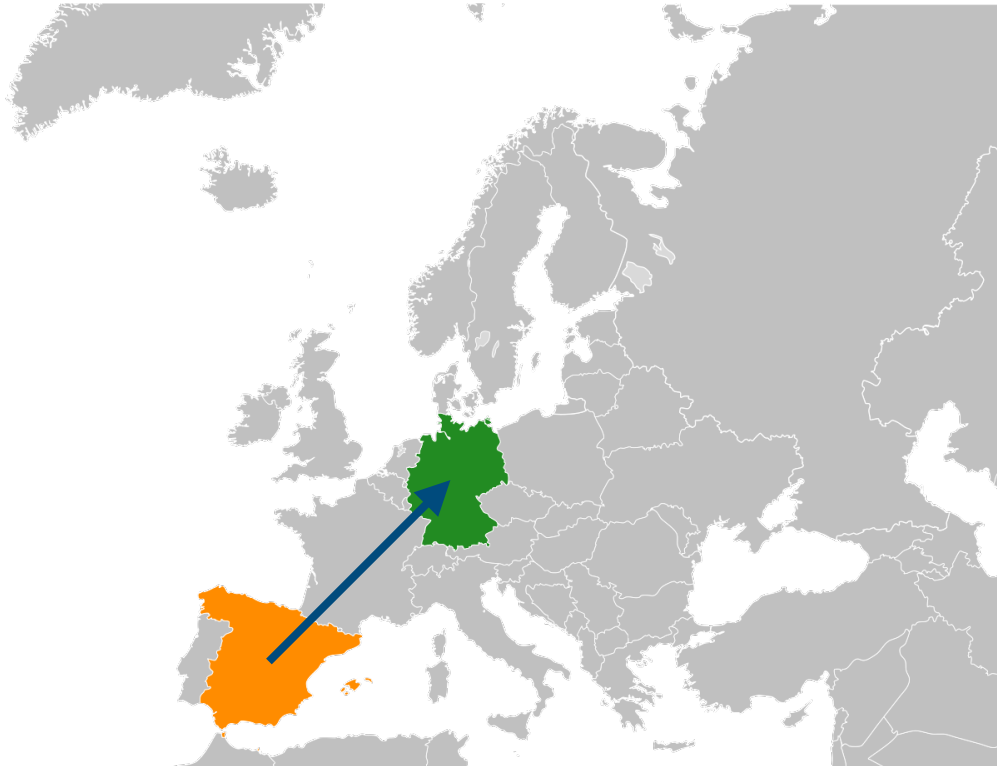
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1st Postdoc: Karlsruhe

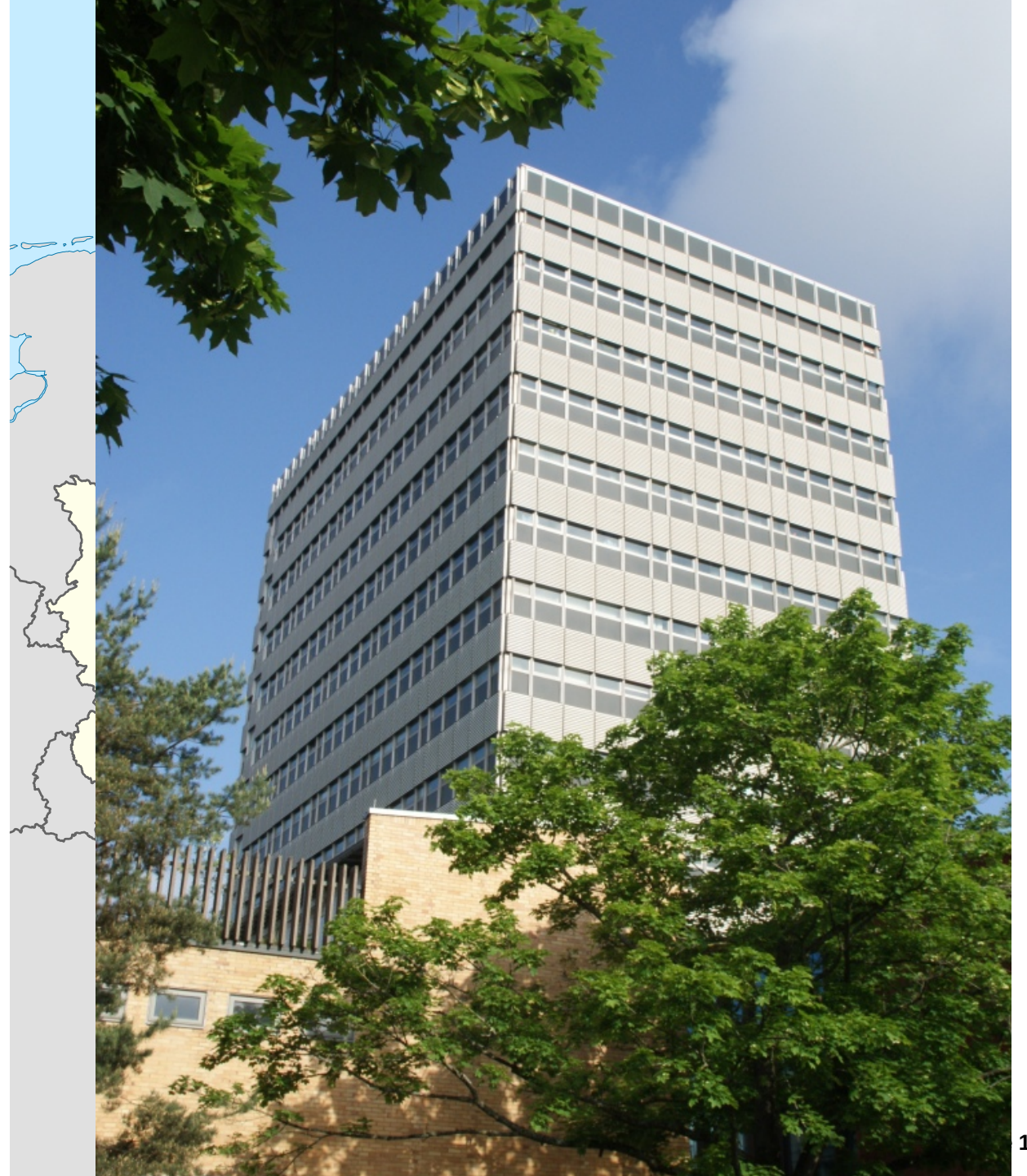
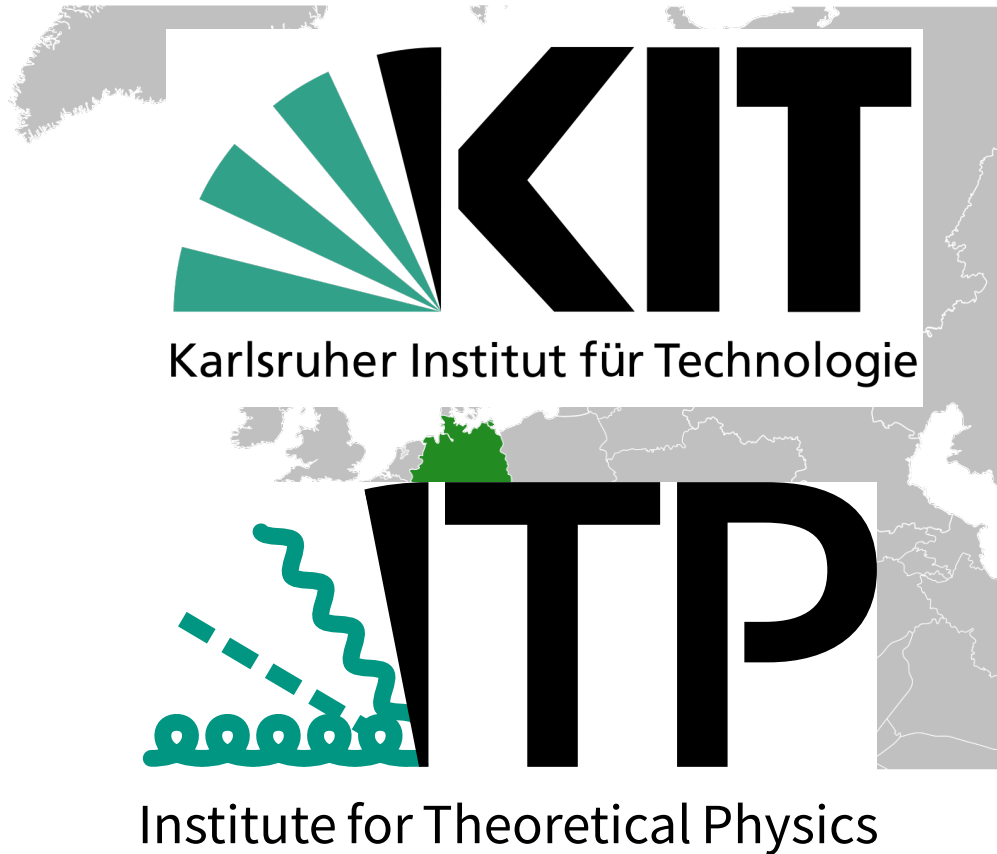
2023 - 2024



1st Postdoc

2023 - 2024

In the group of **Margarete Mühlleitner**



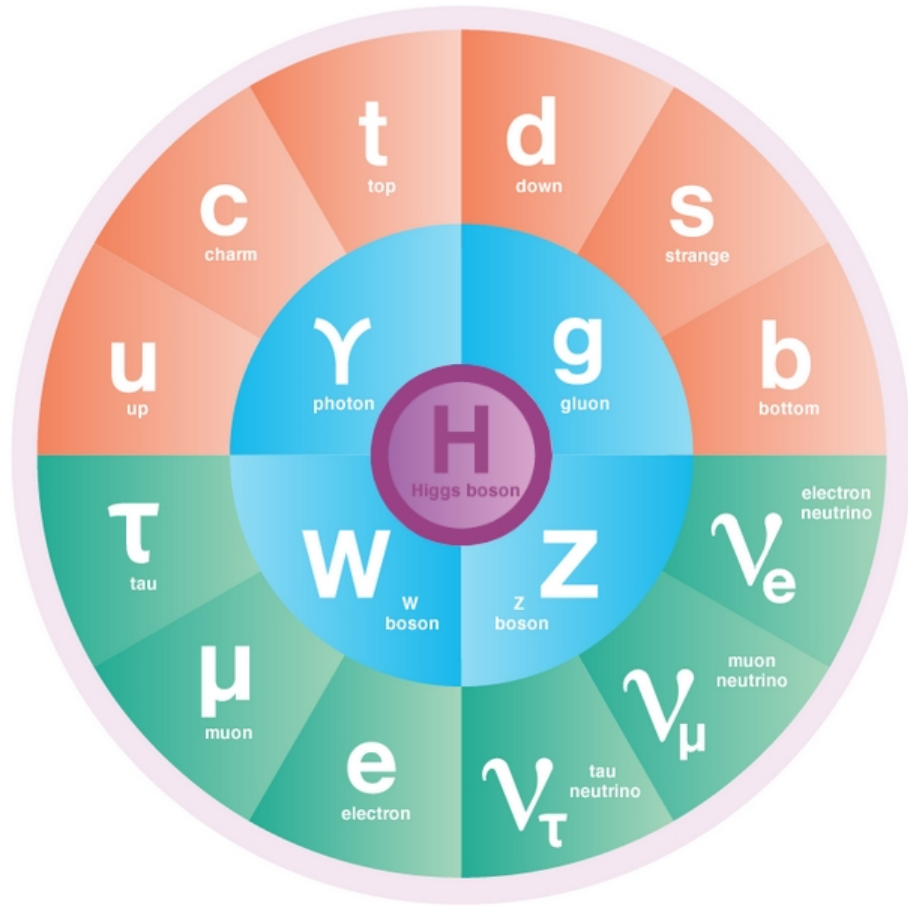
2nd Postdoc: DESY!

2024 – just now!

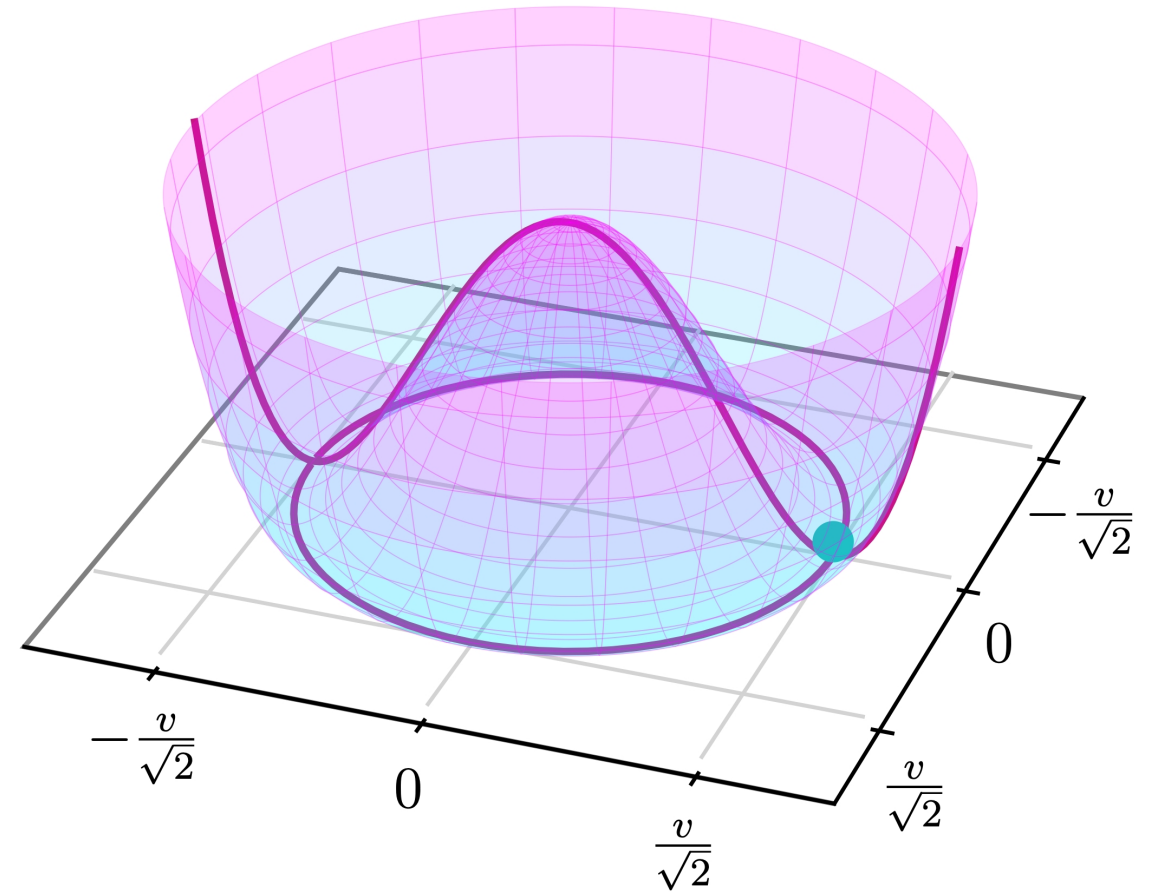
In the group of **Georg Weiglein**
Theory - phenomenology



Second part: Higgs physics

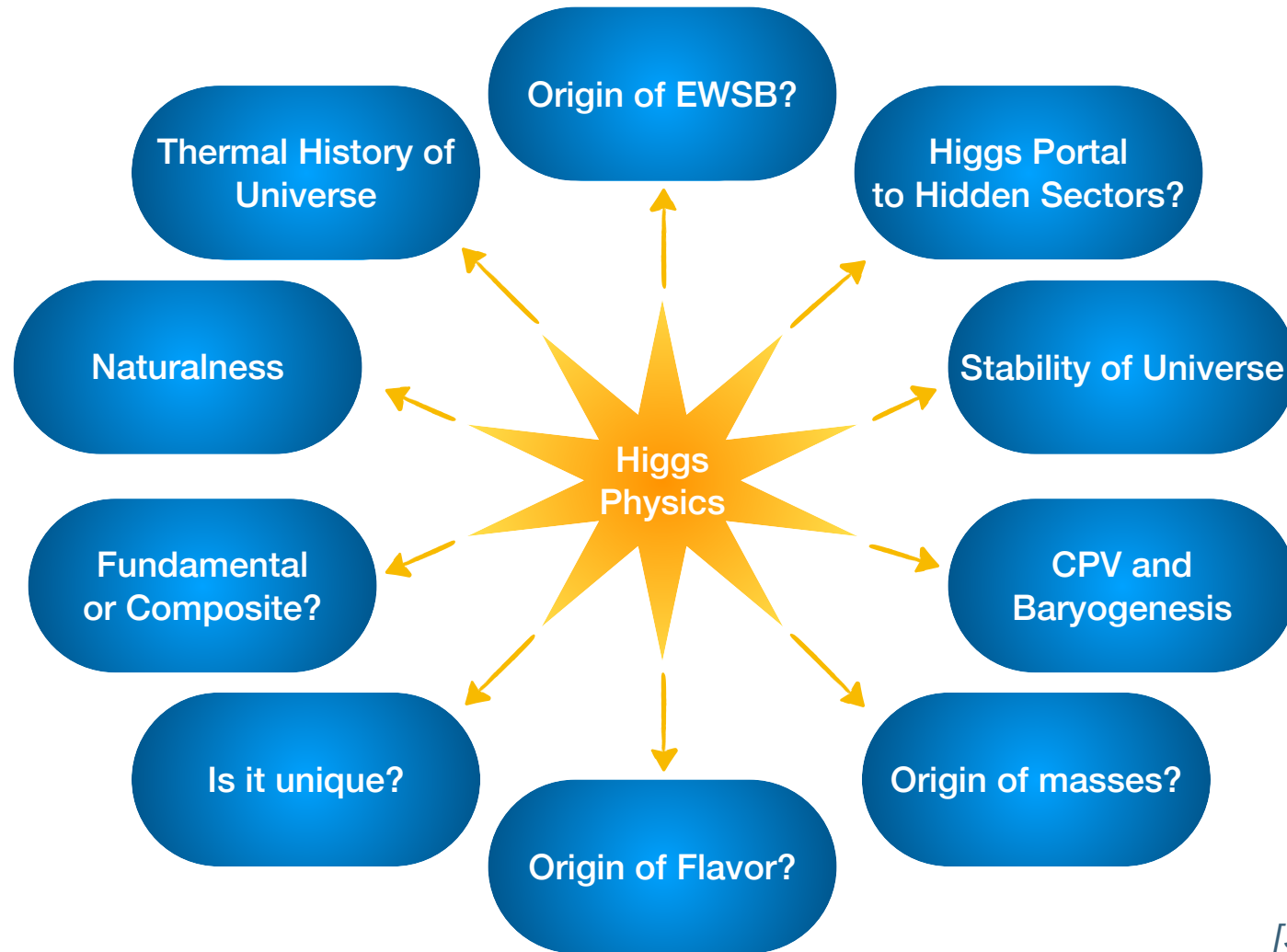


● QUARKS ● LEPTONS ● BOSONS ● HIGGS BOSON



Higgs physics: the SM is not the whole story

Many fundamental questions can be related to Higgs Physics

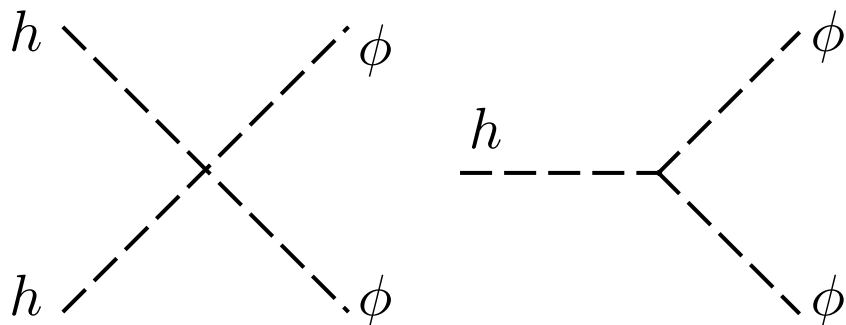


[Snowmass 2021 Report]

BSM extended Higgs sectors

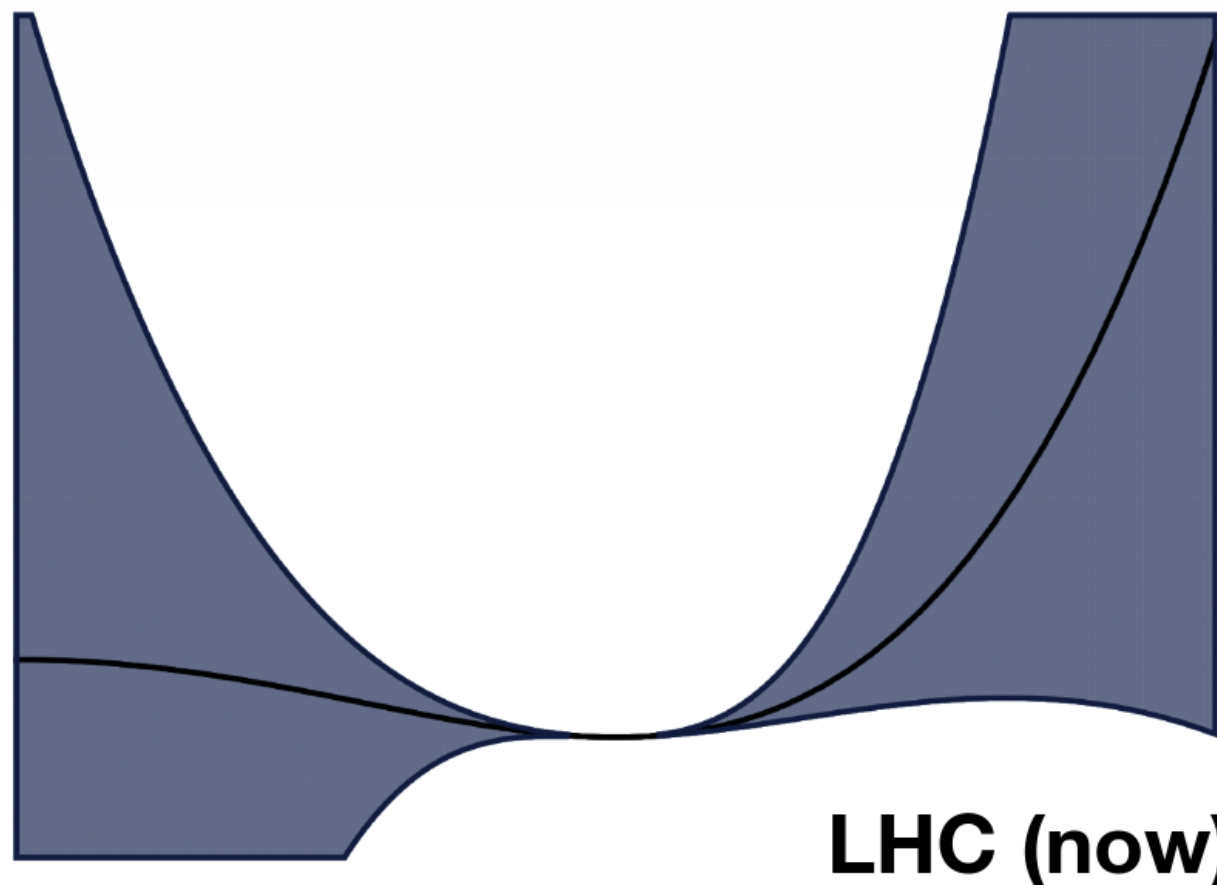
Extra bosons and scalar interactions

- The Higgs potential is almost *untested*
- **Add more scalar fields to the SM potential**
 - Extra Higgs bosons
 - Extra scalar interactions



- They can be **large**, even involving the SM-like Higgs boson! *[FA, Heinemeyer, Herrero, 21, 22]*
- **How can we probe them?**

Sketch of the current uncertainty in the (SM) Higgs potential (*Credit: Nathaniel Craig*)



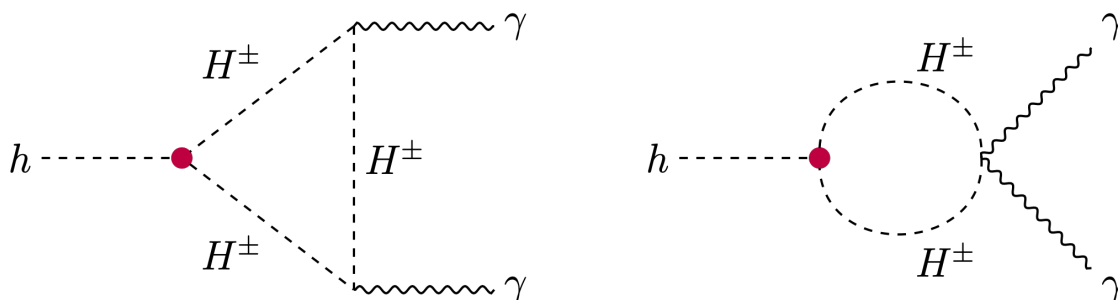
The effects may not disappear for heavy Higgs bosons

Nondecoupling effects in the two Higgs doublet model (2HDM)

- Do not panic: SM top quark does not decouple (e.g. the hgg coupling)
- Nondecoupling effects** if the Higgs bosons are heavy
[FA, Domenech, Herrero, Morales, 23]

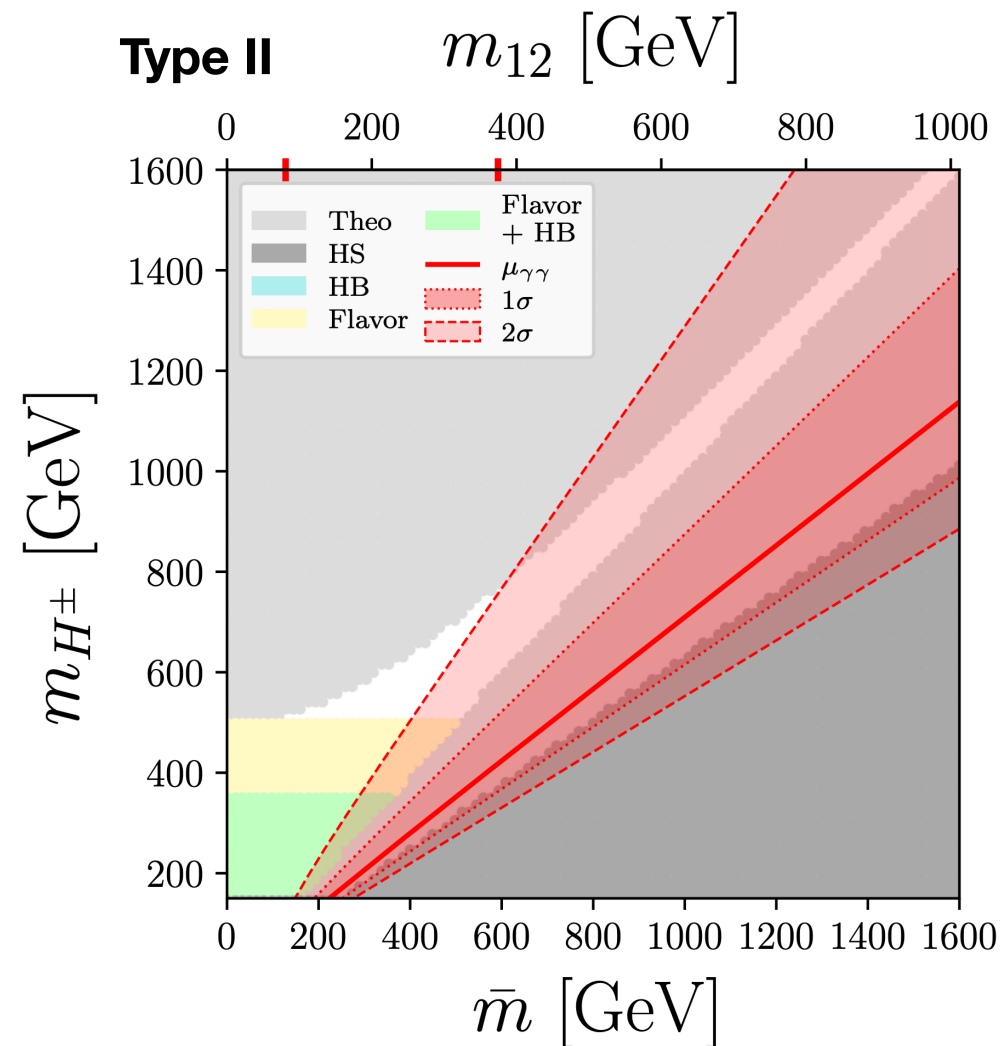
Decay to photons: sensitive to new physics!

[FA, Heinemeyer, Herrero, 22]



- Constraints from current exp measurements
 - In the future: point at a value of $\lambda_{hH^+H^-}$

$$v^2 \lambda_{hH^+H^-} \propto m_{H^\pm}^2 - \bar{m}^2$$

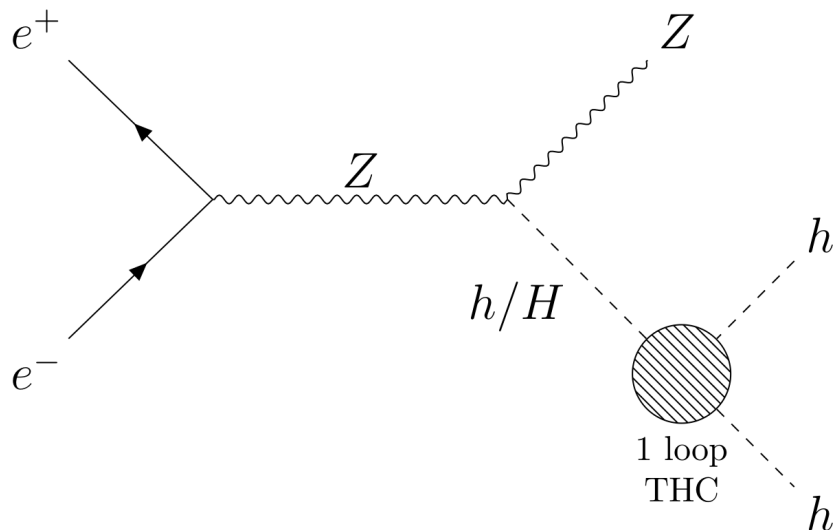


At future high-energy e^+e^- colliders

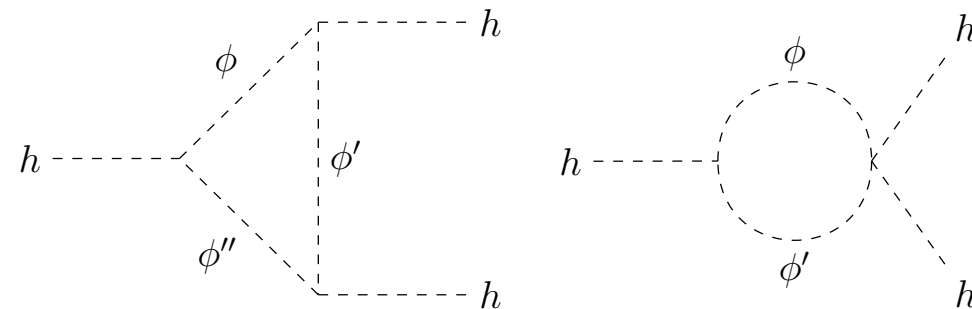
Important loop effects to the SM-like Higgs self coupling!

- **Large loop effects** on the hhh coupling even if h is very SM-like!
- **Double Higgs production: sensitivity to triple Higgs couplings at one loop**

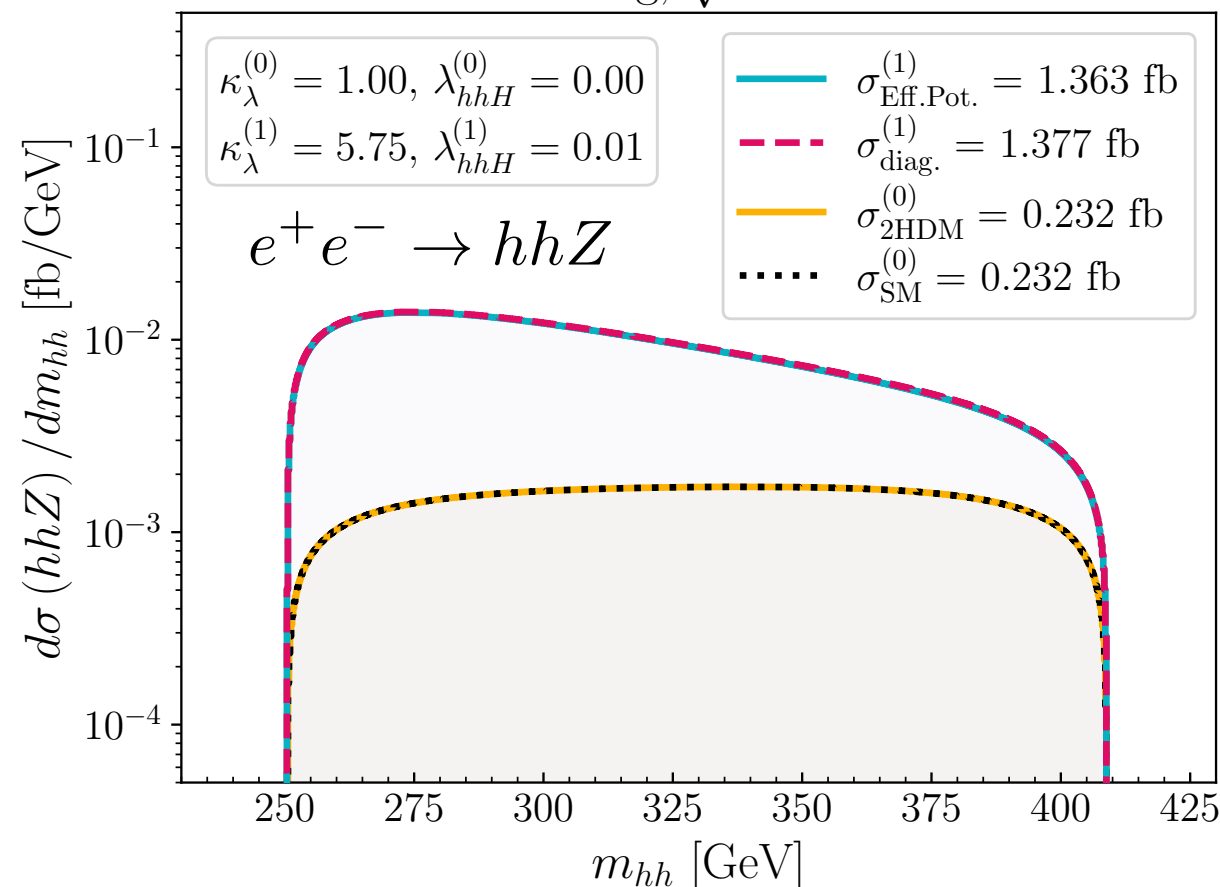
[FA, Heinemeyer, Mühlleitner, 24 tbp]



- Tree level triple Higgs couplings (in the 2HDM) at the LHC [FA, Mühlleitner, Heinemeyer, Radchenko, 22] and at e^+e^- colliders [FA, Heinemeyer, Herrero, 21]



No smearing, $\sqrt{s} = 500$ GeV

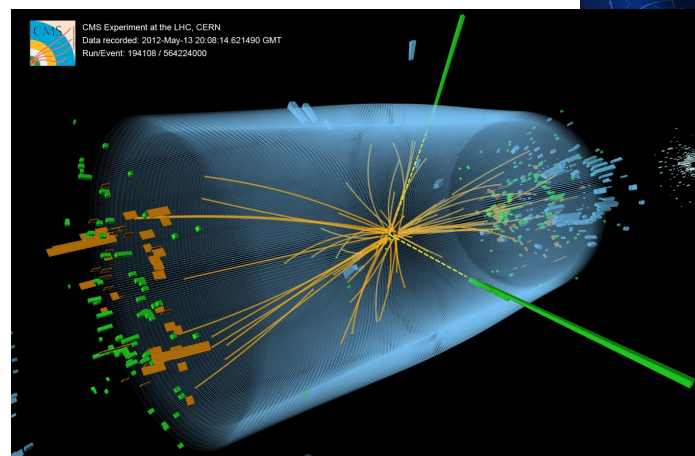
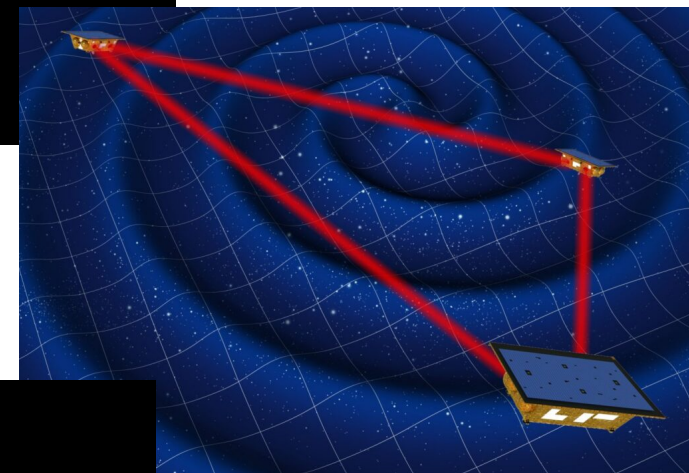
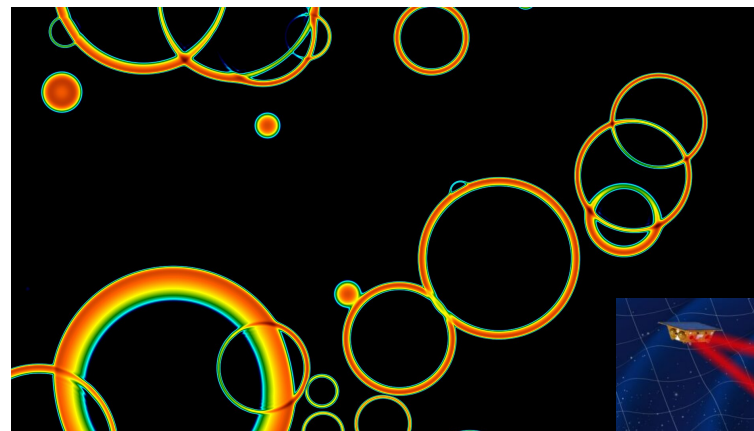


Future directions and ideas

At DESY !!!

- **Cosmological history** of extended Higgs sectors
 - Baryogenesis and first order electroweak phase transitions
 - Gravitational wave signals
- **Collider searches**, both e^+e^- and hadron colliders
 - Where to look? More observables sensitive to new Higgs physics
 - Explore the Higgs potential, direct or indirectly
- **Effective field theories**
 - SMEFT vs. HEFT, possible nondecoupling nature of the Higgs

Interplay between all of them !!!



Thanks for your attention :)