Higgs Physics at Complementary Collider, with the **search at LHC for double-Higgs production for the measurement of the Higgs self-coupling**, and **prospects for Higgs mass and self-coupling measurements at the Future Circular Collider in e^+e^- collision**

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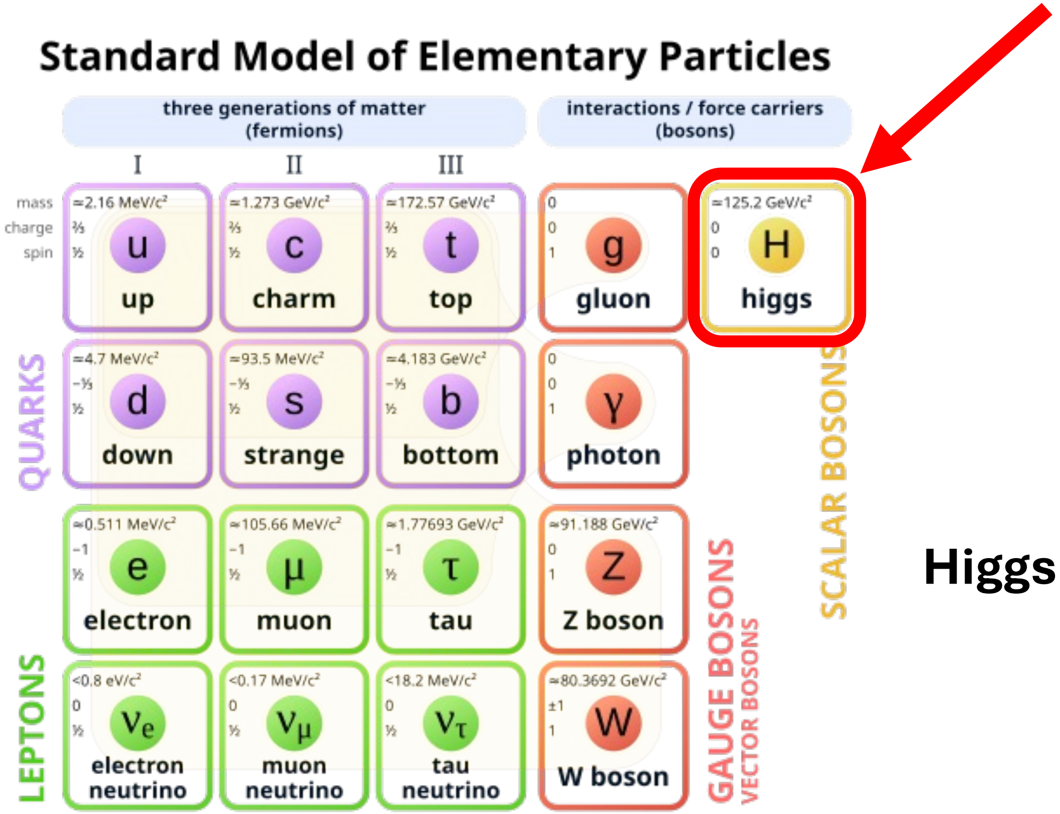
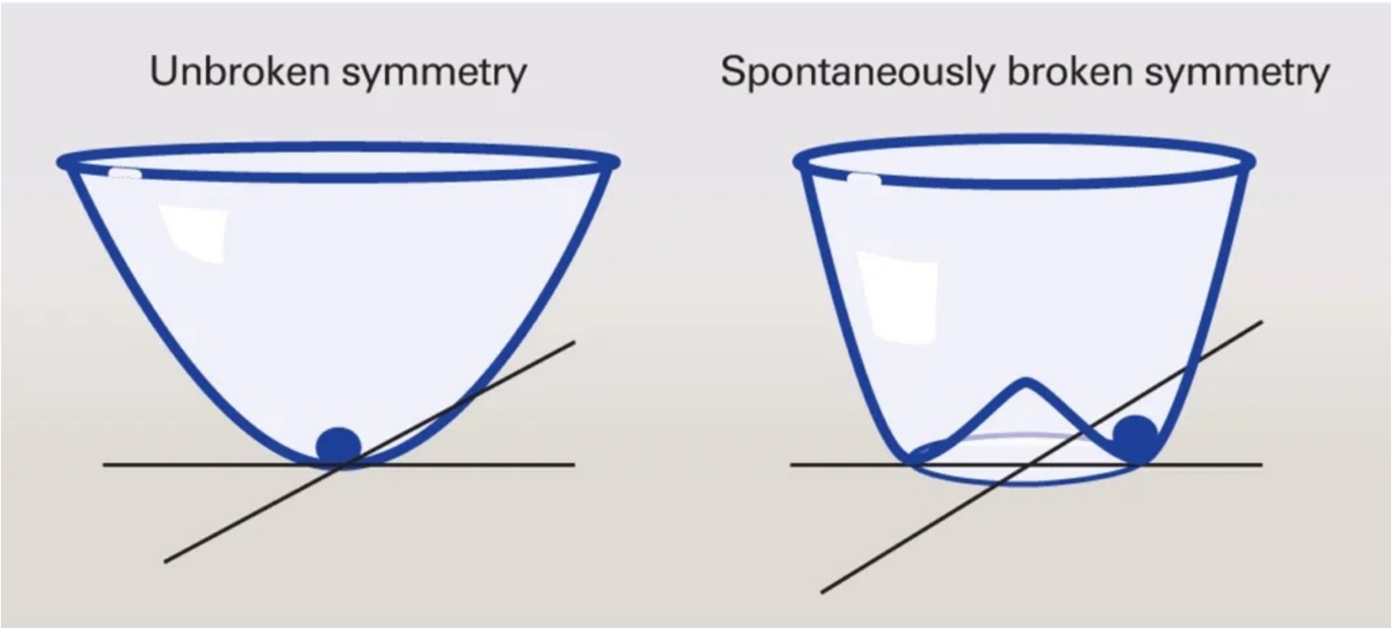
Supervised by Gregorio Bernardi

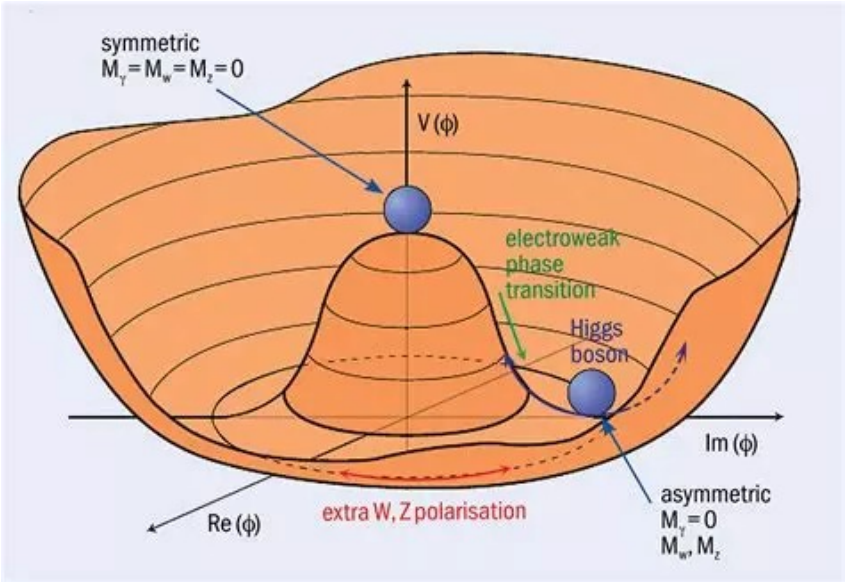
Thesis presentation: Biennale

Introduction





Higgs potential after EWSB: $V(h) = \frac{1}{2} m_H h^2 + \lambda_3 v h^3 + \frac{1}{4} \lambda_4 h^4$

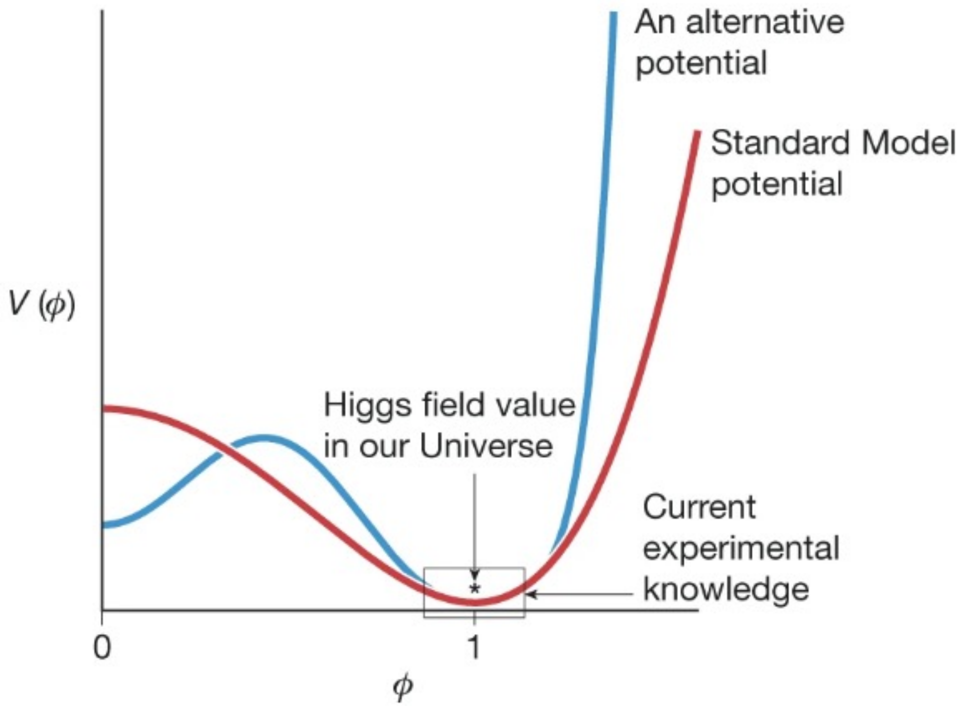


- m_H: already measured at 125 GeV
- λ_3: not measured yet but constrained in LHC
- λ_4: not measured, very poorly constrained in LHC

Introduce the coupling modifier: $\kappa_\lambda = \frac{\lambda_3}{\lambda_3^{SM}}$ (in the SM, $\kappa_\lambda = 1$)

One of the main goals in Higgs physics is to measure κ_λ

Why do we want to measure κ_λ?



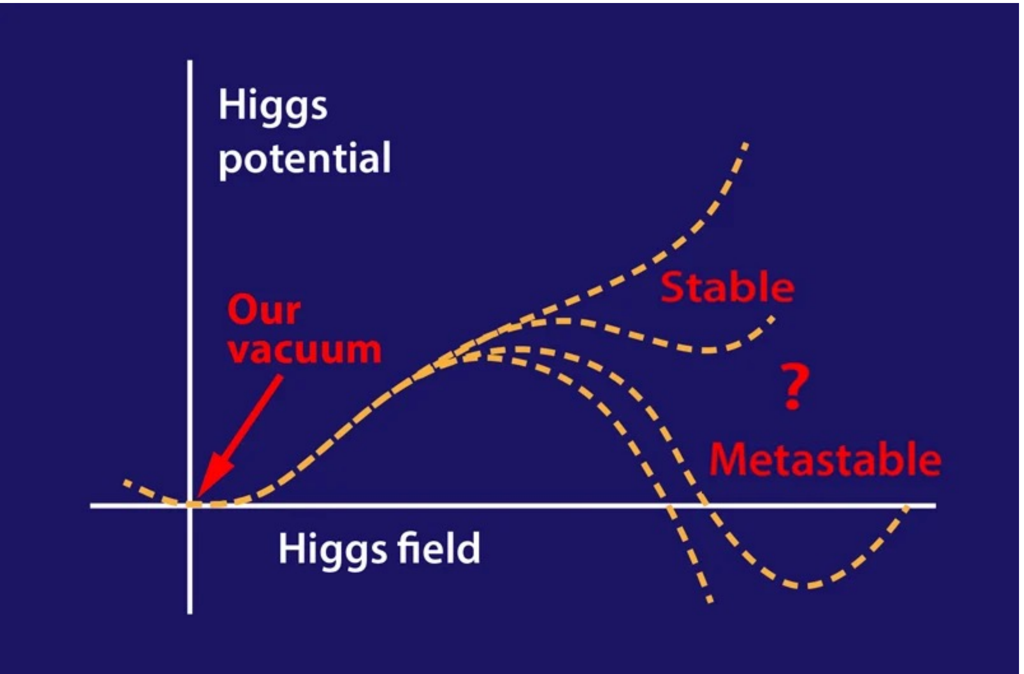
<u>Obvious answer:</u> To test the Standard Model predictions

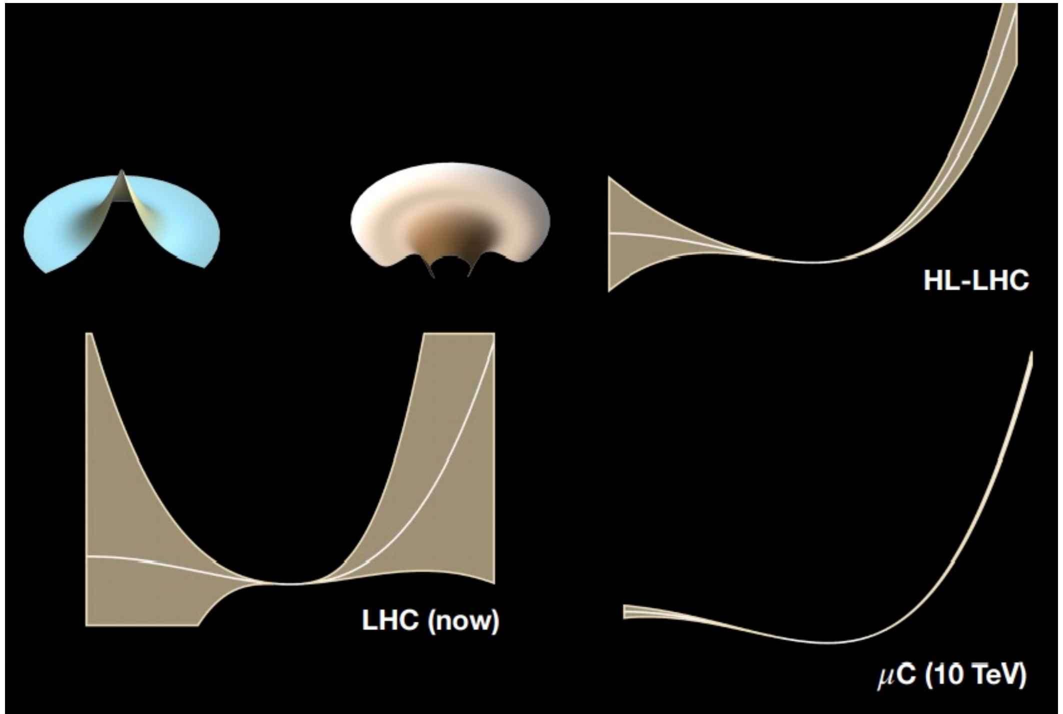
<u>Less obvious answer:</u>

Open questions in the Standard Model

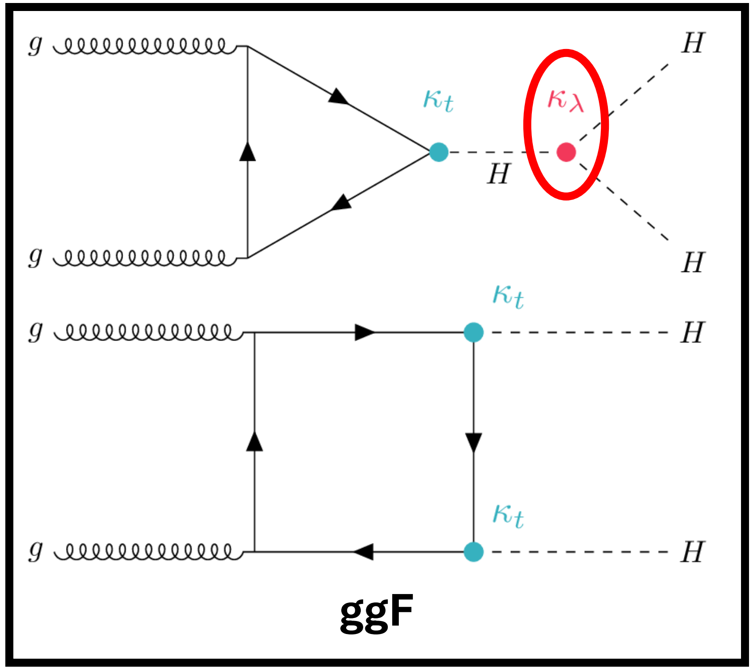
- Origin of mass
- Baryogenesis
- Hierarchy problem
- Stability of the vacuum
- Dark matter

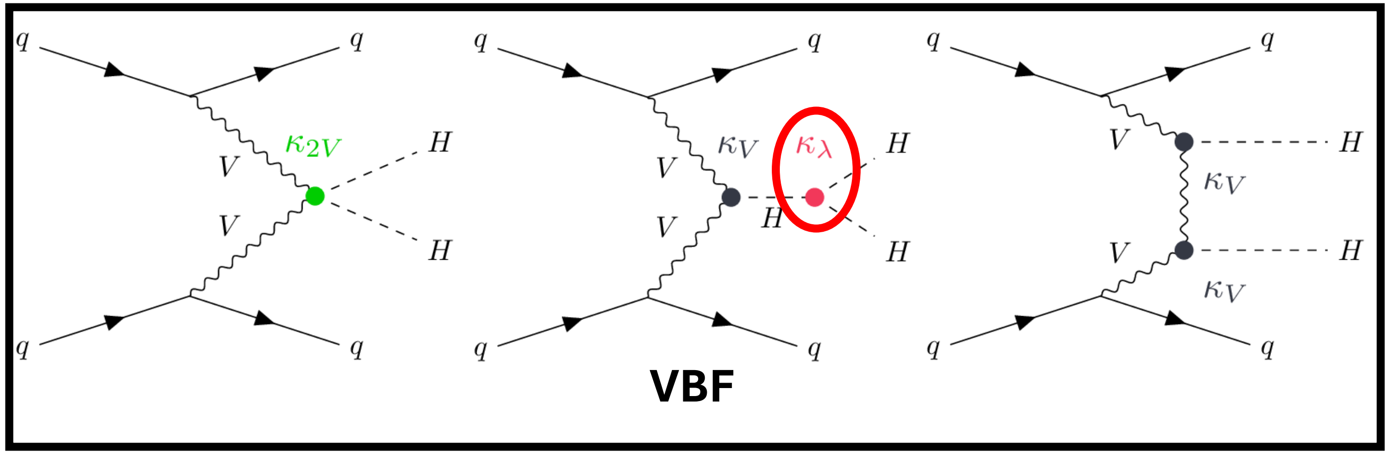
Measuring κ_λ and the other Higgs properties could answer these questions





ATLAS part of the thesis





Analysis separated in different channels:

$HH \to b\bar{b}b\bar{b}$, $HH \to b\bar{b}\tau^+\tau^-$, $HH \to b\bar{b}\gamma\gamma$

	bb	WW	ττ	ZZ	γγ
bb	34%				
WW	25%	4.6%			
ττ	7.3%	2.7%	0.39%		
ZZ	3.1%	1.1%	0.33%	0.069%	
γγ	0.26%	0.10%	0.028%	0.012%	0.0005%

$HH \to b\bar{b}b\bar{b}$:

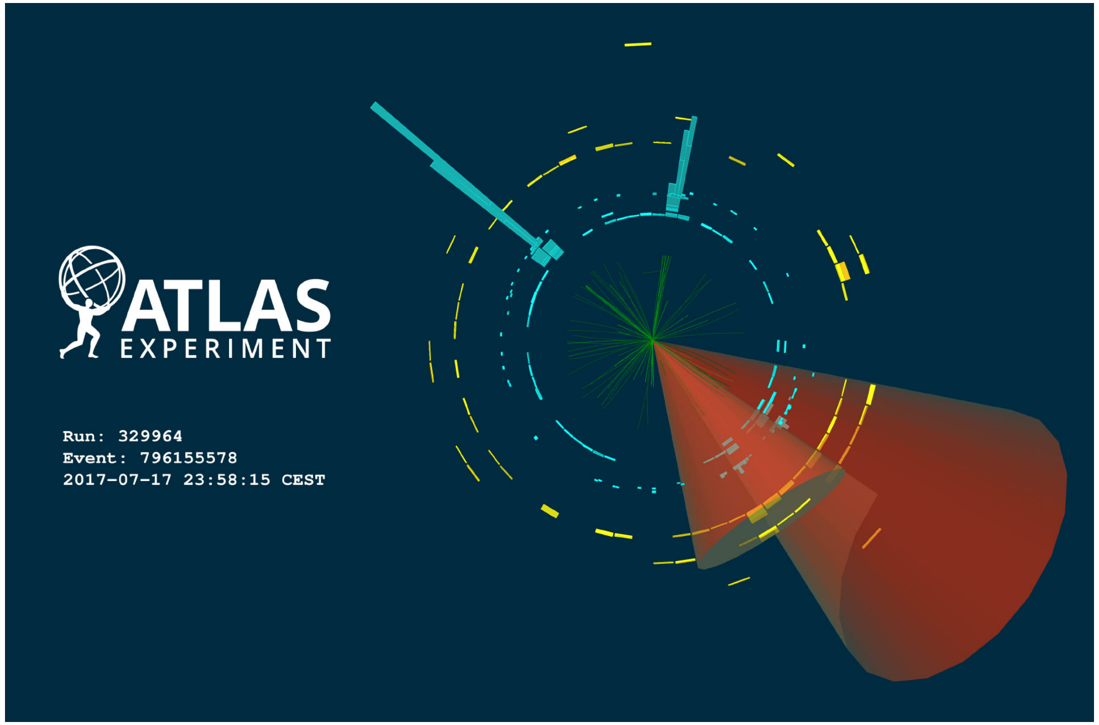
- High branching ratio
- High background

$HH \to b\bar{b}\tau^+\tau^-$:

- Medium branching ratio
- Medium background

$HH \to b\bar{b}\gamma\gamma$:

- Low branching ratio
- Low background



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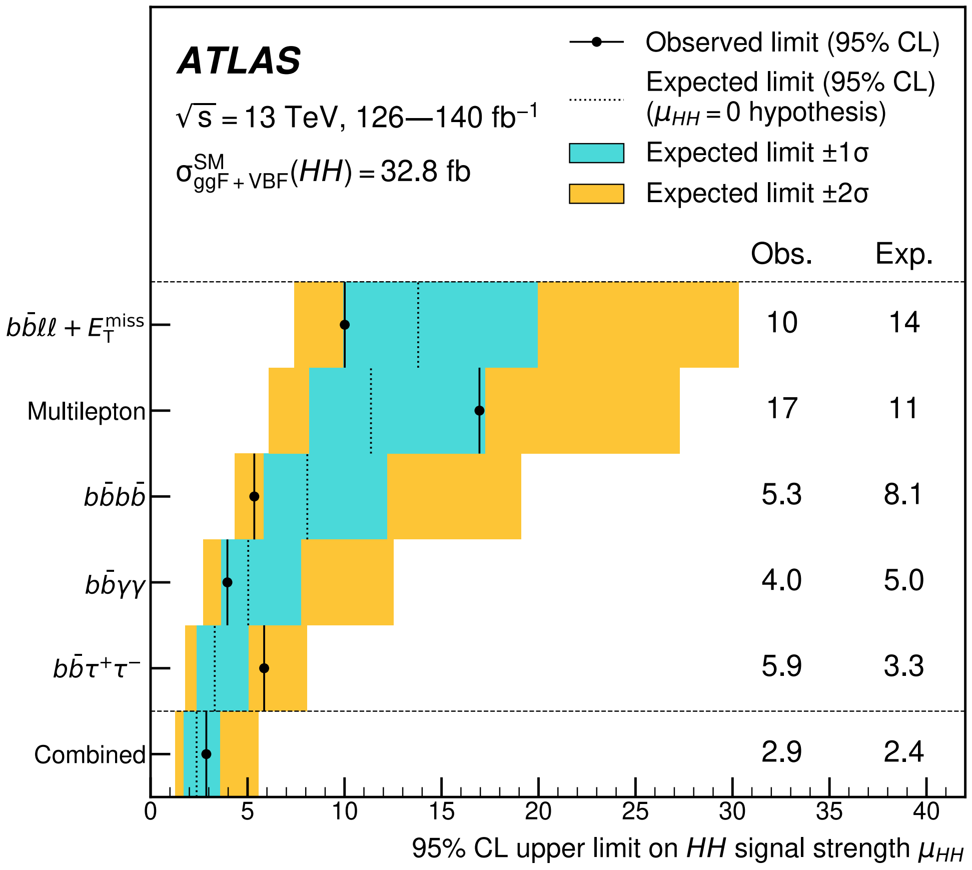
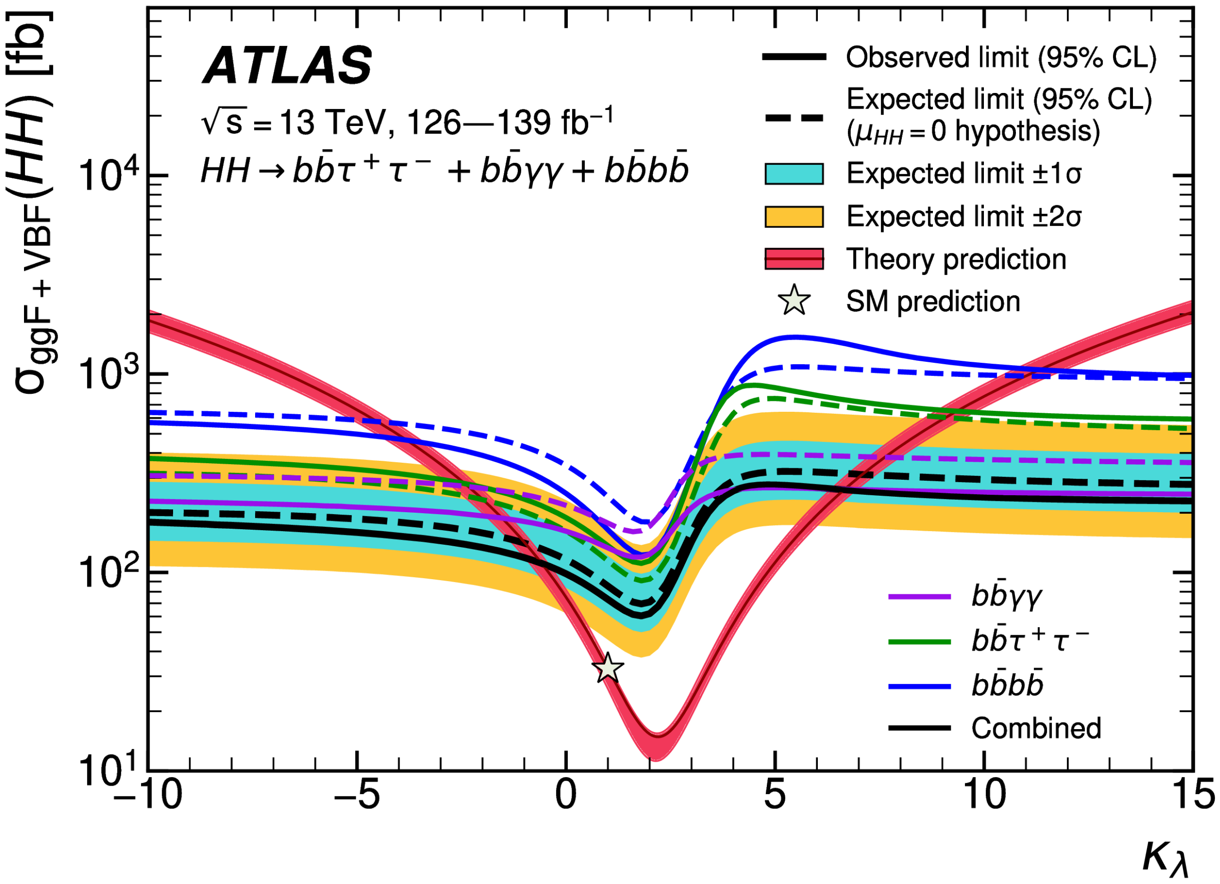




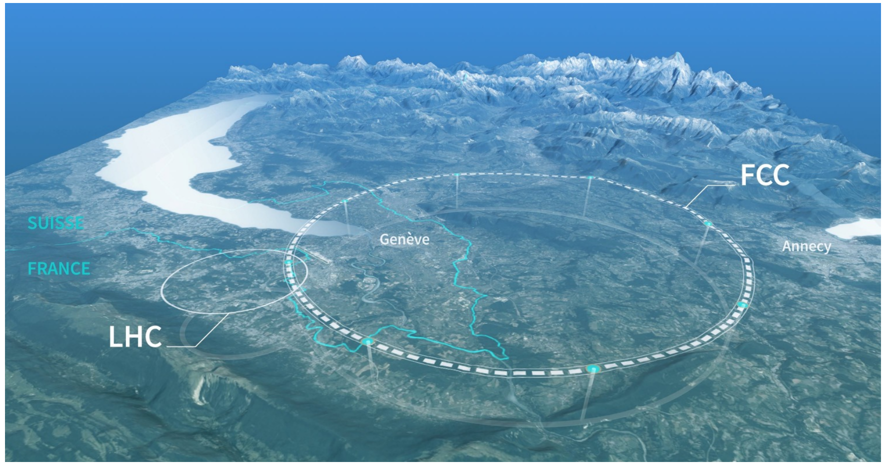
Currently:

- Di-Higgs production not currently observed
- Can only put upper limit on the production cross-section
  - Current limit: $\mu_{HH} < 2.9(2.4)$
- This limit can constrain κ_λ
  - Current constrain: $-1.2 < \kappa_\lambda < 7.2$ $(-1.6 < \kappa_\lambda < 7.2)$

My works is to contribute to the $HH \rightarrow b\bar{b}\tau^+\tau^-$ analysis

- Will start contributing next year
- Currently doing a qualification task to become an ATLAS author

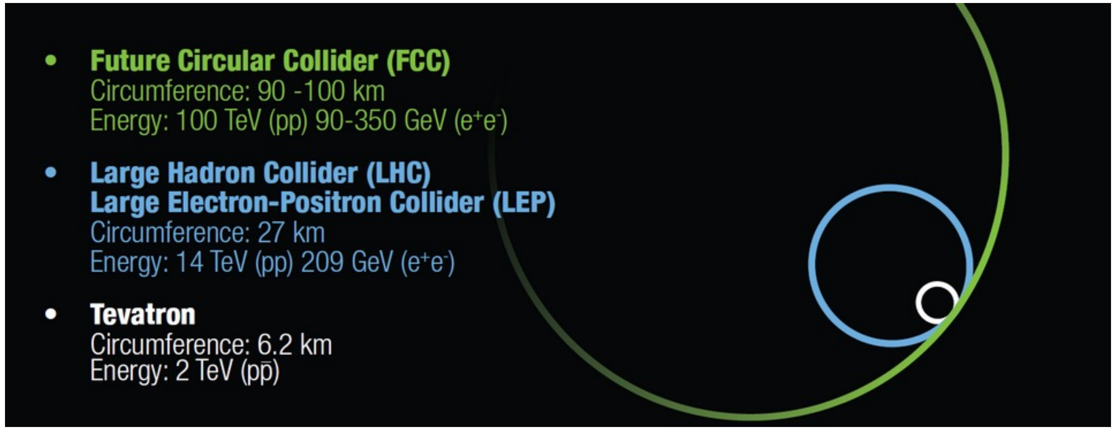
FCC part of the thesis



Working point	Z pole	WW thresh.	ZH	$t\bar{t}$	
$\sqrt{s}$ (GeV)	88, 91, 94	157, 163	240	340–350	365
Lumi/IP (10^{34} cm^{-2}s^{-1})	140	20	7.5	1.8	1.4
Lumi/year (ab^{-1})	68	9.6	3.6	0.83	0.67
Run time (year)	4	2	3	1	4
Integrated lumi. (ab^{-1})	205	19.2	10.8	0.42	2.70
Number of events	6×10^{12} Z	2.4×10^{8} WW	2.2×10^{6} ZH + 65k WW $\rightarrow$ H	2×10^{6} $t\bar{t}$ + 370k ZH + 92k WW $\rightarrow$ H	

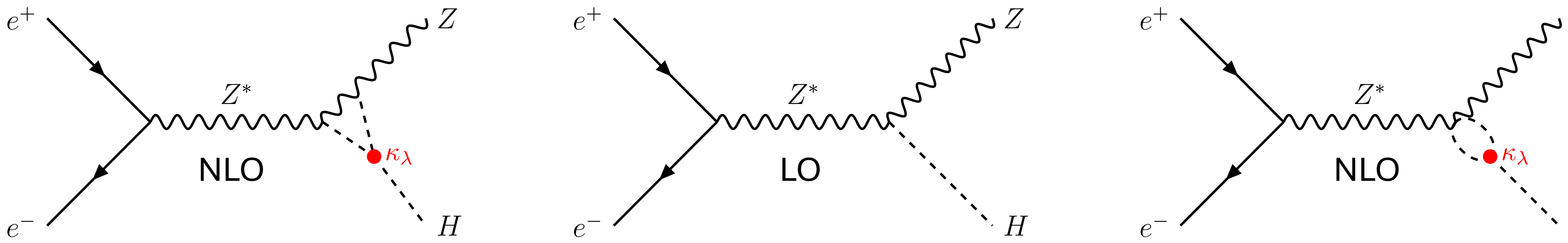
FCC is a candidate to replace LHC, it is separated in 2 phases:

- FCC-ee: e^+e^- collisions at different $\sqrt{s}$
- FCC-hh: pp collisions at $\sqrt{s} = 85\ TeV$



Higgs properties measurable through ZH production cross-section

- **Higgs coupling** g_{HXX}
- **Higgs width:** Γ_H
- **Higgs mass** m_H
- **Higgs self-coupling** κ_λ

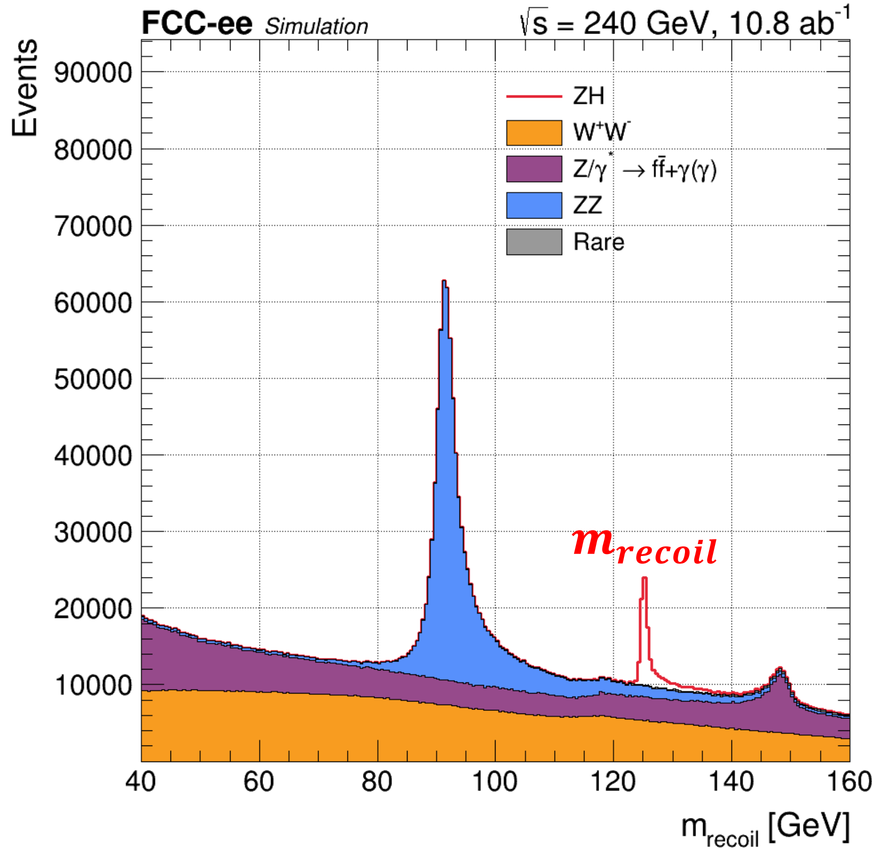


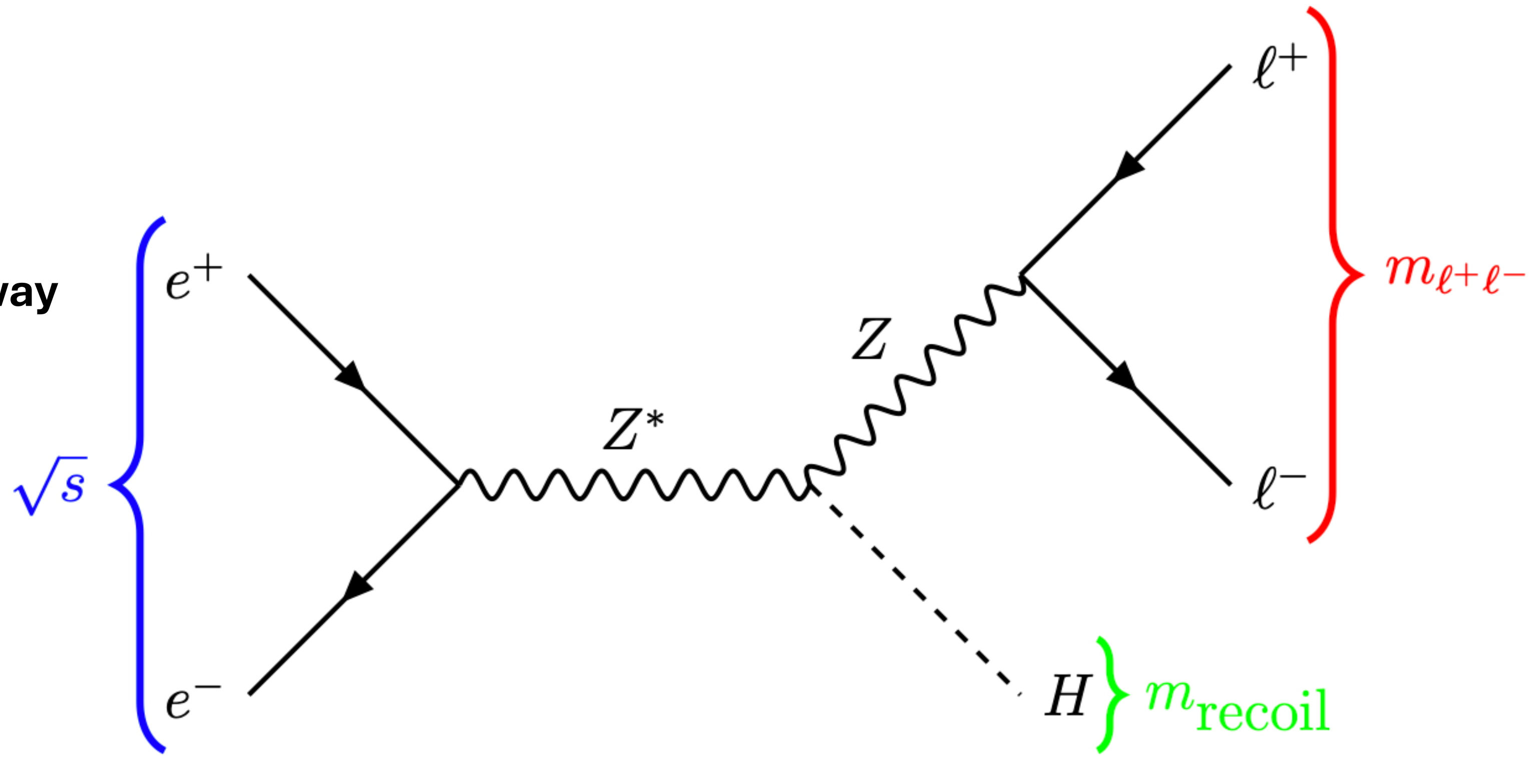
FCC part of the thesis

Initial state known → can use **recoil mass method**: $m_{recoil}^2 = s - 2\sqrt{s}E_{\ell^+\ell^-} + m_{\ell^+\ell^-}^2$ to reconstruct the Higgs in **model-independent way**

Analysis separated in three channels:

- $Z(\mu^+\mu^-)H, Z(e^+e^-)H$ → leptonic channel
- $Z(q\bar{q})H$ → hadronic channel





My work consists in improving this selection

- Done for the leptonic channel (~20% improvement)
- Currently doing the hadronic channel

After this:

- Work with full simulation
  - To reconstruct the detector's effect
  - To optimize the detector's design
- Improve the Higgs mass measurement analysis

Thanks for listening