

# Higgs(es) now and in the future

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DESY.



Universität Hamburg  
DER FORSCHUNG | DER LEHRE | DER BILDUNG



# About me

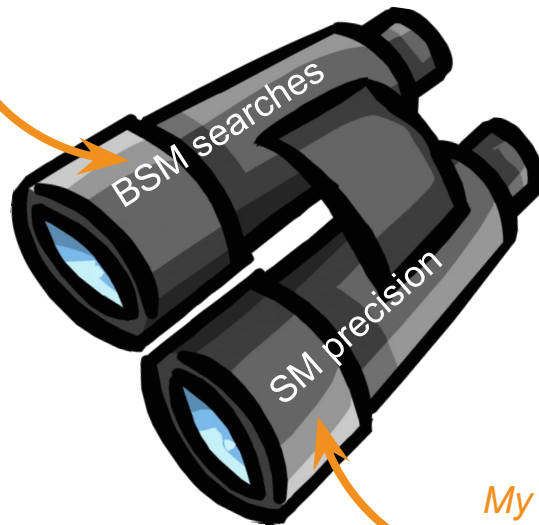
## My route in the world and in physics



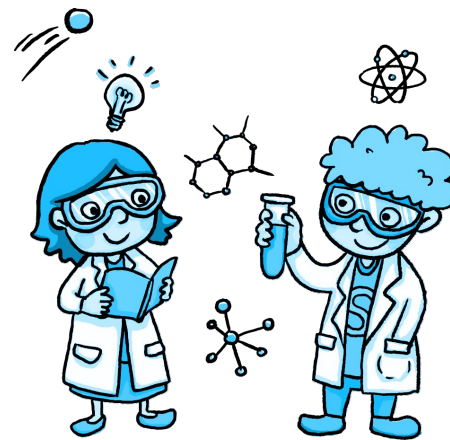
- Born in Aachen, DE
- Studied in Bonn, DE
  - Bachelor & Masters thesis in ATLAS, on  $\tau$ -mass reconstruction and  $t\bar{t}H(\tau\tau)$  studies
- PhD in Amsterdam, NL
  - 1 year at CERN
  - Heavy Higgs search in  $ZZ(\ell\ell\nu\nu)$  with ATLAS
- Post-doc in Hamburg, DE
  - QU cluster
  - Higgs studies & prospects with ATLAS and FCC-hh



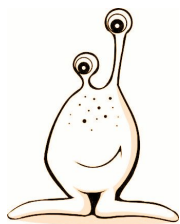
*My (Phd) past*



*My (post-doc) present & future*



*Us*

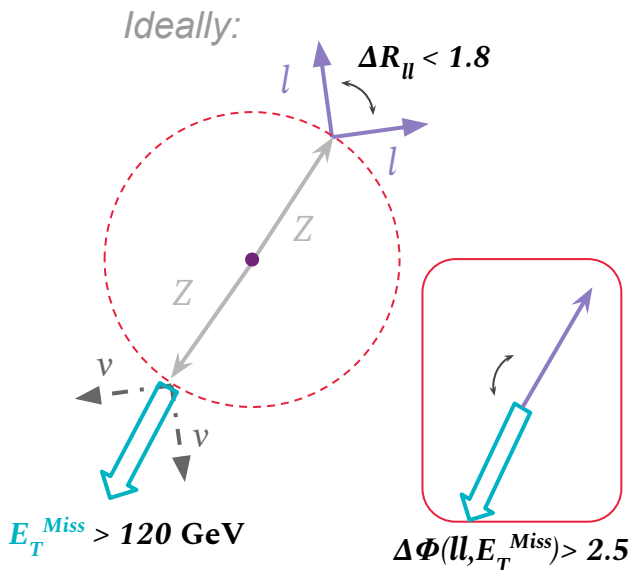


*New (Higgs) physics*

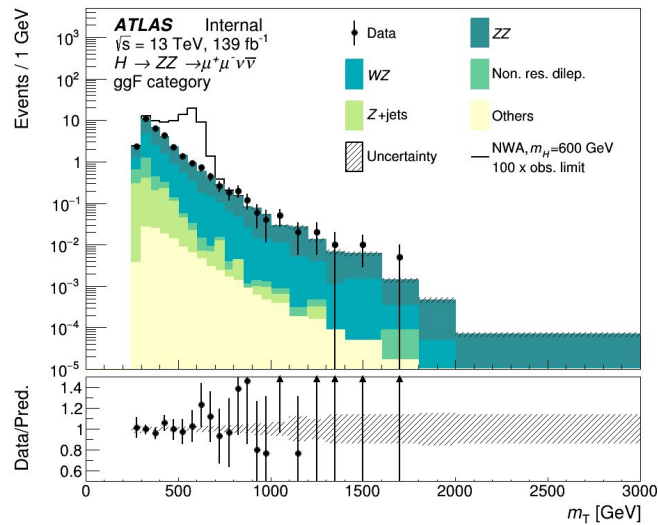
# Past work

## Heavy $H \rightarrow ZZ \rightarrow ll\nu\nu$ analysis concepts

- Mass range:  $300 \text{ GeV} < m_H < 2 \text{ TeV}$
- Widths: NWA and LWA (1%, 5%, 10%, 15% of  $m_H$ )
- Major backgrounds: ZZ, WZ, Z+jets
- Cut-based analysis, exploit signal event kinematics



arXiv:2009.14791

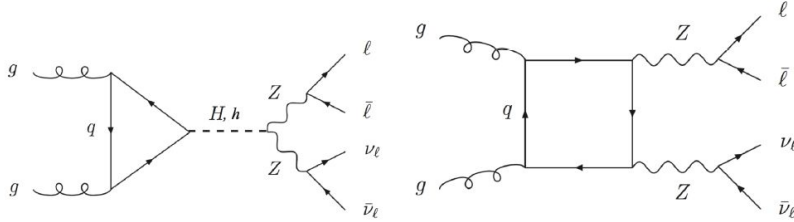


$$m_T^2 \equiv \left[ \sqrt{m_Z^2 + |\vec{P}_T^{ll}|^2} + \sqrt{m_Z^2 + |\vec{P}_T^{miss}|^2} \right]^2 - \left[ \vec{P}_T^{ll} + \vec{P}_T^{miss} \right]^2$$

- No excess in ATLAS data!
- ➡ Set limits on heavy Higgs cross section in the various scenarios

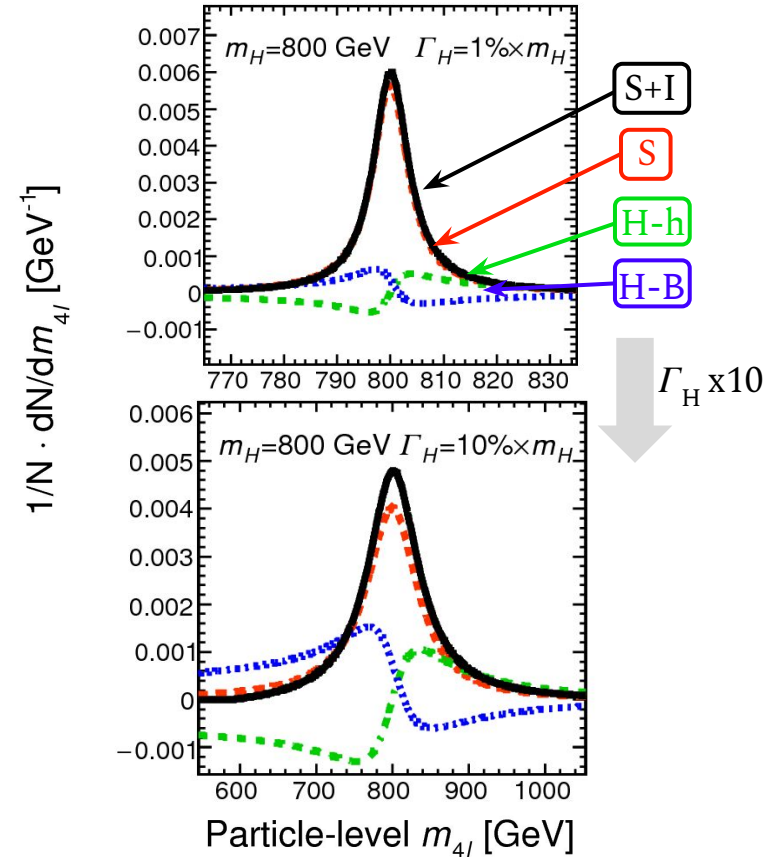
# Past work

## Heavy $H \rightarrow ZZ \rightarrow \ell\nu\nu$ interference modelling



- For LWA, interference effects become relevant, between ggF signal and:
  - 125 GeV Higgs in ggF: **H-h**
  - $ggZZ$  background: **H-B**
- Impact on yields up to  $\sim 10\%$
- Both interferences modelled
  - **H-h** with analytic reweighting function
  - **H-B** from empirical function fit to simulation

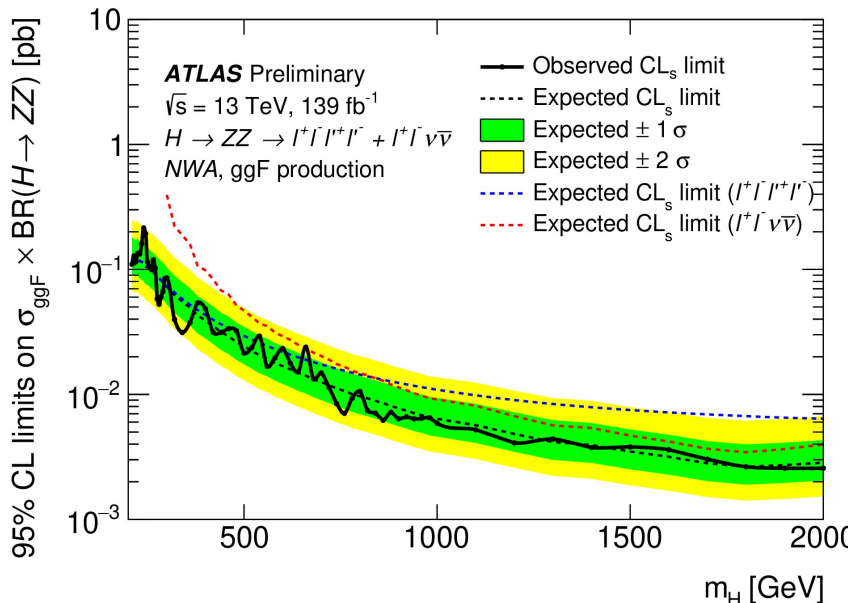
## ATLAS Simulation $\sqrt{s} = 13$ TeV



# Past work

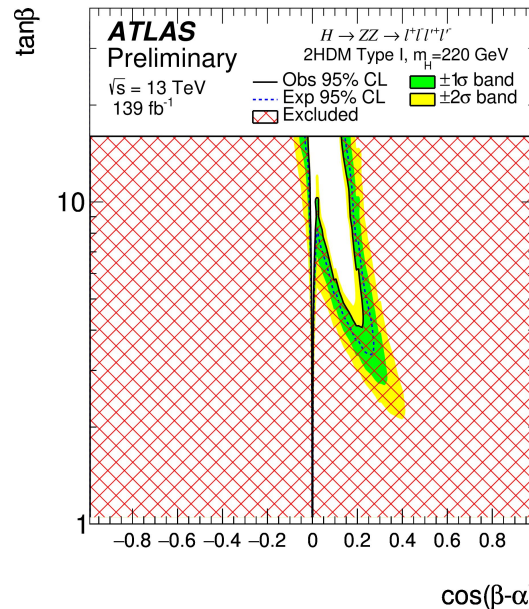
## Heavy $H \rightarrow ZZ \rightarrow 4l\nu\nu$ results

NWA ggF limits



arXiv:2009.14791

## 2HDM Type I, $m_H = 220 \text{ GeV}$

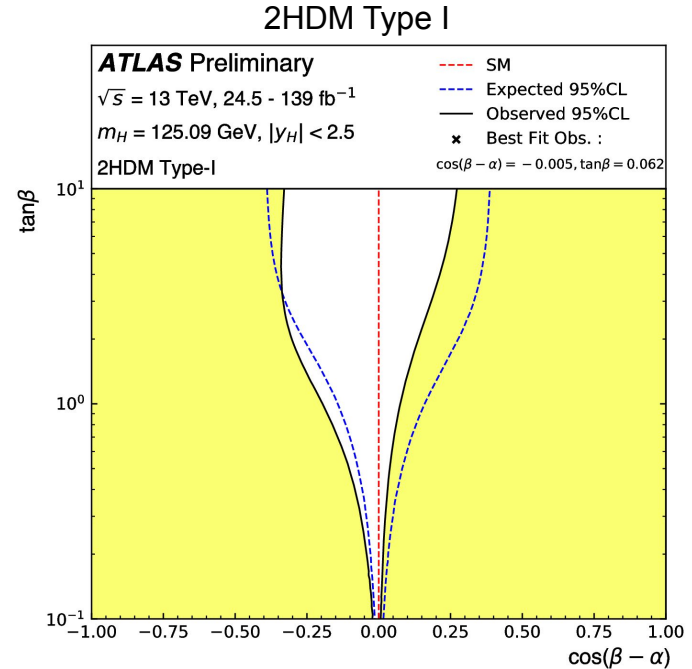
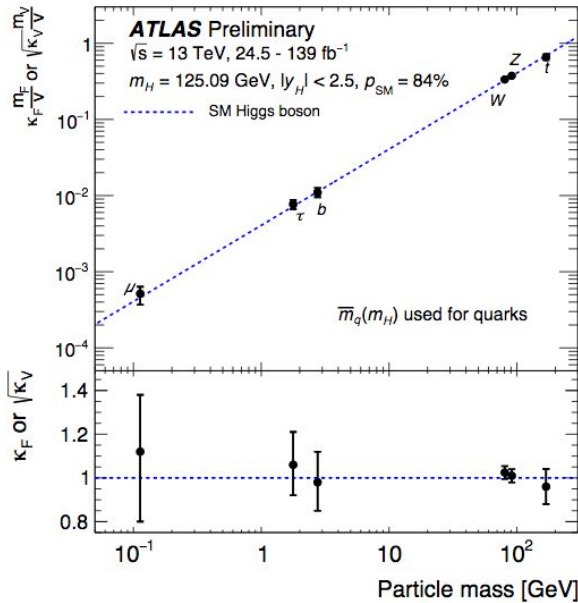


2HDM has 5 Higgses:  $h, H, A, H^+, H^-$

- Combine with  $H \rightarrow ZZ \rightarrow 4l$  analysis to maximize sensitivity
- No heavy Higgs anywhere ...
- 2HDM contours exclude much phase space for  $m_H \sim 200 \text{ GeV}$

# Current & future work

## ATLAS Higgs combinations



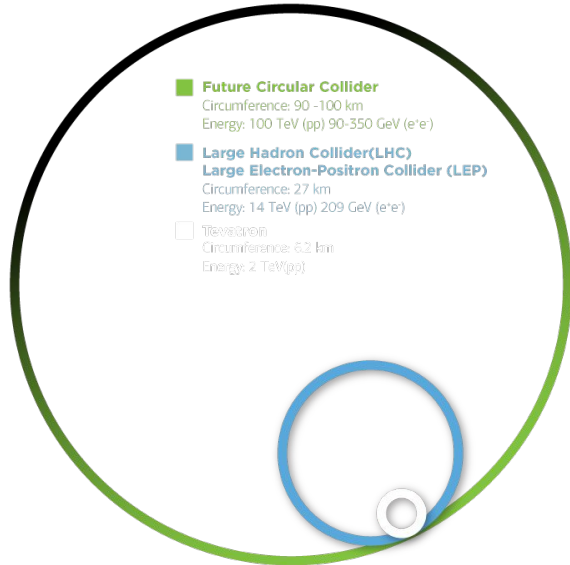
- Joined DESY ATLAS team working on Higgs combinations: Improve precision by combining results from the different measurement channels

➡ Find small deviations from SM, constrain BSM parameter space!

# Current & future work

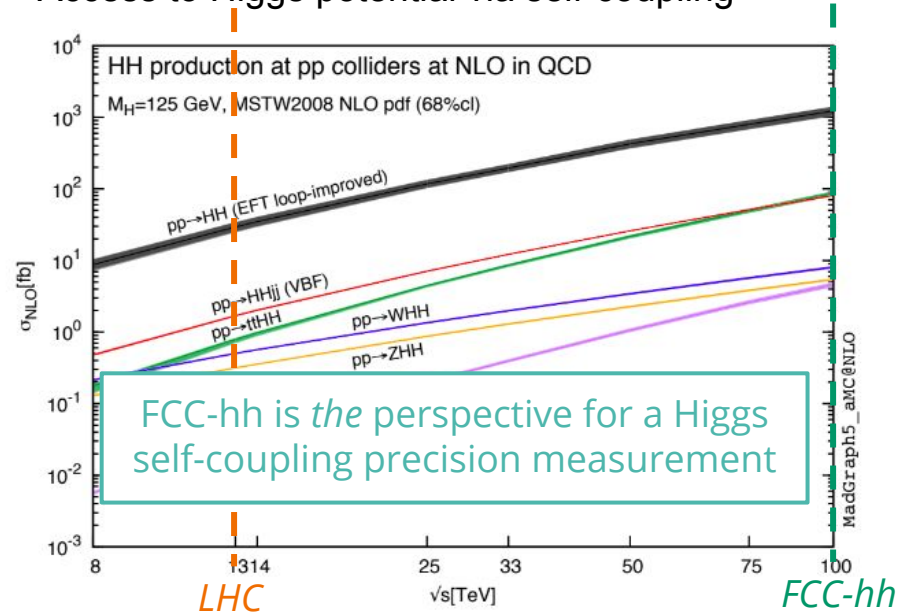


## Di-Higgs studies for FCC-hh

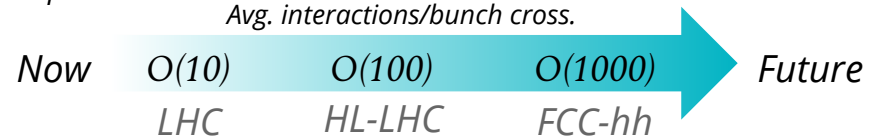


- $pp$ -collisions at 100 TeV, collect  $30 \text{ ab}^{-1}$  of data
- "Far" in the future (after FCC-ee) but need to continue working on the foundations now
  - Physics potential established in CDR
  - .. but more details to be filled in!

- Currently investigating possibility of neutrino channels for di-Higgs analyses
- Access to Higgs potential via self-coupling



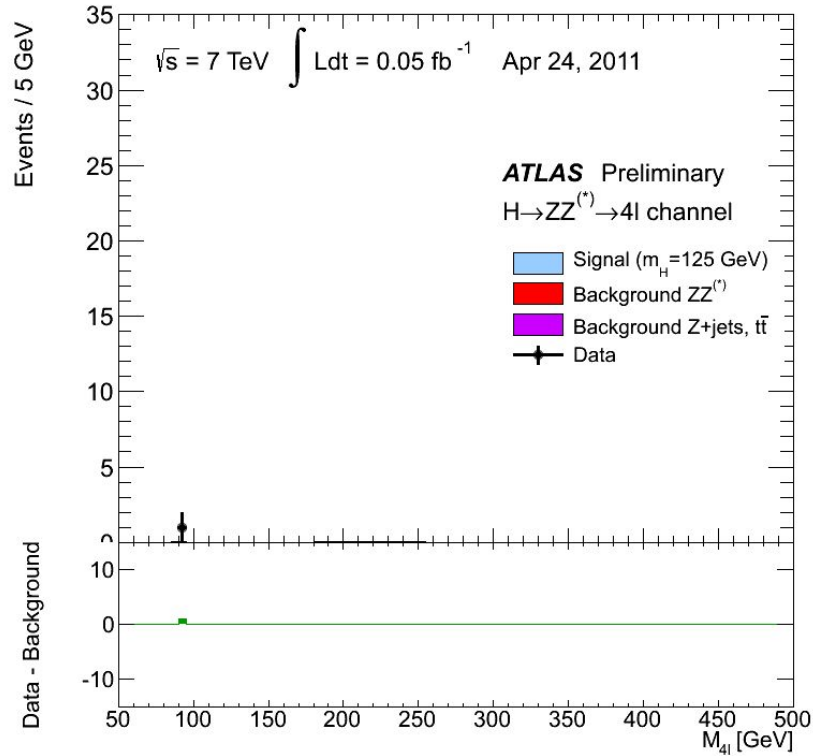
- Involve neutrinos for missing detail: What about  $E_T^{Miss}$  in such high pile-up conditions?  
 Avg. interactions/bunch cross.





# My favourite plot

## About Higgs physics



# My favourite plot

## Warming stripes

