HELMHOLTZ

MATTER AND THE UNIVERSE MU

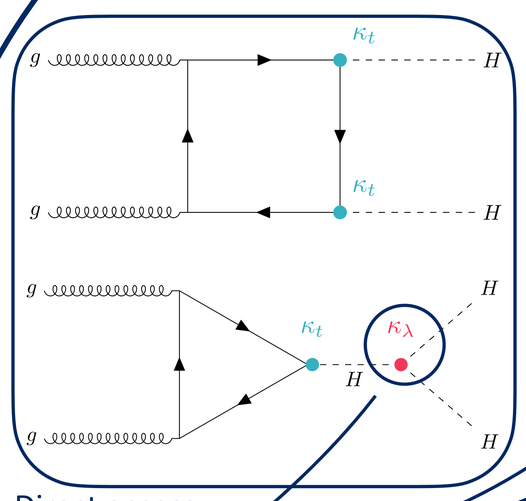
Topic: FPF

$HH \to b\bar{b}\tau^+\tau^-$ and HH combination in ATLAS

Serhat Ördek

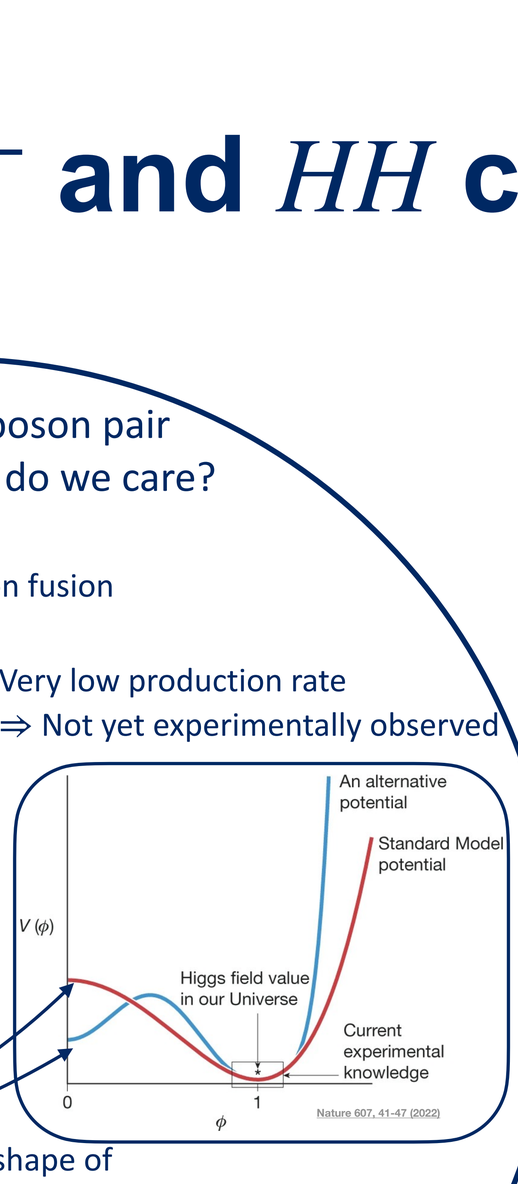
What is Higgs boson pair production? Why do we care?

Leading HH production mode: gluon fusion



Very low production rate

⇒ Not yet experimentally observed



Direct access to Higgs self-coupling!

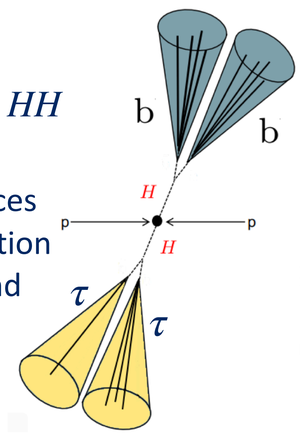
Affects shape of Higgs potential, so far unknown

Guiding questions:

- **Is our Universe's vacuum state stable?**
- **Could the electroweak phase transition have enabled baryon asymmetry?**

Strategy of the search for $HH \to b\bar{b}\tau^+\tau^-$

- Many possible HH final states
- $b\bar{b}\tau^+\tau^-$ balances branching fraction and background rejection



1. Split by leptonic/ hadronic decays of τ leptons

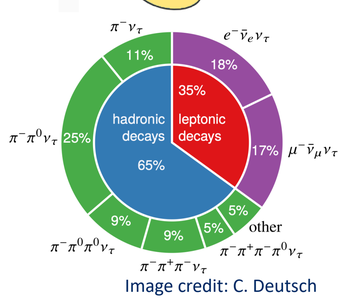
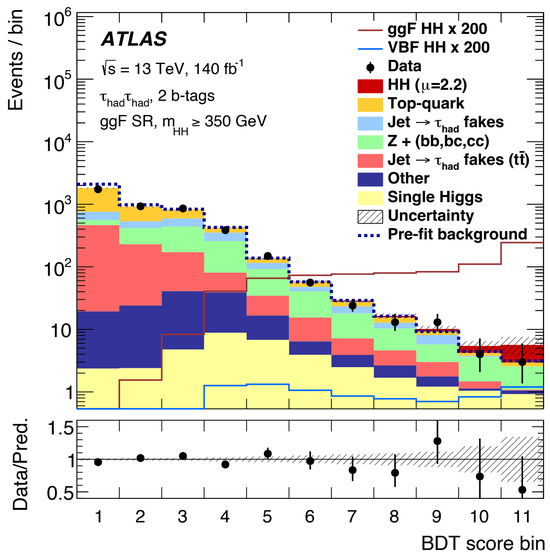


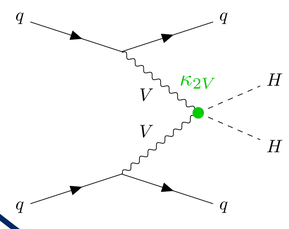
Image credit: C. Deutsch

3. Train Boosted Decision Trees to separate signal from background

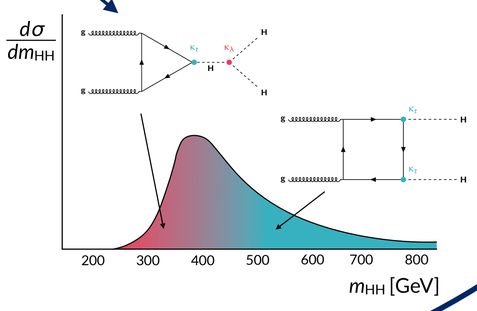


2. Split by type of HH production event

Vector-boson fusion

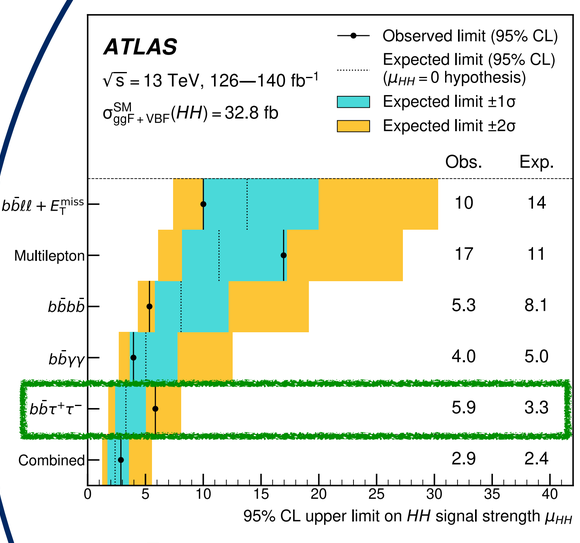


Low-/high-m_{HH} gluon fusion

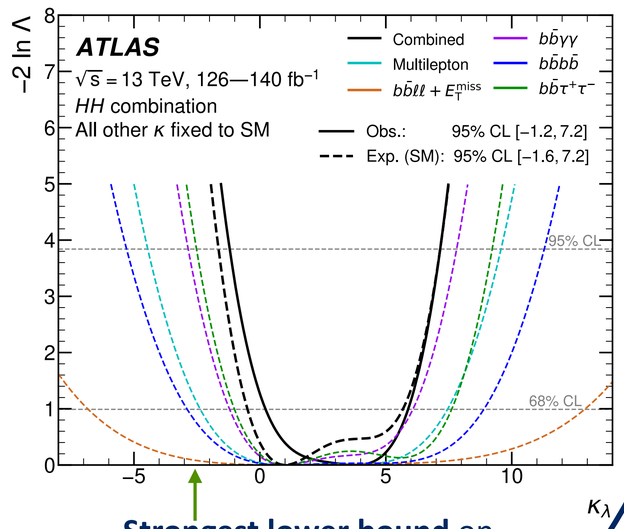


Combination of searches in different HH final states

	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%



$b\bar{b}\tau^+\tau^-$ has **highest expected sensitivity to HH production** as predicted by Standard Model



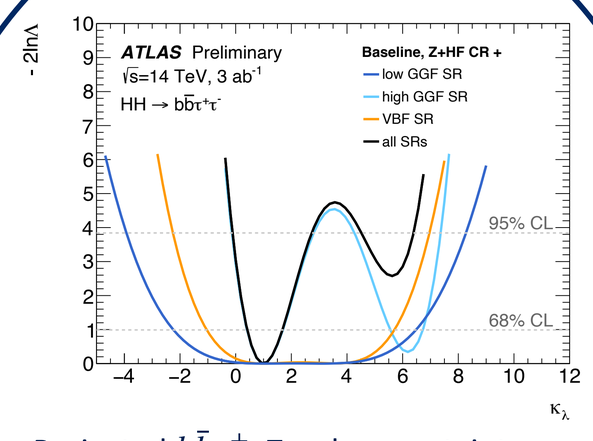
Strongest lower bound on self-coupling modifier κ_λ

ATLAS 95% CL observed upper limits on μ_{HH}

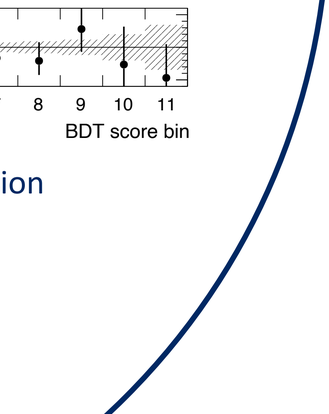
Run 1: 70 ⟶ Run 2: 2.9

Huge improvement, but more precision needed!

How far can we take it?



Projected $b\bar{b}\tau^+\tau^-$-only uncertainty on κ_λ of $\approx 60\,\%$ at end of HL-LHC



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- Mar 2017 - Jan 2021: PhD @ Göttingen
- Mar 2021 - Feb 2023: PostDoc @ Uppsala
- Mar 2023 - now: PostDoc@UHH+DESY

[1] ATLAS Collaboration, *Search for the non-resonant production of Higgs boson pairs via gluon fusion and vector-boson fusion in the $b\bar{b}\tau^+\tau^-$ final state in proton-proton collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector*, Phys. Rev. D 110 (2024) 032012

[2] ATLAS Collaboration, *Combination of searches for Higgs boson pair production in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector*, Phys. Rev. Lett. 133 (2024) 101801

[3] ATLAS Collaboration, *Updated projection of the sensitivity of searches for Higgs boson pair production in the $b\bar{b}\tau^+\tau^-$ final state from LHC Run 2 to the High Luminosity LHC with the ATLAS detector*, ATL-PHYS-PUB-2024-016

ATLAS EXPERIMENT

DESY.