LAPP
Laboratoire d'Annecy de Physique des Particules

New measurement of Higgs self coupling with ATLAS detector

cnrs
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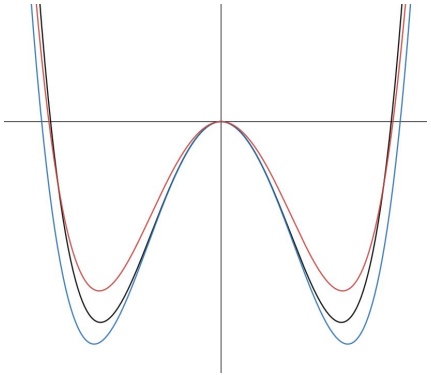
- 2012 : discovery of Higgs boson by ATLAS & CMS.
- Now : Most of Higgs parameters are measured : mass, spin, width, cross-section and coupling to fermions/bosons.
- Higgs self-coupling still resists to physicists:
  - Any deviation from Standard Model leads to new physics.

→ Very important to experimentally reconstruct Higgs potential shape.

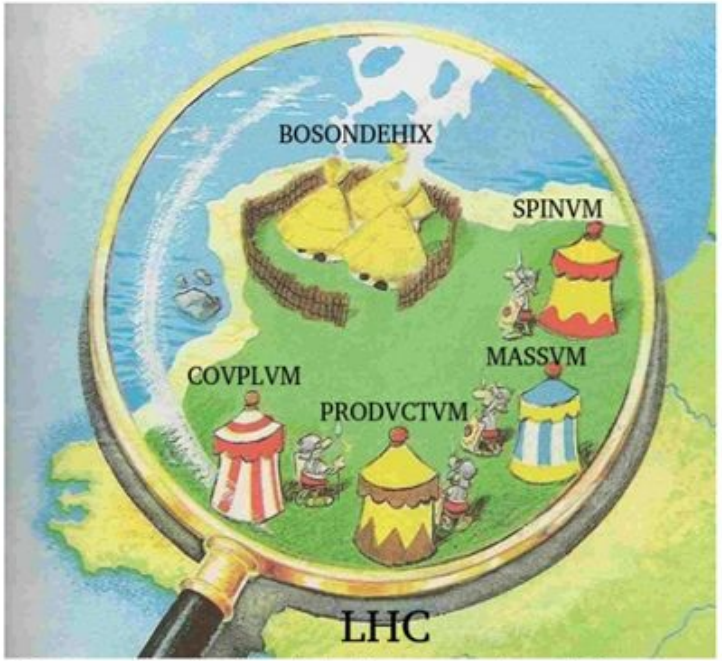
$$V(\phi) = -\frac{1}{2}m_H^2 h^2(x) + \lambda_{HHH} h^3(x) + \lambda_{HHHH} h^4(x)$$

Trilinear coupling

What we want to measure



Schematic of Higgs potential variations



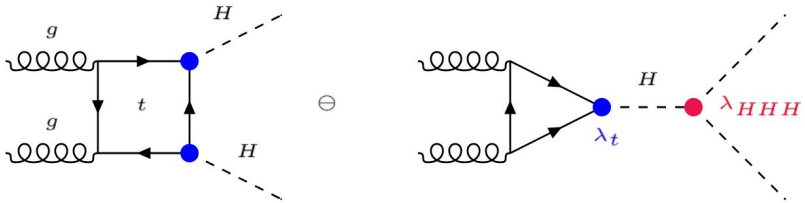
Nous sommes en l'an VII après la découverte du boson de Higgs. Toutes ses propriétés ont été mesurées. Toutes ? Non ! Un petit couplage, le tri-linéaire, résiste encore et toujours aux physiciens. Et la vie n'est pas facile pour les chercheurs des camps retranchés d'ATLAS et CMS.

Double Higgs production

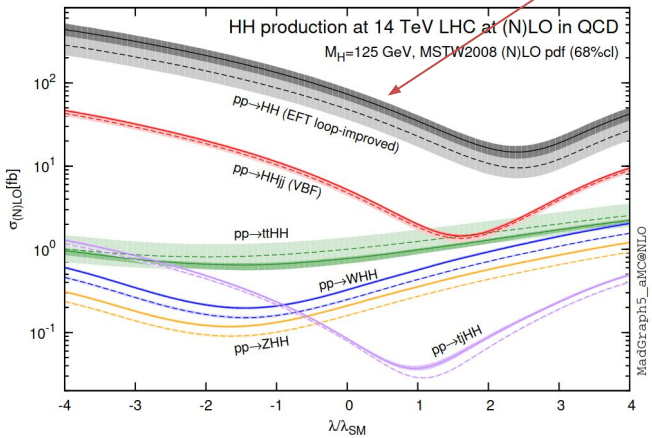
Di-Higgs production provide a **direct** access to Higgs self-coupling.

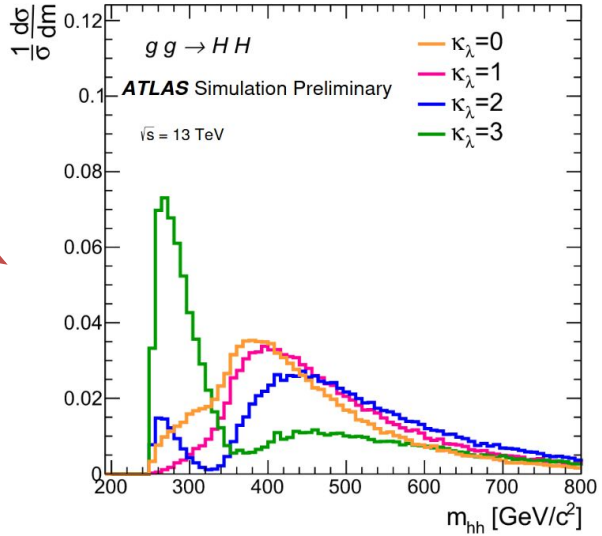
- σ(HH) ~33fb is 1000x smaller than σ(H)
- Standard Model predicts λ^{SM} = 0.13, deviation are quantified through:

$$\kappa_\lambda = \frac{\lambda^{new\ physics}}{\lambda^{SM}}$$



- New physics ⟶ deviation in the total and differential cross-section

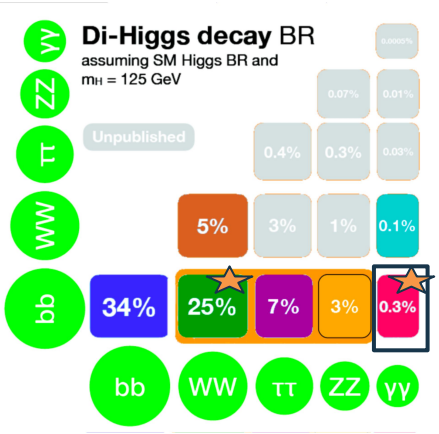


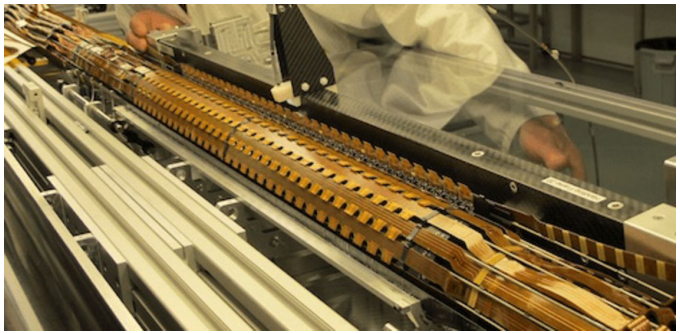


Aim is to look for HH events in the full Run 2 data (2015-2018).

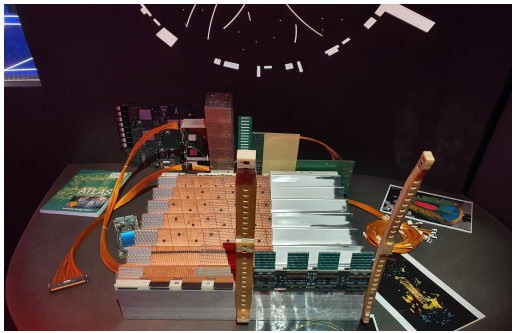
Choice of HH decay channels

- LAPP focus on H(→bb)H(→yy) channel (Golden channel):
  - H→bb largest branching ratio.
  - H→yy benefit from good photon energy resolution→$m_{\gamma\gamma}$ discriminant variable.
  - Coherent with LAPP technological expertises:
    - photon : LAPP built EM calorimeter + Expertises in e/gamma reconstruction.
    - b-quark : LAPP built IBL (pixel detector) + ITk upgrade.



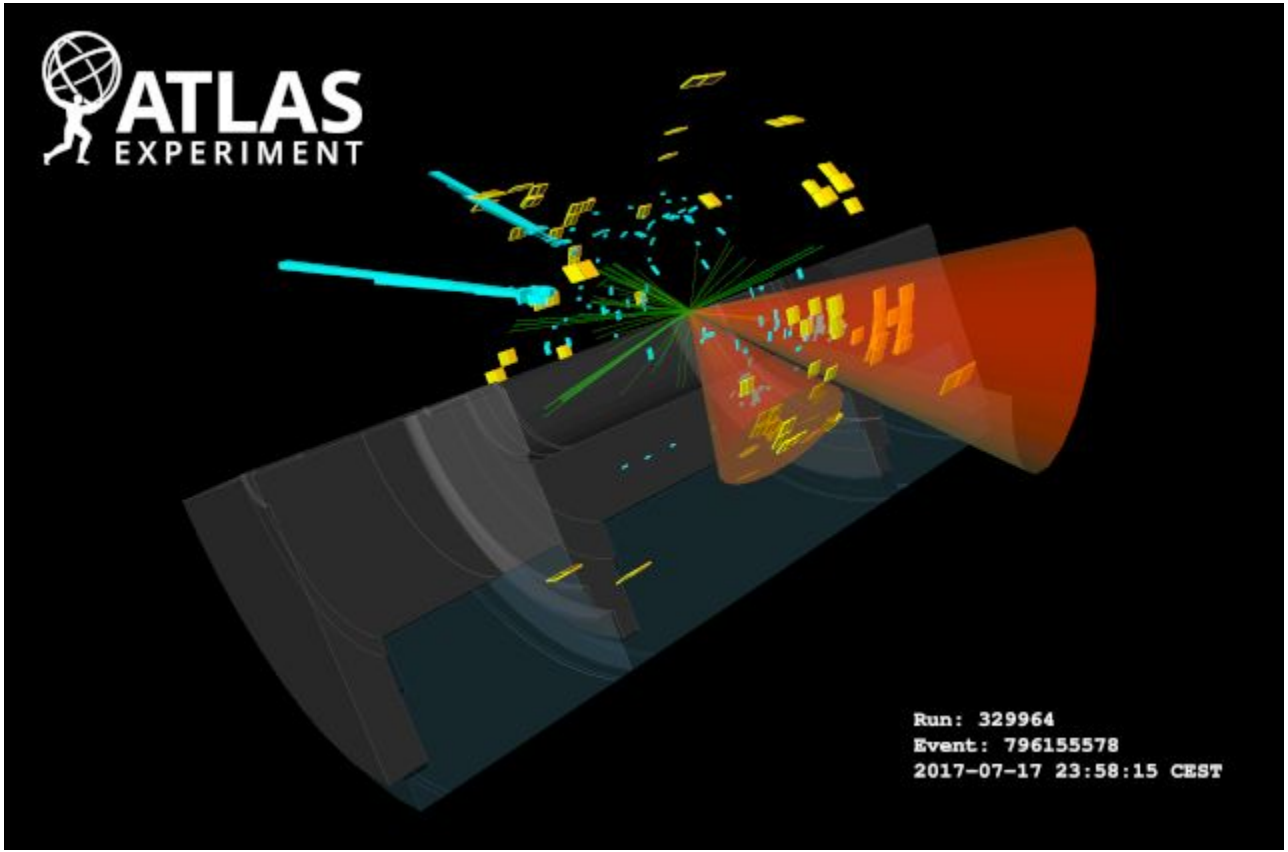


IBL : (improve charged particle (tracks) reconstruction)



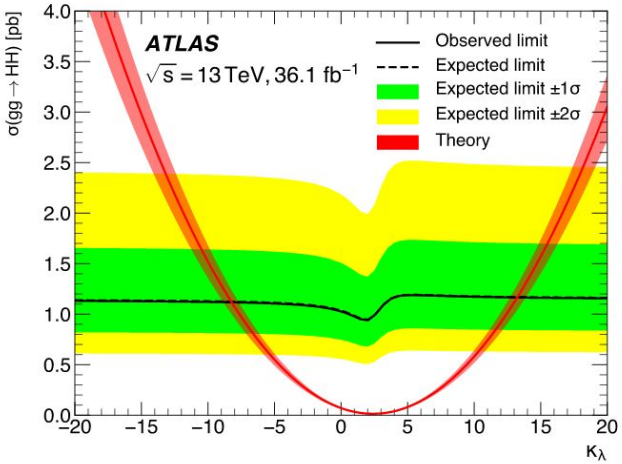
EM Calo : (Measure electrons/photons energy)

HH→ yybb candidate



Where are we?

- With data collected between 2015-2016 (36 fb^{-1}) :
  - → $\sigma(HH)/\sigma^{SM}(HH) <$ 28 @ 95% CL
  - → Constraint on κ_λ : [-8.2, 13.2] @ 95% CL
- Full Run-2 integrated luminosity is 139 fb^{-1} (~ 4 times larger than 2015-2016), Expected events :



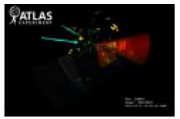
Single Higgs	HH	HH→bbγγ	Efficiency (~10%)
6.7M evts	4.3k evts	13 evts	0-1 evt

Full run-2 Analysis : Aim to improve analysis efficiency on top of luminosity increase.

LAPP group has mainly contributed to the full Run-2 analysis just published (LAPP article)

16 avril 2021

Nouvelle mesure de l'auto-couplage du boson de Higgs



Le groupe ATLAS du LAPP a participé à la mesure de l'auto-couplage du boson de Higgs avec les données du Run 2 dans le canal désintégration "en or" HH→bbyy. La mesure, qui est la plus précise à ce jour, (...)

Lire la suite

What's new?

b-quark jet correction (Born at LAPP)

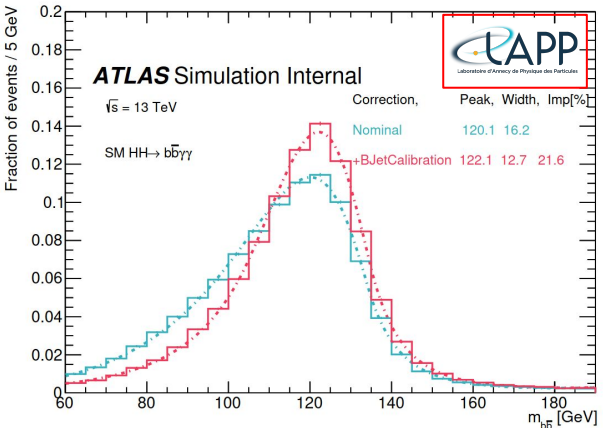
- b-jet energy usually underestimated⟶ specific calibration
- ~22% improvement of m_{bb} resolution.
- Translated to 10% improvement on analysis sensitivity.
- baseline correction for all Di-Higgs channels.

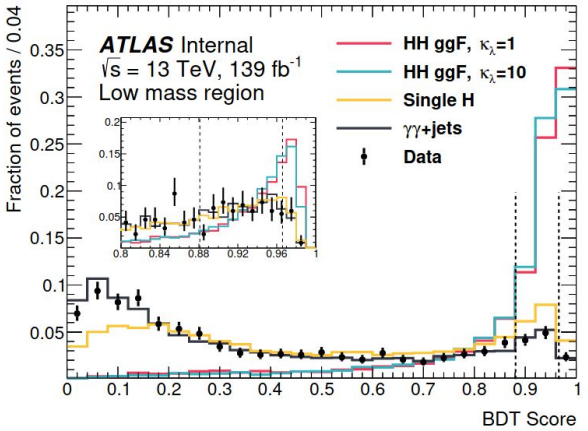
Additional Improvements:

- b-tagging algorithm
- Jet reconstruction

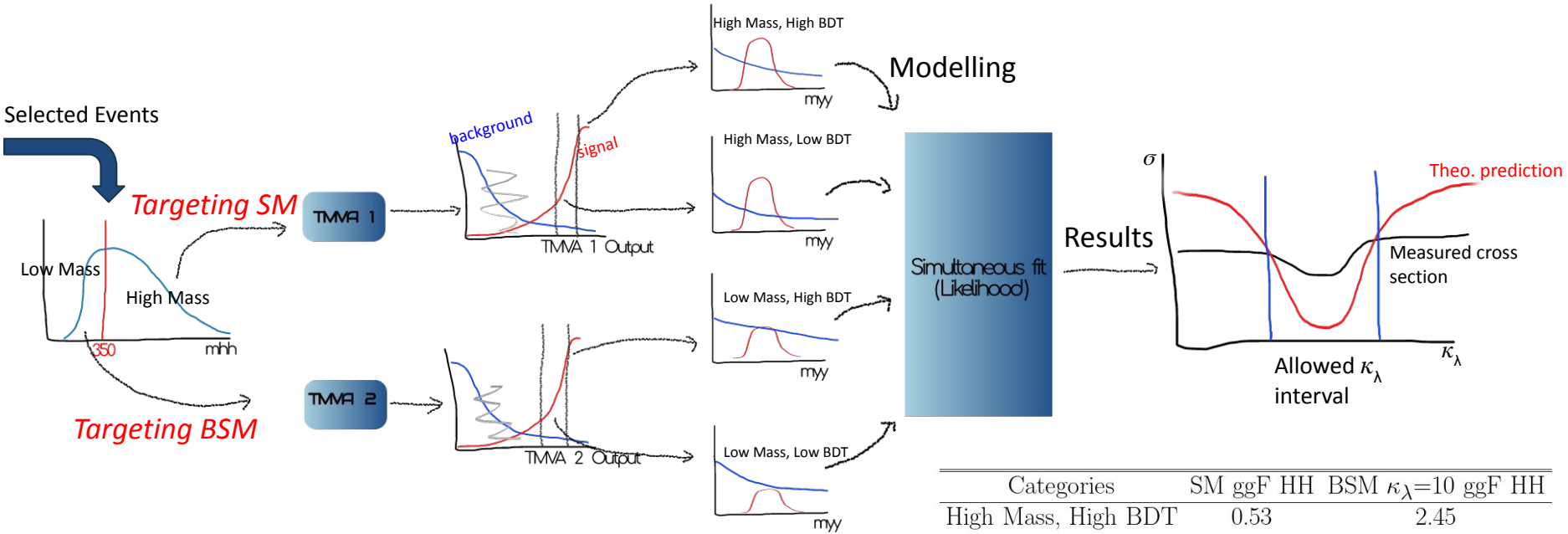
MVA categorization (LAPP contribution)

- MVA 20% improvement on analysis sensitivity.
- BDT-based analysis strategy.
- Future improvement using Deep Neural Network.





Overview of analysis strategy

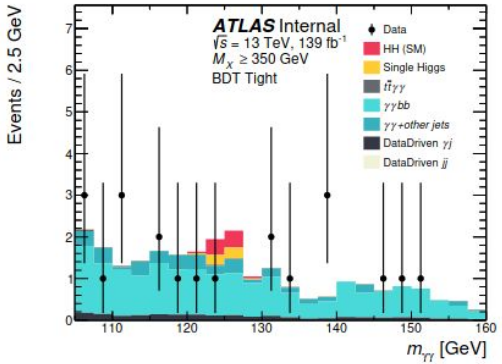


Categories	SM ggF HH	BSM κ_λ=10 ggF HH
High Mass, High BDT	0.53	2.45
High Mass, Low BDT	0.11	0.94
Low Mass, High BDT	0.03	2.21
Low Mass, Low BDT	0.01	0.54
Combined	0.54σ	3.47σ

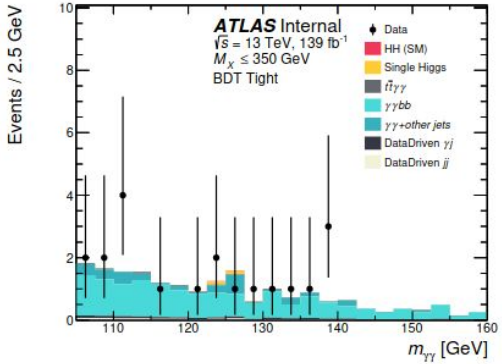
Results

- Backgrounds:
  - H(→ yy) : ttH, ZH
  - Continuum : yy+jets

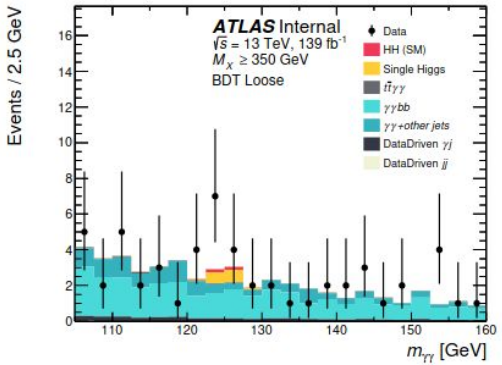
- Data match SM expectation
- No deviation from the background-only hypothesis.



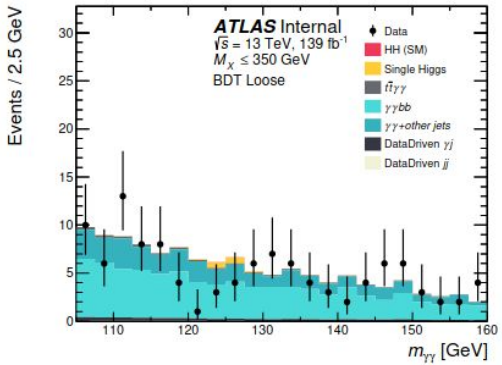
(a) High mass, BDT tight



(b) Low mass, BDT tight



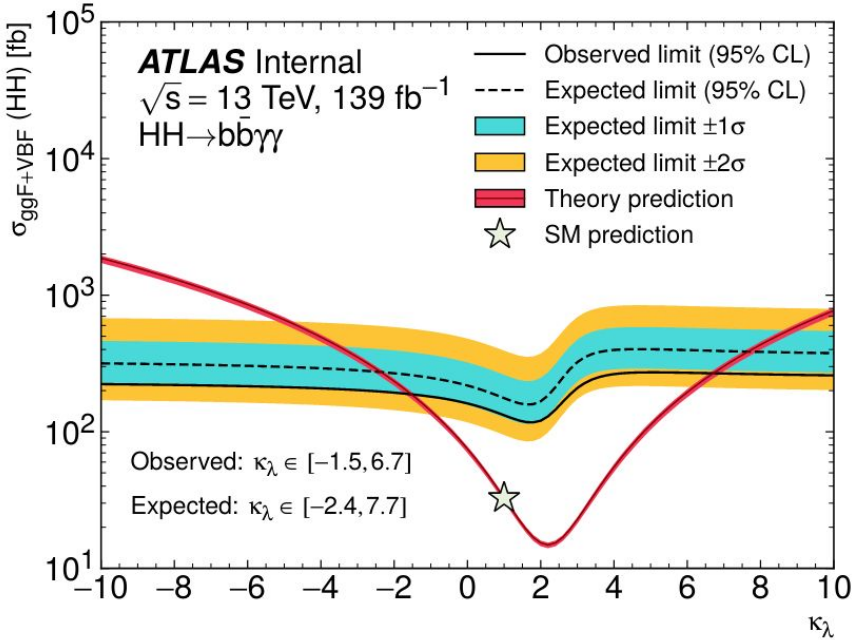
(c) High mass, BDT loose



(d) Low mass, BDT loose

- $\sigma(HH)/\sigma^{SM}(HH) <$ 4.1 (5.5 exp.) @ 95% CL
- Constraint on κ_λ : [-1.5, 6.7] @ 95% CL

- x5 improvement from 36 fb^{-1} analysis :
  - x4 from increasing luminosity.
  - x3 from analysis improvement.
- Results are statistically dominated.

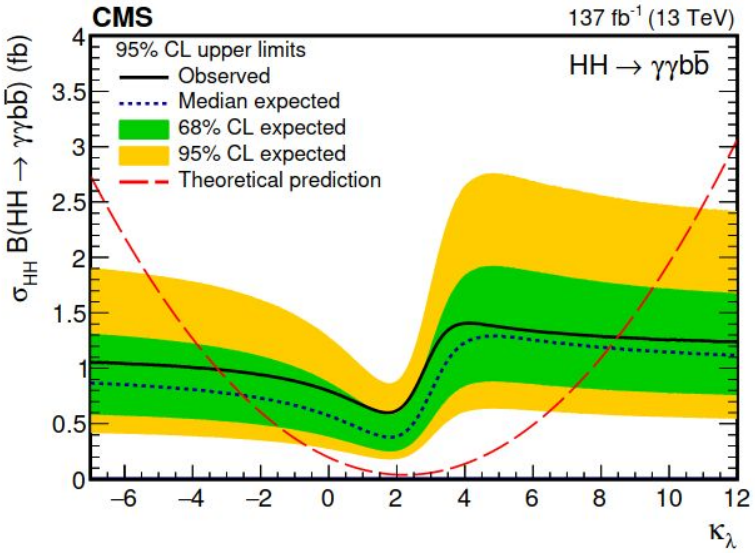


Comparison to CMS results

- CMS also publish their result with full Run 2 data on HH search. JHEP
  - Different analysis strategy :
    - No HH event is observed.

- ATLAS is more sensitive to the κ_λ variation than CMS (better constraint).

	Expected	Observed
CMS $\sigma_{HH}/\sigma_{HH}^{SM}$ limit	5.2	7.7
CMS κ_λ interval	[-2.5, 8.2]	[-3.3, 8.5]
ATLAS $\sigma_{HH}/\sigma_{HH}^{SM}$ limit	5.5	4.1
ATLAS κ_λ interval	[-2.4, 7.7]	[-1.5, 6.7]



Conclusion

- LAPP contribute to the measurement of Higgs self-coupling with the yybb final state using the full Run 2 data. Ref
- Most precise result today, κ_λ : [-1.5, 6.7] @ 95% CL
- Similar performance with H(→bb)H(→$\tau\tau$): publication soon
- Longer term :
  - Run-3 : Additional integrated luminosity up to 300 fb^{-1}
    Expect ~x2 improvement in limit and κ_λ ~ [-0.5, 5] @ 95% CL
  - HL-LHC : x20 increase in luminosity (3000 fb^{-1}): expected significance of ~4σ by combining ATLAS and CMS results

More details in my Thesis defence on 15-09-2021