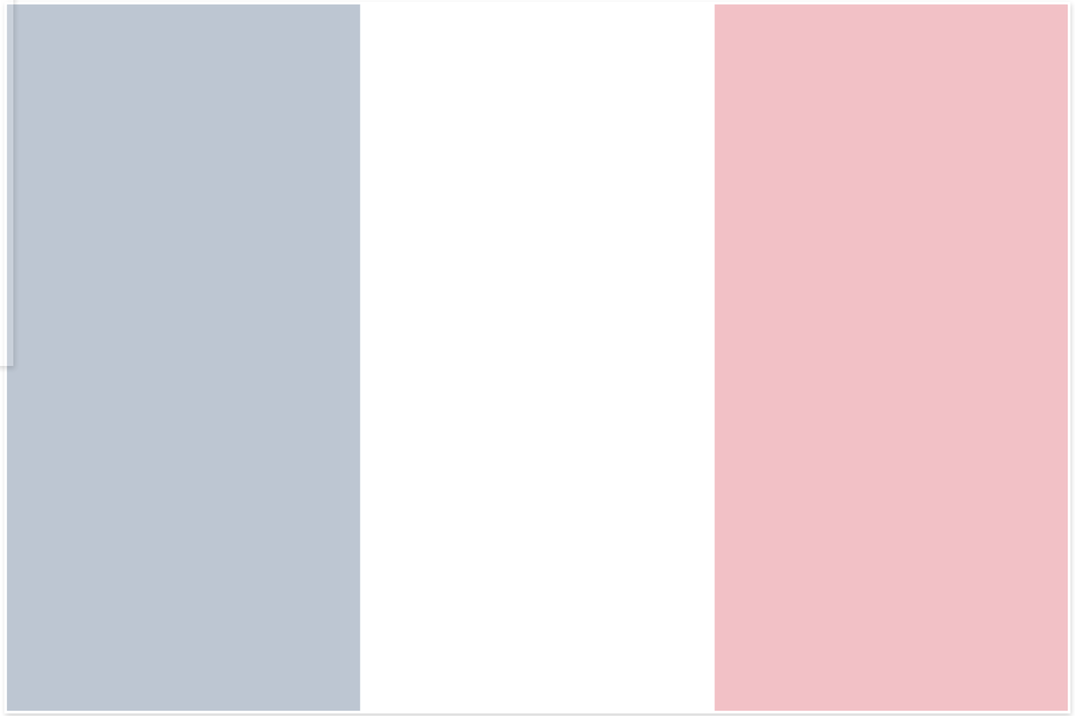
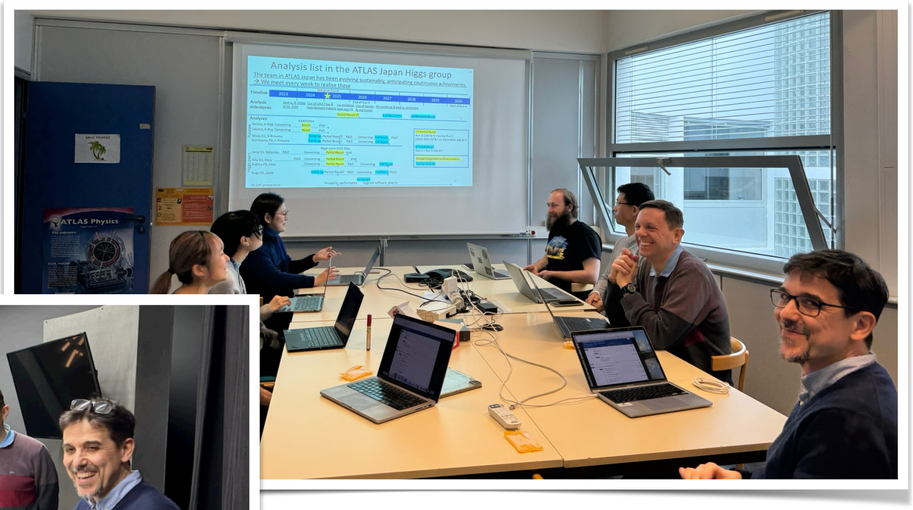
Introduction of Japanese HH activities (FJPPN project HEP_18)

Tatsuya Masubuchi
The University of Osaka



2nd meeting at LAPP

- **Thanks a lot for setting up everything at LAPP!!**
- 1st meeting at LAPP
  - Agenda of 2025 meeting: https://indico.in2p3.fr/event/35618/
  - Discussion: gDoc link



Japan contributors in FJPPN

- From HEP_17(2024-2025)→HEP_18(2026-)

Japan members(2024)	
Yu Nakahama(PI)	**KEK**
Tatsuya Masubuchi	Osaka
Louis Vaslin	KEK
New PD(KEK) →Kazuki Kojima	KEK
Lakmin Wickremasinghe	Osaka
New PhD →Rina Kugo	Osaka

Japan members(2025)	
Yu Nakahama(PI)	**KEK**
Tatsuya Masubuchi	Osaka
Rina Kugo	Osaka
Sayuka Kita	Tsukuba
Kazuki Kojima	KEK

Japan members(2026)	
Tatsuya Masubuchi(PI)	**Osaka**
Yu Nakahama	KEK
Rina Kugo	Osaka
Kosuke Itabashi	Osaka

Will be expanded in next year application! (new students/PD will join)

Lakmin graduated in 2025 (VH, H→cc)
→ went to EIC experiment…

Sayuka graduated in 2026 (HH→bb$\gamma\gamma$)
→ went to UTokyo

ATLAS-Japan wide activities

- ATLAS Japan communites have regular physics meetings in ATLAS Japan-wide
- WG1 (for Higgs analysis)
  - Coordinator: Yu and Tomoya → Arely and Kazuki (from Oct 2026)

Ongoing (or ~recently finished) analyses

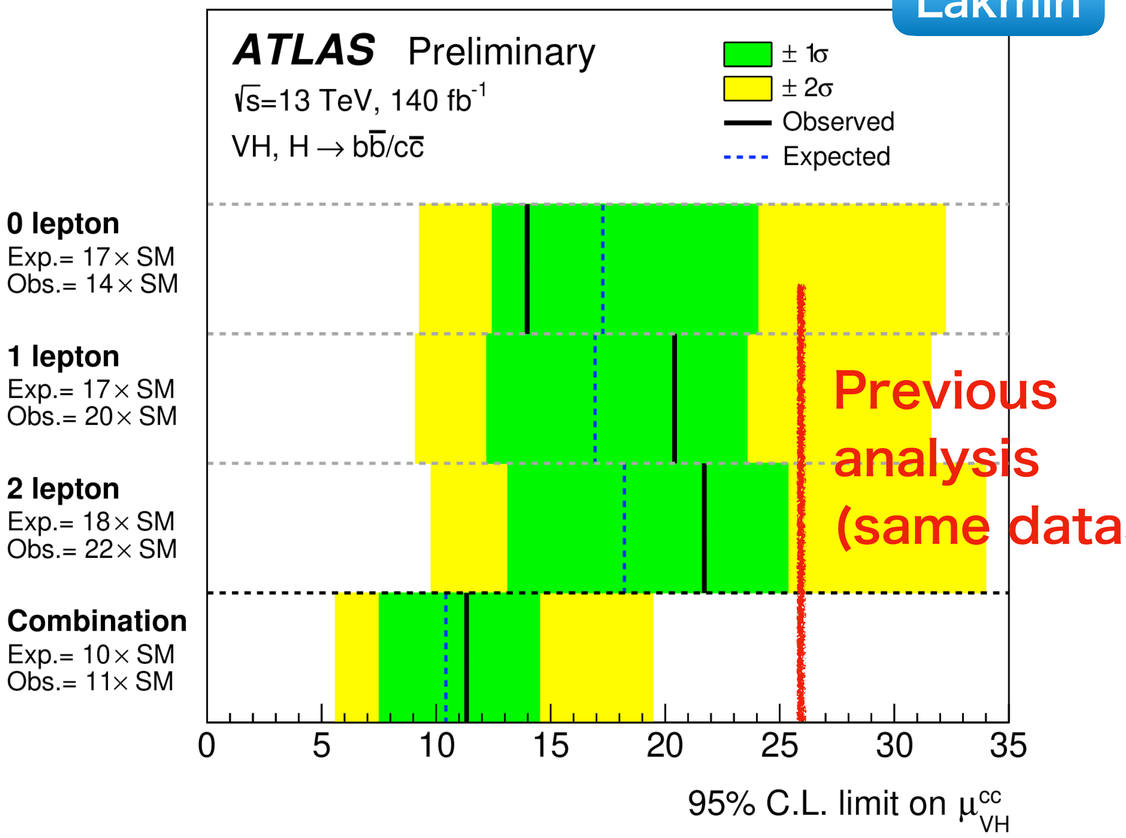
- **HH→bb$\gamma\gamma$**
  - **Yu Onoda (Science Tokyo): 2D fit ($m_{\gamma\gamma}$×m_{bb})**
  - Kazuki Kojima (KEK) : will be present later
- **HH→bb$\tau\tau$**
  - **Wonho Jang (UTokyo): non resonant bb$\tau\tau$ (arXiv:2607.26879), will graduate soon**
  - Issei Horikoshi (Tsukuba) : will present later
- **HH→bbbb**
  - Rina Kugo (Osaka): Will present later
  - **Kosuke Itabashi (Osaka): GN3X calibration, non-resonant boosted 4b**
  - **Daisuke Hashimoto(Nagoya): trigger calibration, resolved non-resonant 4b**
  - **Shota Izumiyama(Nagoya): resolved non-resonant 4b**
- H→cc/bb
  - Jian Wu (UTokyo): boosted H→cc
- BSM tau
  - Hiroki Ito: H/A→$\tau\tau$ (unblinded. will graduate soon)
  - Jiaqi Zang: LQ $\tau\nu$+b (unblidned will graduate soon)

HEP_17 Highlight

Phys. Lett. B 876 (2026) 140280
ATL-PHYS-PUB-2025-034

- Run2 VH bb/cc legacy

Lakmin

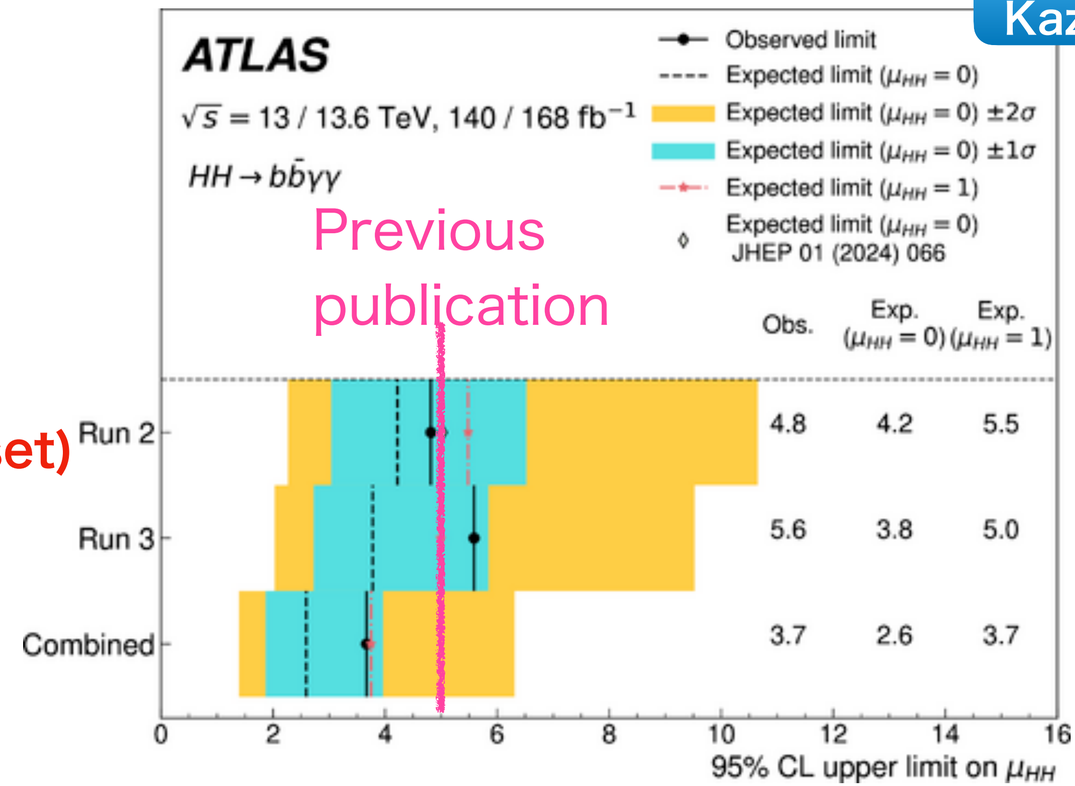


95% CL upper limit on μ_{VH}^{cc} : $11 \times \mathrm{SM}$

Limit improved by > 200% w.r.t. previous analysis

- Run2 + partial Run3 (~300fb^{-1})
  HH→bb$\gamma\gamma$ Results

Sayuka Kazuki

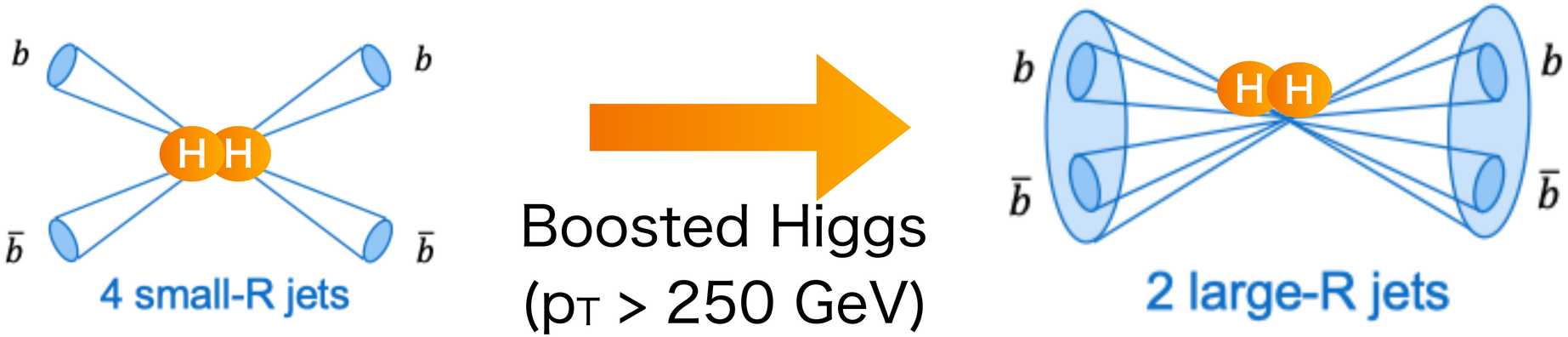


Improve upper limit by a factor of 2 from previous publications!

$-1.6 < \kappa_\lambda < 6.6$ **at 95% CL**

Ongoing analysis developments

- One of the crucial developments is object identification and its calibration
  - HH→4b, HH→2b2γ, HH→2b2τ: b-tagging, tau-ID and photon
  - GN3X calibration ongoing for boosted topology (H→bb/$\tau\,\tau$)



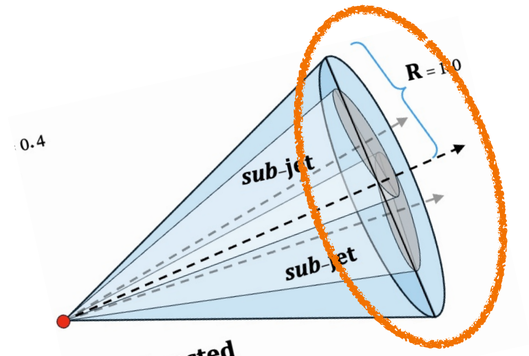
- 4b channel suffers from huge QCD multi-jet background
- Issue with jet pairing to reconstruct Higgs

➡ Two Higgs(large-R) jets requirement reduces bkg significantly

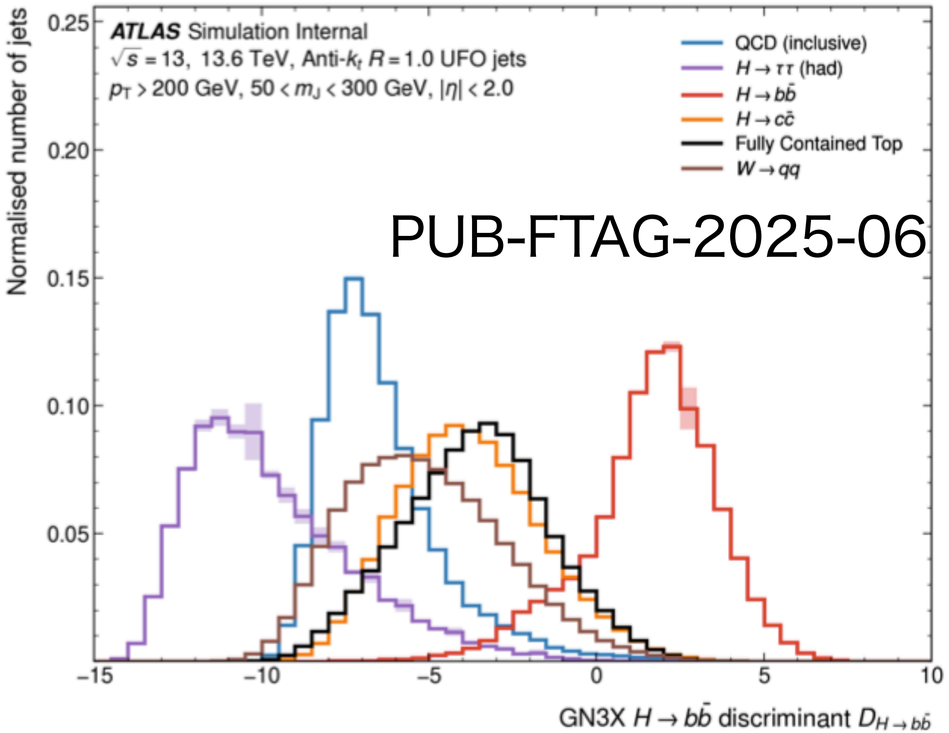
GN3X tagging/calibration are key for 4b channel

Ongoing analysis developments

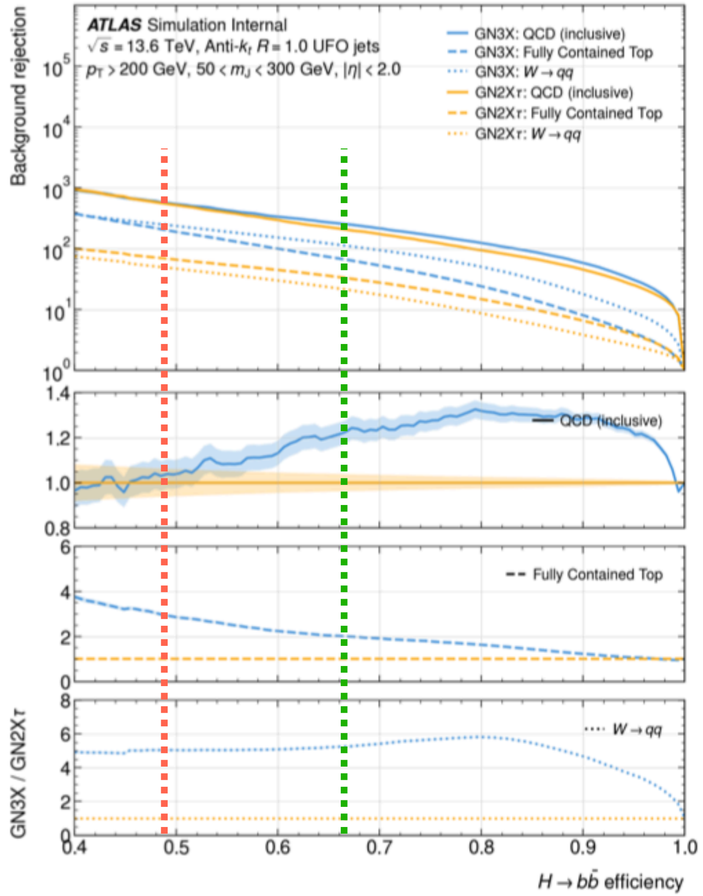
- Transformer-based H→bb tagging (GN) development
  - The latest tagging (GN3X) includes calorimeter information in addition to tracking info
  - Improve Higgs mass resolution with b-jet energy regression



H→bb tagging



PUB-FTAG-2025-06



Signal eff ~50%
QCD jet rejection
~670(0.15%)

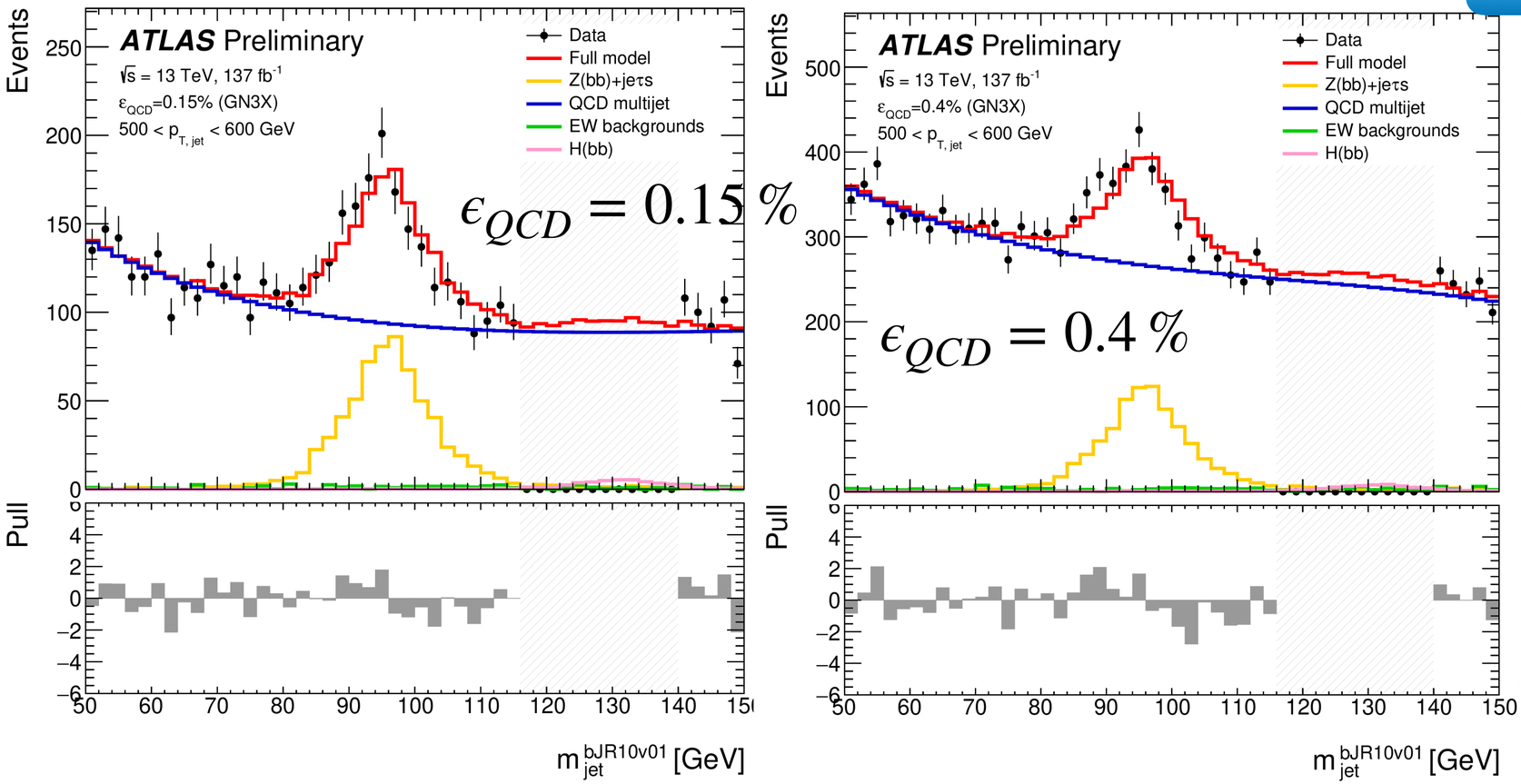
Signal eff ~65%
QCD jet rejection
~250(0.4%)

Ongoing Activities in Japan

- Calibrate GN3X tagger using boosted Z(→bb)+jets/γ
  - **Z+jets (p_T^Z >500 GeV)**, Z+γ (p_T^Z <500 GeV)

FTAG-2023-10

Kosuke



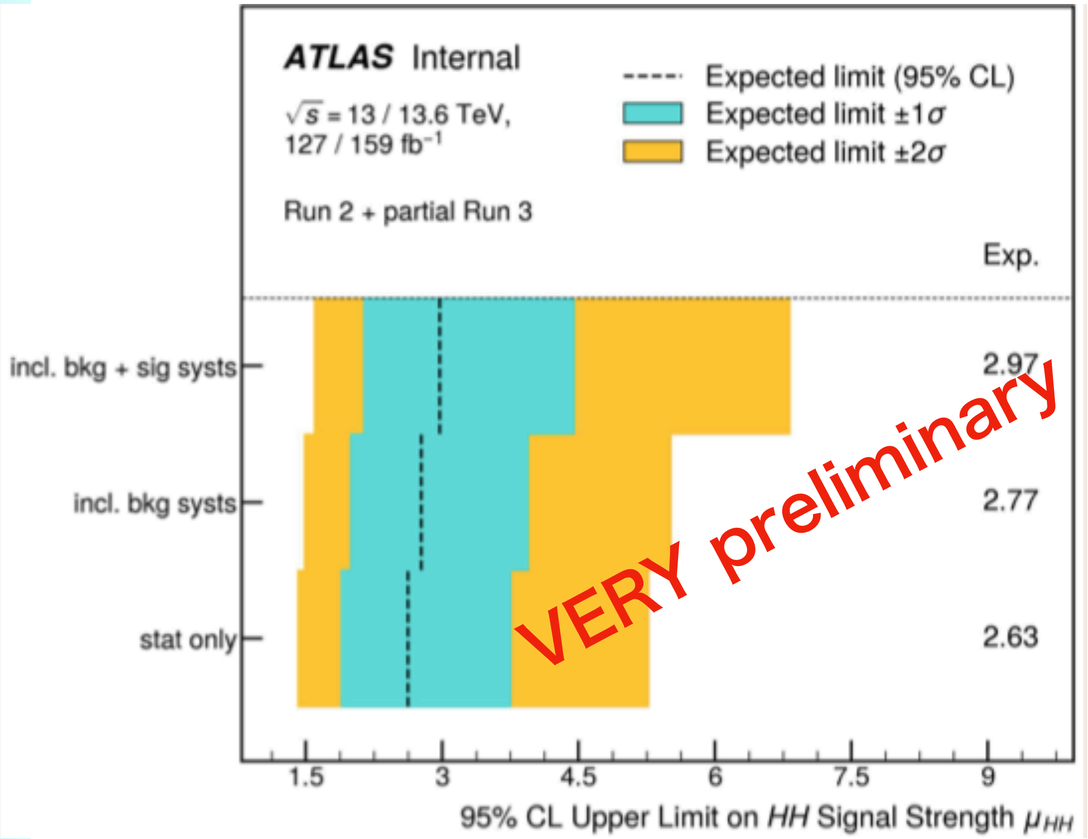
Z+jets calibration ~completed(finalizing sprious signal uncertainty)

Z+γ , Z→ll(denominator) calibration ongoing

Calibration is ready for physics ~Oct

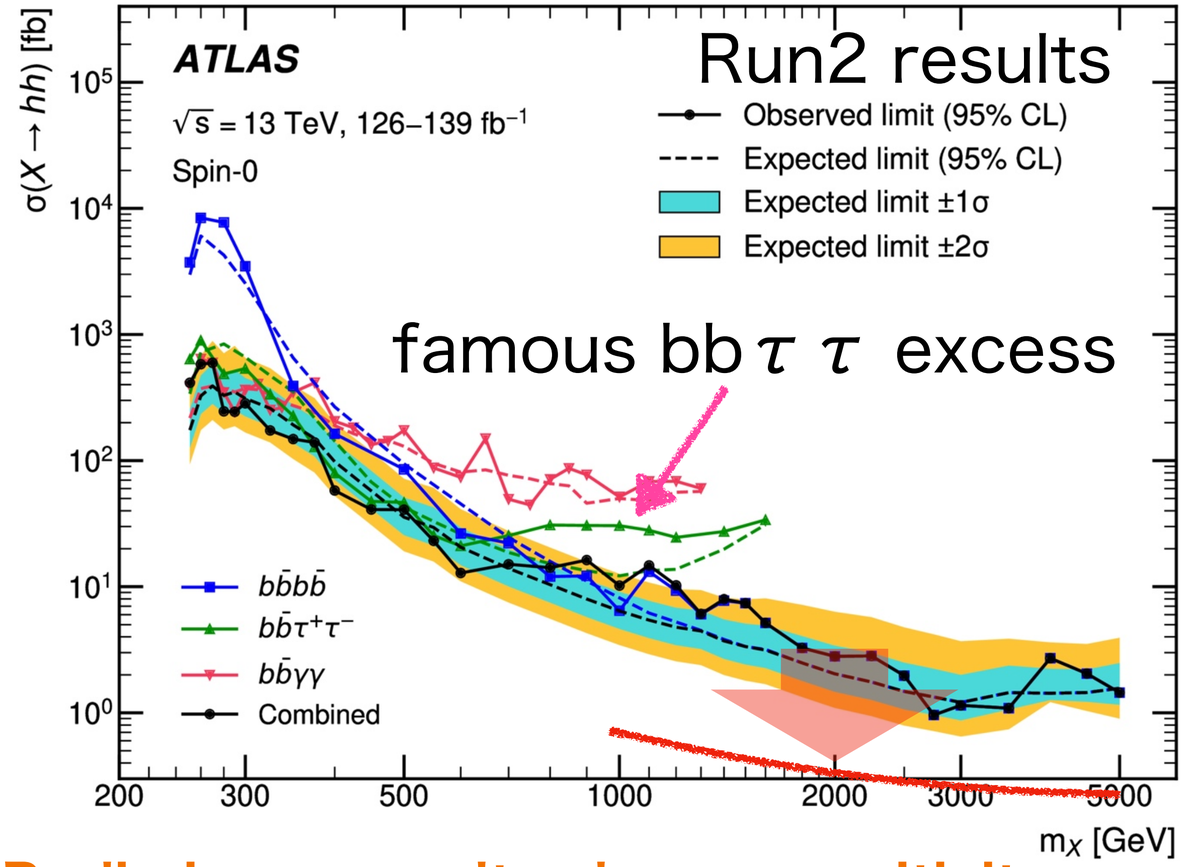
Ongoing analysis developments

- Non-resonant HH→4b search (boosted region only)
  - Not full systematic uncertainty



Resolved 4b(ggF): limit 2.94

- Heavy resonance search (bb$\tau\tau$、4b)

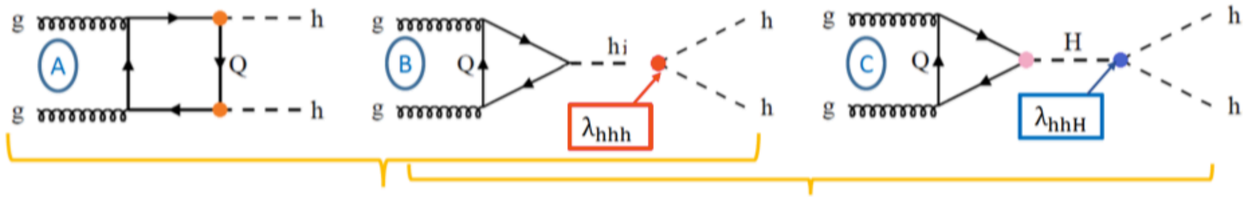


Preliminary results shows sensitivity improvement ×~10 in same data amount

Not only non-resonant analysis

- Most of non-SM case, Higgs sector is extended (2HDM(+S), triplet…)
- Other Higgs may appear
- Important to look at non-resonant and resonant at the same time
- Interference provides new model information

BSM THCs at the HL-LHC



σ_{SM} ~ 38 fb at NLO

Diagrams that exist in the SM: They have a negative interference

Diagrams that are sensitive to triple Higgs couplings

⇒ possible strong resonance with BSM Higgs

Important: experimental limtis are obtained for

– non-resonant production

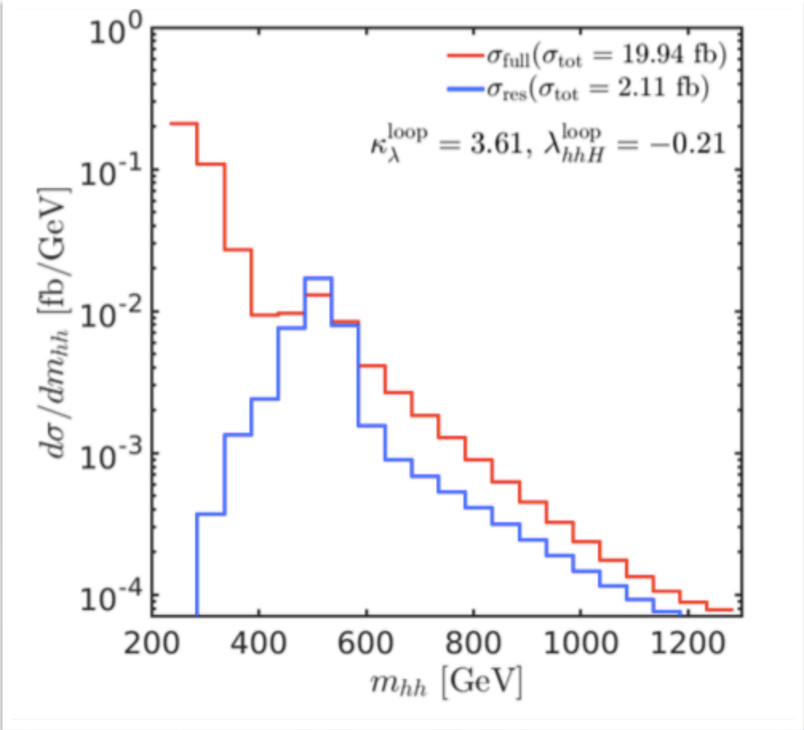
– purely resonant production

⇒ no limits available for mixed scenarios :-(

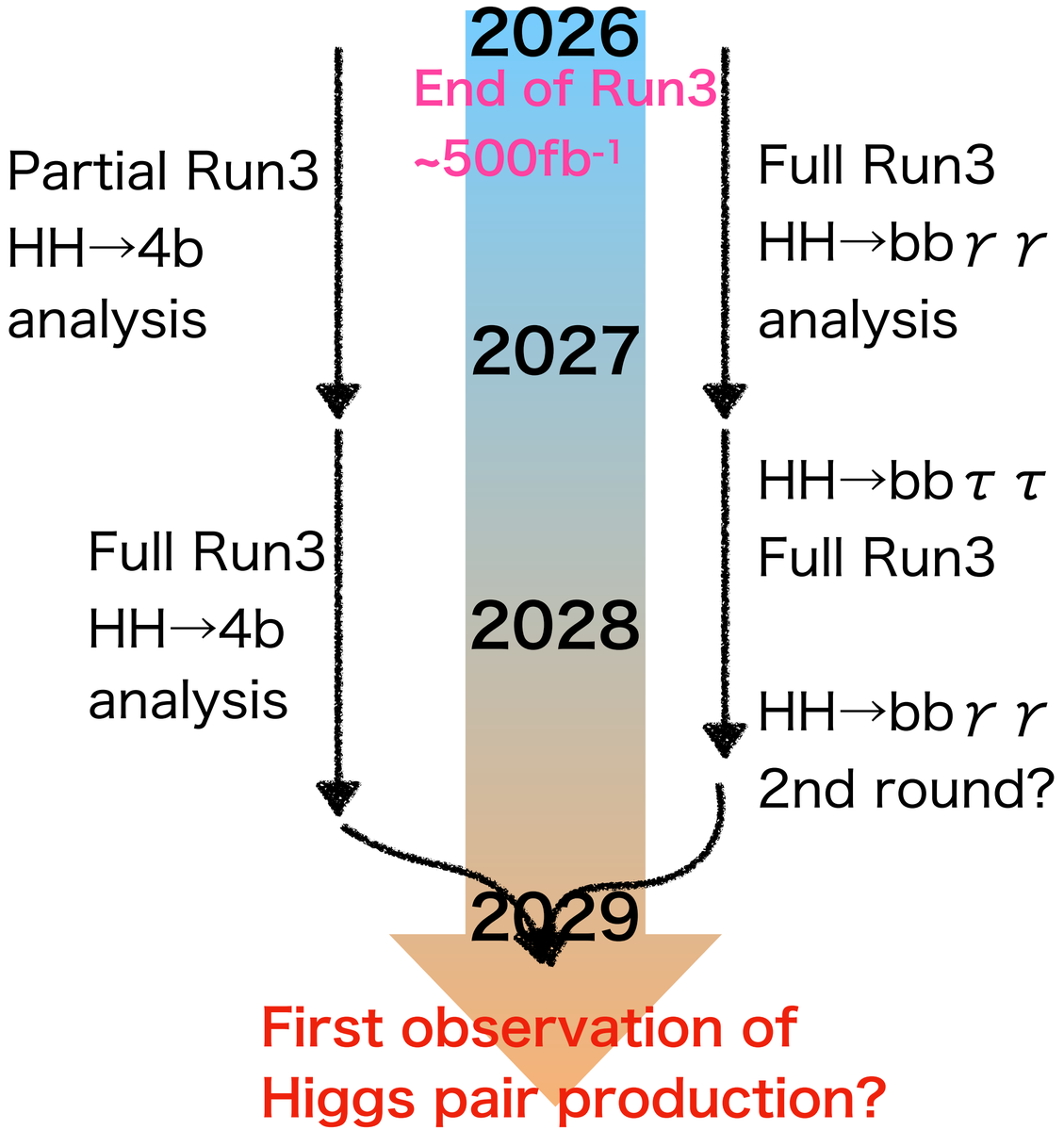
⇒ existing exclusion bounds questionable!

Sven Heinemeyer

HPNP2025



Project Timeline and Topics



- **Boosted H→bb tagger (GN3X) calibration (~mostly done)**
- **Search for non-resonant and resonant boosted HH→4b (~300fb^{-1})**
- **non-resonant HH→bbγγ (~500fb^{-1})**

- Advance object identification (GN3, GN3X) and core analysis development for HH→bbγγ, HH→4b toward the full Run 3 analysis
- Complete 4b, bbγγ, bbττ analyses using the full Run 3 dataset (~500fb^{-1})
- Combine all HH channels
- Interpret results in the context of Effective Field Theories (EFT)

Higgs 2027 at Osaka

- We host Higgs 2027 at the university of Osaka
- Data
  - **Nov 8-12, 2027**
- Venue
  - **Univeristy of Osaka, Toyonaka cumpus, Sigma-hall, Nambu-hall**
- LOC
  - **Theory**: Shinya Kanemura, Ryosuke Sato, Yu Hamada (Osaka), Kentaro Mawatari(Iwate), Koji Tsumura(Kyushu)
  - **Exp**: Tatsuya Masubuchi(Chair), Minoru Hirose (Osaka), Yu Nakahama (KEK), Junichi Tanaka(Tokyo), Shigeki Hirose(Waseda), Yasuyuki Horii(Nagoya)

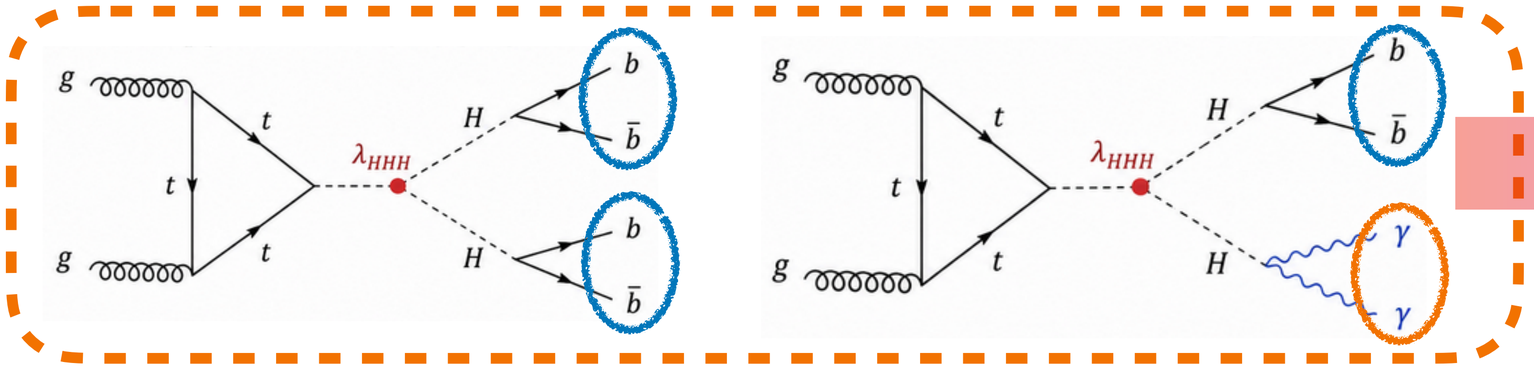
Backup

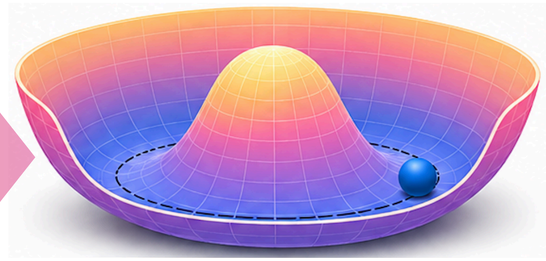
Network and synergy

The France and Japan team have good complementarities

➡Collaboration network will maximize HH search capabilities

Japan's expertise	France's expertise
b-tagging (resolved jet, boosted jet) calibration	Photon reconstruction
HH Resonance search	Boosted H→$\tau\,\tau$ identification
	Combination, EFT interpretation





Understanding of Higgs potential

Common framework/technologies can be shared in this network

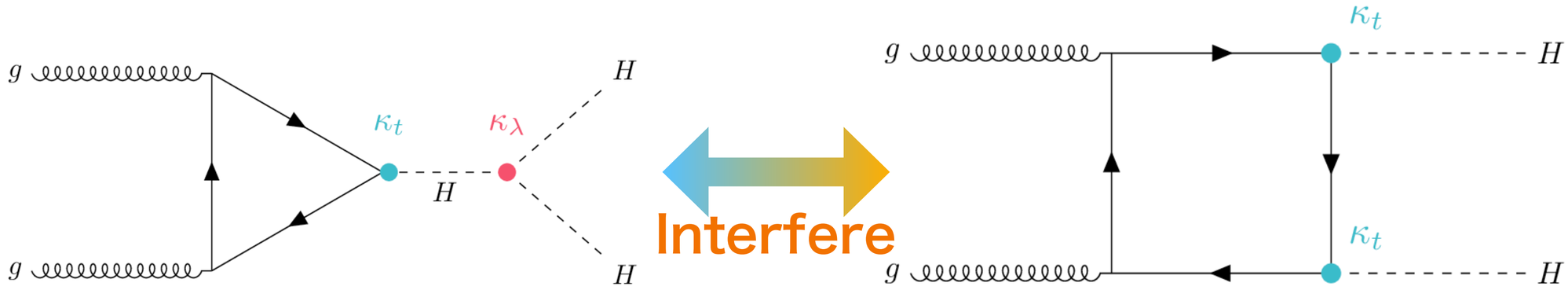
ECRs (3PD, 2 PhD) are involved in this network

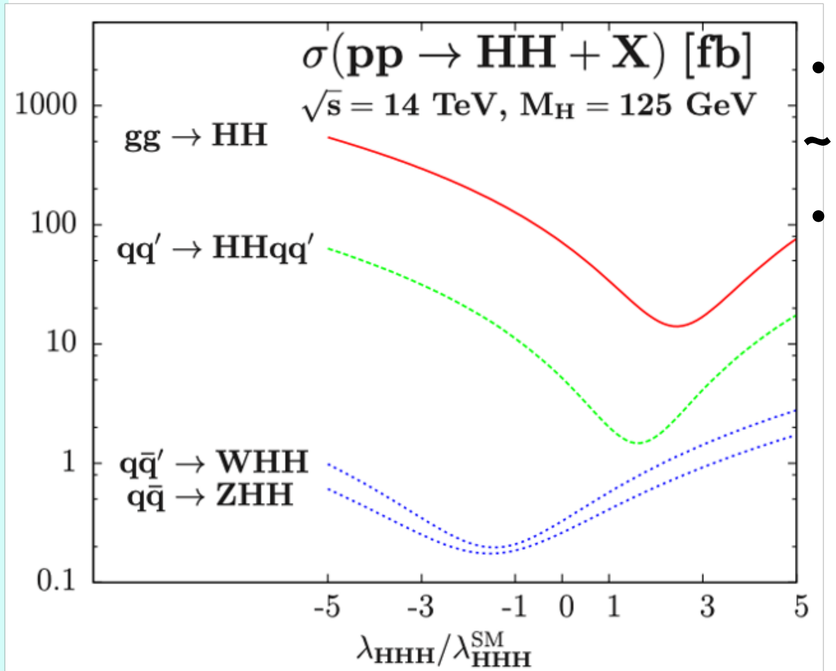
➡ 2 PhDs Jointly supervised (will join more for future)

➡ More regular meetings and in-person workshops using this funding

Higgs Self-coupling measurement

Need to meaure Higgs pair production mode





- gg→HH is dominant
  ~1/1000 of single Higgs
- ggHH cross-section is minimum ~2.5

Variety of decay modes

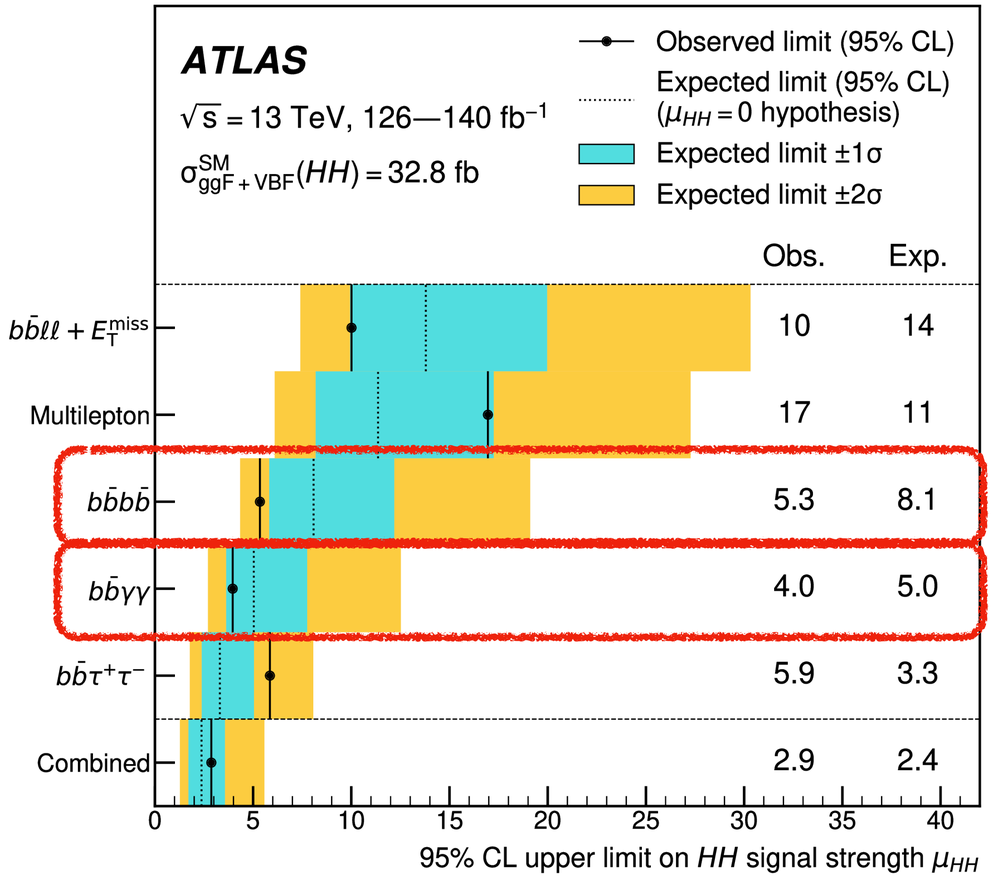
4b, bb$\tau\tau$, bb$\gamma\gamma$ are most powerful

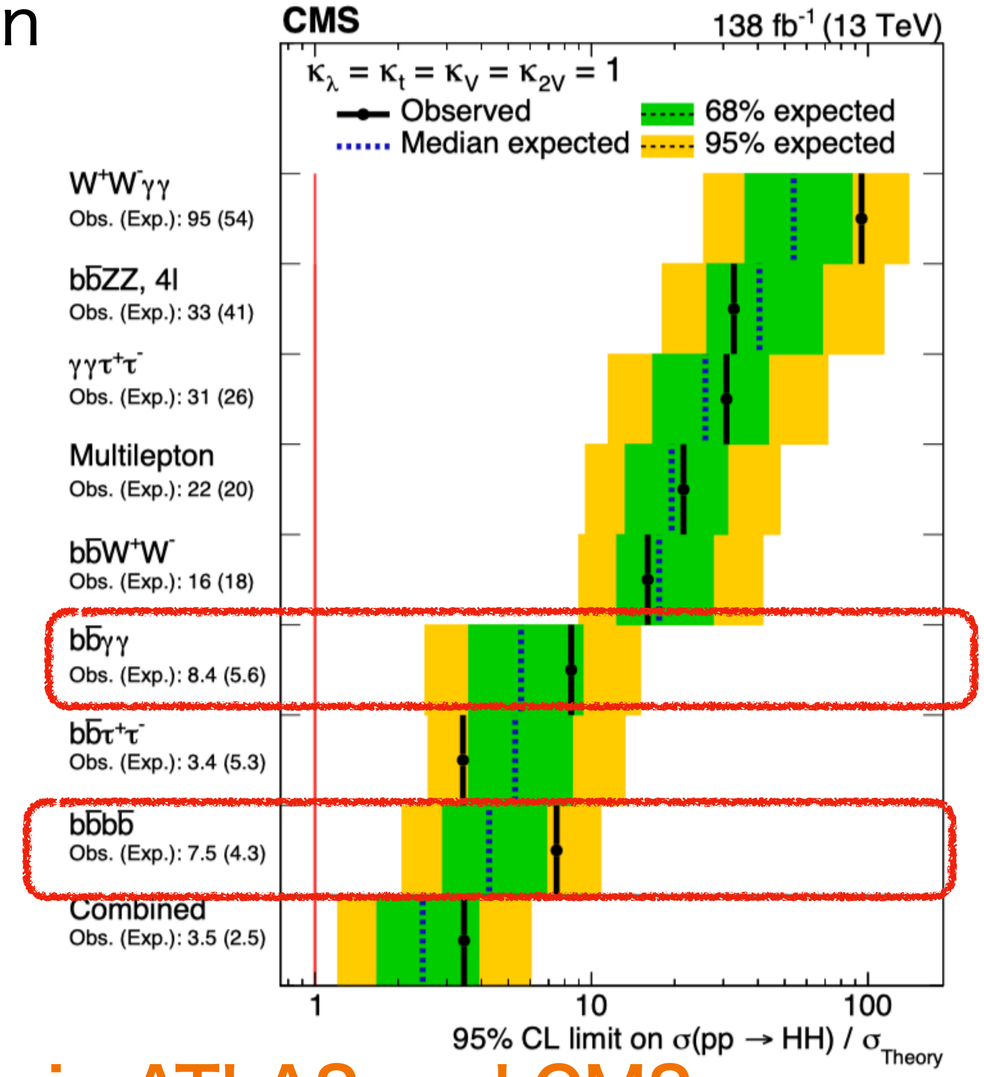
	bb	WW	ττ	ZZ	γγ
bb	34%				
WW	25%	4.6%			
ττ	7.3%	2.7%	0.39%		
ZZ	3.1%	1.1%	0.33%	0.069%	
γγ	0.26%	0.10%	0.028%	0.012%	0.0005%

Experimental Results

Phys. Rev. Lett. 133 (2024) 101801
arXiv:2510.07527v1

- Combined many final states analyzed in Run2



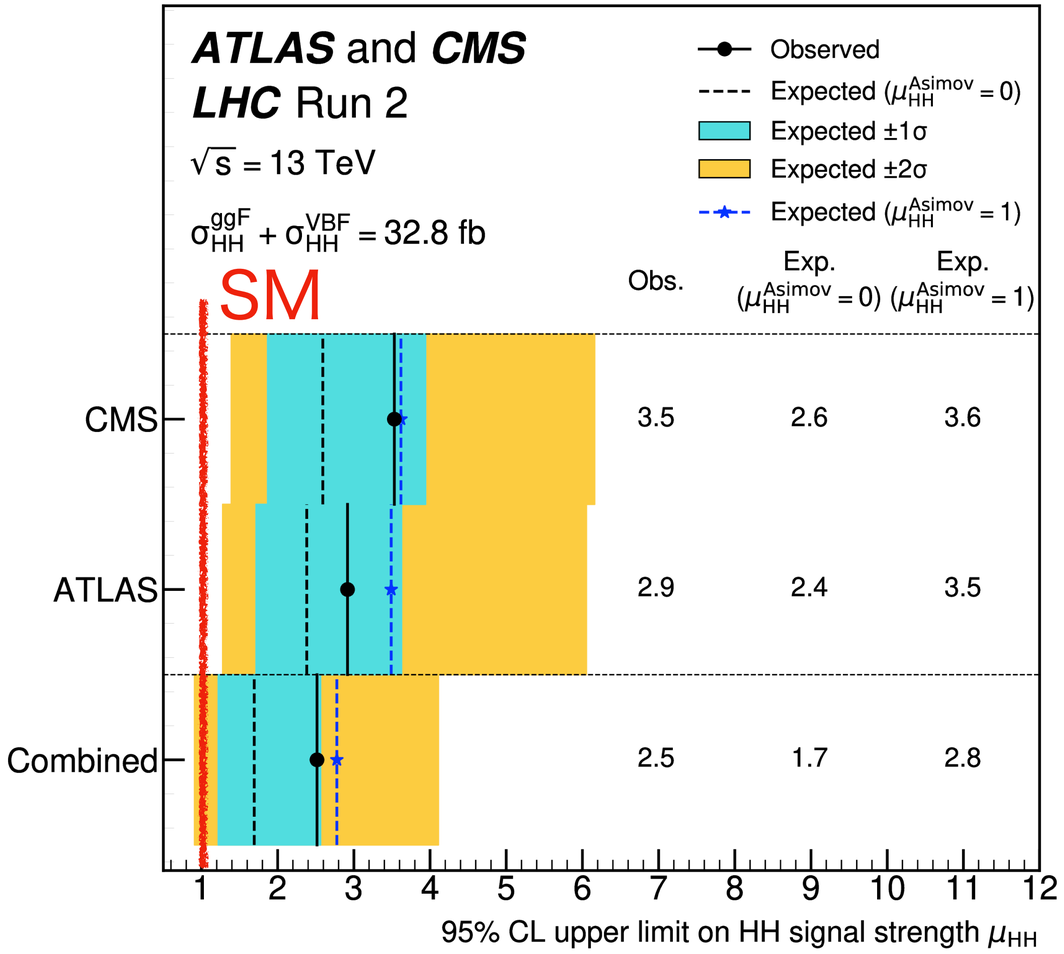


Combined sensitivity are similar in ATLAS and CMS

Observed upper limit 2.9-3.5×SM

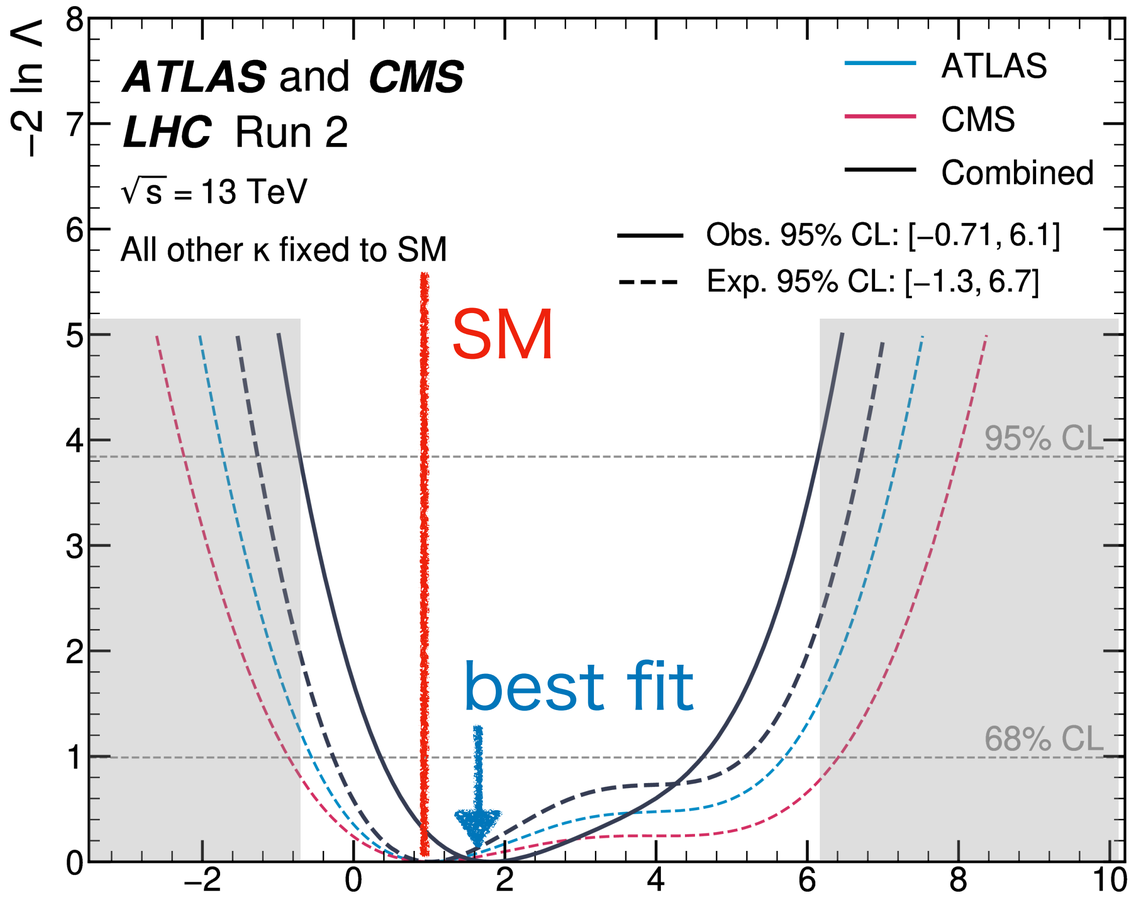
Run2 ATLAS+CMS Combination

arXiv:2602.23991



2.5 (1.7 exp. assuming μ=0)

(2.8 exp. assuming μ=1)



-0.71 < κ_λ < 6.1 at 95% CL

(Expected: -1.3 < κ_λ < 6.7)

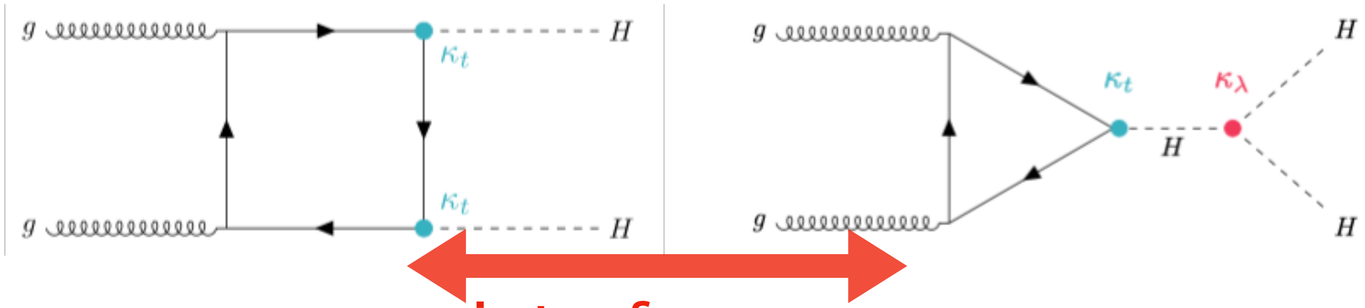
Significance 1.1 σ (1.3 σ exp.)

Self-coupling and DiHiggs

- Crucial to find DiHiggs events to measure self-coupling
- Cross section is quite tiny (~30fb) at even LHC (1/1000 of pp→H)

  ➡ Challenging to observe HH signal

ggF(~31.05fb at NNLO QCD+NLO EW)



VBF(~1.73fb at N³LO QCD)