

HHH YR5 Contribution(s)

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30.09.25 - 2nd HHH Workshop, Dubrovnik, Croatia

Group Logistics

- The HHH subgroup of WG4 was formed last December, with the mandate to oversee studies of the triple-Higgs-boson signature, both in non-resonant and resonant production
- The formation of the new group reflects growing interest in this signature, not only as a window to constrain the quartic Higgs self-coupling (λ_4), but also as a complementary signature to constrain triple Higgs self-coupling (λ_3)
- We have created the e-group lhc-higgs-hhh@cern.ch (self-subscribed, with conveners' approval; 35 people already signed up, following the WG4 announcement)
 - To subscribe, follow this link: <https://e-groups.cern.ch/e-groups/EgroupsSubscription.do?egroupName=lhc-higgs-hhh>
- For now will use the main WG4 Twiki page: <https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCHWGHH>
- Had a kick-off meeting during the WG4 meeting in February, followed by a discussion at the HH Workshop in Elba (May)
- Plan regular meetings to discuss Yellow Report 5 contributions and to hear experimental and theoretical updates

2025-2026 Conveners

- lhc-hhh-wg4-conveners@cern.ch



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Possible YR5 Contributions

- YR5 is organized differently from earlier YRs
 - Organized as individual contributions
 - However, we could consider a single HHH contribution, with recommendations related to the HHH analyses, benchmark points, etc.
 - The discussion today is to generate some ideas on what's useful to have in YR5 from the point of view of our group
 - Benefits from many experts, both on the theoretical and experimental sides, present

Some Ideas

- Cross section
 - The NNLO ggF cross section and NNLO/LO K-factor have been calculated only for 14 and 100 TeV [de Florian, Fabre, Mazzitelli JHEP 03 \(2020\) 155](#)
 - The way experiments handle these is to do the 13 or 13.6 LO generation with MadGraph5_aMCNLO and use the 14 TeV K-factor
 - Close, but we should really add the 13 and 13.6 points to the NNLO calculations

Some Ideas

- HH treatment
 - No uniform approach in treating the HH background
 - Not an issue for the limits on the HHH signal strength μ , for which the HH cross section is fixed to the SM value
 - Becomes an issue for the κ_3 vs. κ_4 scan
 - ATLAS: does not touch the HH cross section, still fixing it at the SM value
 - CMS: more consistent approach by varying HH κ_3 value, but still fixing κ_4 at the SM value
 - The most consistent approach: vary both HH κ_3 and κ_4 when performing the scan, as is done for the HHH signal

Some Ideas

- HH treatment (cont'd)

- The HH signal strength dependence on κ_4 has been calculated in at least two papers

- $\mu_{HH}^{14\text{TeV}} = 1 - 0.867(\Delta\kappa_3) + 1.48 \cdot 10^{-3}(\Delta\kappa_4) + 0.329(\Delta\kappa_3)^2$

- $+ 7.80 \cdot 10^{-4}(\Delta\kappa_3 \Delta\kappa_4) + 2.73 \cdot 10^{-5}(\Delta\kappa_4)^2$

- $- 1.57 \cdot 10^{-3}(\Delta\kappa_3)^2(\Delta\kappa_4)$

- $- 1.90 \cdot 10^{-5}(\Delta\kappa_3)(\Delta\kappa_4)^2 + 9.74 \cdot 10^{-6}(\Delta\kappa_3)^2(\Delta\kappa_4)^2$

Bizori, Haisch, Rotolly
JHEP 10 (2019) 267

- $\mu_{2h}^{\text{HL-LHC}} = 2.18 - 1.50\kappa_3 - 1.00 \cdot 10^{-3}\kappa_4 + 3.24 \cdot 10^{-1}\kappa_3^2 + 3.95 \cdot 10^{-3}\kappa_3\kappa_4$

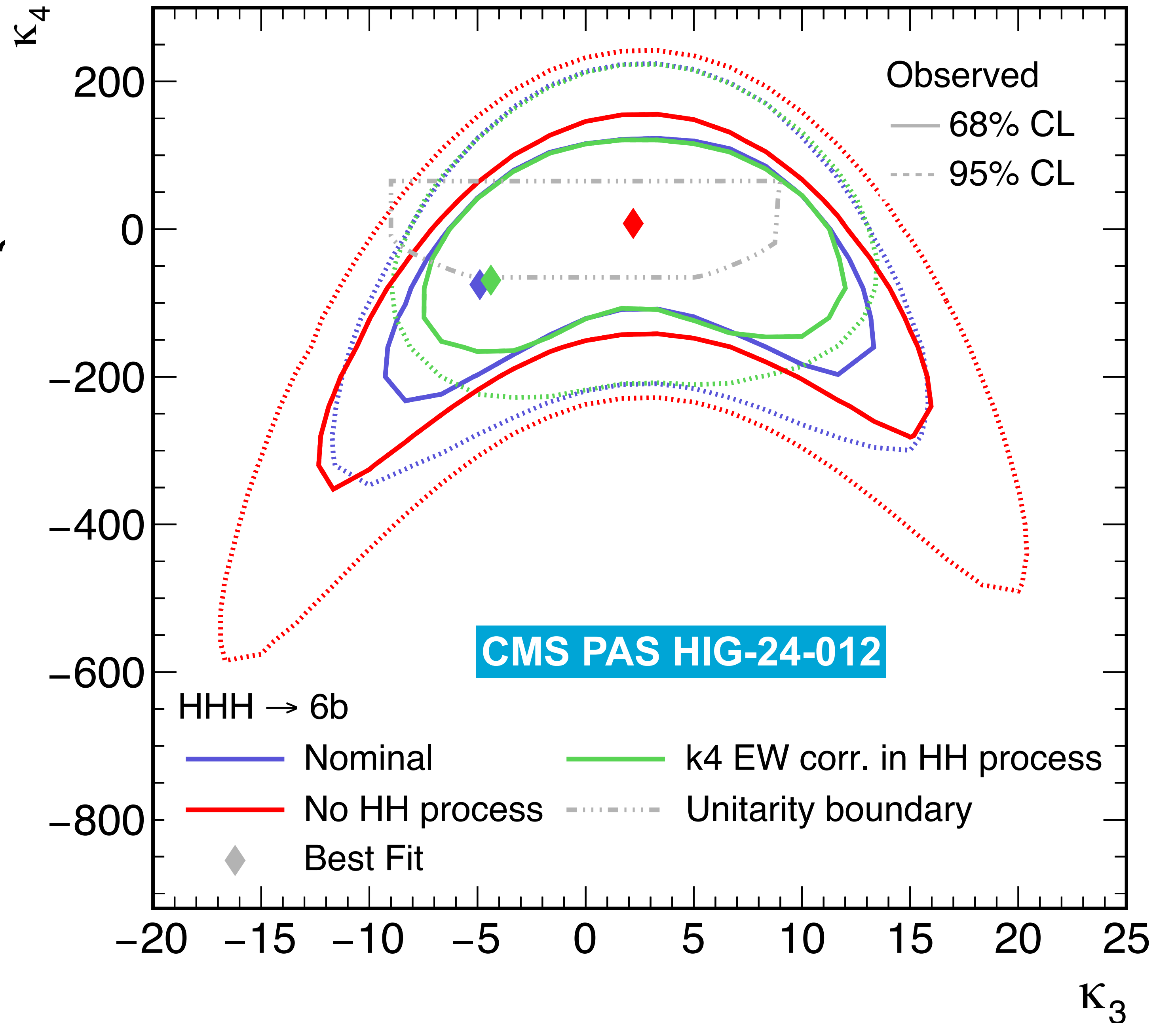
- $+ 5.54 \cdot 10^{-5}\kappa_4^2 - 1.56 \cdot 10^{-3}\kappa_3^2\kappa_4 - 3.78 \cdot 10^{-5}\kappa_3\kappa_4^2 + 9.56 \cdot 10^{-6}\kappa_3^2\kappa_4^2,$

Haisch, Sankar, Zanderighi
arXiv:2505.20463

- Unfortunately they do not look exactly the same (look at the double-quadratic term)
- It would be good to understand the difference, which should be easy, given the author overlap :) and come up with the HH signal strength recommendation

Some Ideas

- HH treatment (cont'd)
- Does κ_4 scan really matter?
- Yes, it does, in the κ_3 direction
- Croissant → Muffin!



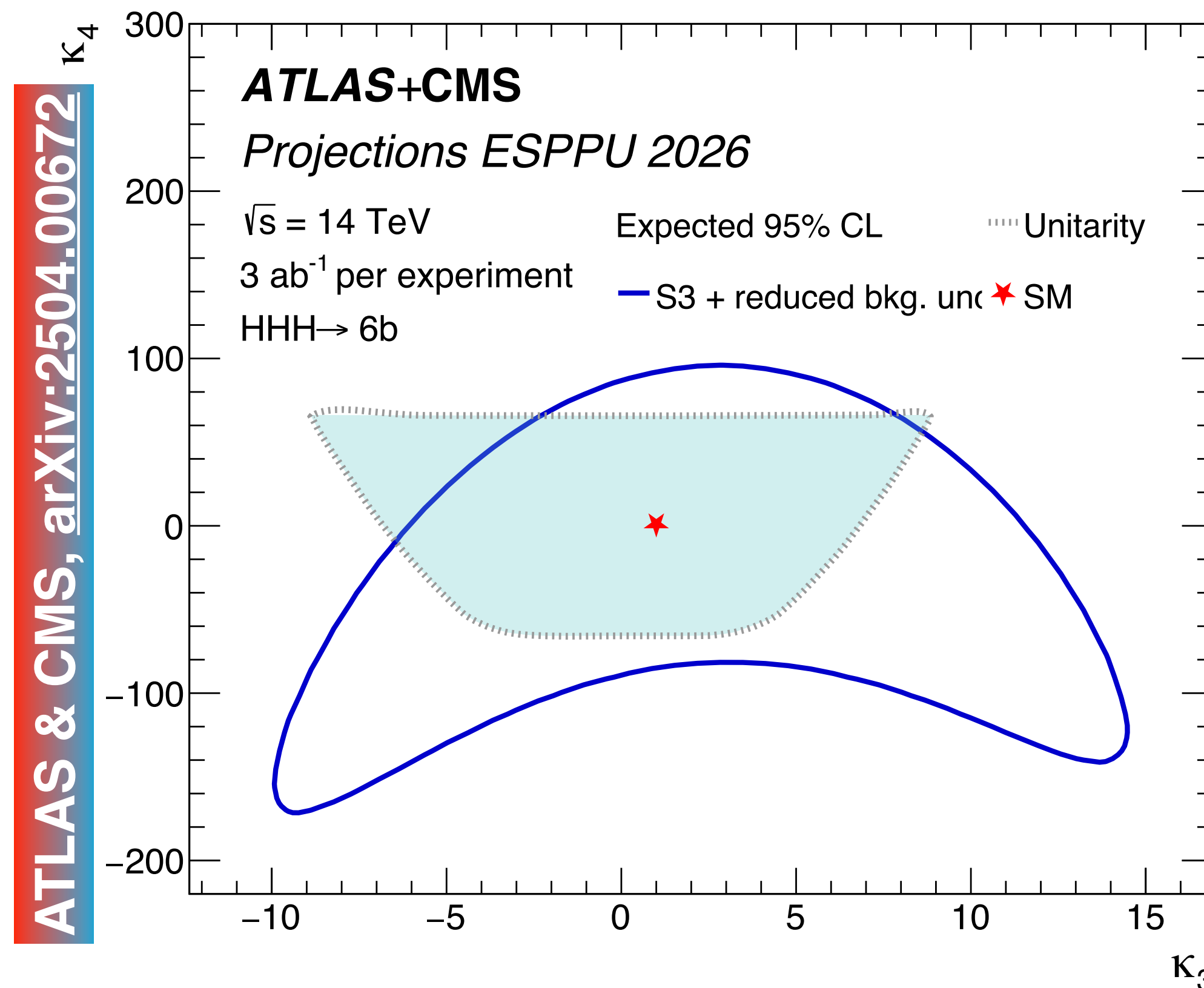
Some Ideas

- HL-LHC Projections

- ATLAS & CMS submitted ESPPU projections a few months ago, based on the ATLAS 6b analysis; unfortunately they are now obsolete

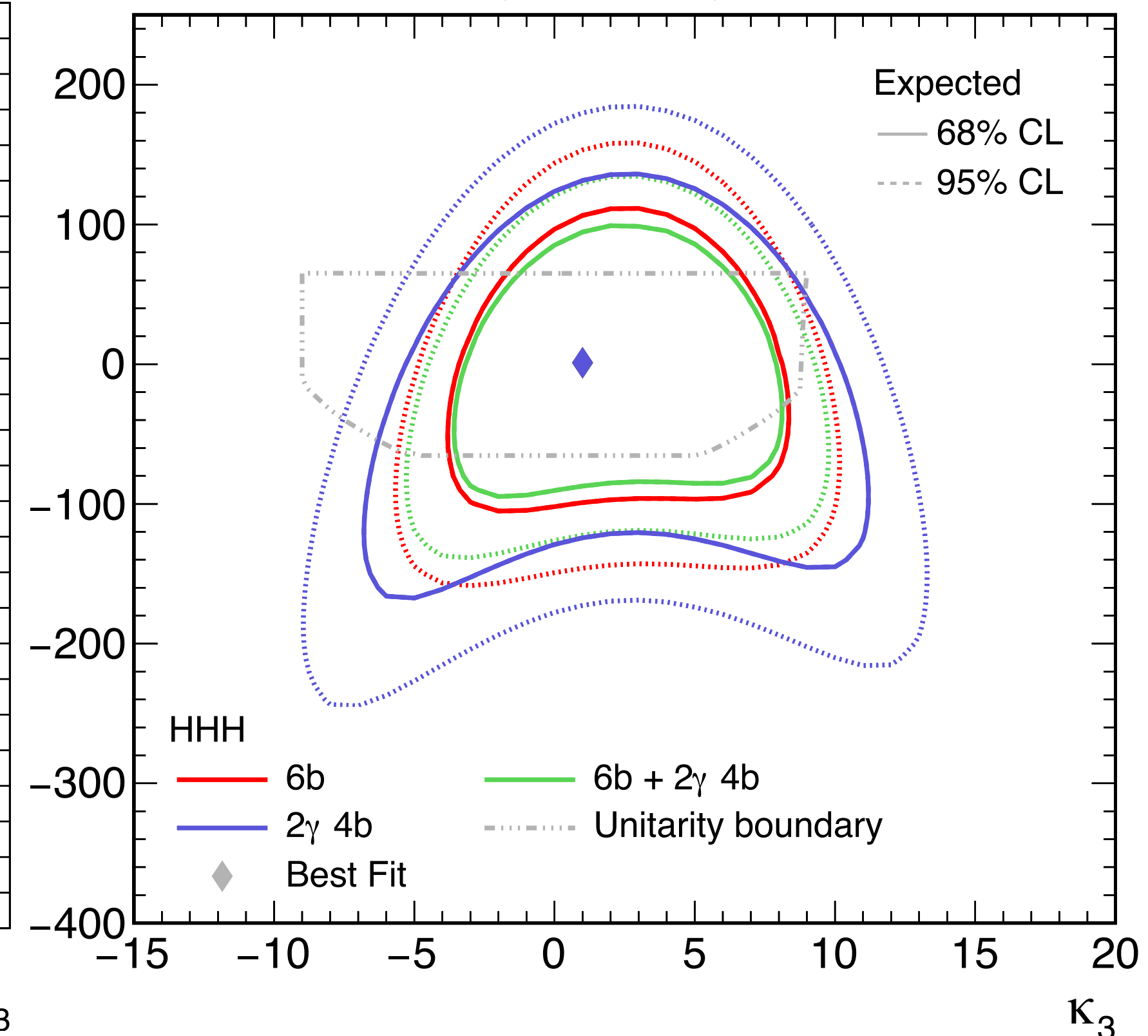
CMS PAS HIG-24-012

- Too late to update for ESPPU, but could add to YR5, perhaps with the κ_4 update



ATLAS & CMS, arXiv:2504.00672

CMS Supplementary Preliminary 3000 fb^{-1} (14 TeV)



Anything Else?

Thank You!