Co-funded by the Horizon 2020 Framework Programme of the European Union

Shape analysis for HH(bbaa) at FCC

G. Ortona, M. Selvaggi

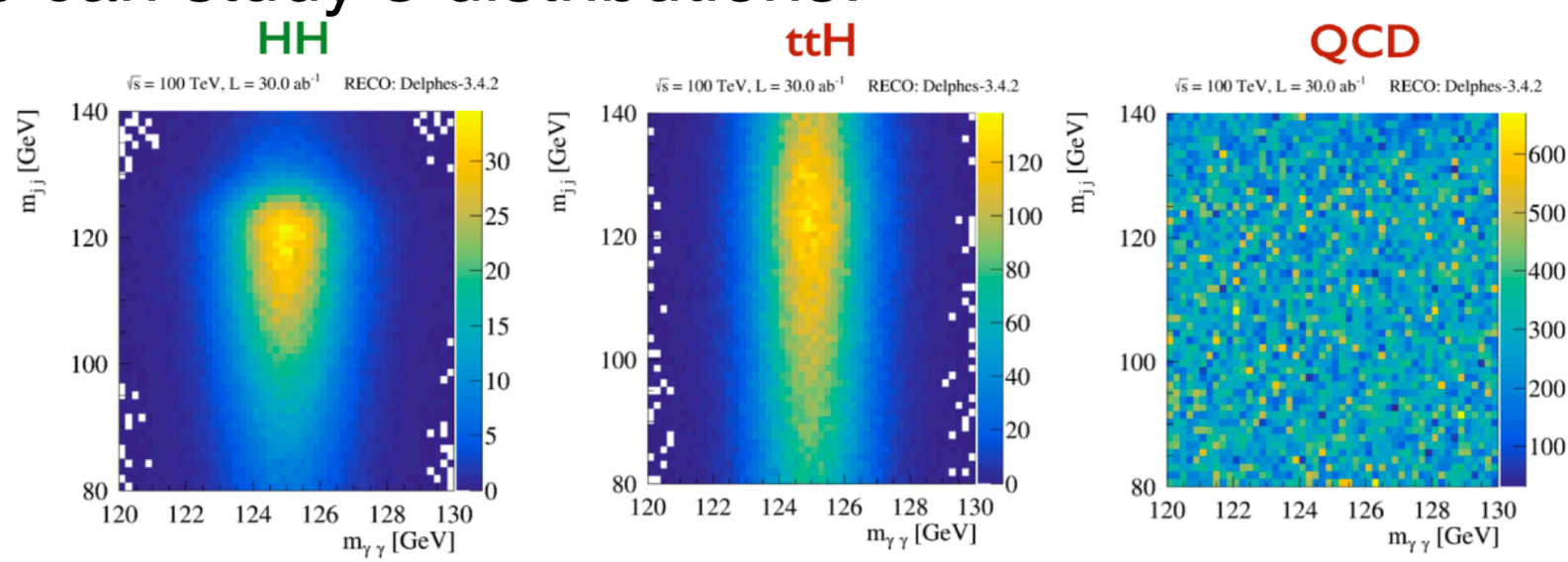
Shape and HH

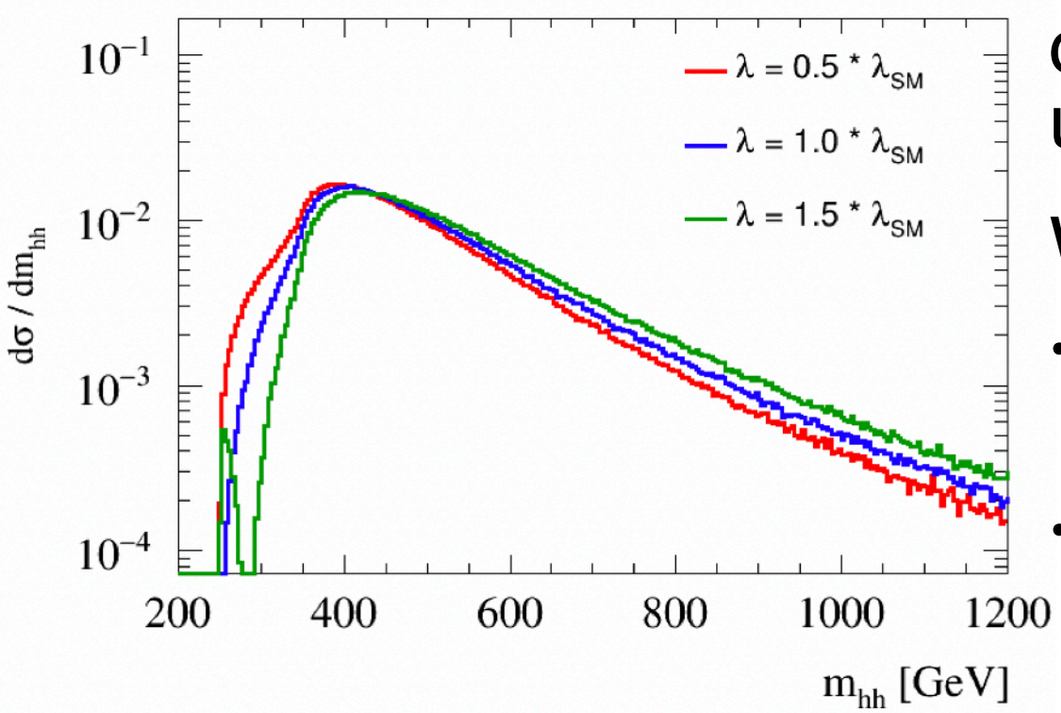
Our goal is a 2D analysis, with limits set on signal strength r and trilinear coupling k_λ

When studying hh→aabb we can study 3 distributions:

- m_{aa}, m_{bb}, m_{hh}

m_{aa}, m_{bb} provide good S/B separation, increase sensitivity to yield variations





k_λ is known to have an effect on the distribution of m_{hh}. We lose this information using only m_{aa}, m_{bb}

We can try to model the m_{hh} k_λ dependence

- Template morphing (see Michele's talk at FCC week)
- Parametric functional form of the signal lineshape

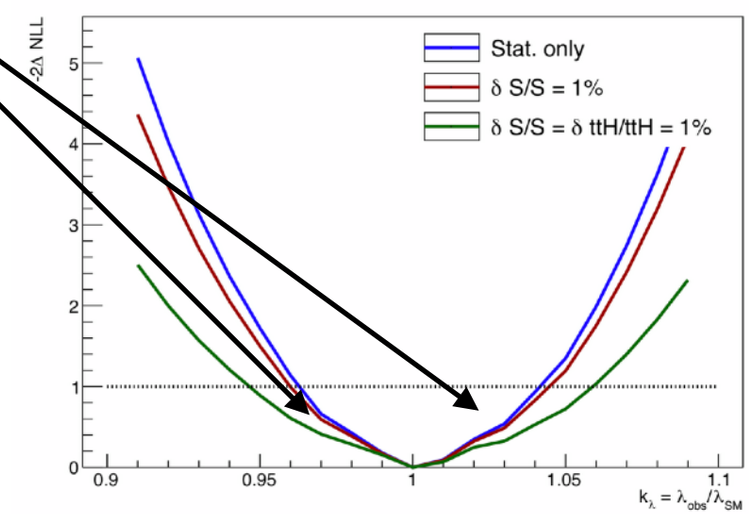
Template morphing

Our first attempt was to use template morphing to model the shape variation from generated templates

Vertical interpolation of each bin in the template, correlated with yield variation k_λ

Final result show “wiggles” in the final limit, especially when using m_{hh}. Sensitive to statistical fluctuations in the input templates, result not optimal

Precision of about ~6% on k_λ, both when using (m_{aa},m_{hh}) and (m_{aa},m_{bb})



- Why do we observe wiggles? Some problem with morphing procedure?
- Why don’t we see an improvement when using m_{hh} instead of m_{bb}?
- What is the optima pair of variables?

MHH signal

The effect of kλ on the shape is small

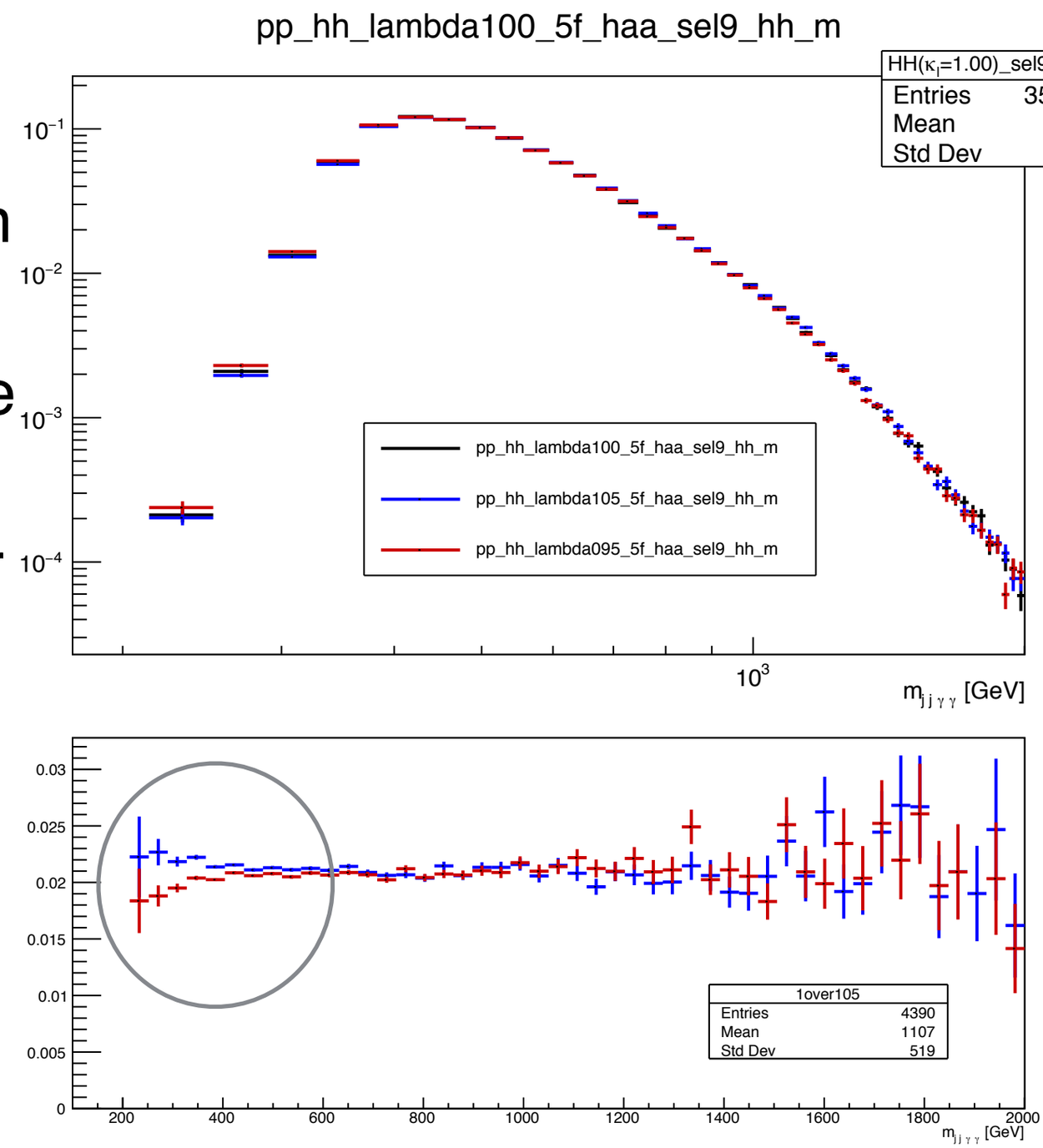
Larger than statistical fluctuations only in the low mass region

For the morphing is very difficult to obtain reasonable interpolation in these conditions

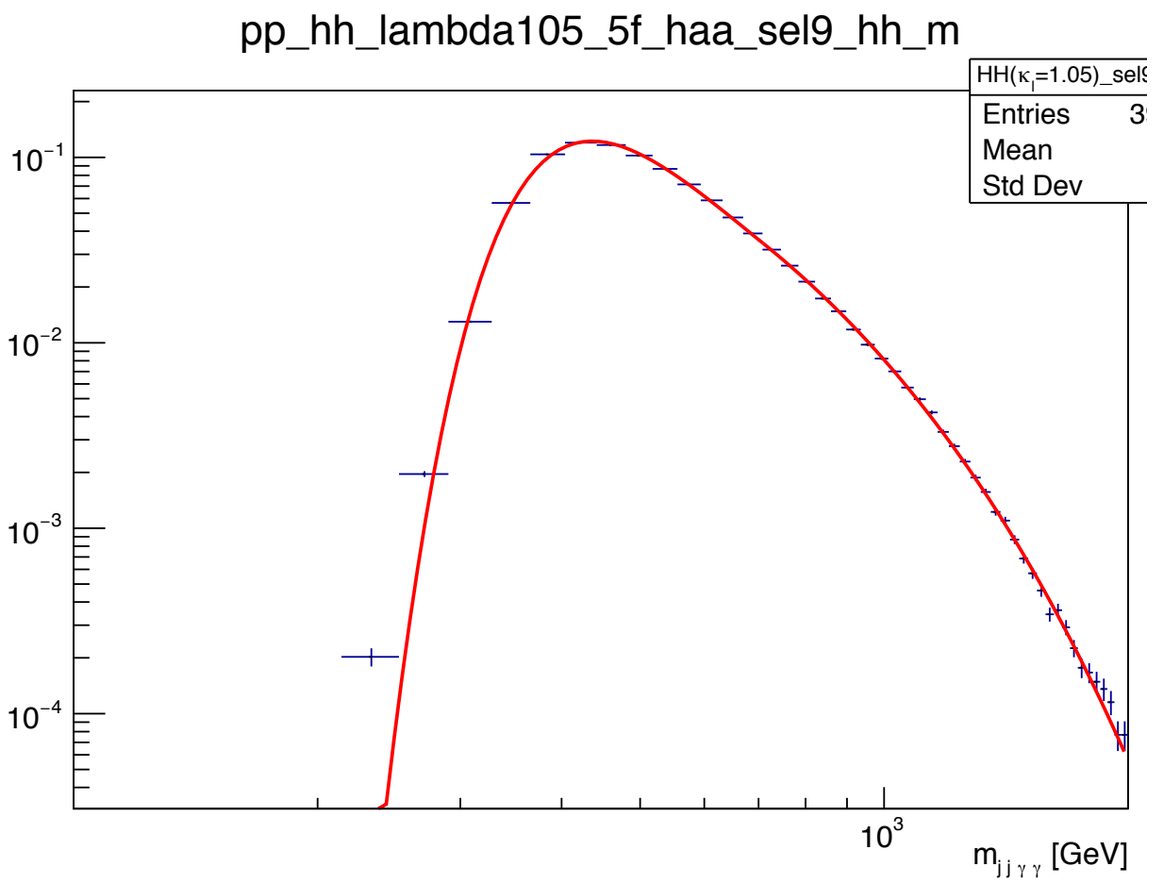
2D(m_{aa},m_{bb}) fit might prove to be better as it provides higher S/B separation

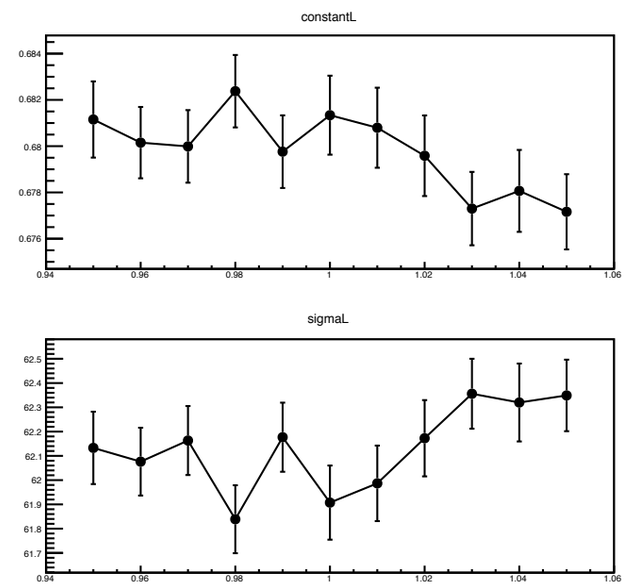
We still want to investigate if we can extract the info from the m_{hh} shape variation

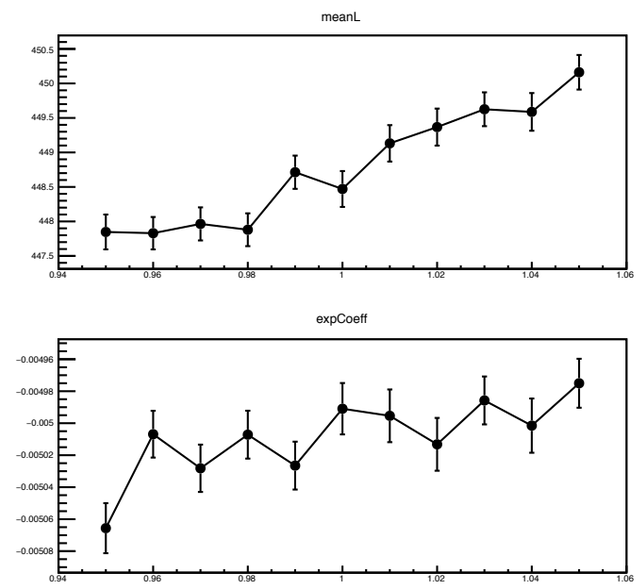
kλ variation is always related to yield effects as well



Signal parametrisation







Landau + expo tail seems to be a good candidate for the signal shape

The shape parameters can be made k_λ dependent to extract a bit more information from the fit

Need to be reevaluated for the boosted topology (similar, not identical)

A simple Gaussian is a good match for m_{aa}. We can then incorporate resolution/smearing effects in the Gaussian width and vary them at will

Fit with parametric shape (or with constant shape/template) is more stable and reliable wrt to template morphing

Options and Plans

Structure of the analysis is rather flexible.

We can do any combination of

- fit dimensions: 1D(m_{aa}/m_{bb}/m_{hh}), 2D(m_{aa}, m_{hh}/m_{aa},m_{bb})
- m_{hh} parametrisation: parametric with parameters depending on k_λ, parametric with constant parameters, template, morphed template
- m_{aa} parametrisation: Gaussian, template
- m_{bb} parametrisation: only fixed template for now
- categories: resolved, boosted, combination of the two

For both k_λ and signal strengths scans

What we can vary/check at the moment

- Background normalisation by any factor (we are doing 0.5/2 for now)
- fake rate on b-jets
- photon resolution by smearing Gaussian width
- Normalisation (lumi) uncertainties on signal and backgrounds processes

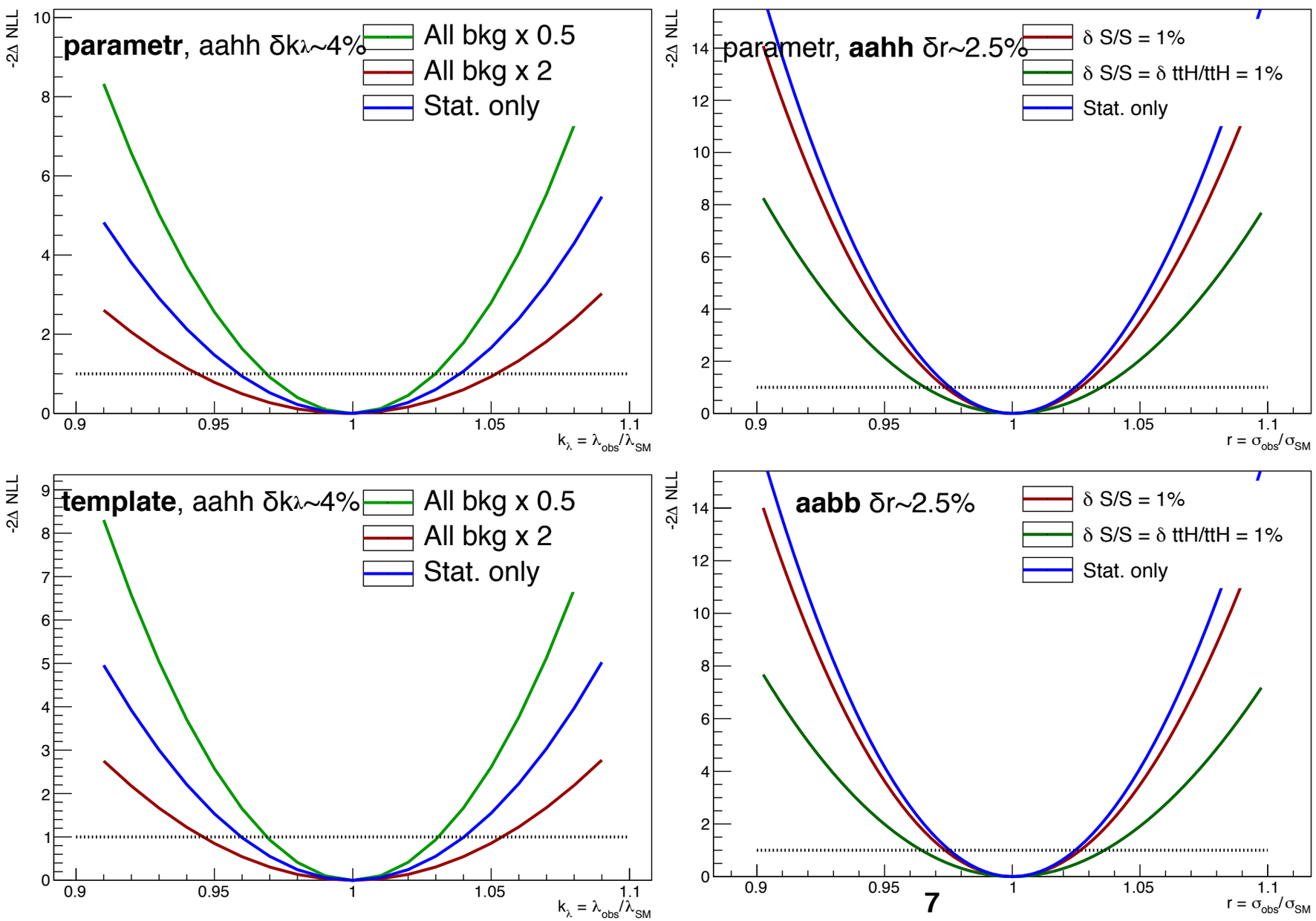
Results

Not many differences between parametric/templates

But param gives more flexibility for studies, so is probably the best option

2D(aa,bb) has slightly better sensitivity, default for our results

We might even think of a **3D**(m_{aa},m_{bb},m_{hh}) fit, but statistics is an issue

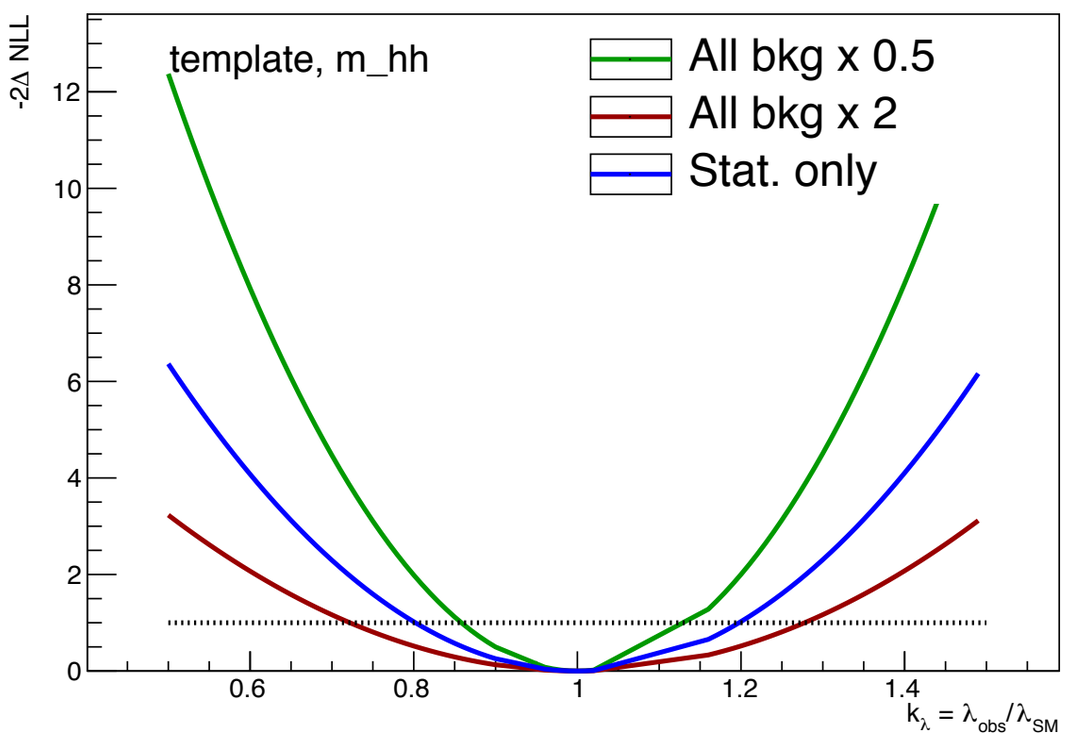


Sensitivity:

4% on coupling,

2.5% in signal strength

Results (some example of…)



Boosted category:

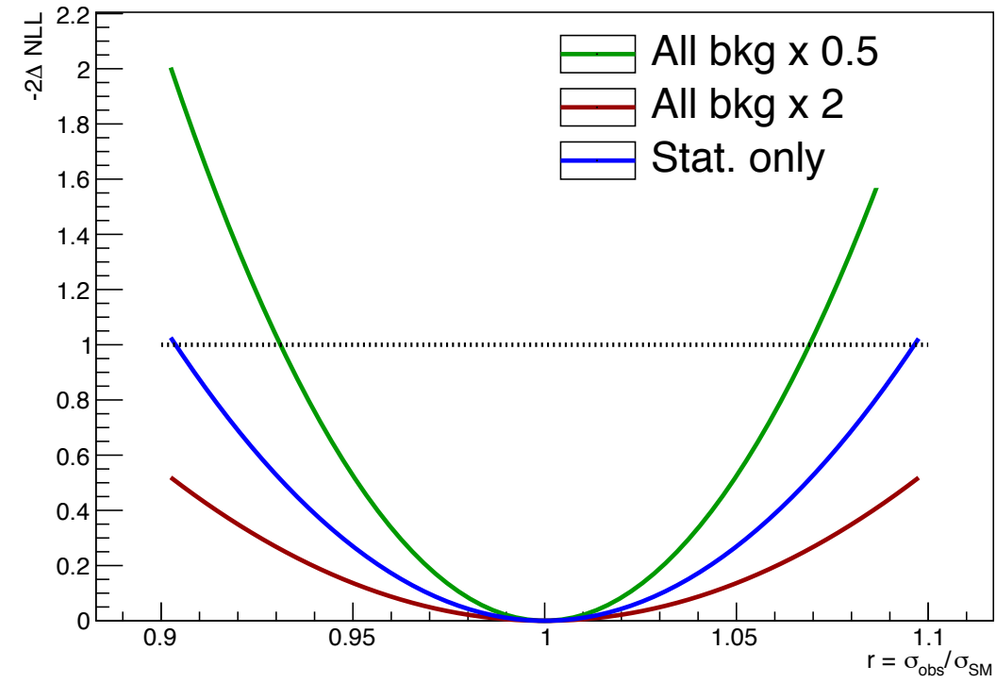
~20% precision on couplings, 10% on r

1D(m_{hh}) fit after cut on diphoton mass

We can probably still gain something

Parametric shape for the boosted category is not ready yet

Maybe we can stay with templates here

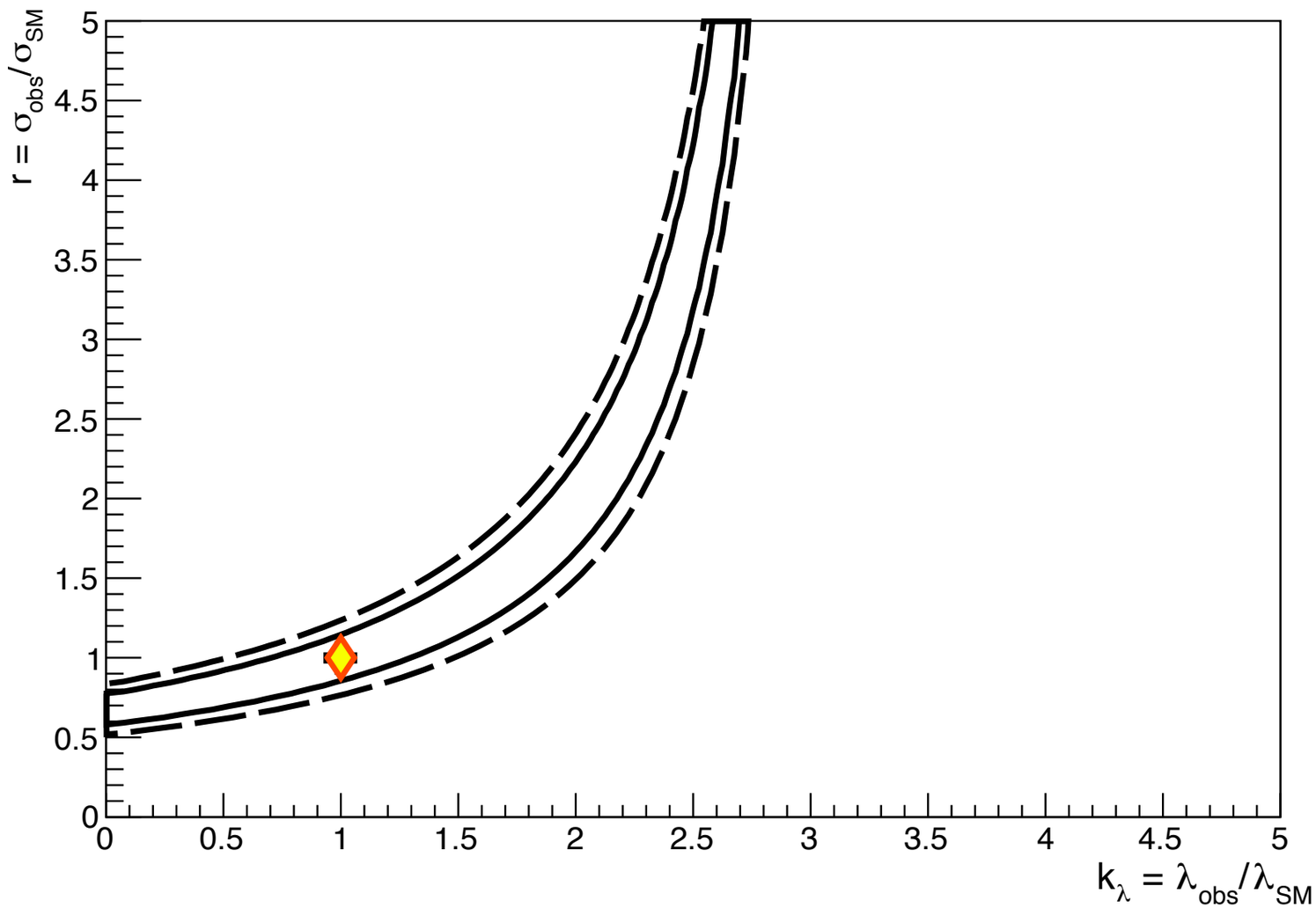


The code can be found at
https://github.com/giacomoortona/PersonalStuff/tree/master/FCC

Not meant for a general analysis, but we can work on integrating it in the FCC repository

BACKUP

2D scan

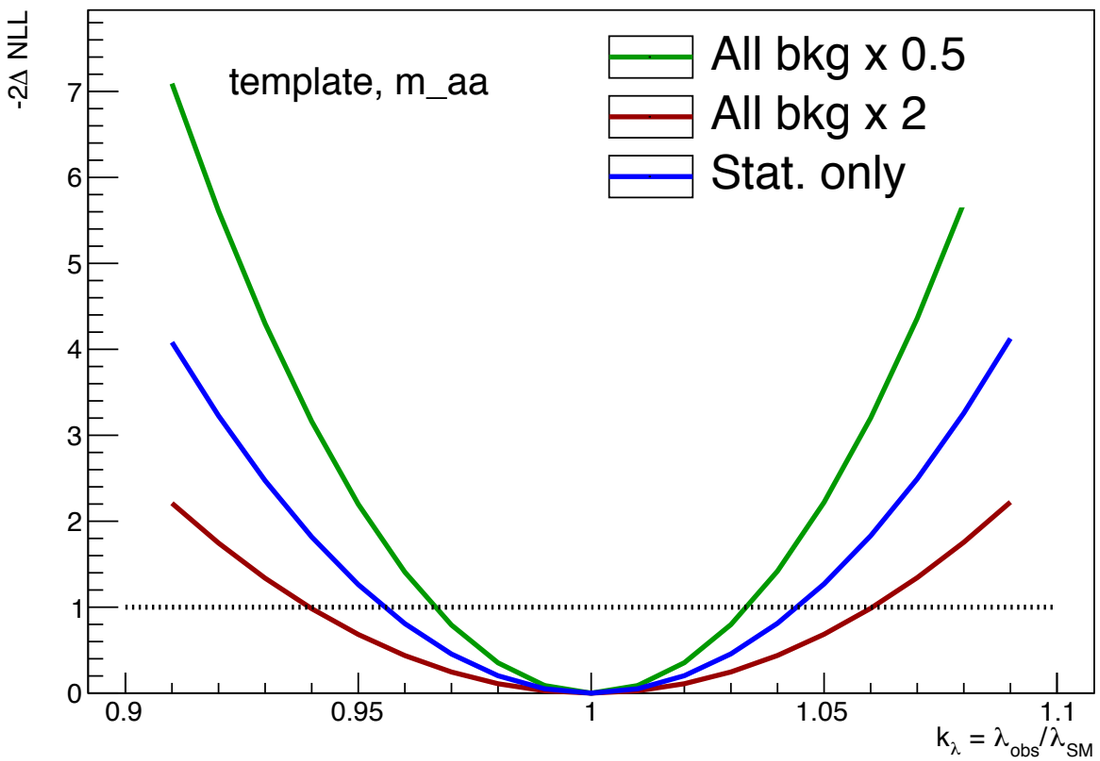


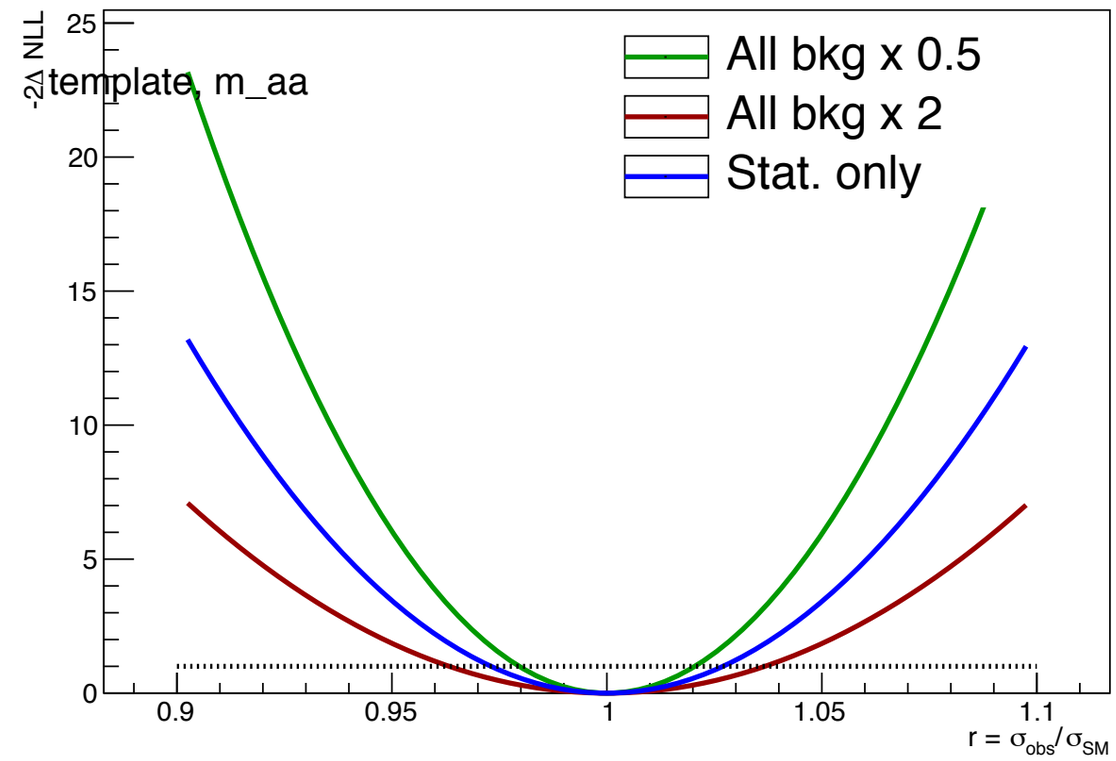
Remember: negative correlation between kl,r

This is not actually realistic as the shape varies wildly across this range

Maybe we can use the morphing here, or impose boundaries

maa scan





Sensitivity:

~4.5% on coupling,

3% in signal strength