HH → bbZZ(4ℓ) for FCC-hh studies

E. Fontanesi

L. Borgonovi, S. Braibant

University & INFN Bologna

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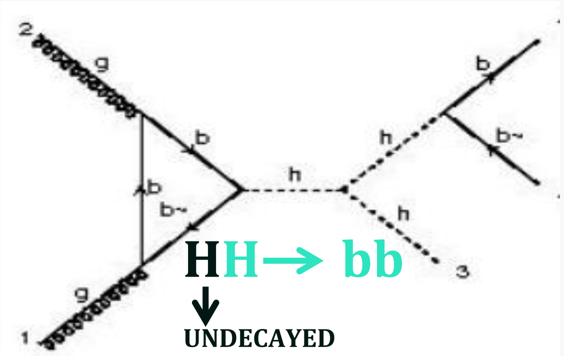
OUTLINE

- MC samples
- Event selection
- Signal strength
- k_λ studies

MC samples

MADGRAPH5_amc@NLO
(theoretical cross-sections except for the bb+ggH(4ℓ) sample)

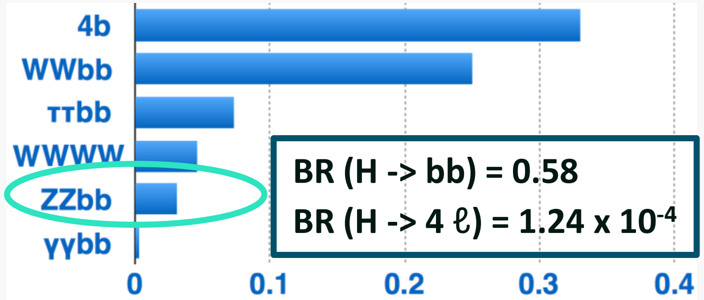
+ DELPHESPYTHIA8
(hadronizaton and decay of the H/Z bosons in leptons)



Process	σ x BR [fb]	K-factor
H(bb)H(4ℓ)	0.178	
ttH(4ℓ)	4.013	1.22
bb+ggH(4ℓ)	0.369	3.2
Z(bb)H(4ℓ)	0.071	1.1
ttZ(2ℓ)	2594.4	

SIGNAL

- Signal events were generated for **several values of k_λ** in the range [-1, 3] in step of 0.5.



BACKGROUND

- The **ttZZ background** is **negligible**.
- The contribution of the 4ℓ+jets **(ZZ*, Z*Z*, ZZ) continuum** was evaluated using a lllljj (ℓ =e, μ) sample, generated with the 4ℓ invariant mass in the range [100, 150] GeV and only heavy flavour partons (b/c). It is found to be **negligible**.

Event selection

4ℓ analysis + 2 b-jet request

- $|\eta| < 4$ & $p_T > 5$ (7) & iso < 0.7 GeV to identify a good muon (electron)

$N(\ell) \geq 4$

$N(\ell^+\ell^-$ pairs$) \geq 2$

M_{Z1} = [40, 120] GeV

M_{Z2} = [12, 120] GeV

$N($isolated $\ell) = 4$

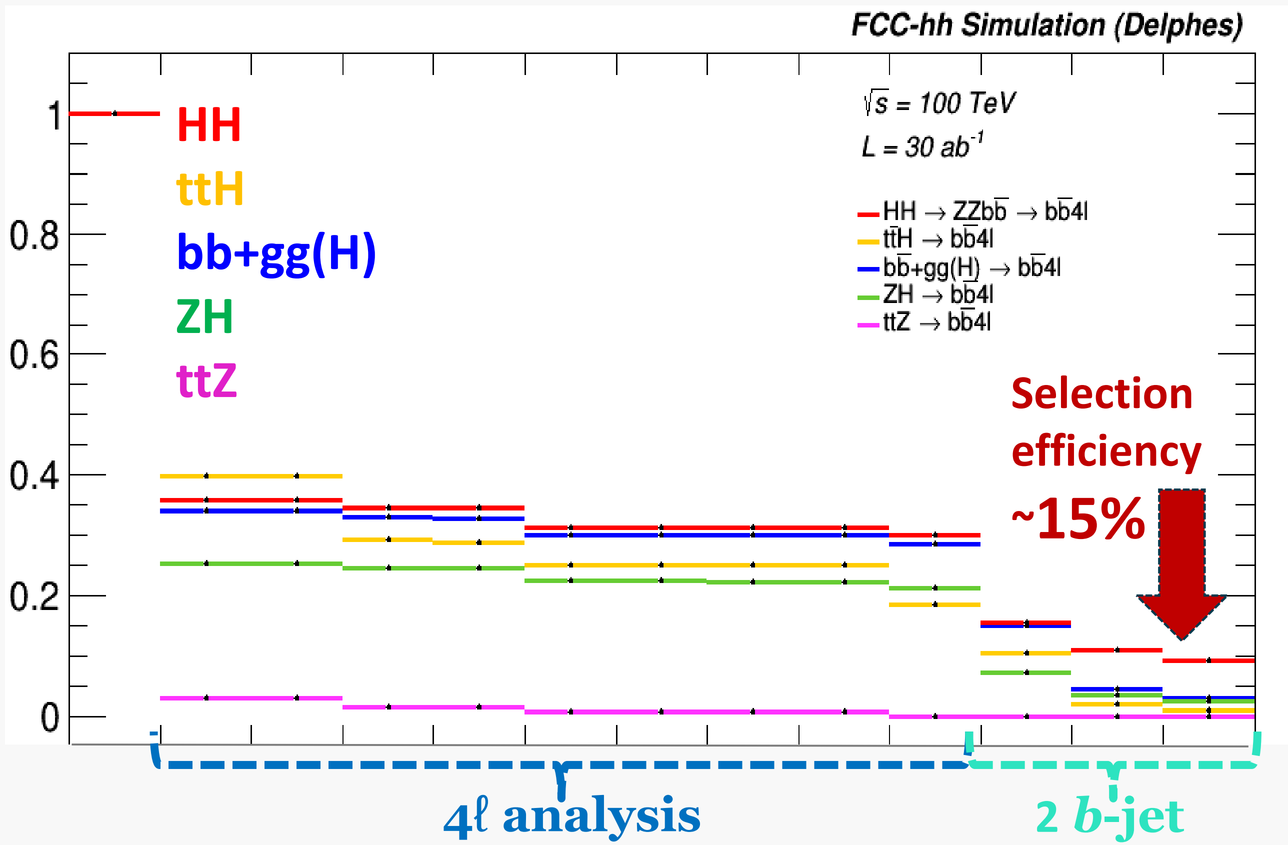
p_T cuts on two ℓ

$M_{4\ell}$ = [120, 130] GeV

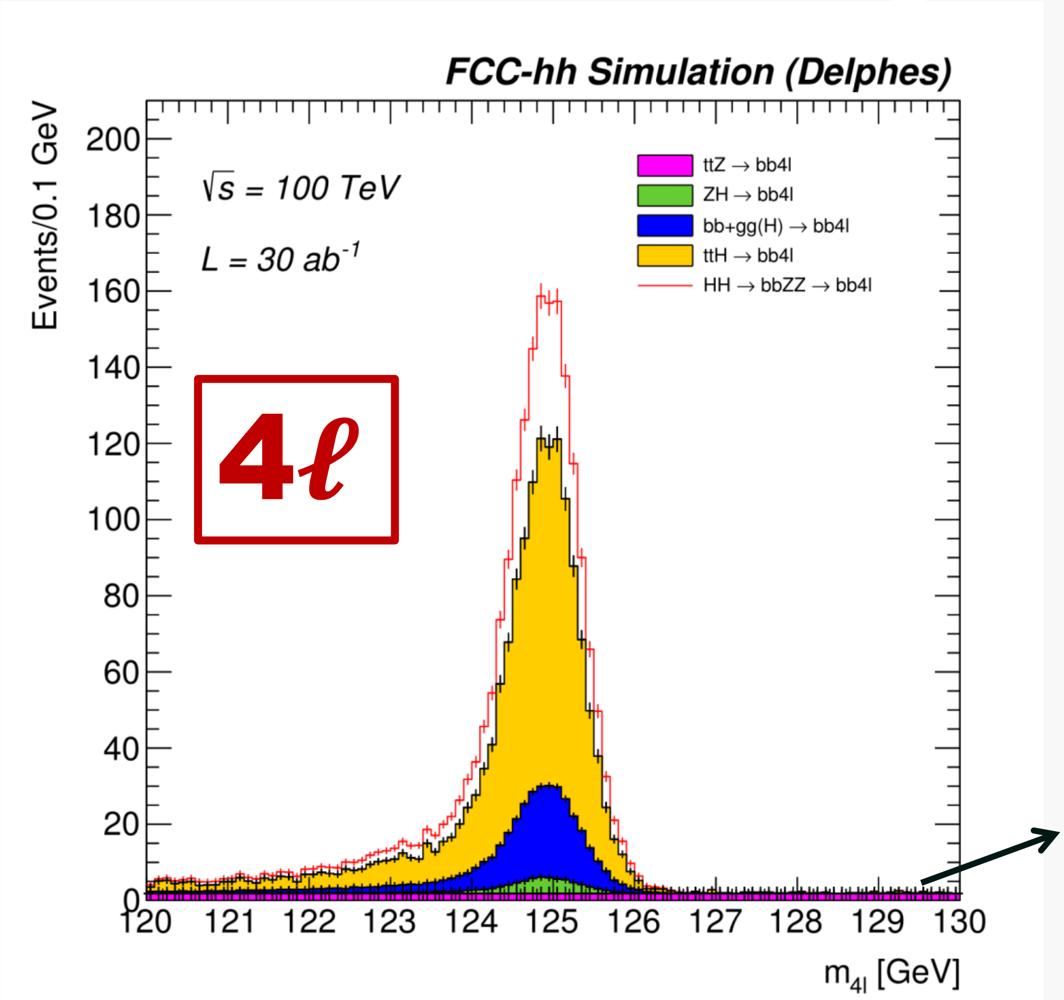
$N(b$-jet$) = 2$

M_{bb} = [80, 130] GeV

$\Delta R(bb) < 2$



4ℓ invariant mass

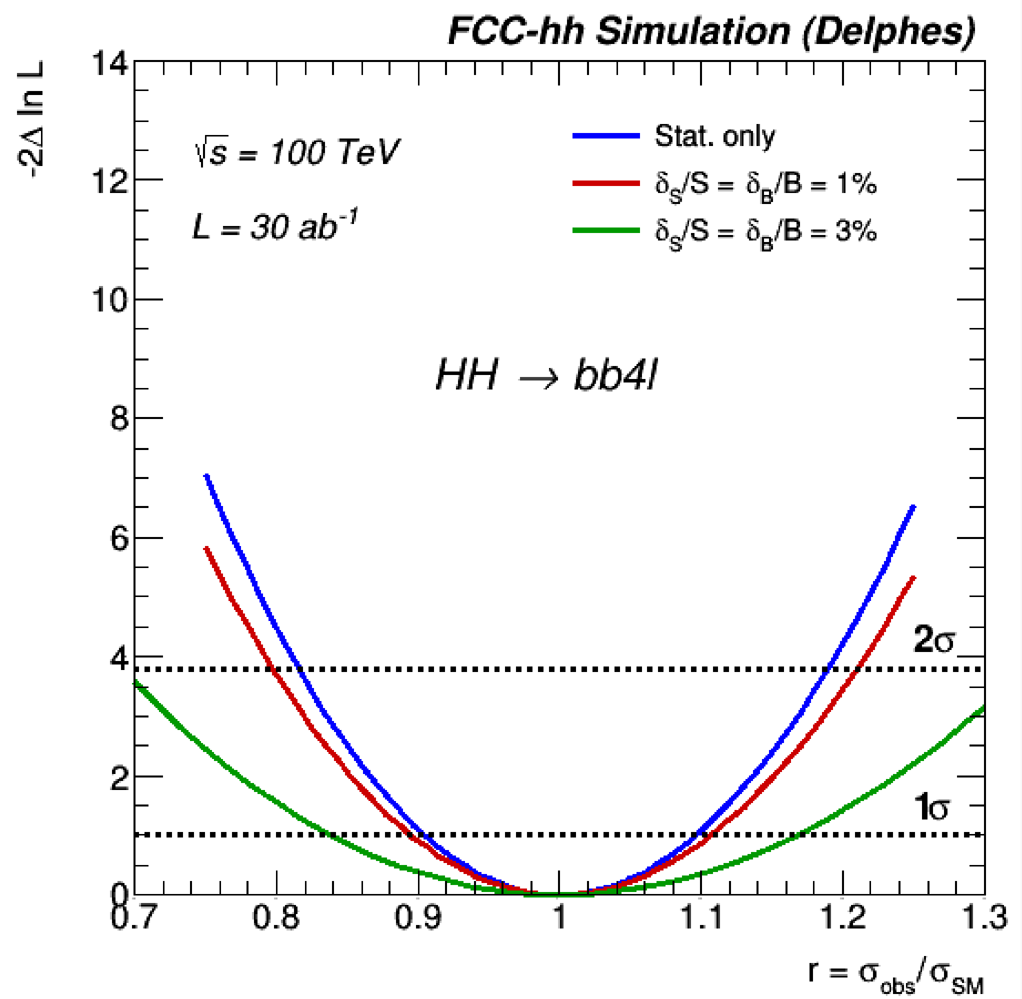


The invariant mass spectrum of the selected 4ℓ was normalized to an integrated luminosity of **30 ab^{-1}**:

Process	Yield
HH	489
ttH	1162
bb+gg(H)	317
ZH	52
ttZ	179

The **flat contribution** of the **ttZ** background has been added wrt the last version of the CDR.

Precision on the signal strength



- **COMBINE** tool was used to perform the statistical analysis.
- Three different scenarios for three different assumptions on the systematic uncertainties were considered: **no systematics**, **1%**, **3%**.
- **Expected precision on the signal strength r:**

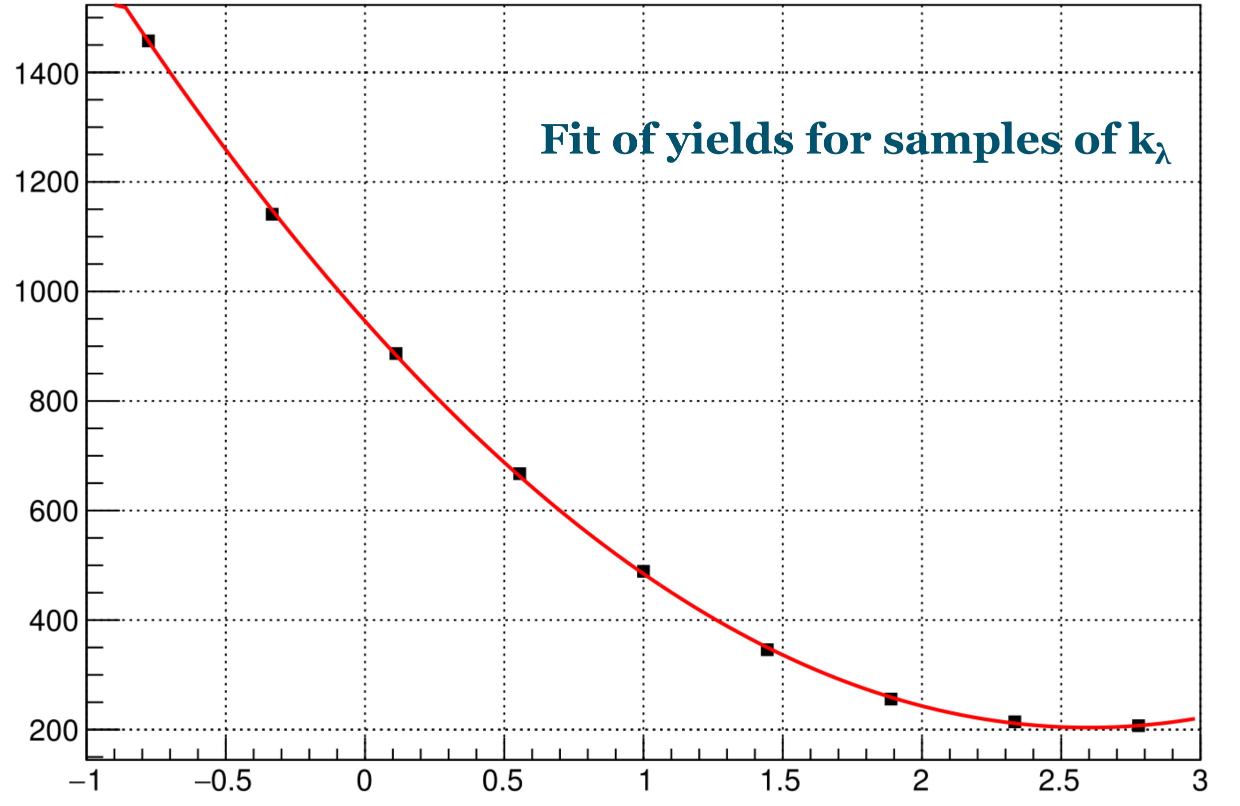
	No syst.	1%	3%
1σ (68% CL)	**10%**	11%	17%
2σ (95% CL)	19%	21%	34%
Significance @95%CL[σ]	11.32	10.39	6.86

Precision on k_λ

To estimate the **sensitivity on k_λ** nine signal samples for different k_λ values were generated:

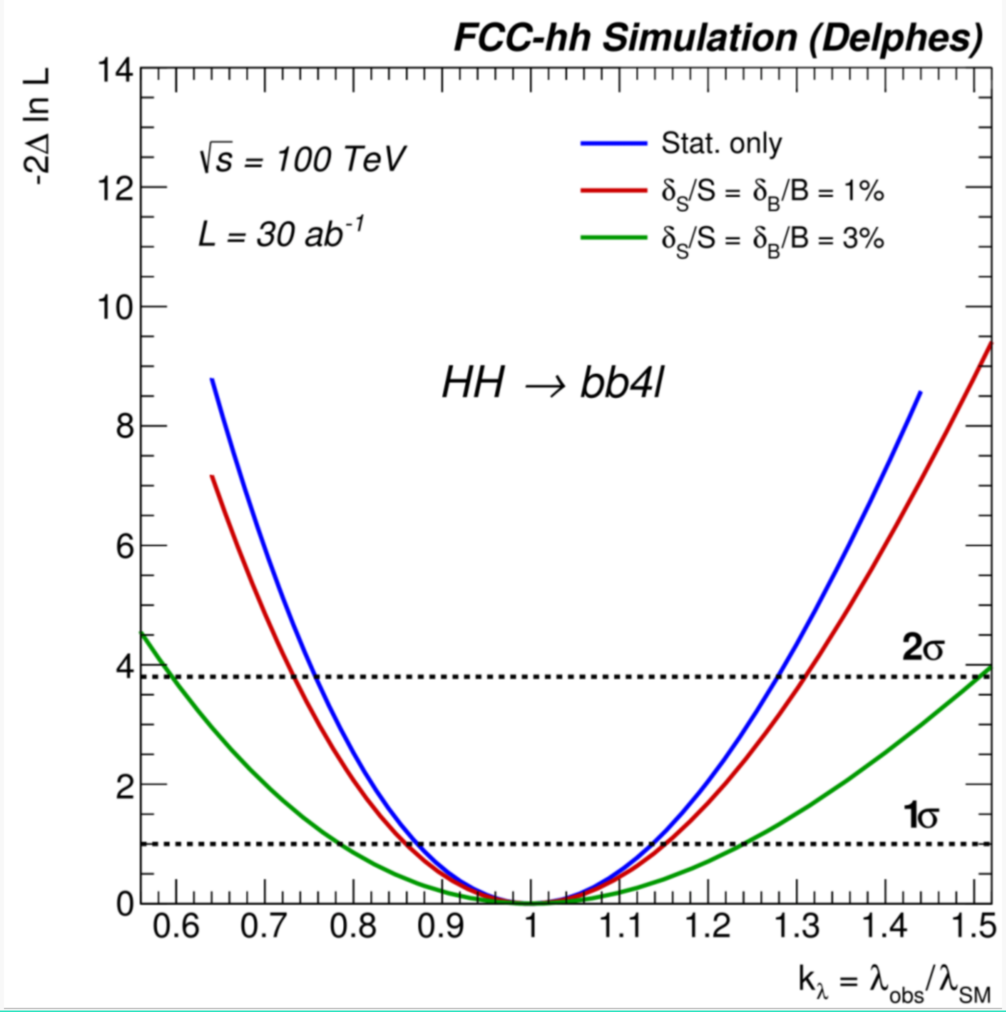
-1, -0.5, 0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0

Cross section from: https://github.com/FCC-hh-framework/EventProducer/blob/master/config/param_FCC.py#L772-L796



Approach to model anomalous k_λ signals in **COMBINE** (counting experiment, k_λ is a POI): yield parametrized vs k_λ with **quadratic function** by fitting various k_λ samples after the full selection.

Precision on k_λ



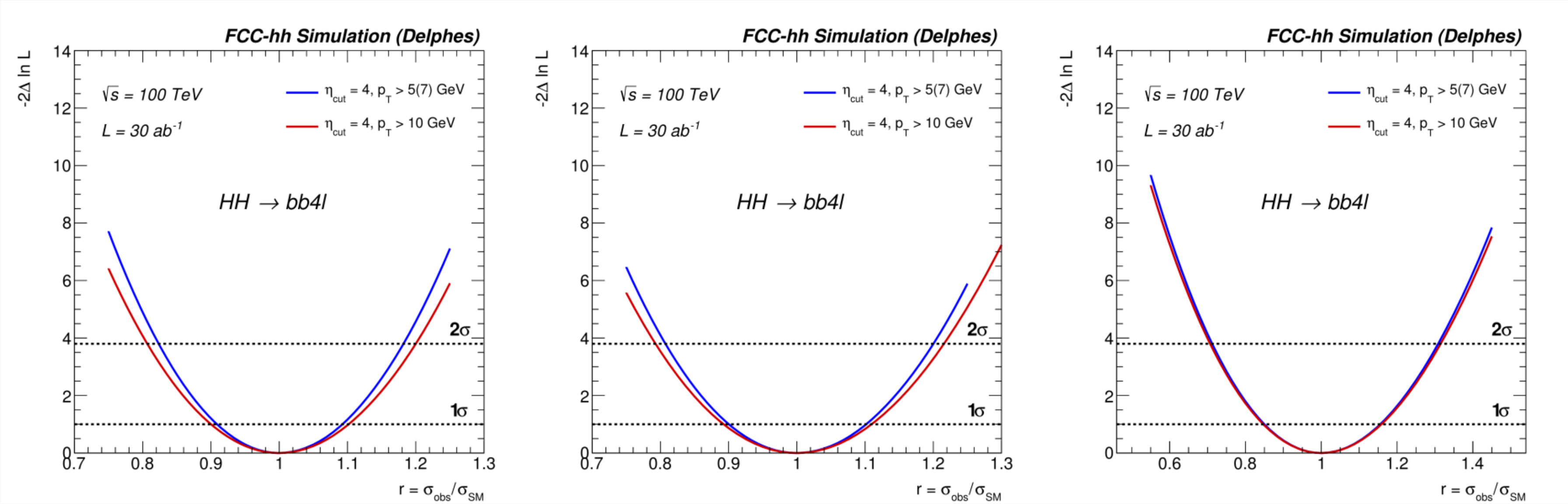
- Three different scenarios for three different assumptions on the systematic uncertainties were considered: **no systematics**, **1%**, **3%**.

- **Expected precision on the self-coupling modifier k_λ :**

	No syst.	1%	3%
1σ	**14%**	15%	24%
2σ	28%	31%	51%

Different detector assumptions: r

Assuming a different detector configuration, for example a larger tracker and/or higher magnetic field and consequently a different request on the p_T of muons and electrons, $p_T > 10$ GeV, the precision on the signal strength is not significantly affected.



No syst | 1% | 3%

Different detector assumptions: k_λ

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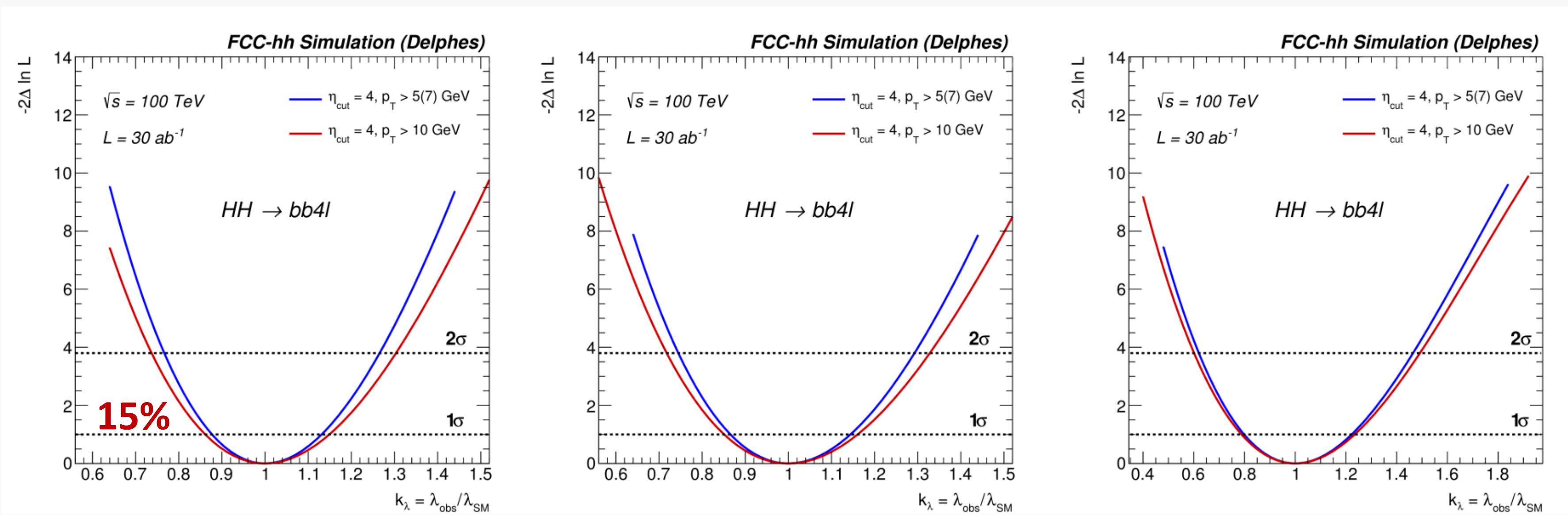

No syst | 1% | 3%

Conclusions

- A complete study of the bbZZ(4ℓ) channel in all the possible final states (4μ, 4e, 2e2μ, 4ℓ) has been performed.

- The expected precision on the signal strength r and on the Higgs self-coupling modifier k_λ without systematics at 68% CL is:

  δr(stat) ≈ 10% → **δk_λ(stat) ≈ 14%**

- The precision on r and k_λ is not significantly affected by varying the detector configuration as considered in this study.

- **Plots for the CDR** - The four lepton invariant mass (without the inclusion of the ttZ background) and the negative log-likelihood on k_λ in the 4ℓ final state (also for two different detector assumptions) were included in the CDR as most relevant results.

- An **analysis note** to include all the documentation and results will be completed before Christmas.