Higgs Activities in the FCC-hh

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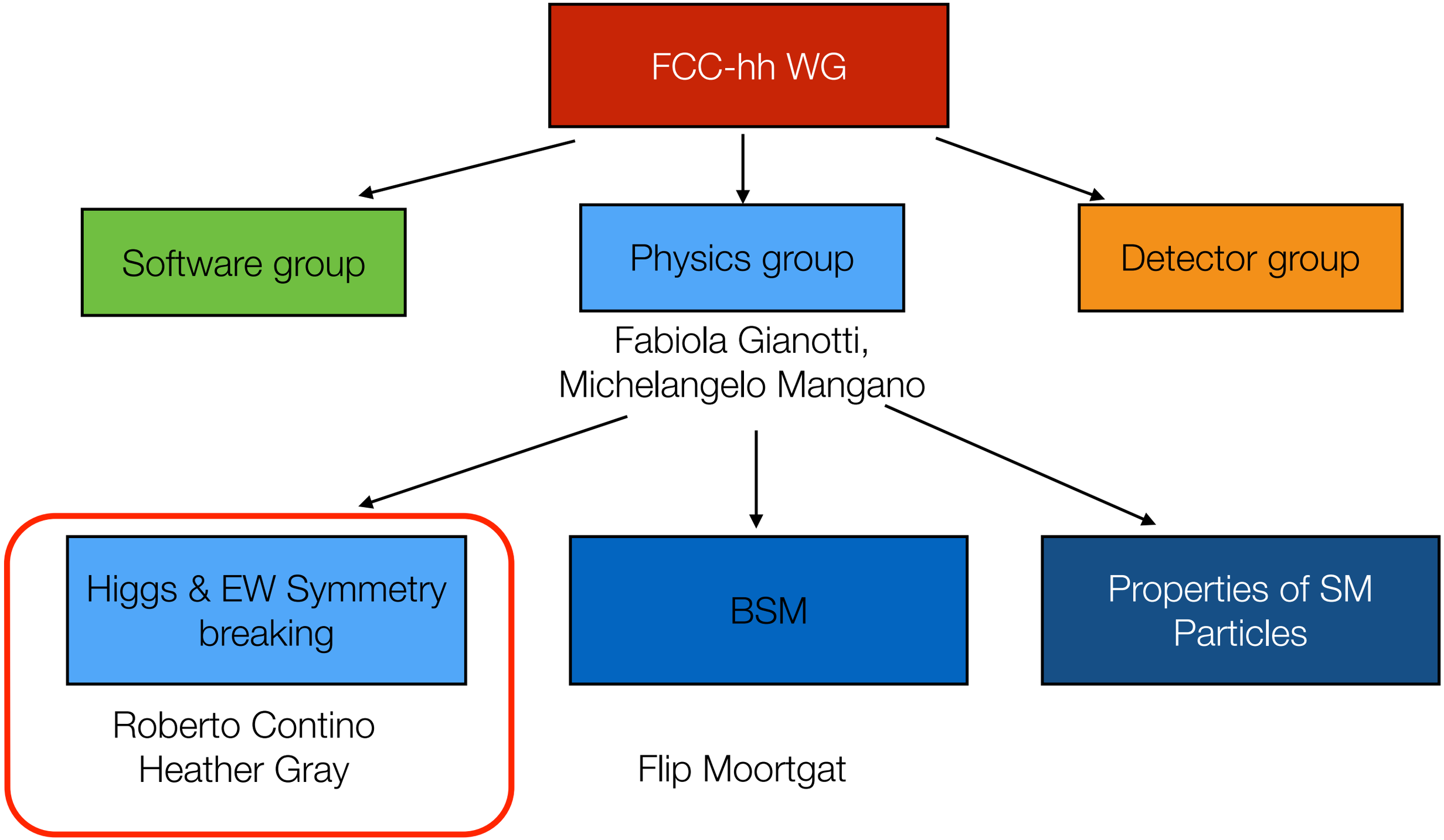
Quick Reminder: What is the FCC ?

- Future-Circular-Colliders

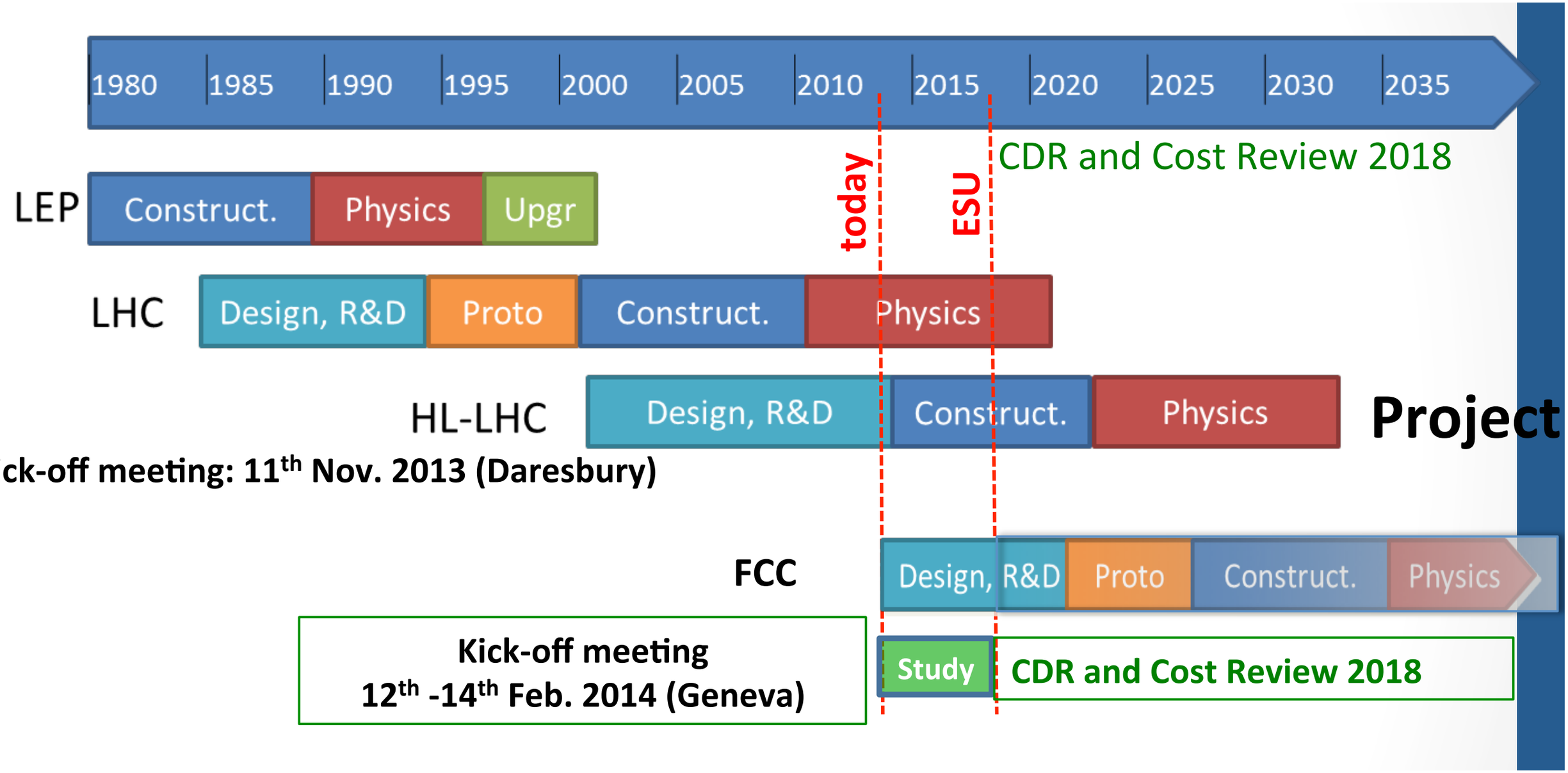
  - Goal: Build a 80-100km tunnel to host new collider(s)
- pp-collider (**FCC-hh**) defining infrastructure requirements
  - 8.3 Tesla (LHC dipoles) ⇒ √s=42 TeV pp in 100km (NbTi)
  - 16 Tesla ⇒ √s=100 TeV pp in 100km (NbSn3)
  - 20 Tesla ⇒ √s=100TeV pp in 80km (HTS)
- e+e- collider (**FCC-ee**, old TLep) as potential intermediate step
- p-e option (**FCC-he**)

FCC-hh structure



FCC hh workshop: http://indico.cern.ch/event/304759/other-view?view=standard

Timeline



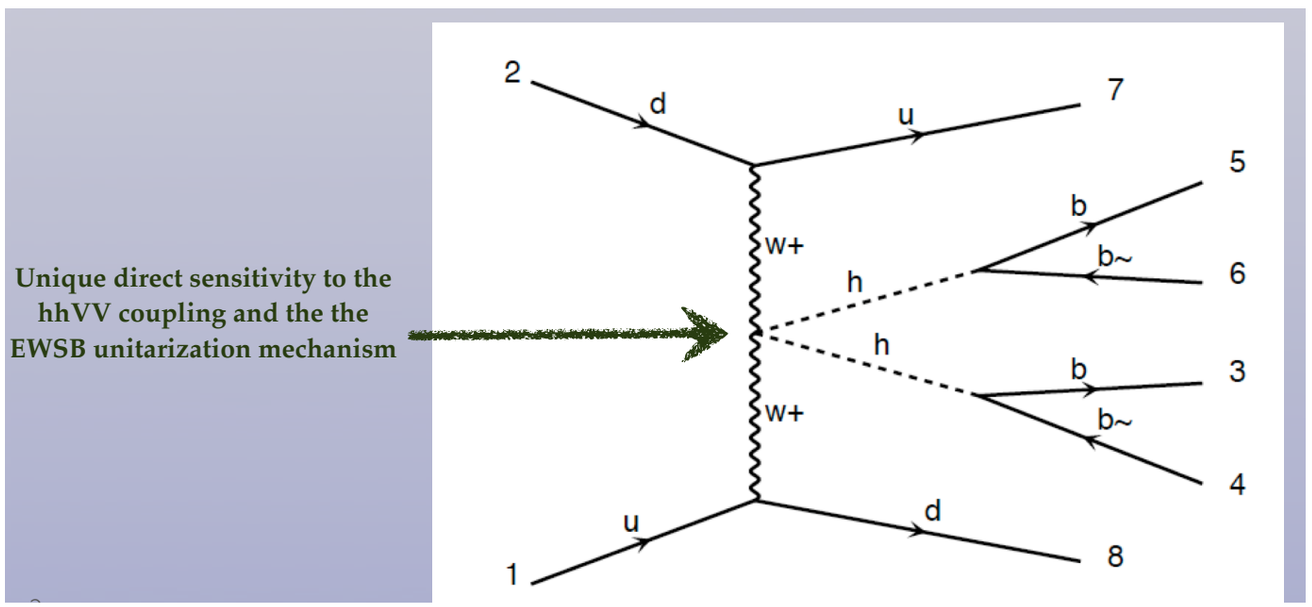
Kick-off meeting: 11th Nov. 2013 (Daresbury)

Kick-off meeting
12th -14th Feb. 2014 (Geneva)

Topics Higgs & EW Symmetry Breaking

- Precision studies of **Higgs Properties**
- **Rare Higgs** production and decays
- High-mass **WW scattering**
- high-mass **HH production**
- Additional **BSM Higgs bosons**: discovery reach and precision physics program

- New handles on the study of **non-SM EWSM dynamics**
- **New ideas !**



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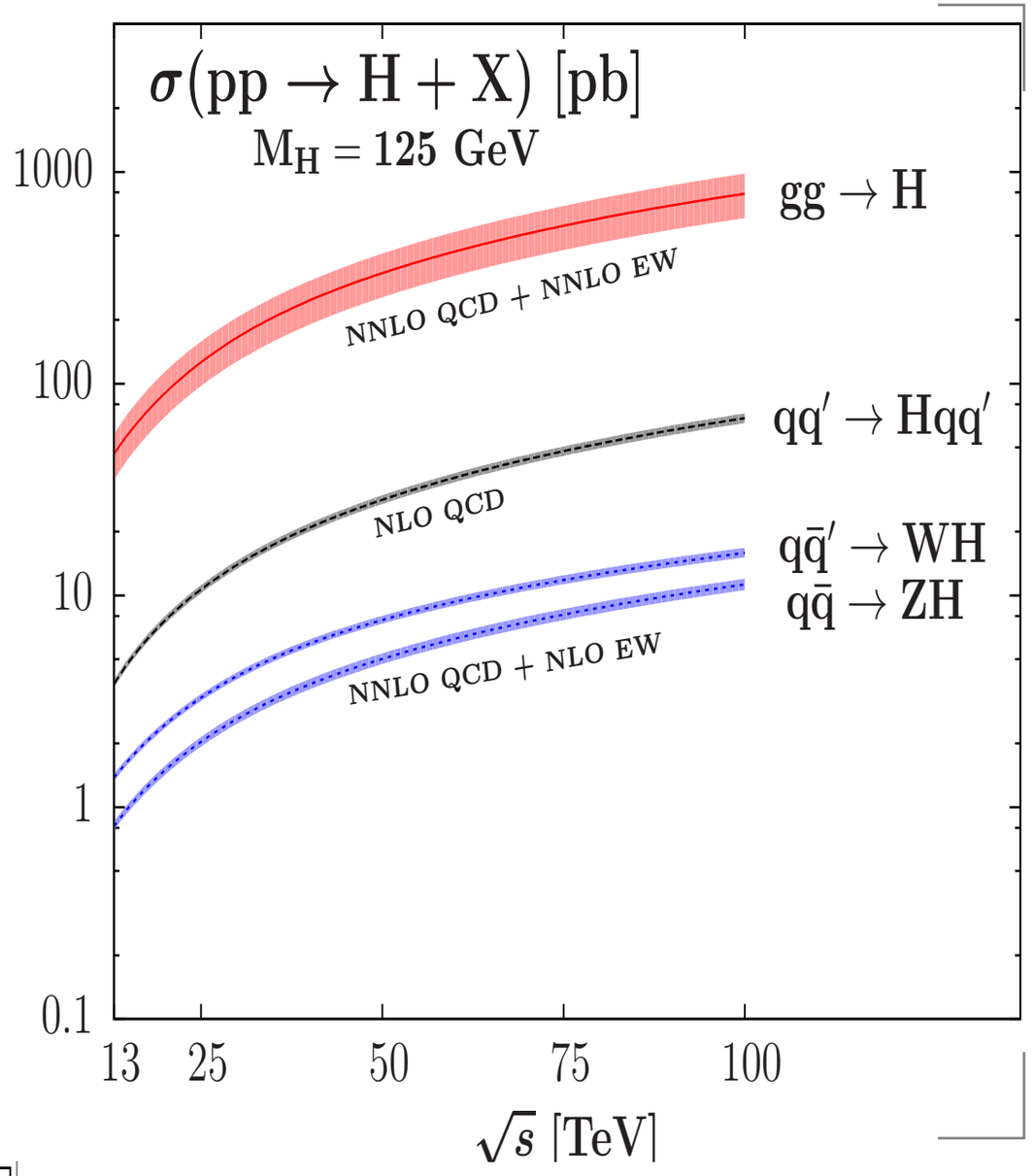
Precision Higgs Studies

- Extrapolation of basic Higgs channels
  - ‘A Higgs factory’
  - σ_{ggF} = 740 pb
    - cf. ~800 pb for ttbar at LHC
- VBF provide input for detector η coverage
- Theoretical errors are key, including uncertainties on EFT treatment

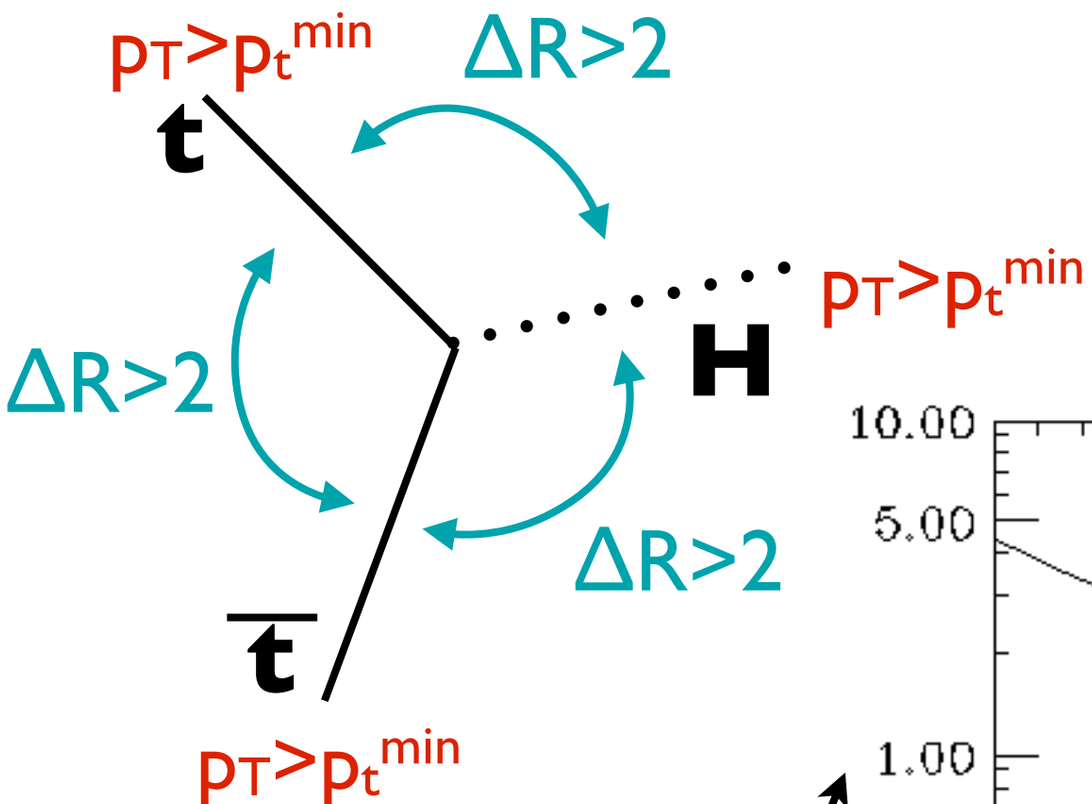


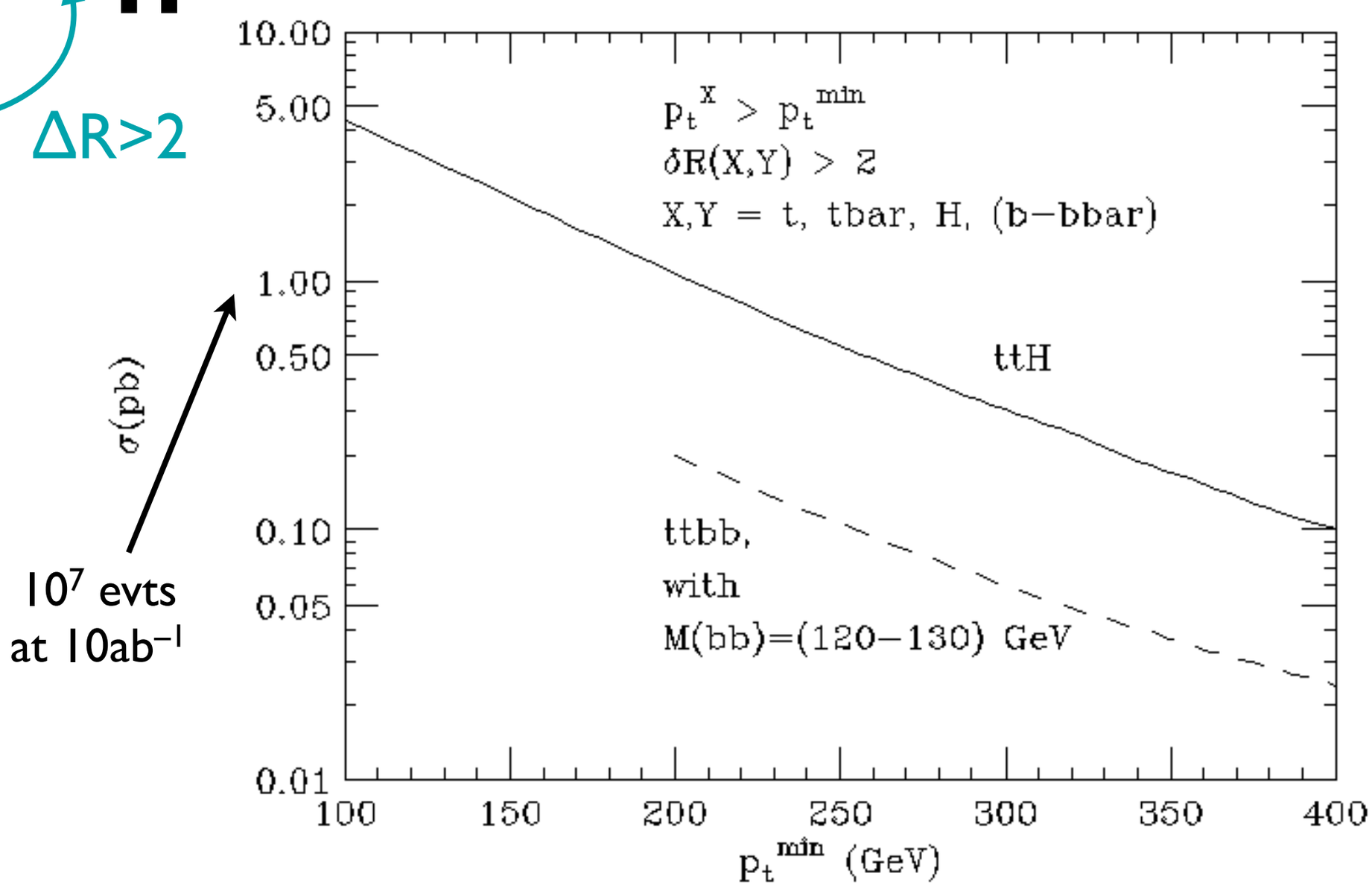
Baglio+Quevillon+Djouadi

Process	σ^{NNLO}[pb]	Scale[%]	PDF+α_s[%]	EFT[%]	Total [%]
$gg \to H$	788.6	$+7.1\ -6.1$	$+8.3\ -8.0$	± 5	$+20\ -19$
$qq' \to Hqq$	68.74	$+2.2\ -2.1$	$+3.1\ -3.2$	0	$+5.3\ -5.2$
$q\bar{q}' \to WH$	15.88	$+0.7\ -0.1$	$+5.0\ -4.7$	0	$+5.7\ -4.8$
$q\bar{q} \to ZH$	11.28	$+1.8\ -1.7$	$+4.5\ -4.3$	0	$+6.3\ -6.0$

Example, ttH at large pt

- S/B > 1
- 10 M evts at 10ab^{-1} w. ptmin=200 GeV, before further cuts





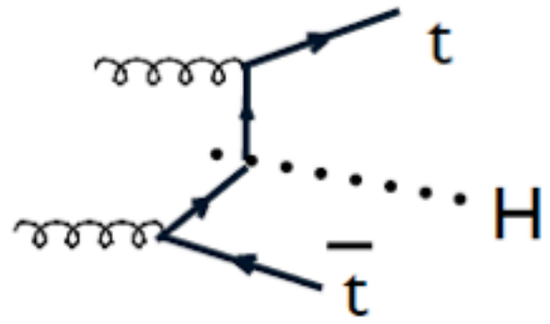
10^7 evts at 10ab^{-1}

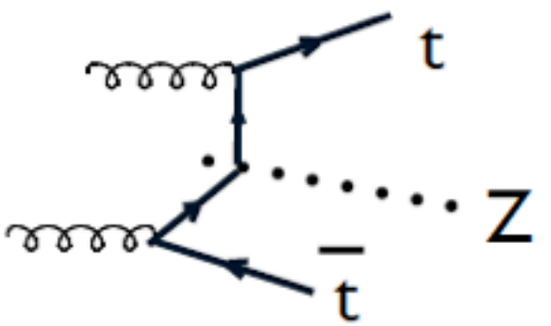
Measure ttH/ttZ

Hua-Sheng Shao, Michelangelo Mangano

To the extent that the qqbar → tt Z/H contributions are subdominant:

- **Identical production dynamics:**
  - **o correlated QCD corrections, correlated scale dependence**
  - **o correlated α_S systematics**
- **$m_Z \sim m_H \Rightarrow$ almost identical kinematic boundaries:**
  - **o correlated PDF systematics**
  - **o correlated m_{top} systematics**





For a given y_{top}, we expect σ(ttH)/σ(ttZ) to be predicted with great precision

Theoretical Uncertainties

MSTW2008NLO, $\mu_0 = H_T/2$, FCC100

	ttH (pb)	ttZ (pb)	ttH/ttZ
NLO QCD	33.9 $[^{+7.06\%}_{-8.29\%}]$Scale $[^{+0.941\%}_{-1.26\%}]$PDF	57.9 $[^{+8.93\%}_{-9.46\%}]$Scale $[^{+0.901\%}_{-1.20\%}]$PDF	0.585 $[^{+1.29\%}_{-2.02\%}]$Scale $[^{+0.0526\%}_{-0.0758\%}]$PDF

HH Production

- Measuring HH production at the LHC will be very difficult

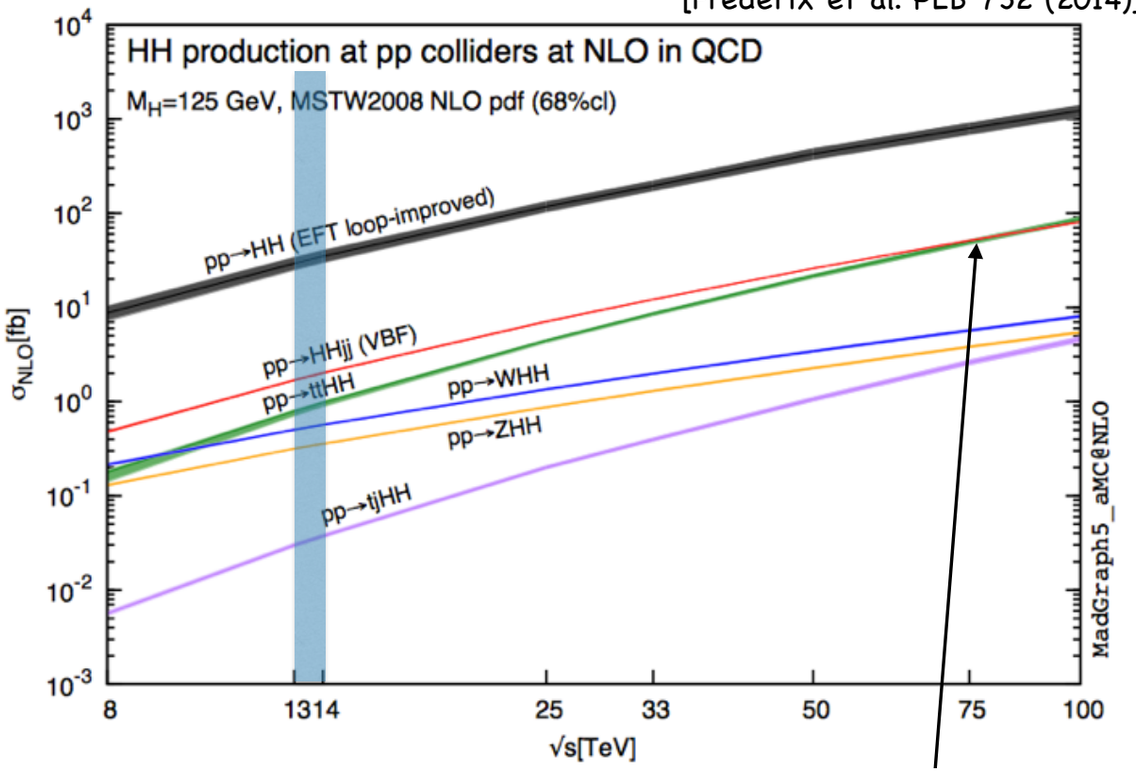
$b\bar{b}\gamma\gamma$:

Prospects for 14 TeV dire…

process	ATLAS		CMS
SM HH→bbγγ	8.4± 0.1		9.9
bbγγ	9.7 ± 1.5	γγ+jets	8.5
ccγγ, bbγj, bbjj, jjγγ	24.1 ± 2.2	γ+jets, jets	7.4
top background	3.4 ± 2.2		1.1
ttH(γγ)	6.1 ± 0.5		1.5
Z(bb)H(γγ)	2.7 ± 0.1		3.3
bbH(γγ)	1.2 ± 0.1		0.8
Total background	47.1 ± 3.5		22.6
S/√B (barrel+endcap)	1.2		
S/√B (split barrel and endcap)	1.3		

Michael Spannowsky

[Frederix et al. PLB 732 (2014)]



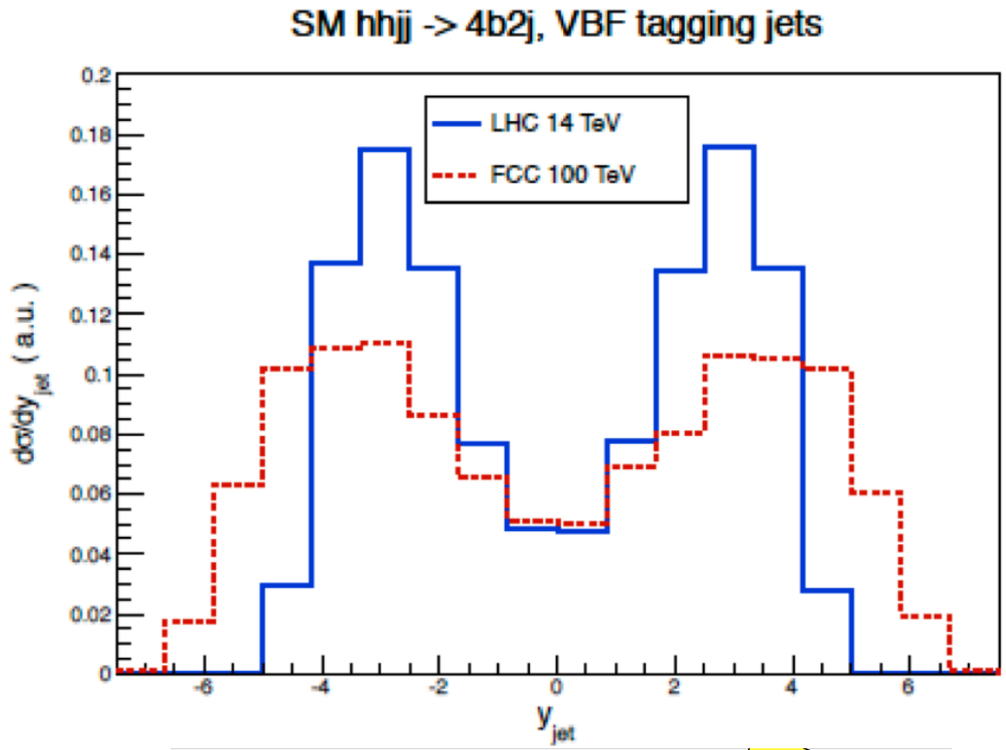
- The energy and luminosity of the FCC make it far more accessible
  - Even potentially non-traditional channels like bbμμ
- Also ttHH, VBF HH, etc.
- Clear benchmark for FCC-hh

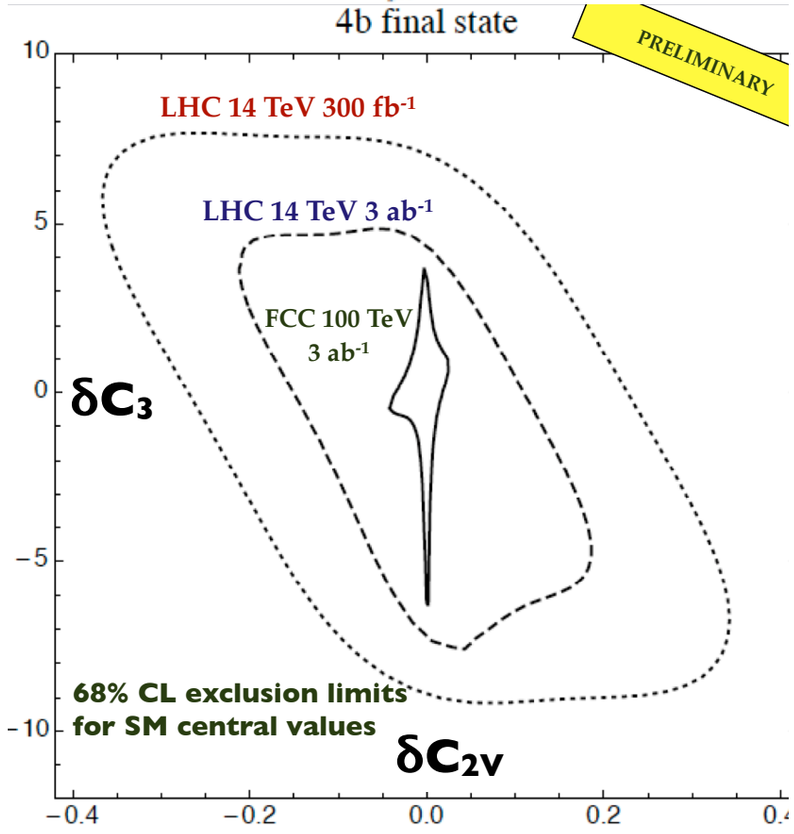
Decay channel	Branching ratio	Uncr. (±)
$b\bar{b}b\bar{b}$	$3.33 \cdot 10^{-01}$	$1.55 \cdot 10^{-02}$
$\tau\tau b\bar{b}$	$3.65 \cdot 10^{-02}$	$2.40 \cdot 10^{-03}$
$W^+(\to l\nu)W^-(\to l\nu)b\bar{b}$	$5.47 \cdot 10^{-03}$	$2.97 \cdot 10^{-04}$
$\tau\tau\tau\tau$	$3.99 \cdot 10^{-03}$	$3.22 \cdot 10^{-04}$
$\gamma\gamma b\bar{b}$	$1.32 \cdot 10^{-03}$	$7.88 \cdot 10^{-05}$
$W^+(\to l\nu)W^-(\to l\nu)\tau\tau$	$5.99 \cdot 10^{-04}$	$4.28 \cdot 10^{-05}$
$\gamma\gamma\tau\tau$	$1.44 \cdot 10^{-04}$	$1.09 \cdot 10^{-05}$
$b\bar{b}\mu^+\mu^-$	$1.26 \cdot 10^{-04}$	$8.65 \cdot 10^{-06}$
$W^+(\to l\nu)W^-(\to l\nu)W^+(\to l\nu)W^-(\to l\nu)$	$8.99 \cdot 10^{-05}$	$5.47 \cdot 10^{-06}$
$Z(\to l^+l^-)Z(\to l^+l^-)b\bar{b}$	$7.04 \cdot 10^{-05}$	$3.82 \cdot 10^{-06}$

Sergei Chekanov

VBF HH Production

- VBF production provides unique information on the HHVV coupling
  - Can be substantially enhanced in scenarios where EW symmetry breaking is broken by strong dynamics
- Need large η coverage
- FCC would provide powerful constraints on non-SM couplings





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Conclusion

- The **FCC-hh Higgs program** is an exciting playground for the future
- Currently exploring the **physics potential** of such a machine
- Next: determine a few selected **benchmark studies** to provide input into the machine and detector design
- The work so far has largely driven by theorists
  - Excellent opportunity for **experimentalists** to participate
    - Feel free to contact us with ideas !
- Not so often that we get to dream **what physics might be possible** and **how we might design a detector**
- Higgs and BSM @ 100 TeV workshop, CERN, March 11-13 2015
  - https://indico.cern.ch/event/352868/
- FCC week 2015, Washington DC, 23-27 March 2015
  - http://indico.cern.ch/event/340703/