

Some (Physics) Impressions from Granada - And Follow Ups

J. List (DESY)

ILC@DESY General Project Meeting, May 24 2019

Before Granada

- intense iterations of LCC Physics WG with
 - ECFA Higgs@FutureCollider WG (c.f. talk by Christophe in last project meeting)
 - BSM conveners / speakers on:
 - SUSY
 - Dark Matter
 - Strong resonances
 - Feebly interacting particles (FIPs)
 - Extended Higgs sectors
- most experimentalists shared their slides / material with us beforehand
 - theory talks came as “surprise”

Higgs & EW - Overview

Mon 13/5

15:00	Prospects for Higgs and EW measurements at HL-LHC (20'+10')	Patrizia Azzi	15:00 - 15:30
	García Lorca Room, Granada Conference Center		
	QCD uncertainties on Higgs and EWK measurables (20'+5')	Fabrizio Caola	15:30 - 15:55
	García Lorca Room, Granada Conference Center		
16:00	Theoretical Perspective on direct and indirect searches for new physics(30'+5')	Riccardo Rattazzi	15:55 - 16:30
	García Lorca Room, Granada Conference Center		
	Discussion		16:30 - 16:50
	García Lorca Room, Granada Conference Center		
	Coffee Break		16:50 - 17:20
17:00			
	Overview and technical challenges of proposed Higgs factories (20'+10')	Daniel Schulte	17:20 - 17:50
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18:00	Capability of future machines for precision Higgs physics (30'+5')	Maria Cepeda	17:50 - 18:25
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Tue 14/5

15:00	Electroweak Precision Measurements at future experiments (collider and non-collider) (20'+10')	Mark Lancaster	15:00 - 15:30
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	Precision Electroweak calculations (Giga-Z,WW, Higgs BRs, etc) (20'+10')	Stefan Dittmaier	15:30 - 16:00
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16:00	The Higgs potential and its cosmological histories (20'+10')	Geraldine Servant	16:00 - 16:30
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17:00	Path towards measuring the Higgs potential (25'+5')	Elisabeth Petit	17:00 - 17:30
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kappa fit only

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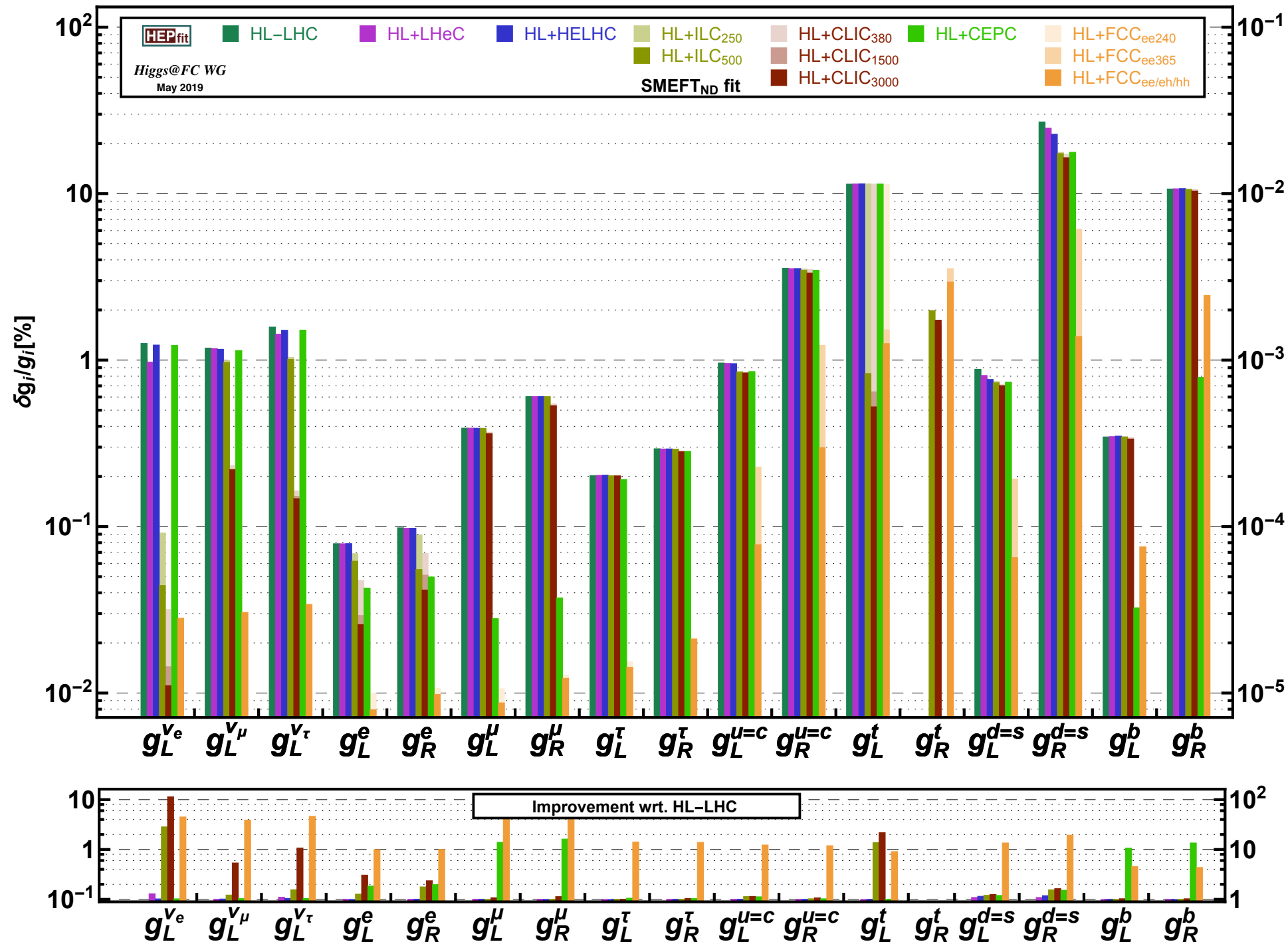
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EFT fit only

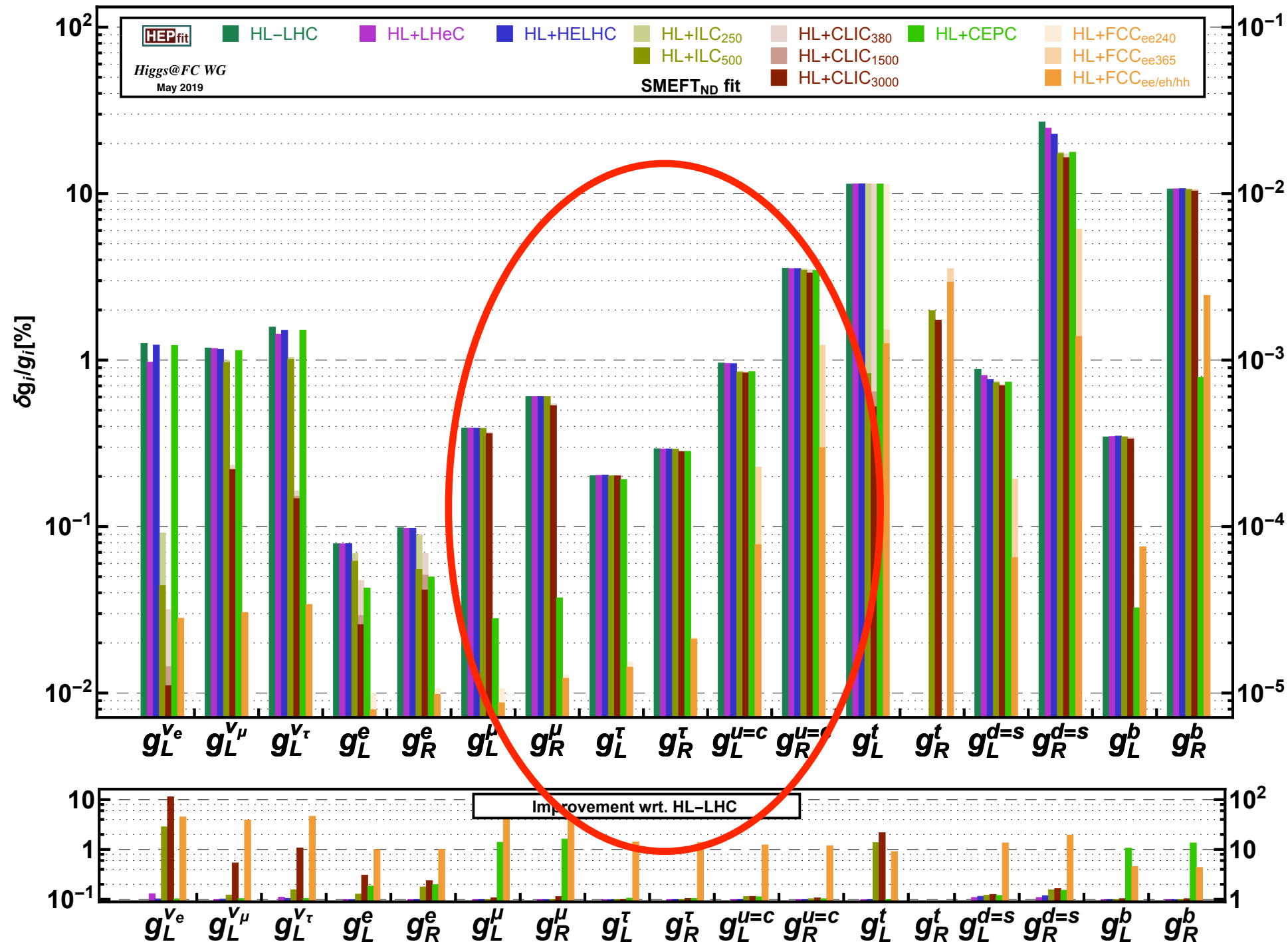
Higgs & EW - open issues

from arXiv:1905.03764



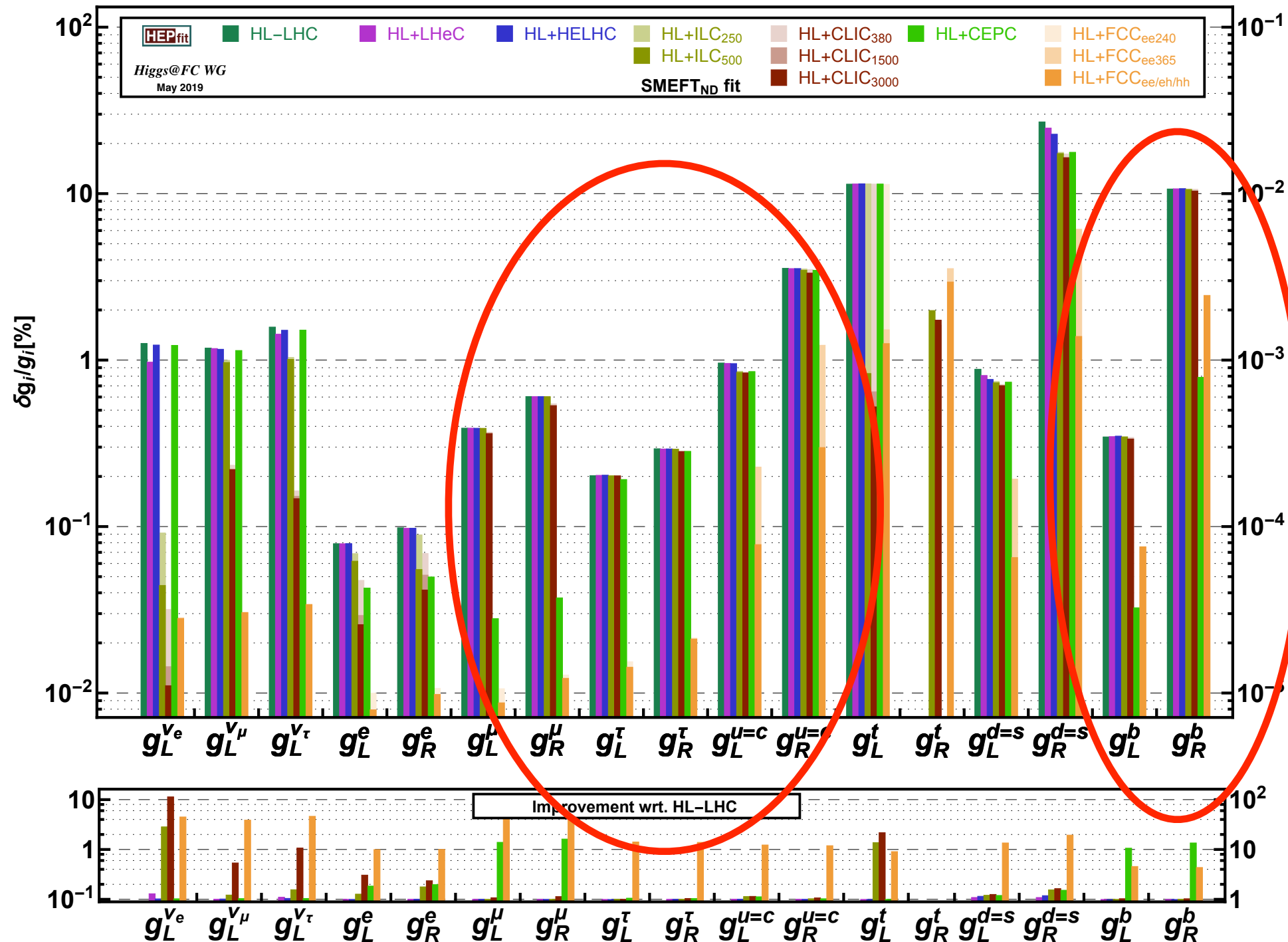
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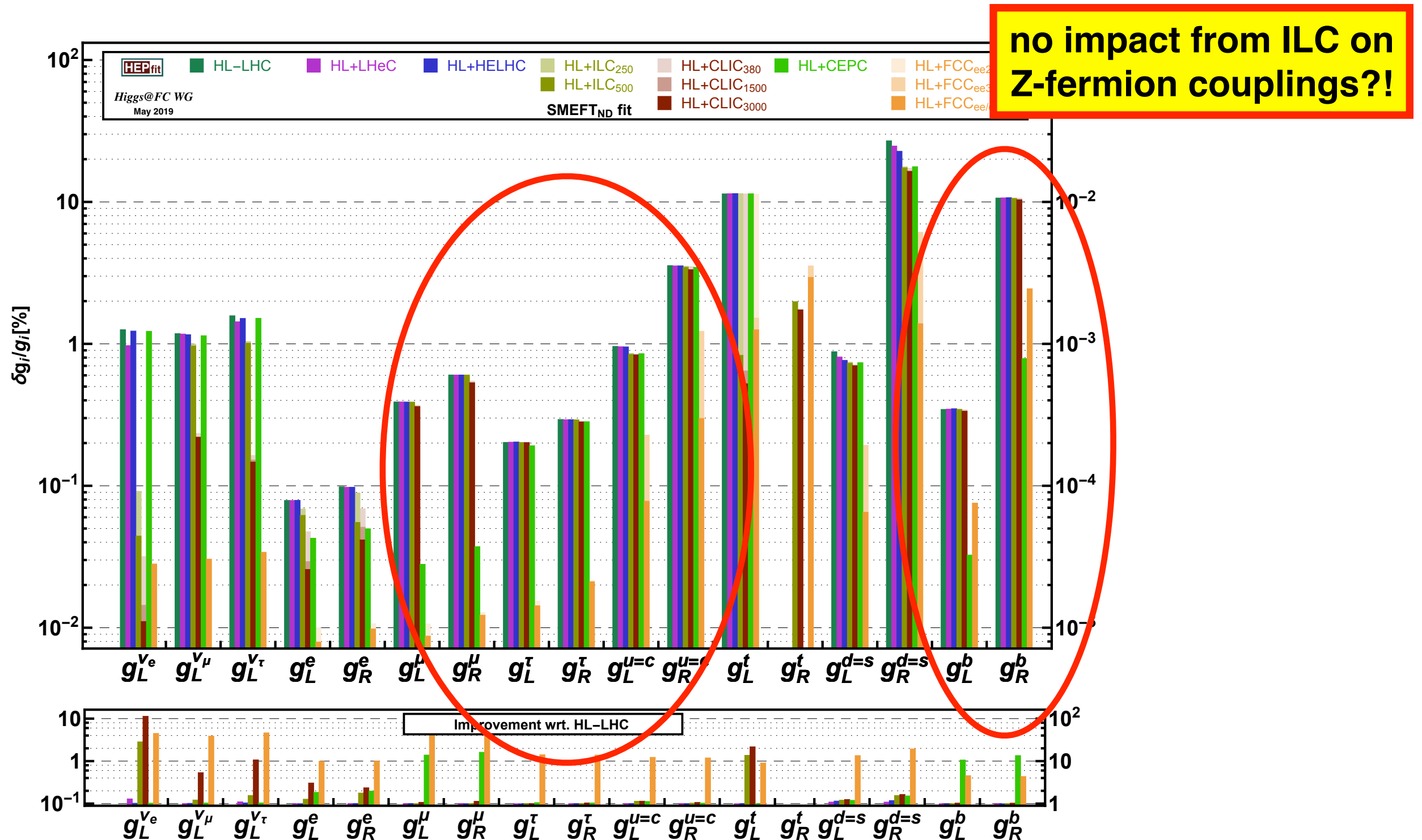
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Z-fermion couplings

- important for EFT Higgs coupling fit with *hadron collider* observables
- for e^+e^- , need in principle only Z-electron couplings
- only Z pole measurements from FCCee were included in fit, because required for FCChh
- for higher energies, only $ee \rightarrow tt$ was included - no other di-fermion processes
- our proposal:
 - include GigaZ
 - include $ee \rightarrow ff$ at higher energies:
 - minimum: Z pole couplings from radiative returns
 - better: include also off-pole measurements
=> excellent studies exist eg from Marcel Vos et al, fitting a much more complete set of operators etc

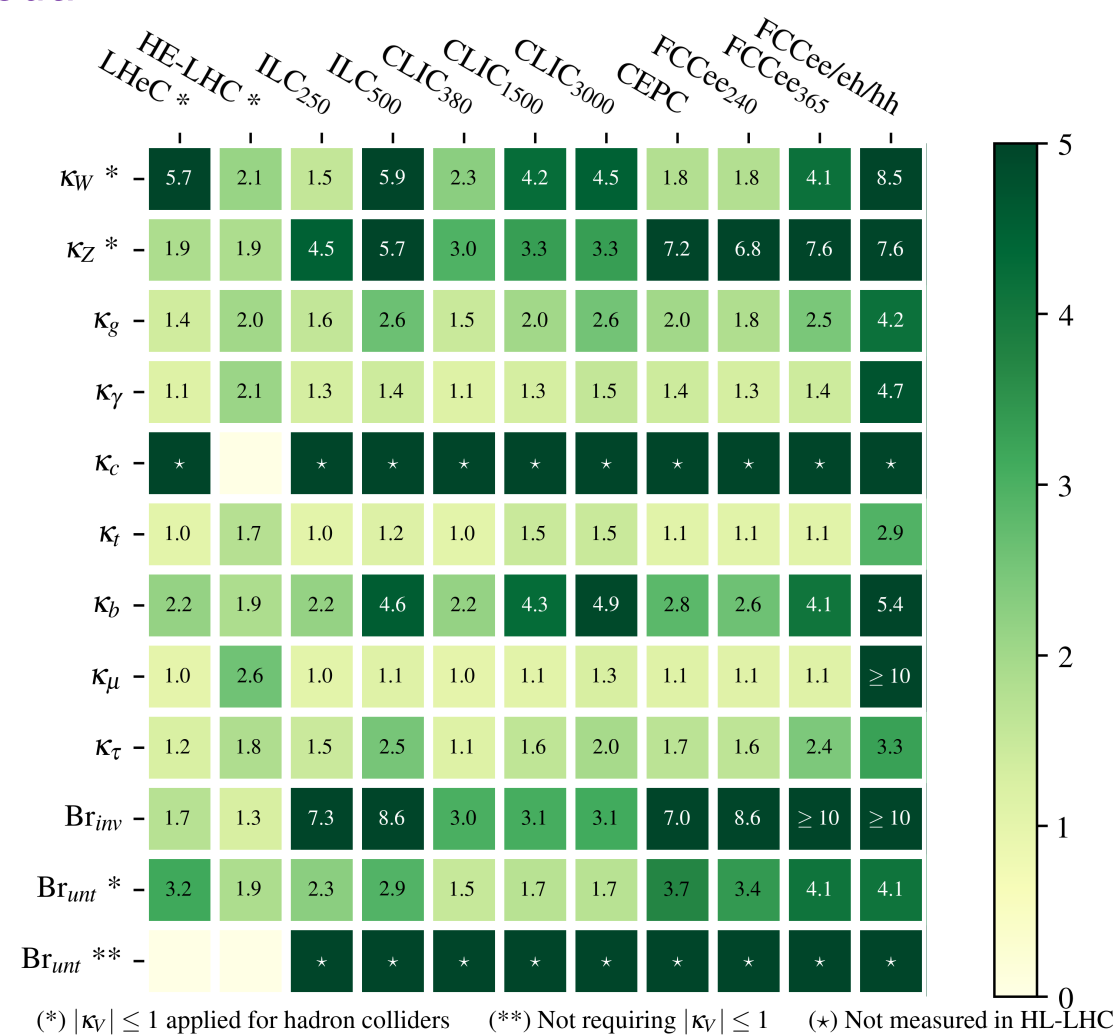
=> drafts collecting all information for the Higgs@FutureCollider WG /Preparatory group are being prepared within the next two weeks

Higgs summary plots (B.Heinemann)

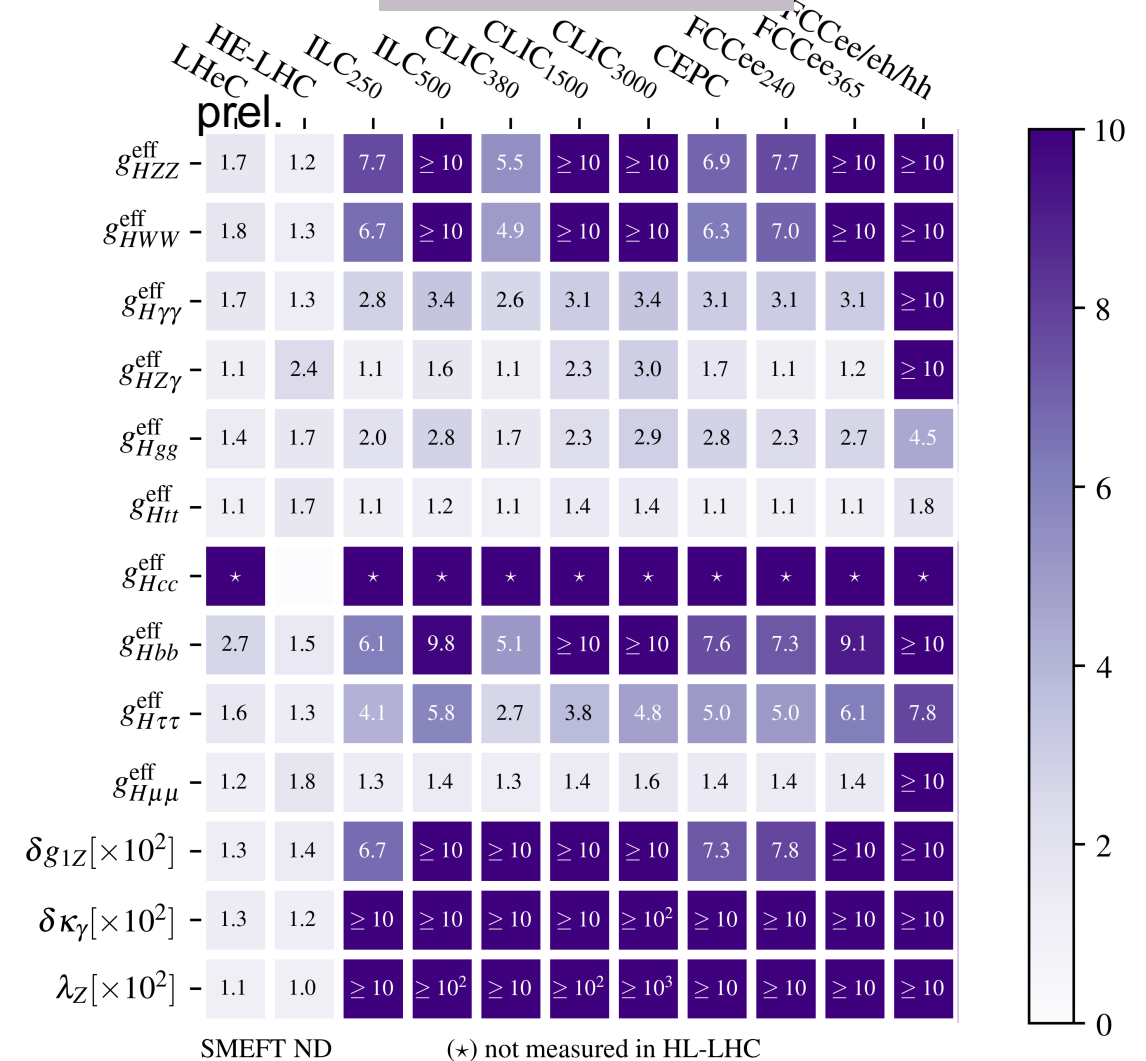
Improvements w.r.t. HL-LHC

M. Cepeda

Kappa-framework



EFT-framework



Higgs summary plots (B.Heinemann)

of “largely” improved H couplings (EFT)

	Factor ≥ 2	Factor ≥ 5	Factor ≥ 10	Years from T_0	
Initial run	CLIC380	9	6	4	7
	FCC-ee240	10	8	3	9
	CEPC	10	8	3	10
	ILC250	10	7	3	11
2 nd /3 rd Run ee	FCC-ee365	10	8	6	15
	CLIC1500	10	7	7	17
	HE-LHC	1	0	0	20
	ILC500	10	8	6	22
hh	CLIC3000	11	7	7	28
ee,eh & hh	FCC-ee/eh/hh	12	11	10	>50

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hh	CLIC3000	11	7	7	28
ee,eh & hh	FCC-ee/eh/hh	12	11	10	>50

we will ask them to add also ILC 1 TeV here!

BSM - Overview

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	García Lorca Room, Granada Conference Center		
	Discussion		09:30 - 09:40
	García Lorca Room, Granada Conference Center		
	EWSB dynamics and resonances: Implications for theory	Andrea Wulzer	09:40 - 10:10
10:00	García Lorca Room, Granada Conference Center		
	Discussion		10:10 - 10:20
	García Lorca Room, Granada Conference Center		
	Supersymmetry: what we can expect from experiments	Monica D'Onofrio	10:20 - 10:50
	García Lorca Room, Granada Conference Center		
	Discussion		10:50 - 11:00
	García Lorca Room, Granada Conference Center		
11:00	Coffee break		11:00 - 11:30
	García Lorca Room, Granada Conference Center		
	Supersymmetry: Implications for theory	Andreas Weller	11:30 - 12:00
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12:00	Discussion		12:00 - 12:10
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	Extended Higgs sectors and High-energy flavor dynamics: what we can expect from experiments	Philipp Roloff	12:10 - 12:40
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	Discussion		12:40 - 12:50
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Wed 15/5

09:00	Feebly interacting particles: theory landscape	Gilad Perez	09:00 - 09:30
	García Lorca Room, Granada Conference Center		
	Discussion		09:30 - 09:40
	García Lorca Room, Granada Conference Center		
	Feebly interacting particles: what we can expect from experiments	Gaia Lanfranchi	09:40 - 10:10
10:00	García Lorca Room, Granada Conference Center		
	Discussion		10:10 - 10:20
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	García Lorca Room, Granada Conference Center		11:30 - 12:10
12:00	Summary of BSM session	Gian Giudice et al.	
	García Lorca Room, Granada Conference Center		12:10 - 12:40
	Discussion on BSM session and its summary	Gian Giudice et al.	
13:00	García Lorca Room, Granada Conference Center		12:40 - 13:30

BSM - strong ESWB / resonances

- benchmark chosen such that strengths of LCs like eg top / bottom ew couplings does not play a role:

- Y-universal Z' :

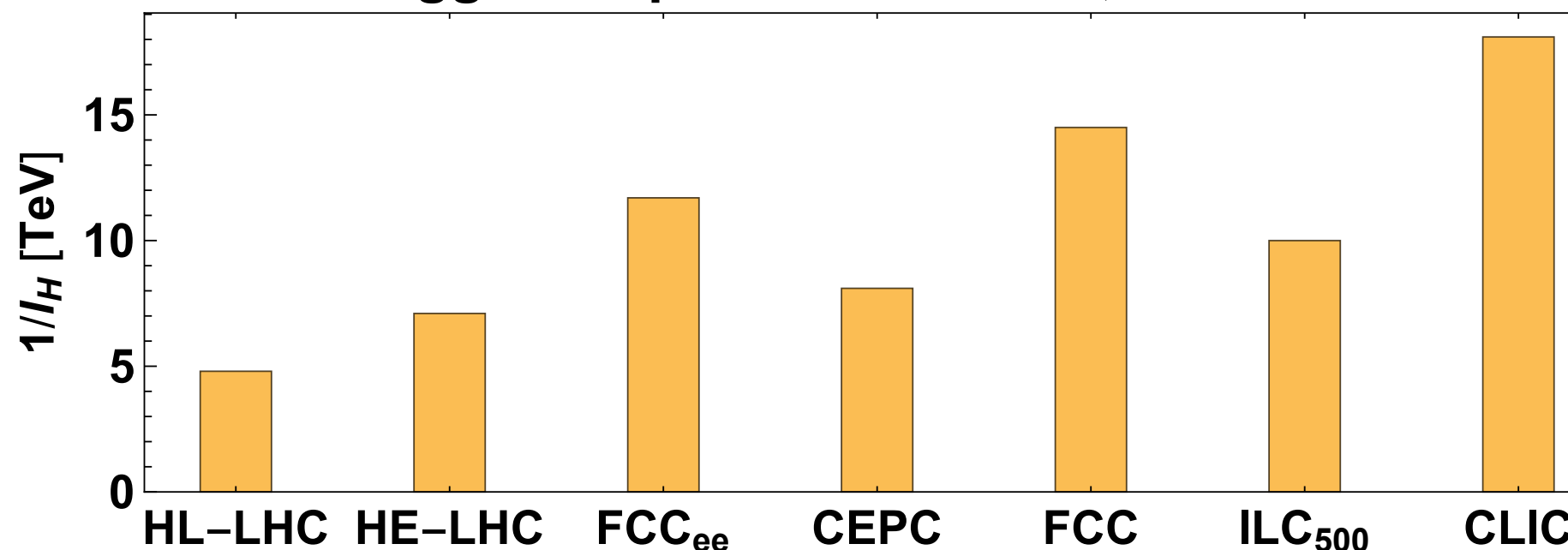
New Gauge Force:

CLIC is the only lepton collider that competes with hadron ones

- composite Higgs:

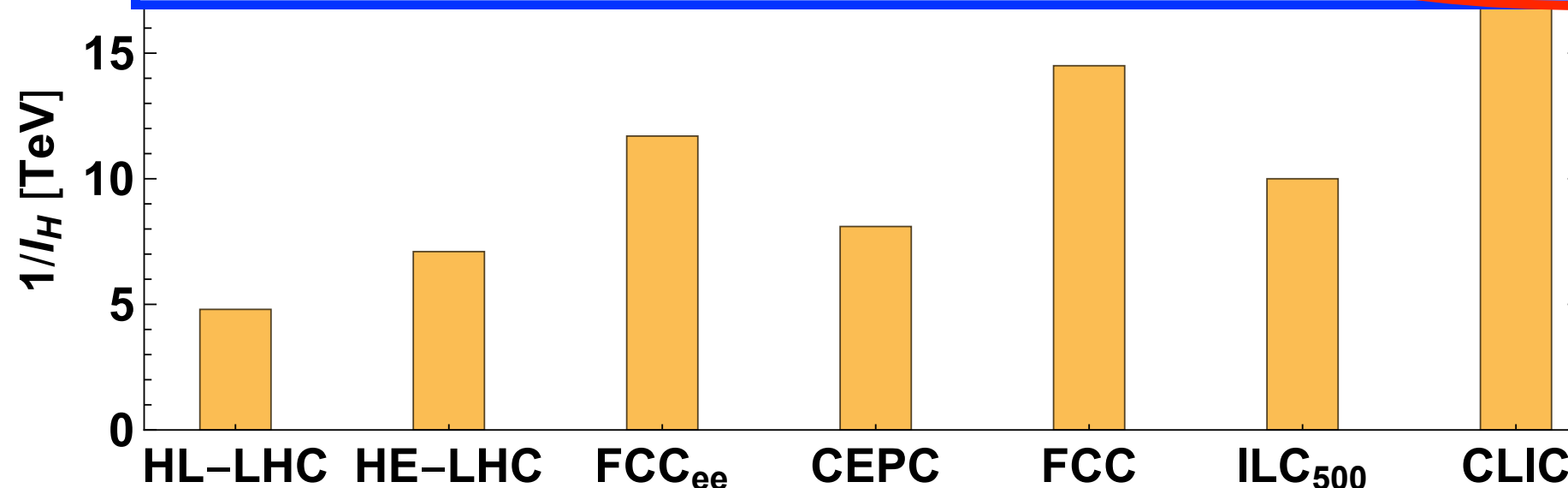
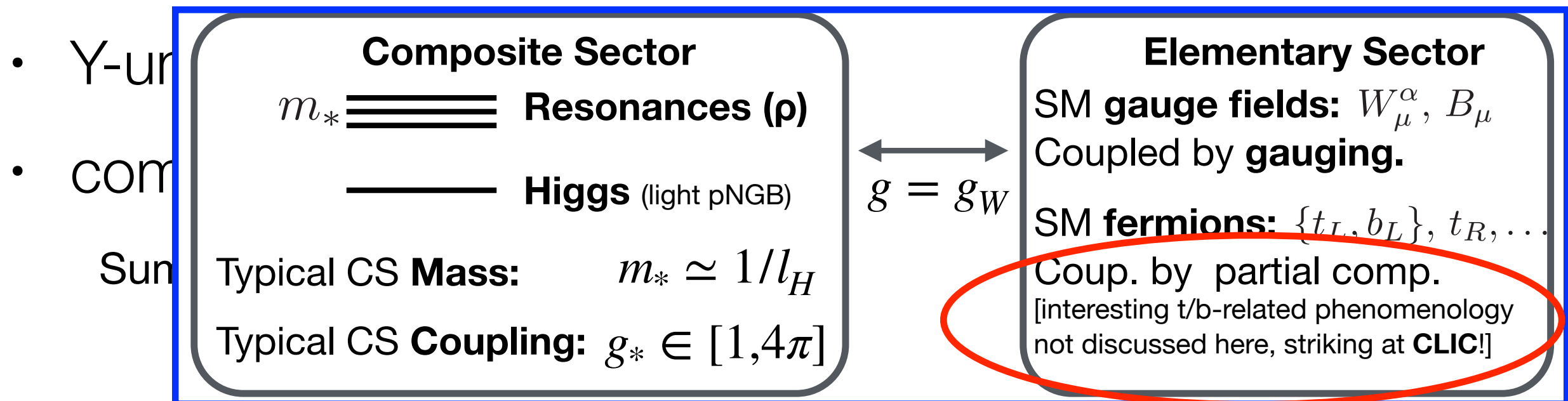
Summary: Reach on Higgs size

Higgs compositeness scale, 2σ reach



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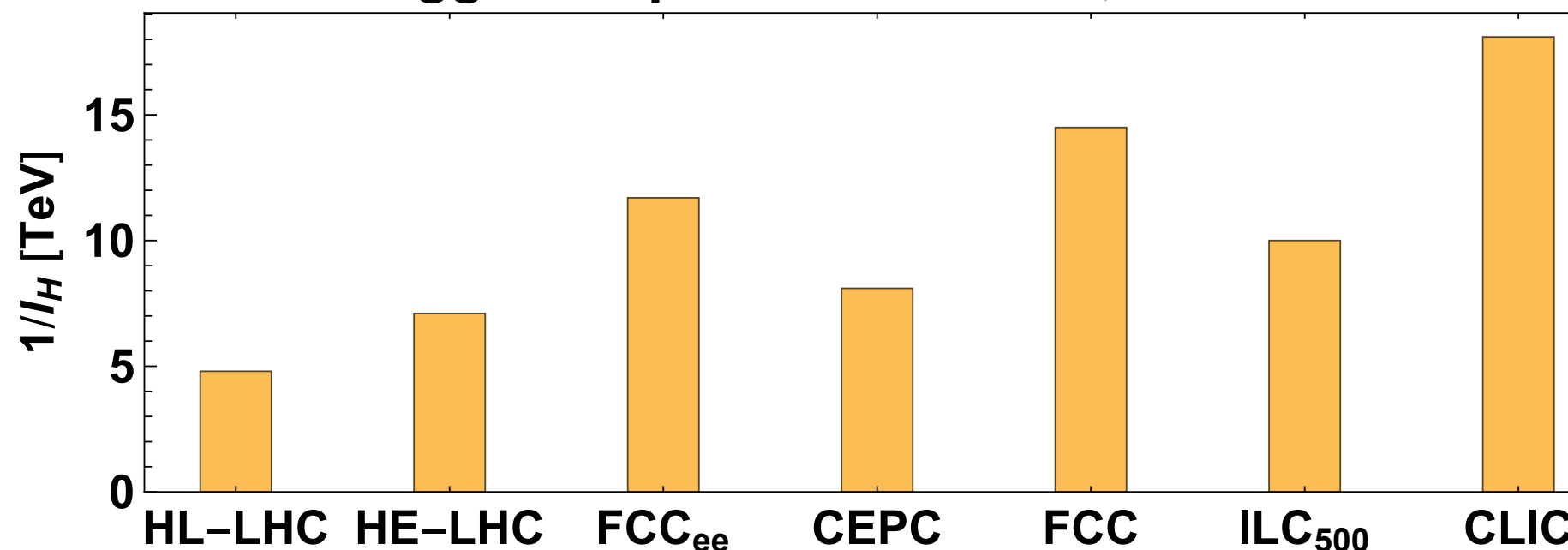
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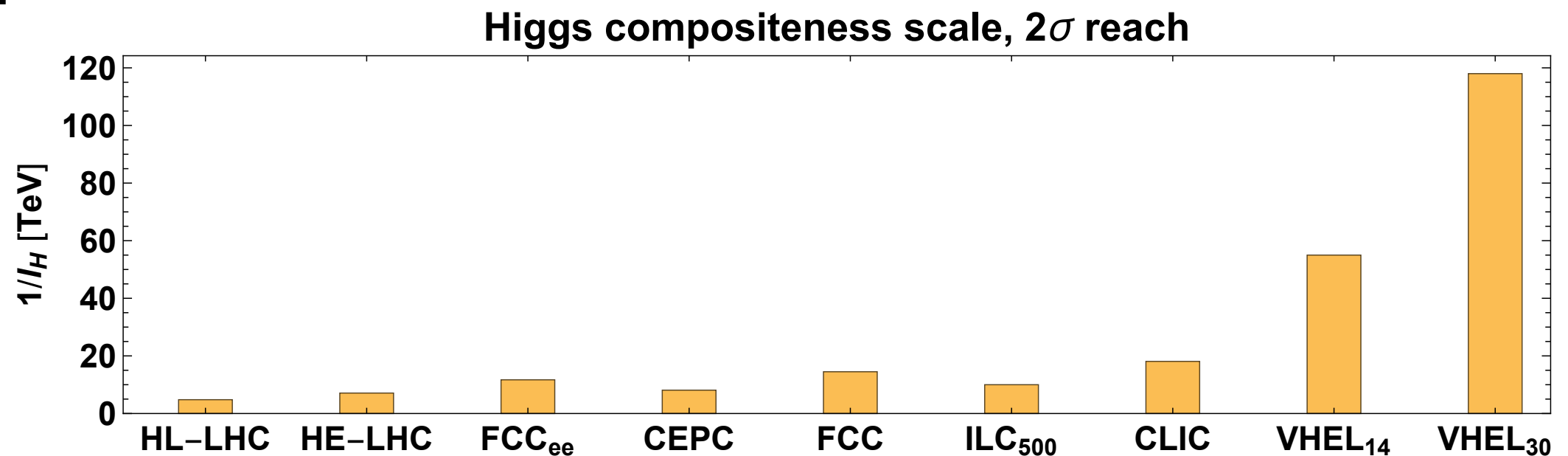
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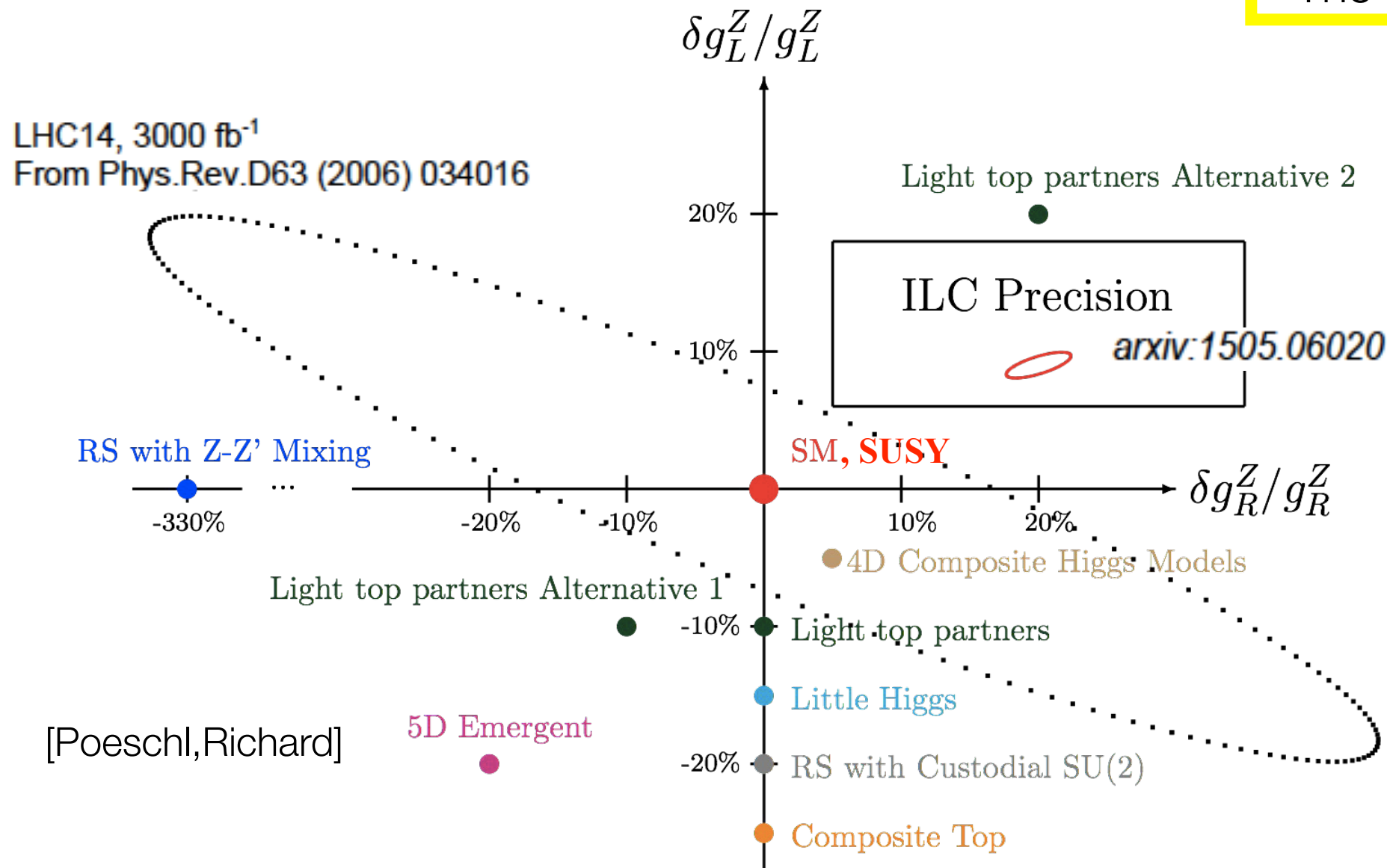
Compositeness Reach:



Top EW Couplings at 500 GeV



The Top Quark



Sensitivity to huge variety of models with **compositeness and/or extra-dimensions** complementary to resonance searches

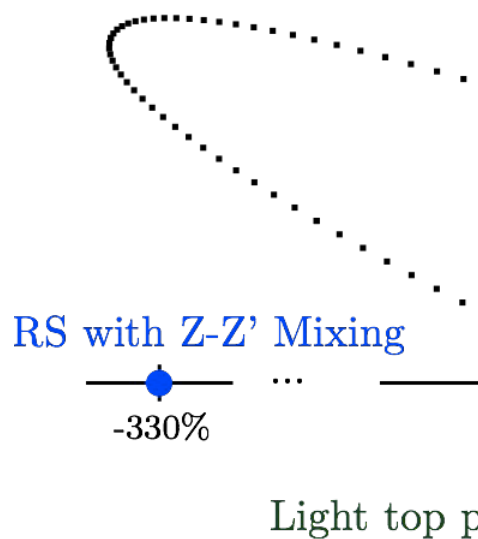
- ILC precision allows model discrimination
- sensitivity in g_L^Z, g_R^Z plane complementary to LHC
- **Can probe new physics scales of ~20 TeV in typical scenarios**
(... and up to 80 TeV for extreme scenarios)

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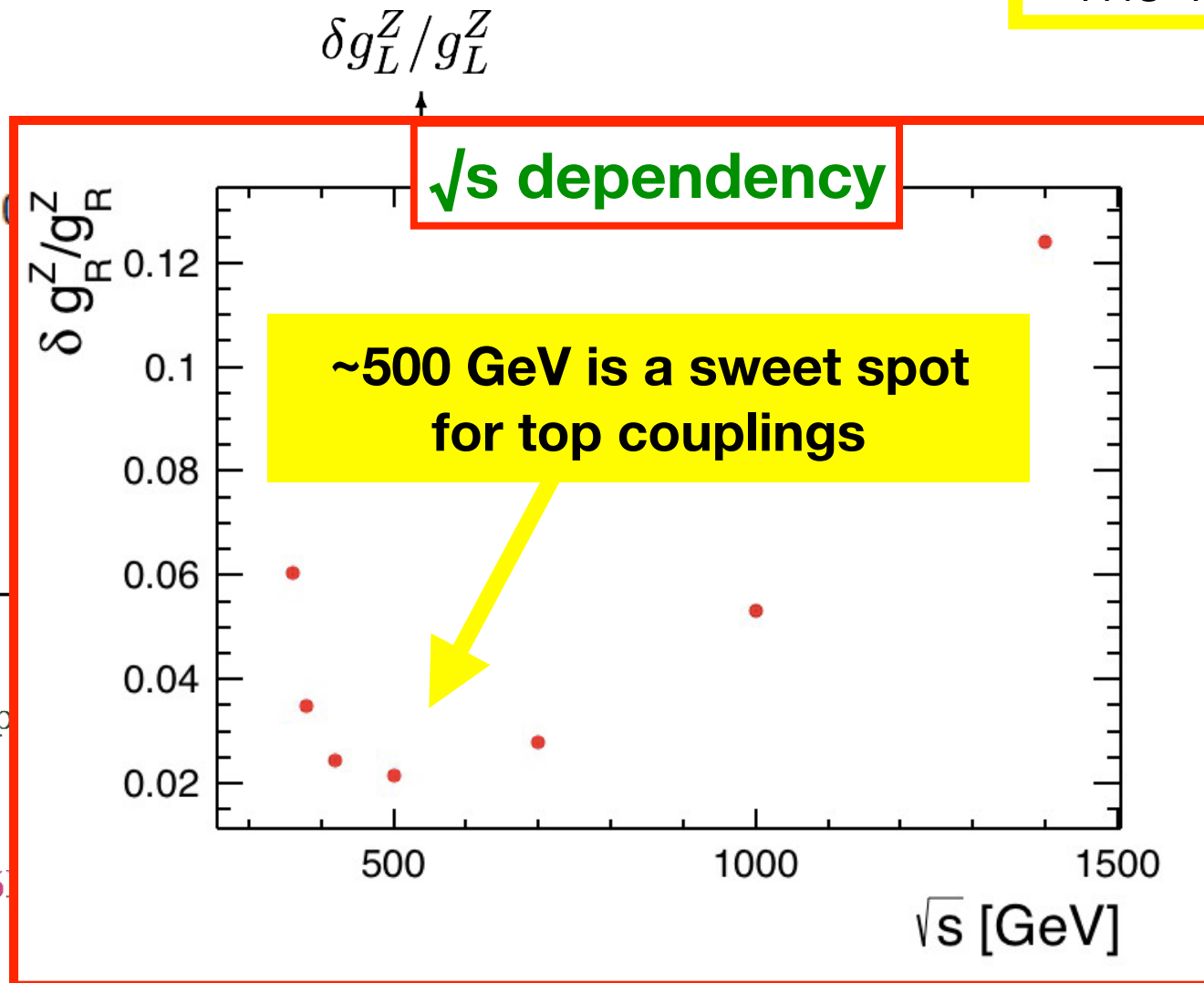


The Top Quark

LHC14, 3000 fb⁻¹
From Phys.Rev.D63 (2006)



[Poeschl, Richard]



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- **Can probe new physics scales of ~20 TeV in typical scenarios** (... and up to 80 TeV for extreme scenarios)

BSM - SUSY

- no relevant indirect reach eg from Higgs precision observables?! (A.Weiler)
- conclusion based solely on reach for stops ?

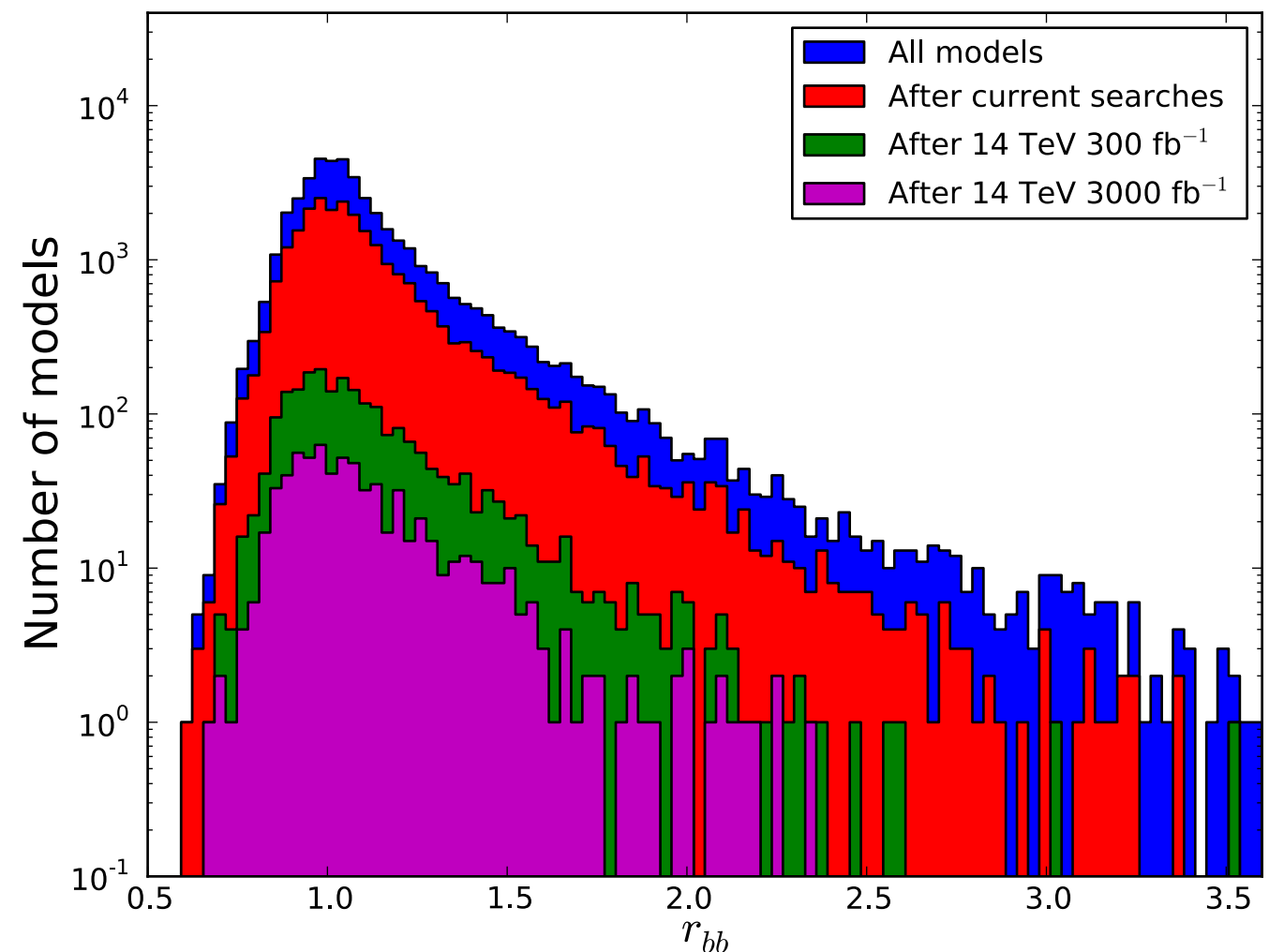


A closer look at SUSY: pMSSM scan

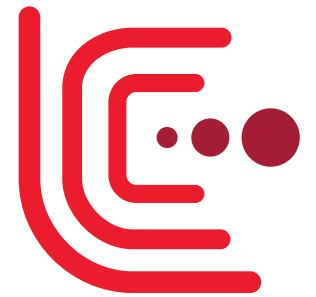
- scan over 250 000 pMSSM points

Phys. Rev. D 90, 095017 (2014)

- check against direct searches
- even after HL-LHC projections for direct searches, many models with sizeable coupling deviations remain!
- **EFT fit ILC 250 GeV:**
 $\delta g(hbb) = 1.7\%$
- EFT fit ILC H20:
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$$r_X = \frac{\Gamma(h \rightarrow X)}{SM}$$



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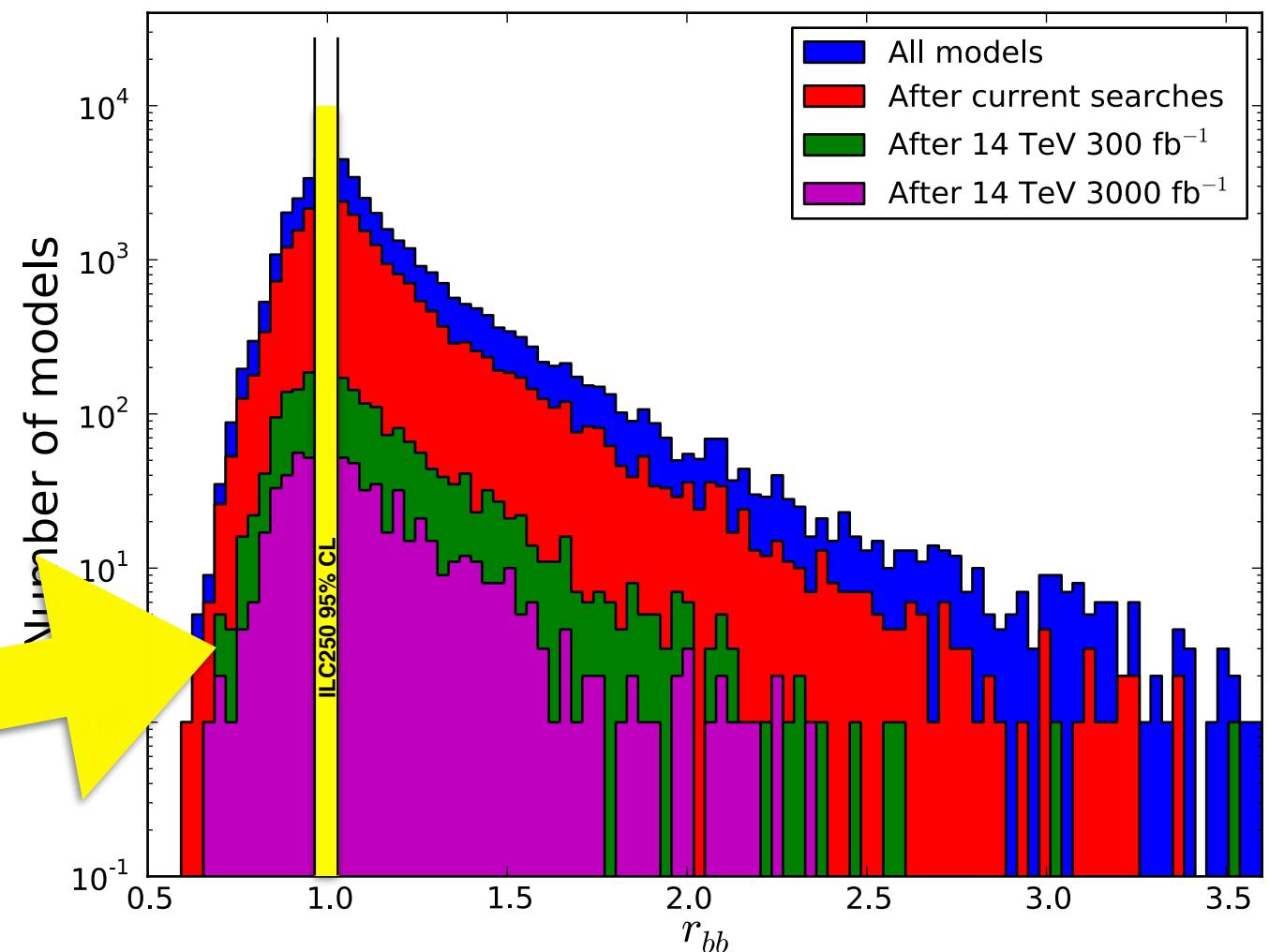
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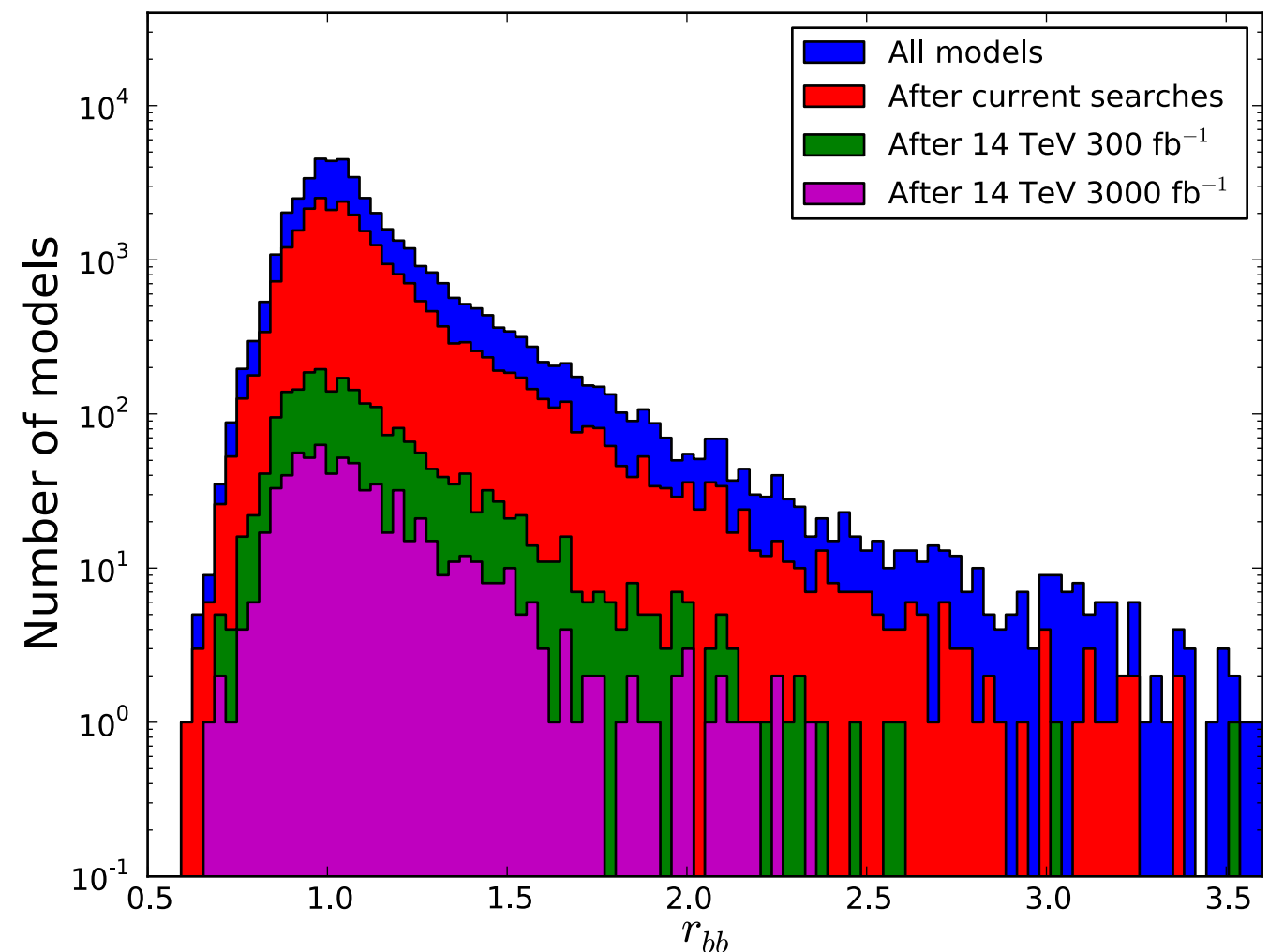


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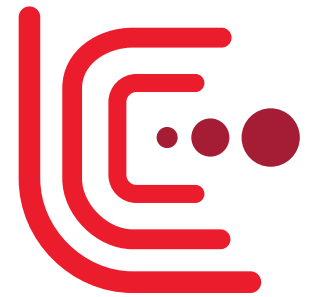
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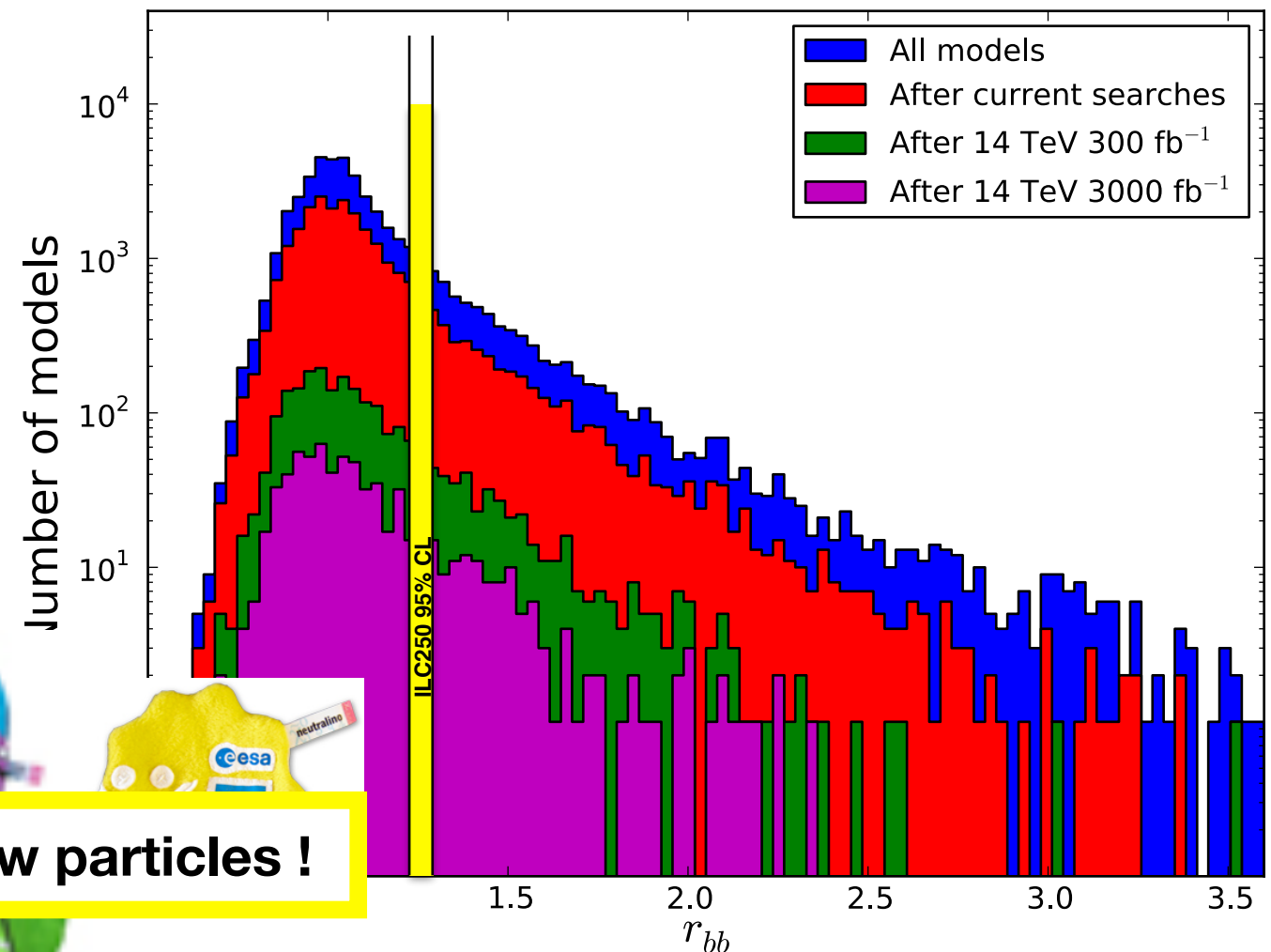
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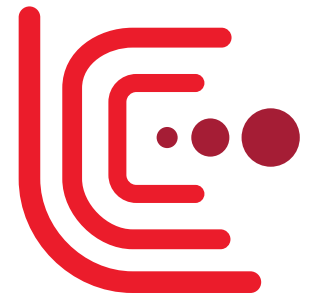
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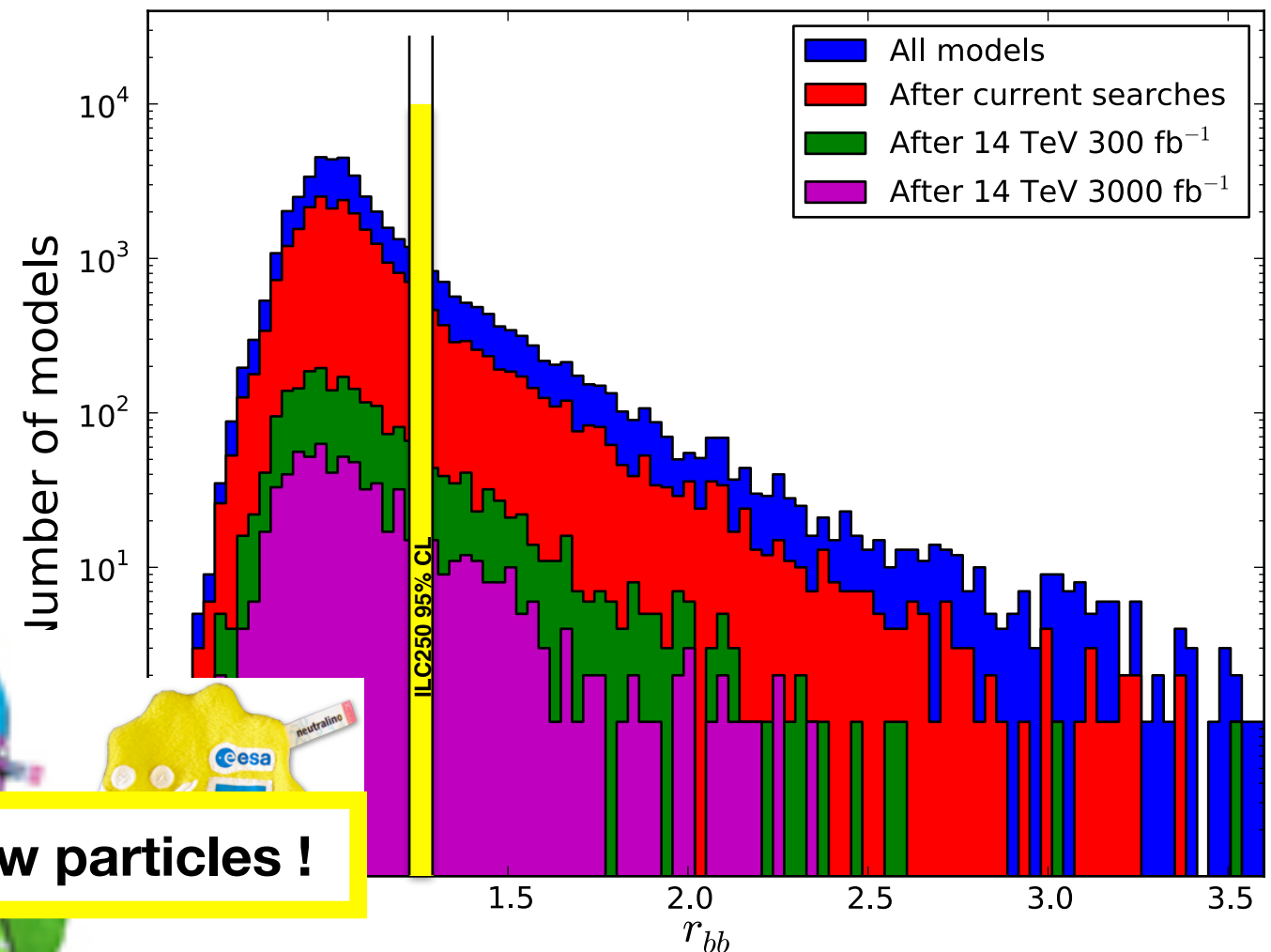
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Discovery of new particles !

- EFT fit ILC H20:
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again clear added value
and complementarity w.r.t.
HL-LHC



$$r_X = \frac{\Gamma(h \rightarrow X)}{SM}$$

New Physics Interpretation of Higgs & EW

**Test various example BSM points -
all chosen such that
no hint for new physics at HL-LHC**

Model	$b\bar{b}$	$c\bar{c}$	gg	WW	$\tau\tau$	ZZ	$\gamma\gamma$	$\mu\mu$
1 MSSM [36]	+4.8	-0.8	-0.8	-0.2	+0.4	-0.5	+0.1	+0.3
2 Type II 2HD [35]	+10.1	-0.2	-0.2	0.0	+9.8	0.0	+0.1	+9.8
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9 Higgs Singlet [41]	-3.5	-3.5	-3.5	-3.5	-3.5	-3.5	-3.5	-3.5

Table 3: Percent deviations from SM for Higgs boson couplings to SM states in various new physics models. These model points are unlikely to be discoverable at 14 TeV LHC through new particle searches even after the high luminosity era (3 ab^{-1} of integrated luminosity). From [15].

arXiv:1708.08912



Discoveries of new particles ?

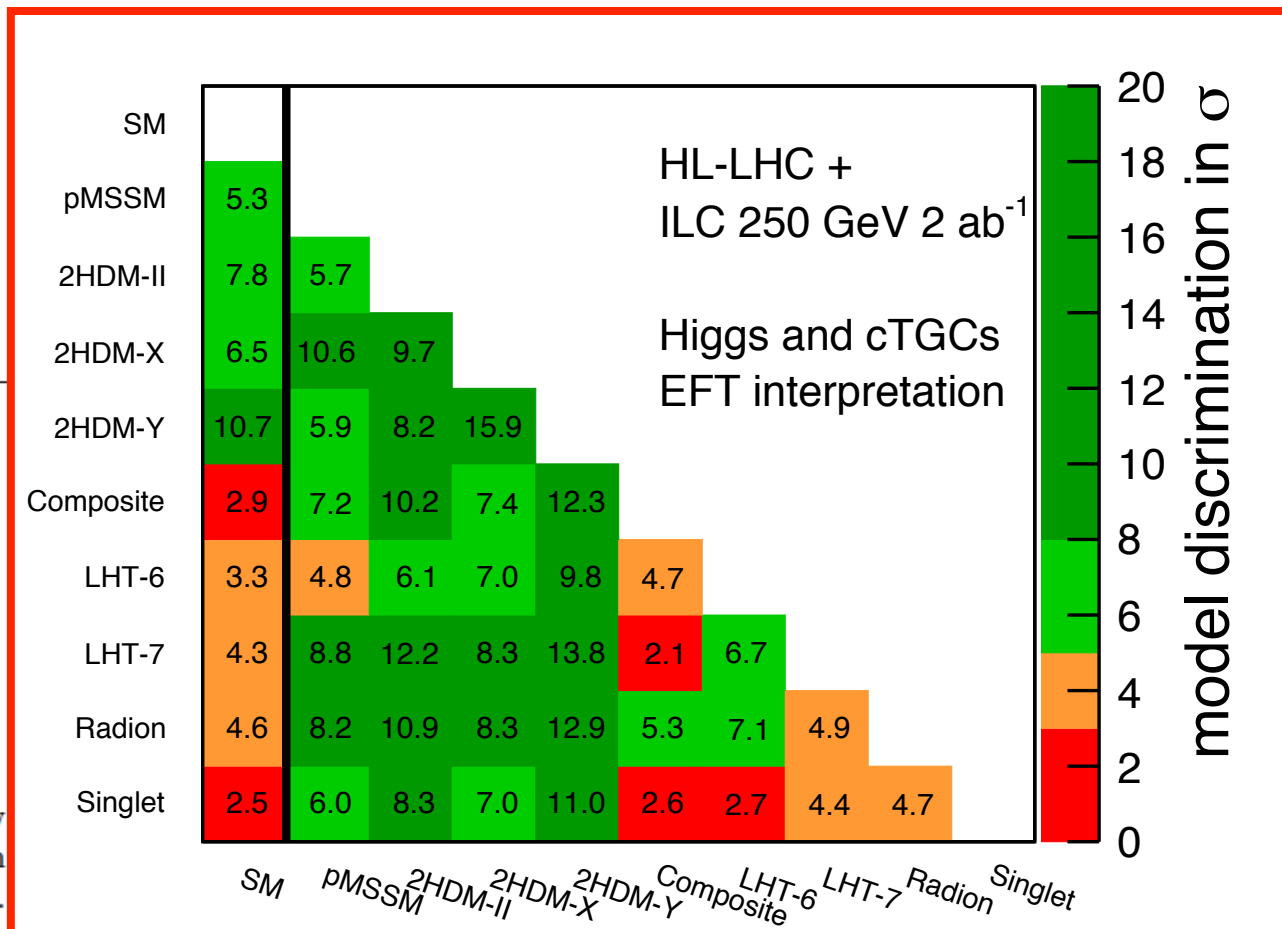
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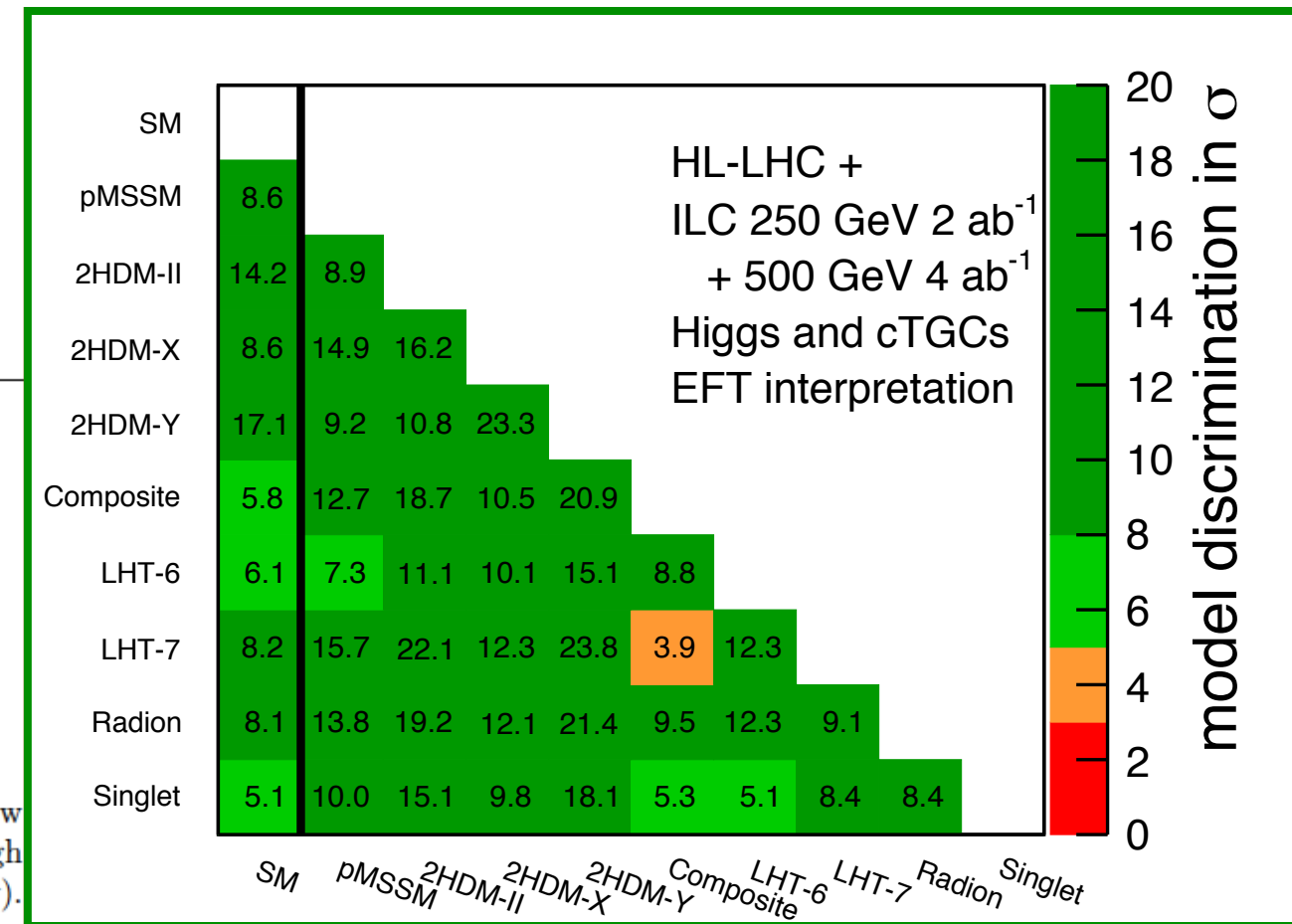
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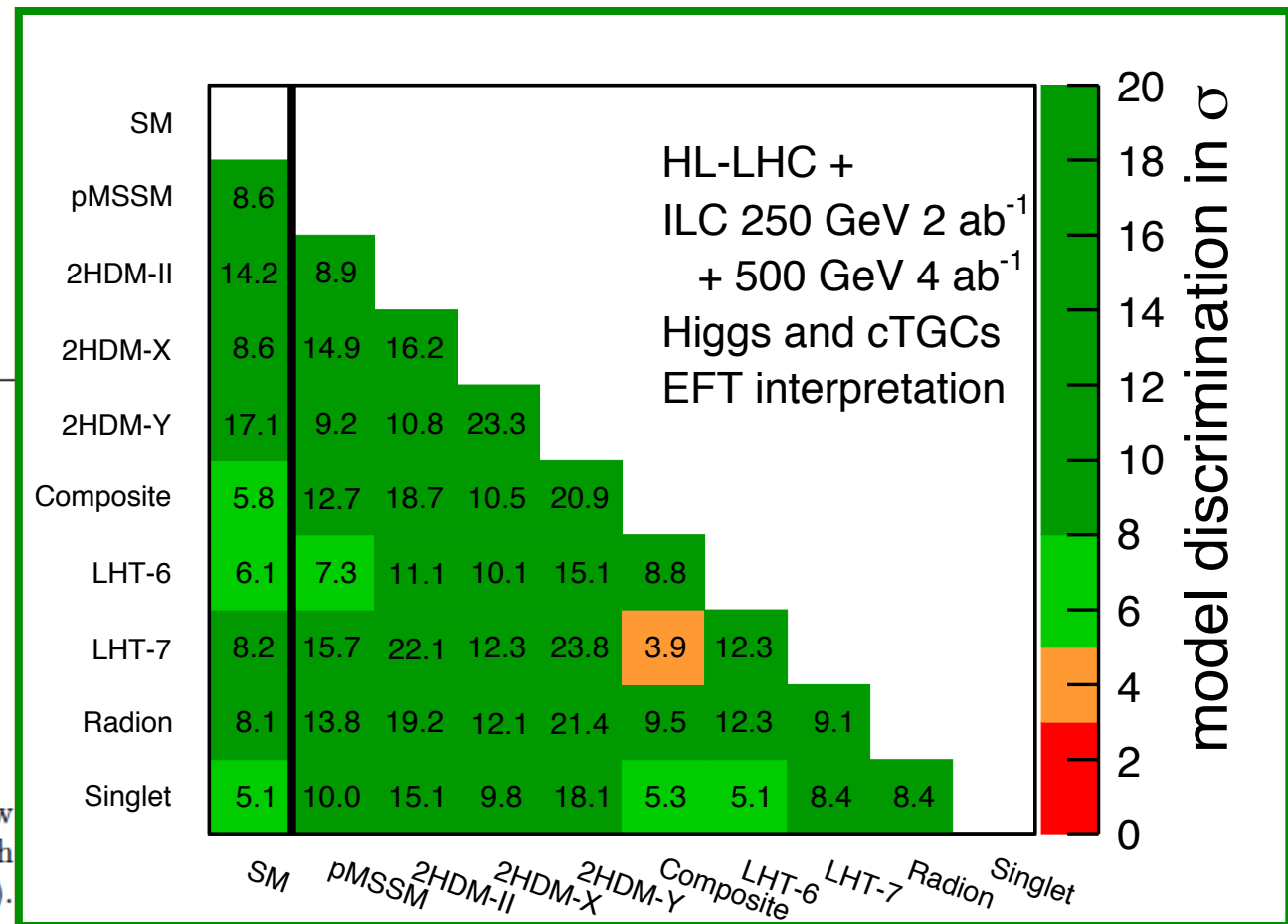
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**illustrates the ILC's
discovery and identification potential
- complementary to (HL-)LHC!**



BSM - my personal remarks

- whole perspective complete focussed on *exclusion* limits
- no discussion of discovery reach
(apart from side remark in exp SUSY talk by Monica Onofrio)
- no discussion of characterisation of eventual signals
- no discussion of impact of discoveries / confirmed anomalies
(flavour, $g-2$ -mu, direct detection, ...) on strategy
- happily discussing >50 year timelines - but not considering that we could *find* something?!

=> does this give a convincing case for huge particle physics projects compared to other dynamic fields of science?

Conclusions

- meeting went rather well for ILC:
 - constructive discussions with preparatory group & conveners
 - an e^+e^- “Higgs factory” was recognized as the next priority
 - 10-20 year gap for changing FCCee into FCChh is seen critically
 - the idea of e^+e^- in Asian + hadrons in Europe was ventilated by several influential people (Karl Jakobs, Geoff Taylor, ...)
- in particular our Japanese colleagues left with very positive impressions !
- still, there are several physics issues to clarify
- even if at the end politicians & funding agencies decide, a correct and fair representation of the ILC’s physics capabilities in the briefing book is essential
- the LCC Physics WG continues to put all their effort into achieving this!