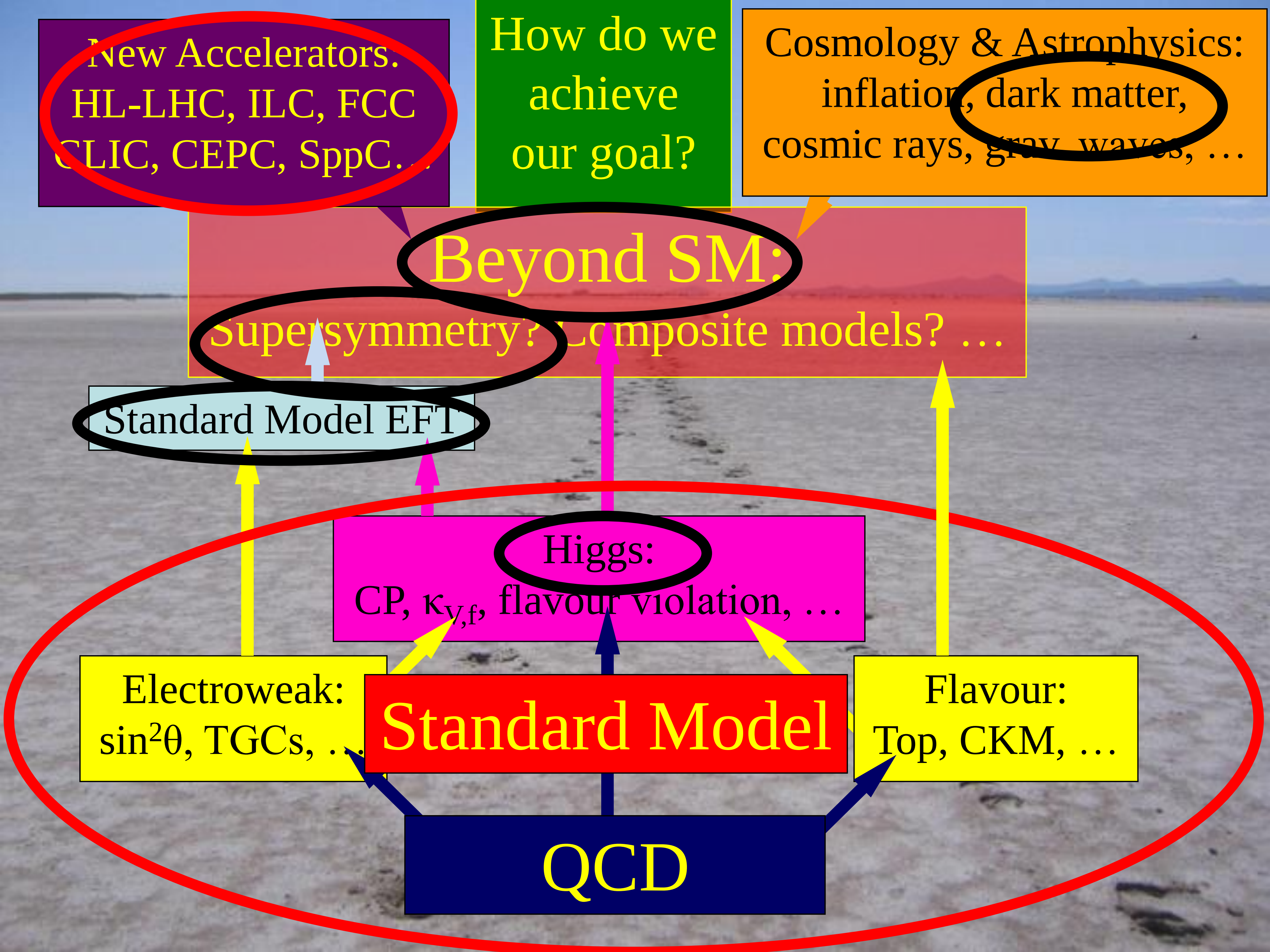
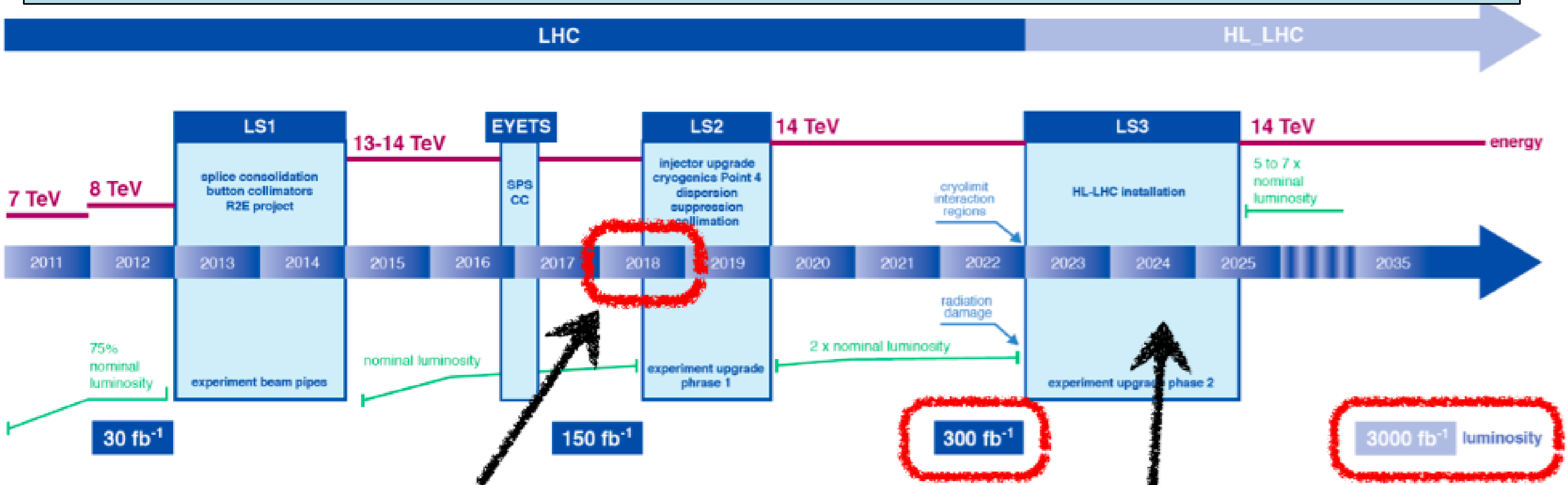

New Accelerators:
HL-LHC, ILC, FCC
CLIC, CEPC, SppC…
How do we achieve our goal?
Cosmology & Astrophysics:
inflation, dark matter,
cosmic rays, grav. waves, …
Beyond SM:
Supersymmetry? Composite models? …
Standard Model EFT
Higgs:
CP, $\kappa_{V,f}$, flavour violation, …
Electroweak:
$\sin^2\theta$, TGCs, …
Standard Model
Flavour:
Top, CKM, …
QCD

HL-LHC Plans



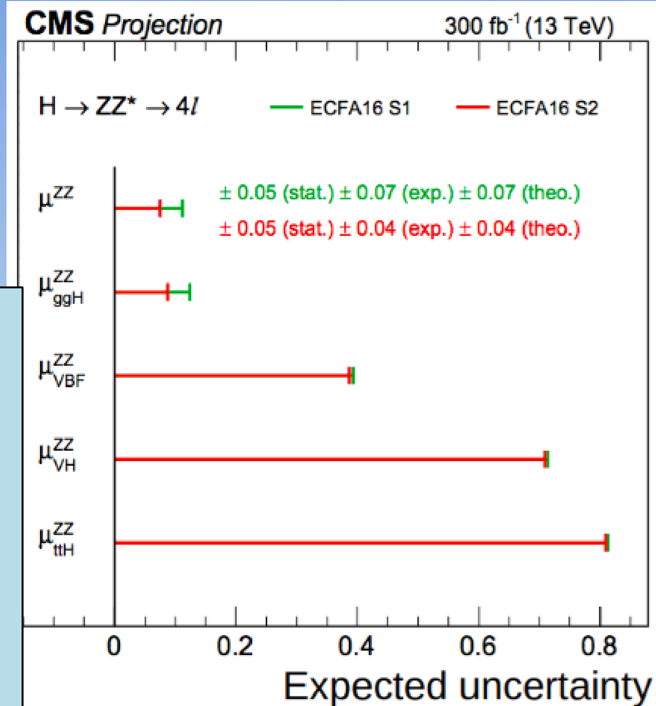
Now (√s=13 TeV), ‹μ›~38 (2017 data-taking)

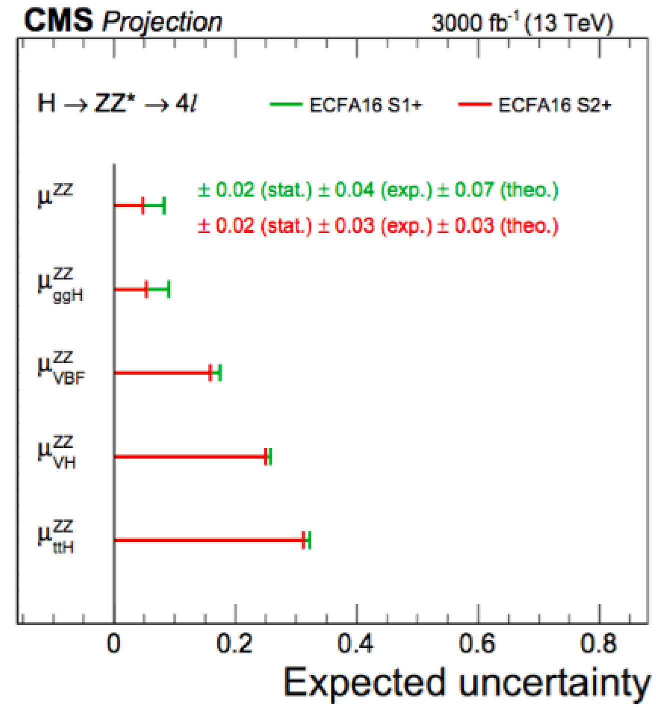
Phase-II Atlas and CMS Upgrade

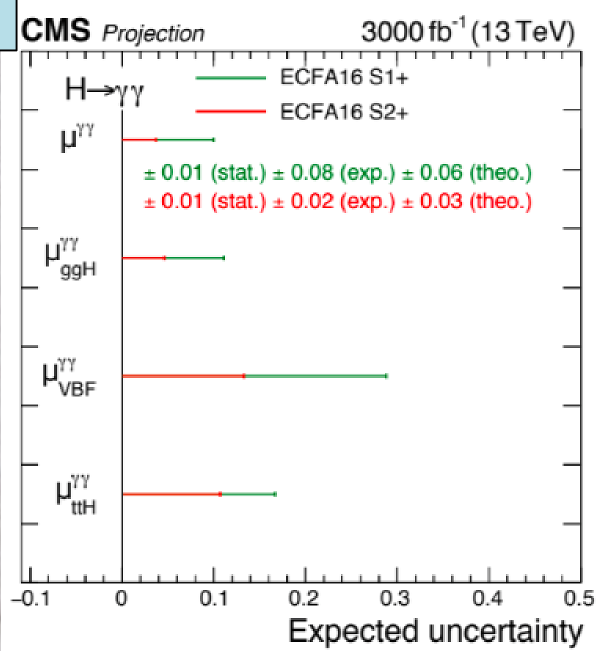
	Peak luminosity ($cm^{-2}\ s^{-1}$)	μ (pile-up)
Current	$1.3 \cdot 10^{34}$	~40
HL-LHC baseline	$5 \cdot 10^{34}$	140
HL-LHC ultimate	$7.5 \cdot 10^{34}$	200

- Increased instantaneous luminosity and mean number of interactions per bunch-crossing (pile-up)
- Integrated luminosity collected during HL-LHC ~ 3000 fb^{-1}
- Precision measurements on the Higgs sector (couplings, self-couplings, VBF production), rare-decays

H → ZZ*, γγ @HL-LHC

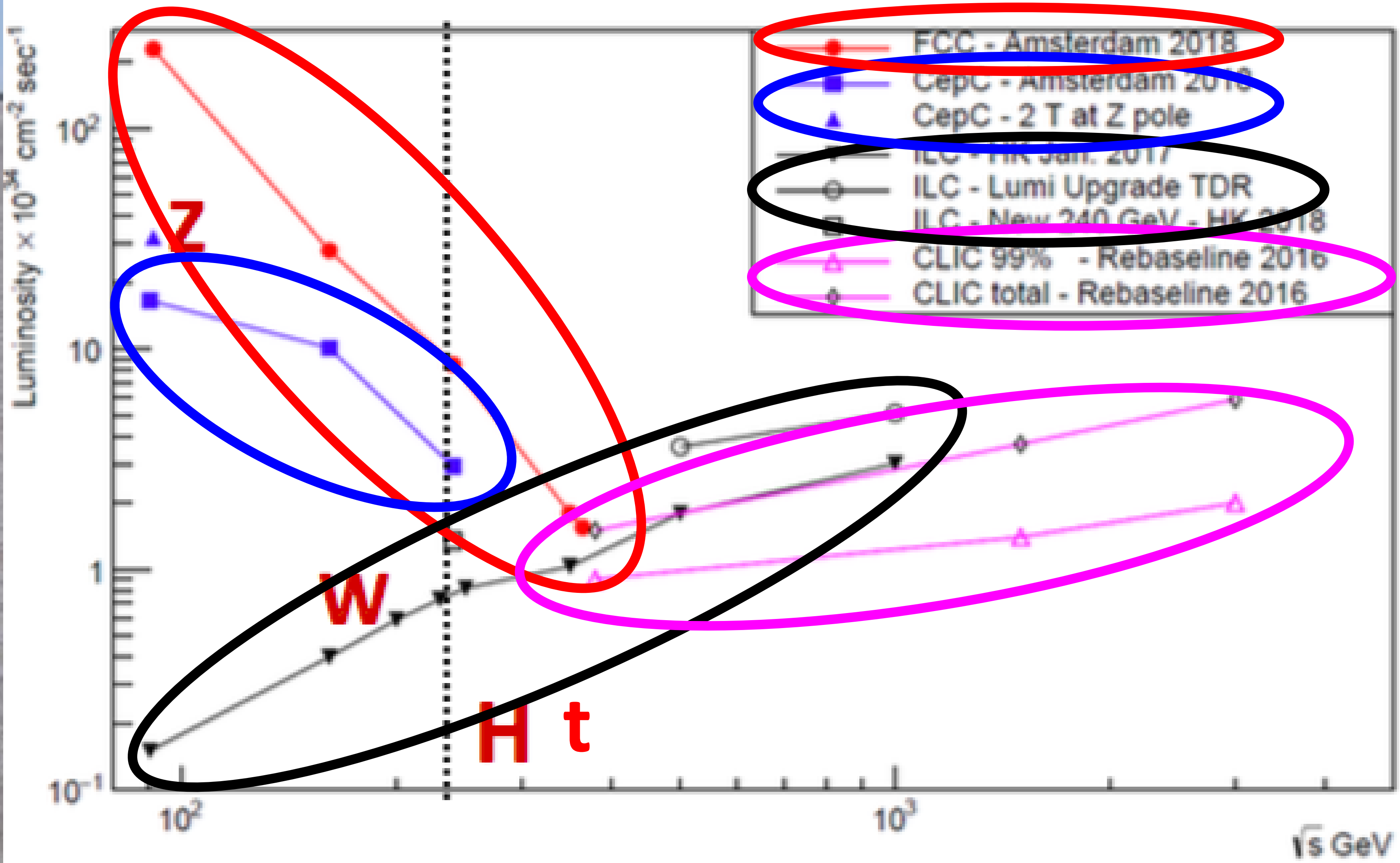




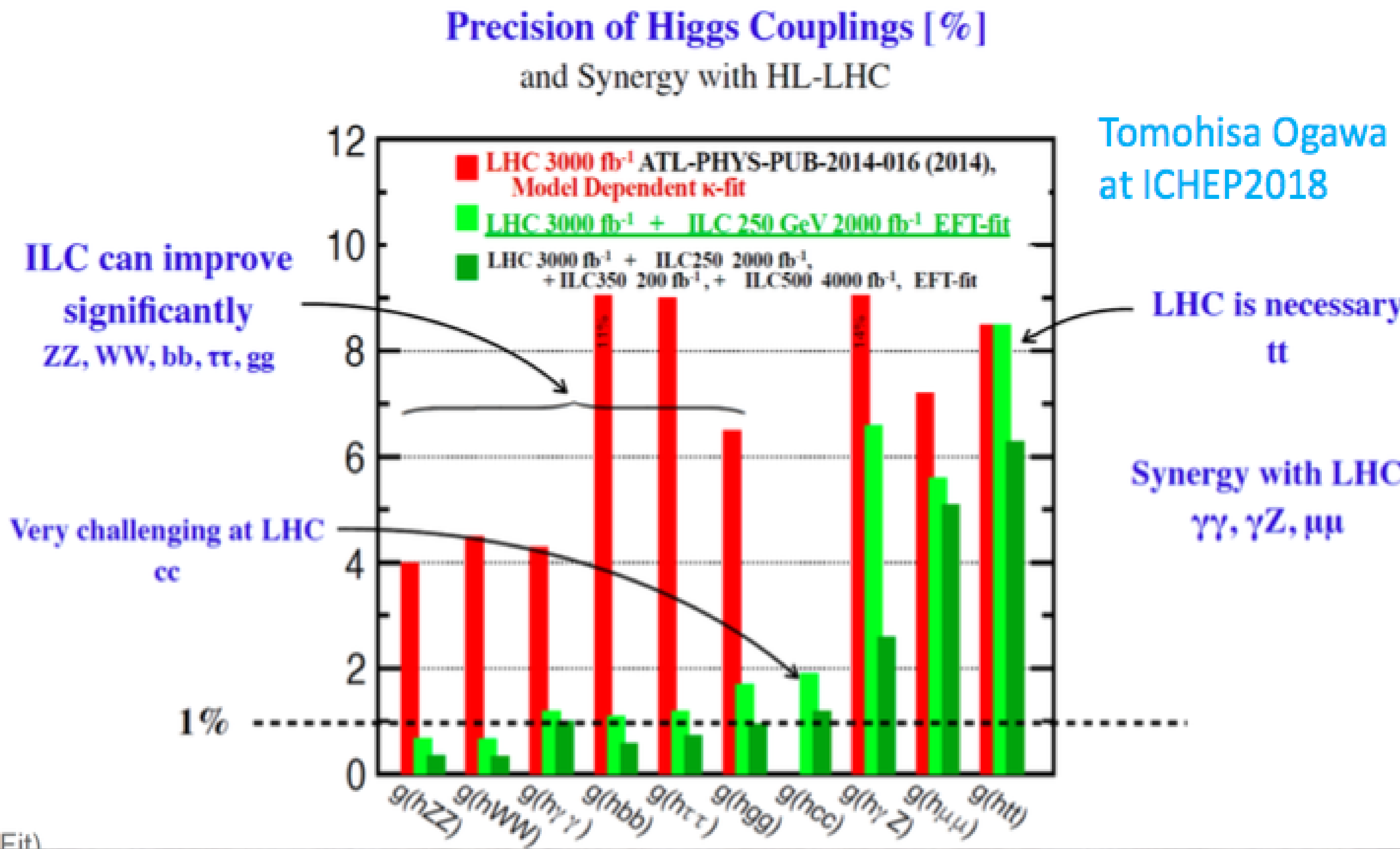


- Scenario 1+: All systematics remain constant with luminosity + some detector upgrade effects included
- Scenario 2+: Experimental nuisances scale with √L, theory uncertainties halved + some detector upgrade effects included

Projected e^+e^- Colliders: Luminosity vs Energy



ILC Measurements of H Couplings



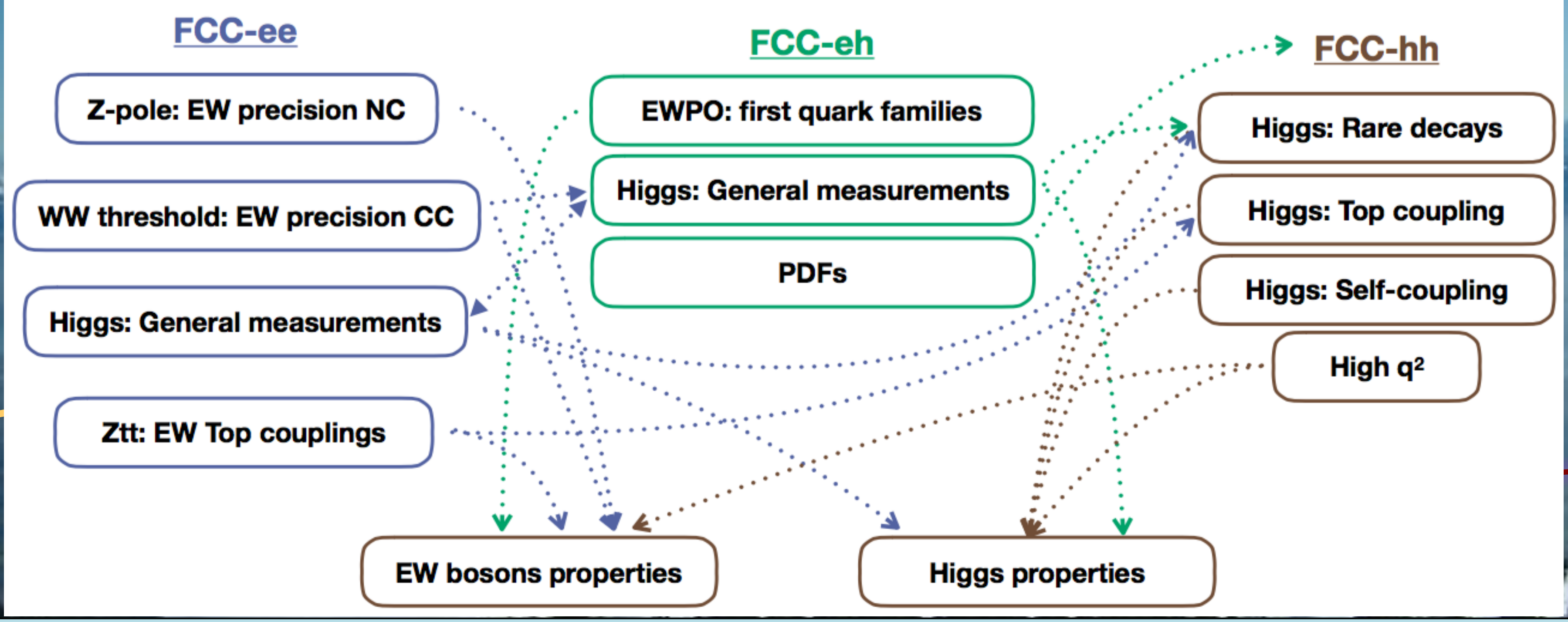
Tomohisa Ogawa at ICHEP2018

FCC hh ee he

CEPC-SPPC

Preliminary Conceptual Design Report

Future Circular Colliders



The vision:

explore 10 TeV scale directly (100 TeV pp) + indirectly (e^+e^-)

FCC-ee Parameters & Run Plan

parameter	Z	WW	H (ZH)	ttbar
beam energy [GeV]	45	80	120	182.5
beam current [mA]	1390	147	29	5.4
no. bunches/beam	16640	2000	393	48
bunch intensity [10^{11}]	1.7	1.5	1.5	2.3
SR energy loss / turn [GeV]	0.036	0.34	1.72	9.21
total RF voltage [GV]	0.1	0.44	2.0	10.9
long. damping time [turns]	1281	235	70	20
horizontal beta* [m]	0.15	0.2	0.3	1
vertical beta* [mm]	0.8	1	1	1.6
horiz. geometric emittance [nm]	0.27	0.28	0.63	1.46
vert. geom. emittance [pm]	1.0	1.7	1.3	2.9
bunch length with SR / BS [mm]	3.5 / 12.1	3.0 / 6.0	3.3 / 5.3	2.0 / 2.5
luminosity per IP [10^{34} $cm^{-2}s^{-1}$]	>200	>25	>7	>1.4

Working point	Z, years 1-2	Z, later	WW	HZ	tt threshold	365 GeV
Lumi/IP (10^{34} $cm^{-2}s^{-1}$)	100	200	31	7.5	0.85	1.5
Lumi/year (2 IP)	26 ab^{-1}	52 ab^{-1}	8.1 ab^{-1}	1.95 ab^{-1}	0.22 ab^{-1}	0.39 ab^{-1}
Physics goal	150		10	5	0.2	1.5
Run time (year)	2	2	1	3	1	4

Parameters of HE-LHC & FCC-hh

High-field magnets in LHC tunnel

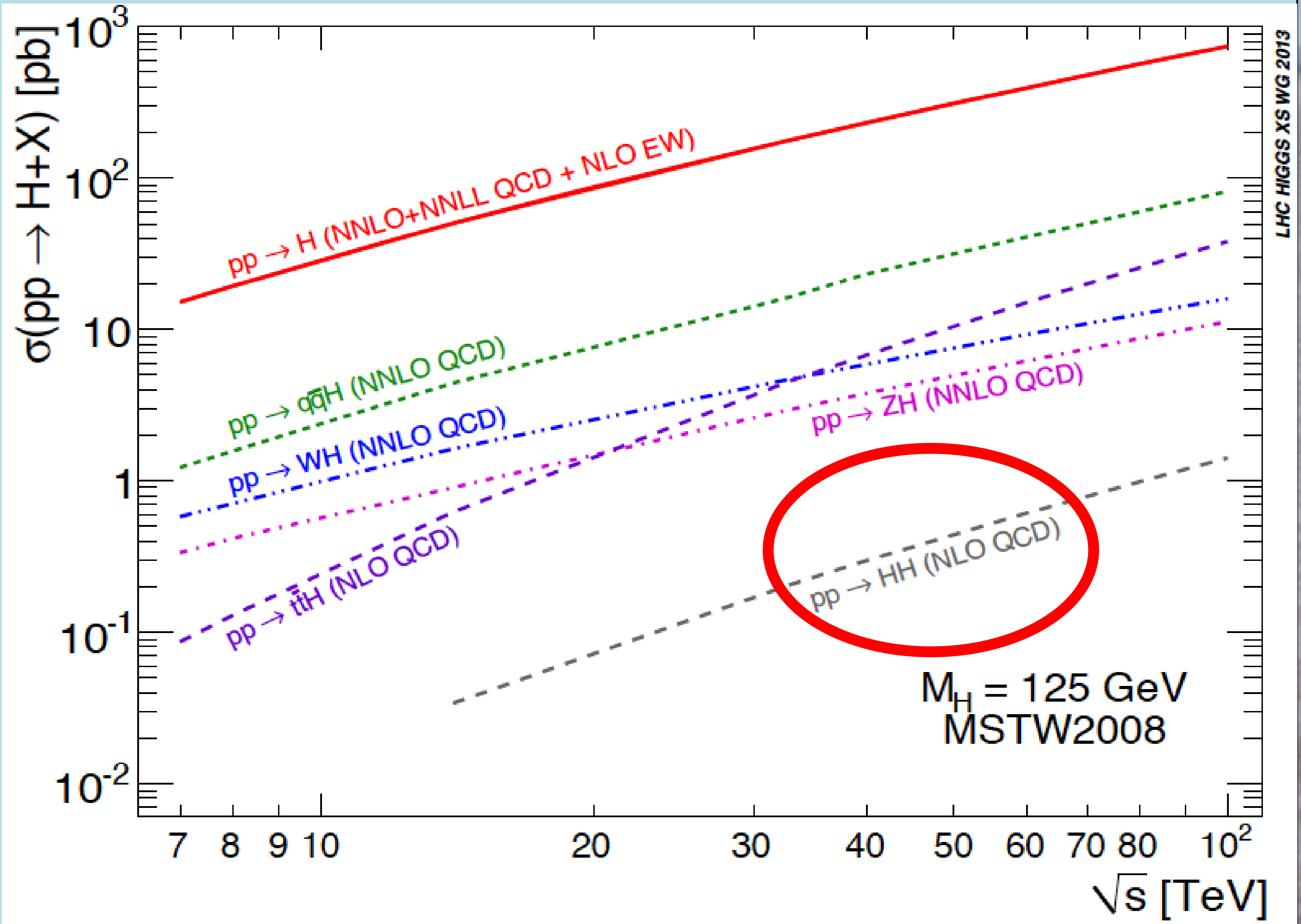
parameter	HE-LHC
collision energy cms [TeV]	27
dipole field [T]	16
circumference [km]	27
straight section length [m]	528
# IP	2 & 2
beam current [A]	1.12
bunch intensity [10^{11}]	2.2 (0.44)
bunch spacing [ns]	25 (5)
rms bunch length [cm]	7.55
peak luminosity [10^{34} cm^{-2}s^{-1}]	25
events/bunch crossing	~800 (160)
stored energy/beam [GJ]	1.3
beta* [m]	0.25
norm. emittance [μm]	2.5 (0.5)

High-field magnets in 100km tunnel

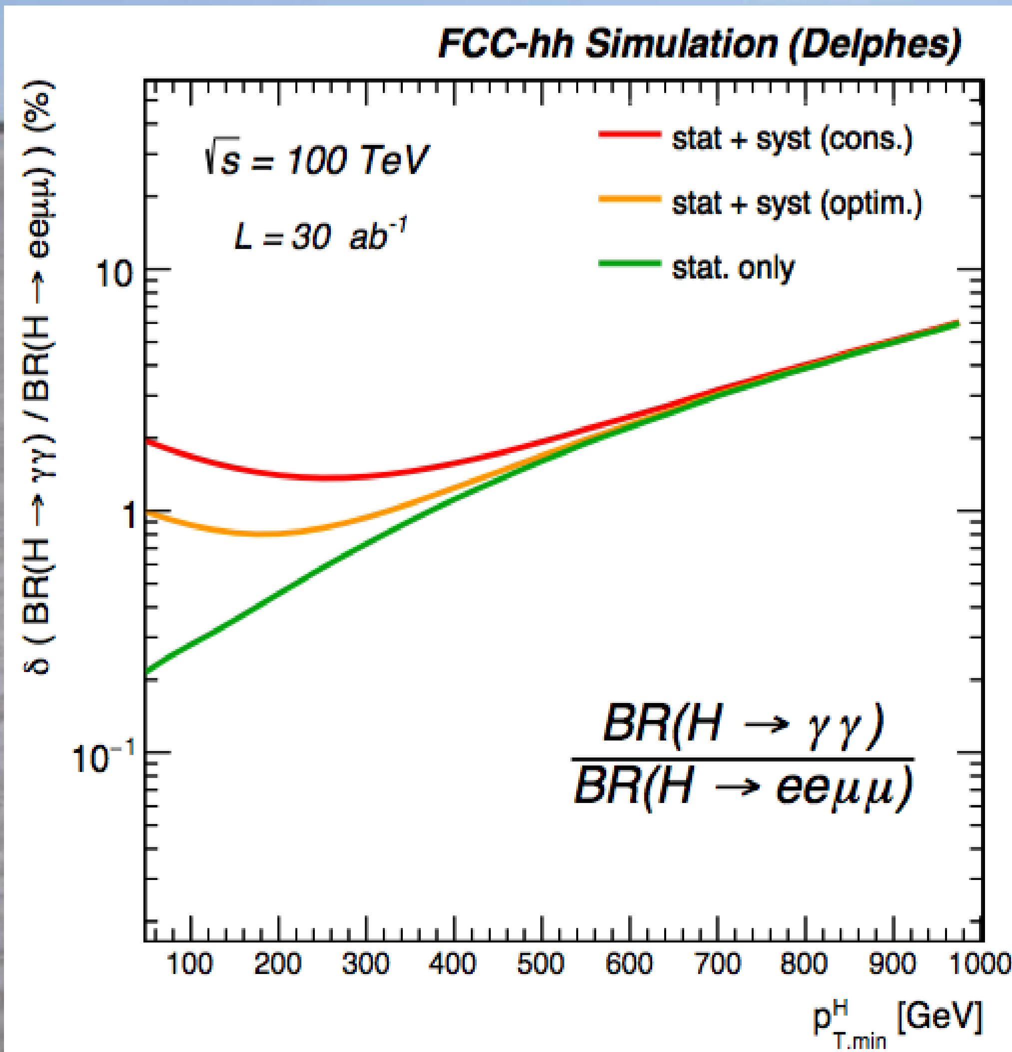
parameter	FCC-hh	
collision energy cms [TeV]	100	
dipole field [T]	16	
circumference [km]	97.75	
beam current [A]	0.5	
bunch intensity [10^{11}]	1	1
bunch spacing [ns]	25	25
synchr. rad. power / ring [kW]	2400	
SR power / length [W/m/ap.]	28.4	
long. emit. damping time [h]	0.54	
beta* [m]	1.1	0.3
normalized emittance [μm]	2.2	
peak luminosity [10^{34} cm^{-2}s^{-1}]	5	30
events/bunch crossing	170	1000
stored energy/beam [GJ]	8.4	

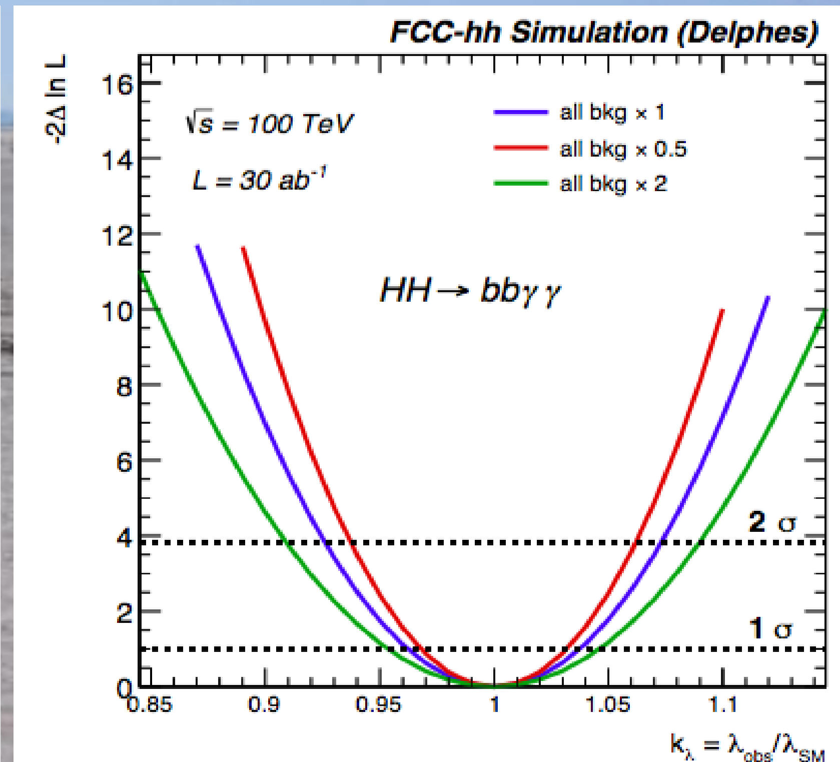
Higgs Cross Sections

- At the LHC and beyond:



Examples of Higgs Measurements





varying (0.5x-2x) background yields:

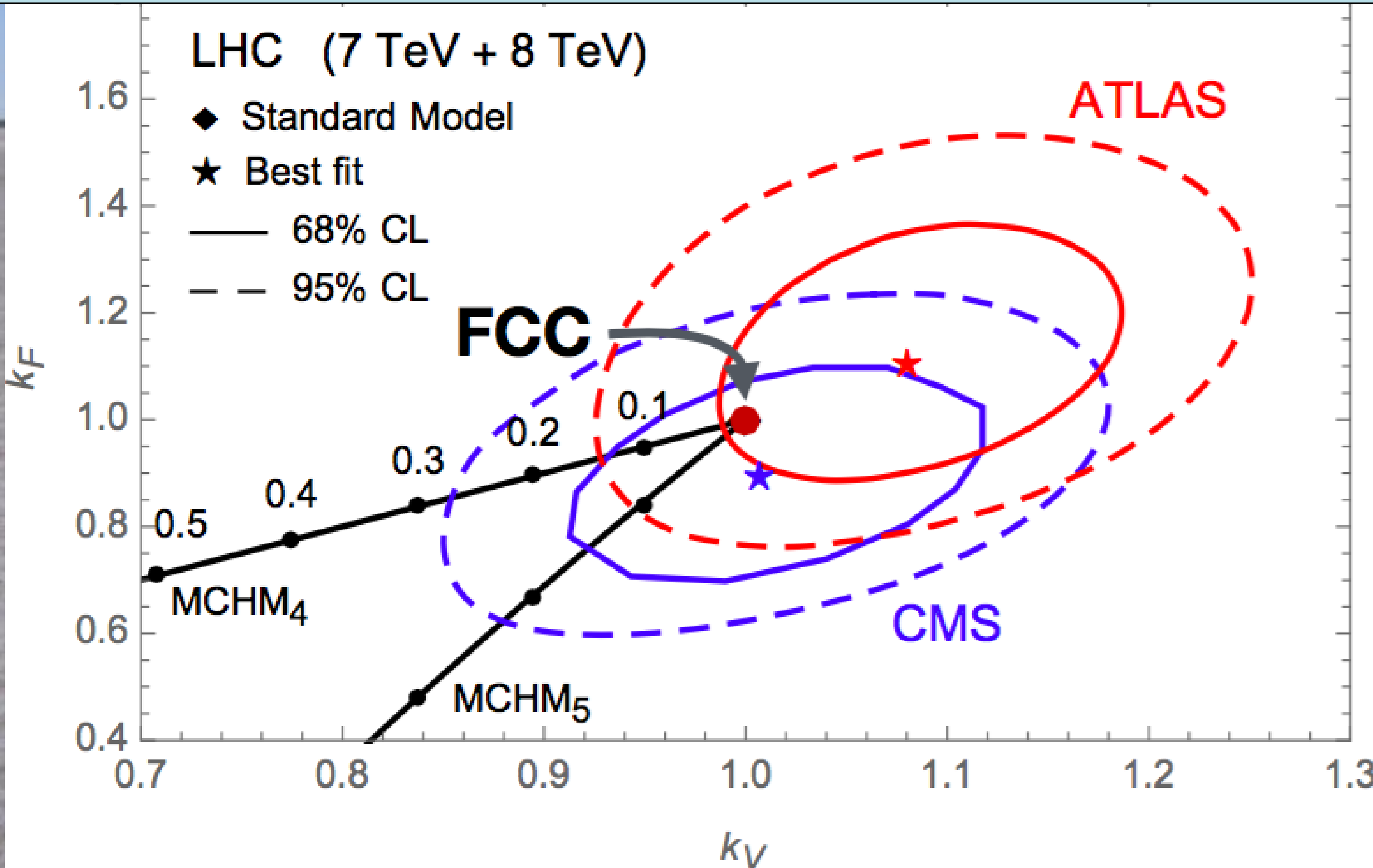
$\delta\kappa_\lambda$(stat) ≈ 3 - 5 %
δr(stat) ≈ 2 - 3%

FCC Accuracy in H Couplings

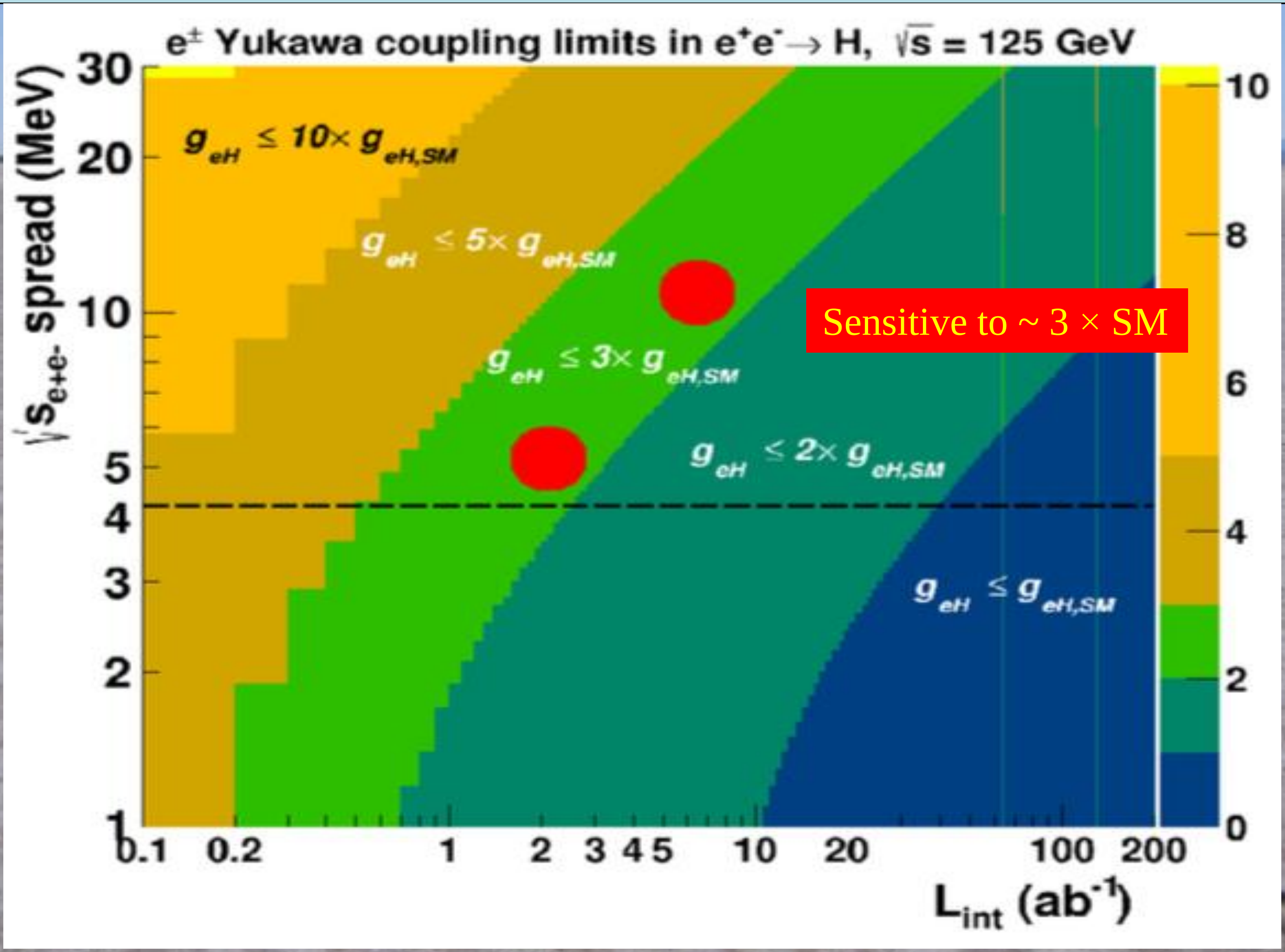
HLLH+FCC-ee/FCC-eh	
Coupling	Relative precision
κ_b	0.39%
κ_t	5.16%
κ_τ	0.59%
κ_c	0.79%
κ_μ	5.17%
κ_Z	0.14%
κ_W	0.17%
κ_g	0.74%
κ_γ	1.19%
$\kappa_{Z\gamma}$	14.3%

HLLHC + FCC	
Coupling	Relative precision
κ_b	0.38%
κ_t	0.51%
κ_τ	0.58%
κ_c	0.79%
κ_μ	0.42%
κ_Z	0.14%
κ_W	0.17%
κ_g	0.74%
κ_γ	0.40%
$\kappa_{Z\gamma}$	0.52%

FCC Constraints on $\kappa_{V,F}$



Sensitivity to e^+e^-H Coupling



SM Effective Field Theory: Tool to Search for BSM

- D=6 operators in electroweak, diboson data

$$\mathcal{L}_{\rm SMEFT}^{\rm Warsaw} \supset \frac{\bar{C}_{Hl}^{(3)}}{v^2}(H^\dagger i\overleftrightarrow{D}^I_\mu H)(\bar{l}\tau^I\gamma^\mu l) + \frac{\bar{C}_{Hl}^{(1)}}{v^2}(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{l}\gamma^\mu l) + \frac{\bar{C}_{ll}}{v^2}(\bar{l}\gamma_\mu l)(\bar{l}\gamma^\mu l)$$
$$+ \frac{\bar{C}_{HD}}{v^2}\left|H^\dagger D_\mu H\right|^2 + \frac{\bar{C}_{HWB}}{v^2}H^\dagger\tau^I H\, W^I_{\mu\nu}B^{\mu\nu}$$
$$+ \frac{\bar{C}_{He}}{v^2}(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{e}\gamma^\mu e) + \frac{\bar{C}_{Hu}}{v^2}(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{u}\gamma^\mu u) + \frac{\bar{C}_{Hd}}{v^2}(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{d}\gamma^\mu d)$$
$$+ \frac{\bar{C}_{Hq}^{(3)}}{v^2}(H^\dagger i\overleftrightarrow{D}^I_\mu H)(\bar{q}\tau^I\gamma^\mu q) + \frac{\bar{C}_{Hq}^{(1)}}{v^2}(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{q}\gamma^\mu q) + \frac{\bar{C}_W}{v^2}\epsilon^{IJK}W^{I\nu}_\mu W^{J\rho}_\nu W^{K\mu}_\rho$$

$$\bar{C} \equiv \frac{v^2}{\Lambda^2}C$$

- D=6 operators affecting Higgs observables

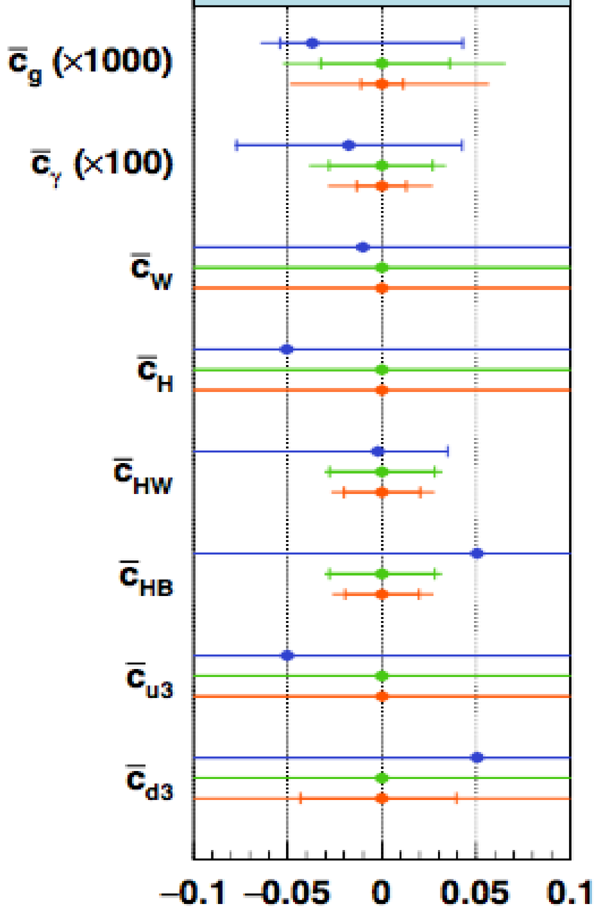
$$\mathcal{L}_{\rm SMEFT}^{\rm Warsaw} \supset \frac{\bar{C}_{eH}}{v^2}(H^\dagger H)(\bar{l}eH) + \frac{\bar{C}_{dH}}{v^2}(H^\dagger H)(\bar{q}dH) + \frac{\bar{C}_{uH}}{v^2}(H^\dagger H)(\bar{q}u\widetilde{H})$$
$$+ \frac{\bar{C}_G}{v^2}f^{ABC}G^{A\nu}_\mu G^{B\rho}_\nu G^{C\mu}_\rho + \frac{\bar{C}_{H\Box}}{v^2}(H^\dagger H)\Box(H^\dagger H) + \frac{\bar{C}_{uG}}{v^2}(\bar{q}\sigma^{\mu\nu}T^A u)\widetilde{H}\, G^A_{\mu\nu}$$
$$+ \frac{\bar{C}_{HW}}{v^2}H^\dagger H\, W^I_{\mu\nu}W^{I\mu\nu} + \frac{\bar{C}_{HB}}{v^2}H^\dagger H\, B_{\mu\nu}B^{\mu\nu} + \frac{\bar{C}_{HG}}{v^2}H^\dagger H\, G^A_{\mu\nu}G^{A\mu\nu}\,.$$

Present & Future LHC Constraints on D=6 Operators

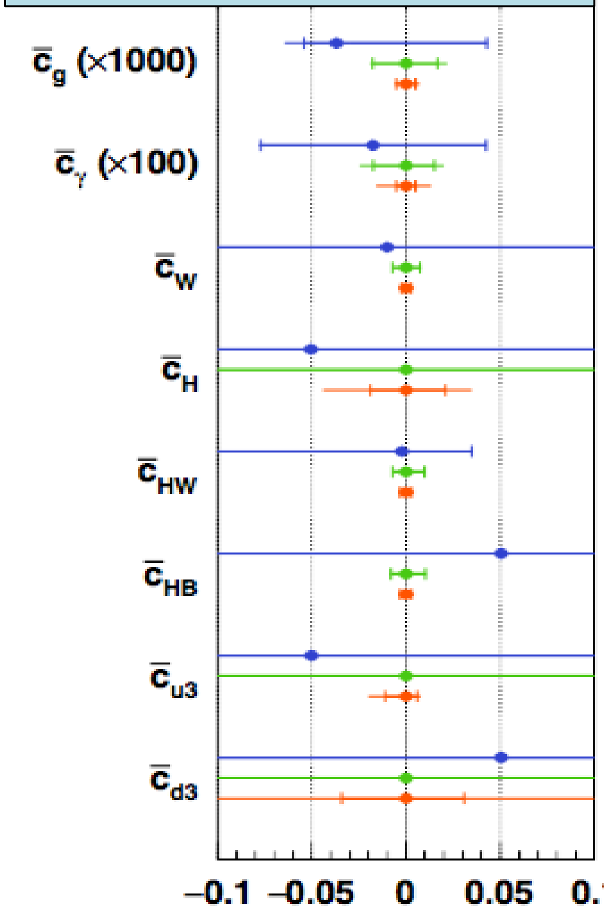
Operators

Bosonic CP-even	
O_H	$\frac{1}{2v^2}\left[\partial_\mu(H^\dagger H)\right]^2$
O_T	$\frac{1}{2v^2}\left(H^\dagger \overleftrightarrow{D}_\mu H\right)^2$
O_6	$-\frac{\lambda}{v^2}(H^\dagger H)^3$
O_g	$\frac{g_s^2}{m_W^2} H^\dagger H\, G^a_{\mu\nu}G^a_{\mu\nu}$
O_γ	$\frac{g'^2}{m_W^2} H^\dagger H\, B_{\mu\nu}B_{\mu\nu}$
O_W	$\frac{ig}{2m_W^2}\left(H^\dagger\sigma^i \overleftrightarrow{D}_\mu H\right) D_\nu W^i_{\mu\nu}$
O_B	$\frac{ig'}{2m_W^2}\left(H^\dagger \overleftrightarrow{D}_\mu H\right) \partial_\nu B_{\mu\nu}$
O_{HW}	$\frac{ig}{m_W^2}\left(D_\mu H^\dagger \sigma^i D_\nu H\right) W^i_{\mu\nu}$
O_{HB}	$\frac{ig'}{m_W^2}\left(D_\mu H^\dagger D_\nu H\right) B_{\mu\nu}$
O_{2W}	$\frac{1}{m_W^2} D_\mu W^i_{\mu\nu} D_\rho W^i_{\rho\nu}$
O_{2B}	$\frac{1}{m_W^2} \partial_\mu B_{\mu\nu} \partial_\rho B_{\rho\nu}$
O_{2G}	$\frac{1}{m_W^2} D_\mu G^a_{\mu\nu} D_\rho G^a_{\rho\nu}$
O_{3W}	$\frac{g^3}{m_W^2}\epsilon^{ijk} W^i_{\mu\nu} W^j_{\nu\rho} W^k_{\rho\mu}$
O_{3G}	$\frac{g_s^3}{m_W^2} f^{abc} G^a_{\mu\nu} G^b_{\nu\rho} G^c_{\rho\mu}$

Constraints from rates



Constraints including kinematics



Current 300/fb 3000/fb

Englert, Kogler, Schulz & Spannowsky, arXiv:1511.05170

Updated Global SMEFT Fit
to Higgs, Diboson and Electroweak Data

- Global fit to dimension-6 operators using precision electroweak data, W^+W^- at LEP, Higgs and diboson data from LHC Runs 1 and 2
- Results in Warsaw and SILH bases
- Improvements in the constraints from Run 2
- Constraints on BSM models
  - Some contribute to operators at tree level
  - Stops that contribute at loop level

Murphy, JE, Sanz & You, arXiv:1803.03252

Run 2 Higgs Measurements used in SMEFT Fit

Include all available kinematical information + 1 W^+W^- measurement at high p_T

Probe 12 SMEFT directions

CMS

Production	Decay	Sig. Stren.
1-jet, $p_T > 450$	$b\bar{b}$	$2.3^{+1.8}_{-1.6}$
Zh	$b\bar{b}$	0.9 ± 0.5
Wh	$b\bar{b}$	1.7 ± 0.7
$t\bar{t}h$	$b\bar{b}$	$-0.19^{+0.80}_{-0.81}$
$t\bar{t}h$	$1\ell + 2\tau_h$	$-1.20^{+1.50}_{-1.47}$
$t\bar{t}h$	$2\ell ss + 1\tau_h$	$0.86^{+0.79}_{-0.66}$
$t\bar{t}h$	$3\ell + 1\tau_h$	$1.22^{+1.34}_{-1.00}$
$t\bar{t}h$	$2\ell ss$	$1.7^{+0.6}_{-0.5}$
$t\bar{t}h$	3ℓ	1.0[illegible]
$t\bar{t}h$	4ℓ	[illegible]
0-jet	WW	[illegible]
1-jet	W[illegible]	[illegible]
2-jet	[illegible]	[illegible].0
VBF 2-j[illegible]	[illegible]	[illegible]4 $\pm$ 0.8
Vh[illegible]	[illegible]	$2.1^{+2.3}_{-2.2}$
[illegible]	[illegible]	-1.4 ± 1.5
[illegible]	$\gamma\gamma$	$1.11^{+0.19}_{-0.18}$
[illegible]	$\gamma\gamma$	$0.5^{+0.6}_{-0.5}$
[illegible]	$\gamma\gamma$	2.2 ± 0.9
Vh	$\gamma\gamma$	$2.3^{+1.1}_{-1.0}$
ggF	4ℓ	$1.20^{+0.22}_{-0.21}$
0-jet	$\tau\tau$	0.84 ± 0.89
boosted	$\tau\tau$	$1.17^{+0.47}_{-0.40}$
VBF	$\tau\tau$	$1.11^{+0.34}_{-0.35}$

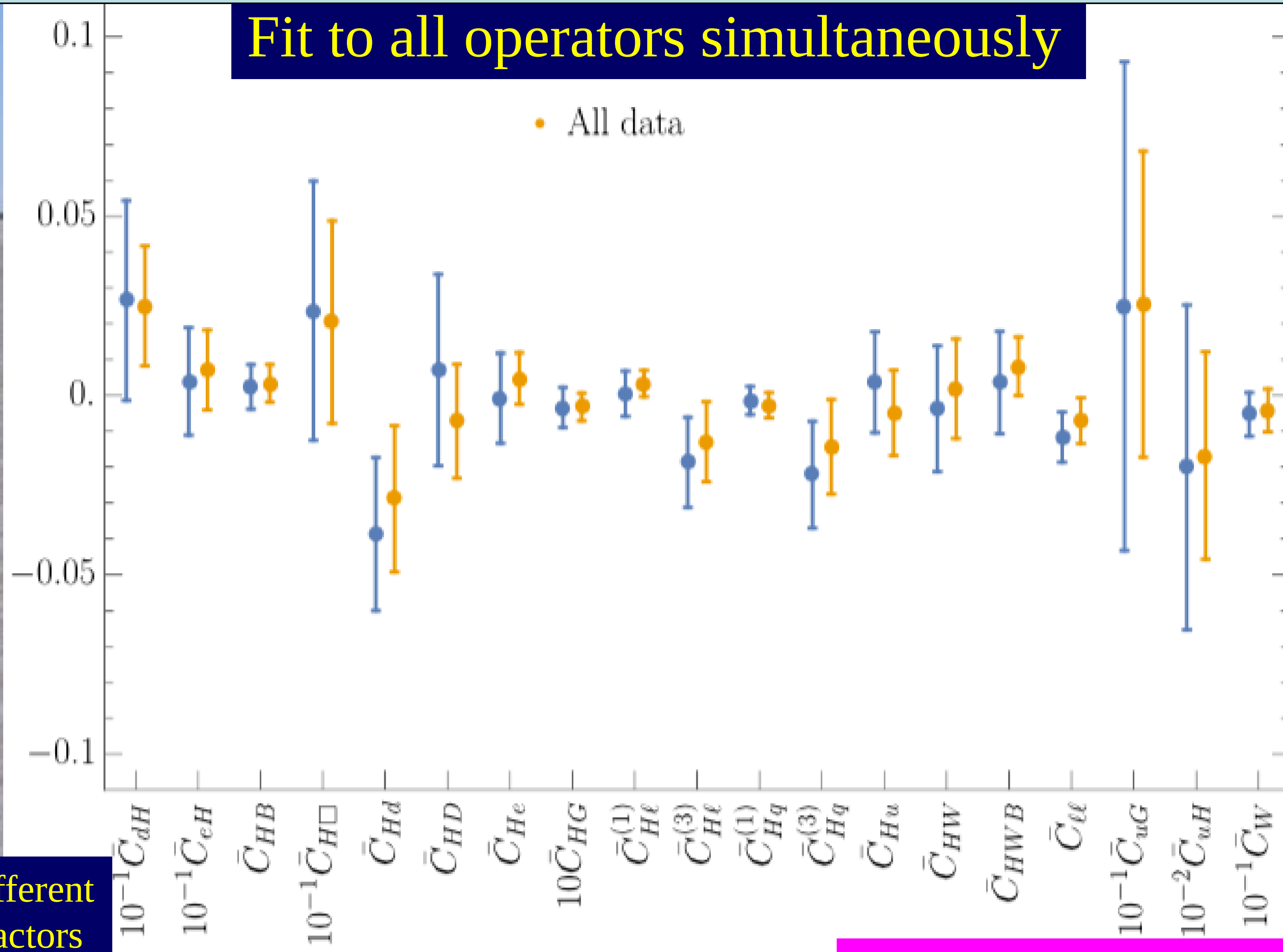
ATLAS

Production	Decay	Si[illegible]en.
pp	$\mu\mu$	[illegible]
Zh	[illegible]	[illegible]
Wh	[illegible]	[illegible]
$t\bar{t}h$	[illegible]	[illegible]$4^{+0.64}_{-0.61}$
$t\bar{t}h$	[illegible]	$1.7^{+2.1}_{-1.9}$
[illegible]	[illegible]τ_h	$-0.6^{+1.6}_{-1.5}$
[illegible]	[illegible]$+ 1\tau_h$	$1.6^{+1.8}_{-1.3}$
[illegible]	$2\ell ss + 1\tau_h$	$3.5^{+1.7}_{-1.3}$
[illegible]	3ℓ	$1.8^{+0.9}_{-0.7}$
[illegible]	$2\ell ss$	$1.5^{+0.7}_{-0.6}$
ggF	WW	$1.21^{+0.22}_{-0.21}$
VBF	WW	$0.62^{+0.37}_{-0.36}$
$B(h \to \gamma\gamma)/B(h \to 4\ell)$		$0.69^{+0.15}_{-0.13}$
0-jet	4ℓ	$1.07^{+0.27}_{-0.25}$
1-jet, $p_T < 60$	4ℓ	$0.67^{+0.72}_{-0.68}$
1-jet, $p_T \in (60, 120)$	4ℓ	$1.00^{+0.63}_{-0.55}$
1-jet, $p_T \in (120, 200)$	4ℓ	$2.1^{+1.5}_{-1.3}$
2-jet	4ℓ	$2.2^{+1.1}_{-1.0}$
"BSM-like"	4ℓ	$2.3^{+1.2}_{-1.0}$
VBF, $p_T < 200$	4ℓ	$2.14^{+0.94}_{-0.77}$
Vh lep	4ℓ	$0.3^{+1.3}_{-1.2}$
$t\bar{t}h$	4ℓ	$0.51^{+0.86}_{-0.70}$
Wh	WW	$3.2^{+4.4}_{-4.2}$

Murphy, JE, Sanz & You, arXiv:1803.03252

Results of Global Fit in Warsaw Basis

Fit to all operators simultaneously



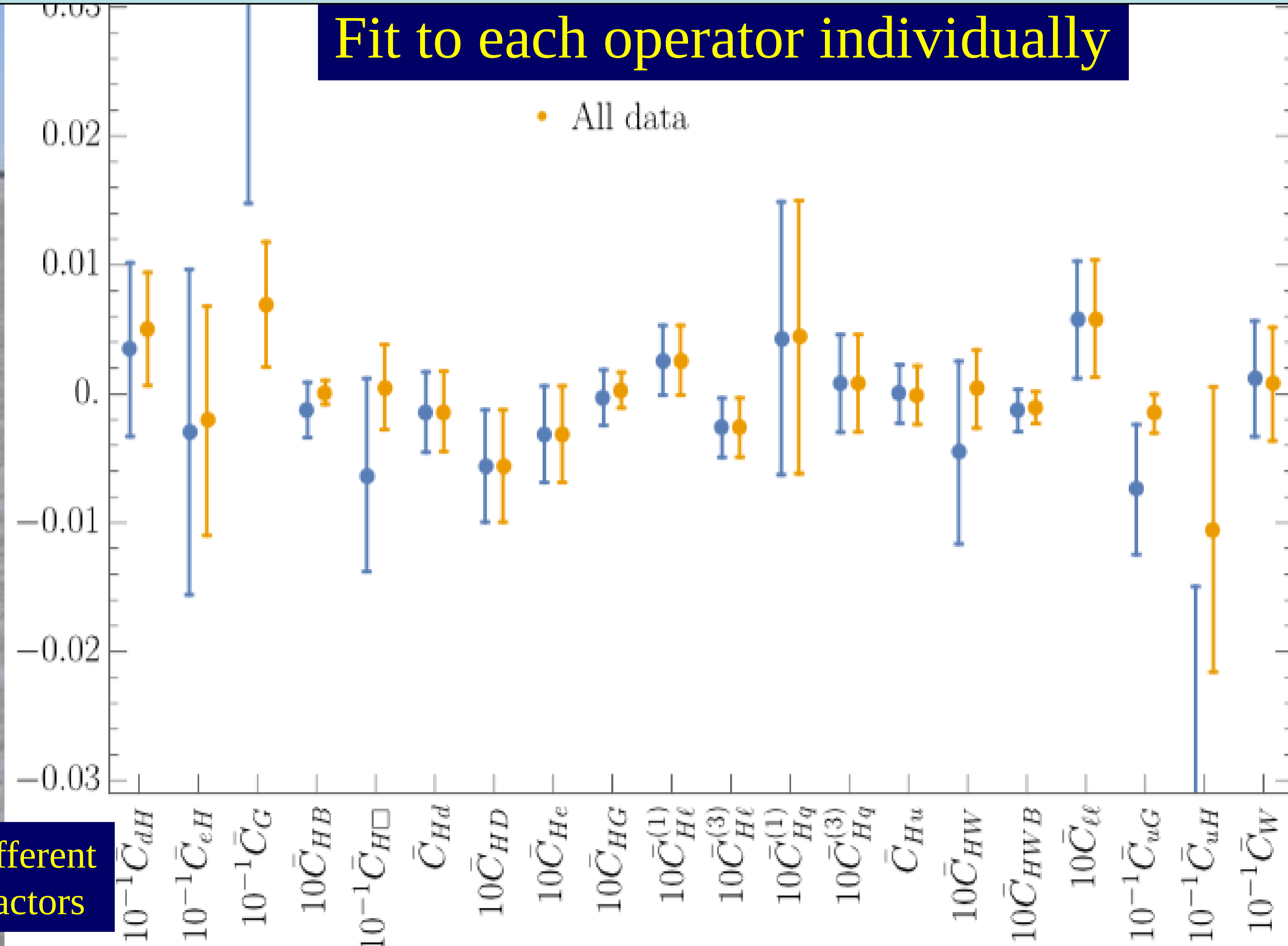
NB: Different scale factors

Murphy, JE, Sanz & You, arXiv:1803.03252

EMSY, arXiv:1803.03252

Results of Global Fit in Warsaw Basis

Fit to each operator individually

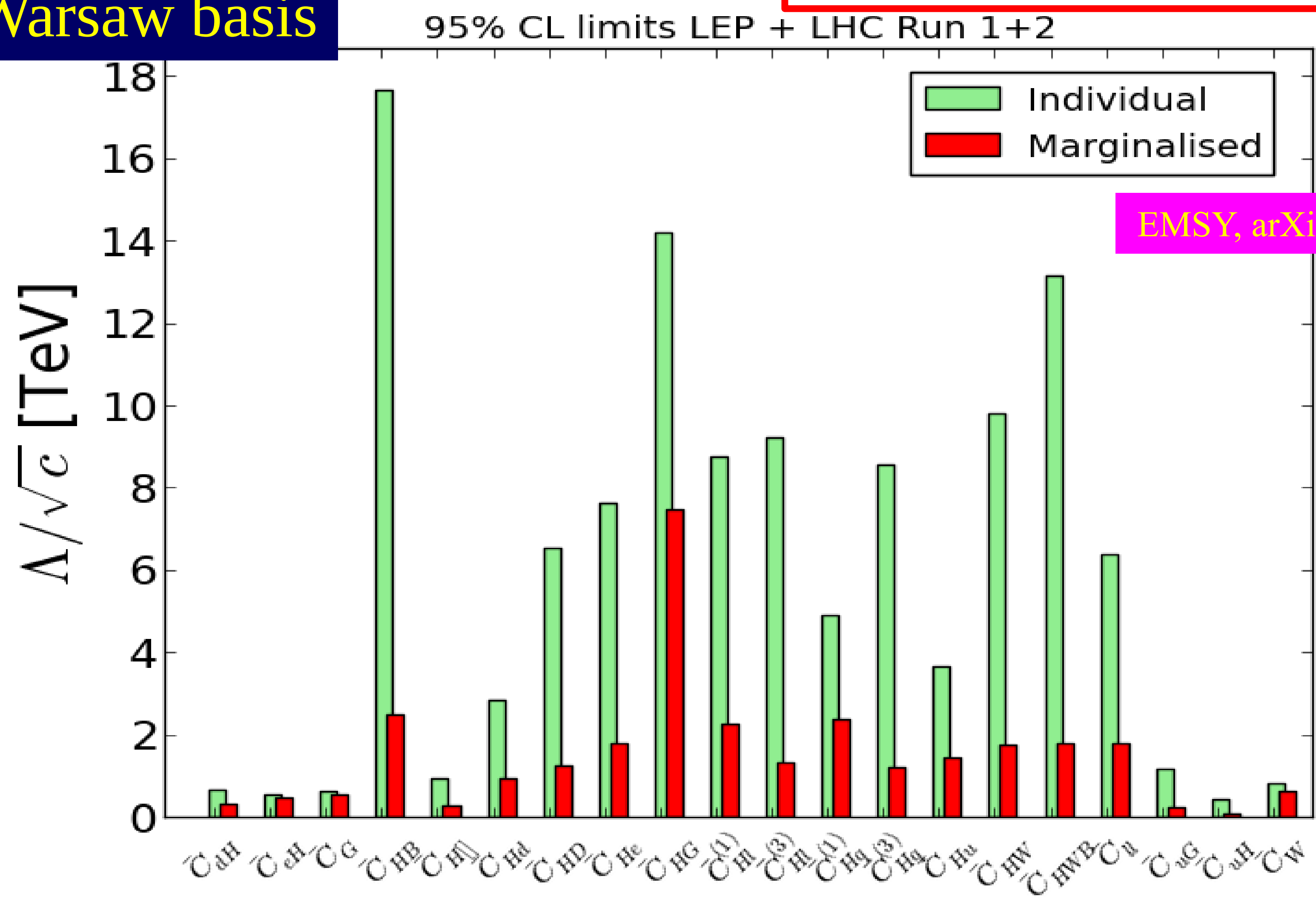


NB: Different scale factors

Summary

Theory	χ^2	$\chi^2/n_{\rm d}$	p-value
SM	157	0.987	0.532
SMEFT	137	0.987	0.528
SMEFT*	143	0.977	0.564

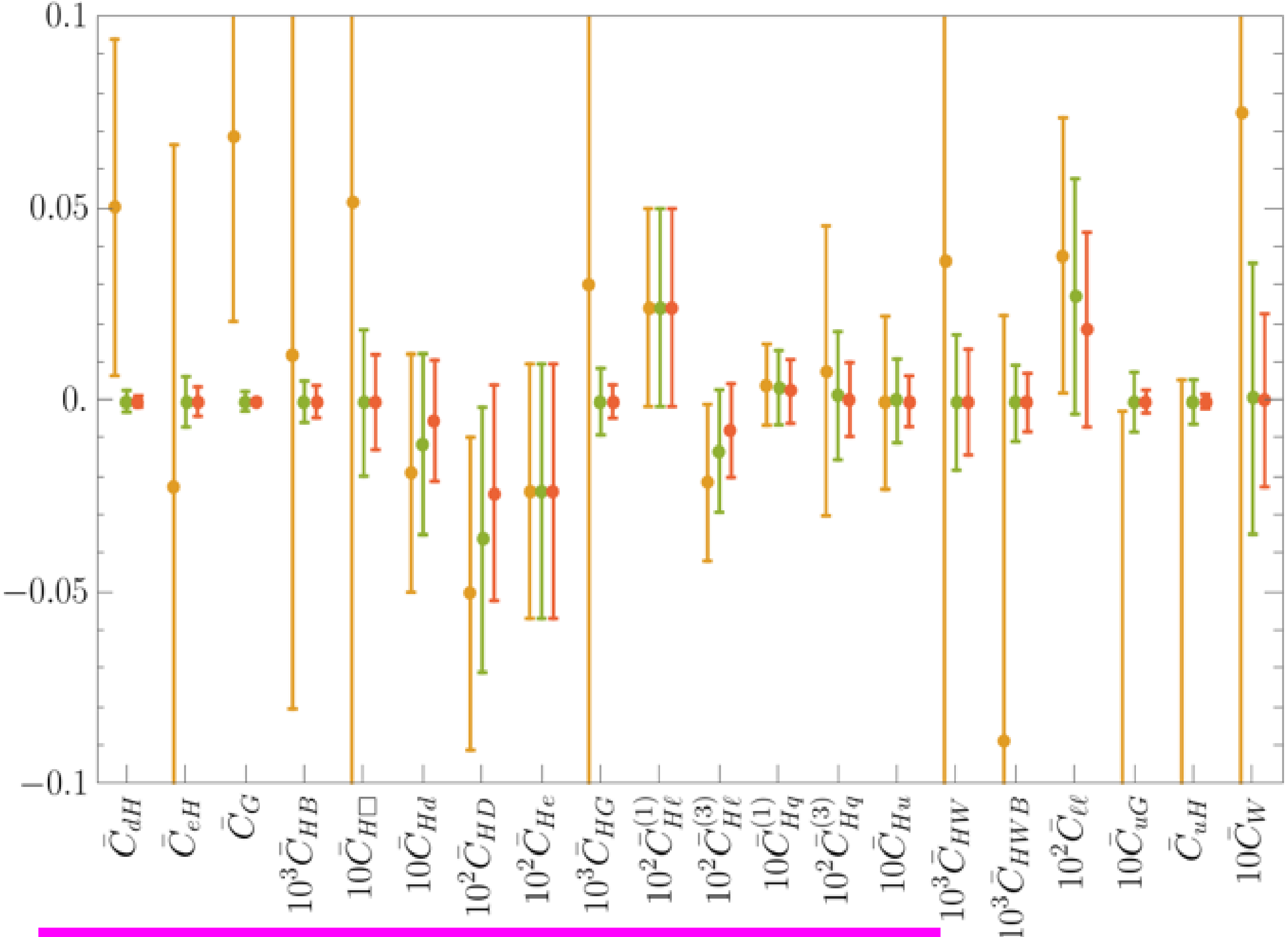
Warsaw basis



EMSY, arXiv:1803.03252

Extrapolating Global Fit in Warsaw Basis

Fit to each operator individually



Current fit

HL-LHC 3/ab

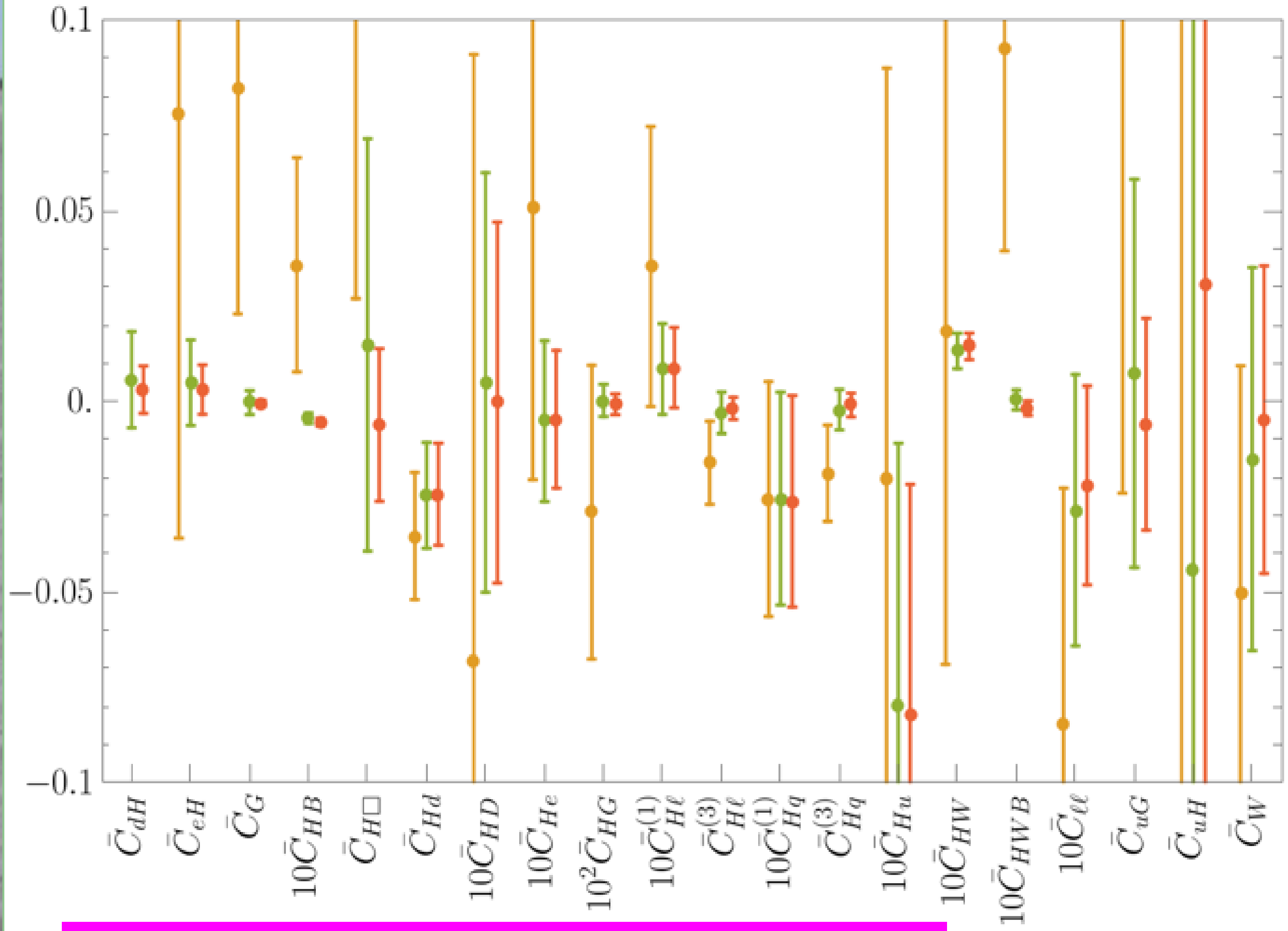
HE-LHC 15/ab

Assuming precision ~ $\sigma/\sqrt{L}$

Murphy, based on EMSY, arXiv:1803.03252

Extrapolating Global Fit in Warsaw Basis

Fit to all operators simultaneously



Current fit

HL-LHC 3/ab

HE-LHC 15/ab

Assuming precision ~ σ/√L

Murphy, based on EMSY, arXiv:1803.03252

Precision Electroweak Measurements with FCC-ee

Blondel et al, arXiv:1809.01830

BU-HEPP-18-04, CERN-TH-2018-145, IFJ-PAN-IV-2018-09, KW 18-003
MITP/18-052, MPP-2018-143, SI-HEP-2018-21

Standard Model Theory for the FCC-ee: The Tera-Z

Report on the 1st Mini workshop: Precision EW and QCD calculations for the FCC studies: methods and tools, 12-13 January 2018, CERN, Geneva

https://indico.cern.ch/event/669224/

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Precision Electroweak Measurements

Observable	Present value ± error			FCC-ee Stat.	FCC-ee Syst.	Source and dominant exp. error
m_Z (keV/c^2)	91186700	±	2200	5	100	Z line shape scan Beam energy calibration
Γ_Z (keV)	2495200	±	2300	8	100	Z line shape scan Beam energy calibration
R_ℓ^Z ($\times 10^3$)	20767	±	25	0.06	1	Ratio of hadrons to leptons Acceptance for leptons
$\alpha_s(m_Z)$ ($\times 10^4$)	1196	±	30	0.1	1.6	R_ℓ^Z above
R_b ($\times 10^6$)	216290	±	660	0.3	<60	Ratio of $b\bar{b}$ to hadrons Stat. extrapol. from SLD [7]
σ^0_{had} ($\times 10^3$) (nb)	41541	±	37	0.1	4	Peak hadronic cross-section Luminosity measurement
N_ν ($\times 10^3$)	2991	±	7	0.005	1	Z peak cross sections Luminosity measurement
$\sin^2\theta_W^{eff}$ ($\times 10^6$)	231480	±	160	3	2 - 5	$A_{FB}^{\mu\mu}$ at Z peak Beam energy calibration
$1/\alpha_{QED}(m_Z)$ ($\times 10^3$)	128952	±	14	4	small	$A_{FB}^{\mu\mu}$ off peak
$A_{FB}^{b,0}$ ($\times 10^4$)	992	±	16	0.02	<1	b-quark asymmetry at Z pole Jet charge
$A_{FB}^{pol,\tau}$ ($\times 10^4$)	1498	±	49	0.15	<2	τ polar. and charge asymm. τ decay physics
m_W (keV/c^2)	803500	±	15000	600	300	WW threshold scan Beam energy calibration
Γ_W (keV)	208500	±	42000	1500	300	WW threshold scan Beam energy calibration
$\alpha_s(m_W)$ ($\times 10^4$)	NA		NA	3	small	R_ℓ^W
N_ν ($\times 10^3$)	2920	±	50	0.8	small	Ratio of invis. to leptonic in radiative Z returns
m_{top} (MeV/c^2)	172740	±	500	20	small	$t\bar{t}$ threshold scan QCD errors dominate
Γ_{top} (MeV/c^2)	1410	±	190	40	small	$t\bar{t}$ threshold scan QCD errors dominate
$\lambda_{top}/\lambda_{top}^{SM}$	m = 1.2	±	0.3	0.08	small	$t\bar{t}$ threshold scan QCD errors dominate
$t\bar{t}Z$ couplings		±	30%	<2%	small	E_{CM} = 365GeV run

Blondel et al, arXiv:1809.01830

Precision Electroweak Measurements

Present and future EWPO errors

Blondel et al, arXiv:1809.01830

	$\delta\Gamma_Z$ [MeV]	δR_l [10^{-4}]	δR_b [10^{-5}]	$\delta \sin^2\theta_{\rm eff}^{\rm l}$ [10^{-6}]	$\delta \sin^2\theta_{\rm eff}^{\rm b}$ [10^{-5}]
Present EWPO errors					
EXP1	2.3	250	66	160	1600
TH1	0.5	50	15	45	5
FCC-ee-Z EWPO error estimations					
EXP2	0.1	10	$2 \div 6$	6	70

Comparison of future EWPO errors with TH estimates

FCC-ee-Z EWPO error estimations				
	$\delta\Gamma_Z$ [MeV]	δR_l [10^{-4}]	δR_b [10^{-5}]	$\delta \sin^2\theta_{\rm eff}^{\rm l}$ [10^{-5}]
EXP2 [40]	0.1	10	$2 \div 6$	6
TH1-new	0.4	60	10	45
TH2	0.15	15	5	15
TH3	< 0.07	< 7	< 3	< 7

Numbers of Diagrams to be Calculated

Blondel et al, arXiv:1809.01830

$Z \to b\bar{b}$			
Number of topologies	1 loop	2 loops	3 loops
	1	$14 \xrightarrow{(A)} 7 \xrightarrow{(B)} 5$	$211 \xrightarrow{(A)} 84 \xrightarrow{(B)} 51$
Number of diagrams	15	$2383 \xrightarrow{(A,B)} 1074$	$490387 \xrightarrow{(A,B)} 120472$
Fermionic loops	0	150	17580
Bosonic loops	15	924	102892
Planar / Non-planar	15 / 0	981/133	84059/36413
QCD / EW	1 / 14	98 / 1016	10386/110086

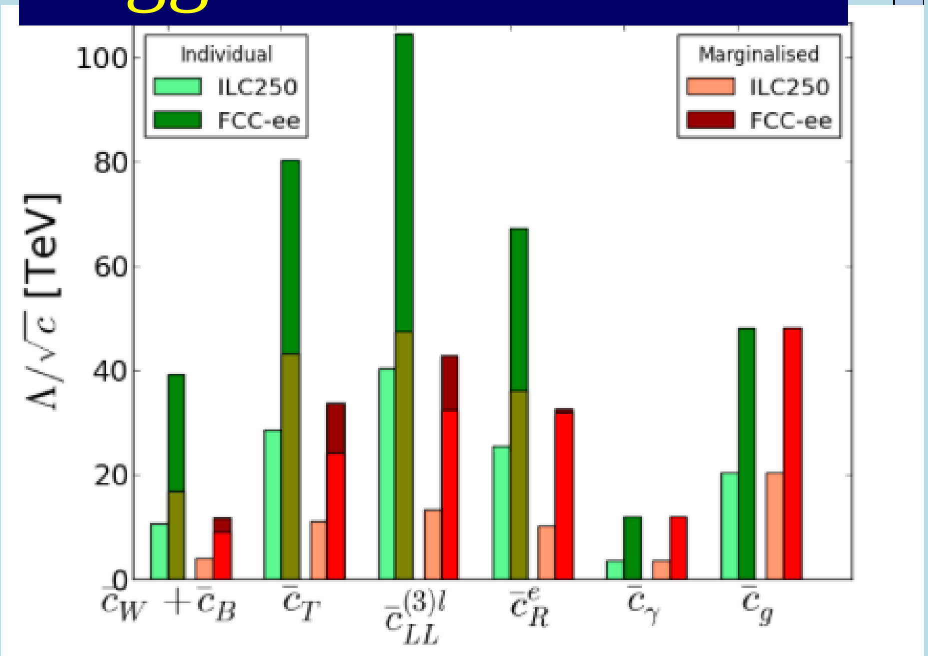
$Z \to e^+e^-, \ldots$			
Number of topologies	1 loop	2 loops	3 loops
	1	$14 \xrightarrow{(A)} 7 \xrightarrow{(B)} 5$	$211 \xrightarrow{(A)} 84 \xrightarrow{(B)} 51$
Number of diagrams	14	$2012 \xrightarrow{(A,B)} 880$	$397690 \xrightarrow{(A,B)} 91472$
Fermionic loops	0	114	13104
Bosonic loops	14	766	78368
Planar / Non-planar	14 / 0	782/98	65487/25985
QCD / EW	0 / 14	0 / 880	144/91328

A lot of work for theorists, but feasible!

e^+e^- H, Electroweak & TGC Measurements

JE & Tevong You, arXiv:1510.04561

Higgs and electroweak

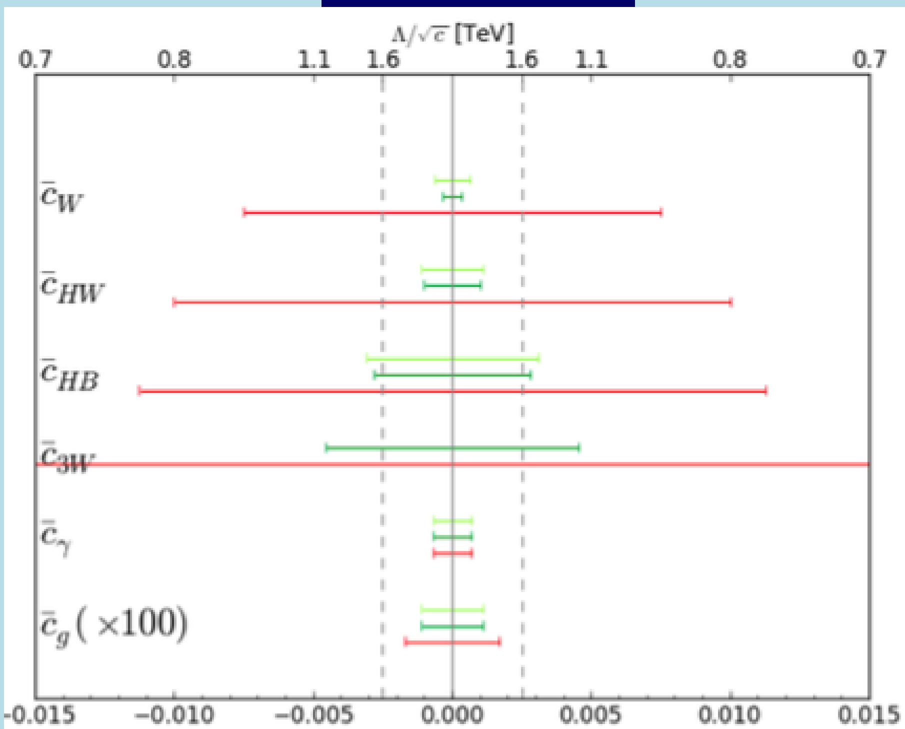


- Shadings:
  - With/without theoretical electroweak uncertainties

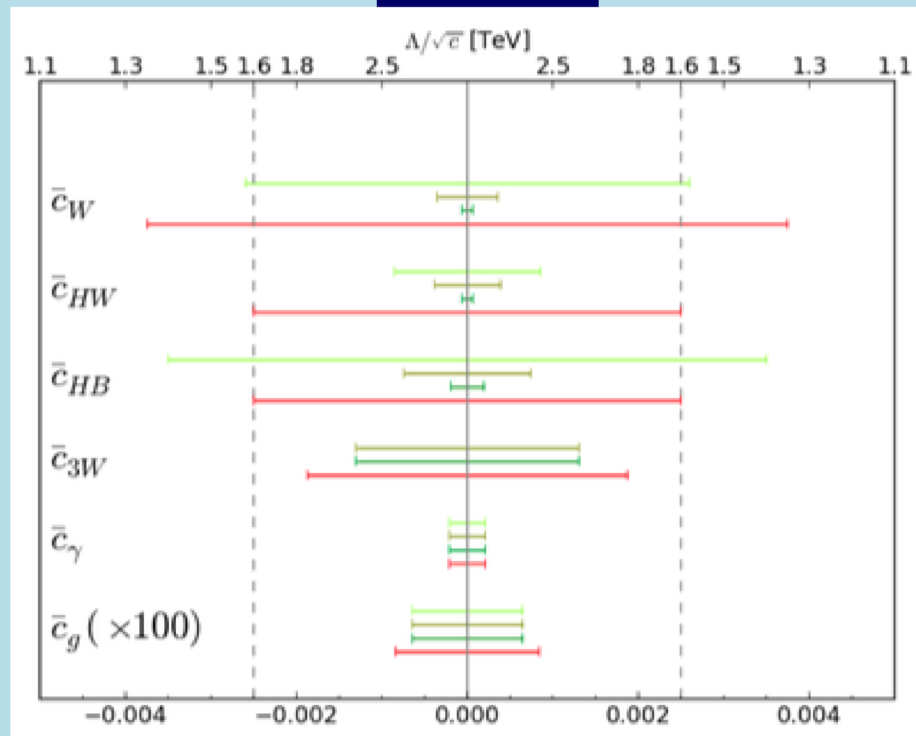
Should extend to include prospective FCC-hh measurements of TGCs, …

CLIC Sensitivities to Dimension-6 Operators

350 GeV



3 TeV



Global fit | Individual operators | Omitting W^+W^-

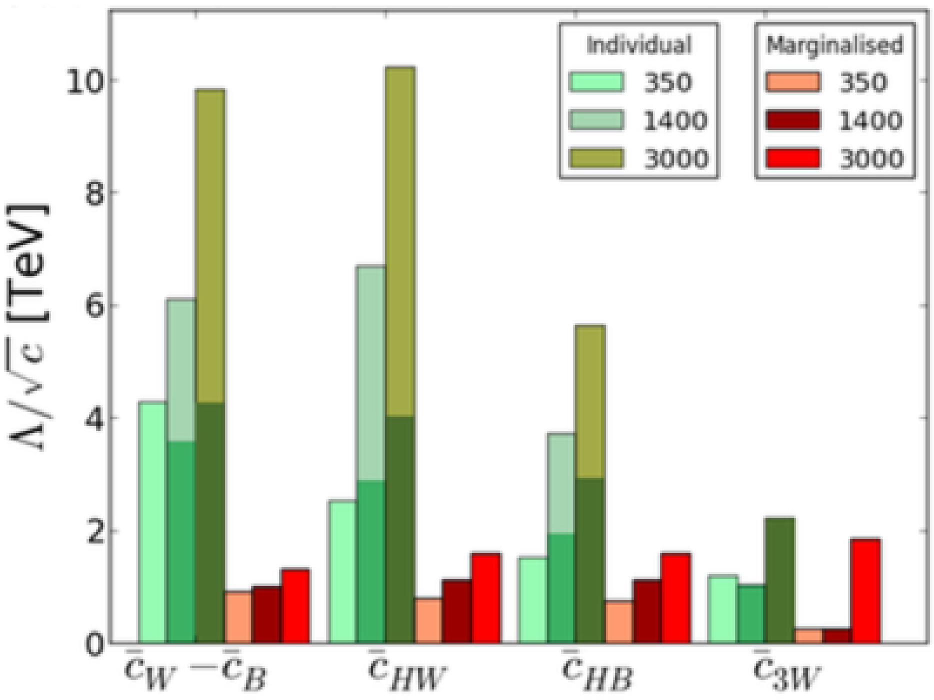
Sensitivity enhanced by higher centre-of-mass energy

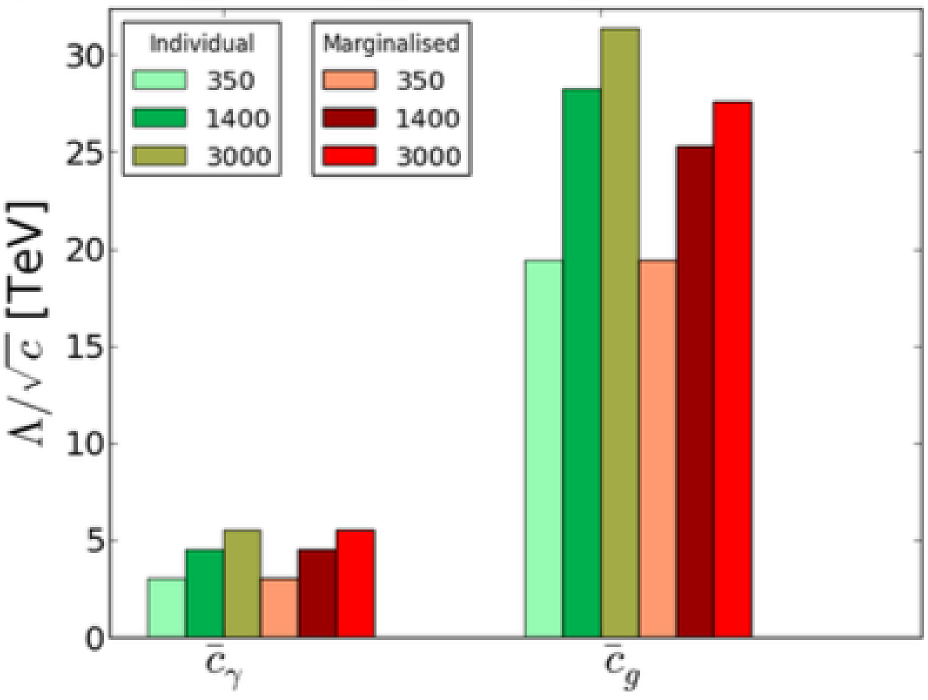
JE, Roloff, Sanz & Tevong You, arXiv:1701.04804

CLIC Sensitivities to Dimension-6 Operators

Individual operators

Global fit





Sensitivity enhanced by higher centre-of-mass energy

JE, Roloff, Sanz & Tevong You, arXiv:1701.04804


We still believe in supersymmetry
You must be joking

What lies beyond the Standard Model?

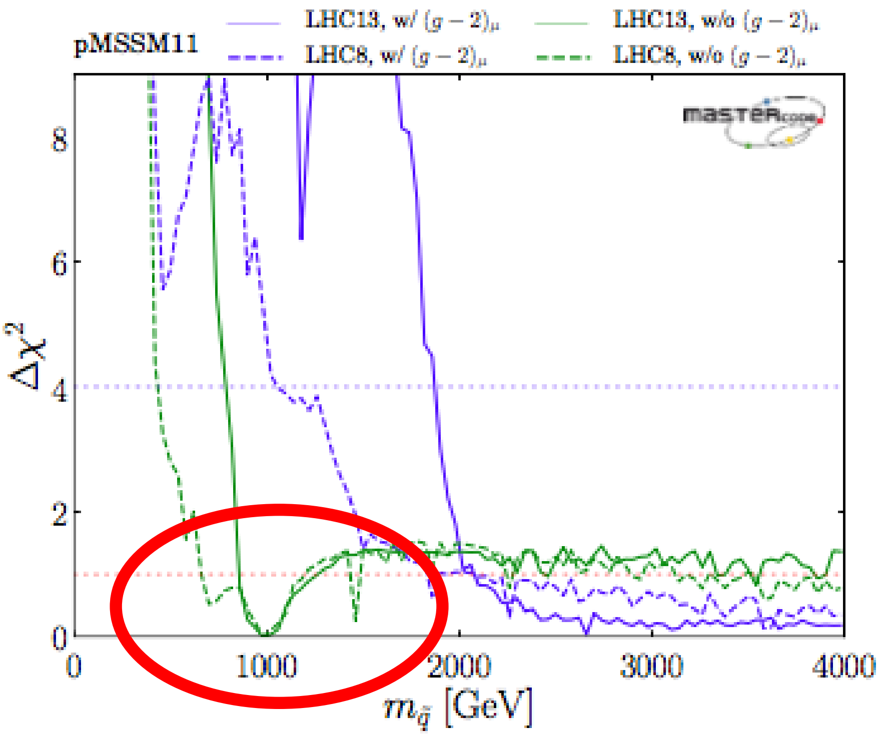
Supersymmetry

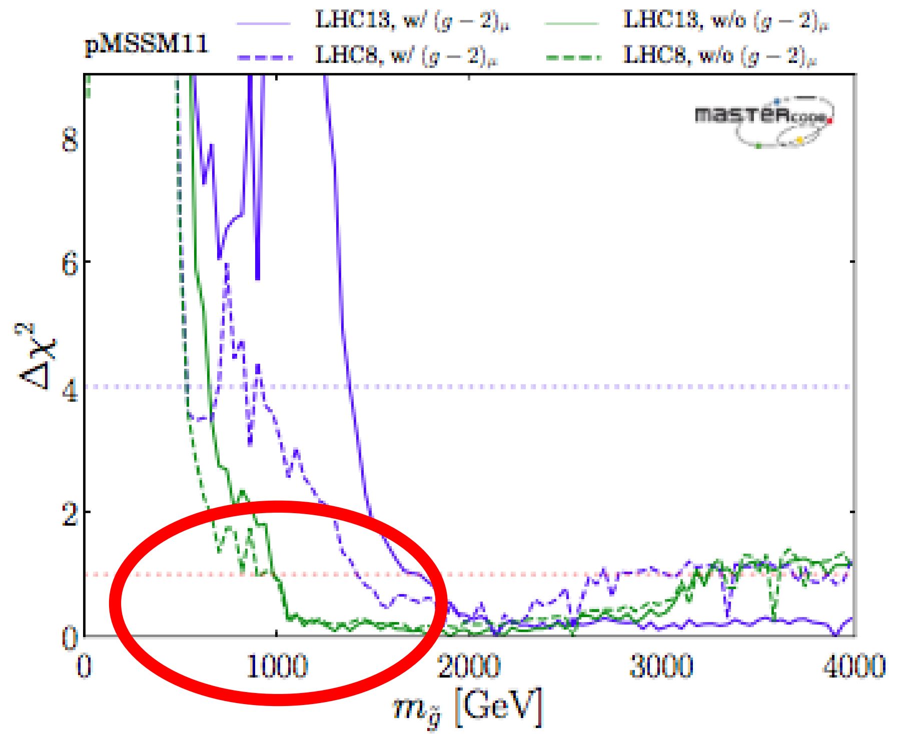
New motivations
From LHC Run 1

- **Stabilize electroweak vacuum**
- **Successful prediction for Higgs mass**
  - **Should be < 130 GeV in simple models**
- **Successful predictions for couplings**
  - **Should be within few % of SM values**
- Naturalness, GUTs, string, …, dark matter

How Light can Squarks & Gluinos be?

Phenomenological MSSM





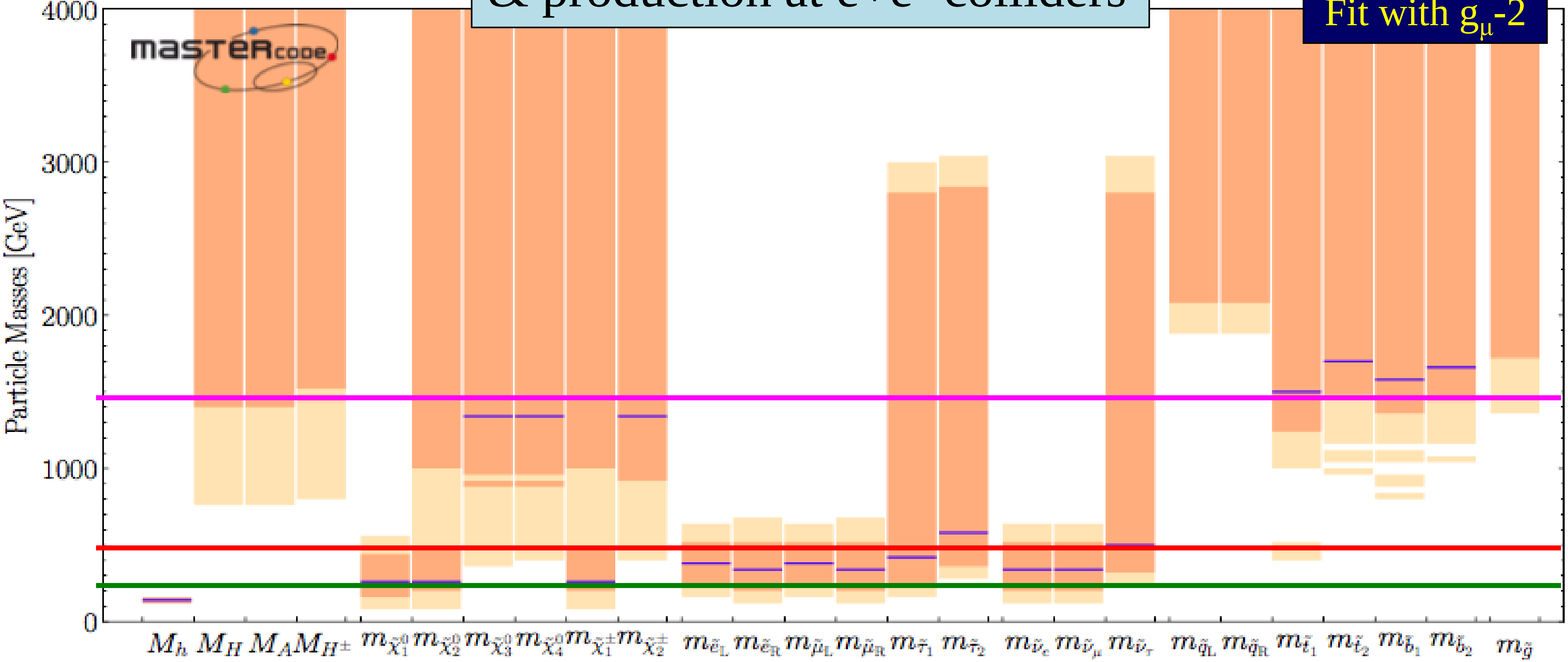
Squarks, gluinos could weigh ~ 1 TeV if drop g_μ-2

Bagnaschi, Sakurai, JE et al, arXiv:1710.11091

Sparticle Masses in the pMSSM

& production at e+e- colliders

Fit with g_μ-2



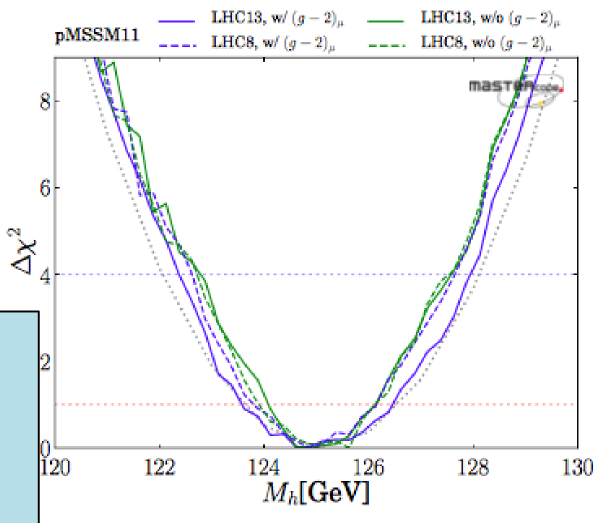
- **68 & 95% CL ranges**
- **Best-fit values**
- Accessible in pair production at **((ILC500))**, **(ILC1000)**, **CLIC**

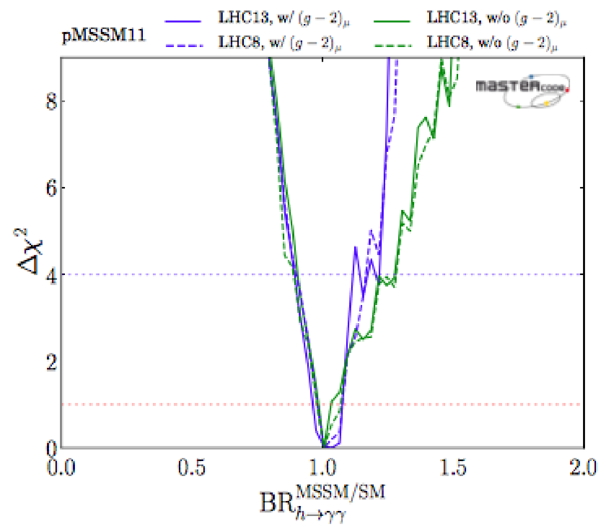
Bagnaschi, Sakurai, JE et al,

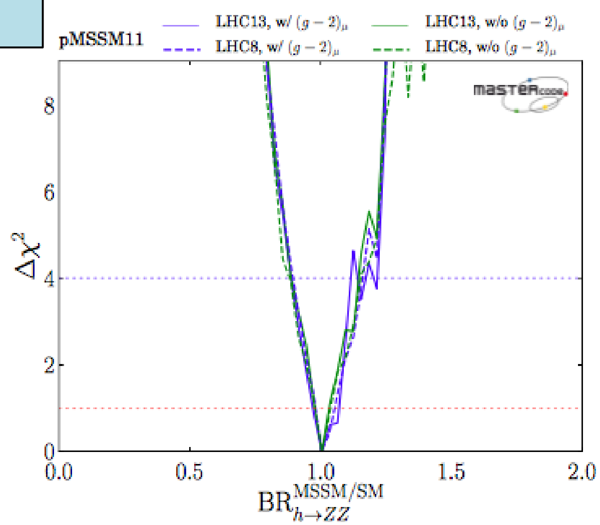
Higgs properties in the pMSSM

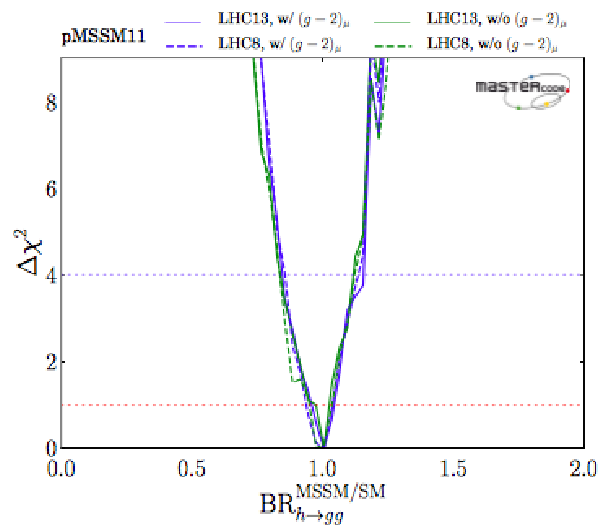
- **No issue with measured Higgs mass**
- Central values of decay BRs similar to SM
- **Substantial deviations possible**

Bagnaschi, Sakurai, JE et al, arXiv:1710.11091





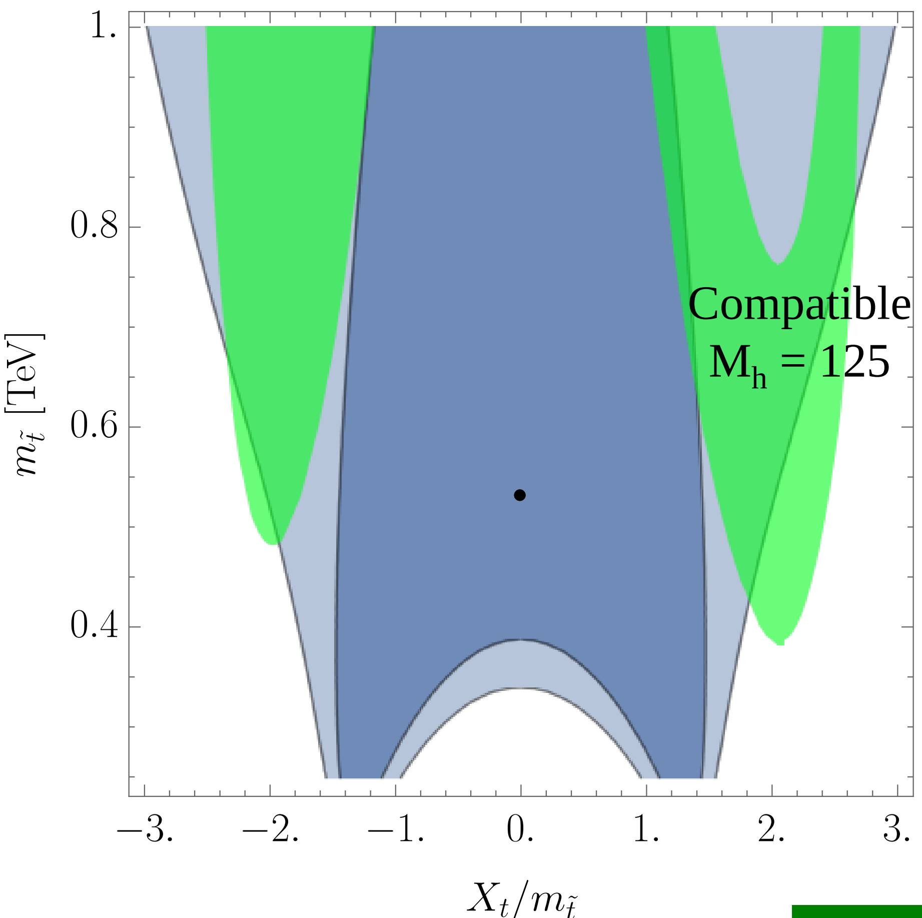




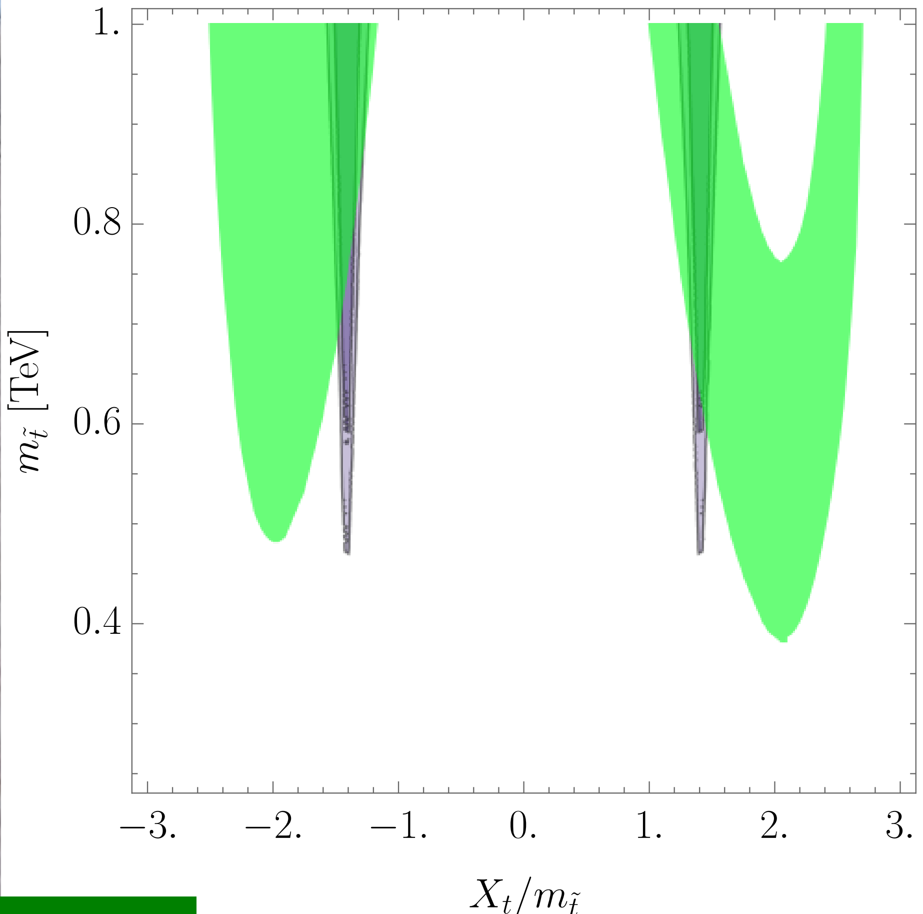
SMEFT Constraints on Light Stops

EMSY, arXiv:1803.03252

Current bounds



Possible HE-LHC bounds



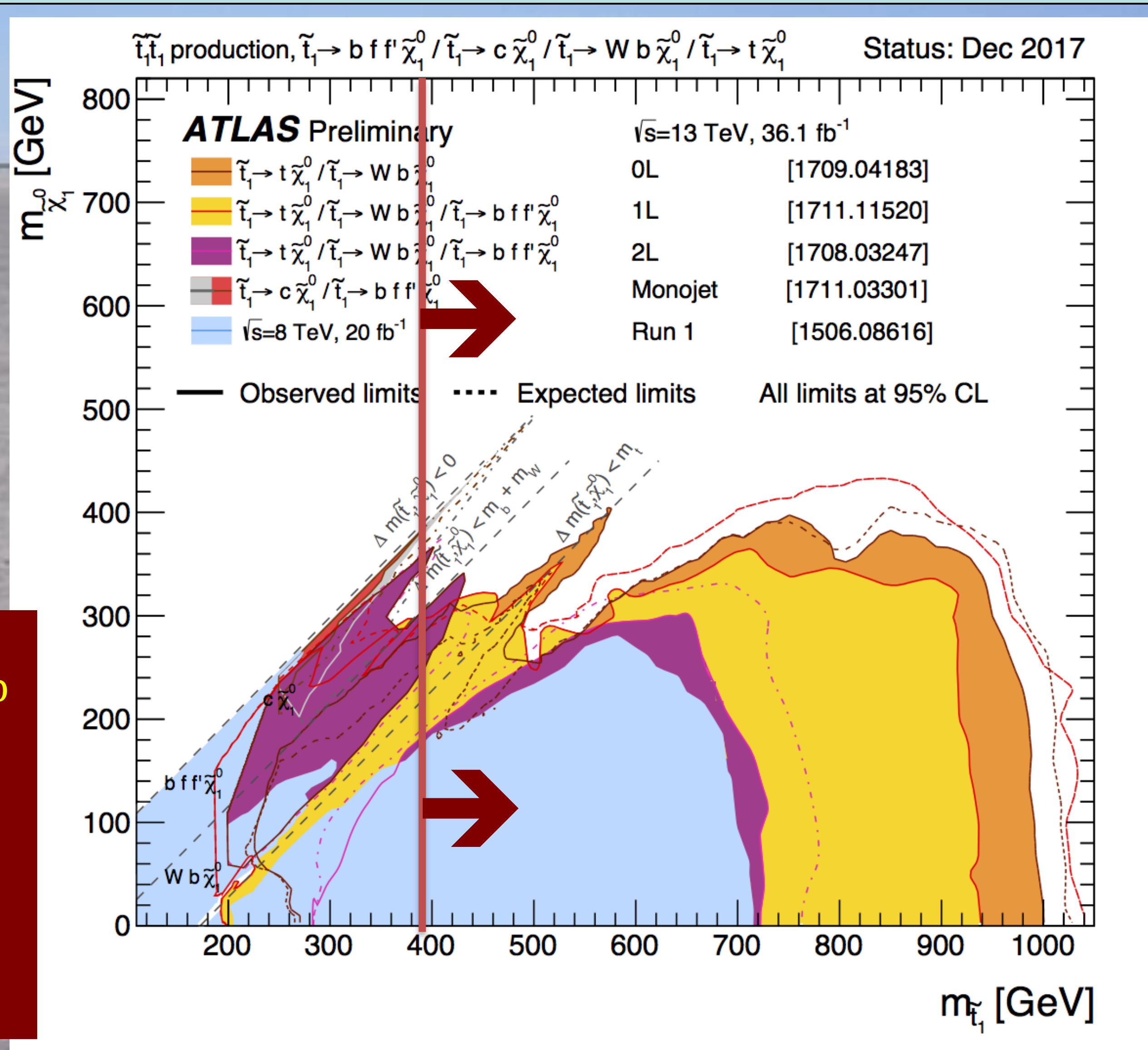
tan β = 20

Direct Constraints on Light Stops

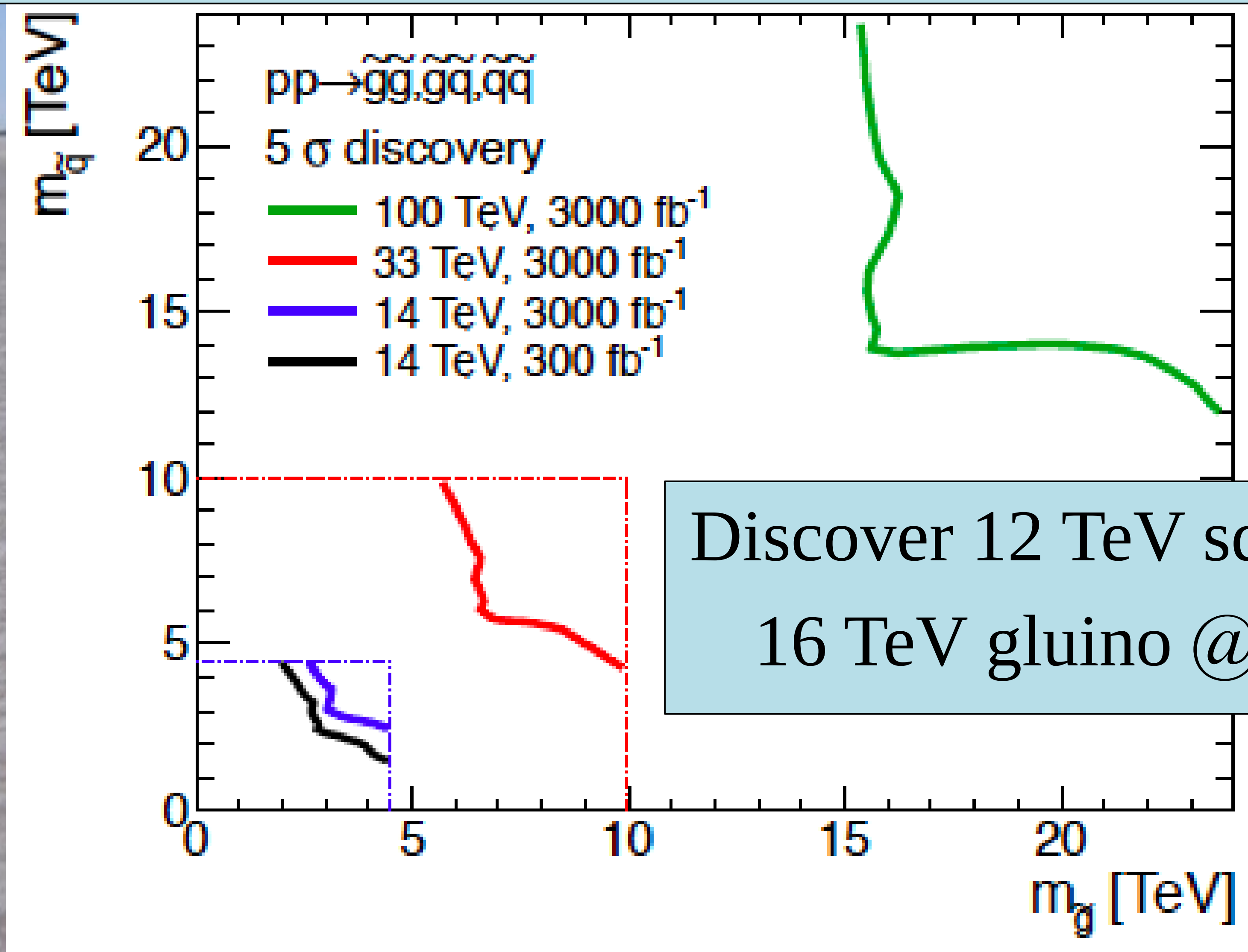
Depend on m_{LSP} not on tan β

Comparison with SMEFT depends on mixing X_t

Range of m_{stop} compatible with SMEFT and m_H constraints



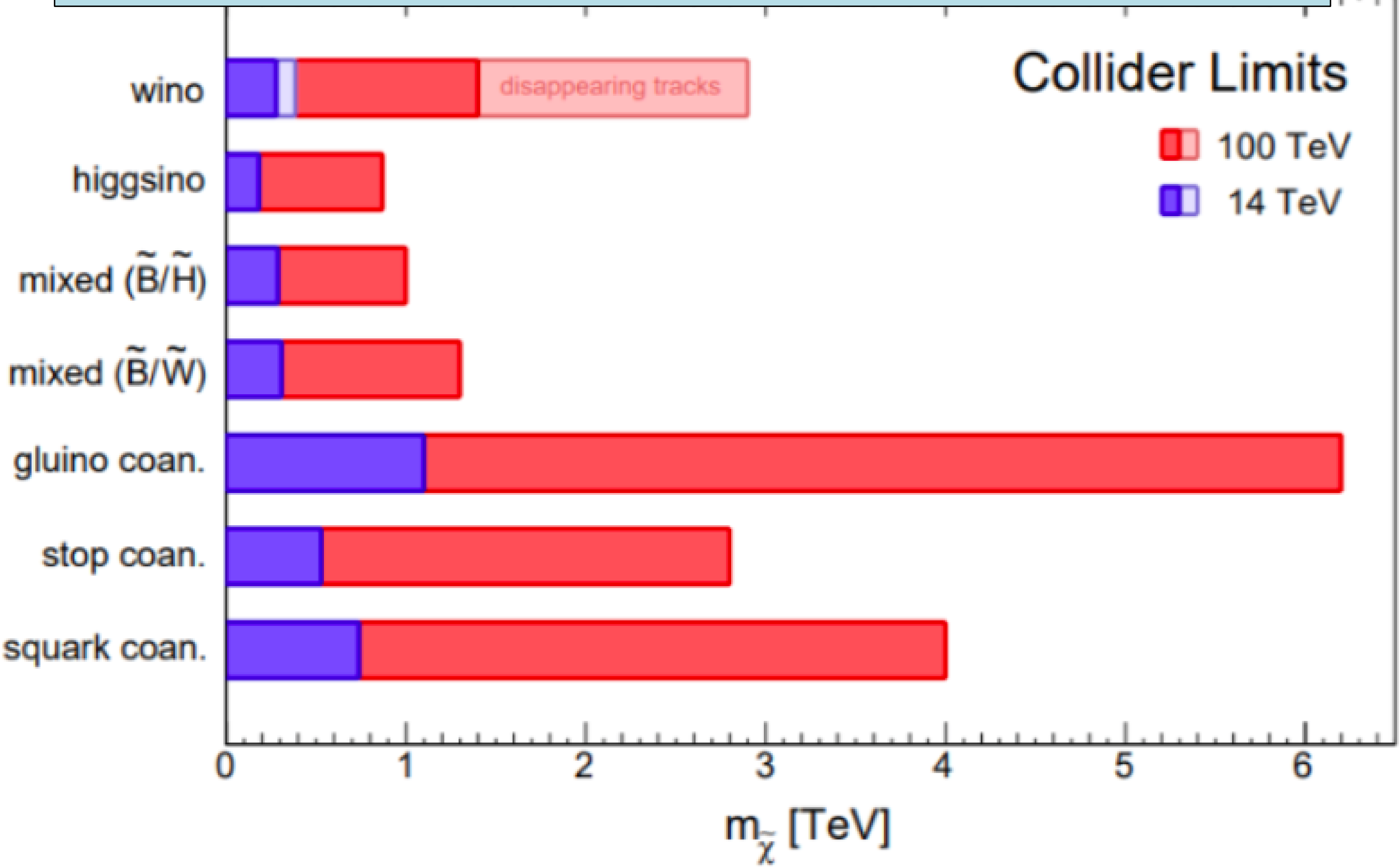
Squark-Gluino Plane



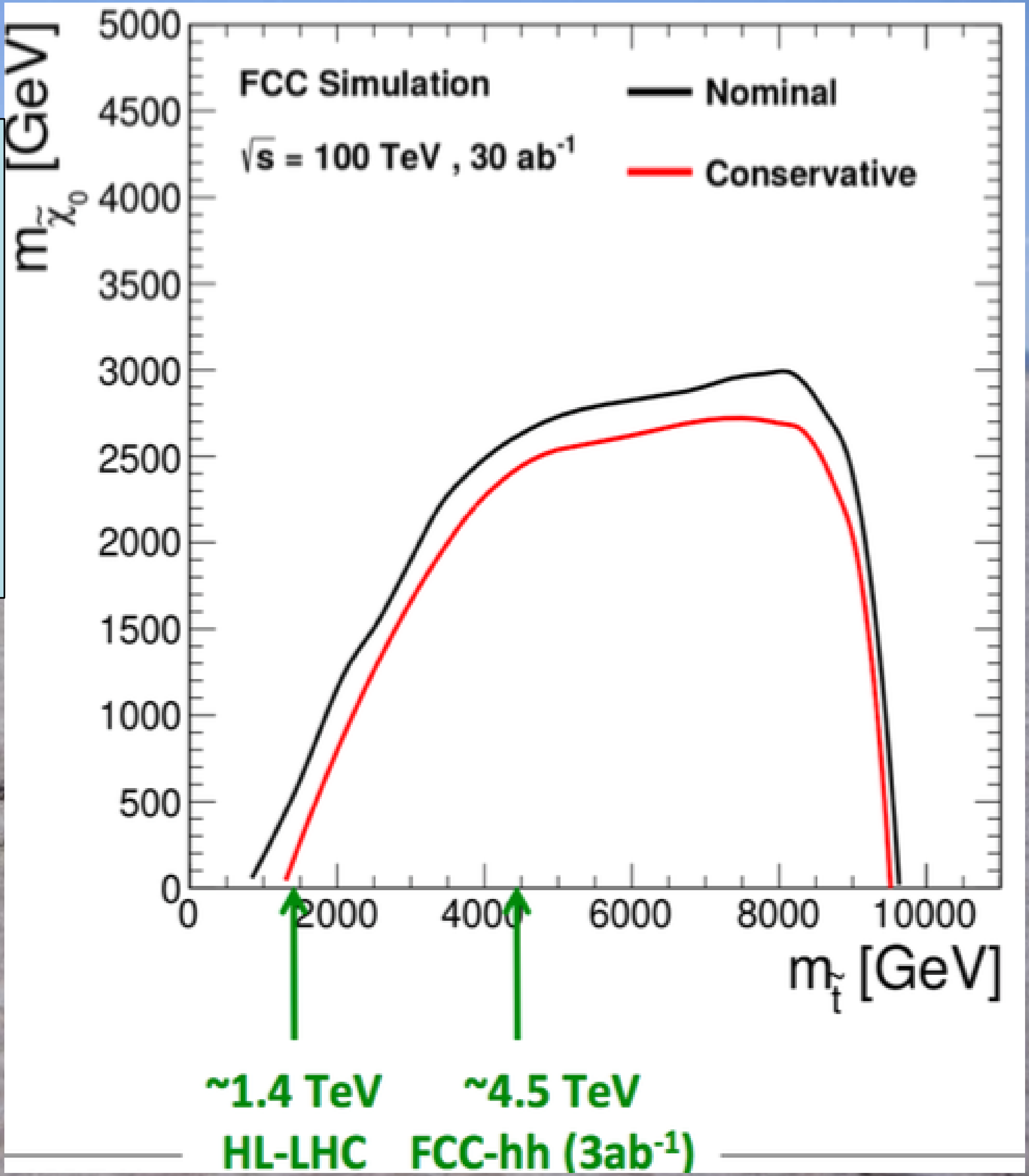
Discover 12 TeV squark,

16 TeV gluino @ 5σ

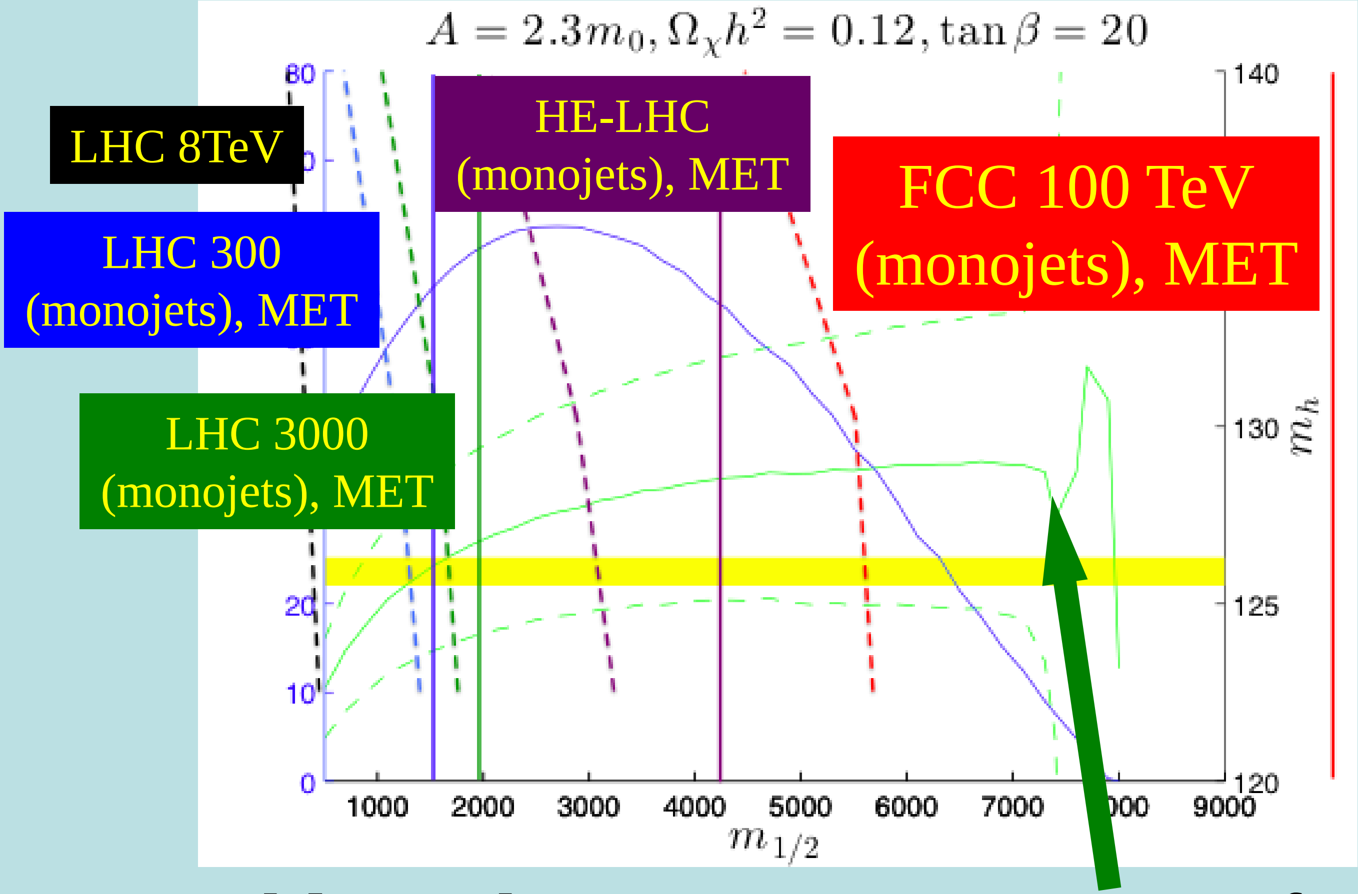
Neutralino Reach



Stop-Neutralino Plane



Exploring the **Stop Coannihilation Strip**



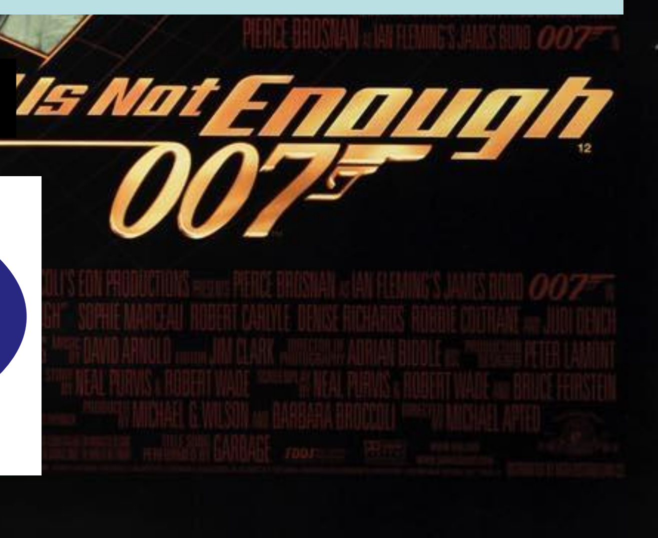
- Compatible with LHC measurement of m_h
- May extend to $m_\chi = m_{stop} \sim 6500$ GeV

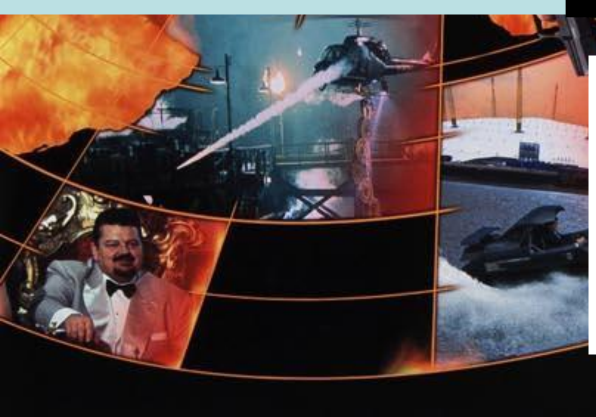
JE, Olive & Zheng: arXiv:1404.5571

- « Empty » space is unstable
- Dark matter
- Origin of matter
- Hierarchy/naturalness
- Masses of neutrinos
- Inflation
- Quantum gravity
- …

- HL-LHC is on its way
- ILC might be next
- CLIC’s energy advantageous
- FCC most versatile

The *Standard Model*





FCC
hh ee he