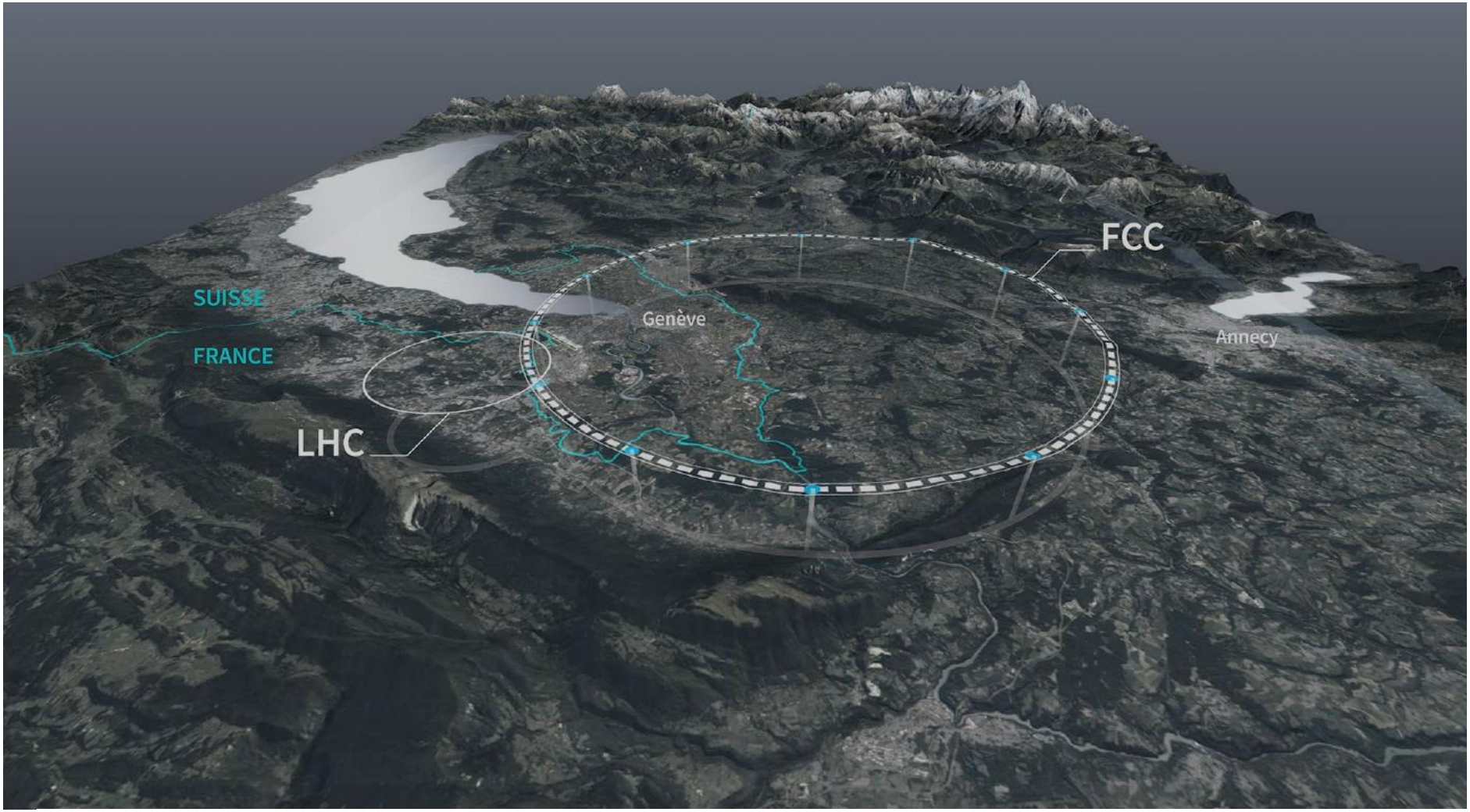
FCC: a beginners guide



Higgs Maxwell Workshop
19/2/25

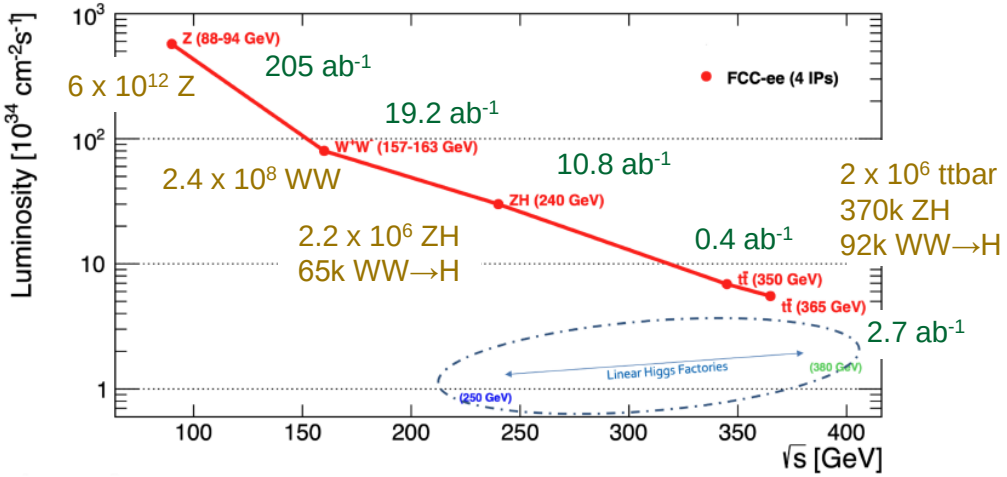
Guy Wilkinson
University of Oxford and CERN

FCC-ee energy points and luminosity goals

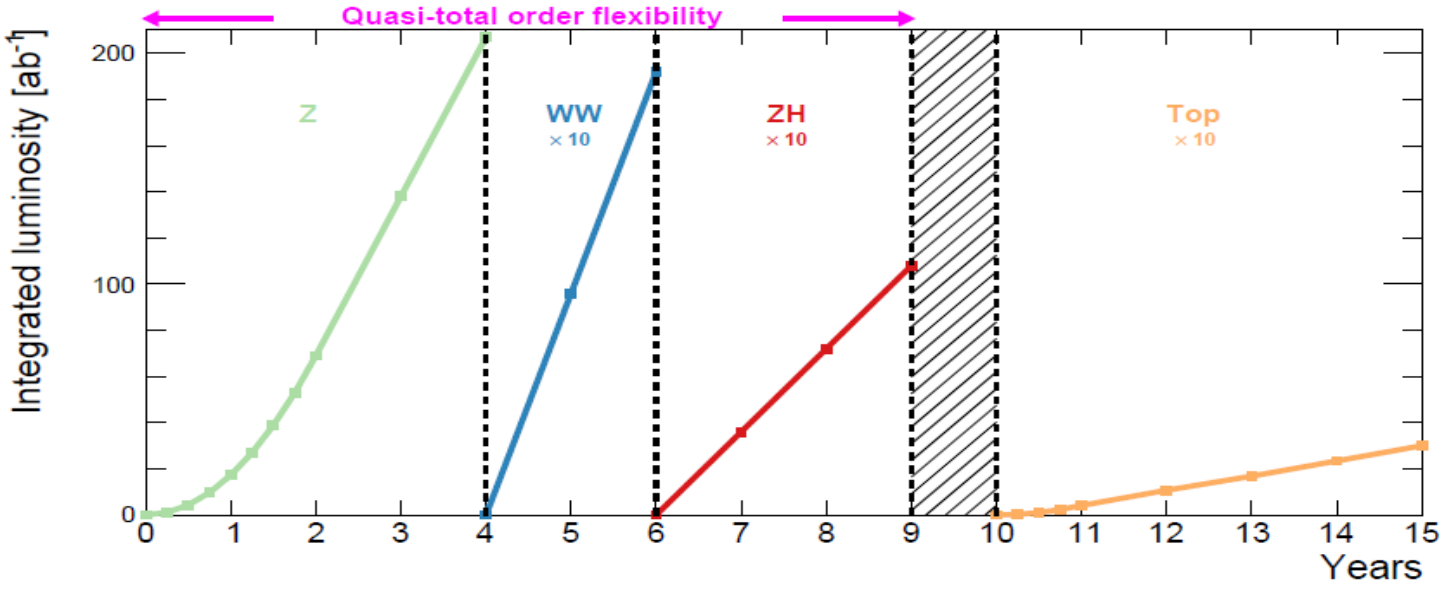
FCC-ee: two ring synchrotron with top-up injection, giving very high lumi between 88 & 365 GeV

Four interaction points.

Four (+) energy points in baseline plan, others (*e.g.* Higgs pole) under consideration.



Flexibility in order of operation for all energies below the ttbar threshold.



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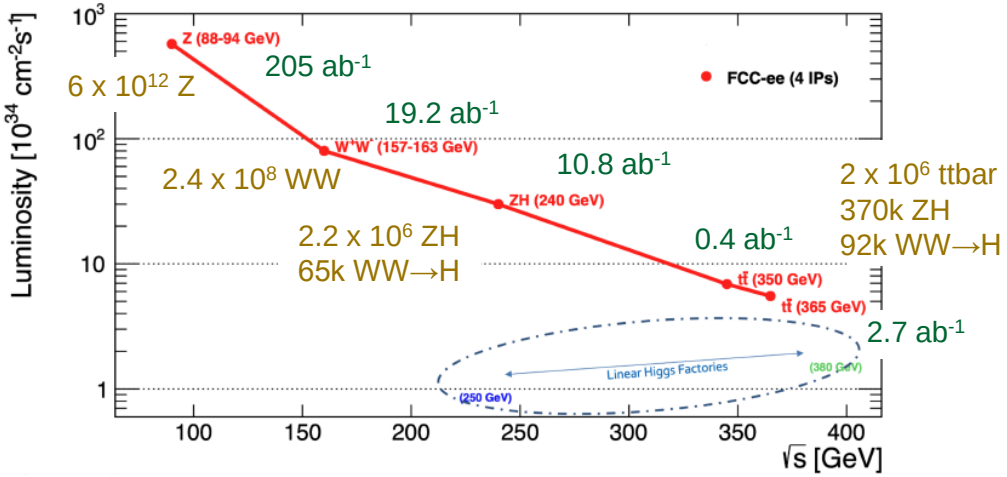

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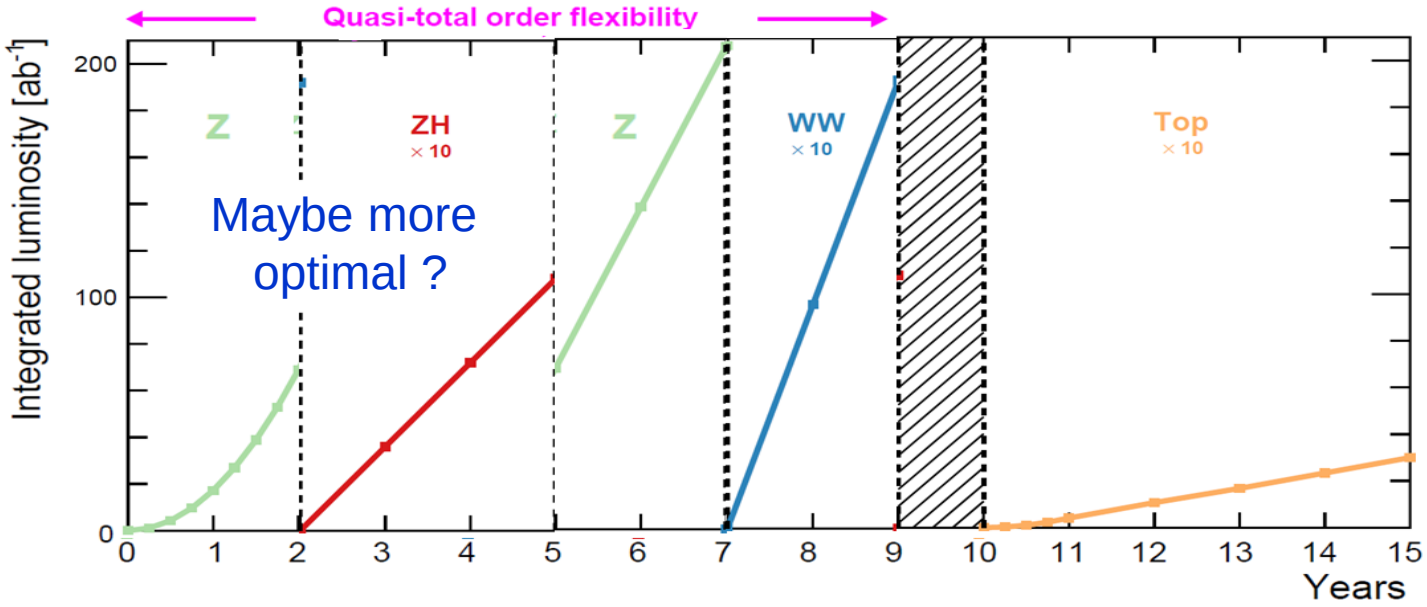
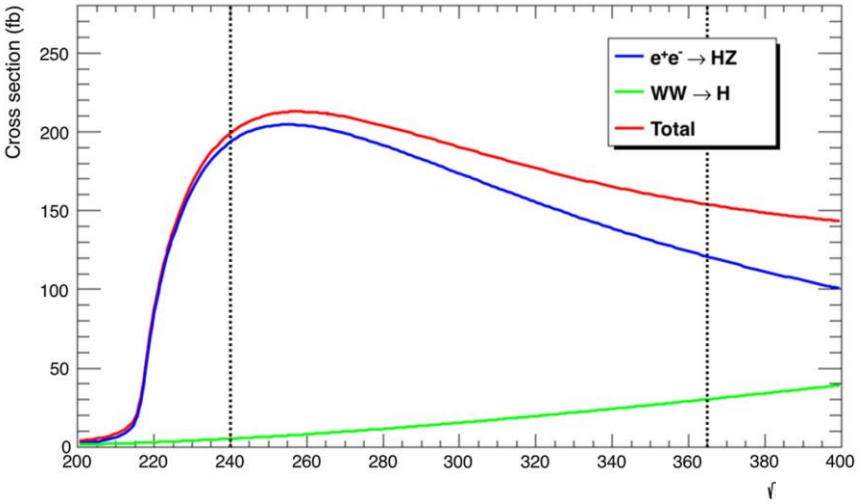
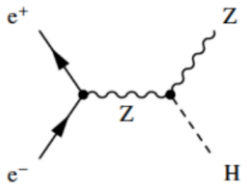
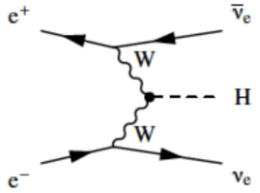


Higgs studies at FCC-ee

Central goal of FCC-ee: *model-independent* measurement of Higgs width and couplings with (<)% precision. Achieved through operation at two energy points.







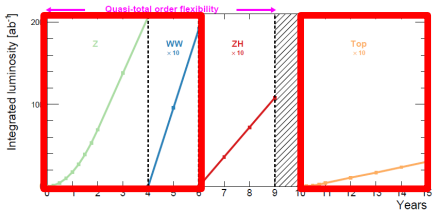
10.8 ab^{-1} at 240 GeV
2.2 x 10^6 ZH events
65k WW→H events

~3 ab^{-1} at 350-365 GeV
370k ZH events
92k WW→H events

- Sub-percent precision for most couplings, often with order of magnitude improvement on HL-LHC expectation (or for first time, *e.g.* H→ccbar).
- Higgs width measured → model independent !
- Mass measured to a few MeV.
- Not shown here: high hopes for H→ssbar, and tantalising possibility to get close to SM expectation for H→e$^+$e$^-$ (unique to FCC-ee).

Coupling	HL-LHC	FCC-ee (240–365 GeV)
κ_W [%]	1.5*	0.29
κ_Z [%]	1.3*	0.11 ← !
κ_g [%]	2*	0.68
κ_γ [%]	1.6*	0.18
$\kappa_{Z\gamma}$ [%]	10*	10.2
κ_c [%]	–	0.96
κ_t [%]	3.2*	3.1
κ_b [%]	2.5*	0.50
κ_μ [%]	4.4*	3.50
κ_τ [%]	1.6*	0.47
BR_{inv} (<%, 95% CL)	1.9*	0.12
BR_{unt} (<%, 95% CL)	4*	0.72

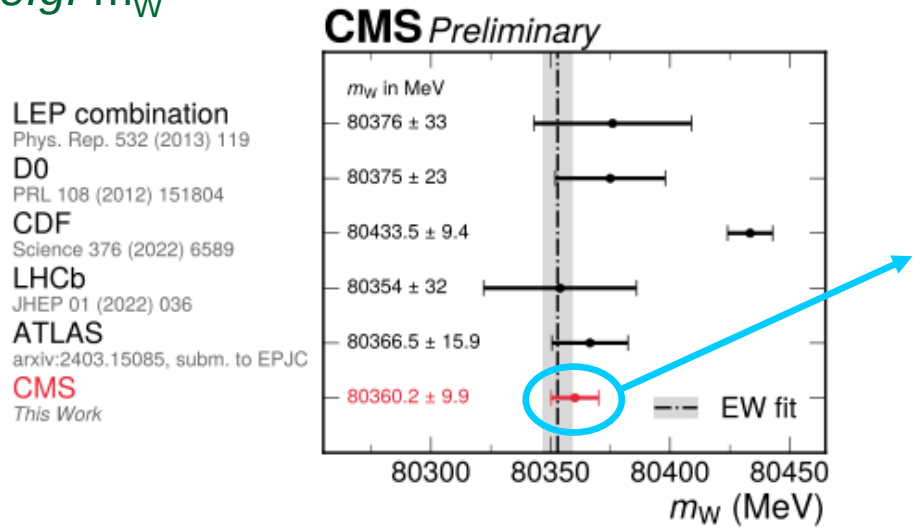
Precision electroweak

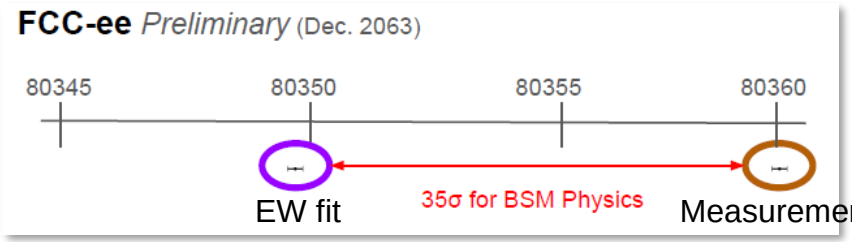


Precision EW measurements are central element of FCC-ee programme. At Z pole, FCC-ee will accumulate 10^5 more decays than LEP. If systematic challenge can be met, gain in indirect new physics sensitivity will be remarkable. Ditto WW threshold.

Key feature: ability to measure E_b ultra precisely through resonant depolarisation !

e.g. m_W

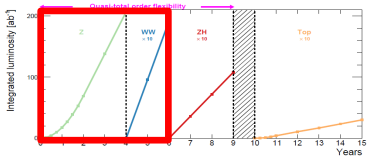




(2025 central values, FCC-ee sensitivity)

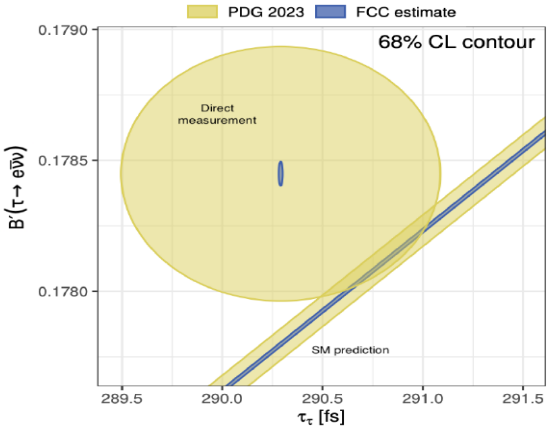
Estimated statistical sensitivity of 180 keV, with E_{CM} uncertainty subdominant, a ~50x improvement on CMS result. Need to then match this sensitivity for the predicted value (`EW fit'); for this FCC-ee must measure the top mass precisely - foreseen!

Flavour physics & direct searches



Tera-Z will produce a huge number of b hadrons in a very clean environment. Many measurement opportunities that are highly complementary to LHCb Upgrade II. FCC-ee will also provide world's largest sample of 'background free' tau decays.

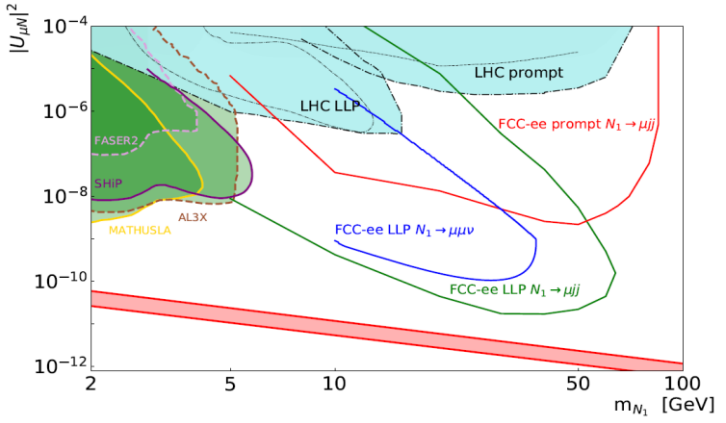
e.g. lepton universality tests with taus.

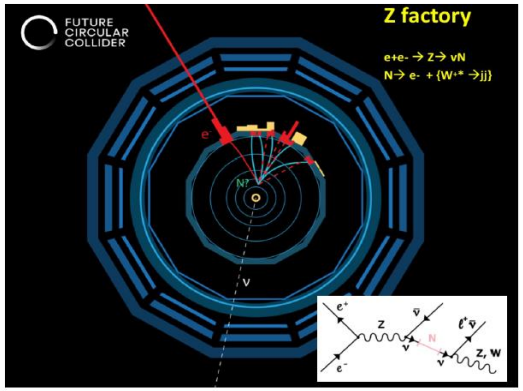


FCC (+ CEPC) is the *only* planned collider where b, c and τ physics can be significantly advanced in the post HL-LHC / Belle II era.

(Also great opportunities to measure 'on-shell' CKM elements in W decays).

Furthermore, high direct search potential from decays in Tera-Z sample
e.g. heavy neutral leptons, with sensitivity complementary to LHC and SHiP



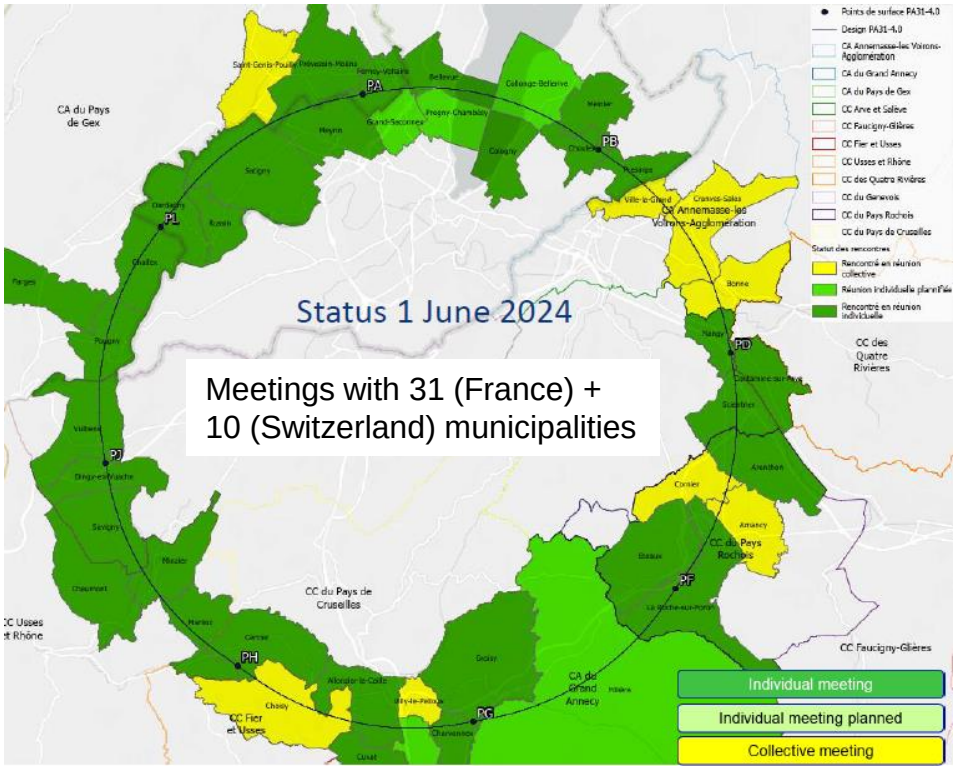


Status of project

Final report of Feasibility Study to be submitted end of March. Culmination of ~10 years work, of which physics & accelerator studies have been only one aspect.

For example, reference ring layout chosen from ~100 initial variants.
Input considerations:

- Geology (test drillings underway);
- Surface constraints;
- Environment;
- Infrastructure;
- Machine performance.



Continual and ongoing engagement with local communities.

Technical, scientific and financial feasibility carefully scrutinised.
Verdict on Mid-Term Report very positive.

Assumed timeline

Overall project + machine:

2025-2027	‘pre-TDR phase’
Late 2027 / early 2028	CERN Council approval decision
2033-2041	Civil engineering
2039-2043	Technical infrastructure installation
2041-2045	Accelerator installation
2046	Start of beam commissioning and operation
2048	Nominal beam operation

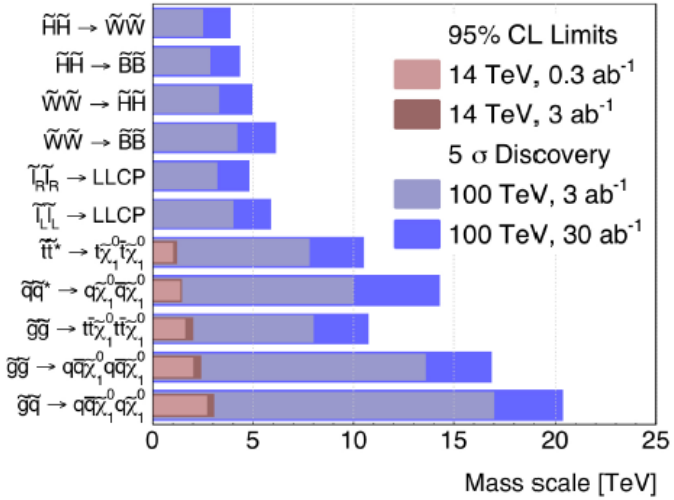
Experiments:

Early 2028	Call for CDRs, formation of collaborations
2030	Submission of CDRs
2035	Submission of TDRs, start of construction
2041	Detector installation
2045	Start of commissioning

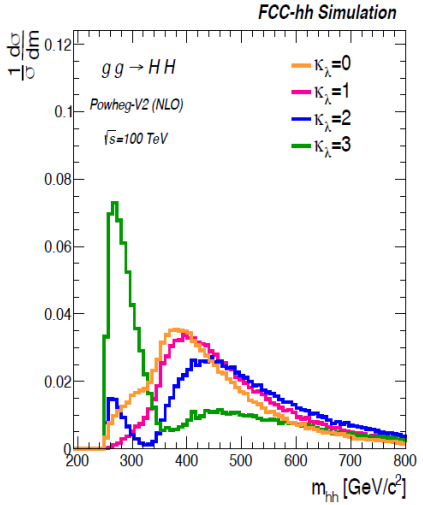
FCC-hh: the infinity machine

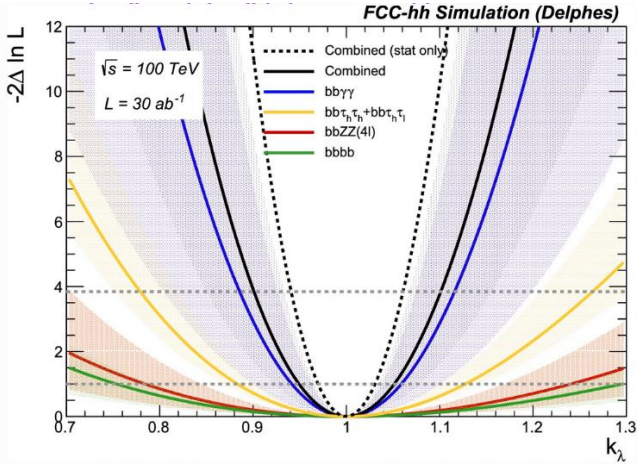
FCC-hh could begin 10 years post FCC-ee, *i.e.* 2070. Eye-watering physics reach.

FCC-hh will have awesome direct search potential….



…and also complete our study of the Higgs with a precise measurement of the self-coupling.





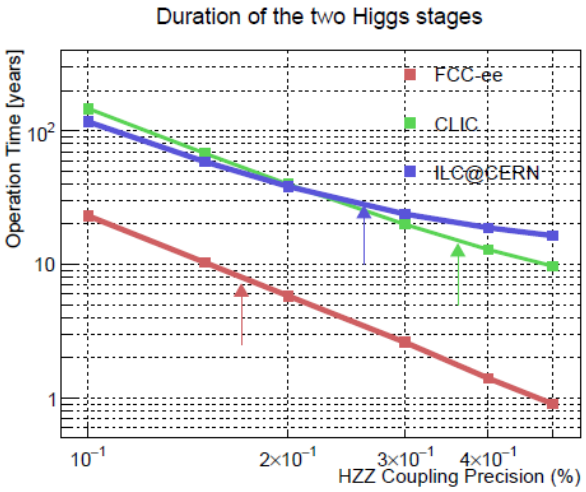
And again, the physics will be *diverse*, just as at the LHC. All of the above, plus flavour physics, heavy ion physics, forward-physics facility *etc.*

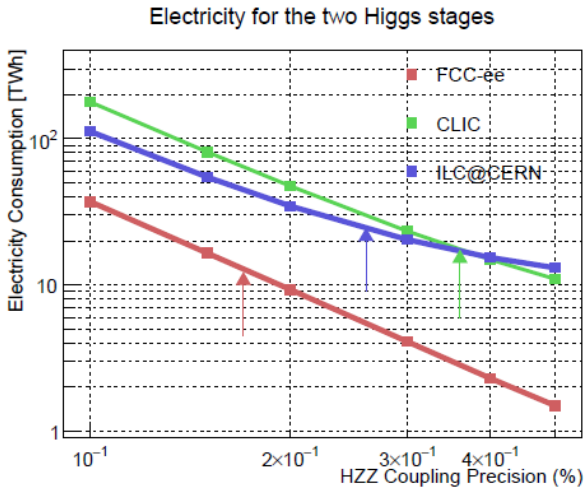
Current baseline: 14T Nb_3Sn dipoles operating at 1.9K (but 4.5K looks feasible…), to allow for 85-90 TeV CoM. Progress on HTS could push this to above 100 TeV. Some breaking news: recent updates on power consumption extremely positive !

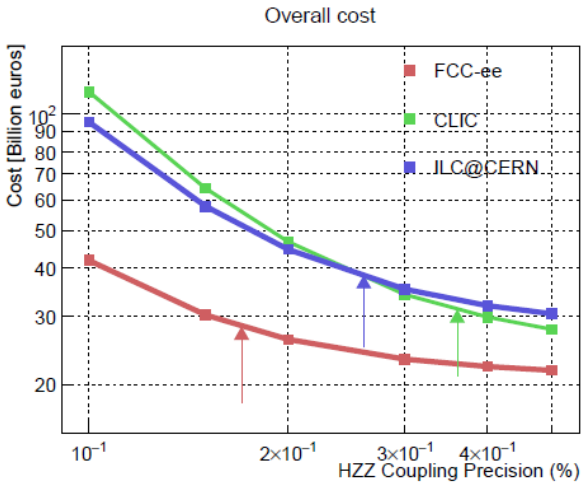
Backups

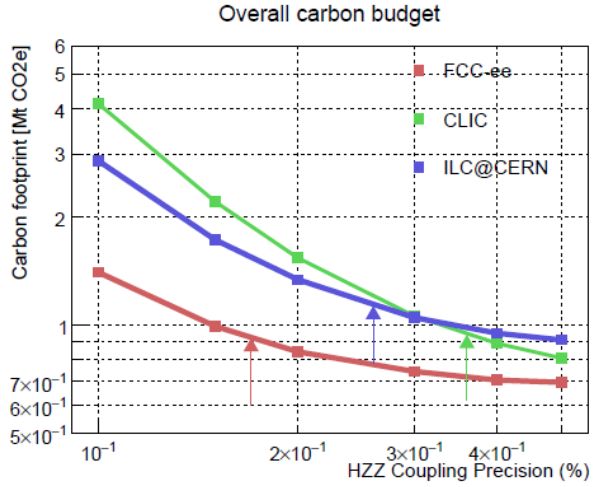
HZZ coupling for FCC-ee and linear colliders

Precision vs time, electricity usage, cost and carbon budget [arXiv:2412.13130].









(arrows indicate nominal run plan)