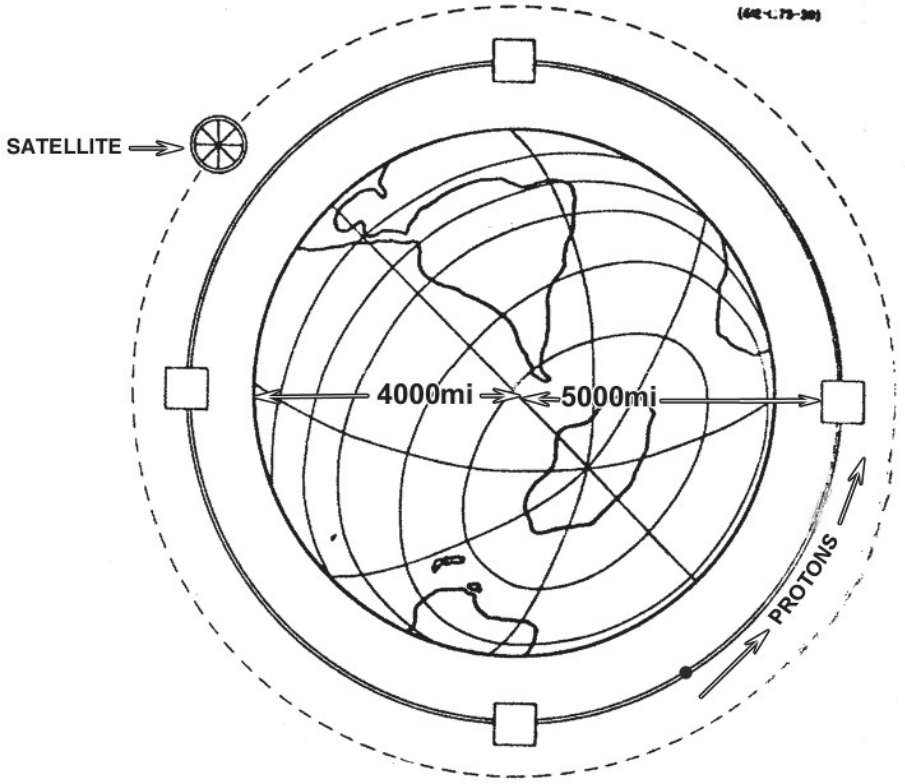
A strategy for high energy physics



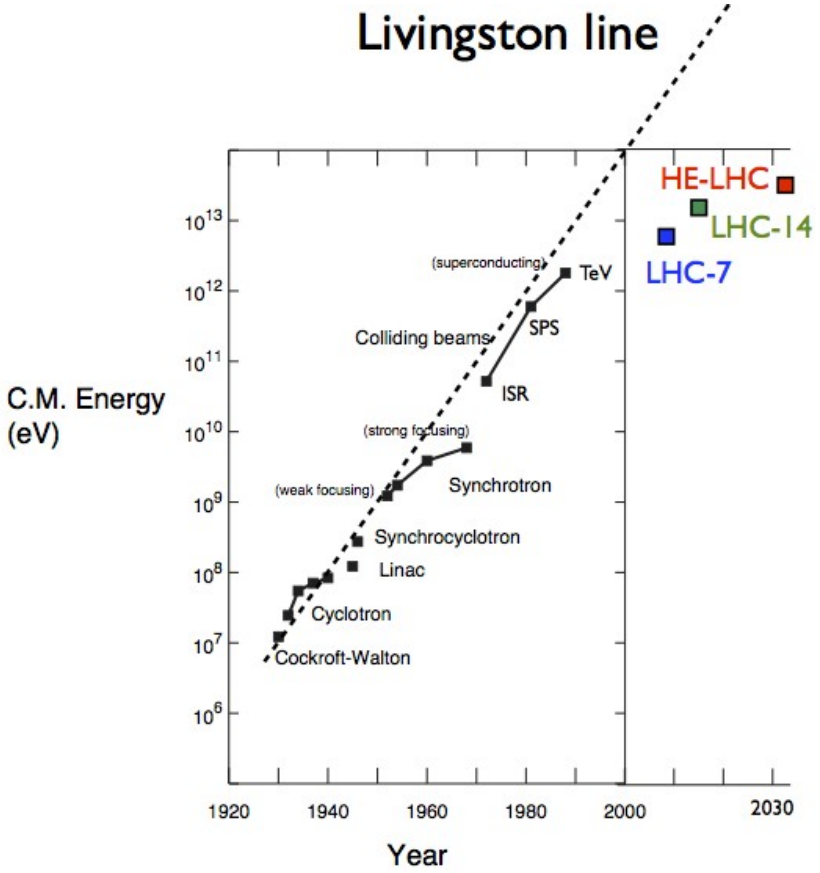
The short and long-term future of HEP (and some words on my favourite projects)

Round table, 28/05/2019, IFIC Valencia

Marcel Vos, IFIC (UV/CSIC) Valencia

Note:
Fermi, in his 1954 Nobel lecture,speculated that by 1994 we might need to build a planet-sized accelerator
The size of the LHC may be a deception, its center-of-mass energy is not far behind what Fermi hoped for
The long-term future of science is hard to predict

How did we get here?



Livingston's law: a factor 10 increase every 6 years!

Not an adiabatic development of one technology; continued progress is the result of a sequence of breakthroughs: generator → cyclotron → synchrotron → collider → ?

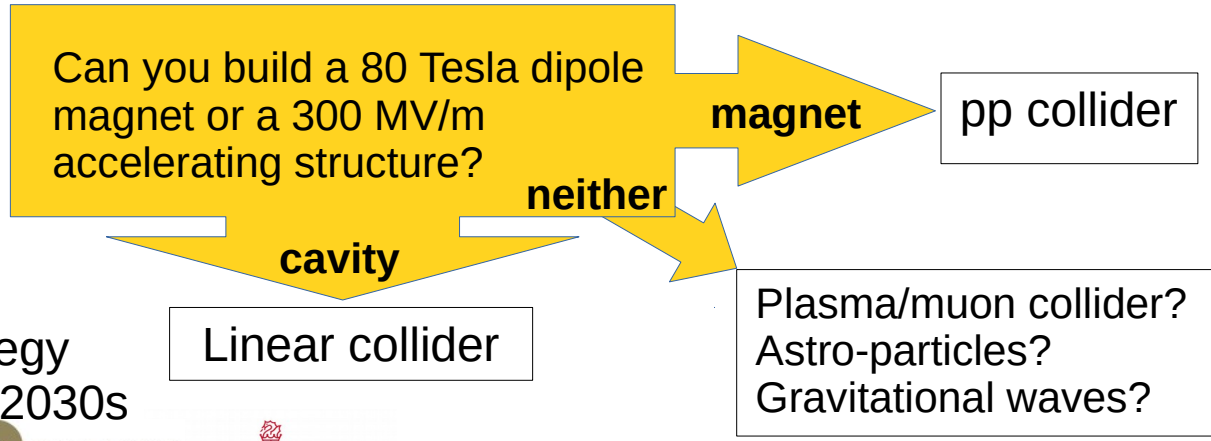
Circular (hadron) colliders have dominated HEP in the last decades. It is hard to predict what will be the winning technology for the second half of this century.

A long-term vision for HEP

From the Spanish input to the European strategy update (A. Pich, T. Rodrigo et al.):

o R&D in novel acceleration techniques is considered a must for the future of the field. The AWAKE program should be completed and complemented with other initiatives (plasma wakefield acceleration, muon collider, etc.). A coordinated R&D program between CERN and the individual national initiatives should be consolidated in a timely manner.

Long-term progress in HEP driven by technological progress…
Can we make colliders a factor 10 better by 2050?



D. Schulte, μ collider CDR by next strategy
W. Leemans, wakefield collider CDR in 2030s

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The next large-scale facility

There is a consensus that the next large facility in HEP should be an e^+e^- collider

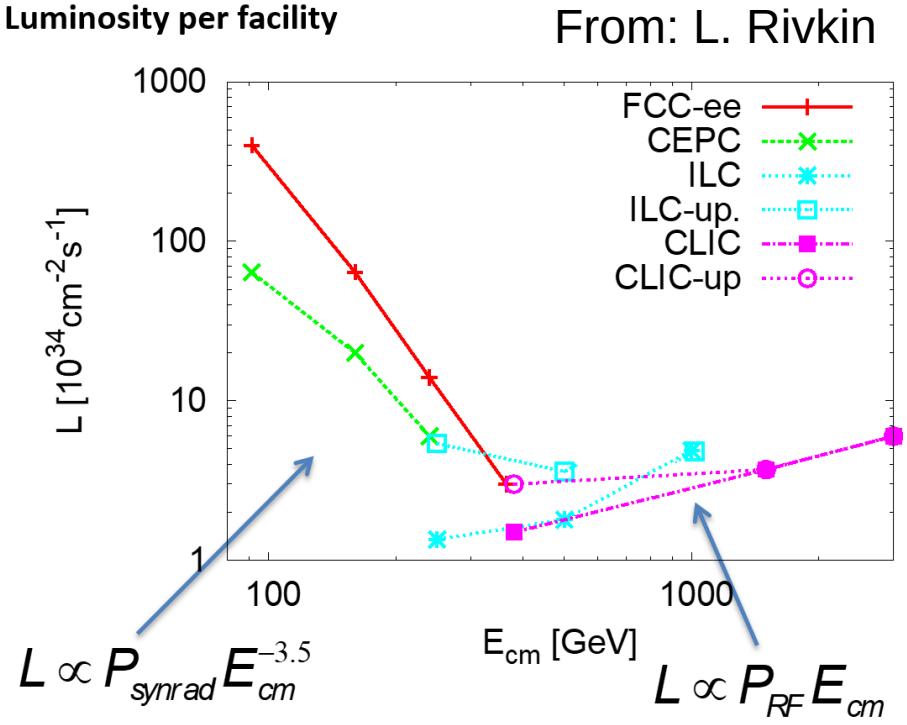
Not necessarily in Europe (cf. Geoff Taylor for Asia, Young-Kee Kim for America's)

Circular:

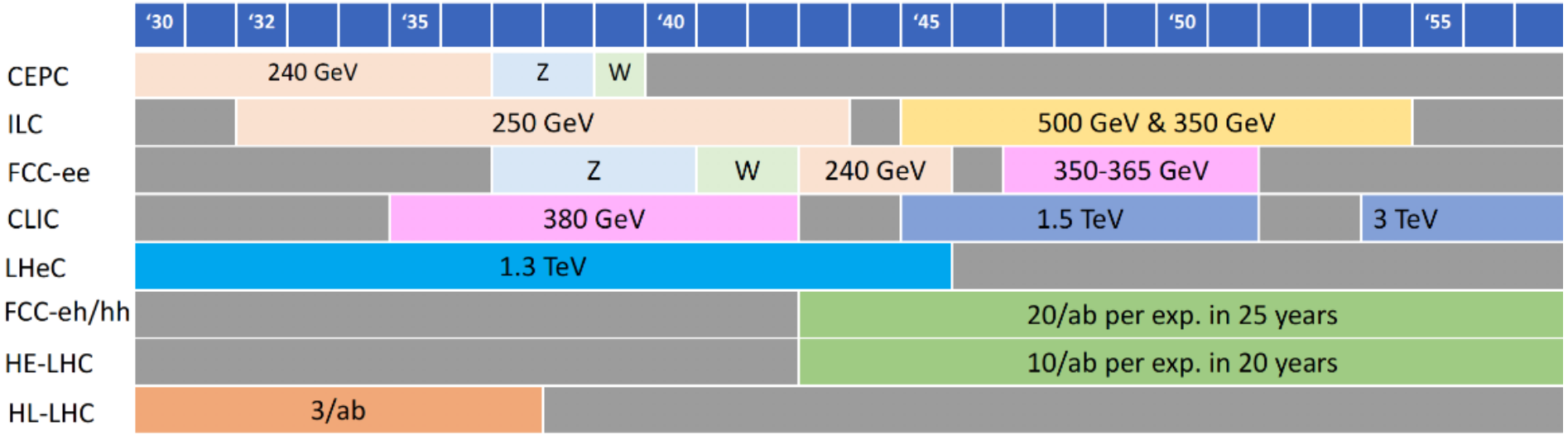
- **Higgs factory**
- **+ Z-pole extravaganza**
- **+ top (FCCee, not CEPC)**

Linear:

- **Higgs factory**
- **+ top**
- **+ Higgs self-coupling**
- **+ ….**



Technical readiness



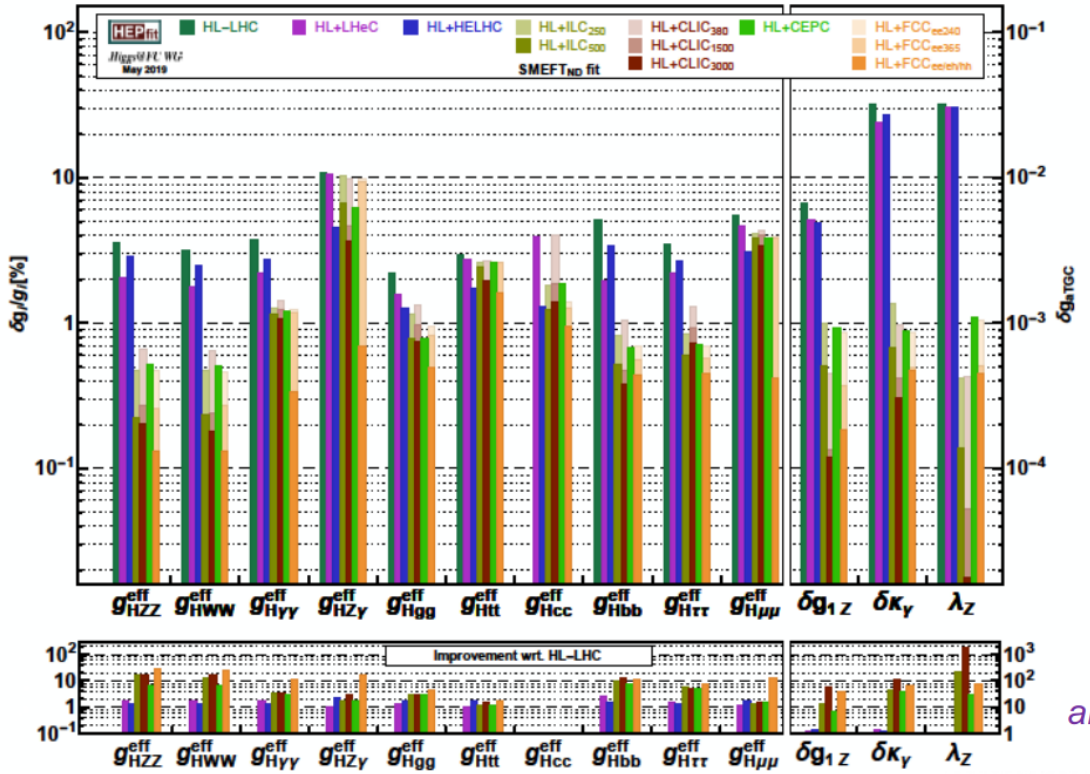
Note: planning well into the second half of the century (FCCee + FCChh)
ILC (TDR 2013), CLIC (CDR 2012), FCCee/CEPC (CDR 2018)
Earliest date for physics: CEPC (2030), ILC (2033), CLIC (2035), FCC-ee (2039)

“Do not anticipate obstacle to commit to either CEPC, FCC-ee, ILC or CLIC”, D. Schulte

Higgs physics potential

Cross-project comparison of Higgs physics potential

From: B. Heinemann



Effective Higgs couplings

- Constraints approach 0.1% precision for gauge bosons
- Major improvement w.r.t. HL-LHC for many colliders for fermions

Trilinear gauge couplings

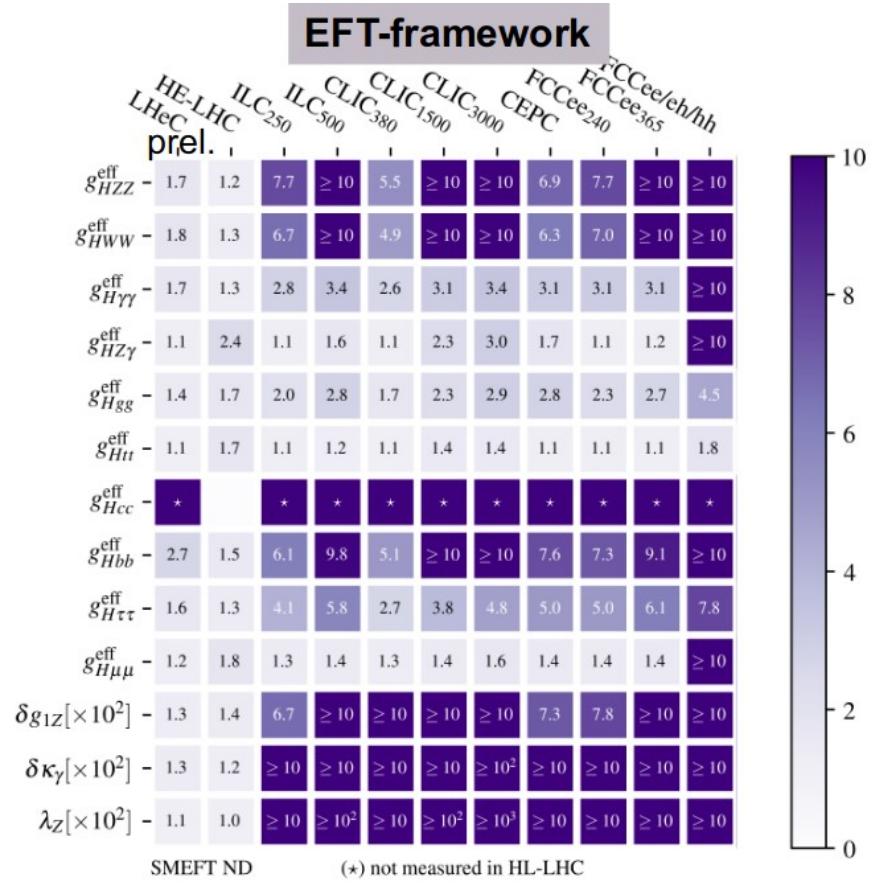
- Will achieve precision 10^{-3}-10^{-4}
- About 2-3 orders of magnitude better than LEP

Tremendous amount of work by J. de Blas et al.

arXiv:1905.03764

Higgs physics potential

From: B. Heinemann



"All e^+e^- colliders achieve major (and comparable) improvements in their first stage already in probing Higgs sector compared to HL-LHC"

Beware of the small-print:
- *S1 vs. S2 scenarios*
- *full vs. fast simulation*
- *EFT vs. Kappa fit*
- *still preliminary!!*

		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
2nd/3rd 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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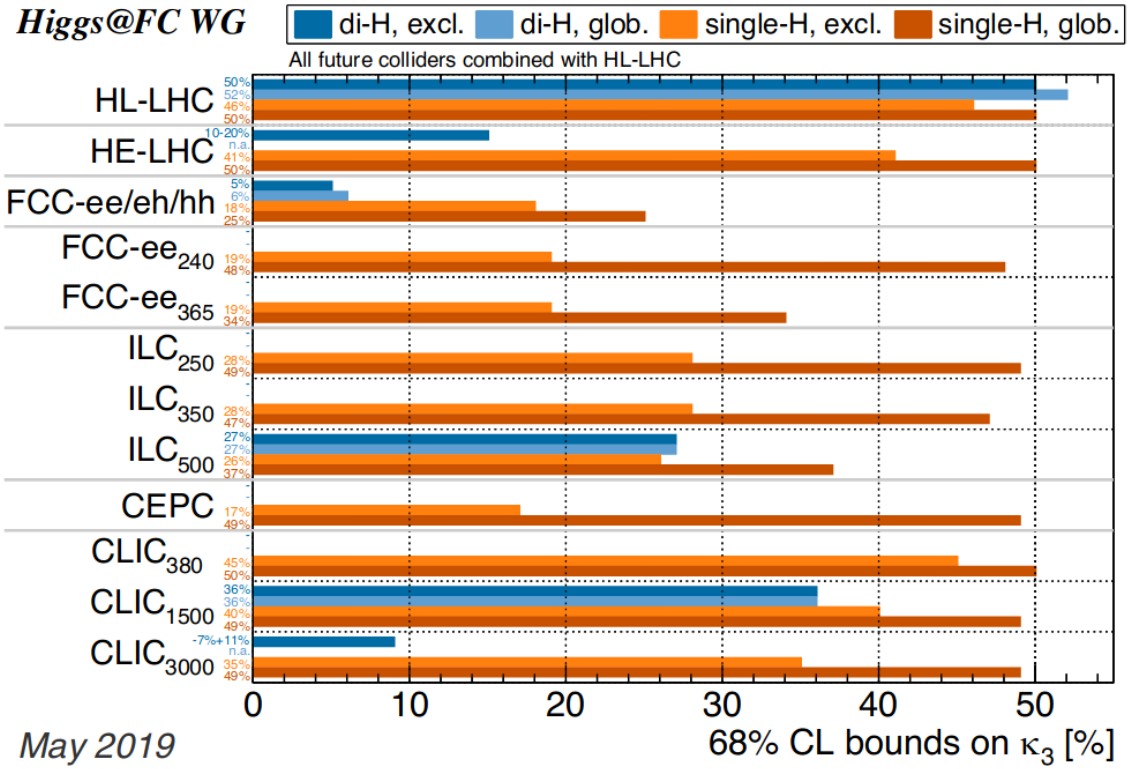
Higgs self-coupling

Di-Higgs:

- HL-LHC: ~50% or better?
- Improved by HE-LHC (~15%), ILC_{500} (~27%), $CLIC_{1500}$ (~36%)
- Precisely by $CLIC_{3000}$ (~9%), FCC-hh (~5%),
- Robust w.r.t other operators

Single-Higgs:

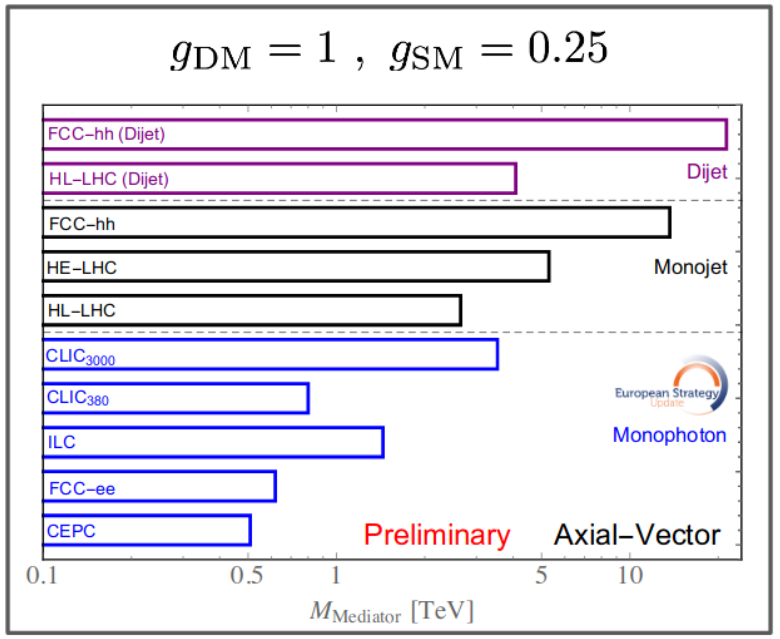
- **Global** analysis: FCC-ee365 and ILC500 sensitive to ~35% when combined with HL-LHC
  - ~21% if FCC-ee has 4 detectors
- **Exclusive** analysis: too sensitive to other new physics to draw conclusion



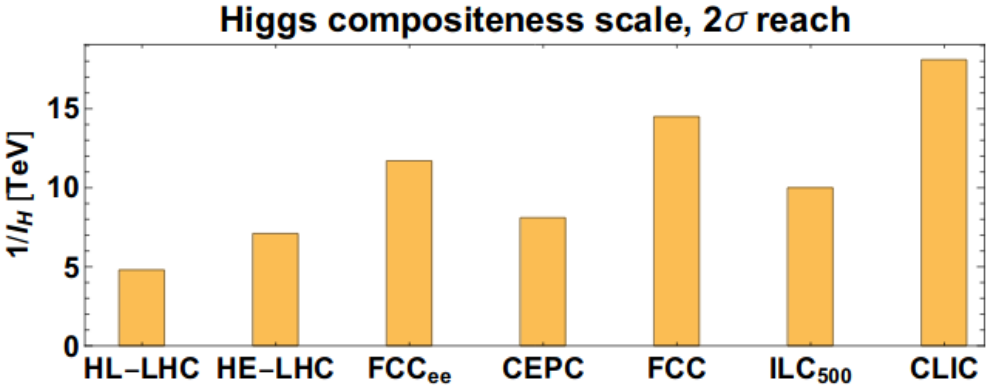
From: B. Heinemann

Robust, direct and precise self-coupling requires high energy (ILC500 - FCChh)

Top, EW, BSM...



From: B. Sphicas



Searches obviously benefit from energy reach

Energy + precision (CLIC 3 TeV) very competitive

Note: top (mass, EW couplings) largely absent in discussion in Granada
EW precision analysis not ready; obviously benefits from GigaZ/TeraZ

Summary

Lively (but very civilized) discussions…

There is some consensus on the overall direction (e^+e^-),
but different views on the implementation details (where?, how?, when?)

Optimal strategy depends on int'l developments (ILC in Japan, CEPC in China,...)

Longer-term future of CERN and HEP
- old vs. new accelerator technology: when will muon/wakefield colliders take over?
- CERN mandate: diversify into other branches of fundamental physics?

Let's not forget detector R&D or computing!

Good luck to those who draft the briefing book and the strategy!!