Muon Collider Physics&Benchmarks I

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Short-Term Goal: SnowMass21

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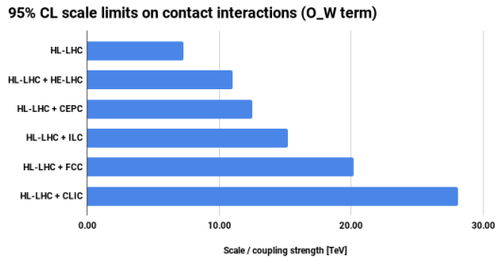
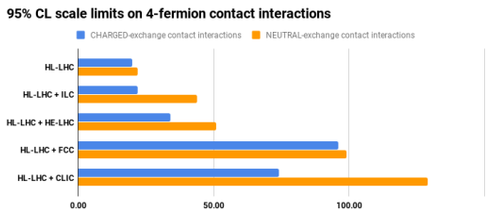
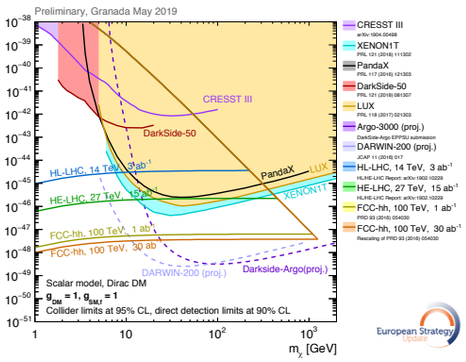
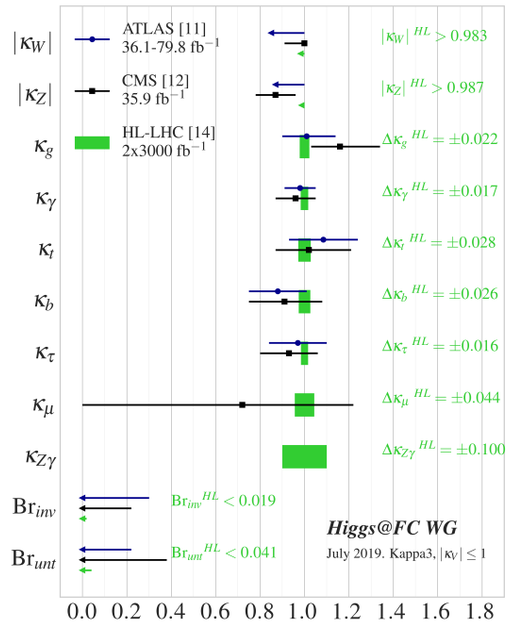
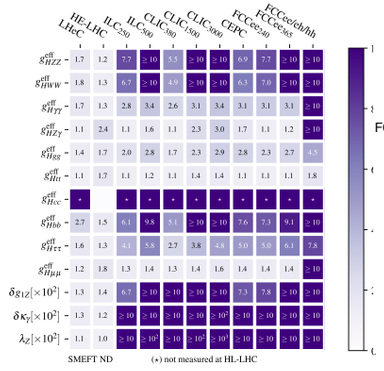
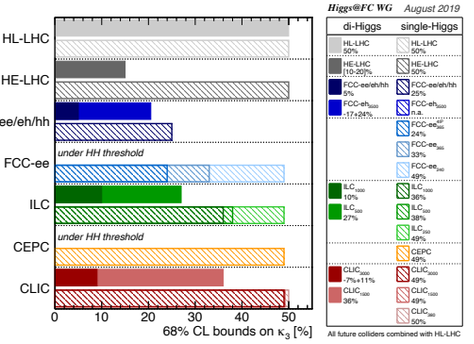


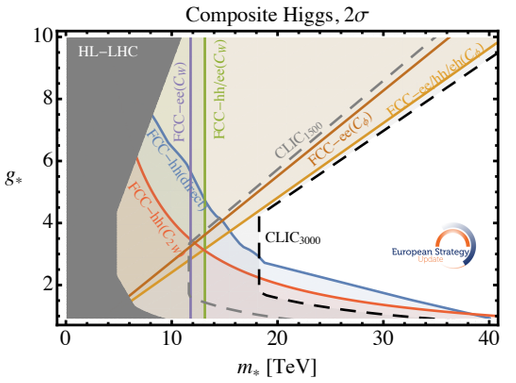


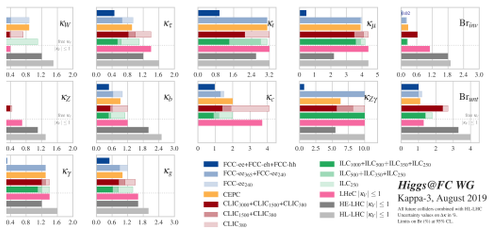


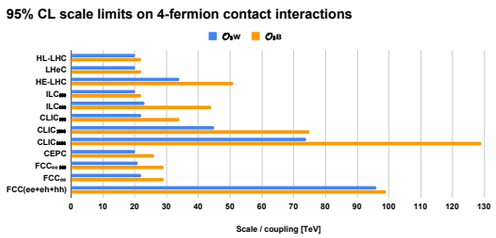


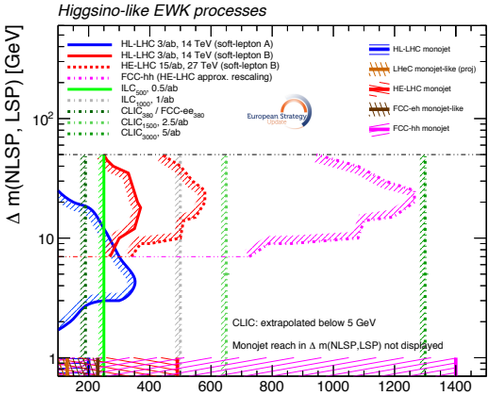


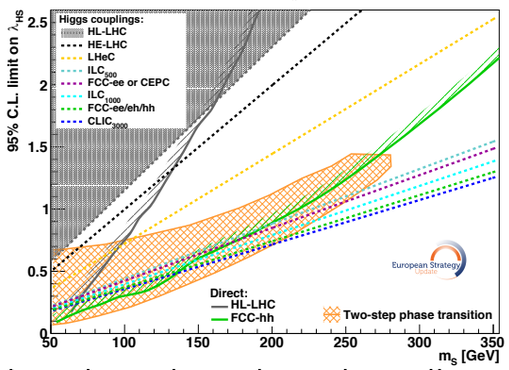


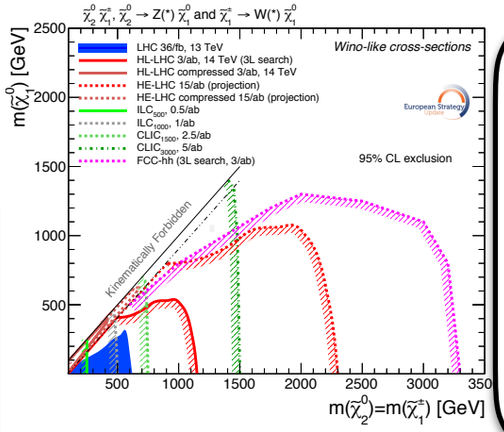


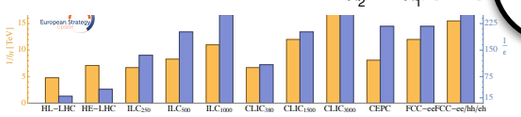


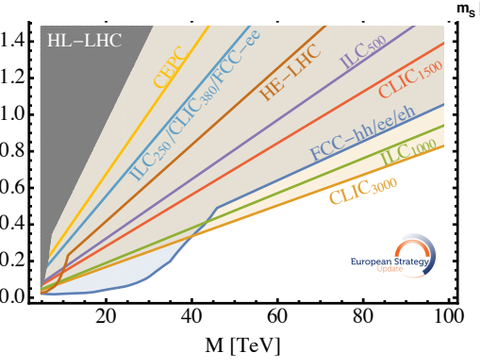


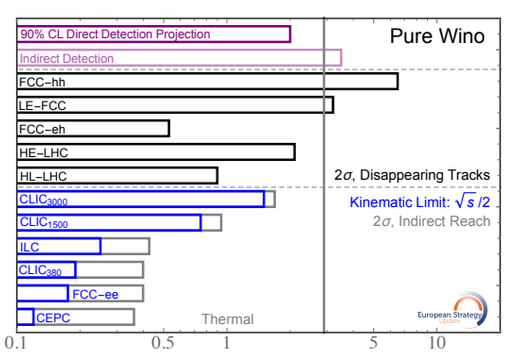


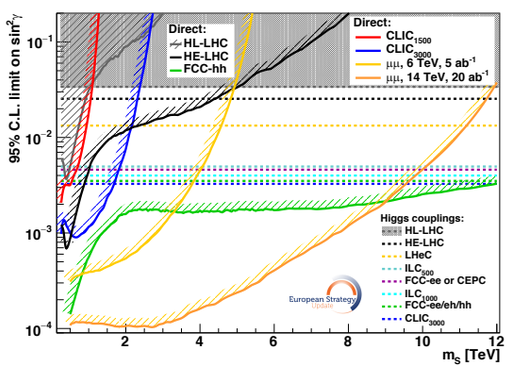


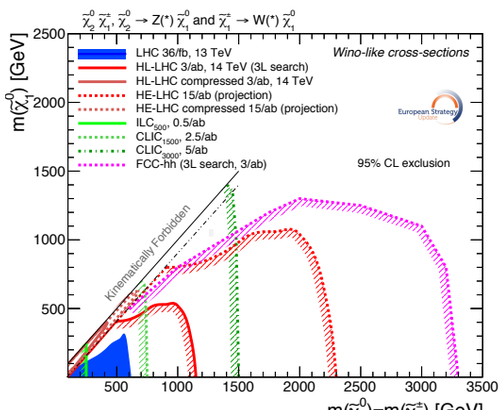


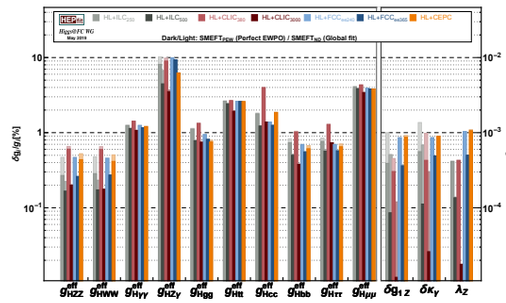


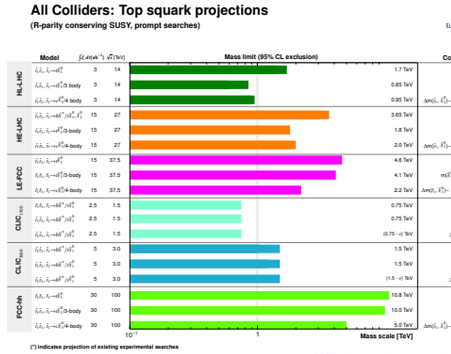






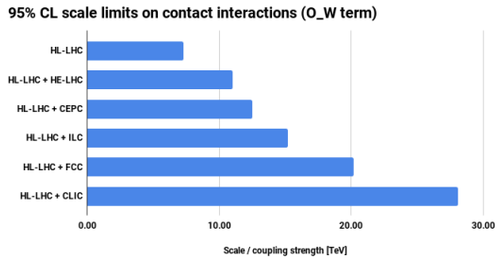


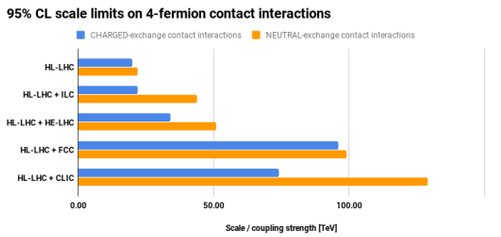


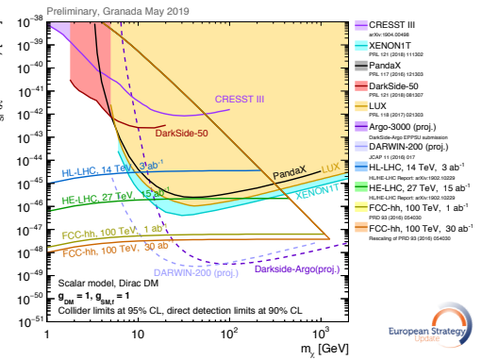


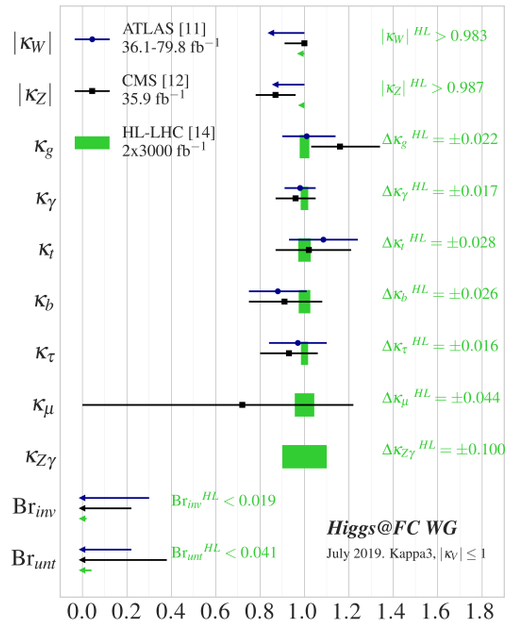
This is ~1/3 of the Physics Briefing Book [1910.11775] plots, that are relevant for the μ-coll, where there is no μ-coll line.

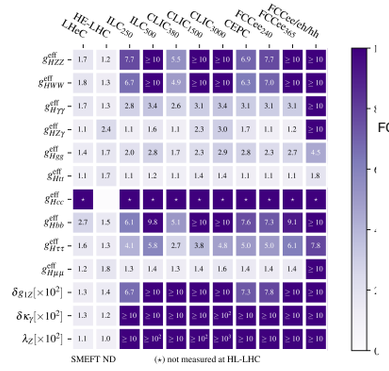
Short-Term Goal: SnowMass21

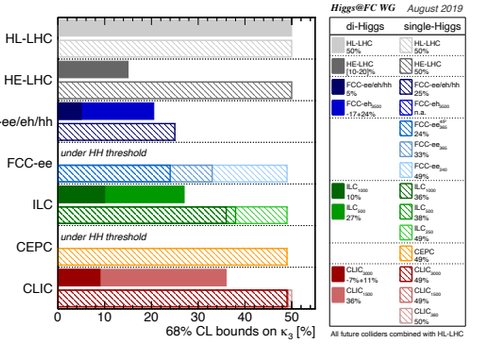


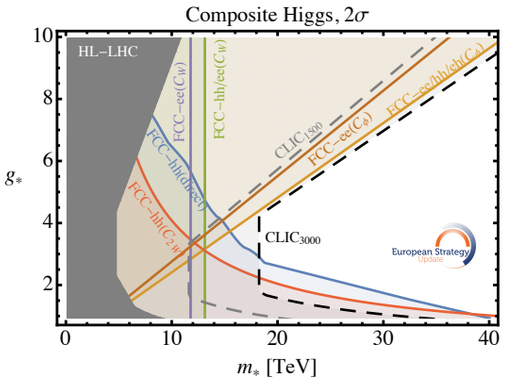


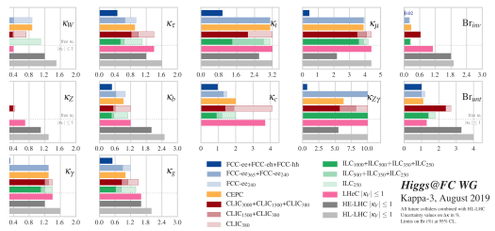


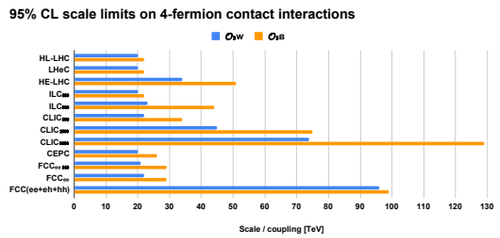


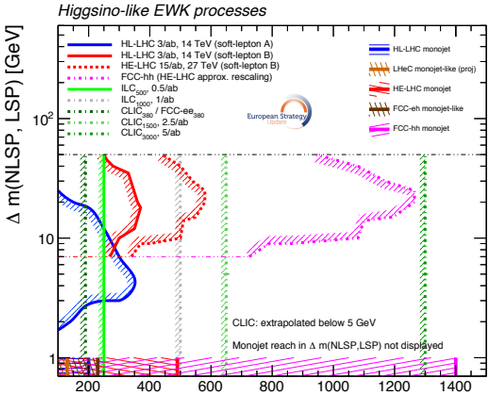


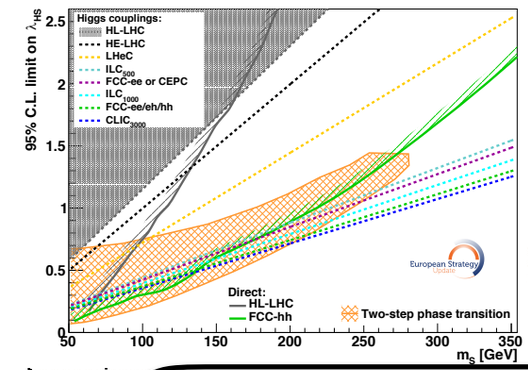


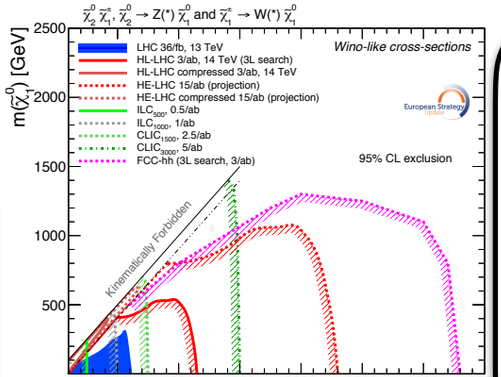


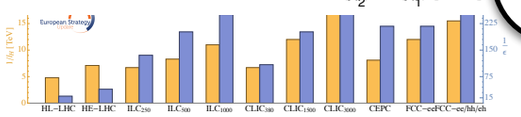


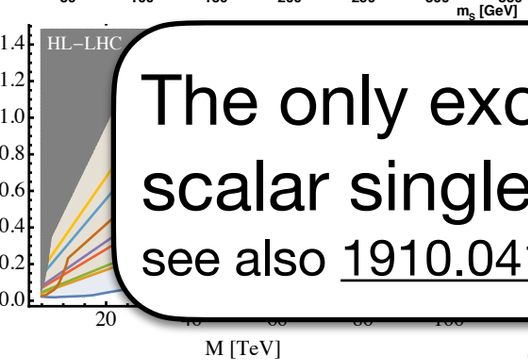


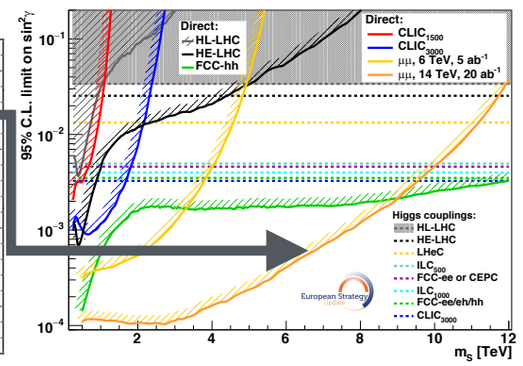


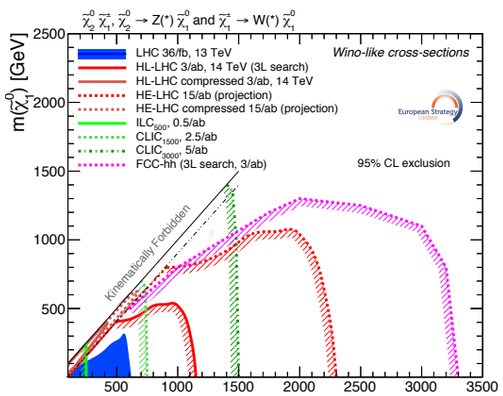


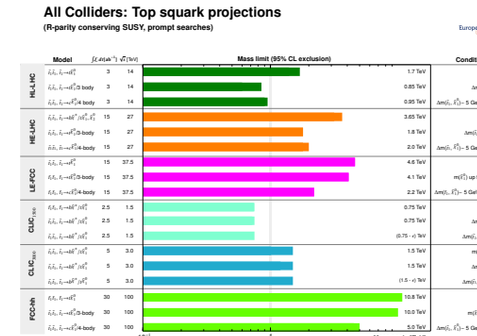


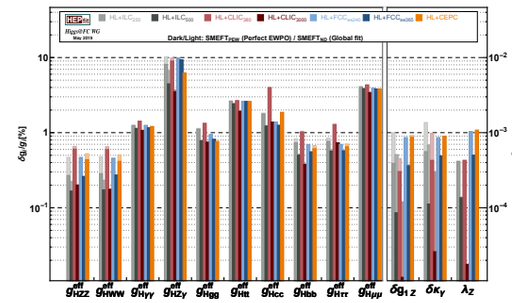








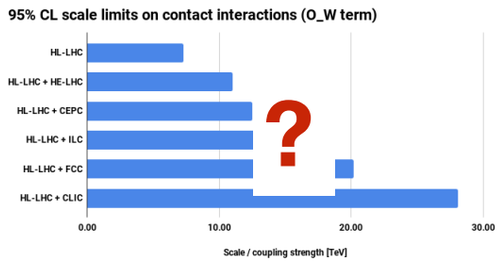


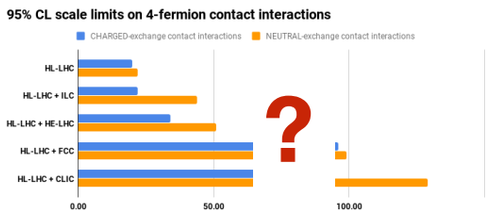


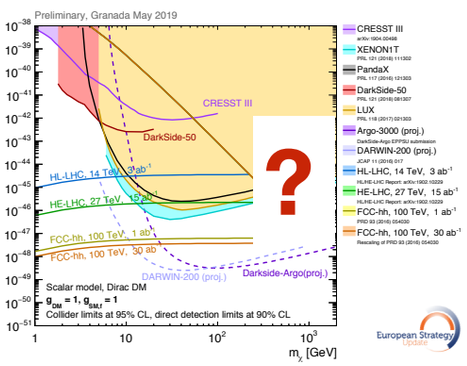
This is ~1/3 of the Physics Briefing Book [1910.11775] plots, that are relevant for the μ-coll, where there is no μ-coll line.

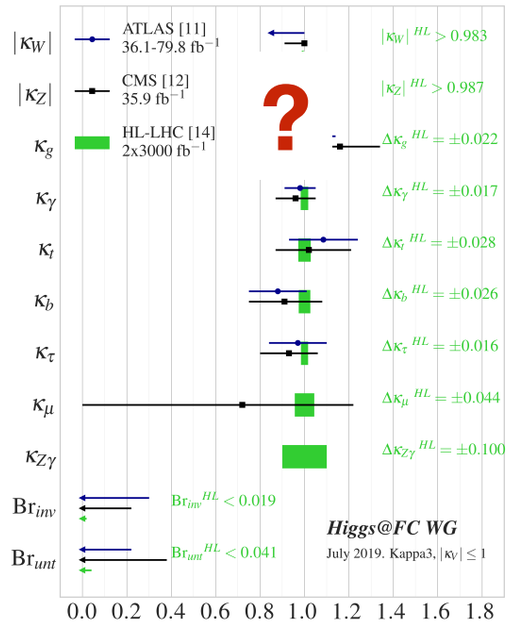
The only exception: scalar singlet [1807.04743, see also 1910.04170]

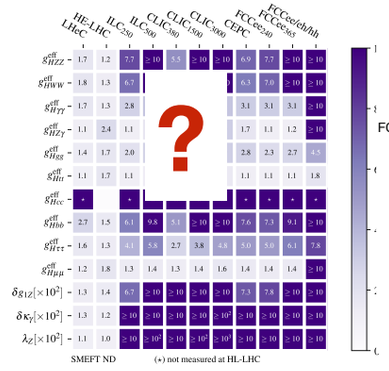
Short-Term Goal: SnowMass21

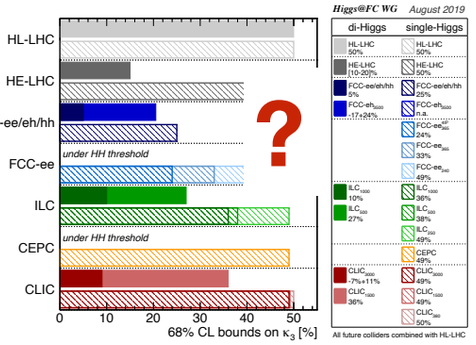


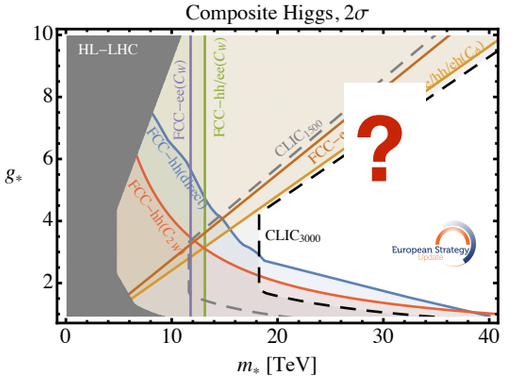


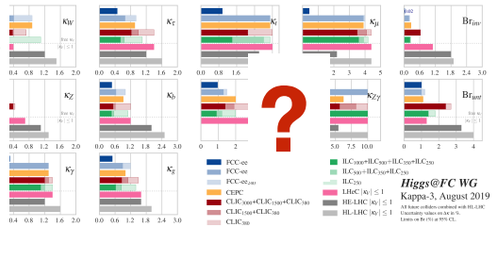


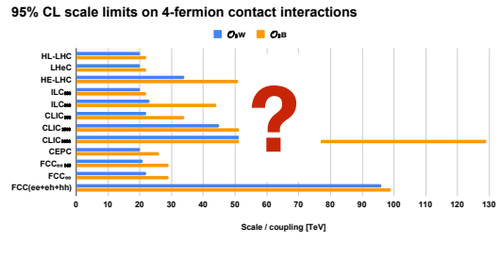


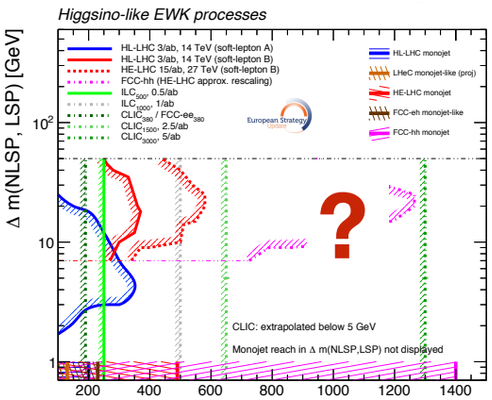


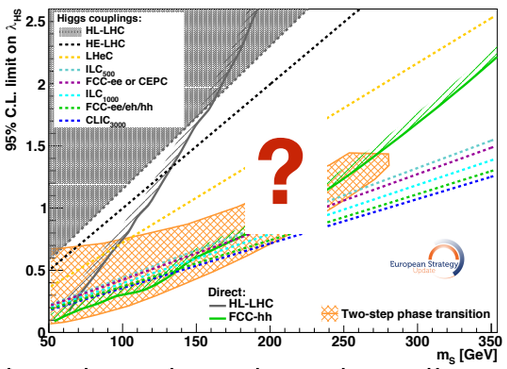


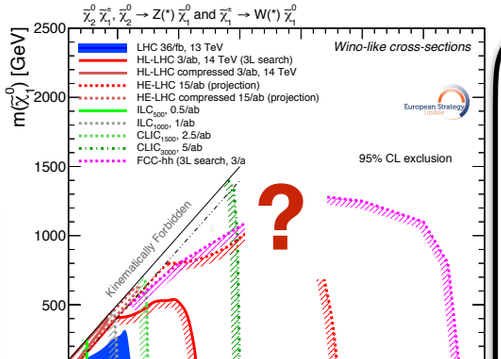


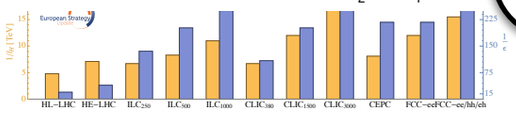


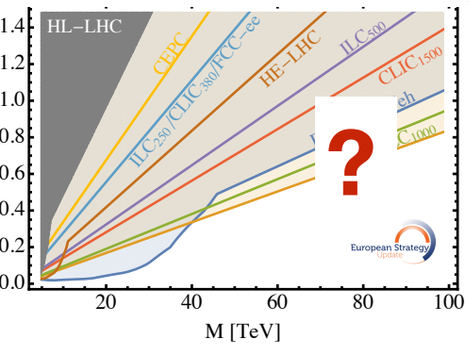


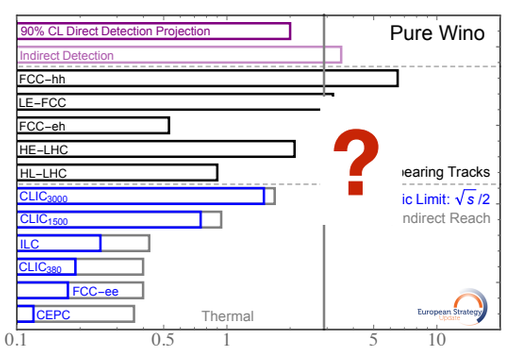


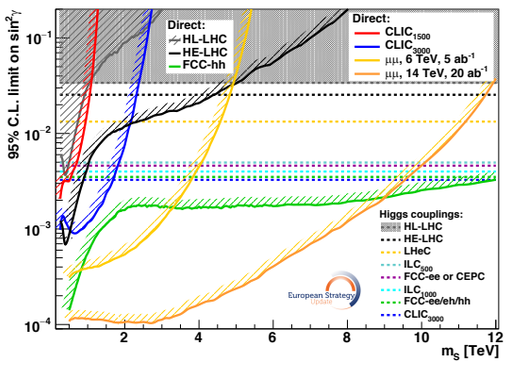


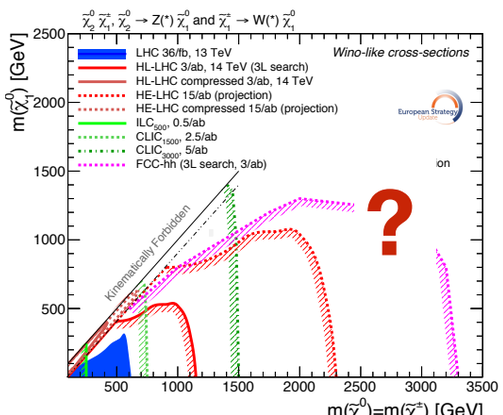


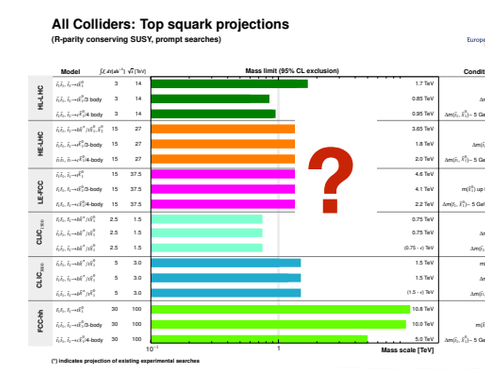


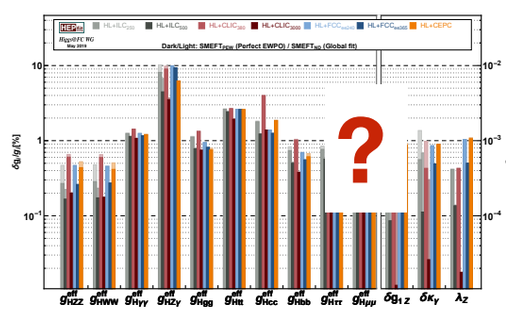












This is ~1/3 of the Physics Briefing Book [1910.11775] plots, that are relevant for the μ-coll, where there is no μ-coll line.

A lot of work to do!

Physics

Link

Physics and Benchmarks

[Thanks for comments to Dario Buttazzo, Roberto Franceschini, Fabio Maltoni, Maurizio Pierini, Michele Selvaggi, Lian Tao Wang, Marco Zanetti, …]

Physics:

Based on previous meetings and on on-going activities, below a list of items to be studied in view of presenting the muon collider physics case for Snowmass. As for FCC, and CLIC, the studies should produce independent publications to be eventually collected in input documents for the Snowmass process. Ideally, we would like the muon collider to appear in all the relevant Physics Briefing Book [1910.11775] plots. However the list below [possibly truncated at point “5”, included] is considered a sufficient and realistic target for Snowmass:

The goal is to produce sensitivity estimates assuming a target for final detector performances on high-level objects. This target should evolve while Detector/Beam-Induced-Background (BIB) studies proceed.

Physics

Link

1. Direct reach on heavy particles. Stop, Top Partners, EW-inos. Suggestion: Open and compressed spectra [see “benchmarks”]”.
   Many more particles could be considered, if there is manpower. E.g. Sleptons, Extra scalars not coupling to quarks, Heavy Neutrinos, Axions, ...

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2. Higgs 3-linear and 4-linear with backgrounds, realistic cuts and some shape analysis.

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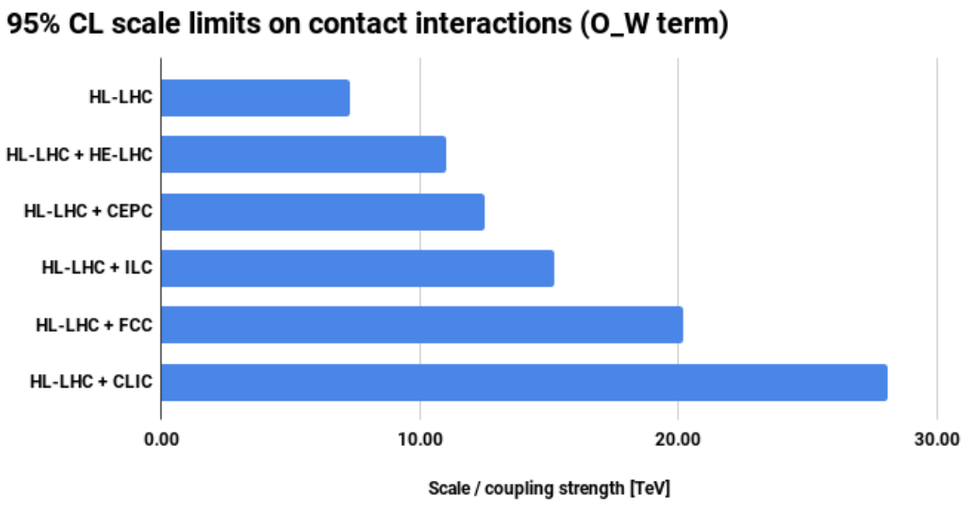
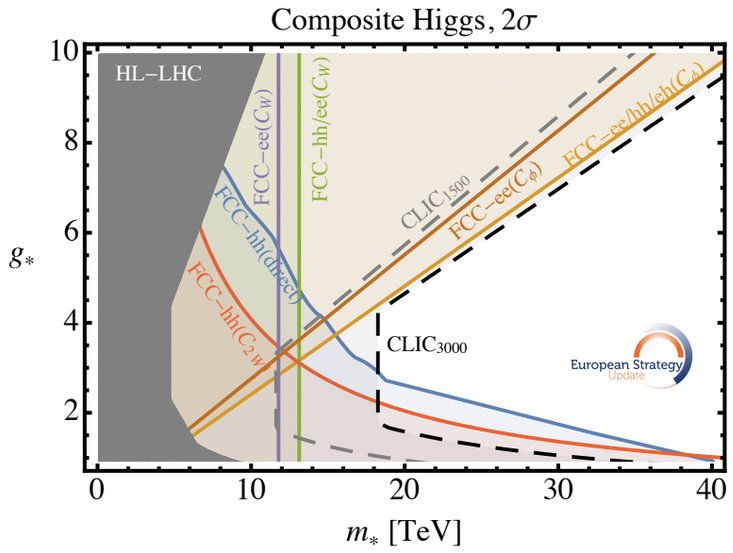
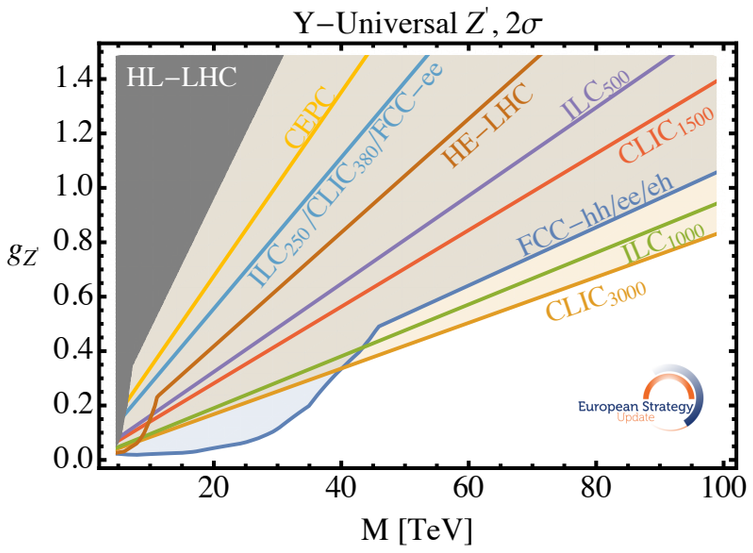
2. Higgs 3-linear and 4-linear with backgrounds, realistic cuts and some shape analysis.

3. Measurements of WW, ZH, ff (including tt) for Effective Field Theroy projections, with interpretations in Composite Higgs, Top Compositeness, Z’ models.







High-energy measurements are guaranteed success.

Physics

Link

1. Direct reach on heavy particles. Stop, Top Partners, EW-inos. Suggestion: Open and compressed spectra [see “benchmarks”]”.
   Many more particles could be considered, if there is manpower. E.g. Sleptons, Extra scalars not coupling to quarks, Heavy Neutrinos, Axions, ...

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5. Single-Higgs coupling measurements and EFT interpretation. In order to contribute to the ECFA effort on Higgs factories. The essential question is what do we lose by not having low-energy runs to measure HZ

Benchmarks

Link

Benchmarks:

A subset of the items above should be studied with the full detector simulation. The aim is to establish how far [or close] we are from the target performances on real physics sensitivity. And to outline concrete physically relevant use cases for the detector.

Some of the items below have been studied already and/or are already under investigation.

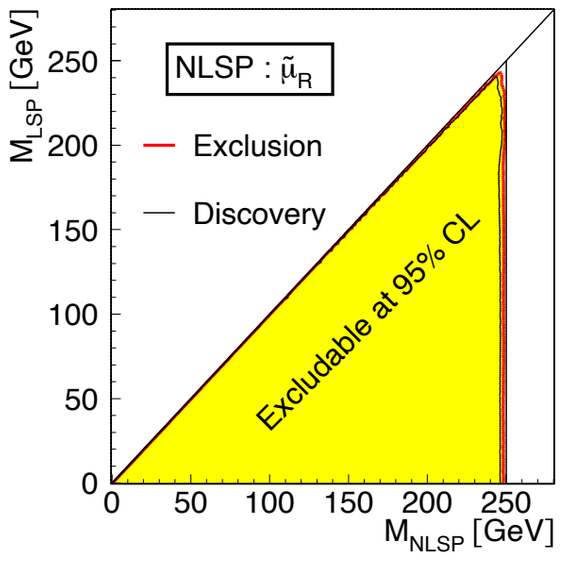
It would be ideal if the experimental groups active on each item were supported by and analysis “expert” [theorists or experimentalist] with direct experience on the specific item.

Benchmarks

Link

1. SUSY production, from “open” to “compressed” spectra, using standard Simplified Models for LHC/Future Colliders. This could prove sensitivity to heavy particles in the easy open spectrum configuration and in the increasingly harder case where the mass-splitting decreases. The soft objects produced in the compressed decay could be hard to see because of BIB, allowing to quantify its impact. For example, 1308.1461 studies sleptons at ILC in the compressed region. Also, see 2002.01239v1. However choosing sleptons is because of the low mass-reach of ILC. One should do the same for particles like the Stop, which are more central in the SUSY paradigm. On the other hand, if the purpose is to quantify detector performances on low-pt objects, one can consider any SUSY compressed decay to muons, tau, bottom, ...

Target plot:



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2. Long-lived Particles. Few examples of Future Collider studies that could be repeated using the same benchmark models.
https://agenda.linearcollider.org/event/8217/contributions/44770/attachments/34895/54069/UIrikeSchnoor_chargedLLP_CLIC3TeV.pdf (charged long-lived)
https://cds.cern.ch/record/2625054] Hidden pion (neutral long-lived)
A standard long-lived particle benchmark is “X” produced from H -> XX

Benchmarks

Link

3. Measurement of the di-Higgs differential cross-section.
   The suggestion is to target a measurement of the doubly-different di-Higgs invariant-mass and c.o.m.-angle di-Higgs distribution.
   At low mass (and not too forward in angle), this is sensitive to the 3-linear [see CLIC studies].
   At high mass, this is sensitive to one important EFT operator [see previous bullet “6”] and also to the direct production of the scalar singlet [see bullet “7”].
   Such a measurement in the entire spectrum would thus cover Higgs physics, EFT, and BSM reach at once.

4. Measurements of Higgs cross-sections and BR in all final states.

Delphes Card

Link

The goal is to produce sensitivity estimates assuming a target for final detector performances on high-level objects. This target should evolve while Detector/Beam-Induced-Background (BIB) studies proceed.

An (evolving) Delphes card seems the most effective way to encapsulate the (evolving) target.
A “v0” of this card, based on target performances similar to those of CLIC and/or FCC-hh should be produced as soon as possible.

Recommendations

Link

Target energies for the studies should be: 3, 10, 14, 30 TeV. While 30 TeV is currently not a target, it is useful to understand trends and limitations of the tools, could be a target for Snowmass studies in the US, and matches the “Alegro” study group energy, making the independent publications partially “reusable” in that context.

Some recommendations:

- Vary luminosity around (or widely below) the current target [1] and quantify impact in each analysis, in view of a global assessment of the required luminosity.
- Discuss the impact of critical parameters (see below) related with the detector response.
- Consider discussing if and to what extent the absence of Beamstrahlung and the reduced ISR, compared with CLIC, helps the analysis [in e.g. mono-photon or mono-X, or in backgrounds due to the Beamstrahlung tail or by photon-photon]
- Study if relevant gain with beam polarizations [low priority].

[1] https://arxiv.org/pdf/1901.06150.pdf integrated over 5 years and 1 interaction point

Requests

Link

Some request for the Detector experts, concerning the critical parameters:

- Should we have benchmarks for the reduced angular acceptance of the detector due to nozzles? [on top of what built-in in the Delphes card]
- Should we have benchmarks for the lower pT threshold of reconstructed objects, possibly reduced by BIB? [again, on top of what built-in in the Delphes card]

Link

Thank You !