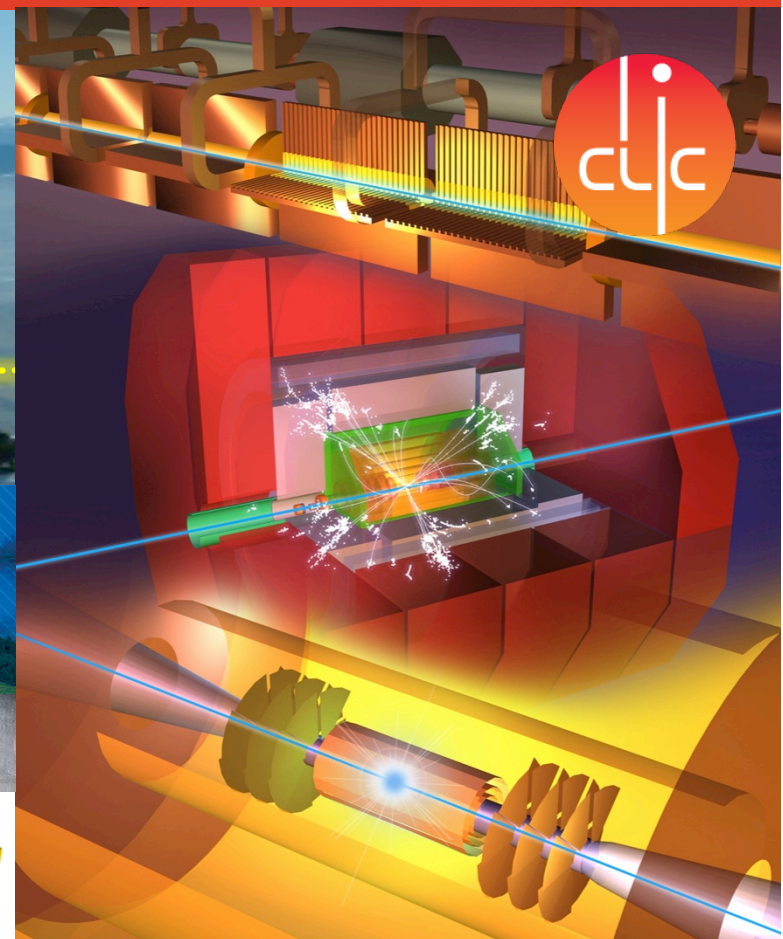


Plans and timeline for the ECFA study



ECFA e^+e^- Workshop, 5–7 October 2022, DESY
Aidan Robson, University of Glasgow

ECFA studies towards an e^+e^- Higgs/EWK/top factory

High-priority future initiatives

European Strategy Update 2020

- A. An electron-positron Higgs factory is the highest-priority next collider.

Snowmass 21 Energy Frontier Vision

The intermediate future is an e^+e^- Higgs factory

The intermediate future is an **e^+e^- Higgs factory**, either based on a linear (ILC, C³, CLIC) or circular collider (FCC-ee, CepC).

- The various proposed facilities have a strong core of common physics goals: it is important to realize at least one somewhere in the world.

ECFA recognizes the need for the experimental and theoretical communities involved in physics studies, experiment designs and detector technologies at future Higgs factories to gather. **ECFA supports a series of workshops** with the aim to **share challenges and expertise, to explore synergies in their efforts** and to respond coherently to this priority in the European Strategy for Particle Physics (ESPP).

Goal: bring the entire e^+e^- Higgs factory effort together, foster cooperation across various projects; collaborative research programmes are to emerge



- ◆ ***We know why we are here:***
 - bring together communities & activities
 - explore synergies
 - discuss challenges

ECFA Working Groups underway

- ◆ WG1: **Physics programme** conveners Fabio Maltoni, Jenny List, Jorge de Blas, Juan Alcaraz
- ◆ WG2: **Physics analysis methods** conveners Patrizia Azzi, Fulvio Piccinini, Dirk Zerwas
- ◆ WG3: **Detector technologies** conveners Felix Sefkow, Mary Cruz Fouz, Giovanni Marchiori

→ Rich programme of seminars, topical meetings, mini-workshops

June 2022

- 10 Jun ECFA Higgs Factory seminars: Precision physics in the e+e- → WW region
- 07 Jun - 17 Jun Precision calculations for future e+e- colliders: targets and tools (FC CERN Unit Workshop)

May 2022

- 06 May ECFA Higgs Factory seminars: Higgs self-coupling
- 04 May - 05 May ECFA Higgs Factories: 1st Topical Meeting on Reconstruction

April 2022

- 08 Apr ECFA Higgs Factory seminars: Physics with light quarks

March 2022

- 04 Mar ECFA Higgs Factory seminars: Implications of $(g-2)_\mu$ for e+e- Higgs factories: an overview

February 2022

- 01 Feb - 02 Feb ECFA Higgs Factories: 1st Topical Meeting on Simulation

January 2022

- 12 Jan Focus Meeting: Beamstrahlung

November 2021

- 09 Nov - 10 Nov ECFA Higgs Factories: 1st Topical Meeting on Generators

WG1-SRCH: Direct searches (weakly-interacting, directly accessible particles)

May 2022 ECFA HF WG1: 1st Workshop of the WG1-SRCH group
Feb 2022 Brainstorming session

WG1-PREC: theoretical and experimental precision

July 2022 MiniWorkshop: parametric uncertainties: α_{em}

Mar 2022 MiniWorkshop: parametric uncertainties: α_s

Mar 2022 MiniWorkshop: high-precision measurements

WG1-HTE: specific Higgs/Top/EW studies (+ connection w/ LHC)

Sept 2022 ECFA HTE meeting on Z pole physics

Apr 2022 1st Workshop of the Higgs/Top/EW group

WG1-HF: Heavy Flavour

June 22 1st Meeting

WG1-GLOB: global interpretations

Sept 2022 Analyses of concrete models

July 2022 Global interpretations in (SM)EFT and UV complete models

First milestone!

- ◆ Great to see so many people committed to realising an e^+e^- Higgs factory, in person here in Hamburg!

First ECFA WORKSHOP.
on e^+e^- Higgs / Electroweak / Top Factories
5-7 October 2022, DESY, Hamburg

Topics:

- Physics potential of future Higgs and electroweak/top factories
- Required precision (experimental and theoretical)
- EFT (global) interpretation of Higgs factory measurements
- Reconstruction and simulation
- Software
- Detector R&D

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The European Committee for Future Accelerators (ECFA) organises a series of workshops on physics studies, experiment design and detector technologies towards a future electron-positron Higgs/Electroweak/Top factory.

The aim is to bring together the efforts of various e^+e^- projects, to share challenges and expertise, to explore synergies, and to respond coherently to this high-priority item of the European Strategy for Particle Physics

U+H Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

CLUSTER OF EXCELLENCE QUANTUM UNIVERSE

DESY

<https://indico.desy.de/event/33640/>



Looking ahead to the final report

- ◆ **Study will be documented as an ECFA Report**
- ◆ Initiating this now, to help planning and to stimulate activity
- ◆ Vision for the report:
 - a major input to the next European Strategy Update
 - building on extensive body of previous studies
 - most recently:
 - ILC report to Snowmass
 - FCC CDR
 - CLIC Yellow Reports
 - ...etc
 - ⇒ **this report should focus on new work**
 - brief 'summary of current state' also to be included
 - **emphasise what is added:**
 - what can the ECFA Higgs Factory study add beyond the current state-of-the-art?
 - what will a Higgs Factory add beyond the state-of-the-art at the end of HL-LHC?
- ◆ Hope that by starting this now, whole community can start to plan contributions, over the next 1–2 years.

All contributions are welcome

◆ **Community-driven activity:**

As with previous studies generated by e^+e^- community, *everyone* is welcome to bring their own contributions

→ leads to a rich field of inputs

– relevant WG conveners are glad to be contacted

→ Started to lay out preliminary draft report structure, based on ongoing WG activity

Overall editorial team: AR + conveners of WG1, WG2, WG3.

→ Three main 'chapters', on WG1, WG2, WG3

◆ ***In addition***, the ECFA study is proposing a limited set of 'high-priority' topics as presented by Jenny on Wednesday morning

– motivation is to lower threshold for participation, focus limited effort, and promote cross-group activity

→ planned to lead to dedicated feature sections of report

WG1 – example outline

◆ Just as an example, a *very preliminary* draft of WG1-FLAV topics for inclusion

(Note: this has not yet been widely discussed or circulated for input and suggestions – that step is coming!)

5.1 CKM profile prospects

Leptonic decays and magnitude of the CKM matrix elements

CKM from hadronic decays

Global analyses. NP in neutral meson mixings

5.2 Rare decays of b- and c-flavoured particles

Flavour anomalies and related channels

LFU tests, angular observables, ...

5.3 Theory challenges

Expected precision from Lattice QCD

Prospects for $b \rightarrow s(d)l^+ l^-$ ($l = e, \mu, \tau$) predictions

Prospects for predictions of semileptonic decays

Impact of QED uncertainties

5.4 τ Physics

LFU tests in τ decays

LFV from τ decays

5.5 Heavy Flavour spectroscopy

5.6 Flavour Physics from $e e \rightarrow qq^*$

5.7 Interplay with top, Higgs and electroweak precision measurements

WG1 – example outline

- Systematic limitations for precision measurements (parametric, experimental, ...).
- Consistent assumptions for estimation of systematic uncertainties for all collider proposals. What is collider-specific and what is common?
- Discussion on α_s , α_{QED} , m_b , m_c , ... : measurements and as input parameters in other determinations.
 - Discussion of methods and their prospects for future improvement:
 - * Lattice QCD
 - * Direct measurements and other data-driven approaches
 - Interplay of new (more precise) experimental data vs. improved theory (perturbative and non-perturbative)
 - Understanding of existing discrepancies (ρ - γ mixing for photon vac. pol. from tau decays, difference data-lattice for muon $g-2$)
- Cross section lineshape measurements and extraction of Z , W , H , top masses and widths. Control of luminosity, beam energy, polarisation and acceptance. Mass and width measurements from final state kinematics, compare methods, precision and requirements.
- Z and W decay rates and related precision requirements Z pole asymmetries, weak mixing angle,
 - Flavour tagging and particle identification (for kinematic reconstruction), charge id. and hemisphere correlations etc. (for asymmetries); with WG2
- Theory and MC needs for high-precision studies (coordinate with WG2 on MC)
 - Types of theory inputs for different observables (Z -pole, WW , ZH , $t\bar{t}$, lumi measurement)
 - * for data analysis (background, MC generators, ...)
 - * for testing SM (SM predictions; (mostly) fixed-order loop calculations)
 - What is known today; how do we evaluate their uncertainty?
 - What is needed to match future HTE factory precision? [calculations, tools, modeling]
 - Ongoing work and promising techniques ...
- Discussion on non-perturbative QCD uncertainties, how to make progress ? Models and methodology, e.g. color reconnection (in WW fully hadronic), hadronization, parton shower, CR, fragmentation fct.

◆ As another example, *very preliminary* draft of WG1-PREC topics for inclusion

(Note: this has not yet been widely discussed or circulated for input and suggestions – that step is coming!)

WG2 outline

◆ Preliminary sketch of WG2 report 'chapter'

- Introduction
- Software Ecosystem
- Beamstrahlung
- Monte Carlo Generators
- Simulation and Reconstruction

for example:

Section Monte Carlo Generators:

- 1 subsection for each generator group
 - brief outline/overview
 - new/recent features to highlight
- N subsection(s) on combined activities (technical benchmarks.....)

similar structure for the others e.g.:

Section Reconstruction

- subsections on "existing" reco algs (ACTS, CLIC, ILD,.....)
- N subsections on "combined activities",
e.g. running different algs on the same set through KEY4HEP

Next steps (1)

- ◆ **Draft section outlines** will be refined over the next few months
 - first draft outlines to be completed
 - input & additions to be solicited from community
 - start to associate names with (planned) activities
 - > will be 'living documents'

Note on authorship

- ◆ Single overall author-list envisaged for report
- ◆ Where appropriate, authors are likely to create their own detailed preprints or papers, which are summarized and referenced in the ECFA Report contributions
- ◆ Where appropriate, specific ECFA Report sections could be acknowledged. e.g.:

2.2.1 *Global perspective on the Higgs self-coupling*⁶

[from CLIC YR]

High-energy

The optimal way to measure the Higgs trilinear self coupling at high-energy lepton colliders is through the exploitation of Higgs pair production processes, whose cross section is affected by the Higgs self

⁶*Based on a contribution by S. Di Vita, G. Durieux, C. Grojean, J. Gu, Z. Liu, G. Panico, M. Riembau, T. Vantalón.*

WG3 outline

◆ **Main aims of WG3 outlined in Felix's talk from Thursday morning:**

- demonstrate that detectors can be built that match the precision physics potential of future Higgs factories
- provide guidance for coherent detector R&D efforts to address the priority requirements of Higgs factory experiments
- support roadmap implementation process
 - provide input on detector requirements
 - provide a forum for feedback on R&D plans
 - help R&D groups to convincingly make their case for a strategic R&D program
 - make sure that Higgs factories are well represented among other targets of DRDs

◆ **Inputs to report likely to include:**

- Update of detector requirements
 - State of the art, new developments, and planned programmes for:
 - Tracking and Vertexing
 - Calorimetry and Particle ID
 - Electronics and integration
- to be established as activities develop**

High-priority topics

- ◆ Proposed 'high-priority topics' are not intended to map the physics programme comprehensively. Instead, should serve to:
 - complete the current overall picture where it's (most) necessary
 - offer guidance for contributing to the ECFA study
 - highlight processes particularly suitable for studying the **interplay of the three WGs**

◆ Higgs

1. $e^+e^- \rightarrow Zh$ at $\sqrt{s} = 240..250$ GeV and 350 GeV:

- comparisons of theory calculations and MC generators for $e^+e^- \rightarrow f\bar{f}h$
- reconstruction of production (all channels)
- and decay angles ($h \rightarrow ZZ^*/WW^*/Z\gamma$) incl CP angles
- dependence on detector performance and reconstruction capabilities:
 - Higgs restframe reconstruction, also for $Z \rightarrow qq / \tau^+\tau^-$
 - q vs qbar separation, ...
- SMEFT interpretation

Most studies of Higgs couplings and SMEFT interpretation so far assume CP conservation – add CP studies

2. $e^+e^- \rightarrow Zh$ with $h \rightarrow ss$ ($Z \rightarrow$ anything) at $\sqrt{s} = 240..250$ GeV:

- branching fraction precision / discovery reach
- dependence on detector performance and reconstruction capabilities:
 - e.g. K^\pm ID, $K^0_S \rightarrow \pi^+\pi^-$, JER, ...
- SMEFT & BSM interpretation

H \rightarrow ss addressed only recently – reconstruction and PID challenges, and interpretation

High-priority topics

◆ W/Z

- 3.** W Couplings in $e^+e^- \rightarrow W W$ and $e\nu W$ at $\sqrt{s} = 240..250$ GeV and ~ 350 GeV including e.g.:
 - comparison of theory predictions and MC generators
 - detector-level studies including full differential angular information, reconstruction of CP angles, optimal observables / interface to global interpretations
 - CP violating operators and other effects beyond "standard" TGCs

add full detector-level studies at 240GeV; include CPV operators

- 4.** W mass from $e^+e^- \rightarrow W W$ and $e\nu W$ at threshold and continuum
 - theory predictions and MC generators
 - detector-level studies including mass reconstruction techniques
 - systematic limitations and calibration strategies

M_W ultimate precision? assessment/development of analysis and calibration methods to highlight aspects of detector performance requirements

- 5.** $e^+e^- \rightarrow bb, cc, ss, \tau+\tau^-$ at $\sqrt{s} = M_Z$ and above including e.g.
 - comparison of theory predictions and MC generators
 - detector-level studies of differential cross-section / asymmetry measurements
 - interface to global interpretations
 - for $\tau+\tau^-$: τ polarisation and A_e extraction

2-fermion production hardly studied at Z. Focus on channels with detector/reco challenges; include τ polarisation

High-priority topics

◆ Top

6. $e^+e^- \rightarrow t\bar{t}$ at a typical threshold-scan energy, $\sqrt{s} = \sim 350$ GeV

- detector-level studies of total & differential cross-section, asymmetries, CP observables
- detector requirements and reconstruction/analysis methods
- interface to global interpretations

full analysis at threshold
(threshold calculations not all reflected in MC generators, polarisation & beam spectrum etc)

7. threshold scan optimisation, including

- theory predictions and MC generators
- backgrounds, polarisation, energy-step optimisation
- interpretation incl. "classic" threshold scan parameters as well as electroweak coupling parameter extraction, also CPV

◆ Direct discovery potential

8. $e^+e^- \rightarrow$ (very) weakly coupled / light / long-lived particles

LLPs with exotic signatures

- detector-level studies of "exotic" signatures: "kinks", "prongs", "V0", ...
- detector requirements, pattern recognition, reconstruction algorithms
- interface to BSM interpretations: plethora of models!

=> can one develop a "matrix"/"database" to map experimental performance given eg in terms of boost, lifetime, decay mode onto model parameter space of BSM models predicting LLPs ?

High-priority topics

◆ Flavour

9. $B_s \rightarrow D_s K$ at $\sqrt{s} = M_Z$

- detector-level study with all backgrounds
- dependency on vertexing, Kaon-ID, ...
- global interpretations...

10. $B_s \rightarrow K^{0*} \tau^+ \tau^-$:

- detector-level study with all backgrounds
- topological reconstruction,
- dependency on τ and K^* reconstruction, vertexing...
- global interpretations

B mesons that are too heavy to be produced at Belle-II; final states that are difficult at LHCb, e.g. τ

High-priority topics

◆ Systematics

11. Luminosity measurement from low-angle Bhabha scattering

- theory and MC generators: comparison of state-of-the-art and ultimate requirements
- detector-level simulations at all \sqrt{s} , including backgrounds etc
- measurement strategies
- requirements on LumiCal: resolutions, alignment

Understand how to control with unprecedented precision

12. Measurement of b- and c-fragmentation functions / hadronisation

- detector-level study with all backgrounds
- new ideas how to model them theoretically => new measurement strategies?

Understand how well these can be constrained, as input to precision Higgs and EWK measurements

13. Measurement of gluon splitting to bb / cc & interplay with separating $h \rightarrow$ gluons from $h \rightarrow$ bb/cc

Next steps (2)

- ◆ A series of forthcoming meetings will launch discussion on the 'High-priority topics' to refine scope/definitions, and gather interest and momentum

Timeline

- ◆ **ECFA study is a key input for the next European Strategy Update**
→ should be coherent with the European Strategy timeline



- ◆ For the 2020 Update:
 - project inputs: December 2018
 - open community meeting: Granada, May 2019
 - drafting session: Bad Honnef, January 2020
 - strategy presented later in 2020
- ◆ The next European Strategy Update is provisionally expected in **2026–27**
→ provisionally expect strategy inputs to be due in late 2025
- ◆ ECFA study should coordinate with project inputs and timelines,
e.g. FCC Feasibility Study report is scheduled for end 2025, writing from 2025Q2
- ◆ **ECFA report should be available as reference for projects' individual ESPP inputs**
→ **target spring 2025 for ECFA study final report**

Future workshops

- ◆ Matching the ECFA study timeline to the European Strategy timeline implies two further 'overall' workshops, in both 2023 and 2024
- ◆ Call for proposals to host the Second ECFA Workshop, in 2023, will be made soon

First ECFA WORKSHOP.
on e^+e^- Higgs / Electroweak / Top Factories
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UHH Universität Hamburg CLUSTER OF EXCELLENCE QUANTUM UNIVERSE DESY <https://indico.desy.de/event/33640/>

Thanks again to the local organisers for a wonderful welcome to Hamburg!

Short-term next steps

- ◆ Over the next ~2 months:
Refining of provisional report section contents,
consultations and input from community via WG (/activity) conveners
→ ***please start thinking where your contributions will fit!***
- ◆ Over the next 3–6+ months:
Series of topical meetings (WG1 and cross-group) focused on 'high-priority topics'
WG2 mini-workshop on **Reconstruction**
WG3 mini-workshops on:
 - Tracking and Vertexing for Higgs factories (TF1, TF3)
 - Calorimetry and Particle ID for Higgs factories (TF4, TF6)
 - Electronics and integration (TF7, TF8) (separate or interleaved, t.b.d.)
- ◆ Useful practical suggestions arising from workshop discussions to follow up:
 - Unified calendar of events/meetings among concepts
 - Software tutorials to lower threshold for people to contribute

◆ ***Let's work together
towards the next collider***

