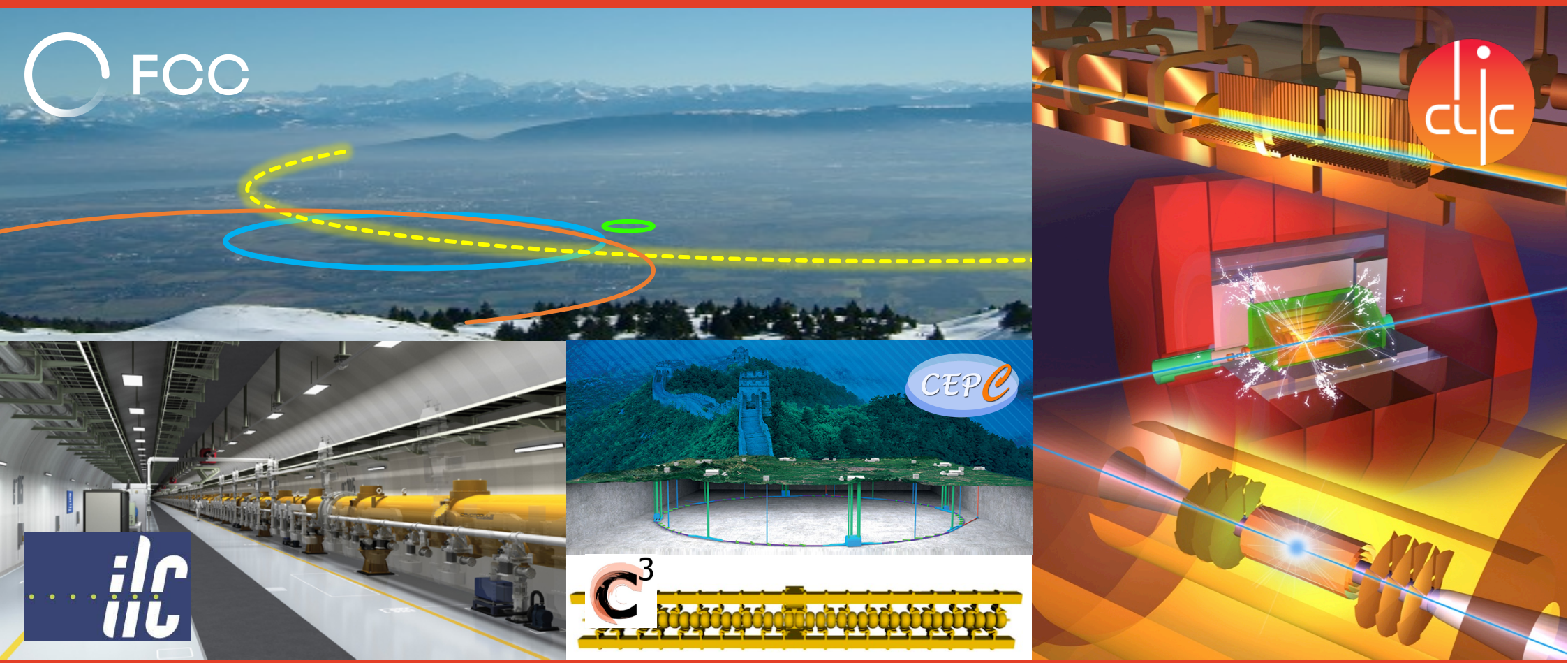


ECFA studies towards an e^+e^- Higgs/EWK/top factory : Summary of ECFA workshop, and future plans



Plenary ECFA 18th November 2022, CERN
Aidan Robson, University of Glasgow on behalf of the IAC

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

- ◆ *Activities of the study, and First Workshop*
- ◆ *Near-future plans*
- ◆ *Towards a final report*
- ◆ *Important messages to the collider physics community*

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



- ◆ ***ECFA study is intended to:***
 - 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)_μ 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

Main entry point:

<https://indico.cern.ch/event/1044297/page/22669-overview>

First milestone: First workshop, DESY 5–7 October

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

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



Universität Hamburg

CLUSTER OF EXCELLENCE
QUANTUM UNIVERSE



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




Local organisers: **Ties Behnke**, Freya Blekman, Frank Gaede, Elisabetta Gallo, Alexander Grohsjean, Christophe Grojean, Johannes Haller, Katja Krüger, Gudrid Moortgat-Pick, Krisztian Peters, Jürgen Reuter, **Christian Schwanenberger**, Felix Sefkow, Marcel Stanitzki, Georg Weiglein

- ◆ 200 registrants in person and 145 online
- ◆ Plenary & parallel sessions, organised by WG conveners
- ◆ Poster session
- ◆ Public evening event

→ Great to see so many people in Hamburg
& many thanks to local organising team



Encouraging wider participation / more activity

- ◆ **Good number of people in Hamburg, especially ECRs**
 - experts across projects/geometries are connecting 
 - Common approach to software framework is agreed, and many topics in simulation & reconstruction being actively worked on together 
 - Thematic topics are emerging as good places for people to contribute 
- ◆ **However, participation and activity remains at a limited level**
 - many reasons for this:
 - everyone busy with LHC
 - Snowmass study ran later
 - concrete e^+e^- project not yet approved
- ◆ **Essential for the field that there is a strong community & participation in e^+e^- studies**
By working across projects, ECFA study can provide an entry point for national groups

Encouraging wider participation / more activity

- ◆ *Whole community is strongly encouraged to think how to contribute*
- ◆ *Crucial to engage community, especially ECRs, in future preparations*
- ◆ *Message especially to PIs / Group Leaders / Seniors:*
 - how can you support the studies?*
 - can you encourage your ECRs / PhD students to do a study?*
 - at level of e.g. 10–20% of time?*
 - with aim of leading to chapter of thesis, or small paper?*

Encouraging wider participation / more activity

- ◆ So far, study has been 'community-led'; everyone bringing their own contributions
 - leads to a rich field of inputs
 - **continues to be very warmly encouraged**
 - relevant WG conveners are glad to be contacted
- ◆ *In addition to this, the ECFA study is proposing a limited set of 'focus topics'*
 - use topics of active interest as a vehicle to:
 - engage new people
 - connect people working on similar topics on different projects and encourage them to work together
 - develop tools for use across projects
(e.g. reco algorithm / analysis technique / MC generator improvement / ...)
 - build community across projects
 - motivation is to:
 - lower threshold for participation in e^+e^- studies
(e.g. repository of example analysis codes is suggested)
 - focus limited effort,
 - and promote cross-group activity
 - 'newcomers' can get up to speed on e^+e^- / get some 'training',
and make a significant contribution

Encouraging wider participation / more activity

- ◆ Proposed 'focus 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***
- ◆ ***Topics and scope are still under discussion (and there will be opportunity for input through WGs)***

Following 3 slides are just to give a flavour...:

Draft focus topics

◆ Higgs at $\sqrt{s}=240\dots250$ GeV and 350 GeV

Many aspects are of course well-studied – focus on those that are less so, e.g. :

1. CP studies of Higgs couplings and SMEFT interpretation (most so far assume CP conservation)
→ *can incorporate e.g. theory calculations / MC generators / reconstruction techniques (e.g. taus and $q/qbar$ separation) / EFT interpretation / ...*
2. $H \rightarrow ss$ (addressed only recently – extend studies)
→ *can incorporate e.g. reconstruction and PID challenges / SMEFT & BSM interpretation / ...*

◆ W/Z

3. W Couplings at WW threshold and 240..250 GeV / ~350 GeV
→ add full detector-level studies at 240GeV and go beyond 'standard TGCs' with CPV operators
→ *can include theory predictions / MC generators / detector-level studies / ...*
4. W mass at threshold and continuum
→ ultimate precision on M_W ?
→ *can include theory predictions / MC generators / assessment/development of analysis and calibration methods to highlight aspects of detector performance requirements / ...*
5. 2-fermion production at Z pole
→ focus on channels with detector/reco challenges e.g. $e^+e^- \rightarrow bb, cc, ss, \tau^+\tau^-$
→ *can include theory predictions / MC generators / detector-level studies / interface to global interpretations / studies on tau polarisation / ...*

Draft focus topics

◆ Top

6. Full analysis of top threshold scan

→ can include updates to MC generators to reflect newest threshold calculations / polarisation & beam spectrum / reco/analysis / interface to global interpretations / ...

7. threshold scan optimisation

→ can include backgrounds / polarisation / energy-step optimisation / parameter extraction / ...

◆ Direct discovery potential

8. Weakly-coupled / light / long-lived particles

→ can include detector-level studies of “exotic” signatures: “kinks”, “prongs”, “V0” / detector requirements, reco/pattern recognition / interface to BSM interpretations / ...

◆ Flavour

can e.g. focus on B mesons that are too heavy to be produced at Belle-II and final states that are difficult at LHCb:

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

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

→ can include detector-level study with all backgrounds / dependency on reconstruction, vertexing, PID / global interpretations / ...

Draft focus topics

◆ Systematics

11. Luminosity measurement from low-angle Bhabha scattering

→ understand how to control with unprecedented precision

→ *can include theory and MC generators / detector-level sim. including backgrounds / measurement strategies / LumiCal detector requirements / ...*

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

13. Measurement of gluon splitting to bb / cc

& interplay with separating $h \rightarrow \text{gluons}$ from $h \rightarrow \text{bb/cc}$

→ understand how well these both can be constrained, as input to precision Higgs & EWK

→ *can include detector-level studies / new ideas in theoretical modelling / ...*

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
 - *in the same way that the ECFA Higgs@Future Colliders report was in 2020*
 - 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, cross-project where possible**
 - > 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 towards study report

◆ **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

→ 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 'focus topics' are planned to lead to dedicated feature sections of report

Next steps (1)

- ◆ **Draft report section outlines** will be refined (~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'

Very preliminary sketch of WG1-FLAV report topics

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 $e^+ e^- \rightarrow q\bar{q}$

5.7 Interplay with top, Higgs and electroweak precision measurements

Very 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

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 Yellow Report]

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:**

- 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**

Next steps (2)

- ◆ A series of forthcoming meetings will launch discussion on the 'Focus topics' to refine scope/definitions, and gather interest and momentum
- ◆ Coherently with this: next in the ongoing series of WG1 seminars is on Flavour Physics, Friday 25th November, 14h CET
<https://indico.cern.ch/event/1218956/>

ECFA Higgs Factory seminars: Flavor Physics at Future e+e- colliders

Friday 25 Nov 2022, 14:00 → 15:40 Europe/Zurich

14:00	→ 14:10	Opening & introduction	🕒 10m	✎
Speakers: Prof. Fabio Maltoni (Universite Catholique de Louvain (UCL) (BE) and Università di Bologna) , Jenny List (Deutsches Elektronen-Synchrotron (DE)) , Jorge de Blas (Universidad de Granada (ES)) , Juan Alcaraz Maestre (CIEMAT - Madrid (ES))				
14:10	→ 14:35	Opportunities for flavor physics at future e+ e- EW/Higgs/Top factories	🕒 25m	✎
Speaker: Javier Fuentes-Martin (Universidad de Granada)				
14:35	→ 15:00	Novel experimental channels in Flavour Physics at a Tera-Z factory	🕒 25m	✎
Speaker: Roy Aleksan (Université Paris-Saclay (FR))				
15:00	→ 15:30	Discussion	🕒 30m	✎

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

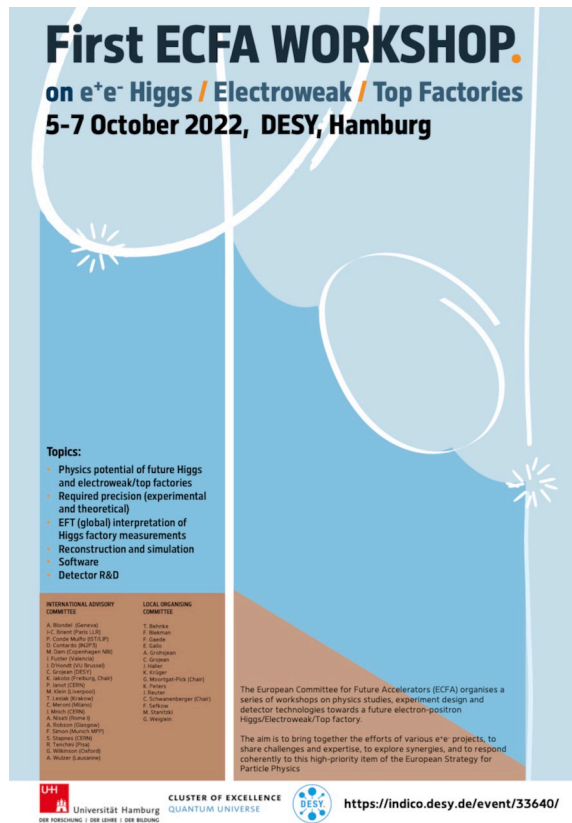
◆ ECFA study should coordinate with project inputs and timelines, e.g. FCC Feasibility Study report is scheduled for **end 2025**

→ target spring 2025 for ECFA study final report

◆ Aspects of ECFA report should be available as reference for projects' individual ESPP inputs, e.g. WG2 sections. Where there is a codependence, some update may be required with final results.

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



Thanks again to the organisers of the First Workshop, in 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 think where you could contribute!***
- ◆ Over the next 3–6+ months:
Series of topical meetings (WG1 and cross-group) towards 'focus 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 all work together
towards the next collider***



Encouraging wider participation / more activity

And once again:

- ◆ *Whole community is strongly encouraged to think how to contribute*
- ◆ *Crucial to engage community, especially ECRs, in future preparations*
- ◆ *Message especially to PIs / Group Leaders / Seniors:*
 - how can you support the studies?*
 - can you encourage your ECRs / PhD students to do a study?*
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