

ECFA Roadmap for Detector R&D and Plans for ECFA Workshops on an e^+e^- Higgs/EW/Top Factory

FCC Week 2021
28th June 2021

Karl Jakobs, ECFA Chair

ECFA

European Committee for Future Accelerators





3. High-priority future initiatives

An **electron-positron Higgs factory is the highest-priority next collider**. For the longer term, the **European particle physics community has the ambition to operate a proton-proton collider at the highest achievable energy**. Accomplishing these compelling goals will require innovation and cutting-edge technology:

- *the particle physics community should ramp up its R&D effort focused on advanced accelerator technologies, in particular that for high-field superconducting magnets, including high-temperature superconductors;*
- *Europe, together with its international partners, should investigate the technical and financial feasibility of a future hadron collider at CERN with a centre-of-mass energy of at least 100 TeV and with an electron-positron Higgs and electroweak factory as a possible first stage. Such a feasibility study of the colliders and related infrastructure should be established as a global endeavour and be completed on the timescale of the next Strategy update.*

The timely realisation of the electron-positron International Linear Collider (ILC) in Japan would be compatible with this strategy and, in that case, the European particle physics community would wish to collaborate.



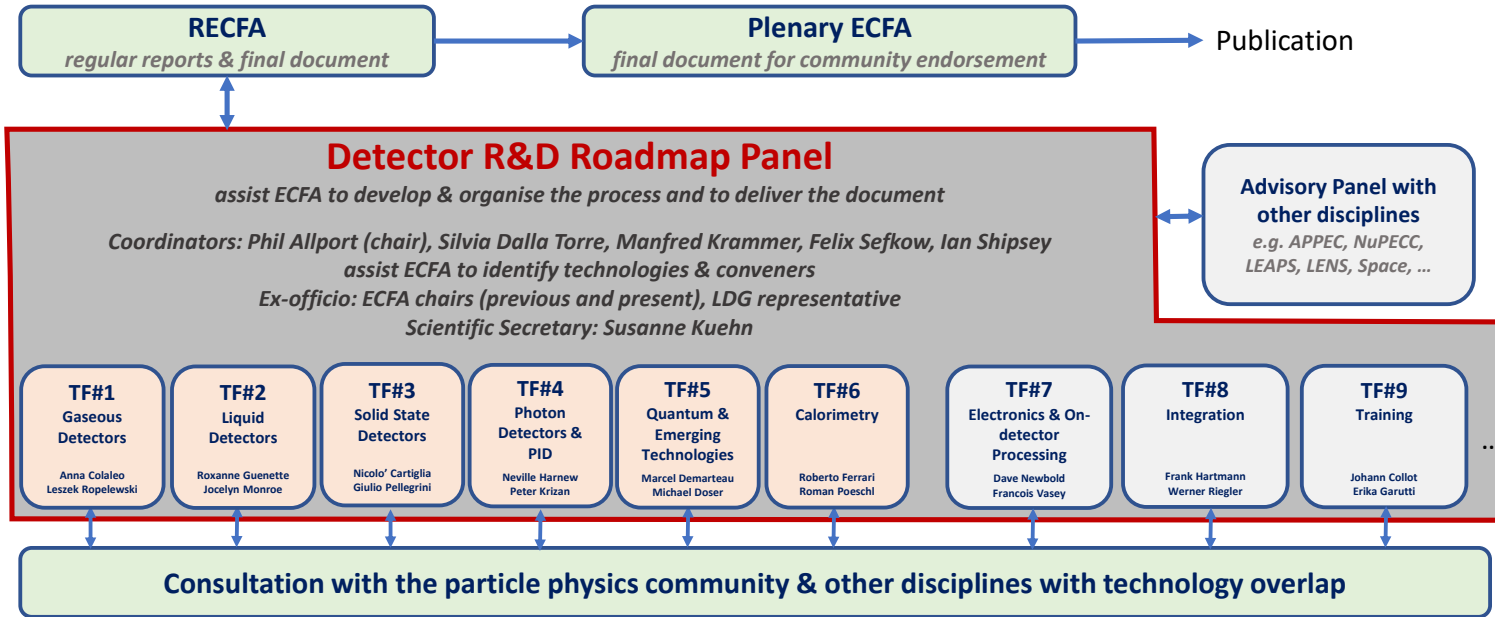
4. Other essential scientific activities for particle physics

...

- c) *The **success of particle physics experiments relies on innovative instrumentation and state-of-the-art infrastructures.** To prepare and realise future experimental research programmes, the community must **maintain a strong focus on instrumentation. Detector R&D programmes and associated infrastructures should be supported at CERN, national institutes, laboratories and universities.** Synergies between the needs of different scientific fields and industry should be identified and exploited to boost efficiency in the development process and increase opportunities for more technology transfer benefiting society at large. Collaborative platforms and consortia must be adequately supported to provide coherence in these R&D activities. The community should define a **global detector R&D roadmap that should be used to support proposals at the European and national levels.***

Organised by ECFA, a roadmap should be developed by the community to balance the detector R&D efforts in Europe, taking into account progress with emerging technologies in adjacent fields. The roadmap should identify and describe a diversified detector R&D portfolio that has the largest potential to enhance the performance of the particle physics programme in the near and long term. ...

The Detector R&D Roadmap Process



- **Task forces** are composed of experts from the community covering key sub-topics in the relevant technology areas, including **two conveners** (who are part of the Roadmap Panel)
- Progress with emerging technologies in adjacent fields is provided through an **Advisory Panel with Other Disciplines** (→ expert contacts by Task Forces area)
- ECFA has provided a list of **National Contacts** (also consulted by Task Forces)

Information on the full process: [ECFA Detector R&D Roadmap](#)

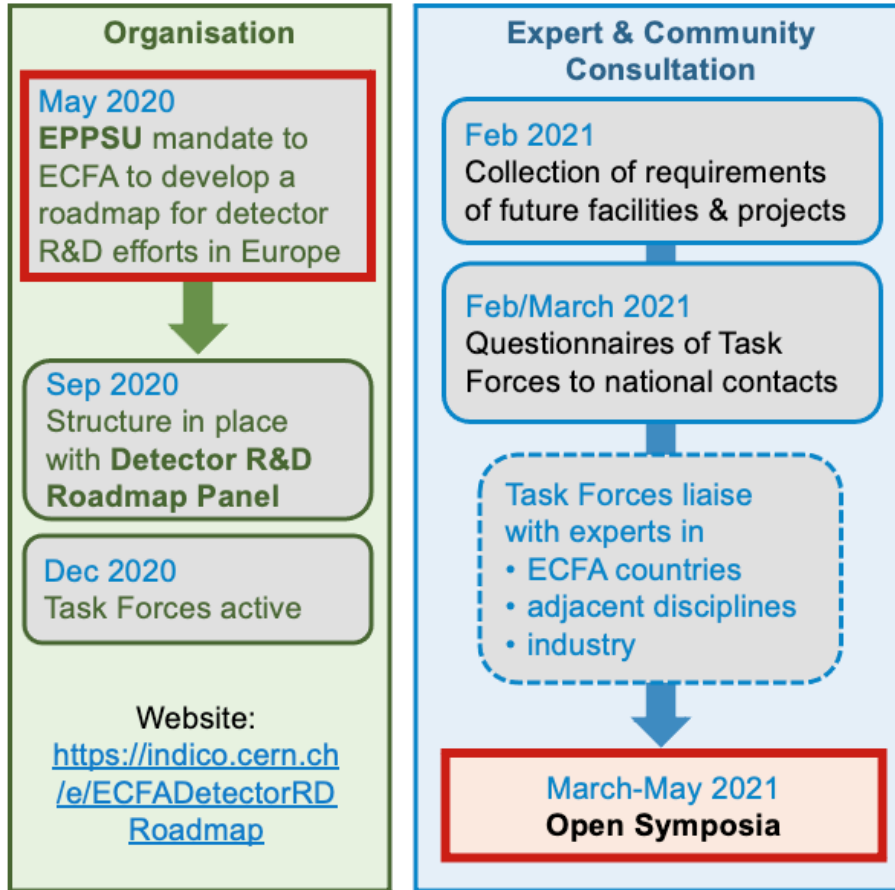
Grouped targeted facilities emerging from the EPPSU

1. Detector requirements for **full exploitation of the HL-LHC** (R&D still needed for LS3 upgrades and for experiment upgrades beyond then) including studies of flavour physics and quark-gluon plasma (where the latter topic also interfaces with nuclear physics).
2. R&D for **long baseline neutrino physics detectors** (including aspects targeting astro-particle physics measurements) and supporting experiments such as those at the CERN Neutrino Platform.
3. Technology developments needed for detectors at **e^+e^- EW-Higgs-Top factories** in all possible accelerator manifestations including instantaneous luminosities at 91.2GeV of up to $5 \times 10^{36} \text{cm}^{-2} \text{s}^{-1}$.
4. The long-term R&D programme for detectors at a **future 100 TeV hadron collider** with integrated luminosities targeted up to 30ab^{-1} and 1000 pile-up for 25ns BCO.
5. Specific long-term detector technology R&D requirements of a **muon collider** operating at 10 TeV and with a luminosity of the order of $10^{35} \text{cm}^{-2} \text{s}^{-1}$.
6. Detector developments for accelerator-based studies of **rare processes**, DM candidates and high precision measurements (including strong interaction physics) at both storage rings and fixed target facilities, interfacing also with atomic and nuclear physics

Grouped targeted facilities emerging from the EPPSU (cont.)

7. R&D for optimal exploitation of dedicated collider experiments studying the **partonic structure of the proton** and nuclei as well as interface areas with nuclear physics.
8. The very broad detector R&D areas for **non-accelerator-based experiments**, including dark matter searches (including axion searches), reactor neutrino experiments, rare decay processes, neutrino observatories and other interface areas with astro-particle physics.
9. **Facilities needed for detector evaluation**, including test-beams and different types of irradiation sources, along with the advanced instrumentation required for these.
10. **Infrastructures facilitating detector developments**, including technological workshops and laboratories, as well as tools for the development of software and electronics.
11. **Networking structures** in order to ensure collaborative environments, to help in the education and training, for cross-fertilization between different technologically communities, and in view of relations with industry.
12. **Overlaps with neighbouring fields** and key specifications required for exploitation in other application areas
13. **Opportunities for industrial partnership** and technical developments needed for potential commercialisation

The Detector R&D Roadmap Process



Input session of Future Facilities I

Friday Feb 19, 2021, 1:00 PM → 6:00 PM Europe/Zurich

Description [Return to Previous Page](#)

<https://indico.cern.ch/event/957057/>

- 1:00 PM** → 1:30 PM **Detector R&D requirements for HL-LHC**
Speaker: Chris Parkes (University of Manchester (GB))
 ECFA_RD_Parkes_1...
- 1:30 PM** → 2:00 PM **Detector R&D requirements for strong interaction experiments at future colliders**
Speaker: Luciano Musa (CERN)
 MUSA_ECFA_IS_20...
- 2:00 PM** → 2:30 PM **Detector R&D requirements for strong interaction experiments at future fixed target facilities**
Speaker: Johannes Bernhard (CERN)
 Detector R&D requir...
- 2:30 PM** → 2:45 PM **Coffee-Tea Break**
- 2:45 PM** → 3:15 PM **Detector R&D requirements for future linear high energy e+e- machines**
Speaker: Frank Simon (Max-Planck-Institut fuer Physik)
 LC_DetRoadmapinp...
- 3:15 PM** → 3:45 PM **Detector R&D requirements for future circular high energy e+e- machines**
Speaker: Mogens Dam (University of Copenhagen (DK))
 ECFA_Detector_R&D...
- 3:45 PM** → 4:15 PM **Detector R&D requirements for future high-energy hadron colliders**
Speaker: Martin Aleksa (CERN)
 20210219-ECFA-Det...
- 4:15 PM** → 4:35 PM **Detector R&D requirements for muon colliders**
Speaker: Nadia Pastrone (Universita e INFN Torino (IT))
 MuonColliders_Dete... MuonColliders_Dete... MuonColliders_Dete...

Input session of Future Facilities II

Monday Feb 22, 2021, 2:00 PM → 6:00 PM Europe/Zurich

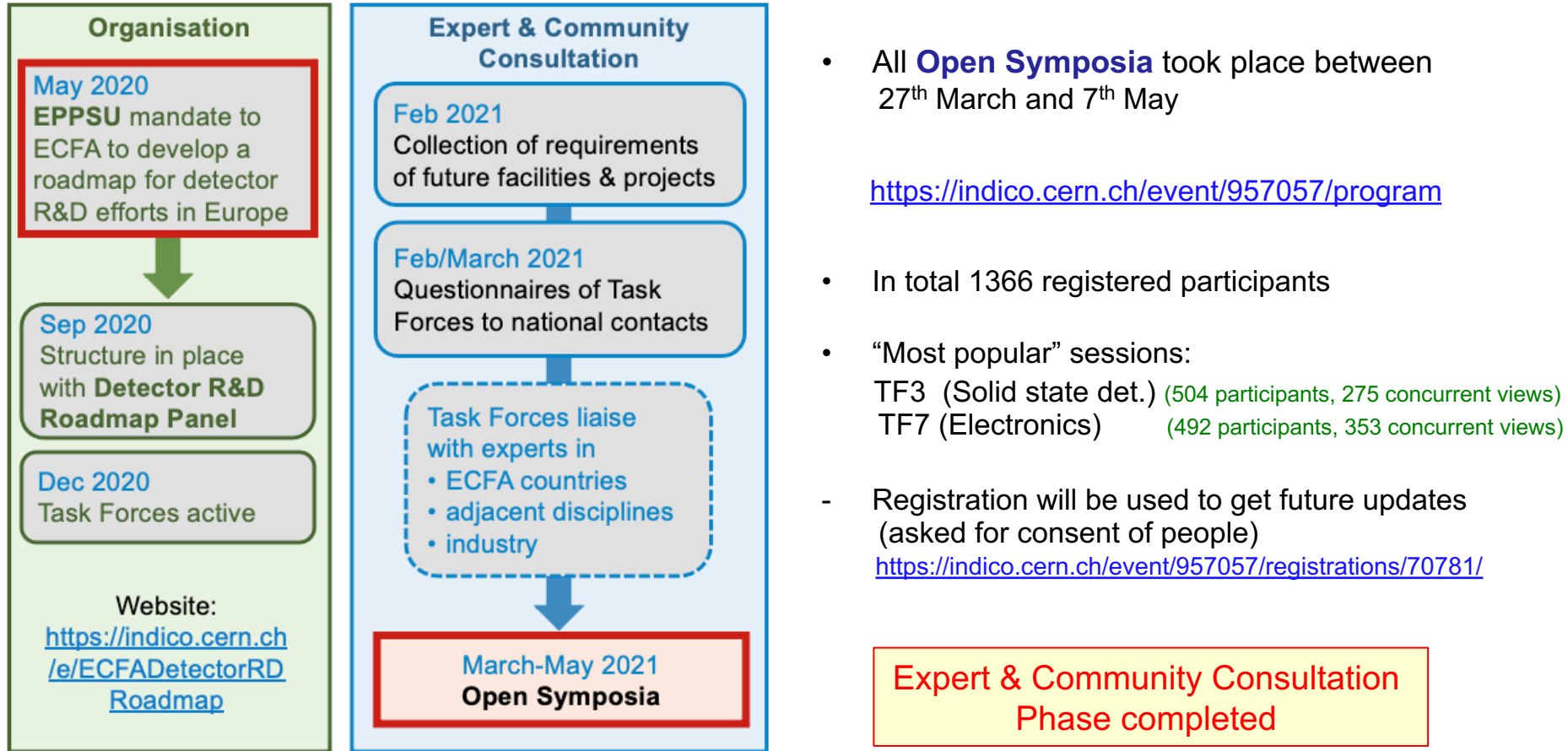
Description [Return to Previous Page](#)

<https://indico.cern.ch/event/994687/>

- 2:00 PM** → 2:30 PM **Detector R&D requirements for future short and long baseline neutrino experiments**
Speaker: Marzio Nessi (CERN)
 21-02-22-ECFA-Neut... 21-02-22-ECFA-Neut...
- 2:30 PM** → 3:00 PM **Detector R&D requirements for future astro-particle neutrino experiments**
Speaker: Maarten De Jong (Nikhef National Institute for subatomic physics (NL))
 ECFA - Maarten de ... ECFA - Maarten de ...
- 3:00 PM** → 3:30 PM **Detector R&D requirements for future dark matter experiments**
Speaker: Laura Baudis (University of Zurich)
 baudis_ecfa_feb21...
- 3:30 PM** → 3:40 PM **Coffee-Tea Break**
- 3:40 PM** → 4:10 PM **Detector R&D requirements for future rare decay processes experiments**
Speakers: Cristina Lazzeroni (University of Birmingham (GB)), Cristina Lazzeroni (University of Birmingham (GB))
 ECFA_Lazzeroni.pdf
- 4:10 PM** → 4:40 PM **Detector R&D requirements for future low energy experiments**
Speaker: Dr Alexandre Obertelli (TU Darmstadt)
 ECFA_LowEnergyFa...

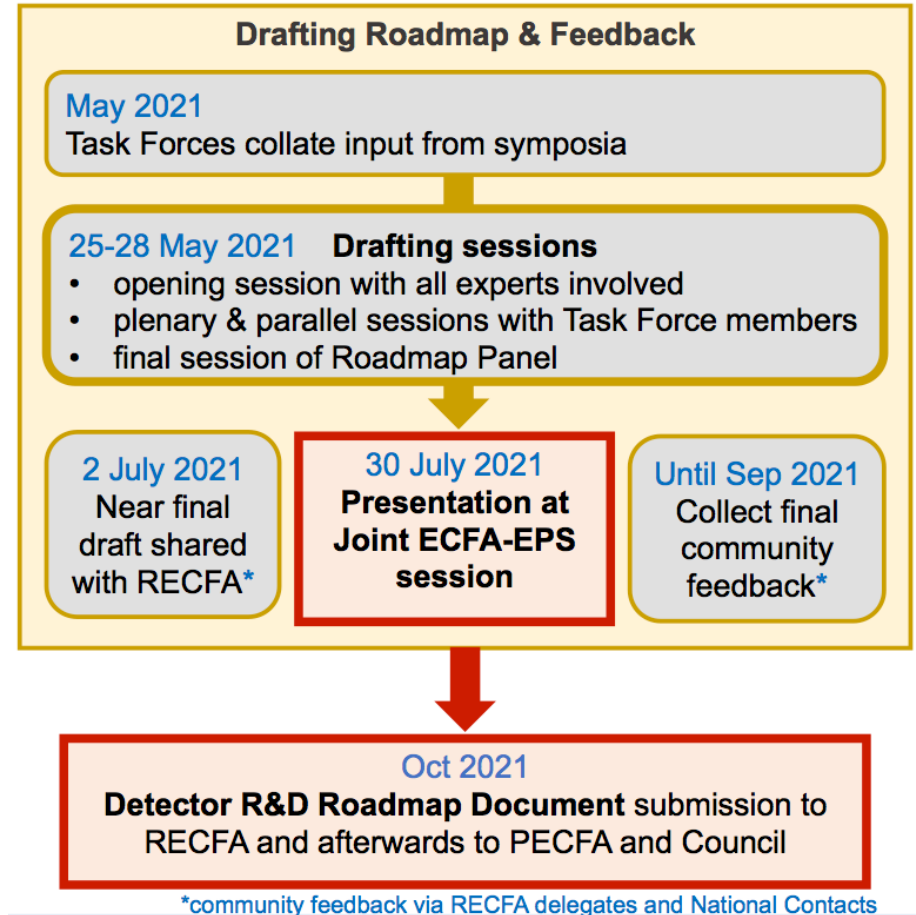
Brief: Emphasise unmet detector R&D needs;
long time scales → extends decades into the future

The Detector R&D Roadmap Process (cont.)



The Detector R&D Roadmap Process (cont.)

- **Drafting Session during week 25 – 28 May**
Worked very well, stressful due to full online format, but interactions between TFs needed and fruitful
- Major issues addressed:
 - Agreed on main priorities (“Detector Research Themes”) in the different technology areas
 - Identified overlap, transversal activities
 - Finalise layout of the various chapters
 - Discussion of common timeline with LDG for large high-priority projects
- **Finalisation of “near final draft” during June,** will be shared with RECFA by 2nd July



Major considerations for final recommendations

- Important principle: bring out synergies and stress interconnections between developments of similar technologies needed at different times by different programmes
 - For projects without fully defined schedules, adopt to work in terms of “the earliest technically feasible start date”, such that detector technology readiness would not become the limiting factor
 - Each Task Force has sub-divided their technology area into broad sub-topics and, using the list of targeted facilities, defined the most pressing requirements as a function of time (when needed, or could be needed)
- **Define major Detector Research & Development Themes**
- It is certainly not possible to foresee all different ways current detector R&D may evolve to enable future experimental programmes, however, **need for greater coherence and coordination is clearly seen** and guidance should be provided on what are currently viewed as most urgent topics to be addressed
 - Conclusions will also contain recommendations of more general significance (infrastructure, funding lines, organisation of R&D efforts, career paths, ...)
 - In addition to the roadmap document of about 200 pages, an 8-page **Glossy Summary Document**, is planned to be produced, addressed to Funding Agencies and Policy Makers (proper language)

Next steps in Detector R&D Roadmap Process

- 1st draft shared with RECFA on 2nd July
- Review and discussion by (R)ECFA (July 2021)
Feedback by RECFA delegates and National Contacts on structure, major research lines and other recommendations
- **Open Presentation at the [EPS Conference](#)
[ECFA-EPS Session on 30th July](#)**
(Speaker: Phil Allport, Univ. Birmingham, Roadmap Panel Chair)

→ Further community feedback
- Finalisation of document during August / September 2021
- ECFA endorsement in November 2021
- Presentation to CERN Council in December 2021
(goal to have printed copies available for this)

Physics, Experiments and Detectors at a Future Higgs/EW/Top Factory

ECFA statement (endorsed at the Plenary ECFA meeting on 13 July 2020)

- *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

- Setting up an **International Advisory Committee (IAC)** was agreed to be the next step with involvement of some RECFA members and European leaders of possible future Higgs factories. In addition the (HL)-LHC community should be represented.

- ECFA-chair would act as chair: Karl Jakobs
- From RECFA: Jean-Claude Brient, Tadeusz Lesiak, Chiara Meroni
- With (HL)-LHC experience: Jorgen D'Hondt, Max Klein, Aleandro Nisati, Roberto Tenchini
- For theory: Christophe Grojean, Andrea Wulzer
- For Linear Colliders: Steinar Stapnes, Juan Fuster, Frank Simon, Aidan Robson
- For Circular Colliders: Alain Blondel, Mogens Dam, Patrick Janot, Guy Wilkinson
- For CERN: Joachim Mnich

IAC Recommendations

- Extension to include **electroweak** and **top** factory
- Extend physics studies, where relevant (not all completed at time of EPPSU), however, focus on e^+e^- potential (no discussion of pros and cons of various machines or alternatives to e^+e^- Higgs factories)
- Understand better the interplay between (HL)-LHC and an e^+e^- Higgs/EW/Top factory
- Development of common tools important (software, simulation, fast simulation, ...)
- Development of common analysis methods of high interest
- Exploit synergies, discuss challenges, do not restrict to common items
- Need for theoretical accuracy and MC generator improvements ...
- ...

- Overall goal: make sure community works coherently together
- Open for collaboration with other ongoing activities, e.g. Snowmass, ...
- Process is open for all interested physicists

There was unanimous agreement within the IAC that these objectives can only be reached if **Working Groups** would be set up
Conveners (theory and experiment), regular meetings, working towards ECFA workshops, ...

ECFA Working Groups

WG 1: Physics Potential

Convener: Juan Alcaraz (CIEMAT - Madrid), Jenny List (DESY), Fabio Maltoni (UC Louvain / Bologna) and James Wells (Univ. Michigan)

WG 2: Physics Analysis Methods

Convener: Patrizia Azzi (INFN-Padova / CERN), Fulvio Piccinini (INFN Pavia) and Dirk Zerwas (IJCLab)

[Kick-off meeting](#) to start WG1 and WG2 activities took place on 18th June:

WG 3: Detector R&D

Activities will be started once the [ECFA Detector R&D Roadmap](#) is defined

- **EFT** (global) interpretation of Higgs factory measurements, including EW, Z pole and top physics, and its impact on concrete new physics scenarios and models.
- **Extend the study of the impact also on specific models that cannot be matched onto EFT.**
- **Exploration of different flavour scenarios and interplay with flavour data.**
- Identification of measurements that **HL-LHC** can do in order to increase the physics potential of the future Higgs and top/EW Factory.
- **HL-LHC precision physics interplay** with the Higgs and top/EW factory potential, including the not-yet-complete assessment of the high-pT probes potential at the HL-LHC. Comparative attention should also be paid to the potential of other future colliders.
- Requirements for accuracy in **theoretical calculations** and **parametric uncertainties**, and perspectives to achieve it.
- Perspectives for **experimental uncertainties**.
- Broad exploration of the **new physics discovery potential** of the future Higgs and top/EW factory, including the search for Feebly Interacting Particles also in connection with “Physics Beyond Colliders” activities.
- Availability and development of **Monte Carlo generators** required to achieve the physics goals.

Mandate WG 2

- Monte Carlo generators for e+e- precision EW, Flavour, Higgs, and top physics
- Software framework
- Fast simulation and the limitations of such techniques
- Track and vertex reconstruction algorithms
- Jet algorithms / jet reconstruction
- Constrained kinematic fits
- Particle-flow reconstruction and global event description
- Requirements on particle identification
- Flavour tagging algorithms
- Importance of timing information
- Luminosity measurement

Kick-off meeting of ECFA workshops

14:00	Introduction of the ECFA study 40/S2-D01 - Salle Dirac, CERN	Karl Jakobs	14:00 - 14:15
	Experimental challenges at future e+e- colliders 40/S2-D01 - Salle Dirac, CERN	Emmanuel Francois Perez	14:15 - 14:40
	Challenges in global interpretation of data from future e+e- colliders and interplay with HL-LHC 40/S2-D01 - Salle Dirac, CERN	Jorge de Blas	14:40 - 15:05
15:00	Theoretical challenges for future e+e- colliders 40/S2-D01 - Salle Dirac, CERN	Michael Peskin	15:05 - 15:30
	Coffee / tea break 40/S2-D01 - Salle Dirac, CERN		15:30 - 15:45
	Physics Event Generators, BeamConditions (Beamstrahlung, Polarization), Standard Candles and Luminosity Wolfgang Kilian		
16:00	Physics Performance (reco Pflow, Kinematic fit, tracking, PID) 40/S2-D01 - Salle Dirac, CERN	Philipp Roloff	16:05 - 16:25
	Detector Simulation (FastSim and Full Sim etc.) 40/S2-D01 - Salle Dirac, CERN	Daniel Jeans	16:25 - 16:45
	Software Ecosystem 40/S2-D01 - Salle Dirac, CERN	Gerardo Ganis	16:45 - 17:05
17:00	Way-ahead with the WG1 and WG2 activities 40/S2-D01 - Salle Dirac, CERN	Jenny List	17:05 - 17:25

<https://indico.cern.ch/event/1033941/>

Physics, Experiments & Detector studies for an e^+e^- Higgs/EW/Top factory

- The working groups will carry out work over the forthcoming years in preparation of **community-wide plenary ECFA workshops**
- Major milestones: **ECFA workshops** are planned to be held in 2022 and 2023

In 2021: presentation at the **Open Plenary ECFA meeting** on 19th November at CERN

- Final report: “ECFA report”
(à la Aachen for LHC, or Aix-Les-Bains for LHC Phase-II upgrade)
- Major entry portal to collect information on the ongoing activities:

<https://indico.cern.ch/event/1044297/>

All upcoming events will be announced there!

- Registration of kick-off meeting will be used to define an e-group for further information

Until and between the ECFA Plenary Workshops

Plans of conveners, as presented on 18th June

Organize smaller events:

- Seminar series
- Topical workshops

Seminar series:

- ~monthly, mostly theory / physics topics

Topical workshops:

- Remote zoom: ½ day maximum
- Presence (+remote): 1+ day, in nice easy access places: Louvain, Madrid, Pavia, Padua, CERN, Orsay, DESY....
- Informal, intense discussions

Topics:

- Scope defined in mandates of the groups
- What is most urgent to discuss?
=> **your input welcome!**

Examples for topical workshops:

- Specific **reconstruction** topics: ACTS, kinematic fitting, PID, jet clustering, ...
- Specific **experimental** topics: luminosity measurement, control of experimental systematics, standard candles for detector performance, ...
- Specific **physics topics**: Higgs properties, M_W , A_{FB} , ...
- Specific **theory** questions: precision calculations, event generators
- Global **interpretation**: EFT fitting, UV complete BSM models, ...
- **Interplay with HL-LHC**
- How to **promote the need for a next collider** to other scientists / general public / politicians?

Examples for seminars:

- "BSM Higgs decays with colinear photons / leptons / quarks"
- "From top observables to top Yukawa coupling"