

ECFA Higgs/Top/EW Factory WG 1 - Physics Potential



Higgs Top Electroweak

30 November 2022



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ECFA-WHF-WG1-HTE-conveners@cern.ch

ECFA Higgs/Electroweak/Top Factory Workshop Series

Based on the **recommendations of the Update of the European Strategy for Particle Physics**, the **European Committee for Future Accelerators (ECFA)** has decided to organise a series of **workshops on physics studies, experiment design and detector technologies towards a future electron-positron Higgs/EW/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 strategy item.

To set up the relevant structures and to define a path towards such workshops, an International Advisory Committee (IAC) has been formed. It suggested to establish **three Working Groups**, led by conveners from both experiment and theory:

- [WG 1: Physics Potential](#)
 - Conveners: Juan Alcaraz (CIEMAT - Madrid), Jenny List (DESY), Fabio Maltoni (UC Louvain / Bologna) and Jorge de Blas (Univ. Granada)
- **WG 2: Physics Analysis Methods**
 - Conveners: Patrizia Azzi (INFN-Padova / CERN), Fulvio Piccinini (INFN Pavia) and Dirk Zerwas (IJCLab/DMLab)
- **WG 3: Detector R&D**
 - Starting off, as [Detector R&D Roadmap documents](#) are finished now ([Synopsis](#) and [Full Document\(10.17181/CERN.XDPL.W2EX\)](#))

[Informational Kick-off Meeting](#) was held online on Friday 18th June 2021.

Time frame: March 2021 – ~December 2024

Top-level indico page: <https://indico.cern.ch/event/1044297/>

Working Group 1 - Physics Potential

WG 1 activities ([indico](#)) and organization ([twiki](#)):

Subgroups:

- **WG1-PREC (Precision in theory & experiment):**
 - Conveners: Ayres Freitas (Pittsburgh), Paolo Azzurri (Pisa), Adrian Irlles (Valencia), Andreas Meyer (DESY)
ecfa-whf-wg1-prec-conveners @cern.ch
- **WG1-GLOB (Global interpretations in (SM)EFT and UV complete models):**
 - Conveners: Sven Heinemeyer (IFCA/IFT), Alexander Grohsjean (DESY), Junping Tian (Tokyo), Marcel Vos (Valencia), Jorge de Blas (Granada) ecfa-whf-wg1-glob-conveners @cern.ch
- **WG1-HTE (HIGGS-TOP-EW and connection with (HL-)LHC):**
 - Conveners: Chris Hays (Oxford), Karsten Köneke (Freiburg), Fabio Maltoni (Louvain)
ecfa-whf-wg1-hte-conveners @cern.ch
- **WG1-FLAV (Heavy Flavours):**
 - Conveners: David Marzocca (Trieste), Stephane Monteil (Clermont Ferrand), Pablo Goldenzweig (KIT)
ecfa-whf-wg1-flav-conveners @cern.ch
- **WG1-SRCH (Feebly interacting particles, direct low mass searches):**
 - Conveners: Roberto Franceschini (Rome III), Rebeca Gonzalez (Uppsala), Filip Zarnecki (Warsaw)
ecfa-whf-wg1-srch-conveners @cern.ch

WG1 Seminar series, workshops, etc, see [this indico](#) category

Subgroup on Higgs-Top-EW and connection with HL-LHC (HTE)

Organization:

- Group meetings: WG1-HTE
- egroup [mailing list](#)
 - You can also subscribe to the egroups of the groups; just search in egroups for “ECFA-WHF-WG1”.
- Conveners: Chris Hays (Oxford), Karsten Köneke (Freiburg), Fabio Maltoni (Louvain)
- Convener's email: ecfa-whf-wg1-hte-conveners @cern.ch
 - **Please don't hesitate to talk to us for any ideas, suggestions, questions!**

Mandate:

- Identify measurements that the **(HL-)LHC** can perform in order to increase the physics potential of a future Higgs/Top/EW Factory.
 - High-precision inclusive measurements
 - Differential measurements, e.g., at high p_T
 - ...
- The physics potential of an e^+e^- HTE factory will also be compared to the potential of other future colliders.

You can find all our events, meetings, and workshops in our [HTE indico category](#).

Events of the HTE Group

First kickoff workshop: April 20-22 2022 (hybrid CERN/zoom)

- <https://indico.cern.ch/event/1132480/>, 129 registrants
- Overview of activities, including reports from Snowmass

Series of mini-workshops (3-4h), going up in e^+e^- cms energy [zoom-only]:

- First mini-workshop: September 23 2022
 - <https://indico.cern.ch/event/1196494/>
 - Z-pole physics
- Next mini-workshops on WW threshold physics, then ZH,... (dates TBC)

1st ECFA Workshop on Higgs/EW/Top Factory

2022 ECFA e+e- Workshop in Hamburg

5 – 7 October 2022: <https://indico.desy.de/event/33640/>

- Nearly 200 participants
- Status of Working Group activities
- Discussions of future plans
- Interactions between theory and experiments
- ...
- Plenary talks were recorded... have a look!
- ...
- Very nice public talk by Hitoshi Murayama
“Does the World need a new particle collider -
and why?”
(including panel discussion) [\[link to youtube\]](#)



Two more “overall” workshops envisioned in 2023 and 2024

Some messages from Hamburg Workshop

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.

Some messages from Hamburg Workshop

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, $K_S^0 \rightarrow \pi^+\pi^-$, JER, ...
- SMEFT & BSM interpretation

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

Contributions to HTE group: CPV in Higgs Couplings

Important to test the CP structure of Higgs-boson couplings

e⁺e⁻ colliders complement the HL-LHC

Bounds on α at 95% CL ($\kappa_t = 1$)	Channel	Collider	Luminosity
$ \alpha \lesssim 36^\circ$ [1]	dileptonic $t\bar{t}(h \rightarrow b\bar{b})$	HL-LHC	3 ab ⁻¹
$ \alpha \lesssim 25^\circ$ [2]	$t\bar{t}(h \rightarrow \gamma\gamma)$ combination	HL-LHC	3 ab ⁻¹

e⁺e⁻ constraints weaker

Expect $H\tau\tau$ CP angle constraint of 75 mrad at an e⁺e⁻ collider (5° at HL-LHC)

Caterina Vernieri, April 20

Nicholas Wardle, April 20

Polarized e⁺e⁻ beams:

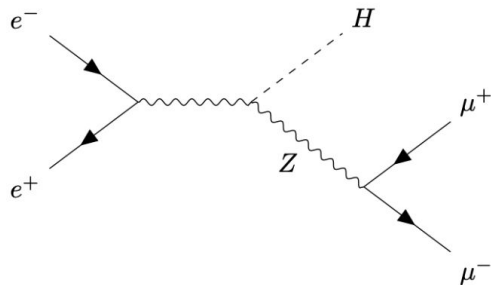
- > The azimuthal angular distribution of μ^- from Z decay would be P-odd when $\tilde{\kappa}_V = 1$, while the SM distribution is pure P-even.
- > One can construct the observables by partially integrating the ϕ_{μ^-} for the cross section, which can be sensitive to the CP-odd structure of the ZZH couplings

$$\mathcal{A}_\mu = \frac{\sigma(\sin 2\phi_{\mu^-} > 0) - \sigma(\sin 2\phi_{\mu^-} < 0)}{\sigma(\sin 2\phi_{\mu^-} > 0) + \sigma(\sin 2\phi_{\mu^-} < 0)}$$

$$\mathcal{A}_\mu(\text{SM}) = 0 \quad \mathcal{A}_\mu(\tilde{\kappa}_V = 1) = 19.55\%$$

Next step

- > We can estimate the uncertainties of the asymmetry at the ILC with specific luminosity



$$e^+e^- \rightarrow HZ, Z \rightarrow \mu^+\mu^-$$

[Chris Hays, Karsten Köneke, Fabio Maltoni \(workshop summary\)](#),
7th October 2022

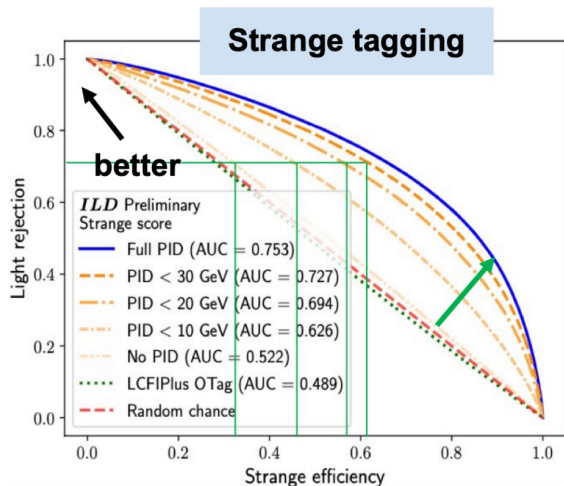
Contributions to HTE group: $H \rightarrow s\bar{s}$



Alternative approaches

2203.07535

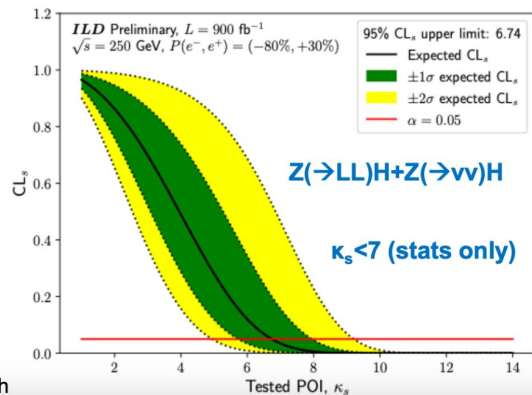
- Jet tagging using Recurrent Neural Net (RNN)
 - **Inputs:** jet-level info + particle-level info [10 highest- p_T particles]
 - **Multiclass output:** b, c, s, ud, gluon
 - Designed for ILD; uses FullSim



- Significant improvement compared to previous ILD tagging algorithm (LCFIPlus)
- PID capabilities up to $p_T \sim 30$ GeV important

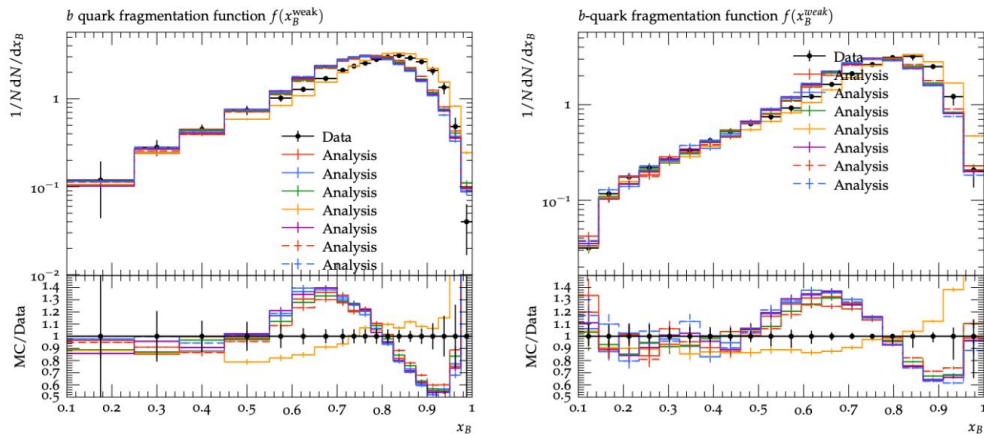
Application on $H \rightarrow s\bar{s}$

- ILC @ 250 GeV; 900 fb^{-1}
- Signal: $Z(\rightarrow \nu\nu)H$ and $Z(\rightarrow LL)H$
- Analysis design: selection on evt-level vars
- Signal extraction: fit strange-tagging discriminant



Contributions to HTE group: Hadronization Models

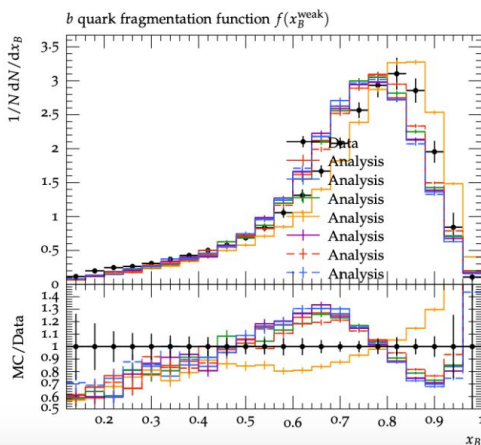
LEP b-fragmentation measurements discrepant between experiments



ALEPH

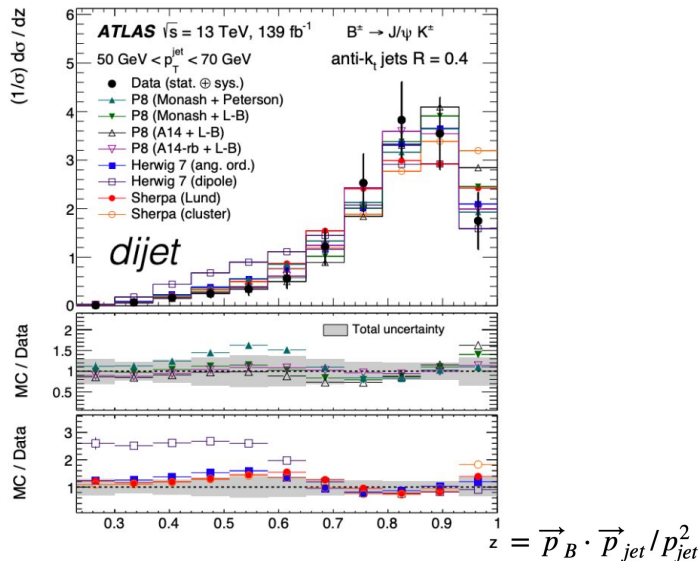
OPAL

SLD



Frank Krauss, October 6

Can LHC b-fragmentation measurements resolve differences?



Chris Pollard, April 21

[Chris Hays, Karsten Köneke, Fabio Maltoni \(workshop summary\)](#),
7th October 2022

Some messages from Hamburg Workshop

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

We welcome all of you
to get engaged!

Some messages from Hamburg Workshop

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