

SUMMARY

FA Higgs Factories Study
and topical meeting on
Reconstruction
July 11-12 , 2023

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<https://indico.cern.ch/event/1283129/>

WG2: Physics Analysis Methods

GENERATORS

SIMULATION

RECONSTRUCTION

ALGORITHMS & TOOLS

SOFTWARE ECOSYSTEM

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

Software Ecosystem - Key4hep

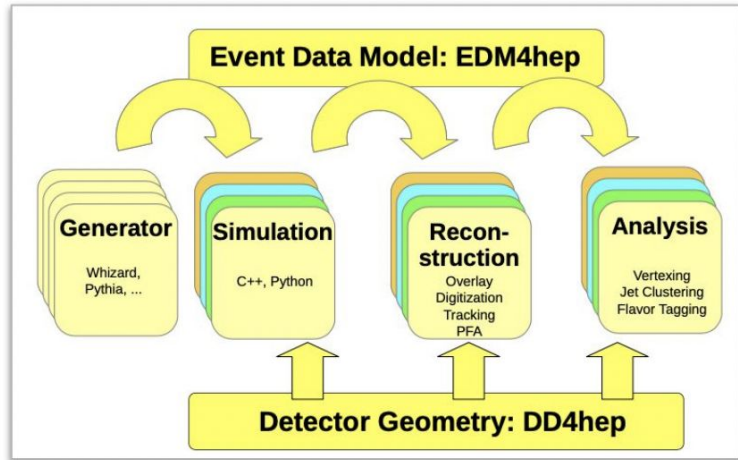
Create a software ecosystem integrating in optimal way various software components to provide a ready-to-use full-fledged solution for data processing of HEP experiments

- *Key4hep* federates FCC, ILC, CLIC , CEPC and other experiments
- In use or medium term migration plan
- Supported by R&D efforts (AIDA, CERN EP etc.)
- KEY4HEP coordinators consulted and involved in the the organisation of all WG2 meetings

Frank Gaede

Gerardo Ganis

André Sailer



LIST OF WG2 TOPICAL WORKSHOPS

1st Topical Meeting on Generators

(jointly with WG1)

<https://indico.cern.ch/event/1078675/>

(9-10 November 2021, CERN, hybrid format)

(118 participants)

as a follow up: **Focus Meeting on Beamstrahlung** (12 January 2022, online only)

<https://indico.cern.ch/event/1100734/>

(65 registrants)

1st Topical Meeting on Simulation

<https://indico.cern.ch/event/1097819/>

(1-2 February 2022) (forseen in Padua but moved online)

(141 participants)

1st Topical Meeting on Reconstruction

<https://indico.cern.ch/event/1124095/>

(4-5 May 2022, Desy, hybrid format)

(107 participants)

2nd Topical Meeting on Generators

(jointly with WG1)

<https://indico.cern.ch/event/1266492/>

(21-22 June 2023, Brussels hybrid format)

2nd Topical Meeting on Reconstruction

<https://indico.cern.ch/event/1283129/>

(11-12 July 2023, CERN, hybrid format)

1st Reconstruction Topical Workshop

Focused on taking stock of the different algorithms currently developed for lepton colliders and the latest ideas and experience from the LHC

- **Tracking I**

- MarlinTrk and Tracking in ILD (Frank Gaede)
- Conformal Tracking (SiD, CLIC, CLD) (Erica Brondolin)
- Special Tracking Gaussian Sum Filter@LHC (Ying An)

- **Tracking II**

- Tracking for CEPC (Chengdong Fu)
- ACTS (Paul Gessinger)
- Tracking for FCC IDEA (Nicola De Filippis)

- **Fundamentals**

- PFA or no PFA (Jean-Claude Brient)

- **Particle Flow I**

- Particle Flow: Pandora (John Stuart Marshall)
- Particle Flow with CMS (Kenneth Long)
- Particle Flow: Arbor (Manqi Ruan)
- Energy Flow in ATLAS (Mark Hodgkinson)

- **Particle ID**

- Flavour Tagging in ILD (Adrian Irles)
- Particle Identification with Gaseous Tracking and Fast Timing (Ulrich Einhaus)
- Flavour Tagging from CMS to FCC (Loukas Gouskos)

2nd Reconstruction Topical Workshop Agenda

Focused on following up on developments from last year. How to integrate and satisfy the needs of the “ECFA focus topics” physics analyses. Fostering the cross-projects work profiting of the key4hep ecosystem

FIRST DAY

- ECFA TOPICS
- KEY4HEP
- TRACKING & OBJ RECO

SECOND DAY

- PARTICLE ID
- ML BASED RECONSTRUCTION
- KINEMATIC FITS

ECFA Focus Topics List

- 1 **HtoSS** – $e^+e^- \rightarrow Zh: h \rightarrow s\bar{s}$ ($\sqrt{s} = 240/250$ GeV) (JdB)
- 2 **ZHang** – $e^+e^- \rightarrow Zh$: reconstruction of production and decay angles ($\sqrt{s} = 240/250$ GeV) (JdB)
- 3 **Hself** – Determination of the Higgs self-coupling (JdB)
- 4 **Wmass** – W mass from WW threshold and continuum ($\sqrt{s} = 161, 240/50, 350/380, \dots$ GeV) (JdB)
- 5 **WWdiff** – Full studies of WW and $e\nu W$ ($\sqrt{s} = 240/250, 365$ GeV) (JdB)
- 6 **TTthres** – Top threshold: Detector-level simulation study of $e^+e^- \rightarrow t\bar{t}$ at a typical threshold-scan energy ($\sqrt{s} = 350, 365$ GeV) and threshold scan optimisation (JL)
- 7 **LUMI** – Precision of the luminosity measurement from low-angle Bhabha scattering (JL)
- 8 **EXscalar** – New exotic scalars (JL)
- 9 **LLPs** – Long-lived particles (JL)
- 10 **EXtt** – Exotic top decays (FM)
- 11 **CKMWW** – CKM matrix elements with on-shell and boosted W decays at $\sqrt{s} \geq m_W$ (PK)
- 12 **BKtautau** – $B^0 \rightarrow K^{0*}\tau^+\tau^-$ (PK)
- 13 **TwoF** – EW precision: 2-fermion final states ($\sqrt{s} = M_Z$ and beyond) (PK)
- 14 **BCfrag** – Measurement of b - and c -fragmentation functions and hadronisation rates ($\sqrt{s} = M_Z$ and beyond) (FM)
- 15 **Gsplit** – Measurement of gluon splitting to $b\bar{b} / c\bar{c}$, interplay with separating $h \rightarrow$ gluons from $h \rightarrow b\bar{b}/c\bar{c}$ ($\sqrt{s} = M_Z$ and beyond) (FM)

ECFA Topics needs/input

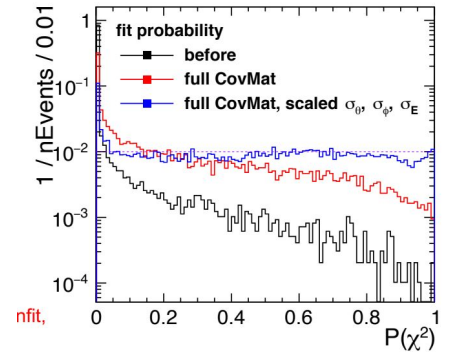
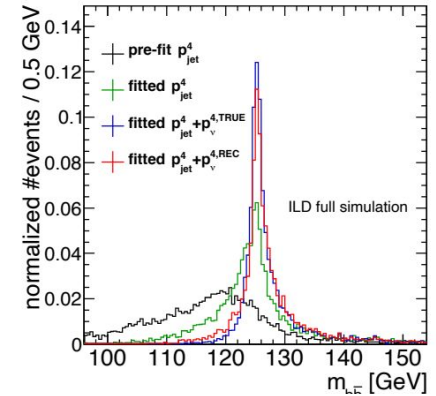
Summary by Jenny List: see here for details

https://indico.cern.ch/event/1283129/contributions/5480277/attachments/2681888/4652352/focus_topics_reconee_ds_jlist_230711.pdf

- **Two fermions: ee→bb/cc/ss/uu/dd/tautau/mumu : Precise measure of total rates, differential xs and tau polarization**
- Needs:
 - Jet flavor tagging with high-purity → ML developments → **work in progress to cross-test ParticleNet**
 - Efficiency measurement via double tagging (other hemisphere tagging)
 - Quark charge determination:
 - Kaon charge: role of PID, strange tagging → **work in progress for a PID “framework”**
 - Vertex charge: new algorithms to check (LCFIVertex)? Constraints on vertex detectors in the forward?

ECFA Topics needs/input - continue

- **Multi-jet processes (WW, ZHH, tt...): Jet clustering + fitting**
 - Jet clustering implemented in Fastjet for studies
 - Valencia new algorithm specific for high-energy ee colliders (CLIC)
 - Seems limiting factor for Higgs self-coupling: studies at higher energy → need to check the situation at FCC-ee range.
 - **Noticed (last FCC-ee Higgs meeting): when many soft jets, wrong candidate association to jets.**
 - PFA studies for LC done on light jets, not really on heavy flavour. → **Improvement in semileptonic decays with electron reco in jets (Leonhard Reichenbach) helping with neutrino recovery (ongoing)**
 - Kinematic fitting: lots of development in LC for fits → **MarlinKinFit available to be tried on FCC-ee events via converters (some work to adapt is needed of course)**



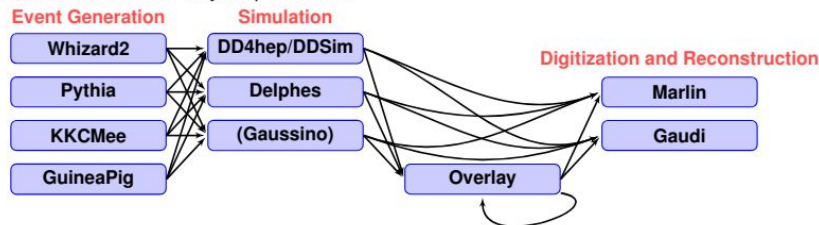
ECFA Topics needs/input - continue

- **LLP final states:** focus on alternative track and very displaced vertex reconstruction techniques (LHC experience useful)
https://indico.cern.ch/event/1283129/contributions/5480256/attachments/2681834/4652413/ETorro_ECFA_ReconstructionWS_072023.pdf
- **Strange tagging & Higgs to strange:** PID crucial both as reconstruction algorithms and detector concepts. Need development of both:
 - new detector ideas → simulation → reconstruction algorithms
- **WMass, WW, CKMWW, Luminosity (but also BCfrag, Gsplit):**
 - qqlnu channel workhorse for WWdiff and Wmass requires a lot of pieces from reconstruction (similar issues in top): from lepton ID and reconstruction, tau ID, to JES, kinematic fits, vertexing etc...
 - Luminosity, center of mass energy calibration, absolute momentum scale, etc: studies in progress for FCC-ee that has more stringent needs seem to be more advanced than the ILC ones. → **need more resources to close the loop on the ultimate needs from a complete analysis**

New developments in key4hep

- **New LCIO-to-EDM4hep conversion library & standalone lcio2edm4hep available.**
 - Will be used in k4MarlinWrapper as well → **This allows to try kinematic fits over our Delphes samples**
 - https://indico.cern.ch/event/1283129/contributions/5469144/attachments/2682151/4652889/lcio2edm4hep_ecfa_reco_2023.pdf
- **Discussion on overlays** (background pileup in LHC jargon): not such a big problem for FCC-ee however, still needed for background studies. C3 proposing ideas taken from CMSSW → **worth try on FCC-ee once DD4HEP description of IDEA is available for the DC background study?**

Workflow Modules for Key4hep Software

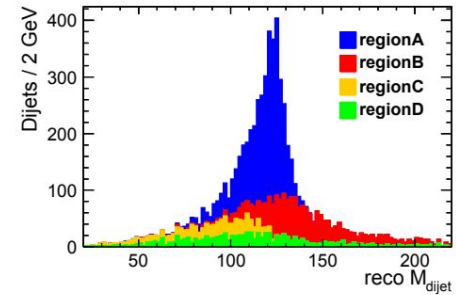
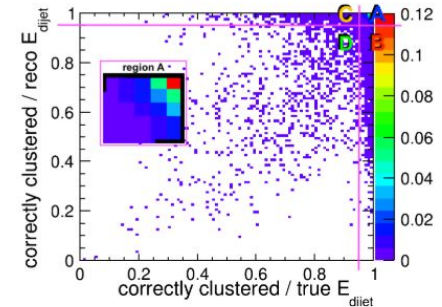


study with CLD done fully in DD4hep, worth trying these tools too?

- ▶ **Overlay System for adding beam background files to MC jobs efficiently and effectively**
- ▶ Pandora Particle Flow calibration service (Marlin based)

Other developments...

- Interesting discussion on **ML tools for tagging** (DNN from ILC and ParticleNet for FCC) and **event reconstruction** (adding ML to Pandora framework for clustering)
- Development to create a “**framework**” (CPID) to collect the various ParticleID techniques in a single code accessible with key4hep.
 - PID information of different origin is passed to a NN that returns a score.
 - Currently in MarlinProcessor (can be tested now) but **ongoing work to make it as a native key4hep/GAUDI.**
- **Tracking algorithm:** ACTS and others to be tried on FCC-ee detector concepts
- **Discussion on kinematic fitting in multijet events (HH): starting from an old analysis for higgs self-coupling analysing how to improve the result.**
 - effects from jet clustering and wrong association degrade the mass resolution strongly affect the uncertainty on λ_{33}
 - at ILC maybe high \sqrt{s} can help...still need to improve the kinematical fitting from the jet classification itself, to the association of constituents...
 - Fitting program can already be tested



ECFA Workshop in Paestum (Italy)

- October 11-13
- <https://agenda.infn.it/event/34841/>
- Registration open
 - attractive pricing to facilitate participation of ECRs
- **Abstracts for poster can still be submitted!!!**
- **DEADLINE TO REGISTER FOR key4hep TUTORIAL extended**
- Priority to new and/or cross-project work



SECOND • ECFA • WORKSHOP
on e^+e^- Higgs / Electroweak / Top Factories

11-13 October 2023
Paestum / Salerno / Italy

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

Take away message

- The approach from FCC-ee to start from state-of-the-art tools from LHC and Key4hep is starting to pay off.
- It has become clear that many studies/algorithm from the LC community now need to be updated to be comparable as “physics results”
 - more interest from the LC side to move to newer tools/collaborate
- Some work cross-platform is starting or could start: tagging, tracking, kinematic fitting, background overlay
 - still a lot of (painful) need for converter between LCIO/EDM4HEP but effort to “extract” more generic tools (kin fitting for instance) as native key4hep
- **Check the Workshop slides for more details and contact us if you are interested in any of these topics for your analysis**