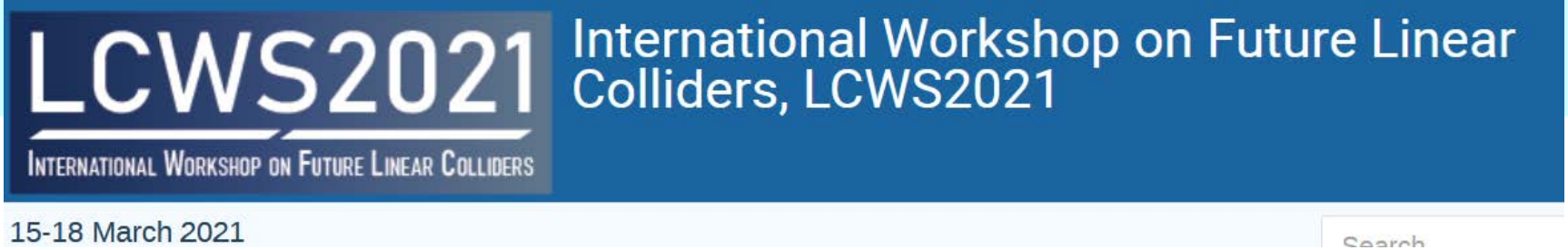
FCC-contacts – March 18th

- News, ILC, FCC, IN2P3
- Debrief du Workshop de Janvier, Calorimétrie part II
  - Crystal calorimeter Suzanne
  - IDEA Greg
  - Discussion
- Organisation prochain workshop
- Tour de Table
- AOB



https://indico.cern.ch/event/995633/

- *ILC250 accelerator is 20 km long e-/e+ collider for the Higgs factory.*
- *Key technologies at the ILC are superconducting rf (SRF) and nano-beam.*
  - *Nano-beam technology has been demonstrated at ATF hosted by KEK*
  - *SRF technology has been widely adopted at XFELs such as European XFEL.*
- *We assume 4-year preparation and 9-year construction.(now we are at pre-preparation phase (IDT))*
- *Preparation phase activities are*
  - *Technical preparation*
  - *Final engineering design*
  - *Planning and preparation of Hub lab.*
  - *Civil engineering*
  - *Human resources for ILC construction …*
- *Technical preparation document is summarized by IDT-WG2 and IDT-EB organized its review.*
- *Report on "Strategic Environmental Assessment of the ILC Project" is now available.*
- *We would be happy to discuss further possibilities of the ILC accelerator.*

Rough timeline of the ILC under discussion

ILC IDT (~1.5 years)

- Prepare the work and deliverables of the ILC Pre-laboratory and workout with national and regional laboratories a scenario for their contributions
- Prepare a proposal for the organisation and governance of the ILC Pre-laboratory

ILC Pre-laboratory (~4 years)

- Complete all the technical preparation necessary to start the ILC project (infrastructure, environmental impact and accelerator facility)
- Prepare scenarios for the regional contributions to and organisation for the ILC.

ILC laboratory

- Construction and commissioning of the ILC (~10 years)
- Followed by the operation of the ILC
- Managing the scientific programme of the ILC

In parallel:
Positive "signs" from the host country (Japan) government and agreements by the national/regional laboratories for providing their contributions.

In parallel:
Positive outcomes of the inter-governmental negotiation for the responsibility and cost sharing among the host (Japan) and partner countries

The next step for the ILC

- To complete studies on some open technical issues, such as the positron source and beam dump.
- To complete R&D for the superconducting cavities for the performance improvement.
- To bring the ILC from the current technical design (TDR) level to the engineering design (EDR) level, including the civil engineering and site related issues, in order to be ready for starting construction, when the ILC Laboratory is set up.

⇒This a part of the ILC Pre-Laboratory work.

What is the Pre-lab?

- Pre-lab is set up as an international collaboration of national, intergovernmental and university laboratories governed through the Memorandums of Understanding (MoUs).
- Technical preparation works are defined as work packages and delivered by the participating laboratories as in-kind contributions.
- Directorate headed by the director is running the Pre-lab and coordinate the overall work, but the execution of the work packages are fully under the control of responsible laboratories, including the resource acquisition.

In order to set-up the Pre-lab

ICFA

ILC International Development Team

Executive Board

Andrew Lankford (UC Irvine): Americas Liaison
Shinichiro Michizono (KEK): Working group 2 Chair
Hitoshi Murayama (UC Berkeley/U. Tokyo): Working group 3 Chair
Tatsuya Nakada (EPFL): Executive Board Chair and Working group 1 Chair
Yasuhiro Okada (KEK): KEK Liaison
Steinar Stapnes (CERN): Europe Liaison
Geoffrey Taylor (U. Melbourne): Asia-Pacific Liaison

Working group 1 Pre-lab set-up	Working group 2 Accelerator	Working group 3 Physics & Detectors

To conclude

- IDT was set-up to move the ILC to the preparation phase, i.e. establishing the Pre-lab
- The operation model of the Pre-lab allows easy entry for the industry to the ILC activities through the local laboratories of their own country.
- Realisation of the ILC needs push to the government at the highest level, in Japan and all the other countries, by noting the value of the ILC beyond the academic interest.
- Help from different sectors of the society is needed!!!

News FCC from CERN

- FCC week will take place 28 June-2 July. It will be a remote-connection meeting.

- The snowmass delay gives us some time, and the contributions to the EPJ do no longer conflict with the production of the snowmass write-ups, which are delayed to 15/3/2022.

- The ECFA detector R&D roadmap is now requesting input from the various projects. Mogens Dam has given a presentation on 19 February.

- The ECFA workshops on PED for 'Higgs (+EW and top) factories' will have 3 working groups

- 4IP layout : in addition to the increase in total luminosity (by a factor 1.7) it is important to insist on other aspects (see slides), for instance
  - the flexibility offered by the 4 detectors to match the detection possibilities to the many challenges of the very rich physics programme;
  - the broadest appeal to the physics community.

ECFA detector R&D road map

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

Symposia

Nine one-day symposia are foreseen as listed below.

Task Force 1: Gaseous Detectors

Symposium date: Thursday 29.4.2021 Indico link to agenda

Task Force 2: Liquid Detectors

Symposium date: Friday 9.4.2021 Indico link to agenda

Task Force 3: Solid State Detectors

Symposium date: Friday 23.4.2021 Indico link to agenda

Task Force 4: Photon Detectors and Particle Identification Detectors

Symposium date: Thursday 6.5.2021 Indico link to agenda

Task Force 5: Quantum and Emerging Techologies

Symposium date: Monday 12.4.2021 Indico link to agenda

Task Force 6: Calorimetry

Symposium date: Friday 7.5.2021 Indico link to agenda

Task Force 7: Electronics and On-detector Processing

Symposium date: Thursday 25.3.2021 Indico link to agenda

Task Force 8: Integration

Symposium date: Wednesday 31.3.2021 Indico link to agenda

Task Force 9: Training

Symposium date: Friday 30.4.2021 Indico link to agenda

ECFA Detectors Experiments and Physics Workshops

See previous news for goals of the ECFA workshops on D,E&P.

Three working groups defined and conveners agreed for WG 1 and 2.

Group 1, Physics Potential: Juan Alcaraz, Jenny List, Fabio Maltoni and James Wells

Group 2, Physics Analysis Methods : Patrizia Azzi, Dirk Zerwas, Fulvio Piccinini

Group 3 Detectors (pending ECFA road map completion)

Will be proposed at r-ECFA tomorrow 12 March.

Pending minutes and actions from last meetings (26 January)

from 26 January

-- AB & PJ to prepare document summarizing the arguments in favour of having 4IP at FCC-ee

-- slides done. excellent feedback from FCC-PED coordination group!

→ slides presented to the FCC CGM on 5 March are attached to this entry

-- at CGM Frank Zimmermann presented a 4-fold symmetric FCC layout which is encouraging.

→ some worry about the additional Civil Engineering cost

Reviews to come starting 19-22 April 2021

-- SRF review including “Higgs first” possible run plan

-- Design, Layout & Placement review, including 4IP layout and costs.

-- Injector review

-- need to follow-up with a 4IP write-up.

Motivation

One of the great advantages of the circular e+ e- colliders is:
-- The possibility of serving several interaction points with net overall gain
both in integrated luminosity **and** luminosity/MW.

The FCC-ee is a machine with a very rich menu of physics possibilities
-- this leads to many detector requirements, which cannot be simultaneously satisfied by only two detectors. example: EM calorimeter
(high E precision vs high granularity vs high stability vs geometric accuracy vs PID vs cost)

Furthermore
-- many measurements will serve as input to future programmes in particular FCC-hh
-- many are statistically limited
-- redundancy provided by 4IPs is essential for high precision measurements
-- and different detector solutions will be invaluable in uncovering hidden systematic biases.

Last but not least
-- some key physics capabilities are nearly missed with the present run plan and 2 IPs.

FCC-ee physics programme

M. Dam ECFA R&D road map input
https://indico.cern.ch/event/994685/

"Higgs Factory" Programme

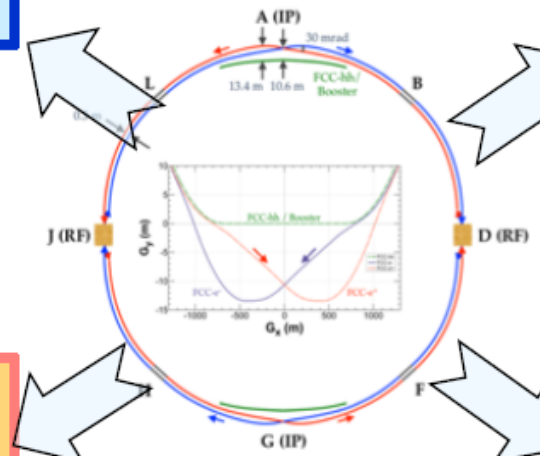
- At two energies, 240 and 365 GeV, collect in total
  - 1.2M HZ events and 75k WW → H events
- Higgs couplings to fermions and bosons
- Higgs self-coupling (2-4 σ) via loop diagrams
- Unique possibility: measure electron coupling in s-channel production $e^+e^- \rightarrow H$ @ $\sqrt{s}$ = 125 GeV

Ultra Precise EW Programme & QCD

Measurement of EW parameters with factor ~300 improvement in *statistical* precision wrt current WA

- 5×10^{12} Z and 10^8 WW
  - m_Z, Γ_Z, Γ_{inv}, $\sin^2\theta_W^{eff}$, R^Z_ℓ, R_b, α_s, m_W, Γ_W,...
- 10^6 tt
  - m_{top}, Γ_{top}, EW couplings

Indirect sensitivity to new phys. up to Λ=70 TeV scale



Heavy Flavour Programme

- Enormous statistics: 10^{12} bb, cc; 1.7×10^{11} ττ
- Extremely clean environment, favourable kinematic conditions (boost) from Z decays

- CKM matrix, CP measurements, "flavour anomaly" studies, e.g. b → sττ, rare decays, cLFV searches, lepton universality, PNMS matrix unitarity

Feebly Coupled Particles - LLPs

Intensity frontier: Opportunity to directly observe new feebly interacting particles with masses below m_Z:

- Axion-like particles, dark photons, Heavy Neutral Leptons
- Signatures: long lifetimes - LLPs

Physics of the Higgs boson

Baseline (2IP): at 240 and 365 GeV, collect in total 1.2MHZ events and 75k WW →H events

Statistics-limited:

-- Higgs couplings to fermions & bosons; model-independent, normalized to e+e- →ZH cross-section

→ fixed candle for past (HL-LHC) and future (FCC-hh) studies at hadron colliders (H→ ZZ)

-- Higgs properties: CP violation, H→ gg ... ...

Close to discovery level

-- Higgs self-coupling (2-5? σ) via loop diagrams : a very fundamental question!

complementary w.r.t. HH production at higher energy machines (CLIC3000(9%) , FCC-hh (2-3%))

-- Unique possibility: measure electron coupling in s-channel production e+e-→H @ √s = 125 GeV

highly demanding on luminosity, monochromatization with 1, 2 or 4 IPs?

Improvement with 4IP, (as of arxiv 1809.10041)

AB,P. Janot 1809.10041

- First scenario: keep the same operation model as with 2 IP
  - Total luminosity increases by a factor 1.7
    - Precision on Higgs couplings and Higgs width improves by a factor 1.3
- Second scenario: optimize the operation model towards the Higgs
  - For example, maximize the sensitivity to the Higgs self-coupling

    spend 10 years at 240 and 365 GeV, instead of the baseline 7 years

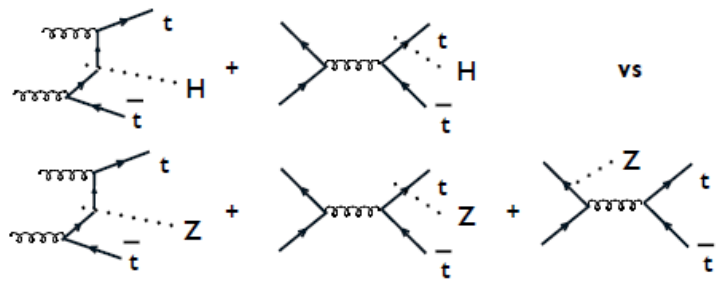
    Say 3.5 years at 240 GeV and 6.5 years at 365 GeV (plus 0.5 yr at 340-350 GeV)

    With a total luminosity / year ~1.7 larger than in the baseline

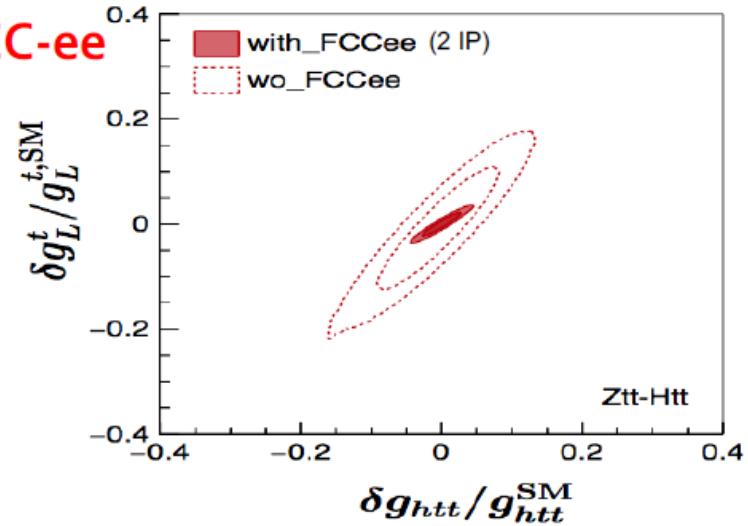
	κ_Z	κ_W	κ_b	κ_c	κ_g	κ_τ	κ_μ	κ_γ	BR_{inv}	Γ_H
2 IP	0.17%	0.43%	0.61%	1.21%	1.01%	0.74%	9.0%	3.9%	< 0.3%	1.3%
4 IP	0.10%	0.24%	0.36%	0.73%	0.60%	0.43%	5.5%	3.0%	<0.2%	0.77%

Top electroweak couplings @ 365 GeV

- **Top Yukawa coupling@FCC-hh: dominated by top EW couplings@FCC-ee**
  - Measure σ(ttH) / σ(ttZ) at FCC-hh
    - Similar production mechanism
    - Most theory uncertainties cancel
      - ➔ <1% precision possible

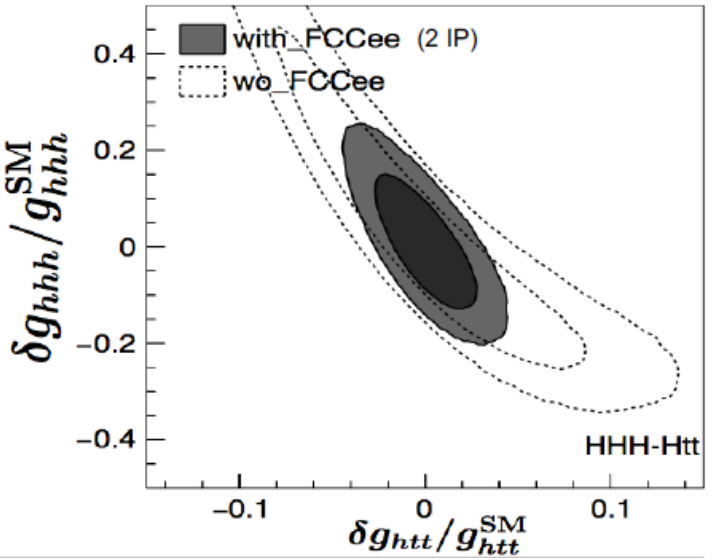


  - Information needed from FCC-ee
    - Measure $t_L t_L Z$ couplings to fix the denominator (precision ~1.5%)
    - Measure Higgs branching ratios to fix the numerator (precision ~0.5%)
  - Top EW precision@FCC-ee is statistically limited: 4IP reduce FCC-hh precision by a factor $\sqrt{4.5/1.5} \sim 1.7$



- **Help in turn the precision of the Higgs self-coupling @ FCC-hh**
  - The top Yukawa coupling is needed to predict HH production cross section

  - The aforementioned factor 1.7 is precious to reach the ultimate κ_λ precision



Precision measurements -- examples

Many key measurements lead to new detector systematics. Three examples:

-- $\mathbf{R_\ell\,(Z) \equiv \Gamma_{Z\to had} / \Gamma_{Z\to leptons}}$: dominated by knowledge of acceptance boundary at 10 μm level → $\alpha_s(m_Z)$

-- σ^0_{had} (peak hadronic cross-section); dominated by luminosity meast (acceptance boundary at 1 μm) → N_ν

-- **tau life-time, tau mass & tau branching ratios** –> G_F from taus at O(10^{-5}) precision (heavy neutrino mixing etc..)
Errors dominated by life-time scale error (few nm), detector momentum scale (10^{-6}), lepton separation

For all of these, detector systematics will scale as 1/√N(exp) *AND* 4 exp will be instrumental in finding 'unexpected effects'

At the limit of sensitivity: feebly coupled particles and forbidden processes

Heavy Neutrinos

Massive Neutrinos is today the construction zone of the Standard Model

The search for Heavy neutrinos, motivated by the see-saw model (Dirac *and* Majorana mass terms) has become an active branch of the Energy Frontier. We noted this already in 2013 (see FCC Kick-off meeting!)

The main region of interest is for couplings of magnitude $m_\nu/m_N = O(10^{-12})$.

Complementary with FCC-hh where Lepton Number Violation is "easier" to see...

➔ potentially of great impact on the design of FCC-hh detectors.

Dark Sector

The heavy neutrinos are almost sterile and constitute the poster child of a generic type of dark sector solutions to SM puzzles invoking feebly coupled particles. These have the added benefit of not affecting the SM radiative corrections and running of coupling constants thus avoiding associated hierarchy problem and Stability of the Universe

A good example is given by Axion-Like Particles (ALPs).

Any increase of luminosity is welcome!

CP violation / CKM program:

Two categories of the most important statistically limited observables :

-- The CP-violating phases γ and the ϕ_s phase.
Determined at the *Z* pole, the precision w/ 5 10^{12} Z is commensurate w/ LHCb upgrade II.

-- The Vcb CKM matrix element magnitude: a critical element of the CKM profile (normalisation) but also a key element of the New Physics energy scale one can set from *B* mixing observables.

FCCee is unique here with the on-shell W decays (FCC-ee at W threshold and higher energies)
Any statistical gain translates into a higher NP energy scale.

Conclusion(I): FCC-ee really calls for four interaction points

One of the great advantages of the circular e+ e- colliders is:
-- The possibility of serving several interaction points with net overall gain
both in integrated luminosity **and** luminosity/MW.

The FCC-ee is a machine with a very rich menu of physics possibilities
-- precision measurements that will rebaseline particle physics for many years
on Higgs, top, Electroweak, QCD and Flavour Physics
-- significant chances of discovery from precision, rare processes and high sensitivity to feebly coupled particles
-- several will impact FCC-hh physics results and detector design
-- High luminosity, redundancy and careful preparation of detector set-ups will be key to success
-- many measurements are statistics limited and will immediately benefit from four Interaction points.
-- several key physics targets are tantalizingly close (but missed) with the present set-up

Having four IPs will allow for a range of detector solutions to cover FCC-ee all physics potential opportunities
-- example: EM calorimeter requirements (high precision vs high granularity vs high stability vs geometric accuracy vs PID vs cost)
unlikely to be all satisfied with only two detector concepts.
-- different solutions will be invaluable in uncovering hidden systematic biases and avoid conspiracy of errors.
-- and provide an attractive challenge for all skills (detector design and R&D, software, analysis, theory...)

Pending minutes and actions from last meetings (11 February)

Physics programme:

a few decisions:

-- topics as proposed by Michelangelo agreed

-- ee--> H to remain a dedicated acc+exp task force
possibly unified with the EPOL group

-- Question of overall Physics Program Coordinators
to be tackled when considering proposals for names

-- Mandate to be elaborated (AB, PJ, MLM)
Status: first draft exists, under construction

-- Interface with Physics Performance
'Benchmark committee' or other name?
-- task agreed as well as who should do it
-- discussion on how/where it should take place
-- PED coordination or PP meetings, etc..

WORKING GROUPS

WGs provide the forum to present recent results (pheno papers and ideas, progress with studies and analyses), stimulate and monitor new studies, promote "physics benchmarks" and trigger "Case Study" activities

1. **EW physics,** covering:
   - precision EW at the Z peak and WW thresholds, including W mass
   - High energy EW: Diboson, difermion
   - precision theory calculations
   - Monte-Carlo generators and fitting formulae
2. **Higgs**, including ee->H, and including precision TH calculations, MCs and fitting formulae
3. **Flavour physics**:
   - heavy quarks
   - tau lepton
4. **BSM**:
   - Bring all BSM-related topics under the same WG. In particular:
   - indirect sensitivity, including model-specific global fits
   - direct BSM searches, including Feebly interacting particles, LLPs, light DM, ...
5. **QCD** (includes the dedicated precision theory calculations, MC generators, fitting formulae..)
6. **Top** (includes the dedicated precision theory calculations, MC generators, fitting formulae..)

Pending minutes and actions from last meetings (11 February)

Extensive discussion on the Detector Concept effort

collected a number of suggestions
in particular for the connection to detector technology and R&D collaborations.
slides with notes have been appended to 11 February meeting

Action: propose an ad-hoc task force to prepare a proposal for the organization and the mandate of an FCC-ee "detector concept" effort, within the FCC PED

Mogens Dam has accepted to chair the task force

-- invitations to task force members will be sent to fix first meeting
detector experts incl. members of the (connected) PED efforts (PPC, FCCSW, MDI)
action AB/PJ, MD

-- first meeting to happen between now and next PED SG meeting (TBD 8 or 15 April)
action AB

Brief summary of P&P activities

- **Nice progress and momentum on vertexing**
  - Quite some progress since the topical meeting of mid-Feb, see report from Clement at the last General meeting
  - Impact of the beam-pipe radius, configuration of the VXD: studies have started, progressing well.
  - Trying to engage more people on well-defined projects

- **Case Studies activity keeps a good momentum. Several aspects covered.**
  - Different processes also highlight different needs from the software and tools
  - First studies of jets and jet algorithms
  - Started inviting collaboration of groups interested in similar processes (i.e. Higgs recoil) to cross check and share the work
    - Organizing working meetings
  - Next Monday : « ALPS and photons »

- **On software tool side usage of edm4hep MC datasets and FCCAnalysis tools expanding:**
  - more development of features
  - more complex capabilities
  - helps improve documentation

Production of MC samples

- Goal: samples for the analyses to be presented at the FCC week in July
- Converged on a list of samples to produce
  - With some input from the community
  - https://docs.google.com/document/d/1-3L_8u542-dlaL6ws41PYmCgwzffgsleaQKs_qQb6AM/edit - heading=h.qd2y5jew1yc
- Round-table at our last Physics Performance meeting
  - a dedicated forum with MC authors and MC users would be better suited
- Progress since then :
  - Follow-up with S. Jadach to include beam-energy spread in KKMC
  - Validation of Z $\nu\,\nu$
  - Improved interface of EVTGEN w Pythia (see SW report)
  - Update of the beam-pipe model (following recomm. from MDI)
- Collection and validation of MC cards, definition of Nevts / sample, etc
  - « new » groups helping out with generation of specific processes
  - A lot of work... Any volunteer to help there ?

Software news

FCCSW Moving steadily towards key4hep

Common software for all FCC experiments. FCCSW is a collection of components intended to be run in the Gaudi framework. Because of the modular nature of the software, this repository contains little actual code, which can instead be found in the following places:

- `key4hep/k4FWCore` : Basic I/O components
- `key4hep/k4Gen` : Generators and Particle Guns
- `key4hep/k4SimDelphes` : Delphes Fast Sim
- `key4hep/k4SimGeant4` : Geant4 Full Sim
- `hep-fcc/fccdetectors` : DD4hep models of FCC detector geometries for Full Sim
- `hep-fcc/k4RecCalorimeter` : Calorimeter Reconstruction Code
- `hep-fcc/dual-readout` : DD4hep model of the DREAM dual readout calorimeter

- Vertexing
  - Updated and fixed versions of codes made available (Delphes, ...)
  - First integration with Acts (PVertex finder AMVF, Vertex fitter full billoir) in FCCAnalyses
  - Discussion about integration of DecayTreeFitter (planning on a technical meeting soon)
  - On-the-fly converter LCIO-EDM4hep still delayed (needed to use LC algorithms)
    - Person dedicated slowed down by Cremlin+ activities (SCTF)
      - Should change from June (switch to full EP R&D)
- Generators ⇒ Preparing for the MC campaign
  - Pythia8+EvtGen interface re-written in k4SimDelphes (allows to select exclusive decays)
- FCCAnalyses
  - Re-wrote jetclustering interface, added Valencia and other plugins
  - Trying awkward arrays in C++ (useful for dealing with combinatorics)
  - Need dedicated discussions (first tomorrow) to understand the limit of generic/specific code

Software news (II)

- External access to CERN resources
  - Requests from people without CERN account popping-up
  - Need a way to register them at CERN
    - FCC 'group' will help in this respect
- Event Display
  - Established contacts with Phoenix people
  - L Bernardi possibly interested in working on this
- Simulation/Reconstruction effort
  - Continue to foster collaborations with existing standalone sub-detectors implementations (IDEA Drift Chamber, Dual readout calorimeter)
  - Interest on using full simulation tracking
    - Start with CLD tracker, ILC conformal tracking and Acts tracking
  - LAr calorimetry making nice progress
    - See: https://indico.cern.ch/event/1014834/

News IN2P3

- Création d'une équipe ATLAS/FCC/Higgs à l'APC à partir du LPNHE (**G.B.**, M.Bomben, **G. Marchiori, A. Li**, R. Bouquet)

  Giovanni sera le FCC-contact APC

- Nouveaux stagiaires depuis notre revue des FTE ?

  L3 à l'IJCLab cet été

  M1 à l'APC à partir de Juin

  ?