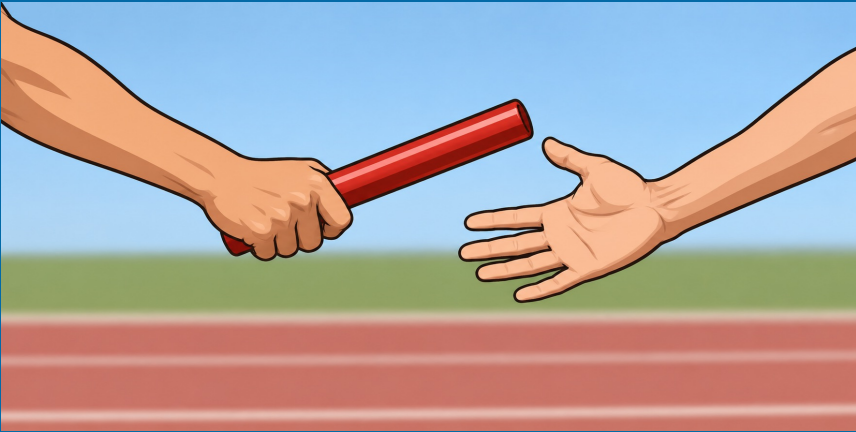


Status of ILD: Where are we, where are we going



M.C Fouz
CIEMAT

A detector for the next CERN flagship project: ILD
CERN, Geneve Sep 2026

Grant PID2024-158190NB-C22 funded by



MINISTERIO
DE CIENCIA, INNOVACIÓN
Y UNIVERSIDADES



https://indico.cern.ch/event/1439855/contributions/6461486/attachments/3045859/5381786/The_ILD_Detector%20submitted.pdf

The ILD Detector: a Versatile Detector for an Electron-Positron Collider at Energies up to 1 TeV

The ILD Concept Group

Contact: T. Behnke, Deutsches Elektronen Synchrotron, DESY

(Dated: March 29, 2025)

The International Large Detector, ILD, is a detector concept for an experiment at a future high energy lepton collider. The detector has been optimised for precision physics in a range of energies from 90 GeV to about 1 TeV. ILD features a high precision, large volume combined silicon and gaseous tracking system, together with a high granularity calorimeter, all inside a central solenoidal magnetic field. The paradigm of particle flow has been the guiding principle of the design of ILD. ILD is based mostly on technologies which have been demonstrated by extensive research and test programs. The ILD concept is proposed both for linear and circular lepton collider, be it at CERN or elsewhere. The concept has been developed by a group of nearly 60 institutes from around the world, and offers a well developed and powerful environment for science and technology studies at lepton colliders. In this document, the required performance of the detector, the proposed implementation and the readiness of the different technologies needed for the implementation are discussed.

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FCC-ee has been recommended by the ESPP as the preferred option for the next flagship collider at CERN

Final approval decision by the CERN Council in 2028

CEPC was not included in the last five-year Chinese plan

They “plan to submit CEPC for consideration again in 2030, unless FCC is officially approved before then, in which case we will seek to join FCC, and give up CEPC.”

Wang Yifang, (IHEP) in Beijing. <https://cerncourier.com/cepc-matures-but-approval-is-on-hold/>

LEP3 Re-emerging as a lower-cost alternative if FCC-ee is not approved; studies ongoing as required by CERN Management

LCF (CLIC, ILC) Further studies of a **380 GeV LCF based on superconducting RF technology** mandated by CERN Management as an alternative if FCC-ee is not approved.

Details to be presented on Wednesday

<https://agenda.linearcollider.org/event/11033/contributions/59564/>

HALHF — ~15-year R&D program, still at an early stage with a long way ahead

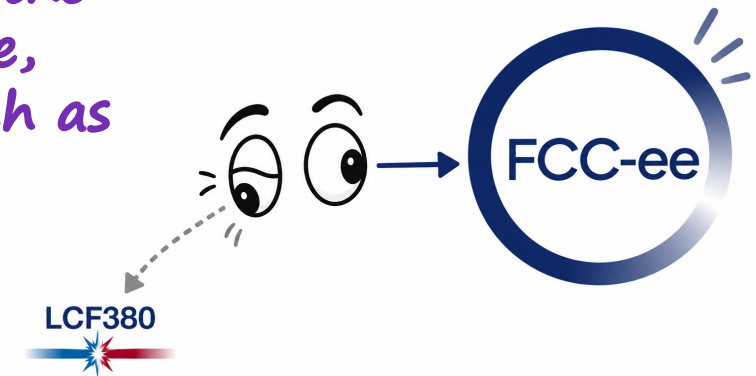
Details to be presented on Wednesday

<https://agenda.linearcollider.org/event/11033/contributions/59563/>

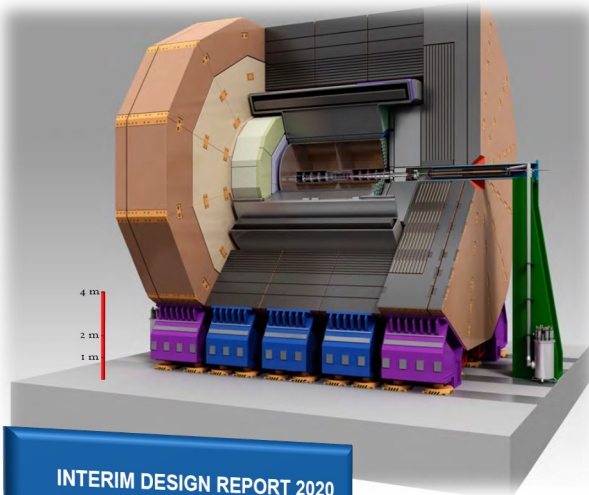
The FCCee is now entering the Reference Design Phase (RDP) (2026–2028)
Final approval decision by the CERN Council in 2028.

FCC aims to produce six (or more) detector EoIs after the final FCCee approval.
At 2029 should start the Reference Design Phase, the Detector Conceptual Design Report is envisaged ~2033

ILD should work over the next two years to be in the best possible position to prepare an EoI for FCC-ee, while not losing sight of other collider options, such as LCF380.



ILD is a robust and mature detector concept for e^+e^- colliders up to 1 TeV, already providing an excellent basis for meeting the physics requirements of FCC-ee.

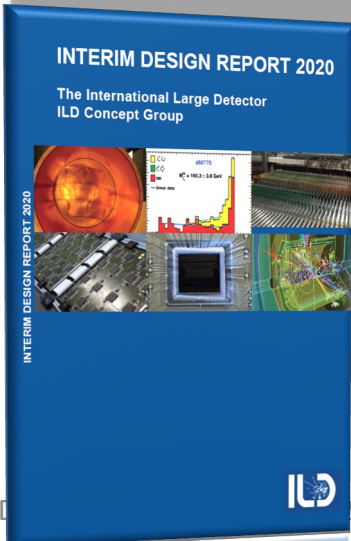


ILD has always evolved hand in hand with detector R&D collaborations (CALICE, LC-TPC...) — today, in close connection with the DRD collaborations.

Ten years after the present concept was established, and with CERN's next flagship project on the horizon, this is the right time to **revisit the design and profit from recent technological advances, particularly in silicon tracking and vertexing.**

There is room for improvement for linear colliders, while **FCC-ee** brings additional requirements and calls for further adaptations. **New linear-collider scenarios with two IPs** also require dedicated design changes, particularly in the MDI.

We are open to new collaborators and also to new ideas which can improve our detector including new technologies



You are invited!

Parameter	FCC-ee (Z)	ILC (GigaZ)	FCC-ee (ZH)	ILC (250)
CM Energy	91.2 GeV	91.2 GeV	240 GeV	250 GeV
Instantaneous Luminosity	$182 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$	$4 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$	$7.3 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$	$2.7 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$
Collision Frequency	100 MHz	$5 \times 1312 \text{ Hz}$	3.3 MHz	$5 \times 1312 \text{ Hz}$
Bunches per beam	16640	1312	440	1312
Particles per bunch	1.7×10^{11}	2.0×10^{10}	1.8×10^{11}	2.0×10^{10}
Bunch Spacing	15 ns	554ns	994 ns	554 ns
Repetition Rate	Continuous	5 Hz	Continuous	5 Hz

*Continuous vs Pulsed structure
Massive difference in event rate.*

Power Consumption: Active **COOLING** could be needed
(impacts on **material budget** and calorimetry **homogeneity** and **compactness**)

How to deal with these rates without introducing trigger bias? (**T-DAQ**)

Is it still possible to stream out all detector data? How can it be processed and stored?

Below 380 GeV, linear and circular colliders target similar physics processes, but the **much higher statistics at FCC-ee** require even tighter control of systematic uncertainties to fully exploit its physics potential, and, in particular, the flavour studies are very demanding

Some examples:

- Up to two orders of magnitude tighter control of **systematics**
 - Higgs Factory: $\mathcal{O}(10^{-3})$
 - Tera Z: $\mathcal{O}(10^{-4} - 10^{-5})$
- Luminosity precision** requirements relies on μm -level control of luminometer geometry and acceptance and high stability between center-of-mass energy scans
 - IL 250 GeV: $\sim 10^{-3}$ (absolute)
 - Tera-Z: $\sim 10^{-4}$ (absolute) $\sim 10^{-5}$ (relative)
- Track angular Resolution** < 0.1 mrad
- Electromagnetic resolution** perhaps down to $3-5\%/\sqrt{E}$

<https://doi.org/10.1016/j.nima.2025.170648>

Physics programme

Higgs Factory

- At $\sqrt{s} = 240$ GeV and 365 GeV, collect 2.6M HZ and 150k WW $\rightarrow$ H events
- Higgs properties: mass and width, couplings to fermions and bosons, self-coupling measurement via loop diagrams

Precision electroweak

- Collect 6×10^{12} Z and 2.4×10^8 WW events: Factor ~ 500 improvement of statistical precision on EWPOs $m_Z, \Gamma_Z, \Gamma_{inv}, \sin^2 \theta_W, R_\ell, R_b, m_W, \Gamma_W, \dots$
- Collect 2×10^6 $t\bar{t}$ events: m_{top}, Γ_{top} , EW and Higgs couplings
- Indirect sensitivity to new physics up to several tens of TeV

Flavour

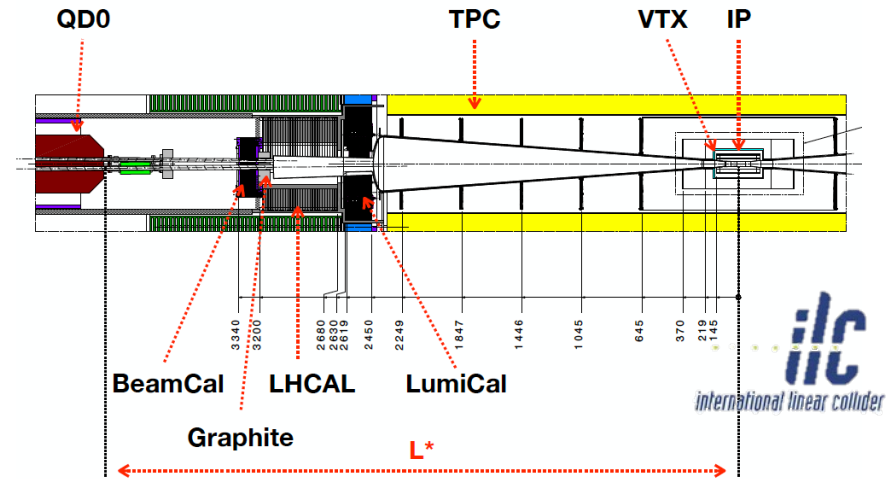
- From Z decays: 10^{12} $b\bar{b}, c\bar{c}, 2 \times 10^{11}$ $\tau^+\tau^-$, clean and boosted
- Heavy quark decays: FCNC searches, CKM matrix, CP measurements
- τ decays: LFV searches, lepton universality tests

BSM particle searches

- High sensitivity direct searches for feebly interacting particles with masses below m_Z
- Axion-like particles, dark photons, Heavy Neutral Leptons
- Long-lifetime signatures, LLPs

Detector Requirements

- Momentum resolution $\delta(p_T)/p_T \approx 10^{-3}$ at $p_T \approx 50$ GeV
- Jet energy resol $\delta(E)/E \approx 3-4\%$ for Z/W/H classification
- Superior impact parameter resolution for b, c tagging
- Charged hadron PID for s tagging
- Absolute normalisation to 10^{-4} or better
- Relative normalisation between channels and between energy-scan points to 10^{-5}
- Track angular resolution to 0.1 mrad
- Stability of B field (momentum scale) to 10^{-6}
- Superior impact parameter resolution
- Precise identification and measurement of secondary vertices
- ECAL resolution of few $\%/\sqrt{E}$; excellent π^0/γ separation
- PID: charged hadron identification over wide momentum range
- Hermeticity
- Precise timing
- Sensitivity to (far) detached vertices (mm to m range)
- Tracking: more layers, "continuous tracking"
- Calorimetry: granularity, tracking capabilities



Crossing angle **14 mrad**
L* 4.1 m: Final Quadrupole **outside** the detector
 Solenoid magnetic field **3.5 – 4 T**
 Lumical at **~2.5m** from IP
 Inner beam pipe radius **16 mm**
 Conical → Tracker acceptance: $\cos\theta \sim 0.996$

VERY DIFFERENT DESIGNS

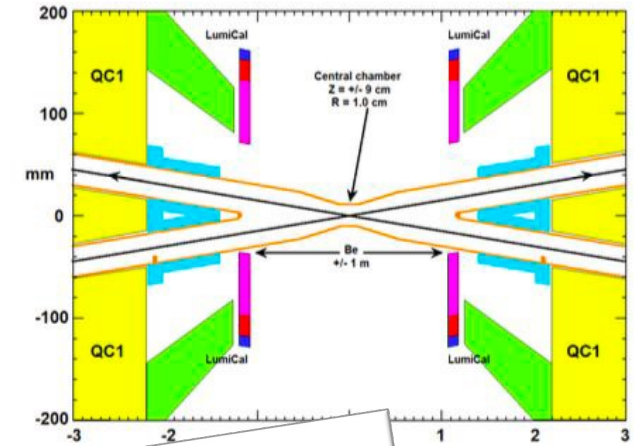
IR and Forward Region to be redesigned

LOWER B FIELD

Impacts on performance?



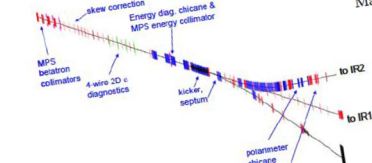
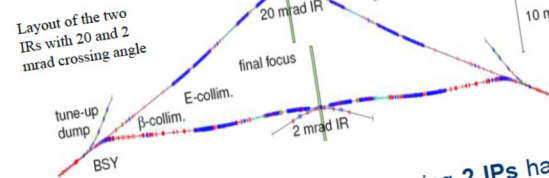
Crossing angle **30mrad**
L* 2m: Final Quadrupole **inside** the detector
 Solenoid B field restricted to **2T** maximum
 Lumical at **~1m** from IP
 Inner beam pipe radius **10mm**
 → Tracker acceptance: $\cos\theta \sim 0.984$



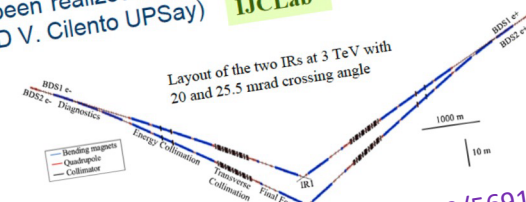
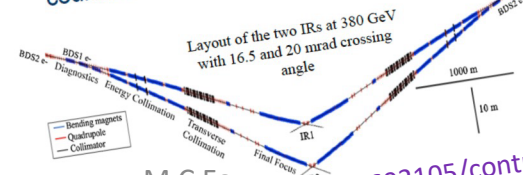
Linear Collider Vision

Two IP

In the ILC Baseline Conceptual Design, the ILC was designed with 2 BDS sections and two independent IRs with 20 and 2 mrad. At that time others schemes were under study, including one of 14 mrad and a head-on scheme.



A detailed study of dual BDS serving 2 IPs has been realized in the framework of the CLIC project, this work could be taken as reference for future studies (PhD V. Cilento UPSay) **IJCLab**



<https://indico.cern.ch/event/1552126/contributions/7128849/attachments/3292819/5888358/FCCweek2026-jeans.pdf>

Incoherent Pair Creation: Comfortable → challenging

Synchrotron radiation: Extremely challenging → impossible

*SR background needs to be reduced by orders of magnitude
Its impact on the calorimeters also needs to be investigated.*

Background levels strongly depend on the inner-region design.

@ 91 GeV	Silicon Tracker pixel rate @ 3 pix/hit	Drift Chamber occupancy	TPC typical distortion
IPC	10 kHz / cm ²	~7%*	few mm
SR my back-of-envelope	~GHz / cm ²	>1000%	few m

Detector and accelerator optimization should proceed hand in hand

More details to be presented at the Background session <https://agenda.linearcollider.org/event/11033/sessions/5702/#20260914>

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*In any case,
MDI detector region needs to be redesign*

Vertex geometry should be revisited

ILD Forward region needs to be redefined to cope with FCCee design

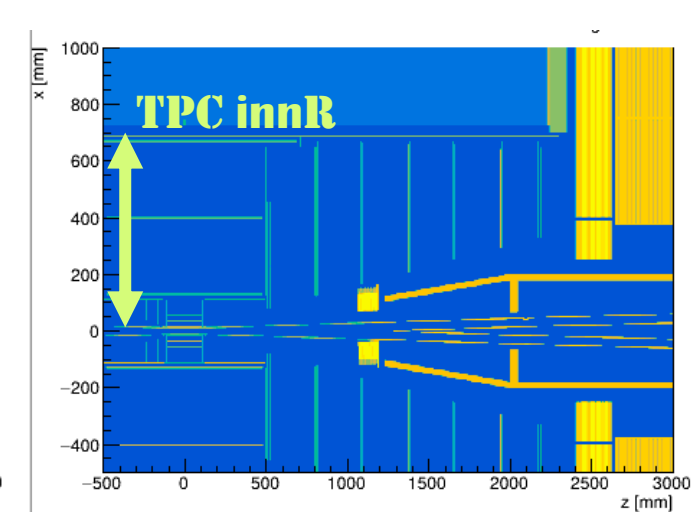
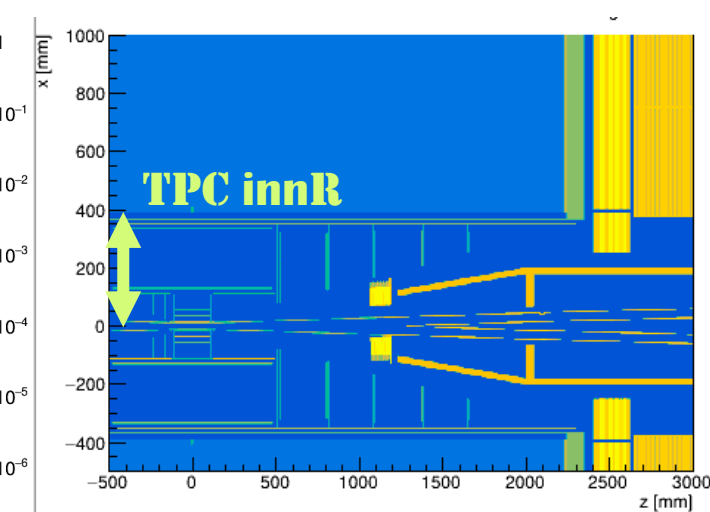
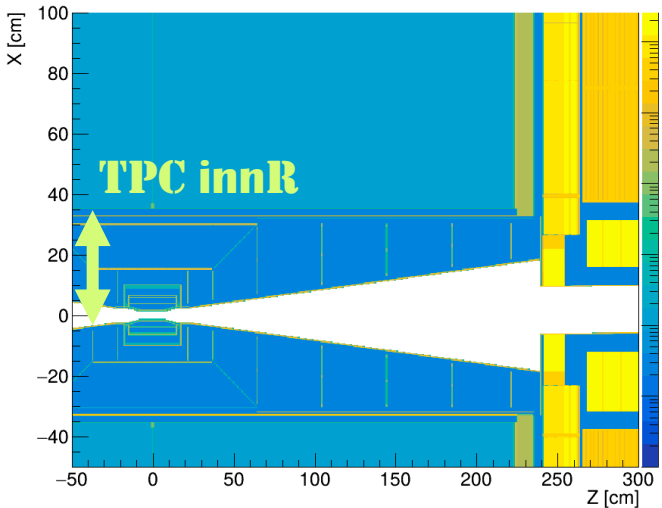
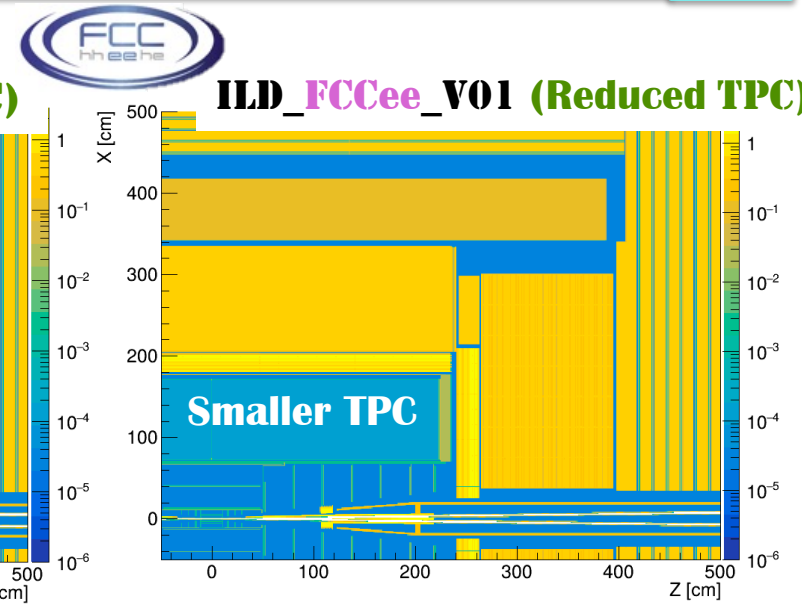
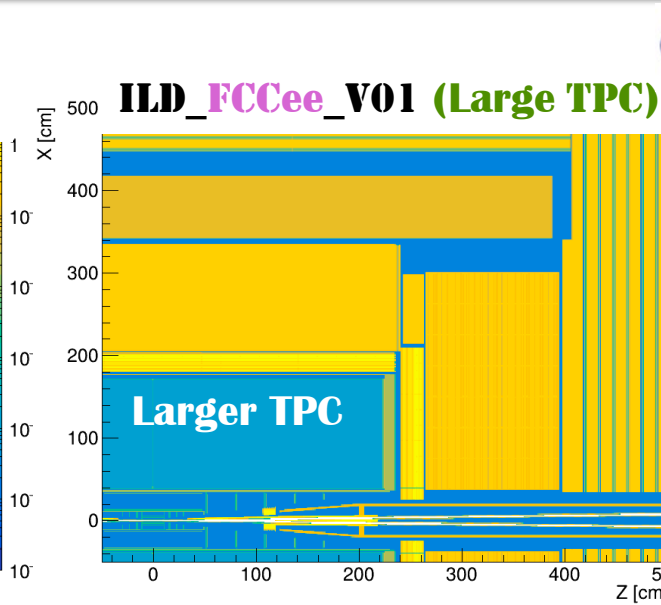
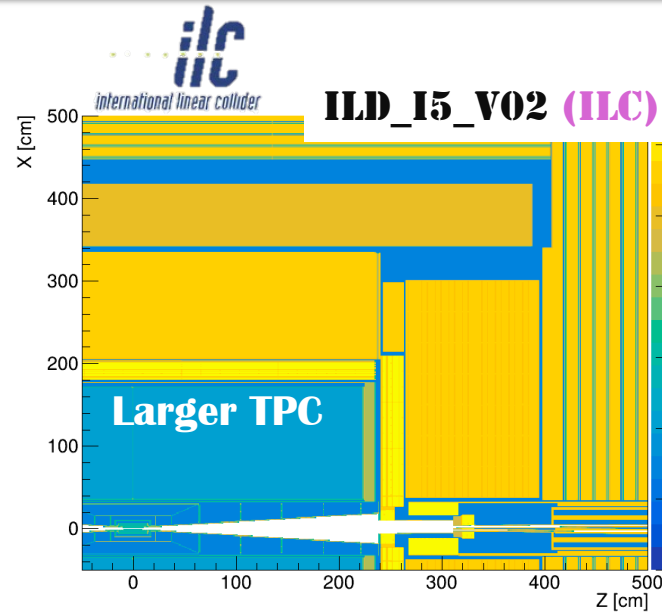
Not only for the Lumi calorimeter

Backgrounds effects in the detectors and physics process to be studied

Effects on reconstruction

Could affect the design parameters/sensor types for the vertex?

Extra shielding at luminometers?



TPC innR=
TPC Inner Radious

Beamstrahlung
background
decreases with
increasing radius.

This also requires adaptation of track reconstruction software

Can the TPC operate at Tera-Z conditions?

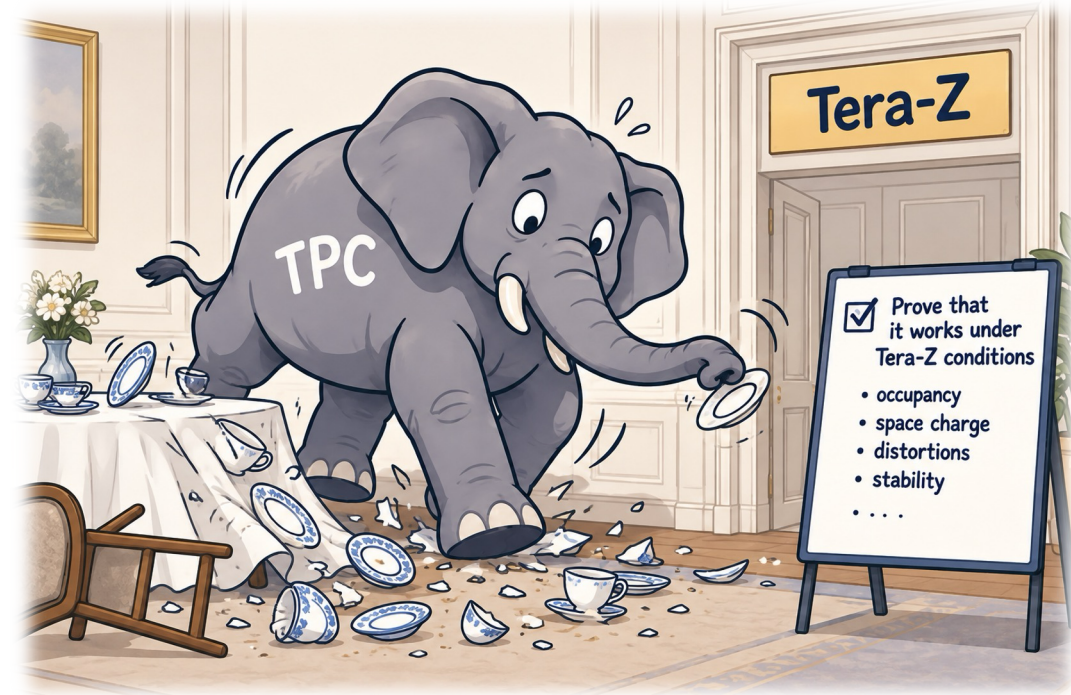
Field distortion by ions caused by

- a large amount of the primary ions from ionization of the tracks from both Z-pole events and the machine background
- the backflowing ions generated in amplification.

Simulation studies are ongoing

Optimization of the tracker design is needed:

- Different TPC inner radius → also redesign of the silicon vertex and tracking layers
- Possible mitigation strategies need to be explored
- Could precise timing from dedicated silicon layers help correct TPC distortions induced by ion backflow? Which precision is needed?
-



TPC Presentation on Tuesday

<https://agenda.linearcollider.org/event/11033/contributions/59556/>

See also dedicated TPC meeting on 7th September

<https://agenda.linearcollider.org/event/11107/>

Detector R&D within ILD is closely linked to the **CERN DRD Collaborations**.

Even for the ILC, the **ILD design is not technologically frozen**: several technology options have always been considered for the different subdetectors.

Emerging and rapidly improving technologies — in particular advanced silicon detectors and sub-nanosecond timing capabilities — should be seriously considered for future ILD developments.

A recent example of these R&D advances is the **FCC-SEED (Smail-shape vErTEx Detector) vertex concept**

https://agenda.linearcollider.org/event/11002/contributions/58731/attachments/40908/65224/FCCseed_ILD_04_2026.pdf

presented by A.Besson
at April ILD meeting

Alternative Proposal: SEED concept = bent ladders + slight overlap

- Stitching not mandatory
- Inner radius minimized and approaching constant value
- Full acceptance in φ
- Option: double sided can be considered.
- Number of layers = free parameter $\Rightarrow$ redundancy
- Competitive for mat. Budget. AND full azimuthal acceptance

FCC-SEED is a vertex detector concept for FCCee

- ✓ Based on bent sensors to optimize inner radius & material budget
 - keeping robustness, flexibility & redundancy
 - ✓ Based on CMOS sensor R&D
 - via DRD3/7 (OCTOPUS, MANTA, CASSIA)
 - ✓ Connected to simulation studies (Full simulation, beam background, digitizer, etc.)
- $\Rightarrow$ Coherent devt to progress in parallel on every aspects



FCC-ee brings additional challenges:

Adapting ILD to FCC-ee requires new detector strategies, particularly to cope with the demanding conditions at the Z pole. The inner and forward regions need special attention, but implications also extend to calorimetry. These developments concern both detector technologies and their associated electronics

ILD present design: 3 double ladders + discs

More details to be discussed at the Detector and the Plenary ILD summary and planning sessions

Detector R&D must be complemented by performance studies

Beyond individual sensors performance studies must address the system as a whole.

Resolution, particle ID, and timing rely on the **combined performance of multiple layers and subdetectors**.
and depend directly on the **overall detector design and configuration**

The studies should both **validate and guide detector R&D and optimization**, and particular attention should be paid to the challenging **Z-pole conditions**, *not yet fully study within ILD*.

Performance studies should be developed in close connection with benchmark physics studies, while clearly distinguishing detector performance from final-state physics analyses.

This connection also helps optimize person-power, bringing together detector, physics, and software expertise.
Not everyone involved needs to be a detector expert.

Dedicated working groups need to be established

Details to be discussed at the Physics and the Plenary ILD summary and planning sessions

Extensive physics studies have been performed over the years, with benchmark processes mainly targeting higher-energy operation.

These studies can be extended and adapted to the final FCC-ee conditions, **but dedicated studies of key Z-pole physics processes are now essential.**

The impact of **reducing the B field** needs to be evaluated.

These studies should be pursued in close connection with the **FCC-ee physics studies.**

Indico of FCC PED Physics Groups meetings

<https://indico.cern.ch/category/15156/>

The plan for physics studies will be discussed tomorrow at the physics session

<https://agenda.linearcollider.org/event/11033/sessions/5704/#20260915>

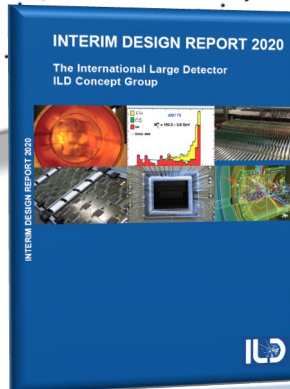
From the ILD Interim Design Report

8.3 Physics Benchmarks

<https://doi.org/10.48550/arXiv.2003.01116>

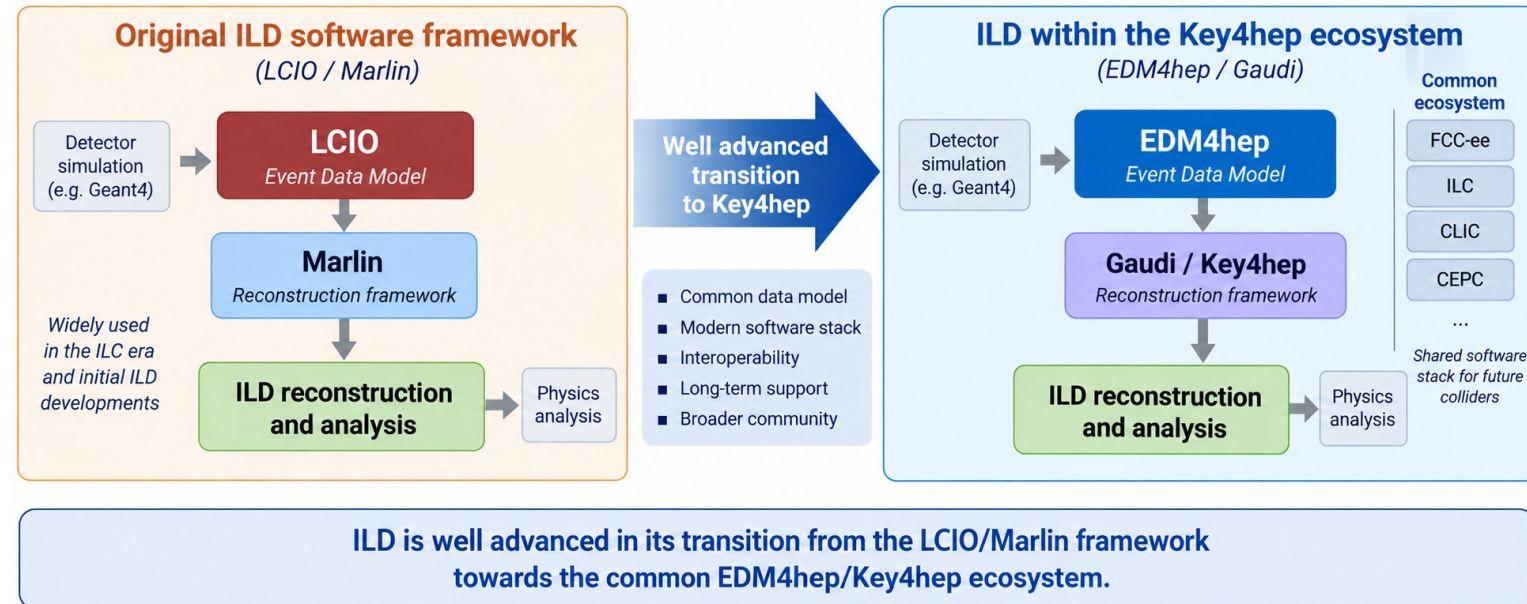
The performance of the two ILD detector models IDR-L and IDR-S has been evaluated on a number of physics benchmarks discussed in this section. Despite the fact that a 250-GeV version of the ILC is currently under political consideration in Japan, the detector benchmarking has been performed at higher center-of-mass energies, mostly at 500 GeV, and in one case even at 1 TeV. This choice has

8.3	Physics Benchmarks
8.3.1	Luminosity, Energy and Polarisation for the Physics
8.3.2	Hadronic Branching Ratios of the Higgs Boson
8.3.3	Higgs Mass from $ZH \rightarrow llb\bar{b}$
8.3.4	Branching Ratio of $H \rightarrow \mu^+\mu^-$
8.3.5	Sensitivity to $H \rightarrow \text{invisible}$
8.3.6	τ polarisation in $e^+e^- \rightarrow \tau^+\tau^-$
8.3.7	Hadronic WW and ZZ separation in Vector Boson Scattering
8.3.8	Photon Energy Scale Calibration from $e^+e^- \rightarrow \gamma Z \rightarrow \gamma\mu^+\mu^-$
8.3.9	A_{FB} and polarised cross sections from $e^+e^- \rightarrow b\bar{b}$
8.3.10	A_{FB} and polarised cross sections from $tt \rightarrow bbqql\nu$
8.3.11	Search for extra Scalars in $e^+e^- \rightarrow ZS^0$
8.3.12	Search for low ΔM Higgsinos
8.3.13	WIMP Search in the Mono-Photon Channel



ILD has a long-standing commitment to common software frameworks, from ILCSoft to the Key4hep ecosystem.

Key4hep integration strengthens interoperability with the FCC ecosystem, making ILD more accessible and attractive to external users for FCC-ee physics studies and detector comparisons.



Continued development of reconstruction and analysis tools is essential.

Modern ML approaches already show significant benefits in PID, flavour tagging, and overall reconstruction performance. Integrating these techniques into the ILD software framework presents a clear opportunity to further enhance detector performance and physics reach

Details will be discussed at the software session

<https://agenda.linearcollider.org/event/11033/sessions/5701/#20260914>

The specific data samples will be defined in coordination with Physics and Detector groups

See also the Physics session

The new data samples should be generated directly within **Key4Hep**

We should investigate the FCC-ee policy for sample production and explore the possibility of benefiting from central production, where available.

The **ILD data access policy should be revisited** within the IA, perhaps considering specific conditions for FCC-ee-related data during the transition period before the new collaborations are formally established, in line with the current FCC policy.

More discussion during the Software Coordinator talk

TECHICAL COORDINATION

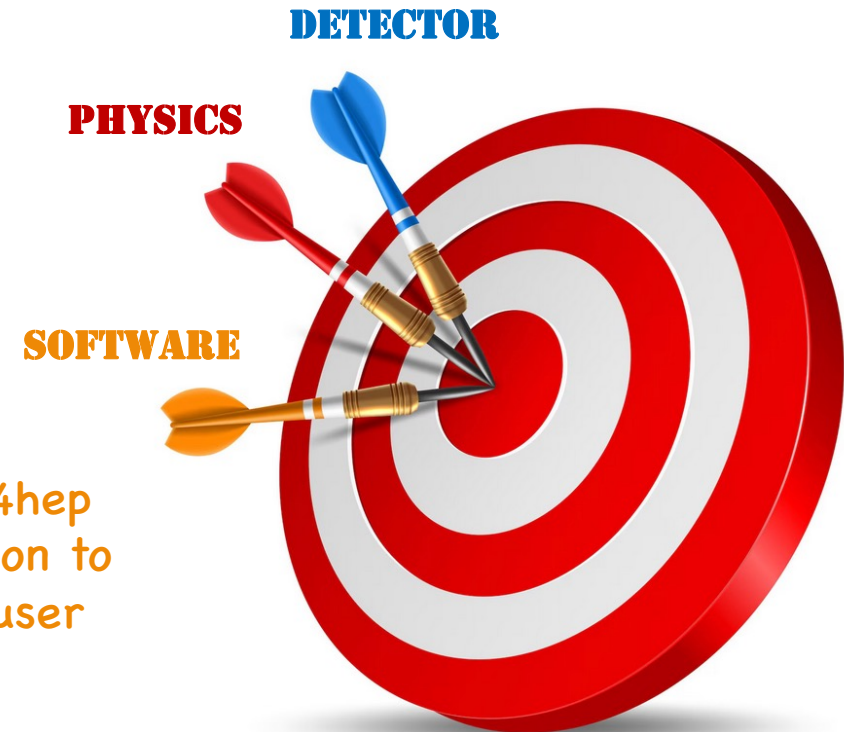
Revisit the **DETECTOR** design to address new challenges and proactively integrate advances emerging from the DRDs, and evaluate and optimise the use of sub-nanosecond timing capabilities to further enhance ILD performance.

PHYSICS COORDINATION

Combine detector R&D with benchmark **PHYSICS** studies to optimise performance and assess ILD's full physics potential, especially at the Z pole.

SOFTWARE COORDINATION

Strengthen ILD **SOFTWARE** through full Key4hep integration and modern AI-based reconstruction to enhance performance and attract a broader user community.



ILD should actively integrate into the FCC-ee study structure, participating in detector and physics working groups, contributing results, helping define common benchmarks, and taking active roles in their coordination.

This engagement must be two-way: sharing ILD expertise while bringing new ideas and technologies back into ILD.

FCC-ee momentum provides a unique opportunity to attract new groups and expand our community.

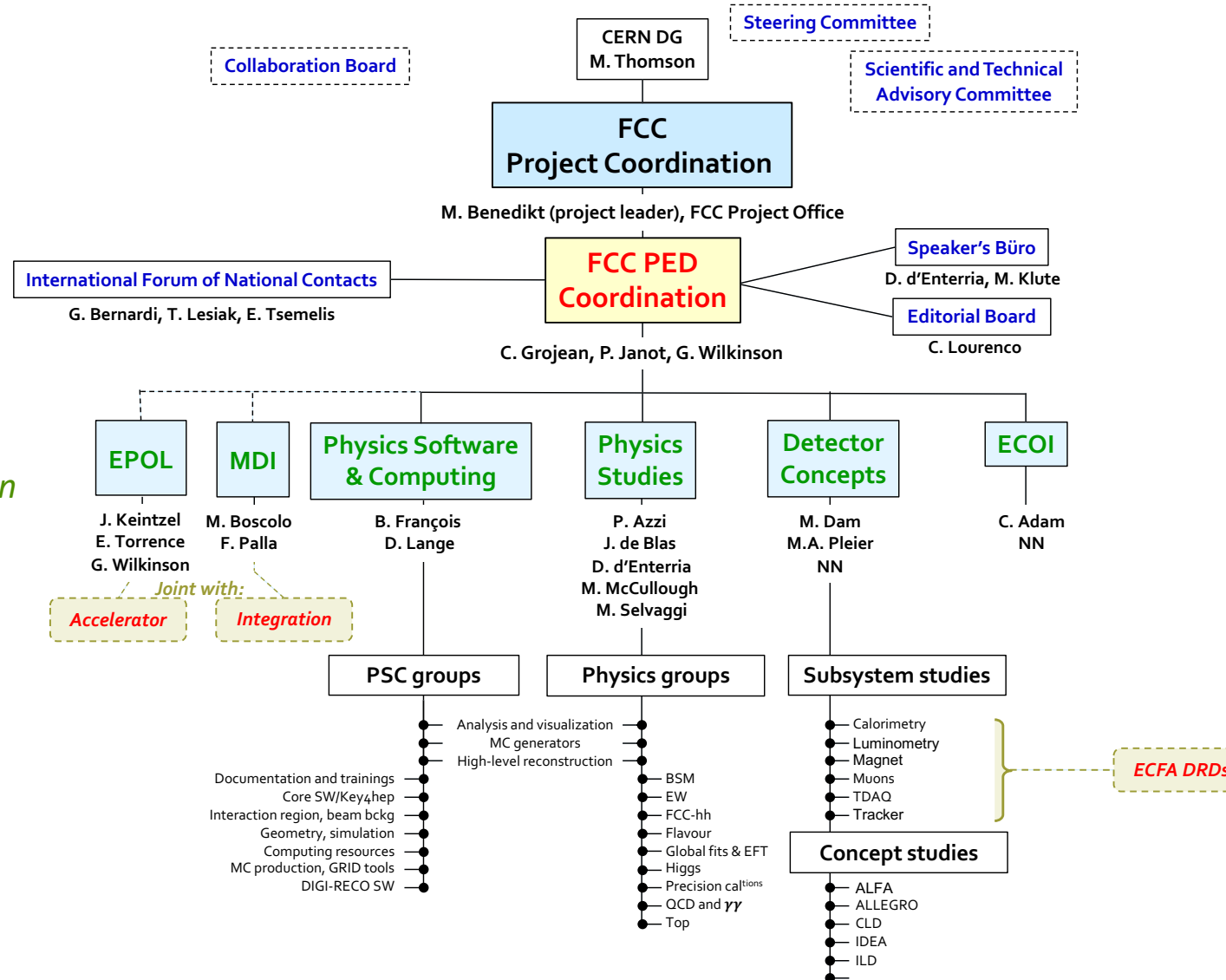
ILD should also seek active integration into the FCC-ee organizational structure, including coordination roles, publication procedures and appropriate ILD membership arrangements...

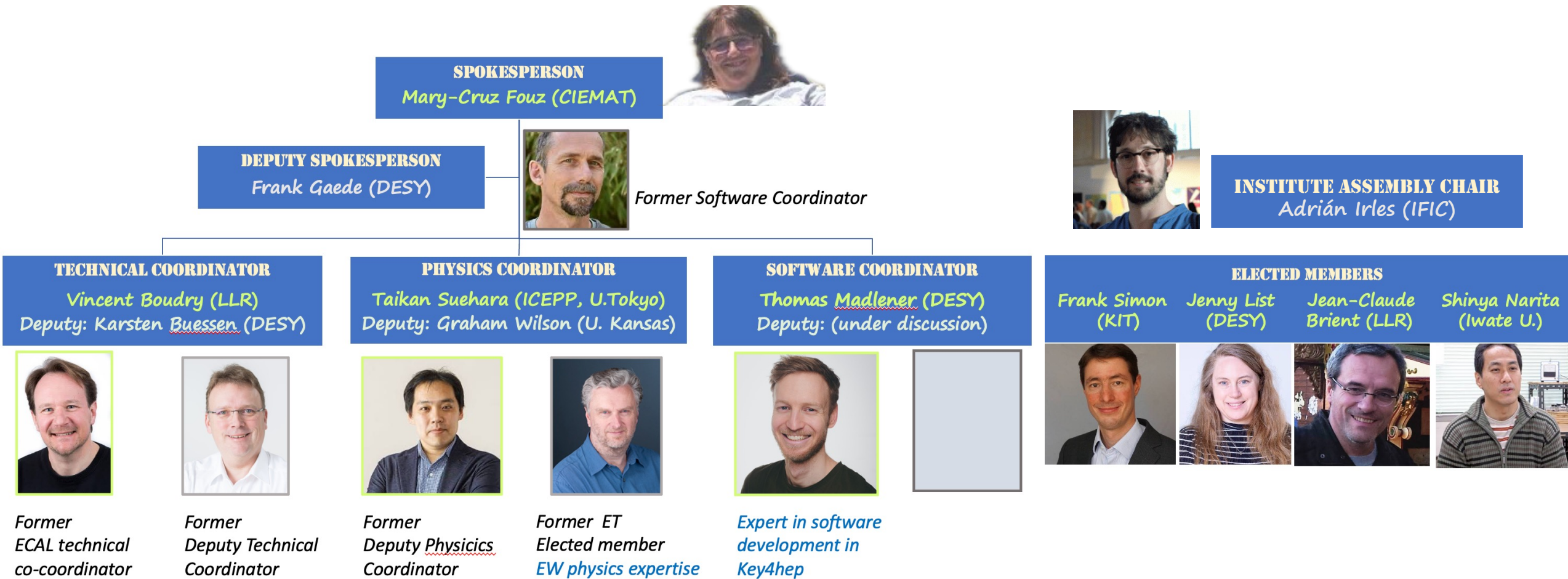
ILD should become an integral part of the FCC-ee studies — not only preparing for FCC-ee, but actively contributing to shaping its detector and physics programme.

Addressing manpower constraints requires a strategic approach, optimizing resource allocation and building synergies across activities.

The complete list of FCC e-groups can be found here:

https://fcc-ped.web.cern.ch/wp-content/uploads/2026/04/PED_egroups_chart_2026_04_28.pdf





Different pacemakers, a common goal

Spokespersons lead the way for a while,
setting the pace and keeping the collaboration on track.
Then they step aside, so another can take over and continue.



I would like to take this opportunity to
sincerely thank **Ties**, our **outgoing**
Spokesperson, for leading ILD and guiding
the collaboration through that long period,
and also all the **members of the Executive**
Team who are now stepping down.



Kiyotomo K.
Deputy SP.



Daniel J.
Software Coor.



Filip Z.
Physics Coor.



Marcel V.
Elected member



Same direction
A stronger collaboration

Concept: M.C. Fouz · Visual: ChatGPT (OpenAI)

You have set the pace and helped bring us this far;
now it is our responsibility to keep that momentum going

Thank you for your commitment, your time,
and everything you have done to keep ILD moving
forward and to bring us to where we are today.