

Experimental roadmap to the FCC



Higgs Hunting 2026,
IJCLab Orsay / APC Paris, 18/9/26

Guy Wilkinson
University of Oxford

Outline

- Where are we now, and how did we get here?
- Higgs physics at FCC-ee (and a reminder that the FCC-ee is not just a Higgs factory)
- The Reference Design Phase (RDP), for the project as a whole...
- ...and for Physics, Experiments and Detectors (PED), with a focus on Detector Concepts
- Conclusions

International consensus



[CERN-ESU-2025-002]

Outcome of ESPPU process:

“ The next CERN flagship collider project

- A. The e^+e^- Future Circular Collider (FCC-ee) is recommended as the preferred option for the next flagship collider at CERN.
- B. A descoped FCC-ee is the preferred alternative option for the next flagship collider at CERN.”

Approved by CERN Council in June.

CERN responds accordingly

Outcome of ESPPU was very clear, and has now been adopted through a resolution by CERN Council. Situation has been well articulated by CERN DG, for example in plenary ECFA meeting in Amsterdam in July [\[link\]](#).

FCC was a key topic of the update of the ESPP

The key points from the European Strategy Group (ESG) report regarding FCC:

- Overwhelmingly strong endorsement of the physics and strategic case for FCC-ee as the next flagship collider at CERN
 - Consensus within the particle physics communities in CERN's Member States
- A descoped/staged FCC-ee is preferred to other options as **the** alternative
- FCC-ee is far ahead of other concepts

The update of ESPP, endorsed FCC-ee as CERN's scientific vision for the future:

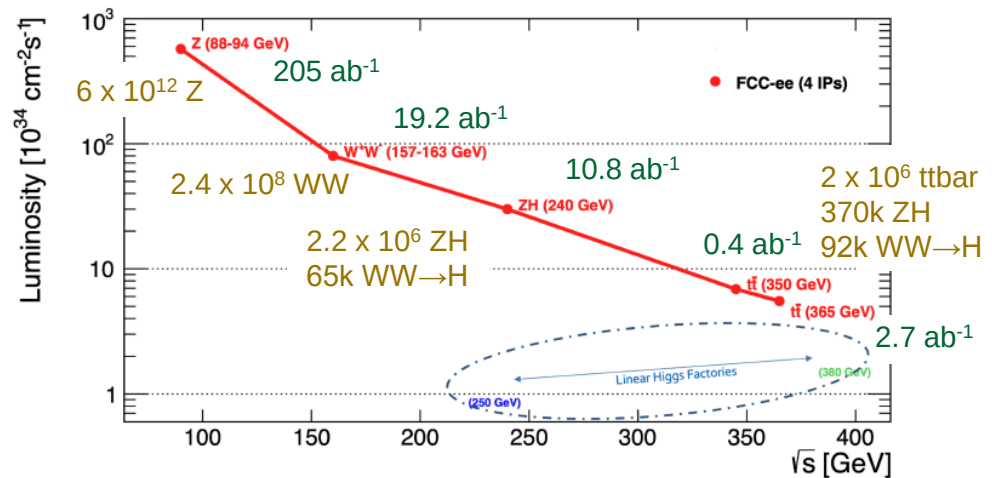
- CERN **strongly** supports this objective
- Our clear aim is to be ready for a decision on FCC-ee in 2028
- CERN's highest objective for the long-term future is to be in a position in 2028 to propose to Council FCC-ee as CERN's next flagship collider
- Seeking a decision on FCC-ee, not a choice between options, that choice has been made in the European Strategy update

But why did this consensus emerge ? Why did the community select FCC-ee ?

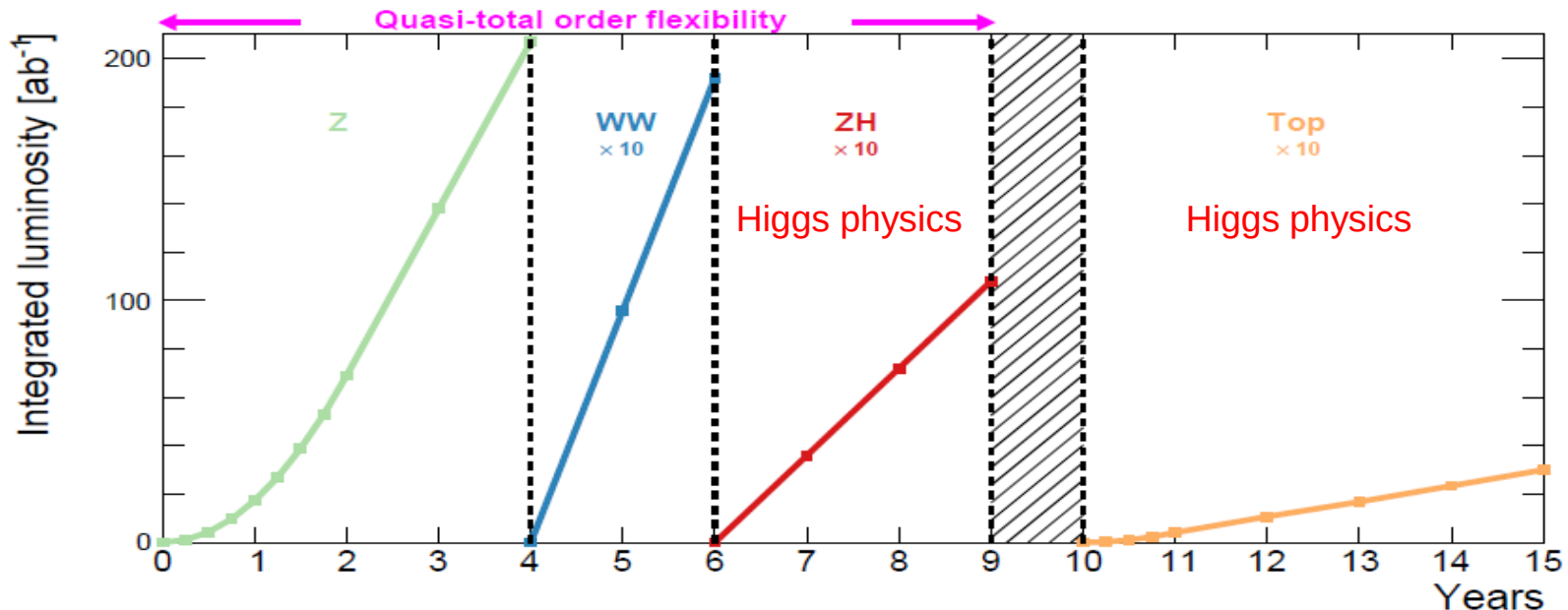
FCC-ee essentials and enabling characteristics

FCC-ee enabling characteristics:

- Huge samples → extreme precision;
- Four (+) energy points, explored in a compact 15-year programme;
- With exciting options for extension.

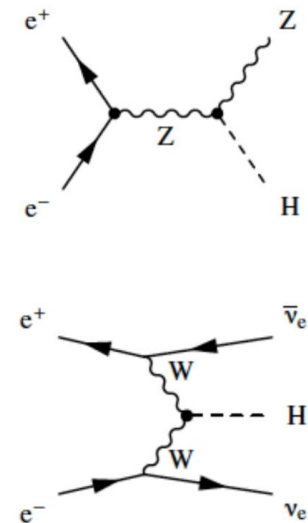
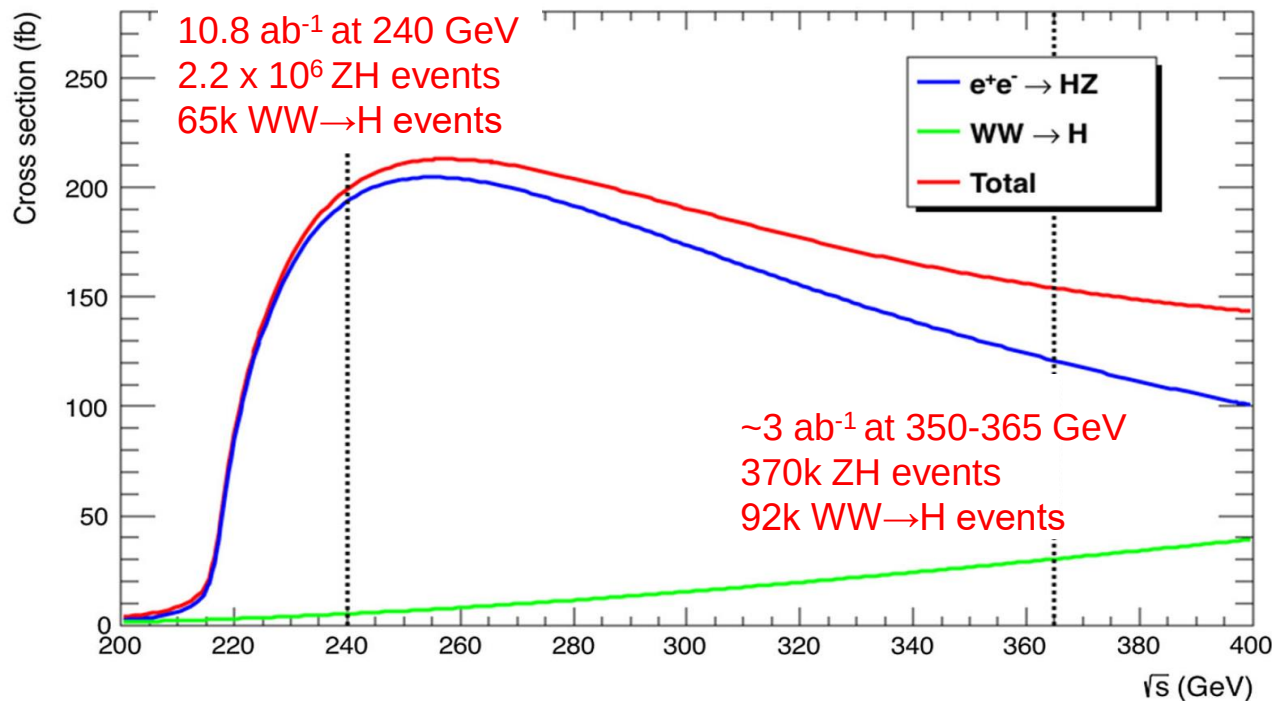


Physics goals encompass Higgs studies:

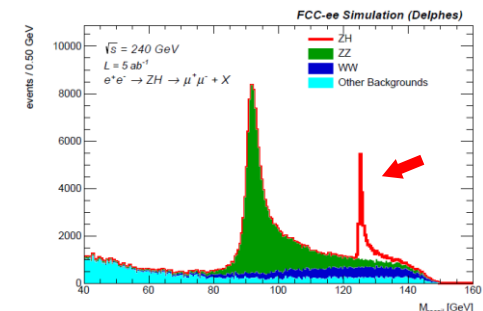


Higgs studies at FCC-ee

Central goal of FCC-ee: *model-independent* measurement of Higgs width and couplings with ($<$)% precision. Achieved through operation at two energy points.



Why model independent? e.g. in $e^+e^- \rightarrow Z^*H$ events, presence of Higgs can be inferred independent of its decay mode by reconstructing recoiling Z decay.



Higgs studies at FCC-ee

Clean environment of FCC-ee and near perfect knowledge of initial state, allow for precise measurements of a wide range of Higgs properties.

e.g. Higgs mass – prospects revisited
in recent paper [\[arXiv:2608.12071\]](https://arxiv.org/abs/2608.12071)

Toward a Measurement of the Higgs Boson Mass with Natural-Width Precision at FCC-ee

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Higgs boson mass measurements with sub-10 MeV precision enable sub-percent determinations of Higgs boson couplings and prevent the Higgs boson mass from becoming a limiting input to electroweak fits. Probing the electron Yukawa coupling through resonant Higgs boson production requires a precision comparable to the Higgs boson natural width of approximately 4 MeV. Using the leptonic ZH recoil channels, we show that FCC-ee can reach a Higgs boson mass precision of 4 MeV, including statistical and systematic uncertainties, thereby enabling this unique measurement. We identify the detector and accelerator performance required to reach this precision.

TABLE I. Summary of the Higgs boson mass precision in the muon, electron, and combined channels, including statistical and systematic uncertainties.

Channel	Stat. only (MeV)	Stat. + syst. (MeV)
Muon	3.9	4.7
Electron	5.0	5.7
Combination	3.1	4.0

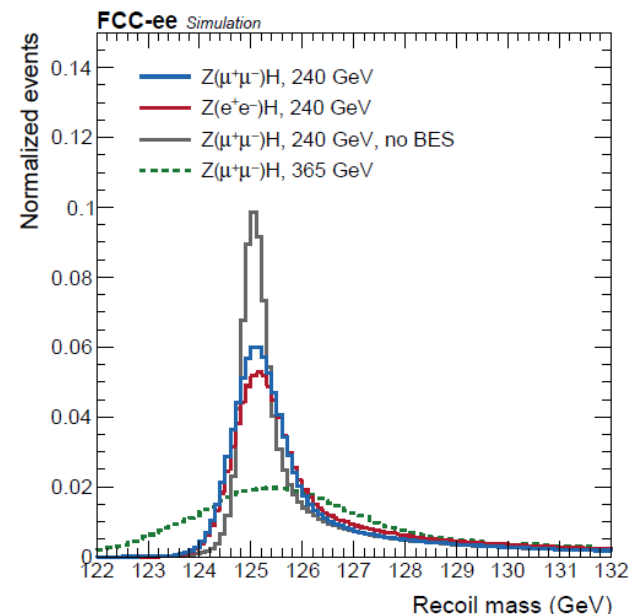


TABLE II. Statistical uncertainty in the Higgs boson mass for various detector and fit configurations, combining the muon and electron channels unless stated otherwise.

Fit configuration	Uncertainty (MeV)
Default (2 T)	3.1
Ideal momentum resolution	2.4
Silicon tracker ($\approx 6\% X_0$)	3.9
Magnetic field (3 T)	2.5
Electron resolution ($2 \times$ muon)	3.2
Default without beam-energy spread	1.7

Critical
detector
features

Higgs-coupling measurements at FCC-ee

Sensitivity of HL-LHC and FCC-ee projections, as ratios of measured coupling to SM expectation (' κ):

- FCC-ee reaches 0.1-0.5% precision on many of the most interesting couplings;
- Accesses, for the first time, second-generation quarks;
- Results are model independent;
- Achieved in a compact period of eight-years operation.

Coupling	HL-LHC	FCC-ee
κ_Z (%)	1.3*	0.10
κ_W (%)	1.5*	0.29
κ_b (%)	2.5*	0.49
κ_g (%)	2*	0.54
κ_τ (%)	1.6*	0.46
κ_c (%)	—	0.87
κ_γ (%)	1.6*	1.1
$\kappa_{Z\gamma}$ (%)	10*	4.3
κ_t (%)	3.2*	3.1
κ_μ (%)	4.4*	3.3
$ \kappa_s $ (%)	—	+29 -67
Γ_H (%)	—	0.78
$\mathcal{B}_{\text{inv}} (<, 95\% \text{ CL})$	$1.9 \times 10^{-2} *$	5×10^{-4}
$\mathcal{B}_{\text{unt}} (<, 95\% \text{ CL})$	$4 \times 10^{-2} *$	6.8×10^{-3}

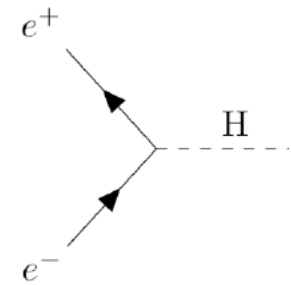
* next to HL-LHC numbers → not model independent

(Caution: HL-LHC numbers may not be state-of-the-art).

Recall that direct measurement of Higgs self-coupling is not possible at FCC-ee, but there is loop-level sensitivity (see backups). FCC-hh measures κ_λ at $O(\%)$.

Run at 125 GeV ?

s-channel Higgs production

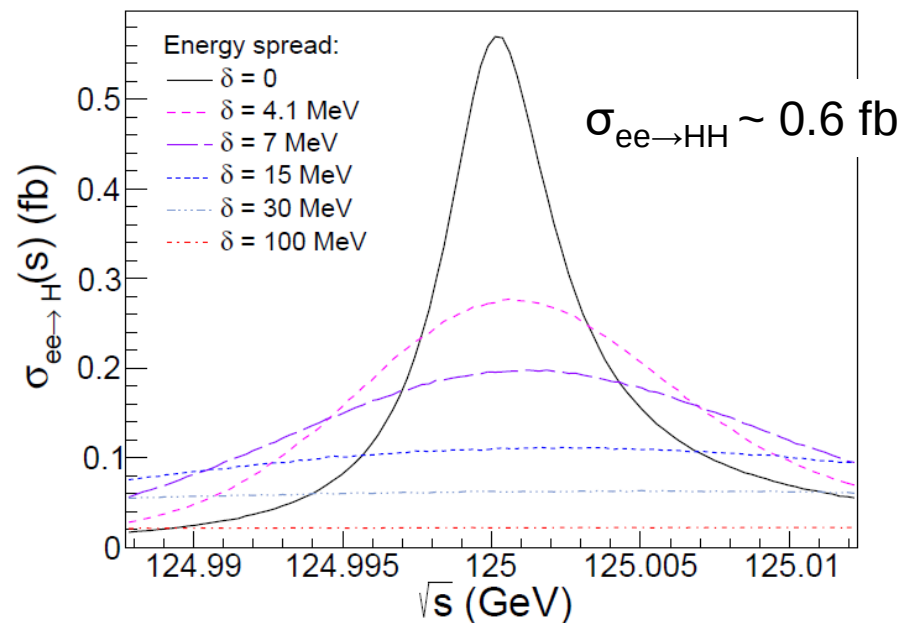


A tantalising possibility, under evaluation and not in FSR baseline, is to devote a few years operation at $E_{\text{CM}}=m_{\text{H}}=125$ GeV to measure Yukawa coupling to electrons.

But cross-section is tiny...

...& effectively decreased further through ISR and because Higgs width (~ 4 MeV) small compared to E_{CM} spread.

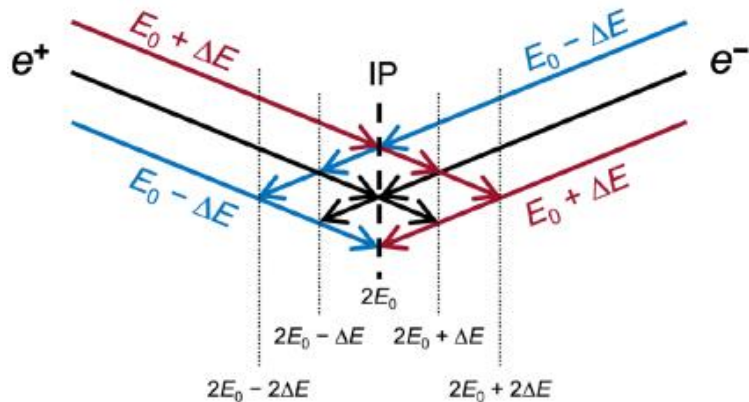
Note that natural E_{CM} spread for colliding beams is ~ 70 MeV. This must be reduced: requires *monochromatisation*.



Also need good knowledge of m_{H} ($\sim \Gamma_{\text{H}}$), good E_{CM} knowledge, & high E_{CM} stability. In addition, must develop refined analysis exploiting all Higgs decay modes to separate signal from background (e.g. Higgs $\rightarrow$ gg becomes an important channel).

The Higgs-pole challenge

Monochromatisation can be achieved through introduced opposite-sign dispersion.



The problem is that this generally also results in an emittance blow up, and hence a decrease in luminosity. Need to find the sweet spot in $\delta_{\sqrt{s}}$ vs. L plane !

First serious attempt to implement such a scheme [\[Zhang et al., arXiv:2411.04210\]](#) achieves monochromatisation factors of >2 . With such

a performance, it would be possible to set 95% CL limit of $2.5 \times$ SM value in 1 year, ~ 20 - $40 \times$ better than is foreseeable at HL-LHC. Efforts ongoing to improve further.

A complementary approach: collide longitudinally polarised beams, with helicities set for Higgs, not Z, production. Not foreseen in Feasibility Study design, but made more conceivable by ongoing studies (transverse) polarised (pilot) bunch injection.

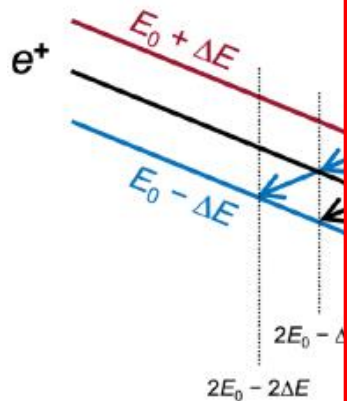
Goal – reach a clearer idea on feasibility by project approval, but not in baseline !

The Higgs-pole challenge

Monochromatized

Recent developments – a significant (four-fold) improvement in $H \rightarrow WW^* \rightarrow \text{lepton} + \text{jets}$ channel, now matching previous golden mode, $H \rightarrow gg$.

sign dispersion.



a performance
~20-40x better

A complementary
set for Higgs,
more conceivable

Goal – reach

erally also
up, and hence
eed to find the
!

ement such a
[arXiv:2604.24152] achieves
of >2. With such
M value in 1 year,
improve further.

s, with helicities
design, but made
) bunch injection.

n baseline !

arXiv:2604.24152v1 [hep-ph] 27 Apr 2026

PREPARED FOR SUBMISSION TO JHEP

Probing the electron Yukawa coupling via resonant
Higgs boson production at FCC-ee via
 $e^+e^- \rightarrow H \rightarrow WW^*$ in lepton-plus-jets final states

Apranik Fatehi,^{a,b,c,d} Reza Jafari Seyedabad,^{b,d} Amir Amiri,^{b,c} Kazem Azizi,^{b,f}
David d'Enterria,^a Louis Portales,^g and Michele Selvaggi^h

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^eDepartment of Physics, Faculty of Science, Ferdowsi University of Mashhad, P.O. Box 1436, Mashhad, Iran

^fDepartment of Physics, Dogus University, Dudullu-Ömraniye, 34775 Istanbul, Türkiye

^gIRFU, CEA, Université Paris-Saclay, Gif-sur-Yvette, France

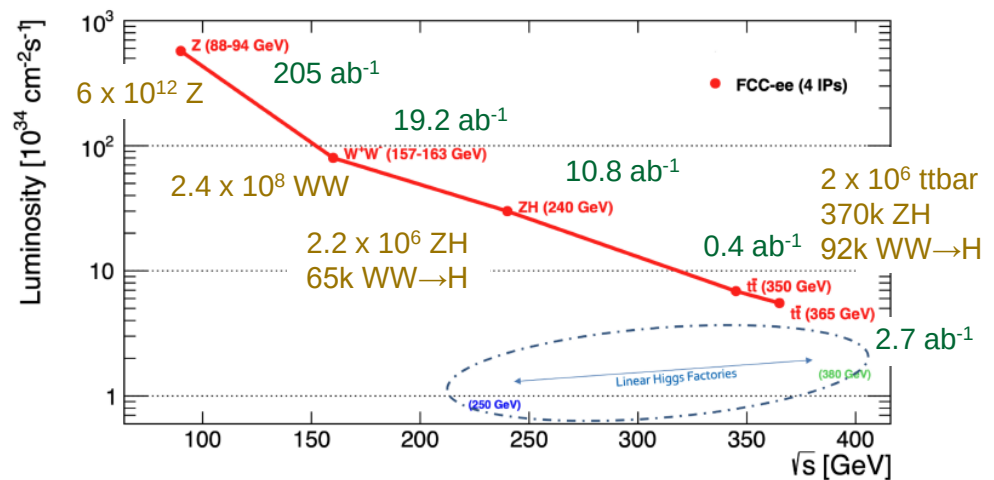
ABSTRACT: We report a detailed simulation study of the search for s -channel Higgs boson production in e^+e^- collisions at a center-of-mass (c.m.) energy of $\sqrt{s} = 125$ GeV at the CERN Future Circular Collider (FCC-ee), as a means to constrain the electron Yukawa coupling, y_e . The process of interest is $e^+e^- \rightarrow H \rightarrow WW^* \rightarrow \ell^\pm \nu + jj$ with four different WW^* final states considered, involving both on- and off-shell W bosons decaying either into dileptons ($\ell^\pm = e^\pm$ and $\mu^\pm$, including those from $\tau^\pm$ decays) or into dijets (jj). Signal and background events are discriminated through a multiclass gradient boosted decision tree exploiting a comprehensive set of kinematic and topological variables across the four final-state categories. Assuming a monochromatized c.m. energy spread of 4.1 MeV, yielding a $\sigma_{ee \rightarrow H} = 280$ ab resonant cross section, and an integrated luminosity of 10 ab^{-1} , the analysis achieves a combined statistical significance of 2.0 standard deviations. This corresponds to an upper limit on the coupling modifier $\kappa_e = y_e/y_e^{\text{SM}} \lesssim 1.35$ at 95% confidence level, and provides the most stringent constraint on the electron Yukawa coupling achieved in simulation-based studies to date.

[arXiv:2604.24152]

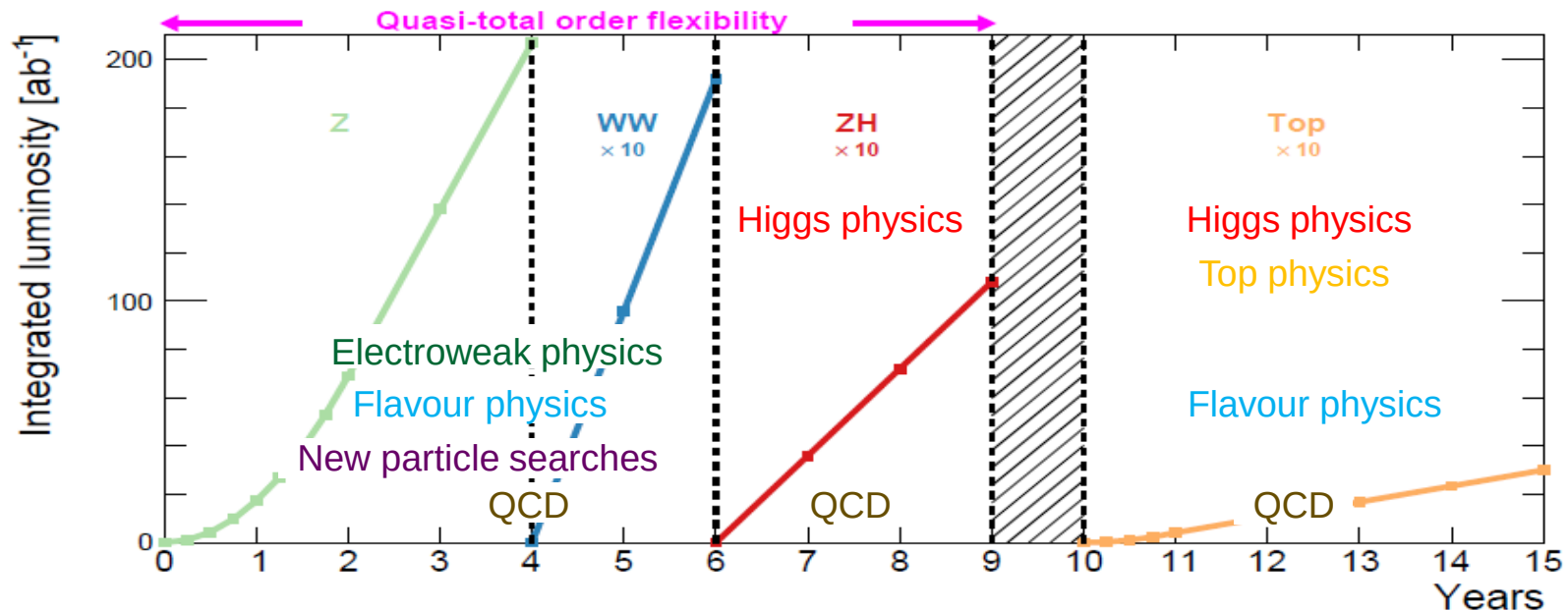
FCC-ee essentials and enabling characteristics

FCC-ee enabling characteristics:

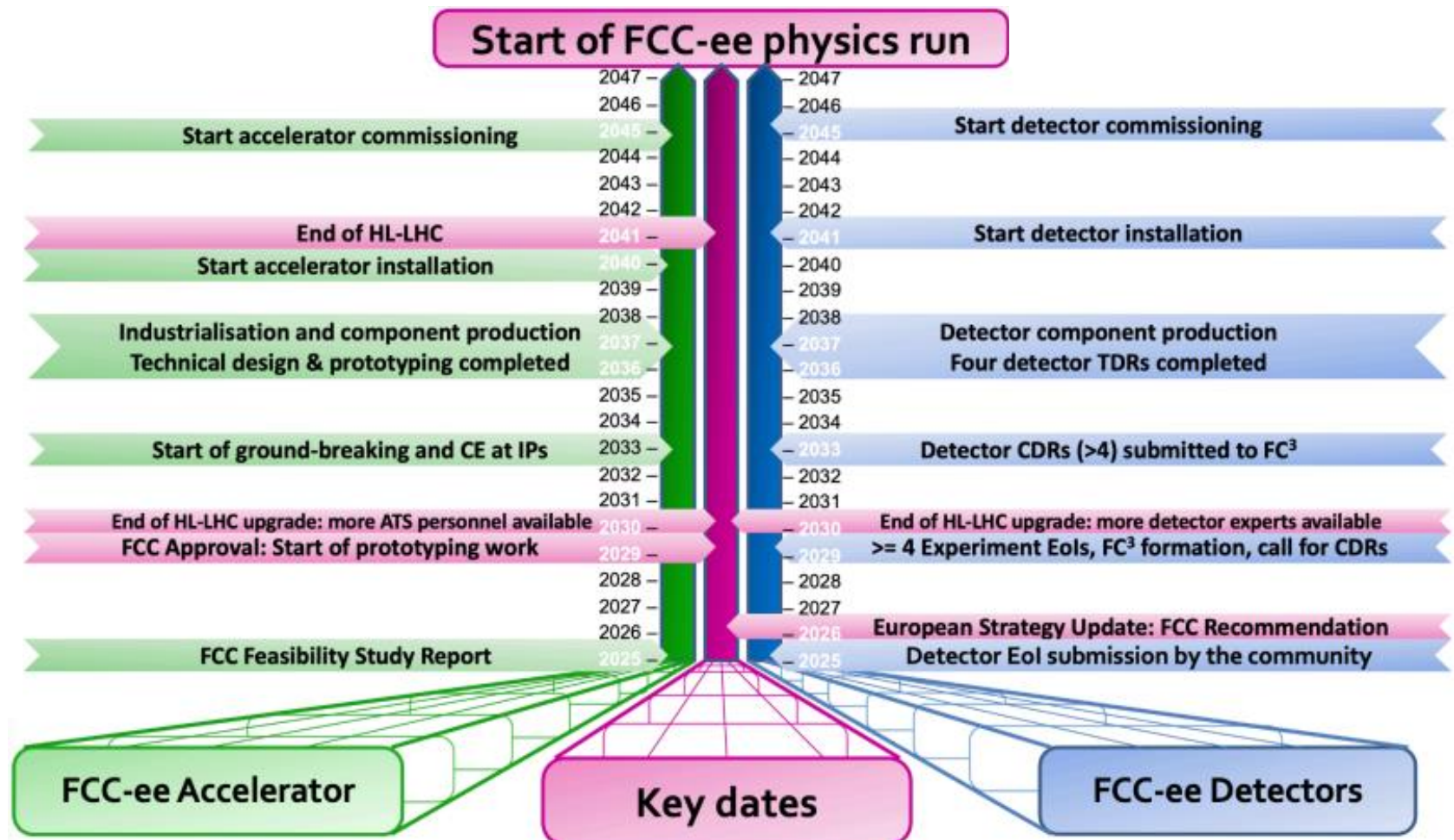
- Huge samples → extreme precision;
- Four (+) energy points, explored in a compact 15-year programme;
- With exciting options for extension.



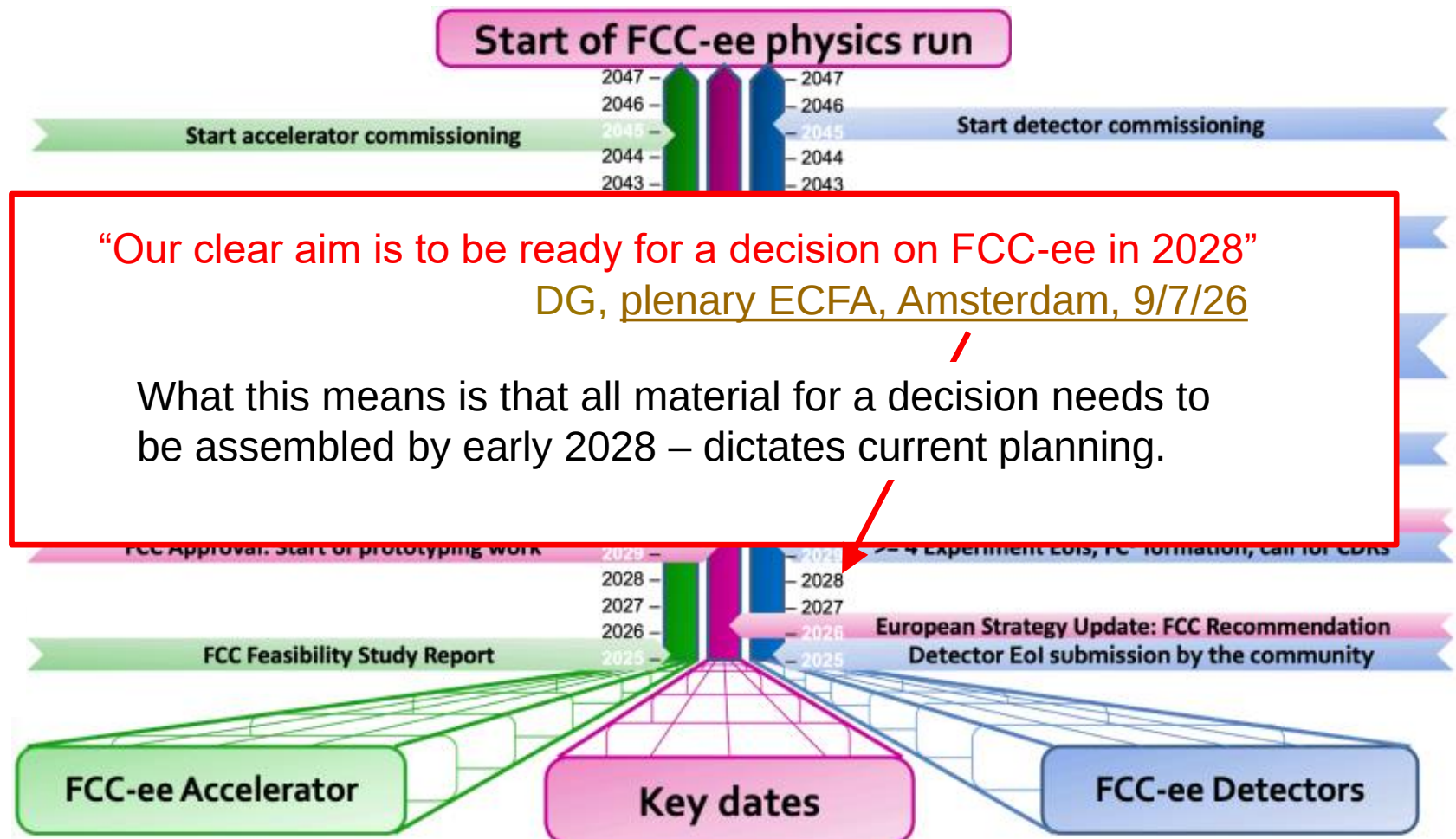
Physics goals encompass Higgs studies, and *very much more*:



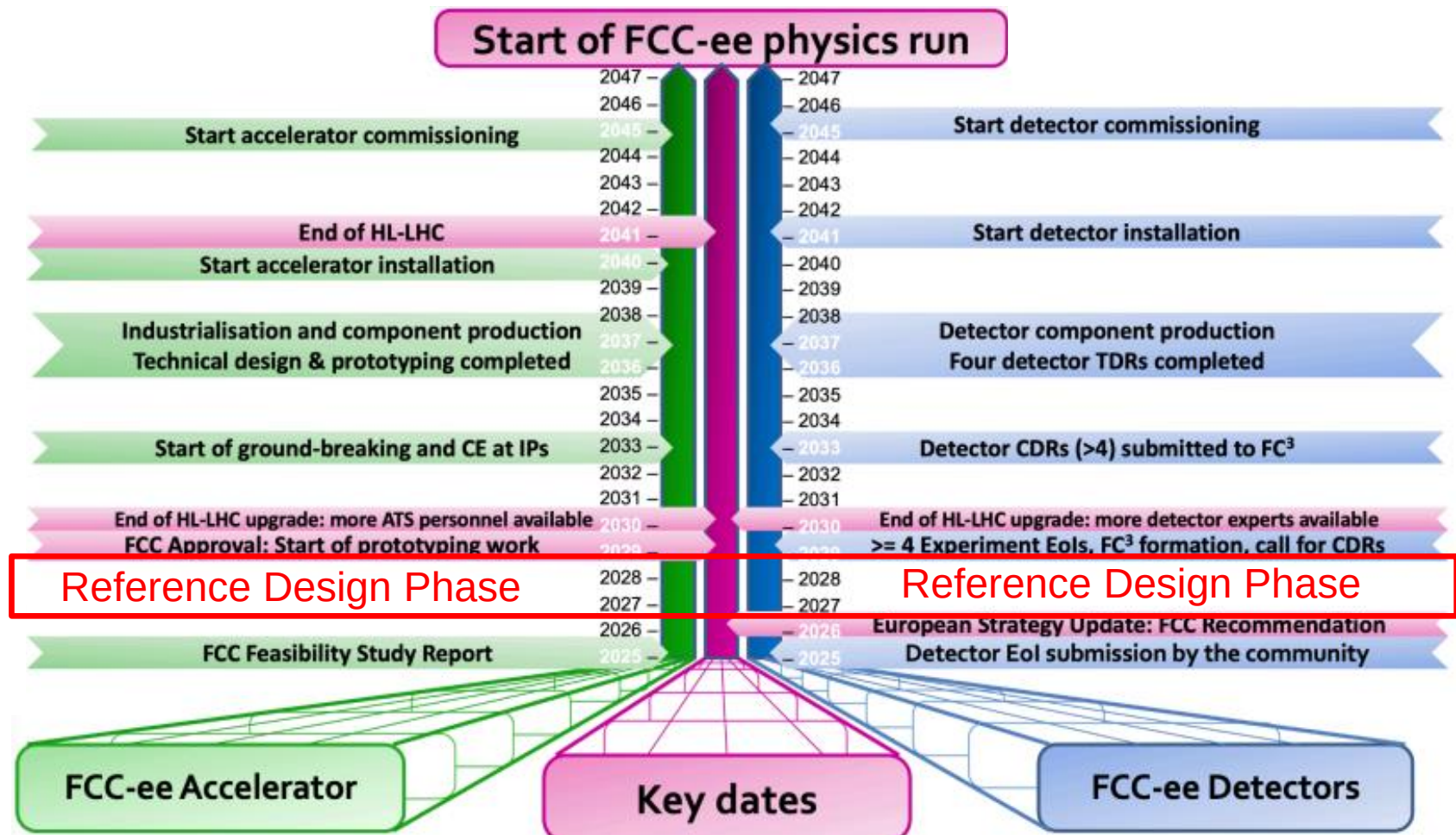
Countdown to physics



Countdown to physics



Countdown to physics



FCC Reference Design Phase

The purpose of the Reference Design Phase (RDP) is to consolidate the technical, organisational, implementation, schedule and cost elements of the project at a higher level of maturity than that achieved during the Feasibility Study phase, establishing the reference design for the project.

RDP aims to deliver a coherent, integrated and sufficiently mature project definition that will allow for a decision on project approval. If approved...

...the RDP will be followed by the Technical Design Phase, starting in ~2029.

Remainder of talk:

Update on key activities in RDP for project as a whole, and then for Physics, Experiments and Detectors (PED).

Reference layout and implementation

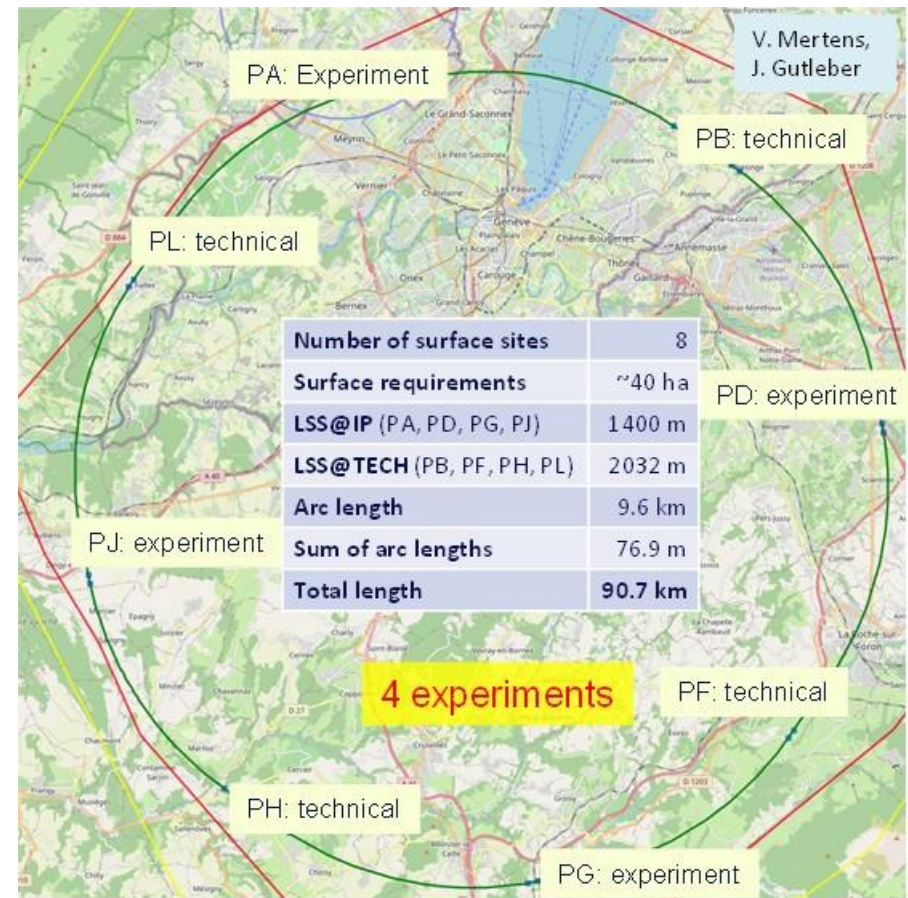
Fitting a ~100 km tunnel, plus access and services, in the Geneva basin is a non-trivial exercise (mountains, lake, towns), but surprisingly it can be done well !

Layout chosen out of ~100 initial variants, based on several criteria:

- **geology,**
- **surface constraints** (land availability, towns, etc.),
- **environment,** (protected zones),
- **infrastructure** (electricity, transport),
- **machine performance**

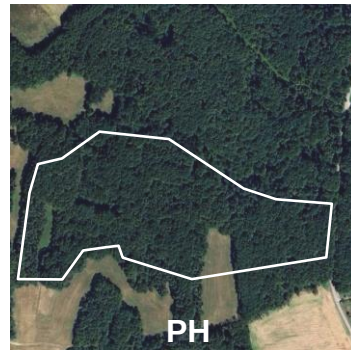
“**Avoid-reduce-compensate**” principle of EU and French regulations.

**Overall lowest-risk baseline:
90.7 km ring, 8 surface points,
4-fold symmetry**



Surface site locations: 7 in FR, 1 in CH

Optimisation performed in consultation with communes.



- Land plot needs communicated to Host States,
- Process in FR: «prise en consideration»,
- Land plot in CH owned by Canton of Geneva.

Territorial dialogue and public participation

First cycle of public information meetings completed (April 2024 – March 2025)

11 sessions reached over 1,500 people in France & Switzerland



During 2025:

Second cycle of **public information meetings**.

Presence days in municipalities affected by surface sites to enable discussion with habitants. Meetings with stakeholders of the territory.



- First dialogue and exchange meeting with local environmental associations, 5 may, 2025

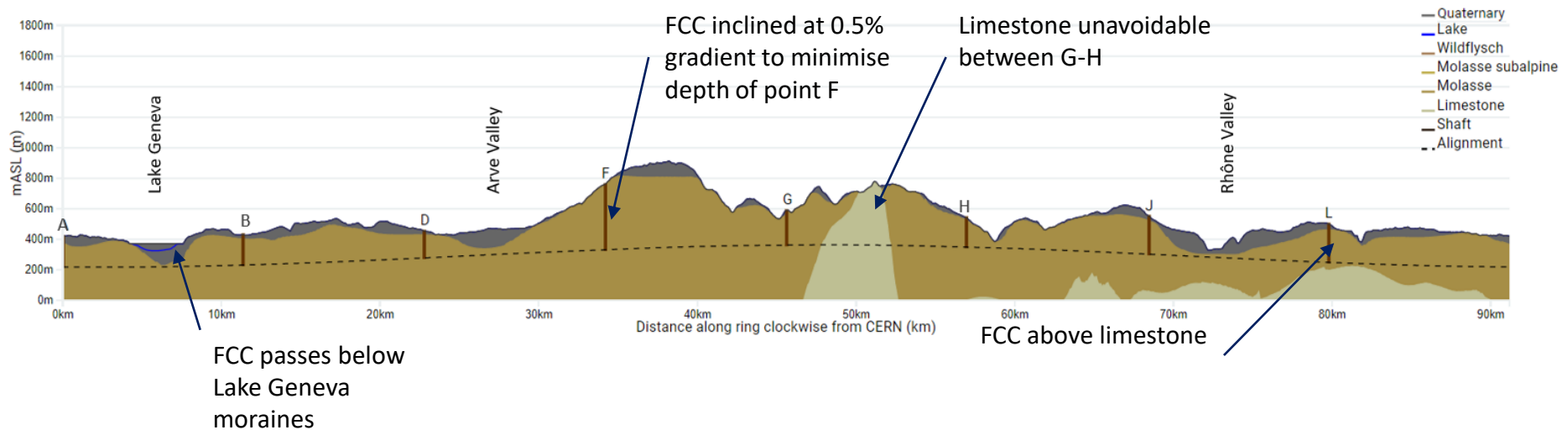
Dialogue Website



During 2026:

Formal public participation process in France (Debat Public) and Switzerland (public concertation). Both began in May/June, and will conclude at beginning of October.

Optimum placement of FCC tunnel and geology



Most tunneling in molasse layer (soft rock) - good for fast, low-risk TBM construction.

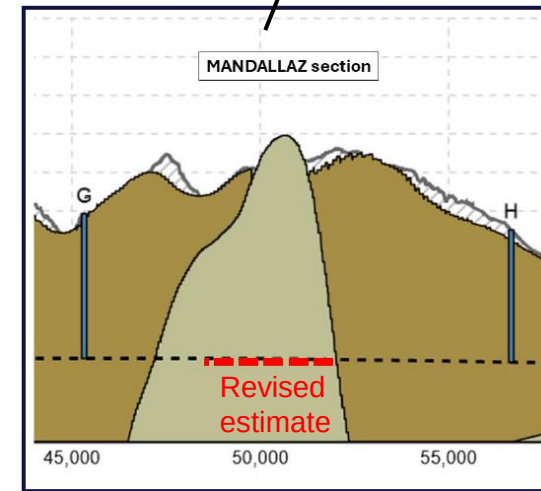
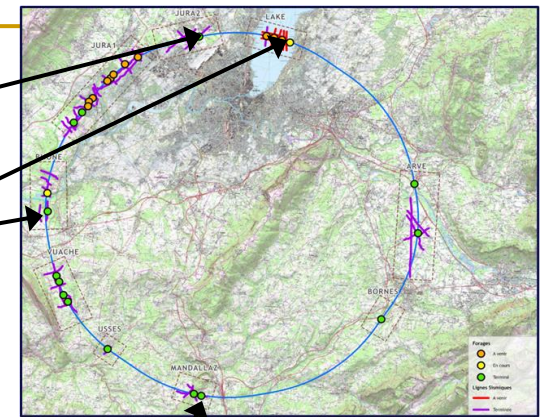
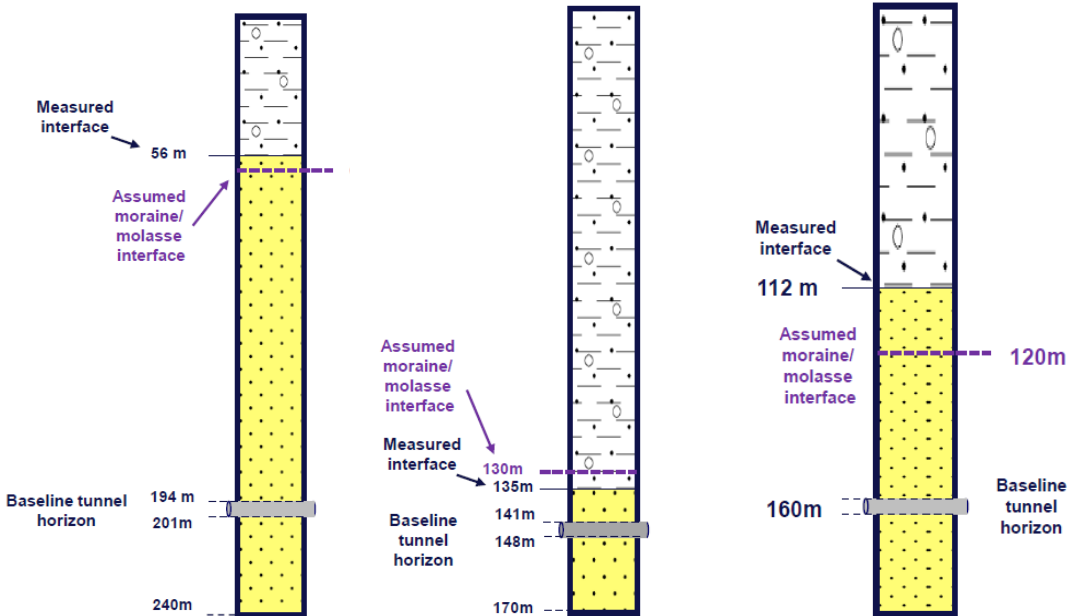
Six million m³ excavated volume → 8.5 million m³ excavation material on surface.

Civil engineering designs of all underground structures developed.

Average shaft depths ~240 m.

Fixing vertical position of tunnel, requires knowledge of interfaces between geological layers. First site investigations: bore holes drilled at critical locations

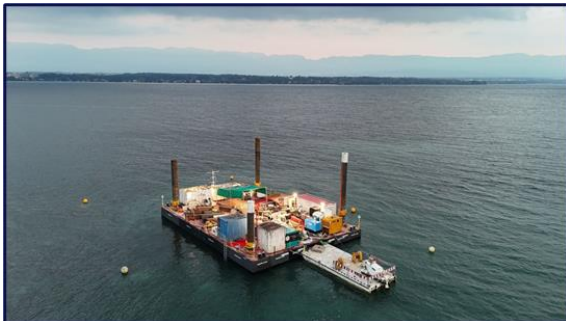
Example findings from site investigations



Boreholes in Mandallaz region suggest 3km of limestone, not 4.7km.

No limestone yet found elsewhere in 'tunnel horizon'.

First indications from lake are good – maybe the tunnel can go shallower ?



Civil engineering: next steps for RDP

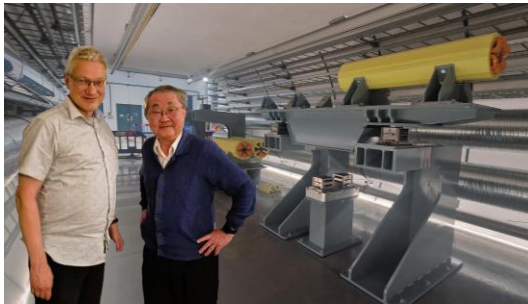
- Imminent: completion of first phase of site investigations, including four drillings on lake. From these fix tunnel depth and inclination (Q2 2027).
- Update to layout of both surface sites and underground structures to prepare new schedule and associated cost estimate.
- Ongoing studies into disposal of excavated material, using external consultant.
- 2027: contract to be signed for pre-architectural studies for surface sites, including full engagement with local communities.
- 2027: establish civil engineering baseline for injector complex.

Important developments: change of lattice

Global Hybrid Chromaticity (GHC)

Katsunobu Oide

Pursued through 2016 to 2026



Local Chromatic Correction (LCC)

Pantaleo Raimondi

Adopted for the RDP (2026-)



Consequences of optics change:

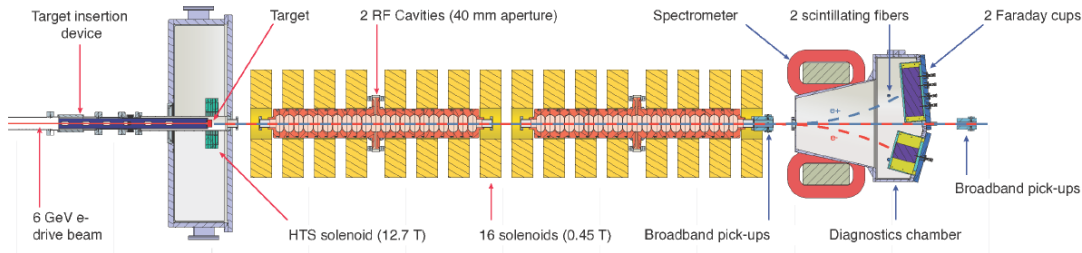
- Larger dynamic aperture, momentum acceptance and additional tuning flexibility
- Higher dipole filling factor, giving 10% reduction in SR power (*i.e.* 45 MW)
→ save money or increase luminosity !
- Reduced number of main sextupole circuits
→ cost and availability benefits !
- Opens attractive possibility of higher RF frequency (400 → *e.g.* 600 MHz). Under evaluation.

Recent news: PSI Positron Production (P^3) experiment

Positron source is a one of major challenges for FCC: e^+ can be produced by e^- impinging on, e.g. tungsten target, but then must be captured and channelled.

Demonstrator proposed for SwissFEL@PSI: e^- beam with up to 6 GeV on target.

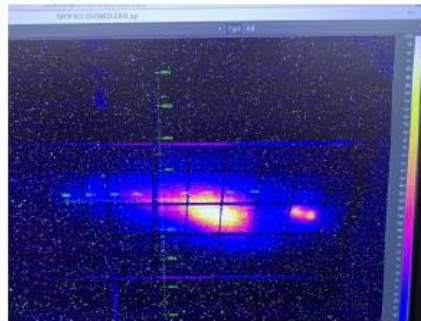
Concept (2020-2021)



Installation (2025-2026)



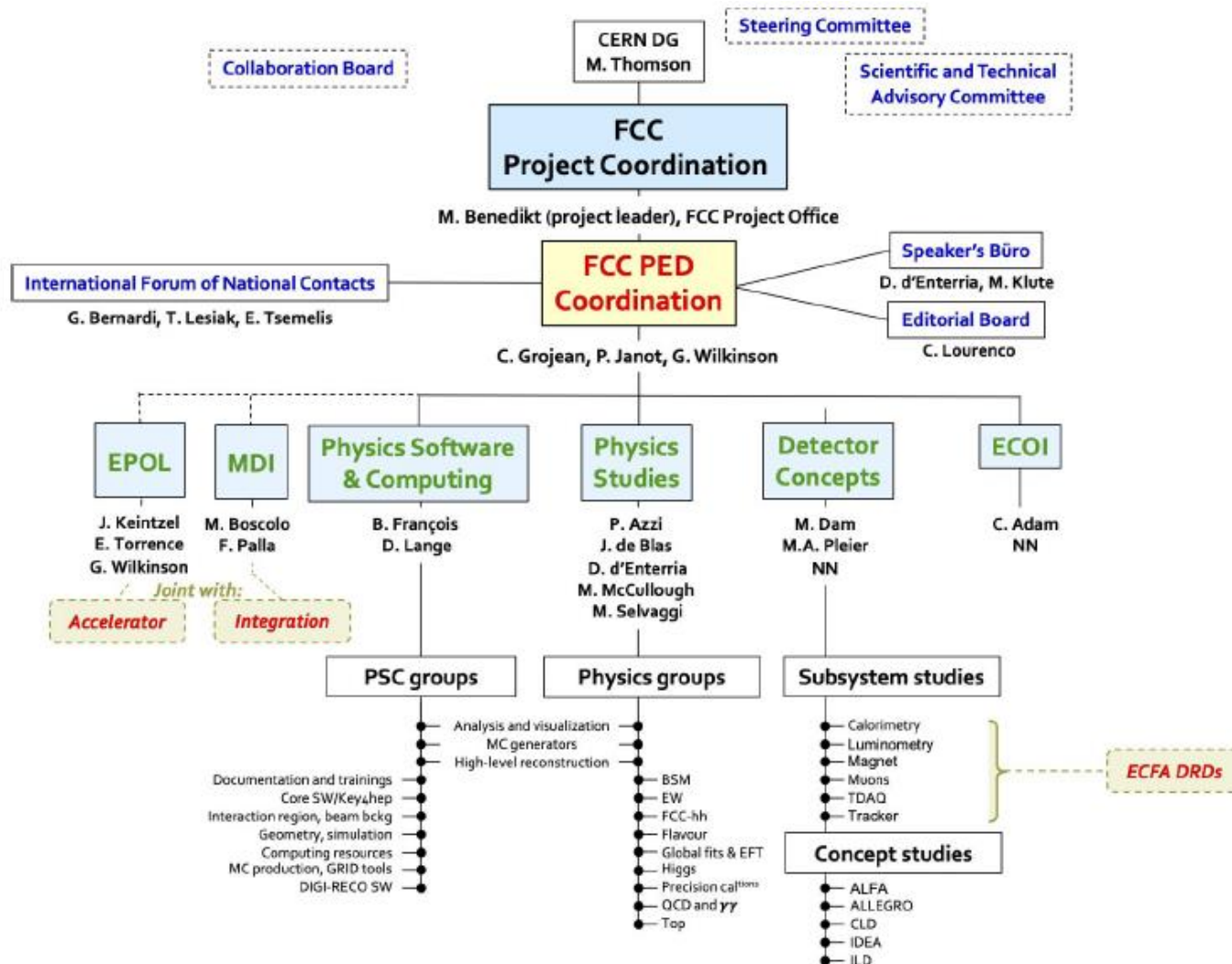
First
positrons
seen
this July !



Ready for studies ! [\[link\]](#)

(Ongoing work: optimise HTS solenoid design to allow operation up to 10 T)

Organisation of Physics, Experiments and Detectors in Reference Design Phase



PED objectives during the RDP

The following is the list of key PED objectives during RDP:

- Continuation of the development of specific conceptual detector designs with the international HEP community;
- Consolidation of IP region layouts & detector integration;
- Background mitigation strategies & machine-detector interface (MDI) optimisation;
- Development of a common computing architecture model & finalisation of a common software/analysis framework;
- Realistic implementation of some of the algorithms needed to confirm the experimental systematic uncertainties on EW precision observables;
- Coordination of the theory community to address the corresponding theory challenges for the FCC-ee;
- Assessment of the physics case, feasibility, and schedule implications for different centre-of-mass energy stages;
- Streamlining & optimisation of the procedures for centre-of-mass energy calibration & for possible monochromatic operation at 125 GeV to explore the electron Yukawa coupling;
- Proposal for staging implementation & improvements of the (staged/descoped) FCC-ee.

PED objectives during the RDP

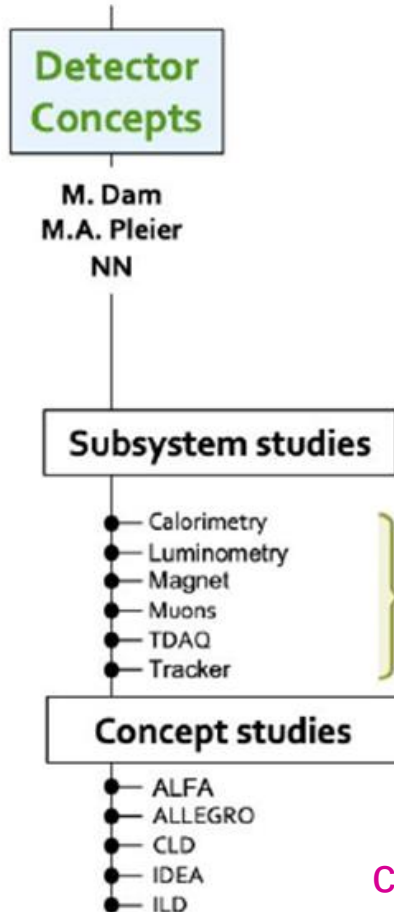
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Detector activities

Goals of 'Detector Concepts' WP in Reference Design Phase is to ensure that at time of decision on project approval:

- It should be clear that there is a path towards detector solutions that will be able to exploit fully the physics opportunities (Higgs, EW, flavour, LLP...);
- Collaborations are ready to form immediately, in preparation for down-select of experiments.



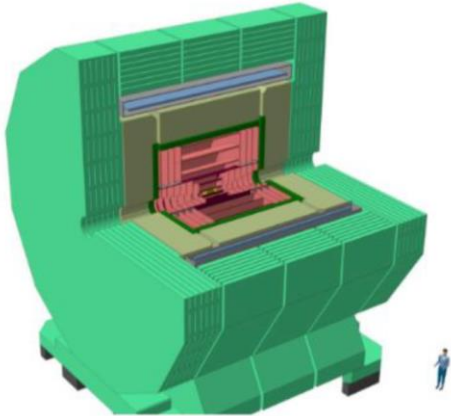
ECFA DRDs

with the EPPSU outcome, the DRDs are being encouraged to align more tightly with the needs of FCC-ee !

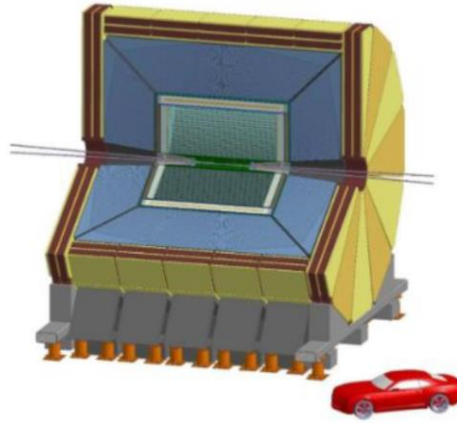
Parallel work on both subsystems and on individual concepts, with concept advocates contributing to the subsystem activities, and vice versa – too early for collaborations or competition !

Emerging detector concepts

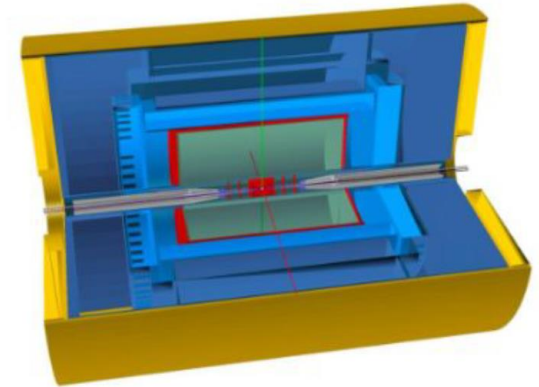
CLD



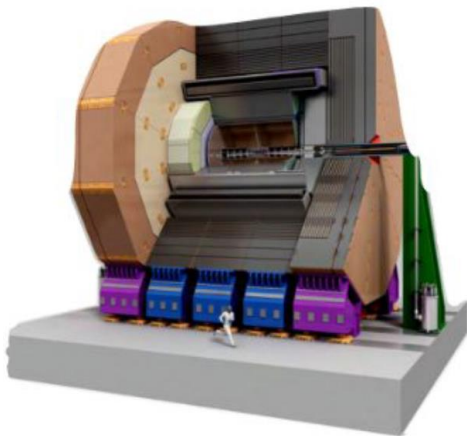
IDEA



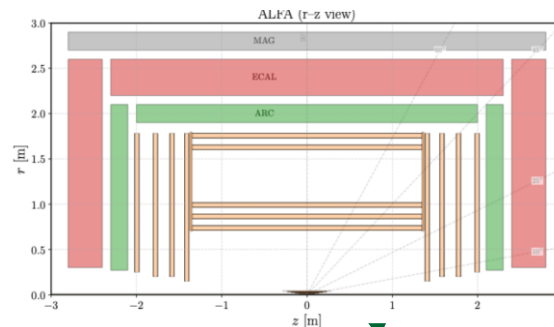
ALLEGRO



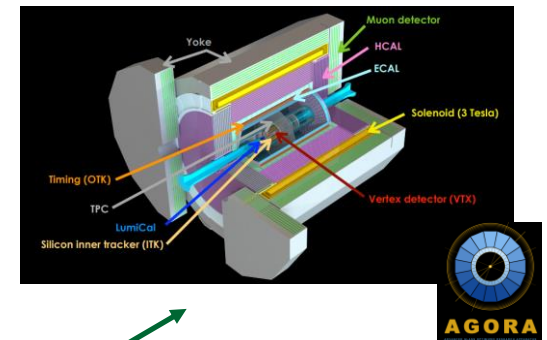
ILD (being ported from ILC)



ALFA



AGORA (being ported from CEPC)



New additions

Not yet collaborations ! These will only form after project approval.

Detector concepts: distinguishing features

	Tracker	PID	ECAL
CLD [FCC week link]	Si based (precise technology under review)	Option for RICH ('ARC')	Silicon tungsten
IDEA [FCC week link]	Drift chamber, plus Si wrapper	dE/dx, dN/dx, plus TOF	Crystal dual readout
ALLEGRO [FCC week link]	Drift chamber or straw tube or SciFi, plus Si wrapper	dE/dx, dN/dx (if available), plus TOF	Noble-liquid
ILD [FCC week link]	TPC	dE/dx, dN/dx, possibly plus TOF	Silicon tungsten
ALFA [FCC week link]	MAPS	RICH ('ARC')	GRAiNITA (novel crystal-based), better than 2%/sqrt(E) + 1%
AGORA [FCC week link]	TPC (for now)	dE/dx, dN/dx Possible forward RICH	BGO crystal 2%/sqrt(E) + 1%

Vertex Detectors

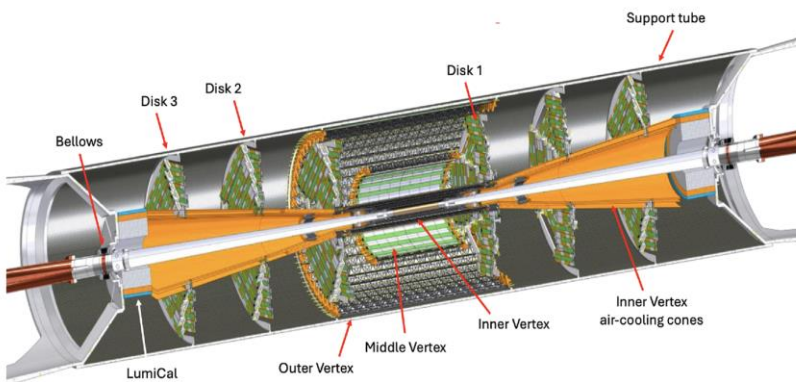
Vertex detector developments highly inspired by ALICE ITS2 and ITS3 designs

- All based on thinned and stitched MAPS
- Ultra-low material, micron precision, low power, efficient cooling, lightweight mechanics, all $\sim 1\text{cm}$ from IP

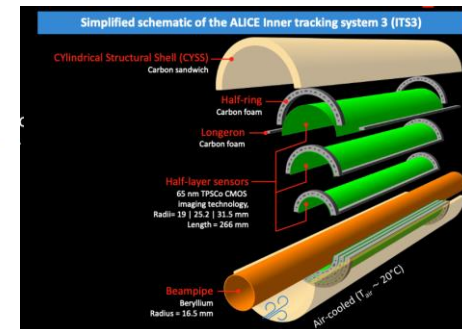
[Workshop, Oct. 2025]

IDEA Vertex Detector (INFN Pisa, Frascati)

- Fully integrated in MDI design
- All sensors are $50\text{ }\mu\text{m}$ MAPS
- Three inner barrel layers:
 $25 \times 25\text{ }\mu\text{m}^2$, 50 mW/cm^2 , air cooling
- Middle + outer layers: $150 \times 50\text{ }\mu\text{m}^2$, water cooled
- Three disks both forward and backward
- Hit resolution: $\sim 3\text{ }\mu\text{m}$; material: $2.5\% X_0$ at 90°

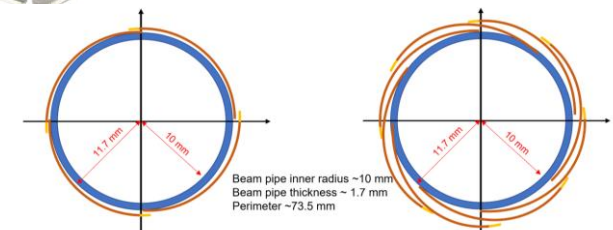


FCC-SEED: curved sensors wrapping around beam pipe (French institutes)



12-mm curvature reached

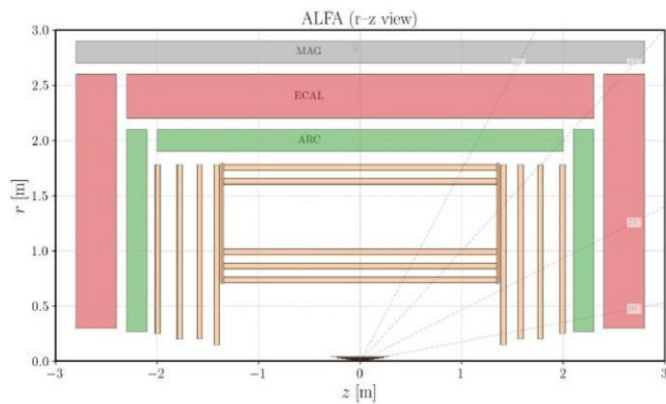
FCC-SEED



Central Trackers

[Sign up for workshop: [CERN,16-20 Nov](#)]

Tracking is one of the places where the relevant design space remains widest.

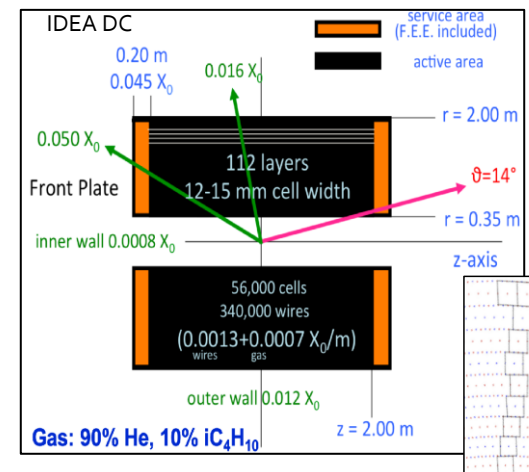


Full silicon tracker

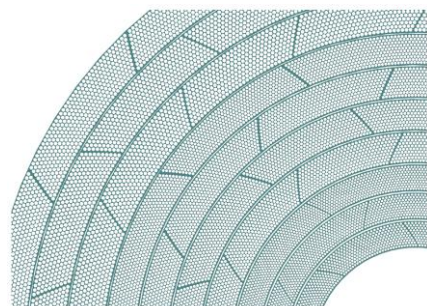
- CLD
- ALFA

Drift Chamber

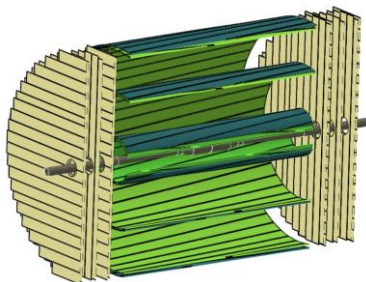
- IDEA
- ALLEGRO



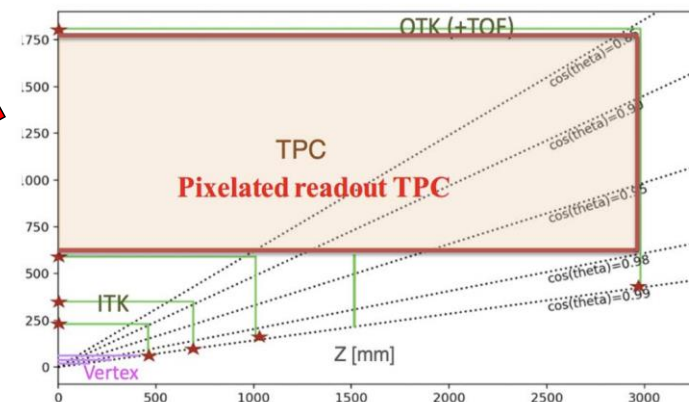
Straw Tracker (ALLEGRO ?)
Robust alternative to DCH?



Time Projection Chamber
- ILD and AGORA



Scintillating Fibre (SciFi) Tracker
- studied for ALLEGRO



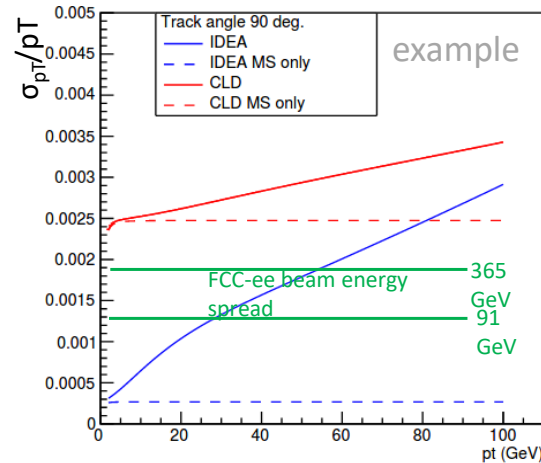
Central Trackers: gaseous or Si ?

[Sign up for workshop: [CERN,16-20 Nov](#)]

At FCC-ee energies, momentum resolution in the CLD Si Tracker limited by multiple scattering.

$$\sigma(p_T)/p_T^2 = a \oplus \frac{b}{p \sin \theta}$$

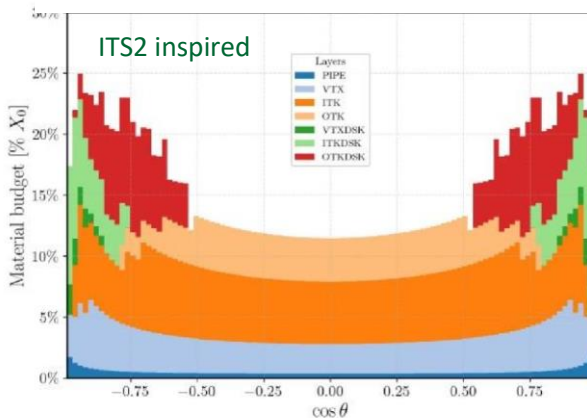
$\downarrow$ mult.scat
 $\downarrow$ point resolution



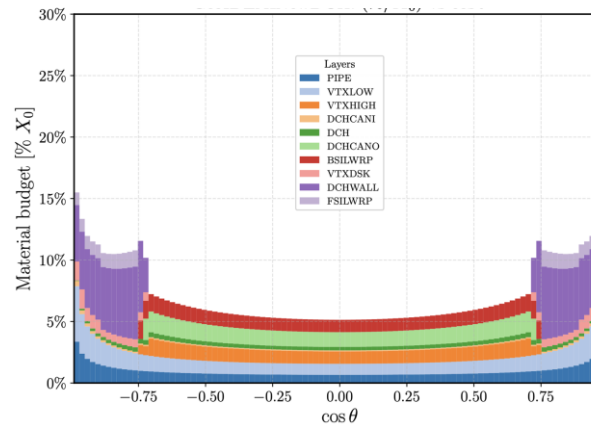
There used to be a strong case for gaseous trackers.

ALFA all-MAPS tracker has a competitive material budget !

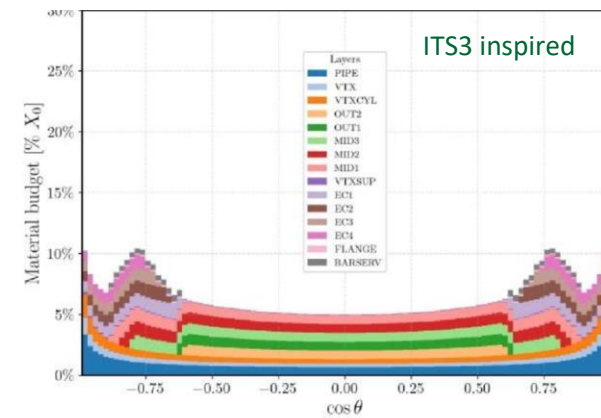
CLD Si pixels + strips



IDEA Drift Chamber + Si



ALFA full Si MAPS



Calorimetry

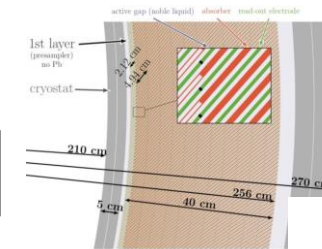
All concepts aim at Particle Flow reconstruction

- with different emphasis on granularity, energy resolution, stability
- R&D activities concentrated within DRD6 (DRDcalo)

Noble Liquid ECAL + Tile HCAL:

- fine longitudinal sampling (w.r.t. ATLAS, 4 → 12 layers)
- Pb+LAr or denser W+LKr; cold (or warm) electronics
- CALICE or ATLAS style scintillating tile HCAL

$$\begin{aligned}\text{EM: } \sigma(E)/E &\simeq 8\text{-}10\%/\sqrt{E} \\ \text{Jet: } \sigma(E)/E &\simeq 4\% \text{ @ } 50 \text{ GeV}\end{aligned}$$

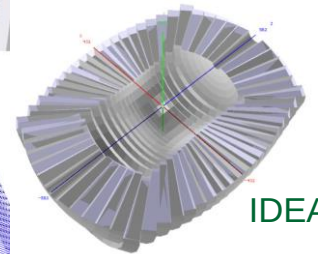


Allegro

Fibre-based Dual Readout :

- copper or steel matrix; Cherenkov and scintillating fibres, SiPMs
- very fine transverse granularity, (some) longitudinal inf. via timing

$$\begin{aligned}\text{EM: } \sigma(E)/E &\simeq 11\%/\sqrt{E} \\ \text{Jet: } \sigma(E)/E &\simeq 3\text{-}4\% \text{ @ } 50 \text{ GeV}\end{aligned}$$

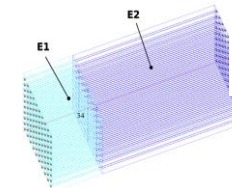


IDEA

Segmented crystals with Dual Readout:

- Fine transverse segmentation, two longitudinal layers; SiPMs
- Excellent EM energy resolution of $\sim 3\%/\sqrt{E}$
- Combined with fibre-based DR calorimeter as HCAL

$$\begin{aligned}\text{EM: } \sigma(E)/E &\simeq 3\%/\sqrt{E} \\ \text{Jet: } \sigma(E)/E &\simeq 3\text{-}4\% \text{ @ } 50 \text{ GeV}\end{aligned}$$

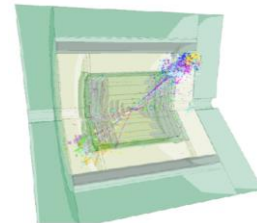


CLD,ILD

CALICE-style sandwich with embedded front-end electronics:

- Tungsten-silicon ECAL; extremely fine segmentation: $(0.5 \text{ cm})^3$
- Steel-scintillator HCAL; SiPM-on-Tile; fine segmentation: $(2.5 \text{ cm})^3$

$$\begin{aligned}\text{EM: } \sigma(E)/E &\simeq 16\%/\sqrt{E} \\ \text{Jet: } \sigma(E)/E &\simeq 3\text{-}4\% \text{ @ } 50 \text{ GeV}\end{aligned}$$

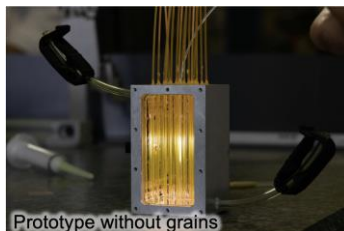
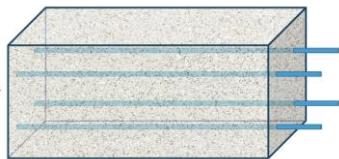


Calorimetry – new additions

ALFA: Grainita ECAL concept

- 1mm crystal grains (ZnWO_4) immersed in heavy liquid (sodium-tungstate-water solution) or resin
- Emitted light collected by WLS fibres

.....
Incoming particle

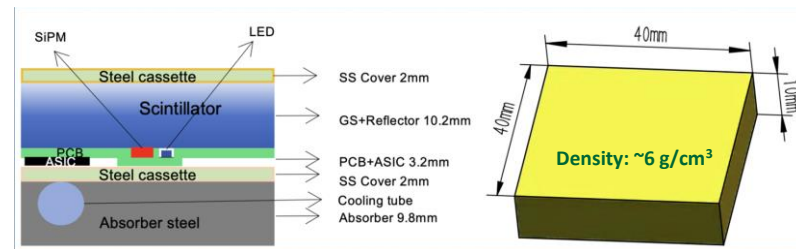


- Excellent energy resolution
- High transverse granularity
- Cost-effective compared to homogenous crystals
- First (small) prototype: $28 \times 28 \times 55 \text{ mm}^3$

ALFA: Dual-Readout Tile HCAL ?

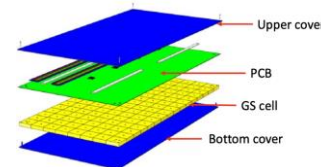
- For example, CALICE-style Steel / Quartz / Scintillator Tile HCAL
- Also to function as a yoke
- To be studied as an extension of AHCAL (DRD6) ?

AGORA: Glass Scintillator HCAL

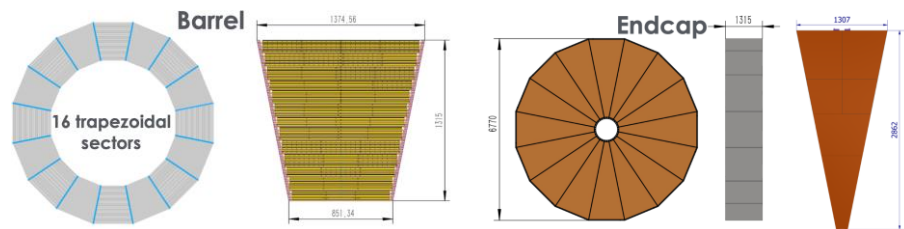


Single layer structure

- Total of 85 m^3 glass scintillator
- High sampling fraction ($\sim 30\%$)
- Resolution of $\sim 30\%/\sqrt{E}$



48 layers stacked per module



Charged-particle identification

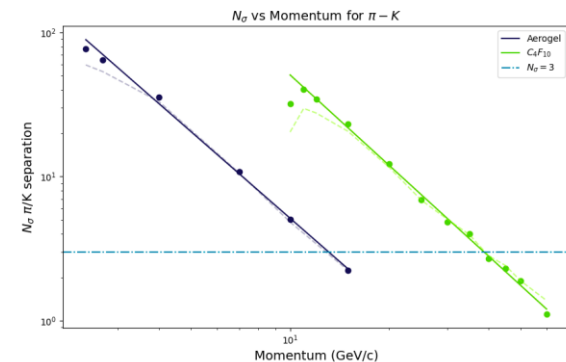
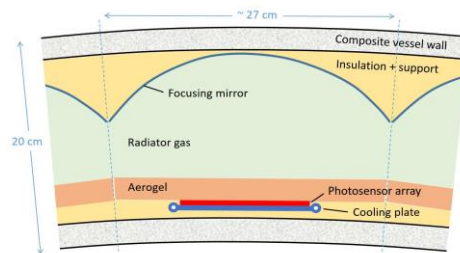
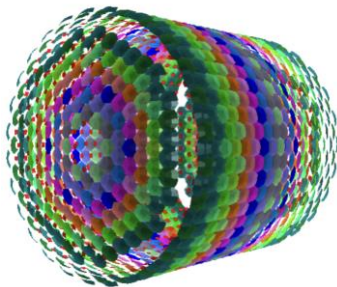
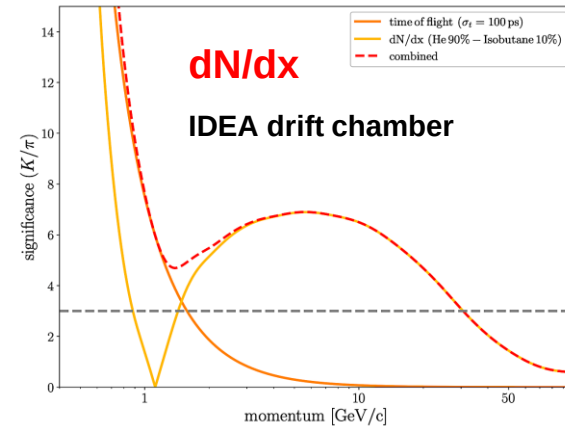
[Sign up for
workshop:
CERN, 16-20 Nov]

Essential for flavour physics, over a wide momentum range (up to 50 GeV).
Useful also for flavour-tagging jets in Higgs, W and top physics.

With gaseous tracking chamber, dE/dx ,
or even better dN/dx (cluster counting).

Complemented by TOF at low momentum,
provided by e.g. LGADs in Si wrapper.

With Si tracker, there needs to be a
dedicated PID detector, preferably RICH to cover full momentum range, e.g. ARC.



The path towards Collaboration formation

From the 'FCC Objectives, Deliverables, Milestones' Council Document:

These 6(+) EoIs can already be prepared during the RDP, so they can be made public very soon after project approval.

These activities are aimed at demonstrating feasibility, integration compatibility and cost realism for the FCC-ee detectors, without committing to a final detector selection or to experiment collaborations forming. Expressions of interest for FCC-ee detectors will be invited after the project approval, with a view to moving towards detector conceptual design reports by 2033.

It is suggested (by PED [see [P. Janot article in 17th ECFA newsletter](#)]) that a process begin immediately after project approval (assumed 2028) to enable community-wide discussion and synthesis of best elements of existing proposals towards four robust LoIs, and collaborations to form by early 2030.

ECFA could facilitate this process through arranging series of 'Evian-like' workshops (recall [Evian Meeting of 1992](#), two years before LHC approval, which considered 12 LHC EoIs and cleared the way to the final configuration).

Everyone is encouraged to widen their engagement with FCC Detector Concepts so that they can play a central role in these discussions !

Concluding message

DG message from plenary ECF, July 2026 [\[link\]](#):

FCC
needs
you !



FCC-ee

The next two years will be critical to our success

- **FCC-ee** is the clear best option for the future of CERN and for global particle physics
- the outcome of the **European Strategy Update** is crystal clear
- At CERN, we will do everything possible to ensure the realisation of FCC-ee

At this time, it is important that the whole community gets behind our collective goal to secure FCC-ee as CERN's next flagship collider

The RDP is a critical period for the FCC, laying both the foundations for project approval and for the future direction of the project.

Much to be done in Physics, Experiments and Detectors. All welcome !

Backups

FCC Week 2027

Next FCC collaboration meeting will be the FCC Week 2027 in Madrid, this year including an integrated FCC Physics Workshop (previously a separate event).

Entire community invited and welcome !



Practical information

E-groups that all can sign up for. The clickable links here will not work, but they will on the version of this list uploaded to indico page of meeting.

  = send an email to the full e-group
 = link to an open e-group  = link to a closed/cumulative e-group
 = send an email to the coordinators/conveners

- > **FCC-PED-Physics**  
 - FCC-PED-PhysicsCoordinationGroup  
 - FCC-PED-PhysicsGroup-BSM  
 - FCC-PED-PhysicsGroup-EWPrecision  
 - FCC-PED-PhysicsGroup-Flavours  
 - FCC-PED-PhysicsGroup-Flavours-Coordination  
 - FCC-PED-PhysicsGroup-Flavours-CPC  
 - FCC-PED-PhysicsGroup-Flavours-CharM  
 - FCC-PED-PhysicsGroup-Flavours-CPV  
 - FCC-PED-PhysicsGroup-Flavours-Rare  
 - FCC-PED-PhysicsGroup-Flavours-TauEW  
 - FCC-PED-PhysicsGroup-GlobalFits  
 - FCC-PED-PhysicsGroup-hh  
 - FCC-PED-PhysicsGroup-Higgs  
 - FCC-PED-PhysicsGroup-HighLevelReco  
 - FCC-PED-PhysicsGroup-MCgenerators  
 - FCC-PED-PhysicsGroup-PrecisionCalculations  
 - FCC-PED-PhysicsGroup-QCD  
 - FCC-PED-PhysicsGroup-Top  
- > **FCC-PED-SoftwareAndComputing**  
 - FCC-PED-SoftwareAndComputing-Coordination  
 - FCC-PED-SoftwareAndComputing-Analysis  
 - FCC-PED-SoftwareAndComputing-Core  

FCC-PED
  

- FCC-PED-SoftwareAndComputing-DB  
- FCC-PED-SoftwareAndComputing-DigiReco  
- FCC-PED-SoftwareAndComputing-Dokumentation  
- FCC-PED-SoftwareAndComputing-Full-Simulation  
- FCC-PED-SoftwareAndComputing-Generators  
- FCC-PED-SoftwareAndComputing-LEPdata  
- FCC-PED-SoftwareAndComputing-MCproduction  
- FCC-PED-SoftwareAndComputing-Resource  
- FCC-PED-SoftwareAndComputing-MDI  
- > **FCC-PED-DetectorConcepts**  
 - FCC-PED-DetectorConcepts-Coordination  
 - FCC-PED-DetectorConcepts-Calorimetry  
 - FCC-PED-DetectorConcepts-Luminometry  
 - FCC-PED-DetectorConcepts-Magnet  
 - FCC-PED-DetectorConcepts-Muon  
 - FCC-PED-DetectorConcepts-TDAQ  
 - FCC-PED-DetectorConcepts-Tracker  
 - FCC-PED-DetectorConcepts-ALFA  
 - FCC-PED-DetectorConcepts-ALLEGRO  
 - FCC-PED-DetectorConcepts-CLD  
 - FCC-PED-DetectorConcepts-IDEA  
 - FCC-PED-DetectorConcepts-ILD  
- > **FCC-ee-MDI**  
- > **FCC-ee-PolarizationAndEnergyCalibration**  
- > **FCC-PED-ECOI**  
- > **FCC-International-Forum-National-Contacts**  
- > **FCC-PED-CoordinationGroup**  
- > **FCC-PhysicsAndExperiments-SteeringGroup**  
- > **FCC-PED-SpeakersBuro**  
- > **FCC-PED-EditorialBoard**  

List of regular meetings on indico: <https://indico.cern.ch/category/5251/>

Where are we now ?

The concept of FCC-ee, and its precursors, dates back to 2011. Since then successive studies have taken place, investigating all aspects of the project: physics, accelerator, civil engineering and infrastructure, environmental impact...

Last year saw the culmination of a 4.5 year full scale Feasibility Study:

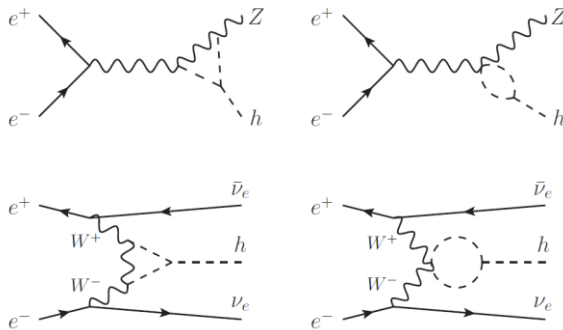


The Feasibility Study Report (FSR) and accompanying documents was a critical input to the European Strategy for Particle Physics Update (ESPPU).

Higgs self-coupling at HL-LHC and FCC-ee

FCC-ee cannot reach energies of di-Higgs production, which are usually thought necessary to learn about self-coupling (often expressed through κ_λ parameter), which is undoubtedly a topic of interest. Is this a concern ?

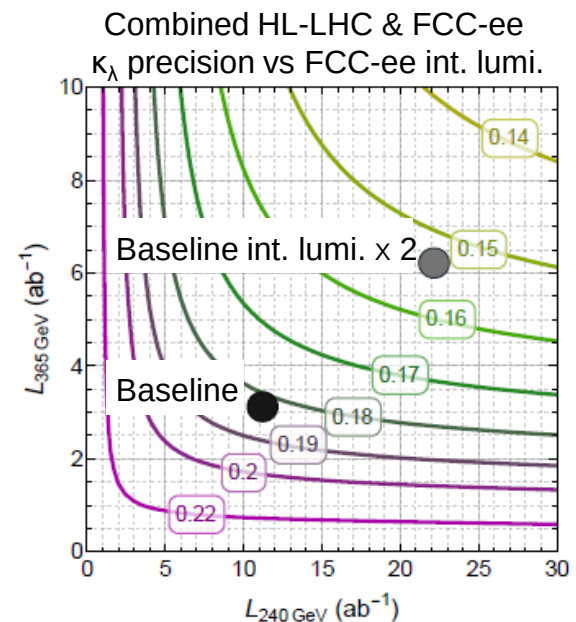
- We will learn something about κ_λ from HL-LHC. New estimates $\sim 25\%$ precision.
- FCC-ee *does* have sensitivity to κ_λ , through loops, so complementary to on-shell approach.



Measure cross-sections precisely at 240 GeV and 365 GeV [M. McCullough, PRD 90 (2014) 015001].

Standalone precision of 28%, becomes 18% when combined with HL-LHC. If thought necessary, can improve by more running time, or more bunches.

- Interestingly, NP can impact the HL-LHC & FCC-ee determinations differently [Asteriadis *et al.*, PRL 133 (2024) 231801, JHEP 02 (2025) 162] – an intriguing possibility !



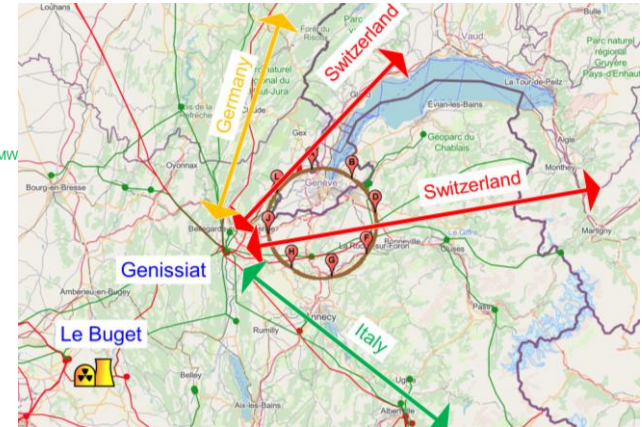
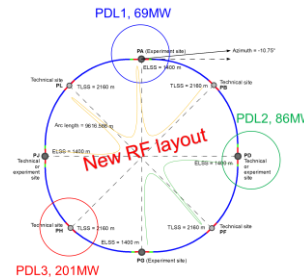
Resource needs & connections to regional infrastructure

Electricity consumption 1.1 – 1.8 TWh/year

Three supply points:

- Two new substations from existing HV grid;
- Reuse of present CERN station;

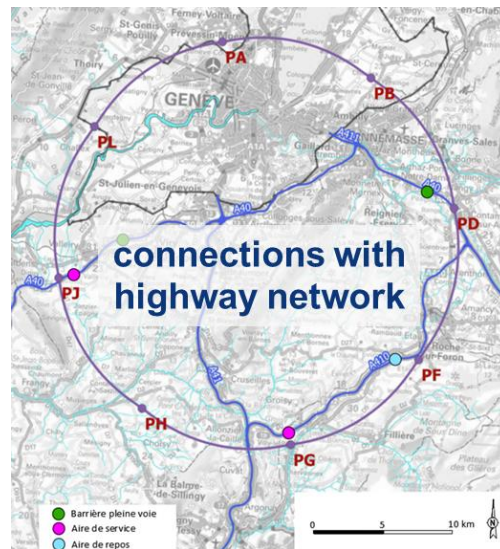
Feasibility confirmed with RTE (FR operator).



Road access
developed for all
8 surface sites.

Four possible
highway connections
defined.

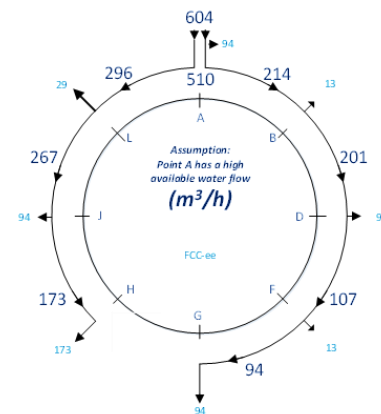
Less than 4 km of
new roads required.



Raw water need:
1-3 million m³ year;

Water supply from Lac
Leman via existing SIG
supply to CERN;

Distribution via tunnel.



PED objectives during the RDP

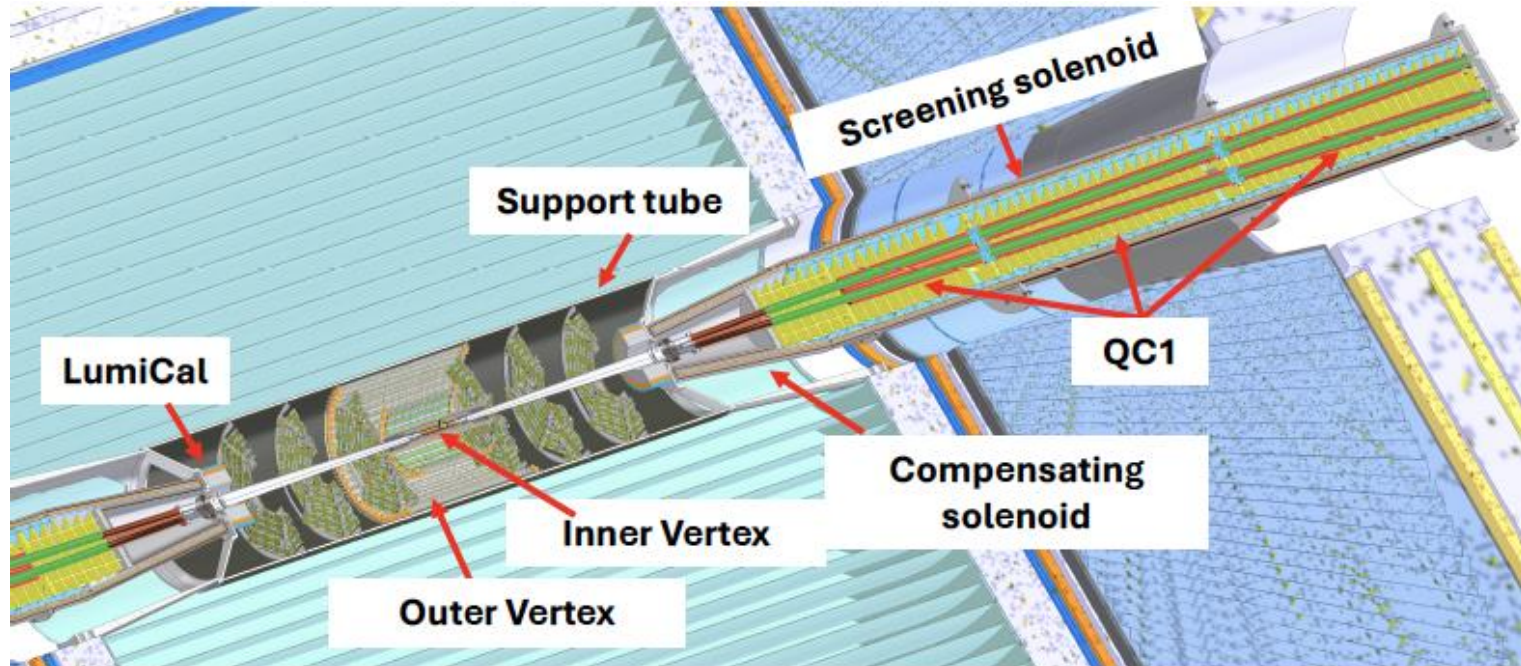
The following is the list of key PED objectives during RDP:

- Continuation of the development of specific conceptual detector designs with the international HEP community;
- Consolidation of IP region layouts & detector integration;
- Background mitigation strategies & machine-detector interface (MDI) optimisation;
- Development of a common computing architecture model & finalisation of a common software/analysis framework;
- Realistic implementation of some of the algorithms needed to confirm the experimental systematic uncertainties on EW precision observables;
- Coordination of the theory community to address the corresponding theory challenges for the FCC-ee;
- Assessment of the physics case, feasibility, and schedule implications for different centre-of-mass energy stages;
- Streamlining & optimisation of the procedures for centre-of-mass energy calibration & for possible monochromatic operation at 125 GeV to explore the electron Yukawa coupling;
- Proposal for staging implementation & improvements of the (staged/descoped) FCC-ee.

Machine detector interface

Common activity – not specific to a particular Detector Concept !

FCC-ee interaction region is a highly complex and crowded environment, whose optimisation demands very close cooperation between physicists & machine.



Key
topics:

- Design and implementation of lumi cal & vertex detector.
- Beam pipe design, including cooling.
- Optimisation of collimators, masks and shielding.
- Evaluation of all sources of machine background.
- Detector opening strategy and impact on cavern dimensions.

Experimental road map towards FCC
Guy Wilkinson

PED objectives during the RDP

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Computing and s/w

Common activity – not specific to a particular Detector Concept !

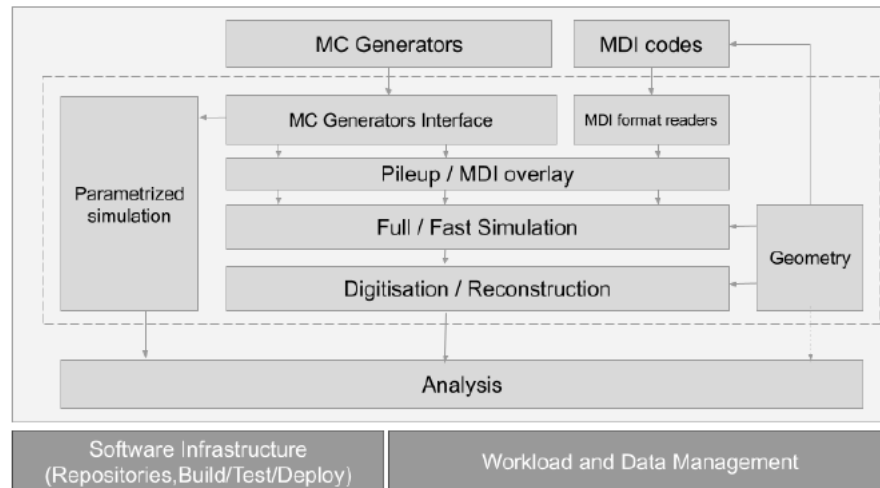
Ever since launch of Conceptual Design Study (2014), the driving goal has been the development of unified, synergistic, and adaptable s/w ‘ecosystem’.

This will continue into operation phase (shared environment for all expts !).

Common s/w framework (KEY4HEP) and data format (EDM4HEP).

Many workflows to be supported.

Help very welcome !



[The FCC software for PED studies]

Bulk of physics studies conducted so far have been based on DELPHES-level parametrised MC, but G4 simulation for all detectors now being implemented.

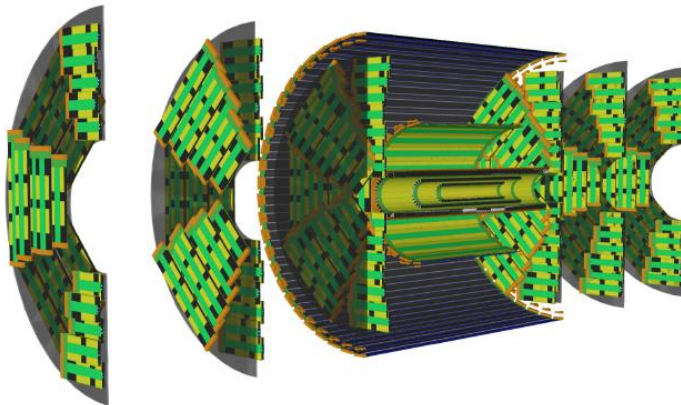
Computing and s/w

Common activity – not specific to a particular Detector Concept !

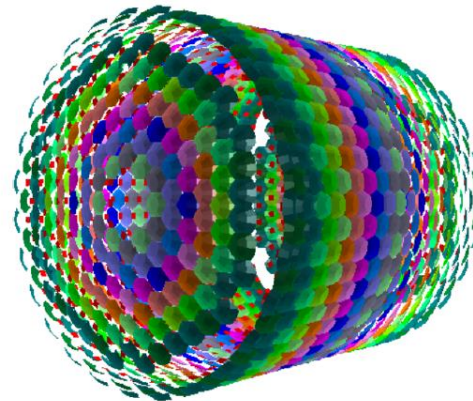
Ever since launch of Conceptual Design Study (2014), the driving goal has been the development of unified, synergistic, and adaptable s/w 'ecosystem'. This will continue into operation phase (shared environment for all expts !).

Progress on detailed detector descriptions

Vertex detector



RICH (ARC concept)



Bulk of physics studies conducted so far have been based on DELPHES-level parametrised MC, but G4 simulation for all detectors now being implemented.

PED objectives during the RDP

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- Proposal for staging implementation & improvements of the (staged/descoped) FCC-ee.

Daunting challenge posed by huge sample sizes for EWPO

Electroweak precision observables

Observable	present value	±	uncertainty	FCC-ee Stat.	FCC-ee Syst.	Comment and leading uncertainty
m_Z (keV)	91 187 600	±	2000	4	100	From Z line shape scan Beam energy calibration
Γ_Z (keV)	2 495 500	±	2300	4	12	From Z line shape scan Beam energy calibration
$\sin^2 \theta_W^{\text{eff}} (\times 10^6)$	231,480	±	160	1.2	1.2	From $A_{\text{FB}}^{\mu\mu}$ at Z peak Beam energy calibration
$1/\alpha_{\text{QED}}(m_Z^2) (\times 10^3)$	128 952	±	14	3.9 0.8	small tbc	From $A_{\text{FB}}^{\mu\mu}$ off peak From $A_{\text{FB}}^{\mu\mu}$ on peak QED&EW uncert. dominate
$R_\ell^Z (\times 10^3)$	20 767	±	25	0.05	0.05	Ratio of hadrons to leptons Acceptance for leptons
$\alpha_S(m_Z^2) (\times 10^4)$	1 196	±	30	0.1	1	Combined R_ℓ^Z , Γ_{tot}^Z , σ_{had}^0 fit
$\sigma_{\text{had}}^0 (\times 10^3)$ (nb)	41 480.2	±	32.5	0.03	0.8	Peak hadronic cross section Luminosity measurement
$N_\nu (\times 10^3)$	2 996.3	±	7.4	0.09	0.12	Z peak cross sections Luminosity measurement
$R_b (\times 10^6)$	216 290	±	660	0.25	0.3	Ratio of $b\bar{b}$ to hadrons
$A_{\text{FB}}^{b,0} (\times 10^4)$	992	±	16	0.04	0.04	b-quark asymmetry at Z pole From jet charge
$A_{\text{FB}}^{\text{pol},\tau} (\times 10^4)$	1 498	±	49	0.07	0.2	τ polarisation asymmetry τ decay physics
τ lifetime (fs)	290.3	±	0.5	0.001	0.005	ISR, τ mass
τ mass (MeV)	1 776.93	±	0.09	0.002	0.02	estimator bias, ISR, FSR
τ leptonic ($\mu\nu_\mu\nu_\tau$) BR (%)	17.38	±	0.04	0.00007	0.003	PID, π^0 efficiency
m_W (MeV)	80 360.2	±	9.9	0.18	0.16	From WW threshold scan Beam energy calibration
Γ_W (MeV)	2 085	±	42	0.27	0.2	From WW threshold scan Beam energy calibration
$\alpha_S(m_W^2) (\times 10^4)$	1 010	±	270	2	2	Combined R_ℓ^W , Γ_{tot}^W fit
$N_\nu (\times 10^3)$	2 920	±	50	0.5	small	Ratio of invis. to leptonic in radiative Z returns
m_{top} (MeV)	172 570	±	290	4.2	4.9	From $t\bar{t}$ threshold scan QCD uncert. dominate
Γ_{top} (MeV)	1 420	±	190	10	6	From $t\bar{t}$ threshold scan QCD uncert. dominate
$\lambda_{\text{top}}/\lambda_{\text{top}}^{\text{SM}}$	1.2	±	0.3	0.015	0.015	From $t\bar{t}$ threshold scan QCD uncert. dominate
ttZ couplings		±	30%	0.5–1.5 %	small	From $\sqrt{s} = 365$ GeV run

Zoom-in on selected examples

	Current knowledge			FCC uncertainties	
				Stat	Syst
Γ_Z (keV)	2 495 500	±	2300	4	12
$\sin^2 \theta_W^{\text{eff}} (\times 10^6)$	231,480	±	160	1.2	1.2
$\alpha_S(m_Z^2) (\times 10^4)$	1 196	±	30	0.1	1
$\sigma_{\text{had}}^0 (\times 10^3)$ (nb)	41 480.2	±	32.5	0.03	0.8
$R_b (\times 10^6)$	216 290	±	660	0.25	0.3
$A_{\text{FB}}^{b,0} (\times 10^4)$	992	±	16	0.04	0.04

In some cases improvement from LEP is in excess of naïve expectation of factor ~600 through , e.g. R_b , ML-aided advances (e.g. in jet tagging), smaller beampipe etc. !

This must be done through data driven studies. RDP aims to see progress on this goal, and impact of realistic detector effects.

Theory must also rise to the challenge.

Theoretical challenges ahead

e.g. theoretical work needed to enable *extraction* of EWPO from measurements (additional work needed for making predictions)

Quantity	Current precision	FCC-ee stat. (syst.) precision	Required theory input	Theory status as of today	Needed theory improvement [†]
m_Z (MeV)	2.0	0.004 (0.1)	non-resonant $e^+e^- \rightarrow f\bar{f}$, initial-state radiation (ISR)	NLO, ISR logarithms up to 6 th order	NNLO for $e^+e^- \rightarrow f\bar{f}$
Γ_Z (MeV)	2.3	0.004 (0.012)			
$\sin^2 \theta_{\text{eff}}^\ell$	1.6×10^{-4}	$1.2 (1.2) \times 10^{-6}$			
m_W (MeV)	9.9	0.18 (0.16)	lineshape of $e^+e^- \rightarrow WW$ near threshold	NLO ($e^+e^- \rightarrow 4f$ or EFT framework)	NNLO for $e^+e^- \rightarrow WW$, $W \rightarrow f\bar{f}'$ in EFT setup
HZZ coupling	– *	0.1 %	cross section for $e^+e^- \rightarrow ZH$	NLO EW plus partial NNLO QCD/EW	full NNLO EW
m_{top} (MeV)	290	4.2 (4.9)	threshold scan $e^+e^- \rightarrow t\bar{t}$	N ³ LO QCD, NNLO EW, resummations up to NNLL, $\mathcal{O}(30 \text{ MeV})$ scale uncert.	Matching fixed orders with resummations, merging with MC, α_S (input)

[†] The necessary theory calculations mentioned are a minimum baseline; additional partial higher-order contributions may also be required.

* No absolute value for the HZZ coupling can be extracted from the LHC data without additional assumptions.

[from FSR and Freitas et al. [arXiv:1906.05379](https://arxiv.org/abs/1906.05379)]

Physics activities during the RDP

Physics structure reorganised for coming period:

- BSM
- EW
- FCC-hh
- Flavour
- Global fits and EFT
- Higgs
- Precision calculations
- QCD and $\gamma\gamma$
- Top

and, in common with s/w and computing:

- Analysis and visualisation
- MC generators
- High-level reconstruction

One important point of emphasis is to explore more deeply those areas where the potential is clear, but where studies are lagging behind those in areas such as Higgs and EW.

e.g. 'Flavours at FCC' – two-year workshop with bi-annual in-person events (Nov '25, June '26).



Watch out for workshops in other areas !

e.g. BSM: CERN, 23-25 Sept

FCC-hh: CERN, 22 Sept

PED objectives during the RDP

The following is the list of key PED objectives during RDP:

- Continuation of the development of specific conceptual detector designs with the international HEP community;
- Consolidation of IP region layouts & detector integration;
- Background mitigation strategies & machine-detector interface (MDI) optimisation;
- Development of a common computing architecture model & finalisation of a common software/analysis framework;
- Realistic implementation of some of the algorithms needed to confirm the experimental systematic uncertainties on EW precision observables;
- Coordination of the theory community to address the corresponding theory challenges for the FCC-ee;
- Assessment of the physics case, feasibility, and schedule implications for different centre-of-mass energy stages;
- Streamlining & optimisation of the procedures for centre-of-mass energy calibration & for possible monochromatic operation at 125 GeV to explore the electron Yukawa coupling;
- Proposal for staging implementation & improvements of the (staged/descoped) FCC-ee.

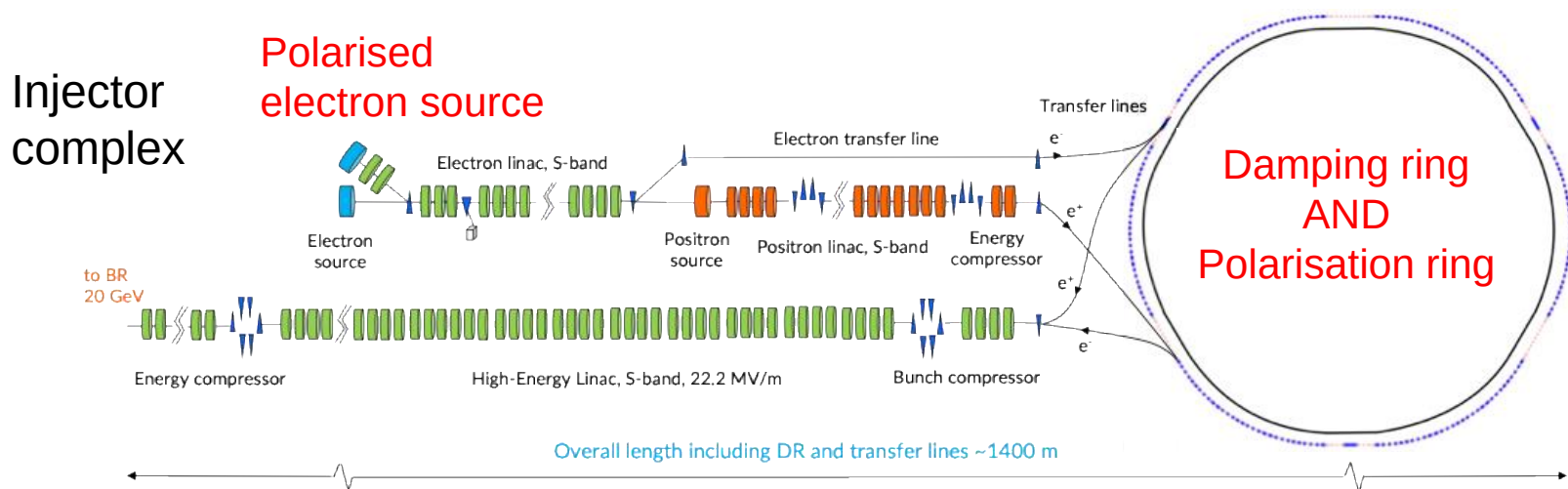
Important developments: feasibility studies for injection of polarised beams

Transversely polarisation of non-colliding pilot bunches needed for precise calibration of beam energy – vital for EW measurement programme at Z and WW.

Until now, baseline strategy for Z was to inject pilot bunches into collider at start of fill, and then spend up to two hours inducing polarisation with wiggler magnets.

→ Impossible to inject colliding bunches during this period – no physics data !

New scheme (not yet baseline, but very likely) – inject already polarised bunches.



Important consequence → increases availability by (at least) 10% ! More data.

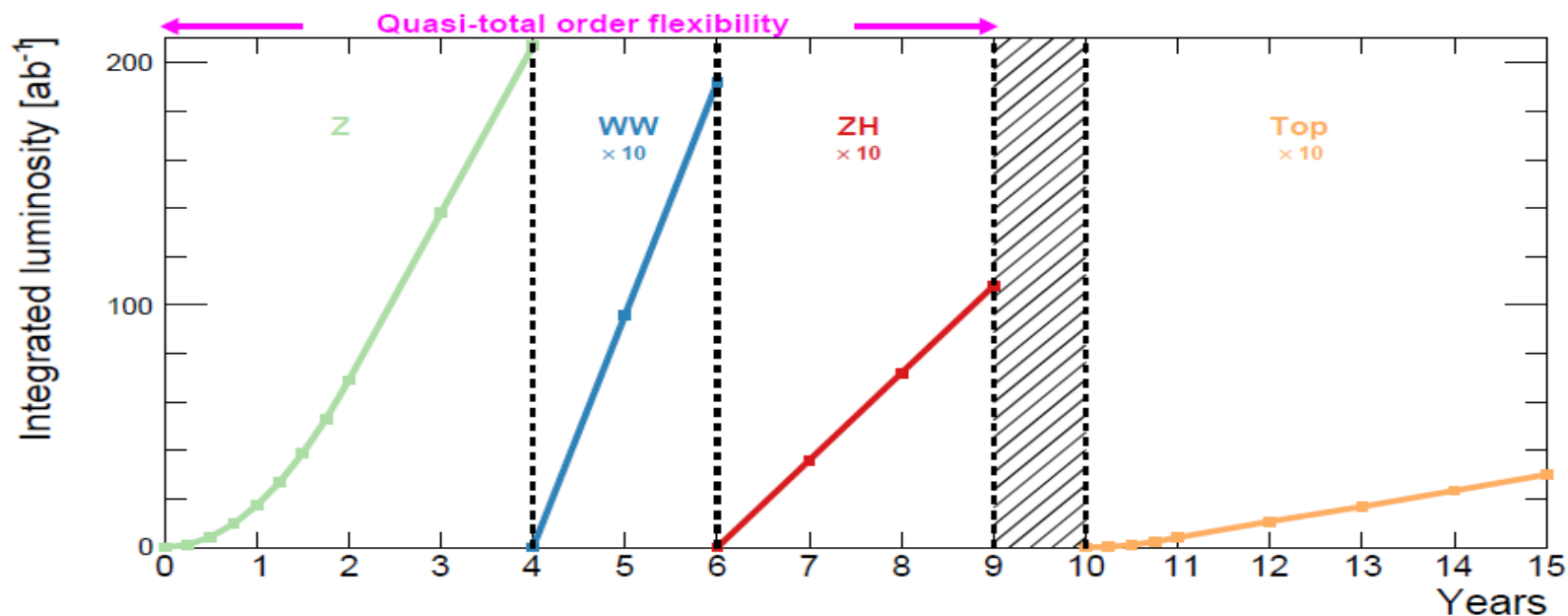
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Optimisation of running strategy

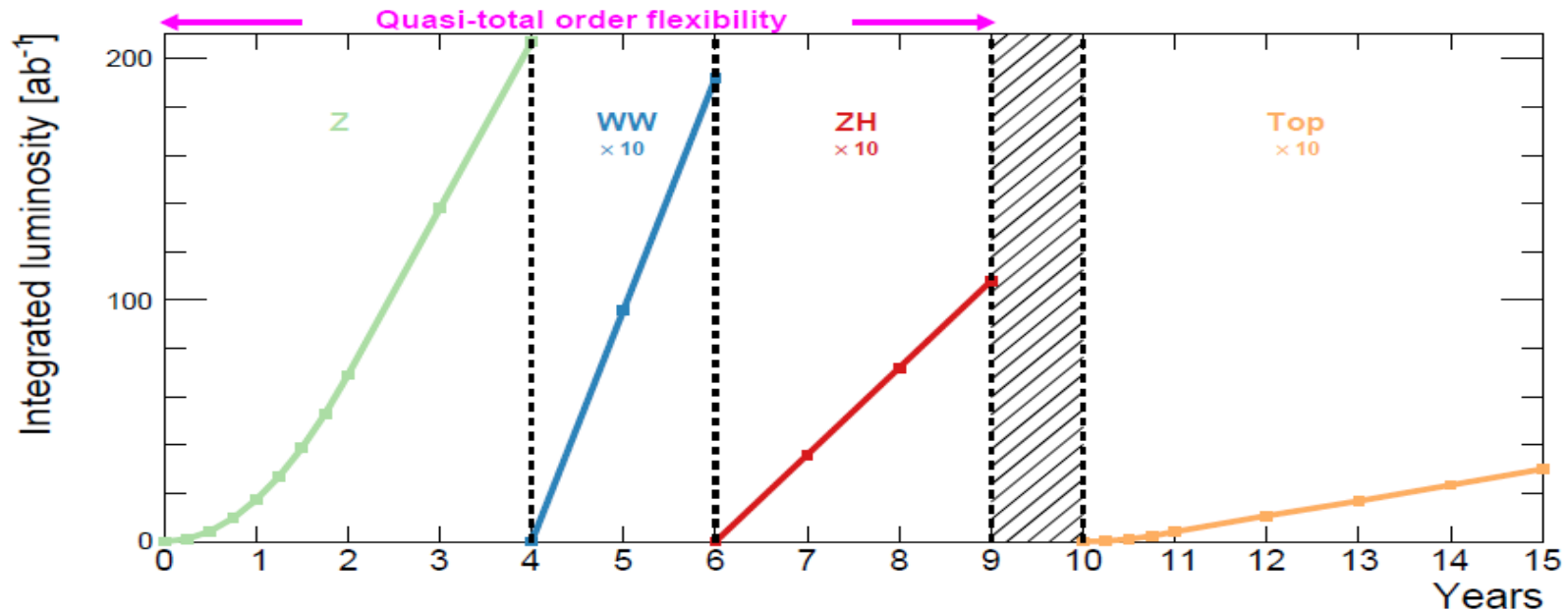
The current baseline plan, which (probably) will be that presented for approval:



Working point	Z pole	WW thresh.	ZH	$t\bar{t}$	
$\sqrt{s}$ (GeV)	88, 91, 94	157, 163	240	340–350	365
Lumi/IP ($10^{34} \text{ cm}^{-2} \text{ s}^{-1}$)	140	20	7.5	1.8	1.4
Lumi/year (ab^{-1})	68	9.6	3.6	0.83	0.67
Run time (year)	4	2	3	1	4
Integrated lumi. (ab^{-1})	205	19.2	10.8	0.42	2.70
Number of events	6×10^{12} Z	2.4×10^8 WW	2.2×10^6 ZH	2×10^6 $t\bar{t}$	
			+ 65k WW $\rightarrow$ H	+ 370k ZH + 92k WW $\rightarrow$ H	

Optimisation of running strategy

The current baseline plan, which (probably) will be that presented for approval:



However, this is not set in stone. Imaginative thinking about how this could be adjusted, or what additional running points could be added, are welcome !

In general, flexibility of operation means no decisions need to be taken now.

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Descoping, staging (and upscoping?)

Reminder:
EPPSU plan B

B. A descoped FCC-ee is the preferred alternative option for the next flagship collider at CERN.

Descoping scenarios include removing the top-quark run, constructing two rather than four interaction regions and experiments and decreasing the radiofrequency (RF) system power. These measures would reduce the construction cost by approximately 15%. Although this would have a significant impact on the breadth of the physics programme and the precision achieved, the descoped FCC-ee would still provide a very strong physics programme and a viable path towards high energies, compared to the alternative collider options. Should additional resources become available, these descoping scenarios would be reversible.

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Physics community needs to be vocal in what would be lost in a true descoping, and push instead that this option be recast as a staging scenario.

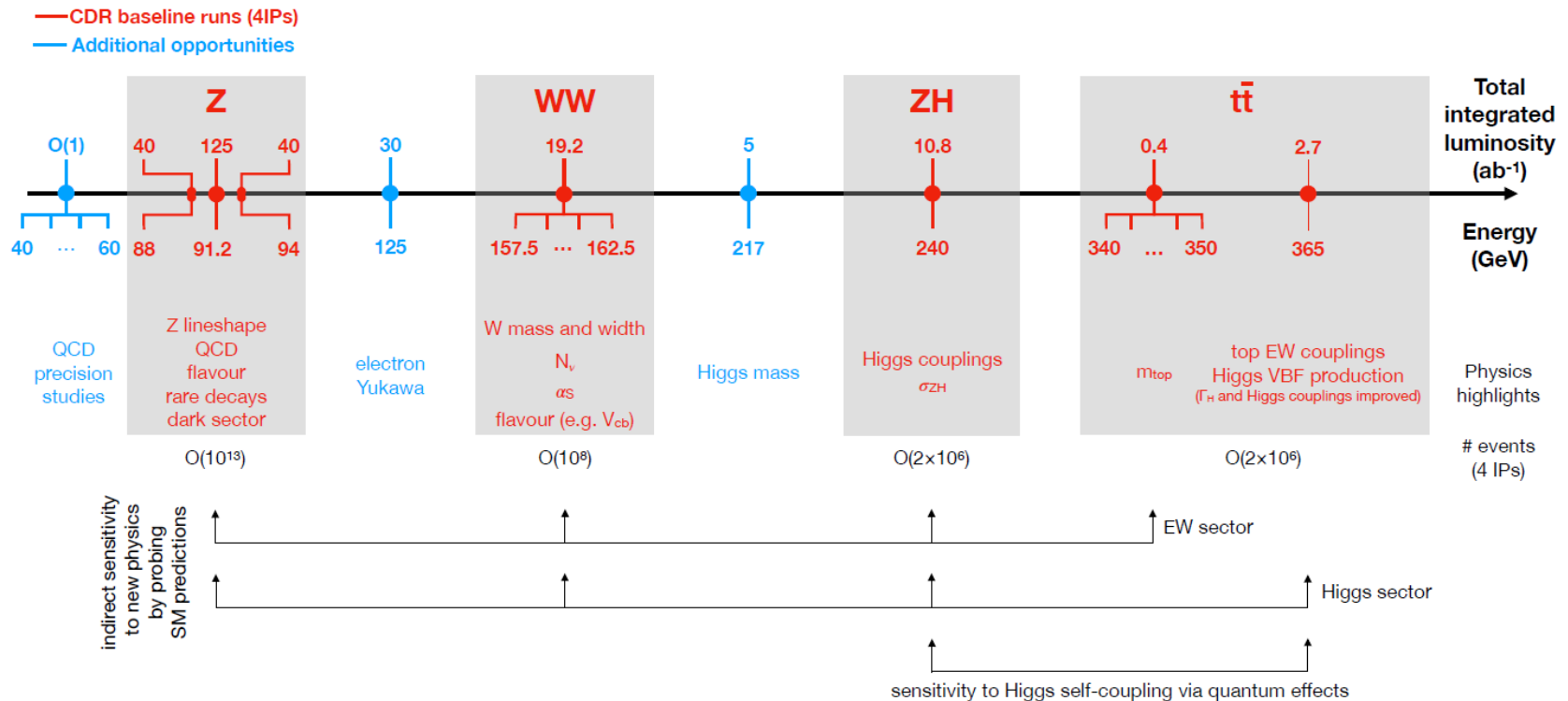
Recoverable descopes: lower RF power (probably reversible), deferred top run
Not recoverable, and a false economy: excavating only two experimental caverns

Meanwhile, recent and ongoing developments may already bring cost benefits

- Very recent adoption of new optics ('LCC' replacing 'GHC') means same luminosity with reduced beam power (OR 10% more lumi for same power);
- Possible further optimisation of RF system requiring fewer cavities & cryo modules, and the increased facilitation of in-kind contributions.

Other running points and dataset optimisation

The run schedule presented in FSR is not set in stone. Other energy points are under consideration, as is the optimisation of the relative sizes of datasets.



Currently under discussion: 40-60 GeV for QCD production studies, 125 GeV for a measurement of the electron Yukawa, and 217 GeV for a Higgs threshold m_H scan.

Optimisation of running strategy

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Baseline: about 40 ab^{-1} (one year each) above and below pole. Off-pole running clearly needed for Z width, but this requirement set by need to measure $\alpha_{\text{QED}}(m_Z^2)$ from QED-EW interference in $A_{\text{FB}}^{\mu\mu}$ at level needed for m_W - m_t closure test.

New strategies under study that only requires on-pole data [Riembau, [arXiv:2501.05508](https://arxiv.org/abs/2501.05508)].

Some measurements may be systematics limited with $6 \times 10^{12} \text{ Z}$ decays, but many will not be (e.g. in flavour physics or in searches for weakly-coupled particles).

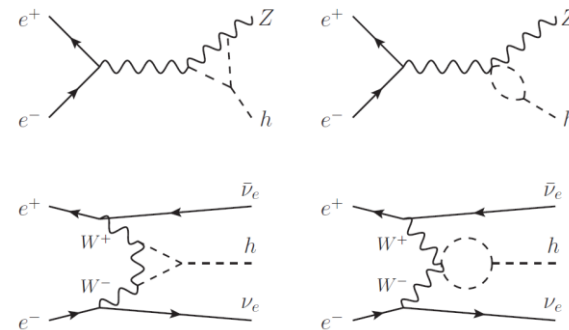
Possibly then an argument for more Z data - to be optimised. However, there is no rush to decide. Full flexibility exists in running strategy when below $t\bar{t}$ bar !

Optimisation of running strategy

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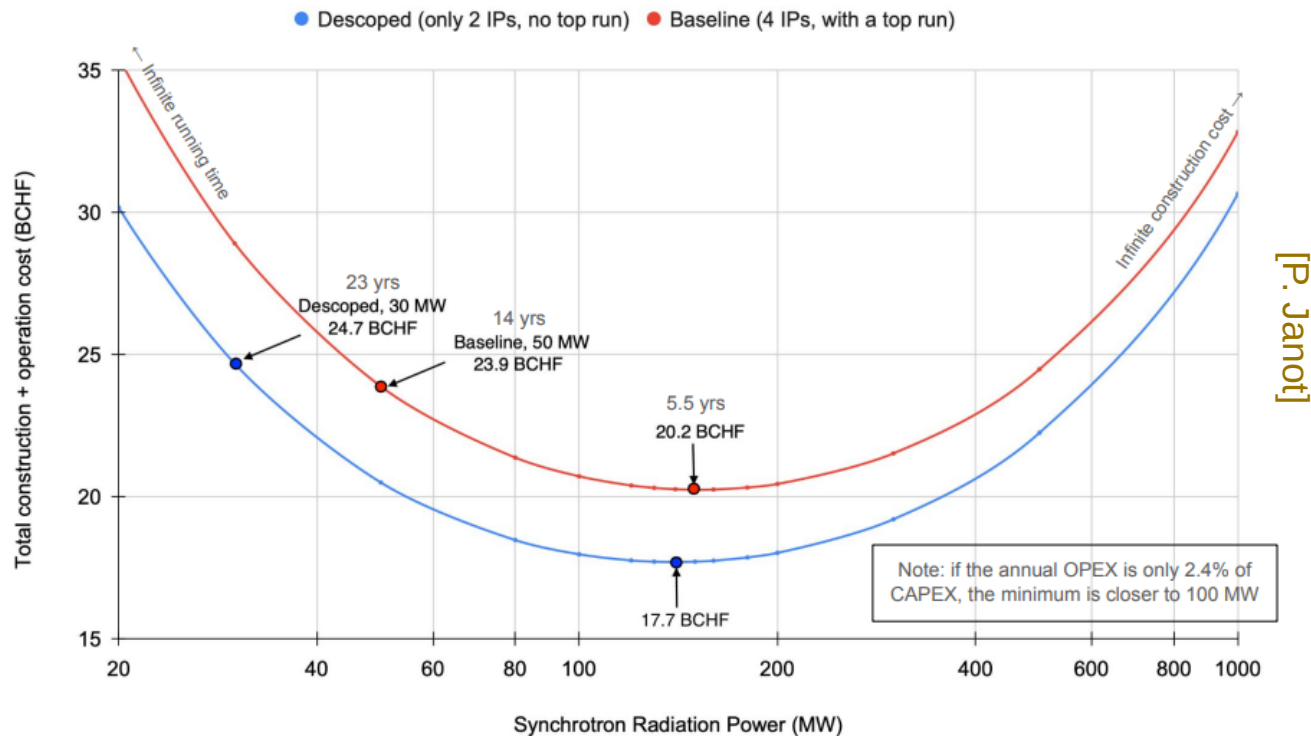
Other questions:

- Is there need for more data at WW threshold, for m_W and V_{CKM} studies ? (*i.e.* what are the ultimate systematic uncertainties on these measurements)
- Is the balance of the 340+ GeV samples correct ? Relevant for assessing indirect sensitivity to Higgs self-coupling, which comes from Higgs x-sec at different energies.



Descoping RF power – a false economy ?

For fixed physics output, it is cheaper (measured in construction + operation costs) to increase RF power rather than decrease it, as latter increases running time.



Of course, increased RF power has other consequences, e.g. detector backgrounds, so this should not be taken as a proposal, just an observation...