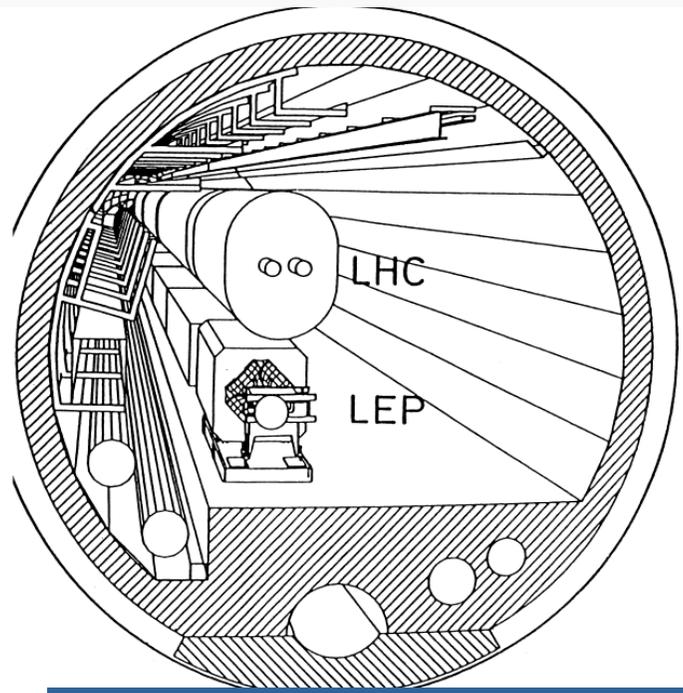


LEP3: Reusing the LEP/LHC Tunnel



T. Camporesi, January 14, IAS Fundamental Physics



Input to the European Strategy for Particle Physics - 2026 update

<https://arxiv.org/abs/2504.00541>



We think that a PLAN b (wrt to FCC ee) would need to be a project which can be built within acceptable financial constraints and still address the fundamental questions which had led to recommend a Higgs Factory as the ‘necessary ‘ next step...and a linear collider does not fit this definition (it is an alternative plan A)

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Recall Recommendations 2019 ESPP

- a. The successful completion of the HL-LHC
- b. Neutrino Platform
- c. An electron-positron Higgs factory is the highest-priority next collider.**
- d. R&D effort focused on advanced accelerator technologies, in particular that for high-field superconducting magnets, including high-temperature superconductors
- e. investigate the technical and financial feasibility of a future hadron collider at CERN with $\sqrt{s} \sim 100$ TeV and with an e^+e^- Higgs and electroweak factory as a possible first stage.**

Point e. clearly points to the FCC project, which has been extensively pursued.

We support FCC-ee and FCC-hh as the preferred option for CERN's future

LEP3 is not competitive with FCC-ee.

ESG Guidance

ESG's remit explicitly states that “The Strategy update should include the preferred option for the next collider at CERN and prioritised alternative options to be pursued if the chosen preferred plan turns out not to be feasible or competitive”.

A major objective in Particle Physics : always to operate an accelerator that allows a leap of a factor of 10 in the constituent centre-of-mass energy with respect to the previous one.
- Today the two possibilities being explored are the FCC-hh operating at $\sqrt{s} \sim 100$ TeV or a muon collider operating at $\sqrt{s} > 10$ TeV.

It is desirable that any back-up to FCC should present fewer technical and/or financial difficulties than those associated with the preferred option, as well as have good physics potential.

To minimise the possibility of such difficulties, the LEP3 strategy is to re-use, as much as possible, the existing infrastructure of CERN, utilise maximally the R&D already carried out for FCCee (needing the same R&D and hardware choices), and keep the required financing within the envelope of the current budget of CERN.

Several others have also discussed such a possibility in the past.

e.g. 2013 ESPP, a Higgs factory (LEP3) was proposed but not pursued any further.

[<https://cds.cern.ch/record/1471486>].

LEP3: A High Luminosity e^+e^- Collider in the LHC Tunnel to Study the Higgs Boson

A.P. Blondel (Geneva U.), F. Zimmermann (CERN), M. Koratzinos (CERN), M. Zanetti (MIT) (May, 2012)

Contribution to: IPAC 2012

LEP3: A High Luminosity e^+e^- Collider to Study the Higgs Boson

A. Blondel (Geneva U.), M. Koratzinos, R.W. Assmann (CERN), A. Butterworth (CERN), P. Janot (CERN) et al.

(Aug, 2012)

e-Print: [1208.0504](https://arxiv.org/abs/1208.0504) [physics.acc-ph]

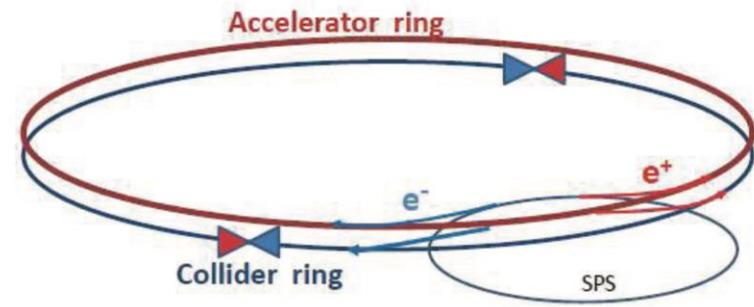
It is not the first time that re-use of the LHC tunnel is proposed

LEP3 installed in the existing LHC/LEP tunnel

Design of LEP3 could follow closely that outlined in FCC Medium Term Report (MTR) and [ESPP 2013: Zimmerman and Blondel (<https://cds.cern.ch/record/1471486>)].

- Separate full energy collider and accelerator (booster) rings, the latter for top-up injection. Electrons and positrons in the collider ring travel in separate beam pipes.
- With top-up - beam lifetime ~ 15 minutes (expected to be dominated by loss due radiative Bhabhas) top up $\sim \text{few } 10^{10}$ electron/s

Earlier work (2013)



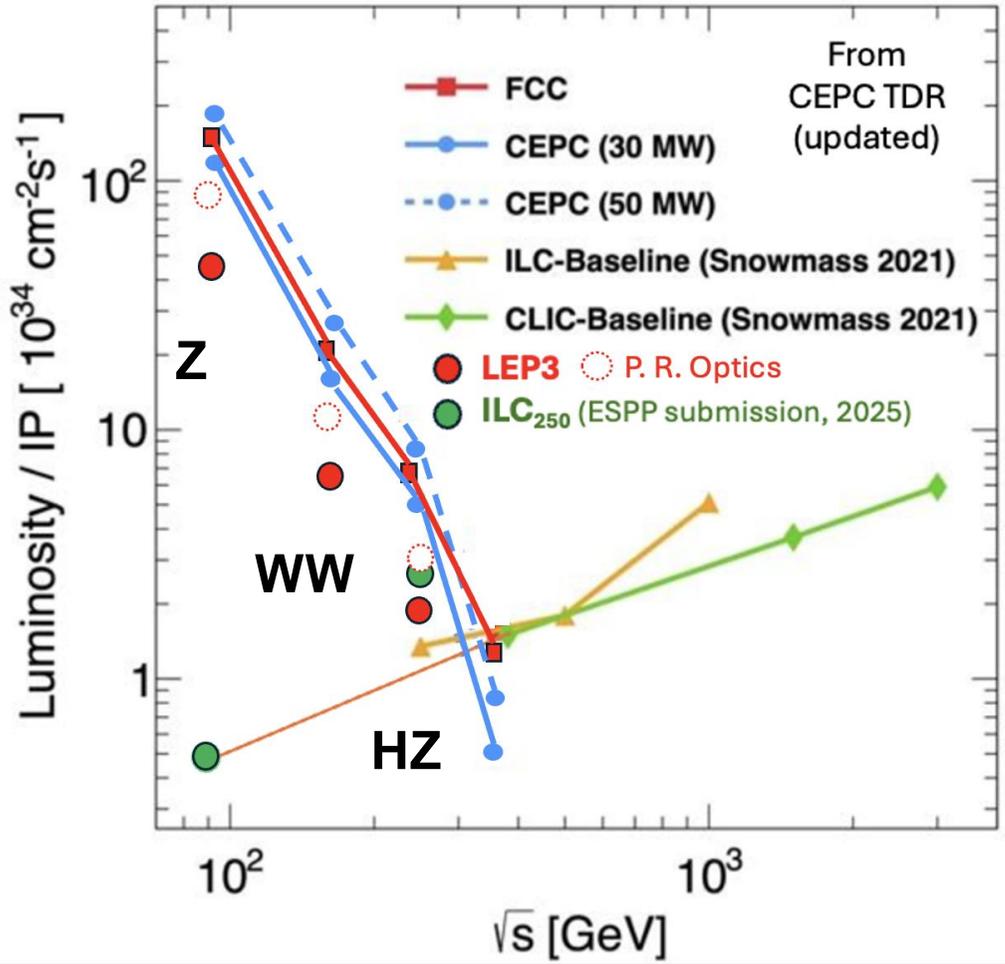
In our proposal

- Reuse substantial parts of ATLAS and CMS experiments
- TLEP(which became FCC later) /LEP3 luminosity ratio of ~ 5

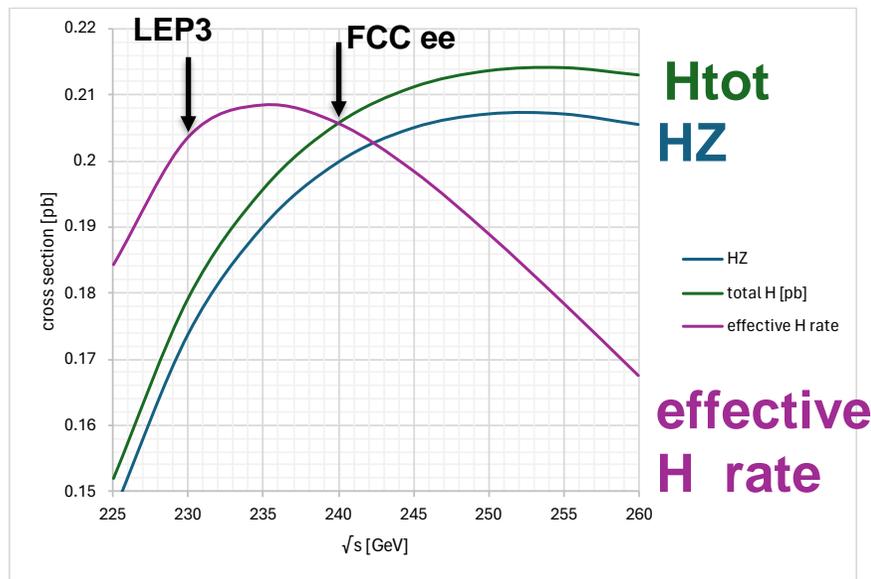
In this presentation, I will use the configuration presented in the note contributed to the ESPP meeting in Venice, in order to ensure coherence with the physics performance assessments discussed there.

As shown yesterday by Mike Koratzinos, recent work indicates substantial improvements in performance. This suggests that, should we wish to further pursue the exploration of reusing the LHC tunnel, additional effort will be required to fully exploit its potential. ..and we all know how to scale the statistical uncertainties accordingly.

Where technically relevant, I will highlight the impact of these recent developments.



In circular e⁺e⁻ colliders, for the same synchrotron power loss, at a lower energy, more current can be put to increase luminosity.



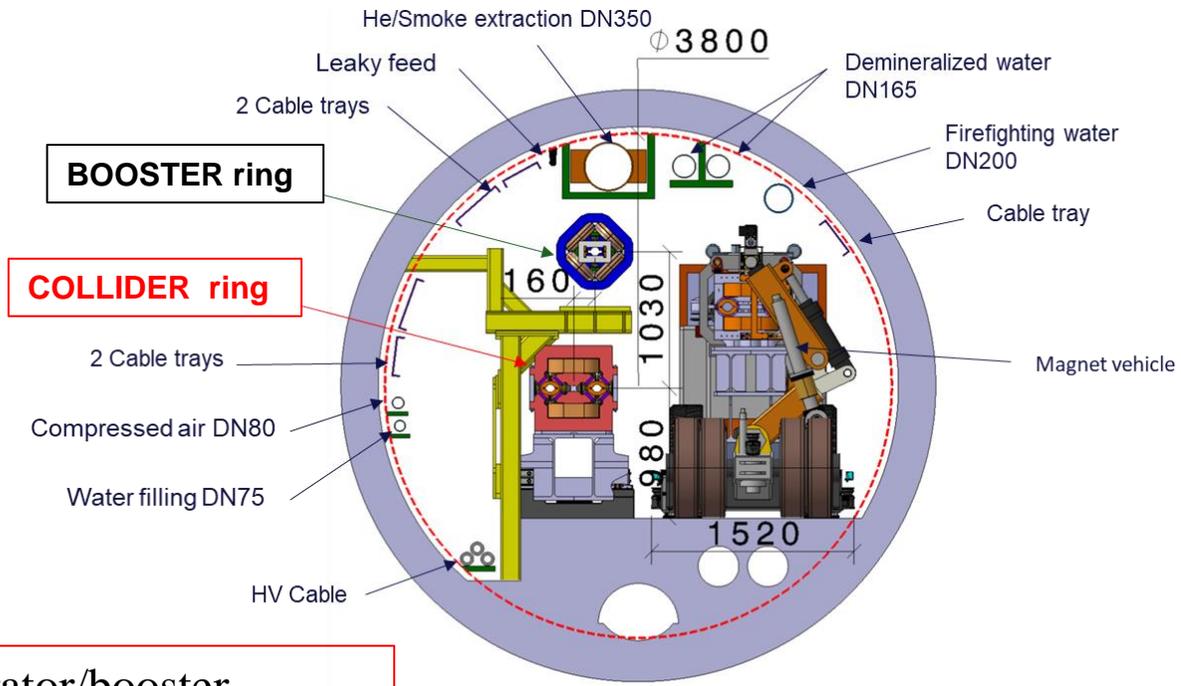
LEP3: Run at $\sqrt{s} = 230 \text{ GeV}$

- Only 10% higher energy than LEP.
- 18% lower synchrotron power loss at $\sqrt{s} = 230 \text{ GeV}$ compared with 240 GeV.

Integration in the tunnel



The LHC has eight arcs and eight long straight sections (LSS). The length of the arcs is ~ 2.45km, and the eight LSS are each~560m long. The inner diameter of the tunnel varies between 3.8m in the arcs and 4.4m in the straight sections (RF would have to be installed in straight sections) .



(courtesy F. Valchkova).

Integration of the accelerator/booster and the collider in the arcs.
 Note that the booster/accelerator ring is situated some 1 m above the collider ring.

LEP3 Parameters



	LEP3				LEP2
	2				4
No. of IPs/Xpts	2				4
com energy \sqrt{s} (GeV). For final state (X)	230 (ZH)	160 (WW)	91.2 (Z)		45.60
Circumference/Length [km]	26.659				26.659
Bending Radius (m)	2958				3026
Crossing Angle at IP [mrad]	30				0
SR Energy Loss/turn [GeV]	5.4	1.3	0.13		0.1
Total RF Voltage [GV]	6	1.5	0.5		0.2
SR Power /beam (MW)	50				0.33
Beam Current [mA]	9	39	371		3
Number of bunches/beam	20	220	800		8
Bunch Intensity (10E11)	2.5	1	2.6		1.8
RF frequency. [MHz]	800				352
Beam Lifetime (Bhabha+Brem) [min]	17	19	28		1390
Inst. Luminosity/IP [10^{34} cm ⁻² s ⁻¹]	1.6	6.2	40		0.002
Integrated L/IP [ab ⁻¹ /yr]	0.192	0.7	4.8		0.001
Effective Years of Operation	6	4	5.5		
rms bunch length (SR only). [mm]	2.4	2.5	1.4		2.3
rms bunch length (SR + BS). [mm]	2.6	2.9	9.4		2.3
horiz. Emittance ϵ_x . [nm]	3.8	1.8	0.6		45
vert. Emittance ϵ_y . [pm]	7.5	3	6.5		300
Longitudinal damping time [turns]	21	63	339		360
Horiz. $\beta^*(x)$ [m]	0.5	0.2	0.1		2
Vert. $\beta^*(y)$ [mm]	1	1	1		50
Horiz. rms IP spot [μ m]	44	19	8		300
Vert. rms IP spot size [nm]	87	55	81		3873
Horiz. beam-beam parameter	0.07	0.03	0.01		0.02
Vert. beam-beam parameter	0.1	0.11	0.11		0

The predicted lumi is scaled from the FCC present FODO optics

But optimized optics (see work by P. Raimondi presented in M. Koratzinos talk) indicate factor ~2 increase possible

ZH	WW	Z
3	11.4	92

LEP3 Principal Parameters Abstracted



No. of IPs	2	
Highest c.o.m. energy	230 GeV	
SR power loss	Fix at 50 MW (as for FCC ee)	This is a fundamental parameter
SR energy loss/turn	~ 5.4 GeV	
Total rf Voltage	~ 6 GV (800 MHz, 20MV/m SCRF cavities)	
Inst Luminosity	see previous slide	
Crossing angle	30 mrad	
Running Scenario	~ 20 years programme e.g. 6 yrs at 230 GeV, 4 years around WW, 5 years around Z	
Est. total no. of Events	4.7x10 ⁵ H, (cf. 6x10 ⁵ for ILC ₂₅₀ and 22 x10 ⁵ FCC-ee) 3.7x10 ⁷ WW at 163 GeV, 1.7x10 ¹² Z (cf. 0.001x10 ¹² for ILC ₂₅₀ and 6 x10 ¹² FCC-ee)	

LEP3 can be competitive with alternatives wrt Higgs and E-W physics

Running scenario: 6 years at 230 GeV, 4 years around WW, 5 years around Z

Why better than LEP ?



- LEP3 orders of magnitude increase of luminosity (at Z peak expect ~10000) are due to making it FCC –like
- synchrotron power loss that is increased from 0.315 MW to 50MW leading to an increase in the instantaneous luminosity of factor 160. (RF power is indeed a key cost item!)
 - LEP was limited in the number of bunches due to its single beam pipe
 - β_y^* is 1mm for LEP3 whilst it was ~40mm for LEP (this increases the instantaneous luminosity by a factor of ~ 40)
 - On the minus side: hourglass factor of 0.76 for LEP3 whilst it was 0.99 for LEP (decrease in instantaneous luminosity of a factor of 1.3)

Follow FCC(ee) design

Luminosity [CEPC or FCC(ee) / LEP3] ~ 5 ; FODO lattice $\sim 1.6 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ per IP

Low emittance lattice : $\sim 3 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ per IP

Use FCC designs for magnets

FCC Feasibility Study

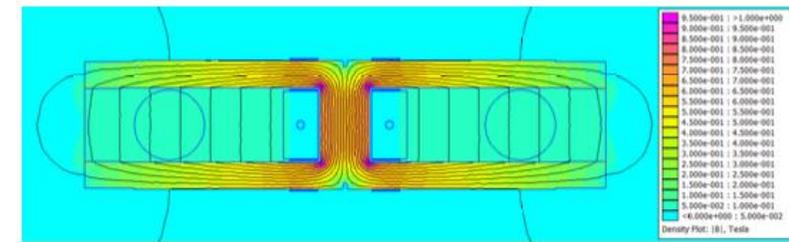
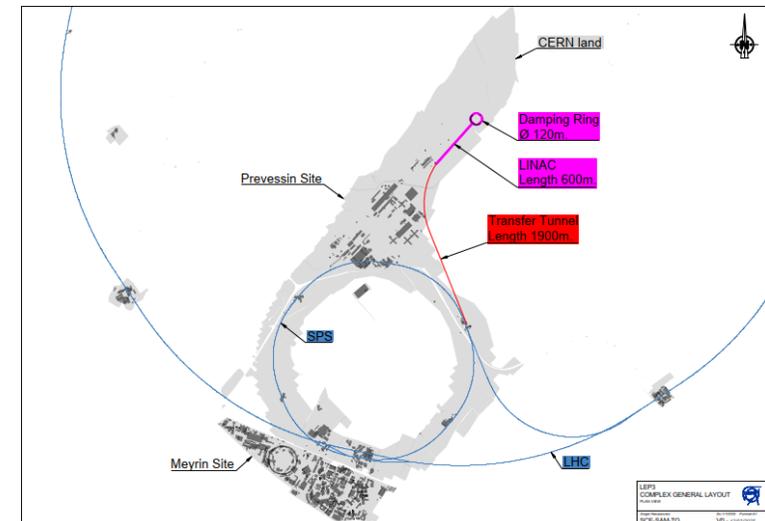


Fig. 3.1: Field map in the dipole cross-section

- **Dedicated linac injector** on Preveessin site;
- Injection energy optimized (lowered from 20 to 10 GeV)
(Sensitive to field quality of bending magnets at injection.) To be studied further



Choice of Components: RF System



RF: Energy loss/turn @ $\sqrt{s}=230$ GeV: 5.4 GeV.

A total 6.0 GV to be installed, with the same margin as FCCee

Running	Z	WW	ZH	Booster
Common RF for two beams	No	No	Yes	No
No. of Cryomodules	104	104	104	66
Frequency (MHz)	800	800	800	800
Cells/Cavity	1	4	4	6
Voltage/Cavity (MV)	2.4	14.4	14.4	22.7
Beam current (mA)	371	39	9	0.9
Power/cavity (kW)	240	240	240	20.1
Accelerating Gradient (MV/m)	12.9	19.3	19.3	20.3
Total Power Required (MW)	100	100	100	5.3
Total Required RF Voltage (MV)	1000	3000	6000	6000

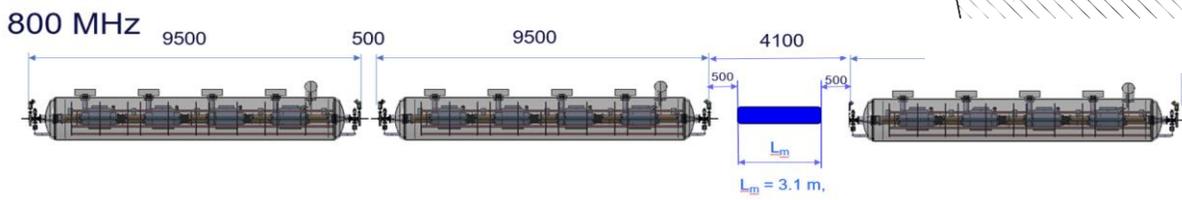
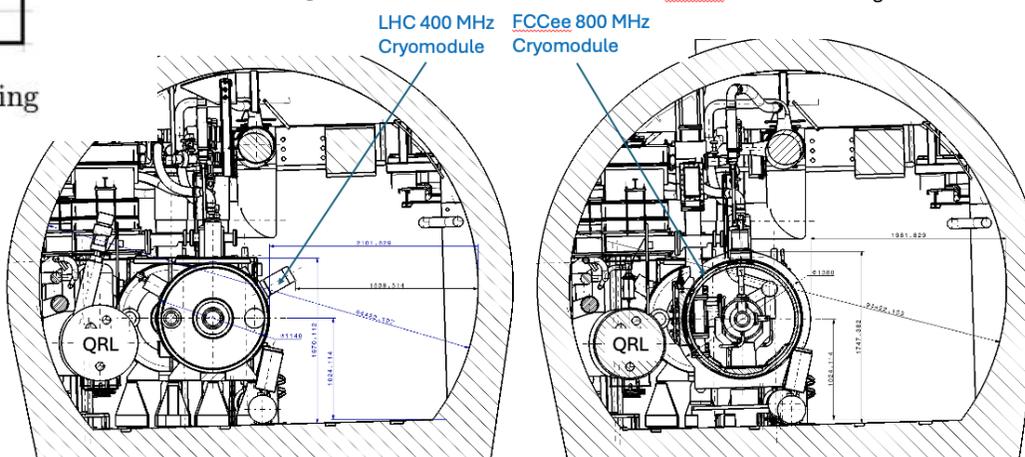
Possible optimization of power coupler to be studied

Table 2: Parameters for the RF system for Z, WW and ZH running



400 MHz CM integration Pt 4

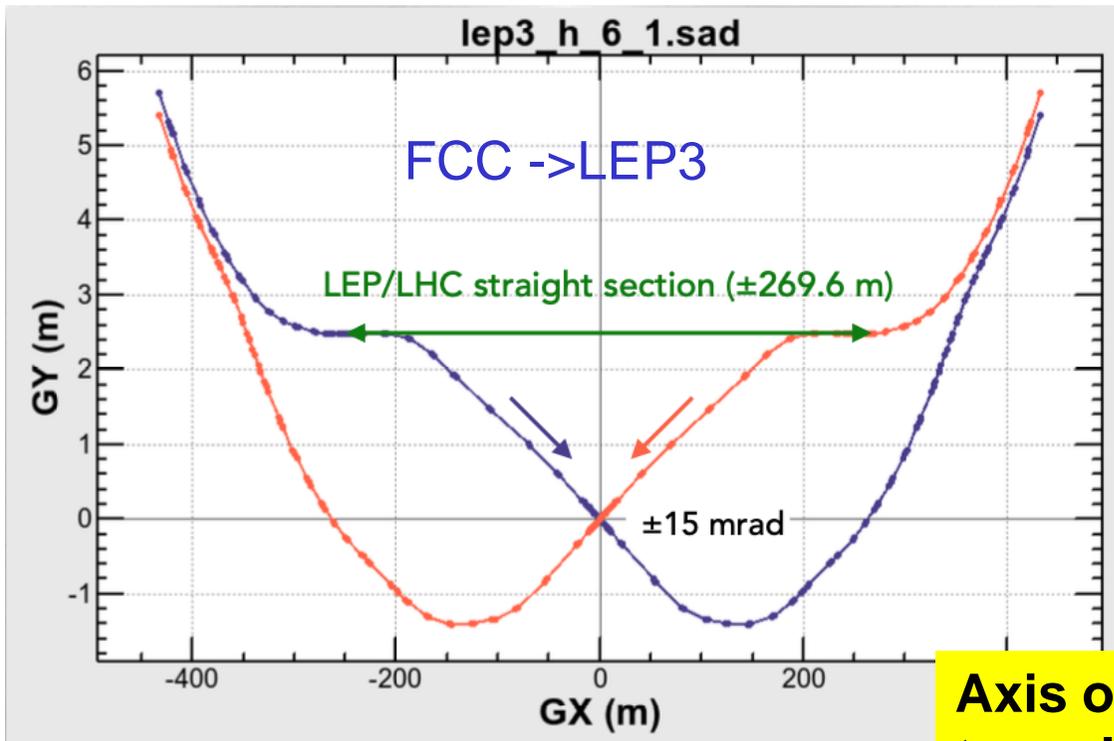
FCCee 800 MHz CM integration Pt 4



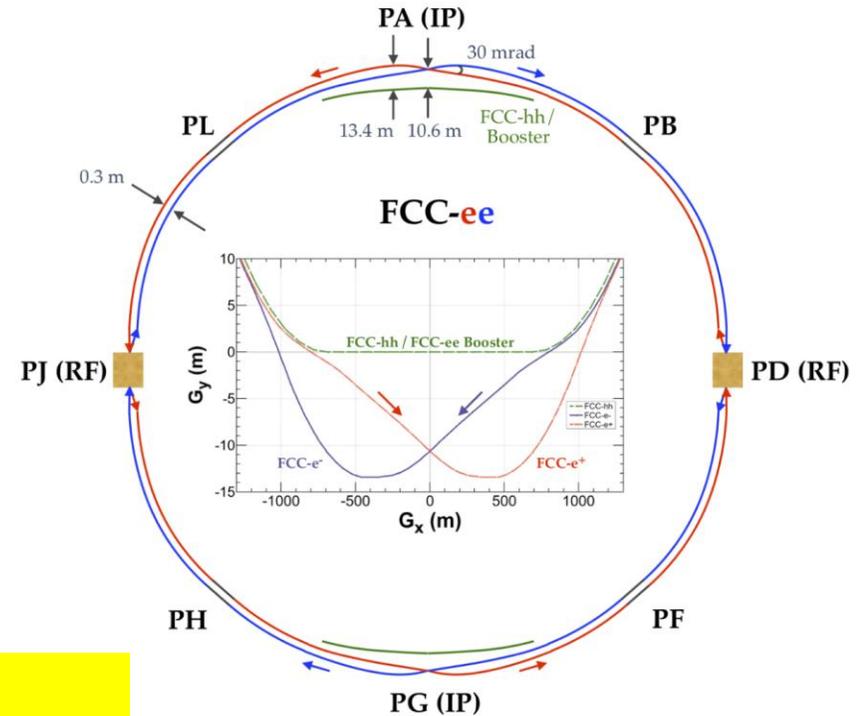
M. Timmins EN/MME - 28/03/2025

Crabbed waist optics = Large Crossing Angle

As for FCC have large crossing angle to have smaller β^* and lower vertical emittances

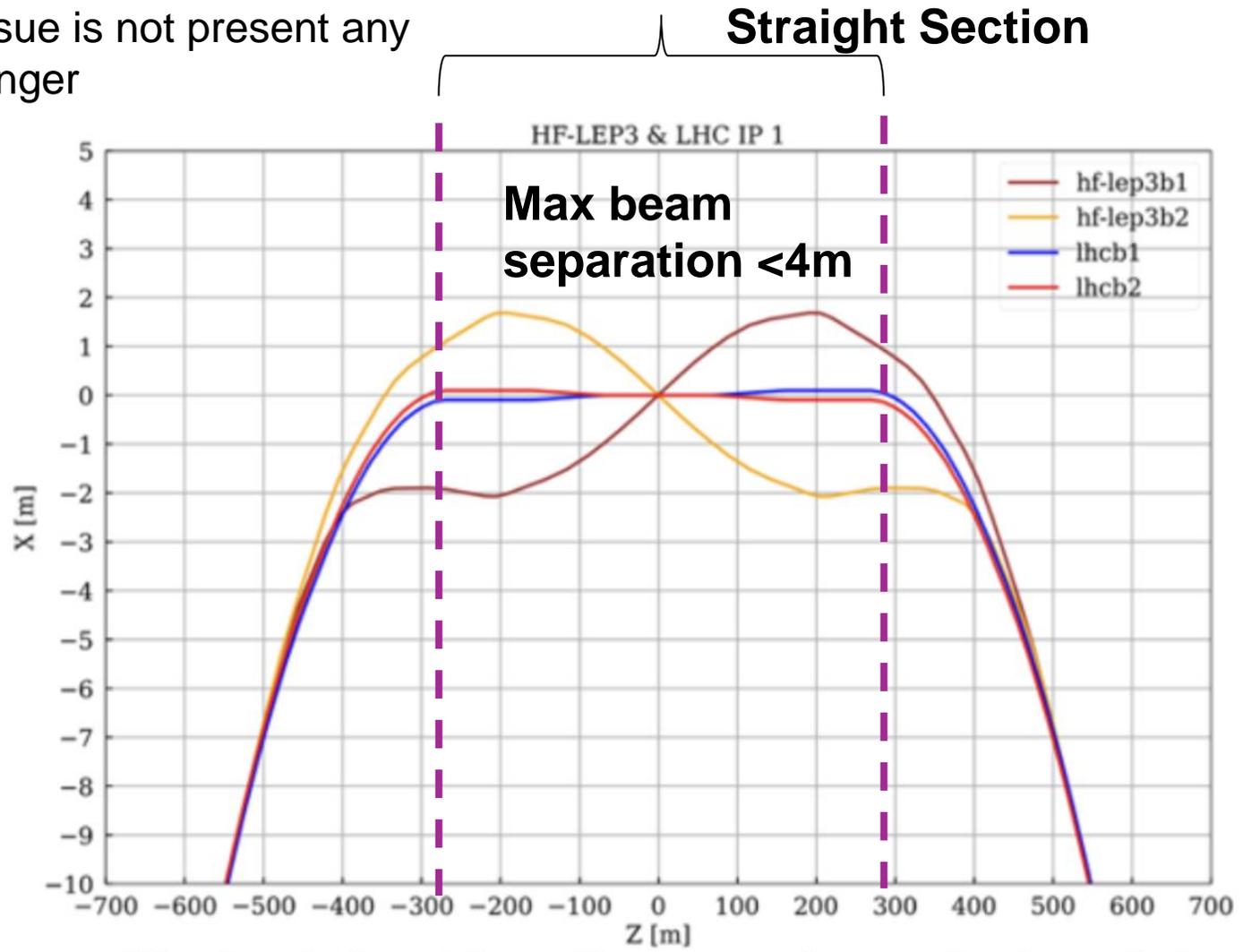


Axis of tunnel off by 2m wrt IP in FCC



FCC crossing angle 30 mrad

In new optics developed by Pantaleo Raimondi the issue is not present any longer

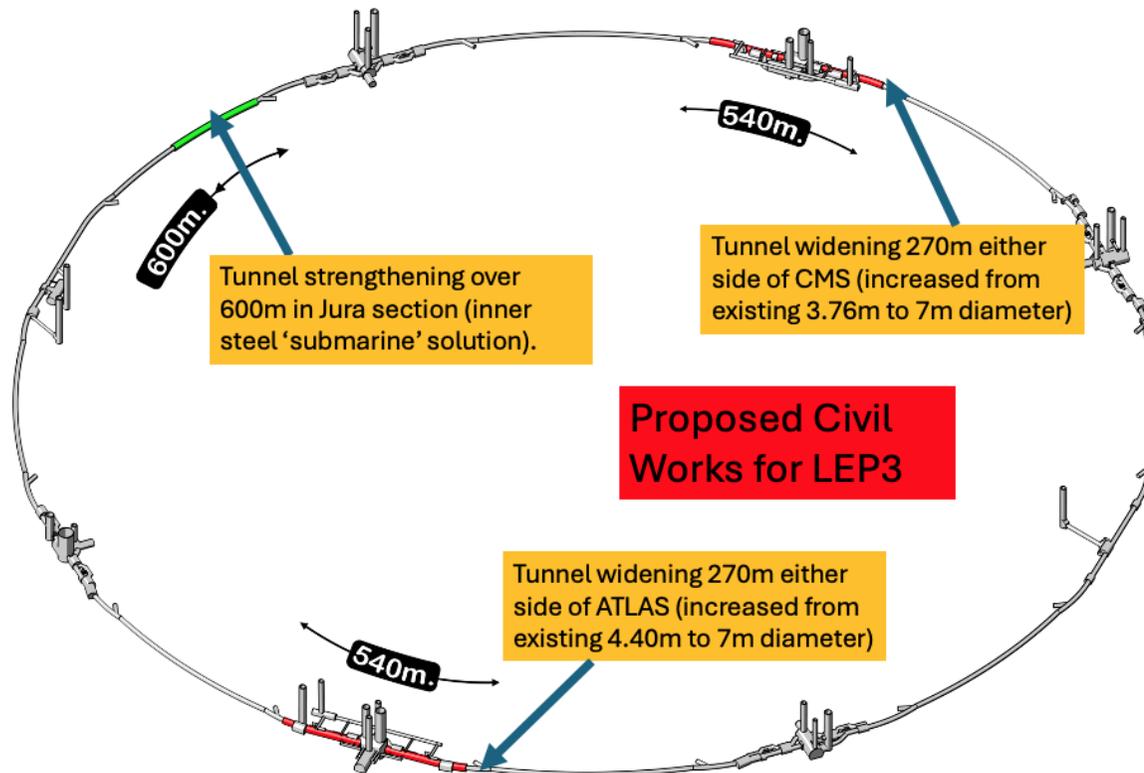


To be understood:

-how much civil engineering is needed to accommodate le 30 mrad crossing angle .

- Path of booster ring across the IP

- 40 years old infrastructure, some parts need maintenance
- High lumi achieved by crab-waist → large xing-angle → need to widen the LSS cross section on either side of the experiments
- possibly need of by-passes (avoidable if booster Beam pipe goes through detector)
- Overall civil engineering cost estimated: 165 MCHF



Assume that the ATLAS and CMS experiments can be re-used with **suitable modification (rebuilding of the inner trackers and the integration of focusing quadrupoles** some 2m from the IP).

Keep magnets but at lower fields. Trackers costing around MCHF 100/per experiment are assumed. (Re-using ATLAS & CMS Should save the community >1BCHF)

Exploit all R&D done for ILC, CLIC and FCC(ee) detectors as well as LHC upgrades.

Baseline: Accelerator(booster) beam passes through tracker. If too much of perturbation then need bypasses.

All of the above need detailed studies.

From FCC MTR:

Integration of IR optics.
Independent beam pipes ~ 1-2m from IP.

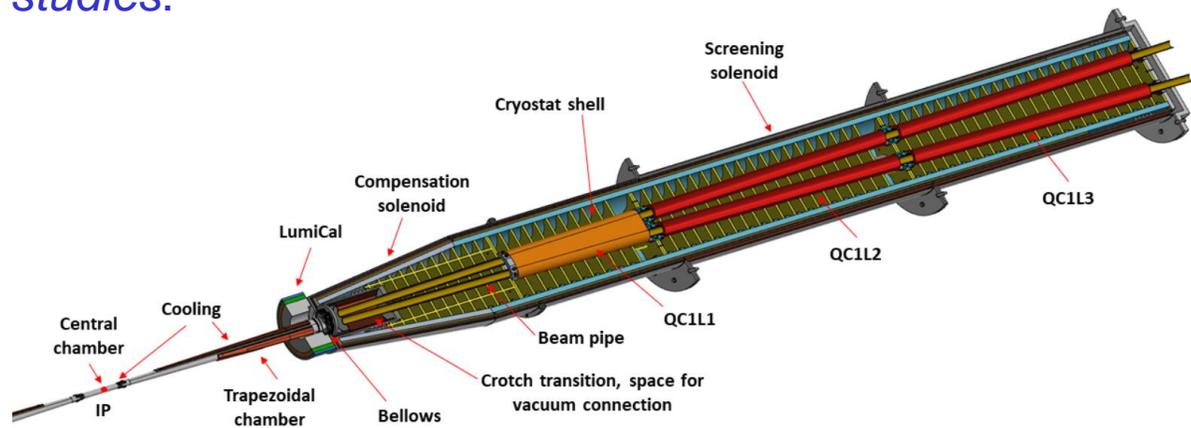


Fig. 217 Section view of the accelerator components from the IP to the end of the first final focus quadrupole (QC1), at about 8.4 m.

Energy Calibration: For Z running, use the FCC-ee approach (ie. Having non colliding bunches which allow frequent monitoring of the polarization

For WW running, see if under special running conditions adequate levels of polarization can be achieved at energies close to or at the WW threshold. Failing this, aim is to use the resonant depolarization method at the highest energy possible, and extrapolate to the WW threshold. **Needs further study.**

Sustainability: We assume that all building permissions/permits for LEP3 should be in place. Environmental impact should be minimal. Allowance probably needed for regulations that may have changed since the time of the construction of LEP. Benefit should be drawn from any relevant studies in these areas carried out for other proposed projects such as FCC-ee or CLIC.

Power Consumption: We estimate that the total power consumption at the highest LEP3 energy will be less than 250MW, similar to that of HL-LHC.

The LEP3 physics programme would have three phases (here based on FCC derived FODO optics)

- i) near or on the Z peak (91 GeV), recording 2×10^{12} **Z decays** over six years
- ii) near the WW threshold~ 4×10^7 **WW events** at and around $\sqrt{s} = 163$ GeV over four years
- iii) near the ZH threshold (at 230 GeV). ~ 4.7×10^5 **$e^+e^- \rightarrow$ ZH events** would be recorded over six years at $\sqrt{s} = 230$ GeV.

With improved optics/performance can save on operation/construction costs

For comparison with other projects:

Statistical errors scale as $\sqrt{\text{ratio of no. of events}}$. Systematic errors have to be evaluated on a case by case basis (using similar recipes to FCC) .

Here comparable detector performance is assumed.

LEP3 is competitive with other alternatives and considerably better for EW physics

Higgs boson physics

	HL-LHC*	LEP3 **	Comment and leading error	FCCee
C.o.M. energy		230		240
No. of Experiments	2	2		4
Prog Integ. Lumi (ab-1)	3	2.5		10.8
Years of Running	10	6		3
Observable (% error)	$\Delta(\sigma.BR) = 2\Delta\kappa$			$\Delta(\sigma.BR) = 2\Delta\kappa$
$\delta m(H)$ (MeV)	100	9.2	Sys: knowledge of $E_b(ee)$	4
$\delta\Gamma(H)/\Gamma_H$ (%)	50	3.8		1.3
$\delta\gamma(HZZ)/g(HZZ)$	1.6	5.7		2.5
$\delta\gamma(HWW)/g(HWW)$	1.6	1.8		0.8
$\delta g(H\tau\tau)/g(H\tau\tau)$	1.9	1.3		0.58
$\delta g(H\gamma\gamma)/g(H\gamma\gamma)$	1.8	8.2		3.6
$\delta g(H\mu\mu)/g(H\mu\mu)$	3	25.2		11
$\delta\gamma(Hcc)/g(Hcc)$	100	3.7	LHC from $\sim\text{CMS}/\sqrt{2}$	1.6
$\delta g(Hbb)/g(Hbb)$	3.6	0.5		0.21
$\delta g(Hgg)/g(Hgg)$	2.4	1.8		0.8
$\delta g(Htt)/g(Htt)$	3.4	x		x
$\delta g(HZ\gamma)/g(HZ\gamma)$	6.8	27.0		11.8
BR ($H>inv$) (%) 95%CL	<2.5	0.2	LHC from CMS/ $\sqrt{2}$	0.55
BR ($H>EXO$) (%) 95%CL	<4	1.5		<1.1
$\delta(H \text{ self-cplg})$ (%) 95%CL	30 (SM)	91.5	HH from LHC, ZH from ee	40

LEP3 can be competitive with other alternatives

LEP3 ~ 4.7×10^5 H bosons (6 yrs 2 expts) cf FCC(ee) ~ 2.2×10^6 (3 yrs 4 expts)

~1.7x10¹² Z bosons (6 yrs at 91.2 GeV), and ~ 4x10⁷ WW pairs (4 eff yrs at √s=163 GeV)
 cf FCC(ee) ~6 × 10¹² and ~1.5 × 10⁸ resp.

Observable	LHC/Present		LEP3	LEP3	LEP3	Comment and leading error
	value	± error	Stat	Sys (FCC FS)	stat+Sys	
No. of Experiments			2 Xpts		2 Xpts	
m(Z) [keV]	91186700	± 2000	7.51	100	100.28	Sys - From Z line shape scan; beam energy calibration
Γ(Z) [keV]	2495200	± 2300	7.51	12	14.16	Sys- From Z line shape scan; beam energy calibration
sin ² θW ^{eff} [10 ⁶]	231480	± 160	2.25	1.2	2.55	From A(μμ)FB at Z peak, beam energy calibration
1/αQED (mZZ)(x10 ³)	128952	± 14	7.33	small	7.33	Stat - From AμμFB off peak, QED & EW errors dominate
RZ/ (x10 ³)	20767	± 25	0.09	0.05	0.11	Sys-Ratio of hadrons to leptons, acceptance for leptons
αs (m ² ZZ) [x10 ⁴]	1196	± 30	0.19	1	1.02	Sys-From Comb. RZl, Gamma(tot),σo(had)
σohad (x10 ³) [nb]	41480	± 32.5	0.06	0.8	0.80	Sys-Peak hadronic x-section, luminosity measurement
Nv [x10 ³]	2996	± 7.4	0.17	0.12	0.21	Sys-Z peak cross-sections, Luminosity measurement
Rb [10 ⁶]	216290	± 660	0.47	0.3	0.56	Sys-Ratio of bb to hadrons
A(b)FB,0 [10 ⁴]	992	± 16	0.08	0.04	0.09	Sys-b-quark asymmetry at Z pole, from jet charge
Apol,τFB [10 ⁴]	1498	± 49	0.13	0.2	0.24	Sys-τ polarisation asymmetry, τ decay physics
τ lifetime [fs]	290.3	± 0.5	0.00	0.005	0.01	Sys-ISR, τ mass
τ mass [MeV]	1776.93	± 0.09	0.00	0.02	0.02	Sys-estimator bias, ISR, FSR
τ leptonic (μνμντ) BR [%]	17.38	± 0.04	0.00	0.003	0.00	Sys-PID efficiency, π0 efficiency
m(W) [MeV]	80360	± 9.9	0.34	1	1.06	From WW threshold, beam energy calibration
Γ(W) [MeV]	2085	± 42	0.51	1	1.12	StatFrom WW threshold, beam energy calibration
αs (m ² W) [10 ⁴]	1010	± 270	3.76	2	4.26	Stat-From combn. RWL, Γ'wtot fit
Nv [10 ³]	2920	± 50	0.94	small	0.94	Stat-Ratio of invis. to leptonic in radiative Z returns
m(top) [MeV]*	172570	± 290	n/a	n/a	n/a	Stat-From ttt threshold scan, QCD errors dominate
Γ(top) [MeV]	1420	± 190	n/a	n/a	n/a	Stat-From ttt threshold scan, QCD errors dominate
λtop /ASM(top) **	1.2	± 0.3	n/a	n/a	n/a	Stat-From ttt threshold scan, QCD errors dominate
ttZ coupling [%]		± 30%	n/a	n/a	n/a	Stat-From √s=365 GeV run

Estimation of EW measurement precision: stat error scaled square root of lumi ratio and syst derived in similar way to FCC ones

Tera-Z factories can discover new elementary particles with couplings to the Z-boson that are orders of magnitude smaller than current bounds.

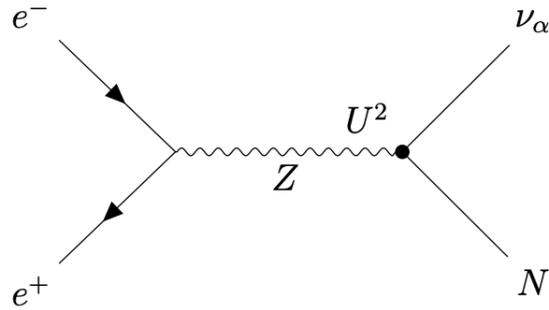
Indirect signatures. If the mass m of a new elementary particle exceeds the collision energy, it can only leave an indirect trace in observables as a virtual mediator. In this case deviations from the SM can be described in the framework of effective field theories (EFTs) involving SM fields. The huge number of events that can be achieved with $NZ \sim 10^{12}$ permits searches for such deviations through very precise measurements of known processes.

Discovery of new elementary particles. It is possible that new elementary particles with masses m below the LHC collision energy have escaped discovery because they rarely interact with ordinary matter. This can either occur in minimal models featuring isolated SM gauge singlets or in more complex theories in which a hidden or dark sector couples to the SM only through so-called portals

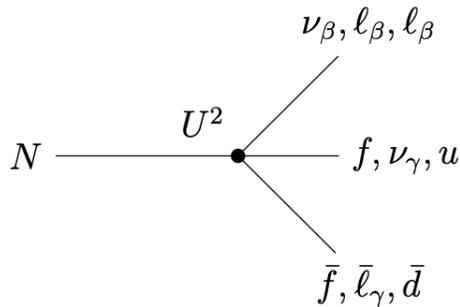
Example :HNL from Z decays

Detector : D=10m, L=9m

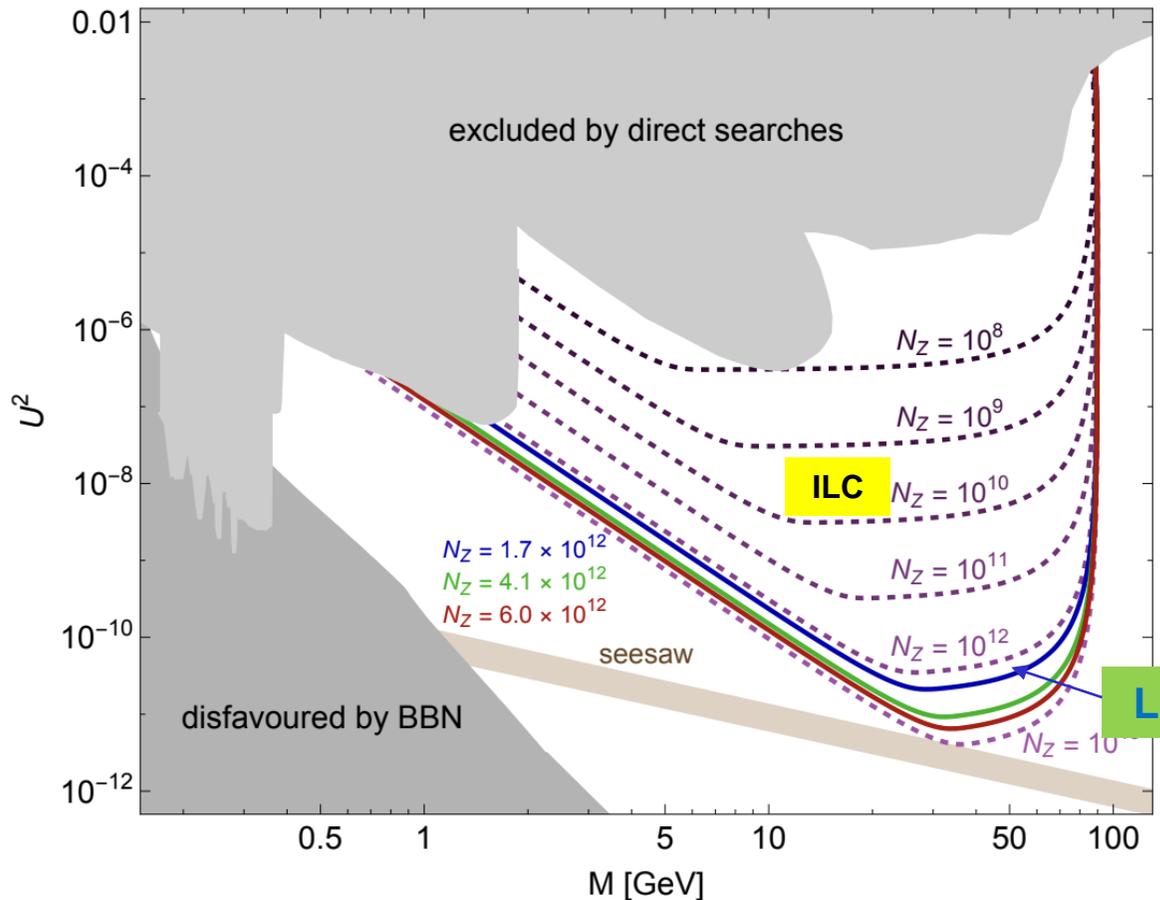
Small coupling= long lived
Example Heavy Neutral leptons

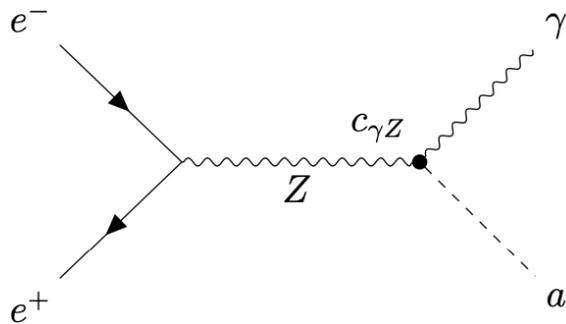


HNL production

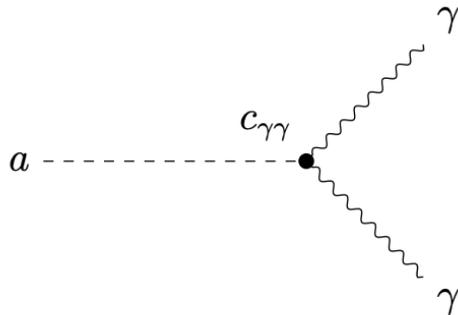


HNL decay (4 fermions)



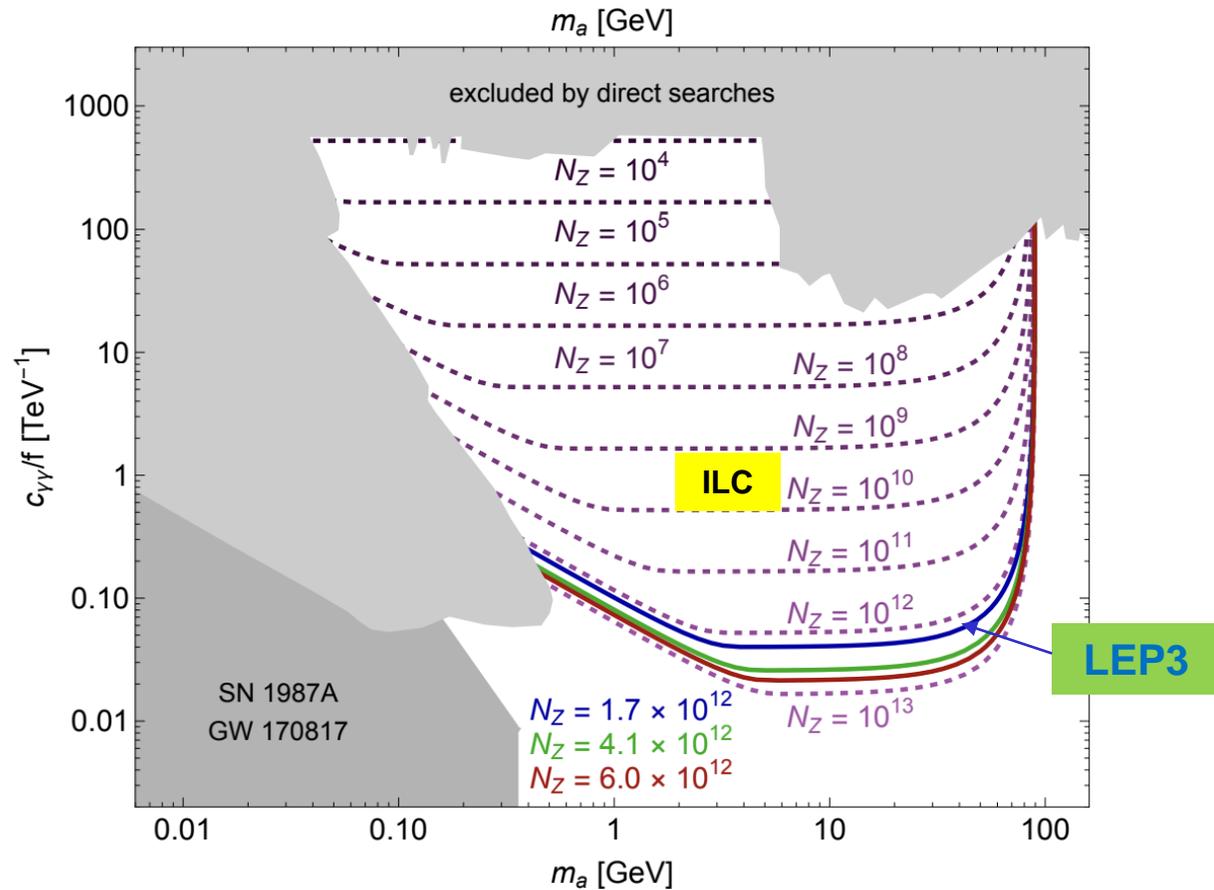


Axion production



Detection

Example Axion coupled to the U(1) hypercharge gauge boson before electroweak symmetry breaking



Example: Shutdown Schedule: After LHC stops



Year	1			2			3			4			5					
Pre-Dismantling & Radiological Activity	[Hatched pattern]																	
LHC Removal	[Green pattern]																	
Sectors 1-2 and 5-6	[Orange pattern]																	
Sectors 4-5 and 8-1				[Orange pattern]														
Sectors 3-4 and 6-7				[Orange pattern]														
Sectors 7-8 and 2-3							[Orange pattern]											
Civil Engineering										[Orange pattern]								
Around CMS				[Yellow pattern]			[Yellow pattern]											
Sector 3-4 - consolidation works				[Yellow pattern]			[Yellow pattern]											
Around ATLAS				[Yellow pattern]			[Yellow pattern]											
RF Even point additional waveguide holes							[Yellow pattern]											
LEP3 Installation										[Blue pattern]								
Sector 5-6										[Blue pattern]								
Sector 1-2										[Blue pattern]								
Sector 8-1										[Blue pattern]								
Sector 4-5										[Blue pattern]								
Sector 3-4										[Blue pattern]								
Sector 6-7										[Blue pattern]								
Sector 2-3										[Blue pattern]								
Sector 7-8										[Blue pattern]								
Hardware Commissioning										[Red pattern]								

Use the FCCee costing methodology.

Costs scaled from FCC(ee) MTR costs: scaled according to numbers of components required

Cost Element	2 new Xpts	2 Exist Xpts
Accelerator	2705	2705
Injectors and Transfer Lines	295	295
Technical Infrastructures	435	435
Experiments	100	60
Civil Engineering	165	165
LHC Removal/LEP3 Installation	140	140
Total CERN (MCHF)	3840	3800
Experiments non-CERN User	700	270
Community Contribution (MCHF)		

With assumed schedule LEP3 cost would be well within the standard CERN budget, allowing pursuit of other future-oriented initiatives [e.g. R&D on rf cavities (high gradient, low power), high-field magnets, muon collider demonstrator]

Cost: assumes careful removal of LHC machine in case it is needed later as an injector.

Funding assumes CBD paid off by 2035; 250 (350) MCHF saved/year when only running HL-LHC (when in shutdown).

Sustainability is an important issue: use ideas/proposals from the other projects

The beam pipe assumed in this study has the same diameter as the FCCee : for FCCee one constraint was the overall impedance of the accelerator . As the the impedance depends linearly on the circumference of the accelerator and inversely with the third root of the beam pipe diameter. LEP3 beam pipe could have a diameter of 30mm to maintain the same impedance of FCCee. As the cost of the magnet varies with the square of the beam diameter this could result in substantial savings.

The optics used for this study is one derived from FCCee without any optimization for the LEP3 setup. Ongoing work (Pantaleo Raimondi) indicates that substantial increases in luminosity are possible. Early investigations indicate that the luminosity could increase by a factor 2

Aim: an accelerator with constituent \sqrt{s} ~ 10 times higher than LHC (1-2 TeV).

If FCC(ee) is built then a ~ 100 TeV hadron collider would be the obvious next step.

R&D Goal: Develop high field magnets - followed by the setting up for industrial production to provide solid cost estimates.

If R&D on high field magnets is successful and their construction cost and production capacity are known and appear affordable, then a decision could be made to go to a higher energy hadron machine FCC(hh) (~ 100 TeV).

Another R&D Goal: increase gradient and efficiency of rf cavities and bring down their cost

We support (FCC-ee + FCC-hh) as the preferred option for CERN's future

An e^+e^- collider in the LHC tunnel, referred to here as LEP3, is proposed as a backup option for FCC-ee

- Compared to the linear e^+e^- colliders proposed, LEP3 provides similar luminosity for ZH production, higher luminosity at lower energies and options for multiple experiments, all at much lower cost.
- LEP3 is a reasonable (perhaps the best) backup option
- Leaves room (time, budget, resources) for further development of THE machine that can probe directly the energy frontier at a constituent $\sqrt{s} \sim 10$ times LHC.

No showstoppers have yet been identified, and we consider this proposal to be sufficiently interesting to deserve further study. We have identified important areas that would require deeper investigation before CERN could commit to LEP3.

As we have heard from Karl on Monday :

Flagship Accelerator Project

- A. *The electron–positron 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.*

Recommendation from Accelerator Technology Section

- B. *In order to realise the visionary plan presented, the highest priority must be the development and industrialisation of key technologies: advanced superconducting and normal-conducting RF structures, efficient RF power sources and accelerator-quality magnets in the 14–20 T range, including those based on high-temperature superconductors.*

Comparison of various proposals



Machine	Precision Physics	BSM physics	Phys vs CEPC	Tech readiness	Const. cost (GCHF)	Path to ≥ 10 TeV
FCC-ee	22	23			15.3	
LCF250/ LCF550	15	17			14.8	
CLIC380/ CLIC1500	14	18			14.6	
LCF250	10	16			9.4	
CLIC380	10	16			7.5	
LEP3	14	17			4.1	
LHeC	8	7			2.1	

Numbers: weighted sum using WG2a (physics)

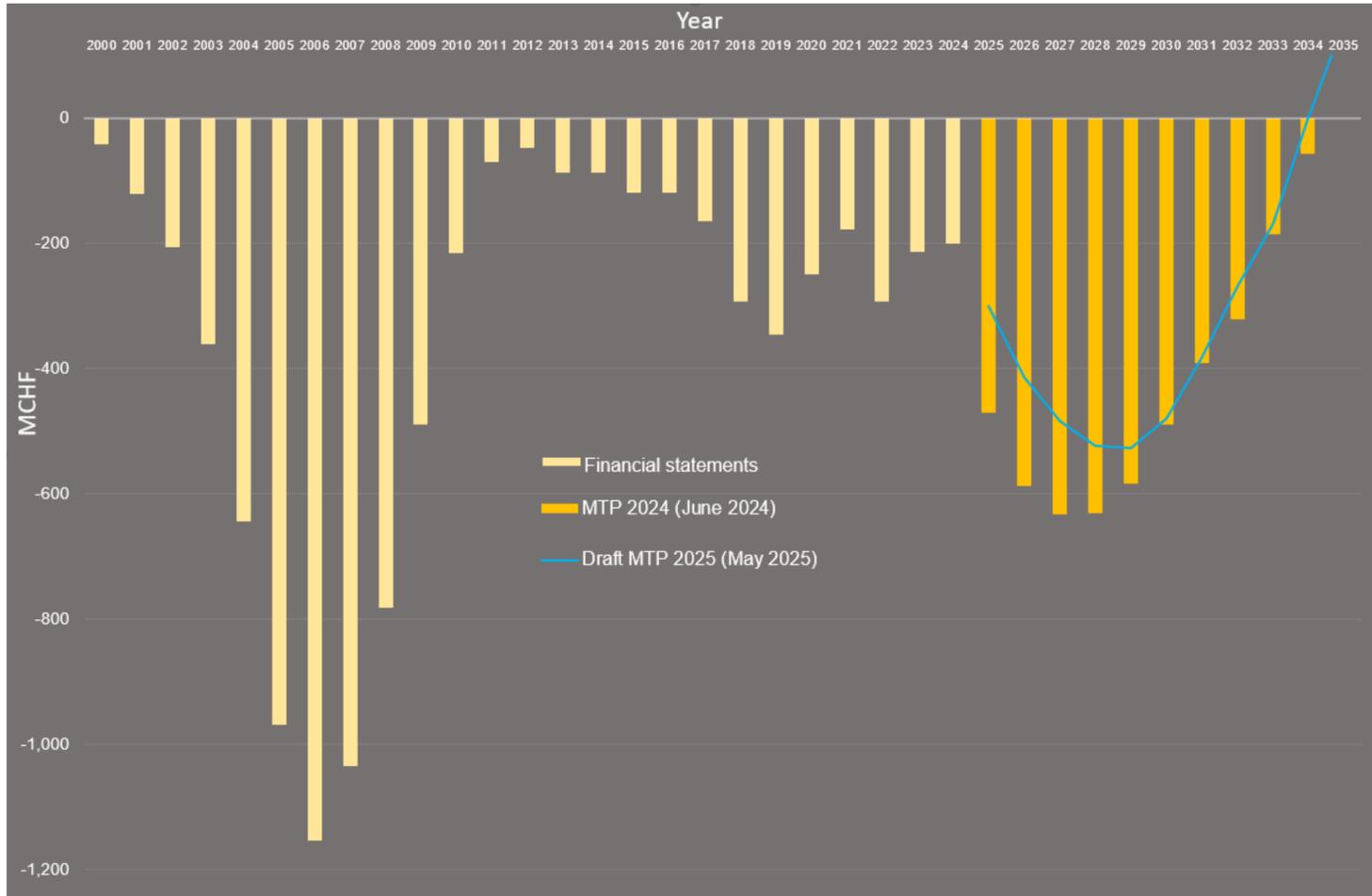
- i) What are the implications of a crossing angle of ~ 30 mrad? Over which length does the tunnel need widening?,
- ii) What rf cavities are the most appropriate for LEP3? Can such cavities fit into the existing straight sections in the LEP/LHC tunnel?
- iii) The tunnel needs enlargement or consolidation in some areas, how easily can it be done? How much time will be needed? Is the cost of civil engineering works reliably estimated?
- iv) What procedures/derogations are required for the removal of LHC elements, especially for those elements considered to be significantly activated? Where will these components be stored?
- v) What is the optimal injection energy into the LEP3 accelerator?
- vi) Present estimate indicate that the total cost of the whole LEP3 project be kept within CERN's current budgetary limits: this assumption needs more studies (RF, Power distribution, magnet design..) .

If one wants to be serious about knowing if LEP3 is a real option some professional work (read by CERN services) needs to be done over the next 2-3 years . We estimate that the cost of this is below 5 MChf /year with ~45 Fellow.Yrs and 16 Staff FTE.Yrs

CBD for LHC and HL-LHC



Chart a: Cumulative budget deficit



Note: LEP3 cost to CERN would be similar to LHC construction