Alternative high energy e^+e^- collider concepts including C^3

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March 22, 2022

Other accelerator concepts beyond the previously well established ones (ILC, CLIC, FCC-ee/CEPC) are being explored for electron-based Higgs factories.

These include **C**^{3}, HELEN, Fermilab Site-Filler/LEP3, XCC, and circular (CERC), and linear (ERLC, ReLiC) energy recovery concepts.

With Snowmass 2021 - many such ideas emerging. Would ILD be suitable?

Snowmass 2021

Initial deadline for Snowmass white papers was 15-Mar-2022. Many white papers are appearing on Higgs Factory accelerator concepts including ILC.

Much of this talk is orientation to some of these ongoing broader initiatives and related presentations. I tried to identify detector related issues for ILD - but to a large extent the main differences are time structure.

Some related forums.

- Snowmass Agoras on future colliders
- Higgs factory considerations paper
- Snowmass Implementation Task Force (T. Roser chair)
- Recently formed Snowmass e^+e^- collider forum
- Snowmass Energy Frontier workshop next week (hybrid)

Snowmass Agoras on Future Colliders

Monthly extended seminar/discussion organized by the Snowmass Accelerator and Energy Frontier.

1. Linear e^+e^- colliders: ILC, CLIC, C^3
2. Circular e^+e^- colliders: FCC-ee, CEPC, **Small Circular**, **ERL based**
3. Muon colliders
4. Circular pp and ep colliders
5. Advanced colliders (plasma wakefield etc.) on April 16th

Prepared by members of the Americas Linear Collider Committee

Higgs Factory Considerations

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ABSTRACT

We discuss considerations that can be used to formulate recommendations for initiating a lepton collider project that would provide precision studies of the Higgs boson and related electroweak phenomena.

1. Large circular: FCC-ee, CEPC
2. Linear colliders: ILC, CLIC, C^3
3. Energy recovery: CERC, ERLC, ReLiC
4. FNAL Site Filler: circular, linear
5. Muon Collider

Considerations related to physics, technical, and general project issues with sections on US and global considerations.

Extensive discussion by Fermilab authors of many possibilities. Common theme: location, location, location! Three of most relevance to us:

- a novel "Cool Copper Collider (C^3)" linear collider concept (250 GeV to potentially 550 GeV collider can fit on Fermilab site)
- linear colliders based on high gradient SRF (in the range of 50 MV/m to 90 MV/m; standing wave or travelling wave structures; 250 – 500 GeV facility at Fermilab).
- 16-km circumference site-filler circular e^+e^- collider, from Z to the Higgs (90 – 240 GeV)

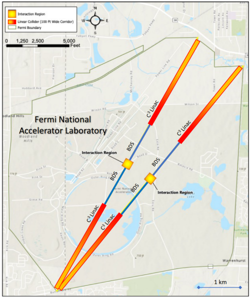

Figure 3: Possible locations for a 7-km footprint linear collider on Fermilab site considered for C^3.

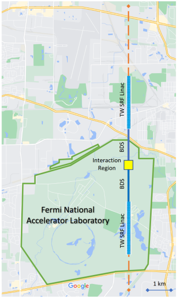

Figure 5: Possible siting of the 250 GeV HELEN collider at Fermilab. The TW option is shown. The orange dashed line indicates a 12-km stretch that might be available for a future upgrade of HELEN to 500 GeV.

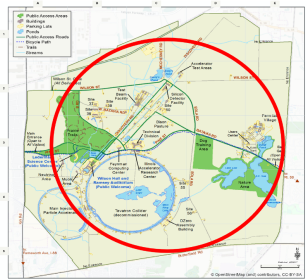

Figure 7: Fermilab site showing the proposed 16-km site-filler collider ring.

The Cool Copper Collider (C^3)(2203.07646)

More details in (2110.15800)

1. New NC RF technology
2. New power distribution scheme
3. Cool - operation at liquid Nitrogen temperatures
4. Much improved efficiency and breakdown rate over NLC
5. High gradients possible - 120 MV/m
6. $\sqrt{s} = 550$ GeV with 8 km footprint
7. Potential path to much higher energies

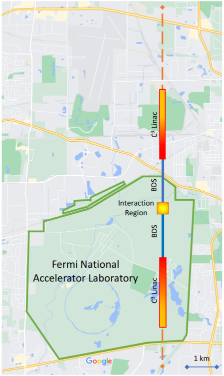

Figure 2: The 8-km footprint consisting of 5 km inside the Fermilab site and extending the facility under the Common Wealth Edison power company's easement.

Has engaged a large community including LHC in a linear collider opportunity. Also seen as a potential upgrade path for ILC especially to higher energies.

C^3 parameter table

Collider	NLC [28]	CLIC [29]	ILC [5]	C^3	C^3
CM Energy [GeV]	500	380	250 (500)	250	550
σ_z [μm]	150	70	300	100	100
β_x [mm]	10	8.0	8.0	12	12
β_y [mm]	0.2	0.1	0.41	0.12	0.12
ϵ_x [nm-rad]	4000	900	500	900	900
ϵ_y [nm-rad]	110	20	35	20	20
Num. Bunches per Train	90	352	1312	133	75
Train Rep. Rate [Hz]	180	50	5	120	120
Bunch Spacing [ns]	1.4	0.5	369	5.26	3.5
Bunch Charge [nC]	1.36	0.83	3.2	1	1
Beam Power [MW]	5.5	2.8	2.63	2	2.45
Crossing Angle [rad]	0.020	0.0165	0.014	0.014	0.014
Crab Angle	0.020/2	0.0165/2	0.014/2	0.014/2	0.014/2
Luminosity [x10^{34}]	0.6	1.5	1.35	1.3	2.4
	(w/ IP dil.)	(max is 4)			
Gradient [MeV/m]	37	72	31.5	70	120
Effective Gradient [MeV/m]	29	57	21	63	108
Shunt Impedance [MΩ/m]	98	95		300	300
Effective Shunt Impedance [MΩ/m]	50	39		300	300
Site Power [MW]	121	168	125	~150	~175
Length [km]	23.8	11.4	20.5 (31)	8	8
L* [m]	2	6	4.1	4.3	4.3

Table 3: Beam parameters for various linear collider designs. Final focus parameters for C^3 are preliminary.

For ILD, main difference with ILC is the bunch spacing and higher rep. rate

C^3 timeline and cost estimate

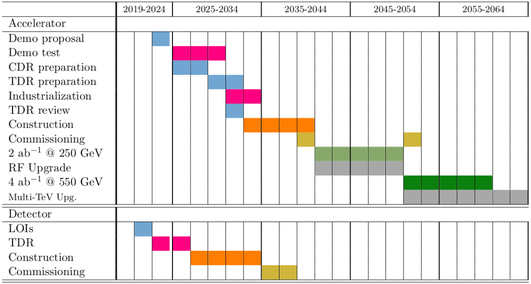

Table 1: Timeline and Milestones for the proposed C^3 development

	Sub-Domain	%	%
Sources	Injectors	8	35
	Damping Rings	12	
	Beam Transport	15	
Main Linac	Cryomodule	10	33
	C-band Klystron	23	
BDS	Beam Delivery and Final Focus	8	13
	IR	5	
Support Infrastructure	Civil Engineer	5	19
	Common Facilities	11	
	Cryo-plant	3	
Total	3.7B$	100	100

Table 6: Cost breakout for C^3 250 operating at 70 MeV/m. Cost of the outfitted tunnel (51k$/m) and the RF source RF source cost ($7.5/peak-kW), derived from ILC and CLIC respectively, are scaled for the length and RF power needed for the Main Linac. The cryomodule cost of (100k$/m) is based on our production costs.

- Needs a demonstrator
- 10 years ahead of FCC
- Detector timeline soon

- Upgrade to 550 GeV assumes advances in RF source cost

Higgs-Energy LEptoN (HELEN) Collider based on advanced superconducting radio frequency technology

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Fermilab, Stony Brook, Brookhaven, Oak Ridge, Cornell, JLab authors

Abstract

This Snowmass 2021 contributed paper discusses a Higgs-Energy LEptoN (HELEN) e^+e^- linear collider based on advances superconducting radio frequency technology. The proposed collider offers cost and AC power savings, smaller footprint (relative to the ILC), and could be built at Fermilab with an Interaction Region within the site boundaries. After the initial physics run at 250 GeV, the collider could be upgraded either to higher luminosity or to higher (up to 500 GeV) energies. If the ILC could not be realized in Japan in a timely fashion, the HELEN collider would be a viable option to build a Higgs factory in the U.S.

HELEN parameter table

Table 2: Tentative parameters of HELEN and other e^+e^- linear collider Higgs factory proposals. Parameters associated with different beam energy scenarios are comma-separated; H and V indicate horizontal and vertical directions; a fill factor of 80.4% is assumed to calculate the real-estate (effective) gradient E_{eff} of HELEN.

Parameter	HELEN	C^3	ILC	CLIC
CM energy $2\times E_b$ (GeV)	250	250, 550	250, 500	380, 3000
Length (km)	7.5	8, 8	20.5, 31	11.4, 50
Interaction points	1	1	1	1
Integrated luminosity (ab^{-1}/yr)	0.2	0.2, 0.4	0.2, 0.3	0.1, 0.6
Peak lumi. $\mathcal{L}$ (10^{34}cm^{-2}s^{-1})	1.35	1.3, 2.4	1.35, 1.8	1.5, 6
CM energy spread $\sim 0.4\delta_{BS}$ (rms, %)	1	1.6, 7.6	1, 1.7	1.7, 5
Polarization (%)	80/30 (e^-/e^+)	tbd	80/30 (e^-/e^+)	80/0 (e^-/e^+)
Rep.rate f_{rep} (Hz)	5	120	5	50
Bunch spacing (ns)	554	5.26, 3.5	554	0.5
Particles per bunch N (10^{10})	2	0.63	2	0.52, 0.37
Bunches per pulse n_b	1312	133, 75	1312	352, 312
Pulse duration (μs)	727	0.7, 0.26	727	0.176, 0.156
Pulsed beam current I_b (mA)	5.8	190, 286	5.8	1670, 1190
Bunch length σ_z (rms, mm)	0.3	0.1	0.3	0.07, 0.044
IP beam size σ^* (rms, μm)	H: 0.52 V: 0.0077	H: 0.23, 0.16 V: 0.004, 0.0026	H: 0.52, 0.47 V: 0.0077, 0.0059	H: 0.15, 0.04 V: 0.003, 0.001
Emittance, ε_n (rms, μm)	H: 5 V: 0.035	H: 0.9 V: 0.02	H: 5, 10 V: 0.035, 0.035	H: 0.95, 0.66 V: 0.03, 0.02
β^* at interaction point (mm)	H: 13 V: 0.41	H: 12 V: 0.12	H: 13, 11 V: 0.41, 0.48	H: 8, 6.9 V: 0.1, 0.068
Full crossing angle θ_c (mrad)	14	14	14	20
Crossing scheme	crab crossing	crab crossing	crab crossing	crab crossing
Disruption parameter D_y	35	12	35, 25	13, 8
RF frequency f_{RF} (MHz)	1300	5712	1300	11994
Accelerating gradient E_{acc} (MV/m)	70	70, 120	31.5	72, 100
Effective gradient E_{eff} (MV/m)	55.6	63, 108	21	57, 79
Total beam power (MW)	5.3	4, 4.9	5.3, 10.5	5.6, 28
Site power (MW)	110	~150, ~175	111, 173	168, 590
Key technology	TW SRF	cold NC RF	SW SRF	two-beam accel.

HELEN is basically ILC, but with much higher gradient.

HELEN gradient and extendability

Parameter	Advanced SW	Traveling wave	Nb_3Sn
Accelerating gradient (MV/m)	55	70	90
Fill factor	0.711	0.804	0.711
Real estate (effective) gradient (MV/m)	39.1	55.6	64.0
Cavity Q (10^{10})	1.0 (2 K)	0.69 (2 K)	1.0 (4.5 K)
Active cavity length (m)	1.038	2.37	1.038
Cavity R/Q (Ohm)	1158	4890	1158
Geometry factor G (Ohm)	279	186	279
B_{pk}/E_{acc} mT/(MV/m)	3.71	2.89	3.71
E_{pk}/E_{acc}	1.98	1.73	1.98
Number of cavities	4380	1527	2677
Number of cryomodules	505	382	309
Collider length (km)	9.4	7.5	6.9
AC power for main linacs (MW)	49	39	58
Total collider AC power (MW)	121	110	129

Table 3: Comparison of some HELEN collider parameters for three option.

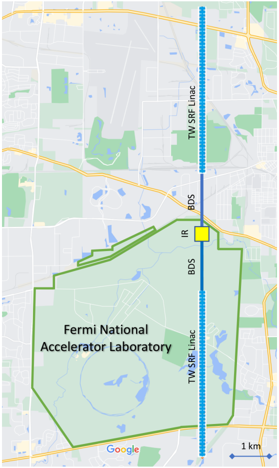


Figure 15: 500 GeV HELEN collider at Fermilab.

Baseline choice is the traveling wave option with RF cavities double the length of the TESLA cavities. With 12 km footprint can extend to 500 GeV with IP (just) within Fermilab site.

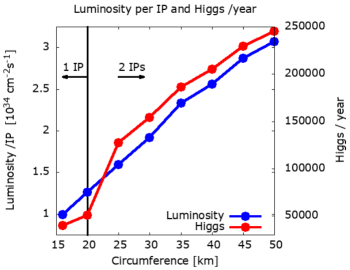
R&D still necessary - estimated 26% main linac cost saving compared with ILC.

Small circular e^+e^- colliders

See Eliana Gianfelice's talk and Chapter 5 in (2203.08088)
While obviously limited in energy scope, and luminosity, the small circular e^+e^- collider approach, is much more affordable than 100 km class concepts.

	Higgs Factory	Z factory
Circumference [km]	16	16
Beam energy [GeV]	120	45.6
Total synchrotron radiation power [MW]	100	60
Beam current [mA]	5.	140
N [10^{11}]	8.3	1.67
Number of bunches	2	279
β_x^* [m] / β_y^*	0.2 m / 1 mm	0.2 m / 1 mm
ϵ_x / ϵ_y [nm]	21 / 0.05	26.1 / 0.065
σ_z [mm]	2.9 (SR)	6.45
beam-beam tune shift per IP	0.075/0.11	0.032 / 0.045
RF frequency [MHz]	650	650
RF voltage [GV]	12	0.24
Momentum acceptance (RF) [%]	± 3	± 9
τ_{bs} [min]	9 - 36	
τ_{Bhabha} [min]	8.7	37
$\mathcal{L}$ per IP [10^{34} cm^{-2}s^{-1}]	1.0	6.3
Production cross-section	200 fb	61 nb
Particle production/year	Higgs: 39751	Z: 7.64 $\times 10^{10}$

Table 1: Parameters of the 2012 Fermilab e^+e^- Higgs and Z Factories



Needs larger circumference to match LC luminosity (L scales as radius for fixed SR power loss) at $\sqrt{s} = 240$ GeV. Note only 1 IP for Fermilab Site Filler.

Compare circular e^+e^- colliders at $\sqrt{s} = 240$ GeV

LEP3 is the obvious Plan-B in this class of collider. Existing tunnel but currently occupied!, leading to a potential physics start pushed to beyond 2050.

	LEP3 (ATS Note)	SiteFiller	FCCee (CDR 2018)
Circumference [km]	26.7	16	98
Beam current [mA]	7.2	5.	29
N [10^{11}]	10	8.3	1.8
n_b	4	2	328
#IPs	2	1	2
β_x^* [m]	0.2	0.2	0.3
β_y^* [mm]	1	1	1
ϵ_x [nm]	25	21	0.63
ϵ_y [nm]	0.1	0.05	0.001
σ_ℓ [mm] (SR)	2.3	2.9	3.2
b-b tune shift/IP	0.09/0.08	0.075/0.11	0.012/0.12
RF frequency [MHz]	1300	650	400
RF voltage [GV]	12	12	2
η [%]	$\pm$4 (RF)	$\pm$3 (RF)	$\pm$1.7 (DA)
τ_{bs}[min]	>17 (*)	9 (**), 36 (***)	18
τ_{Bhabha}[min]	18	8.7	38
$\mathcal{L}$/IP [10^{34} cm^{-2}s^{-1}]	1.1 (****)	1.0 (****)	8.5

SiteFiller cost estimate is not small: 5B$.

Time between bunches is LEP-like at $\sqrt{s} = 240$ GeV for LEP3, Site-Filler.

XCC: An X-ray FEL-based $\gamma\gamma$ Collider Higgs Factory

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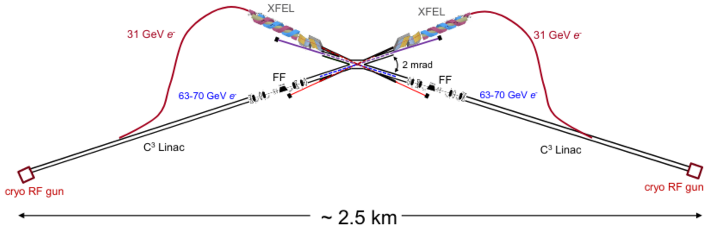
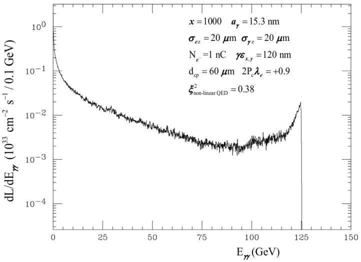
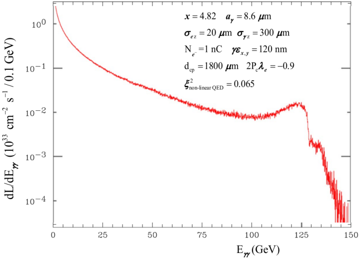
Abstract

This report describes the design of a $\gamma\gamma$ Higgs factory in which 62.8 GeV electron beams collide with 1 keV X-ray free electron laser (XFEL) beams to produce colliding beams of 62.5 GeV photons. The Higgs boson production rate is 32,000 Higgs bosons per 10^7 second year, roughly the same as the ILC Higgs rate. The electron accelerator is based on cold copper distributed coupling (C^3) accelerator technology. The 0.7 J pulse energy of the XFEL represents a 300-fold increase over the pulse energy of current soft x-ray FEL's. Design challenges are discussed, along with the R&D to address them, including demonstrators.

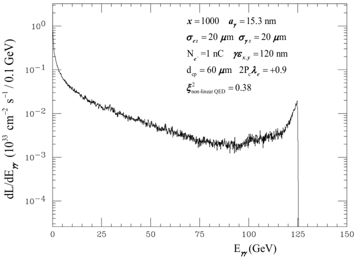


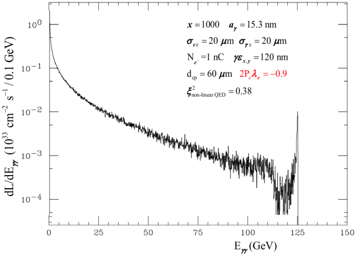
XCC $\gamma\gamma$ Luminosity Spectrum





(Top: X-rays, Bottom: Optical)





(X-rays. Different polarizations)

XCC Features

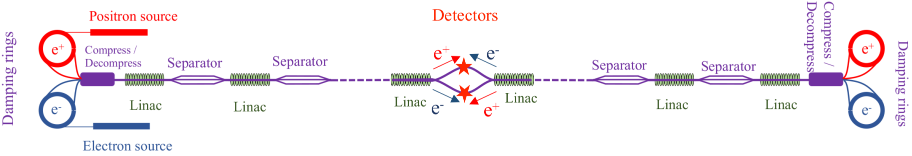
Very interesting ideas.
Has *potential* for lower cost, (estimate 2.3 B$ compared to 3.7 B$ for C^3-250 using same cost model).
Needs substantial R&D, with many technical challenges, and has more limited physics scope than 250 GeV $\mathrm{e^+e^-}$ as a "Higgs factory".

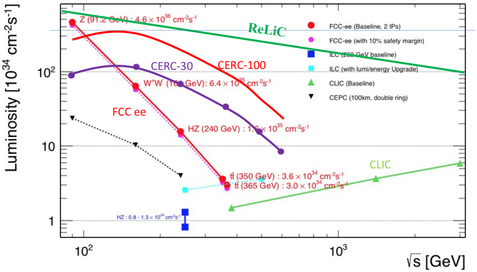
- With X-rays can achieve much narrower $\gamma\gamma$ luminosity spectrum than conventional $\gamma\gamma$ collider (OCC) concepts based on optical wavelength lasers. Leads to lower backgrounds to Higgs production compared to OCC.
- Can produce Higgs in the s-channel ($\gamma\gamma \to H$) at $\sqrt{s_{\gamma\gamma}} = 125$ GeV, and measure $\sigma(\gamma\gamma \to H)B(H \to X) \sim \Gamma_{\gamma\gamma}\Gamma_X/\Gamma^2_{\mathrm{tot}}$.
- Use $e\gamma \to eH$ at $\sqrt{s_{e\gamma}} = 140$ GeV to measure $\Gamma_{\gamma\gamma}$ independent of Higgs decay mode to extract absolute partial widths (with current baseline need to dedicate 2/3 of running time to the $e\gamma$ mode) with paltry 4.1 fb eH cross-section...

My take: worth pursuing further to see if a more attractive future $\gamma\gamma$ option as a LC addition emerges. At present - not compelling as **the** Higgs factory.
Would benefit from improved performance and broader physics scope.

The ultimate e^+e^- collider?

e^+e^- colliders with energy recovery have received attention. Conceptual ideas are CERC (ERL boosted FCC-ee), ERLC (Twin LC - V. Telnov), and the latest Recycling Linear Collider (ReLiC) by the same author team as CERC.





*Plot from ReLiC paper

- Scope for much higher lumi and/or power savings
- Really explore HH production
- Potential for high L performance at high energy

CERC in more detail (FCCee with ERL)

This is the 30 MW SR version.

Table 1. Main parameters of ERL-based e^+e^- collider with synchrotron radiation power of 30 MW.

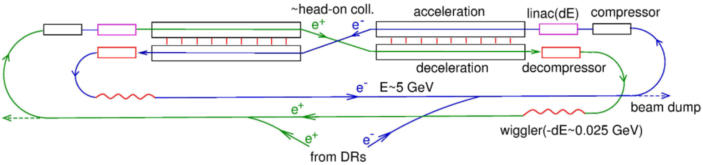
CERC	Z	W	H(HZ)	ttbar	HH	Httbar
Circumference, km	100	100	100	100	100	100
Beam energy, GeV	**45.6**	**80**	**120**	**182.5**	**250**	**300**
Hor. norm ε, μm rad	3.9	3.9	6.0	7.8	7.8	7.8
Vert. norm ε, nm rad	7.8	7.8	7.8	7.8	7.8	7.8
Bend magnet filling factor	0.9	0.9	0.9	0.9	0.9	0.9
βh, m	0.5	0.6	1.75	2	2.5	3
βv, mm (matched)	0.2	0.3	0.3	0.5	0.75	1
Bunch length, mm	2	3	3	5	7.5	10
Charge per bunch, nC	13	13	25	23	19	19
Ne per bunch, 10^{11}	0.78	0.78	1.6	1.4	1.2	1.2
Bunch frequency, kHz	297	270	99	40	16	9
Beam current, mA	3.71	3.37	2.47	0.90	0.31	0.16
Luminosity, 10^{35} $cm^{-2}sec^{-1}$	6.7	8.7	7.8	2.8	1.3	0.9
Energy loss, GeV	4.0	4.4	6	17	48	109
Rad. power, MW/beam	15.0	14.9	14.9	15.0	16.8	16.9
ERL linacs, GV	10.9	19.6	29.8	46.5	67.4	89
Disruption, D_h	2.2	1.9	0.8	0.5	0.3	0.3
Disruption, D_v	503	584	544	505	459	492

Lumi numbers summed over 2 IPs?

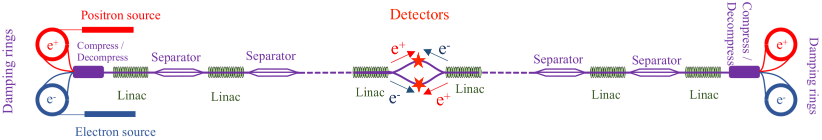
Total AC power estimate at 600 GeV is 215 MW.

ERLC in more detail

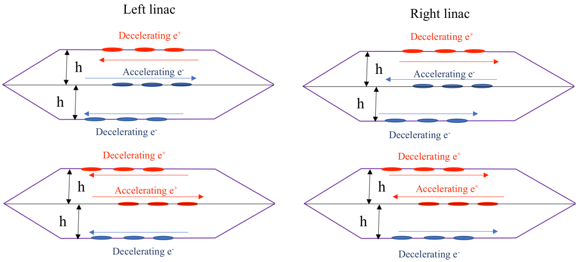
Twin LC with energy recovery



	unit	ERLC pulsed Nb 1.8 K 1.3 GHz	ERLC pulsed Nb 1.8 K 0.65 GHz	ERLC contin. Nb_3Sn 4.5 K 1.3 GHz	ERLC contin. Nb_3Sn 4.5 K 0.65 GHz	ILC Nb 1.8 K 1.3 GHz
Energy $2E_0$	GeV	250	250	250	250	250
Luminosity $\mathcal{L}_{tot}$	10^{36} cm^{-2}s^{-1}	0.39	0.75	0.83	1.6	0.0135
P (wall) (collider)	MW	120	120	120	120	129(tot.)
Duty cycle, DC		0.19	0.37	1	1	n/a
Accel. gradient, G	MV/m	20	20	20	20	31.5
Cavity quality, Q	10^{10}	3	12	3	12	1
Length L_{act}/L_{tot}	km	12.5/30	12.5/30	12.5/30	12.5/30	8/20
N per bunch	10^9	1.13	2.26	0.46	1.77	20
Bunch distance	m	0.23	0.46	0.23	0.46	166
Rep. rate, f	Hz	$2.47 \cdot 10^8$	$2.37 \cdot 10^8$	$1.3 \cdot 10^9$	$6.5 \cdot 10^8$	6560
$\epsilon_{x,n}/\epsilon_{y,n}$	10^{-6} m	10/0.035	10/0.035	10/0.035	10/0.035	5/0.035
β_x^*/β_y at IP	cm	2.7/0.031	10.8/0.031	0.46/0.031	6.8/0.031	1.3/0.04
σ_x at IP	μm	1.05	2.1	0.43	1.66	0.52
σ_y at IP	nm	6.2	6.2	6.2	6.2	7.7
σ_z at IP	cm	0.03	0.03	0.03	0.03	0.03
$(\sigma_E/E_0)_{BS}$ at IP	%	0.2	0.2	0.2	0.2	~ 1



Alternate trains of electrons and positrons in the same linac. Bunch-trains overlap longitudinally only on separators.



Two detectors is a crucial part of the concept! - related to optics for flat beams considerations. Final focus optics similar to FCCee.
Beamstrahlung by design (ultra-flat beams) a lot less than ILC.

ReLiC Parameters (not much detail yet in writeup)

P_{AC} estimates of 300/800 MW for 240/3000 GeV. (3 TeV looks not credible ...)

Table 1. Key ReLiC parameters for two choices of c.m. energy.

C.M. energy	GeV	240	3,000
Length of accelerator	km	20	288
Section length	m	250	250
Bunches per train		10	21
Particles per bunch	10^{10}	2.0	1.0
Collision frequency	MHz	12.0	25.2
Beam currents in linacs	mA	38	40
εx, norm	mm mrad	4.0	4.0
εy, norm	μm mrad	1.0	1.0
βx	m	5	100
βy, matched	mm	0.34	9.7
σ_z	mm	1	17
Disruption parameter, Dx		0.01	0.002
Disruption parameter, Dy		43	15
Luminosity per detector	10^{34} cm^{-2}sec^{-1}	172	47
Total luminosity	10^{34} cm^{-2}sec^{-1}	343	94

Detailed technical validation needed. Gradient (12.5 MV/m with 500 MHz RF).
Looks extremely interesting if it is as elegantly simple as it appears.

Accelerator Parameters for e^+e^- colliders near ZH peak

Lumi/IP is in units of $10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$. Lumi/IP/BX is in $\mu\mathrm{b}^{-1}$.

Parameter	ILC	C^3	HELEN	SiteFiller	LEP3	FCCee
$\sqrt{s}$ [GeV]	250	250	250	240	240	240
L (C) [km]	20.5	8	7.5	16	27	91
n_{IP}	1	1	1	1	2	4
Δt (ns)	554/366	5.3	554	26000	22000	1230
Lumi/IP	1.35/2.7	1.3	1.35	1	1.1	7.26
nBX/s	6560/13125	15960	6560	38460	45000	815000
Lumi/IP/BX	2.1	0.81	2.1	0.26	0.24	0.089
σ_z (mm)	0.3	0.1	0.3	≥ 2.9	≥ 2.3	6
Rep rate (Hz)	5	120	5	NA	NA	NA
P_{AC} (MW)	111/138	150	110	SR100+	SR100+	282

FCCee numbers from Table 2 of 2203.06520
CERC/ERLC/ReLiC parameters omitted from the comparisons; concepts are ideas at this point and designs likely to evolve.
Note linear/circular lumi numbers would be about 4%/13% less at 240/250 GeV in a more apples-to-apples comparison.

Summary

- There are a number of alternative collider concepts that are worth keeping an eye on beyond the well established $\mathrm{e^+e^-}$ collider concepts.
- A number of them are not that novel, and quite feasible, namely C^3, HELEN, small circular (SiteFiller/LEP3).
- Some emerging new ideas include new approach to $\gamma\gamma$ colliders (XCC) and especially new concepts for applying energy recovery to high energy $\mathrm{e^+e^-}$ colliders.
- Having at least two detectors for all these concepts is not guaranteed.

Concluding Remarks

ILC has basically been around for more than 30 years. We are confident that ILC can be built, and should continue to support it as the current most feasible path. But ILC and the prospect for e^+e^- colliders in general are challenged/confronted/delayed/enriched by

- the considerable **cost** of any such machine
- the current lack of a willing **host**
- the appearance of **other approaches** differing in maturity that claim either higher L at low E, higher E, reduced costs, or even high L, high E and low P
- the continual interest to explore new ideas
- the limited direct new physics potential of the first stage ILC250

While continuing to support efforts on LCs in general, it seems that the HELEN initiative and C^3 are well aligned with advancing R&D that furthers a LC.

- It should be relatively easy to propose an ILD-like detector for either.
- ILD should also still work well with a TPC for the smaller circular collider possibilities (SiteFiller/LEP3). Note these are not pushed for now...
- We should consider future-proofing: evolving to a concept with **options** that can work well for any of these potential e^+e^- colliders.
- Any near-term funding opportunities are likely to promote more generic studies for e^+e^- Higgs factory detectors.

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