AF and Implementation Task Force Summary

Thomas Roser for the Implementation Task Force

CCC meeting

January 18, 2022

Accelerator Frontier – Key Questions

1. What is needed to advance the physics?
2. What is currently available (state of the art) around the world?
3. What new accelerator facilities could be available on the next decade (or next next decade)?
4. What R&D would enable these future opportunities?
5. What are the time and cost scales of the R&D and associated test facilities as well as the time and cost scale of the facilities?

Snowmass'21 Accelerator Frontier

Topical Group		Topical Group co-Conveners			
AF01	Beam Phys & Accel. Education	Z. Huang (Stanford)	M. Bai (SLAC)	S. Lund (MSU)	
AF02	Accelerators for Neutrinos	J. Galambos (ORNL)	B. Zwaska (FNAL)	G. Arduini (CERN)	
AF03	Accelerators for EW/Higgs	F. Zimmermann (CERN)	Q. Qin (ESRF)	G.Hoffstaetter (Cornell) A.Faus-Golfe (IN2P3)	
AF04	Multi-TeV Colliders	M. Palmer (BNL)	A. Valishev (FNAL)	N. Pastrone (INFN) J.Tang (IHEP)	
AF05	Accelerators for PBC and Rare Processes	E. Prebys (UC Davis)	M. Lamont (CERN)	Richard Milner (MIT)	
AF06	Advanced Accelerator Concepts	C. Geddes (LBNL)	M. Hogan (SLAC)	P. Musumeci (UCLA)	R. Assmann (DESY)
AF07	Accelerator Technology R&D				
	Sub-group RF	E. Nanny (SLAC)	S. Posen (FNAL)	H. Weise (DESY)	
	Sub-Group Magnets	G. Sabbi (LBNL)	S. Zlobin (FNAL)	S. Izquierdo Bermudez (CERN)	
	Sub-Group Targets/Sources	C. Barbier (ORNL)	Y. Sun (ANL)	Frederique Pellemoine (FNAL)	
ITF	Implementation Task Force	T. Roser (BNL)			

Steve Gourlay (LBNL)

Tor Raubenheimer (SLAC)

Vladimir Shiltsev (FNAL)

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329 AF Letters-of-Intent (incl.71 joint - EF, NF, RPF, …)

- AF1: Beam Physics and Accelerator Education 61 (14)
- AF2: Accelerators for Neutrinos 18 (5)
- AF3: Accelerators for EW/Higgs 32 (4
- AF4: Multi-TeV Colliders 56 (10)
- AF5: Accelerators for PBC and Rare Proc. 37 (22)
- AF6: Advanced Accelerator Concepts 71 (5)
- AF7: Accelerator Technology R&D (Magnets, RF, Targets and Sources) 137 (6)

Snowmass 2021

Snowmass AF Timeline

	2021			2022								
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep
Snowmass Timeline						Whitepaper Due Date: March 15th				Snowmass at Seattle: July 17-26		
AF Timeline	AF Restart	Whitepaper Preparation				WP Initial Review	Complete AF TGC Report Drafts		Prepare Snowmass Discussion Materials	Snowmass	Final TGs and AF Report Editing	

April 15: Requests for Clarification (if needed)

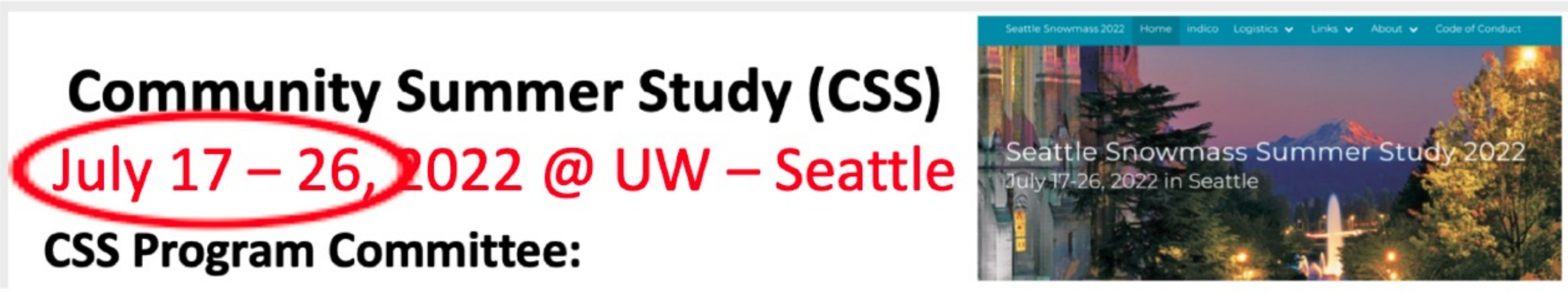
May 30:

1. **Preliminary TG Drafts Circulated to POCs for Comment**
2. **Executive Summaries Sent to AF Conveners to Incorporate into Snowmass Meeting Documents**

August 31: Request POC Comments

Final Reports Due September 30, 2022

Note:



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AF Implementation Task Force

- Key question for Snowmass’21 Accelerator Frontier to address: “…What are the time and cost scales of the R&D and associated test facilities as well as the time and cost scale of the facility?”
- A large number of possible accelerator projects: ILC, Muon Collider, gamma-gamma and ERL options, a large circumference electron ring, and a large circumference hadron ring amongst others.
- Comparison of the expected costs, using the same accounting rules, schedule, and R&D status for the projects.
- The Accelerator Implementation Task Force is charged with developing metrics and processes to facilitate a comparison between projects.


Steve Gourlay (LBNL)


Philippe Lebrun (CERN)


Thomas Roser (BNL, Chair)

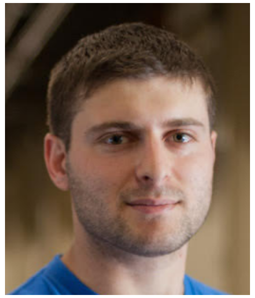

Tor Raubenheimer (SLAC)


Katsunobu Oide (KEK)


Jim Strait (FNAL)


Sarah Cousineau (ORNL)


Marlene Turner (LBNL)


Spencer Gessner (SLAC)


Vladimir Shiltsev (FNAL)


Reinhard Brinkmann (DESY)


John Seeman (SLAC)

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Status

- ITF continues to meet over Zoom every other week
- ITF is focusing on collider facilities. ITF developed a set of metrics to evaluate the proposals and concepts.
- Parameter spreadsheets of 27 collider proposals were collected from proponents. Several proposals have multiple parameter sheets.
- Four subcommittees are analyzing and comparing the proposals with regard to:
  - Physics reach and impact
  - Size, complexity, power consumption, and environmental impact
  - Technical risk, technical readiness, and validation
  - Cost and schedule
- With the delay of Snowmass, we have accepted additional proposals or updates to submitted proposals until the end of November 2021
- Tentative schedule:
  - draft report by February 2022 to be shared with proponents
  - Submit final ITF report by May 2022
  - Snowmass discussions in Seattle in July 2022

LHC example

CRITERION	SUB-CRITERION	ESTIMATOR [1]	VALUE	UNITS
Physics reach	Center-of-mass collision energy	Minimum ECM / maximum ECM	7000 / 14000	GeV / GeV
Physics reach	Center-of-mass energy spread at collision	RMS value	1.4	GeV
Physics reach	Vertex length	RMS value	45	mm
Physics reach	Design peak luminosity at nominal collision energy per IP		1.00E+34	cm^-2*s^-1
Physics reach	Length between IP and final focussing quad	Space available for detector	23	m
Physics reach	Minimum IP detector radius		0.03	m
Physics reach	Time between collisions		25	ns
Physics reach	Number of events per bunch crossing		~20	
Physics reach	Number of collision points		4	
Beam parameters	Nominal beam energy		7000	GeV
Beam parameters	Range of operational beam energy	Minimum energy / Maximum energy	3500 / 7000	GeV / GeV
Beam parameters	Stored Energy (per beam)	Enter numbers separated by slash for two unequal beams	362	MJ
Beam parameters	Beam power (per beam) at collision energy	Reactive power for rings, total beam power for Linacs and ERLs	4000000	MW
Beam parameters	Total lost power for both beams	Lost beam, synchrotron radiation power, beam power at beam dump ...	7.2	kW
Beam parameters	IP Beam sizes	Actual size; horizontal/vertical	16	micro-meter / micro-meter
Size and complexity of facility	Length of all accelerators	Perimeter/length	34	km
Size and complexity of facility	Length of new accelerators	Perimeter/length	27	km
Size and complexity of facility	Length of all tunnels	Perimeter/length	40	km
Size and complexity of facility	Length of new tunnels	Perimeter/length	6	km
Size and complexity of facility	Length of special insertions (final focus, collimation, ...)	included in lengths above		km
Size and complexity of facility	Number of new magnets		~9600	
Size and complexity of facility	Number of new acceleration cavities		16	
Size and complexity of facility	Total length of new vacuum chambers		60	km

LHC example

CRITERION	SUB-CRITERION	ESTIMATOR [1]	VALUE	UNITS
Technical risk	Three most important key technologies that require R&D	List of items; i.e.: SRF, undulators, collimation, SC magnets, ...	Hi-field SC magnets, handling of beams with large stored energy	
Technical risk	For each key technology fill in the three rows below:			
Technical risk key technology 1	Technology Readiness Level (TRL)	TRL value	N/A	
Technical risk key technology 1	Maturity	Select one: Concept, CDR, TDR, Demonstrator, Prototype, Preseries	N/A	
Technical risk key technology 1	Validation: demonstration projects required, ...	Select one: Full-scale/partial with scaling, separate/combined technologies	N/A	
Technical risk key technology 2	Technology Readiness Level (TRL)	TRL value	N/A	
Technical risk key technology 2	Maturity	Select one: Concept, CDR, TDR, Demonstrator, Prototype, Preseries	N/A	
Technical risk key technology 2	Validation: demonstration projects required, ...	Select one: Full-scale/partial with scaling, separate/combined technologies	N/A	
Technical risk key technology 3	Technology Readiness Level (TRL)	TRL value	N/A	
Technical risk key technology 3	Maturity	Select one: Concept, CDR, TDR, Demonstrator, Prototype, Preseries	N/A	
Technical risk key technology 3	Validation: demonstration projects required, ...	Select one: Full-scale/partial with scaling, separate/combined technologies	N/A	
Technical risk	Alignement tolerance	RMS value	50	micro-meter
Technical risk	Vibration tolerance	Frequncy and vibration amplitude of tightest contraint		micro-meter @ Hz
Technical Risk	Tuning stability	(if quantifieable)		
Schedule	Study and R&D to CDR (pre CD-1)	Duration *(Time to CDR)*	8	Years
Schedule	Design, industrialization, and TDR (post CD-1)	Duration	5	Years
Schedule	Civil Construction, fabrication. and Installation (post CD-3)	Duration	11	Years
Schedule	Commissioning	Duration	1	Years
Schedule	Operation to first physics results	Duration	1	Years
Schedule	Operation to full physics goals	Duration	Still pending	Years
Validation and preparation	Scope of demonstration projects	List of demonstration projects	Full-scale industrial prototype magnets, Lattice full cell	
Validation and preparation	size of demonstration projects	Total length/perimenter	0.12	km
Validation and preparation	Estimated total cost of demonstration projects	Cost	30	2021 MUSD [4]
Validation and preparation	Industrialization, planning (pre-CD2: R&D and design)	Cost (needed investments and cost for personnel)		2021 MUSD

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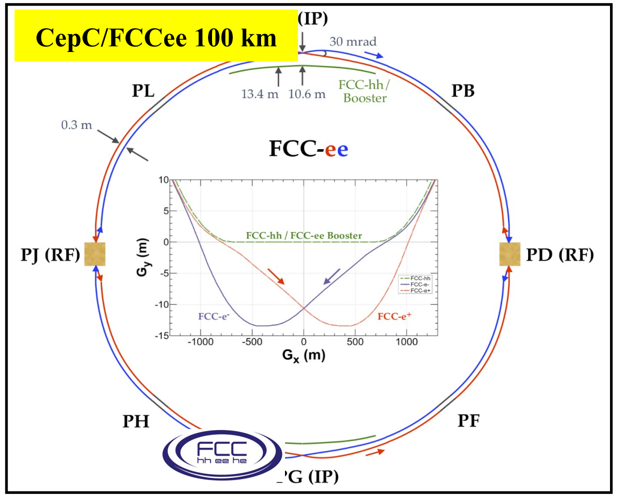
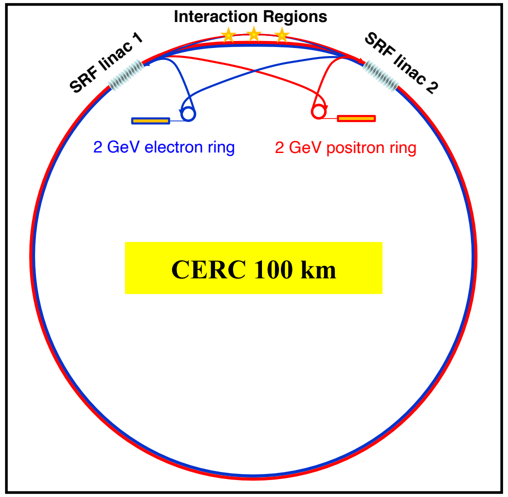
LHC example

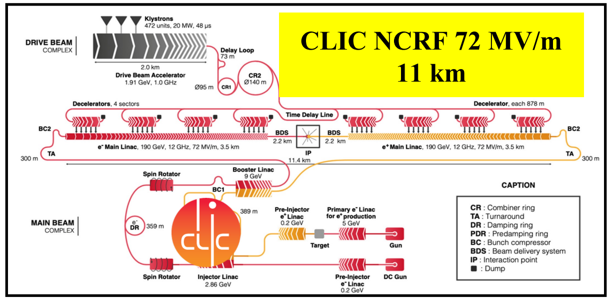
CRITERION	SUB-CRITERION	ESTIMATOR [1]	VALUE	UNITS
Construction cost	New accelerator systems	Cost [2]	4060	2021 MUSD
Construction cost	New accelerator infrastructure	Cost [2] (i.e.: utilities, cryogenics and safety/access systems, etc.)	940	2021 MUSD
Construction cost	New civil construction	Cost [2]	1810	2021 MUSD
Construction cost	Personnel	Explicit labor [3]	7000	Person years
Construction cost	Estamted uncertainty	Percent of total cost	N/A	%
Commisioning cost	including personnel, electric energy, M&S - get KPPs	Cost	200	2021 MUSD
Decommissioning cost		Cost, if known		2021 MUSD
Operation & maintenance	Electrical power consumption	Total power consumption of complete facility	122	MW
Operation & maintenance	Annual electrical energy consumption		750	GWh/year
Operation & maintenance	Energy management	e.g. Turndown capability in peak hours, etc	Limited turndown capability, 90 MW in cold standby	
Operation & maintenance	Maintenance & spares	Cost		2021 MUSD/year
Operation & maintenance	Personnel	Explicit labor [3]		Person years/year (FTEs)
Environmental impact	Land use	Total above ground area		km^2
Environmental impact	Radiation risk (low-medium-high)	Types and doses at the boudary; might be qualitative assessment		Dose mSv/year
Environmental impact	Effluents	Types and quantities of pollutants, excluding CO2		Quantity/year
Environmental impact	Carbon footprint reductions	List of planned activities and equipment to reduce carbon footprint		
Environmental impact	Heat rejection & disposal	Cooling tower, re-usage, etc		
Economic/technological impact		if known		
Cultural/educational impact		if known		
[1] « Cost & explicit labor »: methodology, independent of any particular accounting system, adopted by ITER & ILC	[2] Cost: lowest reasonable estimate of the price of goods and services procured from industry on the world market in adequate quality and quantity	[3] Explicit labor: personnel provided by central laboratory and collaborating institutes		[4] Escalate to 2021 in local currency at 2% per year and then covert to USD.

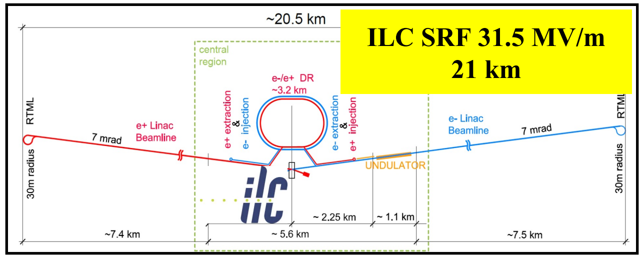
Higgs factory concepts (12)

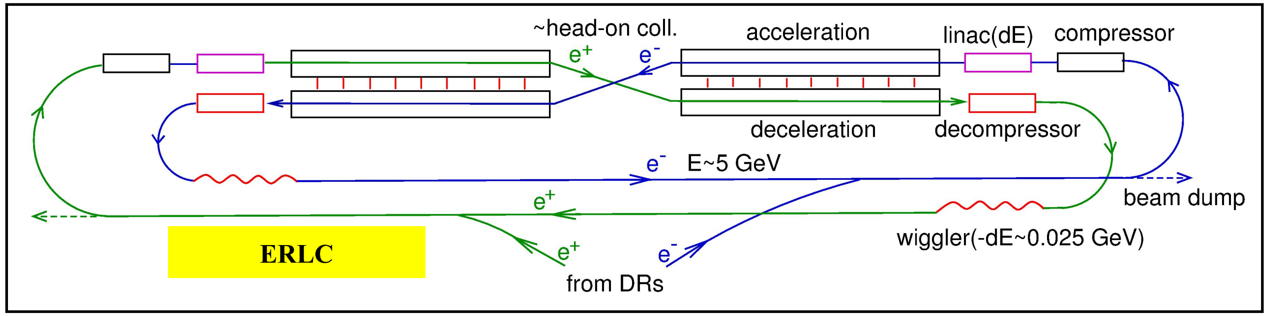
Name	Nominal COM energy and peak luminosity per IP at nominal energy
FCC-ee	e+e-, $\sqrt{s}$ = 0.24 TeV, L= 8.5 $\times 10^{34}$
CEPC	e+e-, $\sqrt{s}$ = 0.24 TeV, L= 2.9 $\times 10^{34}$
ILC (Higgs factory)	e+e-, $\sqrt{s}$ = 0.25 TeV, L= 1.35 $\times 10^{34}$
CCC (Cryo Cooled Collider)	e+e-, $\sqrt{s}$ = 0.25 TeV, L= 1.3 $\times 10^{34}$
CLIC (Higgs factory)	e+e-, $\sqrt{s}$ = 0.38 TeV, L= 1.5 $\times 10^{34}$
CERC (ERL ee collider)	e+e-, $\sqrt{s}$ = 0.24 TeV, L= 78 $\times 10^{34}$
ReLiC (Linear ERL Cillider)	e+e-, $\sqrt{s}$ = 0.24 TeV, L= 115 $\times 10^{34}$
ERLC (ERL Linear Collider)	e+e-, $\sqrt{s}$ = 0.25 TeV, L= 100 $\times 10^{34}$
XCC FEL-based $\gamma\gamma$ collider	ee ($\gamma\gamma$),$\sqrt{s}$ = 0.125 TeV, L= 0.1 $\times 10^{34}$
Circular ee Fermi site filler	e+e-, $\sqrt{s}$ = 0.24 TeV, L= 1.2 $\times 10^{34}$
TWLC Fermi site filler	e+e-, $\sqrt{s}$ = 0.25 TeV, L= 1.4 $\times 10^{34}$
MC (Higgs factory)	$\mu\mu$, $\sqrt{s}$ = 0.13 TeV, L= 0.01 $\times 10^{34}$

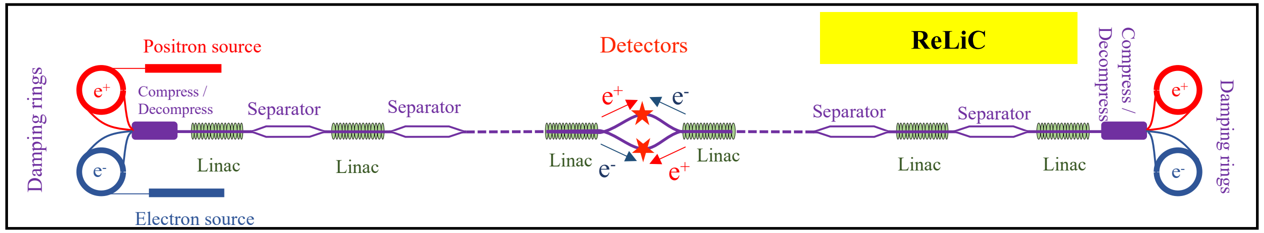


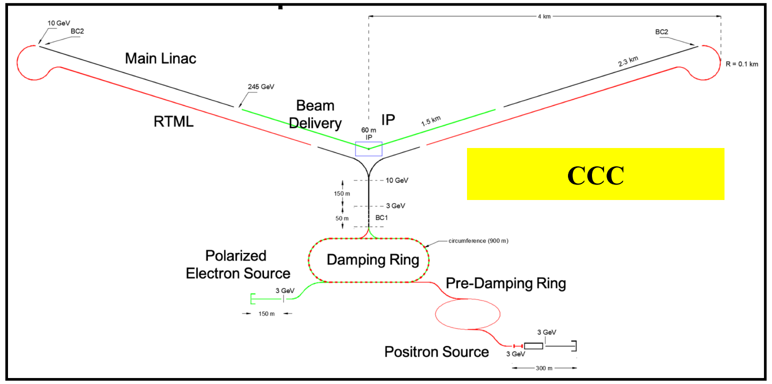












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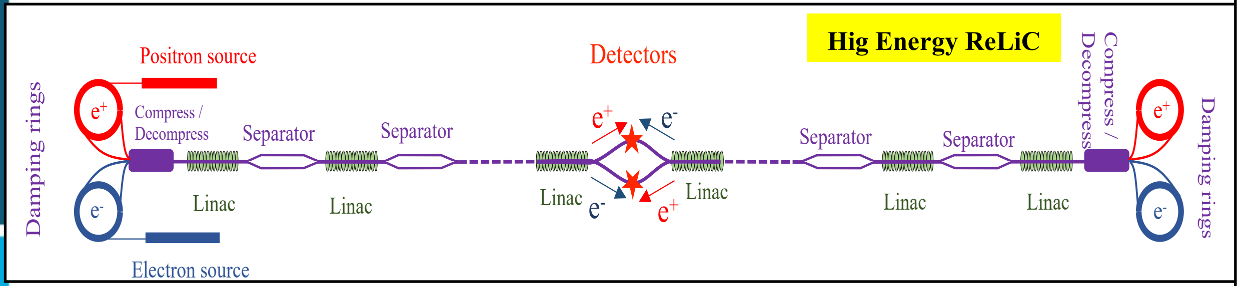
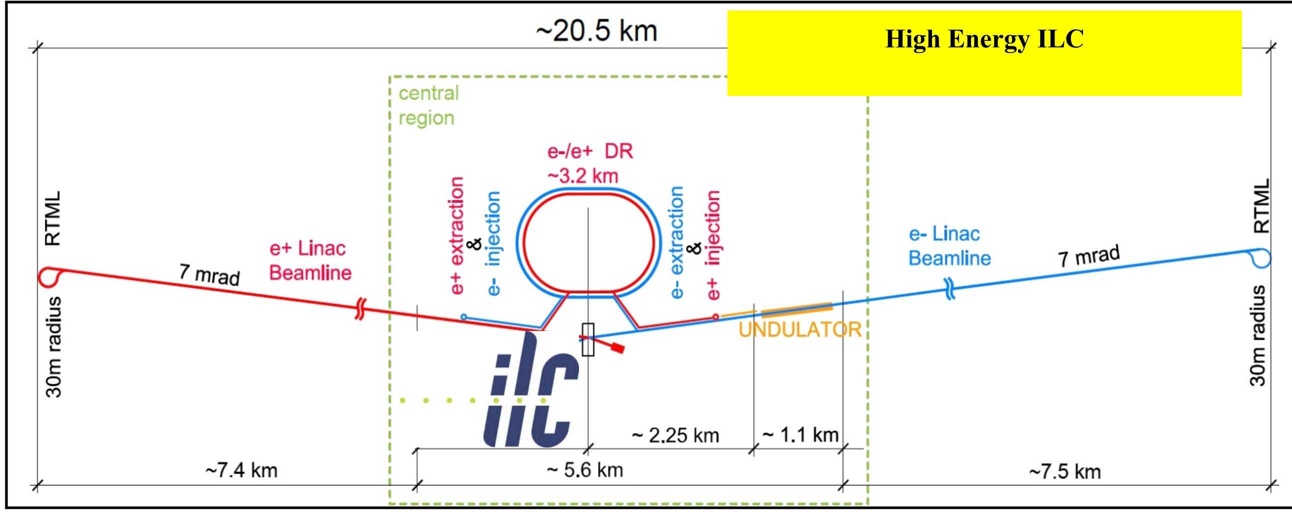
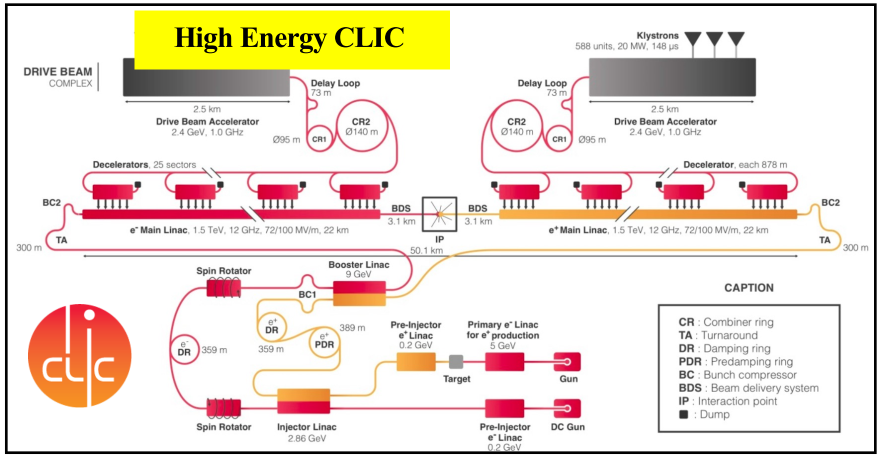
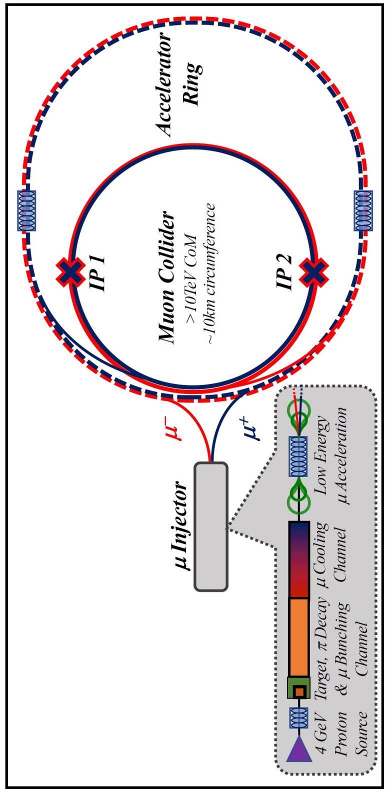
High energy lepton collider concepts(9)

Name	Nominal COM energy and peak luminosity per IP at nominal energy
High Energy ILC	e+e-, $\sqrt{s} = 3$ TeV, L= 6.1 $\times 10^{34}$
High Energy CCC	e+e-, $\sqrt{s} = 3$ TeV, L= 6.0 $\times 10^{34}$
High Energy CLIC	e+e-, $\sqrt{s} = 3$ TeV, L= 5.9 $\times 10^{34}$
High Energy ReLiC	e+e-, $\sqrt{s} = 3$ TeV, L= 33 $\times 10^{34}$
MC – Proton Driver	$\mu\mu$, $\sqrt{s} = 3$ TeV, L= 2.25 $\times 10^{34}$
MC – Fermi site filler	$\mu\mu$, $\sqrt{s} = 6 - 10$ TeV, L= 20 $\times 10^{34}$
LWFA-LC (e+e- and $\gamma\gamma$)	Laser driven plasmas; e+e-, $\sqrt{s} = 1 - 30$ TeV
PWFA-LC (e+e- and $\gamma\gamma$)	Beam driven plasmas; e+e-, $\sqrt{s} = 1 - 30$ TeV
SWFA-LC	Structure wake fields; e+e-, $\sqrt{s} = 1 - 30$ TeV

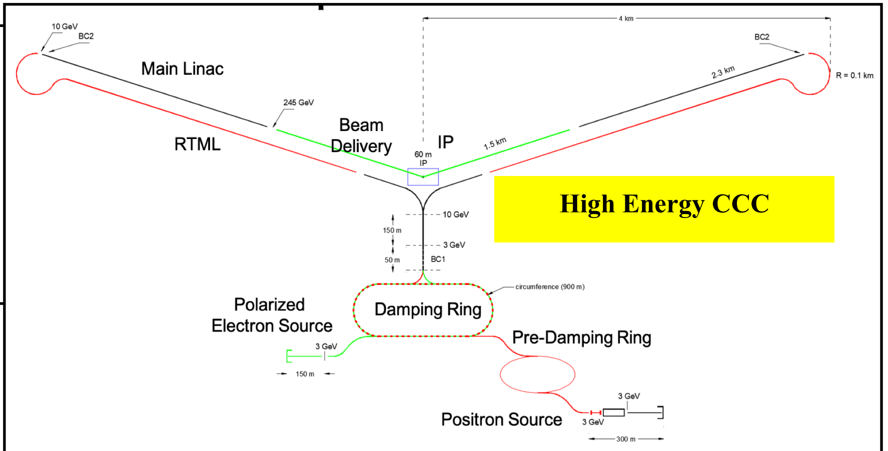






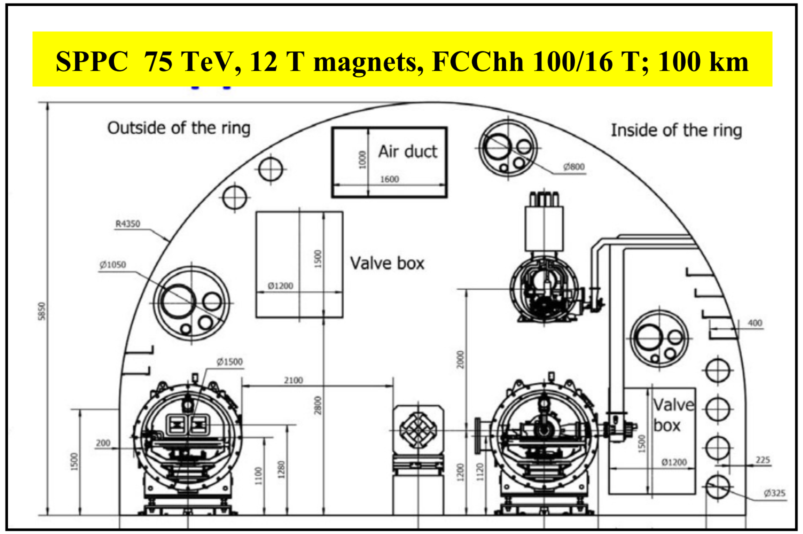


$\mu^+\mu^-$ 10-14 TeV cme
10-14 km, 16 T magnets



High energy hadron and lepton/hadron collider concepts (6)

Name	Nominal COM energy and peak luminosity per IP at nominal energy
FCC-hh	pp, $\sqrt{s} = 100$ TeV, L= 30 $\times 10^{34}$
SPPC	pp, $\sqrt{s} = 75/150$ TeV, L= 10 $\times 10^{34}$
Collider-in-Sea	pp, $\sqrt{s} = 500$ TeV, L= 50 $\times 10^{34}$
LHeC	ep, $\sqrt{s} = 1.3$ TeV, L= 1 $\times 10^{34}$
FCC-eh	ep, $\sqrt{s} = 3.5$ TeV, L= 1 $\times 10^{34}$
CEPC-SPPpC-eh	ep, $\sqrt{s} = 6$ TeV, L= 4.5 $\times 10^{33}$



Higgs factory summary plot

From European Strategy Study 2021:

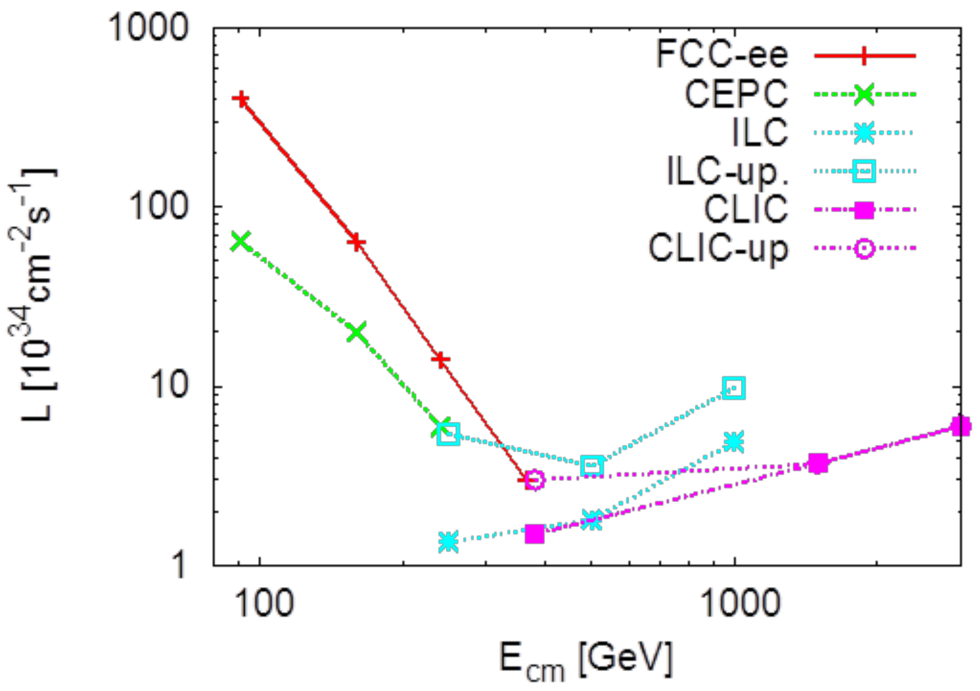
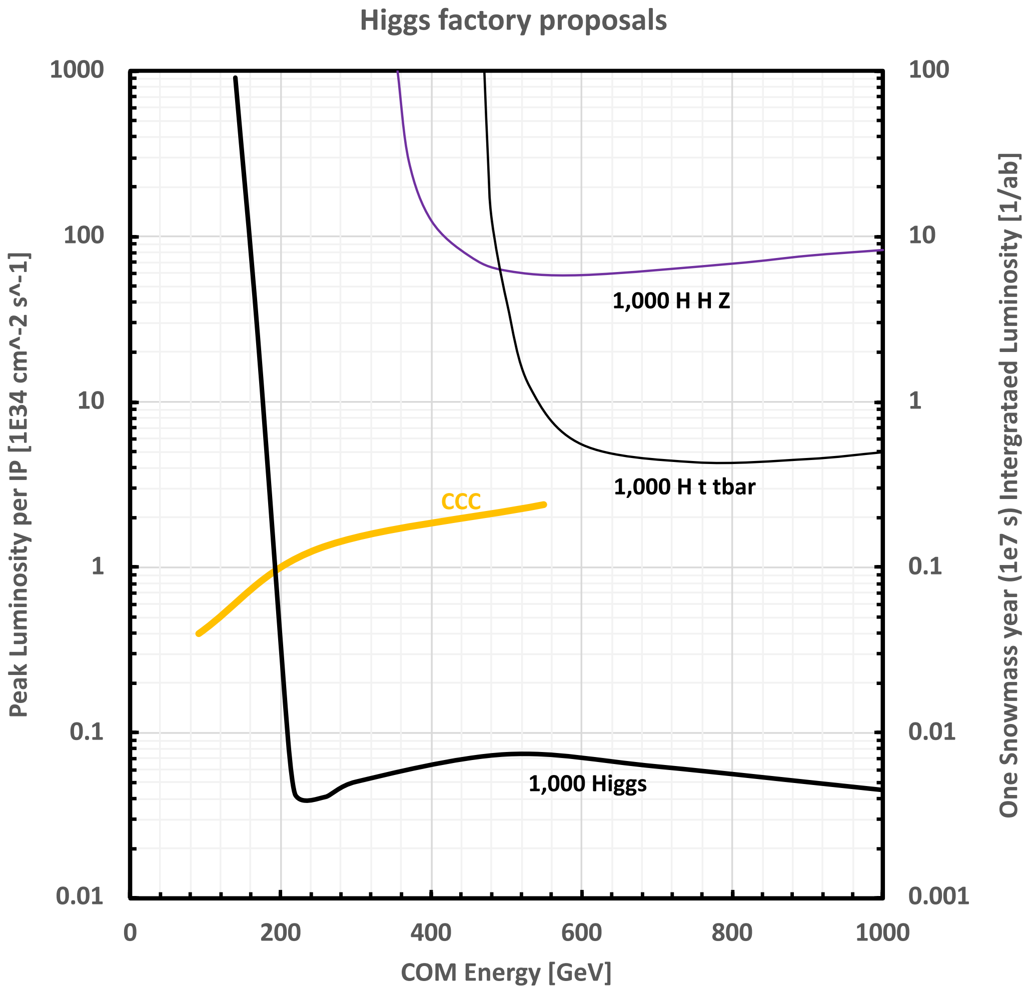


Fig. 10.2: Luminosity versus c.m. energy for e^+e^- Higgs Factories. Two IPs are assumed for the circular colliders FCC-ee and CEPC.



Peak luminosity per IP vs COM energy for the Higgs factory propoals as privided by the proponents. The right axis shows integrated luminosity for one Snowmass year. Also shown are lines correspinding to 1,000 events for processes that include Higgs particles and a line corrsponding to the production of 1,000 Higgs.

- Plot lumi vs. energy as reported by proponents
- Plan to plot lumi/IP (lumi for one IP) and only one version
- What physics measures should be plotted? Requesting input from proponents.

Possible Higgs factory comparison table

Proposal Name	Nominal COM energy (Range) [TeV]	Luminosity per IP at nominal COM energy [10^{34} cm^{-2} s^{-1}]	Years of pre-construction R&D required	Construction cost range, including explicit labor [2021 MUS$]	Estimated operating electric power consumption [MW]
FCC-ee	0.24 (0.09 - 0.37)	8.5			
CEPC	0.24 (0.09 - 0.24)	2.9			
ILC (Higgs factory)	0.25 (0.09 - 3)	1.35			
CCC (Cryo Cooled Collider)	0.25 (0.25 - 0.55)	1.3			
CLIC (Higgs factory)	0.38 (0.09 - 0.38)	1.5			
CERC (ERL ee collider)	0.24 (0.09 - 0.6)	78			
ReLiC (Linear ERL Collider)	0.24 (0.09 - 1.0)	115			
ERLC (ERL Linear Collider)	0.25	100			
XCC FEL-based $\gamma\gamma$ Collider	0.125 (0.125 - 0.14)	0.1			
Circular ee Fermi site filler	0.24	1.2			
TWLC Fermi site filler	0.25	1.4			
MC (Higgs factory)	0.13	0.01			