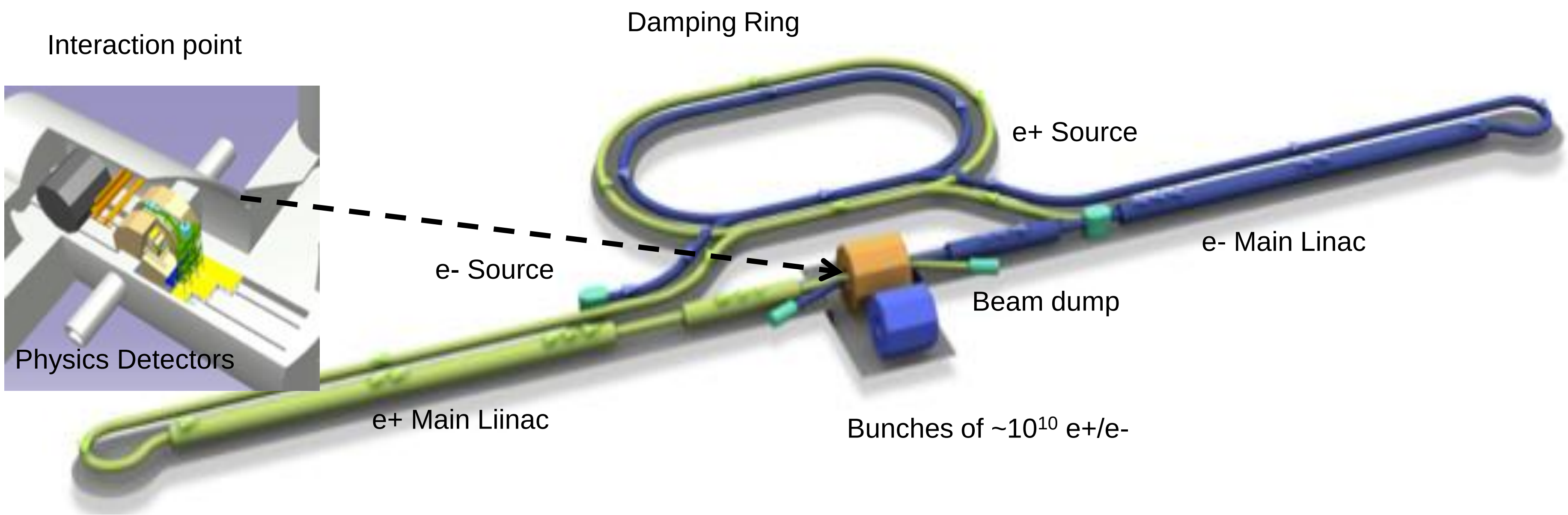
ILC-ITN

Outline

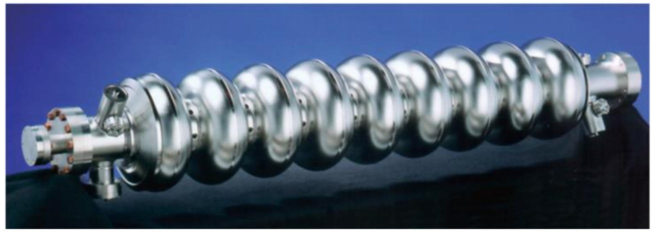
- ILC and the ILC Development Team (IDT)
- The ILC Technology Network (ITN)
- European activities

Steinar Stapnes – CERN

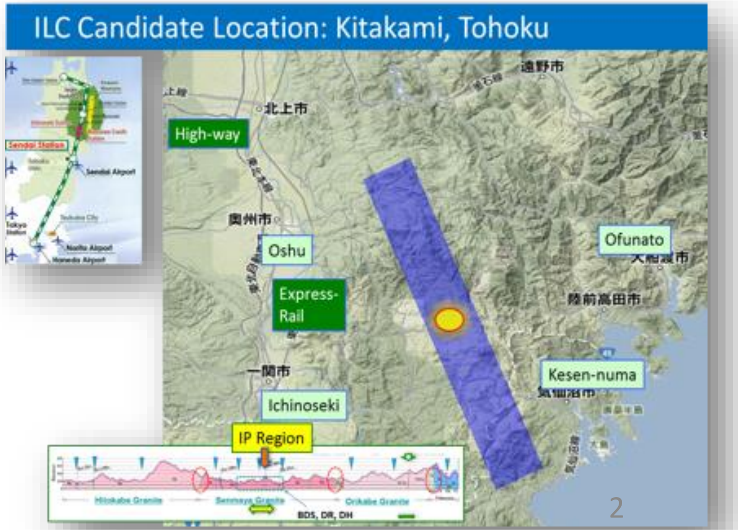
The ILC250 accelerator facility



Item	Parameters
C.M. Energy	250 GeV
Length	20km
Luminosity	1.35 $\times 10^{34}$ $cm^{-2}s^{-1}$
Repetition	5 Hz
Beam Pulse Period	0.73 ms
Beam Current	5.8 mA (in pulse)
Beam size (y) at FF	7.7 nm@250GeV
SRF Cavity G. Q_0	31.5 MV/m (35 MV/m) $Q_0 = 1\times10^{10}$



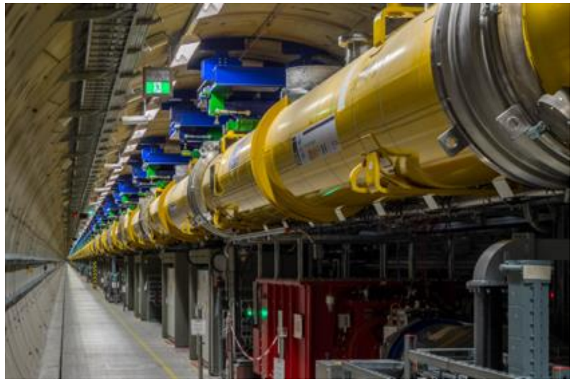
Parameters and plans for luminosity and energy upgrades are available, interesting and relevant SCRF R&D also for such upgrades (Snowmass input)



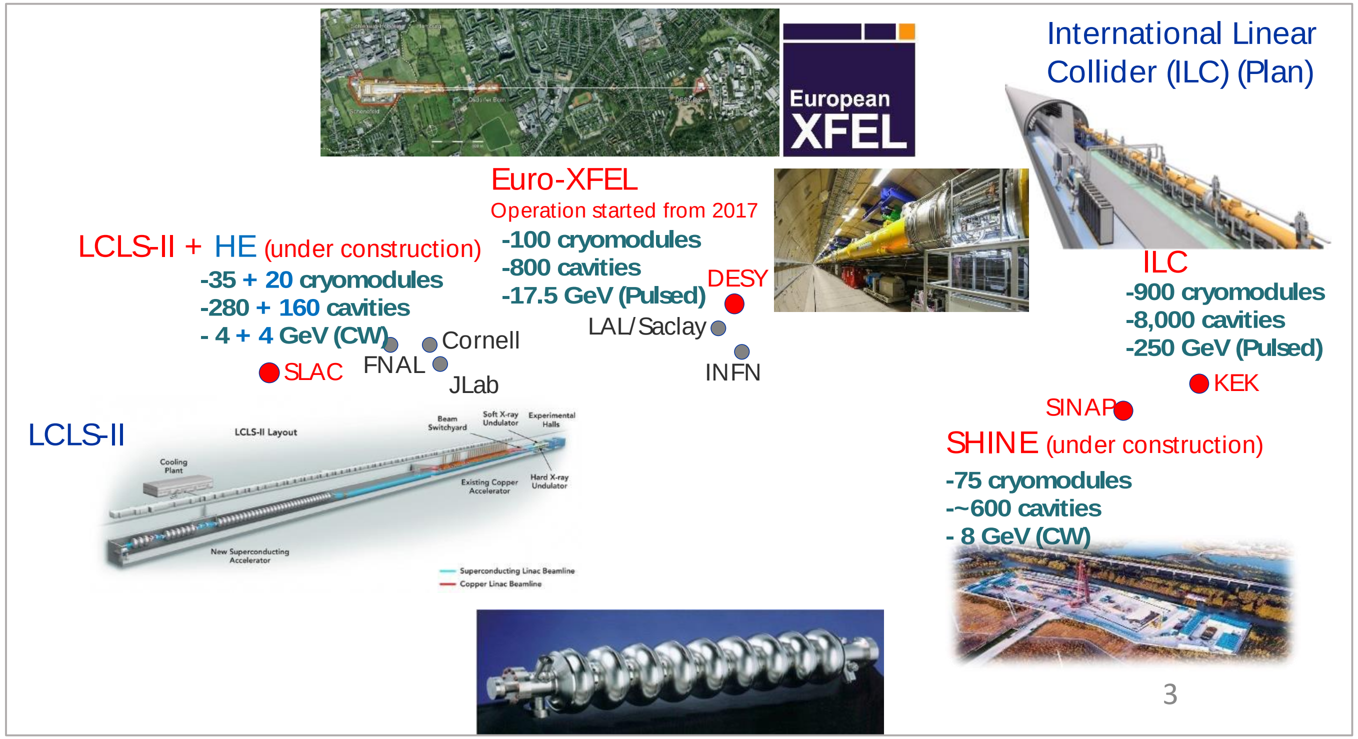
Key systems and challenges

The ILC is a very mature design, with a comprehensive TDR

Next steps involve technical developments and industrial prototyping with final specs as needed for an Engineering Design and in preparation of pre-series and construction



- Creating particles — Sources
  - polarized elections/positrons
- High quality beam — Damping ring
  - low emittance beams
- Acceleration — Main linac
  - superconducting radio frequency (SRF)
- Collide them — Final focus
  - nano-meter beams
- Go to — Beam dumps



The ILC IDT organization – initiated at the ICFA meeting at SLAC February 2020

2020-21: The IDT – created by ICFA and hosted by KEK – was set up to move ILC towards construction. The worldwide structure of the WGs: https://linearcollider.org/team/
A set of key activities were identified in a Preparation Phase Programme.

2022-23: A subset of the technical activities of the full ILC preparation phase programme have been identified as critical (next slide). These are being addresses by a ~4 year programme called ITN – the ILC Technology Network. Moving forward with this work is being supported by the MEXT (ministry) providing crucial increased funding.

As of today: With funding from 1.4.2023 ITN is now starting. An agreement KEK and CERN and several European lab activities have been/are being set up. In the US the P5 process is ongoing, the hope is that ITN planning and interests can turn into important ITN involvements in due time.

S.Michizono - LCWS 2023: IDT Scope for ILC realization

international development team

-success oriented and asuming no major incident-

Technology Network Phase | **Preparatory Phase** | **Construction Phase ~10 years for the construction and commissioning**

2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	• • •

R&D and effort to gain a common view and understanding.

ILC preparation laboratory and intergovernmental discussion

2021 May

Technical Preparation and Work Packages (WPs) during ILC Pre-lab

Work Packages (**WPs**) for ILC Pre-Lab

2022 June

Time-critical WPs for the ILC construction

WP-Primes for Time Critical work

ILC Technology Network (ITN)

-- global collaboration program **--**

- Acc. R&Ds focusing on
  - SRF
  - e- & e+ Sources
  - Nano-beam

} Synergy with other colliders

KEK obtained a budget for these R&Ds and started the activity from this April.

The ITN

Promoting the technological development of the International Linear Collider: Twenty-eight research institutes participated in the ITN Information Meeting

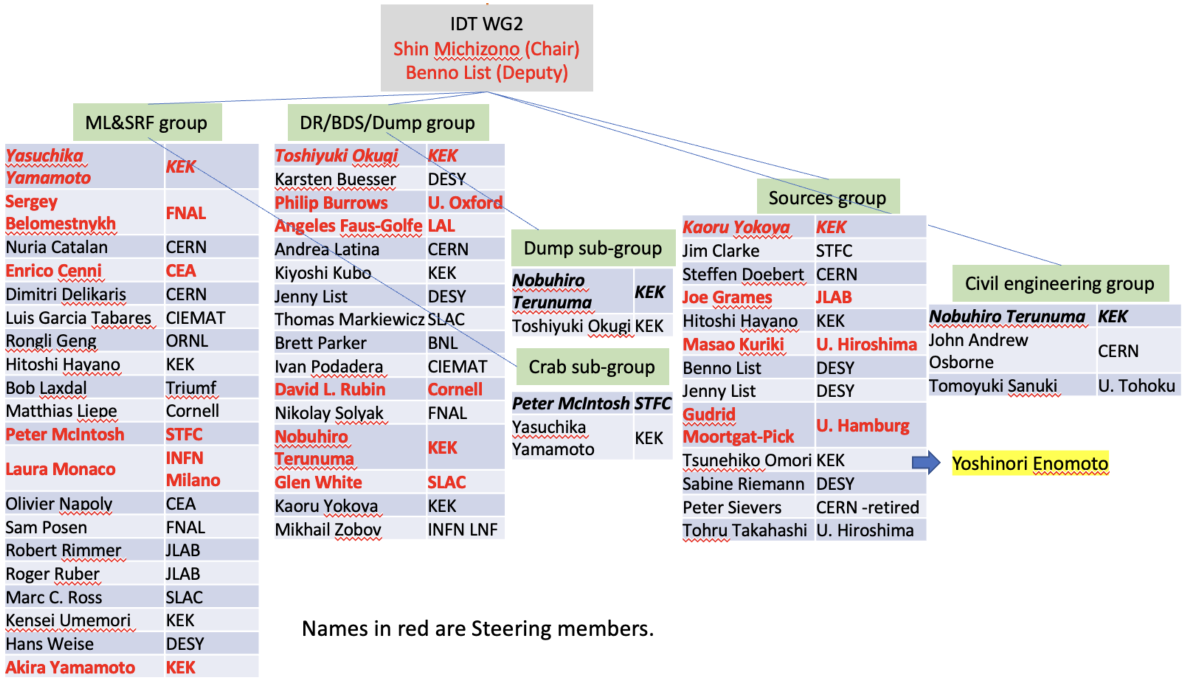
WPP	1	Cavity production
WPP	2	CM design
WPP	3	Crab cavity
WPP	4	E- source
WPP	6	Undulator target
WPP	7	Undulator focusing
WPP	8	E-driven target
WPP	9	E-driven focusing
WPP	10	E-driven capture
WPP	11	Target replacement
WPP	12	DR System design
WPP	14	DR Injection/extraction
WPP	15	Final focus
WPP	16	Final doublet
WPP	17	Main dump

Building the ITN activities:

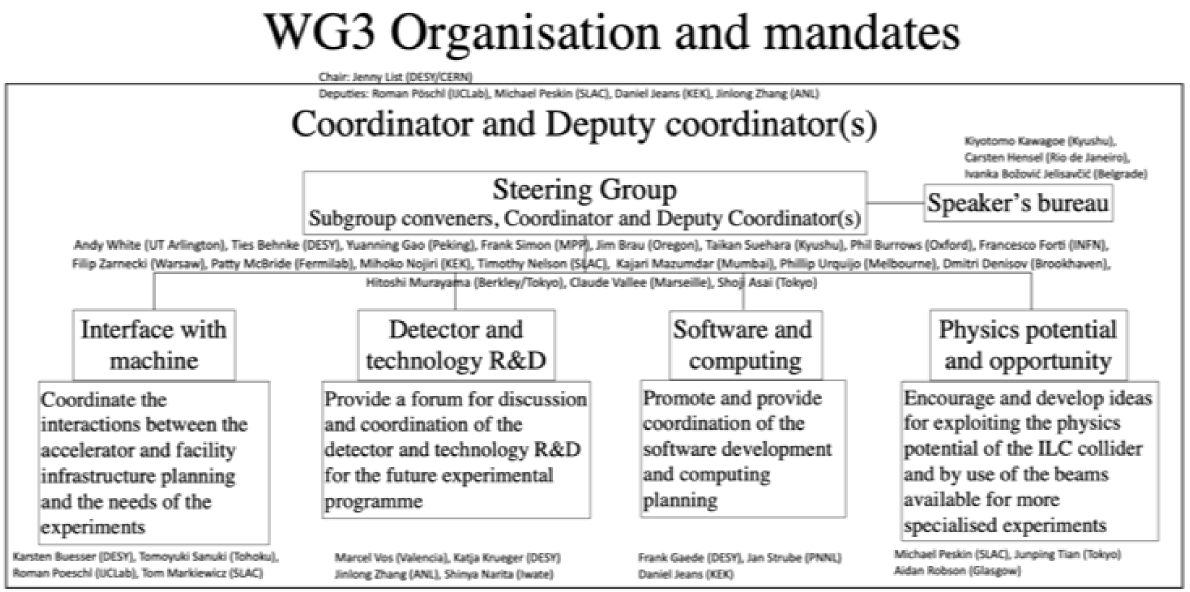
- Planning in the IDT WG2 – significant interests and expertise already represented
- Information meeting at CERN 16-17.10 jointly organized by KEK and the IDT
- Interest matrix for the ITN work-packages, being consolidated
- The next step: Further technical discussion to define deliverables, followed by agreement who among the laboratories will deliver what

SRF	WPP	1	Cavity production	✓		✓	✓	✓			✓	✓	✓				✓	✓	✓		✓	✓		✓	✓	
	WPP	2	CM design	✓				✓				✓			✓	✓	✓	✓	✓			✓		✓	✓	
	WPP	3	Crab cavity			✓	✓							✓					✓			✓	✓		✓	✓
Sources	WPP	4	E-source			✓						✓							✓		✓			✓		
	WPP	6	Undulator target				✓												✓	✓			✓			
	WPP	7	Undulator focusing				✓												✓	✓			✓			
	WPP	8	E-driven target	✓		✓												✓	✓							
	WPP	9	E-driven focusing	✓														✓	✓							
	WPP	10	E-driven capture	✓															✓					✓		
	WPP	11	Target replacement	✓																						
Nano-beams	WPP	12	DR System design	✓	✓				✓	✓		✓							✓				✓	✓		
	WPP	14	DR Injection/extraction	✓					✓										✓				✓	✓		
	WPP	15	Final focus	✓			✓		✓		✓							✓			✓			✓		
	WPP	16	Final doublet	✓	✓													✓								
	WPP	17	Main dump	✓			✓					✓														

Focus on Europe

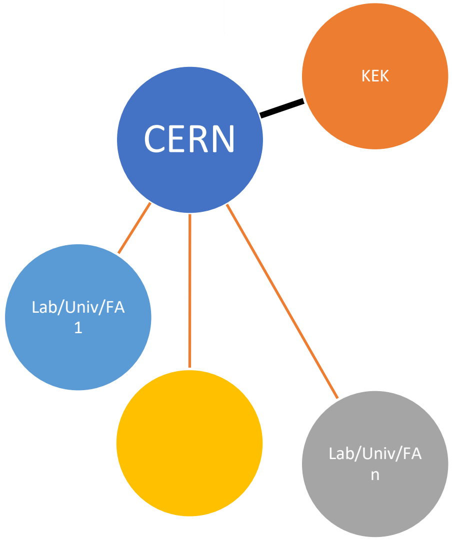


Names in red are Steering members.



European Organisation of the ITN programme

- CERN plays coordinating and facilitating role
- KEK contributes to the material costs
- Main contract for flow of funds between CERN and KEK. Subsequent contracts – similar to what is done for other studies for future colliders – between CERN and European Labs in the cases where money flow is needed (limited number)



The European ITN activities – 2023

European ITN studies are distributed over five main activity areas:

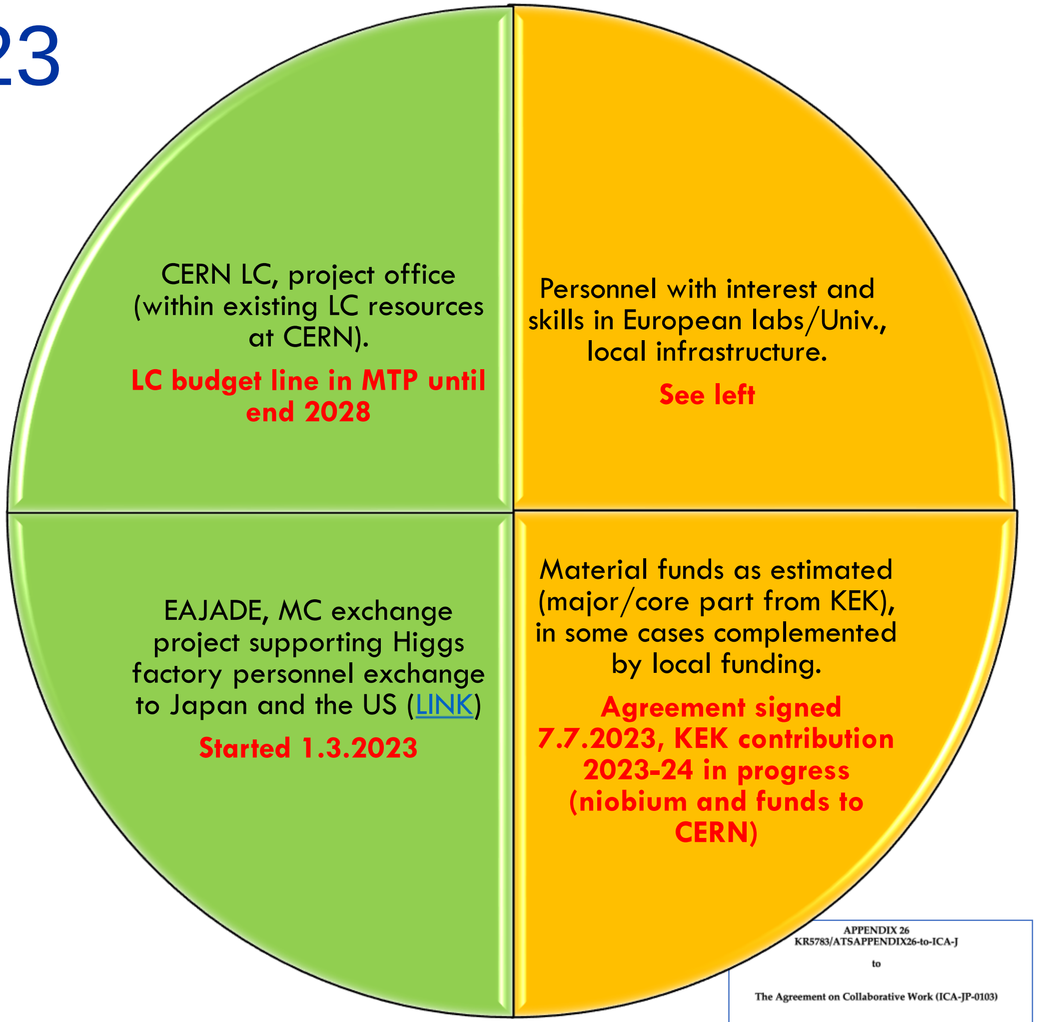
A1 with three SC RF related tasks
- SRF: Cavities and Cryo Module (INFN, CEA, DESY, IJCLAB)
- Crab-cavities (UK)
- Main Linac elements: ML quads and cold BPMs (CIEMAT, IFIC)

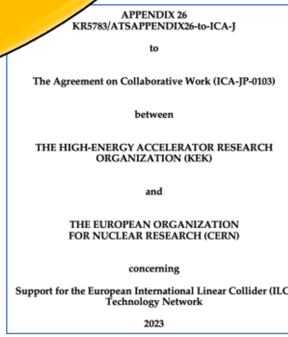
A2 Sources
- Pulsed magnet (Uni.H, DESY, CERN)
- Wheel/target (the same and possibly UK groups)

A3 Damping Ring including kickers
- Low Emittance Ring lab(s) (UK)

A4 ATF activities for final focus and nanobeams
- On-going/restarted (UK, DESY, IJCLAB, CERN, IFIC)
- MDI (DESY, IJCLAB, Tel Aviv, UK groups)

A5 Implementation including Project Coordination
- Dump, CE, Cryo – significant earlier efforts at CERN, follow up under discussion
- Sustainability, Life Cycle Assessment (CERN, DESY, CEA, UK groups)
- EAJADE started (EU funding) (DESY, UK, CEA, CNRS, IFIC, INFN, UHH, CERN)




APPENDIX 26
KR5783/ATSAPPENDIX26-to-ICA-J

to

The Agreement on Collaborative Work (ICA-JP-0103)

between

THE HIGH-ENERGY ACCELERATOR RESEARCH ORGANIZATION (KEK)

and

THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

concerning

Support for the European International Linear Collider (ILC) Technology Network

2023

Green: Being implemented
Yellow: Programme being defined with partners
Red: Programme in Europe less well defined

A1: SRF Cavities, Cryomodule design, Crab cavities

Production process

	# of cavities to be produced		
	Americas	Europe	JP/Asia
single-cell	2	2	2
nine-cell	8	8	8 (+ 12)

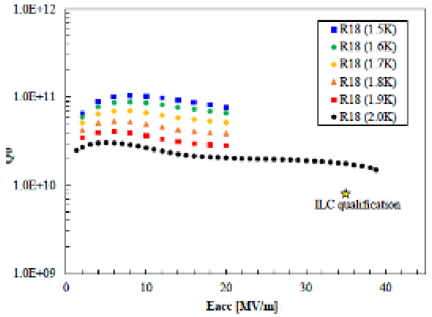
Material/Sub-component

QA of Material/Sub-C

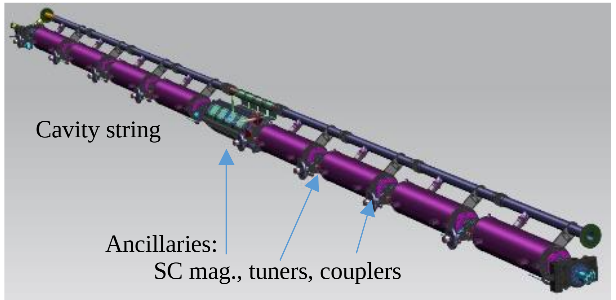
Cavity Production

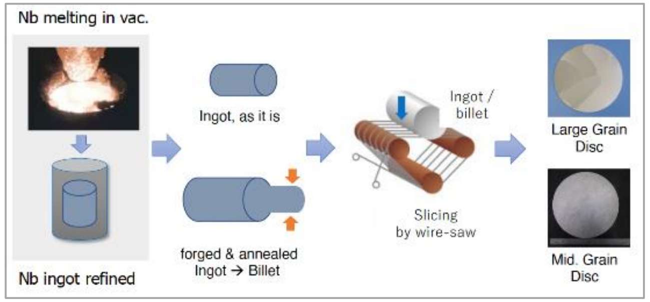
Surface Process

Vertical Test = Cavity RF Test



Unify cryomodule (CM) design with ancillaries, based on globally common drawings and data-bases.

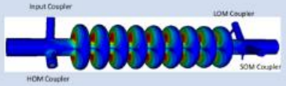
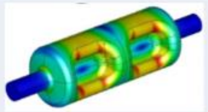
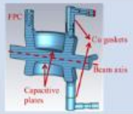
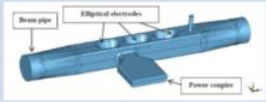




SCRF (Grad, Q) is a priority for most future high energy accelerators, also beyond HEP

Crab cavity down-selection, including developments of evaluation to choose final cavity design

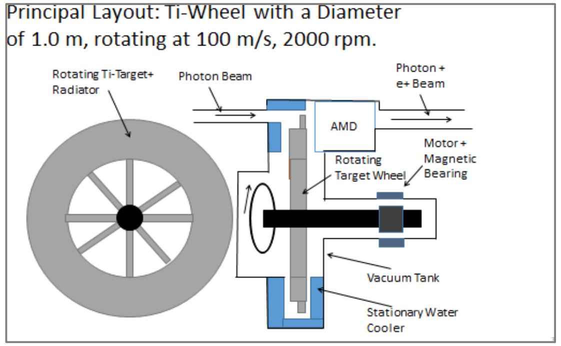
Cryomodule design based on final cavity design

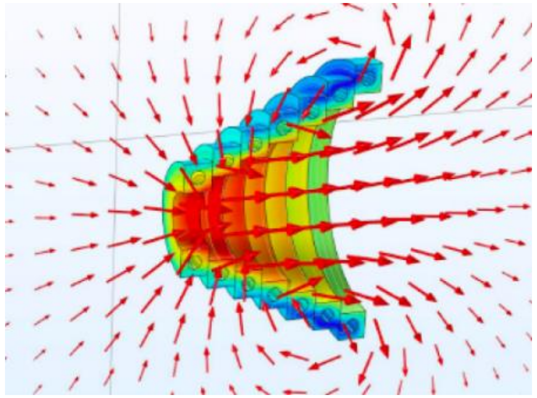
Elliptical/Racetrack (3.9 GHz)	Lanc. Univ.	
RF Dipole (RFD)	ODU	
Double Quarter Wave (DQW)	CERN	
Wide Open Waveguide (WOW)	BNL	
Quasi-waveguide MultIcell Resonator (QMIR)	FNAL	

Links to general studies of crab cavity solutions: (among others for HL-LHC, EIC and Elettra2.0)

A2: Positron Source

- A priority item for the undulator scheme is the magnetic focusing system (OMD) right after the target
- The main candidate is a pulsed solenoid (PS), design and prototyping

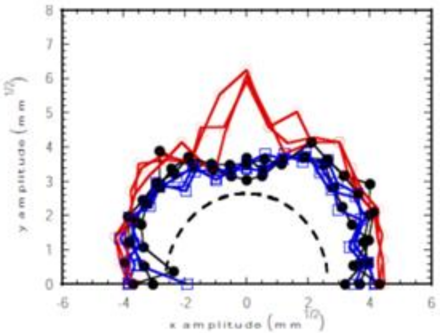


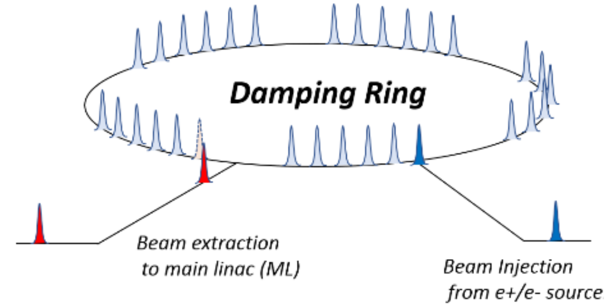


For polarized positrons, providing physics advantages, linking also to FEL/undulators studies.

A3: Damping Ring optimization and injection/extraction

- The ILC damping ring (DR) is required to satisfy the low emittance and the large dynamic aperture simultaneously.
- The ILC DR will be further improved by incorporating the findings of the latest light source design. Increasing the dynamic aperture is also important in the design of DR.
- The technical evaluation of the fast kicker system, prototyping



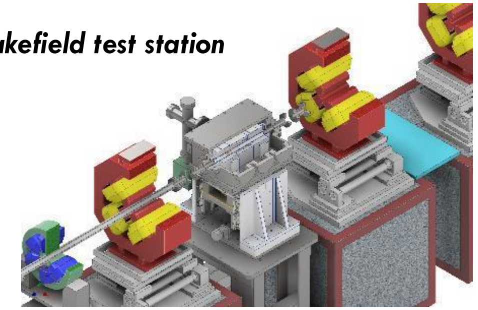


Many group can find this interesting and have capabilities to do it, there is a large and well organised low emittance ring community in Europe – and many also with experience from similar studies and prototyping for CLIC and FCC-ee.

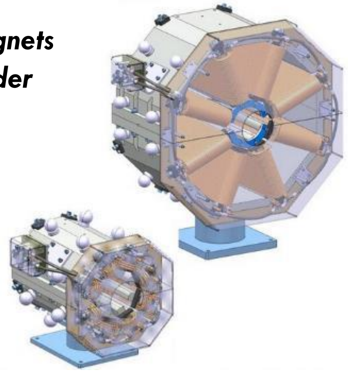
A4: ATF3 (final focus, nanobeams)

- ATF2 beamline at KEK is the only existing test accelerator in the world to test the final focus system (FFS) of linear colliders.
- The following 3 research topics are important topics to be pursued at the ATF; wakefield mitigation, correction of higher-order aberration, ILC beam tuning studies

Wakefield test station



Octupole magnets for higher-order aberration



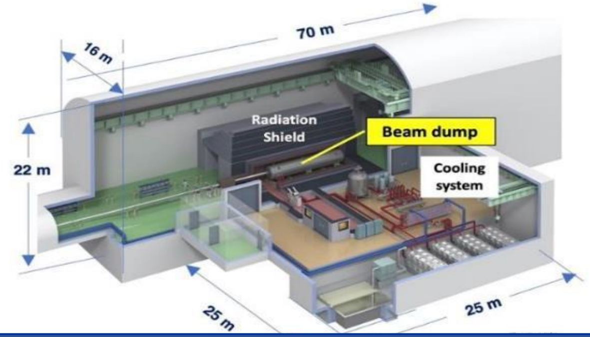
ATF2 beamline

Very relevant studies for any linac and Higgs factory closely related to low emittances and nano beams, e.g. alignment, stabilisation, instrumentation, beam-dynamics, etc.

- Strong European leadership with several group from France, UK, Spain, Germany and also CERN, also extensively used for PhD training
- Supported also by MC researcher exchange programme and EAJADE (LINK)

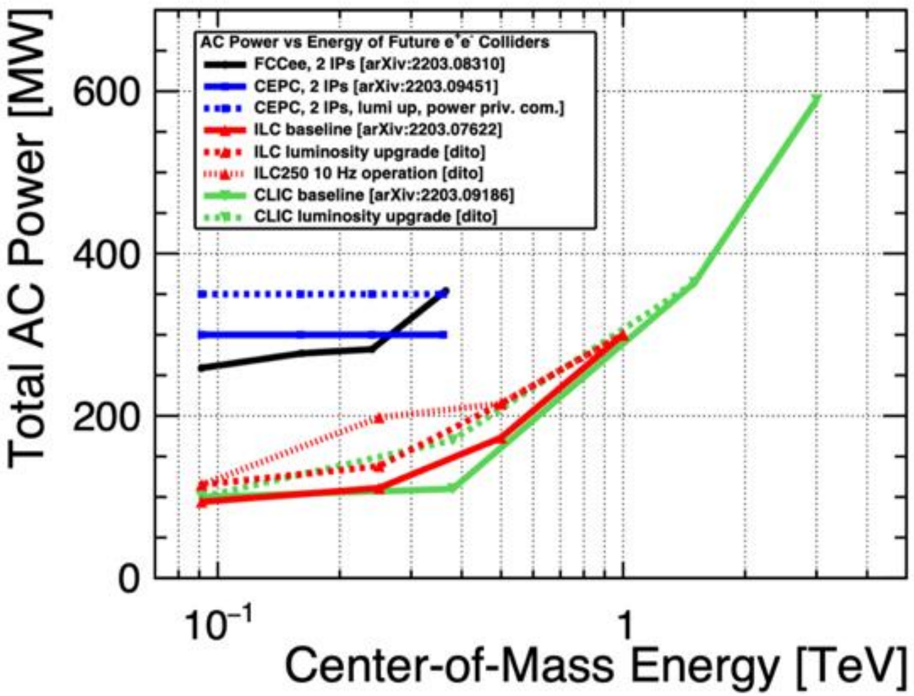
A5: Implementation studies

- ITN integration activities – in Europe and within international effort, and interfaces to other ILC activities and related R&D studies
- Link to existing collaborative efforts on CE and Cryo (CERN, DESY, KEK)
- Common studies CLIC/ILC on sustainability issue (ongoing), e.g. power, energy and running models, CO_2 (sustainability is also an EAJADE WP), beam-dump engineering studies.
  - the four activities above are all addressing optimisation of lum. to power, and/or power consumption directly for ILC
  - will also connect to green ILC studies in Tohoku within EAJADE (e.g. facility integration in local environment and infrastructure, carbon emission goals, power availability and sources)
- Connecting to ILC physics and detector developments, in particular MDI (also a focus of EAJADE)



Involved: ITN and EAJADE communities
Many of these topics are related to exploiting communalities between EXFEL, HL-LHC or CLIC and ILC and are continuations of collaborate work.

Power and energy

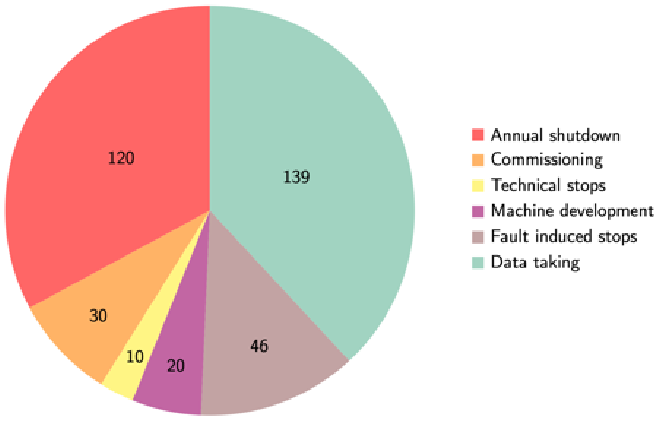


Power at 250-380 GeV in the 100-150 MW range for the projects above, reaching ~500 MW at 3 TeV for CLIC

With a running scenario on the right this corresponds to 0.6-0.8 TWh annually

CERN is currently consuming 1.2 – 1.3 TWh annually

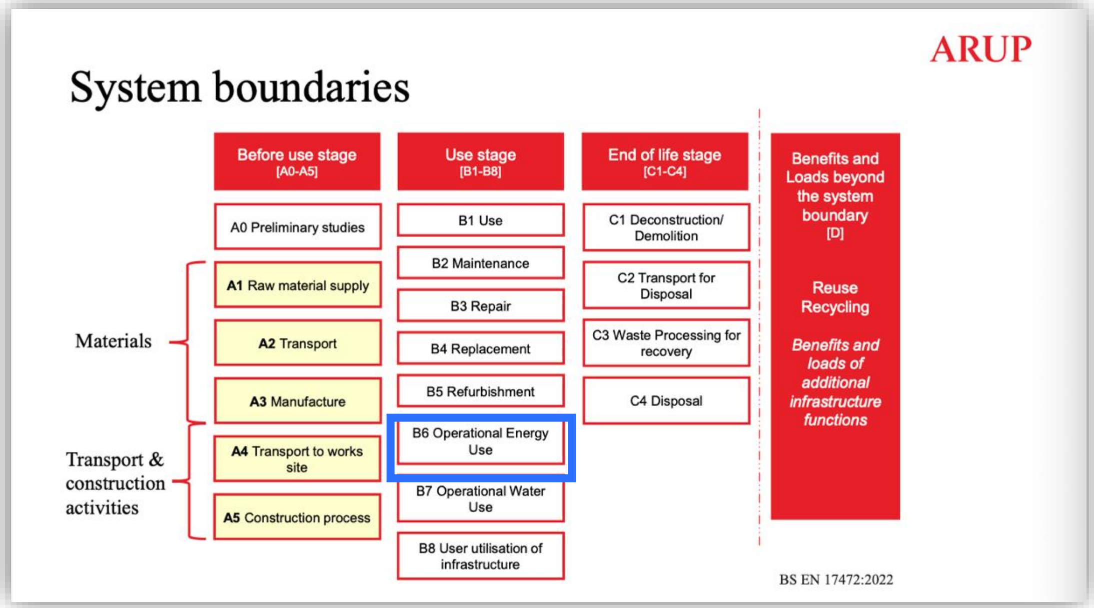
CERN "standard" running scenario used to convert to annual energy use



Includes studies of overall designs optimisation to reduce power, SRF cavities (grad,Q), cryo efficiency, RF power system (klystrons, modulators, components), RF to beam efficiencies, permanent magnets, operation when power is abundant, heat recovery, nanobeam and more.
Recent overview (LINK)

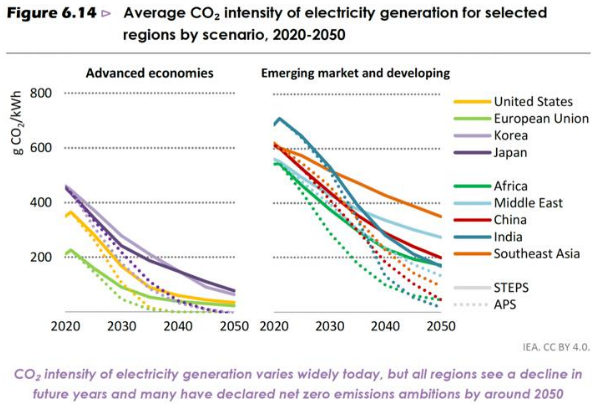
Sustainability: towards a Life Cycle Assessment (LCA) for LCs

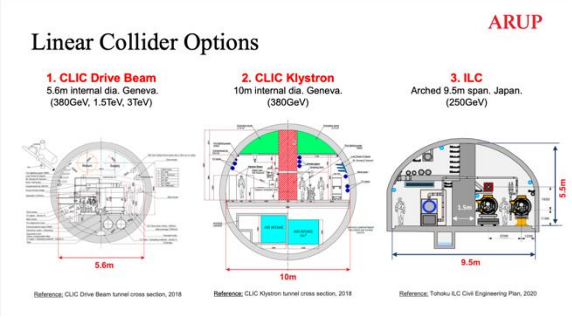
LCA report for Civil Engineering: LINK

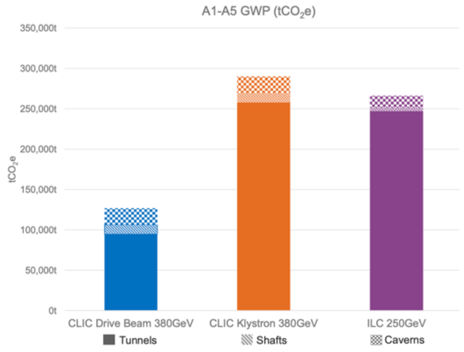


What is the carbon intensity of energy in ~2050 (operation):

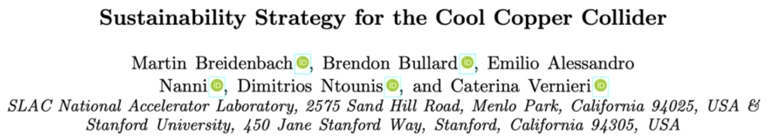
- 50% nuclear and 50% renewable give ~10-15g/kWh
- France summer-months are today ~40g/kWh
- ILC has a green implementation concept including compensation and contracting renewable energy
- Reductions predicted (LINK)







Recent C^3 paper using the LCA "methodology", also including considerations for other projects, is also well worth studying: LINK

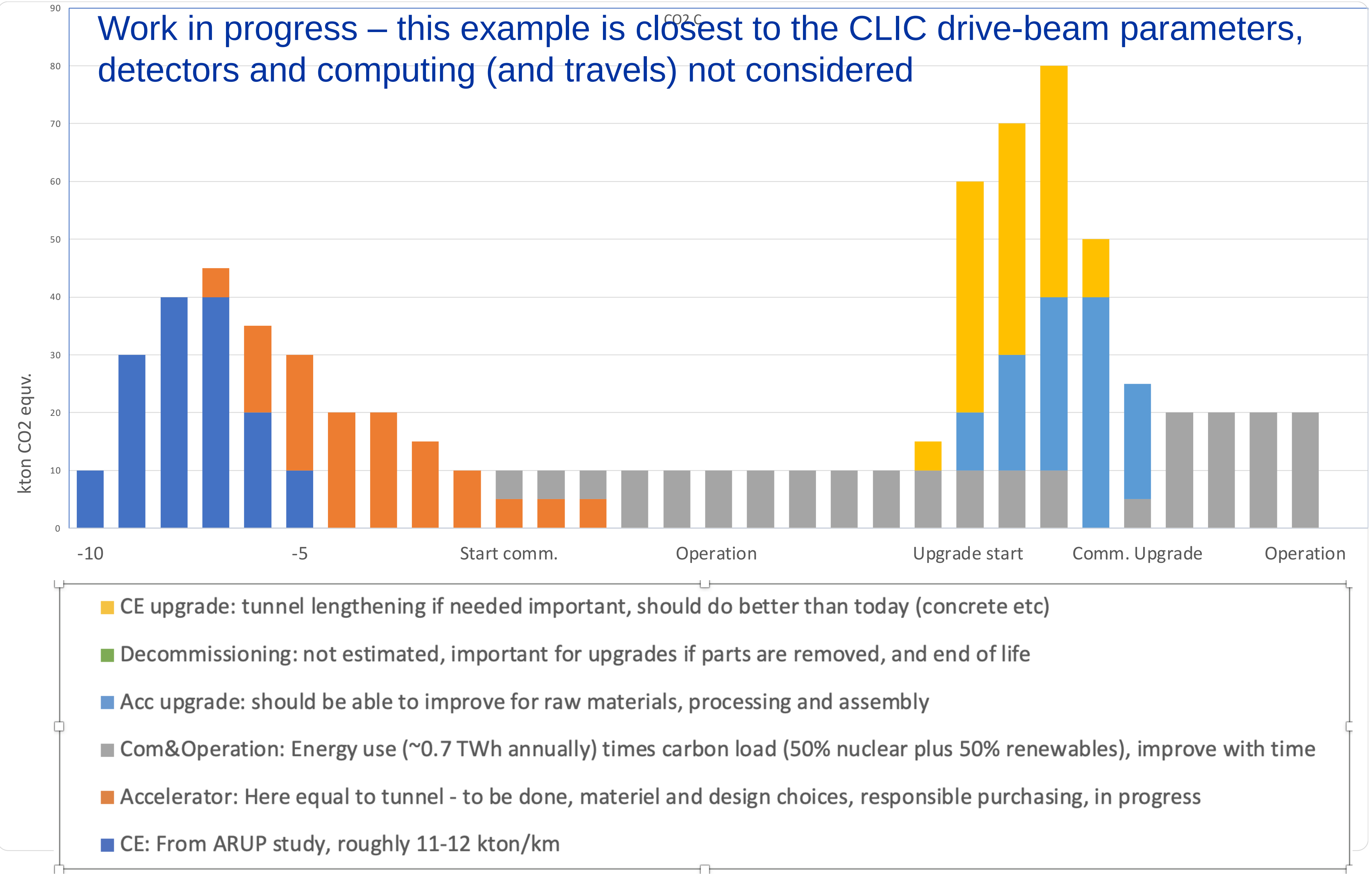

Sustainability Strategy for the Cool Copper Collider

Martin Breidenbach, Brendon Bullard, Emilio Alessandro Nanni, Dimitrios Ntounis, and Caterina Vernieri
SLAC National Accelerator Laboratory, 2575 Sand Hill Road, Menlo Park, California 94025, USA & Stanford University, 450 Jane Stanford Way, Stanford, California 94305, USA

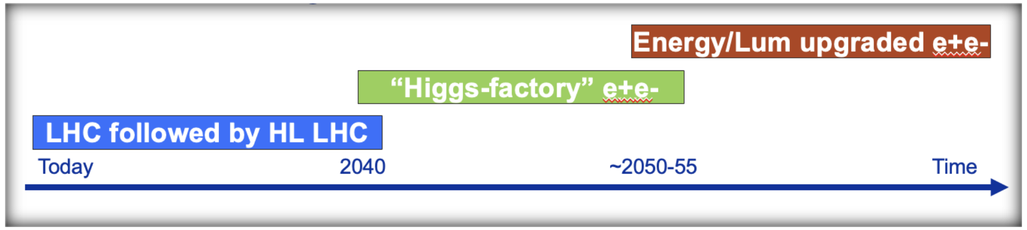
Around 11-12 kton/km main linac (CLIC DB and ILC)

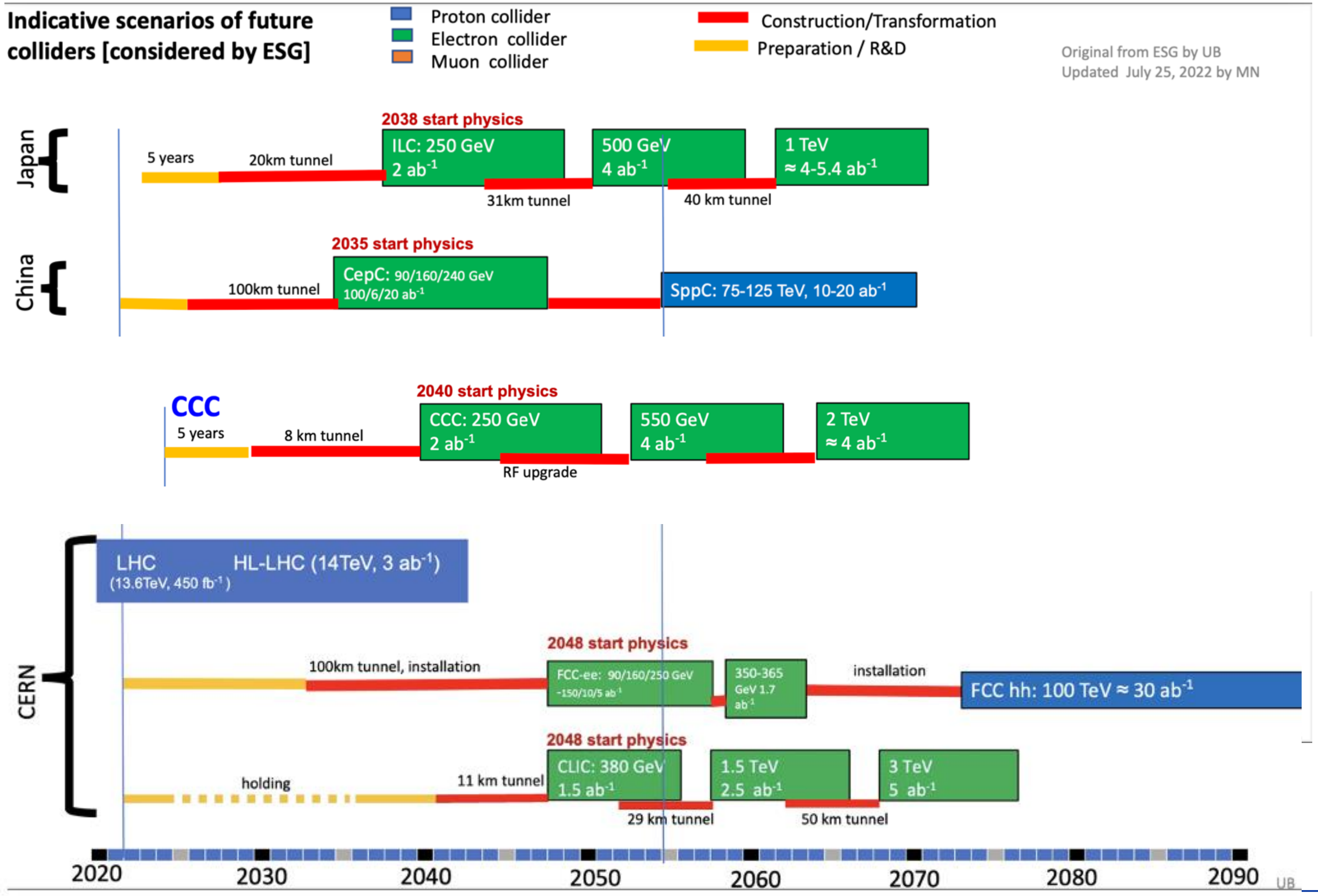
Towards Carbon Accounting with LCA

Work in progress – this example is closest to the CLIC drive-beam parameters, detectors and computing (and travels) not considered



Timelines in Snowmass Energy Frontier summary





Comments:

- Timelines are technologically limited – except the CERN projects that are linked to completion of the HL-LHC
- From Meenakshi Narain EF summary Snowmass

Personnel estimate and cost – Higgs factories

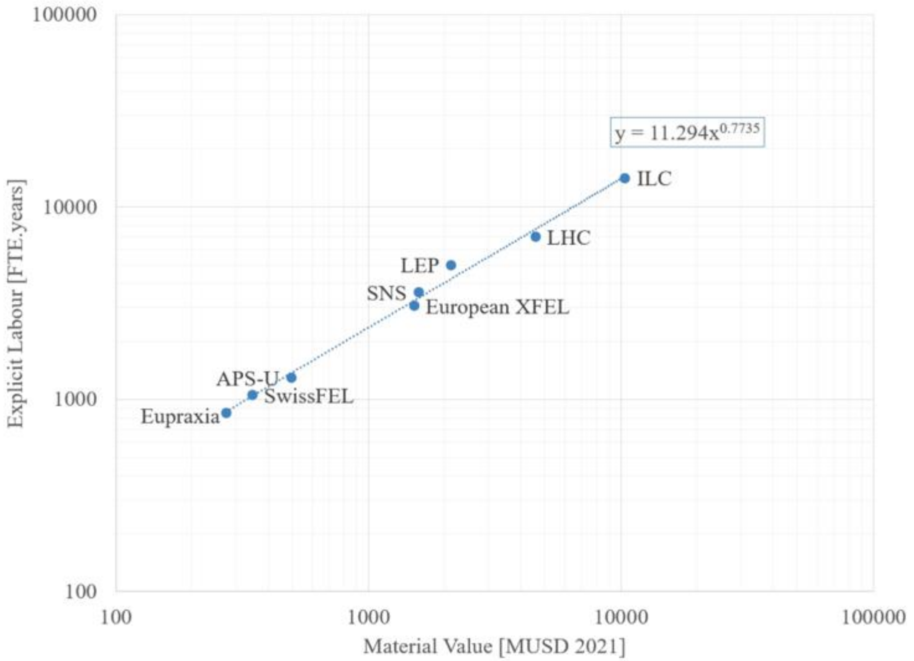


Figure 5: Explicit labor for several large accelerator projects vs. project value.

One FTEy estimated to 200kUS$

Detailed PBS/WBS based reviewed number exists for ILC and CLIC, but not consistently updated to 2023 including currency changes and inflation – nevertheless good agreement

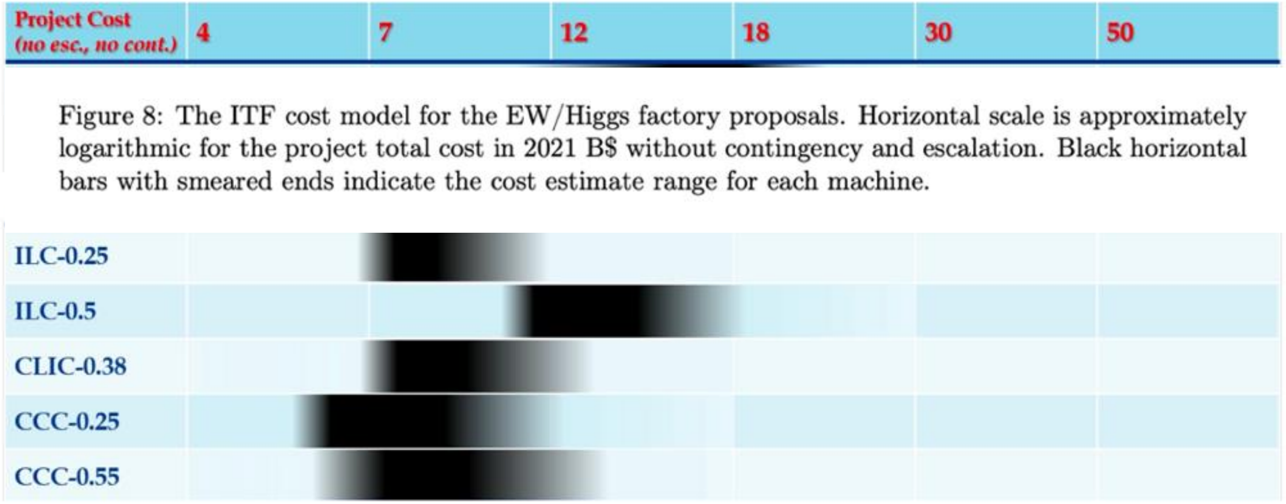
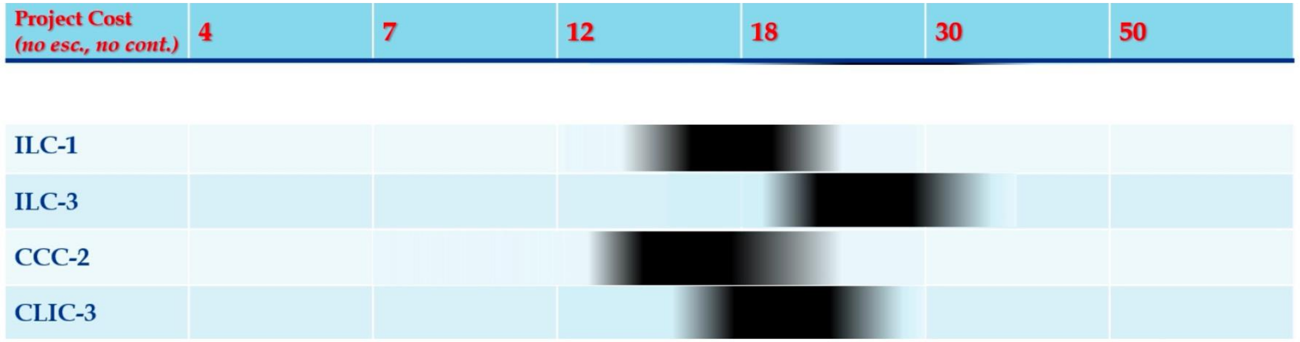


Figure 8: The ITF cost model for the EW/Higgs factory proposals. Horizontal scale is approximately logarithmic for the project total cost in 2021 B$ without contingency and escalation. Black horizontal bars with smeared ends indicate the cost estimate range for each machine.



This estimate from the Snowmass process includes personnel costs (usually kept separate, e.g. ILC and CLIC)

An adaptable e+e- LC facility

A LC facility can be extended in length for higher energies, using the same or improved versions of the same technology, e.g. as suggested for ILC, CLIC, C3 and HALHF.

- It is also possible and realistic to change to more performant (usually higher gradient) technologies in an upgrade, e.g. from ILC to CLIC or C3, maybe even plasma
- Starting point for fast implementation: ILC has the most mature linac technology for large scale implementation, that is also well established in all regions and in industry - it is based on a 20-21km long and ~9-10m wide tunnel
- The physics at higher energies – Higgs sector and extended models with increased reach and precision, top in detail well above threshold, searches and hopefully new physics – will open for a very exciting long term e+e- programme
- Such a programme can run in parallel with future hadron and/or muon colliders that can be developed, optimised and implemented as their key technologies mature

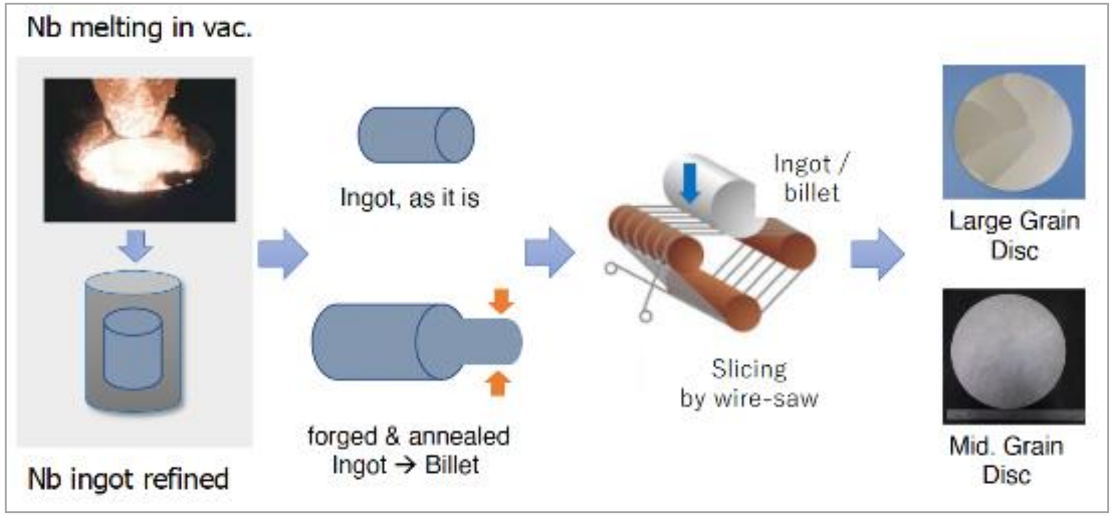
Thanks to many ILC colleagues, in particular I’m using some slides from Shin Michizono

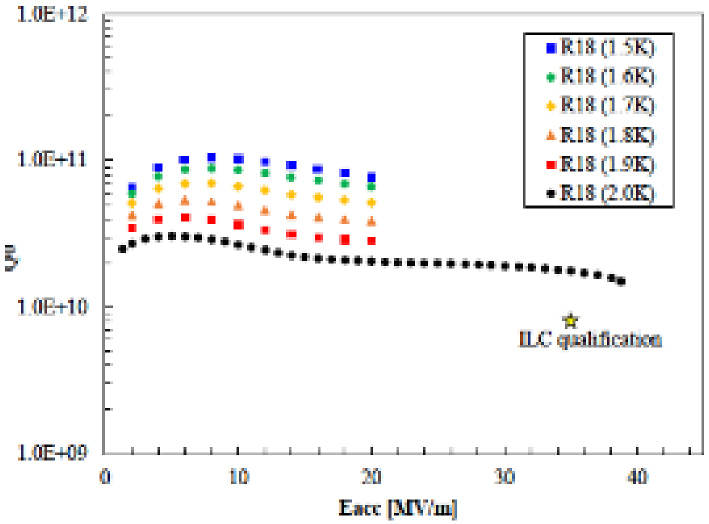
Example - WP-prime 1: SRF Cavity
(Scoping the Industrial-Production Readiness)

Referring European XFEL and LCLS-II experiences

- Research with single-cell cavities to establish the best production process including:
  - Advanced Nb sheet production method
  - Advanced surface treatment recipe
- Globally common design with compatible High Pressure Gas Safety (HPGS) regulation
- 24 nine-cell cavities are to be developed for industrial-production readiness
  - 8 cavities (4 / batch) in each region
  - Production process encouraged to be optimized in each region
  - Cavity performance expected: E_{acc} = <35 MV/m> (+/− 20%), $Q_0 = 1.0 \times 10^{10}$, Yield = ≥90%
- RF performance/success yield to be examined (including 2nd pass and further)
  - 3rd pass to be examined if effective

	# of cavities to be produced		
	Americas	Europe	JP/Asia
single-cell	2	2	2 (+4)
nine-cell	8	8	8 (+ 4)

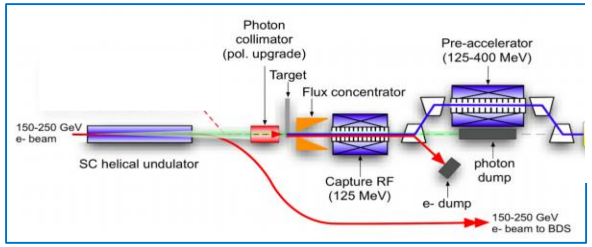




Material/Sub-component
↓
QA of Material/Sub-C
↓
Cavity Production
↓
Surface Process
↓
Vertical Test = Cavity RF Test

Production process

Example - WP-Prime 6/7:
Undulator-driven e+ Source

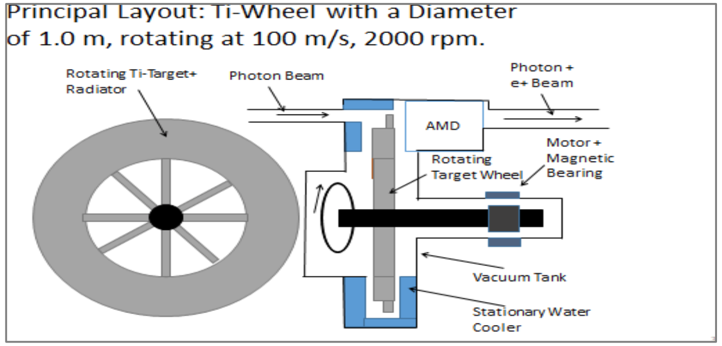


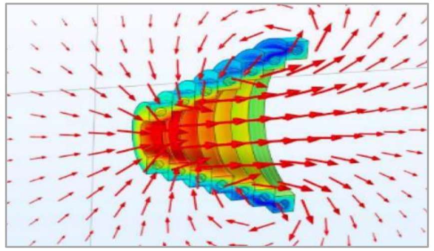
WP-prime 6: Rotating Target for Undulator Scheme

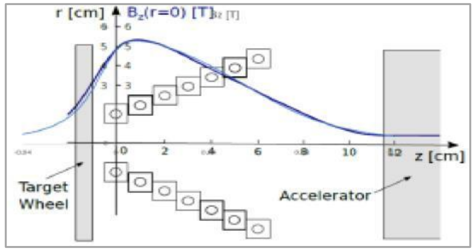
- Target specification
  - Titanium alloy, 7mm thick (0.2 X_0), diameter 1m
  - Rotating at 2,000 rpm (100 m/s) in vacuum
  - Photon power ~60 kW, deposited power ~2 kW
  - Radiation cooling
  - Magnetic bearings
- R&D to be done as WP-prime
  - Design finalization, partial laboratory test, mock-up design (in the first 2 years)
  - Magnetic bearings: performance, specification, test (in the remaining years)

WP-prime 7: Focusing System for Undulator Scheme

- The critical item for the undulator scheme is the magnetic focusing system right after the target
- Possible candidates are: (a) Pulsed solenoid, (b) Plasma lens
- The strongest candidate is (a) pulsed solenoid.
- R&D items to be done as WP-prime
  - Detailed simulations for (a) (already on-going)
  - Principal design for a prototype pulsed solenoid
  - Field measurements with 1kA (pulsed and DC) and with 50kA both in a single pulse mode and finally in a 5ms pulsed mode
  - Prototype of (b) plasma lens (funded study on-going)







For more of the ILC ITN work-packages please see talk of Shin Michizono at LCWS 2023: LINK