

LC / ILC Technical Contributions

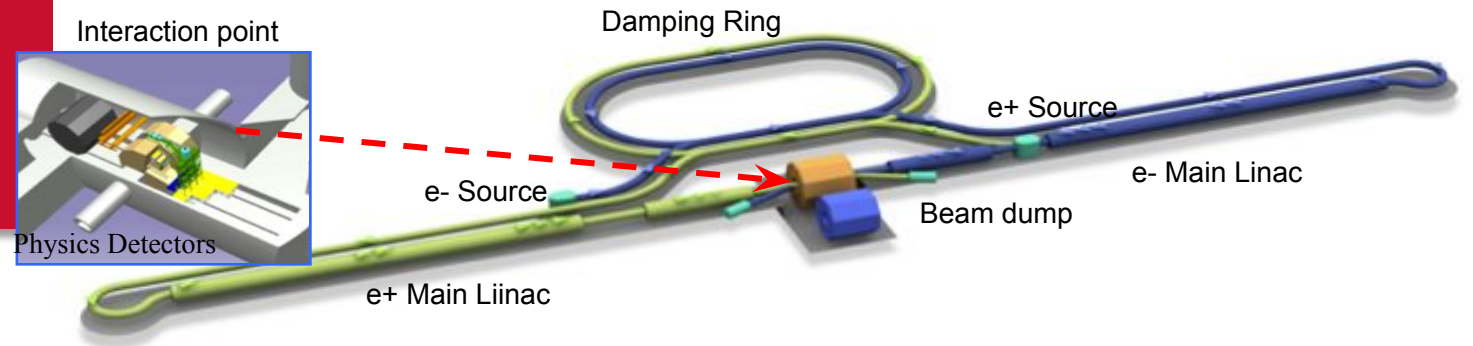
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with help from Vladimir Shiltsev
and the CERN LC Visions Workshop

ILC Technology Challenges

- The ILC design was developed from 2005 - 2013 and concluded with the TDR
 - Concept has been evolving slowly since
 - EU XFEL is a large SRF technology demonstration
- Many technical challenges remain
 - SRF technology, primarily gradient but Q0 as well
 - Positron source: undulator and conventional sources are both beyond SOA
 - Damping rings: instabilities, kickers, diagnostics, wigglers and vacuum
 - Polarized electron source: strained GaAs lifetime and >80% pol.
 - Beam Delivery: direct-wind quads with supports, correction of high-order aberrations with feedback for long-term stability, MDI

ILC



- International Linear Collider (ILC) is an e^+e^- machine based on **superconducting RF linac technology**
- Accelerating gradient 31.5 MV/m (ave.) at $Q_0 = 10^{10}$
- ~8,000 9-cell cavities in ~900 cryomodules
- “Shovel-ready” design: TDR (2013) ...still no host
- Energy is upgradeable with conventional Nb SRF technology to 500 GeV and to 1 TeV (45 MV/m, $Q_0 = 2 \times 10^{10}$) or with advanced SRF (traveling wave or Nb₃Sn)
- The first SRF cryomodule (full ILC specifications) operation with beam was demonstrated at FAST (Fermilab) in 2018; followed by a KEK test in 2021

$$L = \frac{P_{beam}}{E_{c.m.}} \cdot \frac{N_e}{4\pi\sigma_x^*\sigma_y^*} \cdot H_D$$

Quantity	Symbol	Unit	Initial	\mathcal{L} Upgrade	Z pole	E / \mathcal{L} Upgrades		
Centre of mass energy	\sqrt{s}	GeV	250	250	91.2	500	250	1000
Luminosity	\mathcal{L}	$10^{34}\text{cm}^{-2}\text{s}^{-1}$	1.35	2.7	0.21/0.41	1.8/3.6	5.4	5.1
Polarization for e^-/e^+	$P_-(P_+)$	%	80(30)	80(30)	80(30)	80(30)	80(30)	80(20)
Repetition frequency	f_{rep}	Hz	5	5	3.7	5	10	4
Bunches per pulse	n_{bunch}	1	1312	2625	1312/2625	1312/2625	2625	2450
Bunch population	N_e	10^{10}	2	2	2	2	2	1.74
Linac bunch interval	Δt_b	ns	554	366	554/366	554/366	366	366
Beam current in pulse	I_{pulse}	mA	5.8	8.8	5.8/8.8	5.8/8.8	8.8	7.6
Beam pulse duration	t_{pulse}	μs	727	961	727/961	727/961	961	897
Accelerating gradient	G	MV/m	31.5	31.5	31.5	31.5	31.5	45
Average beam power	P_{ave}	MW	5.3	10.5	1.42/2.84*	10.5/21	21	27.2
RMS bunch length	σ_z^*	mm	0.3	0.3	0.41	0.3	0.3	0.225
Norm. hor. emitt. at IP	$\gamma\epsilon_x$	μm	5	5	5	5	5	5
Norm. vert. emitt. at IP	$\gamma\epsilon_y$	nm	35	35	35	35	35	30
RMS hor. beam size at IP	σ_x^*	nm	516	516	1120	474	516	335
RMS vert. beam size at IP	σ_y^*	nm	7.7	7.7	14.6	5.9	7.7	2.7
Luminosity in top 1 %	$\mathcal{L}_{0.01}/\mathcal{L}$		73 %	73 %	99 %	58.3 %	73 %	44.5 %
Beamstrahlung energy loss	δ_{BS}		2.6 %	2.6 %	0.16 %	4.5 %	2.6 %	10.5 %
Site AC power*	P_{site}	MW	111	138	94/115	173/215	198	300
Site length	L_{site}	km	20.5	20.5	20.5	31	31	40

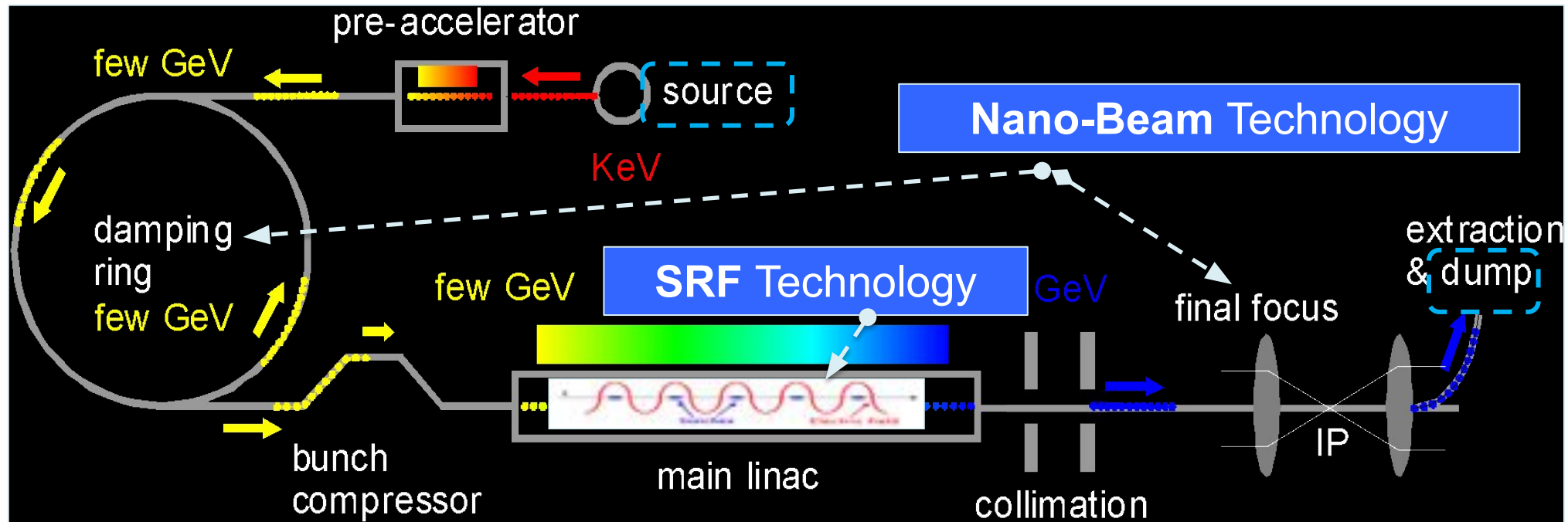
* AC plug-power may be further reduced (10 ~ 20 %), if the RF (Klystron) and SRF/Cryogenics (Q-value) Efficiency may be improved.

ILC Remaining R&D Topics

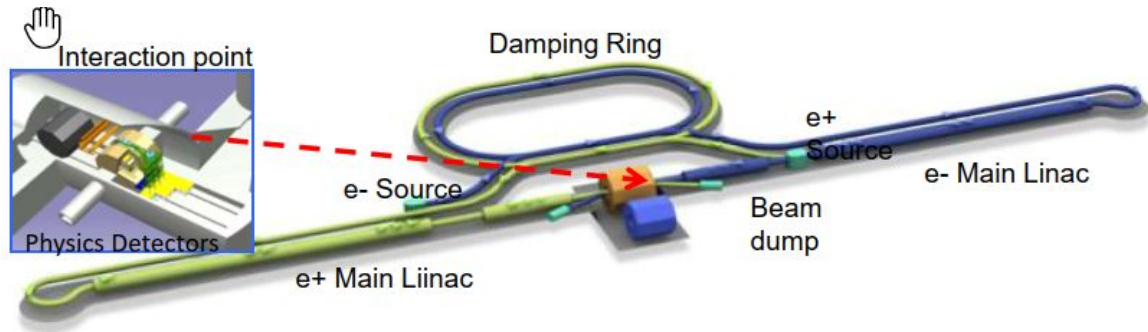


While the ILC is at TDR (“shovel-ready”) since 2013, some R&D is still ongoing to demonstrate beam parameters (nano-beams in ATF2 at KEK), further improve performance and demonstrate industrialization of the SRF linac, develop alternative concepts (e-linac-based positron source)

SRF technology • Nano-beam technology (damping ring and final focus) • Positron source



ILC Technology Network and Pre-lab (ITN)



Not only for the ILC but also for various application

- Creating particles
 - polarized elections / positrons
- High quality beams
 - Low emittance beams
 - Small beam size (small beam spread)
 - Parallel beam (small momentum spread)
- Acceleration
 - superconducting radio frequency (SRF)
- Getting them collided *Final focus*
- Go to *Beam dumps*

Sources

Damping ring

Main linac

Final focus

SRF

e-, e+ Sources

Nano-Beam

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

ILC Technology Network and Pre-lab (ITN)

For **WPP-1&2 (SRF cavity, CM)**, single cell cavity production in Korea/Europe started.

JAI (UK) started WPP-13 (DR Injection/extraction, **synergy with Diamond Light Source upgrade**)

For **WPP-15 (Final Focus System)**, European and Korean researchers have joined to the ATF experiments since 2023.

WPP-1/2 in Asia

SRF cavities

WPP-1 in Europe

- Motivation:** Single-cell cavities will be used to define the nine-cell cavity preparation strategy in terms of surface polishing and heat treatments.
- Materials for single-cell cavities (PG and MO) have been delivered to CERN.
- All friction material was checked with active current scan (ACS) in DESY.
- Clearly marks order by the as
- We are with manufacturer in Japan
- Materials will
- The goal is to have at least two cavities manufactured in the EU ready to be integrated into the supercollider ring by the end of 2025.

Goal/acceptance criteria

Item	Unit	Target	Current	Item	Unit	Target	Current
Q	10 ¹⁰	10 ¹⁰	10 ¹⁰	Q	10 ¹⁰	10 ¹⁰	10 ¹⁰
Q _{ext}	10 ¹⁰	10 ¹⁰	10 ¹⁰	Q _{ext}	10 ¹⁰	10 ¹⁰	10 ¹⁰
Q _{int}	10 ¹⁰	10 ¹⁰	10 ¹⁰	Q _{int}	10 ¹⁰	10 ¹⁰	10 ¹⁰
Q _{ext} /Q _{int}	10 ¹⁰	10 ¹⁰	10 ¹⁰	Q _{ext} /Q _{int}	10 ¹⁰	10 ¹⁰	10 ¹⁰
Q _{ext} /Q _{int}	10 ¹⁰	10 ¹⁰	10 ¹⁰	Q _{ext} /Q _{int}	10 ¹⁰	10 ¹⁰	10 ¹⁰

WPP-2 in Europe

Present activities by Spanish community: Accelerator

IFIC contribution/interest on ITN activities

In 2021 the Spanish network for Future Colliders identified as a promising contribution from CERNAT and IFIC groups to the ILC the development of the **splitable quadrupole magnet (SQM)** and its associated **Beam Position Monitor (BPM)** of the main line.

IFIC is now cost elements in part

In 2023, we have **KEK (A. Yamamoto)**

General requirements for the BPM performance:

- High precision BPM with a time resolution resolution (1-300 ns) and a spatial resolution of 1 μm.
- ILC beam bunch by bunch measurements (fast readout electronics).
- Low beam dynamics impact (subfields studies).
- Ultra-high vacuum and cryogenic temperature performance.
- Special mechanical design for easy cleaning.

WPP-6 in Europe

WPP6: R&D activities rotating wheel

Drive and bearings

- Radiation cooling allows magnetic bearings
- A standard component to support elements rotating in vacuum
- The axis is offset in a magnetic field, provided by

Ongoing discussion with SKF for magnetic bearings/wheel

WPP-7 in Europe

Pulsed Solenoid: towards OMD prototype

Three possible approaches for manufacturing the solenoid coil

- Using a standard conductor from the coils used in the accelerator construction facilities with a hole diameter of
- 3D printing with copper (proposed by Martin Lentz)

WPP-8 in Japan

WPP-8 Rotating target Vacuum test vs target

No significant pressure rise during rotation. Differential pumping works as designed.

WPP-9 in Japan

WPP-9 Magnetic focusing – prototyping

WPP-10 in Japan

WPP-10 Capture cavity - prototyping

- 3D model is ready by A. Yamamoto
- 2D drawings are 70% ready by M. Itoh
- Material (CERN) has been ordered
- Machining and test piece bonding has started

WPP-11 in Japan

WPP-11 Target replacement

Pilox seal connection

WPP-13 in Europe

Pulsar Development for the ILC Damping Ring Kickers

- Injection / Extraction stripline kickers for the ILC damping ring have many similarities with the storage ring injection striplines for Diamond-II.
- Prototype striplines for Diamond-II are under development, with installation and testing planned in the existing Diamond transfer line and storage ring.
- Commercial development of a SIC pulser for Diamond-II with UK company Glenbrook
- Parallel is the same
- Could port
- An agree
- The camp

	ILC	Diamond-II
Operating mode	Baseline	High current
Pulse duration	1312 ns	800 ns
Repetition rate	5 Hz	5 Hz
Pulse duration	40 ns FWHM	40 ns FWHM
Pulse amplitude	350 ns	350 ns
Voltage	400 kV	400 kV
Technology	SiC/SiC	SiC/SiC

WPP-15 (ATF in KEK)

R&D Programs and Experimental Studies

- Wakefield mitigation** (new wakefield test station)
 - Static: mitigation by relocating the sources in lower β -positions: modelling of ATF2 beam line
 - Dynamic: FONT feedback (minimization of injection fluctuation)
- High-order mitigation**
 - Measurer
 - Impact of
 - Ultra low- β studies

WPP-17 in Japan

In 2023 Simplified model for basic operation design

model-A: Integrated unit for mount and unmount the window.

- minimize the number of access
- need wider space in clearance to the beam axis... does not fit to the ILC dump shieldings.

model-B: Dedicated unit for mount and unmount the window.

- minimize the unit working space
- can allocate space to other functions.

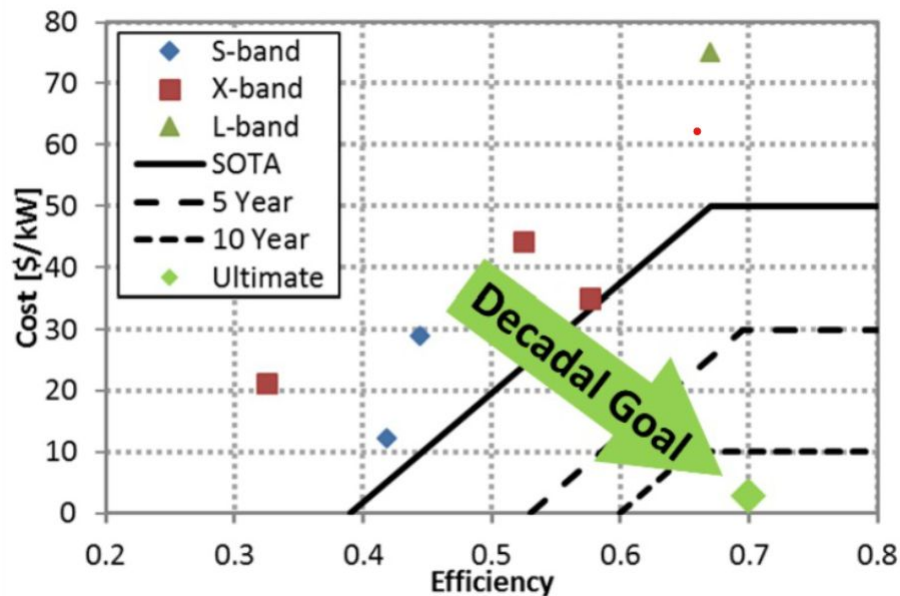
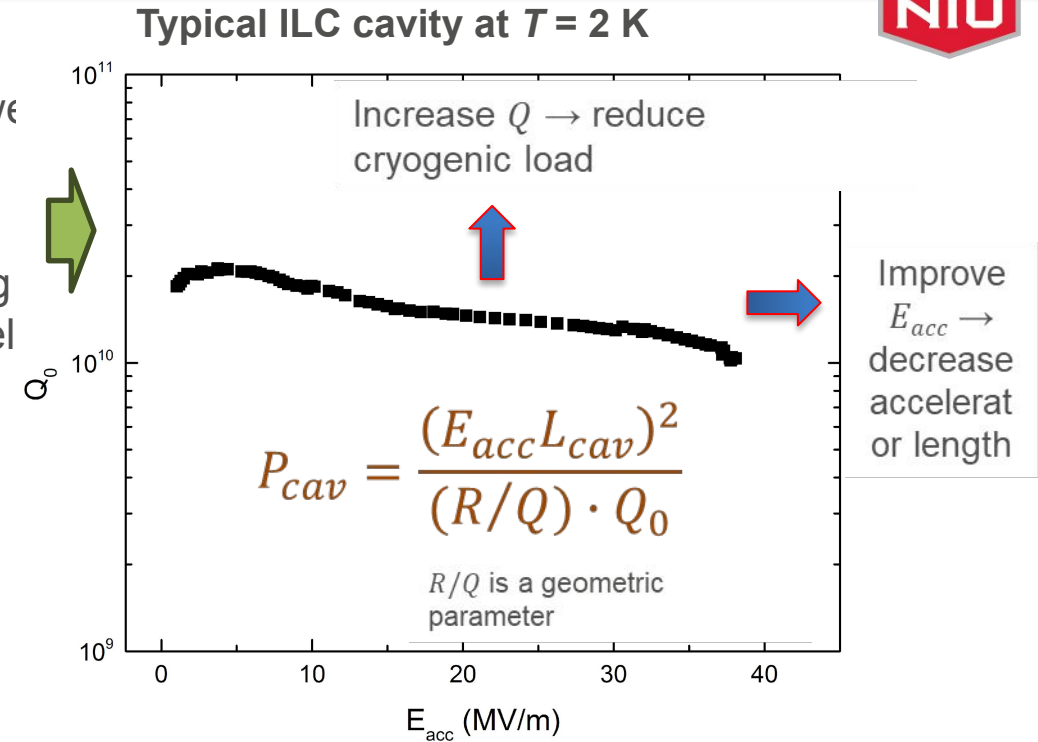
Vacuum chamber ~100kg Sliding support example

RF Technology R&D Thrusts



Three RF technology R&D thrusts

- Superconducting RF (SRF) technology will be used in all colliders that we discuss in this presentation. FCC-ee, ILC, and muon collider will have very large installations. Improving SRF cavity performance is critical.
- High-gradient normal conducting RF – incl. C3 technology and operating RF in high magnetic fields as part of the muon ionization cooling channel
- High-efficiency RF sources (FCC-ee, ILC) to reduce overall AC power consumption of the machine



From the decadal NC conducting RF structure and RF source 10-year roadmap (2017):
RF source cost including modulators in \$ per peak KW vs. efficiency for mature RF source technologies.

Synergies between ILC and FCC-ee

FCC-ee is CERN's preferred option and the most likely option to support

There are a number of synergies between ILC and FCC-ee where studies of one system can be applied to the other

- SRF technology and cryomodule design – can work on 800 MHz for FCC-ee benefit the ILC design?
- MDI – studies on IP quadrupoles, stabilization, or optics tuning and stabilization could likely benefit both designs
- Beam dumps and BID – both designs have very high charge low emittance beams. Are there common collimator or beam dump design or materials studies for both designs?
- Positron sources – ILC is 20x SLC e+ source rate with 5x yield while FCC-ee has similar rate but at ~5x yield, e.g. e+ per power on target
- Damping rings – both FCC-ee/ILC specify ~1 Amp beam currents. Can study of e-cloud, ions, impedance, or transients for FCC-ee benefit ILC?
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Discussion