LC / ILC Technical Contributions

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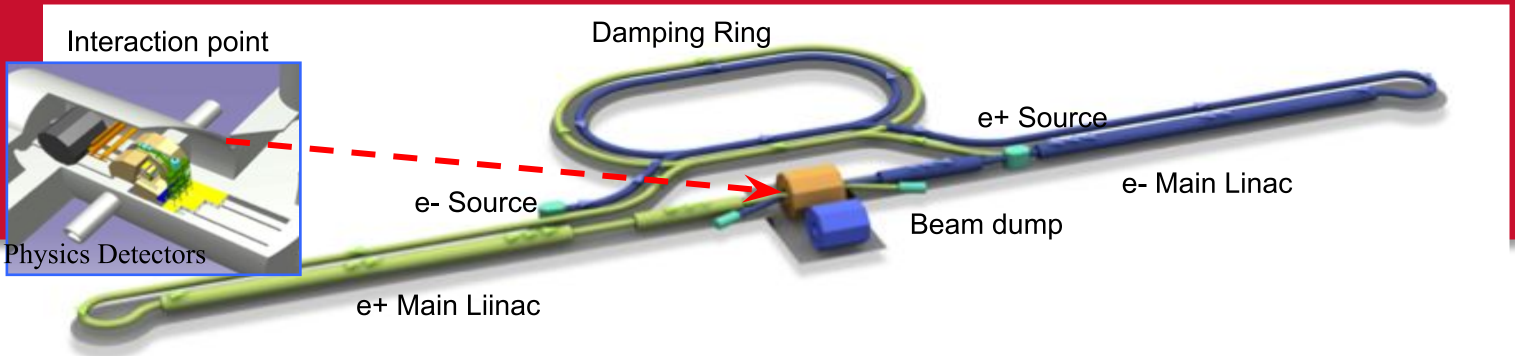
with help from Vladimir Shiltsev
and the CERN LC Visions Workshop

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 Nb_3Sn)
- The first SRF cryomodule (full ILC specifications) operation with beam was demonstrated at FAST (Fermilab) in 2018; followed by a KEK test in 2021

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

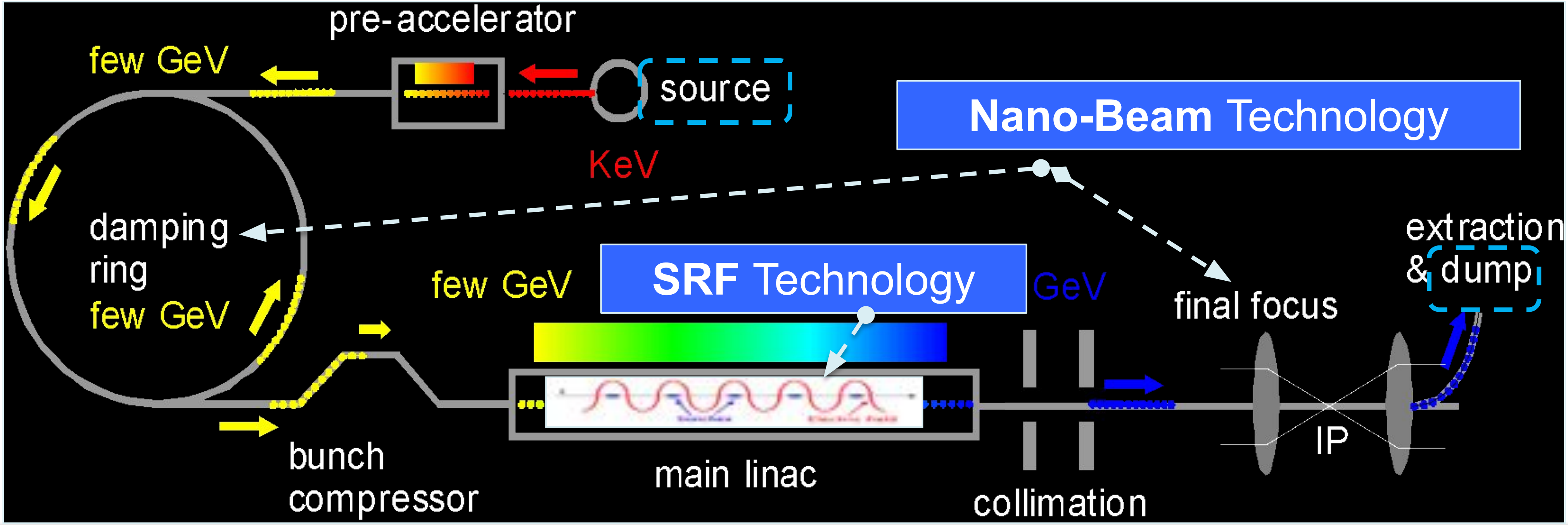
Quantity	Symbol	Unit	Initial	$\mathcal{L}$ Upgrade	Z pole	E / $\mathcal{L}$ Upgrades		
Centre of mass energy	$\sqrt{s}$	GeV	250	250	91.2	500	250	1000
Luminosity	$\mathcal{L}$	10^{34}cm^{-2}s^{-1}	1.35	2.7	0.21/0.41	1.8/3.6	5.4	5.1
Polarization for e^-/e^+	$P_-(P_+)$	%	80(30)	80(30)	80(30)	80(30)	80(30)	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**.

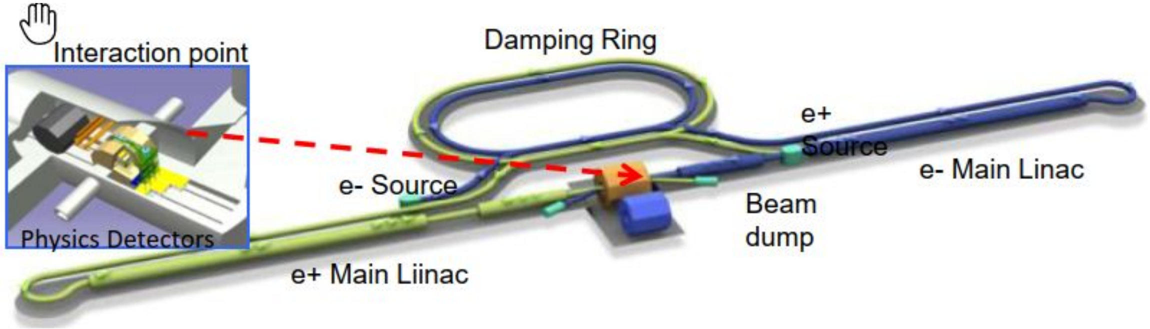
ILC Remaining R&D Topics

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 — ***Sources***
  - polarized elections / positrons
- High quality beams — ***Damping ring***
  - Low emittance beams
    - Small beam size (small beam spread)
    - Parallel beam (small momentum spread)
- Acceleration — ***Main linac***
  - superconducting radio frequency (SRF)
- Getting them collided — ***Final focus***
  - nano-meter beams
- Go to ***Beam dumps***

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

LC Vision (Shin MICHIZONO)

ILC Technology Network and Pre-lab (ITN)

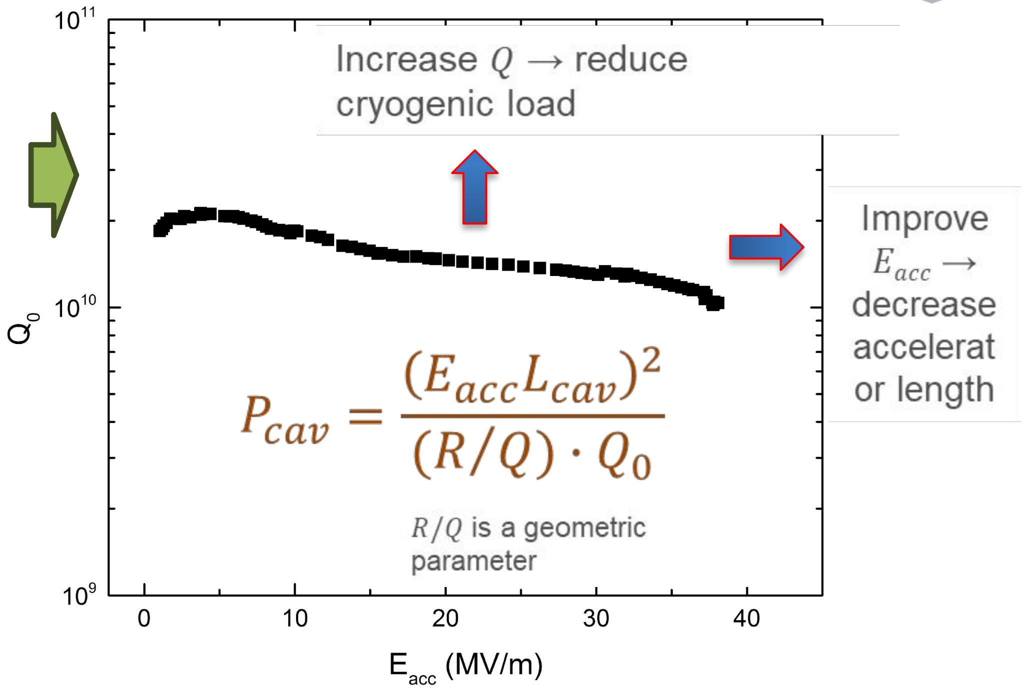
For **WPP-1&2 (SRF cavity, CM)**, single cell cavity production in Korea/Europe started.
JAI (UK) started WPP-13 (DR Injection/extraction, **synergy with Diamond Light Source upgrade**)
For **WPP-15 (Final Focus System)**, European and Korean researchers have joined to the ATF experiments since 2023.

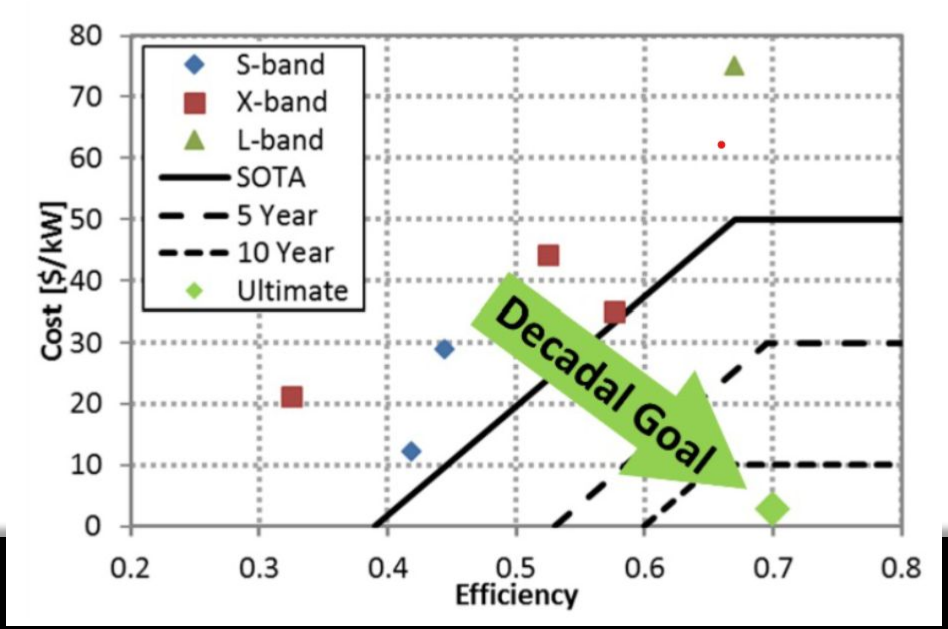
RF Technology R&D Thrusts

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

Typical ILC cavity at $T = 2$ K





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 an 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?
- ….

Discussion