Draft-230403

IDT WG2 Project Introduction

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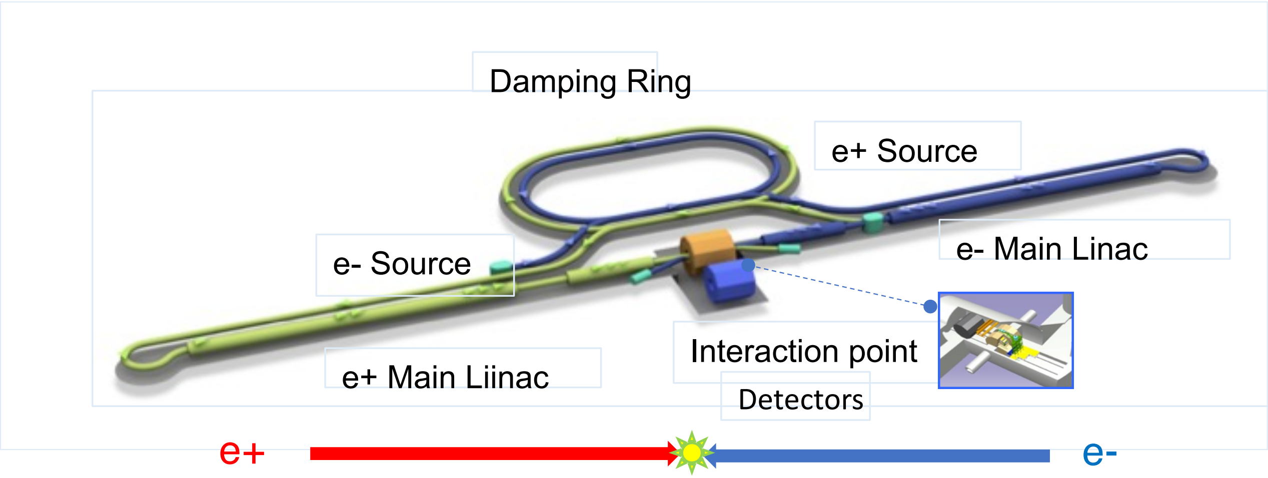
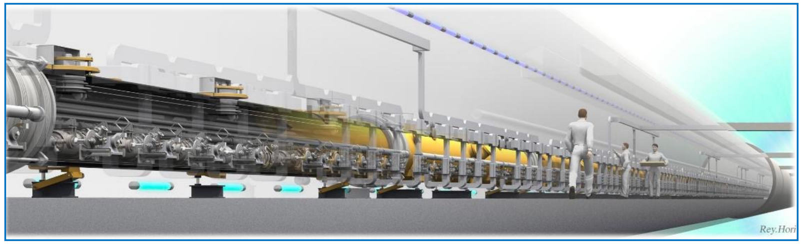
(ILC-IDT and KEK)

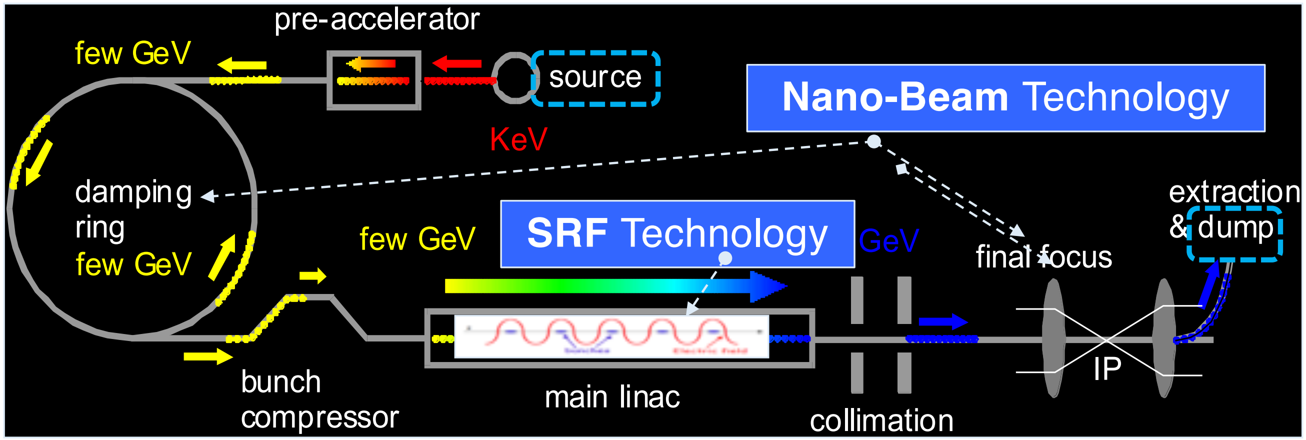
To be presented at ILC CC Down-select Review Meeting, April 4, 2023

https://agenda.linearcollider.org/event/9958/timetable/#20230404

ILC and the Accelerator Technology







Parameters	Value
Beam Energy	125 + 125 GeV
Luminosity	1.35 / 2.7 x 10^{10} cm^2/s
Beam rep. rate	5 Hz
Pulse duration	0.73 / 0.961 ms
# bunch / pulse	1312 / 2625
Beam Current	5.8 / 8.8 mA
Beam size (y) at FF	**7.7** nm
SRF Field gradient	$<$ 31.5 $>$ MV/m (+/-20%) Q_0 = 1x10^{10}
#SRF 9-cell cavities (CM)	~ 8,000 (~ 900)
AC-plug Power	111 / 138 MW

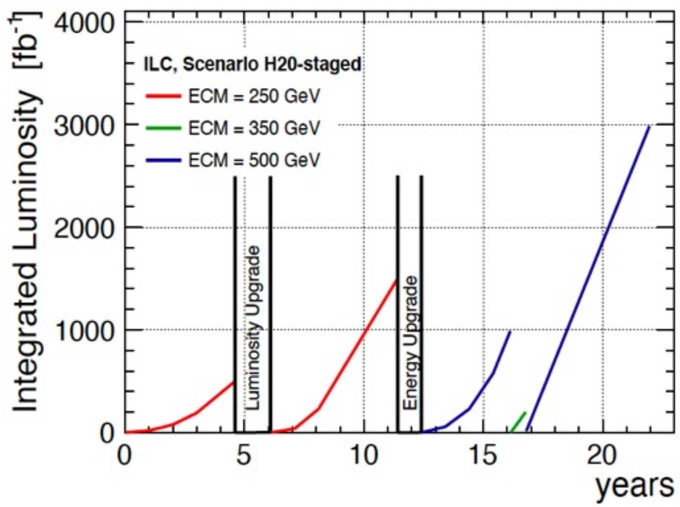
ILC Baseline and the Upgrades

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	$\mathcal{L}$	$10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$	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,** and
- the **peak power reduction** will become **critical important**, as a primary requirement.

Luminosity upgrades:
- 2 x bunches, 2 x RF (**1.35 -> 2.7x10^34**)
  - Run 500GeV-machine at 250GeV, 10Hz:
  - factor 2 (2.7×10^{34} -> 5.4×10^{34})
  - Improve power efficiency

Energy upgrades:
- 500GeV (**31.5 MV/m Q_0=1** x 10^{10})
  - 1TeV (**45 MV/m Q_0=2** x 10^{10}, 300 MW)
  - more SCRF, tunnel extension
  - Site: 50km long, sufficient for 1TeV



History of ILC Collaboration

international development team

2004 ‘06 ’07 ’08 ‘09 ‘10 ‘11 ‘12 ‘13 ‘14 ‘15 ‘16 ‘17 ‘18 ‘19 ‘20 ‘21 ’22 ‘23

RDR | ILC-GDE | TDR | LCC

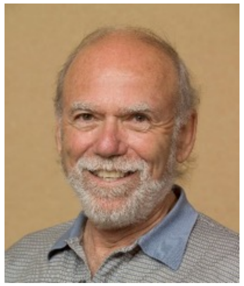
Technology selection

ILC technical design

TDR:
49 countries
392 institutions
>2400 researchers

International ***D***evelopment ***T***eam

Tatsuya Nakada (EPFL)
IDT chair



Barry Barish
GDE director
(the Nobel Prize winnerin 2017)

Lyn Evans
LCC director
(former LHC project manager)

LHC

European XFEL

LCLS-II

ICFA

ILC International Development Team

Executive Board

Americas Liaison Andrew Lankford (UC Irvine)
Working Group 2 Chair Shinichiro Michizono (KEK)
Working Group 3 Chair Jenny List (DESY)
Executive Board Chair and Working Group 1 Chair Tatsuya Nakada (EPFL)
KEK Liaison Yasuhiro Okada (KEK)
Europe Liaison Steinar Stapnes (CERN)
Asia-Pacific Liaison Geoffrey Taylor (U. Melbourne)

Working Group 1
Pre-Lab Setup

Working Group 2
Accelerator

Working Group 3
Physics & Detectors

ILC supported by ICFA

April 2022:

ICFA re-stated support for ILC and extended IDT mandate:

- **IDT,** oversighted by ICFA, has identified:
  - **Time-critical Work Packages** (**WP-prime's**), and is exploring collaboration among KEK and international partners, with **ILC Techical Network** (**ITN**), with new funding expected in Japan, **JFY2023 ~** (starting April 2023) , enabling Japanese contribution to encourage other region's efforts,
  - **Preparing** the phase for **ILC-Prelab** & **E**ngineering **D**esign **R**eport (**EDR**) for the ILC **construction,**

    and
- **ICFA** continues to encourage:
  - inter-governmental discussions between Japan and potential partner nations toward an **ILC** realization.

https://icfa.hep.net/wp-content/uploads/ICFA_Statement_April2022_Final.pdf

The IDT Mandates and Activities

Courtesy: T. Nakada,

- Organising ILC Technology Network,
- Making further advances in the development of ILC related technologies in view of providing more solid **bases for the ILC engineering design** and opportunities for other accelerator **applications.**
- The work programme derived from the work packages in the ILC Pre-lab proposal by selecting technically **most critical items (WP-primes)** and those that require long time to develop, based on **collaboration** agreements between **KEK** and interested **laboratories worldwide**.
- The execution of the work will be managed by each collaborations.

ILC Technology Network and Future ILC

to be explained by **IDT Chair (Tatsuya Nakada)**
in this later afternoon

1. Technical description of the work programme
2. Definition of deliverables and required resources

- Anticipated start in **April 2023**, i.e. the start of the Japanese Fiscal Year 2023 for a period of around two to four years depending on the work.

IDT Scope for ILC Realization

Aug. 2020

IDT → IDT → Pre-lab → ILC construction by ILC Lab. → Experiment at ILC

International **D**evelopment **T**eam, under ICFA

Pre-lab organized by MoU's Among the relevant labs.

ILC lab. based on Governmental Agreement

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 Criticals

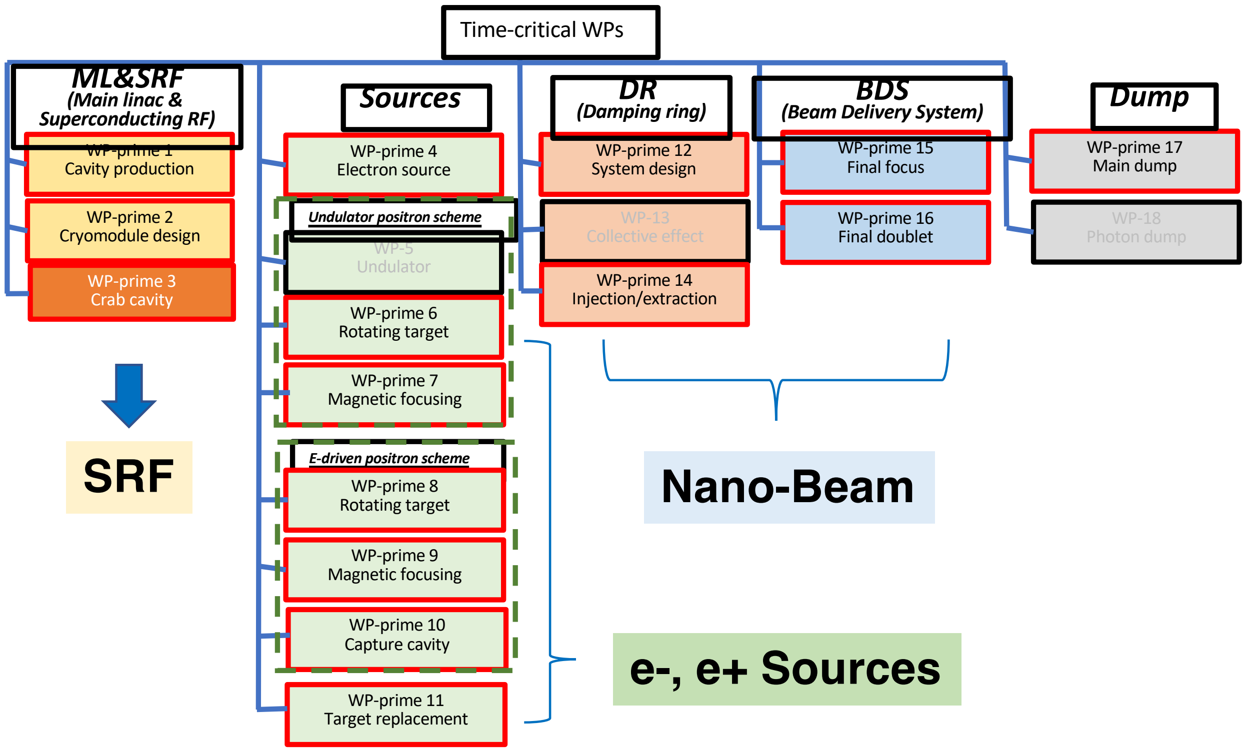
- **ILC Technical Network (INT)**
  - **Acc. R&Ds** to prepare fo EDR, focusing on
    - SRF
    - e- & e+ Sources
    - Nano-beam
    - Beam Dump

http://doi.org/10.5281/zenodo.4742018

https://agenda.linearcollider.org/event/9735/c ontributions/50816/attachments/38190/5996 8/Time-Critical_WPsV8b.pdf

WP-Primes at ILC Technology Network

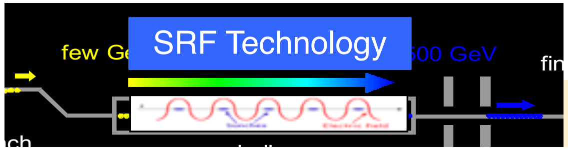
	P1	P2	P3	P4	
Pre-lab proposal	Pre-lab ~4 years				Construction ~10 year
Time-critical WP's	**Y1**	**Y2**	**Y3/P1**	**Y4/P2**	
	(4 years)				
			Pre-lab 3~4 years		Construction ~10 year



WPP	1	Cavity production	SRF
WPP	2	CM design	
WPP	3	Crab cavity	
WPP	4	E- source	
WPP	5		e-, e+ Sources
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	System design	Nano-Beam
WPP	13		
WPP	14	Injection/extraction	
WPP	15	Final focus	
WPP	16	Final doublet	
WPP	17	Main dump	

IDT−WG2

IDT-WG2 has about 50 accelerator researchers from around the world participating in discussions on ILC accelerator development research.



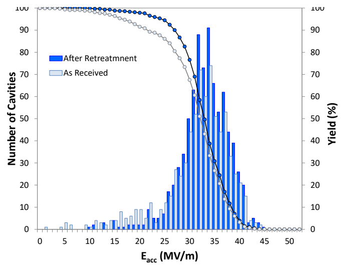
Progress Summary in SRF

～2018	2018～2021	2022～

Cavity

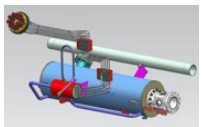
Yield evaluation of cavities based on TDR

Eu-XFEL: 33MV/m achieved at 82%.
(ILC specification: 35MV/m at 90%)



Cryomodule

Eng. design



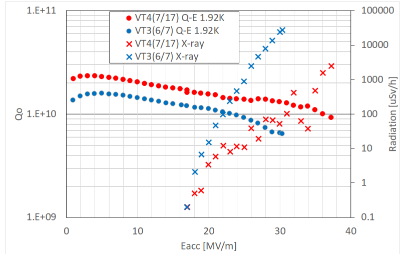
Euro-XFEL Operation (Europe)
~800 cavities/
~100 Modules

LCLS-II Construction (USA)
~280 cavities/
~35 Modules

Realized through international cooperation and procurement

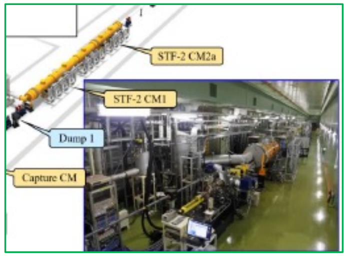
High performance and cost reduction

High performance with new surface treatment, etc.



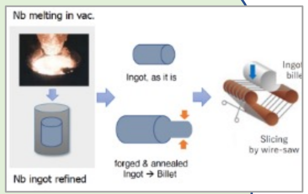
N-infusion cavity Installation to the STF-2 (KEK)

Module assembly



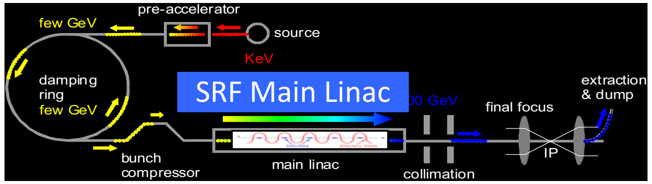
Accelerator performance verification at KEK-STF2

Development of clean environment construction and assembly automation to maintain cavity performance



Cavity manufacturing, performance demonstration (Yield demonstration in three areas)

Update of cryomodule engineering design assembly, and performance



WP-prime 1: SRF Cavity

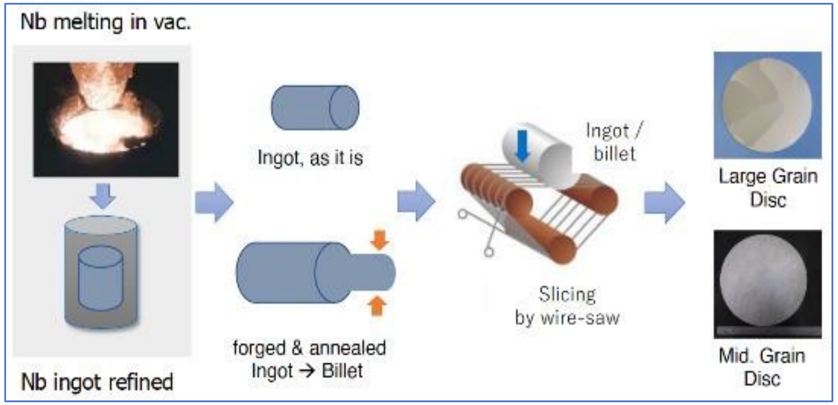
Aiming at Production Readiness with Cost effective production

- ◆Research with single-cell cavities to establish the best production process including:
  - ◆Advanced Nb sheet/disk cost effective production method → MG
  - ◆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 → 4 with **FG** and 4 with MG
  - ◆Production process encouraged to be optimized in each region
- ◆RF performance/success yield to be examined (including 2nd pass and further)
  - ◆3rd pass to be examined if effective

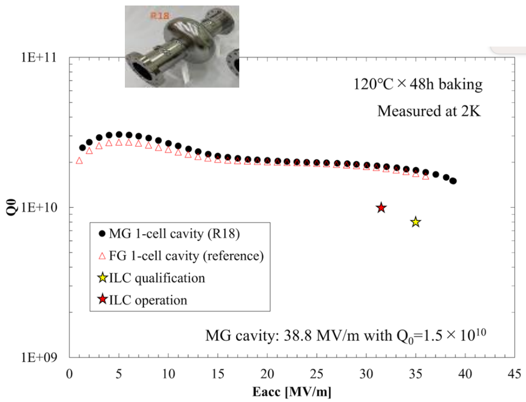
	# cavities to be produced		
	Americas	Europe	JP/Asia
single-cell	2	2	2
nine-cell	8	8	8+a

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

Production process



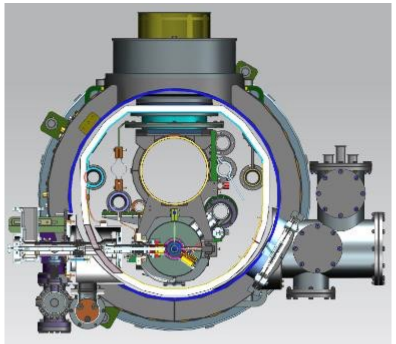
Medium Grain (MG) Nb Disk
A cost-effective production

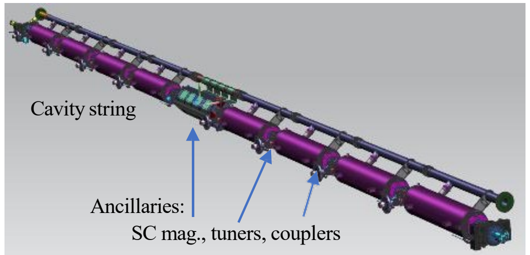


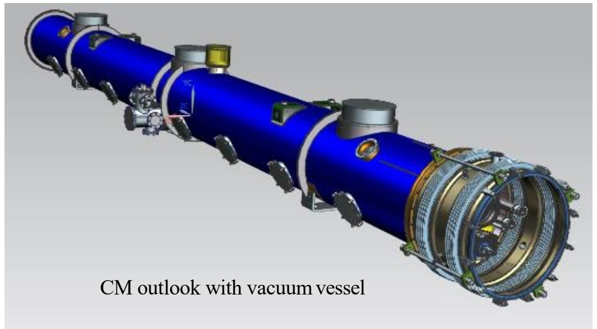
WP-prime 2: Cryomodule (CM) Design

Referring progress in particular LCLS-II experiences

- Unify cryomodule (CM) design with ancillaries, based on globally common engineering design, drawings. and
- Establish globally compatible safety design base to be approved/authorized by HPGS regulations individually in each region, most likely referring ASME guidelines to be compatible with Japanese regulations.







Region Regulation	Americas ASME	Europe Eu-EN, TUV	Japan/Asia JP-HPGS Act
CM tech. design base	LCLS-II	Euro-XFEL	KEK-STF, AST-IFMIF
ILC CM design	Common CM design globally compatible to HPGS regulation in all regions, and most likely ASME guidelines to be compatible with Japanese regulations.		

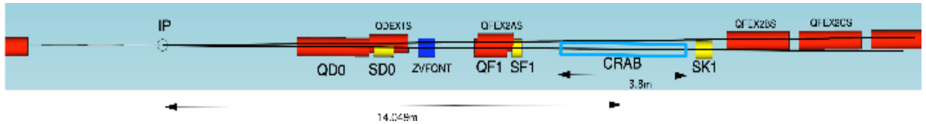
An **International CM,** KEK contributed, to be demonstrated with **cavities globally contributed !!**

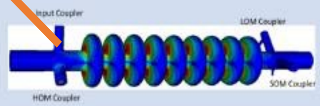
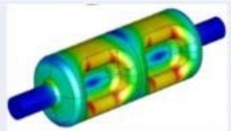
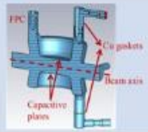
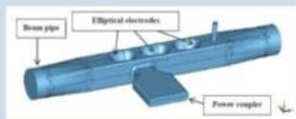
WP-prime 3: Crab Cavity Development with Two-Design Down-selection and Prototypes

- RF property simulation to optimize cavity design
- Pre-down-selection to choose two primary candidates
- Development and evaluation of **two prototype** cavities
- Demonstration of synchronized operation with prototypes
- Down-selection to choose final cavity design
- Cryomodule design based on final cavity design

Item	Recent specification (after TDR)
Beam energy	125 GeV (e^-)
Crossing angle	**14 mrad**
Installation site	14 m from IP
RF repetition rate	5 Hz
Bunch train length	727 μsec
Bunch spacing	554 nsec
Operational temperature	2.0 K (?)
Cavity frequency	1.3/3.9 GHz
Total kick voltage	1.845/0.615 MV
Relative RF phase jitter	0.023/0.069 deg rms (49 fs rms)

two beamline distance 14.049m x 0.014rad = **197mm**



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	

WP-prime 3: Crab Cavity Development with the design down-selection

List of items:

Priority	*Items*	Y1	Y2	Y3	Y4
A	Decision of installation location with cryogenics/RF location accelerator tunnel	All			
A	Confirm the complete CC system specifications	All			
A	Development of CC cavity/coupler/tuner integrated design (ahead of Preliminary CC technology Down-selection)	EU, AM			
A	Preliminary CC technology down-selection (2 cavity options)	All			
A/B	CC Model-work and Prototype production and high-power validation of CC cavity/coupler/tuner integrated system (incl HPGS provision) for two primary candidates (ahead of Final CC technology Down-selection)	EU, AM	EU, AM		
B	Perform harmonized operation of the two prototype cavities in a vertical test to verify ILC synchronization performance (cryo insert development and commercial optical RF synchronization system).		EU, AM	EU, AM	
A/B	Final CC technology down-selection			All	
B	Preliminary Crab Prototype CM (pCM) design – confirming dressed cavity integration and compliance with beam-line specification (incl HPGS provision)			EU, AM	EU, AM
B	Final pCM engineering design prior to production			EU, AM	EU, AM

Note: Production of pCM is assumed after Y5 (P3)

🡐 We are here