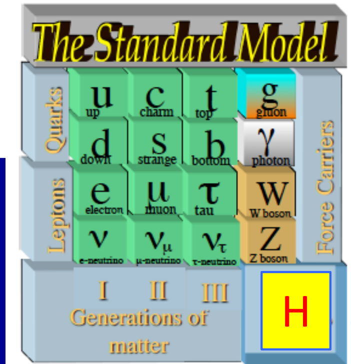
Recent ILC R&D status

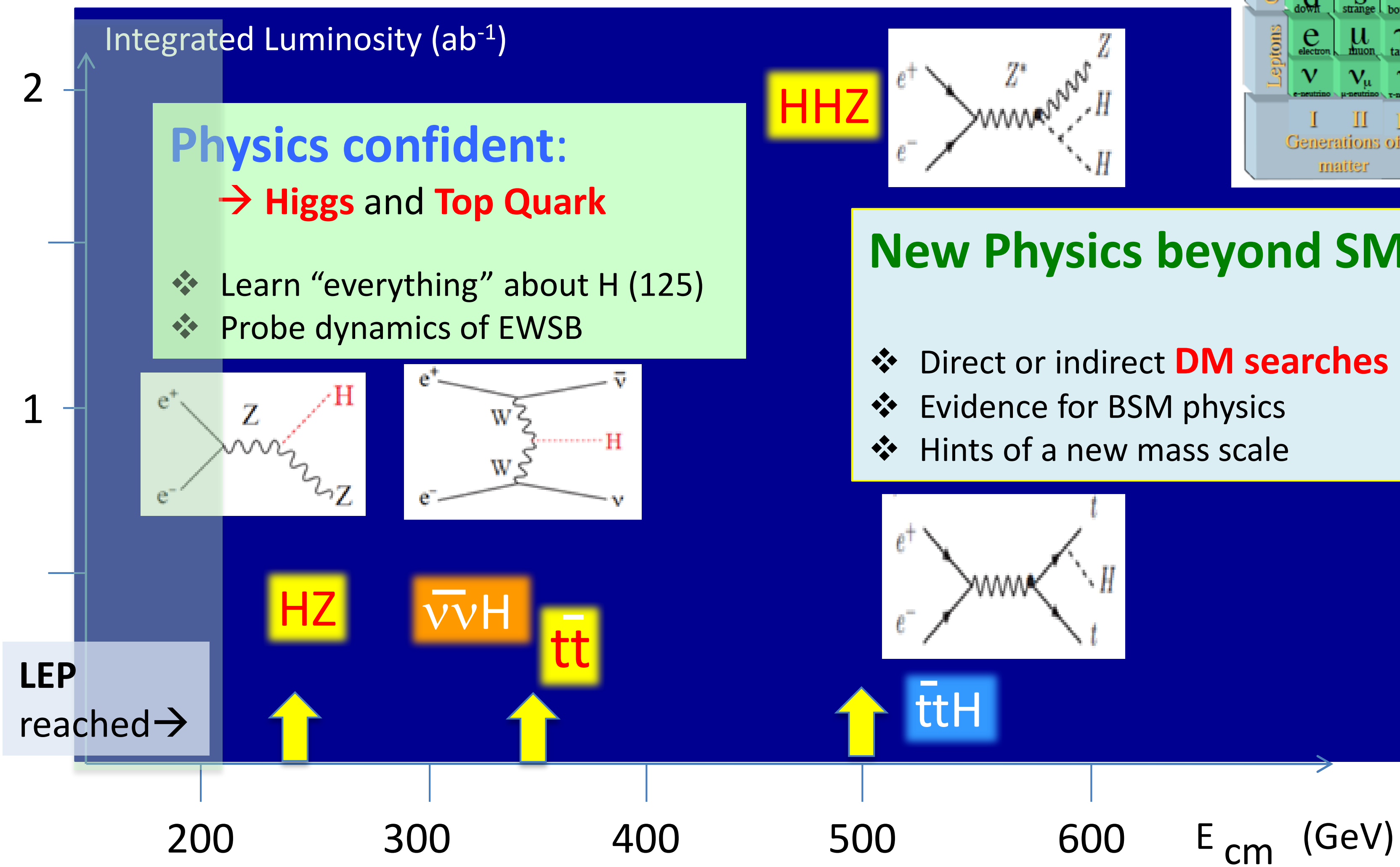
Shin MICHIZONO
KEK/Linear Collider Collaboration (LCC)

- *250GeV ILC*
- *Nano-beam R&D*
- *Cost reduction SRF R&Ds*
    - *Directly sliced Nb material*
    - *N-infusion*
- *SRF accelerators*
- *Fukuoka Statement/ILC symposium*

Important Energies in ILC

125 GeV Higgs discovery reinforcing the ILC importance





Machine/Physics report (October 2017)

https://arxiv.org/abs/1711.00568

KEK 2017-3
DESY 17-180
CERN-ACC-2017-0097

The International Linear Collider Machine Staging Report 2017

Addendum to the International Linear Collider Technical Design Report published in 2013

Linear Collider Collaboration / October, 2017
Editors:Lyn Evans and Shinichiro Michizono

https://arxiv.org/abs/1710.07621

DESY-17-155
KEK Preprint 2017-31
LAL 17-059
SLAC-PUB-17161
October 2017

arXiv:1710.07621v1 [hep-ex] 20 Oct 2017

Physics Case for the 250 GeV Stage of the International Linear Collider

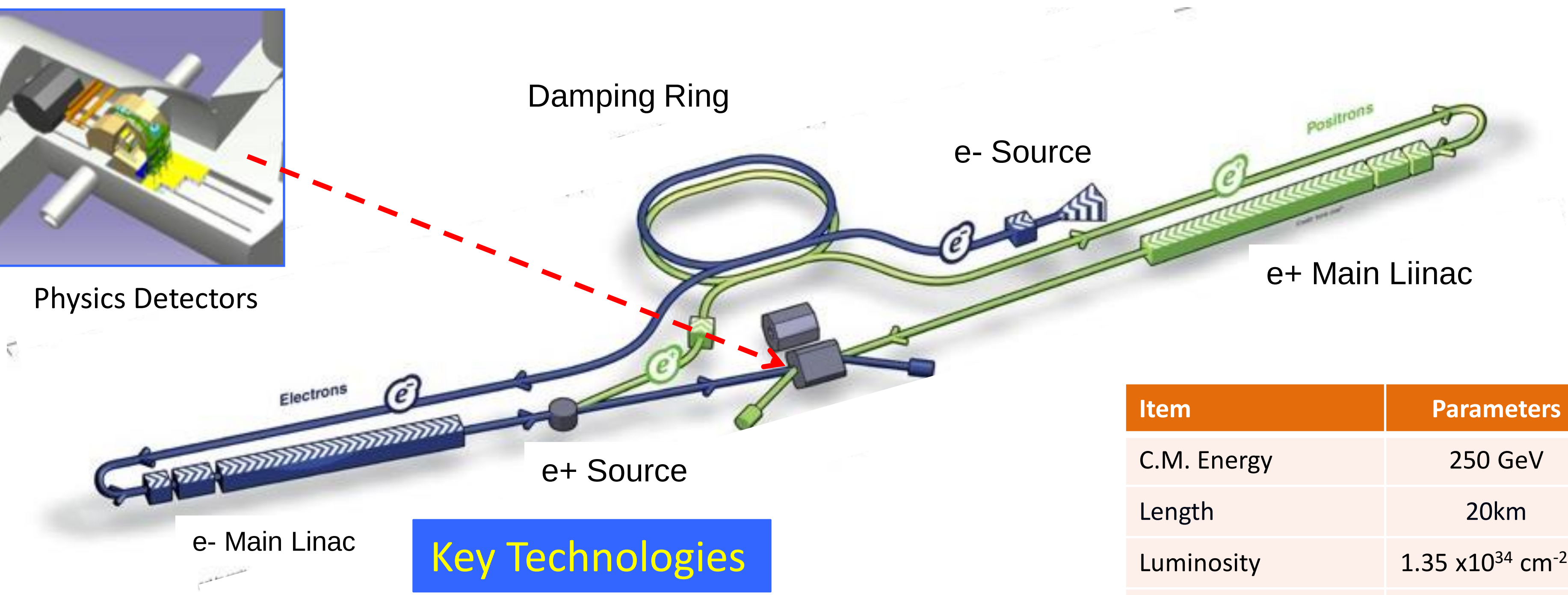
LCC Physics Working Group

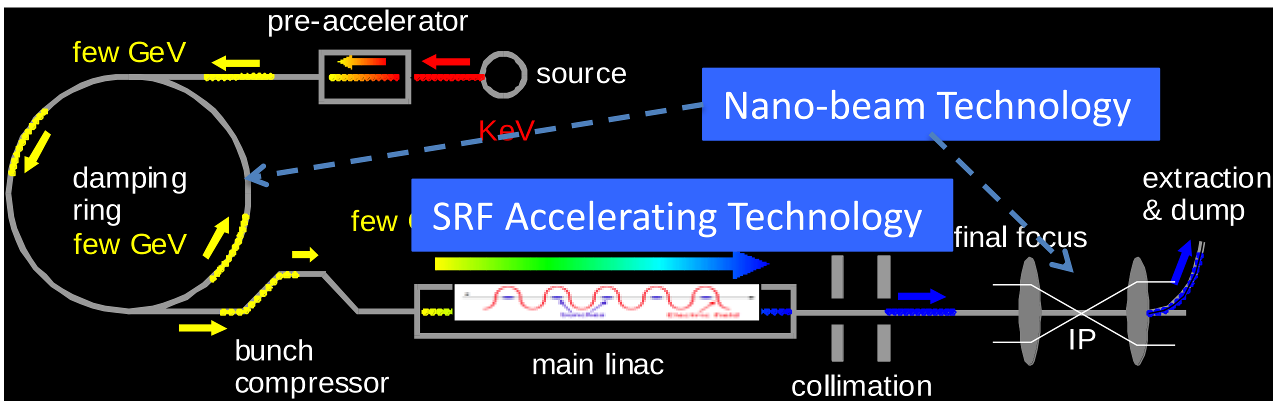
Keisuke Fujii[1], Christophe Grojean[2,3], Michael E. Peskin[4] (Conveners); Tim Barklow[4], Yuanning Gao[5], Shinya Kanemura[6], Hyungdo Kim[7], Jenny List[2], Mihoko Nojiri[1,8], Maxim Perelstein[9], Roman Pöschl[10], Jürgen Reuter[2], Frank Simon[11], Tomohiko Tanabe[12], James D. Wells[13], Jaehoon Yu[14]; Mikael Berggren[2], Moritz Habermehl[2], Sunghoon Jung[7], Robert Karl[2], Tomohisa Ogawa[1], Junping Tian[12]; James Brau[15], Hitoshi Murayama[8,16,17] (ex officio)

ABSTRACT

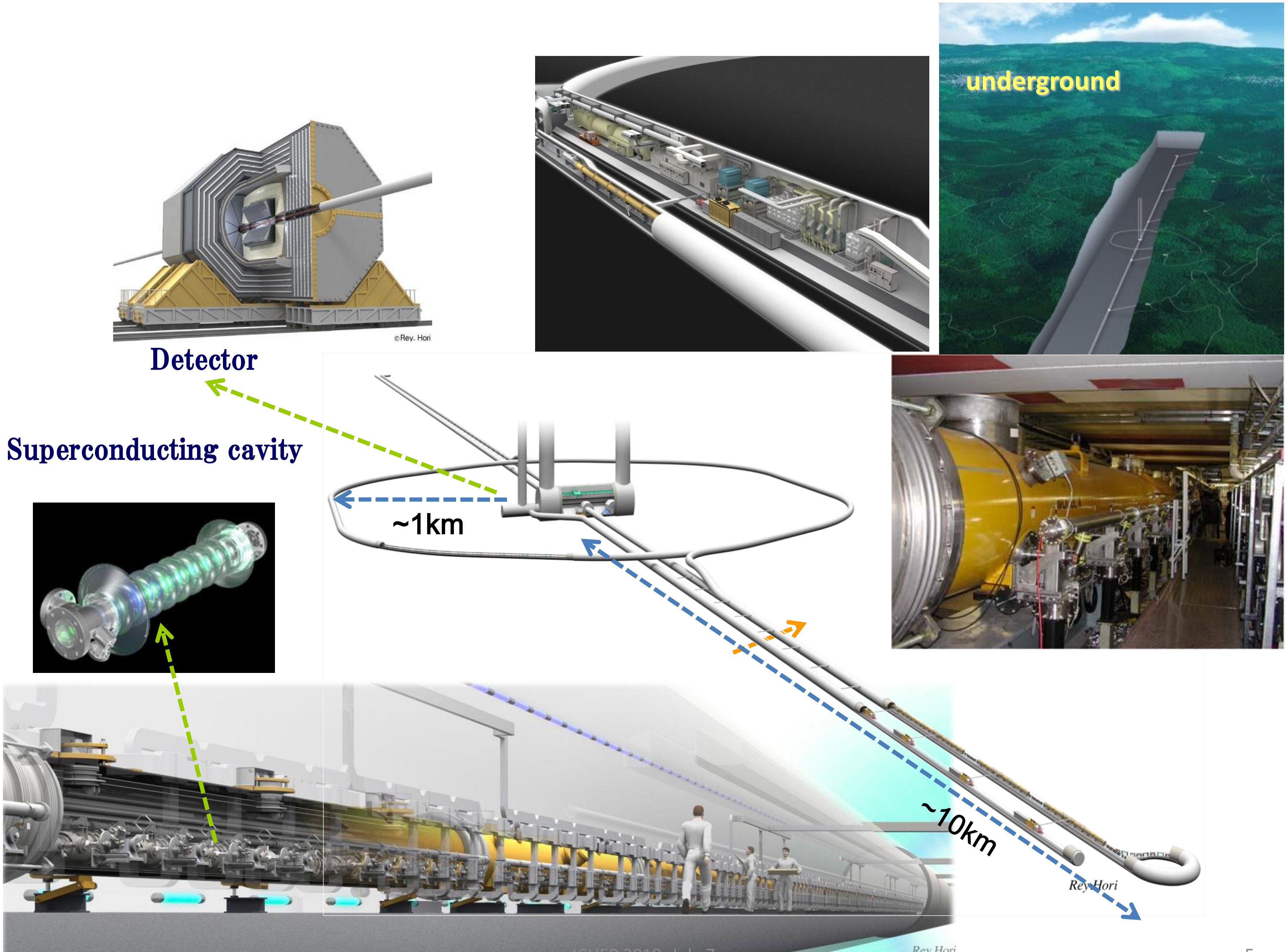
The International Linear Collider is now proposed with a staged machine design, with the first stage at 250 GeV with a luminosity goal of 2 ab^{-1}. In this paper, we review the physics expectations for this machine. These include precision measurements of Higgs boson couplings, searches for exotic Higgs decays, other searches for particles that decay with zero or small visible energy, and measurements of e^+e^- annihilation to W^+W^- and 2-fermion states with improved sensitivity. A summary table gives projections for the achievable levels of precision based on the latest full simulation studies.

ILC250 Acc. Design Overview

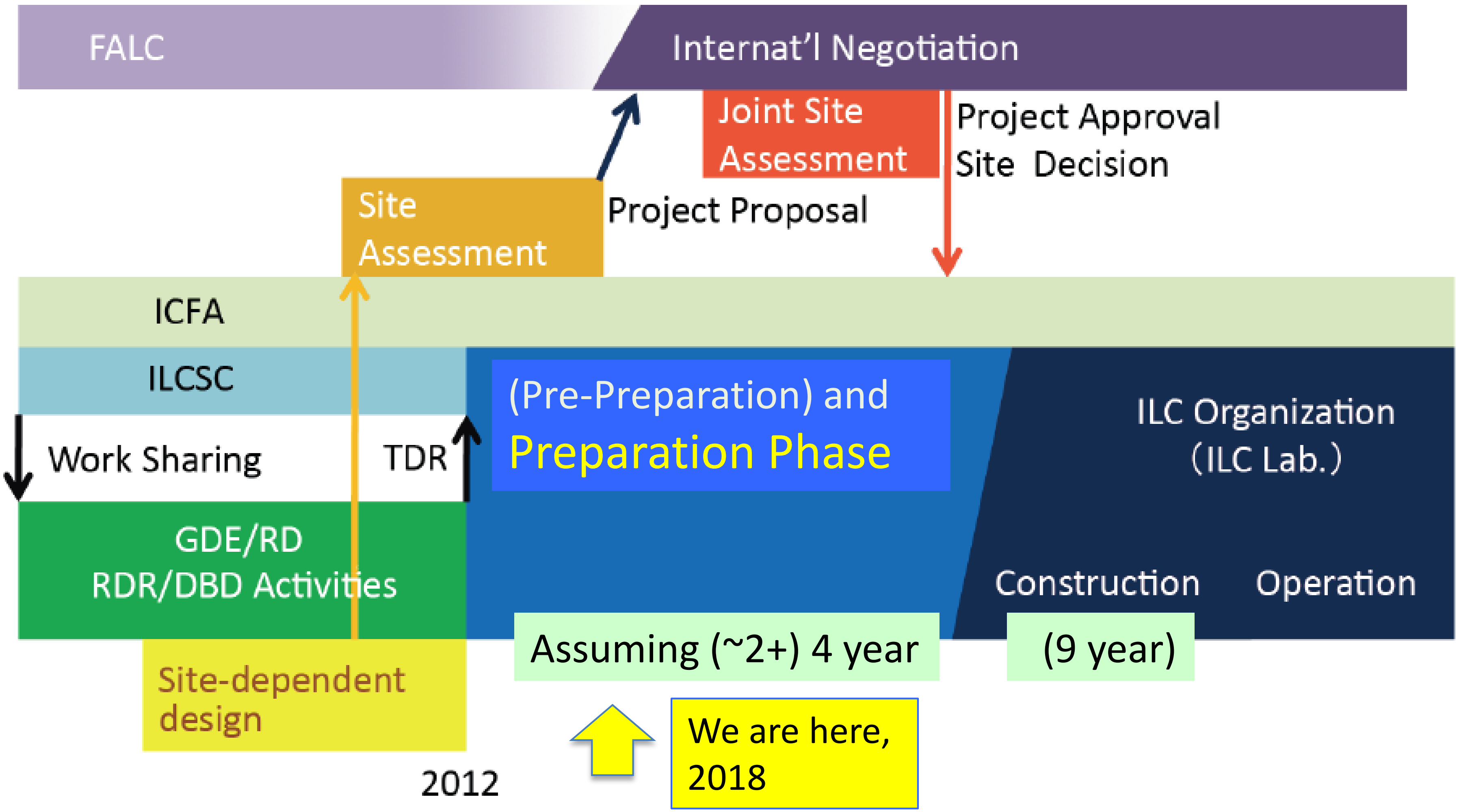




Item	Parameters
C.M. Energy	250 GeV
Length	20km
Luminosity	1.35 x10^{34} $cm^{-2}s^{-1}$
Repetition	5 Hz
Beam Pulse Period	0.73 ms
Beam Current	5.8 mA (in pulse)
Beam size (y) at FF	7.7 nm@250GeV
SRF Cavity G. Q_0	31.5 MV/m (35 MV/m) Q_0 = 1x10^{10}

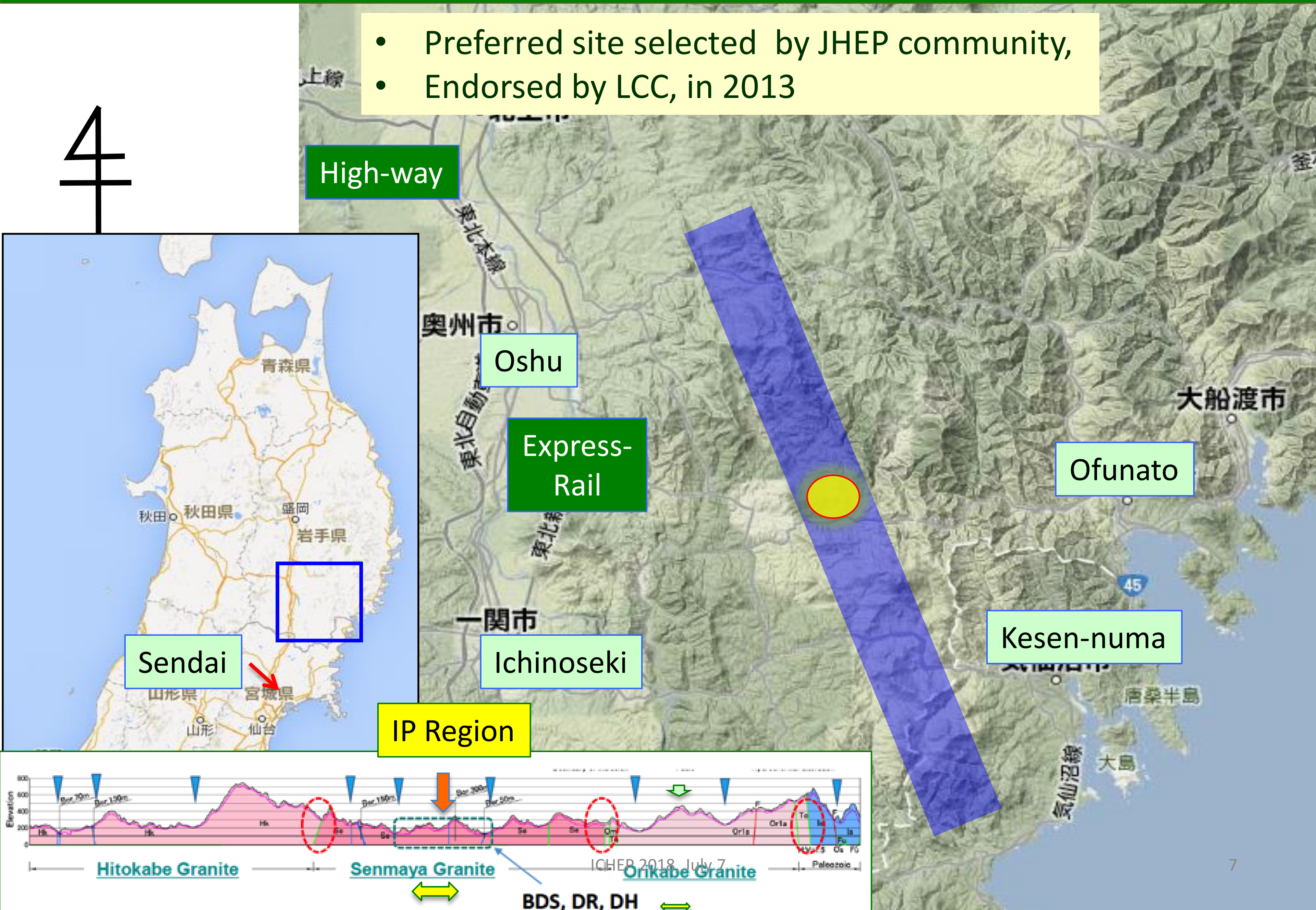

underground
©Rey. Hori
Detector
Superconducting cavity
~1km
~10km
Rey.Hori
Rey.Hori

ILC Time Line: Progress and Prospect



ILC Site Candidate Location in Japan: Kitakami

- Preferred site selected by JHEP community,
- Endorsed by LCC, in 2013



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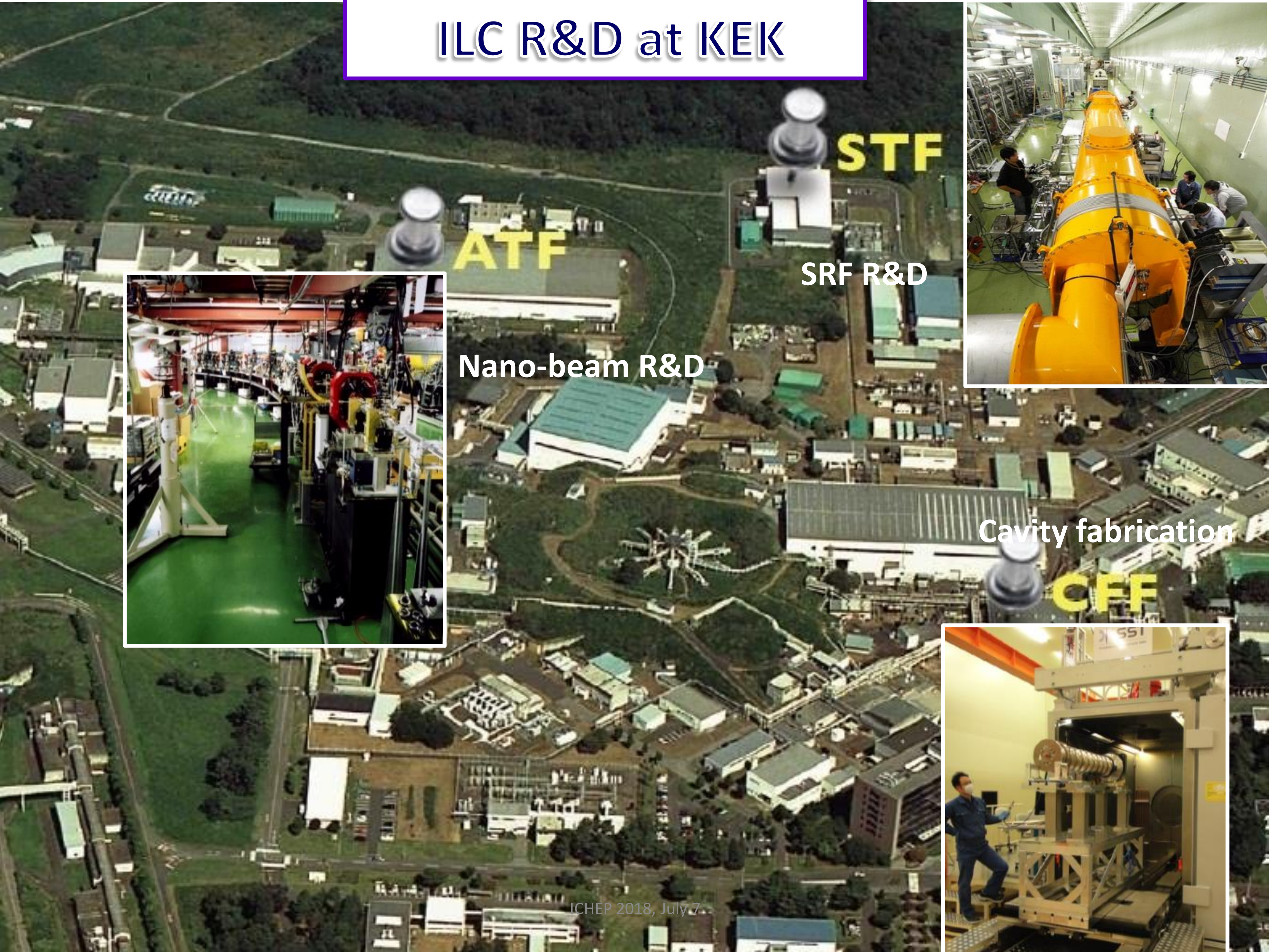
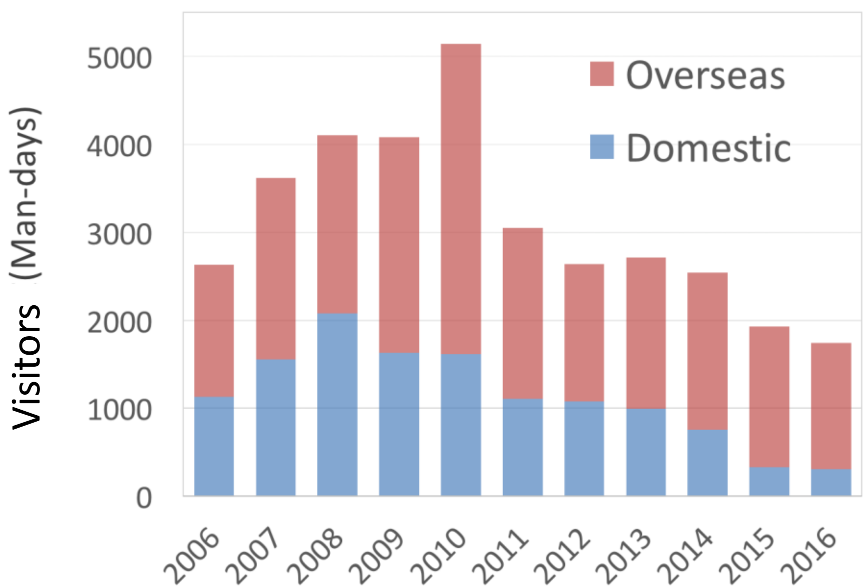
ILC R&D at KEK



STF
ATF
SRF R&D
Nano-beam R&D
Cavity fabrication
CFF
ICHEP 2018, July 7

ATF International Collaboration

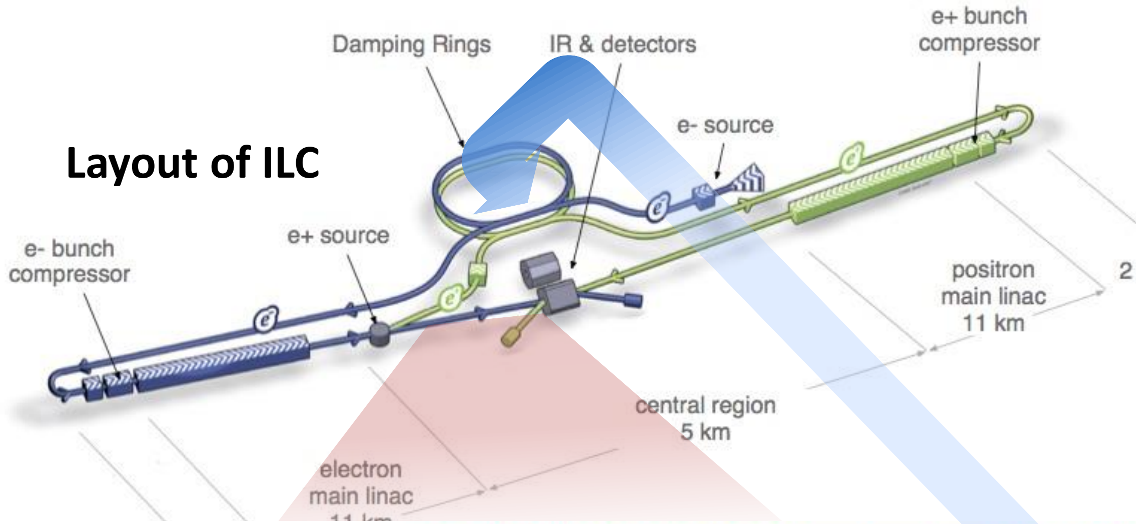
東京大学
THE UNIVERSITY OF TOKYO
Institute of High Energy Physics
Chinese Academy of Sciences
lapp
Laboratoire d'Annecy-le-Vieux de Physique des Particules
Fermilab
KOREA UNIVERSITY 1905
SLAC NATIONAL ACCELERATOR LABORATORY
CERN
IFIC INSTITUT DE FÍSICA CORPUSCULAR
UNIVERSITY OF OXFORD
LAL LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE
ROYAL HOLLOWAY UNIVERSITY OF LONDON



- ATF international collaboration established in 2005.
- During the construction phase (~2010), many researchers joined for the installation of the components of in-kind contribution.
- Since 2011, the researchers visit for mainly the beam study.
- Many researchers are working for this collaboration.

ATF/ATF2: Accelerator Test Facility

Layout of ILC



Develop the nanometer beam technologies for ILC

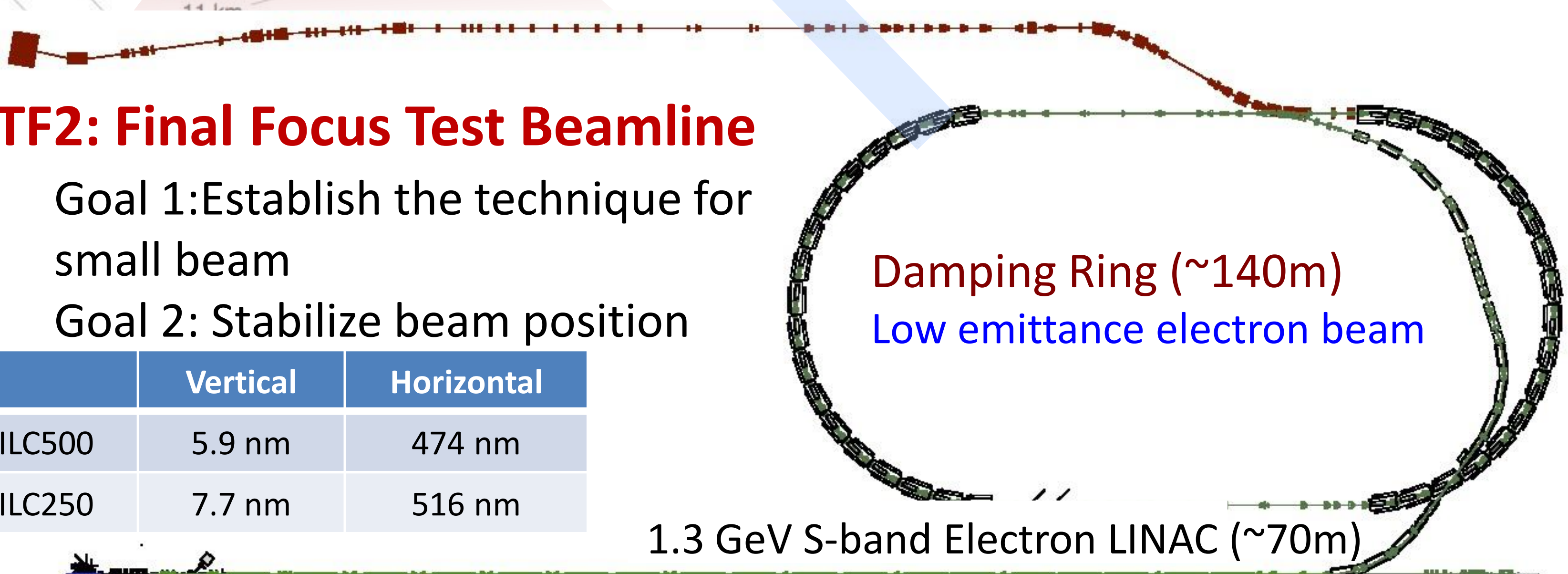
- Key of the luminosity maintenance
- 7.7 nm beam at IP (ILC250)

ATF2: Final Focus Test Beamline

Goal 1:Establish the technique for small beam

Goal 2: Stabilize beam position

	Vertical	Horizontal
ILC500	5.9 nm	474 nm
ILC250	7.7 nm	516 nm



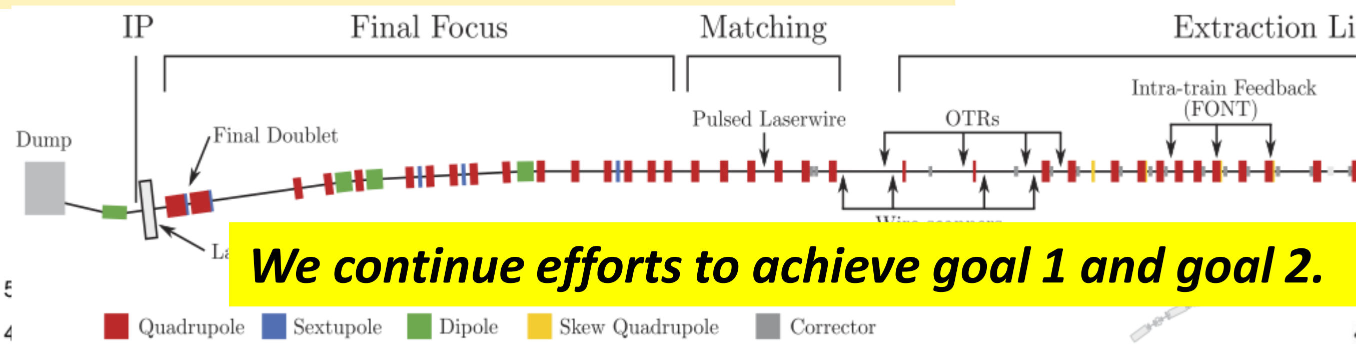
Progress in FF Beam Size and Stability at ATF2

Goal 1: Establish the ILC final focus method with same optics and comparable beamline tolerances

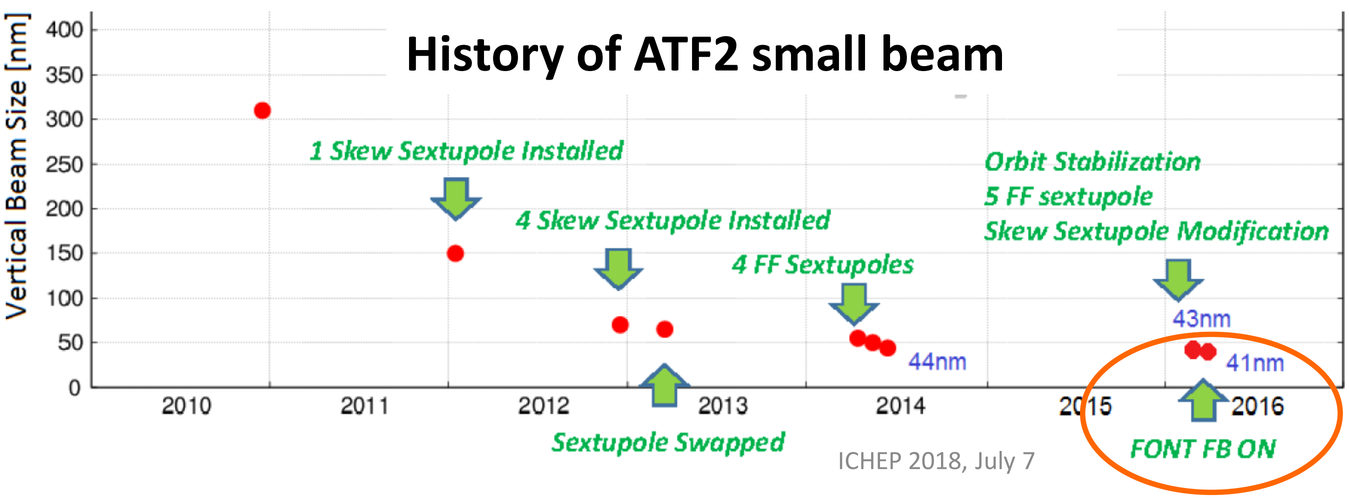
- ATF2 Goal : 37 nm → 6nm @ILC500GeV
  7.7nm@ILC250GeV
  - Achieved **41 nm** (2016)

Goal 2: Develop a few nm position stabilization for the ILC collision

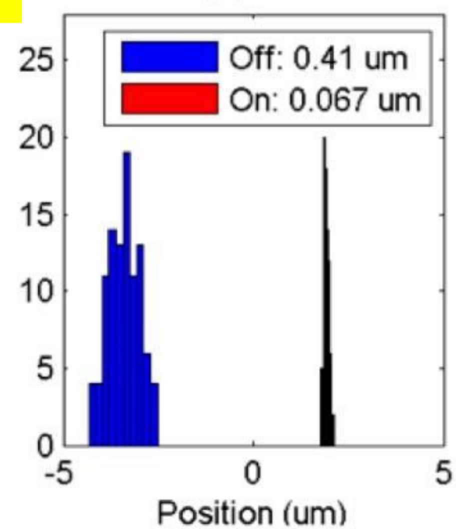
- **FB latency 133 nsec achieved**
  (target: < 300 nsec)
- **positon jitter at IP: 410 → 67 nm (2015)** (limited by the BPM resolution)



We continue efforts to achieve goal 1 and goal 2.



Nano-meter stabilization at IP



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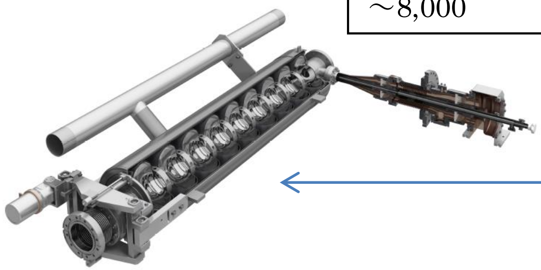
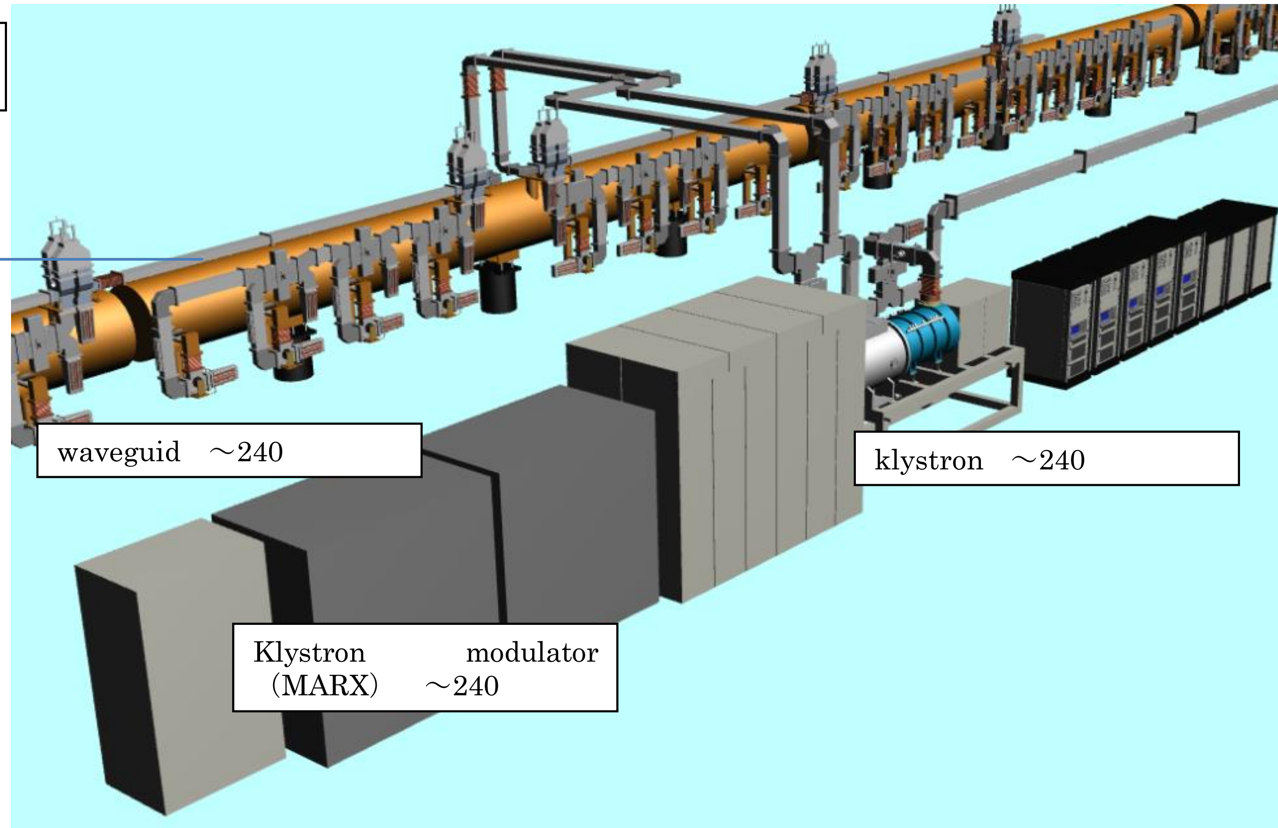
SRF main linac at ILC250GeV





Number of cavities is 10% more than input coupler because of the yield of 90%.

US-Japan Discussion Group on ILC

- First meeting on **May 25, 2016** at Washington D.C
  - Attended by Deputy Director-General, Research Promotion Bureau, MEXT, and Director, Office of Science, DOE.
  - Agreed on item of discussion
- Working level meeting on August 8, 2016 at ICHEP venue in Chicago
  - Attended by Director, Basic Research Promotion Div., MEXT, and Associate Director for HEP, DOE.
  - Heard from KEK and FNAL on the proposal of the joint R&D for cost reduction.
- Second meeting on **October 18**, 2016 by video
  - Attended by Deputy Director-General, Research Promotion Bureau, MEXT, and Director, Office of Science, DOE.
  - Agreed to begin the joint R&D from April 2017.
- Discussion group activity continues. The report on ILC Organization and Management is an input to this activity.

- R&D **program started** in **2017**

ILC Cost-Reduction R&D in US-Japan Cooperation on SRF Technology, for ~3 years

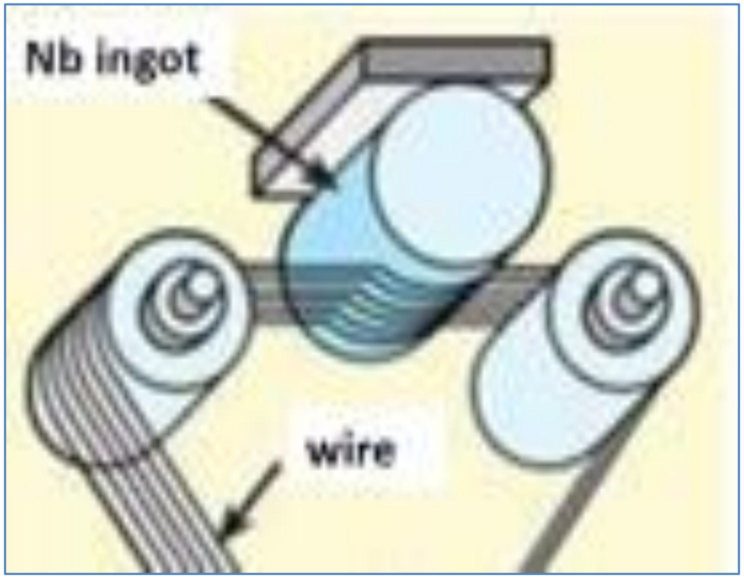
Based on recent advances in technologies;

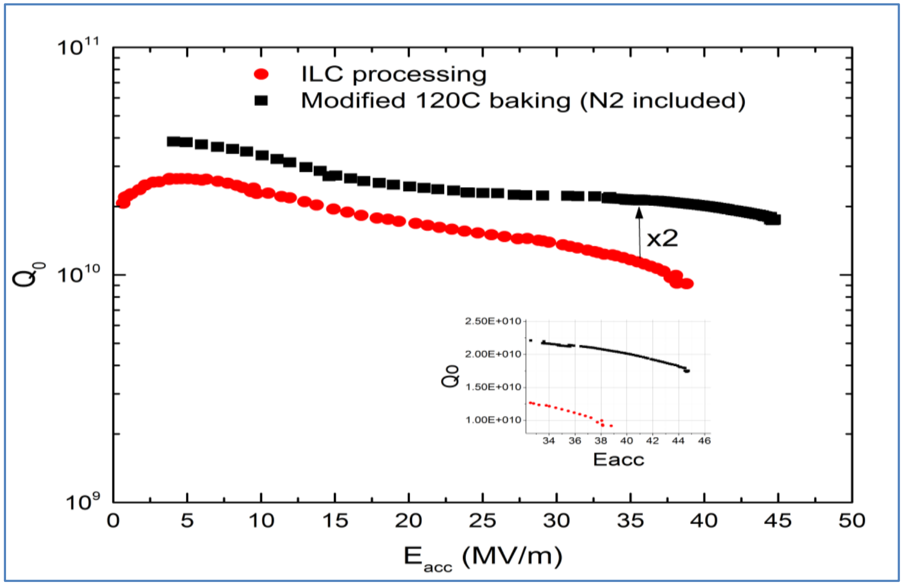
- Nb materia/sheet preparation

  - w/ optimum RRR and clean surface

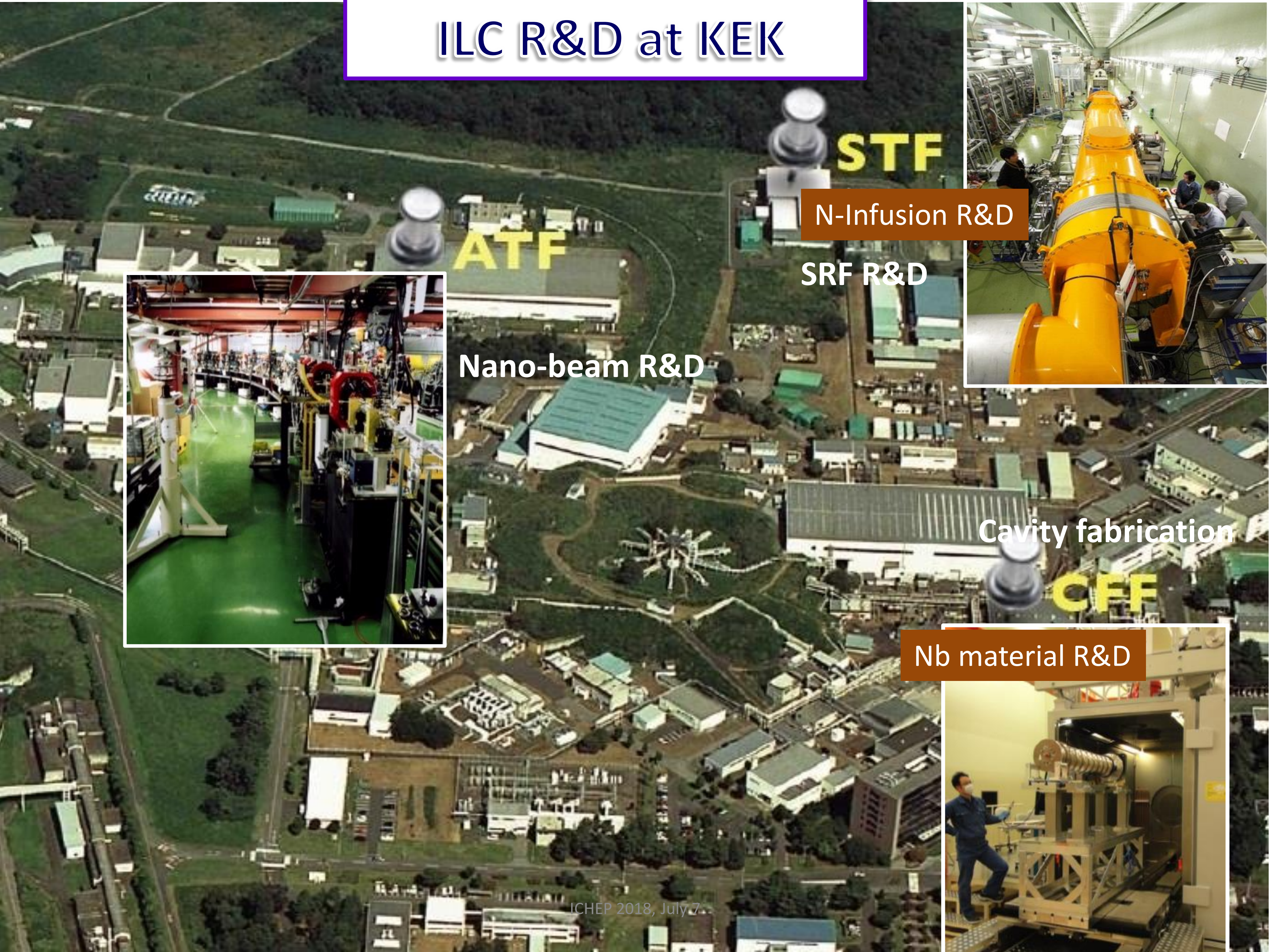
- SRF cavity fabrication for high-Q and high-G

  -w/ a new “N Infusion” recipe demonstrated by **Fermilab**





ILC R&D at KEK

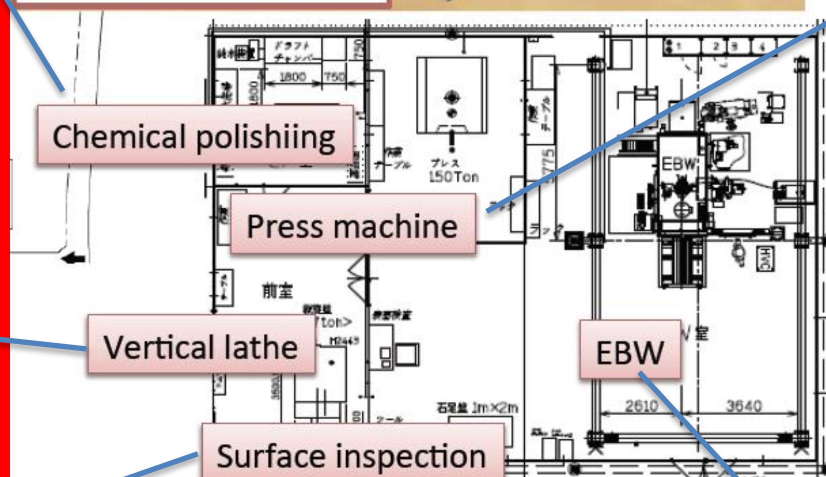

STF
N-Infusion R&D
ATF
SRF R&D
Nano-beam R&D
Cavity fabrication
CFF
Nb material R&D

Main equipments in CFF

Chemical polishiing

CNC vertical lathe
(Moriseiki, Japan)

Microscope
(Surface inspection)

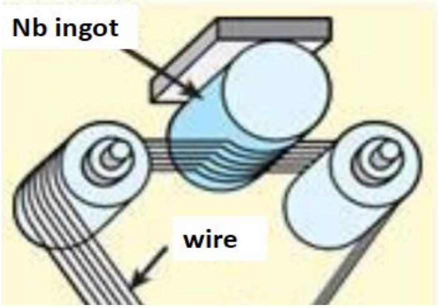


Servo press machine
(AMADA, Japan)
Max. applying force:1500 kN

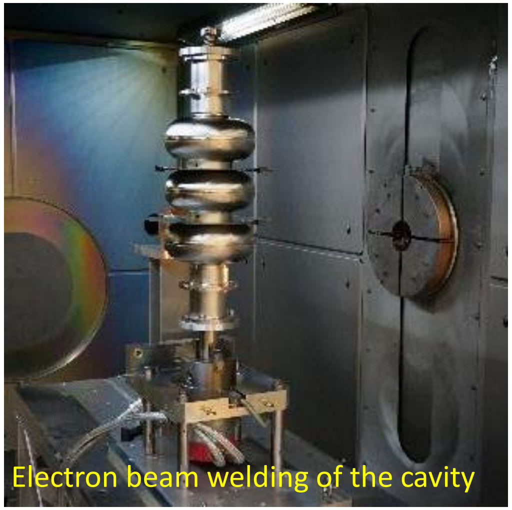
EB welding machine
（SST, Germany）
Max. beam voltage: 150 kV

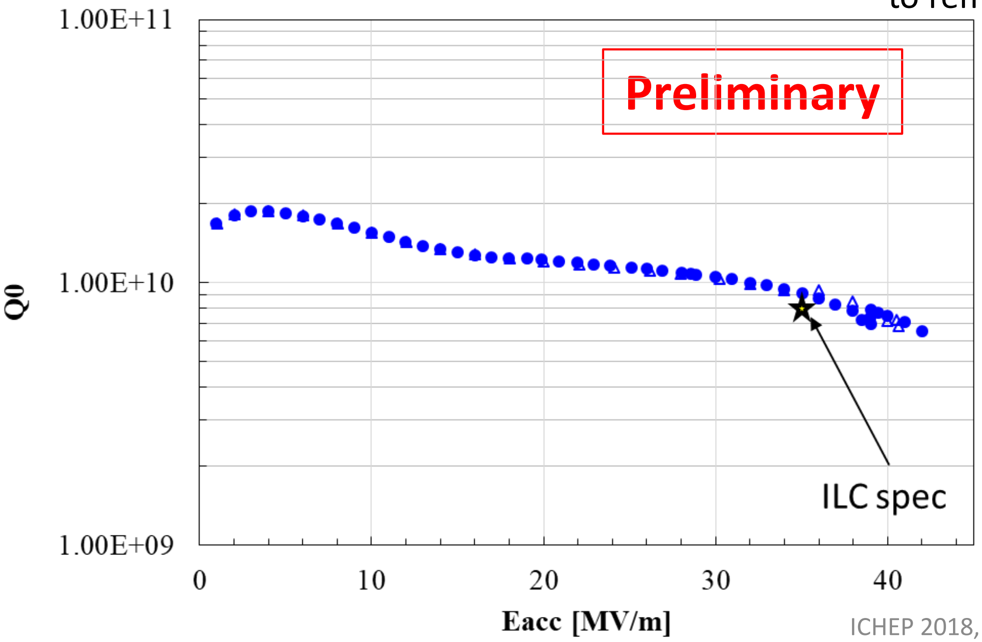
Direct sliced Nb material performance

Made from large grain Nb disks;
medium RRR Nb with high Ta content



Annealed for
800°C × 3hrs
to remove stresses.





- The 3-cell cavity achieved very high gradient (~42 MVm) and satisfies ILC spec.

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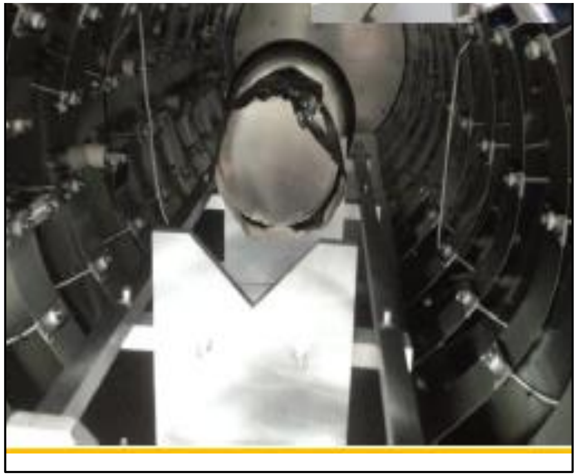
ILC R&D at KEK


STF
N-Infusion R&D
SRF R&D
ATF
Nano-beam R&D
Cavity fabrication
CFF
Nb material R&D

SRF equipments around STF

Electropolishing

Vacuum furnace



Vertical test

High pressure rinsing

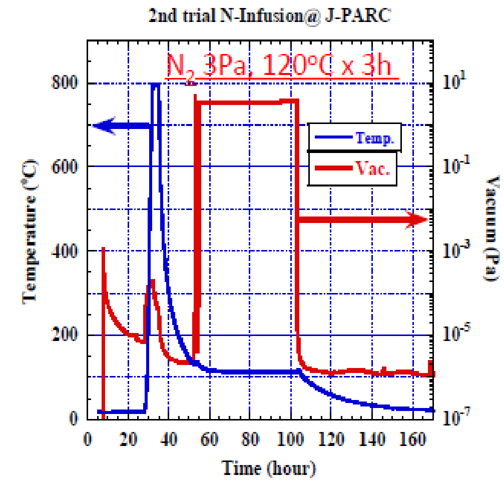
Clean room

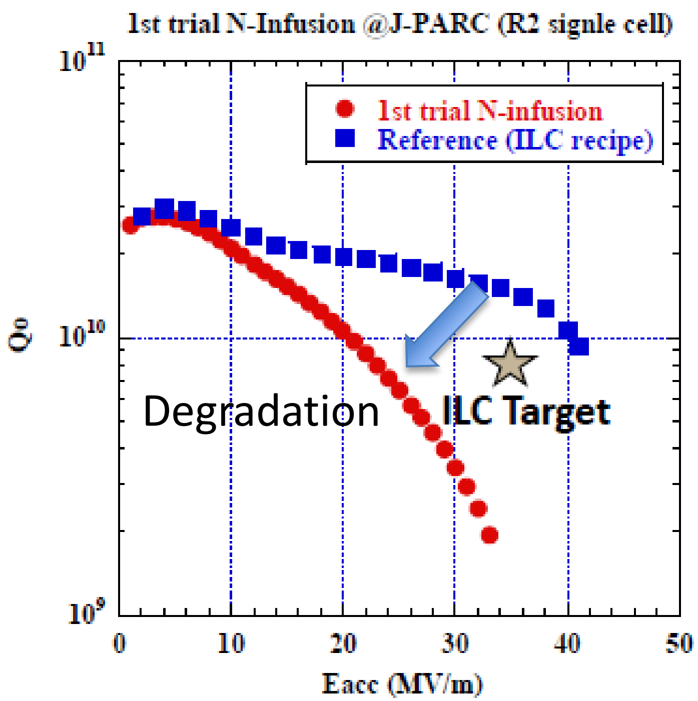
Horizontal test

STF-2

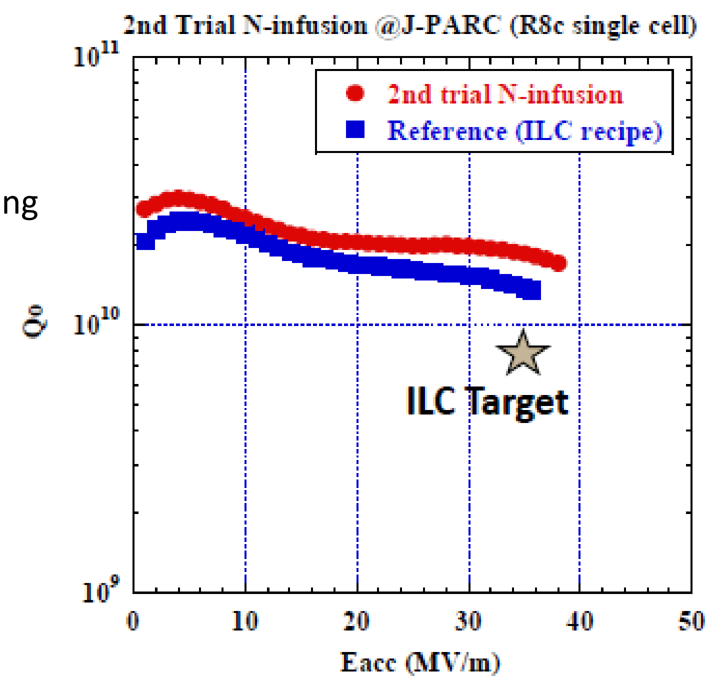
Recent N-Infusion result at KEK

- First trial of N-infusion showed degradation occurred at >5MV/m.
- Degradation seems to come from background vacuum during 120deg. N-Infusion.
- Background vacuum during N-Infusion was improved from 1.7e-2Pa to 1e-5Pa using larger turbo-molecular pump with reduced rotation speed.
- Second trial of N-Infusion was done with improved background vacuum during N-Infusion (120 deg.)
- It showed successful N-Infusion result (Q value +35% gradient +5%).





After the vacuum pumping system improvement



US-Japan cost reduction R&D

Evaluate the cavity performance from vertical test to horizontal test

Cavity fabrication

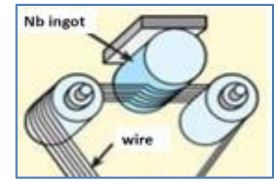
Heat treatment

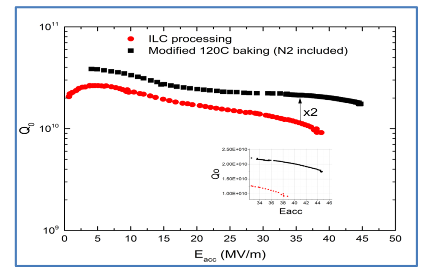
N-Infusion

Vertical test

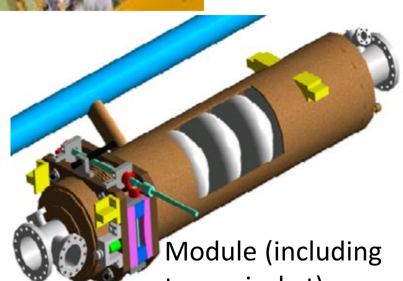
	Standard Fabrication/Process
Fabrication	Nb-sheet purchasing
	Component Fabrication
	Cavity assembly with EBW
Surface Process	EP-1 (~150um)
	Ultrasonic degreasing with detergent, or ethanol rinse
	High-pressure pure-water rinsing
	Hydrogen degassing at ~~> 600 C~~ → 800 C
	Field flatness tuning
	~~EP-2 (~20um)~~
	~~Ultrasonic degreasing or ethanol (or EP 5 um with fresh acid)~~
	High-pressure pure-water rinsing
	Antenna Assembly
	Baking at 120 C (+ N2 infusion)
Cold Test (vertical test)	Performance Test with temperature and mode measurement
Cryomodule	Installation to the cryomodule

New Nb material/process





Degradation-free environment



Module (including tuner, jacket)

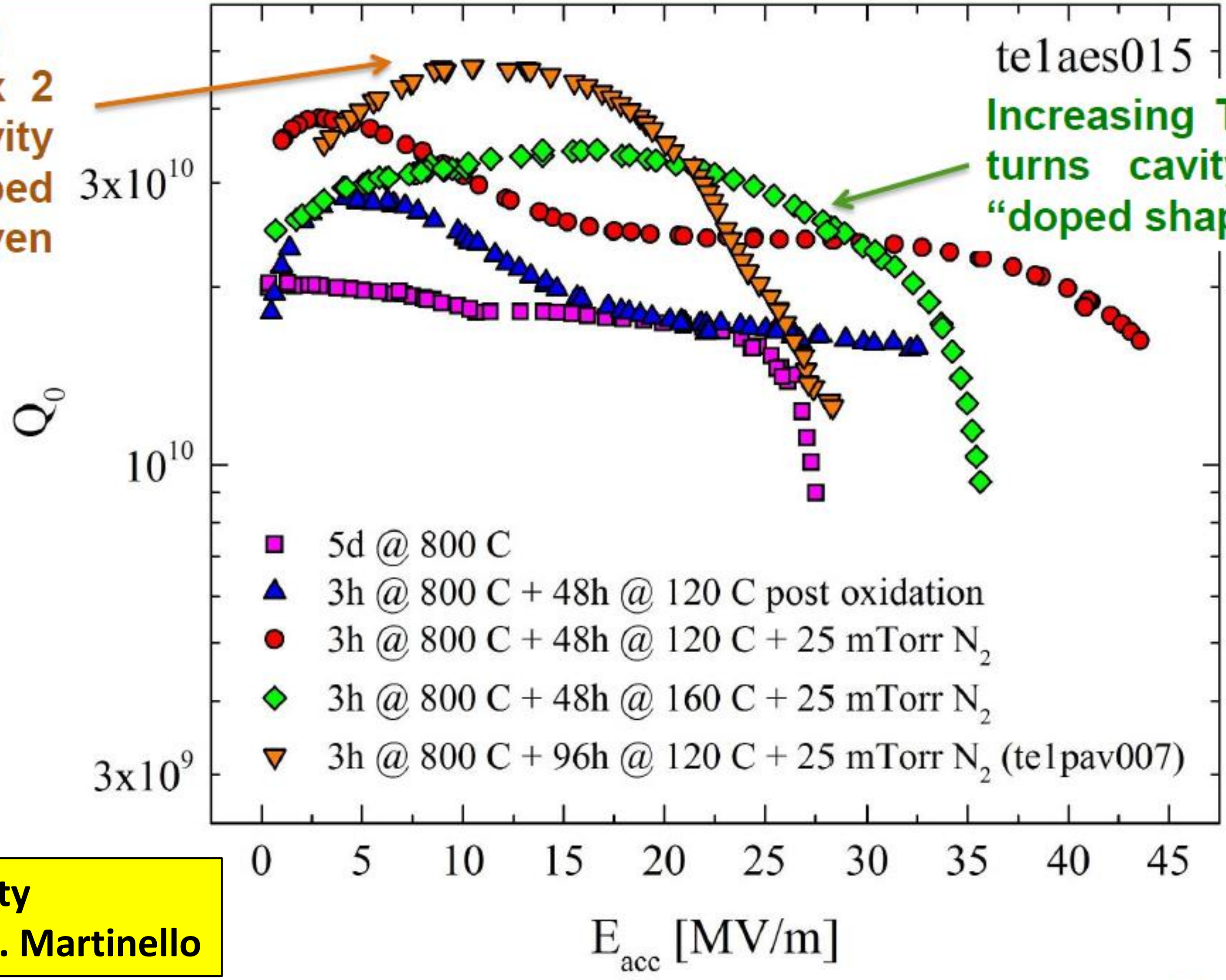
Stand-alone horizontal test

Horizontal test

Module test at stF-2

Cavity evolution – probing the parameter space

Increasing duration x 2 turns cavity into "doped shape", even higher Q!



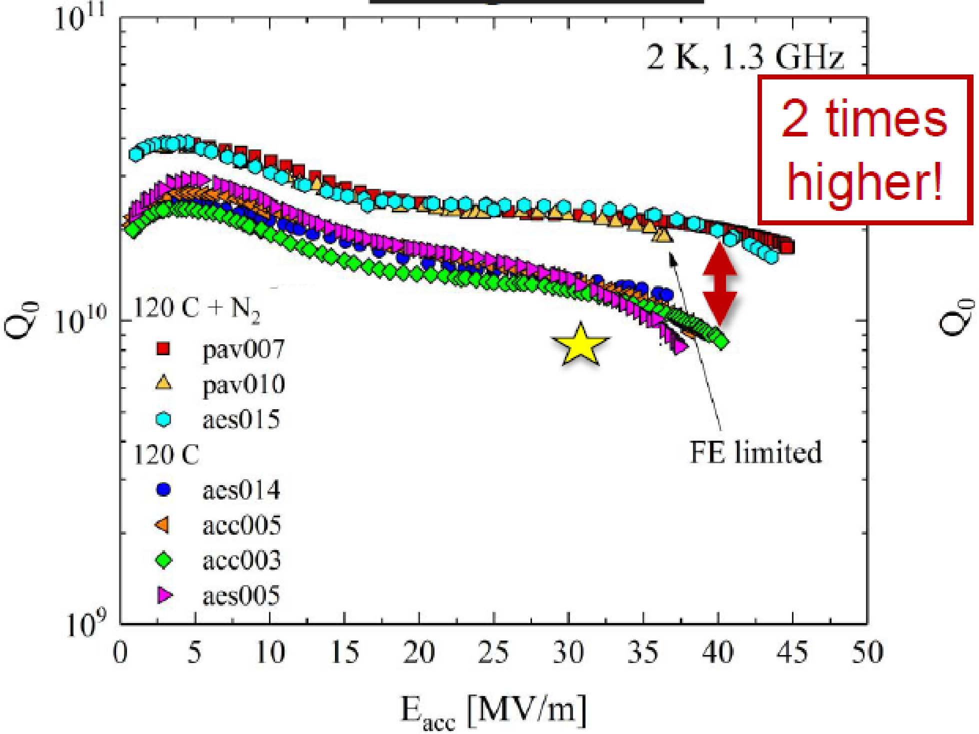
Increasing T ~40C turns cavity into "doped shape"!

FNAL activity
TTC2018 M. Martinello

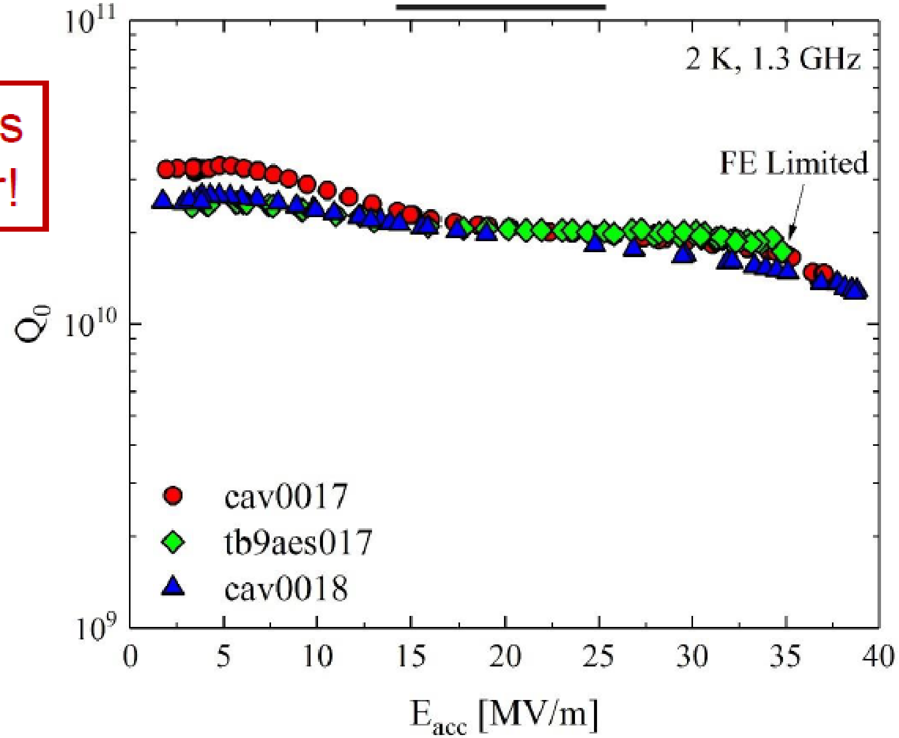
120 C N-infusion: high Q_0 at high gradients

FNAL activity
TTC2018 M. Martinello

Single-cell



9-cells

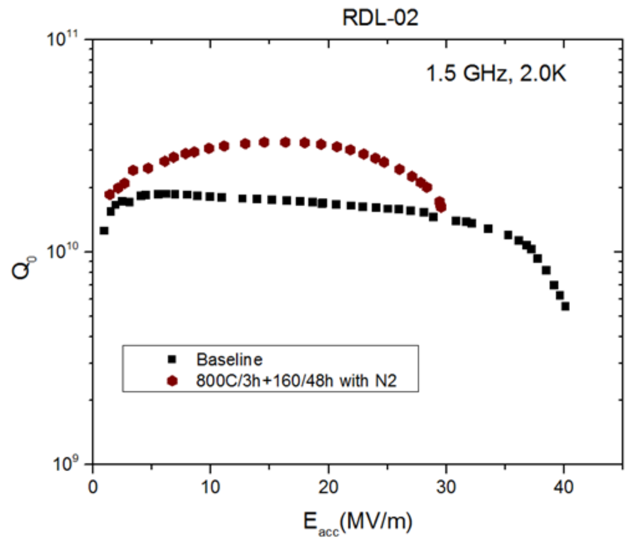


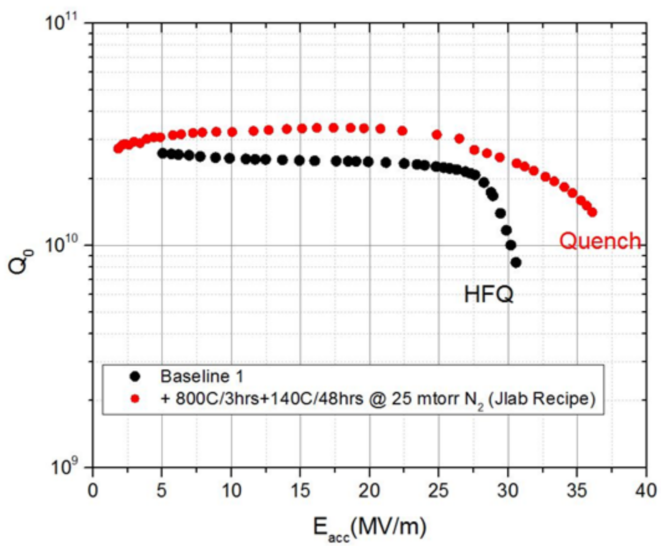
N-Infusion successful also on 9-cell cavities!

A. Grassellino et al 2017 Supercond. Sci. Technol. **30** 094004

TTC2018 Riken
Pashupati Dhakal
J-Lab result

Update on N-infusion at JLab





- Successful infusion runs at multiple temperatures
- Need to inject at higher T to succeed
- Upgrade of furnace diagnostics &

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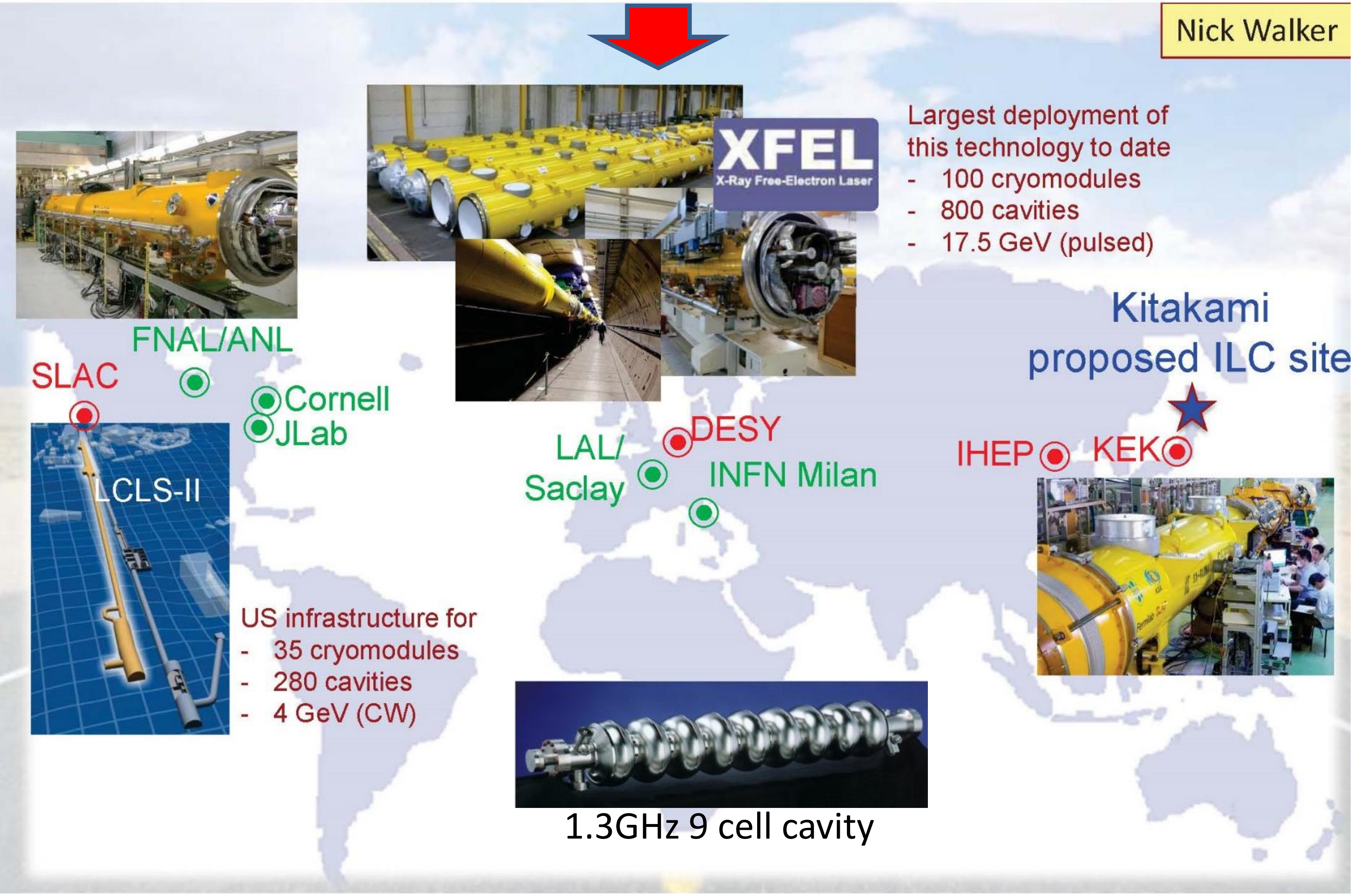
SRF Accelerators Advances 2010 ~

Courtesy, H. Padamsee

Project	Notes	# cavities
CEBAF-JLAB (US)	Upgrade 6.5 GeV => 12 GeV electrons	80
XFEL-Hamburg (EU)	18 GeV electrons – for Xray Free Electron Laser – Pulsed)	840
LCLS-II – SLAC (US)	4 GeV electrons –CW XFEL (Xray Free Electron Laser)	300
SPIRAL-II (France)	30 MeV, 5 mA protons -> Heavy Ion	28
FRIB – MSU (US)	500 kW, heavy ion beams for nuclear astrophys	340
ESS (Sweden)	1 – 2 GeV, 5 MW Neutron Source ESS – pulsed	150
PIP-II–Fermilab (US)	High Intensity Proton Linac for Neutrino Beams	115
ADS- (China, India)	R&D for accelerator drive system	> 200
Globally Int. Effort		> 2000

SRF accelerators in the world



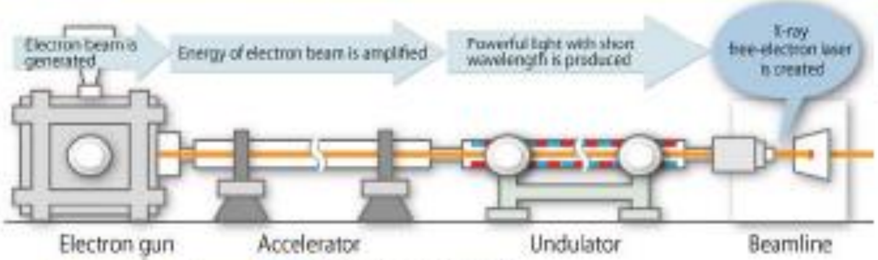
INTRODUCTION: the European XFEL

The European X-ray Free Electron Laser

- 17.5 GeV light source user facility
- TESLA superconducting 1.3 GHz RF cavities
- 1.4 msec RF pulses at 10 Hz
- e- beam 1.35 mA nom., up to 500kW beam power

The XFEL accelerator

- 800 SRF cavities, couplers, tuners
- (720 in operation for now) + 64 next months
- 101 cryomodules, 26 RF stations
- 2 years of cavity / cryomodules tests / tunnel installation



European XFEL

YouTube watch online:
https://www.youtube.com/watch?v=p3G90p4gIQA

HELMHOLTZ GEMEINSCHAFT

DESY

RF COMMISSIONING

- ✓ 12/16 Linac cool down to 4K
- ✓ 01/17 Injector to 130 MeV (3 RF stations)
- ✓ 01/17 Linac 1 (+1 RF station)
- ✓ 02/17 Linac 2 (+3 RF stations)
- ✓ 02-04/17 Linac 3 (+15 + 3 RF stations)
- ✓ 04/17 First beam through undulator section (SASE1)
- ✓ 05/17 First lasing
- ✓ 05-08/17 SASE1 photon beamline + experimental hall
- ✓ 09/17 First users (total 800 hours)
- ❑ 2018 Further commissioning + 2000 hours users
- ❑ 2019 Nominal operation with 6 experiments + 4000 hours users

2 weeks

2 weeks

1 month

2 weeks

2 months

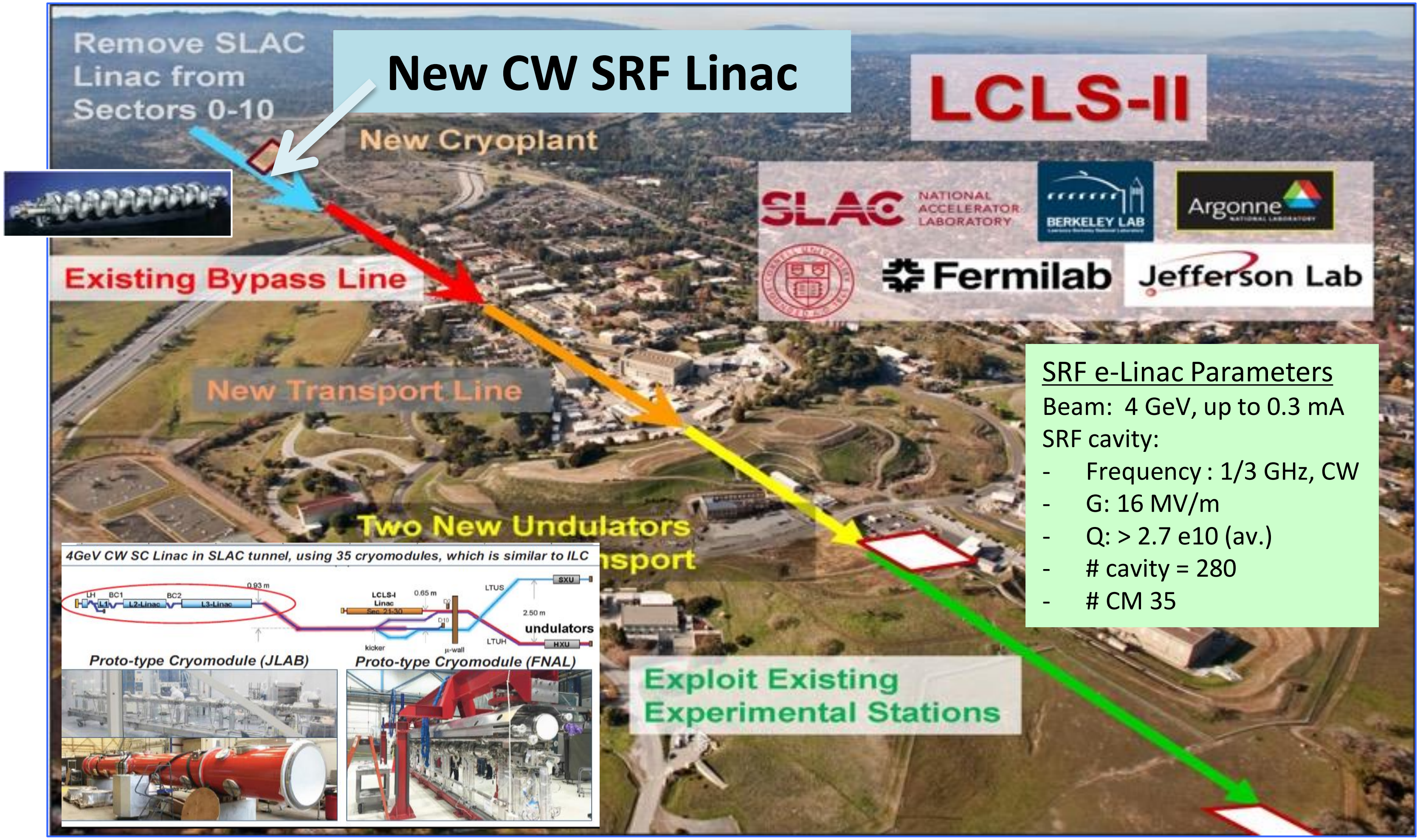
Milestone: RF ready 4 months

Milestone: First lasing 5 months

Milestone: First users 9 months

LCLS-II Concept

Use 1st km of SLAC Linac for CW SCRF Linac



Large Accelerator Projects in China

	Year	Host	Type	Dimen.	Energy	Cost
BEPC-II	2003-08	IHEP	e+e- ring	240m C	2.5 GeV	~100M $
SSRF	2004-09	SINAP	e- ring	432m C	3.5 GeV	220M $
CSR	2004-10	IMP	i ring	129m C	0.4 GeV/u	~50M $
CSNS	2010-18	IHEP-GD	p lin+ring	100+200m	1 GeV	~330M $
XFEL-TF	2014-18	SINAP	e- linac	293m L	0.8 GeV	~30M $
XFEL-UF	2016-19	SINAP	e- linac	532m L	1.5 GeV	110M $
CiADS	2018-25	IMP-GD	p linac	~200m L	0.5 GeV	~400M $
HIAF	2018-24	IMP-GD	i lin+ring	~530m C	4.2 GeV/u	~350M $
H-XFEL	2018-25	SINAP	e linac	3100m L	8 GeV	~1.4B $
HEPS	2018-25	IHEP	e ring	1300m C	6 GeV	~700M $

GD: Guangdong Province (near Hongkong)
Cost: rough amount in USD for easy understanding

[dashed box] : heavily SRF

EXFEL , LCLS-II(HE) and Shanghai XFEL

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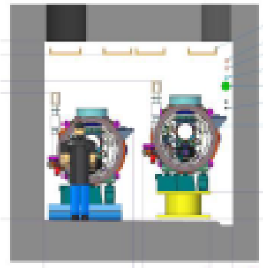
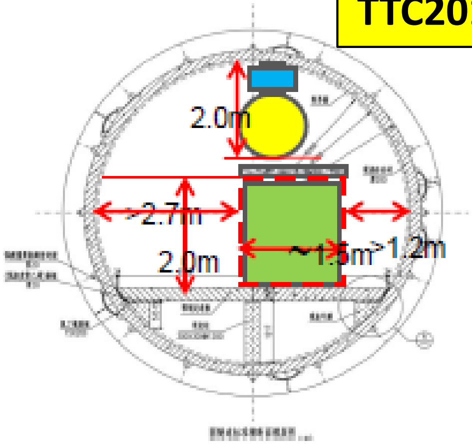
European XFEL


LCLS-II



	EuropeanXFEL	LCLS-II (HE)	Shanghai XFEL
RF mode	Pulsed	CW	CW
Power source	Klystron	SSA	SSA
Install	Single ac Tunnel	Tunnel + Gallery	Single ac Tunnel
2K heat load/CM	~20w/CM	~80w/CM	~80w/CM
Tunnel slope	~	0.5%	~
N of modules	~100	~35 (+19)	~75
2K capability	~3kW	~ 2 x 4kw	~ 3x4 or 4x3 kw

SIOM

SCLF

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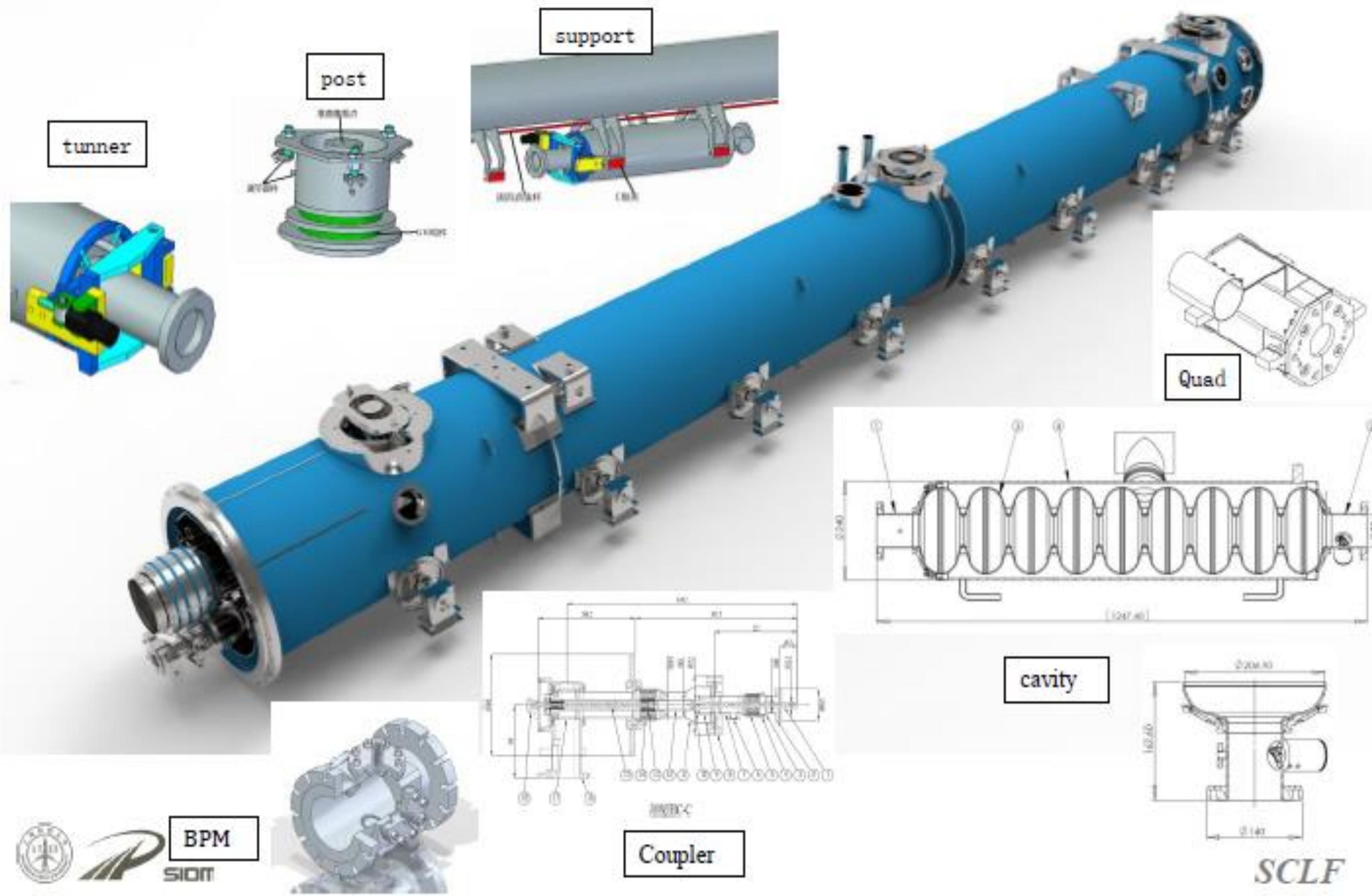
Cryomodule

based on EXFEL&LCLS-II type



Recent ILC R&D status

Shin MICHIZONO
KEK/Linear Collider Collaboration (LCC)

- *250GeV ILC*
- *Nano-beam R&D*
- *Cost reduction SRF R&Ds*
  - *Directly sliced Nb material*
  - *N-infusion*
- *SRF accelerators*
- *Fukuoka Statement/ILC symposium*

Fukuoka Statement

LINEAR COLLIDER COLLABORATION

AsianLinearColliderWorkshop2018
May 28 - June 1, 2018 Fukuoka International Congress Center Fukuoka, JAPAN

Statement on “Towards the realization of the International Linear Collider, an update”

https://www.kek.jp/ja/newsroom/attic/20180531_ilc_fukuokastatement.pdf

31 May 2018, Fukuoka

Scientists who gathered for the Linear Collider Workshop in Tokyo in 2015 issued a statement confirming their strong support for the scientific justification for a prompt realization of the International Linear Collider (ILC). The Linear Collider Collaboration (LCC) and the worldwide participants at the 2018 Asian Linear Collider Workshop (ALCW2018) in Fukuoka, Japan, reconfirm the scientific importance of the ILC. We are closer to the realization of the project, but it is now in a critical phase.

(1) Results to date from the CERN Large Hadron Collider indicate that we are at a crossroads in our quest to uncover the origin and history of the Universe. We now know that precision measurements, in particular of the properties of the Higgs boson, are an essential next step to advance our understanding. Precise measurements in electron-positron interactions at a center of mass energy of 250 GeV at the ILC will deliver a leap in our scientific knowledge and, together with future results from the LHC and SuperKEKB, will propel us toward the ultimate theory of particle physics and a deep understanding of the Universe itself.

(2) We have been preparing for the ILC for many years, in collaboration with industries and in discussion with governments worldwide. The ILC is now the most mature and realizable electron-positron collider project, and offers the energy expandability of a linear collider. The successful operation of the European XFEL in Hamburg and recent advances in the superconducting R&D in Fermilab near Chicago and other laboratories, together with a cost reduction by changing the initial center of mass energy to 250 GeV, increases the ILC technical and financial feasibility whilst maintaining the physics potential of the machine at this energy. The superconducting technology being developed for the ILC has a great impact on industrial and medical applications of accelerators. We deeply appreciate the evaluation process by the Japanese government for the proposal based on the new ILC design.

(3) The ILC can only be realized as an international project, and a nation who wishes to host the project should lead the international negotiations. A positive message from the Japanese government expressing readiness to initiate these discussions this year is critically important because work on the update of the European Strategy for Particle Physics, including collaboration in the ILC construction, will start early next year. This update will have a large impact outside Europe on the future of high energy physics projects worldwide. While we will strongly present the scientific case for the ILC in these discussions, it is essential to hear a positive message from the Japanese government in a timely manner.

Lyn Evans
LCC Director
For scientists from LCC and ALCW2018

LINEARCOLLIDER.ORG

Matured SRF accelerator
Recent R&Ds

An International Symposium

http://www-conf.kek.jp/SRF_for_ILC/index.html

High Energy Accelerator Research Organization (KEK),
Linear Collider Collaboration (LCC) and
International Center for Elementary Particle Physics (ICEPP)
cordially invite you to the symposium on:

The Superconducting RF technology
for the International Linear Collider

Monday, June 25th, 2018, at 10:00
Fukutake Learning Theater, The University of Tokyo

Symposium program

General overview

10:00	**Opening address** Masanori YAMAUCHI (KEK, Japan)
10:10	**Physics at the ILC and international collaboration** Sachio KOMAMIYA (Waseda University, Japan)
10:35	**Accelerator technologies of ILC and their applications** Shinichiro MICHIZONO (KEK, Japan)
11:00	**A global collaboration for the ILC** Lyn EVANS (Linear Collider Collaboration, UK)
11:10	**US SRF R&D status** Sergey BELOMESTNYKH (Fermilab, U.S.A.)
11:35	**European XFEL experiences demonstrating the SRF technology for the ILC** Hans WEISE (DESY, Germany)
12:00	**Advances in SRF technology and future prospects in China** Jie GAO (IHEP, China)
12:25	*Lunch/Media briefing*

Technical discussion

13:30	**N-Infusion, new SRF technology with higher performance** Anna GRASSELLINO (Fermilab, U.S.A.)
13:55	**SRF technology R&D at JLAB, and the future prospects** Ari PALCZEWSKI (Jefferson Lab, U.S.A.)
14:20	**ILC cost reduction R&Ds at KEK** Kensei UMEMORI (KEK, Japan)
14:45	**Collaboration for high efficiency SRF system at reduced cost** Ganapati MYNENI (ISOHIM, U.S.A.)
14:55	*Break*
15:20	**Industrial application of SRF accelerator** Hiroshi KAWATA (KEK, Japan)
15:45	**Application of SRF Linac for IFMIF Prototype Accelrrator** Atsushi Kasugai (QST/Rokkasho, Japan)
16:10	**The history of industrialization in SRF technology and prospects for future** Katsuya SENNYU (Mitsubishi Heavy Industry Machinery Systems, Japan)
16:35	**Adjourn**

Recent status and R&Ds were reported by the world-wide researchers.

Thank you for your attention