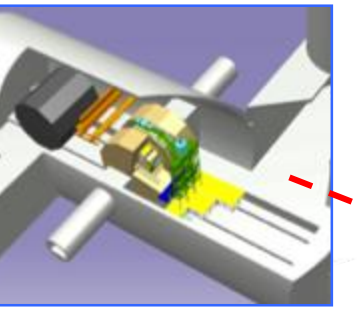
ILC status

KEK/LCC

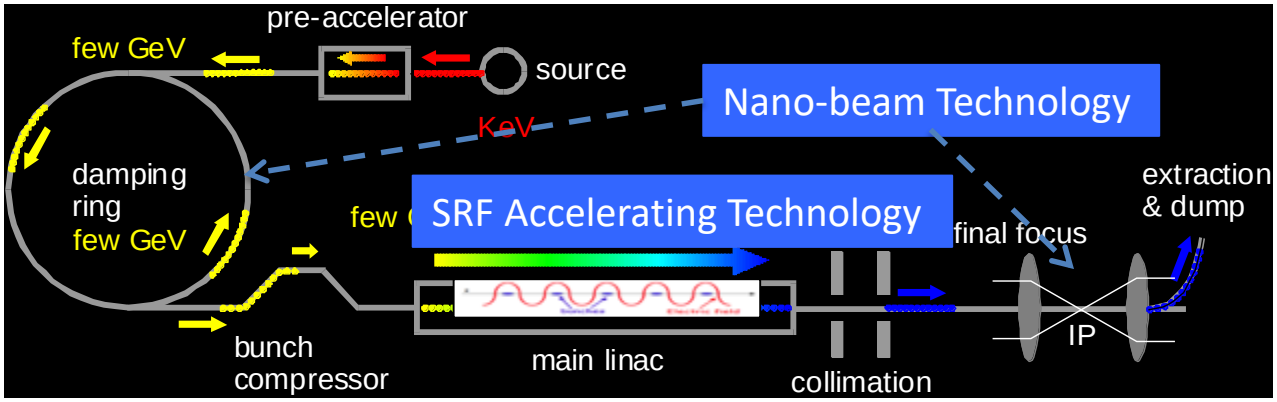
Shin MICHIZONO

- *The ILC*
- *KEK's activities*
- *ILC cost reduction R&D*
- *World-wide R&D for high-Q and high-G*
- *staging*

ILC Acc. Design Overview (in TDR)



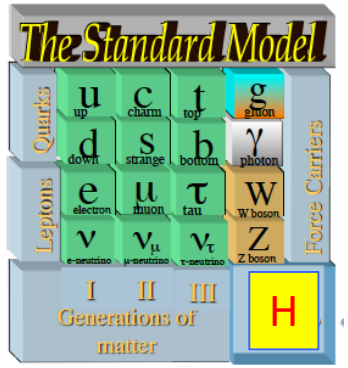
Key Technologies



Item	Parameters
C.M. Energy	500 GeV
Length	31 km
Luminosity	1.8 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	**5.9** nm
SRF Cavity G. Q_0	**31.5** MV/m Q_0 = 1x10 ^{10}

Important Energies in ILC

125 GeV Higgs discovery reinforcing the ILC importance



Integrated Luminosity (ab^{-1})

2

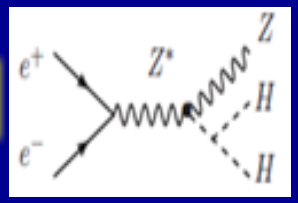
1

Physics confident:

→ **Higgs** and **Top Quark**

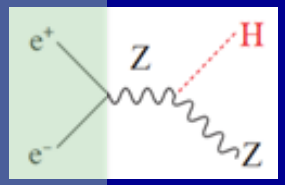
- Learn "everything" about H (125)
- Probe dynamics of EWSB

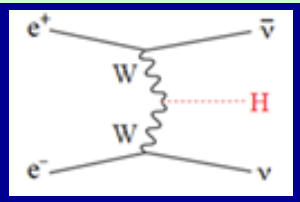
HHZ

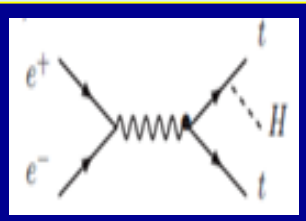


New Physics beyond SM:

- Direct or indirect **DM searches**
- Evidence for BSM physics
- Hints of a new mass scale







HZ

$\bar{\nu}\nu H$

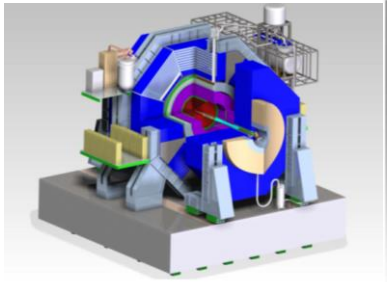
$t\bar{t}$

$t\bar{t}H$

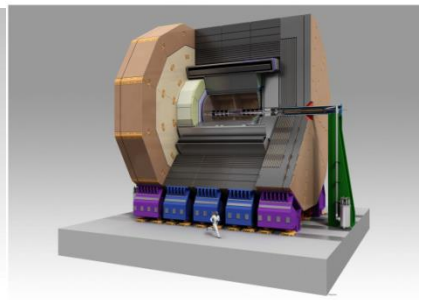
LEP reached→

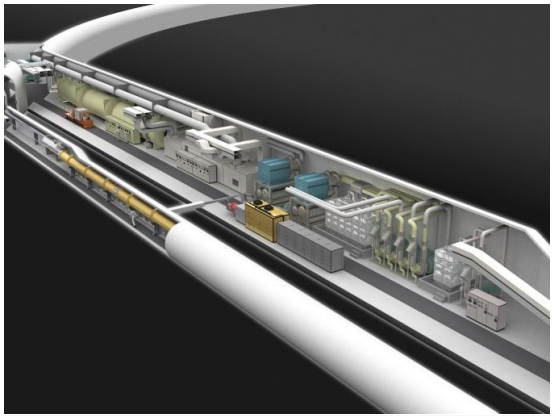
200 300 400 500 600 E_{cm} (GeV)

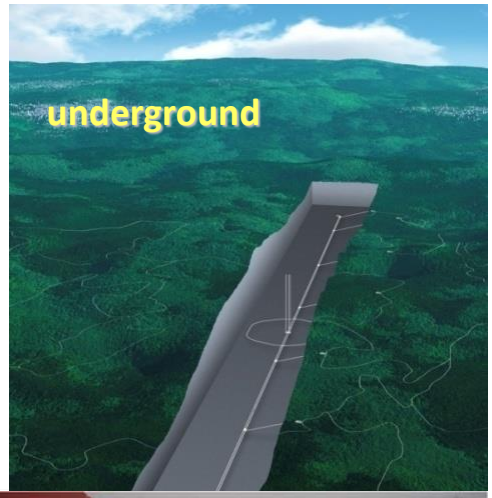
SiD



ILD

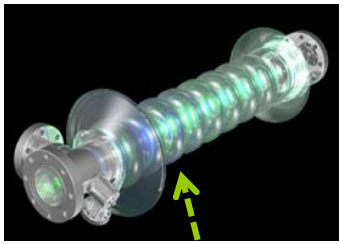


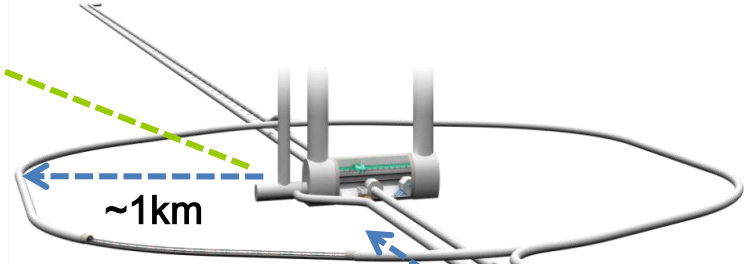


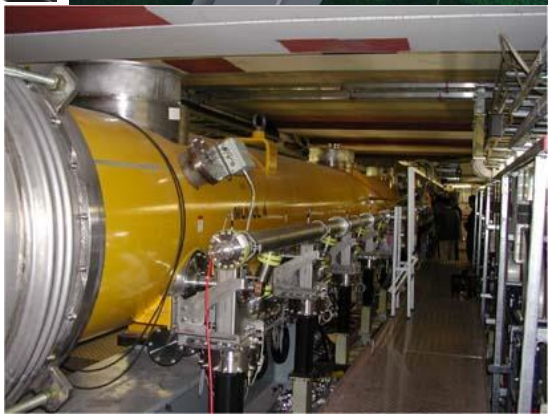


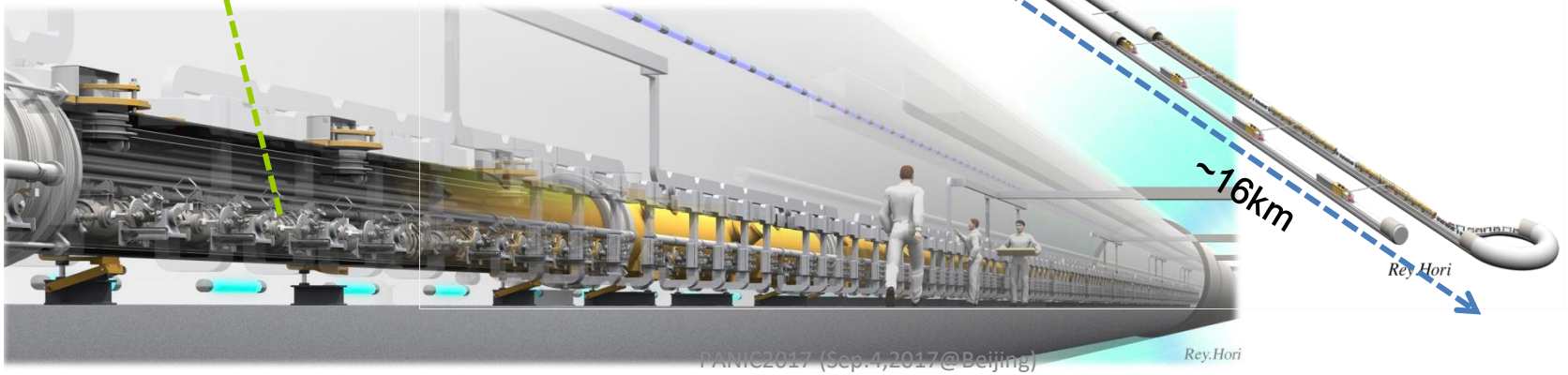
Detectors

Superconducting cavity



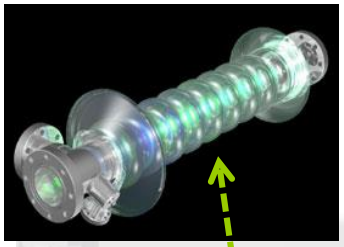


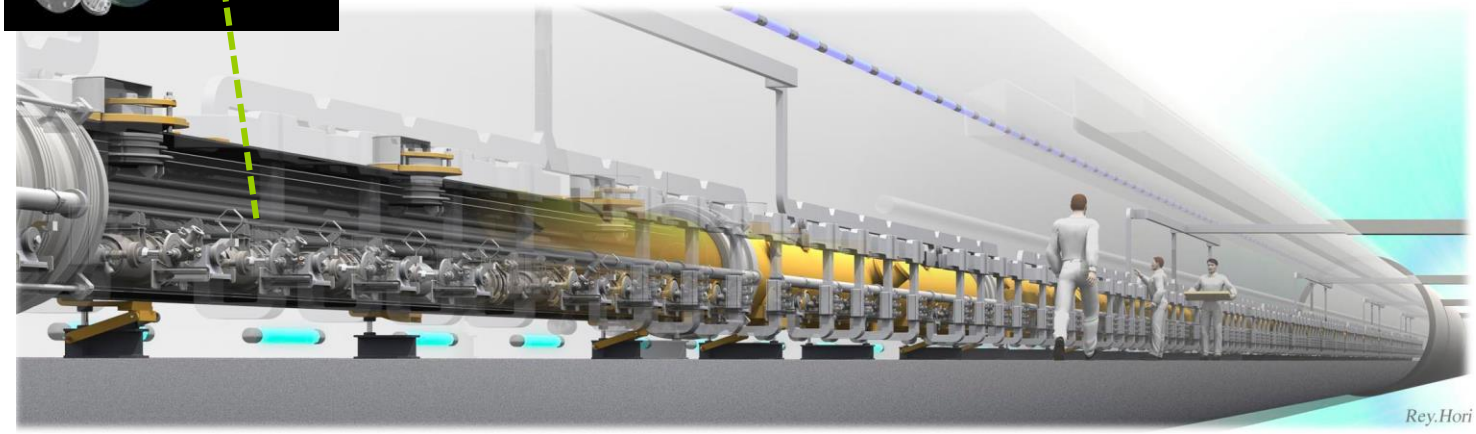


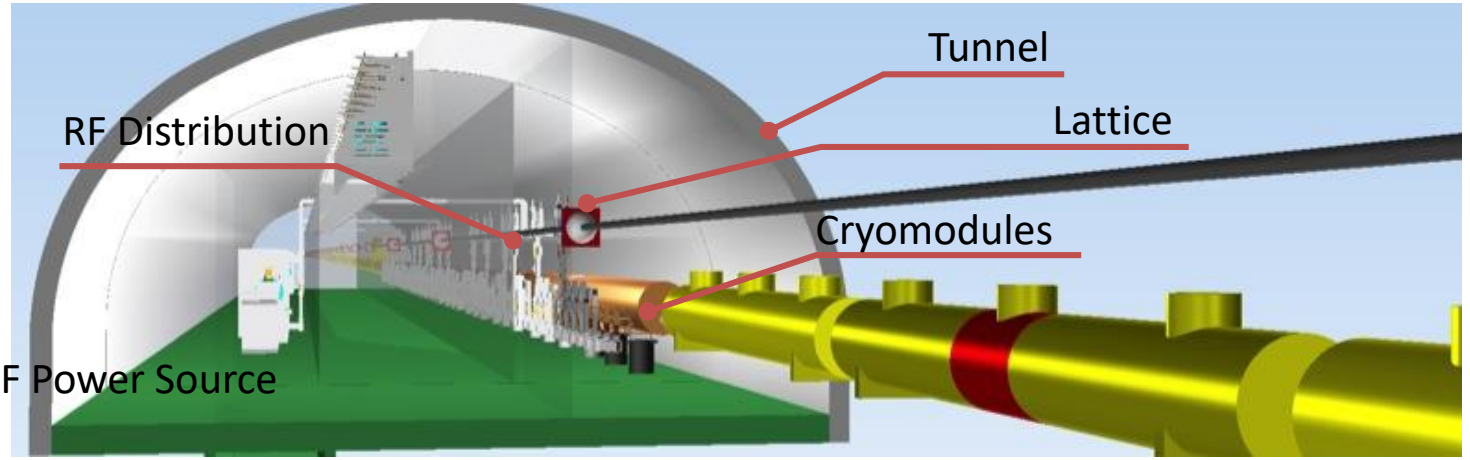


Main Linac at the ILC

# of SRF cavities ~16000







History and Progress in SRF Technology

T. Furuya

50 years after SC discovery.

1965 HEPL (Stanford U.), S-band. 3-cell, Pb plated cavity
Beam acceleration up to 1mA

1978 ATLAS (Argonne NL), Heaviy Ion Acc. with CW SRF

1988 TRISTAN (KEK)
509 MHZ、5-cell, x32 cavity, 5 MV/m, 200 MV
LEP-II (CERN), 352 MHz、4-cell x300 →3 GV

1990 Plan for TESLA (TeV Energy SC Linear Accelerator)。
TDR (2001)

1995 CEBAF (TJNAF) , 1.5 GHz ,5 -cell, 336 cavities
CW-4GeV,1mA。

1997 CESR (Cornell), KEKB (KEK)

2004: ILC: SC technology selected
1.3 GHz, 31.5MV/m (pulse)

2016 EURO-XFEL (TESLA type :pulse, 23.6MV/m)

TBD realization of ILC











ILC GDE to LCC

1980' ~ Basic Study

2004 2006 '07 '08 '09 '10 '11 '12 '13 '14 '15 '16 '17

ILC-GDE

LCC

Ref. Design (RDR)

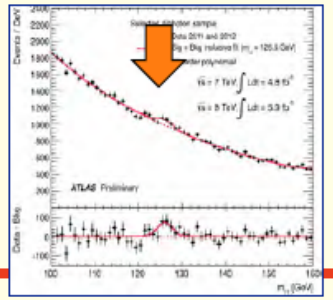
Technical Design Phase

TDP 2

TDR publication

LHC

126 GeV

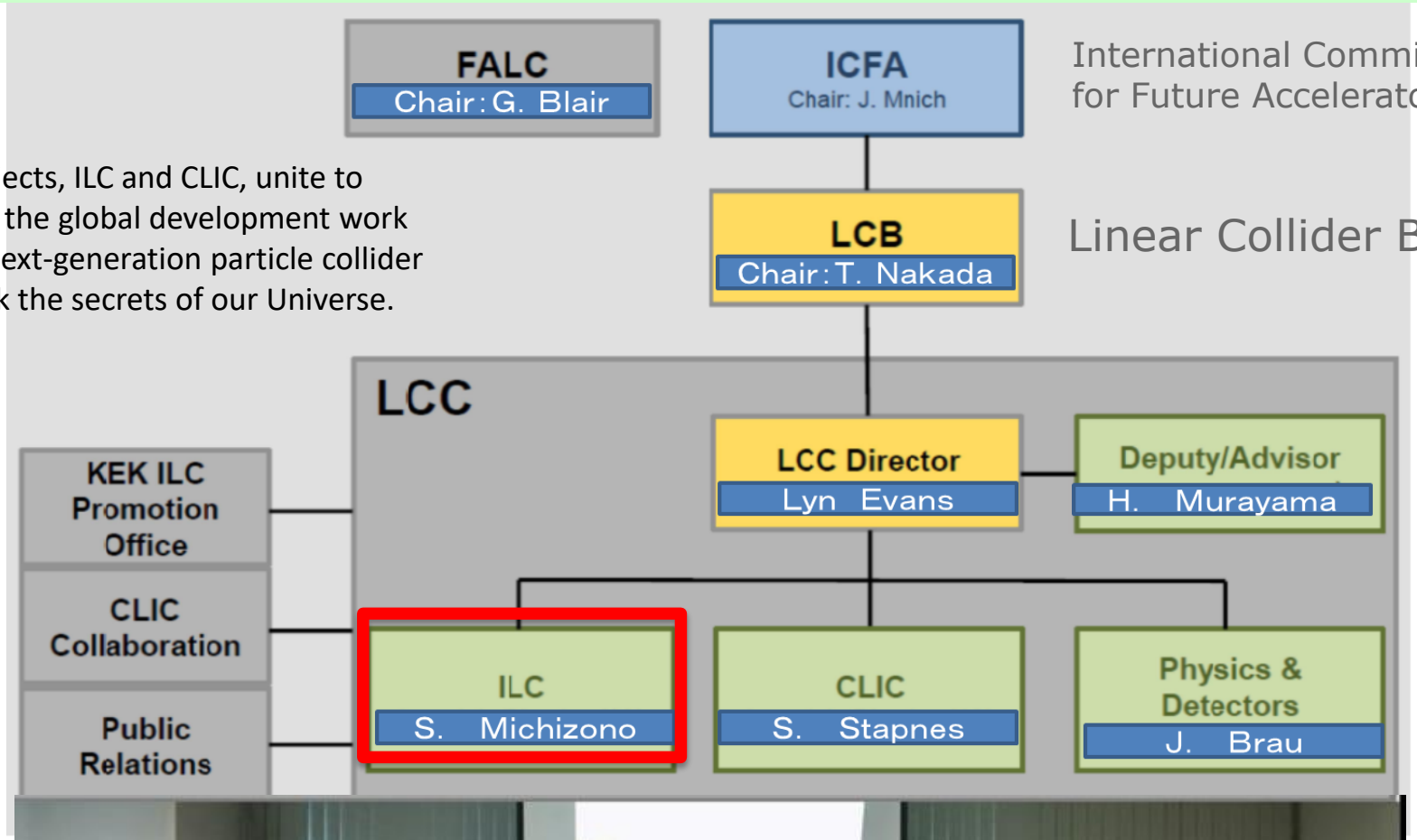


Higgs discovered

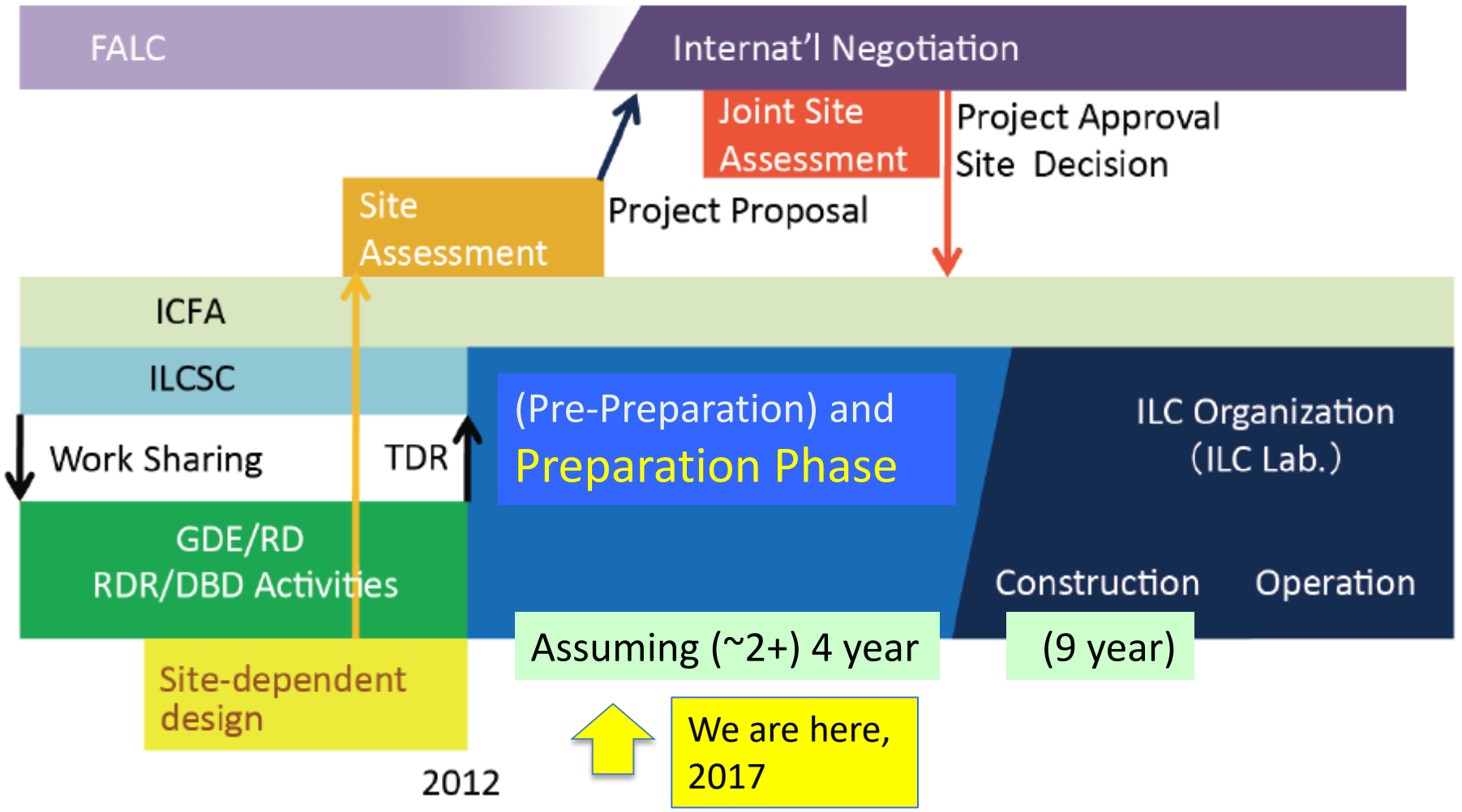
Selection of SC Technology

LCC –Linear collider collaboration-

Two projects, ILC and CLIC, unite to advance the global development work for the next-generation particle collider to unlock the secrets of our Universe.



ILC Time Line: Progress and Prospect



ILC Site Candidate Location in Japan: Kitakami

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

High-way

Express-Rail

Oshu

Sendai

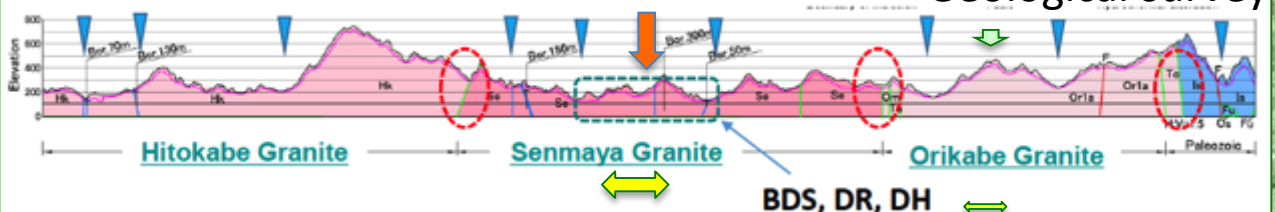
Ichinoseki

Ofunato

Kesen-numa

IP Region

Geological survey



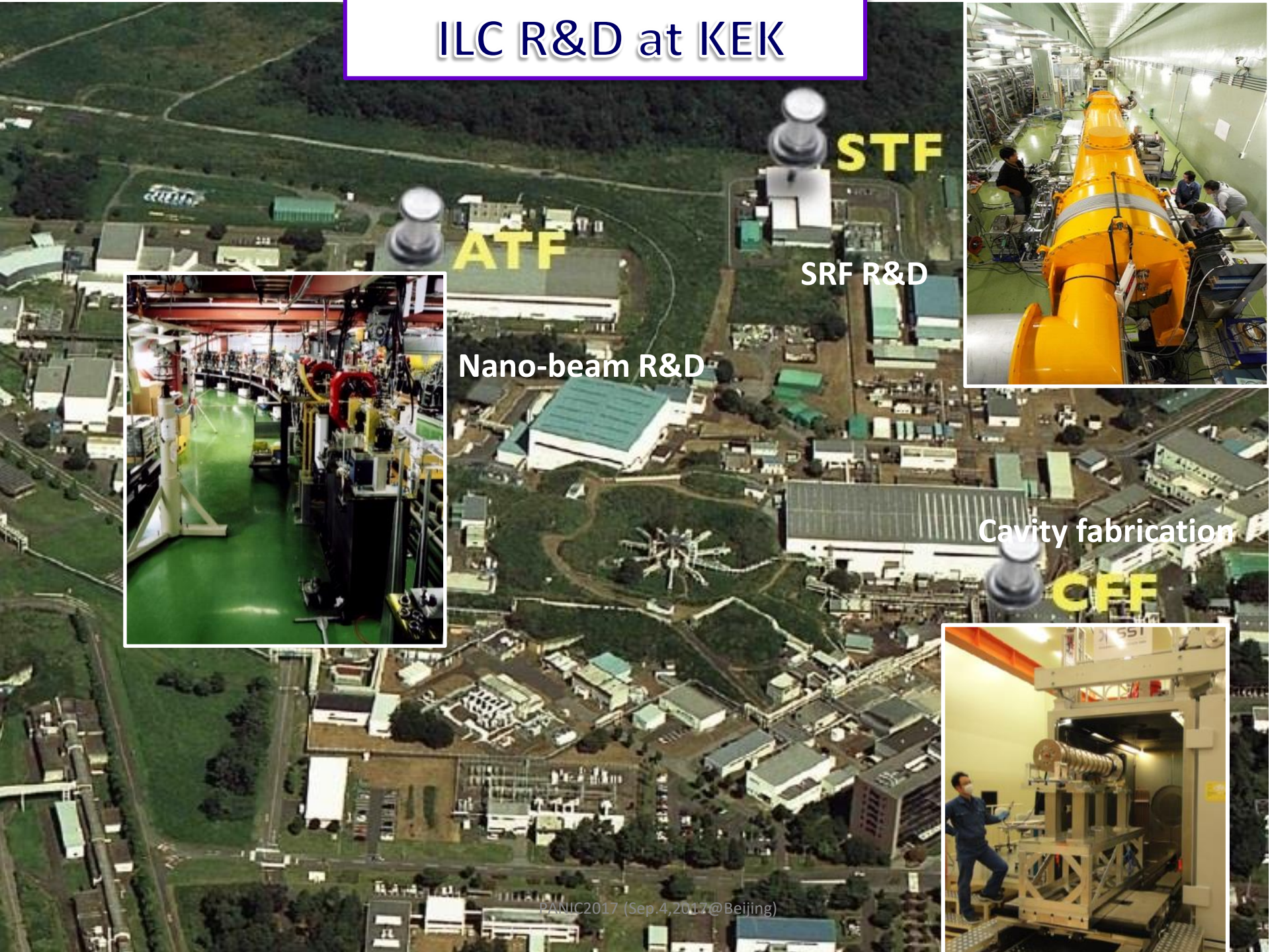
ILC status

KEK/LCC

Shin MICHIZONO

- *The ILC*
- *KEK's activities*
- *ILC cost reduction R&D*
- *World-wide R&D for high-Q and high-G*
- *staging*

ILC R&D at KEK



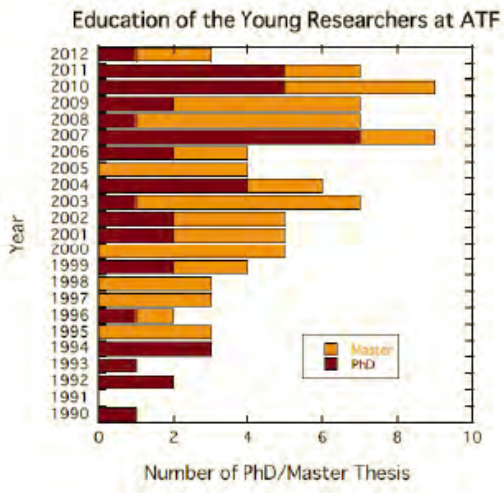
- ATF International Collaboration -

relatively independent R&D teams

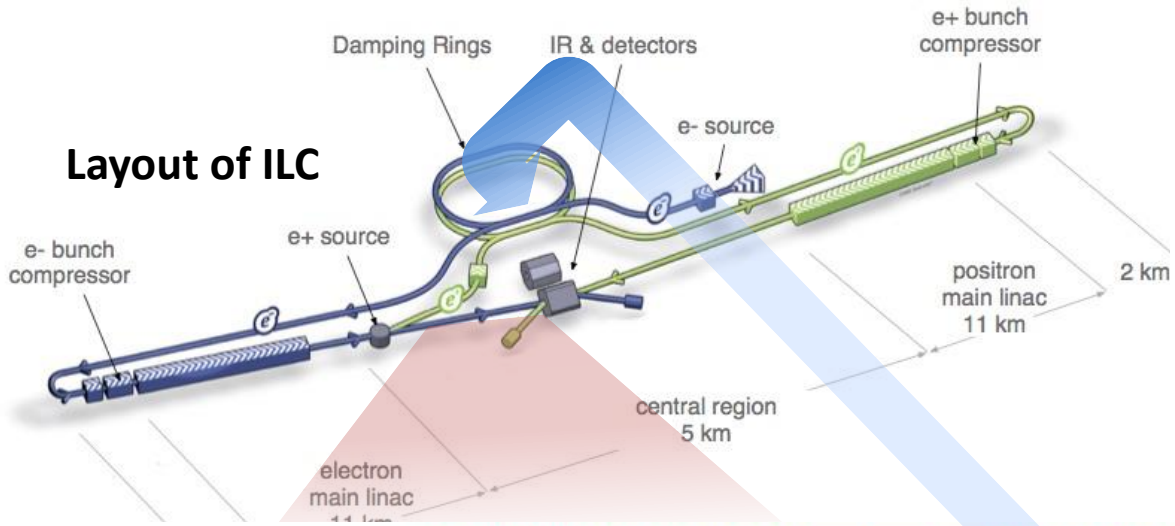
欧州原子核研究機構(CERN)
ドイツ(Germany)
　電子シンクロトロン研究所(DESY)
フランス(France)
　IN2P3; LAL, LAPP, LLR
イギリス(UK)
　Univ. of Oxford
　Royal Holloway Univ. of London
　STFC, Daresbury
　Univ. of Manchester
　Univ. of Liverpool
　Univ. College London
イタリア(Italy)
　INFN, Frascati
スペイン(Spain)
　IFIC-CSIC/UV
ロシア(Russia)
　Tomsk Polytechnic Univ.

アメリカ(USA)
　SLAC国立加速器研究所
　ローレンス・バークレー国立研究所(LBNL)
　フェルミ国立加速器研究所(FNAL)
　ローレンス・リバモア国立研究所(LLNL)
　ブルックヘブン国立研究所(BNL)
　コーネル大学(Cornell Univ.)
　ノートルダム大学(Notre Dome Univ.)

日本(Japan)
　高エネルギー加速器研究機構(KEK)
　東北大学　(Tohoku Univ.)
　東京大学　(Univ. of Tokyo)
　早稲田大学(Waseda Univ.)
　名古屋大学(Nagoya Univ.)
　京都大学　(Kyoto Univ.)
　広島大学　(Hiroshima Univ.)
中国(China)
　中国科学院高能物理研究所(IHEP)
韓国(Korea)
　ポハン加速器研究所(PAL)
　キョンプク大学(KNU)
インド(India)
　Raja Ramanna Centre for Advanced Technology



ATF/ATF2: Accelerator Test Facility



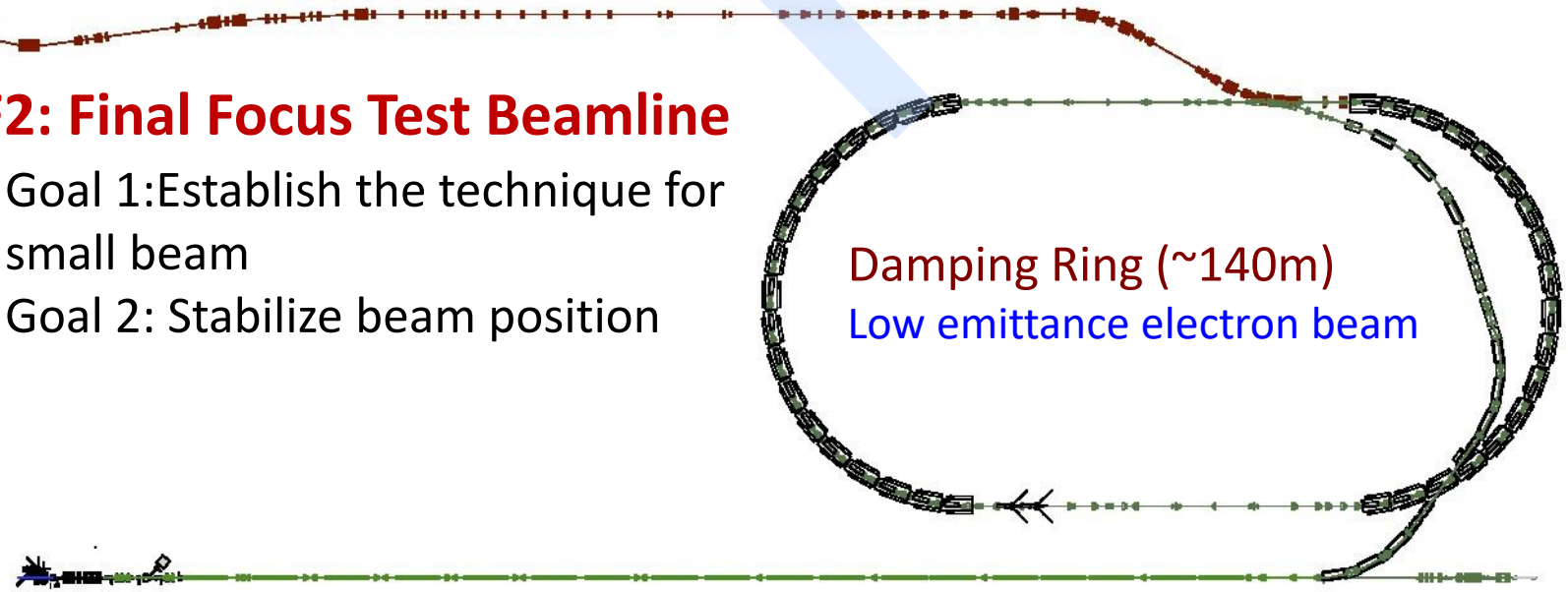
Develop the nanometer beam technologies for ILC

- Key of the luminosity maintenance
- 6 nm beam at IP (ILC)

ATF2: Final Focus Test Beamline

Goal 1:Establish the technique for small beam

Goal 2: Stabilize beam position



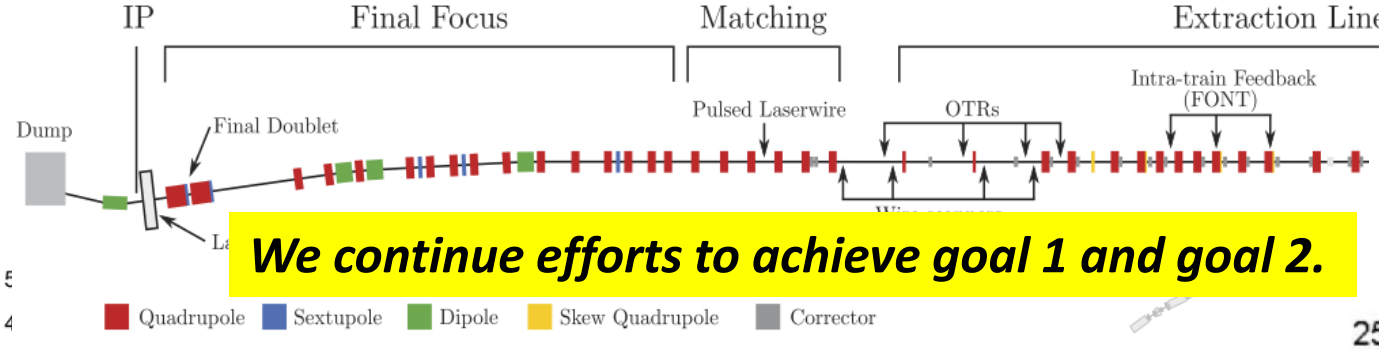
Progress in FF Beam Size and Stability at ATF2

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

- ATF2 Goal : **37** nm → ILC **6** nm
  - Achieved **41 nm** (2016)

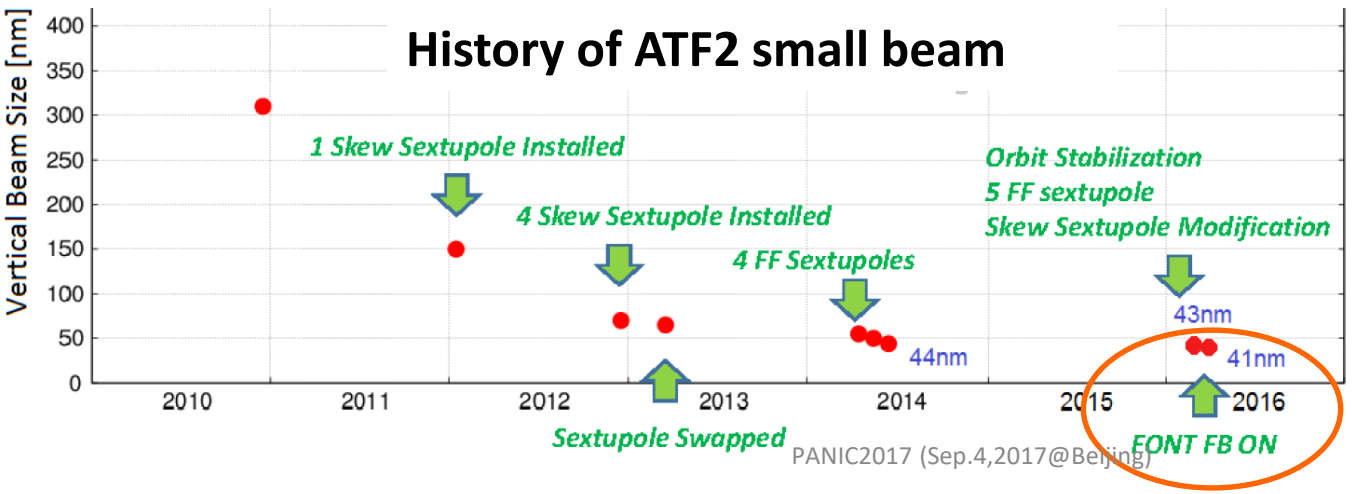
Goal 2: Develop a few nm position stabilization for the ILC collision

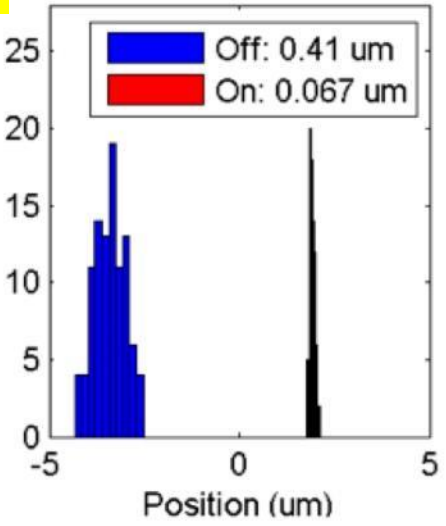
- **FB latency 133 nsec achieved** (target: < 300 nsec)
- **positon jitter at IP: 410 → 67 nm (2015)** (limited by the BPM resolution)



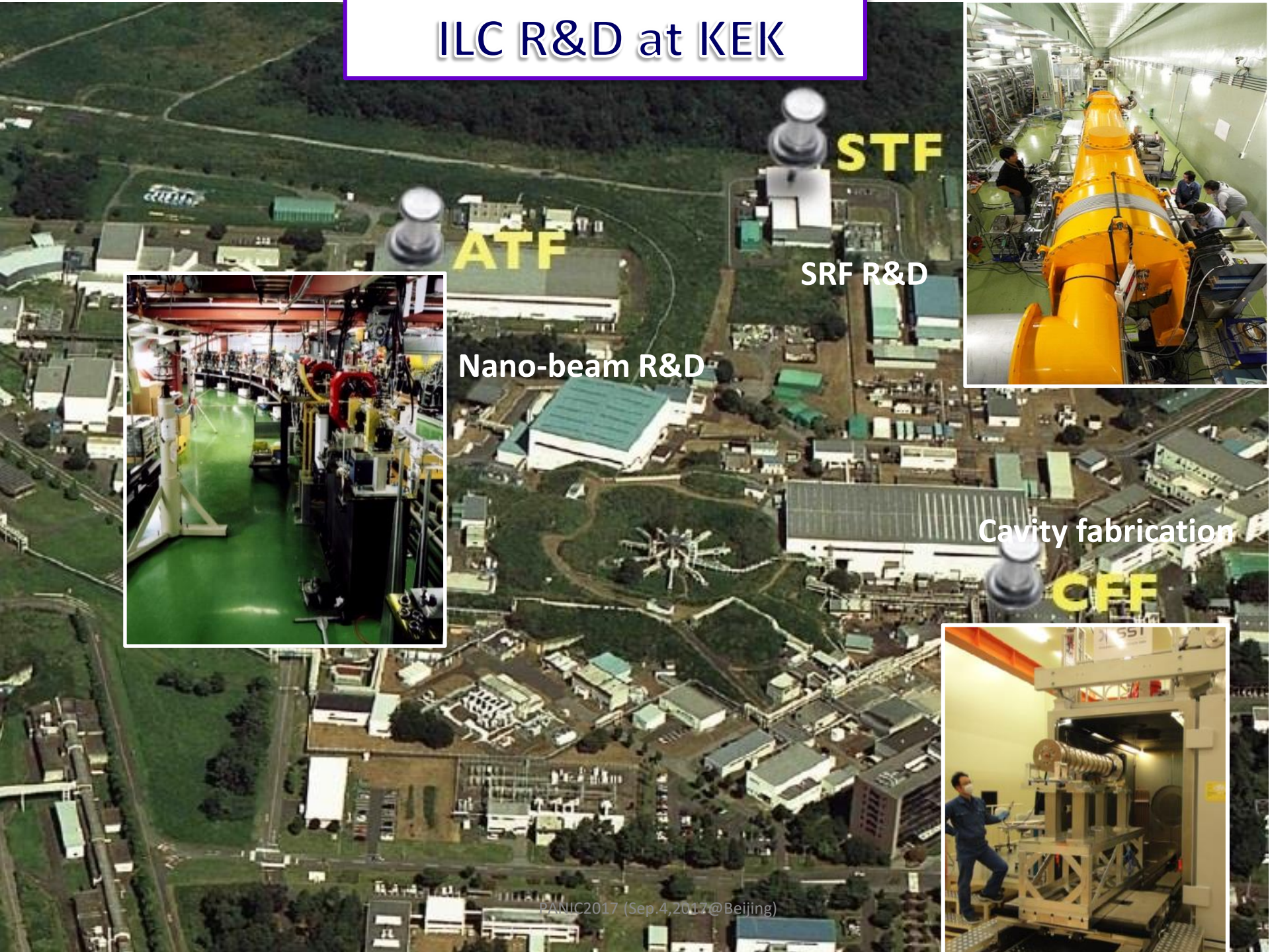
We continue efforts to achieve goal 1 and goal 2.

Nano-meter stabilization at IP





ILC R&D at KEK



Construction of STF cryomodules

STF-1 Cryomodule
Four 9-cell cavities (2008')

S1- Global Cryomodule
Four (+4) 9-cell cavities (2010')

STF tunnel (2011')

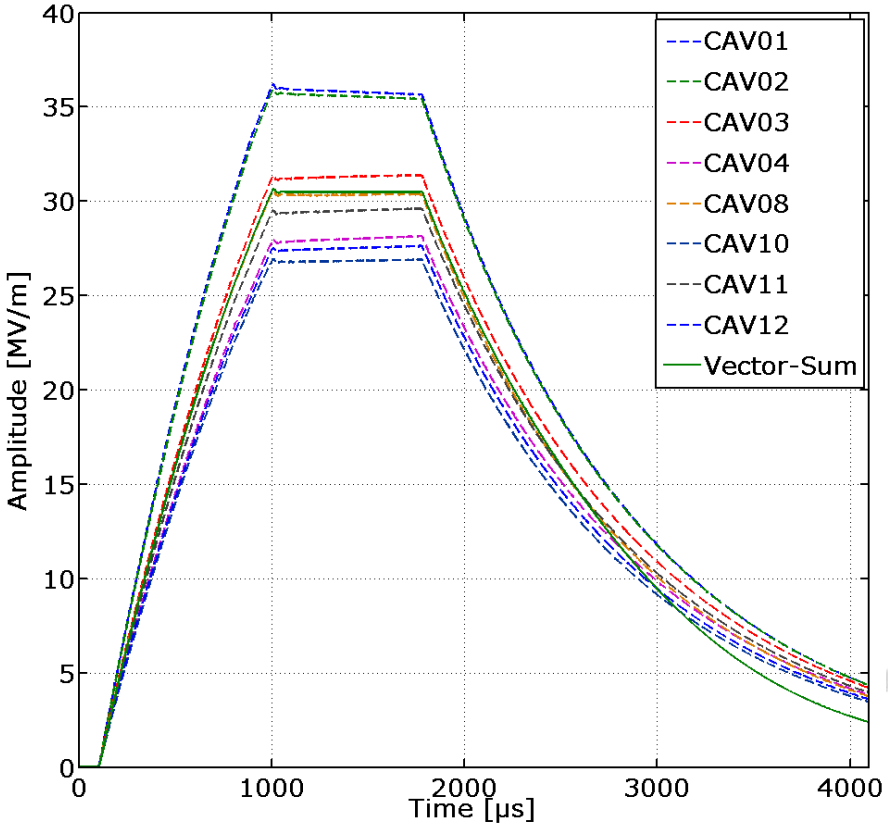
STF-2 - Capture Cryomodule
Two 9-cell cavities (2012')

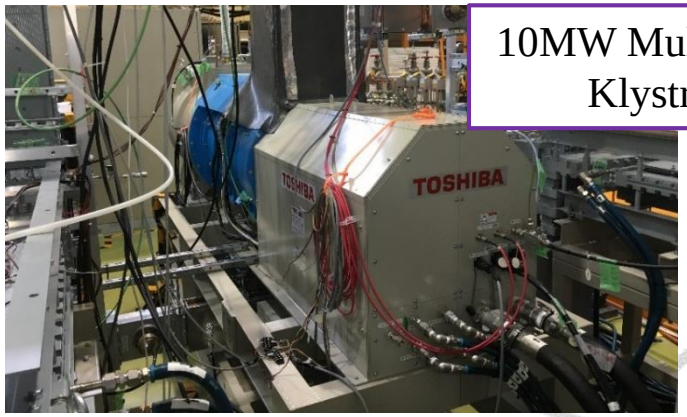
Beam operation

HPG regulation

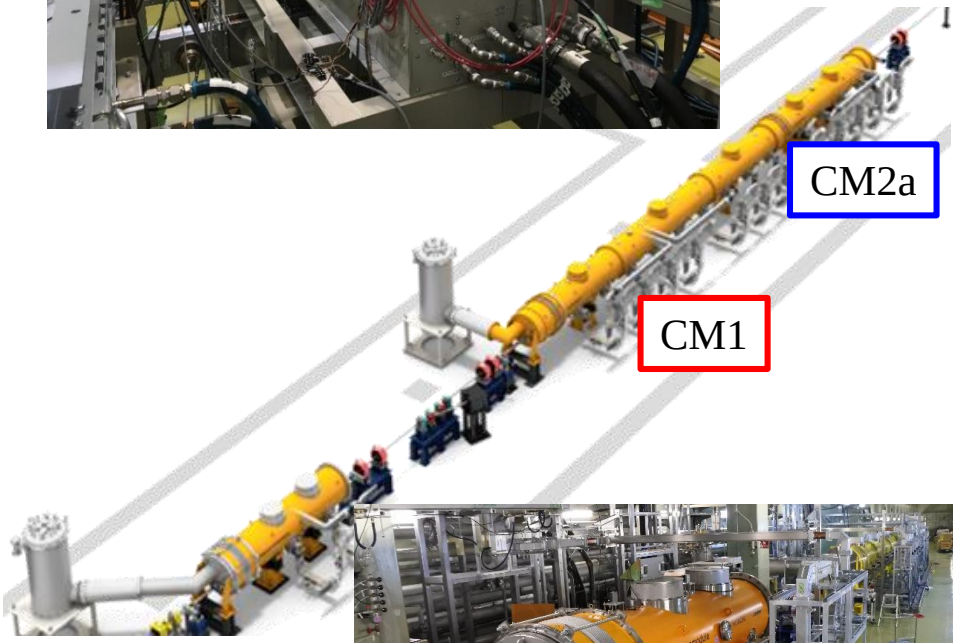
STF-2 - CM1+CM2a Cryomodule
Eight + Four 9-cell cavities (2014')

8 Cavities Operation by Vector-Sum @31MV/m



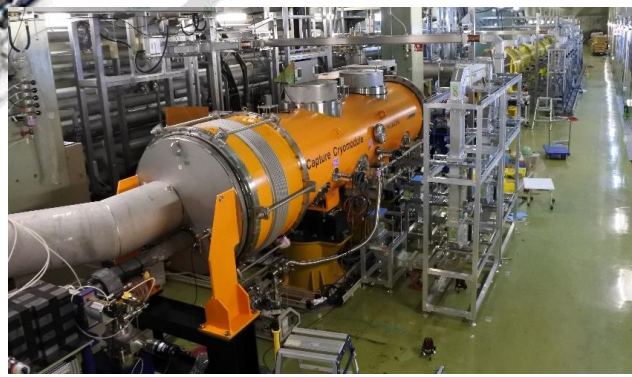


10MW Multi-beam Klystron



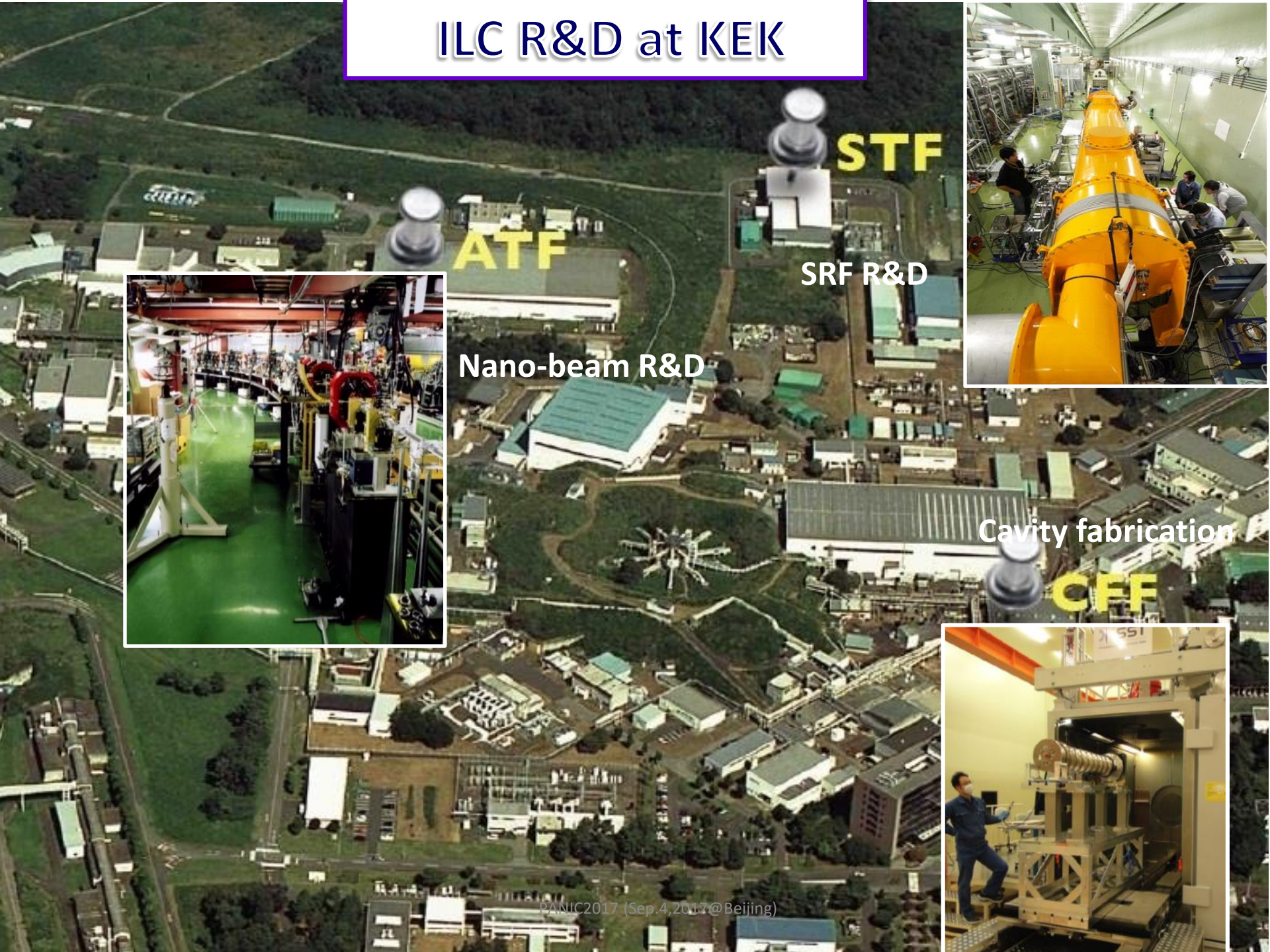
CM2a

CM1



8 Cavities were tuned on resonance by piezo, and vector-sum operation was done at 31MV/m.

ILC R&D at KEK

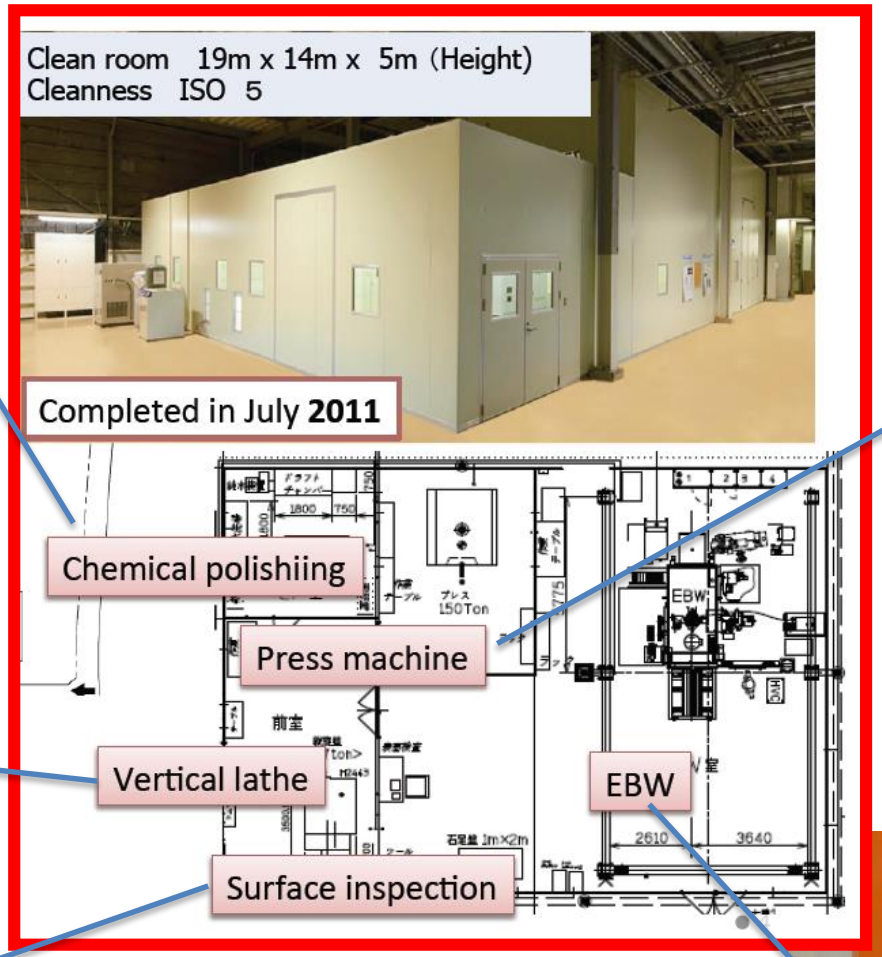


Main equipments in CFF

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

Present status of production

July 2011 Construction of Cavity Fabrication Facility (CFF) is finished.
Feb. 2012 The first cavity named KEK-0 was fabricated in CFF, and its acceleration gradient attained 29 MV/m.
Mar. 2014 The second cavity named KEK-1 was finished, and its acceleration gradient attained **36** MV/m.
April 2014 5 R&D cavities (1-cell & 3-cell) were fabricated, to June 2015
Feb. 2016 The third cavity named KEK-2 was finished, and its acceleration gradient attained **38** MV/m.
April 2016 Fabrication of new R&D cavities and the fourth cavity named KEK-3 are ongoing.

Opening of CFF

KEK-0

KEK-1

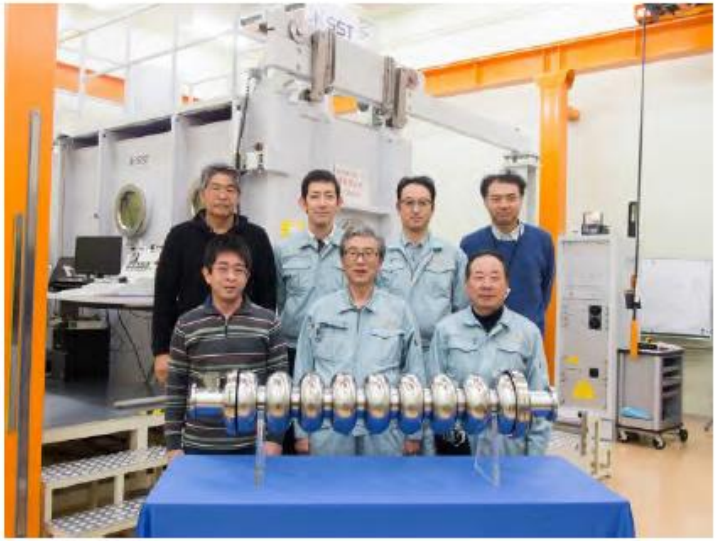
KEK-2

Finish of KEK-2

Using LG niobium expecting high Q value and cost reduction.
We got good performance.

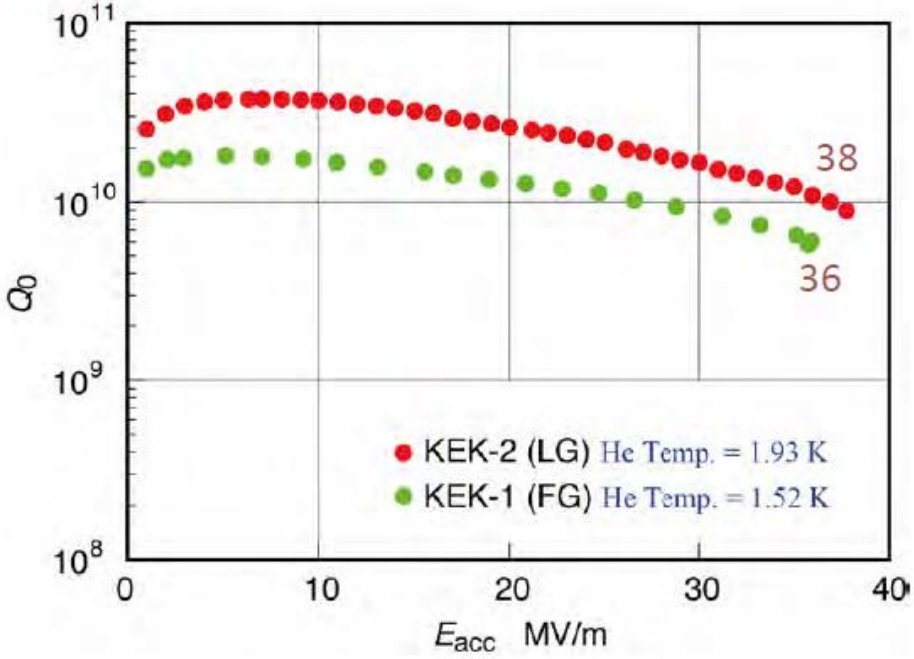
1.3 GHz TESLA-like SRF cavity for ILC (Length: 1.3 m)

Ingot sliced Niobium (Tokyo Denkai)
(Dia : 260 mm)



Member of fabrication (part)

少数精鋭



Result of vertical test
⇒Qualify the ILC spec.（35 MV/m）

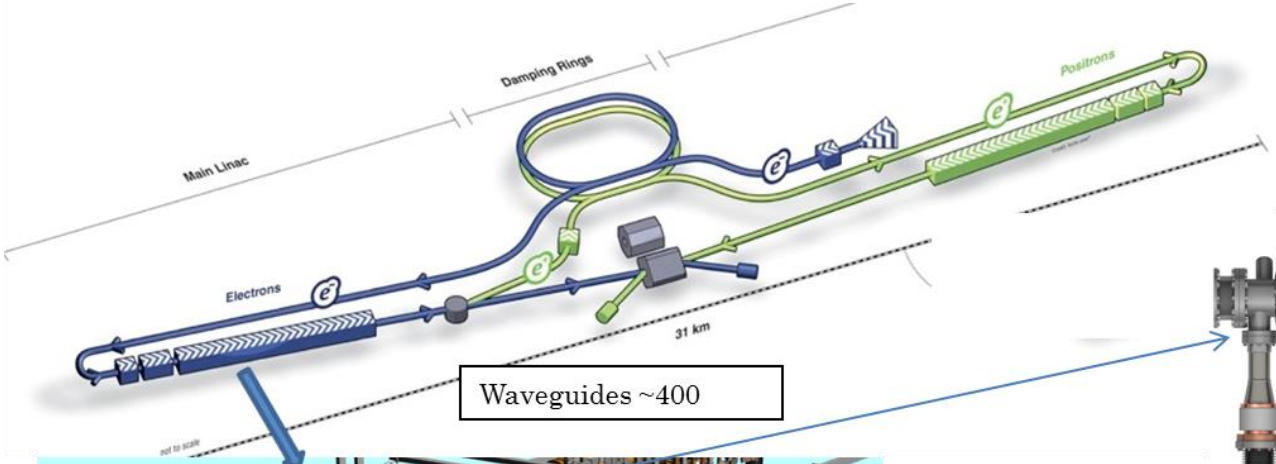
ILC status

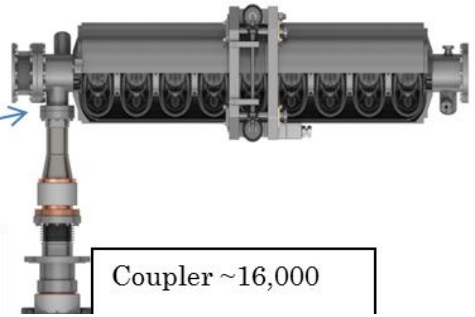
KEK/LCC

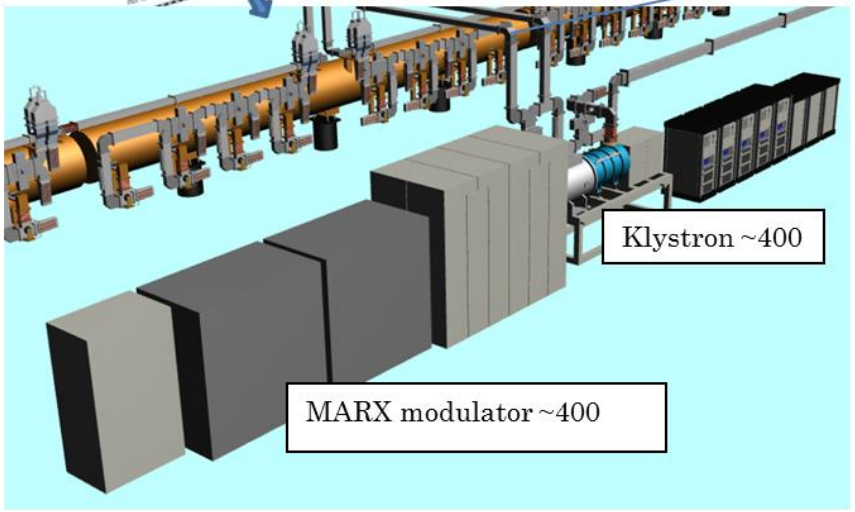
Shin MICHIZONO

- *The ILC*
- *KEK's activities*
- *ILC cost reduction R&D*
- *World-wide R&D for high-Q and high-G*
- *staging*

ILC cost reduction R&D







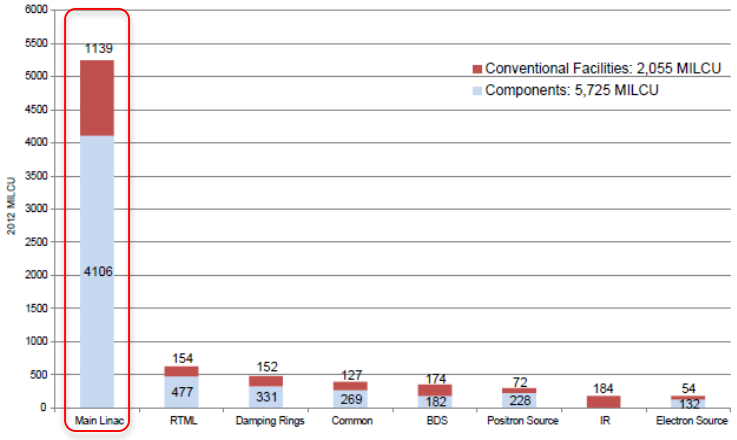
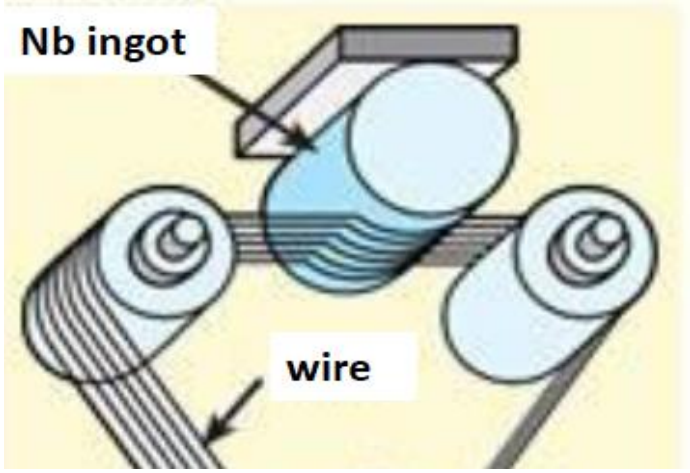


Figure 15.8. Distribution of the ILC value estimate by system and common infrastructure, in ILC Units. The numbers give the TDR estimate for each system in MILCU.

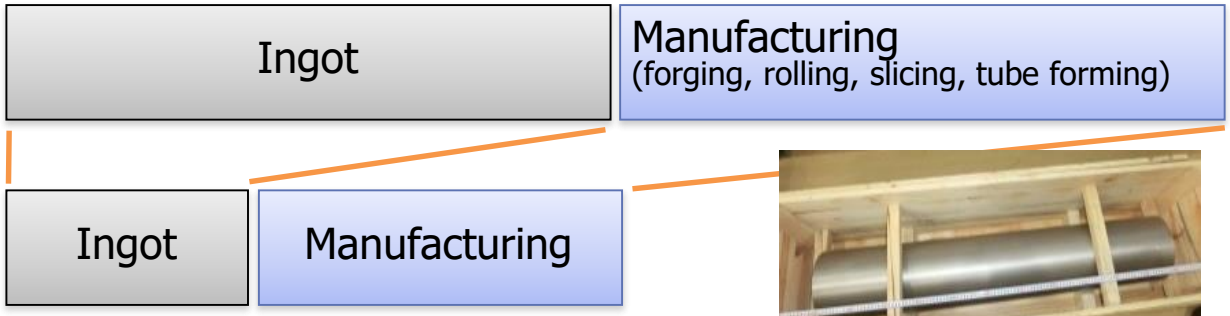
The main fraction of the construction cost is coming from main linac (ML).
Thus we focused our cost reduction R&D into ML (superconducting RF technology)

A-1. Niobium material preparation (with new processing for sheeting and piping)

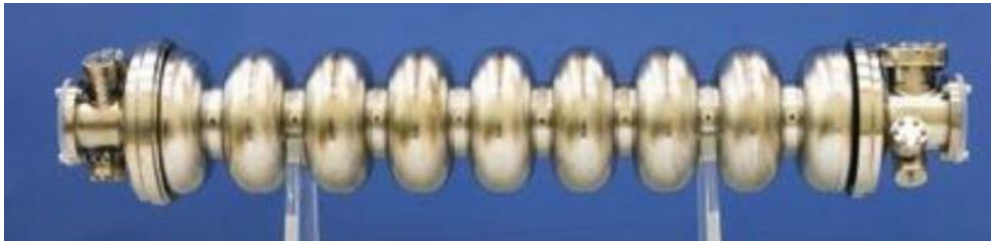
- Niobium material cost for fabricating SRF cavity cell and end-groups is relatively high.
- If we can accept lower residual resistivity ratio (RRR) material, the ingot cost becomes cheaper.
- We will try to simplify the manufacturing process (like direct slicing from the ingot).



Total, **50% off**

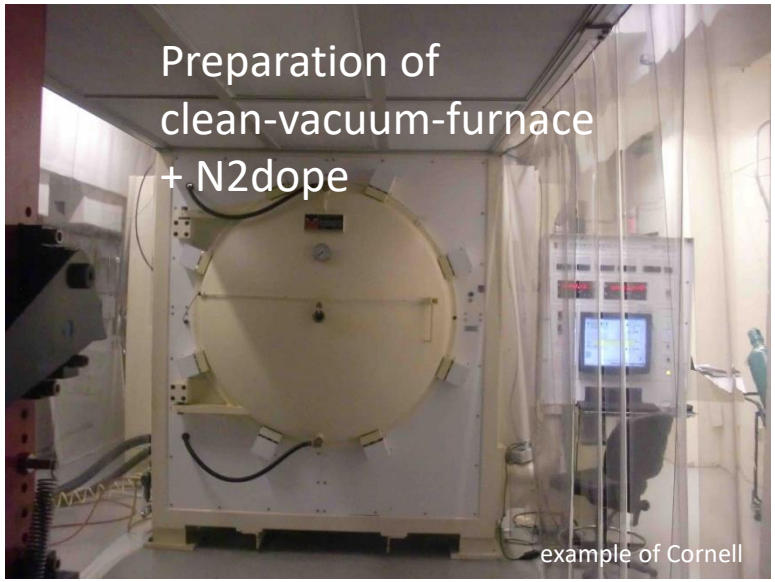


Niobium ingot

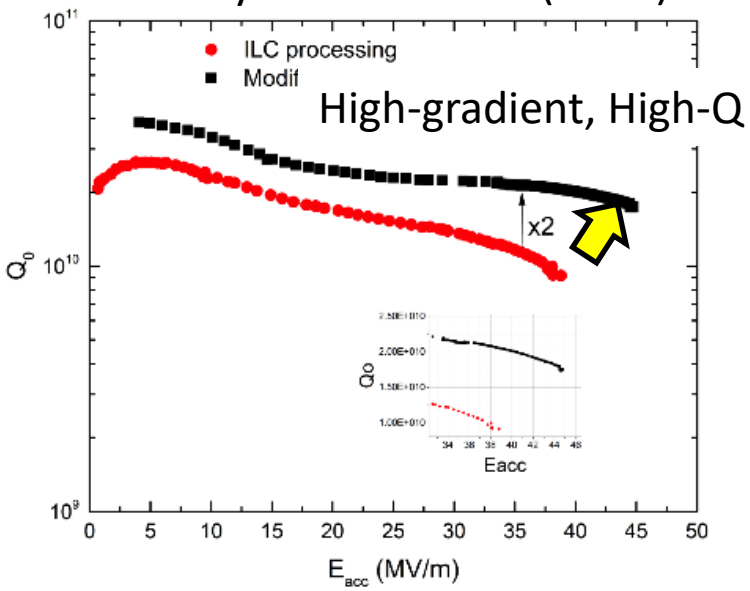


A-2. SRF cavity fabrication for high gradient and high Q (with a new surface process provided by Fermilab)

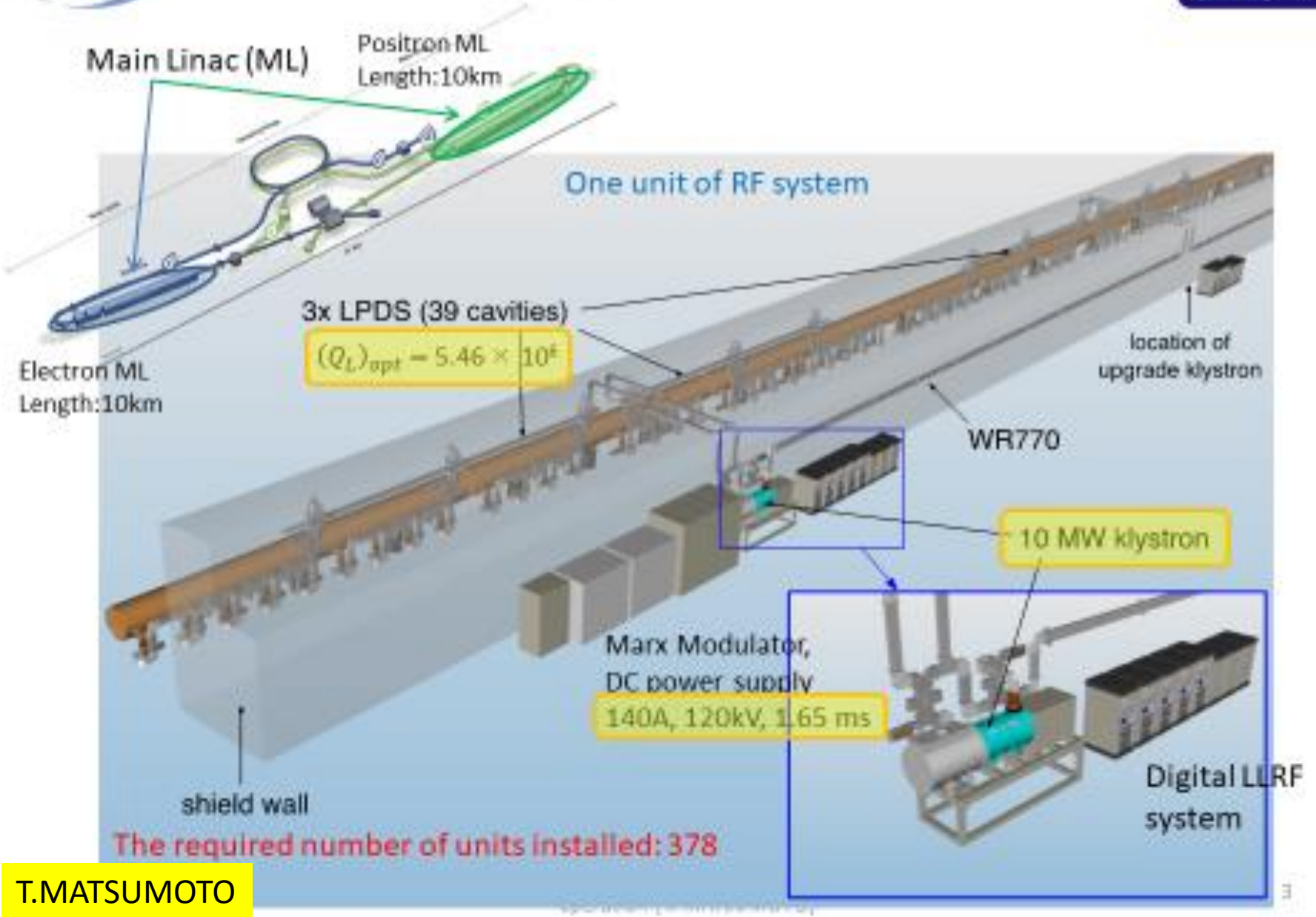
- High Q cavity enables the decrease in number of cryogenics leading to the cost reduction.
- FNAL researcher (A. Grassellino) found the new cavity preparation recipe having high Q and high gradient.
- Demonstrate N2-infusion (High-gradient and High-Q) technology with 9-cell-cavities.



By A. Grassellino (FNAL)

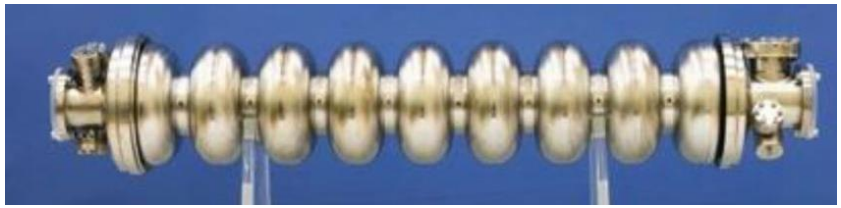


RF system for ILC



T.MATSUMOTO
AWLC17

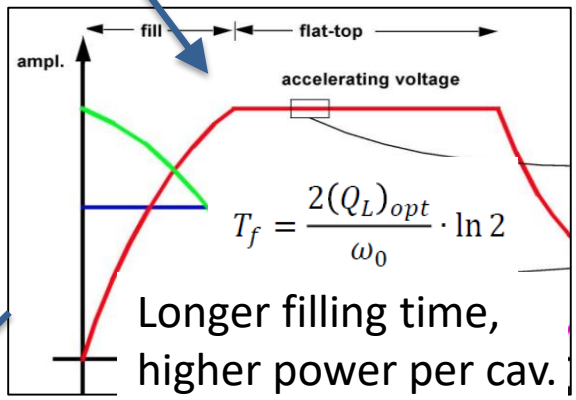
Design optimization for High Q and High Gradient op.



High Q

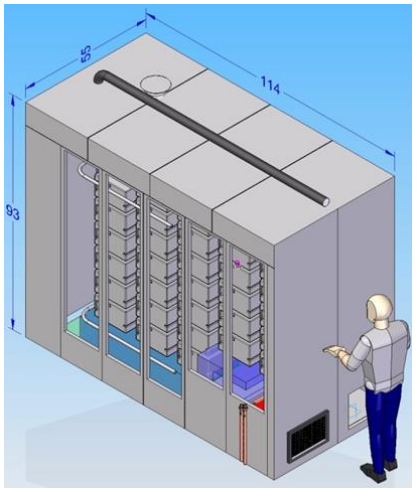
High Gradient (31.5 MV/m→35 MV/m)

Smaller Cryo.



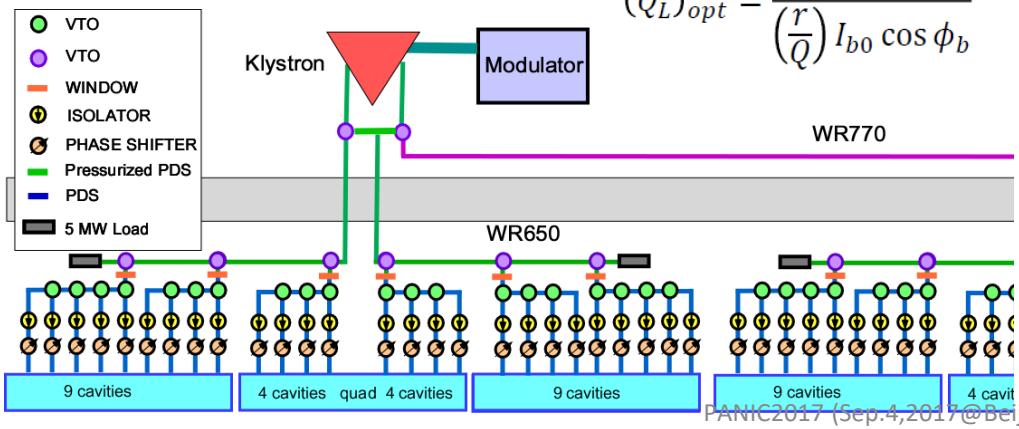
$$T_f = \frac{2(Q_L)_{opt}}{\omega_0} \cdot \ln 2$$

Longer filling time,
higher power per cav.



Longer pulse modulator
(1.65 ms → 1.76 ms)

$$(Q_L)_{opt} = \frac{V_{cav}}{\left(\frac{r}{Q}\right) I_{b0} \cos\phi_b}$$



same rf distribution

Higher efficiency kly.
(11MW)

ILC status

KEK/LCC

Shin MICHIZONO

- *The ILC*
- *KEK's activities*
- *ILC cost reduction R&D*
- *World-wide R&D for high-Q and high-G*
- *staging*

R&D Plans at worldwide Labs

	On-going	R&D: ML Cavity	Assoc. System	Cryomodule	RF
Fermilab	LCLS-II	N_2-infusion (HQ-HG)	Coupler		
JLab	LCLS-II	Nb-LG/FG (Ingot-sliced/rolled) , LSF cavity, N_2-infusion			
DESY	EXFEL	N_2-infusion Nano-Lab study		High-performance CM	
INFN-LASA	ESS	Nb-LG/FG systematic study for ESS			
CEA/ CNRS-LAL	IFMIF ESS, SARAF	Vertical EP (VEP), N_2-Infusion	Magnetic shield Coupler	Assembly robotizing	
KEK	STF	Nb-LG/FG N_2-infusion	Coupler, Tuner Crab. C.		Marx M.
IHEP	ADS	N_2-infusion, Industrialization		Industrialization	Marx M. h.e. Klystron
CERN	HL-LHC Hi-Isolde	Thin-film (Nb on Cu)	Coupler		h.e. Klystron
TRIUMF	ISAS-II, ARIEL	VEP, muSR			
Cornell		N_2-infusion, VEP			

Exploring Phase Space of Nitrogen Treatment

"2/6" Nitrogen "Doping"

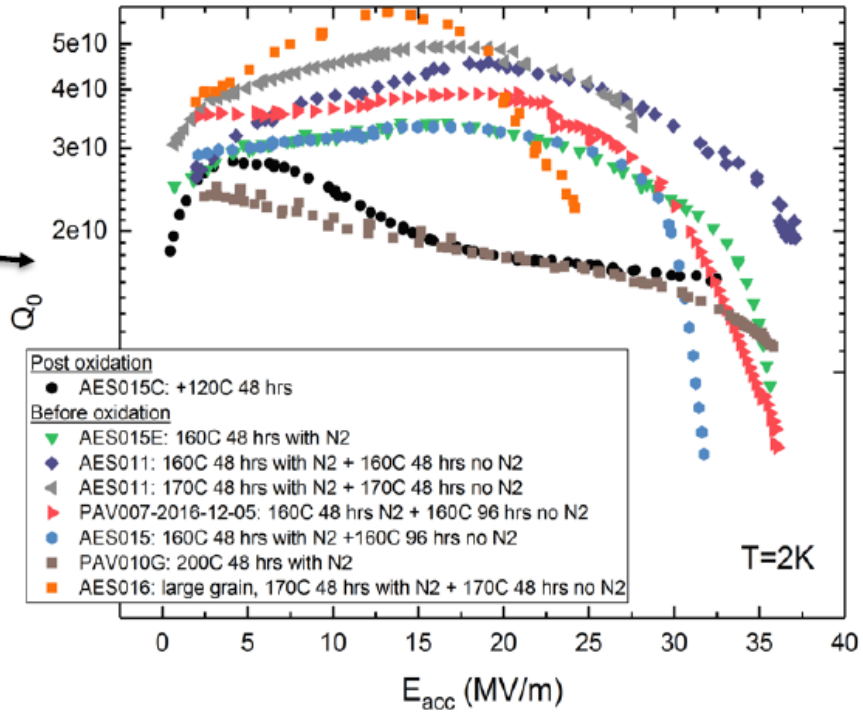
800C UHV, 3 hours → 800C N_2 p = 25 mTorr 2 minutes → 800C UHV, 6 minutes → UHV cooling → 5 um EP

120 C Nitrogen "Infusion"

800C UHV, 3 hours → 120C N_2 p = 25 mTorr 48 hours → UHV cooling

S. Posen (FNAL) at AWLC17

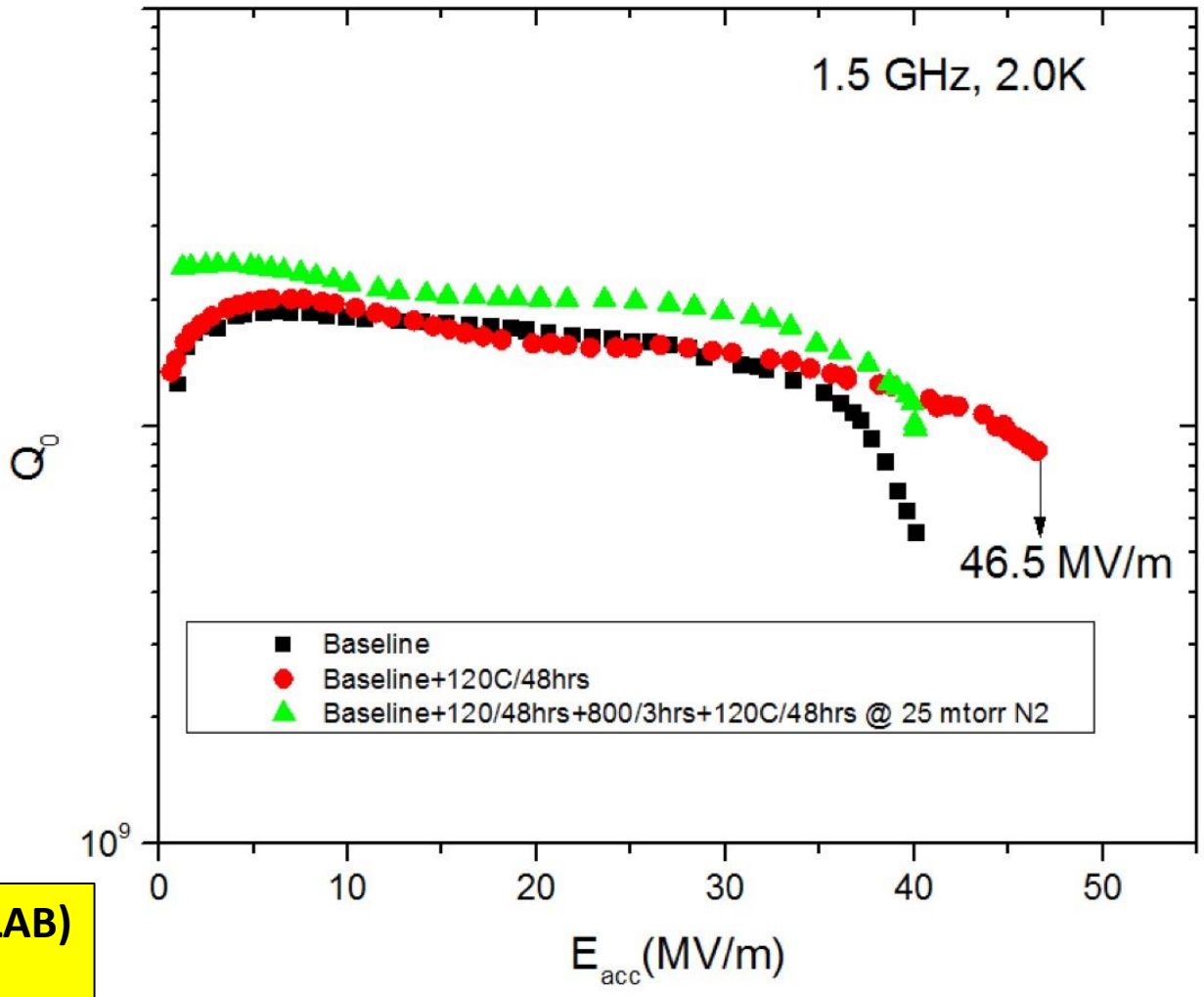
Can tailor treatment to application (optimize for Q_0 at a given E_{acc})



A. Grasselllino et al. arXiv:1701.06077

Fermilab

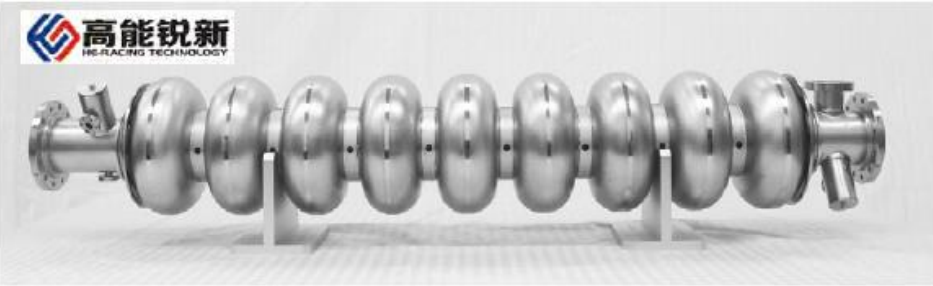
RECENT WORK AT JLAB



P. Dhakal (JLAB) at AWLC17

J. Zhai (IHEP), LCWS-2016

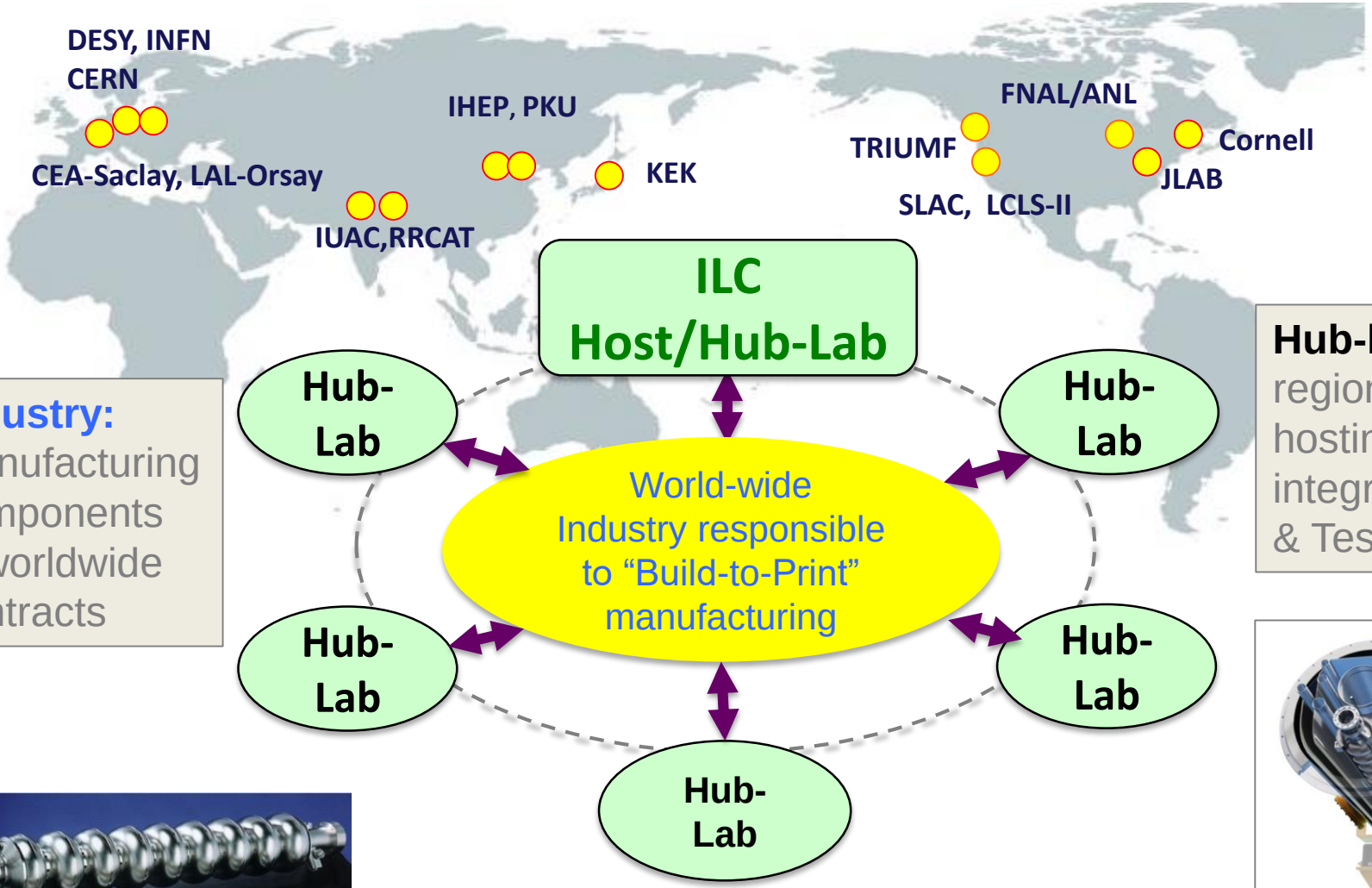
SCRF Industrialization in China



Quality control and cost reduction:

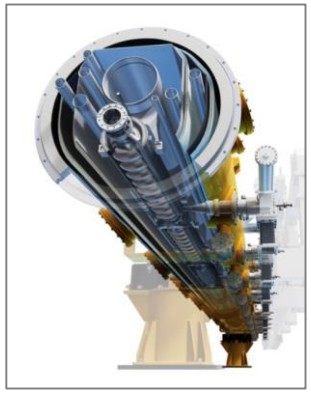
- **Niobium**: OTIC (EXFEL 35% 7 t, FRIB 50% 5 t, LCLS-II 50% 5.6 t …)
- **Cavity**: OTIC, HERT, BIAM (ILC, CADS, FRIB, HEPS, CEPC …)
- **Coupler**: HERT (ILC, CADS, RISP …), JNT
- **Cryomodule**: WXCX (EXFEL 60, LCLS-II 33, FRIB), HFJN (CADS)
  - LCLS-II cryomodule quality control (IHEP & SLAC-FNAL-JLAB collaboration)

ILC SRF Global Manufacture/Integration Model



Industry: manufacturing components w/worldwide contracts

Hub-lab: regionally hosting integration & Test



ILC status

KEK/LCC

Shin MICHIZONO

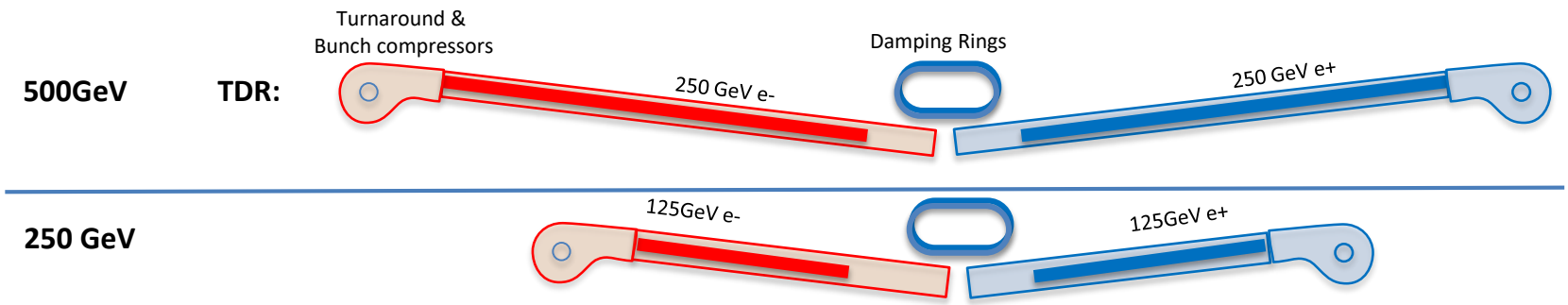
- *The ILC*
- *KEK's activities*
- *ILC cost reduction R&D*
- *World-wide R&D for high-Q and high-G*
- *staging*

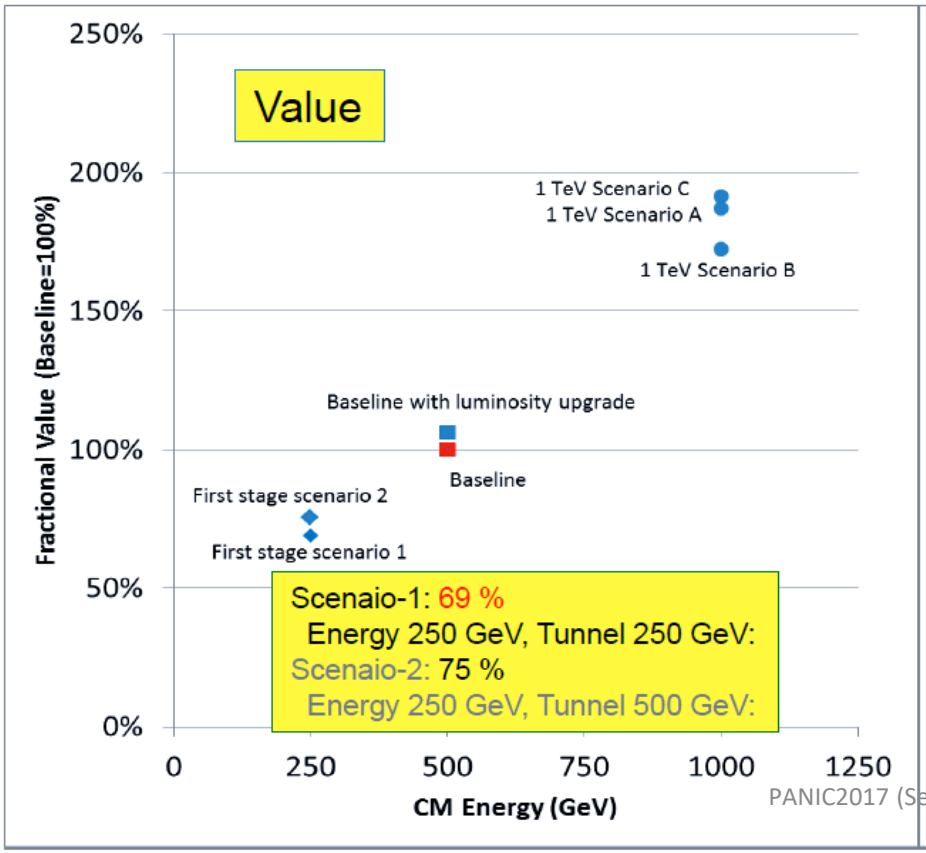
Stated by LCC Director L. Evans in LCWS2016, Morioka

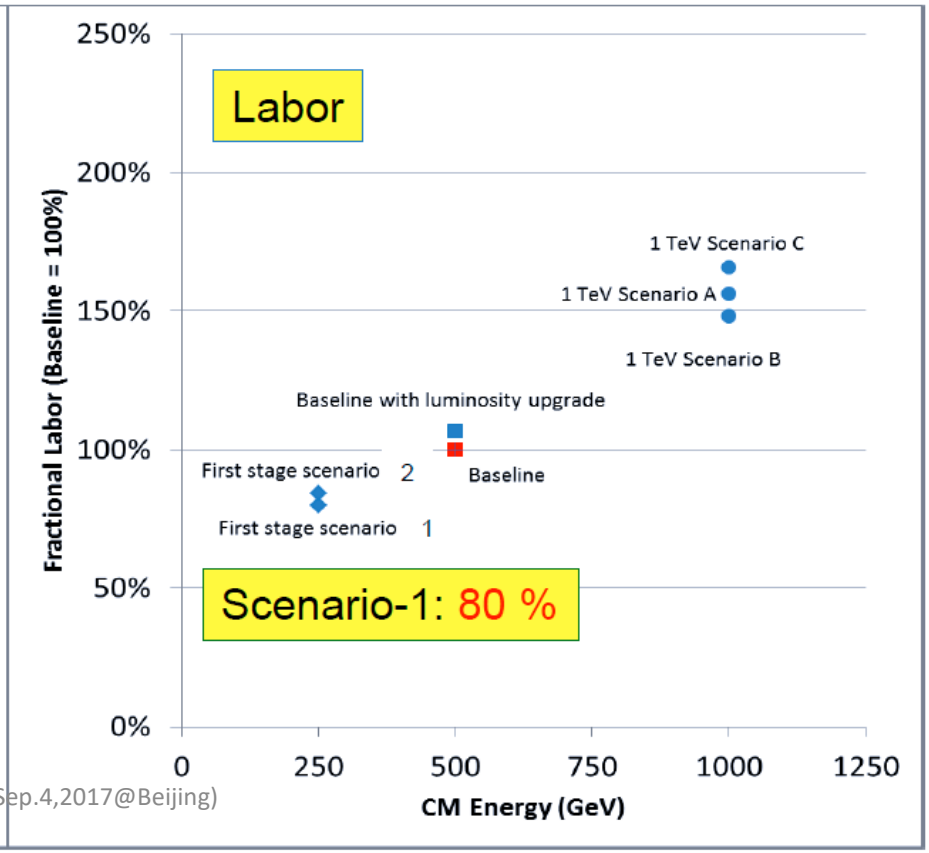
Cost reduction

- All of these measures will reduce the cost by 10-20%, but that is not enough for a realistic project funding.
- The beauty of a linear collider is that it can be staged.
- Serious discussions must now start on realistic staging scenarios to bring the cost of the first stage down.

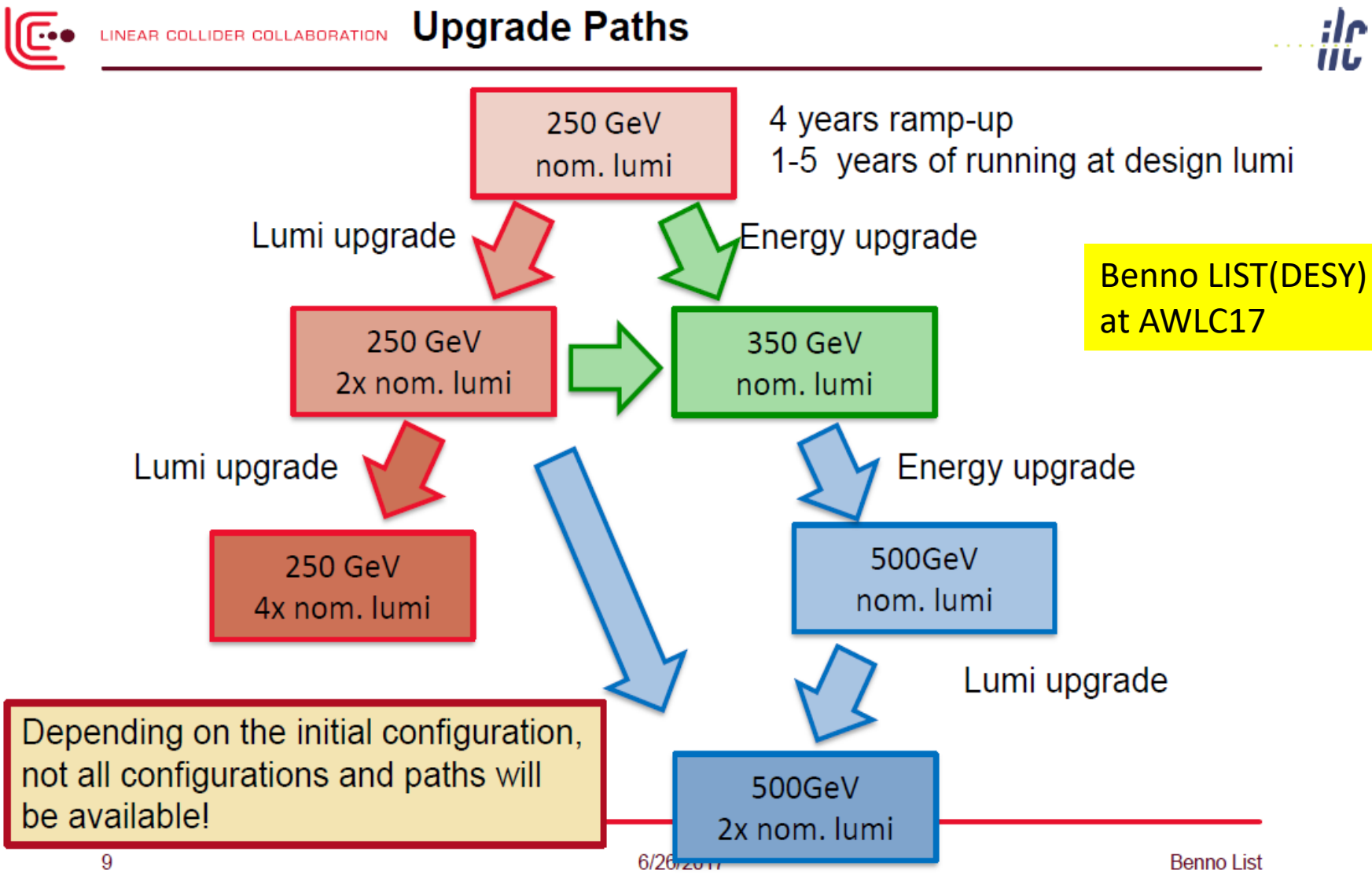
staging


500GeV
TDR:
Turnaround &
Bunch compressors
250 GeV e-
Damping Rings
250 GeV e+
250 GeV
125GeV e-
125GeV e+


Value
Fractional Value (Baseline=100%)
250%
200%
150%
100%
50%
0%
1 TeV Scenario C
1 TeV Scenario A
1 TeV Scenario B
Baseline with luminosity upgrade
Baseline
First stage scenario 2
First stage scenario 1
0
250
500
750
1000
1250
CM Energy (GeV)
Scenaio-1: 69 %
Energy 250 GeV, Tunnel 250 GeV:
Scenaio-2: 75 %
Energy 250 GeV, Tunnel 500 GeV:


Labor
Fractional Labor (Baseline = 100%)
250%
200%
150%
100%
50%
0%
1 TeV Scenario C
1 TeV Scenario A
1 TeV Scenario B
Baseline with luminosity upgrade
First stage scenario 2
Baseline
First stage scenario 1
0
250
500
750
1000
1250
CM Energy (GeV)
Scenario-1: 80 %

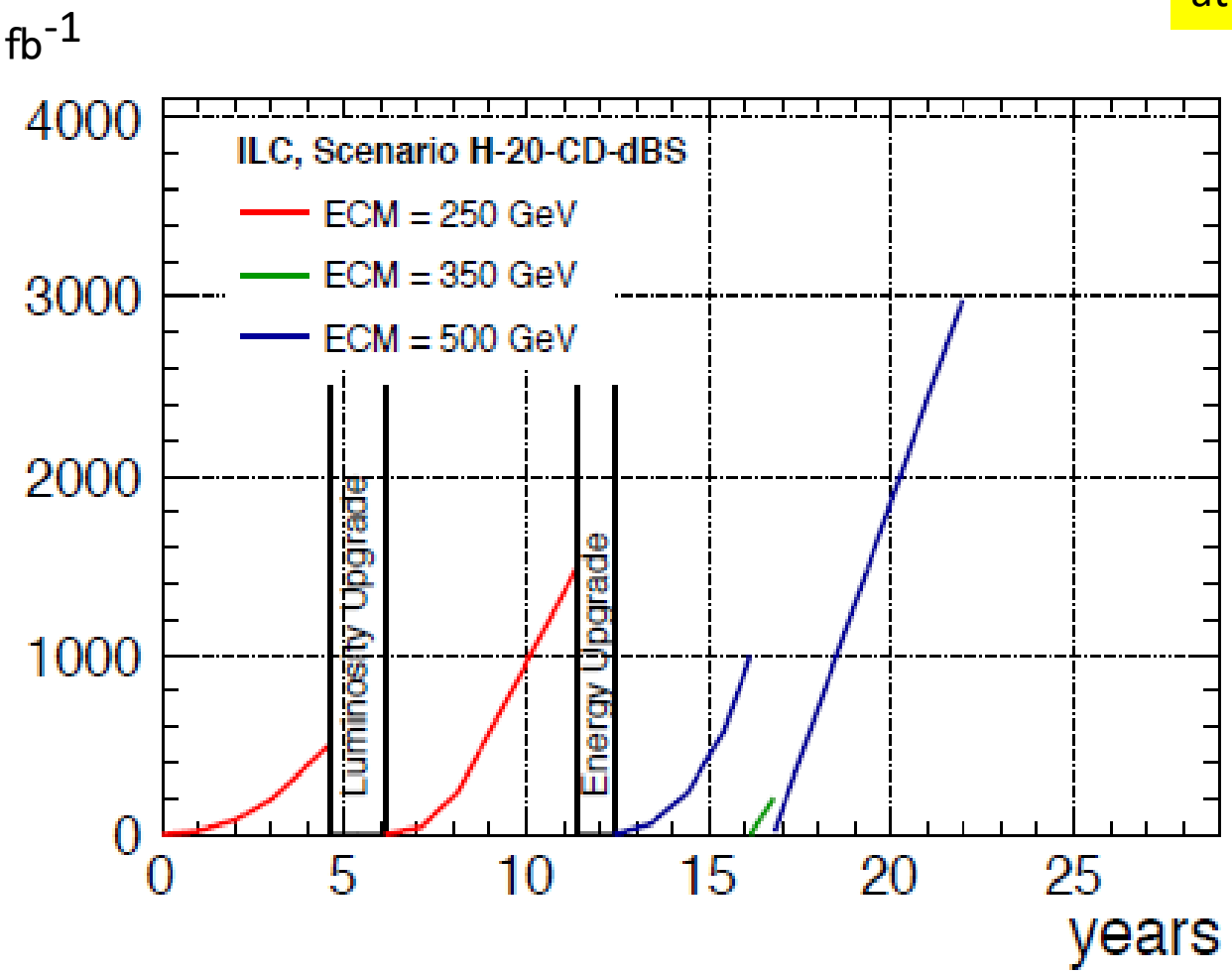
Example of staging plan



Benno LIST(DESY) at AWLC17

Example of luminosity and energy evolution

Junpin Tian (U.Tokyo)
at AWLC17



Summary

- *The TDR was published and we are waiting for the approval.*
- *When the international negotiation starts, we expect 4 years preparatory works and 9 years construction.*
- *KEK has 3 R&D facilities. ATF for nono-beam development, STF for SRF R&D and CFF for cavity fabrication.*
- *ILC cost reduction R&Ds have just started between US and Japan collaboration.*
- *Nb material and N-Infusion are the current R&D topics.*
- *World-wide R&Ds for high-Q and high-G are on going.*
- *Recently staging (ILC250GeV) was proposed and under the consideration from physics and accelerator points of view.*

Thank you for your attention