Linear Colliders

Shin MICHIZONO

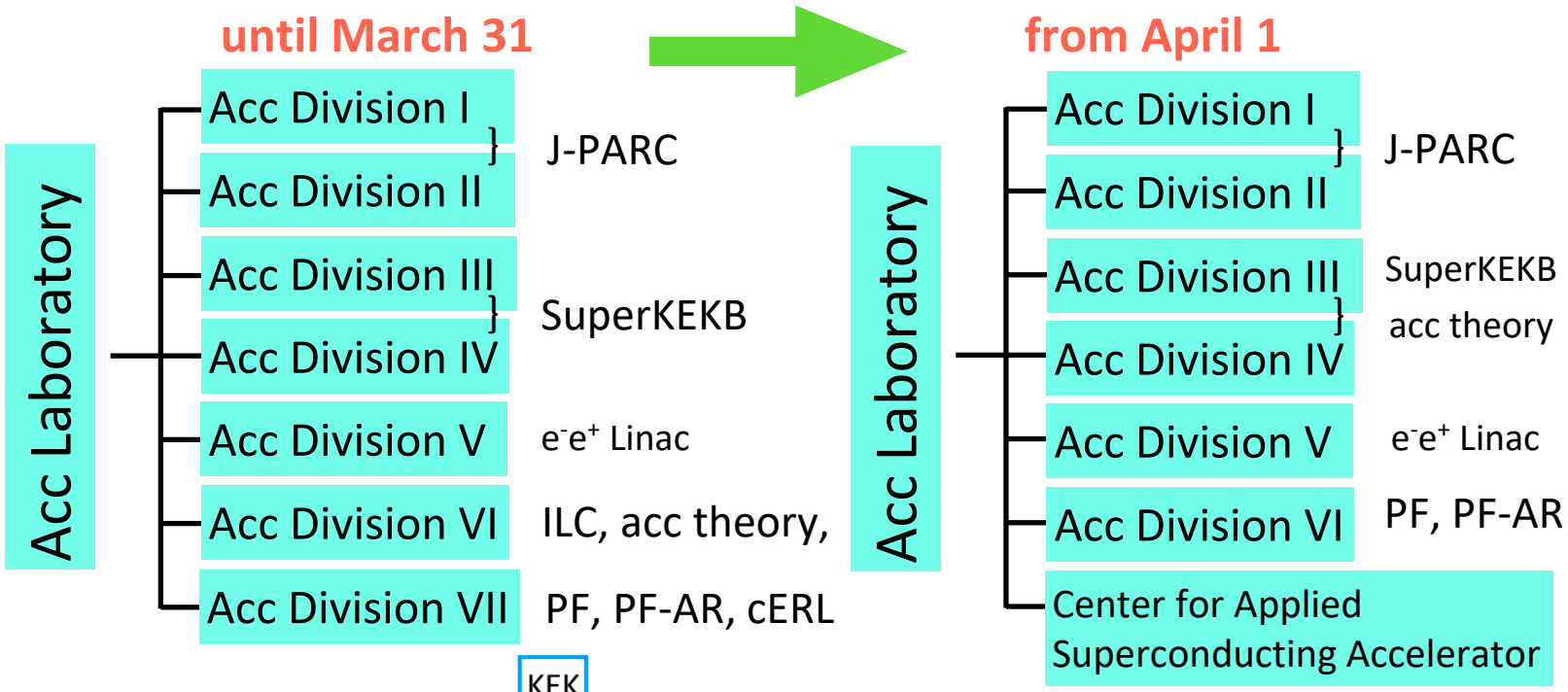
Center for Applied Superconducting Accelerator (CASA),

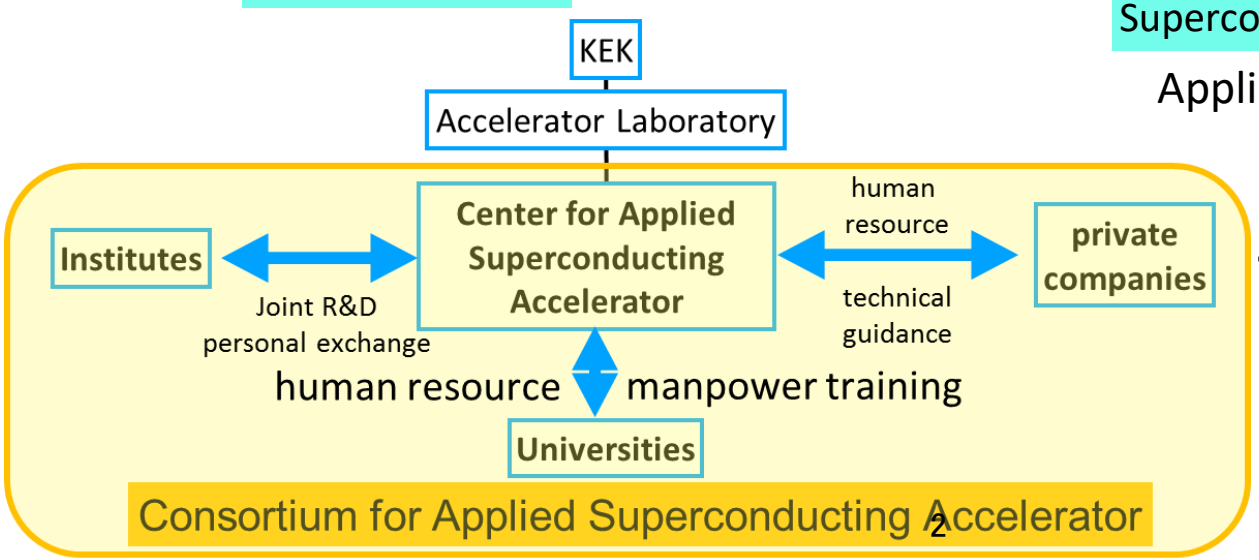
Accelerator Lab. (KEK)

- *ATF collaboration*
- *Beam dump R&D*
- *MgB_2 magnet for CLIC klystron*

Reorganization of Accelerator Laboratory from the April 2019

- Establish Center for Applied Superconducting Accelerator (CASA)





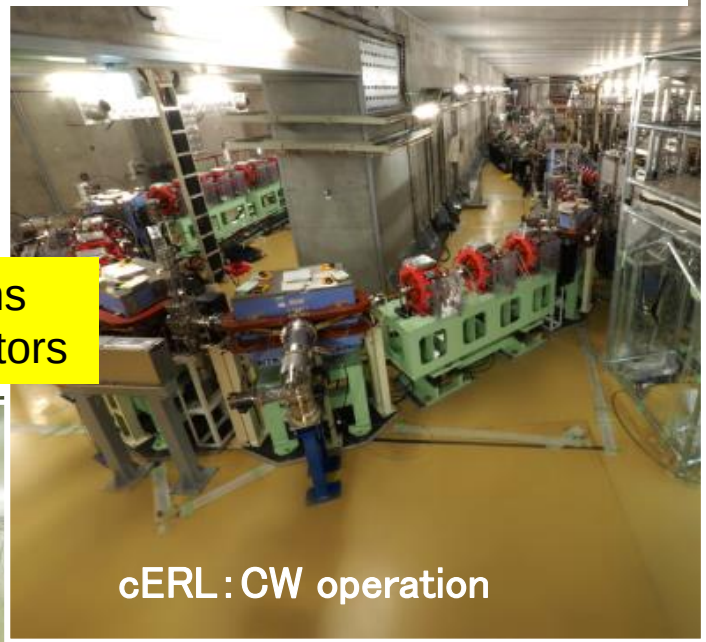
Mission of the Consortium

- Research study on needs and seeds of accelerator application
- Formulate R&D strategy
- Collect & Transmit information

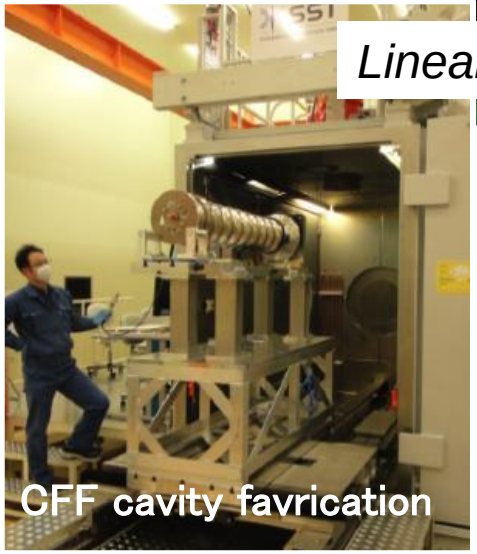
Accelerator related facility in CASA

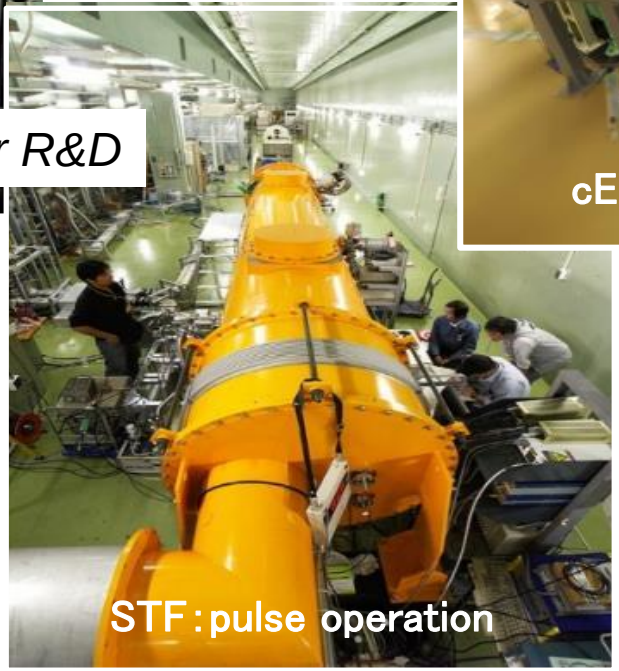
Superconducting accelerator promotion team

Aiming to develop applications on superconducting accelerators



Linear collider R&D





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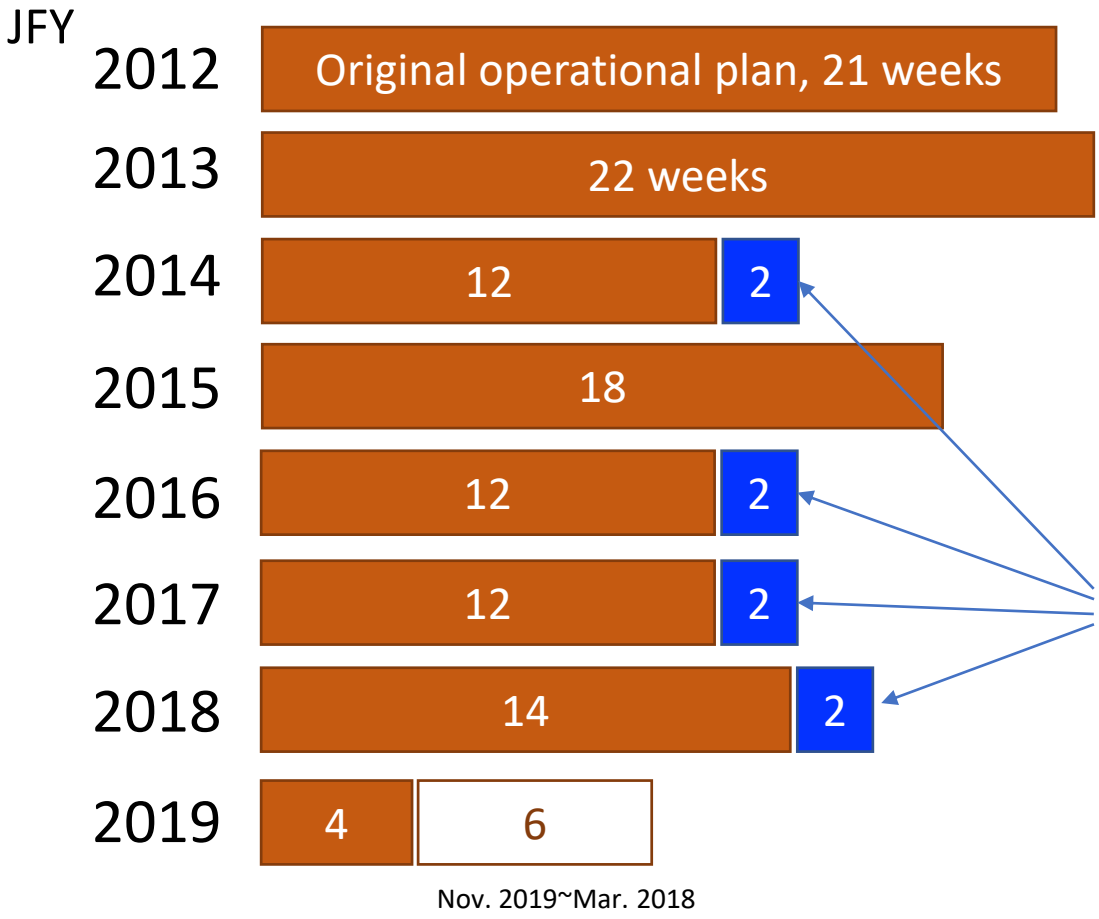
ATF collaboration

S. Michizono, N. Terunuma, and S. Stapnes
KEK-CERN Cooperation

CERN-KEK Committee, at KEK, 18 Nov. 2019

Numbers of ATF beam weeks



Number of ATF operation weeks reduced from 2014 due to the rise of an electricity price.

CERN supports the additional ATF beam weeks.

(by the Collaborative Research Contract between CERN and KEK)

Special thanks for CERN's kindest cooperation and contribution !

22nd ATF2 Project Meeting, KEK, 20 - 22 Novembers, 2018

Beam Size and Stability at ATF2 for final focus at ILC

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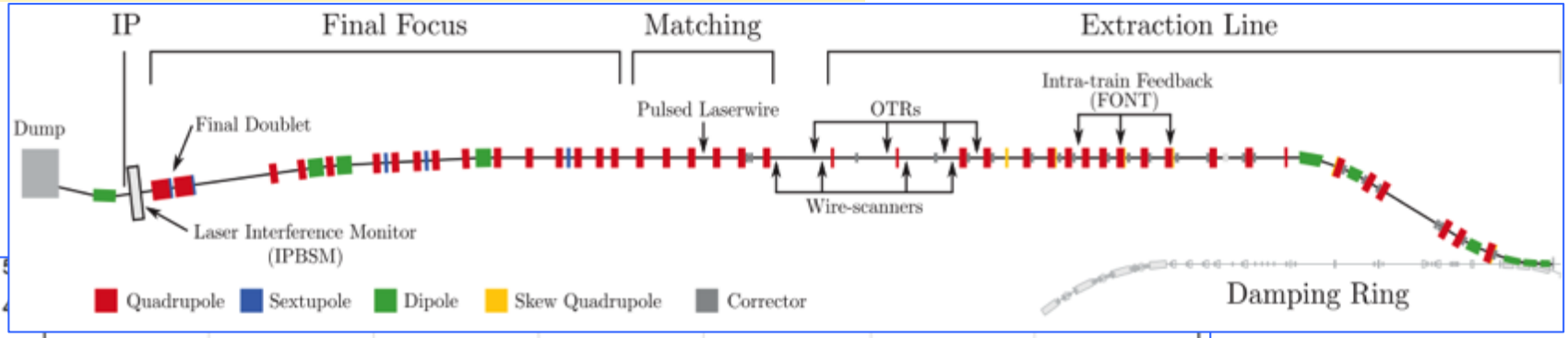
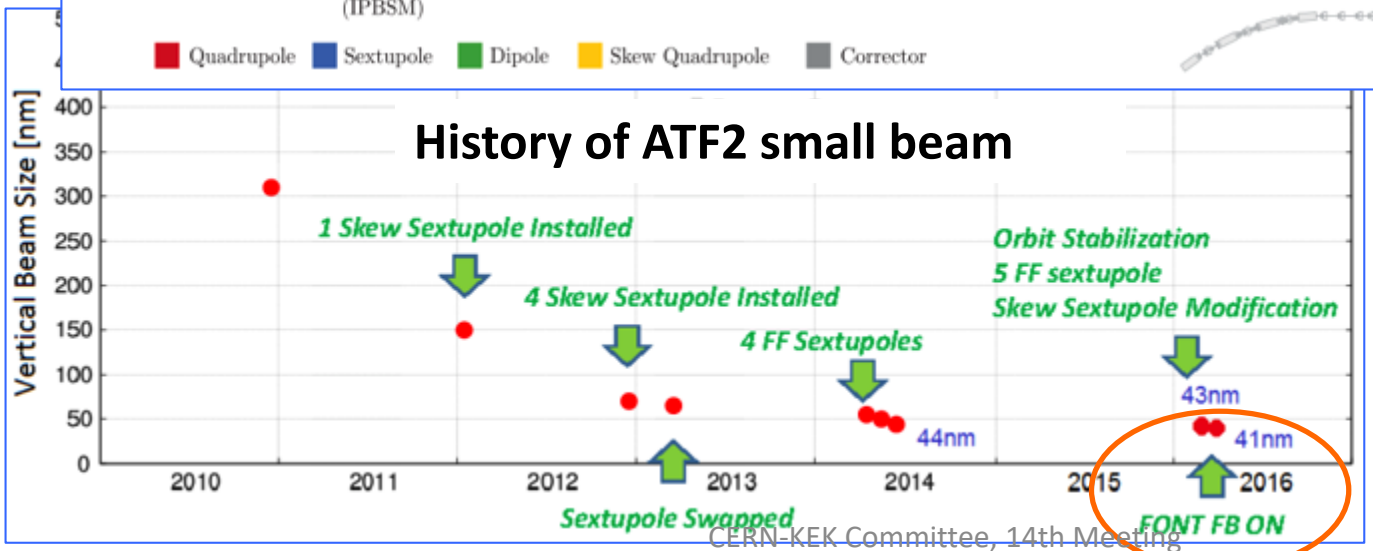
Goal 1: Establish the ILC final focus method with same optics and comparable beamline tolerances

- ATF2 Goal : **37** nm → ILC **7.7** nm (ILC250)
  - Achieved **41 nm** (2016)

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

- **FB latency 133 nsec achieved**
  (target: < 366 nsec)





CERN's Activity for CLIC/ILC at ATF2

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Nanometer Beam Development

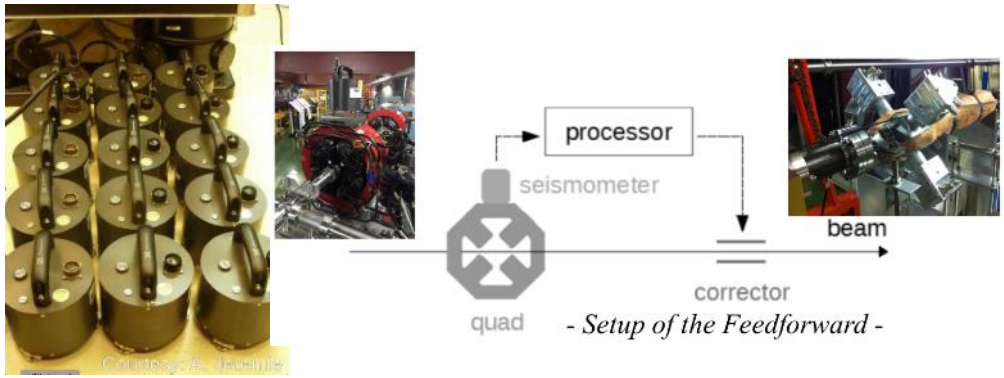
Final Focus System studies for LCs

FONT position stabilization system

Wakefield evaluation

Ground Motion Feed-forward for CLIC

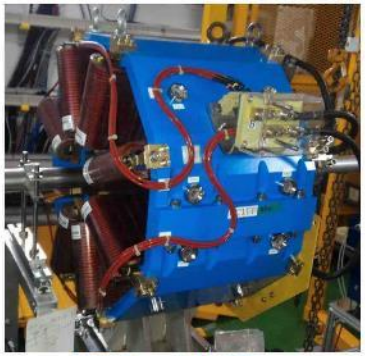
14 Geophones has been installed in ATF2 by CERN and LAPP



Ultra Low-beta optics for CLIC

Two Octupoles by CERN has been installed.

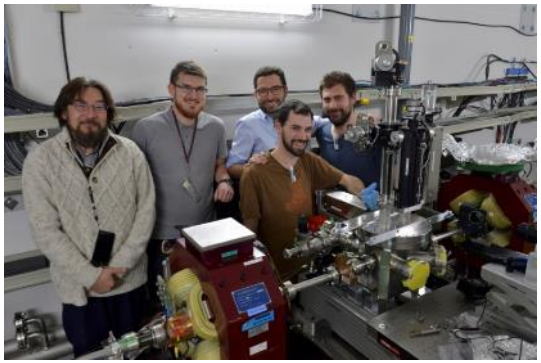
OCTU1 installed in ATF

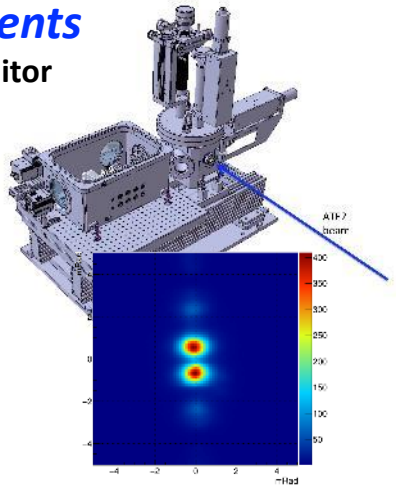


OCTU2 installed in ATF

Beam Monitor Developments

High resolution OTR-ODR, ChDR monitor





Collaborative Research Contract between CERN and KEK supports the ATF beam operation.

FONT* Bunch train feedback for final focus

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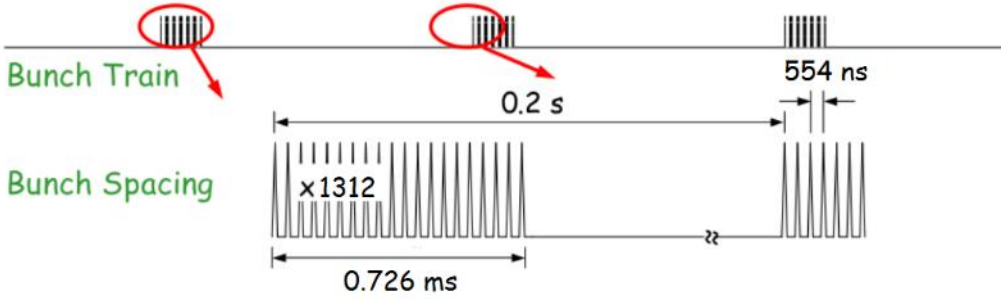
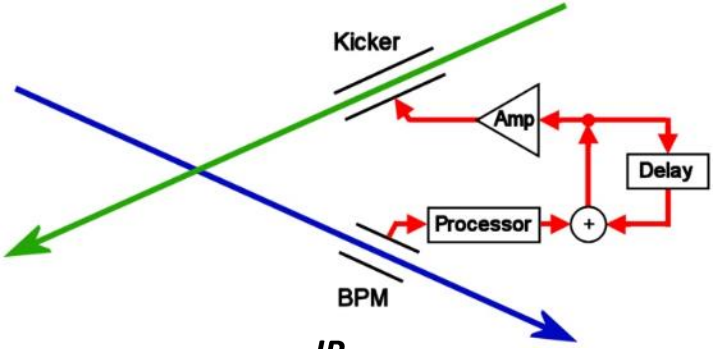
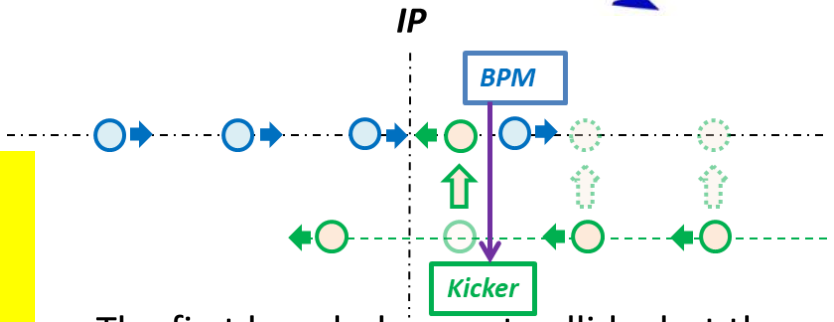
*Feedback On Nanosecond Timescales

https://journals.aps.org/prab/abstract/10.1103/PhysRevAccelBeams.21.122802

ILC bunch structure

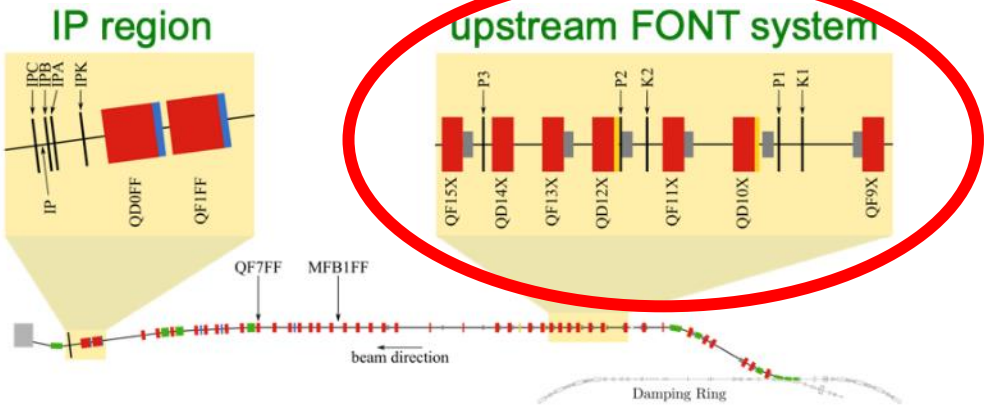


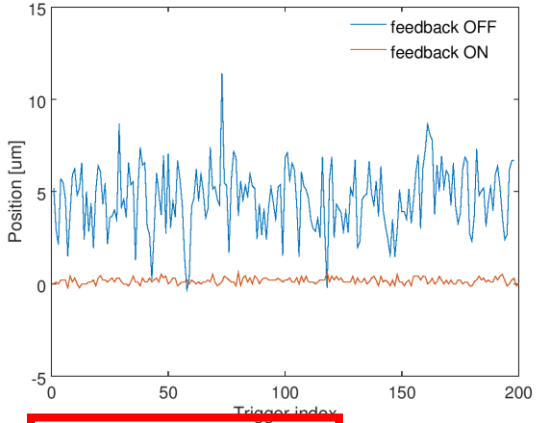




The position of the beam between pulse trains shifts due to ground vibrations and equipment noise.
On the other hand, the position of the beam does not change significantly in the pulse train.

The first bunch does not collide, but the second and subsequent bunches will collide.





D.Bett, 22nd ATF2 Project Meeting, Nov-20-2018

Position jitter of bunch 2
1.78 μm (feedback off)
0.17 μm (feedback on)

Reduction factor
= 10.5

Wakefield study

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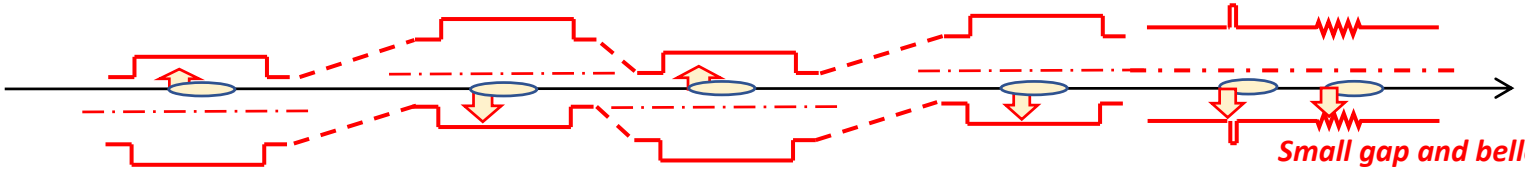
Static wakefield effect

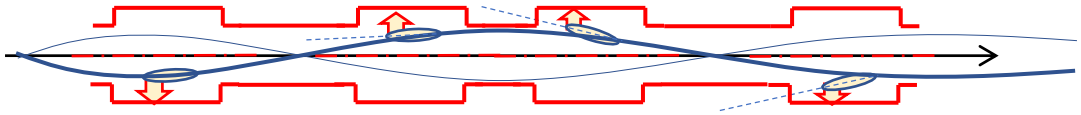
- Generated by **vacuum component misalignment, gap and bellows**
- The amount of the kick depends on the shape and number of the component.



Small gap and bellows also kick the beam.

Dynamic wakefield effect

- Generated by **IP angle jitter,** even when the vacuum components are well aligned.
- The effect can be reduced only by IP angle jitter reduction.



Intensity dependence effect is evaluated to a couple % of ILC250 IP beam size growth.

	Bunch Charge	IP Beam size	Intensity dependence	
			Static Effect	Dynamic Effect
ATF2 results	**1e9**	**41nm**	**5nm/1e9**	**3.3nm/1e9**
Scaled to ILC	0.6～3.8e10 (1)	7.3nm	4.6～8.0nm/1e10 (0.85 nm/1e10 (2))	0.9～1.5nm/1e10
ILC design	2e10	7.7nm	**2.4 % IP beam size growth (2)**	**0.7～1.9% IP beam size growth (3)**

(1) ATF2 N=1.0e9 corresponds to N=0.6～1.1e10 for static effect, and N=2.2～3.8e10 for dynamic effect. (by K.Kubo at ALCW2018.)
(2) Evaluated by ILC250 beam tuning simulation. (by T.Okugi at 2018 ATF2 project meeting.)
(3) Evaluated by simple scaling.

Swapping two Octupoles for Ultra-low beta study (CLIC FF optics)

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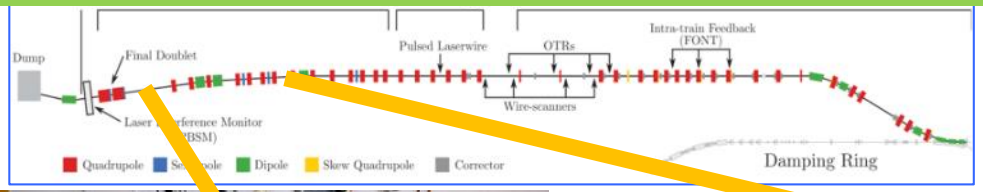
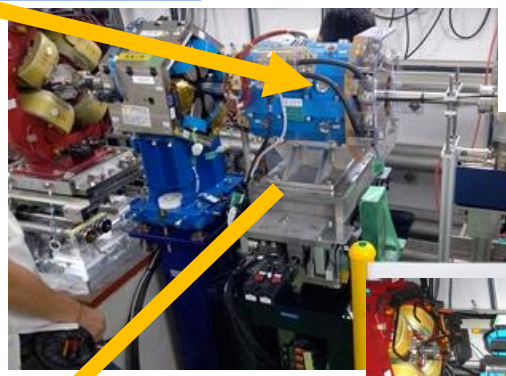
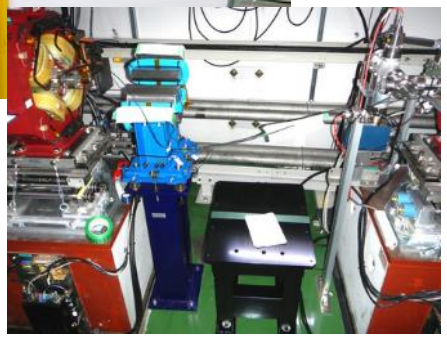
2019-October

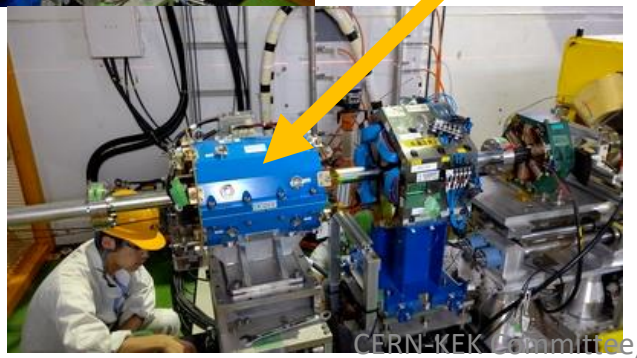


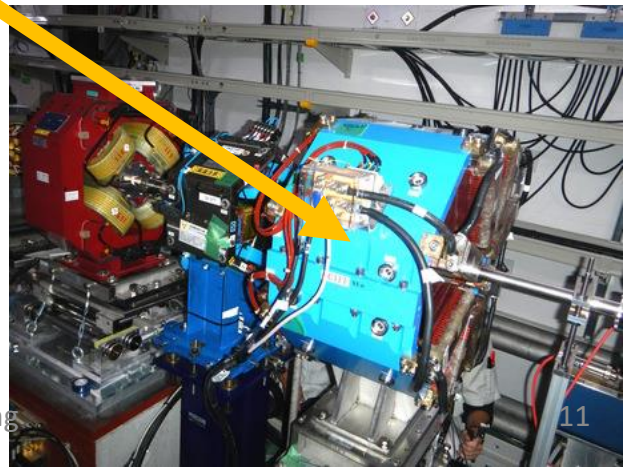
OC1: Bigger Octupole

OC2: Smaller Octupole









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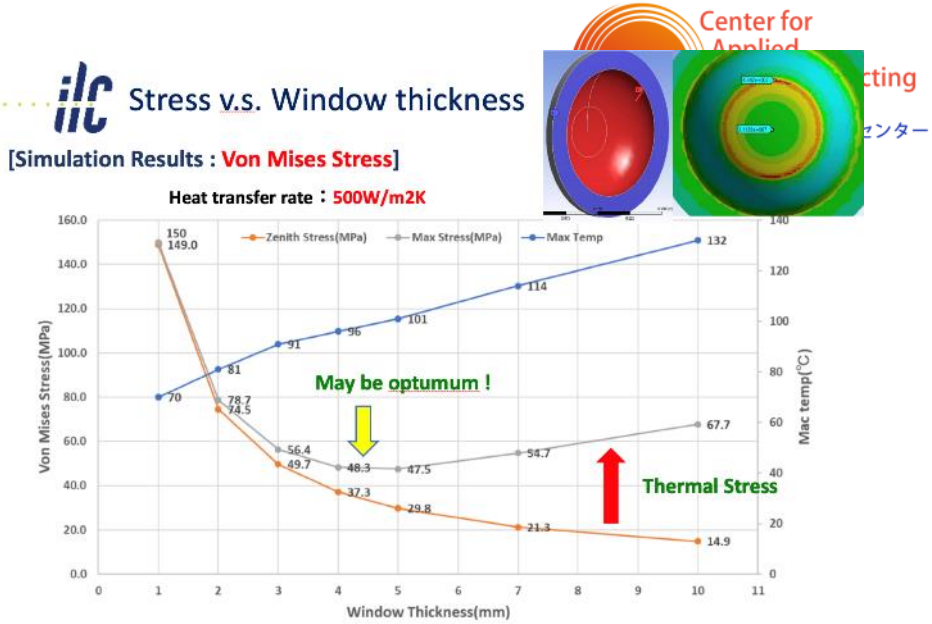
Beam dump R&D

S. Michizono, Y. Morikawa, and S. Stapnes
KEK-CERN Cooperation

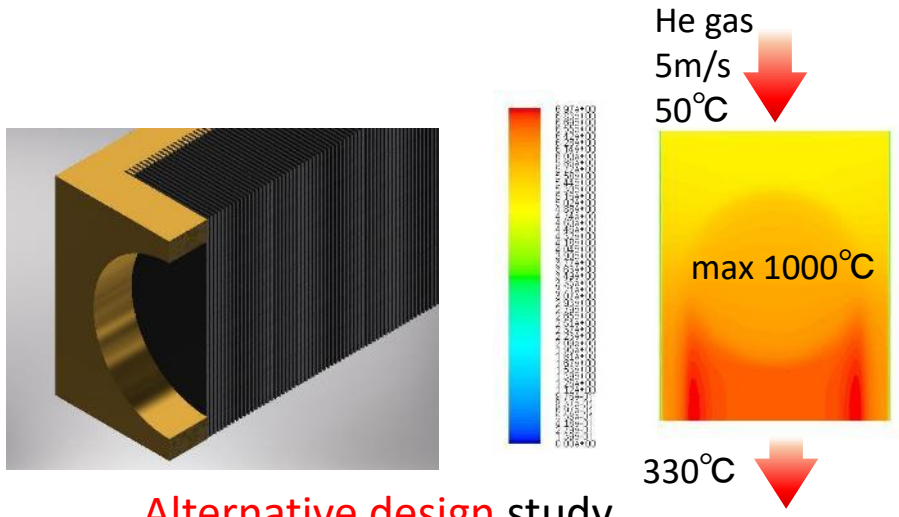
CERN-KEK Committee, at KEK, 18 Nov. 2019

Cooperation of the beam dump design for future LC's

KEK members visited the LHC beam dump in March 2017.



Optimization of the beam window thickness for ILC 17MW beam dump

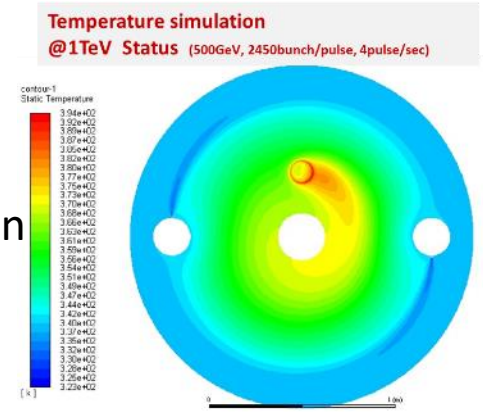


Alternative design study
(graphite dump + He gas-flow)

Beam dump window

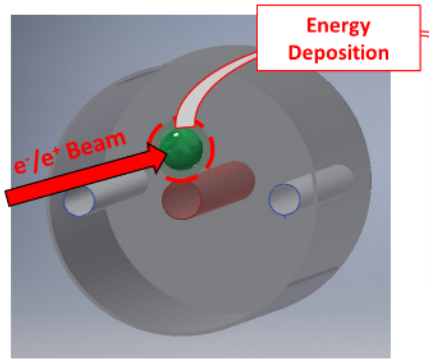
- Advise for Beam Dump Window
  ⇒Beam Window Durability

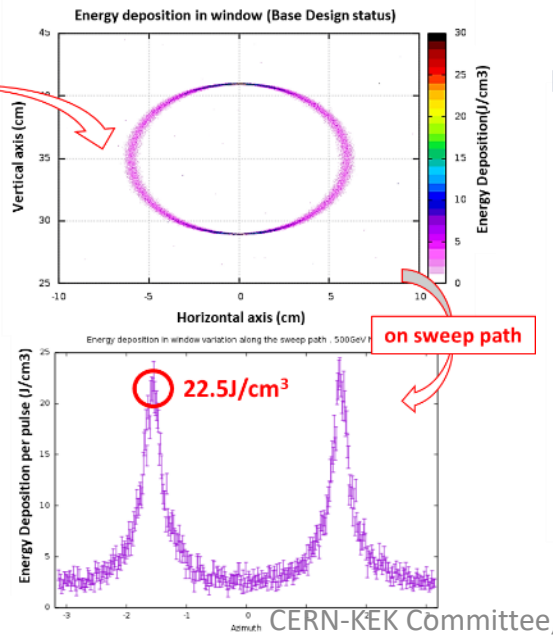
[Simulations]
- FLUKA – Particle transport
  ⇒Energy Deposition,
  Radiation damage, Activation
- ANSYS - Mechanical issues
  ⇒Temp, Stress, Displacement



Beam window simulation : Optimizing the window thickness

Energy deposition

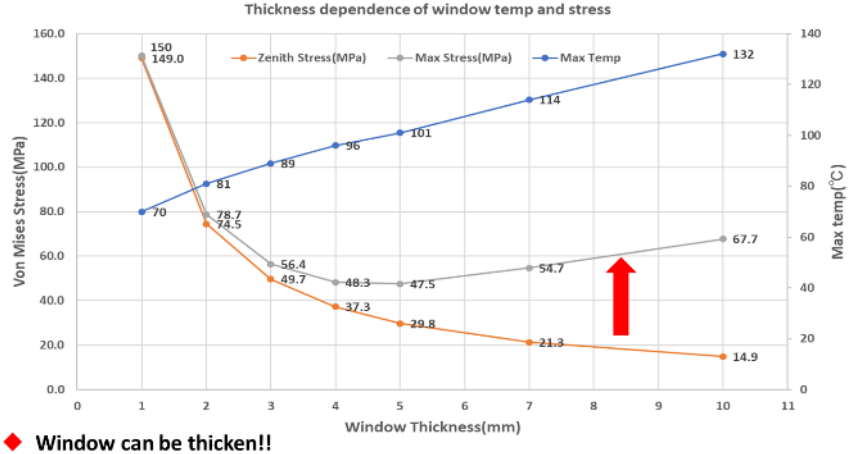




- Peak Density 22.5J/cm³
- Total deposition power 25W/mm.

Thickness dependence of thermal stress

[Simulation Results : Von Mises Stress] Heat transfer rate：500W/m2K



◆ Window can be thicken!!
In normal operation, stress of 5mm thick is the lowest.
But it's necessary to determine the thickness in consideration of emergency scenarios.

Alternative design

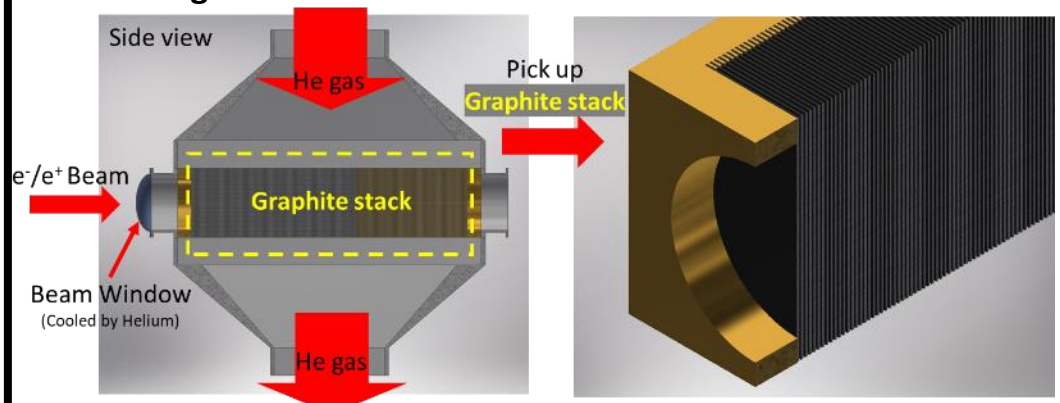
- Alternative Design of main dump
  Graphite plate & gas cooling

・Base design was made and simulation shows possibility that this design can accept 1TeV-Beam.
・This design needs high pressurized He-gas(~1MPa) and big mass flow(He-10kg/sec).

Merit : Tritium production rate in He-gas is lower than water(1/30) and gas purification can be applied.
(Tritium can be removed from coolant).
Demerit : Gas leakage is hard to deal.

Simulations for Alternative design

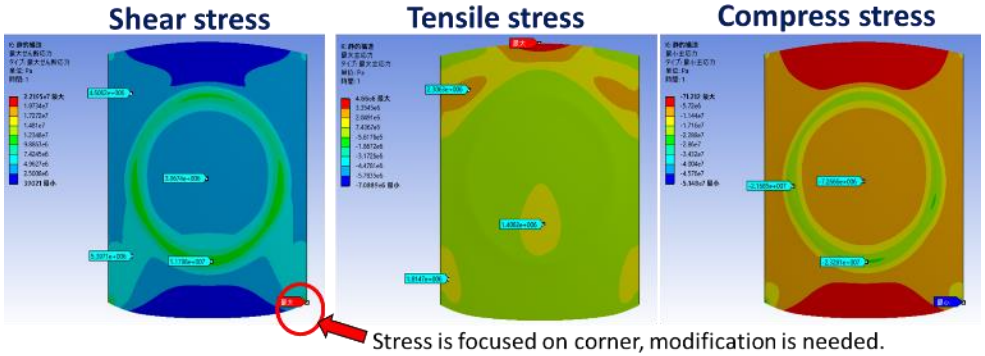
Base Design



・Graphite plate:H500×W400×t5(mm)
・30bar compressed He-gas is supplied from top to bottom.

Thermal Stress

[Case of Max power deposition plate z=190cm]



Stress is focused on corner, modification is needed.

	Simulation results	Graphite strength
Shear stress(MPa)	11.8	18
Tensile stress(MPa)	4.7	37
Compress stress(MPa)	23.3	90

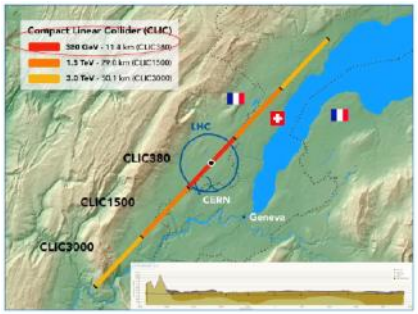
Development of a MgB_2 SC Solenoid for High-Efficieceny X–band Klystrons

S. Michizono, A. Yamamoto, and S. Stapnes
KEK-CERN Cooperation

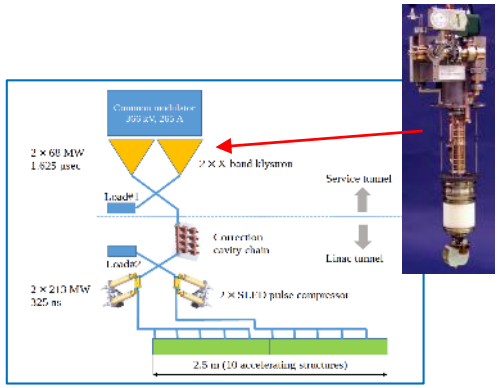
Presented at High-efficiency RF Workshop, Uppsala Univ., 18 June., 2019
Updated for CERN-KEK Committee, at KEK, 18 Nov. 2019

Motivation for MgB_2 Solenoid Development

- A CLIC-380 staging scenario investigated with X-band (12 GHz) klystron-based accelerating structure, as an alternate option.
- The klystron requiring a e-focusing solenoid with
  - Bc = **~ 0.6** T in a warm bore-diameter of 0.24 m



- A Cu-based solenoid, currently used, consuming
  - P = **~20 kW/Klystron** resulting in **~ 100 MW** for ~ 5,000 Klystrons
- A MgB_2 SC solenoid demonstrated:
  - P = **~ ≤ 2 kW**/Klystron resulting in **~ ≤10 MW**, only for Cryogenics - ==> **90 % power saving**



MgB_2 Conductor Parameters and Performance

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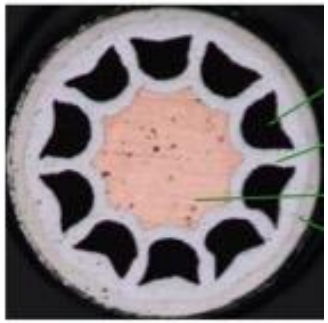
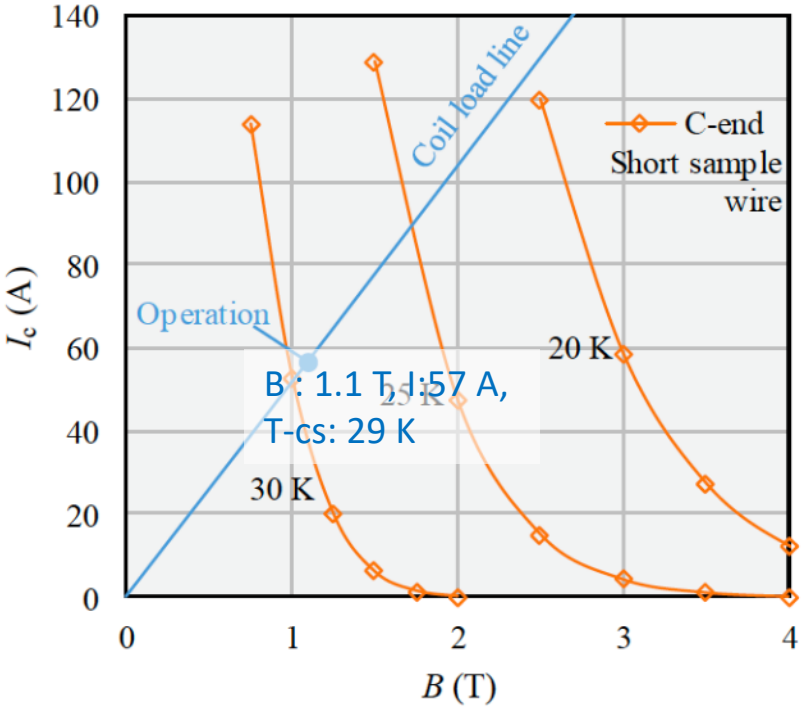
	Hitachi, *in situ Process*
Powder	Mg + B + additive
Metal pipe & rod	Cu, Fe, Ni
Heat treatment temp.	Typically 600℃
W&R or R&W	Mainly Wind & React
Insulation	Glass braid

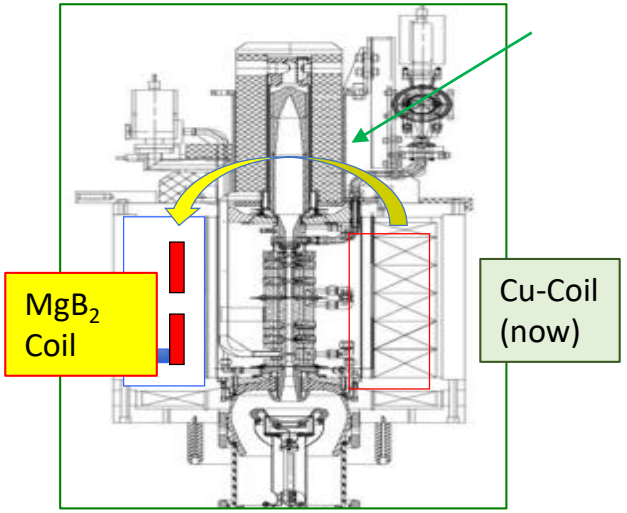


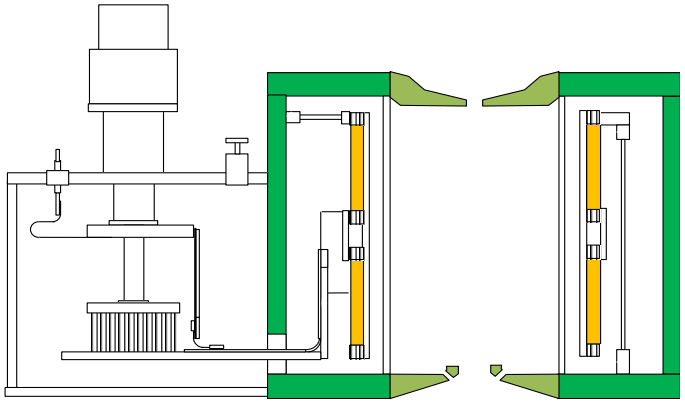
Φ0.67 MgB_2



MgB_2 Prototype Solenoid

Parameters	Parameters
Superconductor	
Material	MgB_2/Cu /Fe/Monel ®
Strand Diameter, Length	0.67 mm, 5,600 m
Solenoid coil	
Inner Diameter, Length	0.34 m, 0.30 m
Bc @ Current, #--turns	0.8 T @ 57.1 A, 4946
Stored energy	11.8 kJ
Weight (coil/-insert/Bobbin)	71 (14/25/32) kg
Heat-treatment	600 C x 6 h
Cryostat	
Warm ID, Yoke OD, Hight	0.25, 0.63, and 0.52 m
Cryo-cooler (SHI-CH204)	
Cooling capacity (@ 20/65K)	6.7 / 13.5 @ 50 Hz
AC plug-power	< 3 kW





Performances Demonstrated

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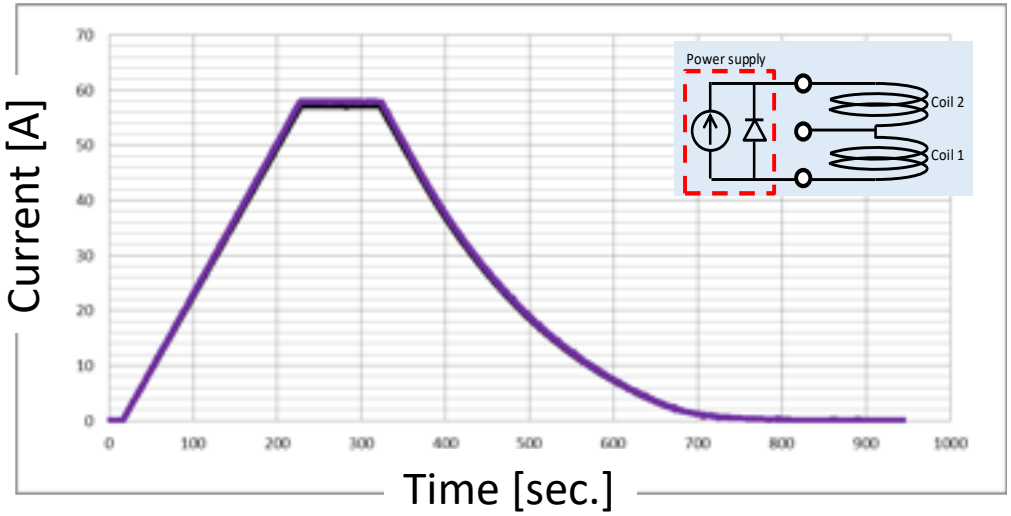
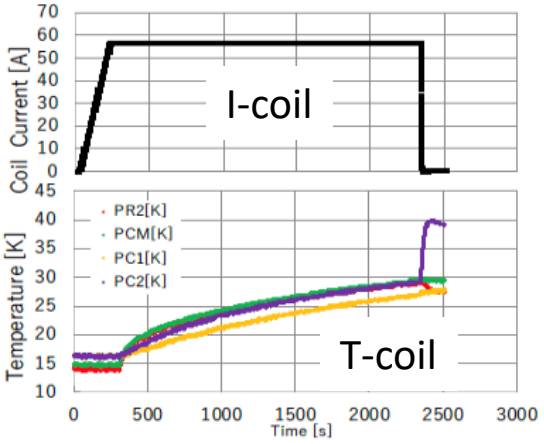
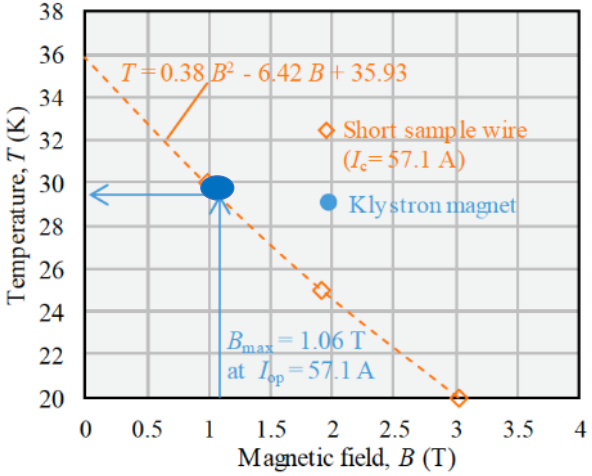
Cool-down by using cryocooler:
7 days

Ordinal Charge/Discharge time:
< 5 min.



T current sharing (Tcs)
Measurement
@ I-coil kept at 57.1 A
Cold-head warmed
By using heater





T-current-sharing at 29 K, 57 A, 1.1 T (at coil-end), 0.8 T at center)

MgB_2 magnet for X-band klystron

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Objective

- MgB_2 SC mag technology demonstrated for high-efficiency X-band Klystron

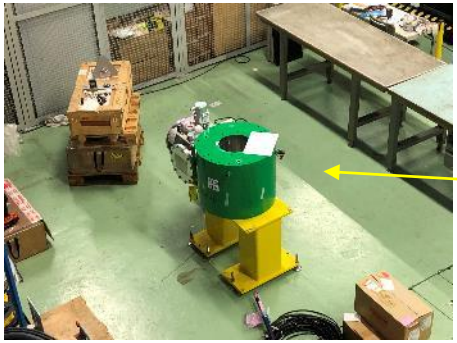
Prototype SC Magnet

- Superconductor: **MgB_2**
- B_c: > **0.7 T** (at a warm bore aperture of ~ 0.24 m)
- T-operation: **20 K** or higher
- AC-plug power: < 3 kW
  - → **< 1.5 KW / Klystron, with pairing,**
  - → **< 1/10 AC-power of Cu-Coil**

Progress and Plan:

- MgB_2 solenoid developed and successfully tested,
- Realizing **B_c = 0.8 T. at T-cs =29 K, (AC-plug = 2.8 kW), and**
- Solenoid to be assembled and tested, with Klystron, at CERN

Solenoid to be assembled w/ Klystron and tested at CERN



Solenoid delivered
to CERN in April 2019

Summary

- *ATF collaboration*
  - *Collaborative Research Contract between CERN and KEK supports the ATF beam operation.*
  - *Nanometer Beam Development*
    - *Final Focus System studies for LCs (FONT, wakefield effect)*
    - *Ultra Low-beta optics for CLIC*
  - *Ground Motion Feed-forward for CLIC*
  - *Beam Monitor Developments*
- *Beam dump R&D*
  - *Advise for Beam Dump Design*
  - *Alternative Design of main dump (Graphite plate & gas cooling)*
- *MgB_2 magnet for CLIC klystron*
  - *MgB_2 SC mag technology demonstrated for high-efficiency X-band Klystron*
  - *Achieved Bc = 0.8 T. at T-cs =29 K, (AC-plug = 2.8 kW)*
  - *Solenoid to be assembled and tested, with Klystron, at CERN*