

20-Year Collaboration on Synchrotron RF Between CERN and J-PARC

C. Ohmori¹, M. Paoluzzi², M. Brugger², M. Brucoli², H. Damerau²,
S. Danzeca², K. Hasegawa¹, Y. Morita¹, H. Okita¹, C. Rossi²,
M. Shirakata¹, Y. Sugiyama¹, F. Tamura¹, M. Yoshii¹

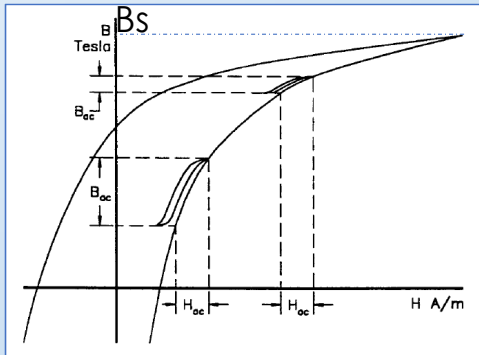
¹J-PARC, ²CERN

Proton Synchrotron Cavity

- For RF frequency sweep, ferrite-loaded cavity has been used.
- By biasing, permeability of ferrite can be changed for resonant frequency sweep.

$$Q = R / \omega L = \mu s' / \mu s'' \sim 100$$

Ferrite cavity has narrow band



$B_s \sim 0.3 \text{ T} \rightarrow$

Limitation of RF voltage

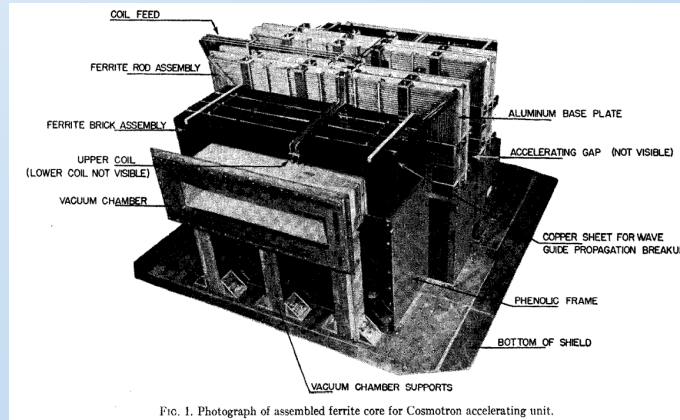
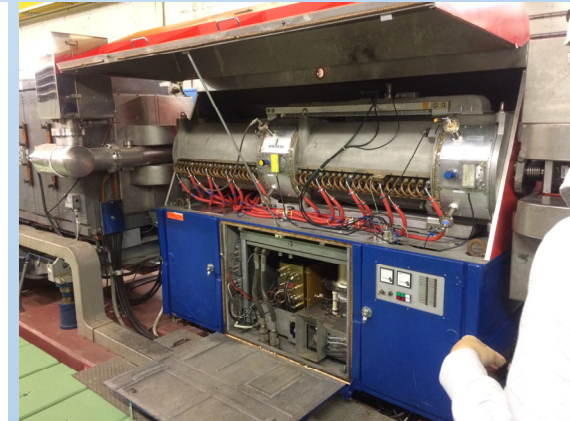


FIG. 1. Photograph of assembled ferrite core for Cosmotron accelerating unit.

Cosmotron Cavity (weak focusing)

Review of Scientific Instruments

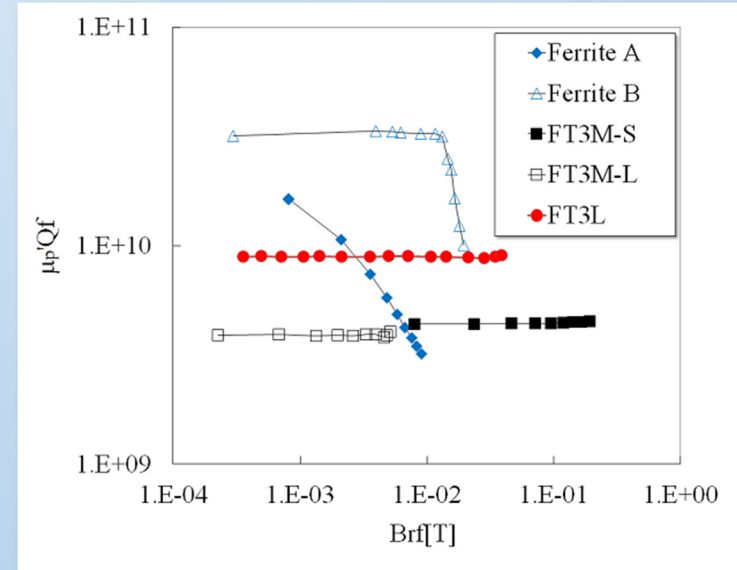
vol24 No.9, "Radio-Frequency System Part IV"



CERN PS cavity (strong focusing)

RF R&D in the mid-1990s

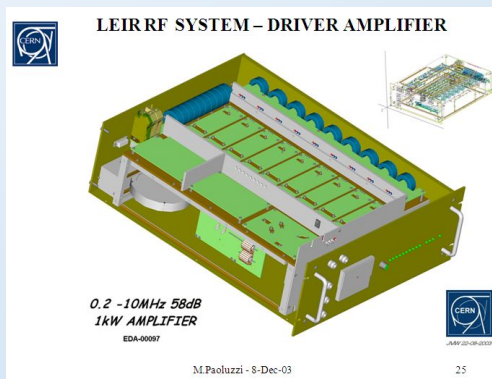
- In 1994, R&D started in Japan.
- Found that **nano-crystalline material**, Finemet®, might be used for cavity.
- $B_s \sim 1.2 \text{ T}$ -> stable at high voltage
-> High gradient
- Very large permeability
-> wideband, no biasing
- In 1998, first acceleration test at HIMAC -> Pb collision at LHC



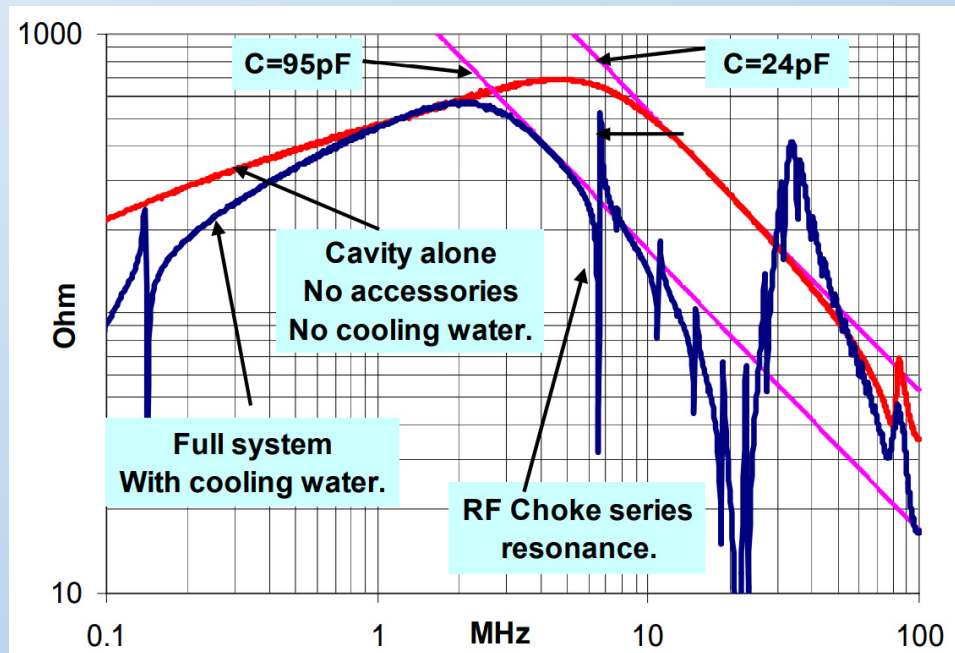
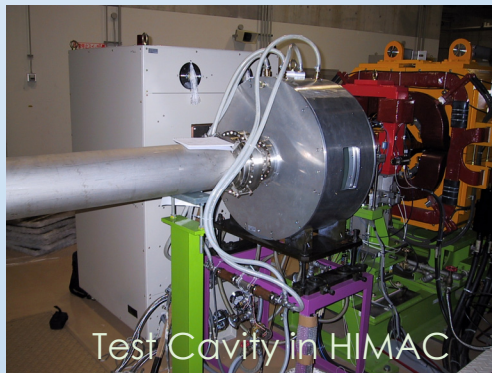
stable at high voltage

Collaboration between CERN and KEK 2002~

CERN supports KEK for solid-state amplifier.

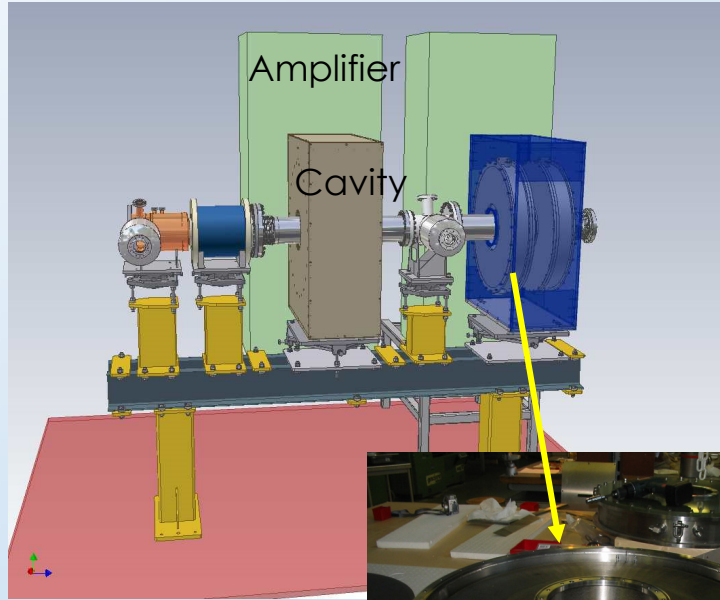


KEK support LEIR (Low Energy Ion Ring) cavities.

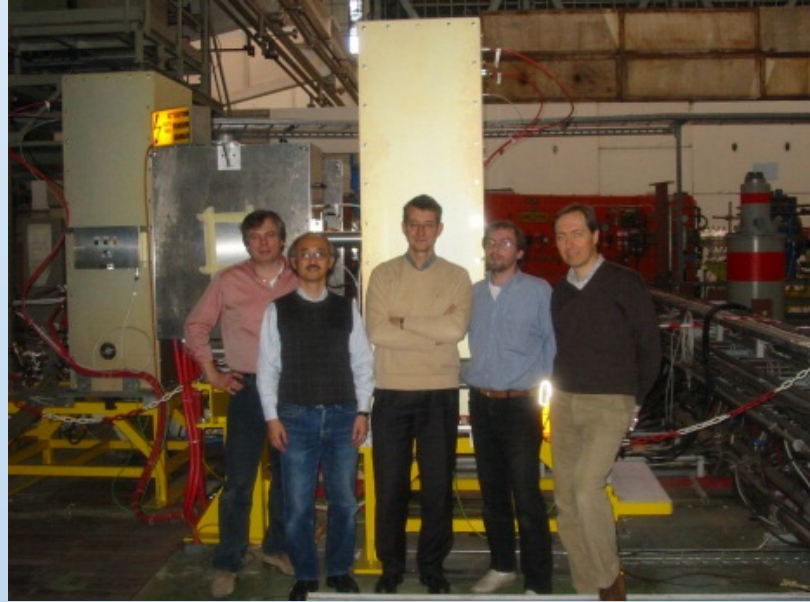


Wideband Cavity Impedance

LEIR Cavities



3 Finemet Cores in
water tank

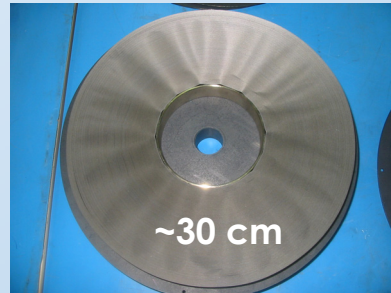


LEIR has been delivering
Pb ion for LHC, successfully.

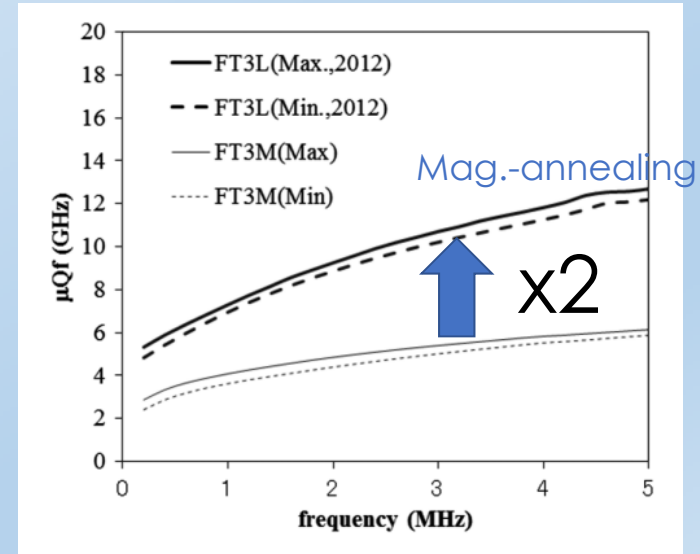
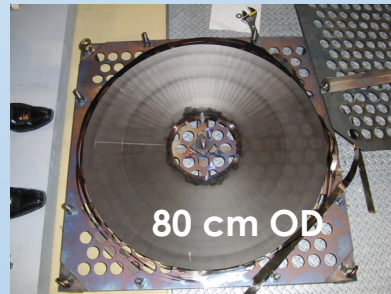
After installation of LEIR cavities

- Started R&D for high impedance core by magnetic annealing.
 - Visiting **Thailand** to test mid-size core production at a factory of Hitachi Metal Ltd.
 - Test production of large-size core for J-PARC

Thailand



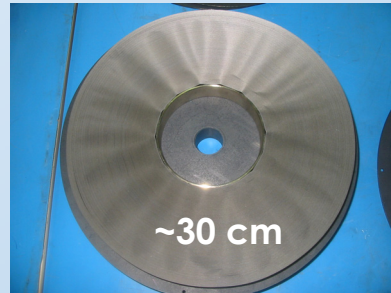
J-PARC



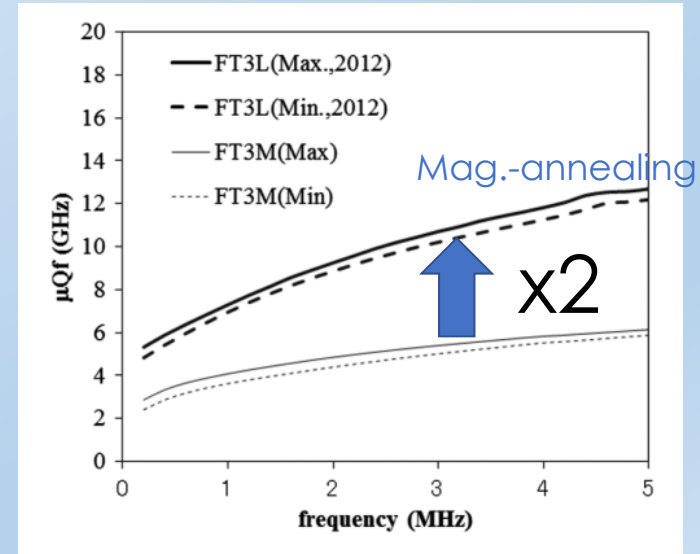
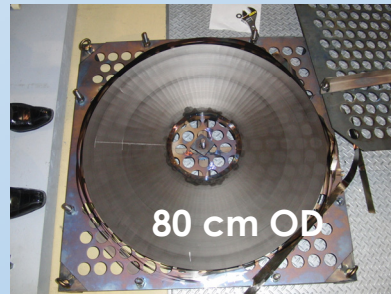
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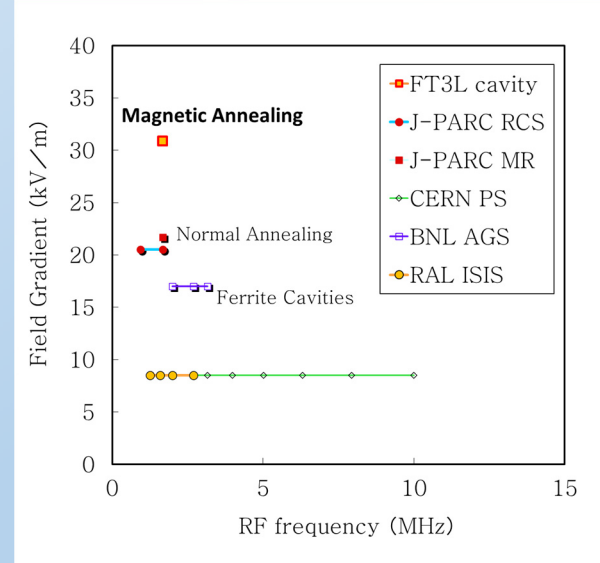


J-PARC



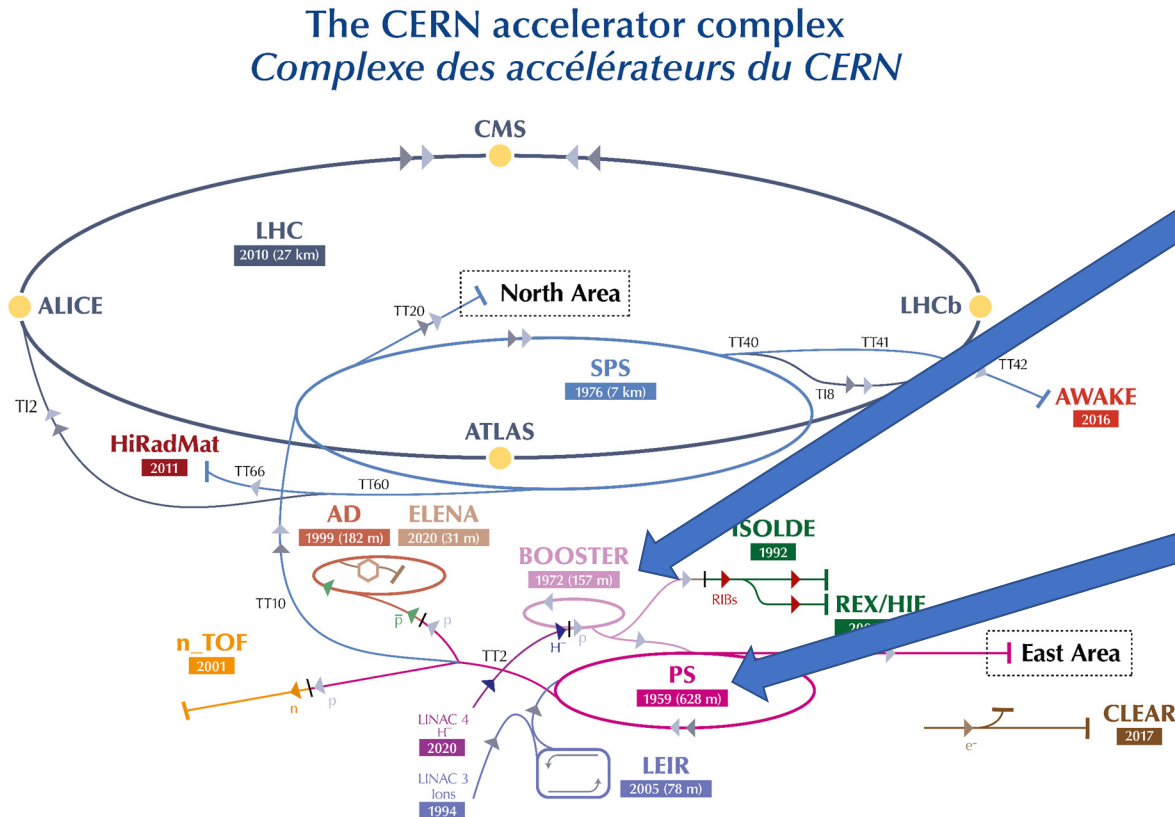
Mass Production of Mag. Annealed cores

- Mass-production system was build in J-PARC using an old spectrometer magnet. And, shipped to a company.
- Higher field-gradient was achieved.
- MR cavities were replaced by new cavities



Field Gradients of Cavities

LIU (LHC Injector Upgrade) RF

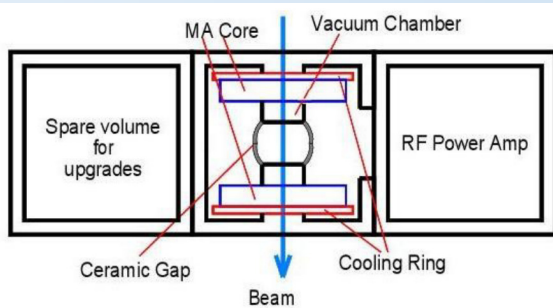


Our collaboration

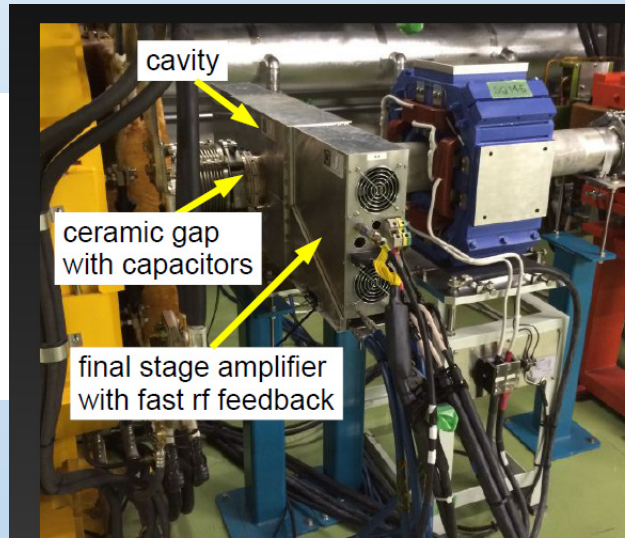
- PSB RF system consolidations/ upgrade for higher energy and intensity
- PS Damper Cavity : to damp Longitudinal Coupled Bunch Instabilities for High Luminosity at LHC

Key Issues : wideband beam loading

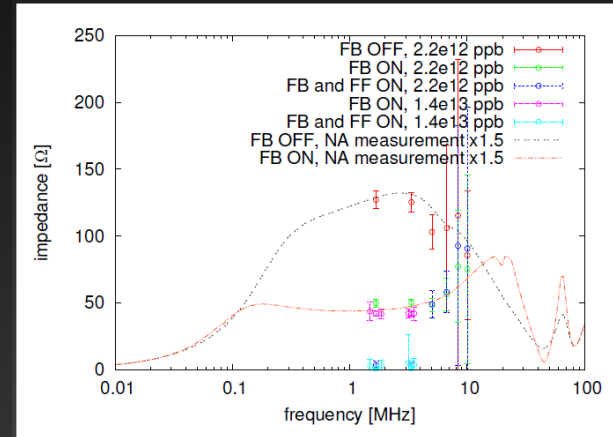
- A single-gap cavity test in J-PARC during a long shutdown of CERN accelerators
- Direct feedback & feed forward work together.



1.4 E13 ppb beam



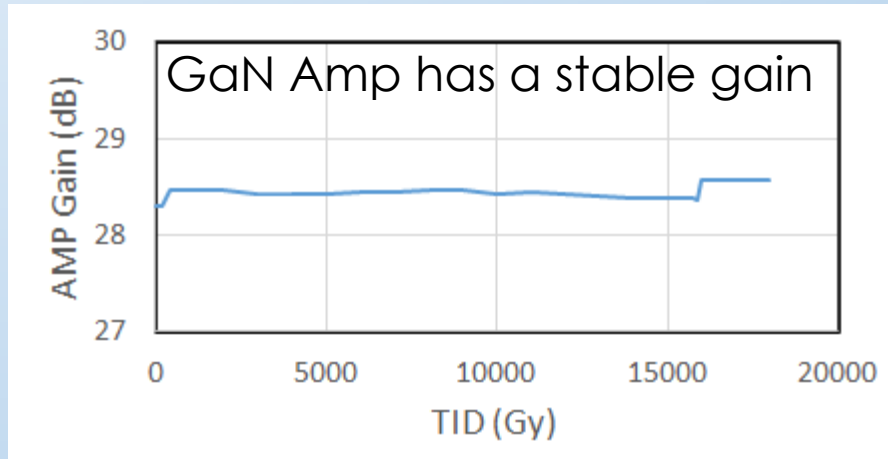
CERN PSB rf system prototype installed in the J-PARC MR.



Gap impedances without and with fast feedback.

KEY ssues : Radiation damage on SSA

- Use in radiation environment
- Mixed-Field Irradiation Test in J-PARC Main Ring Collimator section
 - Choice of high power MOSFET
 - Compensation of Radiation (TID) Effects on COTS MOSFETs
 - Survived in 8.8 kGy γ irradiation, 1.9 kGy with mix-field
IEEE Trans. Nucl. Sci. 66, 2188 (2019)
 - Testing GaN devices in ~ 18 kGy mixed field



PSB

- Based on R&Ds and beam tests, replacements of existing ferrite cavity system with new Finemet® wideband ones was approved.
- Cores were mag-annealed by J-PARC-made mass-production system.

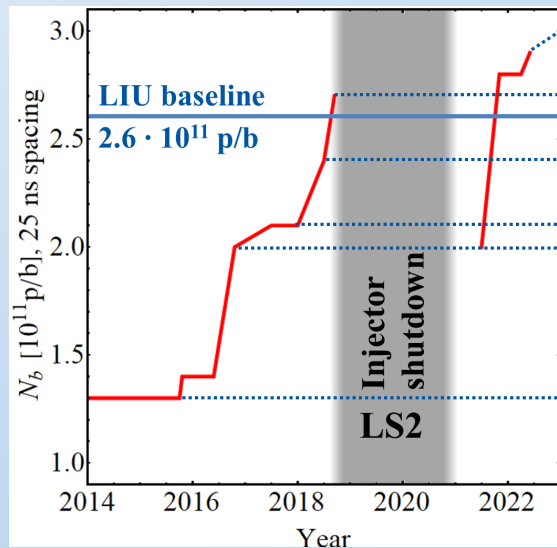
Results

- Higher voltage is available.
- One free straight section
- And, reasonable costs



Coupled Bunch Instabilities in PS

- A big issue to reach 2.6×10^{11} p/b for HL-LHC
 - Many dipole-modes were damped by wideband cavity system.
 - Quadrupole-mode were cured by Landau RF.



LS2 feedback upgrades

New 40/80 MHz cavity controllers

Multi-harmonic feedbacks, Landau RF

Saturation in 40/80 MHz feedbacks

Optimization 2017

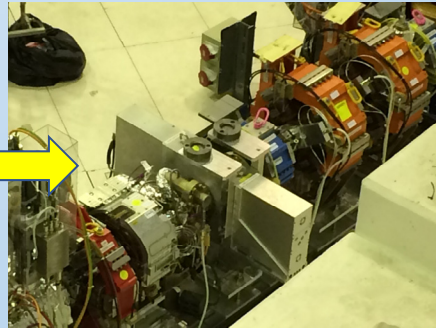
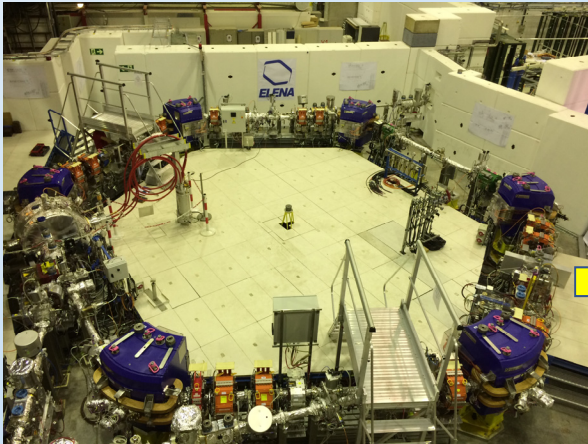
**Finemet dipole-mode
coupled-bunch feedback**

**Reach with C10-86/96 coupled-
bunch feedback (2005)**

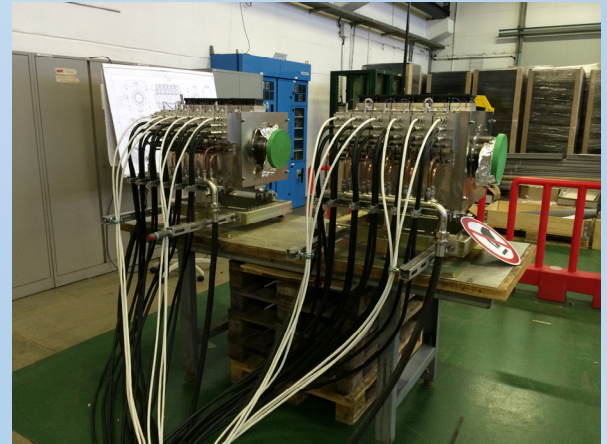
**WEPOTK046 H. Damerau "Improved Longitudinal
Performance of the LHC Beam in the CERN PS"**

Furthermore: Anti-proton and Medical

- Wideband cavity technology is also useful for other applications.
 - Anti-proton deceleration at Extra Low ENergy Antiproton (ELENA) needs wider bandwidth. 100 kHz at bottom for 100 keV anti-proton.
 - Wideband cavity is suitable for cancer therapy synchrotrons. Mag.-annealed cores in MedAustron.



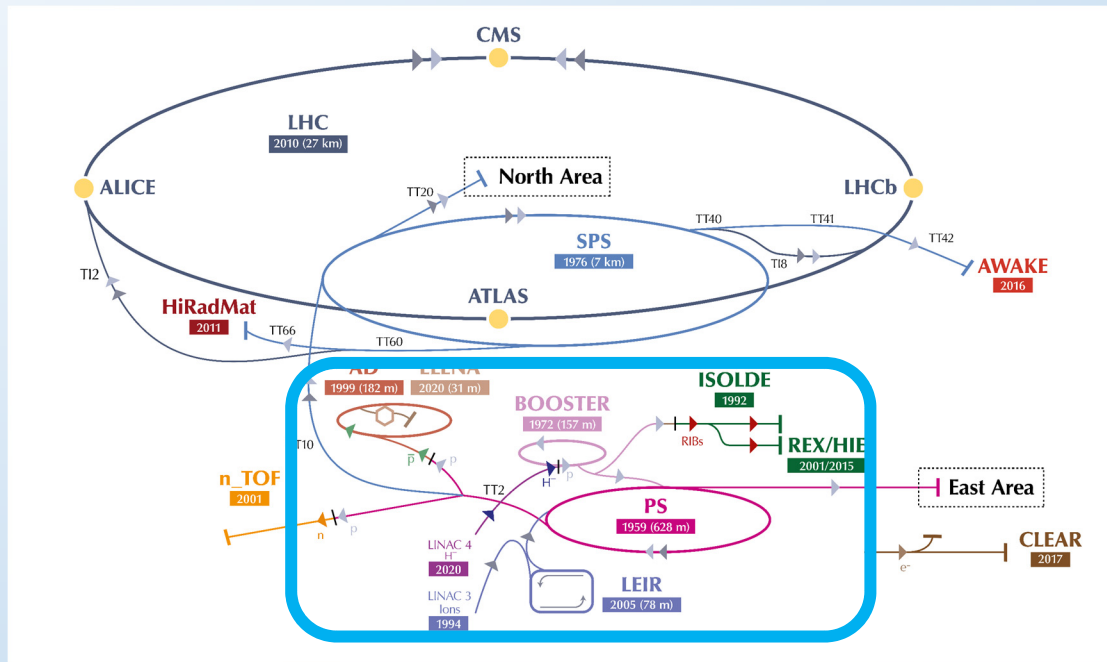
ELENA cavity



MedAustron Cavity under testing



Summary



Solid-state Amplifiers for J-PARC



~160 SSA units for J-PARC



Thank you!

ขอบคุณครับ

