J-PARC Contributions to LHC Injector Upgrade (LIU) Project

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Collaboration history

- 2002: CERN Low Energy Ion Ring (LEIR) Cavities for Heavy Ion collision at LHC and Solid-state amplifiers for J-PARC RCS & MR
- 2010: Information of Low Power Loss Finemet, FT3L
- 2012: Collaboration restarted for LIU
Injectors (Linac4, PSBooster, PS, SPS)

A quick overview on the LIU project

- Main RF system (200 MHz) upgrade → Increased RF power and improved controls
- Longitudinal impedance reduction & partial a-C coating → Increased instability thresholds
- New beam dump and protection devices
- 160 MeV H+ charge exchange injection → Reduced space charge at PSB injection
- Acceleration to 2 GeV with new main power supply and new RF systems - KEK/J-PARC Japanese Contribution
- 2 GeV injection → Reduced space charge at PS injection
- New RF equipment including broad-band feedback → increased instability threshold

Super Proton Synchrotron (SPS)
C = 6.9 km
$E_{\text{out}}^{\text{kin}} = 450$ GeV

PS-Booster (PSB)
4 rings of C = 157 m
$E_{\text{out}}^{\text{kin}} = 2.0$ GeV

Proton Synchrotron (PS)
C = 628 m
$E_{\text{out}}^{\text{kin}} = 25$ GeV

Linac 4
$E_{\text{out}}^{\text{kin}} = 160$ MeV

Linac 2
$E_{\text{out}}^{\text{kin}} = 50$ MeV

23/05/2019
IPAC, Melbourne, 19-24 May 2019
Malika Meddahi
PS Booster New RF systems

• Test of broadband RF system
  • At J-PARC (3GeV injection) in LS1
    
    beam intensity $1.4 \times 10^{13}$ ppb, 8 bunches

• At PSB, beam test after LS1
  • Beam Loading
  • Reliability (>99%)
  • Multi-harmonic RF
  • Broadband system was approved!
PS Booster New RF systems

• New RF systems are under installation!

Please see cavity in OPEN DAYS video (~8min.)
https://www.youtube.com/watch?v=U3vutvLlo-8
Old Ferrite-loaded Cavity system

New Magnetic Alloy (Finemet FT3L)-loaded Cavity

In J-PARC tour, MR FT3L cavities will be seen.
Contributions

• High impedance core by J-PARC-made Magnetic-annealing oven

• Contribution to mass production from ATLAS-Japan

• Quality check
Rad-Hard Solid-State AMP

- Many Solid-State AMPs in PSB tunnel
- Cause of problem is TID effect on bias point of MOSFET.

**Diagram:**
- Large Drain current if same Vg causes problem
- Constant Drain Current
- Stable transconductance & amp gain

175Gy
Rad-Hard Solid-State AMP

- **Mitigation of Radiation effects was applied.**
  - So far, gain variation is ~1 dB up to ~2 kGy in mixed field and 8.8 kGy by Co60!
    - 2 kGy means 100 years in PSB RF areas!
    - Results are published in IEEE TNS in Sep. DOI:10.1109/tns.2019.2937603 “Development of Radiation-Hard Solid-State Amplifiers for Kilogram Environments Using COTS Components”
  - 10 kGy test in fall at J-PARC for PS feedback AMPs in 1k Gy/year environment
PS Damper system

- Suffered by longitudinal coupled bunch instability.
- HL-LHC needs $2.6 \times 10^{11}$ ppb

Damper Cavity

Damper & 40 MHz Landau Cavities

H. Damerau
40 MHz Wideband Cavity Technology
Finemet®-base Landau Cavity R&D

However, instability was solved!
Test cavity is under testing at KEK/J-PARC with the best MA cores.
40 MHz Cavity R&D may be useful for future applications.

Material Research Collaboration using muon beam at MLF in J-PARC
MFL-IN-3: “Magnetic Field Dependence on Crystallization Process of FINEMET®
Nano-crystalline Alloy Detected by μSR Method” by OHTA, Motoki (Hitachi Metals)
Benefits to J-PARC

• Solid-state AMP technology at CERN helped and will help J-PARC.
  • For 1 MW beam, feedback AMP will be helpful.

• Beam Dump, RadMON

E. Jensen, BE-RF highlight 2018
Technology Transfer and Contribution to Society

- J-PARC/KEK developed a large core production system - magnetic annealing oven in 2013.
- The oven may be used to produce transformer cores for power supplies of **transportation systems**. KEK and Hitachi Metal Ltd. agreed to use the system and R&D has been started in 2018.

Wideband Cavity Technology may contribute to downsize transformers, to reduce power consumption and to Conservation of the global environment.
Summary

- J-PARC RF technology contributes CERN accelerators.
  - Wideband cavity is used in ELENA and, from 2020, AD for anti-proton deceleration.

- J-PARC and CERN have been collaborating for many years for ring RF.
- A lot of Benefits for both laboratories.

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