Design of the PIP-II 650 MHz Low Beta Cryomodule

N. Bazin, R. Cubizolles, S. Berry, M. Lacroix, G. Maitre, S. Bouaziz, C. Simon and O. Napol
Université Paris-Saclay, CEA, 91191 Gif-sur-Yvette, France
V. Roger, Y. Orlov and S. Chandrasekaran
Fermilab, Batavia, IL 60510, USA

Computer Contribution to PIP-II: the LB650 cryomodule

- Design of the LB650 cryomodule
- Licensing of the LB650 cryomodules
- System acceptance reviews
- Procurement of cryomodule components:
  - For 1 pre-production cryomodule + 9 series cryomodules
- Some components provided by Fermilab: cavities and tuning systems, power couplers, instrumentation (sensors, actuators, cables and feedthroughs), cryogenic valves, heat exchangers, bayonets, helium guards
- Assembly of all the LB650 cryomodules
- RF tests of all the LB650 cryomodules (including cryogenics and RF equipment)
- Design of the LB650 transport frame with the manufacturing of two units, and road tests
- Disassembly of warm couplers and top port and preparation for shipment of the LB650 cryomodules

Design Strategy

Most of the PIP-II cryomodules have the same design concept: the cavity string is supported by the strongback that stays at room temperature. There one configuration for the single spoke cryomodules and an other one for the elliptical cryomodules (LB650 and HB650).

LB650 & HB650 cryomodules:
- Similar cavity design: β = 0.61 for LB650 cryomodule and β = 0.92 for HB650 cryomodule
- Same power coupler
- Similar frequency tuning system
- Similar configuration: 4 cavities for LB650 cryomodule, 6 cavities for HB650 cryomodule
- Similar layout for the cryogenic circuits

Design strategy for the LB650 cryomodule: benefits from the design, assembly and test of the HB650 prototype cryomodule that comes two years earlier than the LB650 pre-production cryomodule

Maximum reuse of components from the HB650 cryomodule: support assemblies of the cavities, heat exchanger, bayonets, cold-warm transition, bellows between cavities, thermal straps, instrumentation

Close collaboration between FNAL and CEA design teams

Layout of the LB650 cryomodule

Vacuum vessel:
- Made of carbon steel, flanges made of stainless steel
- Design to limit the deformations of the strongback interfaces
- Maximum deformation: 1.2 mm

Thermal shield:
- Shield made of aluminum 1100
- Thermo-mechanical studies to assess the gradient, the deformations and the stress during cool down

Strongback principle:
- Each cavity is supported by two posts that are connected to the strongback
- Cavity attached to the two posts thanks to 4 C clamp assemblies
- The C clamp close to the power coupler fixes the position of the cavity and the three others allow motion in the horizontal plane due to thermal shrinkage during cool down
- The alignment of the cavity string is done before the insertion of the cold mass inside the vacuum vessel
- The strongback stays at room temperature, so the position of each cavity is fixed and the displacement is controlled and monitored using optical devices (HBCAM) to respect the alignment requirements

Conclusion of the thermal analysis of the strongback: in order to keep the its temperature close to room temperature, it is mandatory to have high emissivity of both the surface of the strongback and the inner surface of the vacuum vessel, as the radiation from the vacuum vessel is the main source of heat on the strongback → the magnetic shield shall not be installed between the vessel and the strongback