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IMPROVING THE BEVATRON VACUUM TO 10^{-10} TORR*

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Summary

Pressure of $\sim 10^{-10}$ torr is needed in the Bevatron to accelerate partially-stripped very-heavy ions (e.g. U^{69+}) in the Bevatron without significant loss due to interactions with the residual gas. This ultra-high vacuum will be achieved by installing (summer and fall 1981) a cryogenic liner, mostly 12°K, surrounding the Bevatron circulating beam. The novel construction features are presented along with results from successful tests of prototype sections. This is believed to be the largest application of cryogenic pumping to particle accelerators yet undertaken.

Vacuum Requirement

The High Intensity Uranium Beams project[1], now being constructed at LBL, will extend the performance of the Bevalac facility[2] by providing significantly higher intensities of presently-available ions (e.g. Ne, Ar, Fe) and by providing useful intensities for the still heavier ions (through uranium) that are not presently available. The heavy ions will originate in a new ion source, will be accelerated through an improved SuperHILAC[3] and then will be transported to the Bevatron for further acceleration. Most of the heavy ions entering the Bevatron will be only partially stripped. If such ions should gain or lose charge by interaction with residual gas molecules, their e/m ratio would shift and the ions would spiral to the wall of the Bevatron. While the present Bevatron vacuum[4] in the mid 10^{-7} torr range is adequate for the lighter ions (e.g. Ne, C), estimates[5] indicate that vacuum approaching 10^{-10} torr is required for 99% survival of the heaviest ions (e.g. U^{69+}) during acceleration to full energy in the Bevatron.

Design Features

To achieve 10^{-10} torr, a new cryogenically-cooled liner (cold-bore) will be installed to isolate the circulating ion beam from the remainder of the existing Bevatron vacuum chamber, as shown in Figures 1 and 2. The interior surfaces of the liner will be cooled to ~12°K for 90% of the 120 meter Bevatron circumference. The remaining 10% (in 3 of 4 straight sections) will be cooled to ~77°K. Two extraction magnets (M1 and M2) are impractical to cryo-cool so they will operate near room temperature. Outgassing of the cryo-cooled surfaces will be virtually zero. Thus, the two warm magnets will be the major gas load within the cold-bore.

Surfaces at 77°K will effectively "pump" CO_2, water and organic vapors, while 12°K surfaces will also pump N_2, O_2, CO and some other gasses. H_2, and to some extent He, will be pumped by activated charcoal at 12°K. Altogether, an enormous increase in pumping speed will be achieved.

Quadrant Liner

The quadrant liner (Fig. 2) basically is a set of three curved boxes, one inside another, with multilayer superinsulation between them to minimize heat transfer. The outer box will be installed between the magnet poles of the Bevatron, will be at near ambient temperature (~300°K), and will have a "guard vacuum" of $\sim 10^{-6}$ torr surrounding it. The intermediate box will be cooled by liquid nitrogen to ~77°K, while the inner box will be cooled to ~12°K. Design of the quadrant liner is unique in order to simultaneously (a) minimize eddy currents induced by the time-varying Bevatron magnetic field, (b) achieve cryo temperature throughout and (c) provide adequate mechanical compliance during thermal cycling.

The inner 12°K box is being built of large (36"x 48") copper-clad printed-circuit boards joined at the corners by special fiberglass-reinforced plastic (FRP) angles. Coolant (12°K) tubes at each corner will be attached to the box by metal clips. A radial pattern (Fig. 3) of .040 inch wide stripes (.010 inch between) has been etched into the .0026 inch copper coating on both sides of the .125 inch thick board. The copper stripes minimize eddy currents and electrostatic surface charge yet provide excellent thermal conduction to the coolant tubes because of the enhanced conductivity of copper at cryo temperatures. Activated charcoal pellets are being bonded to separately-cooled 12°K replaceable panels which will slide into the inner box.

The intermediate 77°K box is of similar construction except the copper coatings are .0065 inch thick. The outer 300°K box also is of similar construction except the FRP boards have no copper coating. The boxes are positioned relative to each other by tapered FRP pins.

The quadrant liner boxes are being fabricated in modules ~9 ft. long (10° arc). The ends of each module have tongue-in-groove slip joints that will accomodate thermal contraction yet are labyrinth seals for gasses pumped at that temperature. The coolant tubes have hair-pin loops to accomodate contraction at slip-joints.

Periodically, rectangular holes in the 300°K sidewall open onto louvers through the 77°K box, thereby pumping gas molecules from the "guard vacuum" region on the 77°K louvers and on the outer surface of the 12°K wall. Thus, the quadrant liners act as cryopumps not only for the cold-bore but for the surrounding "guard vacuum" region as well. Louver area has been selected to provide cryopumping speed equal to that[4] now in the Bevatron, so "guard vacuum" pressure below 10^{-6} torr is anticipated.

Tangent Regions

The liner tanks in the North, East and South tangent (straight) regions are being constructed of stainless steel plate, mostly 0.25 inch thick, with superinsulation attached to the outside. These tanks will be cooled to 77°K by liquid nitrogen flowing through attached tubes. The West tangent region will have a 12°K liner similar to the quadrant liner.

All internal components (inflector, perturb/spill magnet, two plunged extraction septum magnet systems,

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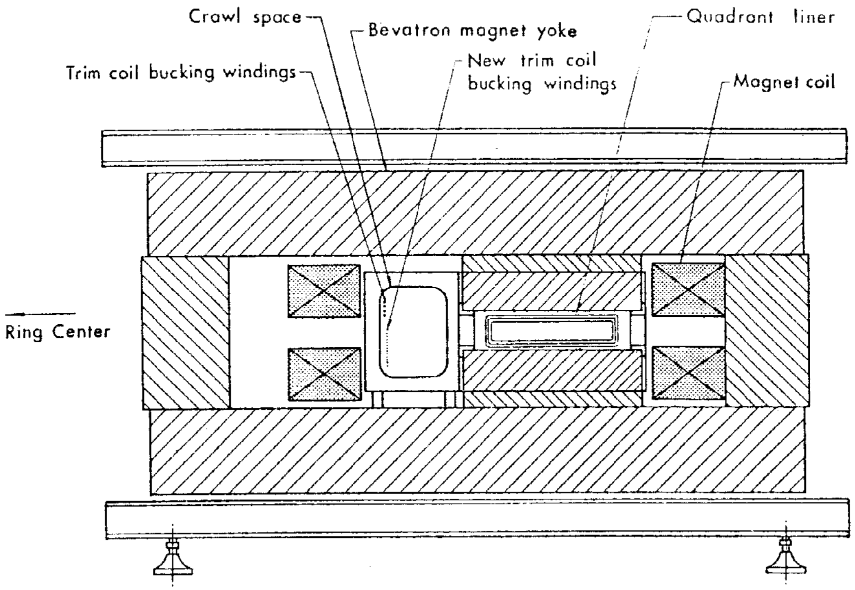

Fig. 1. Bevatron quadrant cross-section.

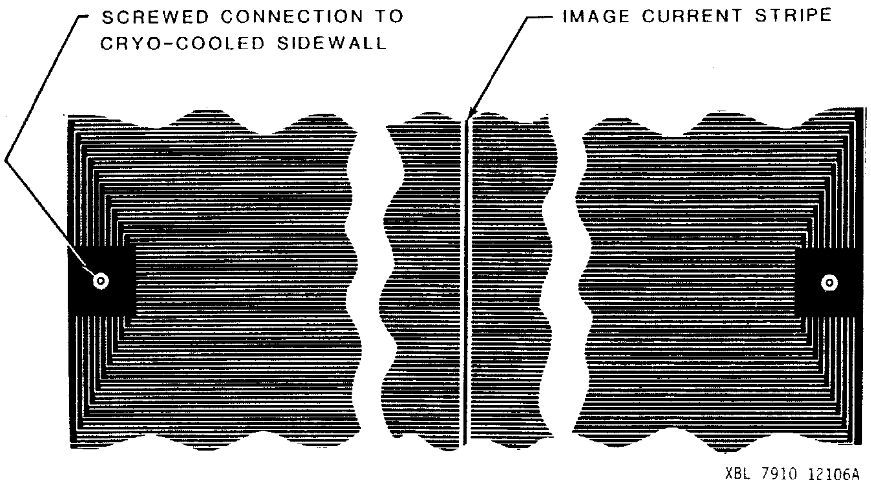

Fig. 3. Etched pattern on printed-circuit board of quadrant liner (Dark portions are copper).

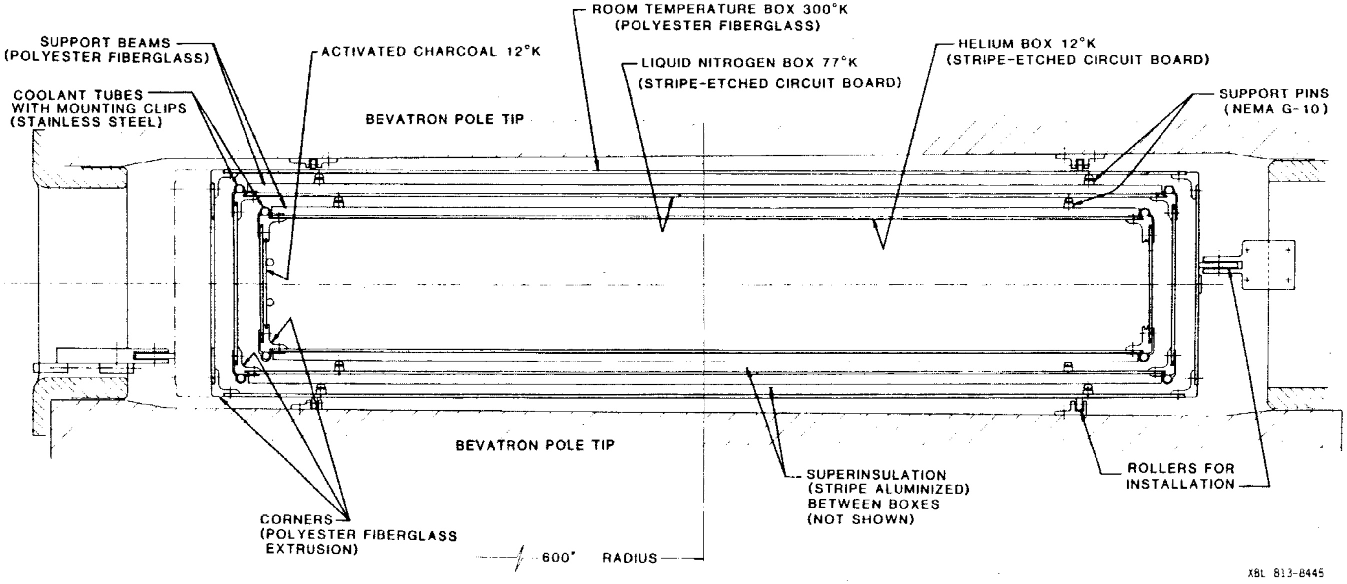

Fig. 2. Cross-section of quadrant liner between Bevatron poletips.

twelve beam diagnostic probes, rf accelerating electrode) will be replaced or extensively modified so as to be compatible with the new cold-bore arrangement.

Special louvered cryopumps (Figure 4), of 1 m^2 projected area each, are being built into the walls of the East and South tangent liners. They provide pumping, including H_2, for the 10^{-10} torr cold-bore and for the 10^{-6} guard-vacuum regions. They also provide free-flow venting between the inside and outside of the liners during pumpdown, venting or emergencies, yet effectively isolate inside from outside when the louvers are cryo-cooled under high vacuum.

Cryogenic cooling (12°K and 77°K) will be provided by a system atop the Bevatron shielding feeding distribution boxes at the East and West tangent regions. The evacuation cycle will be: (a) mechanical pumps to ∿1 torr, (b) special external cryoroughing pump to $\sim 10^{-3}$ torr and then (c) cooldown of tangent liners, cryopumps and quadrant liners. Cooldown is estimated to take two days.

Cold-Bore Tests.

A full-sized section of cold-bore quadrant liner, 10 feet long and including a tongue-in-groove expansion joint was constructed and successfully tested in late 1979. A similar production-prototype section, incorporating design improvements for ease of manufacture, was built and successfully tested during 1980. The inner box (12°K) is shown in Figure 6.

During these tests, LN-trapped ion gauges indicated mid 10^{-11} torr in the cold-bore. Since this is the X-ray limit of the ion gauge, the actual particle density in the cold-bore was probably much less. The test sections successfully pumped one year's worth of gas including hydrogen and helium on the 12°K activated charcoal surfaces. A steady-state heat load to helium of 3.5 watts was measured for the ten-foot prototype section, which is well within planned refrigeration capacity.

Acknowledgements

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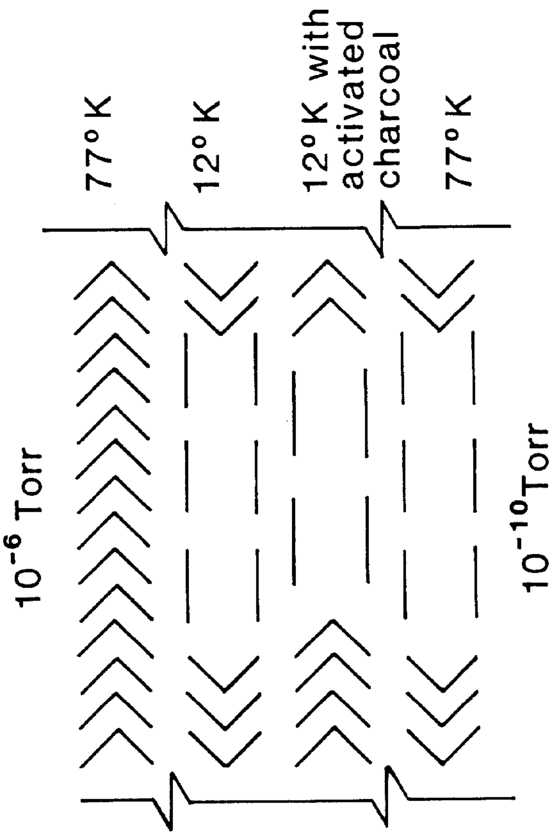

Fig. 4. Louvered cryopump which pumps the 10^{-6} torr guard-vacuum as well as the 10^{-10} torr cold-bore. It also provides venting between the two regions during pumpdown, venting or emergencies.

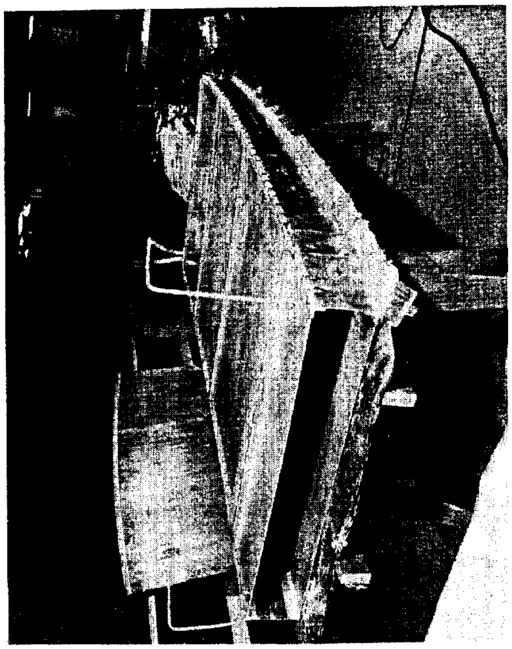

Fig. 5. Photo of production-prototype inner box (12°K) with a short box (foreground) connected by an expansion slip-joint to a full module (10° arc). A panel of the intermediate box (77°K) is standing in background.