650 MHZ CRYOMODULES FOR PROJECT X AT FERMILAB – REQUIREMENTS AND CONCEPTS*

Thomas Peterson, Mike Foley, Camille Ginsburg, Chuck Grimm, James Kerby, Youri Orlov,

Fermilab, Batavia, IL 60510, USA

Rupul Ghosh, Shailesh Gilankar, Abhishek, Jain, Prashant Khare, Pradeep Kush, A. Laxminarayanan,
RRCAT, Indore, India

Abstract

Cryomodules containing 650 MHz superconducting niobium RF cavities and associated components (input couplers, tuners, instrumentation, etc.) will be developed for Project X, a high intensity proton accelerator facility based on an H- linear accelerator at Fermilab. This paper describes the requirements of the 650 MHz cryomodules and the implications of those requirements for the cryomodule design. Cryomodule string segmentation, integration with the cryogenic system, features for maintainability and access, piping and emergency venting considerations, pressure vessel issues, and thermal and mechanical design concepts will be described.

INTRODUCTION

Project X will be a multi-MW proton accelerator facility based on an H- linear accelerator using superconducting RF technology. [1] The Project X 3 GeV CW linac will employ 650 MHz cavities [2] to accelerate 1mA of average beam current of H- in the energy range 160 – 3000 MeV. We describe the requirements of the 650 MHz beta = 0.9 cryomodules (see Figure 1) and implications of those requirements for the design concepts.

The baseline design concept includes cryomodules closed at each end, individual insulating vacuums, with warm beam pipe and magnets in between cryomodules

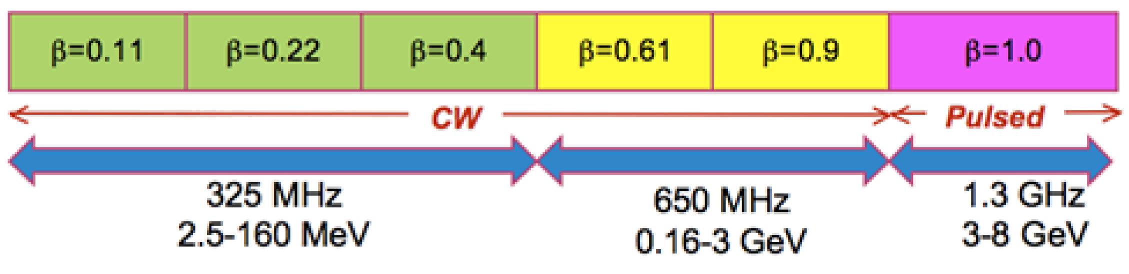

Figure 1. Project X incorporates six types of cryomodules, shown in this map. This paper describes the requirements for 650 MHz, beta = 0.9 cryomodules.

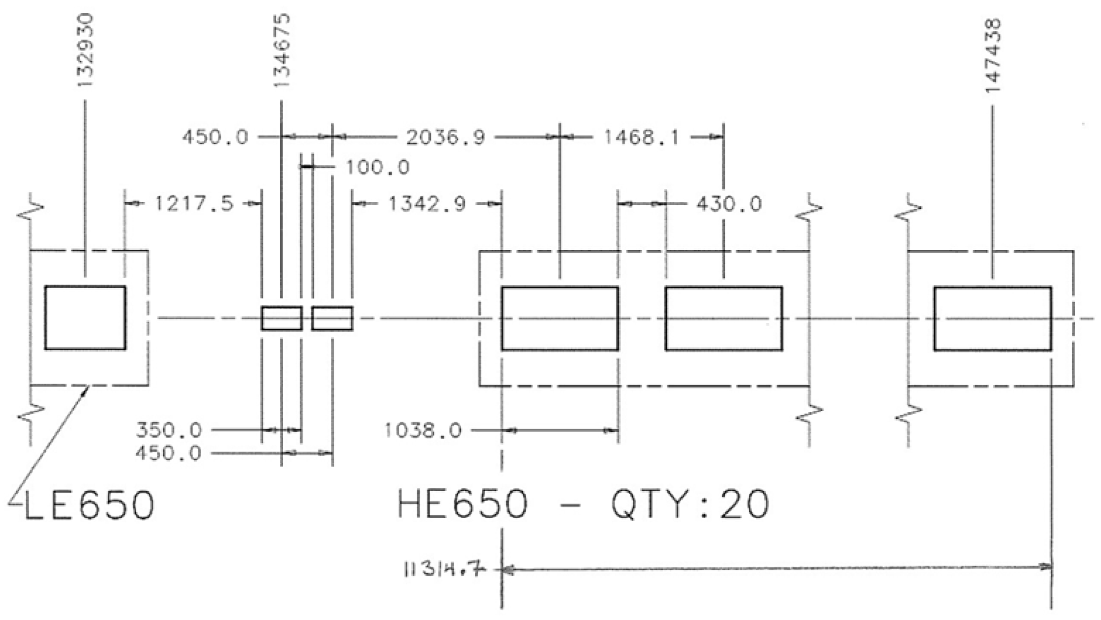

Figure 2. 650 MHz beta = 0.9 cryomodule (HE650) lattice spacing [3]. Dimensions, in mm, are effective RF and magnetic field lengths, which for cavities is approximately end iris to end iris distance. HE650 refers to the 20 beta = 0.9 cryomodules. Large rectangles represent RF cavities.

Table 1. Estimated heat loads

	650 MHz beta = 0.9
most heat (no mulitplier)	
2 K, per cavity (W)	26
2 K, per cryomodule (W)	208
5 K, per cryomodule (W)	34
70 K, per cryomodule (W)	436

PIPE SIZING AND SEGMENTATION

The combination of large steady-state heat loads and stringent venting requirements at the 2 K level combine to dictate rather large diameter 2 K pipes and short distances between relief valves. For heat transport from the RF cavity to a 2-phase pipe (if a closed helium vessel and 2-phase pipe are utilized as illustrated in Figure 3), 1 Watt/sq.cm. is a conservative rule for maximum heat flux through helium II for a vertical pipe [4, 5]. The critical heat flux for a non-vertical pipe connection from the helium vessel to the 2-phase pipe may be considerably less than 1 Watt/sq.cm. Configurations other than vertical require analysis to verify that the anticipated heat flux is less than the critical heat flux.

The two phase pipe size and/or helium vessel vapor space must accommodate a 5 meters/sec vapor "speed limit" over liquid [6]. No downward dips or features of the 2 K vapour piping which could trap liquid as a separate bath from the main 2 K bath are permitted.

During loss of vacuum venting, pressure in the helium vessel of the dressed cavity must be less than the cold maximum allowable working pressure (MAWP) of the helium vessel and dressed cavity. The cold dressed cavity MAWP will be about 4 bar differential. A heat flux as high as 4 Watts/sq.cm. of cavity surface area could result from sudden loss of beam vacuum to air, with a resulting helium flow rate of kg per second to be removed at low pressure. The resulting pressure drops versus number of cavities for a few pipe sizes are shown in Figure 4.

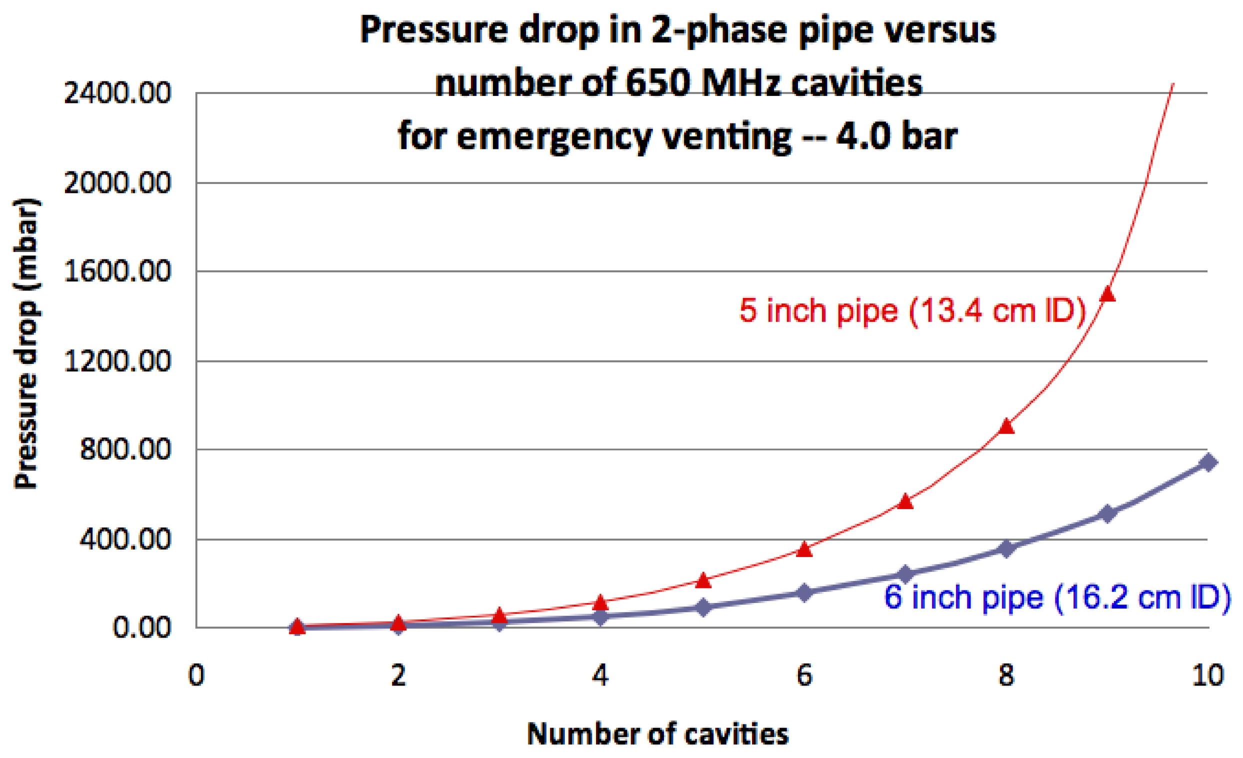

Figure 4. Loss of cavity vacuum to air — venting pressure drop in 2-phase pipe (differential pressure)

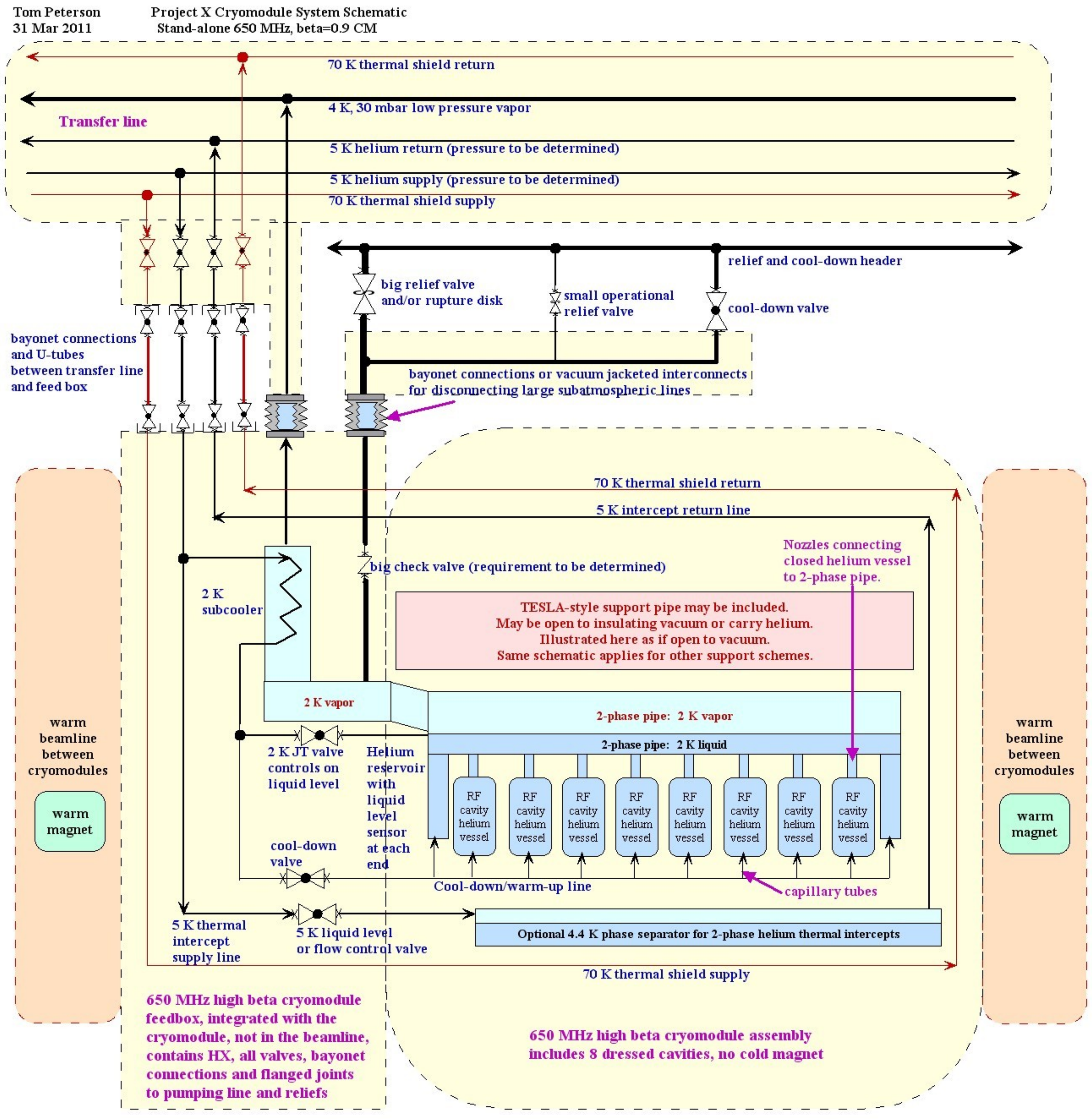

Figure 3. 650 MHz beta = 0.9 cryomodule schematic

CONCLUSION

Due to the desirability of short cryogenic pipe lengths, short 2 K liquid distances for managing liquid level control, frequent vent line spacing, and other advantages such as warm magnets and instrumentation between cryomodules, the baseline cryomodule design selected is a closed, stand-alone cryomodule with connections to an external, parallel transfer line (Figure 3).

REFERENCES

[1] Project X Reference Design Report http://projectxdocdb.fnal.gov:8080/cgibin/ShowDocument?docid=776.

[2] "Functional Requirement Specification, 650 MHz Superconducting RF Cavities," Project X Document 915-v1, by Camille Ginsburg (December 10, 2010)

[3] Drawing # 5520 ME 482343, Project – X, V3.7.4, Optics Layout

[4] "Notes about the Limits of Heat Transport from a TESLA Helium Vessel with a Nearly Closed Saturated Bath of Helium II," by Tom Peterson, TESLA report #94-18 (June, 1994).

[5] "Adapting TESLA technology for future cw light sources using HoBiCaT", by O. Kugeler, A. Neumann, W. Anders, and J. Knobloch, Helmholtz-Zentrum-Berlin (HZB), 12489 Berlin, Germany, published in REVIEW OF SCIENTIFIC INSTRUMENTS 81, 074701 (2010).

[6] "Latest Developments on He II Co-current Two-phase Flow Studies," by B. Rousset, A. Gauthier, L. Grimaud, and R. van Weelderen, in Advances in Cryogenic Engineering, Vol 43B (1997 Cryogenic Engineering Conference).

*Work at Fermilab supported by the U.S. Department of Energy under contract No. DE-AC02-07CH11359.

SRF2011 CHICAGO 15th International Conference on RF Superconductivity

Fermilab