HB2TF (High Brightness Beam Test Facility)

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1 CALL overview

High Brightness Beams Test Facility, HB2TF, is a CALL funded by the INFN CSN5 for the development of a High Brightness Beams Test Facility (HB2TF) at the INFN-LASA laboratory for the period 2023-2025. This CALL is a collaboration between the following participant units of the INFN: Milano, LNF, LNL, LNS, Bologna and Napoli.

The electron bunches produced by the DC Gun exhibit an elongated longitudinal profile to prevent emittance dilution. In order to minimize nonlinear energy spreading caused by the RF waveform in the planned booster, after the gun it is necessary to compress the bunches to a shorter length. Since the beam is still non-relativistic, the simplest method of bunch compression is through velocity bunching. To achieve this, we proposed a sub-harmonic bunching solution by using two $\beta < 1$, 650 MHz spherical re-entrant shape copper cavities. The beam energy prior to entering the first and second cavities is assumed to be 300 keV and 638 keV, respectively.

2 Bunchers' RF cavity and Power coupler Design

The particular frequency of the buncher was selected to be a sub-harmonic of an anticipated 1.3 GHz SC booster cryomodule. Within this context, and with the initial collaboration of the KEK buncher team, the geometries of the buncher cavities were initially formulated in 2D using

Superfish. The design was based on the KEK cERL buncher cavity 1 and scaled to the desired frequency. The buncher cavity has been then designed in 3D with commercial electromagnetic

solvers Ansys HFSS ²) and CST ³). The geometrical structure of vacuum is shown for Buncher 1 in fig. 1. In fig.2, we show the 3D mesh and profile for E and H field in Buncher 1. The parameter "g" is the effective gap length that is 17 cm, corresponding to a cavity $\beta = 0.74$. In tab.1, we outline the main RF parameters of the two bunchers.

The analysis has been performed by employing the eigenmode solvers, with the objective to confirm the correctness of the results in terms of operating frequency and electric field of the employed TM_{010} operating RF resonant mode. The overall comparison among different solvers is resumed in tab.2 for Buncher 1.

We are currently proceeding with the RF design and engineering of the high-RF power coupler up to 20 kW in CW operation. The coupler will include an air-to-vacuum RF window designed ad hoc with a dedicated cooling system.

3 Publications

• D. Giove et al., A high-brightness beam test facility for ERL applications, 14th International Particle Accelerator Conference, Venice, Italy (May 2023).



Figure 1: Buncher 1 geometry (only vacuum volume shown).



Figure 2: 3D mesh and profile for E and H field in Buncher 1. Parameter "g" is the effective gap length that is 17 cm corresponding to a cavity beta 0.74.

	Buncher 1	Buncher 2
$f_0 \ (\pi\text{-mode}) \ [\text{MHz}]$	650	650
$\beta (v/c)$	0.74	0.906
Input beam energy [MeV]	0.3	0.638
E-field ampl. [MV/m]	2.7	2.7
Cell per cavity	1.0	1.0
Active cavity length [m]	0.171	0.209
Cavity quality factor Q0	32000	36700
Ext. Quality factor Qext	30200	32400
$R/Q \ [\Omega]$	195.7	223
Geometry factor $G[\Omega]$	211	244
E_{pk}/E_{acc}	3.07	3.88
$B_{pk}/E_{pk} [\mathrm{mT/(MV/m)}]$	0.96	0.96
$B_{pk}/E_{acc} [mT/(MV/m)]$	2.94	3.73

Table 1: Main RF parameters of the two bunchers.

Table 2: Buncher 1 figures of merit through different solvers.

Parameter	Superfish	CST	HFSS
Radiofrequency, f [MHz]	650.372	650.180	650.3504
Quality Factor, Q	31710	31699	31691
Shunt impedance, R_{sh} [M Ω /m]	6.209	6.210	6.1144
On-axis Electric field peak, E_{peak} [MV/m]	2.7	2.7	2.688
Surface Max Electric field, E_{max} [MV/m]	6.13	6.29	6.536
Input RF power, P_{input} [MW]	10.28	10.26	10.28

References

- T. Takahashi et al., "Development of a 1.3 GHz BUNCHER Cavity for the Compact ERL", in proc. Of 5th International Particle Accelerator Conference (IPAC2014), Dresden, Germany, paper THPRI045, pp. 3866-3868, doi:10.18429/JACoW-IPAC2014-THPRI045
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