Transverse Deflecting Cavity for Longitudinal Beam Diagnostics at bERLinPro

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ABSTRACT: The Berlin Energy Recovery Linac Prototype (bERLinPro) at Helmholtz Zentrum Berlin (HZB) aims to deliver a CW electron beam of high average current (100 mA) and brilliance (normalized emittance below 1 mm·mrad). The achievement of this goal necessitates the determination of the bunch parameters after the first acceleration stages: photoinjector and succeeding booster. For the measurement of the bunch duration, longitudinal phase space and transverse slice emittance, a single-cell 1.3-GHz TM110-like mode vertically deflecting cavity was manufactured by RI Research Instruments GmbH, following the design developed for the Cornell ERL injector. The design parameters, manufacturing procedure and testing of this pulsed RF resonator are summarized below, together with the expected temporal measurement resolution for the nominal beam energies at the initial acceleration stages of bERLinPro.

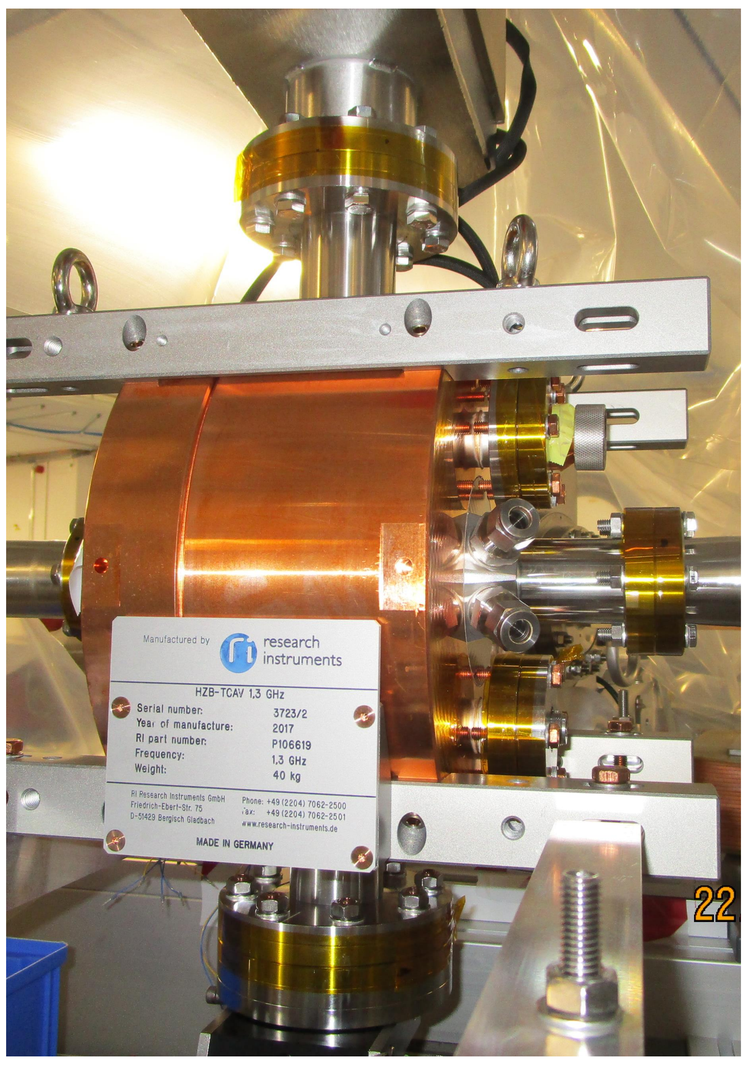
MOTIVATION AND DESIGN

A transverse deflecting RF cavity (TCAV) offers a straightforward **measurement of the longitudinal bunch parameters**. Operated in TM110 mode, it can deflect the head and tail of the bunch in opposite vertical directions. The longitudinal plane is then projected into the transverse after some drift.

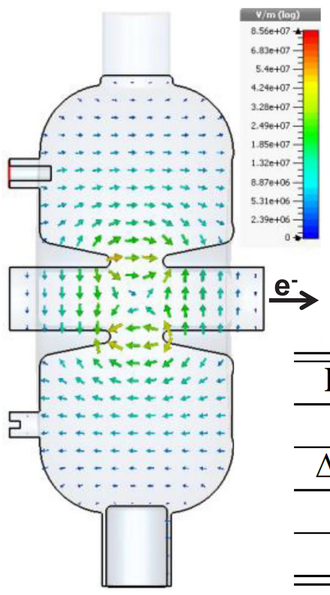
The **Cornell design** [1] was adopted (1.3 GHz resonance frequency, > 5 MΩ transverse shunt impedance), **with** the following **adjustments**:

- ion getter pump at the top of the cavity
- coaxial input coupler (50 Ω , < 2.7 kV_{rms} , < 100 W)
- coaxial RF pickup (50 Ω , -51 dB)
- ± 25 mm frequency-tuning plunger at the bottom.

Operation with low average beam current at **low repetition rate** is foreseen for bERLinPro. High beam current won't interfere with TCAV in passive mode once detuned from its resonant frequency.



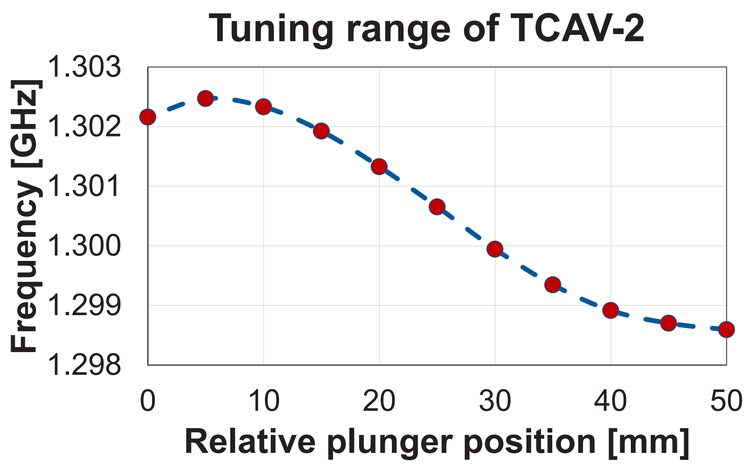
CAVITY MANUFACTURING, TESTING AND CONDITIONING



Increased **manufacturing precision** was achieved with a 5-axis CNC milling machine (surface roughness R_a<0.2 µm). A collar around the inner protrusion cones was iteratively trimmed until the resonant frequency was matched before the final brazing. **Bead-pull** measurements showed a very symmetric field distribution.

Parameter	Specs	TCAV-2	Unit
f (28°C)	1300±0.2	1300.02	MHz
Δf (±10mm)	~2	2.5	MHz
Q_0	>11000	12460	-
β_c	1±0.1	0.97	-

- **Vacuum tests** verified leak-tightness (10^{-10} mbar·l/min) and low particulate concentration.
- **RF tests** demonstrated a 4 MHz total tuning range of the resonant frequency. Coupling was measured between 1.08-1.34 and the unloaded quality factor between 14200-12750 (6850-5550 loaded).
- **RF conditioning** was performed up to 12 kW peak power, 200 Hz repetition rate and 40 µs pulse duration.



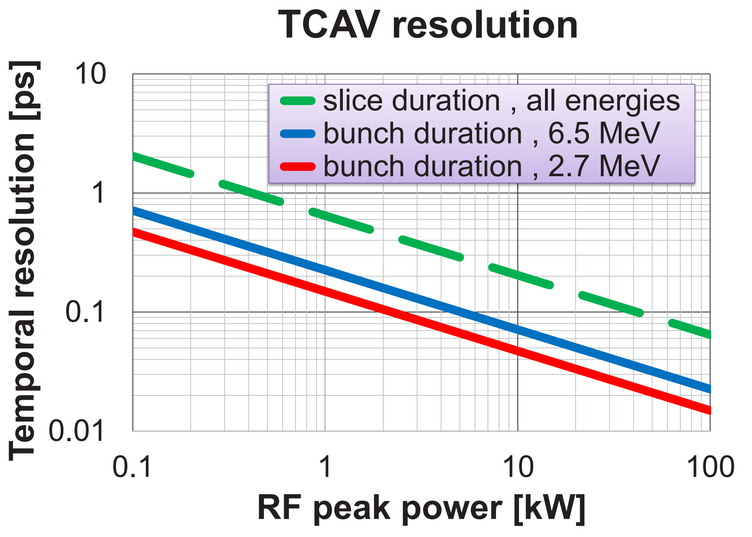
TEMPORAL MEASUREMENT RESOLUTION

Two types of temporal **resolution** were calculated:

- minimum **slice** duration, so that adjacent longitudinal slices do not overlap after deflection
- minimum **bunch duration**, which is detectable by the optical readout system

for the nominal beam energy after injector and booster of the bERLinPro configuration (1.8 m drift, 30 µm optical resolution, 2 mm rms vertical beam size and 1 mm·mrad emittance at TCAV) with maximum achievable beam focusing at the projection screen using a quadrupole 0.7 m upstream.

Maximum input power is **limited by the coupler** to ~40 kW at 200 Hz repetition rate. 5 kW will be available at bERLinPro using a solid-state amplifier.



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KEY REFERENCES

[1] S. Belomestnykh et al., "Deflecting cavity for beam diagnostics at Cornell ERL injector", Nucl. Instr. Meth. Phys. Res. A, vol. 614, pp. 179–183, 2010

ACKNOWLEDGMENTS

The authors would like to thank W. Anders, J. Hwang, F. Pfloksch, M. Schuster, H. Stein and J. Voelker from HZB for their technical support and useful discussions, as well as B. Dunham, F. Sannibale, V. Veshcherevich, D. Mallroy, T. Weis and M. Yan for sharing their work and experience on TCAV and the corresponding components.

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