Pick-Up Electrode System for the CR Stochastic Cooling System

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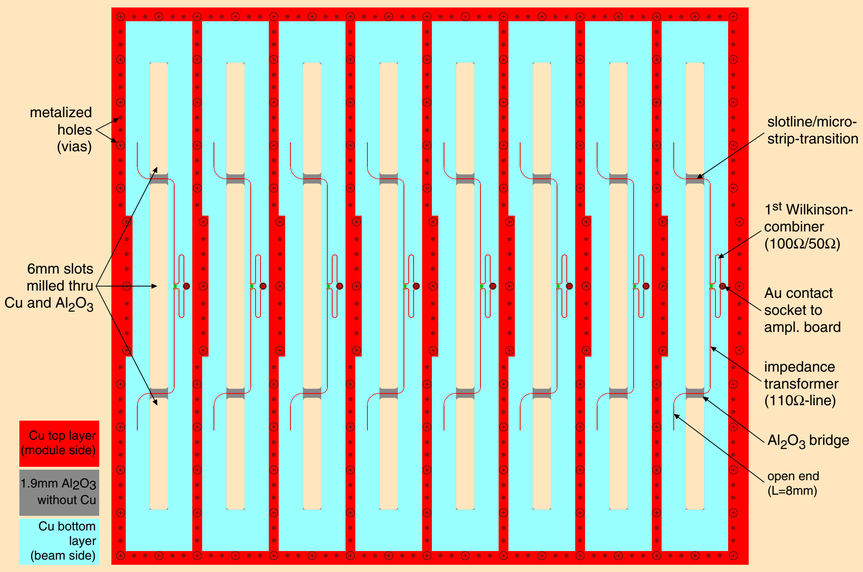
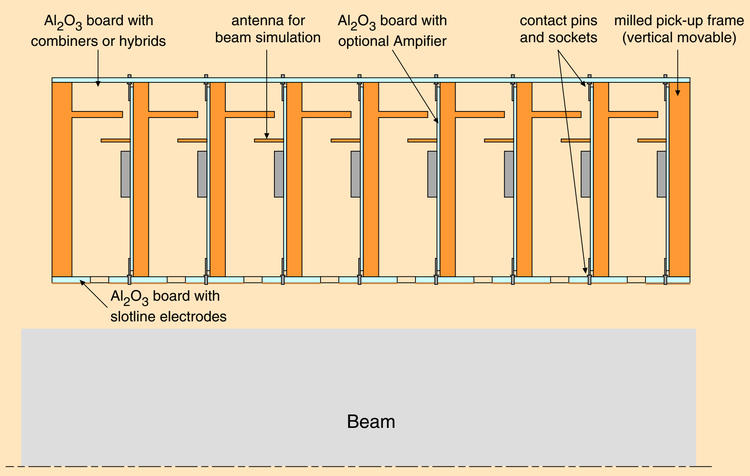
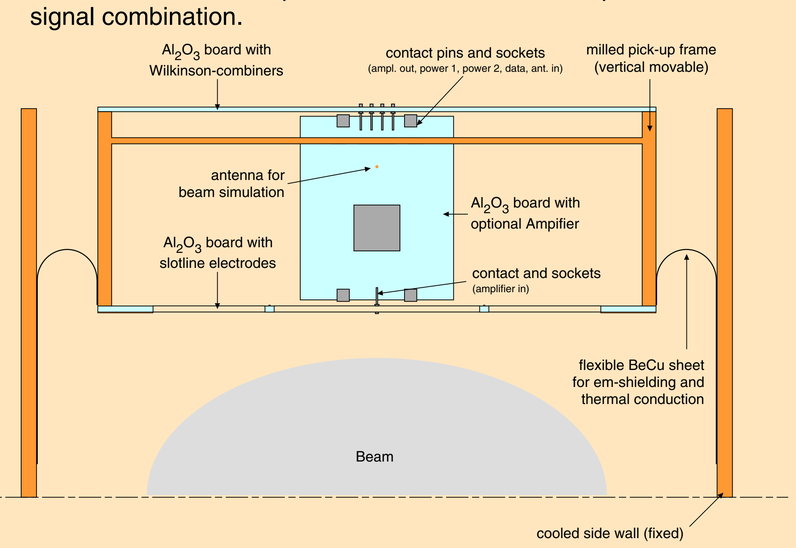
Pick-Up Module



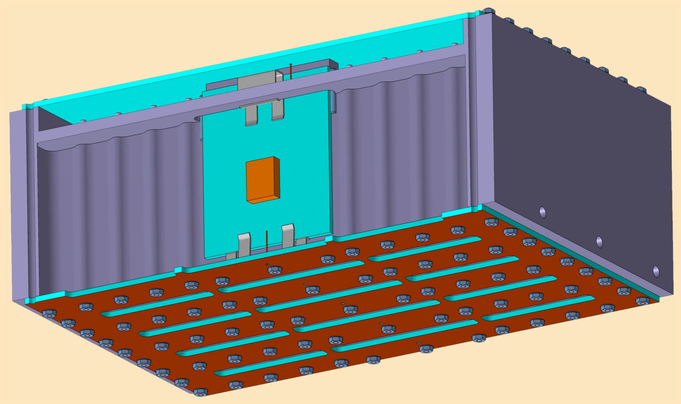




The main task of the collector ring (CR) of the FAIR project is stochastic cooling of rare isotope beams and antiprotons. The pick-ups must have a large bandwidth, a high S/N ratio and a large aperture. The electrodes consist of a slotline perpendicular to the beam and a microstrip circuit on the rear side of a planar Al_2O_3 substrate. The mirror currents induce traveling waves in both directions of the slotline. The two signals are coupled out to microstrip lines and are combined in a Wilkinson combiner.

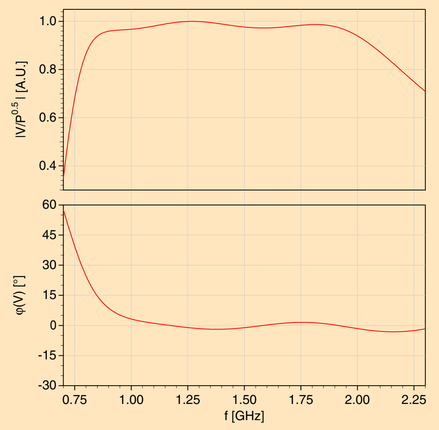
The left figure shows the layout of an eight slot pick-up board in original size. A pick-up tank will consist of two times eight modules. The modules will be cooled down to 30 K using cold heads and will be movable. The two figures below show a simplified design of a module in original size. The right figure shows a cut across the first module prototype.

Beside the PU board, the module also contains vertical connection boards. On these Al_2O_3 boards, a cryogenic low noise amplifier is foreseen. A small antenna can be used to test the module without beam. The board on top of the module contains the phase-correct signal combination.



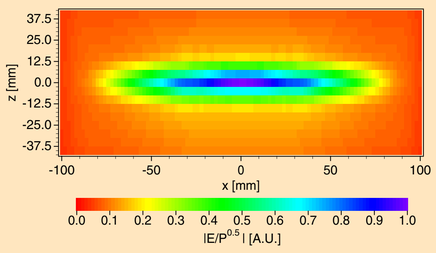
The layout of the pick-up board is the result of numerical field calcu-lations and the equivalent circuit based optimization shown in the box below. Compared to the unoptimized precursor, the position of the Al_2O_3 bridges over the slots and the dimensions of the microstrip lines have been modified. The equivalent circuit, including the first combiner and an additional higher impedance line has been optimized with respect to maximum voltage and flatness.

The right diagram is a result of the optimization. It shows the magnitude and phase of the voltage over the center of the slotline versus the fre-quency. A prototype of a module with this layout is under construction in order to compare the equivalent circuit with measurement results.

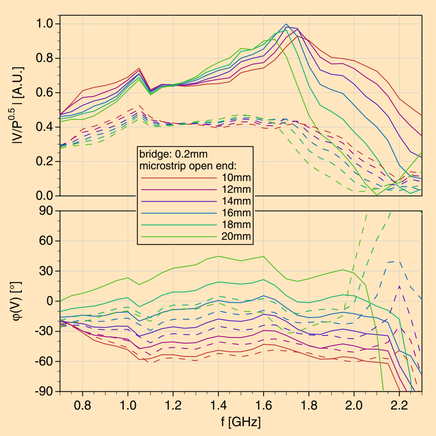


Field Measurement

To perform three-dimensio-nal field measurements, an computer controlled E-Field mapper has been built. A small dipole (8 mm) is used as a near field probe. The photo shows (left to right) the controlling PC, the network analyzer, the CNC-machine which has been abused to move the probe over the test object, and the stepper con-troller.

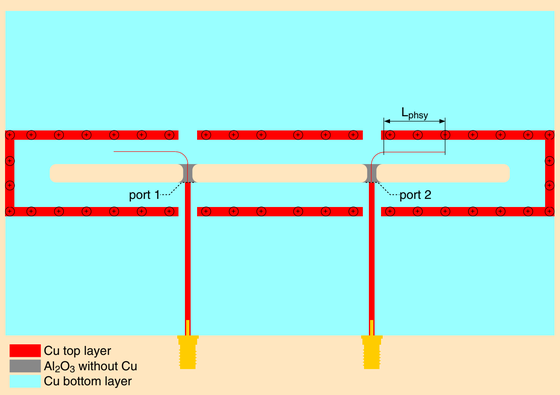


The single slot test pick-up for the equi-valent circuit based optimization (right box) with 0.2 mm bridge and 10 mm open end has been fed with a 1.5 GHz signal at both ports. The diagram shows the magnitude of the E-field in z-direc-tion, 5 mm above the surface. The sen-sitivity is relatively flat in the x-direction. The bridges are at ±30 mm and the the slot ends at ±75 mm. The next slots in a pick-up module would be at z=±25 mm.

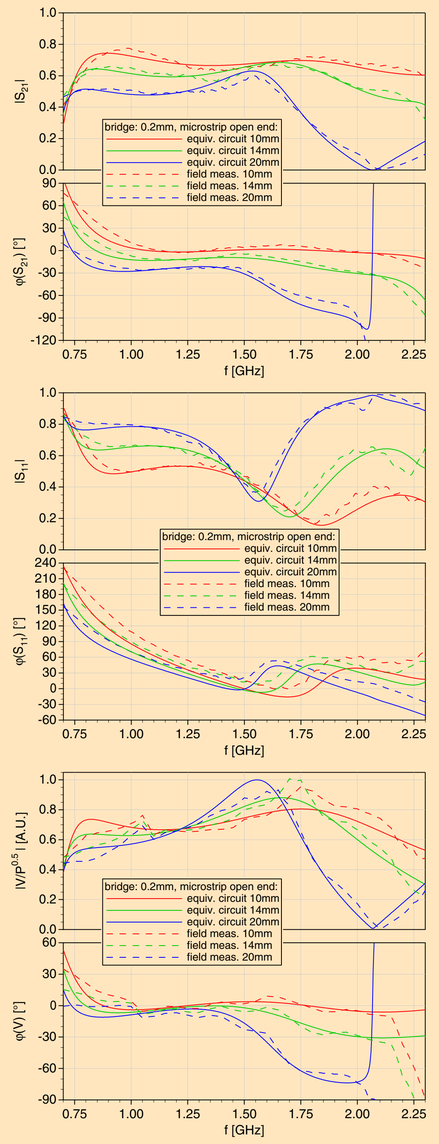


Suitable integration with β=0.97 over z gives the voltage over the particle trajectory. The second diagram shows measured voltages in dependence of the frequency for different lengths of the open end. The solid lines are the voltages at the center of the slot and the dashed ones at x=±30 mm. The peak at 1.1 GHz is an unwanted resonance of the measure-ment setup and will be avoided in the next measurements. The results of this measurements have been used for the optimization (right box).

Equivalent Circuit Based Optimization



To optimize the frequency res-ponse of the pick-up in detail, an equivalent circuit based app-roach has been chosen. To come close to a realistic beha-vior of the equivalent circuit, a simple test structure (drawing left) has been built and measured with the field mapper. The voltage, 5 mm above the slot and the S-para-meters between the two ports has been measured with six different leghths of the micro-strip open end times two different widths of the microstrip lines on the Al_2O_3-bridges. The circuit diagram on the left shows the equivalent circuit of the test structure. The green values are the fit parameters. The parame-ters for the slotline have been derived from a numerical field calculation of the slotline in the module using Microwave Studio. All other fit parameters have been derived from the field and S-parameter measurements.



The three diagrams on the right side show a comparison of the final equivalent circuit parameters with the measured data. All the measurement equipment has an impe-dance of 50 Ω, whereas the pick-up is a 100 Ω device. The interface is at the dashed lines (port 1 and 2) in the drawing above. The influence of this reflection, all cables and connectors as well as the frequency response of the near-field probe has been eliminated from the measurement data in the diagrams. The first diagram shows the transmission and the second one the reflection. The third diagram show the voltage above the center of the slot.
After the "calibration" of the equivalent circuit, it has been used to optimize the pick-up by vary the lengths of the slots and microstrips and the widths of the microstrips. The first result is the pick-up layout in the box above.