Design of an Electron Cloud Detector in a Quadrupole Magnet at CESRTA*

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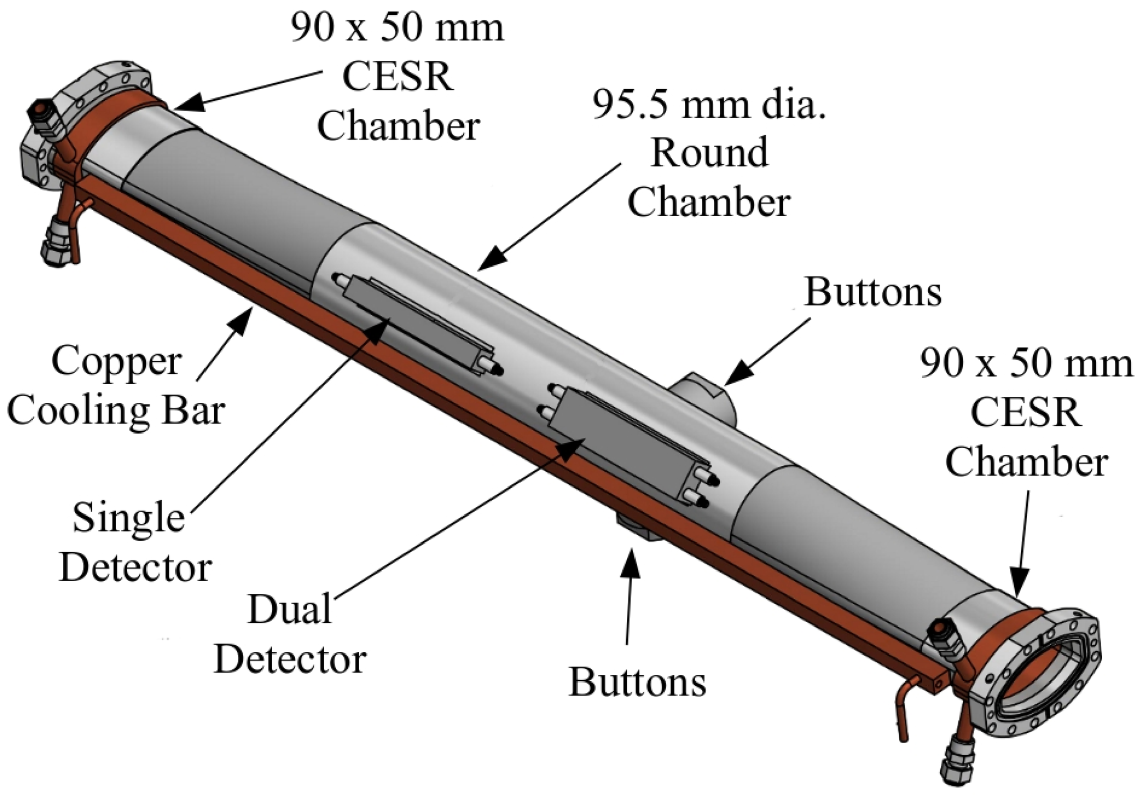
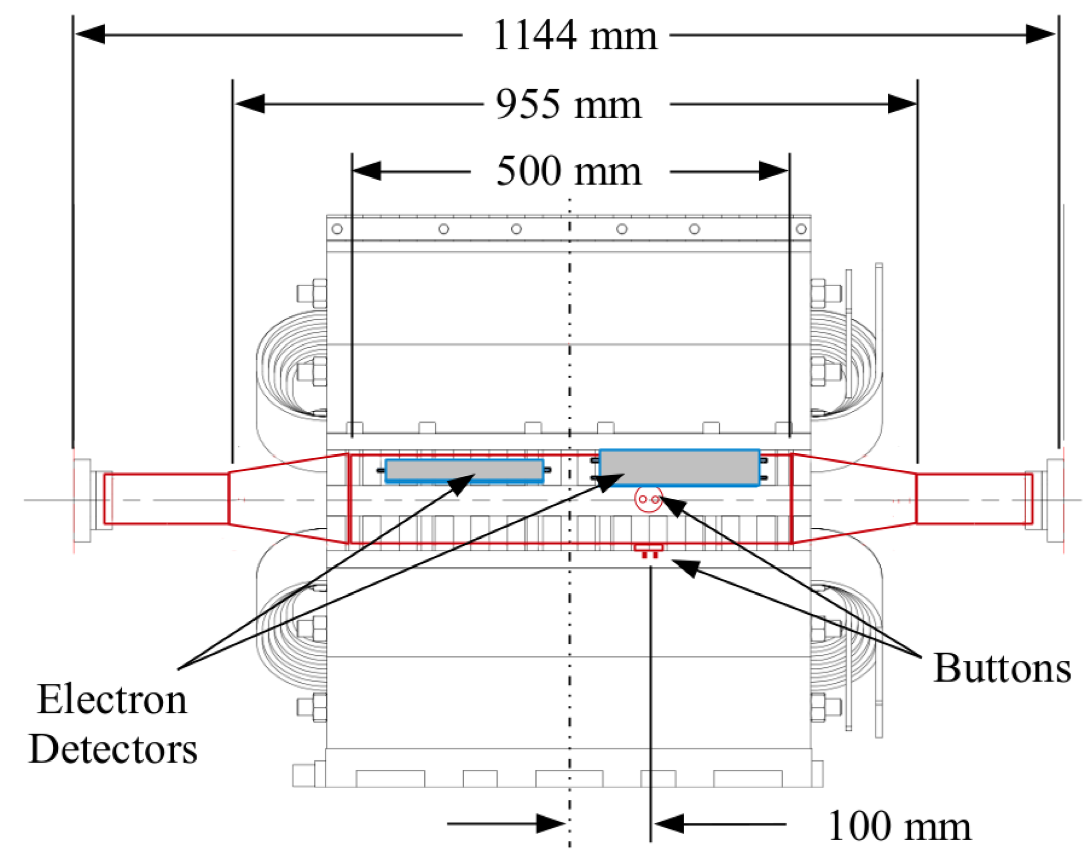


The new chamber supports two independent techniques for measuring electron cloud density: 1) electron detectors using striplines and 2) microwave measurements using beam-position-style button electrodes. The chamber transitions from round beam-pipe in the center to the quasi-rectangular standard CESR cross-section at either end.

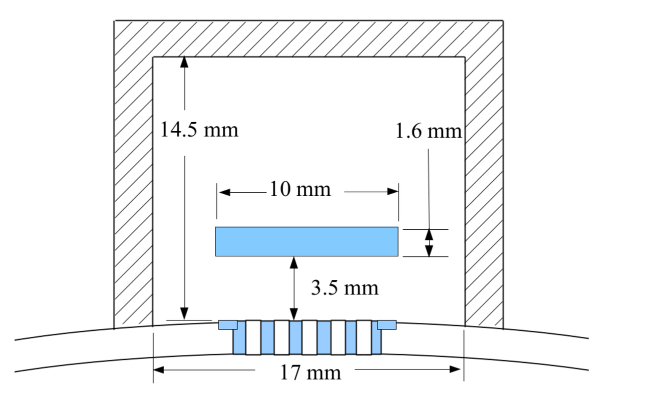
Abstract

We have designed a detector that measures the electron cloud density in a quadrupole magnet using two independent techniques. Stripline electrodes collect electrons which pass through holes in the beam-pipe wall. The array of small holes in the beam-pipe wall shields the striplines from the beam-induced electromagnetic pulse. Three striplines cover a roughly 0.45 radian azimuth near one of the pole tips. The beam-pipe chamber has also been designed so that microwave measurements of the electron cloud density can be performed. Beam position monitor style buttons have been included for excitation and reception of microwaves and the chamber has been designed so that the resonant microwaves are confined to be within the 56 cm length of the quadrupole. This paper provides some details of the design including CST Microwave Studio® time domain simulation of the stripline detectors and eigenmode simulation of the TE_{11} modes in the resonant chamber. The detector is installed in the Cornell Electron Storage Ring and is part of the test accelerator program for the study of electron cloud build-up using electron and positron beams from 2 to 5GeV.

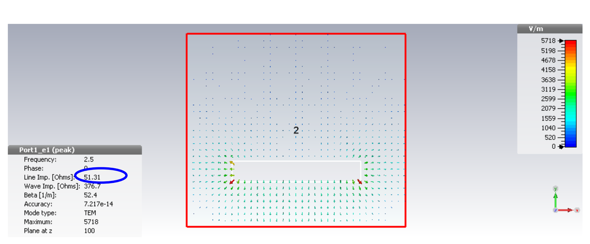


The detector chamber is positioned within a quadrupole magnet. Electron detectors are aligned to one of the pole faces. Beam-position-monitor-style buttons couple to either horizontal or vertical TE_{11} modes

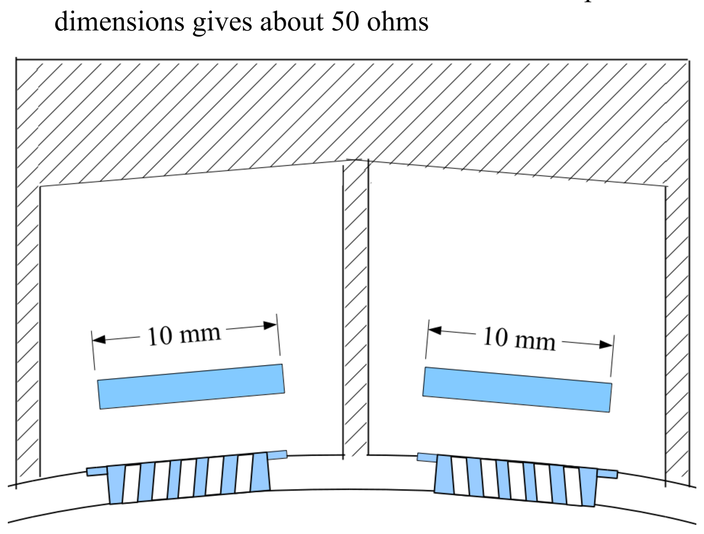
Stripline Design



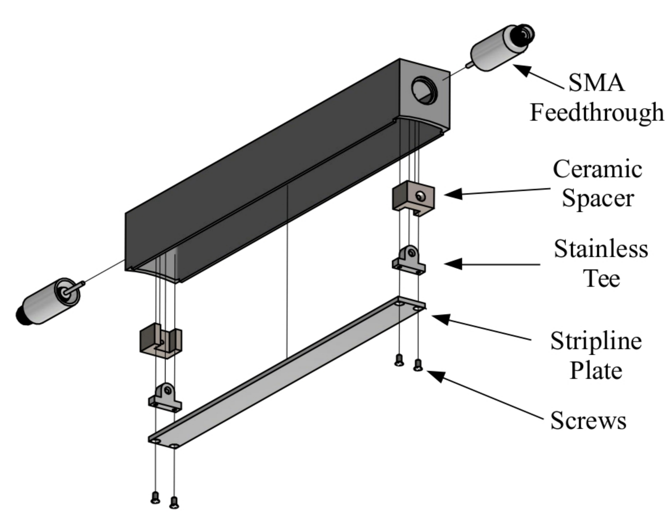
Holes in the beam-pipe wall allow electrons to be collected by the stripline while shielding it from the beam-induced electromagnetic pulse of the beam.



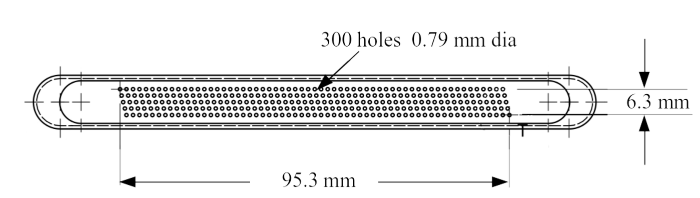
CST Microwave Studio® simulation of the stripline dimensions gives about 50 ohms



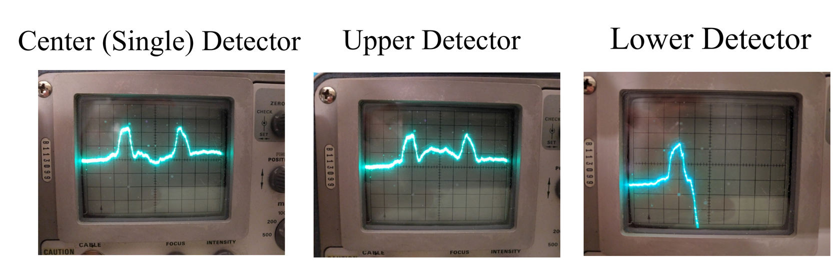
The dual stripline has holes that are angled to follow the magnetic field lines of the quadrupole field. Both the single and dual stripline assemblies are centered on a pole face, but are at different longitudinal positions.



An exploded view of the single stripline detector

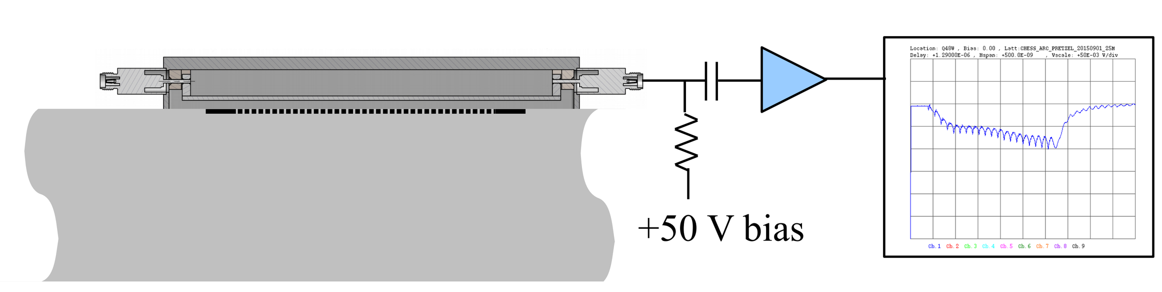


The array of holes is fabricated in stainless plates by electrical discharge machining (EDM). The plates are then welded into slots in the beam-pipe.

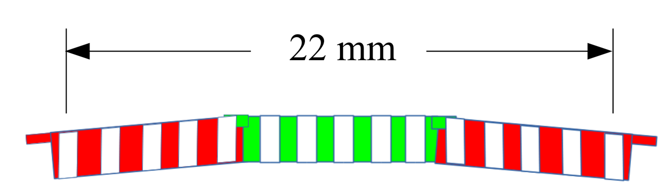


Time delay reflectometer (TDR) tests of the striplines after the final welds show an impedance close to 50 ohms for the center and upper detector, but the lower detector has a short at one end. The vertical scale is 50 mρ/div.

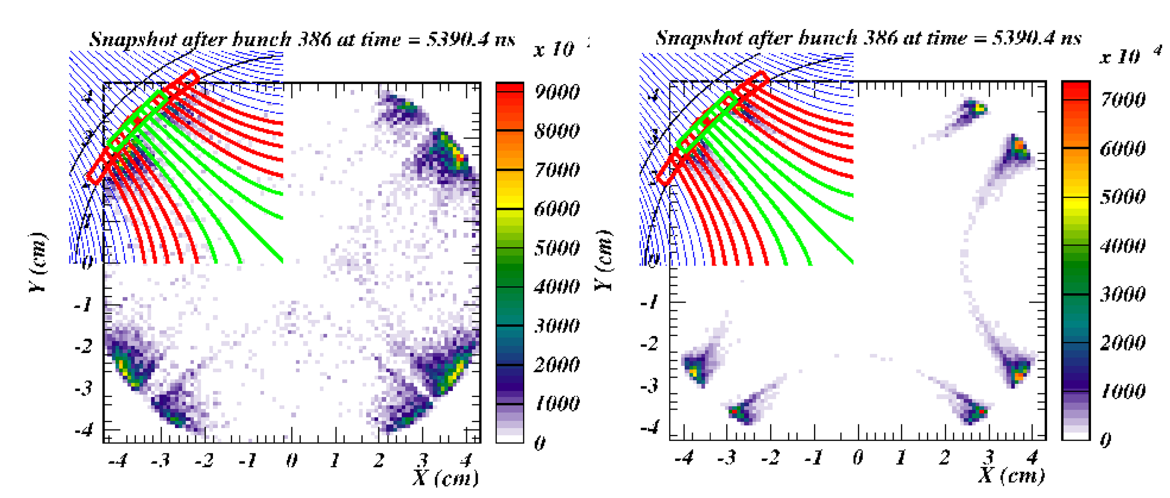
The Electron Detector



For data taking, the stripline signals are amplified and connected to an oscilloscope.

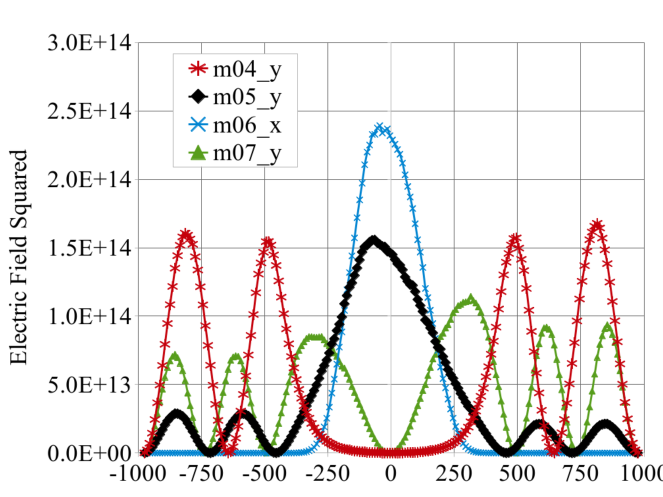


The combination of the single and dual striplines gives an effective detector width of 22 mm.

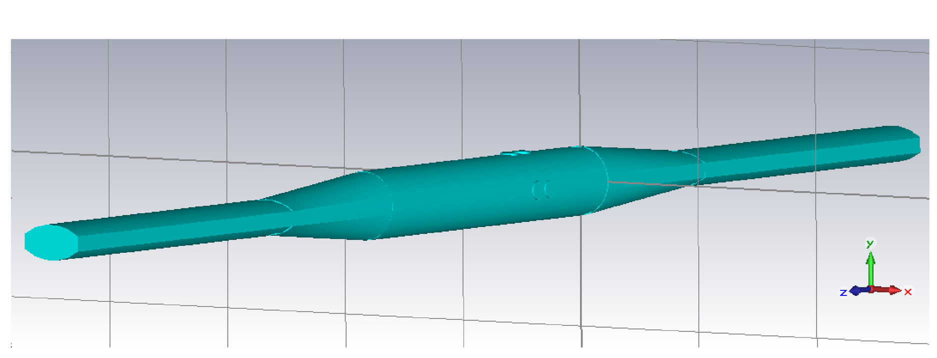


ECLOUD simulation of the EC density just after the passage of a 20-bunch train of 5.3 GeV positrons with 14 ns spacing shows an increase in the splitting of the cloud near the pole face as the bunch population is increased from 1.2×10^{11} (left) to 1.3×10^{11} particles/bunch (right). The green lines represent electron trajectories through the holes of the single stripline detector; red lines are the trajectories into the dual detector.

Microwave Design

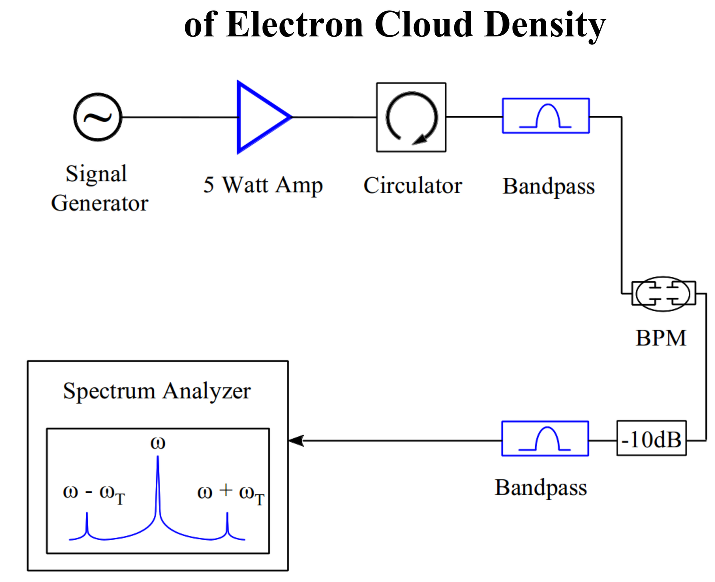


Simulation of a chamber with a **89 mm** dia. round center section showed that most TE_{11} resonances with vertical *E* extended out into the CESR beam-pipe, beyond the 560-mm-long quadrupole magnet.

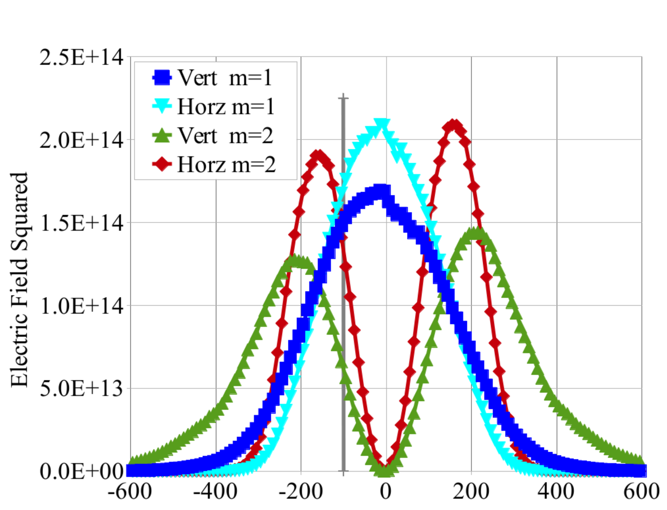


The round chamber with transitions to quasi-rectangular CESR beam-pipe was modeled in Autodesk Inventor®. The model was then imported to CST Microwave Studio® for simulation of the TE_{11} eigenmodes.

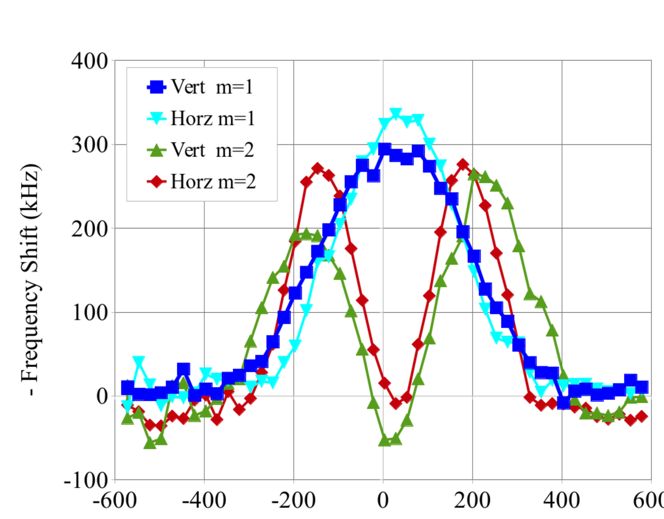
Resonant Microwave Measurement of Electron Cloud Density



A train of bunches in a storage ring will produce a periodic electron cloud (EC) density. If the beam-pipe is resonantly excited with microwaves, the resonant frequency will be modulated by the EC density. The magnitude of the EC density can then be measured through the resulting phase modulation sidebands in the resonant response. In the sketch above, ω is the drive frequency and ω_r the revolution frequency.



When the round chamber diameter was increased to **95.5 mm**, the lowest resonances were confined by the transitions to be mostly within the 560 mm length of the quadrupole magnet. This dimension was used in the final design.



In a bead pull measurement, the shift in resonant frequency is proportional to the square of the resonant electric field at the location of the bead. A bead pull measurement was performed on the fabricated **95.5mm** dia. chamber which confirmed the simulation result – that the lowest modes were mostly within the 560 mm length of the quadrupole magnet.

$$\frac{\Delta\omega}{\omega_0} \approx \frac{e^2}{2\varepsilon_0 m_e \omega_0^2} \frac{\int_V n_e E^2 dV}{\int_V E^2 dV} \qquad (1)$$

The frequency shift is given by Eq. 1 with n_e the EC density, ***E*** the resonant electric field and ***V*** the resonant volume. To measure only the EC density in the quadrupole field, the microwaves must be contained in the section of beam-pipe that is within the quadrupole.

*This work is supported by the US National Science Foundation PHY-0734867, PHY-1002467 and the US Department of Energy DE-FC02-08ER41538, DE-SC0006505.
CLASSE facilities are operated by Cornell and the Cornell High Energy Synchrotron Source (CHESS) with major support from the National Science Foundation.
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