Reentrant Cavity Resonator as a Beam Current Monitor for a Medical Cyclotron Facility at PSI

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TM$_{010}$ mode Reentrant Cavity Resonator

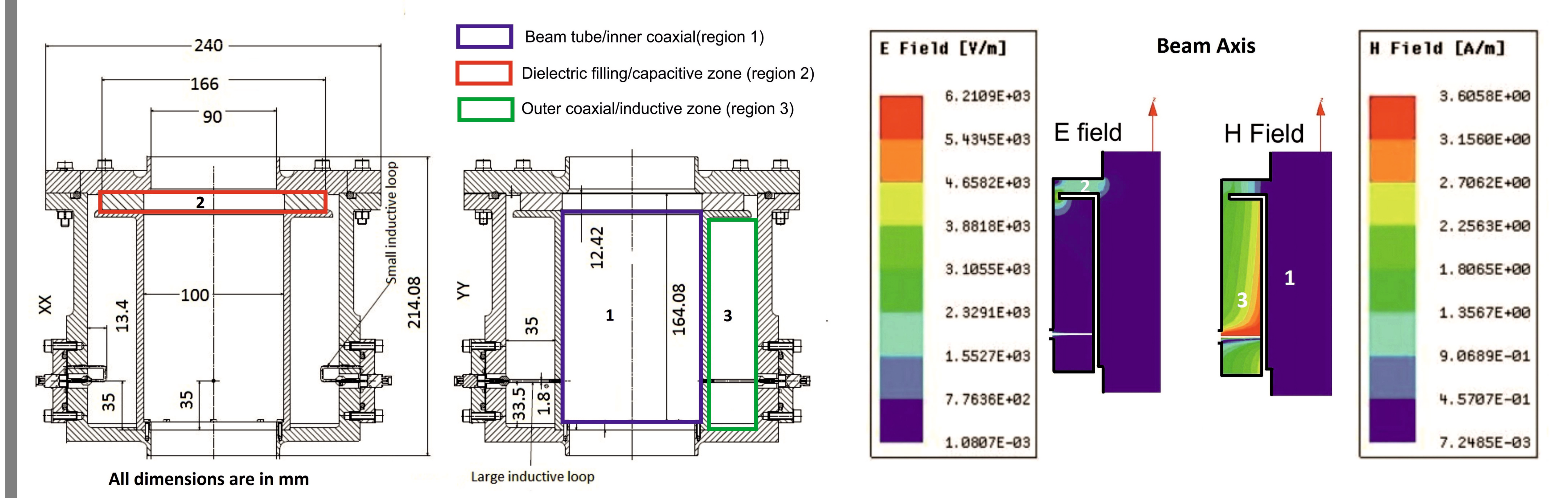

Fig. 1:Dielectric-filled Reentrant Cavity Resonator to measure beam current. Induced E and H fields of the resonator localised in regions 2 and 3 due to the construction as an LC resonator.

Measure beam currents in the range (0.1-10) nA for energies 238-70 MeV

TM$_{010}$ mode matched to 2nd harmonic of 72.85 MHz i.e. 145.7 MHz

Dielectric: Macor, Cavity: Aluminum

Functioning as an LC resonator [1]

Optimize shunt impedance (R/Q) by reentrant design

Noise reduction due to narrowband operation and amplification due to harmonic selection

Position dependence: 0.03%/mm upto 60% of radius

Beamline installation at PROSCAN, PSI and Measurement Chain

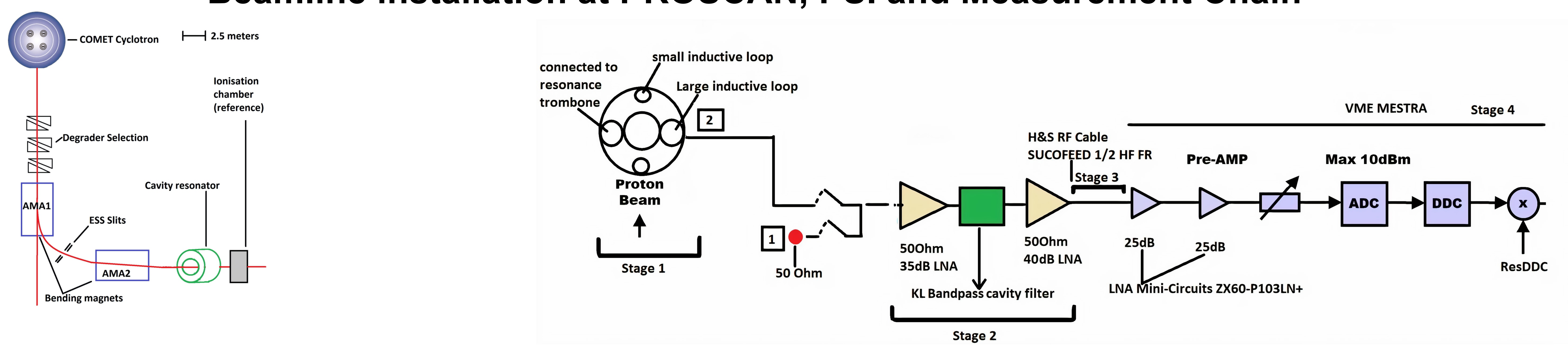

Fig. 2: BCM located at sixteen meters from the degrader exit. Measurement chain representation from the resonator till the electronic cubicle. Two low-noise power amplifiers with gains of 35 dB and 40 dB, a passband filter with a center frequency of 145.0 MHz (3 dB bandwidth = 8.24 MHz), Sucofeed RF cables, VME MESTRA [2] are the measurement chain elements. The small inductive loops are terminated with 50 Ω. Scenario 1 represents 50Ω on the input of the measurement chain represents Stage 2-4. Scenario 2 represents the resonator connected to the measurement chain represents Stage 1-4.

The PROSCAN facility is temperature controlled (28.5±0.5 °C)

Beam energies in the range 238-70 MeV is achieved by means of a carbon wedge degrader

The degradation process of the beam results in growth of emittance and energy spread

The beam is shaped by a set of collimators and an Energy Selection System (ESS) that helps in reducing the energy spread.

The measurement with no resonator and a 50 Ω termination on the measurement cable: scenario 1

The measurement offset, which is the no beam resonator response: scenario 2

For 1 nA beam current, the signal power is approximately -21.0 dBm

The Harmonic amplitude factor normalised to average beam current is approximated by a Sinc function

Resonator sensitivity as a function of energy

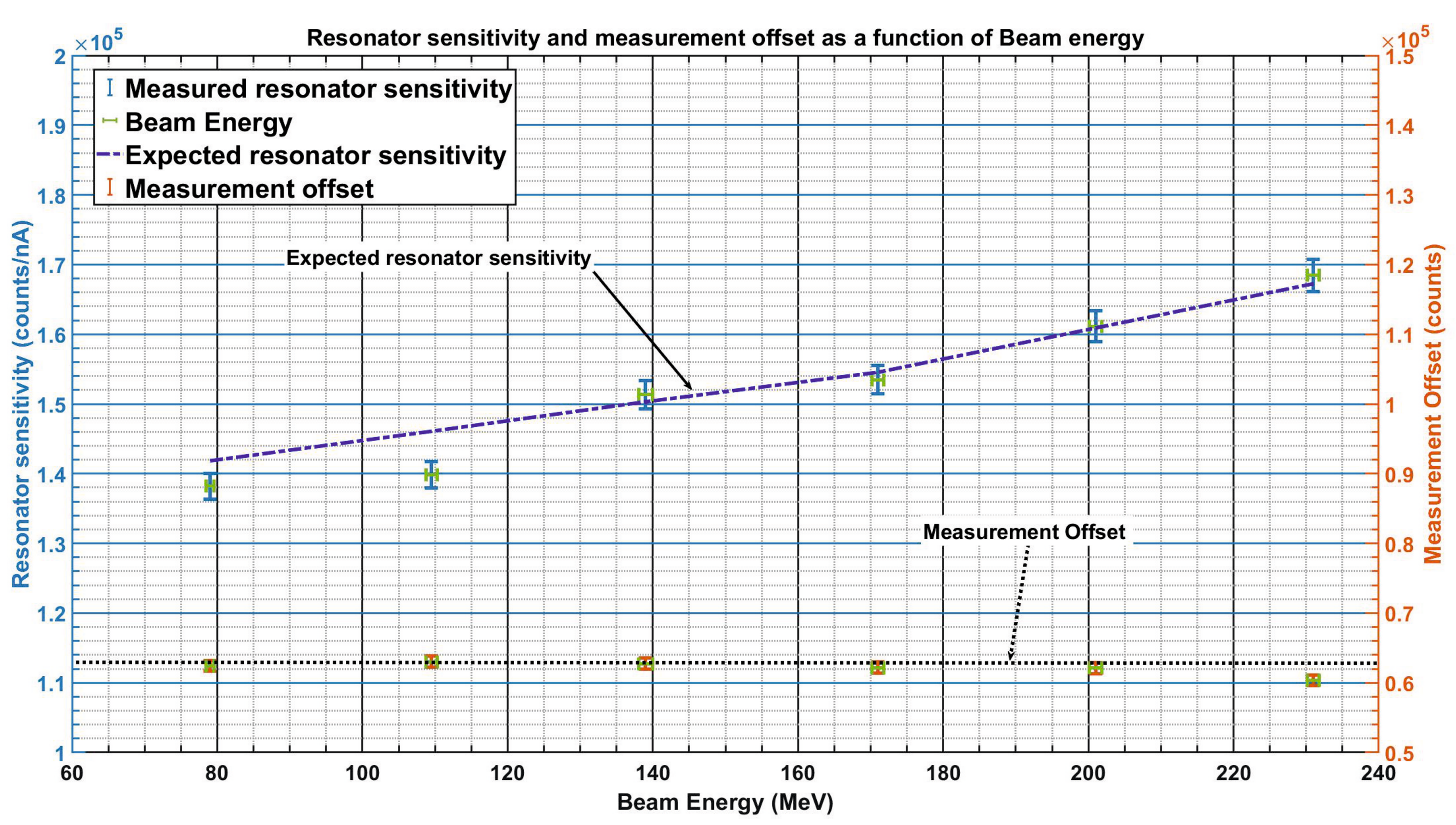

Fig. 4: Resonator sensitivity and measurement offset dependence on beam energy. The resonator sensivitiy decreases with energy due to energy dependent beam current. The data points are represented with one σ deviation. Marked as dotted lines are the trend of the expected resonator sensitivity (blue) and the measurement offset agreement with no-beam resonator response (black).

The effect of energy spread increase leads to an energy dependent decrease in bunch amplitude and an increase in bunch length down the beamline in the beam current [3]

Summary

An absolute measure of the beam current and momentum spread is necessary to have good agreement of the sensitivity within one σ

The measured sensitivity is valid only for the present location of the resonator i.e. 16 meters from the degrader

Beam currents down to 0.15 nA have been measured with 0.05 nA resolution

Performance improvements of this resonator are possible with design of the resonator as a single port or with improved electrical matching

High beam current irradiation as in FLASH etc. a cavity resonator is advantageous and could potentially replace ionisation chambers

References

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2. Johansen E. VME MESTRA Rev C Specification. 2020. https://doi.org/10.5281/zenodo.3887550.

3. Rizzoglio et al., Evolution of a beam dynamics model for the tranport line in a proton therapy facility, doi: 10.1103/PhysRevAccelBeams.20.124702

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