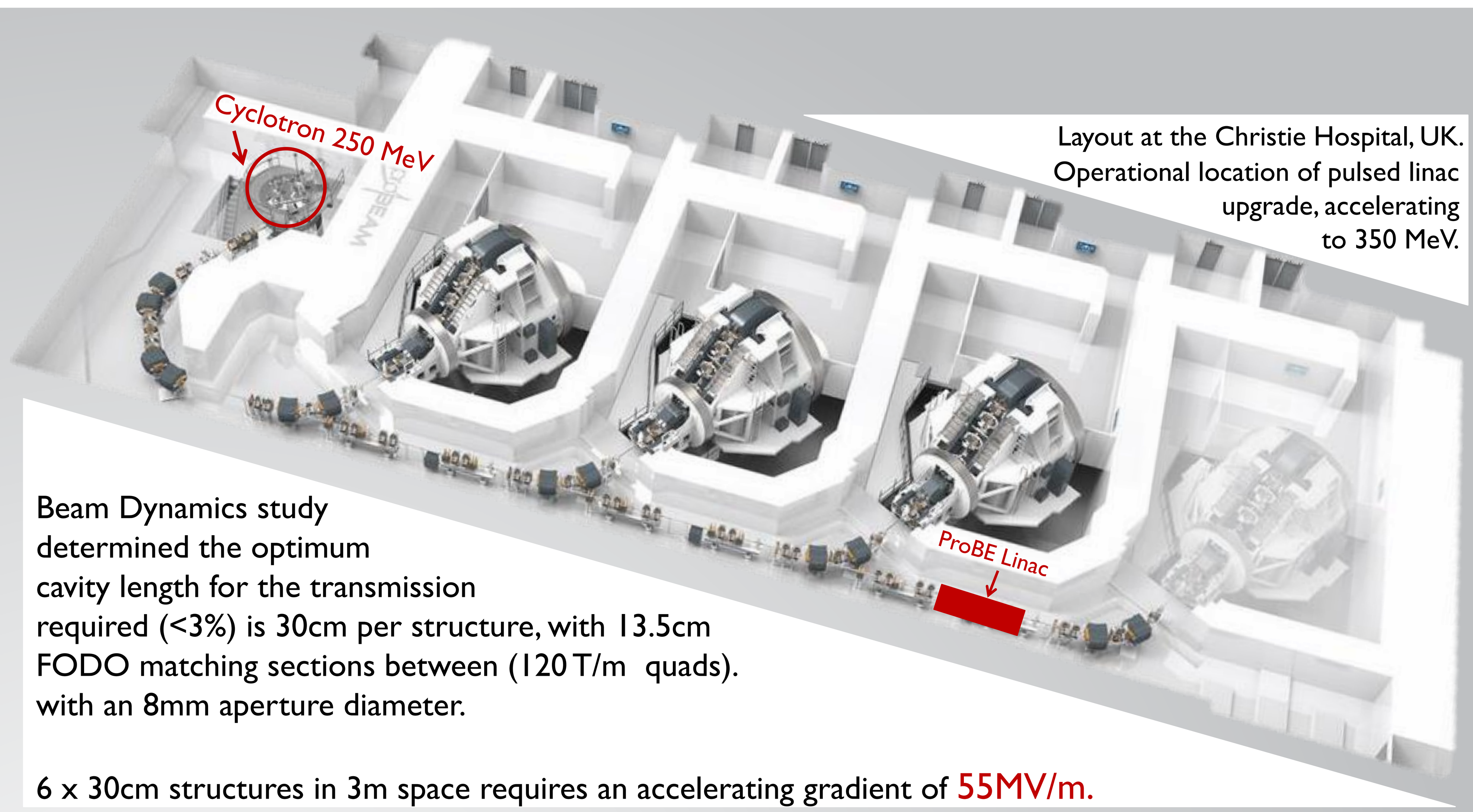
ProBE: Proton Booting Extension for Imaging and Therapy

S. Pitman[1♀], R. Apsimon[1], G. Burt[1], Lancaster University, Lancaster UK
A. Green, H. Owen[1], University of Manchester, Manchester, UK
A. Grudiev, A. Solodko, W. Wuensch, CERN, Geneva, Switzerland
[1]also at The Cockcroft Institute, Daresbury, UK

Abstract

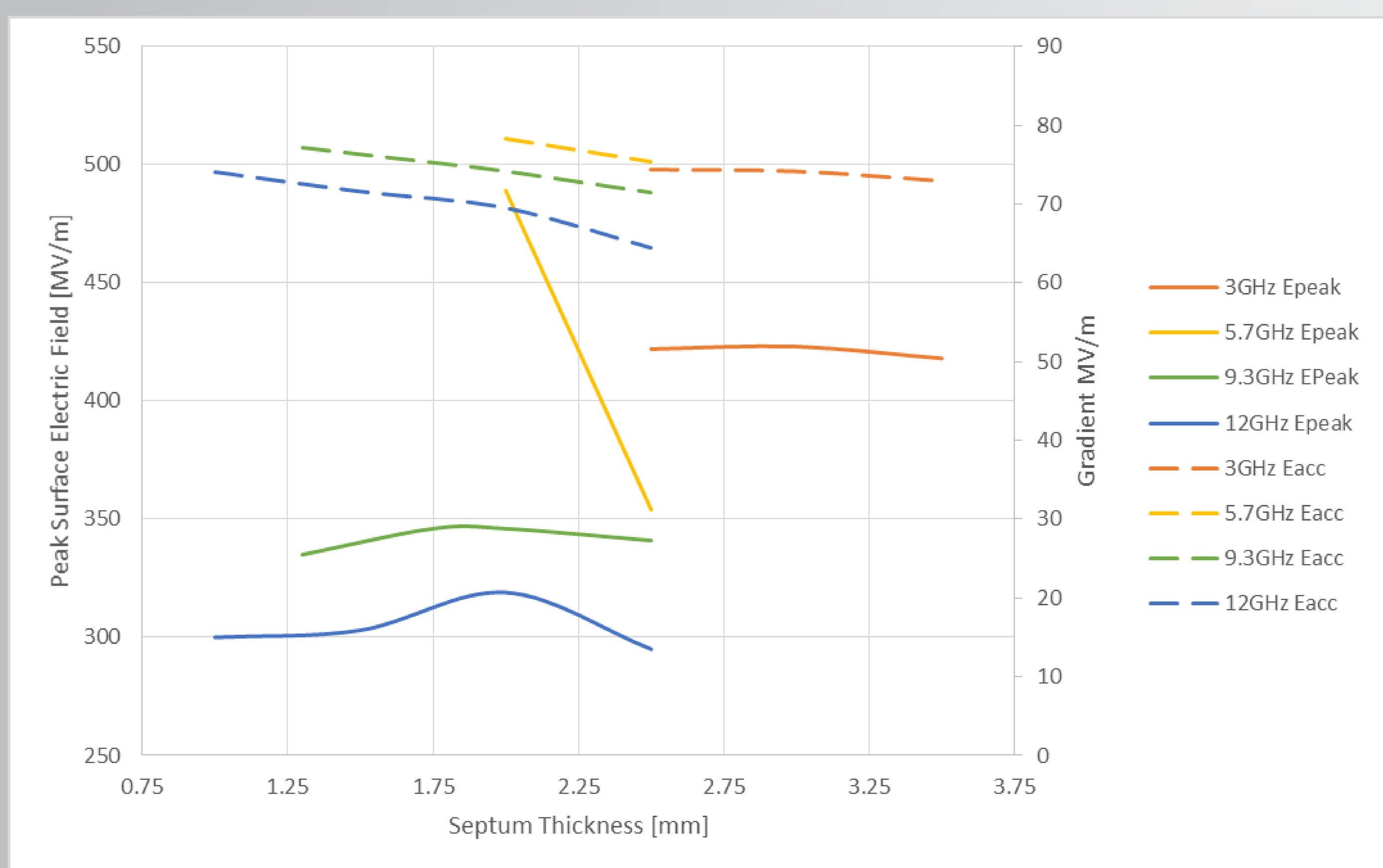
Proton beam therapy has been shown to be a promising alternative to traditional radiotherapy, especially for paediatric malignancies and radio-resistant tumours. Allowing a highly precise tumour irradiation, which is currently limited by range verification. Several imaging modalities can be utilised for treatment planning, but typically X-ray CT is used. CT scans require conversion from Hounsfield units to estimate the proton stopping power (PSP) of the tissue being treated, and this produces inaccuracy. Proton CT (pCT) measures PSP and is thought to allow an improvement of the treatment accuracy. The Christie Hospital will use a 250 MeV cyclotron for proton therapy, in this paper a pulsed linac upgrade is proposed, to provide 350 MeV protons for pCT within the facility. Space contraints require a compact, high gradient (HG) solution that is reliable and affordable.



Layout at the Christie Hospital, UK. Operational location of pulsed linac upgrade, accelerating to 350 MeV.

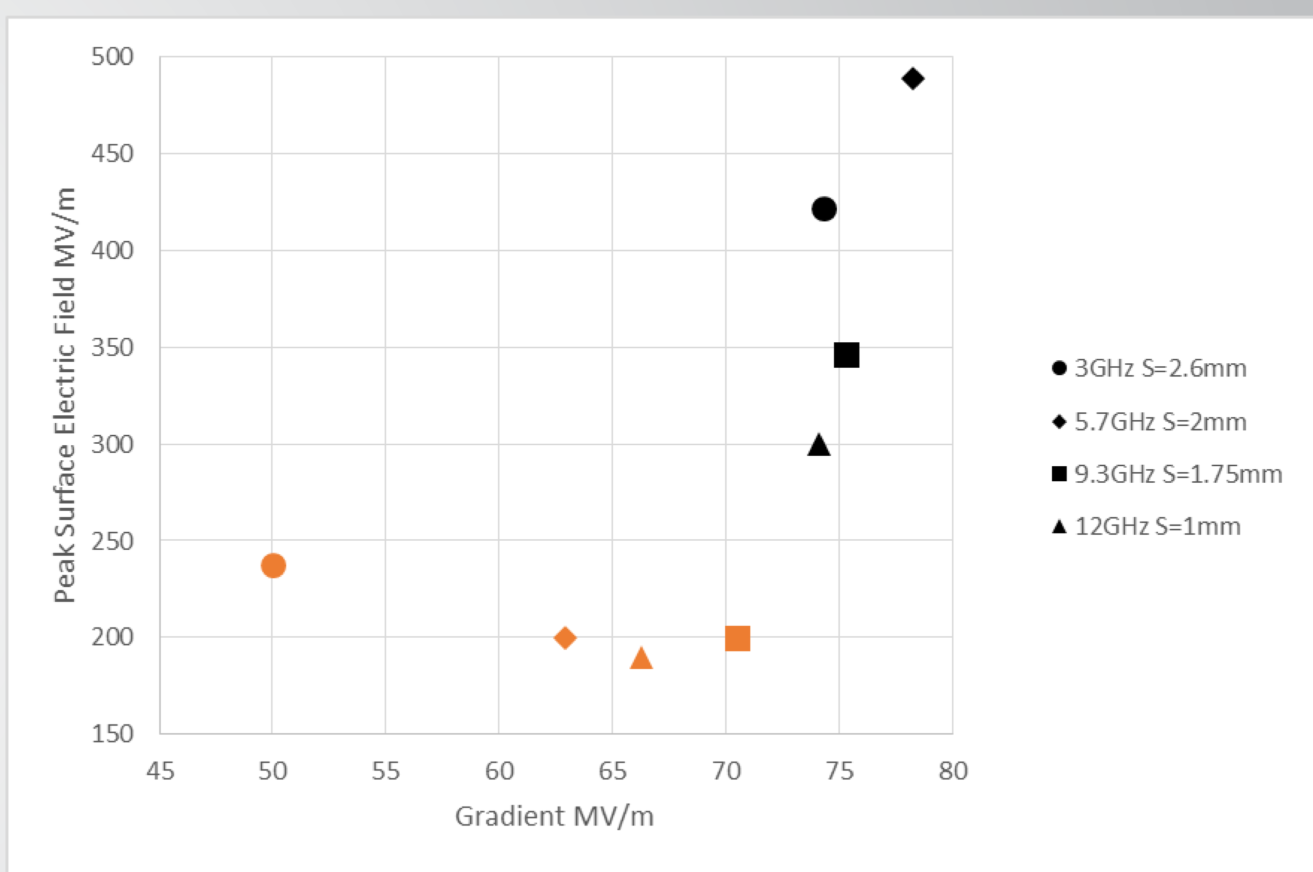
Beam Dynamics study determined the optimum cavity length for the transmission required (<3%) is 30cm per structure, with 13.5cm FODO matching sections between (120 T/m quads). with an 8mm aperture diameter.

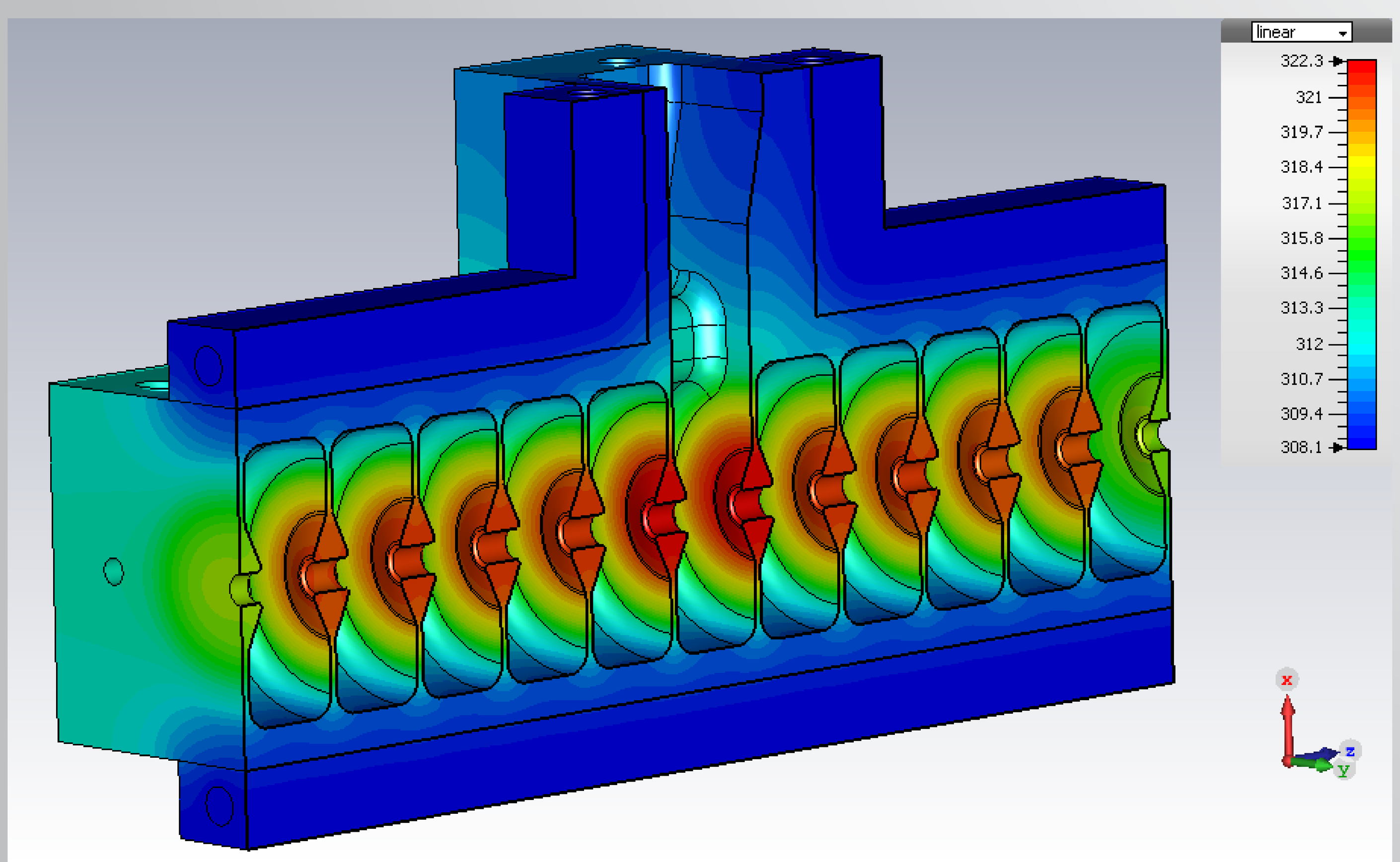
6 x 30cm structures in 3m space requires an accelerating gradient of 55MV/m.



Single cell re-entrant cavities with 3.5mm aperture diameters, were simulated without coupling to investigate frequencies, and iris diameters and thicknesses.

Left: Maximum gradient limited by shunt impedance and Sc alone results in very high peak surface electric field.
Right: Black – Max gradient fields limited by Sc. Orange: Max gradient fields limited by peak surface electric field.





Above: Temperature gradient of 14K between the iris and the cooling water. Average power had to be limited to 2kW to keep the operational detuning below 1 MHz.

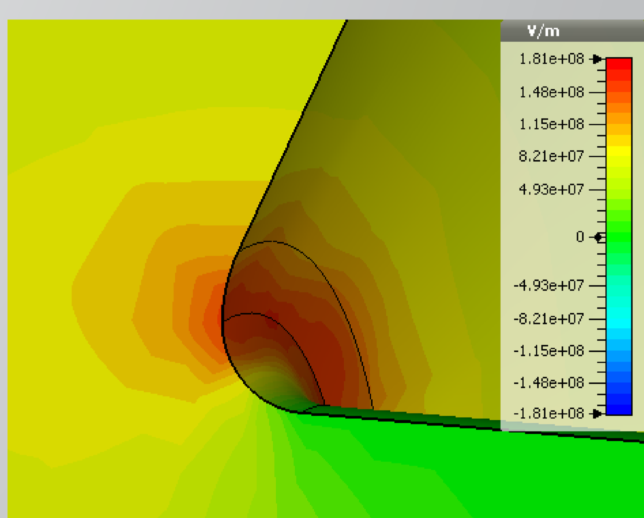
Below: Structure manufactured in disks, cut so as to keep septum intact.

In recent years the modified pointing vector (Sc) has been used a limit to peak fields for high gradient operation [1]. Initially a maximum value of 4 W/m^2 was chosen for optimisation.

High gradient tests performed on S & C-Band cavities [2,3] have suggested a higher peak surface electric field than the traditional Kilpatrick limit can be reached *within* the Sc constraint.

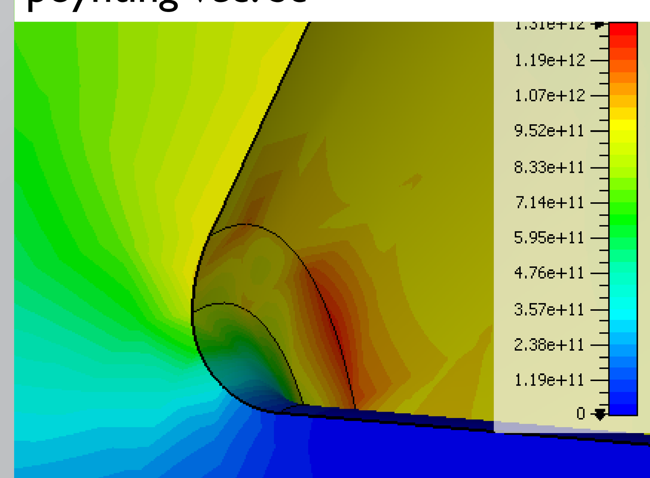
Cavities were re-optimised with a limit of 200 MV/m using the scaling constants found by Alberto Degiovanni [4], to give a maximum breakdown rate of 10^{-6} with a 5μs 3 GHz pulse. The final side coupled standing wave structure reached 54MV/m in simulation.

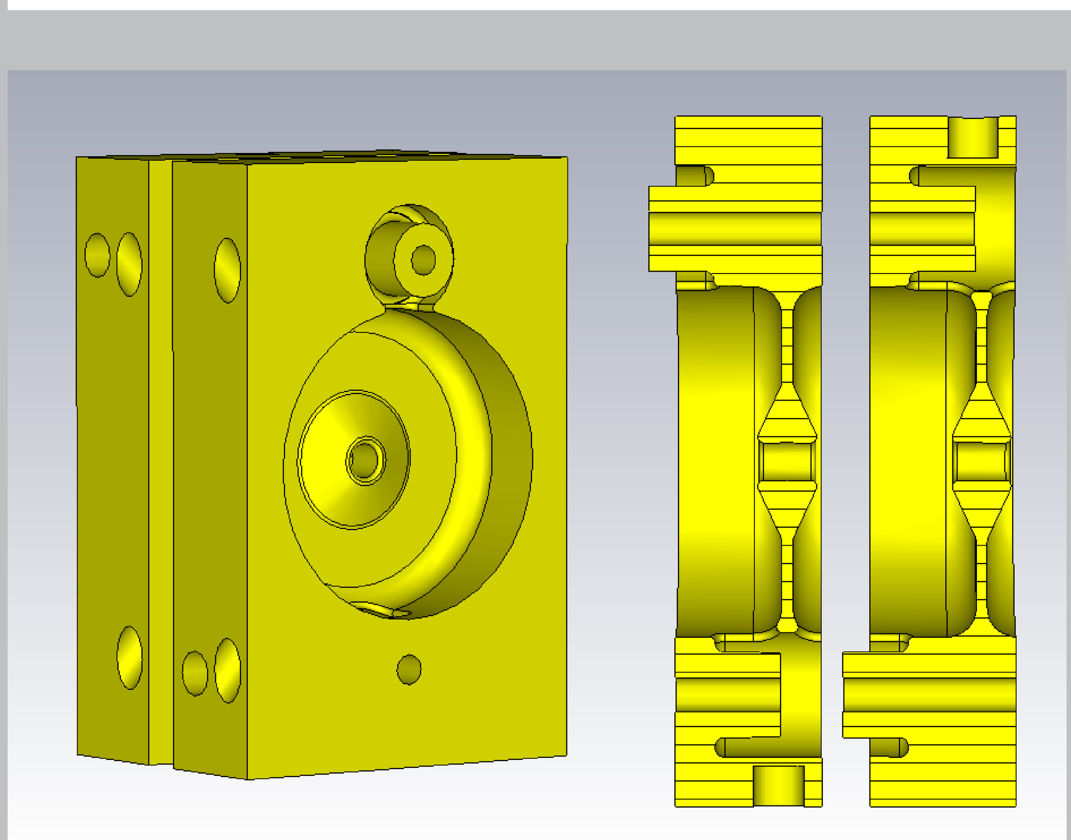
A prototype cavity will be tested at CERN, experimentally verifying the gradient for the full 6 structure linac at the Christie, and also improving understanding of breakdown phenomena and how it relates to peak fields at S-band.



Above: Maximum surface electric field. Epeak

Below: Maximum modified poynting vec. Sc





Acknowlegement

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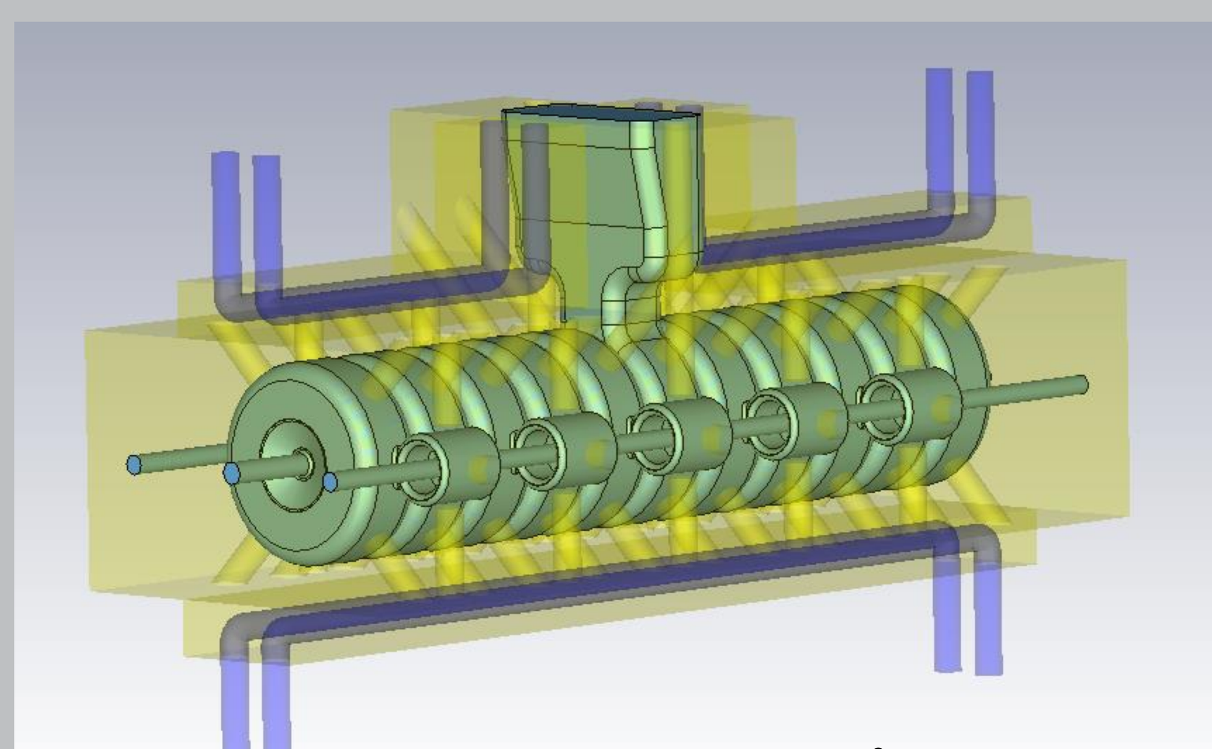

♀ Sam.Pitman@cern.ch