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ACCELERATOR DEPARTMENT
Informal Report

DEFLECTING CAVITIES WITH LARGE APERTURES

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Abstract

Among the dimensions determining the properties of a deflecting cavity the iris diameter 2a plays an outstanding role. In this note the pros and cons for apertures larger than presently used are discussed.

I. Introduction

Present rf particle separators[1-3] use iris-loaded structures with an iris diameter 2a of about 40 mm at S-band. This means that the deflector is operated near the maximum negative group velocity, v_g/c being of the order of -0.03. Figure 1 shows the group velocity as a function of iris diameter. It can be seen that there would be a range of iris diameters above 2a = 58 mm which would allow probably interesting operating points. Several authors[4,5] pointed out that by optimizing a structure with regard to particle fluxes and rf power consumption, larger iris diameters would be preferred. In this note we collect the arguments about the choice of iris diameter with regard to the mechanical, electrical, and deflecting properties of the deflector.

II. Mechanical Considerations

If one considers a deflector which would be usable in a separator for high particle energies, one surely would choose as high a frequency as possible, because of the rapidly growing intercavity distance. The opinions differ in how far one should go in increasing the frequency, but all experts agree that 9 GHz, or X-band, would be an upper limit, because at this frequency the cavity dimensions become very tiny. For instance, an iris diameter of about 40 mm, presently used at S-band,[6] would be scaled to 13 mm. A larger iris diameter is desirable, because it would facilitate the alignment of two cavities, possibly a kilometer apart, and improve the pumping speed. A large iris hole diameter would also allow to remachine the electron beam welds at the outer circumference, which might result in better Q-values and peak fields. Finally, chemical treatments would be facilitated, because the cavity would be filled more quickly with fluids, and electrodes for electropolishing and anodizing could be inserted more easily. So, from the geometrical point of view a larger iris hole than presently used would be highly desirable for an X-band deflector, but would also show many advantages for S-band.

III. Electrical Considerations

It is well known that the shunt impedance decreases and the peak field ratio H_p/E_o increases with increasing iris diameter (Fig. 2).* On the other hand, due to the high group velocity at an iris diameter of about 60 mm, the stability against fabrication tolerances would be improved. Reference 8 shows that tolerances are an important problem, at X-band even more than at S-band. So one has to find a compromise between R and H_p/E_o on the one hand and v_g on the other. To understand what the decrease of R really means, we assume now, that in all cases the magnetic breakdown occurs at the same value $H_p = 400$ G. In Figs. 3 and 4 two deflectors are shown: first a cavity of 3 m length is shown whose deflection falls and whose power consumption goes through a minimum at a = 55 mm. The second case is a cavity, which has for all iris diameters the same deflection as the one shown before at 2a = 40 mm. To achieve this, the power rises to about 40 W, which is surely no serious problem, but the length for a large-hole deflector has then to be about 5 m.

Increasing the length means not only increased costs for cavity and cryostats, but also an increased number of joints with resulting joint currents as demonstrated in Ref. 8. So one must state, that one has either to allow for a reduction in deflecting angle or build a considerably longer cavity, when the advantages of large iris holes are to be used. One problem, which often was thought prohibiting large iris openings, has turned out to be of no importance: Garault[9] shows clearly that for the geometries considered and in the frequency range of the deflecting passband no other modes than the wanted HEM_{11} deflecting mode are possible.

IV. Particle Flux as a Function of Iris Diameter

At very high deflecting fields, one would be limited in the vertical plane by the aperture. We cannot expect that deflecting fields above 5 MeV/m will be reached, so in the deflecting plane the acceptance will be given by the deflection $E_o \cdot \ell$, and in the horizontal plane by the aperture 2a. So one can use as a simplified guide (because finite target size and amplification have not been included), that the number of particles N will be proportional to[10]

*All data about deflector properties are taken from Ref. 7.

$$N \sim \frac{E_o \cdot \ell}{p} \cdot \frac{2a}{\ell} = \frac{E_o}{p} \cdot 2a \quad .$$

This product is zero for 2a = 0 and at large values of 2a when R has dropped to zero. The maximum in between is shown in Fig. 5. It shows that from the standpoint of particle flux it is not necessary to increase the iris hole. On the other hand the number of particles is not severely reduced, when one uses large holes.

Conclusion

Large iris holes are mostly recommended by mechanical reasons. The resulting increase in power consumption is tolerable. A compromise is necessary between deflection angle and cavity length. The particle flux is not affected by the larger iris diameter.

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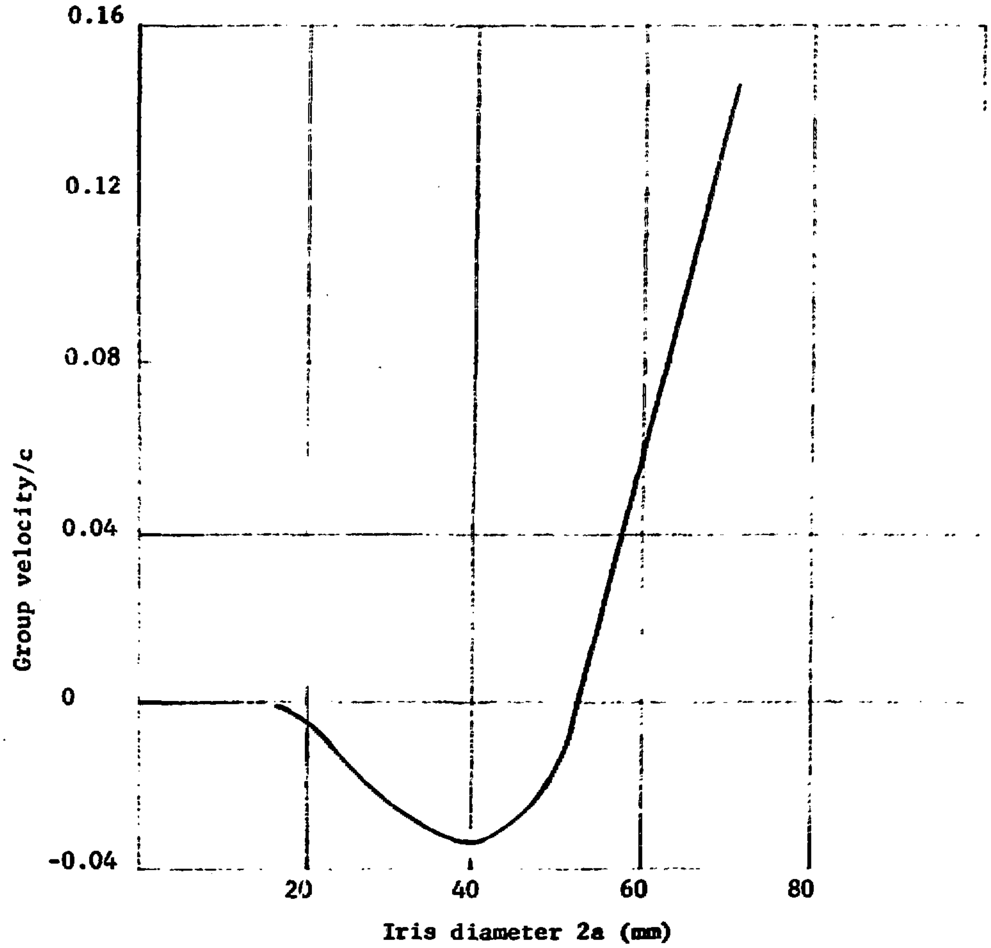

Fig. 1. Group velocity/c as function of iris diameter ($\pi/2$ mode, iris thickness t = 10 mm, S-band).

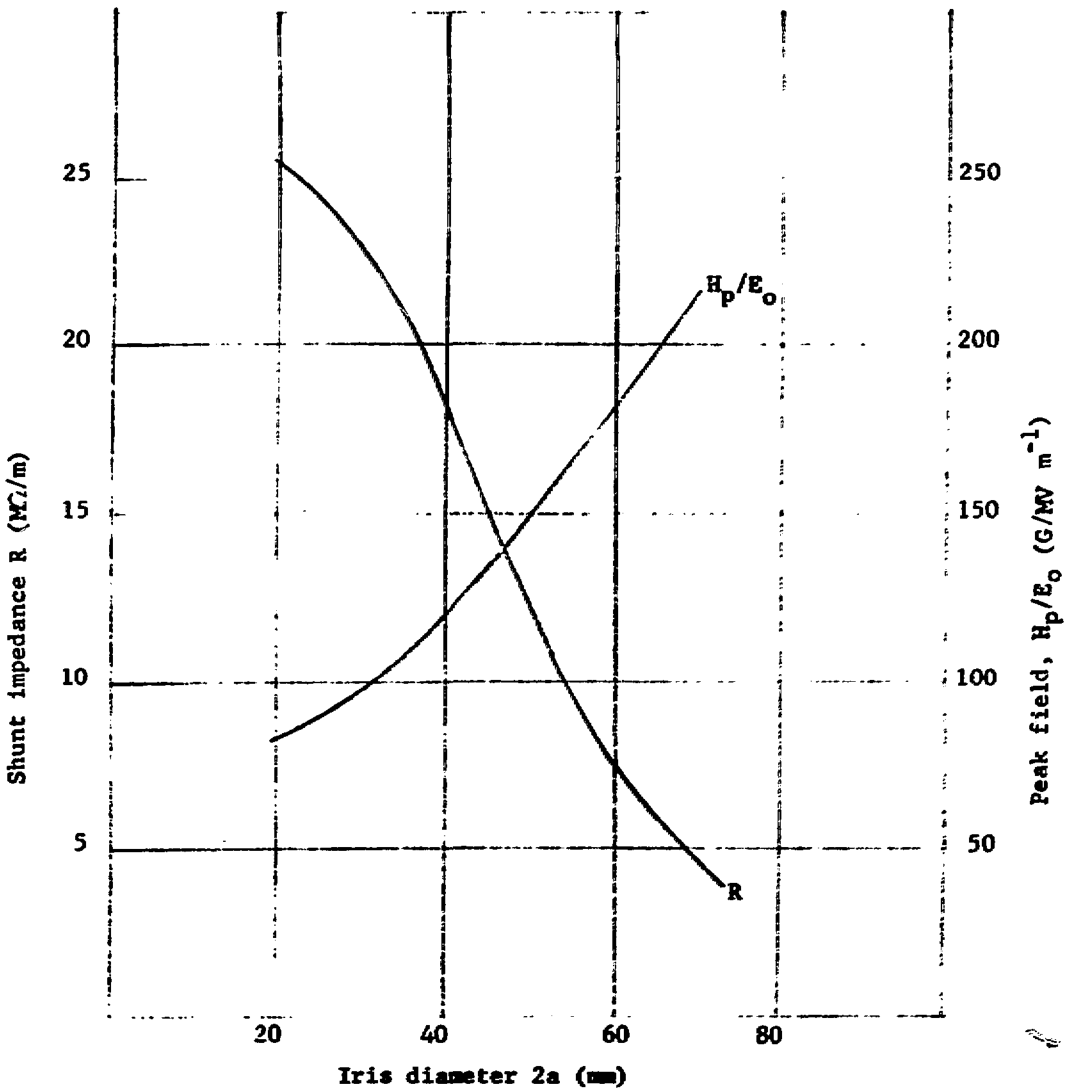

Fig. 2. Shunt impedance R and H_p/E_o as function of iris diameter (π mode, t = 20 mm, S-band).

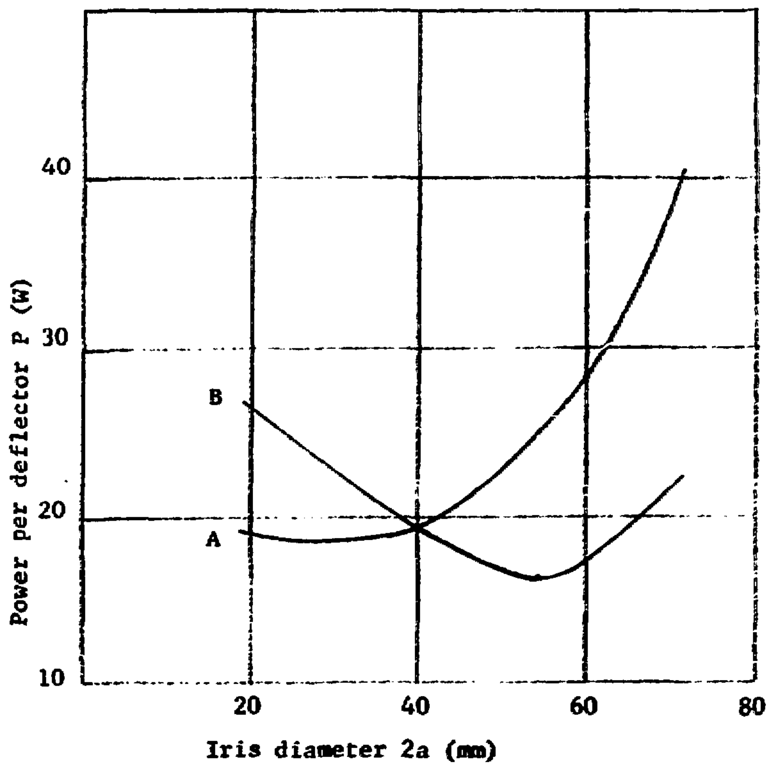

Fig. 3. Rf power per deflector.
A: constant deflection = 10.2 MeV/c ($H_p \equiv 400$ G)
B: constant length, ℓ = 3 m ($H_p \equiv 400$ G)

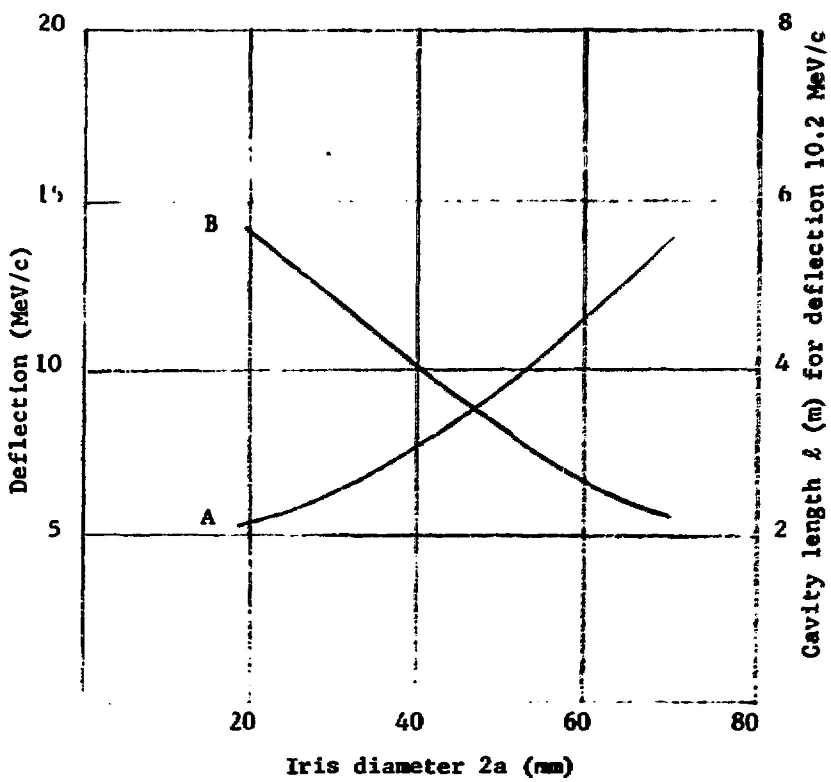

Fig. 4. Deflection as a function of iris diameter.
A: length of a cavity which deflects 10.2 MeV/c
B: deflection in a 3 m cavity

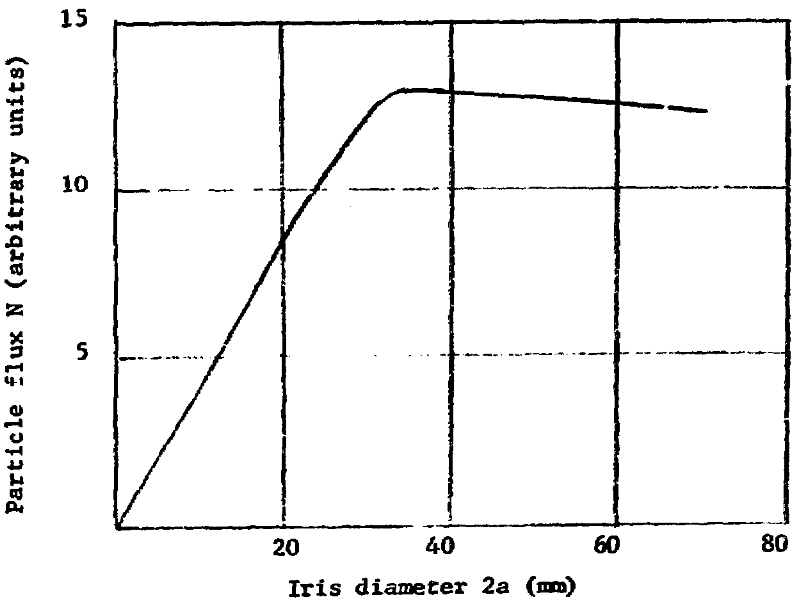

Fig. 5. Particle flux as function of iris diameter.