HOLEBC WITH CLASSICAL OPTICS

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One of the main limitations in the use of lenses to make images of the bubbles of tracks is the relation between resolution and depth of field (fig. 1)

$$R = 0.62\sqrt{2\lambda\delta}\ ,$$

where

λ = wavelength of light -- we shall assume $\lambda = 0.5\ \mu m$,
R = minimum distance between resolved point objects,
δ = half-depth of field,

both R and δ being defined according to the Rayleigh criterion.

Three questions can be asked about this relation:

a) Is it good enough for our physical problems?
b) Can we do as well as it says?
c) Can we do better?

a) Is it good enough? With hadronic SPS beams and with known charmed particles the answer is yes. For instance, the H2 beam can have at the EHS position a horizontal focus with an r.m.s. spread of 0.7 mm. Figure 2 shows the fraction of the beam which is in focus as a function of δ; for δ = 1 mm 80% of the beam will be useful.

As for the resolution, the "known" charmed particles have mean lifetimes in the range $(2\text{-}10) \times 10^{-13}$ s, corresponding to $c\tau$ = 60-300 μm. A value of $R \simeq 20$ μm is adequate to detect them with good efficiency.

A useful working point is therefore around $R \simeq 20$ μm and $\delta \simeq 1$ mm (see Fig. 1).

b) Can we do that well? Yes. A resolution of 20 μm requires a lens with a numerical aperture of $\sim$ 0.015 and -- with a demagnification $m \simeq 1$ -- an f-number f/a = 16. It is not too difficult to design such a lens to be diffraction-limited, provided in the design proper care is taken to correct for the effect of the bubble-chamber and vacuum-tank windows. Working with $m \sim 1$ the film resolution will not be a problem since the cut-off spatial frequency of the pupil is $a/\lambda p = 1.22/R = 61\ mm^{-1}$, i.e. in a region where the usual bubble-chamber films have a good modulation transfer function.

c) Can we do better? Perhaps. It has been suggested by Welford[1] that an annular pupil be used, with an obstruction ratio ε (see Fig. 3) to increase the depth of field for a given resolution, or to increase the resolution for a given depth of field. For a constant depth of field

$$a \sim \frac{1}{\sqrt{1-\varepsilon^2}} \quad \text{and} \quad R \sim \frac{1}{a} \sim \sqrt{1-\varepsilon^2}\ .$$

An obstruction ratio ε = 0.8 could allow an increase of the aperture a by a factor of 1.67 and therefore a resolution of 10 μm could be reached still maintaining $\delta = \pm 1$ mm. Of course, such a pupil would give very bad results for extended objects but the above arguments remain valid for bubble diameters near the resolution limit[2].

At this point a further question could be asked: if classical optics is so good, why worry about holography? There are many good reasons:

i) One might want to use different and less conventional beams which require a larger depth of field.

ii) The search for other particles with possibly shorter lifetimes (b,τ) might make it necessary to aim for a higher resolution.

iii) Holography can allow much higher fluxes of particles in the bubble chamber, thus making possible higher sensitivities if a suitable trigger for the interesting events can be found.

However, for the immediate future classical optics is still going to provide us with very interesting physics.

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REFERENCES

1) W.T. Welford, J. Opt. Soc. Am. 50, 749 (1960).

2) R. Bizzarri and C. Schiller, Internal Report CERN/EP/EHS/PH 81-13 (1981).

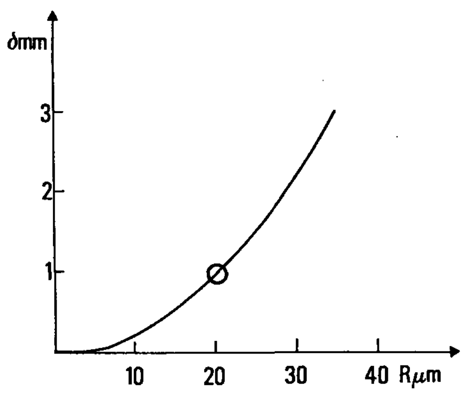

Fig. 1 Half-depth of field δ versus the resolution R. A possible working point is indicated.

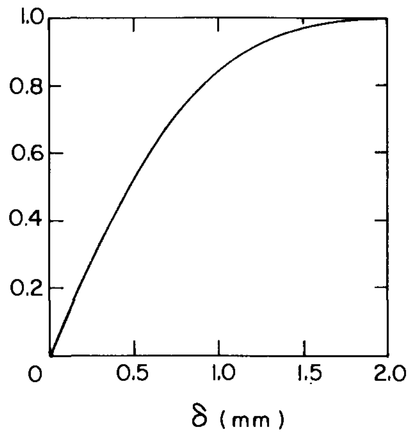

Fig. 2 Fraction of the beam in focus versus the half-depth of field δ

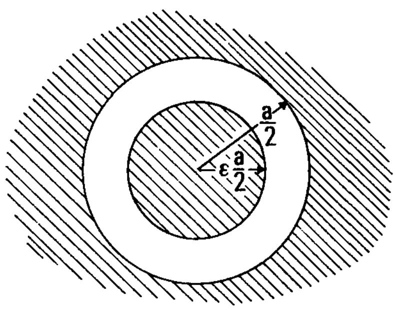

Fig. 3 Sketch of an annular pupil: the outer diameter is a and the inner diameter εa