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Monte Carlo Simulations of Polygonal Concentrators

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1 Introduction

It has been suggested that a concentrator with a polygonal cross-section would be more practical than a cylindrical one. This would not be an ideal concentrator, but it is hoped that a reasonable approximation can be realized.

If a polygonal concentrator is used, the concentration is affected because the shape is different, but also because many rays can escape near the bottom of the reflector (i.e., in the gaps between the polygon and the spherical photocathode). These will be called 'rim' gaps. These Monte Carlo simulations were meant to investigate the effect of such polygonal shapes as well as the loss through the 'rim' gaps.

2 Parameters for the Monte Carlo simulations

The concentrators were designed to fit an 8" Hamamatsu photomultiplier tube (radius 9.5 cm, polar extent 55°) . The cut-off angle was chosen to be 59°. The concentration ratio is thus 1.875 . The cones were not truncated. For simplicity, I set the coefficients of reflection at 100% for the concentrator, and 0% for the photomultiplier. This may be unrealistic, but it serves to separate geometrical effects from other effects.

The polygonal shapes were generated by circumscribing a polygon around the circular cross-section everywhere along the length of the cylindrical concentrator. The first 'petal' was chosen to be normal to the x-axis, and the concentrator was scanned along the x-axis.

3 Results of the Monte Carlo simulations

The simulations make evident the following results:

- The curves approach the ideal circular case as the number of sides is increased. (See fig. 1).
- There is a dip in the transmission curve when the incident angle is near 0°. (See fig. 1).
- The drop-off is sharper as the number of sides is increased. (See fig. 2).

The dip at 0° is investigated more fully in Figure 3 . At 0°, it is due entirely to loss through the 'rim' gaps. It is quite bad for a small number of sides, because the gaps are so large. It reaches 90% at 12 sides, 95% at 17 sides, and 98% at 30 sides.

Naively, one would expect that the fraction of rays lost in the 'rim' gaps would be of the order of the area of the gaps, divided by the area of the entry aperture. It is in fact quite higher, about ten times, for the range of about 20 to 35 sides. (See fig. 4). [1] This shows how well the rays are concentrated near the rim of the photocathode.

Figure 2 demonstrates how the concentration drops off with angle, for different polygons. If we define the drop-off as the spread of angles over which the concentration drops from 90% to 10%, then we get the following table:

Polygon	90% – 10% Spread
6	14°
12	10°
20	9°
30	9°
circle	9°

[1]This is only a rough estimate; a scaling analysis would be more appropriate.

4 Discussion

Obviously, as the number of sides is increased, the polygonal concentrator approaches the cylindrical concentrator.

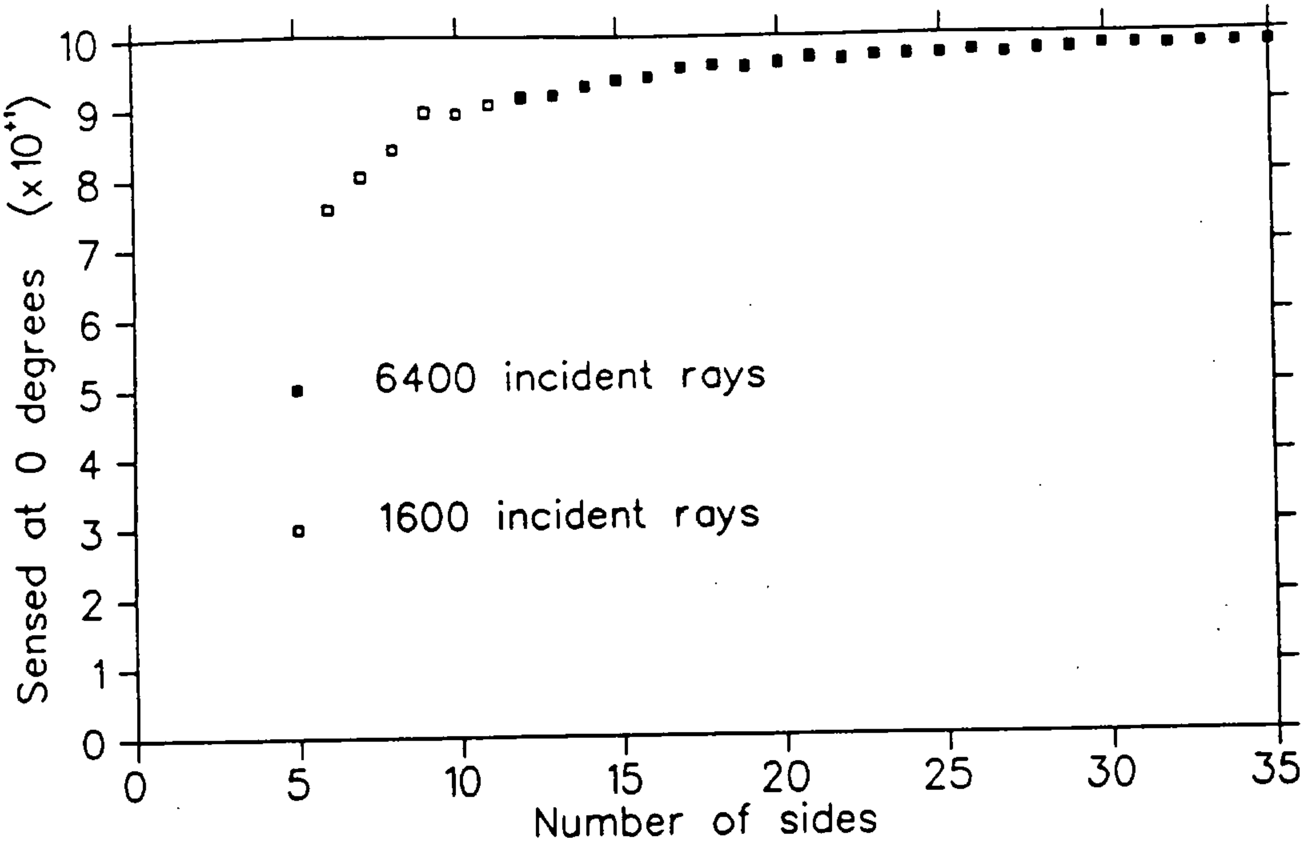
The reflector concentrates rays near the rim of the exit aperture, hence, quite a few rays (2% for a 30-sided cone) escape through the 'rim' gaps. This could be remedied by designing the concentrator with a slightly smaller radius. Thus, the photocathode would be effectively larger, and it could catch those escaping rays. Another method would be to extend the concentrator, thus plugging the gaps.

This simulation investigated only the 'rim' gaps; there are also 'interpetal' gaps, which run along the height of the concentrator, between the petals. Considering that the concentrator has a circumference of about $70cm$, a $.2mm$ gap would produce additional losses of .6% for the 20-sided cone, and .9% for the 30-sided cone. A gap of $.5mm$ would produce losses of 1.4% (20-sided cone), and 2.1% (30-sided cone). A 30-sided cone would then still be better, but a 20-sided cone would be easier to fabricate.

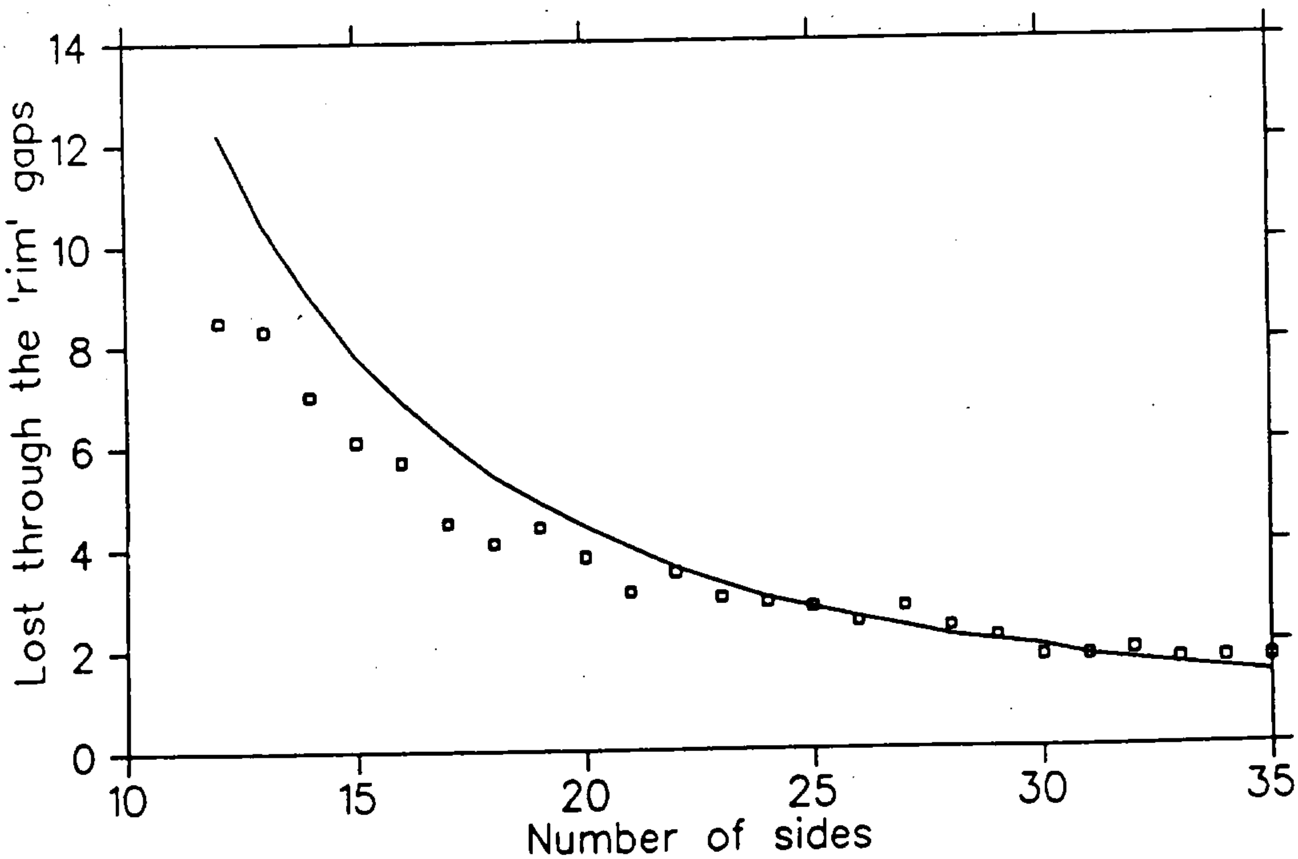
5 Figures

- Figure 1 : Transmission curve, for incident angles between 0° and 60° .
- Figure 2 : Transmission curve, for incident angles between 45° and 61° .
- Figure 3 : Percentage of rays sensed at 0° , for different polygons.
- Figure 4 : Percentage of rays lost through the 'rim' gaps at 0° . The boxes represent the results of the Monte Carlo simulation, whereas the line represents ten times the ratio of the area of the gaps to the area of the input aperture.

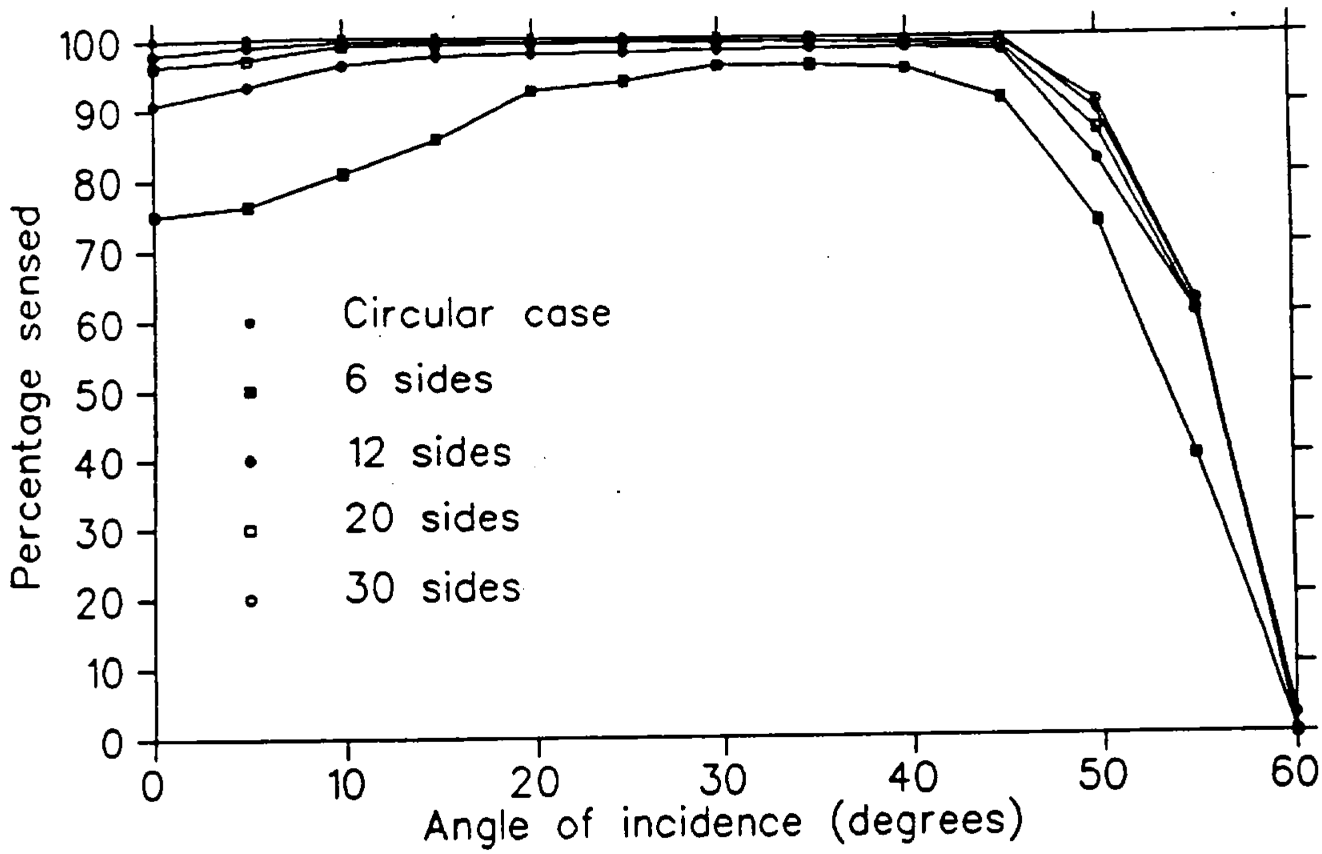
• Figure 3



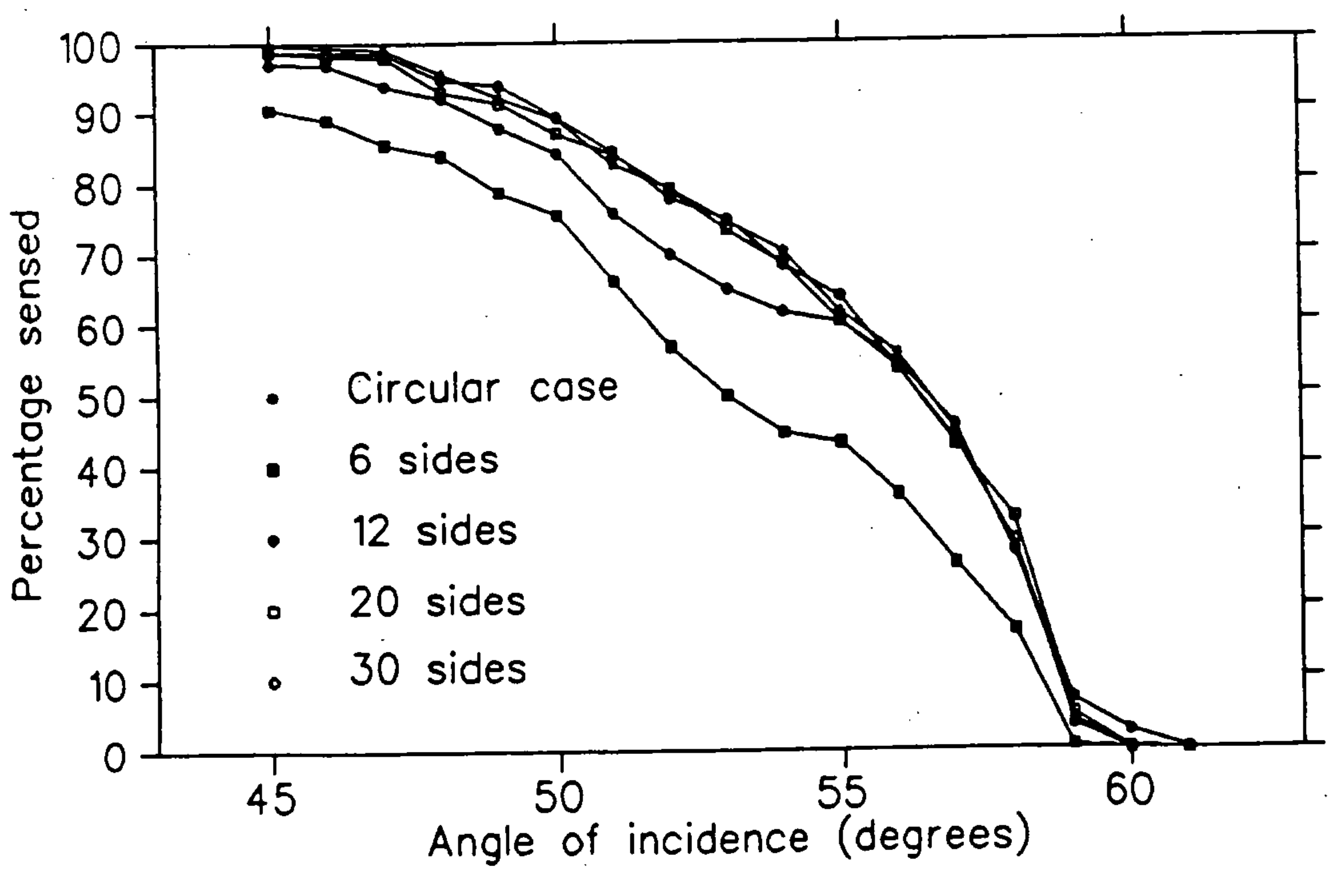
• Figure 4



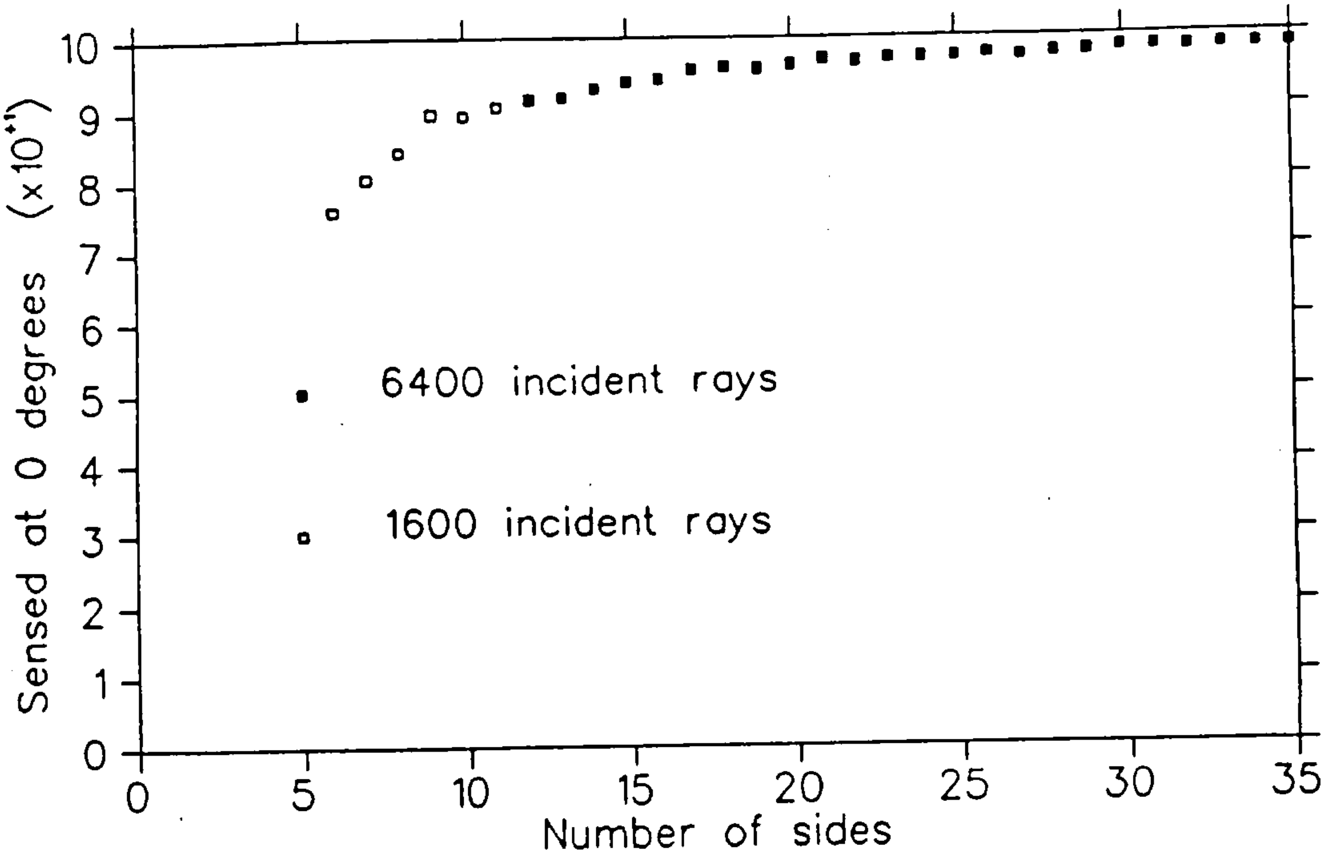
• Figure 1



• Figure 2



• Figure 3



• Figure 4