Fermilab

PBAR NOTE 461

Estimate of the Pbar yields for the CERN ACOL project

G. Dugan
5/19/86

C. Dugan 5/19/86

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Summary

For a check of the yield estimates expected for the new ACOL target station, calculations have been performed for the CERN parameters using the relatively simple semi-analytical techniques outlined in pbar note 449. These calculations correspond to operation with a 15 cm long, 1 cm radius lithium lens at 750 T/m gradient, and a 6.5 cm tungsten production target. Comparison with the current calculated yield number for the AA with the present target station configuration (10**7 pbars per 10**13 protons, into dp/p = 1.5%) indicates an increase of a factor of 15 using the normal ACOL parameters (dp/p = 6%, a(transverse acceptance) = 240 pi mm-mrad). As explained below, the above lens parameters are not optimized: that is, increases in lens gradient and/or radius will result in an increase in yield, providing the corresponding changes in focal distance, beam line matching, etc. are made.

Calculations

The technique used for the yield calculations is outlined in pbar note 449. The method is based partly on the formalism developed by T. Vsevolozskaya (c.f. ref.1). The calculations neglect multiple scattering in the target and lens. For Fermilab energies, this is an excellent approximation; for CERN energies, the approximation is poorer, but should still be adequate for this calculation, which for reasons discussed below will only be good to 10 to 20%.

The pbar production cross section used in the calculations was parameterized as a Gaussian in theta with sigma= 136.9 mrad. The forward yield was taken as $dN/d\Omega/dp$ = 0.013 /steradian/GeV/c. These results come from the parameterization discussed in reference 2.

Essentially all the principal features of the calculation can be displayed in one graph (fig. 1). This graph shows the variation of the yield (in pbars/proton/GeV/c) vs βmin (in cm). βmin is the aspect ratio of the (upright) acceptance ellipse of the optical collection system at the center of the target. Essentially, the calculation is simply an integration of the pbar density distribution from the 6.5 cm tungsten target, projected back (or forward) to the target center, over this ellipse. The area of the ellipse is the systems acceptance, a. The value of βmin is related to the lens gradient G and the value of the beta function at the downstream end of the lens, βlens, according to

$$\beta_{lens} = \frac{1}{\beta_{min}} \frac{1}{k^2 \sin^2 \phi}$$

where k = 0.3*G/p, and ϕ = k*l, with G in T/m, p (pbar momentum) in GeV/c, and l (length of the lens) in m. Usually βlens $\cong$ RO**2/a, where RO = lens physical radius. However, since βlens is determined by the optical match of the beam transport line from the lens to the collection ring, βlens could be larger than this, in which case pbars are collected which pass through the region of the lens radially outside the lithium. In this case, they no longer see a B field linear in radius. In fact, the initial operation of the ACOL target station is planned to operate with a beta matched to a radius of 1.3 cm, for a 1 cm physical radius lens. For simplicity in this calculation, however, the region of R > RO is treated as follows: to estimate the effect of collection at R > RO, the lens radius Rlens is simply increased in the program (with the gradient constant). Since the gradient actually decreases like 1/R**2 for Rlens > RO, this overestimates the yield. The variation of the total yield with gradient over the relevant range is about 20%; since the total yield increase at Rlens = 1.3 cm vs Rlens = RO is 40%, the overall overestimate in the total yield is probably no more than 10%.

Figure 1 presents two curves: one, for σ_p (proton spot size sigma (RMS)) = 0.5 mm, and one for σ_p =1.0 mm. In both cases, the nominal operating parameters (lens G = 750 T/m, Rlens = 1.3 cm) are not optimized (that is, we are not working at the peak of the yield vs βmin curve). This is also shown is figs. 2 and 3, which are derived from fig. 1 by using the equation shown above to vary min with G or Rlens. As G or Rlens is increased above the nominal, the yield grows. The curve of yield vs. Rlens in fig. 2 is of course unrealistic because of the way Rlens > RO is treated in this calculation; in reality, it would peak and turn over at some Rlens. However, the increase of yield with gradient shown in fig. 3 is real; to realize this, of course, the focal distance must be shortened, which may be impractical since it is already very short (5 cm at G = 750 T/m). The alternative is to increase the lens physical radius RO and β lens, which presents obvious technical problems.

Fig. 4 shows the yield vs acceptance; as can be seen, there is a substantial gain from 100 pi to 240 pi, but not much further gain possible thereafter.

On each of the figures, in addition to the yields in pbars/proton/GeV/c, on the right axis is plotted 4 x Yield/ Y (AA), with Y (AA) = 18.7 ppm/GeV/c. This value of Y (AA) corresponds to the current calculated AA yield of 10**7 pbars per 10**13 proton into 1.5% dp/p. This calculation gives about 15 for this ratio. If an iridium target were used, this number would presumably go up by 10 to 15%; on the other hand, because of the way Rlens > RO was treated in this calculation, the yield is probably overestimated by about the same amount. Thus, the ratio agrees roughly (within 15%) with the results of yield calculation performed at CERN, described in a short note left by Colin Johnson during his recent visit (the CERN estimate for this ratio is about 17.5). The accuracy of the calculation described here is no better than 15%, so I would consider the agreement good.

References

1. T. Vsevolozskaya, "the Optimization and Efficiency of Antiproton Production within a Fixed Acceptance", NIM 190,479 (1981).

2. C. Hojvat, A. van Ginneken, "Calculations of Antiproton Yields for the Fermilab Antiproton Source", NIM 206,67 (1983).

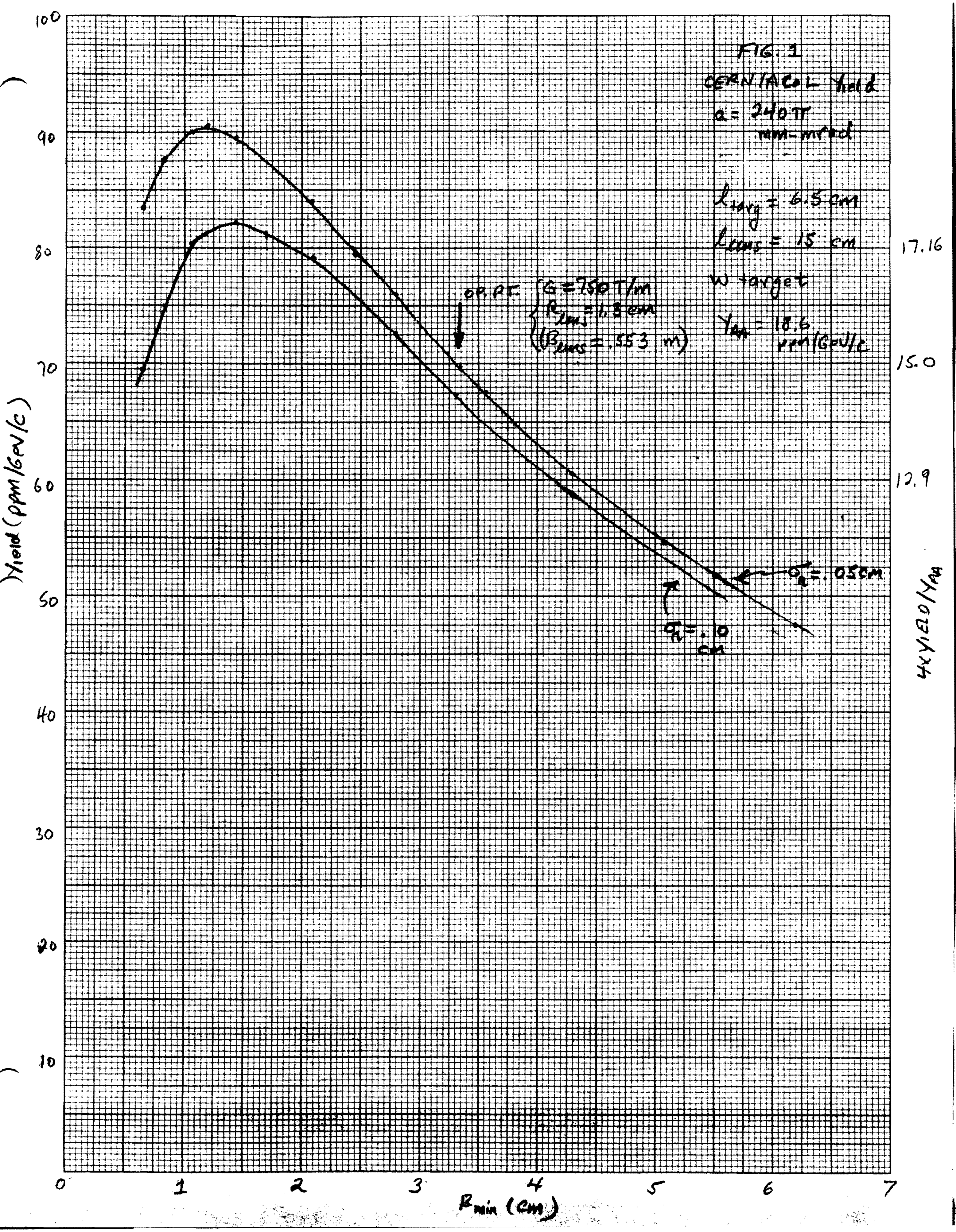

FIG. 1

CERN/ACOL Yield

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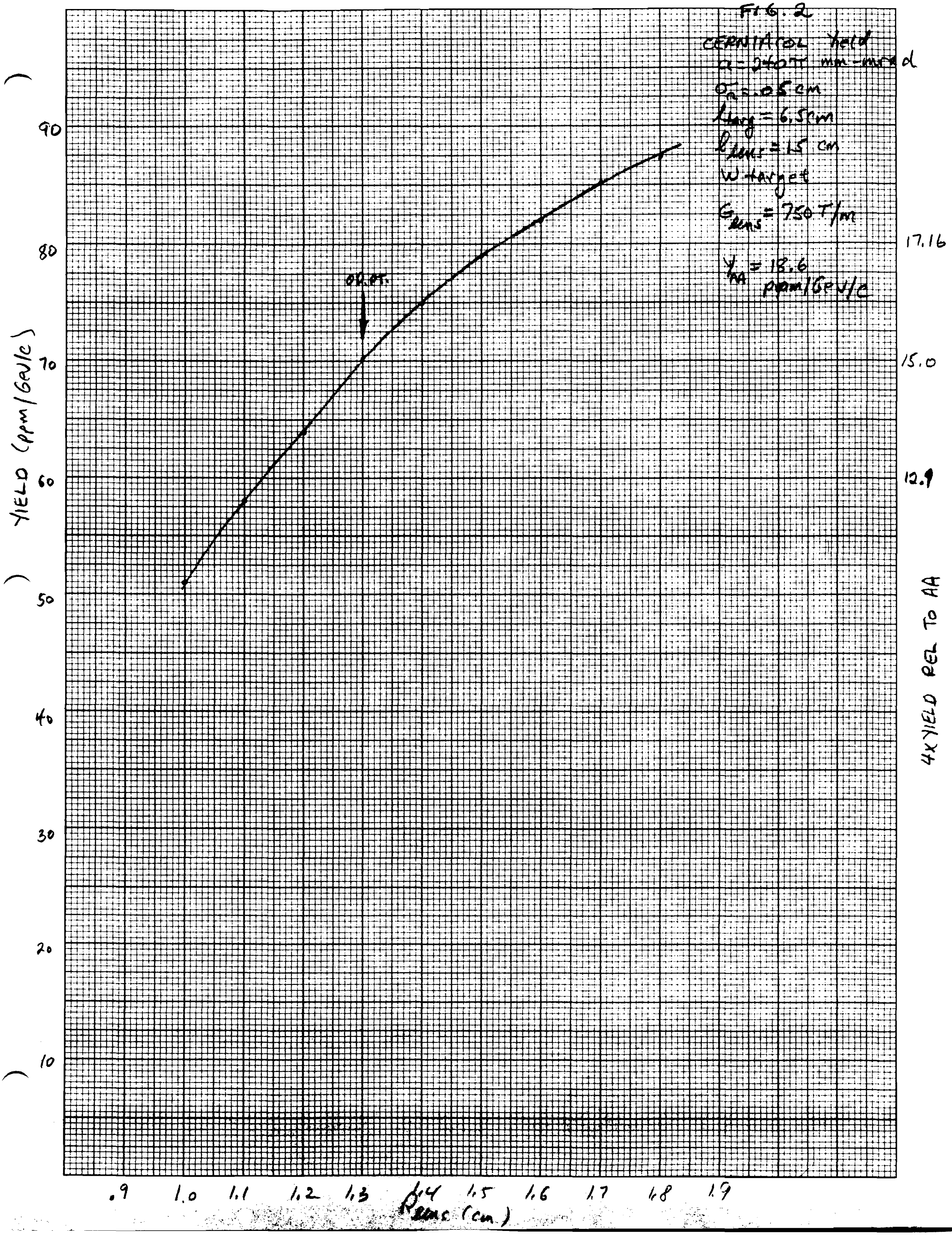
FIG. 2



CERN/ACOL Yield
$\alpha = 240\pi$ mm-mrad
$\sigma_R = .05$ cm
$l_{targ} = 6.5$ cm
$l_{lens} = 15$ cm
W target
$G_{lens} = 750$ T/m

$Y_{AA} = 18.6$ ppm/GeV/c

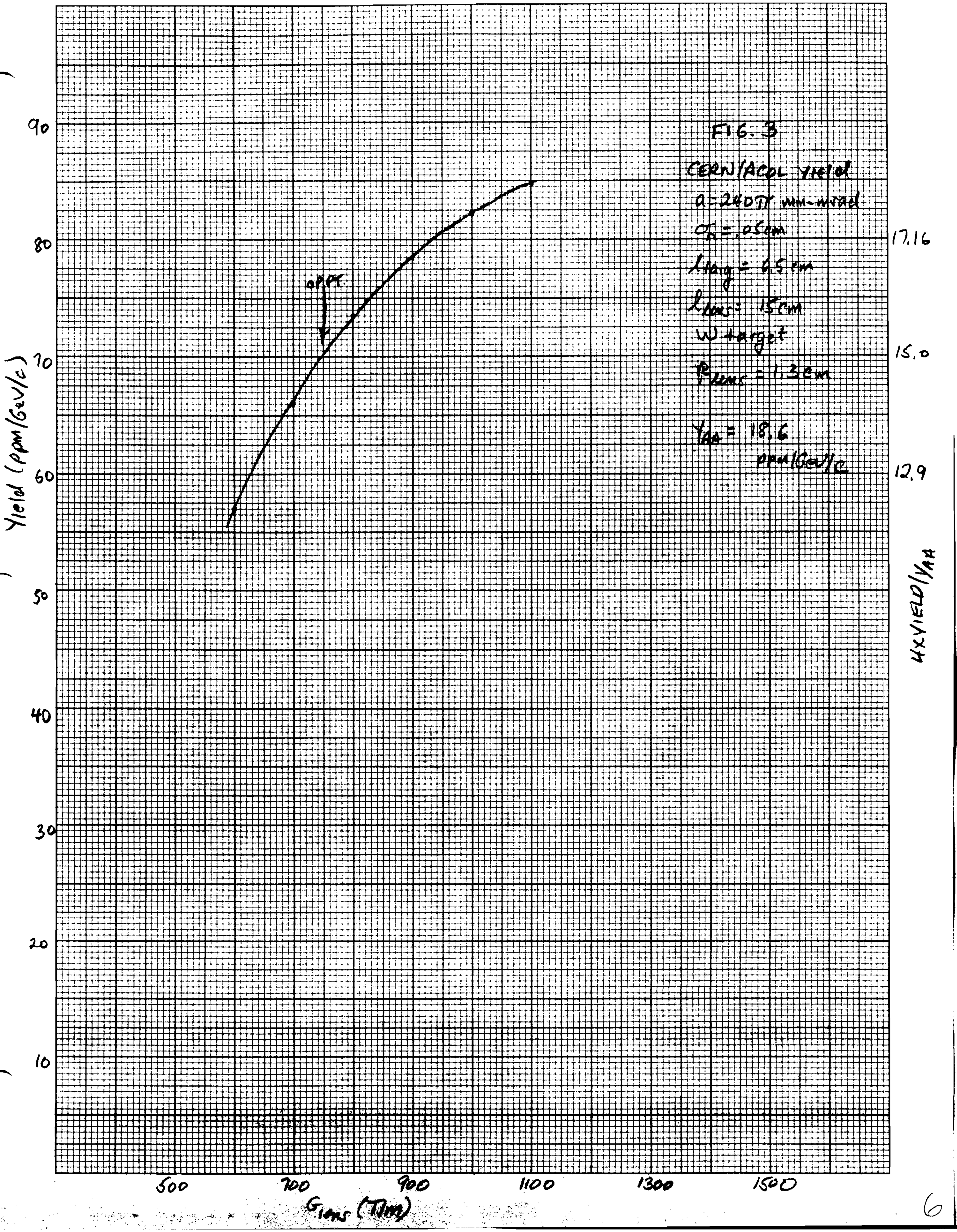


FIG. 3

CERN/ACOL Yield

$a = 240\pi$ mm-mrad

$\sigma_b = .05$cm

$\ell_{targ} = 6.5$ cm

$\ell_{lens} = 15$cm

W target

$R_{lens} = 1.3$cm

$Y_{AA} = 18.6$ ppm/GeV/c

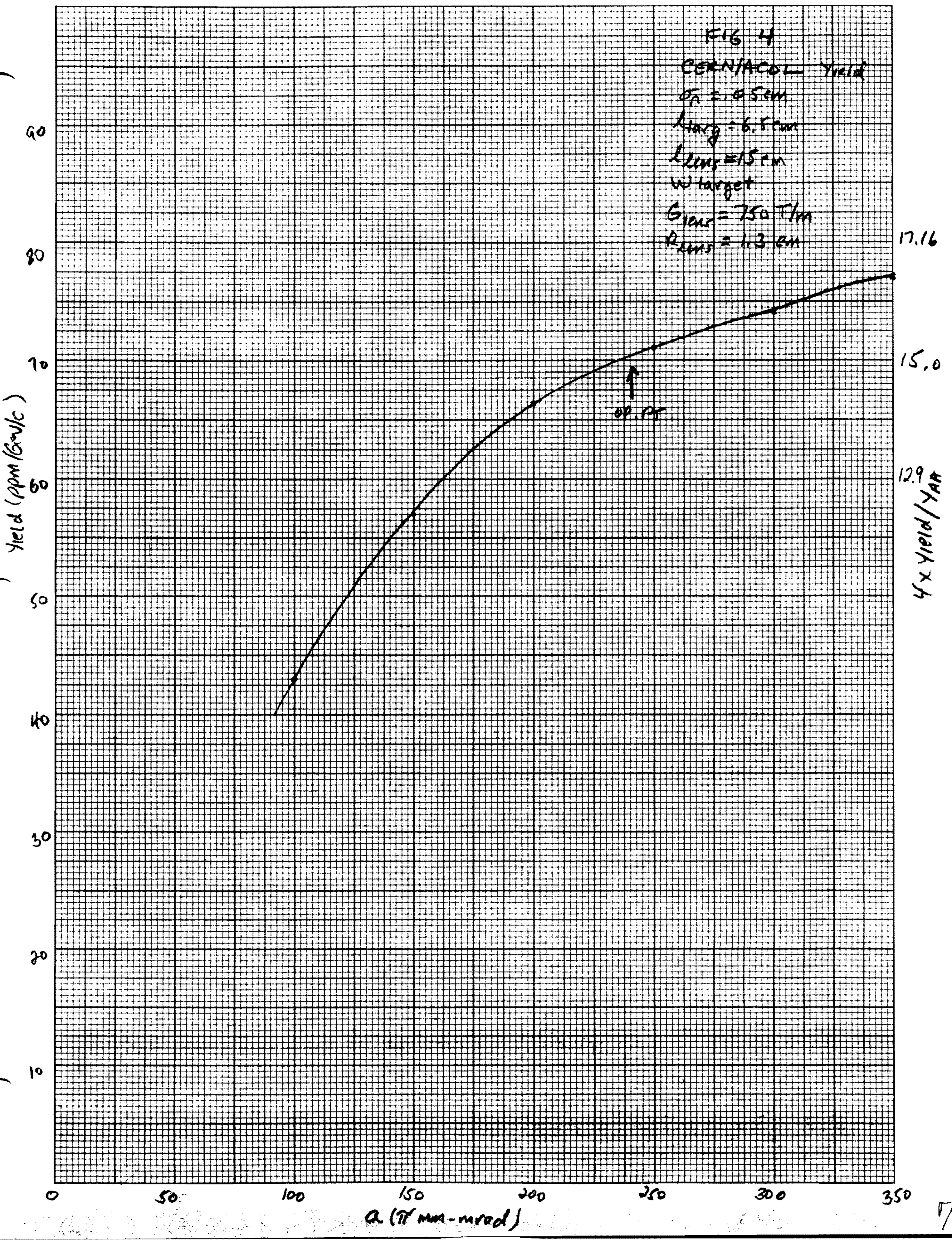


FIG 4

CERN/ACOL Yield

$\sigma_r = .05$ cm

$l_{targ} = 6.5$ cm

$l_{lens} = 15$ cm

W target

$G_{lens} = 750$ T/m

$R_{lens} = 1.3$ cm