CARBON STRIPPER FOIL LIFETIME TESTS

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ABSTRACT

Carbon stripper foils prepared by several different methods have been tested in the terminal of the Argonne FN tandem using a 7.7 MeV $^{58}Ni^-$ beam. The ion transmission ratio, foil lifetime, and beam energy straggling were measured. The results will be presented and discussed.

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1. Introduction

The present measurements resulted from discussions at the meeting of the International Nuclear Target Development Society in Boston, Massachusetts (1979), where it was realized that it could be helpful to compare all of the available different carbon foils in one accelerator. There was interest at Argonne National Laboratory to perform these tests since the laboratory is presently involved in construction of a new superconducting linac, with the Argonne FN tandem accelerator as an injector. Requirements for injection into the linac result in the need for extremely thin and homogeneous stripper foils in the tandem terminal, which, however, should also be long-lived.

2. Experiment

A detailed description of the measurements is given elsewhere [1]. This paper is intended only to point up some of the main results.

Stripper foils from seven places were investigated:

1. Arizona Carbon Foil Company, produced by carbon arc - furnished by John Stonier [2].
2. Argonne National Laboratory, produced by glow discharge - by Patric Den Hartog and George Thomas [3].
3. Chalk River National Laboratory, produced by glow discharge - by Joe Gallant [4].
4. Max-Planck-Institut für Kernphysik, produced by glow discharge - by Herman Wirth [5].
5. Daresbury Laboratory, produced by glow discharge - by David Tolfree [6].
6. University of Pittsburgh, produced by glow discharge - by T. Saylor [7].
7. Technical University of Munich, produced by electron beam and laser beam treated - by Peter Maier-Komor [8].

All of the foils were loaded in the stripper foil changing mechanism in one loading. They were all exposed to a $^{58}Ni^-$ beam with a terminal voltage of 7.7 MeV. The injected $^{58}Ni^-$ beam current and the 85 MeV $^{58}Ni^{10+}$ beam current, after a 90° analyzing magnet, were measured at regular intervals. The average $^{58}Ni^-$ current was $\sim$ 1 μa. In addition, the ion energy straggling in the foils was monitored with the Argonne superconducting bunching system and a time-of-flight method.

3. Results

At the Boston Conference, Dave Galbraith [9] demonstrated (fig. 1) that the lifetimes of carbon stripper foils depend strongly on their thickness. We will see that this is true for essentially all foils which have not been "slackened". The physical reason for this was explained by Maier-Komor [10] at the Tandem Conference at Oak Ridge in April 1981. Further information concerning the ion transmission of the Munich tandem as a function of stripper foil thickness was presented by Maier-Komor [11] at the Gatlinburg Conference of the INTDS, which also demonstrated very strong ion losses for the thicker foils.

In the present experiment a similar behavior is observed with the ANL-Tandem as shown in fig. 2. The foils were prepared and calibrated by Arizona Carbon Foil Company. The transmission data have been analyzed in terms of the Meyer multiple scattering formalism [12]. The data were fit by a least squares analysis with an arbitrary normalization constant and a "cut-off" scattering angle θ_c, ($\approx$0.6 mrad) beyond which a particle will not be transmitted through the tandem.

Figures 3–9 are plots of the ratios of the measured $^{58}Ni^{10+}$ and $^{58}Ni^{-}$ currents, for the various foils tested, as functions of the $^{58}Ni^{10+}$ integrated beam current. Although there are variations in lifetimes and transmission ratios within a group of foils, it is obvious that most foils tested have longer lifetimes than the standard arc-evaporated foils. The foil thickness can be determined by using the transmission-thickness relation of fig. 2. The corresponding foil thickness can be seen on the right-hand vertical axis of figures 3–9. The variations in foil thickness for any given type suggests that production uniformily needs to be improved.

There is a definite lifetime dependence on thickness for the arc-evaporated foils as well as some of the other types tested. In particular, the different batches of Argonne foils show this dependence. Batch three foils broke immediately, probably because they were extremely thin. In addition, the Munich laser-irradiated 4 μg cm^{-2} foils had a much longer lifetime than the 2 μg cm^{-2} ones.

For all of the foils tested there was a near-linear decline in accelerator beam intensity and foil transmission as the ion dose accumulated. Frequently there was initially a short period of increasing intensity which may be due to evaporation of volatiles from the foil surface. The Heidelberg and Munich foils, which did not have collodian backing, showed the smallest increase. Auble [13] and Tait [14] have reported a thinning in the beam spot area of irradiated glow discharge foils. Presumably this would result in increased transmission but this effect may be masked by other ones as, for example, inhomogeneous thinning. Also, cracking of hydro-carbons in the residual gas may increase the foil thickness but the present accelerator tube is a baked all-metal and ceramic system with an additional 25 l/s ion pump in the terminal and an ultimate vacuum of $\sim 5 \times 10^{-7}$ Torr. In the future, foils removed from the system will be examined for local concentrations of hydrocarbons.

4. Conclusions

All of the foils tested from the various laboratories have longer lifetimes than standard arc evaporated ones. Both the foils produced by the ethylene discharge method and those from the laser irradiation of electron beam evaporated foils have been successful. The thinnest foils show short lifetimes, the significantly higher transmission obtained though is important for ion species where high source currents are difficult to obtain. In these cases the thinner laser-irradiated foils are particularly attractive.

References

[1] P. Den Hartog, G. Thomas, W. Henning, R. Pardo, J. Yntema, P. Maier-Komor and D. Tolfree, Proceedings of Third International Conference on Electrostatic Accelerator Technology, Oak Ridge, Tennessee, April 13-16, 1981 (IEEE no. 81CH1639-4) p. 168-171.

[2] J. O. Stonier, Jr., Arizona Carbon Foil Co., Tucson, Arizon 85721.

[3] P. K. Den Hartog and G. E. Thomas, Argonne National Laboratory, 9700 S. Cass Ave., Argonne, IL 60439.

[4] J. L. Gallant, Atomic Energy of Canada Limited, Chalk River Laboratories, Chalk River, Ontario, Canada KOJ 1JO.

[5] H. Wirth, Max-Planck-Institut f. Kernphysik, Heidelberg, D-6900 Heidelberg, West Germany.

[6] D. W. L. Tolfree, Science Research Council, Daresbury Laboratory, Daresbury, Warrington WA4 4AD, Cheshire, United Kingdom.

[7] T. Saylor, University of Pittsburgh, Pittsburgh, Pennsylvania.

[8] P. Maier-Komor, Physik Department, Technische Universitat, Munchen, D-8046 Garching, West Germany.

[9] R. L. Auble and D. M. Galbreth, Proceedings of the World Conference of the International Conference of the International Nuclear Target Development Society, Boston, Massachusetts (1979) edited by J. Jaklovsky, (Plenum Press, New York, 1q981) p. 1-11.

[10] P. Maier-Komor, Proceedings of the Third International Conference on Electrostatic Accelerator Technology, Oak Ridge, Tennessee, April 13-16, 1981. (IEEE no. 81CH1639-4).

[11] P. Maier-Komor, Proceedings of the 1980 World Conference of the International Nuclear Target Development Society, Gatlinberg, Tennessee, October 12-16, 1980, to be published in Nucl. Instrum. Methods.

[12] L. Meyer, Phys. Status Solidi 44 (1971) 253.

[13] R. L. Auble, J. K. Blair, D. M. Galbraith, C. M. Jones, P. H. Stelson, and O. C. Weisser, Nucl. Instrum. Methods 177 (1980) 289.

[14] N. R. S. Tait, D. W. L. Tolfree and D. S. Witmell, Nucl. Instrum. Methods 166 (1979) 333.

Figure Captions

Fig. 1 Lifetimes to mechanical failure under bombardment by 10 MeV ^{35}Cl ions of foils of various types and thicknesses. The heavy line is a visual fit to H-mode failure lifetimes.

Fig. 2 Current-transmission ratios in the Argonne FN tandem for arc-evaporated carbon foils. The closed circles are for foils prepared and calibrated by Arizona Carbon Foil Company. The curve is a fit to the Meyer distribution.

Fig. 3 Current-transmission vs. dosage curves for the foils of ref. 2. Thicknesses were determined with a crystal monitor during the evaporation.

Fig. 4 Current-transmission vs. dosage curves for the foils of ref. 5. No independent thickness measurement was made.

Fig. 5 Current-transmission vs. dosage curves for foils of ref. 6. No independent thickness measurement was made. The release agent for batch 2 foils was RB 25 and for batch 1 foils NaCl.

Fig. 6 Current-transmission vs. dosage curves for the foils of ref. 4. A thickness was determined by the comparison of the optical transmission of a foil to that of a calibrated standard.

Fig. 7 Current-transmission vs. dosage curves for the foils of ref. 3. The batches differ in the duration and pressure of the glow discharge.

Fig. 8 Current-transmission vs. dosage curves for the foils of ref. 7. No independent thickness measurement was made.

Fig. 9 Current-transmission vs. dosage curves for the foils of ref. 8. The thickness was monitored during evaporation but may have been reduced by the laser irradiation.

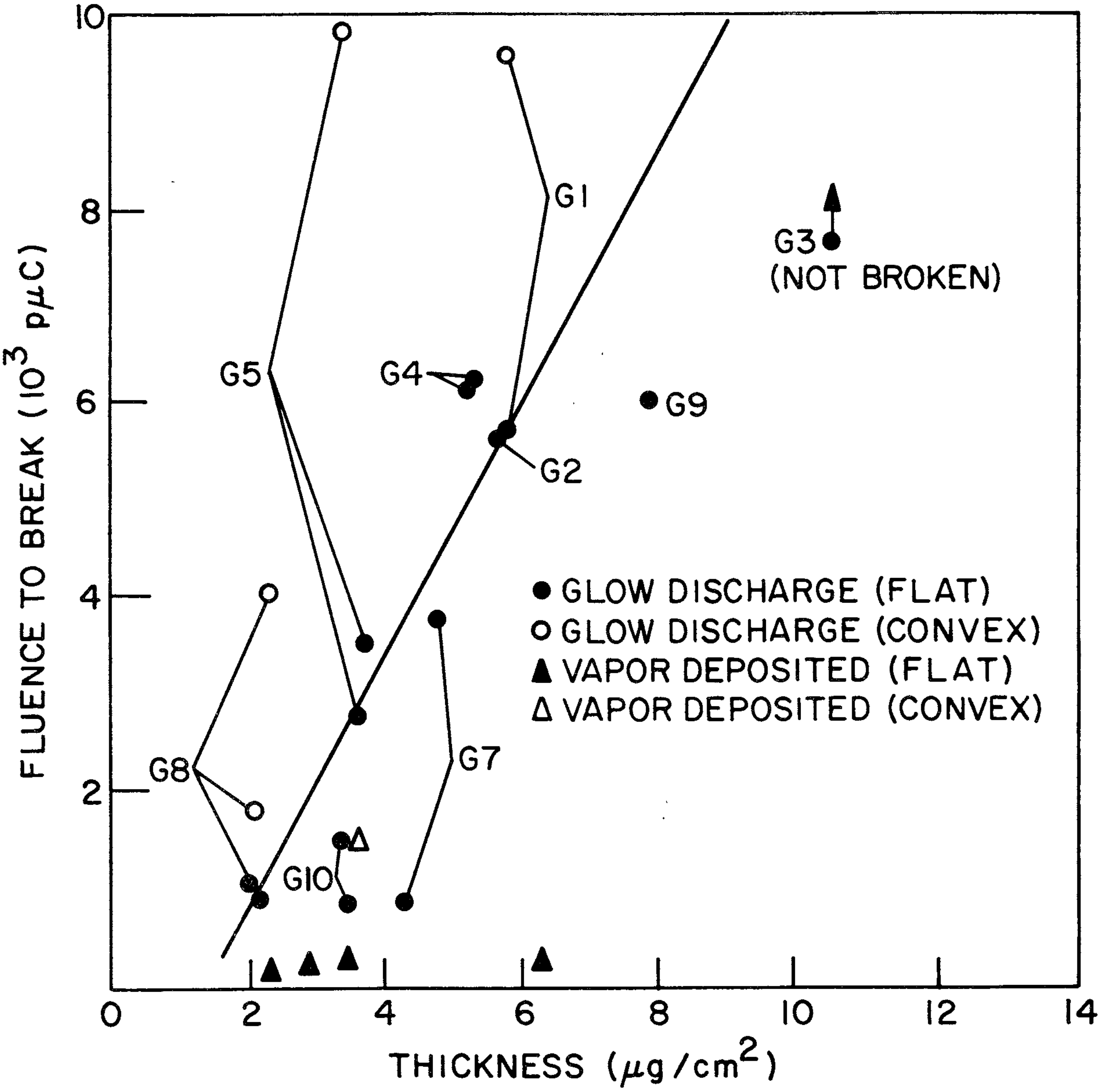
FLUENCE TO BREAK (10^3 pμC)
THICKNESS (μg/cm^2)
0
2
4
6
8
10
12
14
G1
G2
G3
(NOT BROKEN)
G4
G5
G7
G8
G9
G10
● GLOW DISCHARGE (FLAT)
○ GLOW DISCHARGE (CONVEX)
▲ VAPOR DEPOSITED (FLAT)
Δ VAPOR DEPOSITED (CONVEX)

Fig. 1

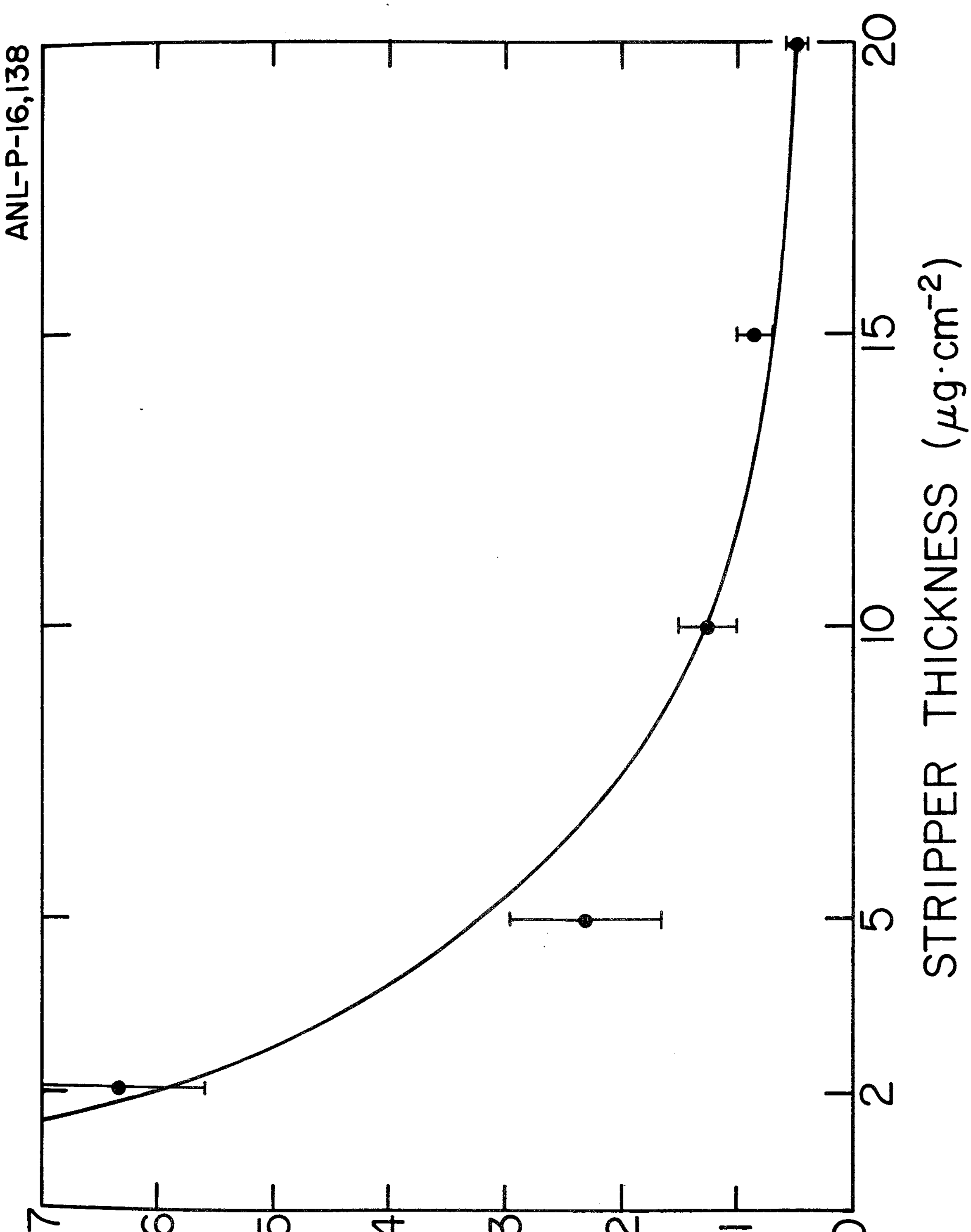
ANL-P-16,138
$^{58}Ni^{+10}/^{58}Ni^{-}$
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2
5
10
15
20
STRIPPER THICKNESS ($\mu g \cdot cm^{-2}$)

Fig. 2

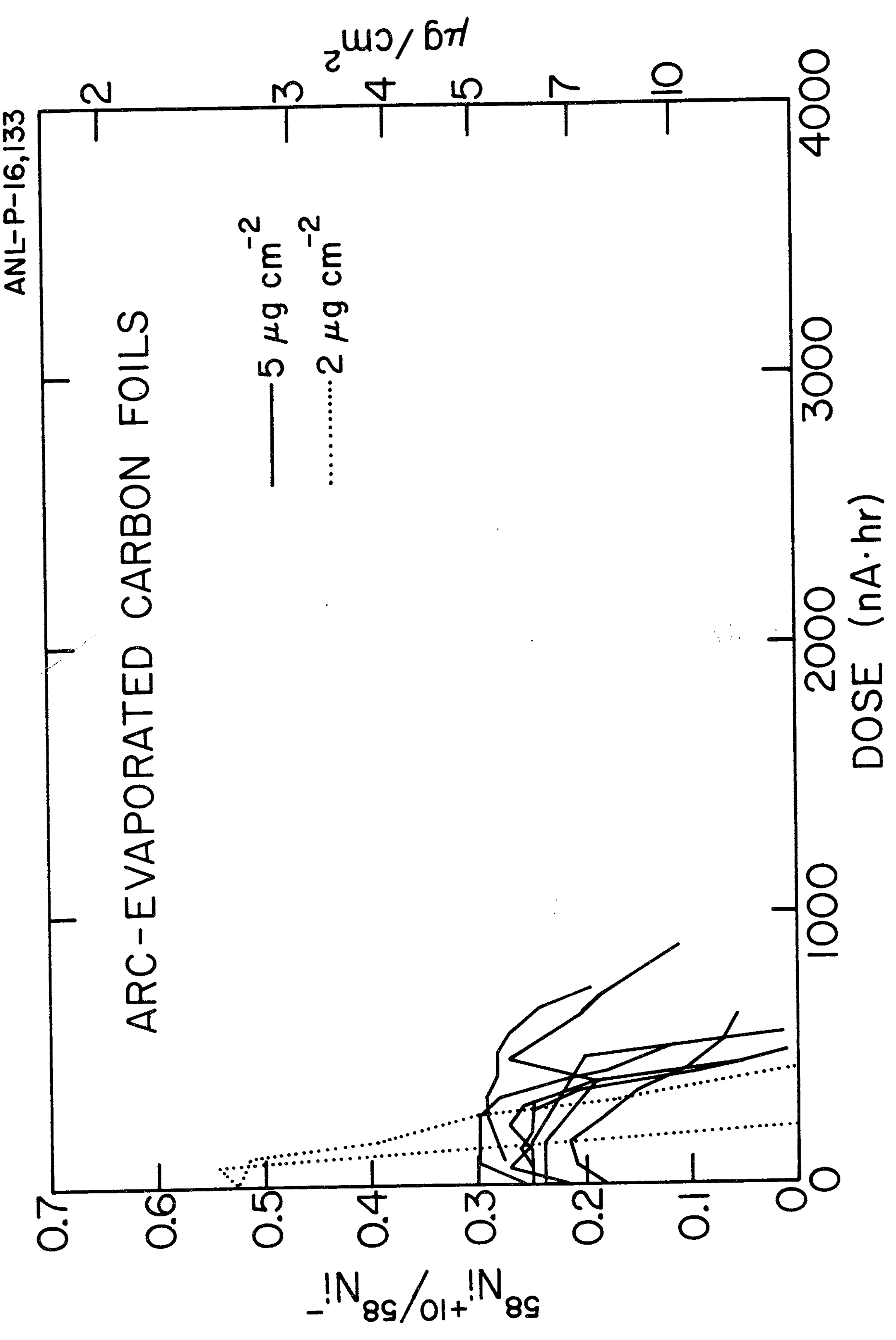
ANL-P-16,133
ARC-EVAPORATED CARBON FOILS
5 μg cm^{-2}
2 μg cm^{-2}
μg/cm^2
2
3
4
5
7
10
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
^{58}Ni^{+10}/^{58}Ni$^-$
0
1000
2000
3000
4000
DOSE (nA·hr)

Fig. 3

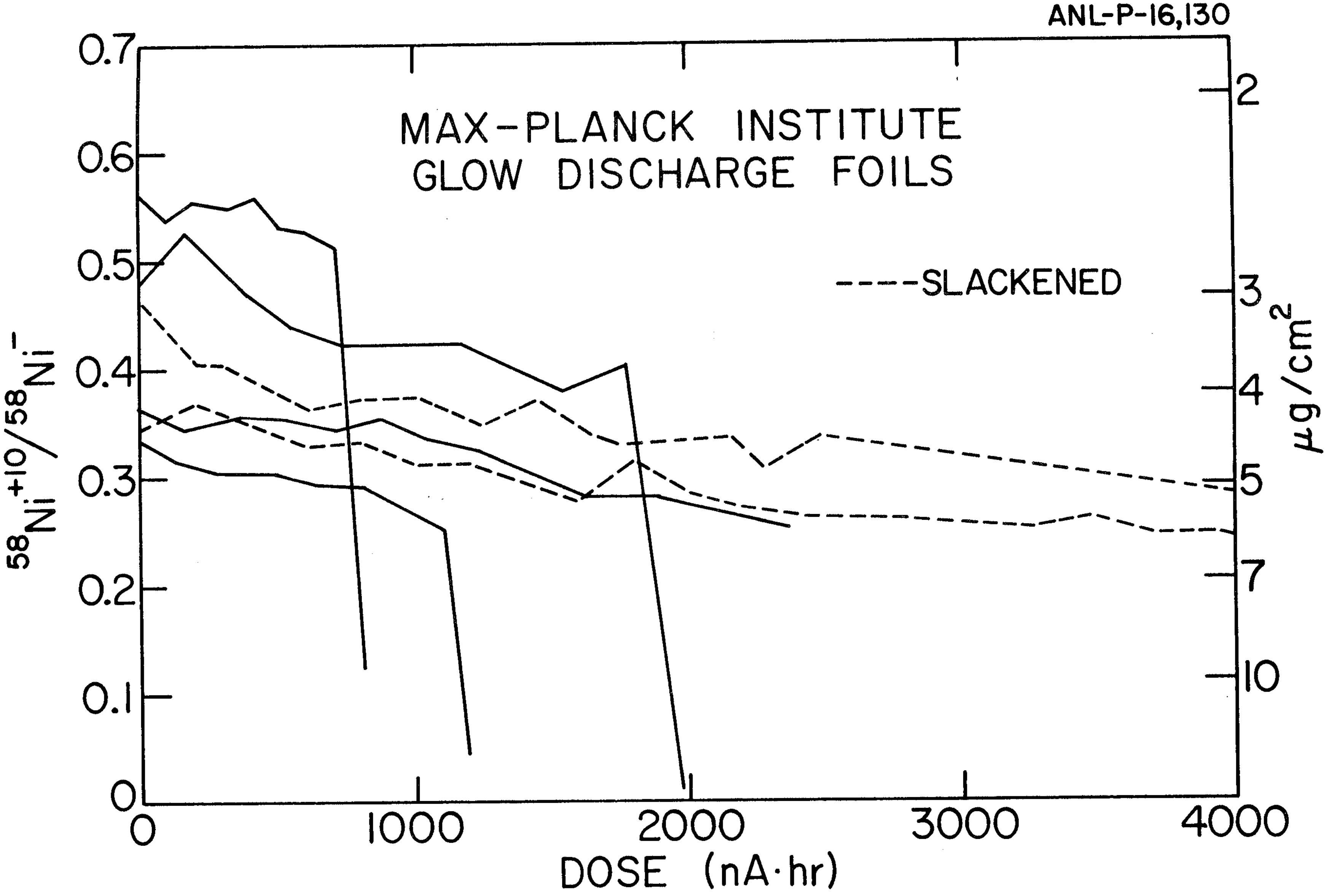
ANL-P-16,130
MAX-PLANCK INSTITUTE
GLOW DISCHARGE FOILS
----SLACKENED
$^{58}Ni^{+10}/^{58}Ni^{-}$
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1000
2000
3000
4000
DOSE (nA·hr)
μg/cm²
2
3
4
5
7
10

Fig. 4

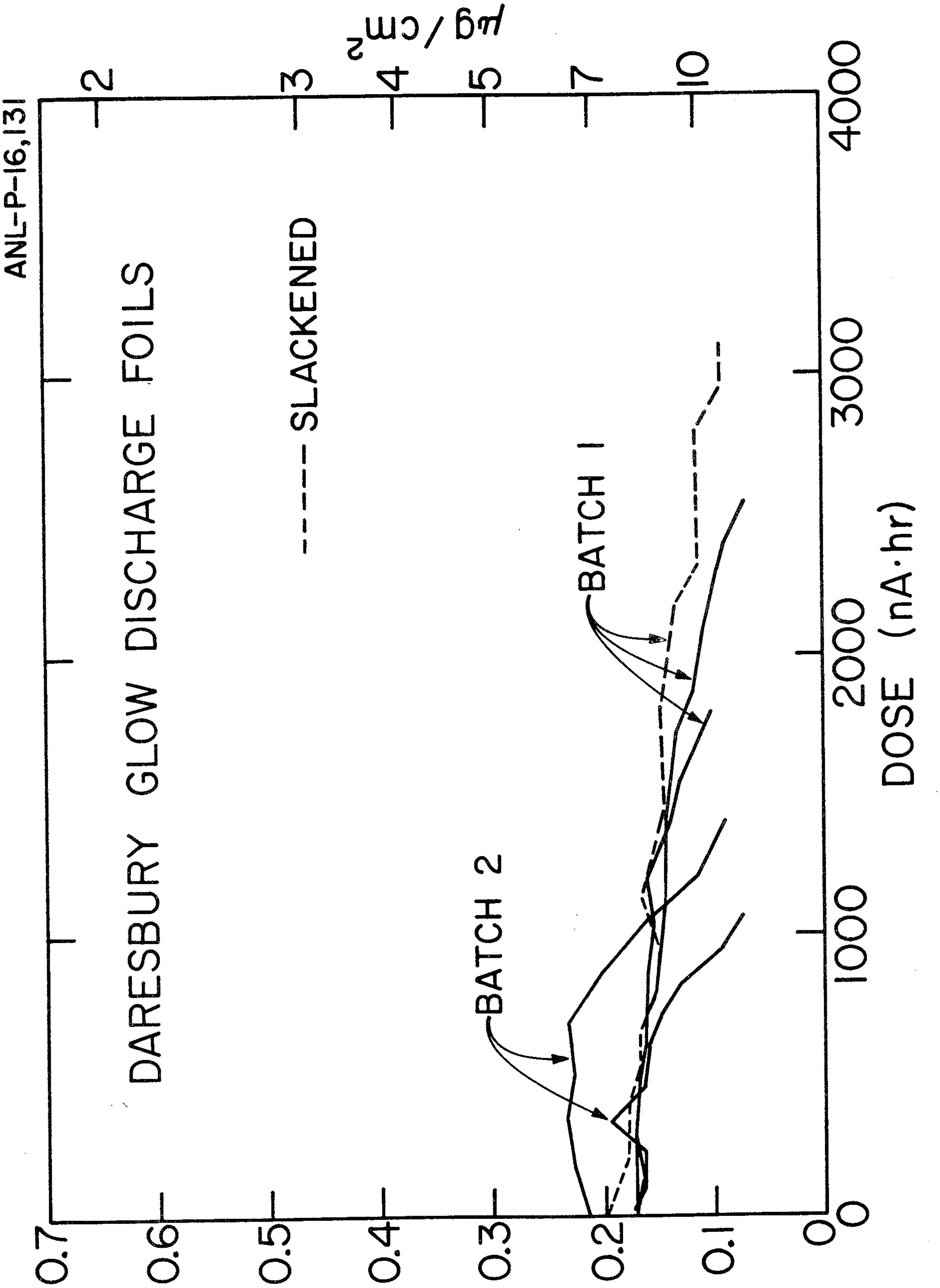
ANL-P-16,131
DARESBURY GLOW DISCHARGE FOILS
- - - - SLACKENED
BATCH 1
BATCH 2
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
$^{58}Ni^{+10}/^{58}Ni^{-}$
0
1000
2000
3000
4000
DOSE (nA·hr)
2
3
4
5
7
10
µg/cm²

Fig. 5

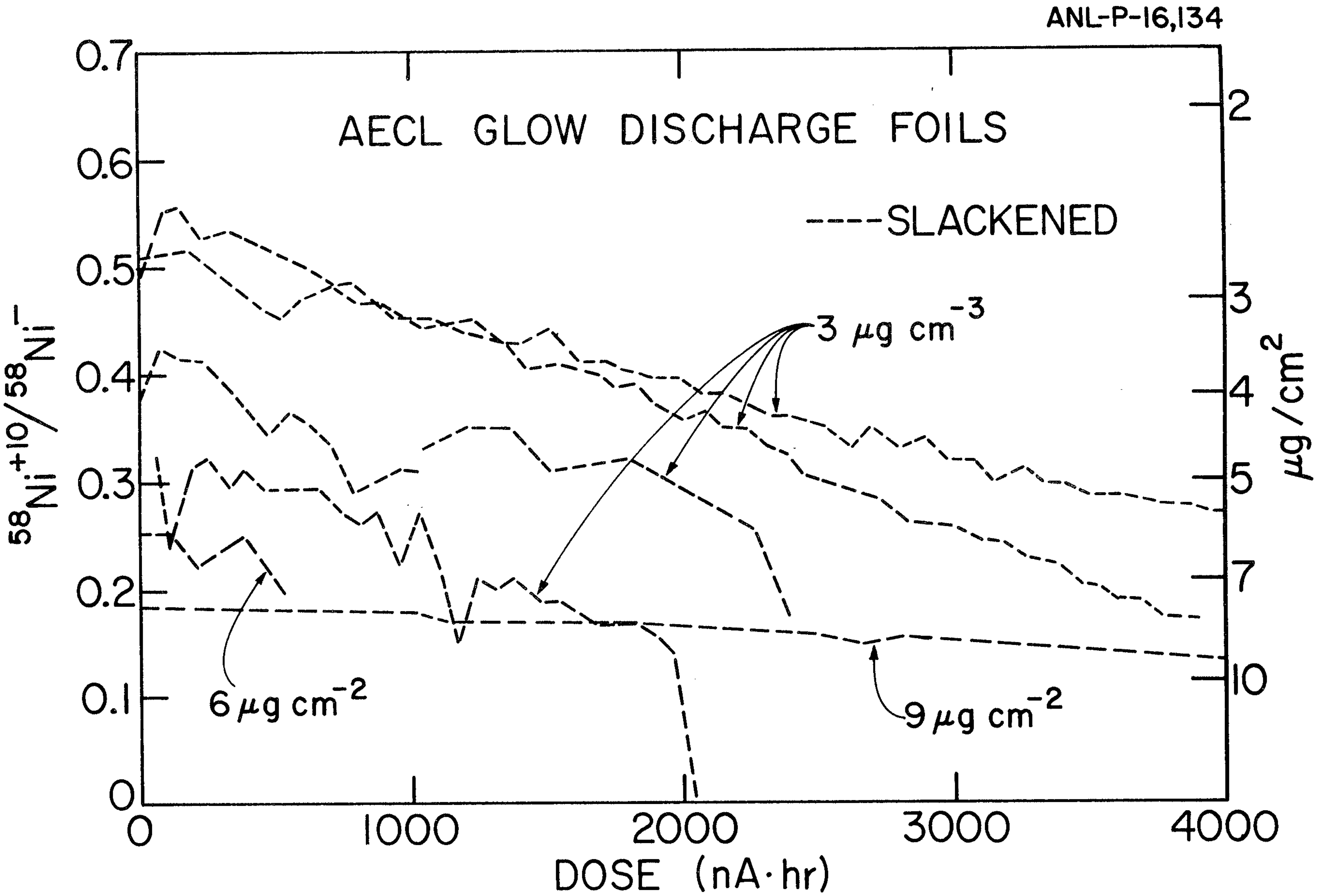
ANL-P-16,134
AECL GLOW DISCHARGE FOILS
----SLACKENED
3 μg cm-3
6 μg cm-2
9 μg cm-2
58Ni+10/58Ni-
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
μg/cm2
2
3
4
5
7
10
0
1000
2000
3000
4000
DOSE (nA·hr)

Fig. 6

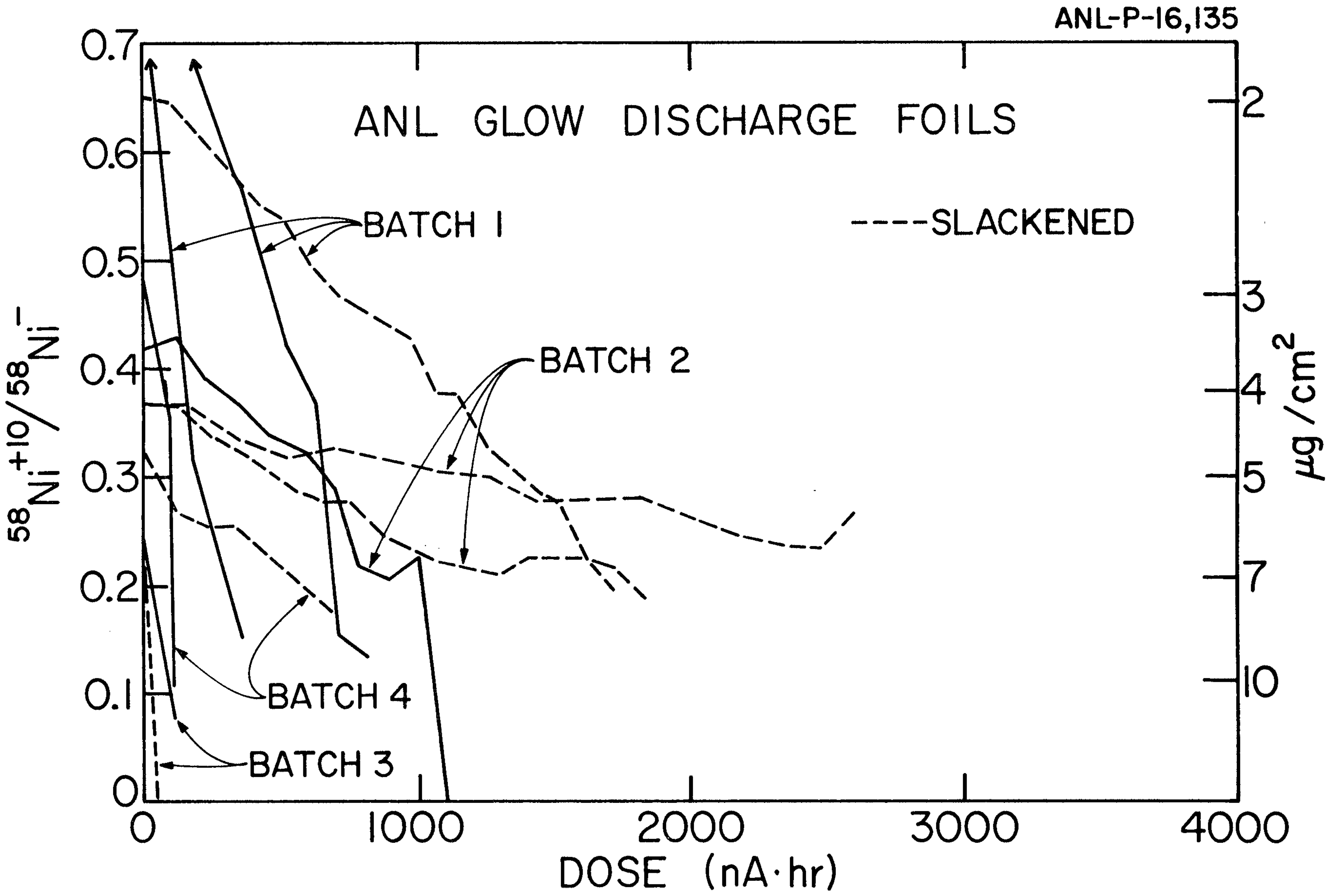
ANL-P-16,135
ANL GLOW DISCHARGE FOILS
----SLACKENED
BATCH 1
BATCH 2
BATCH 4
BATCH 3
$^{58}Ni^{+10}/^{58}Ni^{-}$
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
DOSE (nA·hr)
0
1000
2000
3000
4000
μg/cm²
2
3
4
5
7
10

Fig. 7

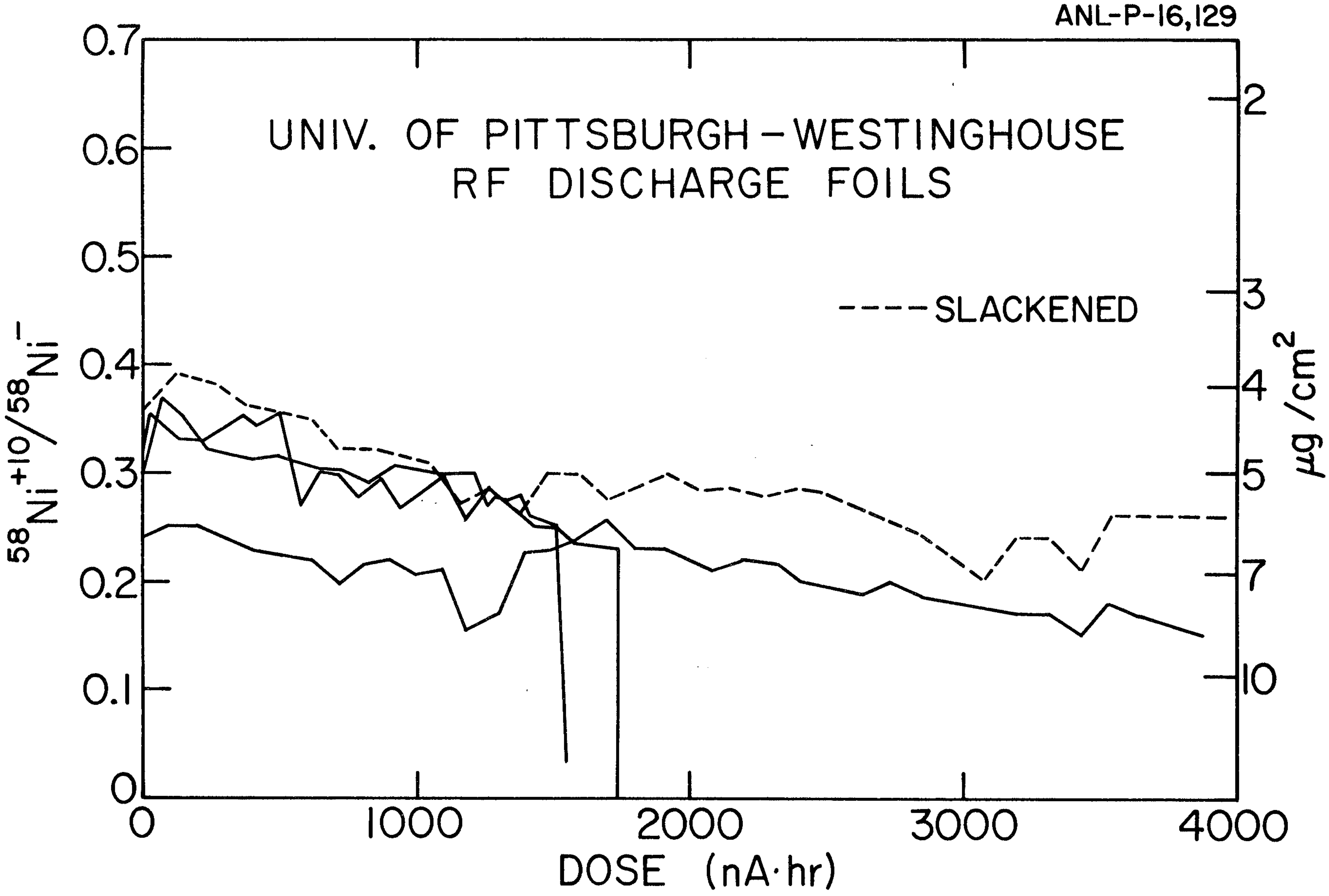
ANL-P-16,129
UNIV. OF PITTSBURGH – WESTINGHOUSE
RF DISCHARGE FOILS
----SLACKENED
$^{58}Ni^{+10}/^{58}Ni^{-}$
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1000
2000
3000
4000
DOSE (nA·hr)
μg/cm²
2
3
4
5
7
10

Fig. 8

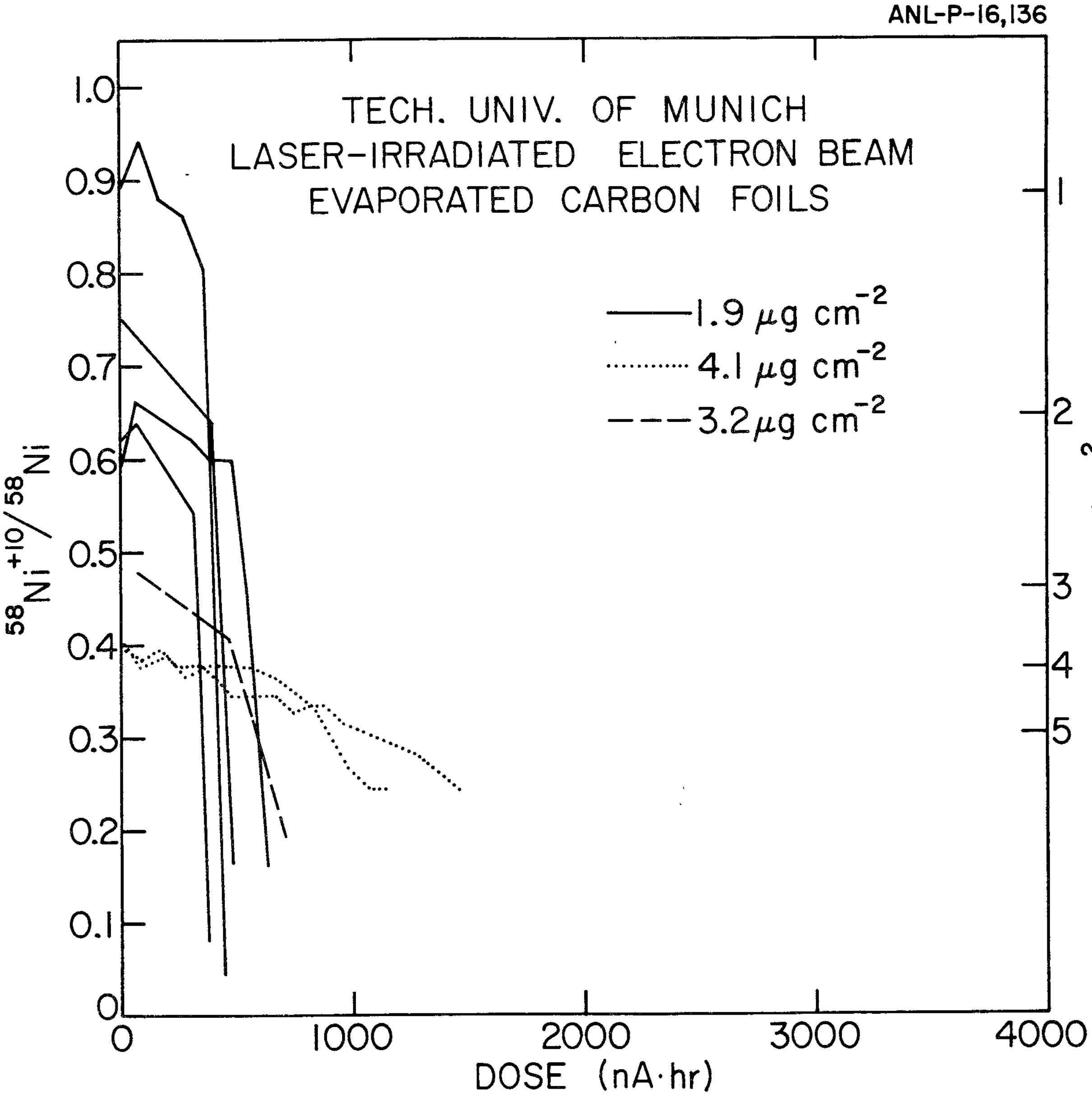
ANL-P-16,136
TECH. UNIV. OF MUNICH
LASER-IRRADIATED ELECTRON BEAM
EVAPORATED CARBON FOILS
1.9 μg cm-2
4.1 μg cm-2
3.2μg cm-2
$^{58}Ni^{+10}/^{58}Ni$
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
μg/cm2
1
2
3
4
5
0
1000
2000
3000
4000
DOSE (nA·hr)

Fig. 9