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A TERMINAL LENS FOR AN FN TANDEM

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SUMMARY

An electrostatic quadrupole triplet (ELQT) will be installed in the terminal of the Argonne FN tandem accelerator. The lens will be used in conjunction with foil stripping to maximize the transmission of heavy ions through the high-energy accelerator tube. The lens has steering capability and is controlled by a microcomputer located in the terminal.

INTRODUCTION

The Argonne nuclear structure facility was constructed in 1962 as a High Voltage Engineering Corp. (HVEC) model EN tandem accelerator and in 1967 this machine was replaced by the HVEC model FN. This accelerator has undergone a number of substantial improvements over the years[1,2) and now functions primarily as an injector into an independently phased superconducting linac booster[3)]. As an injector, the performance requirements of the tandem are substantially altered from those of a stand-alone tandem. Since the energy gain of the linac is greater than the tandem, heavier ions can be accelerated by the tandem-linac combination than by the tandem alone. Figure 1 shows the present and future performance for the FN tandem, the tandem plus the superconducting booster, and the tandem plus ATLAS (Argonne Tandem-Linac Accelerator System) which is now under construction. The mass number for which useful energies can be produced will be extended to at least A=127. The tandem injector must be able to effectively accelerate and transmit these ions.

The fraction of ions transmitted through a tandem accelerator is dependent on the emittance of the ion beam from the source and the acceptance of the low energy and high energy tubes of the accelerator. Ions within the acceptance of the low energy tube will be transmitted to the terminal, but multiple scattering of the ion beam by the stripper at the terminal increases the divergence of the beam, and reduces the transmission through the high energy tube. Since the multiple scattering increases as the thickness$^{1/2}$, strippers only as thick as necessary to produce charge state equilibrium should be used. Self-supporting carbon films are always thicker than required, but are often preferred over gas stripping because the average charge state is higher. Gas strippers may be made as thin as desired, but unless differential pumping is included in the terminal, the transmission of heavy ions will be reduced through scattering collisions with the residual gas and the electron loading will be increased. When light ions are accelerated the increased emittance from the scattering in the foil is small and the ion transmission ratio is not significantly decreased, but when the atomic number of the injected

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ion increases, the scattering becomes the dominant contribution to the beam emittance. Figure 2 shows transmission in the Argonne tandem for $^{58}Ni^-$ as a function of foil stripper thickness. For a carbon beam, the increased scattering which results from the use of thicker foils does not effect the transmission unless $t > 7$ µg cm^{-2}. For nickel, however, even foils as thin as 2 µg cm^{-2} degrade the transmission. Since foil lifetimes are longer for thicker foils, it is important to obtain as high a transmission as possible for a given foil thickness. The transmission of selected charge states can be enhanced through the use of terminal focusing and properly chosen apertures.

OPTICS

Table I gives the specifications of the terminal lens which was designed and built by National Electrostatics Corp.. Although only 12 inches long, it includes six HV feedthroughs to allow the four center elements to be independently excited for steering capability. Figure 3 shows the position of the lens within the terminal. When tuned for a given charge state and terminal voltage, the lens will transmit the chosen charge state while underfocusing lower charge states and overfocusing higher charge states. The undesired ions are intercepted by apertures located at the entrance to the HE tube and at the HE dead section. Figure 4 shows the results of optics calculations for the case of the lens tuned for $^{58}Ni^{+9}$.[4] Also shown are the profiles of the +5 and +11 charge states. The calculated exitation for the lens in this situation is 21.5 Kv for the outer elements and 26 Kv for the center elements. Figure 5 shows calculated and measured charge state distributions for the same beam without the lens. In this case, the HE tube electrostatic focusing is insufficient to focus charge states below +10 through the tube, thus the measured charge state distribution is peaked at 10+ while the calculated most probable charge state is 9+. For heavier ions, the beam divergence increase by the stripper would result in even greater skewing of the measured distribution. As shown in Figure 6, the increase in divergence for ^{127}I using a 2 µg cm^{-2} stripper foil should be about equal to that of a nickel beam with a 5 µg cm^{-2} foil. Thus we expect the FN tandem with terminal lens to provide full transmission of the most probable charge through at least A=127.

CONTROL

All the terminal electronics are controlled through a pair of microcomputers which communicate through fiber optics cables. The system has been used for the past two years to monitor the stripper foil position and the terminal ion pump current. Stripper foil movement has been controlled through a separate fiber optic actuator. The computers and fiber optics have been extremely reliable; more so than the string actuated system which they replaced. To accomodate the more complex controls of the ELQT, the system was expanded with an eight channel DAC and an eight channel ADC. Although initial tests without the HV supplies were completely successful, when the supplies were installed both of the interface devices were damaged by spark induced transients. To alleviate this problem, all of the ELQT HV supplies have been modified to be controlled by frequency modulated light signals through fiber optics. Figure 7 is a block diagram of the control system. All of the terminal data is available to the tandem monitor computer for logging.

CONCLUSION

The installation of the terminal lens system is underway and beam tests are scheduled for the last week in September or early October. The transmission for $^{64}Ni^-$, the heaviest ion beam which is presently accelerated, should be substantially increased. When ATLAS is completed and the experimental program demands heavier ions, the lens should be even more valuable.

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TABLE I

Aperture	40	mm
Element length, actual (L1,L3)	63.5	mm
(L2)	127.5	mm
Element length, effective (L1,L3)	79.25	mm
(L2)	136.5	mm
Element separation, actual	19.0	mm
Element separation, effective	9.5	mm
Element composition	titanium	
Rated element voltage	50	Kv
HV feedthroughs	6	
Rated feedthrough voltage (in air)	30	Kv
Housing diameter	203	mm
Housing length	304.8	mm

FIGURE CAPTIONS

FIGURE 1. Energy gain of the FN tandem alone and in combination with the superconducting booster and ATLAS (under construction). The curves for 1988 assume a continuing improvement in the on-line performance of the linac to the limit of the measured off-line test performance data.

FIGURE 2. Transmission of the Argonne FN tandem and beam transport for $^{58}Ni^{+10}$ as a function of foil stripper thickness at a terminal voltage of 7.7 Mv and an injection voltage of 132 Kv. The solid line is a least squares fit to the Meyer[5)] scattering formulae.

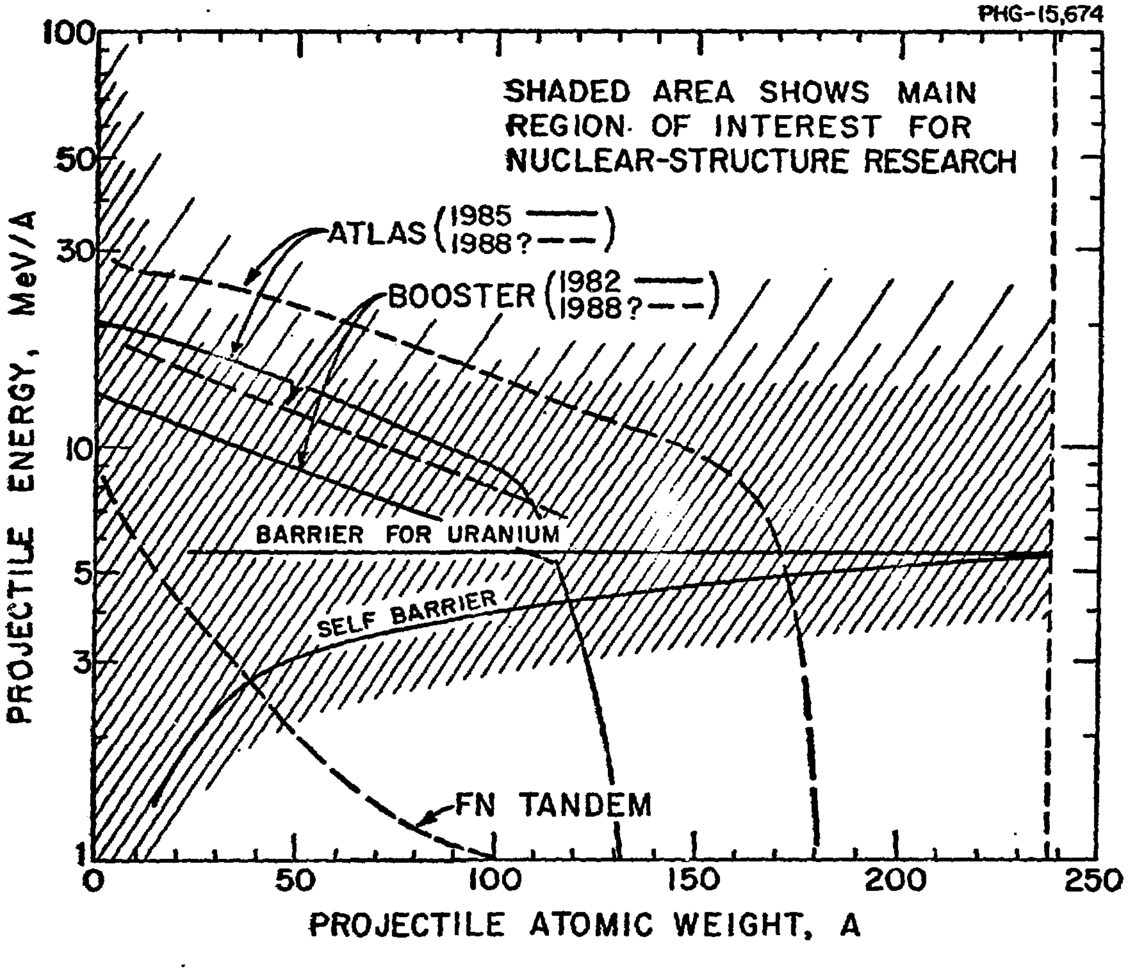
FIGURE 3. FN tandem terminal configuration with ELQT lens.

FIGURE 4. Beam profiles for three charge states of ^{58}Ni. The terminal voltage is 9 Mv, the injected beam emittance is 6 mm mrad $MeV^{1/2}$, and the stripper is 5 μg cm^{-2}. The indicated envelopes include 60% of the injected ions.

FIGURE 5. Calculated and measured charge state distributions for ^{58}Ni. The measured distribution is peaked to a higher charge state as discussed in the text.

FIGURE 6. Beam divergence after a 5 μg cm^{-2} or 2 μg cm^{-2} carbon stripping foil for ions of increasing atomic number. The terminal voltage is 9 Mv and the incident emittance is 6 mm mrad $meV^{1/2}$.

FIGURE 7. Block diagram of the FN tandem terminal control system.



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SHADED AREA SHOWS MAIN REGION OF INTEREST FOR NUCLEAR-STRUCTURE RESEARCH
ATLAS (1985 ——— 1988? – – –)
BOOSTER (1982 ——— 1988? – – –)
BARRIER FOR URANIUM
SELF BARRIER
FN TANDEM
PROJECTILE ENERGY, MeV/A
100
50
30
10
5
3
1
0
50
100
150
200
250
PROJECTILE ATOMIC WEIGHT, A

Fig. 1

TERMINAL LENS CONTROL

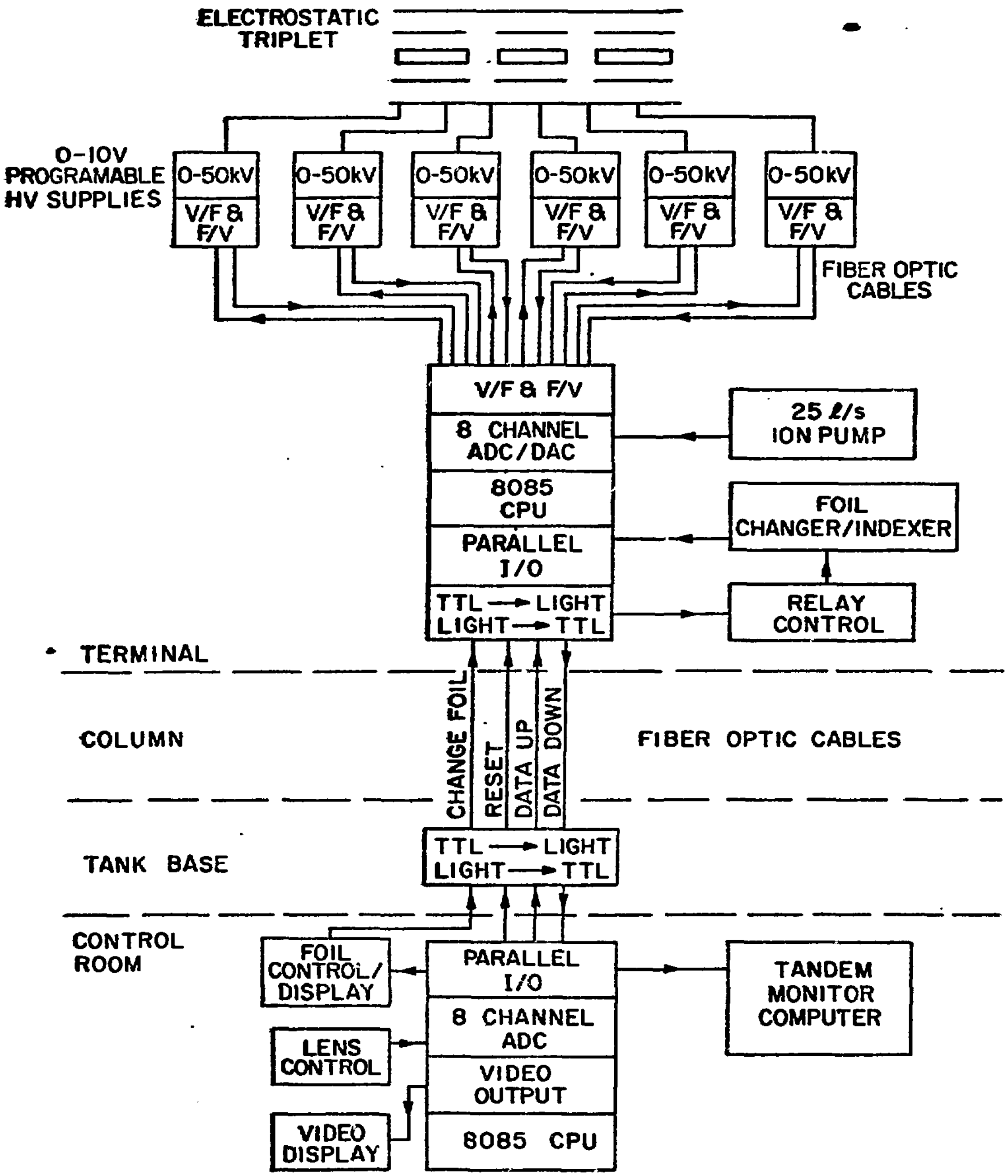

Fig. 2

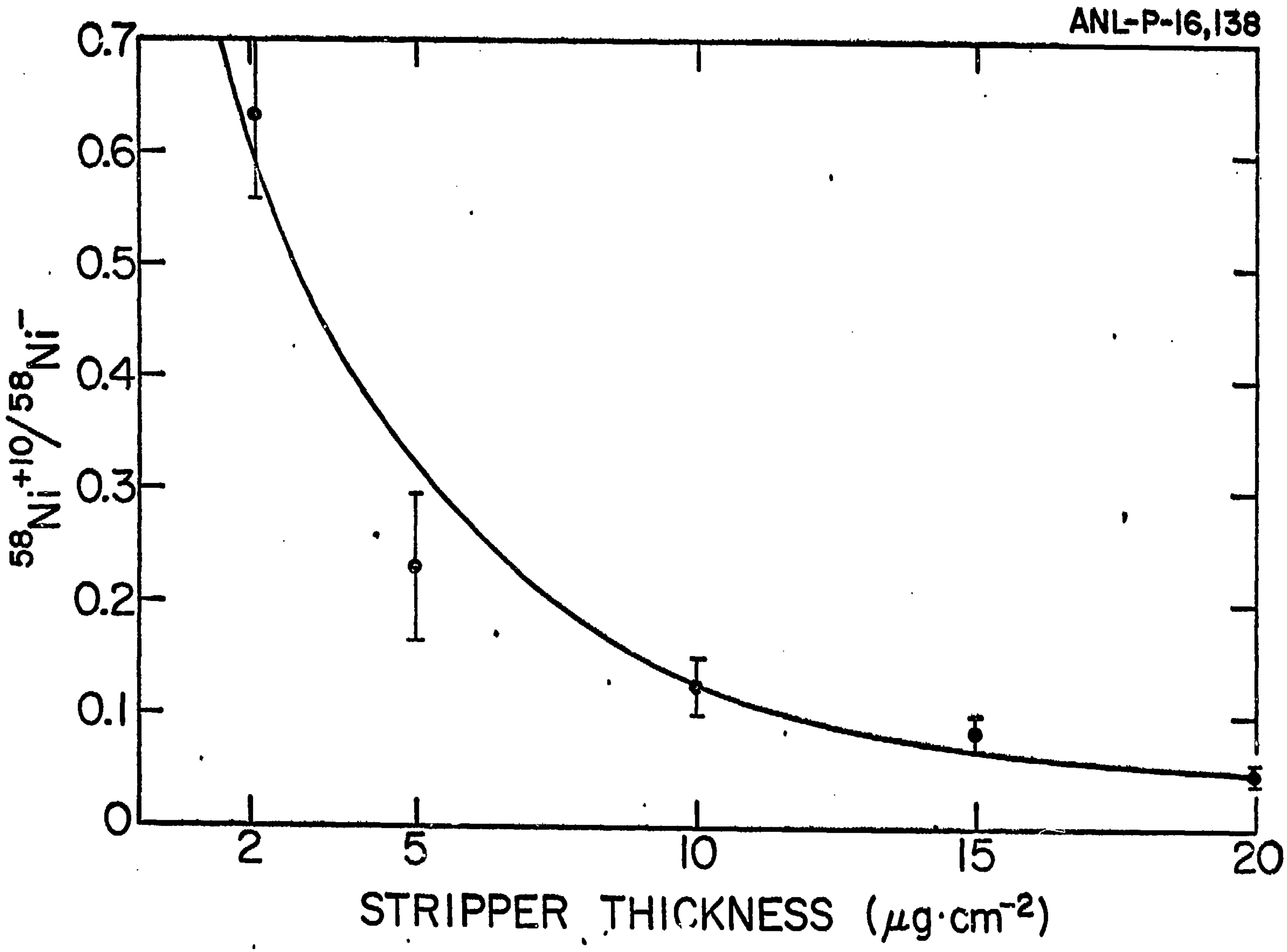
ANL-P-16,138
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
$^{58}Ni^{+10}/^{58}Ni^{-}$
2
5
10
15
20
STRIPPER THICKNESS ($\mu g \cdot cm^{-2}$)

Fig. 3

ANL-P-16,770

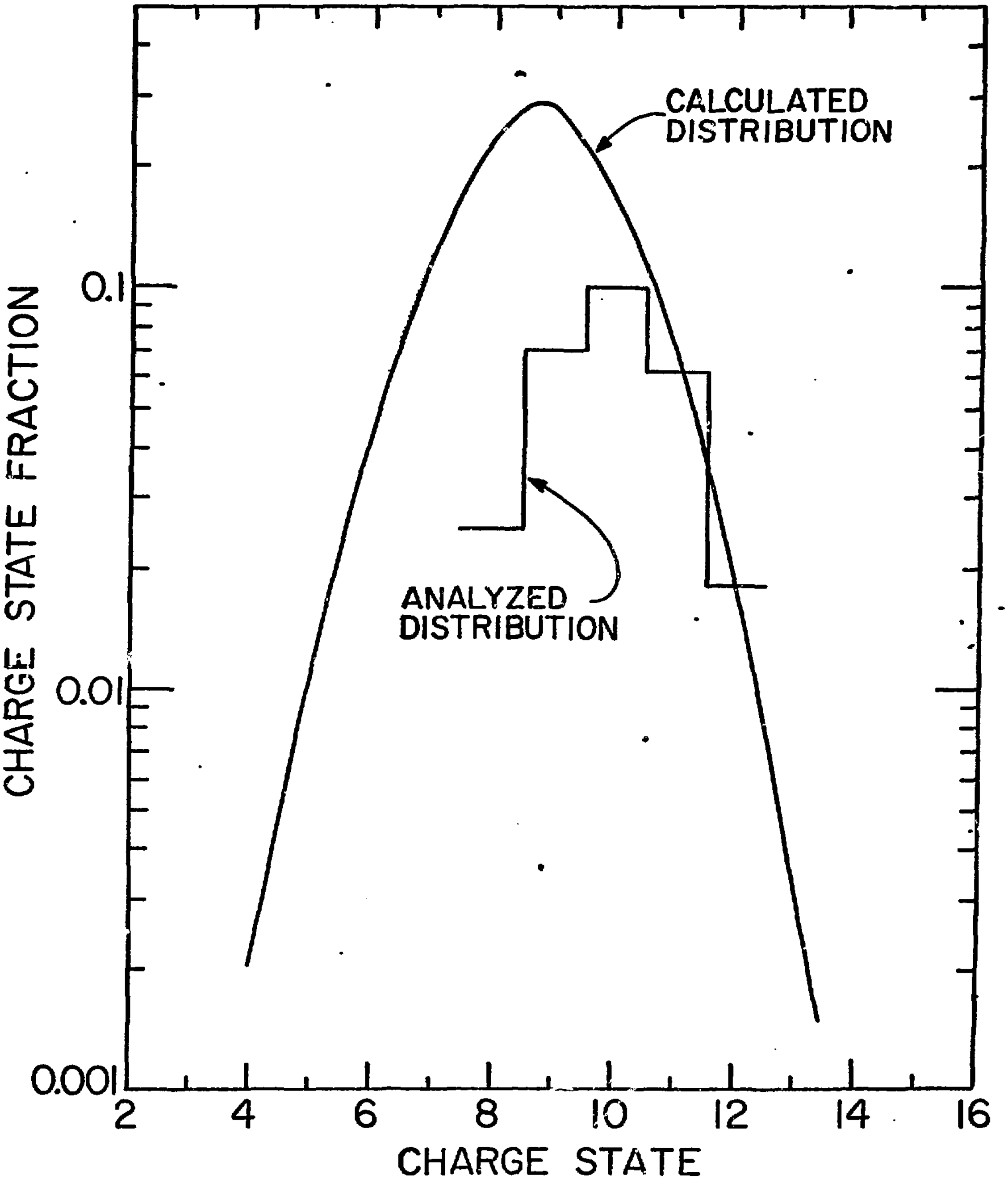

Fig. 4

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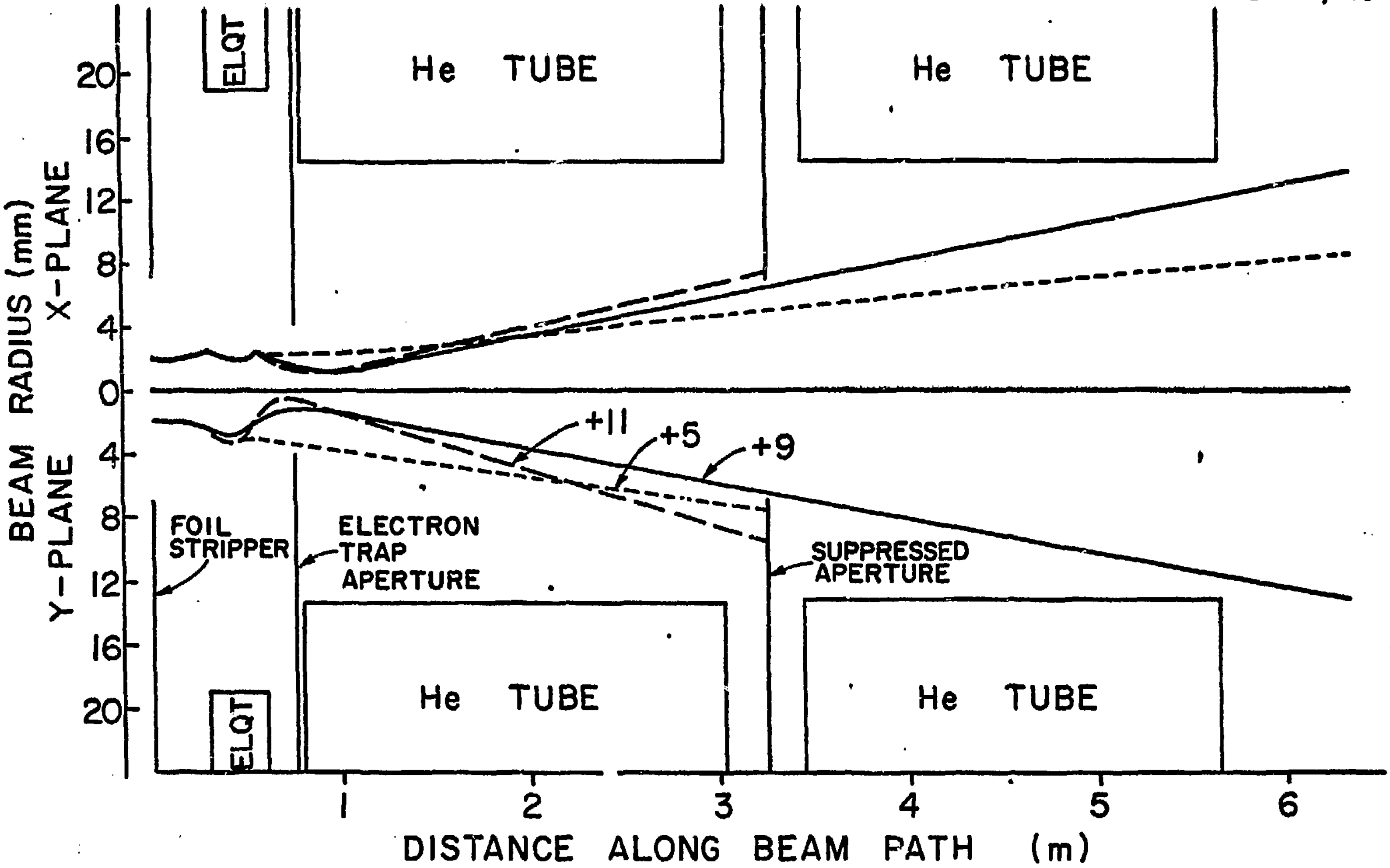
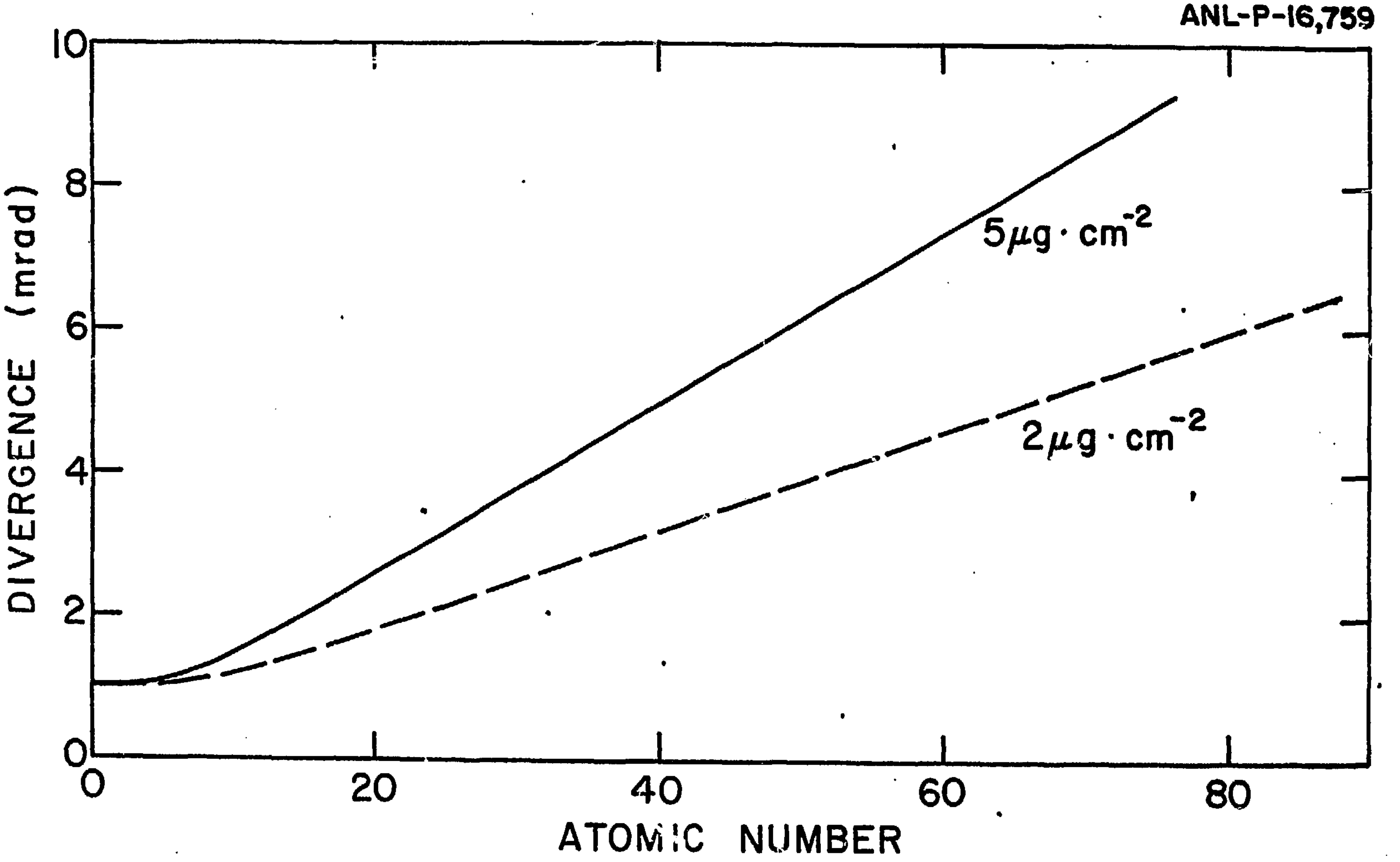


Fig. 5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DIVERGENCE (mrad)
0
2
4
6
8
10
0
20
40
60
80
ATOMIC NUMBER
$5 \mu g \cdot cm^{-2}$
$2 \mu g \cdot cm^{-2}$

Fig. 6

ANL-P-16,758

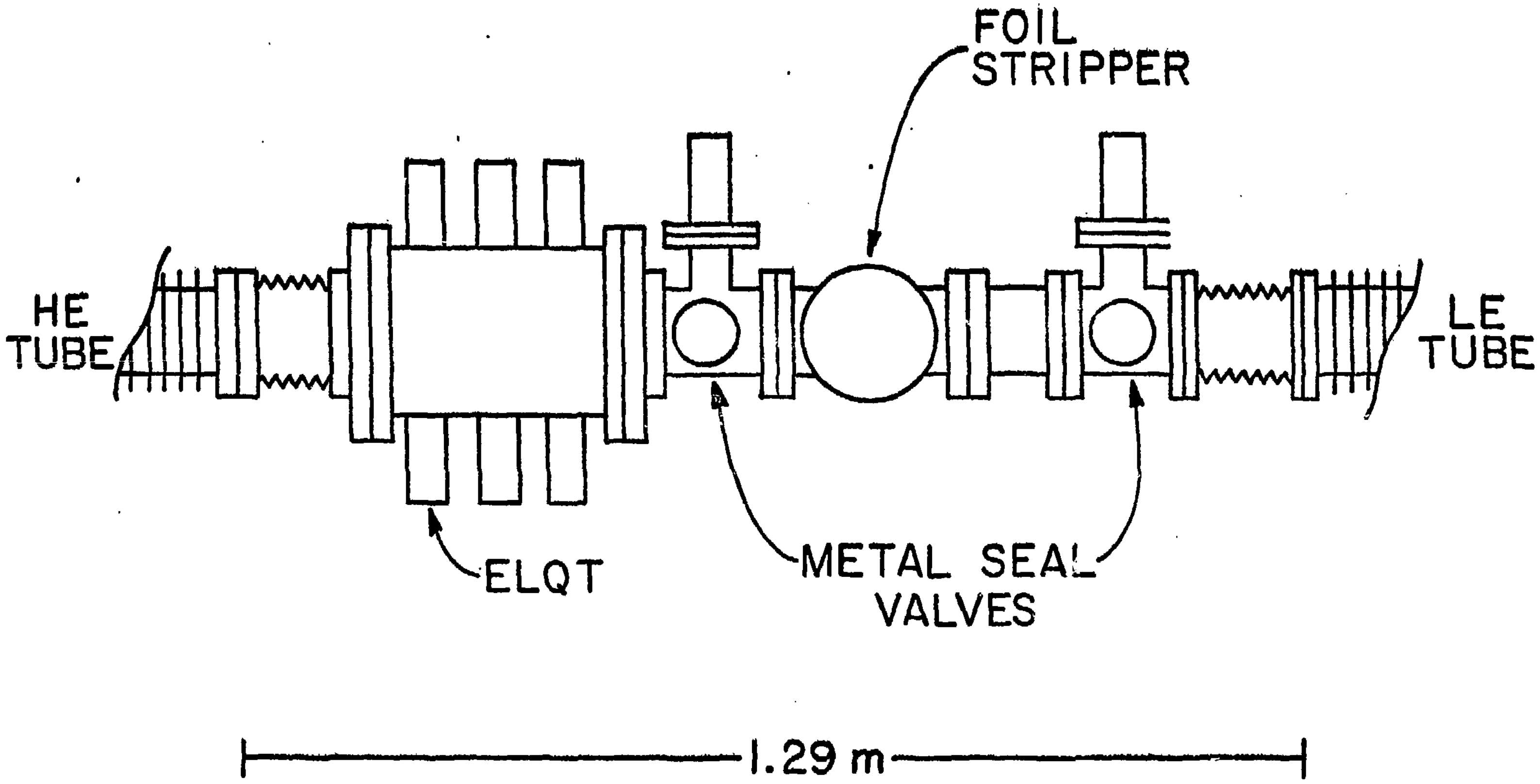

Fig. 7

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