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MEASUREMENTS OF $\sigma_f(02)/\sigma_f(28)$ AND THE VALUE OF $\sigma_f(02)$ AS A FUNCTION OF NEUTRON ENERGY

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WORK DONE BY:

C. L. Bailey
J. M. Blair
K. Greisen
A. O. Hanson
B. Long
R. F. Taschek
C. M. Turner
J. H. Williams

REPORT WRITTEN BY:

R. F. Taschek

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ABSTRACT

The relative fission cross-section of 02 to 28 has been measured as a function of neutron energy in the range 1.2 to 2.0 Mev with one other value at 3 Mev. The 02 threshold is found to be about 1.17 Mev. Values of $\sigma_f(02)$ are determined from the Wisconsin measurements of $\sigma_f(28)$. $\sigma_f(02)$ rises to about 0.1 barn at 1.6 Mev and shows a minimum of about 20 percent near 1.75 Mev. The high energy point indicates a leveling off of the cross-section above 2 Mev.

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MEASUREMENTS OF $\sigma_f(02)/\sigma_f(28)$ AND THE VALUE OF $\sigma_f(02)$ AS A FUNCTION OF NEUTRON ENERGY

Previous measurements of the fission cross-section of thorium have indicated that it has a threshold near 1.2 Mev[1] and rises rapidly to a value of about 0.1 barns[2]. The present measurements consisted of determining the ratio $\sigma_f(02)/\sigma_f(28)$ as a function of neutron energy, the thin foils of these elements being placed in the same parallel-plate ionisation chamber and simultaneously irradiated by mono-energetic neutrons from the Li(p,n) reaction.

The multiple-plate ionization chamber shown in Fig. 1 was used so that sufficient 02 could be used for a reasonable counting rate. Four 02 foils plated by Mrs. B. Long, each ~17 mm in diameter contained a total of 1.940 mg of 02 determined by weighing. Two one inch foils of 28 which were at hand contained a total of 1.823 mg 28; the material in these foils had been depleted and contained a total of only 0.57 γ of 25. These six foils were mounted on the plates of the ionization chamber as shown in Fig. 1. In order to minimize the effects of slow neutrons on the remaining 25, glass insulating rings were used rather than lucite which contains hydrogen. Nearly all the chamber was constructed of aluminum to reduce the effect of γ-rays as reported in LA-19. The two halves of the chamber (each containing two 02 and one 28 foil) were each

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[1] LA-19 -- H. T. Richards

[2] Ladenburg, Kanner, Barschall and Van Voorhis, Phys. Rev. 56, 168 (1939)

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made reversible in such a way that the 28 could also be put outside and the 02 inside, and during the course of observations the foils were reversed in order to reduce the asymmetries in the geometry. A difference of about 10 percent in $\sigma_f(02)/\sigma_f(28)$ was found on reversing the chamber, consistent in direction with the change expected from the $1/r^2$ variation of neutron flux. The chamber was always accurately centered on the target, the distance from target to first foil being 3/4" if it was 02 and 1" if 28, so a maximum angle of about 25° was subtended at the target. The commutator arrangement shown allowed the foils to be kept on the same amplifiers.

Observations were made, at small energy intervals, especially between 1.5 Mev and 1.9 Mev, of 02 fission counts, 28 fission counts and proton current incident on the Li target. In Fig. 2 the observed values of $\sigma_f(02)/\sigma_f(28)$ are plotted at the maximum neutron energy incident upon the foils. The errors shown are those of statistics only and are approximately 5 percent for all points except the first two, for which they are 9.5 percent and 8.5 percent respectively, because of the low counting rate of 02. Due to the unexpected appearance of the minimum in the cross-section of Th (see Fig. 5) near 1.8 Mev repeated observations at closely spaced energies were made with foils direct and reversed and with the whole chamber removed and replaced one or more times at several energies near the minimum. The internal consistency of the data taken in direct or reversed position is in nearly all cases well within the statistical accuracy. At the lowest point especially, at 1.79 Mev, repeated observations were made at different times, all checking very closely.

Since the Li target had a thickness of 70 kv for protons and a finite angle was subtended by the foils at the target, the effective neutron

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energy was some 50 kv lower than the maximum energy if the response of the detectors were independent of neutron energy. The angle correction is due to the variation of neutron energy over the face of the foil, and to the weighting of these energies by the foil area and the asymmetrical neutron yield. The effect of target thickness is simply to reduce the incident proton energy by 35 kv to determine the average proton energy, since in the energy interval used the neutron yield as a function of proton energy is nearly flat. In Fig. 3 the dashed curve shows $\sigma_f(02)/\sigma_f(28)$ after making the above corrections. Since the energy dependence of $\sigma_f(02)/\sigma_f(28)$ is not flat, a further correction, as shown by the solid line, consisted of weighting the energy scale by the ratio obtained from the first corrected curve.

As shown in Fig. 2 it was not practicable to take data below 1.25 Mev since the 02 counting rate was already so low. The threshold energy for the fission of 02 obtained by extrapolation of $\sigma_f(02)/\sigma_f(28)$ data is 1.17 Mev from the completely corrected data; the value 1.145 Mev is obtained if only target thickness and angle corrections are made while 1.22 Mev is found by extrapolating $\sigma_f(02)/\sigma_f(28)$ plotted at maximum energy.

In the neutron energy region up to 2 Mev, the Wisconsin data for $\sigma_f(28)$ were used to obtain $\sigma_f(02)$. The reason for this is seen in Fig. 4 where the 28 counts per μcoulomb of protons are plotted as a function of the average energy. Because of the flatness of the neutron yield at these energies, one can obtain the shape of the $\sigma_f(28)$ curve without knowing the absolute neutron flux. By normalising this curve at 1.25 Mev, where the LA handbook[3] and

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3) LA--11 -- Bethe and Christy

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Wisconsin values are identical, one finds an almost perfect fit to the Wisconsin curve, while the handbook values deviate considerably above 1.4 Mev as shown by the dashed curve in Fig. 4.

The LA-11 curve for $\sigma_f(28)$ has been drawn smoothly through the Wisconsin data and two D(dn) points[4] at 2.7 Mev and 3.8 Mev neutron energy weighting the two latter points heavily. The absolute values of $\sigma_f(28)$ in CF-636 and A-1340 are close to the extrapolated Wisconsin curve if one assumes that the D.T.M. Mn bath flux measurements and the Wisconsin OP counter measurements are both correct.

It appears from the present observations that the Wisconsin data are essentially correct, so far as relative values are concerned, up to 2 Mev, and that the curve in LA-11 gives too low values between 1.4 Mev and 1.7 Mev and too high above 1.7 Mev. A further value of $\sigma_f(28)$ of 0.49×10^{-24} cm^2 at a maximum neutron energy of 4.0 Mev is reported in EM-120.

Also plotted in Fig. 4 are the 02 counts/μcoulomb. It will be seen that while the 28 counting rate rises smoothly, the 02 counting rate (plotted at maximum neutron energy) has a considerable and reproducible dip near 1.8 Mev, showing that the minimum in $\sigma_f(02)/\sigma_f(28)$ is actually due to the 02.

The values for $\sigma_f(02)$ are shown in Fig. 5, the dashed curve plotted at maximum energy, the solid curve after making the necessary energy corrections, both curves being based on the Wisconsin $\sigma_f(28)$ data. The Wisconsin curve has been corrected for target thickness only, but an estimate from the geometry

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[4] CF-636 -- N.P. Heydenburg -- See also A-1340

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used in obtaining $\sigma_f(28)$ indicates that the response correction will roughly compensate for geometry and yield corrections. The minimum in $\sigma_f(02)$ is still clearly present, and is also present even if the LA handbook curve for $\sigma_f(28)$ is used.

To check on background and on the effect of 25 in the samples, observations were made with 600 kv neutrons, first with a quartz plate stopping the proton beam in front of the target and then with the 600 kv neutrons incident on the foils. No appreciable effect was found with the quartz in, while with the quartz out a very small counting rate was obtained from the 28 foil (much less than one percent of the counting rate at 1.4 Mev). No counts were obtained from the 02 foils.

A further value of $\sigma_f(02)/\sigma_f(28)$ was obtained at a maximum neutron energy of 3.1 Mev using the 0° neutrons from the D-D source. This source was made available by the courtesy of the P3 group. The effective neutron energy from the thick D target is not known in this case but lies somewhere between 2.5 and 3.1 Mev. The value $\sigma_f(02)/\sigma_f(28) = 0.175 \pm .01$ from all data taken is subject to some doubt since reversing the orientation of the foils changed the ratio in the wrong direction from what was to be expected. Two separate sets of data, taken on one side before and after reversal, check well within statistical accuracy so the doubt is thrown upon the other orientation on which unfortunately only a single set of observations were made. If data from both foil orientations is used $\sigma_f(02) = 0.118 \pm 6$ percent barns, based on a value of 0.675 barns for $\sigma_f(28)$ extrapolated from the Wisconsin data, while by using the presumably more reliable ratio from the checked foil orientation one finds $\sigma_f(02) = .100 \pm 6$ percent barns. The corresponding values based on the LA

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handbook value of 0.94 for $\sigma_f(28)$ at 3 Mev are 0.165 and 0.139.

Ladenburg et al[2]) have published $\sigma_f(02) = 0.1$ and $\sigma_f(28) = 0.5$ barns with a probable error of about 25 percent at 2.4 Mev effective neutron energy. They have also given four ratios $\sigma_f(02)/\sigma_f(28)$, which are subject to an uncertainty in the relative masses of their samples, but which, if normalized to the above absolute values, become 0.223 barns at 2.11 Mev, 0.20 at 2.42 Mev, 0.20 at 2.9 Mev and 0.21 barns at 3.12 Mev. These overlap in energy the D-D point taken in this experiment, and the presumably most relaible value of the ratio here observed is about 20 percent lower. If, however, one assumes that their $\sigma_f(02)$ value is better than $\sigma_f(28)$ (since even the extrapolated Wisconsin data gives $\sigma_f(28) = 0.58$ barns at 2.42 Mev) then $\sigma_f(02)/\sigma_f(28) = 0.172$ at 2.42 Mev, in much better agreement with the present data. It therefore appears that $\sigma_f(02)$ remains roughly constant above 2 Mev at a value somewhere near 0.1 barns the most doubtful information being the value of $\sigma_f(28)$ above this energy.

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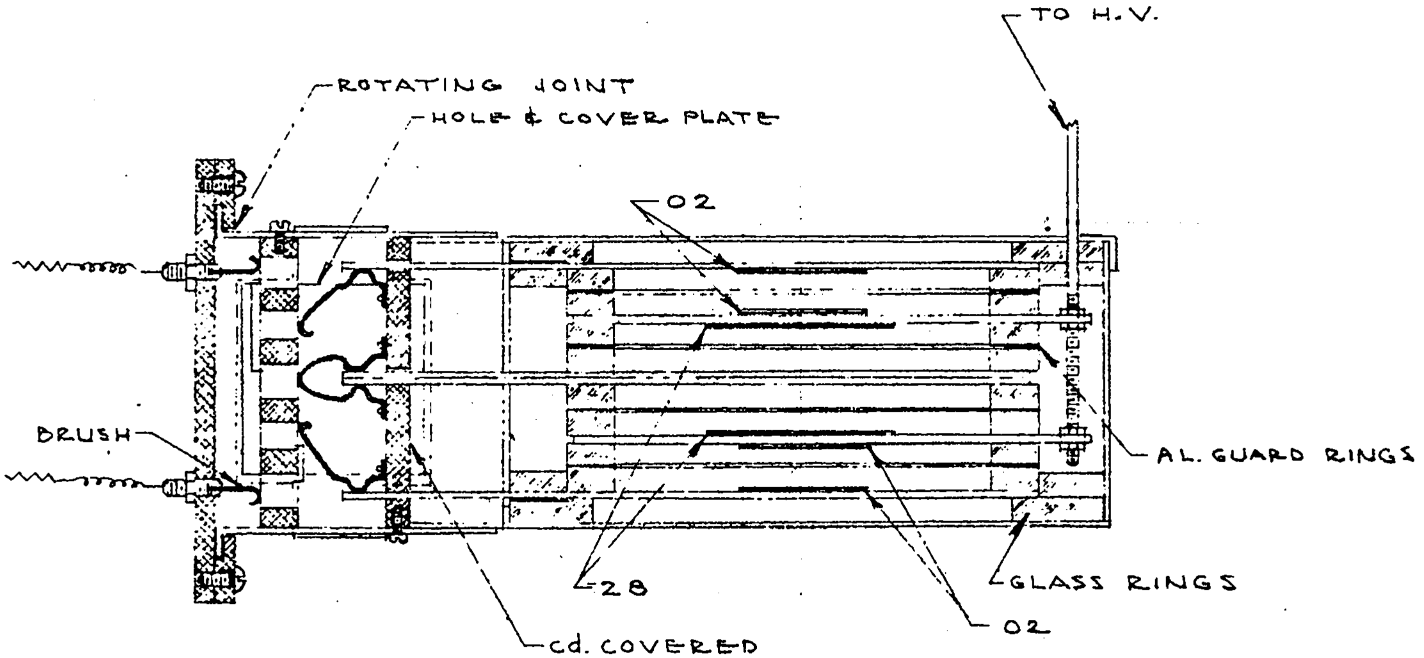

Fig 1

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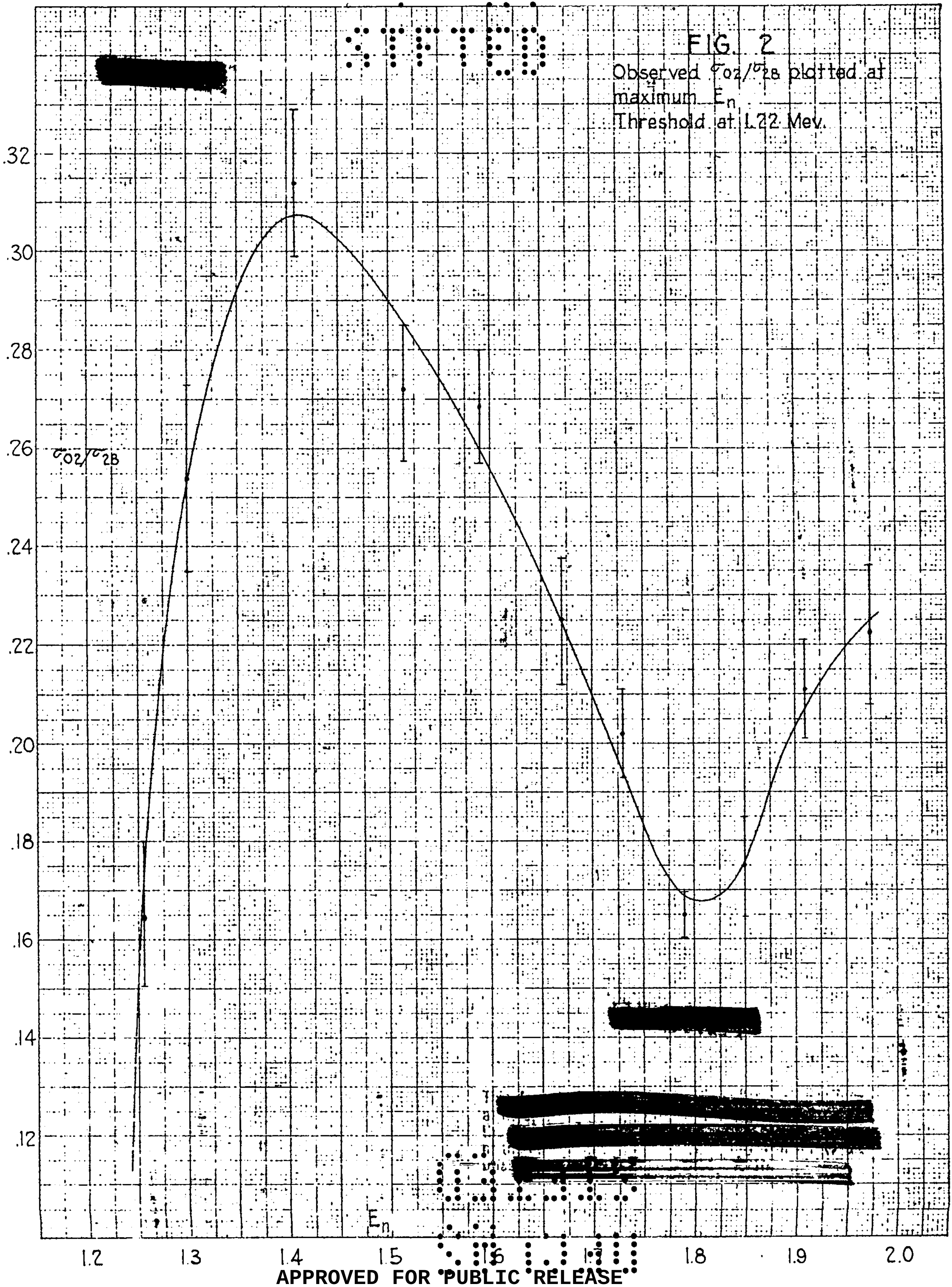

FIG. 2

Observed σ_{02}/σ_{28} plotted at maximum E_n
Threshold at 1.22 Mev.

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FIG. 3

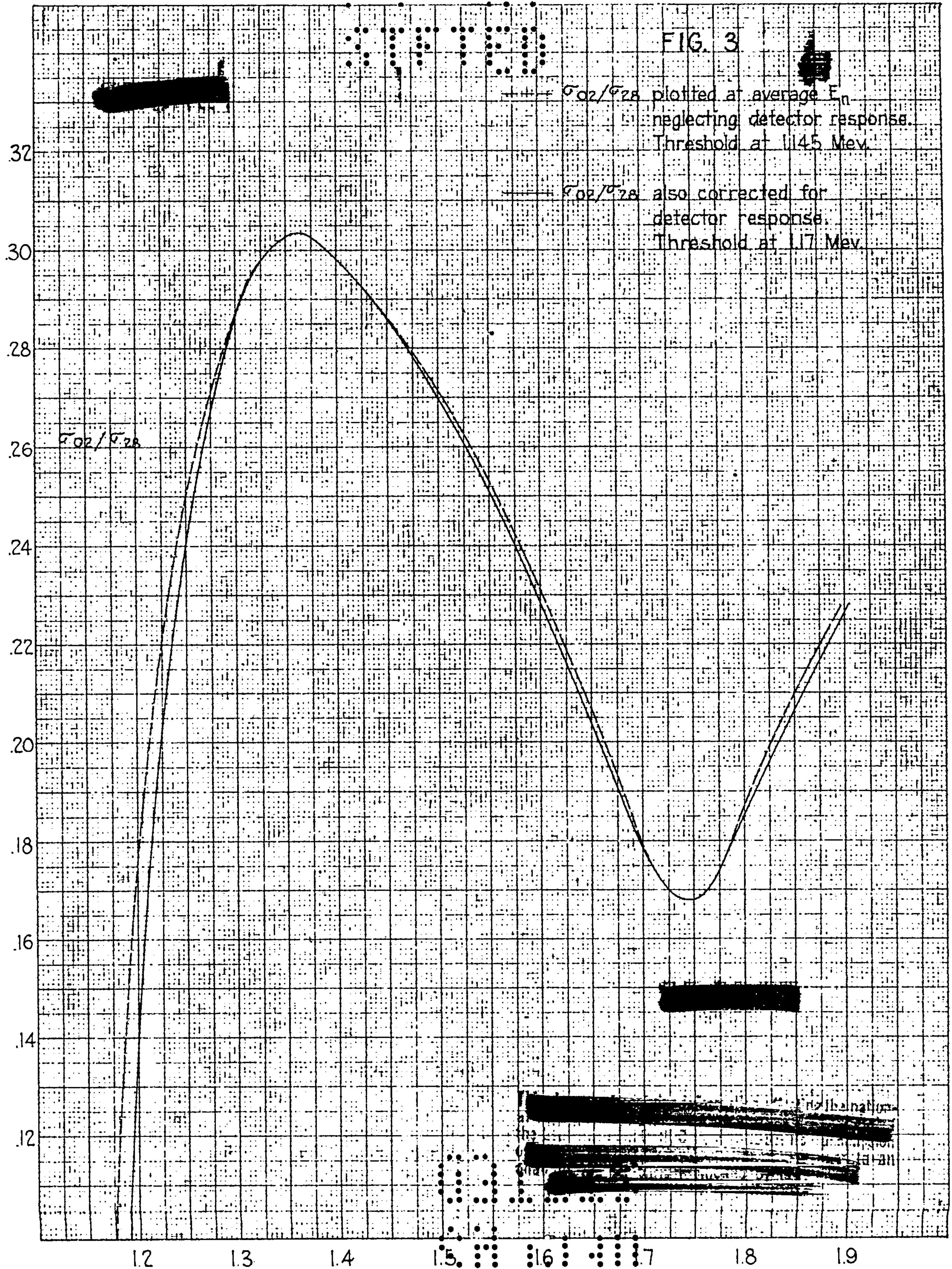

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FIG. 4

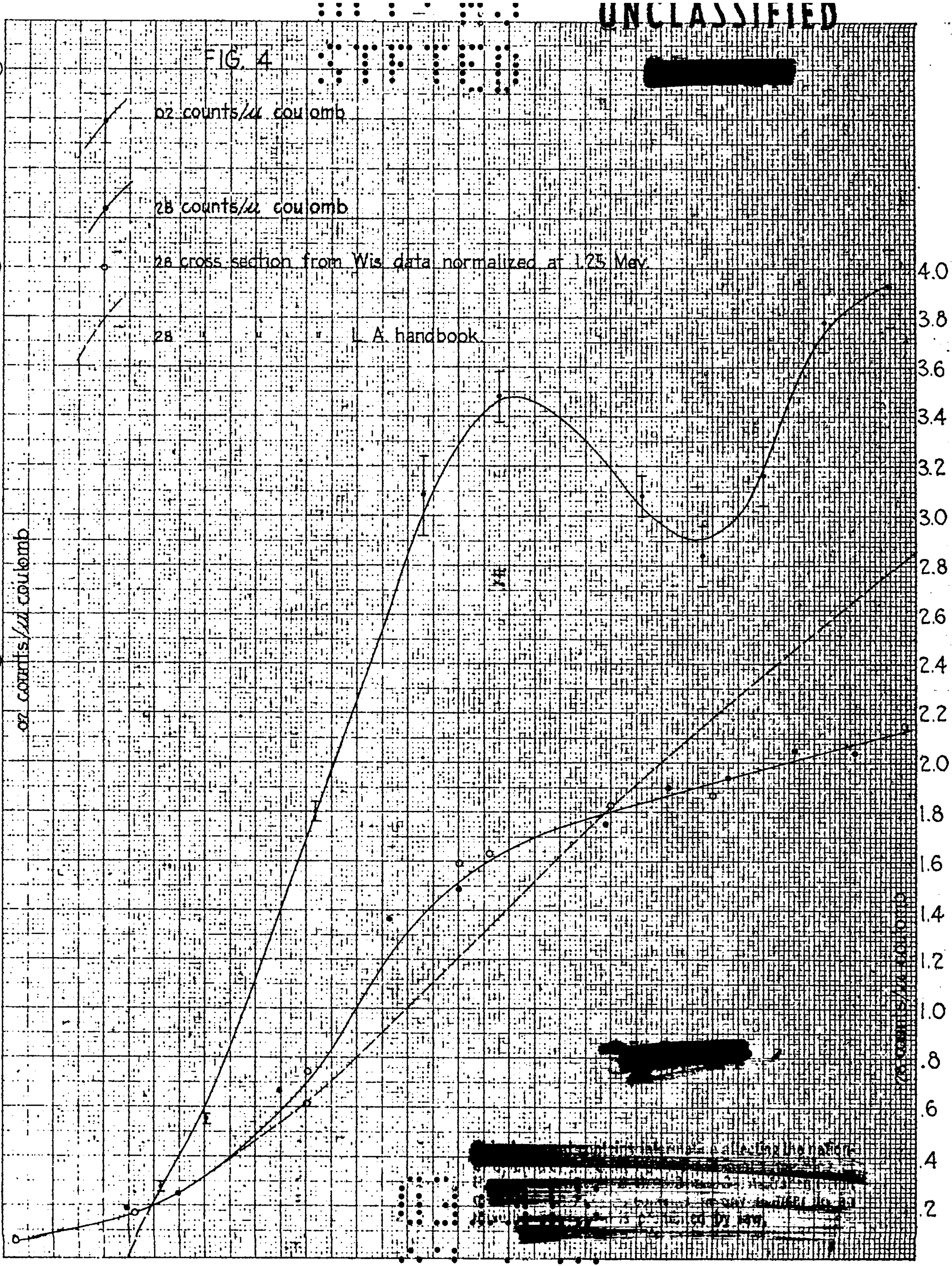

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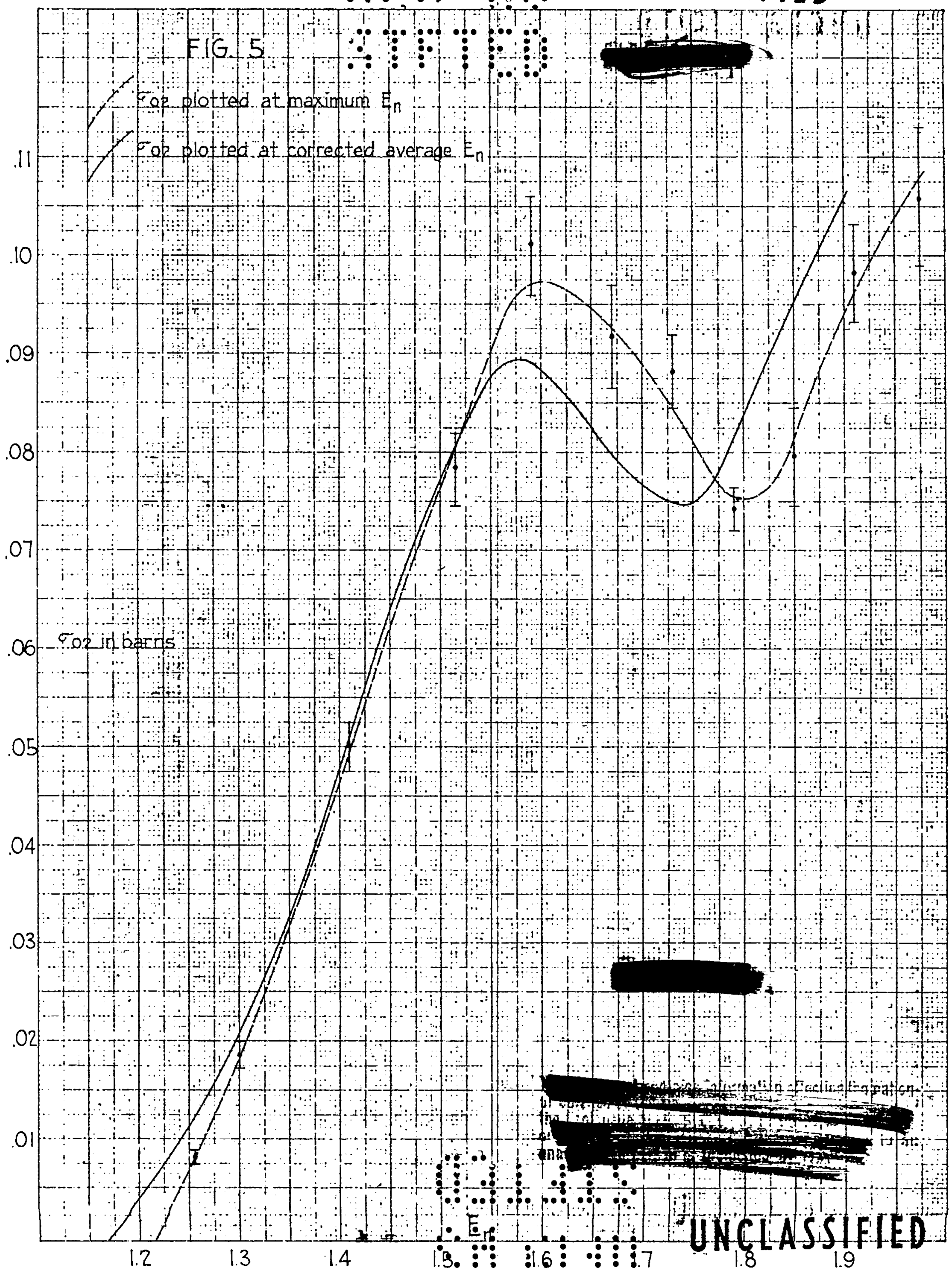
FIG. 5



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