GAMMA RAY ABSORPTION IN PROPANE

A calculation has been made of the absorption of γ-rays by Compton Scattering and by pair production in the field of the carbon and hydrogen nuclei and the atomic electrons.

Compton Scattering

The total cross-section was calculated by integrating the formula of Klein and Nishina [1] and is shown in Fig. 1. However, in practice only electrons above a certain energy will be efficiently observed and correlated with their true origins. Therefore a partial cross-section was also calculated for Compton scattering giving rise to electrons of energy greater than 10 MeV. This cross section is also shown in Fig. 1.

Pair Production

Pair production cross-sections may be calculated with the theory of Bethe and Heitler [2]. The Coulomb corrections calculated by Davis, Bethe and Maximon [3], which are important for lead, are negligible for light elements such as carbon and hydrogen. However, the Bethe-Heitler formula becomes incorrect at low energy and an empirical correction is generally made. This has been done by Grodstein [4] who has tabulated the cross sections upto 100 MeV. Above this energy we have used the fact that for the Bethe-Heitler theory

$$\sigma_{pair} (Z, k) = \sigma_{pair} (Z_o, kZ^{1/3} Z_o^{-1/3}) - \frac{28}{27} \, \phi \, \log \frac{Z}{Z_o}$$

k = photon energy

Z, Z_o are the atomic numbers of two different nuclei

$\phi = \dfrac{Z^2 r_o^2}{137}$ r_o = classical electron radius.

The Bethe-Heitler cross section for lead with the inclusion of the screening corrections is given in Segrè [5]. Using the above formula we have calculated the cross-sections for hydrogen and carbon up to 1200 MeV. At 100 MeV these cross-sections join smoothly to those of Grodstein. The results are shown in Fig. 1.

The pair production in the field of the atomic electrons has not been calculated in a satisfactory way. Grodstein uses the calculation of Joseph and Rohrlich [6] but this disagrees with the experimental measurements which have been made of this process [7]. These measurements are in agreement with the earlier calculation of Wheeler and Lamb [8] which predicts that the total cross-section should be nearly $(\frac{Z+1}{Z})$ times the nuclear cross-section. In view of these uncertainties we have included pair production in the field of the atomic electrons by increasing the nuclear cross-section by a factor $(\frac{Z+1}{Z})$. Since this process accounts for about 20 % of the total pair production its uncertainty constitutes the major uncertainty in the calculated cross-sections. It would seem reasonable to attribute an uncertainty of $\pm$ 5 % to the cross-sections.

In Fig. 2 is shown the mass absorption coefficient μ calculated from the cross-sections shown in Fig. 1. The mass absorption coefficient is defined by :

$$I = I_o \, e^{-\mu t}$$

where I is intensity of γ-ray beam at thickness t

I_o is intensity of γ-ray beam at t = 0

t is thickness of propane traversed in grams/cm^2.

G. Myatt
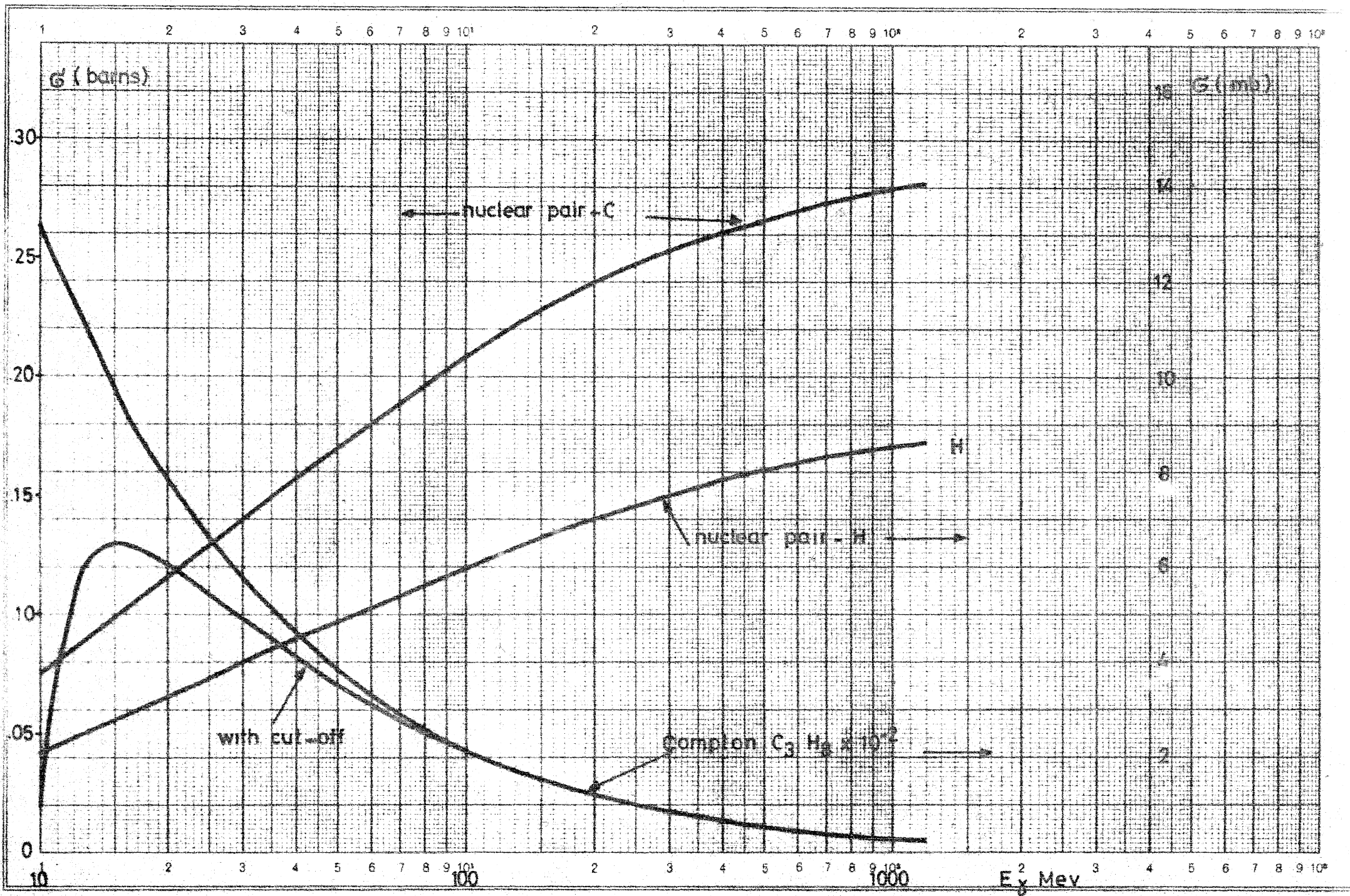
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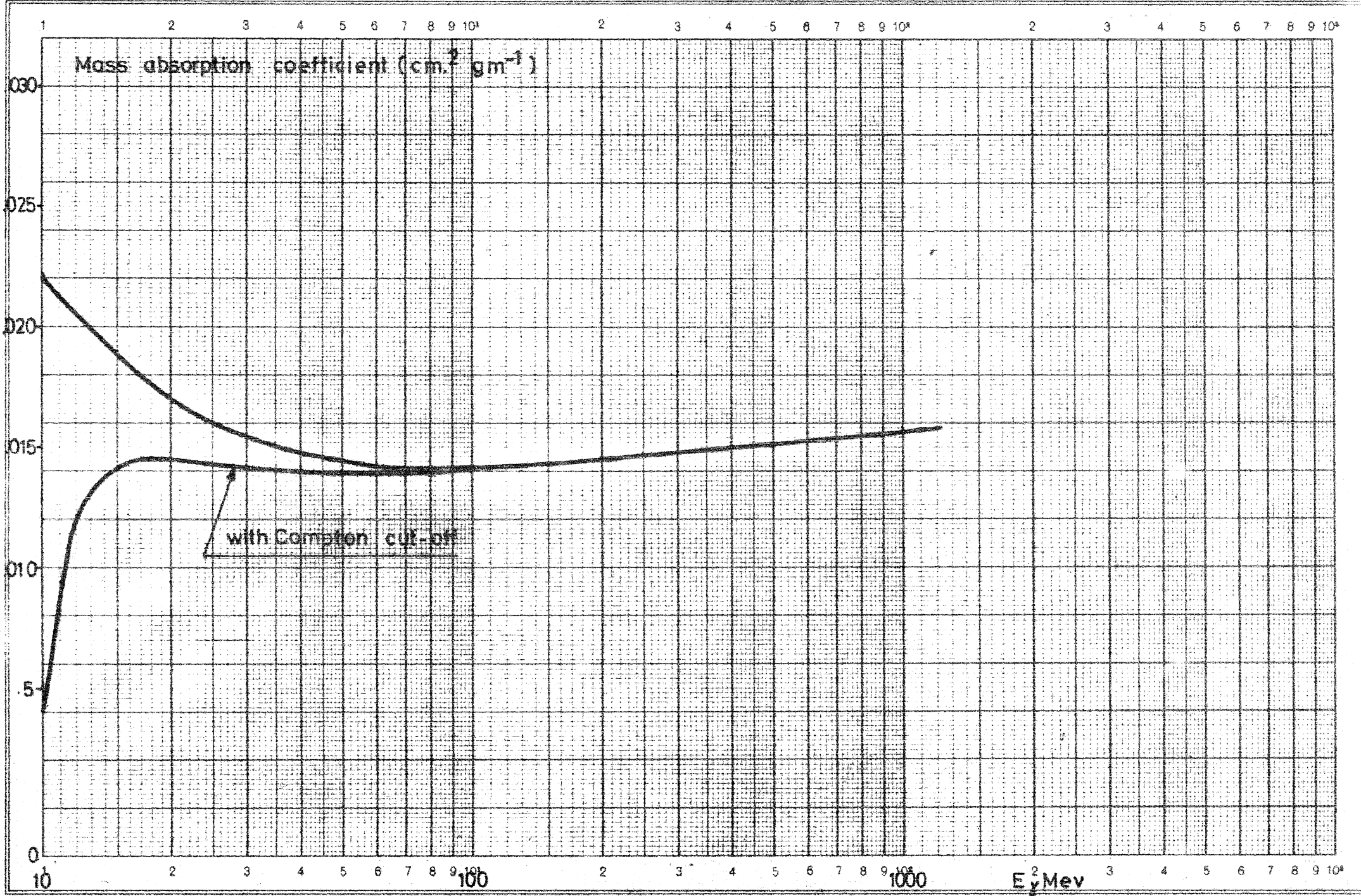Scientific staff of N.P.A.

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Figure Captions

Fig. 1   Calculated cross-sections for Compton Scattering and Nuclear Pair Production.

Fig. 2   Mass Absorption Coefficient for γ-rays in Propane.

σ (barns)

σ (mb)

nuclear pair - C

nuclear pair - H

H

with cut-off

Compton $C_3 H_8 \times 10^{-2}$

E_γ Mev

Fig 2