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THEORETICAL AND EXPERIMENTAL STOPPING POWERS FOR HEAVY CHARGED PARTICLES IN TL PHOSPHORS

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1. INTRODUCTION

In neutron dosimetry and dosimetry of charged particle with thermoluminescent dosimeters the stopping powers of ions in luminophors are needed/1,2/. These stopping powers can be calculated. For stopping calculations the program STOPOW'82 was developed/3/. But it is necessary to determine the stopping power values of different luminophors in experiments. The aim of this work was to develope an experimental method and an apparature for measurement of stopping powers of thin layers of different materials. Furthermore it is necessary to compare the experimental and theoretical results.

2. CALCULATION PROCEDURE

Stopping powers were theoretically calculated by using the program STOPOW/82/3/. This program gives mass stopping powers. One gets the corresponding stopping powers by multiplication with the density of the given material.

3. EXPERIMENTAL DETERMINATION OF STOPPING POWERS

For precise measurements of stopping powers and the so-called relative light conversion factors a special apparatus was developed/2/. Figure 1 shows the schematic construction of this apparatus. The ion beam coming from the accelerator first has to pass the collimator (1). This guarantees that the ions hit the centre of the scattering target (2). Behind this scattering target there is a Faraday cup (3) for the absorption and the current measurement of the primary beam.

In the beam between target and irradiated TL materials one has the possibility of introducing aluminium absorbers (4). By this the energy of the scattered ions can be varied. In the described measurements the energy variation was directly done by changes of the energy of the primary beam.

For the experimental determination of the stopping power averaged over the effective luminophor thickness thin layers of the luminophor material (5) were put over a special diaphragm (6). All particles passing the diaphragm are counted with a semiconductor detector which also enables the determination of the

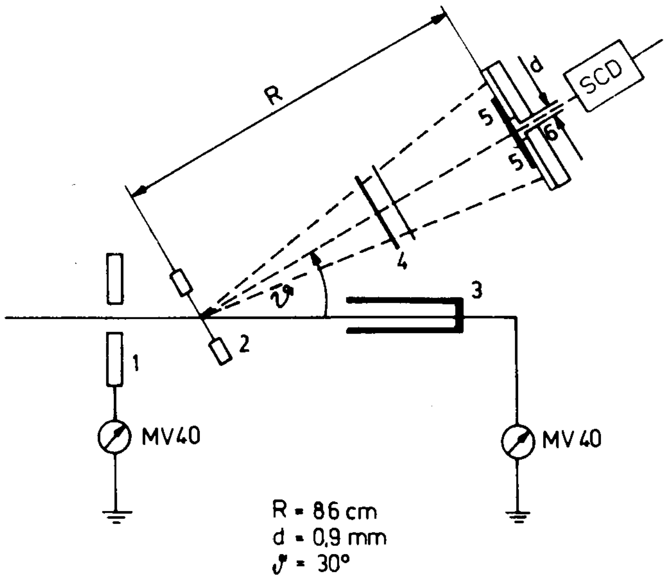


Fig. 1. Equipment for the experimental determination of stopping power (schematically).

energy spectrum. As detector there was used a Si-(Li) semiconductor detector with a sensitive layer of 3 mm (dead layer <0.5 μm); with it one has the possibility of measuring the spectra of protons up to energies of 24 MeV. The energy resolution for 5.14 MeV alpha particles is about 36 keV. The detector signals were amplified and the particle spectra were won by pulse height analysis. For the calibration of the semiconductor spectrometer the alpha radiation of a ^{239}Pu source (E_α = = 5.14 MeV) and a mercury pulse generator were used.

For a material layer of the thickness d the mean stopping power ($\overline{dE/dx}$) can be determined from the energy spectrum of the particles before and after putting the layer:

$$\overline{\frac{dE}{dx}} = \frac{E - E'}{d}$$

with E and E′ as the mean energy without and with the layer. The error in the energy determination amounts to about 0.7%. The stopping powers were measured for LiF, CaF_2 and $CaSO_4$. One must emphasize that these samples were not special TL detectors but single crystals of the given materials. For each material two thicknesses were investigated (see Table 1; there also the used densities are given).

Table 1.

Parameters of the used materials

		LiF	CaF_2	$CaSO_4 \cdot 2\ H_2O$
ρ	$/g \cdot cm^{-3}$	2.60±0.02	3.17±0.03	2.32 /4/
d_1	/μm	62.5±2.5	41±2	72.5±2.5
d_2	/μm	92.5±2.5	92±2.5	77.5±2.5

4. COMPARISON BETWEEN THEORETICAL AND EXPERIMENTAL RESULTS

Experiments were carried out at the Tandem generator EGP-10-1 of the Central Institute for Nuclear Research, Rossendorf. The samples were irradiated with protons in the energy range from 3 to 8 MeV. The calculated stopping powers for the initial energies and the experimental results for the two thicknesses d_1 and d_2 of the luminophor material are summarized in tables 2-4. The errors for the experimental stopping powers amount to about 20% (these high relative errors are caused by the fact that according to eq.(4) one has small differences of big values). The experimental results indicate that there is no need for extreme thin material because the accuracy in all cases for the thicker layer is better.

Table 2.

Calculated and experimental stopping powers for protons in LiF

E in MeV	$(dE/dz)_{calc}$ in MeV/cm	$\overline{(dE/dx)}_{exp}$ in MeV/cm	
		d_1	d_2
4.172±0.036	185.7	209±38	218±32
5.144±0.036	158.2	167±30	170±26
5.857±0.036	143.1	144±27	144±23
6.557±0.036	131.1	128±24	132±20
7.266±0.030	120.9	117±16	121±15
8.136±0.018	110.6	113±14	107±12

Table 3.

Calculated and experimental stopping powers for protons in CaF_2

E in MeV	$(dE/dx)_{calc}$ in MeV/cm	$\overline{(dE/dx)}_{exp}$ in MeV/cm d_1	d_2
3.227±0.054	254,6	268±62	-
4.172±0.036	211.0	219±60	236±44
5.144±0.036	180.7	176±44	183±25
5.857±0,036	164.0	153±38	160±22
6.557±0.036	150.6	137±26	143±20
7.266±0.030	139.3	132±27	129±18
8.136±0.018	127.8	120±22	117±13

Table 4.

Calculated and experimental stopping powers for protons in $CaSO_4 \cdot 2H_2O$

E in MeV	$(dE/dx)_{calc}$ in MeV/cm	$\overline{(dE/dx)}_{exp}$ in MeV/cm d_1	d_2
3.227±0.054	129.8	147±32	158±27
4.172±0.036	107.3	111±24	115±22
5.144±0.036	91.7	105±22	103±22
5.857±0.036	83.1	86±20	104±21
6.557±0.036	76.3	77±18	78±16
7.266±0.030	70.5	-	73±13
8.136±0.018	64.6	-	65±10

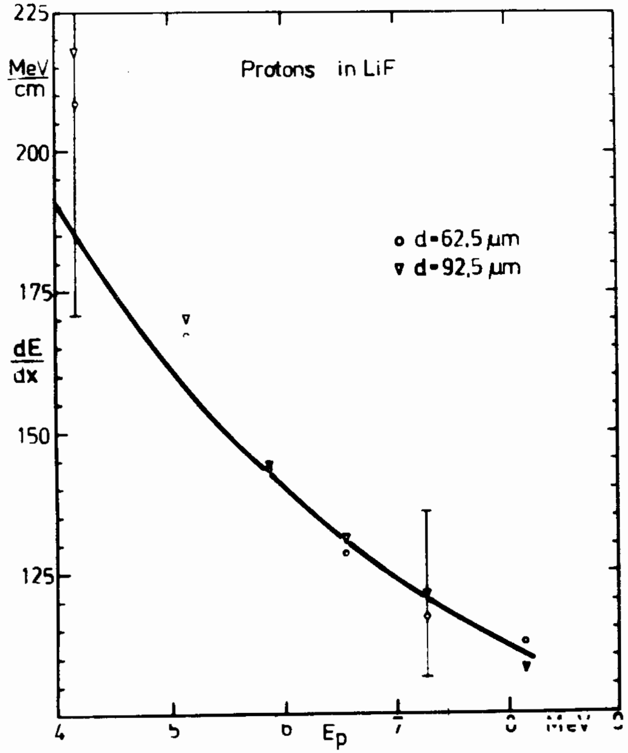
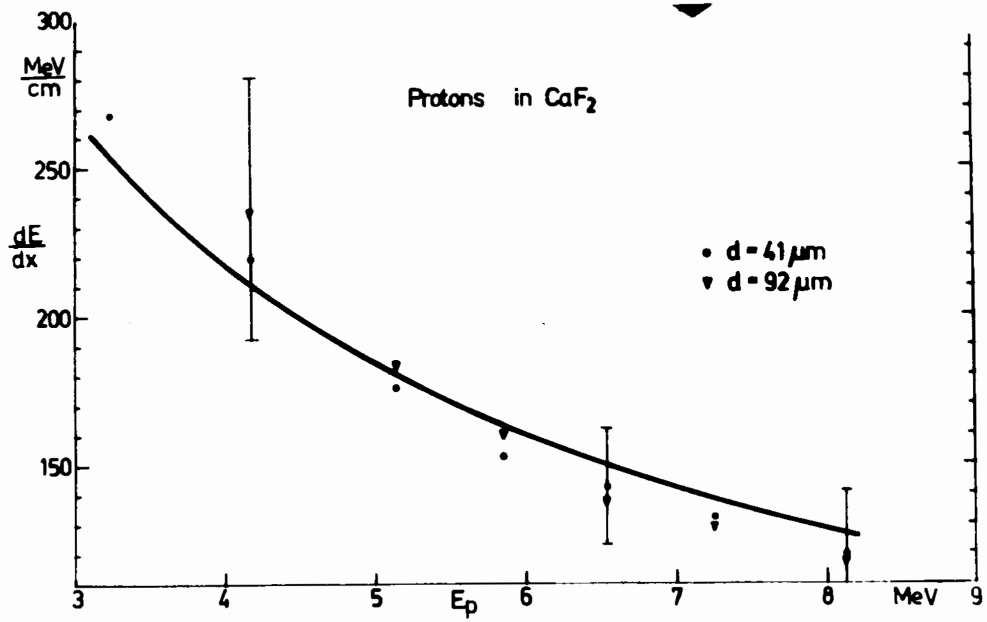


Fig.2. Stopping powers for protons in LiF.

Fig.3. Stopping powers for protons in CaF_2.



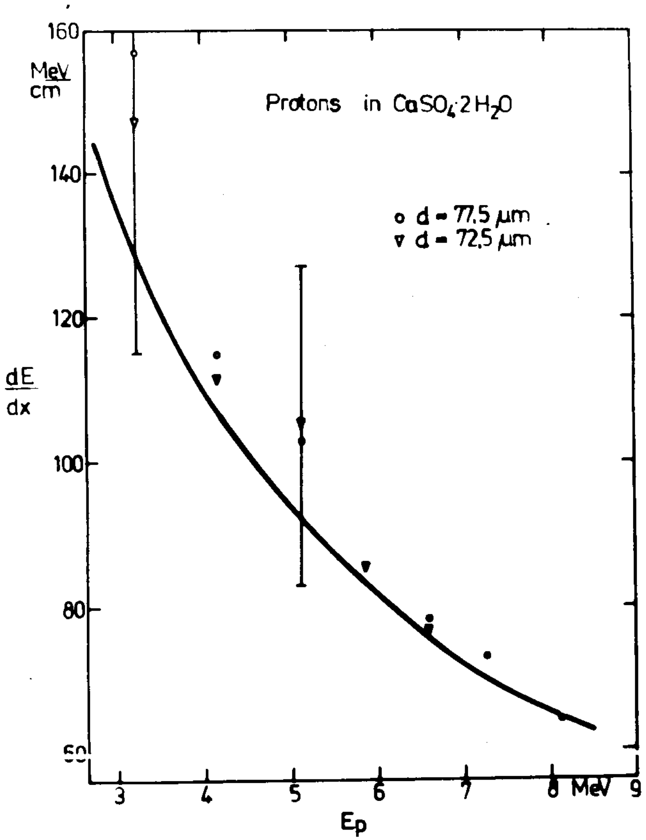


Fig.4. Stopping powers for protons in $CaSO_4 \cdot 2H_2O$.

For comparison of theoretical and experimental results the representation of figs.2-4 is more convenient. The drawn curve in these figures represents the calculated stopping powers. For all 3 TL phosphors there is a good agreement between calculation and experiment.

Therefore one can finally conclude: in all cases where stopping powers for TL materials are needed the use of calculated values is possible.

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Феллингер Ю. и др. E16-83-513
Расчетные и экспериментальные тормозные способности тяжелых заряженных частиц в люминофорах

Тормозные способности ионов вычислялись с помощью программы STOPOW/82. Сделана попытка усовершенствовать экспериментальный метод и систему приборов для измерения тормозной способности тонких слоев различных материалов; сделано сравнение экспериментальных и теоретических результатов, полученных для материалов LiF, CaF_2 и $CaSO_4 \cdot 2H_2O$ и бомбардировки протонов.

Работа выполнена в Отделе радиационной безопасности и радиационных исследований ОИЯИ.

Сообщение Объединенного института ядерных исследований. Дубна 1983

Fellinger J. et al. E16-83-513
Theoretical and Experimental Stopping Powers for Heavy Charged Particles in TL Phosphors

Stopping powers were calculated with the help of the program STOPOW/82. This work was to develope an experimental method and apparature for measurement of stopping powers of thin layers of different materials, and the experimental and theoretical results are compared for LiF, CaF_2 and $CaSO_4 \cdot 2H_2O$ materials and protons bombarding.

The investigation has been performed at the Department of Radiation Safety and Radiation Researches, JINR.

Communication of the Joint Institute for Nuclear Research. Dubna 1983