Gamma Spectroscopy

Anton Haase, Michael Goerz

Introduction:

There are three different types of radioactive decay. They are called α-, β- and γ-decay, where α- and β-decay are elementary particles and γ-decay means the emission of electro-magnetic radiation. The samples used in this experiment decay into stable (or nearly stable) isotopes. In all cases, γ-radiation of different energy is been emitted, which can be measured by a multi channel analyser. This radiation is been absorbed by any matter in dependency of the density of the material and the energy of the radiation. This behavior can be described by the following equation for the intensity:

$$I(x) = I_0 \cdot e^{-\mu \cdot x}$$

I_0 beeing the initial intensity and μ beeing the absorption coefficient.

The absorption described can appear in three different ways. The photoelectric effekt means an energy exchange between a gamma quant and an electron. The whole energy of the gamma quant is ~~been~~ transfered to the electron, which leaves the atomic union. During this process x-rays are ~~been~~

emitted, This is a characteristic radiation for the exposed material.

Another way of absorption is the compton effect. In this case, the incoming radiation is scattered on the material. The energy of the emitted photons is dependents on the angle. The absorbed energy is given as:

$$T = \frac{E_0}{1 + \frac{m_0 c^2}{(1-\cos\vartheta) E_0}}$$

E_0 beeing the initial energy of the radiation

The third possibility of absorption is the pair production effect. This means the transformation of energy in matter (a pair of electron and positron) according to Einstein's equation:

$$E = mc^2$$

The reversal of this process is the transformation of one electron and one positron into a radiation, which can be measured.

Experiment

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Anton Haase, Michael Goerz

Start: 9^{35}

Tutor:

Assignment 1:

Measurement of natural ion dosis rate: 0,111 µSv/h

Measurement of the ion dosis rate of ^{60}Co: 0,178 µSv/h

Assignment 2:

Co:

Kanal	Counts	2nd m.	Kanal	Counts	2nd m.
186	97	151	203	58	69
187	135	158	204	55	107
188	157	215	205	96	127
189	188	247	206	112	219
190	230	391	207	143	239
191	310	332	208	216	293
192	322	355	209	215	282
193	224	289	210	254	286
194	318	245	211	284	289
195	294	266	212	300	241
196	239	176	213	239	206
197	179	139	214	221	153
198	151	87	215	160	91
199	111	73	216	101	60
200	83	59	217	62	35
201	53	49	218	45	33
202	39	51	219	27	18

Cs:

Kanal	Counts	2nd m.
110	63	79
111	71	98
112	104	135
113	136	208
114	190	294
115	270	379
116	375	518
117	533	664
118	706	893
119	853	1066
120	943	1099
121	1069	1100
122	1166	1055
123	1101	930
124	906	696
125	707	562
126	555	356
127	357	228
128	257	138
129	165	82
130	97	50
131	65	57
132	46	38
133	41	30
134	37	35

Na: (e^+e^- - radiation)

Kanal	Counts	2nd m.
85	74	68
86	100	117
87	111	130
88	148	174
89	236	259
90	307	415
91	445	539
92	558	662
93	684	741
94	784	871
95	872	940
96	864	797
97	806	718
98	745	606
99	589	443
100	416	326
101	264	202
102	167	131
103	119	100
104	88	68
105	50	53

Na:

Kanal	Count	2nd m.
195	10	12
196	13	26
197	32	38
198	31	41
199	53	72
200	68	82
201	85	108
202	103	135
203	134	157
204	138	165
205	144	134
206	153	122
207	123	106
208	94	71
209	72	50
210	52	33
211	35	31
212	20	11
213	16	9
214	14	10
215	6	22
216	5	10
217	5	7

Am:

Kanal	Count	2nd m.
6	1	0
7	32	42
8	290	331
9	656	774
10	2473	3114
11	9360	10686
12	10825	10127
13	2675	2086
14	656	576
15	682	532
16	468	453
17	470	418
18	387	402

Assignment 3:
The spectrum has already been measured during assignment 2. The measurement is labeled with "Na: (e⁺e⁻-radiation)"

Assignment 5:

Cs. 300 s

~~Ch~~ Kanal	Counts	2nd m.
80	690	712
81	649	643
82	644	633
83	614	567
84	560	567
85	492	506
86	463	458
87	412	395
88	357	365
89	319	332
90	305	268
91	277	282
92	264	283
93	272	2~~8~~14
94	215	262
95	218	204
96	209	210
97	160	194
98	193	190
98	168	198
100	174	157

Assignment 6:

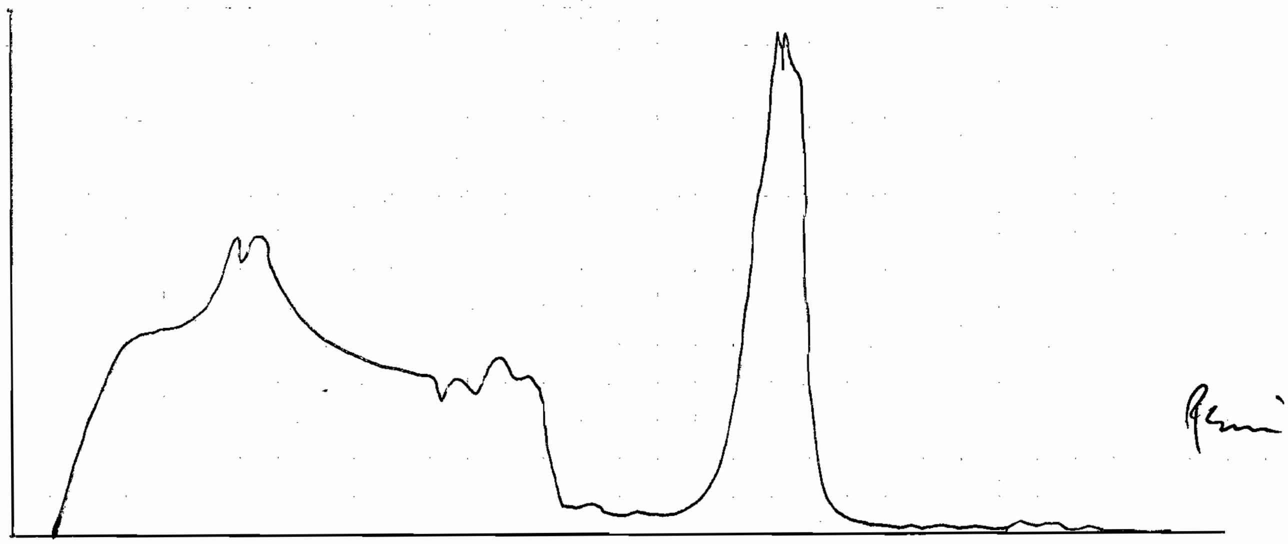
Mesurement with lead: (density: (~~7,8~~ 11,3 ± 0,1) 10^3 $\frac{kg}{m^3}$)

Thickness (mm)	Intensity (Imp/s)
0	85,142
3 ± 0,2	69,625
6 ± 0,2	51,833
9 ± 0,2	38,417
12 ± 0,2	27,425
15 ± 0,2	21,167

Measurement with iron: (density (7,8 ± 0,1) 10^3 $\frac{kg}{m^3}$)

Thickness (mm)	Intensity (Imp/s)
0	86,658
5 ± 0,1	70,375
10 ± 0,1	57,983
15 ± 0,1	48,192
20 ± 0,1	38,650
25 ± 0,1	30,625

Spectrum for Cs:



Analysis

Assignment 1:

The natural ion dosis rate was measured to be: 0,111 µSv/h

From this follows: natural ion dosis rate per years:

$$0{,}972 \ mSv/a$$
$$\Rightarrow 97{,}2 \ mrem/a$$

The ion dosis rate of ^{60}Co in a distance of 50 cm is:

$$1{,}559 \ mSv/a$$
$$\Rightarrow 155{,}9 \ mrem/a$$

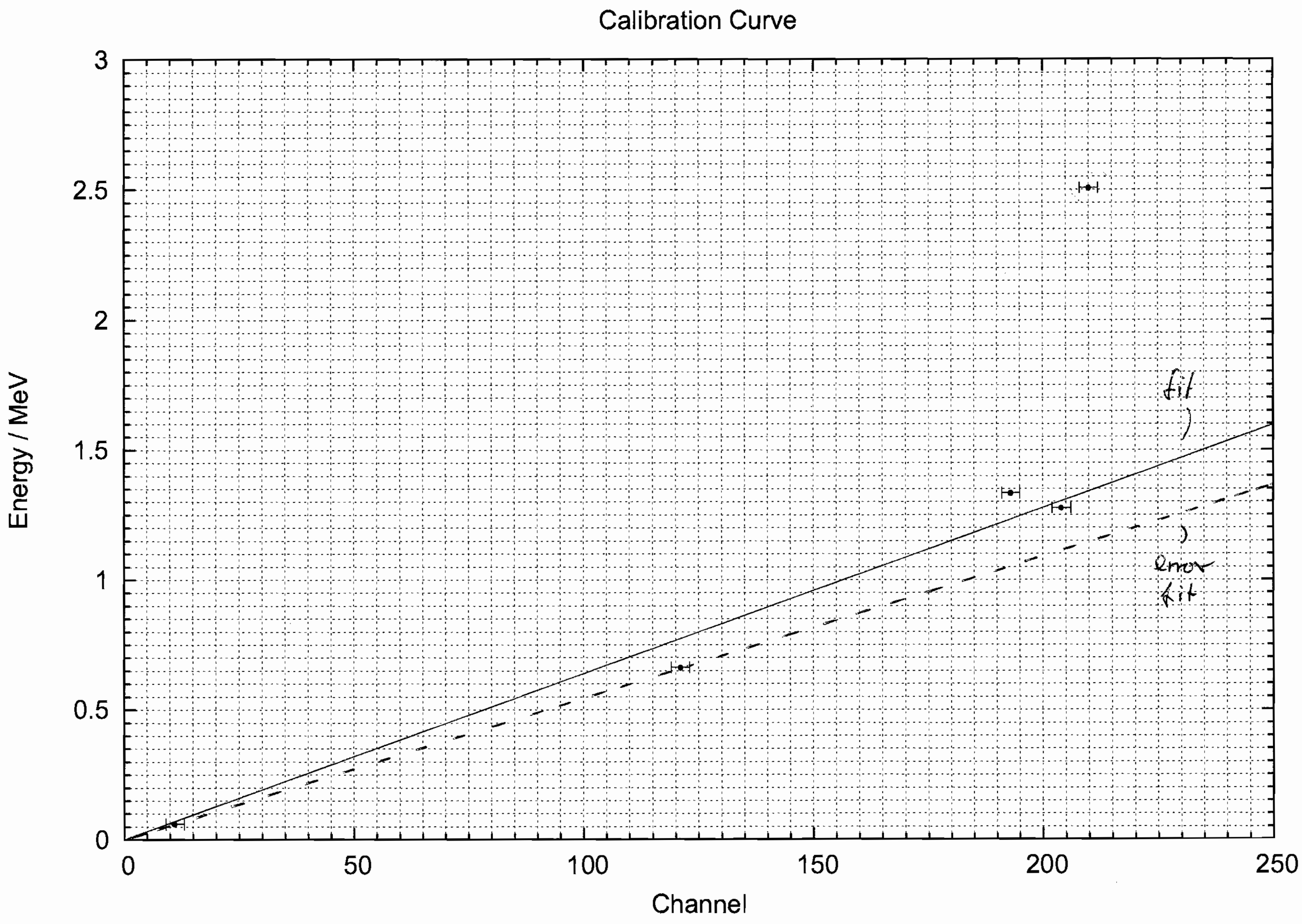
Assignment 2:

The position of the maximum can be calculated from the areage value of one peak:

Therefore weq get:

Co:	1,333 MeV decay:	channel number: 193 ± 2
	2,506 MeV decay:	channel number: 210 ± 2
Cs:	0,662 MeV decay:	channel number: 121 ± 2
Na:	1,275 MeV decay:	channel number: 204 ± 2
Am:	0,060 MeV decay:	channel number: 11 ± 2

The error has been calculated from the standardt deviation. Under the assumption, that the relationship between the channel number and the energy is linear, we get the following calibration curve.



Calibration Curve
Energy / MeV
Channel
0
0.5
1
1.5
2
2.5
3
0
50
100
150
200
250
fit
error
fit

The previous page plot shows a linear calibration curve. The marked reading seems to ~~be a~~ have a wrong energy association. According to the other values, an energy of 2,5 MeV should not be in our measurement range. Therefore, the described value is an unexpected radiation, with unknown origin. It will be ignored in further calculations.

Assignment 3:

During the measurement of ^{22}Na, a additional radiation has been detected. This was the $e^+ e^-$ radiation, emitted during the collision of one positron with one electron. The average channel number was calculated to be:

$$95 \pm 2$$

Using the calibration curve we get the following energy:

$$0,6 \pm 0,1 \ MeV$$

The theoretical value can be calculated using Einstein's law:

$$E = m \cdot c^2$$

$$\Rightarrow E = 0,512 \ MeV$$

Considering the error of our measurement, the values can be called identical.

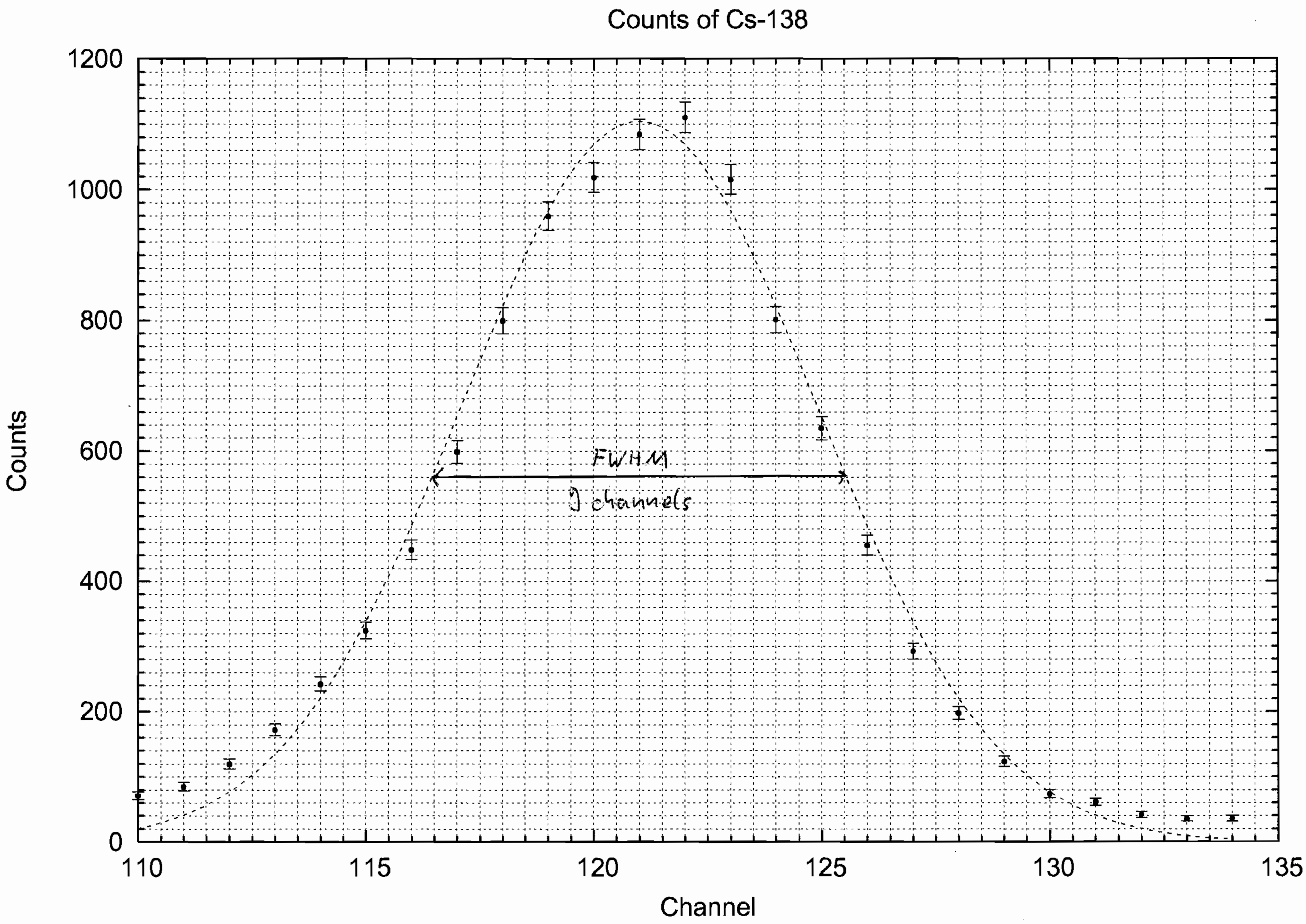
Assignment 4:

The plot on the next page shows the counts measured on ^{138}Cs. From the normal distribution we read $\Delta K = 9$ at FWHM. Considering the error of the average channel $K = (121 \pm 2)$ we get a resolution of:

$$\frac{\Delta K}{K} = (7 \pm 1)\,\%$$

This value corresponds to the typical value of the device type we used in this experiment.

typical value: 8% – 10 %


Counts of Cs-138
Counts
Channel
0
200
400
600
800
1000
1200
110
115
120
125
130
135
FWHM
9 channels

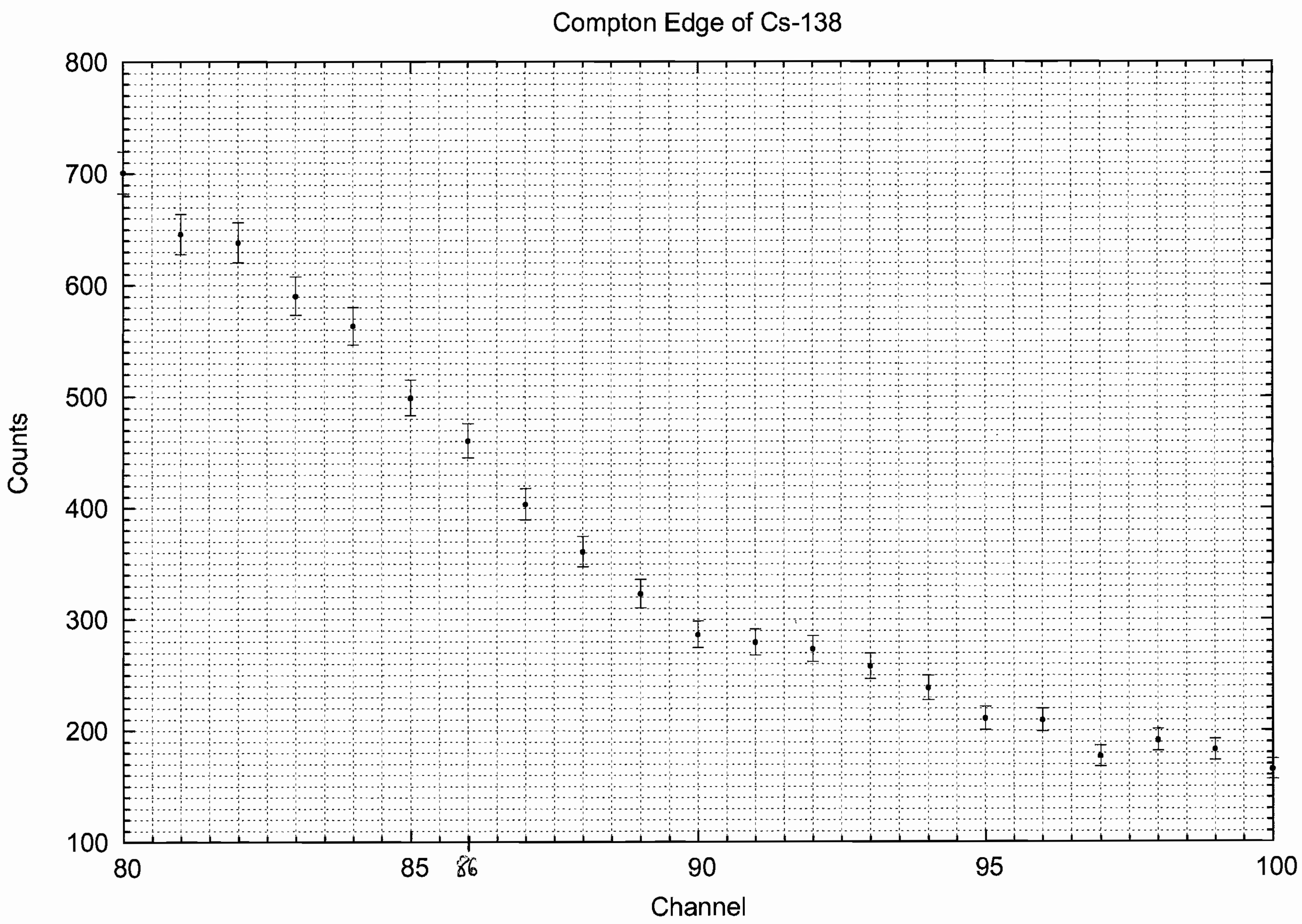
Assignment 5:

The Compton Edge was measured at ^{137}Cs. The plot on the right page shows the values ~~at them~~ in the measured range. On the basis of this plot we estimated the Compton Edge to be at channel 86. According to our calibration curve this corresponds to a energy of (550 ± 100) keV.

The literature value can be calculated from the scattering formula (with an angle of 180°)

$$E_t = 477 \text{ keV}$$

This values ~~can be calle~~ are identical within error.


Compton Edge of Cs-138
Counts
800
700
600
500
400
300
200
100
80
85
86
90
95
100
Channel

Assignment 6:

During this experiment we measured the intensity of the peak of ^{138}Cs at 0,662 MeV. The radiation was absorbed by different materials with a different thickness. The two plots on the following pages show the relationship between intensity and thickness. The error of the intensity was estimated from the initial values without any material.

The linear behavior of our data ~~confirms~~ (using logscale on the intensity) confirms the exponential decrease described by the law of absorption.

The slope of the fits give us the absorption coefficient of the related material.

$$\text{iron: } \mu = (4{,}08 \pm 0{,}50) \cdot 10^{-2}$$
$$\text{lead: } \mu = (8{,}92 \pm 2{,}00) \cdot 10^{-2}$$

From this we get ~~the~~

$$\text{iron: } \frac{\mu}{\rho} = (5{,}2 \pm 0{,}7) \cdot 10^{-6}$$

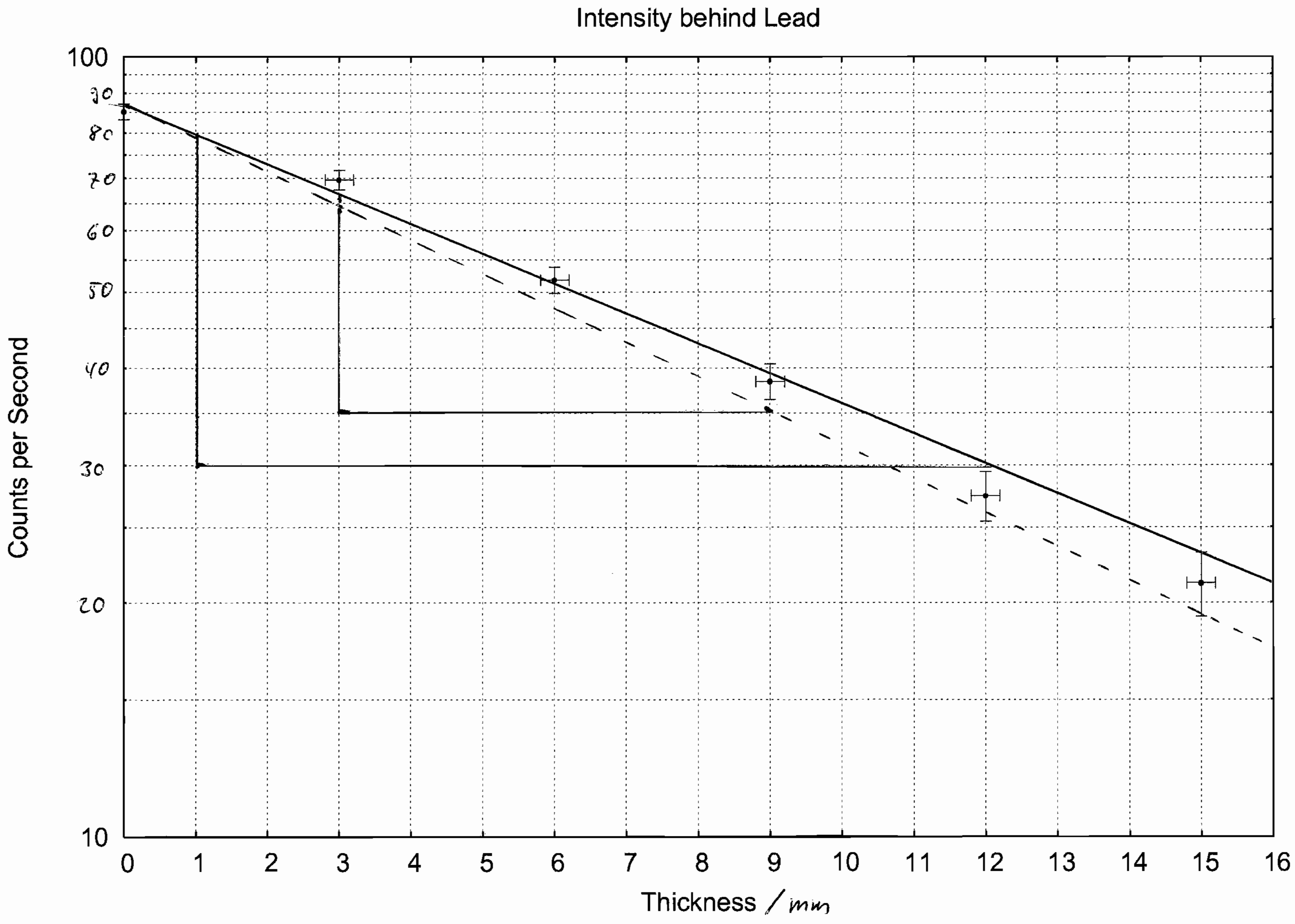
$$\text{lead: } \frac{\mu}{\rho} = (7{,}9 \pm 1{,}8) \cdot 10^{-6}$$

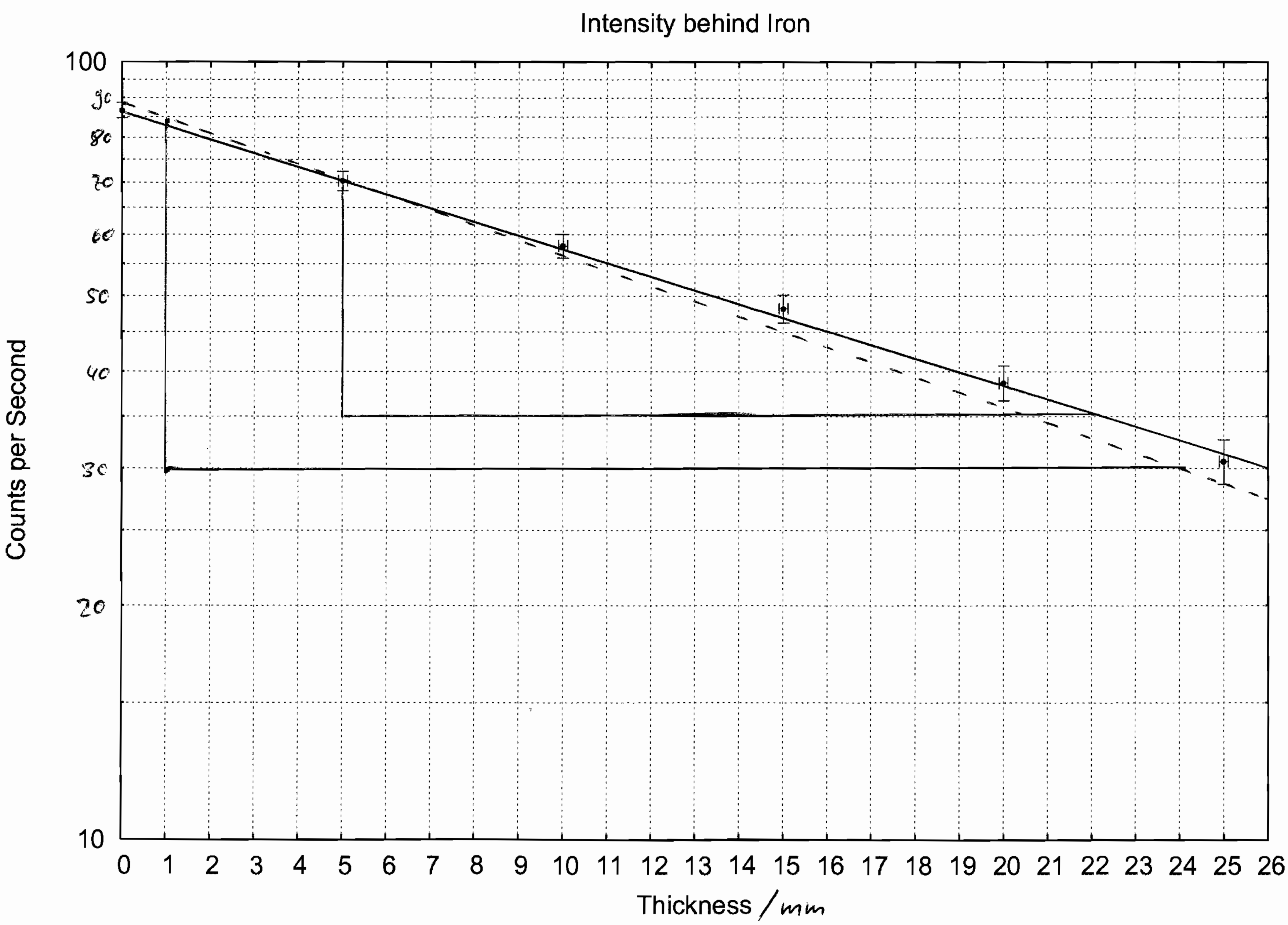
This values should be nearly equal, but they are only compatible within error.

The half intensity thickness has been read as follows:

iron: $(1{,}7 \pm 0{,}1)$ cm

lead: $(0{,}8 \pm 0{,}2)$ cm


Intensity behind Lead
Counts per Second
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Thickness / mm



Intensity behind Iron
Counts per Second
100
90
80
70
60
50
40
30
20
10
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
Thickness / mm

Conclusion

In the first experiment we measured the natural ion dosis rate and the ion dosis rate of ^{60}Co in a distance of aprox. 50 cm. The value of the second measurement was still very low. The "normal" radiation is approx. 1,1 mSv/a. Therefore it was not very dangerous to work with this radiation sources.

The propose of the second measurement was to get a relationship between the channel numbers of the measurement devid and the energy of the radiation. During the analysis we recognized, that not all peaks have been associated correctly. Considering the peaks of the other materials, an energy of 2,5 MeV should be out of range of the device in this configuration. Therefore we ignored this value which has an unknown source.

By using the calibration above, the energy of the e^+e^- radiation has been calculated. The error was very high, because of the inaccurate calibration curve. However our value was identical to the literature value. A better way to determine the energy would be to have much more radioactive materials to get a more accurate calibration of the device.

The resolution calculated in assignment 4 is somehow to accurate in comparison on the expected value. ~~the~~ On the other hand we got a very good approximation of a normal distribution with the measured values. Therefore this resolution seems to be realistic.

In assignment 5 we determined the energy corresponding to the "Compton edge". Our approximation of this value was very rough, which explains the high error of the final value. However, the values are identical.

The last experiment was to examine the absorption of radiation. The reduction coefficient ~~was~~ of iron and lead was expected to be nearly equal but the calculated values have ~~been oth~~ only been barely compatible. This behaviour is hard to explain. More measurements would reduce the ~~error~~ statistical error, which was approx 2 counts/s. In addition to this we ~~have~~ have systematical errors according to the position of the peak and our measurement of the area below this curve.