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U. Hagemann, W. Neubert, W. Schulze,
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Хагеманн У., Нойберт В., Шульце В., Стари Ф. E13-5796

Эксперименты на циклотроне тяжелых ионов с наносекундной структурой пучка

На трехметровом циклотроне тяжелых ионов ОИЯИ был поставлен эксперимент для проведения спектроскопических измерений на пучке. Используя естественные сгустки пучка, можно измерять времена жизни изомерных состояний вплоть до 10 нсек. Гамма-излучение регистрируется плоским германиевым детектором.

Препринт Объединенного института ядерных исследований. Дубна, 1971

Hagemann U., Neubert W., Schulze W., Stary F. E13-5796

Nanosecond Pulsed Beam Experiments at the Heavy Ion Cyclotron

The experimental arrangement has been installed at the 3 m heavy ion cyclotron in Dubna for performing spectroscopic in-beam measurements. By making use of the natural beam bunching isomeric states with lifetimes down to 10 ns can be measured. The gamma radiation is detected by a planar Ge(Li) detector.

Preprint. Joint Institute for Nuclear Research. Dubna, 1971

Introduction

Spectroscopic investigations based on the radioactive decay provided many information on nuclear structure. In-beam measurements, however, offer the possibility of investigating nuclei not attainable with radioactive decay work and gain, therefore, in interest. The use of heavy ion projectiles leads to the formation of product nuclei which are far off the line of beta stability. Beyond that the big linear and angular momentum transfer, the complete alignment of the product nuclei and the high specifity of the reaction product are further important advantages of heavy -ion induced compound-nucleus reactions.

The compound nucleus evaporates some neutrons leaving the product nucleus in a highly excited state with high spin value. During the following gamma deexcitation process high-spin isomeric states may, therefore, be excited with favoured probability.

Of special interest are isomeric states of complicated many-particle nature. During the past years the beam-chopping techniques has been used by us for the investigation of isomeric states in the millisecond range /1/. The utilization of the natural phase grouping of the cyclotron beam and the fast timing characteristics of $Ge(Li)$ detectors make it possible to extend such measurements to isomeric states with complicated decay characteristics and half-lives as short as a few nanoseconds /2/. The zero time signal may be derived from the beam bunches or directly from the r.f. of the cyclotron.

Cyclotron Characteristics

The in-beam experiments were carried out with the external beam of the U-300 heavy ion cyclotron of the Laboratory for Nuclear Reactions, JINR, Dubna. In the table some characteristic features of this 3m-cyclotron are given. Particles with a mass number-to-charge ratio between $A/Q = 5$ and 6.67 can be accelerated and formed to an external beam of sufficient intensity. The extracted beam current amounts to about 10 μA. Energies of 5 to 10 MeV per nucleon are obtained. The relatively low frequencies of the accelerating high voltage result in a period duration between two beam bursts of 200 to 260 nanoseconds, depending on the kind of accelerated particles.

Fig. 1 shows a time spectrum of a single beam burst, measured with prompt conversion electrons [x)] of a 331 keV transition in ^{122}Xe. In consequence of the sharp energy selection by means of a magnetic beta spectrometer and the good time resolution of the 1 mm thick $Si(Li)$ detector this picture reflects nearly exactly the form of the beam burst, for which we can assume a half width of perhaps 6 to 7 nanoseconds. The slope amounts to 1.6 ns. In principle, we should, therefore, be able to measure lifetimes down to 2 nanoseconds. But with our gamma detectors

x) We thank Drs. S. Chojnacki, Ch. Droste and T. Morek for the cooperation.

we are restricted to times above 10 nanoseconds. In Fig. 2 a time spectrum is shown, which was measured with a 10 mm thick *Ge(Li)* planar detector. Prompt gamma radiation appears only during the beam bursts; delayed radiation gives an exponential decay between the beam bursts from which the lifetimes of isomeric states may be concluded. An upper limit of the measurable lifetimes is set by the period duration $T = 1/f$, i.e. the separation of two beam bursts. A lower limit is set by the slope of the in-beam prompt curve of about 6 ns, whereas in coincidence with a *NaJ(Tl)* scintillation counter the same detector gave a half width of 6.5 ns and a slope of 1.3 ns for 511 keV gamma radiation [3].

Besides of the natural high frequency beam bunching the accelerating voltage and the ion source of the *U*-300 are pulsed by a low frequency of about 200 *Hz* . The period duration can be varied between 4 and 7 milliseconds and the pulse width between 0.5 and 2.5 milliseconds. Due to the steep slope of the source voltage the beam current has a relatively short decay time of about 10 μs, which offers the possibility of measuring lifetimes above 10 μs.

Experimental Arrangement

The beam tract, depicted in Fig. 3 is used both for gamma and beta spectroscopic investigations. The magnetic beta spectrometer is not shown on the picture. The ions leaving the accelerator chamber are passing two bending magnets and three pairs of quadrupole lenses before they strike the target. The transmitting beam enters the Faraday cup which is located 4 m behind the target position. A first beam defining slit of 2 cm height and a width, which is adjustable between 0 and 1 cm, is located behind the first bending magnet. In this way the broad edges of the radial intensity distribution of the beam are absorbed far from the detector position. A second aperture of 1 cm diameter has been inserted behind the second bending magnet. In order to measure excitation functions the energy of the heavy ions must be varied by means of attenuation foils. For these foils have been found to be one of the main sources of background radiation, they have been inserted between the second bending magnet and the last quadrupoles in later experiments /4/. The result was a drastically reduced background.

Of extreme importance for the background conditions is also the precise adjustment and the stability of the position and the size of the beam striking the target. This is controlled by a television set. Without attenuation foils the beam diameter amounted to less than 1 cm. A further reduction of the background, e.g. from activation of the target chamber by evaporated neutrons was obtained by lead shielding the *Ge* detector itself. The details of the target-detector arrangement are shown by the insert.

Electronics

The block diagram of the electronic apparatus is shown in Fig. 4. The time-to-pulse height converter is stopped by pulses that are derived from the cyclotron r.f. voltage, i.e. the dee voltage. For this method minimum requirements are needed, but it has the drawback of being sensitive to phase shifts between the accelerating voltage and the beam bursts, which are mainly caused by instabilities of the cyclotron parameters. But without switching off the cyclotron during the measurement, no disturbing phase shift was observed.

The start pulses are delivered by the *Ge(Li)* detector followed by a timing circuit.

Most of the measurements were performed with a 2048 channel analyser, two-dimensionally arranged for 8 time channels and 256 energy channels. For a preliminary survey the version shown in Fig. 5 is used, where the prompt and the delayed parts of the time spectrum are selected by means of two single channel analysers and the prompt and delayed energy spectra of each 1024 channels are selectively stored.

Experimental Result

An already finished experiment /5/ regards to the $(h_{9/2})^2$ two-quasiparticle state in ^{202}Po. A metallic foil of 15 mg/cm^2 thick natural Pt was bombarded with ^{12}C ions of 82 MeV energy. Fig. 6 shows a part of the obtained time-energy spectrum of the prompt and delayed gamma radiation. Three strong gamma transitions of equal intensity and with energies 443, 571 and 677 keV were observed, which follow a half-life of $T_{1/2} = 165 \pm 20$ ns. The weak 526 keV gamma transition decays with $T_{1/2} = 25 \pm 10$ ns. In the prompt spectrum the Coulomb excited gamma transitions from the first excited 2^+ state to the ground state of the three isotopes $^{194,196,198}Pt$ have dominating intensity.

We wish to thank academician G.N. Flerov for his stimulating interest given to this work.

References

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Table

Characteristic features of the heavy ion cyclotron U-300

A/Q	H.I.	f/MHz	T/ns	E/A MeV
5.00	$^{10}B^{2+}$ $^{15}N^{3+}$ $^{20}Ne^{4+}$	5.070	197	10.0
5.33	$^{16}O^{3+}$ $^{32}S^{6+}$	4.778	209	8.6
5.50	$^{11}B^{2+}$ $^{22}Ne^{4+}$	4.590	218	8.0
5.71	$^{40}Ar^{7+}$	4.444	225	7.5
6.00	$^{12}C^{2+}$ $^{18}O^{3+}$	4.216	237	6.8
6.20	$^{31}P^{5+}$	4.134	242	6.3
6.40	$^{64}Zn^{10+}$	3.942	254	6.0
6.67	$^{20}Ne^{3+}$ $^{40}Ar^{6+}$	3.810	262	5.5

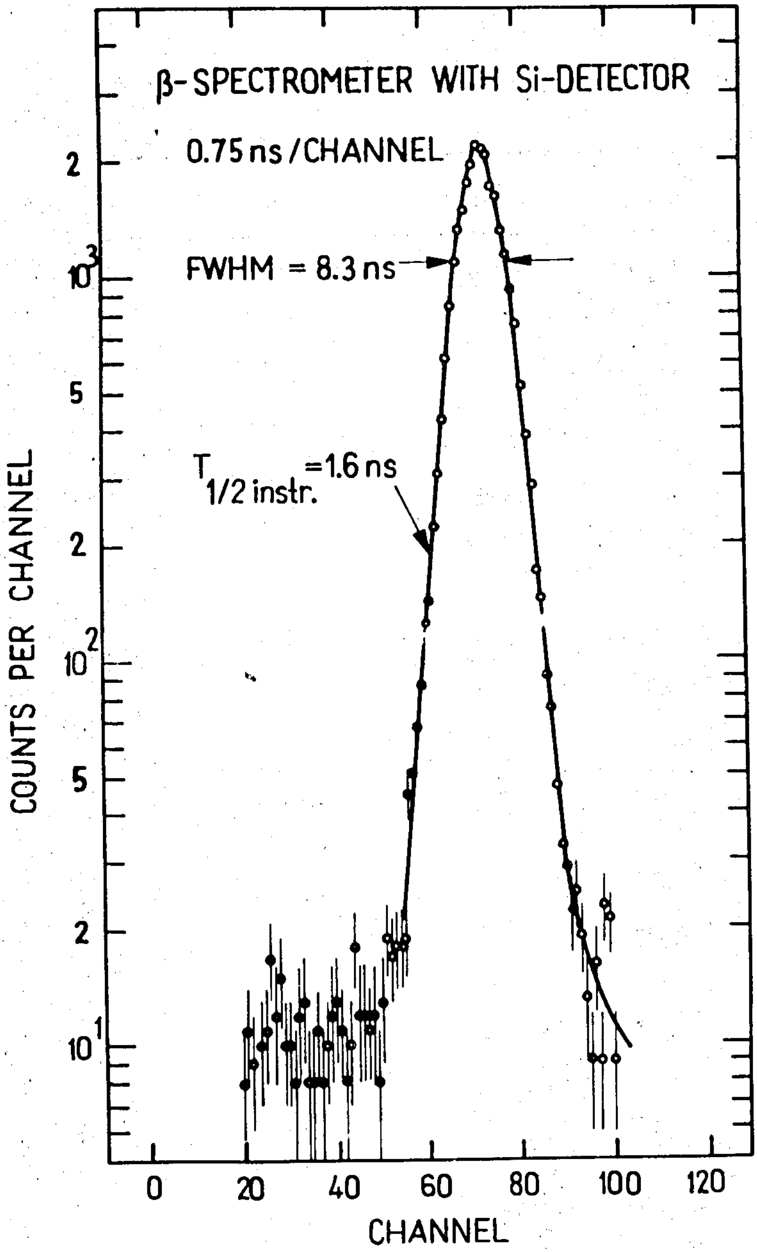

Fig. 1. Time spectrum of a single beam burst.

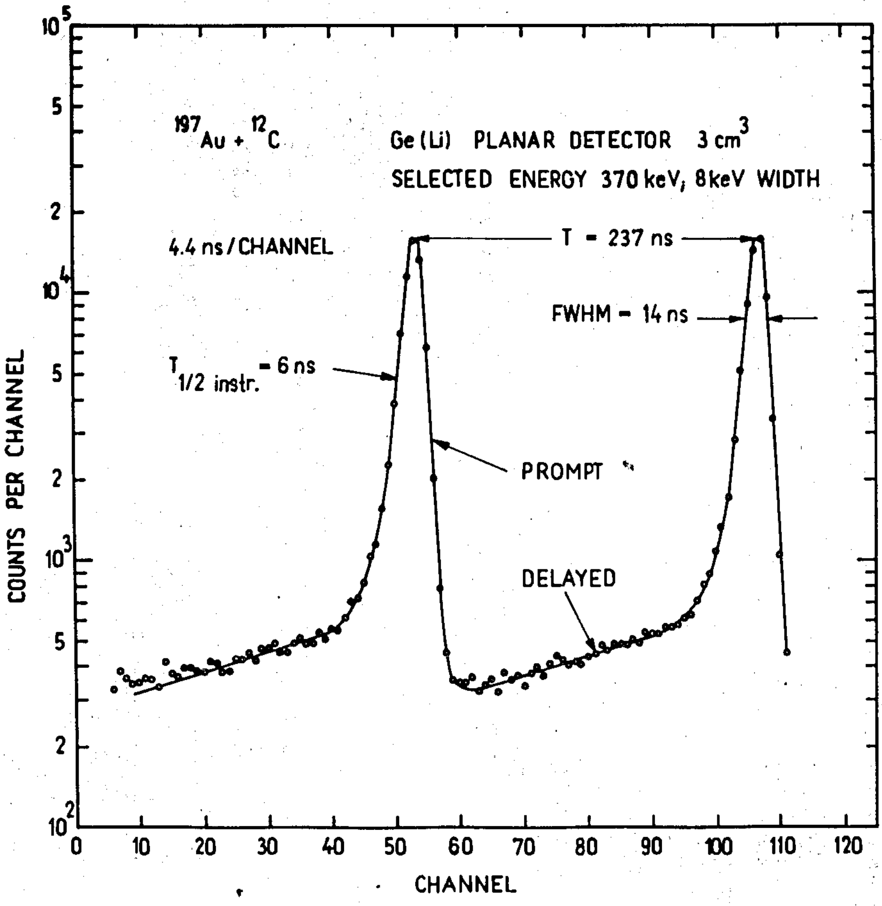

Fig. 2. Time spectrum measured with *Ge(Li)* detector.

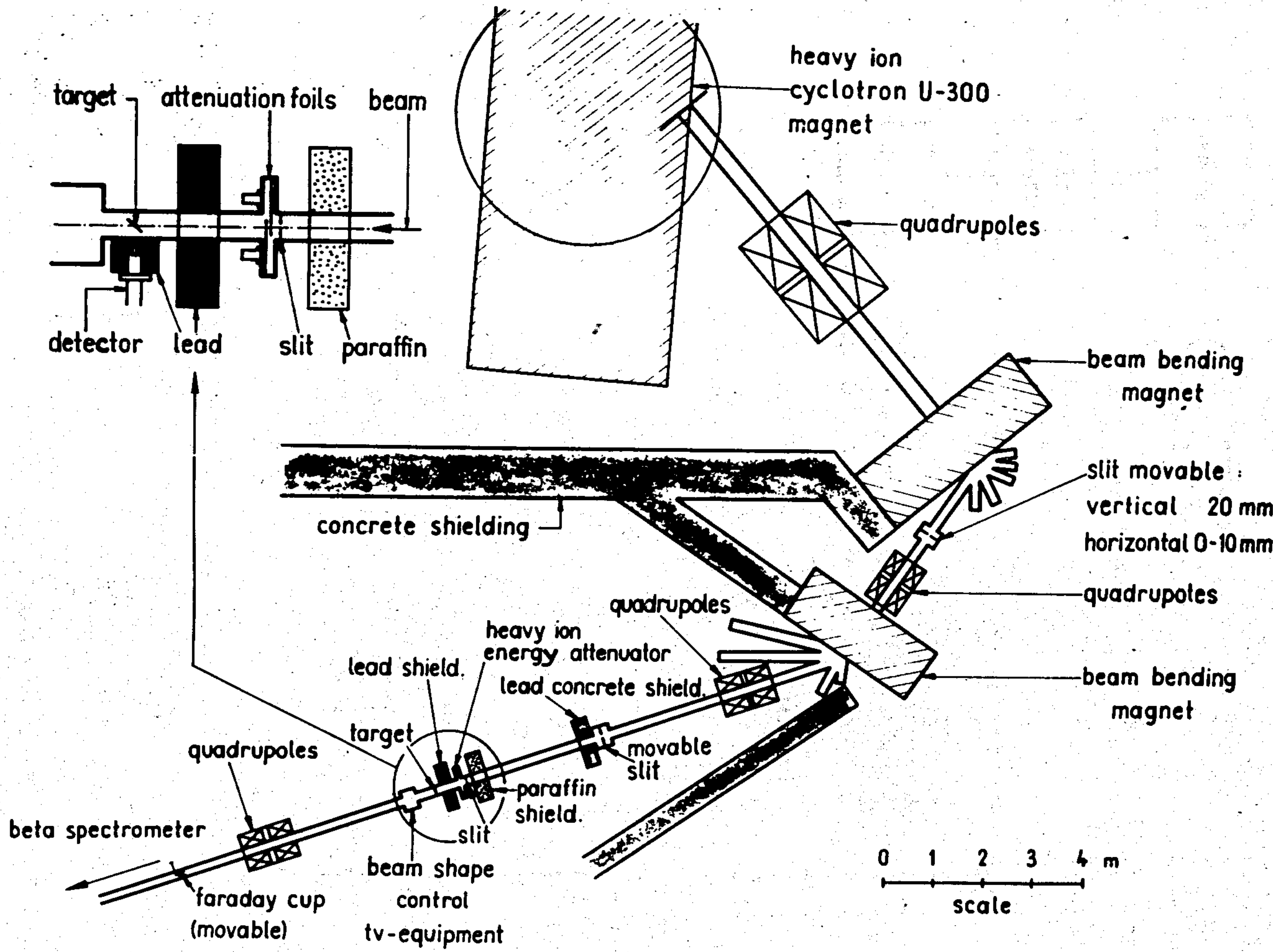

Fig. 3. Experimental arrangement.

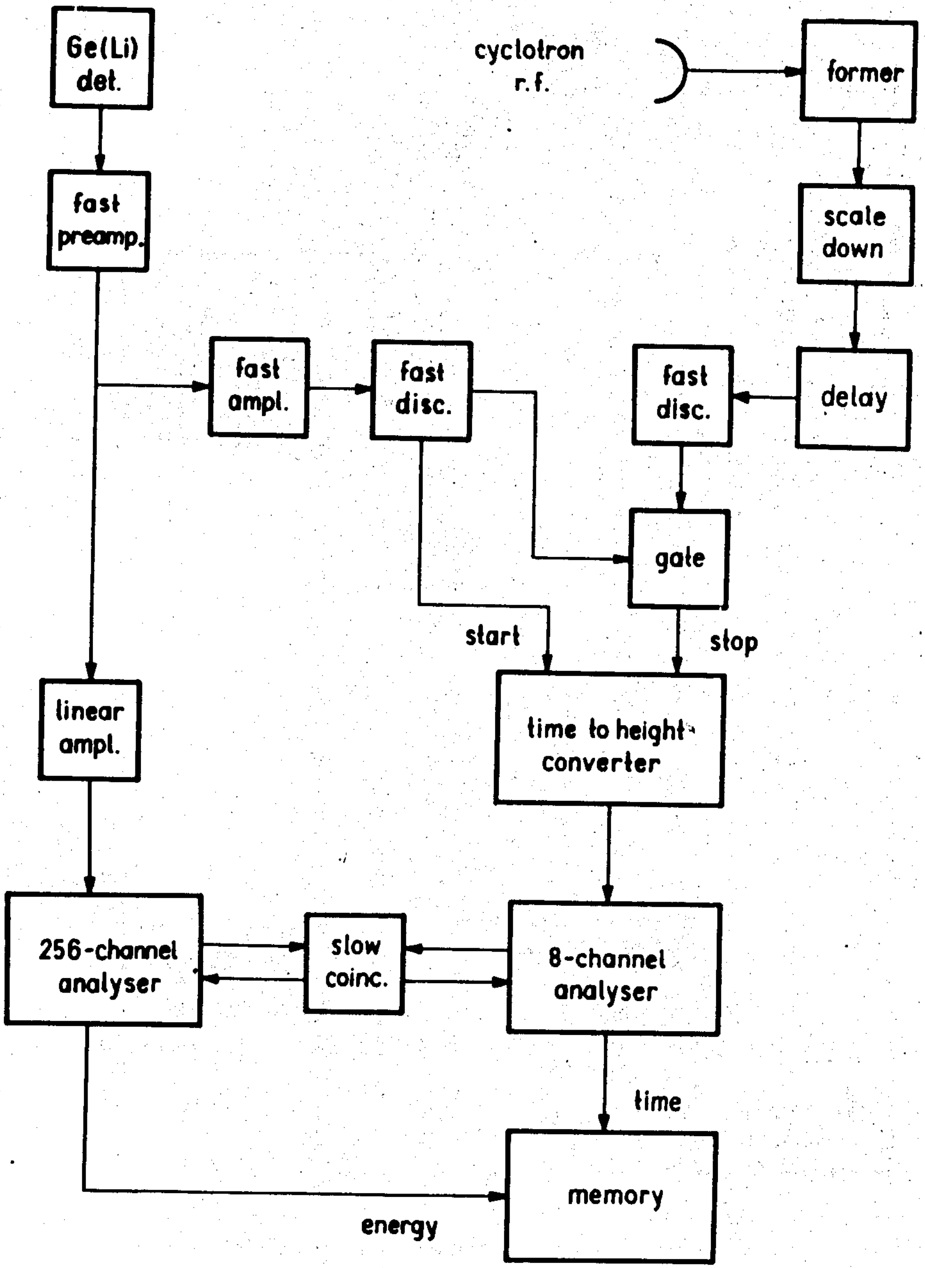

Fig. 4. Block-diagram for two-dimensional measurements.

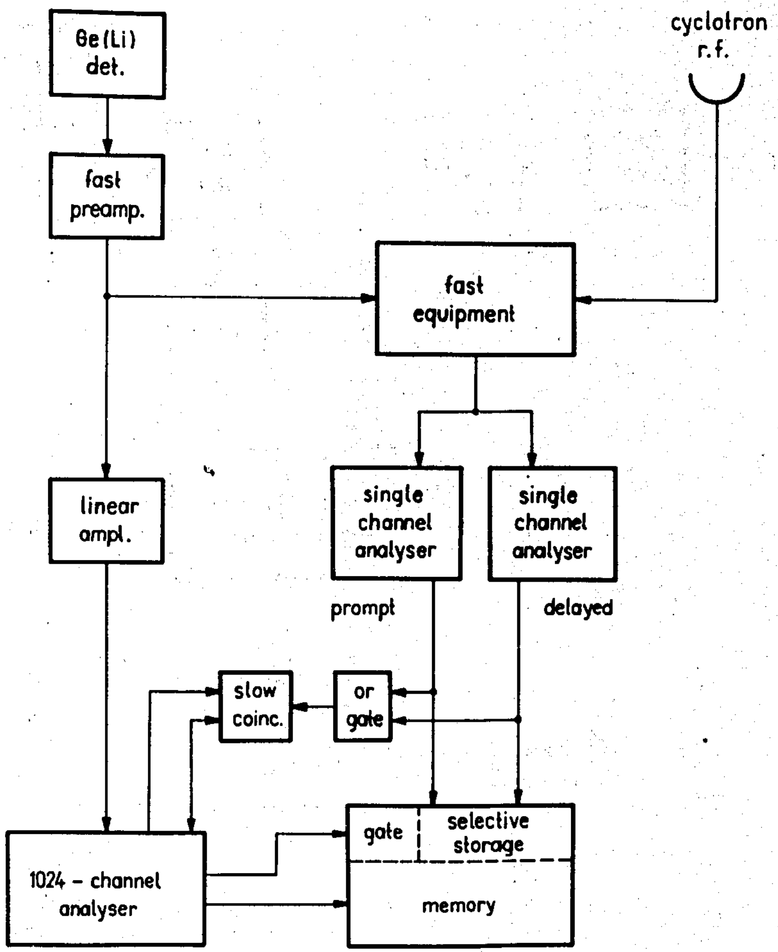

Fig. 5. Block-diagram for measurements of prompt and delayed spectra.

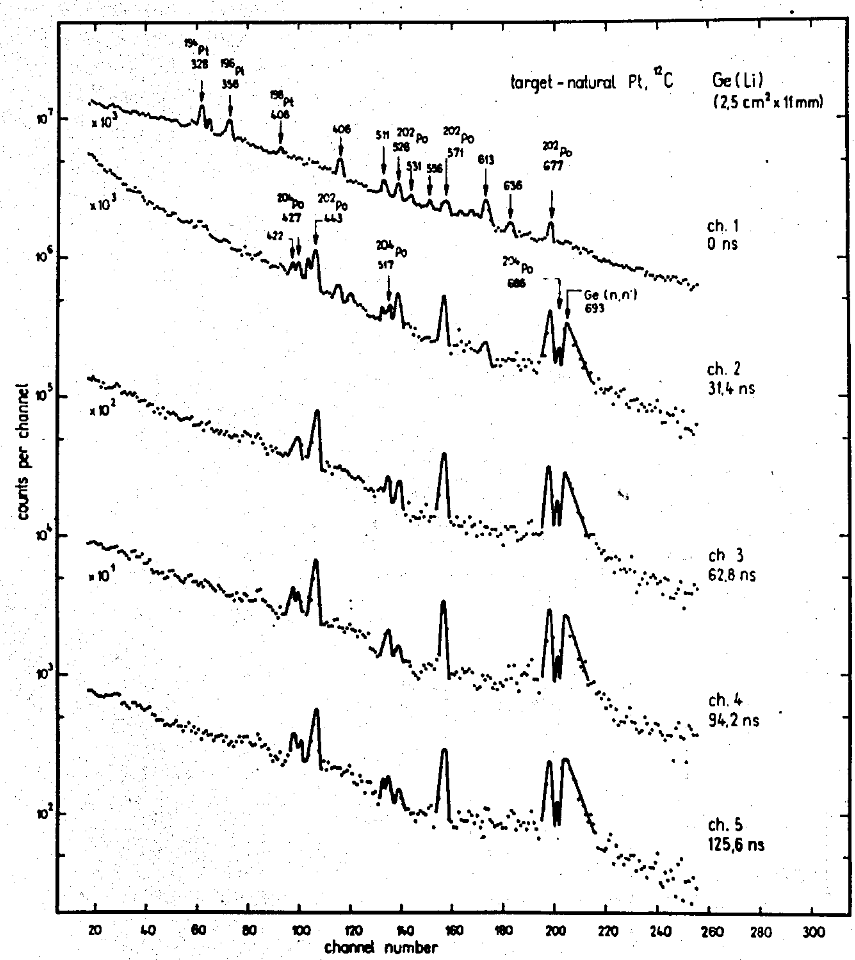

Fig. 6. Two-dimensional gamma spectrum of ^{202}Po .