CEBAF Program Advisory Committee Six (PAC6) Proposal Cover Sheet

This proposal must be received by close of business on April 5, 1993 at:

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Proposal Title

Investigation of the (γ,n) Reaction in the Giant Dipole Resonance Region on the High-Spin Target ^{178m_2}Hf($I^\pi = 16^+$)

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If this proposal is based on a previously submitted proposal or letter-of-intent, give the number, title and date:

Letter to Prof. H. A. Grundev, CEBAF Director, from Prof. Yu. Oganession, Director of the Flerov Laboratory of Nuclear Reactions, JINR, Dubna, Russia, Nov. 1992

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By:

PROPOSAL FOR THE EXPERIMENTAL INVESTIGATION OF THE (γ,n) REACTION IN THE GIANT DIPOLE RESONANCE REGION ON THE HIGH-SPIN TARGET ^{178m_2}Hf(I^{π} = 16^+)

INTRODUCTION AND SCIENTIFIC MOTIVATION

CEBAF AND STATEMENT OF THE PROBLEM. The creation of a new high intensive continuous Electron Beam Accelerator Facility (CEBAF) in Newport News (Virginia state, USA) with electron energies of 0.045-0.40 GeV with intensities of up to 200 μA and energy spread of $5 \cdot 10^{-5}$ opens unique possibilities in the fields of modern nuclear physics and elementary particles. Vibrational modes are a feature of almost all Fermi systems. In nuclei collective vibrations have been known to exist since the discovery of the giant dipole resonance (GDR) in 1947. Many other giant vibrational modes have since been identified, and their gross properties mapped as a function of nuclear species. The study of these modes has generated important information about the bulk behavior of nuclei near equilibrium and, through microscopic efforts at understanding them, provided precise information about the global features of the effective interaction among nucleons. The GDR is one of the most beautiful examples of collective nuclear motion available to us. It has been observed in all composite nuclei, and is found to fully exhaust the appropriate energy weighted sum rule (EWSR) in all nuclei of mass > 40. However, nothing is known about the excitation of the giant dipole resonance from a high spin isomeric state. Information about the GDR for the high spin four-quasiparticle ^{178m_2}Hf isomer $T_{1/2} \approx 31$ yr., $I^{\pi} = 16^+$ can give considerable information about the behavior of nuclei at high spin and high excitation.

CROSS-SECTION AND EXCITATION FUNCTION. Cross-section measurements and excitation functions of the reaction ^{178m_2}Hf(γ,n) in the γ-quanta energy region available from the

CEBAF injector of 10-45 MeV allow one to obtain significant new information about the structure of nuclei with large angular momentum.

1. From the values of the reaction cross-section ^{178m_2}Hf(γ,n), one can gain information about the level density with high-spin (I = 15-17) at high excitation energy corresponding to γ-quanta in the giant dipole energy region.

2. The energy of the giant dipole resonance determines the nuclear rigidity of the broken proton and neutron pairs in relation to dipole vibrations.

3. The splitting of the giant dipole resonance and intensity of both peaks allow one to determine the value and sign of nuclear quadrupole deformation of ^{178}Hf for its high spin isomeric state. In Fig. 1, as an example, there is presented the excitation function of the reaction (γ,n) for the adjacent nucleus ^{181}Ta.

HIGH-SPIN TARGET ^{178m_2}Hf PRODUCTION. Accumulation of a high-spin target of isomeric ^{178m_2}Hf was performed on the 2-meter U-200 cyclotron at the Flerov Laboratory of Nuclear Reactions (FLNR, JINR, Dubna) in reaction ^{176}Yb(^{4}He,2n). At the maximum energy of the α-particles of 36 MeV, the production cross-section of the isomer ^{178m_2}Hf is about 10 mbarns, with an isomeric ratio equal to $5 \cdot 10^{-2}$. With an α-particle intensity of 100 μA, one can store up to 10^{15} isomer-nuclei for one month irradiation. After chemical separation, the target of ^{178m_2}Hf contained also 20 times more ground state ^{178}Hf nuclei and approximately 100 times more ^{177}Hf nuclei produced in the reaction ^{176}Yb(^{4}He,3n).

THE ISOMER YIELD OF ^{177m}Hf AND ISOMERIC RATIO. In order to distinguish the reaction ^{178m_2}(γ,n) against another reaction proceeding for other isotopes of Hf, we propose to measure the yield of the high-spin isomer ^{177m}Hf ($T_{1/2}$ = 51 min, I^π = 37/2$^-$, E = 2.74 MeV).

This isomer can be produced in the reaction (γ,n) only with the isomer $^{178m}{}_2$Hf (Fig. 2). The measurement of the isomer ^{177m}Hf yield performed on the FLNR, JINR microtron at an energy limit of 25 MeV of γ-Bremsstrahlung showed that the isomeric ratio for this isomer is less than 10^{-3} in the reactions ^{178g}Hf(γ,n), ^{179g}Hf(γ,2n) and ^{177g}Hf(γ,γ').

The yield of ^{177m}Hf can be determined by the intensity of the γ-line with energy of 638 keV. This γ-line is above the γ-lines of ^{178m_2}Hf (its highest energy γ-line is at 574 keV).

Estimates show that the reaction cross-section (γ,n) for the high-spin isomer ^{178m_2}Hf is the same as for ^{181}Ta (Fig. 1) and the probability of isomer ^{177m}Hf population ~50%. Then with a target thickness of the 10^{14} atom/cm^2 of the isomer ^{178m_2}Hf, an electron energy of 45 MeV with intensity of 200 μA, the yield of the isomer ^{177m}Hf will be of the same order of magnitude that is comparable with natural activity of the target ^{178m_2}Hf (~10^4 γ/s). This will allow one to observe the γ-lines of the isomer ^{177m}Hf produced in the reaction against the background of γ-rays from ^{178m_2}Hf (Fig. 3a). To achieve higher sensitivity, one can measure spectrum of conversion electrons (Fig. 3b) as the radiative transitions in ^{177m}Hf have higher conversion coefficients than in ^{178m_2}Hf. The induced activity from a 9mg/cm^2 Be-backing as a result of the reaction ^{9}Be(γ,2n)^{7}Be will be of the same order as the γ-activity of the produced isomer ^{177m}Hf (~10^4 γ/s).

DETAILS OF THE PROPOSED EXPERIMENTAL ARRANGEMENT

A high-spin target ^{178m_2}Hf (0.5 cm diameter, 10^{14} atoms on 5 micrometers Be-backing) will be mounted at the CEBAF injector beam dump area for irradiation. After irradiation gamma spectra and conversion electron spectra associated with the decay of ^{177m}Hf ($T_{1/2}$ = 51m) will be measured off line. At the present moment CEBAF is the only place in the world to deliver sufficiently high intensity electron beam to yield a photon flux of the energy and intensity required to produce ^{177m}Hf in an amount that will allow collection of statistically significant gamma and conversion electron spectra associated with ^{177m}Hf decay. The high-spin target of ^{178m_2}Hf in the isomeric state in the amount of 10^{14} atoms produced with ^{4}He beam using 2-meter U-200 Cyclotron at the Flerov Laboratory of Nuclear Reactions (JINR Dubna) is in the present moment the whole available target material.

The electron stopping target can be manufactured in Dubna in agreement with CEBAF requirements to fit the injector beam line and transported to CEBAF. It should have a tungsten cylinder of 155 mm thickness and 10 mm diameter pressed into a copper cylinder of 30 mm length and 100 mm diameter. The layer of tungsten is enough to absorb 45 MeV electron beam. This stopping target can be mounted instead of the brass absorber for the electron beam mounted at the end of the injector. The target will be tested on the electron beam of the Moscow State University microtron injector at an electron energy of 7 MeV and an intensity of up to 500 microA. The irradiated target from ^{178m}Hf is placed 55 mm away from the back surface of the tungsten cylinder. The test sample made of separated isotope ^{176}Hf is positioned behind the target made of ^{178m}Hf in order to compare the reaction of interest with the reaction ^{176}Hf (γ,n) ^{175}Hf ($T_{1/2}$ = 70 days).

After irradiation, the Hf target will be removed from the beam and transported to a counting station where gamma and conversion electron spectra are counted simultaneously. The Ge gamma ray detector and Si electron detector will be delivered by Vanderbilt University. We expect that CEBAF will provide us with electronics for detectors and software for data acquisition, and a turbo pump to produce a vacuum in the electron detection station. Vanderbilt can provide the electronics also, if needed.

It is planned to perform measurements for two electron beam energies, 25 MeV and 45 MeV (both intensity about 200 μA). For each electron energy we plan to make 4 cycles of measurement, each consisting of 3 hours irradiation and 2 hours counting for a total of about 40 hours. The measurement of the yields of isomeric ^{177m}Hf at the two energies allows one to determine the ratio of the (γ,n) reaction cross section in the region of the giant dipole resonance and at high energies, when the direct knocking-out of neutrons takes place.

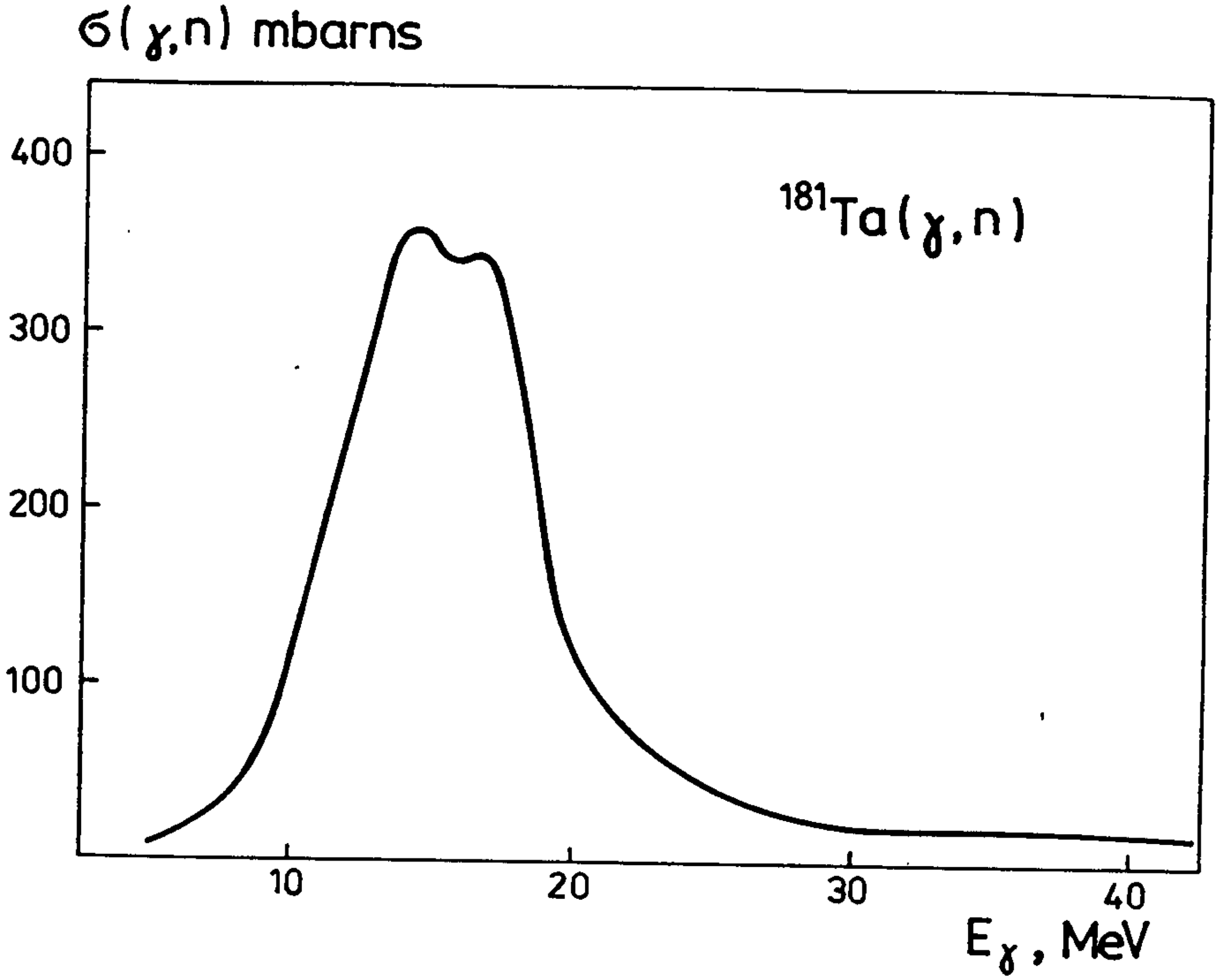


Fig. 1

REACTION (γ, n) ON HIGH-SPIN ISOMER $^{178}Hf(16^+)$

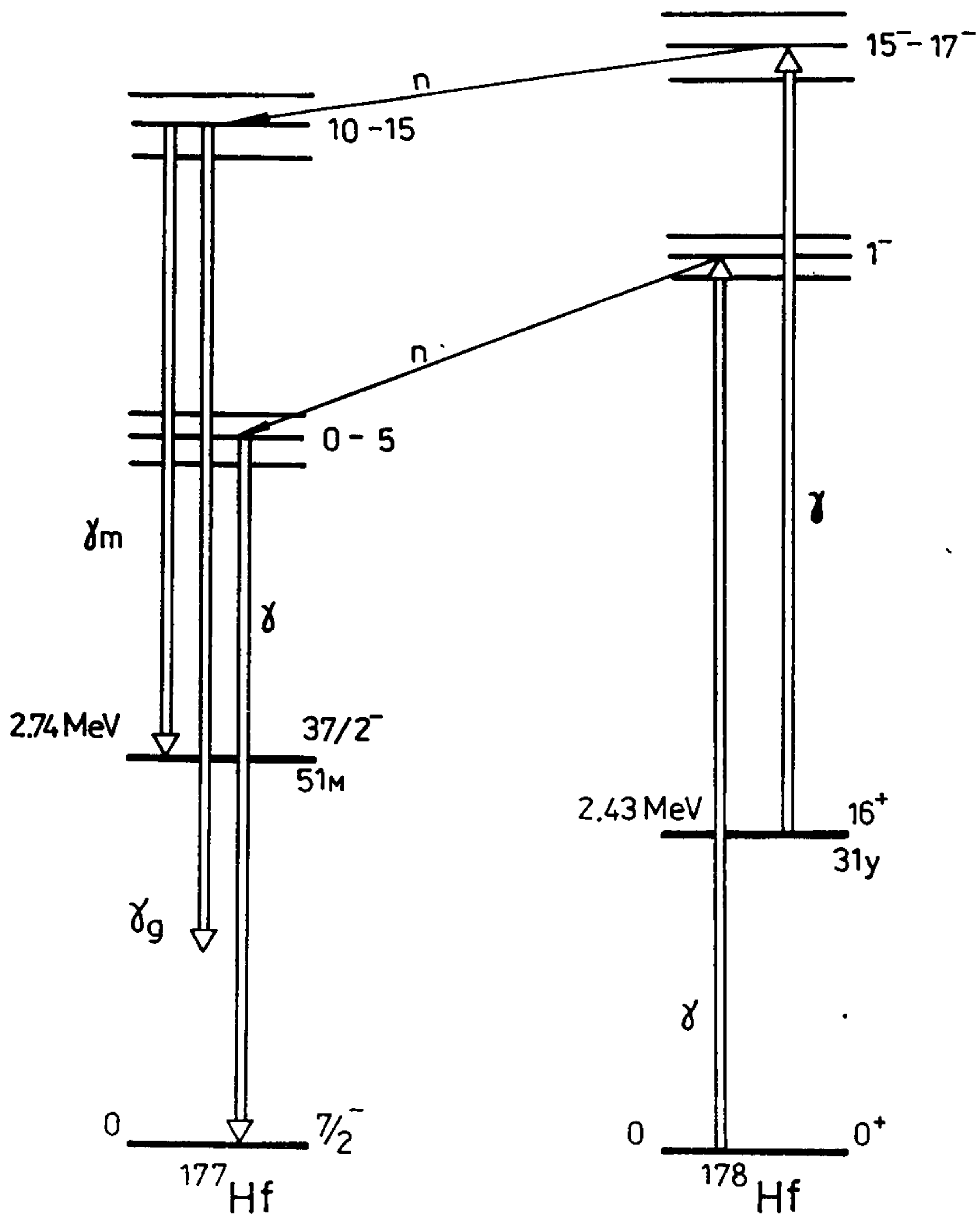
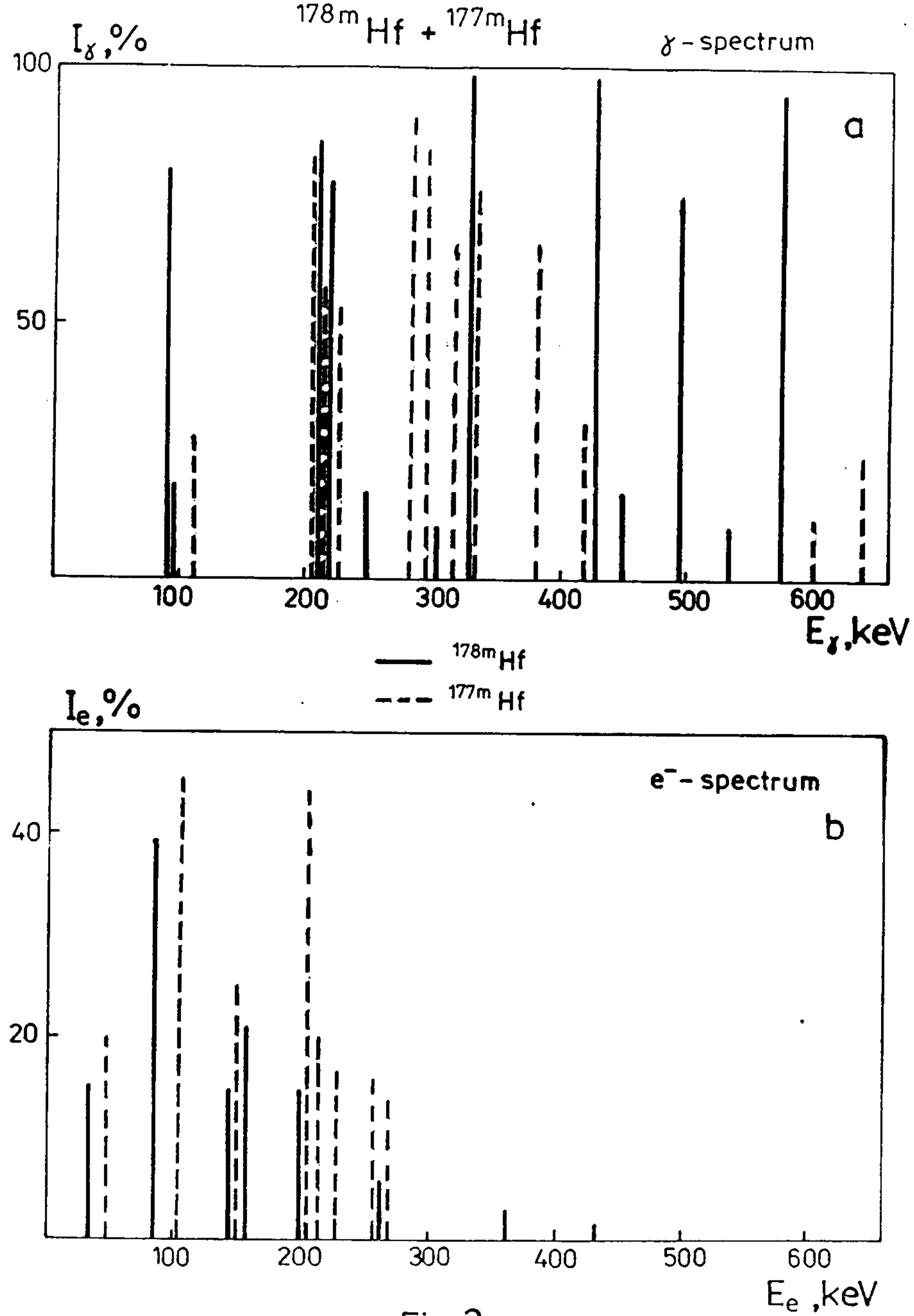


Fig. 2



$^{178m}Hf + ^{177m}Hf$
I_γ,%
γ - spectrum
a
100
50
100
200
300
400
500
600
E_γ,keV
^{178m}Hf
^{177m}Hf
I_e,%
e^- - spectrum
b
40
20
100
200
300
400
500
600
E_e ,keV

Fig. 3

THE BREMSSTRAHLUNG SPECTRUM

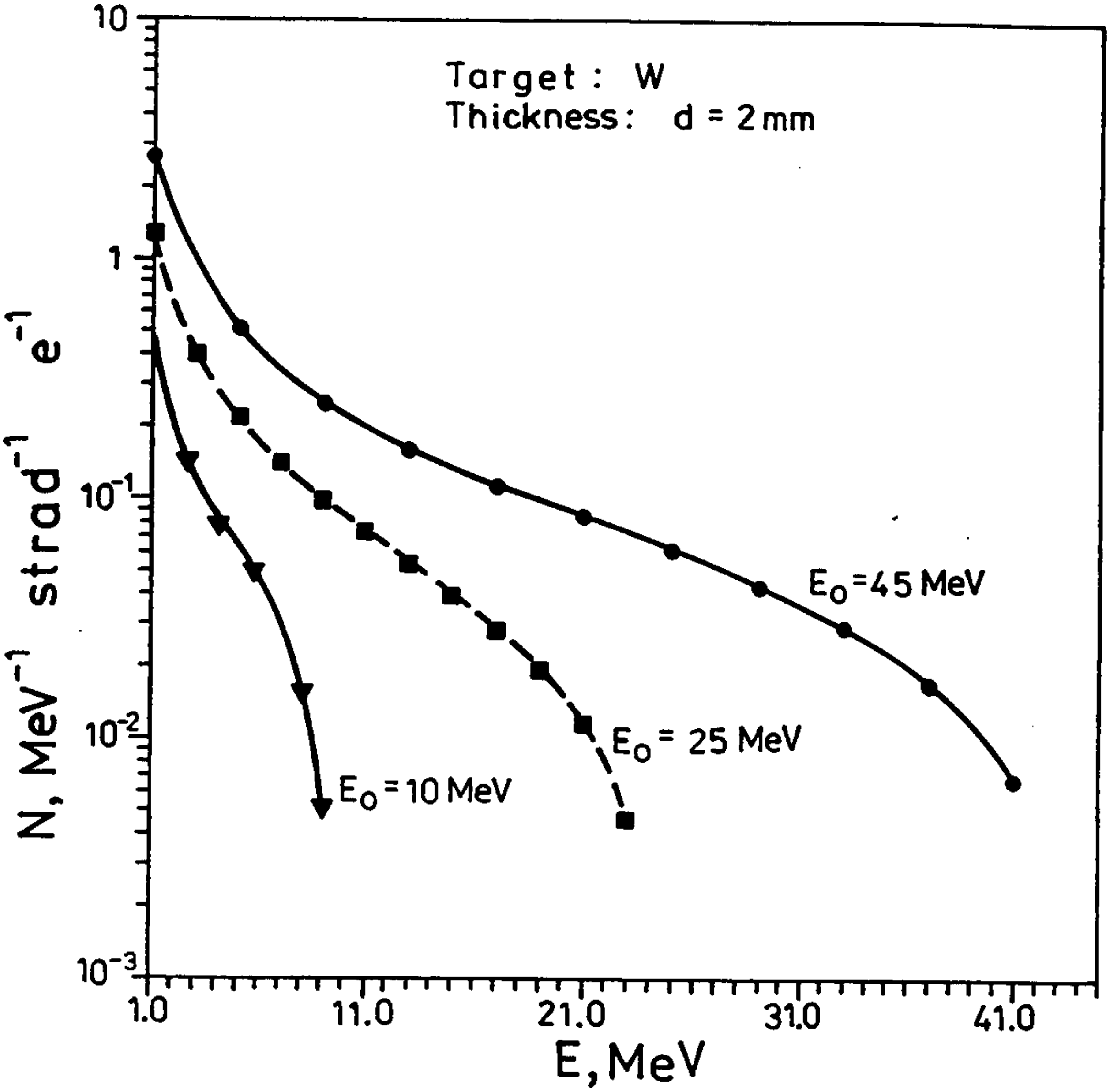


Fig.