NEANDC(J)82/A
INDC(JAP)69/G

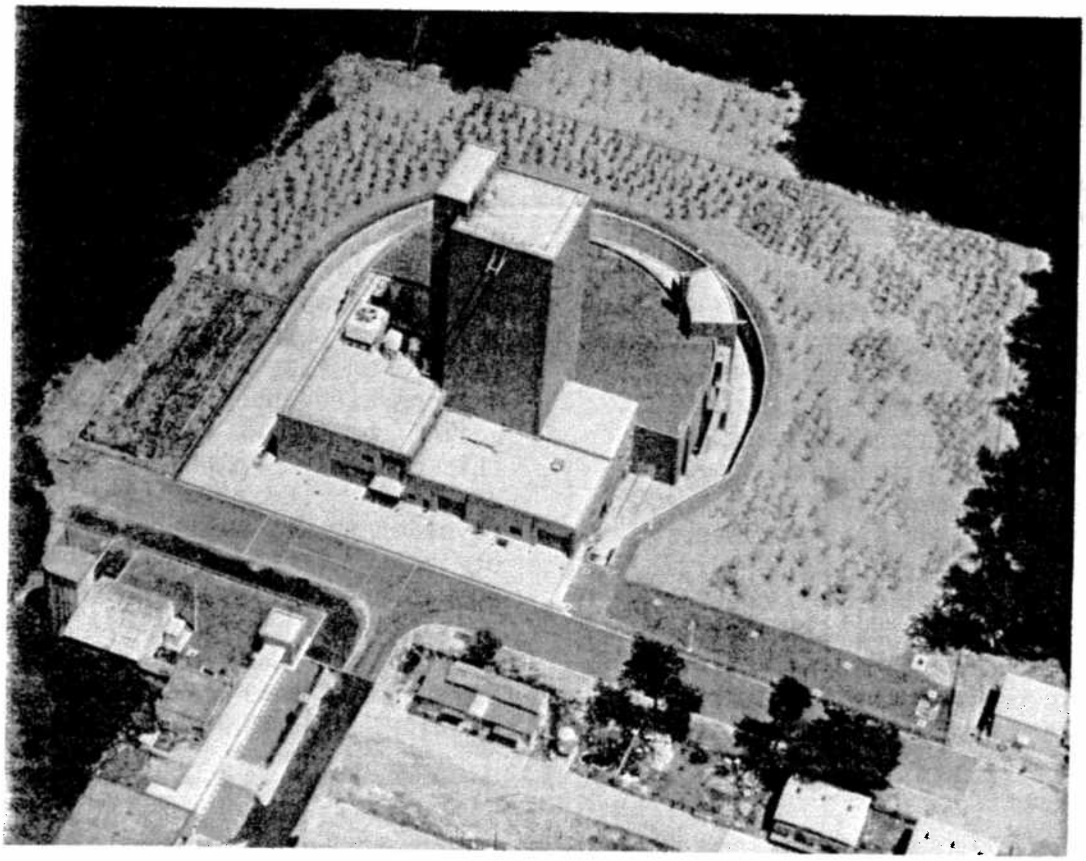
JAERI TANDEM

NEWSLETTER No. 8

December, 1981

Accelerators Section, Division of Physics
Tokai Establishment, Japan Atomic Energy Research Institute
Postal Area Number 319-11
Tokaimura, Nakagun, Ibaraki-ken, Japan
Tel. 02928-2-5439

Contents



JAERI Tandem Accelerator Building

Present Status of JAERI Tandem

Preparation of Apparatus and Beam Acceleration

Having been finished the operation of the tandem accelerator for experiments in mid January 1981, preparation of the apparatus inside of the tank has been made until early in May. Main works were to exchange the corona needles for those of improved type, to remake the protection gaps for accelerating tubes and to prepare the beam pulsing system and the positive ion source in the terminal.

The accelerating tubes protect the inner structures from damage due to voltage discharges, by being equipped with toroidal spark gaps between electrodes outside of tubes. NEC narrowed the gap distance from 85 mil to 67 mil, in order to intensify the protection effect, and, furthermore, its uniformity was improved from ±20 mil to ±5 mil. This time, the accelerating tube gaps of the lowest seven column modules were exchanged tentatively. The result of the voltage test performed in May showed this process to be effective to improve the capability for the terminal to keep high voltage.

For the water pump of the terminal cooling system, a roller pump had been used. Its life time, however, had been rather short (<300 hr, on the average) and it had often brought about water-leak troubles, which caused the tank opening. At the end of June, the pump was exchanged for an enclosed pump of magnetically coupled type. Ever since it has been operated satisfactorily, and the anxiety for water-leak trouble has been swept away.

In mid July, the beam pulsing system, which is set between the injection magnet and the entrance to the low energy accelerating tube, has been tested at the terminal voltage of 10.5 MV. The pulsed proton beam has reached the target room for the first time, with pulse repetition rate of 4 MHz, time width (FWHM) of 1 ns and average current of 0.3 μA (peak current : 75 μA).

From mid August to the end of December, the tandem accelerator has been operated under the control of JAERI. During this period, the accelerator has been operated better than expected, including the control system, the injection system and the beam handling system, except the tank opening only once at the end of August. The operation time amounted to about 1500 hours.

The maximum accelerating voltage experienced this time was 16.7 MV. Higher voltage than this was not tried, because of insufficient conditioning of the accelerating tubes. The kind of ions accelerated were those of H, C, O, Si, Cl, Ni, Cu, Br and I, while the ions used for more than 80% of machine time for experiments were those of O and Cl. Ion sources utilized were a duoplasmatron ion source for H ions, an HPIG type for O, Cl, Br and I ions, and a sputter cone type for C, Si, Ni and Cu ions.

Since the transmussion of the beam handling system, including the accelerating tubes, was good, the loads of the ion sources and carbon foil stripper could be reduced, and it resulted in producing the stable beam for long time continuously. A typical example of the beam transmission is shown in Fig. 1.

The total operation time until December 1981 has amounted to 6000 hours for 6 chains and 7500 hours for the shafts for generators. During this time, no trouble has occurred for the high voltage generator, while troubles have occurred several times for joints between the shafts and drive motors or generators. At each time the shafts have been improved and have now reached the level of practical use.

Continuous Operation for Experiments

Likewise in the period from October 1980 to January 1981, during which the accelerator had been utlized intermittently for experiments, the accelerator was operated under the control of JAERI again from August to December 1981. This was based on the agreement between HAKUTO Co., Ltd. and JAERI, made in relation to the delay of the acceptance of the accelerator to March 31, 1982.

A Program Advisory Committee, which consists of the representatives of the related experimental fields, Health Physics Division and Accelerators Section, has started at July. This committee intends to promote the projects of research with heavy ions smoothly, by advising accelerator users on the safety of the planning, the radiation control and accelerator feasibility in their proposals.

The continuous operation of the accelerator started at August 19, and was carried out until December 24, from 9:00 Monday to 9:00 Saturday every week. The experiments were performed over four experimental projects (cf. JAERI TANDEM NEWS LETTER No.1) at the terminal voltage of 8.3 - 16.7 MeV, by using H, O, Cl and I ions.

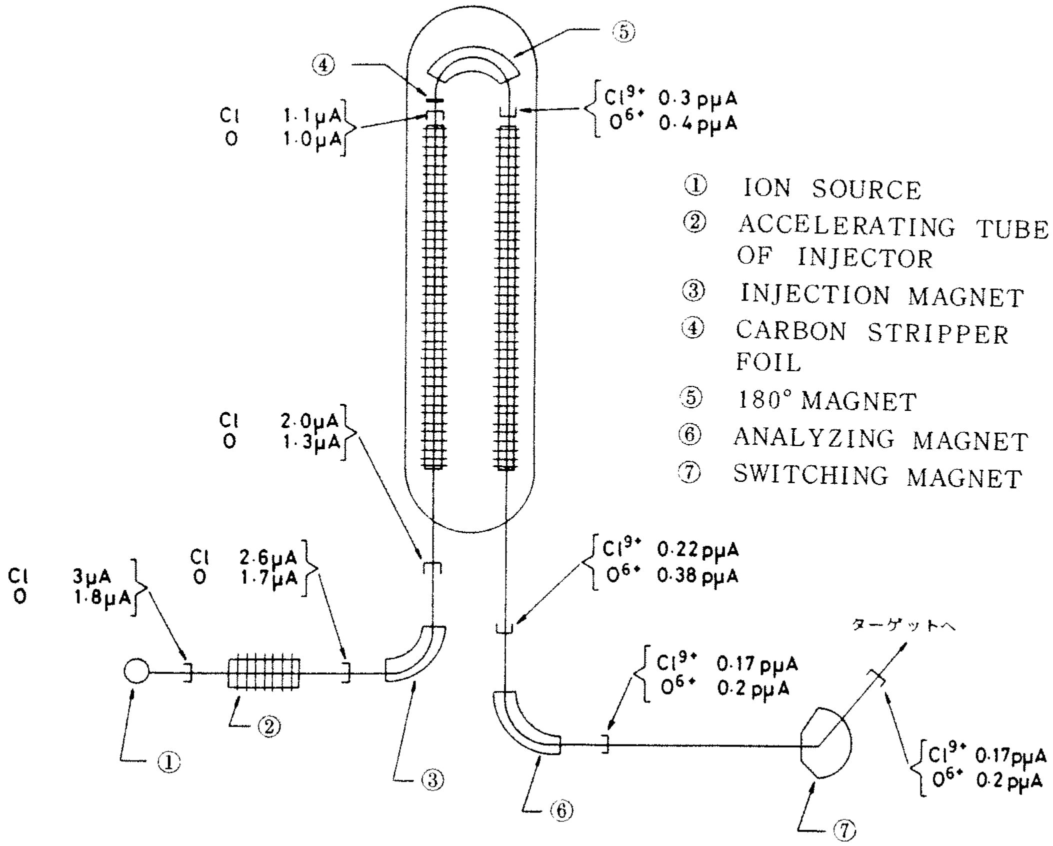


Fig. 1 A typical example of beam transmission

Negative Ion Formation of the Krypton Difluoride

Hitherto, it has not been possible to obtain any negatively-charged atomic and molecular ions of inert gases (Ne, Ar, Kr, Xe, Rn) heavier than helium in ion sources. None of their negative ions are stable, or has been confirmed to be stable. This comes from the negative electron affinities and the inertness of the gases. Therefore, it has not been possible to accelerate any ions of the inert gases by tandem accelerators. However, stable fluorides of krypton and xenon have been synthesized since the 1960's. There is a possibility that negatively-charged molecular ions of krypton and xenon can be obtained by using these fluorides and accelerated by tandem accelerators.

We found metastable or stable negatively-charged krypton monofluoride was extracted from a Penning ion source with radial extraction by using krypton difluoride. A typical mass spectrum of KRF_2 in the KrF mass region is shown in fig. 2a. For comparison, the natural abundance of six krypton isotopes is shown in fig. 2b.

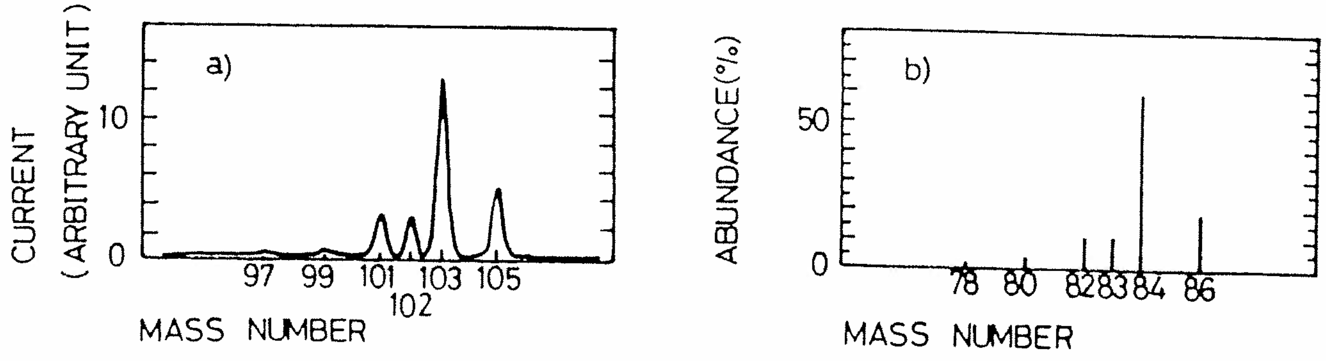


Fig. 2 a) Mass spectrum of KrF^- ions produced
b) Natural abundance of six krypton isotopes

Present Status of Experimental Apparatus

Heavy Ion Spectrometer "ENMA"

The heavy ion spectrometer "ENMA"* (abbreviation of ENergy and Mass Analyzer) has been completed and installed to the beam line. The photograph of ENMA is shown in fig.3.

Development and fabrication of a focal plane detector have been carried out in parallel with the construction of the spectrometer. The Rochester-type detector which has a 46cm-long sensitive area has been made. A performance test of the spectrometer was made using Cl

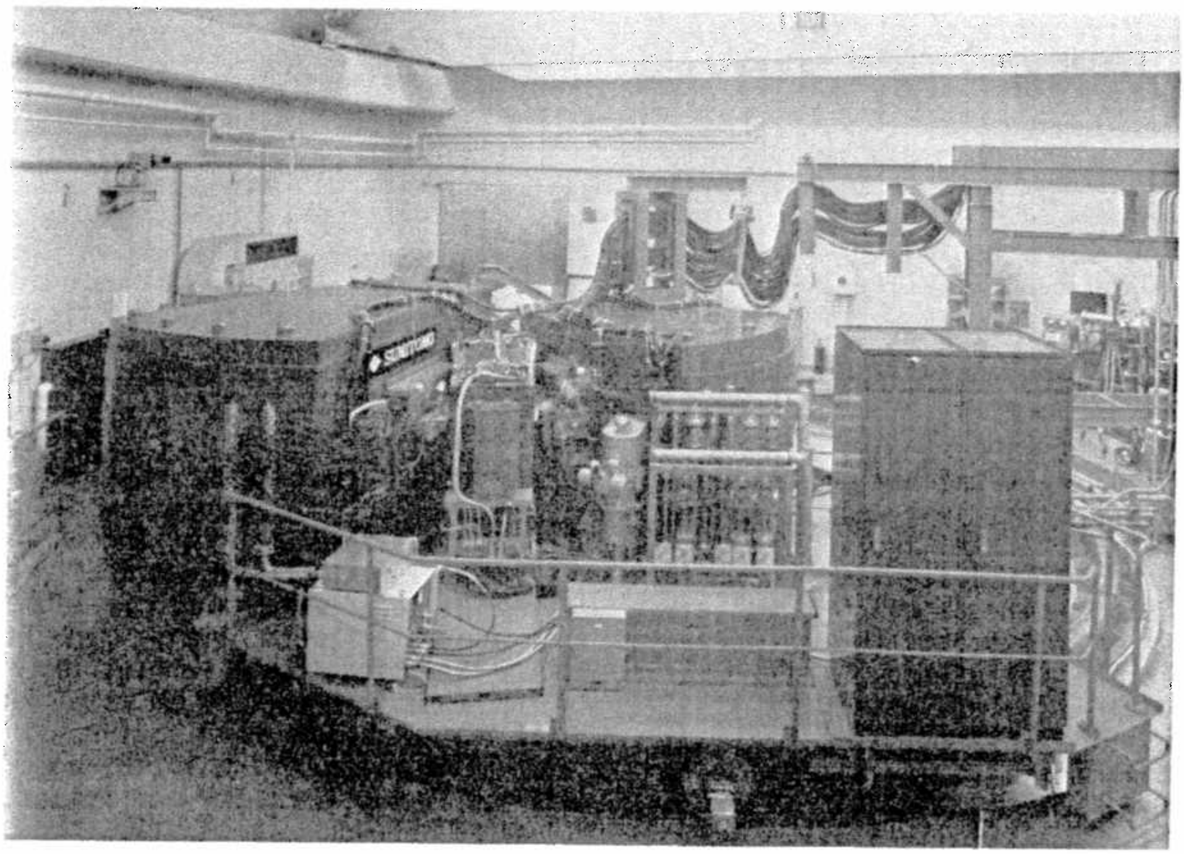


Fig. 3 Heavy Ion Spectrometer "ENMA"

ions from the tandem accelerator, and results were satisfactory. In fig. 4, rays gathered on the focal plane are reproduced from the observed positions on the two position sensitive detectors.

* Long before Buddha was born in India, ENMA (Yamarāja in Sanscrit) was a god of Brightness and Justice in a world of Indian mythology. Later on, he became a king who governed Hades as the first deceased of human being. In a story of Buddhism, he sits in the gate of Hell with 18 officers and 80,000 soldiers and passes judgements on men and women who come into Hell, according to their goodness and badness in their livetime.

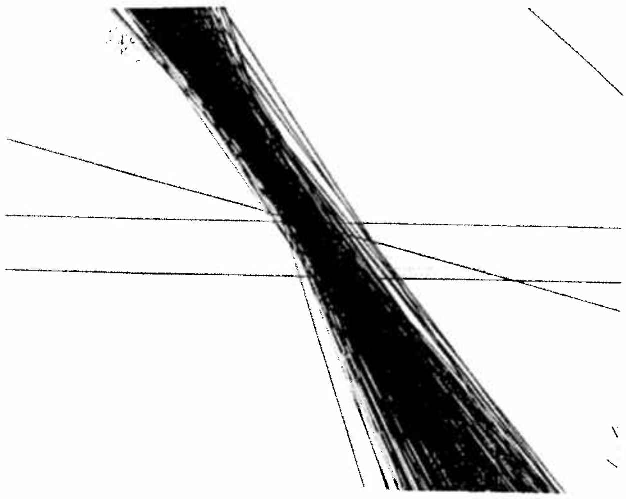


Fig. 4 Rays of Cl ions on the focal plane. The two horizontal lines represent the position sensitive detectors.

Beam-Foil Spectrometer

A beam-foil spectrometer has been constructed in the 2nd Heavy-Ion Target Room for the purpose of measuring the spectrum of ions excited and lifetime following beam-foil or beam-gas interactions, and the charge states of the projectile ions after collisions. Its block diagram is shown in fig. 5.

The spectrometer consists of the three parts, namely, (1) beam-foil chamber, (2) charge selector, and (3) data aquisition system.

The chamber is provided for the followings:
i) Photospectrometer, which is a 2.2 m grazing incidence monochromator (McPherson model 247). Foil-excited radiation emitted at an angle of 90° to the beam axis is collected and dispersed by the spectrometer. The practical wavelength range from ∿50 to 2000 Å is covered by the use of three interchangeable gratings. ii) Electron energy analyzer, which is a 30° electrostatic parallel plate analyzer. Ejected electrons produced in ion-atom collisions

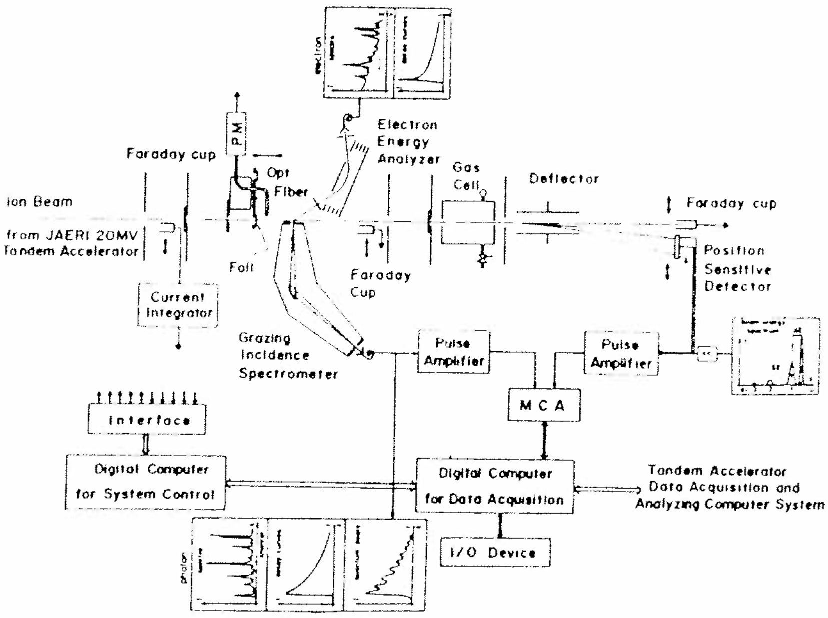


Fig. 5 A block diagram of the beam-foil spectrometer

are energy-analyzed in the energy range from 0 to 3 keV. The analyzer has an energy resolution of a few per cent. iii) Foil-replacing, which is done by mounting 20 targets on a wheel, and foil-translating (300±0.05 mm) parallel to the beam so that the lifetime measurement can be made. iv) Beam current monitor using the optical fiber.

The projectile charge states passing through the target are analyzed electrostatically, and it is helpfull to identify the charge state of the radiative ions. The pressure in the target chamber is kept below 10^{-9} torr. This pressure can be reached by mounting three turbo-molecular pumps. Operation of the spectrometer and data acquisition are performed using two minicomputer systems (Okitac 50/10).

We are planning four types of experiments as follows:
i) beam-foil and beam-gas spectrometry,
ii) charge-changing processes,
iii) stopping power for heavy ions, and
iv) X-ray production in heavy ion-atom collisions.

Preliminary Review of Experimental Result

Coulomb Excitation of ^{167}Er

Nuclear high spin states have been investigated through the multiple Coulomb excitation reaction by means of the in-beam γ-ray spectrometry. The multiple Coulomb excitation by heavy ions is one of the most effective methods to populate the high spin states of stable nuclei. In the present experiment, a self supporting ^{167}Er target was bombarded with beams of $^{35}Cl^{10+}$ ions at the energy of 160 MeV. Very stable beam was obtained at the target with 10-20 pnA current. Fig. 6 shows the singles spectrum of γ-rays emitted from the Coulomb excited levels of ^{167}Er. A Compton-suppression γ-ray spectrometer with a suppression factor of 1/8 was used for the measurement. The systematic peaks in the 80-400 keV energy region (shown by the closed circles) correspond to cascade transitions in the ground state rotational band. A tentative level scheme including some new transitions, levels and spin assignments has been obtained for the band as shown in fig. 7. Further information on the nuclear structure of this nucleus is expected from detailed analysis of γ-γ coincidence and γ-ray angular distribution data, which are now in progress.

The phenomena arround the high spin states will aid to understand the nuclear structure of heavy nuclei. The availability of heavier-ion beams, such as ^{48}Ti, ^{58}Ni will promote investigation for higher spin states.

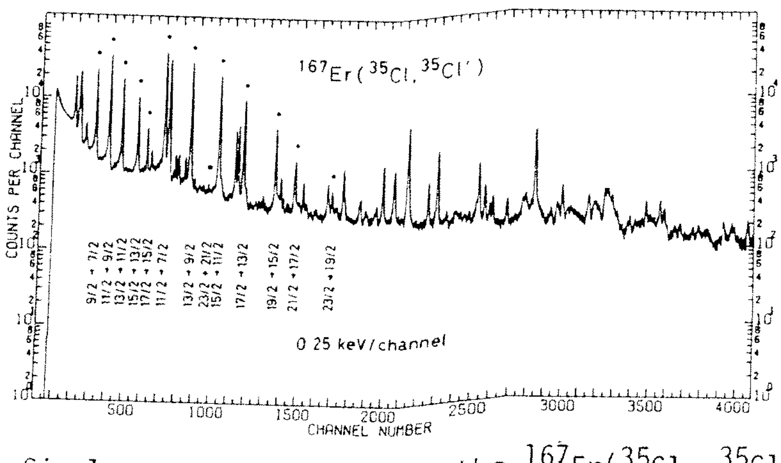


Fig. 6 Single γ-ray spectrum from the $^{167}Er(^{35}Cl, ^{35}Cl'\gamma)$ reaction at bombarding energy of 160 MeV

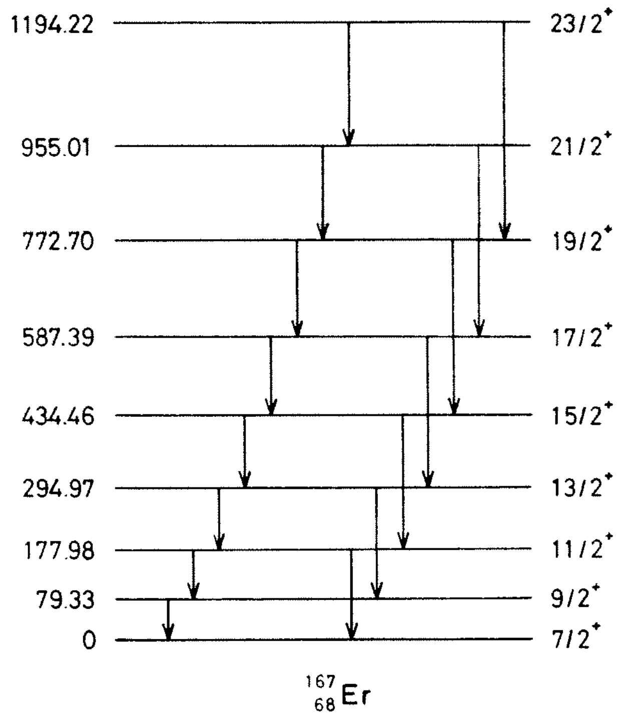
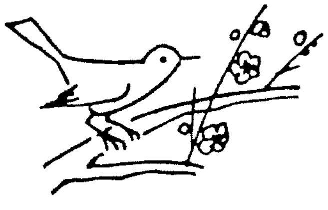


Fig. 7 A level scheme of the ground state rotational band in $^{167}_{68}Er_{99}$. Energies shown are in keV. The 955.01 keV ($21/2^+$) and 1194.22 keV ($23/2^+$) levels are newly assigned.

Publications Related to JAERI Tandem

- Nucl.Inst.Meth.187(1981)25:
  Y.Sugiyama, N.Shikazono, H.Ikezoe and H.Ikegami
  JAERI Magnetic Spectrograph for Heavy-Ion Research
- Nucl.Inst.Meth.190(1981)215:
  E.Minehara and S.Abe
  Mass-Spectrometric Study of the Negatively-Charged Krypton Monofluoride
- Proc.3rd Int.Conf.on Electrostatic Accelerator Technology April 1981: M.Maruyama
  The JAERI Tandem Accelerator Facility
- JAERI-M 9322: S.Takeuchi and E.Takekoshi
  Surface Treatment of Glass Substrates for the Preparation of Long-lived Carbon Stripper Foils
- JAERI-M 9358: Y.Sugiyama, N.Shikazono,T.Sato,T.Takayama and H.Ikegami
  Magnet Design for JAERI Heavy-Ion Spectrograph
- JAERI-M 9514: T.Murakami, H.Ikezoe, Y.Tomita and N.Shikazono
  Bragg Curve Ionization Chamber for Particle Identification



Contributors to this Newsletter are:
M.Maruyama, C.Kobayashi, E.Minehara, N.Shikazono, K.Ozawa, M.Ohshima