ISSN 0915-633X

NATIONAL INSTITUTE FOR FUSION SCIENCE

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(Received - Oct. 24, 1995)

NIFS-418 May 1996

RESEARCH REPORT
NIFS Series

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Extraction of K^- mesonlike Particles from a D_2 gas Discharge Plasma in Magnetic Field

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Abstract

From the outside region of D_2 gas discharge plasma along magnetic field, K^- mesonlike particles are extracted with D^- ions and π^- mesonlike particles. Then, a higher positive bias voltage is necessary for the beam collector of magnetic mass analyzer in order to detect the K^- mesonlike particles, and we must interrupt the diffusion of the positive ions to the back of the beam collector.

Keywords: K^- mesonlike particle, D_2 gas discharge, D^- ion

It has been reported[1] already that negative pionlike particles (π^-) are extracted from the outside region of a H_2 or D_2 gas discharge plasma in magnetic field, together with H^- ions or D^- ions. However, physical differences between the H_2 and the D_2 gas discharge plasma were not investigated precisely under various experimental conditions. In this paper, a remarkable difference of extraction of negatively charged particles between a H_2 and D_2 gas discharge plasma will be clarified by adjusting a bias voltage of the beam collector of magnetic mass analyzer.

A schematic diagram of the experimental apparatus is shown in Fig. 1. The apparatus is constructed from a D_2 gas discharge plasma in magnetic fields, three extraction electrodes (with an aperture of 3 mm in diameter) to extract some negatively charged particles and a magnetic mass analyzer (90° deflection-type).

An electron acceleration-type sheet plasma[2] is produced to generate D^- ions effectively and in wide area. That is, the discharge (cylindrical) plasma flow of about 1 cm in diameter is transformed into a sheet plasma flow of about 3 mm in thickness and about 20 cm in width, while the electron components in the initial discharge plasma are accelerated near 80 eV. The sheet plasma flow passes through the electron acceleration anode (12 in Fig. 1) and enters the main chamber (50 cm long). The electron components in the sheet plasma are reflected by the end plate which is electrically floated. A uniform magnetic field of about 50 gauss is applied along the sheet plasma flow in the main chamber where the D_2 gas pressure is about 1.5×10^{-3} Torr. The electron acceleration anode current I_A is 30A and about 60% of I_A enters the main chamber. A distance between the sheet plasma center and the first extraction electrode (L) is 7.5 cm. The plasma density in the center of the sheet plasma is about 10^{11}/cc and the electron temperature is about 20 eV. The positive ion density in front of the first extraction electrode is estimated to be about 10^{10}/cc from a positive ion saturation current as D_3^+, while the electron density from the Langmuir probe characteristic is about 10^9/cc and the electron temperature is about 3.0 eV. That is, the electron density in front of the first extraction electrode is reduced near 1/10 of the positive ion density.

The negatively charged particles extracted from the D_2 gas discharge plasma, are injected into the ordinary magnetic mass analyzer (MA) through the slit (3 mm × 1 cm) while each mass of the negatively charged particle is estimated by the following relations: From the analyzing magnetic field B_M where the negative current to the beam collector BC shows a peak, the curvature radius r

of the mass analyzer and the extraction (acceleration) voltage V_E, we can estimate the mass m of the negatively charged particle by,

$$m = \frac{Ze\,(B_M r)^2}{2V_E}$$

$$= \frac{8.8 \times 10^{-2}\, Z\,(B_M r)^2\, m_e}{V_E}, \quad \text{(1)}$$

where e is the electron charge, B_M is in gauss unit, r is in cm unit, V_E is in volt unit and m_e is the electron mass and Z is the charge number. For the curvature radius $r = 4.3$ cm of this mass analyzer, the Eq. (1) is rewritten by

$$m = \frac{1.63\, Z\, B_M^2}{V_E}\, m_e. \quad \text{(2)}$$

In the extraction of negatively charged particles, the first extraction electrode (L) is electrically floated, whose potential V_L is about −15V with respect to the electron acceleration anode (12 in Fig. 1). A potential V_M of the second extraction electrode (M) is kept at 300V. The potential V_E of the final extraction electrode (E) is 800V.

A result of the mass analysis for extraction of negatively charged particles from the D_2 gas discharge plasma, is shown in Fig. 2. Dependences of the negative current I^- to the beam collector on the analyzing magnetic field B_M are shown, where the bias voltage V_{BC} of the beam collector with respect to the mass analyzer, is 50V or 140V.

For V_{BC} = 50V [(1) of Fig. 2], the first peak of negative current I^- to the beam collector is seen at $B_M \approx 390$ gauss while the second peak appears at $B_M \approx 1420$ gauss. From Eq. (2), we obtain $m_1 \approx 310\ m_e$ and $m_2 \approx 4100\ m_e$, assuming that Z = 1. On the other hand, for V_{BC} = 140V [(2) for Fig. 2], the third peak appears at $B_M \approx 720$ gauss between the first peak and the second peak, which corresponds to $m_3 \approx 1050\ m_e$, assuming that Z = 1.

For the above experimental results of Fig. 2, we can estimate that the first particle mass (m_1) is near the typical negative pion π^- mass (= 273 m_e) within 14% and the second particle mass (m_2) is near D^- ion mass (= 3680 m_e) within 12%. Here, we find that the third particle mass (m_3) is near the typical K^- meson mass (= 966 m_e) within 9%, assuming that Z = 1 also.

In the experiment of Fig. 3, a Cu plate of 0.5 mm in thickness is put in front of the beam collector of the mass analyzer. Then, the second current peak corresponding to D^- ion disappears while the first and the third current peak appear. This experimental fact shows that the pionlike particle π^- and the K^- mesonlike particle penetrate the Cu plate. It has been reported[3)] already that the pionlike π^- or muonlike particle μ^- penetrates a metal plate if the positive ions exist behind the metal plate. In this experiment, those positive ions may be produced by the gas ionization due to D^- ions. From these experimental results, we find that a physical character of the first peak particle (π^-) and the third peak particle (K^-) is remarkably different from that of the second peak particle (D^-).

Next, in order to clarify differences for the third peak (K^-) between a D_2 gas and H_2 gas discharge plasma, extractions of negatively charged particles from a H_2 gas discharge plasma are tried under experimental conditions similar to the D_2 gas discharge plasma (that is, $B_Z \approx 50$ gauss, $I_A = 30A$, $V_M = 300V$ and $P \approx 1.5 \times 10^{-3}$ Torr of H_2 gas). The experimental results for the H_2 gas discharge plasma are shown in Fig. 4 (in the ordinary method) and in Fig. 5 (in the "Cu plate arrangement" method). In Fig. 4, the first current peak (corresponding to π^-) and the second current peak (H^-) are seen under the beam collector bias voltage V_{BC} = 50V and V_{BC} = 140V. In Fig. 5, only the first current peak (π^-) is seen. As understood from these experimental results, the third current peak corresponding to the K^- mesonlike particle does not appear for H_2 gas discharge plasmas. We have confirmed that the K^- mesonlike particles are not extracted from H_2 gas discharge plasmas even if the experimental conditions are varied greatly.

A dependence of the K^- mesonlike current peak to the beam collector on the extraction voltage V_E is investigated from 700V to 1200V, which satisfys Eq (2). The K^- mesonlike current peak does not appear for $V_E < 700V$ while the π^- current peak does not appear for $V_E < 400V$. That reason may be due to the life time ($\approx 1.2 \times 10^{-8}$ sec) of K^- meson which is shorter than that of π^- meson ($\approx 2.6 \times 10^{-8}$ sec).

In conclusion, the K^- mesonlike particles generate as some physical differences between the H_2 gas and D_2 gas discharge plasma. A higher positive bias voltage of the beam collector is necessary to detect the K^- mesonlike particles and we must interrupt the diffusion of the positive ions to the back of the beam collector [4)] (Fig. 2 MA).

References

1) J. Uramoto: National Institute of Fusion Science, Nagoya, Japan-Research Report, NIFS-377 (1995).

2) J. Uramoto: Journal of the vacuum society of Japan, **37** (1994) 507 in Japanese.

3) J. Uramoto: NIFS-350 (1995).

4) J. Uramoto: NIFS-400(1996).

Figure Captions

Fig. 1 Schematic diagram of experimental apparatus.

1: Cylindrical plasma in discharge anode. 2: Discharge cathode. 3: D_2 gas flow. 4: Discharge power supply. 5: Electron acceleration power supply. 6: Vacuum pump. 7: Area where cylindrical plasma is transformed into sheet plasma. 8: Insulation tube. 9: A pair of permanent magnets. 10: Magnetic field coils. 11: slit of acceleration anode. 12: Electron acceleration anode. 13: Floated end electrode. I_A: Current to electron acceleration anode. CP: Cylindrical plasma. SP: Sheet plasma. B_Z: Magnetic field. L: First extraction electrode. M: Second extraction electrode. E: Final extraction electrode. V_M: Potential (300V) of second extraction electrode with respect to electron acceleration anode. V_E: Potential (800V) of final extraction electrode with respect to electron acceleration anode. I_E: Negative current to final extraction electrode. MA: Magnetic deflection (90°) mass analyzer. B_M: Magnetic field intensity of MA. BC: Beam collector of MA. V_{BC}: Positive potential of BC with respect to MA. I^-: Negative current to BC. I_{MA}: Total negative current to MA. D_0^-: Deuteron negative ions outside of sheet plasma. D^-: Accelerated deuteron negative ions. π_0^-: Negative pionlike particles outside of sheet plasma. π^-: Accelerated negative pionlike particles. K_0^-: K^- mesonlike particles outside of sheet plasma.

Fig. 2 Dependences of negative current I^- to beam collector on magnetic field intensity B_M of MA at V_E = 800V. (1): V_{BC} = 50V. (2): V_{BC} = 140V.

π^-: First peak of I^- corresponding to negative pionlike particle. D^-: Second peak of I^- corresponding to deuteron negative ion. K^- : Third peak of I^- corresponding to K^- mesonlike particle.

Fig. 3 Dependences of negative current I^- on B_M under a case setting a Cu plate in front of beam collector at V_E = 800V. π^-: First peak of I^-. K^-: Third peak of I^-. (D^-): Position of second peak of I^-. Cu: Copper plate of 0.5 mm in thickness, which shields the surface of beam collector. (1): V_{BC} = 50V. (2): V_{BC} = 140V.

Fig. 4 Dependences (for H_2 gas) of negative current I^- on B_M at V_E = 800V.

(1): V_{BC} = 50. (2): V_{BC} = 140V. π^-: First peak of I^-. H^-: Second peak of I^- corresponding to hydrogen negative ion.

Fig. 5 Dependences (for H_2 gas) of negative current I^- on B_M under a case setting a Cu plate in front of beam collector at $V_E = 800V$.

(1): $V_{BC} = 50V$. (2): $V_{BC} = 140V$. π^-: First peak of I^-.

Appendix

Schematic diagrams of the magnetic mass analyzer and the extraction electrodes are shown in Fig. 1 MA and Fig. 2 MA. The (fringe) magnetic field distribution is shown in Fig. 3 MA also.

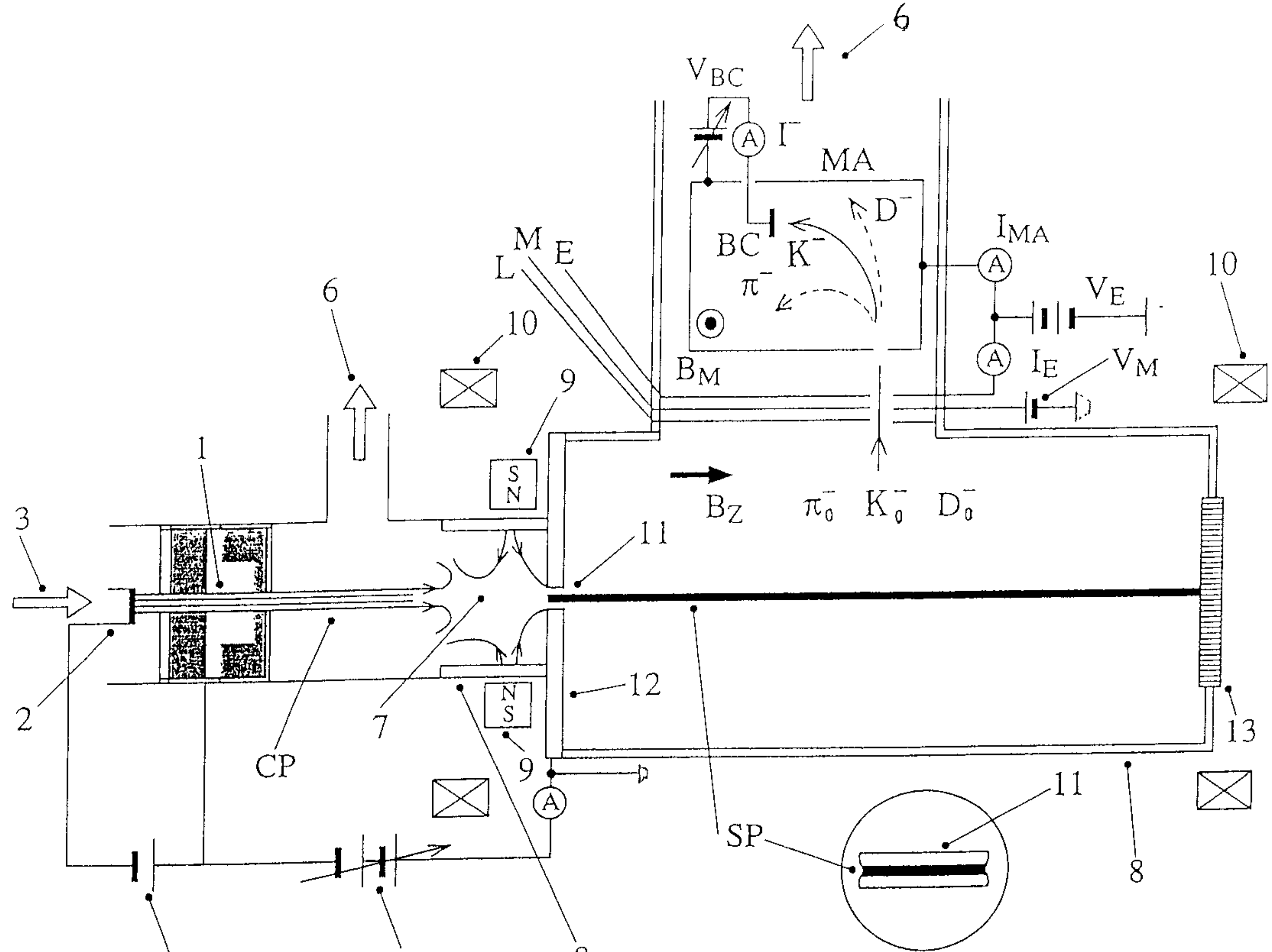
Figure Captions of Appendix

Fig. 1 MA and Fig. 2 MA Schematic diagrams of mass analyzer M.A. and the extraction electrodes E.M.L.

E: final extraction electrode (with an aperture of 3 mm in diameter). V_E: Applied voltage of E. I_E: Negative current to E. S: Entrance slit (3 mm × 10 mm) of M.A. Fe: shows Iron. C: Magnetic coil. (N): North pole of electro-magnet. (S): South pole. B_M: Analyzing magnetic field. B.C: Beam collector. I^-: Negative current to B.C. V_{BC}: Bias voltage of B.C. with respect to M.A. X: Entrance of uniform magnetic field. H^-: Hydrogen negative ion. D^-: Deuteron negative ion. π^-: Negative pionlike particle. K^-: K^- mesonlike particle. Ins: Insulator.

Fig. 3 MA Fringe magnetic field distribution at (1A of M.A. coil current).

B_M: Analyzing magnetic field of M.A. B_0: Uniform magnetic field inside of M.A. S: Entrance slit position. X: End of uniform magnetic field.



6
V_BC
I^-
MA
D^-
BC
K^-
π^-
L
M
E
I_MA
V_E
I_E
V_M
10
B_M
9
S
N
1
3
B_Z
π_0^-
K_0^-
D_0^-
11
2
CP
7
N
S
12
13
SP
8
4
5

Fig. 1

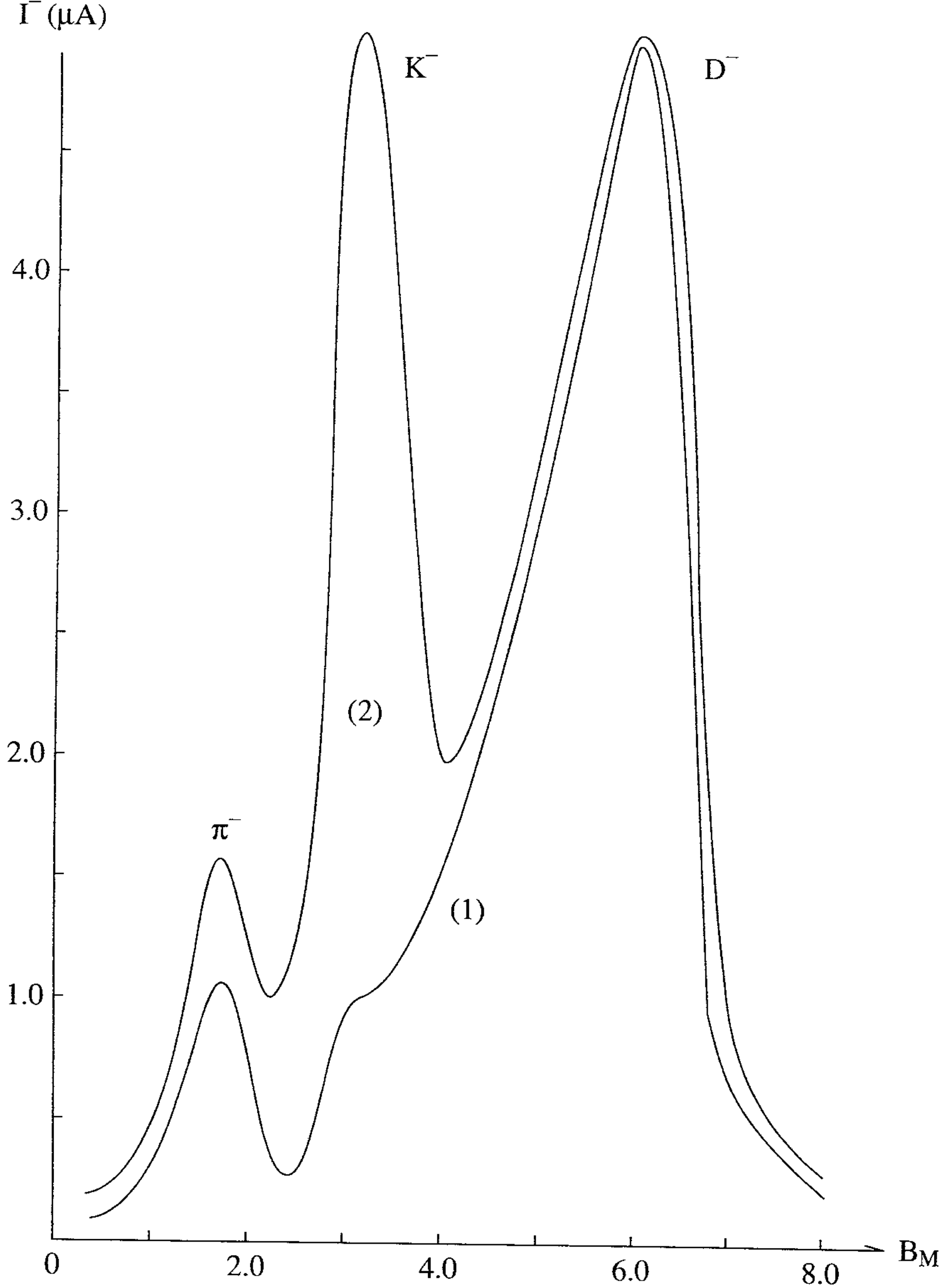
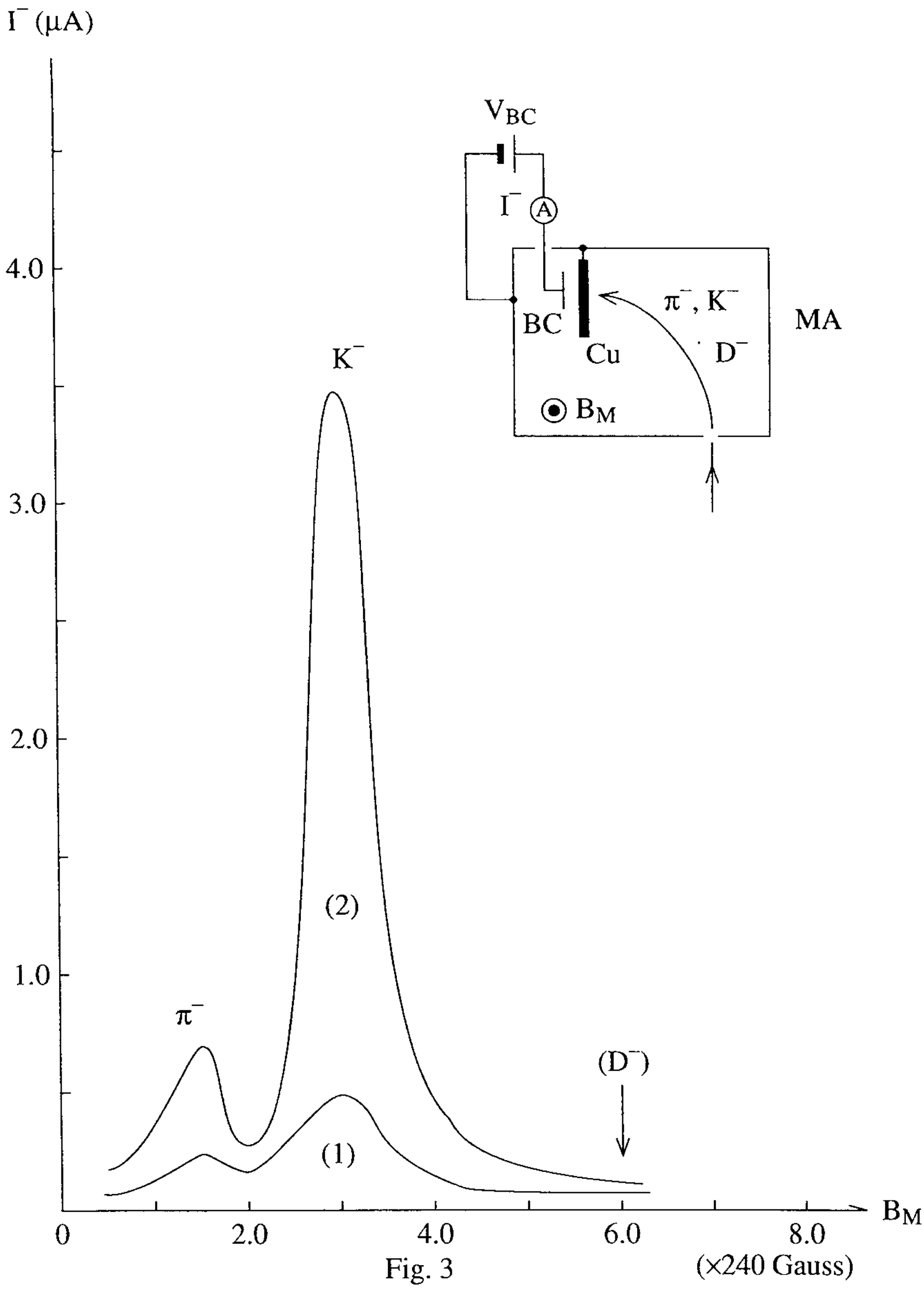


Fig. 2



I⁻ (μA)
4.0
3.0
2.0
1.0
0
2.0
4.0
6.0
8.0
(×240 Gauss)
B_M
K⁻
π⁻
(D⁻)
(1)
(2)
V_BC
I⁻
A
BC
Cu
π⁻, K⁻
D⁻
MA
B_M

Fig. 3

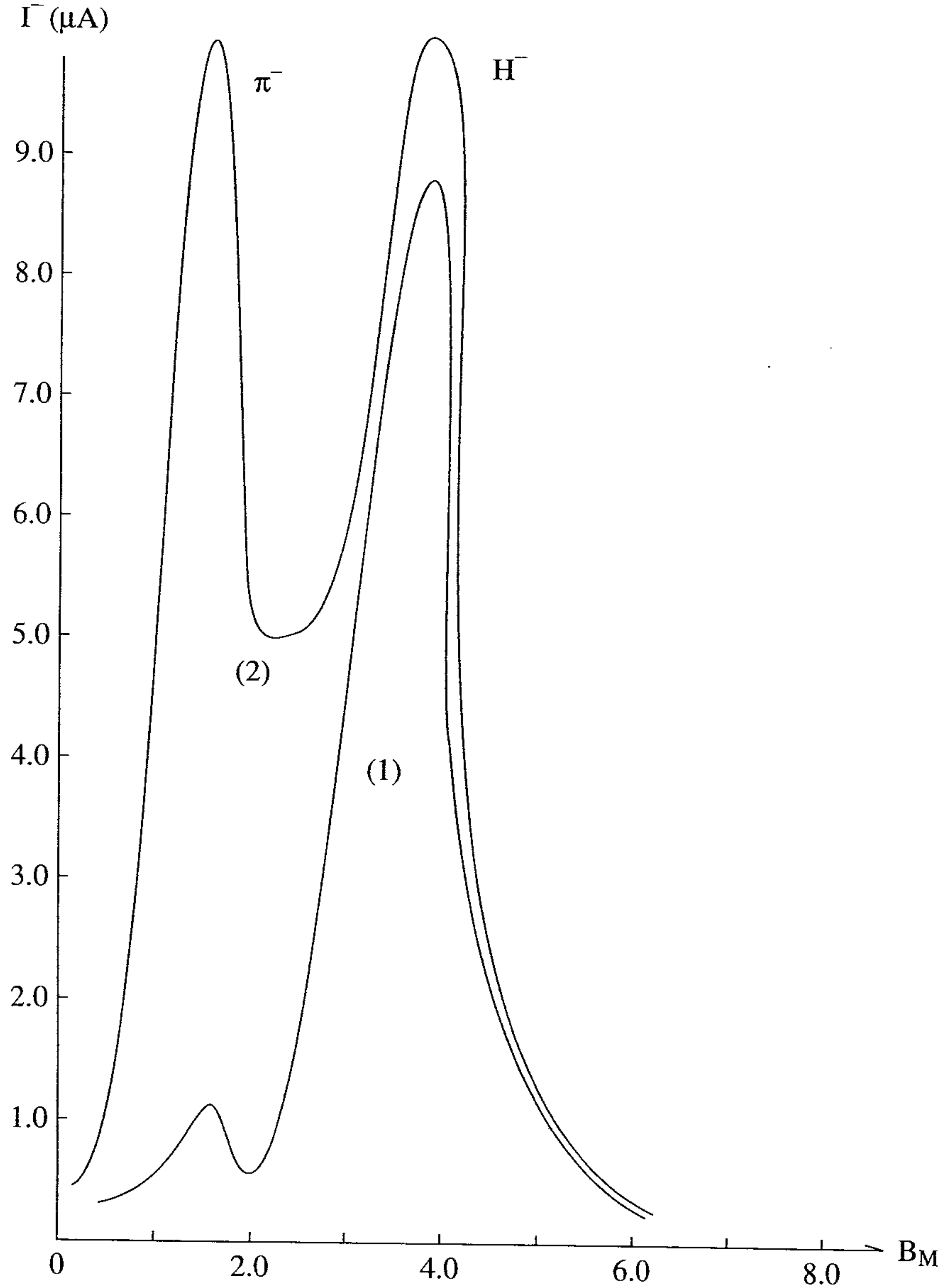


Fig. 4

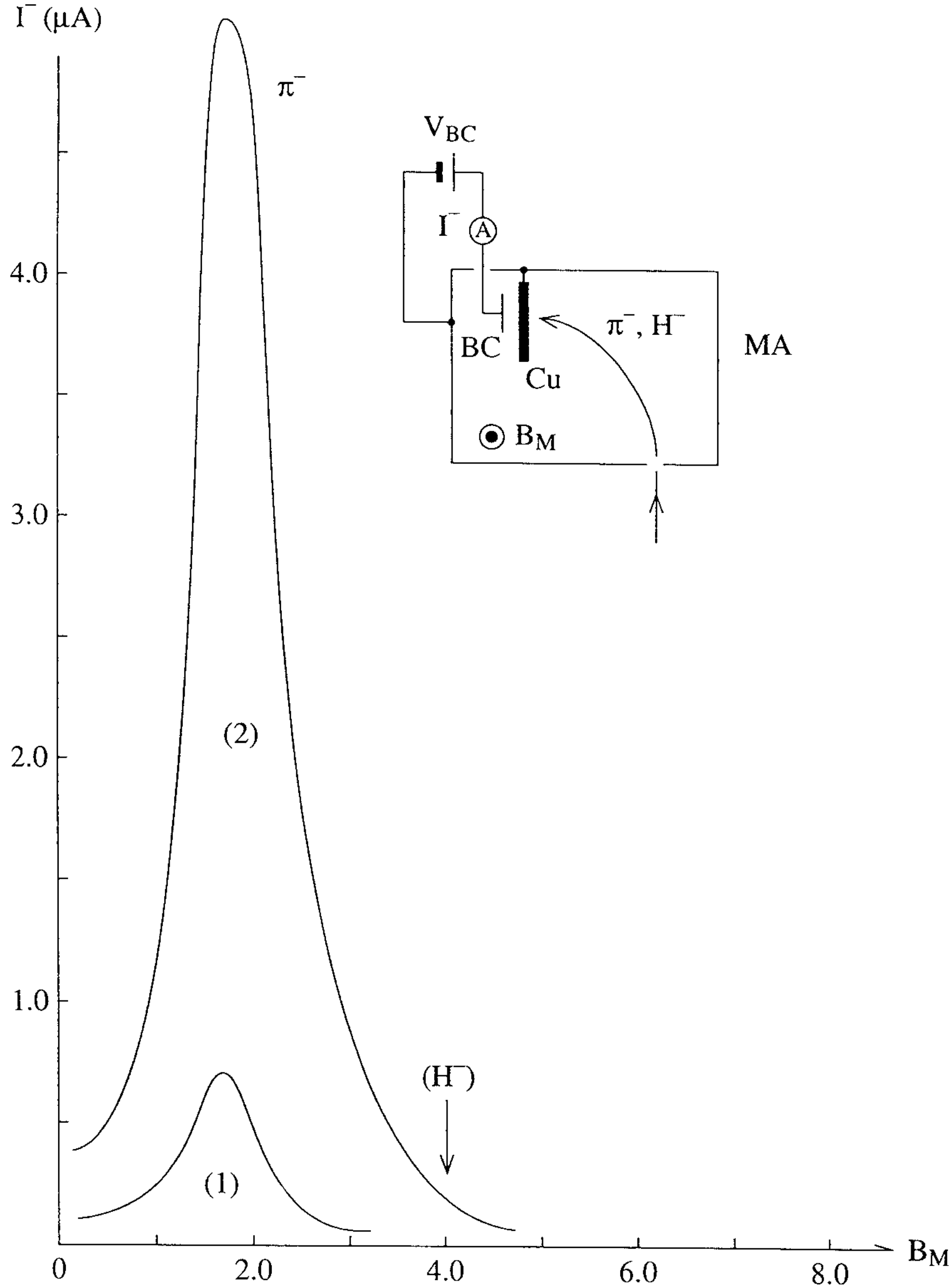


Fig. 5

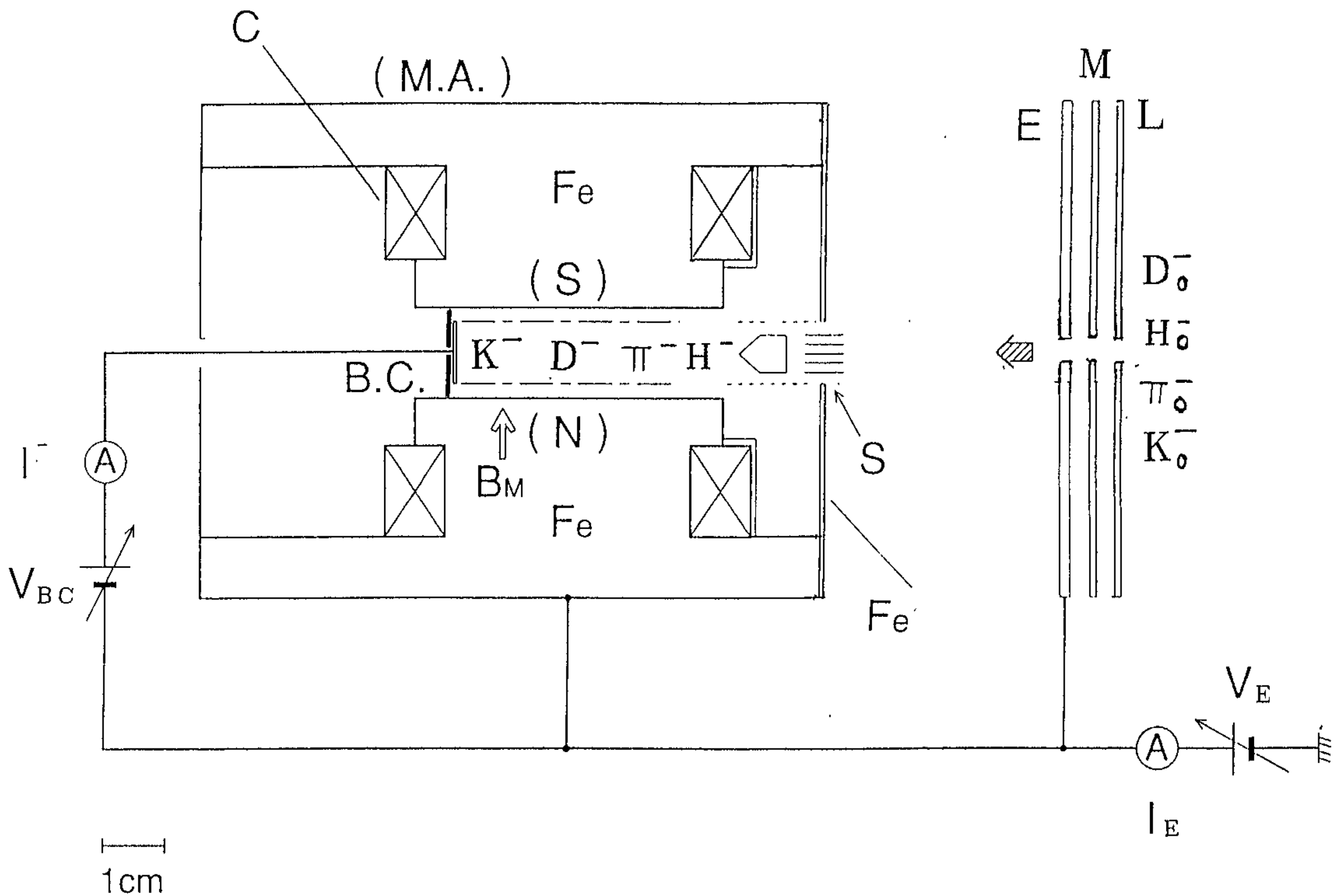


Fig. 1MA

(M.A.)

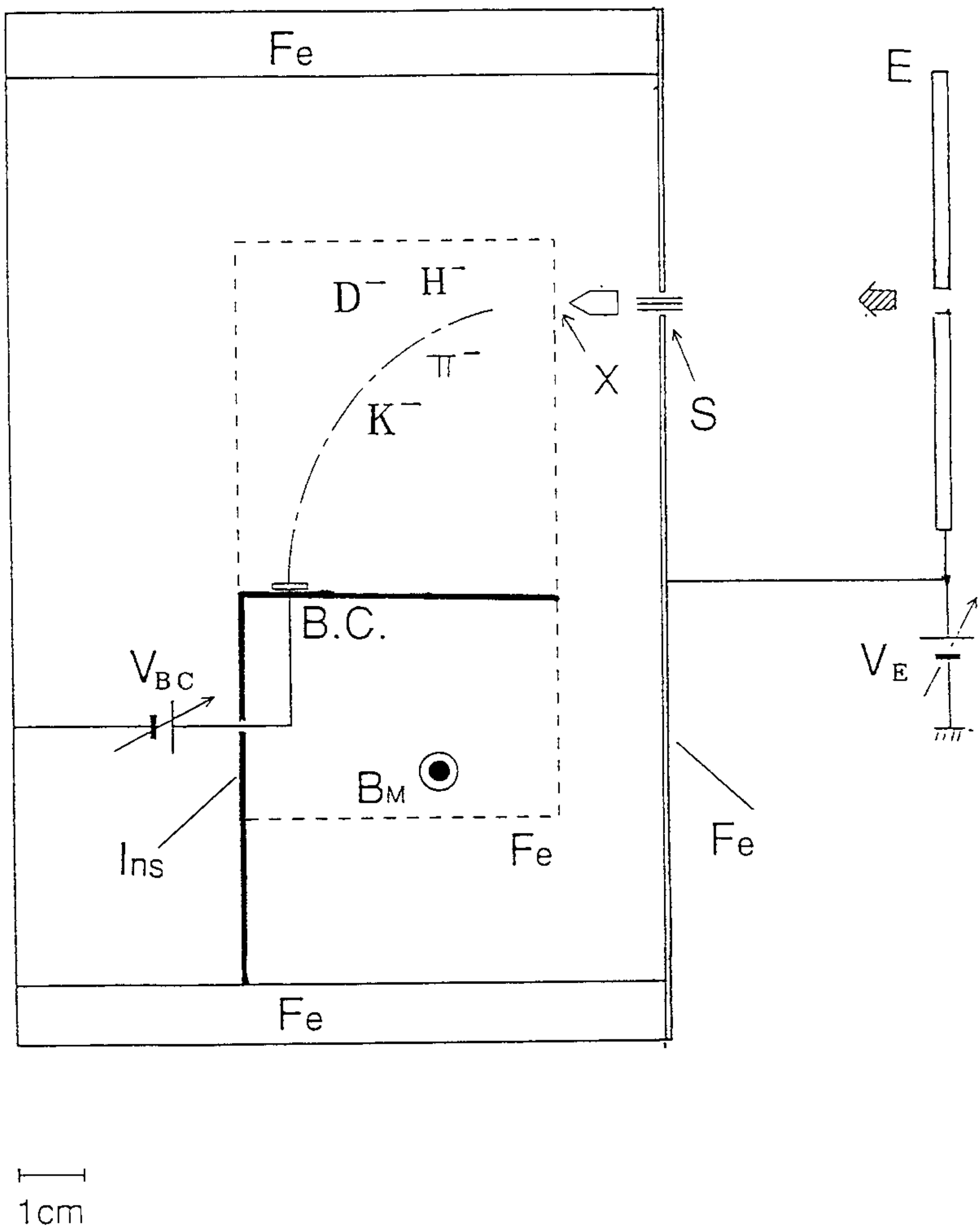


Fig. 2 MA

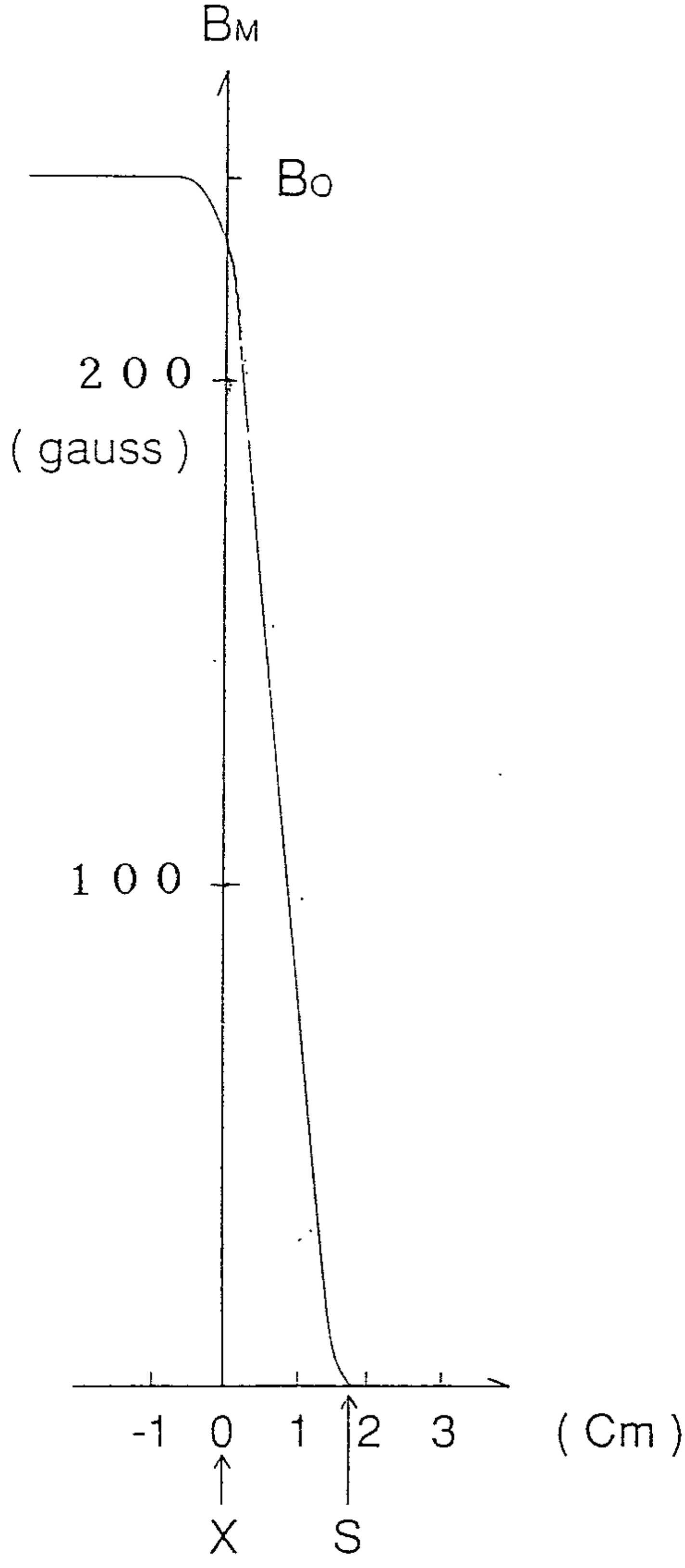


Fig. 3 MA

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