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Development of $\bar{\nu}_\mu$ beam detector and

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Abstract

From outside of a H_2 gas discharge in magnetic field, negative pionlike particles π^- are extracted in a low voltage (800V) with H^- ions and are shot into a thick metal plate MP. When electrons (above a critical electron energy) are supplied in the opposite side of the metal plate MP, some positive muonlike particles μ^+ appear continuously while the energy of μ^+ is corresponding to the π^- extraction voltage. From the thickness of MP, some unknown particles penetrating MP are estimated to be anti-μ neutrinos $\bar{\nu}_\mu$. Thus, a new detector for $\bar{\nu}_\mu$ beam are found and a large area $\bar{\nu}_\mu$ beam source are produced by opening many apertures over large area extraction electrodes of π^- under a sheet discharge of H_2 gas. This large area $\bar{\nu}_\mu$ source is very important when the $\bar{\nu}_\mu$ beam must be detected after a long distance flight or in a very small current. The negative pionlike particles π^- from the H_2 discharge can be concluded to be true negative pions as the characteristics of $\bar{\nu}_\mu$ beam are clarified in this experiment.

Keywords: negative pionlike particles π^-, anti-μ neutrinos $\bar{\nu}_\mu$

positive muonlike particles μ^+

We have already developed a new detection method for μ neutrino ν_μ beam and a new ν_μ beam source in this paper (I). However, it is very important also to develop a new and easy detection method for anti-μ neutrino $\bar{\nu}_\mu$ and a new $\bar{\nu}_\mu$ beam source.

On the other hand, we have observed[1,2,3] under a H_2 gas discharge in magnetic field that negative or positive pionlike particles π^- or π^+ are produced in very low energies. However, up to now, the π^- or π^+ has not been proved as true pion π_t^- or π_t^+.

In this paper, negative pionlike particles π^- are extracted in a low energy (800 eV) from a H_2 gas discharge in magnetic fields and are shot into a thick metal plate. Then, it is investigated whether positive muonlike particles μ^+ appear in the opposite side of the metal plate or not. Thus, we will research some anti neutrinos as unknown particles penetrating the thick metal plate while a detection method (detector) of the anti neutrino and an anti neutrino source are developed. Moreover, it will be concluded whether the pionlike particle π^- is equal to the true pion π_t^- or not.

In the first experiment, H^- ions and negative pionlike particles π^- are detected: The negatively charged particles extracted from the H_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 negativelycharged particles, a potential V_L of the first extraction electrode (L) is −6V with respect to the discharge anode, a potential V_M of the second extraction electrode (M) is . 300V and a potential V_E of the final extraction electrode (E) in 800V.

The dependences of the negative current I^- to BC on $-B_M$ are shown in Fig. 2. Obviously, in Fig. 2, a large peak of I^- at $-B_M \approx (4.0 \times 240)$ gauss = 960 gauss is corresponding to H^- ion, assuming that Z = 1 in Eq. (2). That is, we obtain $m \approx 1880\ m_e$ as $|V_E| = 800$V.

Next, a small peak of I^+ to BC is seen in Fig. 2. We find that the small peak at $-B_M \approx (1.60 \times 240)$ gauss $\approx$ 384 gauss is corresponding to a negative pionlike (π^-) particle, assuming that Z = 1 in Eq. (2). That is, we obtain $m \approx 300\ m_e$ (near the true pion mass 273 m_e) for the small peak.

In the second experiment as shown in Fig. 3, an electron beam are supplied externally by an electron gun (E.G.). Then, the mass analyzer and the electron gun are composed as an independent detector for unknown particles which penetrate thick metal plates (totally, above 10 cm) and atmosphere without energy loss. In Fig. 3a, the unknown particle "source" is constructed from extraction electrodes L, M with multi apertures ($3\phi \times 100$ apertures in 40 cm^2 area) and a thick metal plate E. Thus, the unknown particles can enter the slit of MA easily even if a distance between the unknown particle "source" and the "detector" is very long (~50 cm at present). The unknown particles induced by the negative pionlike π^- particles, enter the "detector" after a flight of about 50 cm through metal plates and atmosphere. In the detector side, a positive muonlike particle μ^+ beam current is observed at the beam collector BC of MA when the electron beam are supplied behind the detector side metal plate DMP as shown in Fig. 3b. The electron density behind DMP is about 0.1 $\mu A/cm^2$ for an electron acceleration voltage $V_e \approx 350$V and an electron current 10 mA to the electron gun anode. Dependences of the positive current I^+ on the analyzing magnetic field B_M are shown in Fig. 3c for the various extraction voltages V_E in the side of unknown particle source. From the experimental results, the detected particle is determined to be positive muonlike particle μ^+ from Eq. (2) and the particle energy is determined by the extraction voltage V_E in the source side.

If the electron beam is not supplied behind DMP, no current to BC of MA appear. That is, the electron beam supply is a necessary condition to observe the μ^+ beam current in the detector side.

We find a lower limit of the supplied electron beam energy varying the electron beam acceleration voltage V_e. The lower limit energy is about 200 eV for the extraction voltage of π^- in the source V_E = 800V. A relation between V_e and V_E is determined. That is, $V_e > V_E/4$ is a necessary condition to observe the positive muonlike particle μ^+ in the detector side.

Estimations of unknown particle are tried: First, even if a high energy muon μ^- near 4 MeV are produced by $\pi^- - \mu^-$ decay, the μ^- can not penetrate a metal plate above 1 mm in thickness. Second, the "negative" pionlike particle π^- changes into "positive" muonlike particle μ^+ after the apparent penetration of metal plate. Third, even if a strong magnetic field of a few K gauss is applied perpendicularly to the orbit of the unknown particle, the orbit is not deviated. Thus, the unknown particle is considered to be some neutral particle which is induced inside of the MP from the pionlike particle π^-. However, if the unknown particle is not considered to be neutron because the low energy (800V acceleration) neutron can not penetrate the thick metal plate.

Through the above discussions, we can consider that the unknown particles are some neutrino. According to the fundamental particle physics, when the negative pion enters into the metal plate, some neutrino are produced. As the neutrino is very small in cross section, the neutrino can penetrate the thick metal plate without energy loss. These processes express for our experiment in the following relations

$$\left.\begin{array}{l} \pi^- \rightarrow \mu^- + \bar{V}_\mu \\ \bar{V}_\mu + P^+ \rightarrow \mu^+ + n^0 \end{array}\right\} \cdots\cdots (3)$$

where P^+ and n^0 are proton and neutron. In the first stage, our experiment can be explained by the $\bar{V}_\mu$ which penetrates easily the thick materials.

However, in the detector side, the necessity of the electron supply behind the metal plate is not yet explained: It is very important for the detection of $\bar{V}_\mu$ that the electrons are supplied behind the final metal plate DMP in Fig. 3. We consider that the low energy positive muonlike particles μ^+ can escape easily from the surface of the final metal plate DMP only under a space charge compensation due to the (negative) electrons. If the electrons are not supplied behind the DMP in Fig. 3, the initial $\bar{V}_\mu$ energy in the source must be increased extremely while a high energy particle accelerator becomes necessary as seen in the original experiment[4] of ($\pi^- \rightarrow \mu^+$).

It has been reported[1,2,3] already in many internal reports that the pionlike particles $\pi^{\pm}$, the muonlike particles $\mu^{\pm}$ and $K^{\pm}$ mesonlike particles generate under only H_2 and D_2 gas discharge. However, we could not judge whether the pionlike, muonlike and K mesonlike particles are the same with the true pions, muons and K mesons, or not. In this experiment, as the anti-μ neutrinos $\bar{\nu}_\mu$ are generated by shooting the negative pionlike particles π^- into the thick metal plate, we can judge that the pionlike particles π^- are true pions (π_t^-). It is confirmed also in this experiment that the $\bar{\nu}_\mu$ generate only for H_2 and D_2 gases.

Through the two papers of (I) and (II), we combined π^+ extraction (by $V_E < 0$) or π^- extraction (by $V_E > 0$) with a detection by +ion beam or another detection by −electron beam. As the experimental results, we have found universal relations of Fig. 4. It should be emphasized that ν_μ and $\bar{\nu}_\mu$ coexist or that ν_μ may be equal to $\bar{\nu}_\mu$.

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4) L.M. Lederman: *Phys. Rev. Letters,* **9** (1962), 36–44.

Figure Captions

Fig. 1 Schematic diagrams of the experiment apparatus are shown. The apparatus (a) is constructed from a H_2 gas discharge plasma in magnetic fields, three extraction electrodes (with an aperture of 3 mm in diameter) to extract some positively charged particles and a magnetic mass analyzer of 90° deflection type (**a** and **b**).

a 1: Discharge cathode. 2 and 3: Discharge intermediate electrodes. 4: Discharge power supply. 5: H_2 gas flow. 6: Vacuum pump. 7: Area where cylindrical plasma is transformed into sheet plasma. 8: Insulator. 9: A pair of permanent magnets. 10: Magnetic field coils. 11: Discharge anode. I_A: Discharge anode current. CP: Cylindrical plasma. SP: Sheet plasma. B_Z: Magnetic field. L: First extraction electrode (Potential V_L = –6V). M: Second extraction electrode. E: Final extraction electrode. V_M: Potential (300V) of second extraction electrode with respect to discharge anode. V_E: Potential (800V) of final extraction electrode with respect to discharge anode. MA: Magnetic deflection (90°) mass analyzer. B_M: Magnetic field intensity of MA. BC: Beam collector of MA. I^-: Negative current to BC. H_0^-: Hydrogen negative ions outside of sheet plasma. H^-: Accelerated hydrogen negative ions. π_0^-: Negative pionlike particles outside of sheet plasma. π^-: Accelerated negative pionlike particles.

b S: Entrance slit (3 mm × 10 mm) of MA. Fe: shows Iron. C: Magnetic coil. (N): North pole of electro-magnet. (S): South pole.

In order to extract H^- ions over wide area, 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. The sheet plasma flow enters the anode through the main chamber (50 cm long). A uniform magnetic field of about 50 gauss is applied along the sheet plasma flow in the main chamber where the H_2 gas pressure is about 1.5×10^{-3} Torr. The discharge anode current I_A is 20A and the discharge voltage is 110V. 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 H_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 as H^- ions are produced outside of the H_2 gas discharge plasma.

Fig. 2 A dependence of negative current I^- to the beam collector BC on the analyzing magnetic field ($-B_M$) is shown under a final extraction voltage V_E = 800V, the second extraction electrode voltage V_M = 300V and the first extraction electrode voltage V_L = –6V. The H^- shows a current peak corresponding to H^- ions. The π^- shows a current peak corresponding to a negative pionlike particle which is estimated from the mass.

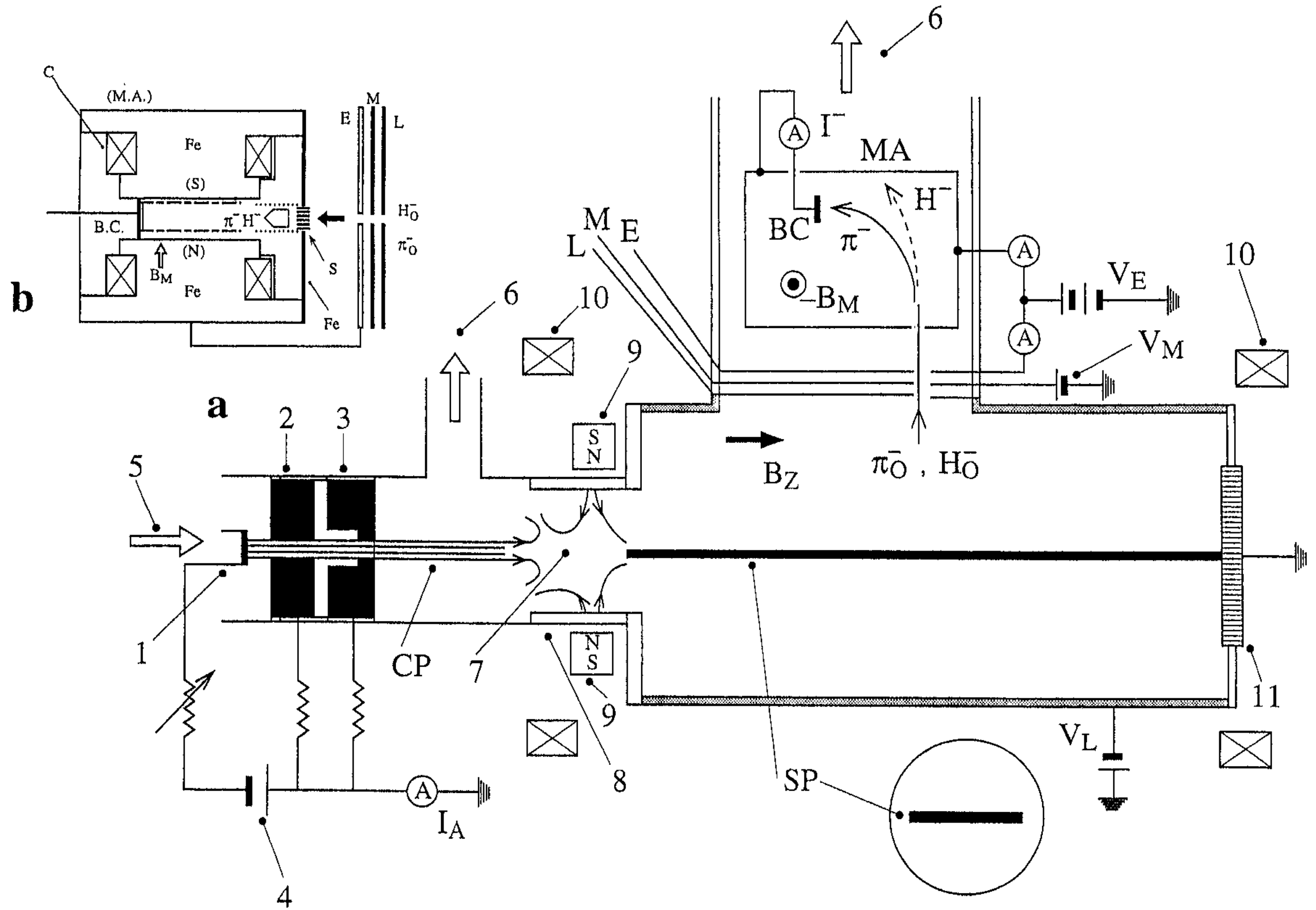
Fig. 3 **a** A schematic diagram of the large area $\bar{\nu}_\mu$ beam source is shown where 100 apertures in an area of 40 cm^2 are opened in the first extraction electrode L and the second extraction electrode and the final extraction electrode is a thick metal plate (of 3 cm in thickness) without apertures.

b A schematic diagram of the $\bar{\nu}_\mu$ beam detector is shown where DMP is a thick metal plate (3 cm in thickness) which receives the $\bar{\nu}_\mu$ beam. E.G. is an electron gun where an electron beam is produced by acceleration of thermal electrons from a filament cathode. V_e is a power supply of the electron gun.

c Dependences of the positive current I^+ to BC on the analyzing magnetic field B_M are shown where three current peaks of I^+ corresponding to μ^+ particles are shown under three extraction voltages V_E = 400V, 800V and 1600V in the $\bar{\nu}_\mu$ beam source. It should be noted that the $\bar{\nu}_\mu$ beam penetrates the thick metal plates and pass through the atmosphere without energy loss.

Fig. 4 Universal relations between $\pi^\pm$ and ν_μ, $\bar{\nu}_\mu$, +Ion Beam and μ^-, and electron beam and μ^+.

MP: Metal Plate.



b
C
(M.A.)
Fe
(S)
B.C.
$\pi^- H^-$
(N)
B_M
Fe
S
Fe
E
M
L
H_O^-
π_O^-
a
1
2
3
4
5
6
7
8
9
10
11
CP
I_A
L
M
E
MA
I^-
BC
π^-
H^-
B_M
B_Z
π_O^- , H_O^-
V_E
V_M
V_L
SP

Fig. 1

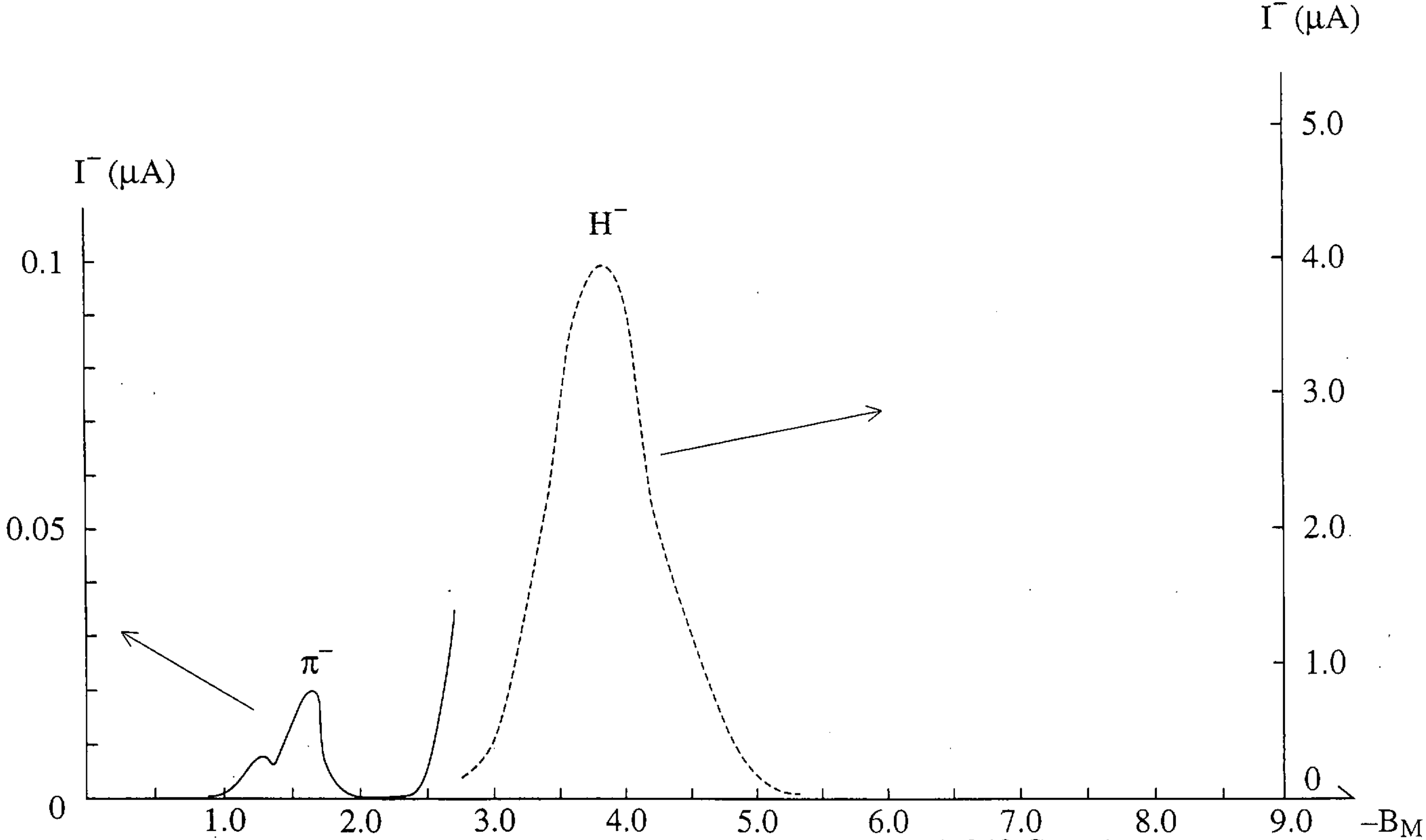
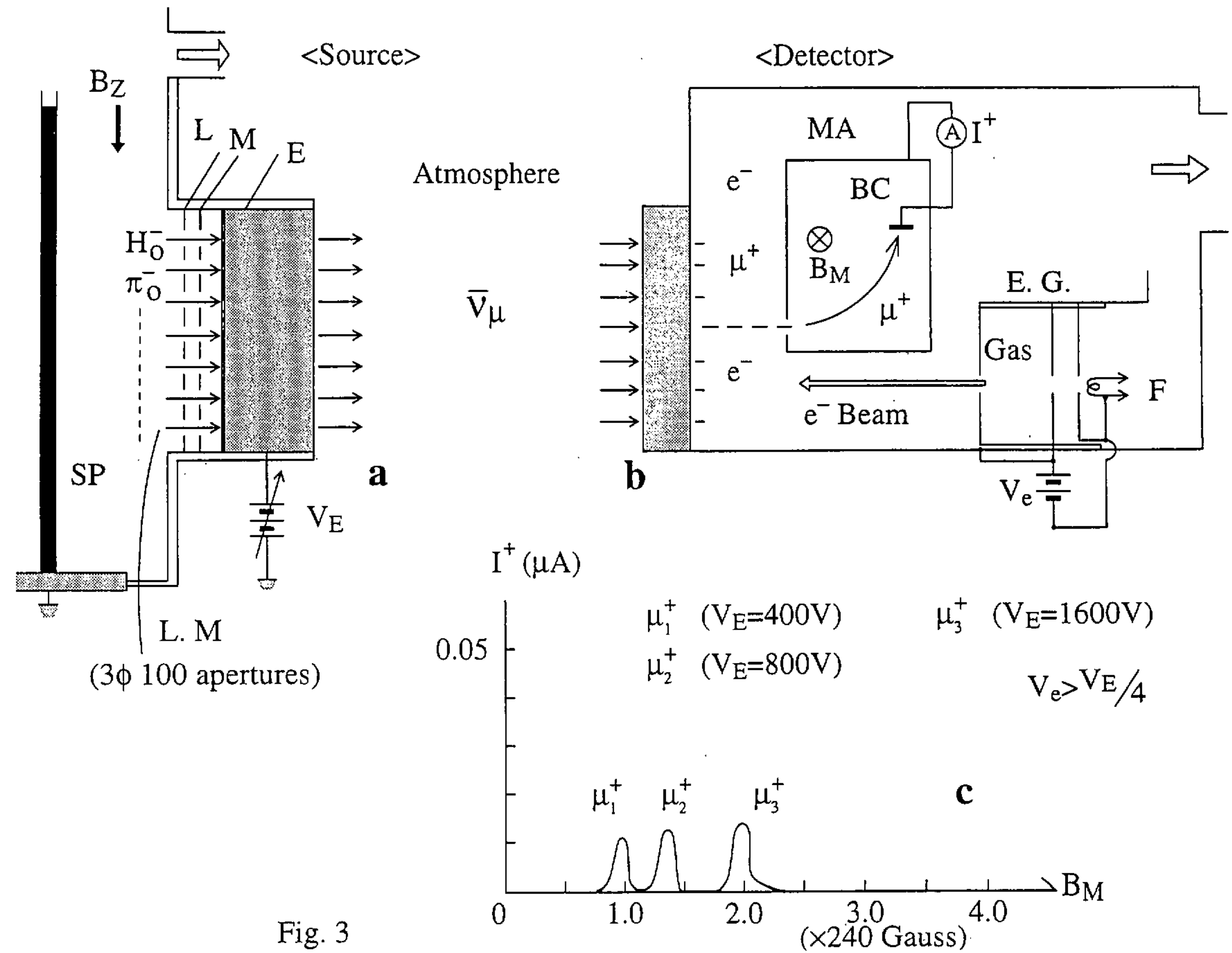

I⁻ (μA)
0.1
0.05
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
$-B_M$
(×240 Gauss)
π^-
H^-
I⁻ (μA)
5.0
4.0
3.0
2.0
1.0
0

Fig. 2



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BZ
L
M
E
H-o
π-o
SP
L. M
(3φ 100 apertures)
VE
a
Atmosphere
ν̄μ
<Detector>
MA
A I+
BC
e−
μ+
BM
μ+
E. G.
Gas
F
e−
e− Beam
Ve
b
I+ (μA)
0.05
μ1+ (VE=400V)
μ2+ (VE=800V)
μ3+ (VE=1600V)
Ve>VE/4
μ1+
μ2+
μ3+
c
BM
0
1.0
2.0
3.0
4.0
(×240 Gauss)

Fig. 3

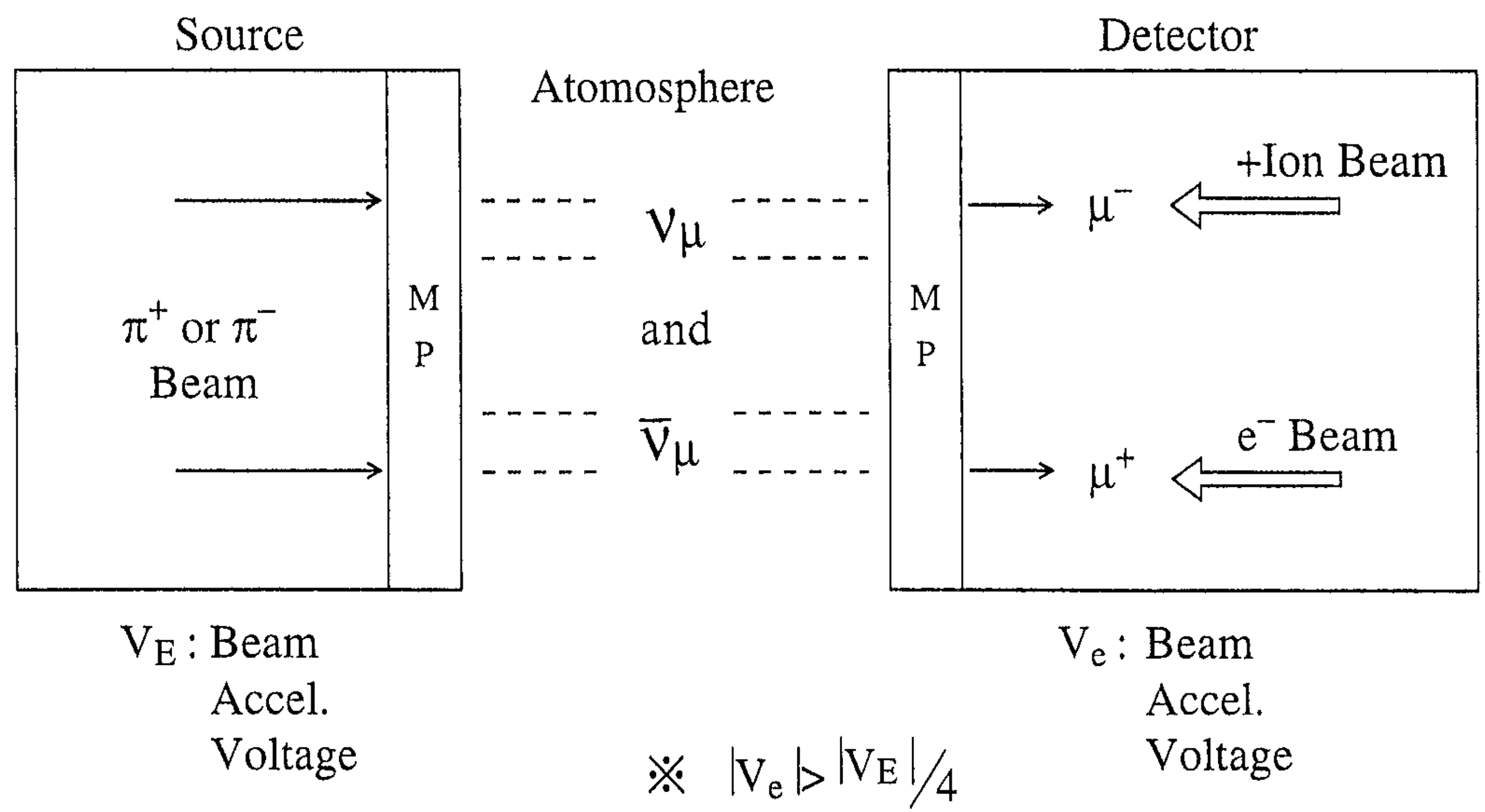

Source
Detector
Atomosphere
π^+ or π^- Beam
M
P
ν_μ
and
$\bar{\nu}_\mu$
M
P
μ^-
+Ion Beam
μ^+
e^- Beam
V_E : Beam Accel. Voltage
V_e : Beam Accel. Voltage
※ $|V_e| > |V_E|/4$

Fig. 4

Appendix

Positive or negative low energy (1 eV ~ 50 eV) muons can be produced easily by the μ -neutrino ν_μ and anti-μ-neutrino $\bar{\nu}_\mu$ beams which are generated secondarily from the pions: As shown in Figs. 1A **a** and **b**, the pions are extracted in a primary voltage V_M of 350V from outside of the H_2 gas discharge as shown in Fig. 1. Next, the final low energy of muons is determined by a final voltage of V_E decelerating the pions which are shot into a thick metal plate.

The above method of muon production will be very useful for an "elementary particle chemistry", which is very simple and economical in comparison with methods decelerating muons from high energy particle accelerators. Furthermore, the positive or negative muons (μ^+ or μ^-) can be generated in a free place by sending the ν_μ and $\bar{\nu}_\mu$ beams as understood from Figs. A1 and Figs. A2.

In Fig. A1 **c** and Fig. A2 **c**, the μ^+ beams or μ^- beams around 10 eV are demonstrated for an "elementary particle chemistry".

Figure captions of Appendix

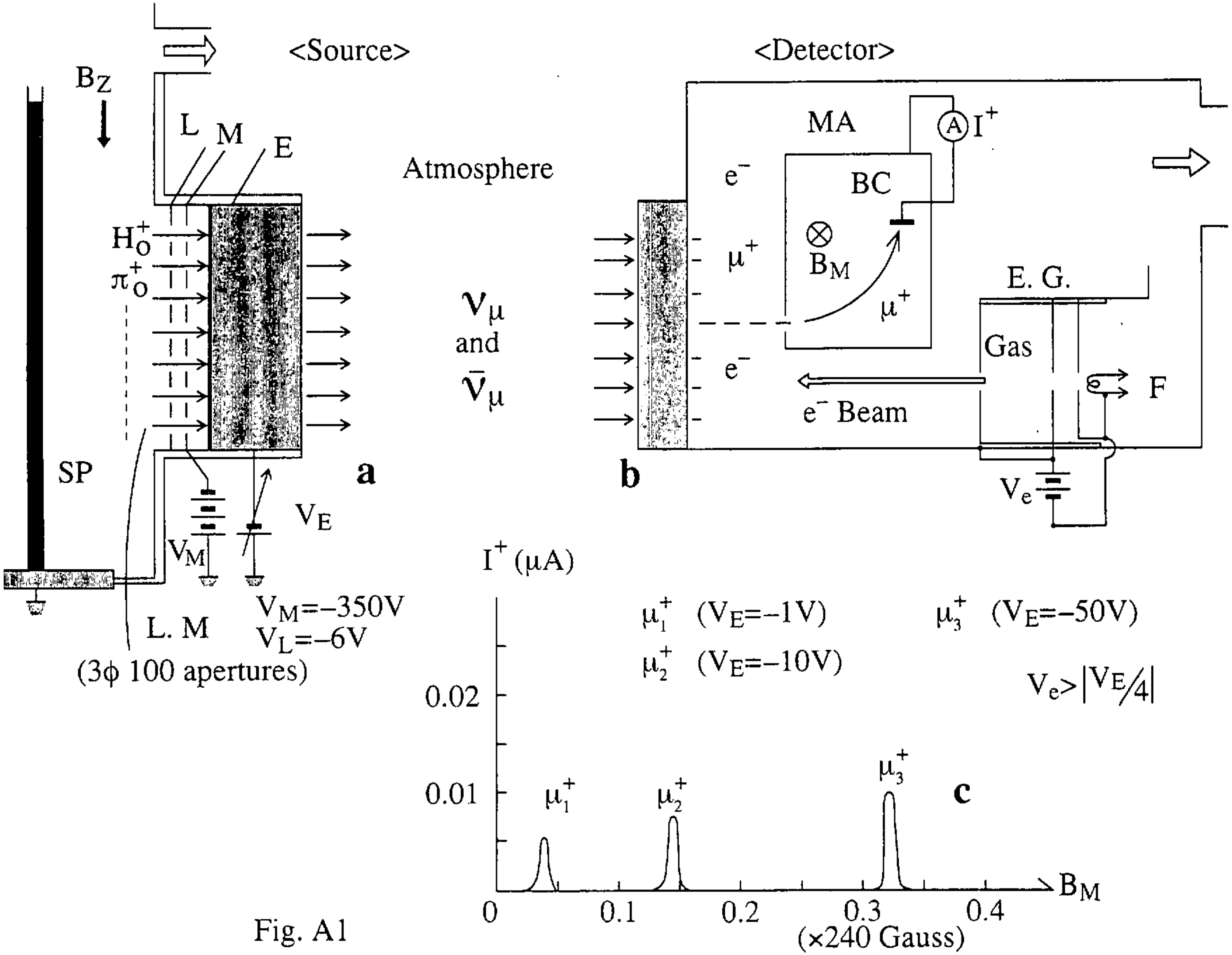
Fig. A1 Schematic diagram of the experimental apparatus for low energy positive muons μ^+.

e–Beam: Electron beam. V_M: Primary extraction voltage. V_E: Voltage for final muon energy.

*See captions of Fig. 4.

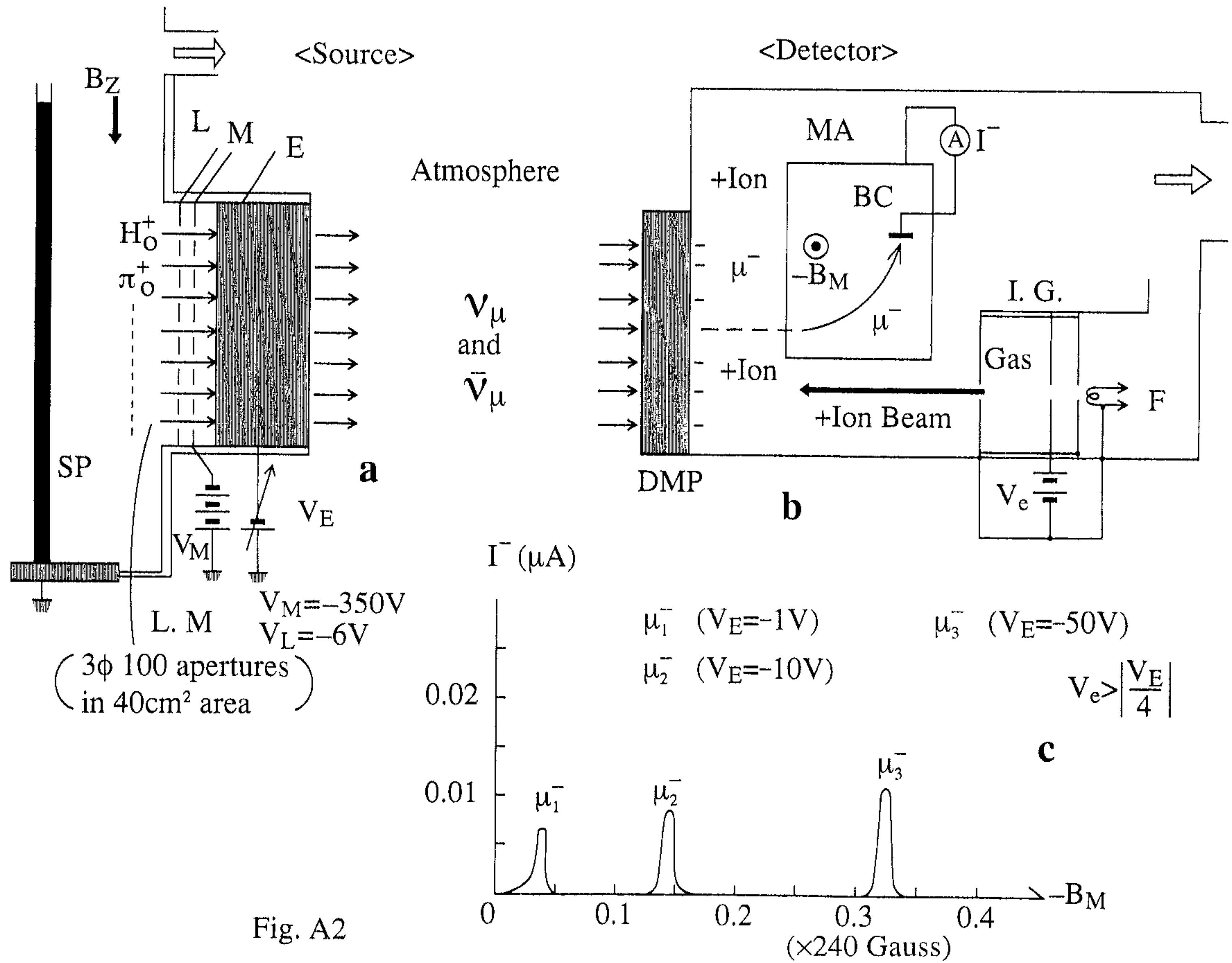
Fig. A2 Schematic diagrams of the experimental apparatus for low energy negative muons μ^-.

*See captions of Fig. 4.



<Source>
<Detector>
B_Z
L
M
E
Atmosphere
H_o^+
π_o^+
SP
a
V_E
V_M
L. M
V_M=−350V
V_L=−6V
(3ϕ 100 apertures)
ν_μ
and
$\bar{\nu}_\mu$
MA
A
I^+
BC
e^-
μ^+
B_M
E. G.
Gas
F
e^- Beam
b
V_e
I^+ (μA)
μ_1^+ (V_E=−1V)
μ_2^+ (V_E=−10V)
μ_3^+ (V_E=−50V)
V_e>|V_E/4|
0.02
0.01
c
0
0.1
0.2
0.3
0.4
B_M
(×240 Gauss)

Fig. A1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B_Z
L
M
E
H_o^+
π_o^+
SP
a
V_E
V_M
L. M
V_M=–350V
V_L=–6V
(3φ 100 apertures in 40cm² area)
Atmosphere
ν_μ and ν̄_μ
<Detector>
MA
A I⁻
+Ion
BC
μ⁻
–B_M
I. G.
Gas
+Ion
F
+Ion Beam
DMP
V_e
b
I⁻ (μA)
μ₁⁻ (V_E=-1V)
μ₂⁻ (V_E=-10V)
μ₃⁻ (V_E=-50V)
V_e>|V_E/4|
c
0.02
0.01
0
0.1
0.2
0.3
0.4
–B_M
(×240 Gauss)

Fig. A2

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