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X-Particle Production in 205 GeV/c Proton Interactions*

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* Exposure of the emulsion chamber was made at the Fermi National Accelerator Laboratory. (NAL proposal No.156)

Introduction

After the discovery of the X-particle [1] with mass of $1.5 \sim 3$ GeV and life time $* \cdot 10^{-14}$ sec, which decayed into one charged particle and one π^0 meson, emulsion chambers specially designed for hunting of similar type of particles were exposed to the proton beam with momentum of 205 GeV/c at the Fermi National Accelerator Laboratory [2].

Experimentation

The construction of the chamber is shown in the Figure I. It consists of producing layer and analysing layer. The producing layer is a pile of 41 emulsion films coated 40μ on the polyester base with thickness of 200μ and 2 emulsion films coated 50μ on both sides of metaacryl base with thickness of 300μ. Each emulsion film is separated by tissue paper with thickness of 90μ. Therefore, the repeat distance for observation of charged particles is 330μ. The analysing layer is a sandwich of 20 lead plates with thickness of 1 mm and the same number of emulsion films.

Emulsion films, lead plates and tissue papers were stamped out to have the exact size of 9.500 ± 0.002 cm x 12.000 ± 0.002 cm. Using these materials, the chamber was accurately assembled on the thick plastic base with three guide poles. And the whole of the chamber was tightly vacuum-packed without air gaps between films in the poly-laminated sheet. Thus, there is only 0.05 g/cm^2 of material before the first film.

This type of chamber was exposed to the beams vertically. The beam density was regulated to be between 10^3 particles/cm^2 and $*\cdot 10^4$ particles/cm^2.

A part of the chambers was scanned for jet showers and 365 events were found by means of plate by plate track following method.

Among them 36 events were analysed applying relative scattering method [3] for estimation of momentum of secondary charged particles.

Up to now, two of jet showers thus analysed contained possible candidates of X-particles.

Figure 2. shows lg tg θ distributions of charged particles of these events.

AJ-21

16 charged particles were produced in the event AJ-21 which was occured in the base of film No.51, and the detailed 3 dimensional views of the most forward part of this event are shown in the Figure 3. On the third film under the origin of this event, a pair of charged particles appeared in the most forward direction with relatively large opening angle. The vertex point of this V track was estimated to be in the tissue paper just 34μ above the film No.48 and 809±10μ under from the origin.

The emitting angle of each charged particle relative to an assumed neutral line OV is 3.68×10^{-2} and 2.01×10^{-2} radians respectively. The neutral line and two charged lines satisfy a coplanarity condition strictly within the experimental error. That is, the angle between the neutral line OV and the plane mVn is less than 10^{-4} radian.

These two charged particles were followed down to the bottom of the chamber, each 4 radiation length in lead plates, without any cascading. Therefore, these particles could not be identified as electrons.

Momenta of these charged particles, m and n, were estimated as 16 and 23 GeV/c respectively by means of the relative scattering method [3] referring to the incident proton tracks with momenta of 205 GeV/c.

The angle between the neutral line and the incident direction of the proton is 1.56×10^{-2} radian. No jet shower was found in the upper volume of the chamber within the circular cone around the neutral line with the angle of 1.1×10^{-1} radian. Therefore, this V track is hardly attributed to other jet showers.

Because of the non existence of other charged particles coming from the vertex point and also the coplanarity condition, this could not be interaction of a neutral secondary particle from the origin of this jet shower.

Above features of this event suggest us that this might be a two body decay of a neutral particle produced in this event into two charged hadronic particles.

Let us assume that this V event is due to $K_s^o(\bar{K}_s^o)$ or Λ^o decay. The flight path of the neutral particle is shorter than 1mm and the opening angle of the V event is relatively large, 5.69×10^{-2} radian.

Referring the data of production cross-section and x distribution of $K_s^o(\bar{K}_s^o)$ or Λ^o at 205 GeV/c proton interaction [5], expected number of observing this type of event in 365 jet showers turned out to be $3 \cdot 10^{-2}$.

Considering the statistical weights and the P_t valance, correction was made for the momenta of the two charged particles the result of which are shown in the Table I.

Observed and corrected P_t values reject the possibility that this V track is due to the decay of Λ^o or $K_s^o(\bar{K}_s^o)$.

Examples of the estimated mass and lifetime of the neutral parent particle, X^o, assuming possible combinations of daughter charged particles are shown in the Table II. The results are mass of 1.2 ~ 2.2 GeV and the life time of 0.7 ~ 1.5×10^{-13}sec for mesons and 1.6 ~ 2.4 GeV and 1.0 ~ 1.6×10^{-13}sec for baryons.

AJ-20

Event AJ-20 contains a charged particle which suffers large angle scattering, 3.6×10^{-2} radian, after 0.57cm flight.

Momenta of three charged particles in the forward part, i, p and h' after large angle scattering were estimated as 115, 5.2 and 13 GeV respectively with about 20 % error. Transverse momentum of particle h' after large angle scattering was estimated as 470 MeV/c.

Detailed 3 dimensional views of these particles are shown in the Figure 4. The scattering point of the particle h was estimated as to be in the film base just 30μ under the emulsion layer of No.30. Upper and lower emulsion films were carefully scanned for charged particles associated to this point and no such track was found. Along the down stream of this jet, scanning was made also for electron pairs due to γ rays from this jet shower. On the area within the angle 10^{-1} radians, no electron pair was found associated with the scattering point of the track h. Because of the above situation, it is quite unnatural to attribute this to a diffraction event or an elastic scattering of charged secondary particle.

As for the energy of the particle h, it is difficult to estimate it by the relative scattering method. Therefore, it was estimated by indirect method, subtracting total energy sum of the secondary particles other than h from the primary energy. Resulting energy of the particle h turned out to be 13 ~ 49 GeV.

Assuming a decay of h into h' and other neutral particle, the partner of h' might be long lived neutral particle such as K^0 or $\overline{K^0}$, because of the above situation.

Thus estimated mass and life time of the particle h assuming two body decay turned out to be followings, as are shown in the Table III. If 3 body decay is assumed, these mass values would be larger and life time would be longer.

Discussions

So far several candidates of X particles have been acummulated in the cosmic ray experiments [1]. These events indicate pair production of X-particles. The clear pair production event is recently observed [4].

X-particles observed in the cosmic ray experiments have the mass, 1.5 ~ 2.2 GeV for meson, 2.0 ~ 3.5 GeV for baryon and the life time distributed between $*\cdot 10^{-12}$ and $*\cdot 10^{-14}$ sec.

The X-particle with such mass and life time might not be contained in the frame work of the conventional elementary particle theory. Therefore, it suggests the new degree of freedom.

The first event of the neutral X-particle, which decayed into two charged particles, is observed in the accelerator experiment as stated in this letter.

The mass and life time observed in the accelerator experiment are similar to those of cosmic ray experiments, respectively. Up to now, however, only single X-particle was found in each accelerator jet shower. Partners of these particles are still under searching.

In both experiments X-particles are often observed in the jet shower whose multiplicity is twice or thrice higher than the mean value.

The production cross section of X-particles can not be decided exactly because of scanning bias. But the order of it is roughly estimated to be between 10^{-2} and 10^{-3} of total inelastic cross section from our statistics of the accelerator experiment. So, sufficient events of X-particles could be collected using the emulsion chambers exposed to accelerator beams.

Acknowledgements

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References

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K. Hoshino et al., Proceedings of International Cosmic Ray Symposium on High Energy Phenomena, Tokyo (1974) 161.
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3) K. Hoshino et al., Proceedings of International Cosmic Ray Symposium on High Energy Phenomena, Tokyo (1974) 155.
4) T. Matsubayashi et al., to be published in Prog. Theor. Phys..
5) G. Charlton et al., Phys. Rev. Lett. 30 (1974) 574.

Figure Captions

Fig. I. The design of the chamber:

Fig. 2. Angular distributions of secondary charged particles of events AJ-21 and AJ-20

Fig. 3. a,b. The side and plan views of the event AJ-21

Fig. 4. The side views of the event AJ-20

Photo I. Superimposed photograph of 6 emulsion films No. 51, 50, 49, 48, 47 and 46 showing the central part of the event AJ-21. (Indicated area of the Figure 3-b)

B_1 and B_2 are spots due to incident beams.

B_o is that of the primary proton.

n and m are spots due to the V track produced just above the emulsion film No.48.

Others are spots due to secondary charged particles.

Photo 2. Photograph of emulsion chamber.
The size is 9.5 x 12 x 7 cubic centimeter.

Table I

	P(obs) GeV/c	P_t(obs) MeV/c	Number of independent cells	P_t (Corrected) MeV/c	P(Corrected) GeV/c
m	16 ± 3	589 ± 110	20	536 ± 106	14.6 ± 3
n	23^{+5}_{-4}	462^{+100}_{-88}	11		26.7^{+5}_{-4}
					41.2^{+6}_{-5}

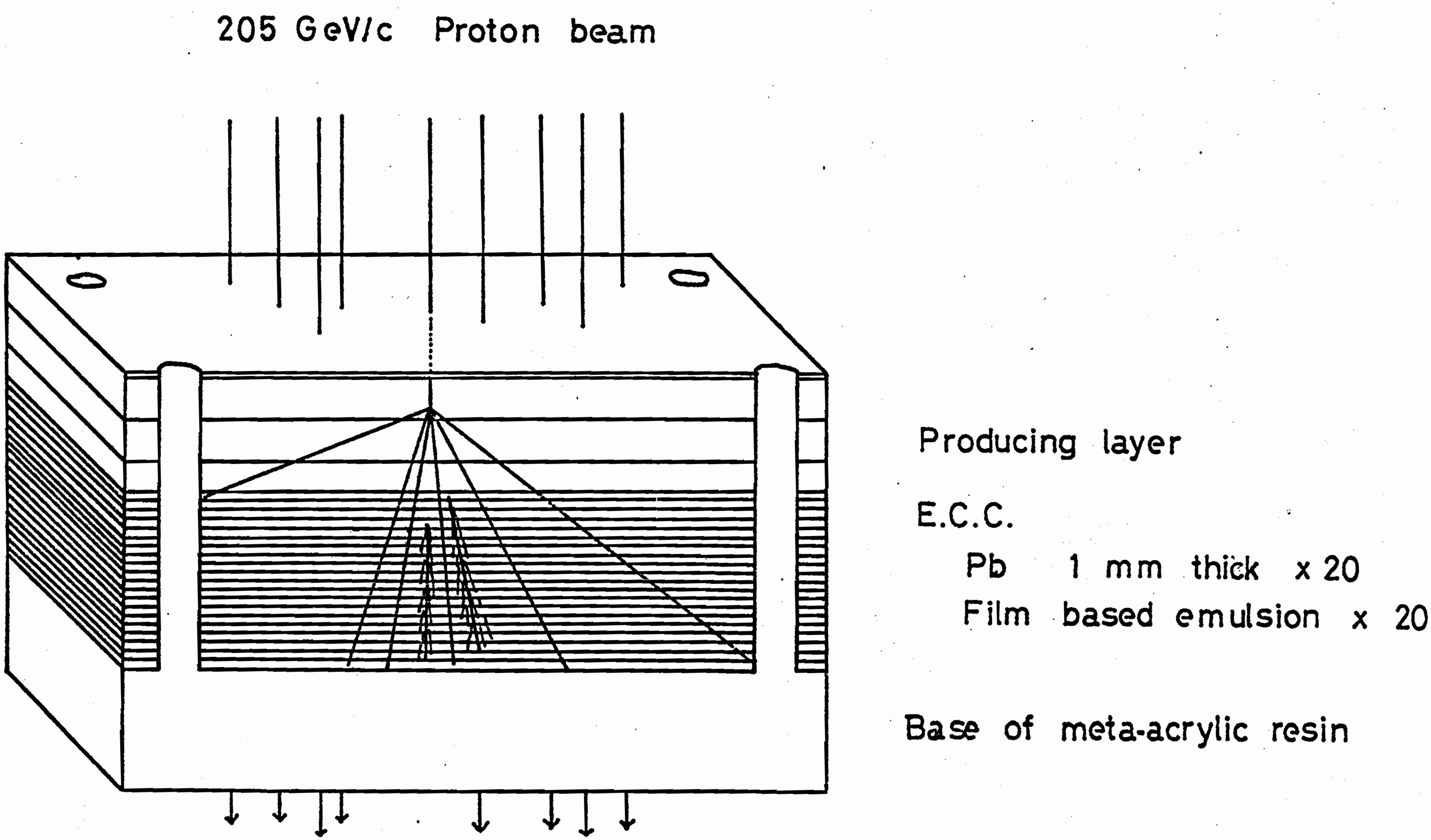
Table II

	m n	Mx^o (GeV)	τx^o (sec)
X^o Meson	π^+ π^-	1.16 ± 0.21	7.57×10^{-14}
	$\pi^\pm$ $K^\mp$	1.30 ± 0.19	8.48×10^{-14}
	$K^\pm$ $\pi^\mp$	1.41 ± 0.18	9.20×10^{-14}
	K^+ K^-	1.53 ± 0.16	9.98×10^{-14}
	P $\bar{P}$	2.26 ± 0.11	1.47×10^{-13}
X^o Baryon	P π	1.94 ± 0.13	1.27×10^{-13}
	π P	1.64 ± 0.15	1.07×10^{-13}
	P K	2.03 ± 0.12	1.32×10^{-13}
	K P	1.82 ± 0.13	1.19×10^{-13}
	Σ π	2.31 ± 0.11	1.51×10^{-13}
	π Σ	1.88 ± 0.13	1.23×10^{-13}
	Σ K	2.39 ± 0.11	1.56×10^{-13}
	K Σ	2.04 ± 0.12	1.33×10^{-13}

Table III

Decay mode	M_x GeV	$\tau_x \times 10^{-12}$ sec
$X^{\pm} \longrightarrow \pi^{\pm} + K^0 \ (\overline{K^0})$	$1.2 \sim 1.6$	$1.2 \sim 1.6$
$X^{\pm} \longrightarrow K^{\pm} + \overline{K^0} \ (K^0)$	$1.3 \sim 1.7$	$1.3 \sim 1.7$
$X^{\pm} \longrightarrow P + K^0 \ (\overline{K^0})$	$1.7 \sim 1.9$	$1.7 \sim 1.9$

Fig.1



205 GeV/c Proton beam
Producing layer
E.C.C.
Pb 1 mm thick x 20
Film based emulsion x 20
Base of meta-acrylic resin

Fig. 2

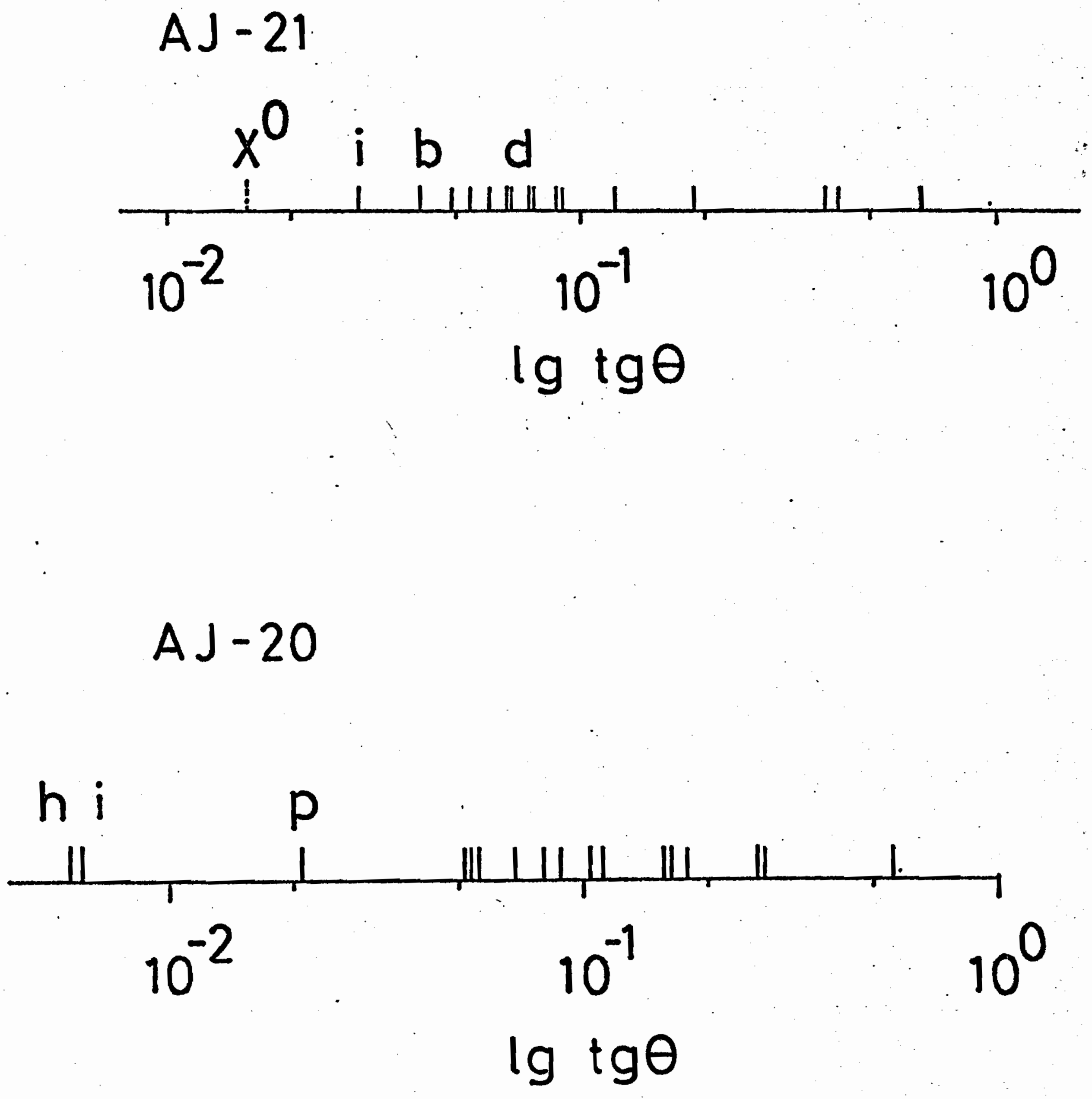


Fig. 3-a X PROJECTION

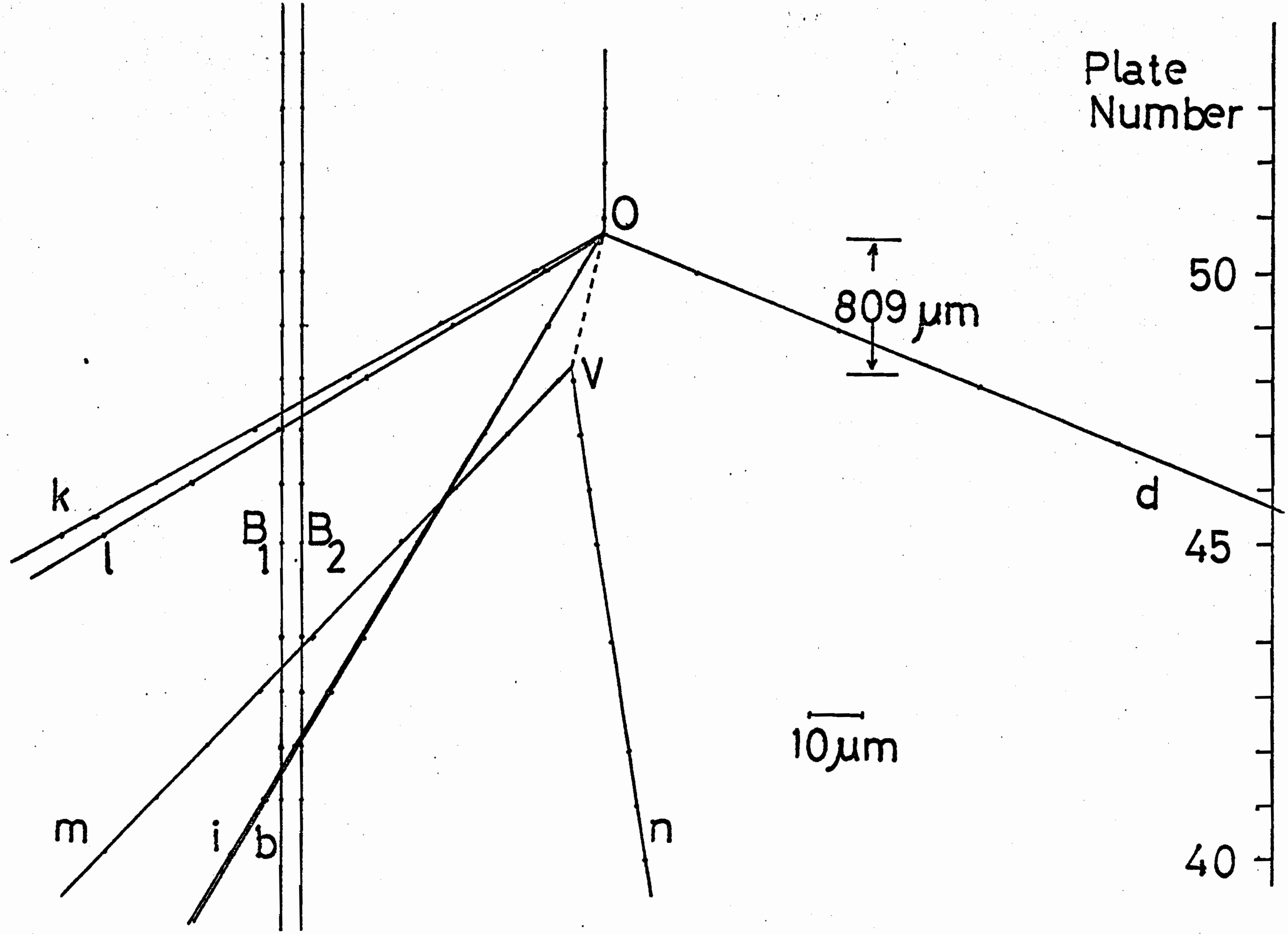


Fig.3-b Z Projection

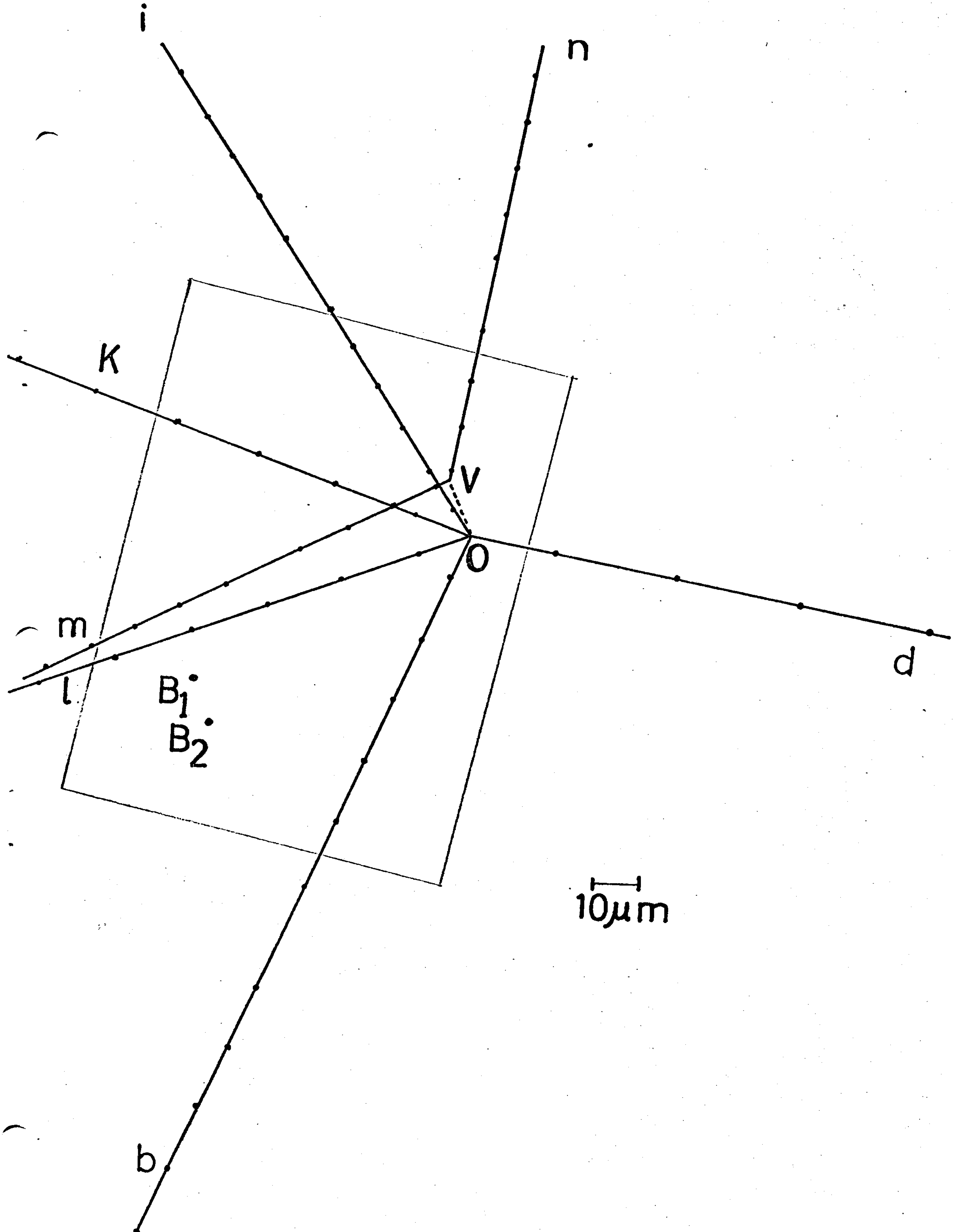


Fig. 4 AJ - 20

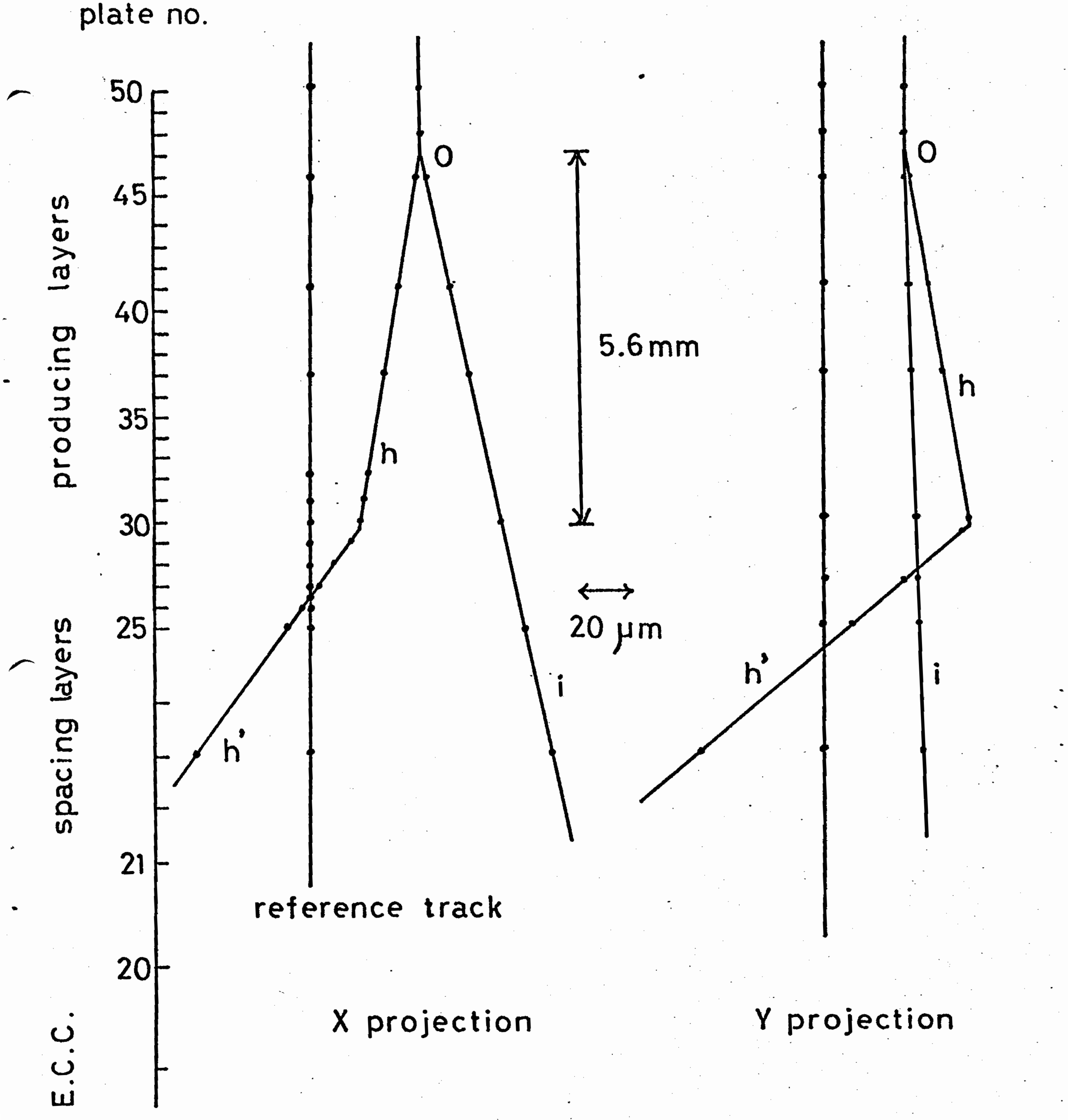


plate no.
50
45
40
35
30
25
21
20
producing layers
spacing layers
E.C.C.
O
h
h'
i
5.6 mm
20 μm
reference track
X projection
Y projection

Photo 1.

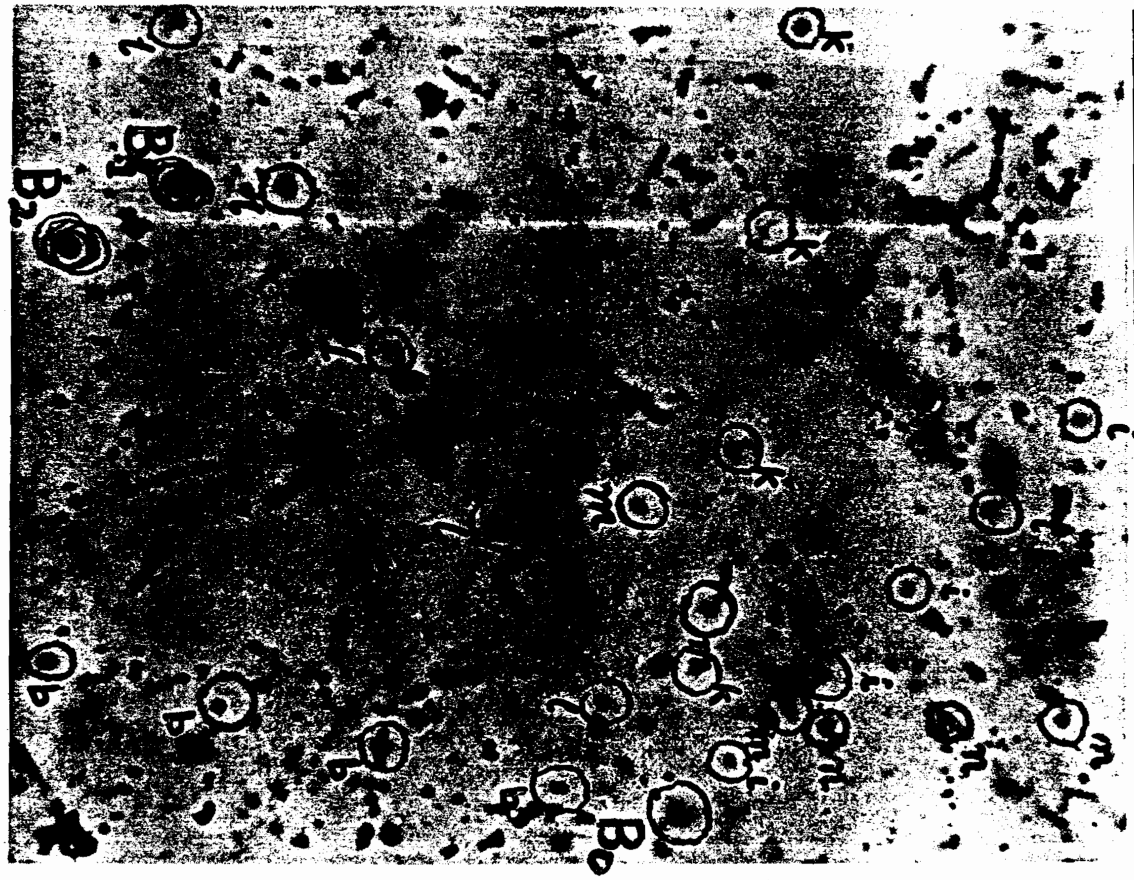


Photo 2.