SECTION VIII. THEORETICAL AND EXPERIMENTAL STUDY OF BEAM PLASMA PHYSICS (TEBPP)

RICE UNIVERSITY 23-24 SEPT. 1980

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THEORETICAL AND EXPERIMENTAL STUDY OF BEAM-PLASMA-PHYSICS

INVESTIGATORS

HUGH R. ANDERSON, P.I. - RICE UNIVERSITY

WILLIAM BERNSTEIN - RICE UNIVERSITY

LEWIS M. LINSON - SCIENCE APPLICATIONS, INC.

K. PAPADOPOULOS - SCIENCE APPLICATIONS, INC.

PAUL J. KELLOGG - UNIVERSITY OF MINNESOTA

EDWARD P. SZUSZCZEWICZ - NAVAL RESEARCH LABORATORY

THOMAS J. HALLINAN - UNIVERSITY OF ALASKA

HAROLD LEINBACH - NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION ENVIRONMENTAL RESEARCH LABORATORIES

COLLABORATION WITH:

A. KONRADI - JSC

R. J. JOST - JSC

MSFC TECHNICAL CONTACT:

DRAYTON TALLEY

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SCIENTIFIC OBJECTIVE -- to understand quantitatively the interaction of an electron beam (0-10 keV, 0-1.5 Amp) with the plasma and neutral atmosphere at 200-400 km altitude.

Applications to near-Earth and cosmical plasmas.

The interaction occurs in four space-time regions:

I. Near electron gun; beam coming into equilibrium with medium

II. Equilibrium propagation in ionosphere

III. Ahead of beam pulse; temporal and spatial precursors

IV. Behind a beam pulse

While Region II is of the greatest interest, it is essential to study Region I because it determines the characteristics of the beam as it enters II-IV.

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SPECIFICALLY IN THE REGIONS

REGION I - WHAT ARE MECHANISMS FOR CHARGE AND CURRENT NEUTRALIZATION

- OF INJECTED BEAM?
- OF ACCELERATOR AND SPACECRAFT?
- IS BEAM PLASMA DISCHARGE (BPD) AN IMPORTANT MECHANISM?

WHAT ARE DIMENSIONS OF THE REGION?

HOW IS BEAM HEATED BY BPD AND ALTERED BY CHARGING?

REGION II - QUANTITATIVELY WHAT IS

VELOCITY REDISTRIBUTION OF BEAM PARTICLES? PLATEAU?

ALTERATION OF AMBIENT PLASMA DENSITY AND TEMPERATURE?

PRODUCTION OF E-S AND E-M WAVES?

PRODUCTION OF LIGHT?

REGIONS III AND IV — WHAT ARE CHARACTERISTIC TIMES FOR THE ABOVE EFFECTS?

ARE THE REGIONS A GOOD ORDERING OF THE PHENOMENA?

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IMPLEMENTATION

THEORETICAL STUDIES

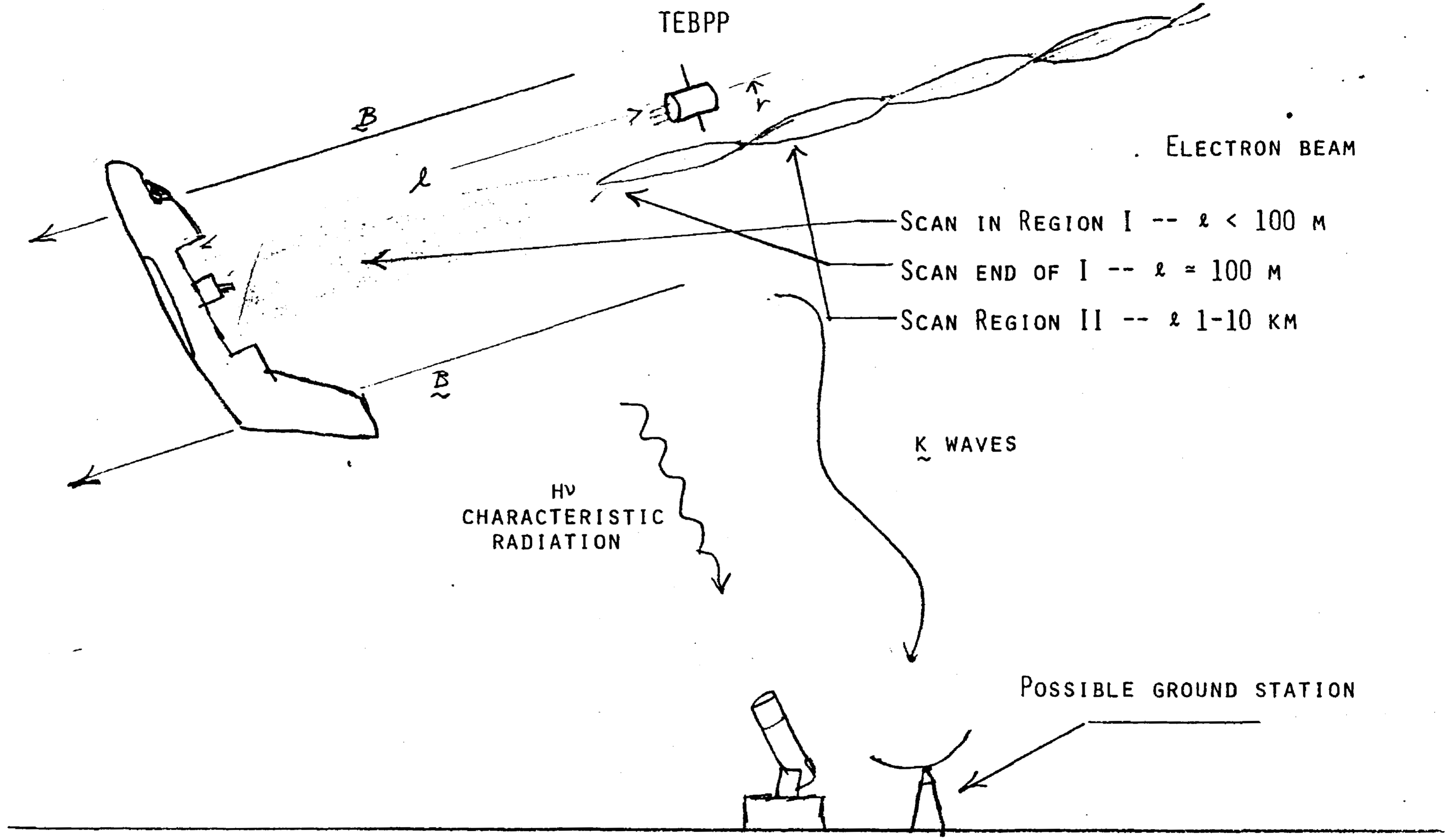
- ANALYTICAL AND NUMERICAL SIMULATION OF PHENOMENA SHOULD PROVIDE
  - MODELS THAT PREDICT QUANTITATIVELY
  - DESIGN PARAMETERS FOR EXPERIMENTS
- INTERPRETATION OF DATA

EXPERIMENTS -- MEASUREMENTS

- ROCKET-BORNE
  - SCEX -- CARRYING ON ELECTRON GUN; KELLOGG IS P.I. 1980-1981
  - PASSIVE AURORAL PLASMA; ANDERSON IS P.I. 1980-1982
  - $E \parallel B$, NRC; BERNSTEIN AND WHALEN 1978; 1979
- LABORATORY
  - LARGE VACUUM FACILITY AT JSC--BERNSTEIN AND ENTIRE GROUP.
    - THESE ARE ONGOING EXPERIMENTS.

IMPLEMENTATION -- CONTINUED

- EXPERIMENTS USING SPACELAB
  - MISSION MUST CARRY
    - ELECTRON ACCELERATOR } SEPAC
    - NEUTRAL GAS SOURCE } SEPAC
    - IMAGER — LLLTV
  - WE BUILD THESE DIAGNOSTICS
    - PULSED PLASMA PROBE -- SZUSZCZEWICZ
      - $3 \times 10^2 < N_E < 10^8$ CM^{-3}
      - $.025 < T_E < 3$ EV
      - PLASMA POTENTIAL, -50 TO +150 VOLTS
    - PLASMA WAVE RECEIVER ($\underset{\sim}{E}$ AND $\underset{\sim}{B}$) -- KELLOGG
      - 10 Hz < F < 20 MHz
    - CHARGED PARTICLE SPECTROMETER -- ANDERSON
      - 10 EV < E < 20 KEV $\quad \Delta E/E \sim 5\%$
      - FLUX 10^6 TO 10^{13}
    - PHOTOMETER IF NOT OTHERWISE AVAILABLE.
  - THESE ARE TO BE MOUNTED ON THE RMS OR A FREE-FLYER TO SCAN ALONG AND RADIALLY FROM THE BEAM.
  - WE WILL ALSO CONSIDER OPTICAL AND E-M WAVE MEASUREMENTS FROM SELECTED GROUND SITES.


TEBPP
B
ℓ
r
ELECTRON BEAM
SCAN IN REGION I -- ℓ < 100 M
SCAN END OF I -- ℓ ≈ 100 M
SCAN REGION II -- ℓ 1-10 KM
B
K WAVES
Hν
CHARACTERISTIC
RADIATION
POSSIBLE GROUND STATION

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CLOSELY RELATED EXPERIMENTS AND FACILITIES

- SEPAC
- LLLTV
- ALL FREE FLYERS
  - MMP
  - PDP
  - STSS
- WISP

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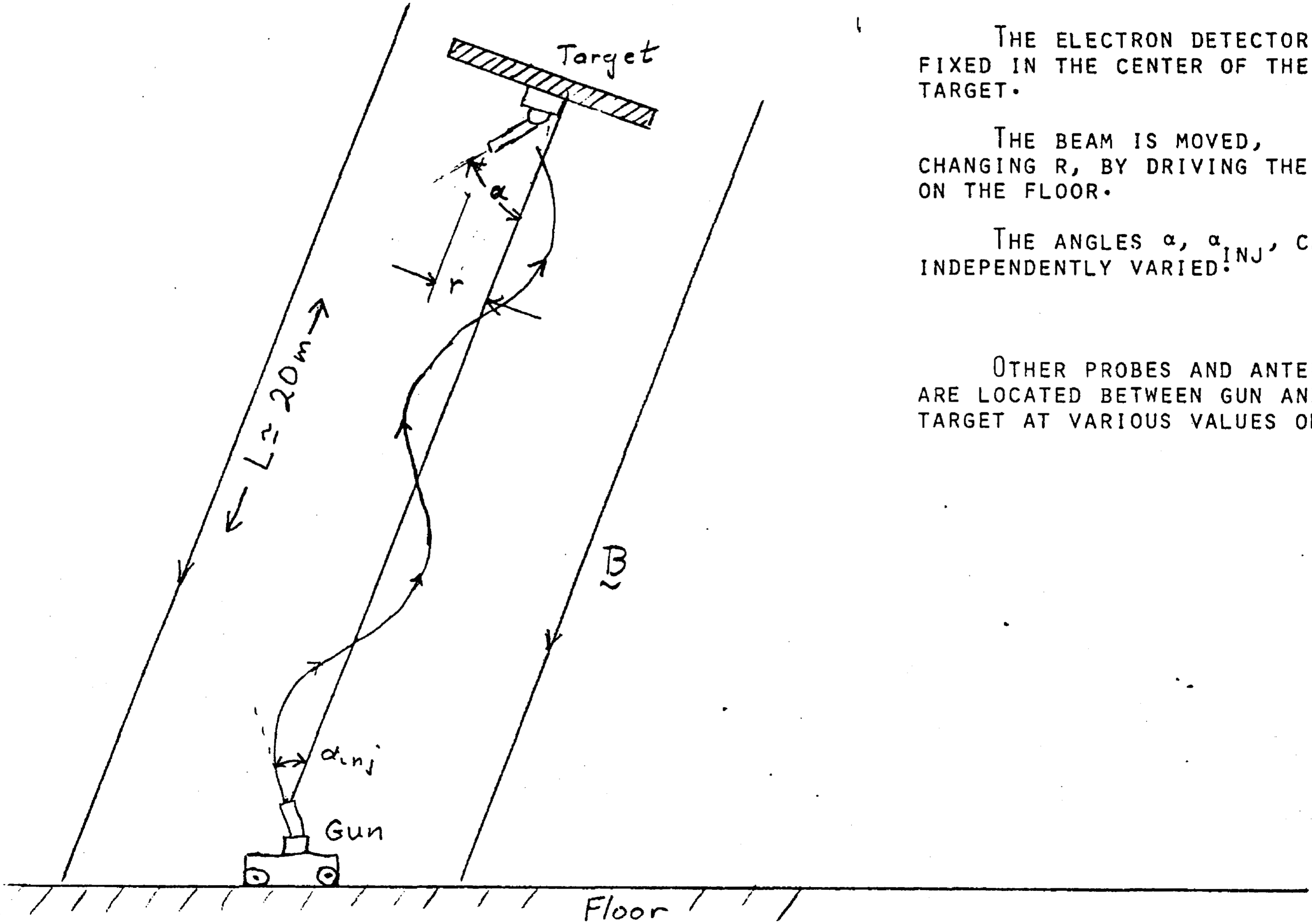
GEOMETRY OF LAB EXPERIMENTS



THE ELECTRON DETECTOR IS FIXED IN THE CENTER OF THE TARGET.

THE BEAM IS MOVED, CHANGING R, BY DRIVING THE CART ON THE FLOOR.

THE ANGLES α, α_{INJ}, CAN BE INDEPENDENTLY VARIED.

OTHER PROBES AND ANTENNAS ARE LOCATED BETWEEN GUN AND TARGET AT VARIOUS VALUES OF R.

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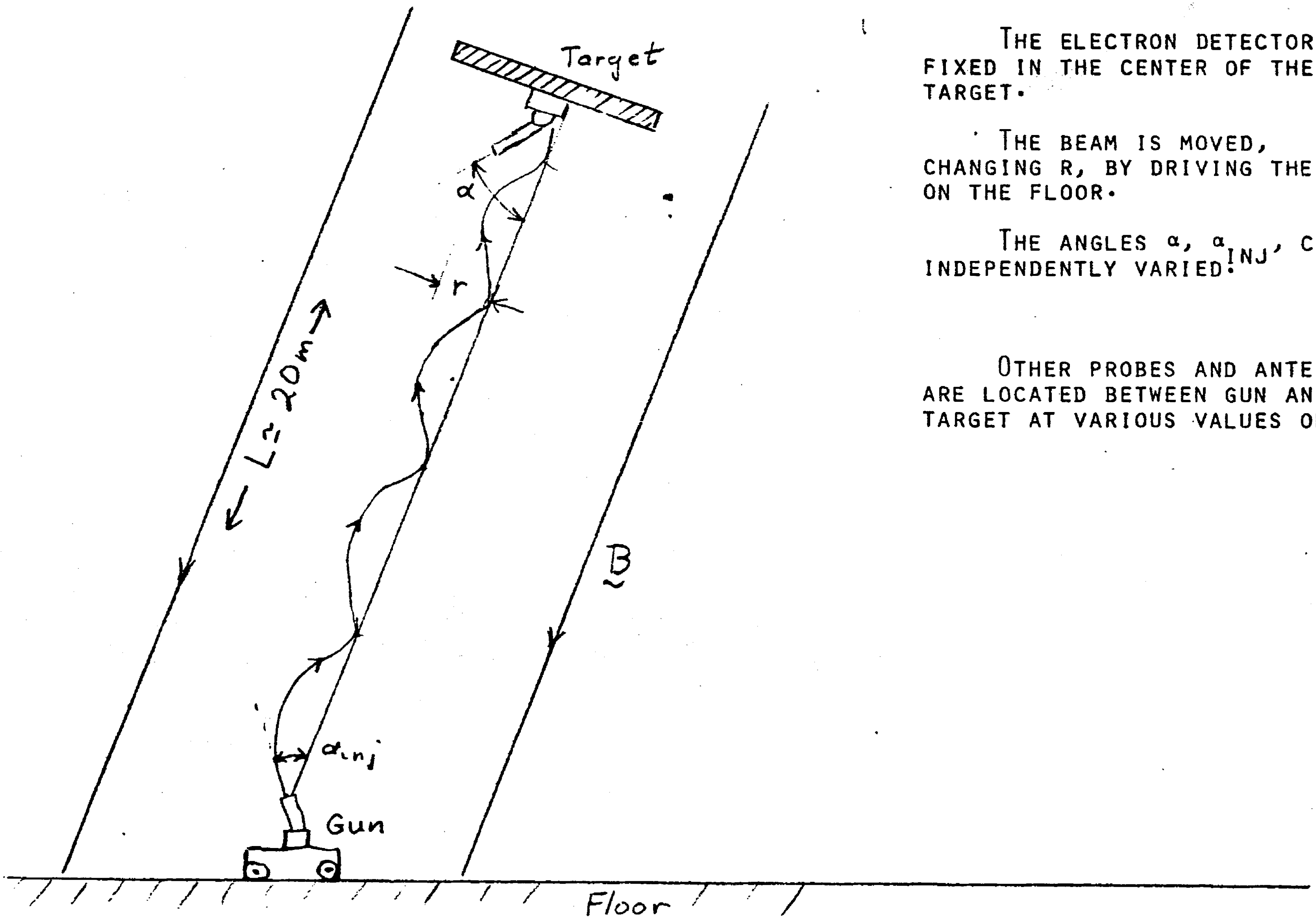
GEOMETRY OF LAB EXPERIMENTS



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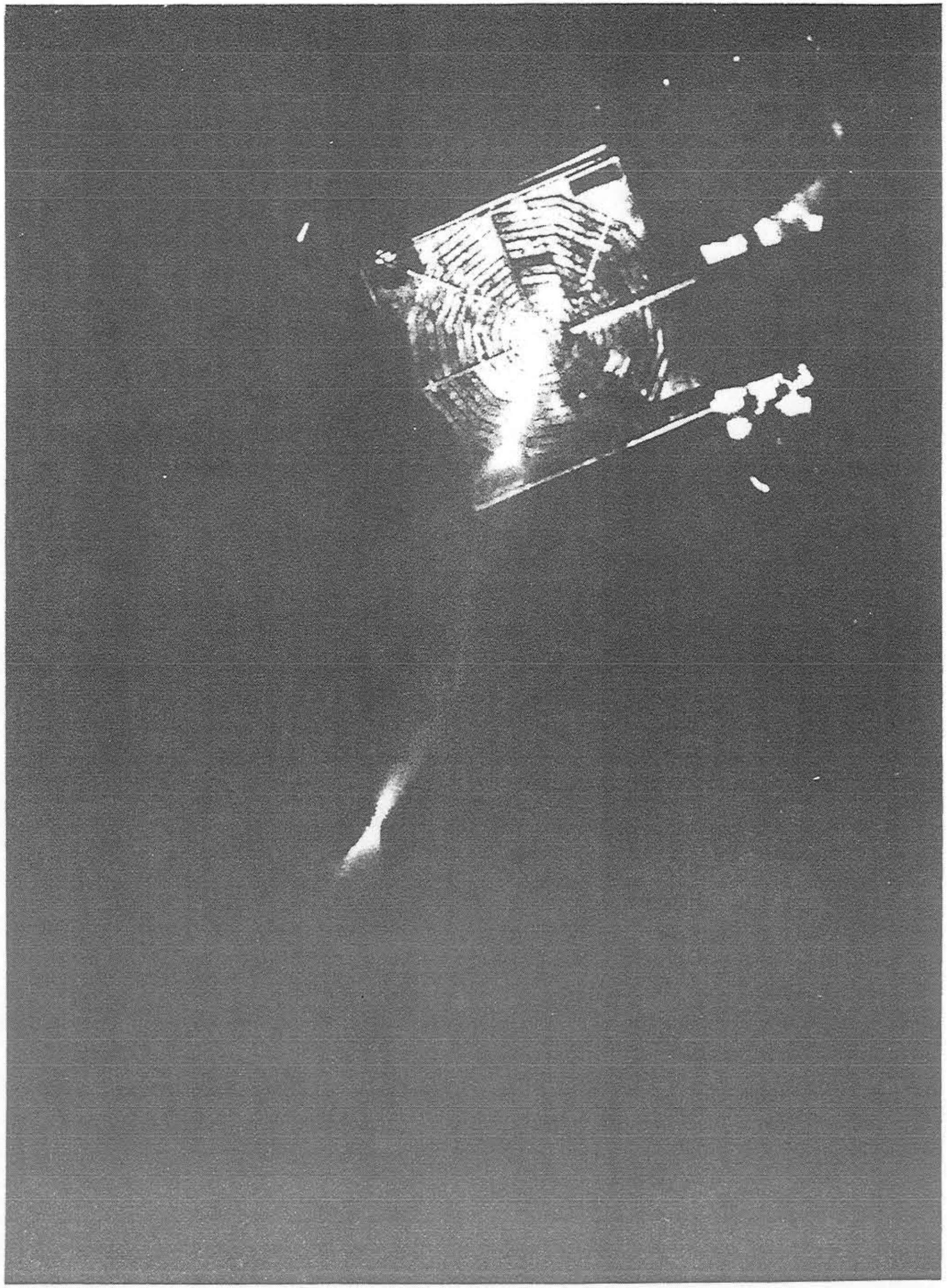
$p = 7 \times 10^{-6}$ TORR

$B = 1.2$ G

$V_G = 2000$ VOLTS

$I = 25$ MA

OBLIQUE INJECTION, $\alpha_{INJ} = 130°$



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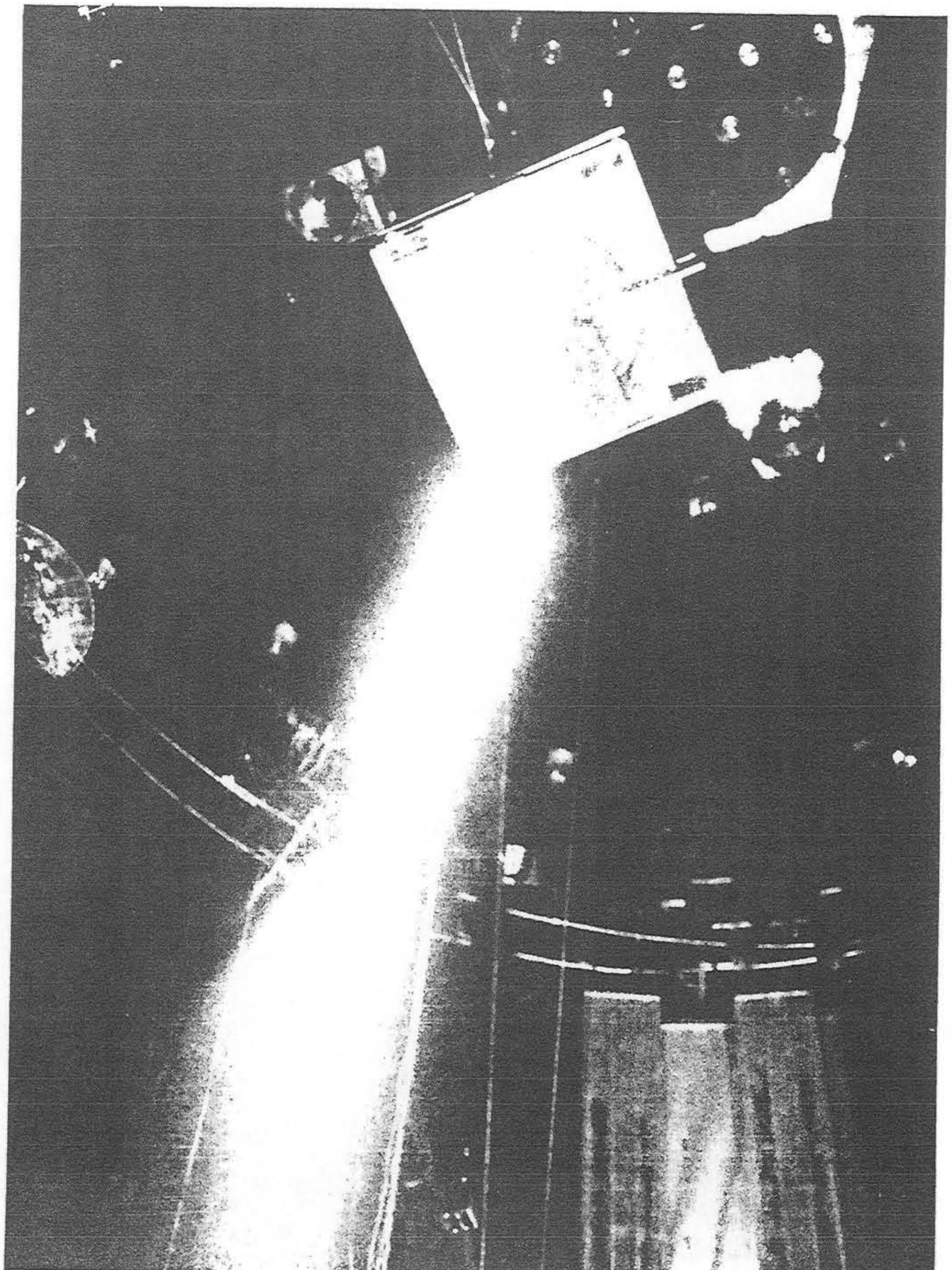
P = 7 x 10^{-6} TORR

B = 1.2 G

V_G = 2000 VOLTS

I = 8 MA

PARALLEL INJECTION, α_{INJ} = 180°



TEBPP

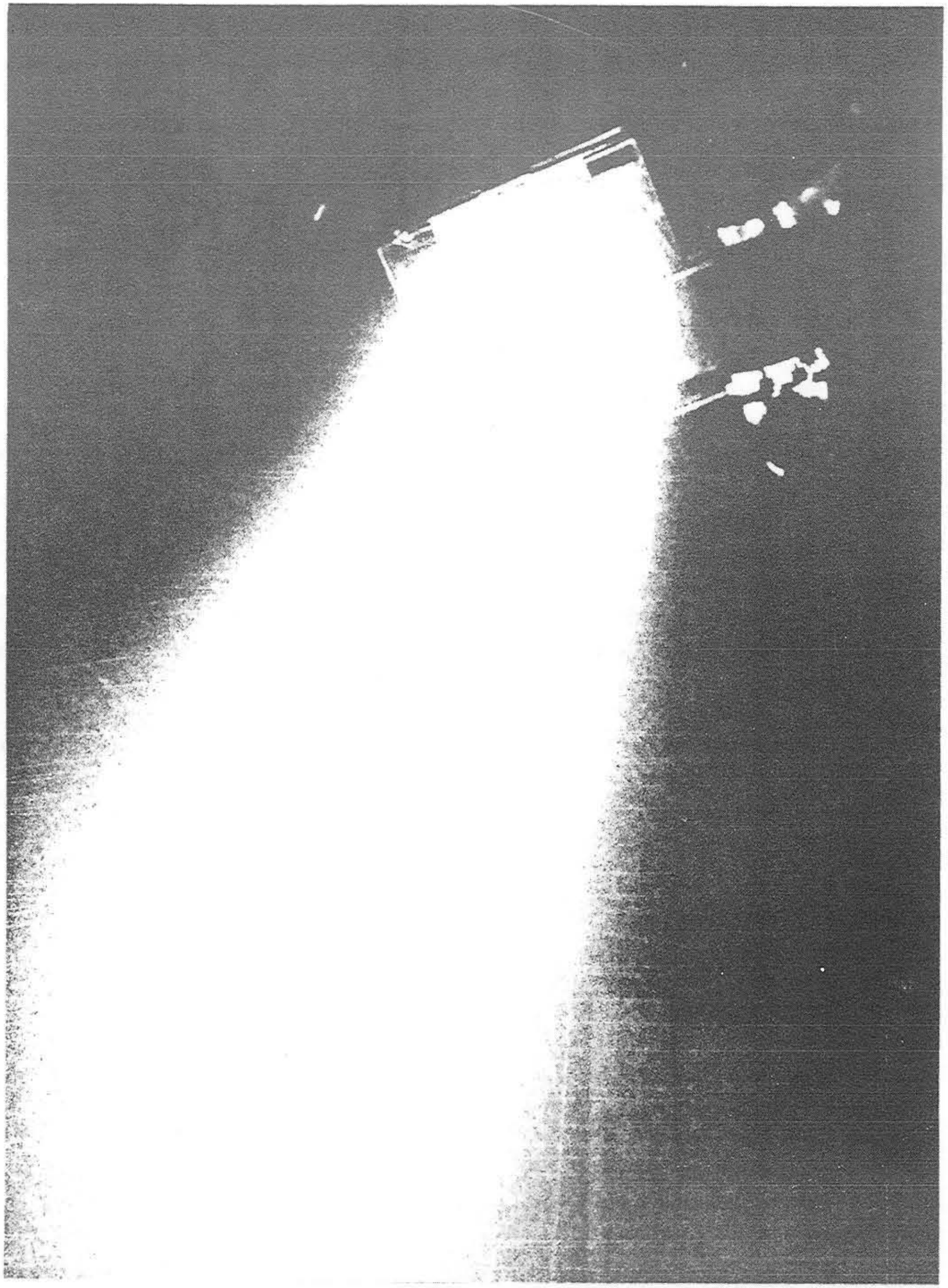
P = 7 x 10^{-6} TORR

B = 1.2 G

V_G = 2000 VOLTS

I = 40 MA

PARALLEL INJECTION, α_{INJ} = 180°



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$P = 7 \times 10^{-6}$ TORR

$B = 1.2$ G

$V_G = 2000$ VOLTS

$I = 70$ MA

PARALLEL INJECTION, $\alpha_{INJ} = 180°$

FULL BPD

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P = 3 x 10^{-6} TORR

B = 1.2 G

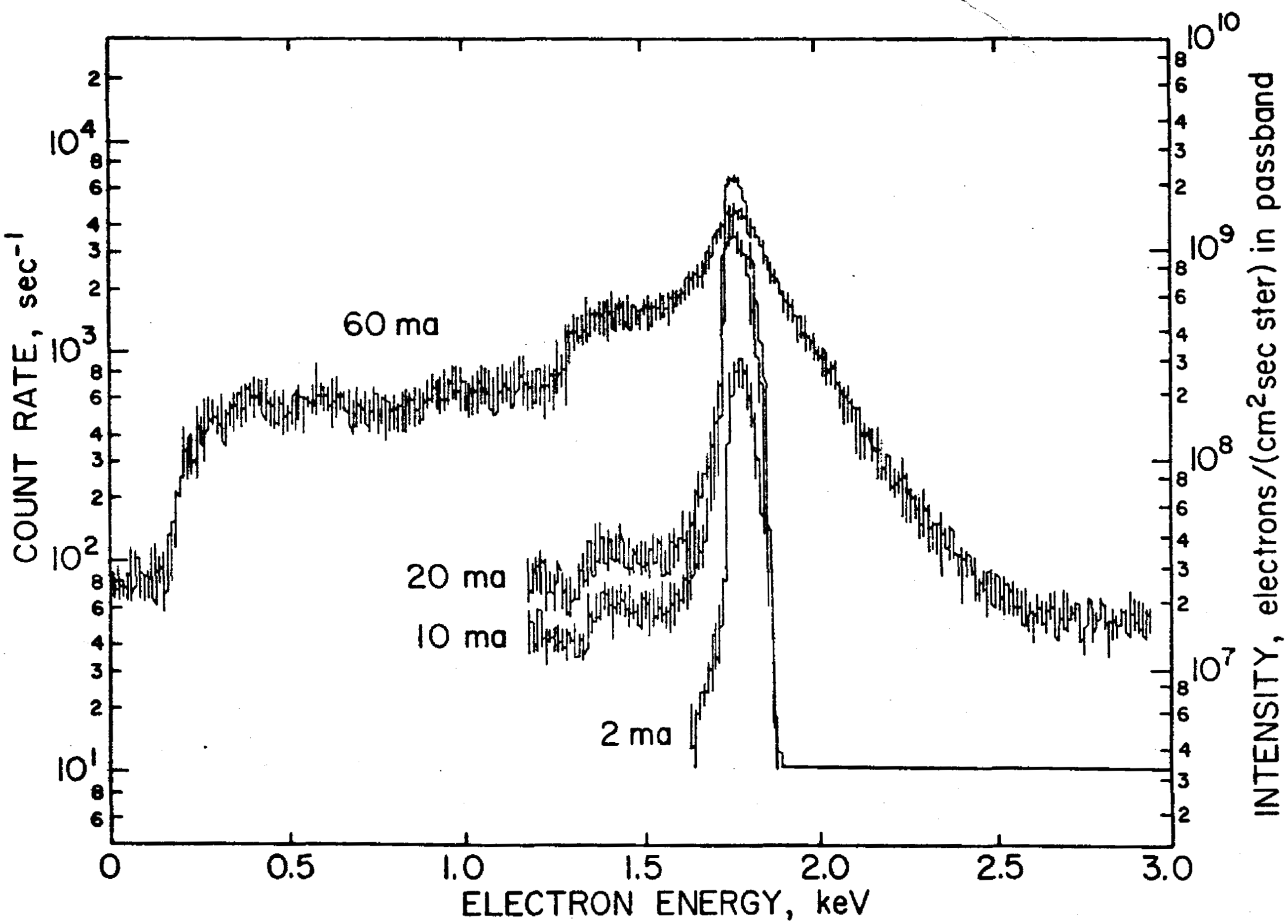
V_G = 1850 VOLTS

I AS GIVEN, BPD AT 80 MA

α = 125° (MAXIMUM FLUX)

α_{INJ} = 180°

R = 2.0 M



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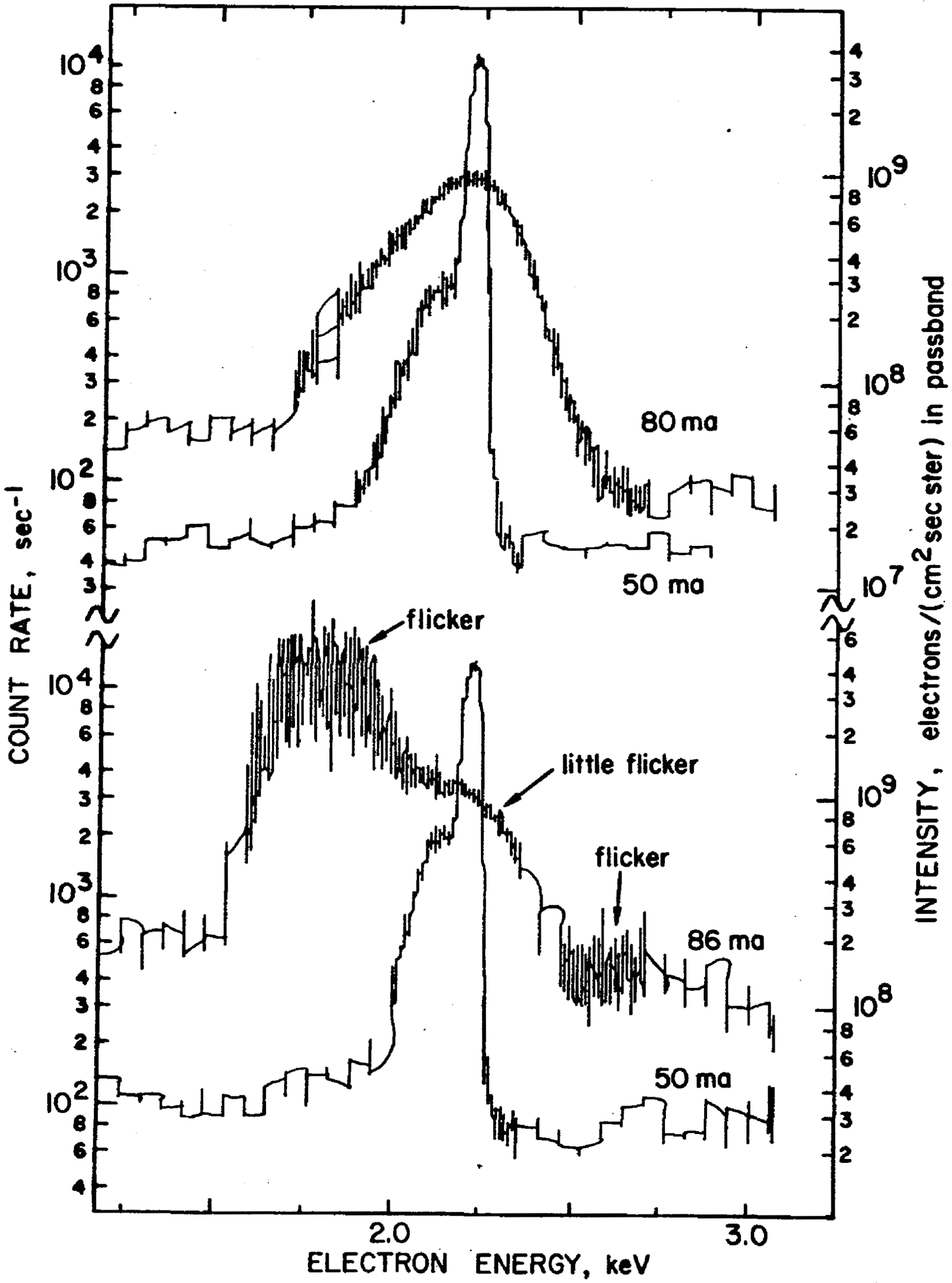

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P = 7 x 10^{-6} TORR

B = 1.2 G

V_G = 2100 VOLTS

I AS GIVEN, BPD AT HIGHER I.

α = 180°

α_{INJ} = 180°

R = 0.9 M

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COMMENTS ON PARTICLE MEASUREMENTS

DEPENDING ON ENERGY, FLUX = E^{-R/R_0} WITH $R_0 \sim .4$ M.

WE PRESENTLY HAVE NO DATA AT ENERGIES BETWEEN ~ 10 eV (IONIZATION POTENTIAL) AND ~ 200 eV.

ENERGIES BETWEEN 200 eV AND V_{GUN} ARE RELATIVELY MORE POPULATED IN BPD FOR LARGE R AND $\alpha < 180°$.

A PARTICLE DETECTOR MOUNTED ALONGSIDE THE GUN LOOKING AT $\alpha = 0°$ SAW ONLY A FEATURELESS ENERGY SPECTRUM. CLEAR EVIDENCE OF BPD IS NOT SEEN IN THESE SPECTRA

PRELIMINARY MEASUREMENTS INDICATE THAT THE BPD MAY REQUIRE SEVERAL MSEC TO DEVELOP, DEPENDING ON THE RATIO I/I_C, AND N_E.

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GRADIENTS OBSERVED IN VARIOUS PARAMETERS

PARAMETER	E-FOLDING DISTANCE ⊥ TO BEAM	E-FOLDING DISTANCE ∥ TO BEAM
PLASMA DENSITY	2.0 M	
PLASMA TEMP.	2.5 M	
ENERGETIC PARTICLE FLUX	.43 TO .14 M	
ELECTRIC FIELD STRENGTH		

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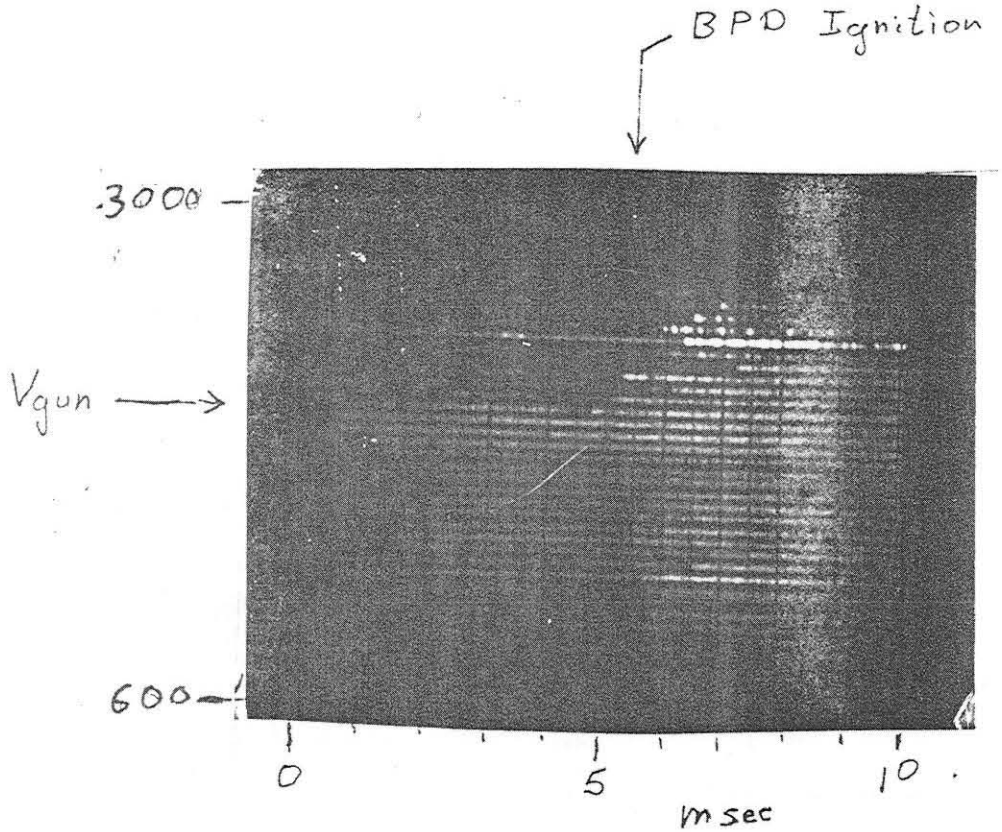

FIGURE 1. BPD IGNITION OCCURS ~ 5 MS AFTER INITIATION OF PULSE. PULSE WIDTH = 30 MS. INTERPULSE PERIOD = 400 MS

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FIGURE 2. BPD IGNITION OCCURS.