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THE LOW ENERGY TELESCOPE (LET) EXPERIMENT ON THE PHOBOS MISSION

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ABSTRACT

The Low Energy Telescope (LET) experiment on PHOBOS forms part of the ESTER complex of instruments that will perform studies of the solar wind, the suprathermal and energetic particle populations, and low energy cosmic rays. Specifically, the LET experiment measures the flux, spectra and elemental composition of nuclei from hydrogen up to iron, in the energy range $\sim$ 1 MeV/n to $\sim$ 75 MeV/n, using a double dE/dX *vs.* E solid-state detector telescope. Isotope separation for light nuclei such as He can also be achieved. The sensor is mounted on a rotating platform to enable coarse anisotropy measurements of low energy protons to be made. Following a summary of the scientific objectives of the experiment, a brief description of the instrumentation is given, together with first results obtained in orbit. Institutes collaborating on the LET experiment are the Space Science Department of ESA, the Space Research Institute, Moscow, the Max-Planck-Institut für Aeronomie, Lindau and the Central Research Institute for Physics, Budapest.

1. SCIENTIFIC OBJECTIVES

Measurements of low energy cosmic rays and solar energetic particles on board the two PHOBOS spacecraft will enable detailed studies to be made of the propagation and acceleration of charged particles in interplanetary space during the rising phase of solar cycle 22. In the following, a brief description is given of specific topics to be addressed using LET data.

1.1 Interplanetary Signatures of Solar Events

The timeframe of the PHOBOS mission is of particular interest since it coincides with the transition in the interplanetary medium between the steady, recurrent solar wind flow patterns characteristic of solar minimum and the transient flows encountered at solar maximum. In the former case, the medium is dominated by so-called corotating interaction regions (CIRs) that are generally formed beyond 1 AU. At the time of solar maximum, on the other hand, transient solar wind streams that are often associated with energetic events on the Sun, such as flares, prominence eruptions and coronal mass ejections, tend to dominate the interplanetary medium, often forming traveling interplanetary shocks.

Together with data from the other ESTER experiments, LET measurements of the characteristic particle signatures found for many of these phenomena will provide important clues regarding their nature and origins.

1.2 Anomalous Cosmic Ray Component

The presence near 1 AU of the so-called "anomalous" cosmic ray component (ACR), consisting primarily of He, N, O and Ne nuclei in the energy range $\sim$ 3 to 30 MeV/n, is known to be a function of the solar cycle. These particles, thought to be interstellar neutrals that have been ionised and accelerated in the heliosphere, were first observed in 1972 near the start of the last solar minimum. The flux subsequently disappeared shortly before solar maximum (1978/79), and recent data indicate its reappearance at 1 AU in 1986. The LET measurement range is ideally suited to studies of the ACR flux, and observations in the 1988 – 1989 timeframe will be invaluable for comparisons between the characteristics of the ACR components at the present and previous epoch.

1.3 Dual Spacecraft Measurements

As a secondary objective, the availability of measurements from identical instruments on two closely separated spacecraft will enable studies to be made of small-scale cosmic ray gradients. On a larger scale, data from the PHOBOS spacecraft will be used in conjunction with observations from a number of other spacecraft, including PVO, ICE and the Japanese Sakigake, to support the international Solar Interplanetary Variability (SIV) programme that has as its objective the study of the transition phase between solar minimum and solar maximum.

2. INSTRUMENTATION

The LET experiment hardware comprises three elements, namely: the LET sensor itself; a rotating platform on which the sensor is mounted in order to permit coarse directional information to be obtained on the 3-axis stabilised spacecraft; the LET Interface Unit (LIU). All three components are attached to a common mounting frame that also accomodates the ESTER SLED experiment. The LET experiment, excluding mounting frame and thermal hardware, weighs 6 kg and has an average power consumption of 2.5 watts. Figure 1 shows the experiment configuration. The electrical interface to the spacecraft is provided by the ESTER Data Processing Unit (DPU-B).

2.1 LET Sensor

The LET sensor consists of a four-element solid-state detector telescope surrounded by a cylindrical plastic scintillator anticoincidence shield, together with its associated analogue electronics. The telescope is shown in schematic form in Figure 2. Detectors D1 and D2 are surface barrier devices of equal active area (6 cm^2), having nominal thicknesses of 30 μm (D1) and 100 μm (D2), while D3 and D4 are 2000 μm-thick Li-drifted devices of 10.0 and 12.5 cm^2 active area, respectively. D4 forms part of the anticoincidence shield. The aperture of the telescope is covered by two thin foils, an inner Ti foil (2 μm) and an outer Kapton foil (7 μm), included for electrical screening and thermal control purposes, respectively. The telescope has a geometrical factor of 0.58 cm^2 sr for the majority of channels.

A block diagram of the complete LET experiment is shown in Figure 3. A summary of the LET digital data channels is given in Table 1.

2.2 Rotating Platform

In order to measure the directional characteristics of the particle fluxes, the LET sensor is mounted on a rotating platform. The full rotation range of the platform (175°) is adjusted so that in the extreme positions, the sensor axis is oriented close to the average direction of the interplanetary magnetic field as shown in Figure 4. This range is divided into steps of 44°, data accumulation occurring for a fixed period of time at each of the 5 positions. In normal operation, the platform makes a complete +60° → -115° → +60° scan cycle in 40 minutes, corresponding to two telemetry periods. The scan plane of the platform is tilted with respect to the ecliptic by 12° in order to avoid obscuration of the LET field-of-view.

2.3 LET Interface Unit

The LET Interface Unit, as the name implies, serves as the interface between the LET analogue electronics and the ESTER DPU-B (see Figure 3). The unit is physically separate from the LET sensor and, as mentioned above, also houses the motor drive control electronics for the platform. Functionally, the LIU comprises: the LET rate channel and PHA digital data interfaces; the telecommand and status interfaces; the analogue housekeeping interface and the power supply interface. In addition, the LIU provides the timing signals necessary for correct operation of the LET.

3. LET PERFORMANCE IN FLIGHT

The Phobos spacecraft 1 and 2 were successfully launched from the Baikonur Cosmodrome on 7 and 12 July, respectively. Following a period of ca. 12 days to allow for outgassing, the LET experiments were switched on on 19 July, 00:30 UT (Phobos 1) and 25 July, 05:59 UT (Phobos 2). Initial data show that the LET sensors on both spacecraft are functioning nominally. Data from selected counting rate channels acquired during the first weeks after launch are presented in Figures 4 and 5 for LET-1 and LET-2, respectively. In Figure 6, a charge spectrum computed using LET pulse-height data is shown for particles stopping in LET-1 detector D2 (so-called D1-D2 events). The data correspond to a $\approx$ 20-hour period starting at 06:34 UT on 21 July. Included as an inset in Figure 6 is the DV1 *vs.* D2 pulse-height matrix for the He events, in which the clear separation of the isotopes He-3 and He-4 can be seen. Despite the relatively small number of events in the sample, the flight data confirm the good species resolution available with LET.

4. ACKNOWLEDGEMENTS

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Channel No.	Code	Measurement			Time resoln. (sec)
1	P1	proton	0.9–1.2	MeV	240
2	P2		1.2–3.0		240
3	P3		1.8–3.8		240
4	P4		3.8–8.0		240
5	P5		8.0–19		240
6	A1	alpha	1.0–5.0	MeV/n	240
7	A2		1.9–3.7		240
8	A3		3.7–8.4		240
9	A4		8.4–19		240
10	H1	Li,Be,B	1.9–4.9		1200
11	H2		4.9–26		1200
12	H3	C,N,O	2.6–7.1		1200
13	H4		7.1–39		1200
14	H5	$z \geq 10$	3.0–9.0		1200
15	H6		9.0–50		1200
16	H7	$z \geq 20$	12.–75		1200
17	E1	e^-	tbd		1200
18	S1	Det. 1 singles			600
19	S2	Det. 2 singles			600
20	S3	Det. 3 singles			600
21	S4	Det. 4 singles			600
22	S5	Det. 5 singles			600
	PHA	pulse heights/flags			30

Table 1

ESTER LET DATA CHANNEL SUMMARY

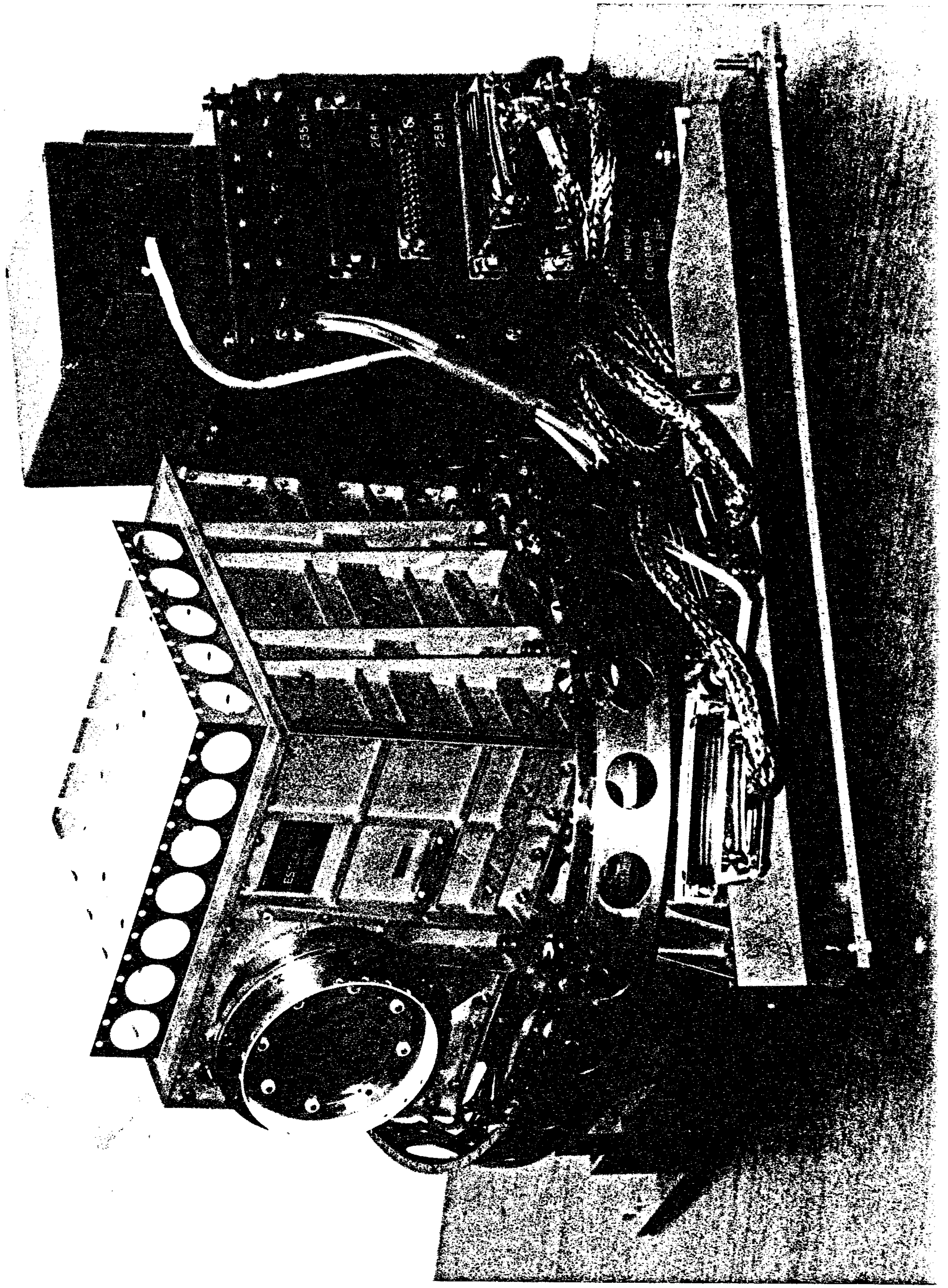

Figure 1

The LET Experiment configuration, showing the LET sensor unit. the rotating platform and the LIU, mounted on the ESTER common

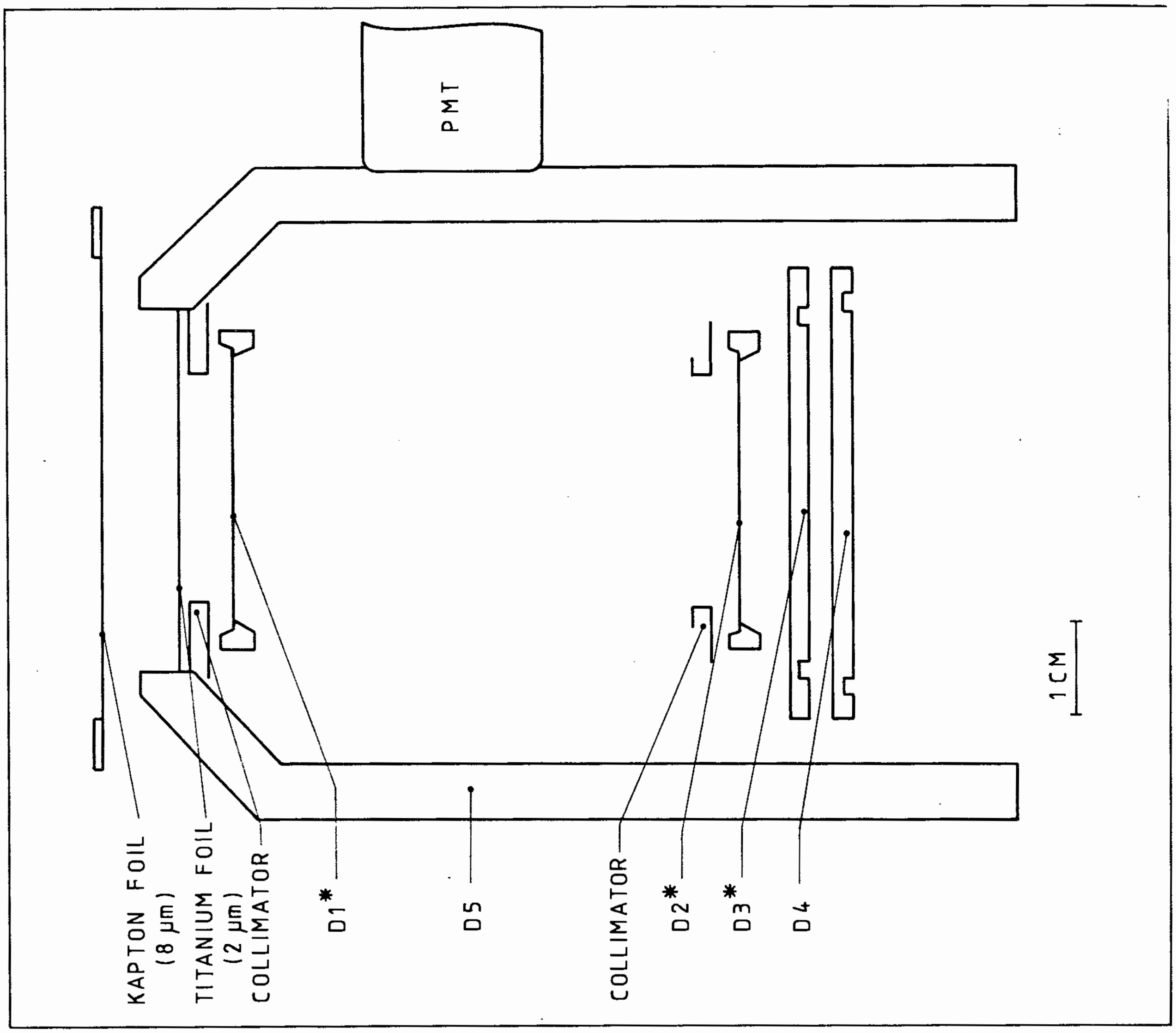

Figure 2
Schematic representation of the LET detector telescope; D_m^* denotes a pulse height analysed detector.

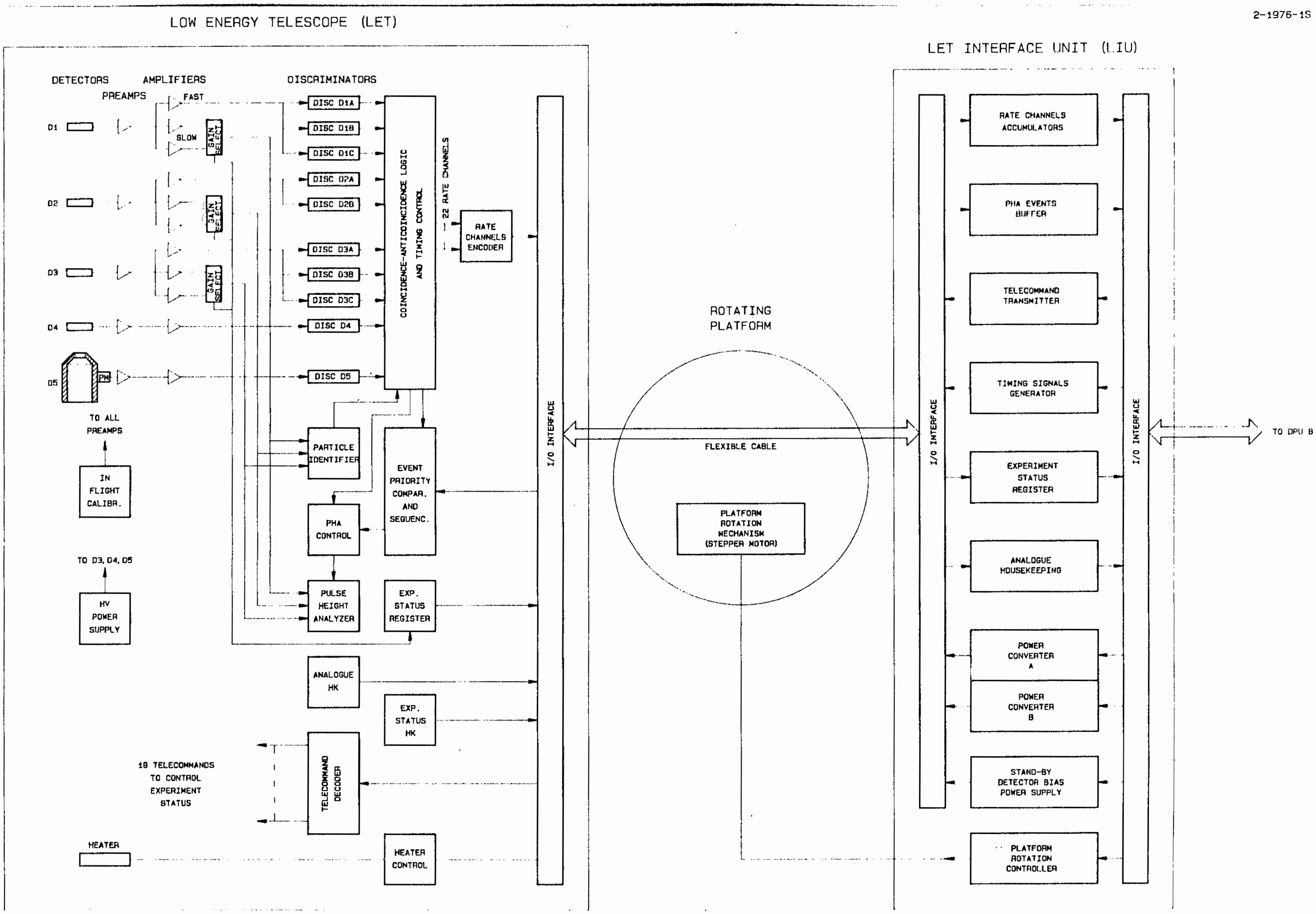

Figure 3

Block diagram of the LET Experiment.

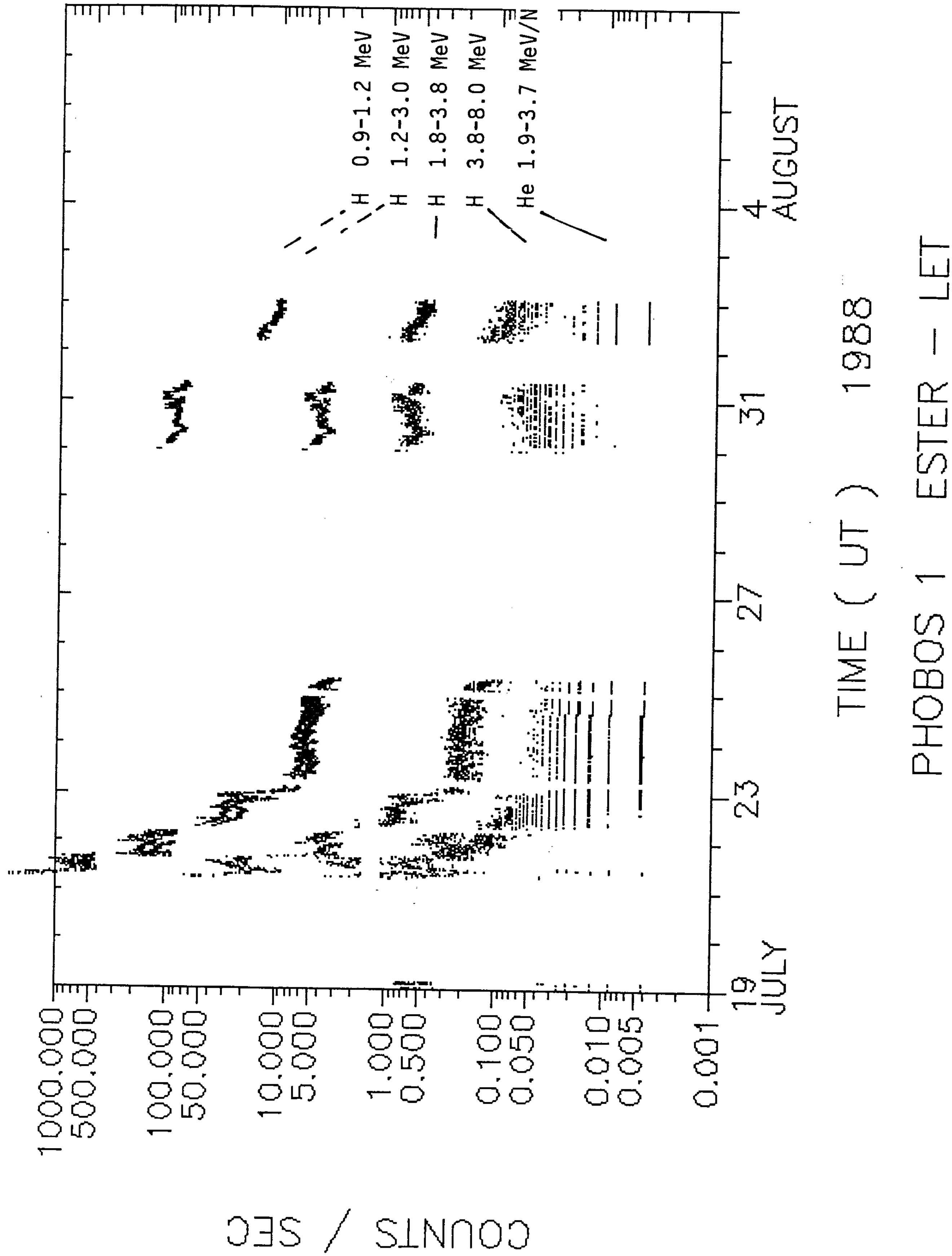

Figure 4
Countrates of protons in four energy channels (H 0.9–8.0 MeV) and α-particles (He 1.9–3.7 MeV/N) during the first weeks after launch,

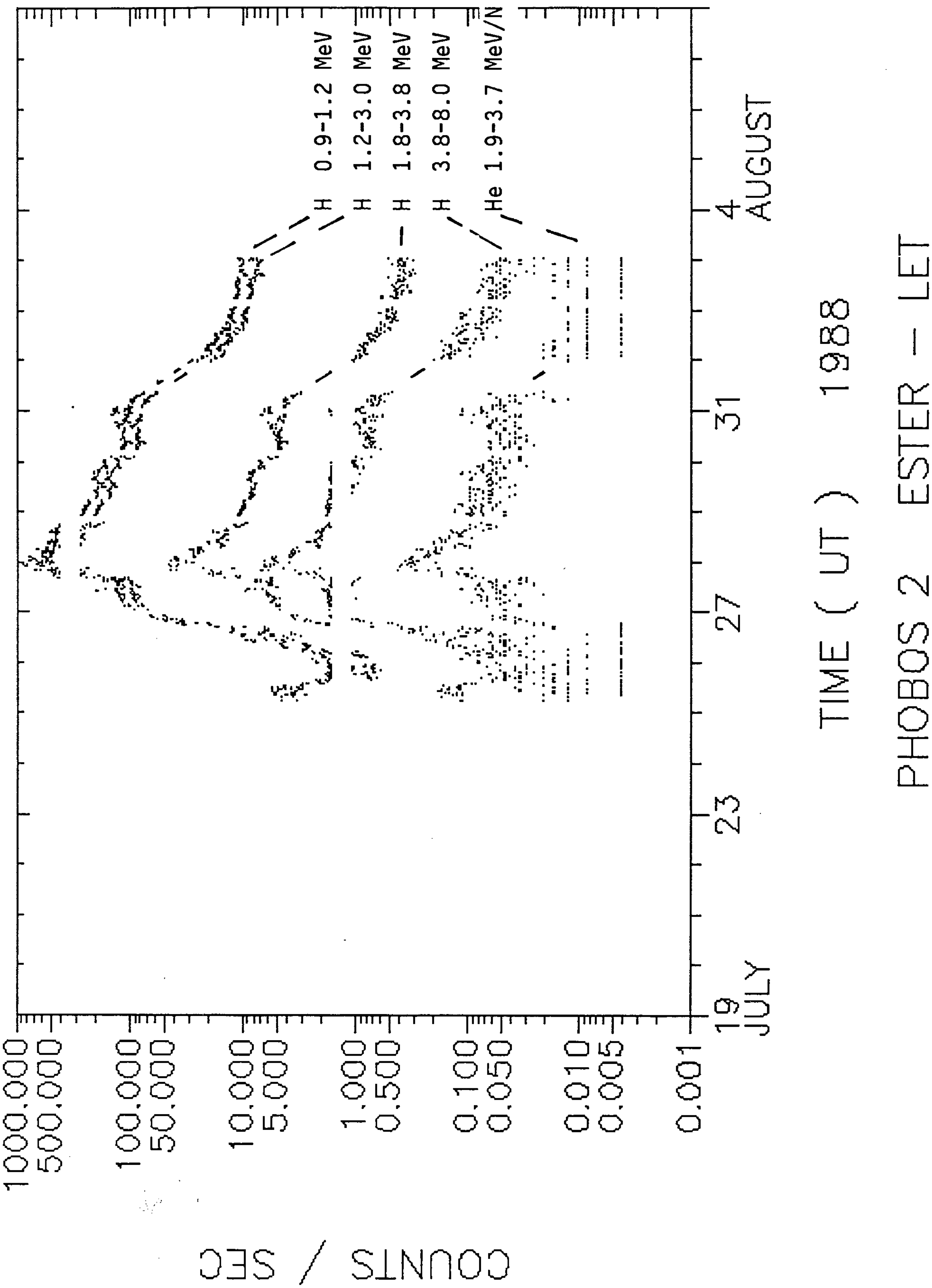

Figure 5
As Figure 4, the same countrates during the same period, but measured on PHOBOS 2, separated from PHOBOS 1 by about 0.02 AU.

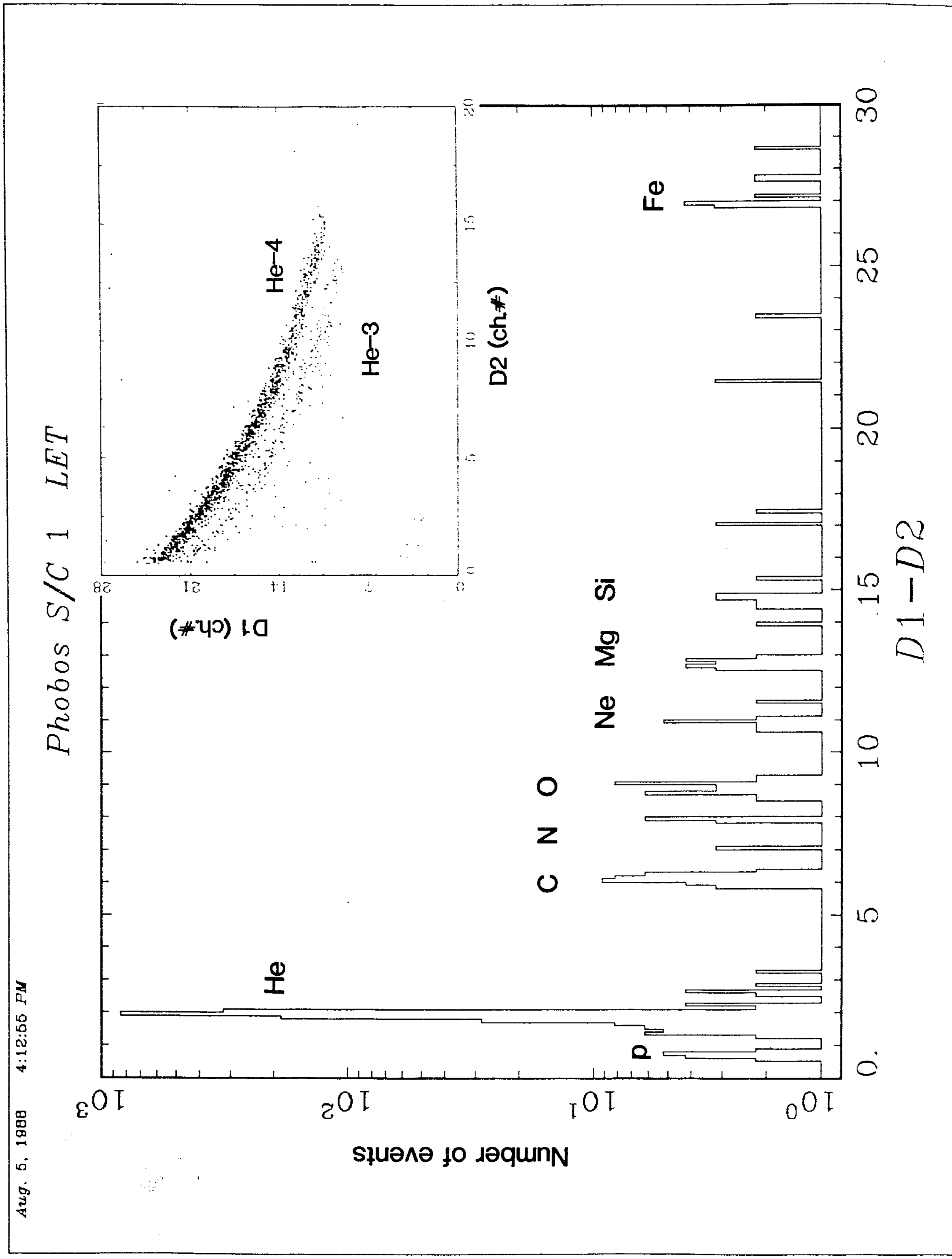

Figure 6
LET-1 charge spectrum for events stopping in D2. The inset is the corresponding D1 *vs.* D2 pulse-height matrix for Helium, showing the clear separation of He-3 and He-4.