The plasma experiment on HELIOS* (E1)

R.SCHWENN, H. ROSENBAUER, H. MIGGENRIEDER,
Max Planck Institute for physics and Astrophysics, Institute for Extraterrestrial Physics, Garching

Four independent instruments are grouped under the name "Plasma Experiment", whose shared responsibility is the investigation of the interplanetary plasma, the so-called solar wind. Primarily, the speed distribution functions of the different types of particles are measured. From this you can derive all hydrodynamic parameters of the solar wind plasma.Three instruments measure the positive component of the solar wind (protons and heavy ions with energy to charge values between 0.155 and 15.32 kV). Two of them allow the determination of particle direction on both the angles of incidence. The fourth instrument analysed electrons with one-dimensional direction resolution in the energy range of 0.5 up to 1660 eV.

The previous history of the mission shows that all instruments that are completely new to the part, fulfill the expectations.The influence of two previously encountered interference could be kept to a minimum.

The "plasma experiment" aboard of the solar probe HELIOS consists of four independent instruments which are designed to investigate the interplanetary plasma, the so-called solar wind. Primarily the velocity distribution functions of the different kinds of particles are measured. All important hydrodynamic parameters of the solar wind plasma can then be derived. Three instruments analyze the positive component of the solar wind (protons and heavier ions with energy-per-charge-values from 0.155 to 15.32 kV).Two of them allow for an angular resolution in both directions of incidence. One instrument measures electrons in the energy range from 0.5 to 1660 eV with a one dimensional angle resolution.

Since the launch all the instruments, which are partially novel developments, perform very well.Two sources of interference have caused data losses of minor importance.

1. THE RESEARCH OBJECT SOLAR WIND AND THE SCIENTIFIC OBJECTIVE OF THE EXPERIMENTS

Since L. Biermann in 1957 concluded from Comet observations, that constantly ionized gas in the interplanetary space must escape from the Sun, many theories have been developed about this phenomenon, and since the first interplanetary spacecraft flights it has also been directly experimentally verified. It was called a "Solar wind", and the interest in his research has continued since then. Several reasons: firstly an astrophysical plasma, which probably is emitted in a similar way by a majority of all the stars, is directly accessible; on the other hand, it influences the physical events in the Earth's magnetosphere and in the vicinity of other planets and also provides information to us about operations on the Sun. In addition, plasma physical findings can be obtained through the study of the solar wind, which are difficult or impossible to obtain in the laboratory.

Close to the Earth's orbit, the parameters of the solar wind are now fairly well known. It is known that it is composed on average about 95% of protons, 4% from alpha particles and small amounts of heavier ions and electrons to compensate the ion charge. The particle density is 10 cm^{-3} in the order of magnitude. This plasma flows with a mean speed of approx. 400kms^{-1} approximately radially outwards away from the Sun. The direction of movement of the individual protons scatter towards this direction slightly due to the "temperature" of the proton component of about 10^5 K. However, the average thermal energy (approx. 15 eV) predominates when the electrons opposite the translation energy (<1 eV), such that their velocity distribution by a spacecraft appears nearly isotropic. The numbers specified here are subject to fluctuations, which are themselves of interest because they indicate, in the plasma between the Sun and Earth, either to structures on the Sun or to operations, e.g. wave propagation.

Yet major questions for understanding of the underlying physical processes are open despite the apparently already very good study of the solar wind. This is because to a large extent, that virtually all previous measurements were made in the solar system beyond the orbit of Venus, so that between the place of origin and approx. 0.7 AU nothing is known about the development of the phenomenon. But above all the various theories differ in the course of important plasma parameters in this field. So just measurements of HELIOS here can provide insight into the accuracy of the various models. Due to the large approaching of HELIOS to the Sun, much more accurate observations in the solar wind should also be possible, as it has been possible to correlate with phenomena on the Sun's surface and so important details to clarify that so far have not been recorded in the theories about the expansion of the solar wind. Finally, the plasma parameters measured at the location of the probe are also an important basic information for other HELIOS experiments, because the electric and magnetic fields (the 4 experiments deal with its measurement) are directly influenced by the solar wind, and the energetic particles (3 experiments) are also influenced by it.

The plasma experiment is designed but not so that it gets its value only through the special orbit by HELIOS; instead attempted to allow for measurements, which have not yet been made so far even close to Earth's orbit, through the development of new tools. Here, especially the analysis of plasma electrons are up to lowest energies and the complete separation of the distribution functions of protons and of α-particles to name a few.

***This experiment was designed and carried out at the Max-Planck-Institute for Physics und Astrophysics, Institute for Extraterrestrial Physics, 8046 Garching bei München, by H. Rosenbauer, H. Grünwaldt, B. Meyer, H. Miggenrieder, H. Pellkofer (currently at Fa. Synelec, München) and R. Schwenn. J. Wolfe from Ames Research Center of NASA is involved as a co investigator.**

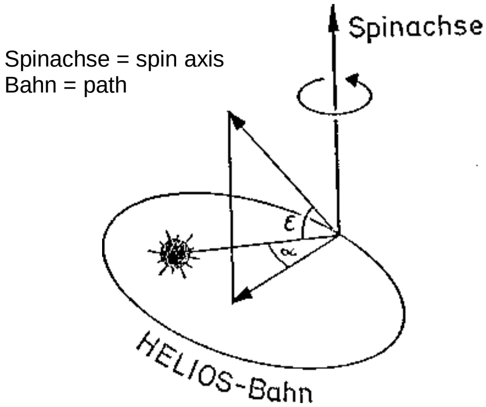
2. OVERVIEW

The term "Plasma Experiment" are the four independent instruments combined, their common task is to study the solar wind plasma. Three of the instruments (I1a, I1b and I3) measure the positive component, one (I2) the electrons of the solar wind. Primarily, the speed distribution functions of the different types of particles are measured. The low density of the interplanetary plasma allows in principle a simple method: the particles are sorted according to their speeds and incident directions and counted individually. All hydrodynamic parameters of the solar wind plasma can be derived from it: flow rate, densities and temperatures of different ions and the electrons, the temperature anisotropies and the composition of the positive component. All E 1-instruments work on the same basic principle: the charged particles pass through static or dynamic deflection systems; but only particles that come from certain directions, and with a ratio of energy to charge (E/q) which is located in a suitable limited area can pass and be counted. As an example, an Analyzer with ball-shaped baffle plates (medium radius R, distance d), where the voltage U_p is called. As a condition for the middle of the passband is:

$$\frac{E}{q} = U_p \cdot \frac{R}{2\,d}$$

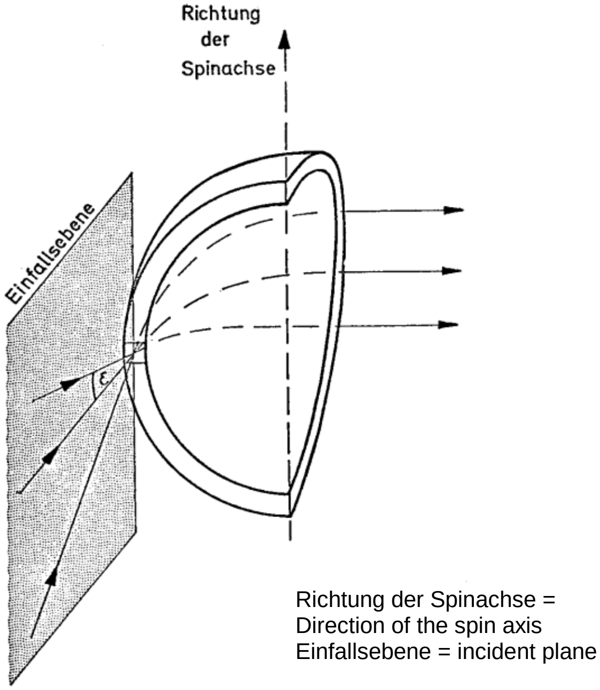
By changing the voltage of plate the permeability range can be moved and therefore gradually a E/q-spectrum absorbed. Such spherical analyzers are used in I1a, I1b, and I2.The plate voltage is switched up here in 32 steps from turn to turn of the probe. Suitably divided "Azimuth channels". The E1-instruments are mounted in the vicinity of the Equator of HELIOS and look with their entrance funnels through gaps in the heat shields radially outward. Due to the orientation of the spin axis of the HELIOS, the middle of the fields is always in the plane of the ecliptic. (Angle in the plane of the ecliptic, see fig. 1) the rotation is taken to the Azimuthal direction resolution of HELIOS directly to help; by spin-synchronous sector pulse, measurement time is divided into each revolution in appropriate "azimuth channels", which correspond to the expected particles incidence direction.

Ion instruments I1a and I3 is also a resolution with regard to the second angle of incidence, the elevation (angle perpendicular to the ecliptic); This allows a three-dimensional measurement of the speed distribution function. As shown schematically in Figure 2, the particles falling through the inlet opening at different elevation angles ϵ to escape after traversing a quarter spherical analyzer in various places and can be registered by separate detectors. This scheme can also derive, that with a hemispherical analyser all particles are focused from the implied plane of incidence to a point opposite the inlet. So, a detector at this point provides a measurement result integrated over all the angles of elevation. This principle use I1b and the electron instrument I2. A highly sensitive electrometer, which directly measures the incoming ion current is used for detecting particles in I1b. In the other instruments, the particles with the help of open "Channeltrons" (continuous Electron multiplier) are counted separately.



Spinachse = spin axis
Bahn = path

Figure 1: Definition of the angle azimuth (α) and elevation (ϵ) of the particles incidence directions.



Richtung der Spinachse = Direction of the spin axis
Einfallsebene = incident plane

Figure 2: Scheme of an electrostatic quarter spehere analyzer. Particles with different incidence angles ϵ emerge at various points of the analyzer and then detected with single detectors.

The most important data of the individual instruments are in TAB. I put together.

3. THE INSTRUMENTS FOR POSITIVE IONS

The main task of the plasma experiment is the measurement of the three-dimensional speed distribution function of protons in the solar wind. Because there is no redundancy for these measurements on board Helios, the instruments I1a and I3 were designed largely equivalent with respect to the Proton measurements, in the sense of a "cold" redundancy: only one of the two instruments is in operation and fills the entire portion of the E1 data frame for three-dimensional proton measurements with its data.

The instruments I1a and I1b are housed in a common box. Their spherical analyzers are

TAB.1: MAIN DATA OF E1 INSTRUMENTS

Instrument 1a for positive ions

		Channels
- Energy per charge	0.155 to 15.32 kV	32 × 2
- Azimuth (based on Sun)	- 54.5° to 32.7°	16 × 2
- Elevation	- 20° to +20°	9

Analyzer: Quarter sphere with R = 60 mm, d = 1.2 mm
Detectors: 9 Channeltrons.

Instrument 1b for positive ions

		Channels
- Energy per charge	0.145 to 14.32 kV	32 × 2
- Azimuth	- 56.25° to +118°	1
- Elevation	- 40° to +40°	1

Analyzer: Hemisphere with R = 54 mm, d = 4.5 mm
Detector: Electrometer with quantization unit
1.6×10^{-16} As.

Instrument 2 for electrons

		Channels
- Energy per charge	0.5 to 15.5 V (A)	16
	10.7 to 1660 V (B)	16
- Azimuth	360°	8 × 2
- Elevation	- 9° to + 9 °	1

- Analyzer: Hemisphere with R = 40 mm, d = 5 mm
Level deflection plates with d = 33.6 mm
Detector: 1 Channeltron.

Instrument 3 for positive ions

		Channels
- Speed	199 to 767 km/s	16
- Azimuth	- 53.2° to 30.8°	16 × 2
- Elevation	- 20° to +20°	9
- M/q values (based on H^+)	1 to 5.33	15

Analyzer: Modified sine wave panels with d = 2 mm,
l = 135 mm
Frequencies of 1.058 to 4.088 MHz
Detectors: 9 Channeltrons.

almost arranged concentrically. The 32 energy channels have 17% distance from each other and are almost exactly the same for both instruments. Every second measuring cycle moves the energy channels by half a channel spacing, the azimuth channels as well. For quiet solar wind then two spectra can be used together which substantially improves the resolution in two dimensions.

The relatively large opening and the wide plate distance of I1b together with the integral effect of the hemisphere allows to measure the flow of ions of the solar wind as ion current. Here, charged ions repeatedly deliver a correspondingly higher contribution than I1a, where each particle is simply counted regardless of its charge. So, the combination of both measurements provides information about the charge level of heavy ions in the solar wind. At the same time, a certain redundancy function has I1b due to its simplicity.

The novel instrument I3 to indicate the composition of the positive component of the solar wind. It contains a "electrodynamic Analyzer" as the core. Its deflection plates have a roughly sinusoidal curve, so that an applied sinusoidal alternating voltage will only allow particles with a corresponding speed to get through. It is determined by the frequency of the applied AC voltage and the geometry of the Analyzer. On the other hand the amount of plate voltage as in the electrostatic Analyzer provides also for the curvature Particle paths and allowing for the excretion of all particles with wrong E/q values. The two independent criteria of speed and energy per charge lead to a selection of particles according to their mass-per-charge ratio (M/q). A total of 15 fixed M/q values can be set for each of 16 speed values. The highest value of 767 km/sec corresponds to Protons of energies of 3.08 keV, compared to 15.31 keV at I1a. But in its azimuth and elevation channels this instrument resembles exactly the instrument I1a.

4. THE ELECTRON INSTRUMENT

The electrons of the solar wind plasmas are of increasing importance in all theoretical models. But the measurement of such electrons in the energy field of a few electron volts is generally difficult and therefore until today not properly managed: Photoelectrons, whose flux density is at low energies to several orders of magnitude higher than that of plasma electrons due to the sunlight on the probe surface and in the instrument.

So, one must distinguish the electrons after their origin. This is possible; because Photoelectrons that fall vertically into the detector have - with some simplifying assumptions - always a lower energy than the electric potential ϕ of the entire probe, if ϕ is positive; Photoelectrons with higher energy than $e \cdot \phi$ can not return to the probe and to the detector. Solar electrons reaching the detector, have always a higher energy than $e \cdot \phi$, because you to are accelerated by this amount. Since now the spectra of photoelectrons and plasma electrons will vary in general, we will expect a discontinuity in the measured energy spectrum of electrons at the point of the probe potential. Here but must avoid photoelectrons only produced within the instrument and hence can have higher energies than $e \cdot \phi$, blur this jump.

This can be achieved through such a geometry which basically makes it impossible for all photoelectrons generated in the interior of the sensor to reach the detector. It is also provided that the probe potential is positive and that no inhomogeneities of the electric field deflect incident electrons in the visual field of the sensor. Unfortunately, a complete coating of HELIOS with a conductive layer to achieve a uniform positive potential for various reasons has been impossible to achieve. Only the central part of HELIOS is covered with two wide conductive rings are electrically connected with the probe structure. They provide enough large photoelectron emission, and thereby compensate for the strong flow of plasma electrons falling from above and below in the turned-off, also conductive and "grounded" surfaces of HELIOS. This potential of HELIOS can be considered positive most of the time.

Interference due to electrostatic charging of non-conductive surfaces by plasma and photoelectrons however remain and must be taken into account in the evaluation.

Figure 3 shows a function drawing of the electron instrument I2 on HELIOS. It contains a hemispherical electrostatic analyzer with an upstream flat panel analyzer. This directs the incoming electrons from the scope of the direct sunlight out to the energy analyzer. The dimensions are chosen so that photoelectrons, e.g. arise on the cutting edges of the input hopper or also on the backs of the sensor, cannot penetrate to the Channeltron because they are not in the visual field of the actual instruments, the hemisphere Analyzer. The energy spectrum is in two parts

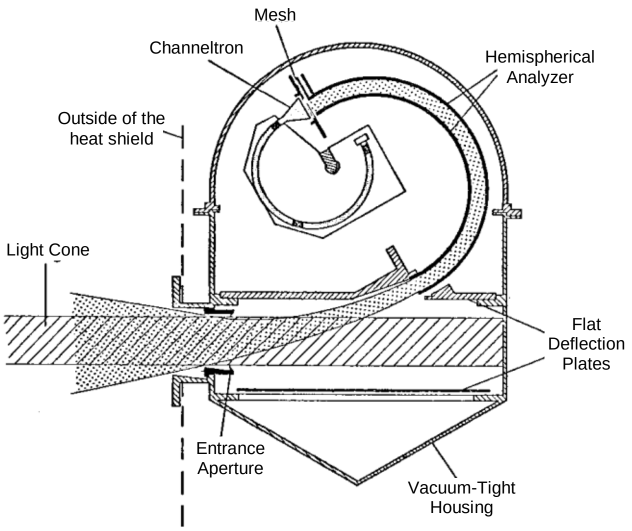


Figure 3: **Function drawing of electron instruments I2.**

The electrons are deflected by the flat baffle plates from the cone of light out into the hemispherical analyzer and registered by a Channeltron after passing through a mesh aperture (for suppression of secondary electrons).

driving through 16 steps: In part A for low-energy electrons from 0.5 up to 15.5 eV and in part B from 10.7 to 1660 eV. The full rotation of 360° is divided into eight same areas here, and is integrated using the elevation from -9° to + 9°.

5. DATA PROCESSING ON BOARD AND MEASURING PROGRAMS

The main instrument I1a produced in every HELIOS rotation, so per second in 9 elevation and 16 azimuth channel together 144 readings in the form of 16-bit counter states. That alone exceeds already the maximum transfer rate of HELIOS. There must occur a pre-evaluation and reducing the data still on board. Initially all data converted into 8-bit words, but at the expense of accuracy. In the "Quasi logarithmic compression" the number is specified in the original 16-bit word before the first "L" zero as a "Quasi Exponent" (E) with 4 bits. The "mantissa" (M) is also four bit. Decoding is performed according to the formula

$$\text{Count rate} = \begin{cases} (M+16)\cdot 2^{11-E} & \text{for } E \leq 11 \\ M & \text{for } E = 12 \\ Incorrect & \text{for } E > 12 \end{cases}$$

Still, two different measuring programs were provided to reduce data that allow even a certain adaptation to the strongly varying bitrates of the probe. The most interesting part of the ion spectrums - protons and α-particles - filled most of the time only a small segment of the entire measuring range, but constantly shifted due to the known fluctuations of solar wind. Which is adapted to the "normal data mode"-measuring programme (NDM) for medium and low bit rates. Here first look up the maximum of the intensity of Proton experiment internal logic, and the address of the measuring channel in energy (EN), azimuth (AZ) and elevation (EL), in which the highest count rate occurred. In the next measuring cycle only a limited number of measuring channels around this maximum is registered, namely 9 X 5 X 5 (EN X AZ X EL), so 225 values.The nine energy channels are designed that even the helium ions - such as the double E/q ratio of protons - are yet covered. Meanwhile, already a new maximum for the next cycle is determined over the whole measuring range. Additionally, the "integration counter" for I1a and I3 in each energy channel provides a counting rate caused by summation of all azimuth and elevation channels – even those that are not transmitted on the basis of the selected maximum -. This allows for the estimation of the marginal areas occasionally cut off the three-dimensional measurement and also a direct comparison with the instrument I1b that is also an integral, but measured the total charge. Also its 32 results per cycle are always transferred.

When I3 is turned on instead of I1a, applies a similar selection process, with some differences in the NDM: when the first 16 turns of a cycle the full speed range is again a maximum of Proton distribution (so for M/q = 1) searches. This is then used as at I1a, as a Centre for the 225 readings from the first 16 turns of the next cycle. Each during the revolutions 17-32, only the integration counter works. With a fixed "speed channel", where the protons previously had the highest intensity, all M/q-values are set in sequence. This program is based on the observation that the average speed of different ions is always pretty much equal to that of the proton. The integration over the angle makes sense due to the very low density of heavier ions.

From I2 all 16 energy channels transmitted by either part A or part B in 8 channels of azimuth, altogether 128 values per cycle. Part A or B are selected by command.

In the case of high bit rate the measurement program "High-Data-Mode" (HDM) can be toggled to a command. Here, the range selection by maximum provision is eliminated. Of I1a and I3 a fixed grid of 7 X 7 (AZ X EL) channels is transmitted for all energy channels. When I3 will be held again in the second part of the cycle of the speed channel and the mass channels - this time angle-resolved - through, but the speed channel is advanced regardless of the Proton maximum after each cycle. After 16 cycles you have got for each of the 15-M/q values a three dimensional spectra as well as 16 additional proton spectra.

By I2 transmitted always fully both parts of the program in the HDM, as of I1b and from I1a/I3-Integration counter.

A compilation of the data shares attributable to the different instruments is given in table 2. Here also it was taken into account by the telemetry format (FM) dependent block length of "experiment-data-frame" (EDF). The first 15 values referred to as the "Initial Data" every EDFs describe the exact coupling condition of E1 and contain the maximum address, as well as some code words. The measurement data not fully fill the available data share in all modes. Then, the spaces designated as "Appendix" are filled with zeros.

TAB.II: BREAKDOWN OF EACH INSTRUMENT TRANSFERRED READINGS IN E1 EXPERIMENT DATA FRAME

	Normal-Data-Mode		High-Data-Mode	
	FM 1/5	FM 2/3	FM 1/5	FM 2/3
"Initial Data"	15	15	15	15
I1b	32	32	8	8
I1a Integr.	32	32	8	8
I 2 (EN X AZ)	16 X 8	16 X 8	8 X 8	8 X 8
I1a/I3 (EN X AZ X EL)	9 X 5 X 5	9 X 5 X 5	8 X 7 X 7	8 X 7 X 6
Appendix	72	0	17	1
Block Length	504	432	504	432

6. THE TECHNOLOGY OF THE EXPERIMENT

Each instrument consists of a sensor and an electronic part. The sensor part includes the admission system, the analyser systems, particle detectors, as well as the high voltage cascade to produce the plate and Channeltron volatges. Only components from metallic or ceramic materials were used to protect the sensitive Channeltron surfaces from contamination by organic vapors in the sensor. Fig. 4 shows a look in the Interior of the sensor of I2. The sensor housings are UHV sealed. Ground tests and calibrations, the sensors are evacuated by their entrance funnel with oil-free UHV pumps. Otherwise, they are locked by firmly screwed metal lid. Each of these cover has a small mirror cube used for adjusting (more precisely than 0.1°) the instruments in the probe. The lids are removed before the start.

The electronic parts of the instruments contain converter for the necessary supply voltages, the arrangements for the high voltages, the amplifier for the Channeltron-pulse and a part of the command and control electronics.

All E1-instruments are supplied by a common electronics box. It contains all interfaces between the instrument and the probe system:

(1) The main converter distributes electric power and provides for galvanic isolation of circuits from the probe system.

(2) The command system ensures the execution of 19 commands, with whom measurement programs, high voltages and instruments can be toggled; there is also feedback about reception and execution of commands the probe system.

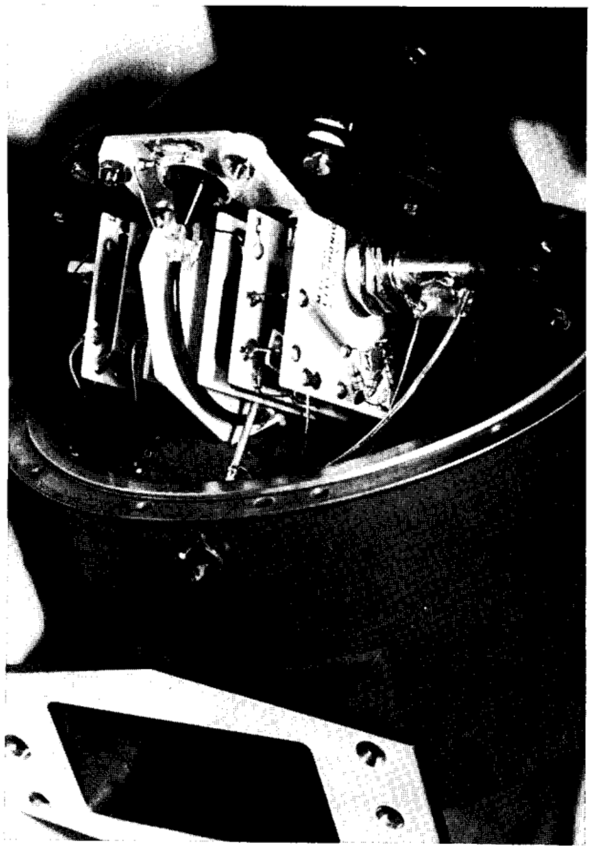


Figure 4: **A look at the open sensor part of the electron instrument (cf. Fig. 3).** You can see among others the particle inlet opening (bottom left) the hemispherical analyser cups (top right), the Channeltron soldered on a ceramic plate and the next lined-up high voltage cascade also. The diameter of the cylindrical housing is only 11.2 cm.

(3) The program system controls the switching of the plate voltage and the location and length of the azimuth with the help of clock pulses offered by the probe.

(4) The data system prepares the measurement data, stores it and passes it to the HELIOS telemetry. These include

— the counter for the preamplified detector pulse from the instruments,
— the encoder for the count rates,
— the logic for determining the maximum channel and selecting the measurement channels
— two magnetic core memory with a capacity of 4096 bits each.

The measurement data of EDF are read synchronous spin in one of the store, while the other time-synchronous emits the data previously stored on the telemetry. The memory switches after the slower of these processes, and a new cycle begins. If this memory readout time more than twice or four times as short as the read-in time, an EDF is read twice or four times. This is possible only with high bit rates and operation of E1 in the NDM. In the reverse case, so at low bit rates, the switching moves so long until the current meter reading is finished. The time distance of two spectra can be between 40.5 seconds and 43 minutes 12 seconds.

The data system is redundant in its main parts. In case of emergency can be toggled via command on the intact part.

(5) The engineering data system to collect the most important data about the technical condition of the instruments (input currents, high voltages, command State, temperatures). The probe transmits these data in the context of the engineering format (FM4). In the Control Panel on the screen can be monitored in real time.

(6) With a command, an automatic test cycle can be used, which is controlled by the electronics box. Instead of the data of two measurement cycles, test data to the control appears, about plate voltages, Channeltron amplifications, zero count rates, and the digital electronics.

TAB. III gives some technical data of the E1-instruments.

TAB.III: **TECHNICAL DATA OF THE E1-INSTRUMENTS**

		I1a/I1b	I2	I3	Electronics	Total
Weight (kg)		2.808	1.631	3.948	4.501	12.888
Electrical Power (W)	I1a at	2.17	0.56	—	6.60	9.33
	I3 at	0.78	0.56	5.6	7.92	14.86
Temperature range (°C)		- 20 + 40	- 20 + 45	- 20 + 40	- 20 + 50	

7. TO THE DEVELOPMENT OF THE EXPERIMENT

The measurement methods have been refined continually since the first measurements of the solar wind by LUNA and MARINER probes out (from 1960). Significant improvements of the resolution brought the first around 1965 at the VELA and IMP satellites, as well as the PIONEER probes used half and quarter sphere analyzers. In the experiment S-210 of the ESRO satellite HEOS-2, which was developed at MPE in Garching, then came in 1972 for the first time in solar wind measurements the use of nine channeltrons detectors behind a quarter sphere analyser, and enter the first three-dimensional measurements with sufficient resolution and sensitivity. This instrument resembled in all essential features of the HELIOS-E1-instruments I1a/I1B.

The plasma experiment for HELIOS was since 1968 designed in the Institute. In the course of development, the functioning of various electrostatic and dynamic analyzer systems was investigated as well as the long term behaviour of channeltrons and other technological issues.

Special importance was attached to the exact calibration of instruments. All electrostatic or dynamic analyzers have an instrument characteristic where the permeability in a fairly complicated way simultaneously depends on the energy and the angle of incidence of the particles. Also, inaccuracies in the analyzer cups production play a major role. Therefore, its own calibration facility was built. Here the instruments with their entrance funnels are pivotally flanged to a vacuum system and fired at with particles from a specially developed ion or Electron source. The count rates measured according to particle energy and direction of incidence deliver reference data necessary for the determination of the solar wind parameters. An example of such a calibration measurement is shown in Figure 5.

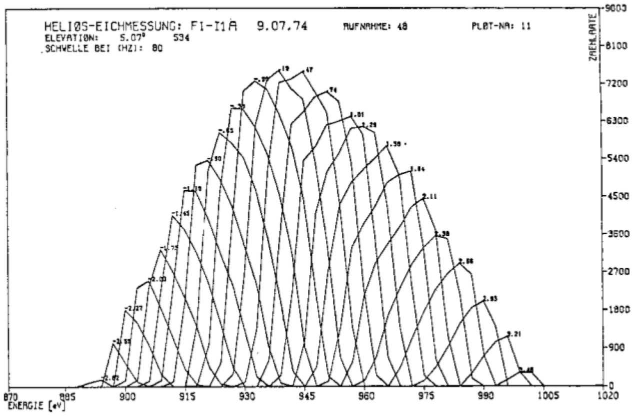


Figure 5: **Example of a calibration measurement of instrument I1a.**

The count rate generated by a ion beam as a function of the particle energy with the azimuthal angle as a parameter is applied.

An industrial company was tasked with the construction of the airworthy devices. From the wide variety of technical problems that were going to solve only some are mentioned:

- Manufacturing spherical Analyzer shells made of aluminium with tolerances under 0.02 mm.
- Flux free soldering by channeltrons on ceramic plates. Protection against the vibration load without application of organic materials.
- Manufacturing of vacuum-airtight sensor housing in lightweight construction.
- Generation of controlled AC voltage at 16 different frequencies up to 4 MHz with high efficiency and small distortion.
- Light attenuation in the UV range by a factor of 10^{10}.
- Control of the heat budget of I2, due to the large inlet.

8. THE FLIGHT BEHAVIOUR OF THE EXPERIMENT

Two days after lauch the instruments were switched on via commands and fully tested.

All instruments worked completely trouble-free and provided correct data in all measurement programs. Figure 6 shows the data of the integration counter by I1a as an example in the form of count rates as a function of the value of E/q. You can see well the proton distribution and – clearly dropped out in this case - the distribution of α-particles, whose maximum is approximately at double the E/q value. At the same time with the switching on of the motor for the corresponding despun antenna strong fluctuations of the zero appeared in the data of I1b. Apparently, the highly sensitive electrometer was disrupted by the structure-borne sound emitted by the antenna bearing of I1b. This effect did not occur during ground testing; probably the bearings due to gravity were different there. The disorder, which affects as a reduction in sensitivity, decreased strongly, but not completely after a few days.

As then the high-gain antenna was - connected first with a moderate, then with high power - unusually high count rates occurred in most measurement channels of the electron instrument, which these measurements have been useless. At the same time also the wave experiments (E5) observed increases their noise levels to several orders of magnitude.

The cause for this disorder was at first totally unclear. Finally, special tests have been undertaken with the antenna of the prototype. They showed that in the narrow slits of the high gain antenna a resonant secondary electron effect can arise ("Multipacting"), as well as the electrons produces electromagnetic interference. Only the cooperative attitude of the other experimenters, the Max Planck Institute for radio astronomy (Effelsberg mirror), the NASA deep space network and also the engineers at the control centre in Oberpfaffenhofen, made it possible that at least temporarily acceptable electron measurements were possible by switching on the medium-gain antenna of HELIOS.

For E1, the perihelion passage brought no problems. Already the provisional evaluation of real time data reveals that the data obtained in this key phase of the HELIOS-Mission will lead to interesting results.

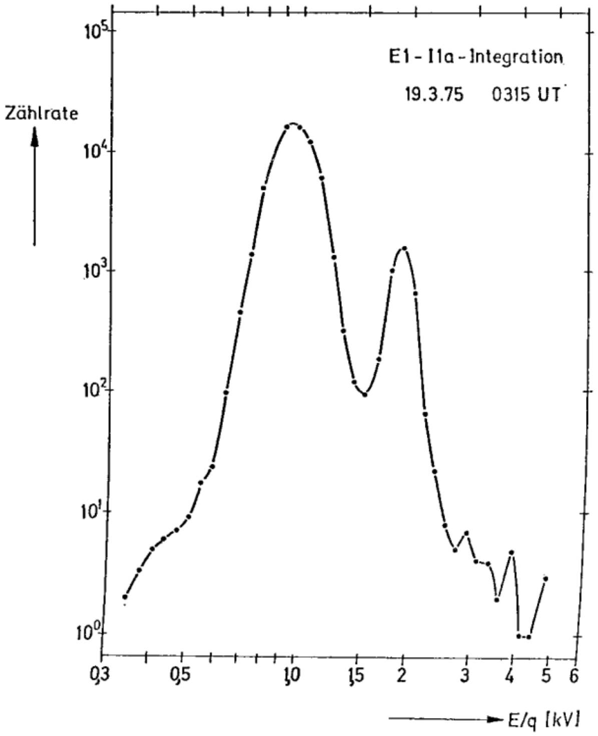


FIG. 6. A spectrum of positive ions measured by the instrument I1a (integrated over all angles of incidence).

Concluding remarks

The plasma experiment was promoted within the HELIOS project on behalf of the Federal Ministry for research and technology by the society for space research at the DFVLR. Services was the company Messerschmitt-Bölkow-Blohm GmbH for the development and production of the experiment. Crucial contributions came also the subcontractor company microelectronic A. Lewicki (Channeltron assembly, thick-film technology), the company Carl Zeiss AG (Analyzer cups) and Dornier System GmbH (production of core memory).
Thanks at this point all institutions, companies, and particularly the staff in different places, which helped the plasma experiment by use of large, sometimes very personal success.

The Förster probe-magnetic field experiment (E2)

Günter MUSMANN, Fritz M. NEUBAUER, Arnold MAIER, Ernst LAMMERS,
Institute for Geophysics and meteorology of the Technical University of Braunschweig

The Förster probe experiment E2 is a three component-vector magnetometer. Its purpose is to continuously observe the interplanetary magnetic field in a frequency range up to 4 Hz. Thereby certain phenomena are to be analysed as a function of the distance from the sun e.g. the spiral structure and discontinuities. The measurement ranges are ± 100 nT and ± 400 nT. The resolution is ± 0.2 nT and ± 0.8 nT respectively.
For accurate measurements of the zero offset of each sensor the component parallel to the spinaxis can be flipped by 90°. Depending on telemetry format and bitrate the digital data are fed into a time average computer or directly connected to telemetry. A shock identification-computer triggers the S/C core memory in case of discontinuities with variations of the ambient magnetic field magnitude.

The Förster probe experiment E2 is a three-axle vector magnetometer. It is used for the continuous observation of the interplanetary magnetic field in a frequency range from 0 to 4 Hz. This will be investigated phenomena such as the spiral structure and discontinuities as a function of the distance from the Sun. The measuring ranges are ± 100 nT and ± 400 nT with a resolution of ± 0.2 nT or ± 0.8 nT. The component that is parallel to the axis of the spin, to perform precise zero point provisions of each sensor is rotated 90 degrees. Depending on format and bit rate digital data pass through an average computer or directly to the telemetry. A shock wave identification computer triggers the S/C core memory in the presence of discontinuities with magnetic field variations.

1. THE SCIENTIFIC OBJECTIVE

The movement of charged particles in the interplanetary medium is determined apart from the generally small influence of the joints by magnetic and electric fields. This is true both for the relatively low-energy particles of the solar wind (proton energy ~ 1 keV, electron energy up to some 10 eV) as well as for the high-energy particles of solar or Galactic origin. For the latter the magnetic field is dominant, although the electric fields are not quite negligible. On the other hand, plasma currents in the solar wind work back again on the magnetic field. Temporal changes of the magnetic field, as well as charge separation to determine the electric field. For not too rapid variations in time and space electric fields $\underline{\mathbf{E}}$ and magnetic fields $\underline{\mathbf{B}}$ by the principle of the frozen fields are connected

$$\underline{\mathbf{E}} + \underline{\mathbf{v}} \times \underline{\mathbf{B}}$$

where $\underline{\mathbf{v}}$ is the bulk speed of the plasma. As a result, that the knowledge of the magnetic field vector is essential to the exact understanding of the plasma measurements of the solar wind, as well as the measurement of high-energy particles. On the other hand, the magnetic field gives important information about the plasma itself. Such magnetic field measurements are by the Förster probe magnetometer experiment E2 the TU Braunschweig delivered for frequencies up to 4 Hz, i.e. about the scope of the concept of the frozen field boundaries. In Earth, the frequency range is about up to the lower hybrid frequency, since the per Proton cyclotron frequency here in the Middle at about 0.1 Hz is located.

The effluent from the sun, solar wind is always connected by a rotating with the solar system from plasma flows at high speed, which is subject of solar rotation to solar rotation, depending on the level of activity more or less strong variations.These currents have a distinctive structure in the interplanetary magnetic field over the frozen fields theorem. This magnetic field is usually awarded for such current rise and waste by a certain polarity of the interplanetary magnetic field. One or more current ranges form a magnetic sector that through a Sun away facing or to the Sun observations near Earth