# 'COSTEP' – COMPREHENSIVE SUPRATHERMAL AND ENERGETIC PARTICLE ANALYSER FOR SOHO

**Horst Kunow**, Harald Fischer, Günter Green, Reinhold Müller-Mellin, Gerd Wibberenz;[1]
Hartmut Holweger;[2] Paul Evenson;[3] Jean-Paul Meyer;[4] Nabuyuki Hasebe;[5]
Tycho von Rosenvinge, Donald Reames;[6] Jose Medina;[7] Manfred Witte;[8]
Masaru Matsoka;[9] R. G. Marsden, Trevor R. Sanderson, K. P. Wenzel;[10]
Susan McKenna-Lawlor;[11] Juan Sequeiros;[12] Tadayoshi Doke, Jun Kikuchi;[13]

[1] *Institut für Reine und Angewandte Kernphysik, Universität Kiel, FRG*
[2] *Institut für Theoretische Physik und Sternwarte, Universität Kiel, FRG*
[3] *University of Delaware Bartol Research Institute, USA*
[4] *CEN Saclay, Institute de Recherche Fondamentale, FRANCE;* [5] *Ehime University, JAPAN*
[6] *Goddard Space Flight Center, USA;* [7] *Instituto Nacional de Técnica Aerospacial, SPAIN*
[8] *Max Planck Institut für Aeronomie, FRG;* [9] *RIKEN, JAPAN*
[10] *Space Science Department, ESA, NETHERLANDS;* [11] *St. Patrick's College, IRELAND*
[12] *Universidad de Alcalá de Henares, SPAIN;* [13] *Waseda University, JAPAN*

## ABSTRACT

The COSTEP group of instruments for the SOHO mission is in turn a subset of the larger CEPAC collaboration. CEPAC has been designed to use particle emissions from the sun over a wide range of species (electrons through iron) and energies (60 keV/particle to 500 MeV/nucleon) as tools to provide for quantum leaps in our knowledge of a number of key physical processes and problems of interest to solar and space plasma physics. Three sensors furnished by the COSTEP consortium, LION, MEICA, and EPHIN, cover unique regions of the overall parameter space investigated by CEPAC.

Keywords: Solar energetic particle; solar flare; solar coronal composition; space plasma physics; suprathermal ions; suprathermal electrons; interplanetary medium.

## 1. INTRODUCTION

Dedicated to the Sun, our nearest star, the SOHO mission provides an unparalleled opportunity to study critical problems in solar physics as well as fundamental problems in space plasma and astrophysics. A broad range of basic processes and particular features of the solar atmosphere and its interaction with the interplanetary medium will be probed by the CEPAC instrument package. The CEPAC collaboration includes the ERNE consortium led by Principal Investigator Jarmo Torsti and the COSTEP consortium led by Horst Kunow. Contributions of the ERNE consortium (two sensors, LED and HED, common low voltage power converter, and common ground support equipment) are discussed in a separate paper.

In the present paper we discuss the design of the COSTEP portion of the collaboration which specifically but not exclusively addresses the following scientific topics:

- Steady state processes in the solar atmosphere.
- Energy release and particle acceleration in the solar atmosphere.
- Samples of solar atmospheric material.
- Processes in the interplanetary medium.

During the past few years it has become possible, for the first time, to distinguish a rich variety of solar phenomena by observing the energetic particles that they emit. Impulsive flares, coronal mass ejections (CME's), disappearing filament events, and interplanetary shock waves each have as distinctive a signature in the timing, composition, and spectra of the accelerated particles as they do in the radio, optical, X-ray and gamma-ray photons that they produce. The COSTEP sensors, LION, MEICA, and EPHIN, will allow a systematic investigation of these topics by measuring energetic particles over a wide range of energies and particle species. This information, combined with simultaneous observations from other experiments in the SOHO payload and with ground based observations, will enable a major advance in the scientific understanding of these phenomena.

## 2. SCIENTIFIC OBJECTIVES

It is at first surprising that suprathermal and energetic particle emissions, which are generally associated with explosive phenomena, also carry vital information about the quiet solar atmosphere. There are two primary reasons for this. First, continuous emissions of suprathermal electrons (and possibly ions) are associated with processes which operate in the "quiet" corona. Second, samples of the solar atmosphere accelerated in flares have ionization state temperatures typical of the ambient corona, not the much hotter flare site, and therefore carry information about the ambient coronal composition. Not only do such composition measurements yield information about coronal regions removed from the solar wind acceleration site, but they also give more complete information about the coronal composition because the measurement technology is highly developed. Suprathermal and energetic particle observations continue to make new and unique contributions towards identification of the mechanisms for heating the corona, acceleration of the solar wind, and transport of matter between the corona and the underlying photosphere.

In Figure 1 we present an overview of the spectra of energetic particles in interplanetary space at the time of solar minimum. At least four distinct solar acceleration processes have been suggested:

- Short time scale (impulsive) acceleration related to the flash phase of flares, e.g from reconnection electric fields.
- Second order Fermi (stochastic) acceleration in turbulent regions generated by a flare.
- Low coronal shock acceleration immediately after the impulsive phase, sometimes operating in closed magnetic loops.

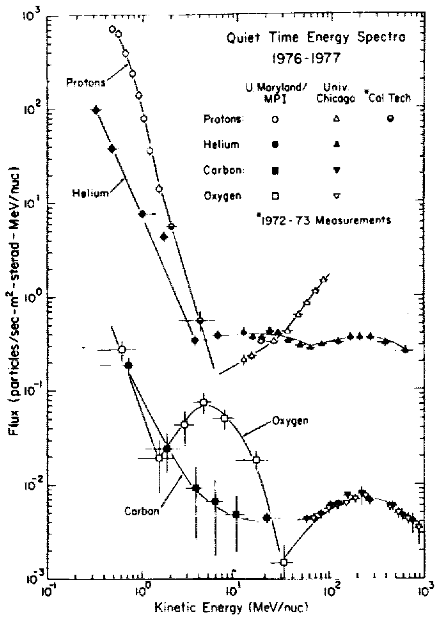


**Figure 1:** *Quiet time energy spectra for H, He, C and O during the last solar minimum. Note low energy "turn up" spectrum below a few MeV/nucleon, and anomalous oxygen spectrum peak near 5 MeV/nucleon (Ref. 1).*

- High coronal shocks associated with the largest flare events and with CME's.

These different processes operate in different coronal sites, and energize different particle populations with the result that distinct suprathermal and energetic particle signatures are created. Impulsive particle energization is most likely due to fast magnetic field reconnection; thus an understanding of this process is central to unraveling the role of field line merging in the corona and at other sites. Particle acceleration by shock waves is important not only because of the central role this process plays in particle acceleration but also because in the case of coronal shocks, much of the shock energy eventually converts to thermal energy and thus may be a significant contributor to coronal heating.

A turnup in the quiet time ion spectrum below a few MeV per nucleon (Figure 1) has long been noted. The source of these low energy ions is not known, but it has frequently been argued that they have a solar origin. Recently the possibility has been investigated that the low energy quiet time ions are accelerated by standing slow mode shocks which have been predicted to exist in coronal holes near the Sun. This interesting hypothesis suggests a possibly important dynamical role for these energetic ions in the solar wind acceleration region.

Identification of different acceleration processes requires use of the full range of electromagnetic signatures including radio, optical, UV, X-ray and gamma-ray, along with particle information from suprathermal through the energetic particle range. In the past, only a subset of these diagnostics was available at any one time, making it difficult to synthesize a coherent picture. With SOHO we have for the first time the exciting opportunity to routinely observe particle events using many of these information channels simultaneously, giving the prospect for rapid gains in our still incomplete understanding of dynamical processes occurring in the solar atmosphere.

Impulsive solar particle events are associated with short duration X-ray events (<1 hour) which originate in compact regions low in the corona. During solar maximum conditions, these events occur about once per day, and generally produce relatively small fluxes of energetic particles and low maximum particle energies. The events are thought to begin with the release of energy via magnetic field annihilation over an active region, which impulsively energizes solar coronal electrons to 10-100 keV. SEP events associated with long duration (>1 hour) soft X-ray emission generally exhibit large fluxes of relativistic electrons, energetic protons, helium, and heavy nuclei observed in interplanetary space. They are observed roughly once per month at 1 AU during solar maximum. These events may begin with acceleration of electrons as in the impulsive events, whose subsequent interactions with the solar atmosphere via, for example, explosive joule heating, produce other phenomena associated with the flare including H$\alpha$ brightening. The explosively heated solar atmosphere produces a shock wave which propagates upward through the corona generating Type II radio bursts. Intimately associated with these processes is the expulsion of material in a Coronal Mass Ejection (CME).

Another type of particle event has its origin in relatively weak solar events. The solar signature is the eruption of a filament with some associated brightenings in H$\alpha$ but not enough to call the event a "flare". The filament eruptions occur outside active regions and have no radio or hard X-ray bursts. It is clear that strong impulsive phenomena are not essential to the production of energetic protons. The important connection between these events and long duration flare events is the presence of a CME.

By measuring electron, proton and heavy ion spectra over a broad energy range with high sensitivity, the COSTEP instruments will probe the particle signatures in these events with great precision. Distinct heavy ion abundance pattern in individual flare events observed by the COSTEP instruments can be compared with measurements of the elemental composition of the solar wind originating from the same coronal regions. Such correlative studies have not been possible before since high resolution solar wind composition instruments have not been flown together as they will be on SOHO. The correlations between energetic particles and solar wind data can give insights into the SEP and solar wind source regions.

Solar particle events carry a sample of the solar atmosphere into interplanetary space where direct measurements by advanced instruments can obtain unique information about the solar atmospheric composition and physical processes operating in the corona. Energetic particle observations in many instances offer the best method for accurately determining the solar elemental and isotopic composition, thereby greatly strengthening our knowledge of the solar system composition which is now based primarily on measurements of terrestrial and meteoritic abundances. Knowledge of solar system abundances forms the benchmark not only for comparison with optical and UV solar observations, such as will be made on SOHO, but also for studies of lunar and planetary composition, stellar objects, and stellar nucleosynthesis. Refinement of our knowledge of the solar atmospheric composition may help to put present estimates of the solar interior $^4$He abundance on a firmer ground, thereby critically aiding the interpretation of helioseismology observations to be carried out on SOHO.

By measuring relative abundances of solar energetic particles (SEP) it is possible to determine the average coronal abundances at the acceleration sites. Relative abundances of more than a dozen elements heavier than H are now known. Comparing these abundances with solar photospheric abundances reveals a deviation dependent on first ionization potential (FIP) shown in Figure 2. Ions with FIP $\leq$ 10 eV appear to be transported into the corona with three or four times the efficiency of higher FIP elements. These SEP observations establish the existence of a difference between photospheric and coronal composition, and thus confirm the operation of a neutral atom separation process operating in the transport of heavy ion material into the corona. By measuring SEP abundances with higher accuracy than previous instruments, and by adding many new elements to the group of known SEP abundances, COSTEP will permit a more com-

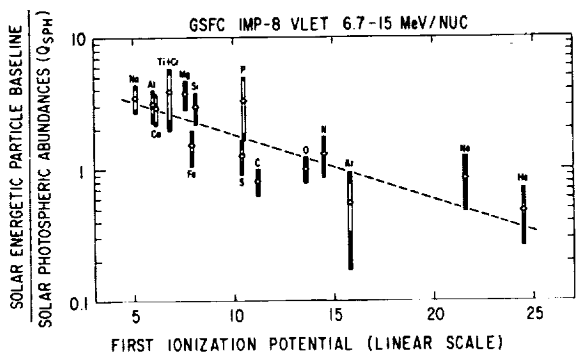


**Figure 2:** *Solar energetic particle abundances normalized to photospheric abundances plotted as a function of FIP. Dashed lines are least squares fits to the points (Ref. 2).*

plete description of this effect, and will help constrain models for heavy ion transport processes into the lower corona.

Measuring the isotopic composition of SEP offers the best hope for obtaining the isotopic composition of the solar atmosphere, since this information cannot be obtained by spectroscopic observations. Fractionation effects, which depend primarily on atomic properties, should be relatively unimportant in the determination of isotope ratios of most elements accelerated in large flares. A knowledge of the isotopic composition of the solar atmosphere, such as will be obtained by the COSTEP instruments, will give key insights into the origin and evolution of the solar system, and into the problem of determining local interstellar medium and local galactic abundances.

Solar particle events rich in $^3$He present a striking example of an enrichment mechanism operating in the corona. These small particle events often have $^3$He/$^4$He ratios of nearly unity, about one to ten thousand times the relative abundance observed in the photosphere or in the solar wind. Originally considered rare since they were being observed only by instruments with relatively high energy thresholds, recent studies with lower threshold instrumentation have shown that they occur more often than once a month, and are associated with impulsive kilovolt electron events (Figure 3), and therefore also with Type III radio bursts. Kilovolt electron events are observed with a frequency of $>1$/day. The COSTEP instruments, with low energy thresholds and increased sensitivity, may detect $^3$He rich events with a similar frequency.

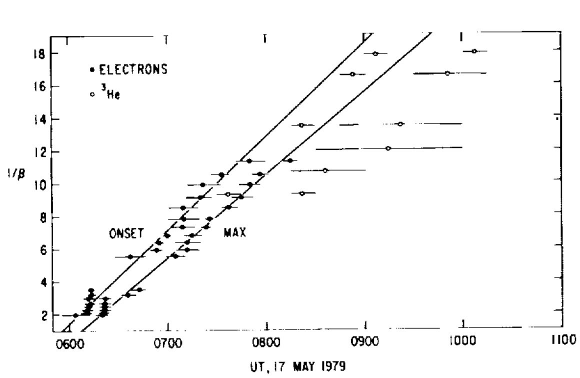


**Figure 3:** *Times of onset, and times of peak flux for electrons and $^3$He plotted vs. $1/\beta$, where $\beta c$ is the particle velocity (Ref. 3).*

The association of these small particle events with kilovolt electrons and Type III bursts has made it possible to often identify the sources, which are typically active regions in the western hemisphere. Most of the keV electron events are not associated with a reported H$\alpha$ flare. The electron spectrum typically extends down to $\approx$2 keV without any obvious bending over, indicating that the source of the electrons is probably high in the corona. By probing associations between $^3$He rich ion events and impulsive electron events for much smaller events using the high sensitivity of COSTEP sensors, it will be possible to explore the extent to which these ion events routinely occur in the corona.

Acceleration of energetic particles continues in the interplanetary medium, most often associated with shocks and other disturbances. Traveling shocks in the interplanetary medium are produced by various types of solar activity including large flares and CME's. Corotating Interaction Regions (CIR) are typically observed for several years around solar minimum when the polar coronal holes expand to the equator, and fast solar wind streams from those coronal holes persist without much evolution for several solar rotations. CIRs are formed when fast solar wind overtakes the slower wind ahead of it forming a compression region of high magnetic field strength and plasma density. The interaction usually steepens to form a shock beyond 1 AU. In some cases two shocks are formed, a forward shock at the leading edge of the CIR and a reverse shock at the trailing edge. If the fast stream is relatively stable, the CIR structure appears to corotate with the Sun.

Measurement with excellent time resolution of suprathermal electrons and ions associated with shocks will permit detailed investigation of the shock structure. Continuous COSTEP energy coverage above 60 keV for electrons and 1.5 MeV for ions will permit the construction of energy spectra from the energetic particle range to facilitate "seed population" identification.

The detailed structure of the interplanetary magnetic field (IMF) is still poorly known. Time intensity and time anisotropy profiles of particles released during solar flares contain information on the interplanetary medium between the Sun and the Earth as well as on the acceleration and release process of the Sun. Energetic charged particles can be used as probes to study both large and small scale properties of the IMF. Spectral and abundance data provided by COSTEP sensors on nuclei above 10 MeV/n and on electrons above 1 MeV will be used for this purpose. Especially interesting topics are the dependence of the scattering mean free path on particle type and energy, the energy dependence of the pitch angle scattering, and the characteristic size of the magnetic irregularities.

The anomalous cosmic ray component consists primarily of He, N, O, and Ne in the energy range of a few to a few tens of MeV/n (Figure 1). These particles are thought to originate when interstellar neutral gas species having high first ionization potentials penetrate deep into the heliosphere before becoming ionized. The ions then can be carried back to the outer heliosphere by the solar wind where acceleration may occur at the heliospheric termination shock. Subsequent preferential propagation back into the inner solar system is facilitated by the high magnetic rigidity of the singly ionized anomalous component compared to that of the totally stripped galactic cosmic rays. Many features of this scenario are not yet firmly established, and alternative explanations are possible. the COSTEP instruments will make excellent elemental and isotopic measurements over the entire anomalous component energy range for the first time.

Jovian electrons dominate the quiet time electron spectrum in the 1-25 MeV range at 1 AU. The intensity of Jovian electrons near Earth varies with a 13 month periodicity with highest intensities occurring when Earth and Jupiter are best connected by the interplanetary magnetic field. Jovian electrons provide a unique probe of the interplanetary medium since they originate from a localized source region which is well separated from the origin of the interplanetary magnetic field lines. As their energy spectrum is not a power law, Jovian electron observations allow a quantitative determination of the amount of adiabatic deceleration in the solar wind. COSTEP instruments will measure Jovian electrons with unprecedented sensitivity.

Baseline measurements of low energy cosmic rays, solar energetic particles, and Jovian electrons in the ecliptic plane at 1 AU are necessary for the proper determination of radial and latitudinal intensity gradients to the deep space probes which are operating during the period of the SOHO mission. Excellent coverage of a wide range of species and energies makes COSTEP ideal for this task.

## 3. INSTRUMENT DESCRIPTION

The scope of the proposed CEPAC investigation is such that its overall objectives can only be accomplished using an instrument complement that covers a wide range in species and energy. The CEPAC package comprises five separate detector systems, each optimized to address a specific subject on the overall objectives, while at the same time possessing a sufficient degree of overlap within the complement to provide adequate redundancy. The measurement ranges of the complete CEPAC package are illustrated in Figure 4.

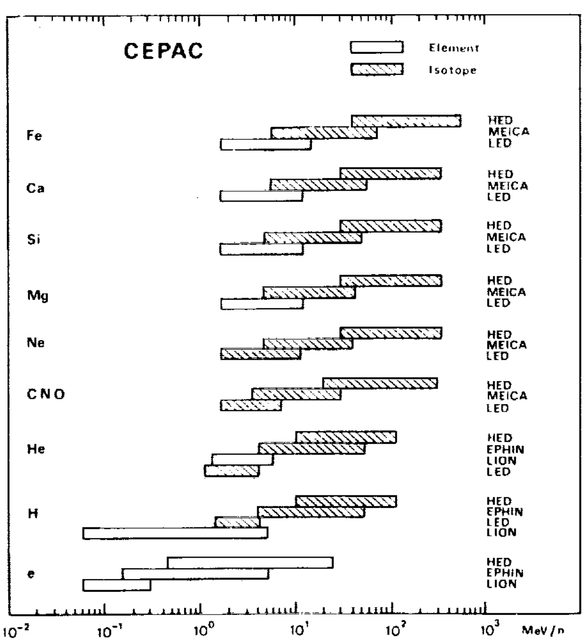


**Figure 4:** *Energy ranges for various particles covered by the CEPAC collection of sensors.*

Three detector systems, the Low Energy Detector (LED), the Medium Energy Ion Composition Analyzer (MEICA), and the High Energy Detector (HED), will measure heavy ion elemental and isotopic composition over the energy range 1.4 MeV/n - 540 MeV/n. In addition, the Electron Proton Helium Instrument (EPHIN) will measure helium isotopes in the range 4 - 53 MeV/n. Spectra of low energy ions (mainly protons) will be returned by the Low Energy Ion and Electron Instrument (LION), starting at 60 keV. Electron measurements will be performed by a combination of three sensors: LION (starting at 60 keV), EPHIN (between 150 keV and >5 MeV), and HED (extending the range up to 25 MeV).

All five instruments will be interfaced to a Central Data Processing Unit (CDPU). Power will be supplied by a common Low Voltage Power Converter (LVPC). All CEPAC sensors will view along the average interplanetary magnetic field direction (-45° in the X Y plane of the SOHO spacecraft coordinate system) in order to provide the maximum collecting power for charged particle instruments mounted on a sun pointing, 3-axis stabilized spacecraft. The COSTEP consortium will provide LION, MEICA, EPHIN, and the CDPU, all of which are discussed in more detail below.

## 4. LION
## LOW ENERGY IONS AND ELECTRONS

The Low Energy Ion and Electron Instrument, has two sensor heads each containing a double telescope to measure energy spectra of ions and electrons in the range 60 keV to 5 MeV for protons and 60 keV to 300 keV for electrons.

The basic LION detector system consists of three ion implanted silicon detectors arranged in a unique "2 in 1" telescope configuration (Figure 5). Square ($12 \times 12$ $mm^2$) detectors A1 and A2 form the dual front elements, separated from the rectangular rear element B ($19 \times 34$ $mm^2$) by 0.3 mm. Detector B is operated in anticoincidence to reduce background from penetrating particles. Both A1 and A2 view the same circular entrance aperture, providing a total field of view of 60° x 40° and a total geometry factor of 0.32 $cm^2$ sr. Each A detector, in combination with the common B detector, thus forms a distinct particle telescope, providing extended angular coverage with a minimum weight penalty. The first LION sensor head employs a "broom magnet" utilizing rare earth NdFeB material to sweep electrons of energies up to ≈ 300 keV away from both A detectors. In order to eliminate stray magnetic fields, the magnet has a closed soft iron yoke. Higher energy electrons will penetrate the A detectors and trigger the B detector enabling separation from higher energy ions. The second LION sensor, identical except that no broom magnet is included, measures the sum of electrons and protons enabling determination by subtraction of electron rates in the energy range 60 keV to at least 300 keV.

Output signals from each sensor head are processed to provide a number of proton and electron differential energy channels covering the energy range 60 keV to 5 MeV plus one channel for Z > 1 particles (mainly alphas in the range 6 to 24 MeV). Nominal sampling times are 4 s for the four lowest energy channels and 16 s for the remainder.

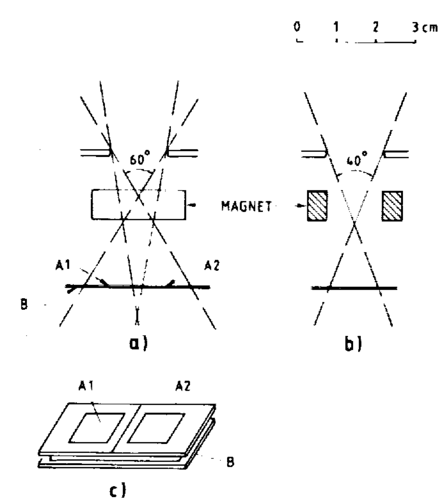


**Figure 5:** *(a) Schematic of one LION sensor, showing "2 in 1" telescope configuration and deflection magnet. Other sensor is identical except that magnet is omitted. (b) As above, seen rotated through 90.° (c) Detail of LION detector stack.*

The LION analog processing electronics consists of two identical sensor interfaces and a section which performs common functions. The part common to both sensors contains an flight test generator to generate test pulses for periodic check of analog signal processing chains. Also provided is a telecommand decoder/buffer to receive and store commands controlling instrument status, an analog housekeeping monitor to select and convert monitored parameters into digital data, and a detector bias voltage supply.

Both LION sensor heads and their associated electronics are packed in one housing having envelope dimensions 18.2 × 15.0 × 13.3 $cm^3$. Baffles protect the sensor apertures from direct illumination and stray light. Entrance apertures point in the direction of the nominal interplanetary magnetic field at 1 AU, 45° ahead of the spacecraft sun line. The instrument has a total power requirement of 1.9 W, a mass of 2.6 kg, and requires a telemetry rate of 40 bits per second.

## 5. MEICA
## MEDIUM ENERGY ION COMPOSITION ANALYZER

The Medium Energy Ion Composition Analyzer (MEICA) measures the chemical and isotopic composition of energetic particles for heavy elements from C (energy range 3.6 – 30 MeV/n) to Ni (energy range 5.5 – 70 MeV/n). An exceptionally large geometry factor, 5 $cm^2$ sr, will permit measurements of rare isotopes in corotating events and of the anomalous quiet time components as well as solar flare events.

The MEICA sensor, illustrated in Figure 6, is an all solid state detector telescope utilizing the energy loss - total energy (dE/dx vs. E) method. It consists of seven layers of detectors, of which the top two are arrays of newly developed position sensitive detectors (PSD's). In addition to making an independent measurement of energy loss, each PSD provides two dimensional position information using charge division. Charge is collected separately from all four corners of each square, ion implanted, resistive surface. Error in the calculated position is greatly reduced by a new approach in which the four corners have been connected by additional implanted line resistance. The resultant precision is 2 percent of the detector edge length. Knowledge of the trajectory of each particle ensures an accurate determination of the path length in each layer.

The top layer (PSD1) consists of a mosaic of four PSD's each 0.03 × 15 × 15 $mm^3$ (one silicon wafer is actually divided into four sensitive regions). The second layer (PSD2) is a single PSD 0.1 × 35 × 35 $mm^3$ at a distance of 35 mm from PSD1. Detectors D1-D4 measure energy losses. Of graded thickness to minimize Landau fluctuations, they have dimensions 0.1 × 40 × 40 $mm^3$, 0.2 × 50 × 50 $mm^3$, 0.4 × 50 × 50 $mm^3$, and 0.8 × 60 × 60 $mm^3$, respectively. D5 is an anticoincidence detector 0.8 × 60 × 60 $mm^3$ which rejects particles penetrating the detector stack. D1, D2, and D3 are surface barrier detectors; D4 and D5 are lithium drifted types. Mass resolution is expected to be 0.23 amu for the isotopes of Ni, and even better for lighter elements.

The electronics for MEICA have been designed to minimize circuitry. Due to ballistic deficit effects associated with the RC time constant of the resistive layers, it is necessary to take a signal from the back side of each of the PSD's, in addition to the four signals discussed above, in order to get a good measure of the energy loss. The total number of preamplifier – shaping amplifier signal chains is 27, with eleven full pulse height analysis chains. For pulse height analysis, CMOS chips holding 14-bit successive approximation types with conversion times of 40 μs, are interfaced to a microprocessor system, as are 24 bit CMOS counters to accumulate the counting rates of various coincidence conditions. The microprocessor system in turn interfaces to the CDPU. Charge sensitive amplifiers are hybridized, four per hybrid package. The highest bias voltage required is less than 220 volts.

The MEICA sensor and electronics will be packaged in one housing with dimensions 30 × 21.6 × 12 $cm^3$. The aperture, with its

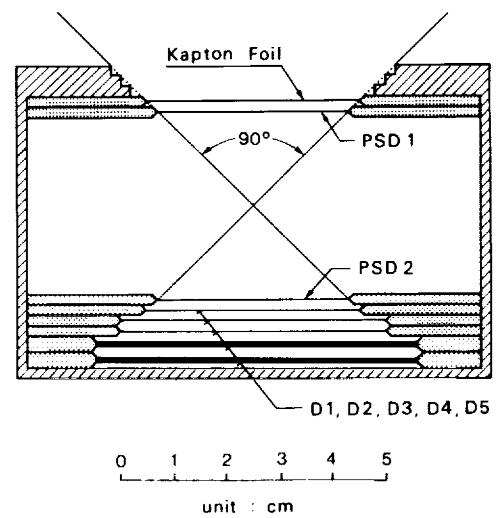


**Figure 6:** *Schematic drawing of the MEICA sensor*

90° × 90° field of view, points in the direction of the interplanetary magnetic field at 1 AU, 45° ahead of the spacecraft sun line. A Kapton foil protects the front detectors from direct illumination by the sun. The instrument has a total power requirement of 5.1 W, a mass of 4.8 kg, and requires a telemetry rate of 200 bits per second.

## 6. EPHIN
## ELECTRON PROTON HELIUM INSTRUMENT

The Electron Proton Helium Instrument (EPHIN) is a sophisticated, state of the art, multi-element array of solid state detectors with a plastic scintillator guard counter to measure energy spectra of electrons in the range 150 keV to > 5 MeV and hydrogen and helium isotopes in the range 4 MeV/n to > 53 MeV/n. Special design efforts are directed towards achieving a large geometric factor (6.1 $cm^2$ sr), clean separation of electrons and protons by measuring the full signature of an incident particle in the detector stack with at least twofold coincidence, and resolution of hydrogen and helium isotopes using coarse position sensing. The instrument will perform successfully when particle fluxes are low (e.g. during quiet interplanetary conditions, shock events, and small solar flares), and by virtue of a self-adaptive geometric factor, during large solar flare events as well.

At the heart of the EPHIN sensor head is a stack of five silicon detectors, surrounded by an anticoincidence shield consisting of a plastic scintillator and a sixth silicon detector to distinguish between absorption and penetration mode. The detector arrangement is shown schematically in Figure 7. Two passivated ion implanted detectors (A and B) define the 90° field of view. Detectors A and B are divided into sectors via the new technology of ion implantation using lithographic masks. This coarse position sensing permits sufficient correction for path length variations (resulting from the large field of view) needed to resolve isotopes of hydrogen and helium. Another important advantage of sectorization is the capability to implement a commandable or self adaptive geometry factor. On detection of sufficiently high coincidence rates between detectors A and B the logic will disable all but the inner circular elements of both detectors reducing the effective size of the detector by a factor of 24 to permit measurement of fluxes as high as $10^6/(cm^2 \text{ s sr})$ without dead time losses.

Lithium drifted silicon detectors C, D, and E stop electrons up to 5 MeV and hydrogen and helium nuclei up to 53 MeV/n. These large area detectors have thickness variations over their surface of less than 10 μm and diffused lithium contact dead layers of less than 50 μm silicon equivalent. Ion implanted detector F

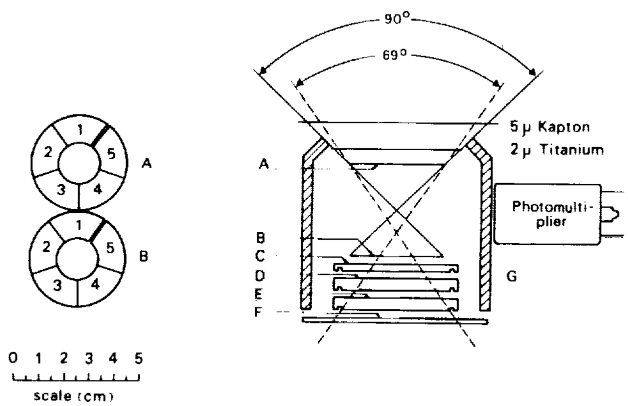


**Figure 7:** *Schematic view of the EPHIN sensor. Detail of segmented detectors A and B is shown at left.*

will allow particles stopping in the telescope to be distinguished from penetrating particles. Fast plastic scintillation detector G, viewed by a 1 inch photomultiplier and used in anticoincidence, is indispensable for accurate electron measurements.

Signals from each detector are independently amplified and fed to several window type discriminators for counting rate information as well as to a pulse height analysis system for particle identification and detailed spectral information. EPHIN readout electronics are based on low noise, low power, hybrid modules developed and qualified for operation in space. These include charge sensitive preamplifiers, pulse amplifiers, shapers, discriminators, counters, and all modules necessary for a pulse height analyzer system. Rates and pulseheight data both are passed to a microprocessor before transmission to the CDPU. Rates are compressed logarithmically and a priority system for the PHA data assures that an adequate sampling with good statistics is obtained for electrons, protons, and helium nuclei that stop in the telescope.

An inflight test pulse generator will be used to check amplifier gains, discriminator thresholds, PHA linearity, and the performance of the coincidence logic. High voltage will be provided for ion implanted detectors (30 - 90 V), lithium-drifted detectors (400 - 600 V), and the PM tube (900 - 1100 V). A multiplexer will step through analog housekeeping channels to monitor detector reverse current, PM tube voltage and temperature. The telecommand decoder will receive and store the different commands to control the instrument status. Failure mode reconfiguration logic allows recovery from detector failures during flight.

The EPHIN sensor and electronics will be packaged in one housing having envelope dimensions $32 \times 14 \times 18.5$ cm.[3] The telescope aperture is covered by two thin foils, an inner titanium foil 2 $\mu$m thick to ensure light tightness, and an outer aluminized Kapton foil 5 $\mu$m thick for thermal control. The aperture with its 90° circular field of view points in the direction of the nominal interplanetary magnetic field at 1 AU, 45° ahead of the spacecraft sun line. The EPHIN sensor mass is 0.54 kg with a total integrated mass of 1.8 kg. Total power consumption is 1.8 W, and the telemetry required after onboard data compression is 70 bits per second.

## 7. CDPU
## CENTRAL DATA PROCESSING UNIT

The data and command interface between the five CEPAC sensors and the SOHO data system is provided by a central data processing unit (CDPU). The CDPU functions are:

- Collect scientific data periodically or on request from the instruments.
- Collect housekeeping data from the six instruments, the CDPU and the low voltage power converter (LVPC) periodically or on request from a ground station.
- Reduce data redundancy.
- Time tag data.
- Format data for transmission by the spacecraft telemetry system.
- Accept and syntactically check commands from the spacecraft.
- Deliver commands to individual instruments for execution.
- Accept and distribute control tables and software to certain of the instruments.

The CDPU is connected to the spacecraft bus by a standard interface, and by simple serial interfaces to the five instruments. Design, including interfacing, is redundant so that any single failure will not reduce experiment performance. A real time multitasking operating system will permit CDPU software to be written in a higher programming language to facilitate structured programming and modularity.

## 8. ACKNOWLEDGEMENTS

The original COSTEP proposal, in order to cover the energy range from the upper end of solar wind energies to energetic particles, included 3 additional instruments. These instruments were deleted for various reasons and several investigators have decided to leave the collaboration. Nevertheless, much of the input to this paper is based on their scientific judgment and contributions. The authors regret their resignation and gratefully acknowledge the excellent contributions of G. Mason and D. Hamilton from the University of Maryland and R. P. Lin, J. P. McFadden and K. A. Anderson from the University of California, Berkeley. L. O'C Drury, Dublin Institute for Advanced Studies, was involved in early discussions and provided valuable input to the proposal. The effort and personal involvement of many members of the COSTEP team who are not co-investigators are also gratefully acknowledged. The proposal and this paper would not have been possible without their support.

## 9. REFERENCES

1. Mason et al., 1979, Carbon poor solar flare events, *Astrophys. J.*, **231**, L87.
2. McGuire et al., 1986, The composition of solar energetic particles, *Astrophys. J.*, **301**, 938.
3. Reames et al., 1985, Solar $^3$He rich events and nonrelativistic electron events: a new association, *Astrophys. J.*, **292**, 716.