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PROCEEDINGS OF THE
IVth INTERNATIONAL SEMINAR

MANUFACTURING OF SCIENTIFIC SPACE INSTRUMENTATION

USSR, Frunze, September 18–24, 1989

ТРУДЫ
IV МЕЖДУНАРОДНОГО СЕМИНАРА

НАУЧНОЕ КОСМИЧЕСКОЕ ПРИБОРОСТРОЕНИЕ

СССР, Фрунзе, 18–24 сентября 1989

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ПЛЕНАРНЫЕ ЗАСЕДАНИЯ

СССР, Фрунзе, 18–24 сентября 1989

Edited by V.M.Balebanov

Под редакцией В.М.Балебанова

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The IVth International seminar on scientific space instrumentation manufacturing was held in Frunze in September 1989. The Seminar was initiated by the Space Research Institute, USSR Academy of Sciences, and by the INTERCOSMOS Council, USSR Academy of Sciences.

More than 200 specialists from the USSR and other countries (including - for the first time - capitalist countries) participated in the Seminar.

These Proceedings include papers submitted to the Program Committee by the time the preparation of seminar materials for publication began.

IV Международный семинар по научному космическому приборостроению состоялся в сентябре 1989 г. в г. Фрунзе. Семинар был организован по инициативе Института космических исследований АН СССР и Совета "Интеркосмос" при АН СССР.

В работе семинара приняли участие более двухсот советских и зарубежных специалистов, в том числе впервые из капиталистических стран.

В настоящий сборник вошли доклады, представленные авторами в программный комитет к моменту начала подготовки материалов семинара к публикации.

7 years passed since the last seminar on scientific space instrumentation manufacturing was held in Odessa. This is a sufficiently long period of time for space science, a rapidly developing branch of human knowledge, accumulating most recent achievements of fundamental and applied sciences: of electronics, information science, cryogen and laser technology, and of many others.

During this time span instruments for space have become much more clever, their intelligence has grown. The electronics has become more sophisticated, recent designs rely upon new measurement methods and principles of data array generation.

Today a tendency to comprehensive studies of phenomena and processes is obvious, hence a necessity to design and develop multifunctional systems characterized by higher reliability and longer lifetime, with a broad spectral range of measurements, with a high resolution, sensitivity, and high-speed of data recording and processing schemes. In some cases such systems should have their own microprocessors to permit self-diagnostics and - depending on its results - reswitching of instruments, devices, changing their operation modes, restructuring the entire time-schedule of measurements. Thus, experiments become more independent which is very essential in studying fast-varying processes or when the time of measurements is short, as is the case, for instance, when a spacecraft is descending in the atmosphere of Venus, passing by a comet's nucleus, etc.

Renewal at an extremely high pace and rapid outdating are very typical of the equipment used in space studies. Close international cooperation makes it possible to maintain the manufacturing of scientific instrumentation for space at a sufficiently high level in the context of contemporary scientific and technological progress. Joint effort and expertise of laboratories and institutes of many countries supply space technologies with the best achievements of each scientific team, and country-participants in this cooperation could choose areas of space investigations in view of their specific instrumentation-manufacturing capabilities.

Each instrument, a product of such joint efforts, is an implementation of advanced scientific concepts and ingenuity of designers and experimenters.

It should be mentioned that research teams of scientists who joined to develop certain scientific systems do not restrict themselves to the solution of partial, however important they might be, research and application problems, to the creation of individual unique instruments for fundamental investigations. The entire industry may profit from these methodological, design and technological achievements. Many instruments for space studies, designed and manufactured in the framework of the INTERCOSMOS program, are now widely used in experimental engineering, in medicine, agriculture, production organization and management. Various branches of applied sciences may greatly benefit from the use of contemporary investigation methods. On the whole space projects as such become more and more useful for our everyday life.

It is not an overstatement to say that scientific instrumentation manufacturing for space, being an integral part of cosmonautics, becomes today an essential branch of the economic activity of man and an essential productive force opening up new horizons in science and industries.

The organizers of the seminar are convinced that such meetings, if held regularly once every two or three years, with subsequent publication of their proceedings, would contribute to a rapid exchange of scientific concepts and data and serve the lofty aims of exploration and better understanding of space, and of using the achievements of cosmonautics for the benefit of mankind.

V.BALEBANOV

Со времени проведения предыдущего семинара по космическому научному приборостроению в г.Одессе прошло 7 лет. Это достаточно большой срок для космической науки – бурно развивающейся области человеческих знаний, в которой аккумулируются самые последние достижения фундаментальных и прикладных наук, включая электронику, информатику, криогенную и лазерную технику и многие другие.

Космические приборы за прошедшее время существенно "поумнели", возрос их "интеллект". Усложнилась электронная часть, в разработках стали использоваться новые методы измерений и принципы формирования информационных массивов.

Сегодня в космических исследованиях наблюдается тенденция всестороннего исследования явлений и процессов, что ведет к необходимости разработки и создания многофункциональных комплексов повышенной надежности и большого ресурса с широким спектральным диапазоном измерений, высокой разрешающей способностью, чувствительностью и быстродействием схем регистрации и обработки информации. В ряде случаев такие комплексы должны иметь и свой микропроцессор, который обеспечивал бы возможность самодиагностики и по ее результатам переключение устройств, приборов, изменение режимов их работы, перестройки всей программы измерений. Тем самым значительно повышается автономность эксперимента, что очень важно при изучении быстро переменных процессов или малом времени измерений, как это имеет место, например, при спуске космического аппарата в атмосфере Венеры, пролете мимо ядра кометы и т.п.

Аппаратуре для космических исследований присущи исключительно высокие темпы обновления и быстрое моральное старение. Тесная международная кооперация позволяет поддерживать развитие космического научного приборостроения на достаточно высоком уровне современного научно-технического прогресса. Объединение усилий и опыта лабораторий и институтов разных стран позволяет использовать лучшее, что создано в каждом коллективе, развивать космическую специализацию с учетом специфической ориентации приборостроительной базы стран-участниц совместных работ.

Каждый из созданных совместными усилиями приборов становится своего рода материальным воплощением передовых научных идей и изобретательности конструкторов и экспериментаторов.

При этом международные научные коллективы ученых, которые объединяются для работы над теми или иными научными комплексами, не ограничиваются решением частных, пусть даже и очень важных, научно-прикладных проблем, созданием отдельных уникальных приборов для фундаментальных исследований. Полученные при этом методологические, конструкторско-технологические достижения становятся, как правило, достоянием промышленности в целом. Так, многие космические приборы, созданные в рамках программы "Интеркосмос", сегодня широко используются в экспериментальной технике, организации и управлении производством, сельским хозяйством, в медицинской практике. Различные направления прикладных наук получили возможность широко использовать современные методы исследований. Все большую практическую направленность приобретают и сами космические проекты в целом.

Без преувеличения можно утверждать, что космическое научное приборостроение, как составная часть космонавтики, становится сегодня полноправной отраслью хозяйственной деятельности человека и значительной производительной силой, открывающей новые горизонты в науке и производстве.

Организаторы семинара выражают уверенность, что регулярное проведение подобных мероприятий раз в два-три года с последующей публикацией его трудов будет способствовать быстрому обмену научными идеями и информацией, послужит благородным целям более глубокого познания и освоения космического пространства, использования достижений космонавтики в интересах всего человечества.

В.М. Балебанов

SOWICOMS: an Instrument for Energy, Mass, and Charge Determination in Solar Wind and Mars Environment

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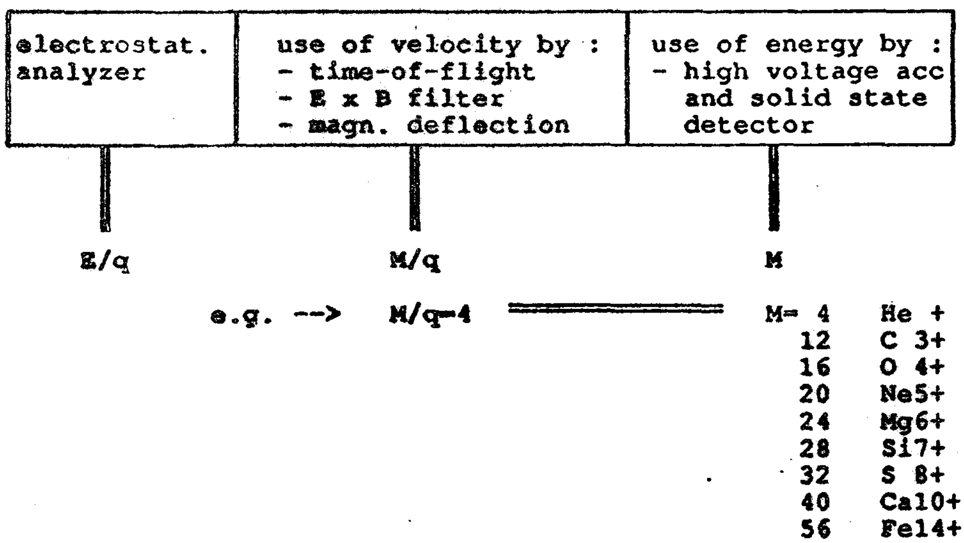
1. INTRODUCTION

The experiment introduced here, SOWICOMS, has been designed for the unique capacity to measure simultaneously the energy/charge, mass/charge, and the mass of ions. The range of 0.05 to 30 keV/q was chosen from requirements of plasma environment envisaged for investigation: solar wind and Mars magnetosphere, versus methodological limitation especially on the low energy side.

In the history of space plasma observation, the classification of ions with respect to their energy/charge (E/q) has been a classical way to find physically meaningful relations for various kinds of plasma population. While the first pioneering work in this area could gain vast amount of new understanding from in situ measurements in as well the supersonic stream of interplanetary plasma as in wide energy distributions in planetary environment, they still could accomplish this without any instrumental distinction of the variety of ions species. But with more detailed knowledge of the physical processes involved, the importance of information about ion composition as a key to further expansion of understanding became more and more obvious.

In the solar wind, the general similarity of bulk speeds as a frequently confirmed and theoretically supported observation could serve under certain conditions as a means of mass/charge interpretation from measured E/q spectra. While this assumption could give essential contribution in various examples of dense and

kinetically cool plasma, this method proved as not applicable in general: either the assumption of bulk speed equality then is
broadening of speed distribution will overlap the distinctive M/q separation by far. So, the demand for inclusion of M/q dimension into the measurement was a necessary consequence. At the time now, however, still very few examples of measurements could be performed with this ability.



But even beyond the demand for distinction of ions in terms of their mass/charge, further evidence is needed about the absolute mass of charge of ions in order to both avoid appreciable ambiguity or uncertainty about the reading of measurements. As one prominent example (see schematic) for the multiplicity of species in one M/q number, M/q=4 is pointed out. The measured rates with this parameter will be the undissolvable accumulation of a range of 9 masses as displayed in the scheme - only counting those species which can be expected with appreciable contribution. This ambiguity concerns key questions of solar wind source processes and plasma processes in the corona, where some of the ions mentioned may give crucial evidence for the interpretation (e.g. post shock plasma). Just taking M/q results, this merging of various ion species cannot be resolved.

In the plasma environment to be encountered within the orbit chosen around Mars, one major task of this experiment was to give evidence about the interaction of the solar wind with the obstacle of Mars magnetosphere and ionosphere. In the various regions of distance from the shock boundery, from clearly outside in the solar wind down to deeply inside the magnetosphere, not only was the abundance of solar wind ions to present indication of the transport of particles and momentum, but in addition, the decline of charge status predictable at least as a principle phenomenon to add significantly to the understanding of processes involved. This decline was probable to occur in quite different rate for various species, and therefore the deconvolution of M/q peaks merged from different masses could be expected even more difficult than in the solar wind. Independant determination of ion masses was here welcomed as an essential help.

As a specific advantage in the environment of Mars where high time resolution is needed to minimize space-time mixing especially at the crossing of boundaries, the principle of measurement used was able to assess all ion species within one E/q channel simultaneously. More clearly, different to most instruments resolving M/q by a crossed fields method, only one scan, over E/q, is necessary here.

In Mars environment charges close to 1 play a major role as compared to free solar wind plasma. For this reason, the lower limit of energy detection was taken as low as permitted by noise consideration. As an updating of technical possibilities, a new type of detector was incorporated in one of the models, an ion implanted silicon with very thin dead layer, for reason of an remarkably lower level of intrinsic noise.

As the instrument flown with independant measurement of M and M/q in the solar wind, SOWICOMS on board of the PHOBOS spacecraft carried our hope that a great number of key questions would have a chance to be answered in case of successful operation. Apart from the apparent curiosity aiming at the Mars encounter, it was the intention to at first concentrate on the interrelated composition and transport processes in the solar corona, the fundamental tool by making use of the ionization state of different ion species being dominated by the coronal density and temperature profile, and transport effects on the observed kinetic temperatures and specific velocities of different ions.

A description of the instrument and operation has been given by the authors before[ref.1]. Beside a short summary, in this article major emphasis is put on a few details of specific interest.

2. EXPERIMENTAL METHOD

The goal to determine mass and charge of an ion entering the instrument can be related to the task to determine mass M and mass/charge M/q as the corresponding factors in two kinetic energy equations, the idealized form of which is given by :

$$M/q = \frac{2 * (E/q)' * t^2}{s^2} \quad \text{and} \quad M = \frac{2 * E'' * t^2}{s^2} .$$

In both these relations, s is the length (70 mm) of a range through that the time of flight (TOF) t of the ion is a value measured in the sensor. (E/q)' is the energy/charge of the ion within this range; it is known from the analyzer setting, and taking into account an acceleration voltage U_a (30 kV) between the analyzer and the TOF sensor:

$$(E/q)' = E/q + U_a - \delta E/q ,$$

t is measured as the time between hitting a thin (4.5 μg/cm²) carbon foil at begin (initiating the START pulse) and the surface of the energy detector (initiating the STOP pulse). The acceleration is to shift the ion energy off the low energy limit of detectability.

E" finally is the energy itself within the range, a value related to that energy which is the part of E" converted to free electrons in a silicon semiconductor and measured as the output signal E :

$$E" = E + \delta E .$$

The two values δ E/q and δ E are the various absorptive energy losses in the carbon foil and in the semiconductor resp., which depend on the energy and on the mass M of the regarded ion. Instead of the unknown parameter M, the two loss terms are developped in terms of the related and known values of time of flight t, and the energy/charge $E/q+U_a$, or the energy E resp.
To get sufficient confidence about these relations is one matter of the experiment calibration. However, from computer simulation a close approach can be given which is part of the following summary on the predicted behaviour of the instrument with regard to the E/q, M and q determination.

E/q : analyzer and quadrupole lens

The impact of the ESA design on mass and charge determination is shortly described: from the chosen analyzer geometry of a radius R=90 mm, and a gap of d=9 mm a energy/charge passband follows with δ(E/q)/(E/q)=± 0.054. The contribution of this uncertainty to M/q determination depends on the relative share of $E/q+U_a$: from almost no contribution for low E/q, it reaches a maximum ± 2.7%, when the two terms are equal 30 kV. The plate voltages are stepped in 128 E/q channels through a range of 600, this is equivalent to just a slight overlap in neighbouring channel transmission.

The angular response of a hemispherical electrostatic analyzer (ESA) is fanlike: wide in the plane of elevation (along the plates), but narrow in the plane of azimuth (across the plates). In order to (1) open up the narrow passband in azimuth (only about ± 2° for the chosen analyzer measures, and (2) to confine the diverging beam at the exit in elevation towards a parallel bundle a set of two quadrupole lenses different in length and refractivity was developped. Both lenses have the effect of an equivalent optical lens being convex in elevation, concave in azimuth. Refractivity and length of the first lens are chosen to transform a wide solid angle at the entrance into the required narrow azimuthal passband while leaving the elevational spread almost unchanged. The parameters of the second lens are chosen such that a beam close to parallel with respect to the elevation emerges while the azimuth stays almost unaffected. For the front lens this actually means a bi-convex device with the focus at half length. The focus of the exit lens coincides with the exit focus of the analyzer. A schematic view and an example of computed ion paths through the whole ESA assemble are shown in figs.1,2. In fig.1 the voltage polarity applied to the pairs of plates is indicated, the plates are shaped as zylindrical (front lens: conical) surfaces instead of rods, in order to optimize the refractivity. Indicated as "accelerator lens" is the high voltage drop before the TOF system entrance. The field lines of this range are shaped in a way to support the confining task of the second quadrupole. The example in fig.2 depicts limiting paths of particles penetrating from a wide range across angles and aperture in both planes. The central area of the figure displays a cut through the whole electrostatic system in the azimuth plane. On the left, the view is tilted into the elevation plane of the front part; on the right, into the elevation plane of the exit part. From this display the characteristic angular transmission profiles can be easily understood: in azimuth, any pitch is closely related to a certain focus in the ESA entrance plane, changing α stays without much effect on the transmissivity between the limiting edges (± 19°): the instrumental profile resembles a symmetric step function. In elevation, changing the pitch to either side of 0° will make more and more of the outer particles hit the positive plates: the instrumental profile is smoothly lowered to the edges, actually close to the shape of a parabola. Details are more complicated, especially in that the second lens plays a limiting role, too, but without a change of the principal characteristic. In fig.3 as a result of computer simulation these transmission profiles for positive α and ß are shown: in careful laboratory calibration of the flight systems these profiles have been very closely confirmed.

M/q and M: time-of-flight sensor and energy detector

The TOF system concept is shown as a part of fig.6: penetrating ions release electrons at the foil, these are accelerated by a grid (+1000 V) in front of the foil, they travel along the sensor axis into the decelerating field of the central triple grid mirror where they are deflected towards the START-MCP (multichannel plate) stack. Electrons which are finally released at the energy detector (SSD) take the equivalent path towards the STOP-MCP. The ions are sufficiently rigid not to be much affected by the grid potentials.

The design was largely guided by experience from related instruments[ref.2,3] and in details by computer simulation. The major effects to investigate were related to various kinds of collisions of low energy particles in solid matter: C in the foil, Au in the SSD front layer, and Si in the SSD lattice.[ref.4] They all cause energy losses as mentioned above; and, as a major additional effect regarding the absolute efficiency, at foil crossing they cause a scattering cone of appreciable width which results in large particle losses for particles beyond about CNO.

The simulations done follow the tables which have been compiled by J.F.Ziegler[ref.5] on nuclear stopping and low energy (1keV - 10 MeV) electronic stopping powers. The undoubtedly present uncertainties in the very low energy nuclear stopping which is of dominant influence at masses heavier than about CNO here has been thoroughly discussed by Wilson[ref.6]. As all stopping effects are strongly energy resp. velocity dependent, the simulation follows the particle history in small path length increments. In fig.4 M/q is given as a result of the time of flight measured in the sensor for constant E/q values of 60 keV/e (maximum value at SOWICOMS), down to 30 keV/e (minimum value at nominal U_a), and 10 keV/e (minimum value at much reduced U_a). The non-linearity in the log-log display especially for heavy masses and the lower E/q end as a result of the respectively growing loss δ(E/q) is visible. In ch.2 these curves can be compared to calibrated results. In which way the calculation of M/q from t was processed on board is described in ch.4.

There is a much more pronounced impact of energy losses to the lattice of the Si crystal (SSD) and of all losses to the Au dead-layer on the available signal from electronic energy stopping[ref.7]. The results given in fig.5 show the relation of electronic energy yield over time of flight measures for various masses as parameter. The (linear) scales are given in channel numbers, where t channel 170 corresponds to 100 ns, the maximum E channel 255 to 600 keV. The growing slope towards higher masses and lower velocities reflects the growing energy losses. These curves are limited to measured energy values being larger than the SSD amplifier threshold of 30 keV. As discussed in ch.4, particles with an energy signal below the threshold will contribute with a meaningful M/q value only.

3. DETAILS ON INSTRUMENT AND CALIBRATION

Basic features of the instrument are given in table 1. Fig.6 shows a cross section, from the ESA, through sensor and Time-of-flight/energy signal conditioning unit, via power-/signal coupler to the DPU interface, as well as the plate voltage and acceleration high voltage converters. Basics of instrument and operation are published in ref.1. Some properties are selected for further description here, which are of specific importance for the operation: trigger modes, background, and as a technical item details on the high voltage performance.

The solar wind has to deal with the problem of a vast majority of protons and alphas suppressing rare ion measurement. Some hardware and software measures are providing sufficient background reduction from this source: (1) the solar wind E/q spectrum is stepped from top to bottom. When the START countrate eventually exceeds a certain value (set by telecommand) the stepping is halted. (2) while the digital AD conversion takes 40 µs to process one event, a fast hardware circuit

Energy/charge	:	0.05 - 30 keV/e,	7 bit log
Energy	:	0, 30-600 keV ,	8 bit lin
Time of flight	:	0-600 ns ,	10 bit lin
sensitivity	:	eps * 0.01 cm² integral	
bitrate	:	cruise/Mars -->	10.4/192 bps
total weight	:	7.1 kg	
power	:	6.5 W	

Table 1 : Instrument parameters

is incorporated (PID=proton-alpha-identifier) which classifies all events with regard to being a certain boundary curve in the E/t plane: protons and alphas thus can be identified within nanoseconds, and further processing of them be suppressed. This circuit can be deactivated by command. As well there are other trigger options for operation, among them the option to have t or E or (t+E) or (t*E) trigger the AD-conversion. For nominal operation t trigger is preferred in order to get M/q information without respect to an E signal being beyond the threshold. However, this trigger mode includes nonidentified protons ≤30 keV as the major portion of background. In all cases in which any ion has released a START pulse protons have different chances to generate an erroneous double coincidence : (1) they arrive faster at the SSD than the ion, (2) the ion fails to release a STOP signal, and a proton succeeeds instead within the OPEN period (t_w) of 1 µs, (3) a proton starts the OPEN period and any other particle releases STOP outside the PID limits. Smaller portions are contributed by MCP noise (r_p ≈1-10 cps). All this variety of erroneous events is dependent on the resp. efficiency for START and STOP generation, eps,1 and eps,2. In fig.7 selected cases of regular as well as irregular trigger events of double and triple coincidence (DCR resp. TCR, both cts/s) are displayed, as they appear in a typical solar wind E/q spectrum mixed of all dominant species. The regular counts are defines by coherent events of ions exclusive of protons and alphas. The irregular - noise-counts contain coherent and incoherent protons and alphas, incoherent ions of all kinds, and UV or MCP background. The curve parameter is given by different commandable trigger conditions: (t), (t*E) for three distinguished thresholds, and PID ON/OFF. Noise/signal ratio varies through many orders of magnitude. The powerful tool of combined TCR/PID trigger mode is demonstrated. From this result the conclusion has been drawn to program the trigger mode as (t*E*PID) in the range of high proton rate and sufficient ion energy provided by fairly high charge states, and as (t) in the range of lower background but low charge states and ion energy.

This short view at the background is much related to the aspect of how much the acceleration voltage is improving the experiment. As on the other hand, the design of a high voltage of 30 kV applied in a device limited in volume, and close to sensible electronics, is still a major challenge, some notes shall be spent on the performance (table 2). Size and position of the cascade stainless steel housing can be seen in fig.6. With one exception (power coupling transformer) all insulation of the sensor system on high potential is made of metal and ceramic, with a general insulation gap of 12 mm.

Voltage range	:	0-30 kV ± 2%
Number of steps	:	8
Load	:	12 G , 100 pF
Power min/max	:	210/800 mW
Total weight	:	1.3 kg
Cascade	:	12 steps, hermetically sealed filled with N/SF_6
ON profile	:	linear ramp of 2 minutes
Housekeeping	:	1 sample/200 ms , 8 bit
S/C tests	:	reduction to 25 %

Table 2 : HV characteristics

Calibration was thoroughly made on the sub-systems: ESA/lenses, the TOF sensor and the integrated TOF sensor, and finally on the integrated system. The goals were, to determine and compare with simulation: transmission function of the ESA/lens system and the response of the TOF system as to t and E measurements in terms of $E/q+U_a$, M and M/q. The calibration was performed at IKI and at the accelerator in Lindau. With mass M=1-39 all common gases were used, energies freely adjustable between 10 and 300 keV. Beam intensities were feedback controlled through channeltrons, and could -for ≥30 keV- be absolute-calibrated in snapshot comparison to an SSD. Pulse-height-spectra were stored, and the instrument parameters derived in an off-line data processing. As a support for data assessment the START, double-/triple-coincidence (DC/TC) and PID reject pulses are available from the TOF system every 200 ms. Fig.8 displays the t vs. incident energy relationship for masses up to Ar, confirming the simulation in fig.4. Much dependent on careful calibration is the assessment of efficiencies, however, theoretical understanding is needed where the results are to be transferred on different masses not easily available as an ion beam.
According to :

$$eps_{total} = p^{14} * eps_F * \Omega * eps_d * eps_{MCP}^2$$

the total efficiency was synthesized in terms of eps_f and eps_d, the electron production at the foil and detector surface, the usable share Ω_f of scatter cone reaching the detector, and as simulated figures the accumulated effect of the sequence of grids (transmission p=0.86). Foil scattering was approached using tables of Meyer et.al.(ref.8) in comparison with recently published Lindau lab measurements(ref.9). In fig.9 a familiy of results reaching from H to Fe is displayed; they have been created fitting a large set of values from the SOWICOMS calibration (derived from START and DC results) to an appropriate numerical model each for eps_r and eps_d and inter-/extrapolating these values in accordance. Three sets of values are given in fig.9 : eps_b, (Ω*eps_d), and eps_{total}. Note that both eps do exceed 1 - due to the number of created electrons larger than 1. Further note the large dependency of eps_{total} on the energy, especially for higher masses, largely an inevitable result of scattering in the foil. For the high energy limits of calibration the total sensitivity of heavy masses is more than the double of hydrogen, i.e. as long the electron production still dominates without the particle direction being too much affected by foil scattering. Even with the drop at Fe for lower energy, however, the experiment is designed to still collect several total iron counts in the course of one spectrum.

4. INFLIGHT DATA PROCESSING

The information about an event contained in E/q (7 bit), t (10 bit), and E (8 bit), is shifted after the digitalization in the TOF signal conditioning unit (on high 30 kV potential) down via two lines of infrared optocouplers, and after merging into one serial string it is sent over to the DPU box. Using each a bi-quadratic representation for the function M/q (E/q+U_a,t) and M (E,t), all scales logarithmic, fast tables of coefficients then perform the computations to get M/q and M as the set of results in classes of 7 bit of E/q[ref10]. Reflecting the different accuracy, log(M/q) is kept with 7 bit, log(M) with 5 bit. Even considering the quasilog rate conversion to 8 bit, this still is much too large an amount of data (128*128*32 bytes/spectrum) than could be transmitted in reasonable time. Therefore, an effective further data reduction was applied. One share of the data was used to transmit one M vs. M/q Matrix per TLM packet (20 min in cruise phase, 1 min in Fast Mode near Mars) integrated over E/q with matrix elements of good resolution. One share was used to transmit -in a limited number of relatively course ranges of prime interest- spectral information, twice per TLM packet. While in the Mars environment the spectrum was reduced to 4 (instead of 7) bit, in the solar wind it was made use of all ion mean speeds considered to be more or less close to equal, and also related to the proton speed. Thus, the spectral range could be limited to E/q values grouped around a peak value individually for each ion M/q specie, and which could be predicted for each spectrum from knowledge of the proton speed. The START rate was assigned 64 bytes, thus keeping the E/q spectrum itself as an information of classical value. In cruise mode, time resolution could be improved by sending the spectral elements twice per TLM packet. The following figures summarize these data shares for the two modes.

	Fine matrix elements	Course, spectral matrix elements	integral counters, an./dig.housek.etc
Cruise mode	264 / 17%	2x32 à 14 ranges near max. / 57%	26%
Fast mode	248 / 17%	1x60 à 16 ranges à 4 E/q / 67%	16%

The proton speed needed for the spectral range assignment in cruise mode could be nominally taken from a measurement regularly sent by TAUS, or from own evaluation of the O6+ spectrum, the spectrum most reliably available for this purpose.

Beside the two modes mentioned there were a few more options, e.g. one for ground tests, and one for a special in-flight test program. In that, various features of the sensor and DPU processing were tested in a programmed cycle, in parts by electronic stimulation. As one special item, direct results of t and E were included in the data packet, a valuable tool to check the performance of the sensor in-flight. As a very comfortable aid the TLM commands were designed to react on sensor drifts in various respects. Especially single or the whole set of coefficients for E,t --> M,M/q conversion could be reinstalled by commands.
The selection of fine and course (spectral) matrix elements representative of certain ranges in the solar wind or Mars environment M vs. M/q field, was largely guided by computer simulation using the calibrated instrument parameters where possible. Some aspects upon the solar wind matrix are discussed with reference to fig.10. In this figure the positions of ions typically present in the solar wind are marked :

H+ 3He++ 4He1+/2+ 12C5+/6+ 16O6+/7+ 20Ne8+ 28Si3+/../6+ 56Fe6+/../11+

Error bars are added as they result from statistical considerations as result from theory and calibration. In addition, ions are included which stem from the highly interesting stock of lower charged masses (q=2 selected), and finally of q=1 (both for: C,O,Ne,Si,Fe): while being of exotic rarity in the solar wind, this latter group plays a major role in planetary environment. In order to study the margins of detectability a certain velocity (400 km/s) is used here, in comparison to the two dotted lines representative of the commandable lower and upper detector thresholds (30 keV, and 45 keV). The acceleration voltage U_a is assumed with the nominal value of 30 kV.

From the figure it can be read how all typical solar wind ions but protons and He will well fall beyond the upper threshold. Of the lower charges still there is a good chance of q=2 to fall beyond the lower throshold, while the major share of q=1 ions are found in E=0 channels. This means that a promising separation and resolution of solar wind and magnetospheric effects has been achieved by the instrument design.

The selection of fine and course (spectral) matrix elements (fig.11) reflects the weight which can be assigned to specific regions in M-M/q in terms of scientific objectives in a trade off with the instrumental capacity. Here the structure defined for the Mars phase is shown. For the integrated elements thin frames are drawn, thick ones for the spectral elements. The fine structure is chosen to both reflect the instrumental resolution, and to cover the whole matrix area as well, up to ranges included mainly for the purpose of background assessment. Beside the range of most topical interest in Martian environment, spectral information in this mode concentrates on a few selected solar wind species which should provide information about effects in the interaction zone with respect to the most abundant ones of rare solar wind ions.

The promising design of the instrument was not crowned by a corresponding harvest of scientific recognition, due to the unfortunate failure of a digital memory component. Part of the collaboration is happy to proceed with a modified SOWICOMS on board of the SOHO spacecraft.

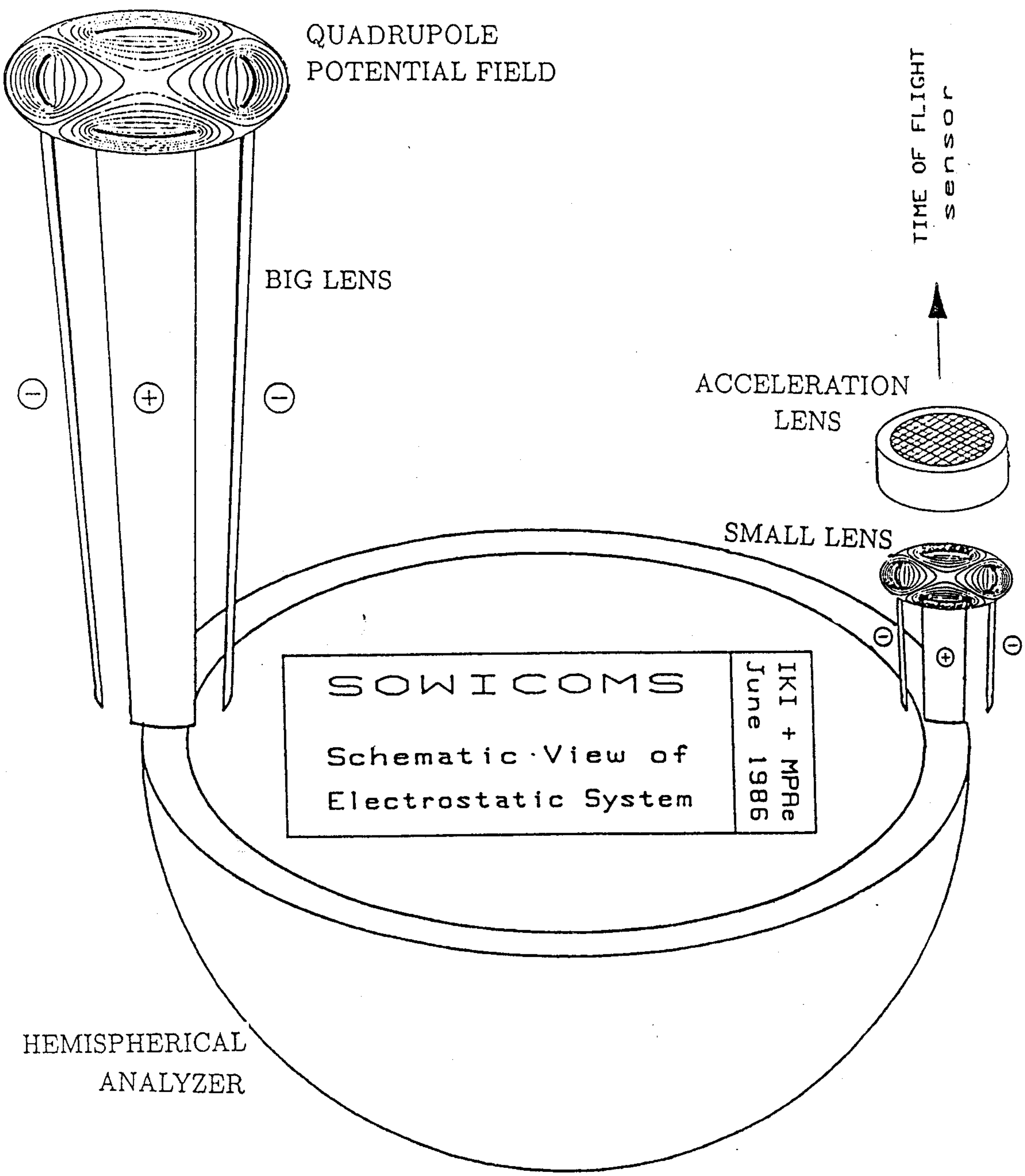


Fig. 1. ESA SYSTEM

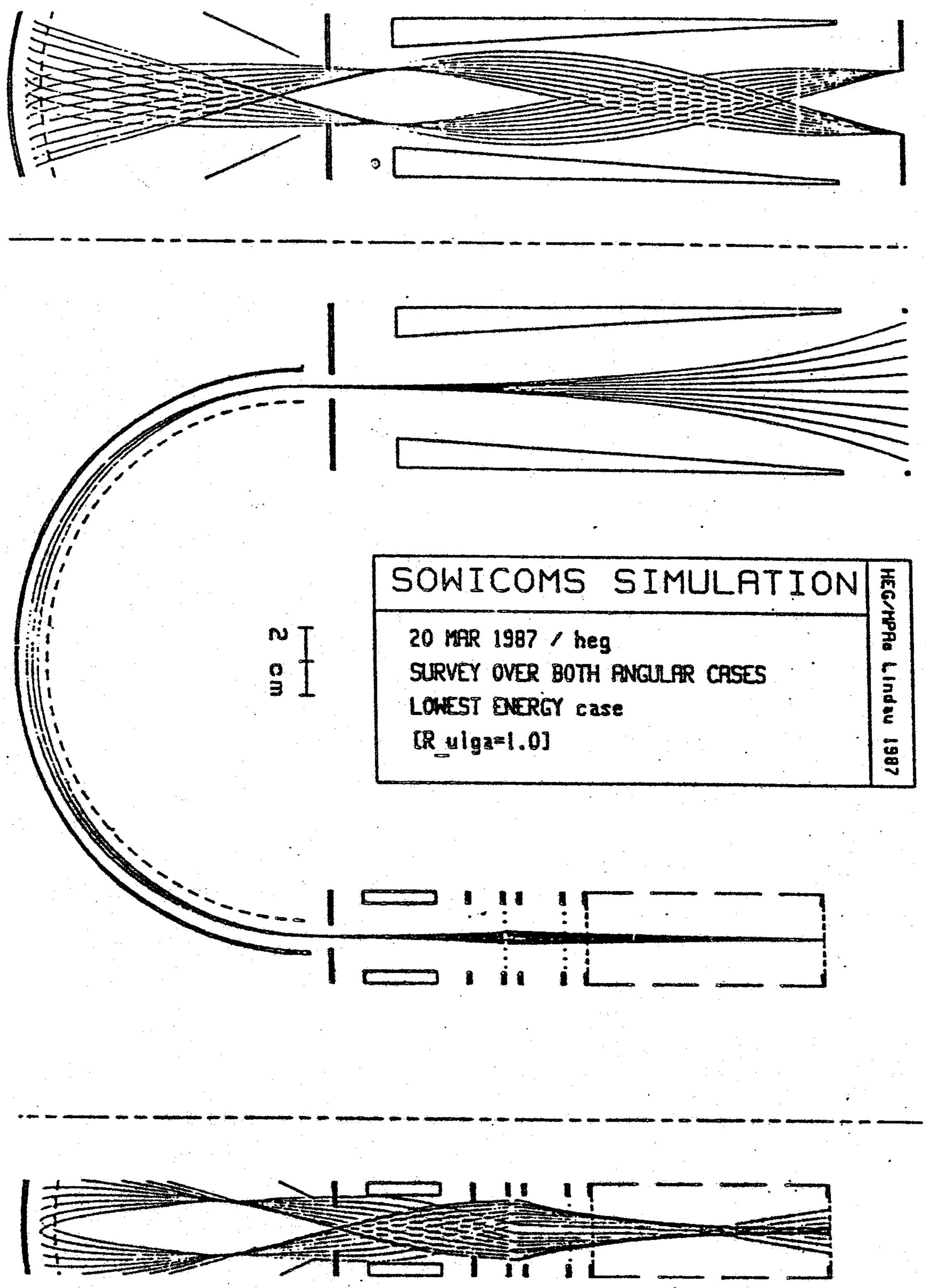


Fig. 2. ION PATHS THROUGH THE ANALYZEN SYSTEM

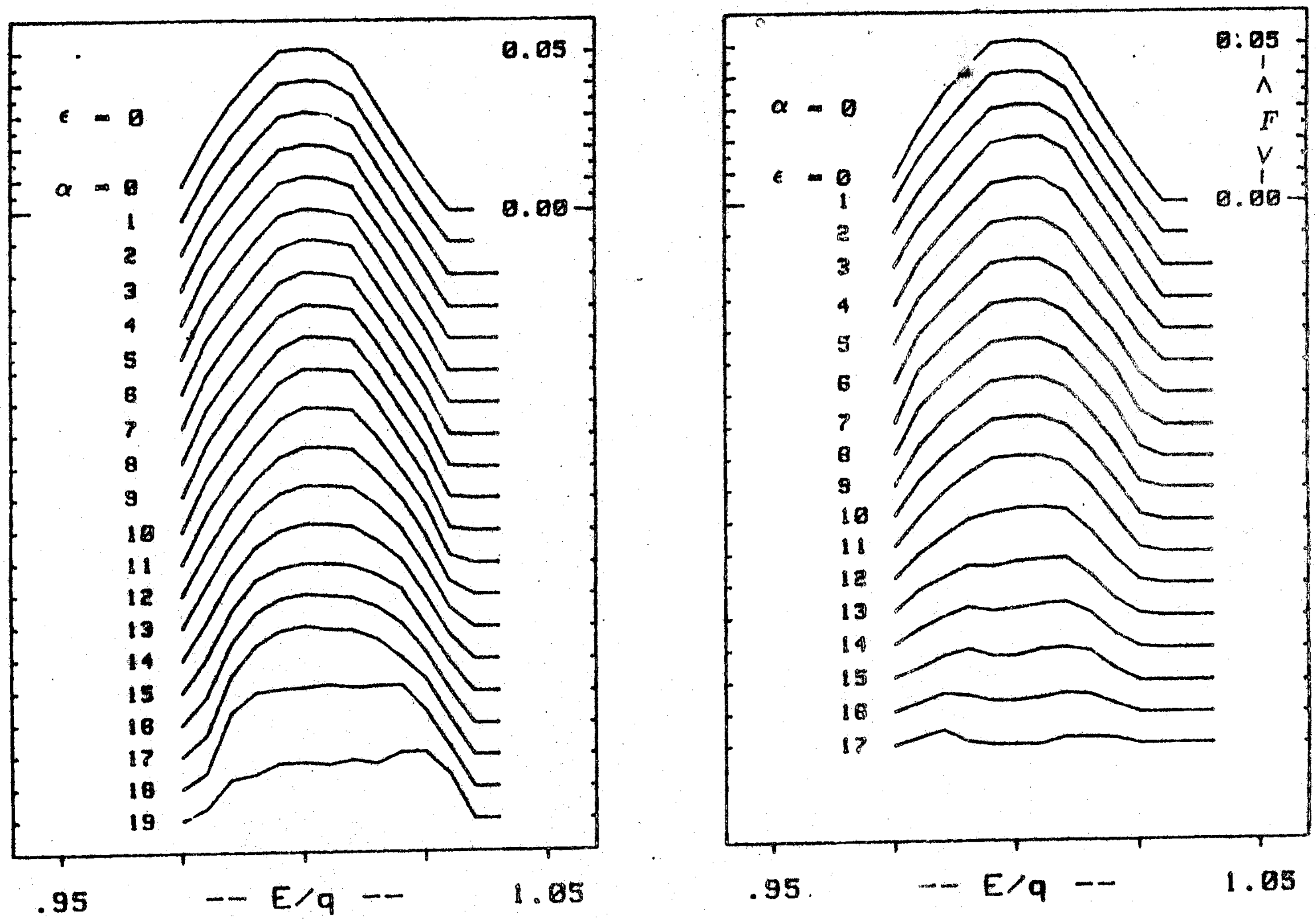


Fig. 3. INSTRUMENT FUNCTION < I > THROUGH α, ϵ

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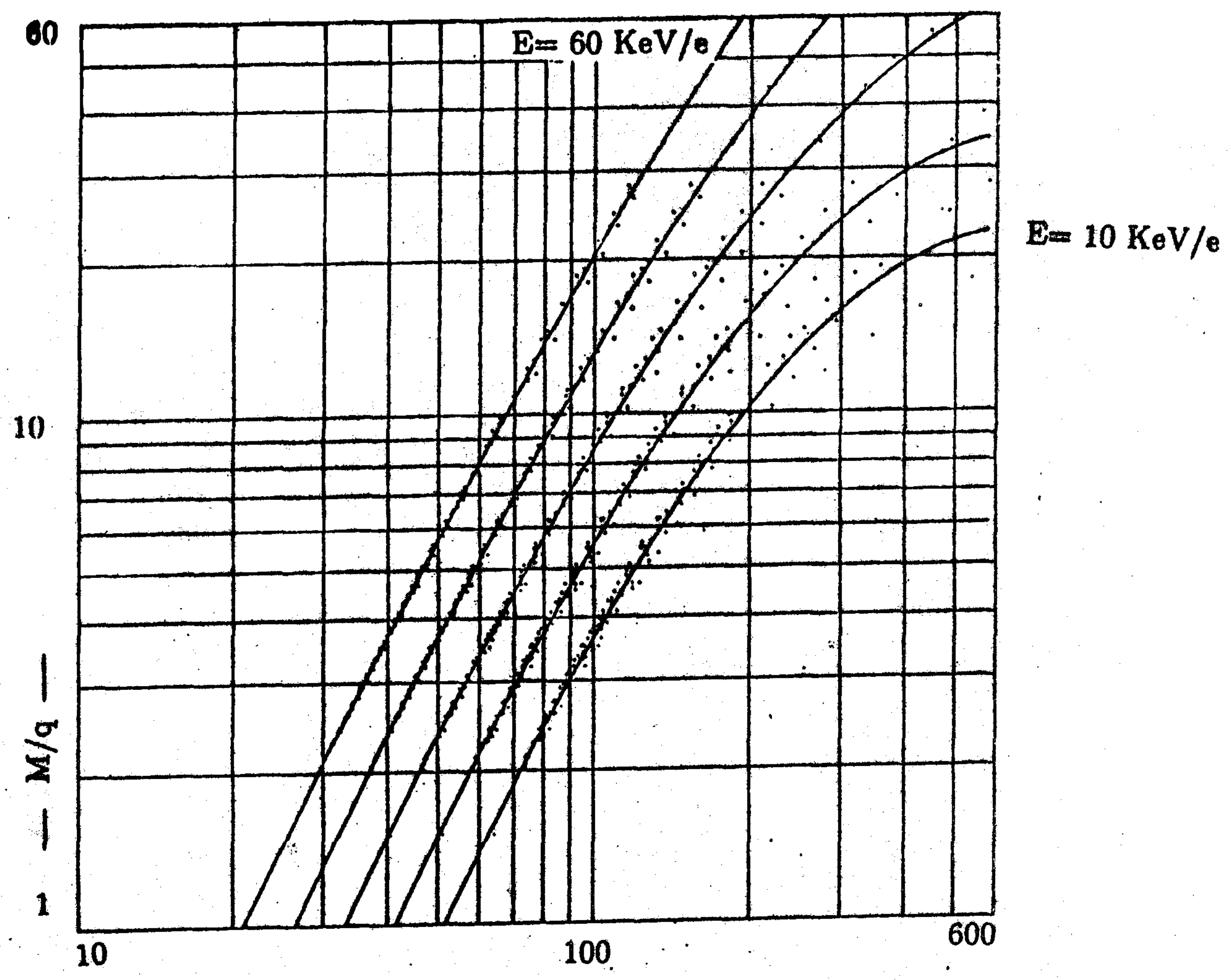

Fig. 4. TIME OF FLIGHT NON- LINEARITY

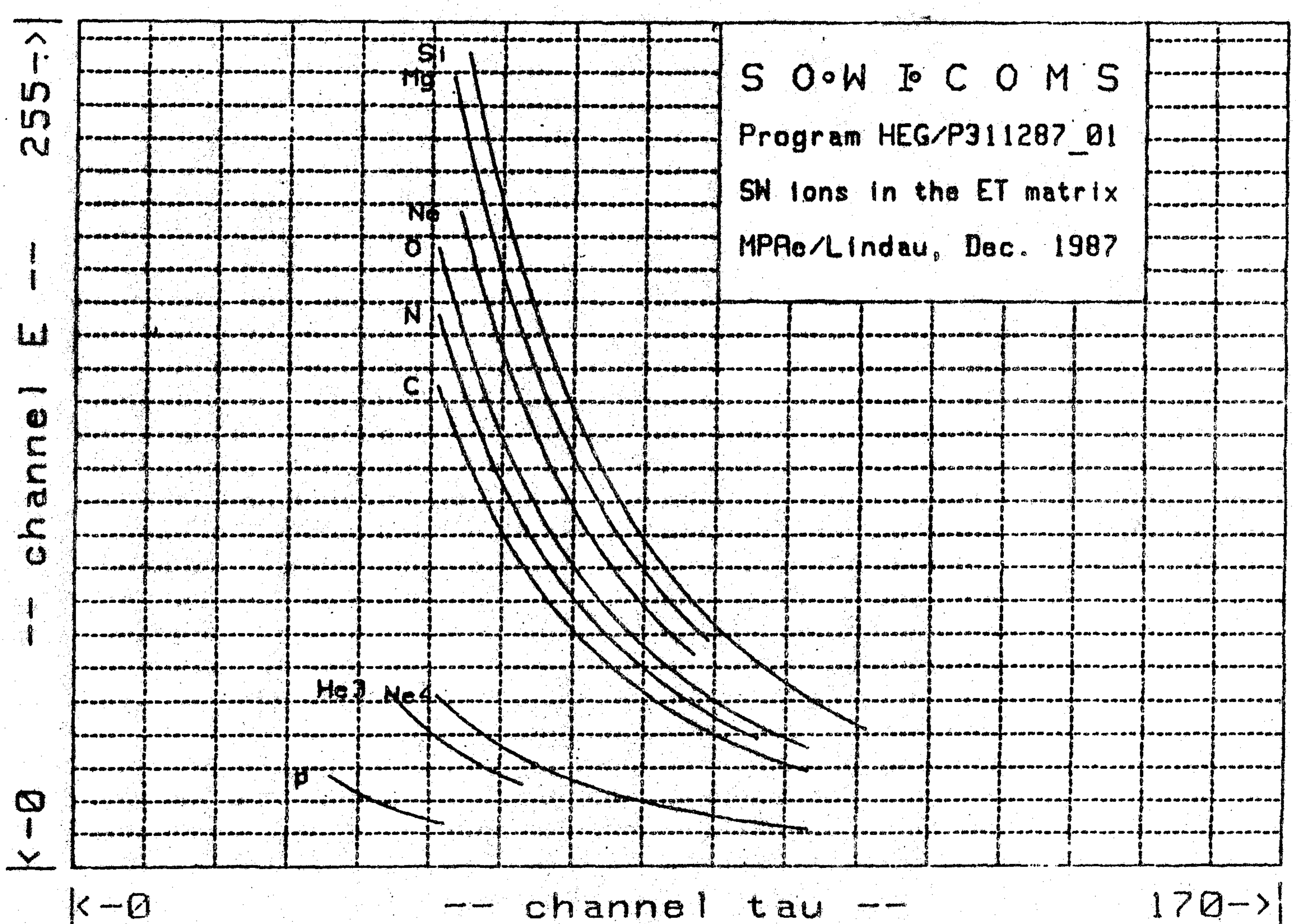

Fig. 5. ENERGY YIELD VS. TIME - OF - FLIGHT

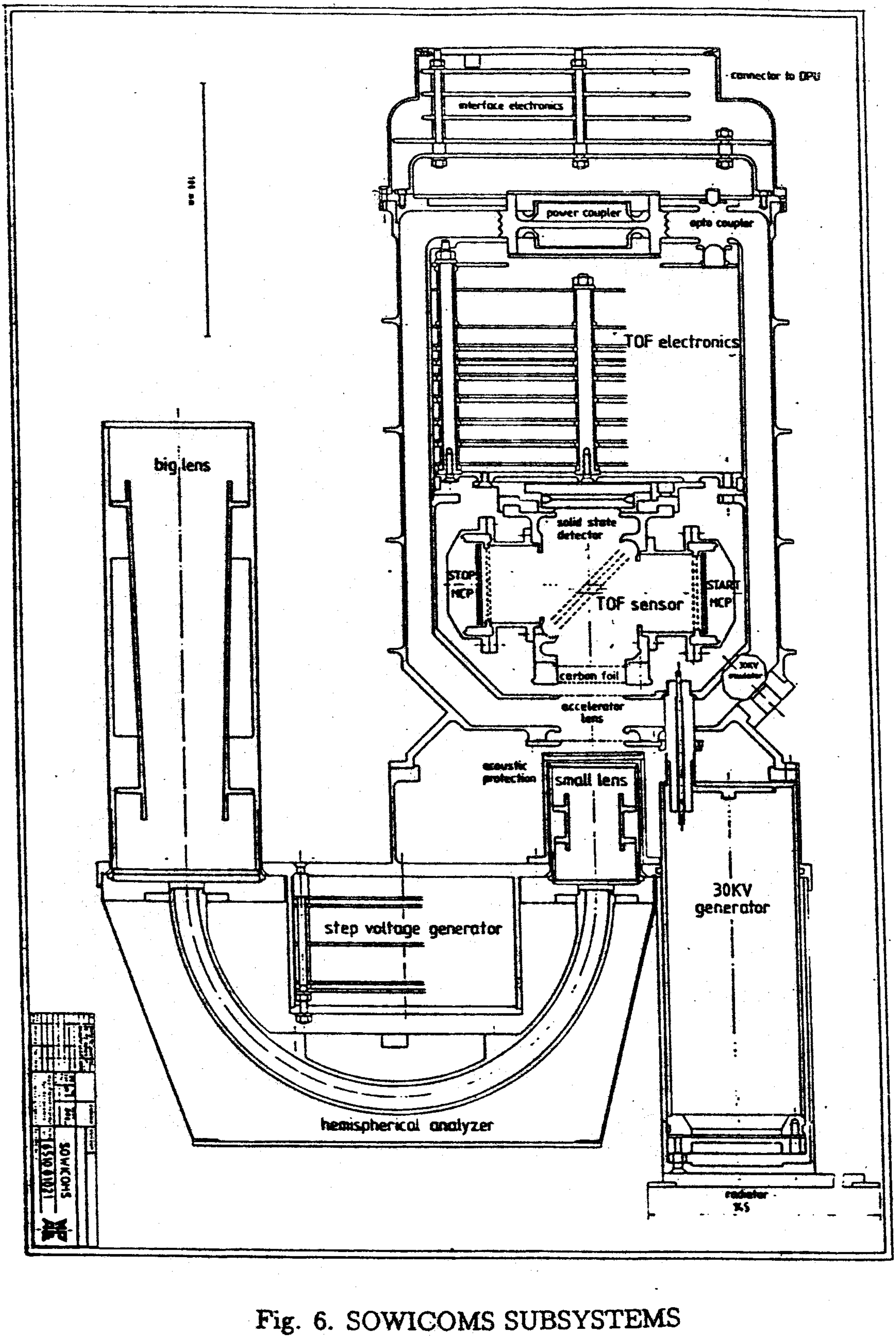

Fig. 6. SOWICOMS SUBSYSTEMS

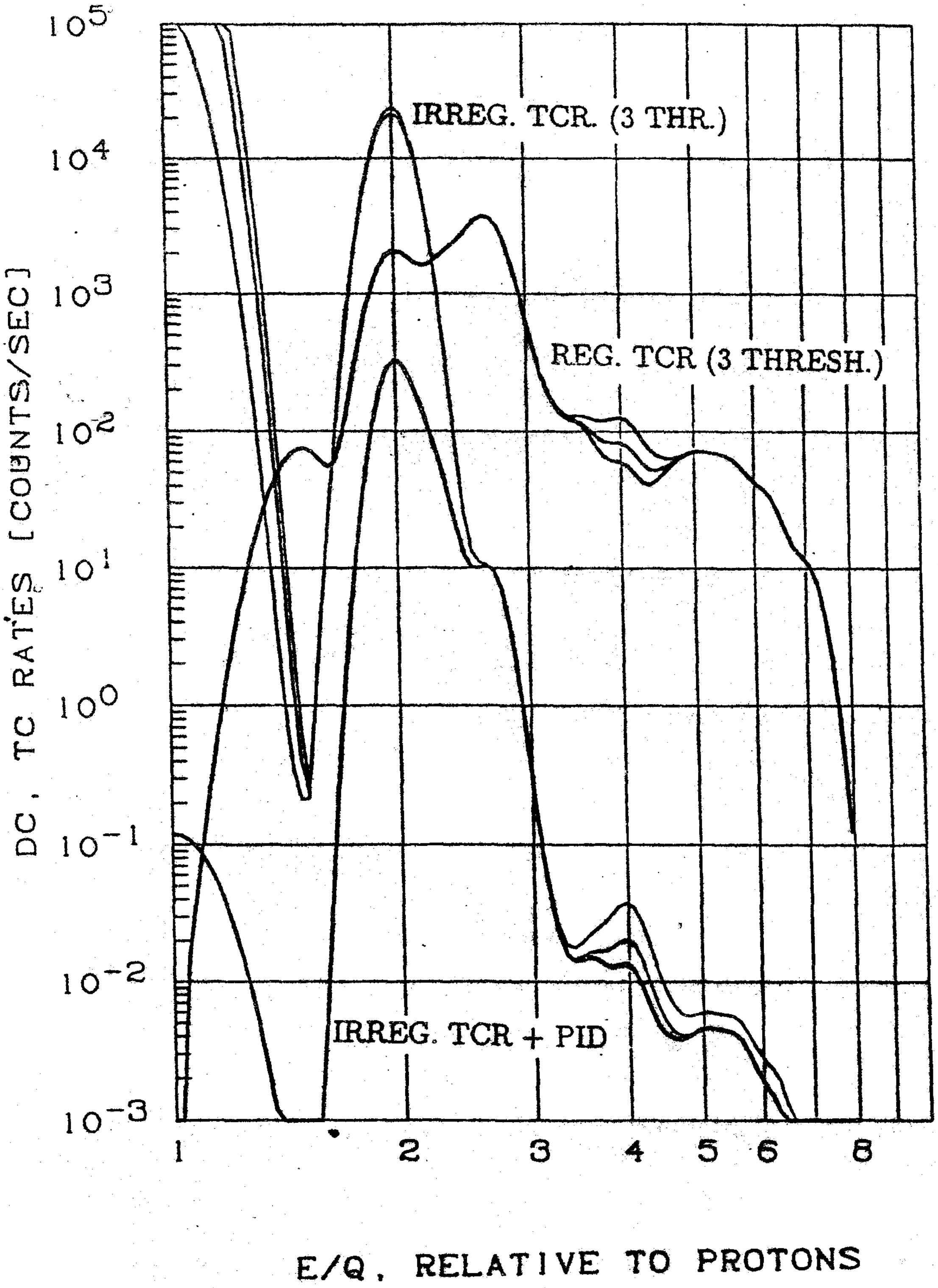

Fig. 7. REGULAR VS. IRREGULAR COINCIDENCE RATES

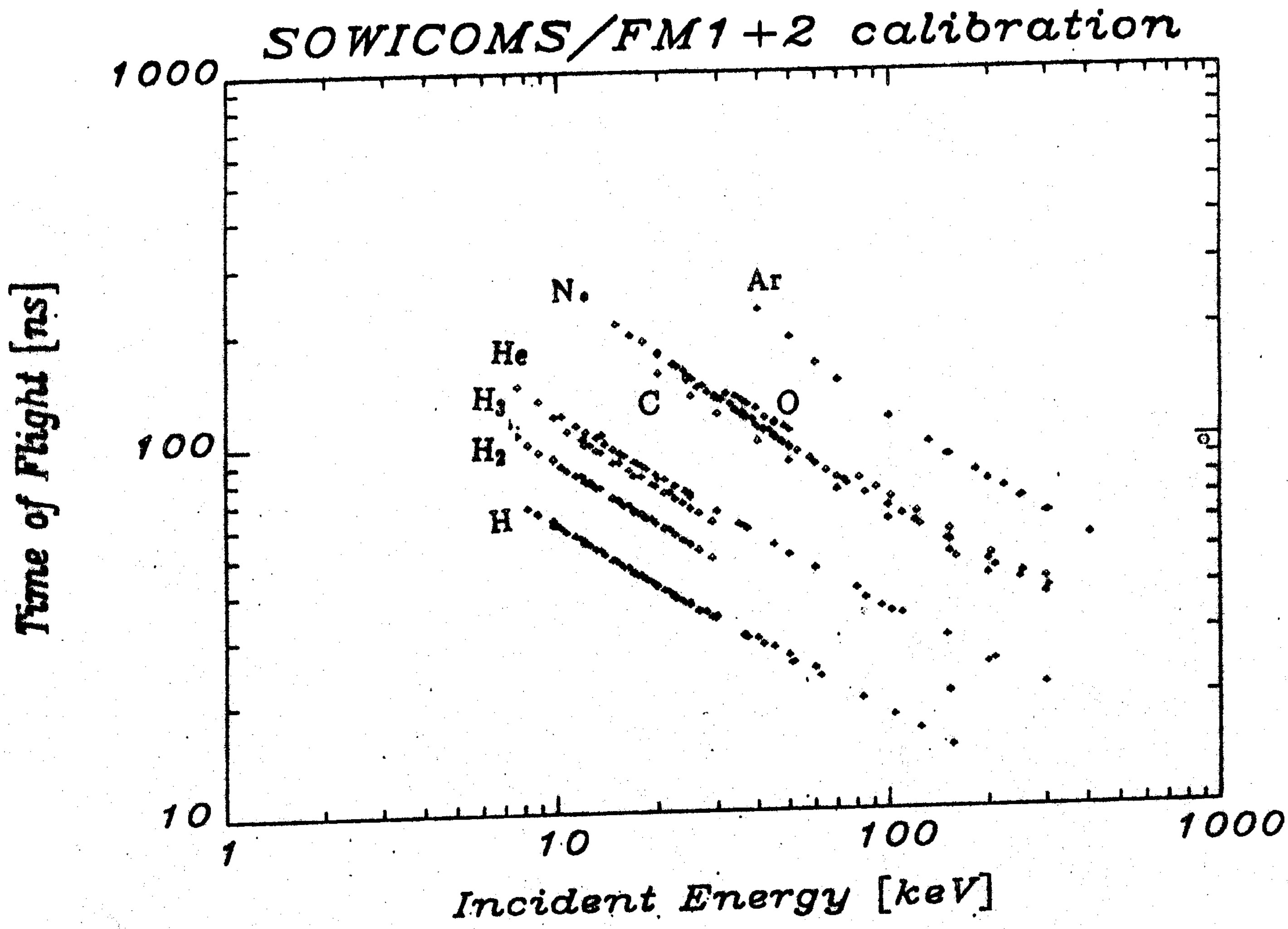

Fig. 8. CALIBRATED TOF RESULTS

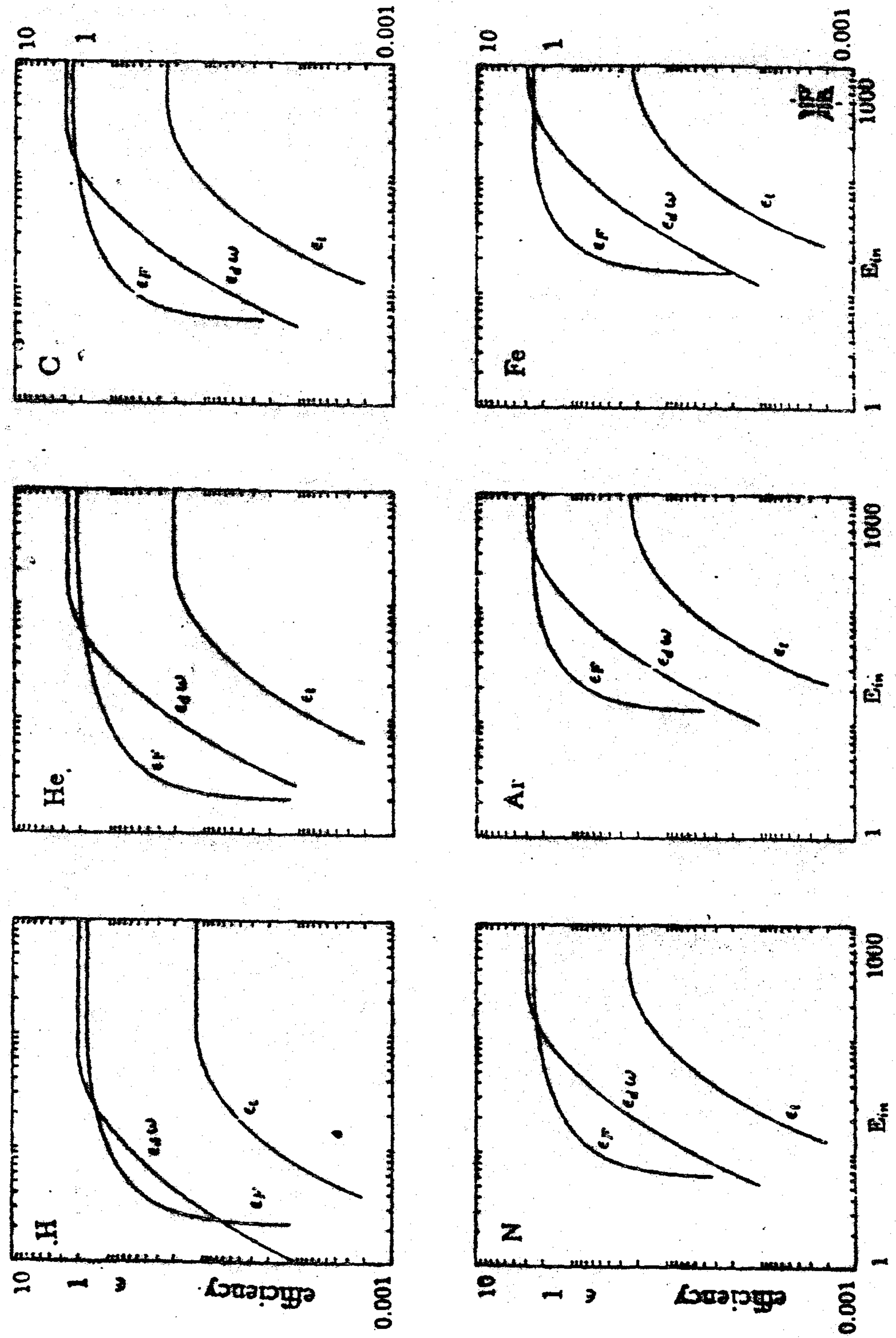

Fig.9. SOWICOMS CALIBRATION: TOF SENSOR EFFICIENCIES

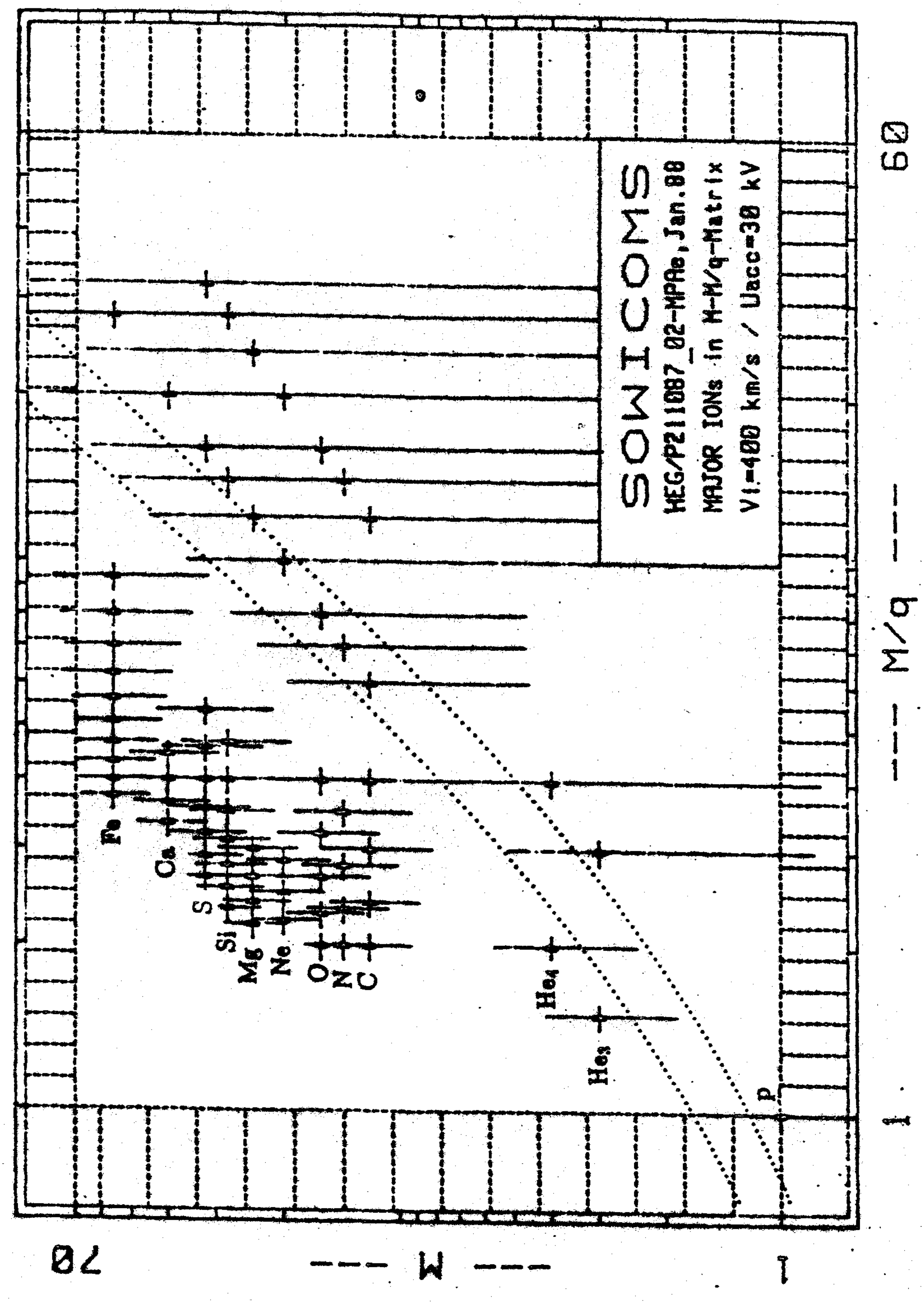

Fig.10. POSITION OF SW IONS IN THE M - M/q MATRIX

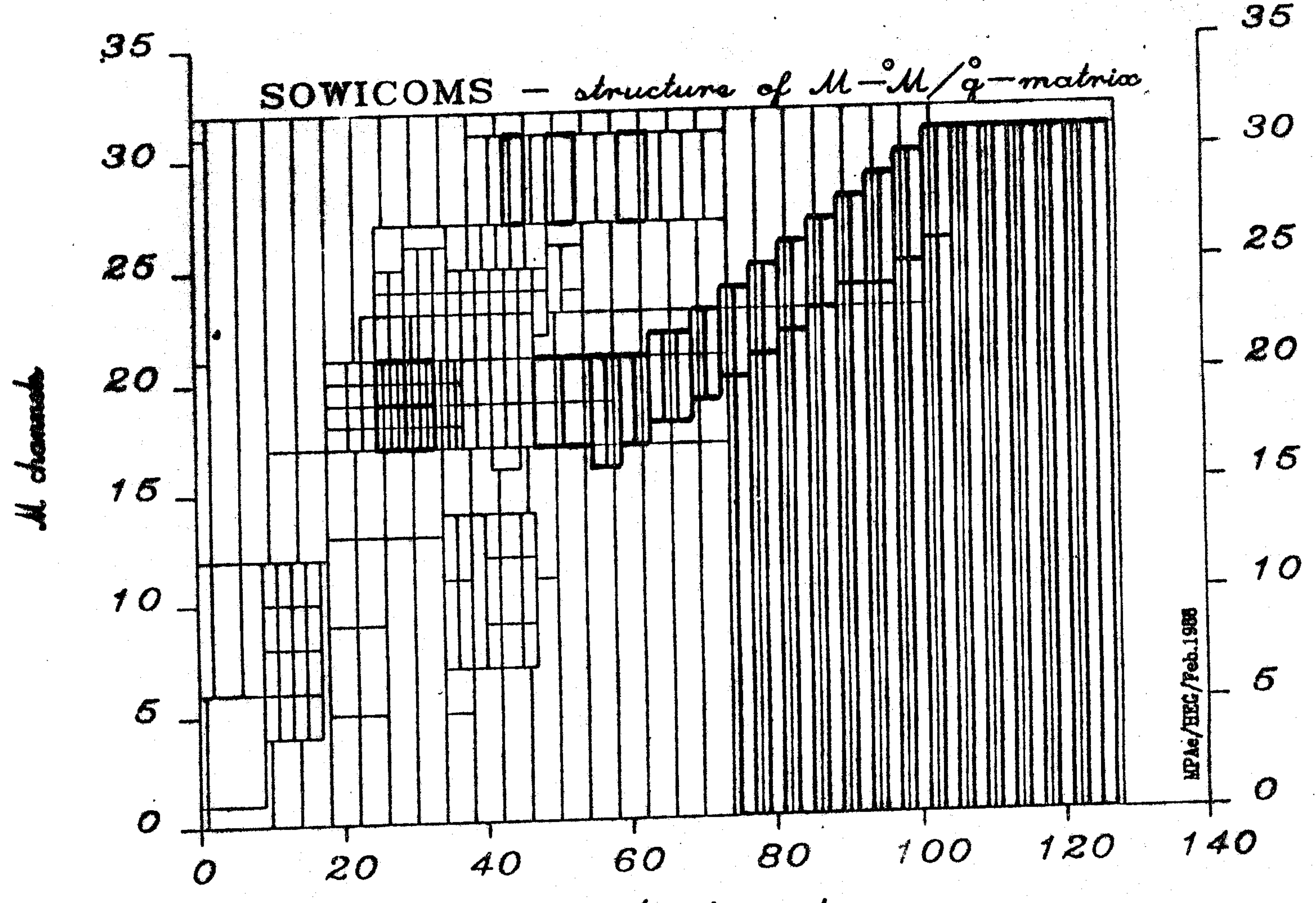

Fig. 11. MATRIX STRUCTURE IN MARS MODE

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