THE ISOTRACE LABORATORY AT THE UNIVERSITY OF TORONTO

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BRIEF HISTORY OF ISOTRACE

The possibility of exploiting the instability of the nitrogen ion to count ^{14}C at natural levels was realized in the early 1960's following unsuccessful attempts to accelerate nitrogen ions with tandem accelerators. In 1973 the negative ion sputter source was developed into a sufficiently high intensity C^- ions source with low carbon consumption and, compared with the previous radiofrequency ion sources, a very low memory effect. The possibility of radiocarbon dating by atom counting and exploiting the negative nitrogen ion stability was subsequently discussed in February 1974 in Physics and Archaeology lectures at the University of Toronto.

During 1976 a nuclear physics group consisting of A.E.Litherland and R.P.Beukens started to look for a suitable tandem accelerator and sputter ion source to rigorously test the instability of the N^- ion and to detect ^{14}C at natural levels by atom counting.

At roughly the same time a proposal by K.H.Purser, T.A.Tombrello and G.Wasserburg was submitted to the NSF for an ion microprobe, using a tandem accelerator as a device for removing molecular interferences with high efficiency.

The Rochester-Toronto-General Ionex group was formed in April 1977 which led to the first observation and quantitative measurement of ^{14}C at natural levels in May 1977 [1].

The significance of this discovery for archaeology as well as for ion microprobe work caused the Physics and Archaeology group to combine its effords in August 1978 with a group in Geology, led by D.W.Strangway, which had been studying the possibility of acquiring a secondary ion mass spectrometer for geological and material science

studies. The ISOTope and Rare Atom Counting Equipment (ISOTRACE) facility was effectively launced in April 1979 at the approval of the Natural Sciences and Engineering Research Council of Canada for the purchase of a General Ionex TANDETRON mass spectrometer. In 1980 the funds to develop the facility for the various applications were obtained from the Department of Supply and Services with the Ministry of Energy, Mines and Resources, the Canadian Geological Survey and Environment Canada as sponsors. A steering committee coordinates this development while a projects evaluation and allocation committee 2), consisting of experts from outside the ISOTRACE group, was put in place in late 1980.

INTRODUCTION

The people currently part of the ISOTRACE group are:

PHYSICS	GEOLOGY	ARCHAEOLOGY
G.E.Aardsma	N.M.Evensen	U.Franklin
R.P.Beukens	M.Gorton	W.Irving
K.H.Chang	J.C.Rucklidge	D.Markovich
E.Hallin	D.W.Strangway	C.Young
W.E.Kieser	G.C.Wilson	
L.R.Kilius		GEOPHYSICS
H.W.Lee		
A.E.Litherland		R.Farquhar

The special interest of these disciplines and the different interests of the people within these disciplines require the detection of many different stable as well as radioactive isotopes, for example:

ARCHAEOLOGY

^{14}C of slag, pottery, linen fragments, bone etc.

$^{26}Al/^{10}Be$ dating of Paleo-Archaeological samples.

HYDROLOGY

^{36}Cl groundwater dating

^{129}I groundwater tracer analysis

PHYSICS

Cross section measurements: Thermal neutron capture on ^{9}Be

$^{7}Li + {}^{7}Li = {}^{14}C + \gamma$

$^{11}B + \alpha = {}^{14}C + p$

Halflife measurements: Spontaneous fission of ^{232}Th into ^{14}C

Proton halflife from ^{98}Tc abundance

Detection of solar neutrinos: $^{7}Li + \nu = {}^{7}Be + e^{-} - 0.86$ MeV

$^{205}Tl + \nu = {}^{205m}Pb + e^{-} - 43$ keV

Search for non-integral charged quarks

Search for super heavy elements

GEOLOGICAL MICROPROBE ANALYSIS

Trace elements analysis

Isotope ratio measurements of light elements

Age determination of minerals: ^{10}Be, K/Ar, Rb/Sr, $^{207}Pb/^{206}Pb$

A number of these applications have been discussed at this conference in detail: 14C dating (R.P.Beukens), Non-integral charged quarks (K.H.Chang), Super heavy elements (L.R.Kilius), Terrestrial (J.Rucklidge) and extra-terrestrial (G.Wilson) trace analysis.

Figure 1 gives a plot of the elements of interest and the expected abundances. The detection and analysis of all these isotopes is well outside the capabilities of a standard 3 MV TANDETRON and a number of extensions and improvements to the system are under construction or have been planned. Figure 2 gives the projected floor plan of the complete facility, build around a standard 3 MV TANDETRON. In the remainder of this article the extensions and improvements will be discussed.

ION MILLIPROBE OPTION

In addition to the standard 3 MV TANDETRON, General Ionex will deliver the so called ion milliprobe option. This includes, in addition to a high energy magnet capable of analysing 18 MeV Cl^{+5} ions, a sputter ion source with a guaranteed caesium spotsize of 200 microns, a mechanism for moving the sample around by 1 cm in the X and Y directions, and an optical microscope to inspect the sample. An extra stable power supply will be provided for the inflection magnet with a mass resolution of 400.

HYDRODYNAMIC CAESIUM FIELD EMISSION SOURCE

From Oxford Applied Research (U.K.) a hydrodynamic field emission source has been purchased for applications in a ion micro probe source with a caesium beam spot of several microns and an intensity of 20 nA. This caesium source, after the addition of appropriate beam optics and scanning fields can be bolted on the source delivered with the TANDETRON.

HIGH CURRENT Al^- SOURCE

For Al/Be dating a high current (5-30 uA), efficient source for Al^- is required as the abundance of ^{26}Al is expected to be three orders of magnitude less than that for ^{10}Be. Caesium sputter negative ion sources produce less than 1 uA of Al^- with low efficiency. A LaB_6 surface ionization source, presently under construction, will provide a 1 mA primary I^- beam. A conservative estimate would indicate that this primary beam should be capable of producing a secondary Al^+ of at least 100 uA from the samples of interest. This Al^+ beam is subsequently charge exchanged to Al^- in a Na charge exchange canal with an efficiency of 10 - 15 % [3].

OPTIMIZED GAS IONIZATION DETECTOR

For particle identification a E-dE/dX gas ionization detector has been used so far by the Toronto-Rochester-General Ionex at high energies. For the detection of isotopes up to ^{36}Cl at the much lower energies, expected with the 3 MV TANDETRON, an optimized detector is being designed. The dead spaces and losses in the window will be minimized as much as possible. The operating pressure is envisioned in the region of a few torr while the gas pressure inside the detector will be accurately controlled by a MKS-254 flow controller while maintaining an accurate mixture of up to three counting gasses.

HIGH RESOLUTION TIME OF FLIGHT MASS SPECTROMETER

As gas ionization detectors cannot be used for particle identification for isotopes heavier than ^{36}Cl, a different identification technique has to be used. In the past at Rochester we have successfully employed a time of flight detector for the detection of ^{129}I, Pt and Ir isotopes. A high resolution (dM/M=2000) mass spectrometer is currently being designed for use on the ISOTRACE facility. The total energy and the flight time, determined in a time of flight mass spectrometer which is isochronous for small energy, angle and displacement variations, will provide the resolution necessary to distinguish between the heavy isotopes and the interferences from molecules such as their hydrides.

ALL ELECTRIC BROAD BAND MASS SPECTROMETER

The addition of an all electric injection system to the time of flight mass spectrometer produces in effect a broad band mass spectrometer as no mass selection is taking place and all species will be detected in the TOF detector. This is ofcourse of great importance for ion microprobe ánalysis where all isotopes of a single element or all elements can be analysed simultaneously.

HIGH SPEED DATA ACQUISITION AND ACCELERATOR CONTROL SYSTEM

A data acquisition and accelerator control system has been designed in cooperation with and is being built by INTEREX Computing Systems (Toronto) (Figure 3). It is based on two high speed (20 MHz) CS-90 processors with each 64kB of 16-bit memory. The two processors emulate the standard PDP-11/45 instruction set. The data acquisition processor analyses the incoming data in real time using specially designed microprogrammed instructions at data rates of up to 100,000 particles/sec from 4 ADC's (400,000 events/sec). The 11-bit, 5 usec per conversion, ADC's, preamplifiers and amplifiers are under computer control. To minimize any limiting by dead time multi-level analog and digital buffering is used. The control processor has, in addition to a special TANDETRON control interface, multiple busses (UNIBUS, CAMAC, IEEE-488, RS-232) for future extension and addition to the system. A 1024x1024 pixel display system will provide online display of the analysed data.

REFERENCES

1) K.H.Purser et al; Revue de Physique Appliquée Tome 12 (1977) 1487

2) Proposals should be submitted to:
ISOTRACE Evaluation and Allocation Committee
Prof. D. Shaw; Dean, Dept. of Geology
Mc Master University
Hamilton (Ont) Canada

3) J.Heinemeier and P.Hvelplund; Nucl.Instr.Methods Vol.148 (1978) 425

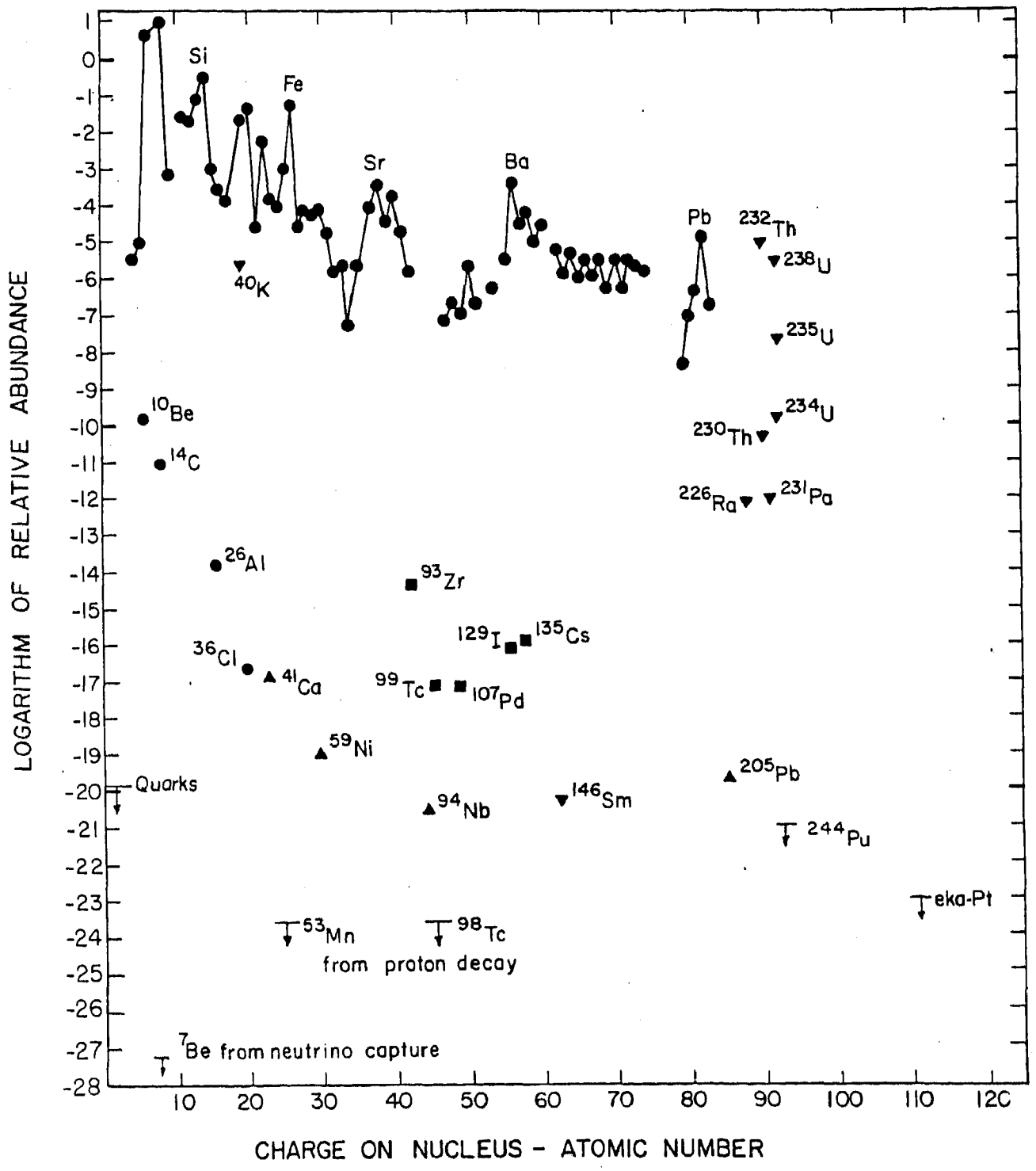

Figure 1. Relative abundance of isotopes of interest to the ISOTRACE group.

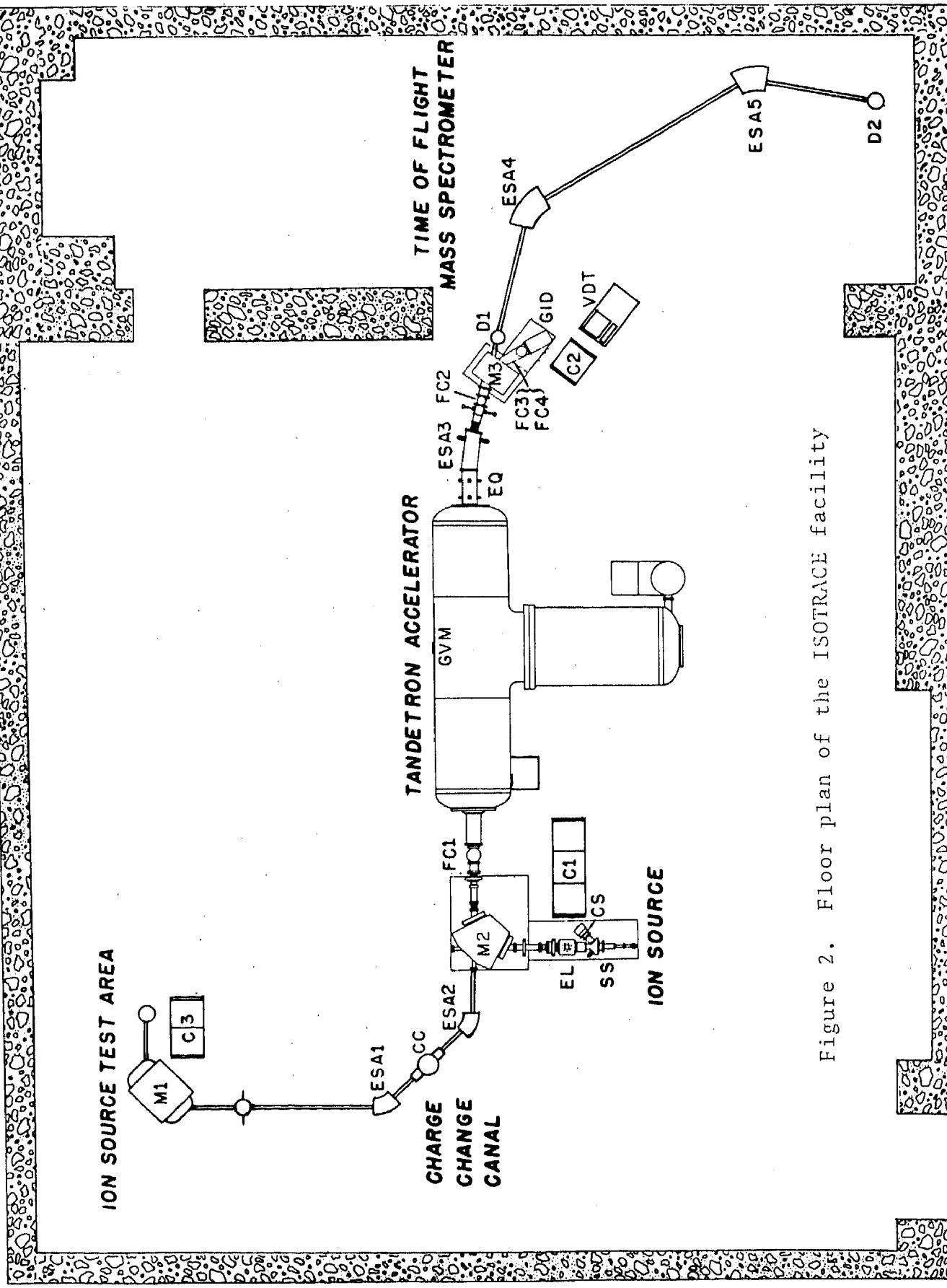

Figure 2. Floor plan of the ISOTRACE facility

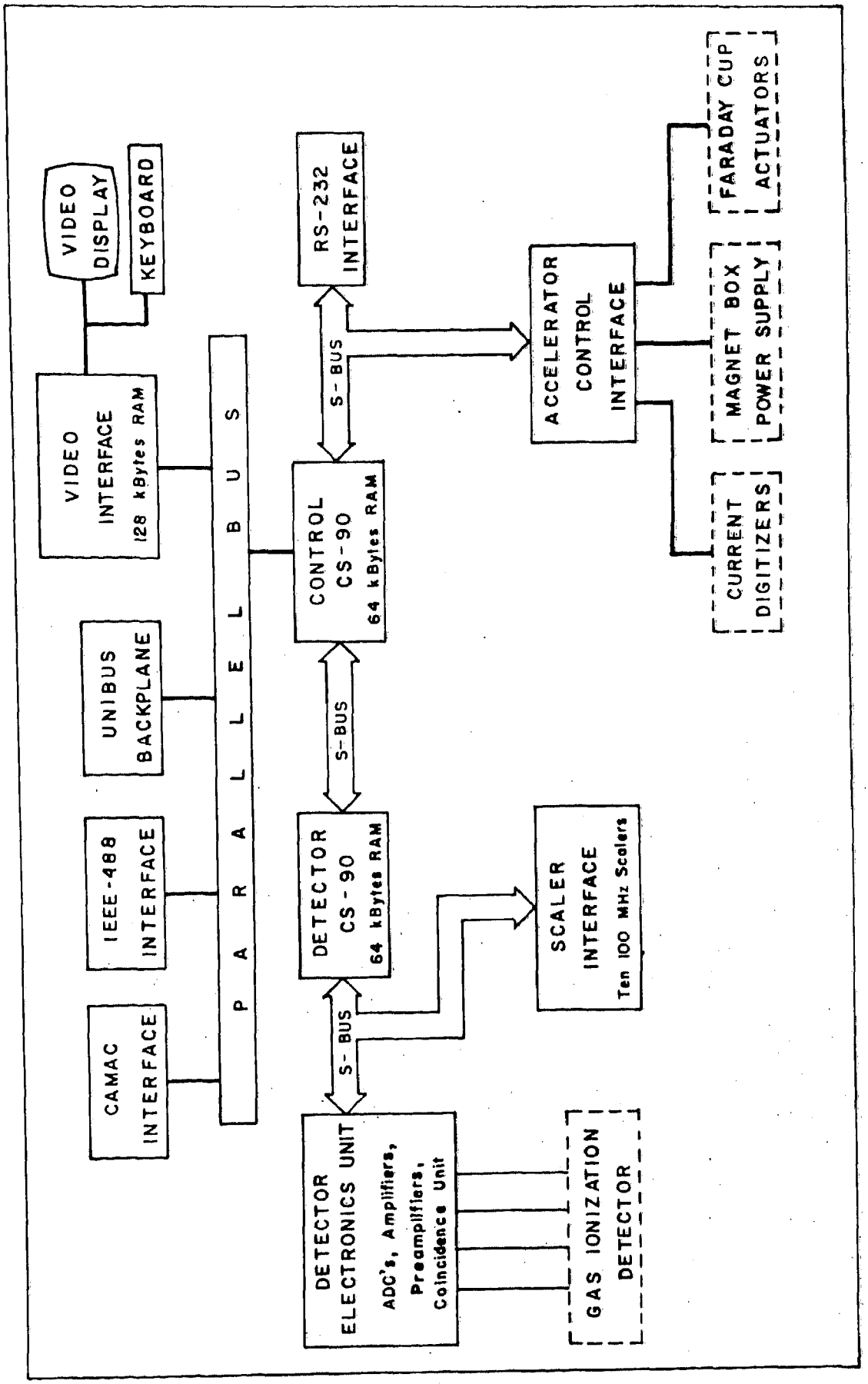

Figure 3. Block diagram of the INTEREX data acquisition and accelerator control system