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PROPOSAL

DEVELOPMENT OF GAS MICRO-STRIP CHAMBERS FOR HIGH RATE RADIATION DETECTION AND TRACKING

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Abstract

Micro-Strip Gas Chambers (GMSC) are a promising high rate, high resolution position detector suited for use in high luminosity hadron collider experiments, as general purpose tracker or to improve the performances of pre-shower counters, transition radiation and inner muon detectors. Large GMSC arrays have been included in proposed LHC and SSC experimental setups. The operating characteristics of GMSC make their use very attractive also for detectors at tau/beauty/charm factories, as well as for synchrotron radiation facilities and medical applications. At the present state of the art, some problems limiting the usefulness of microstrip chambers are the observed gain changes due to charging up of the support, possible long-term degradation due to aging, limited sizes imposed by fabrication technologies and unavailability of dedicated high-speed, high-density readout electronics. Limited experience exists of operation of GMSC in real experimental conditions, and little if anything is known about performances in detecting inclined tracks and operation in strong magnetic fields.

The present R&D proposal tries to address these issues, namely:

- Comparative tests of different substrata, both rigid (glass) and flexible (thin polymer foils);
- Optimization of thin detectors for transition radiation detectors;
- Measurement of the operating characteristics in a wide range of experimental conditions, including magnetic fields;
- Optimization of gas and construction materials to prevent ageing problems, in collaboration with RD-10;
- Development of a technology allowing affordable construction of large size GMSC, in collaboration with the industry;
- Development of a dedicated readout electronics, based on the analog switching memory chip developed by RD-2.

1. Introduction

There is a general consensus that good tracking close to the interaction point in LHC and SSC experiments is crucial to fully exploit the physics potential of the machine up to the highest luminosities. Detection of transition radiation is also one of the few technologies capable to help particle identification at hadron colliders or in fixed target experiments at very high energies. One of the few detector systems presumably capable of performing efficient detection and localization in a very high rate environment at reasonable cost is based on gaseous microstrip chambers [1]. This new device consists of thin parallel metal strips laid on a substratum, acting as anodes and cathodes and detecting, after proportional multiplication, electrons released in a drift space (Fig. 1). Using electron- or photo-lithographic techniques small spacings between electrodes can be realized (100 μm or less), allowing excellent granularity and very fast collection of positive ions produced in the avalanches increasing the rate capability. The small pitch helps reducing occupancy and results in an improved multi-track capability, expected to be of the order of the strip distance; proportionality and energy resolution are also very good.

Although gas microstrip chambers cannot compete with solid state devices in terms of spatial resolution, they offer numerous advantages:

- due to the gas gain in the chamber, signals are typically an order of magnitude larger than in silicon (about 10^5 electrons for minimum ionizing tracks, more for soft x-rays); this results in less stringent requirements on the electronics and better signal over noise ratios;
- because of their high granularity, if care is taken in choosing the proper construction materials and gases, microstrip chambers are expected to have a much greater radiation hardness in comparison with other gaseous detectors;
- construction costs are small (at least an order of magnitude less than for silicon devices of comparable size), allowing to conceive the coverage of large surfaces;
- built on thin glass or plastic supports, the GMSC are considerably lighter than silicon strip detectors and therefore minimize multiple scattering, soft x-rays absorption and and gamma conversions. The use of thin (100μm or less) substrata allows a two-dimensional readout with strips or pads printed on the back plane; this allows also the use of the device for detection of soft x-rays in medical and biological studies. GMSC hold also very promising perspectives for use in Transition Radiation Detectors (TRD), due to their very good double track and energy resolution together with high rate capability. Efficient detection of low-energy x-rays in a multi-layer detector structure requires the use of low Z materials for the detector, and the development of GMSC on thin plastic substrata (100 μm or less) is therefore essential.

Microstrip chambers have been built and tested by various groups. Proportional gains above 10^4, position accuracies of 30 μm for minimum ionizing particles, very good energy resolution (11% at 5.9 keV) have been demonstrated; gain reductions due to space charge in the gas only appear at particle fluxes close to 10^6 $mm^{-2}s^{-1}$ [2-10]. Successful medium-term operation of microstrip chambers in a fixed-target experiment has been reported [11].A certain number of problems has however appeared during the development work of the GMSC: instabilities and gain drops attributed to the charging up of the insulating surface between electrodes, disruption of the strips due to discharges, premature aging due to the deposit of polymerization products on the electrodes. We believe it essential to study these phenomena in more detail in order to understand and hopefully eliminate them in view of long-term operation. The behavior of the GMSC in the detection of tracks non perpendicular to the plane, and the operation in strong magnetic fields (never verified so far experimentally) have to be thoroughly investigated. At the same time, appropriate techniques for construction have to be found, cheap and reliable, both on rigid glass supports and on flexible, thinner plastic substrata. To gain experience, one or more medium-size detectors should be built and operated in real experimental conditions. On a longer time scale a dedicated high-density electronics, capable of withstanding the radiation levels at hadron colliders, has to be realized in close connection with similar works ongoing for silicon detectors. The alignment procedures and the system engineering aspects of designing a light support for GMSC arrays compatible with the accuracy requirements are also fundamental and will have to be faced, but are not included in this proposal.

2. Summary of present technologies and experimental results

The first GMSC detectors were fabricated on standard optical quality glass using high-quality photo-lithography [1]; a wide range of substrata materials have been tested since, from quartz to plastics. To avoid charging up phenomena, slightly conducting supports or surface ion implantation have been tested. Using the technologies available at silicon foundries, such as electron lithography and plasma etching with typically 0.1 µm resolution, has been shown to provide the highest quality artwork and consequently detectors with the best performances. Fig. 2 shows the energy spectrum obtained for the 5.9 keV x-rays from Fe^{55}, having 12 % FWHM [5]. The same technology allows to realize more sophisticated structures, with bi-dimensional and pixel readout [10]; this is the most accurate way to realize GMSC, however rather expensive and limited in size (most present day silicon foundries can handle at most 4" wafers). Moreover, high grade quartz or silicon substrata have to be used, excessively expensive for large sizes. Localization accuracies better than the anode pitch can be obtained recording the induced charge profile on the cathode strips. Fig. 3 [5] shows the accuracy measured in a minimum ionizing particle beam perpendicular to the chamber, by comparison with a silicon strip telescope. After subtraction of the reference monitor contribution, the accuracy is around 30 µm rms for the coordinate perpendicular to the strips in the GMSC.

More conventional photo-lithography and wet etching allow to manufacture GMSC at smaller cost, albeit with a reduced precision (around one micron), with a turnover time of a few weeks, rather convenient in the development phase. Whenever energy resolution is not a prime requirement, as for localization of charged particles, the resolution obtained with conventional lithography appears to be quite adequate for proper operation of the detector. Several types of glasses have been used as supports, namely soda lime, Pyrex, Tempax, quartz; the metal strips are usually realized in chromium, and in some cases in other metals (aluminum, gold). For insulating supports, short to long term decreases of gain have been observed, with a component dependent from the source intensity and with time constants between minutes and days (Fig. 4 and 5 [9]). The shorter term changes are presumably due to polarization effects of the medium or to the depletion of metal ions diffused in the glass. According to some observations, the gain stabilizes at a lower value still allowing to use the detector ; others have reported a continuing decrease of gain attributed to irreversible or long-term charging up of the surface attributed to the accumulation of ions in the insulating area between strips. This problem is avoided by increasing the surface conductivity with ion implantation, but there is only rather short-term experience with these devices when exposed to high fluxes. It is still controversial if one can safely operate in these conditions. The CERN-DRD group has investigated the possibility of using semi-conducting glasses to eliminate charge accumulation on the surface [9]; indeed, there is a strict correlation between the bulk resistivity and the time constant for gain modification. The more stable results have been obtained with a GMSC manufactured on an electronic conductive glass with a bulk resistivity of 10^9 ohms.cm (Figs. 6, 7). In figure 7, the exposure time is expressed as a function of detected charge per cm of strip+. Due to the very high radiation flux used for these measurements, there is a doubt that one may be overlapping charging up phenomena with aging; indeed coatings and perhaps permanent damages in the region of irradiation have ben observed after long term exposure. It is not excluded that the nature and treatment of the surface, together with the metal used for the strips may play a role, possibly major, in the aging process. Understanding and eliminating aging effects in the GMSC structures is of course of extreme importance in view of applications at LHC; these effects will be studied independently in close collaboration with RD-10.

The above mentioned gain drops are due to temporary or permanent modifications of the support due charging up or polymers formation. The intrinsic rate capability of the detectors, determined by space charge in the gas, is much higher as it can be demonstrated if the measurement times are kept short compared to the appearance of the previous effects. An example is shown in Fig. 8 [9]; the gain is constant up to a flux of about 10^6 $mm^{-2}s^{-1}$ (in fact, the drop in pulse height above this value is probably due to electronics pileup).

GMSC manufactured on plastic supports have also provided encouraging results. The technological problem here is to find a substratum having acceptable mechanical qualities, with a resistivity in the range necessary to prevent surface charging up, susceptible to be metalized with good adherence and withstanding the temperatures necessary for the fabrication process (cleaning, vacuum evaporation or sputtering, curing of the photo-resist) without deformations. Kapton was used in early works [6], but has the disadvantage of a very high resistivity (~10^{17} ohms.cm); indeed severe gain drops attributed to charging up have been observed on Kapton [6, 8]. A better candidate has been found to be Tedlar (a polyvinyl fluoride polymer loaded with titanium oxides), albeit on the higher edge of the acceptable resistivity scale, ~10^{14} ohms.cm [8, 9]; recently a high quality engraving on this material has been obtained from a commercial firm, see Fig. 9 [12]. The high rate behavior shown in Fig. 8 has been measured on a GMSC manufactured at CERN+ on a Tedlar foil 100 µm thick. The low mass and flexibility of the plastic foils are very attractive properties for some applications, but a lot of effort has still to be invested to find a more suitable support satisfying all requirements for the construction of reliable devices. Recently, we have obtained very large samples (square meters) of cheaply ion-implanted Kapton and Upilex* foils in the surface resistivity range between 10^{11} and 10^{15} ohms/square and fabrication of GMSC on the supports is on the way. As compared to Tedlar, Kapton and Upilex have the considerable advantage of a better mechanical stability during high temperature treatment, and Upilex is one of the most radiation hard polymers known (stable up to 200 MRads).

+ When detecting minimum ionizing particles (~ 100 ion pairs per track in a thin GMSC with 200 µm pitch at a gain of 10^3) a charge of 3 mC per cm of strip is reached after an integrated flux of about 10^{13} particles cm^{-2}. At full LHC luminosity, the maximum particle flux in the region foreseen for installation of GMSC is estimated to be around 10^6 $cm^{-2}s^{-1}$; in these conditions, 3 mC per cm are reached after one year of continuous operation.

+ Surface Treatment Workshop, MT Division

* Upilex, polyimide film made by UBE Industries

4. Research goals

4.1 Choice of a suitable substratum.

The results obtained so far seem to indicate that one needs a support with a surface resistivity in the range 10^{11} to 10^{14} ohm/square to eliminate gain reduction due to charging up of the surface at high fluxes. This requirement can be met using a material with a bulk conductivity of about 10^9 to 10^{12} ohm.cm, or increasing the surface conductivity of a high resistivity support by ion implantation, chemical surface treatment or deposition of a thin semi-conducting layers. Both approaches have been tried in the laboratory but the results are not yet sufficient to draw a clear conclusion. Given the value necessary to prevent ion accumulation, the surface conductivity solution results in much lower current (and therefore noise) as compared to the bulk conductivity one. Comparing however the electric fields at equal gains for the two solutions with a computer program developed by the DRD group [13], it appears that the field between electrodes in the gas region close to the surface is higher by a factor of two for the case of a thin conducting layer than in the case of a bulk conductor, equal being the equivalent surface resistivities (see Fig. 10). This might increase the risk of damaging the electrodes by discharges, an argument in favor of bulk conductivity. Extensive comparative tests of the two approaches are mandatory.

Glasses with electronic bulk resistivity have been manufactured and tested in the required range of conductivity, with the promising results described in the previous section; they are however not commercially available in quantities at reasonable cost. We will therefore have to find industrial partners willing to produce the necessary material, in collaboration with the specialized research laboratories that produced the samples [14, 15]. On plastics, the range of commercially available materials in the required range of resistivity is wider but the restrictions imposed by the manufacturing process of the detectors (thermal treatment, metal evaporation and etching) limit the choice.

A suitable value of surface conductivity on glass or plastic foils can be obtained by ion implantation or chemical deposition; one will have however to ascertain the influence of the manufacturing process on resistivity and the long-term stability of the implant. Most of the present experience has been obtained with boron-implanted quartz; quartz plates are however difficult and expensive to manufacture in medium and large sizes, especially for thin layers that have to be mechanically cut and polished to obtain optical surface quality. The nature of the implanted ions also plays a role in long-term stability of the surface conductivity; it is known that some metal ions, as for example gold, almost freely migrate in glasses. In collaboration with participating institutes, we plan to make a systematic search on the long-term stability of conductivity in ion-implanted supports, particularly for plastic polymers and cheap floated or laminated glasses.

The resistivity of the surface might not be the only factor in determining the appearance of charging up processes: the nature, cleanness, polishing qualities as well as the modifications due to the etching process may play a role, and perhaps a major one, in the operating characteristics. In this development stage, only the use of a wide range of materials and techniques may provide the clues for a better understanding of the detector performances. The experience and equipments available for surface analysis at CERN and in participating institutes will play a fundamental role in understanding the processes, and to learn the best way to manufacture, clean and handle the detector plates.

4.2 Manufacturing techniques

The maximum size of a microstrip plate is determined by the technology used and by electrical considerations. While processing using sophisticated silicon technology is limited in size by today's current wafer sizes (4" diameter in most foundries), photo-lithographic methods allow to produce metal strips 10 µm wide over about 50 cm on an appropriate substratum. As for the electrical properties, strips 50 cm long made of aluminum 1 µm thick have a resistivity of about 1400 ohms, acceptable if using a fast charge amplifier; use of gold as metal for the strips, as probably demanded by the observations on ageing described in the previous chapter, will further reduce resistivity. The mutual capacitance between adjacent strips (with centers 200 µm apart) is about 40 pF, and the stray capacitance to the back-plane electrode on a 1 mm thick support with the dielectric constant of glass is 10 pF. Both seem acceptable in terms of signal losses and rise time limitations. For thin supports, the capacitance between electrodes and back plane is larger however, resulting in some signal integration, a point that requires further investigation and optimization of the front-end electronics. If the readout is realized for the induced signals on cathode strips, the capacitive cross talk between anode and cathode plays a small role since the polarities of the signals are opposite. In close contact with the industry, we will ascertain the practical limits in the size of the plates and the best compromise between size and costs; presently, modular sizes of around 50 cm by 10 cm or 30 cm by 30 cm with 200 µm pitch anodes seem feasible with a moderate capital investment on a glass support; there are indications that this can be achieved also on polymer supports. Obviously, the maximum length of the GMSC that can be used in an experiment depends from physical constraints, range of incidence angles and rate-dependent pileups or occupancy problems; presumably, one will need a range of sizes to adjust to the local rate in the detector array.

4.3 Choice of frame materials and operating gas

Most of the work with GMSC has been done so far using conventional gas mixtures. To increase ionization yield, and insure good quenching, mixtures of xenon and dimethylether (DME) have been used [5]; fast gas mixtures using CF_4 as quencher have also been investigated [16]. As mentioned in the introduction, one of the problems met with the chambers is permanent gain modification or aging when exposed to high radiation fluxes. In that respect, differences in behavior have been found depending on the material of the electrodes: aluminum, chromium or gold, the most favorable being the last. The fabrication of GMSC with gold electrodes of the desired thickness appears to be however more difficult and requires an extensive research for a suitable process.

A special development work is required to find a suitable way to mount the bare GMSC plates into working devices. The all-ceramic supports used by the authors of Ref. 11 for their beam chambers do not seem to satisfy the requirements for a large tracking array, nor does the simplified fiberglass frames bond with epoxy used by the DRD group due to outgassing generating aging problems (see Figs. 11 and 12). A construction technology that compromises between cost, amount of material and cleanness of the assembly has to be investigated as integral part of this proposal. For the plastic thin-foil solutions, mechanical rigidity and thermal stability for the GMSC will be presumably obtained binding the sensitive plates to a light honeycomb or expanded poliurethane sheet few mm thick, as already done for Multiwire Chamber structures. A systematic verification of the influence of gas and materials on ageing is clearly capital, and will be done in close collaboration with RD-10.

Another point that we want to investigate is the possibility of producing thicker strips to make the detectors more resistant to damage caused by sparks. The thickness of the strips, and perhaps the smoothness of their edges play an important role in this respect. A simple method of high resistance protection for individual strips, for example using a continuous band of resistive epoxy or thin film decoupling resistors for connection to the HV bus bar, has to be developed. The adherence properties of the thin metal layers to surfaces also need further investigation, namely concerning the long term stability; in some cases, a thin flash of a different metal is used prior to the final deposition to improve adherence and this may have consequences in the operating characteristics of the detectors.

4.4 Radiation hardness

As mentioned in the previous section the problem of radiation damage due to polymer formation in the gas at high fluxes will be studied in collaboration with RD-10; the goal is to guarantee gain stability in the detector up and above the maximum integral doses foreseen for years of operation at maximum luminosity. The required tolerance to charge deposition was estimated in chapter 2 to be of about 3 mC per cm of strip per year of LHC operation at full luminosity; this has been already reached in laboratory tests (see for example Fig. 7), but will have to be confirmed in a wider range of operating conditions. A separate problem is the radiation resistance of materials used for construction and supports, and of the readout electronics. These issues are addressed by other research projects and we will closely follow those results. One concern specific to gaseous detectors and to GMSC in particular is the effects of high neutron fluxes produced by the machine or by the albedo induced by support materials and calorimeters. Although the efficiency of detection in the gas of MeV neutrons is negligibly small to play a role in the charge deposition, the effects of a heavily ionizing recoil proton in the gas generated by neutrons could be catastrophic if leading to a discharge. This effect will have to be carefully investigated, by exposing the GMSC to a known flux of neutrons either in a target area at CERN or at a reactor facility. Contacts in this direction are taken.

4.5 Readout electronics and contact techniques

To read out GMSC, one can use either a digital recording of the hit anode strip pattern, or register in narrow time slices the induced charge profile on the cathode strips (see Fig. 13 a and b). The first method, albeit providing a localization accuracy limited to the strip pitch, requires a circuit of smaller complexity and presumably faster to read out; this kind of circuit is being developed for example to readout of large arrays of drift tubes or multiwire drift chambers [17, 18]. The second scheme, despite being more complex and power-hungry, allows to obtain the best localization accuracy and multi-track resolution in GMSC; it is moreover the most advanced in design and of general use for silicon detectors, calorimeters and other detectors requiring the recording of analog information. An analog readout is of course essential for the use of GMSC in transition radiation detectors, allowing discrimination between signals produced by x-rays and charged particles and the best multi-track resolution.

High-density readout electronics specifically designed for use with gas microstrip chambers is not yet available. For laboratory and beam tests, we are using one of the existing high density analog multiplexers developed for solid state devices (the Amplex chip, a 32-channels charge amplifier and analog multiplexer [19]); because of its slow response and non gated operation the circuit is however unsuitable for high rate applications. The same applies to more recent and sophisticated LSI circuits developed for silicon as the SVX chip.

A fast analog memory circuit having characteristics very close those needed for reading out GMSC has been developed by the collaboration for RD-2 [20, 21]. In the present design (Fig. 14), an ASIC circuit contains a bank of 32 fast input charge amplifiers followed by a 64 cells deep analog pipeline. The input charge is sampled at 16 ns intervals and stored in the switched analog memory under control of external clocking signals. On request from a trigger pulse, the stored charge is then readout through a multiplexed ADC. Various schemes for data reduction, sparsification and selective addressing of the information are being developed by RD-2. The major characteristics of the circuit satisfy the general requirements for GMSC readout, namely concerning input sensitivity, dynamic range, time resolution. In collaboration with RD-2, we are currently planning to mount a GMSC on an existing 64-channels board for beam testing. The running experience acquired will suggest if and which modifications are necessary to optimize the design of the chip for GMSC readout; one concern is for example the limited protection against HV discharges, although this problem should be minimized by the high sensitivity of the electronics (permitting to operate the detector at small gas gains). It is conceivable that a reduction of the present 10 bits or larger dynamic range of the chip (designed for solid state calorimetry) to the less demanding needs of GMSC used as tracking device (5 or 6 bits) will result in a reduction of power consumption to the level of about one mW per channel (for use in TRD detectors, a wider dynamic range has to be preserved).

A problem requiring special attention and development is the connection of the detector to the electronics. For some of the technologies (e.g. thick aluminum strips on glass) a bonding method as used for silicon detectors is adequate for the connection of the strips to readout; in other cases (for example thin gold strips on plastics) one will have to find another suitable technique. There is some experience already on mechanical ultra-miniature pressure contacts between GMSC strips and high density printed circuits on flexible supports. The flexible Kapton strip and micro-connector used for interconnections in the RD-2 electronics, with two lines per mm, are almost suited for the needs of the GMSC. Due to the small cost of the detectors modules, a "disposable" approach may be more cost-efficient than a sophisticated one allowing repairs or replacement of components. In the case of the Kapton support, one can envisage to continue the active strips (realized by vacuum evaporation or sputtering) onto a set of conventional copper strips that establish the contact to the electronics board via a miniature connector, or even to directly solder the active electronics components for the signal multiplexing on a thick copper printed circuit layout realized on the same sheet as the detector. An extended research on connectivity is on the way in close collaboration with experts in CERN ECP division and in other participating institutes.

4.6 Test beam measurements and operation in strong magnetic fields

Apart from the pioneering work done by the authors of Ref. 11 in the NA12 experiment, very limited experience exists on medium term operation of GMSC on the floor. Moreover, some fundamental operating characteristics, as for example the dependence of accuracy from the incidence angle and the actual multi-track resolution have never been measured. The behavior in strong magnetic fields is also an unknown; although one may try to estimate and correct for simple geometrical distortions induced by ExB effects, doubts may arise as for the influence of the field on operation (for example due to the modifications in the ions collection). We plan to improve an existing beam test facility (developed and run by the DRD group in the East Hall) in order to allow the study of angular effects and, by installation in a suitable small size magnet, the magnetic behavior. An inquiry is on the way to locate such a magnet capable of reaching fields in the Tesla region, with a minimum gap of around 20 cm. Various gases will be tested, namely mixtures known for the small value of the Lorentz angle for drifting electrons, if compatible with the other requirements (fast collection, little aging).

4.7 Alignment, mechanical and thermal stability

To take full advantage of the foreseen position accuracy one will have to make the detector element mechanically stiff and thermally stable. Holding and aligning large arrays of chambers clearly also needs careful investigation. In the present proposal we want to be concerned only by the problems raised in a moderate size setup, but obviously the experience gained will be determinant for the conception of a full tracker for LHC or SSC. Various systems of mechanical reference and optical survey marks on the devices are under study; to a large extent, we plan to profit from the experience gained with the silicon micro-vertex detectors at LEP.

Depending on the value of resistivity adopted for the substrata to solve the charging problem, power dissipation may become a concern: for a resistivity of 10^9 ohm.cm, the power dissipation will typically be of the order of 100 W/m^2 for the chamber alone. This must be added to power generated by the chamber electronics, particularly high if using a fast readout. These and other system design aspects of installing very large arrays of GMSC are not part of the present research proposal, except for those met in a medium size prototype setup, but they will receive proper attention in the conception of the chambers.

5. Time scale and Milestones for the Research project

We propose a two-years duration for the research project, starting from approval, with the following tentative plan and corresponding milestones:

Year one:

- Realization of prototype GMSC plates on a selected range of bulk and surface conductivity supports, both on glasses and on polymer thin foils; comparative test of performances under medium-term high flux irradiation.
- Optimization of the detector size and transparency for use as detector of transition radiation.
- Extension of the useful lifetime of complete prototypes to the range of interest for LHC and SSC applications (up and above 50 mC of detected charge per cm of strip, corresponding to ten years of continuous LHC operation at full luminosity); study of the filling gases and construction materials to prevent aging, in collaboration with RD-10.
- Test of a high-density charge readout system for the GMSC based on the analog memory circuit developed by RD-2.
- Construction of several prototype chambers, fully instrumented, for the measurements in test beam conditions.

Year two:

- Realization of a modular light chamber and support structure , optimizing the ratio of useful over total area and minimizing construction costs; comparison of various connection schemes to the readout electronics (wire bonding vs pressure contacts).
- Design of a high density readout electronics, based on existing analog multiplexers developed for silicon microstrips; construction of several complete GMSC prototypes for extended testing in test beams.
- Systematic study of the operation in strong magnetic field.
- Experimental verification of tolerance of materials and chambers' operation to high radiation fluxes, both for charged particles and for neutrons, to be realized in a target area at CERN and/or close to a reactor facility.
- Conception of a medium size fully instrumented operational detector to be inserted in an existing or planned experiment. Construction of the full setup will have to be independently approved and funded.

6. Responsibilities, manpower and funding

The participating laboratories will contribute with manpower and funds from their research budget, in a collaborative effort that takes into account the respective main field of know-how and existing hardware support:

- CERN (PPE-DRD) for the realization at CERN of small prototypes and, in collaboration with industry, of large size GMSC; for laboratory testing with high flux x-ray generators and for beam measurements with a silicon microstrip reference telescope; within the activity of RD-10 for the analysis of materials and gases to prevent aging, and for long-term accelerated radiation damage testing of prototypes.

- CRPP and Carleton University for the production, in collaboration with private industry, of lithographic processes to produce GMSC on plastic substrata and for the development of polymer foils of appropriate resistivity by microwave plasma or ion implantation processes.
- INP Novosibirsk for the development of semiconducting glasses and the construction of detectors on them, for systematic measurements of detectors characteristics and the tests under special conditions (high pressures, synchrotron radiation).
- ISA Aarhus for the development of a suitable ion implantation technology to control surface resistivity on glasses and polymers, and for the verification of the long-term stability of the implants.
- MPI Heidelberg for the development of light detector structures optimized for the use as transition radiation detectors; for support in the development of the data acquisition system and participation to the beam testing; for the integration of GMSC prototypes with a transition radiator system to verify the identification capability in a test beam, in the framework of the planned continuation of WA89.
- Physics Dept. Texas A&M University for finding suitable polymer supports and technologies to increase surface conductivity and for the optimization of the fabrication process, and to access high-technology companies in the USA for the manufacturing of large size GMSC plates at reasonable cost.
- TRIUMF for contributing to the study of long-term stability of the GMSC under strong irradiation (aging), particularly using fast gas mixtures based on carbon tetrafluoride.
- Weizman Institute of Science for the surface analysis of the GMSC plates and for a better understanding of the influence of the surface and materials on the operating characteristics of the detectors; for finding and testing various kind of coatings with metals and resistive layers; for contact with local industry towards production of the detectors.

We have also received an offer of help and support from the collaboration for RD-2 for the test of the analog memory integrated circuit in conjunction with our prototypes, and (conditioned by the other engagements of the group) for help in optimizing the circuit for GMSC use if necessary.

7. Requests to CERN

7.1 Manpower

If approved, this R&D project will be the major activity of the PPE-DRD group at CERN. The present size of the group (one staff and three fellows, of which one fully engaged in RD-10) should be maintained through the regular Fellows and Associates program. One technical student position should also be allocated by the corresponding program. The group has presently one mechanical engineer, one mechanicial and one electronics technician (the last detached from ECP); this staff should be maintained for the duration of the project. Help from existing technical services will be needed, namely form PPE-TA1 (vacuum evaporations, assistance in the improvement of the DRD clean assembly room, help in designing the MSCG frames and supports, and in the conception of the basic elements to permit alignment and survey of the detectors in future large systems). We are also discussing with the surface treatment group (MT-SM) possible improvements of their clean room facility for the realization of prototype GMSC with better resolution than what can be achieved today (due to residual dusts and particles in the lithographic processing). Subject to their present engagements, we would like to ask assistance to the micro-electronics design group (ECP-MIC) for the initial testing of the existing 32-channels amplifier-analog memory circuit developed for RD-2, and of the Fastplex digital readout circuit under advanced development. Would the need arise, this assistance should be extended to implement minor modifications to the circuits to make them more suited for use with GMSC.

7.2 Test beam requests

During the duration of the project we would like to get access to a low or medium intensity/energy test beam for intermittent short periods, to be requested separately to the coordinator. A detailed schedule cannot be provided, as it depends from the technical developments, but we anticipate a need for a total beam time of four weeks for the first year and four weeks for the second year of the project. The present test facility of the DRD group in beam T7 is adequate, with small improvements; for the measurements in magnetic fields, a small gap (20 to 30 cm) dipole magnet should be made available and powered in the beam line presumably at the beginning of year two. We are also investigating the possibility of using parasitically an existing magnet of groups interested in the developments. The electronics shack presently used by DRD is adequate for all the duration of the tests.

For the radiation damage tests we plan to use mostly radioactive sources and the x-ray generators available in DRD and in RD-10. A neutron test will be made exposing the detector either at CERN in a target area or at a reactor. This is a short-term test, as we only want to ascertain if conversions of neutrons in the gas or materials of the chamber can induce large ionization losses leading to discharges. Material studies under irradiation are not included here as they are handled by specialized groups.

7.3 Computing needs

For data analysis, computer simulation of electric fields in GMSC, on-line data tacking we estimate an average need of around 200 IBM 168 hours per year (for all DRD and project-related activities). This corresponds to the presently used time by DRD.

7.3 Budget requests

The budget request here concerns only the CERN contribution, an is separated for convenience in two parts, labelled "DRD Support" and "Project" respectively. It is assumed that the first part will be provided as part of the normal PPE-DRD group exploitation budget, if kept at the 1992 level; the second part instead will have to be separately allocated by the DRDC or by the PPE division as project money.

Year One

DRD Support:

Consumables	50	
Upgrade of clean DRD laboratory	35	
Small works	20	
Maintenance, rentals	10	
Project Related travel	10	
Per-diem for collaborators (one man-year)	40	
Technical student (six months)	20	
Upgrade of beam data acquisition system	20	
	TOT	205 KSF

Project:

Production of GMSC plates on glass	30	
Development of GMSC on plastics	30	
Special Glasses and polymers	20	
Consumables	15	
Special electronics, connectors	15	
Pool rentals (CEC for 500 KSF)	20	
	TOT	130 KSF

Year Two

DRD Support:

Consumables	50	
Small works	20	
Precision support in magnet	10	
Clean gas bench for beam operation	10	
Maintenance, rentals	10	
Project Related travel	10	
Per-diem for collaborators (two man-year)	80	
Technical student (six months)	20	
	TOT	210 KSF

Project:

Industrial production of resistive substrata	20	
Manufacturing of large size GMSC plates	30	
Construction of several prototypes	20	
Consumables	15	
Electronics for prototype GMSC	20	
Pool rentals (CEC for 600 KSF)	25	
	TOT	130 KSF

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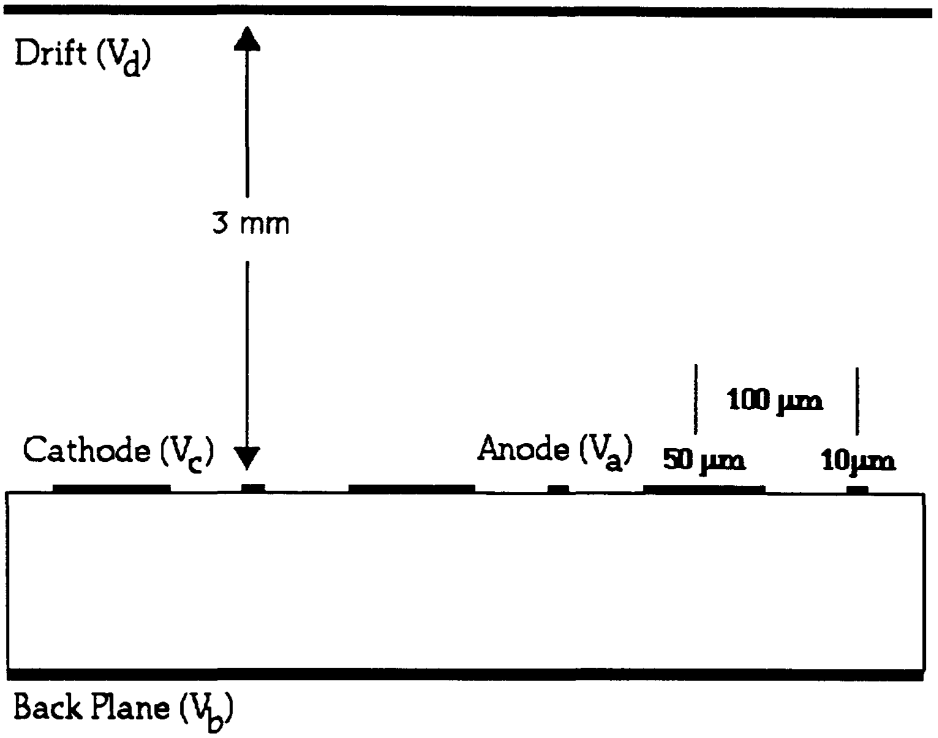

Fig. 1: Schematics of a Micro-Strip Gas Chamber. Thin metal strips, alternatively connected as anodes and cathodes, are laid on an insulating support. Application of suitable potentials result in the collection, amplification an detection of charges released in the drift space.

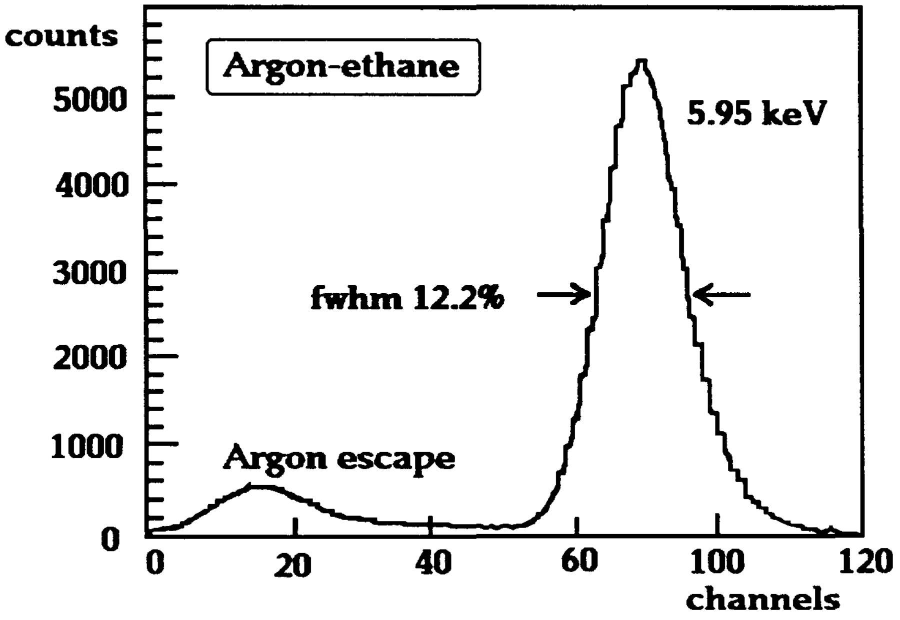

Fig. 2: Energy resolution obtained with a GMSC in the detection of soft x-rays

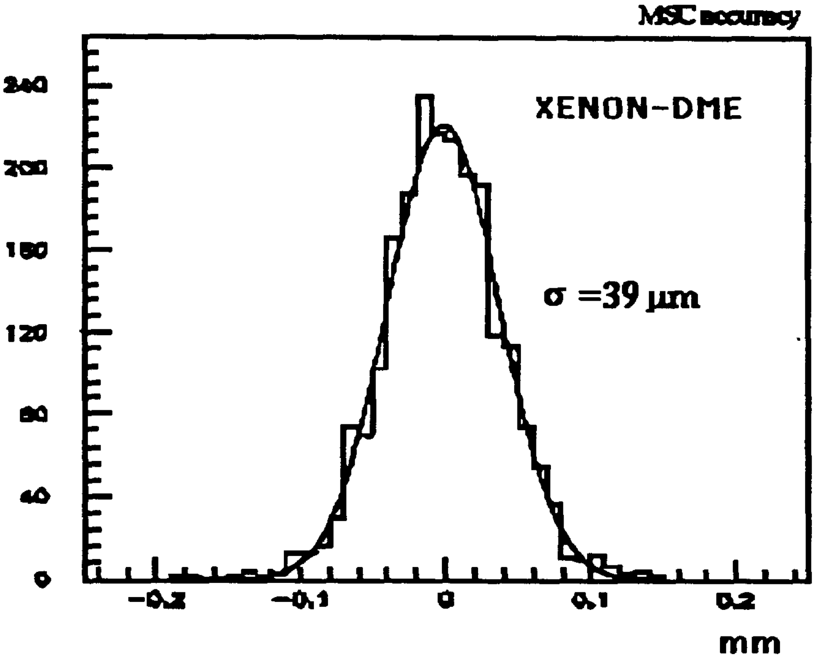

Fig.3: Position accuracy measured with a GMSC with readout of the cathode induced charge for perpendicular minimum ionizing particles.

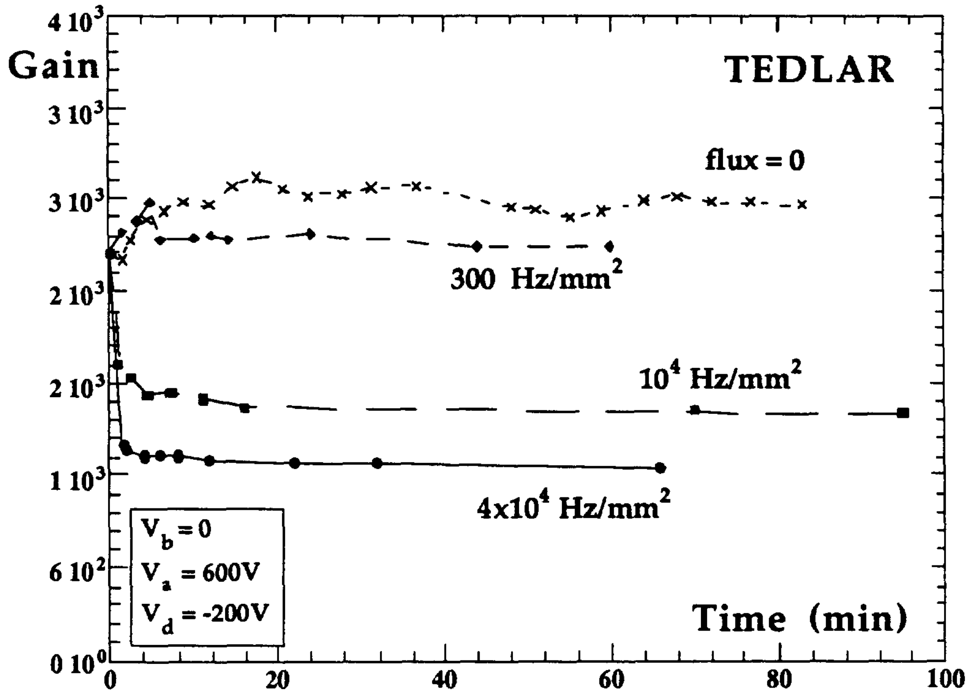

Fig. 4: Modification of gain measured at several radiation fluxes (8 keV x-rays) as a function of time for a GMSC on plastic support (Tedlar, resistivity ~ 10^{14} ohms.cm).

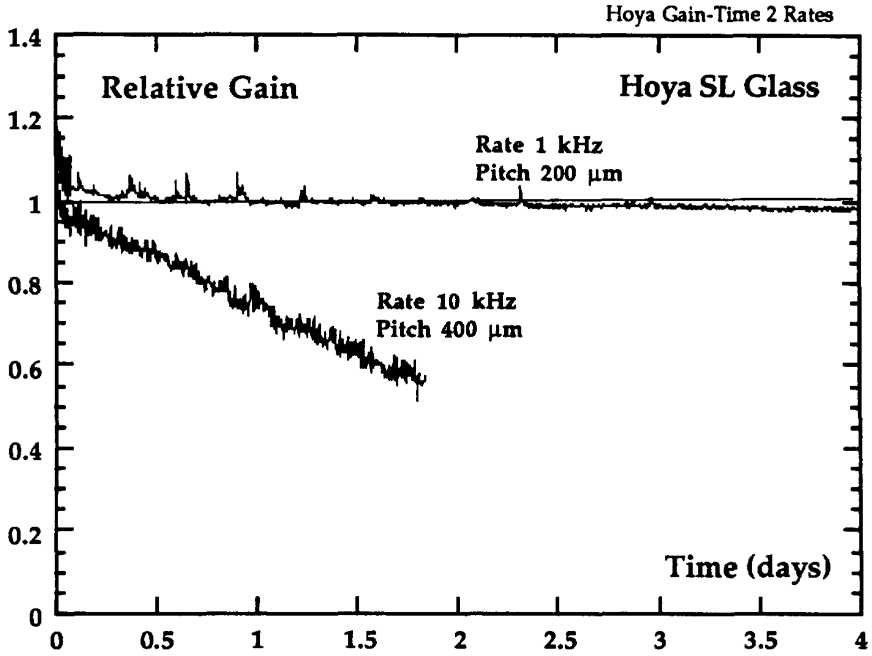

Fig. 5: Relative gain measurement at different rates on soda lime glass support, showing the initial drop due to polarization and the subsequent rate-dependent decrease due to surface charging up.

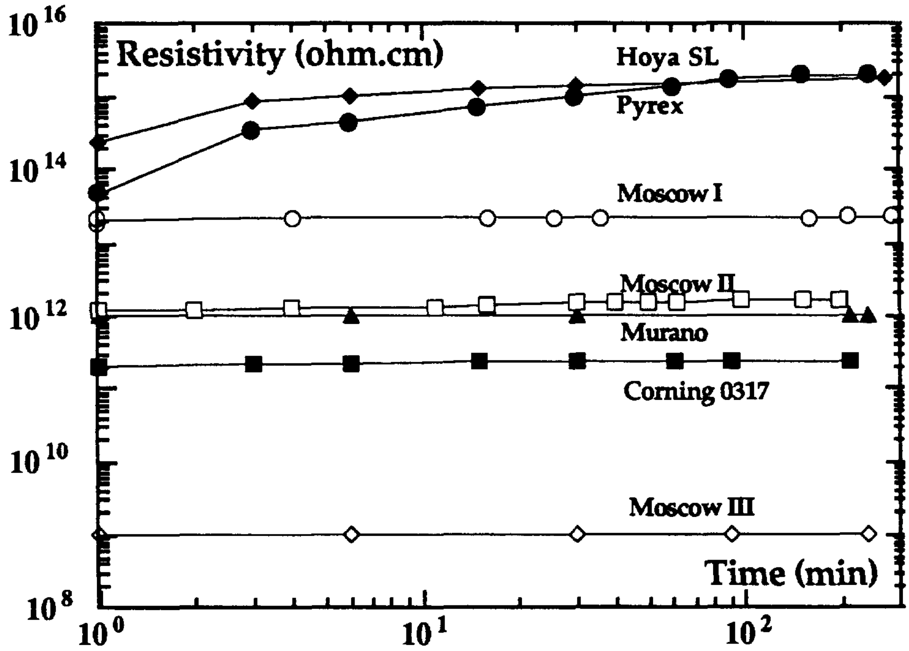

Fig. 6: Resistivity of various glasses used in the development of GMSC. A constant resistivity in time, together with an ohmic behavior, indicates electronic as against ionic conductivity.

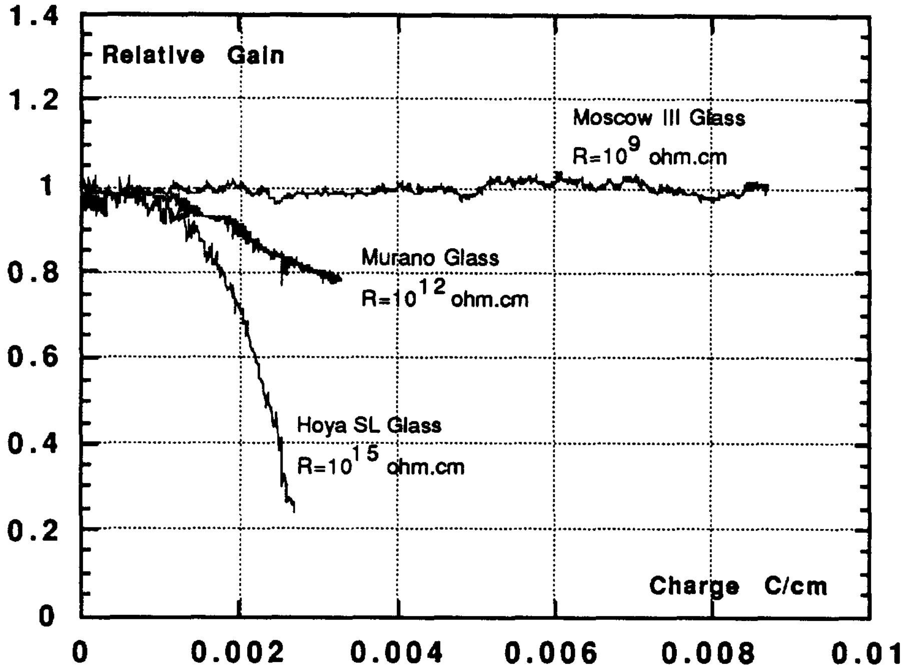

Fig. 7: Long-term gain measurements for GMSC realized on glass supports of different resistivity. For all measurements, the radiation flux was 2.10^4 /mm^2.s of 8 keV x rays.

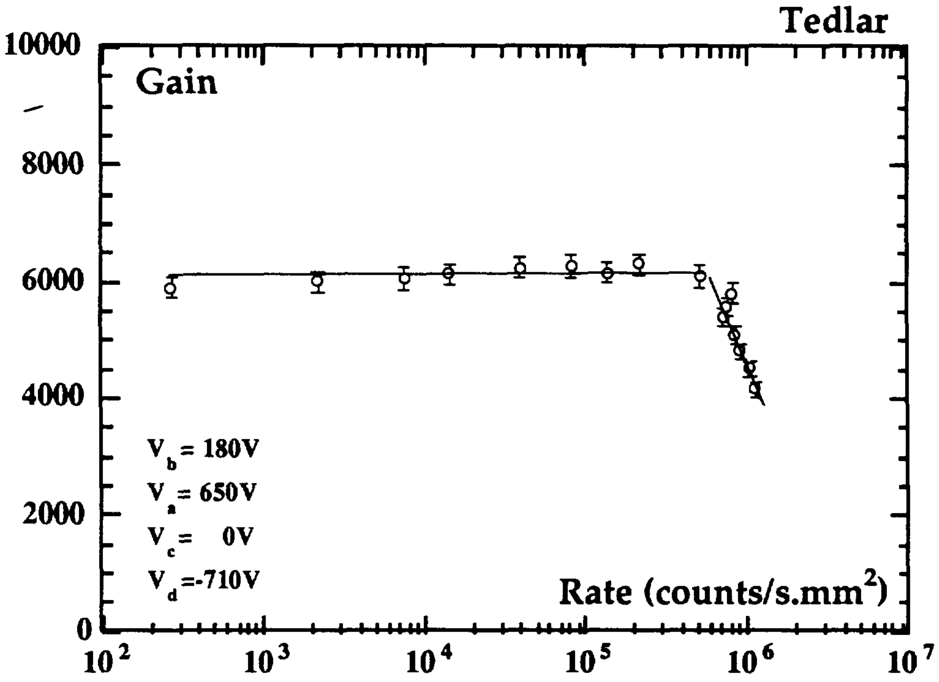

Fig. 8: Intrinsic rate capability of GMSC: short-term gain dependence from rate, measured with a Tedlar GMSC. The duration of the exposure prevents surface charging phenomena.

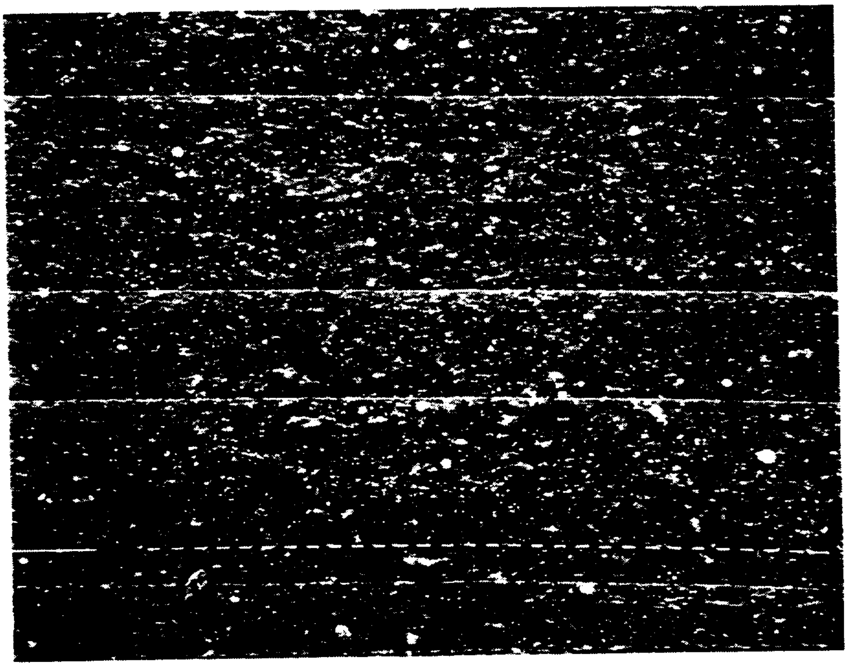

Fig. 9: Micro-photography of a GMSC realized by high-quality etching on plastic support.

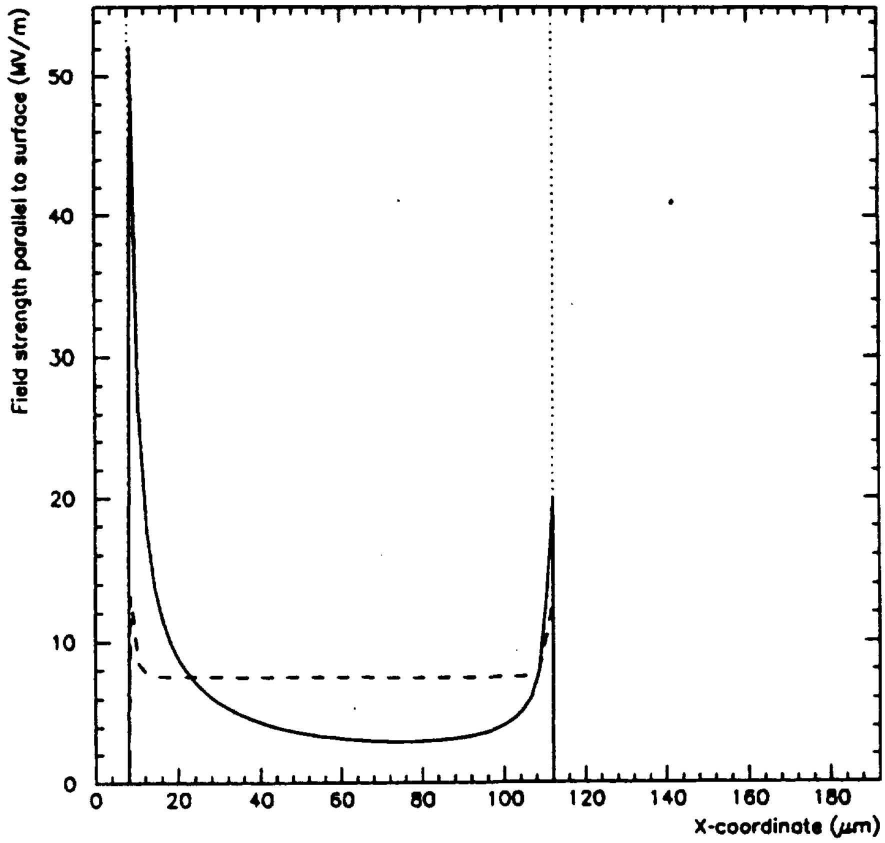

Fig. 10: Comparison of the electric field close to the surface between anode and cathode strips computed for a bulk conductivity support (full curve) and an equivalent thin-layer surface conductivity support (dashed line).

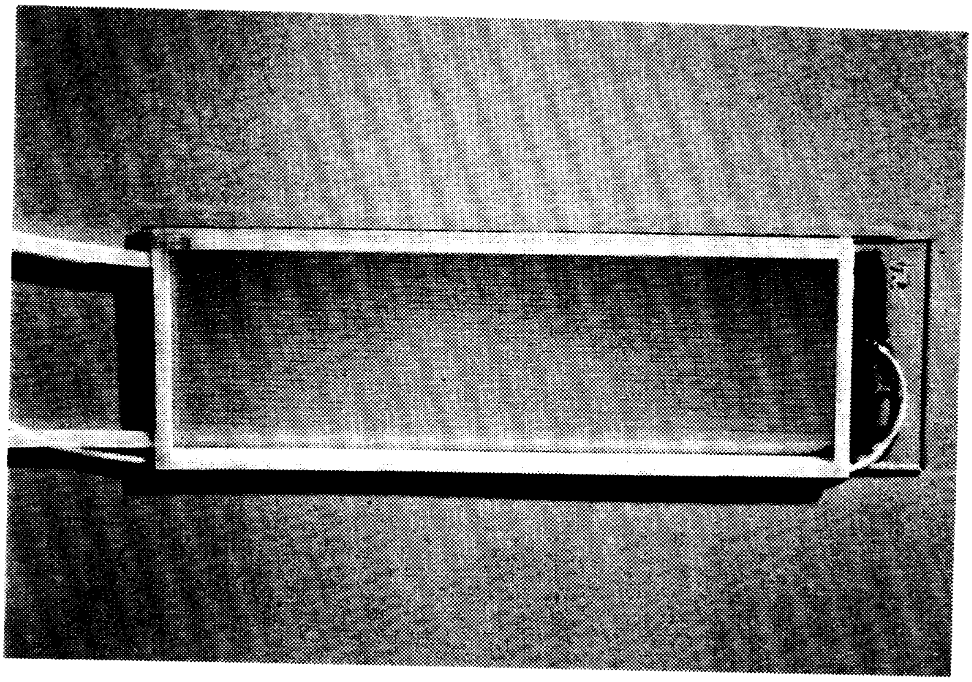

Fig. 11: A prototype GMSC realized by the DRD group. Thin fibreglass frames are glued directly on the glass substratum and hold the drift electrode and window (a mylar foil conductive on the side facing the microstrips).

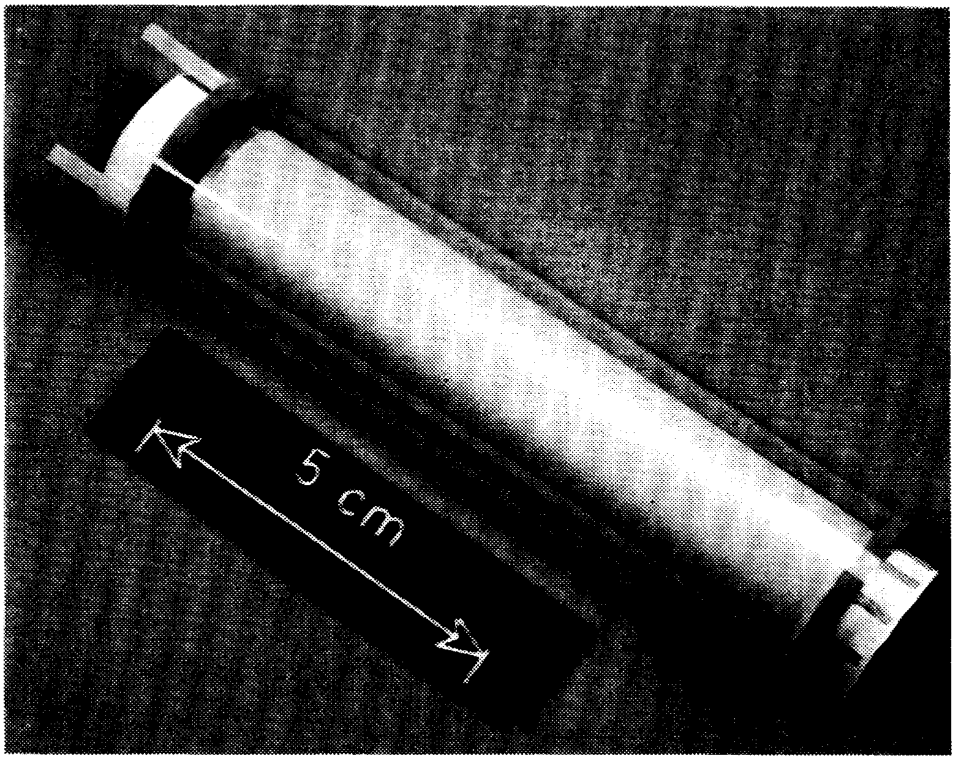

Fig. 12: A cylindrical detector realized with a GMSC plate etched on a 100 μm thick plastic substratum.

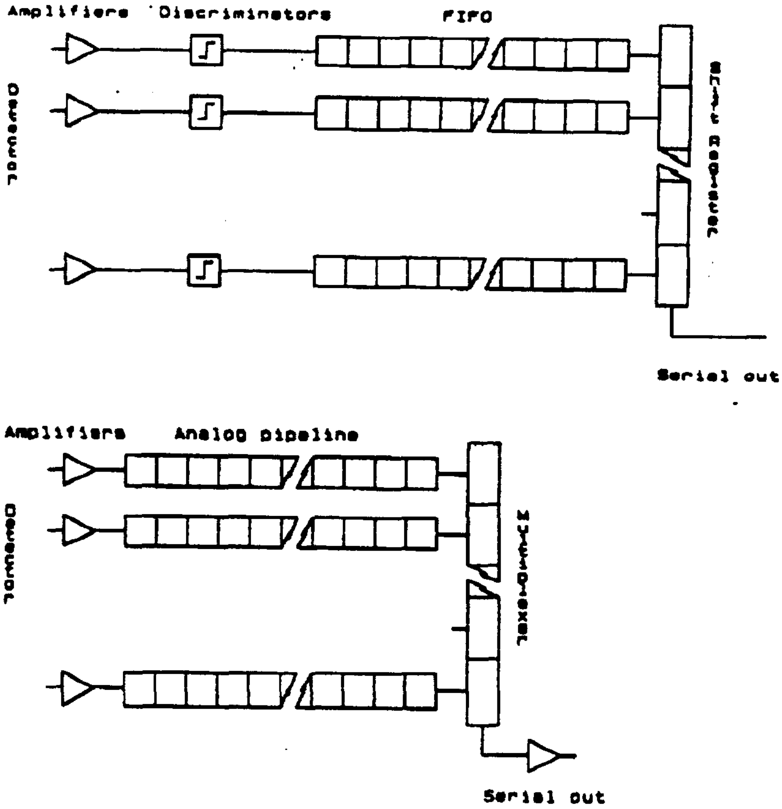

Fig. 13: Schematics of a digital strip count (a) and analogue charge storage (b) readout for GMSC suited for high rate applications.

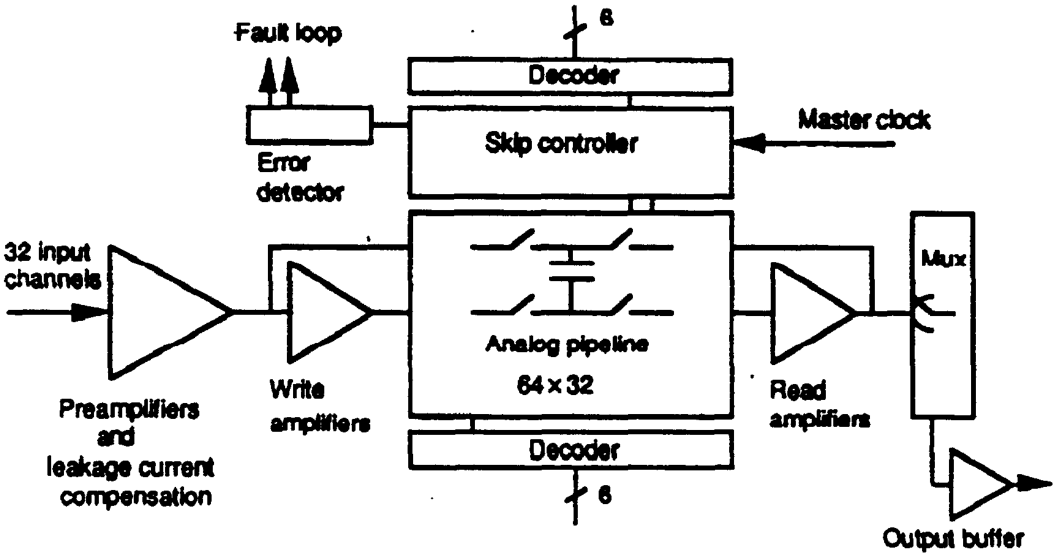

Fig. 14: Schematics of the analog memory circuit developed by the RD-2 collaboration. The circuits' characteristics are well suited for fast recording of induced cathode signals in GMSC.