Brief (not comprehensive) history of Parallel Plate Detectors

THE REVIEW OF SCIENTIFIC INSTRUMENTS VOLUME 20, NUMBER 3 MARCH, 1949

Parallel-Plate Counters

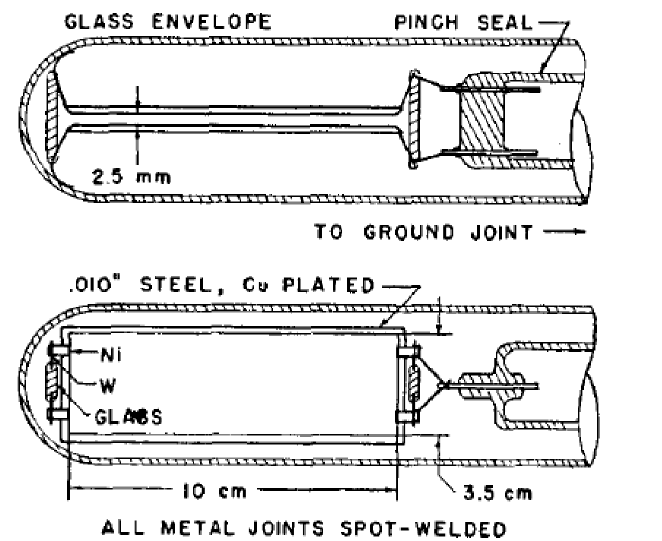
J. WARREN KEUFFEL*
California Institute of Technology, Pasadena, California
(Received November 8, 1948)

The counter characteristics of a discharge tube using plane-parallel electrodes have been investigated, particularly with regard to the short time lags inherent in the streamer type of spark which occur with such a geometry at near-atmospheric pressure. Construction details for parallel-plate counters with good counter characteristics are given. Spurious counts were minimized by an argon-xylene filling mixture and the use of a univibrator quench circuit. The uncertainty in the reaction time of the counters is $\pm 5\times 10^{-9}$ sec.

Parallel Plate Counters

First experimental counter consisted of molybdenum disks with a 3 mm gap and 3.1 cm² area

- rectangular electrodes: Cu (35 cm²)
- 2.5 mm gap
- E ≈ 800 -1200 V/mm
- eff > 90%
- lifetime : two months (spot burns)
- signal amplitude: 100 V
- FWHM: 3-8 ns
- gas: Xylene / Ar ½ Atm
- external quenching circuit→ 50 ms



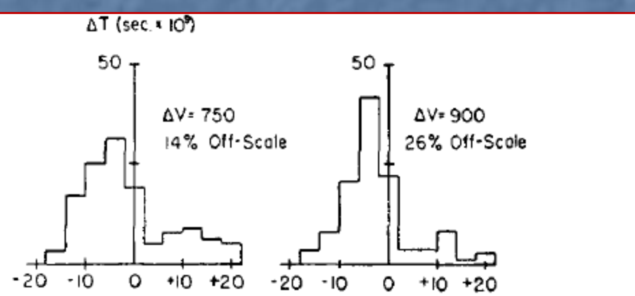


FIG. 5. Distribution of relative lags between two counters tripped simultaneously by a cosmic-ray particle. A relative lag is "off scale" if it lies outside the chronotron range, -20×10^{-9} to $+16\times 10^{-9}$ sec. Distributions are given for four different overvoltages, ΔV.

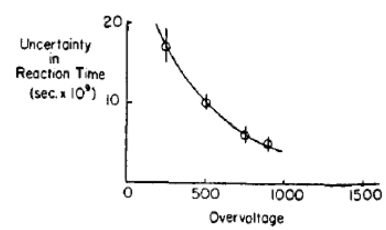


FIG. 6. Uncertainty in the reaction time, $\langle\Delta T\rangle$, as a function of overvoltage. Half the relative lags of two counters tripped simultaneously fall between $\pm\langle\Delta T\rangle$ of the center of the distribution. Data from Fig. 5.

1948 J.W. Keuffel
Rev. of Sci. Instrum. 20 (1949) , 202

PHYSICAL REVIEW VOLUME 75, NUMBER 8 APRIL 15, 1949

Some Properties of the Parallel Plate Spark Counter I

R. W. PIDD AND LEON MADANSKY
Department of Physics, The Johns Hopkins University, Baltimore, Maryland
(Received October 25, 1948)

A parallel plate spark counter was constructed to provide a uniformly sensitive avalanche volume for the detection of ionizing radiation. It is shown that such a counter avoids the random delay errors inherent in counters with cylindrical geometry.

The spark counter provides a pulse of several hundred volts with a rise time of $3\cdot10^{-9}$ second, requiring no additional amplification for detection. The recovery times show a marked dependence on the cathode material and, while they may be several seconds long for some materials, recovery times of the order of one millisecond have been obtained with the use of lead and tin cathodes.

The problem of high resolution counting and also the problem of reducing the recovery time in spark counters is discussed.

QUENCHING

The quenching problem can be stated as follows: How soon can the overvoltage be restored after a spark discharge without causing a spurious counter breakdown? The time during which the overvoltage is removed from the counter is called the quench time or the dead time. Only quench times shorter than several seconds have been investigated, and in this range it has not been possible to quench the counter unless a 10 percent partial pressure of butane is added to the argon gas. With this gas mixture the counter can be quenched with an external resistor or an electronic quench circuit. The quench times then vary from several seconds to a millisecond depending on the cathode metal used in the counter.

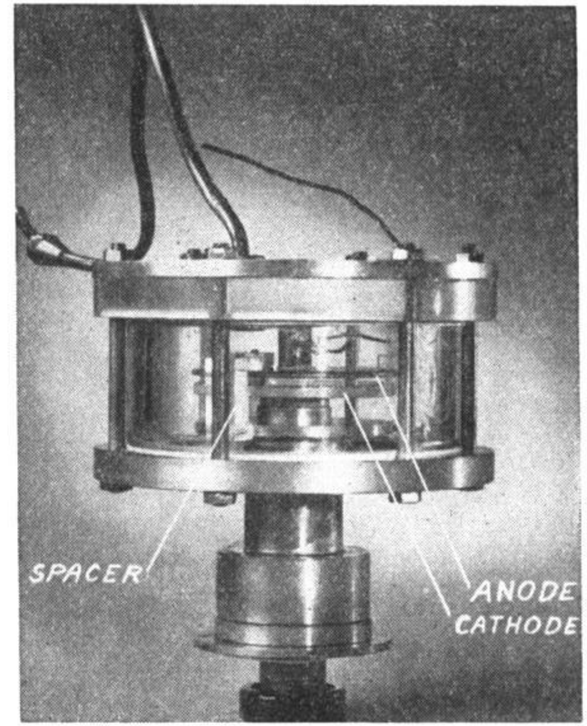


FIG. 2. Parallel plate counter with variable spacing.

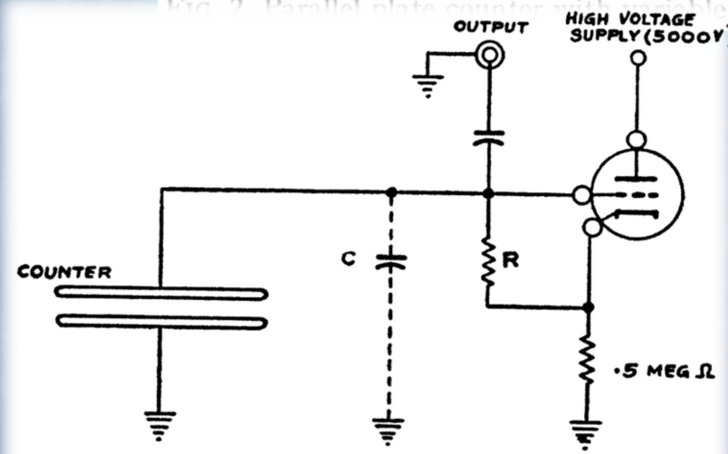


FIG. 4. Schematic diagram of quench circuit.

1949 R.W. Pidd , L. Madansky
Phys. Rev. 75 (1949) , 1175

Spark Counters

[3]
3.1 F. Bella and C. Franzinetti: "On the Theory of the Spark Counter," Nuovo Cimento **10**, 1335-1337 (1953).
3.2 F. Bella, C. Franzinetti and D. W. Lee: "On Spark Counter," Nuovo Cimento **10**, 1338-1340 (1953).
3.3 F. Bella and C. Franzinetti: "Spark Counters," Nuovo Cimento **10**, 1461-1479 (1953).

[8]
8.1 S. Fukui and S. Miyamoto: "A Study of the Hodoscope Chamber," INS-TCA-10 (1957). (INS is the abbreviation of the Institute for Nuclear Study, University of Tokyo.).
8.2 S. Fukui and S. Miyamoto: "A New Type of Particle Detector: The Discharge Chamber," Nuovo Cimento **11**, 113-115 (1959).

The starting point for the development of the new technique was the observation of Gozzini in 1954 that a neon bulb, which is known to glow when placed near an ordinary radiowave (RF) transmitter if RF emission is actually occurring, does not glow at all if the bulb is kept in the dark and irradiated by the short (1 μs), high power (1 MW), single RF pulse emitted from a radar system; whereas it glows again if it is illuminated, even when irradiated by a similar pulse of a much lower power.

When discussing this, Gozzini and I reached the conclusion that in the absence of light, and therefore of photoelectric emission from the body of the bulb, no free electron was present among the $\simeq 10^{20}$ neon atoms filling the bulb, unless some ionizing particle had crossed the gas just before or during the 1 μs radar pulse. (Of course the luminous electric discharge of the glowing bulb is always initiated by some free electrons strongly accelerated by the intense electric field.)

We then thought that a new type of detector of particle tracks, characterized by an unprecedently high over-all space-time resolution, could be realized by stacking a large number of thin, wireless neon tubes covered with black paper for light screening, and subjecting them to an intense impulsive electric field, applied immediately after the passage of the particles to be detected.

(...)

We quickly constructed and assembled all that was needed to test our idea in particular using for the high voltage pulse generator two pulse transformers of a radar modulator providing rectangular pulses of up to 20 kVolt, 2 μs duration. (...)

M. Conversi: "The Development of the Flash and Spark Chambers in the 1950s," Journ. de Phys. **43** Colloque C-8, 91-99(1982) in the Proceedings of International Colloquium on *History of Particle Physics*, July 21-23, 1982, Paris, Journ. de Phys. **43** C-8, 1-493 (1982)

IL NUOVO CIMENTO Vol. II, N. 1 1° Luglio 1955

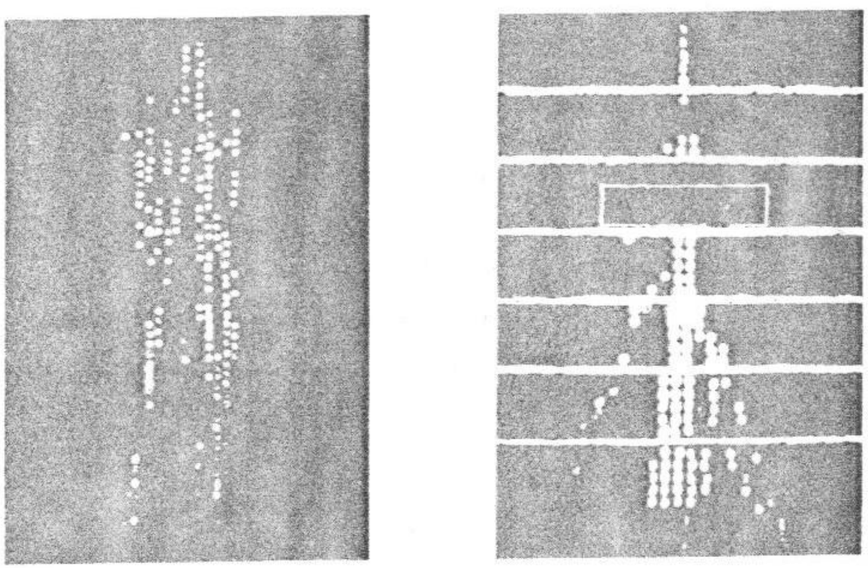
The " Hodoscope Chamber ,,: a New Instrument for Nuclear Research (*).

M. Conversi and A. Gozzini
Istituto di Fisica dell'Università - Pisa
Istituto Nazionale di Fisica Nucleare - Gruppo Aggregato di Pisa

(ricevuto il 17 Giugno 1955)

"Hodoscope Chambers"

- series of parallel plate (Al) (22x 44 cm2) with in between glass tubes (ʘ=0.65 cm , l= 21.5 cm) filled with Neon (350 mmHg)
- $\varepsilon > 95$ % $\varepsilon = f(\tau, gas, E, p)$
- Recovery time: 100 ms
- Possibility of particle tracking



C D

Evolution in '70s "Flash Chambers": glass tubes substituted with cells made by plastic materials (estruded polypropilene)- honeycomb

1955 M.Conversi, A. Gozzini
Il Nuovo Cimento, 2 (1955), 189

NUCLEAR INSTRUMENTS AND METHODS 93 (1971) 269–270; © NORTH-HOLLAND PUBLISHING CO.

A SPARK COUNTER WITH LARGE AREA

V. V. PARKHOMCHUCK, YU. N. PESTOV and N. V. PETROVYKH

Institute of Nuclear Physics, USSR Academy of Sciences, Siberian Division, USSR

Received 21 December 1970

It is shown that spark counters with electrodes of an unlimited area and with time resolution better than 1 nsec with high charged-particle-detection efficiency may be constructed, if one of the electrodes is made of high-resistive material.

Based upon an idea introduced by M.V. Babykin et al (Sov. Jour. of Atomic En. VI (1956), 487) and is part of a series of studies made by different groups in Novosibirsk.

- High resistive material (glass - 10^9-10^{10} Ω cm) for one of the electrodes (the other made of Cu)
- Only a limited region around the discharge is interested to the process itself and only this region remains inactive during the time of electric field recovery
- gap: 0.1 cm 55% Ar 30% Ether 10% Air 5% Divinile (1 Atm)
- Signal amplitude: 2V
- Time resolution FWHM: 0.95 ns

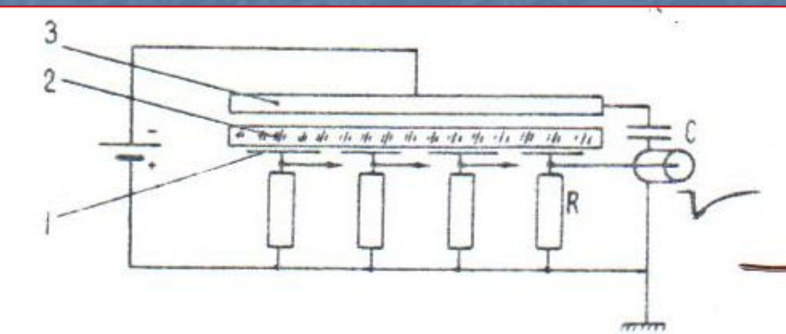


Fig. 1. The principal experimental lay-out. 1. Conductive layer; 2. electrode of semiconductive glass; 3. copper electrode.

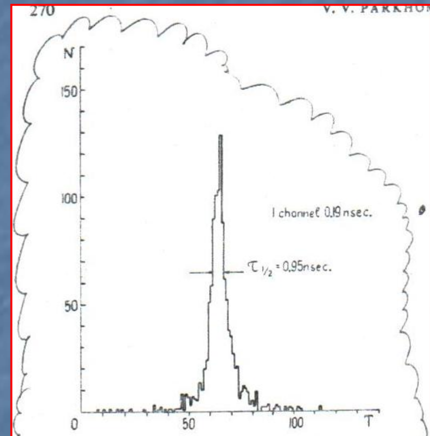


Fig. 4. The histogram of pulse time distribution for two counters.

area which is discharged during the breakdown time was determined by the pulse-amplitude spectrum from cosmic rays. Its averaged value is 5 cm², if the applied voltage is 1.4 times higher than the threshold value (see fig. 3). The mean pulse amplitude was about 2 V on a 50 Ω load.

1971 V.V. Parkhomchuck, Yu. N. Pestov, N.V. Petrovikh
Nucl. Instr. Meth. , 93 (1971) , 269

Evolution in ‘80s : “Planar Spark Chamber” PSC. Aimed to ameliorate $\sigma(t)$;

- High pressure (12 Atm)
- Small gaps (100 um – 1mm)
- High Electric Field (200-600 kV/cm)

$\sigma(t)$ = 10 – 200 ps

Russian Groups

DEVELOPMENT OF RESISTIVE PLATE COUNTERS

R. SANTONICO and R. CARDARELLI

Istituto di Fisica dell'Università di Roma, Roma, Italy; Istituto Nazionale di Fisica Nucleare, Sezione di Roma, Italy

Received 12 January 1981

A dc operated particle detector has been developed and tested, whose constituent elements are two parallel electrode bakelite plates between which, in a 1.5 mm gap, a gas mixture of argon and butane at ordinary pressure is circulated. The counter has 97% efficiency and ~1 ns time resolution at an operating voltage of about 10 kV. The output pulse needs no amplification, being typically 300 mV over 25 Ω.

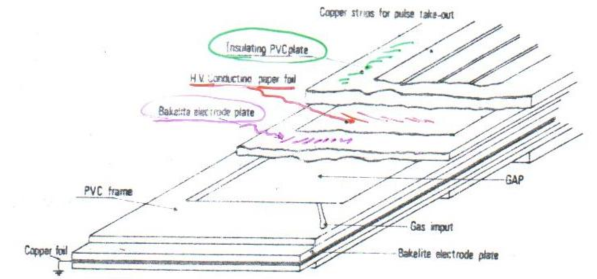
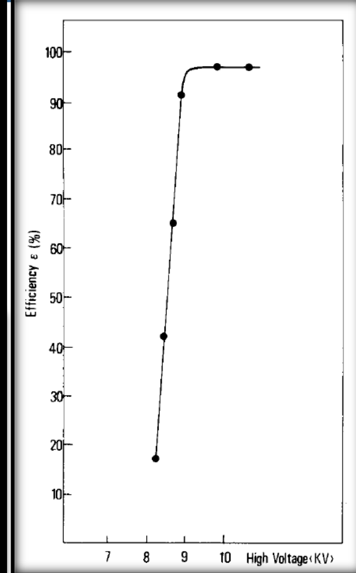


Fig. 1. Sketch of the RPC. The prototype shown consists of two identical counters which are rigidly superposed on one another and have the same copper foil as common ground plate. The experimentation reported refers to only one of them.

Resistive Plate Counter – RPC

- Atmosferic pressure
- plastic material for both electrodes (phenolic resin) : High Pressure Laminates
- $\rho = 10^{10}$-10^{12} Ωcm
- eff > 97%
- gas mixture: 1/3 Ar, ½ Butano
- gap: 1.5 mm
- $\sigma(t)$ = 1 ns



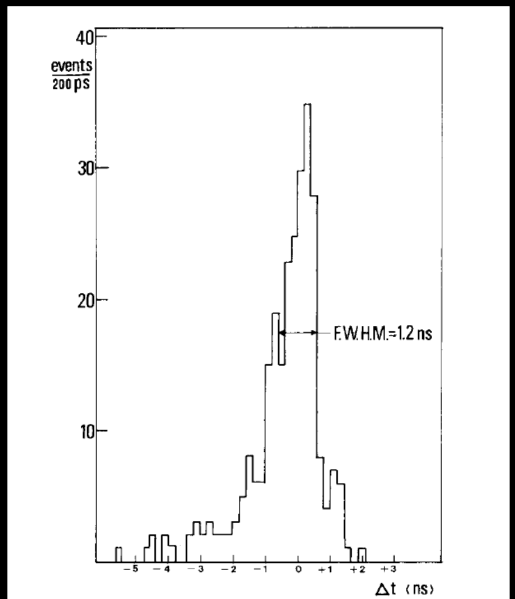


Fig. 5. Distribution of the relative delay Δt between the RPC and a small scintillation counter (T4) viewed by an XP 2020 photomultiplier. The fwhm of the distribution is 1.2 ns. The short tail on the left originates from delayed pulses of the RPC.

1981 R. Santonico, R. Cardarelli
Nucl. Instr. Meth. , 187 (1981) , 377

A new type of resistive plate chamber: The multigap RPC

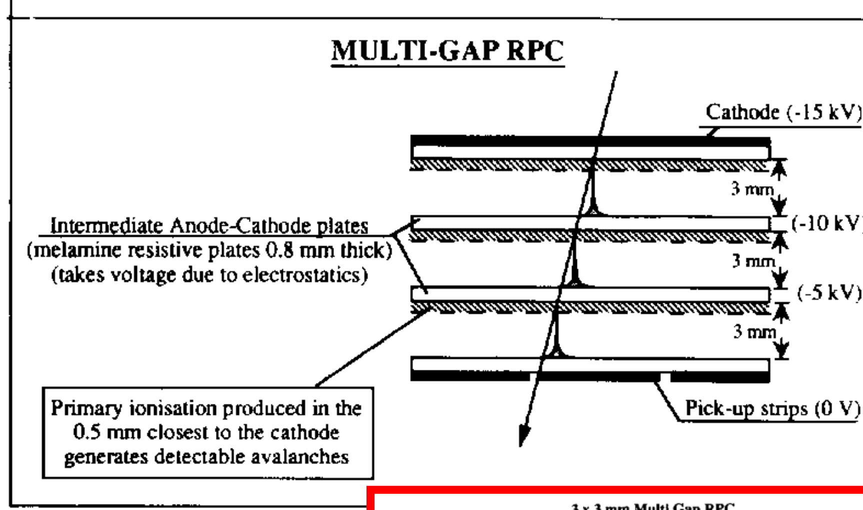
E. Cerron Zeballos [a,b], I. Crotty [a], D. Hatzifotiadou [a,b], J. Lamas Valverde [a,b,c], S. Neupane [a,b], M.C.S. Williams [a,*], A. Zichichi [d]

[a] LAA project, CERN, Geneva, Switzerland
[b] World Laboratory, Lausanne, Switzerland
[c] University Louis Pasteur, Strasbourg, France
[d] University of Bologna and INFN, Bologna, Italy

Received 30 November 1995

Abstract

This Letter describes the multigap resistive plate chamber (RPC). The goal is to obtain a much improved time resolution keeping the advantages of the wide gap RPC in comparison with the conventional narrow gap RPC (smaller dynamic range and thus lower charge per avalanche which gives higher rate capability and lower power dissipation in the gas gap).



Multigap- Resistive Plate Counter – MRPC

- Atmosferic pressure
- glass electrodes : $\rho = 10^{11}$-10^{12} Ωcm
- eff > 97%
- gas mixture: Ar, CO_2 C_4F_{10} DME
- gap: 3 mm
- $\sigma(t)$ = 3-4 ns
- High rate capability : KHz/cm^2

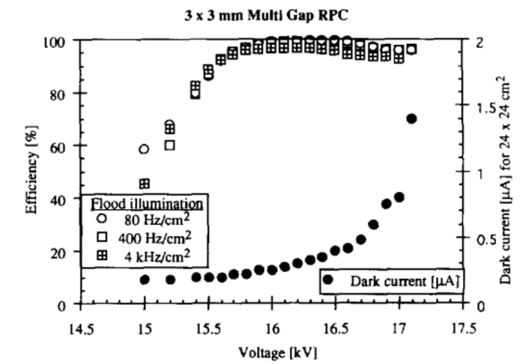


Fig. 2. Efficiency versus high voltage for various fluxes. The beam was defocused, thus the whole active area of the chamber exposed. The gas mixture was 86% argon, 8.5% CO_2, 0.5% C_4F_{10} and 5% DME.

1996 M.C.S Williams et al. , Nucl. Instr. Meth. , 374 (1996) , 132

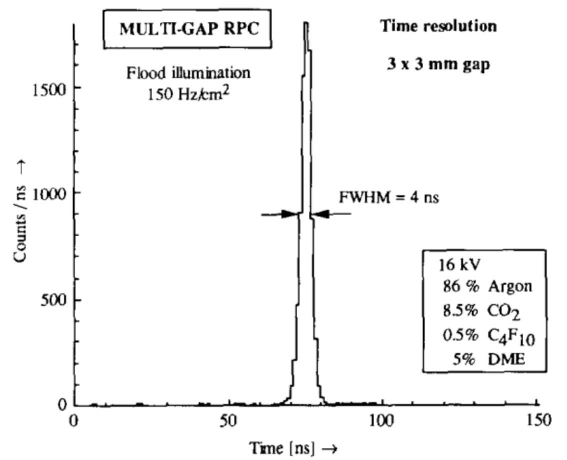
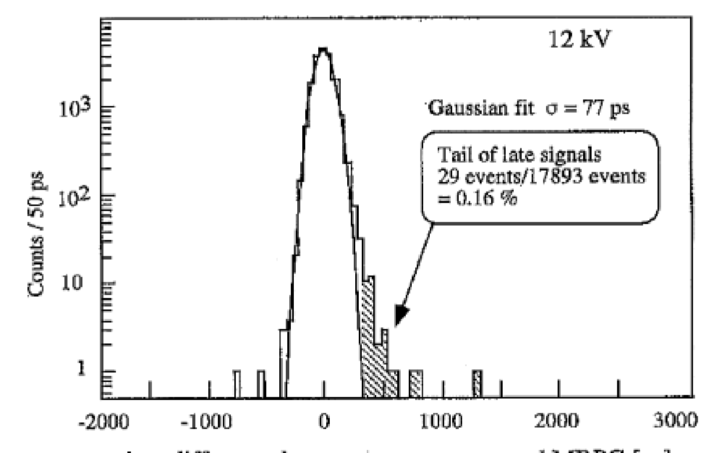


Fig. 3. Time spectra of the average of the leading and trailing edge timing at 16 kV (200 V above the knee of the efficiency plateau).

Reduction of gap size increases the time resolution



Request for

1) good space resolution
2) high rate capability
3) multi-track definition

led to a parallel development of new type of gas multiplication tecniques to ameliorate MWPC:

Micropattern Gas Detectors

POSITION-SENSITIVE DETECTOR WITH MICROSTRIP ANODE FOR ELECTRON MULTIPLICATION WITH GASES *

A. OED

Institut Laue-Langevin, 156 X, 38042 Grenoble Cedex, France

Received 2 December 1986 and in revised form 1 July 1987

A position-sensitive detector of a new type has been developed. A microstrip anode replaces the wires generally used for electron multiplication with gases. The microstrips which are fixed on a glass substrate are produced by means of photolithography. The applied electric potential alternates between each strip. With a position-sensitive neutron detector equipped with this new type of anode a counting rate of 2.3 MHz/cm^2 has been measured. The microstrip anode combines the improved qualities of a proportional counter with certain properties of a photomultiplier tube.

MSGC

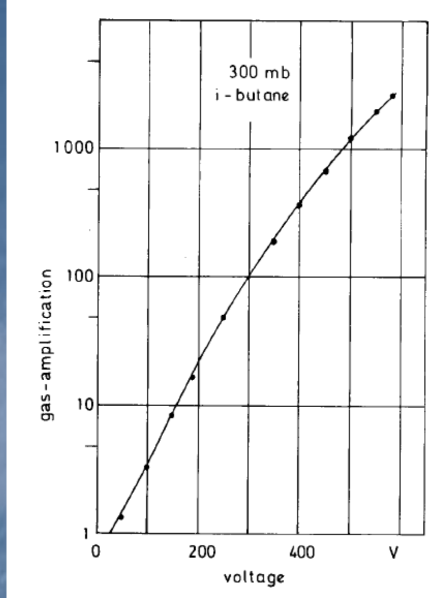
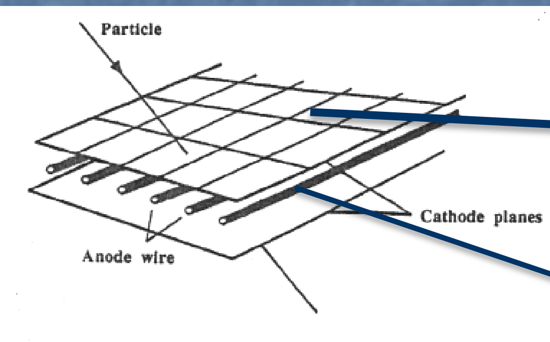


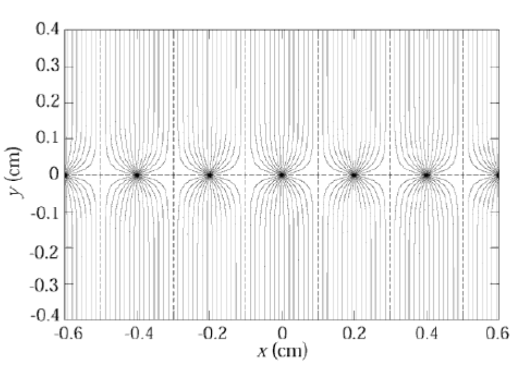
Fig. 4. Gas amplification factor as a function of the applied voltage. The curve was registered with the alpha-particles of a ^{252}Cf source at 300 mbar isobutane as counting gas.

The electric field is now generated between microstrips lines (anodes) and metal cathodes deposited on a substrate.

1988 A. Oed ,
Nucl. Instr. Meth. , A263 (1988) , 351

MWPC





MSGC

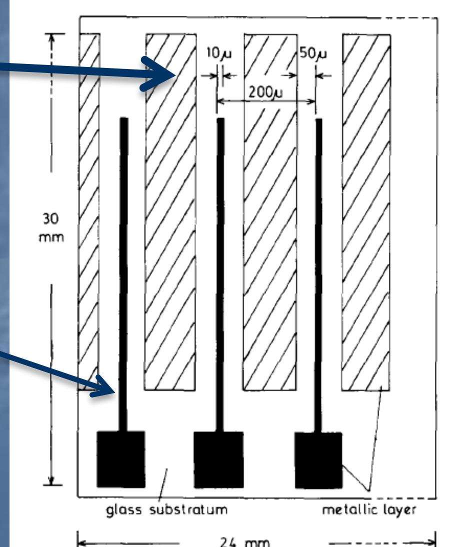


Fig. 1. Dimensions of the microstrip plate (MS-plate) used for the measurements. The chromium layer on the glass substrate is 300 nm in thickness.

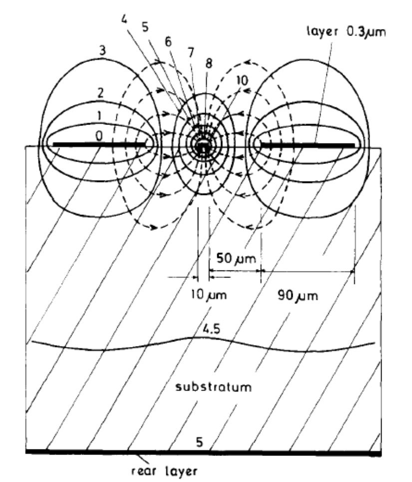


Fig. 2. Measured equipotential lines (continuous line) and approximate electric field lines of the MS-plate (dashed line). The rear layer of the plate is at half the potential of the 10 μm strips.

MICROMEGAS: a high-granularity position-sensitive gaseous detector for high particle-flux environments

Y. Giomataris[a,*], Ph. Rebourgeard[a], J.P. Robert[a], G. Charpak[b]

[a] CEA/DSM/DAPNIA/SED-C.E.-Saclay, 91191 Gif/Yvette, France
[b] Ecole Superieure de Physique et Chimie Industrielle de la ville de Paris, ESPECI, Paris, ESPCI, Paris, France and CERN/AT, Geneva, Switzerland

Received 24 January 1996

Abstract

We describe a novel structure for a gaseous detector that is under development at Saclay. It consists of a two-stage parallel-plate avalanche chamber of small amplification gap (100 μm) combined with a conversion-drift space. It follows a fast removal of positive ions produced during the avalanche development. Fast signals (≤1 ns) are obtained during the collection of the electron avalanche on the anode microstrip plane. The positive ion signal has a duration of 100 ns. The fast evacuation of positive ions combined with the high granularity of the detector provide a high rate capability. Gas gains of up to 10^5 have been achieved.

MicroMesh

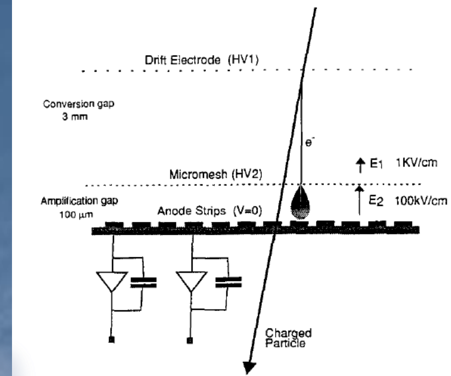


Fig. 1. A schematic view of MICROMEGAS: the 3 mm conversion gap and the amplification gap separated by the micromesh and the anode strip electrode.

The (multiplication) electric field is now generated between a micromesh plate (cathode) and metal anode strips deposited on a substrate. A drift field is

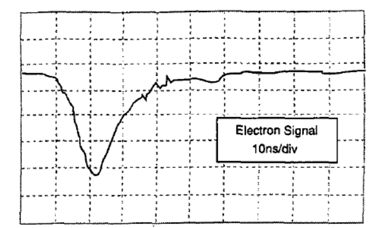
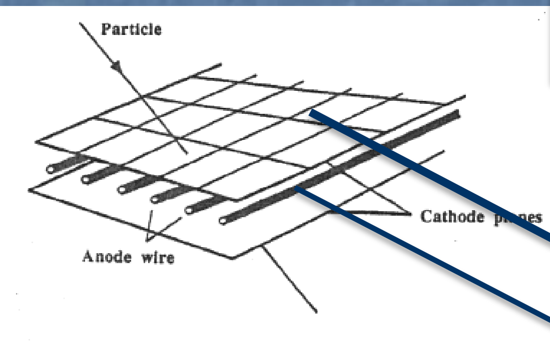
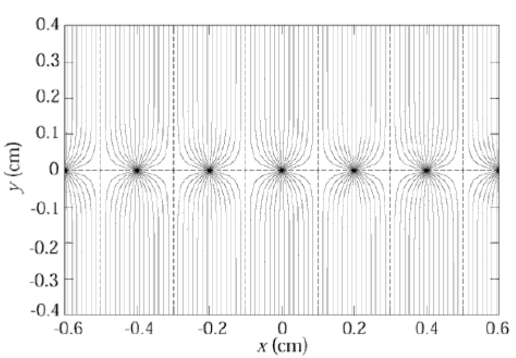


Fig. 8. Fast signal measured on the anode using a fast-current preamplifier.

MWPC

1996 Y. Giomataris et al.,
Nucl. Instr. Meth. , A376 (1996) , 29





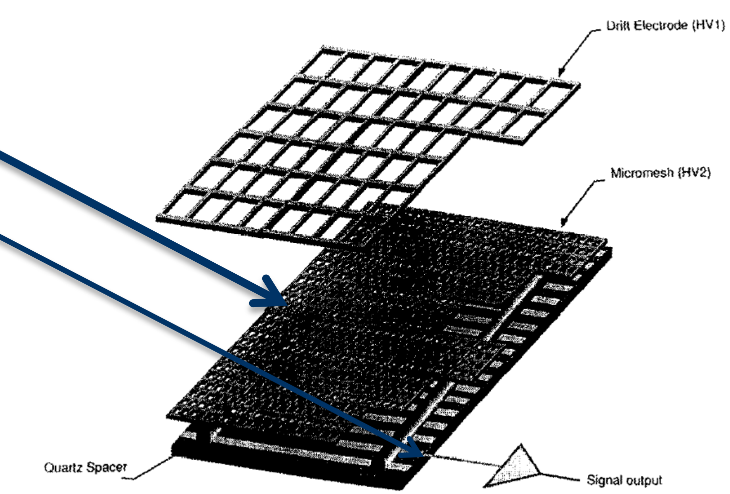


Fig. 3. A three-dimensional view of the detector elements.

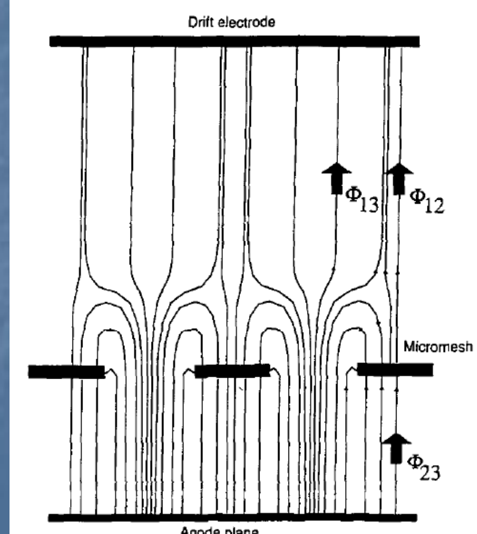


Fig. 11. Electric field configuration and partial flows.

GEM: A new concept for electron amplification in gas detectors

F. Sauli

CERN, CH-1211 Genève, Switzerland

Received 6 November 1996

Abstract

We introduce the gas electrons multiplier (GEM), a composite grid consisting of two metal layers separated by a thin insulator, etched with a regular matrix of open channels. A GEM grid with the electrodes kept at a suitable difference of potential, inserted in a gas detector on the path of drifting electrons, allows to pre-amplify the charge drifting through the channels. Coupled to other devices, multiwire or microstrip chambers, it permits to obtain higher gains, or to operate in less critical conditions. The separation of sensitive and detection volumes offers other advantages: a built-in delay, a strong suppression of photon feedback. Applications are foreseen in high rate tracking and Cherenkov Ring Imaging detectors. Multiple GEM grids assembled in the same gas volume allow to obtain large effective amplification factors in a succession of steps.

Gas Electron Multipliers

- **gain > 10^5**
- **Energy resolution 18% FWHM at 5.9 keV**
- **Space localization accuracy 60μm rms**
- **Rate capability > 10^5 counts/mm²sec**

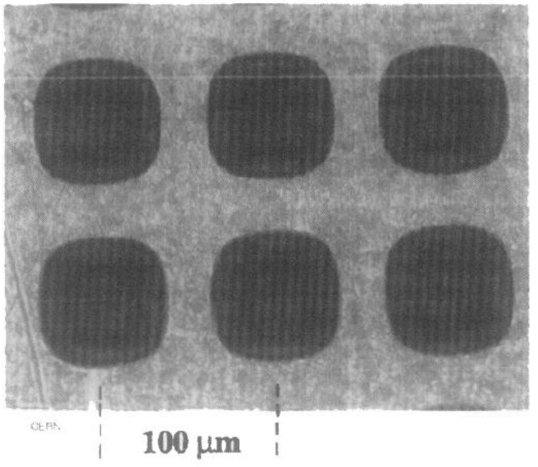
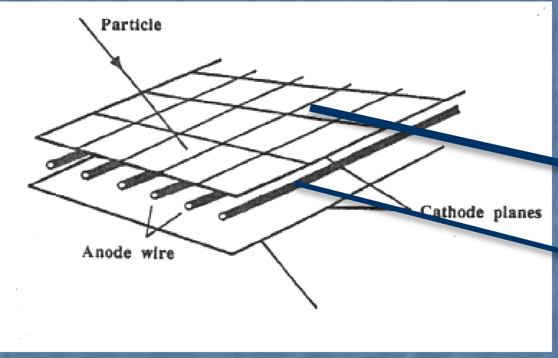


Fig. 1. Microphotography of the three-layer (metal–insulator–metal) GEM grid. The open channels diameter at the surface is 70 μm, with 100 μm distance.



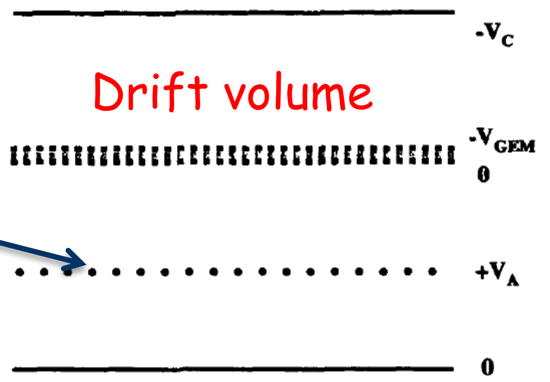
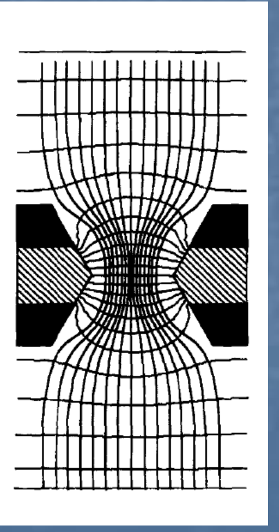
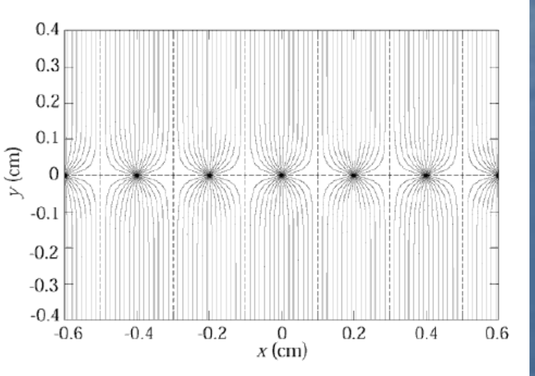


Fig. 3. Schematics of the test chamber used for the measurements. The GEM grid is installed replacing one cathode of a standard MWPC, and a drift volume is added.





1997 F. Sauli
Nucl. Instr. Meth. ,A 386 (1997) , 531