DEVELOPMENT OF A 150 m² PROPORTIONAL CHAMBER SYSTEM WITH A 1 MILLION BIT BUFFER

The EMI for BEBC


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For the identification of muons behind the Big European Bubble Chamber (BEBC) a detector wall of 6 m x 25 m is required. We describe the construction of the wire chambers, the electronics and the performance of the first chambers. The 50 modular 3 m x 1 m chambers contain 75 000 wires and 10 000 cathode strips, grouped into 20 000 electronic channels to give a variable space resolution. Geometrical acceptance is maximized by the suppression of support lines and spacers. The electronics can buffer up to 1023 events without dead time losses and without limitation on the number of hits per event. Ar/CO₂ mixtures have given good results.

1. Introduction

Experiments with the CERN SPS require a detector downstream from BEBC for identification of muons, originating from neutrino or hadron interactions in the bubble chamber. The external muon identifier (EMI) under construction is based on track reconstruction techniques. It uses the principle that after several interaction lengths of absorber only muons will remain close to the extrapolated track. The EMI consists of an additional iron filter and a semi-circular detector wall (6 m high and 25 m wide) behind BEBC (see fig. 1). The trajectories in the bubble chamber are projected through the filter up to the detector wall to give extrapolated crossing points. If a hit is actually found within some multiple scattering circle around one of these crossing points, the track is considered to stem from a muon.

The high background is a problem. Although only one neutrino event is expected in the hydrogen fiducial volume for every 4 photos, there will be several hundred particles per beam spill hitting the EMI. This background is due to muons from the filter upstream from BEBC, to interactions of neutrinos in the material of the BEBC structure and to cosmic rays. Separation of the background from the wanted events is only possible off-line using the bubble chamber film. To allow the EMI to separate and register the high number of background hits, a long beam spill of 2 ms is foreseen.

The detector should:

a) be self-triggering, since the large dimensions make additional trigger counters impractical;

b) separate and register several hundred events

Fig. 1. Schematic side and top view of the EMI chamber and absorber arrangement downstream of BEBC.

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during a beam spill of about 2 ms with no restriction on the number of hits per event;
c) not lose any event in the burst;
d) have high geometrical acceptance;
e) have high counting efficiency to allow a reliable point reconstruction and multihit separation with three coordinates;
f) be modular as far as possible, while allowing adjustment to a variable space resolution (± 0.5 cm to ± 3 cm) and variable event rates across the detector;
g) work in the inhomogeneous stray magnetic field from BEBC;
h) be acceptable in the hydrogen safety zone.

To fulfill these requirements a detector consisting of proportional wire chambers was chosen. A single detector plane with read-out of two independent sense wire planes and one or two cathode planes was considered sufficient.

After describing the construction of the detector, we will present the results from testing the first 8 chambers and also a complete electronic read-out and test chain.

2. Chamber construction

2.1. Basic Principles

It was decided to use a single detector plane, both because of the size of the detector (6 m high, 25 m wide) and because little gain was expected from the use of two planes one behind the other. The largest practicable chambers were chosen. Since maximum geometrical acceptance is essential, close packing with sufficient overlap between the chambers and maximum geometric efficiency inside a chamber was required.

To achieve close packing of the chambers a self-supporting structure was preferred to a frame structure. No spacers or support lines for the wires are used, to avoid local losses of efficiency. The self-supporting structure has additional advantages: handling of the chambers is substantially easier (partly due to lower weight) and the realization of readable cathodes becomes simple.

The various sections of the detector will see very different hit rates, from an average of 30/m² per spill in the central part to 1/m² per spill on the outer parts of the detector. They also require different space resolution, namely ±0.5 cm in the central part to ±3 cm outside. We keep the mechanical structure the same for all chambers, and adjust to the varying resolution requirements by coupling different numbers of wires or cathode strips to each electronic channel.

This modularity simplifies the construction and leaves the system adaptable to different space resolution requirements which might arise during future use of the detector.

2.2. General layout

The chambers were designed with an effective area of 1024 × 2996 mm². Each chamber contains two independent anode wire planes at ±30° with respect to the 1 m side (see fig. 2). In addition, two cathode-strip planes are formed at 90° and 0° with respect to the 1 m side. At present, only the 90° plane is read out.

The design is shown in fig. 3. Two 6 cm honeycomb sandwich panels serve as structural elements. They

Fig. 2. Arrangement of anode wires and cathode strips. Schematic view of the disposition of anode wires and cathode strips with respect to each other [(a) not to scale].

Fig. 3. Cross-section of the chamber.
enclose two anode wire gaps, which are separated from each other by a thin (1 cm) aluminium honeycomb sandwich panel. Thin frames glued on top of the panels define the gaps. The wire diameter is 20 \( \mu \text{m} \), the gap 2 \( \times \) 8 mm and the wire separation 4 mm.

Silver strips, painted on the inner surfaces of the 6 cm plates, make cathode read-out possible. The strips parallel to the 3 m edge are cut in the middle and read out to opposite ends.

The high voltage is applied to the wires, which are capacitively coupled to the amplifiers; all other planes are dc coupled to ground.

Frames for the amplifiers and the chamber cables are mounted on three sides of each outer panel. The fourth side is reserved for a possible later reading of the second cathode.

The specific mass of one chamber is 1.3 g/cm\(^2\) over the sensitive area.

Fig. 4 shows two chambers suspended behind BEBC.

### 2.3. Structural sandwich plates

The mechanical stresses of a chamber are taken up by the two outer sandwich panels. It proved easier to obtain the required tolerances for the large panels (3011 \times 1079 mm\(^2\)) with honeycomb core than with foam core. Each panel consists of a 6 cm thick Nomex honeycomb core and two 0.6 mm glassfibre reinforced epoxy skins. Since no manufacturer guaranteed the flatness required, the glueing of the skins to the honeycomb is done at CERN in a temperature and humidity controlled area [(22 \pm 1)°C; 50%]. The sandwich elements are laid on a surface table and covered by a flexible Mylar membrane: partial evacuation of the volume under the membrane results in a uniform pressure on the panel while the glue is curing.

The edges of the panels are filled with a glass microsphere epoxy composition. This light, hard filling protects the sandwich and allows simple mounting of the frames for the electronics, using threaded inserts. It is also used to mould four inserts, for the chamber suspension, into the outside of the panels.

Both surfaces of each panel are sprayed with silver paint, the inside in a strip pattern. Frames, carrying the printed circuits to which the anode wires are soldered, are glued to the inside of the panels.

The design and production tolerances are:

a) **Flatness of the sandwich panels**: the flatness is measured on panels suspended freely, with the 3 m edge vertical. The most important parameter is the curvature along the line of the wires. This sagitta is at maximum 0.1 mm, as measured on 50 panels so far.

b) **Bending due to the gas pressure**: this bending is negligible for overpressures of a few mm water column: 0.1 mm for an overpressure of 1.5 g/cm\(^2\).

c) **Bending moments from the wires**: with a wire tension of 55 g the theoretical sagitta is 0.05 mm. Measurements on panels agree with this value.

d) **Temperature gradients**: the sagitta along the wires is theoretically 0.05 mm/°C. Since the detector zone is not temperature controlled, special care will be taken to avoid temperature gradients greater than 3 °C between the outside and the inside of the chamber.

e) **Frames and circuits**: the total thickness variation of the frames and circuits glued to the panels was

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* Hexcel, Welkenraedt, Belgium (core: 32 kg/m\(^3\)).
† Glue: FX 104 G, Rezolin, France.
+ Rezomix 234GL1, Rezolin, France.
found to be $\pm 0.1$ mm, mainly caused by thickness variation of the printed boards.

To put these tolerances in context note that, with our chamber geometry, a symmetric variation of the gap of 0.2 mm causes a shift of 50 V in the beginning of the efficiency plateau.

2.4. ALUMINIUM SANDWICH PANEL

An aluminum sandwich panel serves as central cathode, separating the two anode wire gaps. In comparison with the alternative wire or foil plane, this self-supporting panel has the advantage of not causing mechanical stresses on the chamber. The problem is to obtain an acceptable flatness.

The sandwich consists of a 1 cm aluminum honeycomb core between two 0.2 mm aluminum skins. The glueing was done at CERN using the same procedure as for the Nomex panels. The same edge filling was used. Frames, with grooves for rubber seals and for gas distribution, are glued to both sides of the panel.

The aluminum sandwich with the frames is flexible enough to follow the shape imposed on the perimeter of the clamped chamber by the two outside Nomex plates. No spacers are used inside the gaps.

The sagitta measured as for the Nomex plates is about 0.1 mm. However, the bending of a plate mounted inside a chamber can only be estimated from efficiency plateau spreads across the two anode planes (see sect. 5.3). Measurements on the first chambers indicate a sagitta of $\lesssim 0.2$ mm along the wires.

The gas is fed in parallel into both chamber gaps from one short edge of the aluminum panel. The outlet is on the opposite edge.

2.5. FRAMES AND CIRCUITS

The frames are machined from glassfibre reinforced epoxy*). FR 4 was chosen as material for the printed circuits because it is self-extinguishing. Using photographic glass plates for the circuit production, a precision of $+0.1$ mm was achieved for the position of solder pads over a 1 m long circuit.

With our geometry, the limit of stability is determined by the forces between the wires. Theoretically, from3)

$$ T = \left( \frac{1}{4\pi\varepsilon_0} \right) \frac{q^2 l^2}{s^3}, $$

and

$$ q = \frac{U 2\pi\varepsilon_0}{\left[ \ln \sinh(\pi L/s) - \ln \sinh(\pi r/s) \right]}, $$

with wire radius $l = 10$ $\mu$m, spacing $s = 4$ mm, gap width $L = 8$ mm and wire tension $T = 55$ g, we obtain a limit of roughly $U = 4.8$ kV for our wire length $l = 1.2$ m. This is sufficient for Ar/CO$_2$ mixtures with $\sim 50$% CO$_2$.

Special care was taken to define the wire tension to $(57 \pm 2)$ g (breaking stress of the wires $\sim 80$ g). Experimentally, we checked the wire stability up to $U = 3.9$ kV.

At present, we plan to use a mixture with 30% CO$_2$ with operation around 3.0 kV.

2.7. CATHODE STRIPS

The aims were: a low capacitance of the cathode strips to the external ground plane (to reduce noise pick-up), a good conductivity and a low mutual capacitance to minimize both the efficiency variation along the strips and cross-talk between them.

The cathode strips are formed by spraying four layers of silver paint onto the Nomex plates. The strip pattern is obtained by masking with 2 mm wide tape, which is peeled off after the painting. A separation of the strips greater than 2 mm showed a tendency to cause discharges, probably due to electrostatic charging (Malter effect). The 1.5 m strips, 14 mm wide, have an average resistance of 10 $\Omega$. The capacitance per strip to the outside ground is 10 pF, to the wire plane 20 pF; the mutual capacitance between two adjacent strips is about 30 pF.

The second cathode parallel to the 1 m edge is formed by strips 35 mm wide.

2.8. GROUPING OF WIRES AND CATHODE STRIPS

All chambers are constructed with identical wire spacing (4 mm), cathode-1 strips (16 mm, including 2 mm separation) and cathode-2 strips (37 mm, including 2 mm separation). To adapt chambers to varying space resolution requirements, groups of wires and strips are interconnected externally on the printed board. At present, three groupings are foreseen (see fig. 5b).
A change from one type of resolution to another requires essentially the exchange of the printed circuits which support the amplifier cards.

2.9. MOUNTING OF THE ELECTRONICS

The frames for mounting the amplifier cards and the associated wiring are fixed to the edges of the Nomex plates. A pressurized box is mounted around the electronics and power lines, to conform to hydrogen safety standards.

2.10. MOUNTING OF THE CHAMBERS

Most chambers will be mounted in pairs with the 3 m side vertical, one above the other with a 6 cm overlap of the sensitive zones. Five chambers will be mounted around the beam exit with the long side horizontal, stacked on top of each other. The arrangement of the unfolded semi-circle behind BEBC is sketched in fig. 5a.

Special care has been taken to construct a support structure around BEBC, which permits close stacking of the chambers, but at the same time independent dismounting of each chamber.

2.11. PRECISION AND POSITIONING

Eight reference holes around the perimeter of the chamber, drilled with a precision jig, permit accurate positioning of sandwich panels, frames, circuits and holes for the suspension of the chambers.

As a result, the positions of the wires inside all chambers are defined with respect to the reference holes to better than ±0.2 mm over the 3 m. The reference system will also allow an accurate positioning of the wire planes of different chambers relative to each other.

3. Electronics

3.1. BASIC IDEAS

The difficult access to the chambers in the hydrogen safety zone made it necessary to keep the electronics at the chambers to a minimum. Therefore, only the amplifiers are located there; all the storage electronics and logic are separated from them by 75 m of twisted-pair cable and located in the BEBC counting room.

During the 2 ms beam spill all events have to be stored in a self-triggering mode. The events have to be resolved in time, to make reconstruction without ambiguities possible. Two approaches are available:

a) The “scaler-per-wire” scheme, where one or more time-measuring channels are attached to each wire. To reduce the number of scalers required, wires can be grouped together, but then the wire number for a given group and the time have to be recorded for each event. The advantage of such systems is the high time resolution and therefore they are used mainly for drift chamber read-out. For a large system like the EMI (20k channels) this would mean an enormous number of components, and a possible loss of data due to the limited number of scalers.

b) The “shift-register-per-wire” scheme, where big serial shift-registers are attached to each wire. The hit pattern is clocked into all registers whenever an event occurs. Such a system is now feasible since such large registers are available (MOS) at a rather low price. The low speed (2 MHz) is acceptable for this application.

In its simple form the second scheme has the disadvantage of very poor buffer utilization, since for each event only a few channels out of the 20 000 are hit and most of the buffer contains zeros. In particular, the number of events for a single chamber is much smaller than the number of events for the whole system. It was therefore decided to split up the system into one large main buffer and smaller buffers for each chamber.

3.2. TWO LEVEL BUFFER CORRELATION

The chamber buffers are composed of 40-bit MOS-shift-registers (Signetics 2519B) with one register per channel. The main buffer contains 1024-bit MOS-
shift-registers (Signetics 2533B) with one register per chamber. The correlation between these buffers is demonstrated in fig. 6. The columns of the main buffer correspond to events in sequential order. A “one” in the main buffer corresponds to a “hit” in a chamber, which clocks the chamber buffer. If this correlation fails, not only one but all following events during one burst would be mixed up. Great care was therefore given to proper synchronisation as follows (fig. 7). If a coincidence between two planes of a chamber is detected a signal is sent to the main buffer clock generator while the wire information is kept in monostables (see also fig. 8). The clock generator now starts and a pulse synchronous with the main buffer clock is sent in parallel to all chambers. Only chambers with a valid coincidence will react by clocking the data into the chamber buffers and sending a “one” to their rows in the main buffer. In this way the data to the main buffer, the main buffer clock and the chamber buffer clock are always synchronous. Two or more events may be written in one time slot, which has a width of 300–500 ns depending on the event sequence. Since no data must be lost, some overlap of data in adjacent time slots may occur.

3.3. DATA CHAIN

In the following we describe elements of the data chain (fig. 8).

3.3.1. Amplifiers

The amplifier cards (2 channels for anode cards, 8 channels for cathode cards) are directly mounted on the chambers. A full MC 1035 with its 3 stages is used for one channel. A discriminator (½ SN 75108) with variable threshold and a line driver (½ SN 75110) follow the amplifier. Basically the same amplifiers are used for anodes and cathodes. They differ only slightly at the input to accept different polarity. A balanced digital signal (+0.3/−0.3 V) is transferred by twisted pair cables (96 channels per cable) over a distance of 75 m to the storage electronics.

The characteristics of the amplifiers are given in the following:

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**Fig. 6.** Correlation between main buffer and chamber buffers.
Fig. 7. Synchronisation of chamber buffer and main buffer.

Fig. 8. Data chain.
Input impedance: 1.8 kΩ,
Threshold variable from: 150–600 µV,
Bandwidth: 6 MHz,
Cross talk between channels: ≥ −50 dB.
(at 250 µV threshold)
Protection against opposite polarity: ≥ −30 dB.
(at 250 µV threshold)

3.3.2. Storage card
A line receiver (SN 75107) is followed by a mono-stable (SN 74123) with controllable pulse length which provides the data going to the 40-bit MOS-shift register. The FAST OR is derived from the leading edge of the monostables. The 24 channels on one card are read out via parallel-in/serial-out shift registers (SN 7496).

3.3.3. Read-out
Before the read-out starts all data in the MOS-shift registers (chamber buffers and main buffer) are pushed to the right to make them directly accessible. The read-out is controlled from the main buffer which is also read out via parallel-in/serial-out shift registers. Whenever a "one" is detected in the main buffer the corresponding chamber buffer is addressed and in this chamber buffer the data are transferred into the parallel-in/serial-out shift register. A read-out unit scans these registers outputting addresses of wires hit. Empty storage cards are skipped. Control is then returned to the main buffer. The main buffer looks for other chambers hit in the same event. If there are no more, the main buffer is shifted by one column and the scan of the next event starts. All data (event numbers, chamber addresses, wire words and count words) are transferred via a first-in/first-out memory to a CAMAC-bus and via a Direct Memory Access unit to the NORD-10 computer. The time needed for read-out depends on the quantity of the stored data. The coordinates of 600 particles (corresponding to the expected rate) are transferred in some 60 ms.

3.3.4. Capacity and grouping
The main buffer has 63 data channels. It can record up to 1023 events per burst. Extension to more chambers and to more events at the main buffer level is feasible, if necessary. The number of events which any one chamber can handle is now limited to 39, but space is foreseen for an extension to 79 (which may be necessary in the forward cone). These numbers include safety factors according to Monte Carlo simulations. The storage electronics is densely packed. Up to 2 × 16 cards × 24 channels = 768 channels are housed in one crate 4 units high. Two low resolution type chambers (256 channels) are served by one crate (space for reading the data of the second cathode is reserved). For the chambers with higher resolution, crates may be daisy-chained with simple printed circuit jumpers.

3.2.5. Test facilities
Several facilities for tests of the proper performance of the EMI have been foreseen in the hardware. The main buffer and the chamber read-out can be tested by the computer independently of the chambers. Chamber pulsing is foreseen to test the complete data taking chain in a fast and automatic manner.

As there is no possibility of on-line reconstruction of tracks, we provided the facility to record cosmic ray data efficiently for chamber mapping. This feature will be used between bursts and has shown to be rather powerful also for testing the chambers.

Finally, a variety of test points and light emitting diodes is distributed all over the system to make fast error diagnosis possible.

4. Computer
4.1. Specification and selection
It has already been pointed out, in connection with the read-out electronics, that there is no possibility of direct performance monitoring of the EMI by sample data analysis. This led to the requirement for on-line test features to check the buffer and read-out chain digitally, as well as the chamber and electronics performance with cosmic rays. The on-line computer had thus to be chosen with sufficient capacity, not only to cope with expected events from beam spills, but also to enable the operation of the whole EMI to be tested reasonably often using the time between spills. In addition, the EMI will normally be operated by visiting groups having had only short contact with the apparatus, and so it is desirable that as many parameters as possible be monitored automatically by the computer. With these factors in mind, it was clear that the computing capacity needed fell near the top end of the range offered by modern minicomputers. From the software point of view a flexible disc-based real-time operating system backed by a good file system was considered necessary to cope with the large number of different tasks and the variety of data to be logged. The selection of the computer was undertaken in summer ‘74 and led to the choice of a NORD-10 which was installed in its initial configuration in April ‘75.
4.2. Configuration

The current configuration is shown in fig. 9. All interfacing to the EMI and associated monitors, to the neutrino beam monitoring and control complex and to BEBC is implemented in CAMAC with Direct Memory Access where appropriate. The user will interact with the system on the T4010 graphics terminal. Paper copies of plots etc. may be made on the printer/plotter. The large warning panel, which is visible at a distance, will alert the user to carry out periodic operations such as tape changes and will warn of abnormal conditions.

4.3. Software and Operation

A complete chain of test programs has been written and is being used for testing the chamber modules and buffer electronics during production. It has also been used for the proving of techniques for formatting on mag-tape, for histogramming and graphics display and for digital testing of the EMI buffer, which are now being incorporated in a set of programs for the initial version of the data acquisition chain.

Under normal conditions, the time taken to read out the EMI data from a spill, verify its format and record it on mag-tape along with the BEBC data box information will be less than one second. With 5-600 events per spill on the EMI and a spill repetition interval of 6 s, a reel of magnetic tape will be filled in about four hours. Optionally, stronger consistancy checks can be made on the data, and the hit distribution over the chambers accumulated for beam checking. Data is available on the neutrino beam for each spill and as much as wanted may be written on mag-tape or logged on disc for the examination of trends.

During the time remaining between spills, wire maps etc. will be accumulated with cosmic rays for each chamber module in turn. Digital checks of the buffer and read-out system will also be made at intervals. Finally, the status of the gas system and low
voltage supplies and the values of high voltage for each chamber will be periodically monitored and logged.

5. Chamber and electronics performance

Results are presented from chambers with a grouping of eight wires and two cathode strips to one anode and one cathode amplifier, respectively.

5.1. Gas mixture

Extensive investigations have been carried out with various Ar/CO₂ mixtures. Although they show shorter plateaus than Ar/isobutane/methylal mixtures, they offer substantial advantages: they are easy to control, cheap and without safety problems. The plateau length with a threshold of 0.5 mV is considered to be sufficient (see sect. 5.4).

Mixtures with 30% or more CO₂ have not shown any sparking during more than four months of running several 3 m chambers. Even a short time interruption of the CO₂ supply and the resulting 500-fold current increase showed no destructive effect, neither did accidental over-voltages (4 kV instead of 3 kV). In general, the noise in the chambers decreased with time.

Of course, we need not worry in the EMI about possible effects of high beam intensities.

5.2. Electronic threshold and noise

The counting rates of the anode and cathode planes against threshold are constant down to thresholds of 170 µV (on 1.8 kΩ input impedance) (see fig. 10). They are due practically only to cosmics and radioactivity. Below 170 µV the rates increase because of electronic noise. This minimum threshold varies less than 25 µV for high voltages between the beginning of plateau and 200 V above it. We usually work with thresholds of 450 µV for the anode amplifiers and 350 µV for the cathode amplifiers.

5.3. Plateau spread

The “plateau spread” is measured in the following way (as it was done with the chambers for the Split Field Magnet detector at CERN). The beginning of the plateau V_ref is determined for a reference point on each plane as described in sect. 5.4. Placing a source on this reference point the total plane current I_ref is measured. The plane is then scanned with the source and the voltages V(x, y) determined, which result in the same current. The difference MAX V(x, y) - MIN V(x, y) is called the “plateau spread”. A check on these extremes is performed according to sect. 5.4.

The plateau spreads within one plane measured so far are <±40 V.

5.4. Plateau length

The efficiency of the chambers was mostly measured using cosmic rays, the chamber suspended with its

![Fig. 10. Free-running counting rates versus threshold voltage (input impedance = 1.8 kΩ).](image)

![Fig. 11. Efficiencies of anode and cathode for various threshold voltages. (a3): rates of coincidences between both anodes. Gas mixture: 70/30% Ar/CO₂.](image)
3 m side vertical. For the measurement of the efficiency of “anode 1”, the trigger was given by the coincidence between the second anode and a scintillator (15 x 15 cm²), positioned close to “anode 1”. Fig. 11 shows the efficiencies for an anode and the cathode, at various thresholds.

It can be seen that a threshold of 450 μV on the anode results in the same beginning of plateau as a threshold of 190 μV on the cathode. The “beginning of plateau” is defined as the voltage at which 99.5% efficiency is reached with this set-up. The apparent 0.5% inefficiency was caused by the measurement set-up, as was checked.

The variation of the “single rates” (i.e. the untriggered, free-running counting rates) with high voltage is also shown in fig. 11. The single rates are constant in the efficiency plateau and then rise rapidly.

The “end of plateau” is defined as the high voltage which produces 1.5 times the single rates on the plateau.

With a 70/30% Ar/CO₂ mixture we obtain a plateau length of >300 V on the anodes for a threshold of 450 μV and >200 V on the cathode for a 300 μV threshold. The plateau of the coincidence of both anodes extends to higher voltages, as may be expected (see fig. 11, curve a3).

5.5. TIME RESOLUTION

The time resolution for an anode and a cathode plane is shown in fig. 12. A trigger on cosmics from a 15 x 15 cm² scintillator close to the center of the chamber was used (the chamber suspended with the 3 m side vertical). The time resolution was measured at the memory monostable level (FOR, see fig. 8) after 25 m of cable. It contains, therefore, the jitter due to the amplifiers, the cable length variations, and the monostables. The curves shown were obtained about 150 V above the beginning of plateau for the anode. The fwhm is 38 ns for the anode (at 450 μV threshold) and 45 ns for the cathode (at 350 μV threshold). The total widths (99.5%) are about 110 ns and 135 ns, respectively. The peak in the distribution for the cathode is retarded by 20 ns with respect to that for the anode.

For the coincidence between both anodes the distribution shows a fwhm = 31 ns.

So far, eight chambers were tested. Consistent results have been obtained from them.

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