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Mechanical design report of the barrel liquid argon presampler

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Abstract

The note describes the mechanical design of the Atlas barrel presampler and its evolution since the publication of the calorimeter TDR's in December 96.

1 Introduction

This note contains a revised version of the TDR subchapter dealing with the barrel presampler mechanical design. Since January 97, a few changes were suggested and were finally endorsed by the collaboration. These are:

- a 18 mm increase of the presampler length which in practice means that the 8th module is 18 mm longer;
- an enlargement of the electrode thickness tolerance after consultation with industry and a careful analysis of the consequences ($\pm 10 \mu\text{m} \rightarrow \pm 30 \mu\text{m}$);
- the suppression of the top prepreg layer on the central FR4 plates of the modules to avoid glue leakage;
- the substitution of special glass fiber-epoxy by plain FR4 for the fabrication of the support rails after realizing that the cost would exceed by a factor 2 what had been budgeted.

2 Overall geometry

The presampler acts as a thin (11mm) active layer of liquid argon, which provides a first sampling of the showers in front of the accordion electromagnetic calorimeter. In the transverse (R, ϕ) plane, it has a polygonal shape formed by 32 identical azimuthal sectors per half-barrel, each sector spanning 0.2 in ϕ and 1.52 in η . The two barrel halves are identical. The sectors are mounted on rails which are fixed on the barrel internal rings. Figure 1 shows a view of a barrel module with its two presampler sectors suspended at the front. The granularity of this device corresponds to one electromagnetic cell in the η direction (0.025) and four in ϕ (0.1). The opening of the showers in η due to the solenoid's field led us to choose a coarser granularity for this coordinate. The external envelope of a presampler sector consists of a 0.4 mm thin glass-epoxy shell (3086 mm x 281 mm x 21 mm) which houses eight modules of unequal length secured together by 3 m long FR4 bars. Each module covers a constant region of 0.2 x 0.2 in the (η, ϕ) space with the exception of the modules located at the extremities of the EM barrel for which the η coverage is reduced to 0.12. The total number of channels needed to read out this device is 7808 (122 per sector).

3 Modules

Since a presampler module covers a constant interval in pseudo-rapidity, its longitudinal length increases as a function of its z position in the barrel. Consequently, there are eight different types of modules of 64 identical units each. In total, 512 modules (plus 48 spare ones) will have to be produced.

The charge deposited by the showers in the 11mm active layer is collected by 277.5 mm long electrodes which are arranged transversally with respect to the longitudinal

Module No.	length (mm)	gap (mm)	No. of anodes	No. of cathodes	Ganging factor	No. of cells	inclination angle (degrees)
1	281.4	1.96	56	56	7	16	25
2	298.4	1.96	64	64	8	16	12
3	322.3	1.93	72	72	9	16	0
4	356.8	1.93	80	80	10	16	0
5	404.8	2.00	88	88	11	16	0
6	478.4	2.00	104	104	13	16	0
7	563.2	1.90	128	128	16	16	0
8	380.6	1.90	86	87	18(+14)	10	0

Table 1: Characteristics of the presampler modules at 293 K

axis. The liquid argon gap is kept approximately identical at a value of 2 mm throughout the device allowing us to operate the presampler with a fixed high voltage of 2 kV. The number of electrodes per module type varies to keep the liquid gap constant. The electrodes are strictly perpendicular to the longitudinal axis, except for the modules covering the $|\eta|$ range up to 0.4 where the electrodes are slanted with respect to the normal axis to avoid a local dependence of the signal upon the shower impact position. The read-out cells of the required granularity ($\Delta\eta = 0.025$, $\Delta\phi = 0.1$) are obtained by ganging in the longitudinal direction the appropriate number of electrodes on the modules themselves. In ϕ , each electrode is subdivided into two 0.1 compartments by etching. Thus on each module there are 8 cells in η and 2 in ϕ , i.e. 16 in all except for the shorter modules located at the barrel edges where there are only 10 cells (5 x 2). Table 1 summarizes the geometric dimensions of these modules while Figure 2 shows the drawings of the type 3 modules.

4 Electrodes

The electrodes are glass-epoxy FR4 multi-layered circuits. They are of two different kinds: cathodes which are simple 270 μm thick double-sided boards (200 μm of FR4 plated with 35 μm of copper on each side); anodes which are 327.5 μm thick 3-layered circuits (17.5 μm of copper + 150 μm of FR4 + 17.5 μm of copper + 125 μm of prepreg and 17.5 μm of copper). The electrode thickness tolerance is $\pm 30 \mu\text{m}$ with respect to its nominal thickness. A positive HV of 2000 V is applied to the external anode layers, while the shower signals are read out by capacitive coupling to the central anode layer. Many tests including a long-term survey were performed on the anodes up to 4000 V in liquid nitrogen to check their high voltage resistance. In June 1996, two module prototypes of 128 electrodes each were operated for a month at CERN in a liquid argon cryostat installed in the H8 beam facility. Also in November 1997, a first module of type 3 belonging to the pre-series production was tested at CERN for approximately 1 month in the cryostat of the end-cap electromagnetic calorimeter. The average thickness of the anodes made for this latter module was slightly lower than the

nominal value due to the use a thinner prepreg (110 μm instead of 125 μm). In all cases, no failure was ever detected.

Because of the variation of their inclination angle, each kind of electrode comes in three different heights corresponding to modules of type 1, type 2 and types 3 to 8. With the envisaged spares included, the total number of electrodes per kind are 4050, 4650 and 40000 for the three sizes, respectively. Small tabs located on the electrode upper edges offer the possibility to connect the signals, the ground, and the high voltage including some HV protection surface mounted resistors (1 M Ω) at the level of the electrodes themselves.

The production of electrodes will come in three batches: one corresponding to the two presampler sectors needed to equip module 0, and two series production batches one year apart. Figure 3 shows the detailed drawings of the size 3 anodes.

5 Module production

As a result of an extensive prototyping phase, a gluing technique was finally selected for module production. The electrodes are first positioned in a jig by precision shims. Then, glass-epoxy plates covered with epoxy pre-impregnated foils are applied with a proper pressure on the top and bottom of the electrodes by means of tightening screws mounted on the jig. To symmetrize the mechanical structure, especially in view of reducing the deformations due to the thermal contraction, the glass-epoxy plates are coated when possible with prepreg foils on both faces. This is the case of the bottom plates. The pre-impregnated foils are 0.3 mm thick prior to polymerization and have a high epoxy impregnation density, to obtain the formation of glue menisci at the electrode edges that assure a good contact surface. Finally the modules undergo a polymerisation cycle that lasts approximately 16 hours in an automated autoclave with well-defined temperature ramps and plateaus. Thermal contraction and deformation tests were done in liquid nitrogen on the existing prototypes both in the x and y directions. We measured a shrinkage coefficient $\Delta L/L(293\rightarrow 77\text{K})$ of $0.26\pm 0.03\%$, and a sagitta around 0.2 mm

The local connection of the ground lines, HV buses, and signal wires is performed right after the extraction of the module from its gluing jig. It is achieved by means of thin tinned wires that are first inserted through the copper-plated holes made on the electrode tabs and then soldered at each contact point. Two separate HV lines per pair of modules, each connected to the left or the right sides of the electrodes, will be used to prevent the full loss of a module in case of sparks. After completion, a module is cleaned by using high purity ethanol and placed in a protection bag filled with argon.

The module production including the connection soldering will be done by an industrial firm which was chosen in a tendering procedure. The delivery will be organized in four batches: one (16 modules) corresponding to the two sectors of module 0, two annual batches of 192 modules each, and a final one of 160 modules to complete the series production.

6 Sectors

Figure 4 shows a perspective view of a presampler sector. Such an element is assembled by inserting eight modules with their mother boards soldered on their top in a thin glass-epoxy shell. This 0.4mm thick shell acts as a protection and is made conductive on its lateral sides to collect the shower signals at the extremities of the electrodes and thereafter maximize the active coverage. Three long shell prototypes of different composition have already been received from the industry. Their tests revealed no major problems. Their measured thickness (0.38 ± 0.01 mm) is well within our tolerances. The shell with its eight modules in place is then positioned in a guide that will give the sector its precise external geometry. Finally, two long longitudinal glass-epoxy bars are screwed in the lateral upper plates of the modules to secure the assembly.

At this stage the cables for the calibration pulses, HV distribution, and signals are laid down on top of the sector and soldered to the motherboards. The choice of soldering instead of connectors was dictated by the space constraints: 6.9 mm of radial space available for the cables and the motherboards. A connection test is performed immediately after soldering. The thermal shrinkage coefficients of a sector's parts are similar enough to avoid the opening of gaps between contiguous modules in the longitudinal direction. After cooling at the temperature of liquid argon, a sector will shrink by 8mm in the longitudinal direction and 0.7mm in ϕ . Each newly built sector is fully tested in a LN2 cryostat before being placed in an argon-inerted protection vessel for storage.

7 Support structure

As shown in Figure 5, the sectors are mounted on FR4 long rails which are screwed with a tightening clearance (0.1 mm) on the calorimeter internal rings. Since the rails are made of a material which has a lower shrinkage coefficient than the absorber bars, there are oblong holes at the location of the bindings to let these rails differentially shrink with respect to the calorimeter. Contiguous sectors are mounted with a nominal gap of 0.4mm at room temperature. When in liquid argon, this gap expands to 1.1 mm owing to the transverse thermal shrinkage of the sectors. Taking into account the thickness of the shells, there is 2 mm of inactive space between two adjacent sectors: a 0.7% loss. The sliding of sectors on their rails was checked on a full-length model of three sectors in horizontal and vertical position. The internal radius of the device is 1413.3 mm at 293 K and is not expected to change much (< 1 mm) at liquid argon temperature owing to the thermal stability of the calorimeter inner radius (see Section below). A finite-element analysis of the thermo-mechanical behaviour of the sectors is under way, the first results of which confirm that there is no deformation of the presampler modules. In addition, they predict that the shells after thermal contraction will press slightly on the modules with a tiny force.

7.1 Cabling

As already stated, the electrical connections at the level of the presampler sectors will be soldered for reasons of compactness. The sectors will be delivered to CERN with all their electrical connections made and tested in liquid nitrogen. For a sector, two harnesses of 64 coaxial leads each are necessary to ensure the connection of the physics signals according to the following assignment: harness 1 to modules 1-4, harness 2 to modules 5-8 with 6 unused channels soldered to the sector ground.

To distribute the calibration signals, eight coaxial cables (one per module) are needed. They are individual cables, stripped and soldered at both extremities, with a connection at the large rapidity sector edge made to a small intermediate printed board equipped to receive low-profile calibration connectors of the same type as those of the calorimeter. The lengths of these cables are adjusted to provide a time distribution of the calibration signals close to the particle time-of-flight sequence.

The high voltage is supplied by eight coaxial Kapton cables per sector: two lines for each pair of contiguous modules with the left and the right sides of the anodes separately connected. The HV cable shields are soldered at one extremity to the ground of the motherboards and left un connected at the other end. This provides us with a distributed capacitor for HF filtering.

Each sector is electrically insulated from its neighbours and the rest of the calorimeter. The ground of each sector is propagated to the cryostat Faraday cage via the output signal and the calibration cables. The cables lying on top of the sector motherboards are separated from the calorimeter connections by thin glass-epoxy protection plates as depicted in Figure 5.

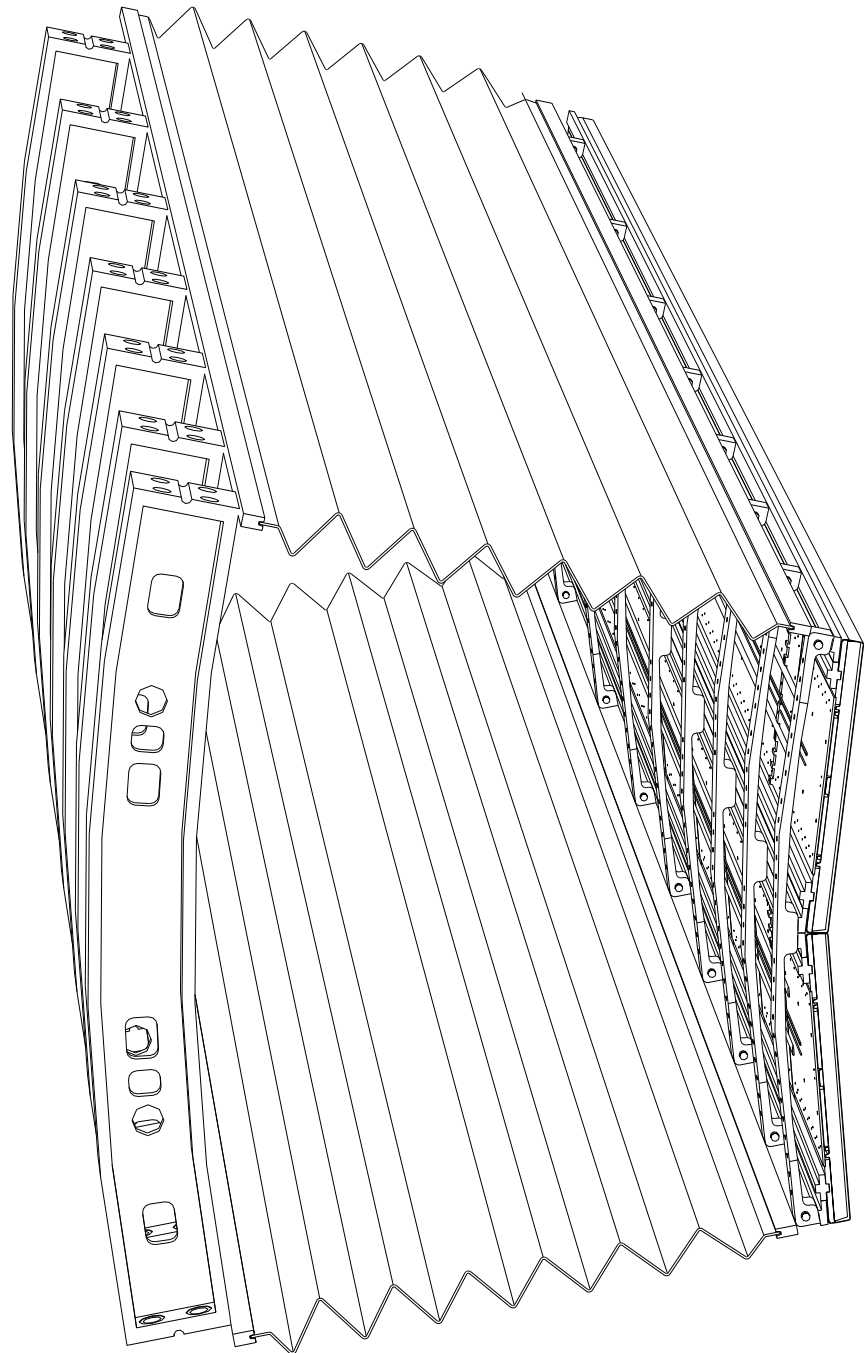


Figure 1: EM barrel module with two presampler sectors

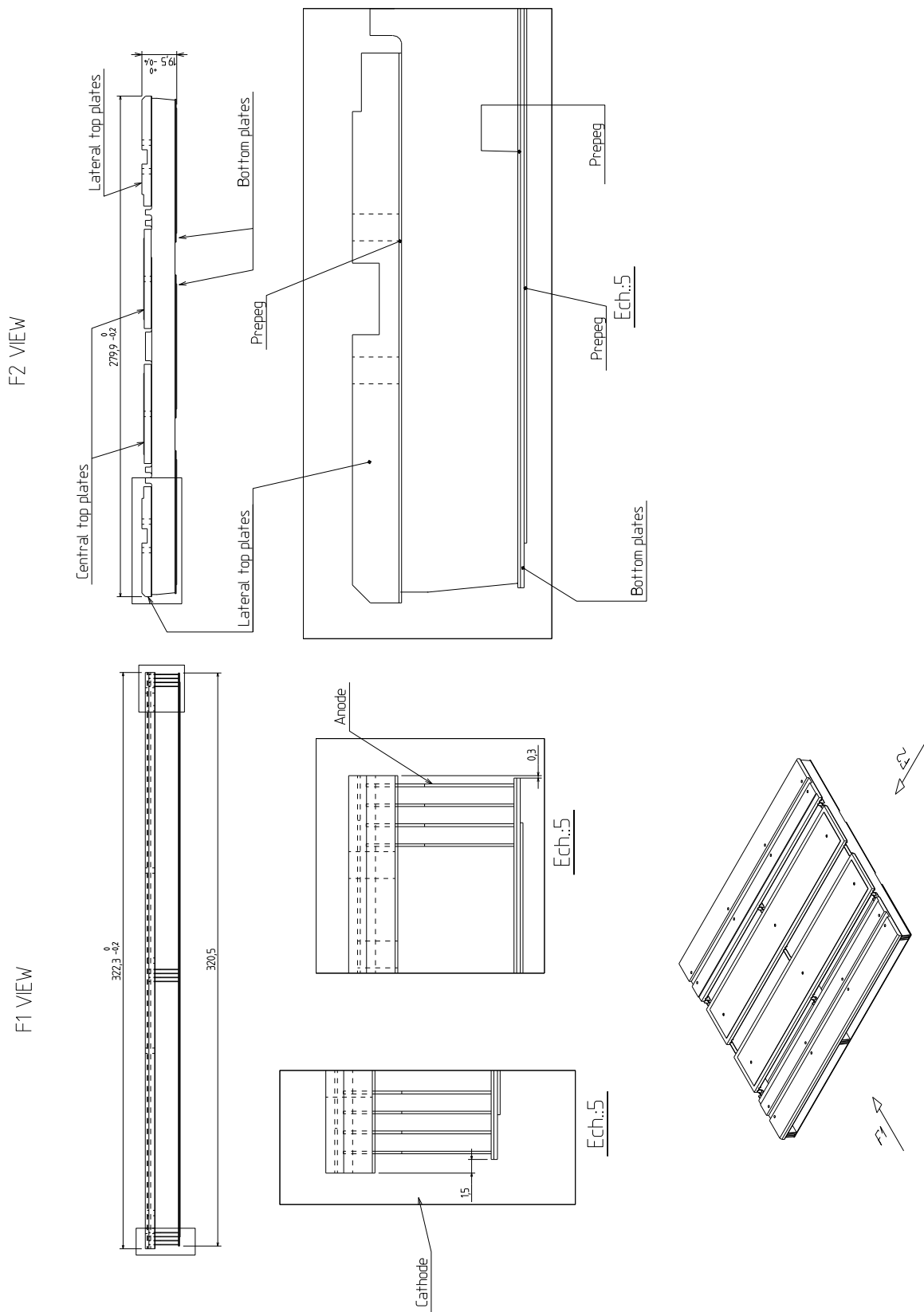


Figure 2: Type 3 presampler module

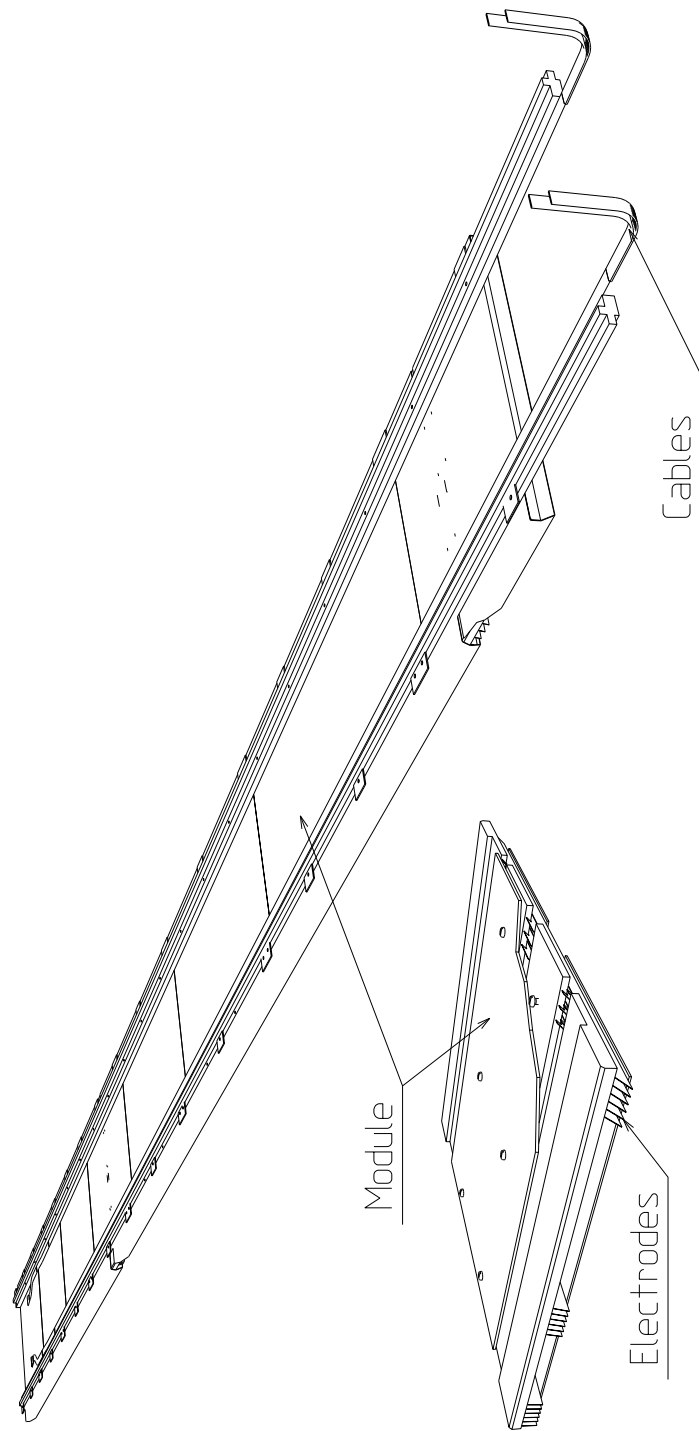


Figure 4: Perspective of a presampler sector

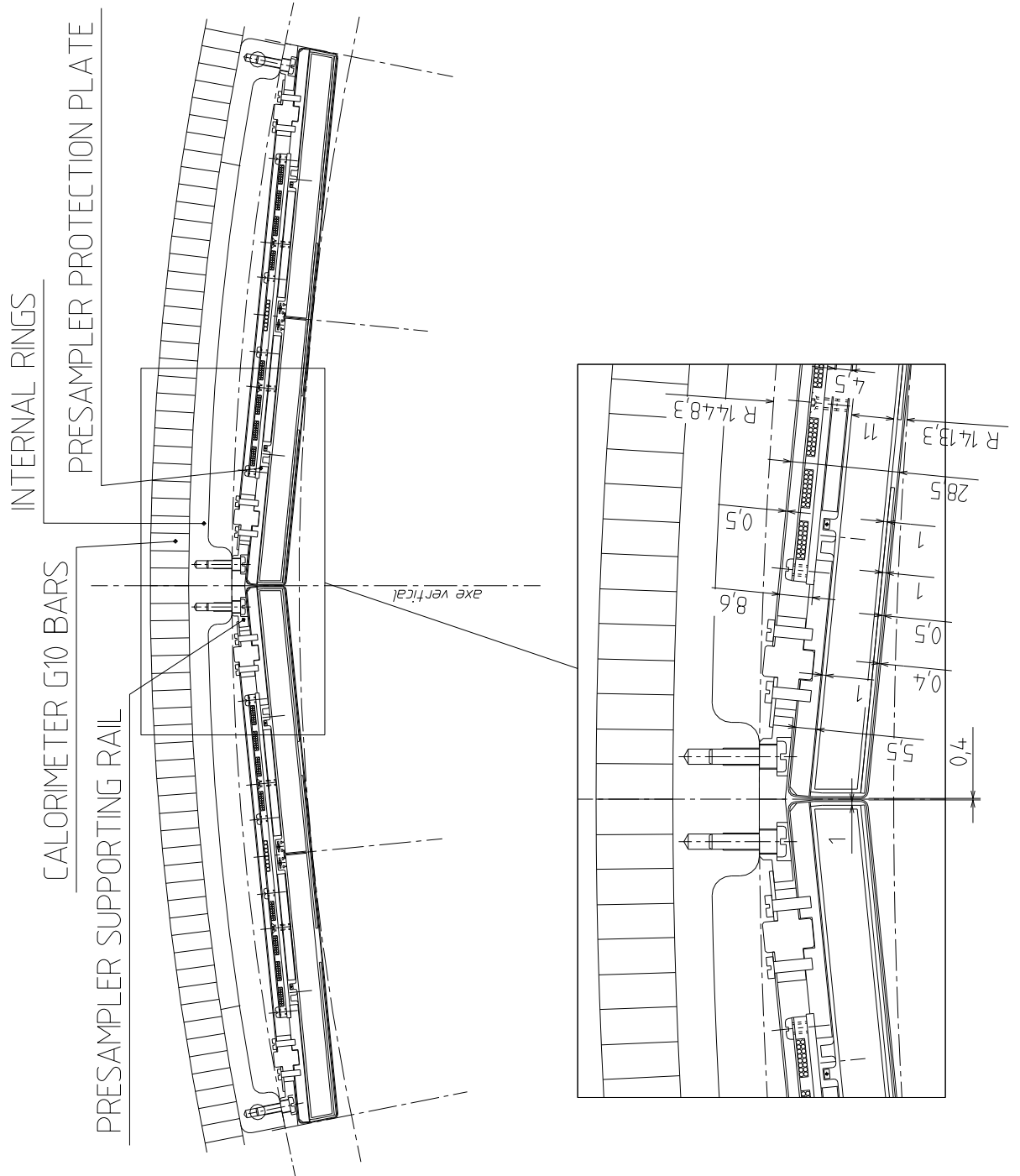


Figure 5: Section of the EM barrel calorimeter with two presampler modules suspended in front

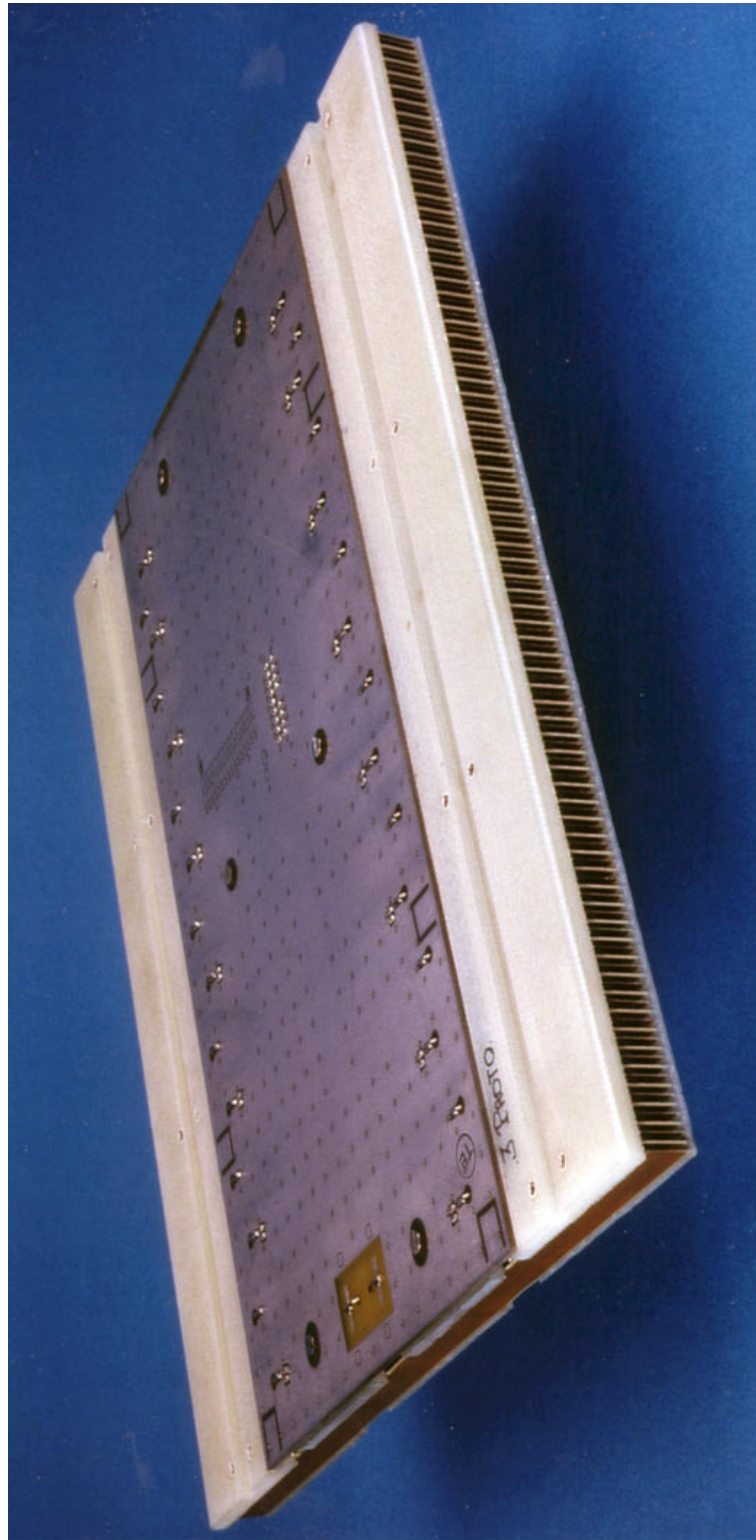


Figure 6: Photograph of a presampler module of type 3