



SEP  
CERN - DRDC  
91-31

CERN LIBRARIES, GENEVA



SC00000691

CERN/DRDC/91-31

DRDC M10

July 24, 1991

## MEMORANDUM

To: E. Iarocci / Chairman DRDC

From: A. Contin / Spokesman of the INFN experiment CPF  
Coordinator of LAA component 2b  
R. De Salvo / Coordinator of LAA component 2b

Copy to: F. Bonaudi, D. Froidevaux, K. Hübner, J.P. Delahaye

Subj.: Test beam requests

---

R&D work on lead/scintillating fibres calorimetry (the so-called "spaghetti calorimetry") started in 1986 in the framework of the LAA Project, component 2b: "Compact EM+Hadronic Calorimetry". Excellent results were obtained during the past four years (see Refs. 1-7 of Annex II).

In continuation of this R&D work, a collaboration between LAA and INFN physicists from Bologna, Italy, presented a proposal: "CPF: Calorimetria Piombo/Fibre scintillanti" (see Annex II for a summary in english of the proposal), to the "Commissione Scientifica Nazionale V" of INFN, which was approved on June 6, 1991 and recommended for financing (see Annex I).

The LAA Project will participate in this programme with premises and material, including the spaghetti calorimeter prototypes built during the past years, and, most important, with the competence of the people which contributed in a fundamental way to the present success of the R&D on spaghetti calorimetry.

The scientific programme approved by the "Commissione V" INFN constitutes the phase-II of spaghetti calorimetry in LAA, aiming at:

- a) Studies with the existing prototypes:
  - i) high-rate performances and uniformity;
  - ii) long-term stability;
  - iii) longitudinal hadronic shower development.
- b) Studies on the control of the energy resolution:
  - i) "external" systems (flashers, LED, radioactive sources, etc.);
  - ii) "internal" systems ( $\gamma$ 's and low-energy hadrons);
  - iii) quality control of fibres.
- c) Studies on the radiation damage of fibres:
  - i) single fibres (optimal combination of base/scintillator/cladding);
  - ii) modules with many fibres (global damage and energy resolution studies).
- d) Systematic studies on a preshower counter.
- e) Studies on the trigger and read-out system:
  - i) trigger electronics (analog);

- ii*) second level trigger.
- f) Studies on new geometries:
  - i*) development of cheap mass production assembly techniques for projective modules;
  - ii*) projective geometry: position resolution and  $e/\pi$  rejection;
  - iii*) projective geometry: trigger;
  - iv*) special modules for fibre attenuation and compensation studies.

Part of this scientific programme requires tests in particle beams, to be carried out in late summer 1991, and in spring 1992.

In particular we shall need:

1. 10 days in summer 1991 in a  $5 \div 50$  GeV electron/pion/muon beam, for a study of the performances of the 155-cells prototype, after irradiation in the WA89 experiment (see point *a.i* above), and for the study of the hadronic shower development (see point *a.iii* above). Part of this beam time (recalibration of the 155-cells calorimeter) has already been assigned to WA89, at the end of their present running period.
2. Some days in summer 1991 in a 150 GeV electron/pion beam for the completion of the measurements on the 15-cells projective prototype, already tested (up to 50 GeV) in May 1991 [7]. This work has been required to us by INFN to establish the limits in  $e/\pi$  separation of such a calorimeter design (see points *f.ii* and *f.iii* above).
3. 10 days in summer 1991 on a  $0.5 \div 5.0$  GeV electron/pion beam for studies on the calorimeter response to low energy particles. We intend to explore the possibility of using low energy particles, which represents the bulk of the background at LHC, as a mean to equalize and calibrate the calorimeter during data taking (see point *b.ii* above).
4. One week in spring 1992 on a  $5 \div 50$  GeV electron/pion beam for studies on the preshower counter (see points *a.ii* and *d* above).
5. The continuation of the present scintillating fibres irradiation tests using the 0.5 GeV electron beam from the LIL/LPI, at a maximum beam intensity of  $4 \times 10^9$  electrons/burst. Other fibre samples are expected to be given to us by industries for testing in the near future (see point *c.ii* above).
6. Following the feasibility studies on the development of cheap mass production assembly techniques for projective modules (see point *f.i* above), we intend to build a  $350 \text{ cm}^2$  front-surface projective prototype. We would need about 10 days in spring 1992 in a  $5 \div 150$  GeV electron/pion beam for measuring the performances of this calorimeter.



ISTITUTO NAZIONALE DI FISICA NUCLEARE  
Sezione di NAPOLI

ANNEX I  
80125 NAPOLI, II 11.08.91 / 947  
Mostra d'Oltremare, PAD. 20-Tel. (081) 7253111  
Telex 720320 INFNNA - Teletax (081) 614508  
Electronic mail INFNNA @ VAXNA1.DECNET

Prof Nicola Cabibbo  
Presidente INFN  
Piazza dei Caprettari ,70 Roma

c.c. :  
Prof. Paolo Blasi  
Membro G.E. INFN  
Sezione INFN - Firenze

Dr. Icilio Agostini  
Amministrazione Centrale INFN  
LNF

Caro Presidente,  
nella ultima riunione della V Commissione Scientifica Nazionale, tenuta a Roma nei giorni 6 e 7 giugno 1991 è stato deciso di chiedere gli sblocchi di sub judge riportati nella seguente tabella:

#### SBLOCCHI SUB-JUDICE

RIFOS:	Roma	CONS.	15
SPLIT:	GE	EST.	12
	PD	EST.	10
	TS	EST.	6
		-----	
		Totale	28
XEC:	PI	EST.	20
		CONS.	20
		-----	
		Totale	40

E' stato inoltre deciso di proporre l'assegnazione dal fondo indiviso ai seguenti esperimenti:

PHD:	NA	CONS.	9
SEDEX:	TS	INT.	3

E' stata decisa anche la approvazione scientifica e proposto il finanziamento sempre dal fondo indiviso per nuovi esperimenti come risulta dal seguente prospetto:

PROPOSTE DI FINANZIAMENTO PER NUOVE INIZIATIVE R&D

MUTRIG:	LNF	CONS.	13
LHC TB:	PV	INV.	70
		CONS.	10
		EST.	40
		-----	
		Totale	120
NEW-SCIC:	LNF	CONS.	9
T&T:	NA	INT.	4
	PV	INT.	4
		-----	
		Totale	8

TOTALE PROPOSTE 162 ML

DISPONIBIL.FONDO INDIVISO 162 ML

RESIDUO FONDO 0

A seguito di queste proposte il fondo indiviso di Gruppo V ,costituito per il 1991, viene azzerato.

**RICHIESTA DI CONTRIBUTO STRAORDINARIO ALLA GIUNTA PER L' ESPERIMENTO CPF:**

Dopo un esame approfondito e la relazione di P.Laurelli a nome del gruppo dei referees nominati nella riunione del 22.3.91 (R.Bernabei,P.Laurelli,L.Mandelli) è stato approvato scientificamente l'esperimento CPF della sezione di Bologna. Tale esperimento costituisce una variante nell'ambito della ricerca e sviluppo sulla calorimetria a fibre scintillanti e piombo. La Commissione ha giudicato adeguate agli scopi le cifre di possibile finanziamento discusse dai referees, pertanto ti chiedo a nome della Commissione un contributo straordinario per il 1991 sotto la seguente forma:

CPF: BO proposta globale 1991:	249	ML
di cui da assegnare subito:		
INV.	20	
CONS.	60	
EST.	14	
	<hr/>	
Totale	94	

e da assegnare al fondo indiviso del Gruppo V per ulteriore assegnazione in corso anno (ancora sub-judice per il Gruppo V):

INV.	75	
CONS.	32	
C.APP.	33	
EST.	28	
	<hr/>	
Totale	168	

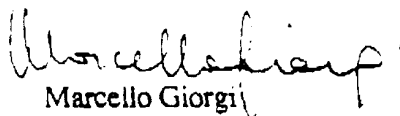
TOTALE PROPOSTA PER CPF 249 ML

Del programma di ricerca CPF così come del programma SPACAL (Pv,Ca,Na) fa parte anche lo sviluppo di un fotomoltiplicatore ibrido a stato solido, che costituisce anche motivo di grande interesse per altri gruppi dell'INFN.

Per lo sviluppo di tale dispositivo viene proposto il finanziamento straordinario di 200 MI per costruzione di apparati da assegnare alle dotazioni di gruppo V della sezione di Bologna.

Per decisione della Commissione le specifiche ed il test dei prototipi dovranno essere curati da P.Benetti(SPACAL) e R.DeSalvo(CPF) e riferite al presidente della V Commissione il quale si farà cura anche di approvare di volta in volta le spese relative allo sviluppo del dispositivo.

Ti saluto cordialmente

  
Marcello Giorgi



## ANNEX II.

Summary of the proposal:

### **“CPF: Calorimetria Piombo/Fibre scintillanti” Calorimetria Elettromagnetica e Adronica Compatta**

Presented at the INFN “Commissine Scientifica Nazionale V” by:

G.Anzivino<sup>8)</sup>, F.Arzarello<sup>1)</sup>, G.Bari<sup>1)</sup>, M.Basile<sup>1,2)</sup>, L.Bellagamba<sup>1)</sup>, C.Bencheikh<sup>4)</sup>,  
D.Boscherini<sup>1)</sup>, G.Bruni<sup>1)</sup>, P.Bruni<sup>1)</sup>, V.Buzuloiu<sup>7)</sup>, G.Cara Romeo<sup>1)</sup>, M.Chiarini<sup>1)</sup>,  
L.Cifarelli<sup>1,9)</sup>, F.Cindolo<sup>1)</sup>, F.Ciralli<sup>1)</sup>, A.Contin<sup>1,2,3)\*</sup>, M.Dardo<sup>10)</sup>, S.DePasquale<sup>1)</sup>,  
R.De Salvo<sup>3)</sup>, F.Frasconi<sup>1)</sup>, A.Gheorge<sup>7)</sup>, P.Giusti<sup>1)</sup>, W.Hao<sup>5)</sup>, G.Iacobucci<sup>1)</sup>,  
G.Laurenti<sup>1,3)</sup>, G.Maccarrone<sup>1)</sup>, A.Margotti<sup>1)</sup>, T.Massam<sup>1)</sup>, R.Nania<sup>1)</sup>, V.Peskov<sup>6)</sup>,  
G.Sartorelli<sup>1,2)</sup>, M.Scioni<sup>1)</sup>, R.Timellini<sup>1)</sup>, Y.Wang<sup>5)</sup>, C.Xu<sup>5)</sup>, K.You<sup>5)</sup> and  
A.Zichichi<sup>1,2,3)</sup>

- 1) INFN, Sezione di Bologna, Italy.
- 2) Università di Bologna, Italy.
- 3) CERN/LAA, Geneva, Switzerland.
- 4) Haute Commisariat à la Recherche, Ain-Oussura, Algeria.
- 5) IHEP, Beijing, People's Republic of China.
- 6) Institute for Physical Problems, Moscow, URSS.
- 7) Institute of Atomic Physics, Bucarest, Romania.
- 8) INFN, Laboratori Nazionali di Frascati, Italy.
- 9) Università di Napoli, Italy.
- 10) Università di Torino and INFN, Sezione di Torino, Italy.

\*) spokesman

## 1. Introduction.

During the last 3.5 years, some of the most relevant problems of the lead/fibre calorimetry have been addressed and solved in the framework of the LAA Project. In particular, during the first 1.5 years:

- a) the fibres with the correct characteristics have been specified;
- b) several test modules have been built;
- c) the longitudinal and lateral response of the calorimeter have been made uniform;
- d) the first measurements of the calorimeter response to electrons and hadrons have been done; very good results have been obtained on  $e/\pi$  separation with a new method based on the signal speed;
- e) the construction method for larger prototypes has been defined;
- f) the first radiation hardness tests of the fibres have been made in Lisbon;
- g) prototypes for a new photon detector (HPD - Hybrid Photo Diode) have been designed and built.

During the following 1.5 years, two large prototypes (20- and 155-cells, respectively) have been built by LAA with the help of interested Institutions, which participated in the subsequent data taking and analysis [1-7].

In July 1990, the proposal CERN-DRDC/P1 was submitted to the DRDC. The goal of this proposal was to study some of the remaining issues on spaghetti calorimetry, in view of its use as a detector for LHC. The proposed activities were a continuation of the work done in the framework of LAA, and, in fact, represented the "phase-2" of spaghetti calorimetry, as presented to the LAA Scientific and Technical Advisory Board in June 1987, and approved by it in September of the same year. Part of these activities had already started within the LAA group at the time of the presentation of the proposal. The proposal was signed by the members of the LAA group, under the condition that a Memorandum of Understanding had to be laid down, defining the responsibilities of each group participating in the collaboration (to be called SPACAL Collaboration).

After discussions inside the collaboration and with CERN officials, the LAA group decided to withdraw. Nevertheless, the component 2b of LAA have not run out of interest in the spaghetti calorimetry. On the contrary, we think that the know-how built up in the past years will allow us to produce very good results on various aspects of it.

In the last six months, the activity of the LAA group has been limited by the low level of funding available within LAA. To help our financial problems, the group was opened to other collaborators, who signed the proposal approved by the INFN Commissione V.

INFN approved the funding for the participation of physicists from Bologna, Italy, to the following R&D programme:

- a) Studies with the existing prototypes:
  - i) high-rate performances and uniformity;
  - ii) long-term stability;
  - iii) longitudinal hadronic shower development.
- b) Studies on the control of the energy resolution:
  - i) "external" systems (flashers, LED, radioactive sources, etc.);
  - ii) "internal" systems ( $\gamma$ 's and low-energy hadrons);
  - iii) quality control of fibres.



- c) Studies on the radiation damage of fibres:
  - i) single fibres (optimal combination of base/scintillator/cladding);
  - ii) modules with many fibres (global damage and energy resolution studies).
- d) Systematic studies on a preshower counter.
- e) Studies on the trigger and read-out system:
  - i) trigger electronics (analog);
  - ii) second level trigger.
- f) Studies on new geometries:
  - i) development of cheap mass production assembly techniques for projective modules;
  - ii) projective geometry: position resolution and  $e/\pi$  rejection;
  - iii) projective geometry: trigger;
  - iv) special modules for fibre attenuation and compensation studies.

The LAA Project, component 2b, will participate in this programme with material and laboratory equipment worth about 1.7 MSF, and with the competence of the people which contributed in a fundamental way to the present success of the R&D on spaghetti calorimetry.

In the following a brief summary of the above items is given.

## 2. Studies on the existing prototypes.

Two big calorimeter prototypes (see Fig.1) have been build in the framework of the LAA Project. Their characteristics are summarized in Table I.

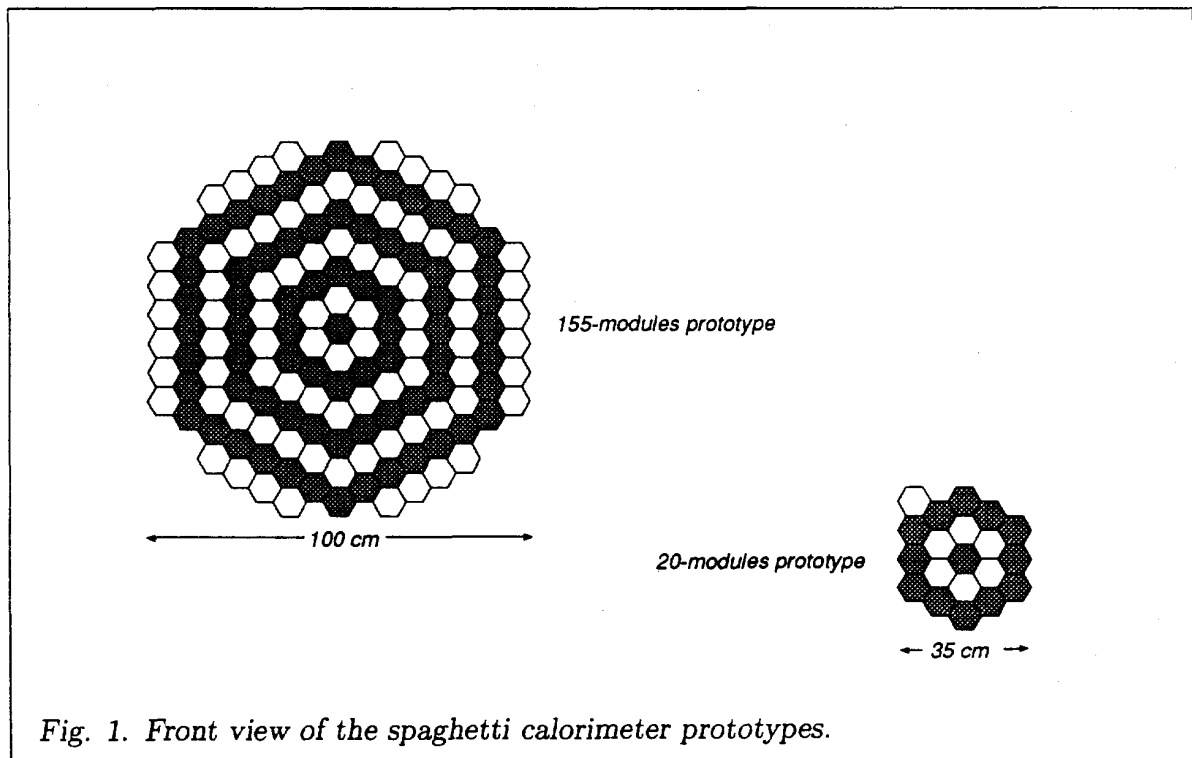


Fig. 1. Front view of the spaghetti calorimeter prototypes.

Table I .Characteristics of the spaghetti calorimeter prototypes.

	20-cells	155-cells
Weight (ton)	2.2	18
Equipped weight (ton)	1.7	13.5
Number of fibres	22820	176855
Total lenght of fibres (km)	49	380
Number of photomultipliers	20	155
Length	2m (9.5 $\lambda_0$ , 266 $X_0$ )	2m (9.5 $\lambda_0$ , 266 $X_0$ )
Diameter	35 cm (1.7 $\lambda_0$ , 47 $X_0$ )	100 cm (4.8 $\lambda_0$ , 133 $X_0$ )

The 155-cells prototype is presently installed in the WA89 experiment, where it will receive a radiation dose equivalent to one year running at LHC at a rapidity of 2.5. At the end of the WA89 run, we intend to proceed with a full recalibration of the prototype and to a scan with muons impinging perpendicularly to the fibre direction, in order to measure the radiation damage both in the light output and in the attenuation length of the fibres.

Long-term stability test will be done with the 20-cells prototype. We plan to measure the performances of this prototype every 6-12 months in an electron/pion beam.

The high granularity of the prototypes allowed a detailed study of the lateral development of the hadronic showers. We intend to study also the longitudinal profile of the showers, placing the prototypes with the fibres oriented perpendicularly to the incident particles (see Fig. 2).

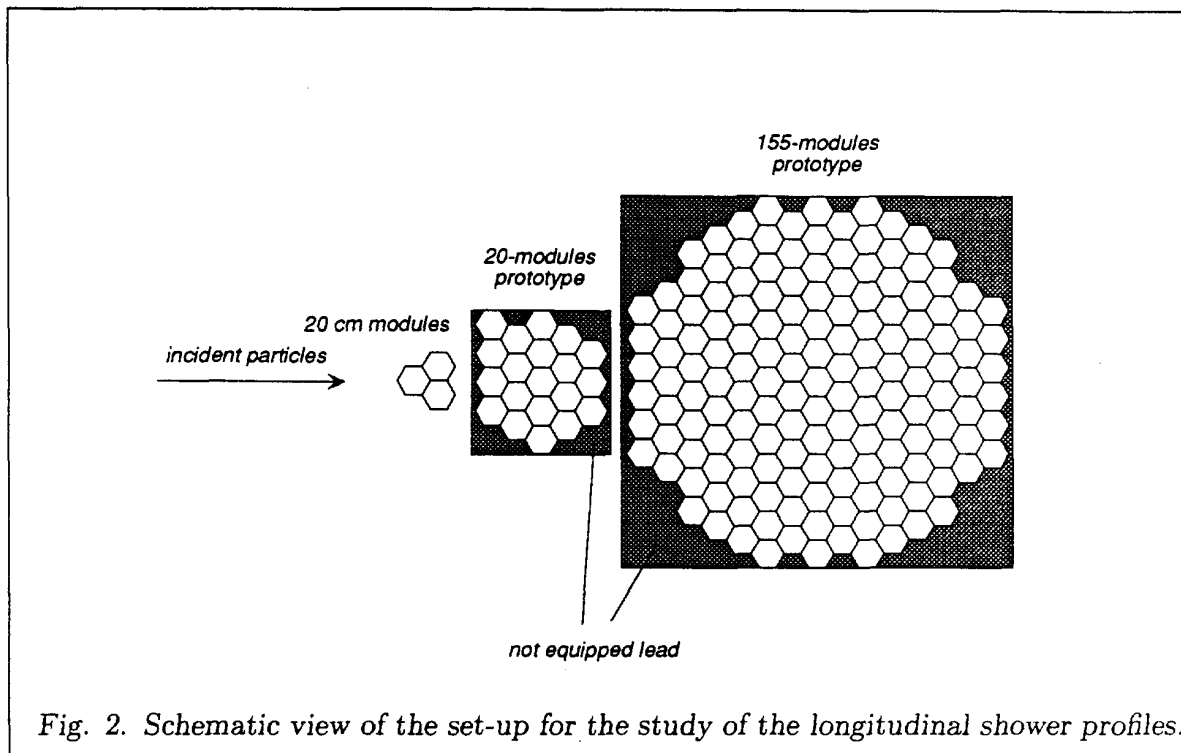
### 3. Studies on the control of the energy resolution.

We intend to develop a complete system which will allow to keep under control the calibration of a spaghetti calorimeter in a future hadron collider, starting from the production of the fibres up to the equalization of the response detector modules and to the absolute calibration of the energy response.

We intend to pursue the development of an automated quality control system for the fibres, based on a circular radioactive source, an image intensifier, a CCD camera, and an image processing computer.

Moreover, we will develop a movable radioactive-source-based system for the absolute calibration of the calorimeter in-situ.

For what concerns the control of the equalization of the module response, we are studing, through Monte Carlo simulations, the possibility to use the  $\gamma$ 's produced in



the proton-proton interactions to keep the inter-calibration of the modules within 1%, by fitting an exponential to the lower part of the  $p_T$  spectrum of the  $\gamma$ 's. Preliminary results indicate that this is possible with a relatively low statistics (about 50000  $\gamma$ /cell – see Fig. 3), *i.e.* with very short calibration runs at LHC.

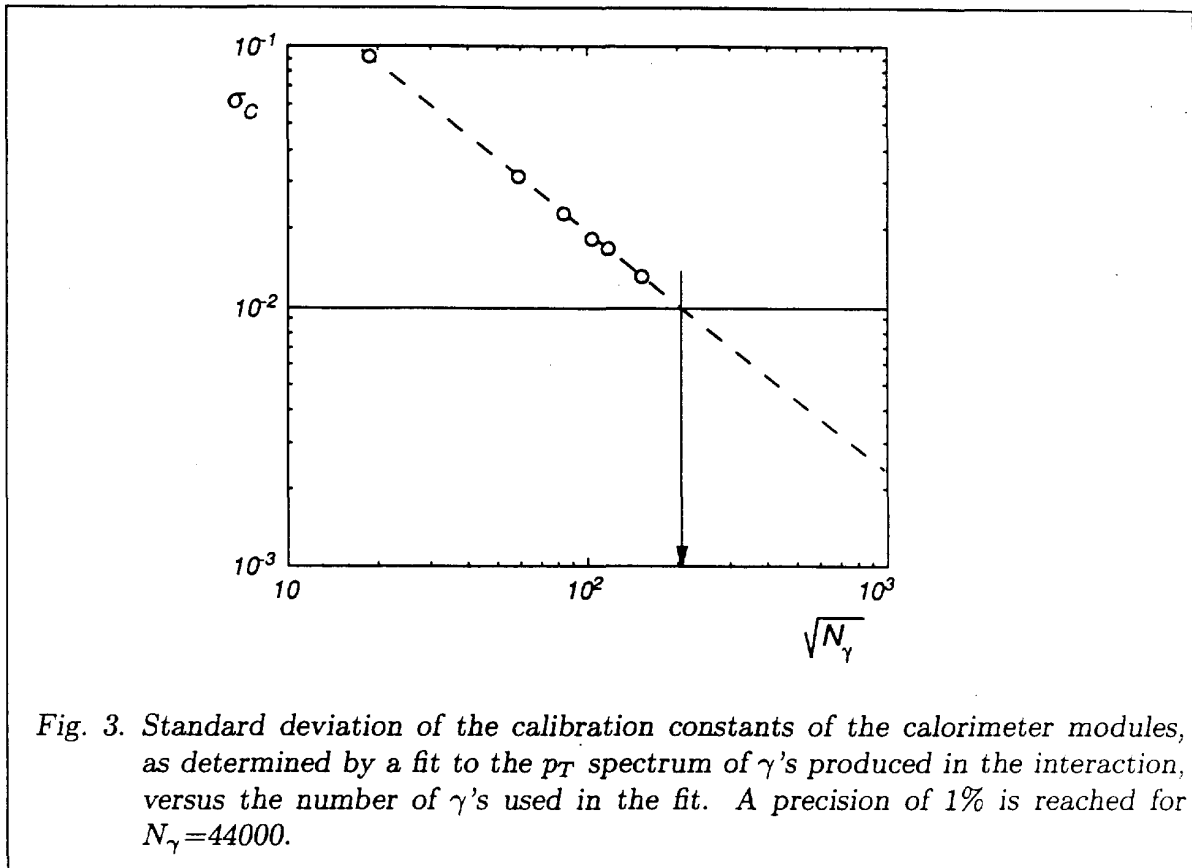
Electromagnetic particles penetrate only 20 ÷ 30 cm of the calorimeter. Therefore, the calibration must be transported to the whole volume of the calorimeter. As hadrons penetrate deeper inside the calorimeter, the same method outlined above can be used.

In order to make a complete simulation of the response to low-energy hadrons, we intend to measure the response of the 20-cells prototype to low-energy (0.5 ÷ 6 GeV) hadrons.

#### 4. Studies on the radiation damage of fibres.

The LAA group is presently performing radiation damage tests at LIL/LPI (0.5 GeV electrons) with full-size modules (2 m long), each equipped with 300 fibres. These tests are foreseen to last for about three weeks of integrated beam time.

We intend to continue these tests using several fibre samples given to us by industry for free specifically for these tests. Moreover, we plan to study the radiation damage induced by hadrons, by simulating the hadronic showers profile with electrons hitting on the module perpendicularly to the fibre direction.



## 5. Systematic studies on a preshower counter.

In order to take advantage of the very high spatial resolution of our calorimeter ( $17.1(\text{mm})/\sqrt{E(\text{GeV})}$  with the old prototypes,  $5.2(\text{mm})/\sqrt{E(\text{GeV})}$  with the new projective one), a very precise preshower counter is needed in order to recognize electrons in hadron jets, and to identify  $\pi/\gamma$  overlaps.

We intend to build a preshower counter based on  $BaF_2$ , read-out by a Parallel Plate Avalanche Chamber, developed by the group of G. Charpak in the framework of LAA. Different crystal sizes and thicknesses will be used to study their influence on the spatial and energy resolution of the calorimeter. A scheme of principle of the experimental apparatus is shown in Fig. 4.

## 6. Studies on the trigger and read-out system.

The very high speed of the spaghetti calorimeter signals (some ns) dictates for a comparably fast analysis, which must be done before digital conversion. We intend to develop the analog electronics which will allow to get "physical" signals from the calorimeter (*e.g.*, particle identification), in the same time-scale of the signals.

We also plan to select algorithms for a second level trigger, starting from the experience in image processing already built up in the LAA Project (group 6: Real-time data analysis).

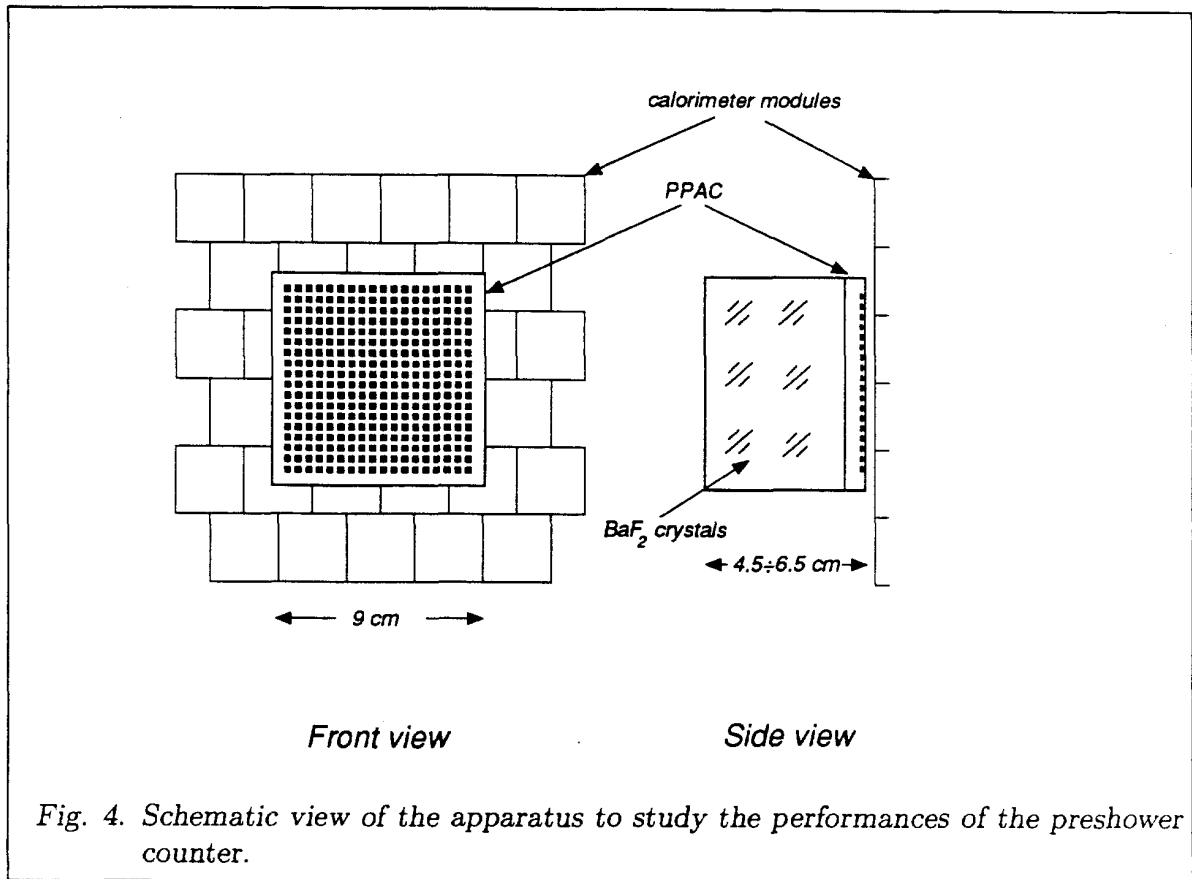


Fig. 4. Schematic view of the apparatus to study the performances of the preshower counter.

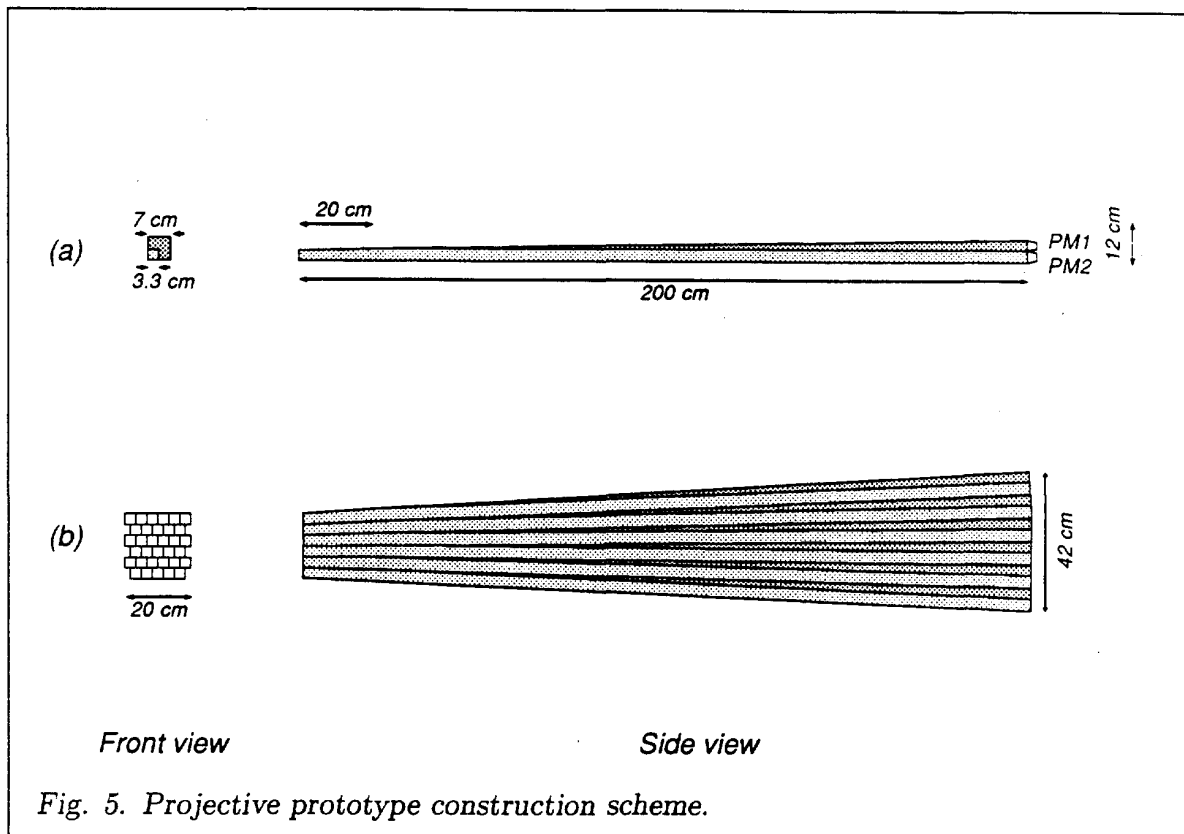
## 7. Studies on new geometries.

The technique used up to now to build spaghetti calorimeter prototypes are either not usable for full projective modules (pile-up technique – the one used to build the 20- and 155-cells prototypes), or combersome and expensive (brasing technique – as the one proposed for the experiment RD1).

We intend to develop new technologies for cheap mass-production of spaghetti calorimeter modules, based on binding together the lead strips. This should reduce the number of steps with respect to brasing, therefore reducing the cost. The possibility to use an automated machine to build complete modules will also be explored.

If these study are successful we intend to build a prototype calorimeter with 33 full-projective modules (400 cm<sup>2</sup> front face – see Fig. 5). This prototype, which will have modules with much smaller surface than the 20- and 155-cells prototypes, will be devoted to study  $e/\pi$  rejection and trigger strategies.

We also intend to build some smaller prototypes for studies on the response of different kind of fibres, on the electron/hadron response with a different lead:fibre ratio, and on the possibility to increase the attenuation length of the fibres.



### References.

- [1] R. DeSalvo et al., Nucl. Instr. and Meth., A279 (1989) 467.
- [2] D. Acosta et al. Nucl. Instr. and Meth. A294 (1990) 193.
- [3] D. Acosta et al., "Electron-pion discrimination with a scintillating fibre calorimeter", preprint CERN-PPE/90-172 (1990).
- [4] D. Acosta et al., "Localizing particle showering in a spaghetti calorimeter", preprint CERN-PPE/91-11 (1991).
- [5] D. Acosta et al., "On muon production and other leakage aspects of pion absorption in a spaghetti calorimeter", in preparation.
- [6] D. Acosta et al., "Electron, pion and multiparticle detection with a spaghetti calorimeter", in preparation.
- [7] B. Bencheikh et al., "First results on the spaghetti calorimeter projective prototype", presented at the V Pisa Meeting on Advanced Detectors, 25-31 May 1991, contribution in preparation.