CERN/SPSC 85-3

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M E M O R A N D U M

Copy to/Copie à:

To/A : SPS Committee

From/De : UA2 Collaboration

Subject/Objet: Status report on the UA2 end caps

Please find enclosed

1) Status report on the end cap tracking and preshower detector

2) Status report on the calorimeter end caps

for consideration by the SPS Committee in relation with the UA2 upgrade programme.

FIGURE CAPTIONS

1. General layout of the end cap calorimeters. The movable support structures which will allow to recess the end caps from the beam pipe are not shown.

2. (a) Side view of the welded iron structure for the hadronic calorimeter of one end cap module.
(b) Perspective view indicating also the space occupied by the electromagnetic calorimeter.

3. A comparison of the response from various scintillator and wavelength shifter combinations. The effective attenuation length is defined from the variation of the light collected over the first 40 cm of the scintillator samples.

4. Results from test beam measurements of a prototype electromagnetic cell. The resolution coefficient α ($\sigma_E/E = \alpha/\sqrt{E}$) and the deviation from linearity, normalized to p_{beam} = 40 GeV, are shown as a function of the beam momentum setting. No corrections are applied for leakage at the back of the calorimeter and for distortions of the energy spectra due to bremsstrahlung effects.

5. Time schedule for the end cap calorimeters.

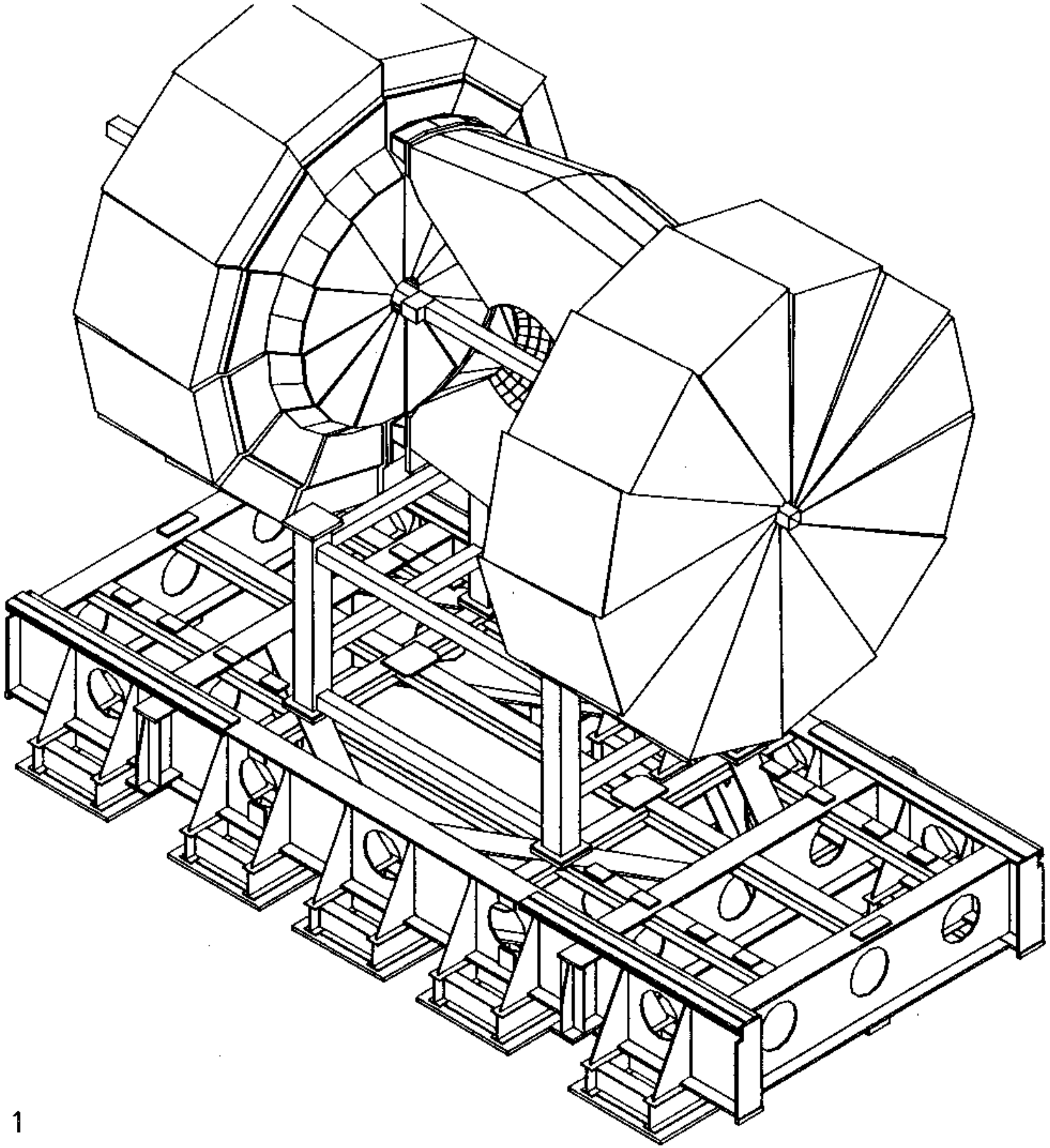
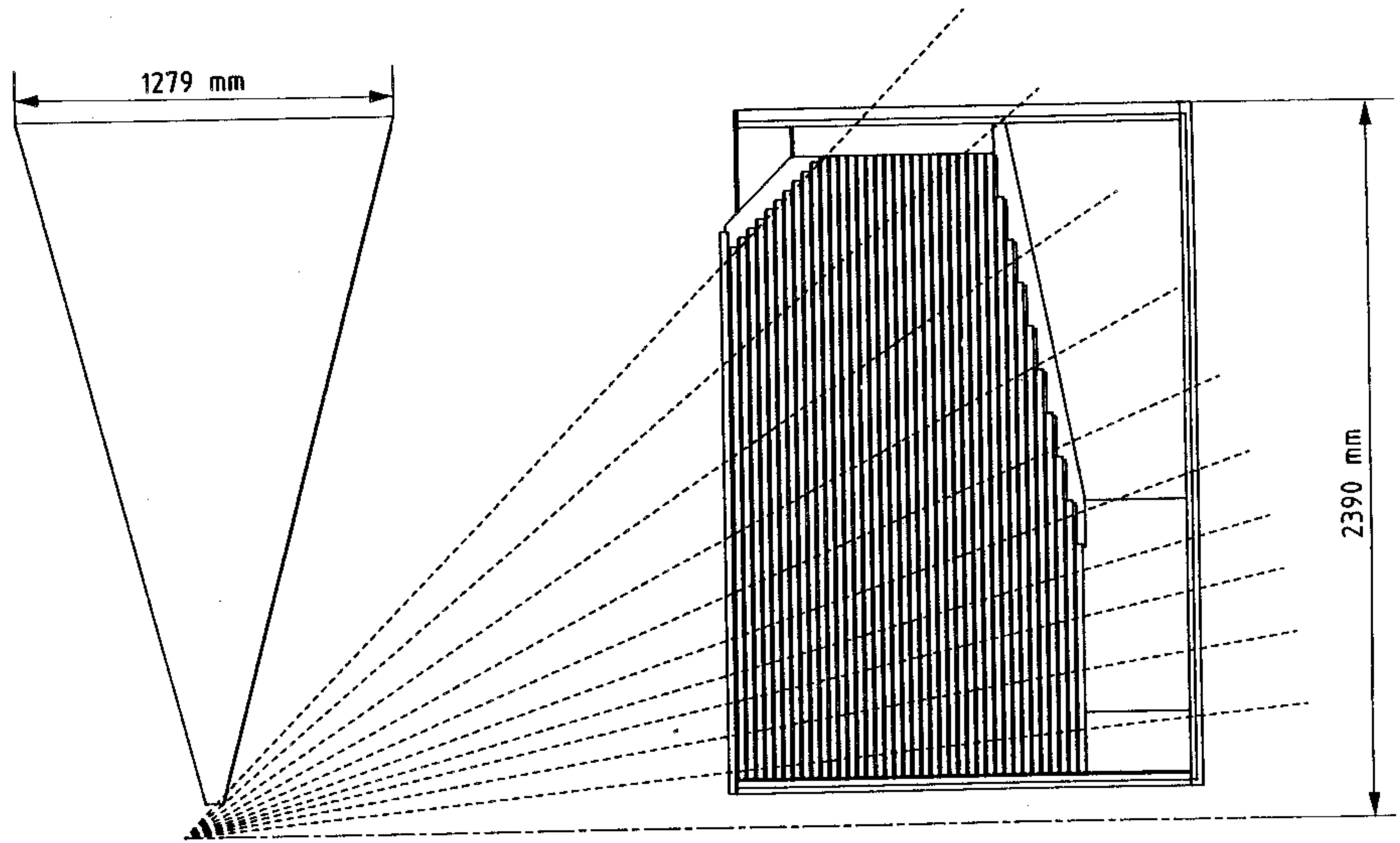


Fig. 1



1/20

Fig. 2a

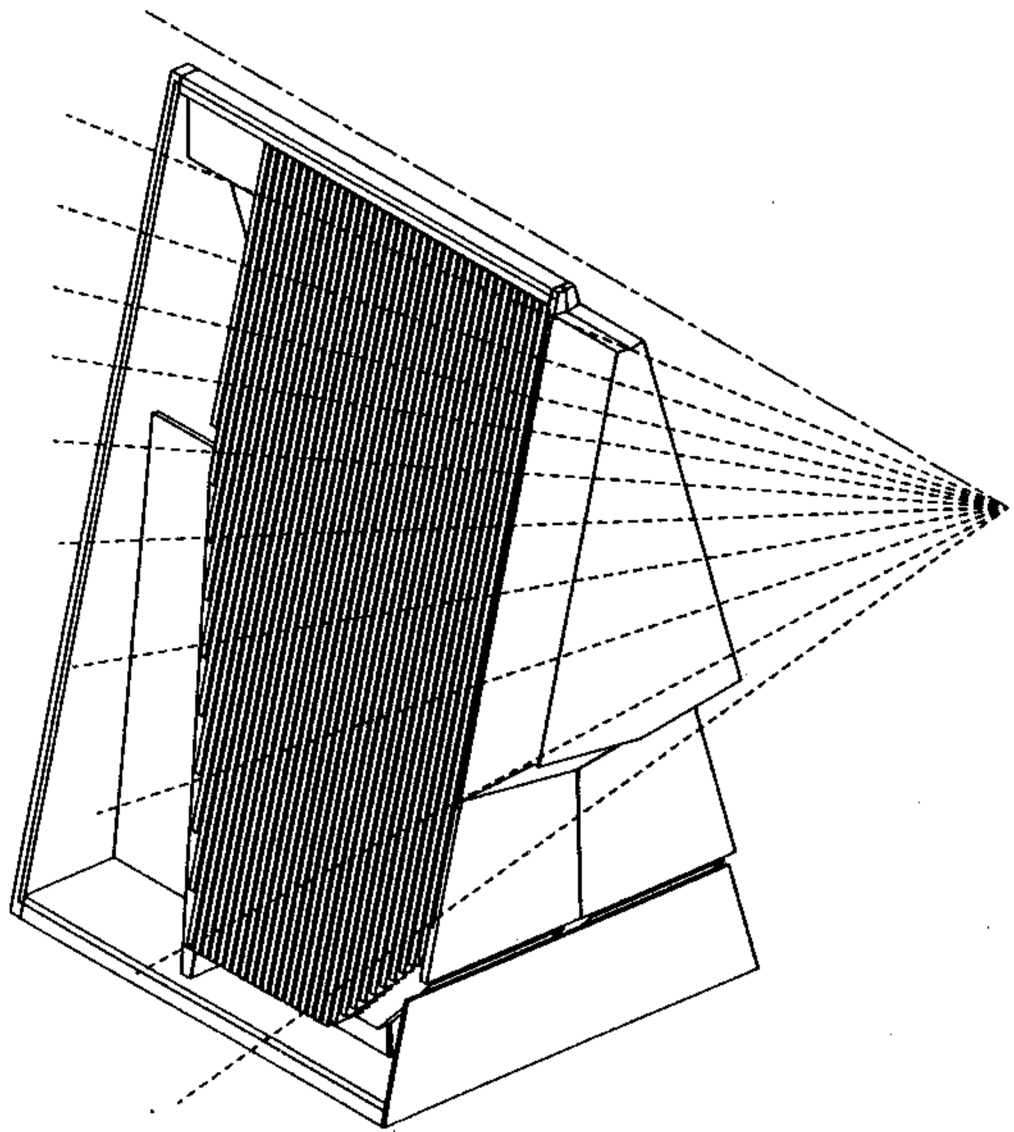


Fig. 2b

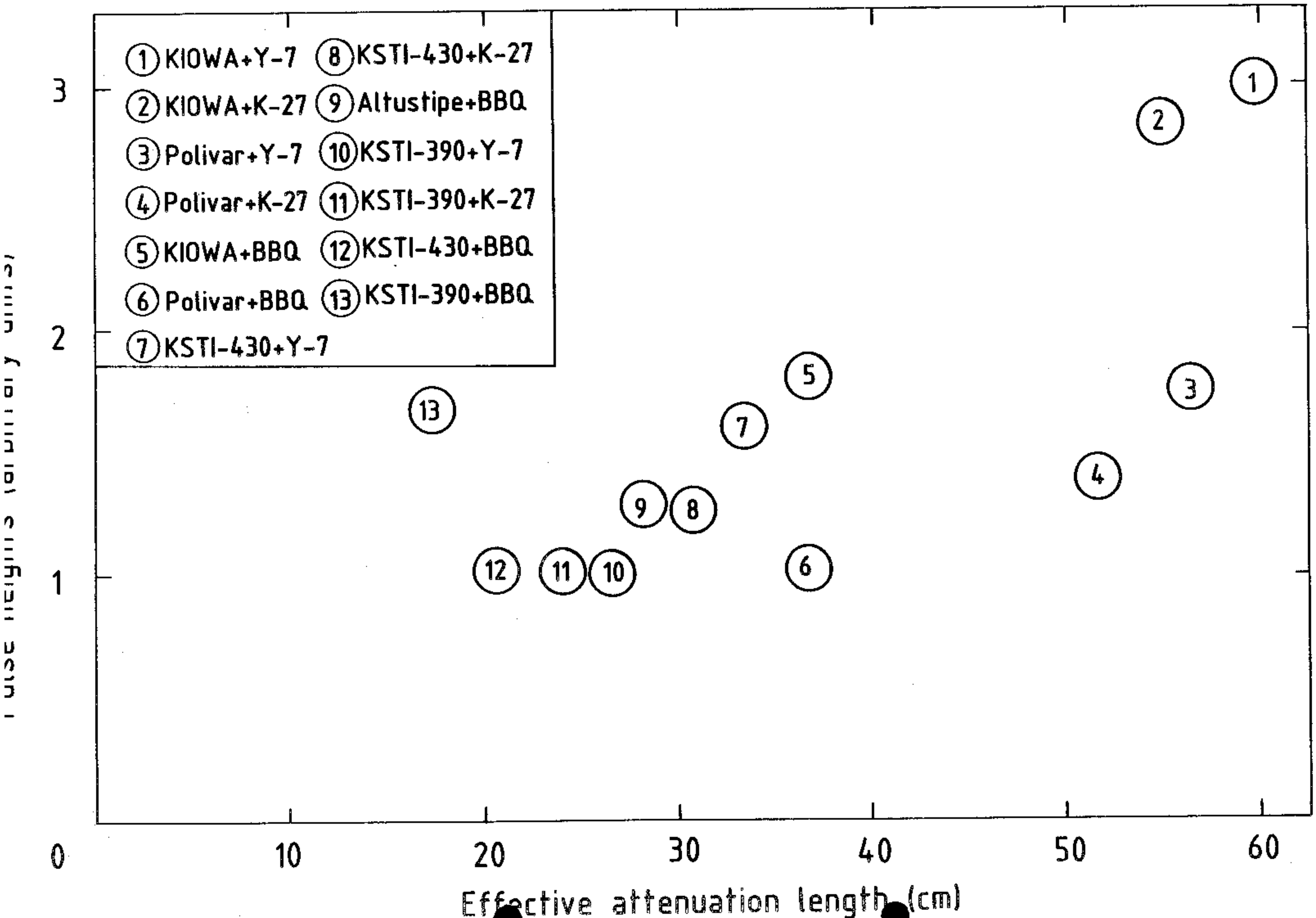

(1) KIOWA+Y-7
(2) KIOWA+K-27
(3) Polivar+Y-7
(4) Polivar+K-27
(5) KIOWA+BBQ
(6) Polivar+BBQ
(7) KSTI-430+Y-7
(8) KSTI-430+K-27
(9) Altustipe+BBQ
(10) KSTI-390+Y-7
(11) KSTI-390+K-27
(12) KSTI-430+BBQ
(13) KSTI-390+BBQ
0
1
2
3
10
20
30
40
50
60
Effective attenuation length (cm)

FIG. 3

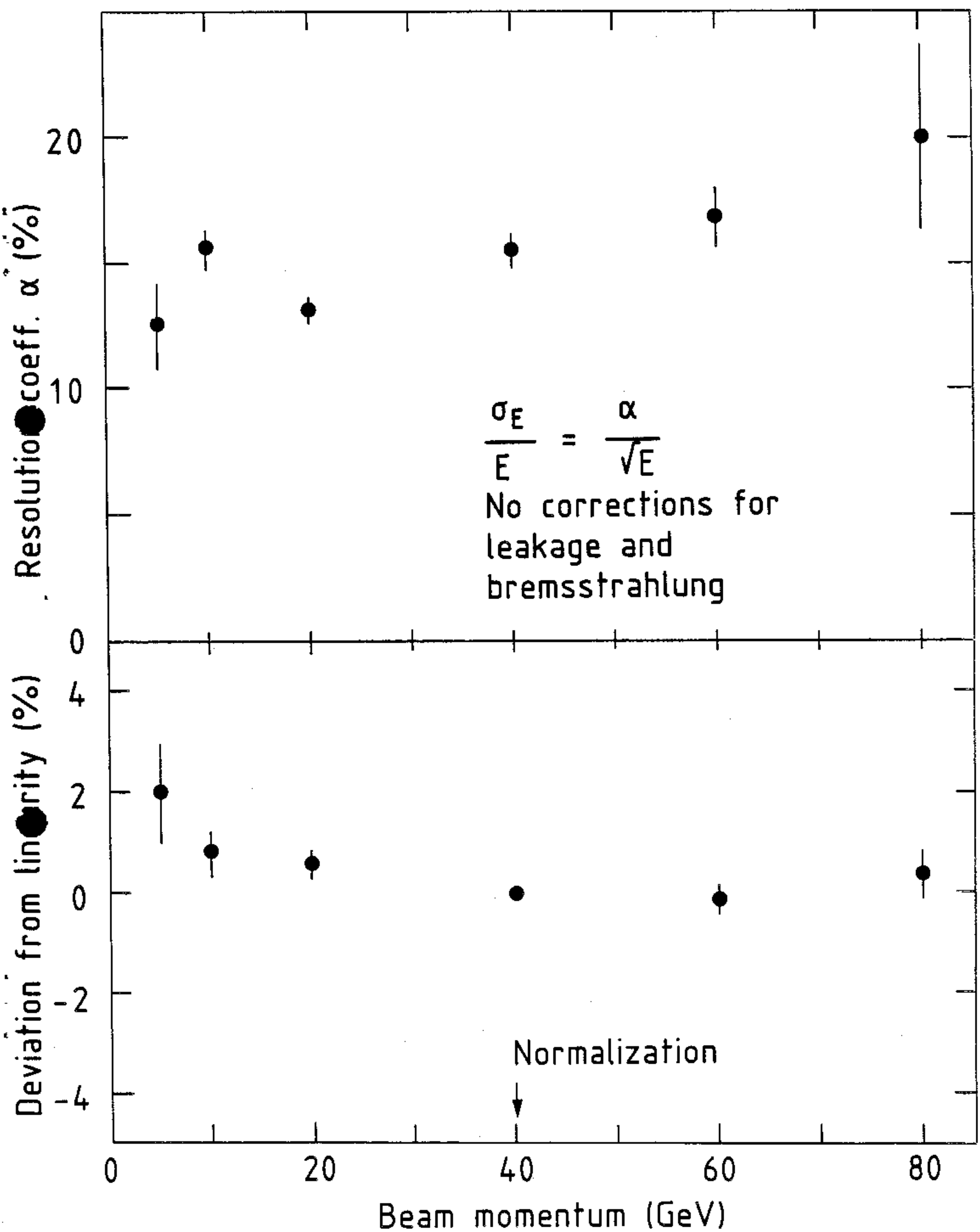

Resolution coeff. α (%)
20
10
0
$\frac{\sigma_E}{E} = \frac{\alpha}{\sqrt{E}}$
No corrections for leakage and bremsstrahlung
Deviation from linearity (%)
4
2
0
-2
-4
Normalization
0
20
40
60
80
Beam momentum (GeV)

FIG. 4

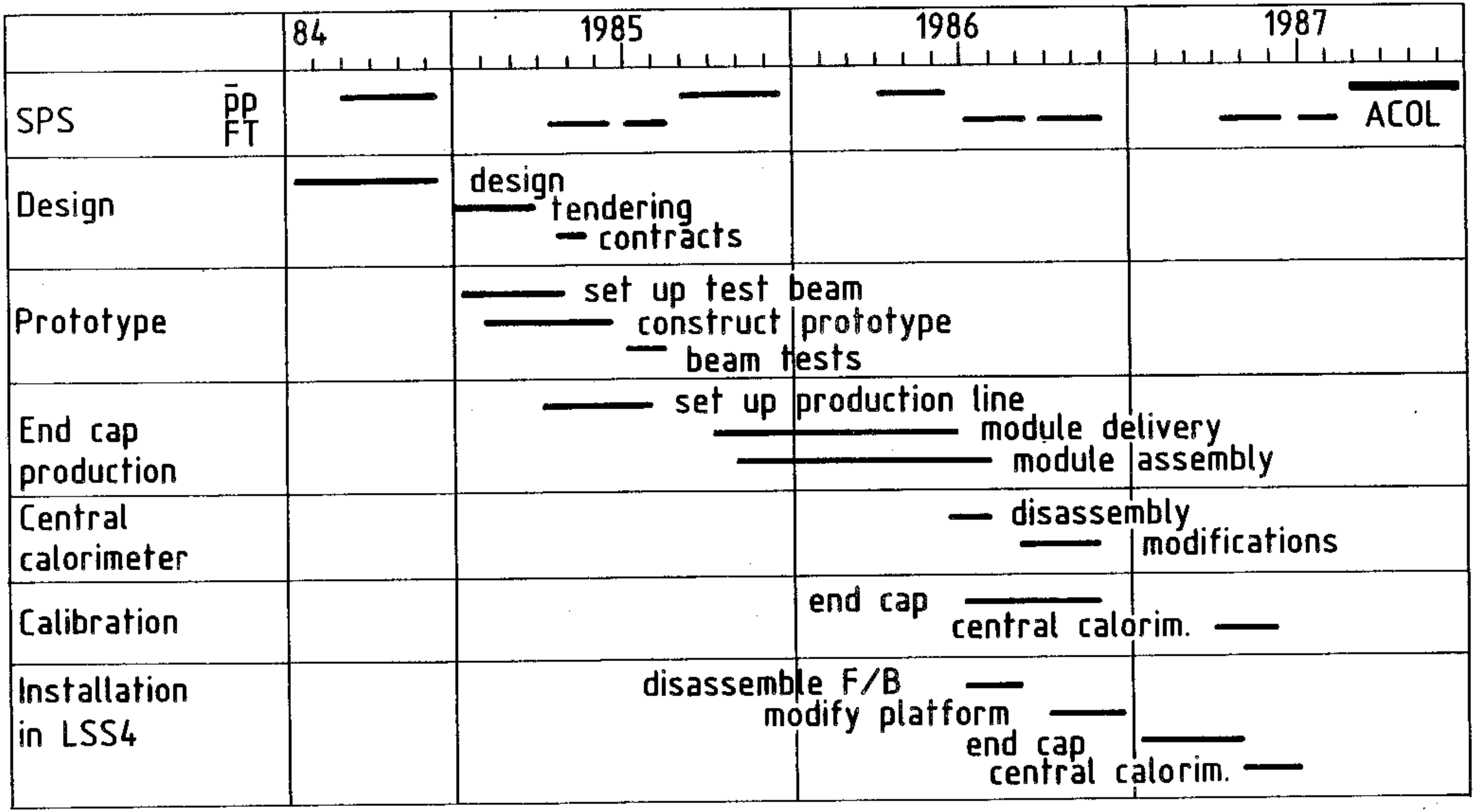

84
1985
1986
1987
SPS
p̄p
FT
ACOL
Design
design
tendering
contracts
Prototype
set up test beam
construct prototype
beam tests
End cap production
set up production line
module delivery
module assembly
Central calorimeter
disassembly
modifications
Calibration
end cap
central calorim.
Installation in LSS4
disassemble F/B
modify platform
end cap
central calorim.

Fig. 5

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

January 5th 1985

STATUS REPORT ON THE END CAP TRACKING AND PRESHOWER

The UA2 Collaboration

Bern[1], Cambridge[2], CERN[3], Milan[4], Orsay[5], Pavia[6], Pisa[7]

R.Ansorge[2], P.Bagnaia[3], M.Bonesini[4], C.Booth[2], K.Borer[1], M.Borghini[3], G.Carboni[7-3], D.Cavalli[4], V.Cavasinni[7], J-C.Chollet[5], A.G.Clark[3], C.Conta[6], G.Costa[4], P.Darriulat[3], B.De Lotto[5], T.Del Prete[7], L.Di Lella[3], K.Einsweiler[3], R.Engelmann[3], J-P.Fabre[3], L.Fayard[5], M.Fraternali[6], D.Froidevaux[5], J-M.Gaillard[5], O.Gildemeister[3], V.G.Goggi[6], C.Goessling[3], B.Hahn[1], H.Haenni[1], J.R.Hansen[3], P.Hansen[3], N.Harnew[3], E.Hugentobler[1], L.Iconomidou[5], P.Jenni[3], S.Katvars[2], M.Livan[6], L.Mandelli[4], L.Mapelli[3], M.Mazzanti[4], K.Meier[3], B.Merkel[5], R.Moning[1], M.Moniez[5], M.Morganti[7], D.Munday[2], C.Onions[3], M.A.Parker[3], G.Parrour[5], F.Pastore[6], L.Perini[4], J-P.Repellin[5], A.Rimoldi[6], J.Rushbrooke[2], J.Schacher[1], F.Stocker[1], M.Swartz[3], S.Tovey[3], W.Tsang[2], M.Valdata-Nappi[7], V.Vercesi[6], A.Weidberg[3], T.White[2].

1. INTRODUCTION

In the proposal to improve the performance of the UA2 detector [1], the forward regions are equipped with a tracking device and a preshower detector for electron-hadron separation and shower localization, followed by calorimeters having both electromagnetic and hadronic compartments [2]. In this status report we first describe a preliminary design for the tracking and preshower detectors along with possible options for the electronics (sect. 2). The design is based on results obtained with a prototype detector in a test beam [3] which are summarized in sect. 3. Finally we present a preliminary time table and the sharing of responsibilities for this part of the forward detectors.

2. TRACKING AND PRESHOWER DESIGN

The tracking and preshower detectors in the forward/backward regions are schematically shown in fig. 1a and 1b.

The compactness of the upgraded UA2 apparatus constrains the tracking and preshower devices to be confined in a small volume inside the open cones of the central calorimeters.

Taking into account the accuracy required for shower localization , proportional tubes with a 1 cm wire spacing, made of extruded aluminum profiles can be adopted,which allows for compactness and easy large-scale production. A proportional mode of operation is chosen for both devices in order to cope with high particle densities as could be expected from the higher luminosity at the collider and the absence of magnetic field, as well as maintaining the widest possible dynamic range for measuring the total particle multiplicity in electromagnetic showers. In addition , analog measurements allow for better space localization of the electromagnetic shower by determining the center of gravity of the charge collected in each plane of the detector.

Stacks of three planes of tubes with an inner cross-section of 9×9 mm^2, at 0° and $\pm 67.5^\circ$ stereo-angle, are used as modular elements. Arranged in sectors covering 45° in azimuth, they realize the best compromise between dead space and total number of electronic channels (about 11500). Adjacent sectors are preferred to overlapping modules since the frame dimensions can be minimized and the advantage of a uniform small distance between preshowers and calorimeters largely compensates for the small losses in sensitive area ($\cong$ 8%) due to the frames.

Each sector consists of two stacks (each with three planes) for the tracking part , to localize the track impact point, followed by a radiator and another stack of three planes to detect and localize the electromagnetic showers. The radiator , built as an iron-lead sandwich 2 r.l. thick, is the supporting element of the entire chamber structure, allowing for a uniform absorber thickness in front of the calorimeters over the full azimuth.

The preshower chambers will be equipped with multiplexed analog readout. The wire signals will be measured with low noise charge amplifiers. Track-and-hold circuits and analog multiplexers allow to reduce the number of ADC channels and of signal cables to the counting house to only one per chamber plane. Commercial ADC's and buffer memories (LeCroy 4300 and 4302 respectively) and a home-made data reduction unit will be used. This part of the electronics will be identical to the corresponding one of the Si-pad detector [4] presently under construction.

The amplifiers, track-and-hold circuits and multiplexers will be located on the front face of the chamber modules. Hybrid circuits and/or SMD (surface mounted device) circuits will be used in order to achieve the necessary small size and low mass of the readout electronics.

The same type of electronics could also be used for the tracking chambers, although a digital readout would be cheaper and would produce less information to be written on tape. Analog information, however, might be useful for rejecting hadrons interacting in the tracking chambers or in the material in front of them. A further study is necessary before deciding on the type of readout for the tracking chambers.

3. TEST BEAM RESULTS

The performance of a set af aluminum proportional tubes of the type described in the previous section was studied using hadron and electron beams at the SPS.

A test chamber equipped with tubes of 9×9 mm^2 in cross-section was placed behind lead converters of 1.5 or 2 r.l. effective thickness taking into account that the chamber plane was tilted at 30^0 to the beam, which is the average angle of incidence in the real detector.

Fig. 2 shows the variation of the total wire charge as a function of high voltage. The solid points are the most probable charge detected with minimum ionizing particles; the crosses represent the results with a 40 GeV/c electron beam and a 2 r.l. converter.

The chamber behaviour, shown for a 50%-50% Argon-Ethane mixture, is linear in the logarithmic plot up to a charge of about 1 pC, above which gas saturation effects appear. Similar measurements with an 80%-20% Argon-CO_2 mixture have the same voltage dependence with a gain about a factor two larger.

The comparison of pulse height distributions for 40 GeV/c electrons and hadrons yields an average charge multiplicity of about 30 m.i.p. for a 1.5 r.l. converter and about 50 m.i.p. for a 2 r.l. converter, with tails extending up to about 150 m.i.p. .

The detector efficiencies for electrons and hadrons are shown in fig. 3 as a function of the cut on the pulse height distributions for various experimental conditions. Fig. 4 shows the correlation between the two efficiencies at 10 and 40 GeV/c.

The space resolution can be evaluated from the distribution of the residuals between the detected charge centroid and the beam impact coordinates measured by a set of multiwire proportional chambers . The residuals are shown in fig. 5a for hadrons and in fig. 5b for electrons. The resulting resolution is about 3 mm on each coordinate plane for non-showering particle tracks and 2.3 mm for the centroid of the shower charge.

An extrapolation to a multiple-plane structure as described in sect.2 yields a space resolution of less than 2 mm.

4. PRELIMINARY TIME-TABLE AND COST ESTIMATE

A full scale prototype of a complete sector will be assembled and tested by summer 1985 in order to study its mechanical and electrical properties and the detailed performance in a test beam.

A detailed schedule for the production of the whole detector is not yet defined but the construction techniques which are being considered allow us to estimate that the time available before the installation is easily sufficient for the construction of all modules.

We estimate the cost to at most 700 kSF.

The full responsibility for this part of the detector is shared between the Bern and Pavia groups.

REFERENCES

1. The UA2 Collaboration, Proposal to improve the performance of the UA2 detector, CERN/SPSC 84-30, SPSC/P93 Add. 2, May 15th 1984.

2. The UA2 Collaboration, Status report on the calorimeter end caps.

3. UA2 Internal Notes 387 and 394.

4. The UA2 Collaboration, Proposal to improve the performance of the UA2 central detector, CERN/SPSC 84-95, SPSC/P93 Add. 3, Dec. 1st 1984.

FIGURE CAPTIONS

1. (a) Schematic cross-section of the UA2 detector in a plane containing the beam line showing the position of the tracking and preshower detectors.
   (b) Schematic view of four octants in a plane perpendicular to the beam line.

2. Dependence of the total wire charge as a function of high voltage. The full points give the value of the pulse height peak distribution of the sum of all wires for minimum ionizing particles. The crosses represent the results with a 40 GeV/c electron beam and a 2 r.l. converter.

3. (a) Electron efficiency as a function of the m.i.p. cut for various electron momenta and two different converters (1.5 and 2 r.l.).
   (b) Hadron efficiency.

4. Hadron efficiency as a funcion of the electron efficiency for various electron momenta and converter thicknesses.

5. Distributions of residuals between the charge centroid and the impact coordinate for:
   (a) hadrons
   (b) electrons

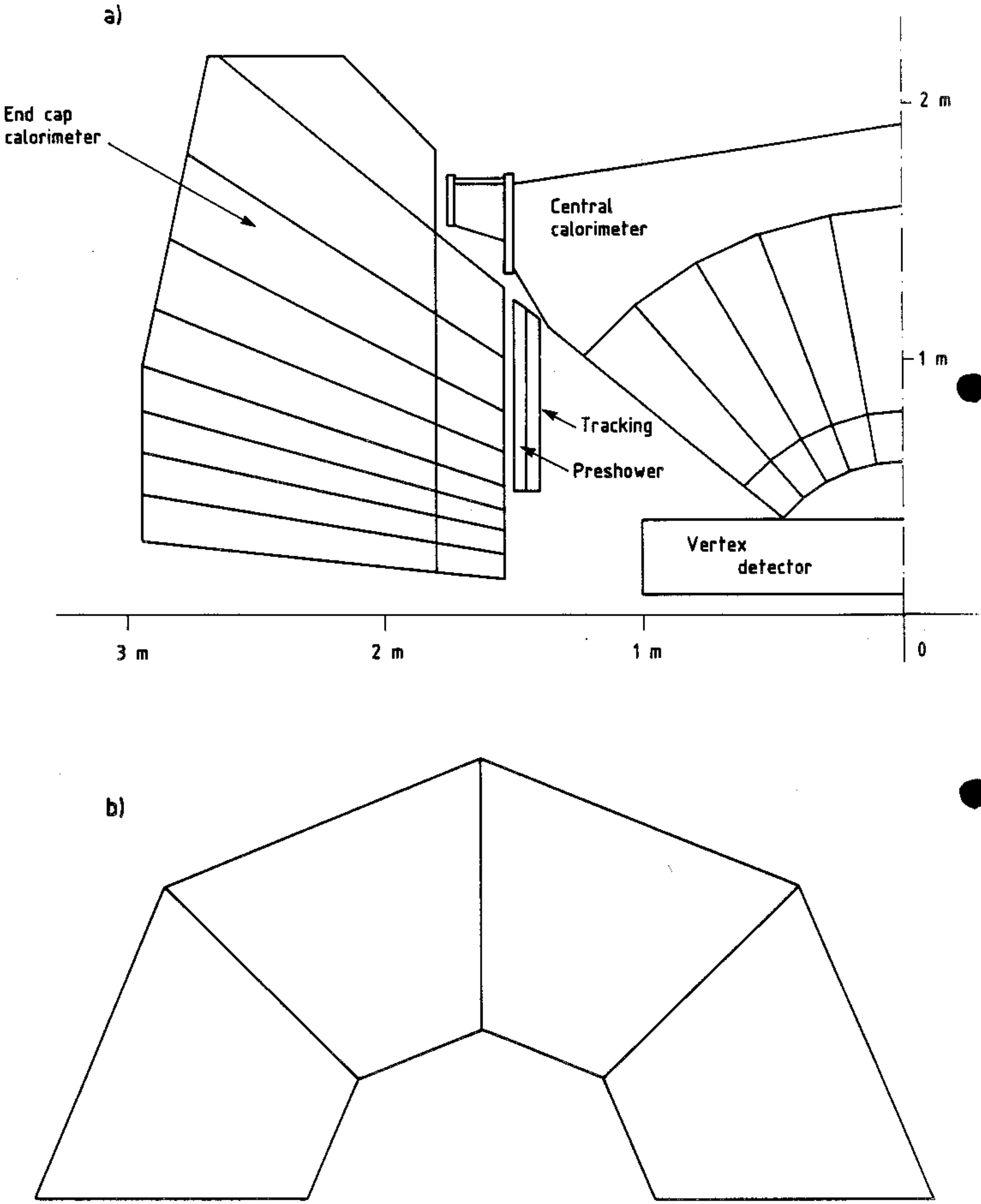
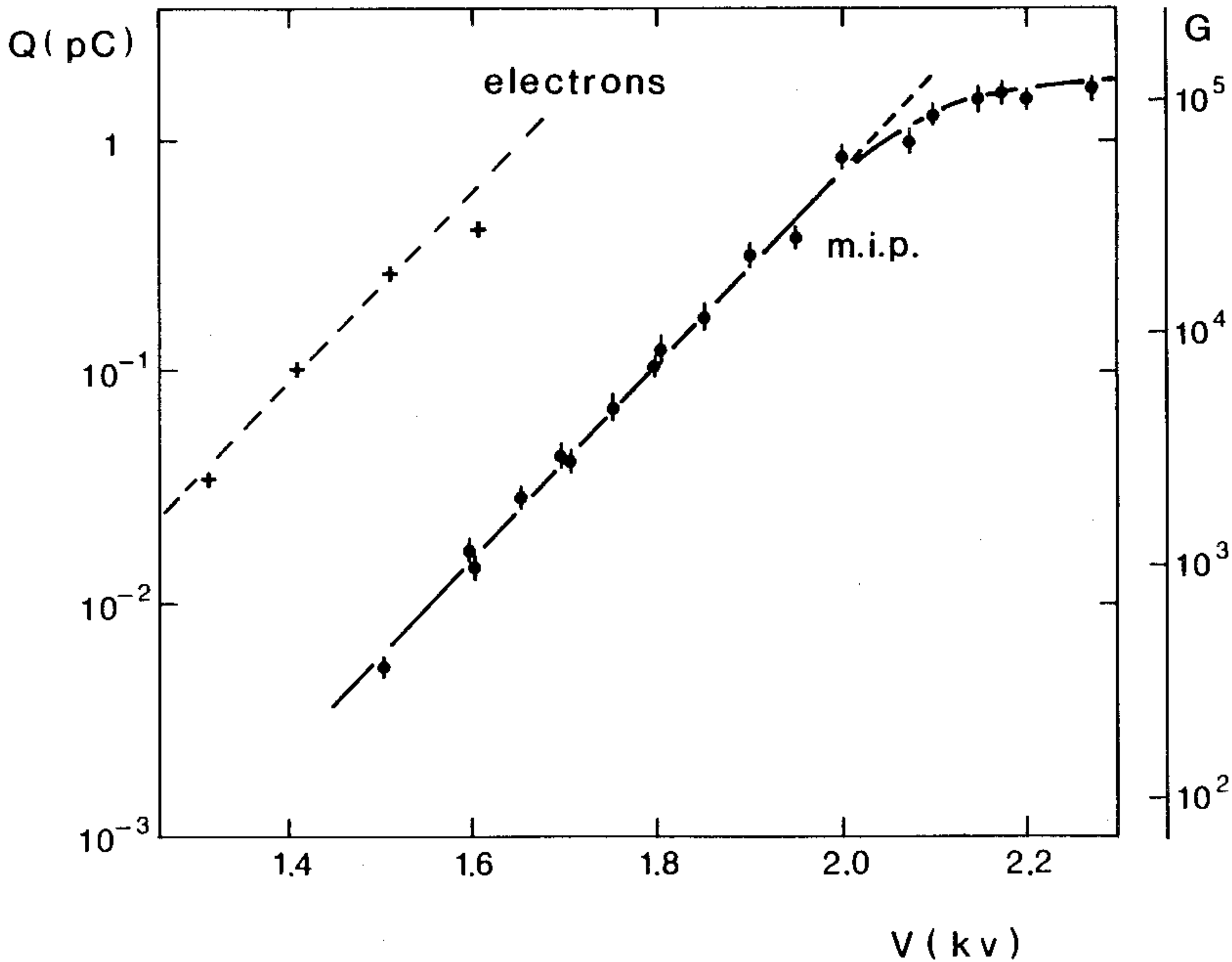
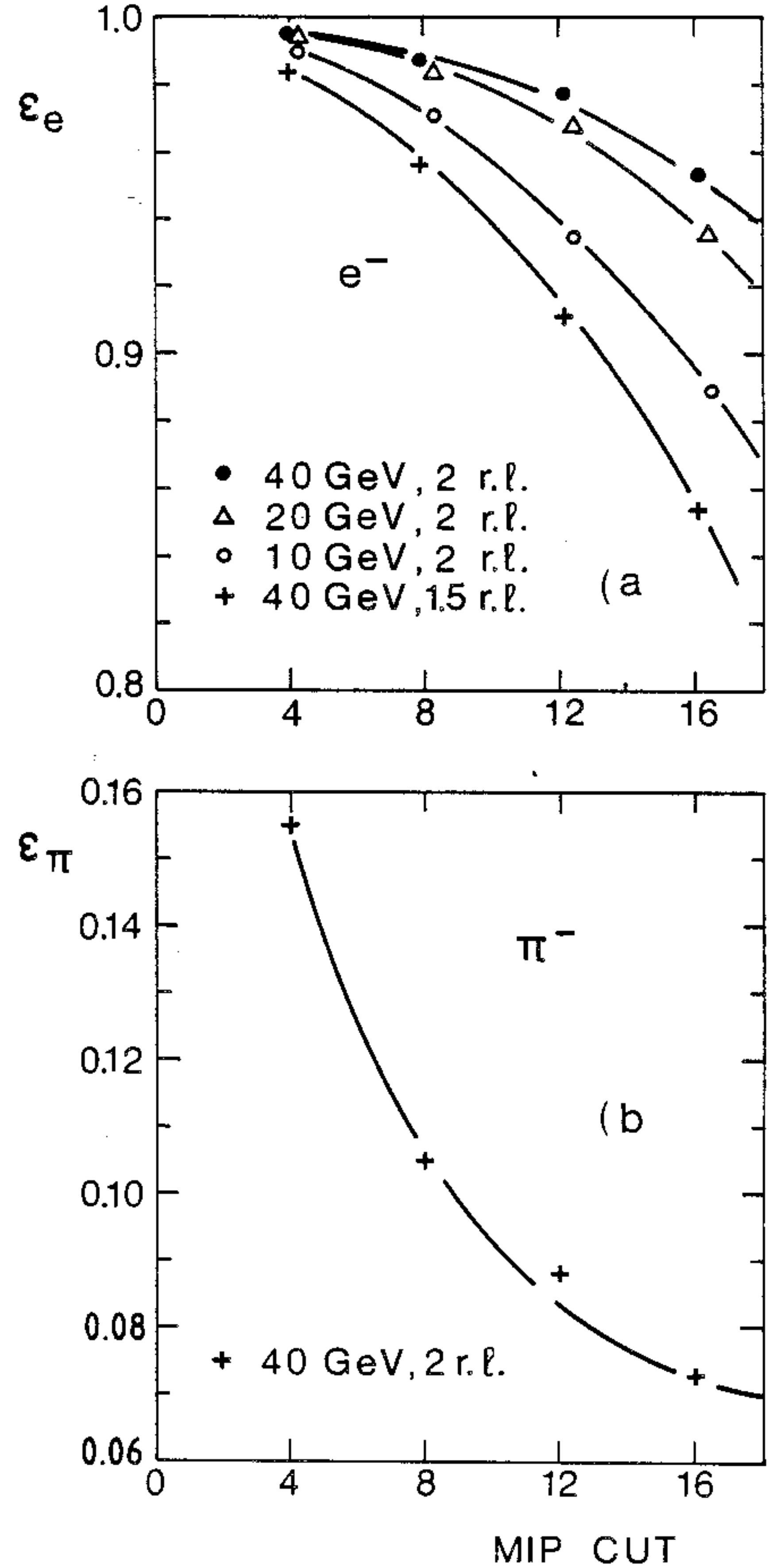

a)
End cap calorimeter
Central calorimeter
Tracking
Preshower
Vertex detector
2 m
1 m
3 m
2 m
1 m
0
b)

FIG. 1


Q(pC)
electrons
m.i.p.
G
1
10⁻¹
10⁻²
10⁻³
10⁵
10⁴
10³
10²
1.4
1.6
1.8
2.0
2.2
V (kv)

FIG, 2



1.0
0.9
0.8
ε_e
e⁻
40 GeV, 2 r.ℓ.
20 GeV, 2 r.ℓ.
10 GeV, 2 r.ℓ.
40 GeV, 1.5 r.ℓ.
(a
0
4
8
12
16
0.16
0.14
0.12
0.10
0.08
0.06
ε_π
π⁻
(b
40 GeV, 2 r.ℓ.
MIP CUT

FIG, 3

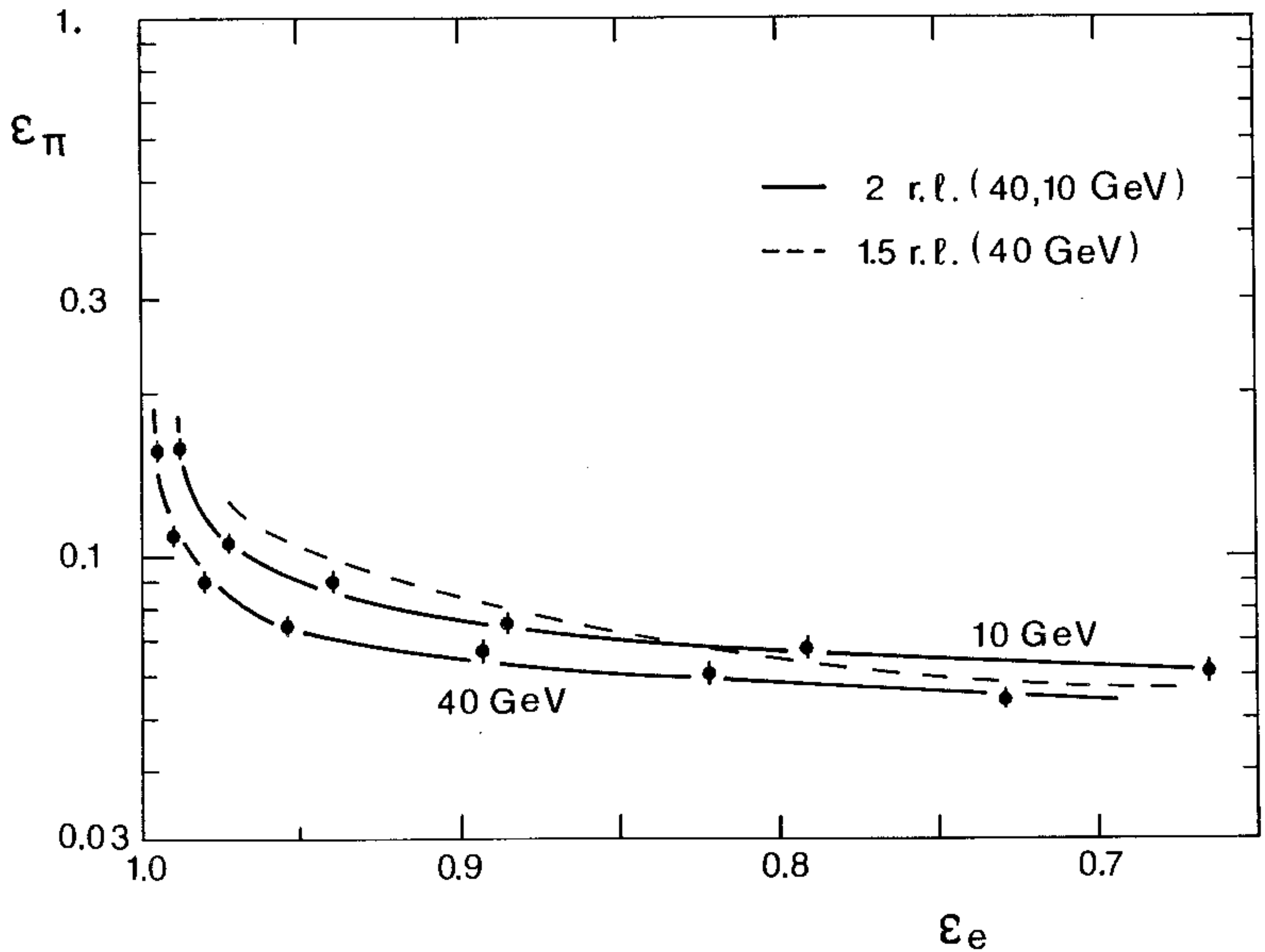
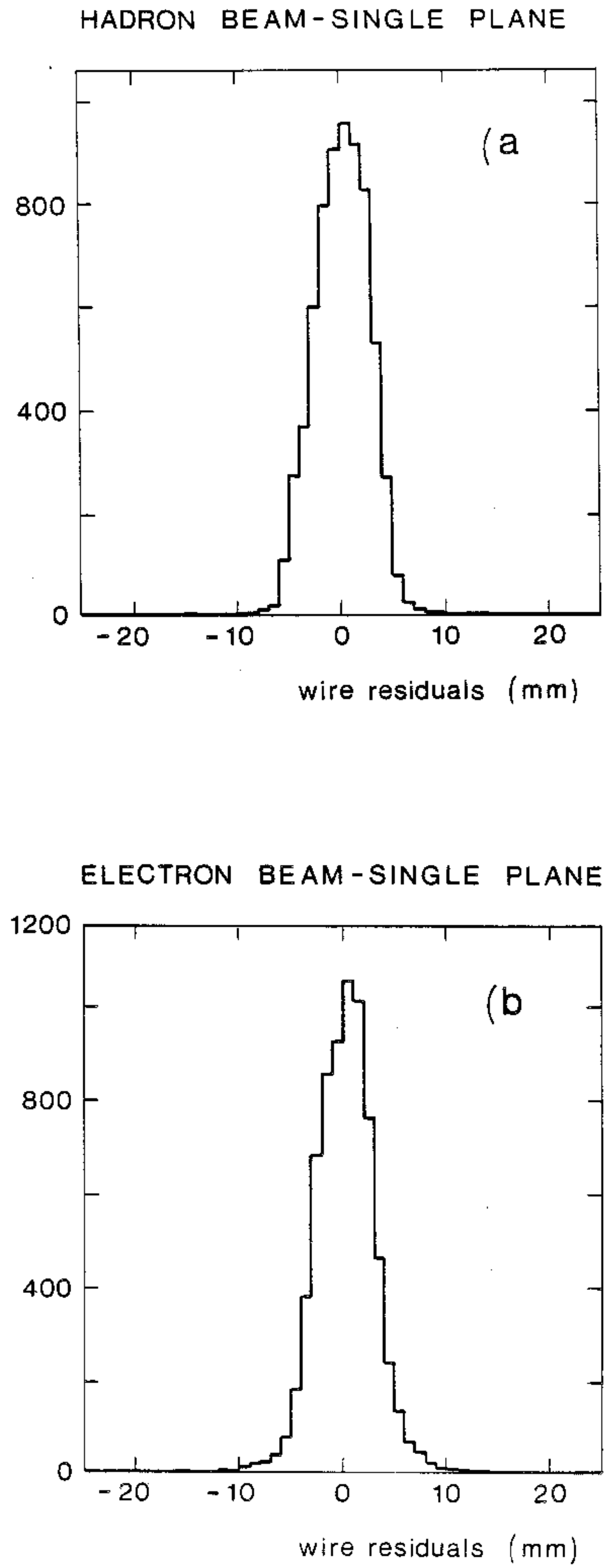


FIG. 4



HADRON BEAM-SINGLE PLANE
(a
800
400
0
-20
-10
0
10
20
wire residuals (mm)
ELECTRON BEAM-SINGLE PLANE
1200
(b
800
400
0
-20
-10
0
10
20
wire residuals (mm)

FIG. 5

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

January 5th 1985

STATUS REPORT ON THE CALORIMETER END CAPS

The UA2 Collaboration

Bern[1], Cambridge[2], CERN[3], Milan[4], Orsay[5], Pavia[6], Pisa[7]

R.Ansorge[2], P.Bagnaia[3], M.Bonesini[4], C.Booth[2], K.Borer[1], M.Borghini[3], G.Carboni[7-3], D.Cavalli[4], V.Cavasinni[7], J-C.Chollet[5], A.G.Clark[3], C.Conta[6], G.Costa[4], P.Darriulat[3], B.De Lotto[5], T.Del Prete[7], L.Di Lella[3], K.Einsweiler[3], R.Engelmann[3], J-P.Fabre[3], L.Fayard[5], M.Fraternali[6], D.Froidevaux[5], J-M.Gaillard[5], O.Gildemeister[3], V.G.Goggi[6], C.Goessling[3], B.Hahn[1], H.Haenni[1], J.R.Hansen[3], P.Hansen[3], N.Harnew[3], E.Hugentobler[1], L.Iconomidou[5], P.Jenni[3], S.Katvars[2], M.Livan[6], L.Mandelli[4], L.Mapelli[3], M.Mazzanti[4], K.Meier[3], B.Merkel[5], R.Moning[1], M.Moniez[5], M.Morganti[7], D.Munday[2], C.Onions[3], M.A.Parker[3], G.Parrour[5], F.Pastore[6], L.Perini[4], J-P.Repellin[5], A.Rimoldi[6], J.Rushbrooke[2], J.Schacher[1], F.Stocker[1], M.Swartz[3], S.Tovey[3], W.Tsang[2], M.Valdata-Nappi[7], V.Vercesi[6], A.Weidberg[3], T.White[2].

1. INTRODUCTION

The motivation for and the general layout of the calorimeter end caps have been given in the proposal to improve the performance of the UA2 detector [1]. In this status report we first give more details on the final design which is nearly completed. Then we describe tests made to guide the choice of scintillator and wavelength shifter materials and we report the results obtained with a prototype electromagnetic cell in a test beam. Finally we update the construction and calibration schedule, the cost estimates and the sharing of the responsibilities for the calorimeter end caps.

2. END CAP DESIGN

The general layout is illustrated in Fig. 1. The calorimeter end caps are shown without their movable support structure which will allow recessing the calorimeters from the beam pipe during machine developments with high radiation levels.

Each end cap is divided into sectors subtending $\Delta\phi = 30°$ in azimuth. The absorber plates in each sector are continuous over the whole polar angle region $5.6° < \theta < 45°$ (Fig. 2), the segmentation into cells (towers) is defined by the scintillator plates. The wavelength shifter (WLS) plates collect the light of each cell at about constant azimuth with a segmentation of $\Delta\phi = 15°$ for $\theta > 12.7°$ and `$\phi = 30°$ for $\theta < 12.7°$. The necessary space for the WLS plates and their mountings between neighbouring cells in azimuth is 7 mm for the electromagnetic and 13 mm for the hadronic compartments. However, in order to avoid an alignment of these cracks with the event vertex each sector will be rotated by an angle of 50 mrad around the symmetry axis of the first absorber plate of the hadronic calorimeter when mounting the sectors in the calorimeter end caps (see Fig. 1). As a consequence the opening angle of the sectors is reduced from $\Delta\phi = 30°$ to $\Delta\phi = 29.96°$.

The iron structure, absorber plates and supports of the hadronic calorimeter are shown in Fig. 2. We recall that one sector contains two azimuthal subsectors of $\Delta\phi = 15°$ each. The absorber plates will be welded to a support. All scintillator plates of a given plane will be mounted together between thin ($\lesssim$ 1 mm) Fe sheets and inserted in the gaps between the absorber plates. The tolerances on the gaps resulting from the welding procedure have been studied on a full size model with four absorber plates. This model has also been used to find the best mounting technique for the scintillator plates.

The electromagnetic calorimeters will be assembled separately in azimuthal subsectors of $\Delta\phi = 15°$ by making stacks of continuous Pb plates alternating with scintillator plates which define the cell (tower) structure. The stacks will be held together by pressure between a rigid front face and a Fe back plate which will also serve as the first absorber plate of the hadronic calorimeter. The pressure will be maintained by four 6 mm diameter bolts traversing the stack (not aligned with the particle directions) and a support structure replacing the electromagnetic calorimeter cell at the smallest polar angles.

For both the hadronic and the electromagnetic calorimeter compartments the readout will be made by WLS plates on opposite sides of each cell. The light is channeled via a twisted strip light guide optics onto Philips XP2012 B photomultipliers.

An updated list of the parameters of the calorimeter end caps is given in Table 1.

3. SCINTILLATOR AND WAVELENGTH SHIFTER TESTS

A variety of tests have been made to select the most satisfactory combination of scintillator and wavelength shifter (WLS) materials. Of primary interest for the present design are long attenuation length λ_{att} in the scintillator plates because of the large cell dimensions at large polar angles (up to 50 cm between WLS plates in the hadronic calorimeter), to a lesser extent high light yield I_0 and low cost. The results on λ_{att} and I_0 are summarized in Fig. 3 for the materials considered. The best result is obtained with the combination of the polystyrene scintillator KIOWA SCSN-38 with KIOWA Y-7 WLS. A satisfactory performance is however also observed for the acrylic scintillator of POLIVAR read out with HOECHST K-27 WLS, at a cost of only about 20% of the previous combination. We retain this choice.

Tests on radiation damage have been made using the 1.2 MCi Co^{60} radiation facility at the CONSERVATOME in Dagneux.
With a radiation dose of 1.1 x 10^3 Gray we have measured degradation effects of the order of 20% on the polystyrene and 50% on the acrylic scintillators. This radiation dose is more than a factor 50 times larger than measured directly on the beam pipe integrated over three months of $\bar{p}p$ operation [2]. Furthermore, the integrated radiation dose on the end caps will be reduced by at least two additional orders of magnitude by recessing the calorimeters during Collider machine developments. We therefore maintain the choice of POLIVAR scintillator. Concerning the WLS, we have observed no effects on both the Y-7 and K-27 samples whereas a 50% degradation for the BBQ samples has been measured.

The scintillator and WLS sample tests mentioned above have been made with radioactive sources by measuring the direct current from the photomultiplier (PM) attached to the WLS. In order to check the performance in a real calorimeter we have made measurements in a test beam with an electromagnetic cell of typical dimensions from the end cap. The test calorimeter contains alternating Pb plates (3.5 mm thick) and POLIVAR scintillators (4 mm thick) with a total depth of 21 radiation lengths. The read out is made with two K-27 WLS plates (2 mm thick, 250 mg/l) channelling the light via flat light guides to two

XP2012 PM's. The SPS electron test beam X5 has been used. The results are given in Fig. 4 where the energy is defined as the geometric mean of the two pulse height measurements from the two PM's. As aimed for, the resolution and the linearity are the same as for the central calorimeter of UA2 [3]. A scan has been made by varying the electron beam impact on the trapezoidal front face of the cell. The response corrections are found to be smaller than ±15%, except for impact points very near the cell boundaries where leakage into adjacent cells would have to be included. It will be of course necessary to measure the response as a function of particle impact for a complete end cap module in the same way as it has been done for the UA2 central calorimeter [3].

4. UPDATED CONSTRUCTION AND CALIBRATION SCHEDULE

The time schedule of the end cap construction and calibration is displayed in Fig. 5. This time table takes into account updates in the scheduling of the SPS fixed target and Collider periods for 1985 as well as a possible SPS scheduling for 1986 and 1987.

The design phase of the end cap modules is now approaching completion. The tendering period for the iron structure of the hadronic calorimeters will begin in January 1985. The design of the electromagnetic calorimeter will be finalized before the end of this year. In parallel design studies have started for the movable support structure on the UA2 detector platform and for the scanning table for the test beam measurements.

It is intended to construct the first complete end cap module as a prototype preceding the serial production which will begin at the end of Summer 1985. The machining of the iron for the prototype module has started at the CERN Main Workshop. We plan to assemble the prototype end cap module during Spring 1985 and to make extensive test measurements in the SPS beam H2 during period P3 in Summer 1985.

The planning for the years 1986 and 1987 is based on the assumption that a $\bar{p}p$ Collider run may take place in spring 1986 followed by fixed target running in autumn 1986 and spring 1987, and that the first Collider run with ACOL will be towards the end of 1987. This fixed target time will be sufficient to calibrate all the end cap calorimeters as well as to recalibrate the central calorimeter as requested in [1]. Furthermore during this time, the present forward detectors will have to be dismounted and the modifications to the UA2 detector platform will be made for the mounting of the end caps. The installation in LSS4 of the upgraded UA2 detector will take place in the first half of 1987. It should be noted that the time schedule does not tolerate any substantial delays, in particular a late $\bar{p}p$ Collider run in 1986 would prevent UA2 from being ready for the ACOL running period in 1987.

5. UPDATED COST ESTIMATE

The revised cost estimate for the end caps is specified in Table 2. The total budget for the end caps stays within the 3.5 MSFr quoted in the proposal [1]. This sum reflects the fact that we intend to reuse some components of the present forward detectors as well as ADC's from the present vertex detector [4] corresponding to a value of 400 and 100 kSFr respectively.

6. SHARING OF RESPONSIBILITIES

The responsibility for the construction, calibration, installation as well as for the financing of the end cap calorimeter is shared between the CERN and Milan groups of the UA2 Collaboration.

REFERENCES

1. The UA2 Collaboration, proposal to improve the performance of the UA2 detector, CERN/SPSC 84-30, SPSC/P93 Add. 2, May 15th 1984.

2. SPS Rapport Surveillance Radiations, RSR/SPS/RING/83-1.

3. A. Beer et al., Nucl. Instr. Meth. 224 (1984) 360.

4. The UA2 Collaboration, proposal to improve the performance of the UA2 central detector, CERN/SPSC 84-95, SPSC/P93 Add. 3, Dec. 1st 1984.

TABLE 1 : End Cap Calorimeter Parameters

Electromagnetic calorimeter	
technique	Pb-scintillator sandwich K-27 wavelength shifter read out
material	32 Pb plates, 3 mm thick 33 scintillator plates, 4 mm thick
sampling	0.54 to 0.70 X_0
total thickness	17.1 to 24.4 X_0
Hadronic calorimeter	
technique	Fe-scintillator sandwich K-27 wavelenght shifter read out
material	Fe plates, 25 mm thick scintillator plates, 4 mm thick $5^\circ < \theta < 20^\circ$: 38 plates $20^\circ < \theta < 40^\circ$: decreasing from 38 to 29 plates
sampling	0.15 to 0.19 λ_0
total thickness	5.6 to 6.2 λ_0 (0.6 to 0.8 λ_0 in addition from the electromagnetic calorimeter)
Segmentation	
structure	towers pointing to the centre of the detector
cell size	$1.0 < \|\eta\| < 2.2$: $\Delta\phi \times \Delta\eta = 15^\circ \times 0.2$ $2.2 < \|\eta\| < 2.5$: $\Delta\phi \times \Delta\eta = 30^\circ \times 0.3$ $2.5 < \|\eta\| < 3.0$: $\Delta\phi \times \Delta\eta = 30^\circ \times 0.5$ (only hadronic)
depth segmentation	one electromagnetic and one hadronic compartment
sector	30° in azimuth, 24 sectors in total rotation angle 50 mrad (see text)
number of cells	electromagnetic 312 hadronic 384
number of channels	2 PM's per cell, 1392 total
Approximate weight	
	120t for each end cap

The thicknesses in radiation length (X_0) and absorption length (λ_0) vary as a function of the polar angle θ between 5° and 40° with respect to the beam axis.

Table 2 : End Cap Cost Estimate

	KSFr
end cap modules	
hadron calorimeter iron structure	875
em calorimeter lead	85
scintillator and cutting	300
wavelength shifter, light guides, adaptors	320
photomultipliers, mounting and calibration	330
subtotal	1910
movable support structures	400
external manpower	
(mechanics and scintillator mounting)	500
test beam scanning table	50
standard electronics	425
reserve for trigger electronics	
(not yet specified)	215
overall total	3500