Construction and Test Results of the ATLAS EM EndCap Calorimeter[a]

Luis Labarga
Universidad Autónoma de Madrid
for the ATLAS LARG EM calorimeter group

Outline

- The physics case. Implications on apparatus.
- Brief description; the EndCap.
- Manufacturation of the parts; Quality Control
- Calorimeter module stacking and QC.
- Module testing; main results.
- Status and Summary.

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[a] 8^{th} Topical Seminar on Innovative Particle and Radiation Detectors. Siena, October 2002

The Physics Case; its Implications

The main focus for ATLAS at the LHC is the study of the origin of mass at the electroweak energy scale. For SM Higgs boson (**H**) searches, the detector has to be sensitive to:

1. **H**$\rightarrow \gamma\gamma$; m$_H$ < 150 GeV.
2. **H**$\rightarrow ZZ^* \rightarrow 4l$; 130 GeV < m$_H$ < 2 m$_Z$
3. **H**$\rightarrow ZZ \rightarrow 4l$ or $2l + 2\nu$; m$_H$ > 2 m$_Z$
4. **H**$\rightarrow WW, ZZ \rightarrow l + \nu +$ 2jets or $2l + 2$ jets ; for m$_H$ up to 1 TeV.

$\rightarrow$ In particular the significance of (1) is proportional to the rapidity range coverage.

$\rightarrow$ Also (1) needs an energy resolution well below 1% at high energy.

$\Rightarrow$ A superb measurement of γ's and $e^{\pm}$'s is required along as much solid angle as possible.

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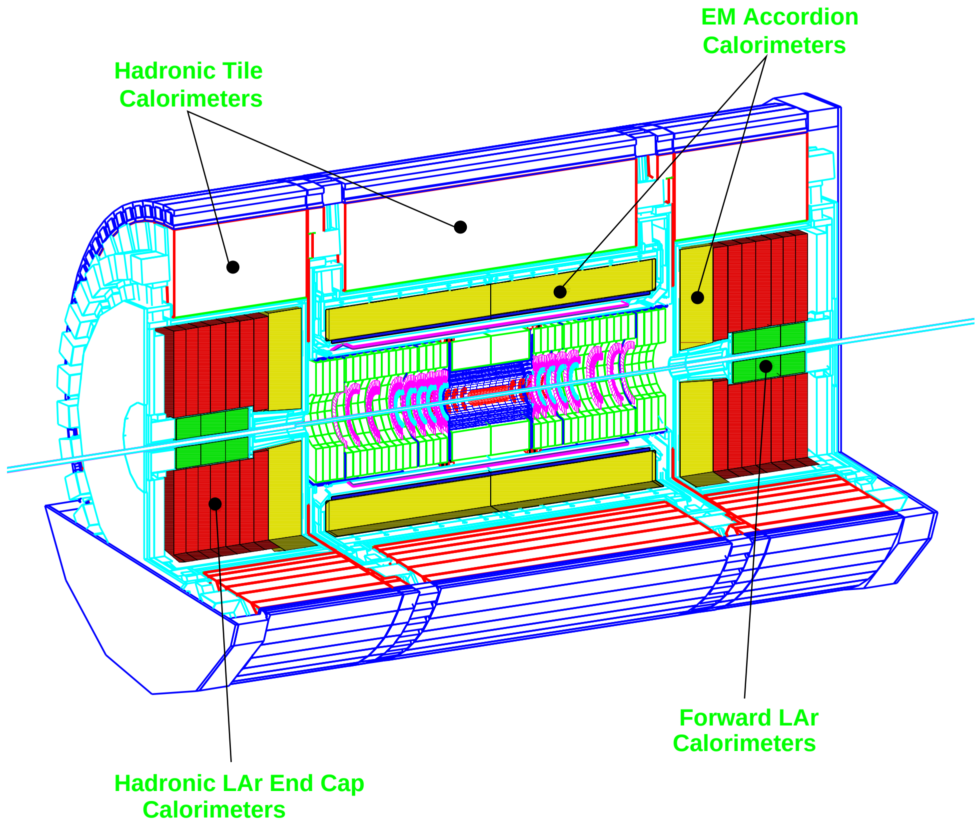
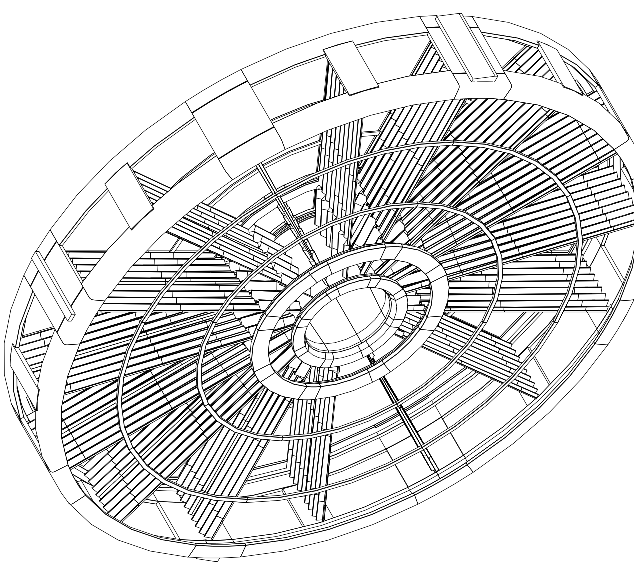
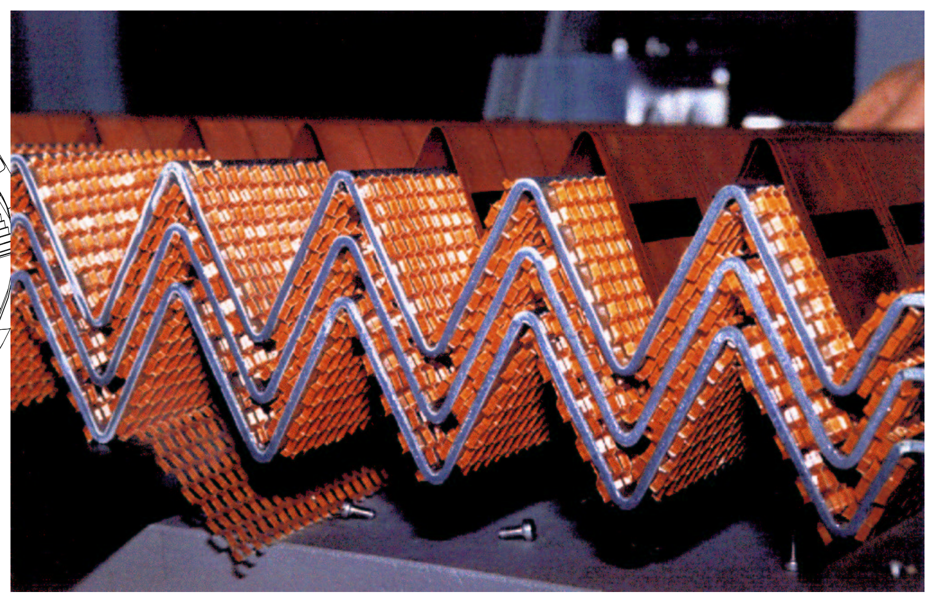
$\Rightarrow$ EM sampling calorimetry with ionizable liquid **(LArg)** and novel **accordion** geometry with extreme geometrcal and electrical **uniformity requirements.**

The EndCap of the LArg EM Calorimter







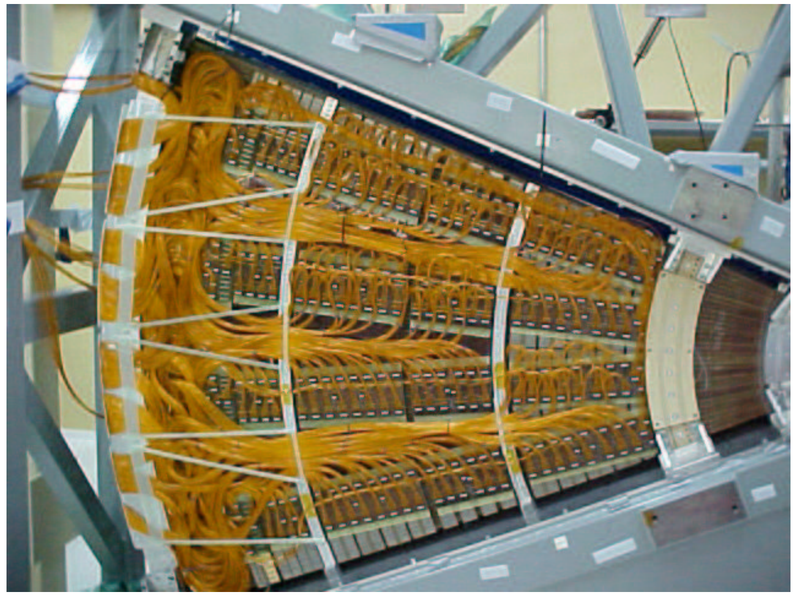
⇒ Main difference with Barrel comes from geometry

(*Barrel: prev. talk by Y. Hostachy*)

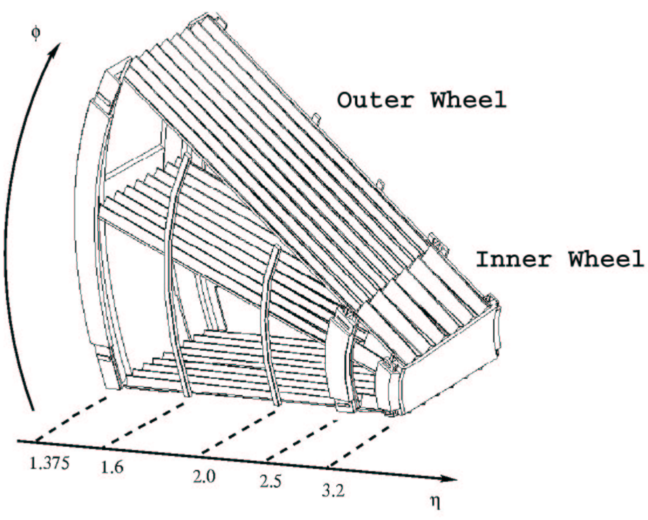
Main Particularities

Each EndCap wheel is splitted into two “sub-wheels” due to mechanical limits

- pseudorapidity ranges:
  OW: $1.375 < \eta < 2.5$
  IW: $2.5 < \eta < 3.2$
- 8 modules per EndCap

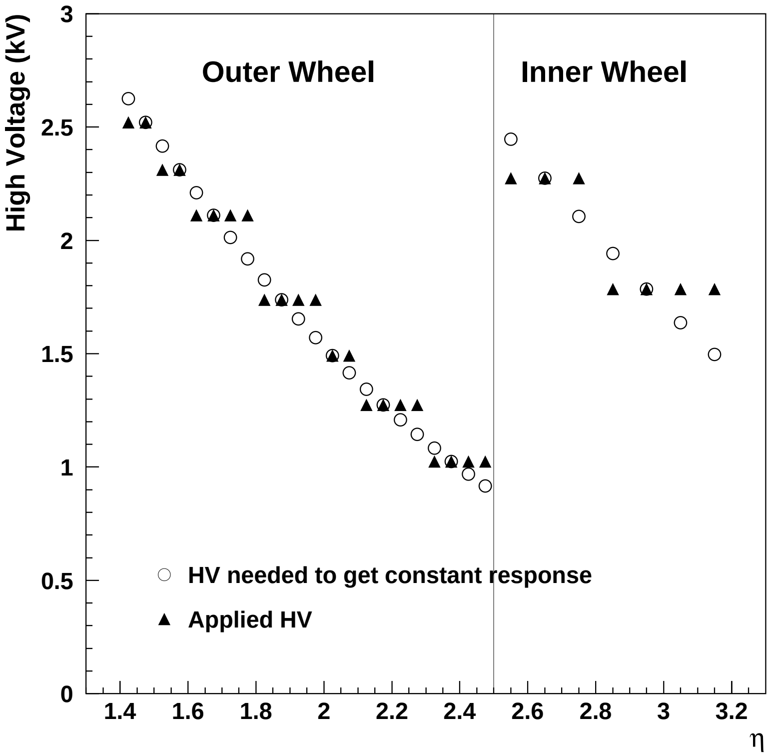


96 / 32 gaps (absorber - *spacer* - **electrode** - *spacer* - absorber) at the outer / inner “wheel” per module.



- Main components vary along R:
  - Fold angle
  - Gap distance
  - HV settings
  - Capacitances

for instance: Gap Size vs. HV settings



$$\frac{I_0}{E_0} \propto \frac{U^b}{gap^{1+b}}$$

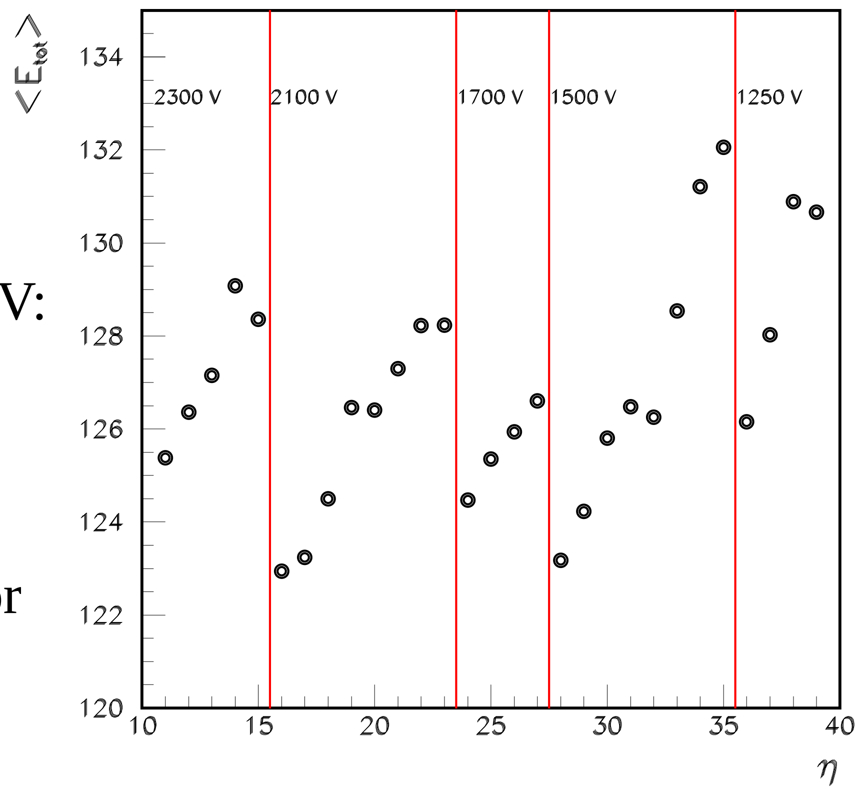
In practice 7 (3) HV sectors at the OW(IW) to compensate the gap variation.

Residual of steppy HV:

$$\approx 2\%$$

(Test beam data)

$\Rightarrow$ To be corrected for



the Absorbers

Thickness of:/at	O. W.	I. W.
Lead plates	**1.7 mm**	**2.2 mm**
Stainless steel	**0.2 mm**	
Glass-fibre prepreg adhesive	**0.15 mm**	
Absorber	**2.4 mm**	**2.9 mm**

The contribution of the non uniformities at the mechanical parts to the constant term should be kept at $\approx 0.2\%$.

$\rightarrow$ lead thickness better than 1% (from M.C. studies) $\Rightarrow$ RMS thicknesses smaller than $17\mu m$/$22\mu m$ for OW/IW

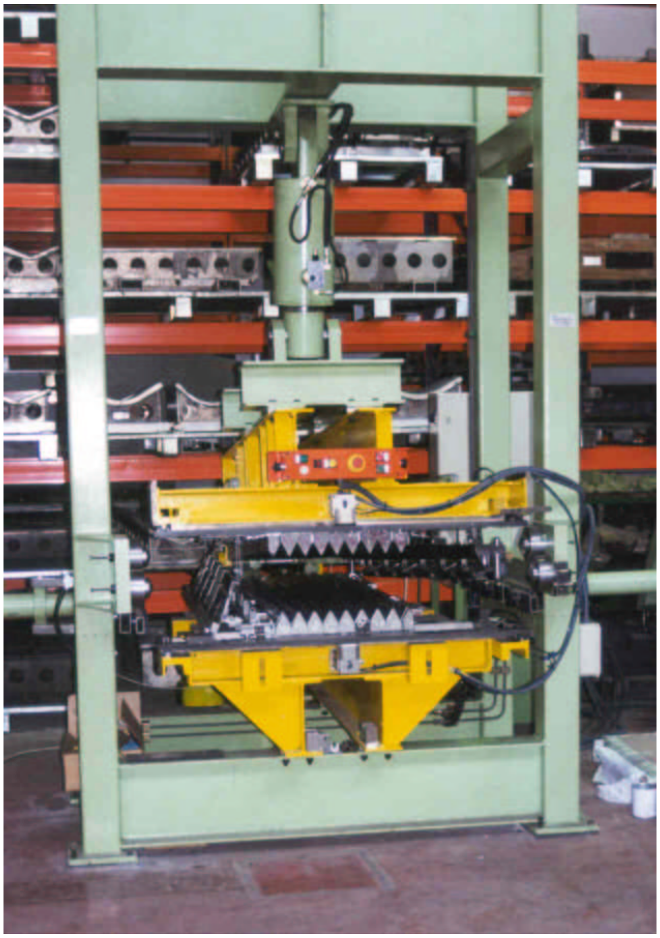
$\rightarrow$ LArg gap better than $3\% \Rightarrow$ absorber geometry reproducibility at the level $\approx 200\mu m/50\mu m$ for large/inner radius part

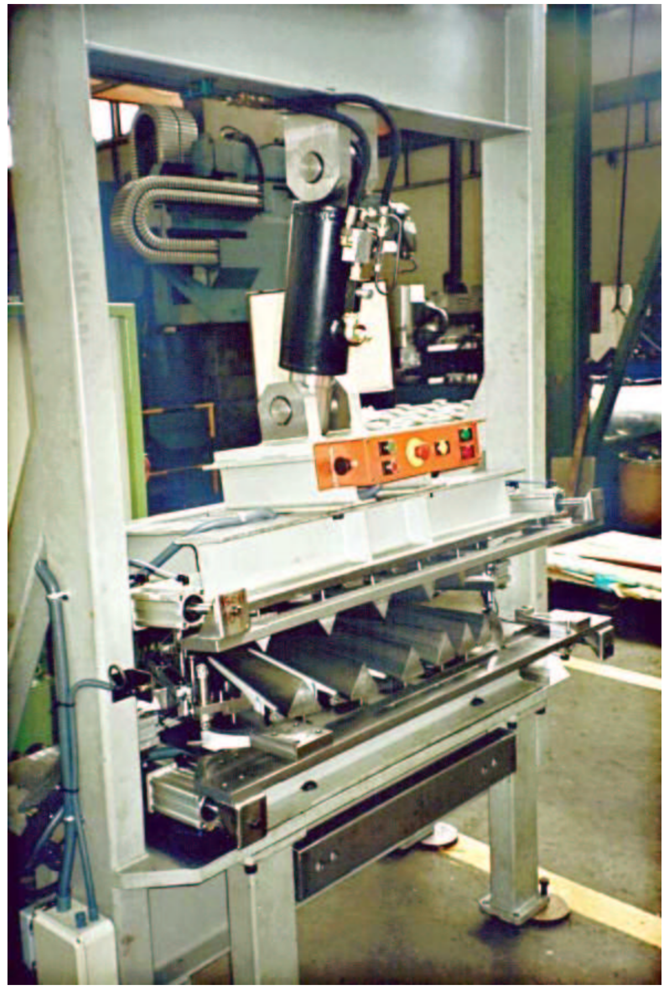
Lead plates were obtained by lamination on a $\approx$ standard foundry, with the thickness measured and corrected on -line by an X-ray absorption measurement system.

$\Rightarrow$ better than $9\mu m$ thickness uniformity **achieved**

The Absorber Fabrication[a]

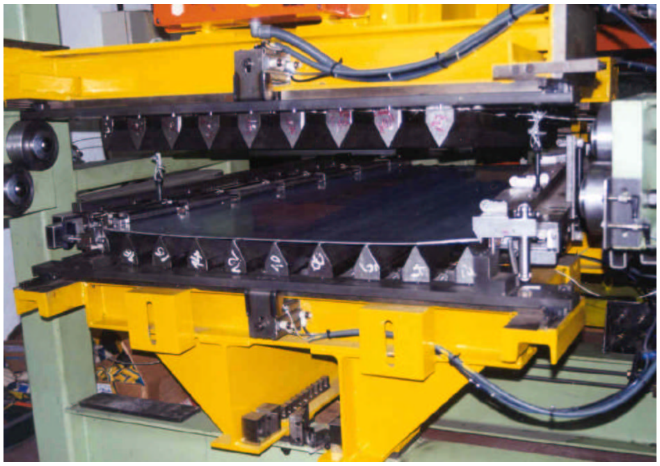
Flat sandwich bending:

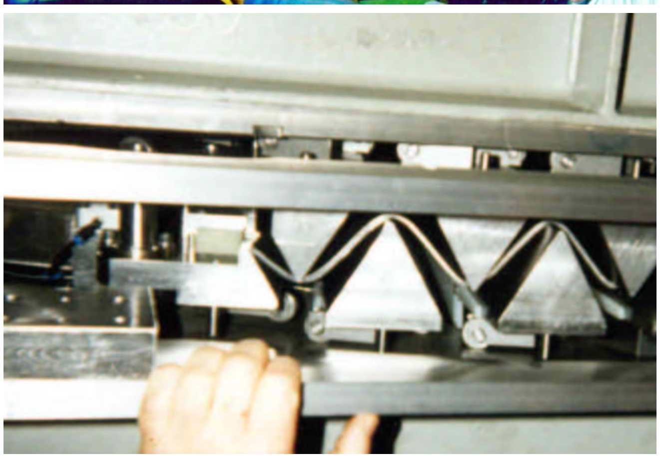




Mechanical tolerances at the **150** μm level (over distances of **2** m)

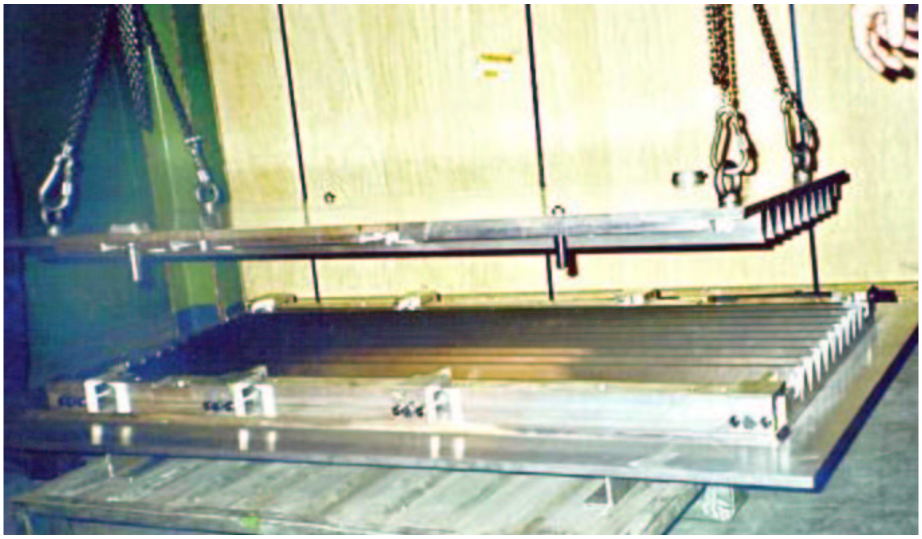
[a]Tooling manufacturated by Talleres Aratz S.A.; absorber fabrication itself by Fibertecnic S.A.. Both companies are located at Vitoria (Spain).





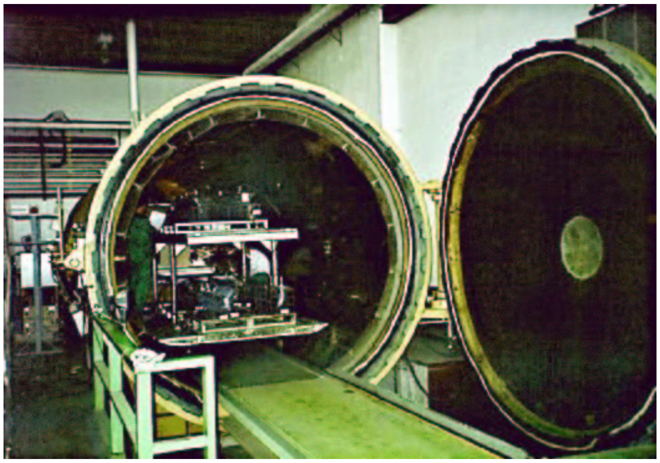

Absorber moulding and curing (Autoclave technique):

10(4) OW(IW) absorber moulds



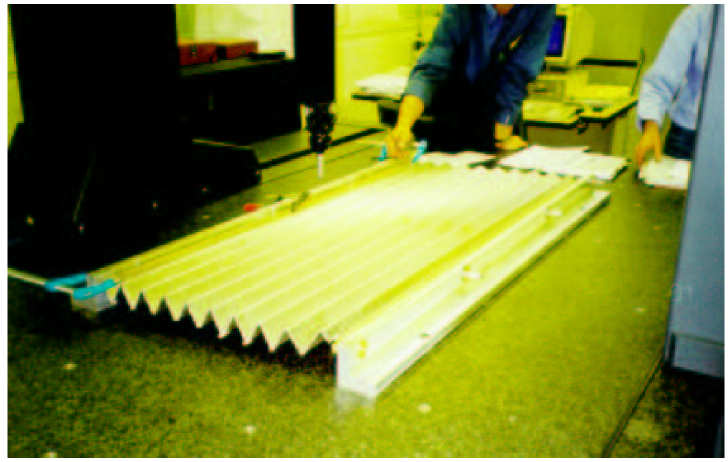
mechanical reproducibility at the $\mathbf{40 \mu m}$ level

Temperature/Preasure cycle (120 ^{o}C/2.7 bars) for the pre-preg to polimerize and the absorber to get its final shape.

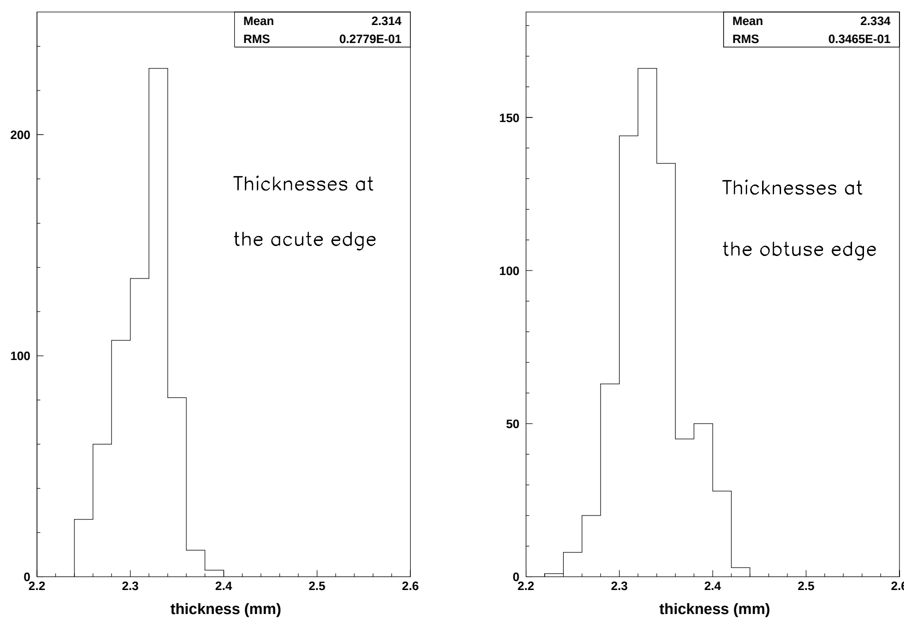


Quality Controls on the produced absorber:

- Optical inspection (100%)
- Thicknesses and widths at predifined positions (100%)
- Full 3D mapping (10%)



For example, the thicknesses at the edges:

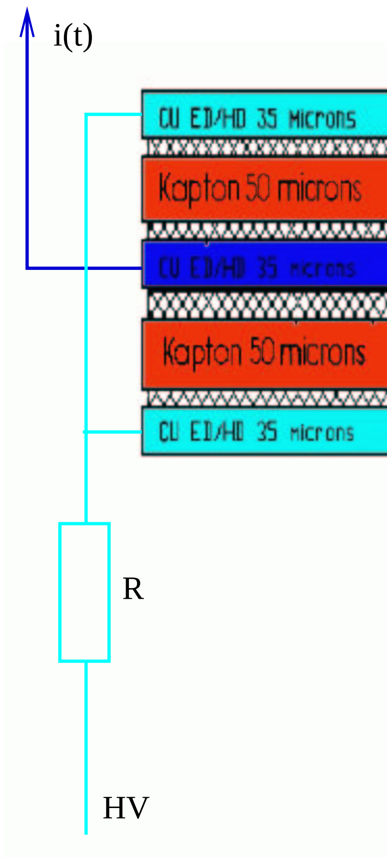


Thickness RMS	Acute edge	Obtuse Edge
obtained:	$28\mu m$	$35\mu m$
tolerances:	$110\mu m$	$36\mu m$

The prod. yield (along the whole process) is ≈ 96 %

the Read-Out Electrodes

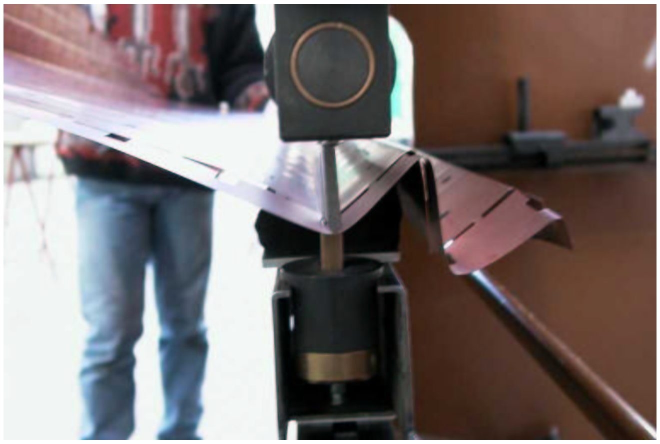
flat electrode



Cicorel S.A.

La Chaux de Fond

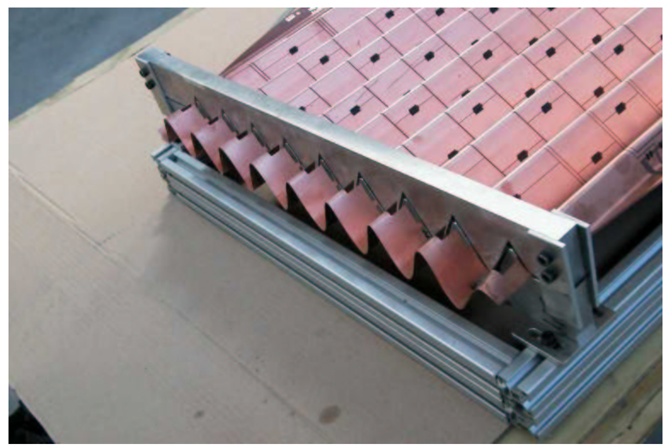
Switzerland



They are bent to its final shape by a Single-Knife Standard press guided by high precision machined notches.

RIPM (Aix-en-Provence, France)

The electrodes follow an extensive Quality Control for both, geometrical and electrical characteristics.



Final OW electrode fully equipped:

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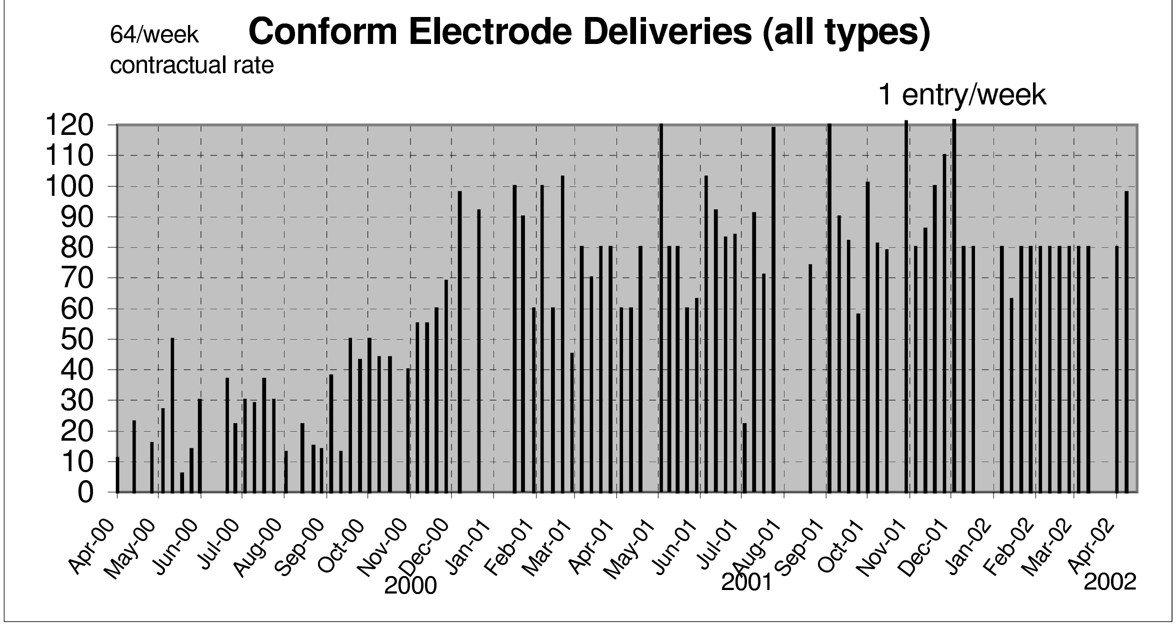
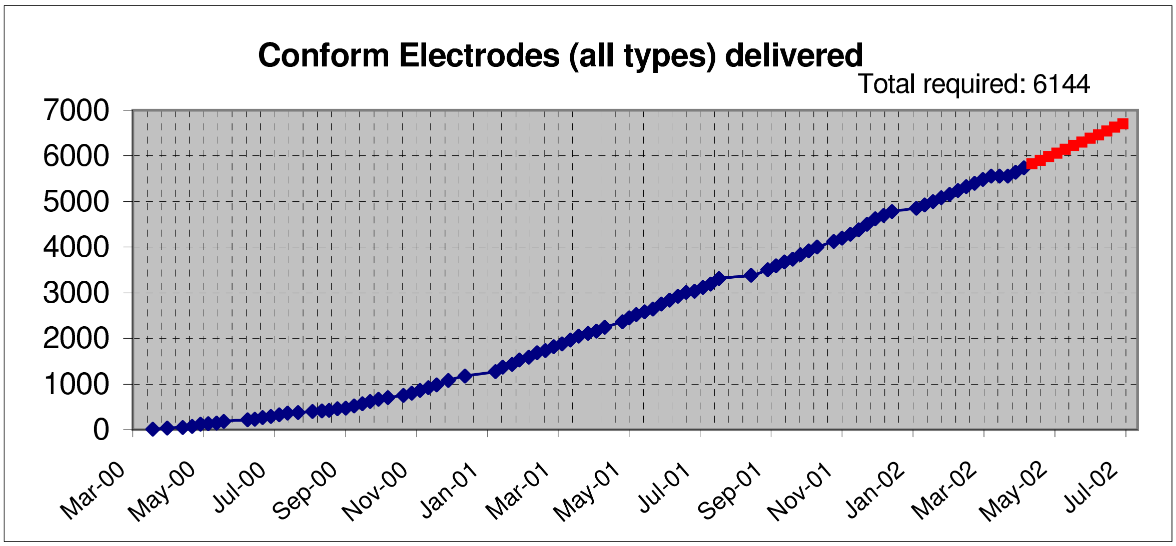
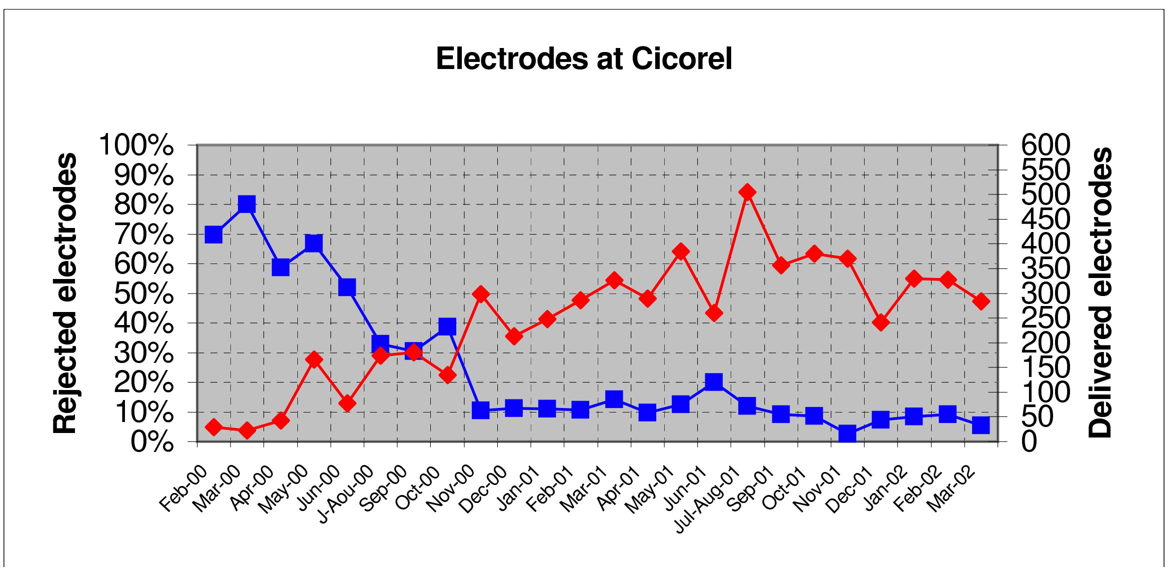


64/week
contractual rate
Conform Electrode Deliveries (all types)
1 entry/week
120
110
100
90
80
70
60
50
40
30
20
10
0
Apr-00 May-00 Jun-00 Jul-00 Aug-00 Sep-00 Oct-00 Nov-00 Dec-00 Jan-01 Feb-01 Mar-01 Apr-01 May-01 Jun-01 Jul-01 Aug-01 Sep-01 Oct-01 Nov-01 Dec-01 Jan-02 Feb-02 Mar-02 Apr-02
2000
2001
2002

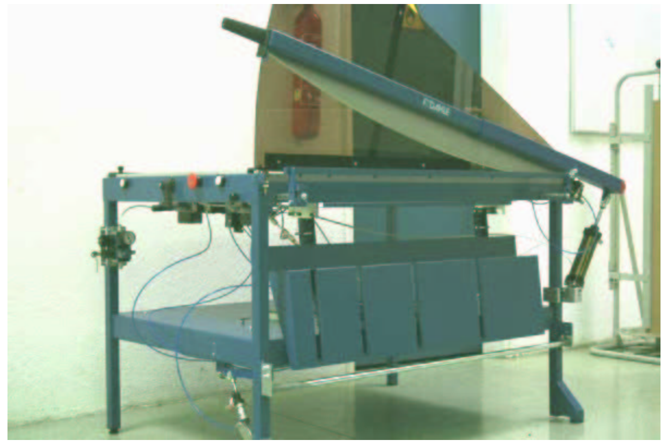


Conform Electrodes (all types) delivered
Total required: 6144
7000
6000
5000
4000
3000
2000
1000
0
Mar-00 May-00 Jul-00 Sep-00 Nov-00 Jan-01 Mar-01 May-01 Jul-01 Sep-01 Nov-01 Jan-02 Mar-02 May-02 Jul-02

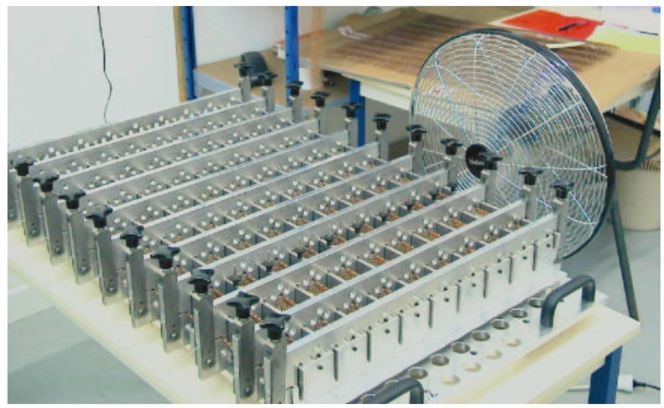


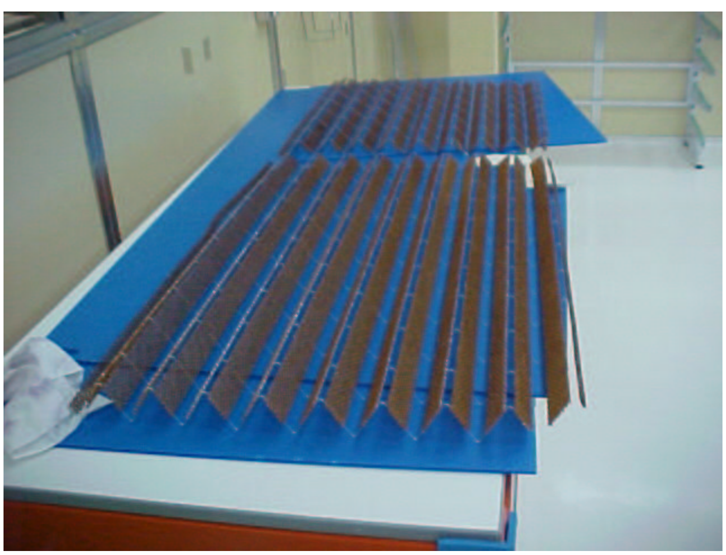
Electrodes at Cicorel
Rejected electrodes
Delivered electrodes
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
600
550
500
450
400
350
300
250
200
150
100
50
0
Feb-00 Mar-00 Apr-00 May-00 Jun-00 J-Aou-00 Sep-00 Oct-00 Nov-00 Dec-00 Jan-01 Feb-01 Mar-01 Apr-01 May-01 Jun-01 Jul-Aug-01 Sep-01 Oct-01 Nov-01 Dec-01 Jan-02 Feb-02 Mar-02

the Honeycomb Spacers



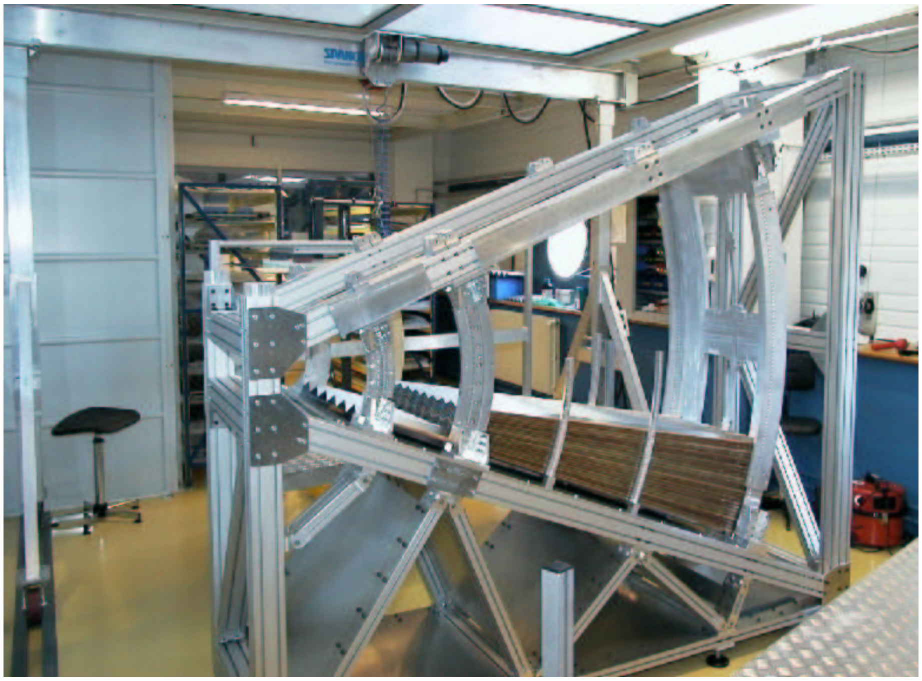
thickness varying radially
from 0.9 mm to ≈ 3 mm



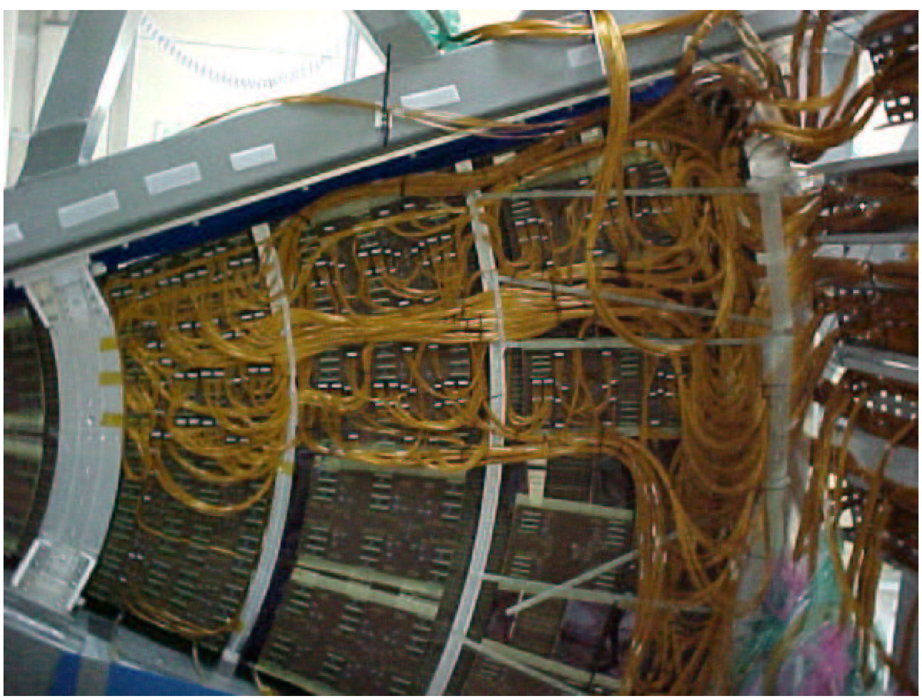


Module Stacking

Two fully equipped stacking sites:



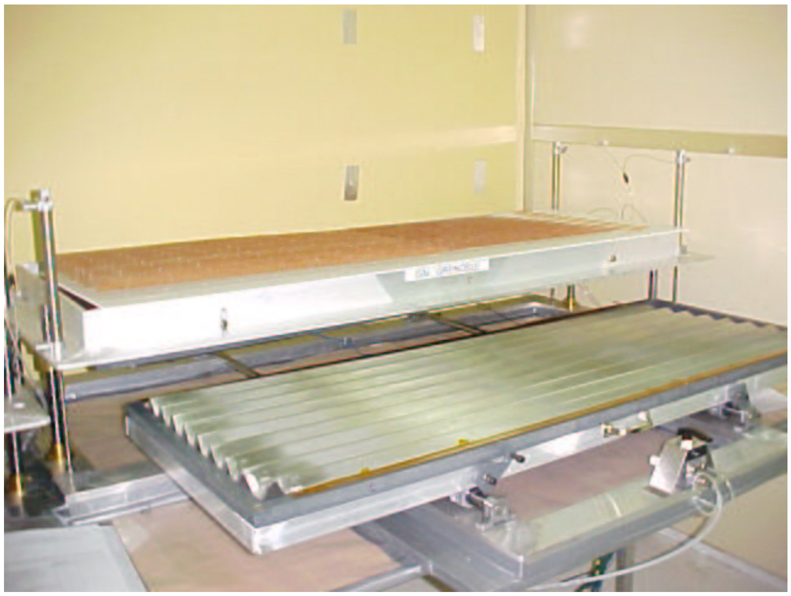
C.P.P.M.
(Marseille)



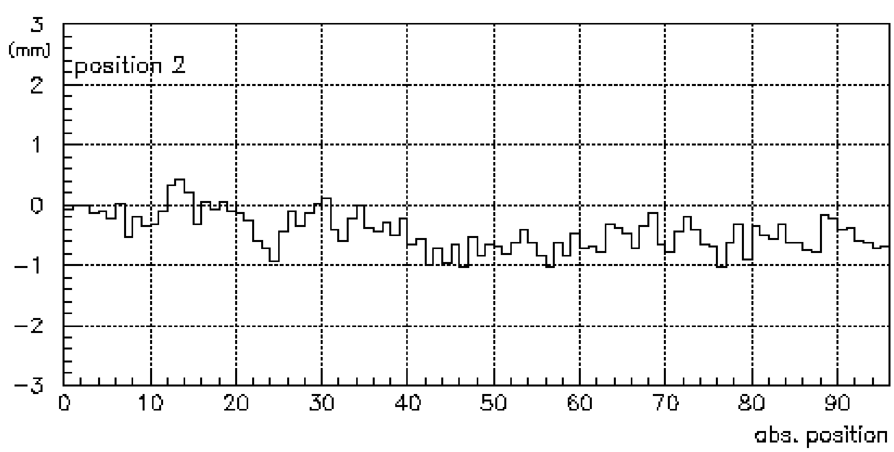
U.A.M.
(Madrid)

Stacking Procedure:

- last inspection and cleaning of absorber and electrode
- HV test of spacers (Voltage $\approx 1.6\times$ nominal at LArg)



- stack gap (spacers - electrode - spacers -absorber)
- bulging check/measurement i.e. relative height of each fold (severe problem at the first modules):



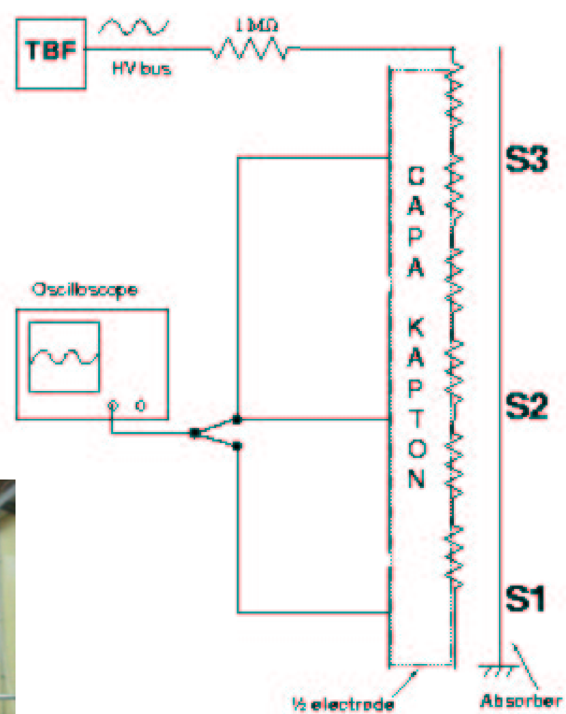
Stacking Quality Control I: Low Frequency Test

What:

Check the continuity/integrity of the electrical circuit at the electrode: read-out and HV distributions

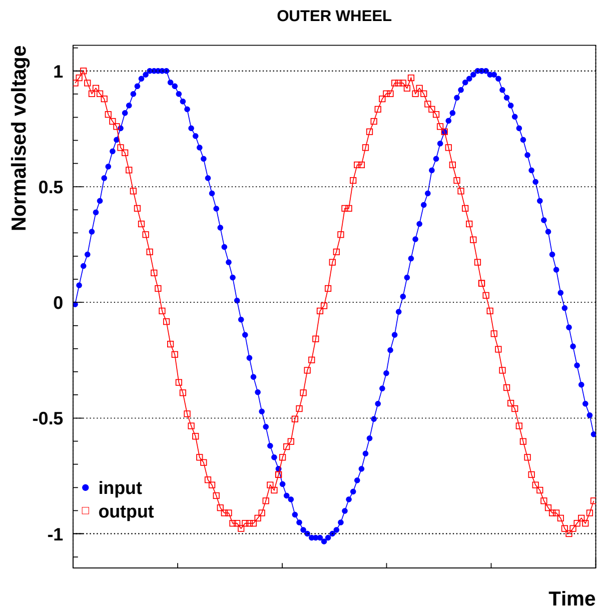
How:

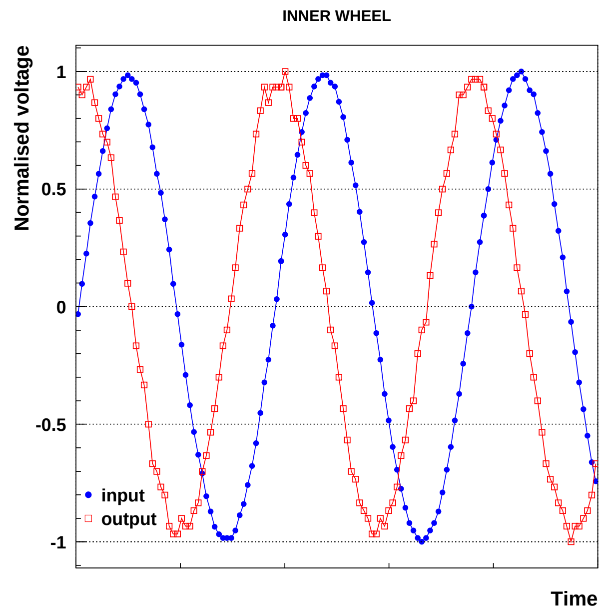
1) a low freq. sinusoïdal signal is injected on the HV lines
2) the current induced on the signal layer is measured in groups of few cells and analysed
3) their capacitance is calculated and compared to nominal



⇒ less than 0.2% of the electrodes show any failure

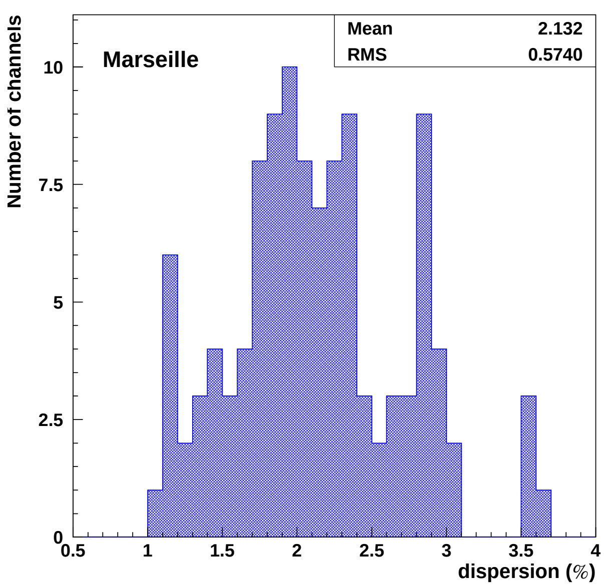
Input/Output signal:

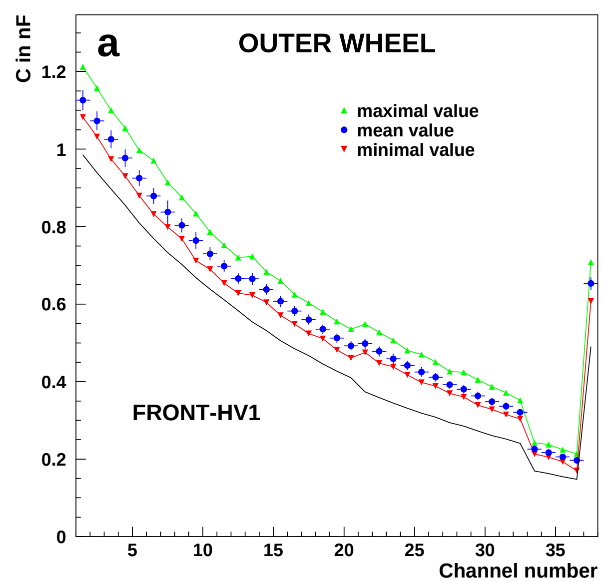




Dispersion:

Capacitance:

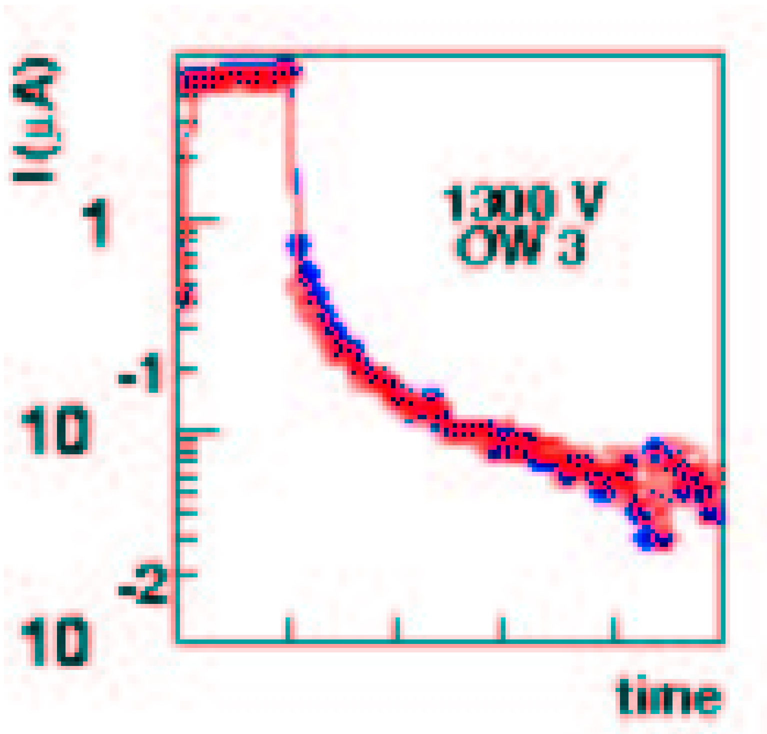




Stacking Quality Control II: HV test program

HV settings: those nominal at LArg (notice that the ratio between the dielectric coefficients of LArg and Air is ≈ 1.6)

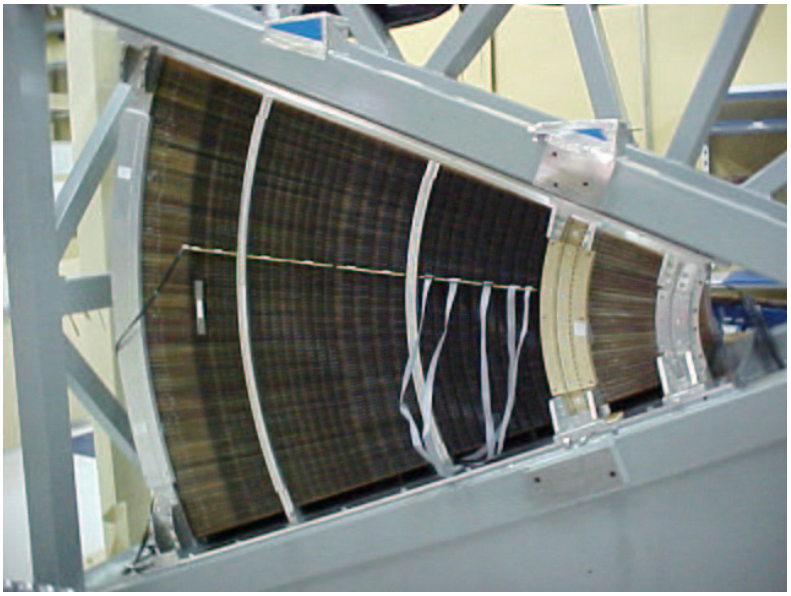
- After stacking one gap (≈ 10 min.): test the stacked gap and the previous one
- Night test (≈ 12 hours): leave at HV the gaps stacked during the day + 2
- Week-End test (≈ 60 hours): leave at HV the gaps stacked during the week + 5



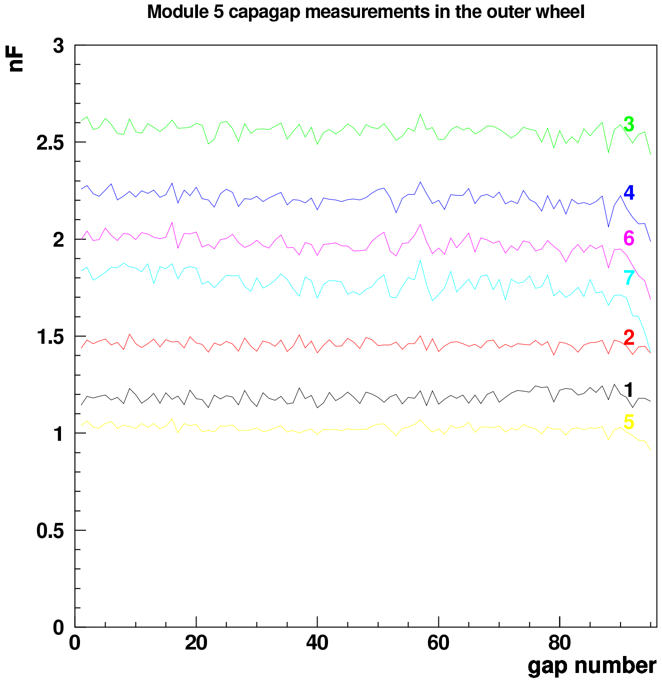
Stacking Quality Control III: miscellanea

- Structure Deformations (4 times during the stacking of a module)

Deformations smaller than $\approx 200\mu m$; first modules showed as much as 2 mm



- Gap Distances from Gap capacitances (50% of the gaps):



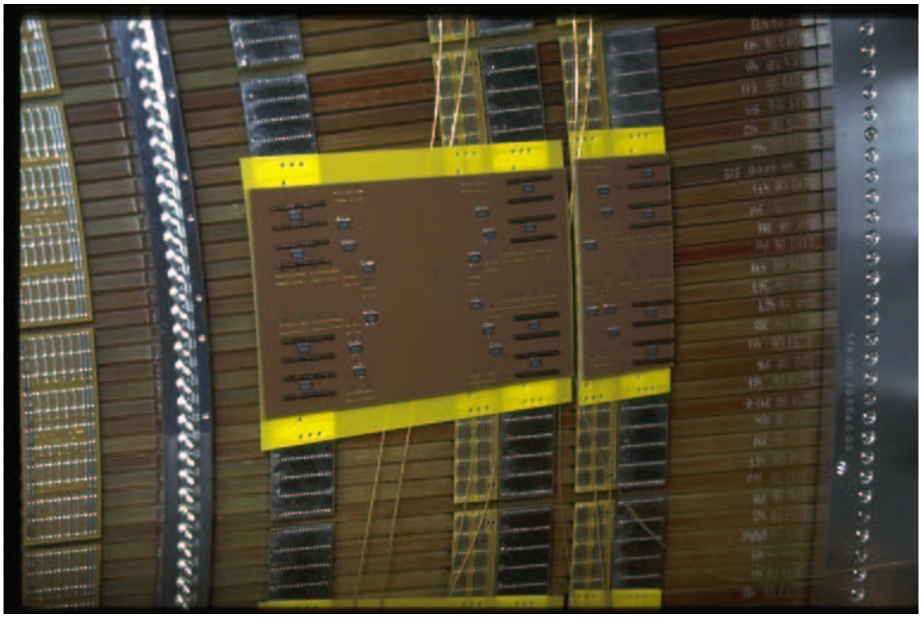
a sinusoïdal signal is injected on one cell; the gap capacitance value is deduced from the measured impedance.

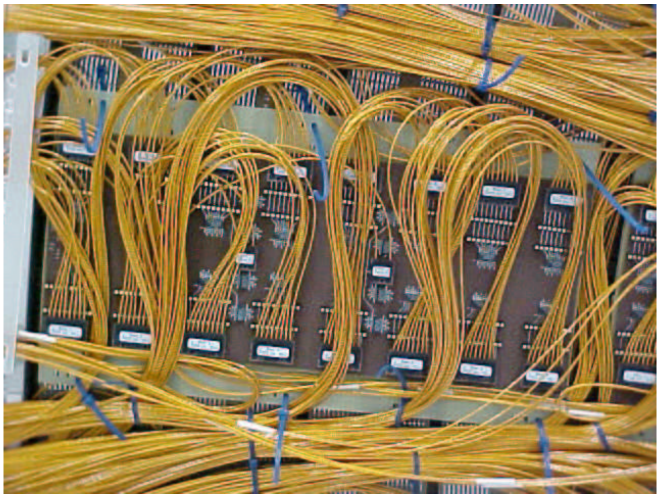
Cold Electronics and Cables

Dominique Sauvage 1960-2002

- Summing boards
- Mother boards
  (to house the injection calibration resistors and the signal cable connec-ors)

- HV distribution boards





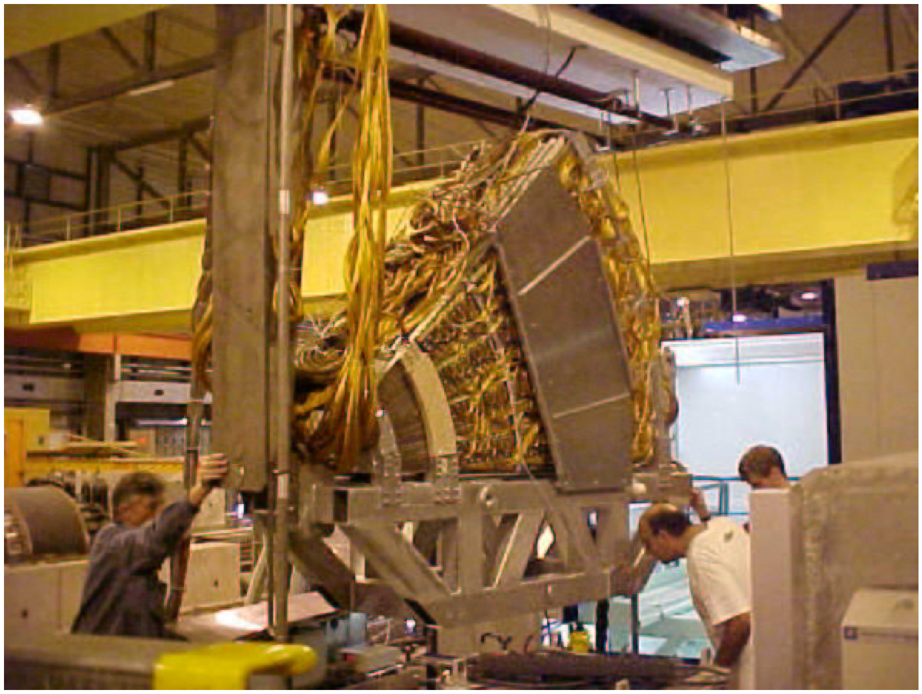
Cold cables:
- signal
- calibration
- HV
- monitoring

Warm electronics and read out: J. Parsons (wed. afternoon)

Module Testing

Cold Test Program at CERN (all modules)

we use the NA31 cryostat



- Charge Injection Resistance at Mother Board measurement: to check the MB and the signal cable continuity.
- Stand-alone calibration system to a) fully check the calibration and read-out circuitry b) cell gains
- High Voltage (at warm, at cold, at warm): HV problems that were not present at the stacking site develop (or dissapear) during the above cycle.

  Major concern. ⇒ The problematic electrode sectors are connected to individual spare HV lines.

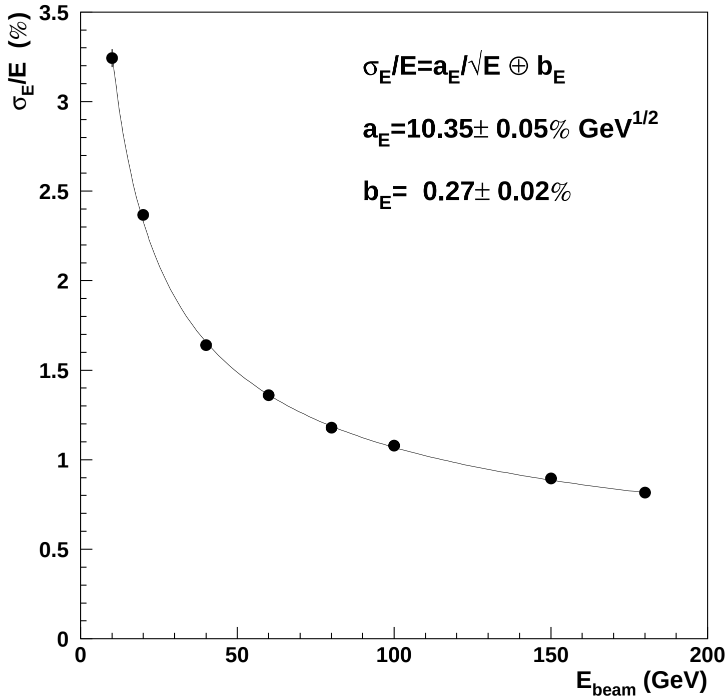
Beam Test Program (20% of the modules):
(Details at prev. talk by M. Fanti)

CERN H6 beam line (North Hall E.A.)

Resolution vs. Energy

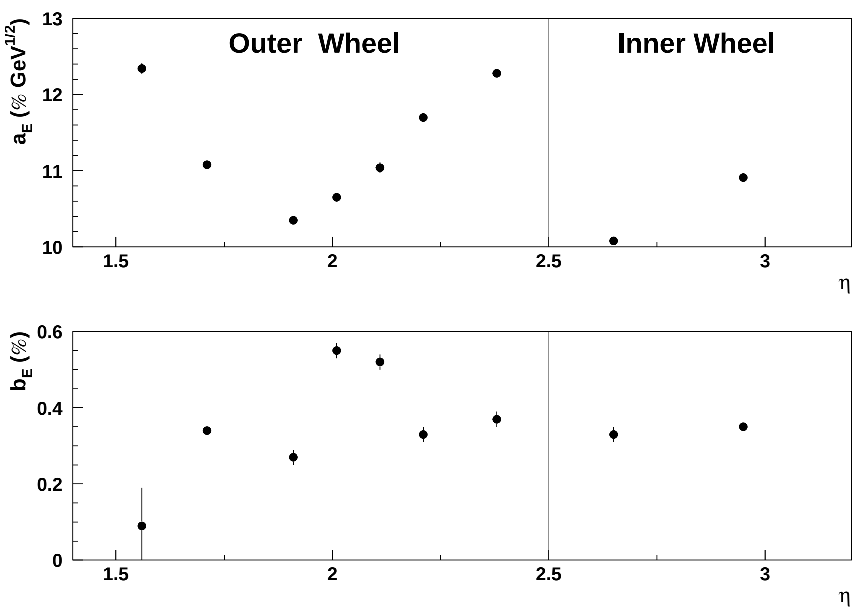
at Module 0. Fit to

$$\frac{\sigma_E}{E} = \frac{a}{\sqrt{E}} \oplus b$$

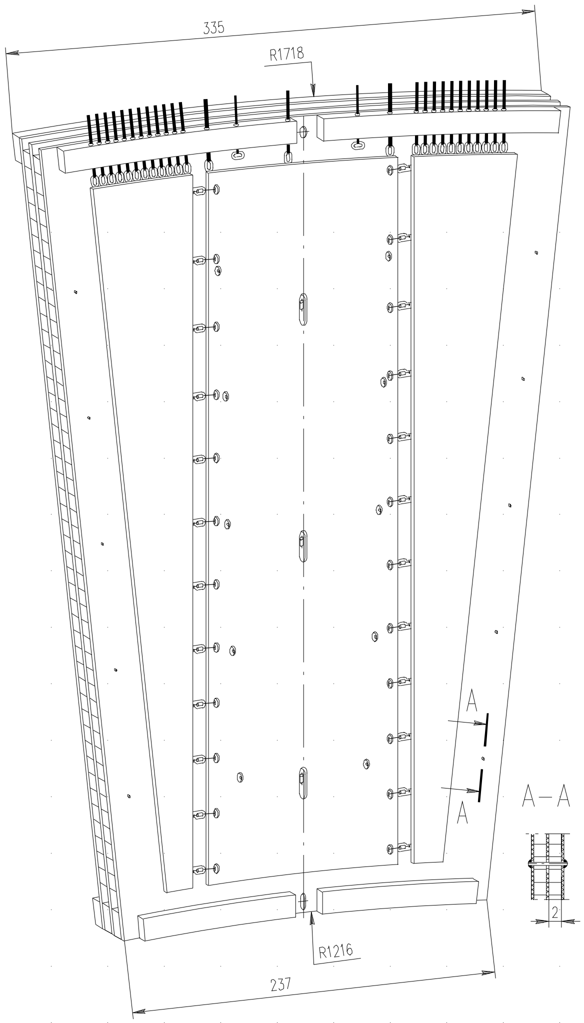


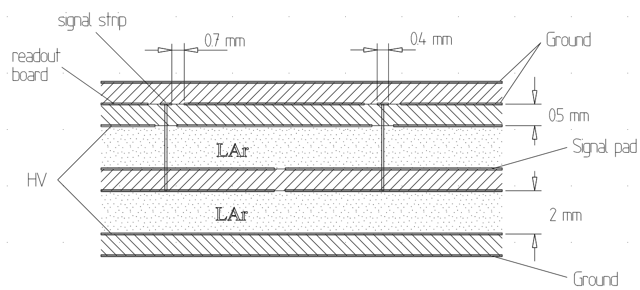
Evolution with E

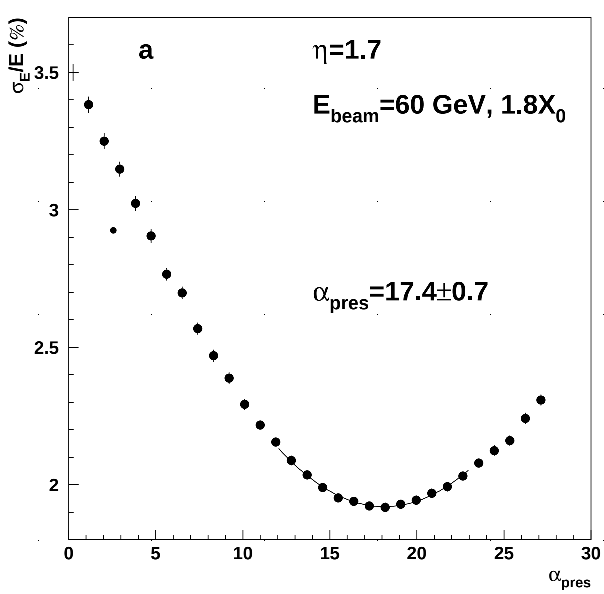
of a and b terms

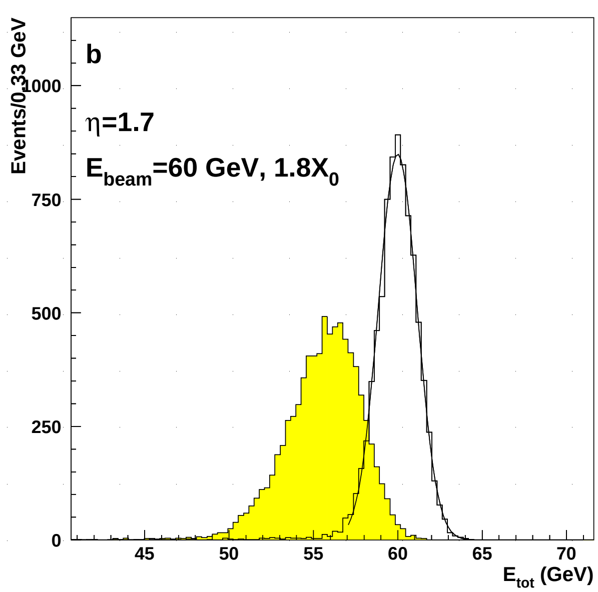


the EndCap Presampler





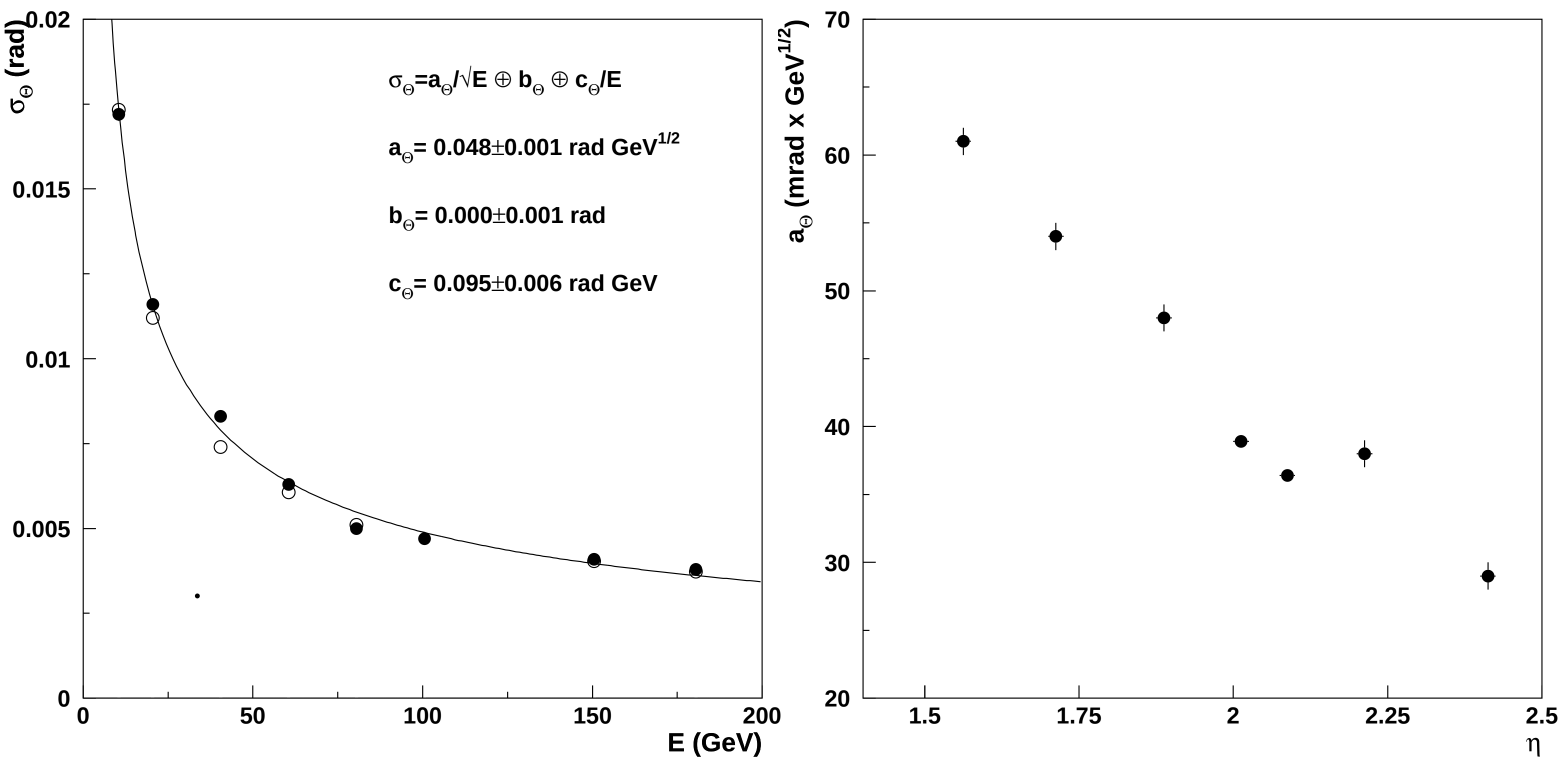




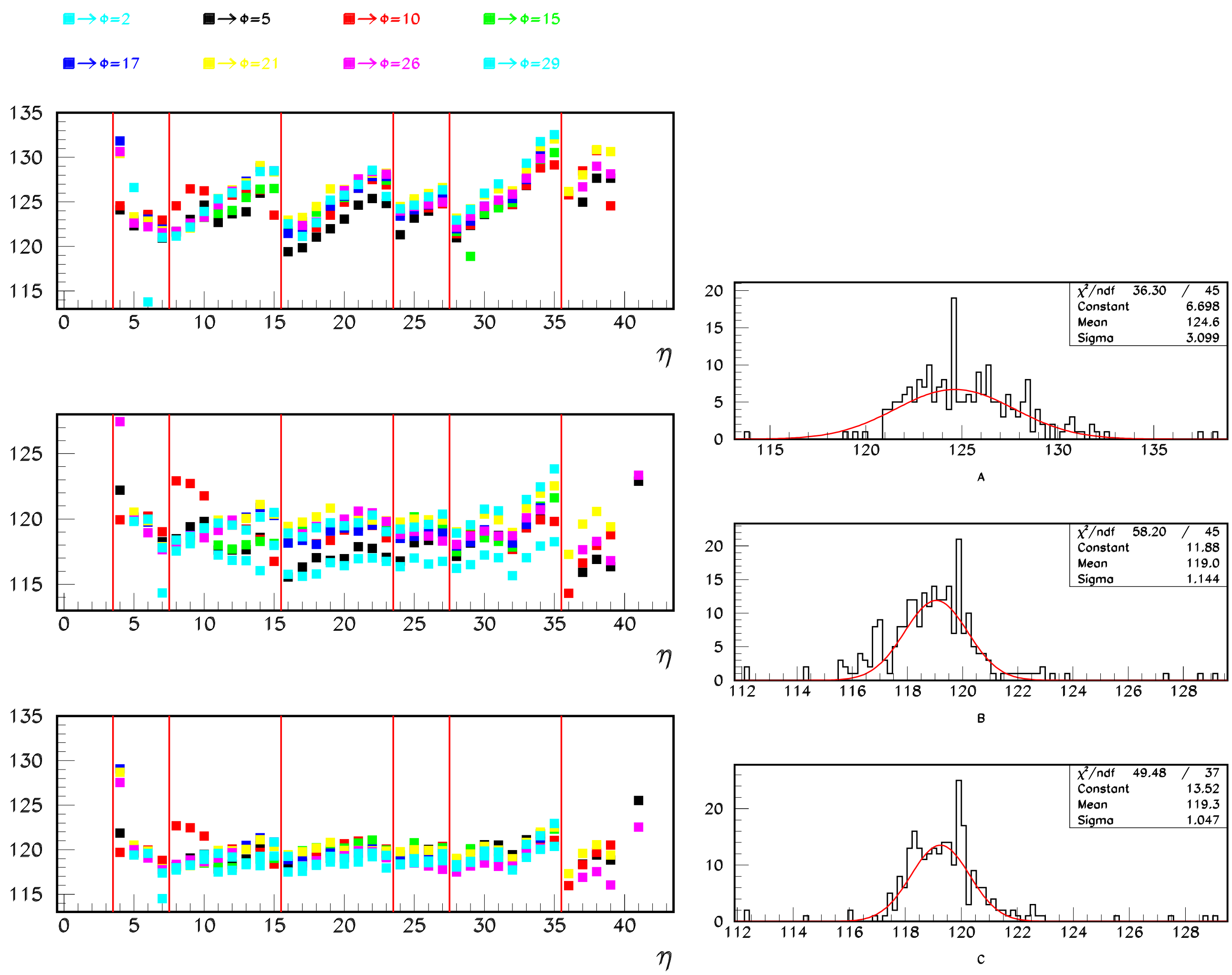
Test Beam: Polar Angle Resolution (Module 0)

Combining the η measurements at front and middle calorimeter sections with their corresponding longitudinal shower barycentes (estimated), θ is derived.

$\Rightarrow$ Determine the primary vertex position in ATLAS for **H** $\rightarrow \gamma\gamma$ at high luminosity (*needed:* $\approx$ *50 mrad GeV*$^{1/2}$ *at* $\eta = 1.9$)



Production Module M05: η scans



Uniformity results (preliminary):

	no corrections	time, HV, ϕ and η	+ slope
σ/E	2.48%	0.96%	0.88%

Status

- Status of Components:
  - Structure' parts (rings etc.): ready
  - Absorbers: producing those for module no. 13
  - Electrodes: ready
  - Spacers: producing those for module no. 9
  - Cold Electronics: ready
- Status of Modules:
  - 6 modules at CERN fully tested and qualified
  - 1 module at CERN ready to be cold-tested
  - 2 modules being stacked at CPPM and UAM

  ⇒ Hope to have the 8 modules of the first EndCap before Chritsmas !

Summary

- We are almost half of the way
- The produced modules show an energy resolution less than 1% at high energy
- We dont envisage new major problems on the modules
- But now comes the EndCap assambly ...