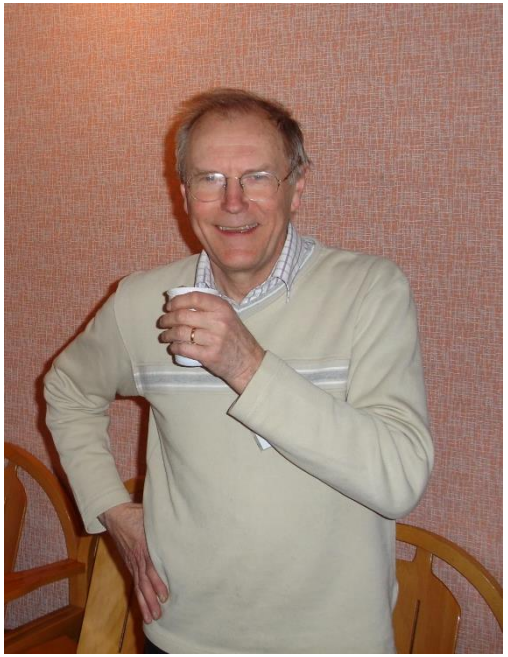
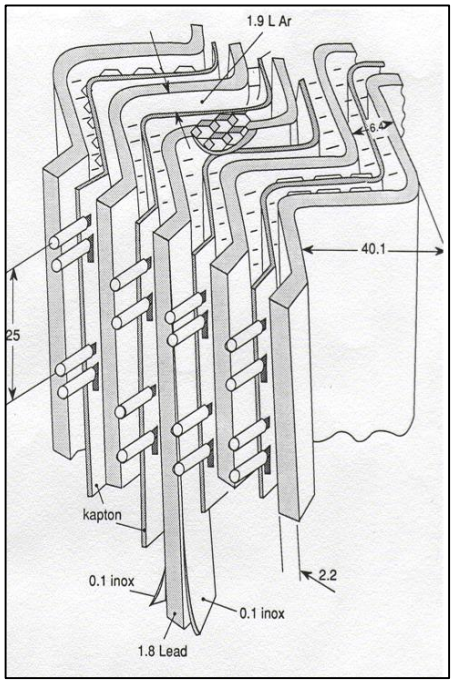
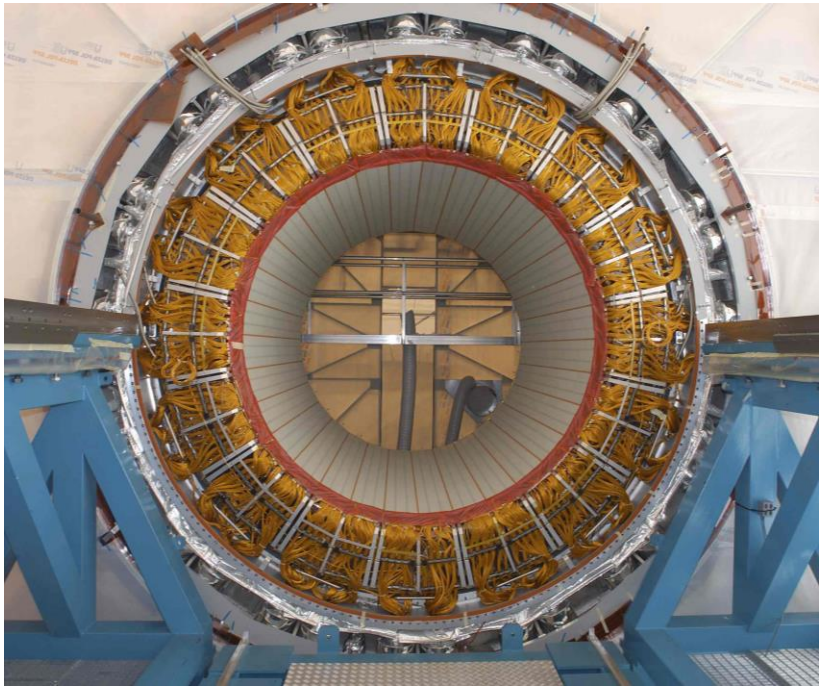
Design and construction of the ATLAS Liquid Argon EM calorimeter

Award of the Lagarrigue Prize to Daniel



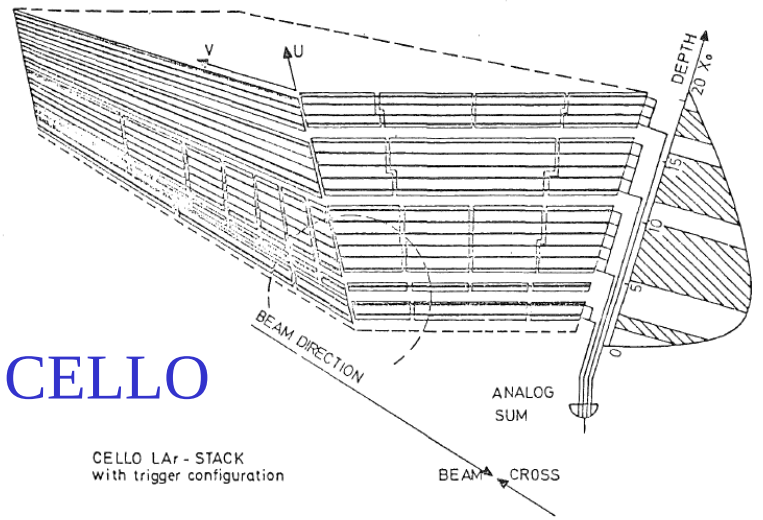




Bruno Mansoulié
Département de Physique des Particules CEA, Université Paris-Saclay
and *CERN - Genève*

The origins

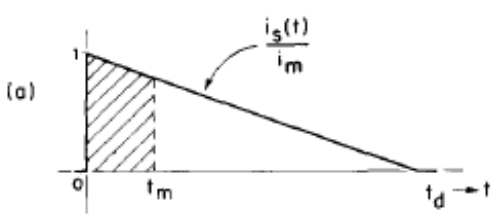
- **Daniel and the Liquid Argon technology**
  - **CELLO at PETRA (Davier, Haïssinski…)**
  - **NA31**
  - **Proposal for ALEPH** ☹
  - **(but Mark II and SLD, Yes!)**

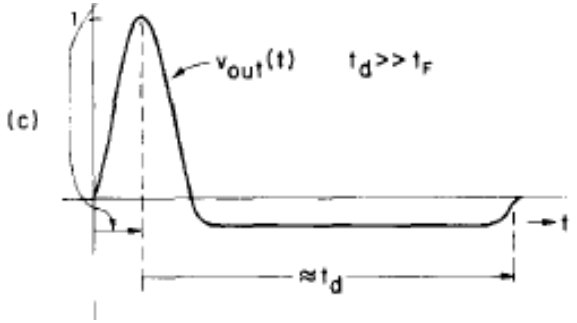


CELLO

- **LAr calorimeters for colliders**
  - **D0, H1**

- **Understanding the speed limitations**
  - **Radeka Rescia 1988**



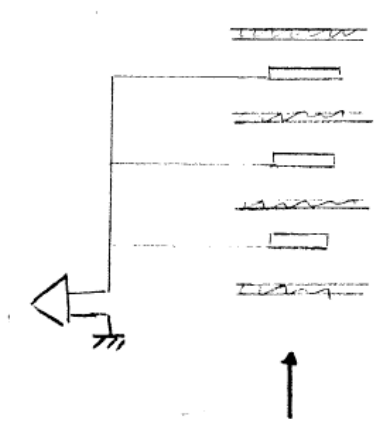


THE idea!

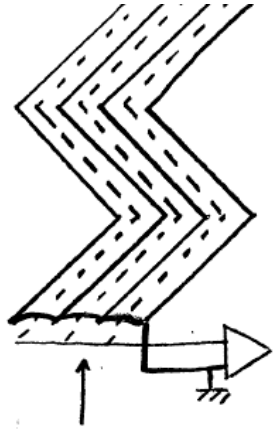
- **The accordion geometry :**

lower inductance of connections

cell = transmission line



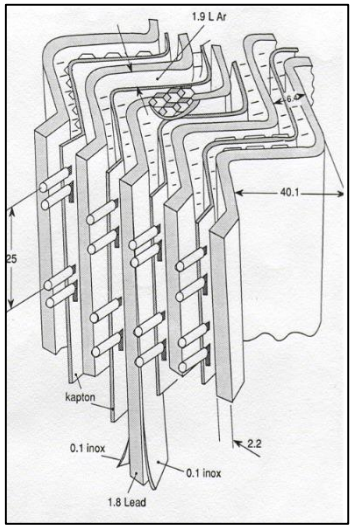
Classical

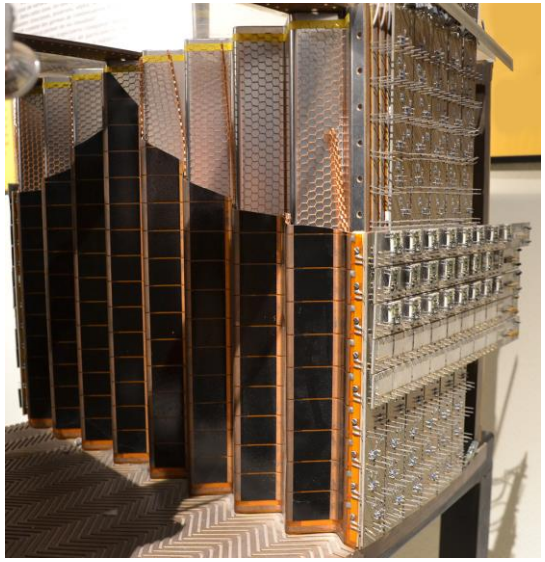


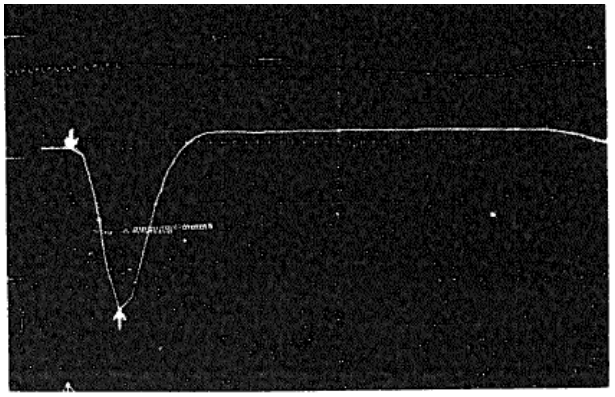
"Accordeon"

- **The small prototype**

1990

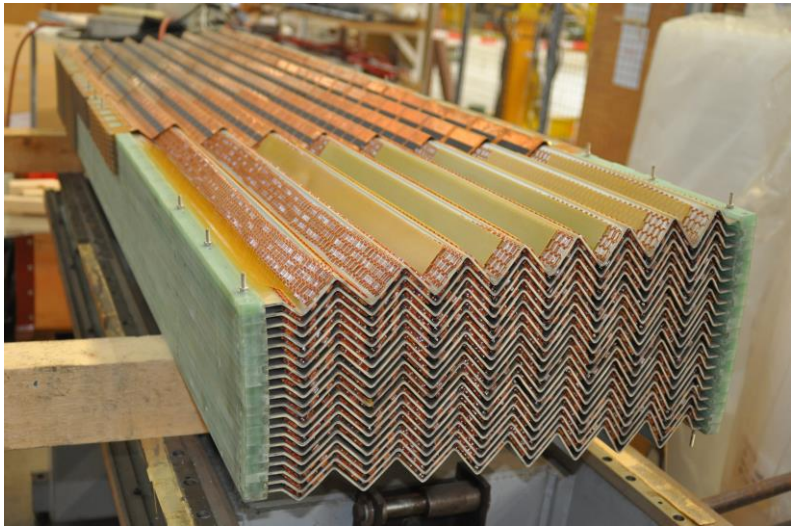




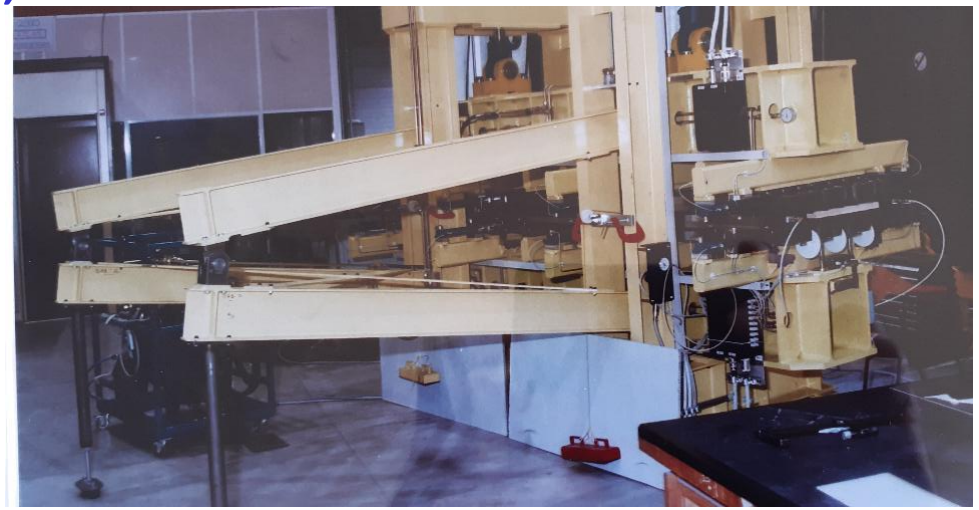


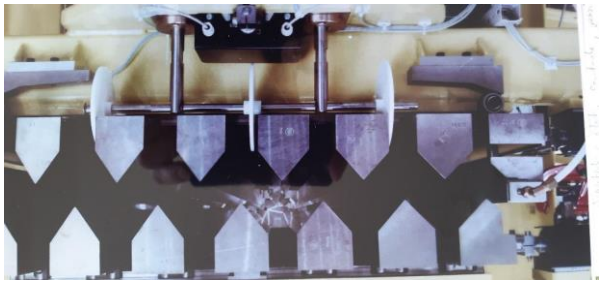
2m Prototype

- **Projective accordion**
  (angle changes with radius)



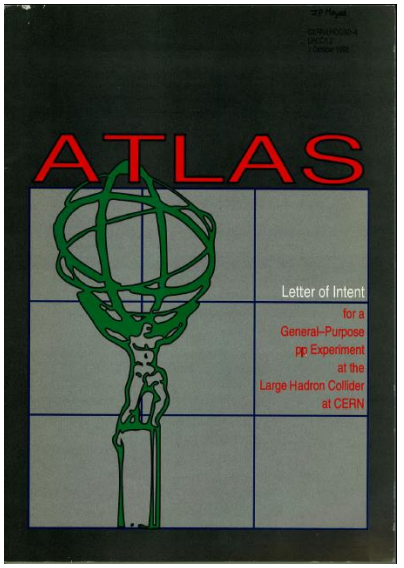
- **The “crocodile”**
  (J-L. Chevalley)

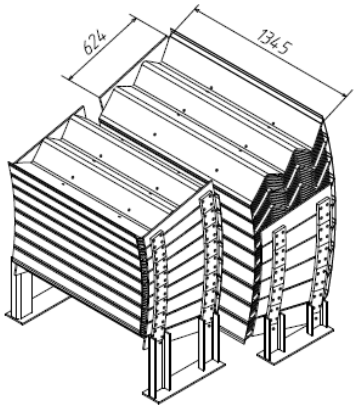




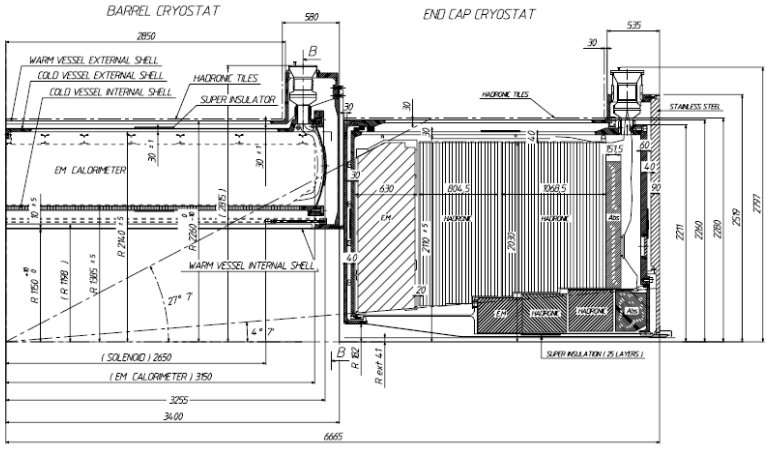
Liquid Argon in ATLAS

- **ATLAS LOI 1992:**
  - **EM: LAr.**
    - **Solenoid in front of EM, in the same cryostat**
    - **High-density feed-thrus**
    - ***Fine-grained PreSampler***
  - ***Hadronic: LAr or Tile?***





- **ATLAS Technical Proposal 1994**
  - **LAr : Barrel EM, End-caps EM+Had**
  - **Barrel and End-Caps (“*spanish fan*”): Accordion .**
  - ***Liquid : LAr of LKr?***
  - **Simple PreSampler**
  - ***Fine first sampling: η or U-V?.***
  - ***Preamps: barrel: cold*, End-caps: “0T ” (warm)**



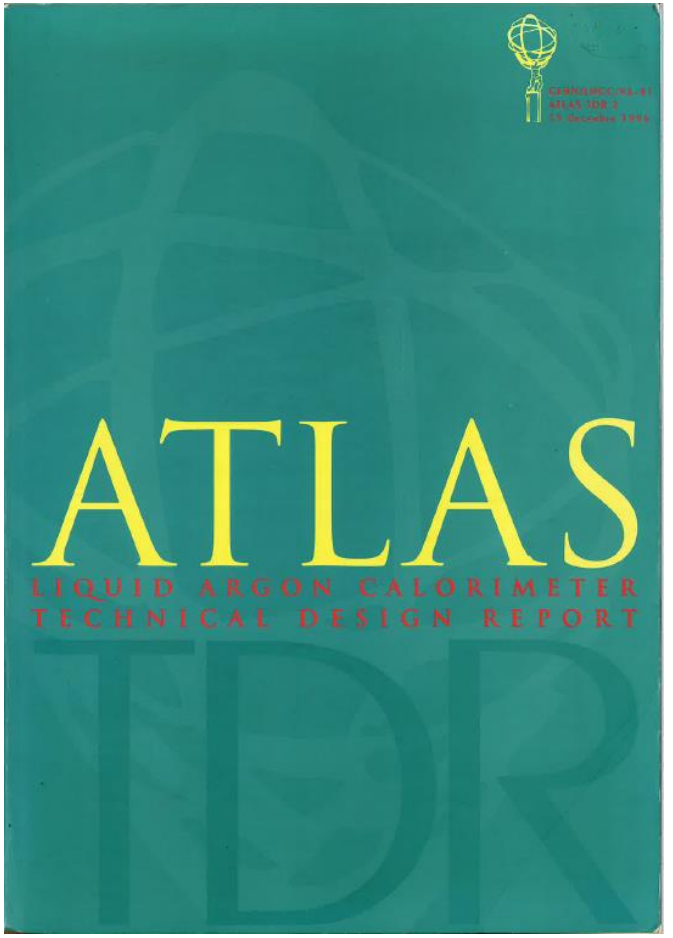
The LAr Calorimeter TDR (1996)

- **All internal features: fixed.**

  LAr, warm preamps, S1: η-strips
  - **Dimensions, granularities…**
  - **Construction and assembly procedures**
  - **Cold and Front-End electronics**

- **Lots and lots of simulation!**
  - **H(γγ) : energy resolution, pointing**
  - **Lead thickness, LAr (~~Kr~~), etc.**

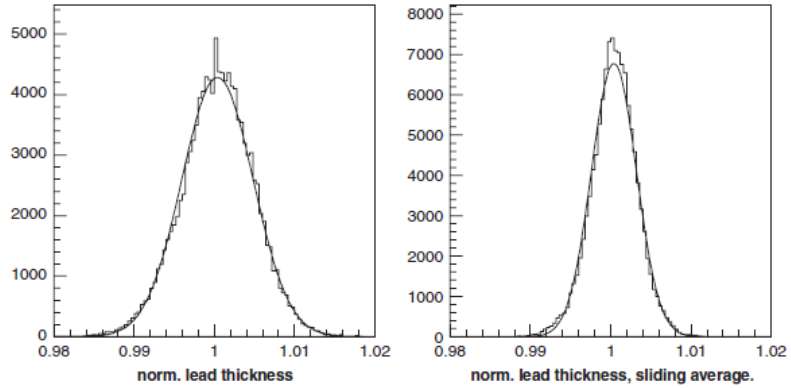
- **Lar gets organized for construction *(by Daniel)***
  - **EM Barrel : Absorbers : Orsay, Electrodes: Annecy/Milano/Orsay, Boards: BNL**
  - **Modules assembly sites : Annecy, CERN, Saclay**



Absorbers

- **Lead production in Germany**
  - **X-ray thickness online measurement**
  - **Philippe's fluent german helped!**

- **Lead plates measurement and sorting**
  - **Pairing in modules to reduce apparent thickness fluctuations!**

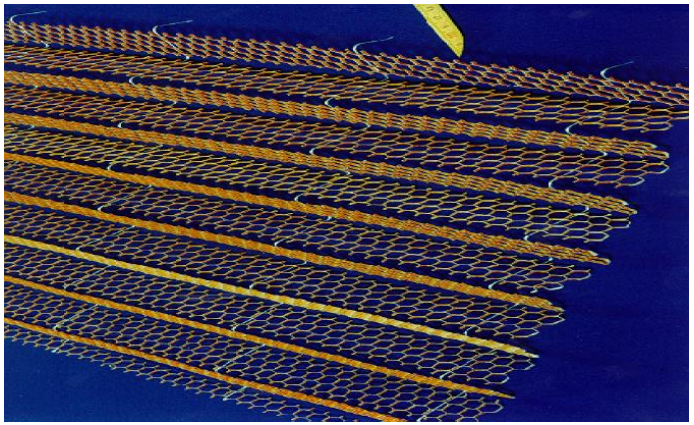


- **Gluing**
- **Folding**
- **Measuring (3D, Orsay)**
- **G10 bars**
  - **very special, very accurate**

Multi-Layer Electrodes (“Kaptons”), spacers

- **Electrodes**
  - **Made in industry**
  - **Large size // very precise pattern**
  - **Resistive ink // bending**

- **Spacers**
  - **Paper honeycomb + threads**
  - **Dust // high Voltage**



Support rings

Inner rings (very light…)

Outer rings machining at the company.
large diameter, high accuracy

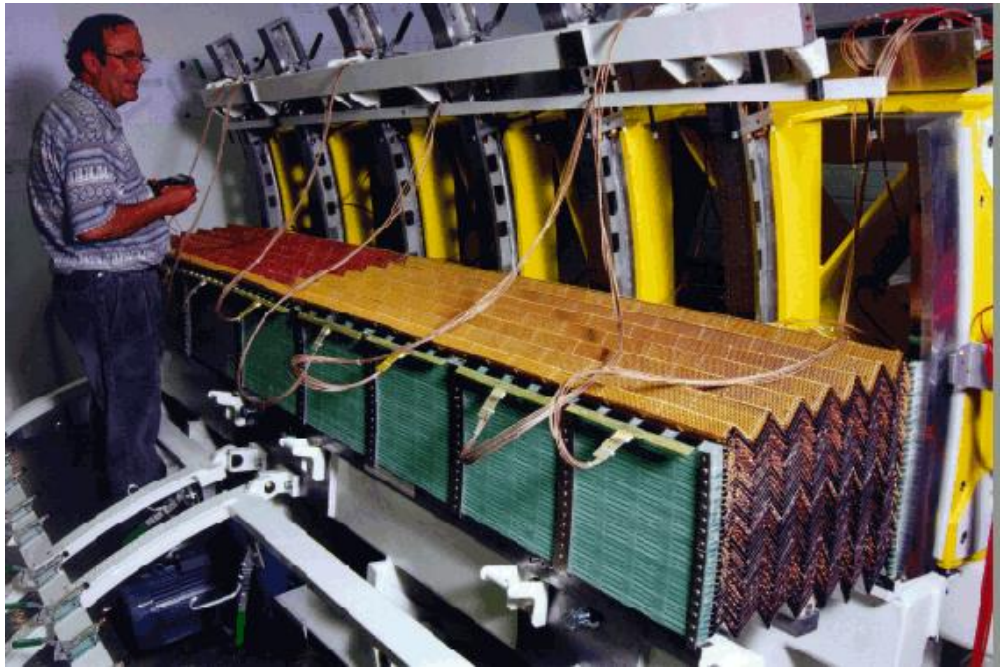
Module Assembly (Barrel)

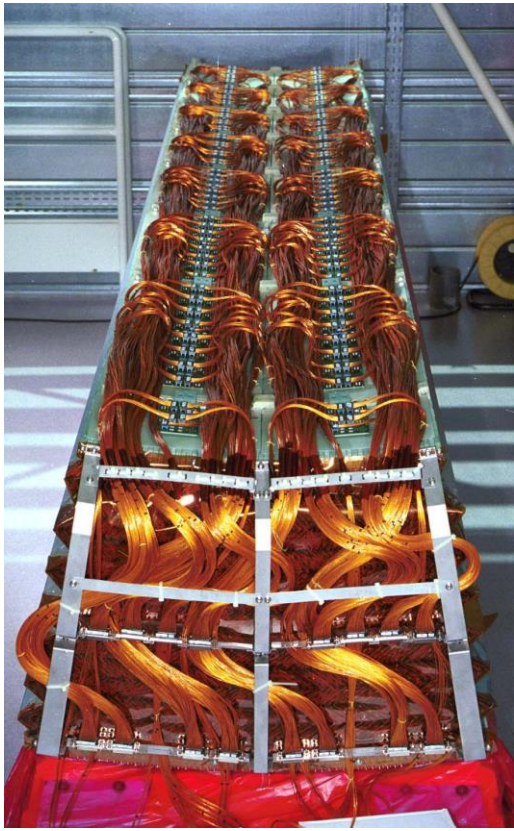
- **Modules:**

3 assembly sites:

~ identical benches and procedures

– Lots of measurements/QC





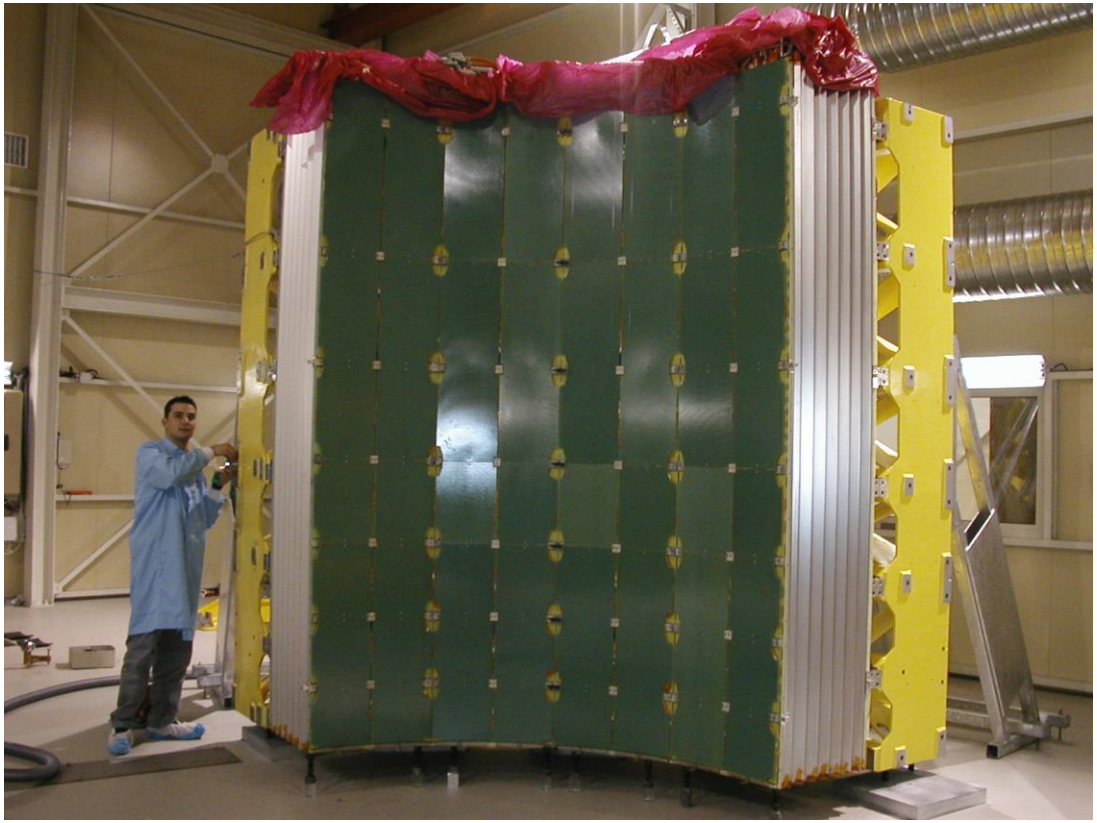
- **PS modules**

Grenoble, Marocco, Stockholm

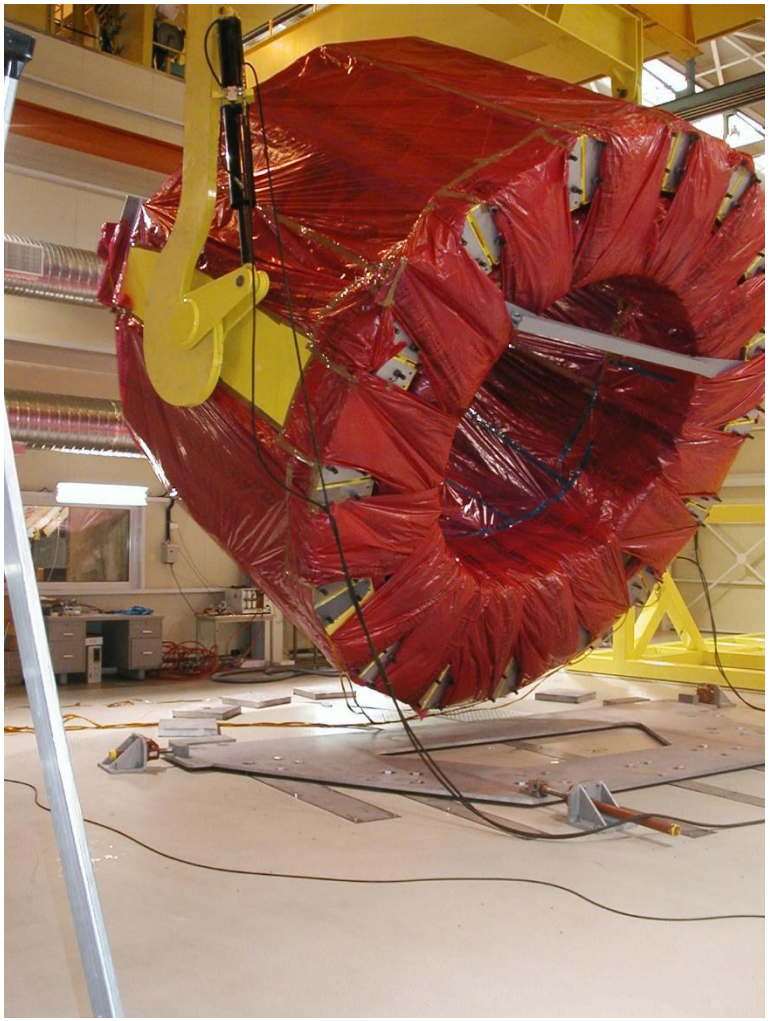
Module cold tests and beam tests

- **Cold tests**
  - **LAPP, Saclay (cryostats)**
  - **CERN (test beam)**

Barrel assembly



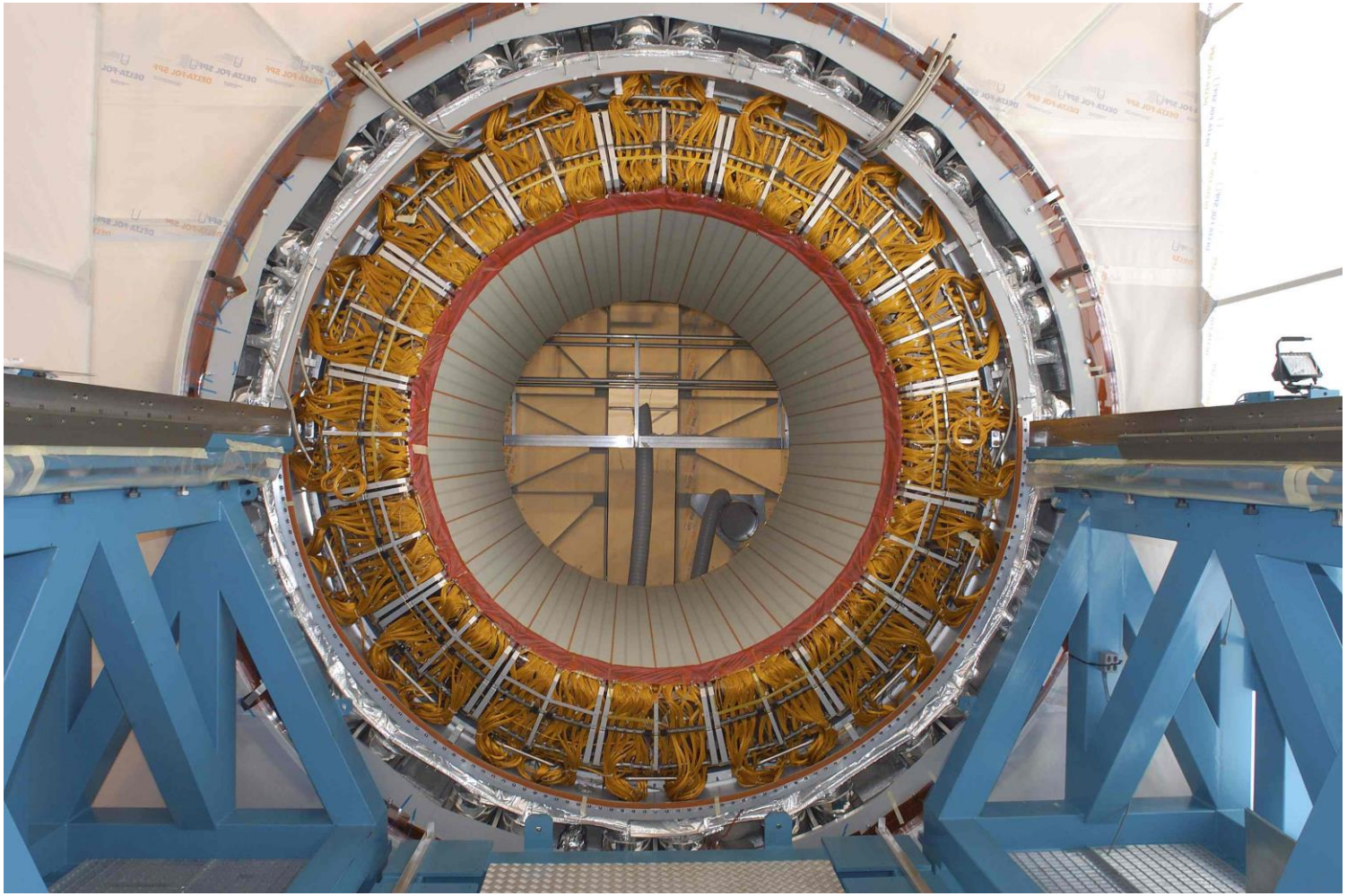
Barrel rotation and insertion



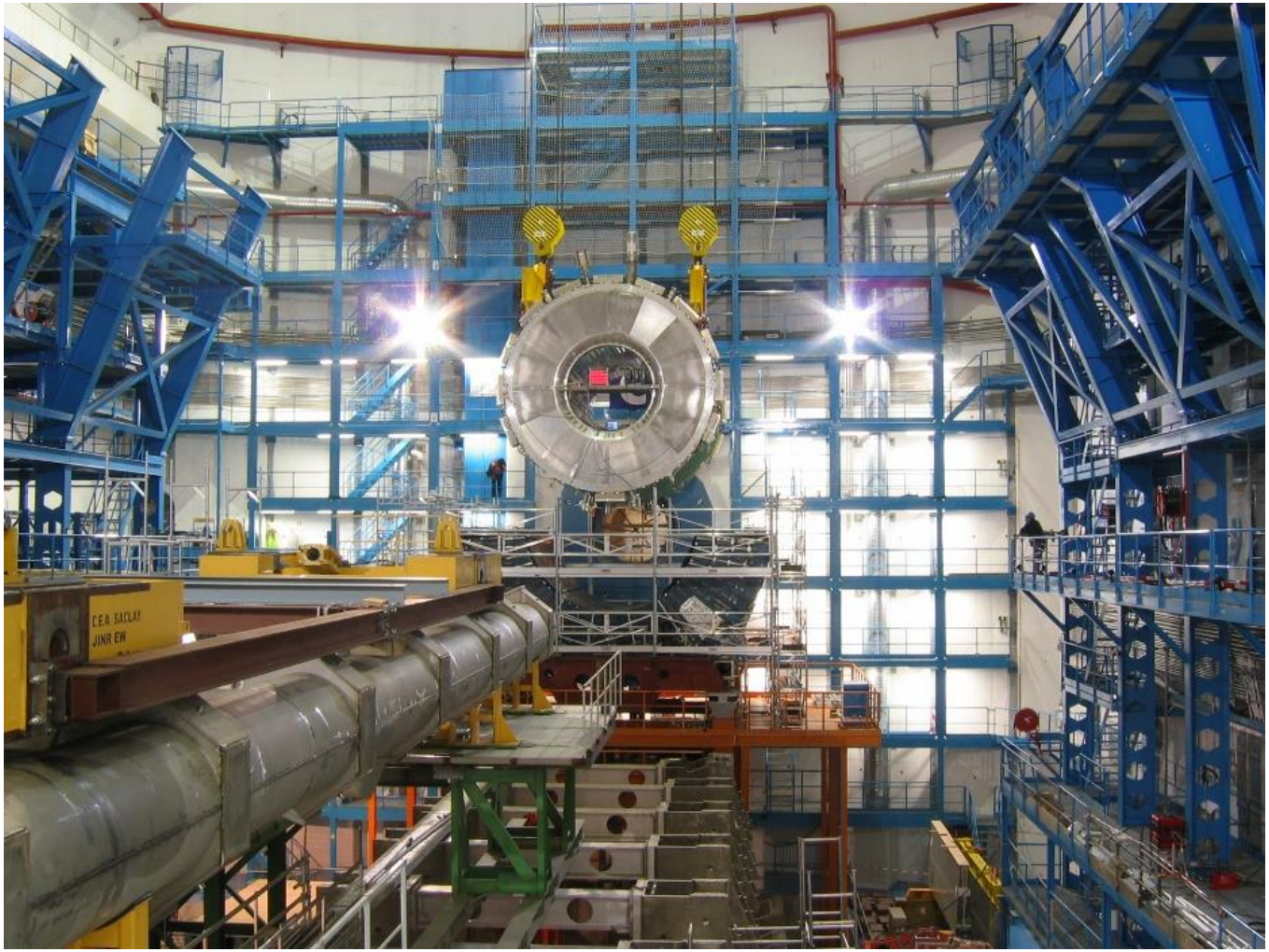
80 t, fragile object

PS modules

- **Ready to close the cryostat.**
  - **Last chance for a fix!**



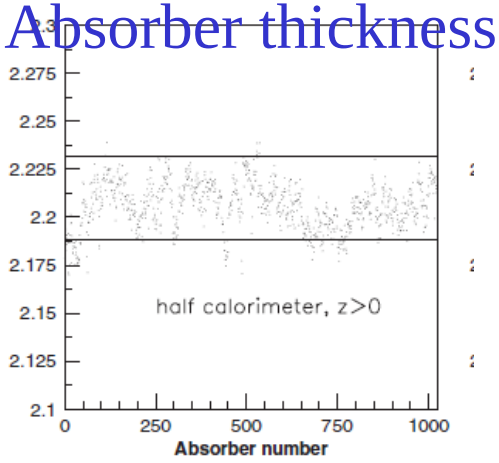
30 October 2004



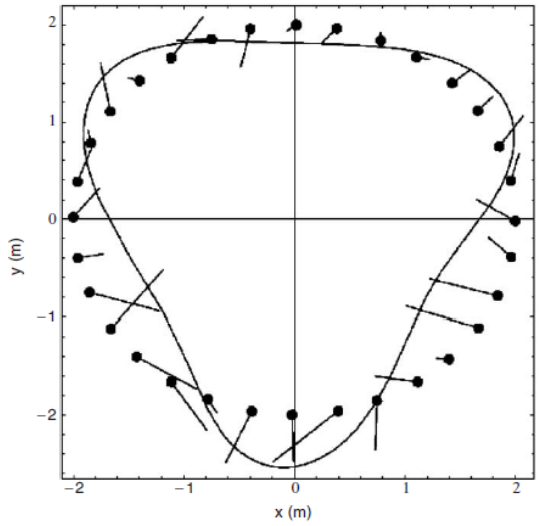
Quality Control for the EM

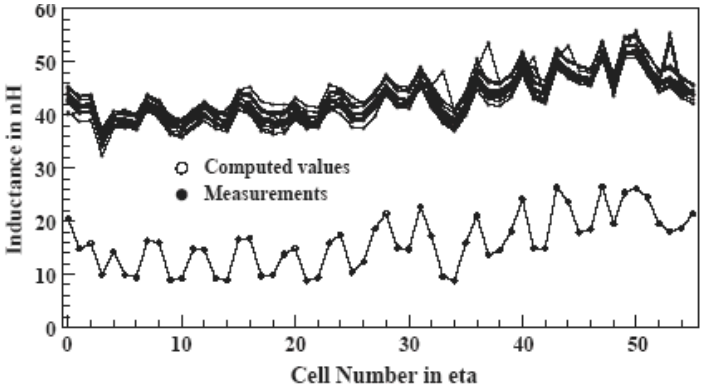
- **Inaccessible once in cold : strong concern of Quality from the start**
  - **Lots of measurements on the ingredients**
    - **Lead, G10 bars, kaptons, cables…**
  - **Tests/measurements continuous during module assembly and barrel assembly: Geometry, Electrical**
    - **Every plane, every cell…**
  - **Full wheel/barrel**

Absorber thickness



Barrel shape

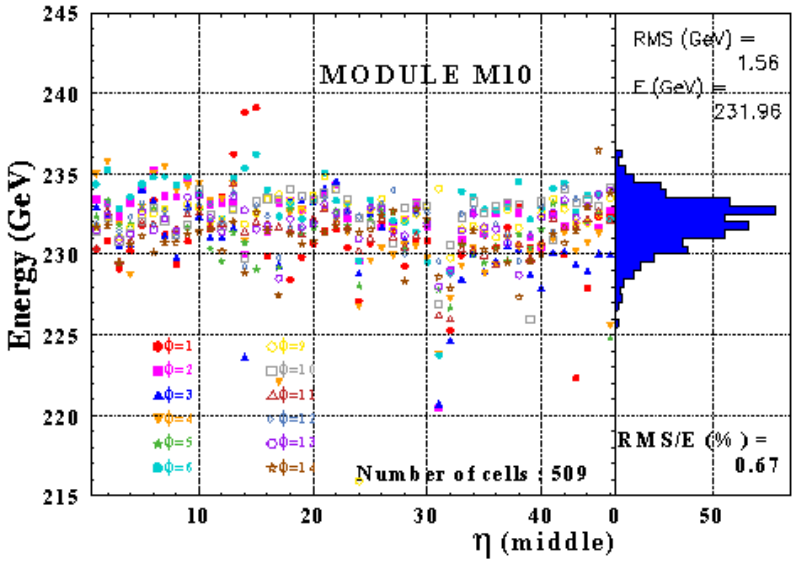


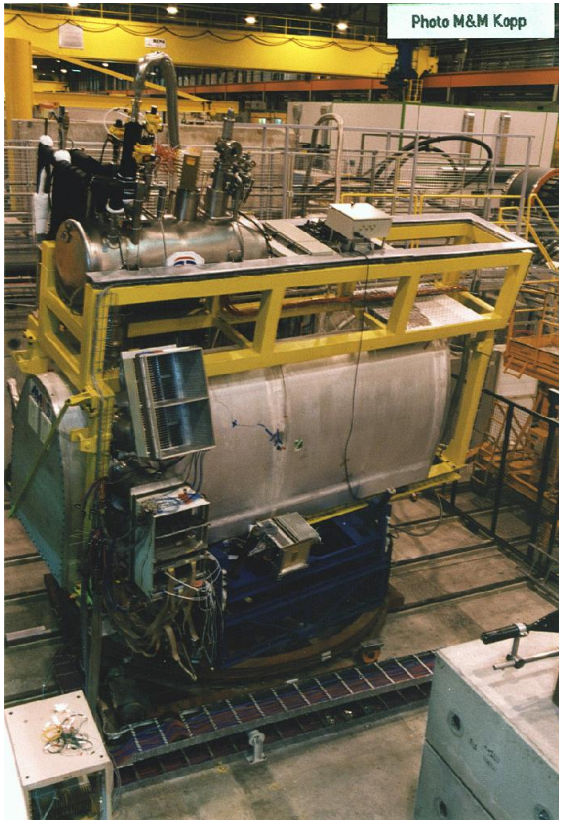


Cell inductance vs η

Beam tests

- **Lots of beam tests**
  - **2m prototype**
  - **Module 0**
  - **4 series modules**



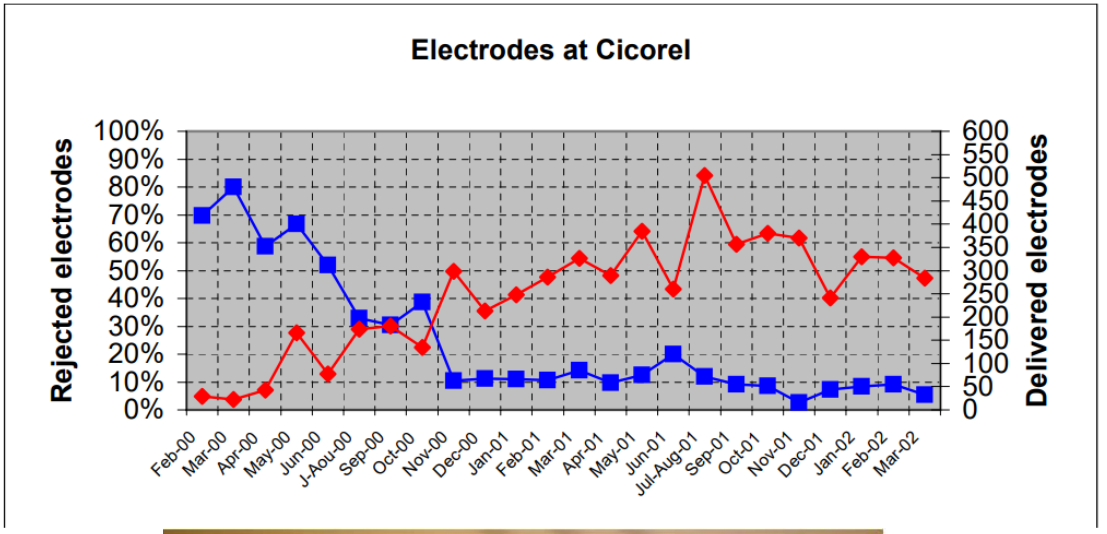


- **Fast analysis and feed-back!**
  - **The electrodes “ground springs” , retrofitted in urgency…**
  - **Protection diodes, also retrofitted…**

A few crises on the way…

- **Kapton electrode production**
  - **Geometry difficult to get right for large electrodes. *Split them?***
  - **Resistive paint difficult to get right, breaks when bending!**

  Repaired one by one…



- **Kapton electrode folding**
  - **Modules inflate as they grow!**
- **Special G10 bars production**
- **Spacers dust**

Daniel's dream coming true…

- **All this only for the EM Barrel !**
  Also: 2 EM End-caps, 2 HAD End-caps, 2 FWD and electronics, trigger, etc. etc.

- **Thanks to Daniel's leadership**
  - **No-nonsense management**
  - **Amazingly efficient in case of crisis: never overreact, keep cool, work hard to understand the problem, find a solution**
  - **Demanding style, but always available to help**
- **Such a pleasure to work with => very strong team**

Thank you !

- **Thank you Daniel for the wonderful work and years!**
- **Congratulations for the Lagarrigue Prize, so well deserved!**