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The ATLAS Liquid Argon Calorimetry: an Overview

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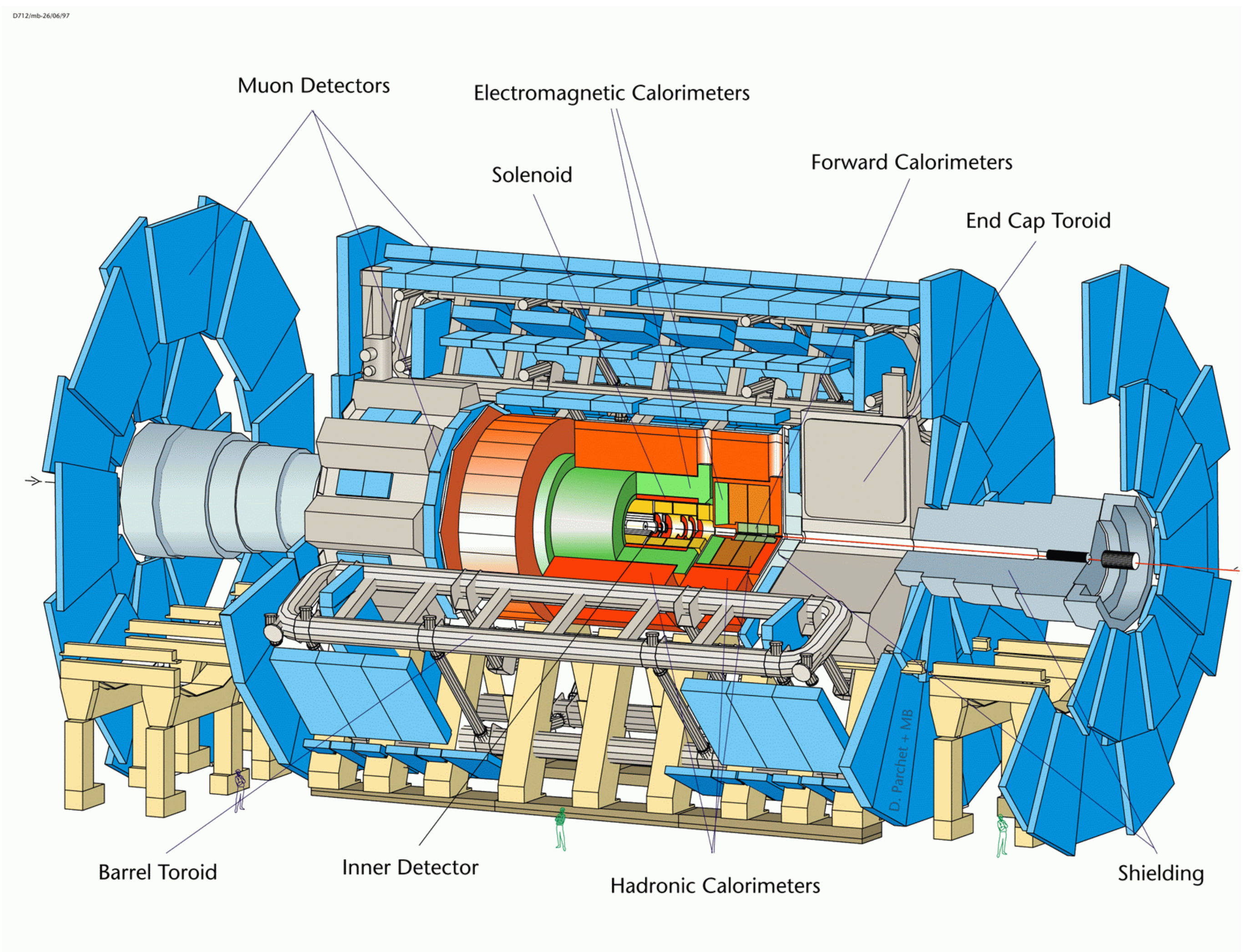
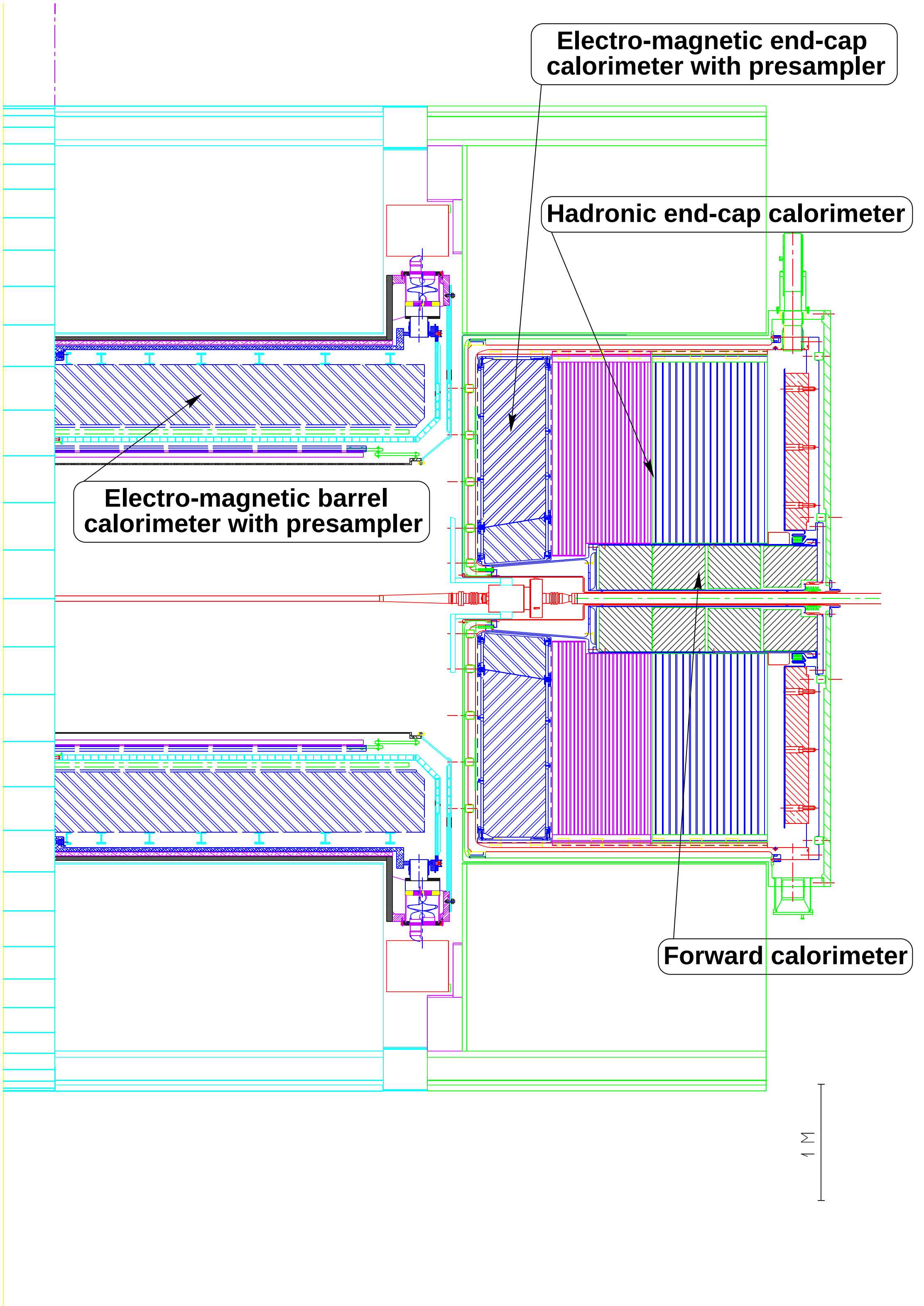
LHC

- Large centre-of-mass energy 14 TeV
- High design luminosity $L = 10^{34}$ cm^{-2}s^{-1}
  (23 collisions, in average, every bunch crossing)

ATLAS




Electro-magnetic end-cap calorimeter with presampler
Hadronic end-cap calorimeter
Electro-magnetic barrel calorimeter with presampler
Forward calorimeter
1 M

Main features of ATLAS liquid argon calorimetry

- **Intrinsically radiation hard**
- **Pseudorapidity coverage $|\eta| \leq 4.9$**
  (region $|\eta| < 2.5$ for precise measurements)
- **Fine granularity (transverse and longitudinal)**
- **Sufficient total thickness**
- **Fast detector response and fast electronics**

Design goals for electro-magnetic (EM) calorimeters

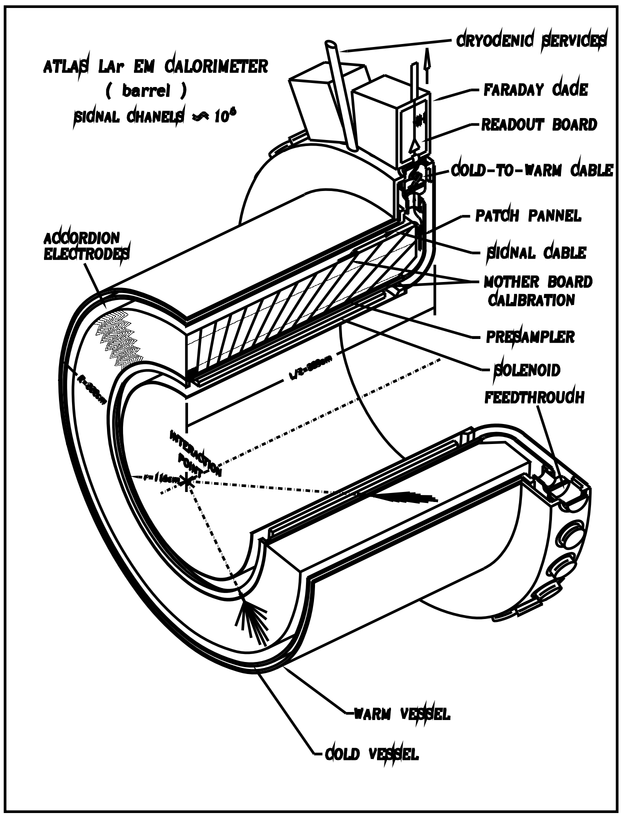
- **Energy resolution:**
  - **sampling term ≤ 10 % / $\sqrt{E(GeV)}$**
  - **constant term ≤ 0.7 %**
- **Linearity of response: better than 0.5 %**
- **Energy-scale precision: 0.1 %**
- **Dynamic range: from 50 MeV to 3 TeV**
- **Angular resolution in θ: ∼50 mrad / $\sqrt{E(GeV)}$**

Design goals for hadronic calorimeters

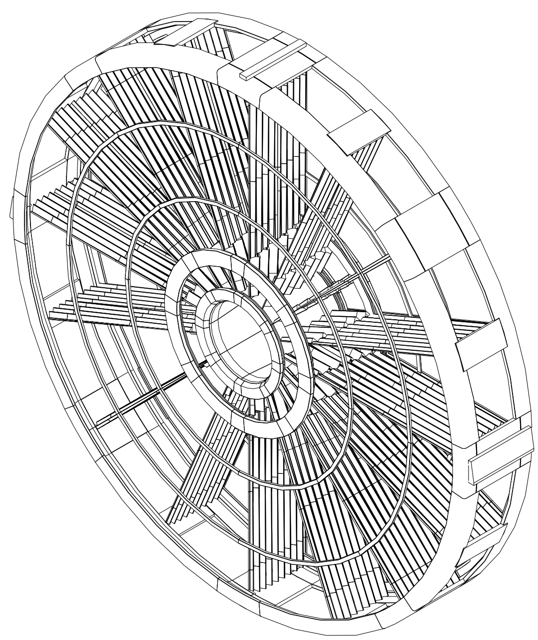
- **Energy resolution for jets:**
  $\sigma/E = 50\ \%/\sqrt{E(GeV)} \oplus 3\ \%$ **for** $|\eta| < 3$
  $\sigma/E = 100\ \%/\sqrt{E(GeV)} \oplus 10\ \%$ **for** $|\eta| \geq 3$
- **Linearity of response: within 2 %**
- **Energy-scale precision: 1 %**

Electro-Magnetic Calorimeters

- **Electro-magnetic barrel (EMB) and two end-cap calorimeters (EMEC)**
- **Lead / liquid argon detector with accordion-shaped electrodes and absorbers**
- **Complete φ-symmetry without azimuthal cracks**



One half of EMB



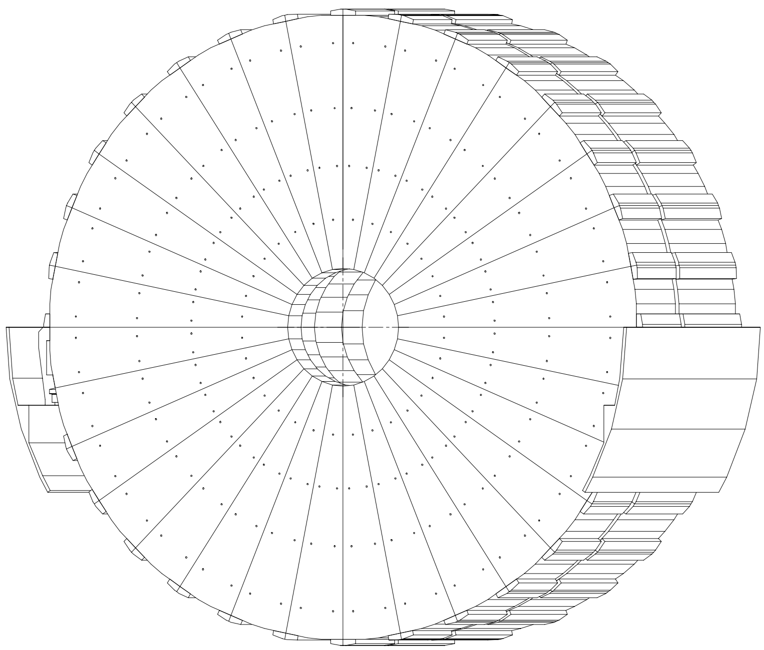
One of EMEC

	EMB	EMEC
Number of modules	32	16
Pseudorapidity-coverage	$\lvert\eta\rvert < 1.475$	$1.375 < \lvert\eta\rvert < 3.2$
Total thickness	$>24\ X_0$	$>26\ X_0$
Longitudinal samplings	3	3 $(2)^{\dagger}$
Main‡ transverse granularity $\Delta\eta \times \Delta\varphi$	0.025×0.025	0.025×0.025 $(0.1 \times 0.1)^{\dagger}$

† — values in brackets for $\lvert\eta\rvert > 2.5$
‡ — granularity of middle samplings

- Front sampling at $\lvert\eta\rvert < 2.5$ (6 X_0 thickness)
  (equipped with η-strips)
- Presampler at $\lvert\eta\rvert < 1.8$
  (immediately behind the cryostat cold wall)
- Number of channels $\sim$190 000

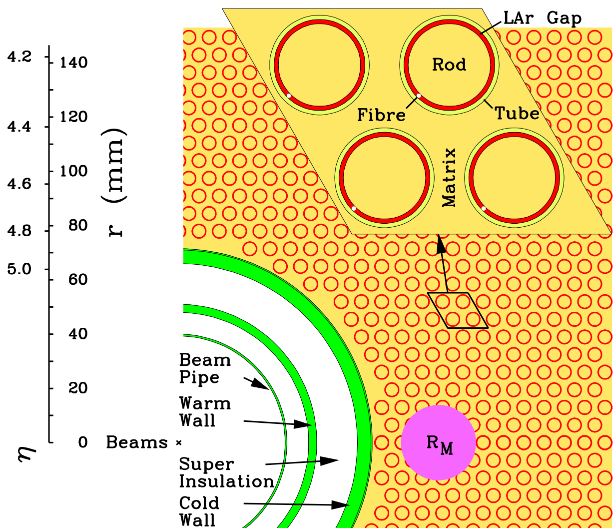
- Copper / liquid argon detector with parallel-plate geometry
- Plates — perpendicular to the beam direction
- Plate thickness:
  - 25 mm in front wheels (HEC-1)
  - 50 mm in rear wheels (HEC-2)



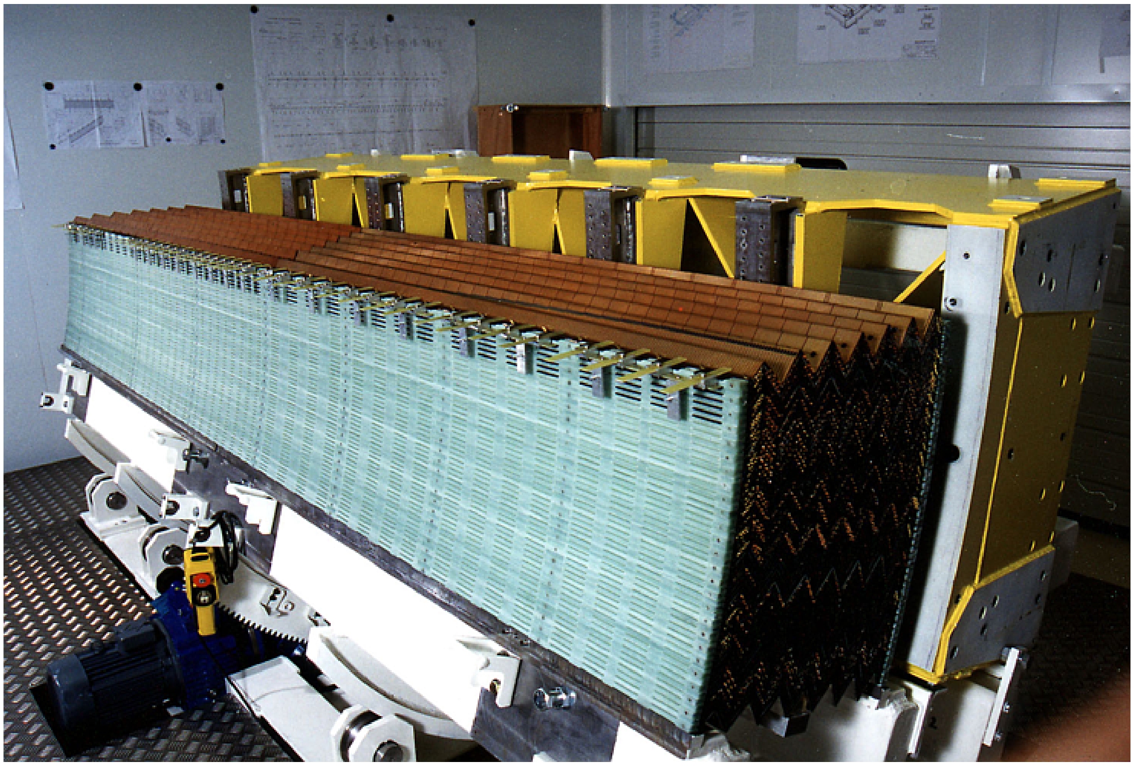
	HEC
Number of modules	128
Pseudorapidity-coverage	$1.5 < \|\eta\| < 3.2$
Total thickness	$\geq 10\ \lambda$
Longitudinal samplings	4 (4)†
Transverse granularity $\Delta\eta \times \Delta\varphi$	0.1×0.1 (0.2×0.2)†
Number of channels	~5 600

† — values in brackets for $|\eta| > 2.5$

- Dense liquid argon calorimeters, integrated in end-cap cryostats
- Tube electrodes — parallel to the beam direction
- Three modules:
  - FCAL-1 with copper absorber
  - FCAL-2 and FCAL-3 with tungsten absorber

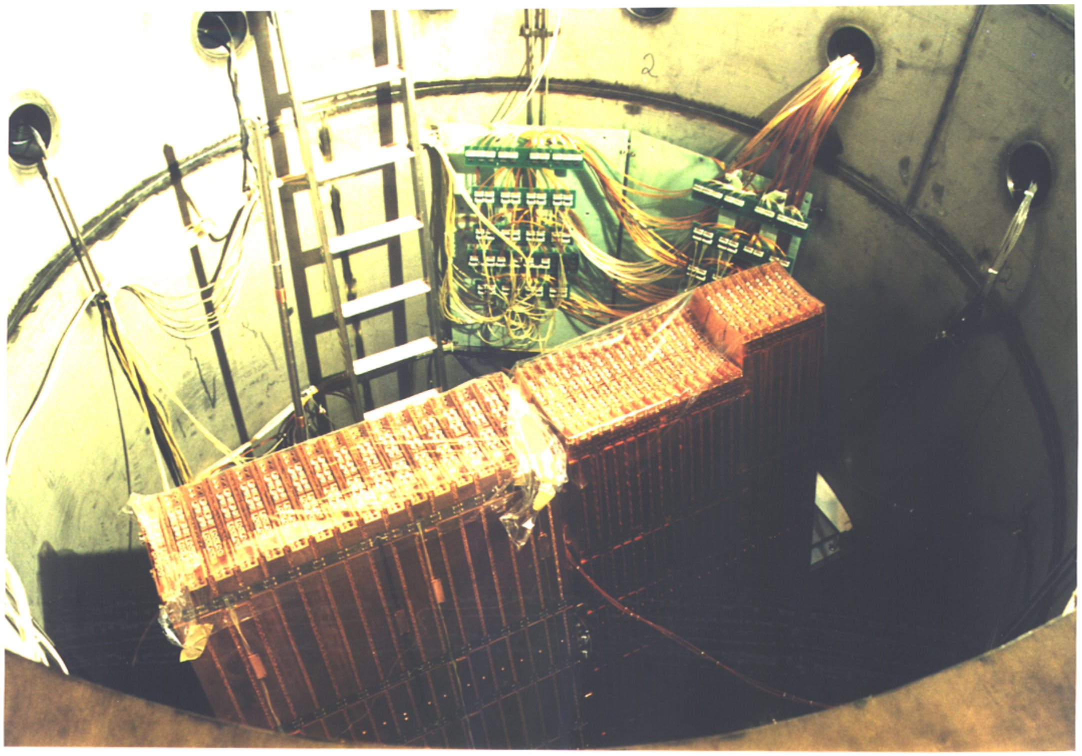


	FCAL
Number of modules	6
Pseudorapidity-coverage	$3.1 < \|\eta\| < 4.9$
Total thickness	$9.5\ \lambda$
Longitudinal samplings	3
Transverse granularity $\Delta\eta \times \Delta\varphi$	$\sim 0.2 \times 0.2$
Number of channels	~3 600

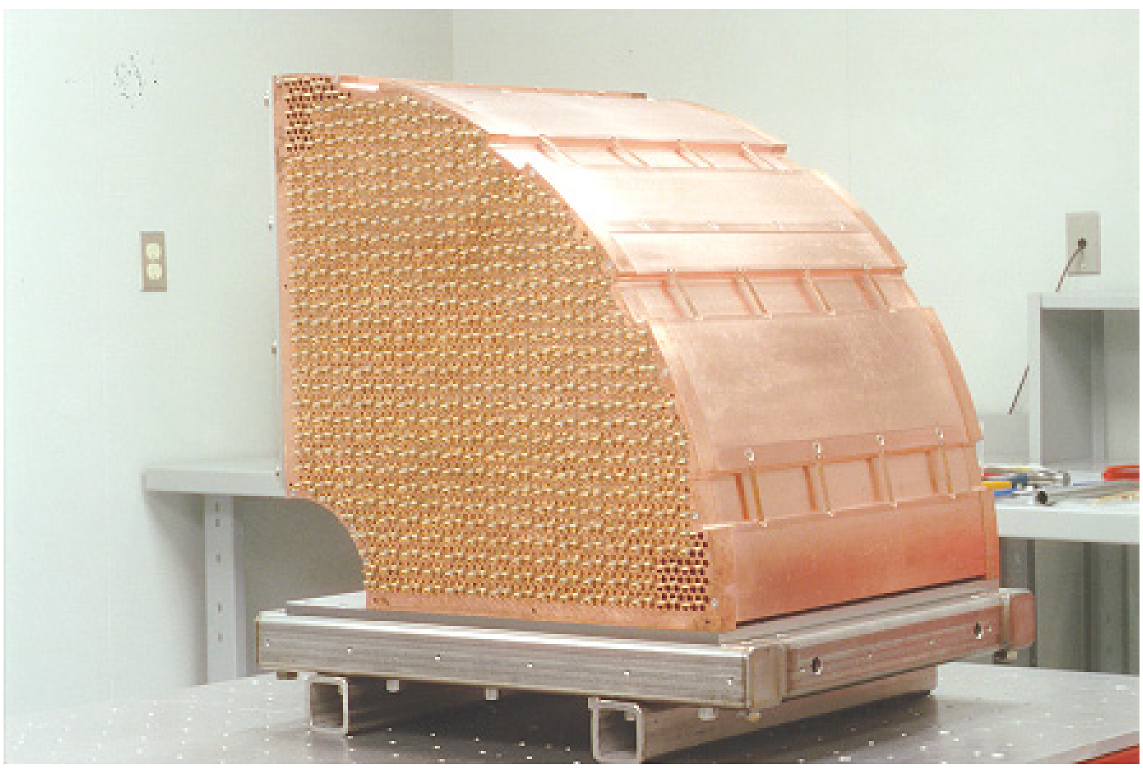


Module 0 of EM barrel calorimeter

Module 0 of EM end-cap calorimeter after completion of the outer wheel



HEC modules in the test-beam cryostat



Module 0 of FCAL-2

Separate talks:

- **C. Clement**
  Electro-magnetic calorimeters: barrel and end-cap

- **A. Minaenko**
  Hadronic end-cap calorimeter

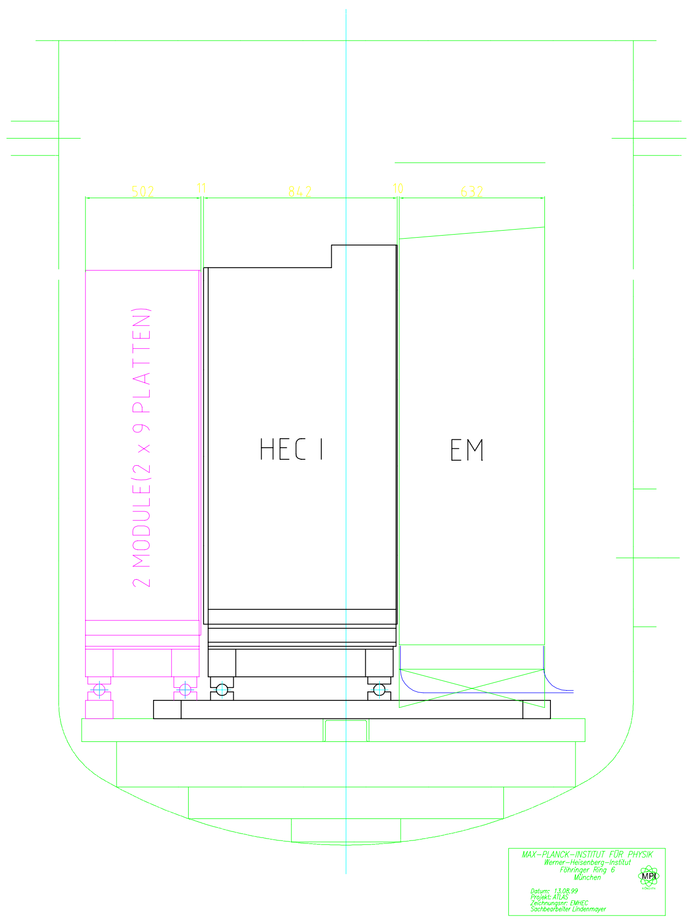
- **R. Orr**
  Forward calorimeter

Combined tests of EM and hadronic end-cap calorimeters

- **Configuration of modules**

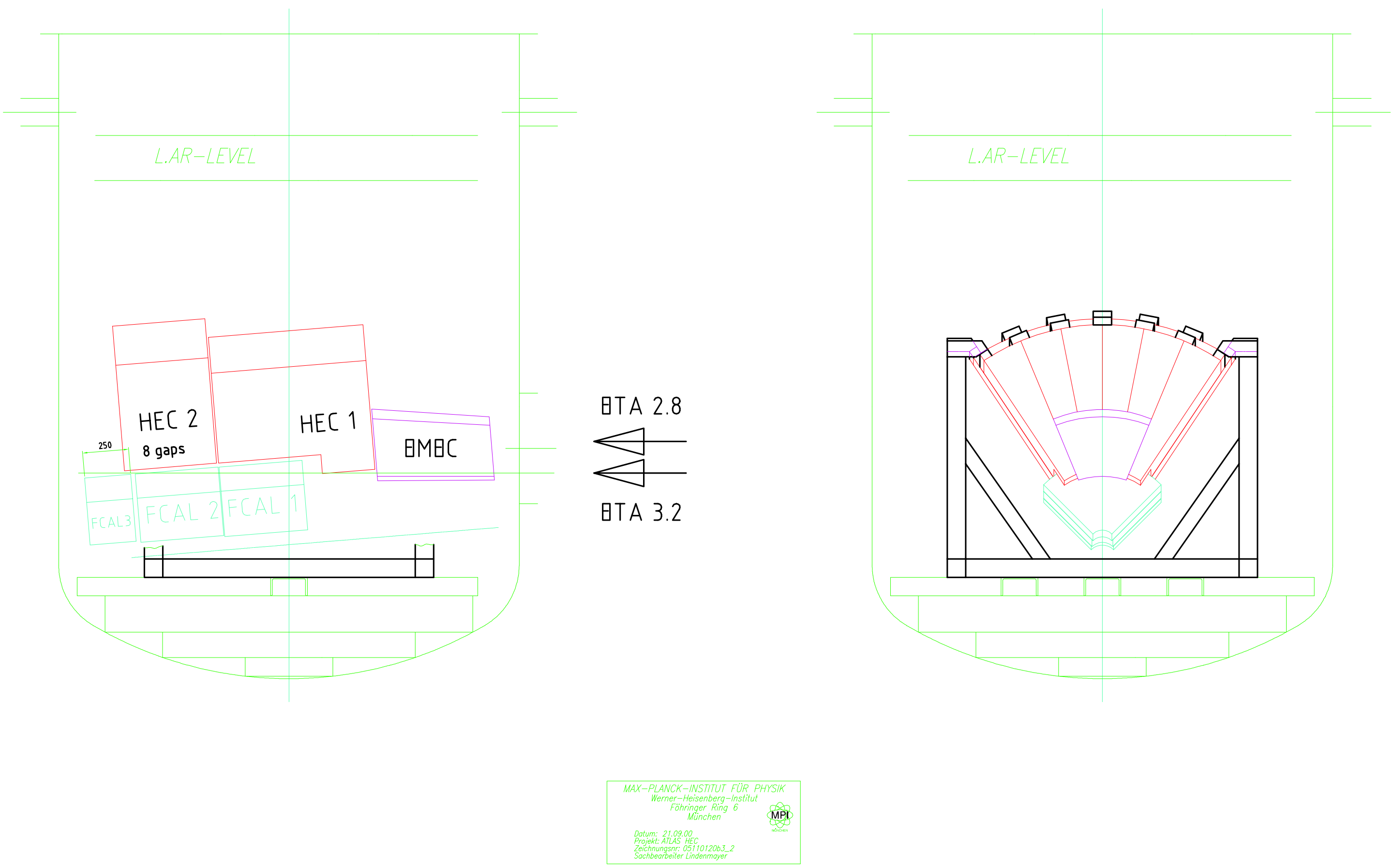
Calorimeter	φ-coverage	η-coverage	z-coverage
EMEC	1/8 (45°)	full	full
HEC-1	3 wedges (33.75°)	full	full
HEC-2	2 wedges (22.5°)	full	1/2

- **Test beam in 2001-2002**



Combined tests of EM, hadronic end-cap and forward calorimeters ("crack at $|\eta| \sim 3.2$")

- **Different configuration under studies**
- **Necessity of special (non-serial) modules**
- **Test beam in 2003 or 2004 ???**



Outlook

- Production and tests of serial modules of all liquid argon calorimeters are going on
- Assembly of first calorimetry wheels — 2001
- Present working schedule for calorimeter installation:

Operation	Cryostat		
	End-cap C	Barrel	End-cap A
Calorimeters inserted	Jan. 2003	Dec. 2002	Mar. 2004
Start cold test	Feb. 2003	Jun. 2003	Apr. 2004
Ready for pit	Aug. 2003	Dec. 2003	Sep. 2004

The Liquid Argon community is currently working on a "best effort scenario" in order to match the general ATLAS installation schedule