Introduction to Hadronic Final State Reconstruction in Collider Experiments (Supplement to Part IV: The ATLAS Calorimeter System)

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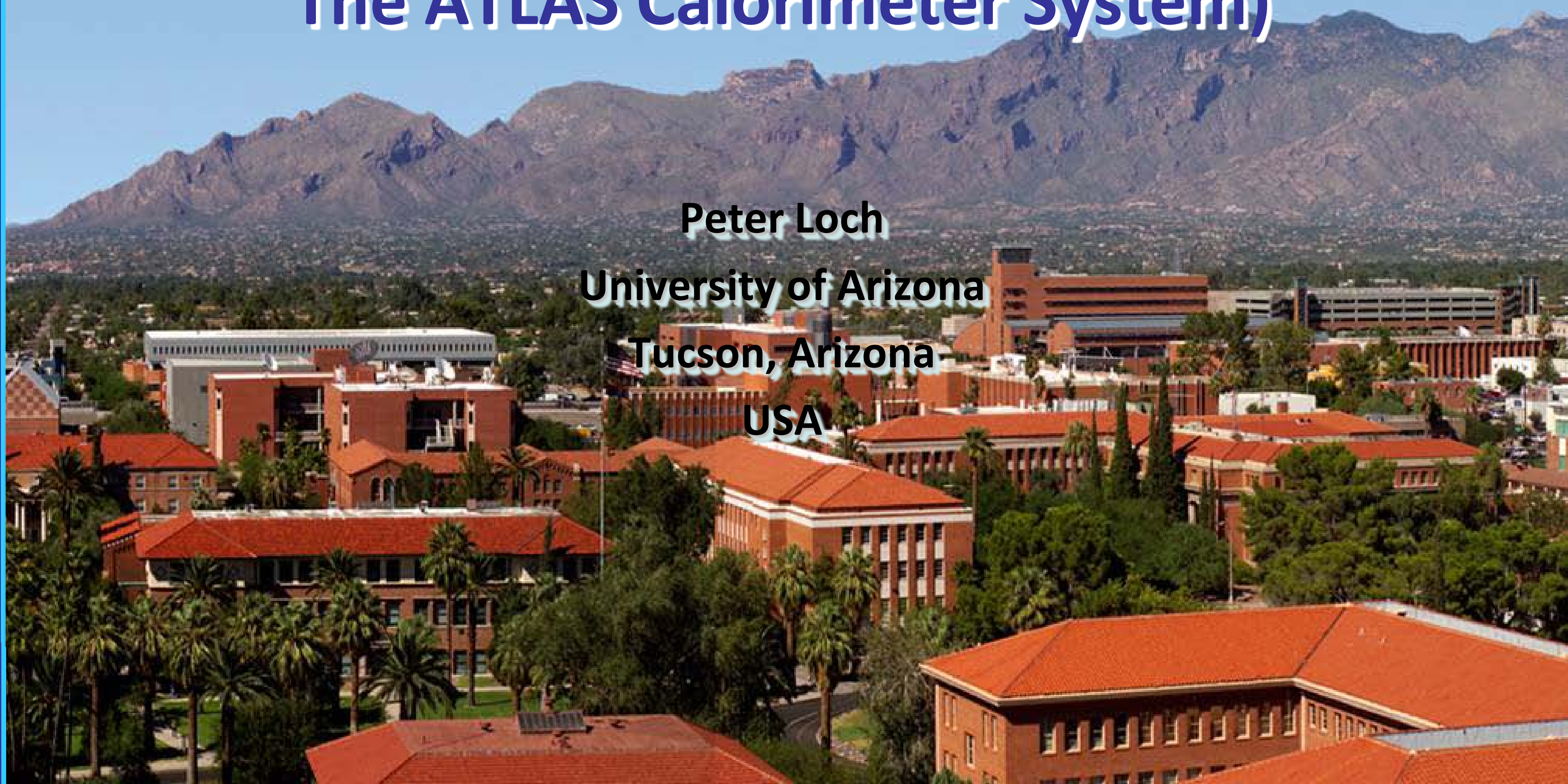

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ATLAS: A General Purpose Detector For LHC

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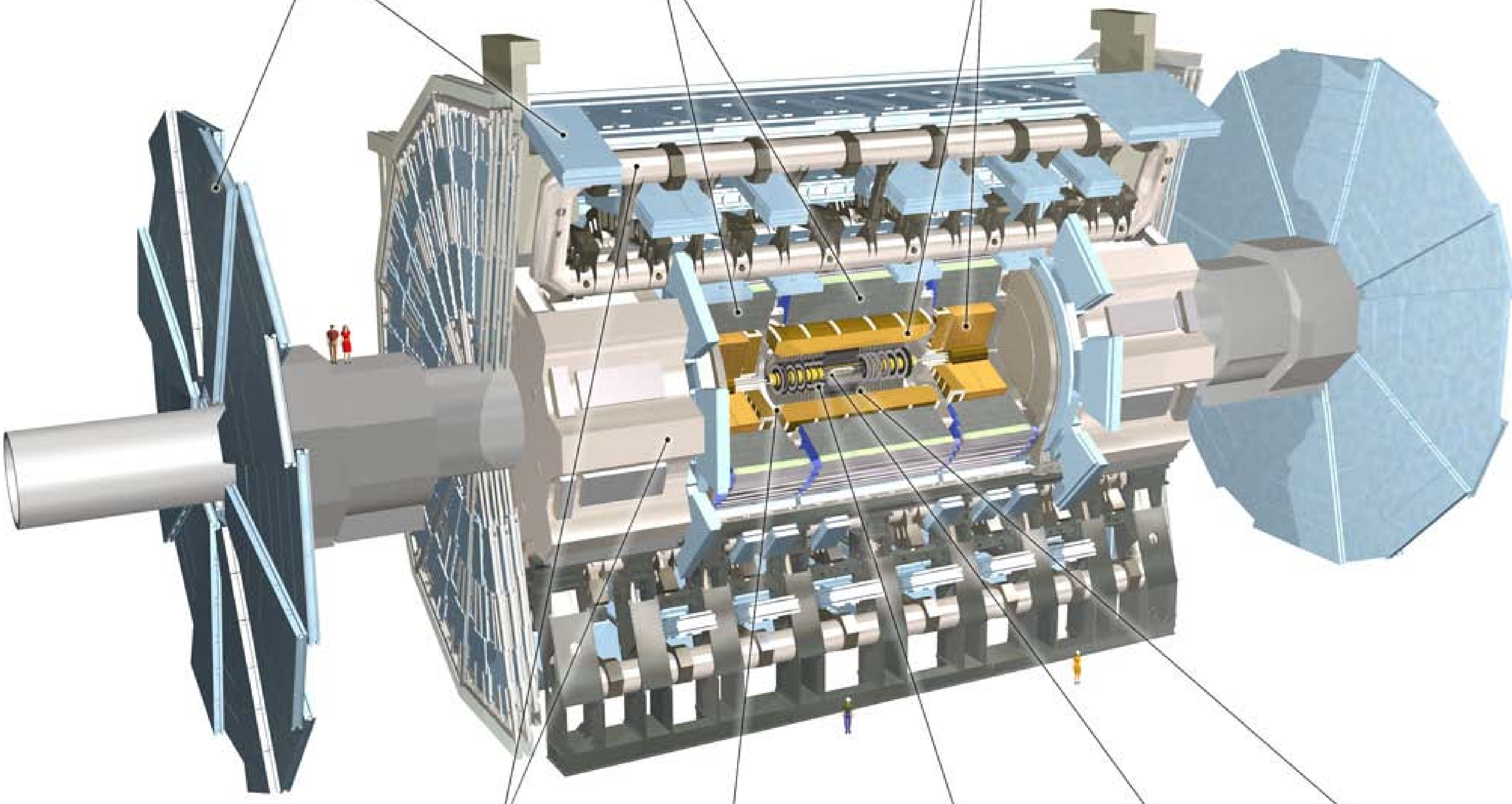

Total weight : 7000 t
Overall length: 46 m
Overall diameter: 23 m
Magnetic field: 2T solenoid + (varying) toroid field

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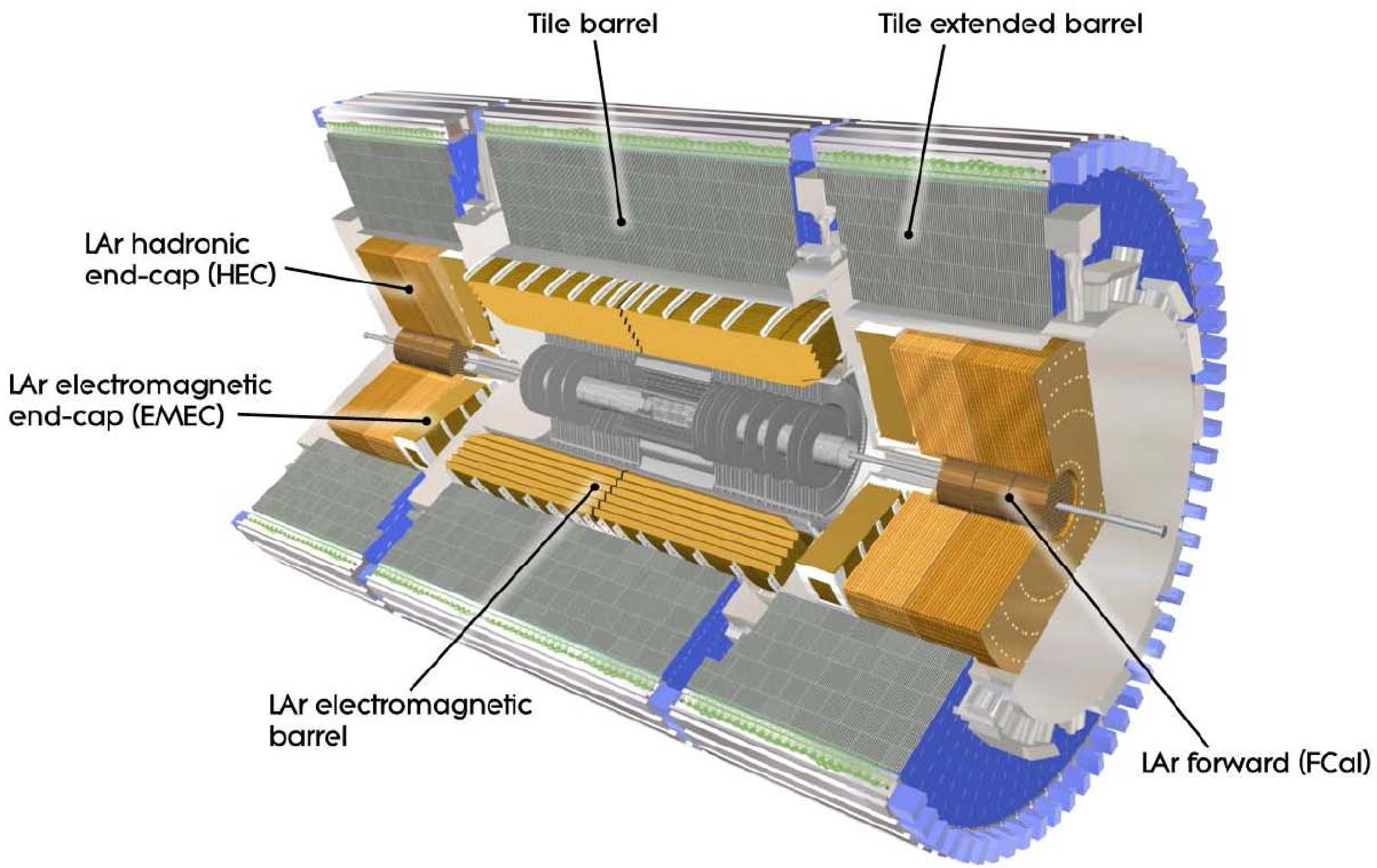
ATLAS Calorimeters



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The ATLAS Calorimeters

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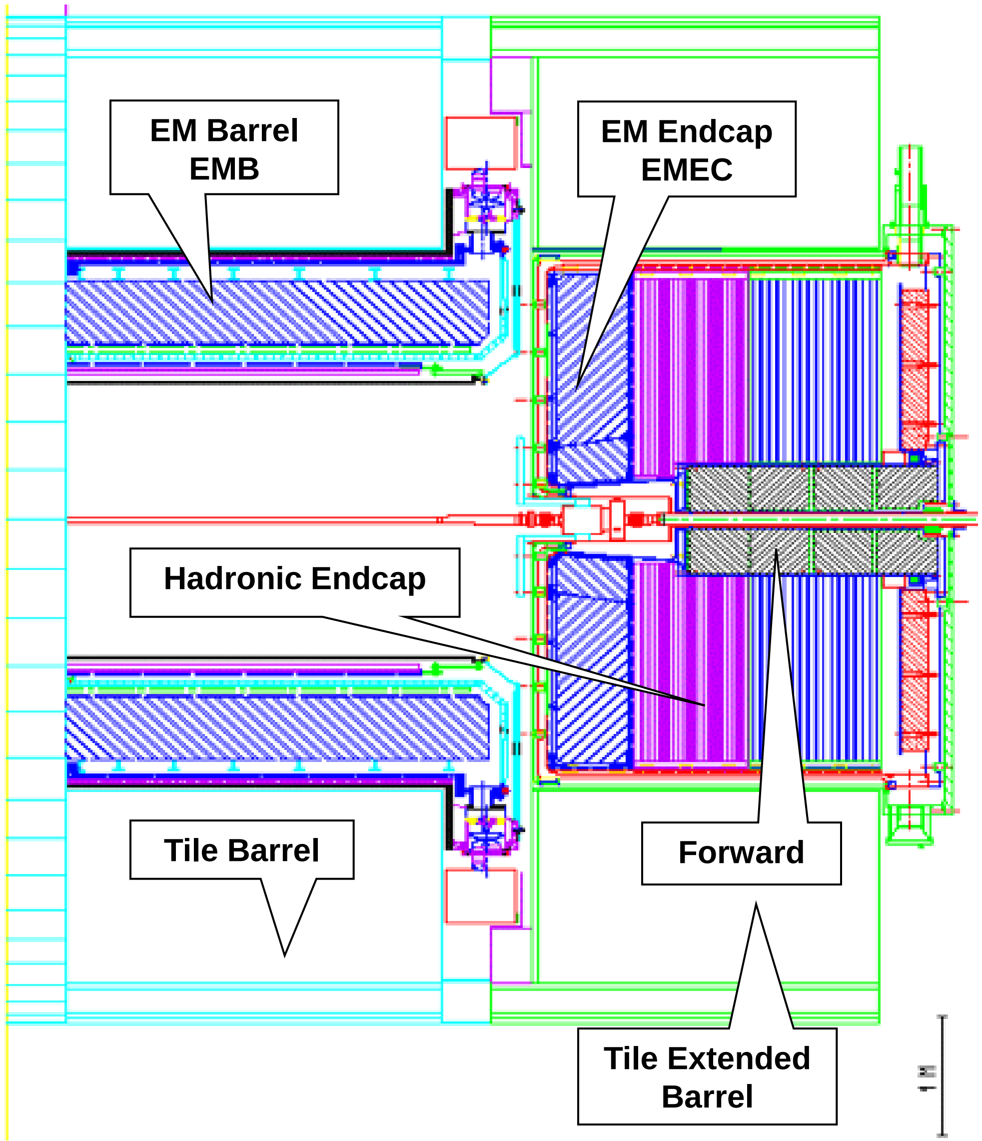

Electromagnetic Barrel
- $|\eta| < 1.4$
- Liquid argon/lead

Electromagnetic EndCap
- $1.375 < |\eta| < 3.2$
- Liquid argon/lead

Hadronic Tile
- $|\eta| < 1.7$
- Scintillator/iron

Hadronic EndCap
- $1.5 < |\eta| < 3.2$
- Liquid argon/copper

Forward Calorimeter
- $3.2 < |\eta| < 4.9$
- Liquid argon/copper and liquid argon/tungsten

Varying (high) granularity
- Mostly projective or pseudo-projective readout geometries
- Nearly 200,000 readout channels in total

Overlaps and transitions
- Some complex detector geometries in crack regions

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Electromagnetic Calorimetry

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Highly segmented lead/liquid argon accordion calorimeter

- Projective readout geometry in pseudo-rapdity and azimuth
  - More than 170,000 independent readout channels
- No azimuthal discontinuities (cracks)
  - Total depth > 24 X_0 (increases with pseudo-rapidity)
- Three depth segments
  - + pre-sampler (limited coverage, only $\eta < 1.8$)

Strip cells in 1st layer

- Thin layer for precision direction and e/π and e/γ separation
  - Total depth ≈ 6 X_0 (constant)
- Very high granularity in pseudo-rapidity
  - $\Delta\eta \times \Delta\varphi \approx 0.003 \times 0.1$

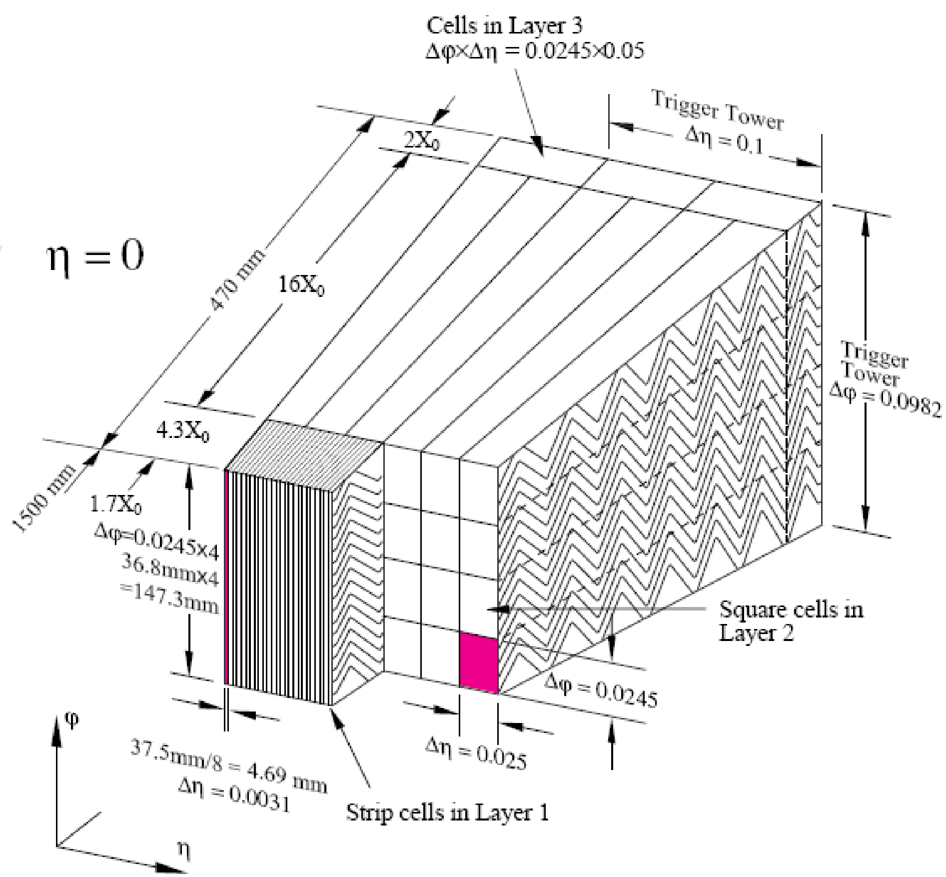
Deep 2nd layer

- Captures electromagnetic shower maximum
  - Total depth ≈ 16-18 X_0
- High granularity in both directions
  - $\Delta\eta \times \Delta\varphi \approx 0.025 \times 0.025$

Shallow cells in 3rd layer

- Catches electromagnetic shower tails
  - Electron and photon identification
  - Total depth ≈ 2-12 X_0 (from center to outer edge in pseudo-rapidity)
- Relaxed granularity
  - $\Delta\eta \times \Delta\varphi \approx 0.05 \times 0.025$

Electromagnetic Barrel



Hadronic Calorimetry

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Central and Extended Tile calorimeter

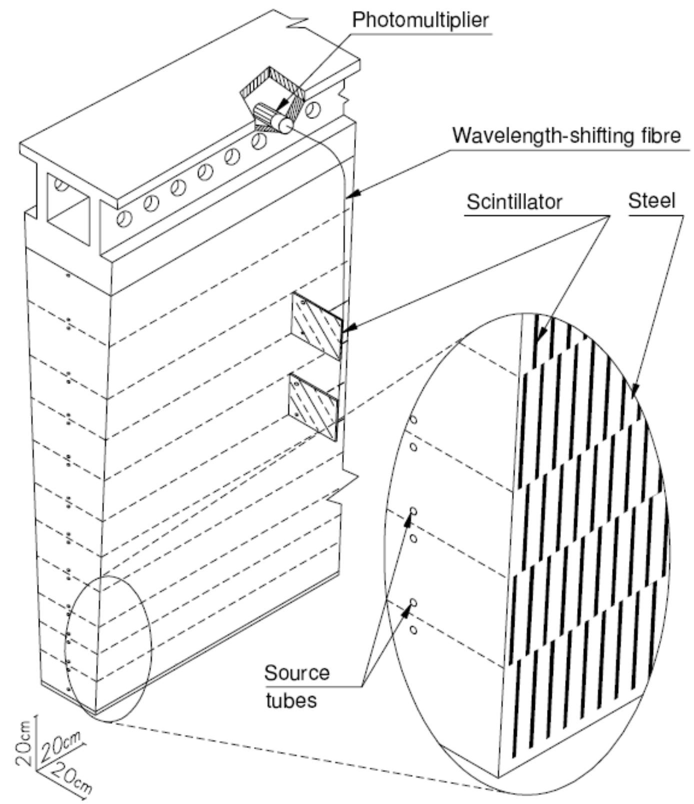
- Iron/scintillator with tiled readout structure
- Three depth segments

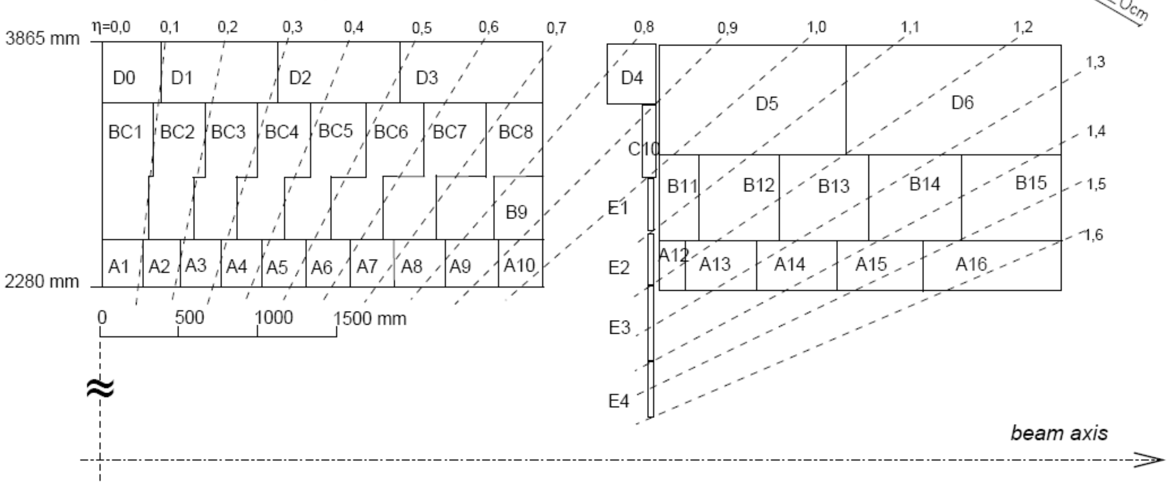
Quasi-projective readout cells

- Granularity first two layers
  - $\Delta\eta \times \Delta\varphi \approx 0.1 \times 0.1$
- Third layer
  - $\Delta\eta \times \Delta\varphi \approx 0.2 \times 0.1$

Very fast light collection

- ~50 ns reduces effect of pile-up to ~3 bunch crossings
- Dual fiber readout for each channel
  - Two signals from each cell





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EndCap Calorimeters

Electromagnetic "Spanish Fan" accordion

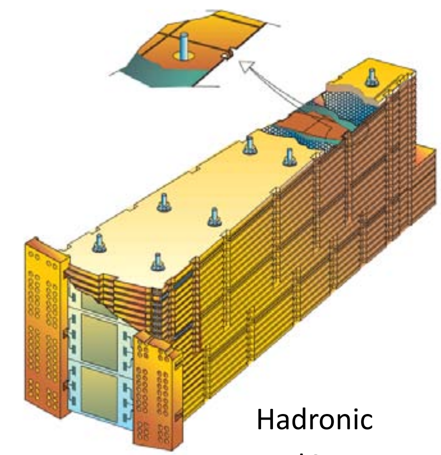
$$\Delta\eta\times\Delta\varphi\approx\begin{cases}0.025\times0.025 & |\eta|<2.5\text{, middle layer}\\ 0.1\times0.1 & 2.5<|\eta|<3.2\end{cases}$$

- Highly segmented with up to three longitudinal segments
- Complex accordion design of lead absorbers and electrodes
  - Looks like an unfolded spanish fan

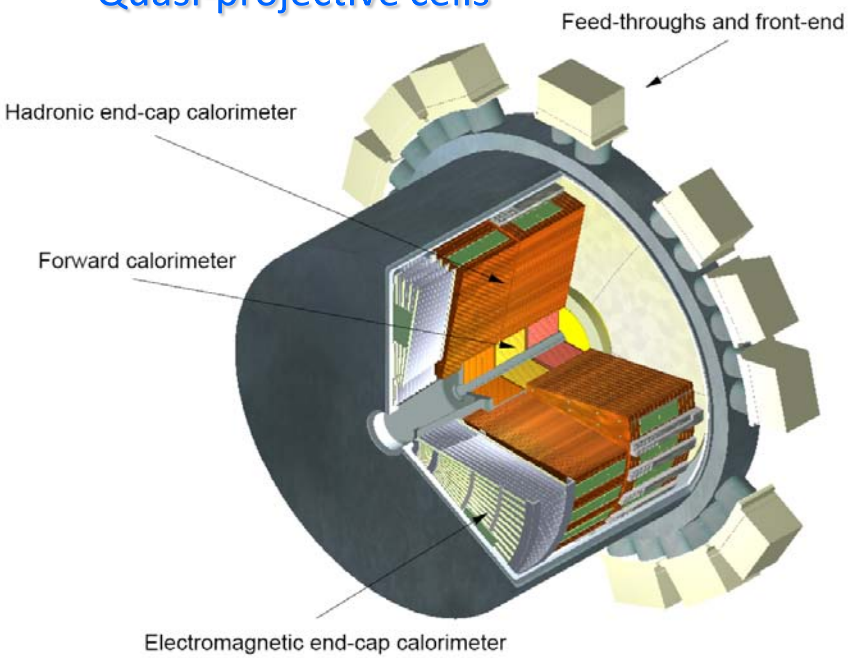
Hadronic liquid argon/copper calorimeter

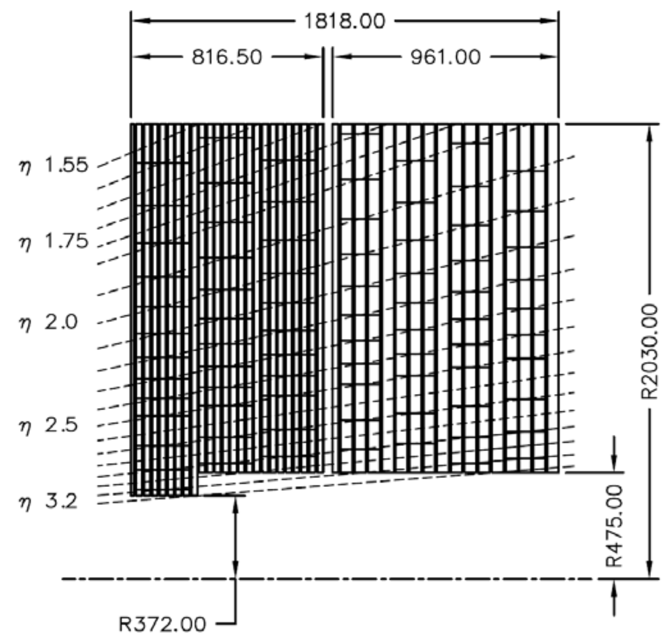
$$\Delta\eta\times\Delta\varphi\approx\begin{cases}0.1\times0.1 & |\eta|<2.5\\ 0.2\times0.2 & 2.5<|\eta|<3.2\end{cases}$$

- Parallel plate design
- Four longitudinal segments
- Quasi-projective cells



Hadronic EndCap wedge





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Forward Calorimeters

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Design features

- Compact absorbers
  - Small showers
- Tubular thin gap electrodes
  - Suppress positive charge build-up (Ar+) in high ionization rate environment
  - Stable calibration
- Rectangular non-projective readout cells

Electromagnetic FCal1

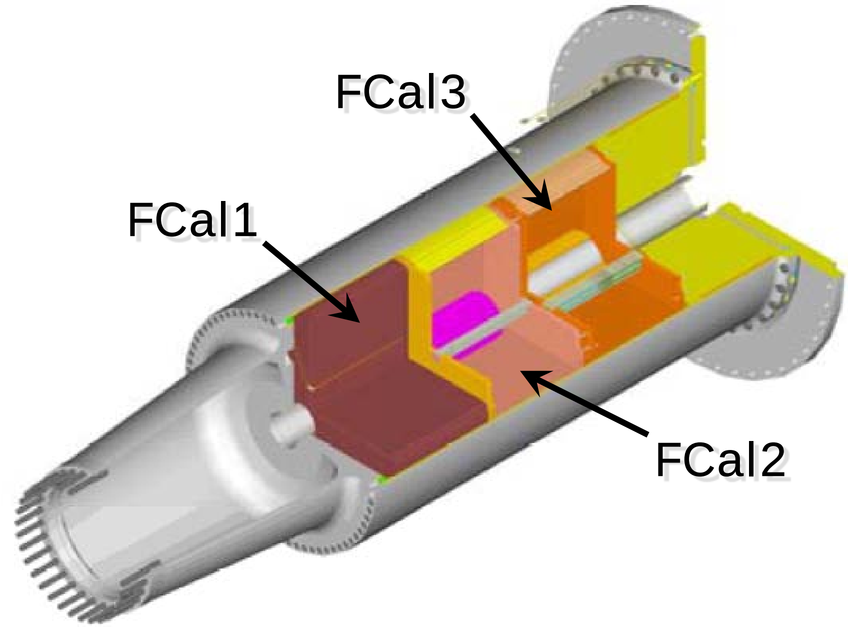
- Liquid argon/copper
  - Gap ~260 µm

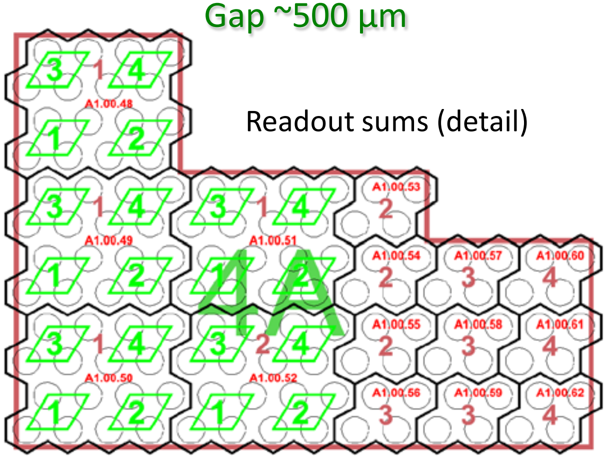
Hadronic FCal2

- Liquid argon/tungsten
  - Gap ~375 µm

Hadronic FCal3

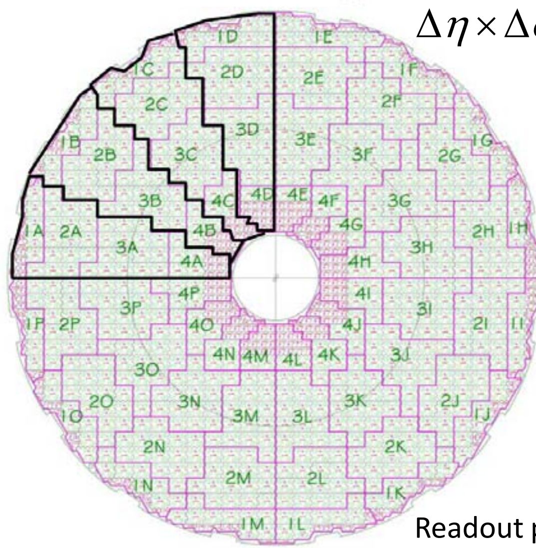
- Liquid argon/tungsten
  - Gap ~500 µm



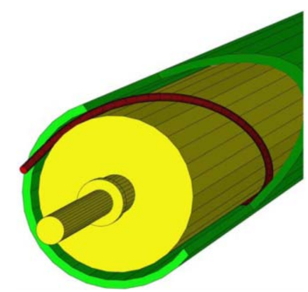


Readout sums (detail)

$\Delta\eta\times\Delta\varphi\approx 0.2\times 0.2$



Readout pattern



Forward calorimeter electrode

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ATLAS Calorimeter Summary

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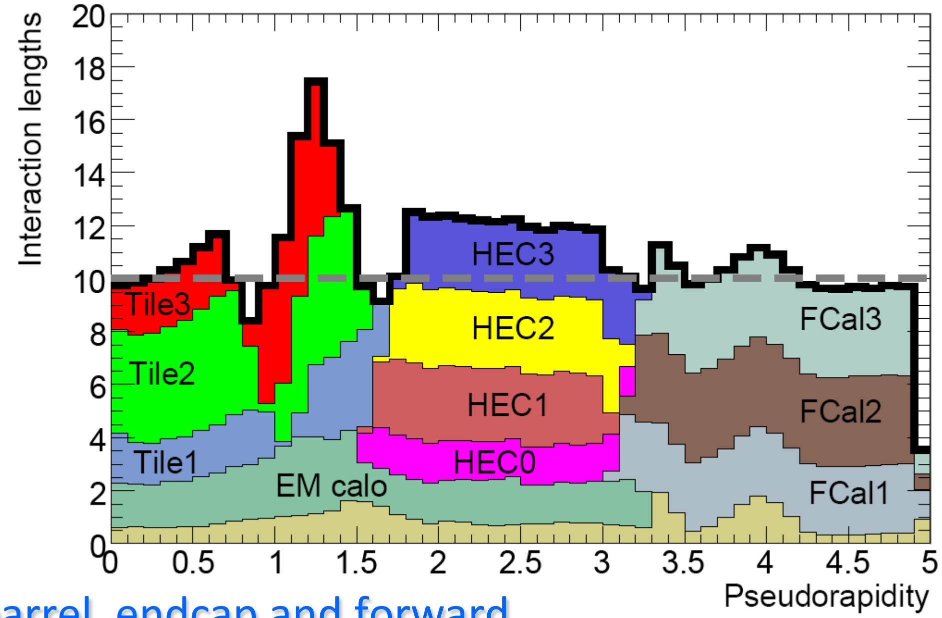
Non-compensating calorimeters

- Electrons generate larger signal than pions depositing the same energy
  - Typically $e/\pi \approx 1.3$

High particle stopping power over whole detector acceptance $|\eta|<4.9$

- ~26-35 X_0 electromagnetic calorimetry
- ~ 10 λ total for hadrons



Hermetic coverage

- No significant cracks in azimuth
- Non-pointing transition between barrel, endcap and forward
  - Small performance penalty for hadrons/jets

High granularity

- Nearly 200,000 readout channels
  - Highly efficient particle identification
  - Jet substructure resolution capabilities
  - Local hadronic calibration using signal shapes
  - …

ATLAS