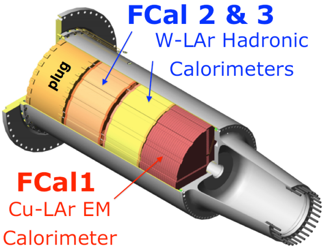
# Performance of the ATLAS Forward Calorimeters in First LHC Data


Dag Gillberg, on behalf of the
ATLAS Liquid Argon Calorimeter Group

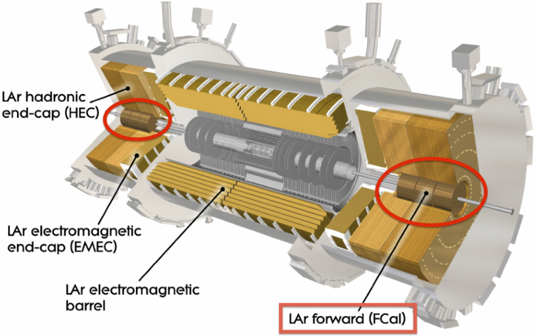



# The ATLAS Forward Calorimeters (FCal)

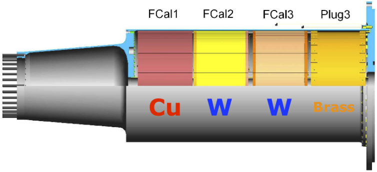
- Covers very forward region: $3.1 < |\eta| < 4.9$
- Designed to operate in very high rate environment: **Large noise from pileup**

## Motivation

- Improve reconstruction of **missing transverse energy**
- Tag forward jets (e.g. **VBF**$\rightarrow$Higgs )
- Forward physics




| Layer | Absorber | LAr gap | $N_{\text{electrodes}}$ | $N_{\text{channels}}$ |
|---|---|---|---|---|
| FCal1 | Cu | 269 $\mu$m | 24,520 | 2,016 |
| FCal2 | W | 376 $\mu$m | 20,400 | 1,000 |
| FCal3 | W | 508 $\mu$m | 16,448 | 508 |



# Design of the FCal

## Requirements

- Adequate $E_T$ **resolution** with **small non-Gaussian tails** $(\sigma E/E = 1/\sqrt{E} + 0.1)$
- **Fast response** in order to minimize noise from pileup, $\mathcal{O}$(25 ns)
- **Radiation hardness** – cope with design luminosity of $\mathcal{L} = 10^{34}$ cm$^{-2}$s$^{-1}$ at $\sqrt{s} = 14$ TeV :

  In FCal: **7 TeV/evt**, 45 Watts

## Placement

Original idea: FCal at $z = 15$ m from IP

Chosen location: **inside endcap**, $z = 5$ m

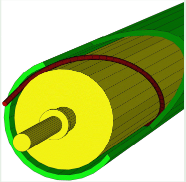
→ **Smooth transition** from other calorimeters

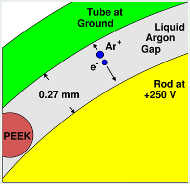
→ Natural **shielding** for muon system

→ Less upstream material

→ But **more radiation** ($\times 9$)

## Design






- Long and skinny electrodes:

  $\sim$ 5 mm diameter, $\sim$ 45 cm deep arranged **parallel** to the beam line
- Very narrow LAr gaps:

  → **Fast readout**

  → Avoids ion buildup
- Dense material (tungsten) for FCal2,3

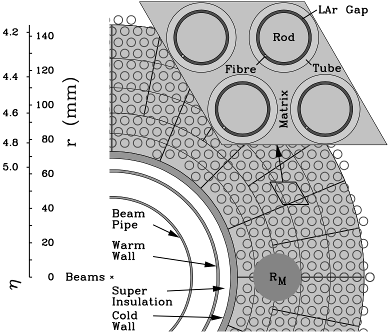
  → **limits** hadronic **shower spread**

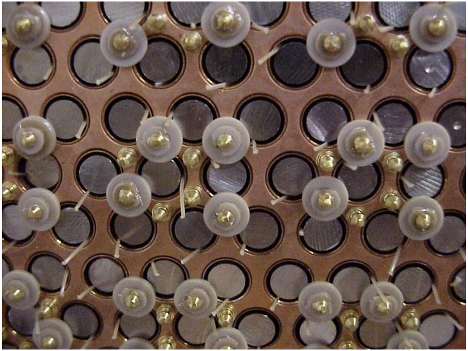
  → compact, still **10$\lambda$** ($28X_0$ FCal1)

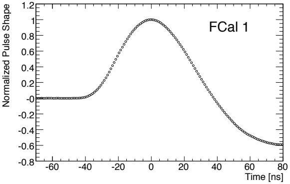
  → placed deeper: less neutron albedo

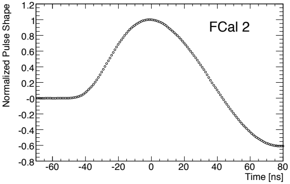
  → heavy: $2\times12$ tonnes

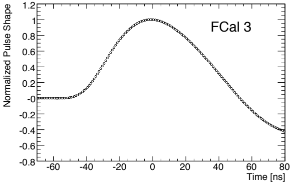
# FCal electrode arrangement and pulse shapes





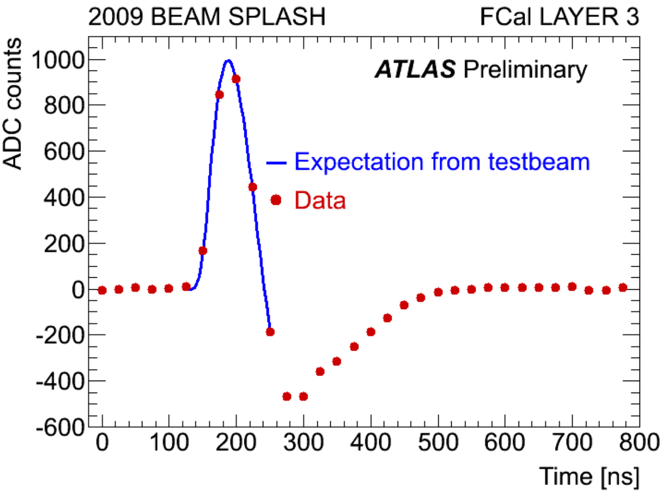



# Pulse Shape

- **Fast response** due to small LAr gaps
- **Good agreement** in data with expected pulse shape derived from beam test
- **Optimal filtering** technique used to derive the amplitude $A$ and timing $\tau$ of the pulse

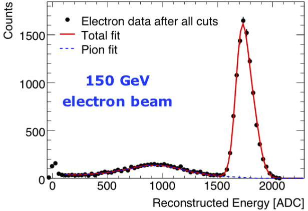
$$A = \sum_{i=1}^{5} a_i S_i$$

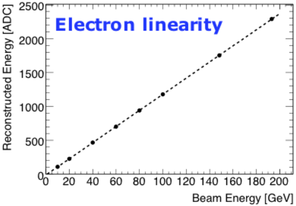
$$A\tau = \sum_{i=1}^{5} b_i S_i$$

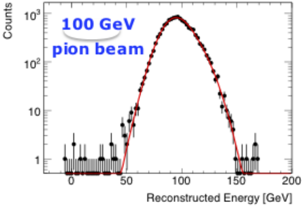



*Example of a signal pulse in the second hadronic layer recorded in beam splash data.*

# Results from beam test



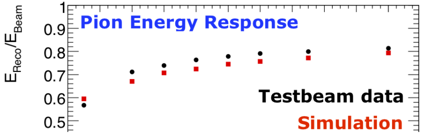



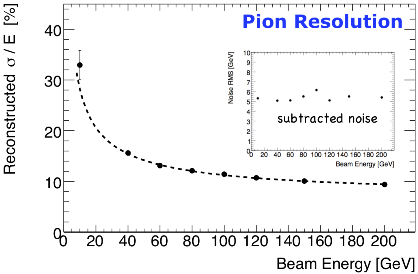




- Pion and electron beam tests with $E_{\text{beam}}$ in the range 10–200 GeV
- Studies of shower shapes, clustering, hadronic weights, etc.
- **Noise subtracted resolution**:

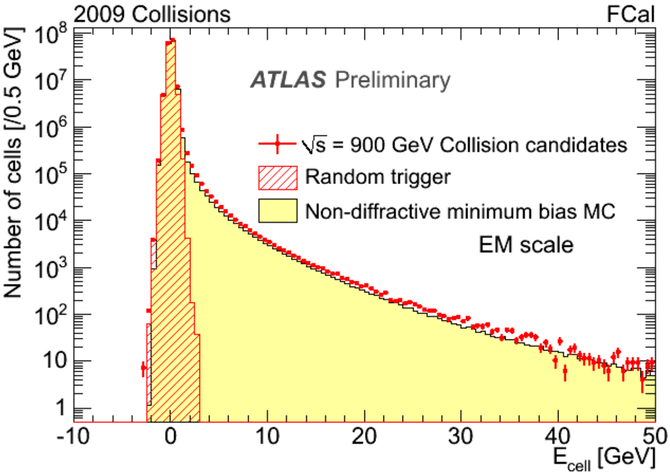
$$\frac{\sigma_E}{E} = \frac{S}{\sqrt{E/\text{GeV}}} \oplus C$$

| | Beam Test | Requirements |
|---|---|---|
| $e$ | $S$: 28.5%, $C$: 3.5% | $S$: 35%, $C$: 5% |
| $\pi^{\pm}$ | $S$: 95%, $C$: 7.5% | $S$: 100%, $C$: 10% |



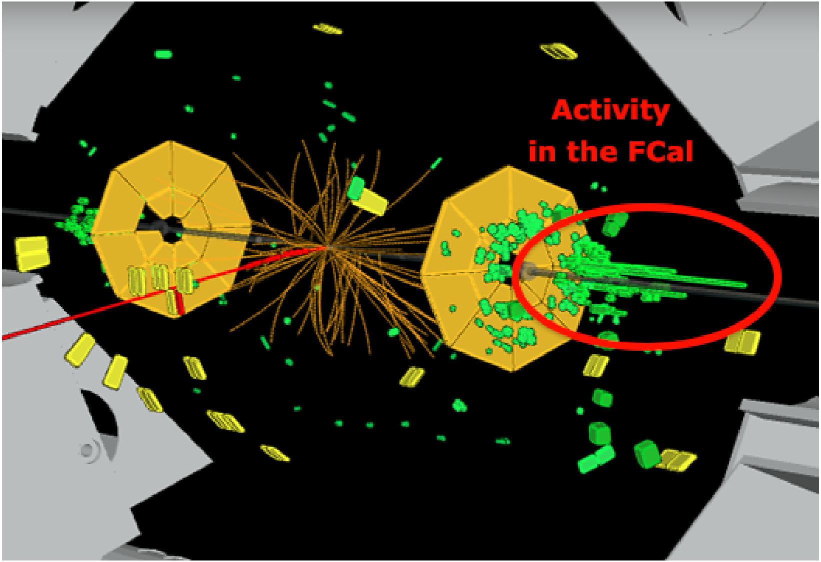



## Reconstructed FCal cell energies in 900 GeV collision data




- **Nice agreement** between data and simulation
- Distributions of jet properties, such as jet energy, transverse width and electromagnetic fraction are also in good agreement with Monte Carlo

# Event Display



# Position Measurement

- FCal close to the beam pipe
- Energy density **increases with $\eta$**

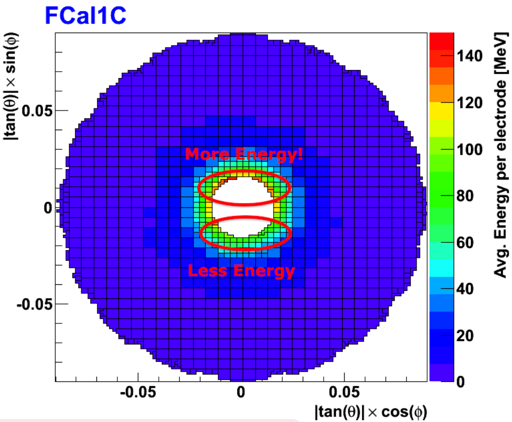
→ **FCal sensitive to translations relative to the beam spot**

**Average energy per cell**:

- **strongly depends on** the transverse distance to the beam spot, $\mathbf{r_T}$ (or $\eta$)
- $\phi$ symmetric around the beam spot
- roughly described by:

  $E_{avg} = k \cdot r_T^{-m}$

Can measure location of the FCal by looking at $E_{avg}$ over many events

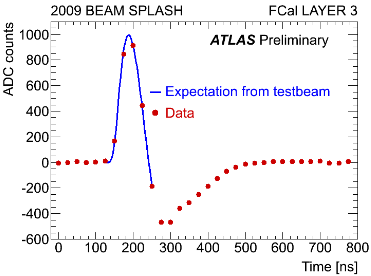


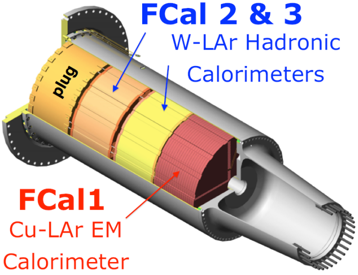

First measurements indicate that the **FCal sits ≈ 2 mm low**
→ consistent with possible sag in support structure

# Summary

## The ATLAS Forward calorimeters

- Covers the forward region: $3.1 < |\eta| < 4.9$
- **Novel design** to operate under high radiation
- Performance in **beam tests** meets **design requirements**
- Pulse shapes agree very well with expectation
- Distributions of cell energies and jet properties in **first collision data** agree with MC expectations
- The position of the FCal can be measured in data




→ Important for precise $\not{E}_T$ and forward jet $p_T$ reconstruction