# Upgrade Plans for ATLAS Forward Calorimetry for the HL-LHC

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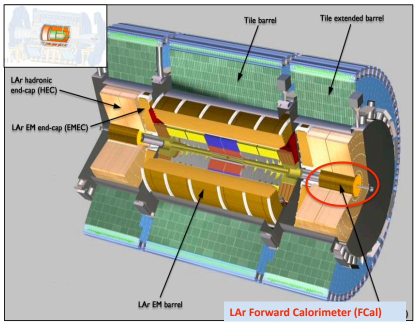
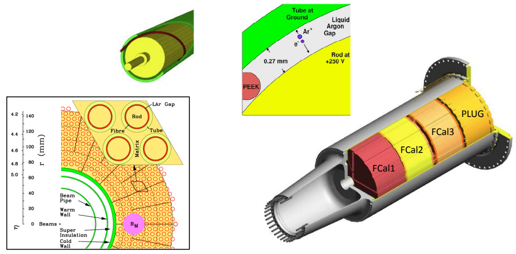
## The ATLAS Detector




## The existing ATLAS Forward Calorimeter (FCal)

- LAr/Cu (FCal1); LAr/W (FCal2,FCal3) ; (η ~ 3-5)
- Concentric rod and tube electrodes embedded in Cu/W absorber matrix
- Annular LAr gaps (maintained by helically wound PEEK fibre; FCal1: 0.27mm; FCal2: 0.375mm; FCal3: 0.5mm )




## Expected Luminosities LHC → HL-LHC

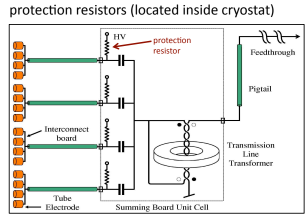
- 2009 LHC startup, √s = 900 GeV
- 2010–2012: √s=7~8 TeV, $L=6\times10^{33}$ cm$^{-2}$ s$^{-1}$, BS: 50ns — ~20-25 fb$^{-1}$
- 2013 Go to design energy, nominal luminosity
- 2014–2017: √s=13~14 TeV, $L\sim1\times10^{34}$ cm$^{-2}$ s$^{-1}$, BS: 25ns — ~75-100 fb$^{-1}$
- 2018 LHC Phase-1 upgrade to full design luminosity
- 2019–2021: √s=14 TeV, $L\sim2\times10^{34}$ cm$^{-2}$ s$^{-1}$, BS: 25ns — ~350 fb$^{-1}$
- 2022 HL-LHC Phase-2 upgrade
- 2023–2030?: √s=14 TeV, $L=5\times10^{34}$ cm$^{-2}$ s$^{-1}$, luminosity leveling — ~3000 fb$^{-1}$

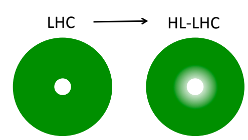
## Motivation for an Upgrade of the ATLAS Forward Calorimetry

At HL-LHC luminosities the rate of minimum bias events will lead to:

- Degradation of the FCal signal (particularly the high η region of FCal1) due to:
  - Positive ion buildup in the LAr gap
  - Large ionization current leads to large HV drop across protection resistors; adequate HV across LAr gap cannot be maintained at high η.
  - → Hermeticity of the detector coverage is compromised, which will lead to an increase in fake missing $E_T$ .
  - → Performance of the FCal will vary with instantaneous luminosity.
- Risk of argon boiling due to beam heating

Schematic layout of signal summing board with protection resistors (located inside cryostat)




Qualitative illustration of the expected degradation of FCal1 in r/ϕ with luminosity increasing from LHC to HL-LHC

If a decision for an upgrade is made, it would be for the HL-LHC (~2022)

## Possible Options and Practical Issues

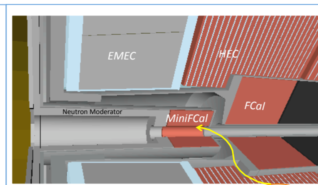
### FCal Replacement (sFCal)

- Similar design as the existing FCal, but with a smaller LAr gaps to prevent positive ion buildup (smallest foreseen gap-size: 0.1mm for FCal1).
- Installation of cooling loops to prevent boiling of argon.
- New HV protection with lower resistance to prevent HV sag across LAr gap. Existing resistors are located on signal summing boards inside the cryostat. If only the FCal compartment of the cryostat is opened, new signal and HV connections will have to be made, and new installation of resistors and summing boards will be necessary.
- Installation requires at least partial opening of the ATLAS endcap cryostat. Complicated and time-consuming. Radiation levels will be high and there is a risk of damaging existing working components inside the cryostat.
- A small prototype has been built and proven to work without degradation in a high luminosity testbeam at Protvino. ( NIM A 669 (2012) 47-65 )

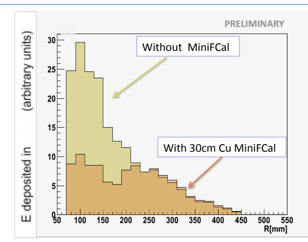
### A (warm) MiniFCal based on pCVD Diamond Detectors

- A new calorimeter module (MiniFCal) to be placed into an existing recess of the cryostat in front of the FCal. This calorimeter would have to survive the harsh radiation environment at the HL-LHC, which is an extreme challenge for any warm sensitive calorimeter material. Radiation damage will be non-uniform across the detector. Ganging of wafers has to be such that the diamonds within each readout channel will degrade at approximately the same rate.
- Installation would be comparatively easy and fast.
- A baseline design exists of a module comprised of parallel Cu plates with pCVD diamond wafers as the active material. Degradation of diamonds has been explored in beam tests at TRIUMF. ( JINST 6 P05011 (2011) )
- Simulations have explored the baseline design, taking into account results from the beam tests and predictions of the expected neutron flux (up to approx. 6 $10^9$ n cm$^{-2}$ s$^{-1}$) at the HL-LHC.

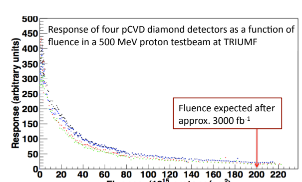
**→The ATLAS Collaboration continues to work towards a decision for an FCal High Luminosity Upgrade**

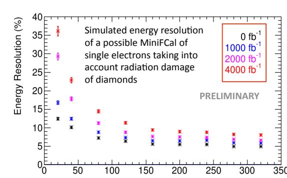


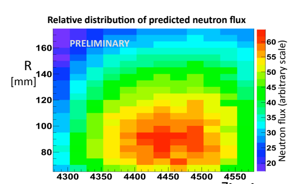

**MiniFCal baseline design:**
12 Cu plates
11 diamond detector planes
Length: 30cm (18.8$X_0$)
R = 65mm - 175mm (η ~ 4-5)

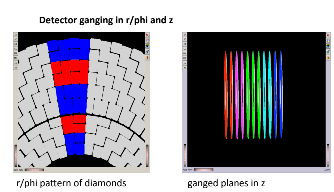



Simulated comparison for the energy deposited in FCal1 with and without a MiniFCal present




Simulation of performance include the effects of: Ganging of diamond wafers into readout channels, radiation damage, electronic noise, charge collection efficiency .