Upgrade plans for the ATLAS Forward Calorimeter at the HL-LHC

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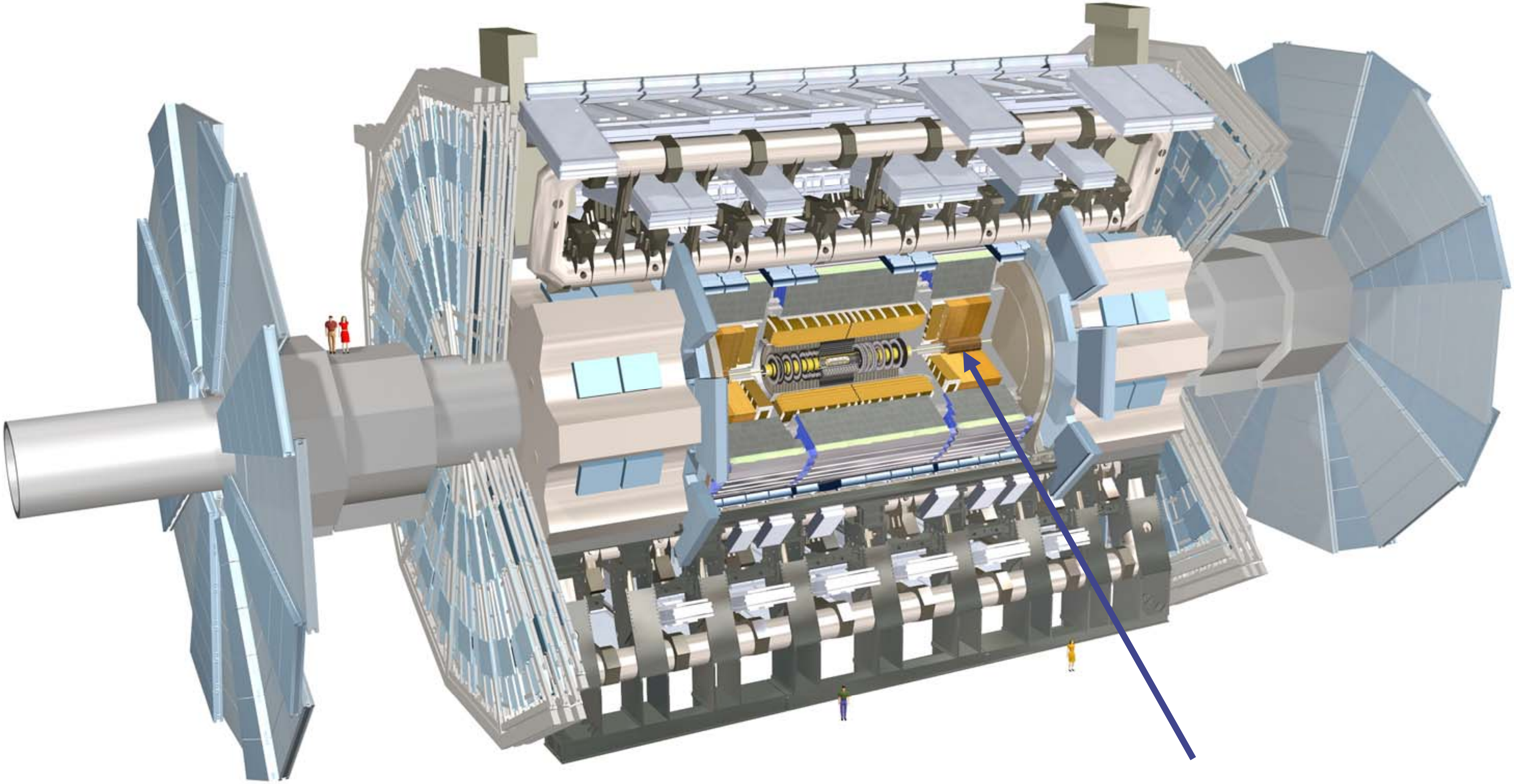
On behalf of the
ATLAS Liquid Argon Calorimeter Group

5 June 2012

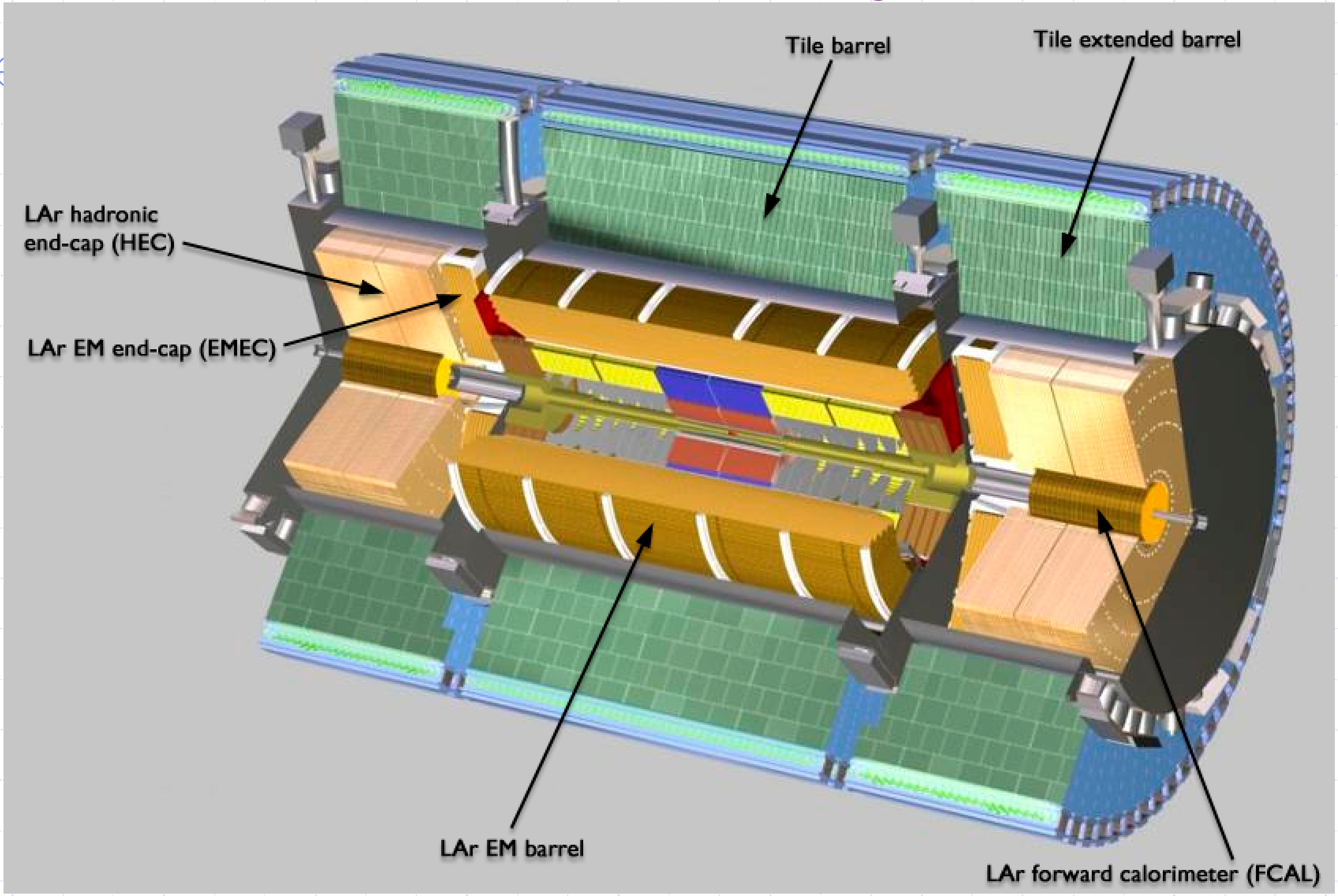
V2.0

ATLAS detector at the LHC

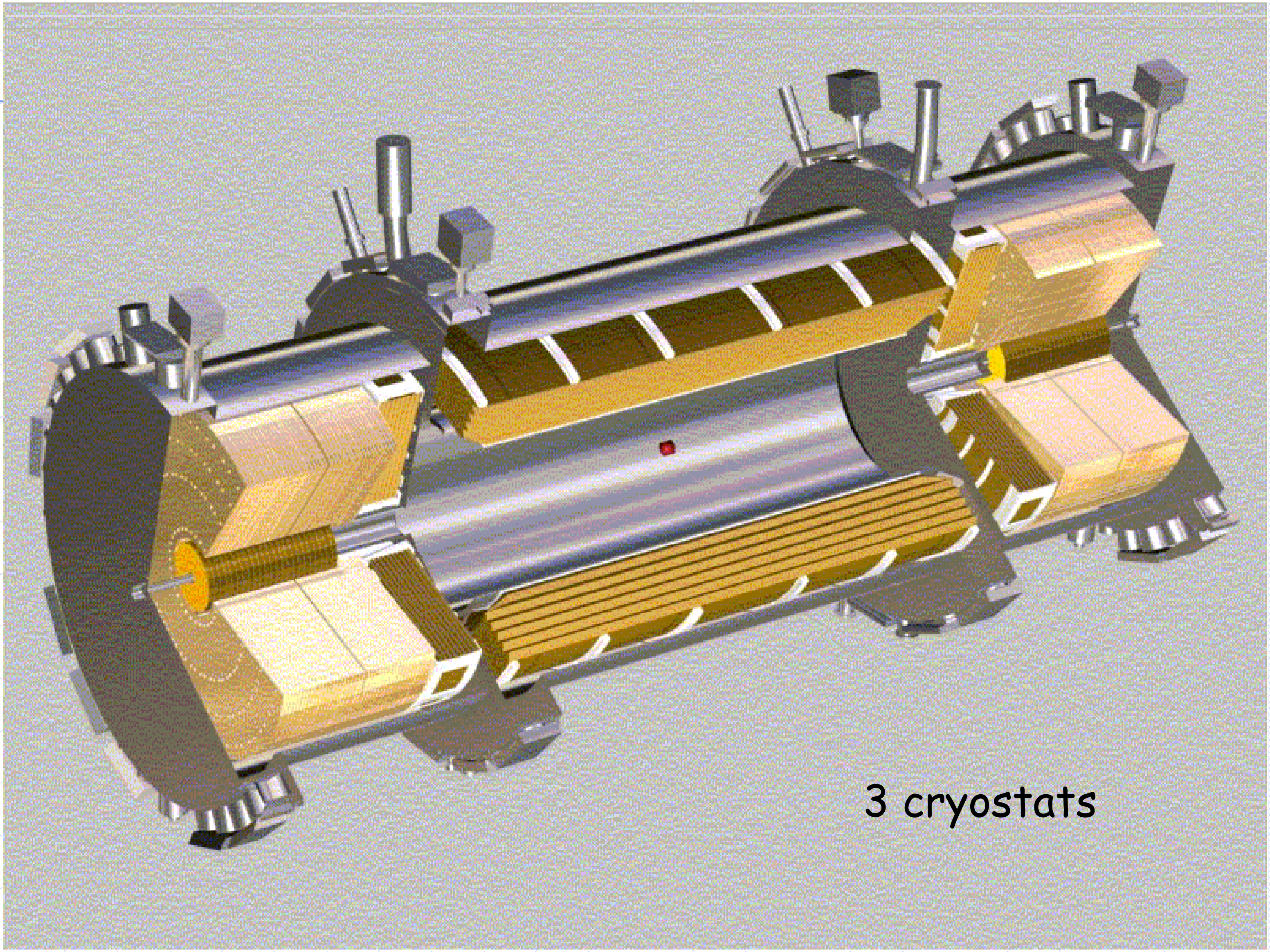


One of two
Forward Calorimeters

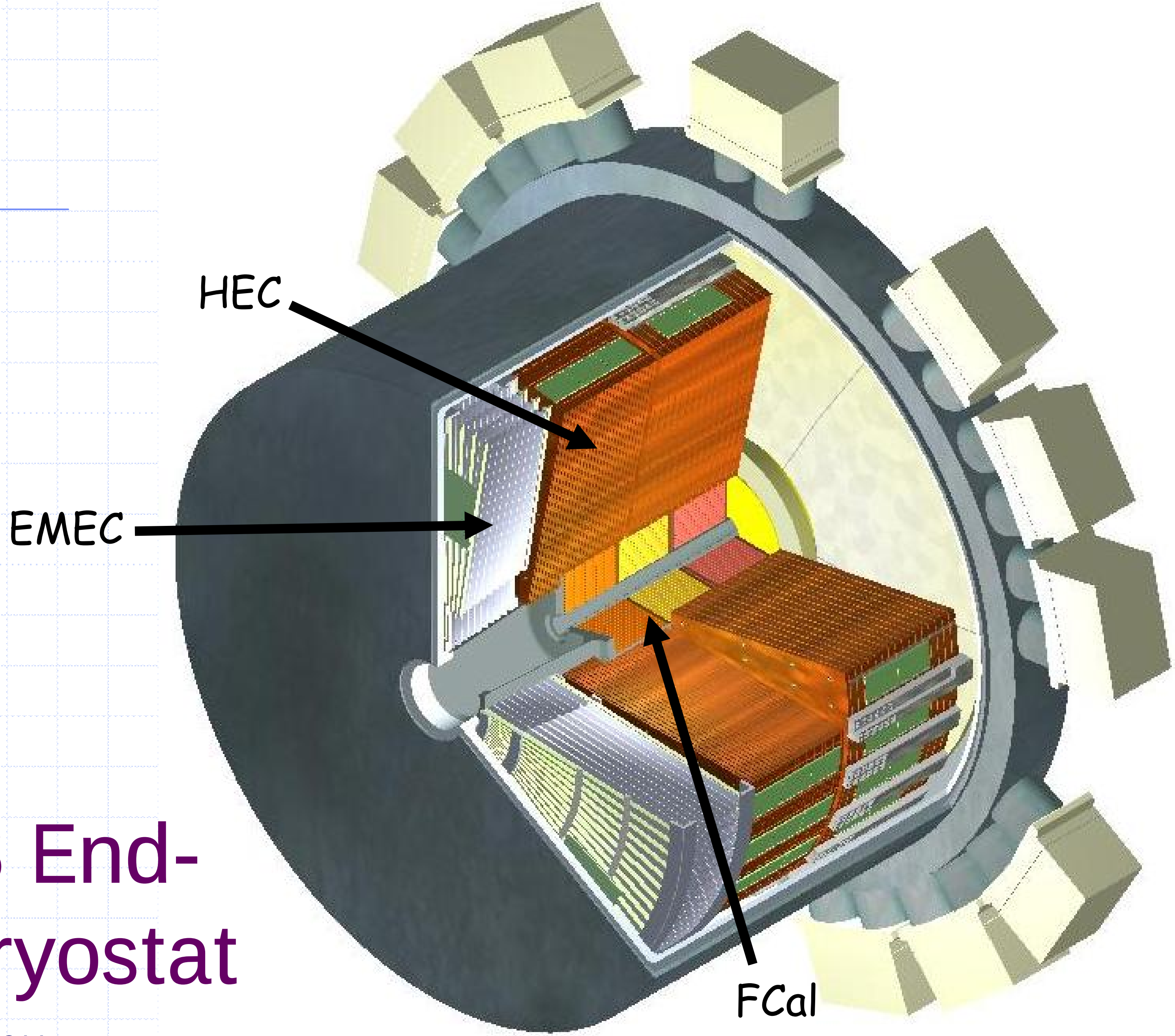
ATLAS Calorimeter System



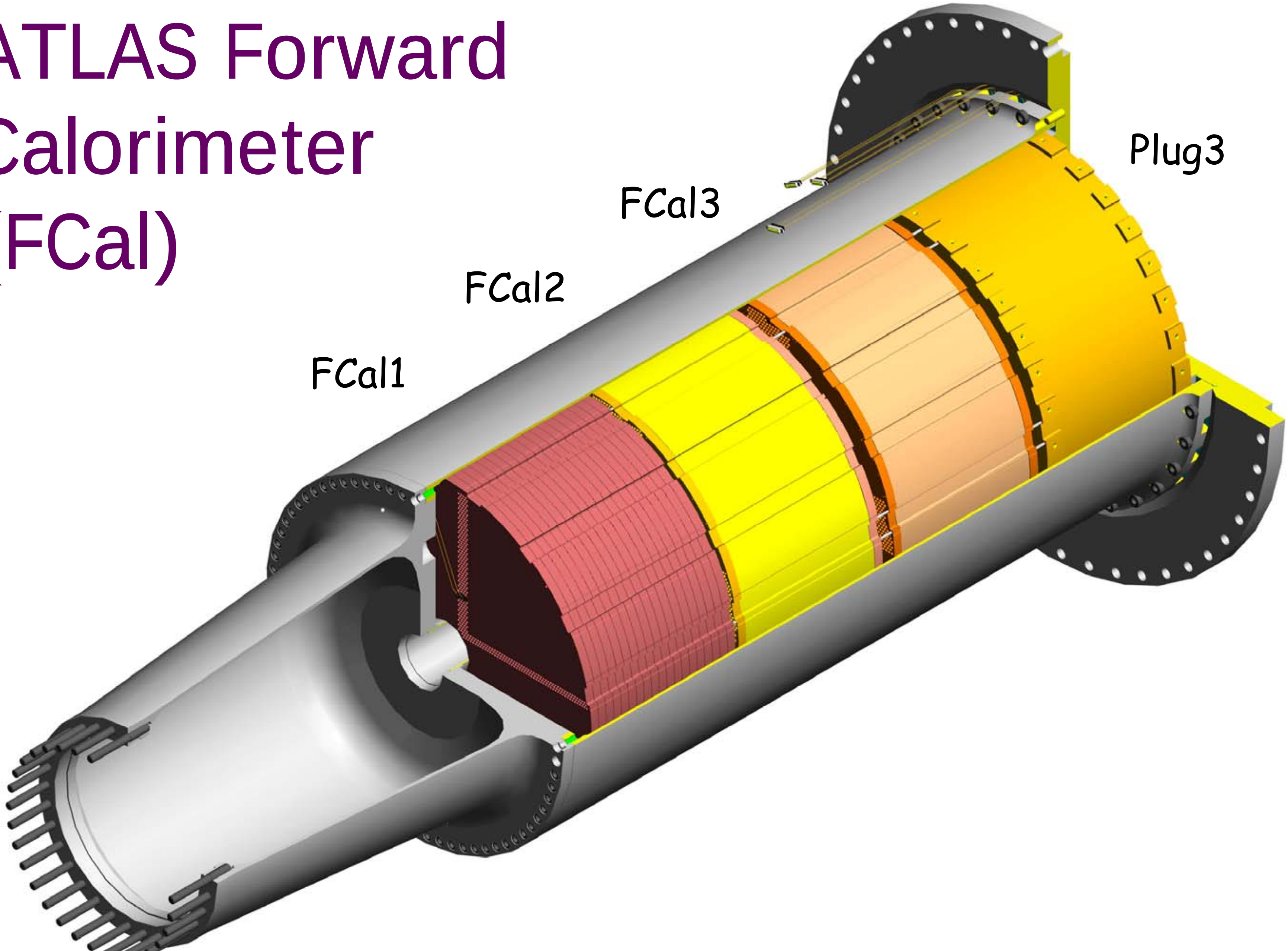
Liquid Argon Calorimeter System



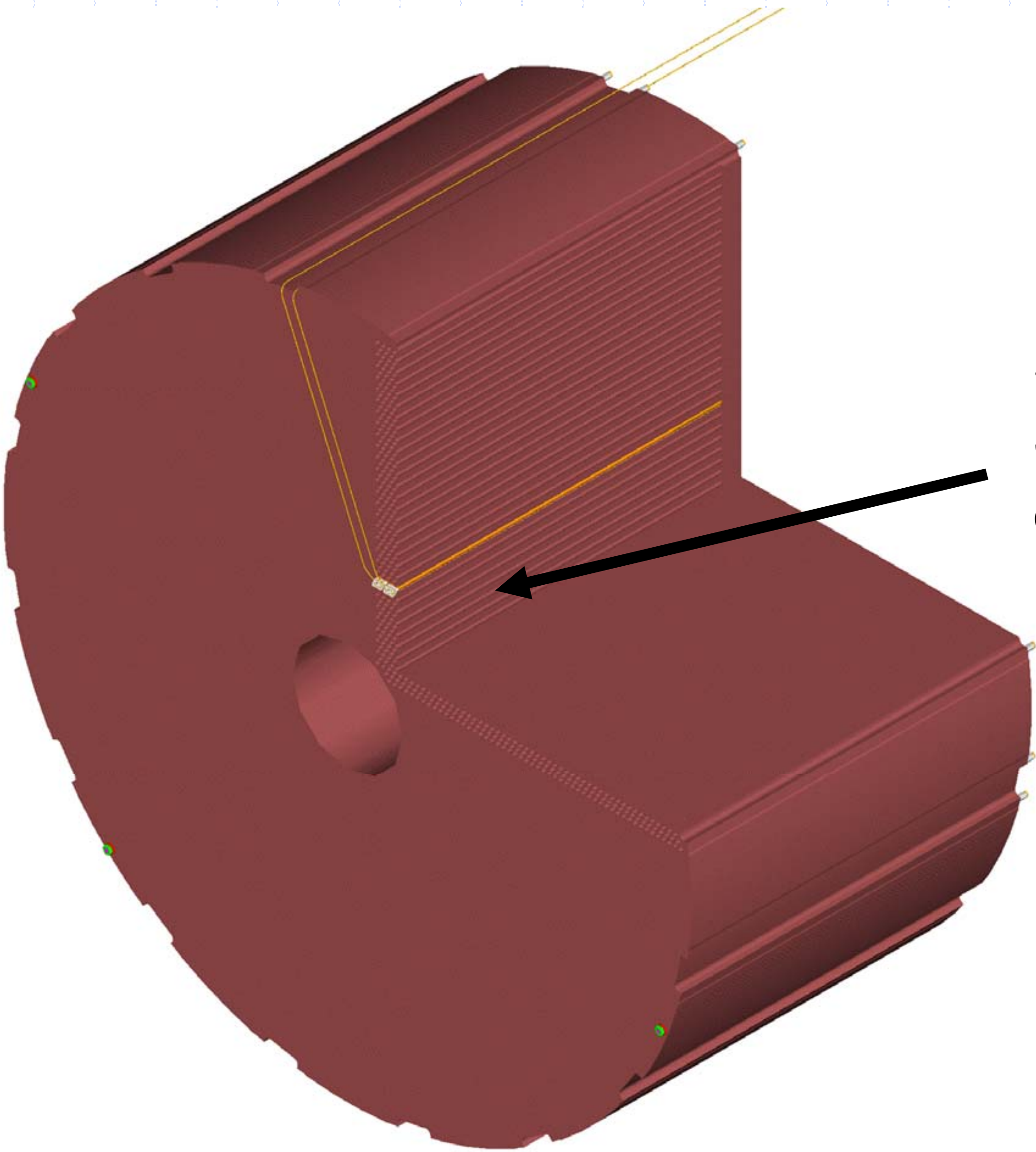
ATLAS End-Cap Cryostat



ATLAS Forward Calorimeter (FCal)



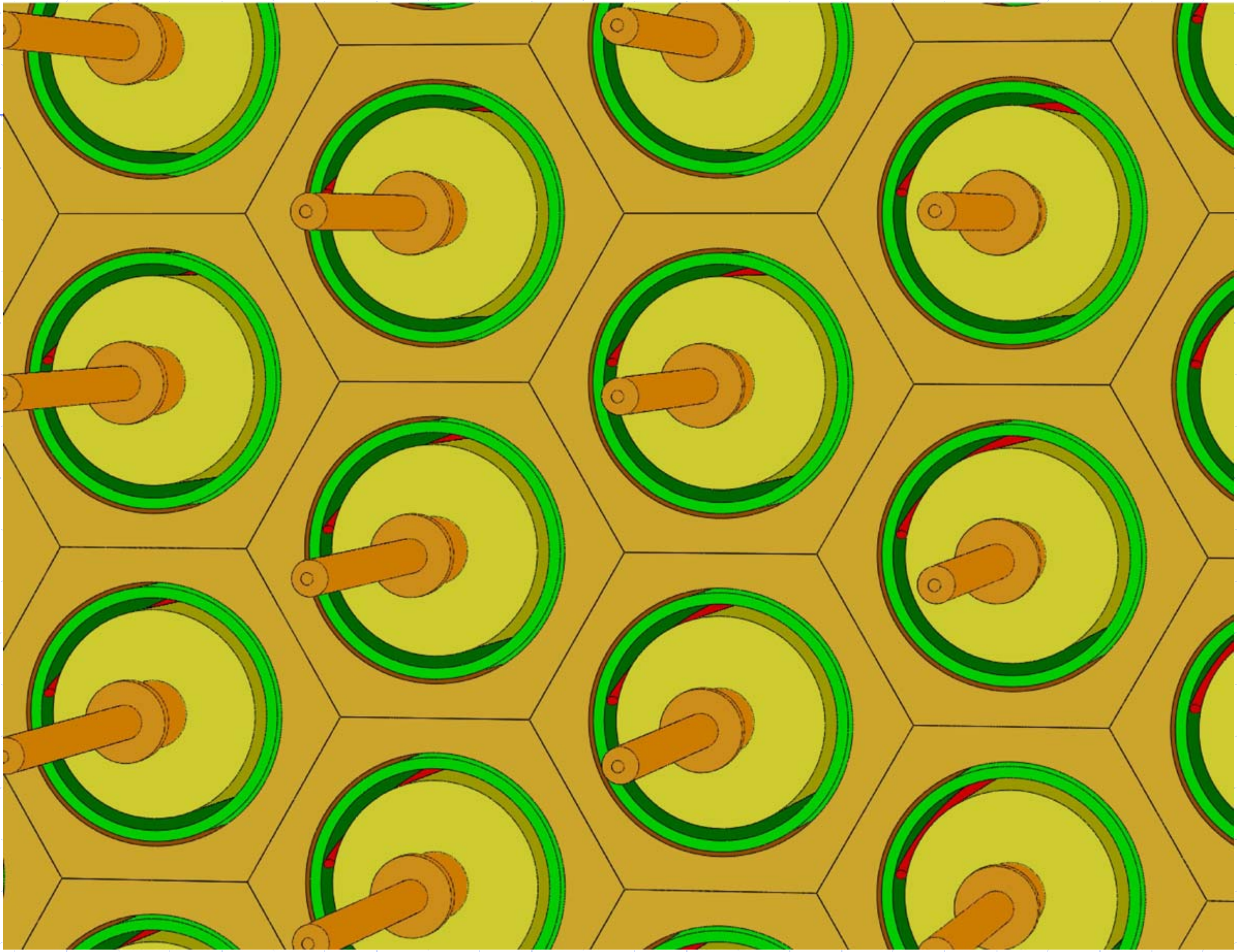
Cut-away of FCal1 Module



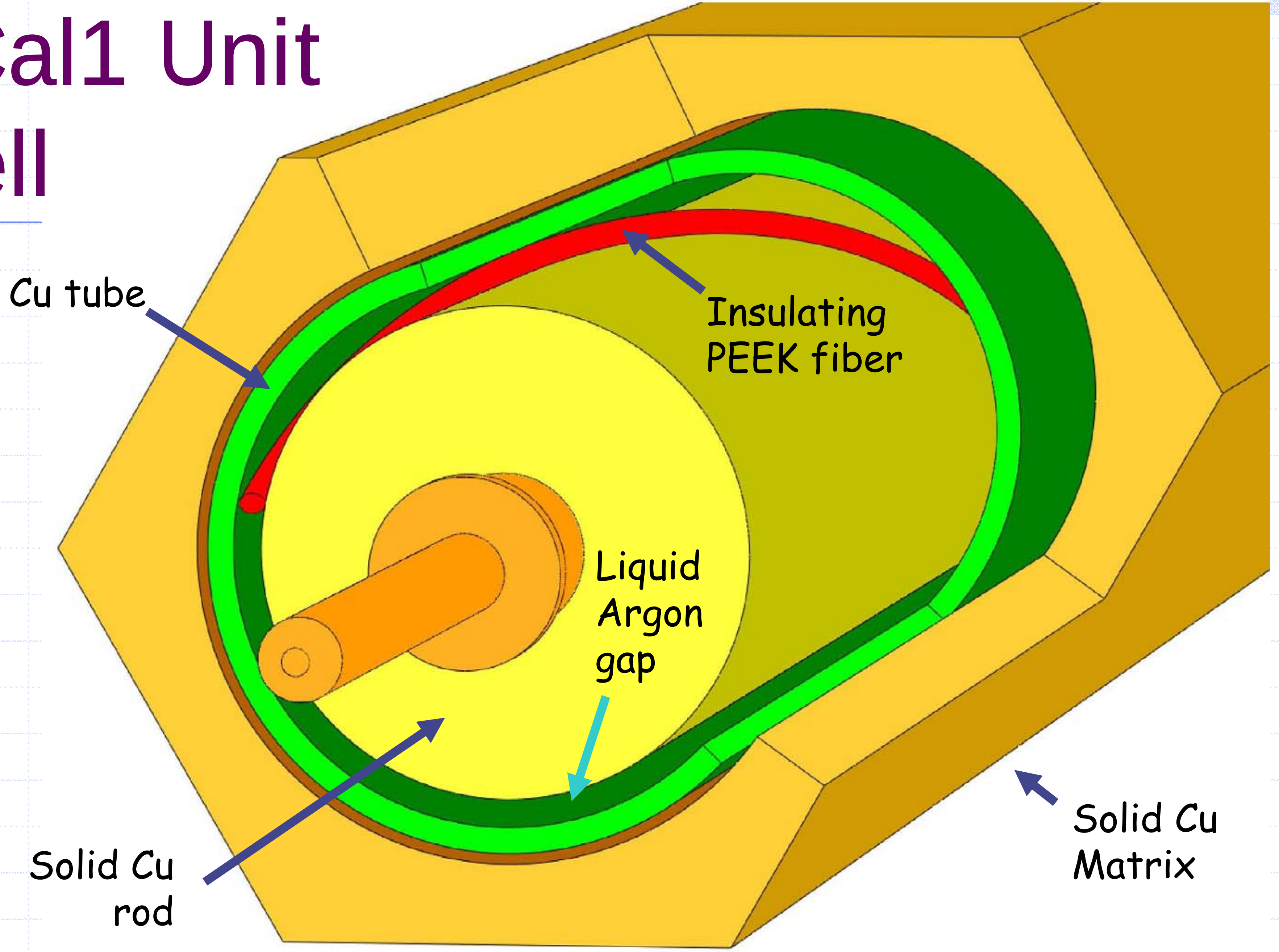
Ionization rate is worst near inner edge at $|\eta|$~4.7 at depth near EM shower max

Module surrounds the LHC beam pipe about 5 m from the IP

Close-up of front face of FCal Module 1



FCal1 Unit Cell



FCal features

- Very robust
- Made of very simple, rad-hard materials
- Excellent performance
- Minimal transitions to neighboring calorimeters

Performance vs instantaneous $\mathcal{L}$

- Up to LHC design $\mathcal{L}$ the FCal is expected to work well with some safety margin.
- No difficulties, so far, as the luminosity increases.

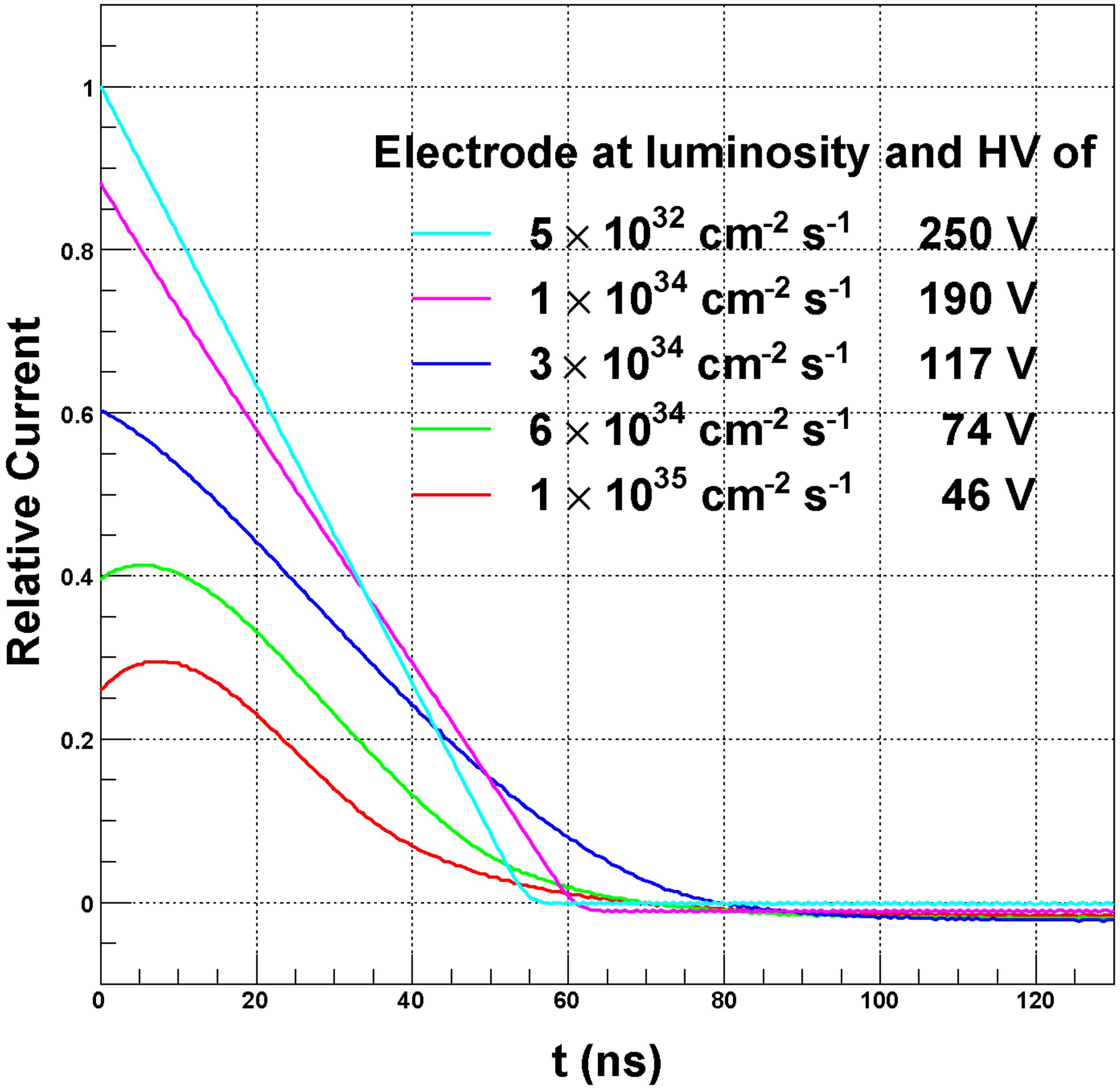
But ...

- At HL-LHC $\mathcal{L}$ we expect ...
  - Space-charge effects to degrade the signal
    - See next two talks
  - Potential across the gaps to sag due to excessive current drawn from the HV supply. (Basically the values of the protection resistors are too high.)
  - Heating is on the verge of boiling the argon

Distortion of the Triangle Pulse

FCal1 signals at |η|=4.7 on top of various levels of min-bias pileup.

See. JR @ NIMA 482 (2002) 156.



Three solutions being considered

0) Do nothing

1) Replace the present FCal

2) Insert a new, small module in front of the present FCal

1) Replace present FCal

- New FCal will look the same except
  - Liquid argon gaps will be narrower
    - ~0.25 mm $\rightarrow$ ~0.10 mm in FCal1
    - Substantial R&D on this already
  - Reduce protection resistor values
    - These protect the front-end electronics. Because we've had no failures we were probably too conservative.
  - Add cooling at FCal periphery
- In terms of performance, this is the best of the three solutions.

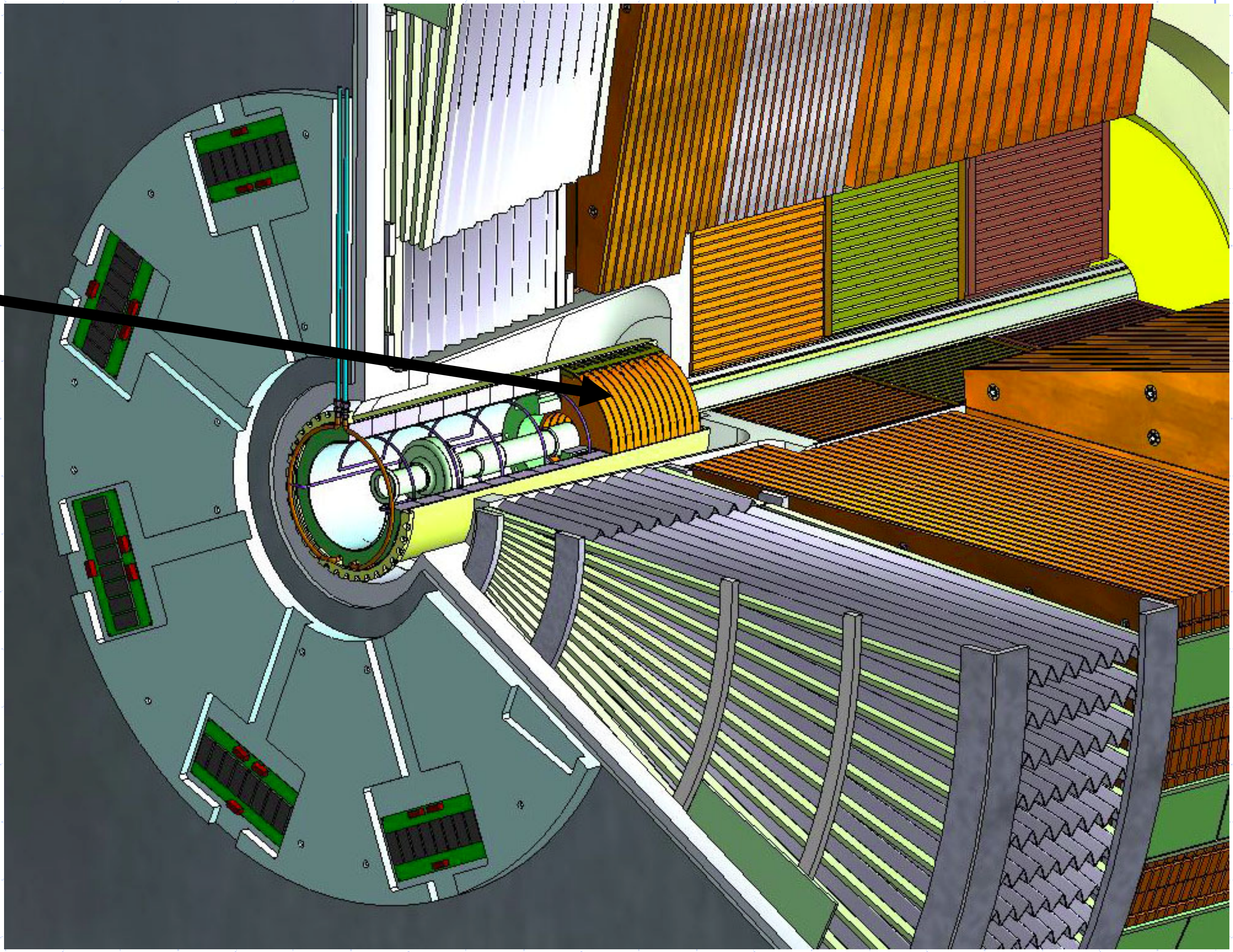
Difficulties with this solution

- The cold cover of the cryostat is welded shut. Risk, cost, and schedule concerns.
  - Caveat: We may have to open the cryostat if the Hadronic Endcap Calorimeter cold electronics must be replaced. (See talk by Martin Nagel on Friday.) In this event we will replace the present FCal with a new one.

2) Insert a new, small module in front

Locate module at end of Cryostat Alcove.

The alcove is open to air.

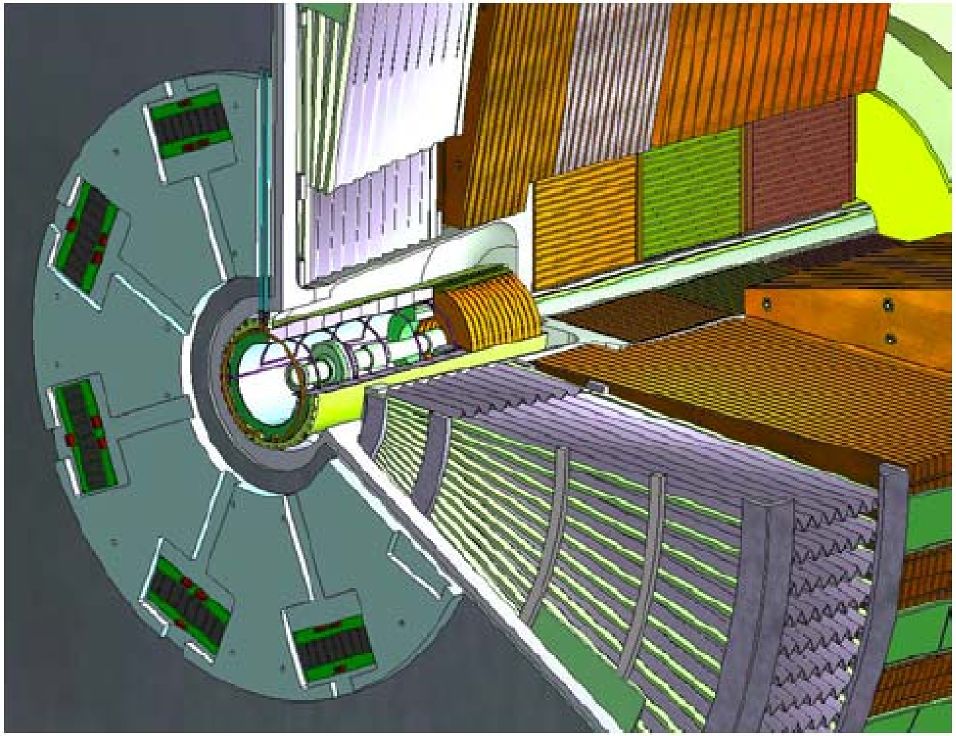


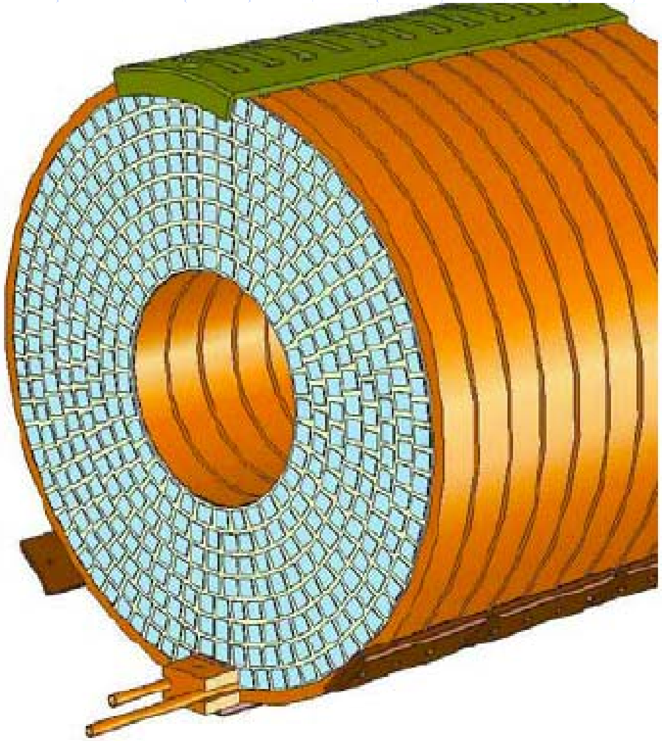
miniFCal Solution

Gerald Oakham et al.

Default miniFCal design - diamond wafers

- 12 copper absorber plates with 11 detector planes
- Detector plane is ceramic disc covered with 9 rings of 1 cm square diamond wafers.





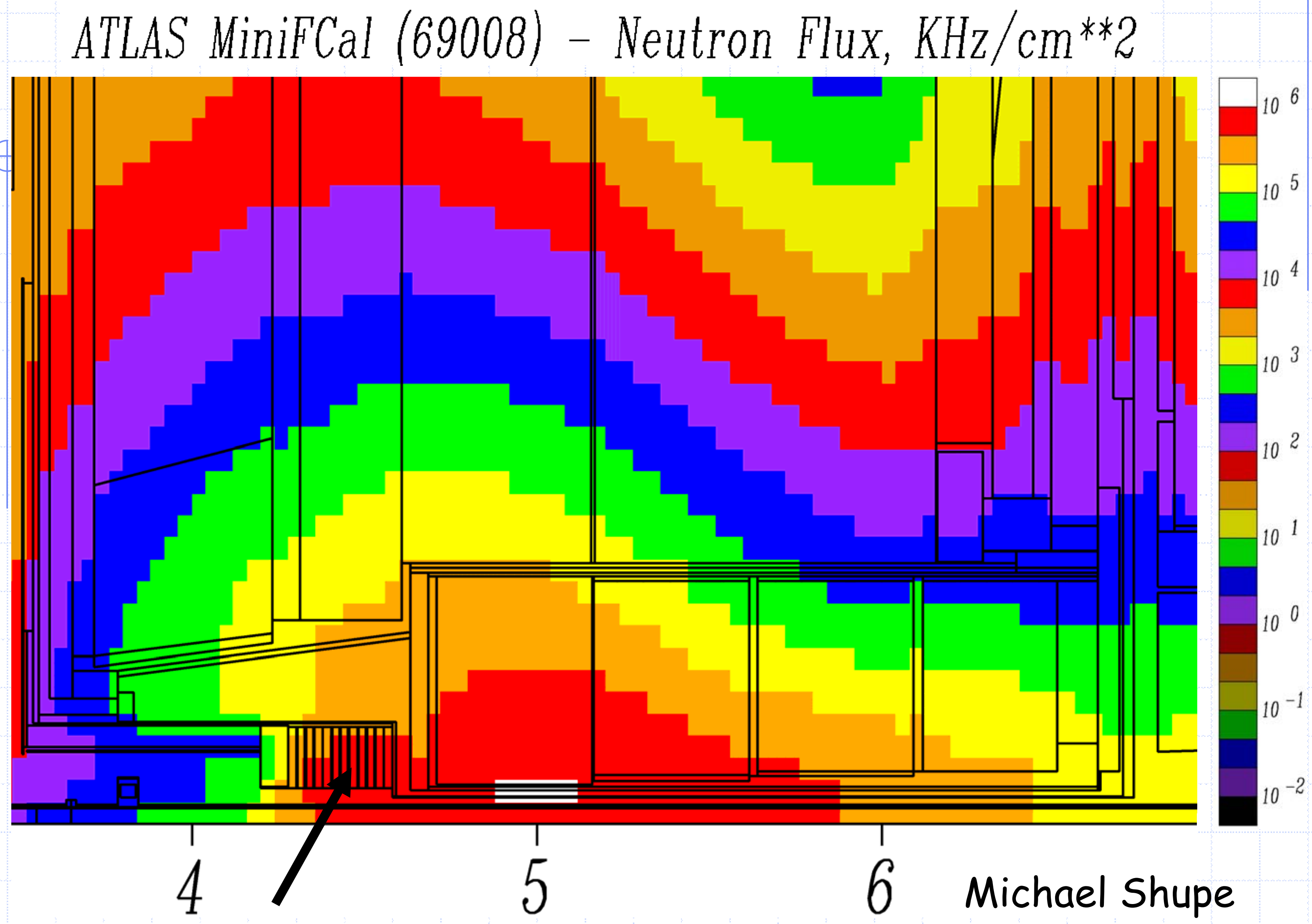
One Cu disk removed

Advantages

- miniFCal protects the present FCal from the worst of the min-bias energy deposits.
- Present FCal will not suffer from ...
  - Space-charge effects
  - Excessive HV current draw
  - Boiling the liquid argon
- Installation is relatively easy and fast

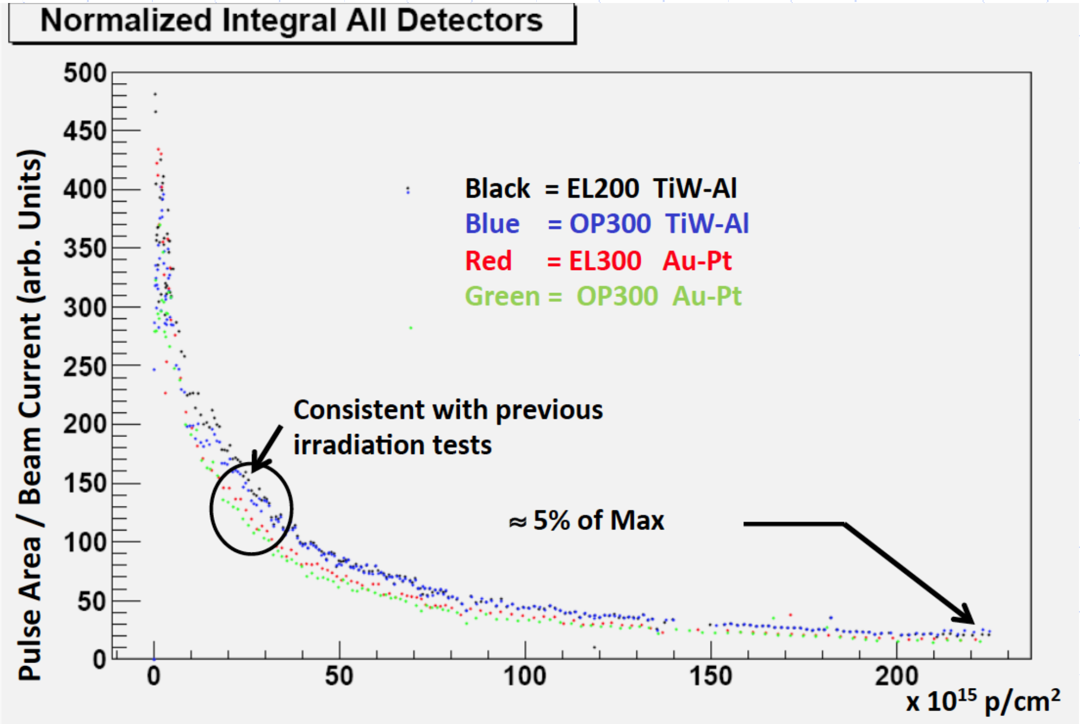
Questions and problems

- Unknown calorimetric performance
  - Linearity?
  - Dynamic range?
  - Energy resolution?
  - Calibration method?
  - Stability?
  - Sampling and uniformity? Some R&D on this.
  - Radiation hardness? See next slides.
- Adds another awkward η-transition
- Cost is high



~3×10^{16} n/cm^2/yr

Irradiation test at TRIUMF in 2010



- 500 MeV protons
- Average fluence (across detector 2.2 x 10^{17} protons/cm^2 (shown in plot)
- Peak fluence 5 x 10^{17} protons/cm^2 at centre of sensors.
- Pulse amplitude dropped to 5 percent of original level after this irradiation
- Response function best fitted with double exponential function
- Response is consistent with RD-42 result, allowing for different particle energies.
- No evidence of annealing effects – after beam off periods.

If not diamond, then what about …

- High pressure Xenon gas
  - Safety concern with pressure vessel in delicate confined volume open to tracker
  - Poor sampling fraction
- Liquid argon in its own cryostat
  - Cryostat walls will eat up a major fraction of the available volume
  - Cabling, feedthrus, and services will be a challenge

0) Do nothing

- If the performance with a miniFCal is worse than the performance of a degraded FCal, then “do nothing” might make sense.
- But only if boiling of the argon is not a worry.

Summary

- The present ATLAS FCal works well now and is expected to continue to work well up to a little above $\mathcal{L} = 10^{34}$ cm^{-2} s^{-1}
- Above this, the present FCal performance will begin to degrade, starting at the highest $|\eta|$
- Upgrade options at the HL-LHC Phase 2: either
  - suffer degraded performance of the present FCal or
  - replace the present FCal with a new sFCal or
  - supplement the present FCal with a miniFCal in front

Backup Slides

Physics justification

- Backgrounds
  - Required statistics are too high for full simulation. Must find faster methods.
  - False MET signals increase dramatically with loss of highest $|\eta|$ regions
    - For MET ≳ 120 GeV, the loss of $4.5<|\eta|<4.9$ increases the fake signal by ~ factor 10