Summary and Conclusions

ECFA Workshop: Calorimetry Preparatory Group

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A. Straessner - ATLAS, A. Valero - ATLAS

Upgrade Roadmap in the next two decades

2012	2013 2014	2015	2016	2017	2018	2019	2020	2021	2022 2023	...	2030
	LS1				LS2				LS3		

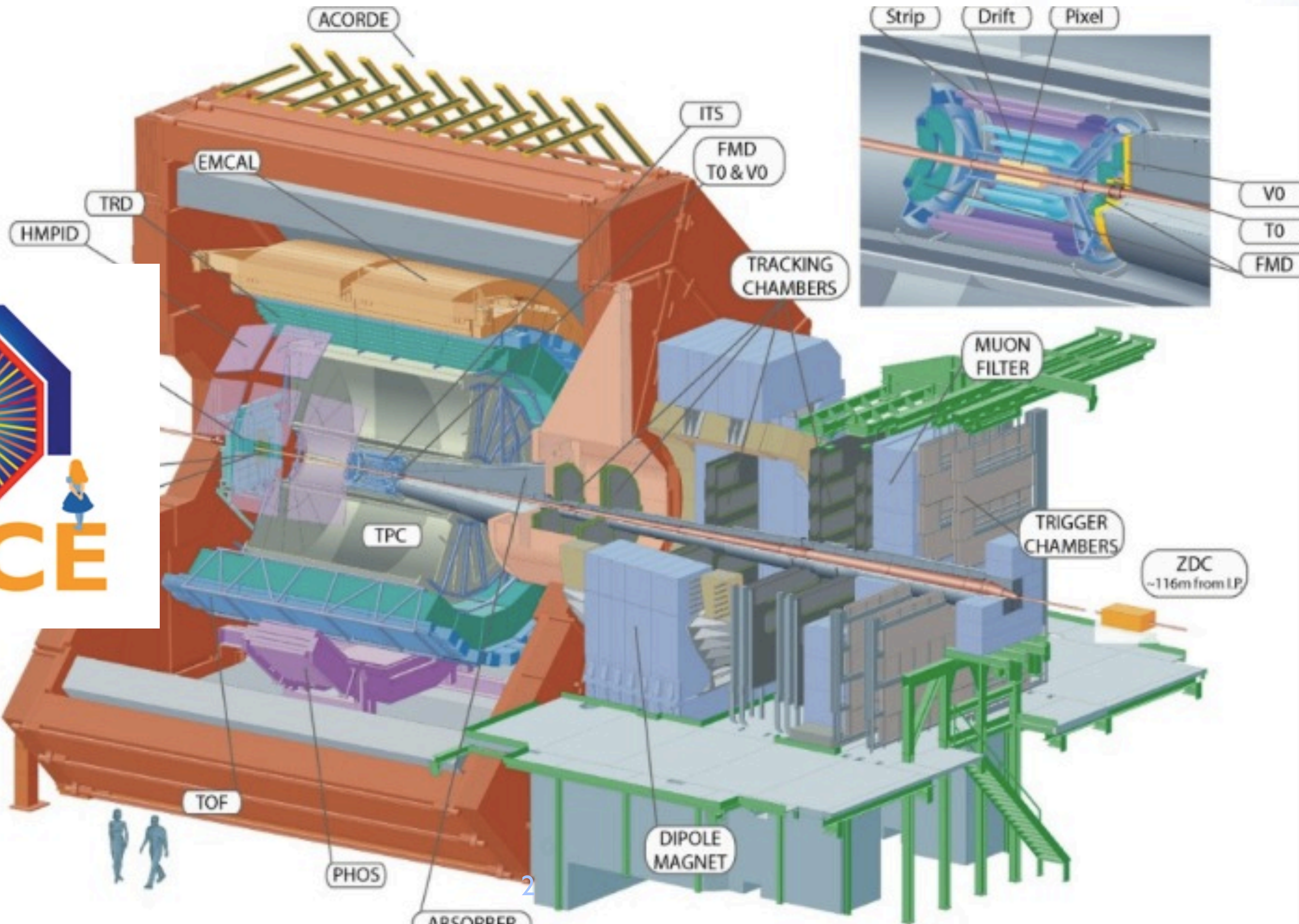
Detector Consolidation

Phase-I Upgrades

Phase-II Upgrades

Detectors

Electronics and Trigger



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EMCal extension (DCal):

- 17.7k Pb/Scint Shashlik towers (from 12.3k)

PHOS 4th module installation:

- 14.3k $PbWO_4$ crystals (from 10.8k)

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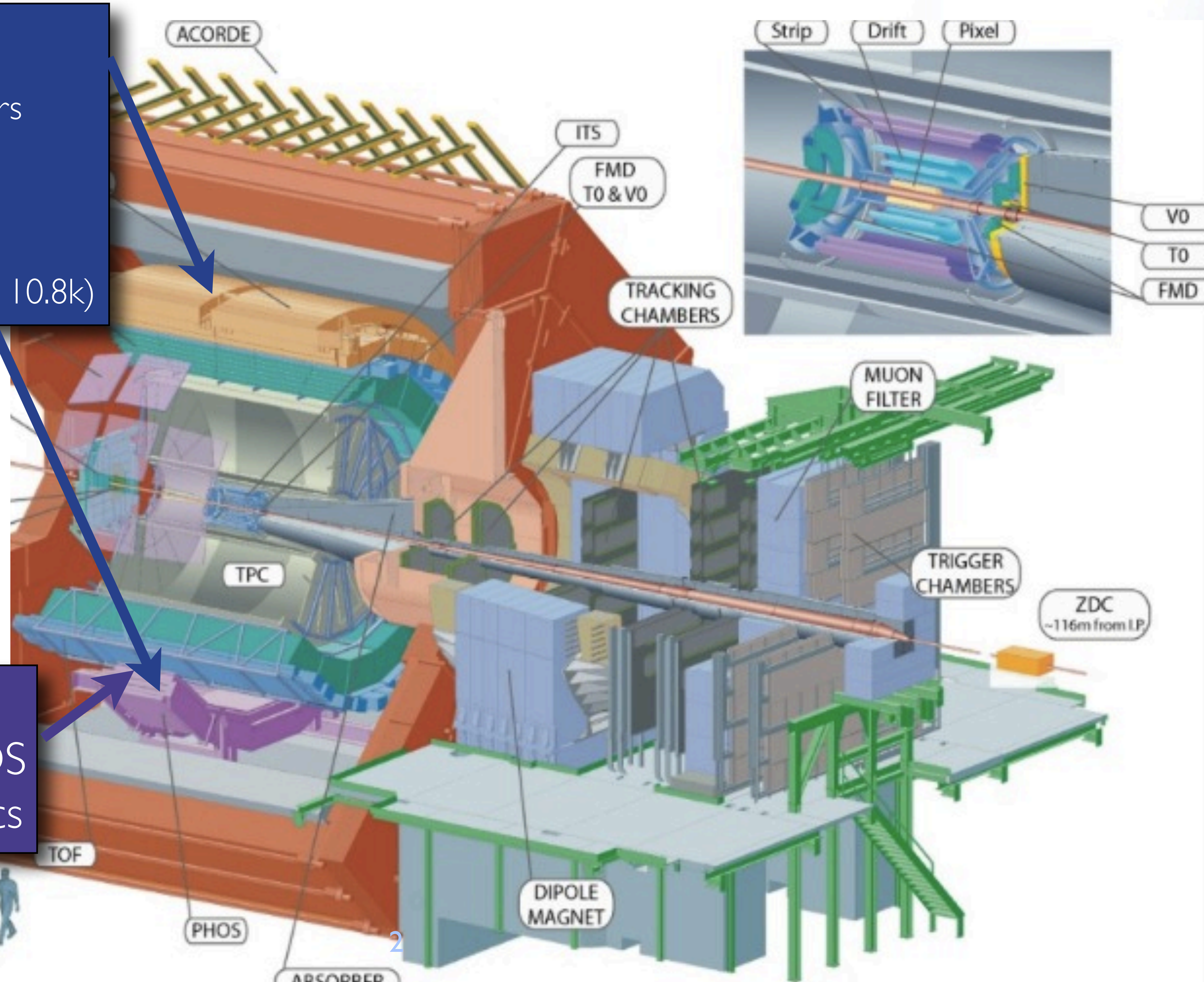
Electronics and Trigger



Upgrade of the EMCAL and PHOS readout electronics

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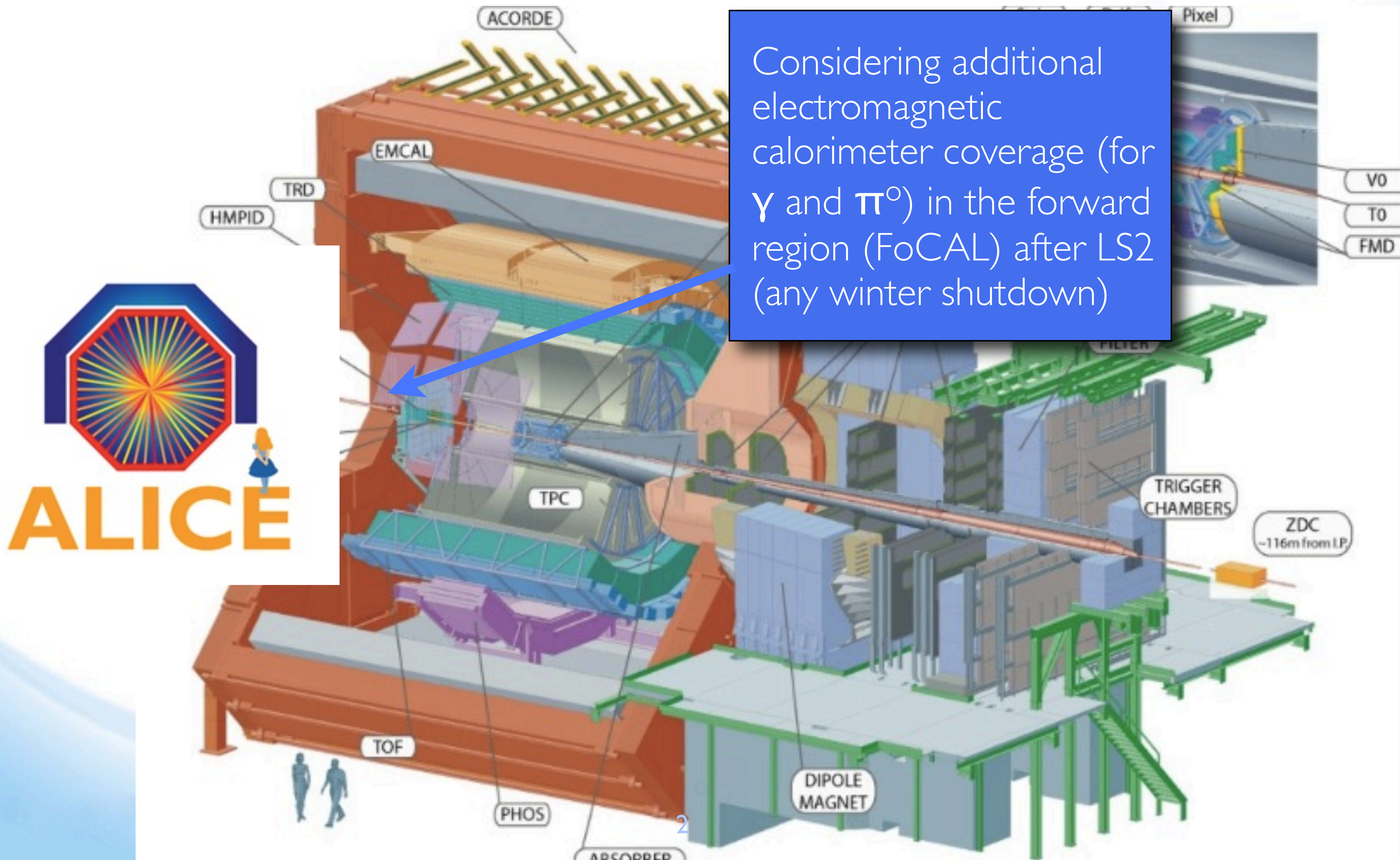

Considering additional electromagnetic calorimeter coverage (for γ and π^0) in the forward region (FoCAL) after LS2 (any winter shutdown)

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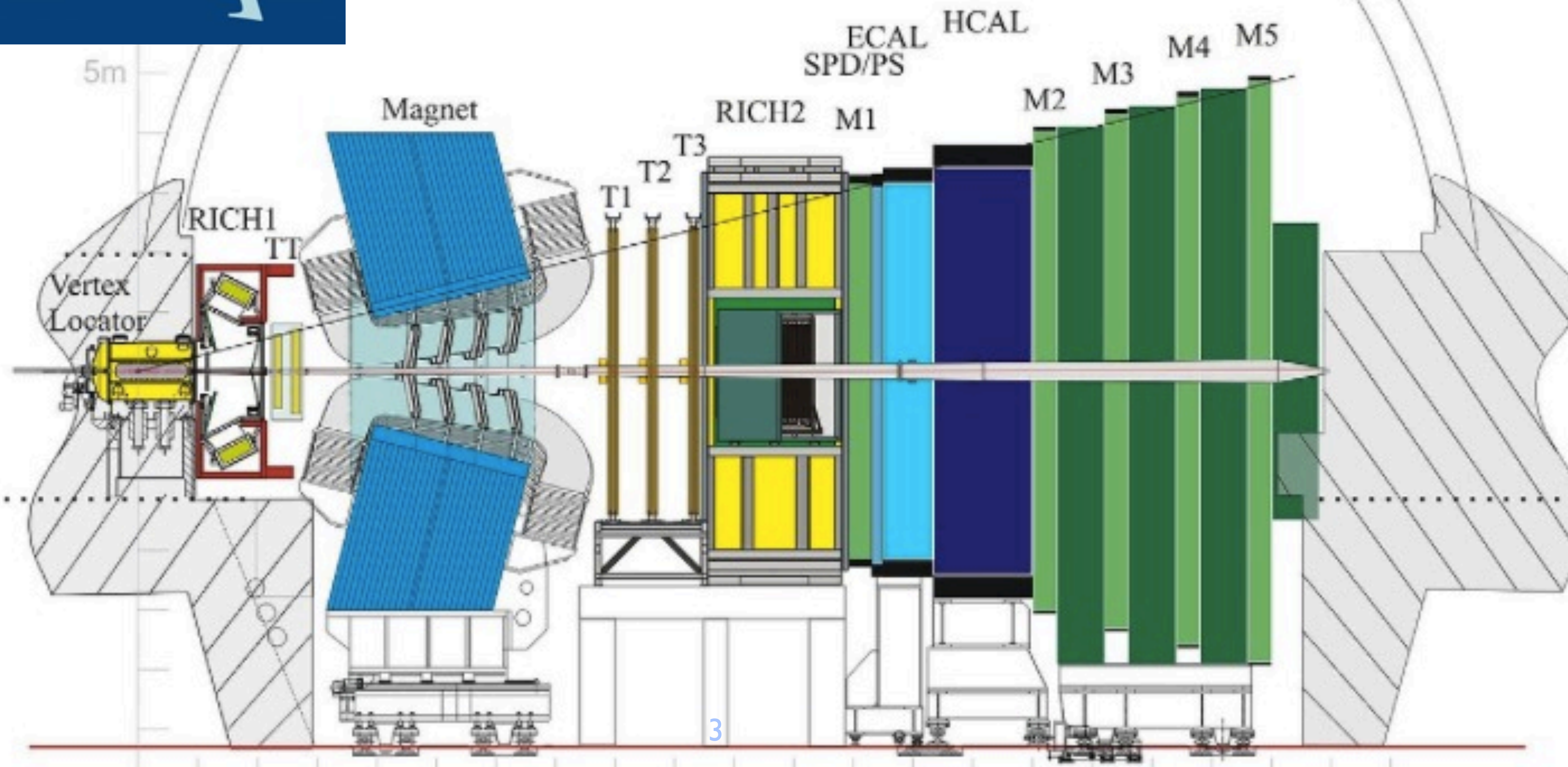

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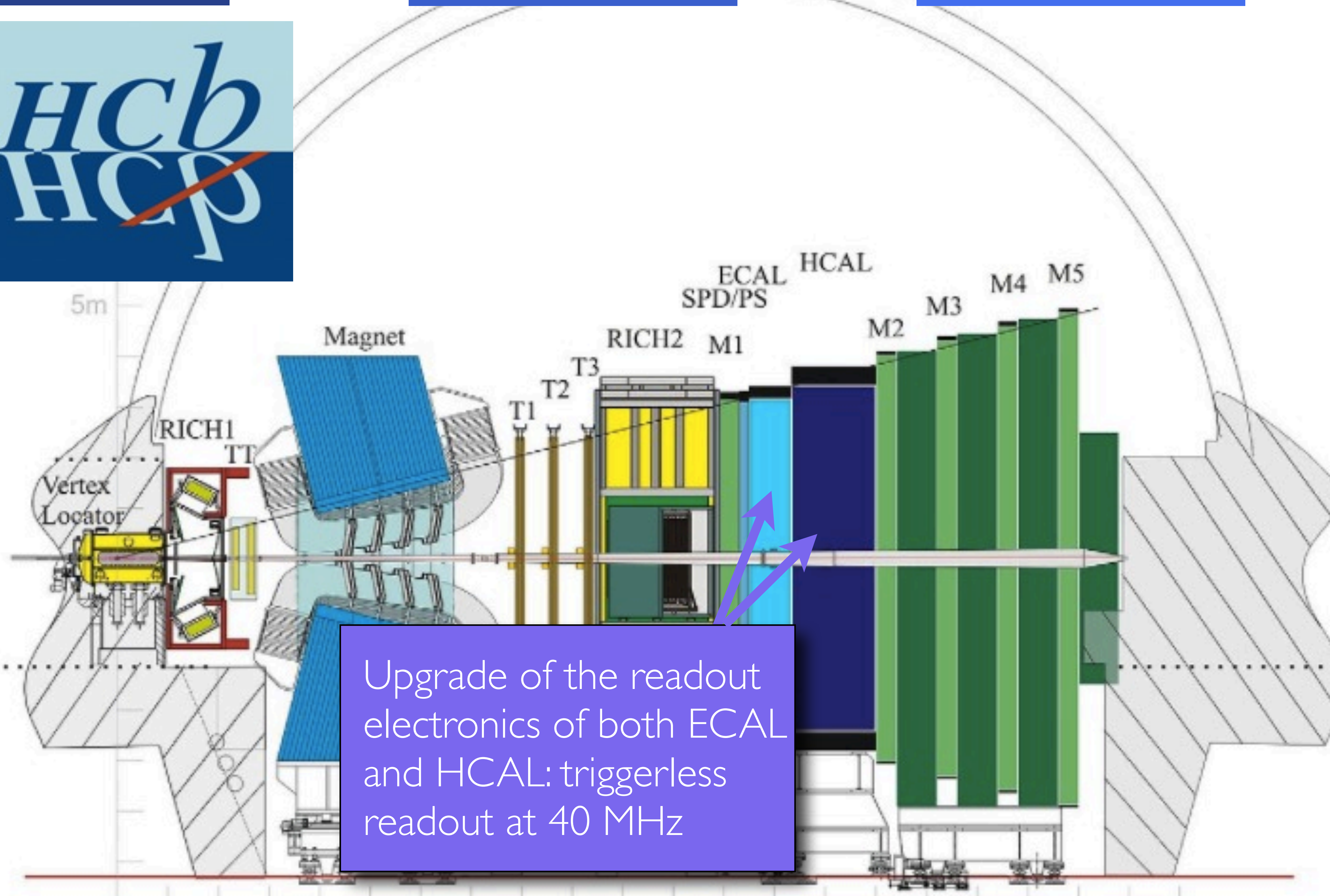

Upgrade of the readout electronics of both ECAL and HCAL: triggerless readout at 40 MHz

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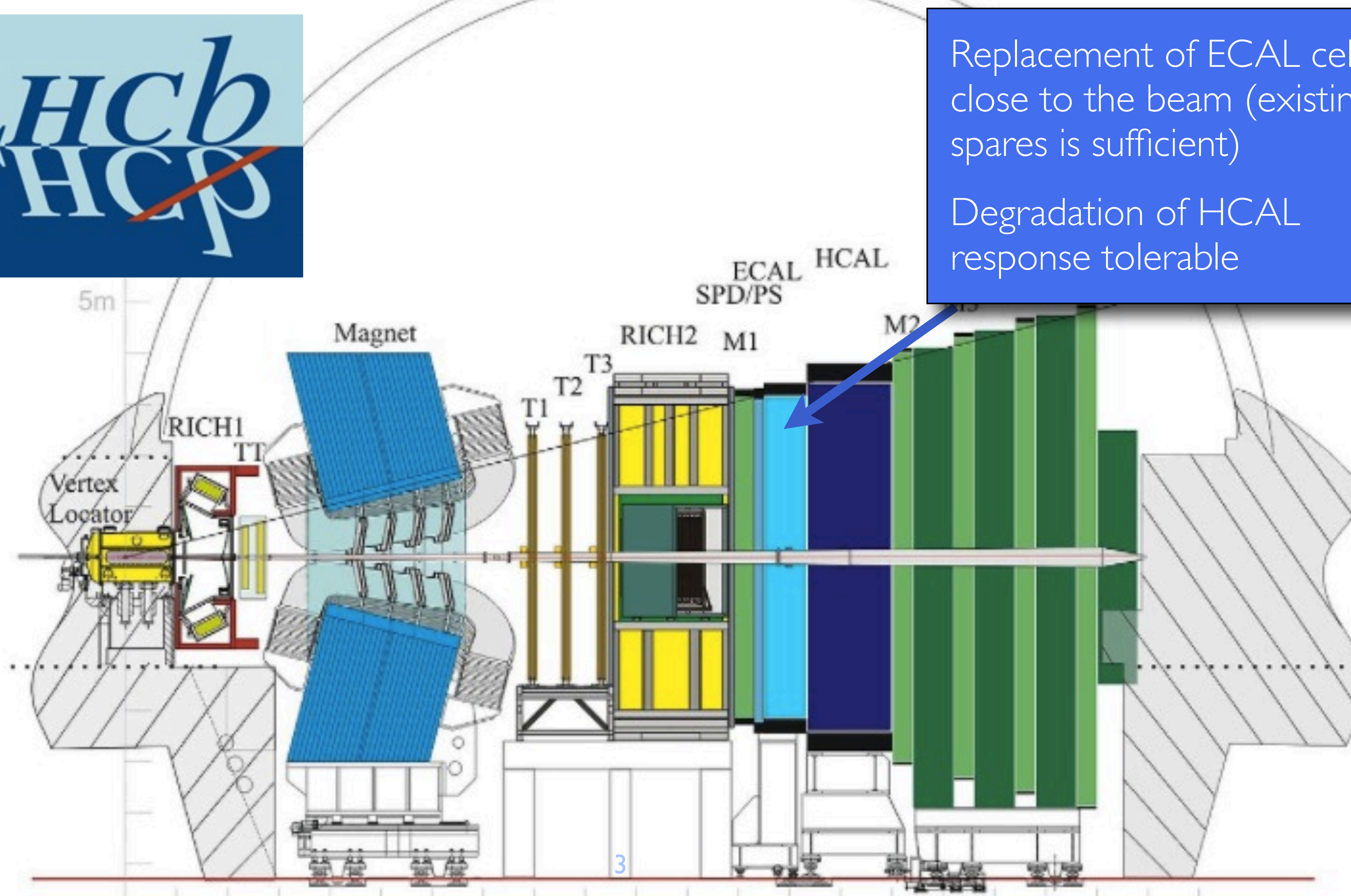
Replacement of ECAL cells close to the beam (existing spares is sufficient)

Degradation of HCAL response tolerable



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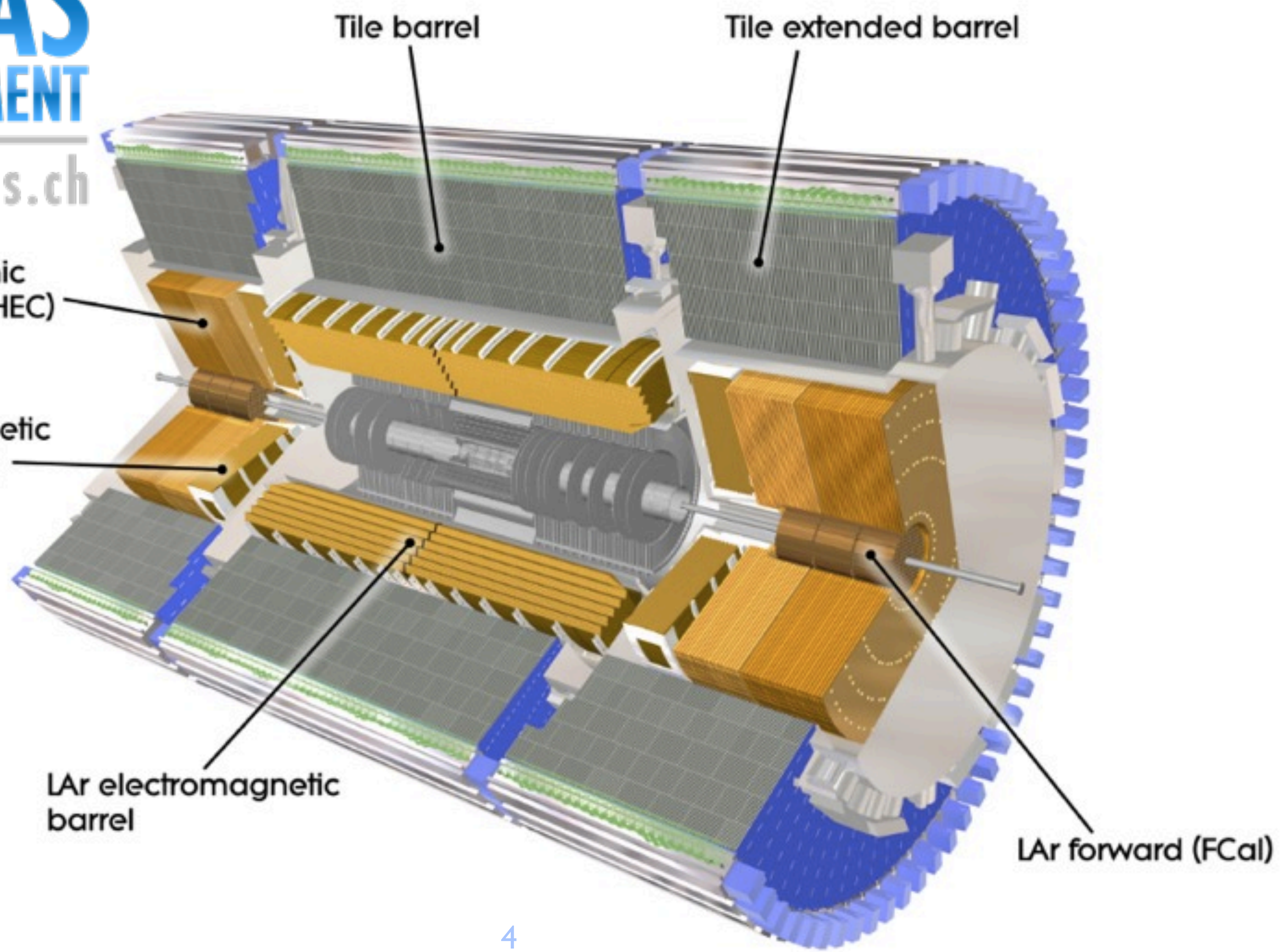

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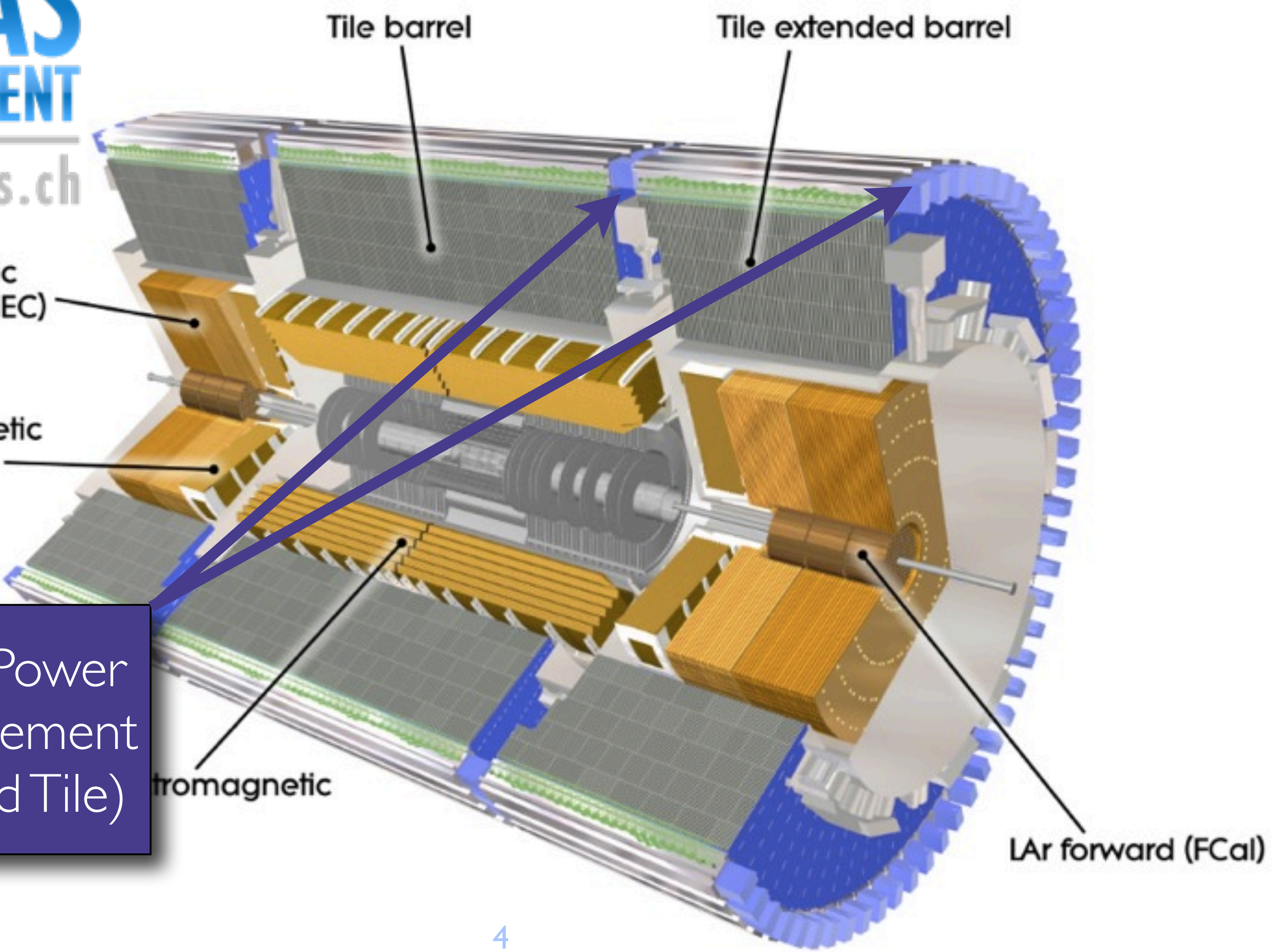

Low Voltage Power Supply replacement (both LAr and Tile)

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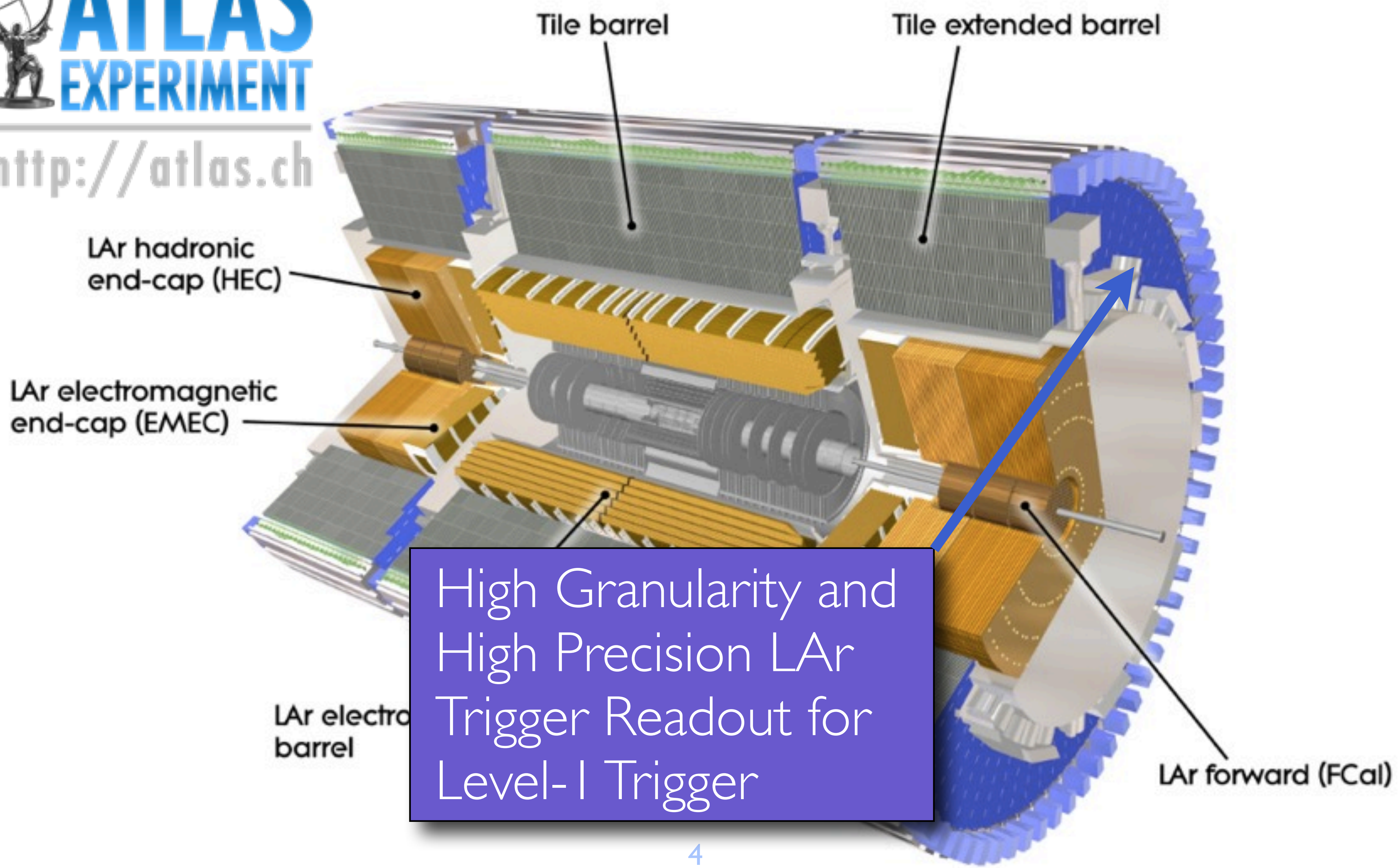

High Granularity and High Precision LAr Trigger Readout for Level-1 Trigger

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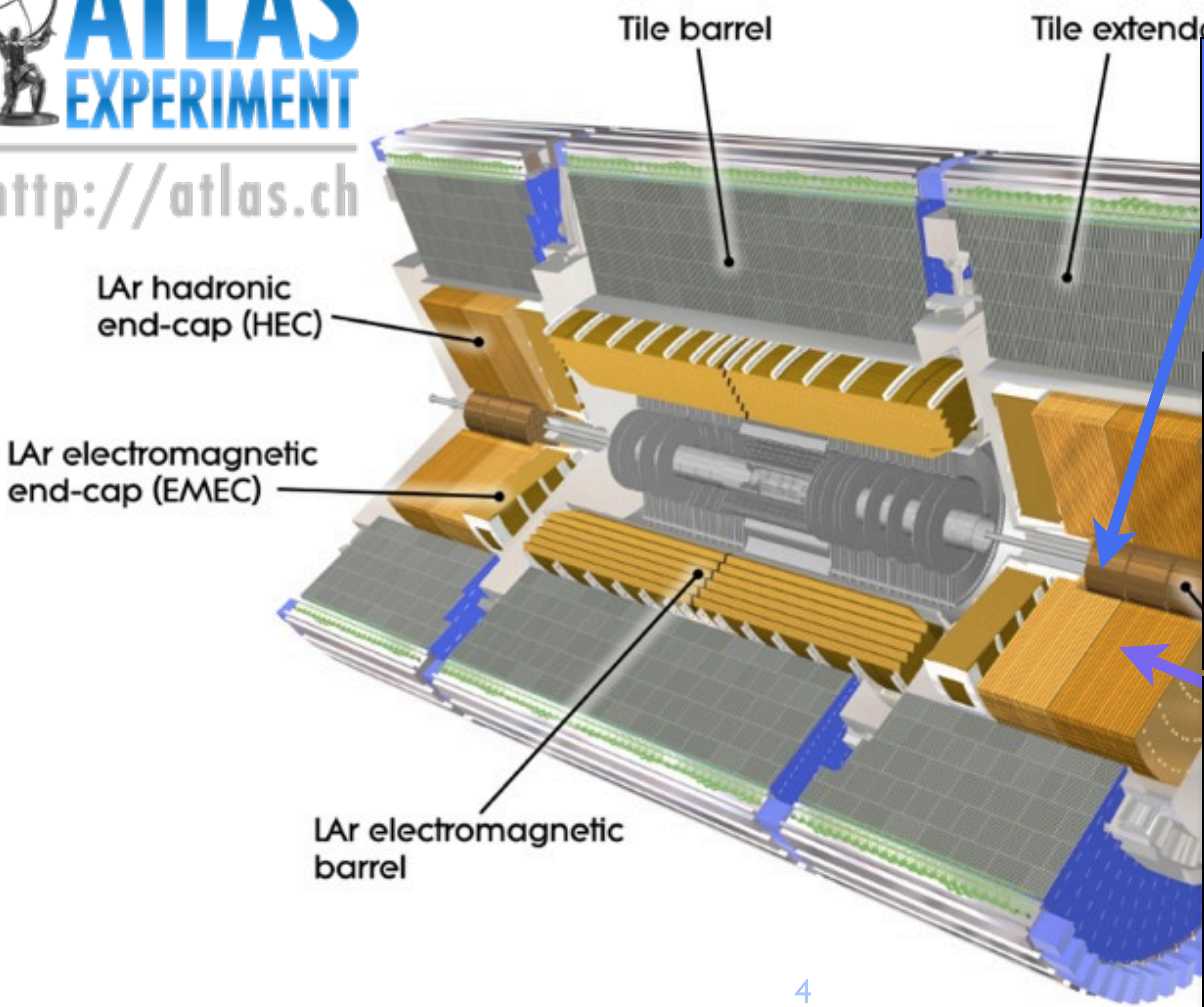

Possible upgrade of the Forward Calorimeter (FCAL)

Upgrade of the main readout (both Tile and LAr): 40 MHz data stream

Possible upgrade of the cryogenic analog front-end of the LAr hadronic endcap (HEC)

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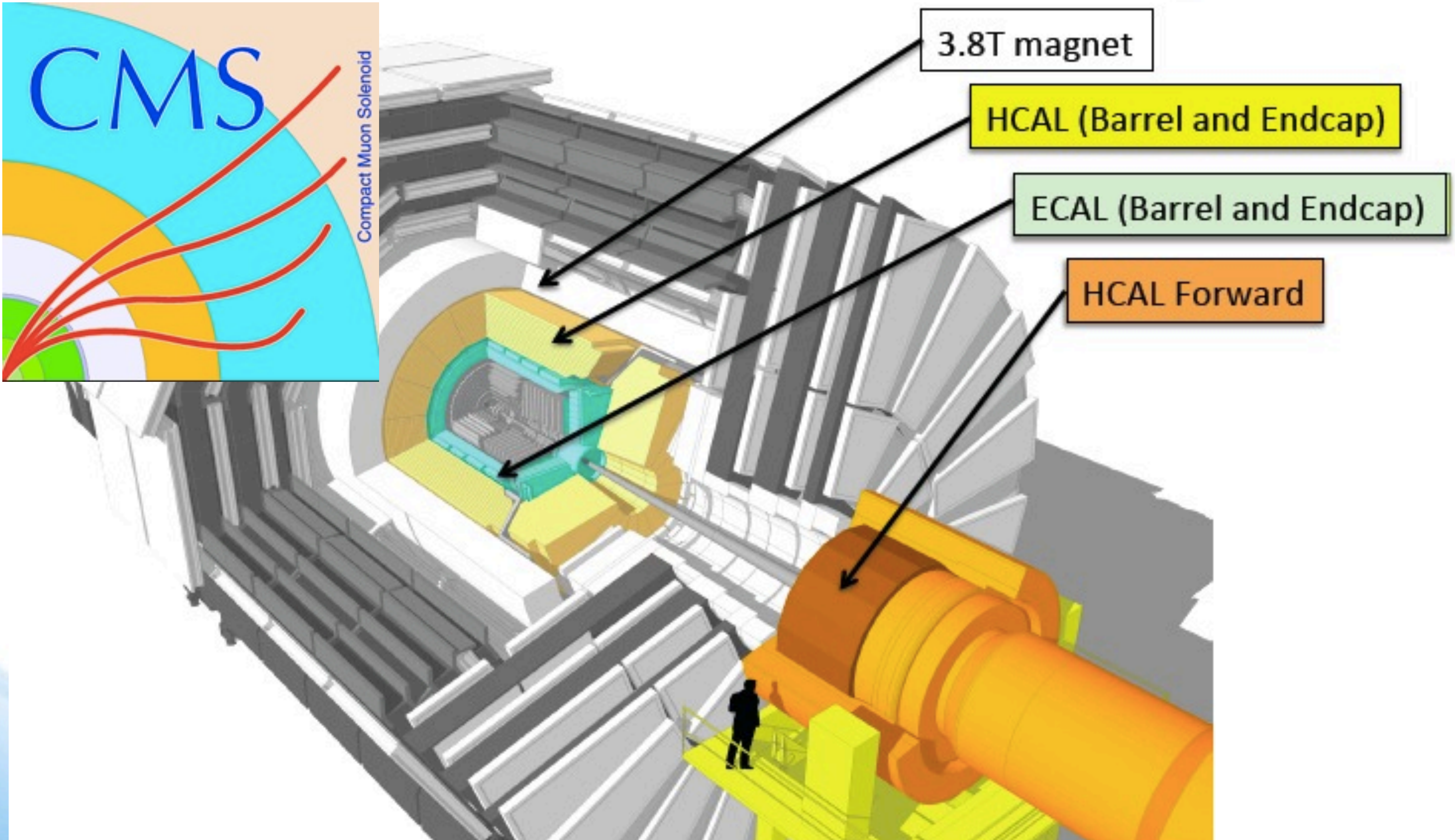

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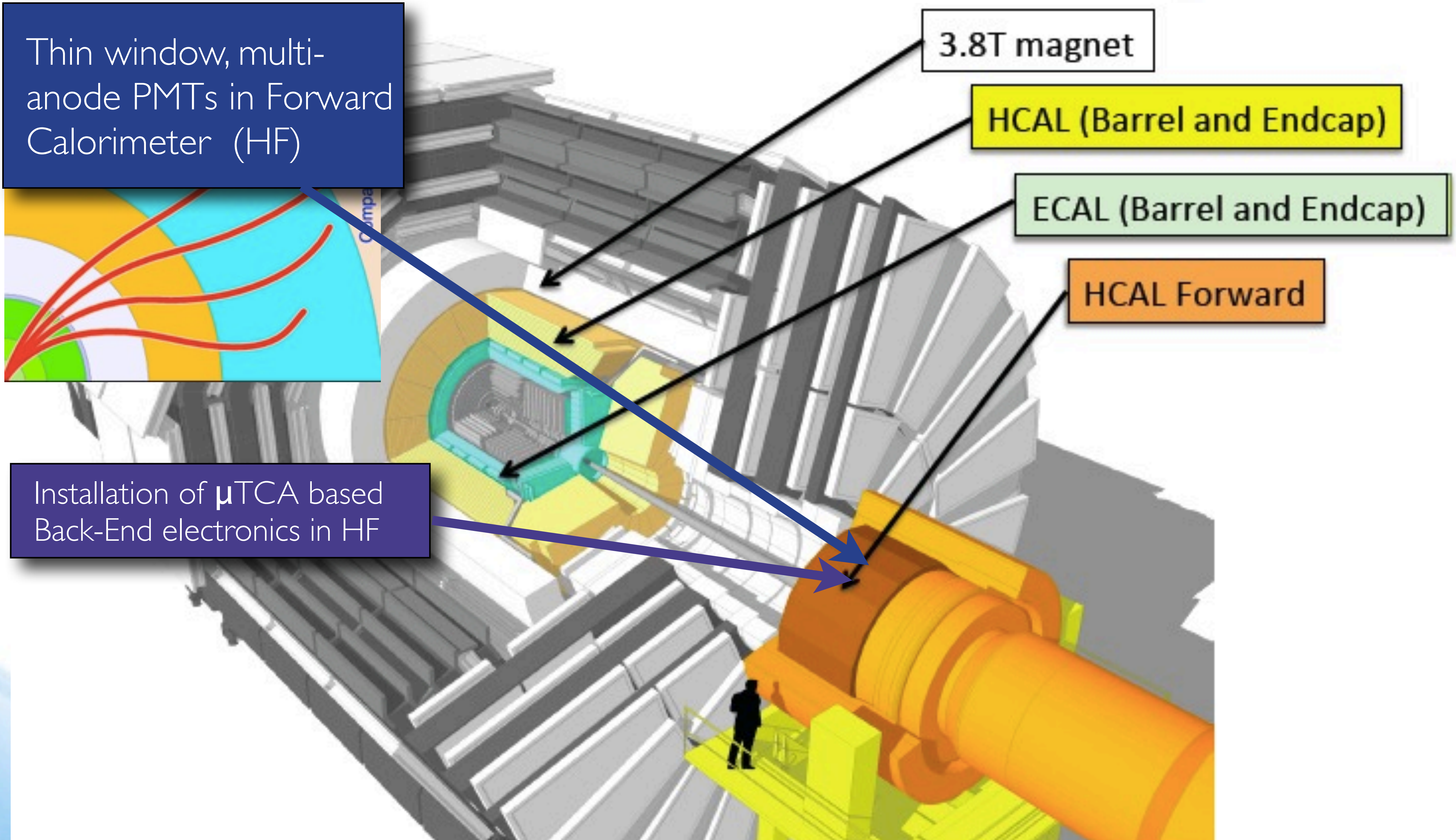
Thin window, multi-anode PMTs in Forward Calorimeter (HF)

Electronics and Trigger

Installation of μTCA based Back-End electronics in HF



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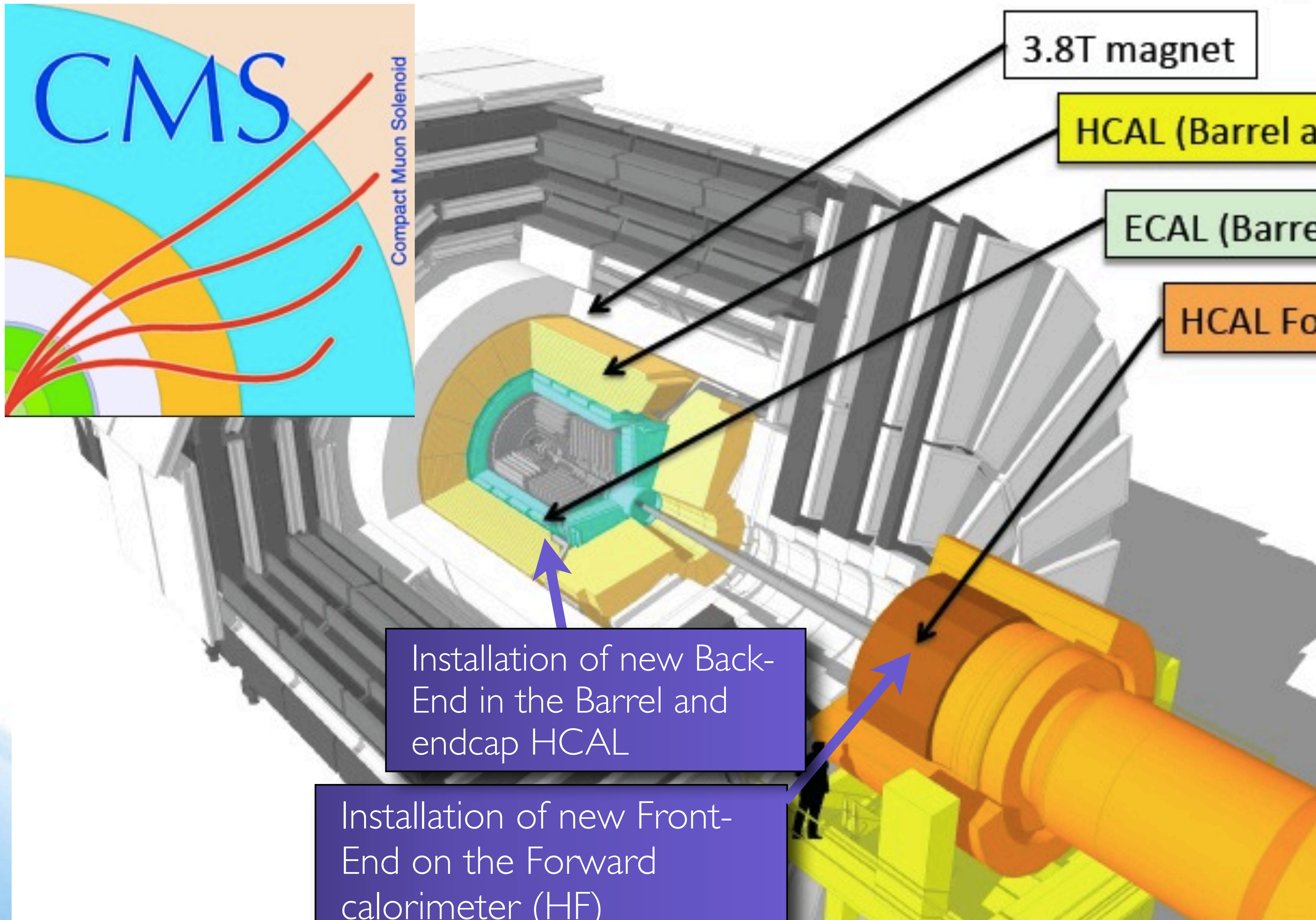

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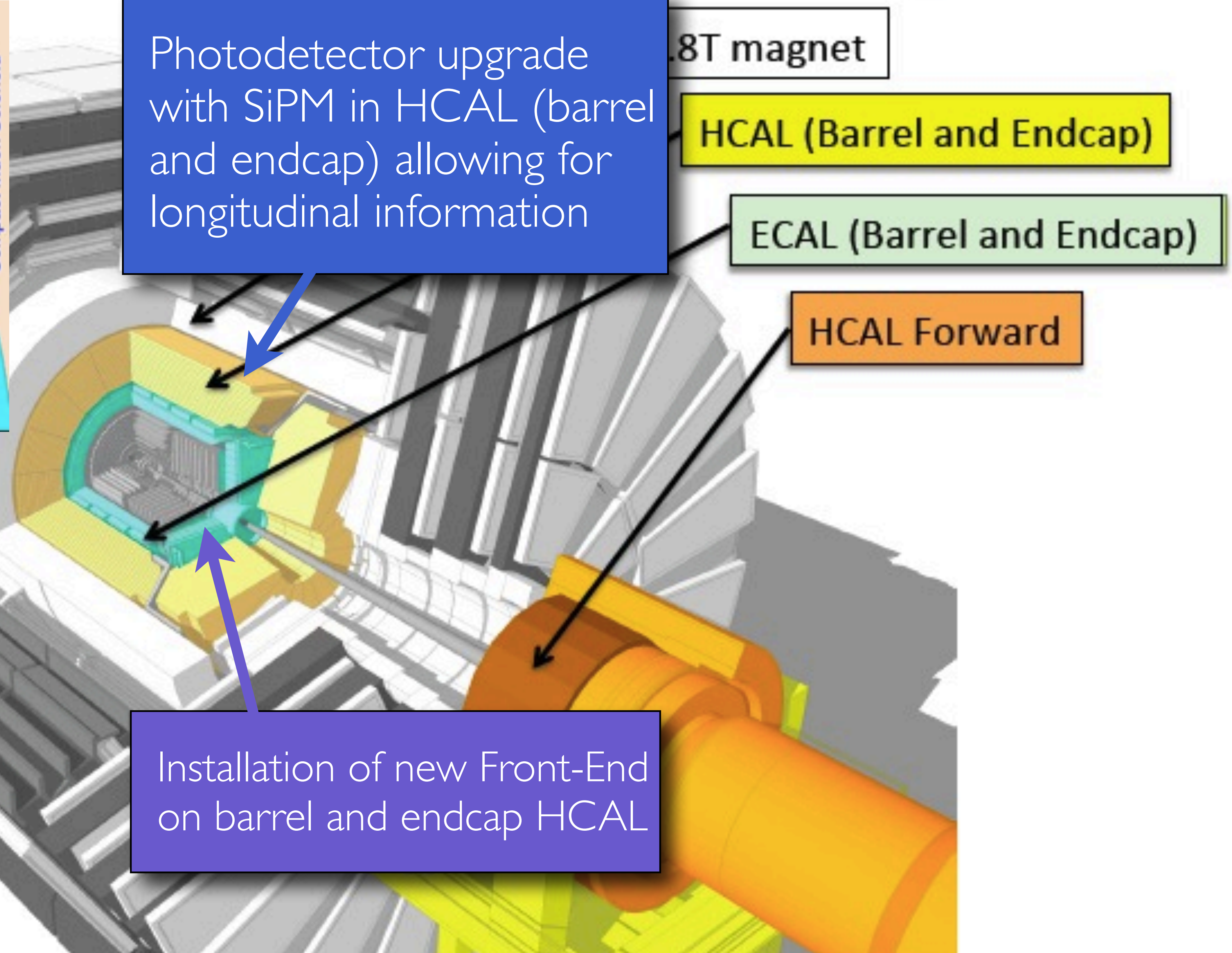

Photodetector upgrade with SiPM in HCAL (barrel and endcap) allowing for longitudinal information

Installation of new Front-End on barrel and endcap HCAL

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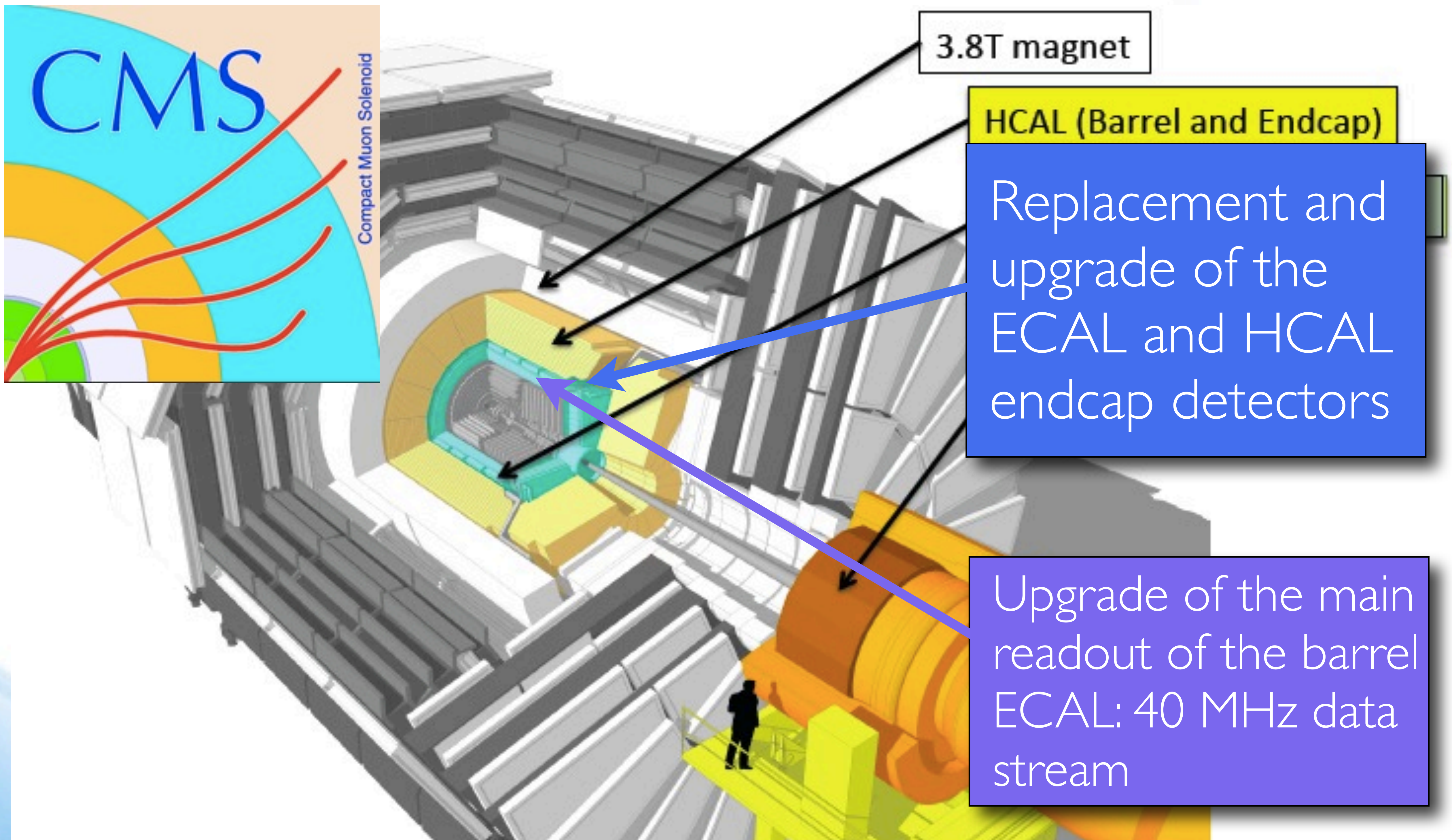


Summary: Detectors

- Detector upgrade plans are specific to the experiments.
- ATLAS LAr calorimeters are intrinsically radiation tolerant.
  - FCAL is potentially the only exception. An upgrade of the detector or the installation of a new detector in front to the existing calorimeter may be needed due to high instantaneous rates.
- The LHCb ECAL modules near the beam-pipe will suffer from radiation damage and will need to be replaced (spares should suffice)
- ALICE is considering the possible addition of a forward calorimeter after LS2.

Summary: Detectors (II)

- The main challenges are for the CMS endcap detectors (homogeneous $PbWO_4$ crystal for the ECAL and Tile/Scint. sampling calorimeters)
  - Significant degradation after $500fb^{-1}$
- Targeted R&D program underway to meet all the challenges of replacing the endcap modules
- Different options:
  - Replace the ECAL homogeneous calorimeter with a radiation tolerant Crystal sampling detector and the Plastic/Scint. HCAL with similar detector technology but having a higher radiation resistance.
    - ✦ *Specific R&D: rad-tolerant scintillators, WLS capillary fibers, photo-detectors*
  - An integrated ECAL/HCAL approach based either on:
    - ✦ Particle flow / Imaging Gas Calorimetry
      - ✓ *Specific R&D: high number of channels ($\sim 10^6$), compact and inexpensive eletronics and data transmission, trigger, linearity, high rates*
    - ✦ Dual ReadOut with Cerenkov/Scintillator sampling detector
      - ✓ *Specific R&D: rad-hard scintillating fibers, photo-detectors*

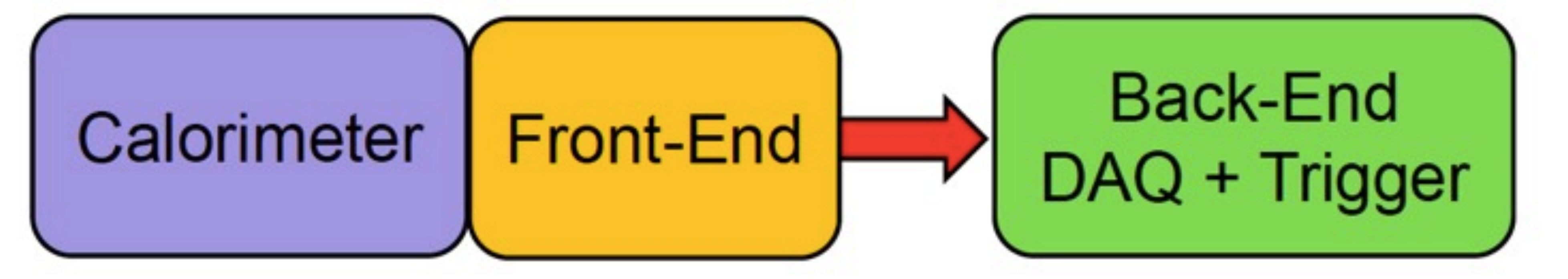
Summary table

Experi -ment	detector	technology	Critical condition	maximal value for Phase2 of LHC	Risk level, considered mitigation
ALICE(*)	PHOS	PbWO4	Radiation Dose	~ 0.1 kRad	OK
ALICE	EMCal/Dcal	Pb/Scint Shashlik	Radiation Dose	~ 0.1 kRad	OK
LHCb	ECAL	Pb/Scint Shashlik	Radiation Dose	~ 6 Mrad	will replace central cells during LS3 (spares exist)
LHCb	HCAL	TileCal	Radiation Dose	~ 1 Mrad	Not critical, accept the loss
ATLAS	ECAL Barrel	LAr	Inst. luminosity	OK up to 10^{35} cm^{-2}/s	OK
ATLAS	ECAL Endcap	LAr	Inst. luminosity	OK up to $5*10^{34}$ cm^{-2}/s	OK, re-calibrate if required
ATLAS	HCAL Endcap	LAr	Inst. luminosity	OK up to $8*10^{34}$ cm^{-2}/s	OK
ATLAS	HCAL Barrel	TileCal	Radiation Dose	~ 0.3 Mrad	Re-calibrate
ATLAS	Forward	LAr	Inst. luminosity	Possible degradation above $2*10^{34}$ cm^{-2}/s	May have to replace or add new detector during LS3
CMS	ECAL Barrel	PbWO4	Hadron fluence	$2*10^{12}$ h/cm^2	Re-calibrate
CMS	HCAL Barrel	Brass/Scint	Radiation Dose	~ 0.1 Mrad	Re-calibrate
CMS	ECAL Endcap	PbWO4	Hadron fluence	~ $2*10^{14}$ h/cm^2	Will be replaced during LS3
CMS	HCAL Endcap	Brass/Scint	Radiation Dose	~ 10 Mrad	Will be replaced during LS3
CMS	Forward	Steel/Quartz fibers	Radiation Dose	~ 500 Mrad	Re-calibrate

(*) considering additional coverage in the forward region after LS2

Summary: Electronics

- Readout electronics for calorimetry seem to offer more opportunities to identify commonalities and share developments, infrastructures and resources.



- A common goal (for both ATLAS and CMS) is to provide highest possible granularity and resolution at the Level-1 trigger processors to handle increasing pileup
- LHCb is even going to the next level, i.e. to upgrade to a completely "trigger-less" readout
  - ***All the experiments are planning significant upgrades of their readout systems on different timescales***

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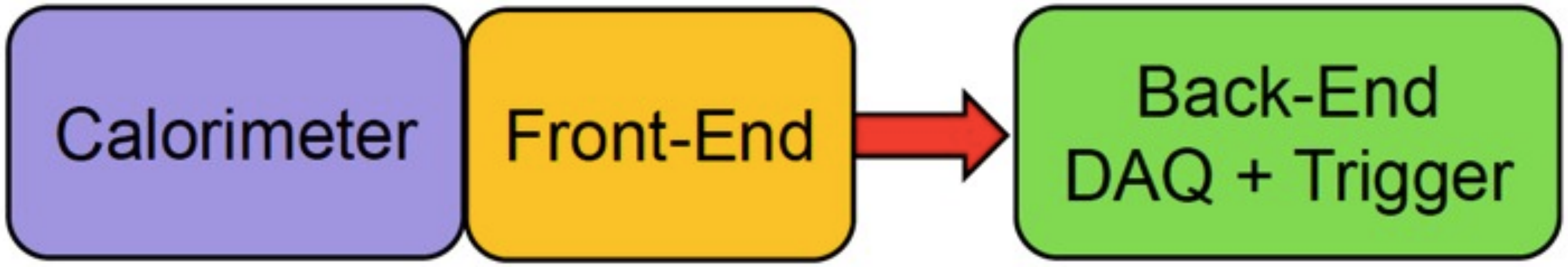

- The common trend is to design a readout architecture where:
  - the data are not buffered in the front-end, but rather streamed off-detector at 40 MHz (LHCb, CMS HCAL are already doing it)
  - fast pre-processors convert raw-data into calibrated information that feed the trigger system where improved and more complex algorithms are applied.
  - Off-detector buffers allow for a much higher trigger latency or purely software-based triggers.

Summary: Electronics

- Key enabling technologies:
  - On-detector front-end electronics with sufficient resolution and large dynamic range (~16-bit)
    - *COTS vs. ASIC development. Is it possible to identify synergies across the experiments?*
    - *If an ASIC is required - what technology/foundries will be available/used [across the experiments at least 5-6 developments exploring different processes]*
    - *Low power, low latency (10-12bit resolution)*
    - *Radiation tolerant (in particular SEE)*
  - High speed optical data links (≳10 Gbps)
    - *Clearly looking into developments at CERN (GBT) and elsewhere (including COTS). But a clear convergence of interest toward technologies enabling 10Gbps data transmission or higher*
    - *Radiation tolerant (in particular SEE)*
  - High performance back-end systems:
    - *ATLAS, CMS, LHCb, using similar approaches based on x-TCA family: ATLAS and LHCb with ATCA, CMS with μTCA*
    - *Alternatively development of high bandwidth system based on PCIe cards in "commodity" PCs to interface detector specific front-end to DAQ systems on a switched-network.*
- System aspects also to consider. For example:
  - High power DC-DC converters
  - Local regulation on the front-end element on-detector.

Possible Timeline for upgrades to be installed in LS3