

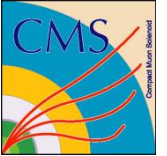


CMS HL-LHC EM Calorimeter Upgrade

M. Hansen, CERN
for the CMS ECAL upgrade project(s)



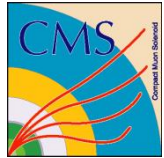
Content



- Legacy system design and Status
- Requirements
- Barrel Calorimeter electronics upgrade
- End Cap calorimeter upgrade
- Conclusion



Legacy ECAL Barrel FE electronics system - Design and Status



- **Modularity**

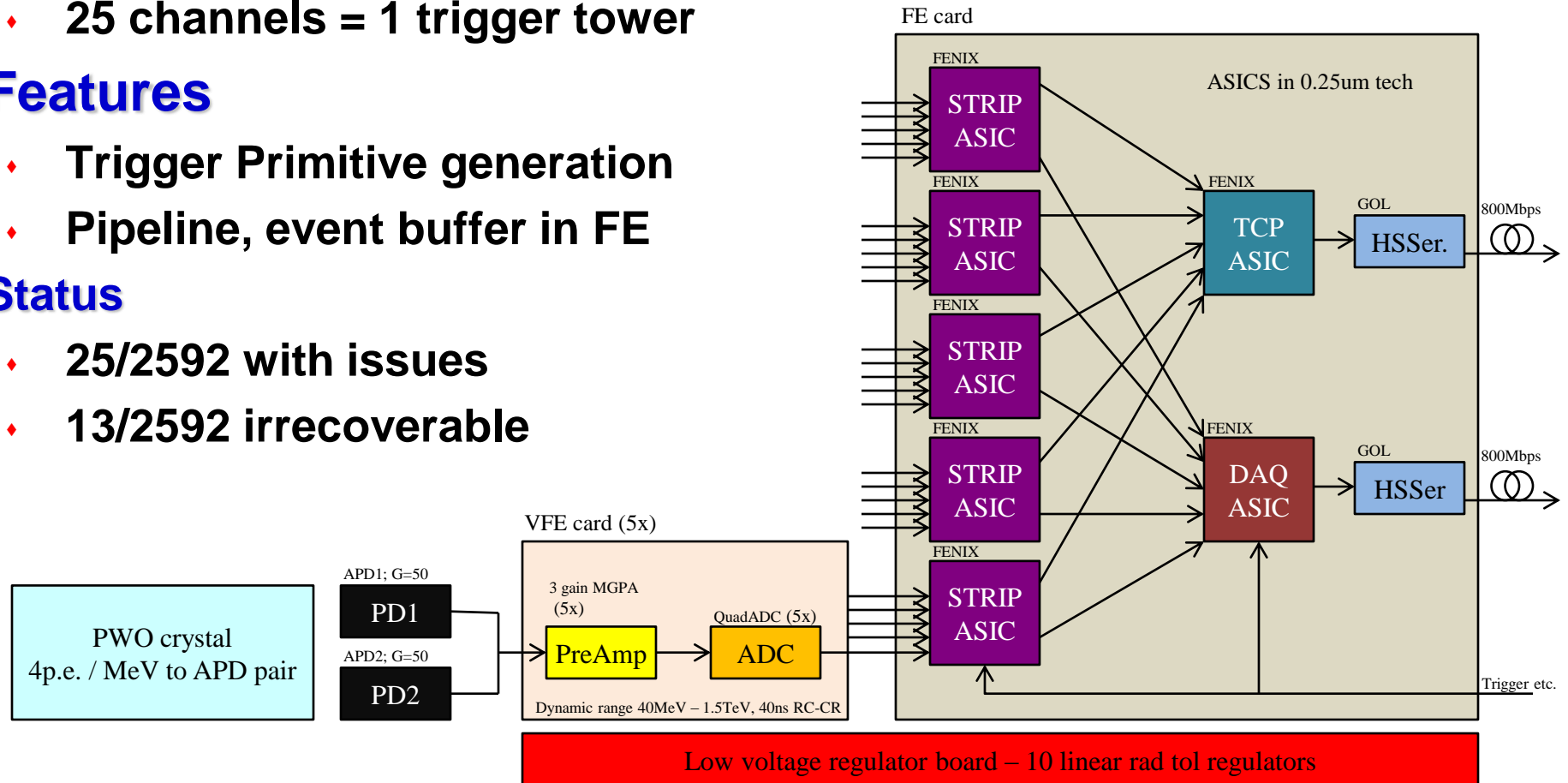
- ◆ 25 channels = 1 trigger tower

- **Features**

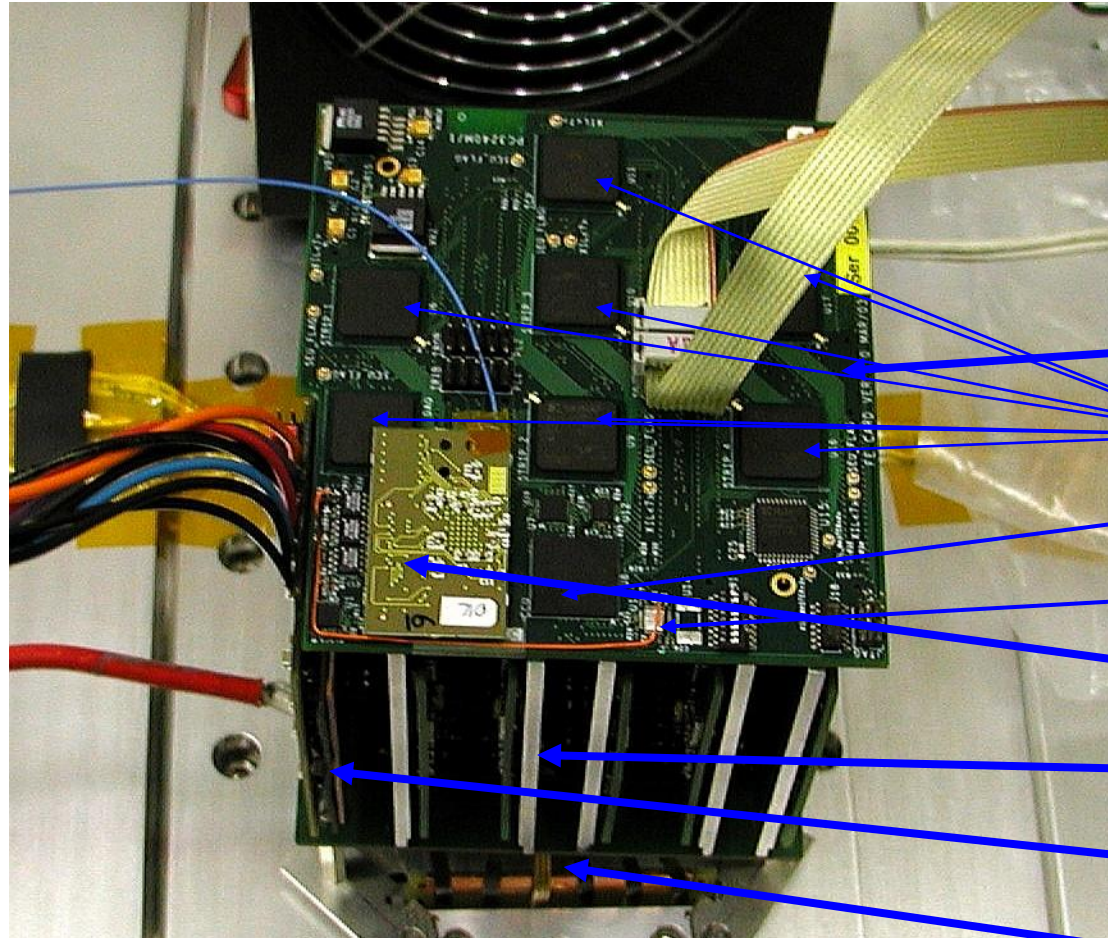
- ◆ Trigger Primitive generation
- ◆ Pipeline, event buffer in FE

- **Status**

- ◆ 25/2592 with issues
- ◆ 13/2592 irrecoverable



Legacy ECAL Barrel trigger tower



FE

Front end chip

CCU (Slow control)

QPLL (clock cleaning)

GOH (GOL hybrid)

VFE

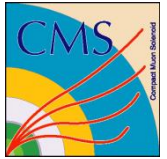
Low voltage regulators

Mother board

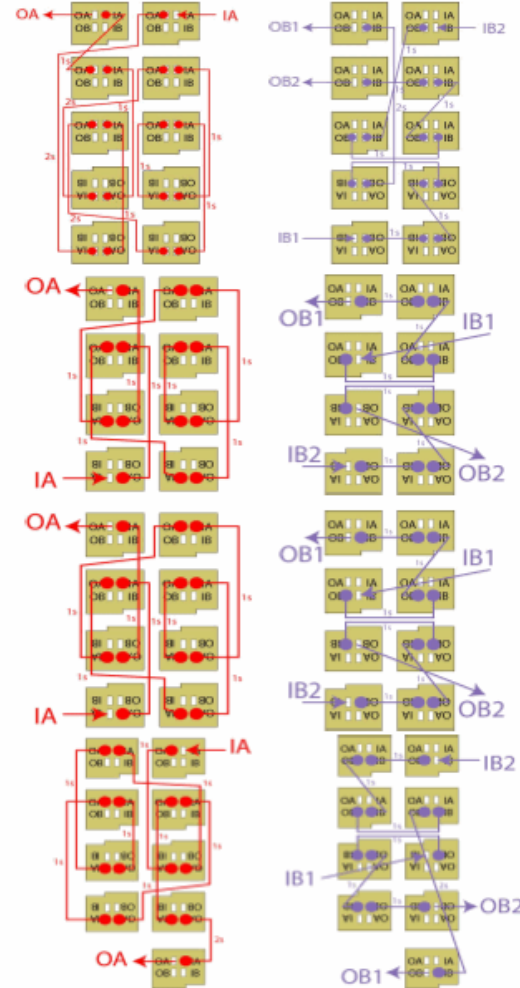
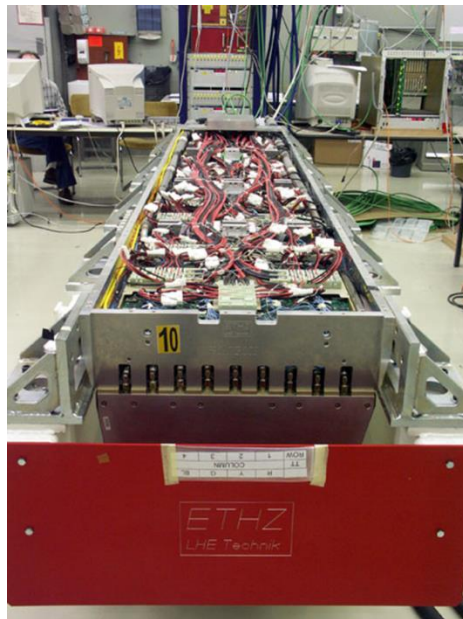


Legacy

ECAL Supermodule integration & Slow control

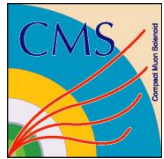


- 72 legacy towers in SuperModule
 - ♦ 36 SM in total
- Slow and fast control in 8 rings
 - ♦ Single tower of fibre failure recovery; very few issues to date

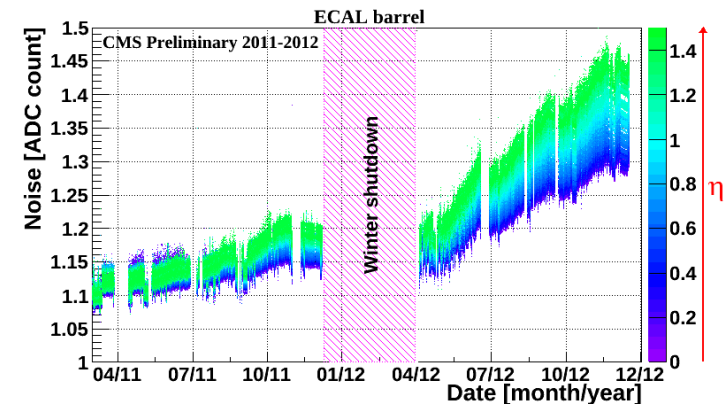
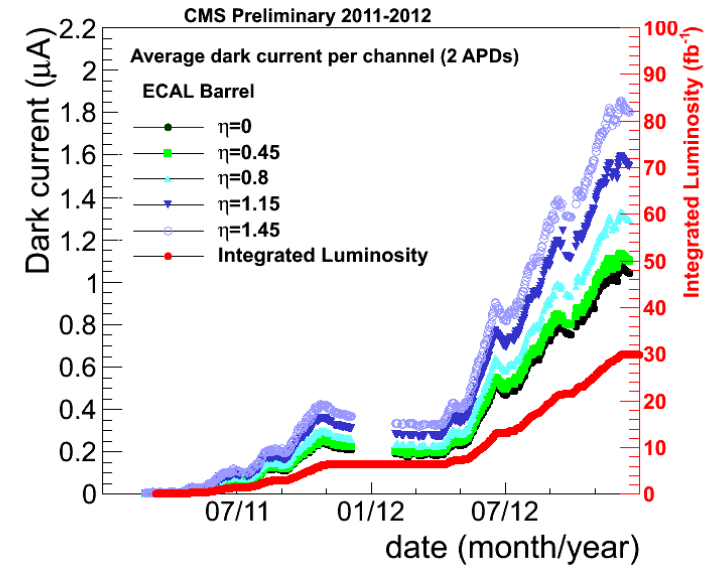




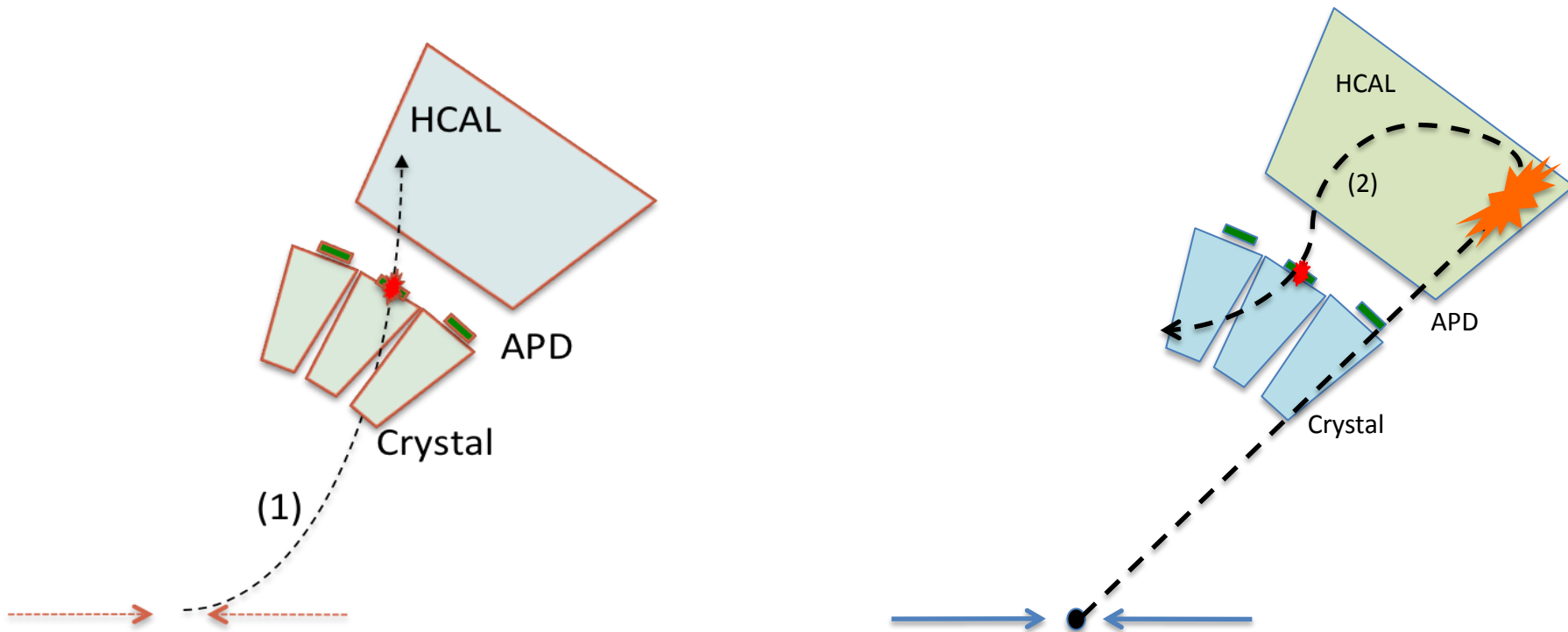
Noise vs ageing



- **Electronic noise vs ageing and eta**
 - ♦ APD dark current predicted to increase with integrated luminosity – confirmed ->
- **Large Extrapolation suggest noise increase by a factor 10 after 3000fb⁻¹**
 - ♦ Roughly corresponds to 400 MeV/channel
 - ♦ TBC by measurements
- **The feasibility to operate the ECAL barrel colder and thereby decrease the APD dark current noise is under study**



Hadrons interacting with the APD's causing anomalous high E deposits

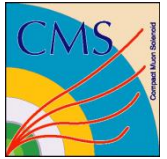


Hadrons come from primary interaction and backslash

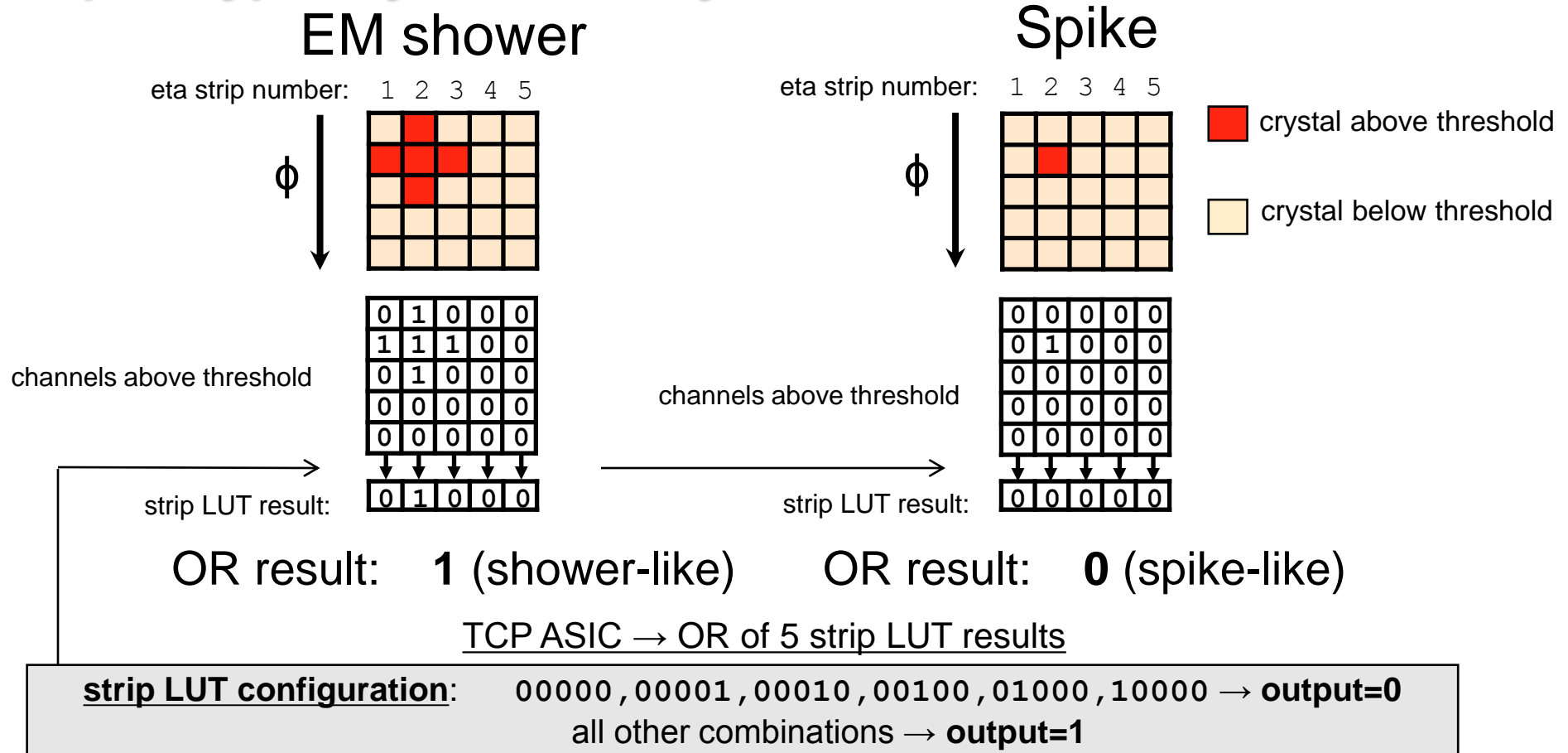


Legacy

Real Time Spike rejection Algorithm

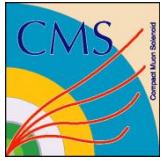


- An EM shower deposit E in more than one crystal
- A spike typically occurs only in one APD

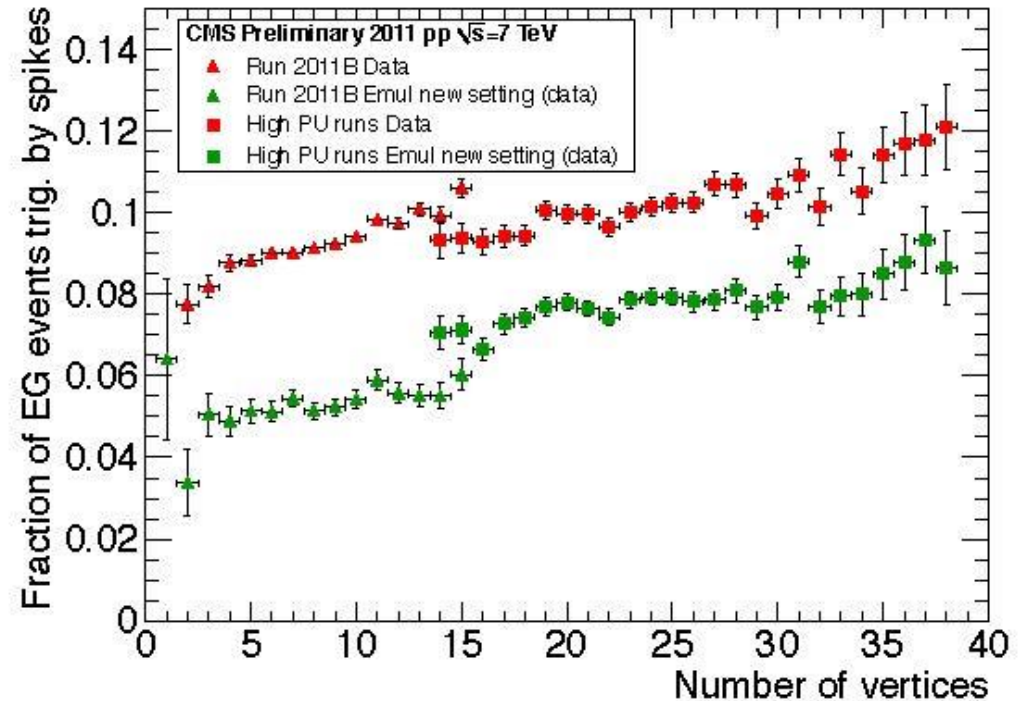




Spike rates

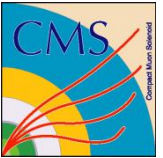


- **L1 Spike rejection in 2012**
O(95%)
 - ♦ **Rate sustainable up to LS3**
with somewhat raised
channel threshold
- **Legacy Spike Rejection**
Algorithm is sensitive to PU (see
plot ->)
- **Exploring improvements having**
access to full granularity of data
in the trigger path
 - ♦ **Single crystal readout**
- **Exploring pulse-shape variables**
to provide an additional
efficiency/rejection safety margin
 - ♦ **Analogue Signal Processing**





ECAL barrel Phase 2 Upgrade Requirements



- **Requirements**

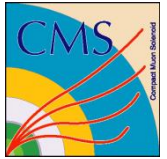
- ◆ **Trigger rate up to 1 MHz**
 - Legacy max ~150 kHz
- ◆ **Trigger latency up to 25 us**
 - Legacy max ~5 us
- ◆ **Full installation during LHC Long Shutdown 3**
- ◆ **Maintained or improved reliability and availability**
- ◆ **Improve the EB spike mitigation**

- **High on the wish list**

- ◆ **Decrease the Low Voltage Current delivered to the Front End system in order to decrease the physical volume required for services**
- ◆ **Solid failure mitigation scheme**
 - E.g. avoid dependence between neighbours



Phase 2 ECAL Barrel FE electronics system - Design idea



- **Modularity**

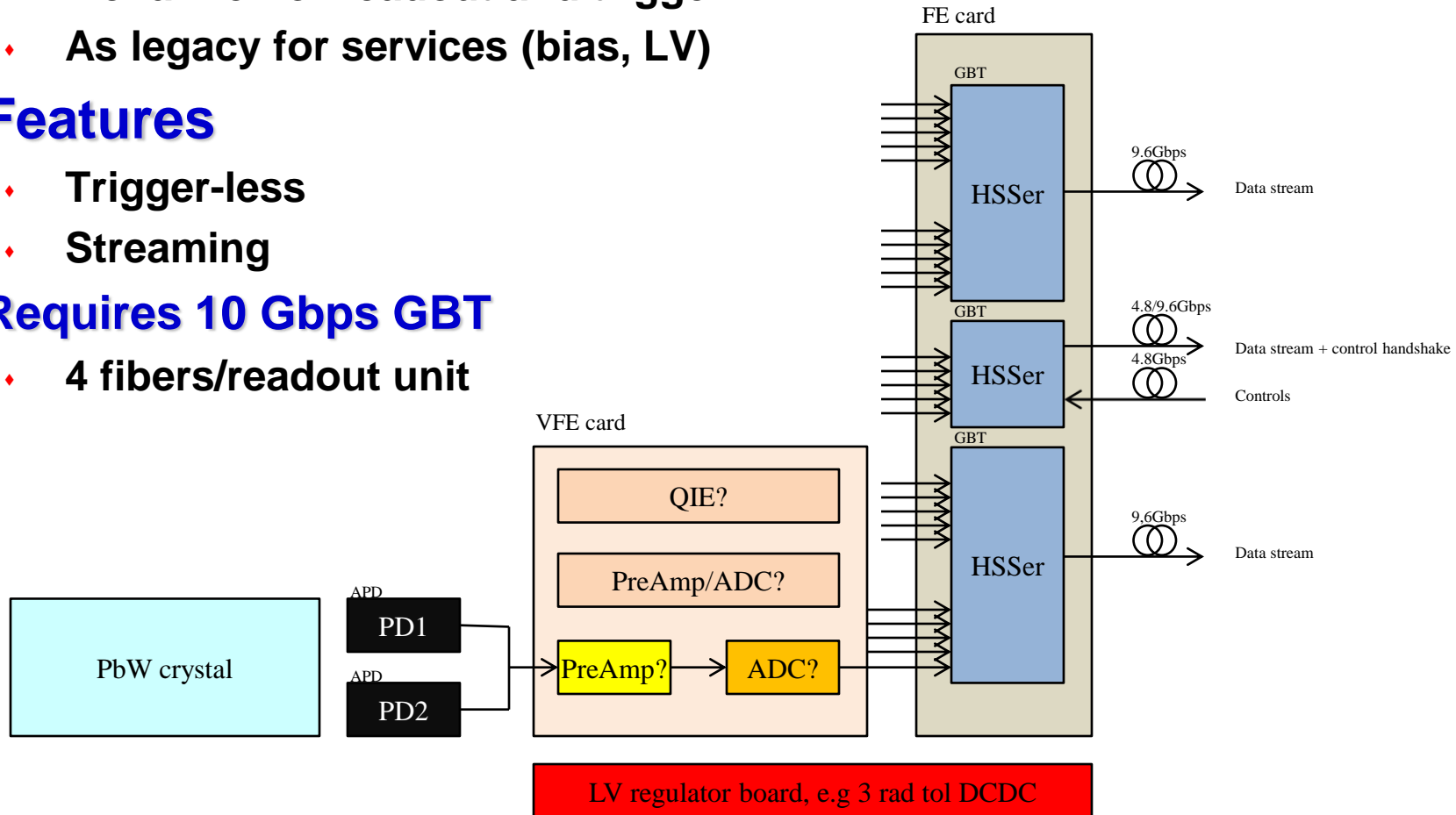
- ◆ 1 channel for readout and trigger
- ◆ As legacy for services (bias, LV)

- **Features**

- ◆ Trigger-less
- ◆ Streaming

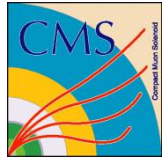
- **Requires 10 Gbps GBT**

- ◆ 4 fibers/readout unit





Phase 2 ECAL Barrel FE electronics system - Design idea



- **Modularity**

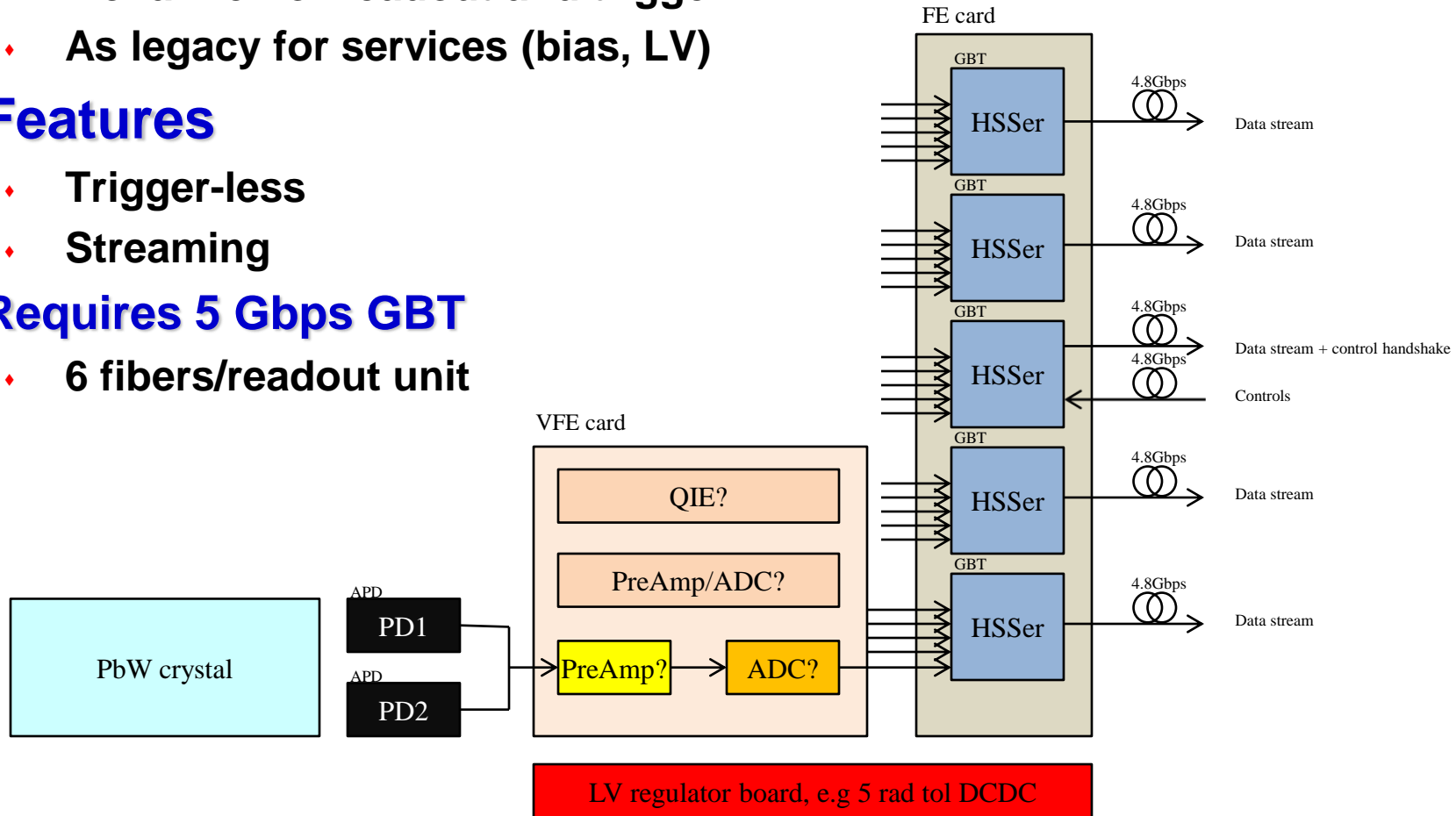
- ◆ 1 channel for readout and trigger
- ◆ As legacy for services (bias, LV)

- **Features**

- ◆ Trigger-less
- ◆ Streaming

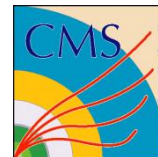
- **Requires 5 Gbps GBT**

- ◆ 6 fibers/readout unit





Current EB R&D plan for TP VFE



- **Develop a VFE chip set and Carrier**
 - ◆ **Develop the optimal scheme for spike detection**
 - At the source, i.e. in the very front end amplifier and ADC
 - In the back end exploiting fine granularity of channel level data
 - ◆ **Define the best compromise between noise and power consumption**
 - Considering the increased APD noise due to radiation damage
 - Considering the possibility to operate the ECAL barrel below room temperature
 - ◆ **Optimise sensitivity to out-of-time Pile-Up**
 - Optimise sampling rate and pulse shaping time for HL-LHC conditions



Current EB R&D plan for TP



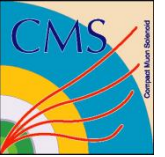
- **Develop the upgraded front end power system demonstrator**
 - ◆ Develop a carrier for e.g. the DCDC module described last Tuesday afternoon by Federico Faccio
 - ◆ Evaluate with legacy front end system
 - ◆ Look out for issues with Noise and Thermal management
- **Develop a front end card Demonstrator**
 - ◆ Streaming data to the back end
 - ◆ Look out for issues with Thermal management
- **Study existing CMS back end cards and define requirements for the future ECAL back end system**
 - ◆ E.g. cards developed for the CMS level 1 trigger phase 1 upgrade



CMS EB upgrade Working Groups

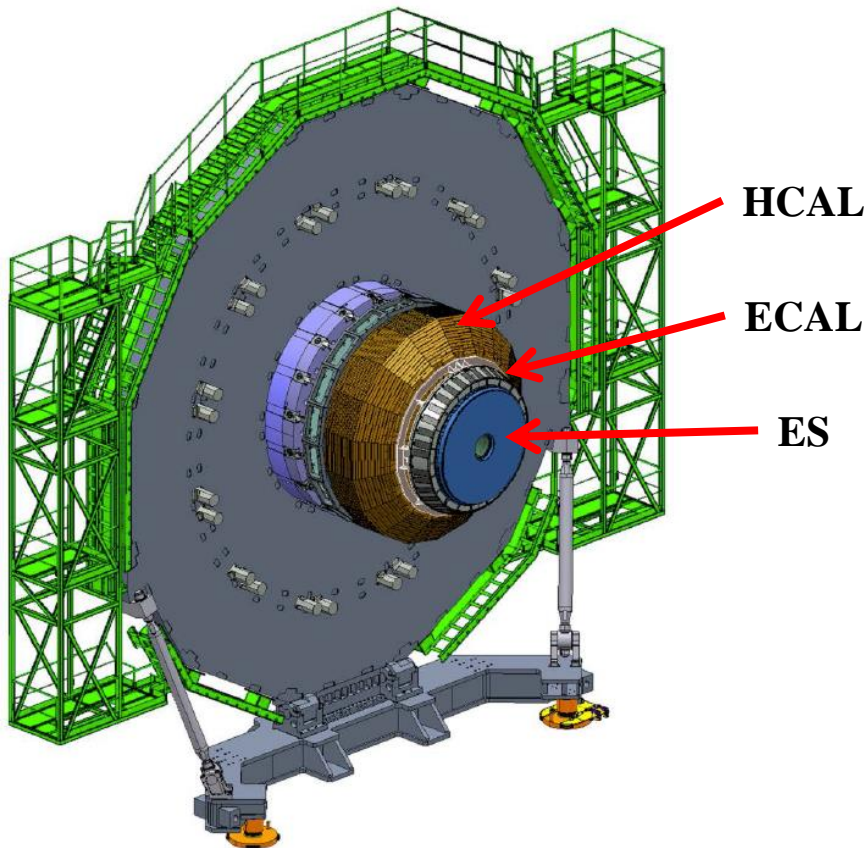


- **WG1: Evaluate Scope of Upgrade with regard to Risk and Schedule**
 - ◆ W. Funk, M. Hansen, et al.
- **WG2: Develop motivation and Evaluate options for upgrading the VFE and the LVR**
 - ◆ M. Dejardin et al.
- **WG3: Evaluate the desired Functionality and characteristics of replacement FE card**
 - ◆ A. Singovsky, J.C. Silva, et al.
- **WG4: Detector Monitoring**
 - ◆ D. Bailleux, P. Gras, et al.
- **Group of electronics developers is growing**



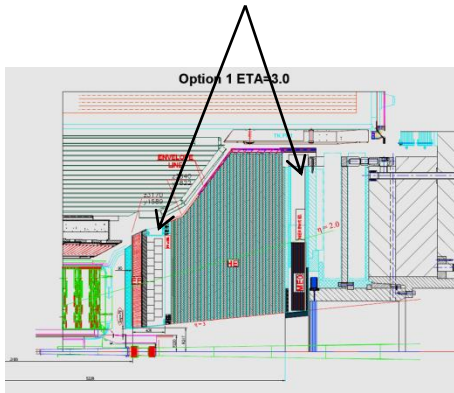
ENDCAPS SECTION

CMS Endcap calorimeter upgrade

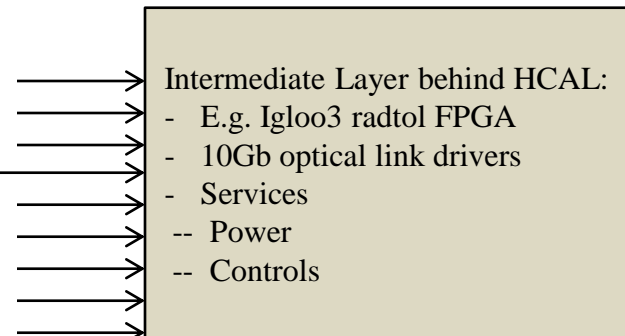
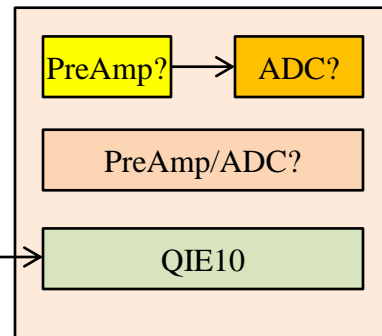
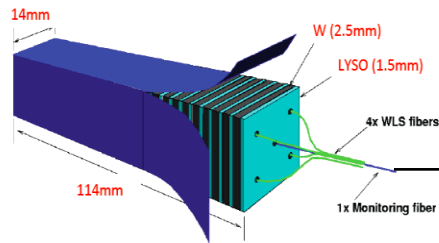


- ECAL and HCAL Endcaps are suffering radiation damage
- Planning re-build or fully replace ECAL and HCAL Endcaps for HL-LHC
- Three proposals on the table

Electronics location(s)



- The Shashlik proposal comprises ECAL and a re-built full HCAL endcap
- Readout chain very similar to ECAL barrel HI-LHC upgrade and HCAL legacy / Phase 1
 - ♦ ~ECAL barrel system size: 61k channels
- SiPM location alternatives
 - ♦ In front of HCAL: InGaP PM and 3m analogue cable
 - ♦ Behind HCAL: SiPM and 3m fiber carrying Shashlik light

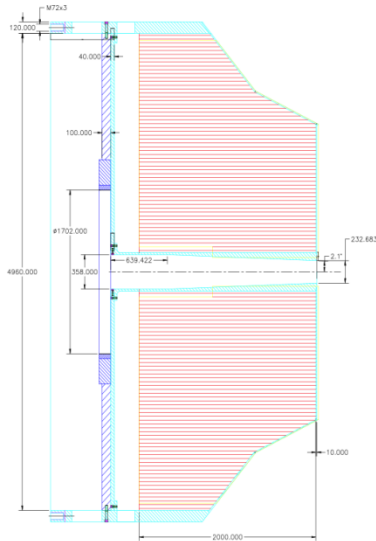
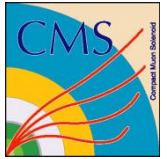


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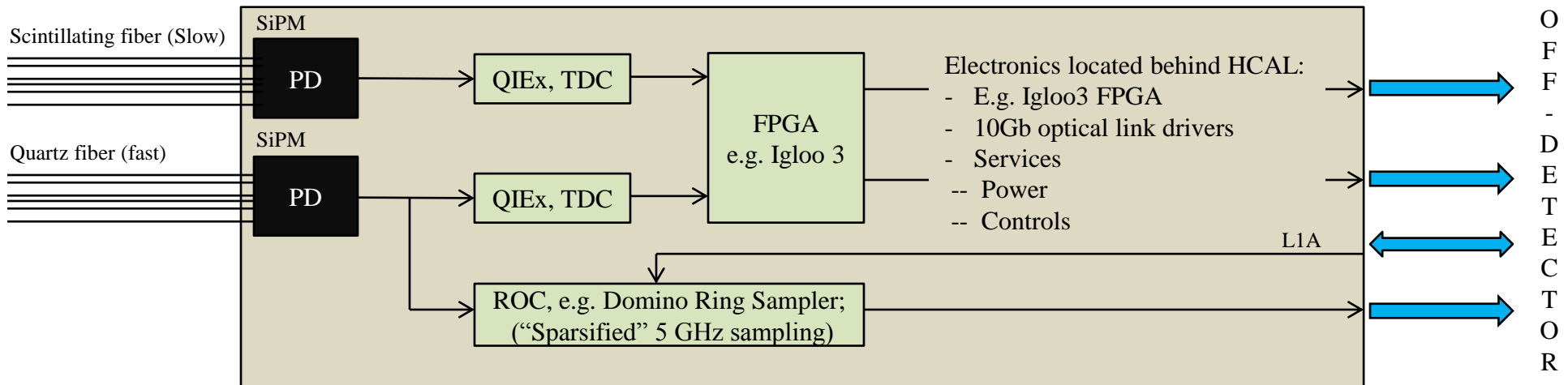


End-cap calorimeter upgrade Proposal 2

Combined Forward Calorimeter

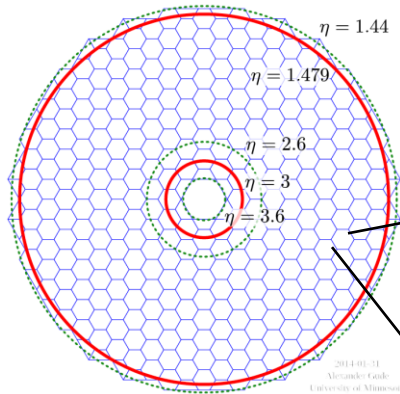


- CFC Comprises full ECAL and full HCAL endcap
- Essentially three ~ECAL barrel sized readout systems
 - ◆ Scintillating, quartz, timing
- Fine timing data stored in ROC
 - ◆ Read out after L1A



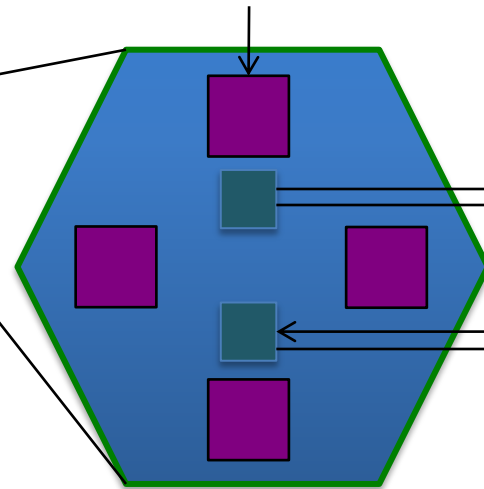


- HGC Comprises full ECAL and half HCAL endcap
 - Combined with half re-built legacy HCAL Endcap
- “Coarse” trigger primitives sent off detector
- Full granularity data stored in ROC
 - Read out after L1A



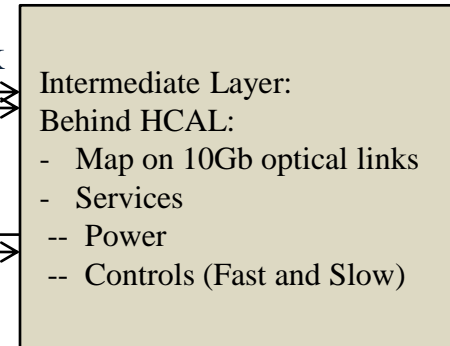
30k modules in 41 planes
Absorber interleaved

64 Chan FE ROC



Trigger
Primitives
5Gbps e-link

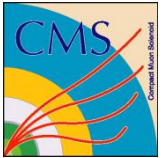
RO/CTRL



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Conclusion



- **Described the Legacy CMS ECAL Electronics system design and Status**
- **Described few issues to be addressed with the upgrade of the CMS ECAL electronics system**
- **Listed a set of CMS Requirements, general to CMS phase 1 and Phase 2 upgrades**
- **Listed future R&D for the ECAL Barrel Calorimeter electronics upgrade**
- **Briefly described options for the Endcap calorimeter upgrade**
- **All in all, interesting time ahead of us**