Calorimeter Upgrade

Introduction

On behalf of the LHCb Calorimeter upgrade group

Calorimeter Architecture review
Friday June 14th, 2013

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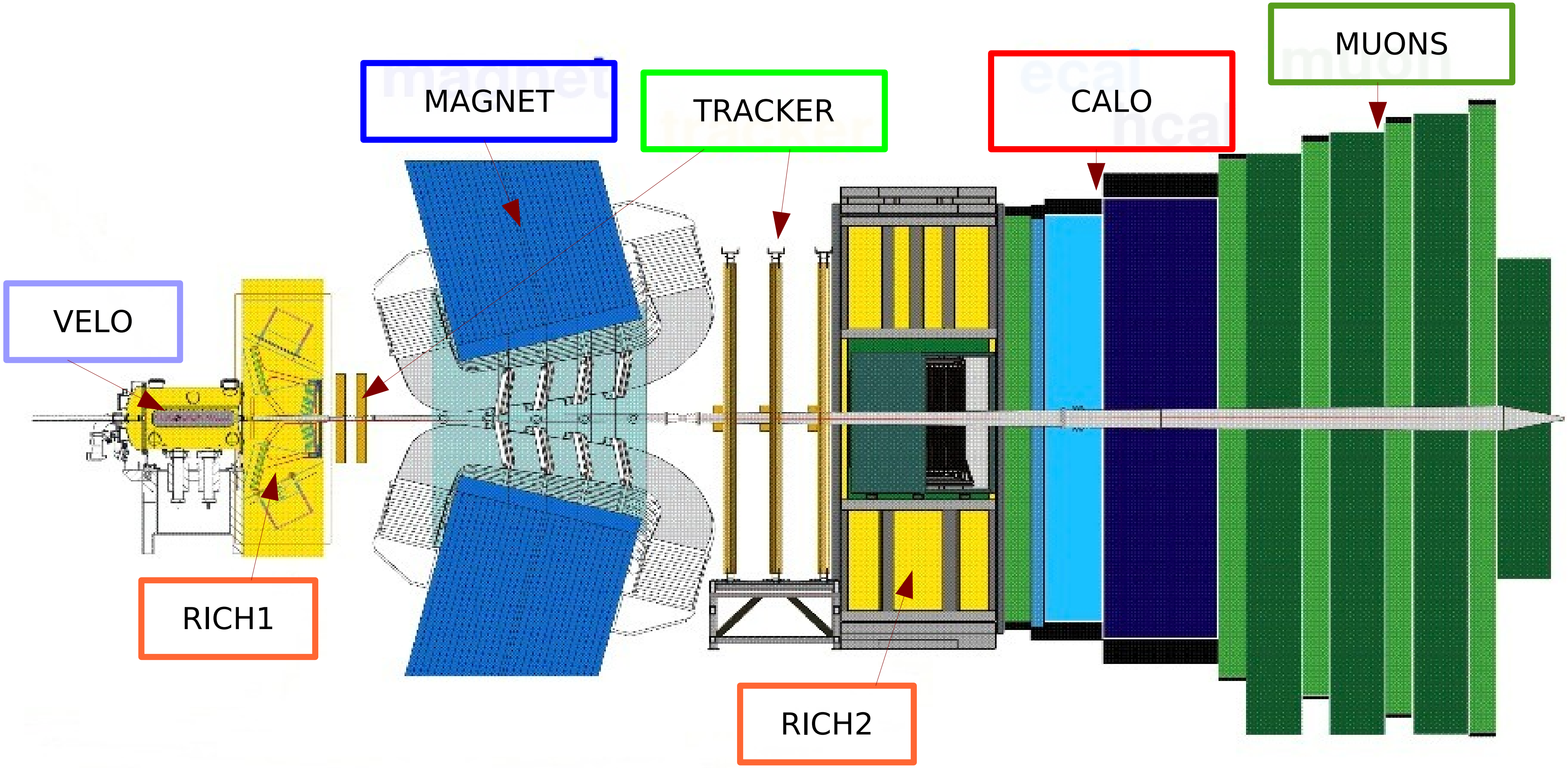
The LHCb detector



- Vertex locator (surrounding the IP)
  - At present → strips detector
- Magnet (~4Tm)
- Tracking stations
- Particle identification based on
  - 2 RICH
  - Calorimeter system
    - ECAL/HCAL/SPD/PS
  - Muon system

LHCb calorimeter system: SPD, PRS, ECAL, HCAL

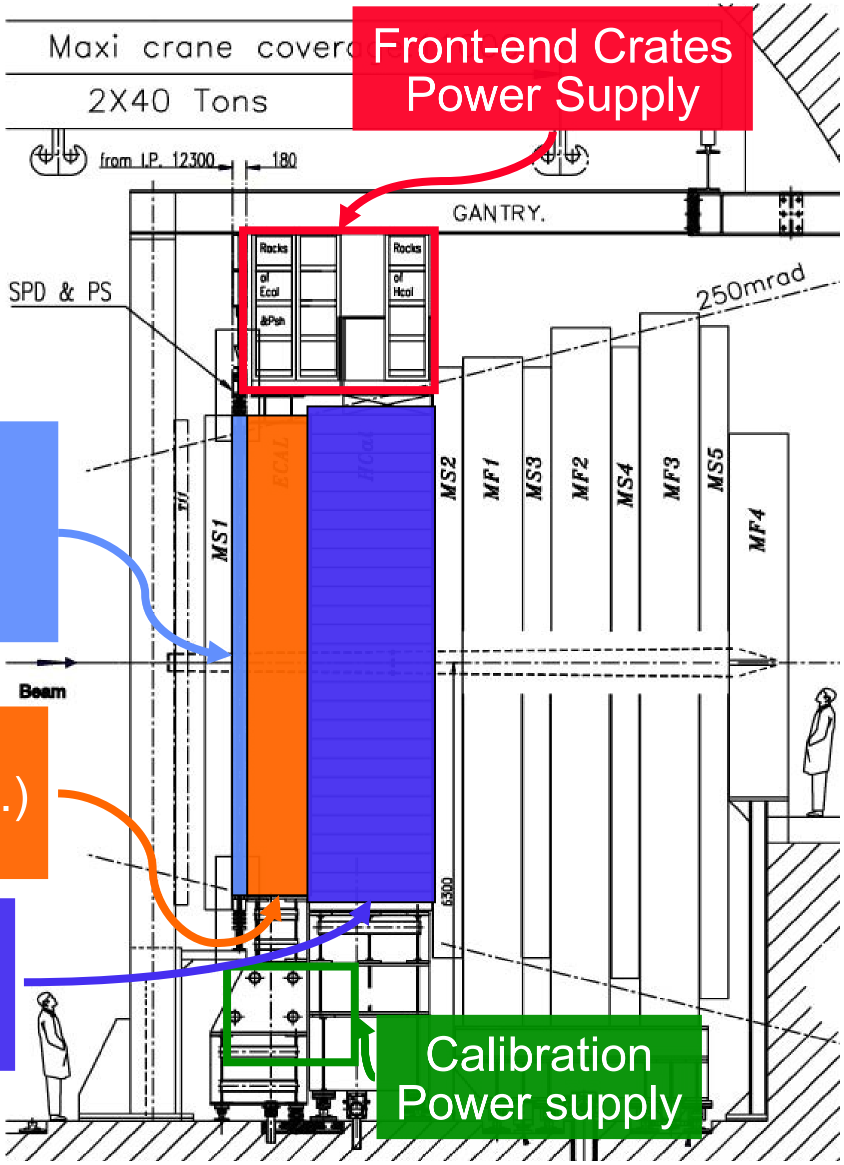
- Requirements:
  - Energy/position measurement
  - Identification of γ, electrons, hadrons
  - High sensitivity
  - Fast response (40MHz)
    - Clean sampling in 25ns (no spill-over)
  - L0 trigger input

Scintillating Pad Det (SPD)
Preshower (PS)
Scint. Pad + Fibres+ MAPMT
6016 cells each

ECAL
Shashlik (Pb-scint.)
6016 cells

HCAL
Tiles (Iron-scint.)
1488 cells

Front-end partly common



Upgraded LHCb calorimeter system: ECAL, HCAL

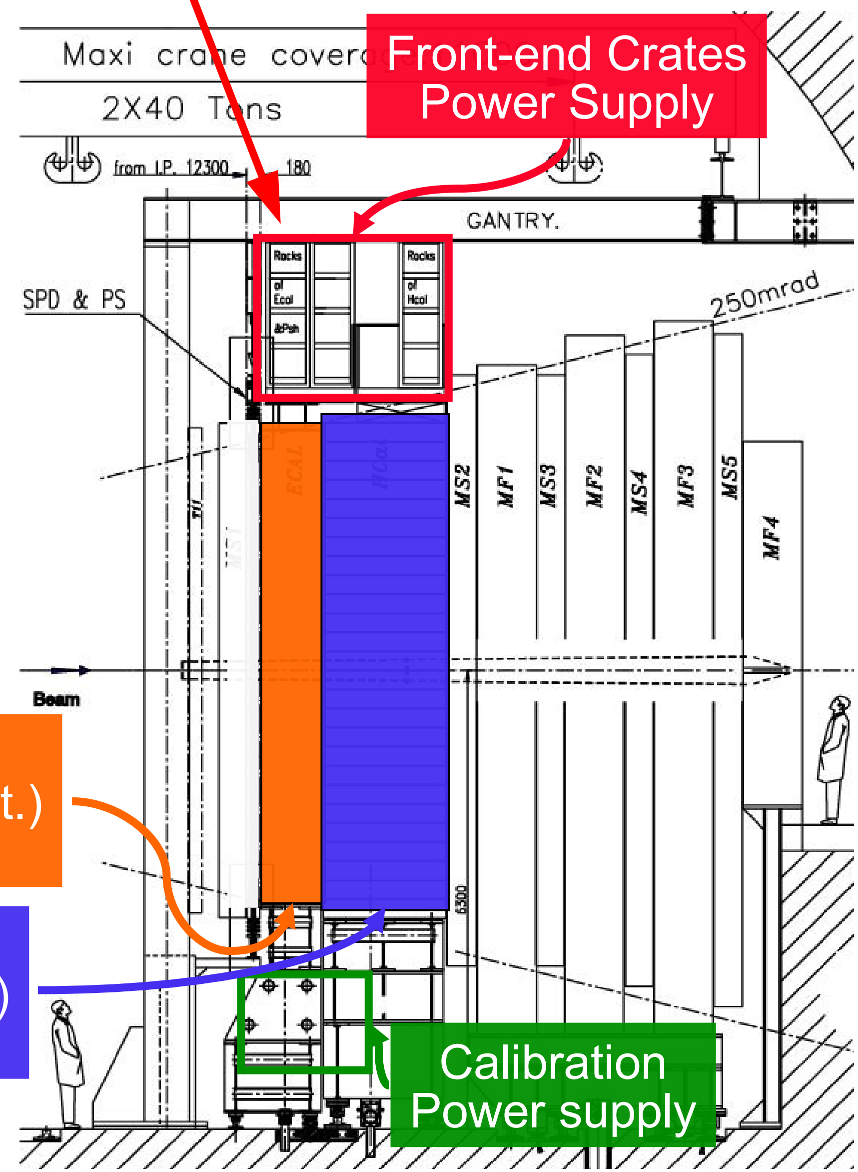
Expected dose in the electronics area ~ 100rad/fb^{-1}
(estimated from simulations)

- SPD/PS/Lead are removed
  - Trigger
    - No real need with HLT-upgrade
  - Particle identification
    - Compensated by better tracking
    - Calorimeter resolution should improve
    - ECAL calibration easier without PS

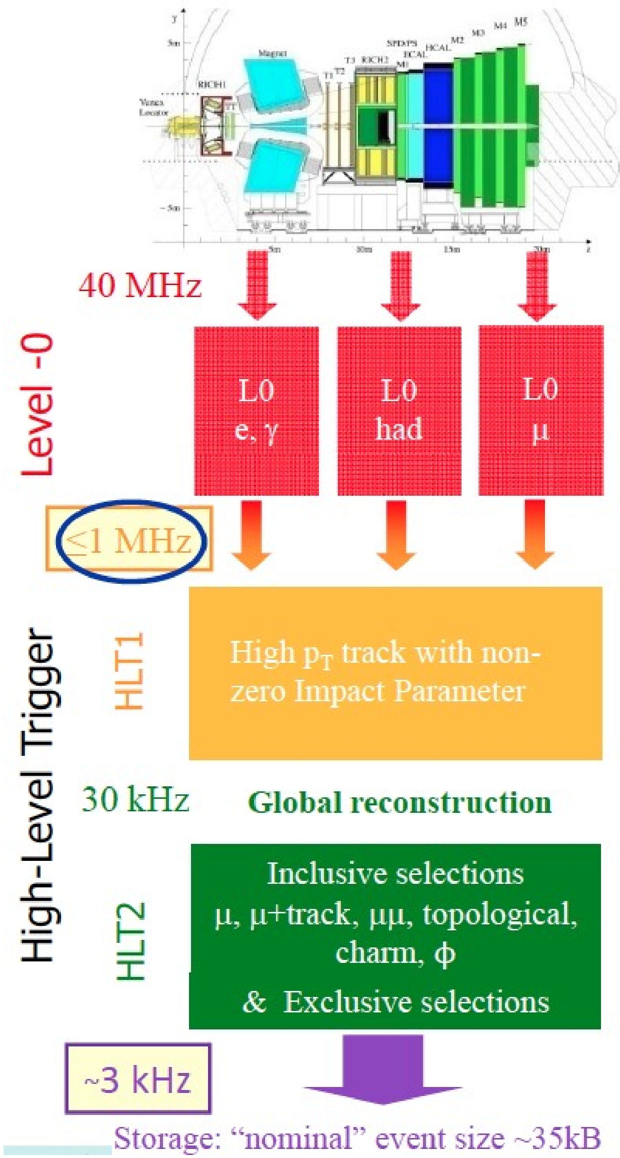
Common Front-end

ECAL
Shashlik (Pb-scint.)
6016 cells

HCAL
Tiles (Iron-scint.)
1488 cells

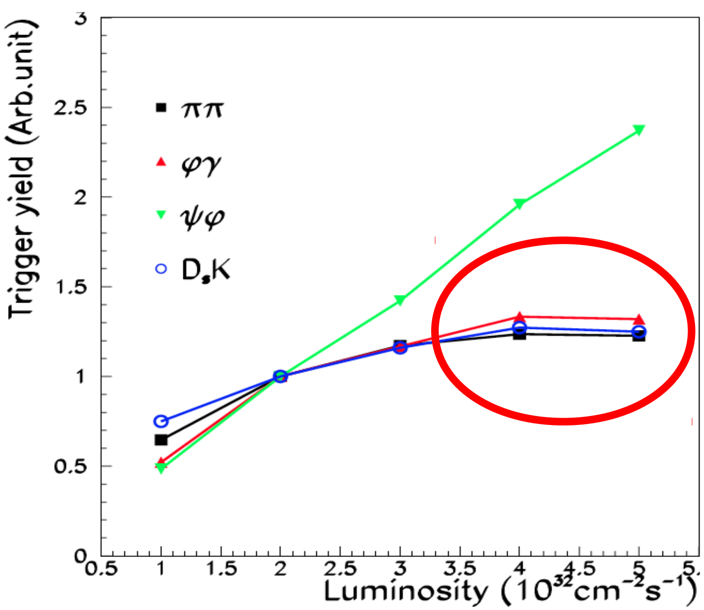


The current trigger

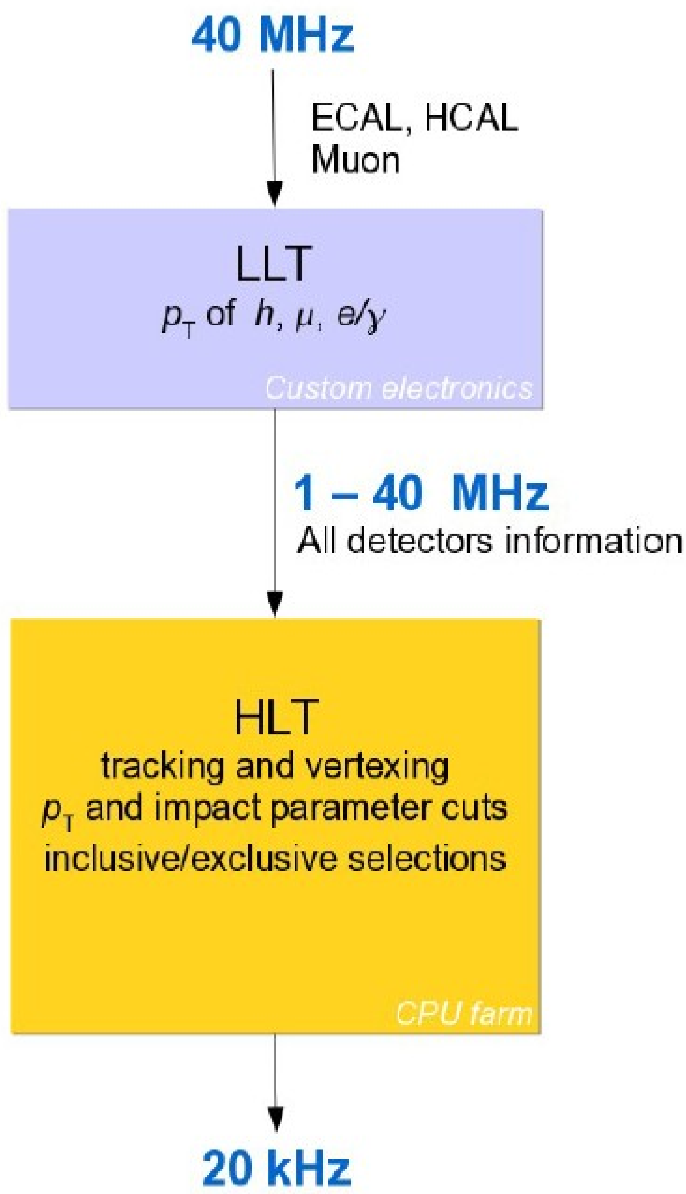


HLT « Trigger software » : 29000 CPU running the same code as the offline reconstruction

- The acquisition rate is limited to 1MHz
  - Interaction rate (~12MHz) is reduced to 1MHz by a hardware trigger (L0)
    - L0 decision based on
      - High Pt particles (Calo and Muon)
        - Electrons, photons, hadrons
        - Muons
- The 1MHz « bottleneck » is an efficiency limitation for the detector if we want to run at a high instantaneous luminosity
  - Especially for hadronic channels



The upgraded trigger

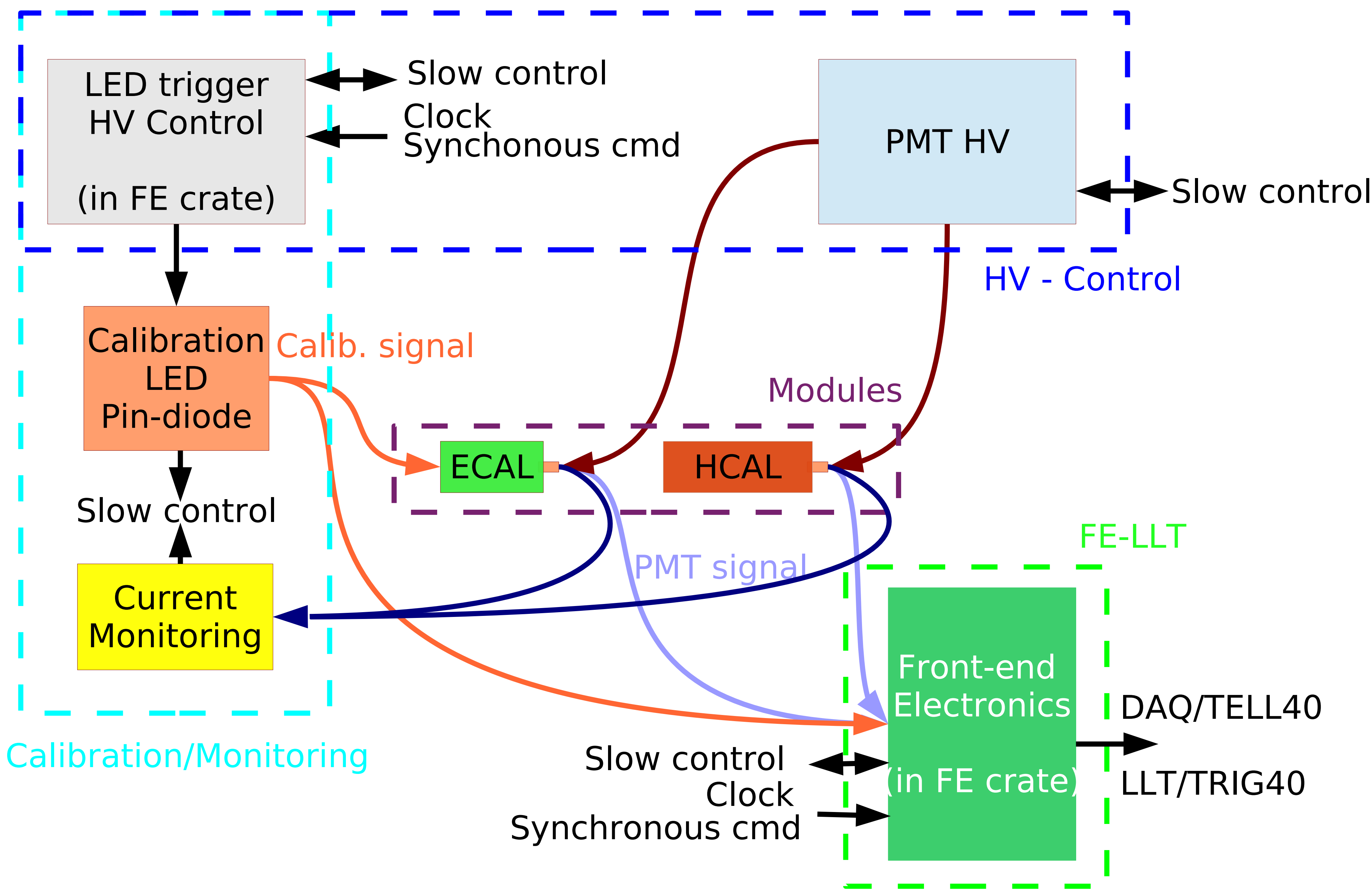


- Remove the L0
  - Fully software trigger
    - efficient : full detector information
    - Flexibility : can be easily adapted
- Still keep a low level trigger (LLT)
  - Adjust the bandwidth between 1 and 40MHz
  - LLT is similar to L0 with tunable thresholds
  - Requested by
    - Progressive increase of the PC farm size
    - Throttling mechanism in case of trouble
- Replacement of the front-end electronics and implementation of a 40MHz readout

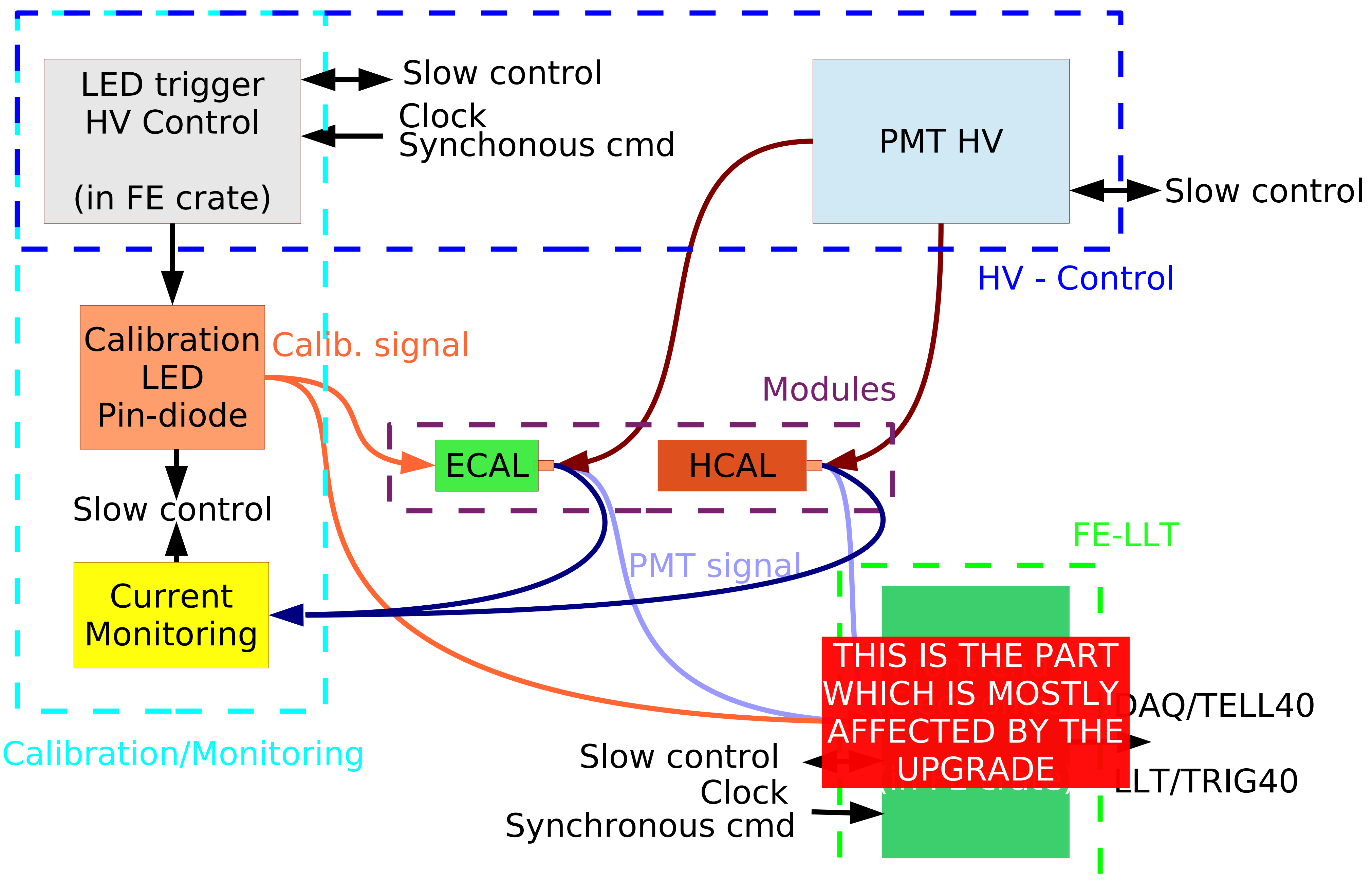
Scope of the Upgrade of the calorimeter

- The upgrade consists of
  - running the experiment up to $2x10^{33}cm^{-2}.s^{-1}$
    - x5 with respect to max reached (2012)
  - Integrate up to $L=50fb^{-1}$
- Scope of the upgrade – what is (un)changed ?
  - On the detector side:
    - most of the modules are kept → some modules (inner region) replaced (LS3)
    - PMT → a reduction factor is applied on the gain to keep them alive
    - Cockcroft-Walton bases (and PS) , signal cables, etc... are kept
    - Remove the SPD, PRS and Lead absorber
  - On the balcony:
    - Keep the crates, backplanes, power supplies,...
    - Replace the Front-end electronics (GBT 40MHz readout)
      - Make it compliant with the crates, power supplies, ...
    - Keep the L0Calo electronics → modified to be a LLT-Calo
  - Counting room:
    - TELL1 → TELL40 (GBT)
    - Slow control : GBT

Schematics of the Calorimeter system



Schematics of the Calorimeter system



Resources

- Manpower
  - The groups involved are
    - **Barcelona**, **IHEP**, **INR**, **ITEP**, **Orsay**, Annecy, **Bologna**
  - Barcelona: 2.5 FTE + physicist contribution → analog electronics
  - Orsay : ~2 physicistq + 2x0.5FTE (engineers) + punctual needs (CAO) → digital
  - IHEP/INR/ITEP: 1p+ for HV/Monitoring/calibration system – 2p. For CW/PMT
  - Bologna: 1 engineer → optical mezzanine (GBT)

- A small group of (very motivated) people is involved
  - Very few physicists → many aspects are not covered (pile-up, reconstruction)

- Budget
  - The cost of the project has been presented to the funding agencies
    - France, Italy, Spain
  - Italian colleagues did not manage to get the support from their agencies.
    - The group from Bologna still wish to develop the mezzanine

- TDR should be ready by the end of the year
- Front-end board
  - Analog
    - Choice of the technology (ASIC/COTS) → beginning of 2014
    - Final prototype → 2014-Q1
    - Analog PRR → 2014-Q3
  - Digital board
    - Final prototype (32 channels) → beginning of 2014
    - FEB PRR → 2015
- Control Board
  - Design starts from Autumn 2013
  - First prototype to be launched at the beginning of 2014
  - Control Board PRR → 2015

Year	Energy	Int. Lumi.
2010	7 TeV	37 pb^{-1}
2011	2.76TeV	71 pb^{-1}
2011	7 TeV	1.0 fb^{-1}
2012	8 TeV	2.2 fb^{-1}
2013	LHC splice repair	
2014		
2015	13 TeV 25 ns bunch crossing	>5 fb^{-1}
2016		
2017		
2018	LHCb upgrade	
2019	5-10 fb-1/year	
2020		
2021		
2022	LHC lumi upgrade	
2023		
2024		

Summary

- Radiation effect → still in specifications up to 20fb^{-1}
  - Studies ongoing to
    - Predict high luminosity effects (after a few years of running)
    - Cope with them → replacement of a few (inner) modules during LS3
  - Expect improvement from the upgraded monitoring system
- Baseline is no SPD/PS
  - Limited degradation of the particle identification
    - with a "pessimistic" MC sample
  - Far easier calibration of the calorimeter
  - Should be helped by the upgraded tracker
- Pile-up is a problem but should be fine in outer and middle regions
  - Performances slightly degraded in a limited acceptance

- Front-end electronics fully re-designed
  - Full software trigger → readout at 40MHz
  - PMT gain reduced by a factor 5
  - L0 Calo adapted for the LLT-Calo

} Scope of the review

- TDR to be written by the end of the year