PhD project:
Design and Implementation
# of the CMS Phase-2 Global L1 Trigger

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September 2020

Context

- **CMS is upgrading its Level-1 Trigger system for Phase-2 (due to start in 2027)**

- **A Technical design report for this upgrade has been submitted in 2020**
  - http://cds.cern.ch/record/2714892/files/CMS-TDR-021.pdf
  - See especially sections 3.7 and 5.6 about the Global Trigger system and
  - Chapter 4 about the Trigger Menu

- **Over the coming years, pre-production firmware covering the full functionality is being developed, tested and integrated**

- **The CERN EP/CMD group is responsible for building the Global Trigger System**
  - The global trigger implements the trigger menu of CMS consisting of O(1000) algorithms

CMS Level-1 Trigger for Phase-2
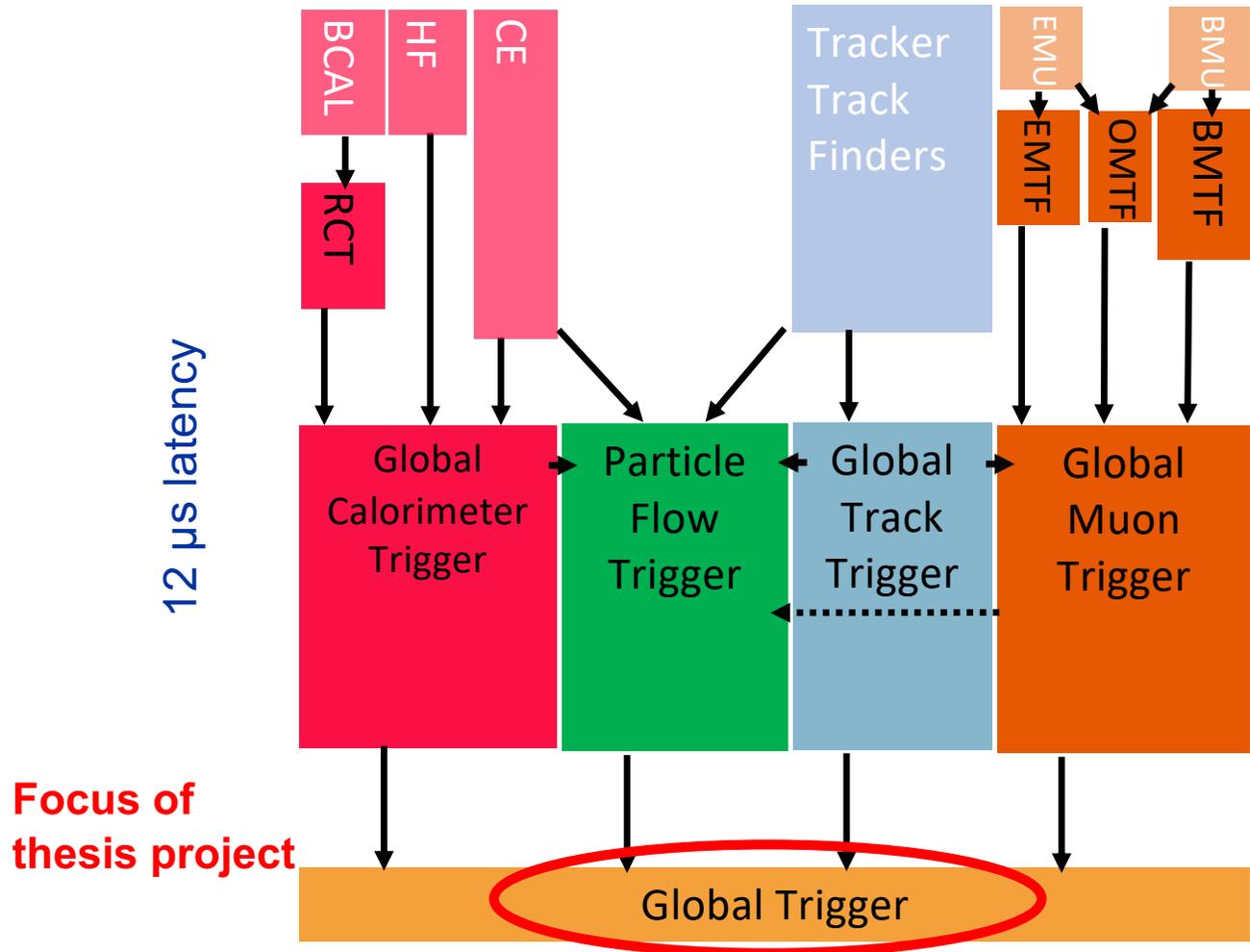
New in Phase-2: high resolution objects

- Tracker track reconstruction in firmware
- Vertex finding
- Kalman filter muon reconstruction
- Displaced muons
- High precision calorimetry
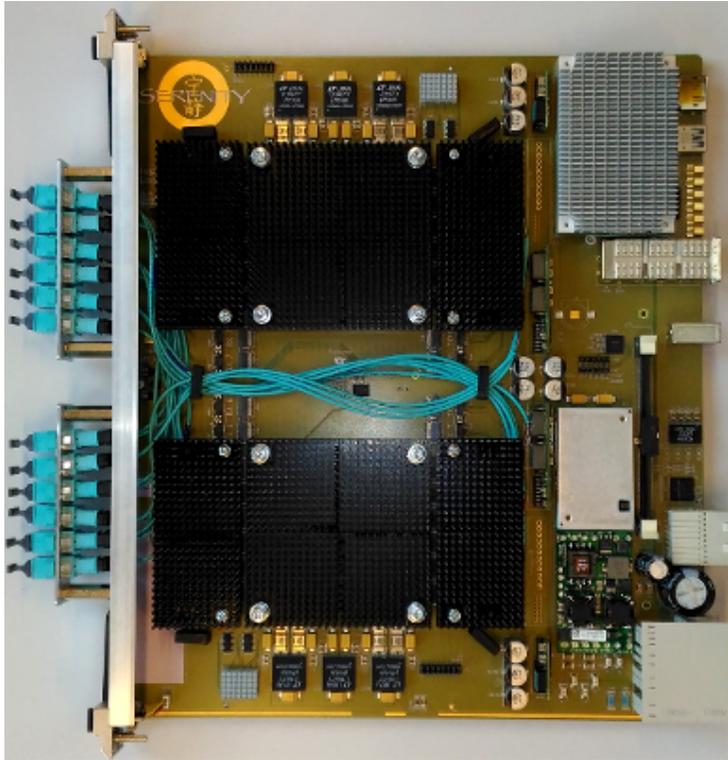- Particle flow reconstruction

At the Global Trigger:

- Topological algorithms including invariant/ transverse mass cuts
- Machine learning algorithms
- Inter-bx algorithms (limited to +/- 3 bx)

CMS Global Trigger Architecture for Phase-2
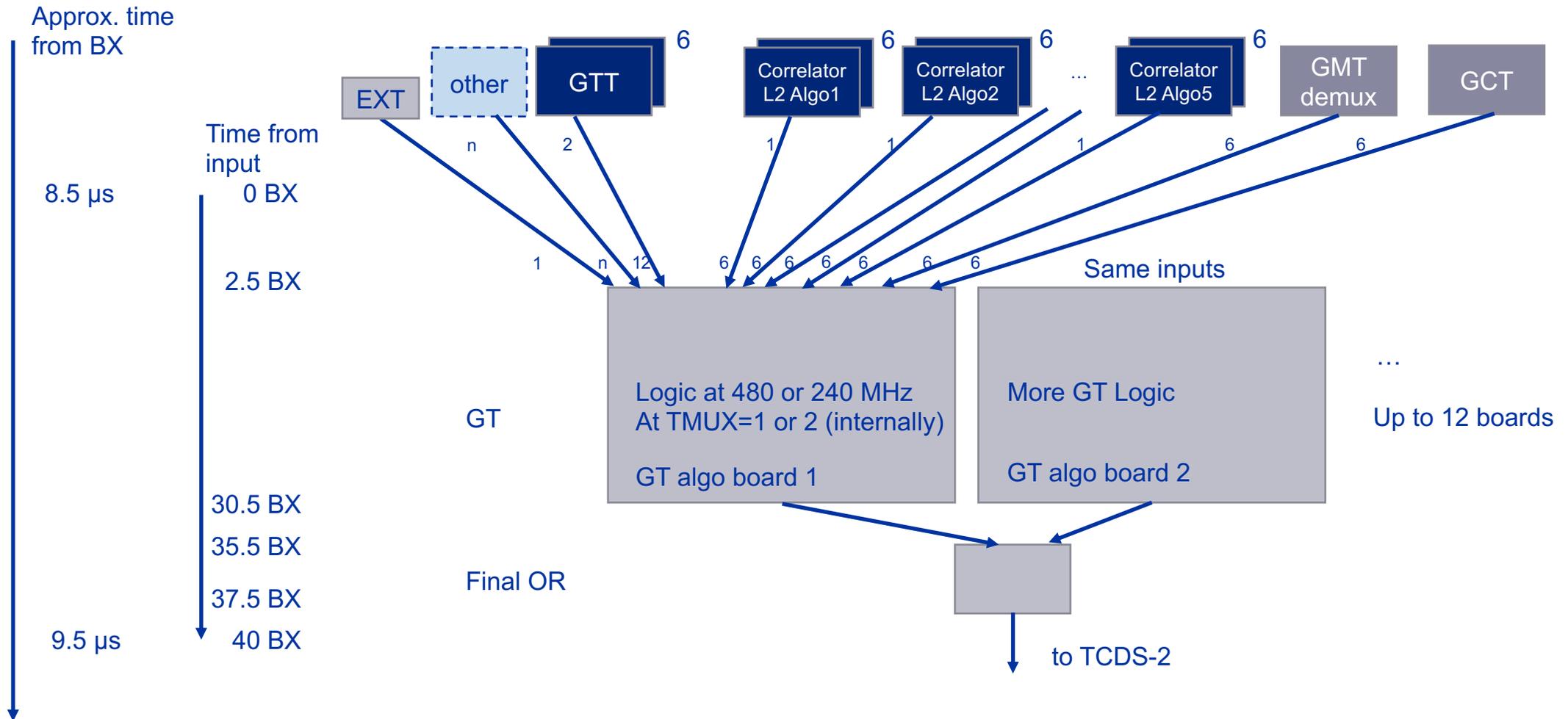
Example Target Hardware

SERENITY

Imperial College Serenity board with Xilinx
Ultrascale+ Field Programmable Gate Arrays (FPGAs)

Global Trigger Algorithms

Basic menu

- Single/Double/Triple Lepton (electron, muon) seeds

- Photon seeds

- Taus seeds

- Hadronic seeds (jets, H_T)

  - E.g.: Single, double, quad jets, H_T

- E_T^{miss} seeds

- Cross Lepton seeds

- Cross Hadronic-Lepton seeds

- VBF seeds

  - E.g.: Double Puppi jet with invariant mass cut

- B-physics seeds

  - E.g.: Double / Triple Tracker muon with inv. mass cut

New algorithms

- Extended pseudorapidity leptons

- L1 soft and correlated muons

- Light mesons with L1 tracking

- Displaced muons

- Displaced jets

- Displaced tracker jets

- Displaced jets using timing information

- VBF Higgs boson production and other L1 trigger algorithms based on machine learning techniques

Description of the thesis project

- **Study of trigger algorithms at the Global Level-1 Trigger of the CMS Phase-2 upgrade**
  - Simulation (C++, Python) to be developed
  - Physics topic(s) to be decided

- **Study of efficient implementation in FPGA firmware at 240 or 480 MHz clock frequency**

- **Implementation of trigger algorithms in FPGA firmware**
  - using VHDL & possibly Xilinx High Level Synthesis

- **Study of workflows to dynamically generate firmware images for changing trigger menus**

- **This project is in the framework of the CERN Doctoral student programme :
  If successful, you will receive an allowance to stay at CERN for up to 36 months**

Your profile

- **(Particle) physics student with Master's degree**

- **Solid experience in software development (C++)**
  - Ideally fluent in git, Continuous Integration

- **Experience or strong interest in developing firmware of modern FPGAs**

- **Eligible for the German Gentner or Austrian CERN Doctoral Student programme**
  - https://careers.cern/special-programmes

Eligibility Conditions
- **German national or national of an EU country**, which also needs to be a CERN Member Country (Member State or Associate Member State)
- Enrolled (or to be enrolled) at a **German university** during the Scholarship
- Graduated (Master degree) and **eligible for doctoral studies** when starting at CERN
- Good knowledge of English **or** French

Gentner Programme

- Application Deadline: 19 October, 2020

The team

- **At CERN EP/CMD (Firmware / Software / Workflows / Over-all system design)**

  - Hannes Sakulin (Hannes.Sakulin@cern.ch) ⎤
  - Dinyar Rabady (Dinyar.Rabady@cern.ch) ⎦ supervising algorithm implementation, firmware, workflow development, tests
  - You

- **At University of Zuerich (Algorithm physics studies)**

  - Cristina Botta (Cristina.Botta@cern.ch) - supervising algorithm studies
  - Several PhD students

- **CMS L1 Trigger group**

  - World-wide collaboration including
    - Imperial College, London, UK (hardware design)
    - HEPHY Vienna, Austria (designers of the current CMS L1 Global Trigger)

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