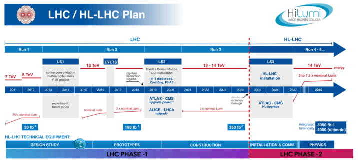
Imperial College London

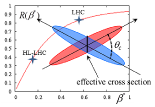
System Design and Prototyping for the CMS Level-1 Trigger at the High-Luminosity LHC

Alex Tapper for the CMS Collaboration

The Phase-2 Upgrade of the CMS Level-1 Trigger
CERN-LHCC-2020-004; CMS-TDR-021
http://cds.cern.ch/record/2714892

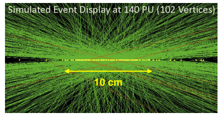
Introduction to High-Luminosity LHC





- Initial LHC design luminosity 1x10^{34} cm^{-2} s^{-1} ➞ already exceeded by factor 2 in Run 2
- High-Luminosity era 5-7.5 x10^{34} cm^{-2} s^{-1} ➞ factor of 5 to 7.5 beyond design specification
- Accumulate 3000 - 4000 fb^{-1} ➞ extend physics reach

Detector challenges



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- HL-LHC 140-200 int/bunch crossing
- Higher pileup ➞ higher occupancy, degraded performance (e.g. failure of pattern recognition)

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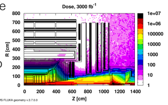

Run period	W→lν rate
Run1	80 Hz
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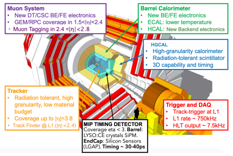
Run 3	400-600 Hz
HL-LHC	1KHz

- Current L1 trigger 4 MHz @ HL-LHC
- Increased particle flux ➞ high radiation dose
- Detector performance degraded ➞ lower response, higher noise

CMS Detector upgrade



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Over 200 m^2 of silicon
10^9 channels
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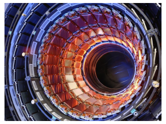

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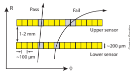

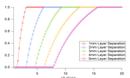

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- FPGA-based track finding @ 40 MHz in 4 µs

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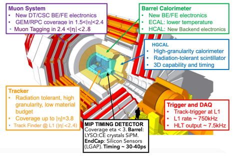

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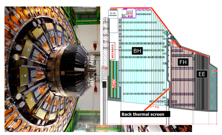

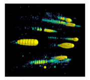

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ATCA based electronics R&D
Generic high I/O processing boards

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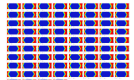

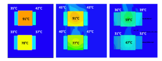

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  - Xilinx Virtex Ultrascale+ (VU9P) FPGA
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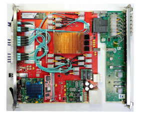

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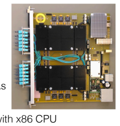

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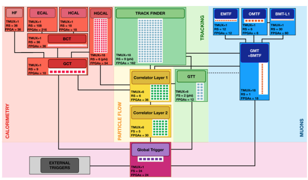

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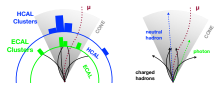

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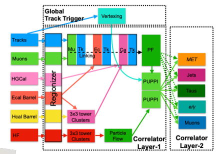

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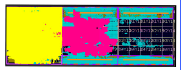

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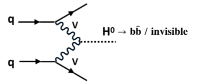

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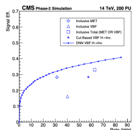

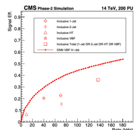

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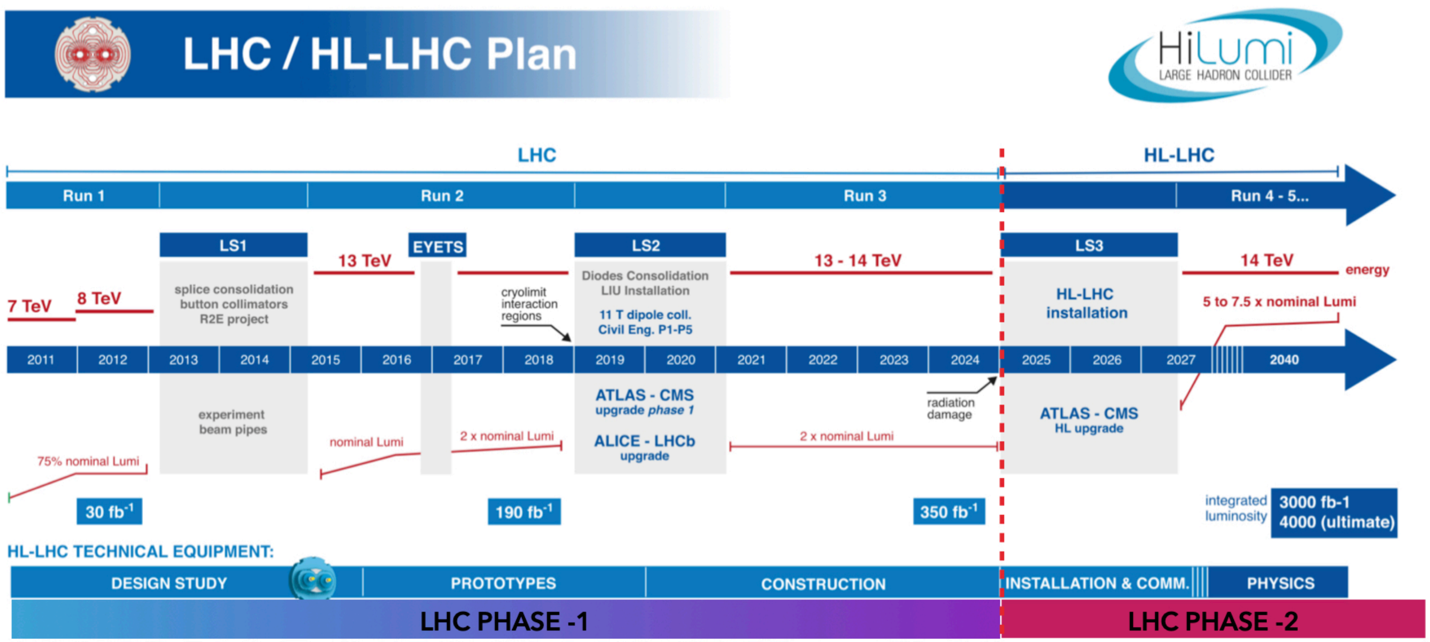

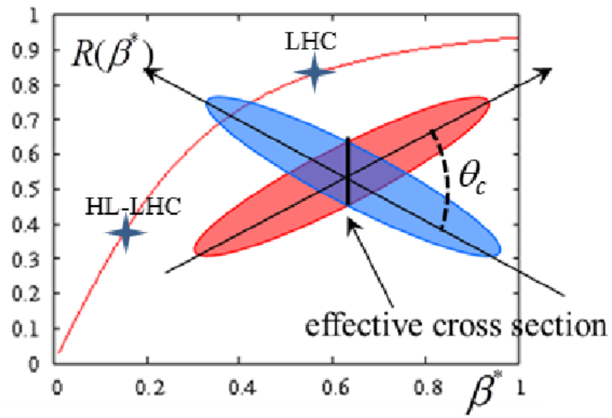

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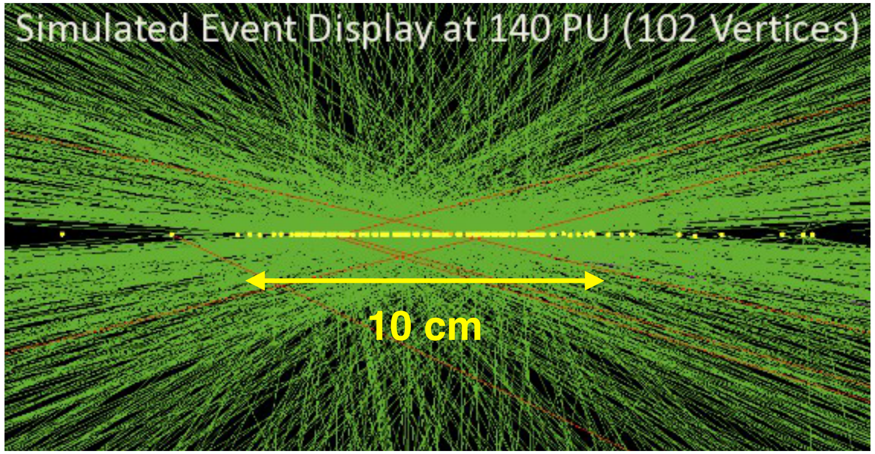

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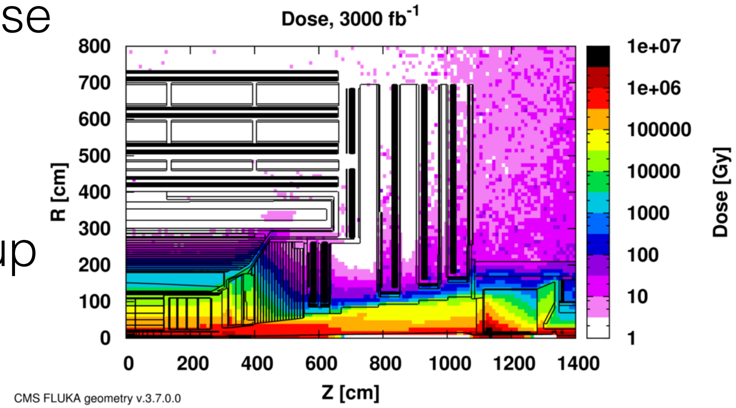

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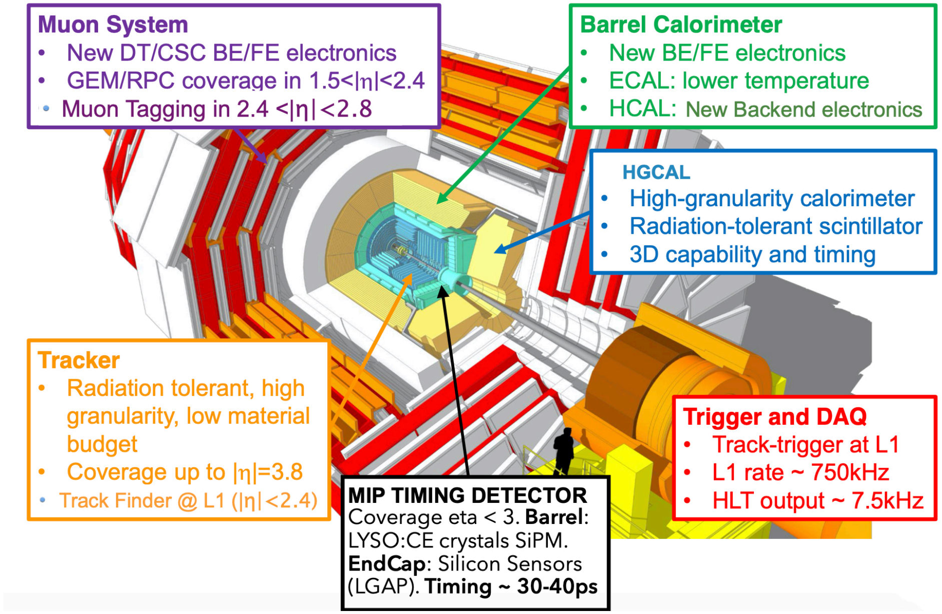

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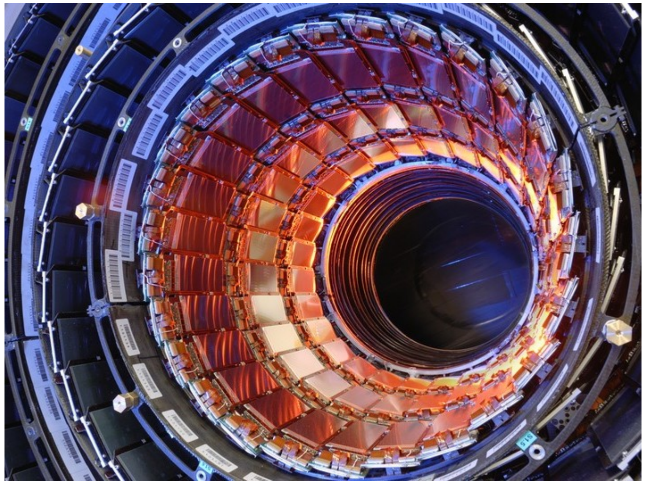

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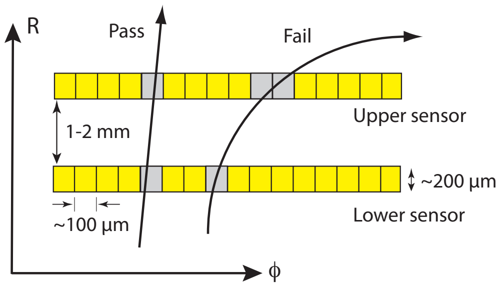

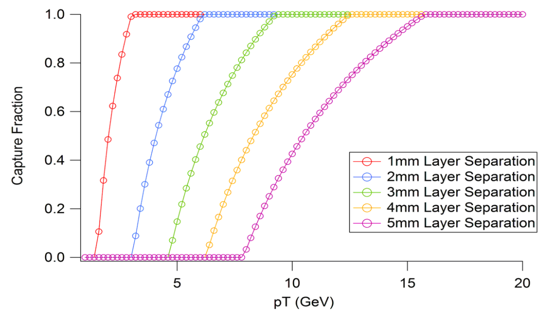

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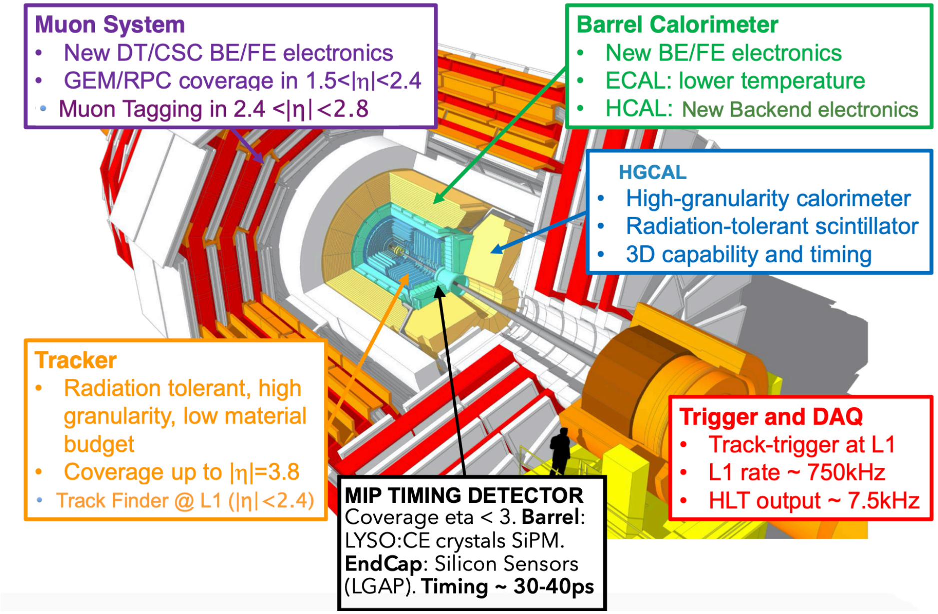

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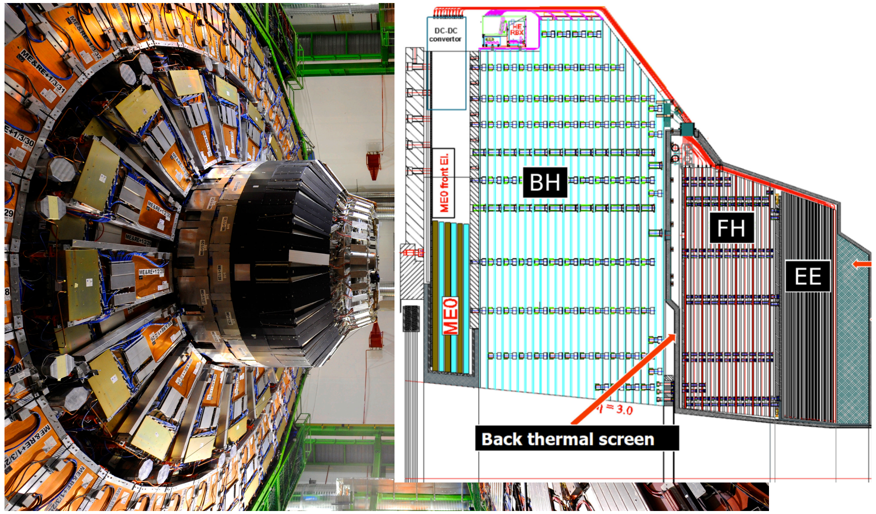

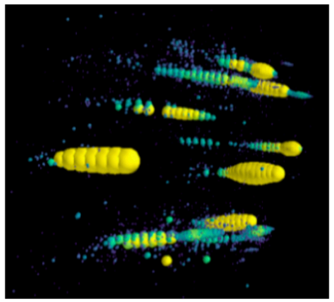

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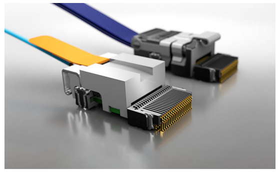
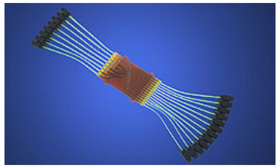

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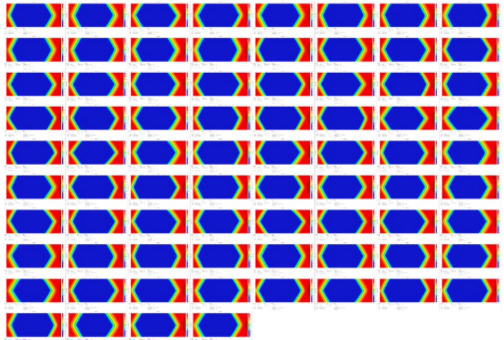

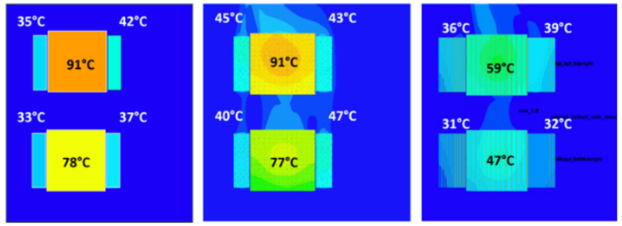

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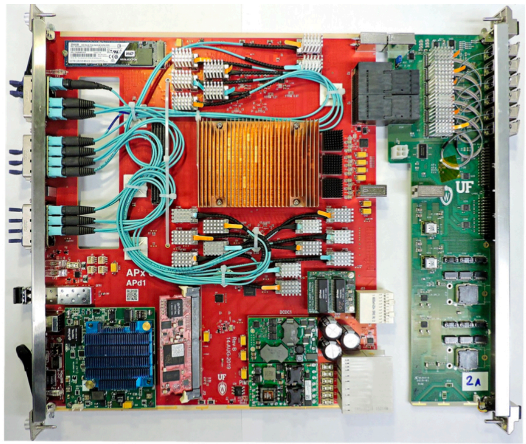

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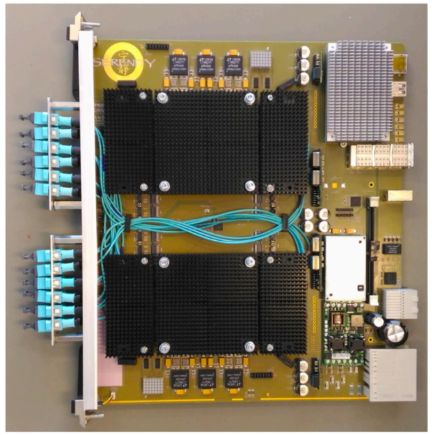

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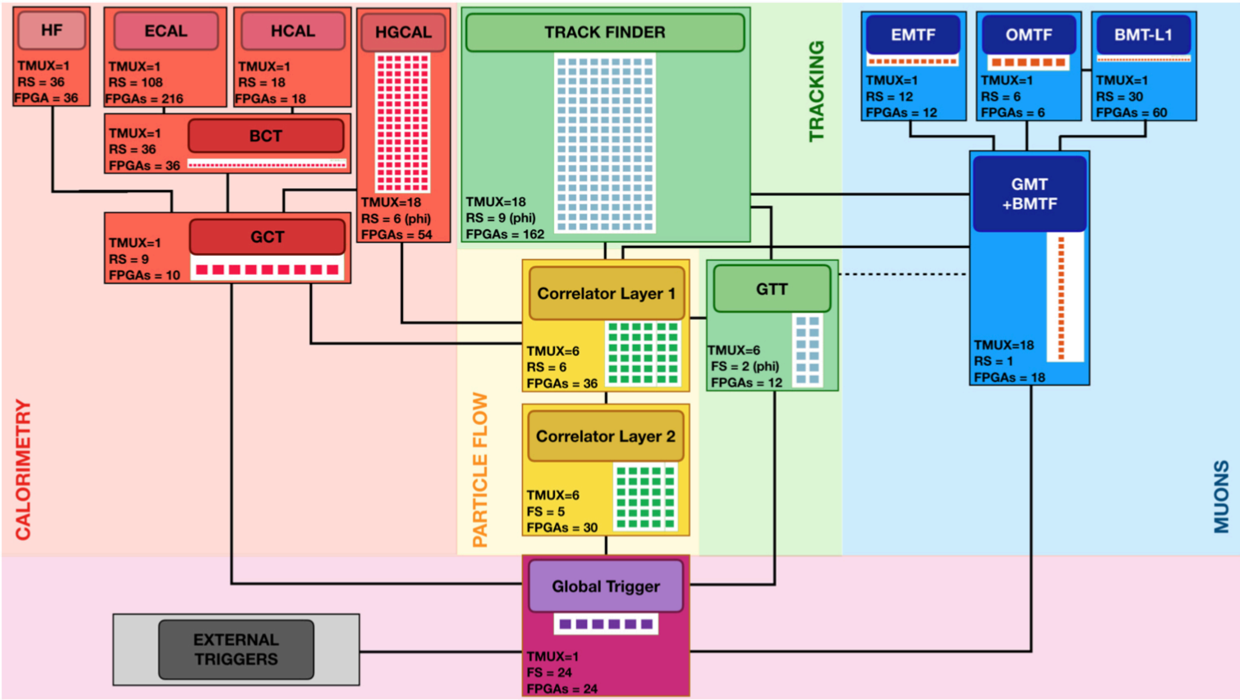

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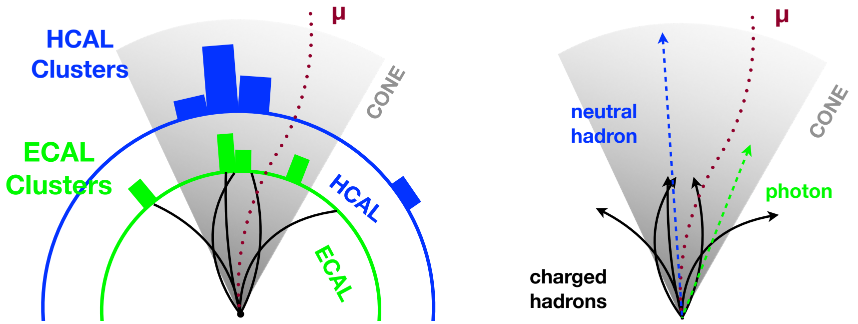

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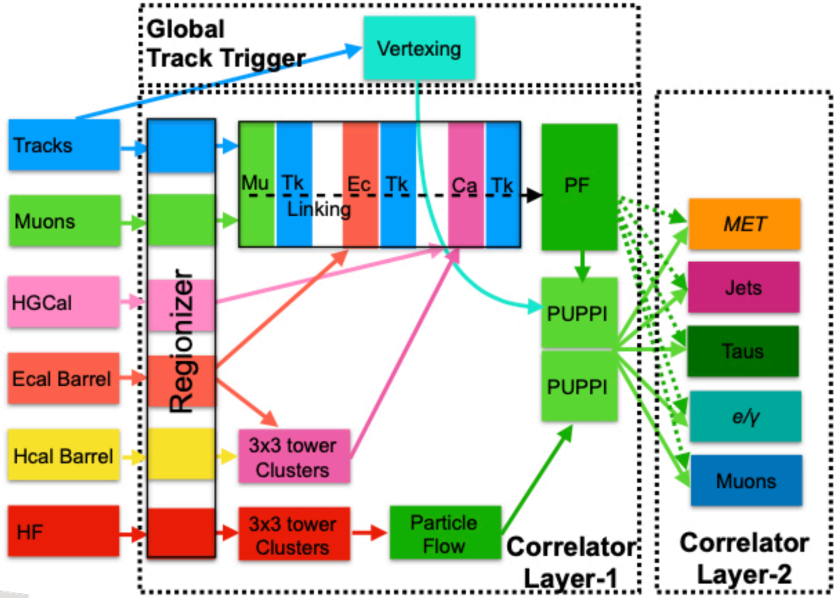

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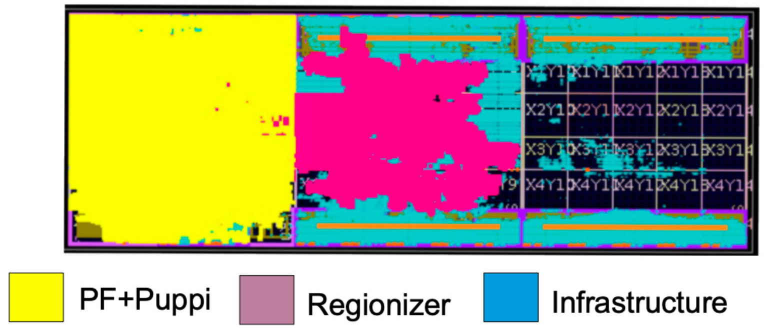

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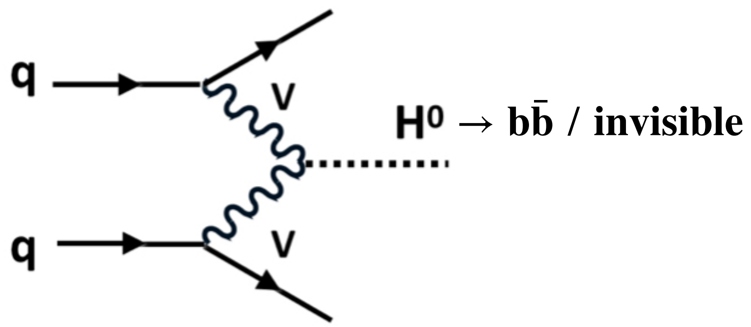

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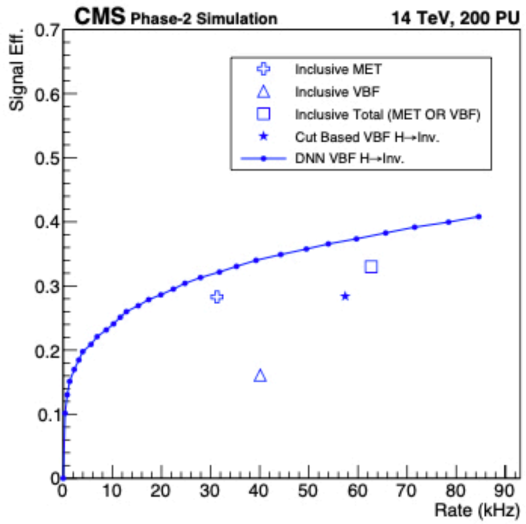
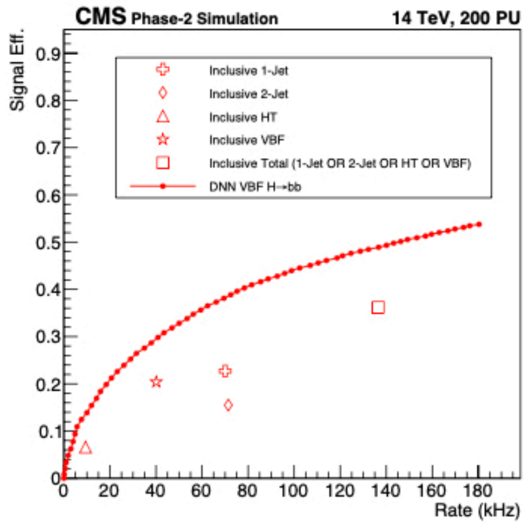
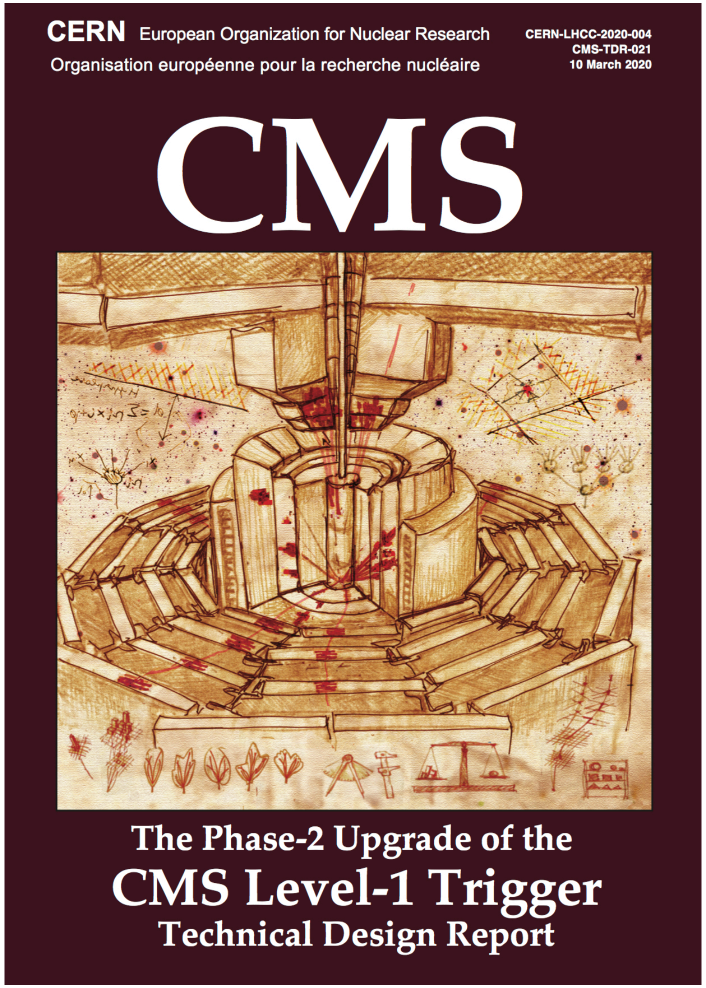
  - 4300 multiplications/inference
  - Latency ~0.5 μs DSP usage ~40% in VU9P





Further information



The Phase-2 Upgrade of the CMS Level-1 Trigger
CERN-LHCC-2020-004; CMS-TDR-021
http://cds.cern.ch/record/2714892