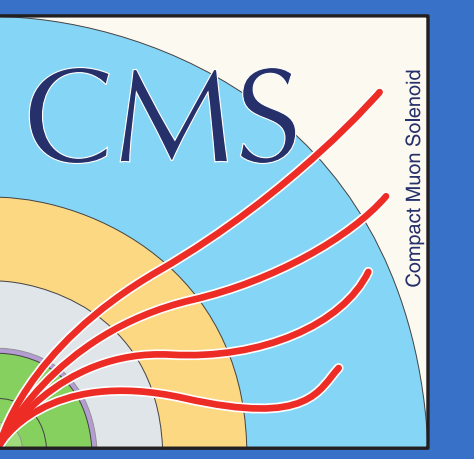# Design and Performance of the Phase I Upgrade of the CMS Global Trigger

Johannes WITTMANN*, Gregor ARADI, Bernhard ARNOLD, Herbert BERGAUER,
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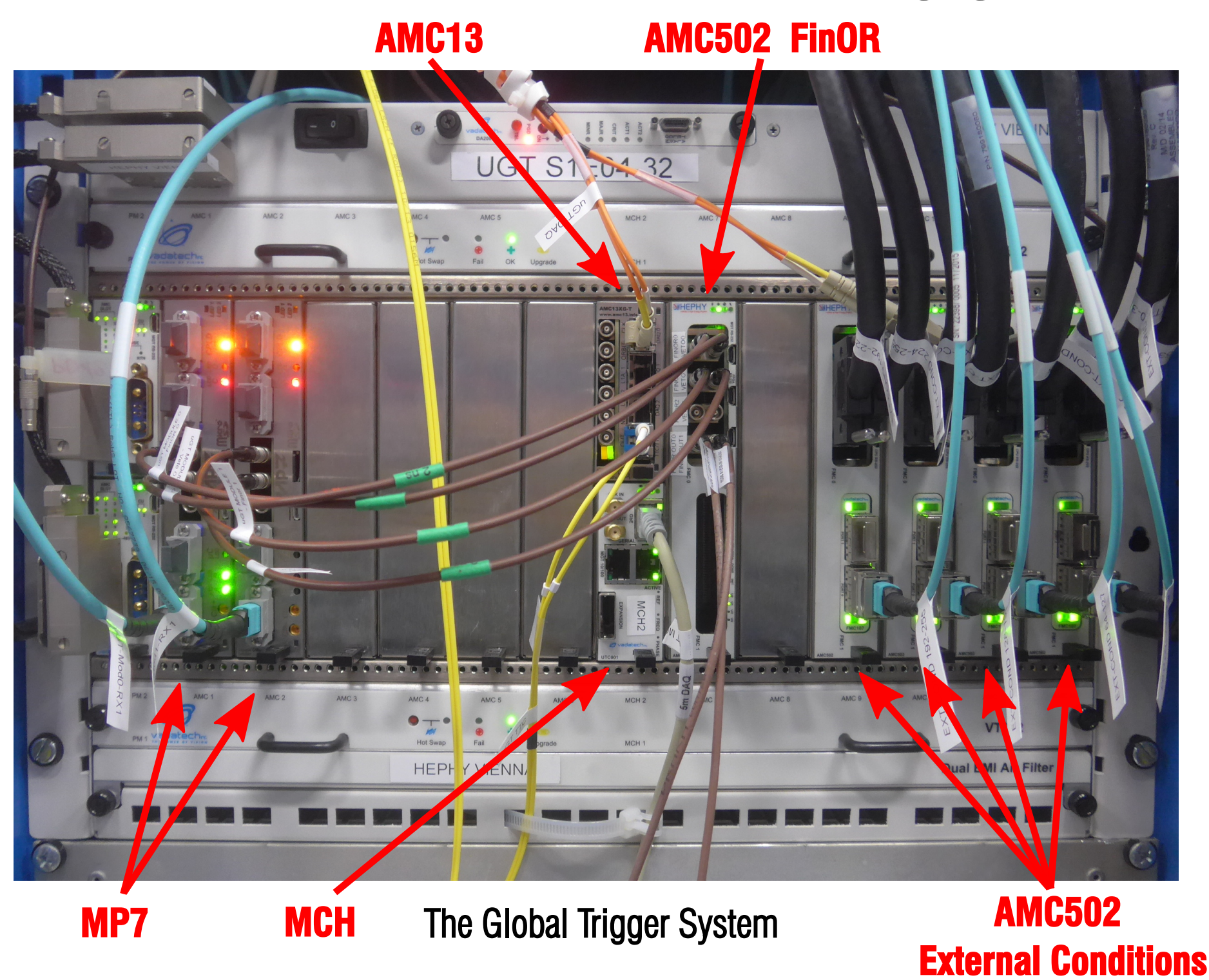**TWEPP 2016**

## CMS Level-1 Trigger

- The Phase I Upgrade of the CMS experiment allows the Level-1 Trigger to cope with the challenges of LHC Run-II. The Global Trigger (GT) is the final decision stage of the Level-1 Trigger.

- LHC increased its collision energy from 8 TeV to 13 TeV and the peak luminosity measured from CMS is now more than $1.2 \times 10^{34} cm^{-2} s^{-1}$. This leads to increasing pile-up (proton collisions during one bunch crossing). The Global Trigger is designed to adjust to this increase.
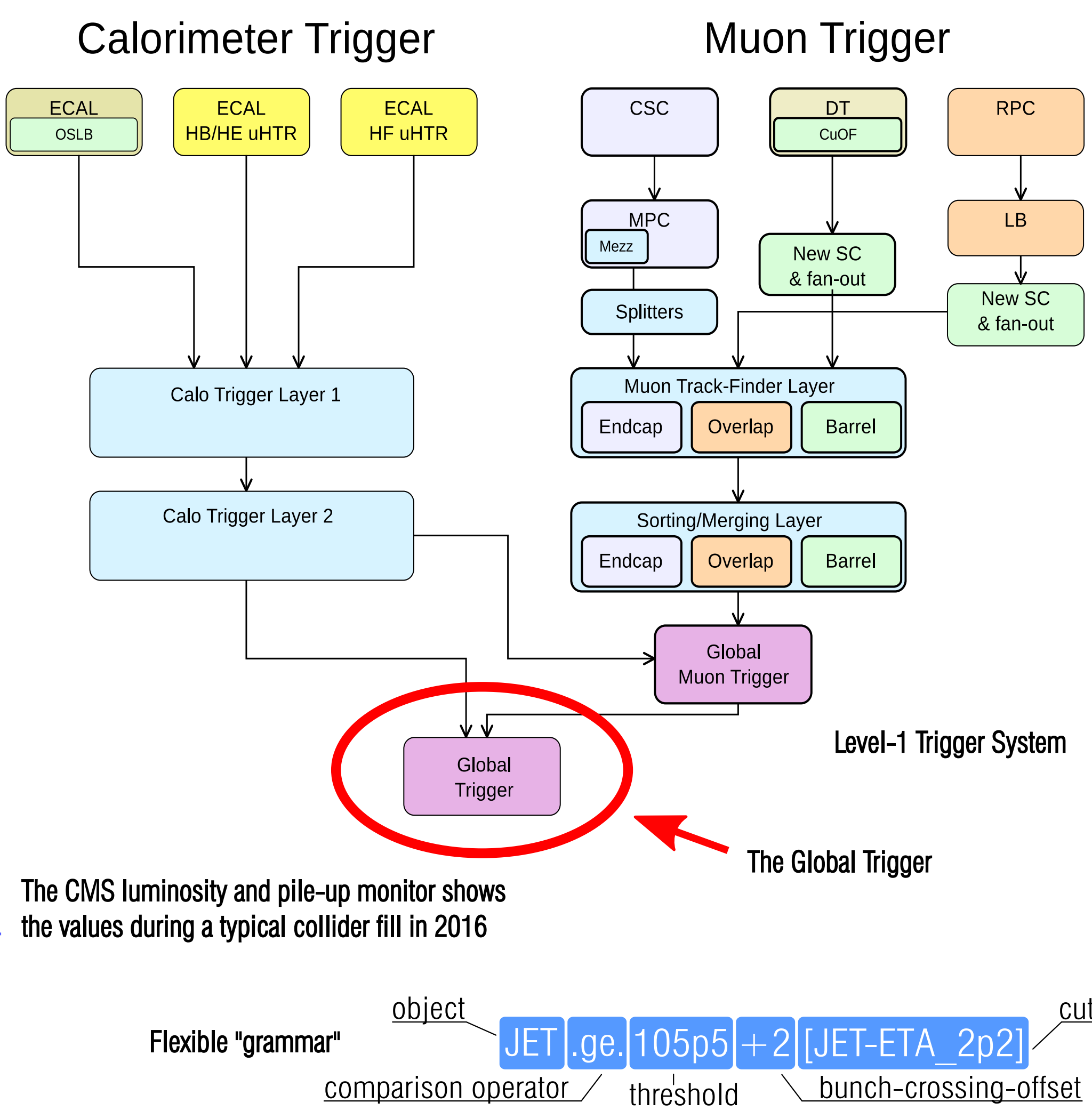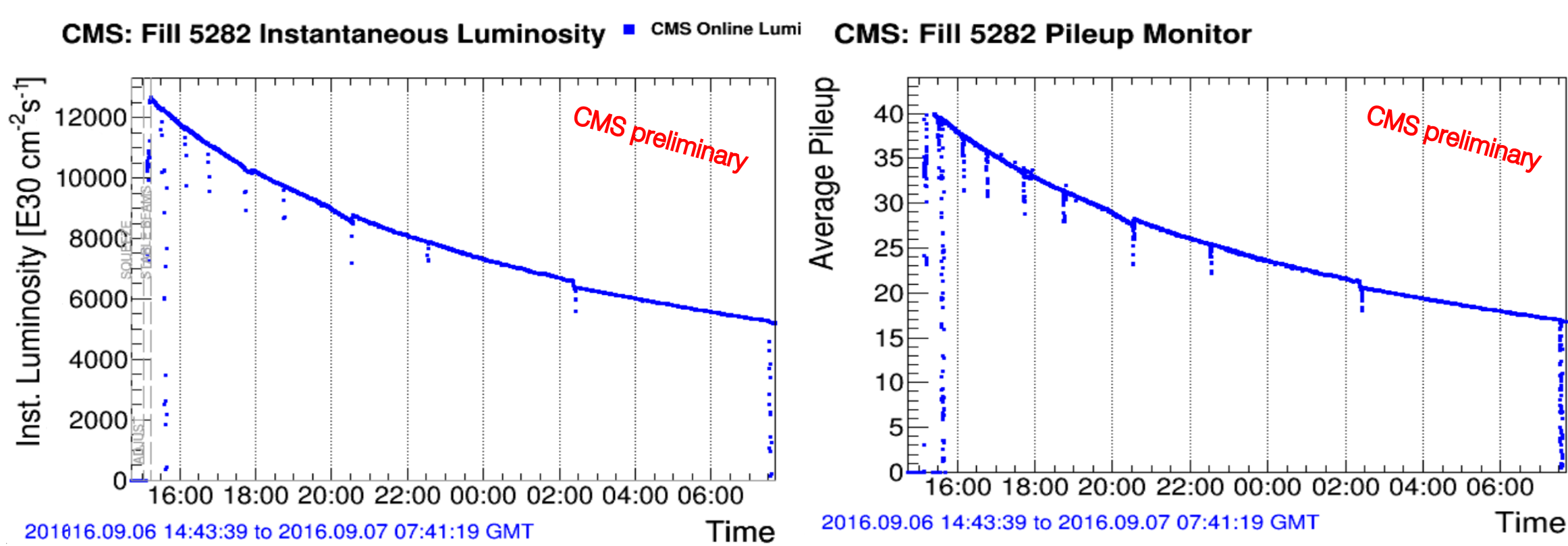


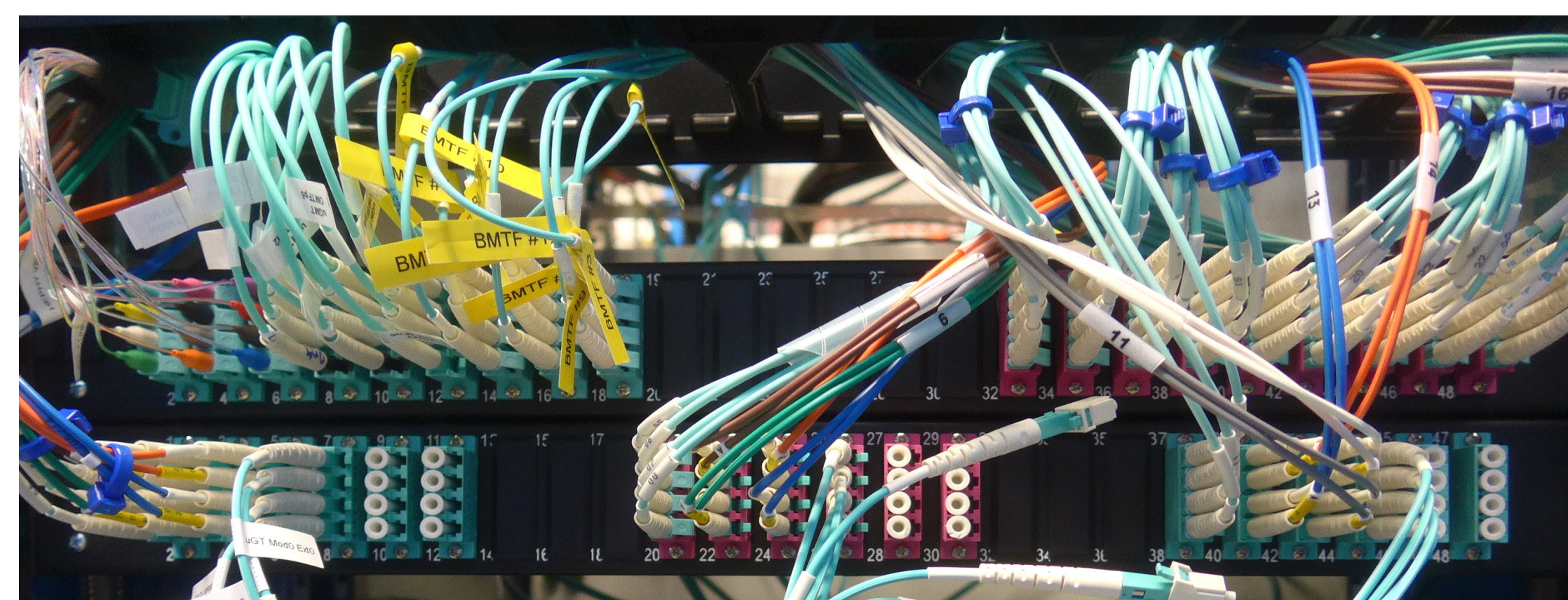The CMS luminosity and pile-up monitor shows the values during a typical collider fill in 2016

Flexible "grammar"
object — JET | comparison operator — .ge | threshold — 105p5 | +2 | cut — [JET-ETA_2p2] | bunch-crossing-offset

## The CMS Global Trigger: on the road to High-Lumi LHC



The Global Trigger System

- Scalable implementation using powerful XILINX Virtex-7 FPGAs on the MP7 module developed inside the CMS collaboration and the $\mu$TCA environment[1].

- Over 500 trigger algorithms are calculated in parallel and allow optimized triggering for each expected physics signal and scenario[2].

- Flexible "grammar" allows easy, menu-based development of trigger firmware by physicists[3].

- Several processor boards (up to six MP7 modules) can operate in parallel in one $\mu$TCA crate to multiply the GT's resources.

- A second $\mu$TCA crate was installed to serve as a test platform during physics runs or as a backup system for the Global Trigger.

- The majority of the interconnections in the trigger system are realised with fast optical fibres (10 Gbps). Complex optical patchpanels are installed between the different subsystems.

- A special AMC card (AMC502) and several different mezzanine boards have been developed both for input of binary trigger signals and for merging the output from several MP7 boards into one final trigger signal[4].



Optical patchpanels guarantee the correct transfer of the physics data

## Run 2016

- The whole new uTCA based Level-1 trigger system was put into operation in early 2016.

- CMS has successfully taken 30fb$^{-1}$ already with this system.

- The first implementation of the Global Trigger using more than one MP7 module was commissioned in September 2016. All results show a perfect agreement of the installed hardware and the software emulator.

- Possible to run with completely different setup for heavy-ion running to adapt to different requirements.

- Flexibility has allowed us to make frequent adaptations to running conditions.
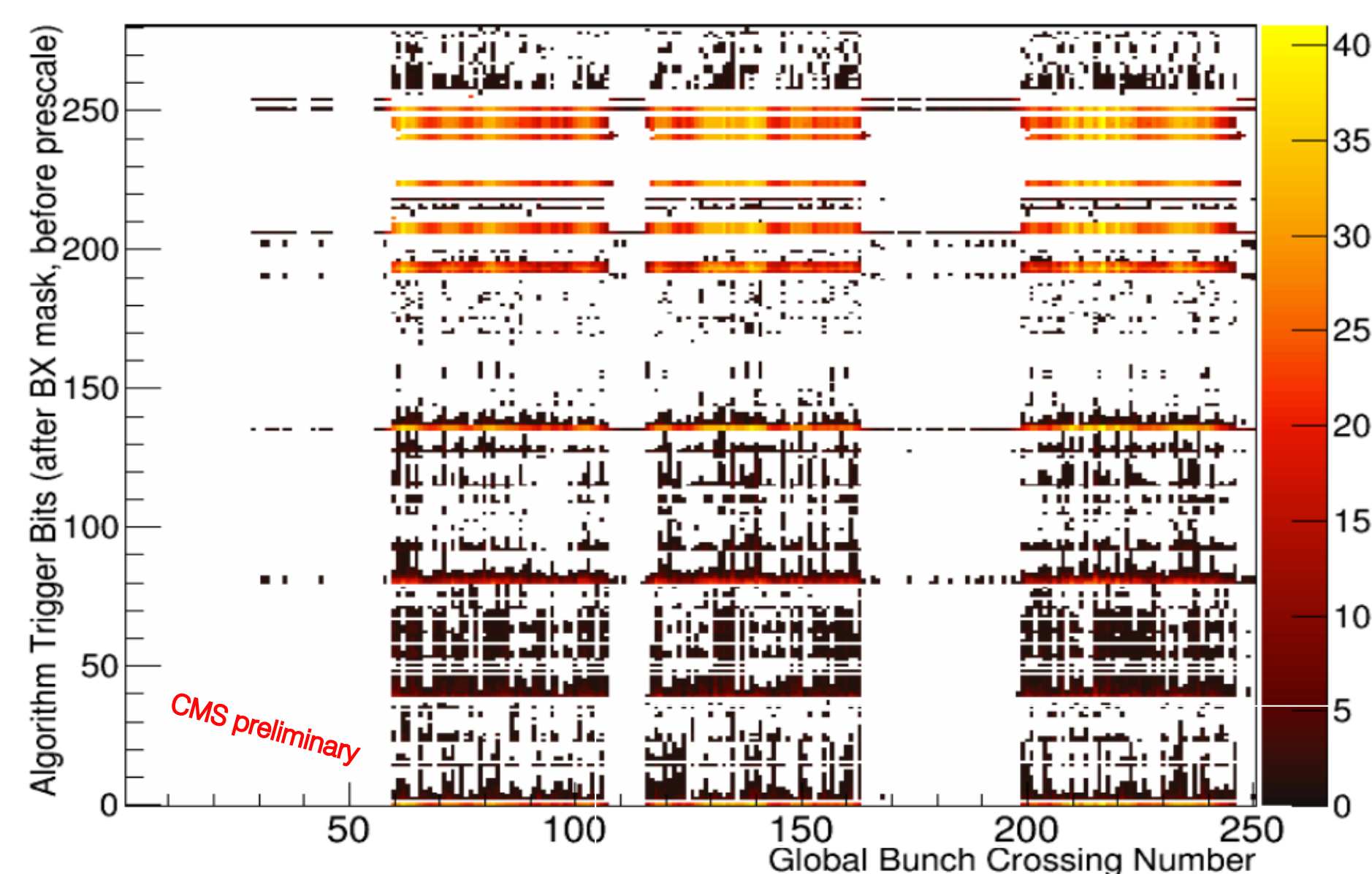


The Global Trigger is capable of processing more than 500 physics algorithms in parallel. This plot shows a section of the trigger results of a given run.
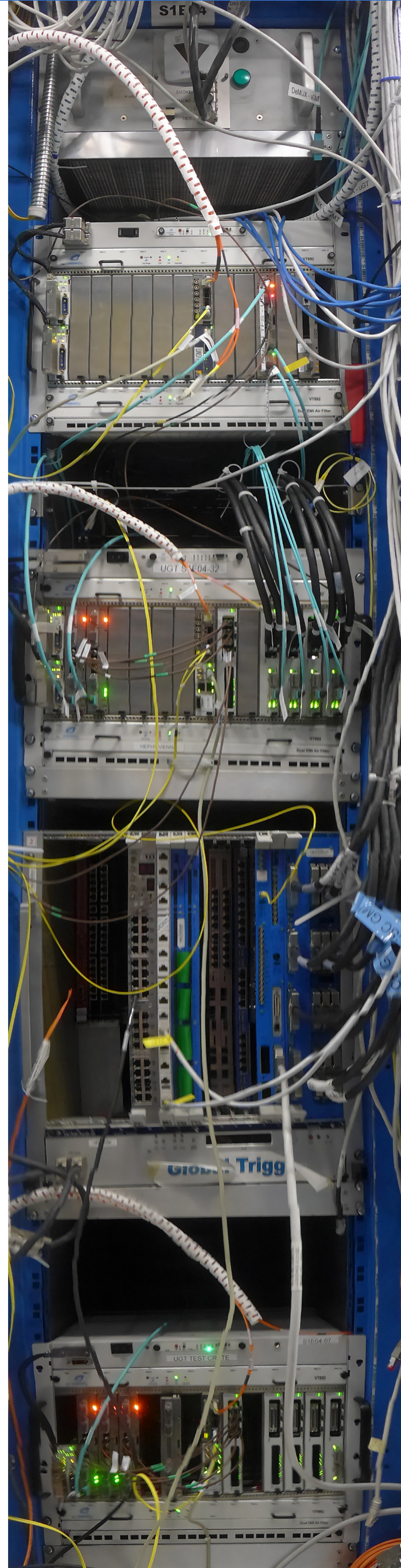


The Global Trigger rack at CMS. It contains from top to bottom: the Global Muon Trigger crate, the GT crate, the legacy GT crate and the GT test/backup crate.

References:
[1] A. Rose et al.: The MP7 and CTP-6: multi-hundred Gbps processing boards for calorimeter trigger upgrades at CMS, Journal of Instrumentation Volume 7, C12024, 2012.
[2] B. Rahbaran et al.: Global Trigger Upgrade firmware architecture for the level-1 Trigger of the CMS experiment, Journal of Instrumentation Volume 10, C02042, 2015.
[3] T. Matsushita: Software for implementing trigger algorithms on the upgraded CMS Global Trigger System, CMS Note (CMS-CR-2015-083), 2015.
[4] J. Wittmann et al.: The upgrade of the CMS Global Trigger, Journal of Instrumentation Volume 11, C02029, 2016.