Real-time Particle Identification at the CERN Compact Muon Solenoid (CMS) Experiment

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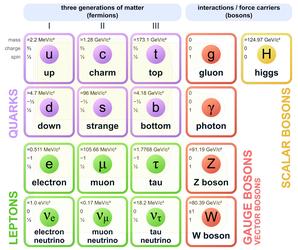
Motivation

The Standard Model describes electromagnetism, strong and weak forces, but **open questions remain:**



Matter and force carrier particles in the Standard Model.[1]

A galaxy collision, with total mass (mostly dark matter) in blue. Dark matter is not accounted for in the Standard Model.[2]

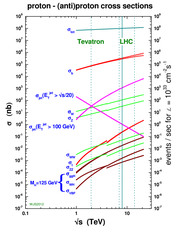
The **High-Luminosity Large Hadron Collider (HL-LHC)** will collide particles at 5-7.5x its current rate, but the CMS detector can only save a fraction of this data!

…due to computing/storage constraints,[3]

… and because interesting physics is rare.[4]

Proton-proton collisions:
~ 40 MHz

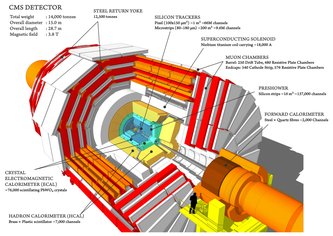
Higgs production:
~ 1 Hz



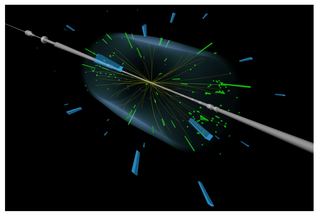
The hardware-based **CMS Level 1 Trigger** will select collisions in less than 12.5 microseconds at the HL-LHC, by reconstructing particles from high-granularity detector readouts.

Methodology

The **CMS Level 1 Trigger** will reconstruct and identify particle signatures using the calorimeters, the muon system, and for the first time at the HL-LHC, the tracker.



Sub-detectors at CMS.[5]

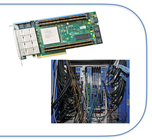


A collision with tracks (yellow), and energy deposits in ECAL (green) and HCAL (blue).[6]

Develop algorithm and emulate detector in software

High-Level Synthesis

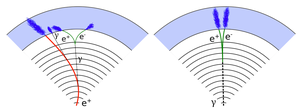
Firmware implementation (FPGA) and testing[7]



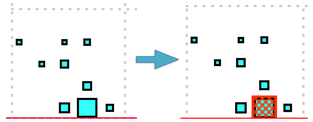
Results: Electrons/Photons

1. Emulating **electron/photon clustering** in the calorimeter trigger

Single electrons/photons interact with the detector material, leaving multiple deposits in ECAL (blue).[8]



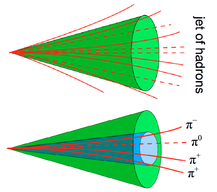
New algorithm reconstructs original electron/photon by summing ECAL crystal hits (highest granularity possible).



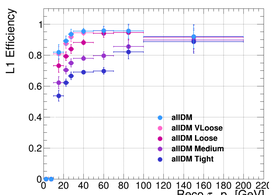
Results: Tau Leptons

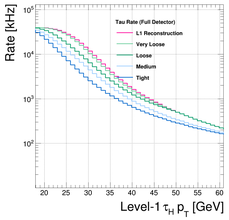
2. Developing **trigger for tau leptons** (new to the L1 Trigger) using tracking information (newly available in the HL-LHC)

Jets *(top)* are often mis-identified as decays of tau leptons *(bottom)*, but are far more common.[9]



- Train a Boosted Decision Tree on energy & track variables.
- Various cut-offs on the BDT's output discriminant provide trade-offs on signal efficiency for genuine tau leptons *(left)*, and reducing the event rate *(right)*.

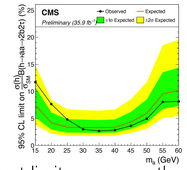




Future Work

The L1 Trigger will be key to collecting data at the HL-LHC, which will enhance:

- Precision tests of the Standard Model
- Sensitivity of searches for new physics



Current limits on a new, theorized decay of the SM Higgs boson.[10]

Link to poster

References

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6. iSpy-WebGL (2012 data)
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11. Poster template by Nikki Marinsek

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