The Particle Flow Algorithm in the Phase II Upgrade of the CMS Level-1 Trigger

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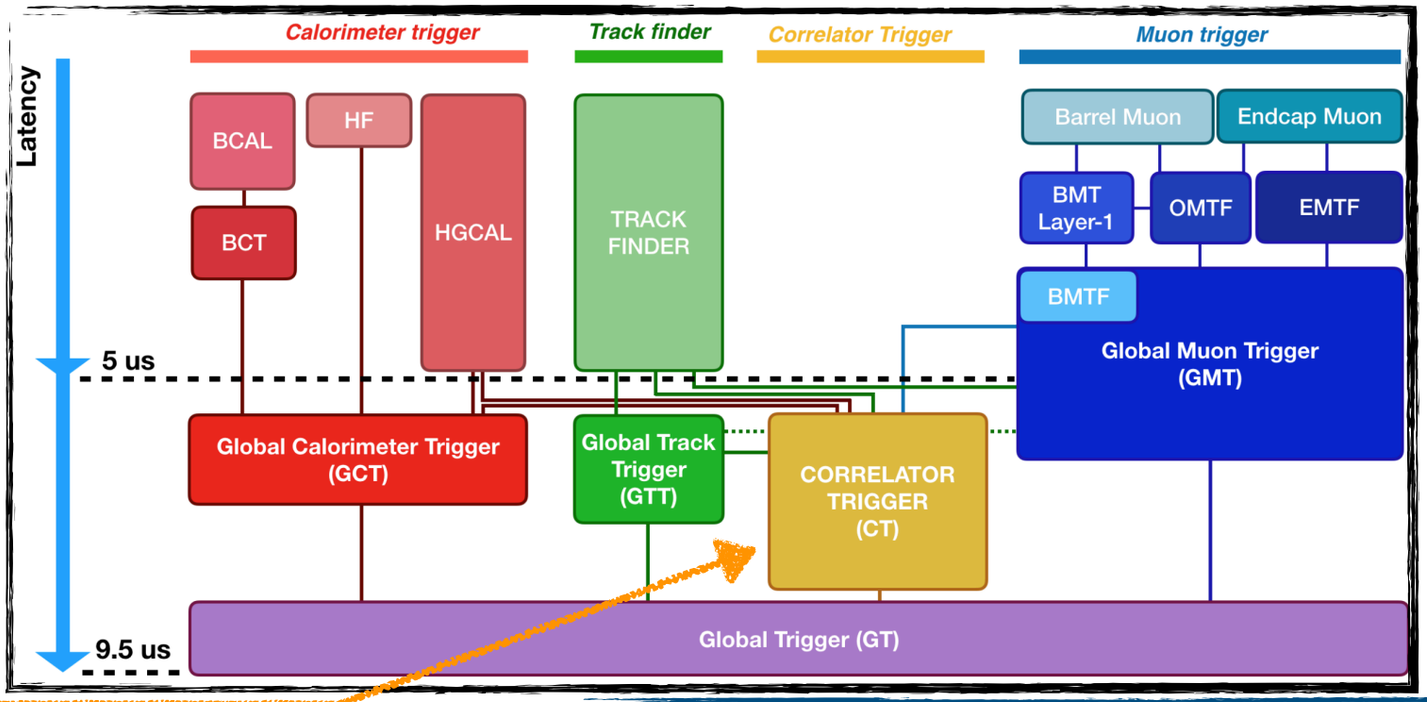
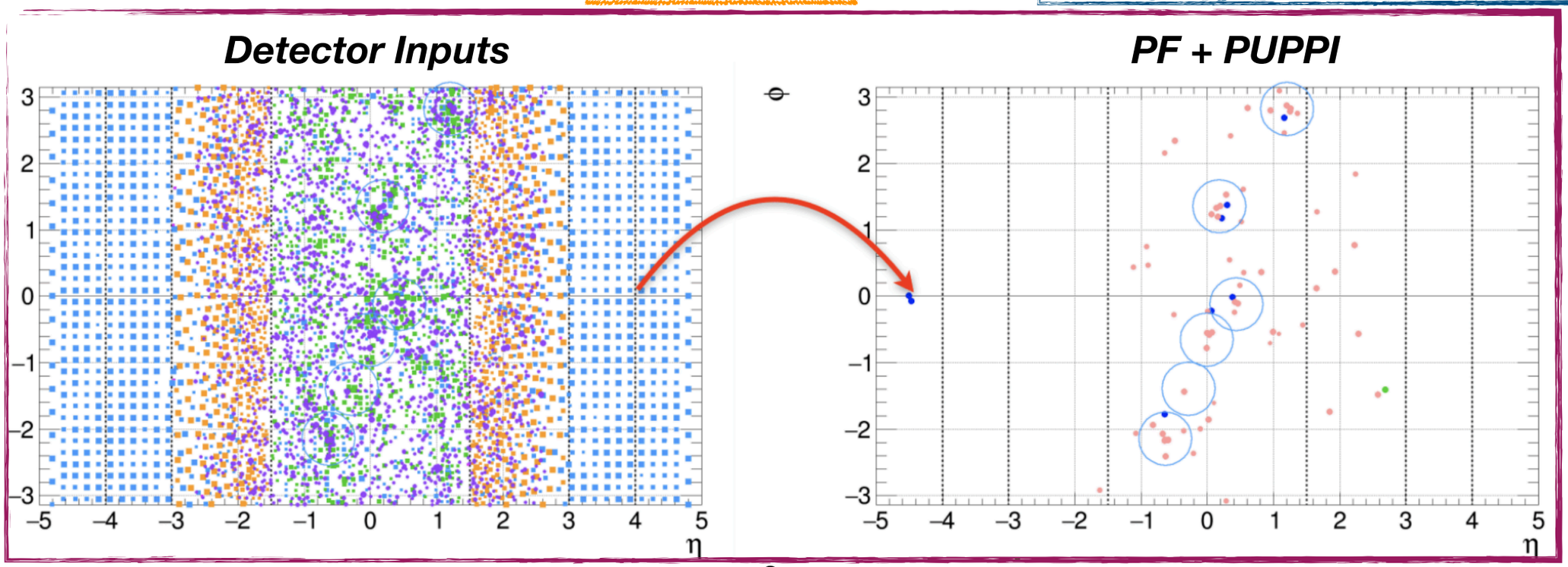
Introduction

- Phase II CMS upgrade adds information from tracking detector to Level-1 trigger
- Enables (among others):
  - Particle flow (**PF**)
  - Pile-Up Per Particle Identification (**PUPPI**)
- Critical to maintaining performance in harsh HL-HLC environment, high pileup
- PF + PUPPI requirements:
  - Run in ~ 2 μs
  - Process events at 40 MHz



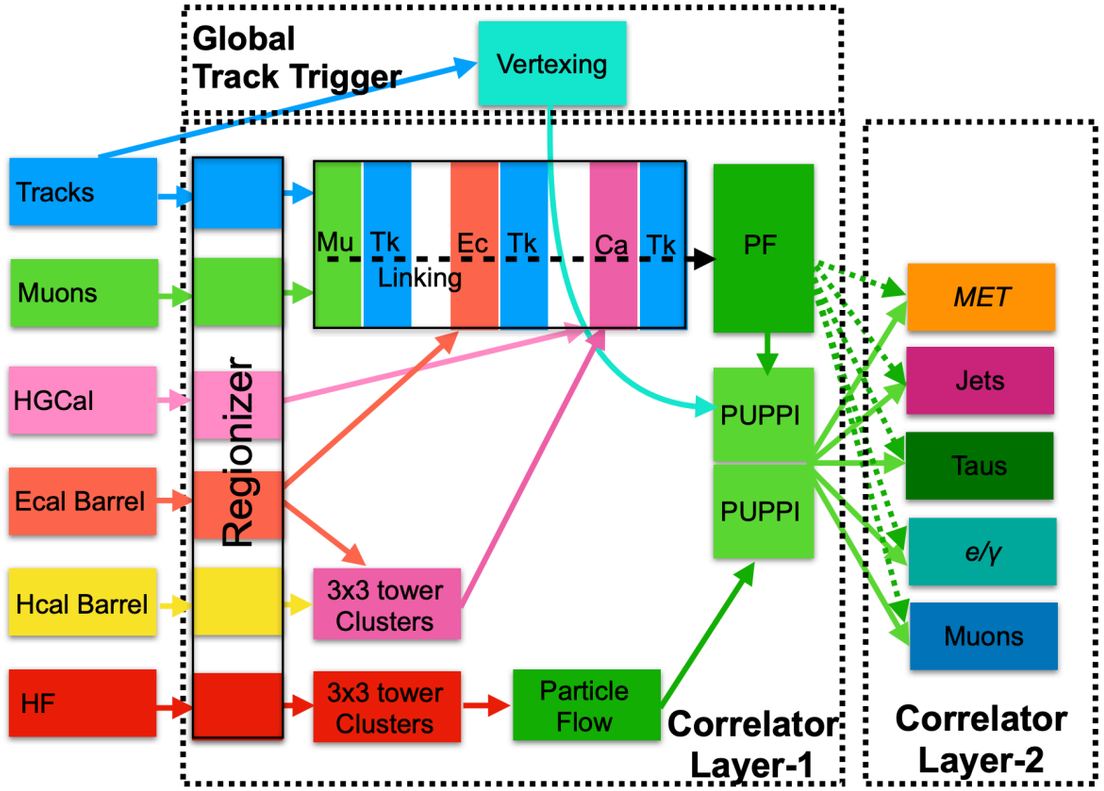
PF & PUPPI

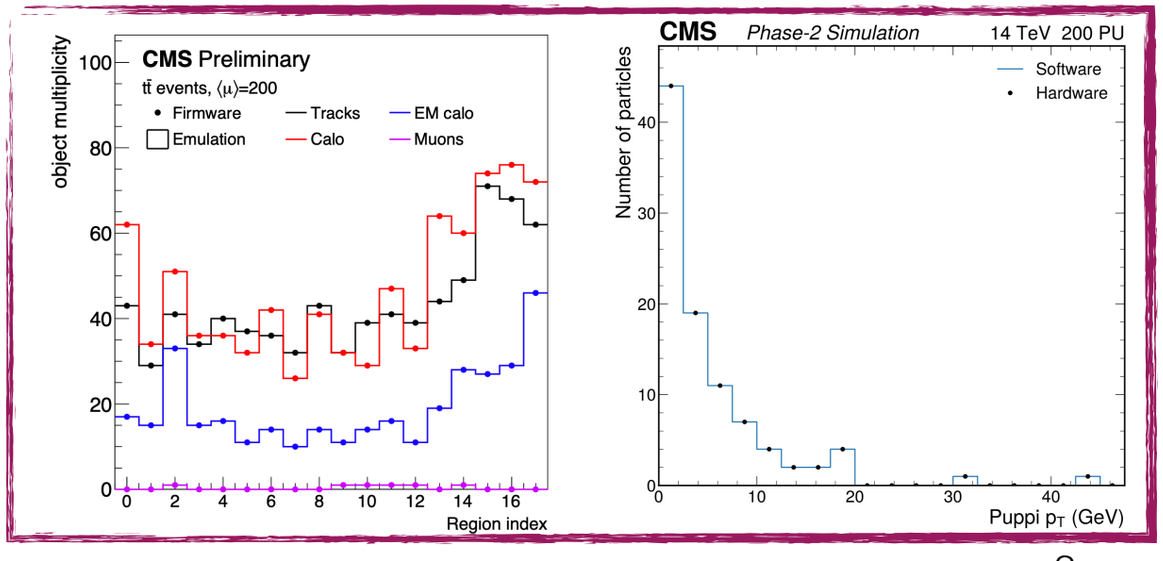
CMS Collaboration, The Phase-2 Upgrade of the CMS Level-1 Trigger, CERN-LHCC-2020-001, CMS-TDR-20-001 (2020)

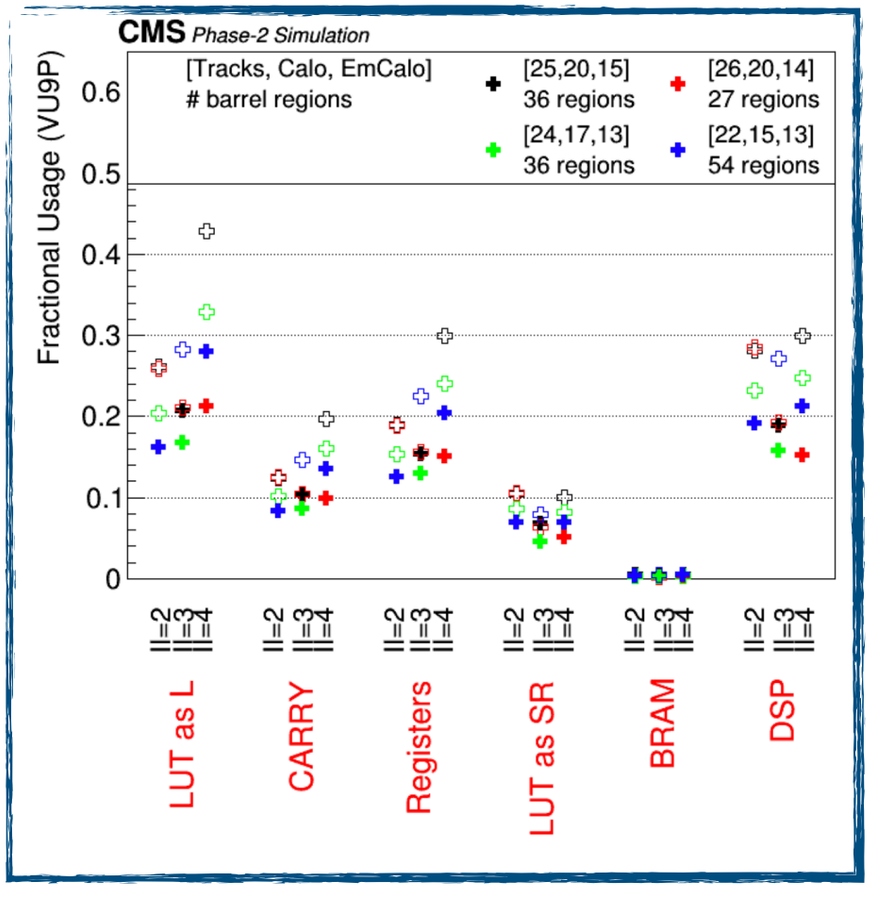


Implementation and Testing

- Design separated into multiple blocks to handle inputs from detectors with different rates and schemes
  - Layer-1
    - Partition inputs into regions (regionizer)
    - Particle flow
    - PUPPI
  - Layer-2
    - Object reconstruction
- Significant work in balancing performance and FPGA resources/latency
- Implemented using High Level Synthesis
- Tested on prototype boards with targeted Virtex Ultrascale 9+ (VU9P) FPGA, 25 Gbps GTY links
  - Perfect agreement between HW and emulation



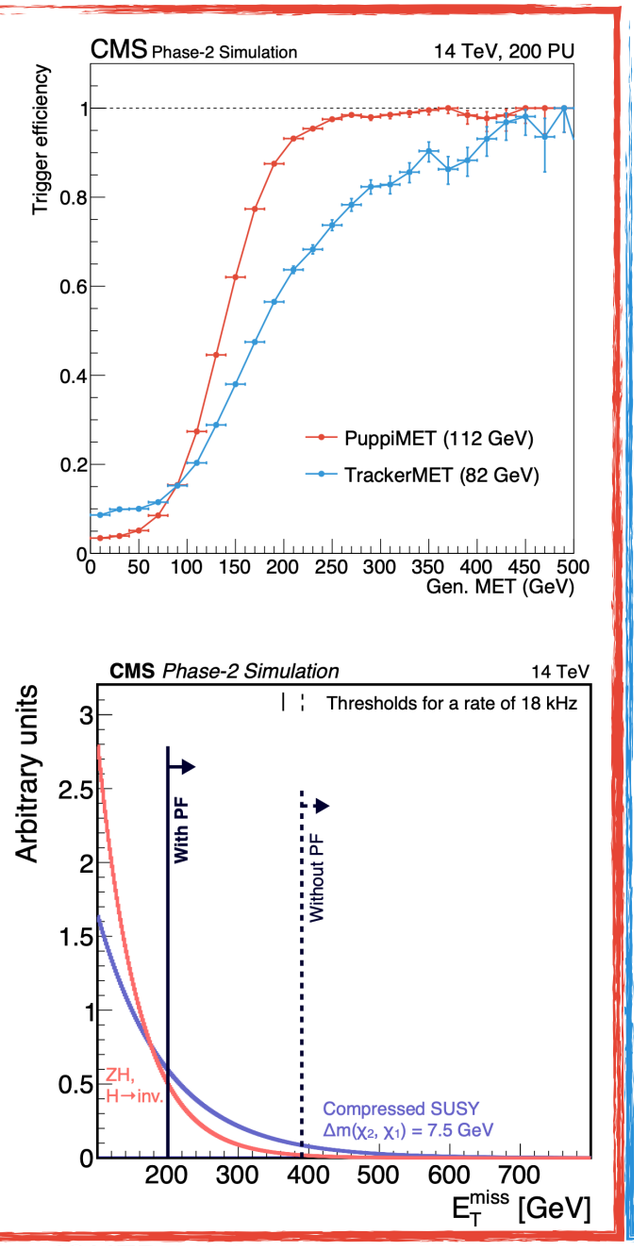




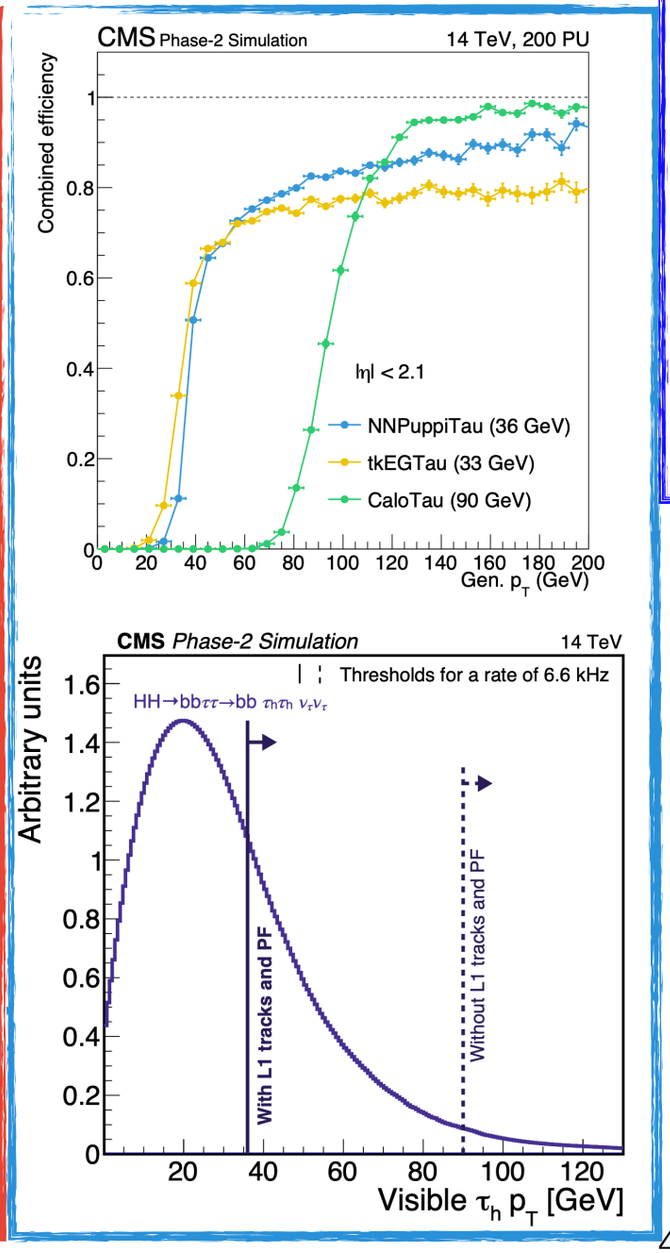
Performance

- Compared to calo- or track-only:
  - Improved jet response and resolution with PF
  - **Sharper** and **earlier** turn-ons possible with PUPPI across trigger landscape (MET, τ_h, H_T)
- Major gains in signal acceptance

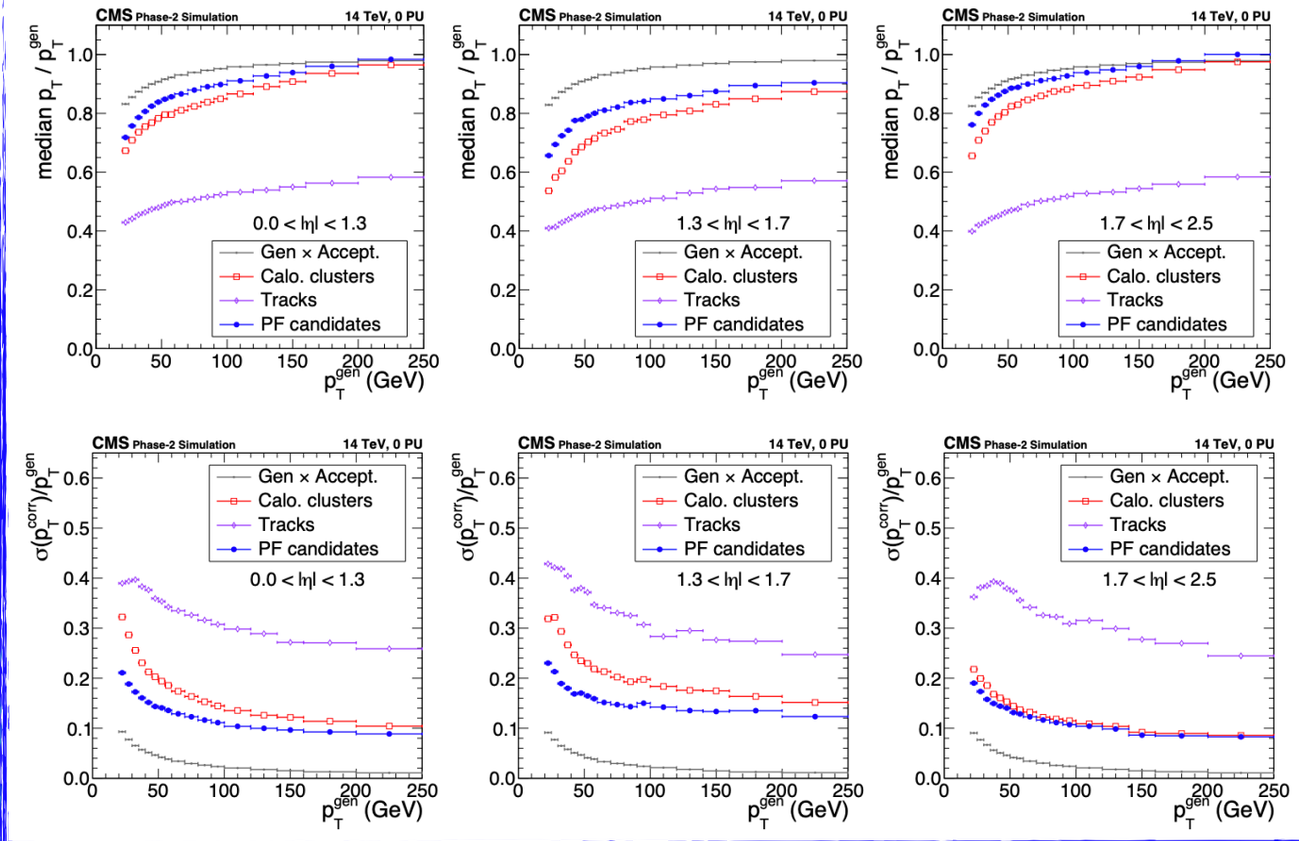
MET



τ_h



Jets



H_T