CMS Detectors and Upgrades





CMS at LHC

For the first time since 2018, CMS is taking high-energy collision data again







During the Long Shutdown, many detector systems were improved/ refurbished

Continuing LIP responsibilities in ECAL and PPS

CMS for HL-LHC

Looking beyond Run 3:

CMS has a large upgrade program in progress, with significant LIP involvement in multiple systems



Neutron and mixed-field radiation monitors

21 PPS

Most detectors will be significantly improved, and completely new detectors will be installed, to maintain physics performance in the harsher pileup/radiation conditions ³

MIP Timing Detector (MTD)









Provides improvements in longlived/stable particle searches, di-Higgs, b-tagging, PID for heavy ions/flavor physics... Ambitious project to provide precise timing over a large range of rapidity

~30ps resolution at beginning of life, ~50ps over lifetime of HL-LHC

Increase of physics sensitivity by exploiting "4-D" vertexing in space+time





MTD technologies 📷



Barrel (BTL): $|\eta| < 1.5$

LYSO crystals and SiPMs

LIP responsibility for electronics, including Front-End boards, and new TOFHIR ASIC developed at TagusLIP

Total of 340k channels, with 14k designed, produced, and tested!

Endcap (ETL): $1.6 < |\eta| < 3$

Silicon Low-Gain Avalanche detectors (LGAD)



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TOFHIR



Measurements with sensor modules confirm excellent expected time resolution

~30ps beginning of life, ~55ps end of life



New dark count rate cancellation method implemented

Compensates expected large increase in DCR from silicon PMs

TOFHIR status and timeline

Several iterations of TOFHIR passed through extensive tests (system/electronics integration, testbeams, irradiation with ions...)

TOFHIR1: First adaptation of TOFPET chip for initial system tests in 2019

TOFHIR2: Full 32-channel chip and functionality, tested in 2020

TOFHIR2X: Improved DCR cancellation, tested in 2021

TOFHIR2B: Improved single event upset protection, under test now



Chip dimensions: 8.5x5.2mm²



Electromagnetic Calorimeter (ECAL)



ECAL

Many years of LIP responsibility for ECAL electronics

Now continuing for LHC Run 3

For HL-LHC: full replacement of electronics, to meet pileup/rate requirements

Collaboration with Portuguese industry to develop new low-power ADC IP block

12-bit resolution, with 160MS/s sampling rate

First production integrated and evaluated in LITE-DTU chip in 2021, with good results



Precision Proton Spectrometer (PPS)



PPS in Run 3 and beyond

Forward proton tracking and timing detectors, in Roman Pots ~200m from the CMS interaction point

PPS is now taking data in Run 3, with improved detectors compared to Run 2

Vertical movement system, to mitigate radiation damage on pixel/tracking detectors

Improved "Double diamond" timing detectors, with time resolution goal of <= 50ps

After Run 3: pursuing upgrade proposal to reinstall PPS-like system for HL-LHC (Expression of Interest in arXiv:2103.02752)



PPS@HL-LHC

New activity started at LIP-Lisbon/TagusLIP: R&D on LGAD silicon-timing detectors for PPS@HL-LHC

Adapted from MTD-ETL design

Collaboration started with CMS-ETL institutes on market survey

Variety of different sensors from several vendors evaluated for I-V curves, interpad spacing, time resolution





Unique issue for PPS: highly non-uniform irradiation profile

PPS@HL-LHC

Huge flux mainly concentrated on first columns nearest the LHC beam

Simulation studies to optimize LGAD segmentation in terms of radiation dose, occupancy, HV, complication of bonding to readout chips, etc.



Results will be used to guide 1st prototype production of a PPS-like LGAD sensor

Summary

After nearly 4 years, the LHC and CMS are running again

LIP-CMS group continues it's long-standing involvement in ECAL and PPS electronics/operations in Run 3

The CMS HL-LHC upgrade program is in full swing

LIP has a major role in timing detectors and/or electronics in several systems

On track to provide new TOFHIR ASIC and Front-End cards for MTD, and ADC blocks for ECAL, with excellent performance

New R&D program on silicon LGAD sensors and electronics for PPS timing underway



MTD: Particle reconstruction

CERN-CMS-TDR-020

- Improve particle reconstruction/ID
 - Increase b-tagging efficiency
 - Increase photon and lepton Id, efficiency and isolation
 - Improve missing transverse momentum resolution
 - Reduce fake jet reconstruction
- 10%-20% gain in S/B in many Higgs decay channels



M. Gallinaro - "The CMS group" - LIP Jornadas - July 2022