



LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

The Portuguese participation in the Large Hadron Collider at CERN

Joao Varela
LIP Lisbon

11 September 2019



LHC program at LIP

The leadership



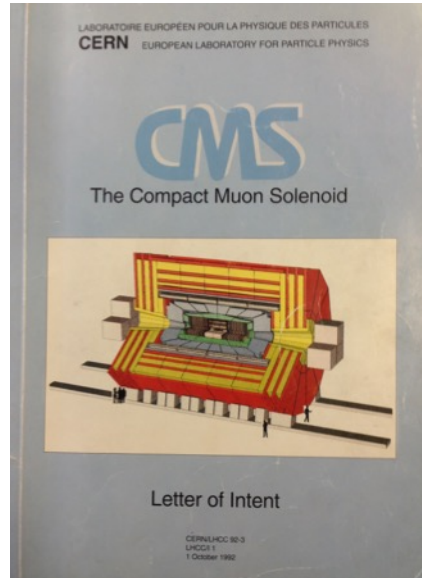
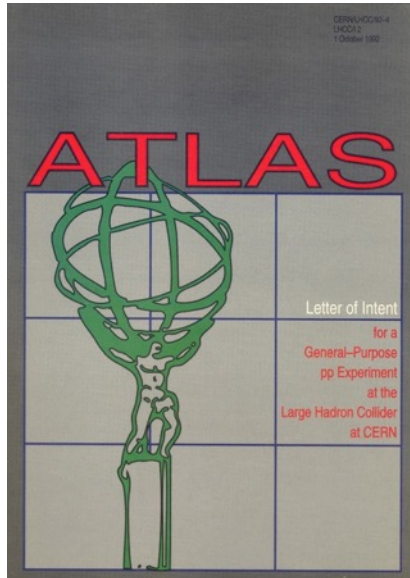
Gaspar Barreira, Amélia Maio and João Varela were the initiators of the Portuguese participation in the LHC experimental program in 1992.

Gaspar Barreira was the Portuguese representative in the Resources Review Boards and initiator of the GRID project in Portugal.

Amélia Maio and João Varela were the coordinators of the ATLAS and CMS groups respectively

The ATLAS and CMS Letters of Intent in 1992

with the participation of LIP members



ATLAS Letter of Intent,
CERN/LHCC/92-4, 1992, with the participation of LIP (A. Amorim, A. Henriques, G. Barreira, A. Maio, A. Gomes, L. Peralta).

CMS Letter of Intent,
CERN-LHCC-92-003, 1992, with the participation of LIP (P. Bordalo, C. Lourenço, R. Nóbrega, S. Ramos, J. Varela).

LHC program at LIP

The people

And many more!



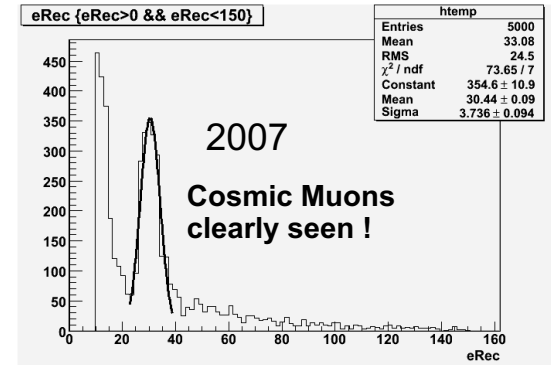
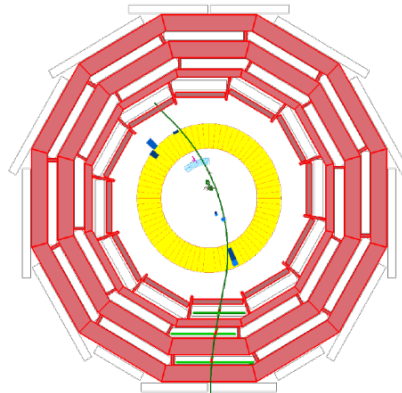
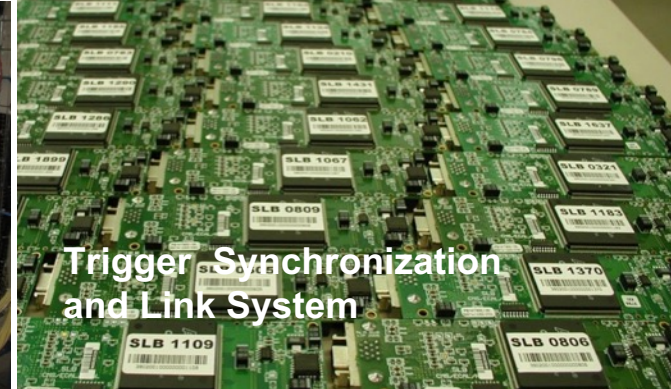
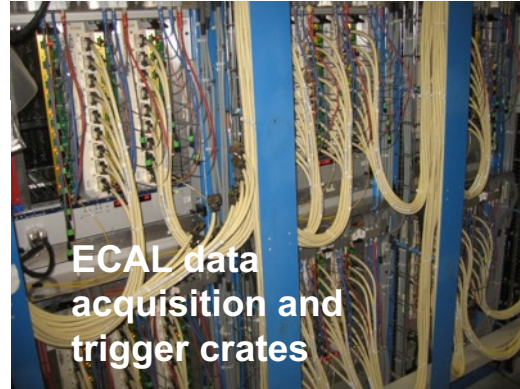
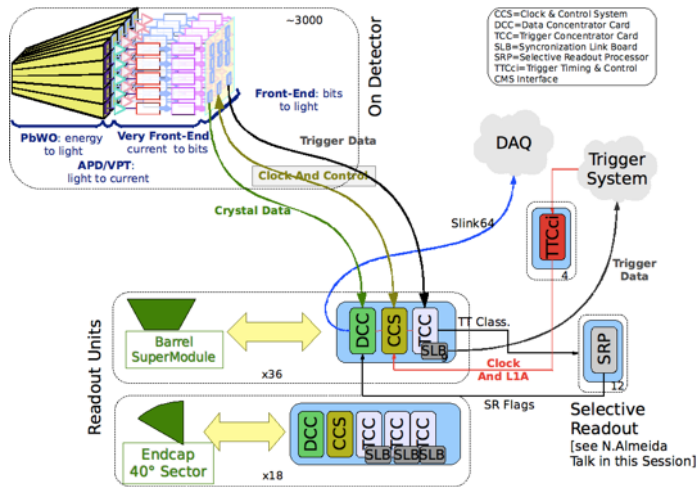
15 JULY 2005

A 3D perspective diagram of a rectangular plate. A diagonal line is drawn across the plate. Three curved arrows are shown along the bottom edge, indicating a sequence of rotations. The first arrow is at the bottom-left corner, the second is in the middle, and the third is at the bottom-right corner. The arrows point in a clockwise direction, suggesting a sequence of rotations that would eventually bring the plate back to its original orientation.



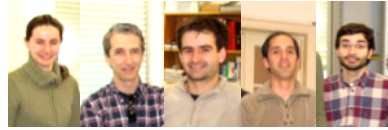
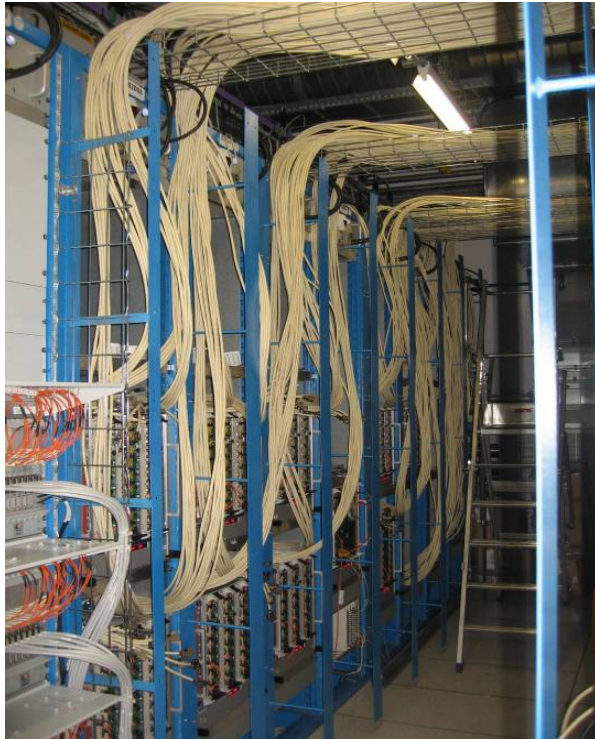
LIP in the construction of the LHC experiments

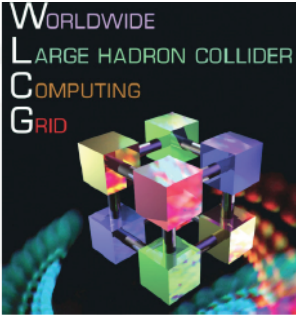
The CMS ECAL Data Acquisition and Trigger System



LIP in the construction of the LHC experiments

CMS ECAL trigger integration in 2006-07



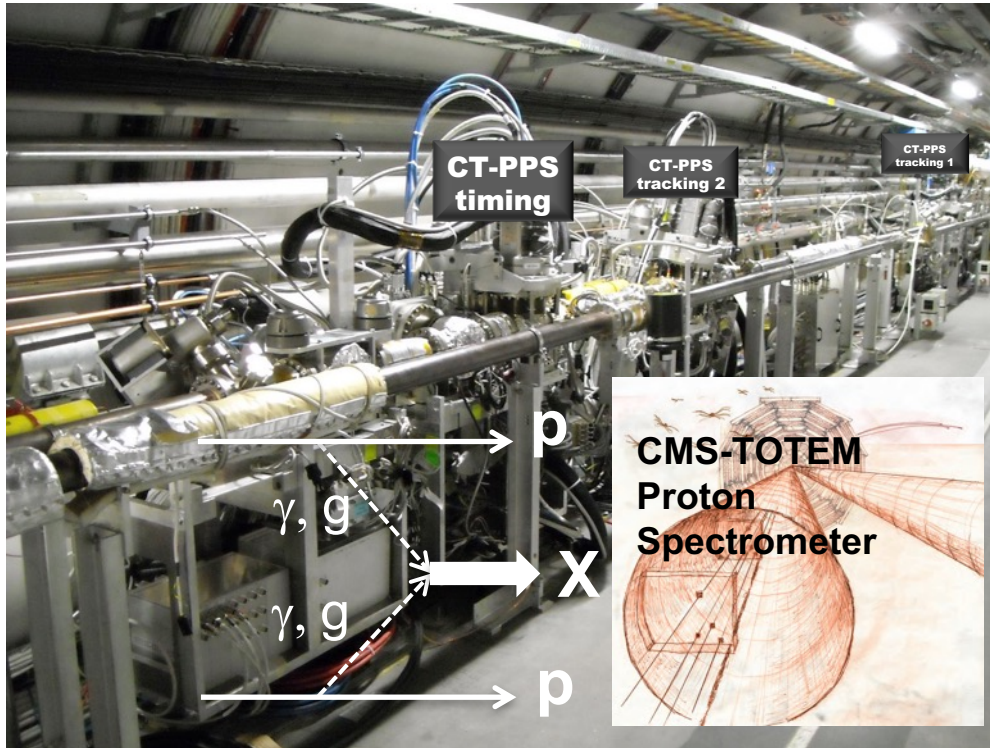


The development of the LHC GRID
had a major impact in the development
of scientific computing in Portugal

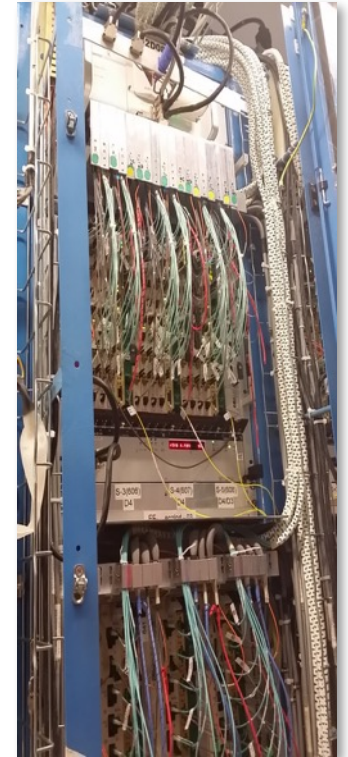


Upgrades of LHC experiments

Participation in CMS Phase 1 Upgrade 2014-15



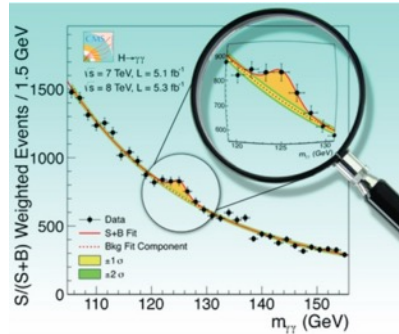
Optical links of the
ECAL
Trigger System



LIP contributions to CMS Physics Results

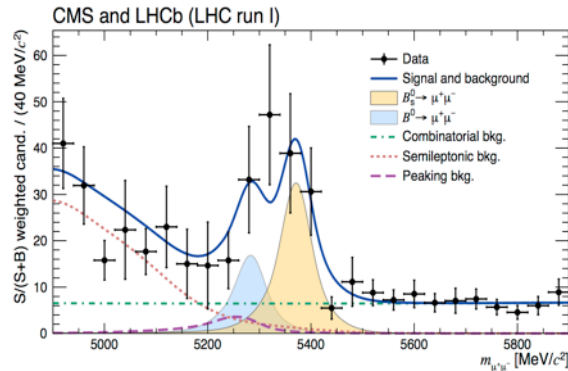
Higgs Physics

- Discovery of a Higgs boson in the two-photon decay channel
- Study of the Higgs properties



Rare B decays

Leading role in one the CMS flagship results $B_{s,d} \rightarrow \mu\mu$ rare decay



TOP quark measurements LIP-CMS long term effort

Cross section: PLB 695(2011)424

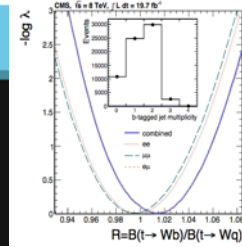
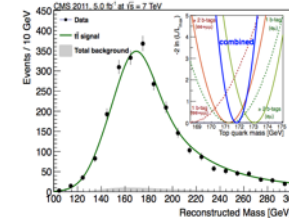
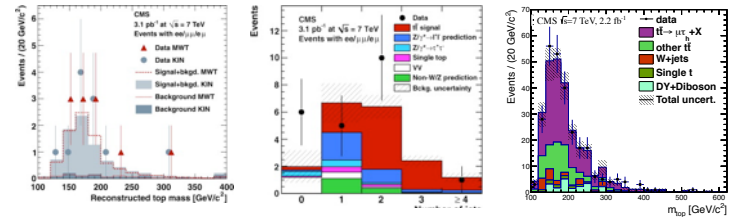
Cross section and mass: JHEP 07(2011)049

Cross section with taus: PRD 85(2012)112007

Top quark mass: EPJC 72(2012)2202

Cross section with taus @8TeV: PLB 739(2014)23

Heavy flavor content (xsec, V_{tb} , width): PLB 736(2014)33



Convener B Physics Group, 2014-15 (N. Leonardo)

Convener Top Physics Group, 2015-16 (P. Silva*)

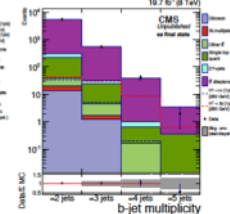
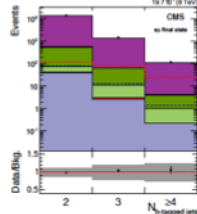
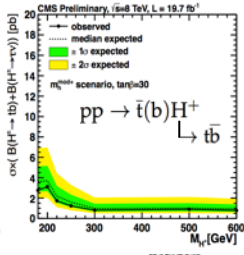
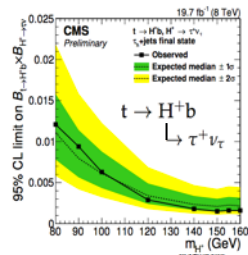
Convener Higgs Physics Group, 2015-16 (A. David*)

* now with CERN

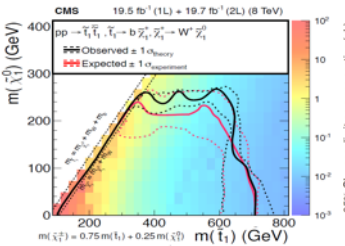
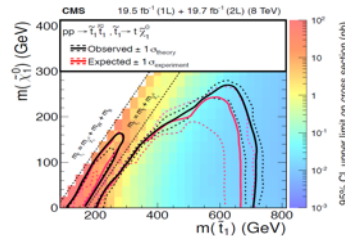
LIP contributions to CMS Physics Results

Search for Charged Higgs

- in top decays
- heavy Higgs decaying to top

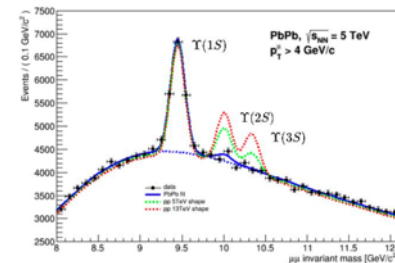
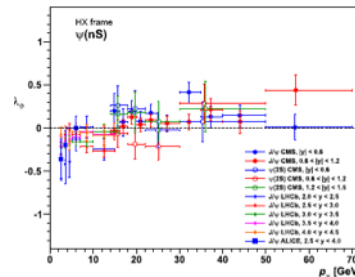


Search for stop quark single lepton channel 3 and 4 body decays

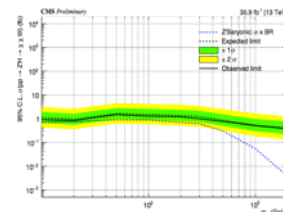


Quarkonia physics

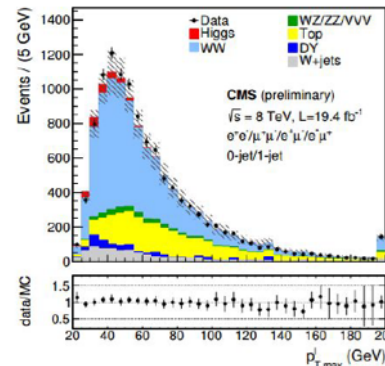
- polarization measurements
- Z and H radiative decays to quarkonia.
- Upsilon suppression in heavy ions



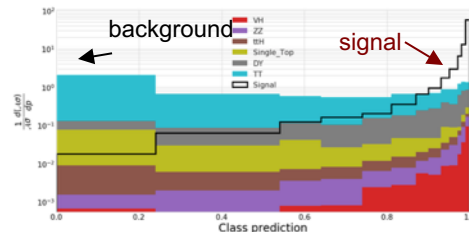
Dark matter search

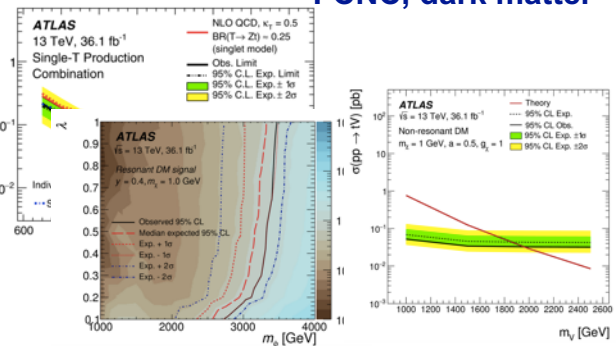


Standard models physics WW cross section



Di-Higgs search with DNN





Awards for special contributions



F. Martins: Outstanding Achievements Award
TileCal for his contribution to TileCal DCS



CMS Thesis Award 2011
Pasquale Musella
Universidade Técnica de Lisboa

"Measurement of the inclusive photon production cross section and study of associated W-photon production in proton-proton collisions at the LHC"



A. Peixoto, ATLAS PhD Grant



J. Machado Miguéns: ATLAS PhD prize

CMS Achievement Award 2014
Dr. Michele Gallinaro

"For his strenuous effort to assure the timely completion of the CT-PPS TDR and for the excellent coordination of its physics studies"

Awards for special contributions

CMS Achievement Award 2008

André David

"For key efforts on the ECAL DAQ and central CMS operations"



CMS Young Researcher Prize 2017

Pedro Ferreira Da Silva

"For his sustained and critical contributions to the physics of the Higgs boson and the top quark and the simulations for the development of the endcap high granularity calorimeter for the HL-LHC Upgrade."



CMS Achievement Award 2007

Pasquale Musella

"For important contributions to ECAL Data Acquisition"

CMS Achievement Award 2014

Jonathan Jason Hollar
"For his outstanding contributions to the CT-PPS TDR, particularly the feasibility study on the measurement of exclusive WW production."



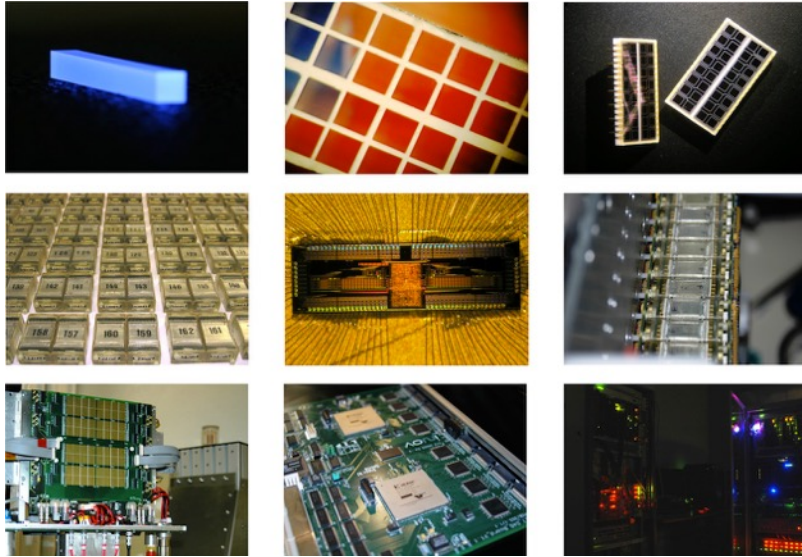
CMS Lifetime Achievement Awards

José Carlos da Silva

"For his outstanding contributions to the construction on the ECAL data acquisition and trigger systems"

Application of LHC technologies

Crystal calorimeter technologies applied to PET



Examples of the technologies developed for the ClearPET scanner

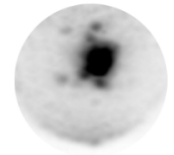
Whole-body PET image



Supine position

10.7329
5.3665

ClearPET image



Prone position

PET :
Resolution is insufficient
to identify multiple focus

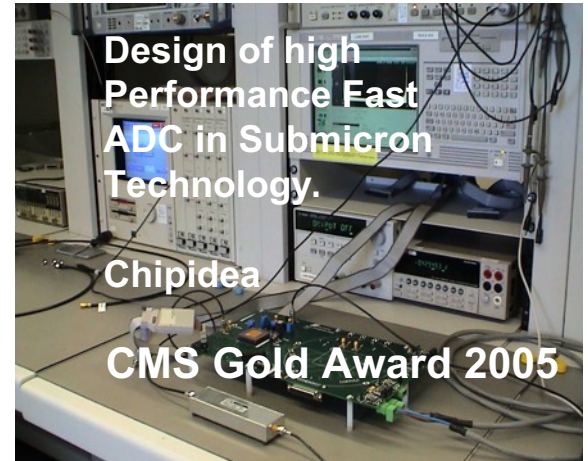
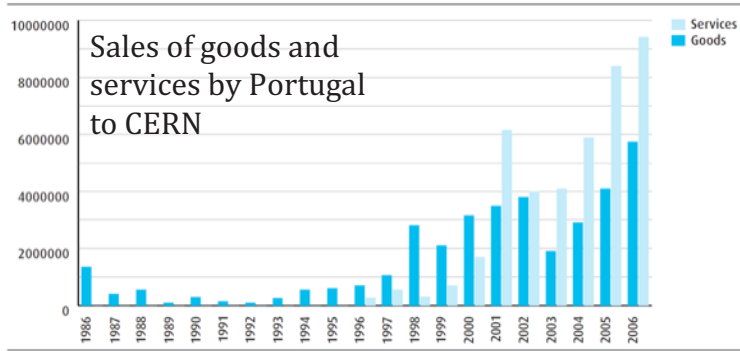
PET:
Multifocal Lesions are observed
Strong impact on surgery planning

ClearPET scanner built in Portugal and the
aiXplorer UltraSound probe at Marseille.



The participation of Portuguese industry

Accelerator and experiments



HL LHC

ATLAS experiment upgrade

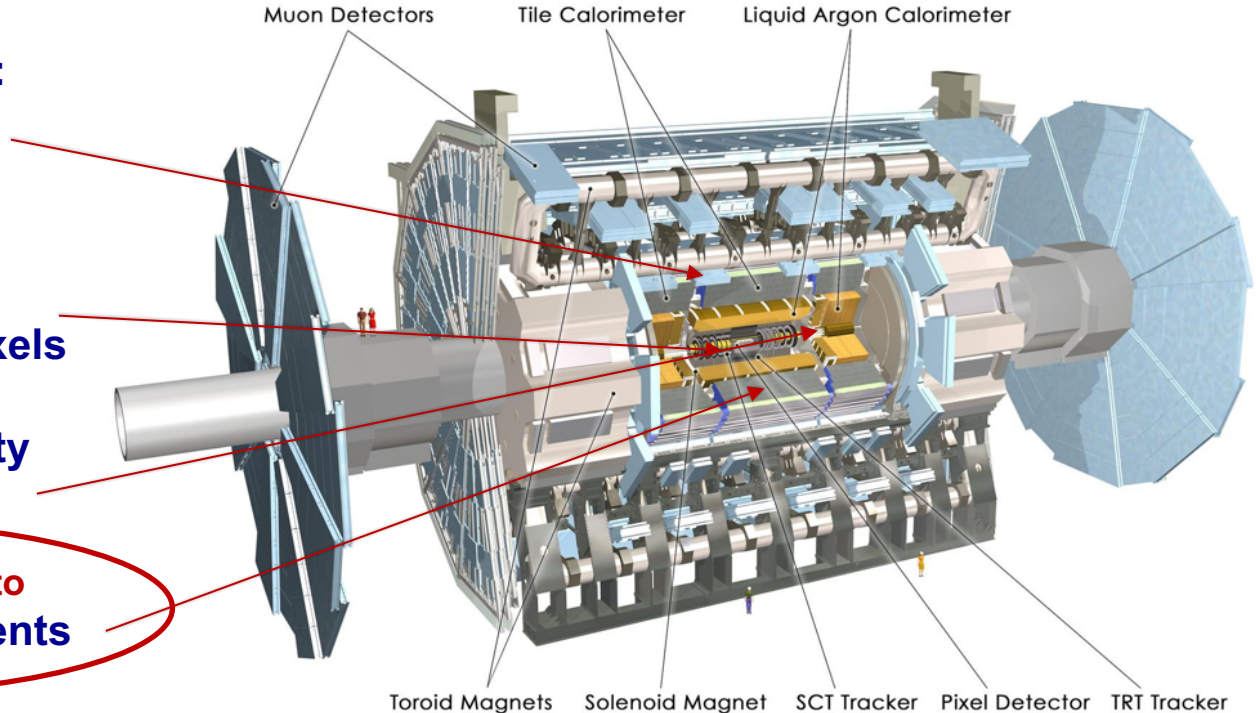
**LIP contributions to
Upgraded trigger and
data acquisition system**

**Muon system upgrade:
new chambers in the
inner barrel region**

**New Inner Tracking
Detector: Strips and Pixels**

**New High Granularity
Timing Detector**

**LIP contributions to
Tilecal improvements**



HL LHC

ATLAS experiment upgrade: Portuguese participation

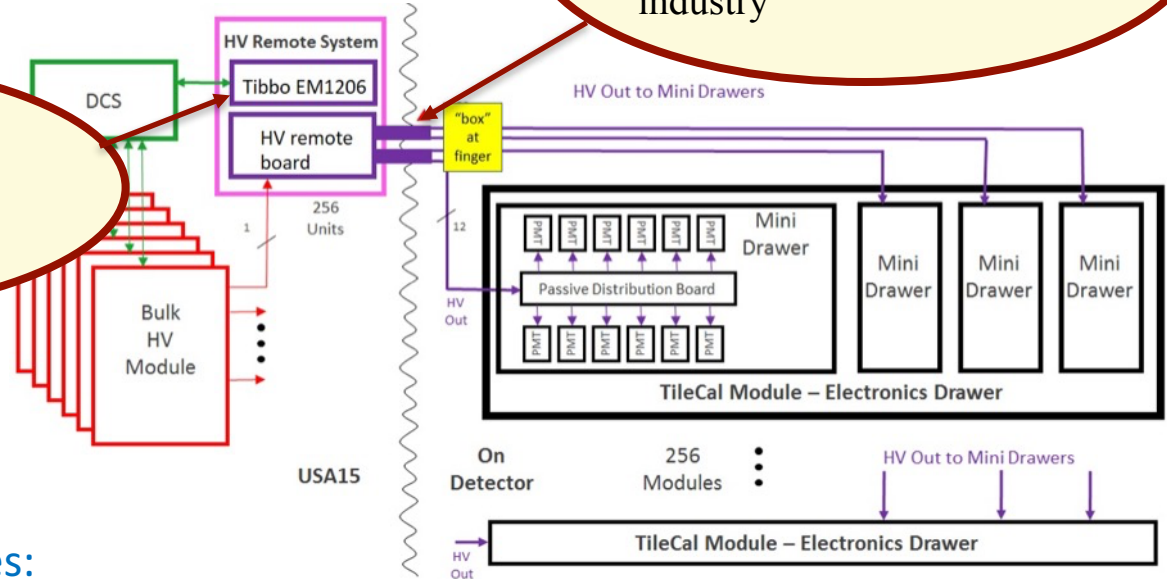
- Tilecal high voltage regulation system
 - HV remote system:
 - distribution boards being designed at LIP and production will be done in the Portuguese industry
 - small diameter cables being developed by Portuguese industry
- Hardware Track Trigger (HTT)
 - Will provide local tracking at 1 MHz and full event tracking at 1 kHz
 - Rear Transition Modules:
 - 75% to be produced in Portuguese industry
 - Testing and quality control at LIP

ATLAS upgrade

TileCal HL-LHC HV regulation system

Distribution boards being designed at LIP
Production in Portuguese industry

Small diameter cables with 48 and 32 pairs being developed by Portuguese industry



Regulation and control system off detector requisites:

- easy maintenance
- no radiation
- always accessible

~20 000 wires
100m long cables

HVbus (passive distribution board) in detector

HL LHC

CMS experiment upgrade

New paradigms (design/technology) for an HEP experiment to fully exploit HL-LHC luminosity

L1-Trigger/HLT/DAQ

- Tracks in L1-Trigger at 40 MHz
- PFlow-like selection 750 kHz output
- HLT output 7.5 kHz

LIP contributions to Barrel Calorimeters

- ECAL crystal granularity readout at 40 MHz with precise timing for e/γ at 30 GeV
- ECAL and HCAL new Back-End boards

LIP contributions to Calorimeter Endcap

- 3D showers and precise timing
- Si, Scint+SiPM in Pb/W-SS

Muon systems

- DT & CSC new FE/BE readout
- RPC back-end electronics
- New GEM/RPC $1.6 < \eta < 2.4$
- Extended coverage to $\eta \approx 3$

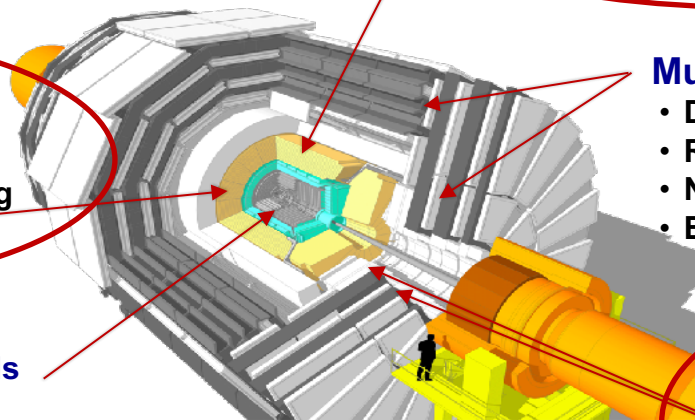
LIP contributions to MIP Timing Detector

Precision timing with:

- Barrel layer: Crystals + SiPMs
- Endcap layer: Low Gain Avalanche Diodes

Tracker Si-Strip and Pixels increased granularity

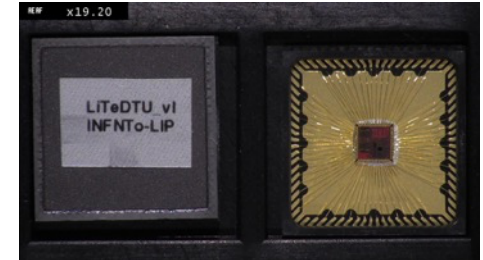
- Design for tracking in L1-Trigger
- Extended coverage to $\eta \approx 3.8$



HL LHC

CMS experiment upgrade - Portuguese participation

- Portuguese contribution:
 - Primary responsibility and leadership
 - Readout system of the new Barrel Timing Layer (BTL) of MTD
 - Secondary contributions
 - New front-end electronics system of the ECAL
 - Trigger system of the new High-Granularity Calorimeter
- ASICs by Portuguese microelectronics industry:
 - TOF ASIC for the BTL frontend electronics.
 - Precision timing measurement
 - ADC ASIC for the ECAL frontend electronics
 - Fast analog to digital conversion
 - LVR ASIC for the HGCAL frontend electronics
 - Radiation tolerant voltage regulation

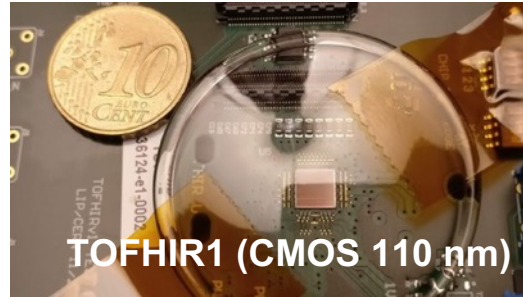
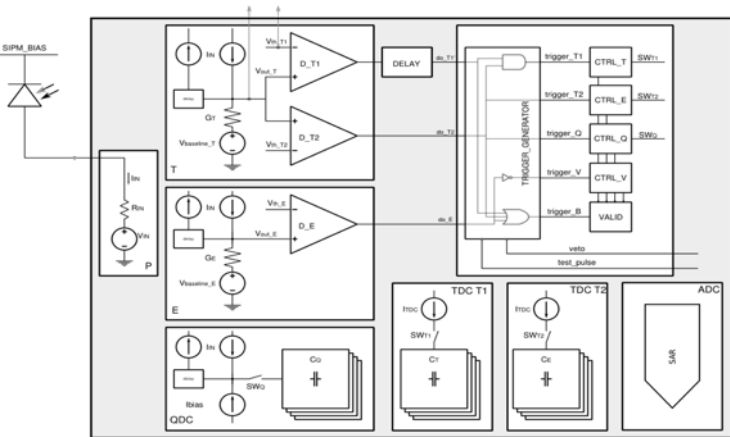


- IP core ADC 12-bit 160 MHz (S3 group)
- Integration in ECAL LiTE-DTU ASIC (INFN-Torino, LIP)

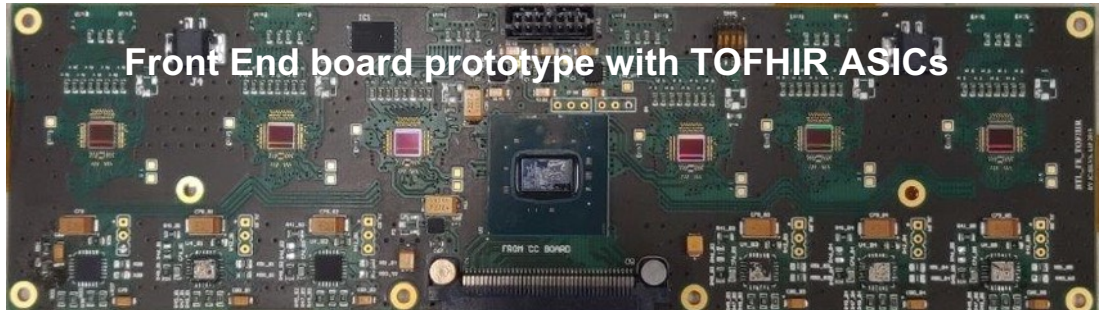
CMS upgrade

TOFHIR ASIC and readout of Timing Detector

TOFHIR ASIC developed by LIP in collaboration with PETsys



	TOFHIR1	TOFHIR2
Number of channels	16	32
Technology	UMC 110 nm	TSMC 130 nm
Voltage	1.2 V, 2.5 V	1.2 V
Radiation Tolerance	No	Yes
Compatibility with IpGBT	Yes	Yes
I/O links	LVDS	CLPS
L1, L0 Trigger	Yes, No	Yes, Yes
10-bit SAR ADC (MHz)	10	40
Bandwidth (MHz)	350	350
Input impedance (Ω)	6	6
DCR noise filter	No	Yes
Number of TACs and QACs	4	6
TDC bin (ps)	20	20
Reference voltages	External	Internal
Maximum MIP rate/ch (MHz)	1	2.5
Max low E rate/ch (MHz)	3	5
Clock frequency (MHz)	160	160





Final words

The Portuguese participation in the LHC experimental programs has been a success story

Bright prospects for the participation in the future upgrades