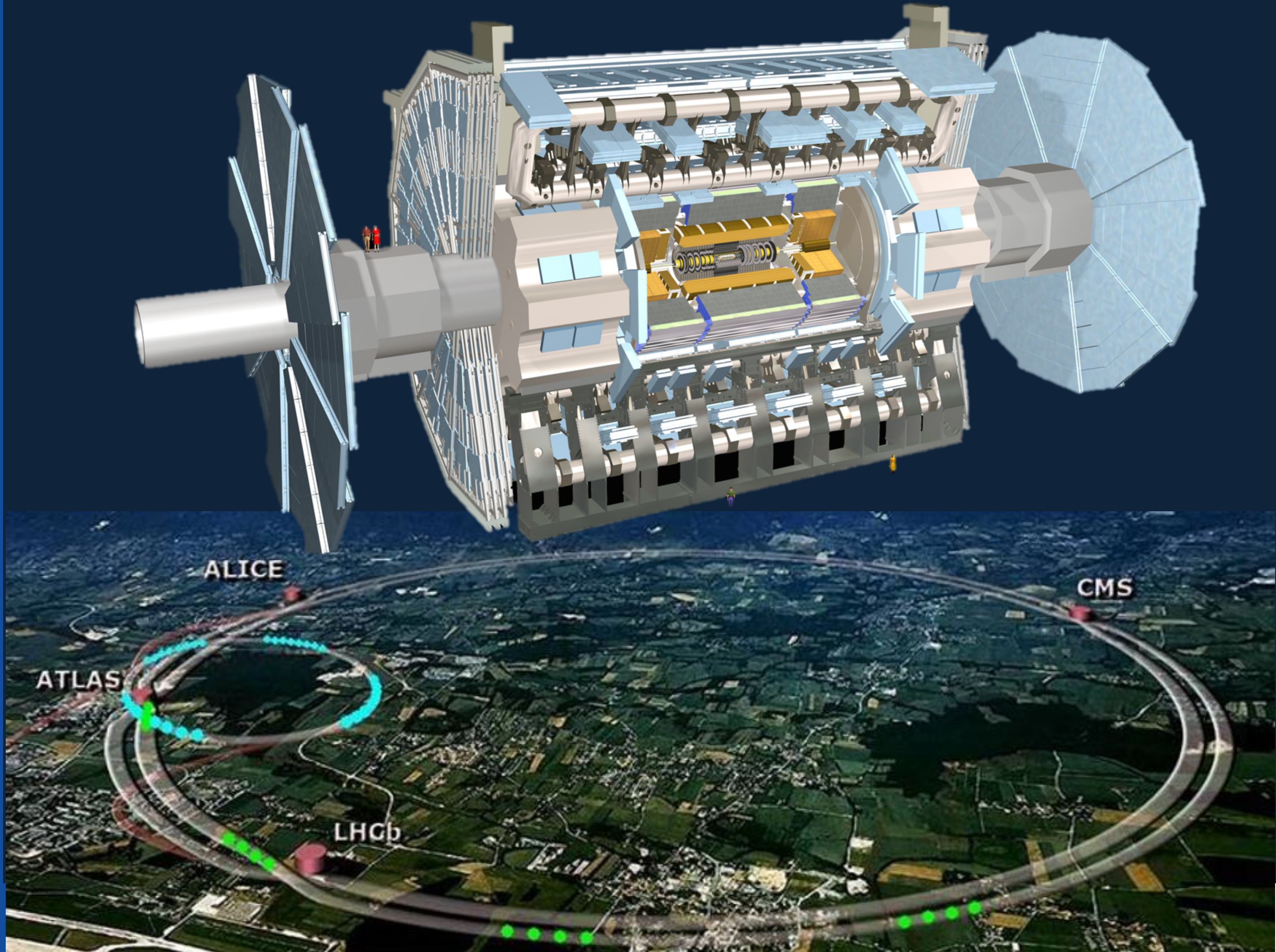
LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

Master and PhD Possibilities at ATLAS

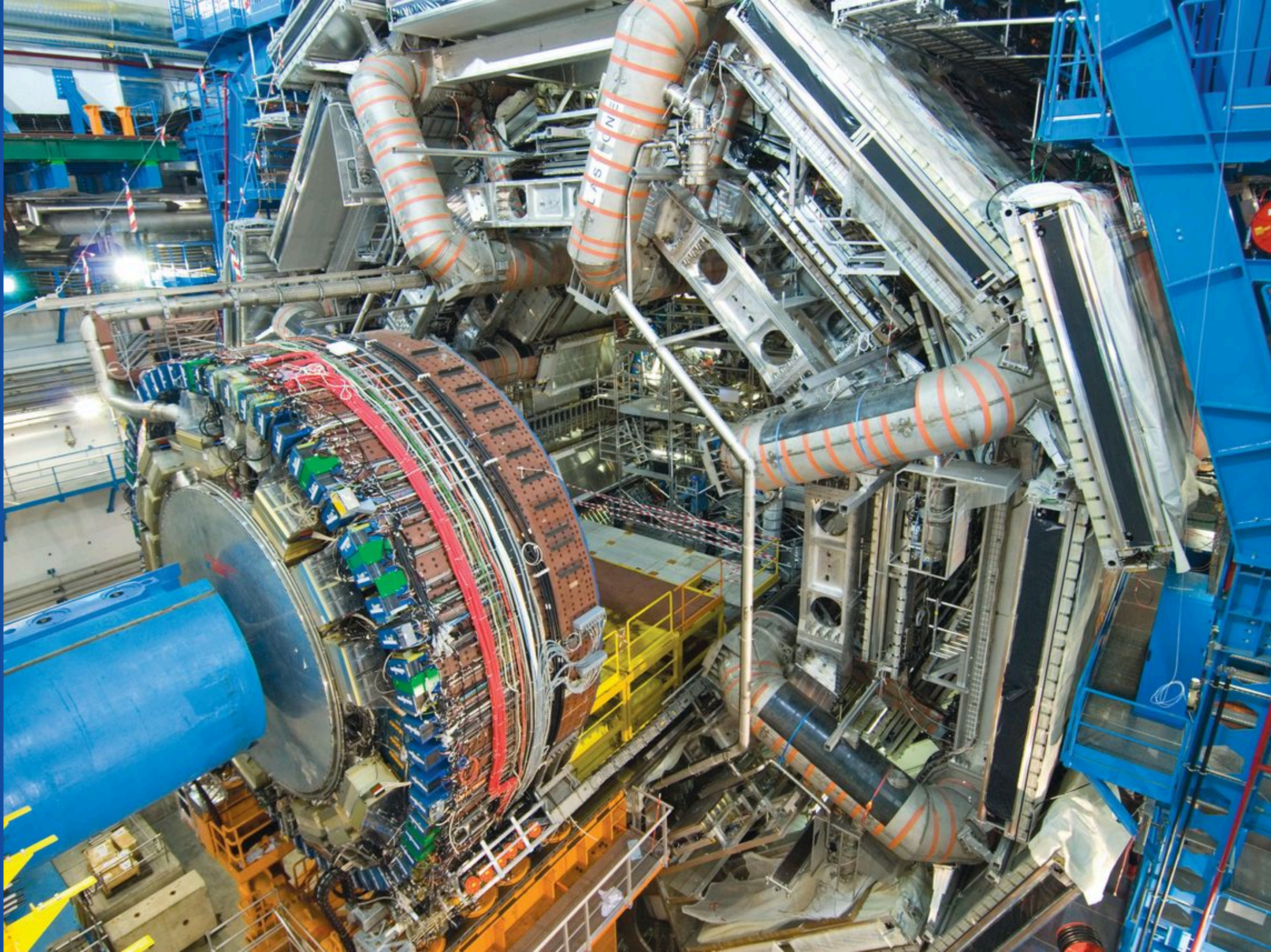
Patricia Conde Muíño
(IST, LIP)

The ATLAS Experiment



The ATLAS experiment

- Specialised detectors
- Cutting edge technology
- 10^8 electronic channels
- Home made fastest electronics



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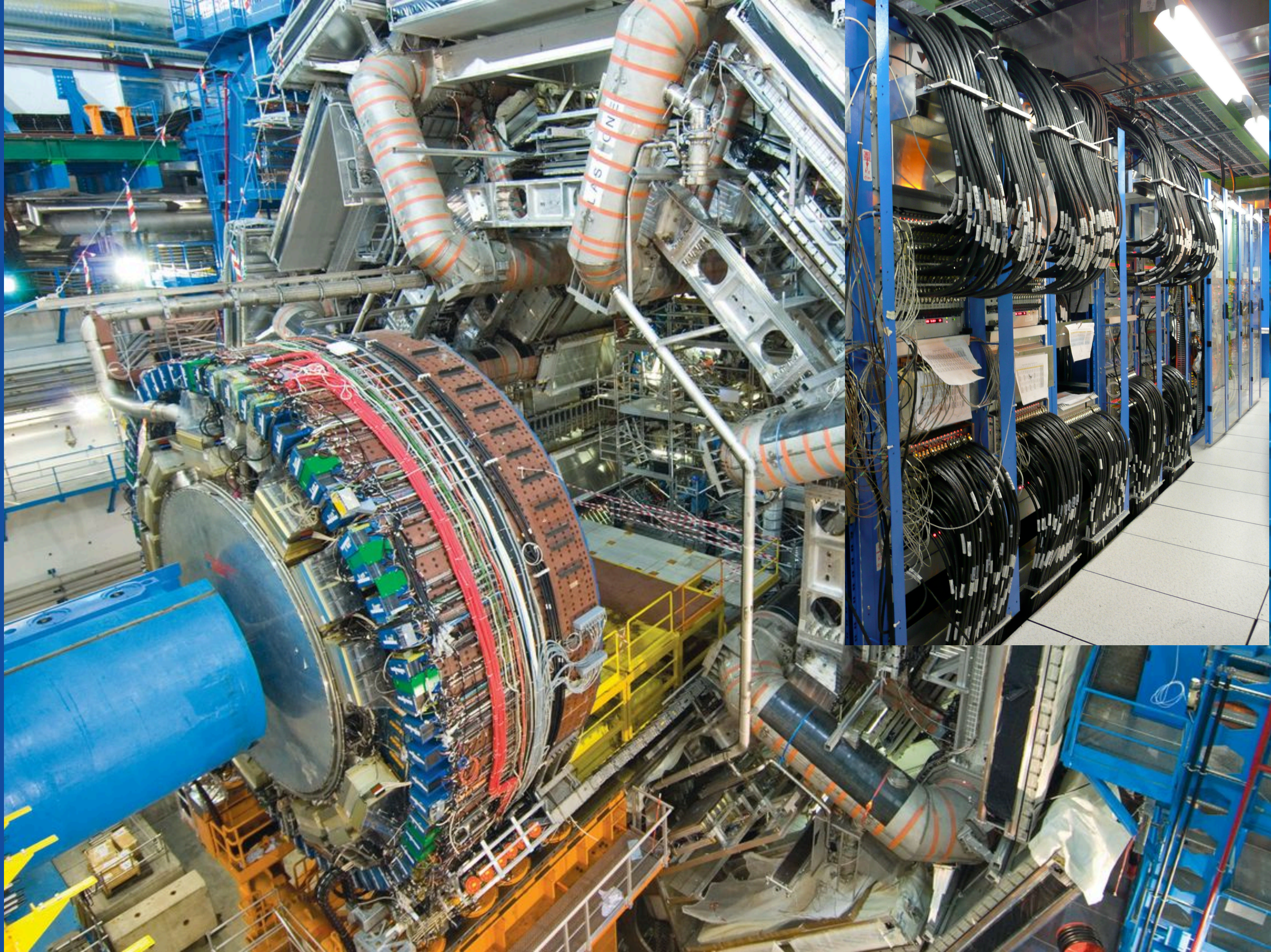
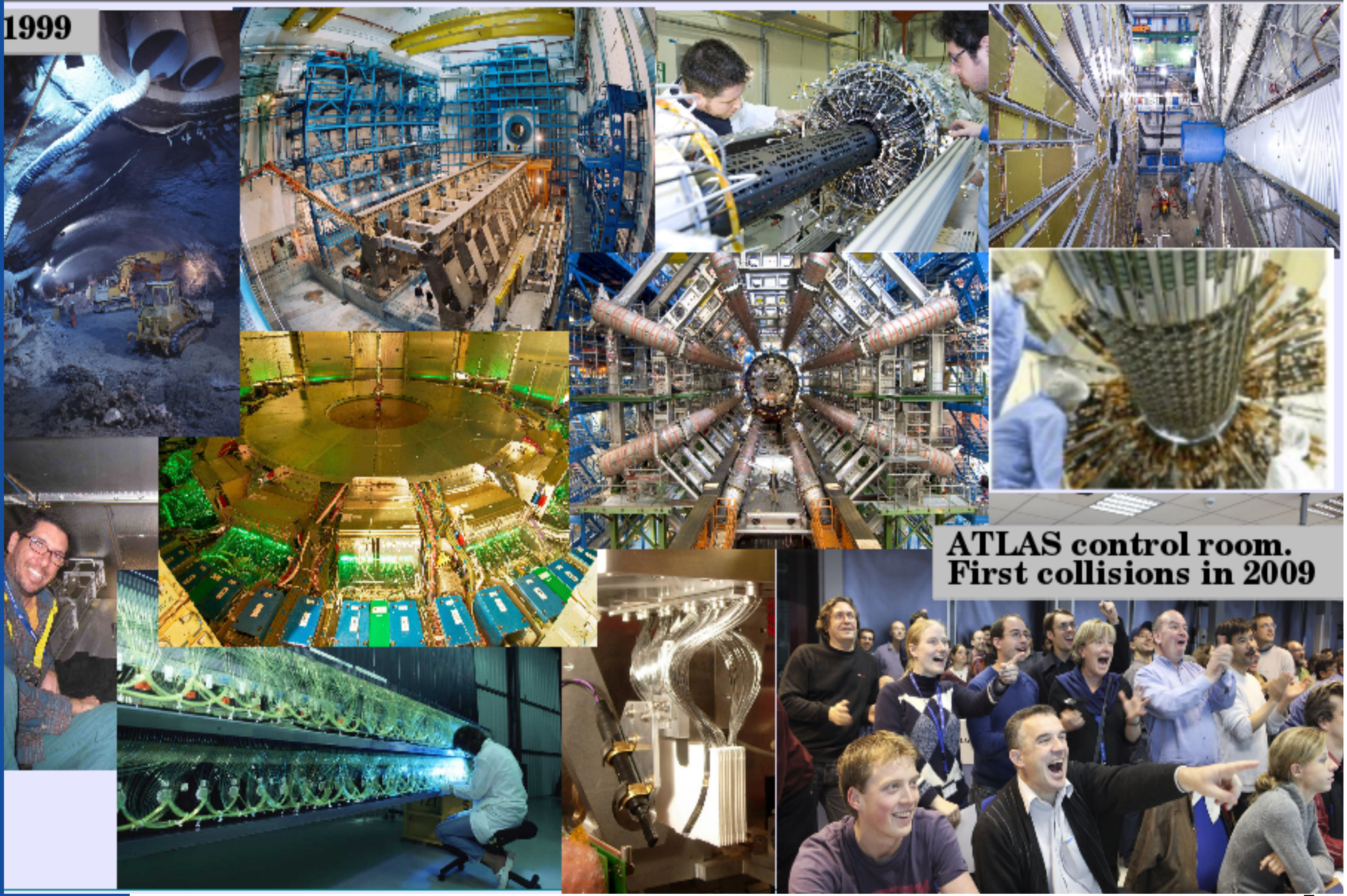


More than 30 years of continuous work



ATLAS Week in Lisbon

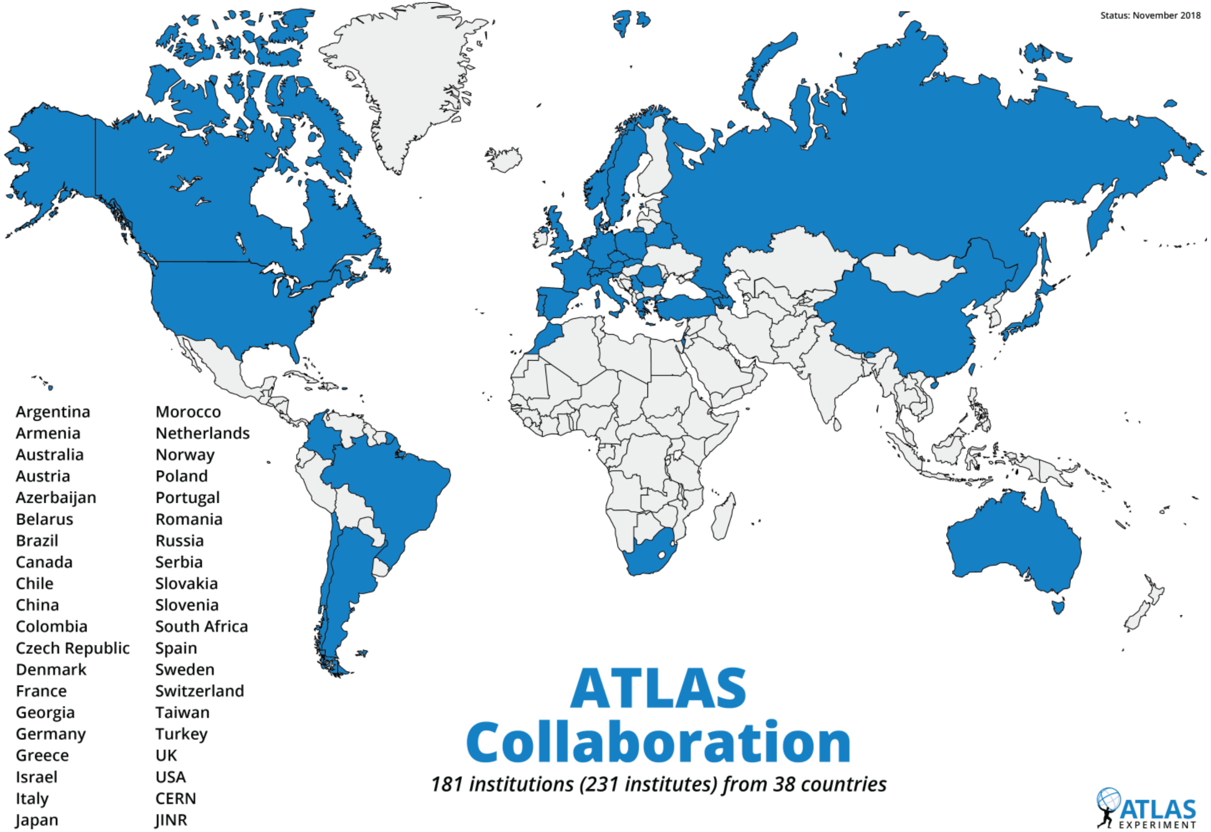
- 30 Anniversary of the Collaboration

ATLAS Collaboration

- Truly global:
- 181 Institutes,
- 38 countries

Composed of:

- >5000 members
- >3000 scientists
- ~1000 PhD students



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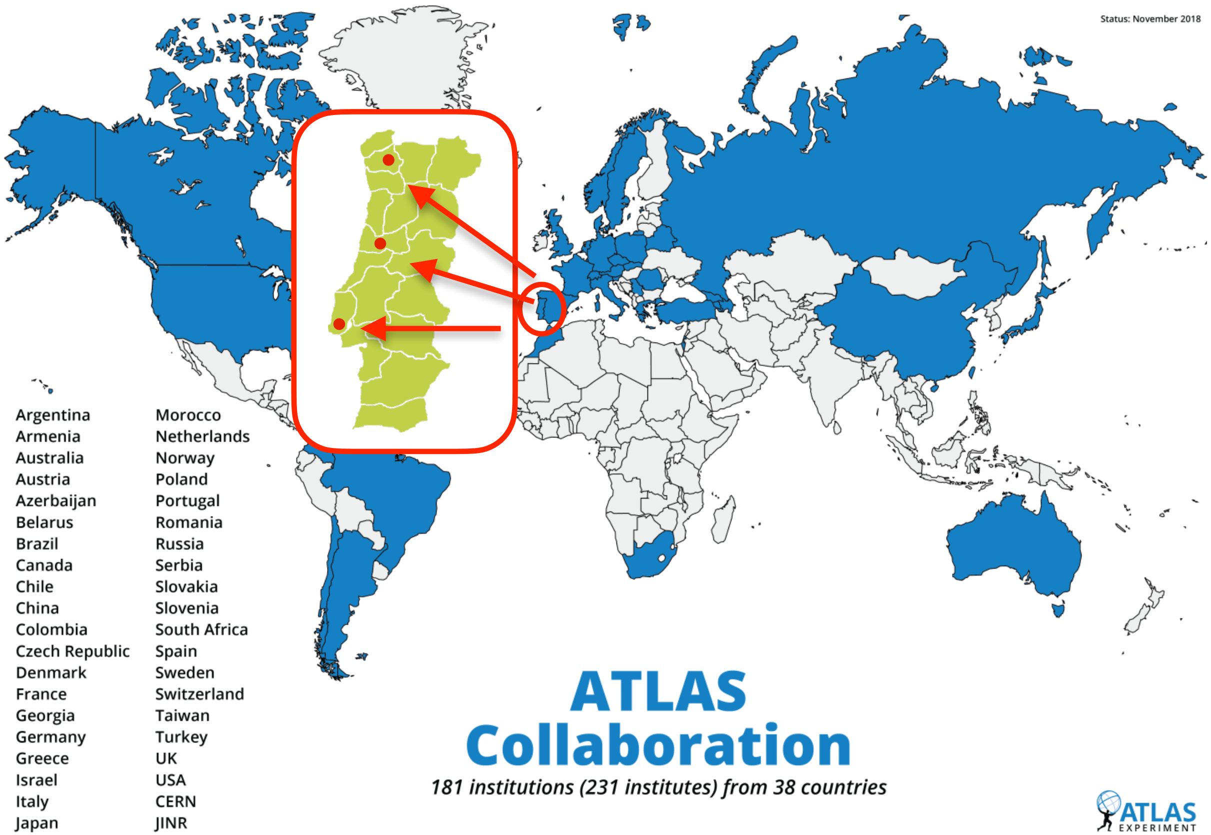


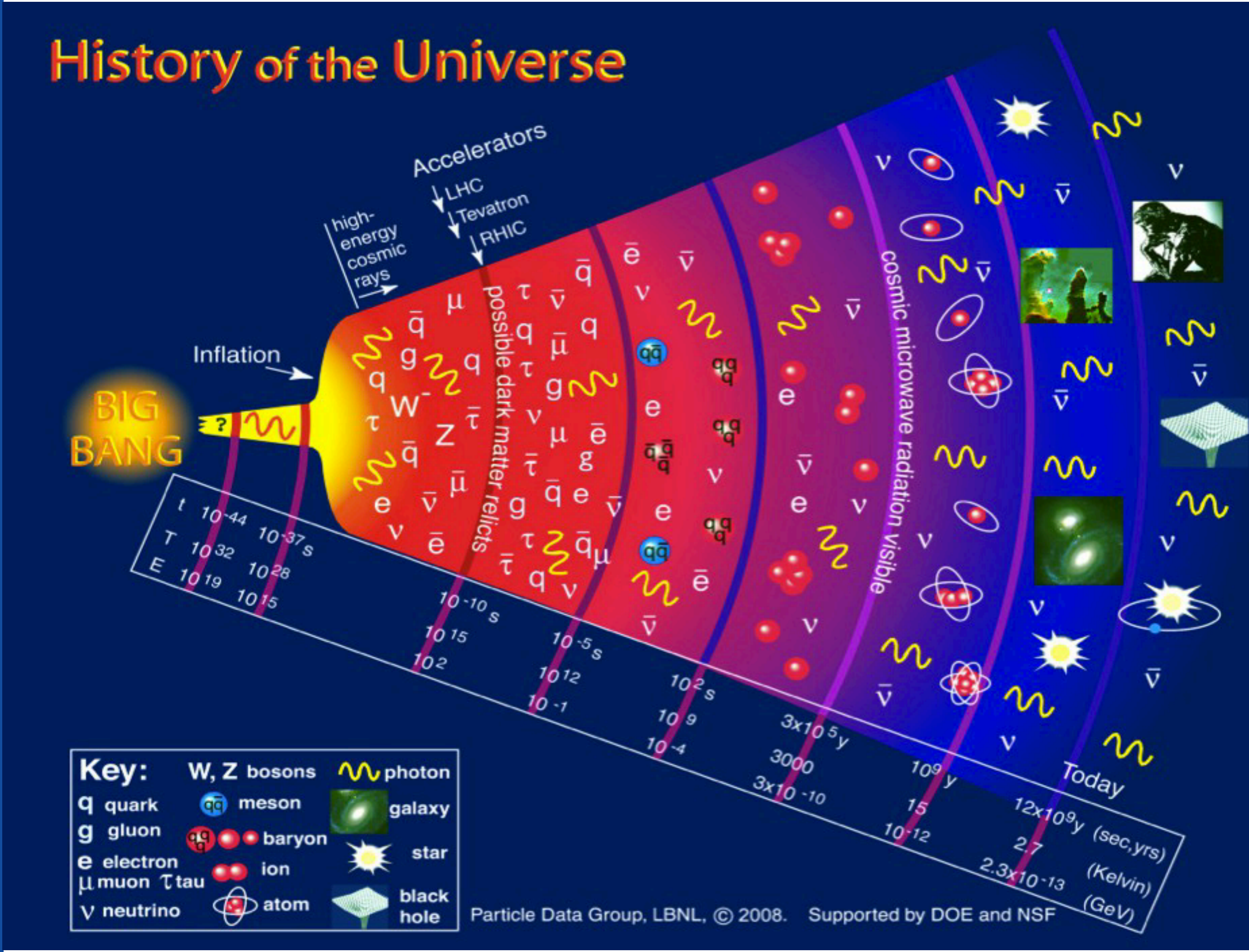
Portuguese ATLAS Team: national team

LIP (Lisbon, Coimbra, Minho), FCUL, FCTUC, U. Minho, CFNUL

CEFITEC/UNL, INESC, CFMC, AdI engineers training program

Physics topics

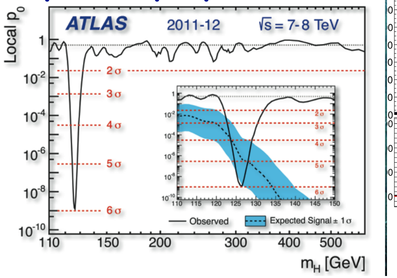
- Higgs couplings to quarks and W's
  - Spin/CP properties
- Search for new physics
  - Anomaly detection
- Study of the Quark Gluon Plasma
  - B-jets
  - Time evolution

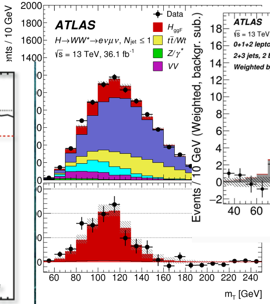


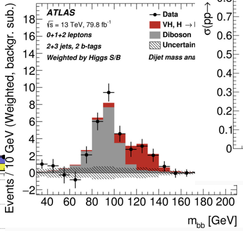
Portuguese contributions to ATLAS Physics Results

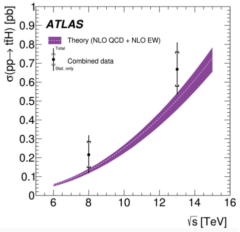
Higgs boson discovery and properties

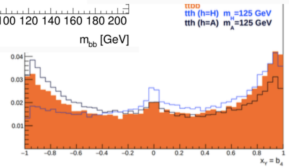
H→WW, H→bb, ttH
Spin/CP properties





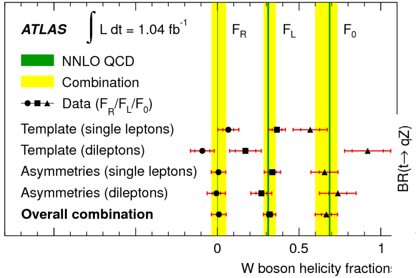


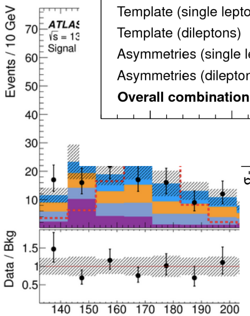


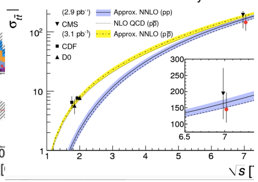


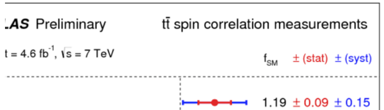
Top quark properties

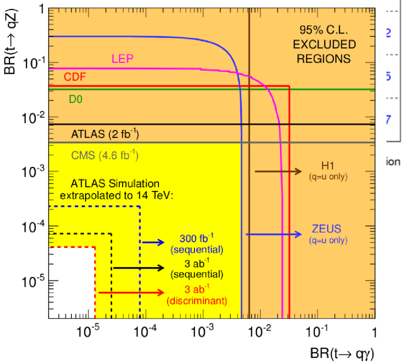
Comprehensive programme of top properties measurements









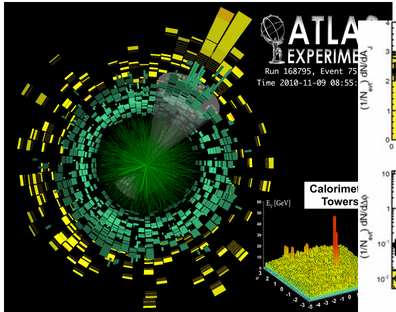


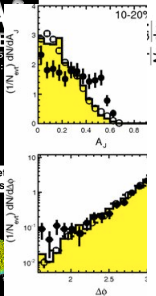
Searches for New Particles & Interactions

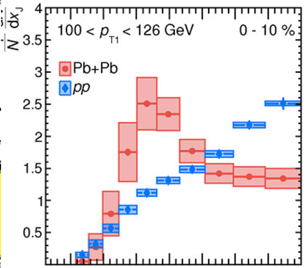
Dark matter, anomaly detection, …

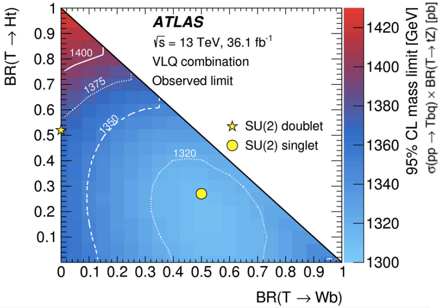
Heavy Ion Physics

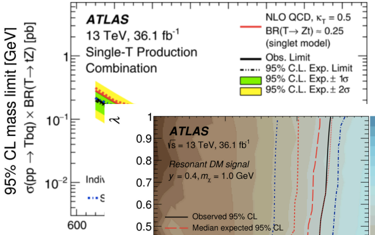
QGP jet quenching



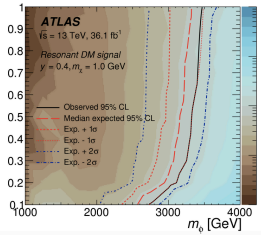


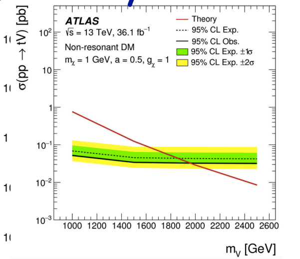






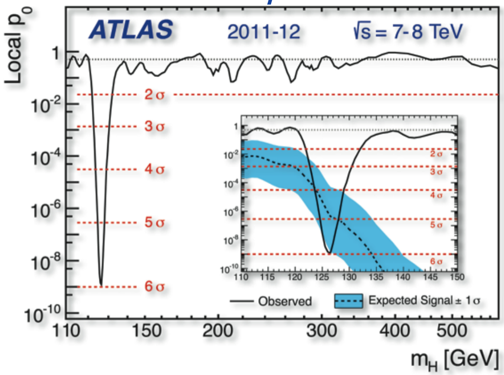
Leading positions in few analysis





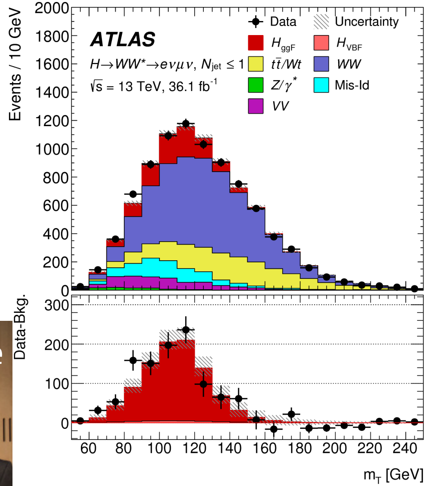
From discovering the Higgs to measuring its properties

- Discovery (2012)



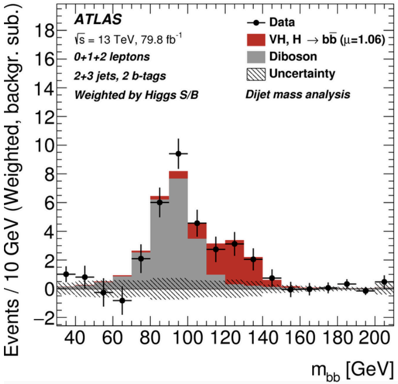
2015

- First observation of H→WW→$\ell\nu\ell\nu$



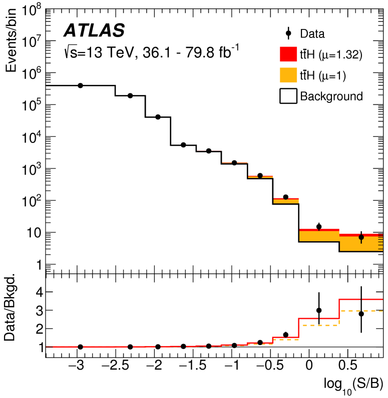
2018

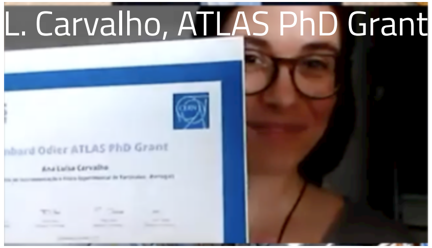
- First observation of H→bb



2018

- First observation of ttH production





And now what?

$$\mathcal{L}_{SM} = D_\mu H^\dagger D_\mu H + \mu^2 H^\dagger H - \frac{\lambda}{2}\left(H^\dagger H\right)^2 - \left(y_{ij} H \bar{\psi}_i \psi_j + \text{h.c.}\right)$$

Couplings to EW gauge bosons

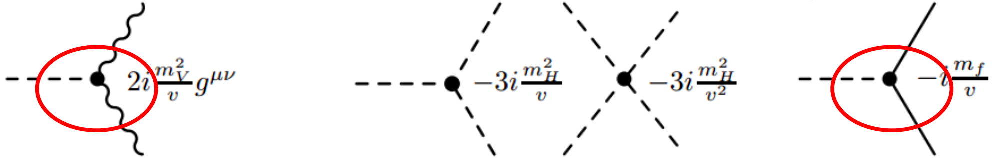
$$\left[m_W^2 W^{\mu+} W_\mu^- + \frac{1}{2} m_Z^2 Z^{\mu 0} Z_\mu^0\right] \cdot \left(1 + \frac{h}{v}\right)^2$$

Higgs self-couplings

$$-\mu^2 h^2 - \frac{\lambda}{2} v h^3 - \frac{1}{8}\lambda h^4$$

Couplings to fermions

$$-\sum_f m_f \bar{f} f \left(1 + \frac{h}{v}\right)$$

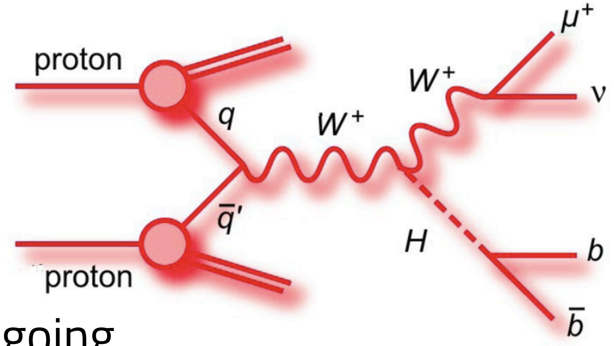


$$m_H = \sqrt{2}\mu = \sqrt{\lambda} v \quad (v = \text{vacuum expectation value})$$

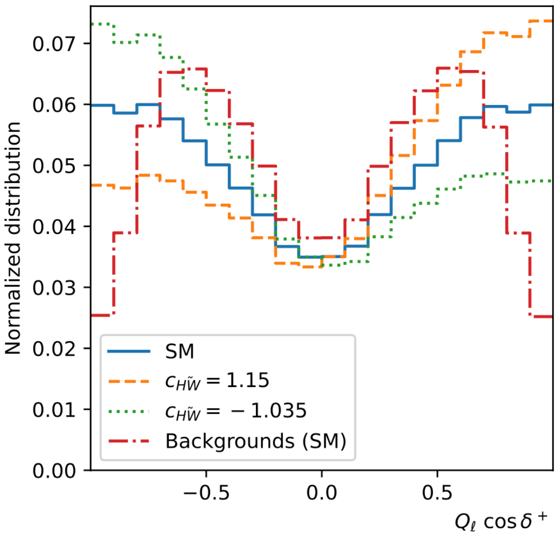
Measure couplings even more precisely

- Spin/CP properties of the vertices
- Probe SM predictions
- Search for new physics
  - Are they new particles in the loops?
  - Other Higgses?

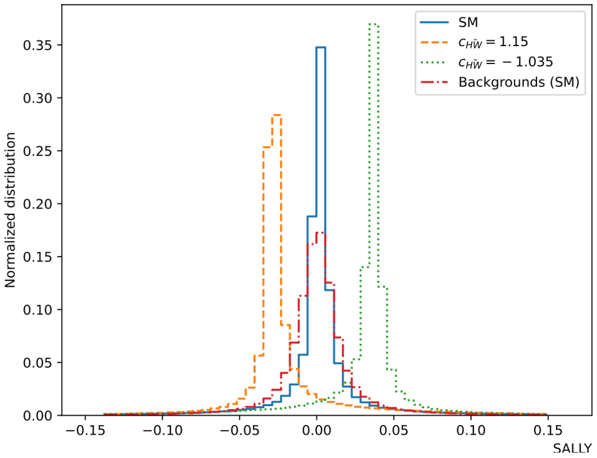
Higgs coupling to W bosons



- Spin/CP properties of the HWW vertex
  - Angular observables - Run 2 measurements - ongoing
  - Machine Learning Inference methods — future?



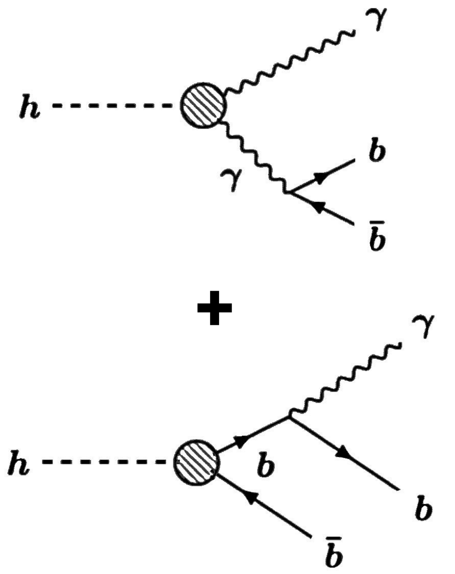
ArXiv: 2308.02882

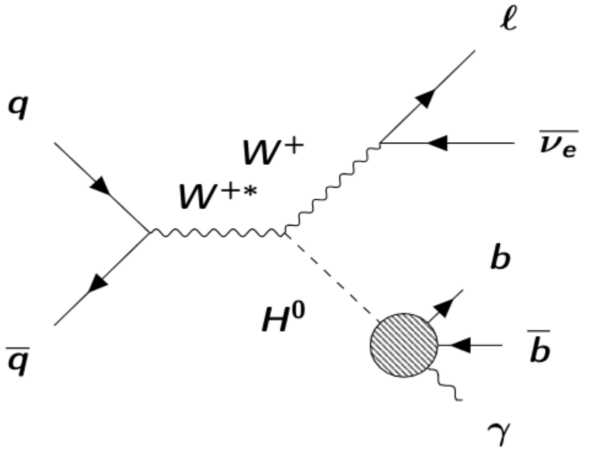


R. Barrué, PhD thesis
M. Kholodenko, PhD thesis
M. Silva, Master thesis
B. Rosalino, Master thesis

Measuring the Higgs coupling to the b-quarks

- $H \to b\bar{b}\gamma$ decay sensitive to anomalous couplings in the $H \to \gamma\gamma$ and $H \to b\bar{b}$ interaction vertices
  - How sensitive is the ATLAS experiment to measure this decay using jets in the final state?

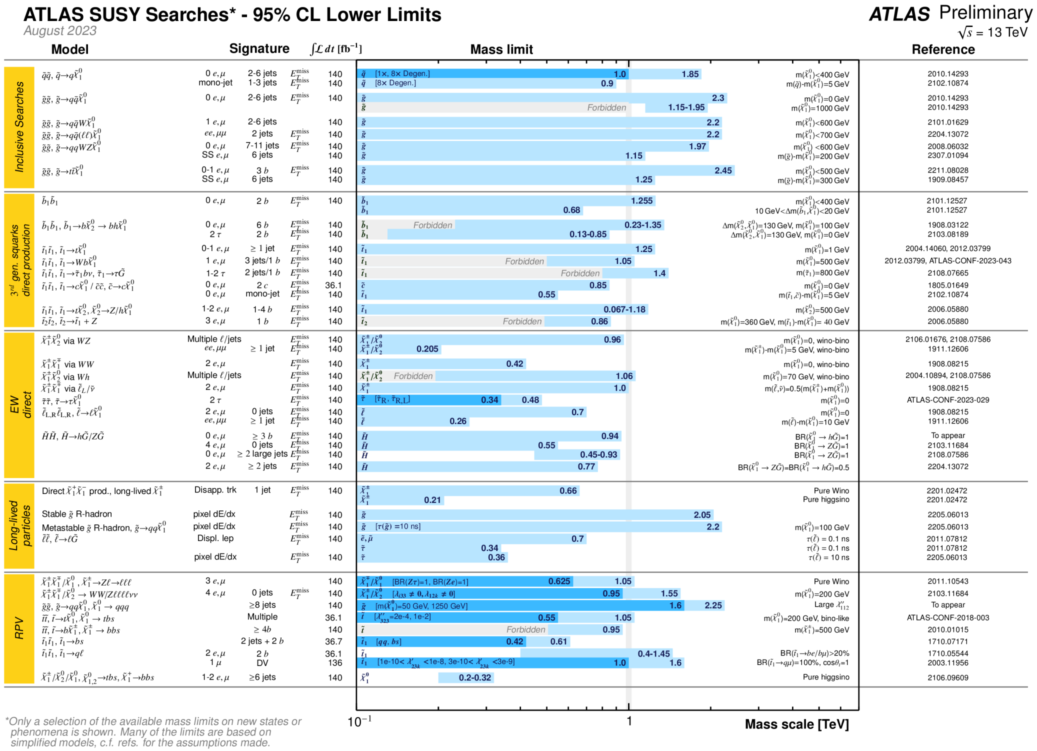




Carolina Costa, master thesis

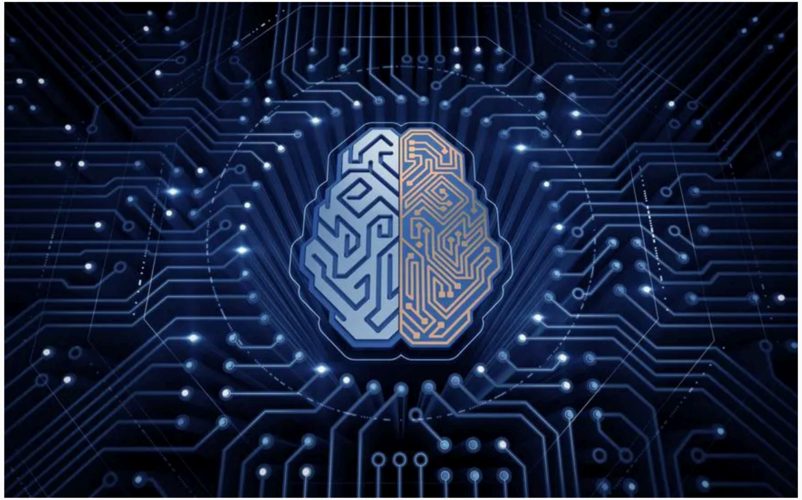
Searching for the unknown...

- Despite our efforts, no new particles have been observed at the LHC
-

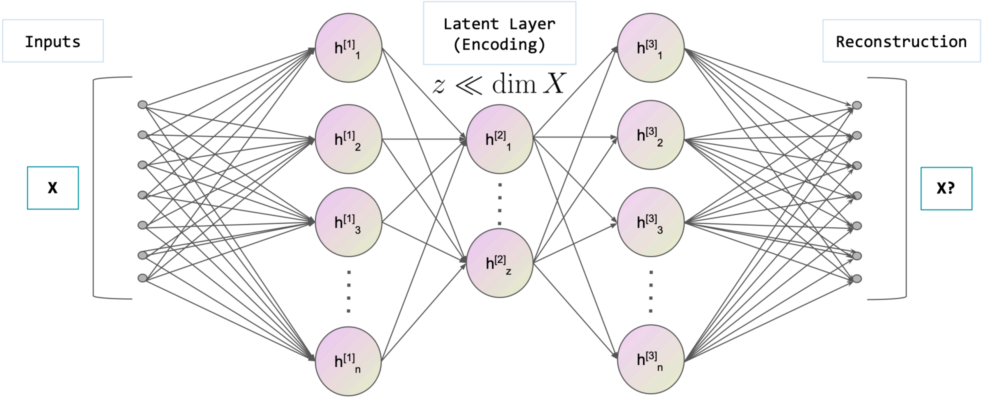


Searching for the unknown…

- Despite our efforts, no new particles have been observed at the LHC
- ML Anomaly Detection
  - Train deep learning models to learn SM background
  - Reconstruction error is a measurement of anomaly
  - Increases search generality

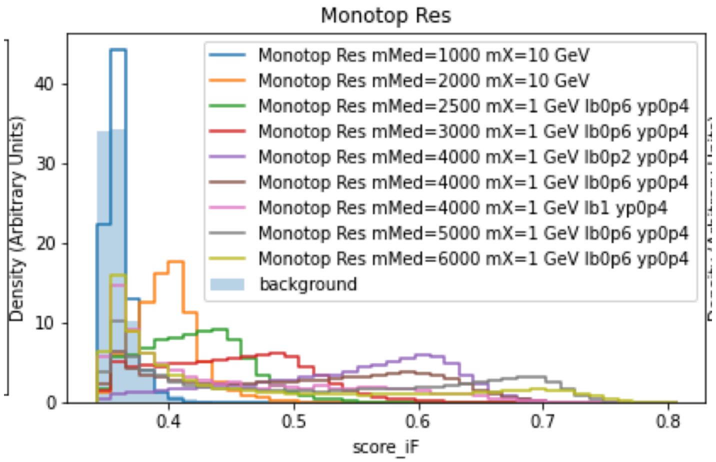


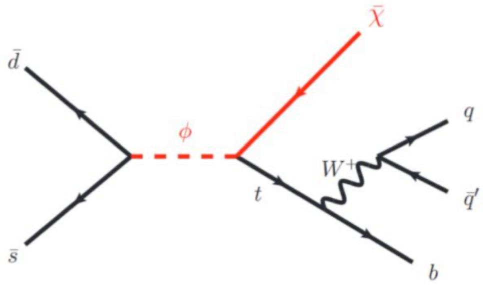
Artificial Intelligence FOTOLIA - SERGEY TARASOV



Example:

- Method: auto-encoder
- Background: Standard Model
  - Top quark production
  - Di-boson production
  - Top quark + vector boson production
  - W+jets
  - Z+jets
- Testing several signal models of dark matter production





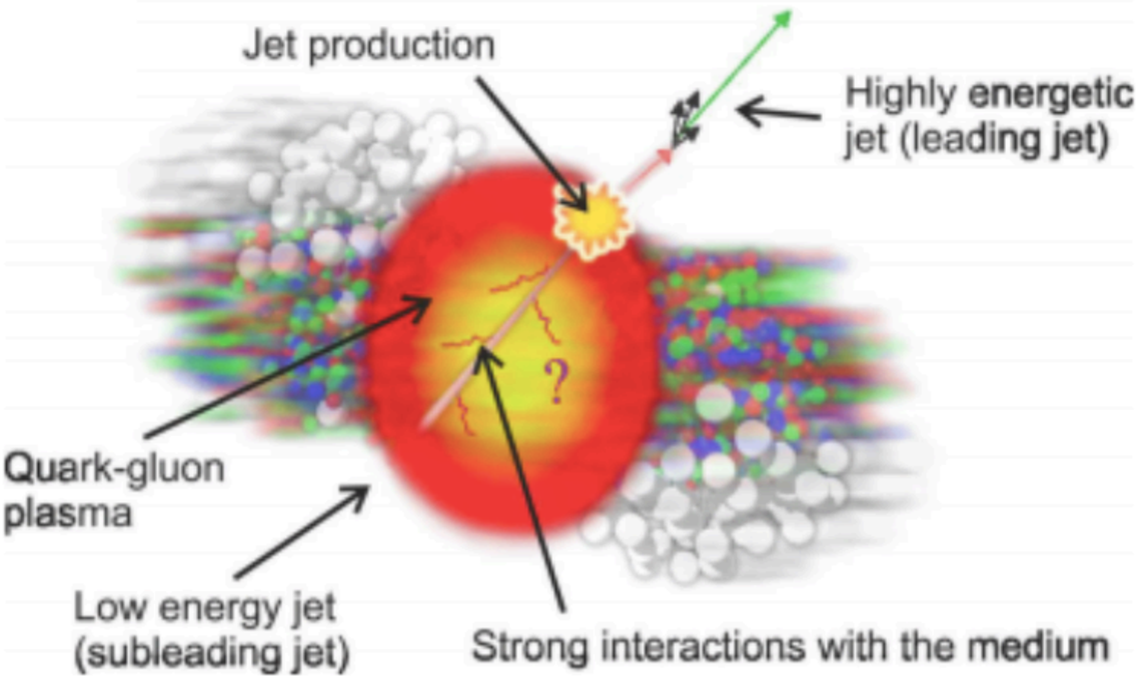
I. Pinto, Master thesis

I. Moreira, Master thesis

A. Berti, PhD thesis (Minho U.)

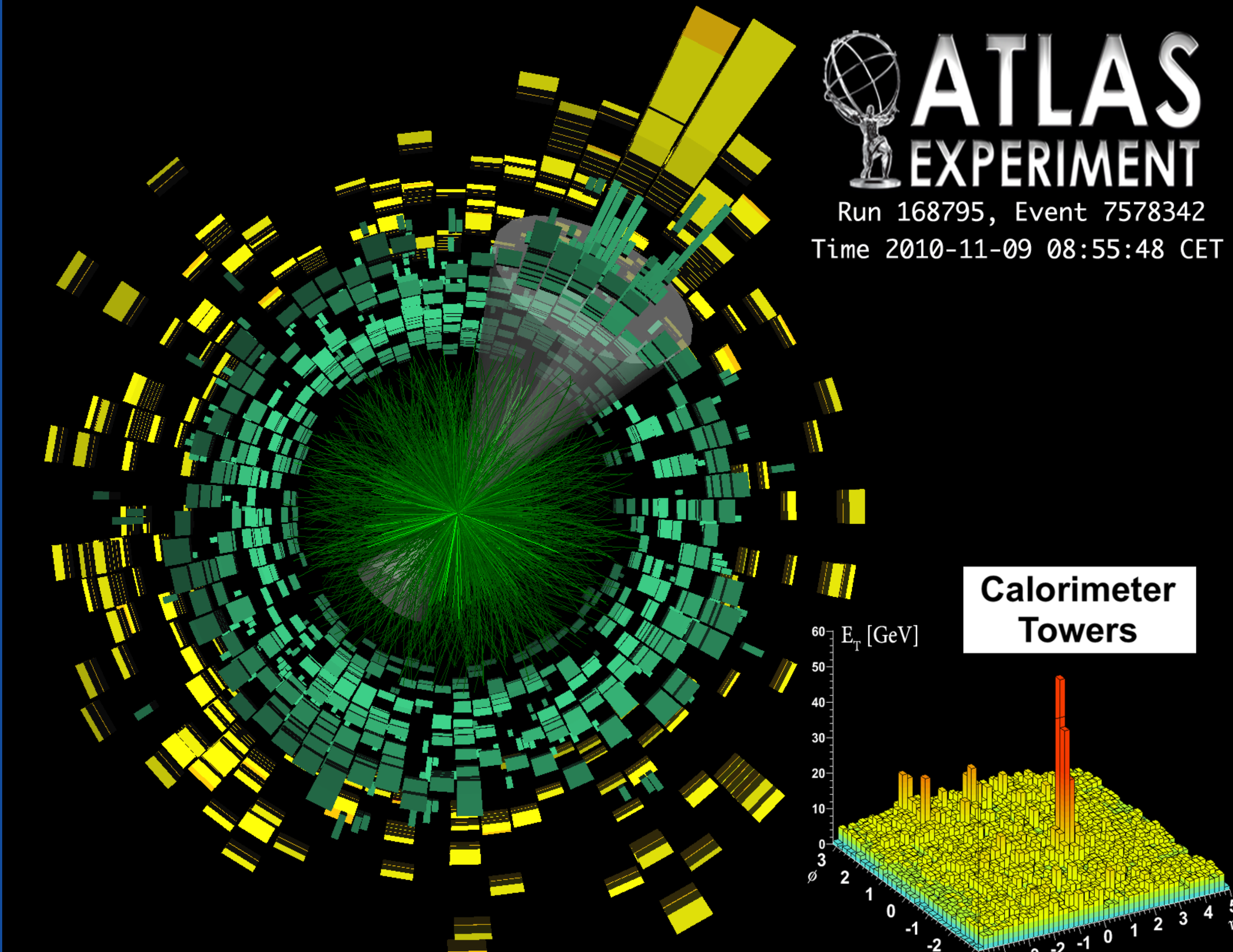
The Quark Gluon Plasma

- New state of matter created in PbPb collisions
- Jets are suppressed as they cross the QGP
- Study jets to understand the way particles interact with the QGP
- b-quark jets particularly interesting



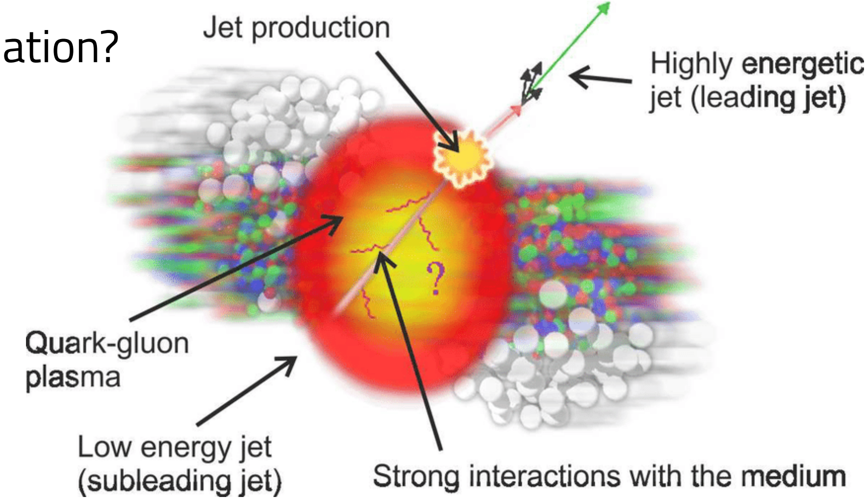
The Quark-Gluon Plasma Heavy Ion Collisions

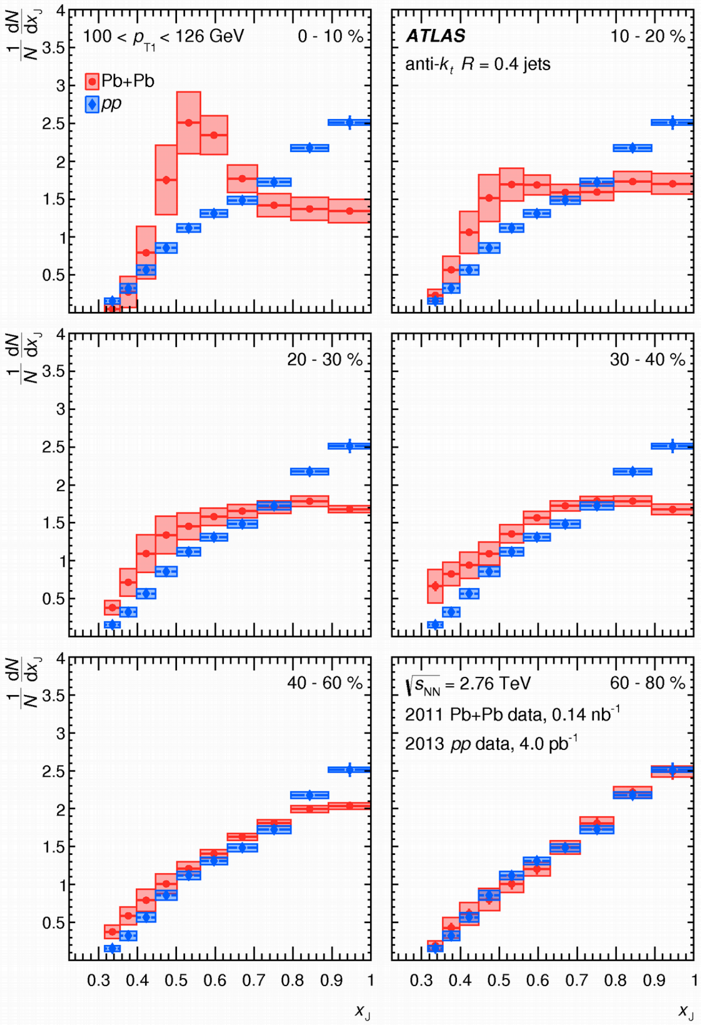
- First observation in 2010
- Probe of Quark-Gluon Plasma



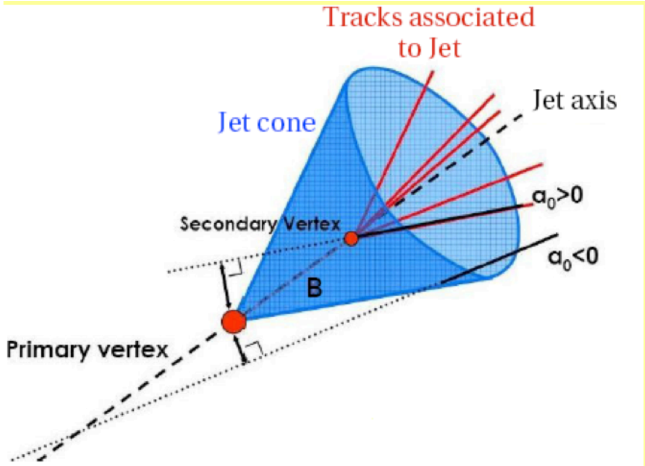
b-jet suppression to probe the QGP

- Distinguish the nature of the energy loss
  - Collisional?
  - Radiation?



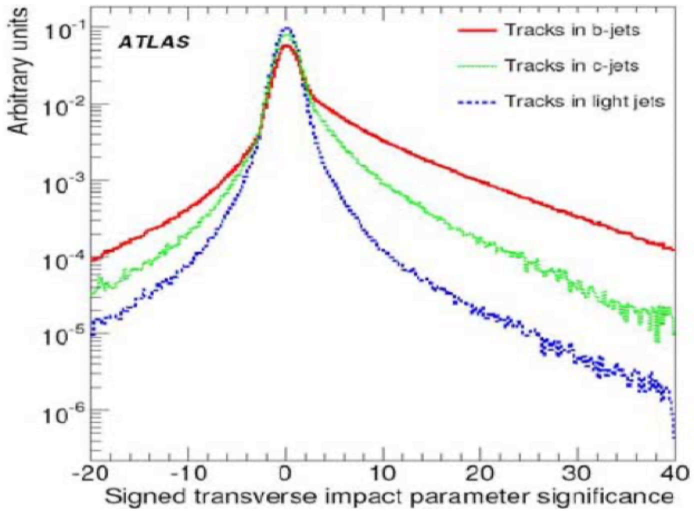


B-tagging algorithms



Master thesis proposal for 2024

- Development of b-tagging algorithms for Heavy Ion Collisions in ATLAS
- GN2 flavour-tagging algorithm (2nd generation Graphical Neural Learning)
  - New approach using Graph Neural Nets
  - The focus is to evaluate the ability of the GN2 tagger to differentiate and consequently identify the flavour of the jets produced in Pb+Pb collisions.

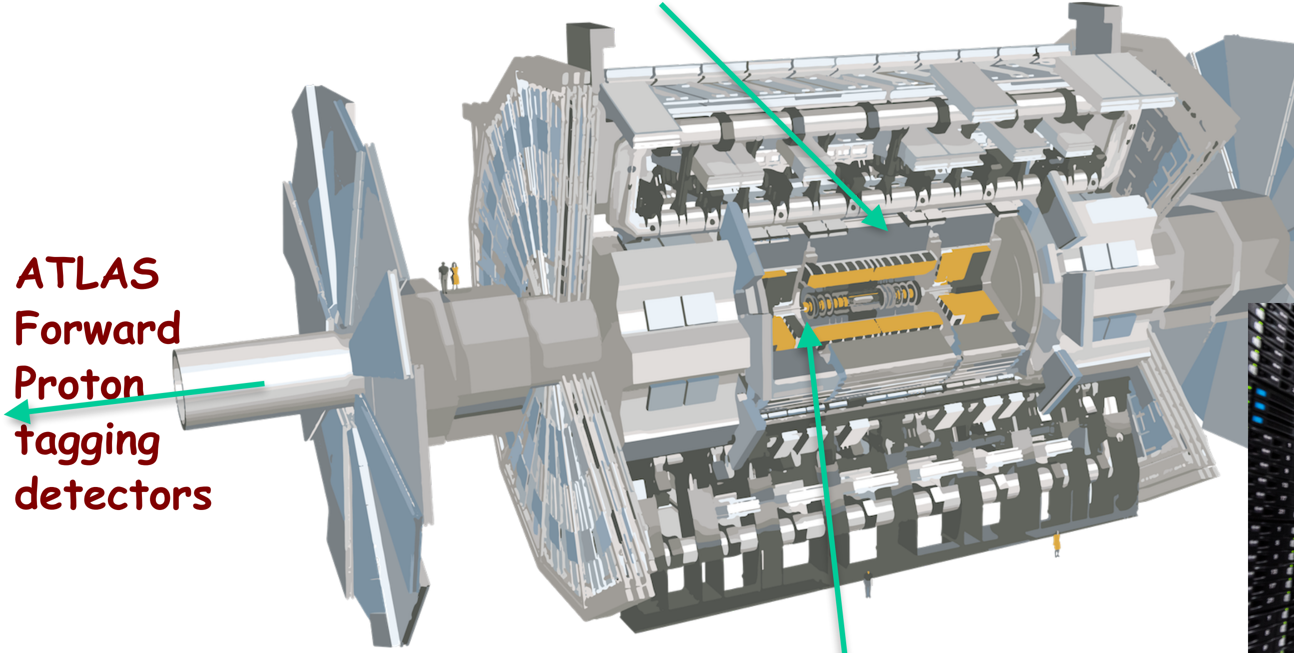


Portuguese Responsibilities

in ATLAS

Detector Control System

TileCal Hadronic Calorimeter

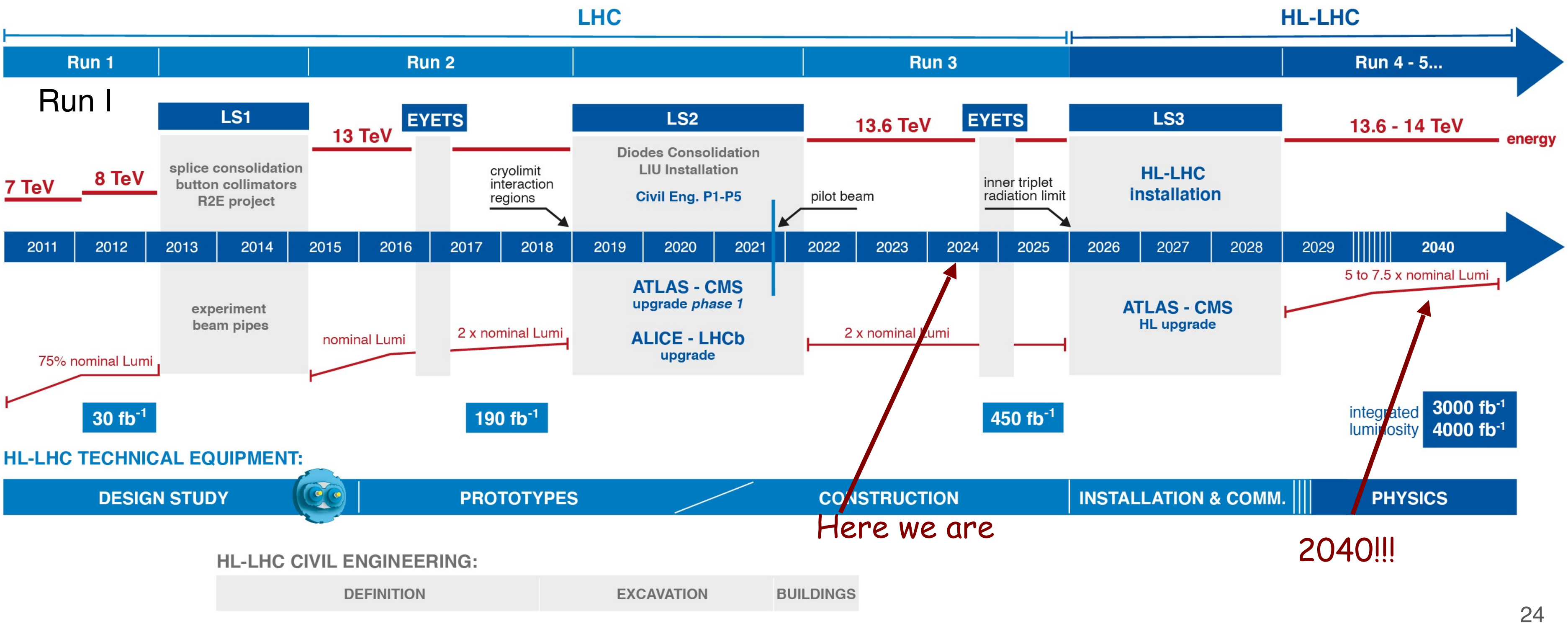


ATLAS Forward Proton tagging detectors

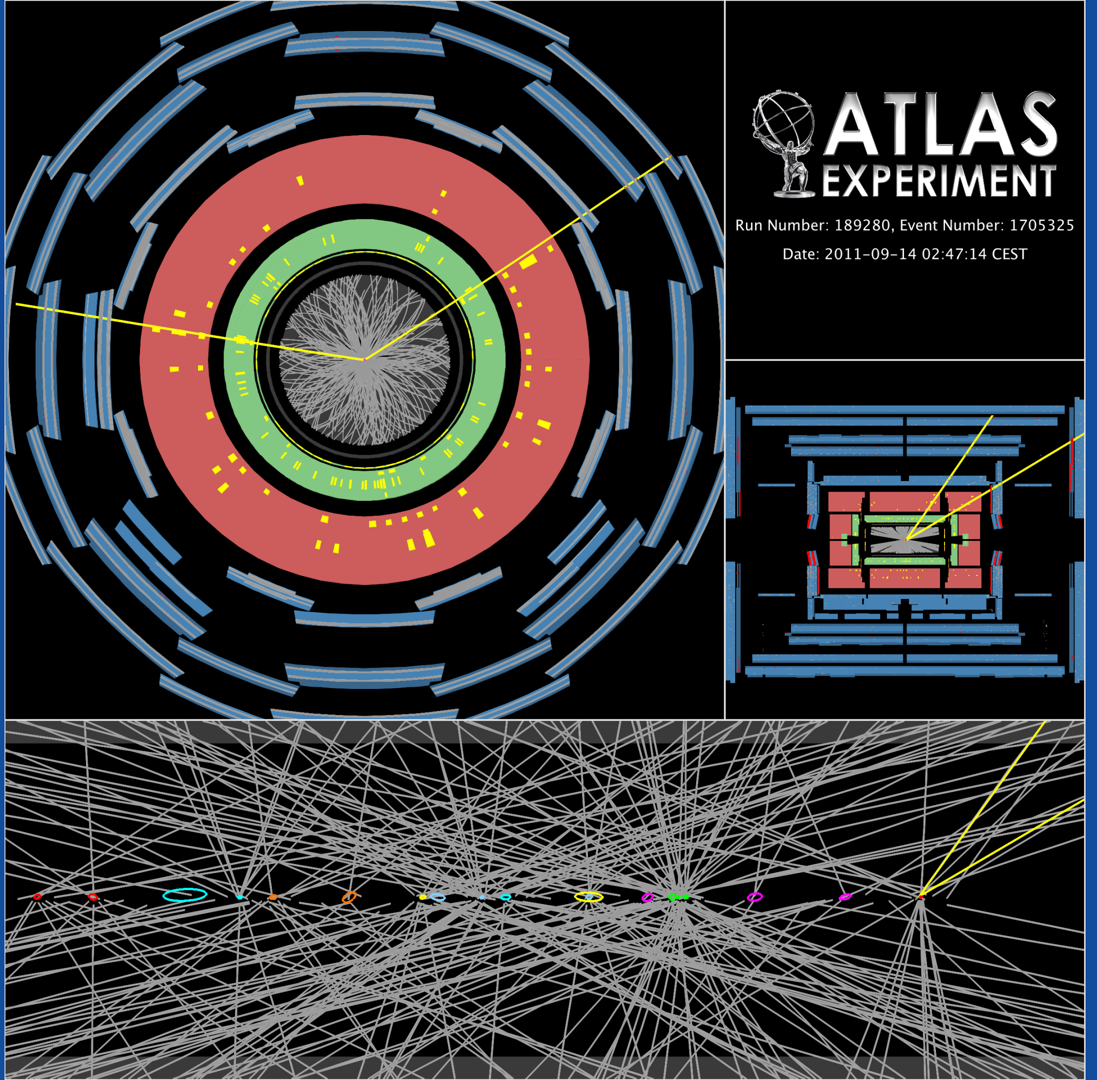
High Granularity Timing Detector

High Level Trigger

LHC / HL-LHC Plan

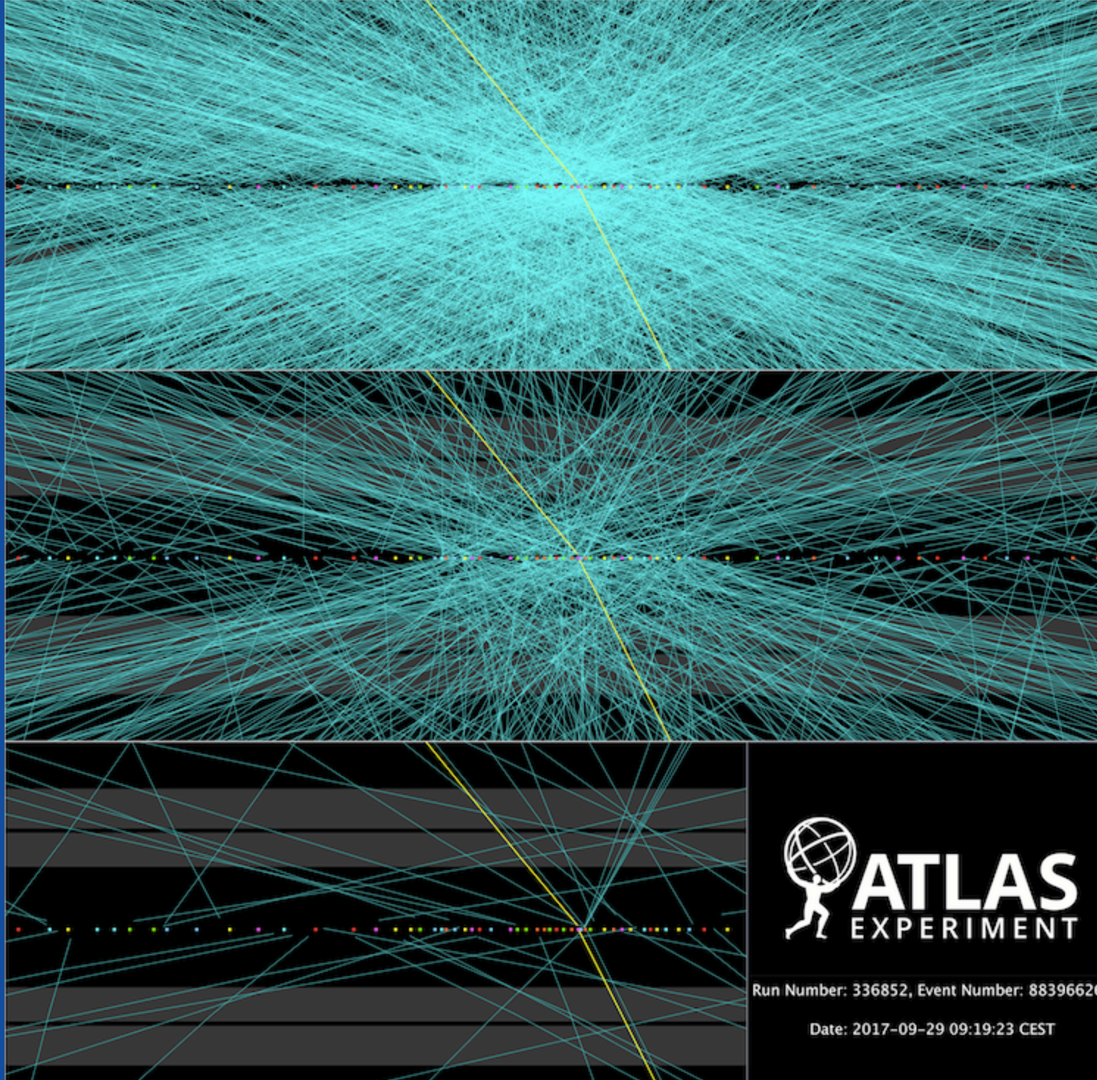


Z→$\mu\mu$ event with 20 pile-up interactions



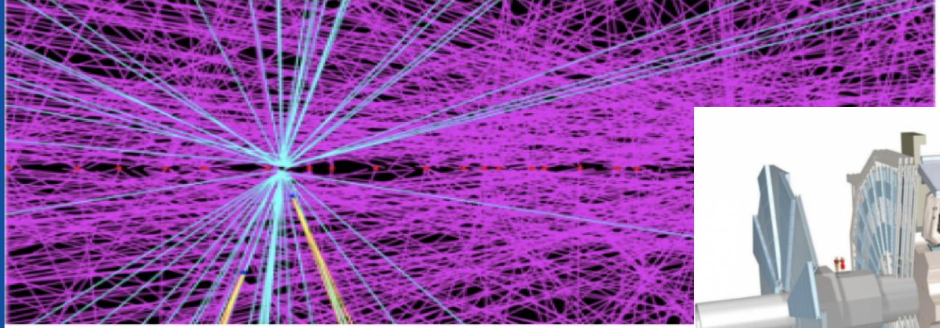
Upgrade challenges

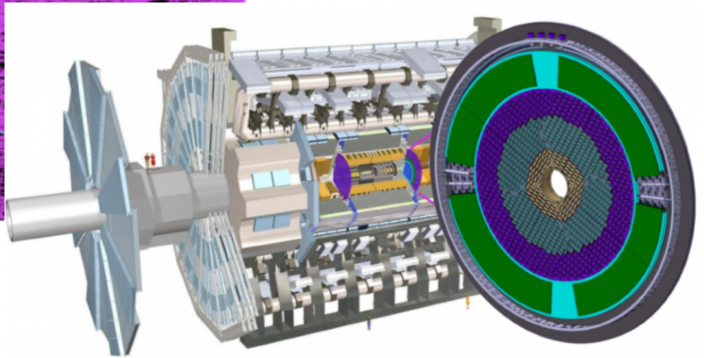
- Huge detector occupancy
- Evento com um decaimento Z→$\mu\mu$ e mais outras 65 colisões pp

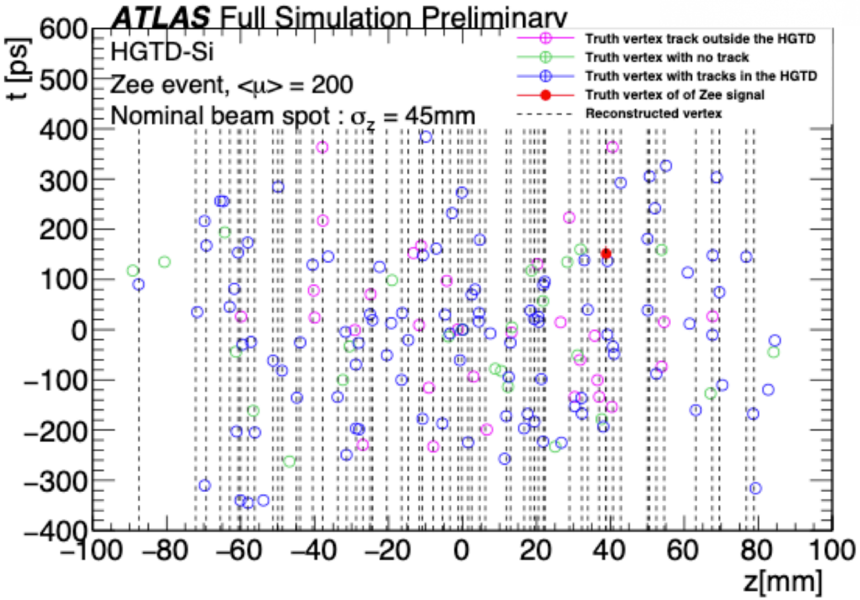


High Precision Timing Detector

- Improve primary vertex identification
- 30 ps resolution timing

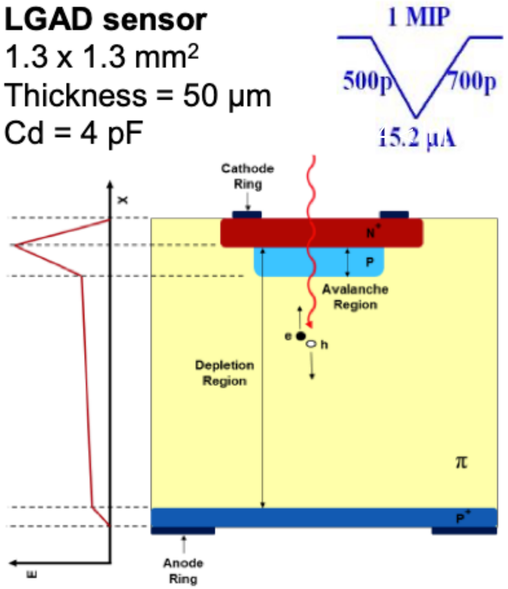


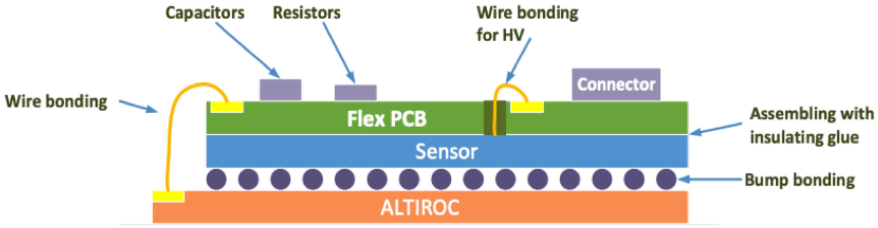




High Precision Timing Detector

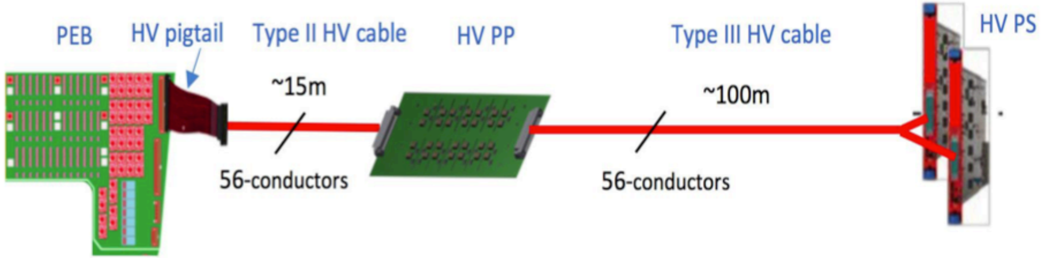
- 30 ps resolution timing using Silicon Low Gain Avalanche Diodes (LGAD)
  - Improves pileup vertex separation and luminosity measurements
- LIP contributes to several areas
  - Electronics: readout ASIC tests, High Voltage filtering
  - Detector control system and safety Interlocks
  - Monitoring
- Other possibilities being followed
  - Cable production in Portuguese industry
  - Mechanical design and production at LIP

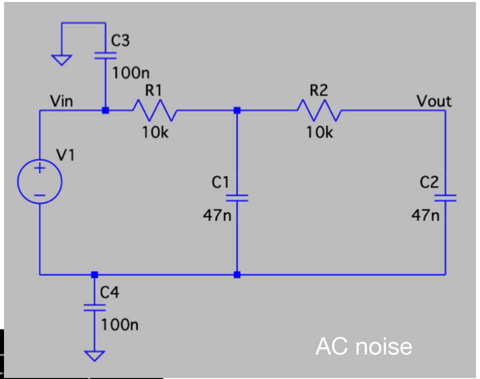


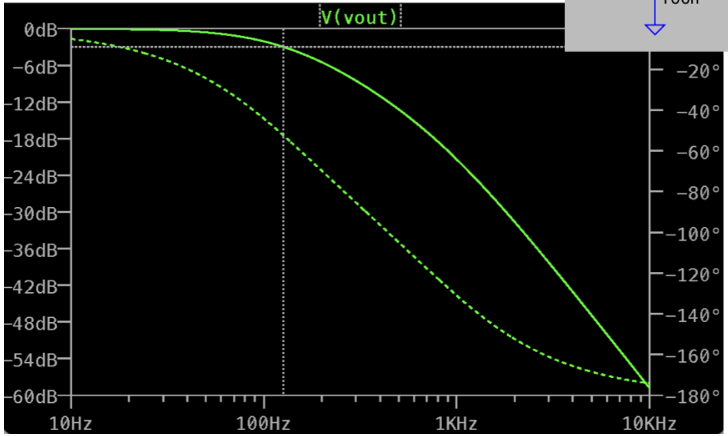


Electronics and High-Voltage

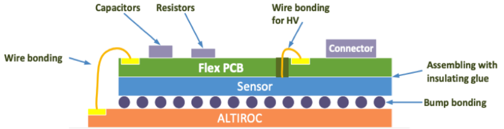
- HV patch panels
- Routing the High Voltage to HGTD detector
- HV brought to low pass filters in the patch panels to filter AC noise
- LIP responsability - Master student António Caramelo (U. Coimbra) developed this project

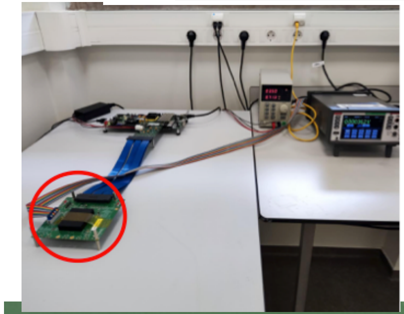


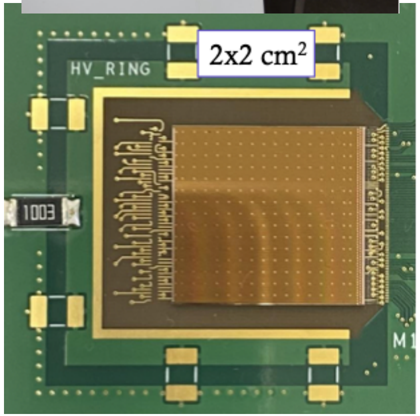


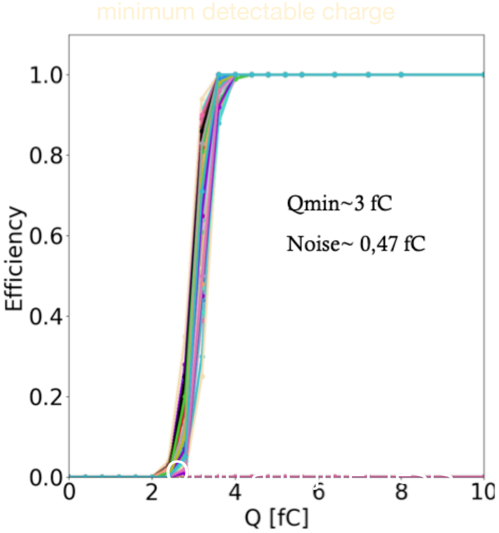


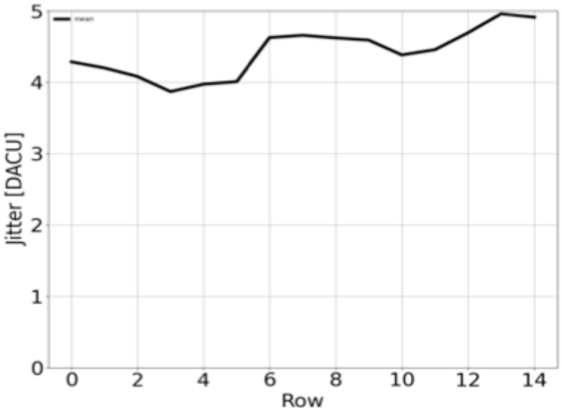
ALTIROC ASIC tests at LIP

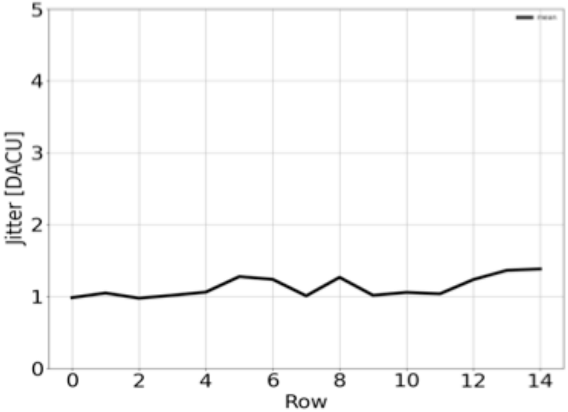








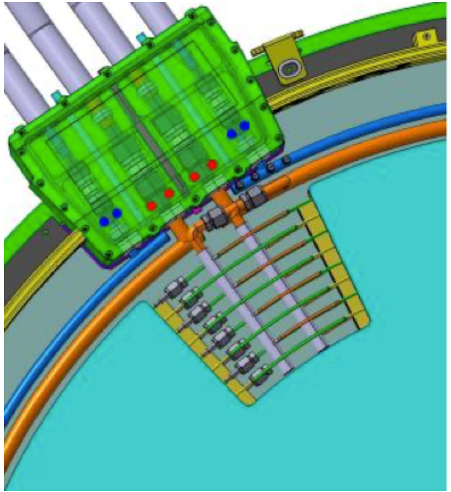




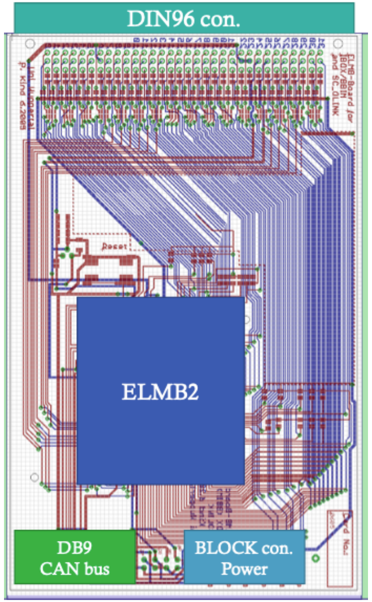
Detector Control System (DCS)

- DCS architecture design
- Readout of DCS environment data through ELMB2 communication board

monitoring of the CO_2 cooling system via Pt10k sensors



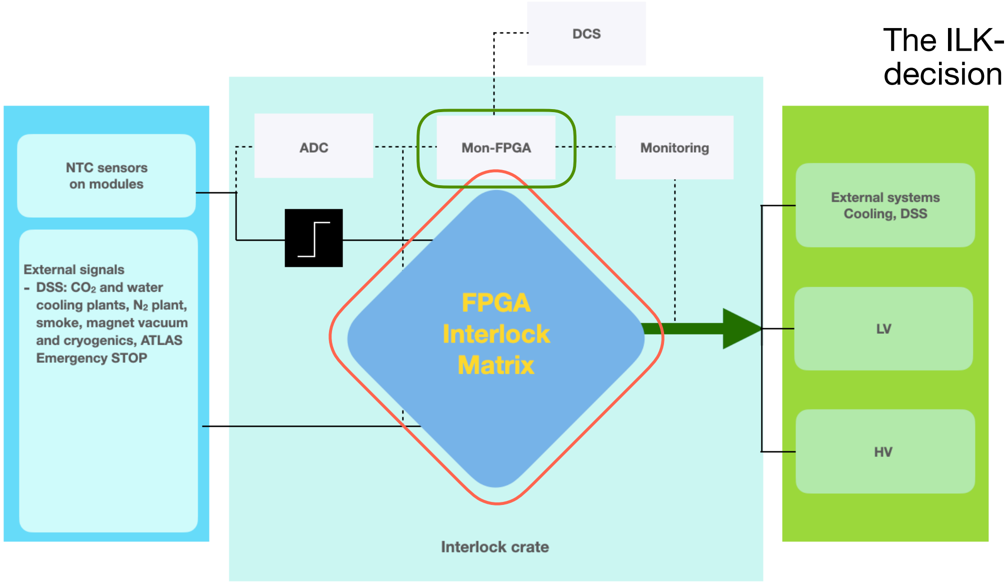
- Temperature range: from −45○C to +20○C
- Maximal tolerable offset (accuracy) of sensor: ±0.2○C
- Precision of sensor: ±0.5○C



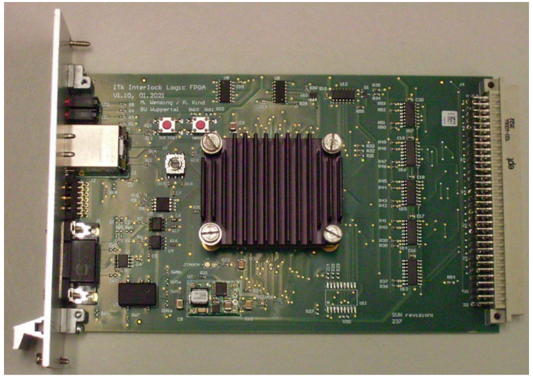
- same ELMB board as ITk
- Signal Conditioning board, backplane of both boards and power supply to be designed

The Interlock of the High Granularity Timing Detector

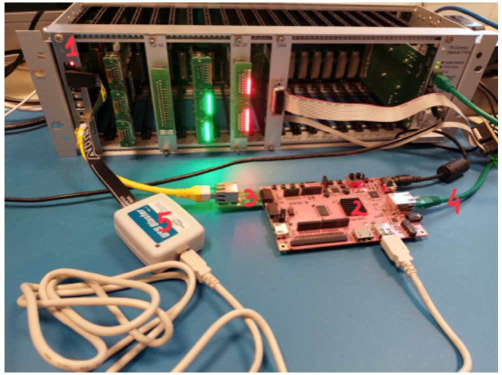
- LIP responsibility
- Master students Rui Vieira and Alexandre Parreira (FCUL) configure the FPGAs



The ILK-FPGA is the central decision unit

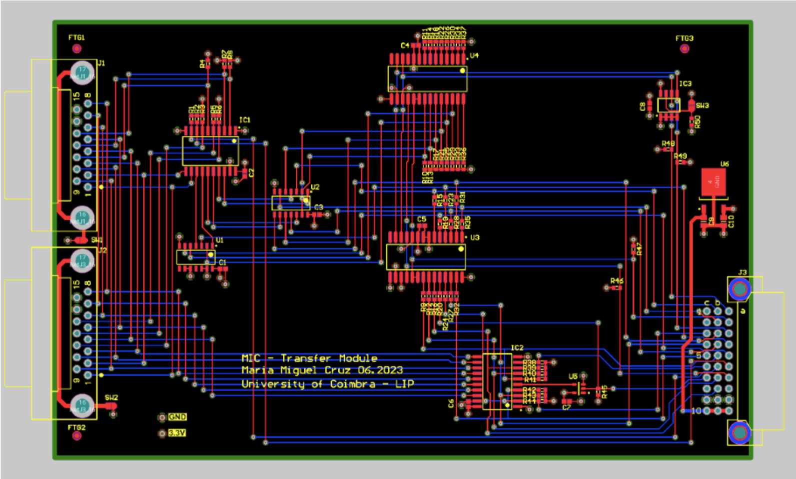


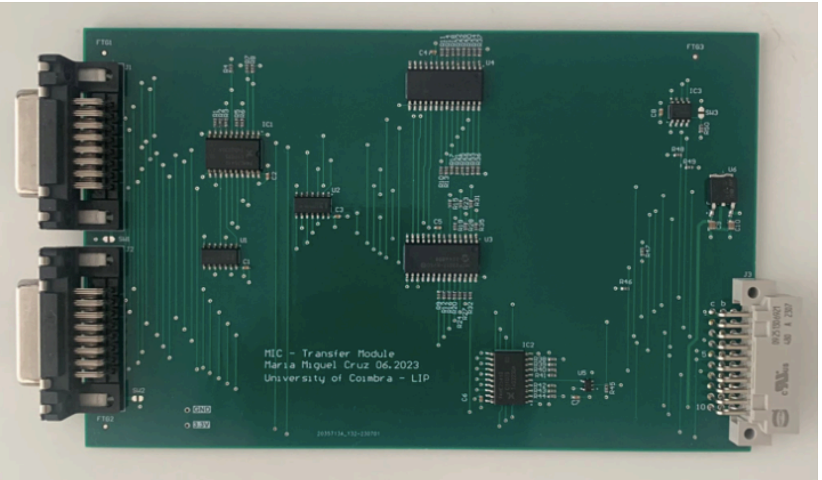
The MON-FPGA is responsible for the monitoring of all parameters which are required to debug an interlock event.



The Interlock of the High Granularity Timing Detector

- LIP responsibility
- The Transfer Module in the Main interlock Crate propagates the signals from ATLAS Detector Safety System to the FPGA Interlock Matrix



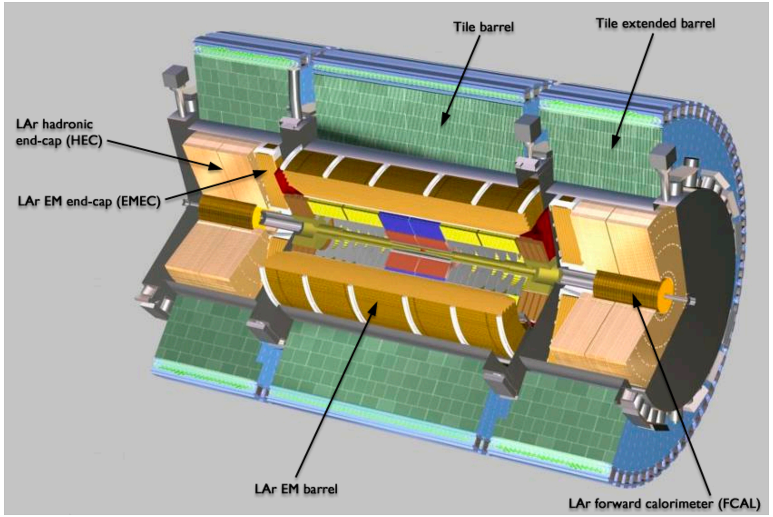


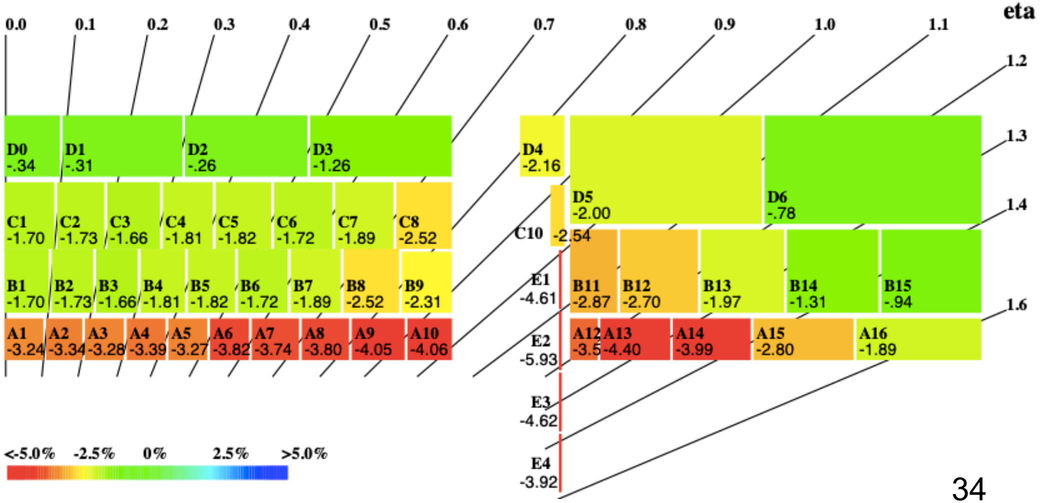
- Prototype under tests

Master student Maria Miguel Cruz (U. Coimbra) developed this project

TileCal Hadronic Calorimeter Upgrade

- Calibration
  - Optimize performance
- Study radiation hardness with pp collisions
- Development of scintillators for future colliders



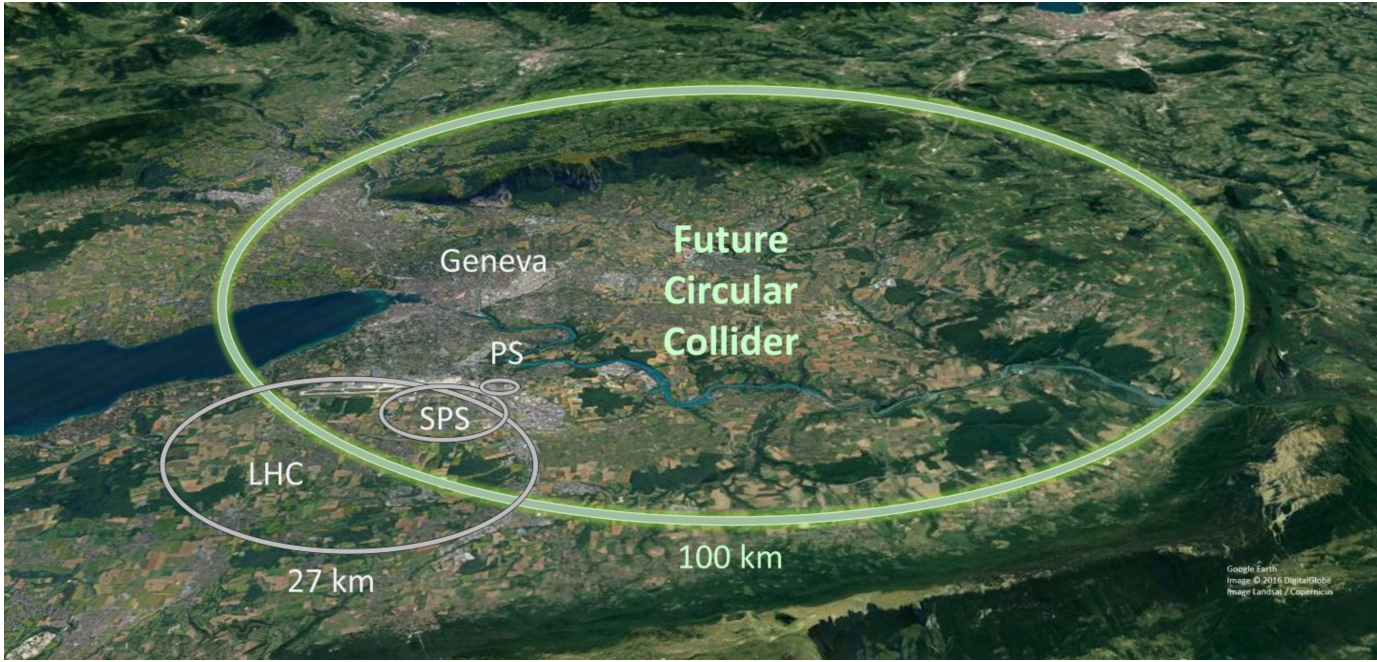


TileCal-like calorimeter for FCC

- Simulation studies of a TileCal-like calorimeter
- Development of new scintillators materials to meet the challenges of the future collider

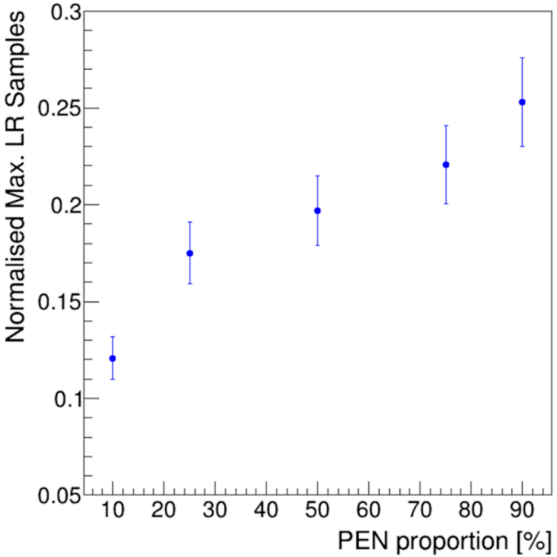
Future Circular Collider

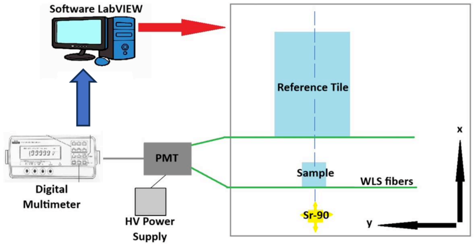
- 100 km ring!
- Two possible colliders:
  - First: e+e- collisions for precision electroweak physics
  - Next: pp collisions @ 100 TeV to explore the energy



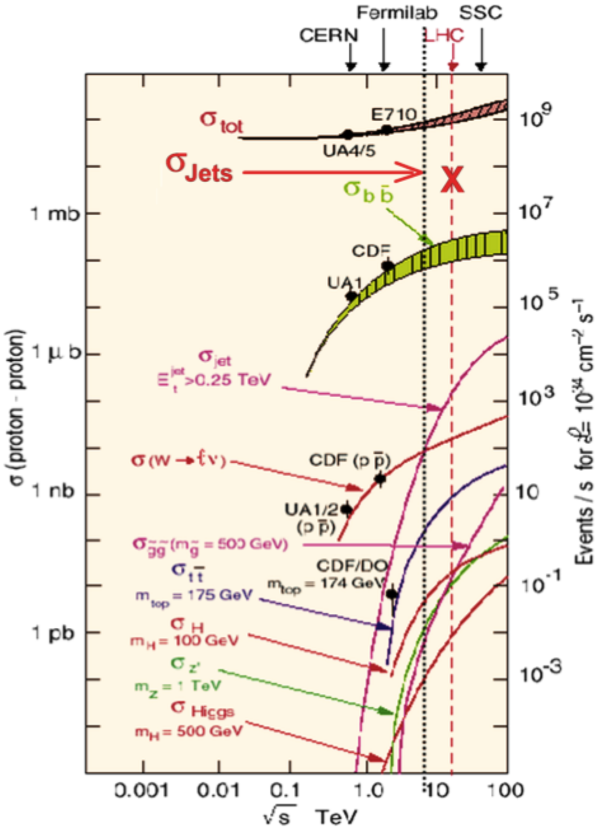
Development of new scintillators

- Collaboration with IPC (Minho)
- Using PEN and PET
- Study
  - Light output
  - Emission spectra
  - Transmittance spectra
  - Pure PEN/PET and mixtures
  - Future:
    - Optimize light output, transparency
    - Increase size of the scintillators
    - Industrialize process
    - Study radiation hardness





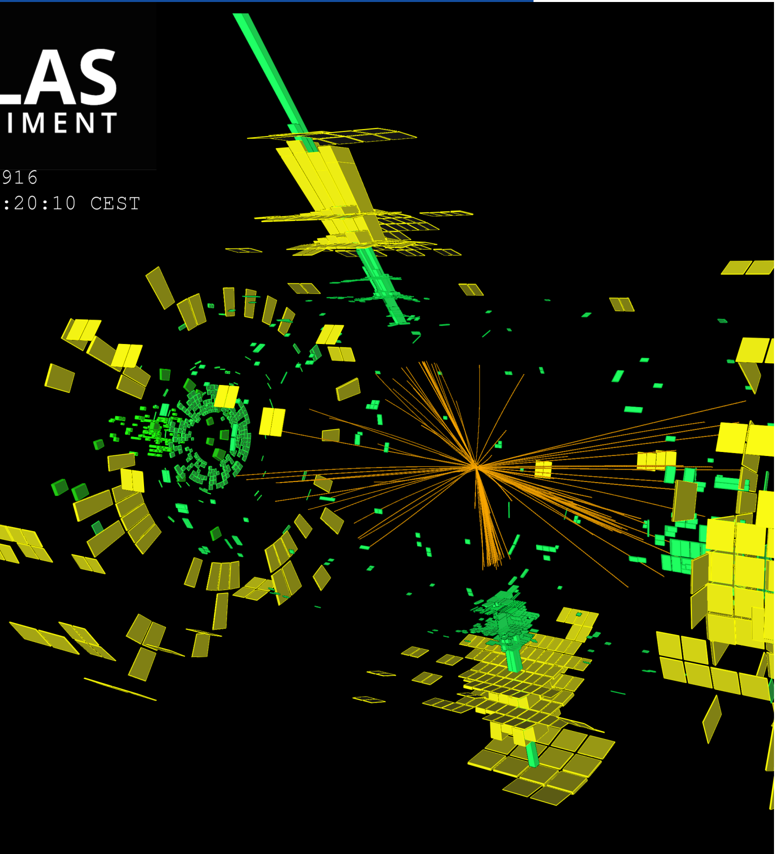
LHC Upgrade Challenges



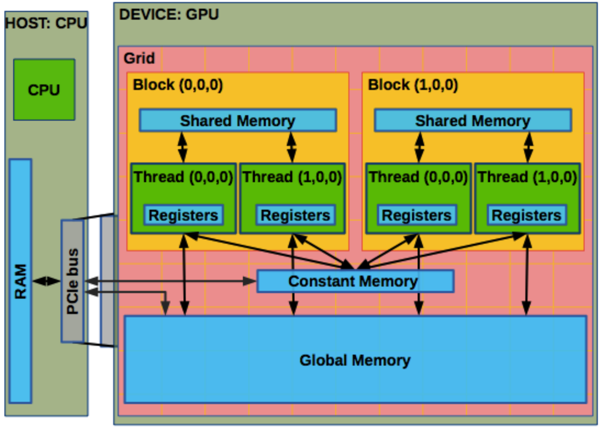
- Interesting processes have small cross-sections
- Need to process & select interesting events in real time
- 40 MHz event rate
- Very large number of interactions/event

	Run 2	Run 3	Run 4
Energy (√s)	13TeV	14 TeV	14 TeV
Max. Luminosity ($cm^{-2}s^{-1}$)	$1\text{-}2\times10^{34}$	$2\text{-}3\times10^{34}$	$5\text{-}7\times10^{34}$
Interactions/event	40	55-80	140-200
Bunch crossing rate	40 MHz	40 MHz	40 MHz
Offline storage rate	1000 Hz	1500 Hz	10 kHz
Bunch spacing	25 ns	25 ns	25 ns

GPUs for Accelerating Jet Trigger Algorithms



- Exploit parallelism
- New paradigm: single instruction-multiple data
- Calorimeter clustering on GPUs
  - 1st prototype demonstrated great potential
  - New framework update and optimisation ongoing

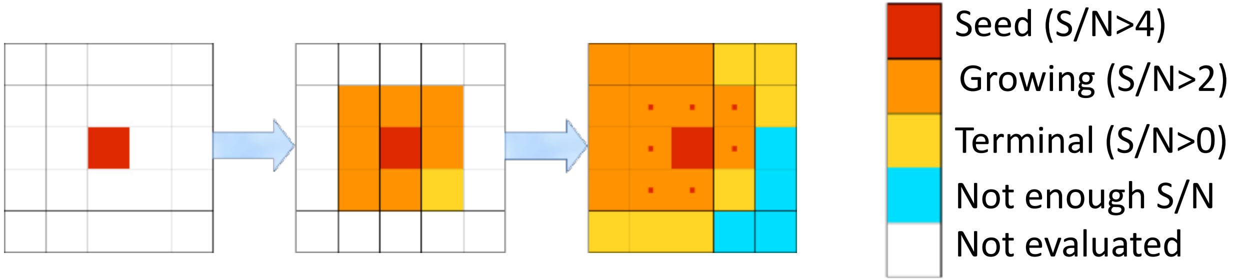


- Study also FPGAs as alternative

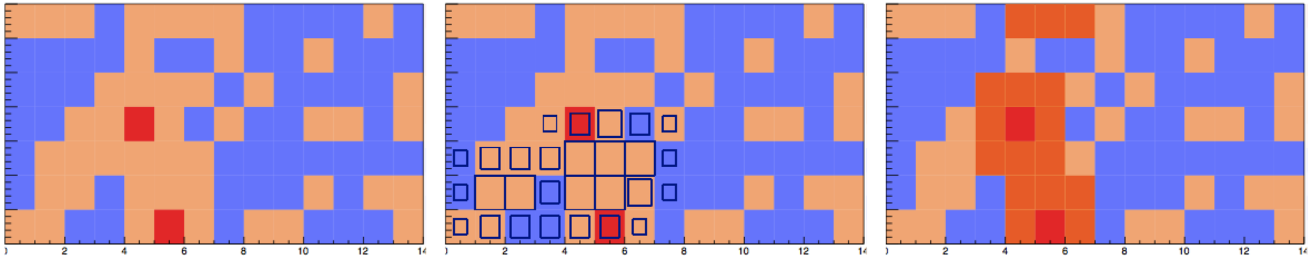
Topo-Automaton Clustering (TAC)

- TopoClustering:

Groups neighbours according to signal/noise



- TAC:
  - Maximimize parallelism:
    - Data organised in cell pairs
    - Use cellular automaton
      - Propagate flag on a grid of elements (cell pair)
  - Cells get the largest flag on each iteration



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Thanks!

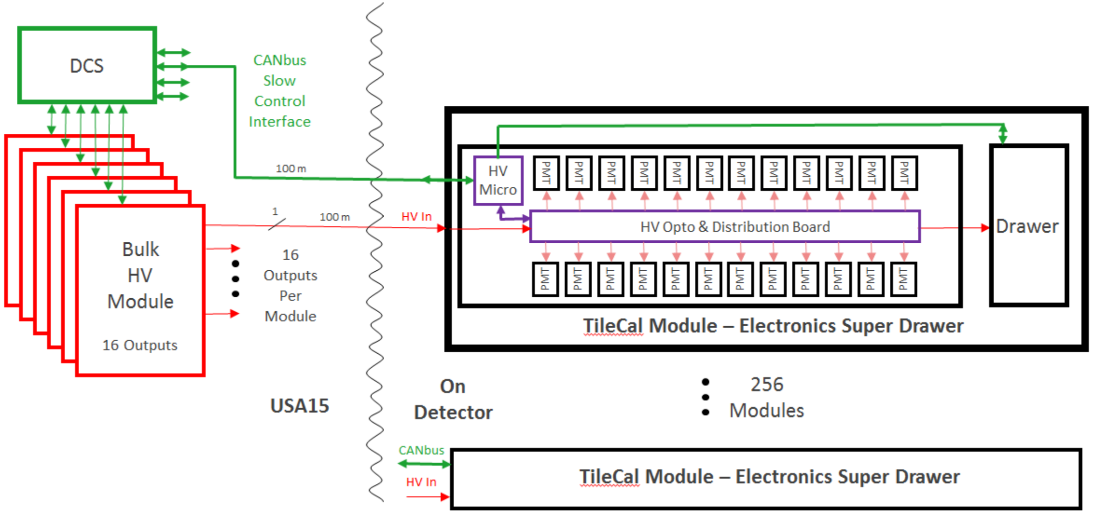
- Acknowledgments

REPÚBLICA PORTUGUESA

FCT Fundação para a Ciência e a Tecnologia

TileCal current HV regulation system

- Located inside the detector
- Will become old and difficult to maintair
- Not expected to survive to Phase II radiation
-



The ATLAS Experiment