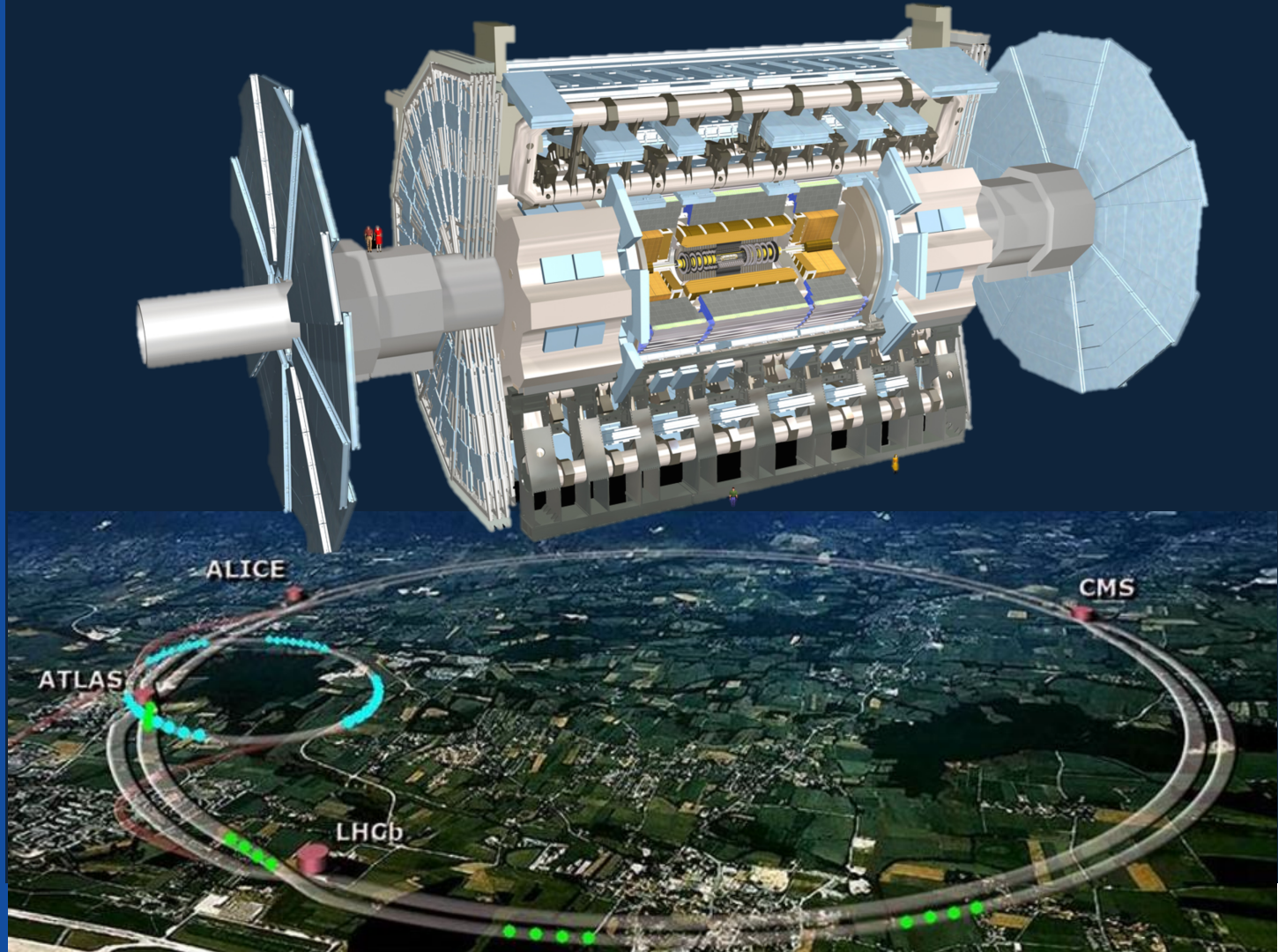
LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

PhD Possibilities at ATLAS

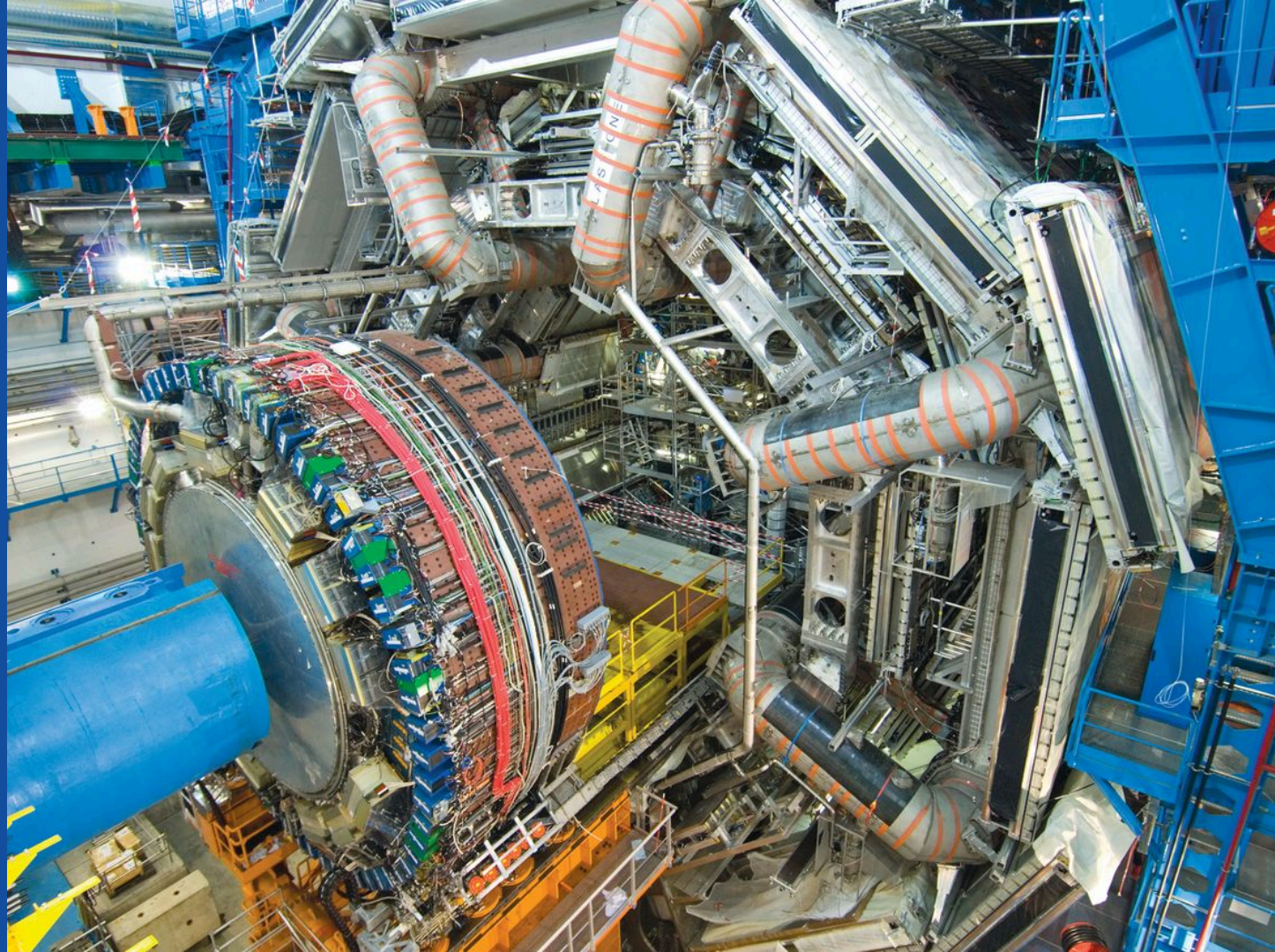
Patricia Conde Muíño
(IST, LIP)

The ATLAS Experiment



The ATLAS experiment

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



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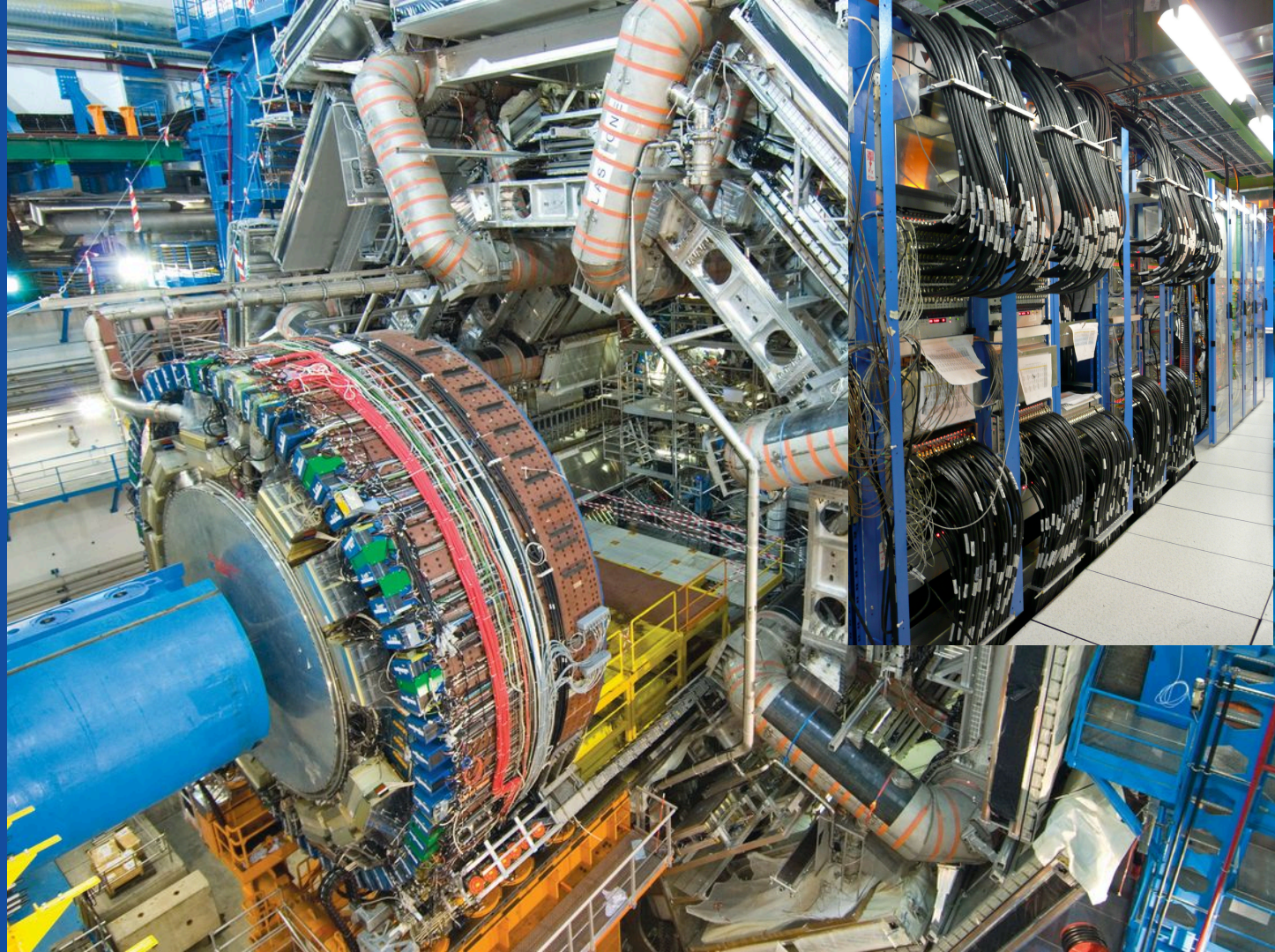
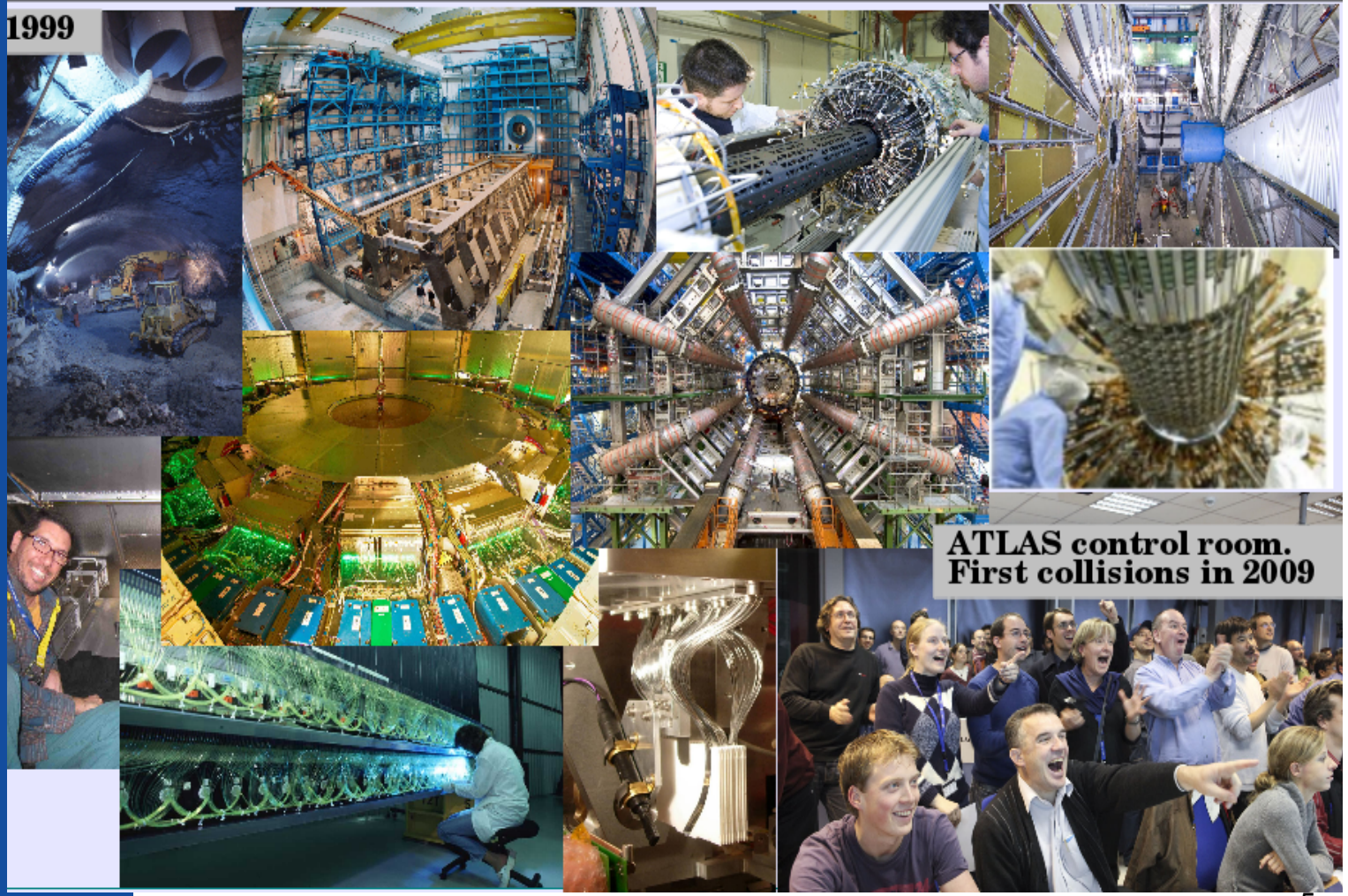


More than 30 years of continuous work

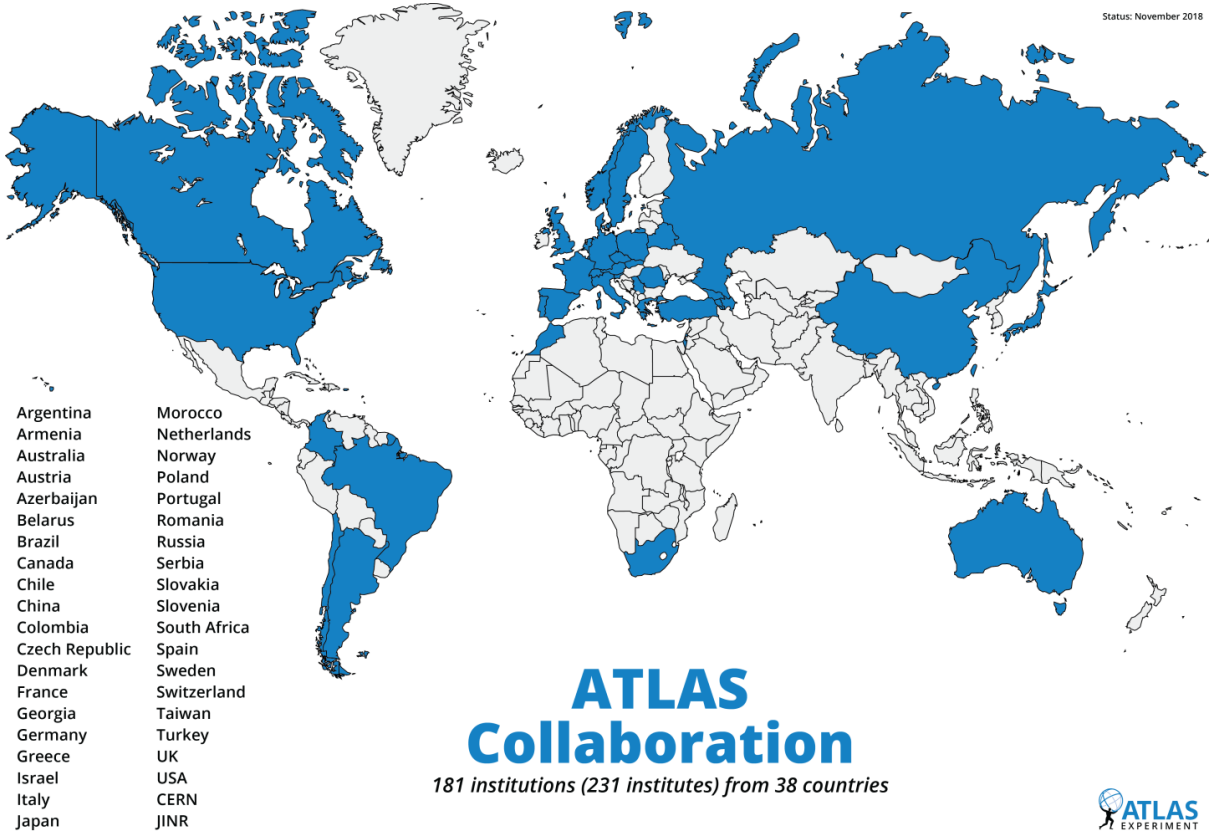


ATLAS Collaboration

- Truly global:
- 181 Institutes,
- 38 countries

Composed of:

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



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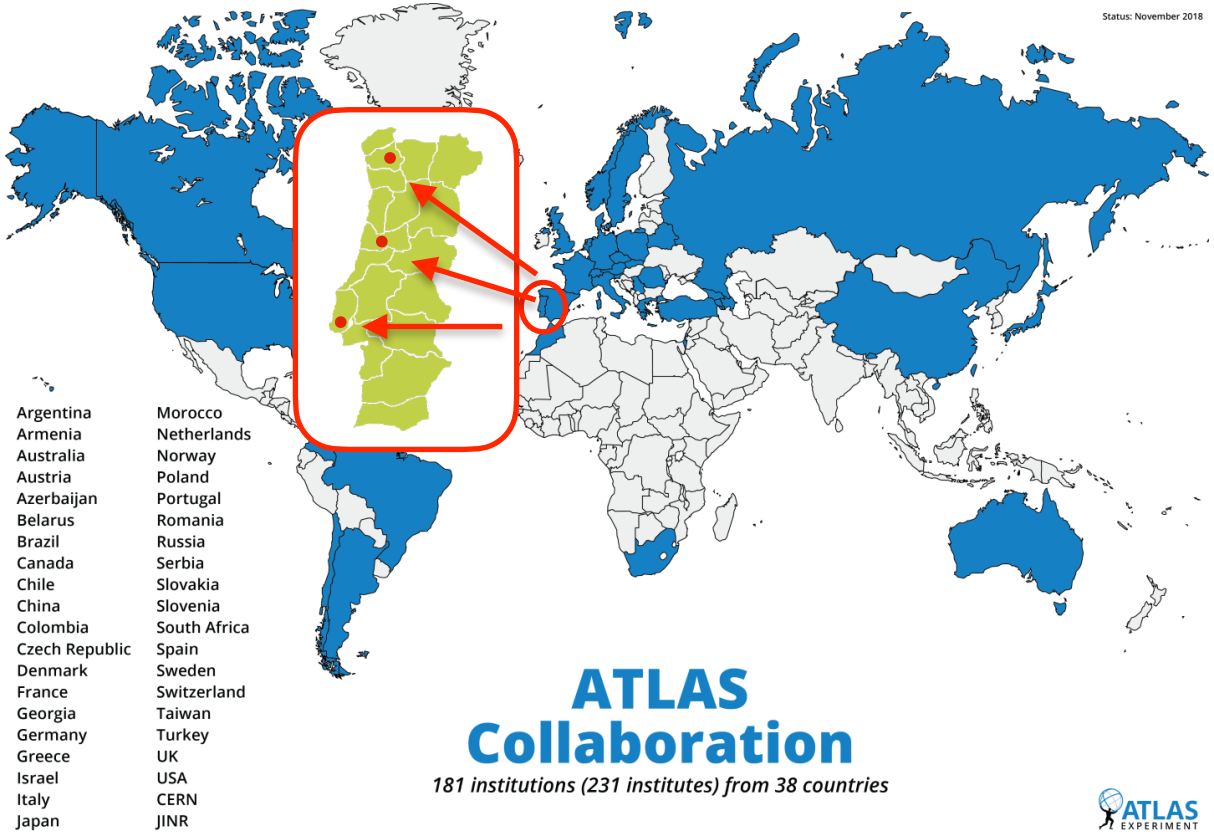
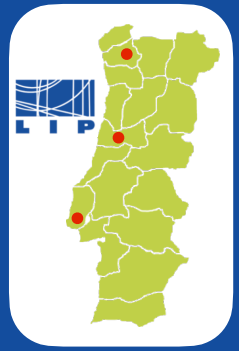


Portuguese ATLAS Team

National group:

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

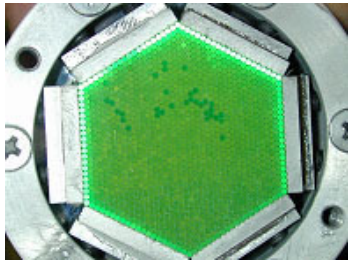
CEFITEC/UNL, INESC, CFMC, AdI engineers training program



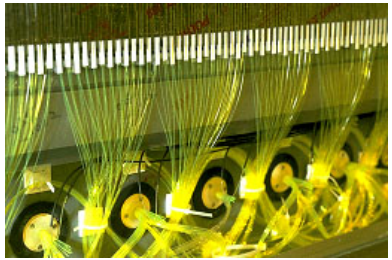
Portuguese contributions to ATLAS construction

TileCal hadronic calorimeter

600 k WLS fibres aluminized

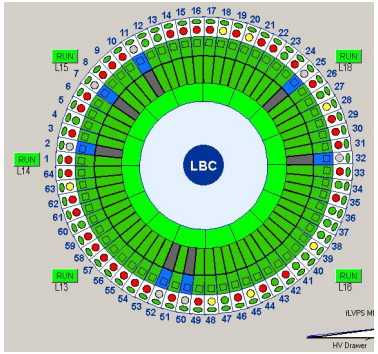


Design of the cells and fibres routing

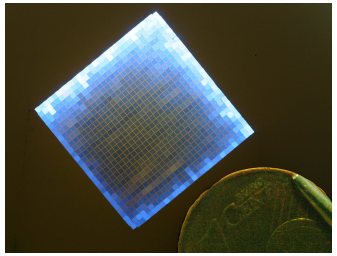


Fibres insertion with robot in 15 k plastic profiles

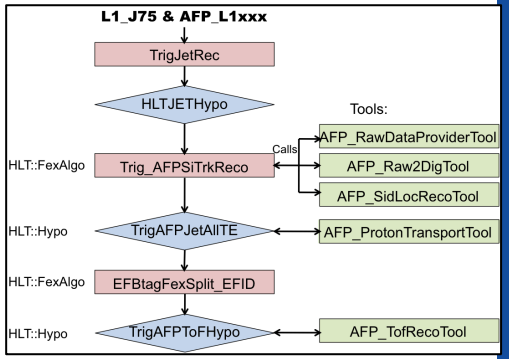
Detector Control System



Forward detectors



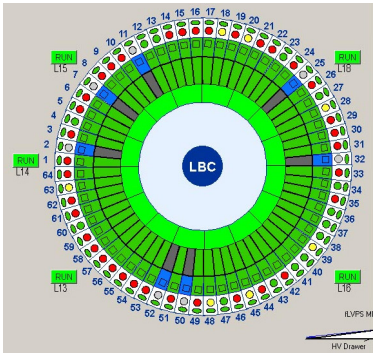
Trigger/DAQ



In addition: scintillators, laser calibration, PMT quality control, instrumentation of the modules, calibration, certification and commissioning

Current Portuguese Responsibilities in ATLAS

TileCal Calibration, DCS

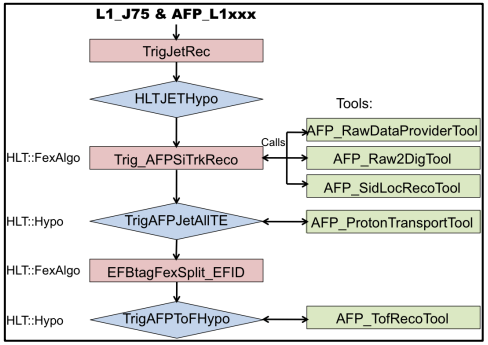


Leading TileCal DCS

Distributed computing

Iberian Cloud Coordination

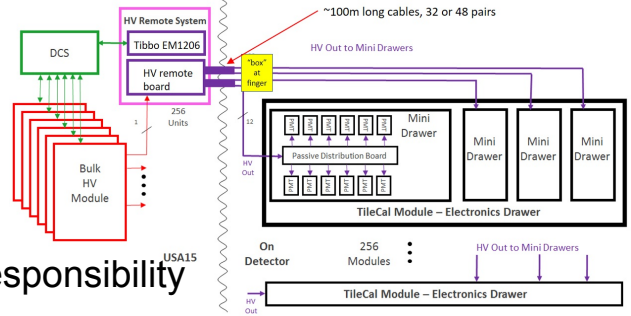
Jets HLT



ATLAS Roman Pot DCS and HLT

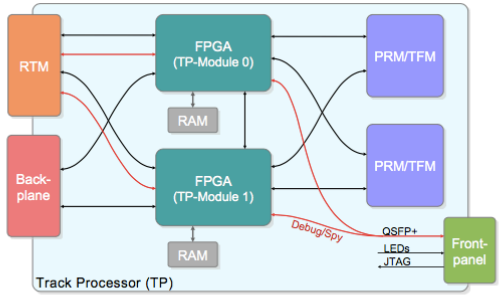
Co-leading ARP DCS

TileCal Upgrade HV distribution system



Full responsibility

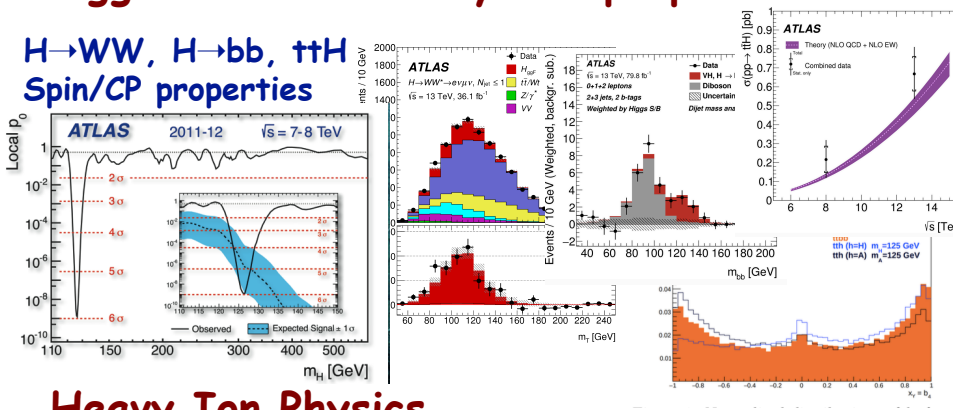
Trigger Upgrade: HTT DCS, simulation, mezzanine production



Portuguese contributions to ATLAS Physics Results

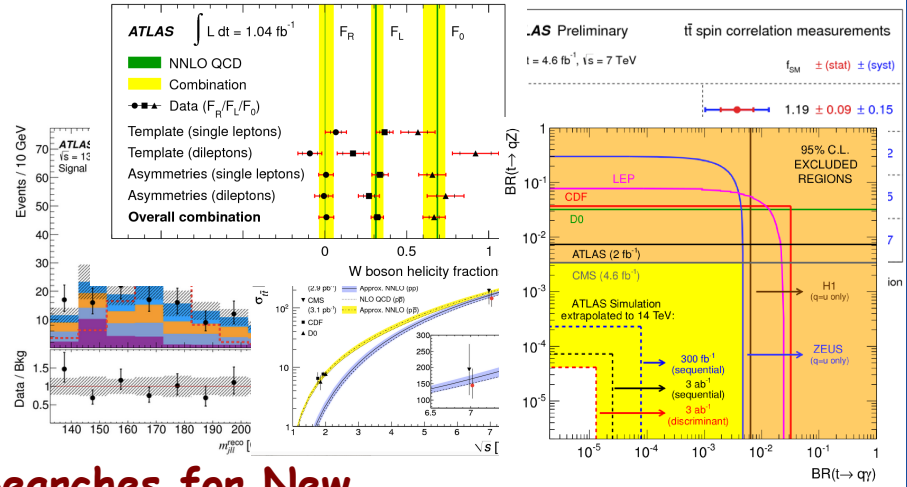
Higgs boson discovery and properties

H→WW, H→bb, ttH
Spin/CP properties



Top quark properties

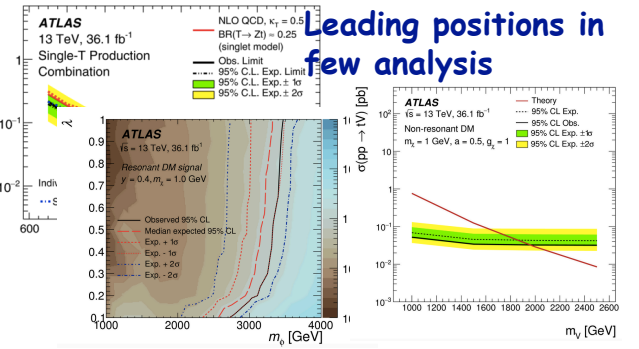
Comprehensive programme of top properties measurements



Searches for New Particles & Interactions

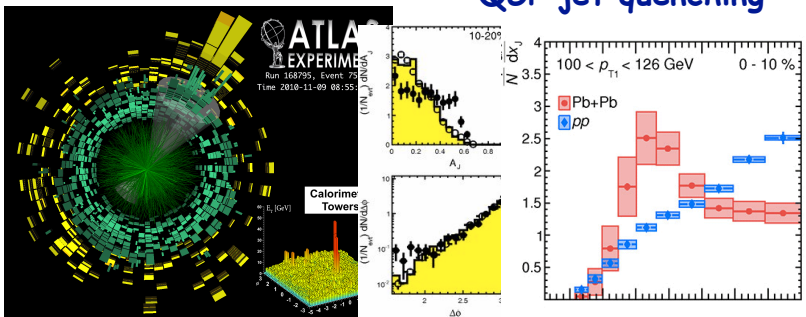
Vector-like quarks, FCNC, dark matter, …

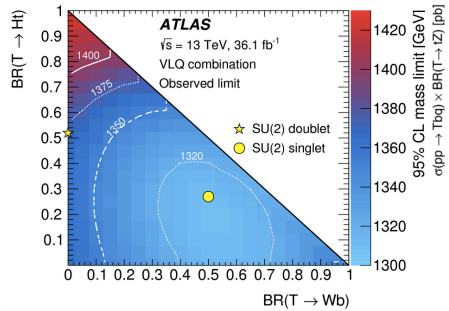
Leading positions in few analysis



Heavy Ion Physics

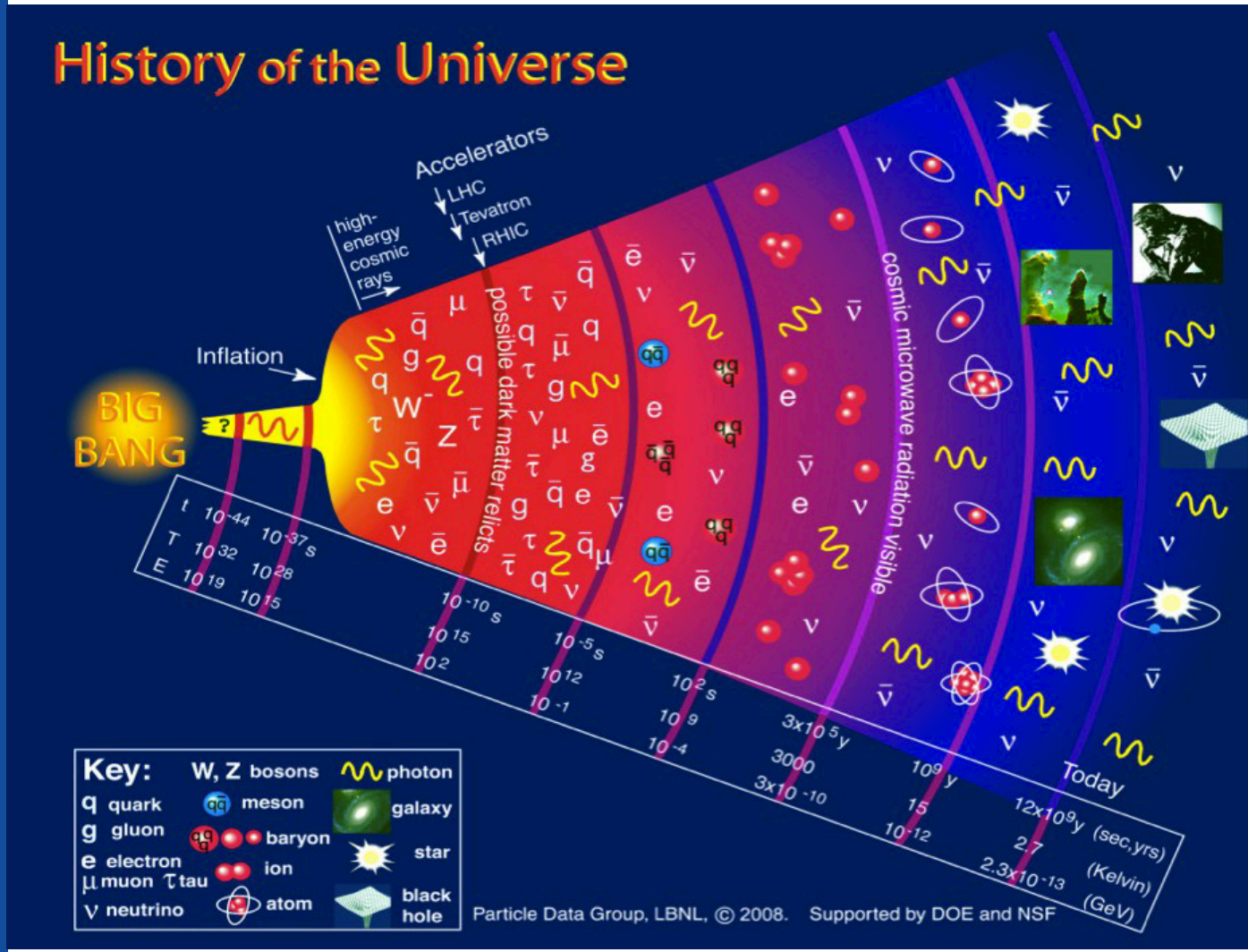
QGP jet quenching





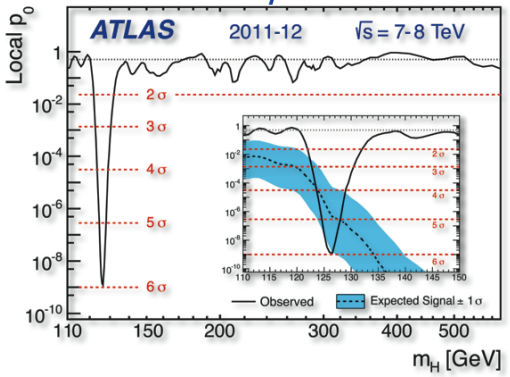
Physics topics

- 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



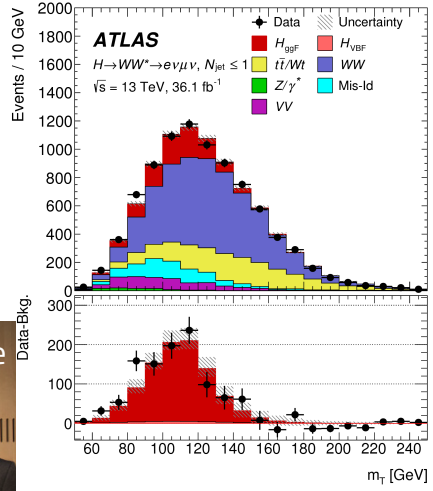
From discovering the Higgs to measuring its properties

- Discovery (2012)



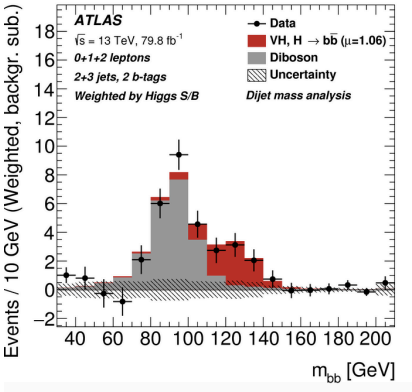
2015

- First observation of H→WW→ℓνℓν



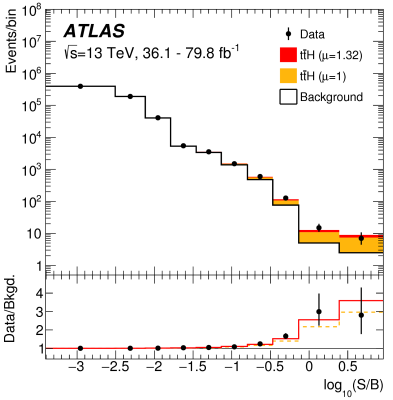
2018

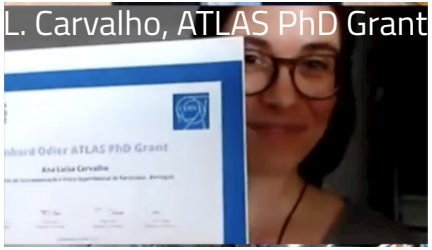
- First observation of H→bb



2018

- First observation of ttH production



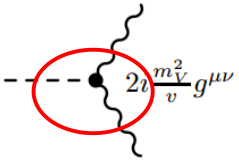


And now what?

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

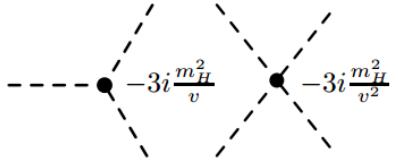
Couplings to EW gauge bosons

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



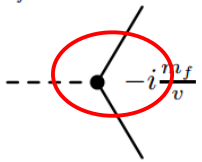
Higgs self-couplings

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



Couplings to fermions

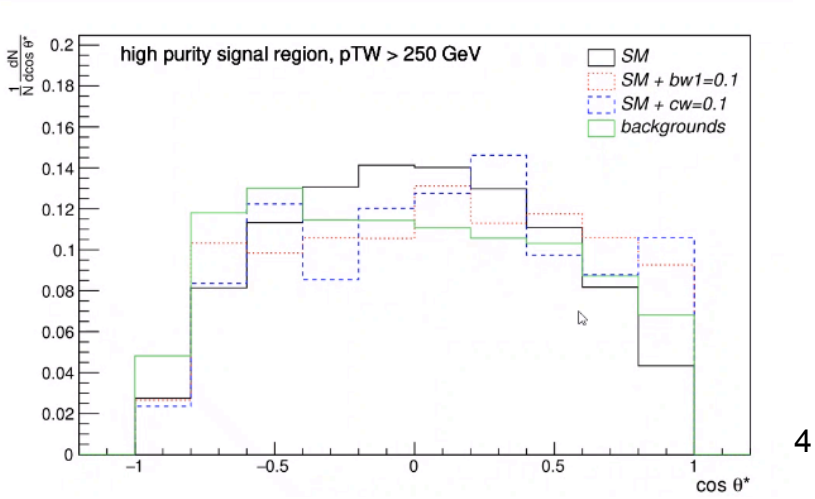
$$-\sum_f m_f \bar{f} f \left(1 + \frac{h}{v}\right)$$



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

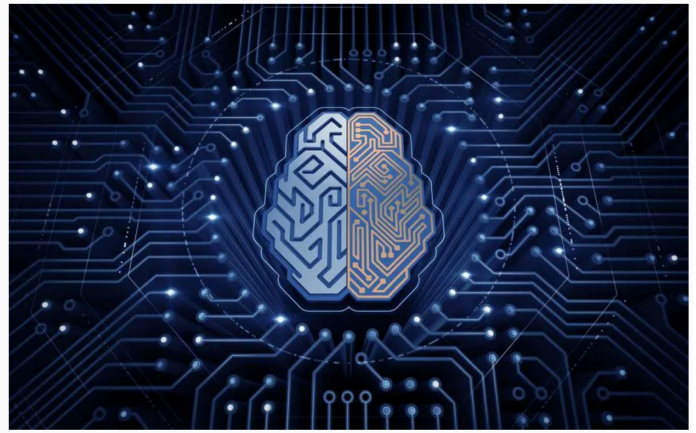
Measure couplings even more precisely

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

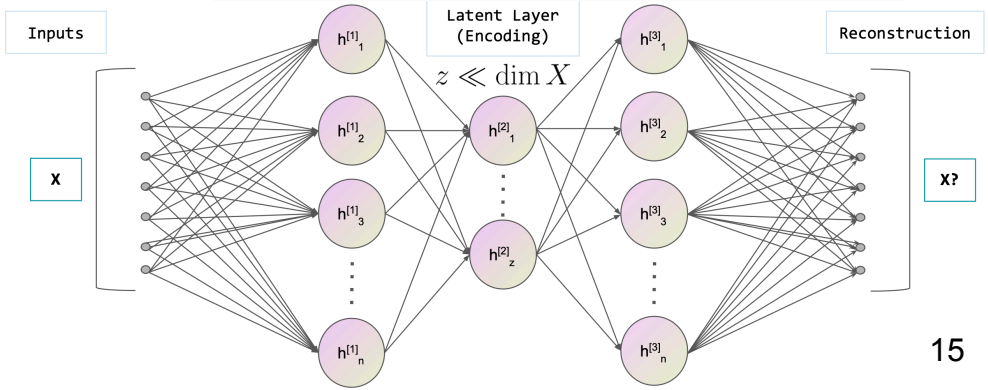


Searching for the unknown…

- Train deep learning models to learn SM background and provide an anomaly score for New Physics
  - Increases search generality
- Reconstruction error is a measurement of anomaly

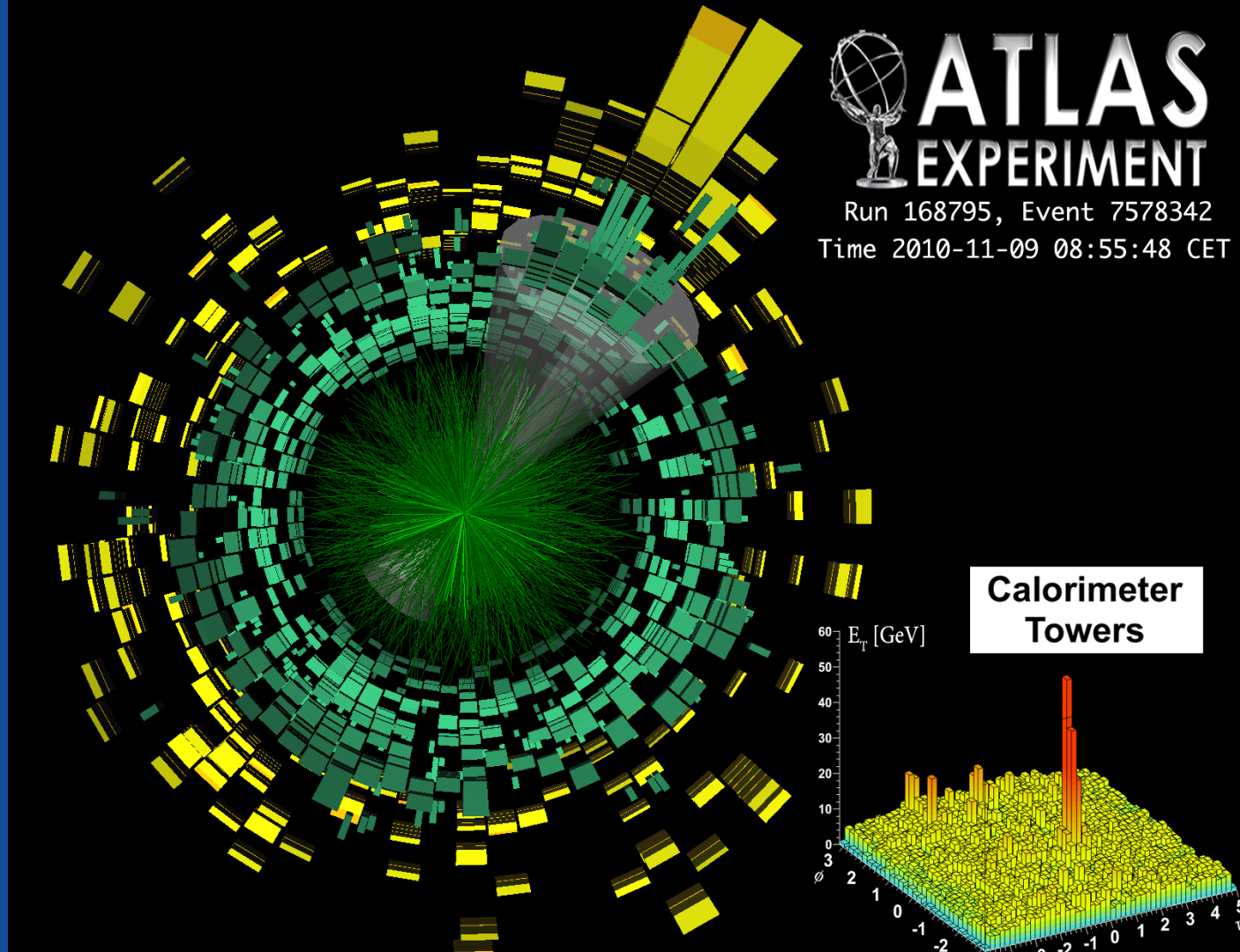


Artificial Intelligence FOTOLIA - SERGEY TARASOV



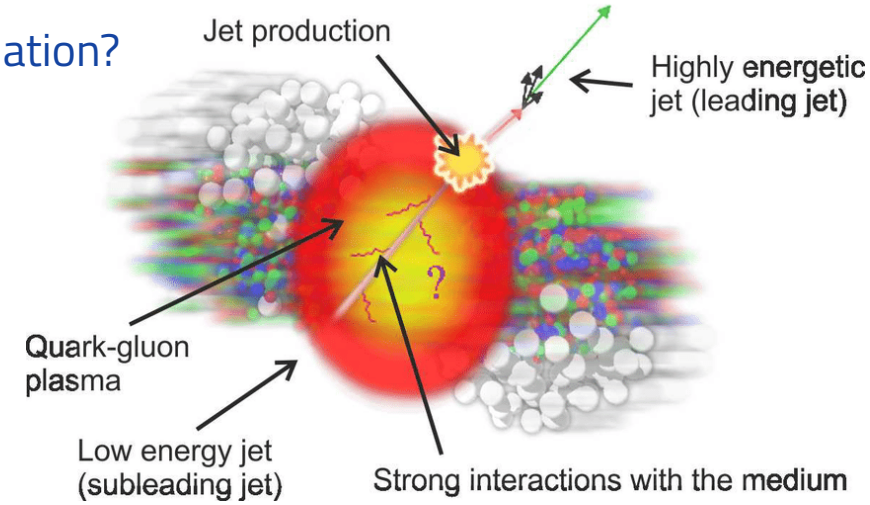
The Quark-Gluon Plasma Heavy Ion Collisions

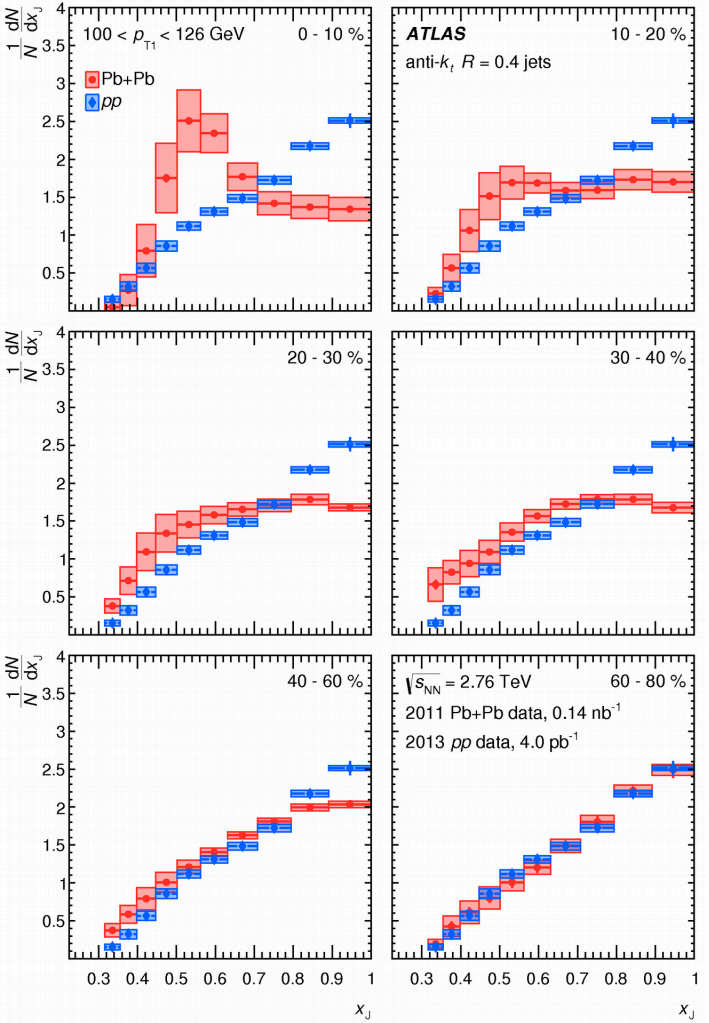
- First observation in 2010
- Probe of Quark-Gluon Plasma



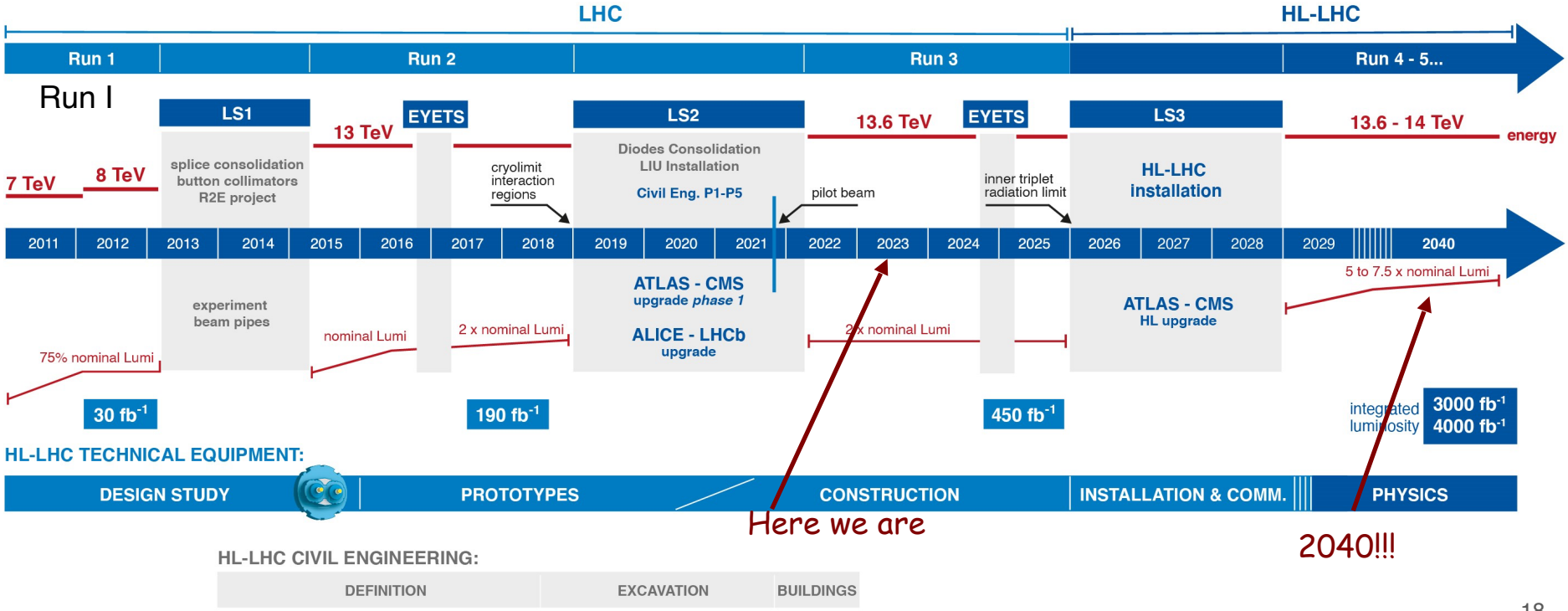
b-jet suppression to probe the QGP

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

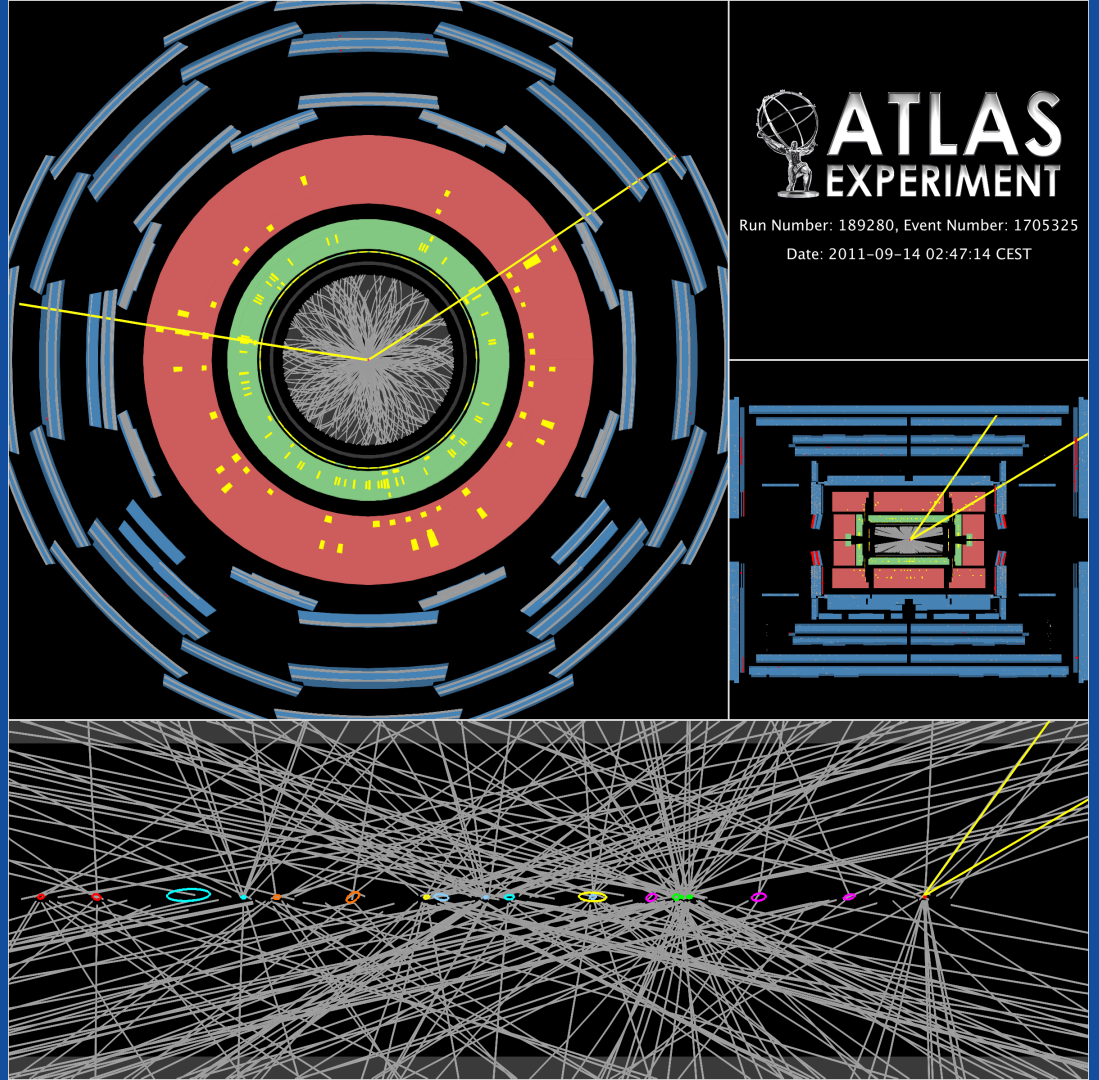




LHC / HL-LHC Plan

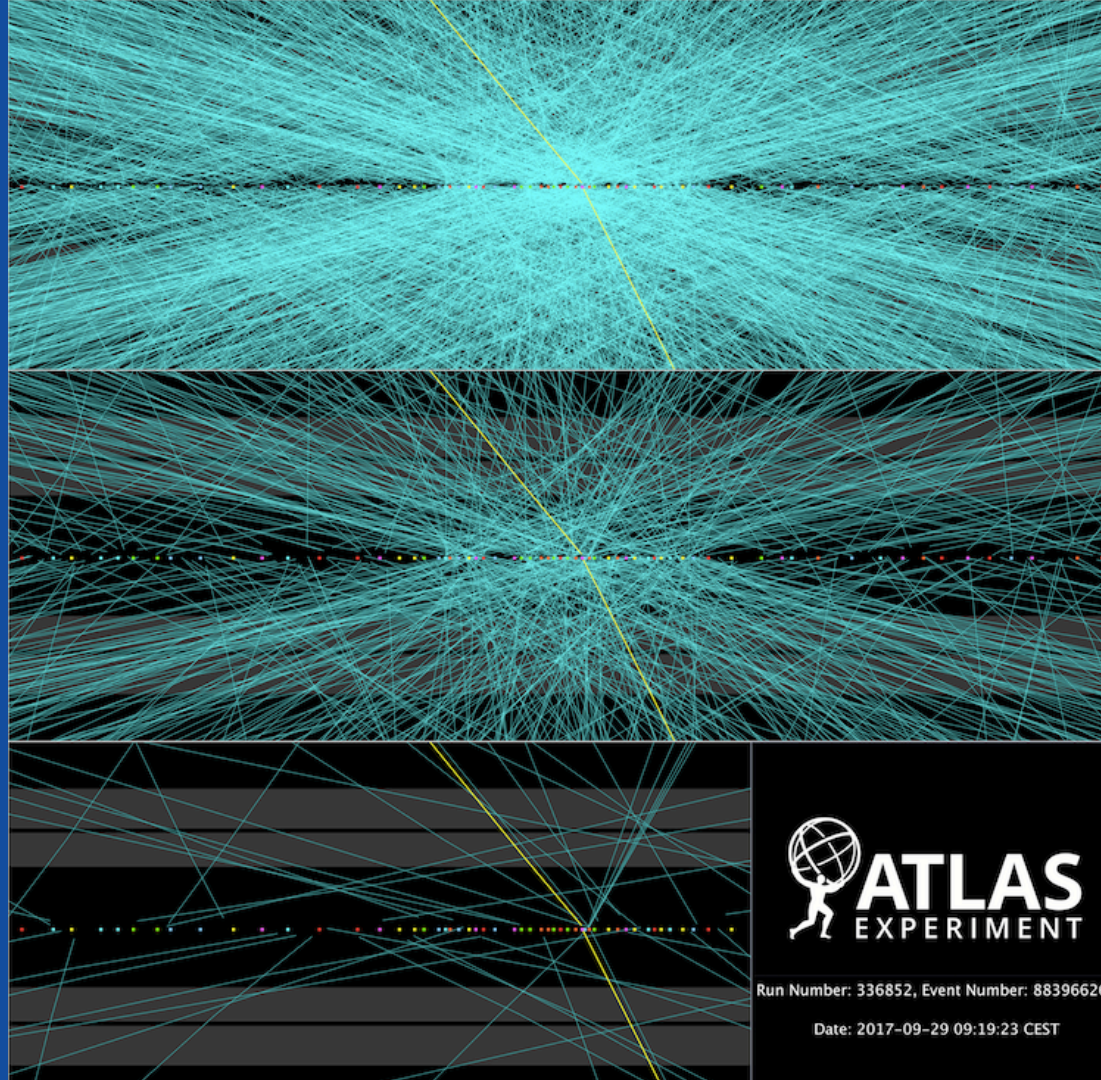


$Z \rightarrow \mu\mu$ event with 20 pile-up interactions



Upgrade challenges

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

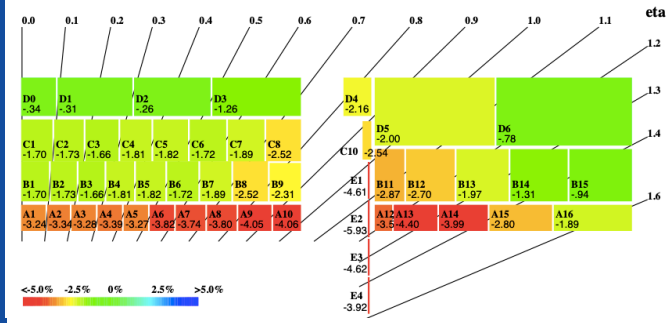


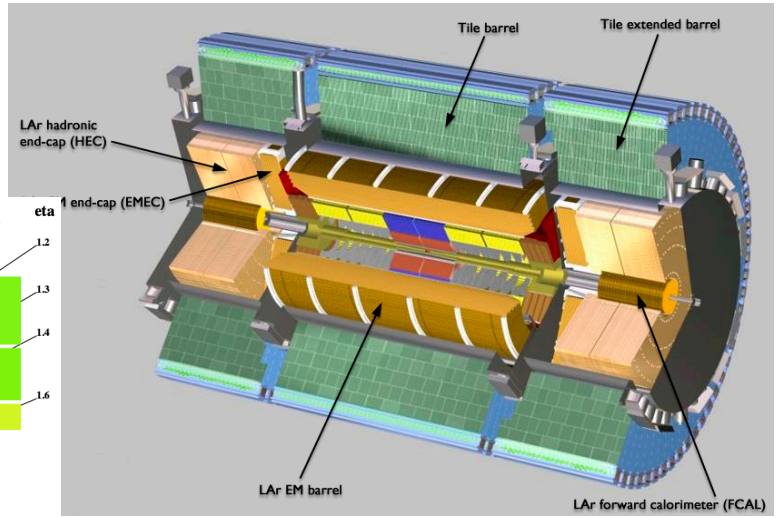
TileCal hadronic calorimeter

- Calibration
  - Optimize performance
- Study radiation hardness with pp collisions
- HV distribution system
- Detector Control System

TileCal calibration

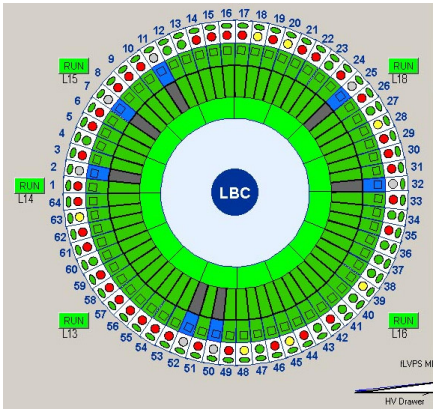
ML to study TileCal ageing
Impact in FCC detector design!





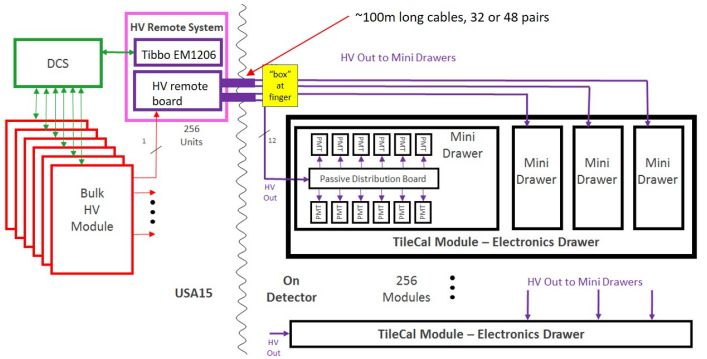
DCS

Leading TileCal DCS



Upgrade HV distribution system

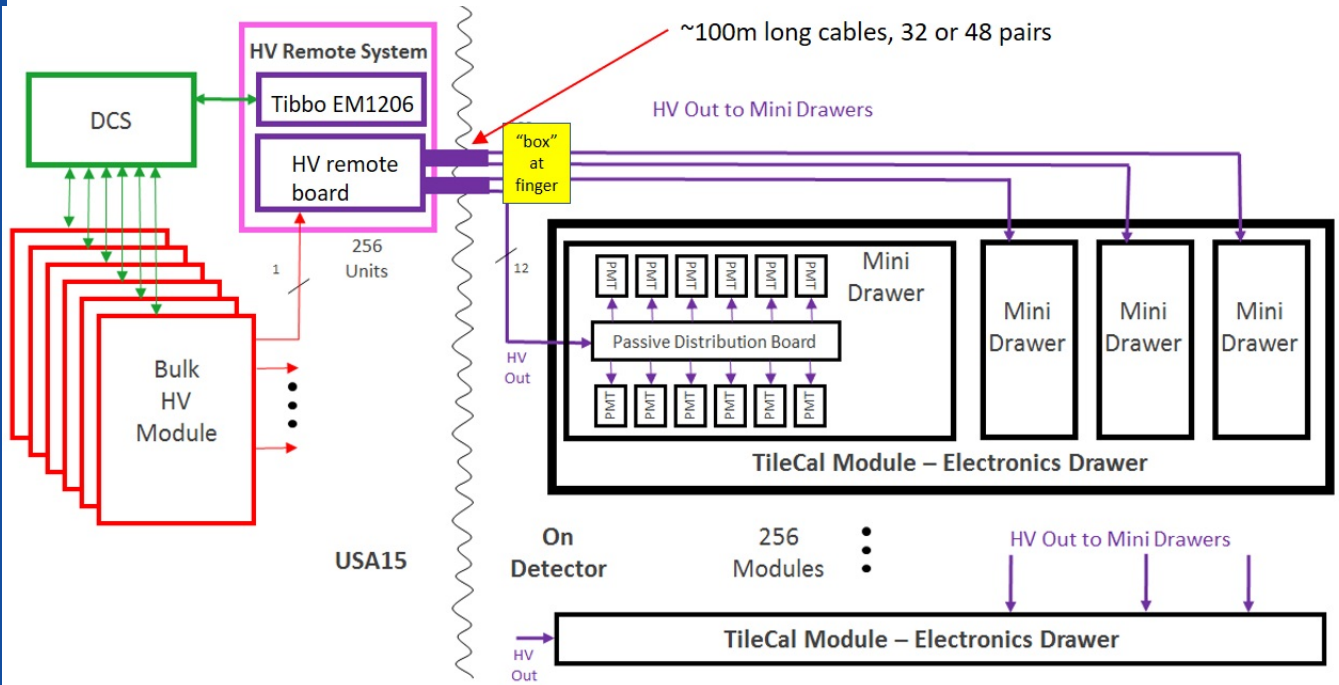
Full responsibility



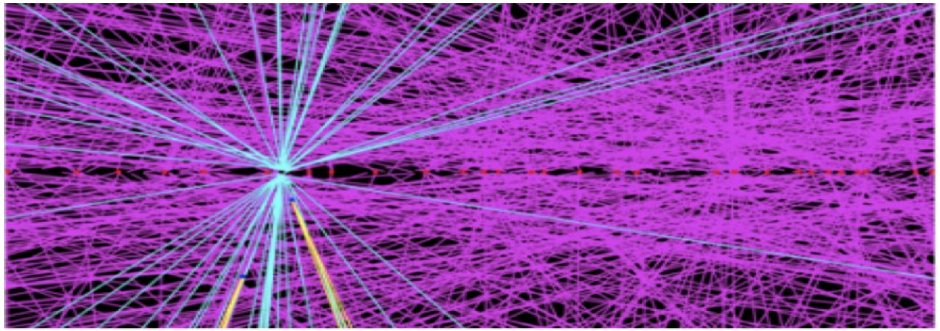
TileCal hadronic calorimeter

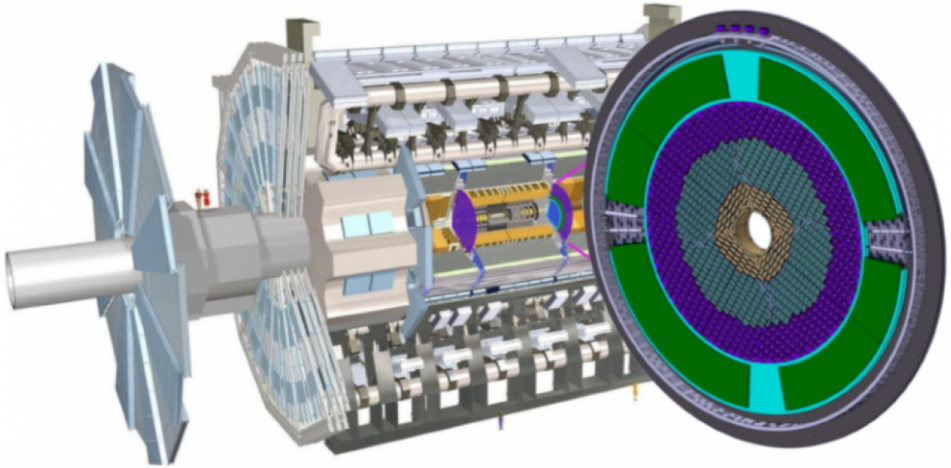
- Calibration
  - Optimize performance
- Study radiation hardness with pp collisions
- HV distribution system
  - Test beam performance studies

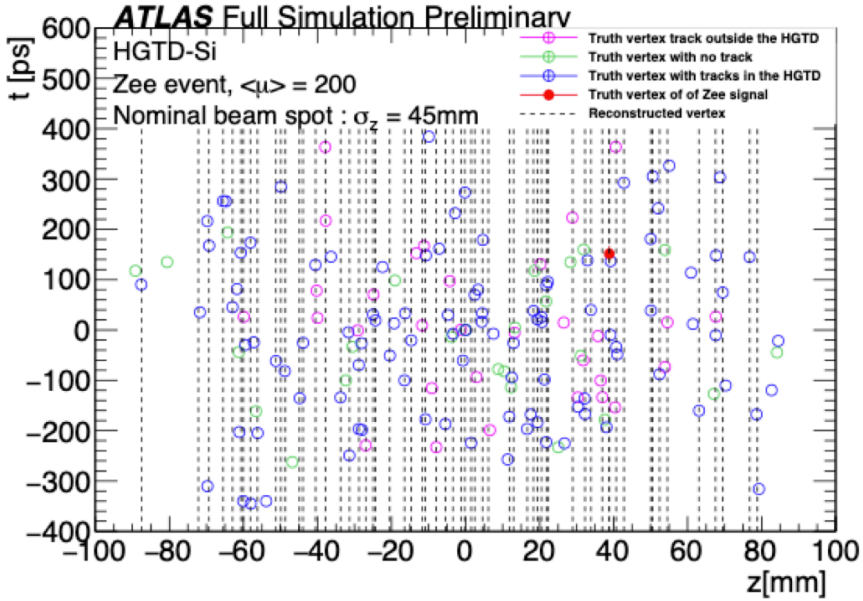
Full responsibility



High Precision Timing Detector (HGTD)







HGTD - DCS and Interlock

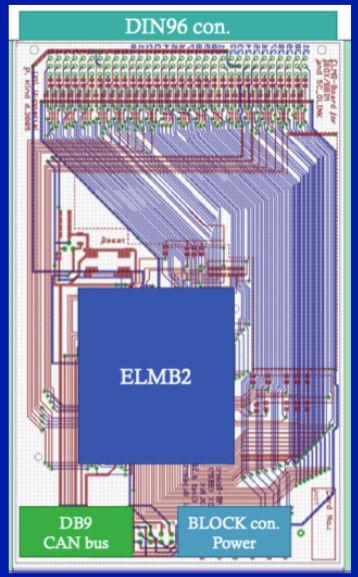
Detector Control System (DCS)

– Contributing to DCS architecture definition

– Readout of DCS environment data through ELMB2 communication board

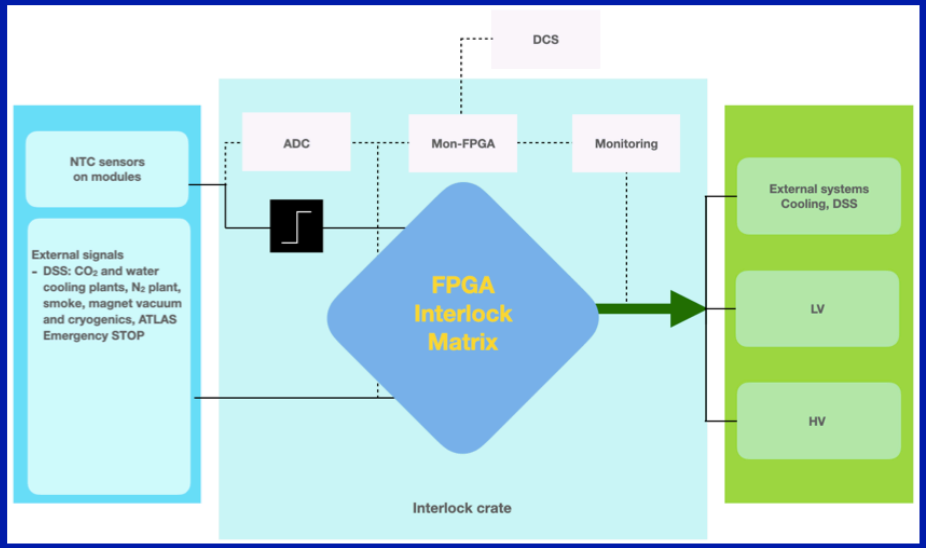
monitoring of the CO_2 cooling system via Pt10k sensors

- 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

HGTD - DCS and Interlock

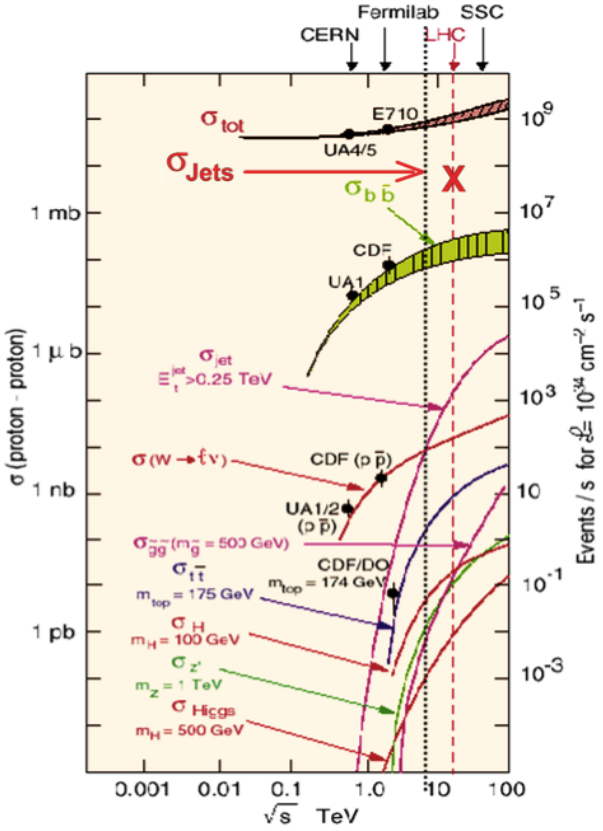


Interlock

- Mostly re-use the ITk one
- Contributing to module production
- Safety algorithms to be built
- Passed PDR (Preliminary Design Review)
- LIP responsability

- On the left are detectors that recognize threats from which protection is necessary.
- On the right are the devices that should be switched off.
- The central part is the interlock crate, which contains FPGA to define interlock matrix.

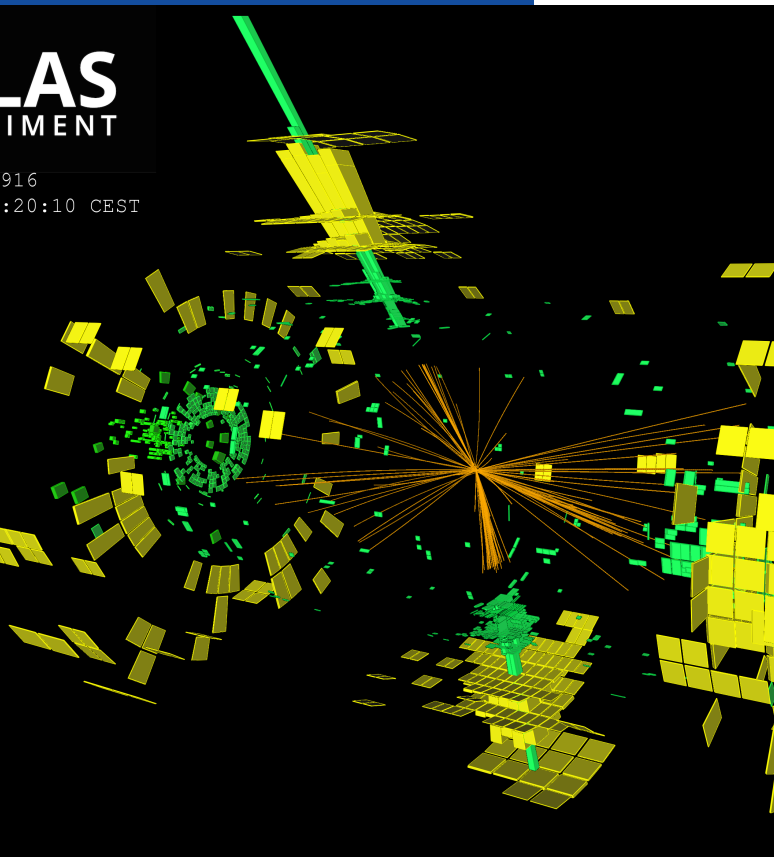
LHC Upgrade Challenges



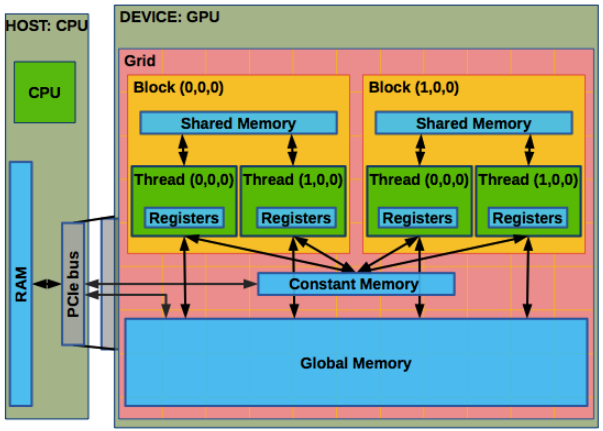
- Interesting processes have small cross-sections
- Need to process & select interesting events in real time
- 40 MHz event rate
- Very large number of interactions/event

	Run 2	Run 3	Run 4
Energy (√s)	**13TeV**	**14 TeV**	**14 TeV**
Max. Luminosity ($cm^{-2}s^{-1}$)	**1-2×10^{34}**	**2-3×10^{34}**	**5-7×10^{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

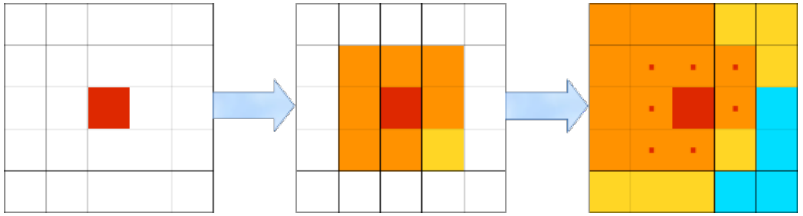


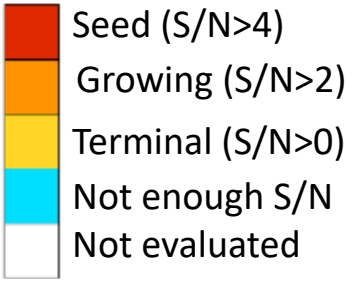
- Study also FPGAs as alternative

Topo-Automaton Clustering (TAC)

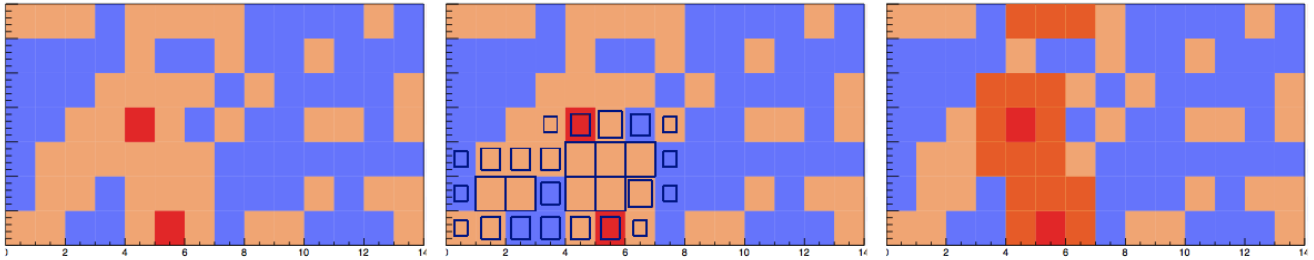
- TopoClustering:

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



More information:

- atlasinfo@lip.pt
- www.lip.pt/atlas
- pconde@lip.pt

- PhD students
  - ricardo.barrue@cern.ch
  - ana.luisa.mc@ua.pt
  - beatriz.catarina.pinheiro.pereira@cern.ch
  - nuno.fernandes@cern.ch

Thanks!

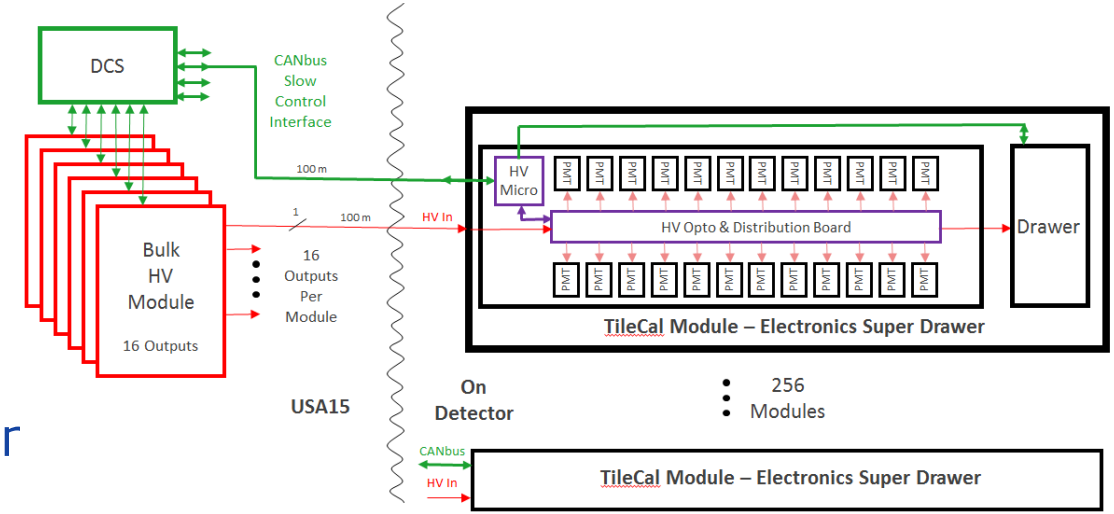
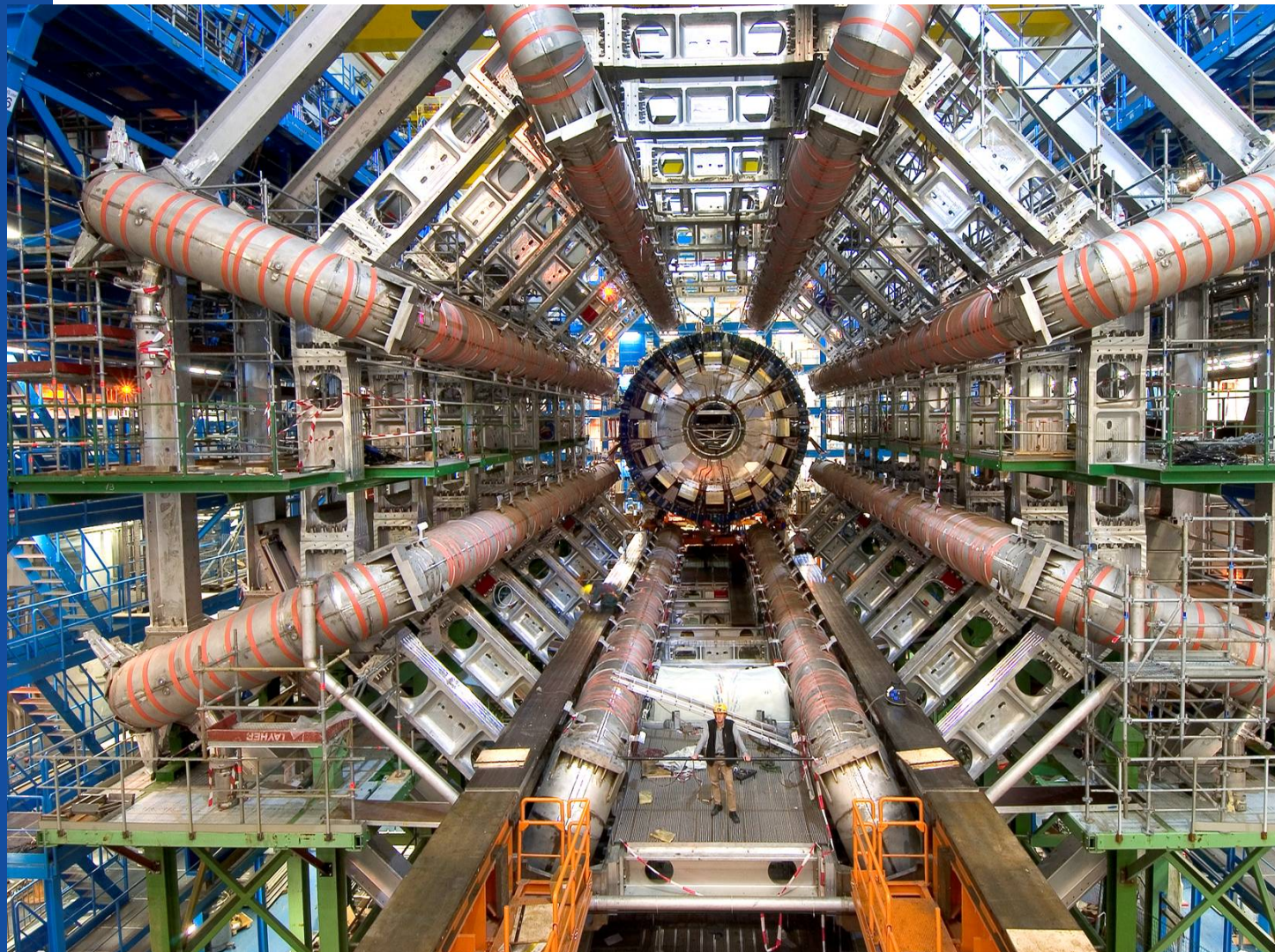
- Acknowledgments

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