# Investigação na Experiência ATLAS

FCT
Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA EDUCAÇÃO E CIÊNCIA

Cofinanciado por:
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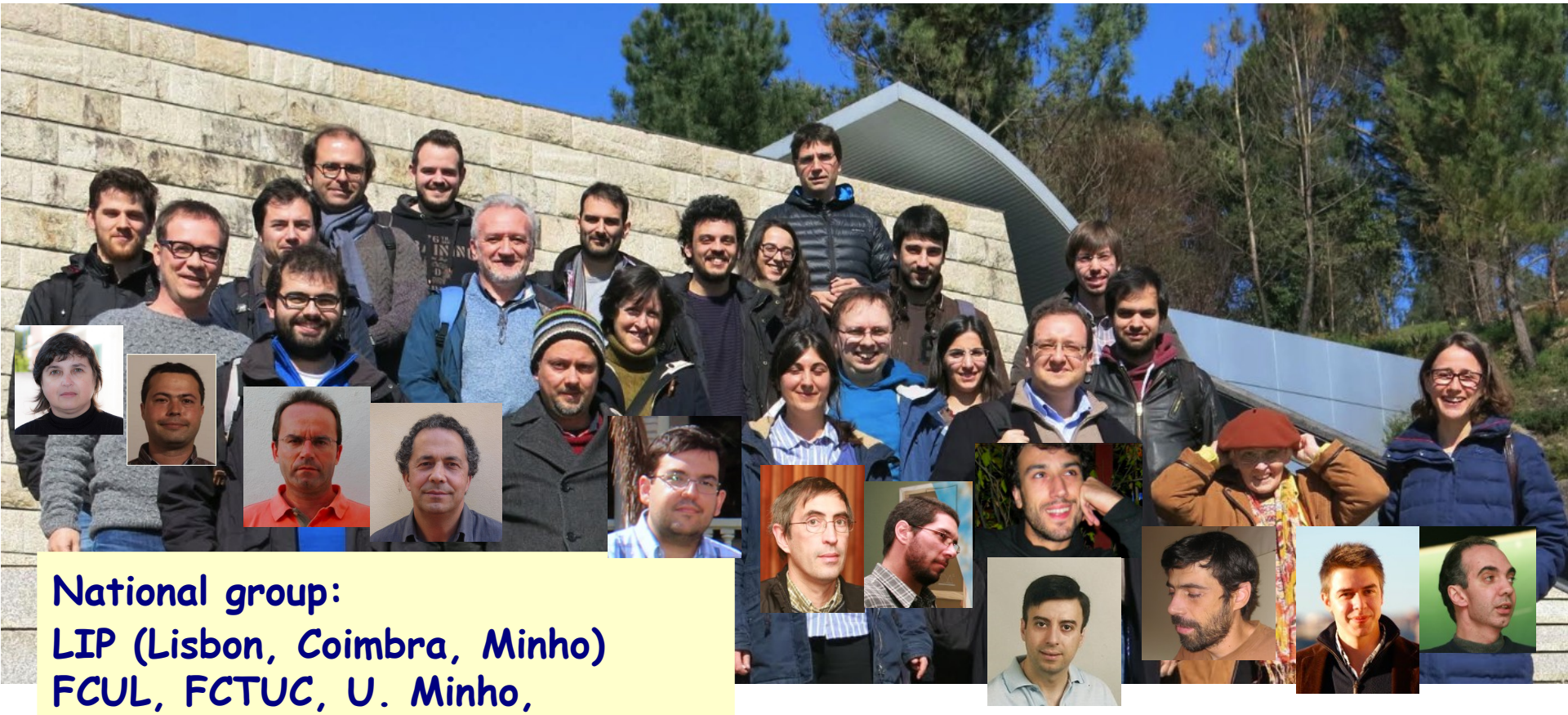
PROGRAMA OPERACIONAL COMPETITIVIDADE E INTERNACIONALIZAÇÃO
PORTUGAL 2020
UNIÃO EUROPEIA
Fundo Europeu de Desenvolvimento Regional

IF INVESTIGADOR FCT

LIP

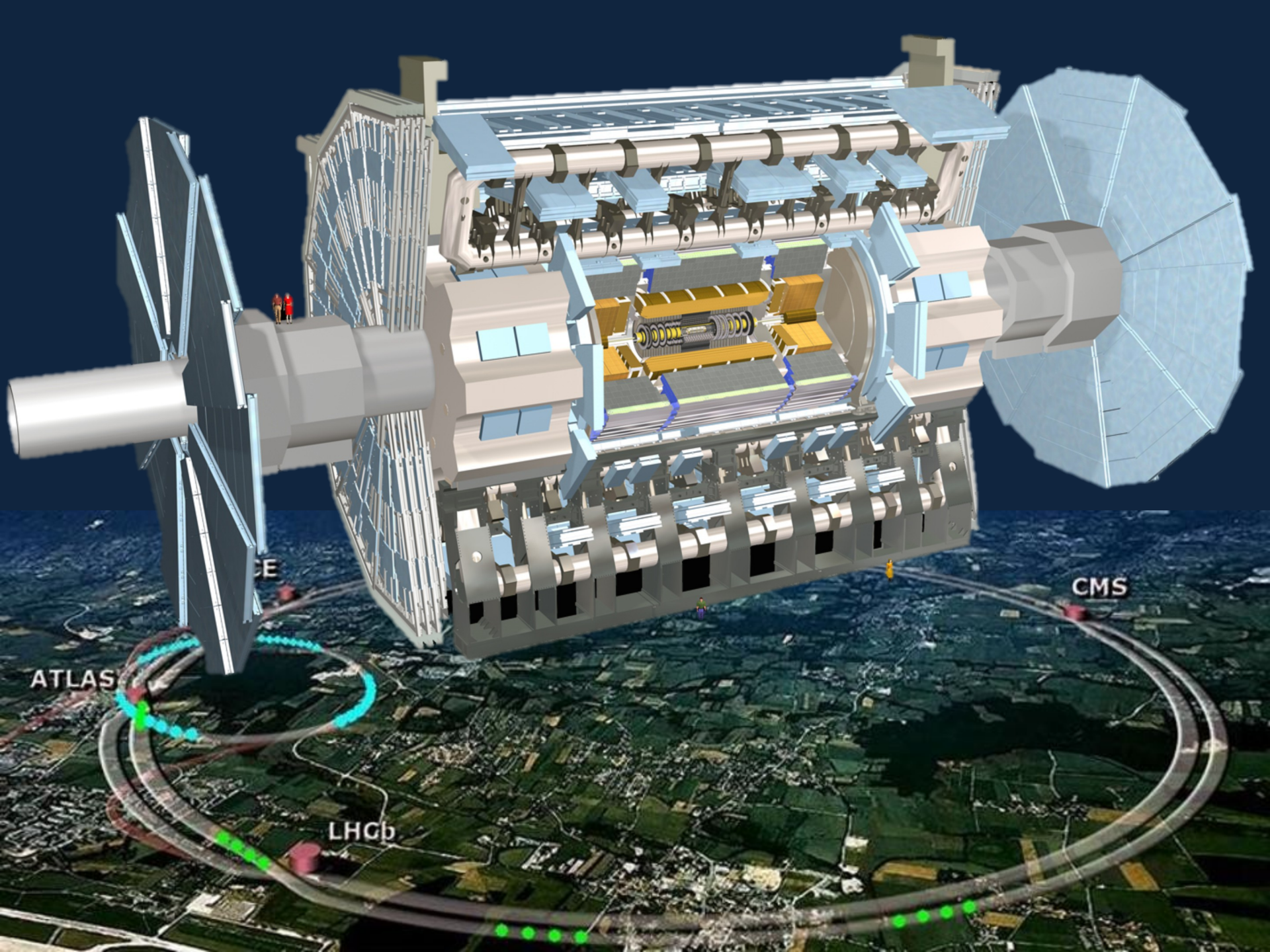
# A equipa ATLAS Portuguesa



**National group:**

**LIP (Lisbon, Coimbra, Minho)**
**FCUL, FCTUC, U. Minho,**
**IBEB, INESC, CEFITEC/UNL,**
**CFNUL, CFMC**

**AdI engineers training program**


CMS
ATLAS
LHCb

# Overview

- Large variety of research topics, covering different interests
- Physics:
  - Higgs properties: couplings to quarks (b, t), couplings to W's
  - Study of the quark gluon plasma in PbPb collisions using b-jets as probes
- Detector Upgrades
  - Parallel trigger algorithms with GPUs as accelerators
  - Radiation damage in scintillators and fibres
  - HV distribution system for the TileCal
- More information:
  - atlasinfo@lip.pt
  - pconde@lip.pt

# Higgs boson properties

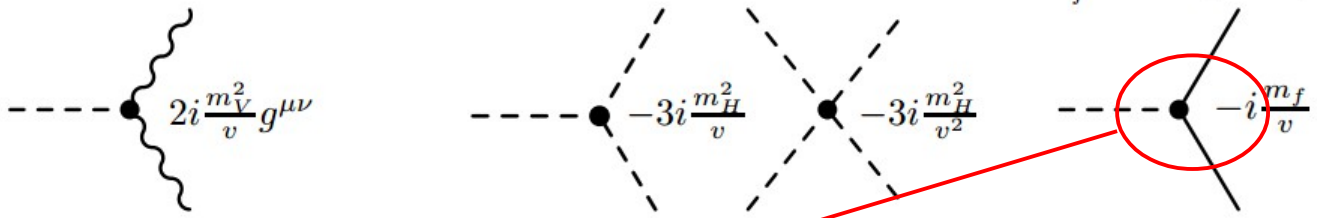
$$\mathcal{L}_{SM} = D_\mu H^\dagger D_\mu H + \mu^2 H^\dagger H - \frac{\lambda}{2}\left(H^\dagger H\right)^2 - \left(y_{ij} H \bar{\psi}_i \psi_j + \text{h.c.}\right)$$

Couplings to EW gauge bosons

Higgs self-couplings

Couplings to fermions

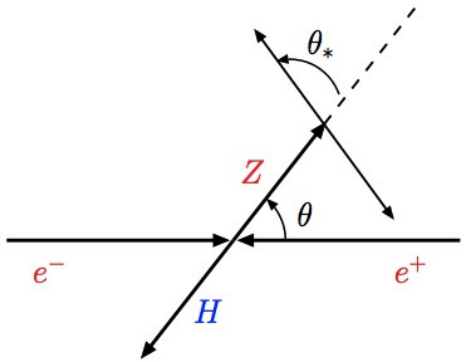
$$\left[m_W^2 W^{\mu+} W_\mu^- + \tfrac{1}{2} m_Z^2 Z^{\mu 0} Z_\mu^0\right] \cdot \left(1 + \tfrac{h}{v}\right)^2 \qquad -\mu^2 h^2 - \tfrac{\lambda}{2} v h^3 - \tfrac{1}{8}\lambda h^4 \qquad -\sum_f m_f \bar{f} f \left(1 + \frac{h}{v}\right)$$

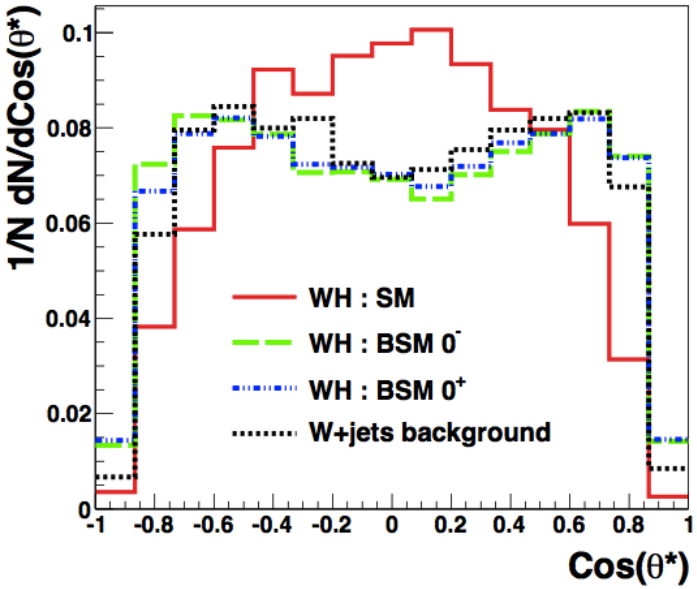



$$m_H = \sqrt{2}\mu = \sqrt{\lambda} v \ (v = \text{vacuum expectation value})$$

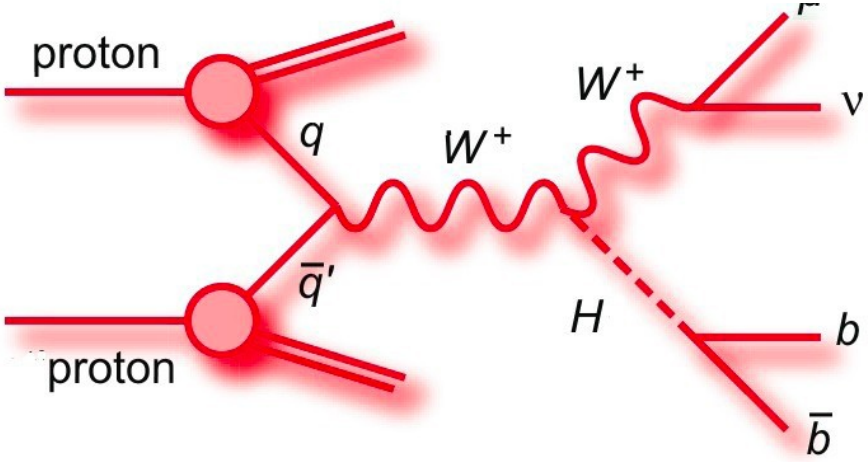
- Couplings to fermions
  - H→bb in associated production with a W or Z boson
    - Observation
    - Tensor structure of the coupling vertexes --> anomalous couplings?
  - H→bb in associated production with a ttbar pair
    - Direct probe of the coupling to the top quark, anomalous couplings

# H→bb in association with a W or Z




ArXiv:1306.2573v2 (Godbole et al.)




$$\cos\theta^* = \frac{\vec{p}_{l_1}^{(V)} \cdot \vec{p}_V}{|\vec{p}_{l_1}^{(V)}|\,|\vec{p}_V|},$$

# H→bb in association with a ttbar pair

## Angular distributions in $t\bar{t}H(H \to b\bar{b})$ reconstructed events at the LHC

S.P. Amor dos Santos[1], J.P. Araque[2], R. Cantrill[3], N.F. Castro[2,9], M.C.N. Fiolhais[1,4], R. Frederix[5], R. Gonçalo[3], R. Martins[2], R. Santos[7,8], J. Silva[6], A. Onofre[2], H. Peixoto[6], A. Reigoto[2]

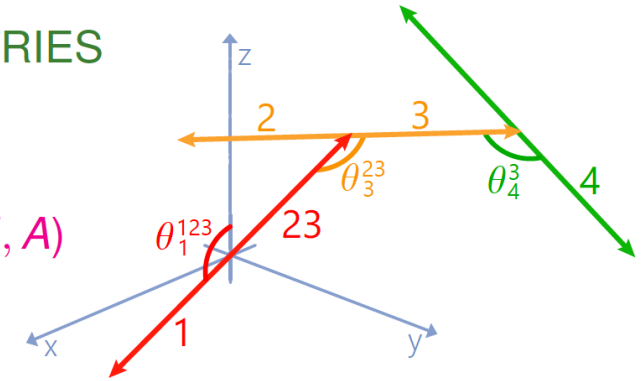
[1] *LIP, Departamento de Física, Universidade de Coimbra, 3004-516 Coimbra, Portugal*
[2] *LIP, Departamento de Física, Universidade do Minho, 4710-057 Braga, Portugal*

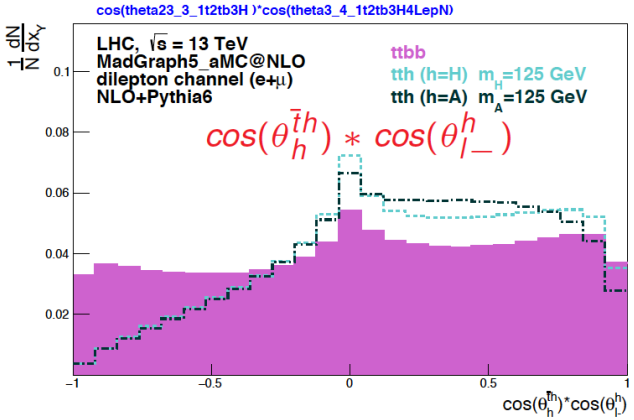
NEW ANGULAR DISTRIBUTIONS AND ASYMMETRIES

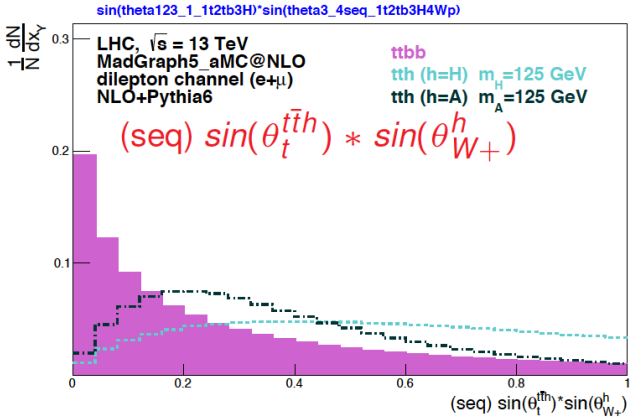
☞ (1) PARTON LEVEL observables NO CUTs

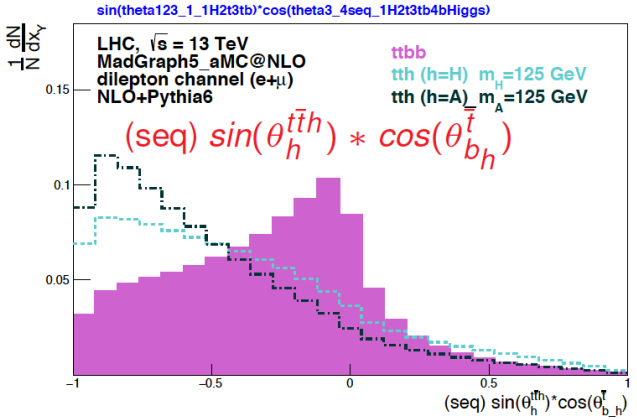
motivated by spin helicity formalism

are there good discriminators to separate signals ($H, A$) from dominant backgrounds? Yes!

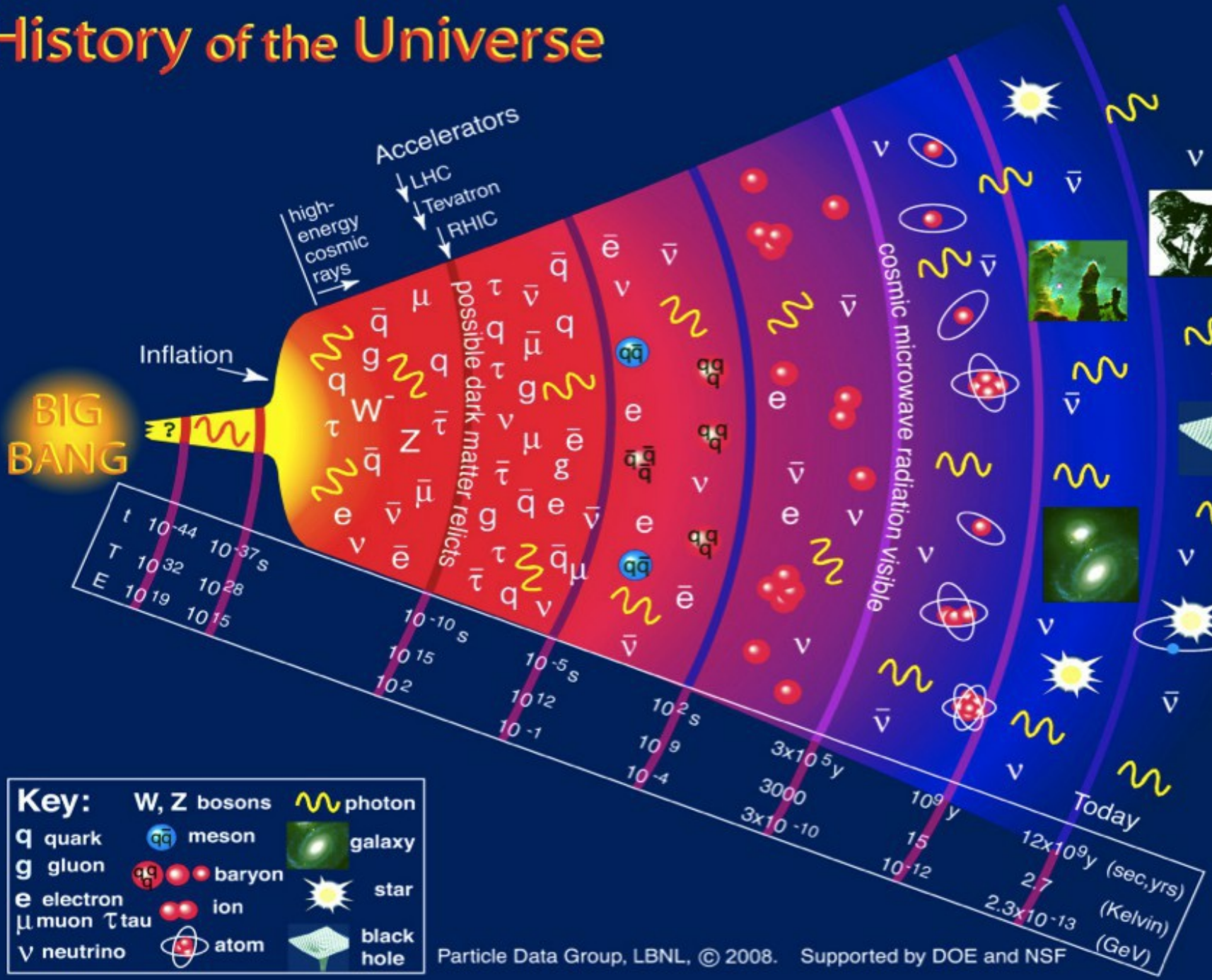


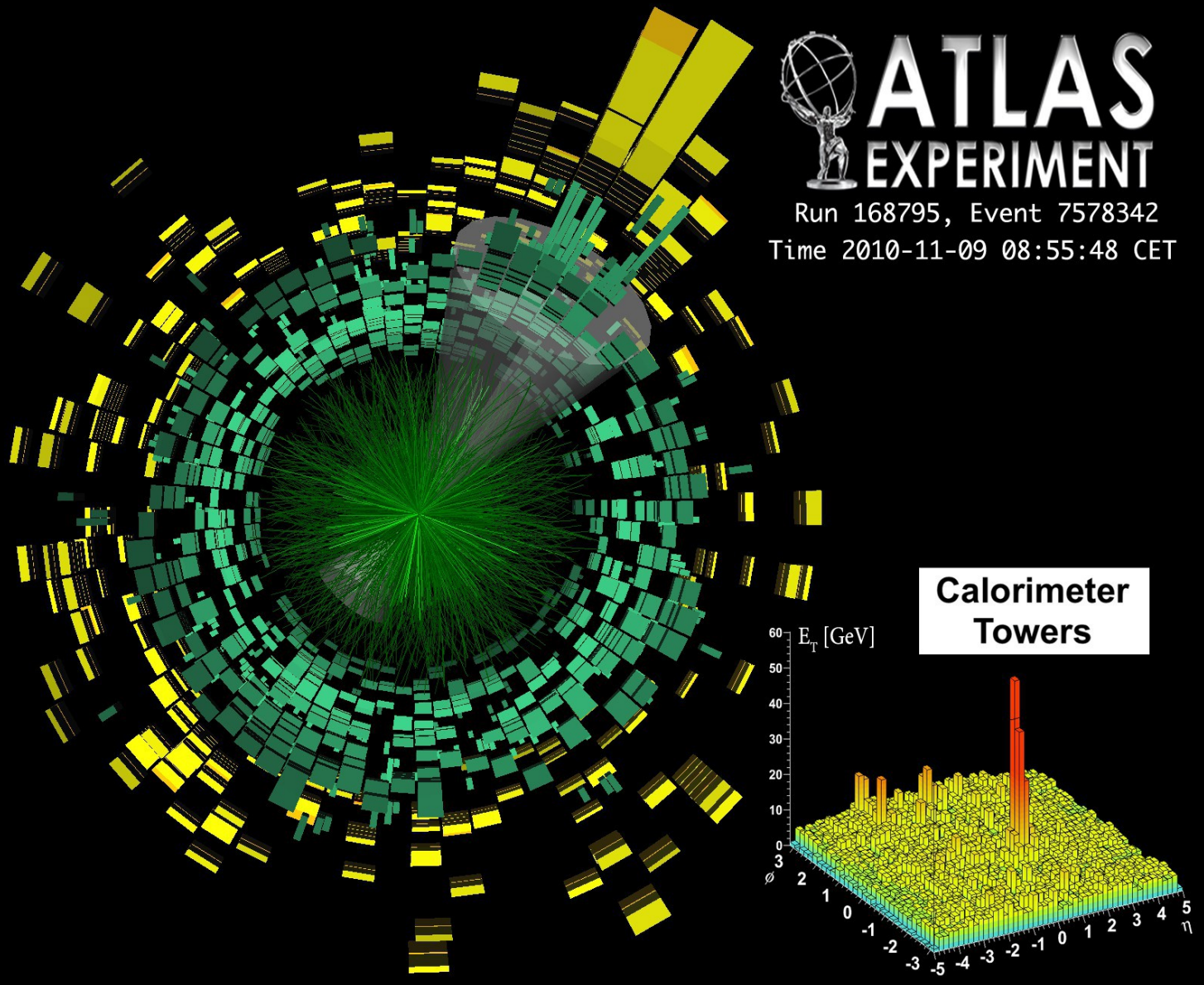



# History of the Universe

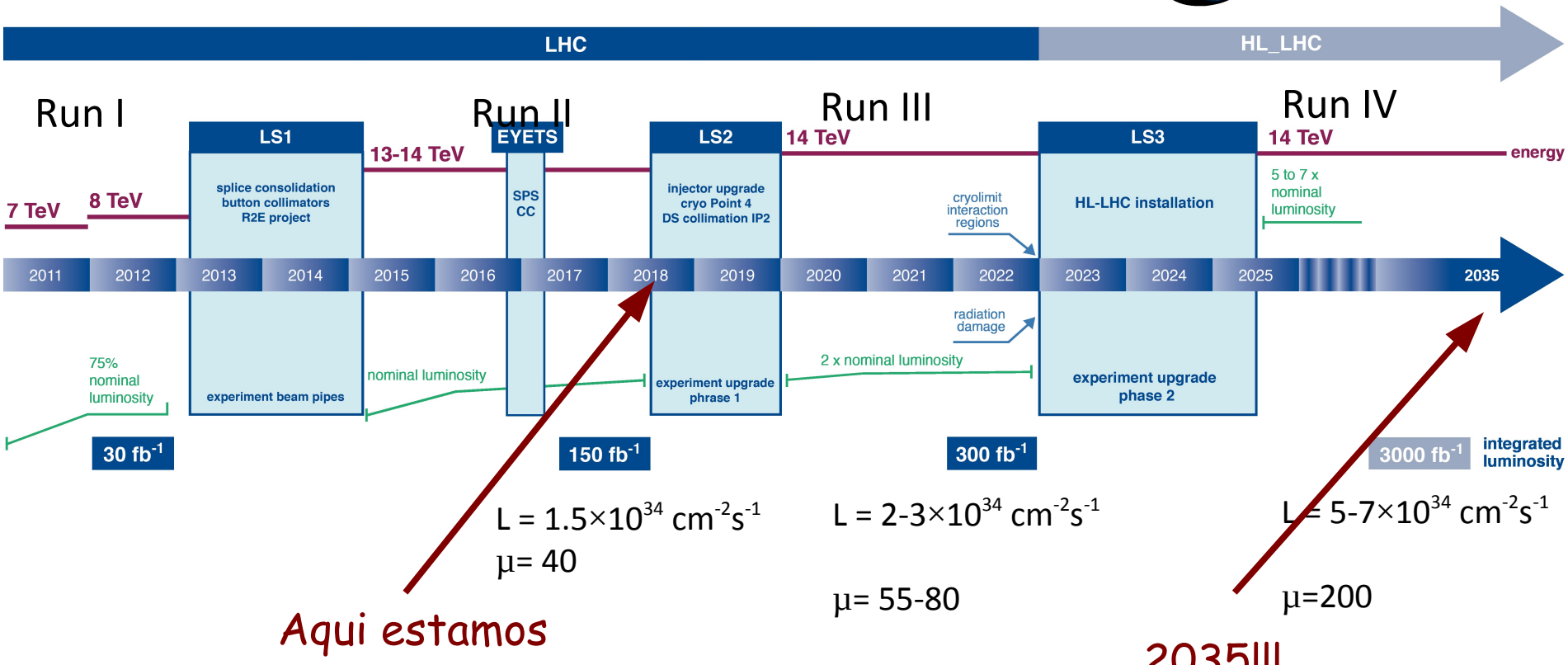



Particle Data Group, LBNL, © 2008. Supported by DOE and NSF


ATLAS
EXPERIMENT
Run 168795, Event 7578342
Time 2010-11-09 08:55:48 CET
Calorimeter Towers
$E_T$ [GeV]
60
50
40
30
20
10
0
3
2
1
0
-1
-2
-3
ϕ
-5
-4
-3
-2
-1
0
1
2
3
4
5
η

# Futuro do LHC e de ATLAS

## LHC / HL-LHC Plan




$L = 1.5\times10^{34}\ cm^{-2}s^{-1}$

$\mu = 40$

Aqui estamos

$L = 2\text{-}3\times10^{34}\ cm^{-2}s^{-1}$

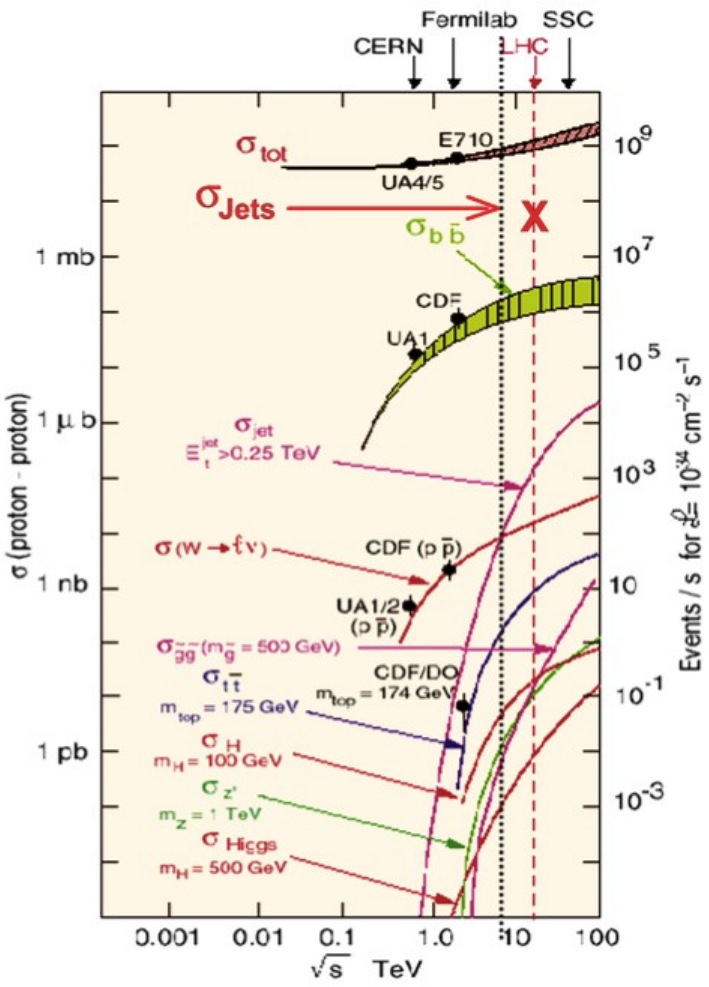
$\mu = 55\text{-}80$

$L = 5\text{-}7\times10^{34}\ cm^{-2}s^{-1}$

$\mu = 200$

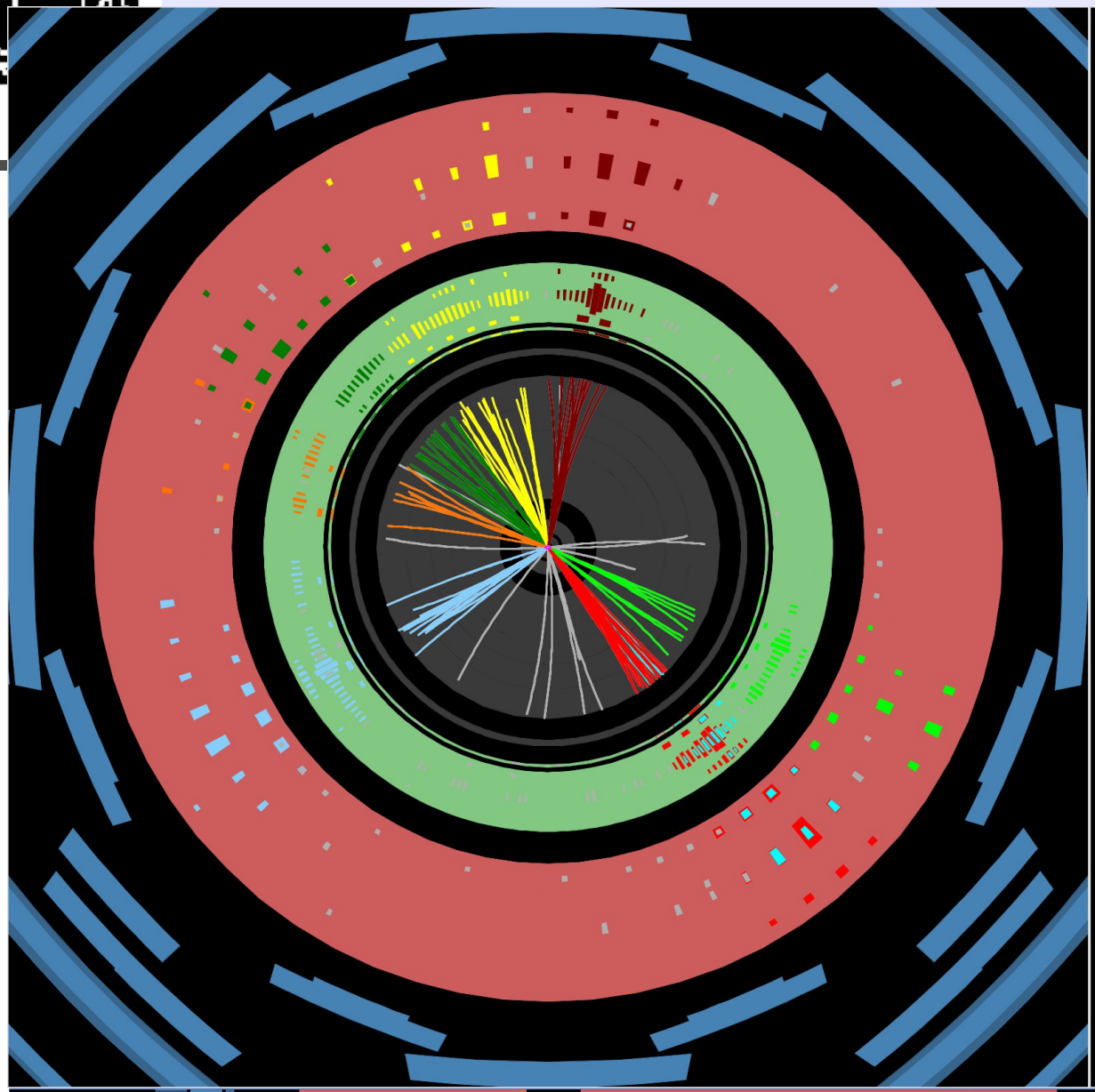
2035!!!

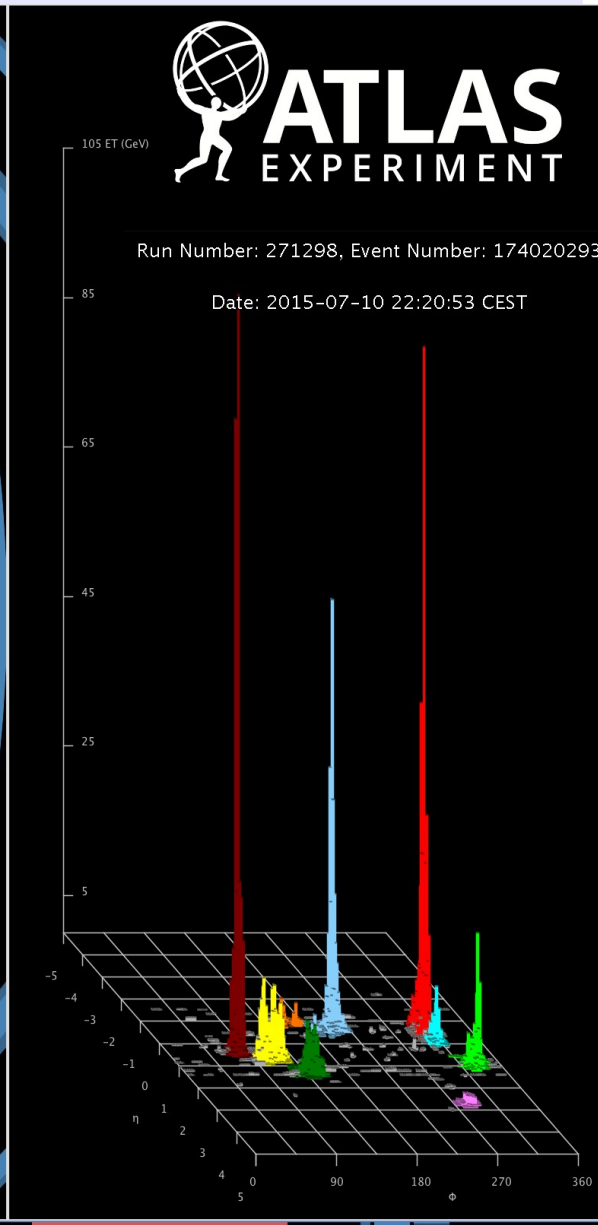
# LHC Upgrade Challenges

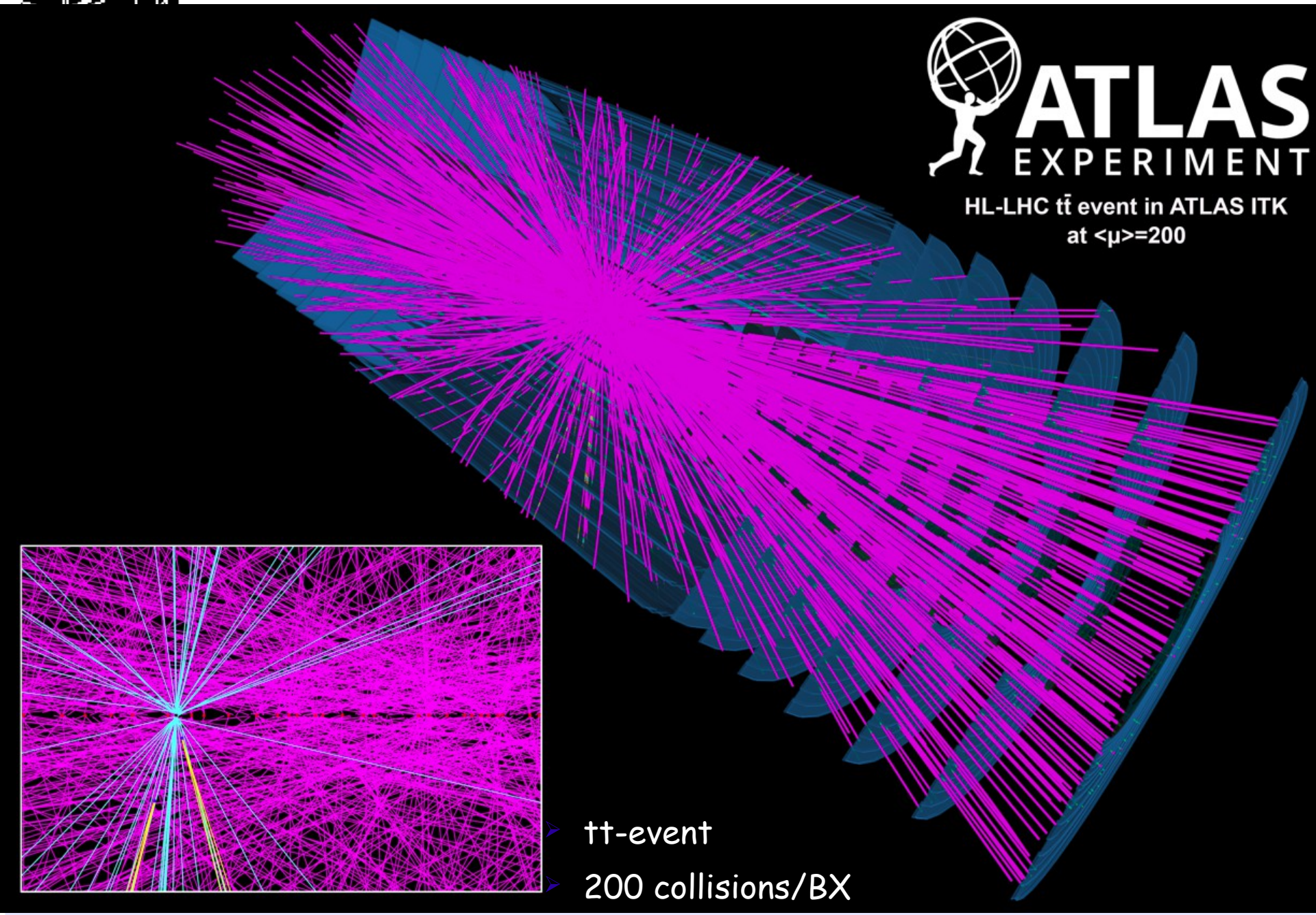



- Interesting processes have small cross-sections
- Need to process & select interesting events in real time
  - 40 MHz event rate
  - Very large number of interactions/event
  - $10^8$ electronic channels

| | Run 2 | Run 3 | Run 4 |
|---|---|---|---|
| Energy (√s) | 13TeV | 14 TeV | 14 TeV |
| Peak Luminosity ($cm^{-2}s^{-1}$) | $1.2\times10^{34}$ | $3\times10^{34}$ | $7\times10^{34}$ |
| Interactions/event | 40 | 55-80 | 140-200 |
| Bunch crossing rate | 40 MHz | 40 MHz | 40 MHz |
| Offline storage rate | 1000 Hz | 1000 Hz | 1000 Hz |
| Bunch spacing | 25 ns | 25 ns | 25 ns |



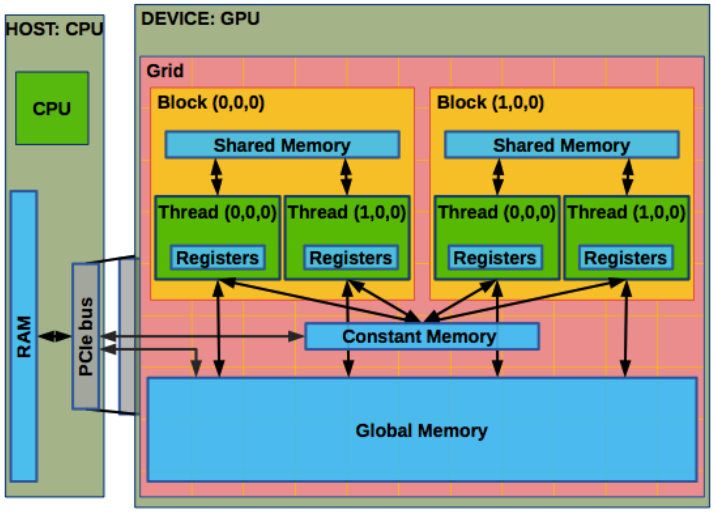

ATLAS
EXPERIMENT
Run Number: 271298, Event Number: 174020293
Date: 2015-07-10 22:20:53 CEST
105 ET (GeV)
85
65
45
25
5
-5
-4
-3
-2
-1
0
1
2
3
4
5
η
0
90
180
270
360
Φ

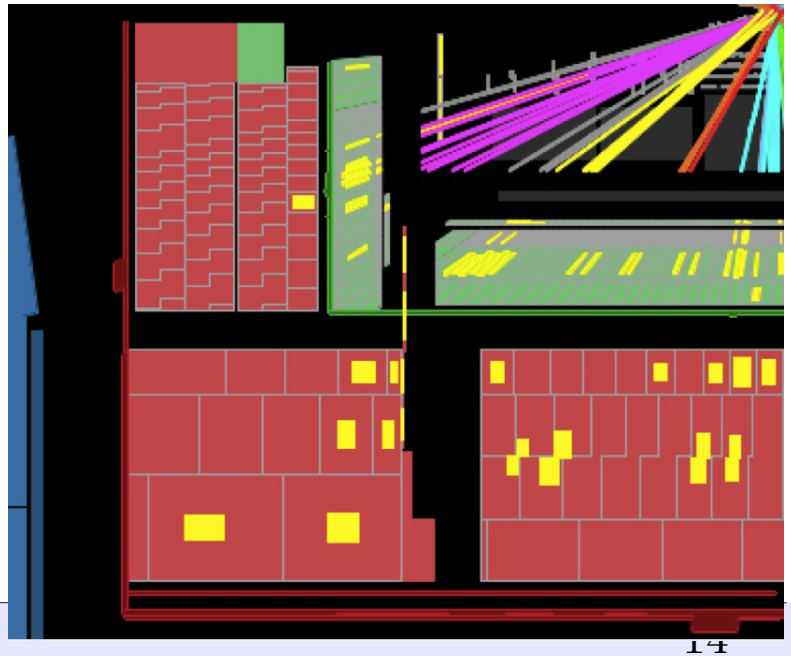



- tt-event
- 200 collisions/BX

# Using GPUs at trigger level

- Thousands of cores with limited processing speed/core
- Different programming paradigm:
  - Single-instruction-multiple-data
- Great potential to improve
  - events processed/(s×CHF)
- Demonstrator prototype:
  - LIP group responsible for the calorimeter reconstruction
    - Cluster reconstruction
    - 3D particle energy depositions
  - Up to a factor of five performance improvement

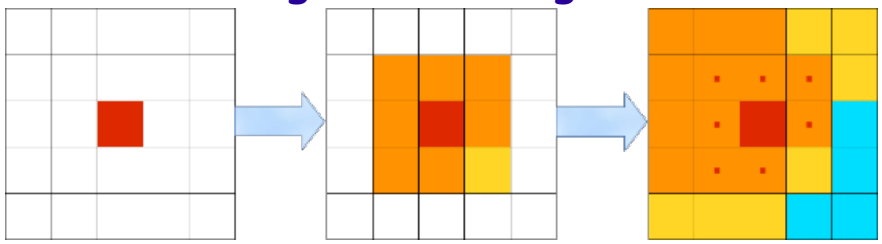


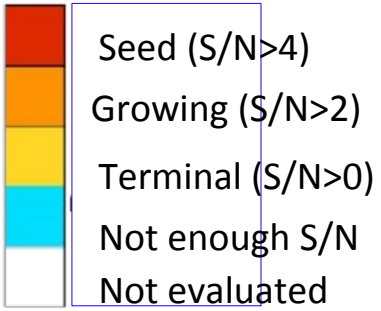



# GPGPU Calorimeter Clustering Algorithm

- TopoCluster reconstruction on CPU (~8% of total time)

  Group cells according to their signal/noise ratio





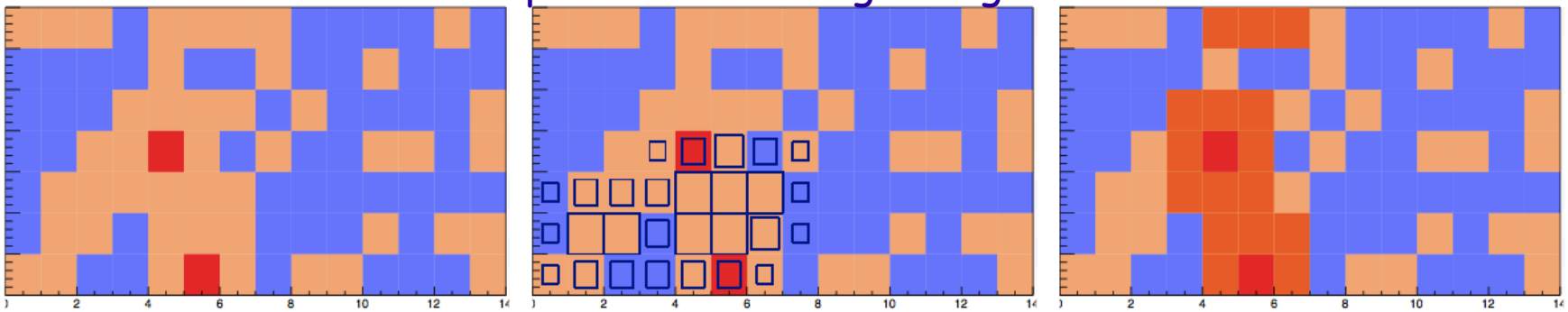

- TAC: Topo-Automaton Clustering

  Use a cellular automaton for the GPU (maximize parallelism)

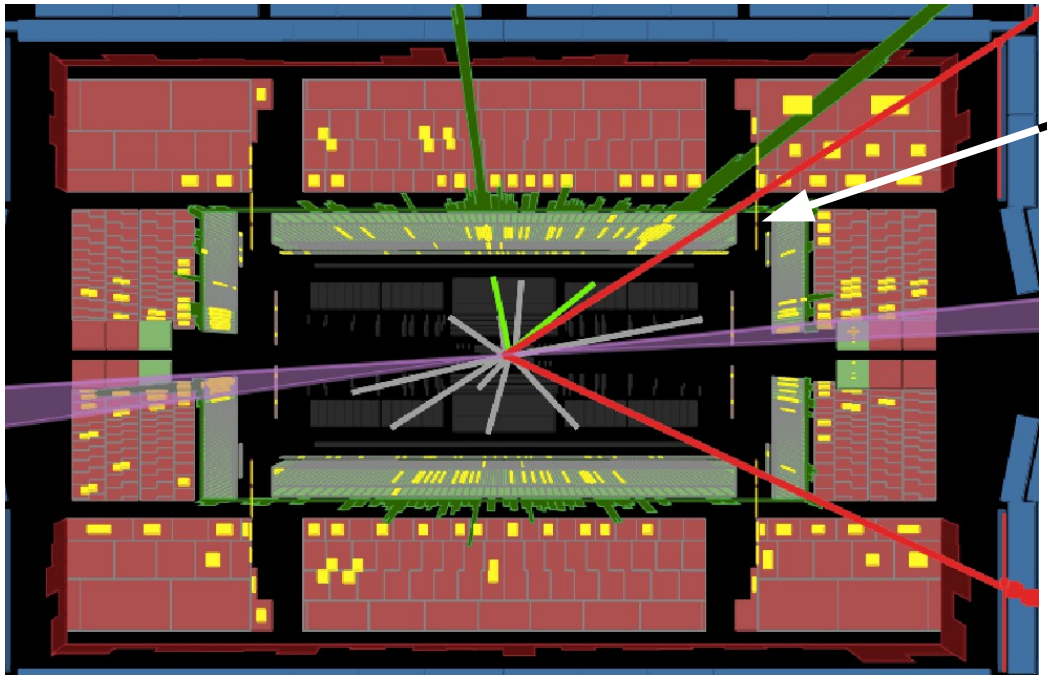
  Propagate flag on a grid of elements (cell pair)

    Cells get the largest flag on each iteration

  Process all cells pairs until no flag changes



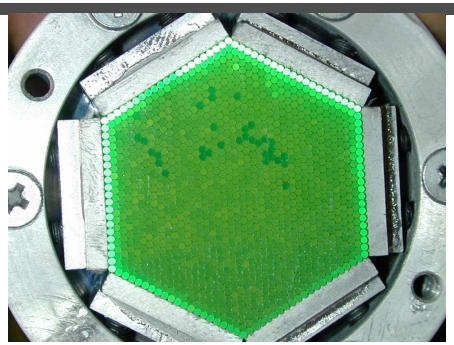
# Phase I TileCal hadronic calorimeter Upgrade

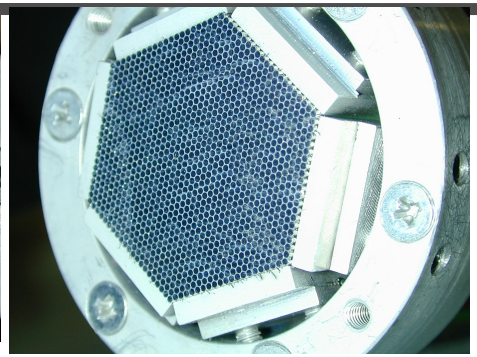


Phase I

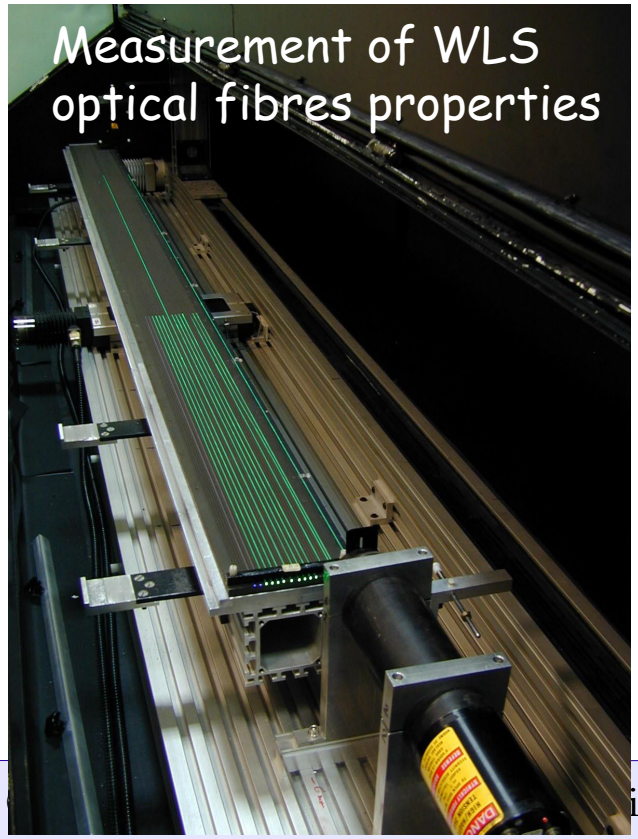
- Gap scintillator/fibres replacement due to radiation damage
- R&D on radiation hard scintillators
  - Irradiations at CTN
  - Tests at the LOMAC lab
- Fibres preparation and quality control

# LOMAC: Laboratório de Ótica e Materiais Cintilantes

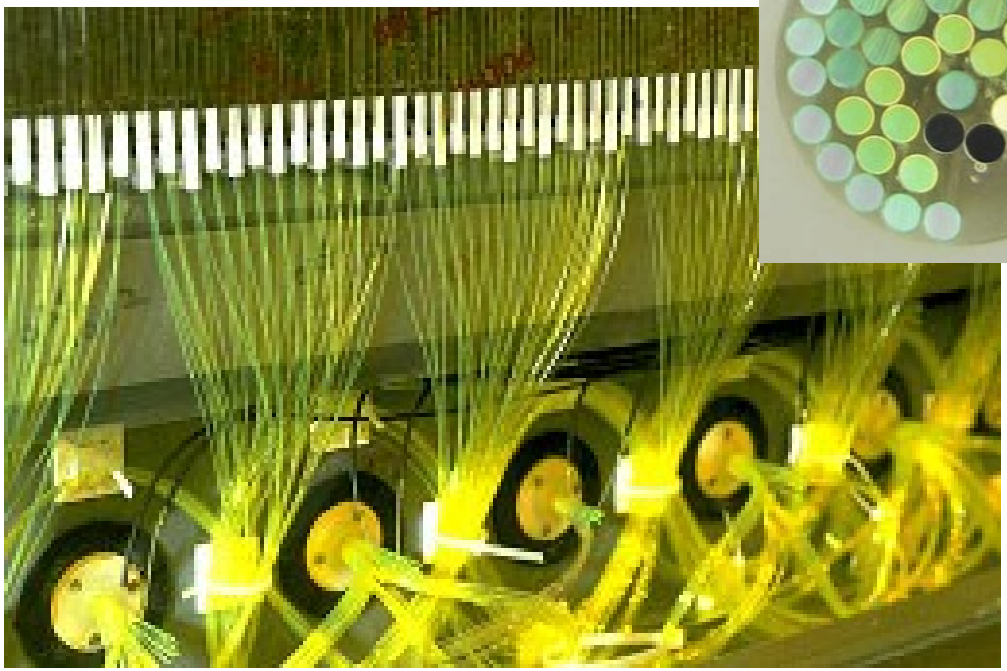


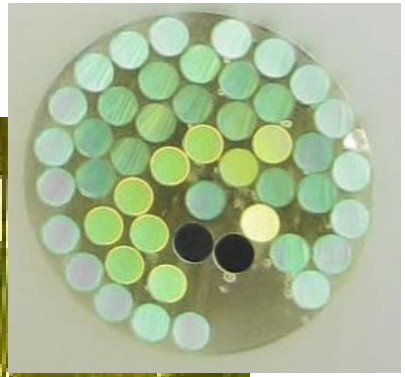


Optical fibre preparation

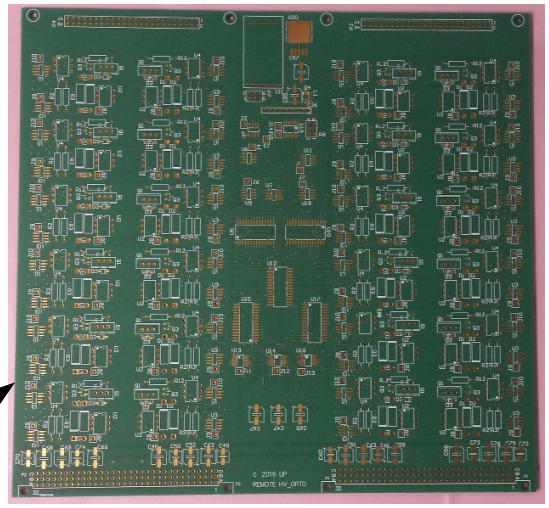



Tile calorimeter readout

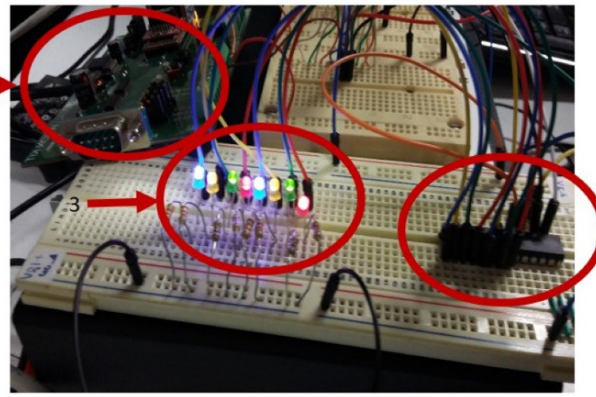




# Phase II TileCal Upgrade



- Detector electronics replacement
  - HV distribution boards
  - New boards designed @ LIP/FFCUL/INESC-ID
  - First prototype under implementation
  - To be tested with beams of particles at CERN (2018)




1- Placa TIBBO EM1206-EV
2- Expansor MCP23S17
3- Controlo feito com o painel

We explore the energy frontier in collider physics

We work and learn with people from around the world

We have great projects that need clever students

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