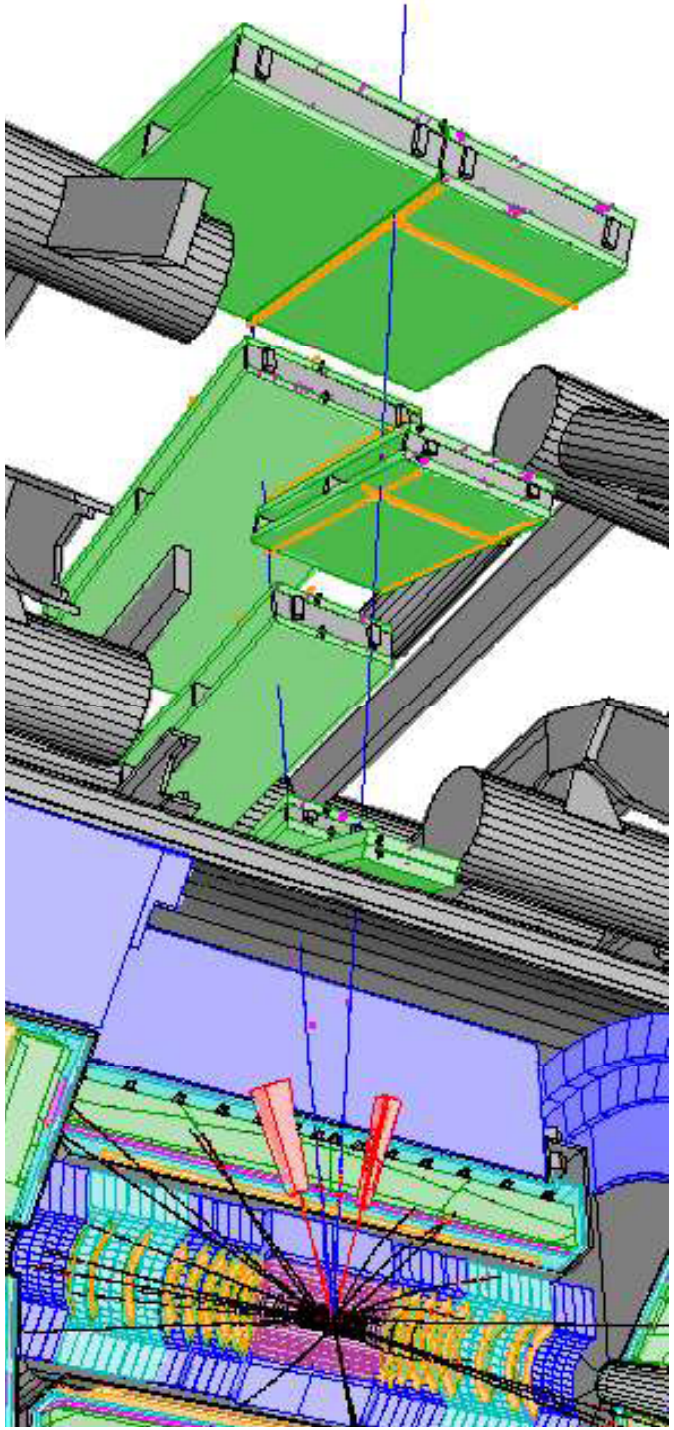
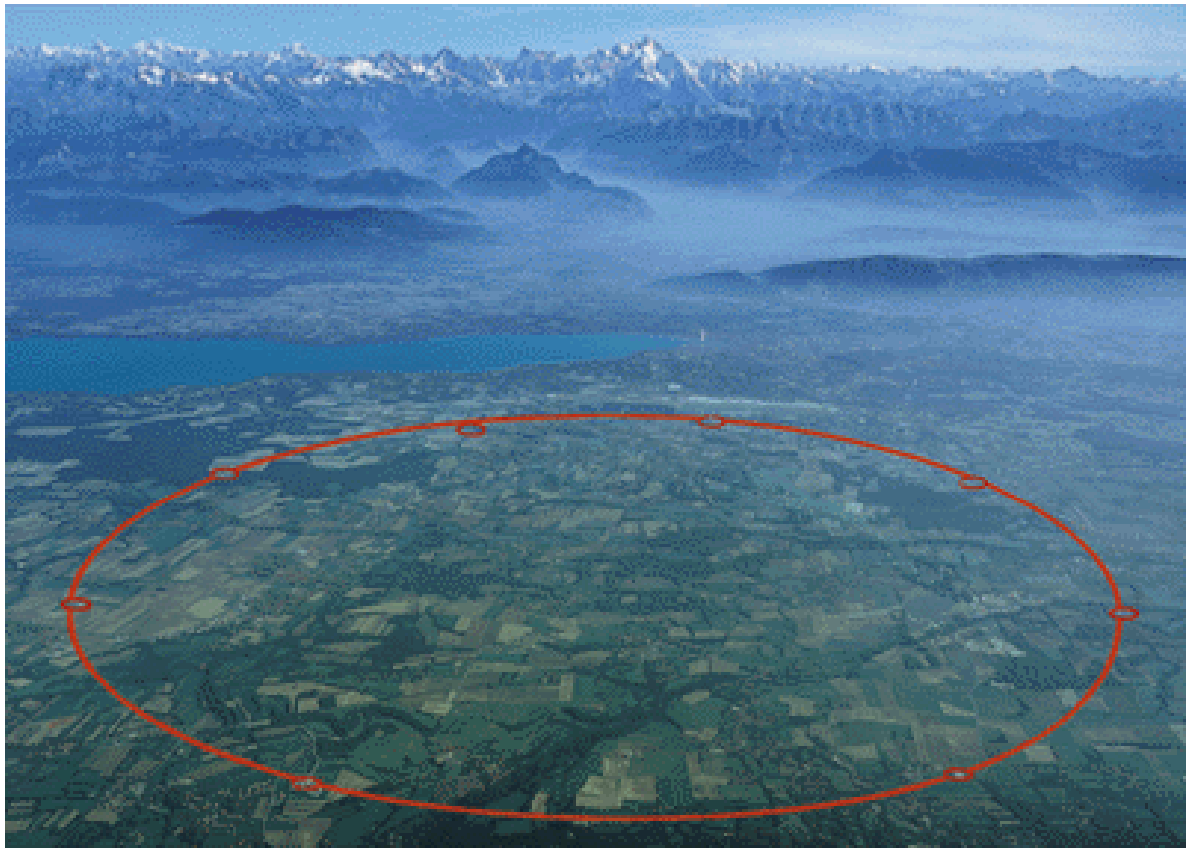


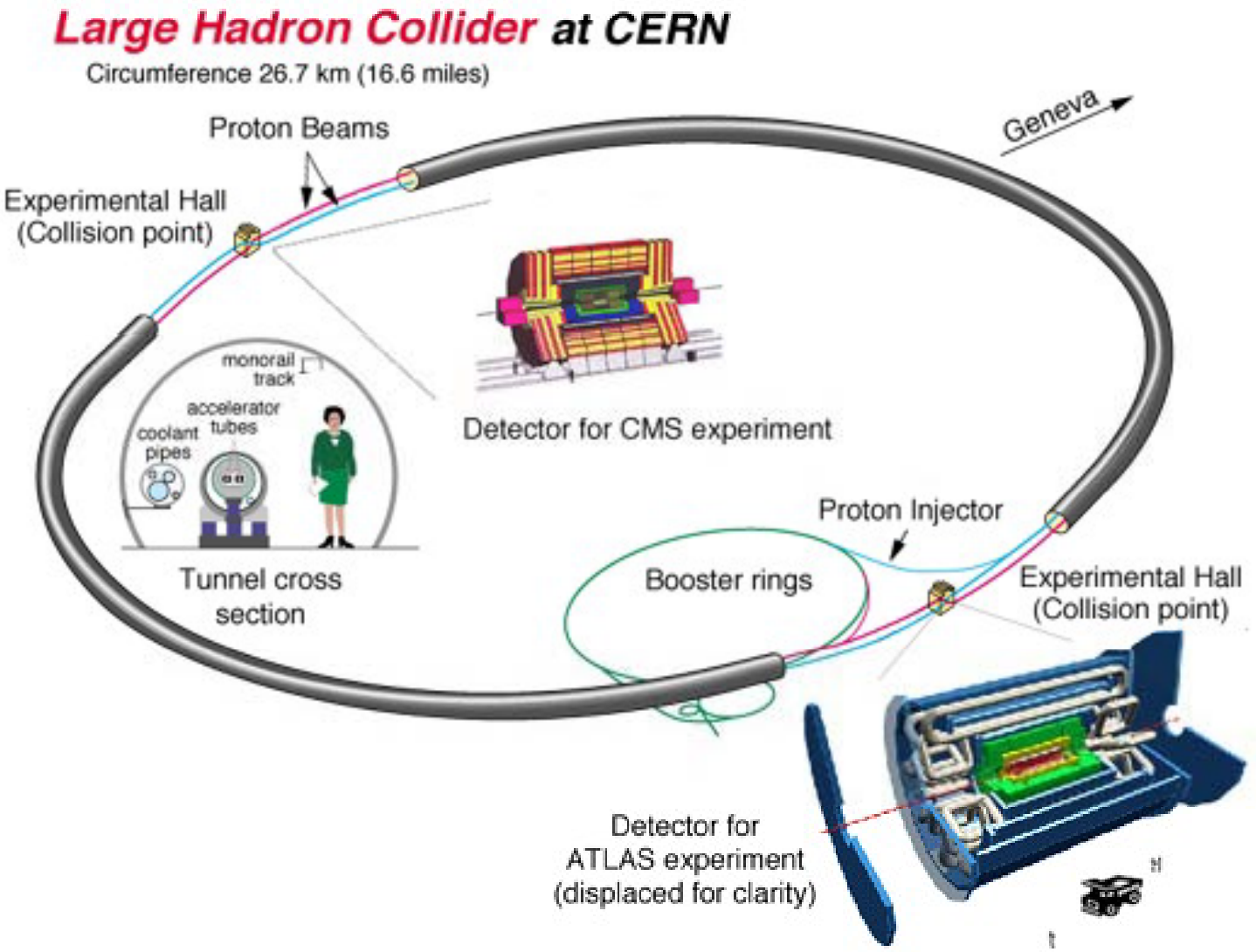
The ATLAS trigger

Ricardo Gonçalo
Royal Holloway University of London

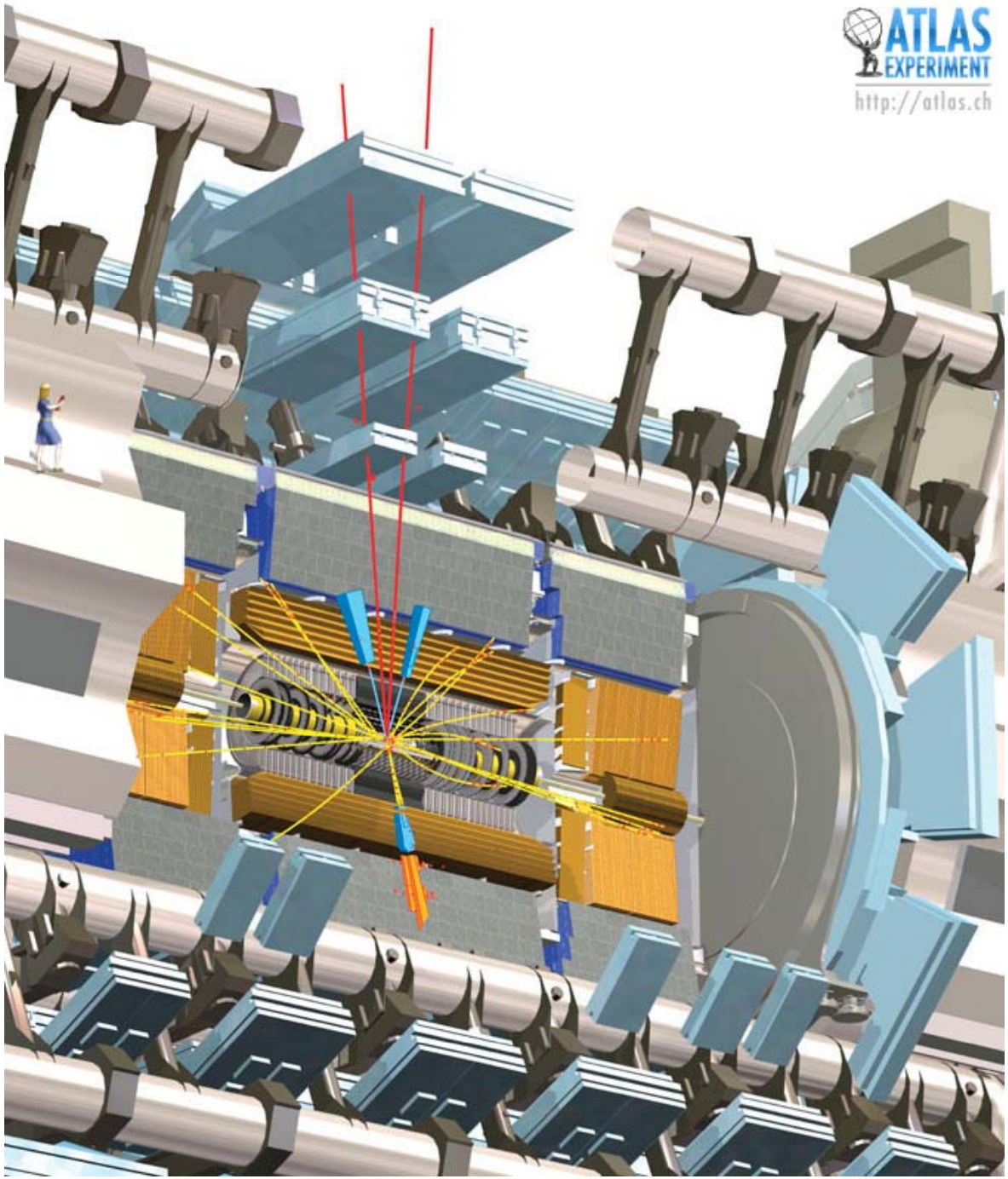
ATLAS and the LHC

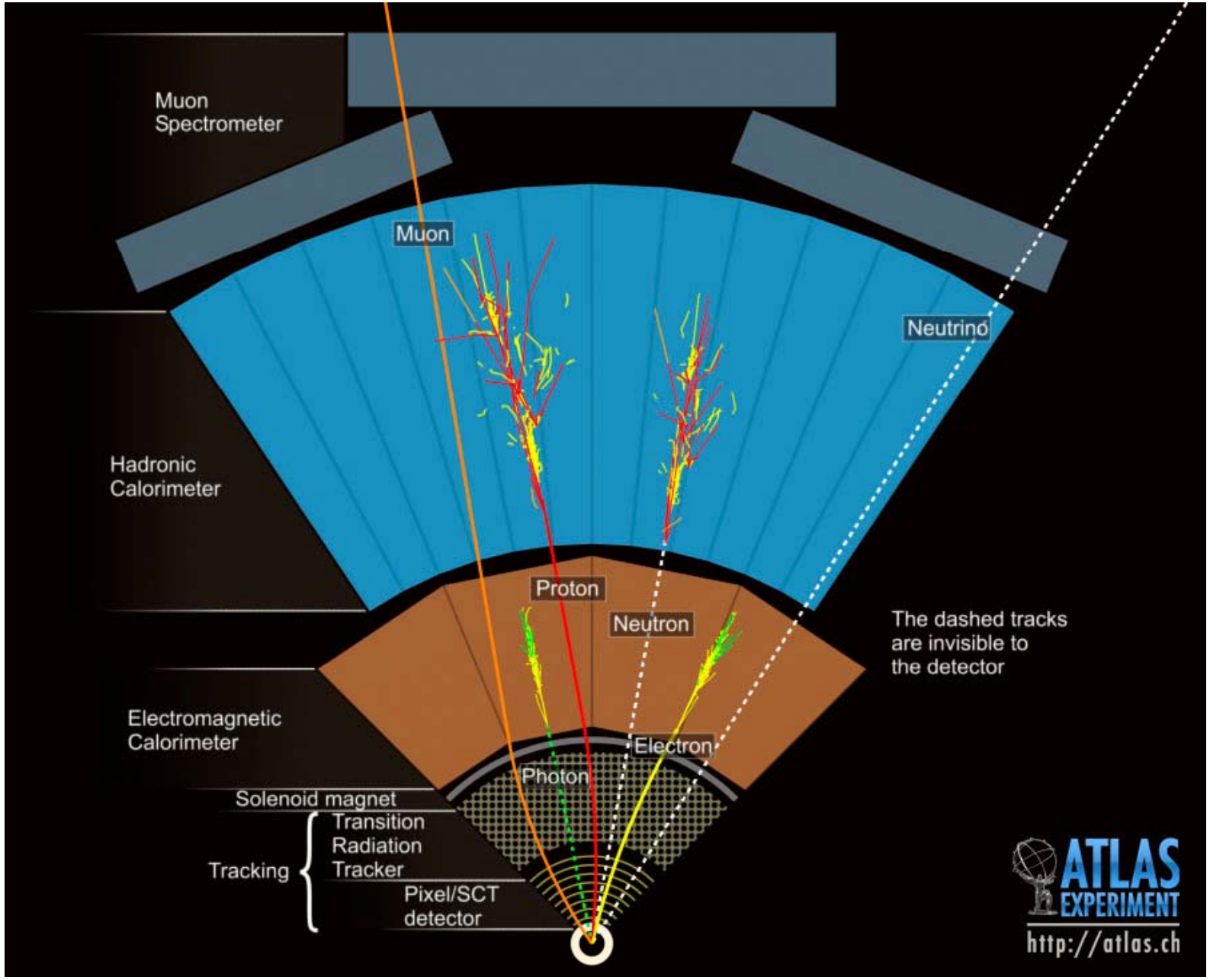
- 2 proton beams of 7 TeV/proton
- …roughly as much kinetic energy as the french TGV traveling at 200km/h
- colliding at 25ns interval… 25ns x *c* = 7.5m … not much longer than this room!




Large Hadron Collider at CERN
Circumference 26.7 km (16.6 miles)
Proton Beams
Geneva
Experimental Hall
(Collision point)
Detector for CMS experiment
monorail track
accelerator tubes
coolant pipes
Tunnel cross section
Proton Injector
Booster rings
Experimental Hall
(Collision point)
Detector for
ATLAS experiment
(displaced for clarity)

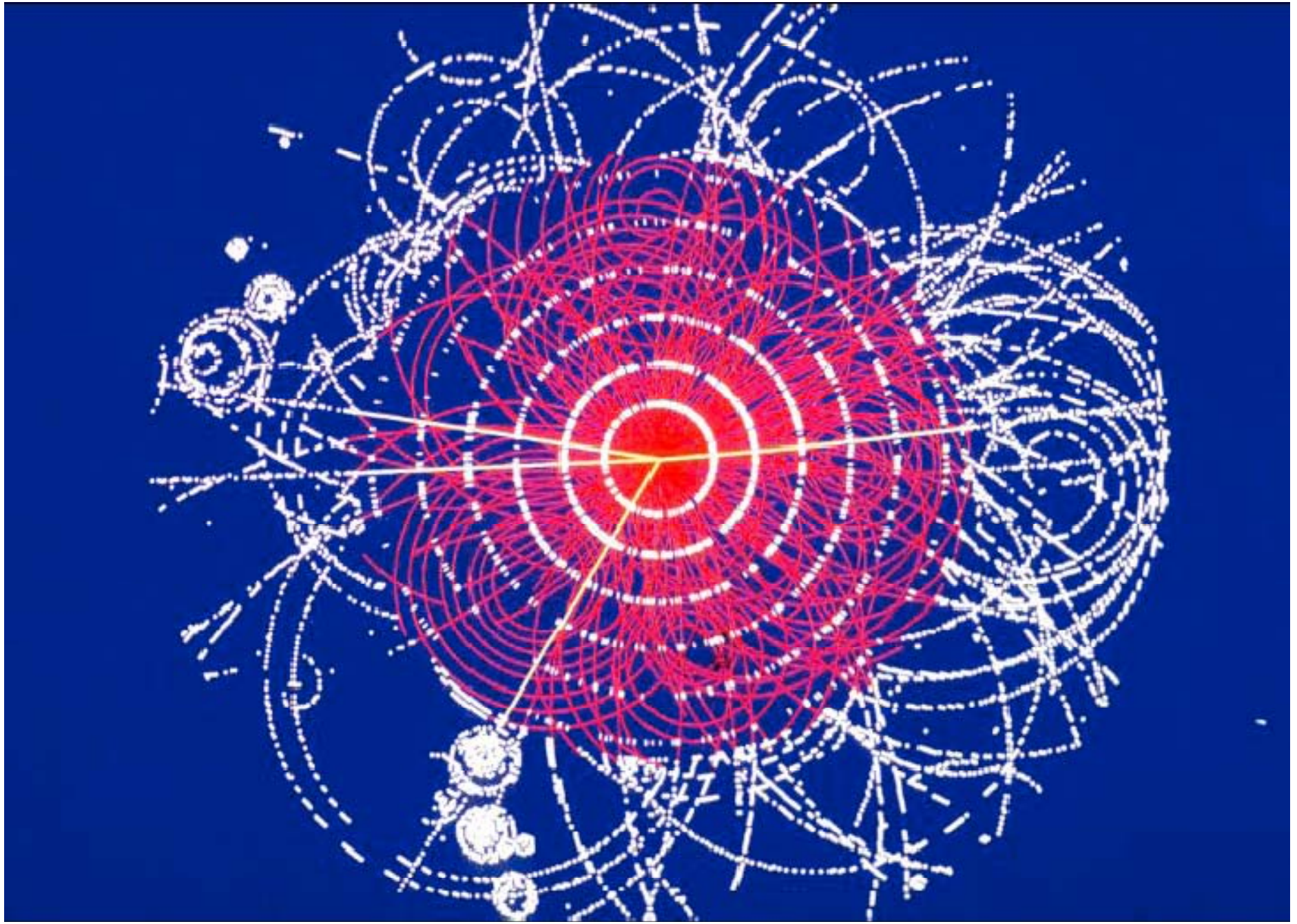
D712/mb-26/06/97
Muon Detectors
Electromagnetic Calorimeters
Solenoid
Forward Calorimeters
End Cap Toroid
D. Parchet + MB
Barrel Toroid
Inner Detector
Hadronic Calorimeters
Shielding


ATLAS
EXPERIMENT
http://atlas.ch



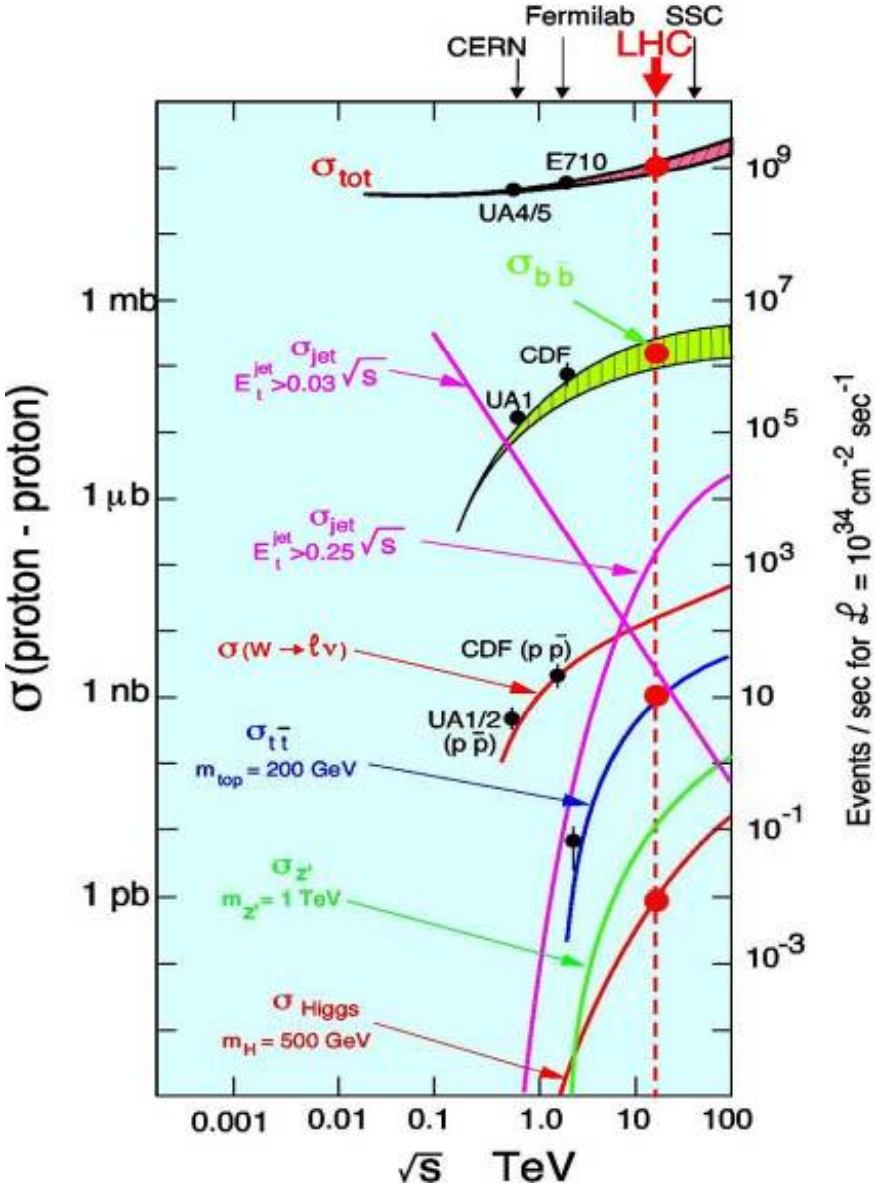
- http://atlas.ch/multimedia/html-nc/animation_wedge.html

LHC physics



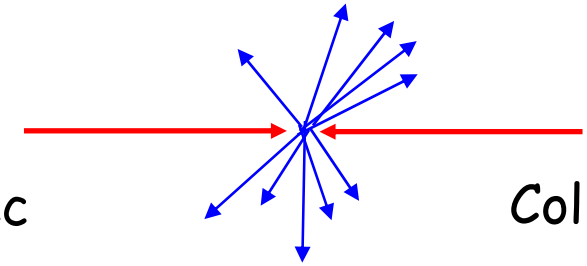
Challenges faced by the ATLAS trigger

- Much of ATLAS physics means cross sections at least ~10^6 times smaller than total cross section
- 25ns bunch crossing interval (40 MHz)
- Offline storing/processing: ~200 Hz
  - ~5 events per million crossings!
- In one second at design luminosity:
  - 40 000 000 bunch crossings
  - ~2000 W events
  - ~500 Z events
  - ~10 top events
  - ~0.1 Higgs events?
  - **200 events written out**
- The right 200 events should be written out!



The ATLAS trigger

Finally…the trigger



40 TB/sec

Collision Rate 40 MHz

Level 1 Special Hardware Trigger

10-100 GB/sec

~ 75 kHz

Level 2 Processor Farm

1-10 GB/sec

~1 kHz

Level 3 Processor Farm

~300 MB/sec

~200 Hz

Raw Data Storage

Offline Data Reconstruction

Selecting interesting events based on progressively more detector information

The ATLAS trigger

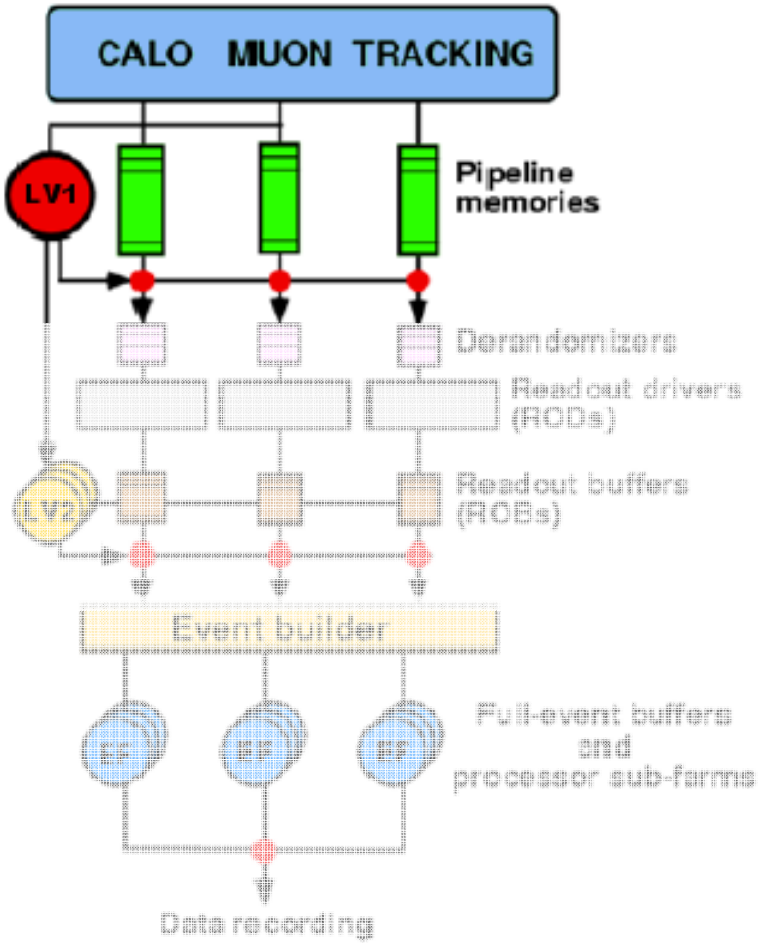
Three trigger levels:

- Level 1:
  - Hardware based (FPGA/ASIC)
  - Coarse granularity detector data
  - Calorimeter and muons only
  - 2.5 μs latency (buffer size)

High-Level Trigger

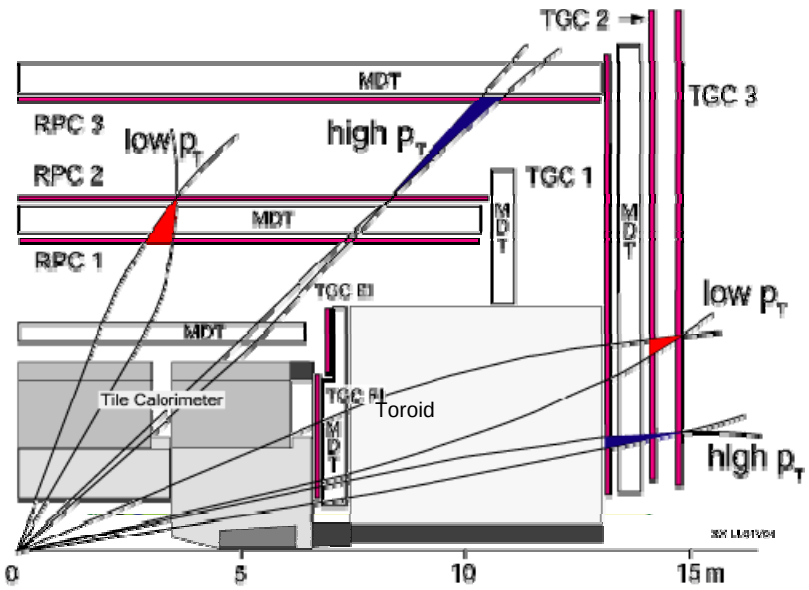
- Level 2:
  - Software based
  - Only detector sub-regions (Regions of Interest) processed; seeded by level 1
  - Full detector granularity in RoIs
  - Fast tracking and calorimetry
  - Average execution time ~40 ms
  - Output rate ~1 kHz

- Event Filter (EF):
  - Seeded by level 2
  - Full detector granularity
  - Potential full event access
  - Offline algorithms
  - Average execution time ~1 s
  - Output rate ~200 Hz



Level 1

LVL1 - Muons & Calorimetry



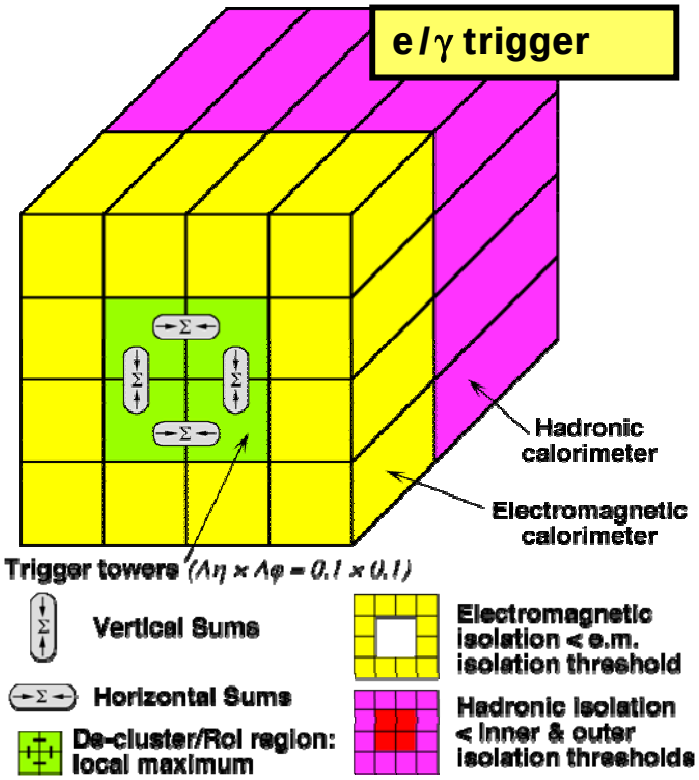
Muon Trigger looking for coincidences in muon trigger chambers

3 out of 4 (low-p_T; >6 GeV) and

3 out of 4

+ 1/2 (Barrel) or 2/3 (Endcap)

(high-p_T; >20 GeV)



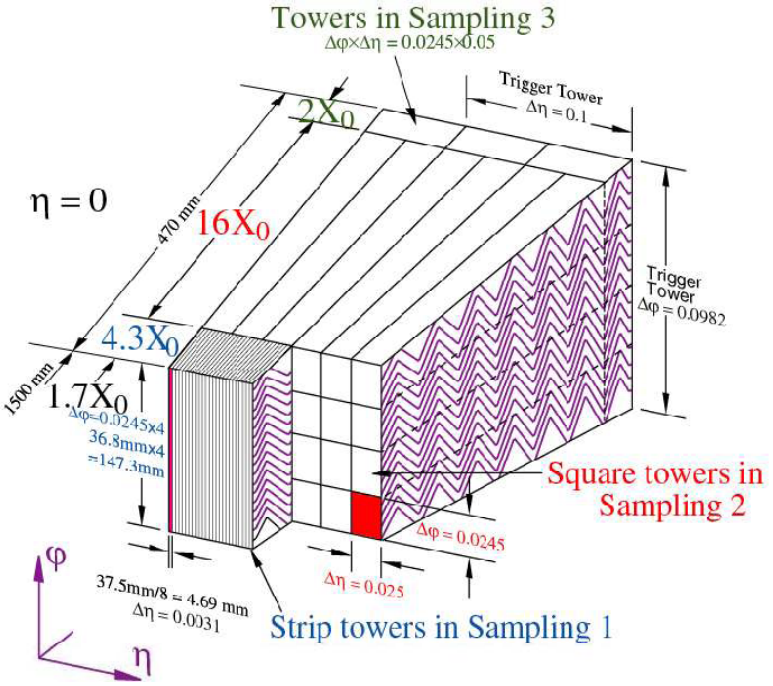
Calorimetry Trigger looking for e/γ, τ,/isolated hadron, jets

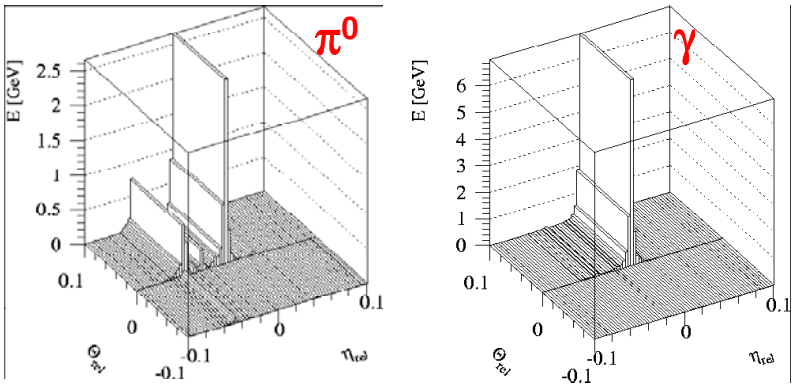
- **Various combinations of cluster sums and isolation criteria**
- **$\Sigma E_T^{em,had}$, E_T^{miss}**

High Level Trigger

Example: level 2 e/γ calorimeter reconstruction

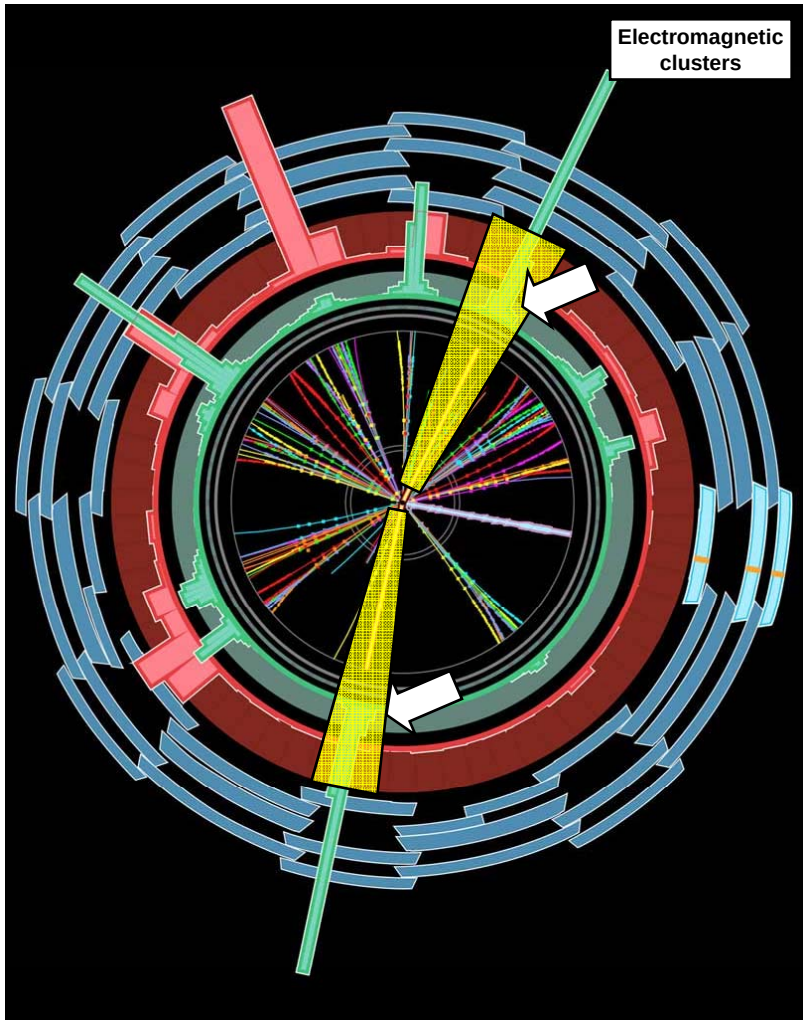
- Full granularity but short time and only rough calibration
- Reconstruction steps:
  1. LAr sample 2; cluster position and size (E in 3x3 cells/E in 7x7 cells)
  2. LAr sample 1; look for second maxima in strip couples (most likely from $\pi^0 \rightarrow \gamma\gamma$, etc)
  3. Total cluster energy measured in all samplings; include calibration
  4. Longitudinal isolation (leakage into hadronic calorimeter)
- Produce a level 2 EM cluster object (note EDM different from offline)





HLT Selection

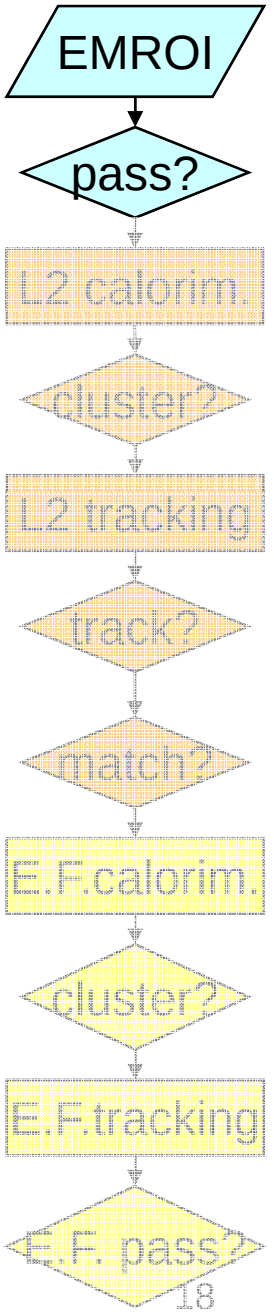
Event rejection possible at each step



Level1 **Region of Interest** is found and position in EM calorimeter is passed to Level 2

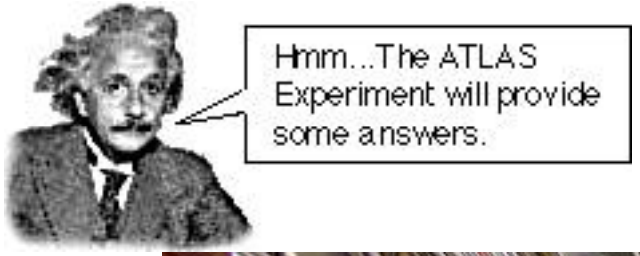
Level 2 seeded by Level 1
Fast reconstruction algorithms
Reconstruction within RoI

Ev.Filter seeded by Level 2
Offline reconstruction algorithms
Refined alignment and calibration



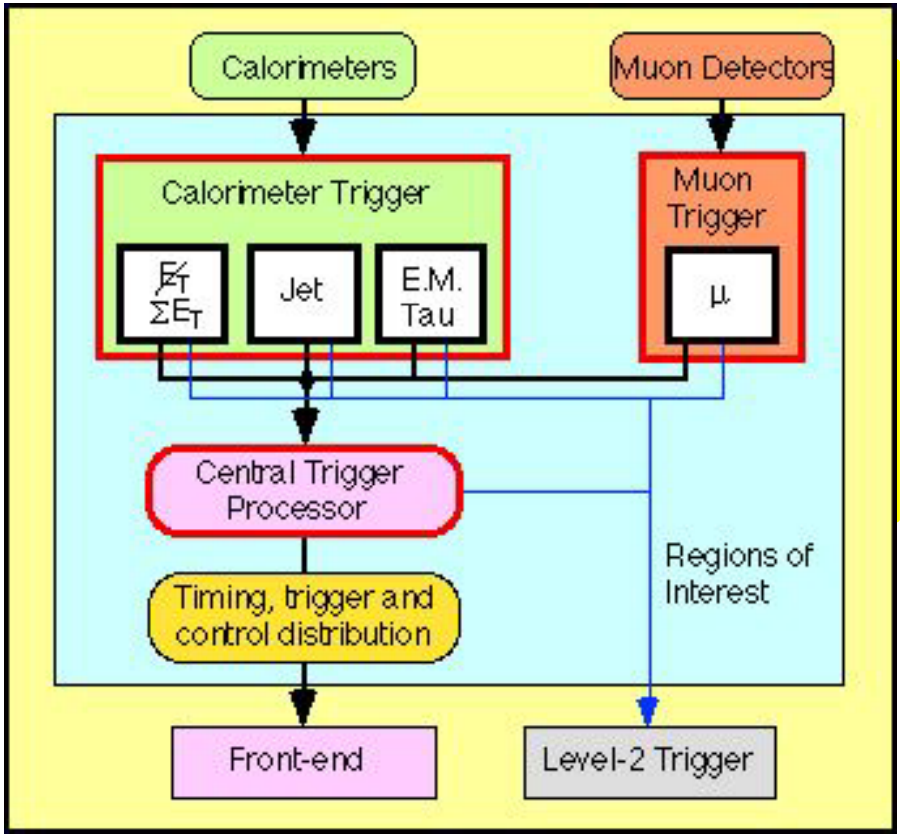
Example Menu

Object	Example physics coverage
Electrons	Higgs (SM, MSSM), new gauge bosons, extra dimensions, SUSY, W, Z, top
Photons	Higgs (SM, MSSM), extra dimensions, SUSY
Muons	Higgs (SM, MSSM), new gauge bosons, extra dimensions, SUSY, W, top
	Rare b-decays ($B \rightarrow \mu\mu X$, $B \rightarrow J/\psi X$)
Tau+missing E_T	Extended Higgs models (e.g. MSSM), SUSY
Jets	SUSY, compositeness, resonances
Jet+missing E_T	SUSY, leptoquarks
Others	Prescaled, calibration, monitoring

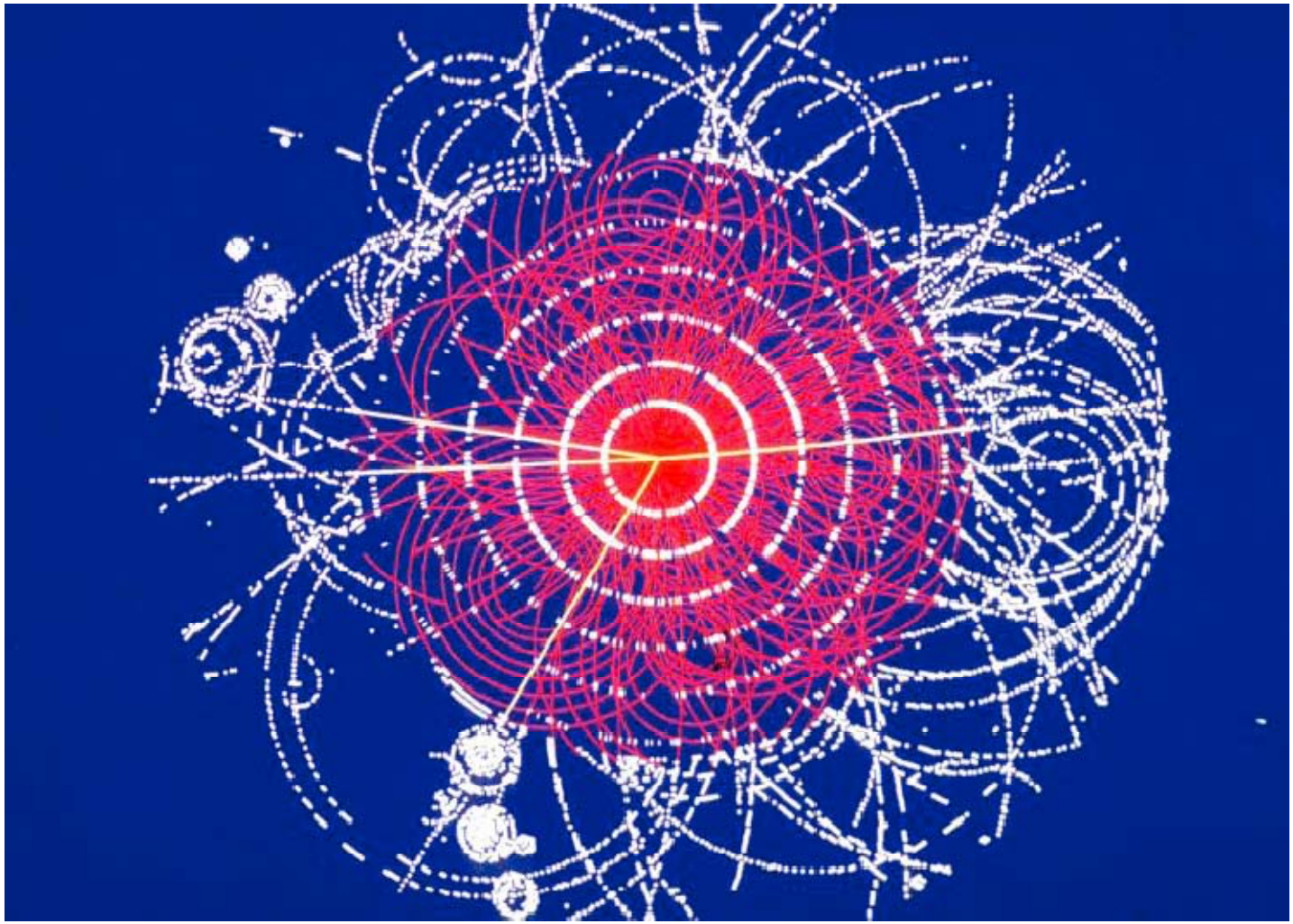

Hmm...The ATLAS Experiment will provide some answers.

Level 1 architecture

- Level 1 uses calorimeter and muon systems only
- Muon spectrometer:
  - Dedicated trigger chambers
    - Thin Gap Chambers – TGC
    - Cathode Strip Chambers – CSC
- Calorimeter:
  - Trigger towers group calorimeter cells in coarse granularity: $\Delta\eta\times\Delta\varphi = 0.1\times0.1$ (EM/Tau); $\Delta\eta\times\Delta\varphi = 0.2\times0.2$ (Jets)
- Identify regions of interest (RoI) and classify them as MU, EM/Tau, Jet
- Information passed to level 2:
  - RoI type
  - E_T threshold passed
  - Multiplicity
  - Location



The response of the level 1 hardware is emulated in Athena.



Example: level 2 tracking algorithm

1. Form pairs of hits in Pixel and SCT in thin ϕ slices;
   - extrapolate inwards to find Z_{vtx} from a 1D histogram
2. Using Z_{vtx}, make 2D histogram of hits in η-ϕ plane;
   - remove bins with hits in too few layers
3. Do 2D histogram using space point triplets in $1/p_T$-ϕ plane;
   - Form tracks from bins with hits in >4 layers
4. Use Kalman technique on the space points obtained in previous steps
   - Start from already estimated parameters: Z_{vtx}, $1/p_T$, η, ϕ

- Full granularity but short time
- Algorithms optimised for execution speed, including data access time
- Produce level 2 tracks