МИСИС
УНИВЕРСИТЕТ

Seminar
Principles of particle detection

Shorkin Roman
roman.shorkin@cern.ch

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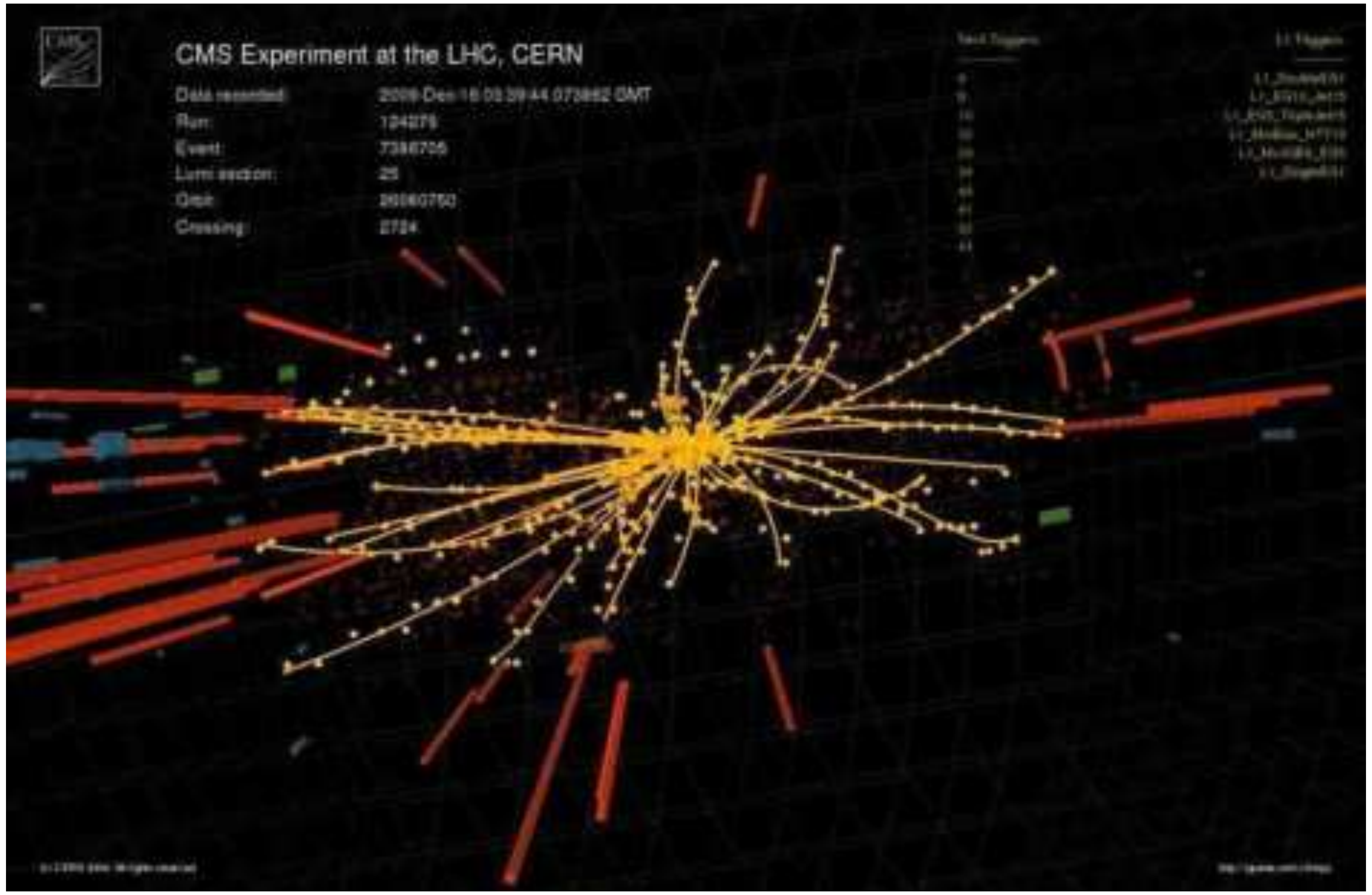
Plan of the seminar

- ❑ Main detection principles: a quick recap
- ❑ Practical example: ATLAS detector
    - ❑ Radiation shielding
    - ❑ General features
    - ❑ Tracking
    - ❑ Calorimetry
    - ❑ Muon system
- ❑ Please ask your questions!!

A quick recap

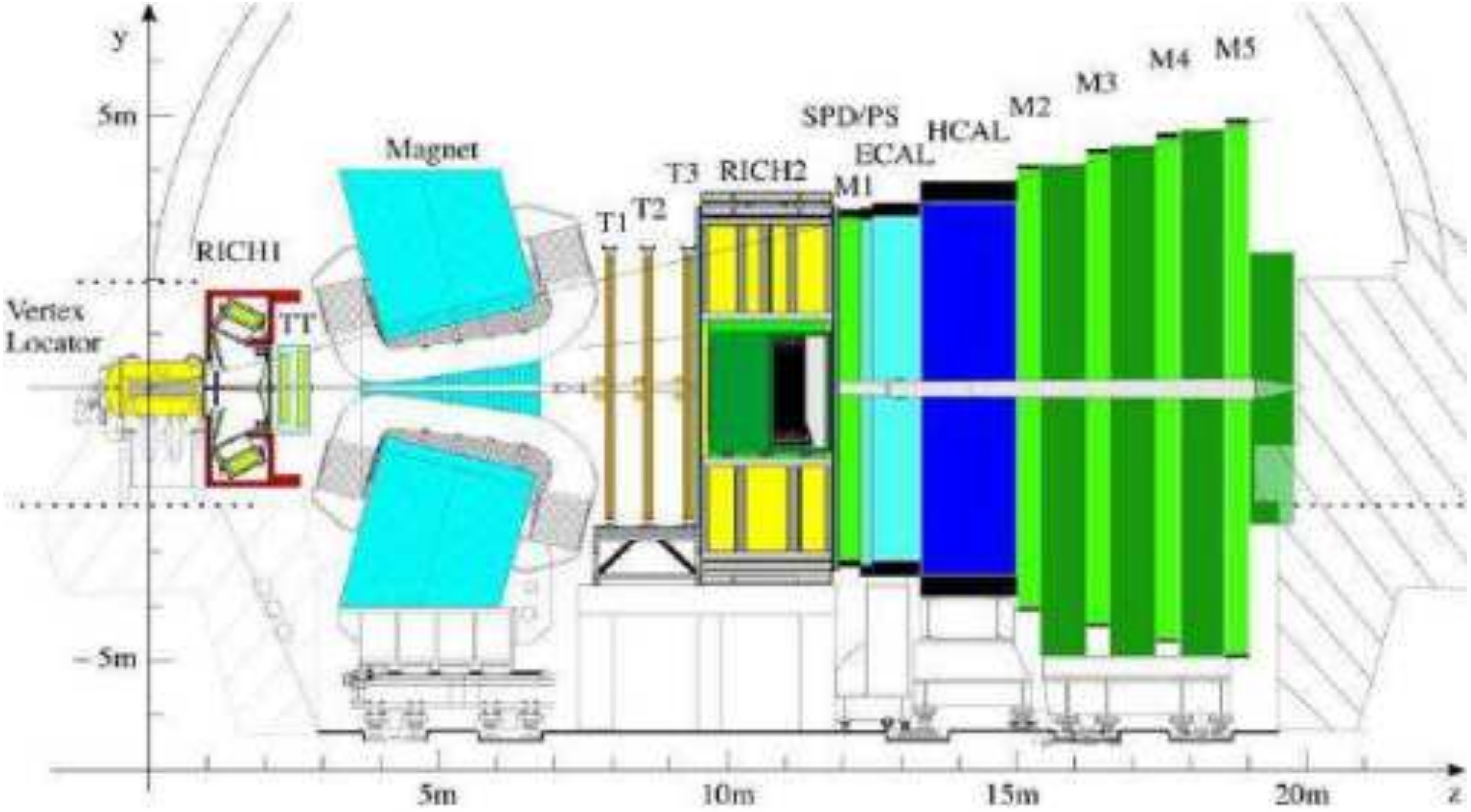
Quick recap

- *Stable charged* particles are **accelerated** to high energies
- Accelerated particles **collide** with another *beam/fixed target*
- Particles created in the collision are **observed** with the *detectors*



Quick recap

- Most interesting particles are short-lived: can only measure the properties of their **decay products**
- Need to reconstruct:
  - *Momentum* (tracking)
  - *Energy* (calorimetry)
  - *Particle type* (various detectors, e.g. RICH)

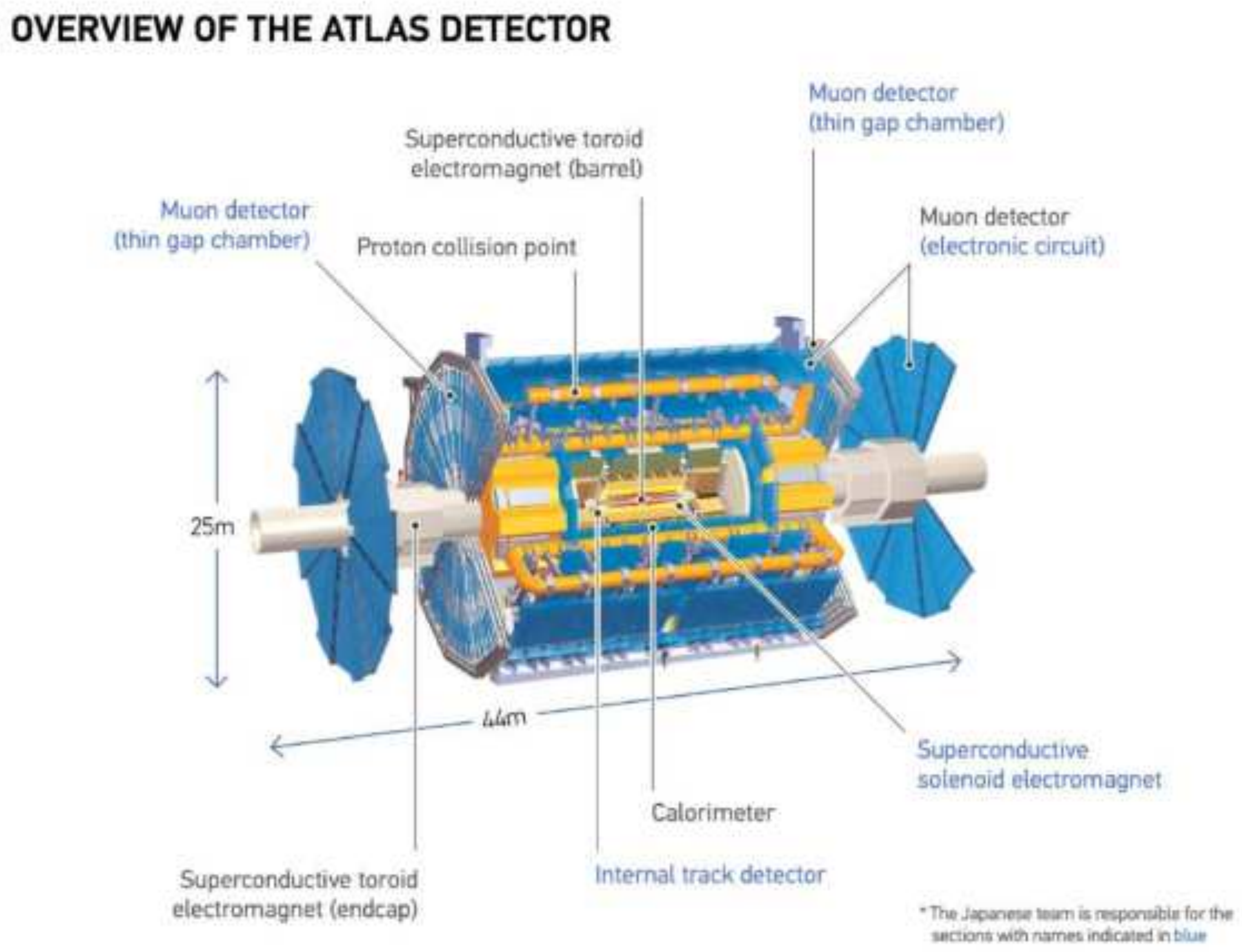


ATLAS detector

ATLAS detector

The LHC general purpose detector requirements:

- Fast, radiation-hard electronics and sensors
- High detector granularity
- Large acceptance in pseudorapidity
- (Almost) full azimuthal angle coverage
- High charged-particle momentum resolution
- Very good EM calorimetry
- High quality muon measuring detectors
- Highly efficient triggering with sufficient background rejection



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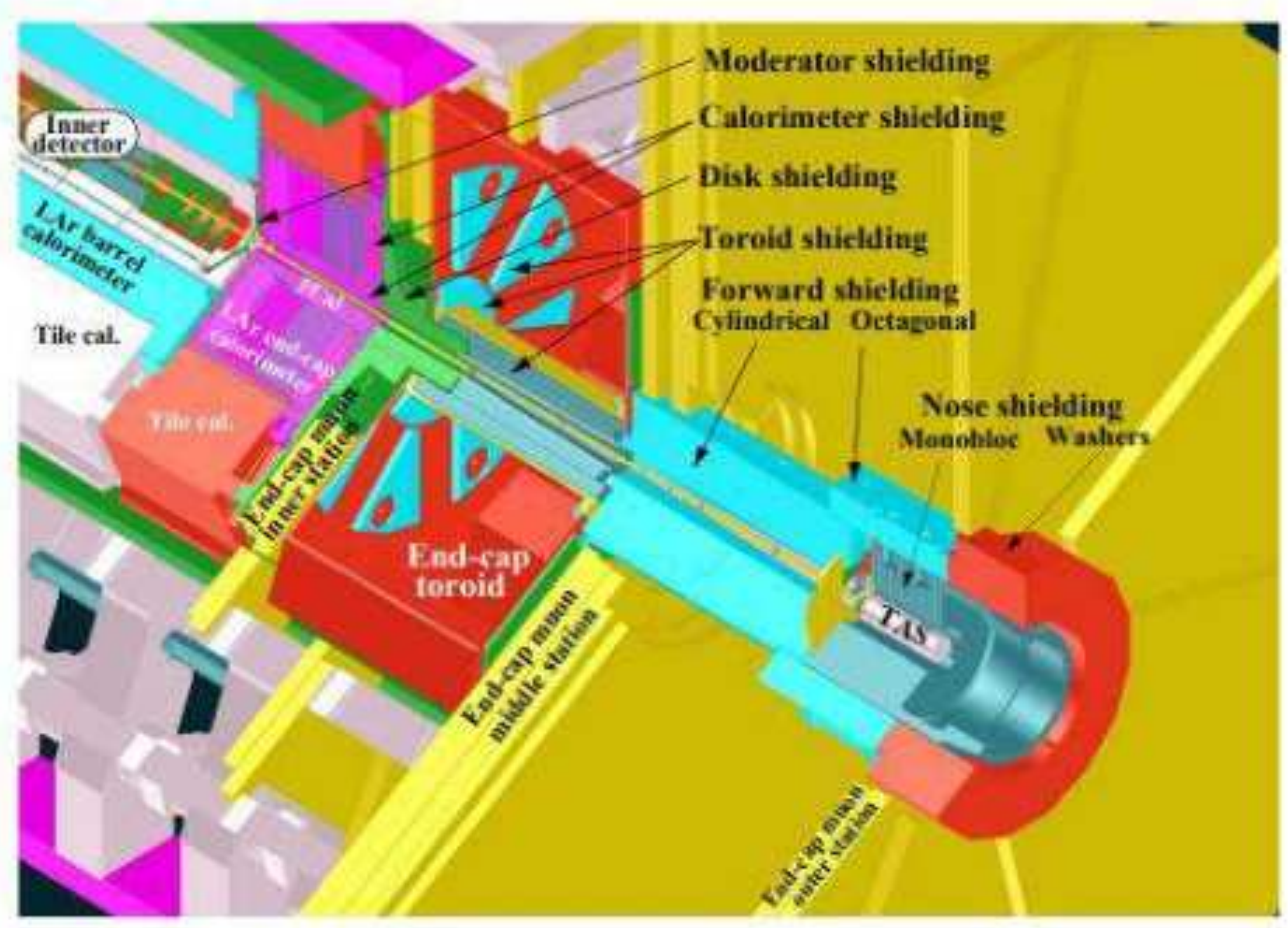
Radiation dangers:

- Increased detector occupancy
- Hits from slow neutrons in the muon system
- False triggers from penetrating particles
- Damage to silicon detectors and read-outs
- Single-event upsets
- Wire “ageing” due to radiation-detector gas interactions
- Radialogical hazards when operating in the cavern

ATLAS detector

Main **source of background radiation**: collisions
Secondary radiation from Fcal (pink) and Target Absorber Secondaries collimators, beam-pipe (shallow angle particles)



Radiation shielding:

- Different materials for different types of radiation -> multilayer approach
- Iron or copper (small interaction length) to stop high energy hadrons
- Few percent of carbon in iron to stop neutrons
- Boron-doped polyethylene to stop neutrons
- Neutron capture creates photons -> stop them with steel or lead

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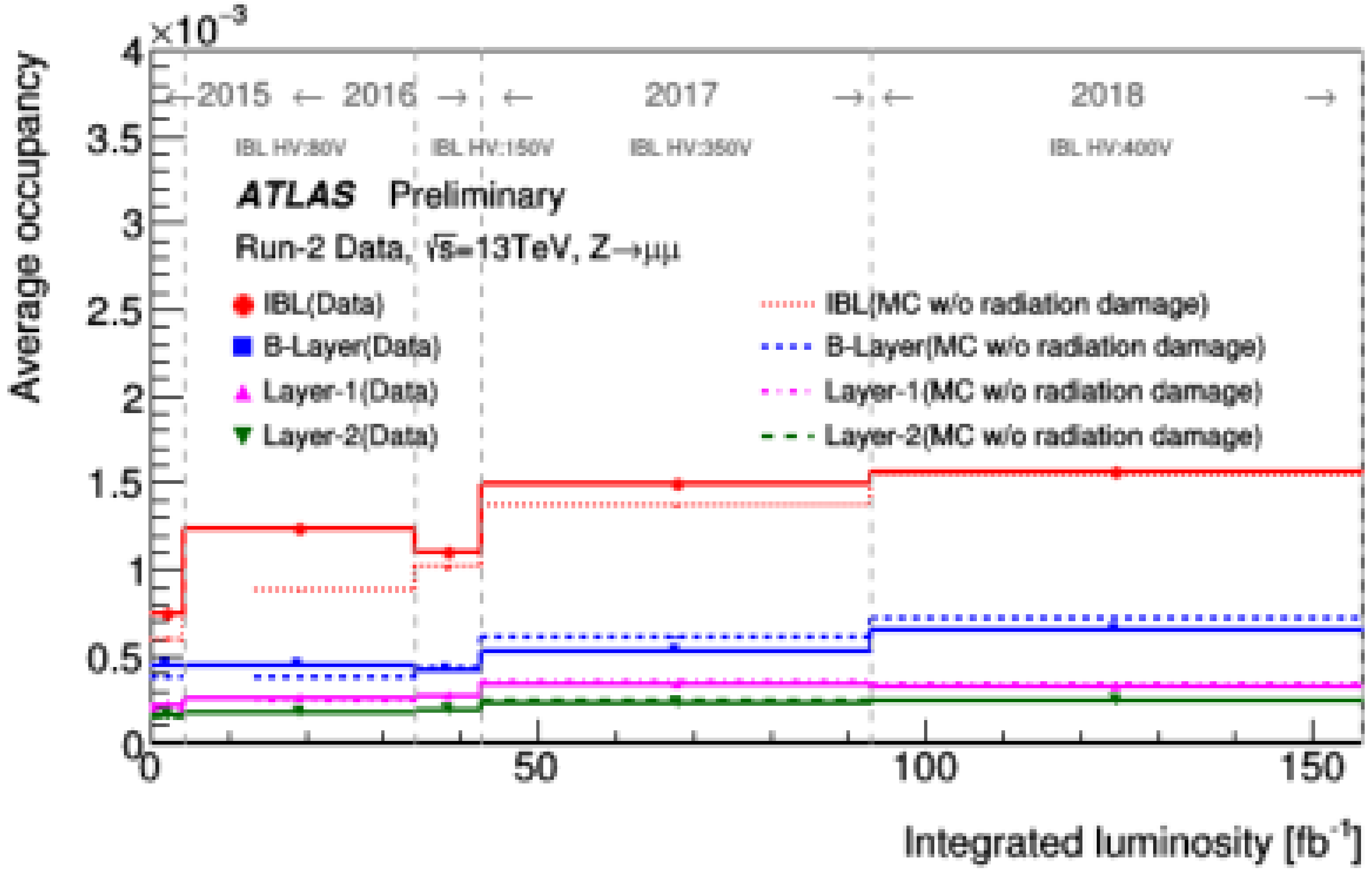

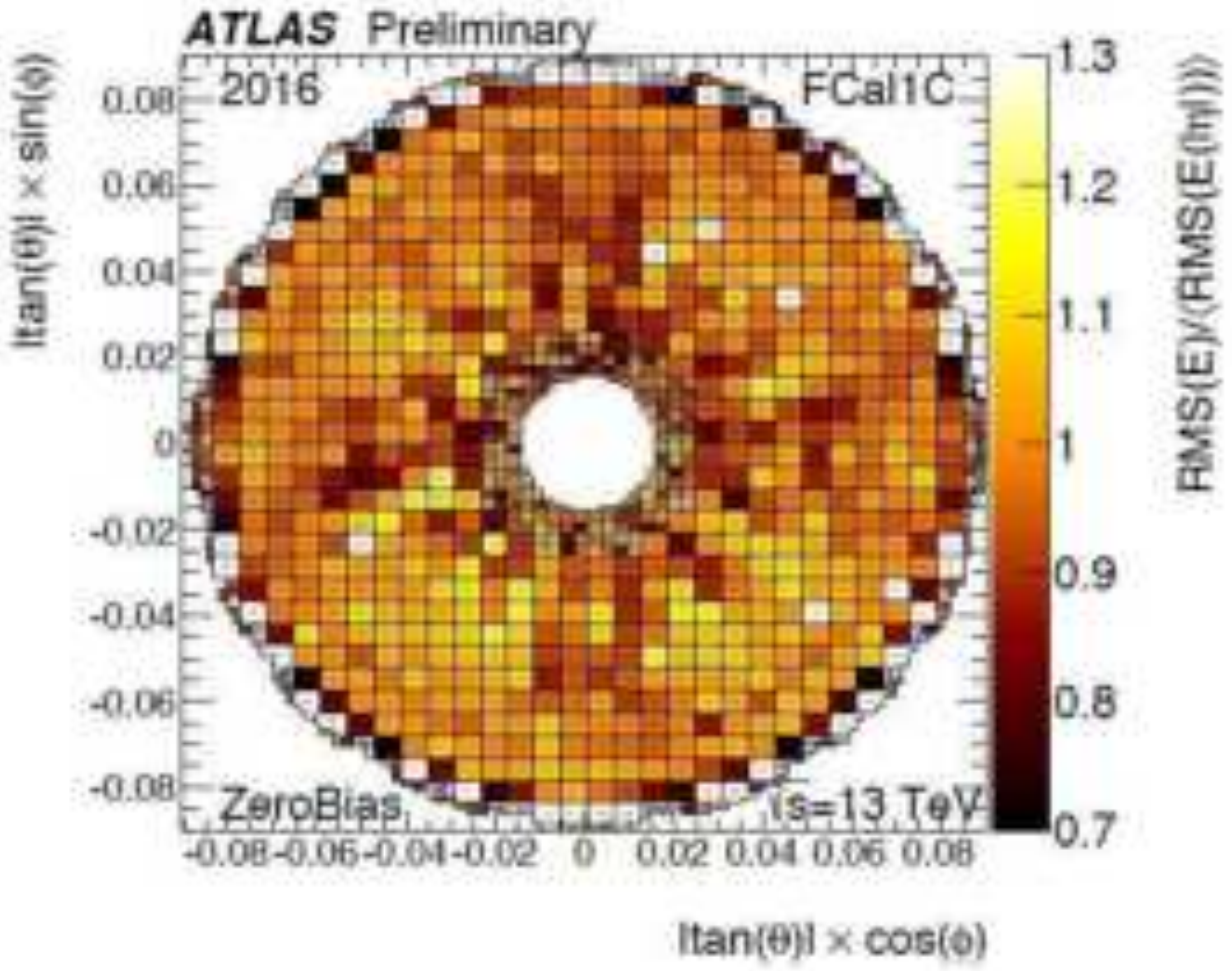

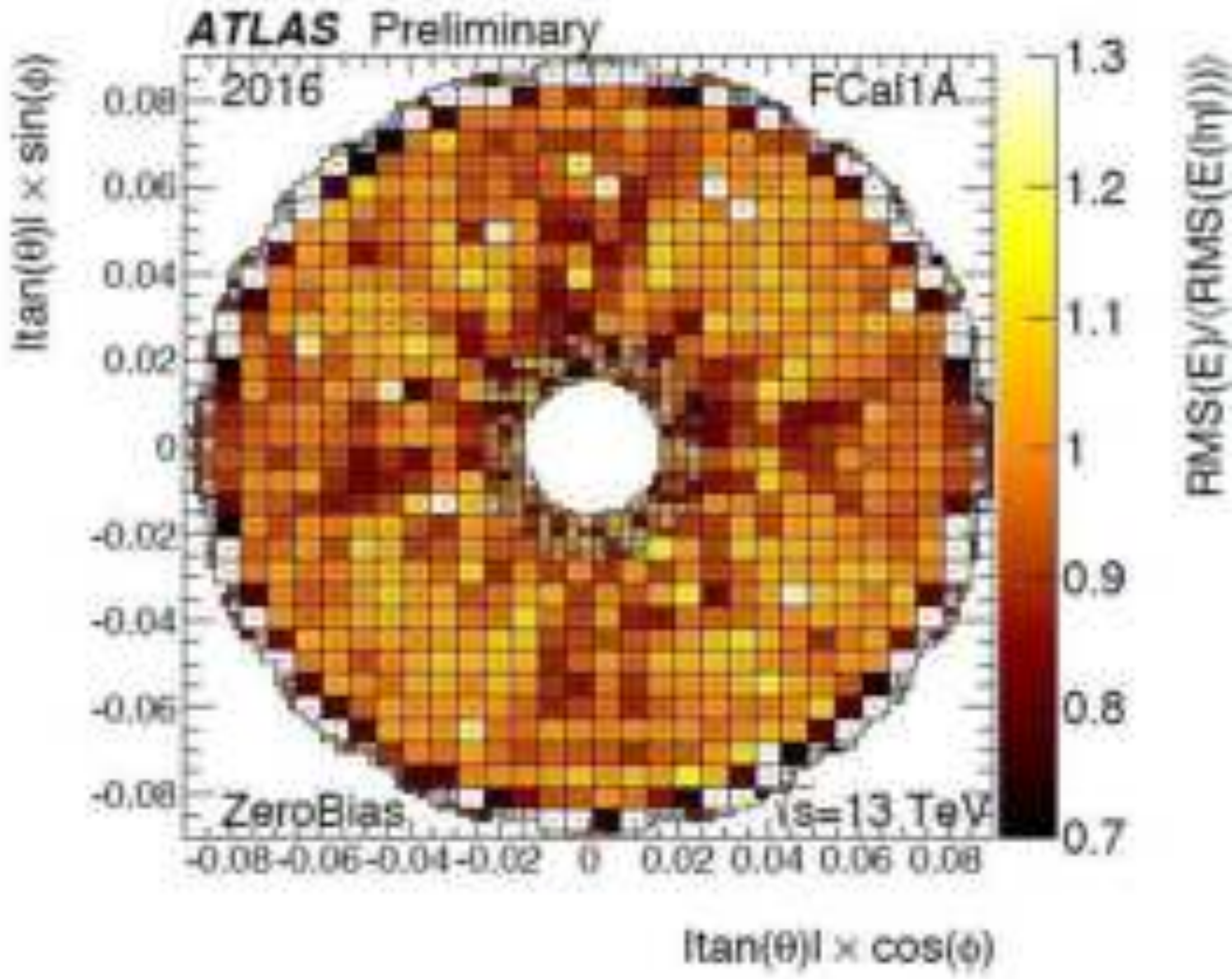

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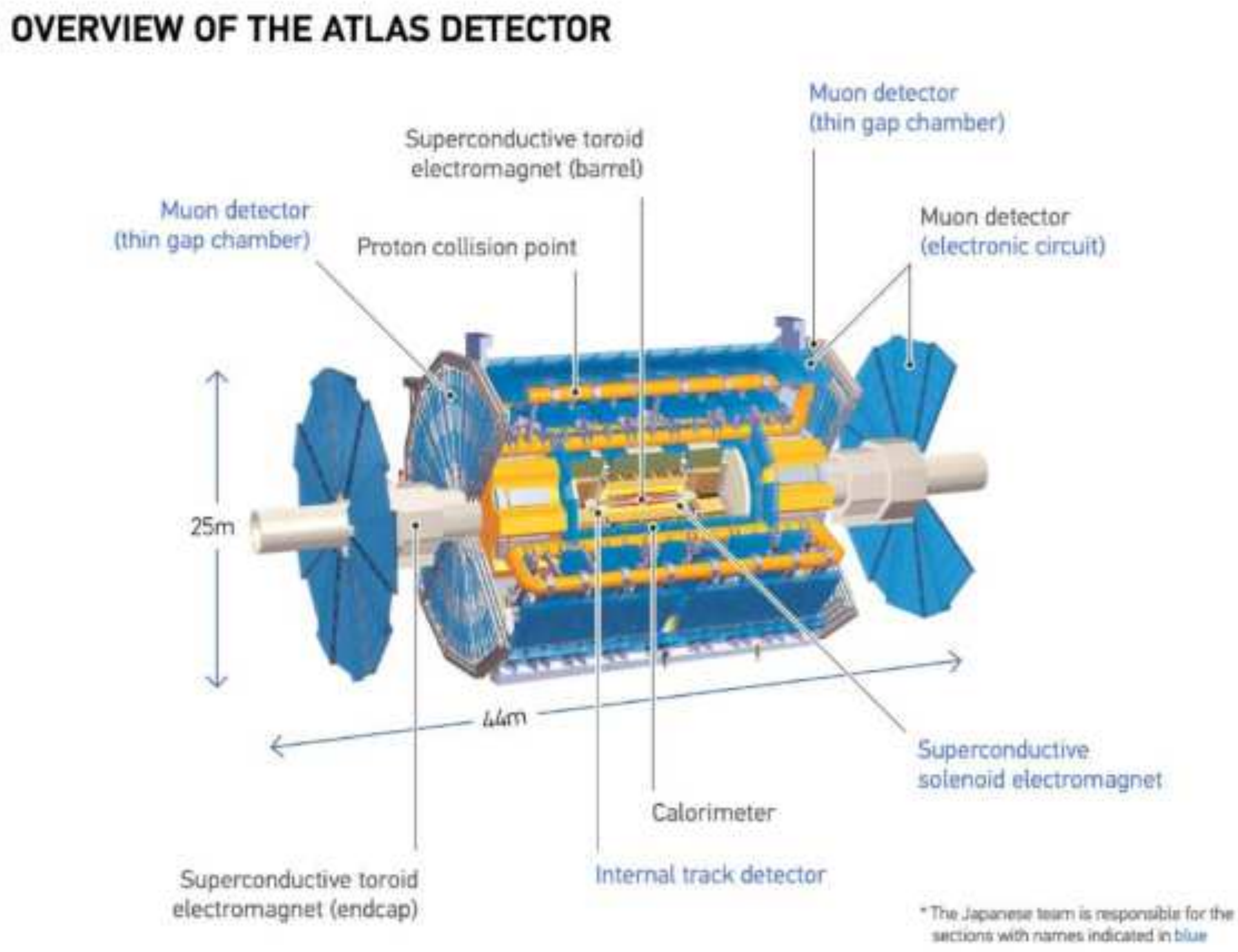

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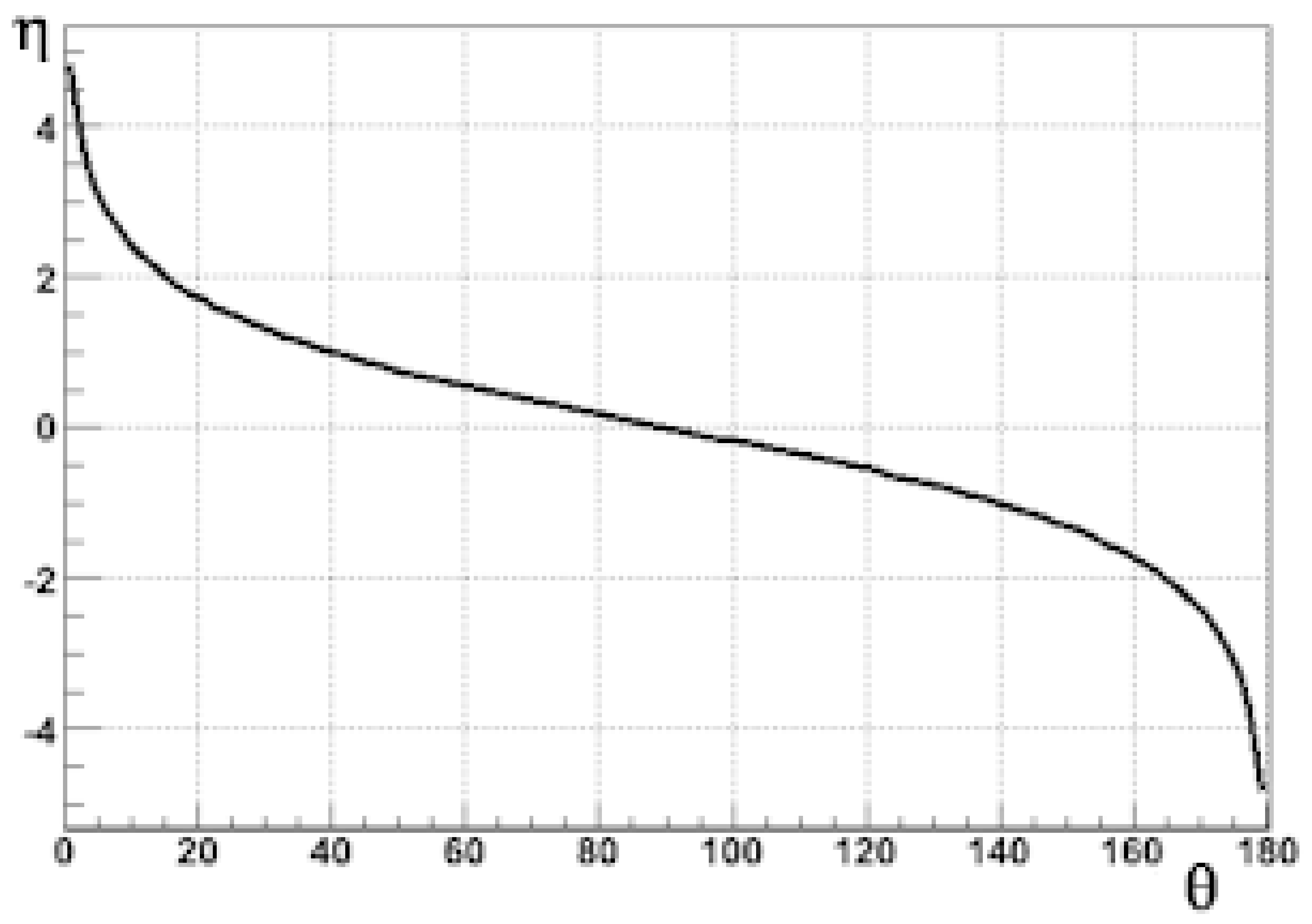
Pseudorapidity: $\eta = -ln\, tan\left(\frac{\theta}{2}\right)$



Missing transverse energy:

- No way to directly measure neutrinos
- Can measure every charged particle energy in transverse plane: missing energy from conservation law
- Signature for semileptonic decays of particles of interest (W bosons, tau-leptons form Higgs, etc.)

ATLAS detector

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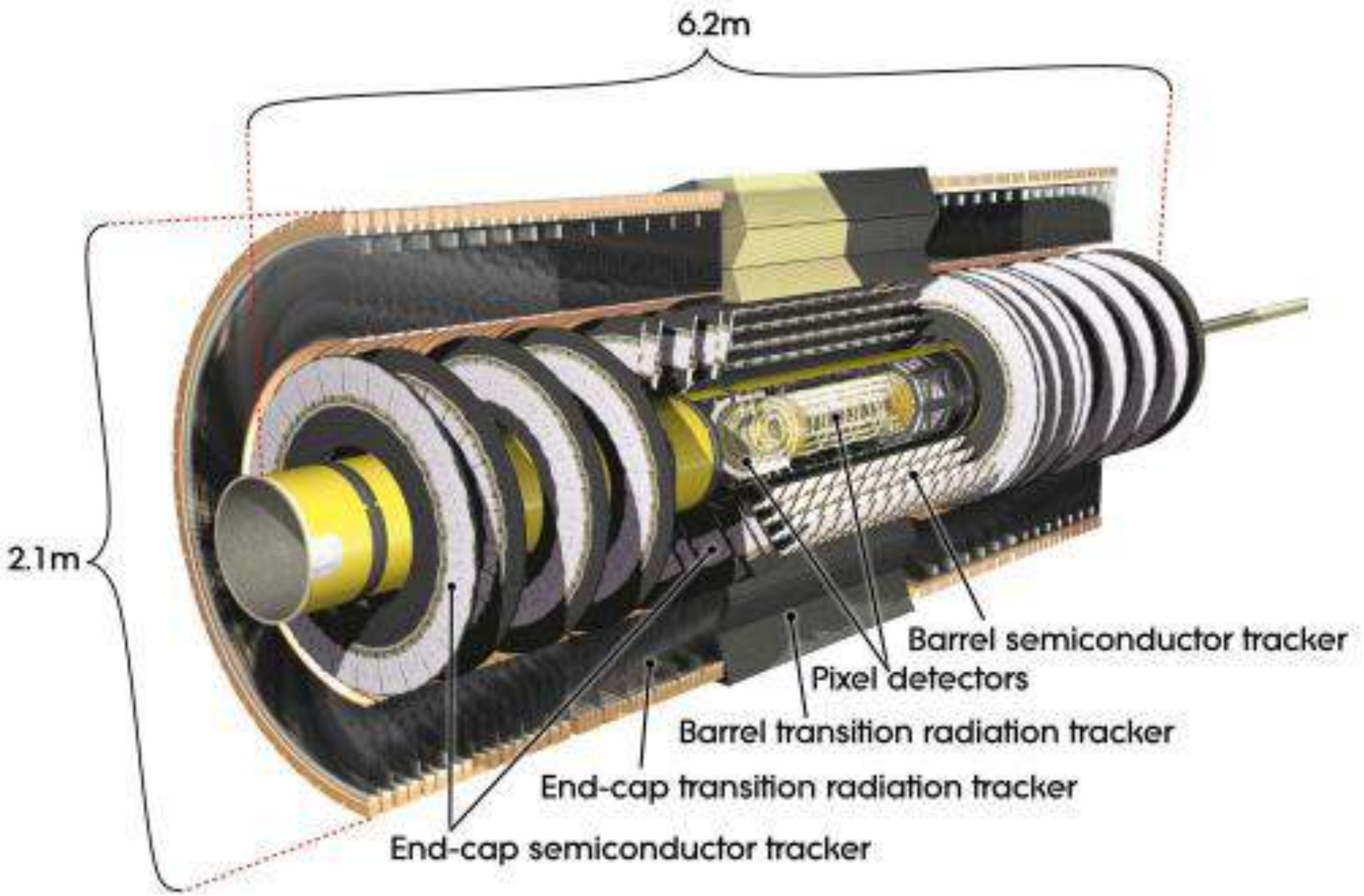
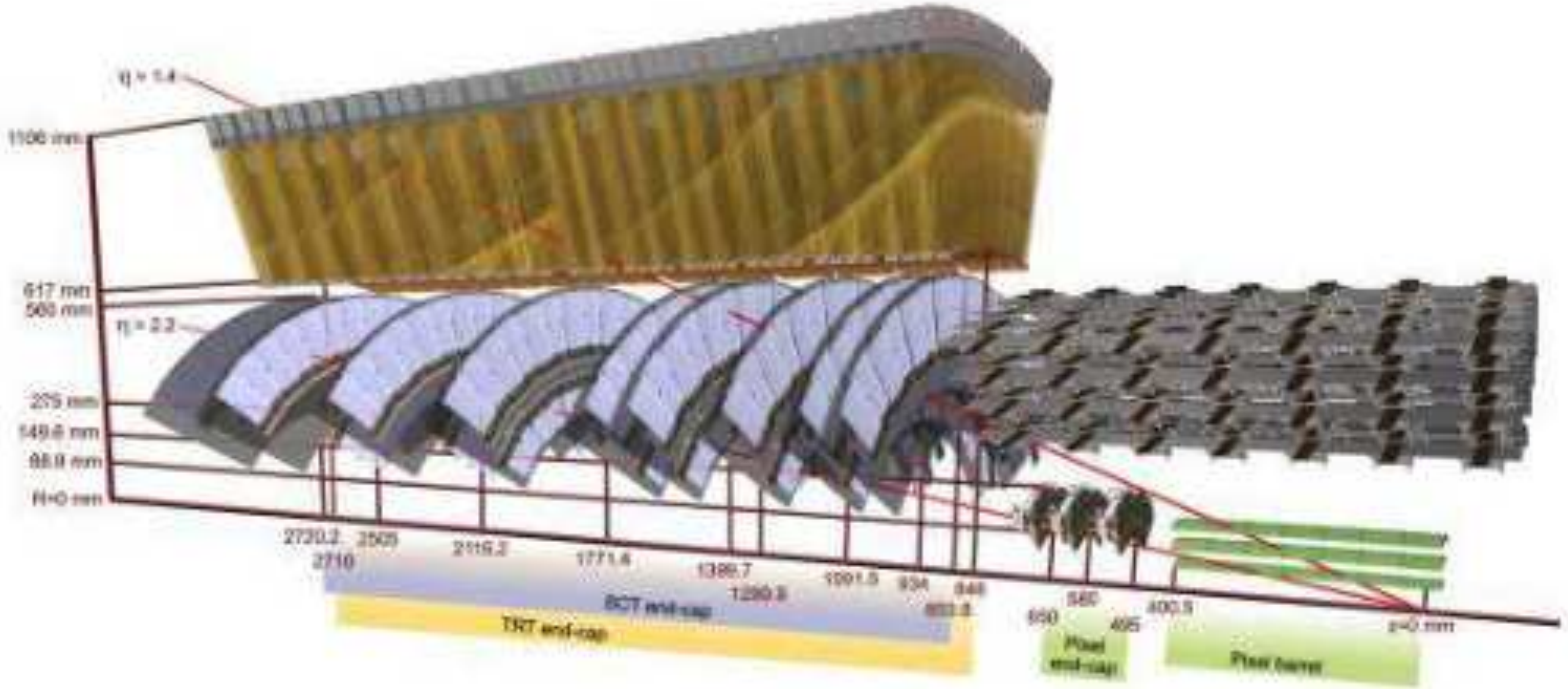


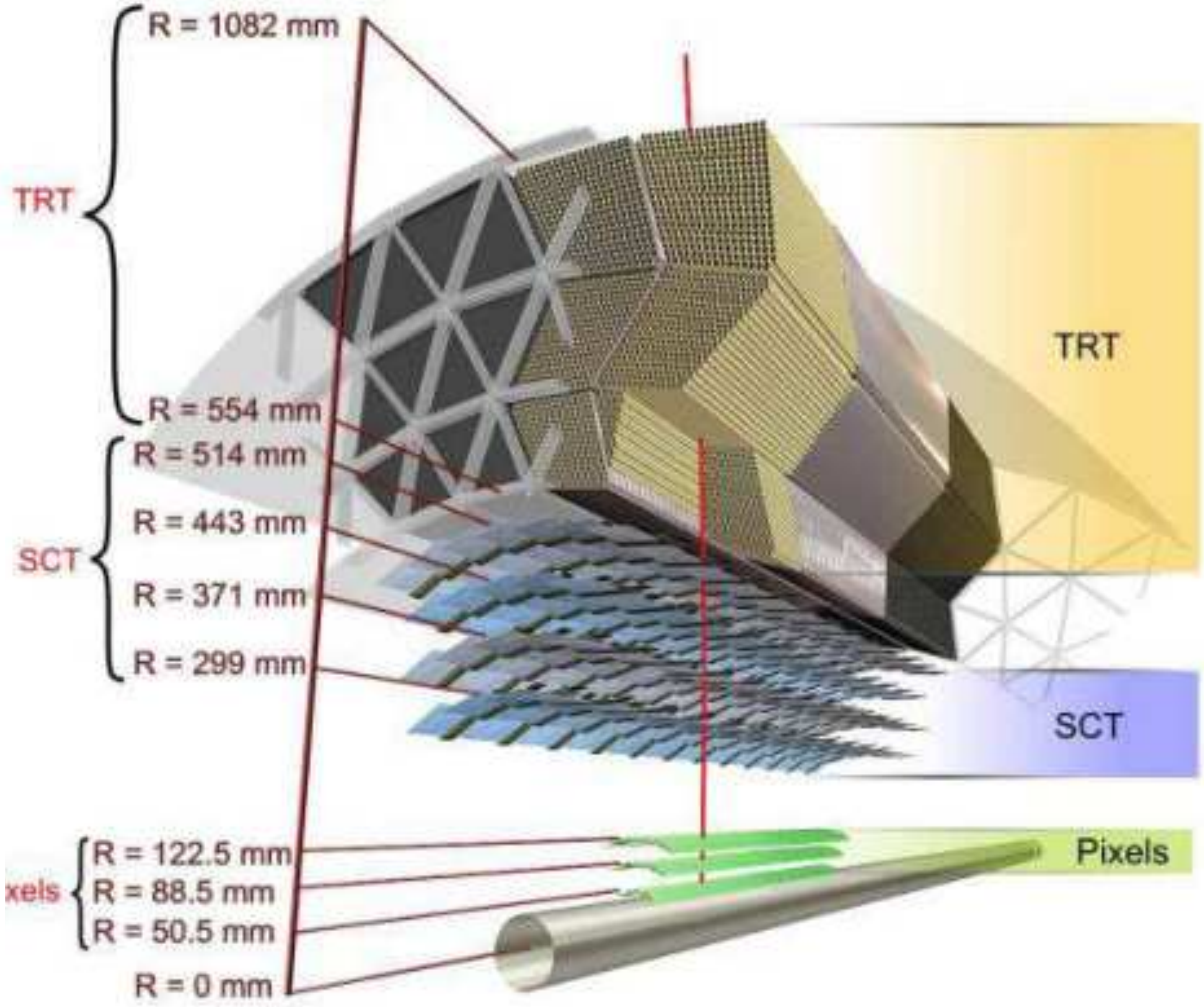
ATLAS detector

Inner **tracking system**:

- Inner detector in 2T solenoid field
- Pixel detectors
- Silicon microstrip trackers (SCT)
- Transition Radiation Tracker (TRT)

$|\eta| < 2.5$

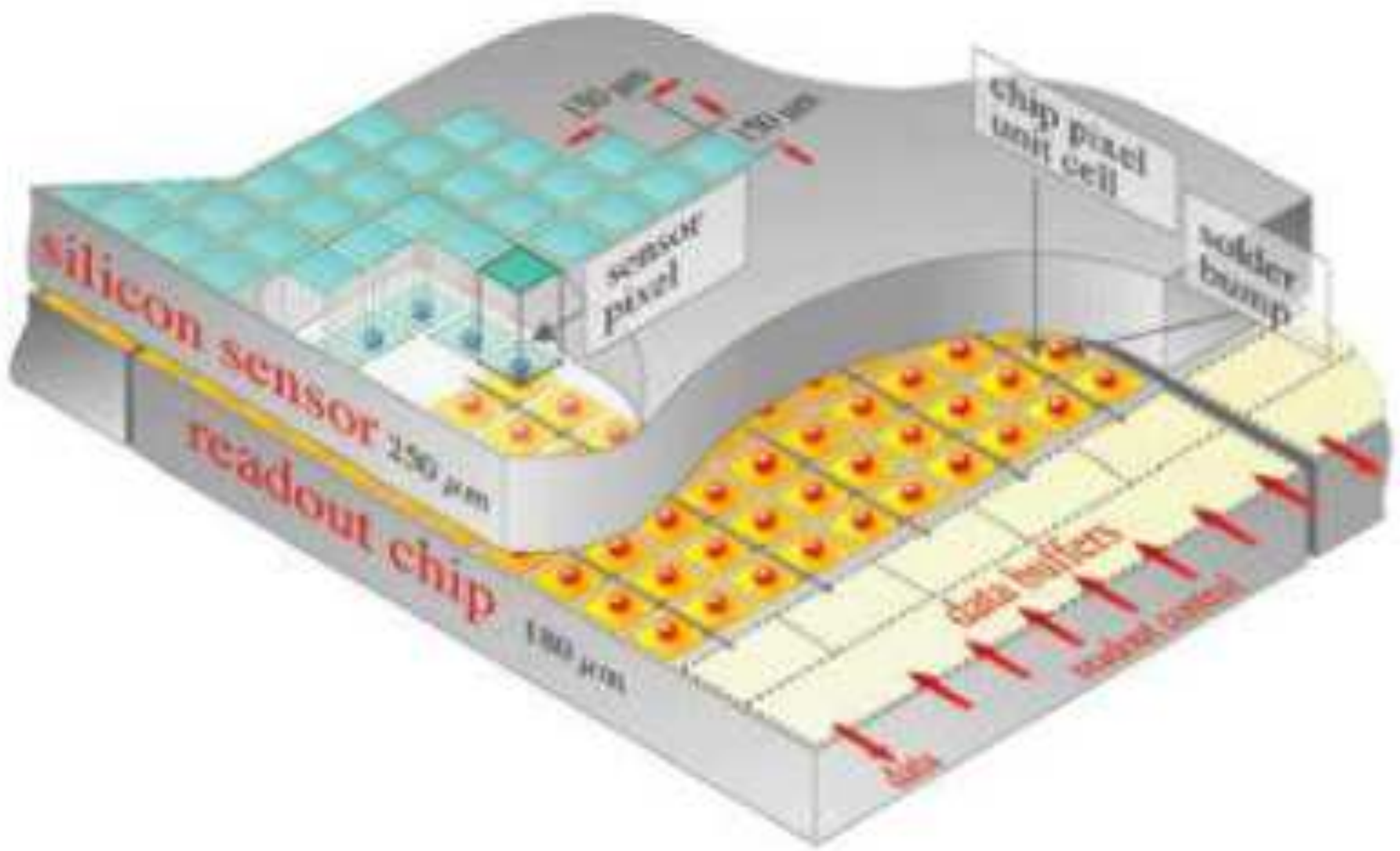




ATLAS detector

Inner **tracking system** principles of detection:

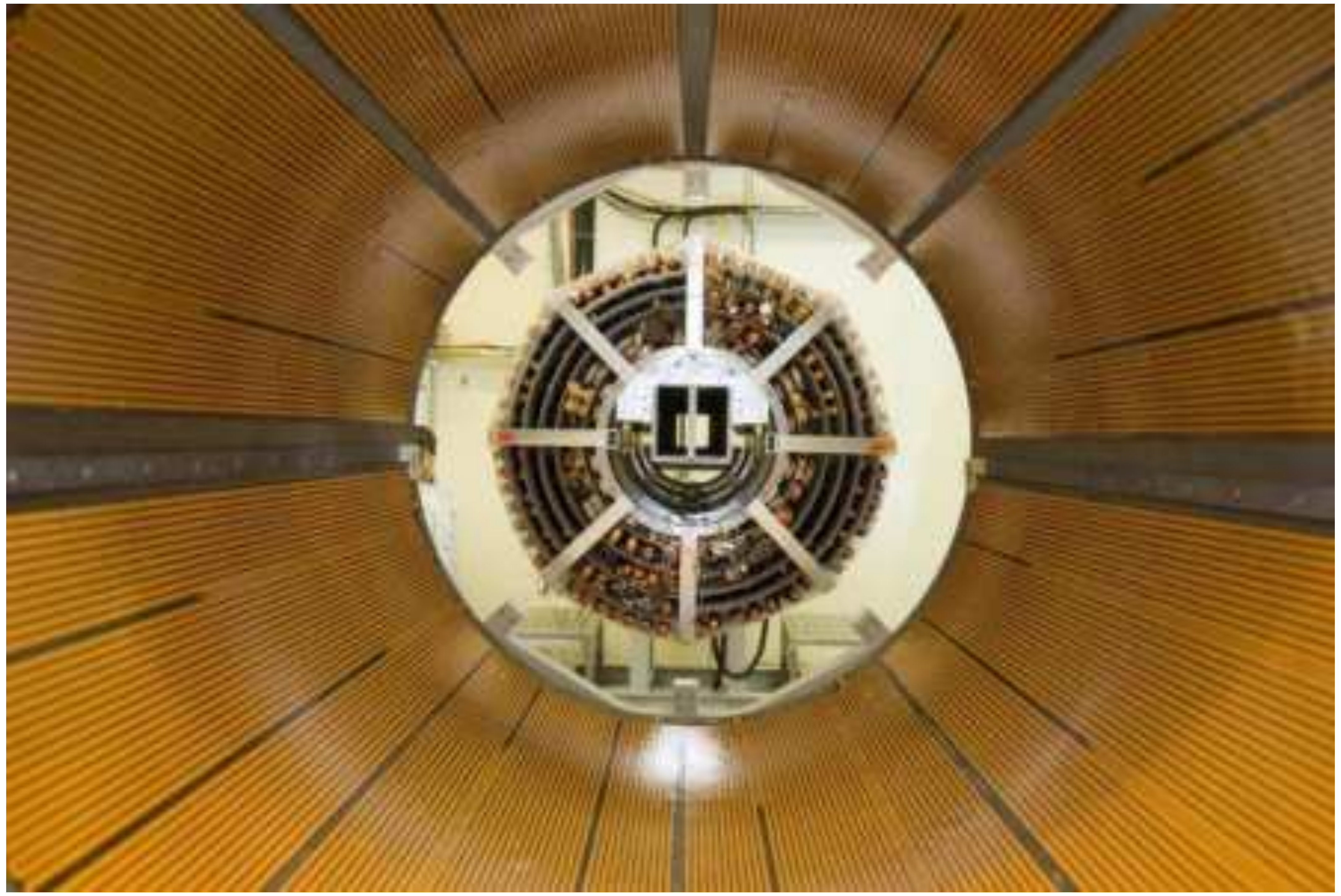
- Silicon pixel detectors: passing charged particles can eject electrons from atoms. Collect them via applying voltage and convert into signal
- 92 million pixels
- 10 μm precision
- Silicon area of 1.9 m^2
- Pixel size of $50 \times 400\ \mu m^2$ in the external layers and $50 \times 250\ \mu m^2$ for the innermost layer



ATLAS detector

Inner **tracking system** principles of detection:

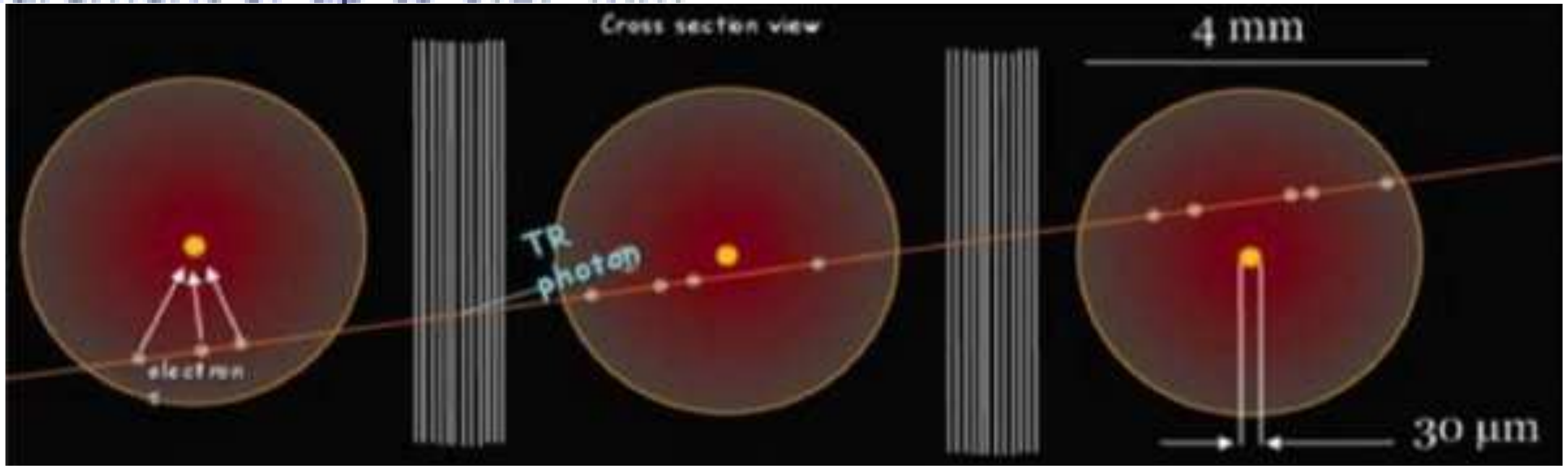
- Semiconductor Trackers (SCT): passing charged particles can eject electrons from atoms. Collect them via applying voltage and convert into signal
- Over 6 million channels
- 60 m^2 of silicon
- Readout strips every 80 μm of silicon



ATLAS detector

Inner **tracking system** principles of detection:

- Transition radiation trackers (TRT): Drift tubes with wires in the center. Gas ionization for tracking + transition radiation for pion-electron identification. If the charge collected by anode is higher than threshold – electron
- $I = 2e^2 \frac{ln\gamma}{\pi c}$
- 350 000 readout channels
- 12 m^3 of volume
- Precision measurement of up to 0.17 mm



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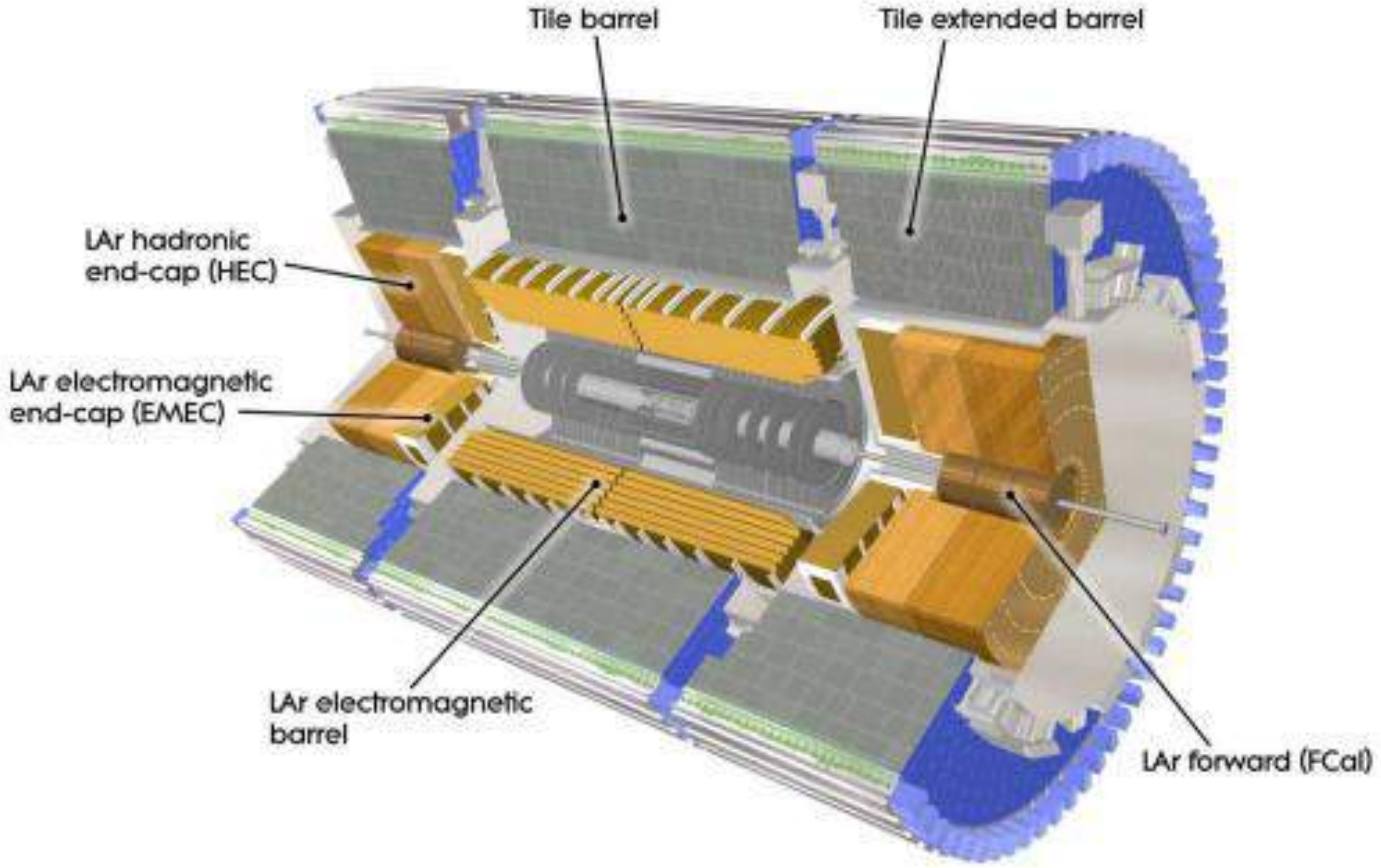
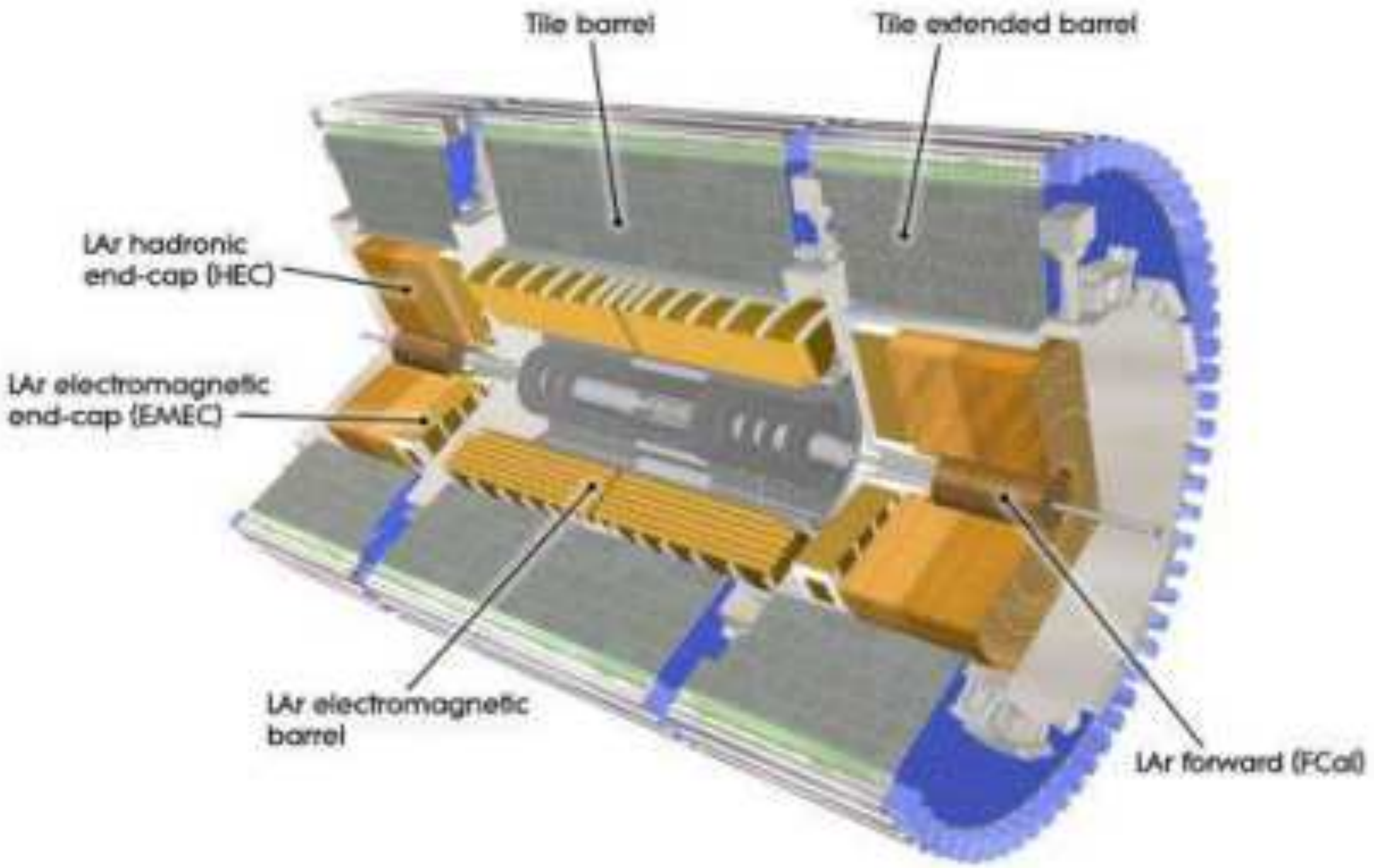


ATLAS detector

Calorimeter principles of detection:

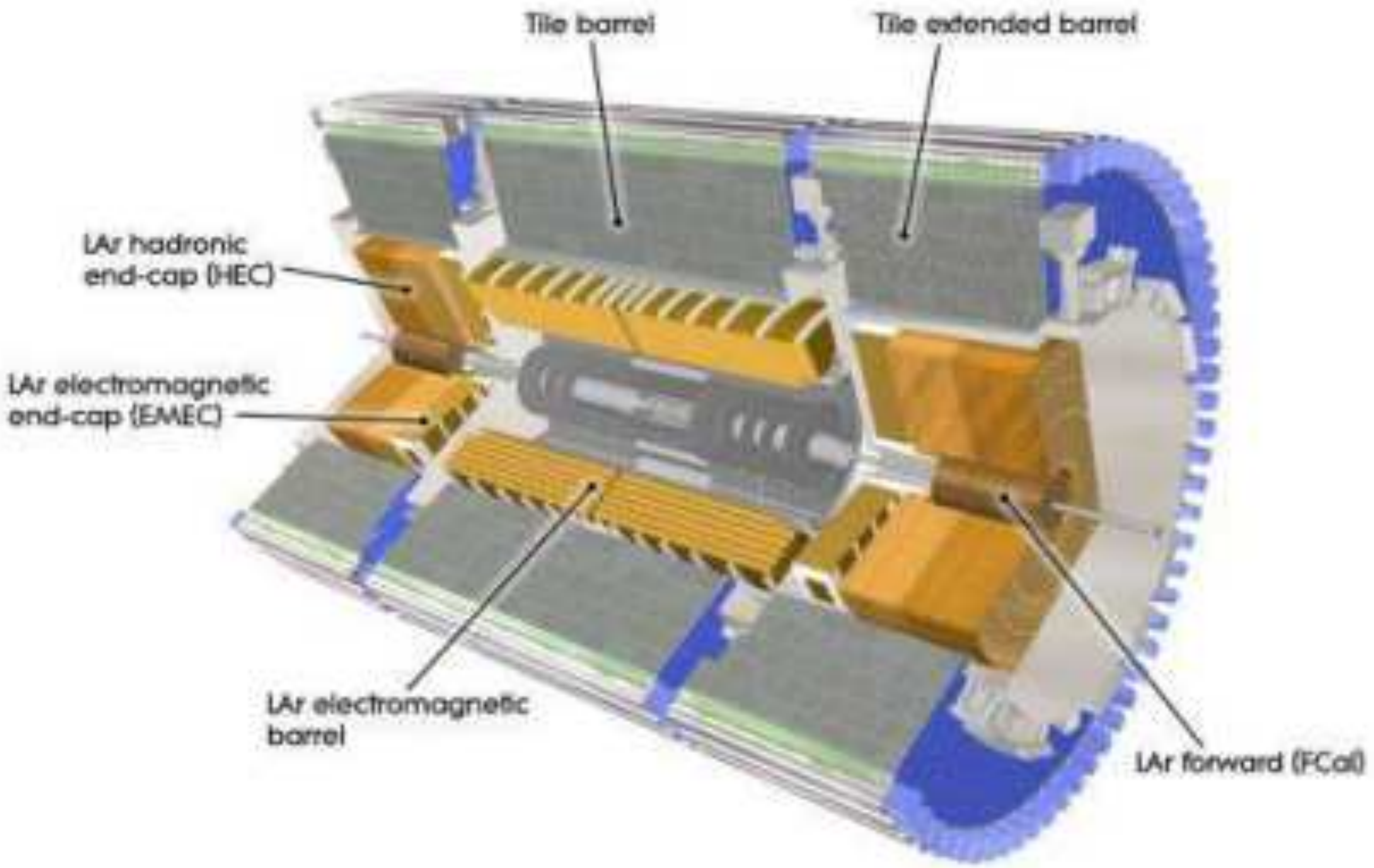
- LAr Calorimeter: layers of absorbing material to stop particles and active medium to measure their energy
- Metal (tungsten, copper or lead) as absorber
- Liquid argon at 160 K as active medium
- Electric current from ionized medium allows to determine original particle's energy
- Barrel 6.4 m long, 53 cm thick, 110 000 channels
- ECal and HCal endcaps with different thickness
- FCal for the forward particles
- Over 22-24 X_0 total thickness



ATLAS detector

Calorimeter principles of detection:

- Tile Hadronic Calorimeter: layers of steel and plastic scintillator
- Electric current from ionized medium allows to determine original particle's energy
- 420 000 scintillating tiles
- 2900 tonne total weight
- ECal and HCal endcaps with different thickness
- FCal for the forward particles
- Over 10 λ_{int} total thickness



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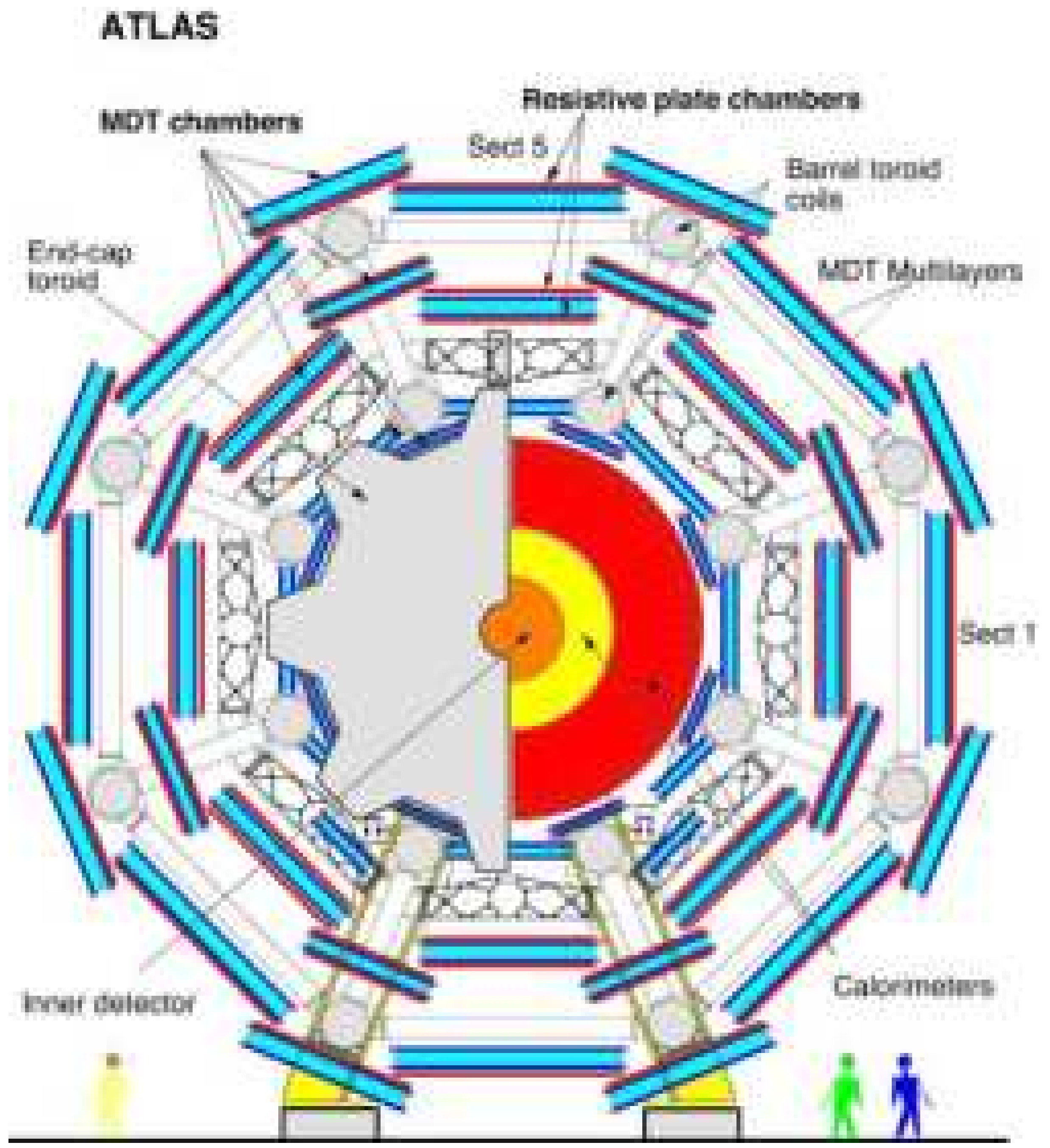
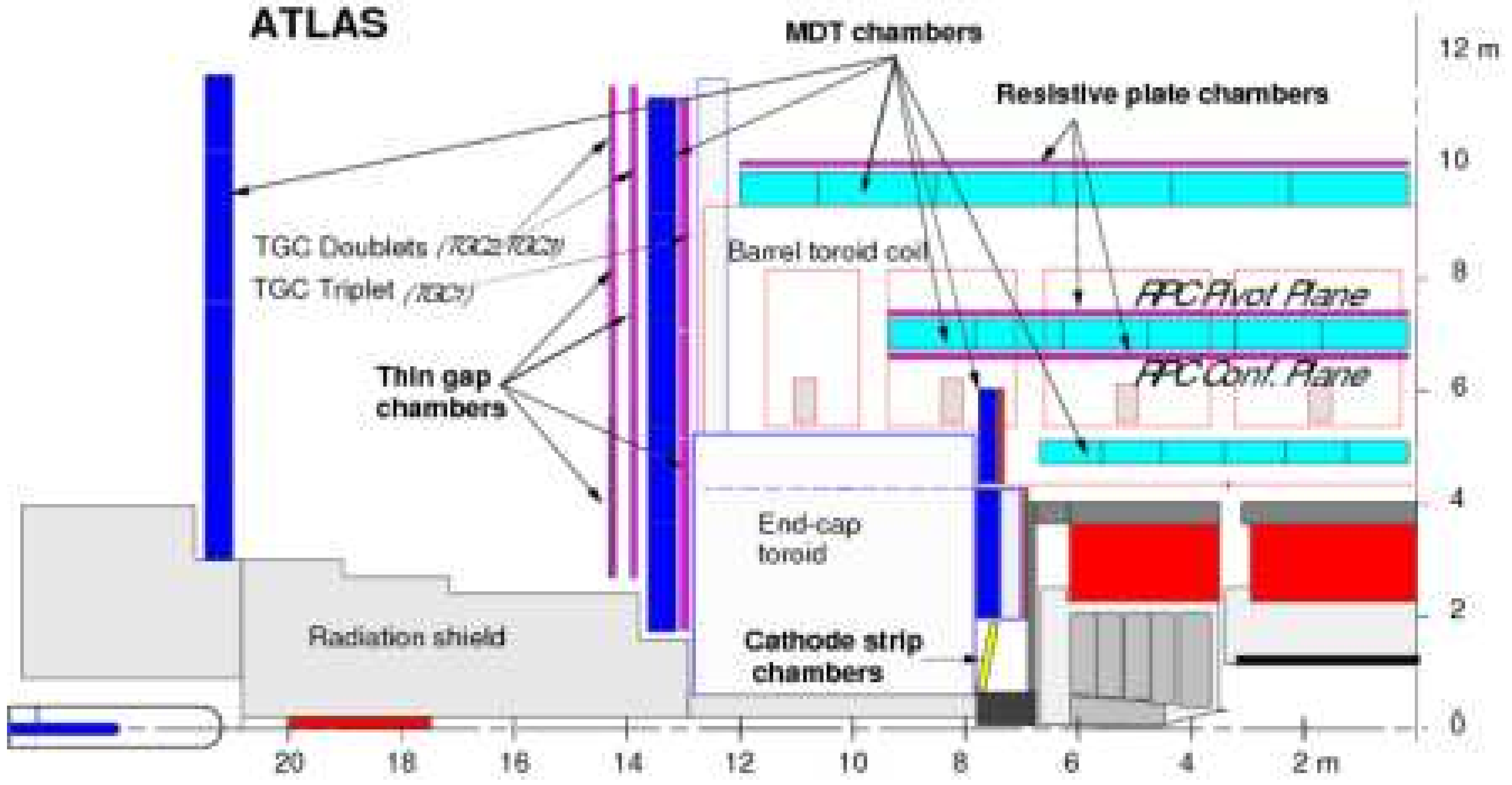
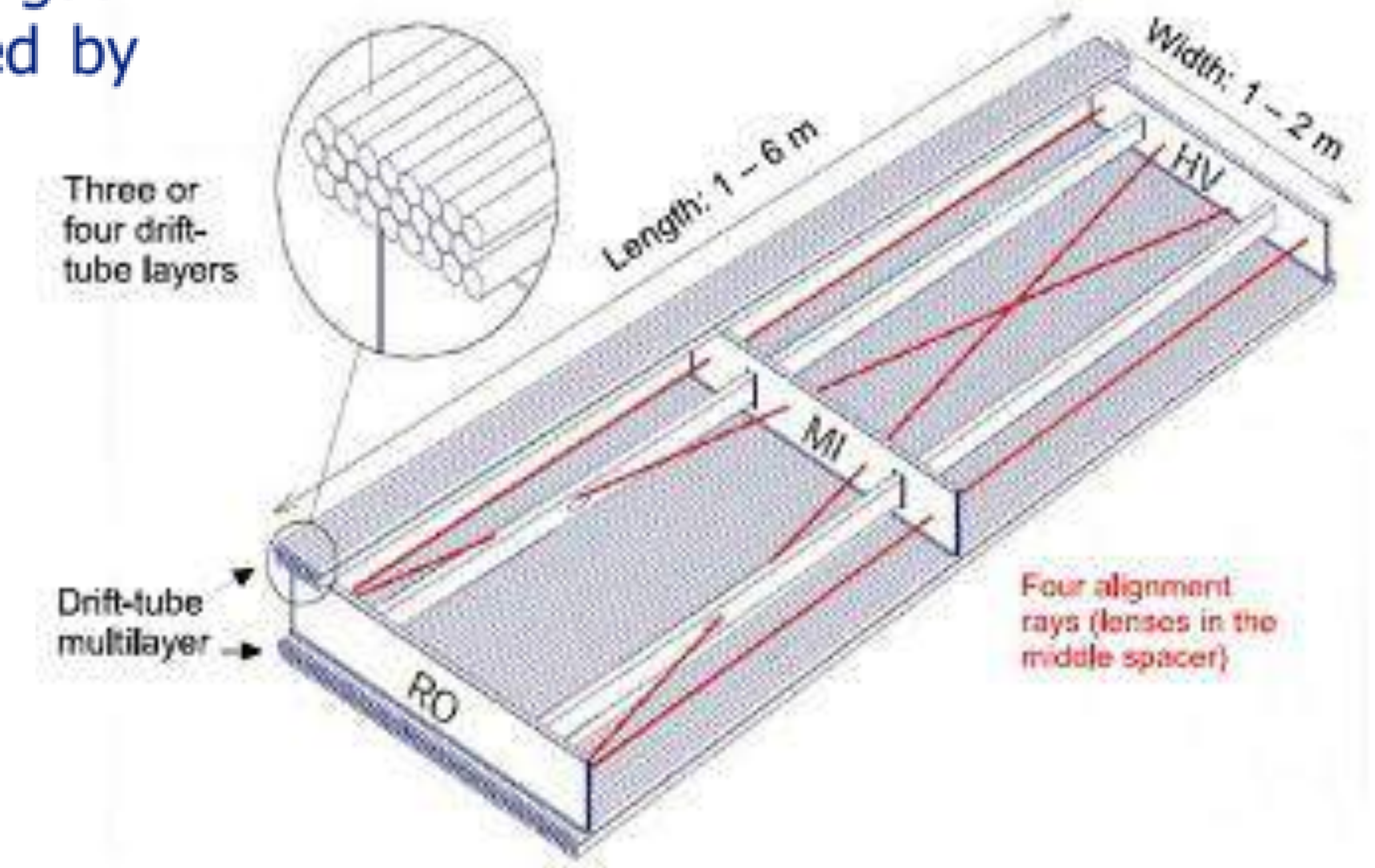




ATLAS detector

Muon principles of detection:

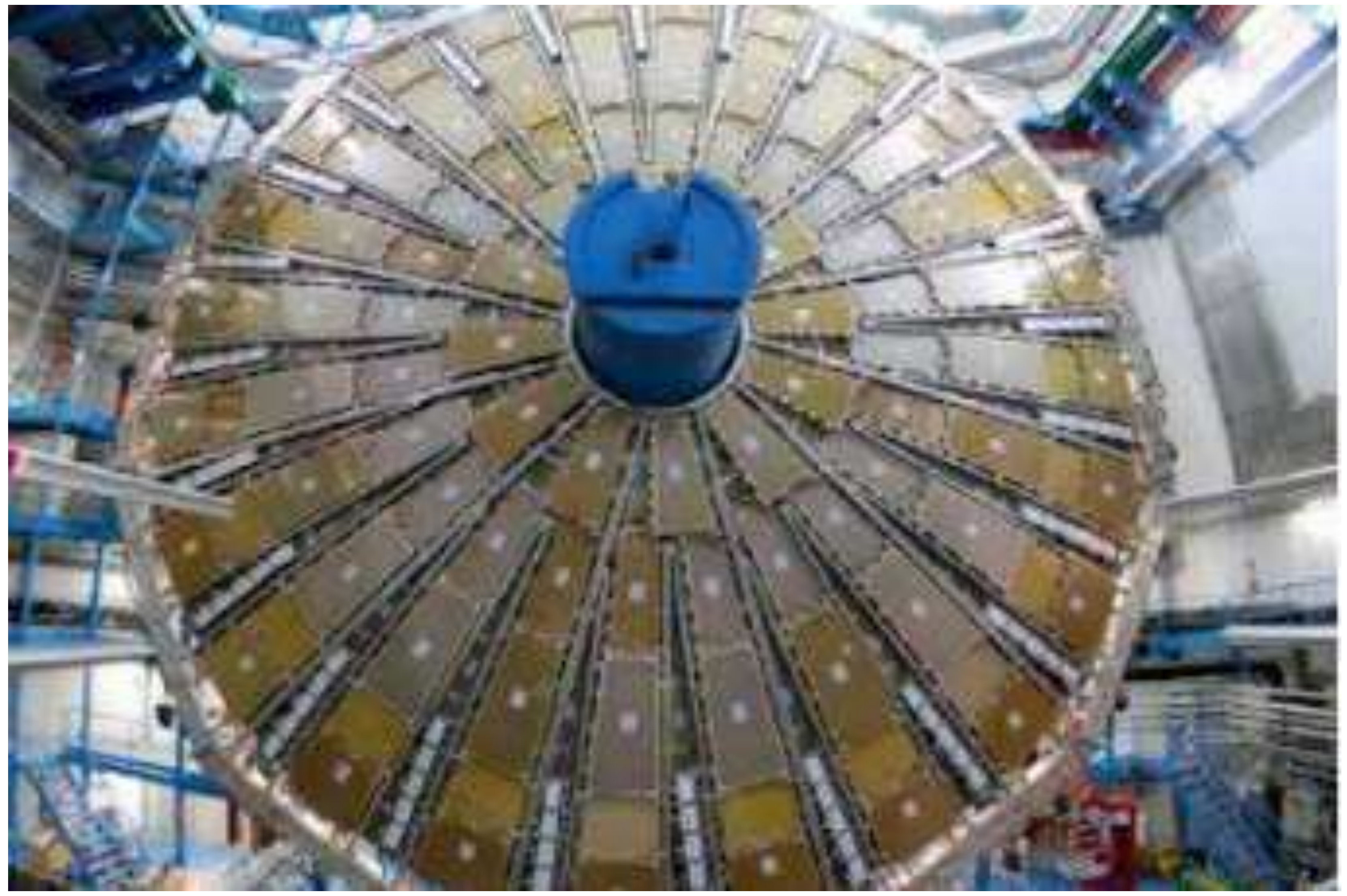
- MDT precision chambers: drift tubes filled with gas. Passing particle ionazes gas, electrons are collected by anode wire
- Measure curves of track
- Over 350 000 tubes
- 80 μm resolution

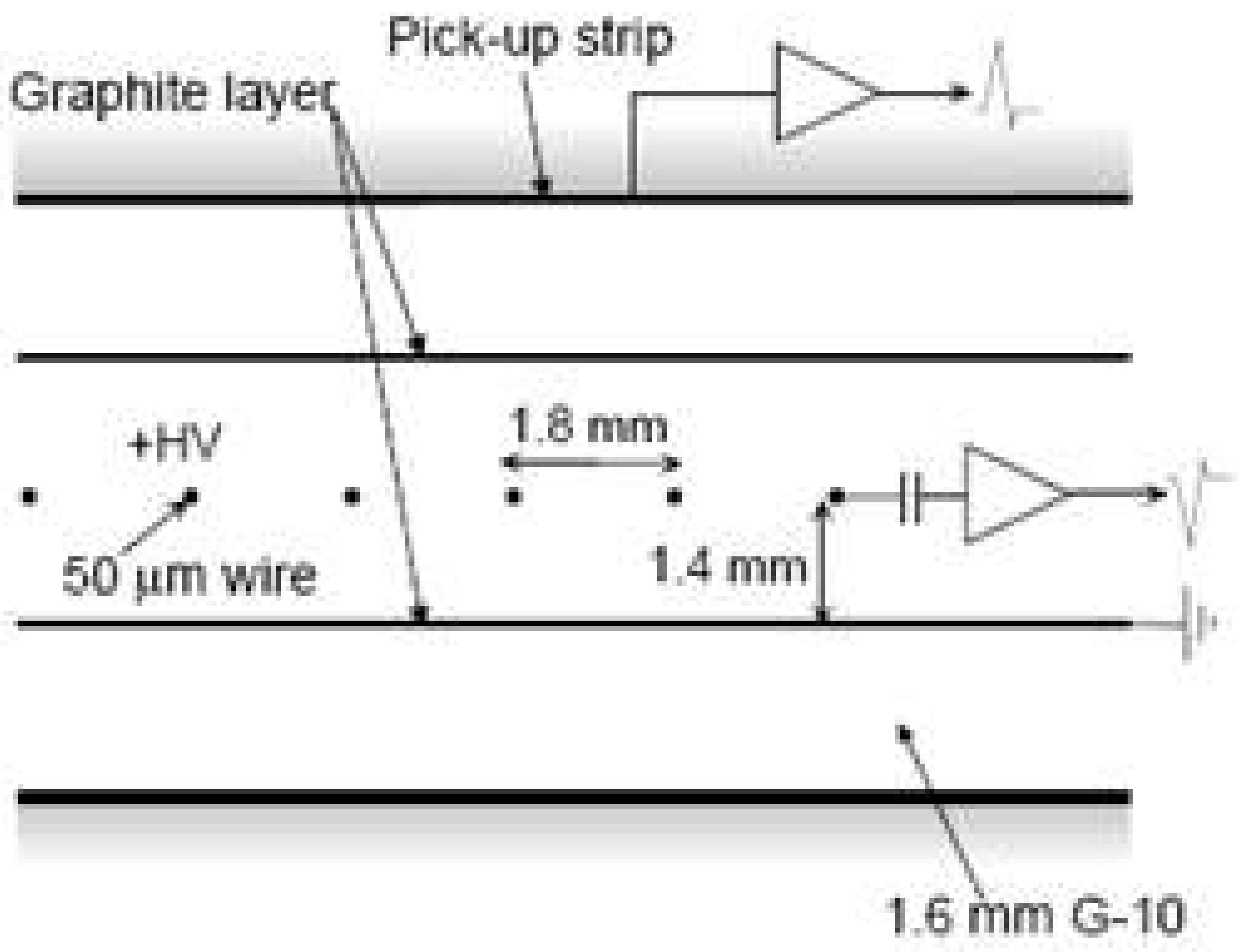


ATLAS detector

Muon principles of detection:

- Thin gap chambers**:** multiwire proportional chambers. Passing particle ionizes gas; the electromagnetic shower reaches anode wires; the closest wires are reached first
- 440 000 channels
- Triggering
- 2D coordinate measurement

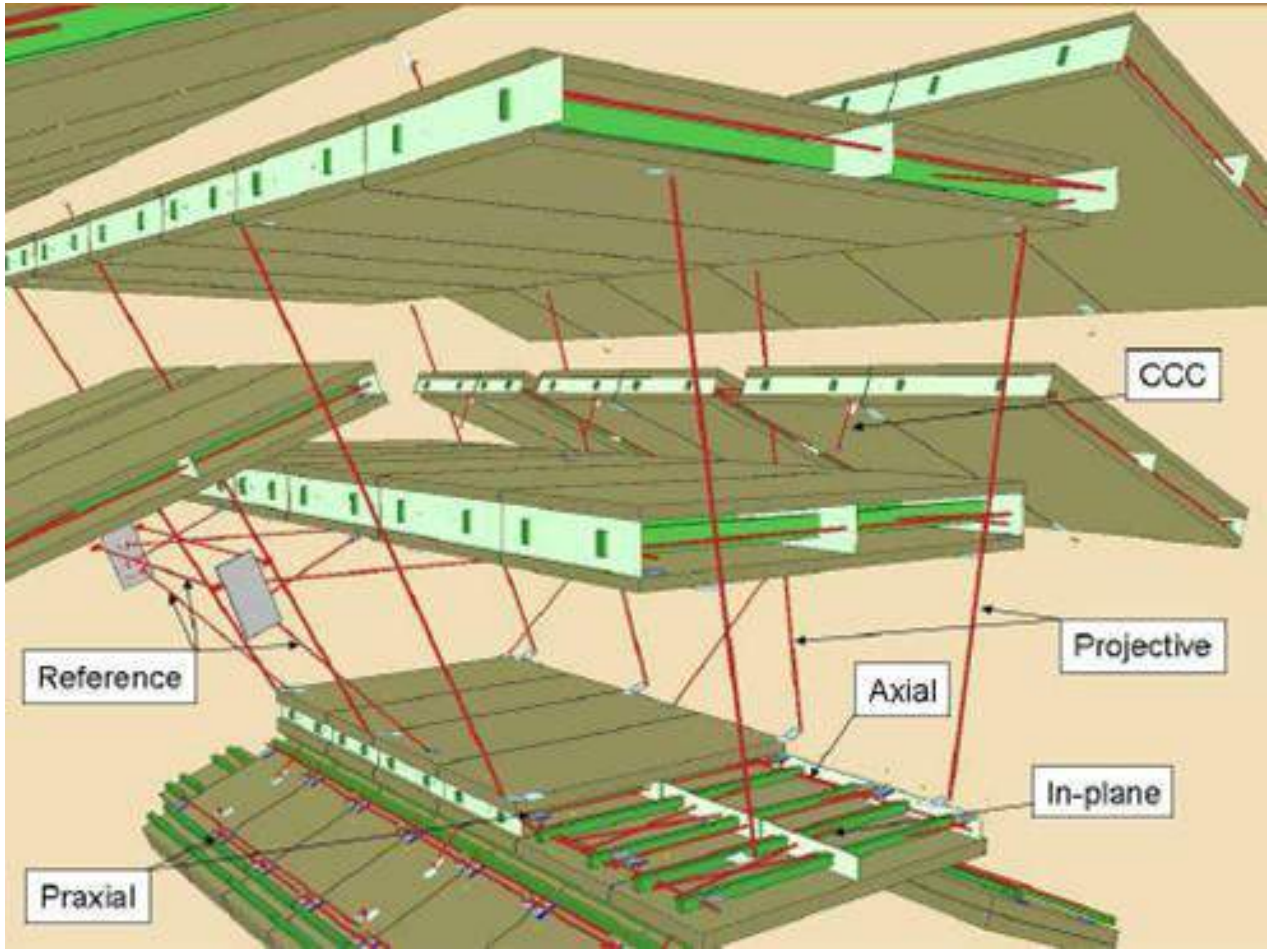




ATLAS detector

Muon principles of detection:

- Muon detector **positioning system:** muon chambers are installed with 30 μm precision
- Must know their exact position to measure momentum from tracks
- Using optical system to detect relative movement



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Thanks for listening!

Ленинский проспект, д. 4
Москва, 119049
тел. +7 (495) 955-00-32
e-mail: kancela@misis.ru
misis.ru

Sources:

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- https://atlas.cern/Discover/Detector
- ATLAS Collaboration. "The ATLAS Experiment at the CERN Large Hadron Collider"