The ATLAS Detector
- Inside Out -

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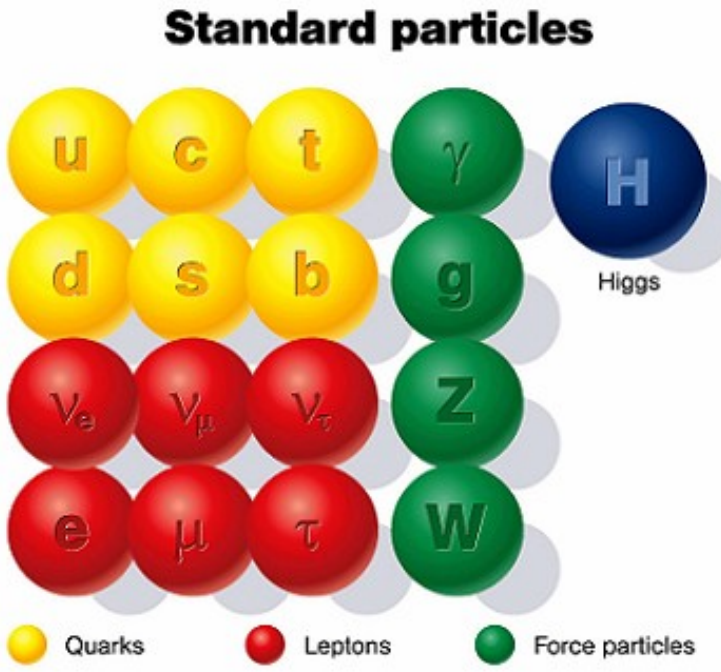
Outline:
1st lecture: The Detector
2nd lecture: The Trigger
3rd lecture: The Analysis (mine)

Motivation



Physics Goals:

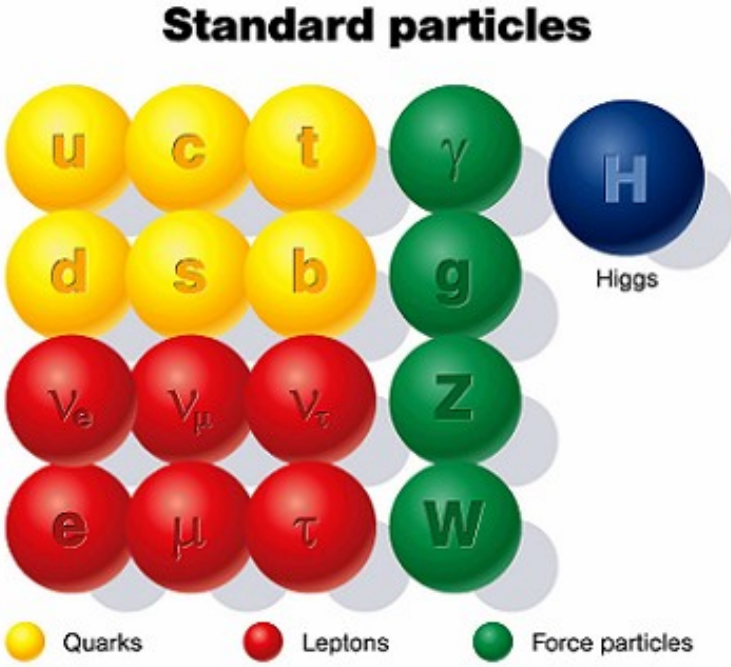
- Study Standard Model of Particle Physics
  → find the Higgs boson

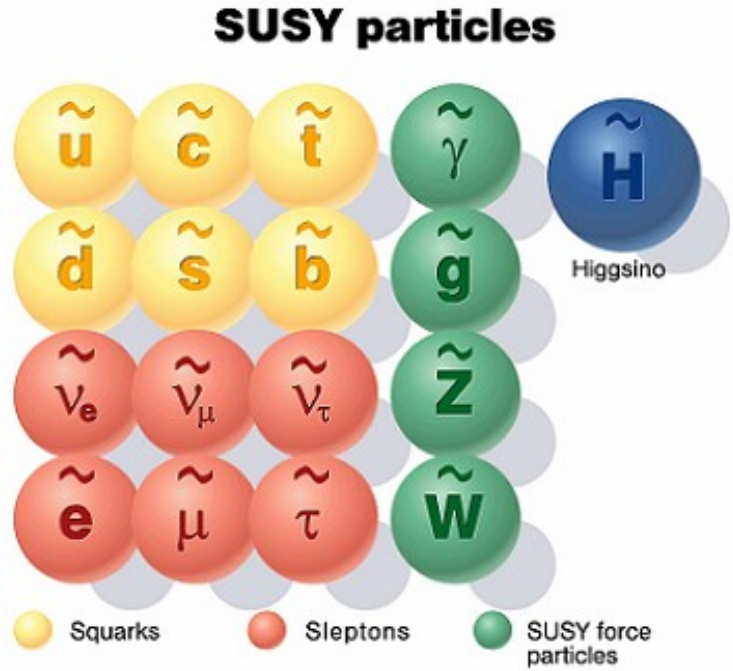
Motivation

Physics Goals:

- Study Standard Model of Particle Physics
  → find the Higgs boson

- Search for “new physics processes”:
  - SUSY
  - microscopic black holes
  - …

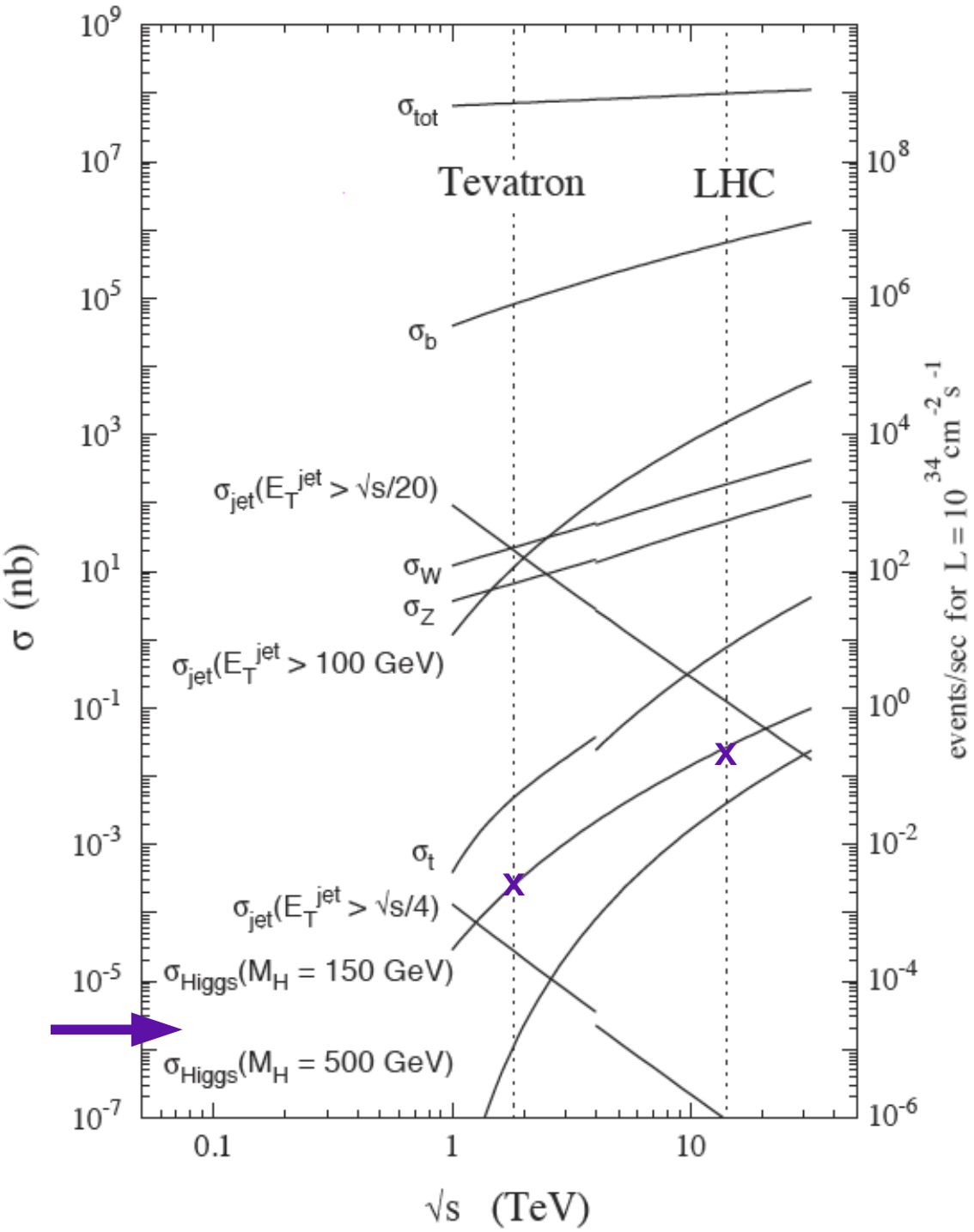




Motivation

Needs:

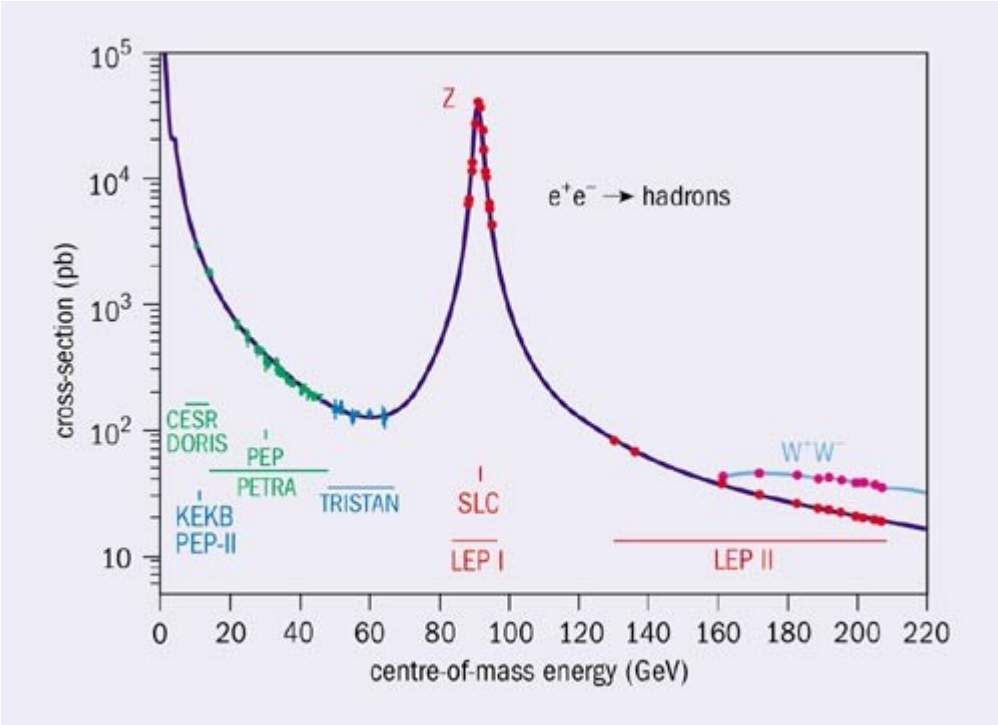
- High energy particle collisions
- High luminosity sample
- Detector to measure plenitude of final state (multi purpose)

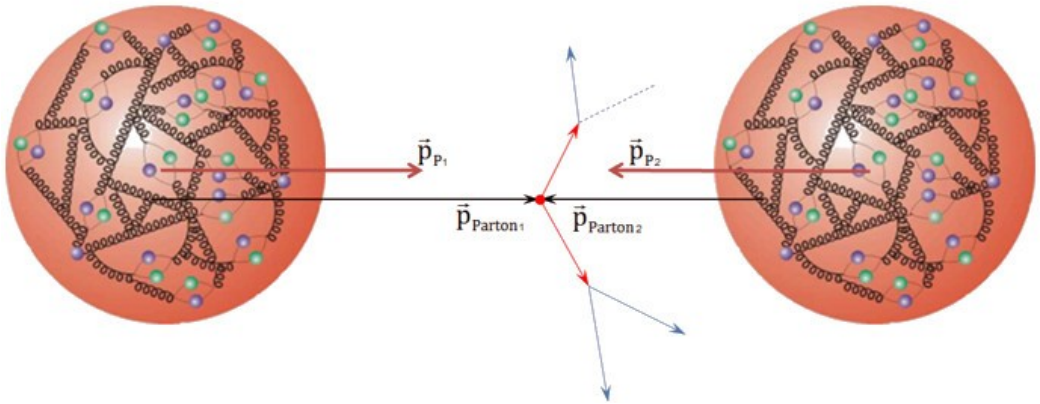


The Large Hadron Collider

Discovery Machine:

- proton-proton collisions
  - no knowledge about initial state
  - broad range of center-of-mass energy of collision

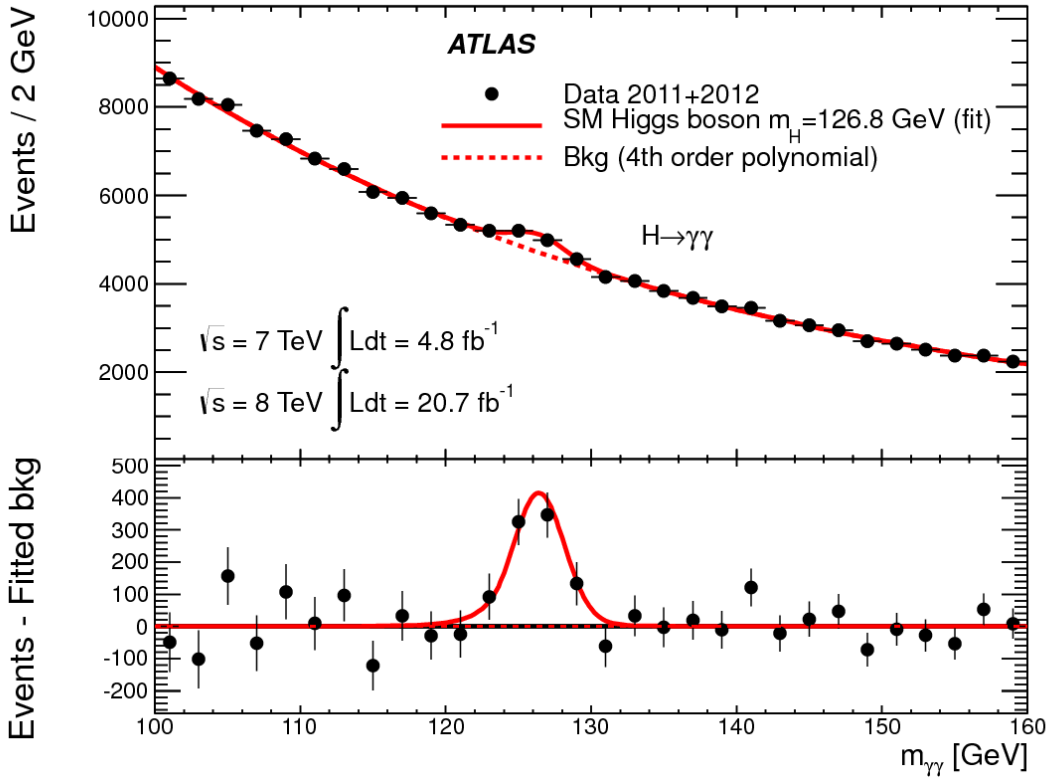




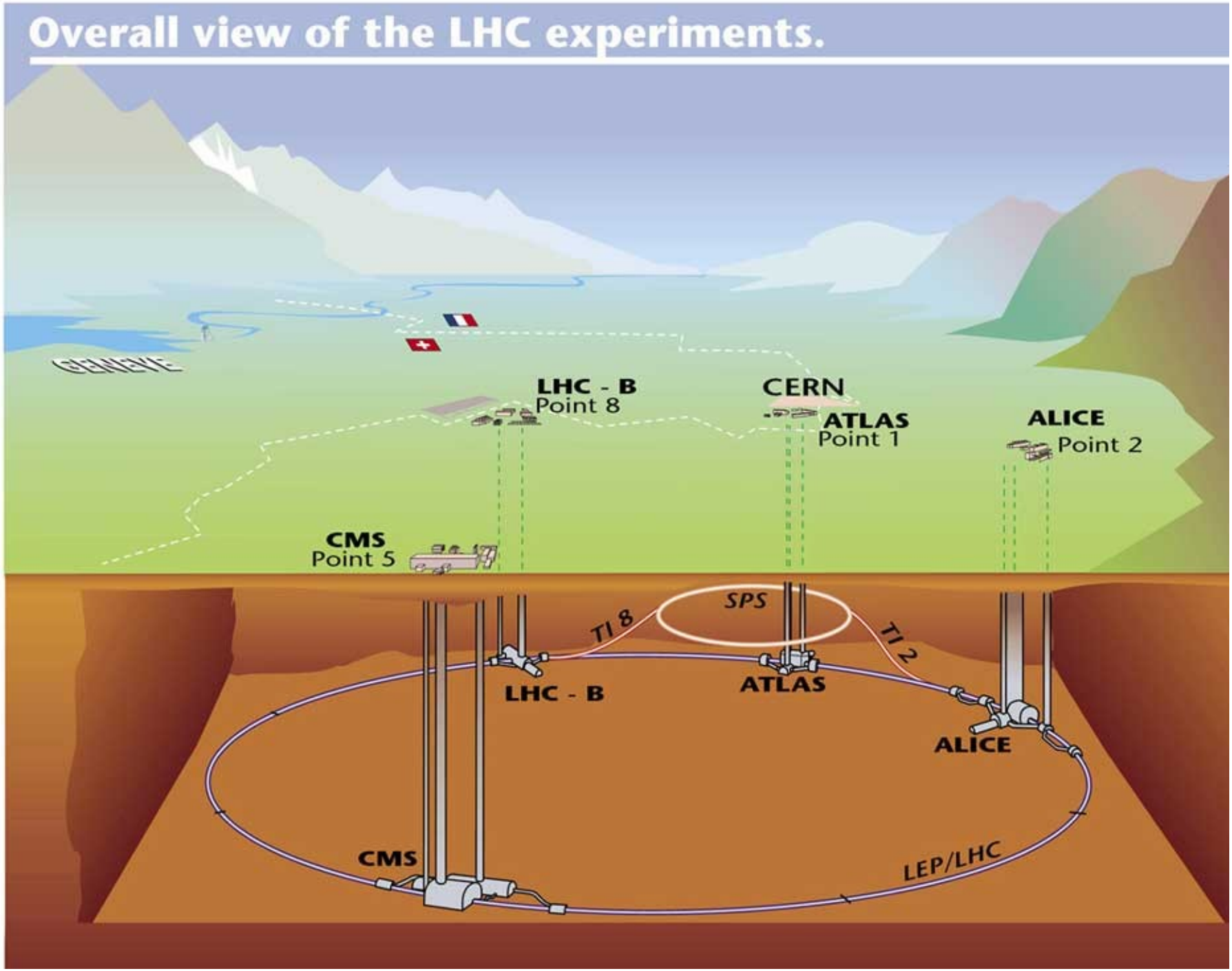
The Large Hadron Collider

Discovery Machine:

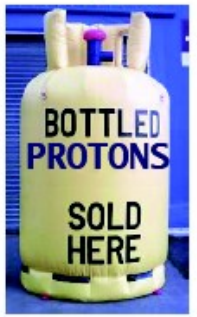
- proton-proton collisions
  - no knowledge about initial state
  - broad range of center-of-mass energy of collision
- two concurrent detectors



Overall view of the LHC experiments.



7 TeV
↑ LHC
450 GeV
↑ SPS
26 GeV
↑ PS
1.4 GeV
↑ BOO-STER
50 MeV
↑ LIN-AC2



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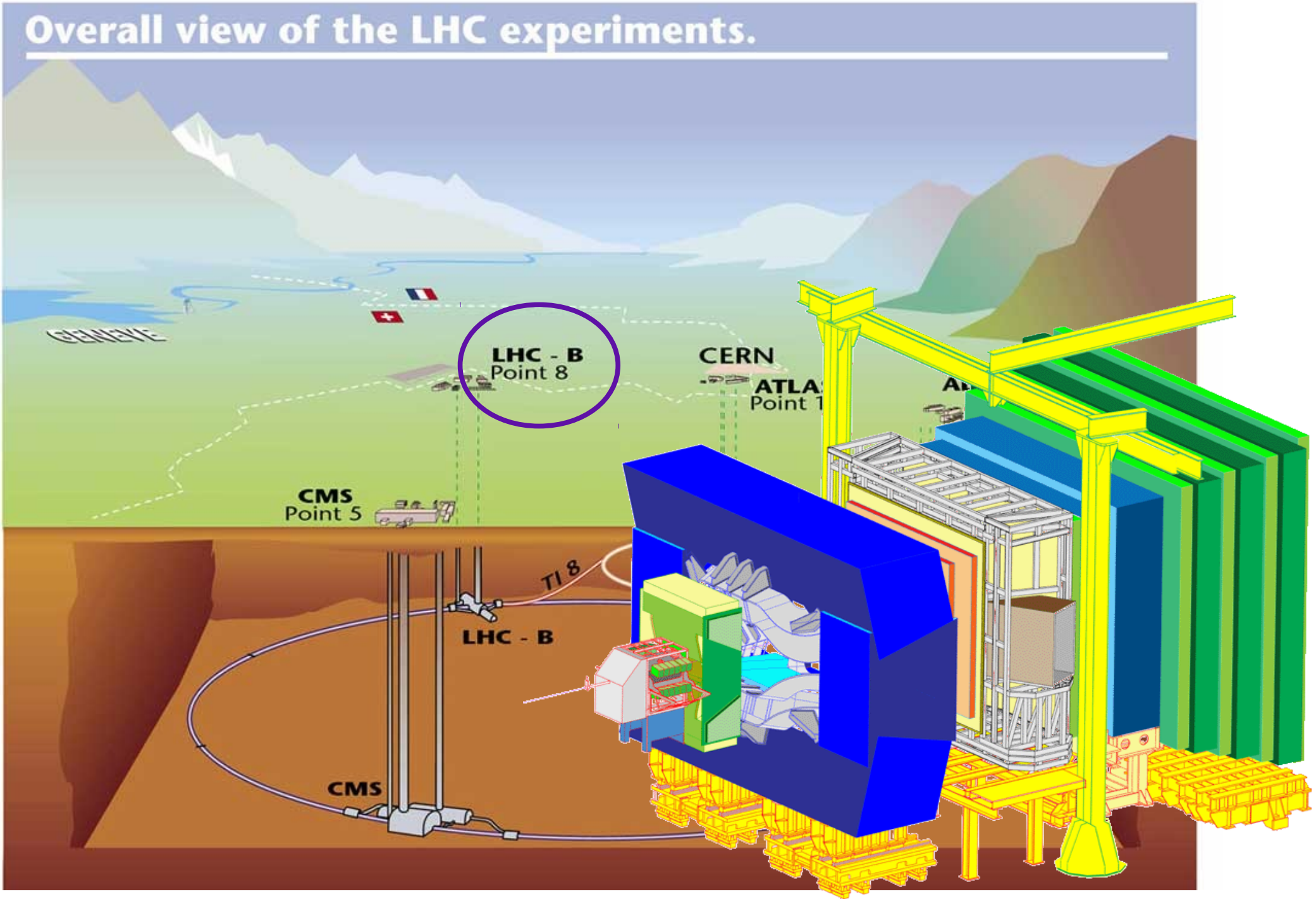
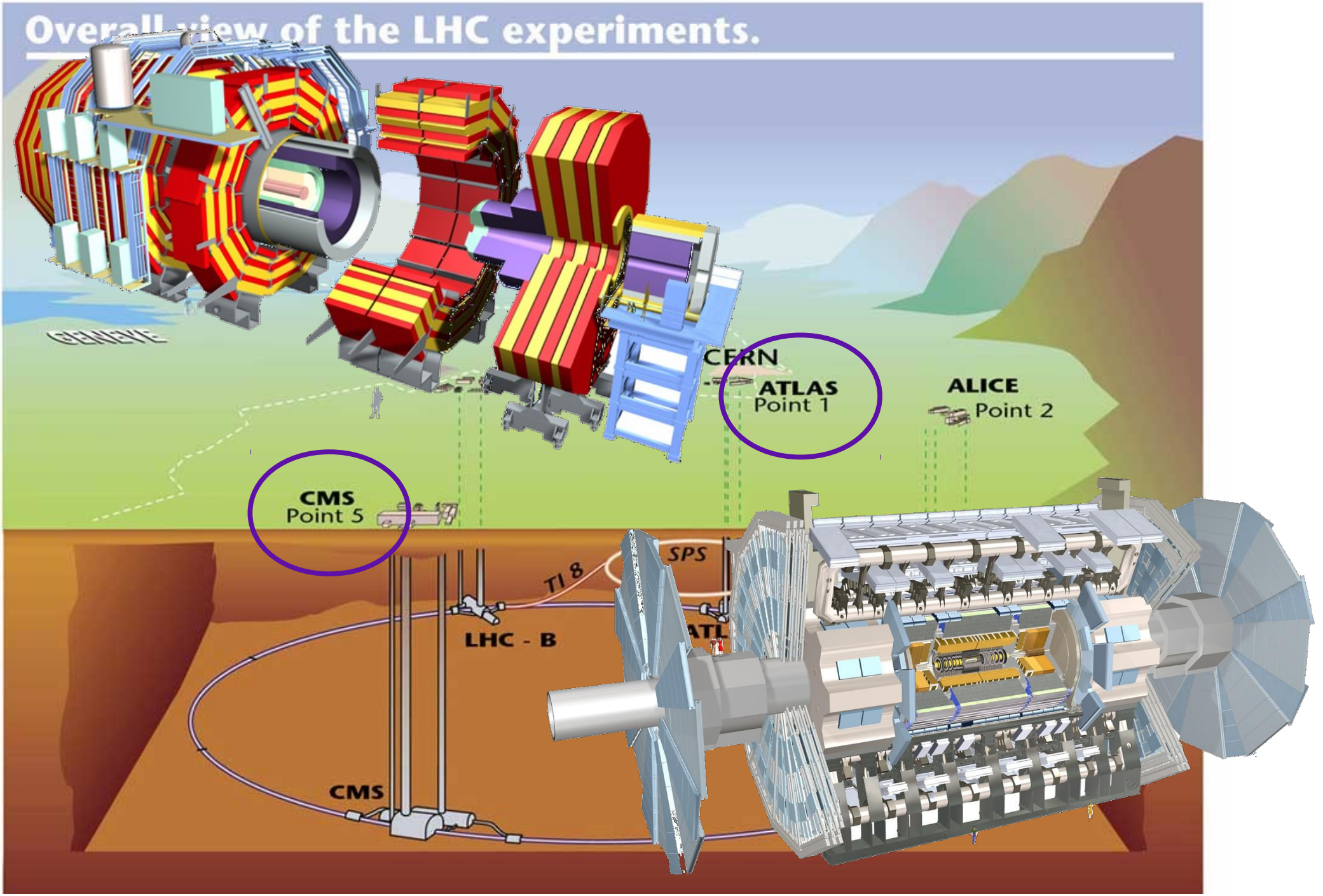
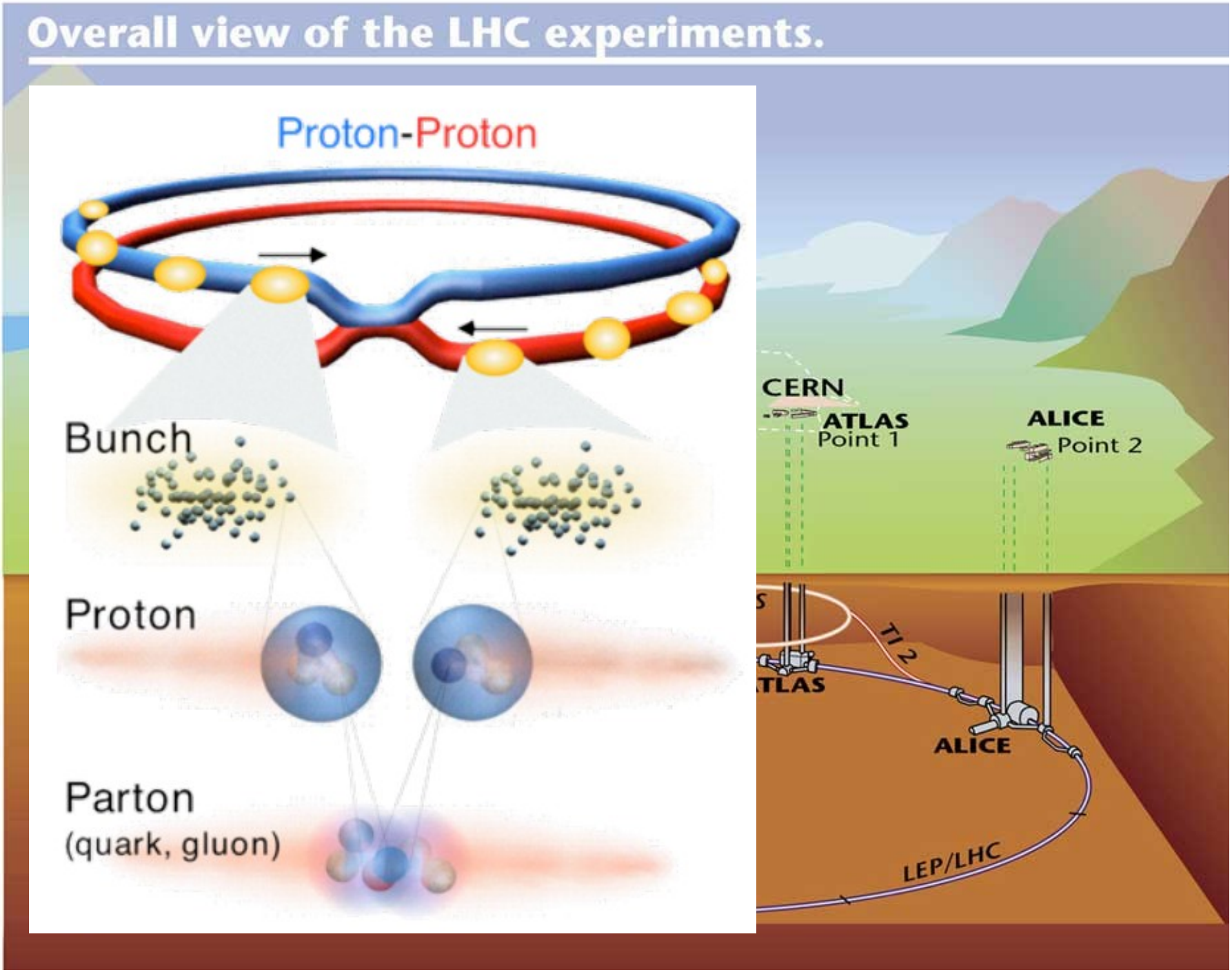



Overall view of the LHC experiments.
CERN
ATLAS
Point 1
ALICE
Point 2
CMS
Point 5
SPS
TI 8
LHC - B
CMS

Overall view of the LHC experiments.



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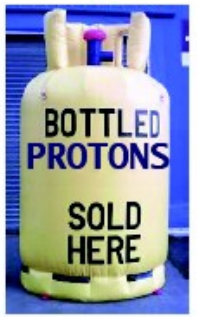
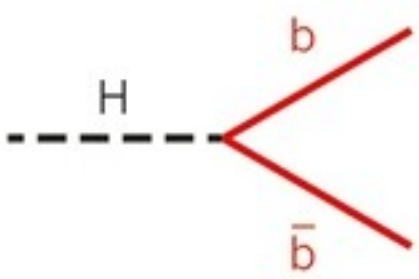
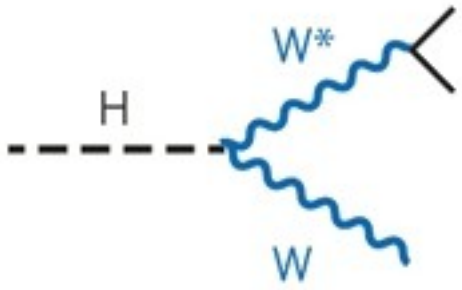
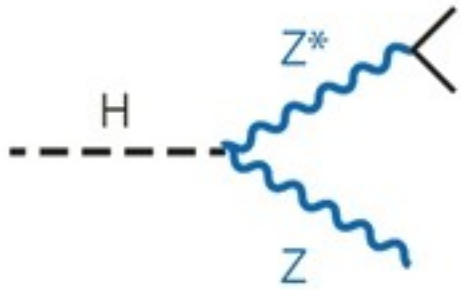
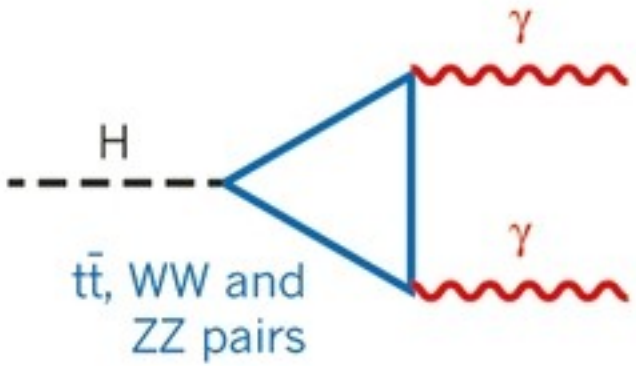


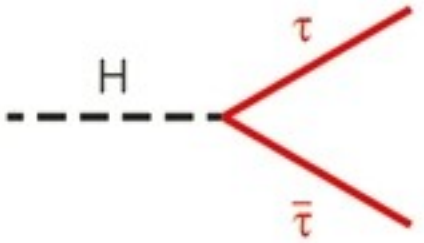
Higgs Decay



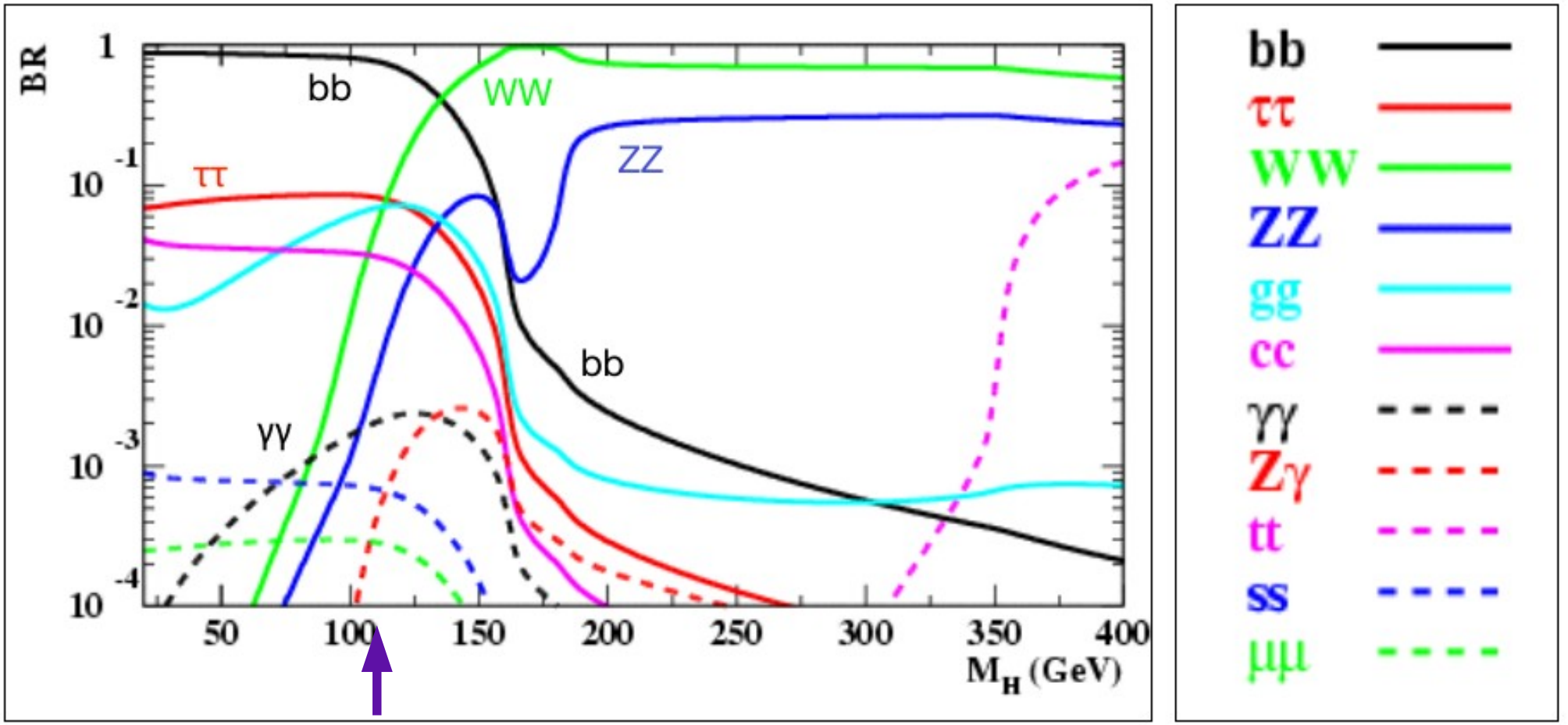








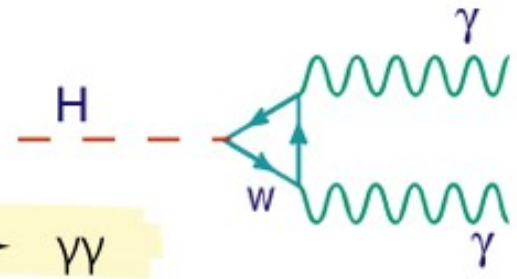
Higgs branching ratios



For M < 135 GeV: H → bb, ττ dominant

For M > 135 GeV: H → WW, ZZ dominant

Tiny but also important: H → γγ

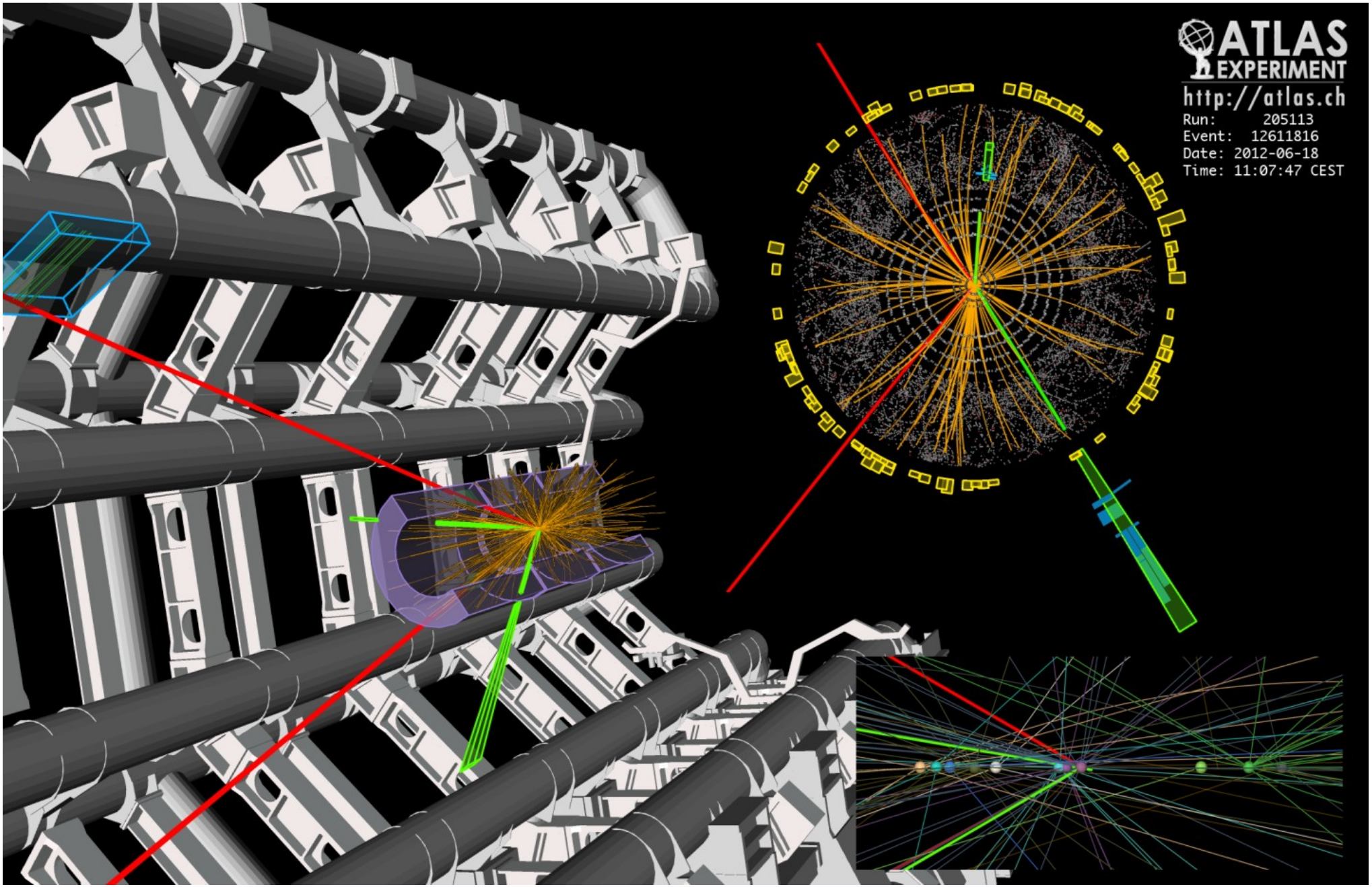


Wishlist for Detector

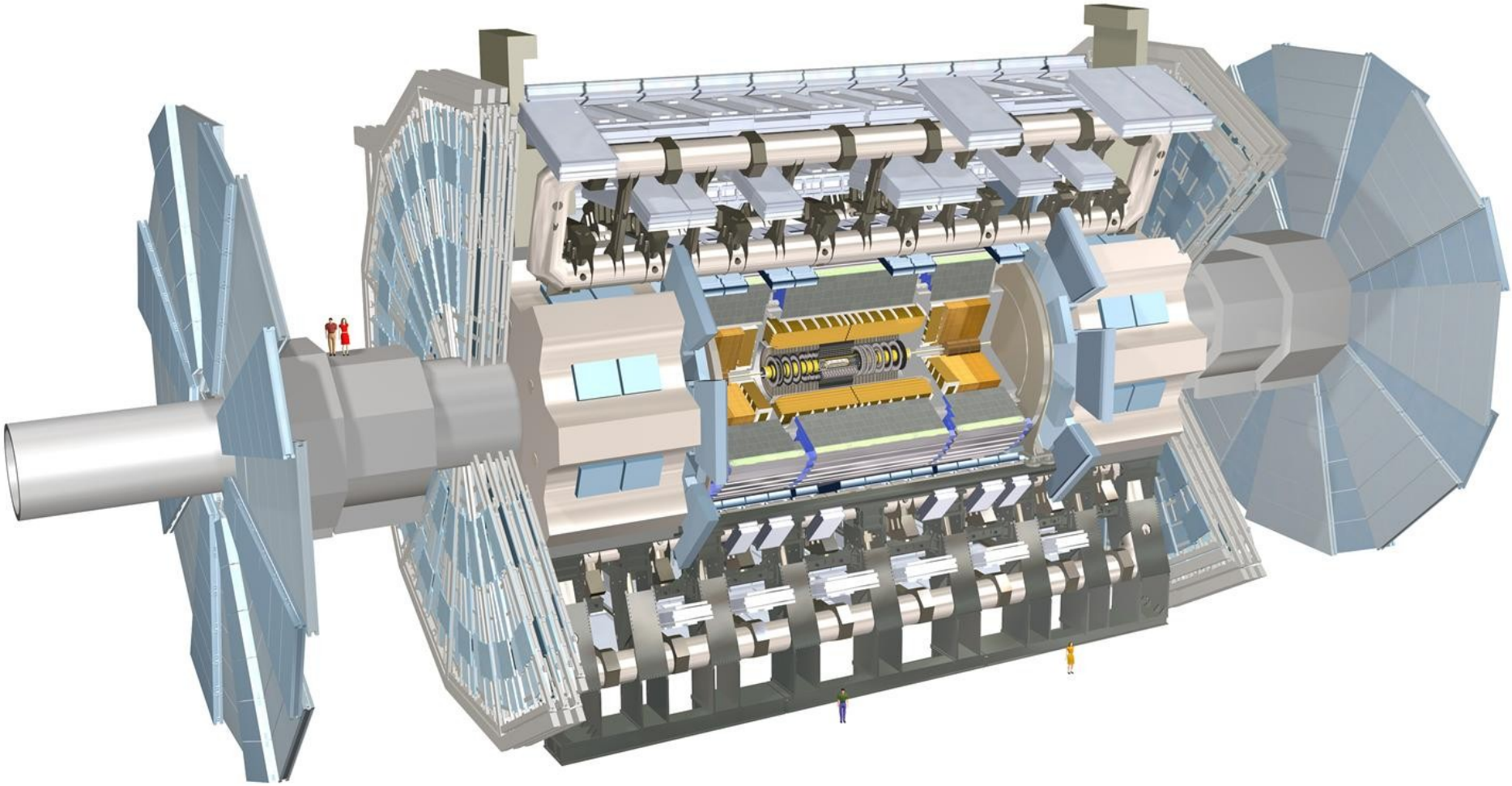
- recording of full event:
  - maximal coverage of the solid angle
  - measure and distinguish different particle species
    - electrons
    - photons
    - muons
    - jets

→ different specialized sub components

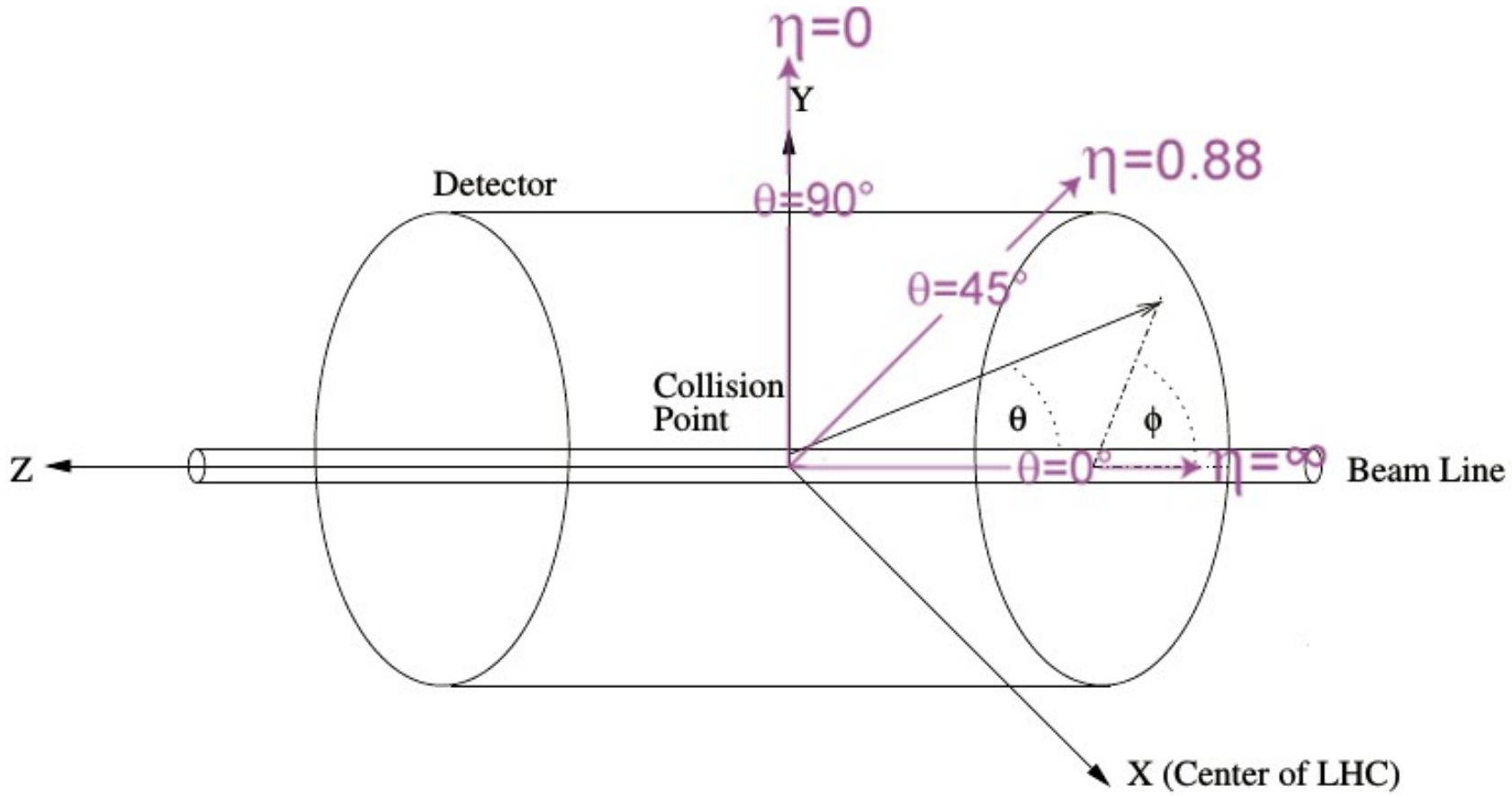
Finding the Higgs



The ATLAS Detector



Coordinate System



Pseudo rapidity

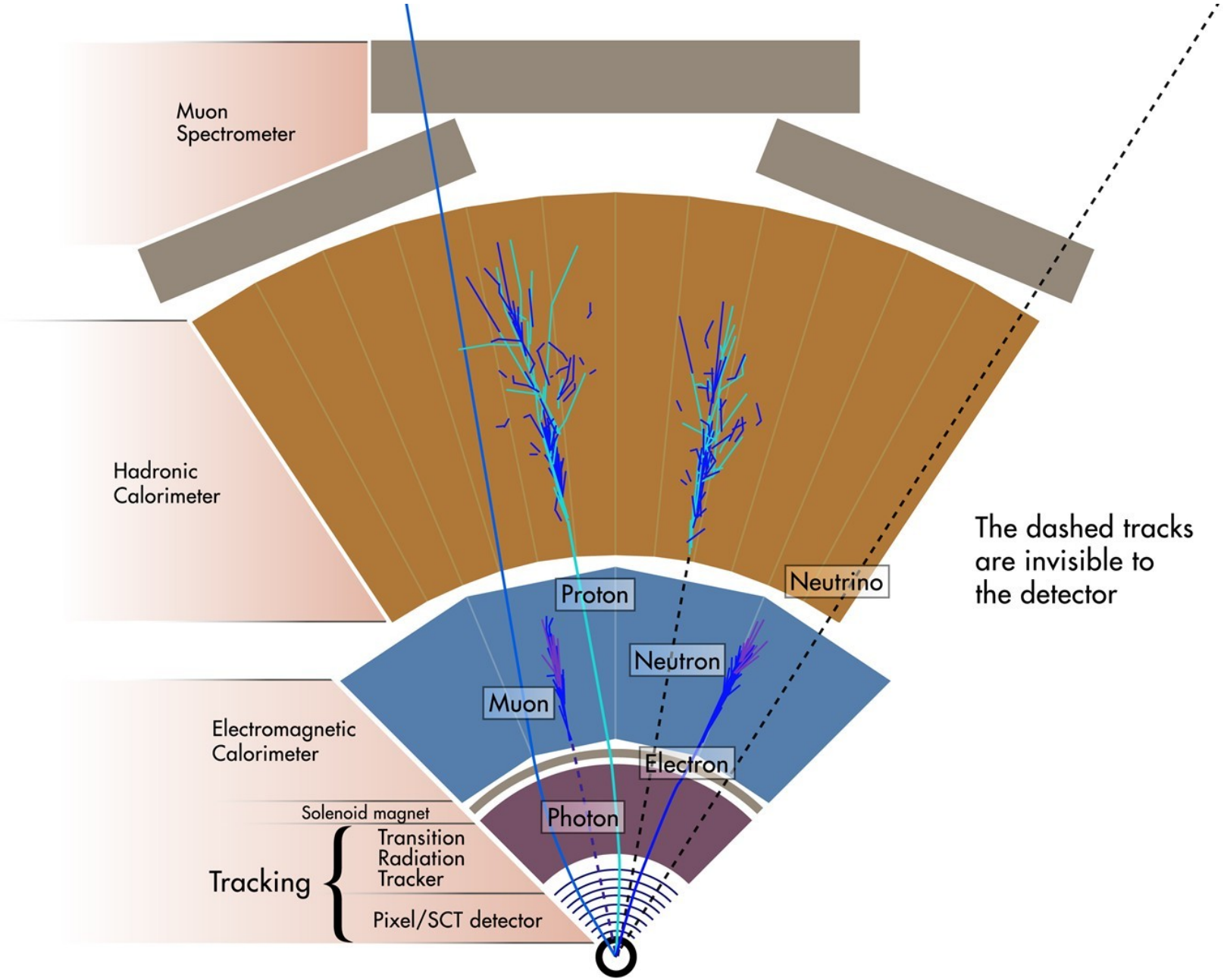
$$\eta = -\ln\left(\tan\frac{\theta}{2}\right)$$

E, P in transverse plane

$$p_T = P\sin\theta$$

$$E_T = E\sin\theta$$

The ATLAS Detector



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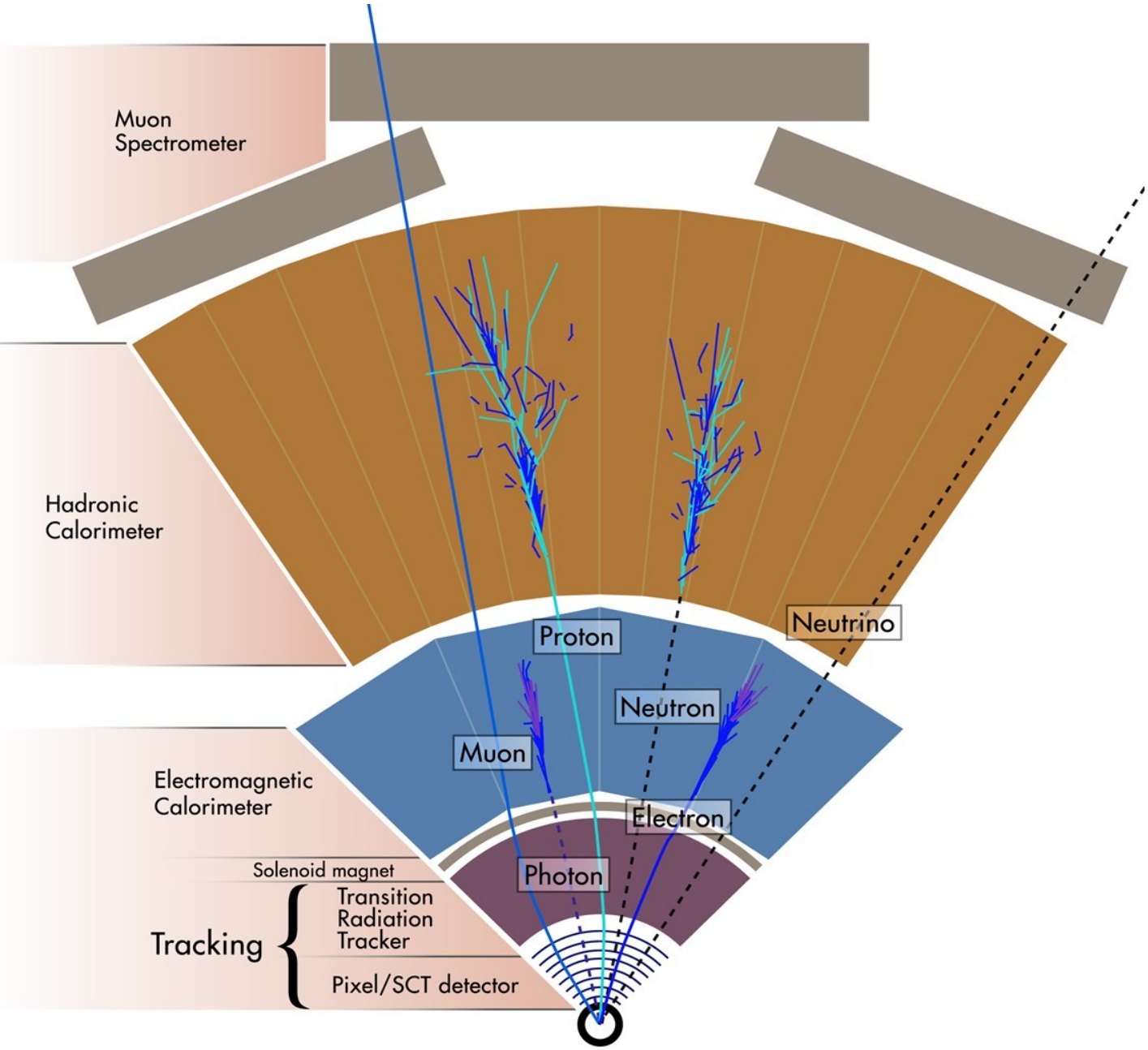
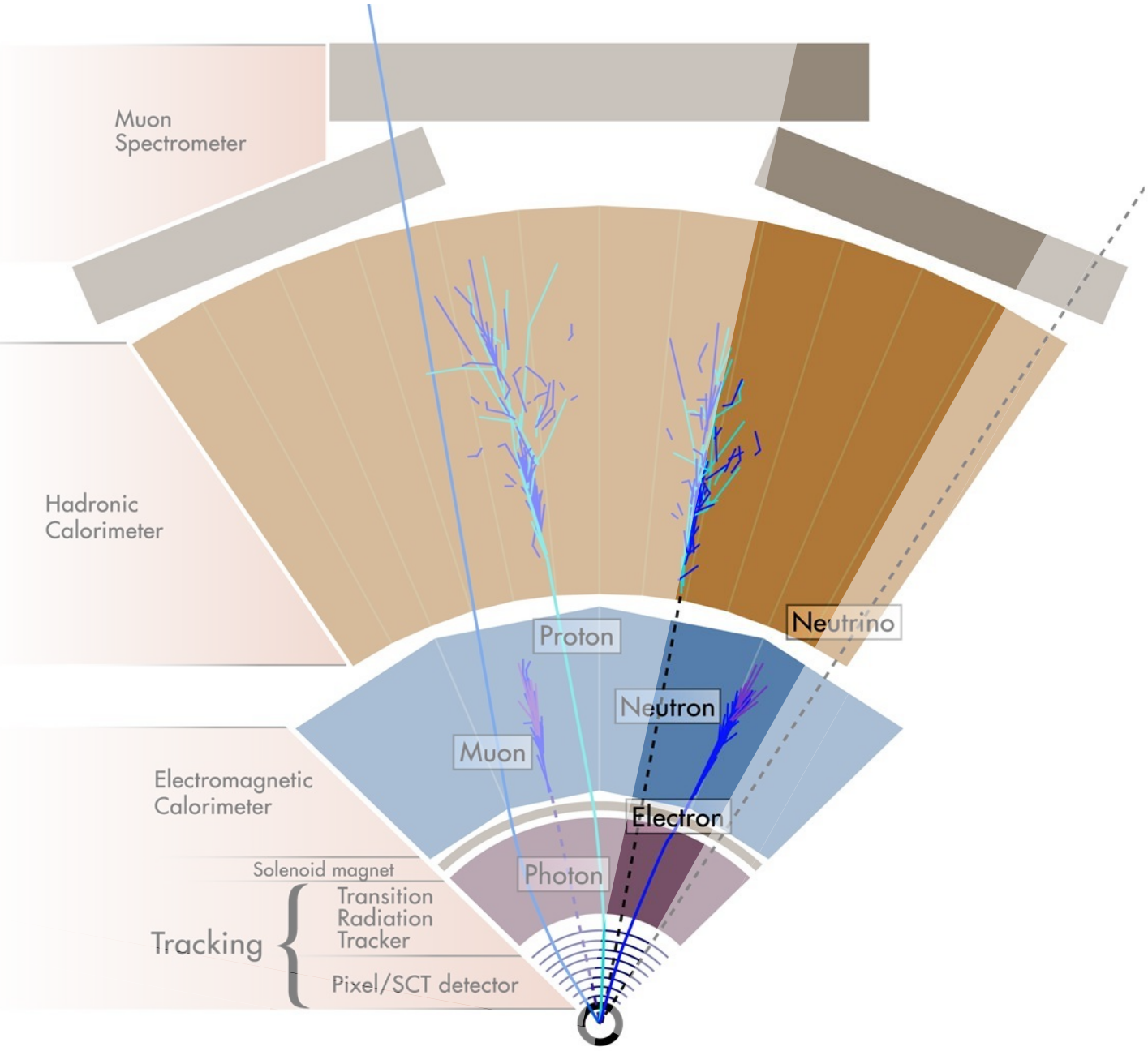


Particle detection via their energy loss in material they traverse

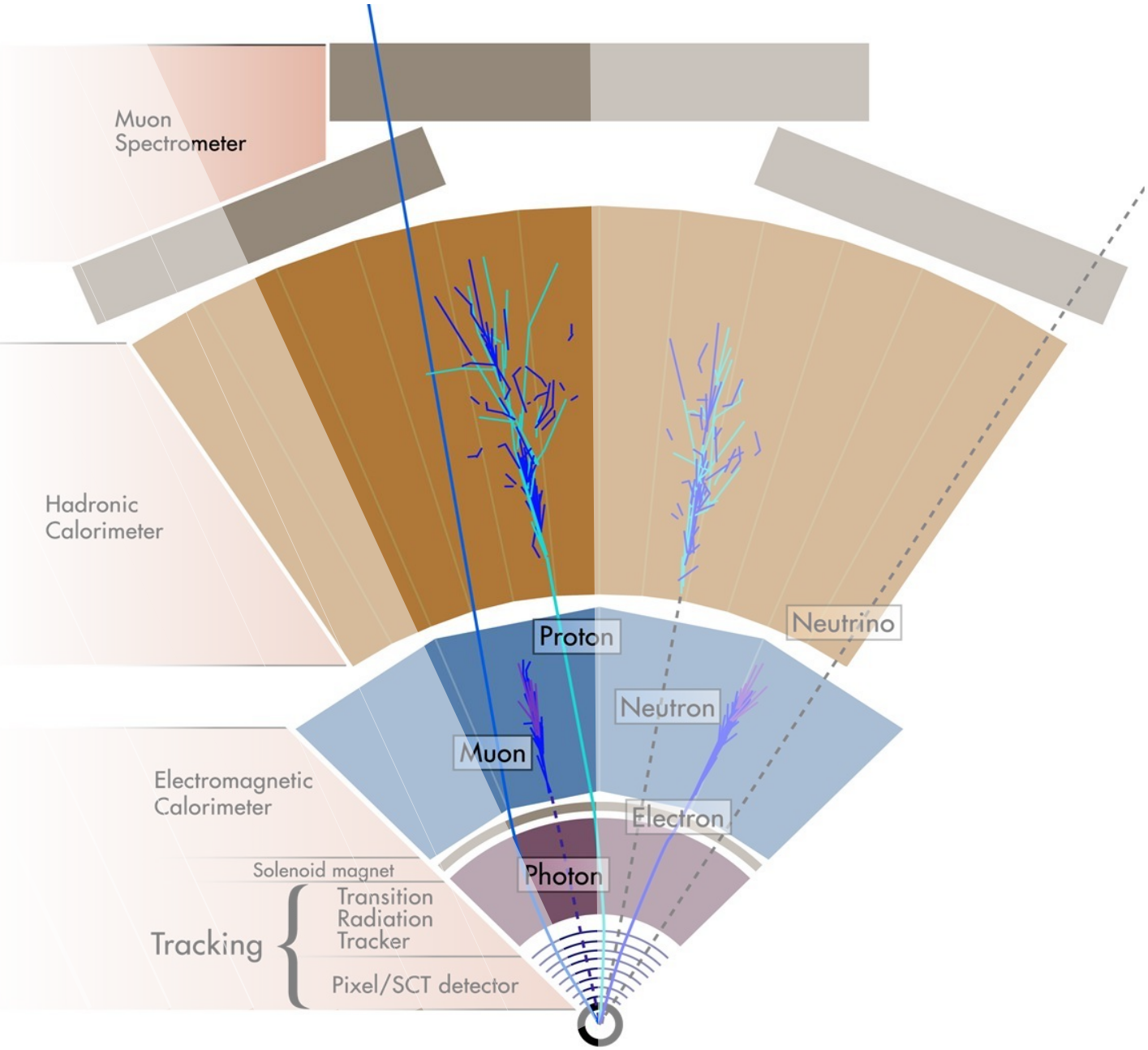
The ATLAS Detector



Electrons:

- mainly bremsstrahlung:
  - $dE / dx = E / X_0$
- Energy down to 1/e after X_0(Radiation length)
  → want little material in front of calorimeters and thick (> 20 X_0) calorimeter
- Examples: X_0/ρ for water 36 cm, for lead 0.56 cm

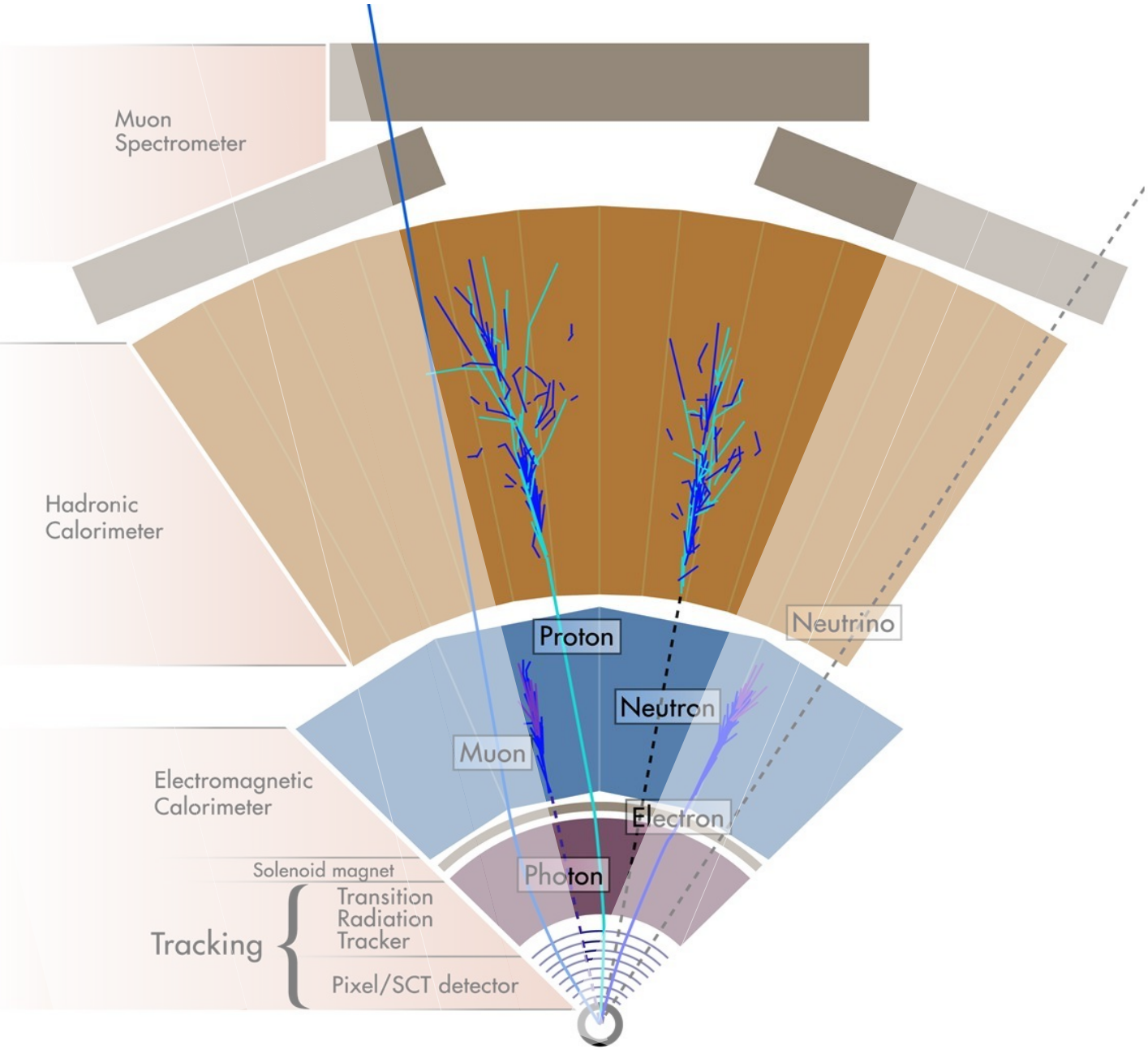
The ATLAS Detector



Photons:

- e+e− pair production
- Mean free path 7/9 X_0

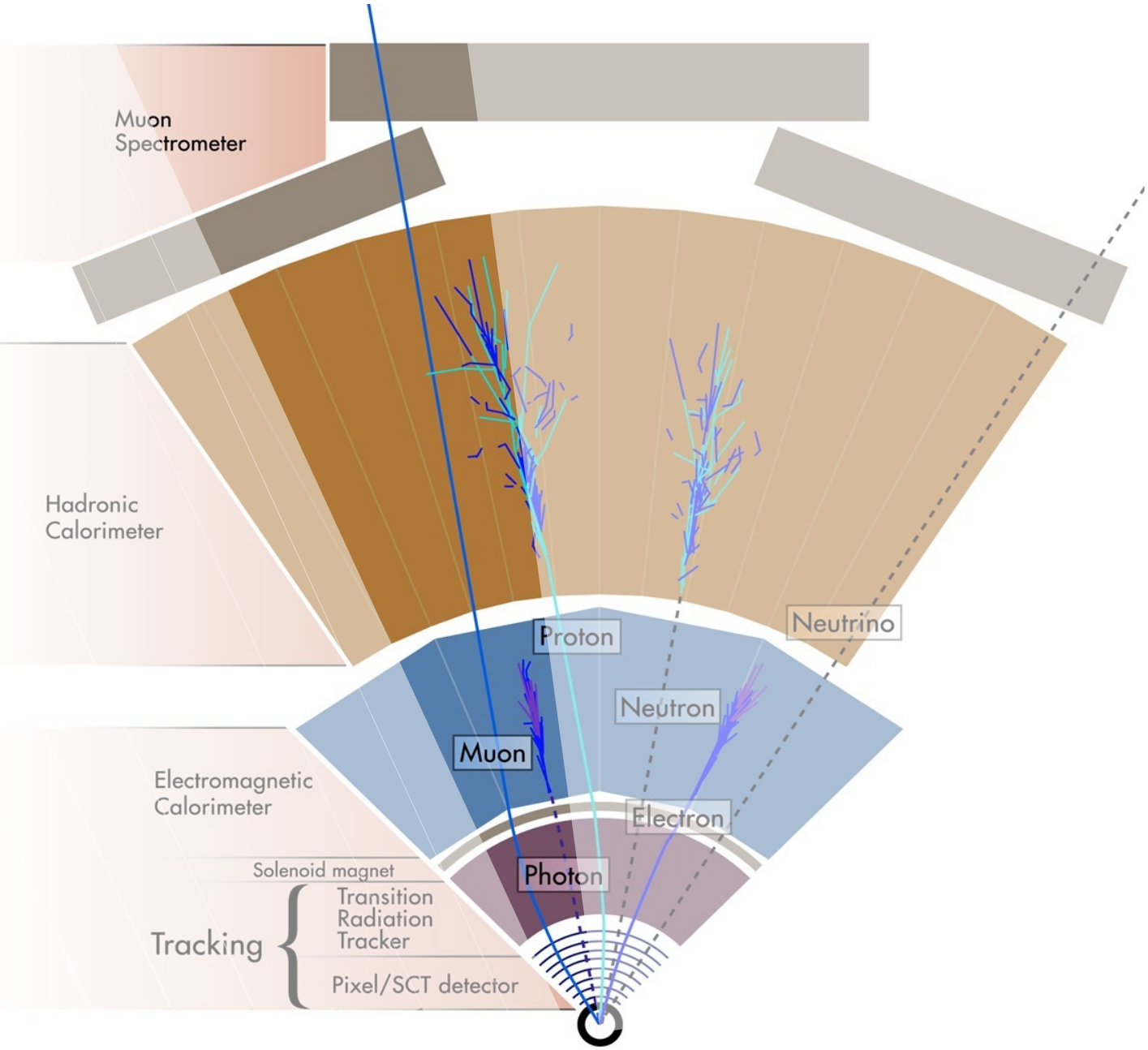
The ATLAS Detector



Hadrons:

- Characteristic scale: nuclear interaction length λ
- Relevant for total calorimeter depth (hadronic + electromagnetic)
- Examples: λ/ρ for water 83.6 cm, for steel 17 cm

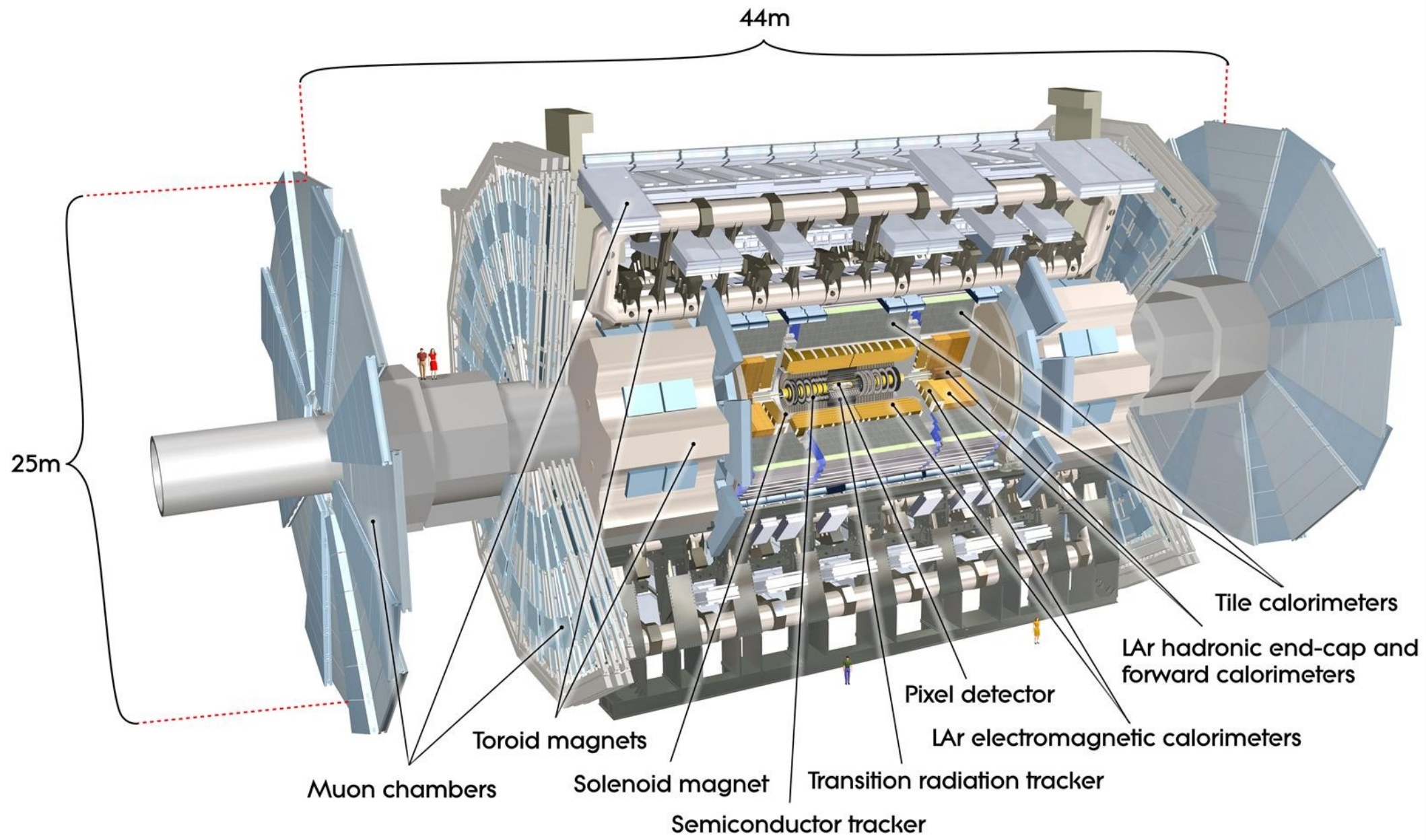
The ATLAS Detector



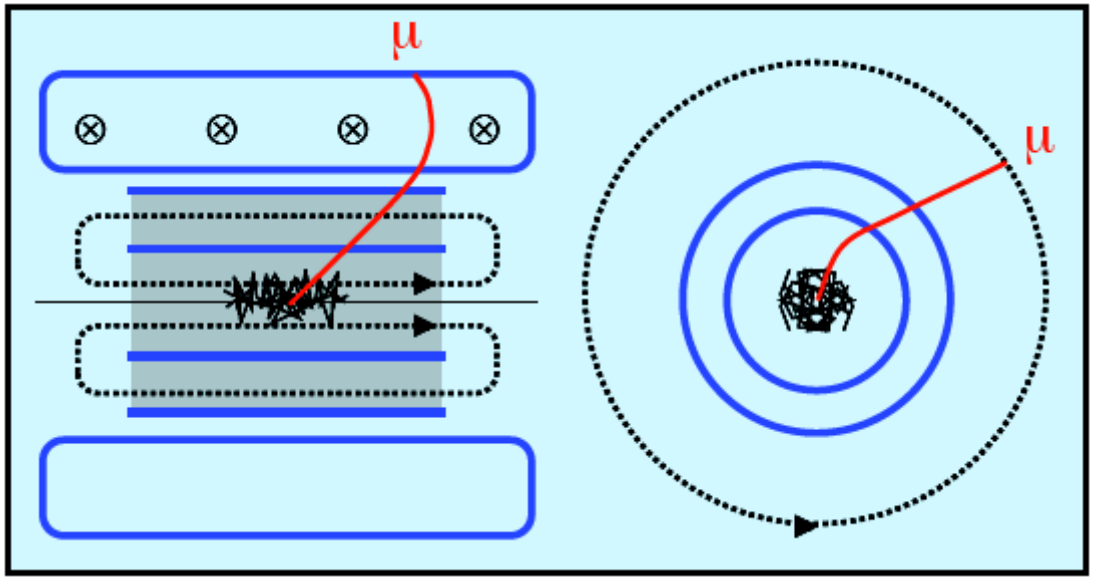
Muons:

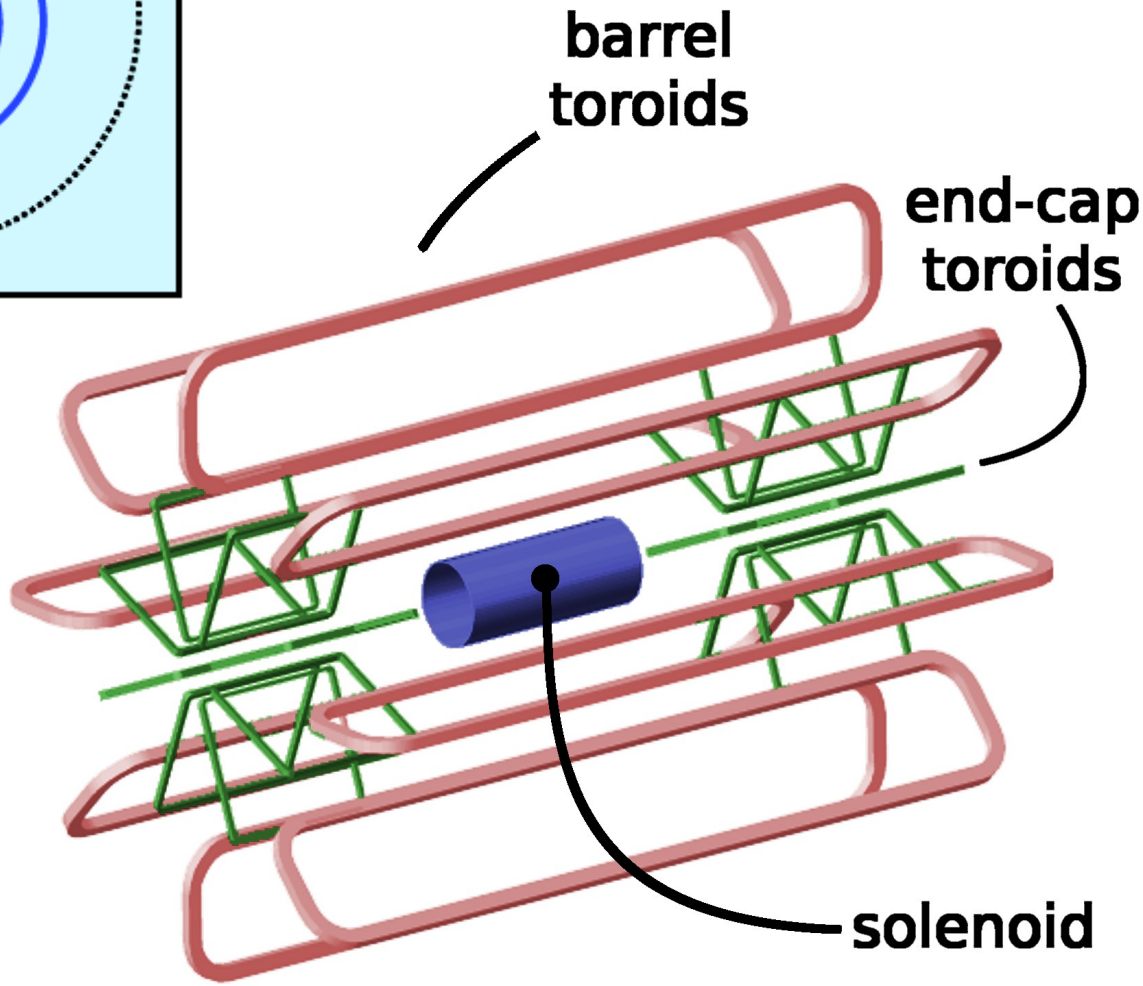
- basically heavy electrons
- radiation length much longer

The ATLAS Detector



Magnets



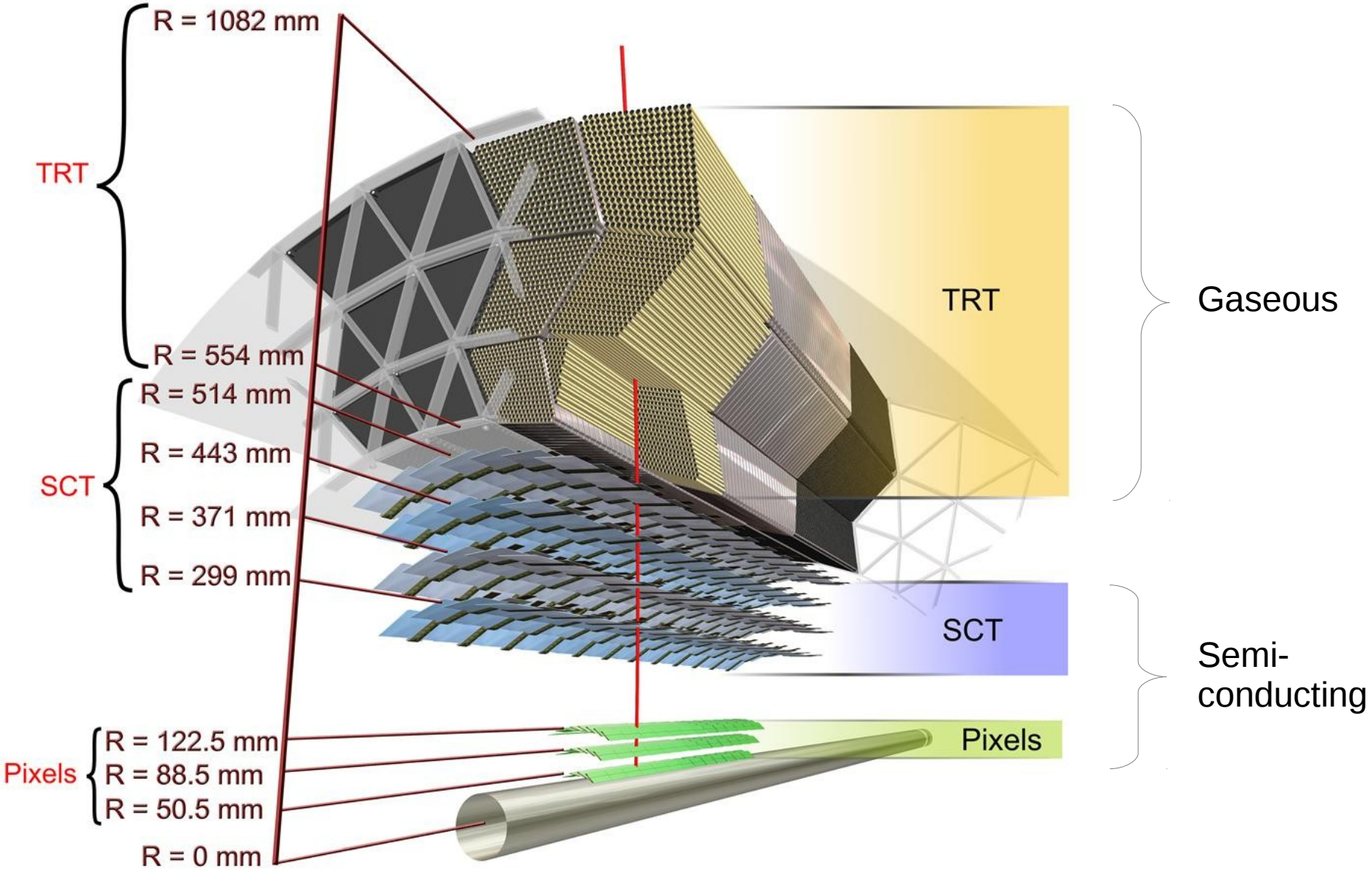


Needed for

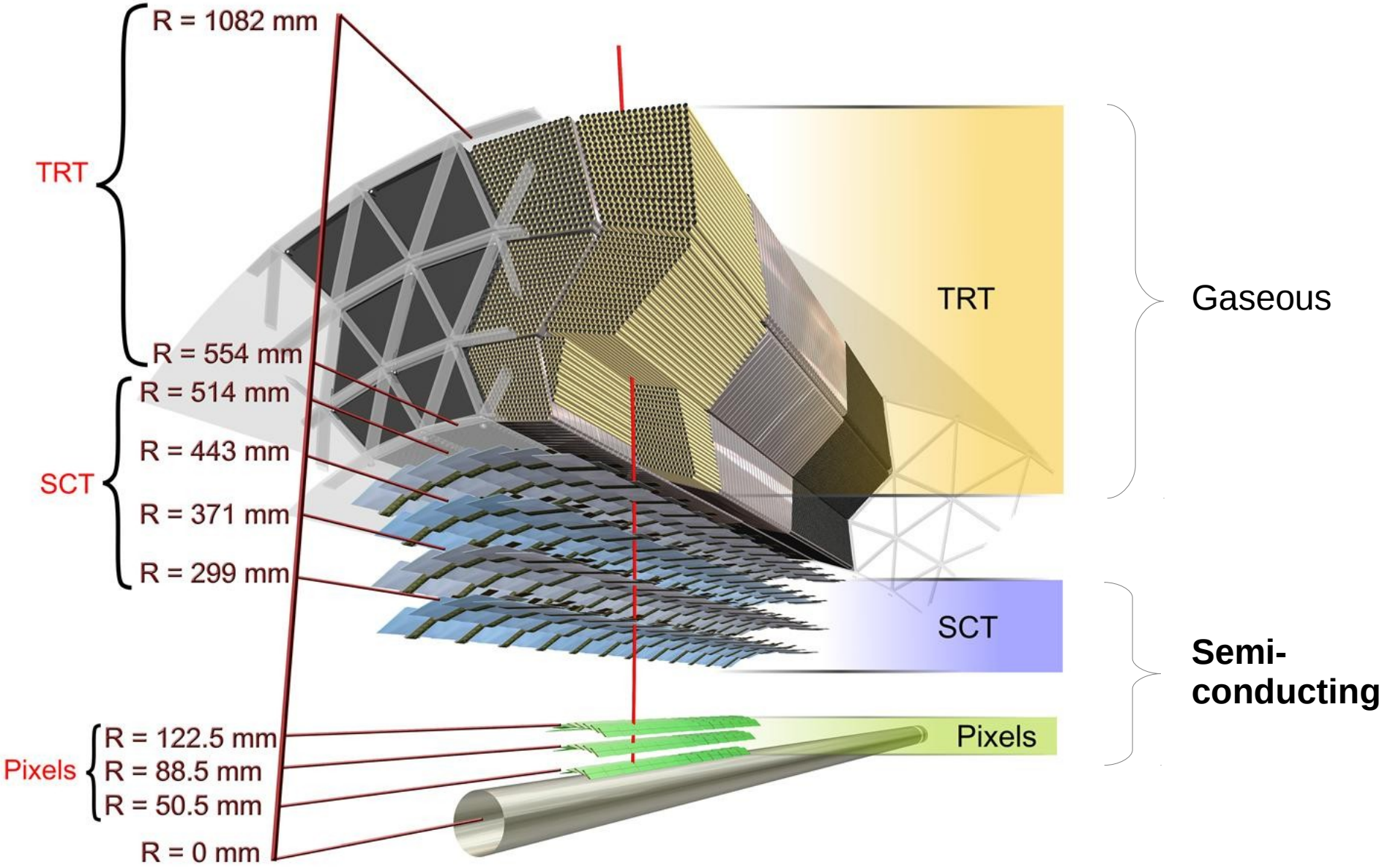
momentum

measurement

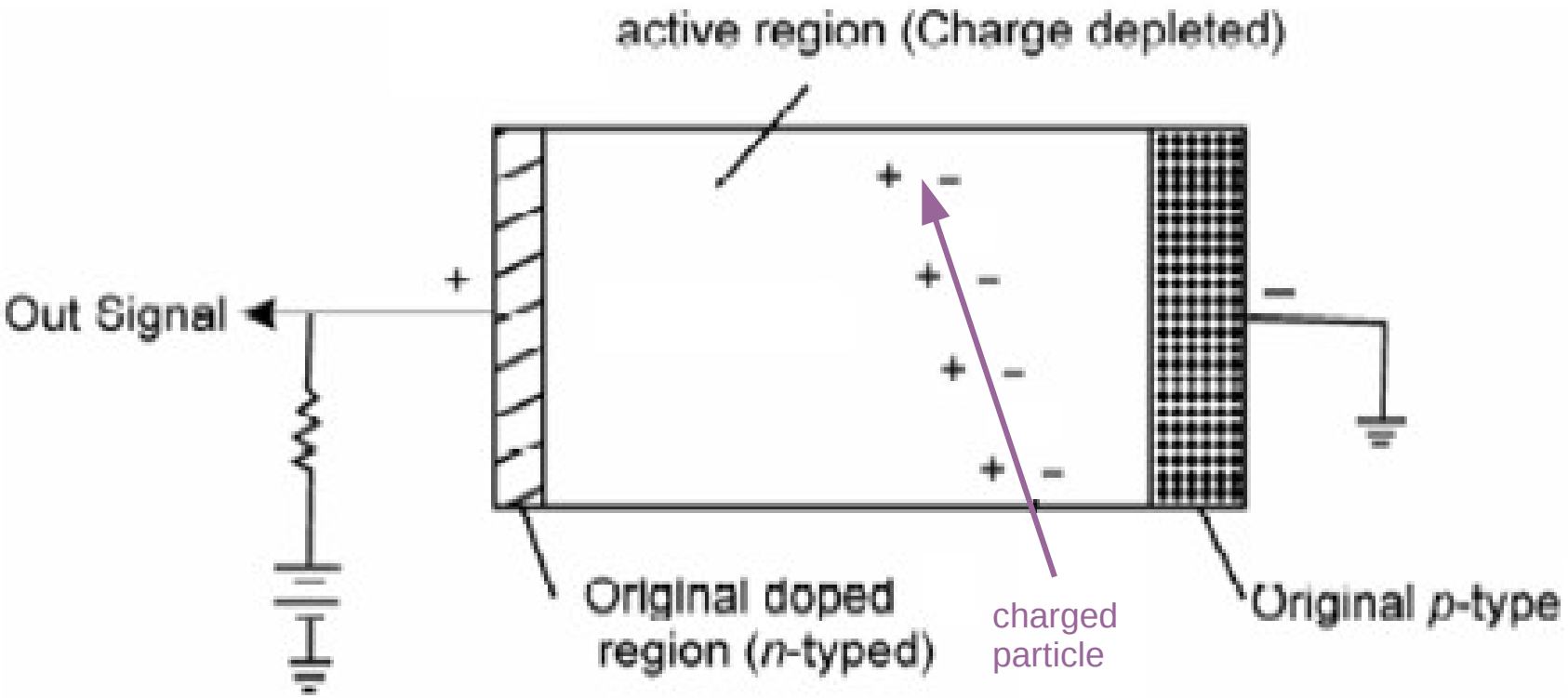
Inner Detector



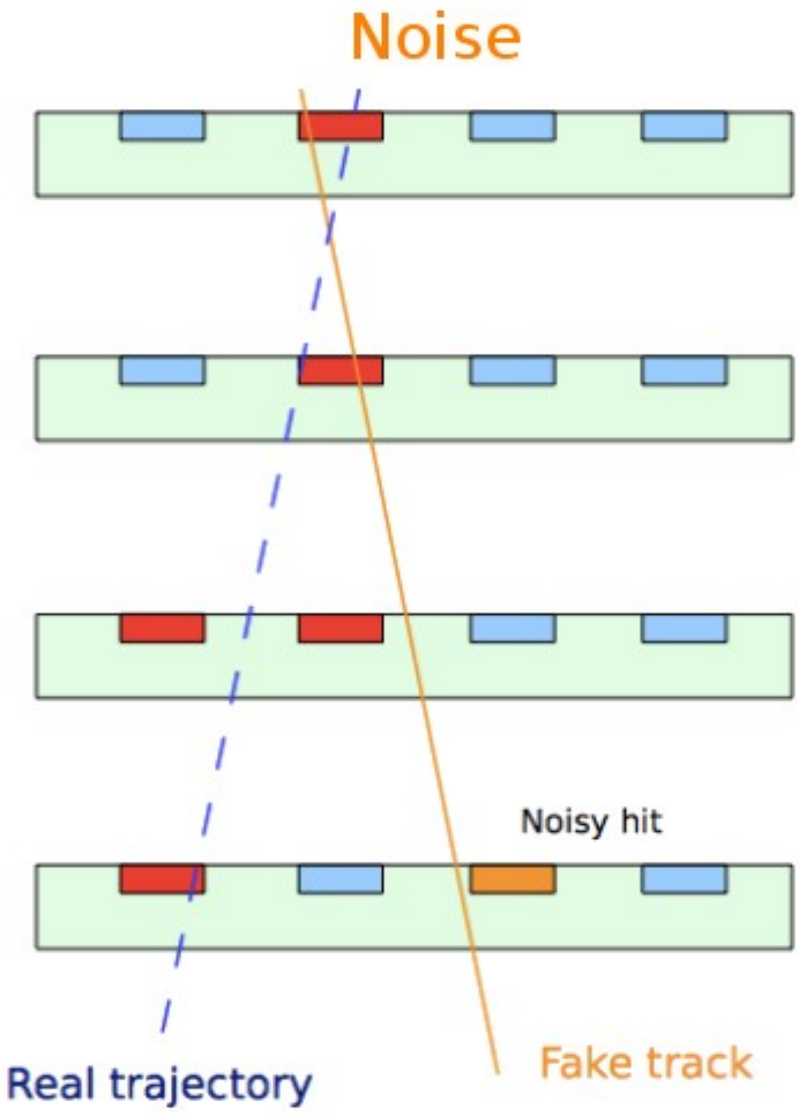
Inner Detector

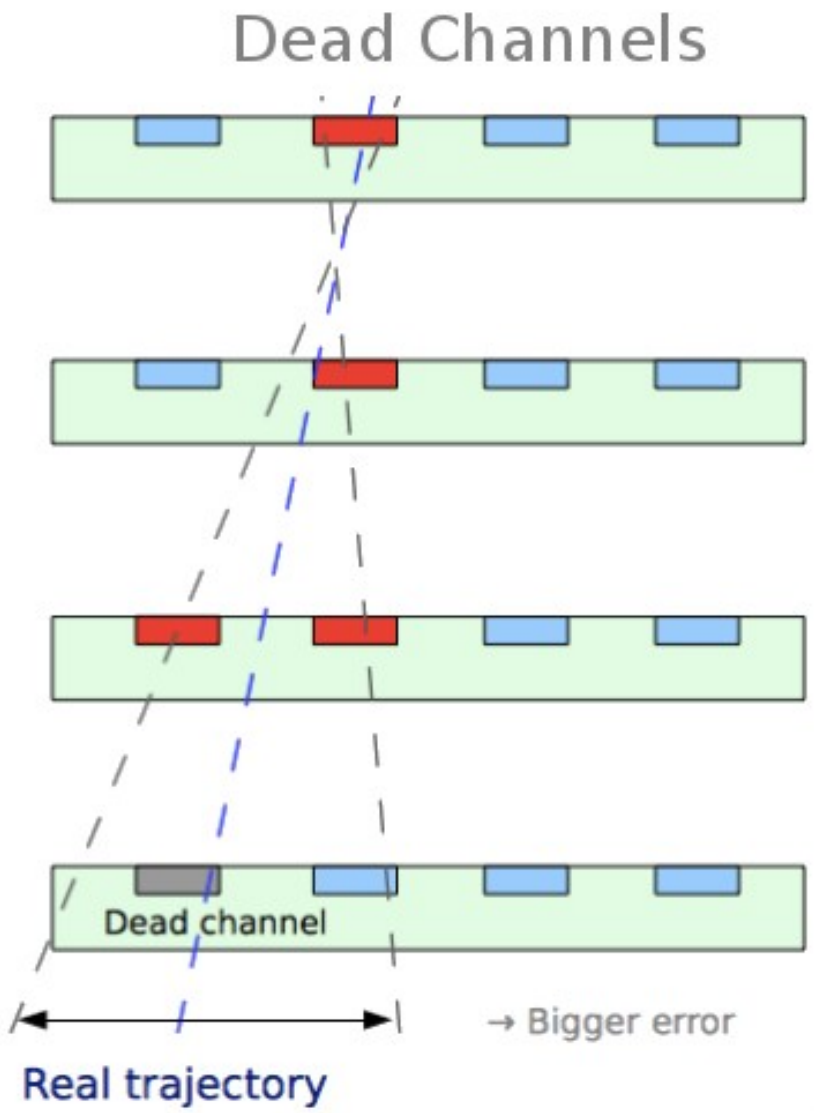


Semi Conductiong Detectors



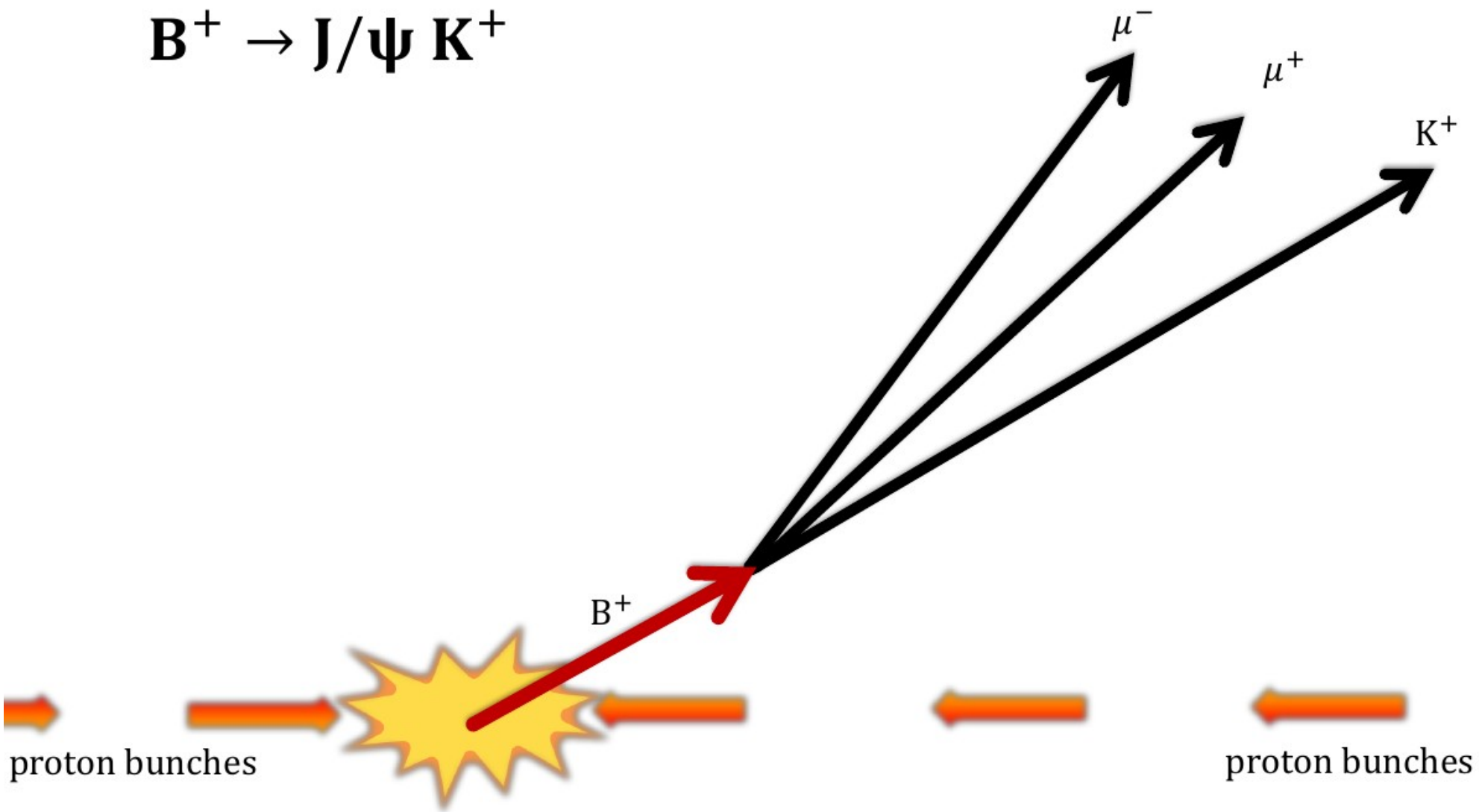
Tracking


Noise
Noisy hit
Real trajectory
Fake track


Dead Channels
Dead channel
→ Bigger error
Real trajectory

Tracking

from Thomas



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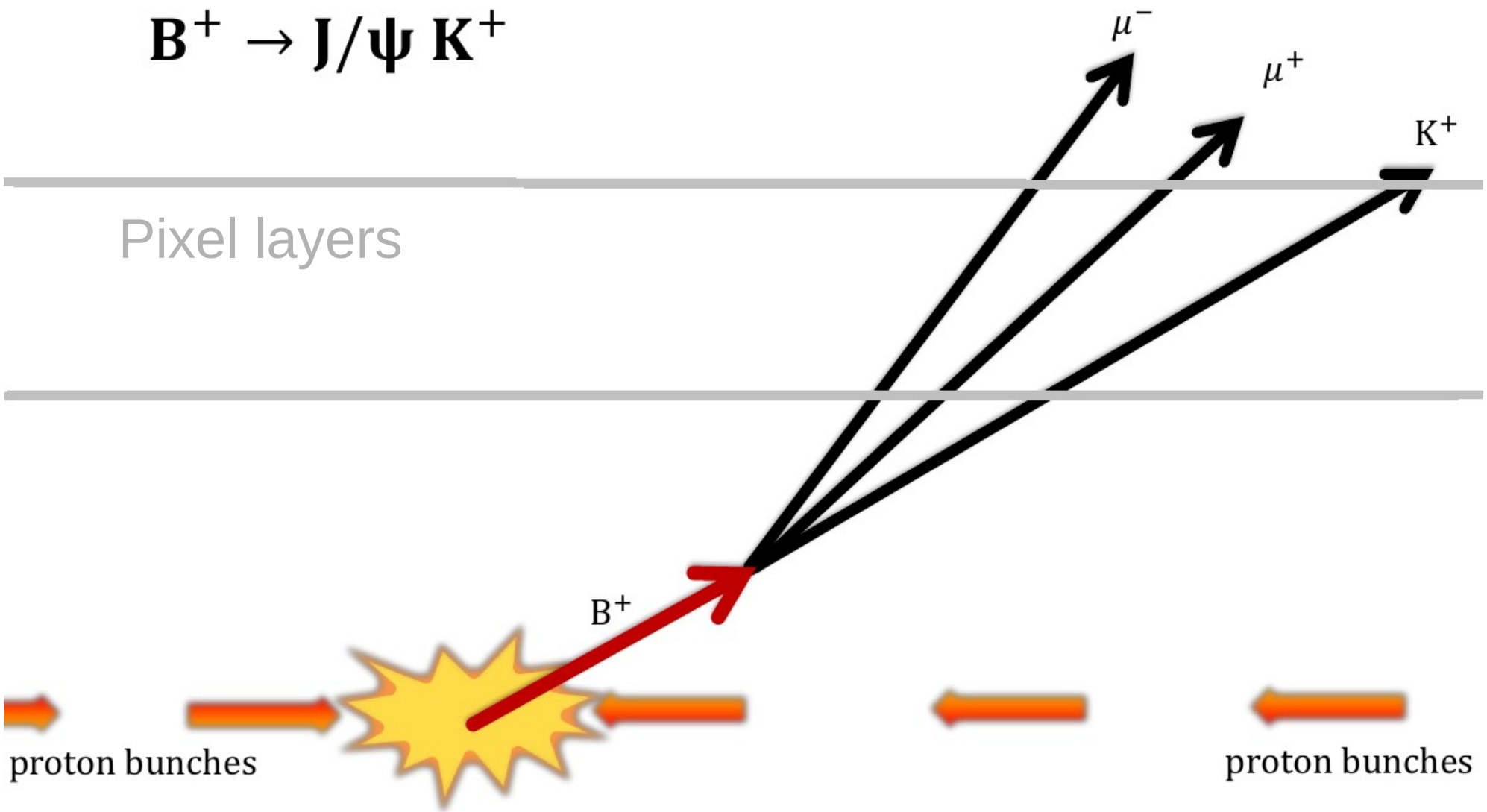
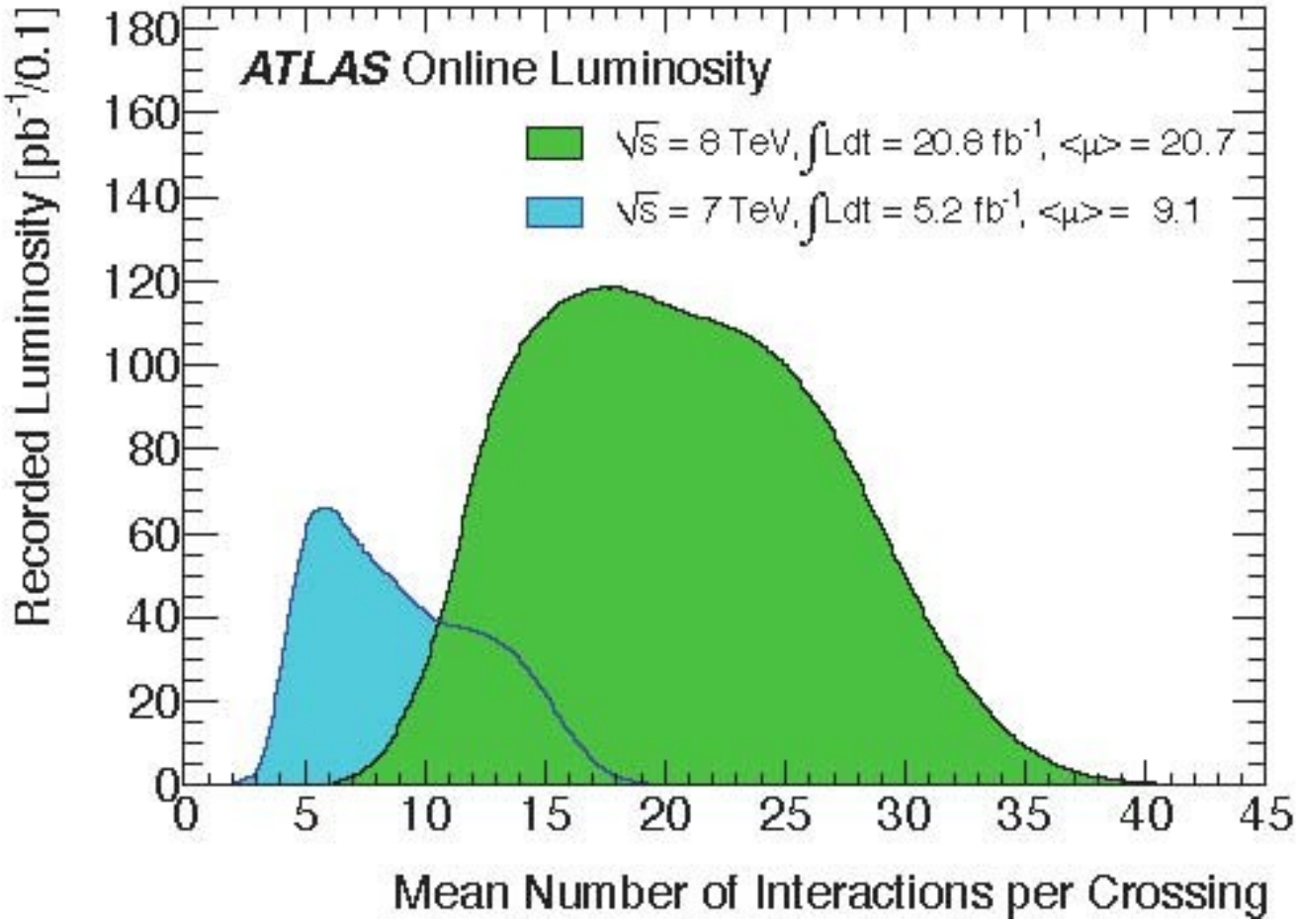


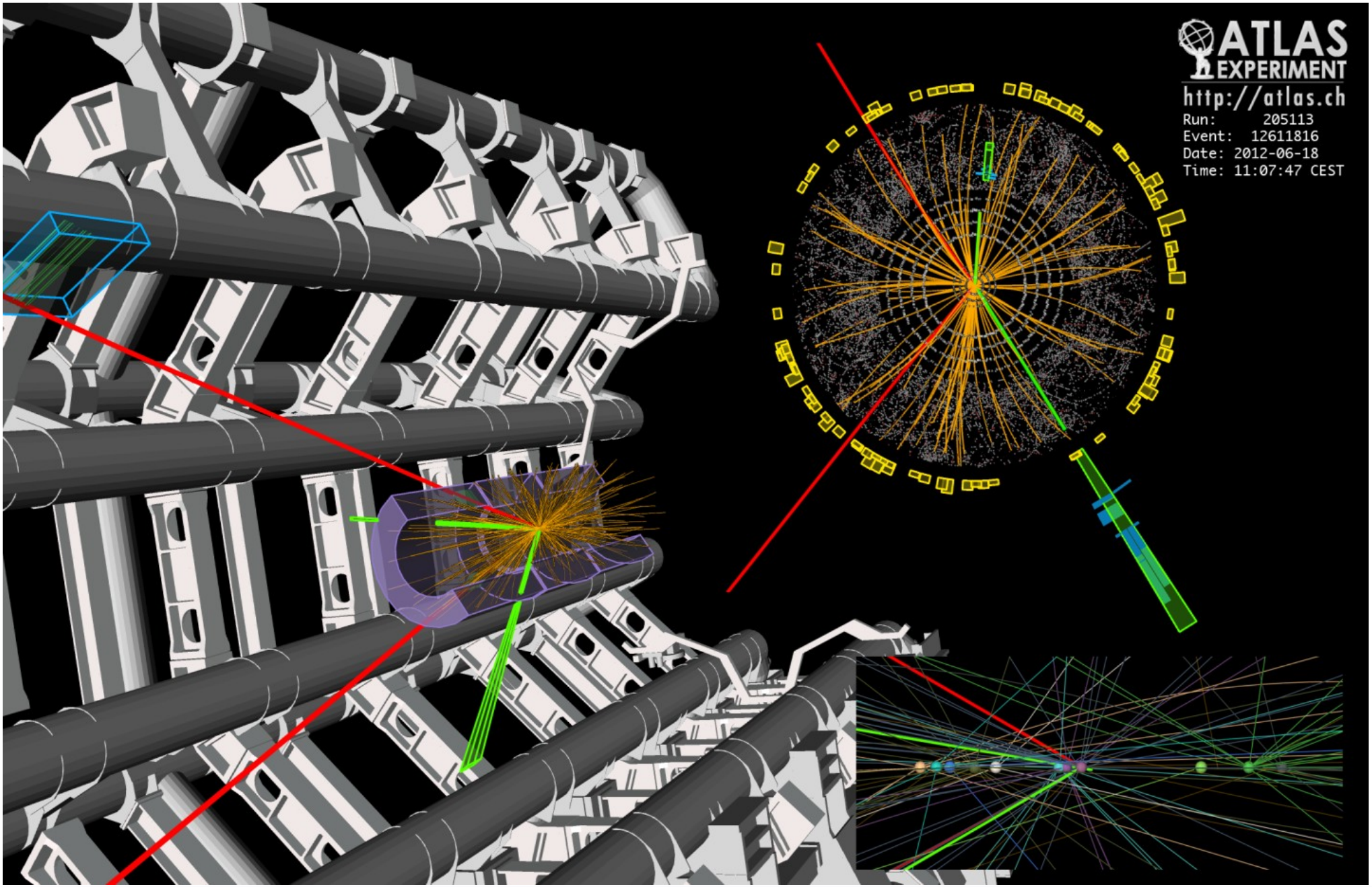
Pileup

Pile-up is multiple proton-proton collisions at the same time

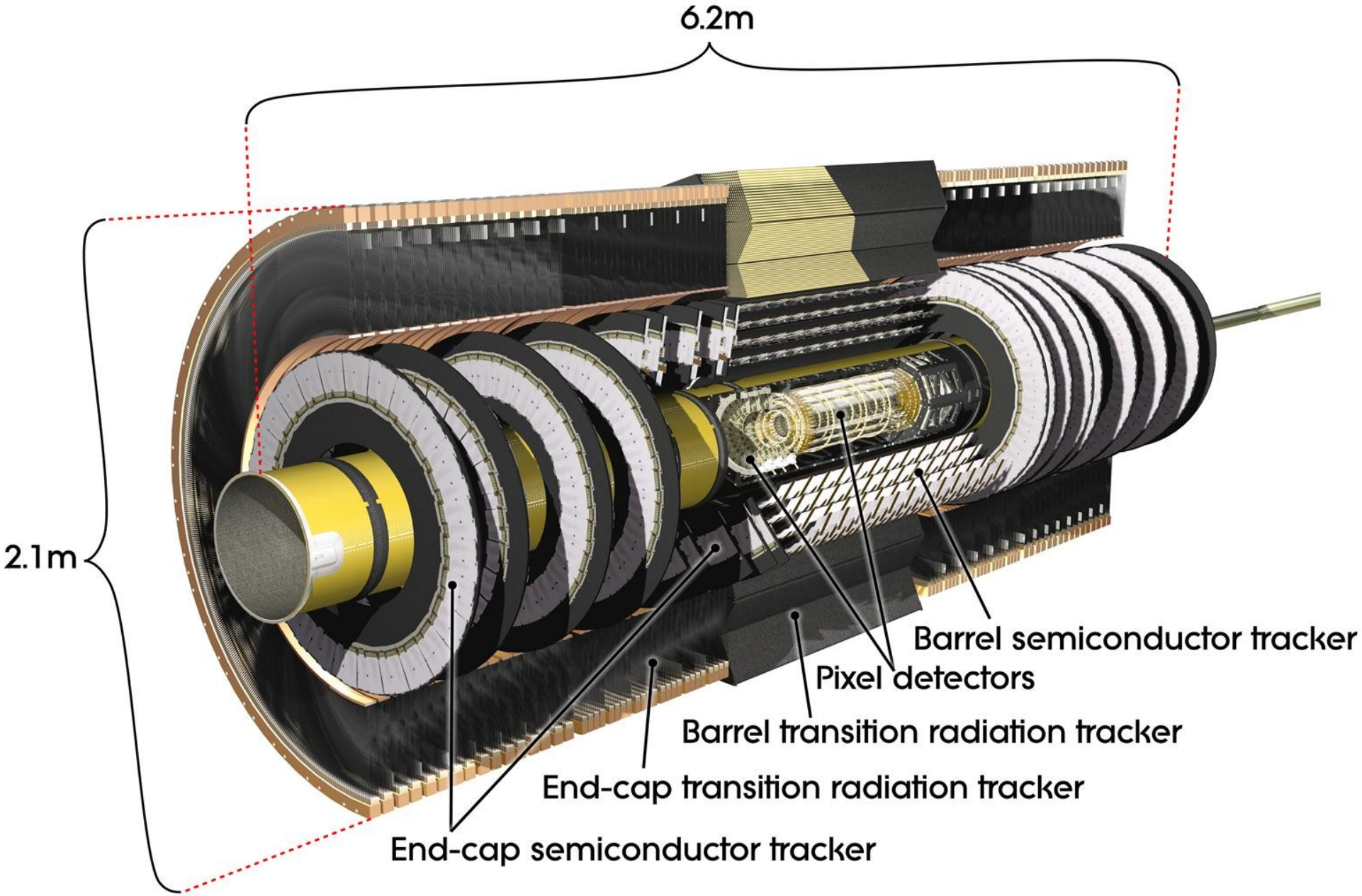
- In 2012: up to 40 simultaneous interactions
- Need precise tracking information to reject this
- soft interactions usually low energetic



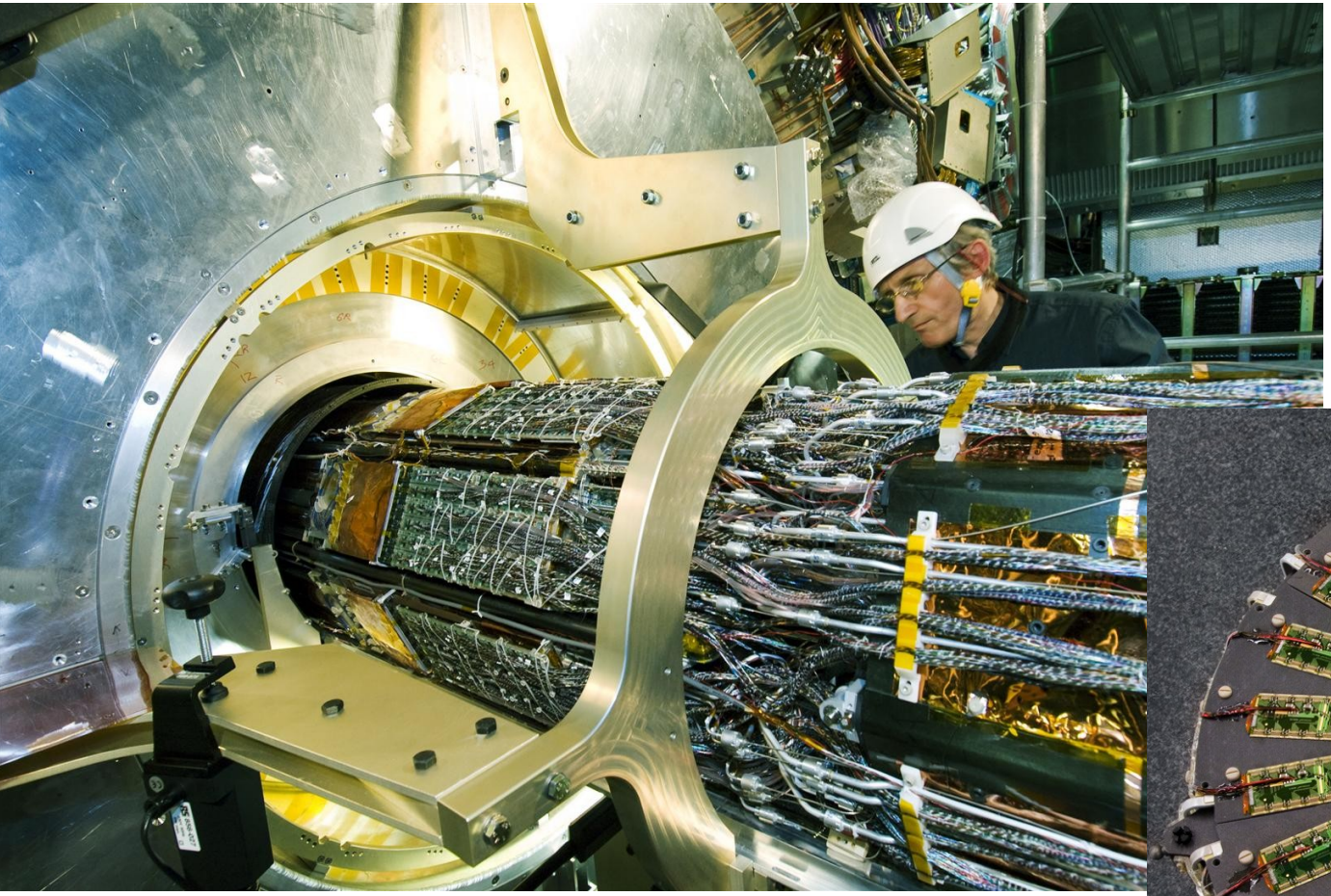
Finding the Higgs

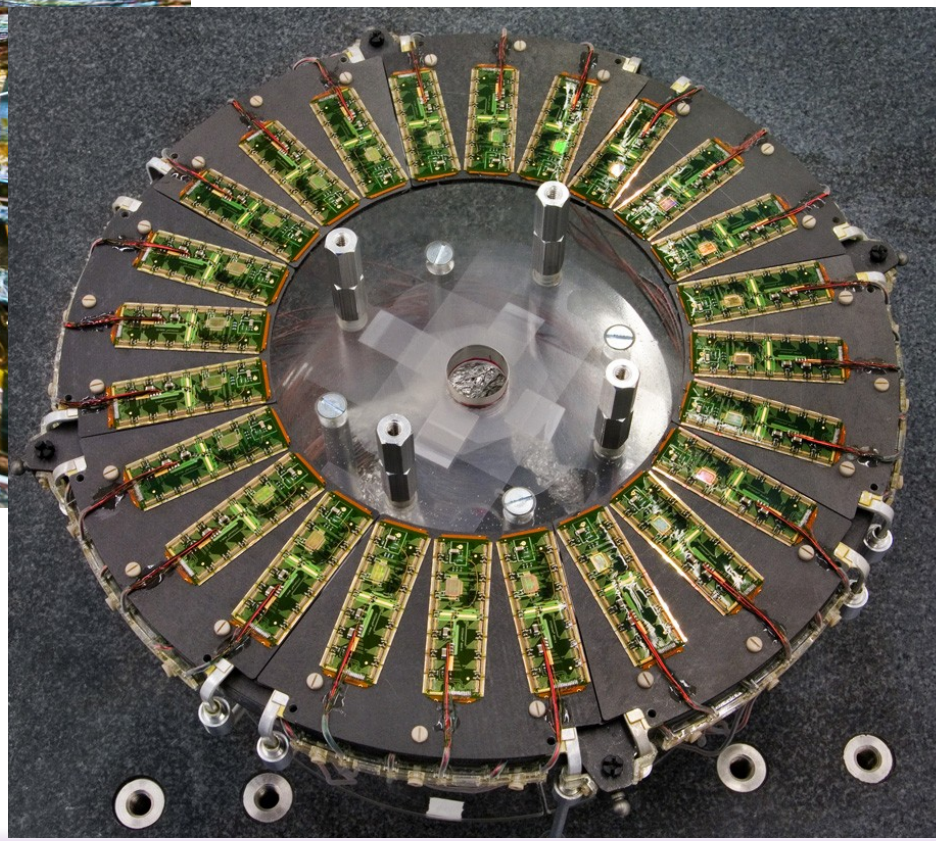


Inner Detector

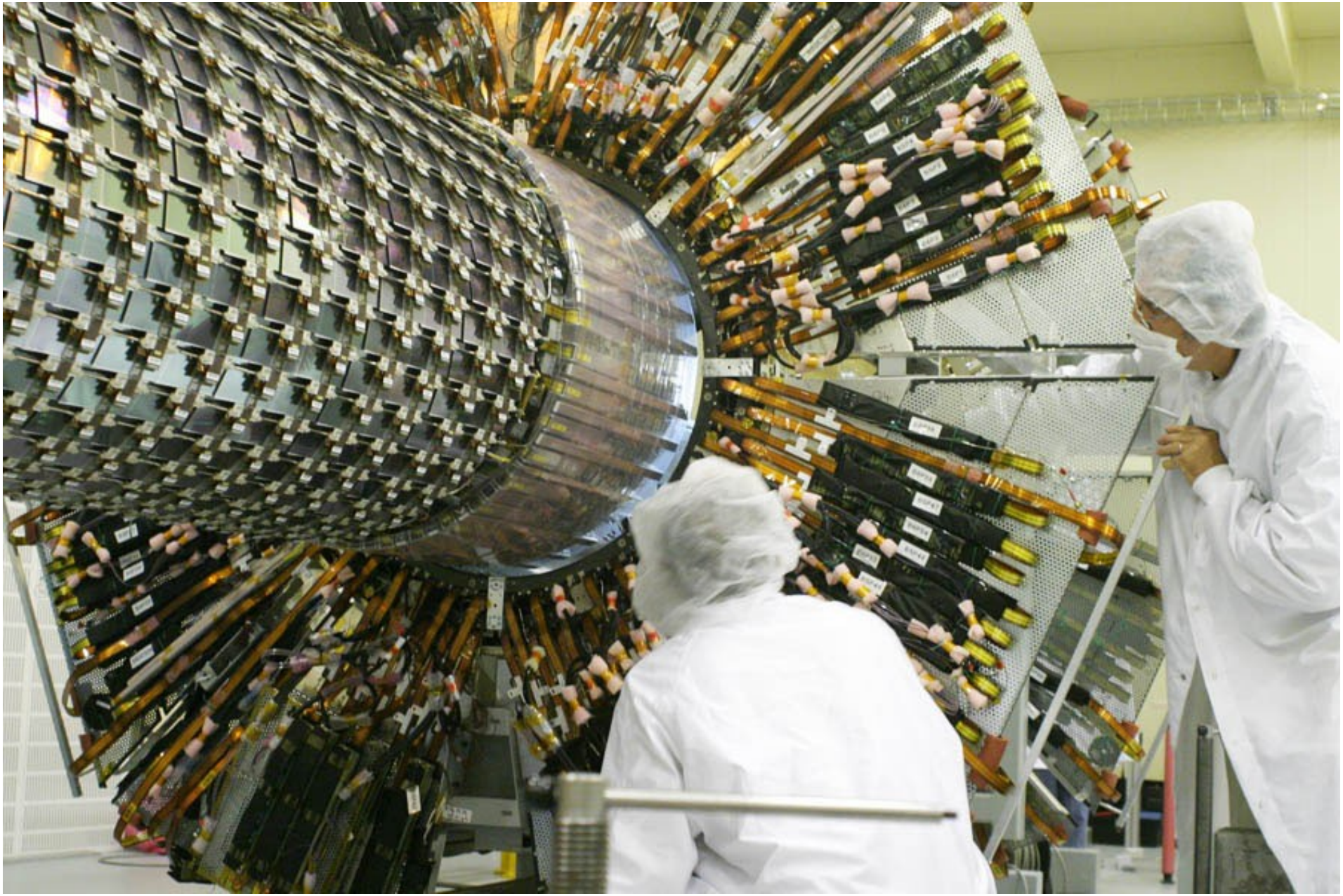


Pixel Detector





SemiConductor Tracker



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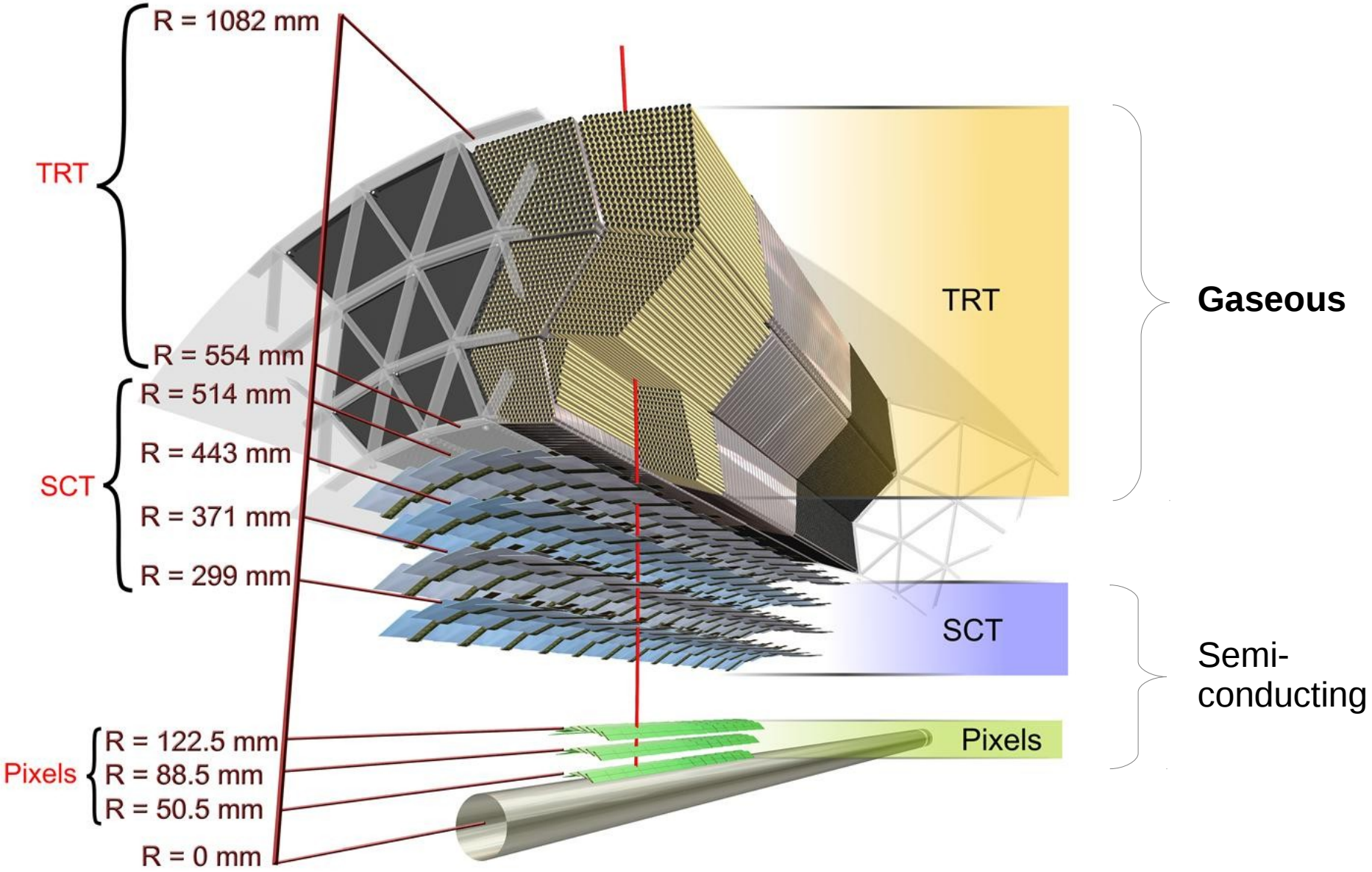
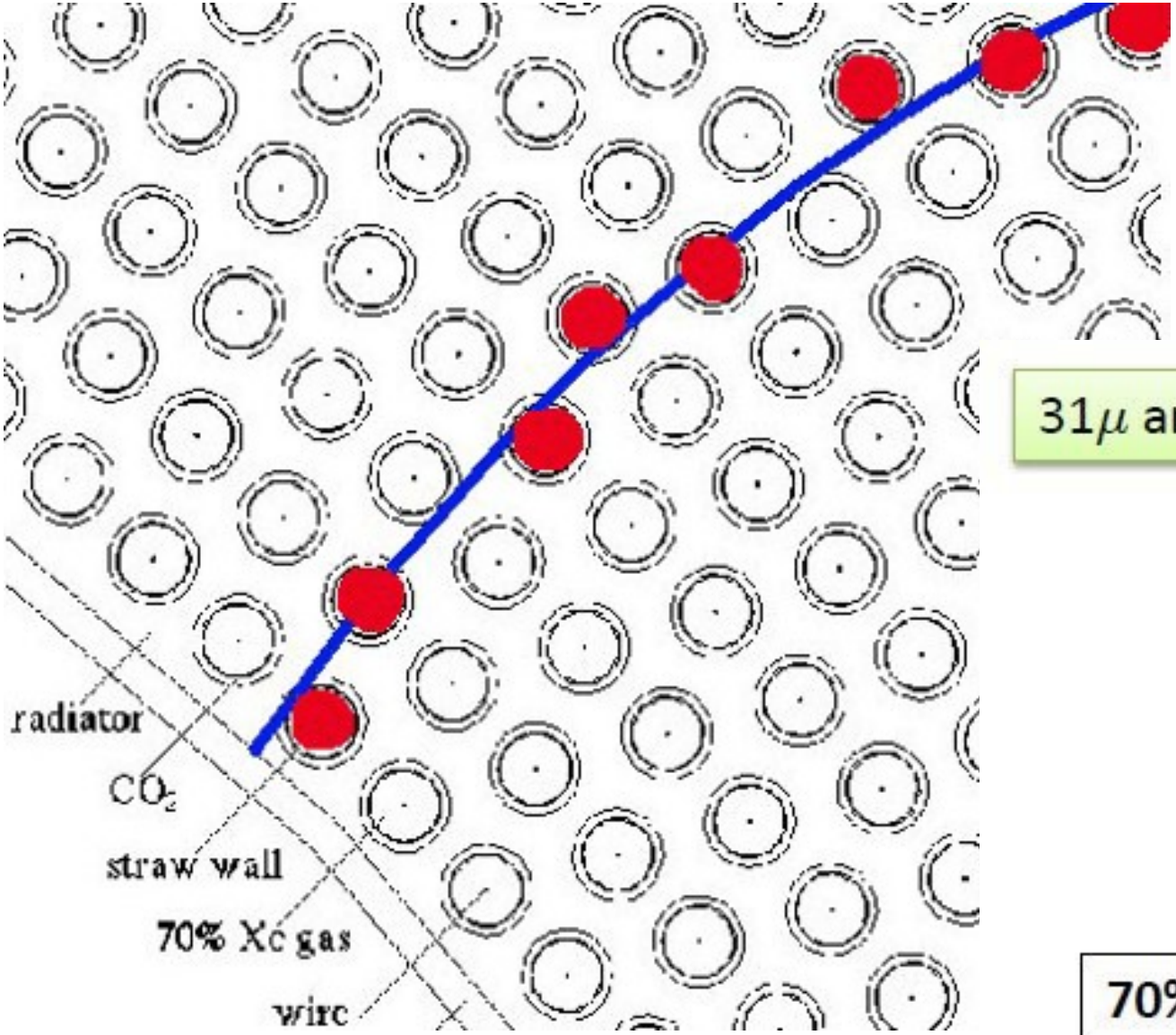
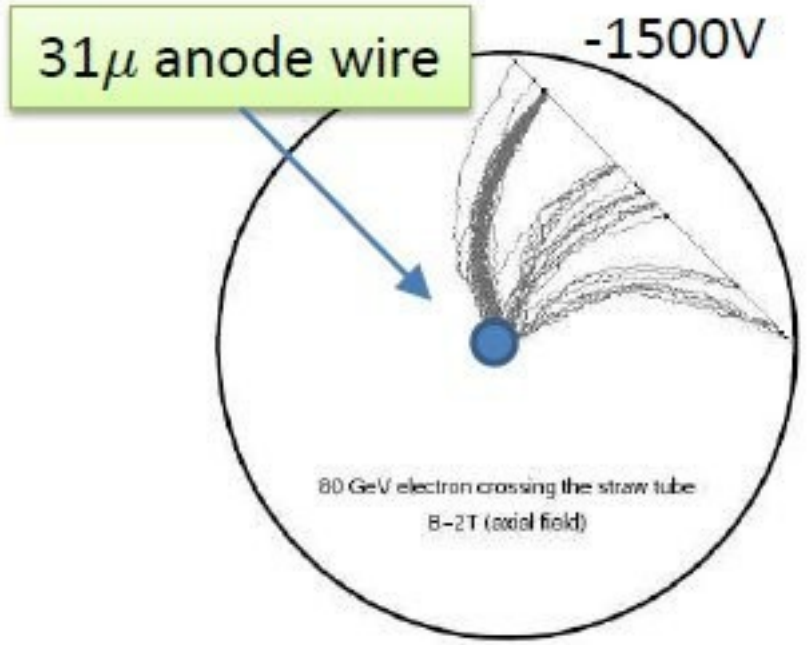


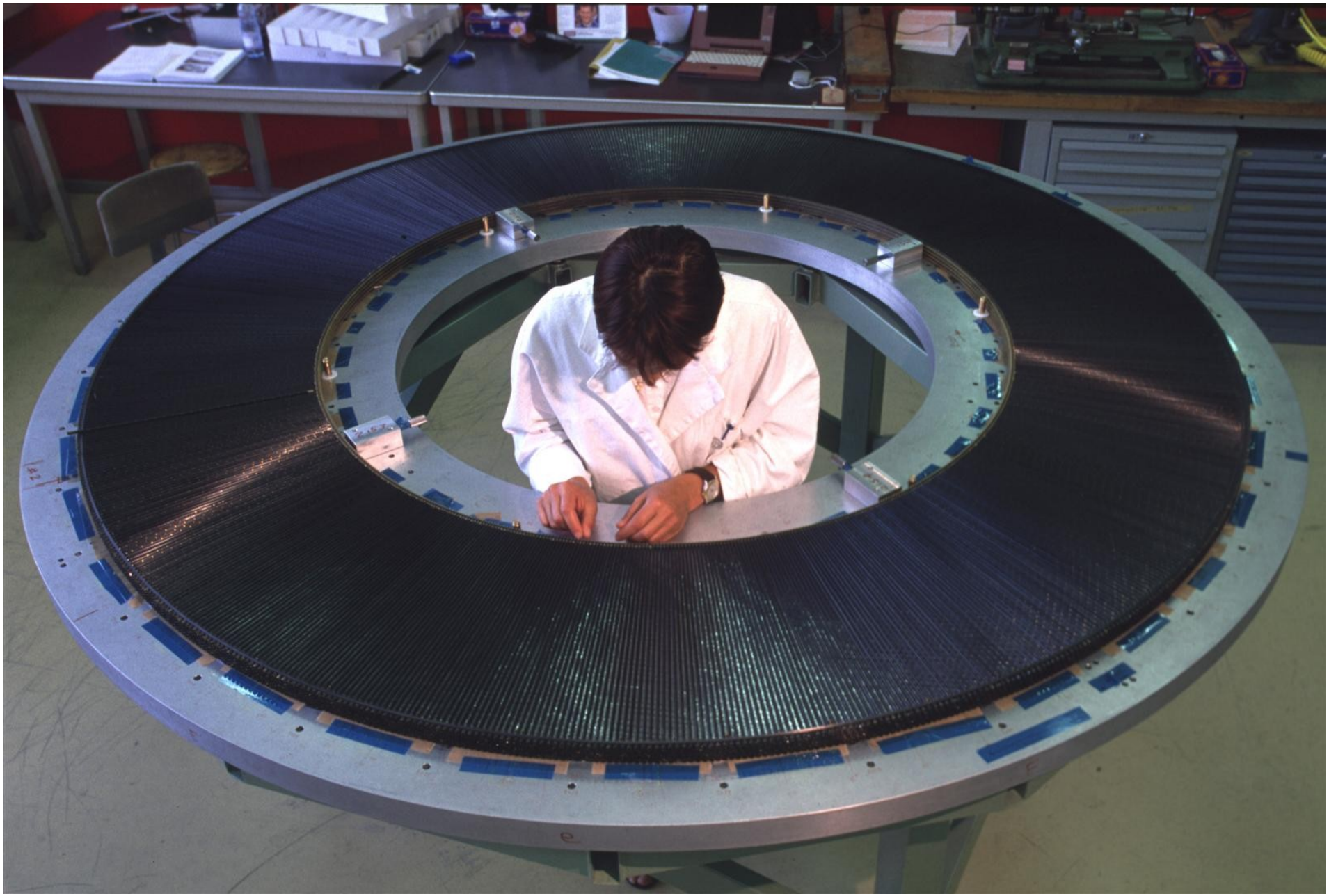
Transition Radiation Tracker

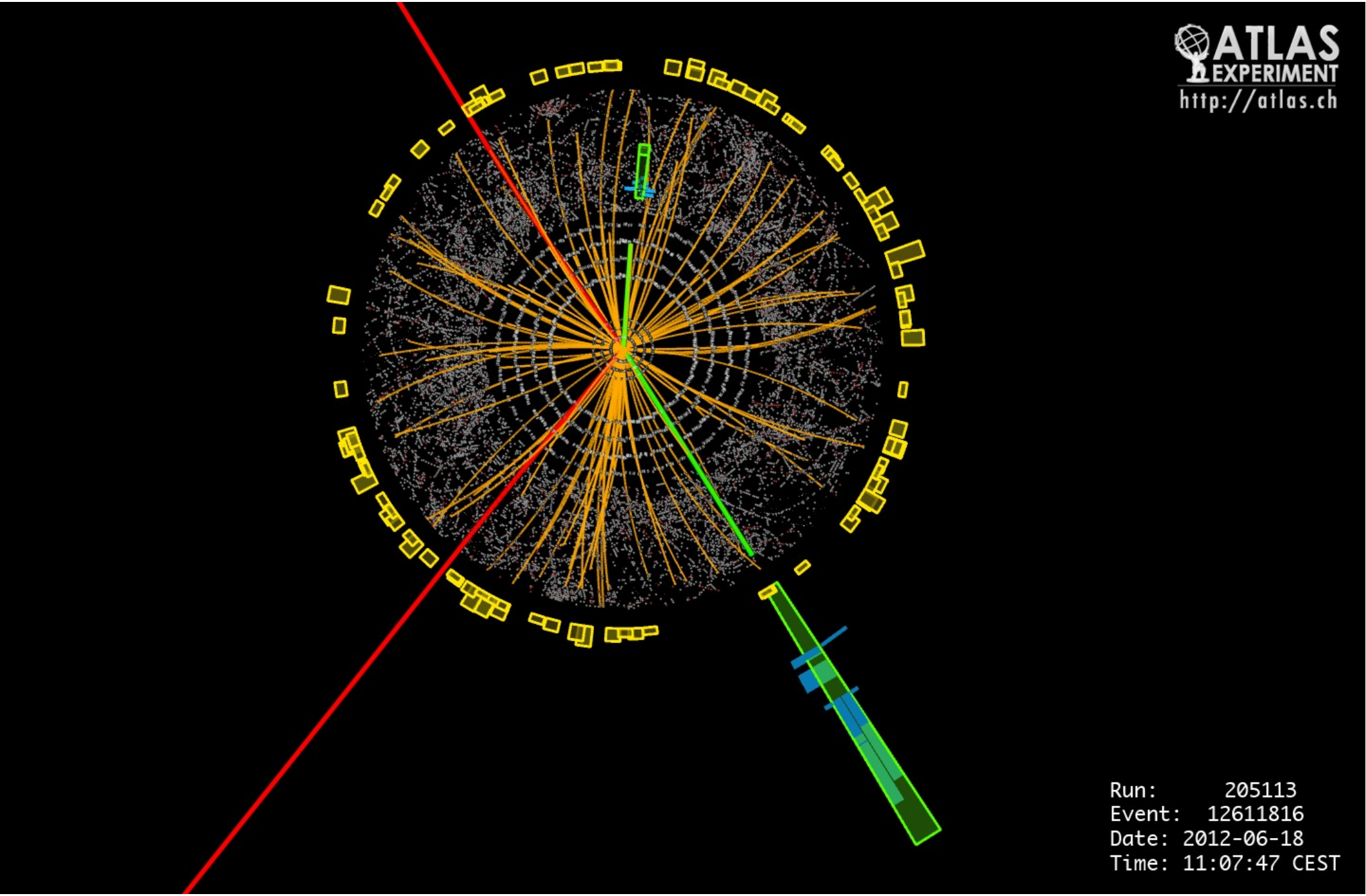




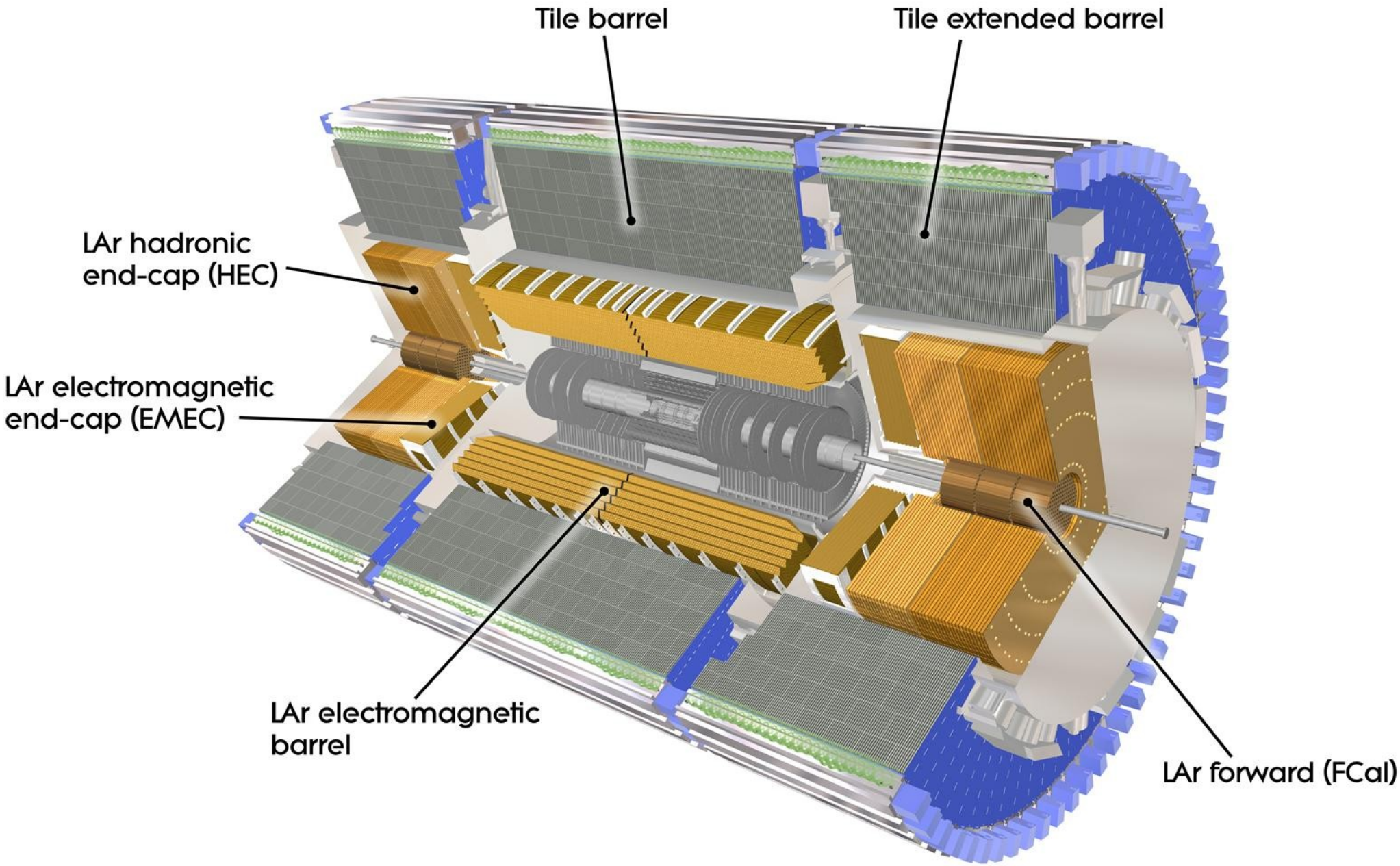
70% Xe, 27% CO_2, 3% O_2

Transition Radiation Tracker

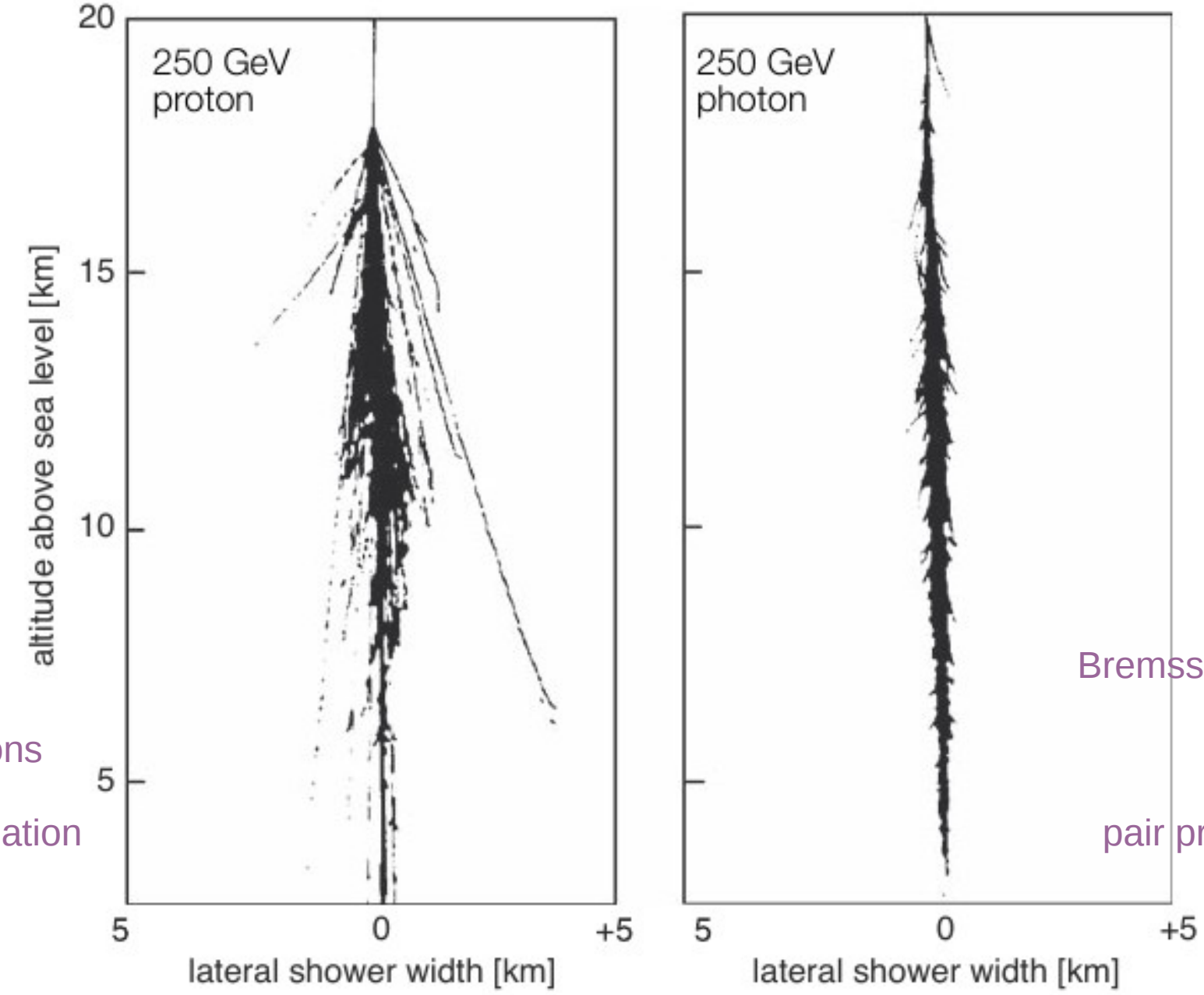



ATLAS
EXPERIMENT
http://atlas.ch
Run: 205113
Event: 12611816
Date: 2012-06-18
Time: 11:07:47 CEST

Calorimeters



Two Calorimeter Types



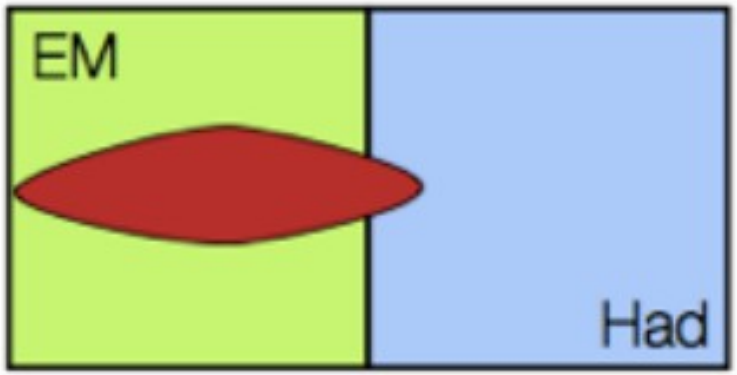
Nuclear interactions and ionisation

Bremsstrahlung and pair production

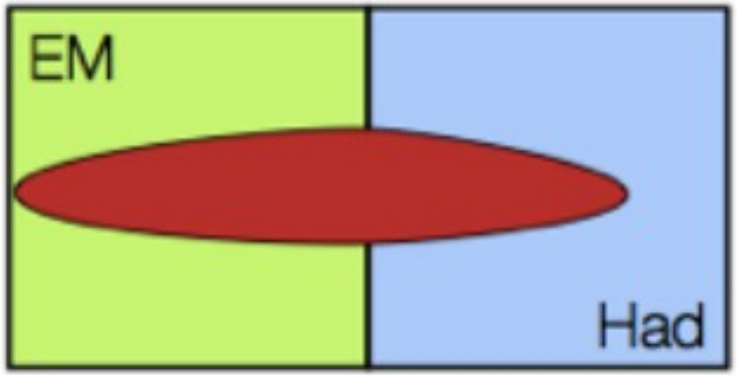
Two Calorimeter Types

Particles in ...

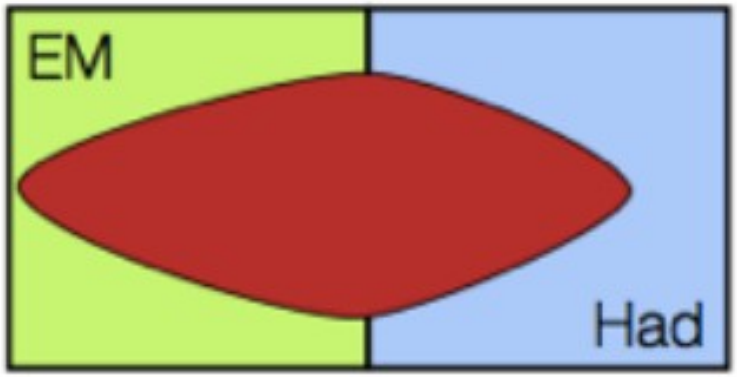
Electrons
Photons



Taus
Hadrons



Jets

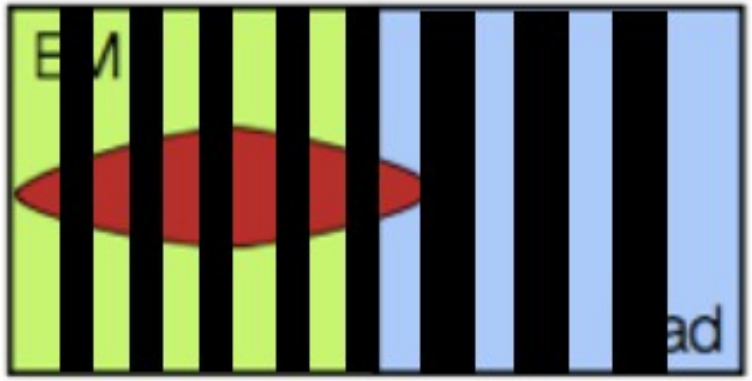


no particles out!

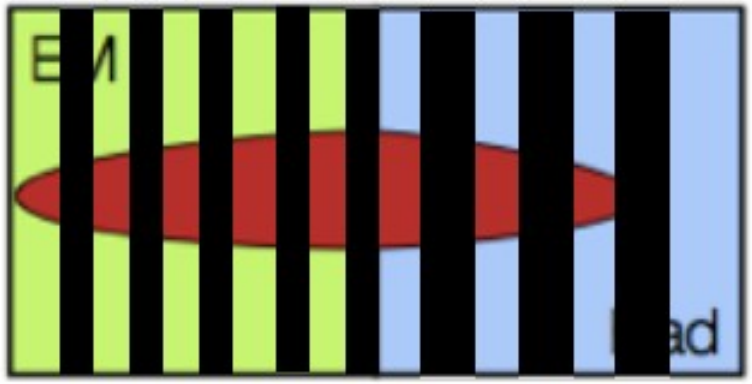
Sampling Calorimeters

Particles in ...

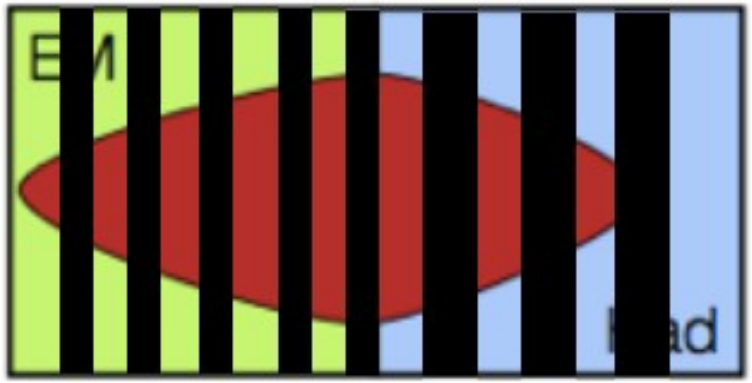
Electrons
Photons



Taus
Hadrons

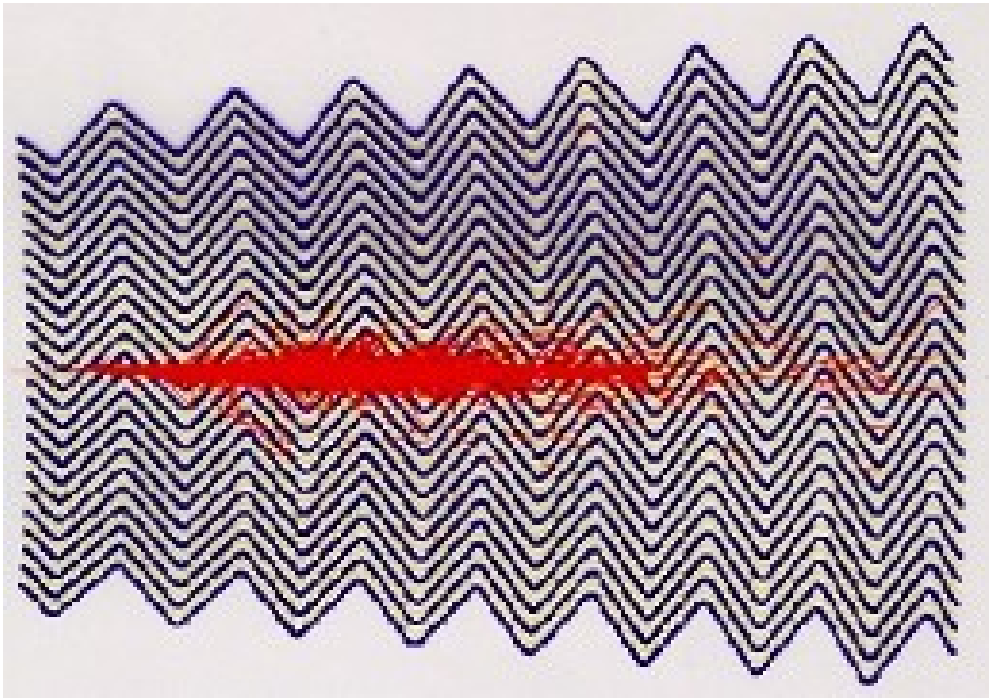


Jets

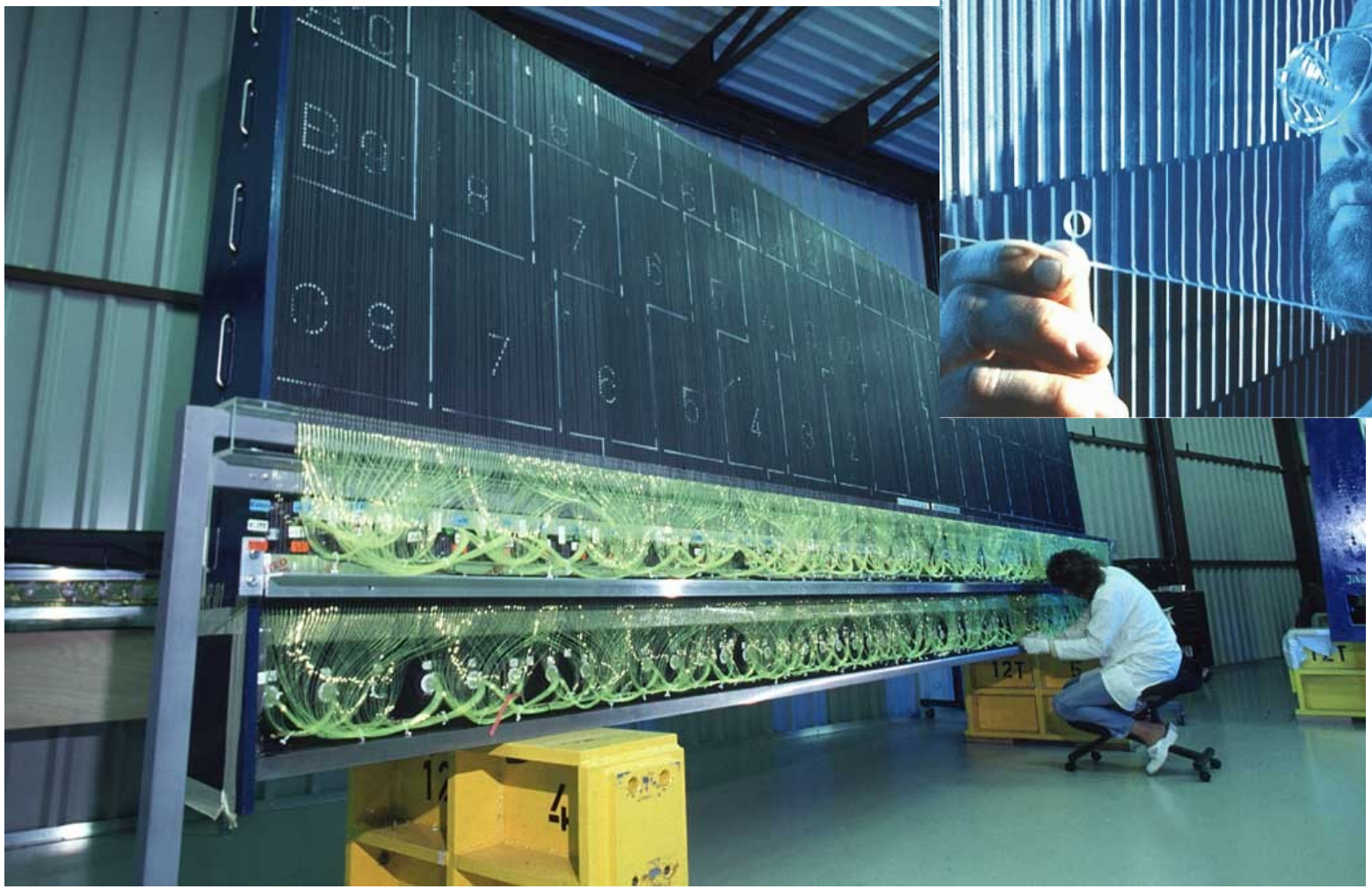


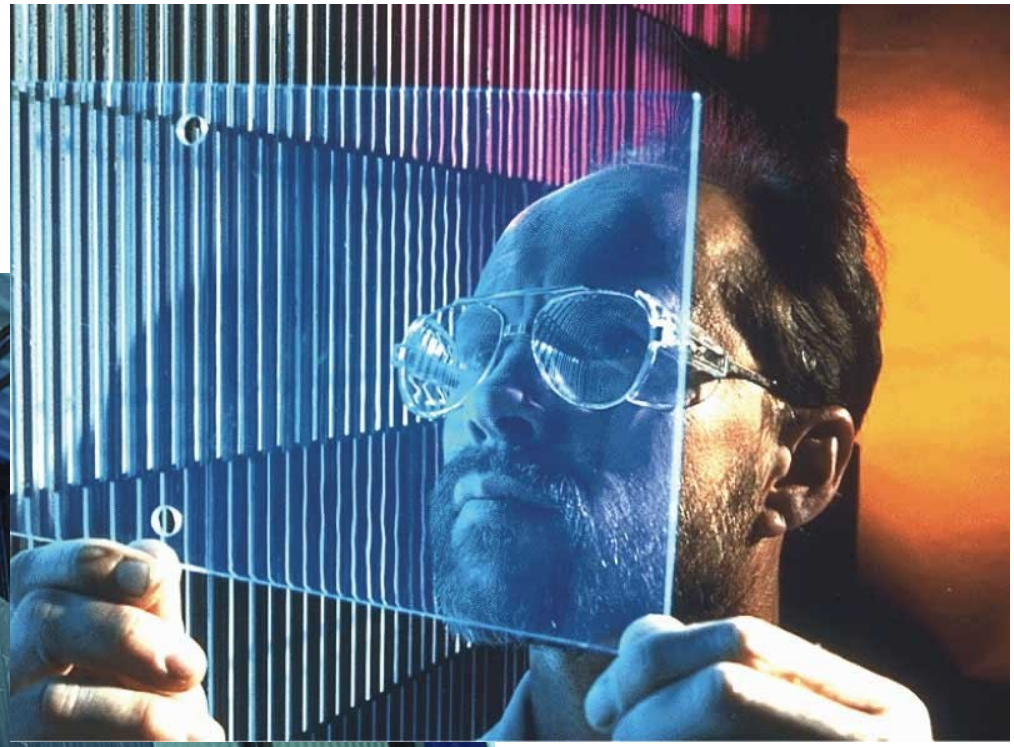
no particles out!

Electromagnetic Calorimeter



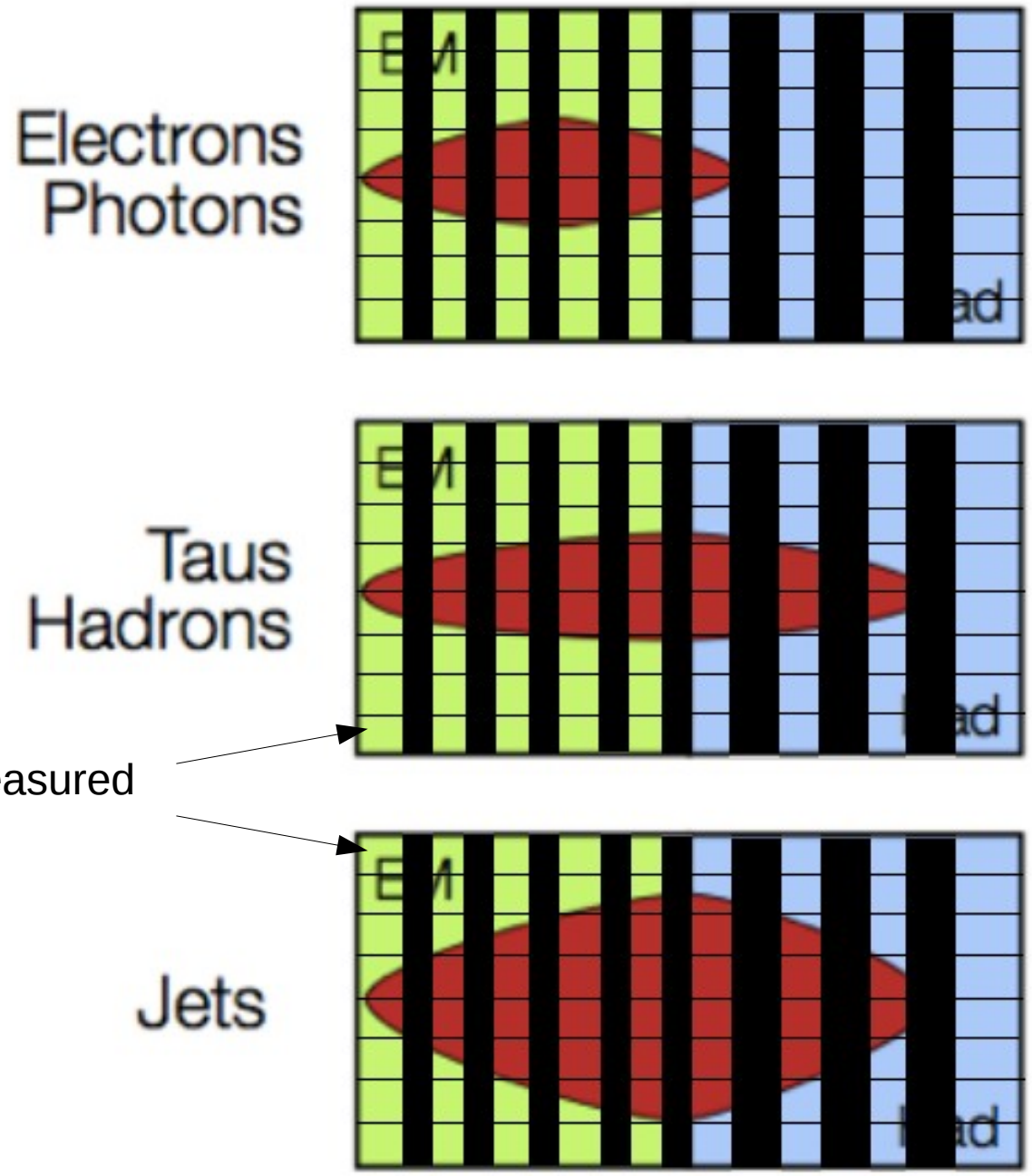
Hadronic Calorimeter





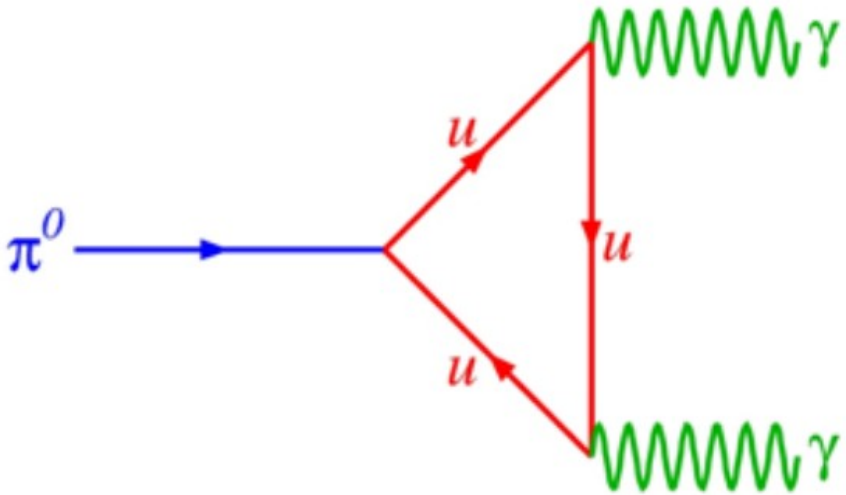
Granularity

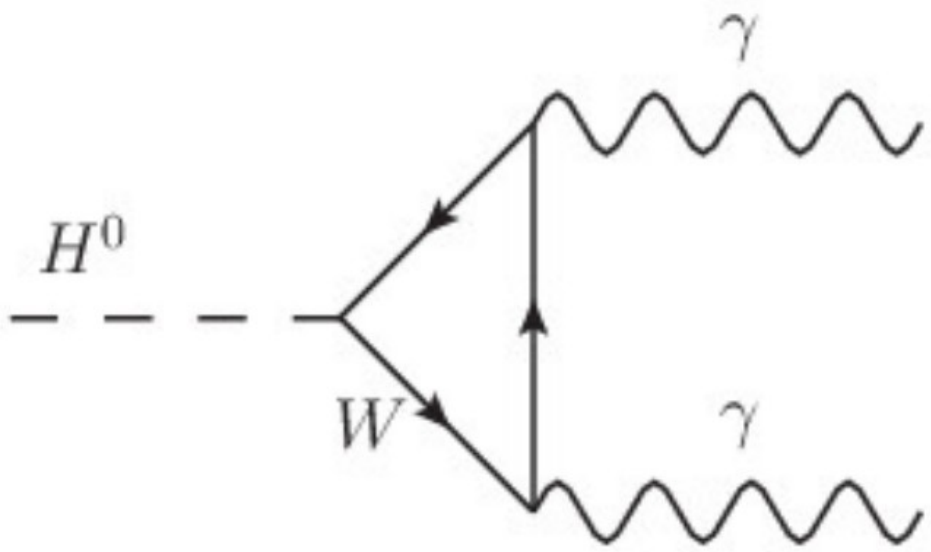
Particles in ...

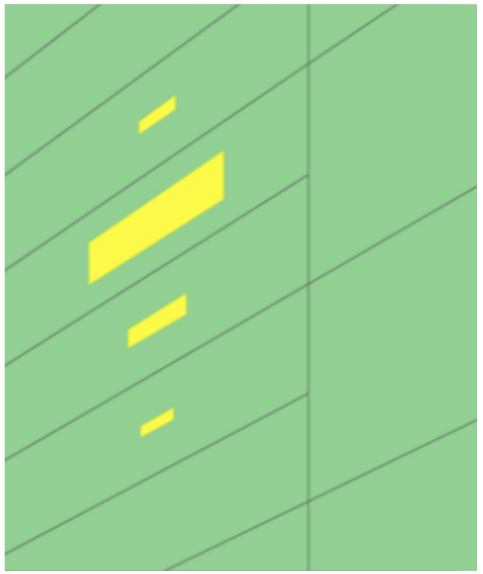


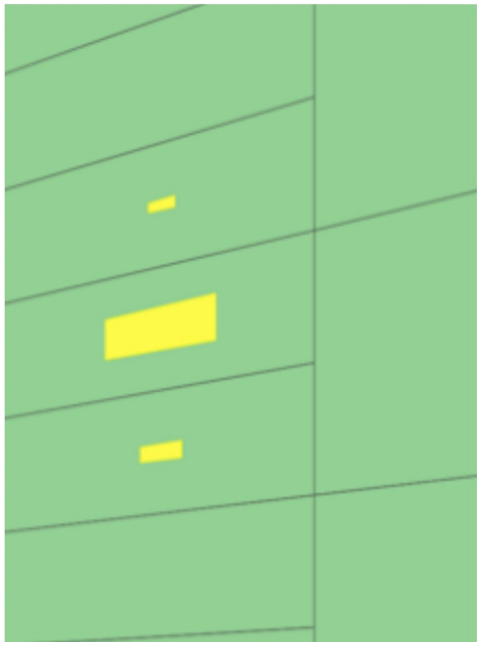
no particles out!

Granularity

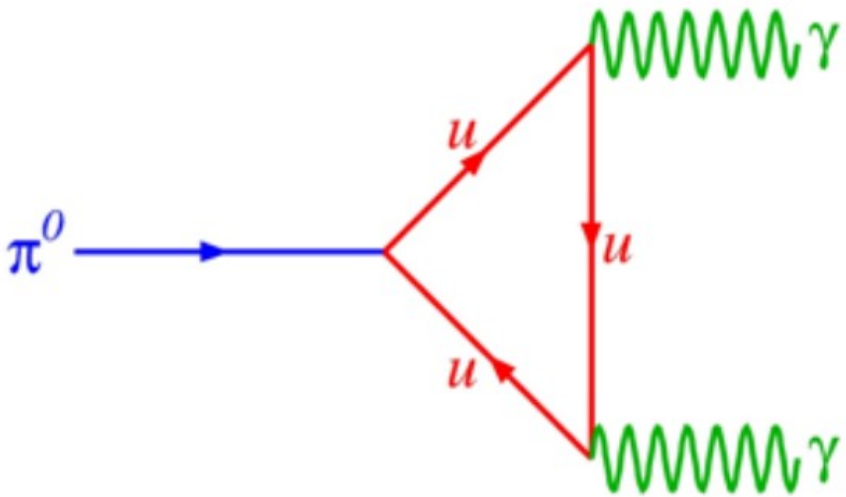


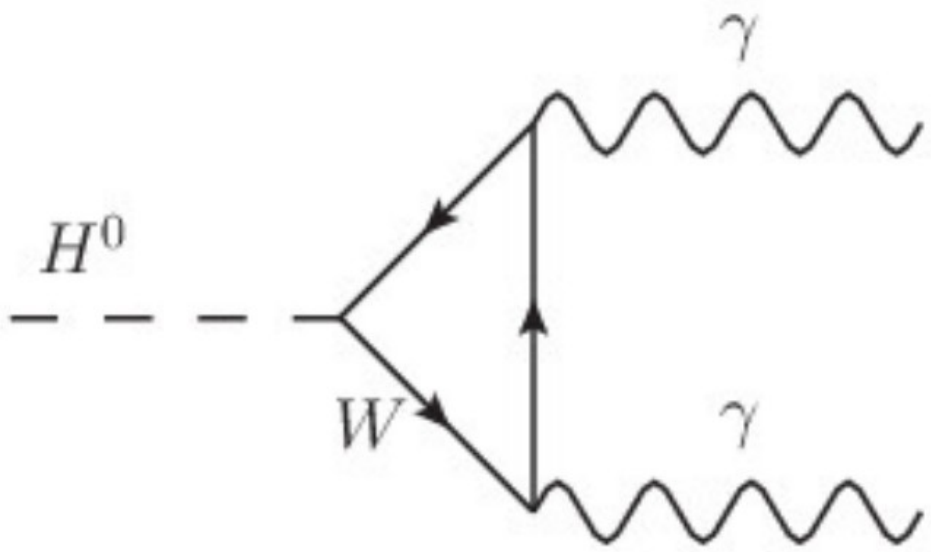


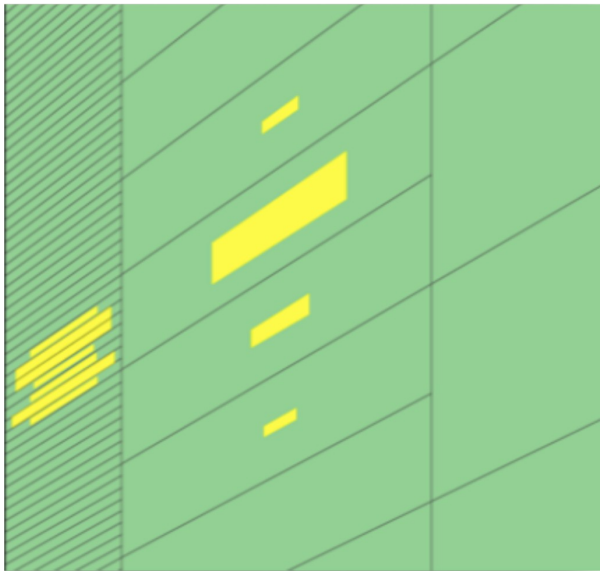


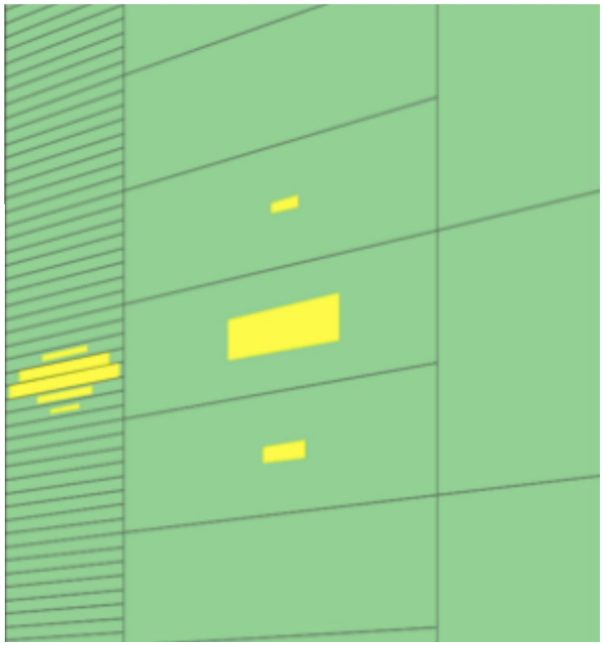


Granularity

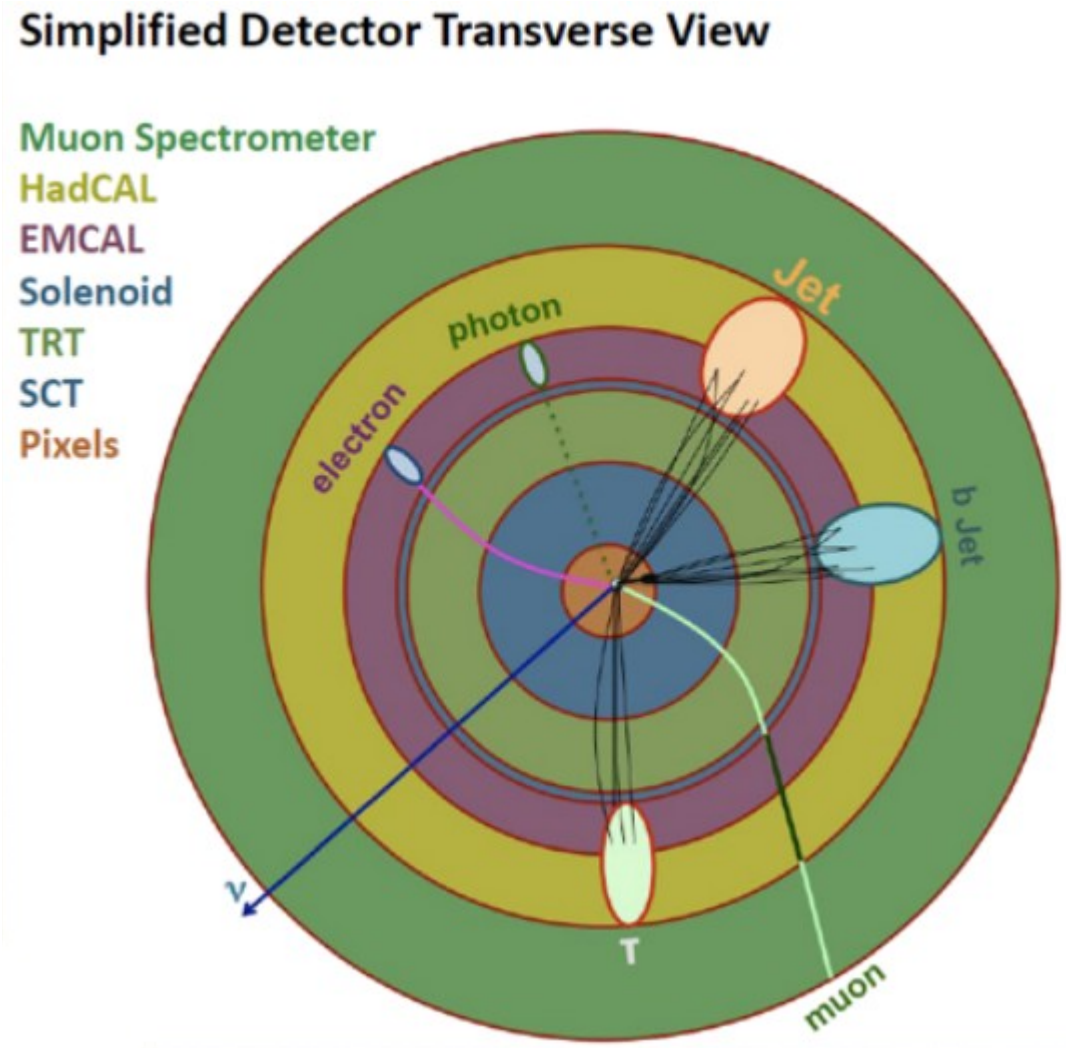








Energy Imbalance



Neutrinos don't interact with detector

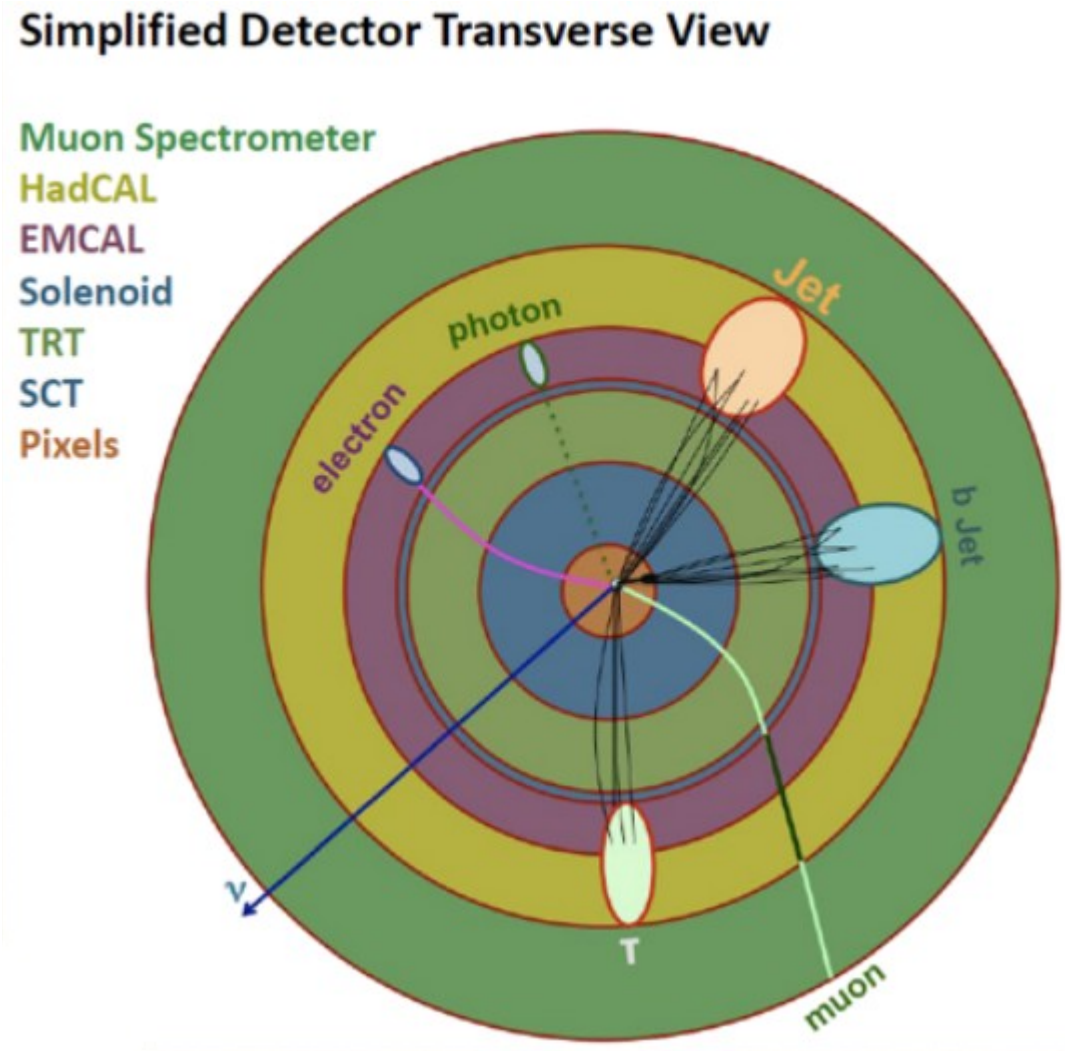
→ impossible to fully reconstruct processes containing neutrinos e.g. leptonic W decay or Z →υυ (without knowledge about intital state)

But: energy and momentum are conserved

→ escaping particle would manifest by momentum imbalance: missing transverse energy E_T^{miss}

→ important to have full φ coverage

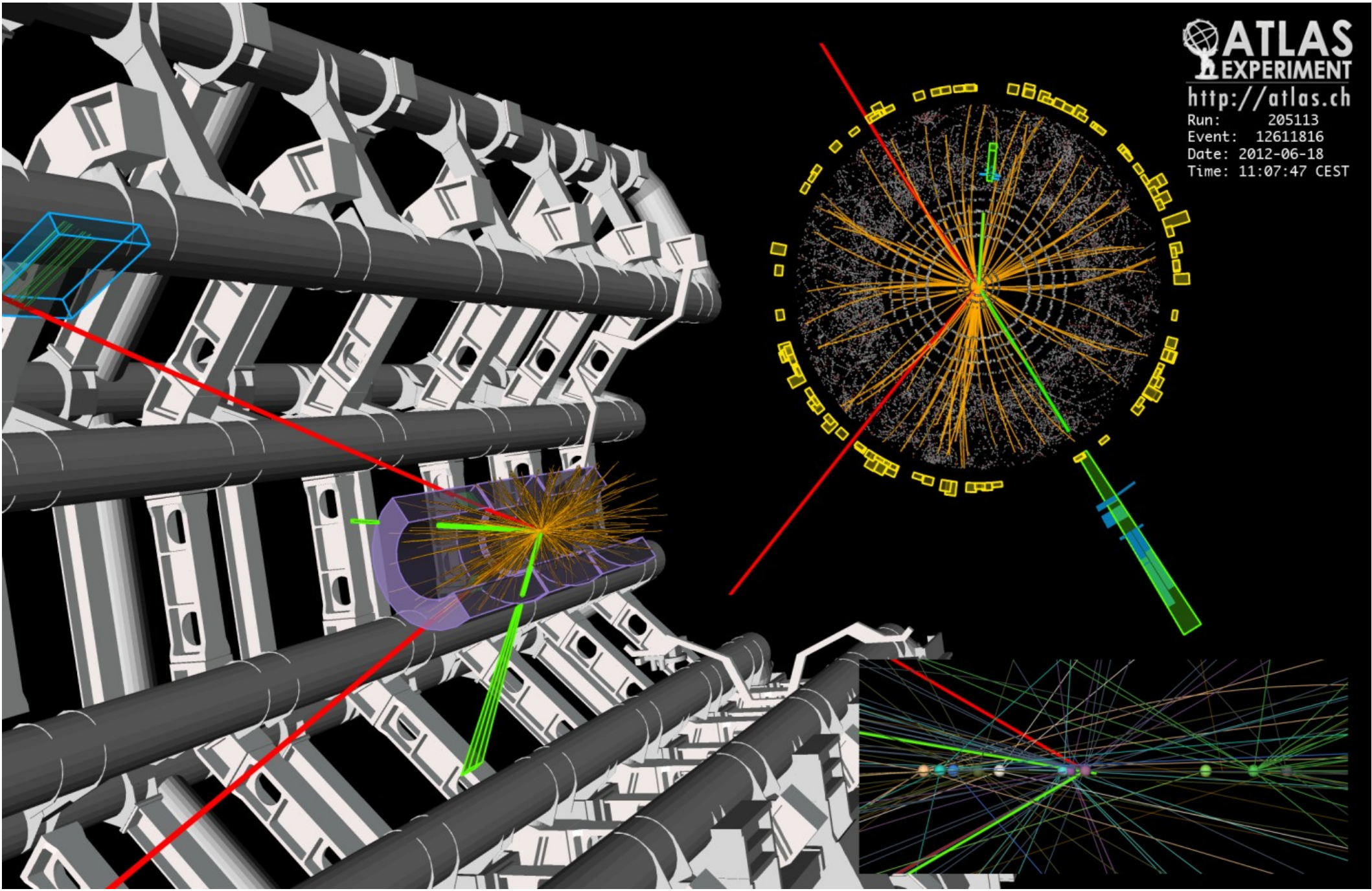
Energy Imbalance



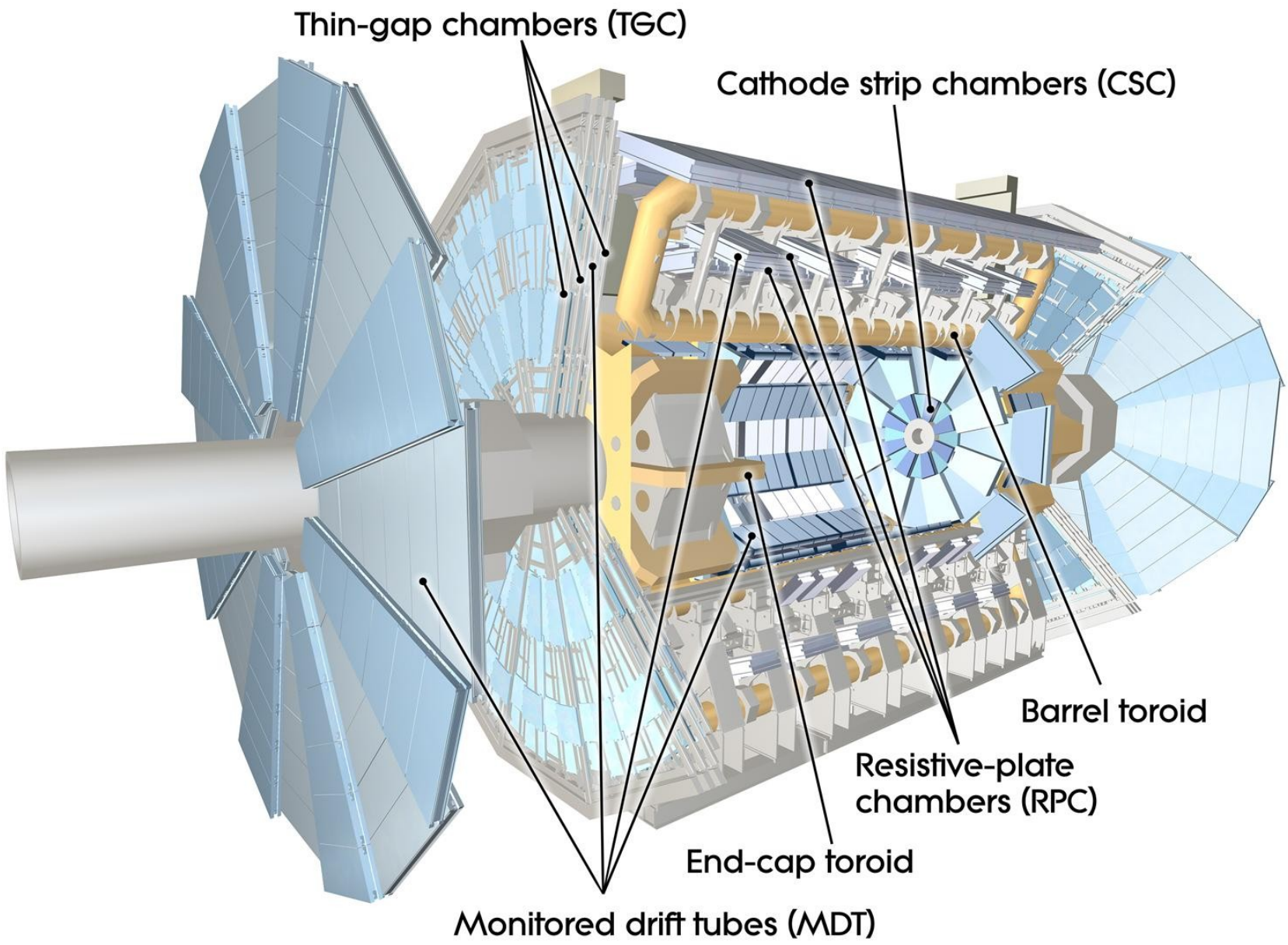
E_T^{miss} computed by:

- summing all energy deposits from calibrated objects vectorially
- adding muons
- adding unmatched calorimeter clusters

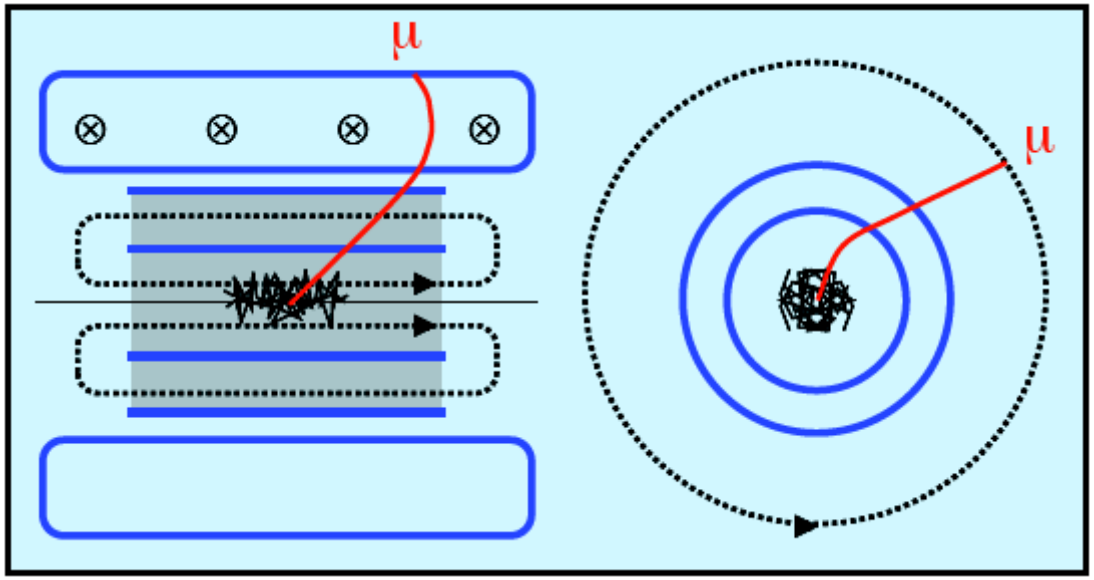
- $E_T^{miss} = |\vec{E}_T^{miss}|$

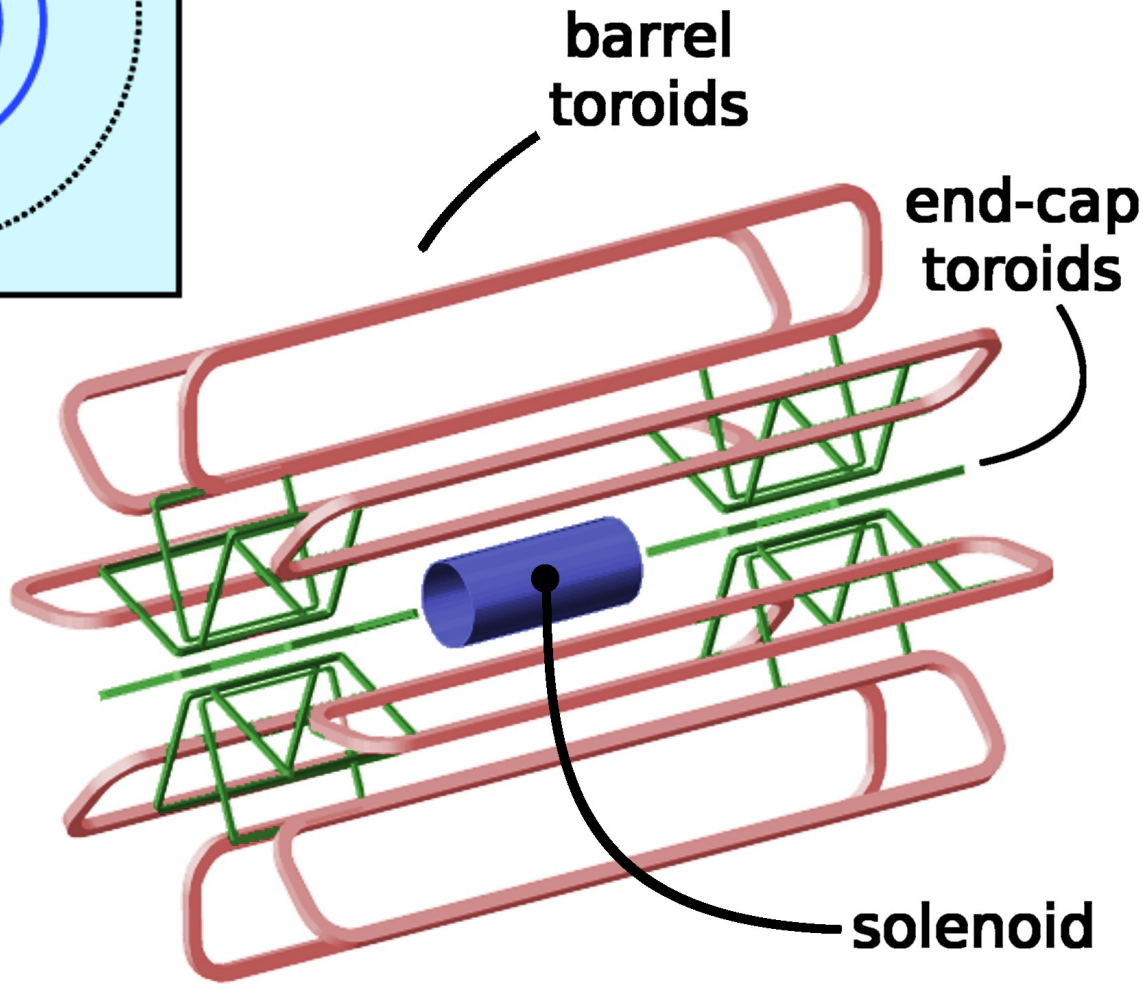

ATLAS
EXPERIMENT
http://atlas.ch
Run: 205113
Event: 12611816
Date: 2012-06-18
Time: 11:07:47 CEST

Muon System


Thin-gap chambers (TGC)
Cathode strip chambers (CSC)
Barrel toroid
Resistive-plate chambers (RPC)
End-cap toroid
Monitored drift tubes (MDT)

Magnets



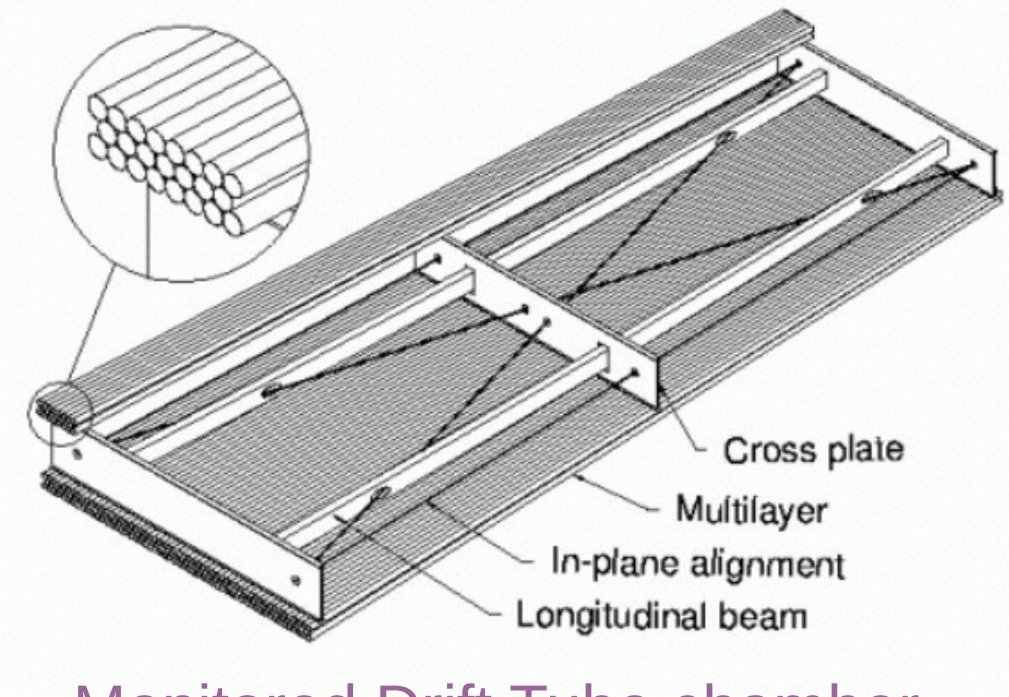


Needed for

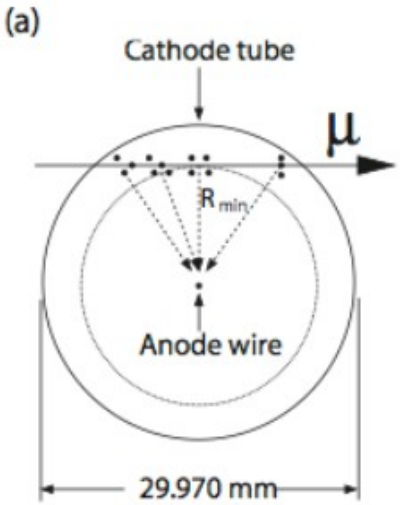
momentum

measurement

Muon Spectrometer

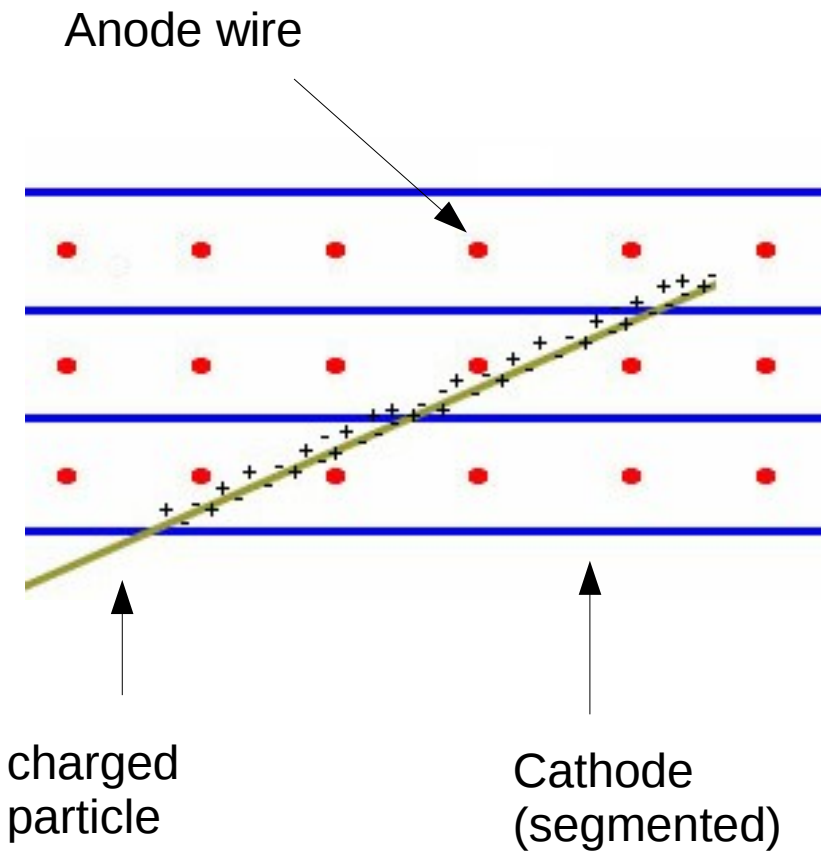


Monitored Drift Tube chamber

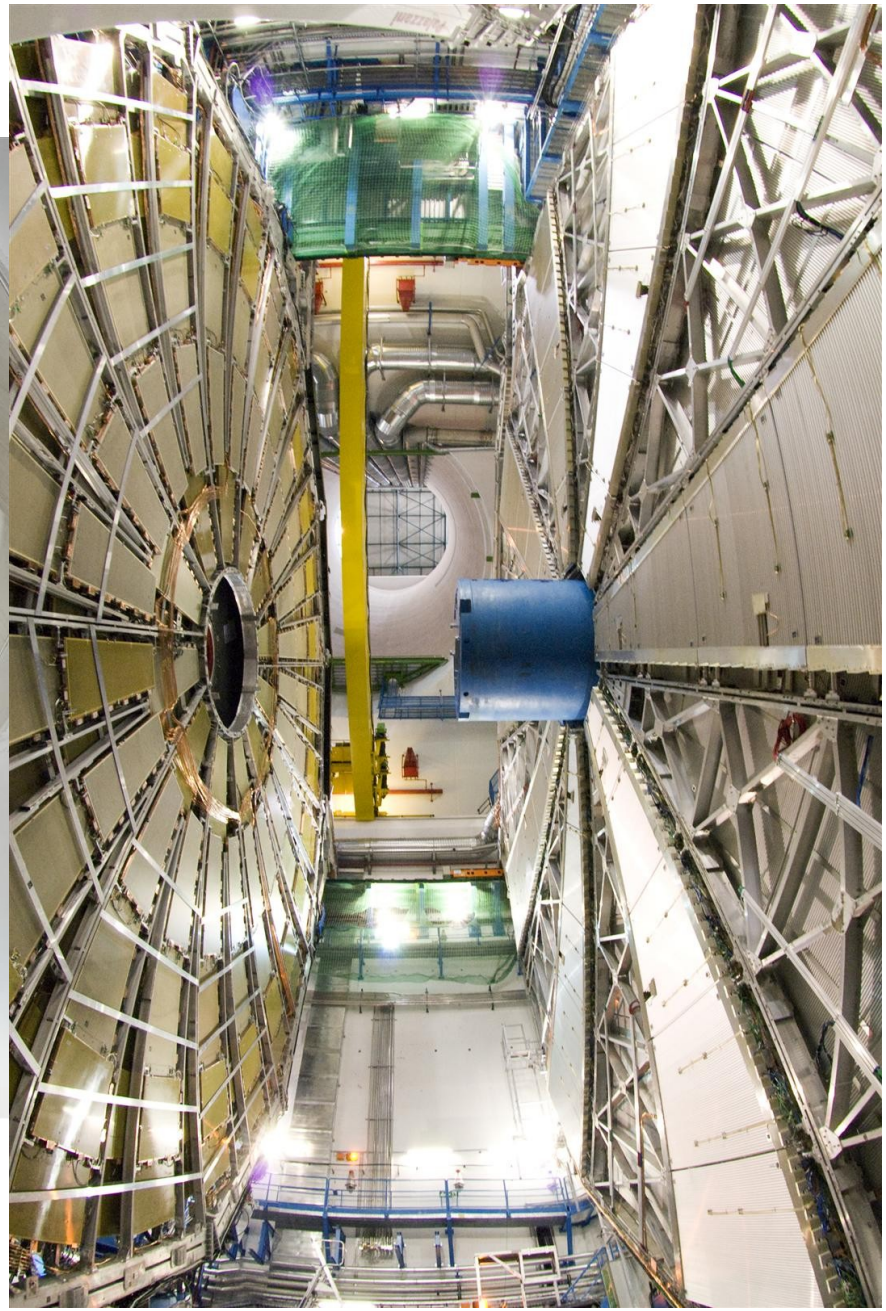


Cathode Strip Chambers

using the principle of multi-wire proportional chamber



Muon Spectrometer



Summary

- ATLAS is a multi purpose particle detector
  - → measure Higgs in all channels
  - → searching for BSM particles
- various technologies used in order to precisely identify particles and measure their properties
- In operation since 2010
  - results for $\sqrt{s}$ = 2.76 TeV, 7 TeV and 8 TeV

Next week: Trigger - Which events are we recording?

Thank you!