Detector Basics

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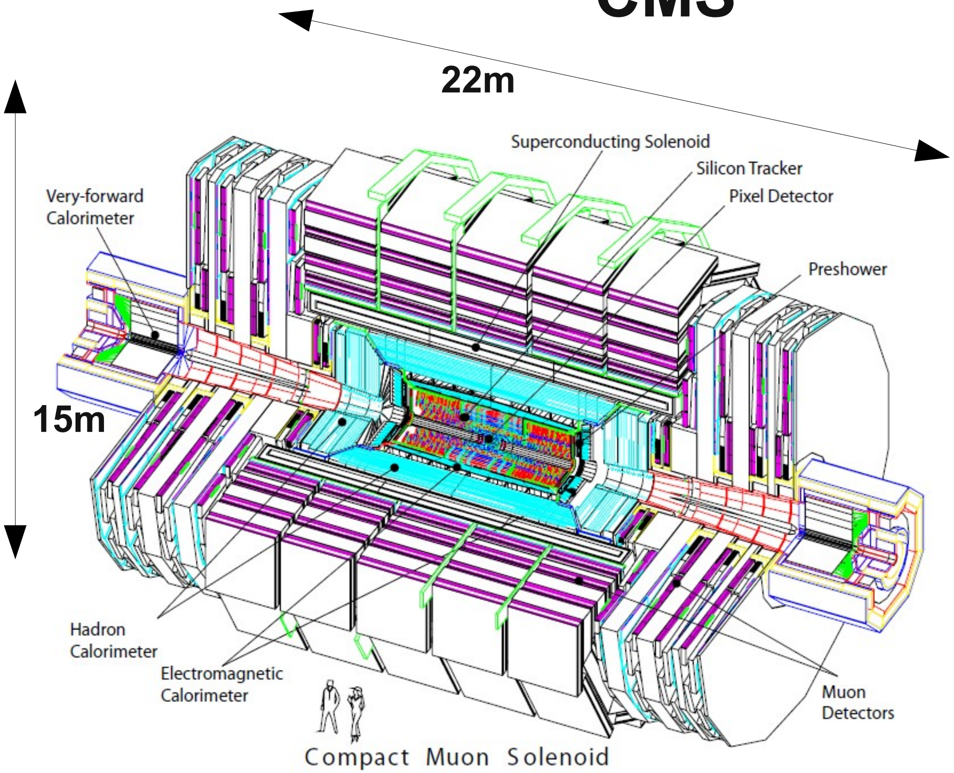
(Contributions from G.Y. Jeng(CMS) and E.F. Torregrosa(ATLAS))

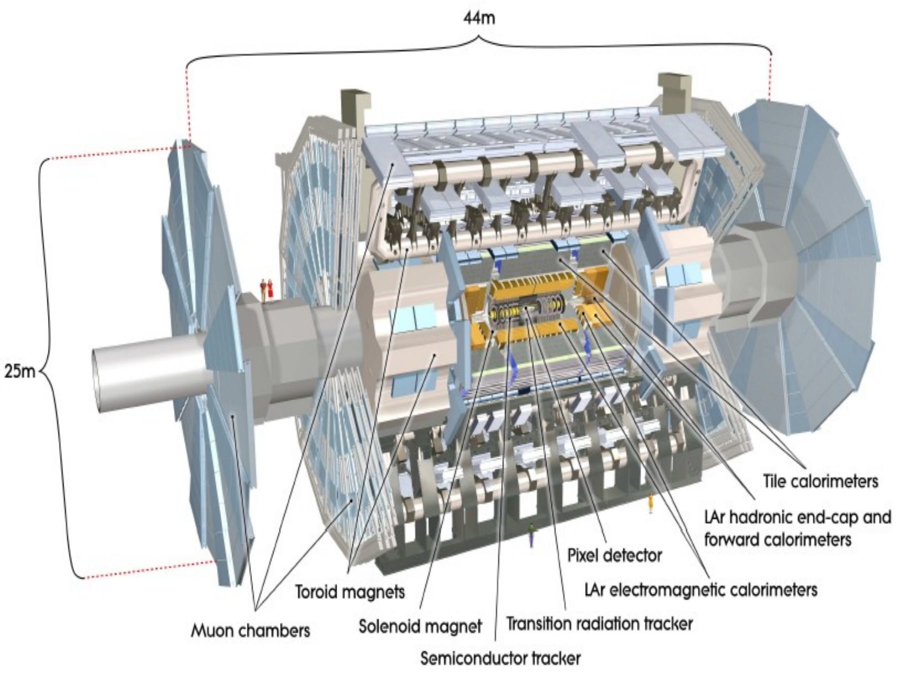
http://jinst.sissa.it/LHC/

General Purpose LHC Detectors

CMS



ATLAS

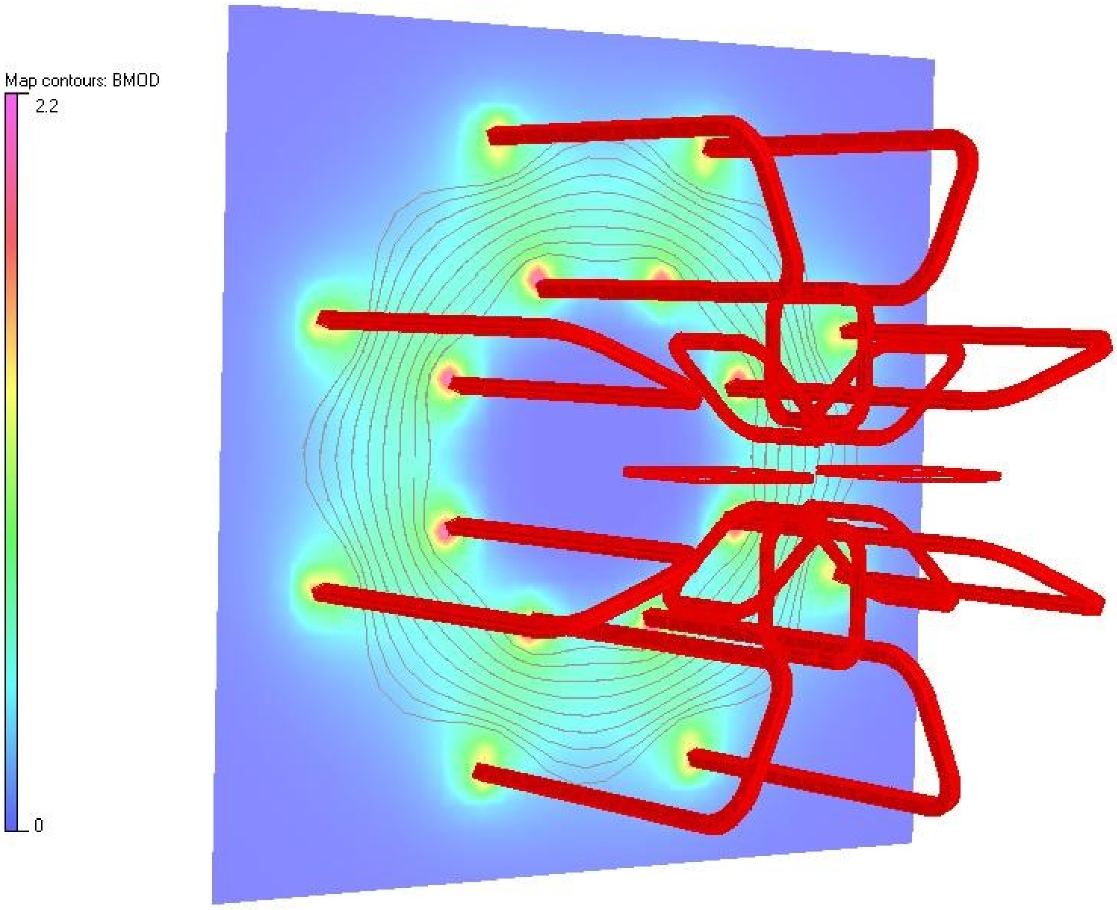


Why x2 different size?

(A Toroidal LHC ApparatuS)

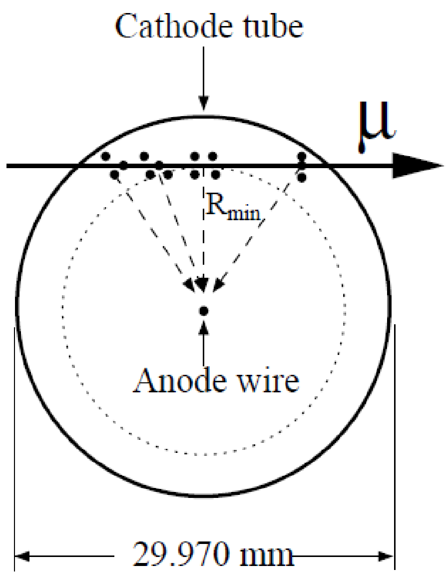
Choices...

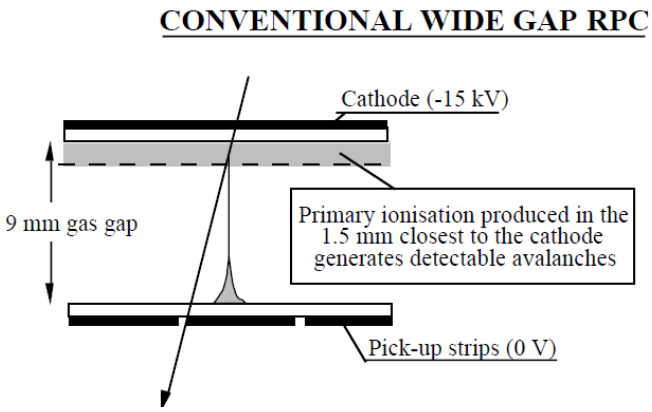
- Size difference mainly due to ATLAS Muon Toroid System.
- ATLAS priority to measure 1 TeV muons to ~10%, independent of inner detector and muon angle.
- CMS standalone measurement is 15-40% depending on angle, but both detectors measure to ~5% using inner+outer detectors.

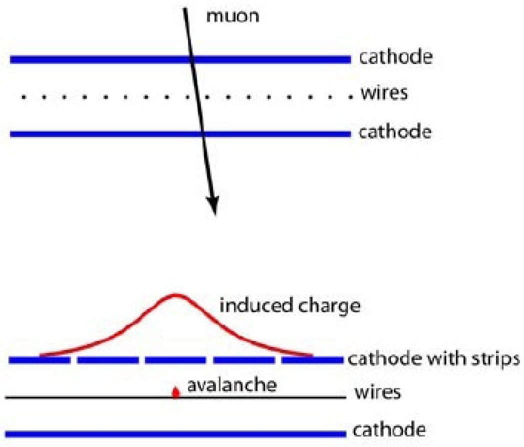


ATLAS Toroid Coils and Outer B Field

Muon Detectors







Drift Tubes

- Cheap, Robust, ~10K m^2
- 400-750ns drift time
- MDT = ATLAS
- DT = CMS

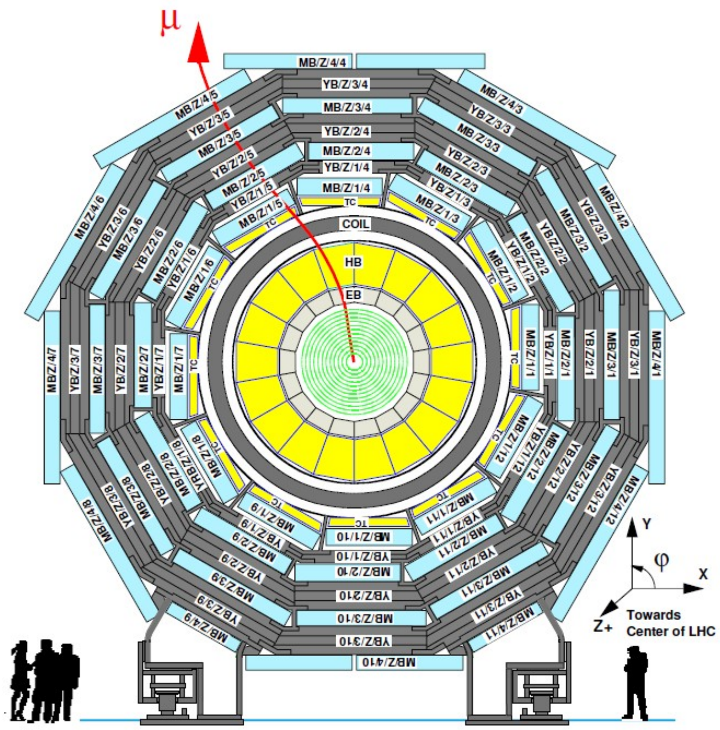
Resistive Plate Chambers

- Fast enough for L1 Trigger
- Determine Beam Crossing
- Reduce random backgrounds
- Single gap or Multi-Gap, ~4K m^2
- RPC = ATLAS, CMS

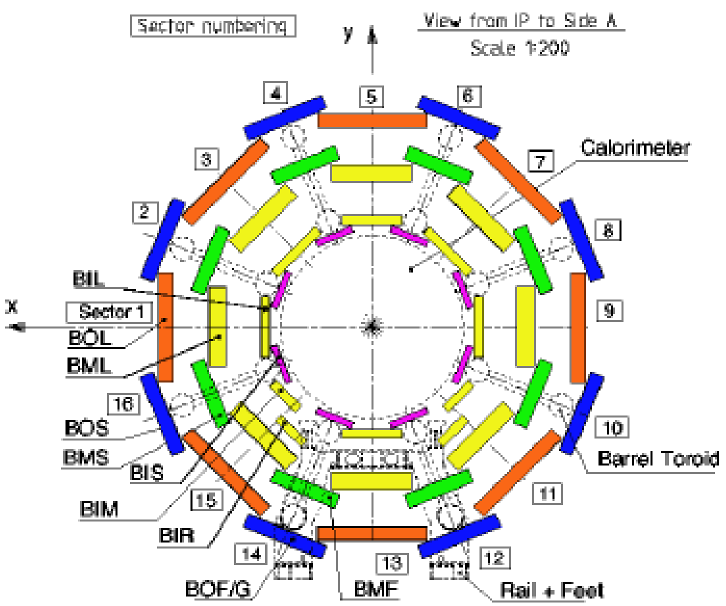
Multi-wire Proportional Chambers

- Cheap, Robust, ~6K m^2
- <10 mm gaps, 2D position
- CSC = ATLAS, CMS
- TGC = ATLAS, very thin for timing

Muon Barrel Geometries

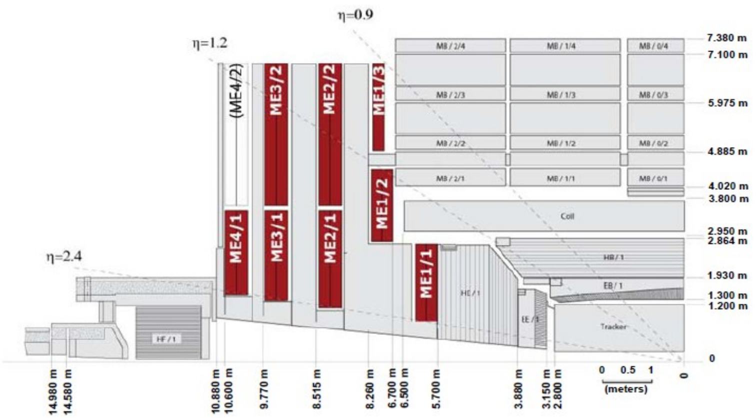


CMS

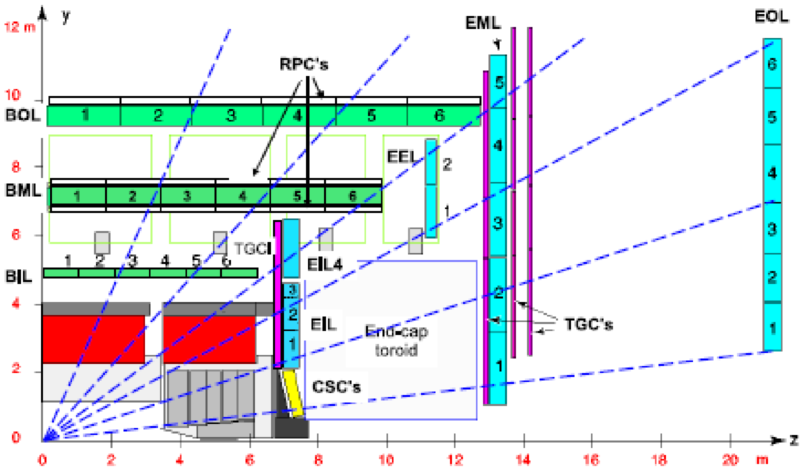


ATLAS

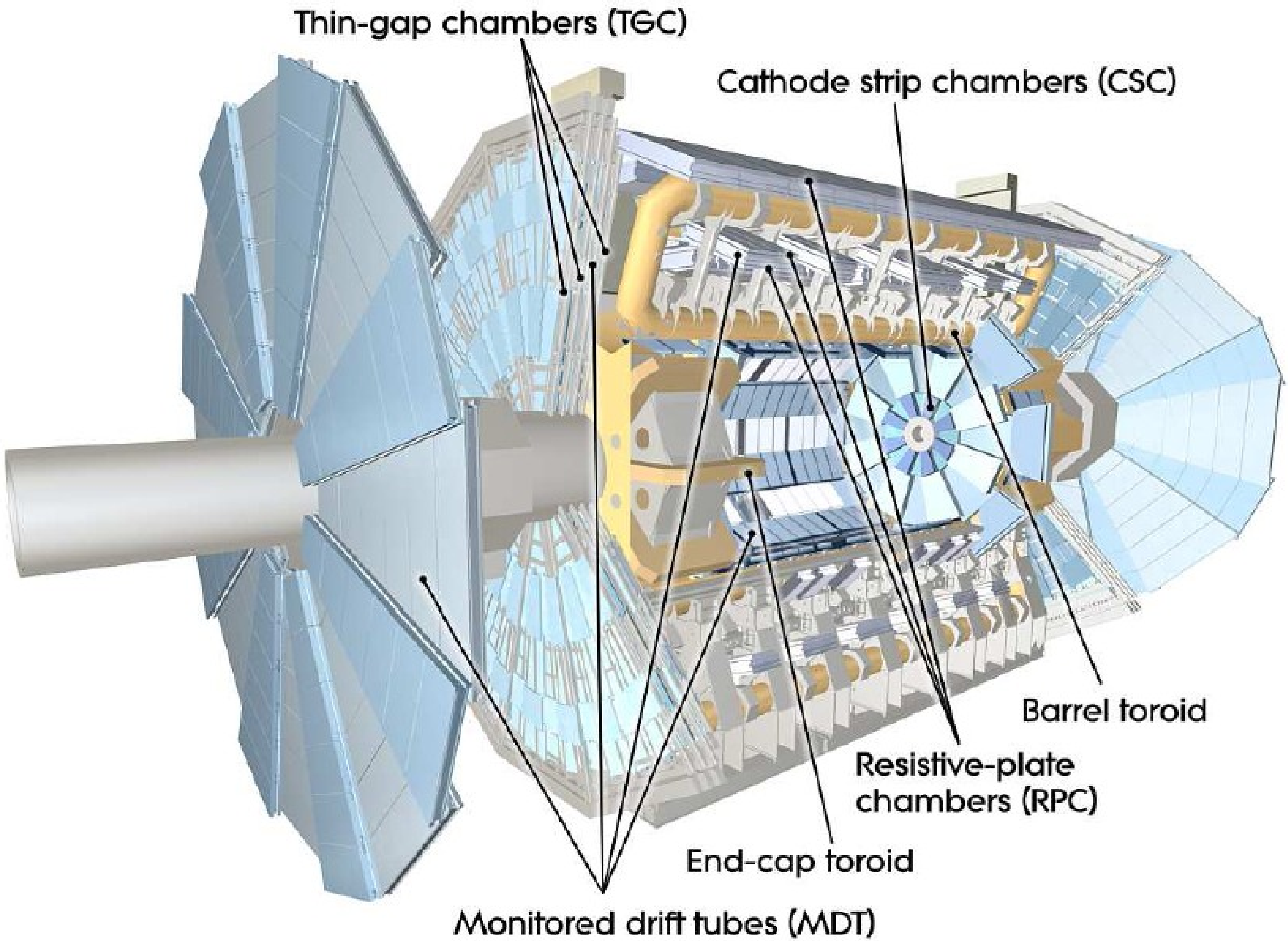
Muon EndCap Detectors



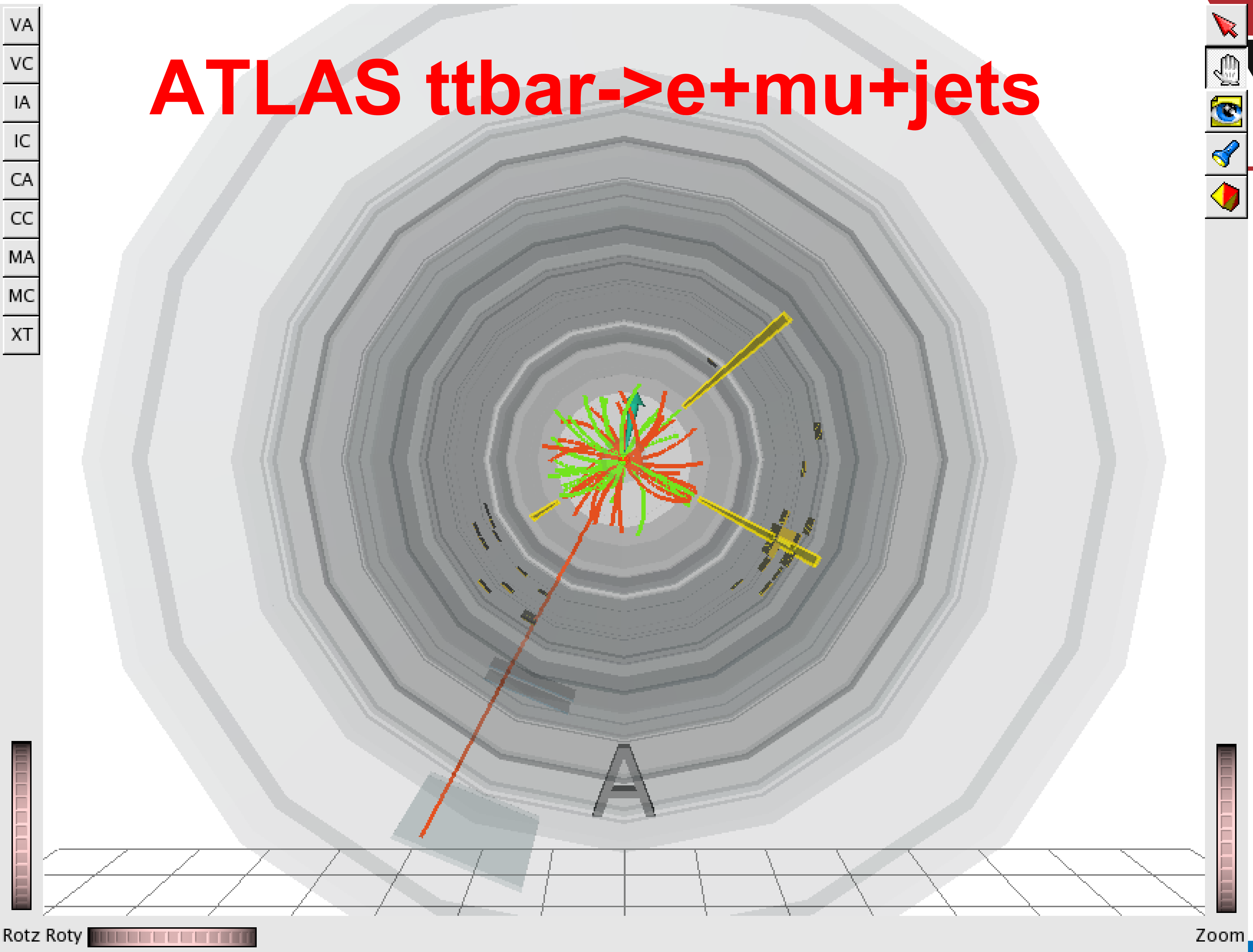
CMS



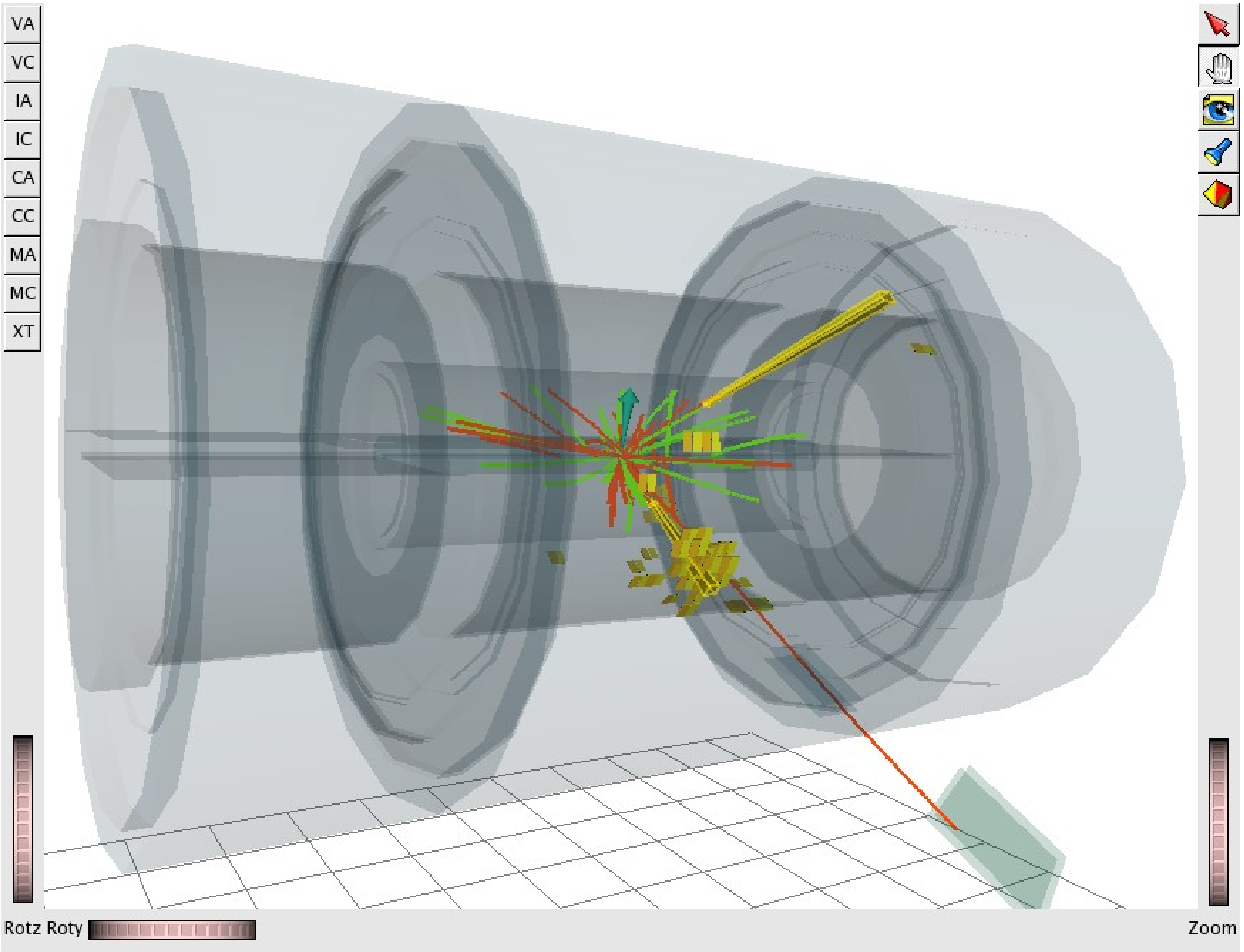
ATLAS


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

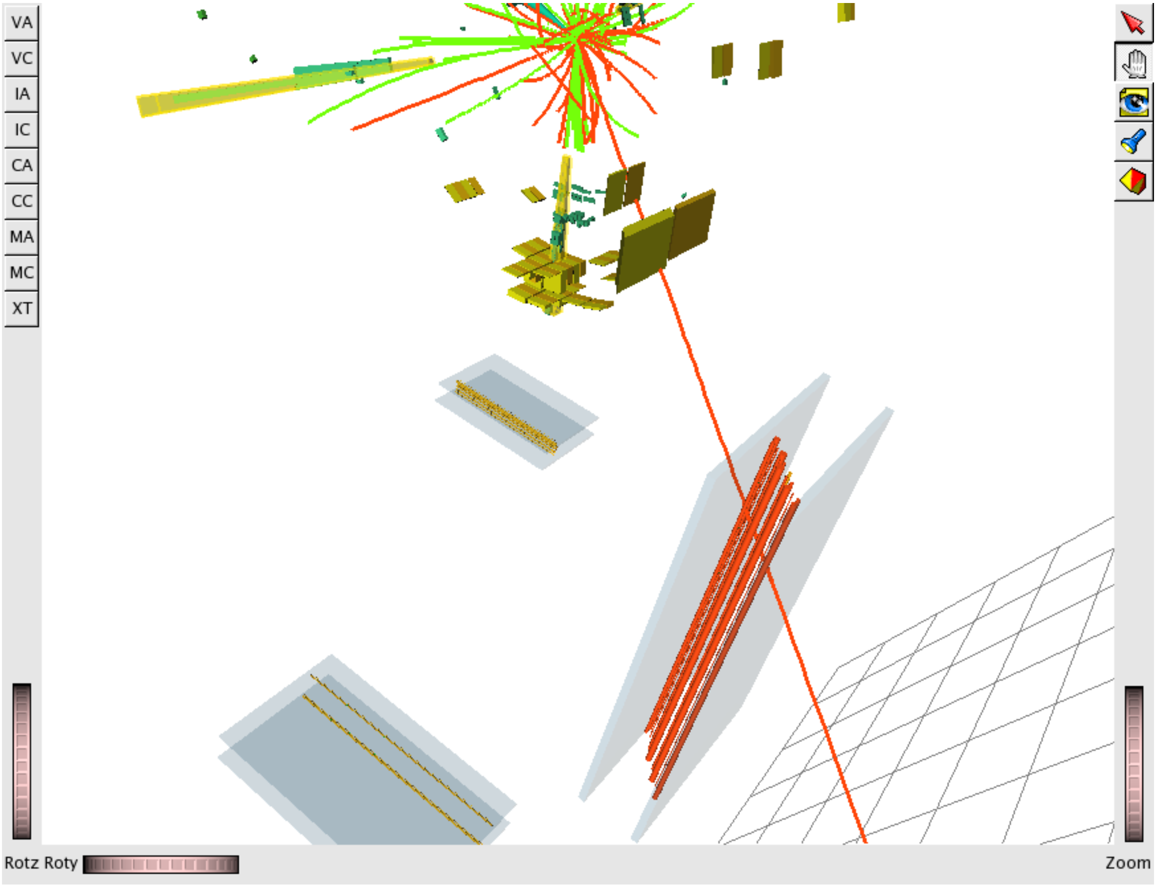
ATLAS ttbar->e+mu+jets



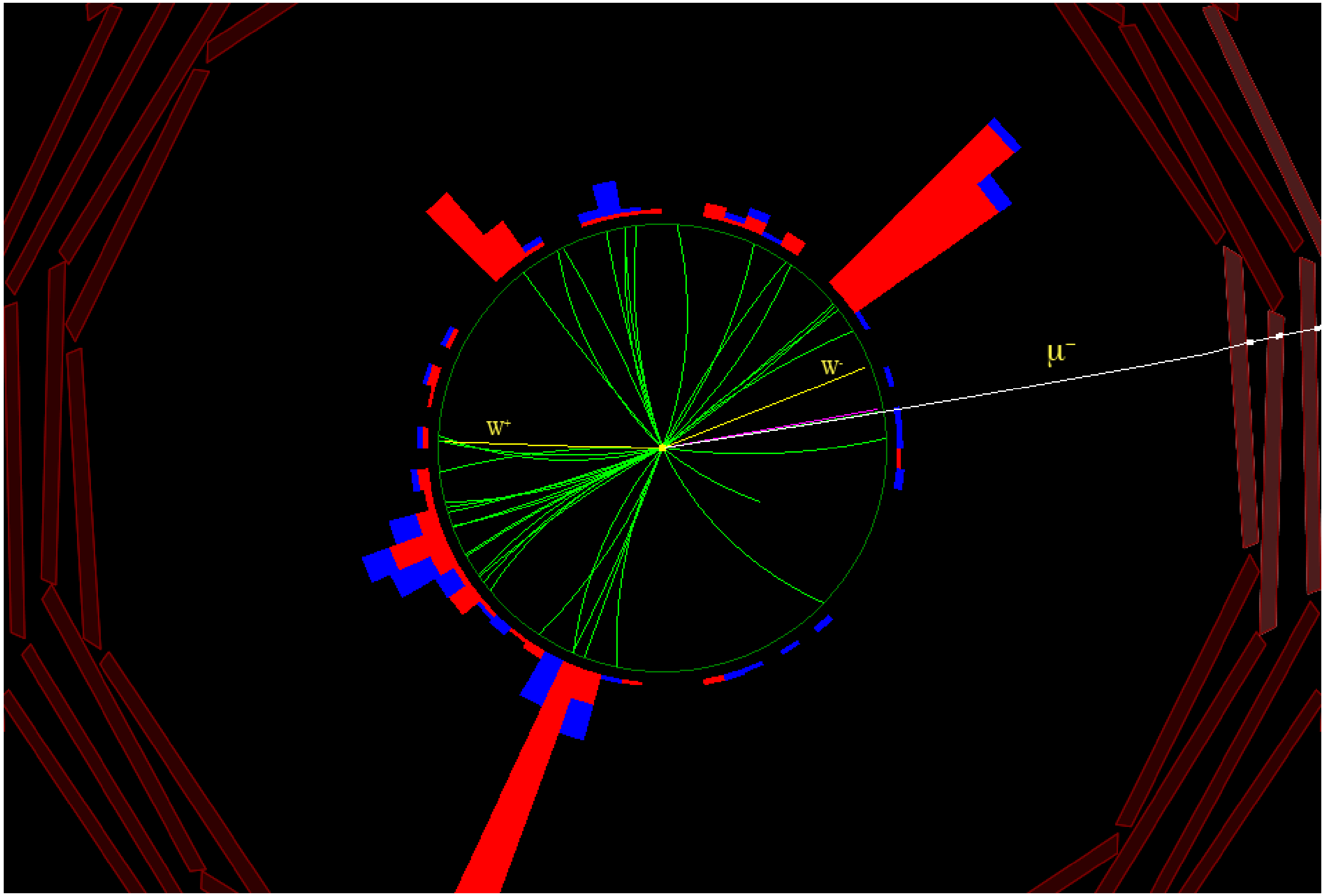
ATLAS ttbar->e+mu+jets



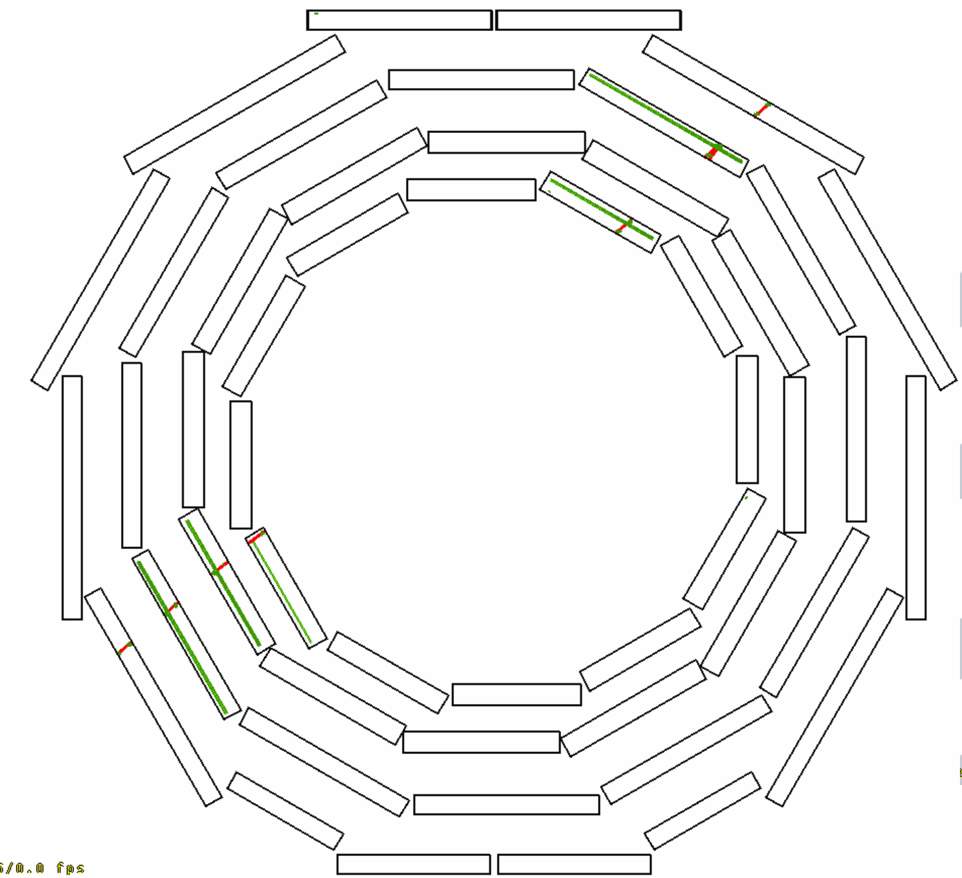
ATLAS ttbar->e+mu+jets



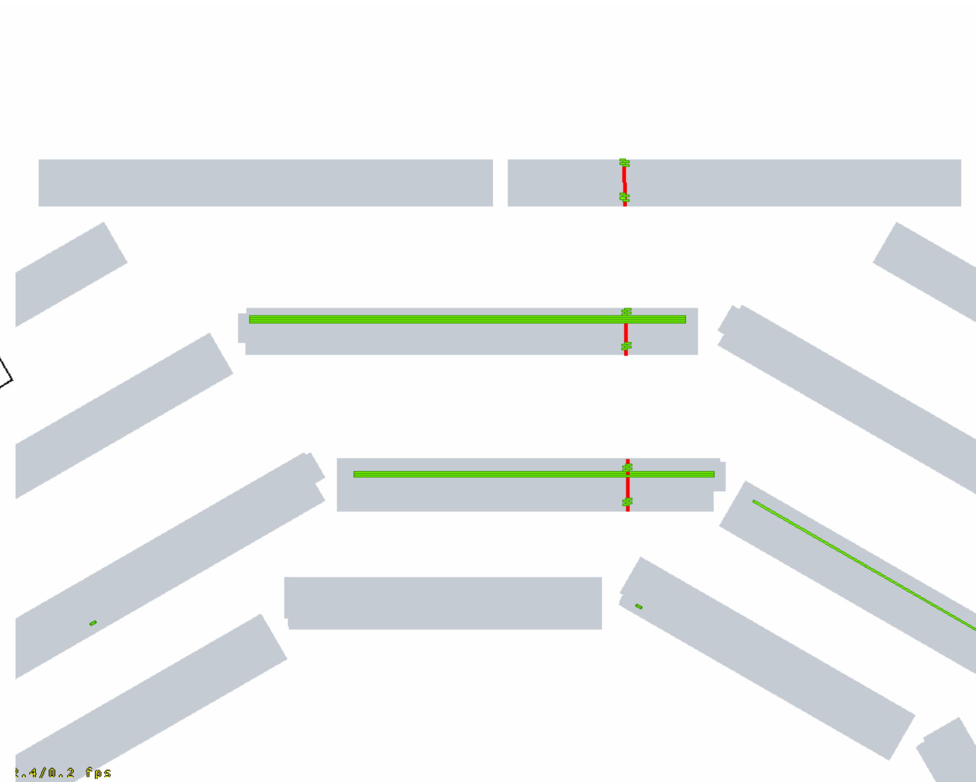
CMS ttbar->mu+jets



Cosmic Rays in CMS



B Field off

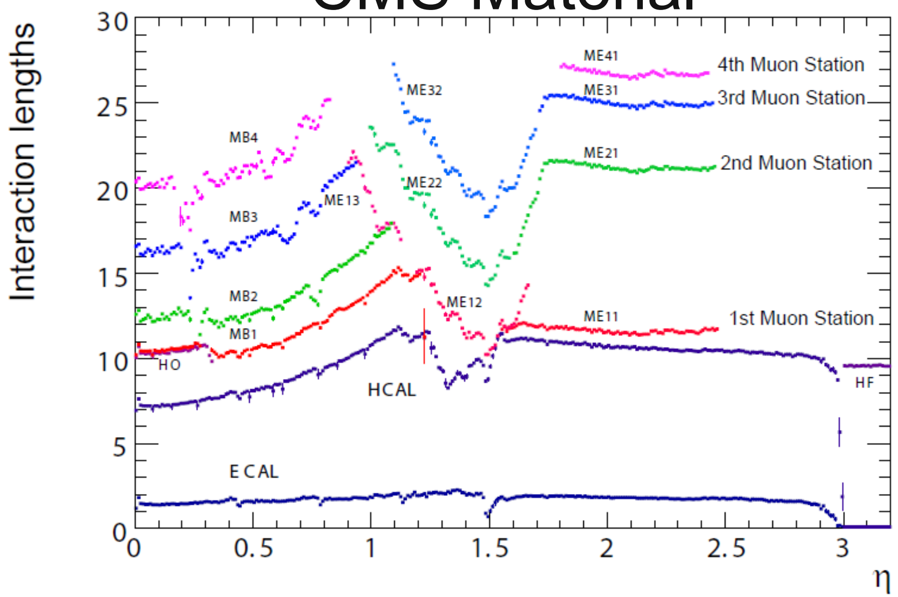


B Field on

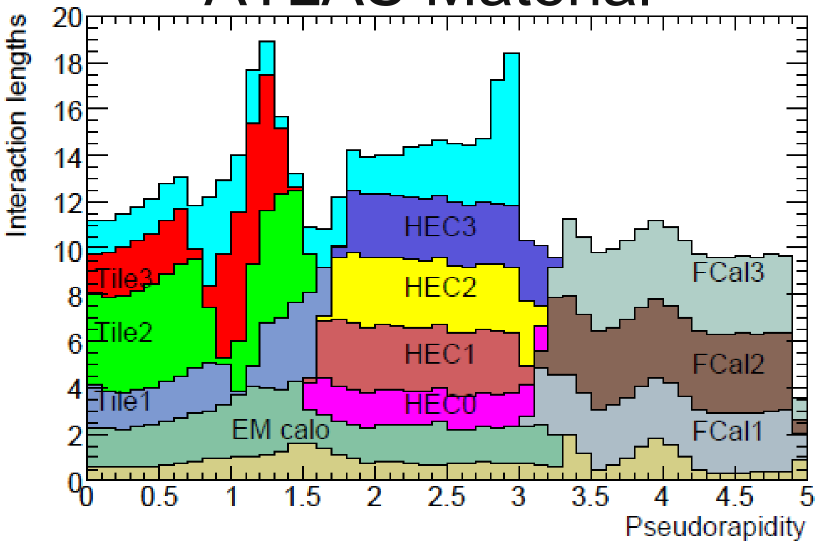
Muon Backgrounds

- Particle Decay-in-Flight (small at high Pt)
- Punchthru
- Random spray + random track (shielding)

CMS Material



ATLAS Material



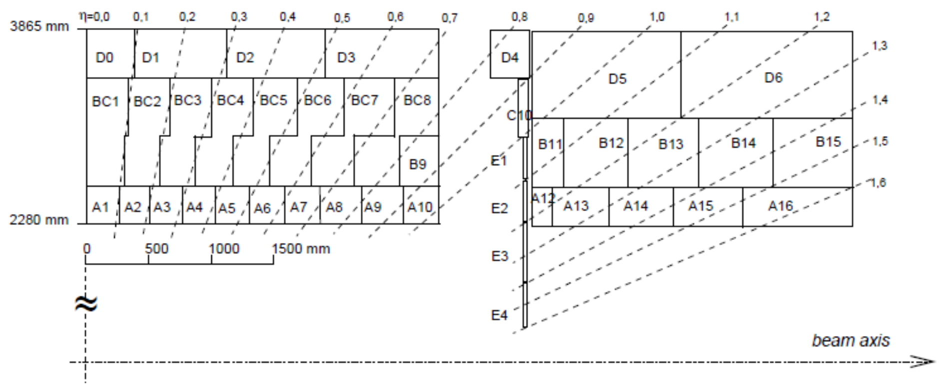
Punchthru probabilities $e^{-10} = 5\times10^{-5}$ $e^{-20} = 2\times10^{-9}$

Hadron Calorimeters

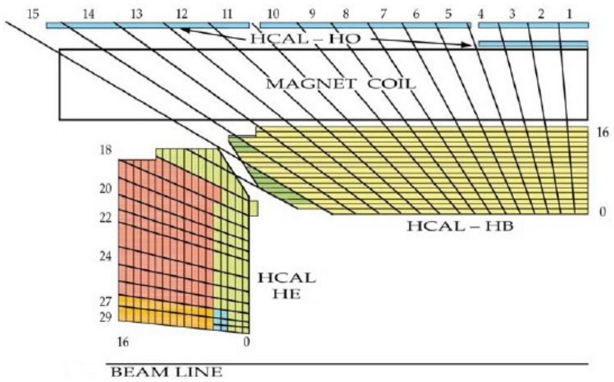
- CMS: HB=Barrel, HE=Endcap, HO=Outer,   Steel/Brass+Scintillator
- ATLAS: Tile=Barrel, HEC=Endcap,   Steel+Scintillator
- Issues include pion shower containment, segmentation, jet reconstruction.

Hadron Calorimeters

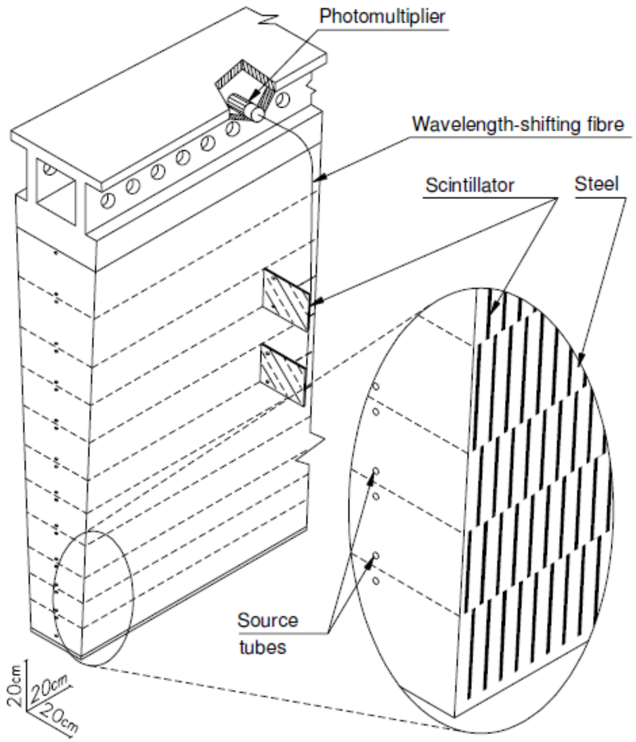
ATLAS



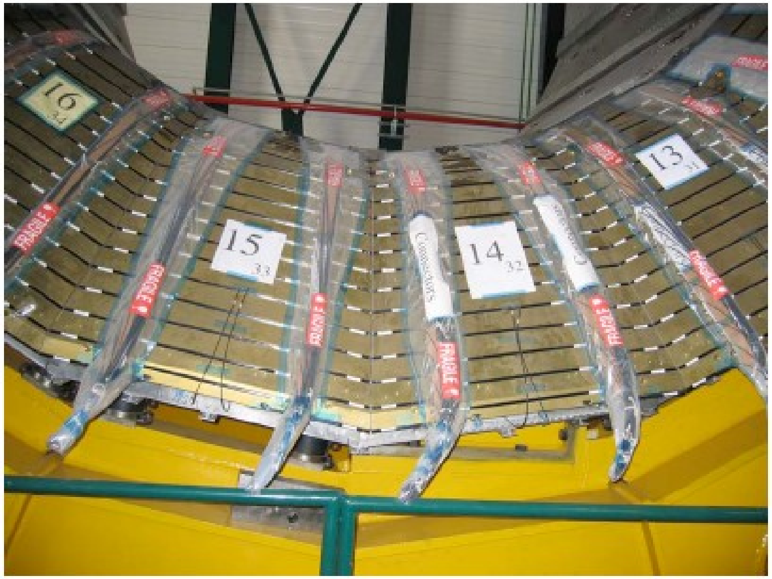
CMS



Hadron Calorimeters

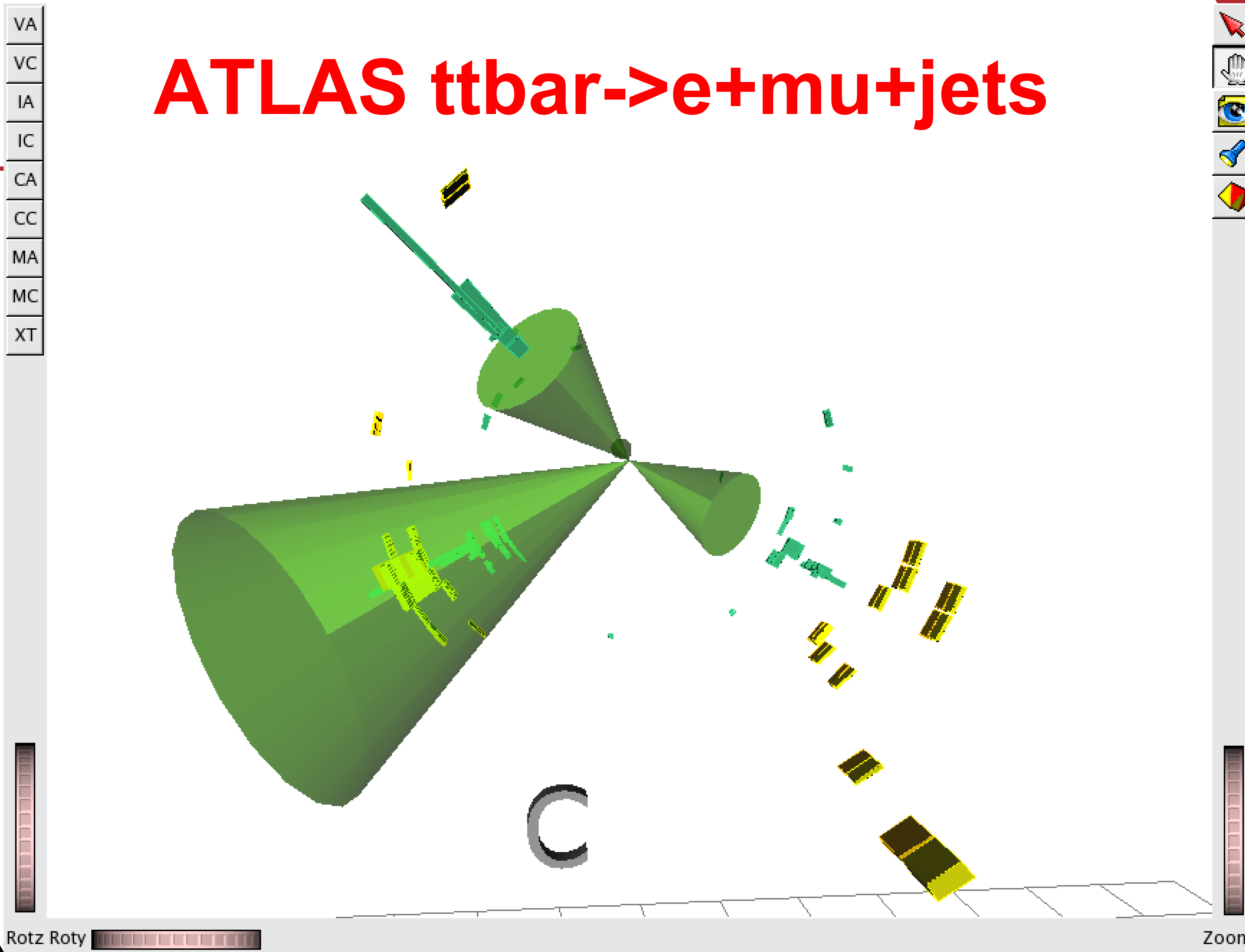


ATLAS

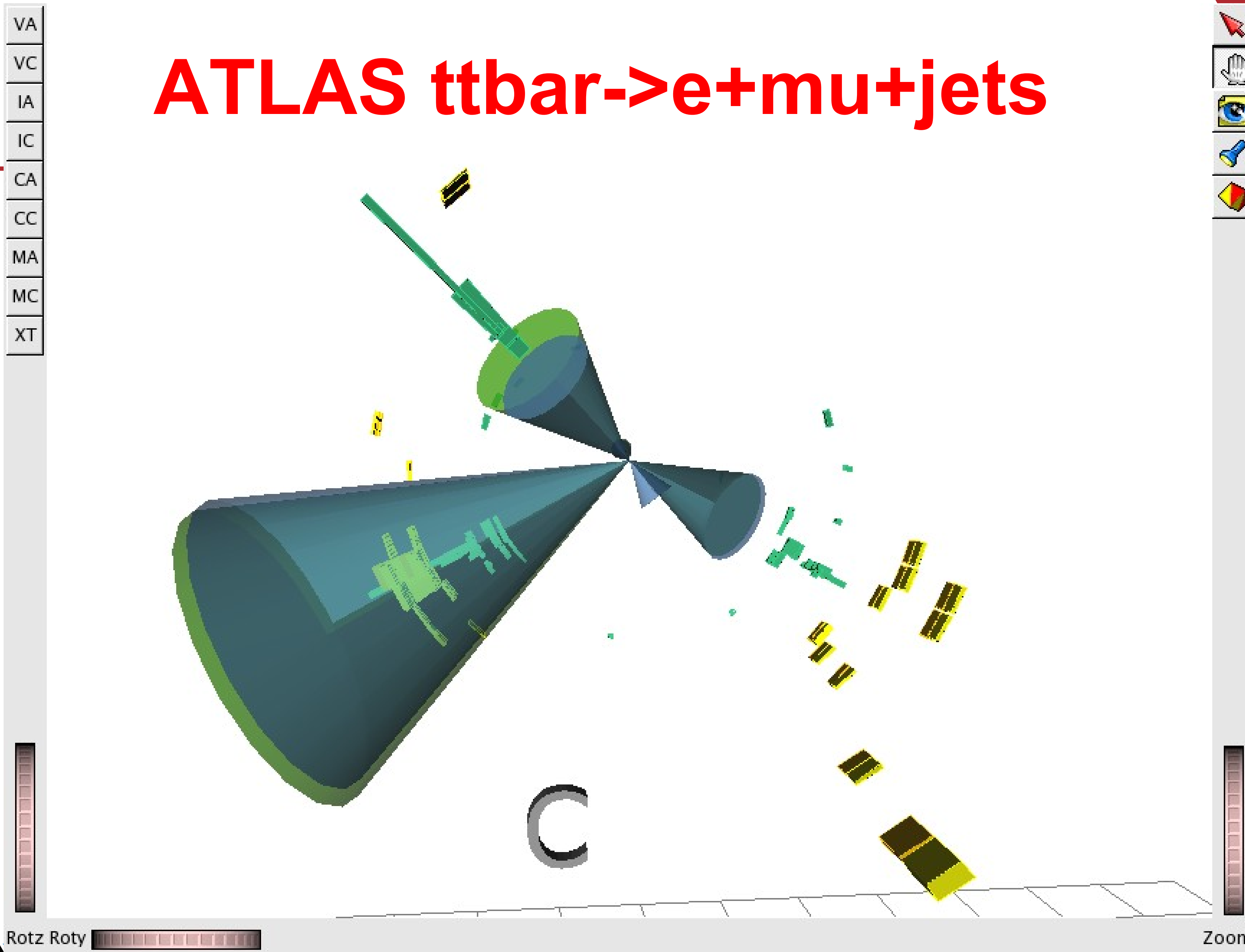


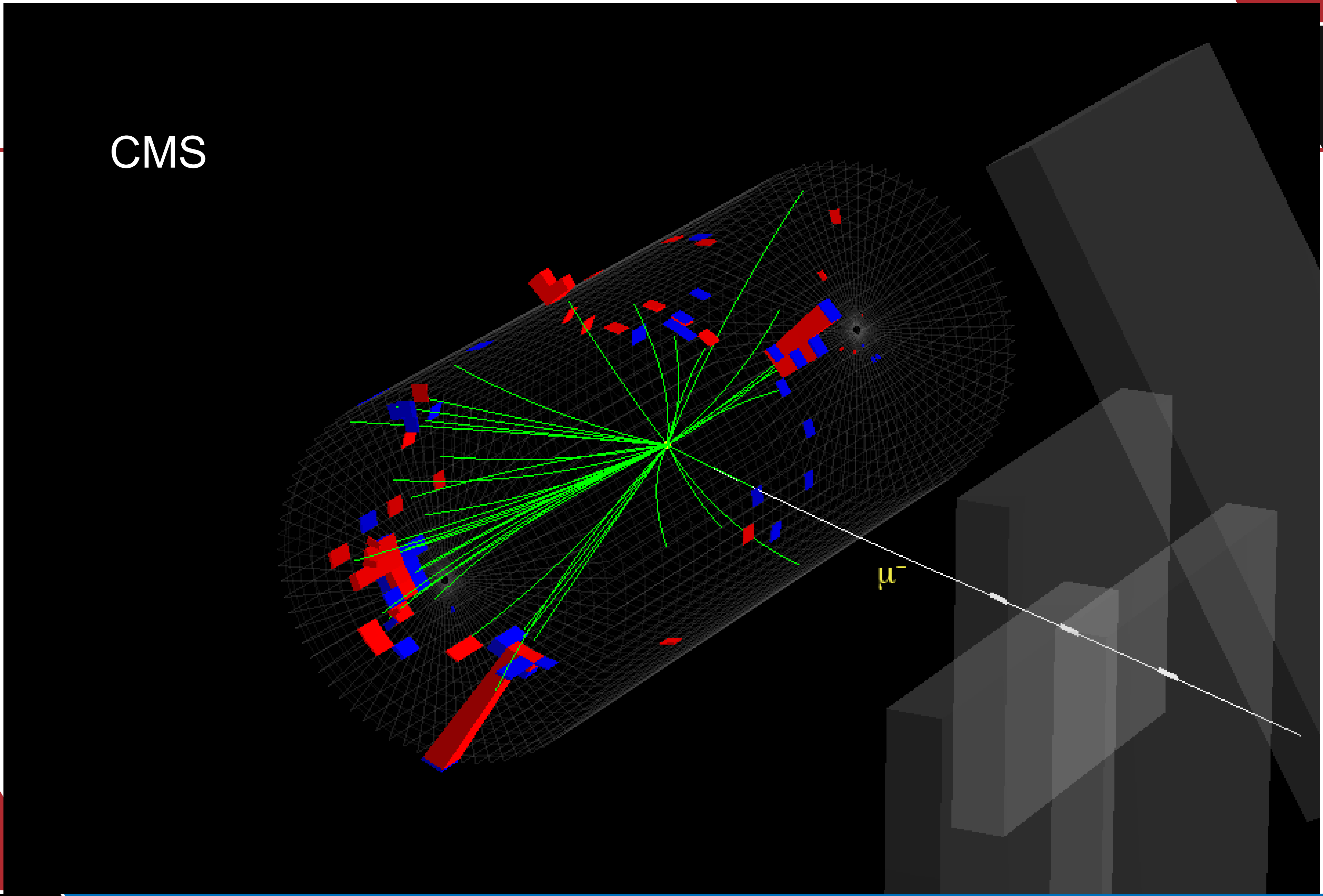
CMS

ATLAS ttbar->e+mu+jets



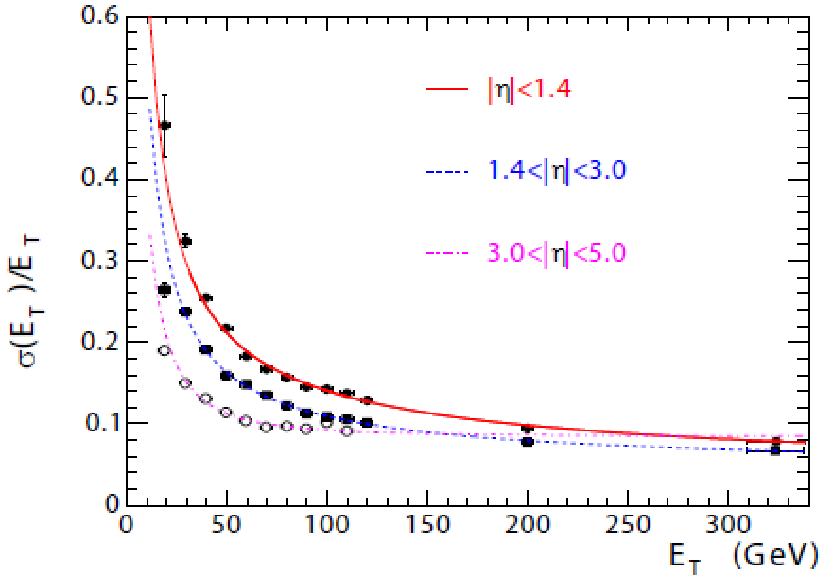
ATLAS ttbar->e+mu+jets



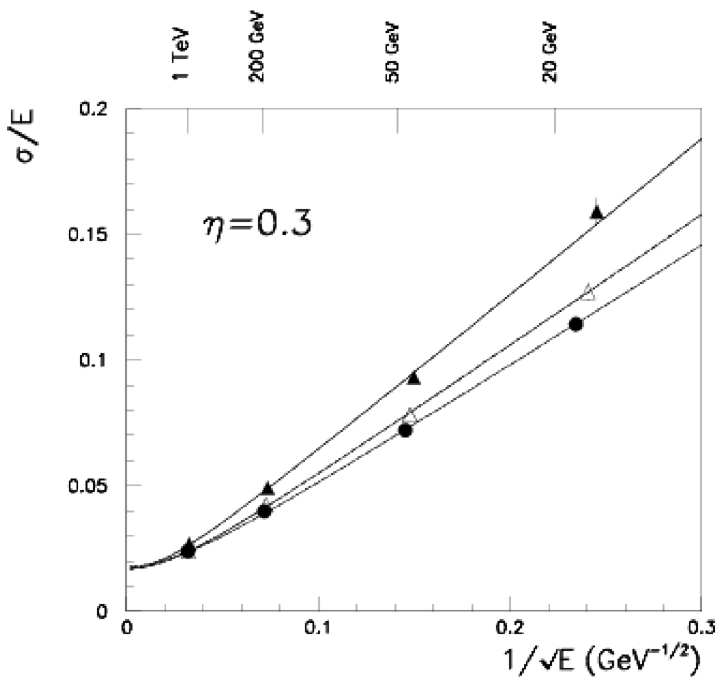

CMS
μ⁻

Jet Resolutions

Main point to make is difficulty in making comparison, depends on angles, algorithm, handling of non-gaussian tails, etc.



CMS

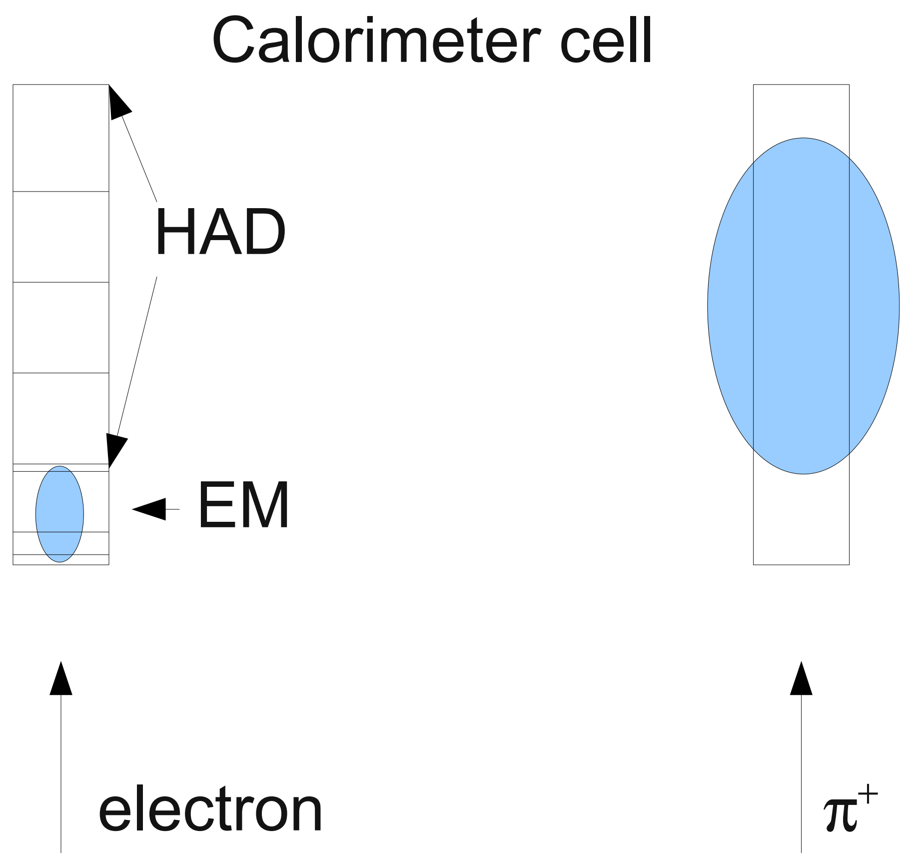


Cone sizes 0.4, 0.7, 1.5

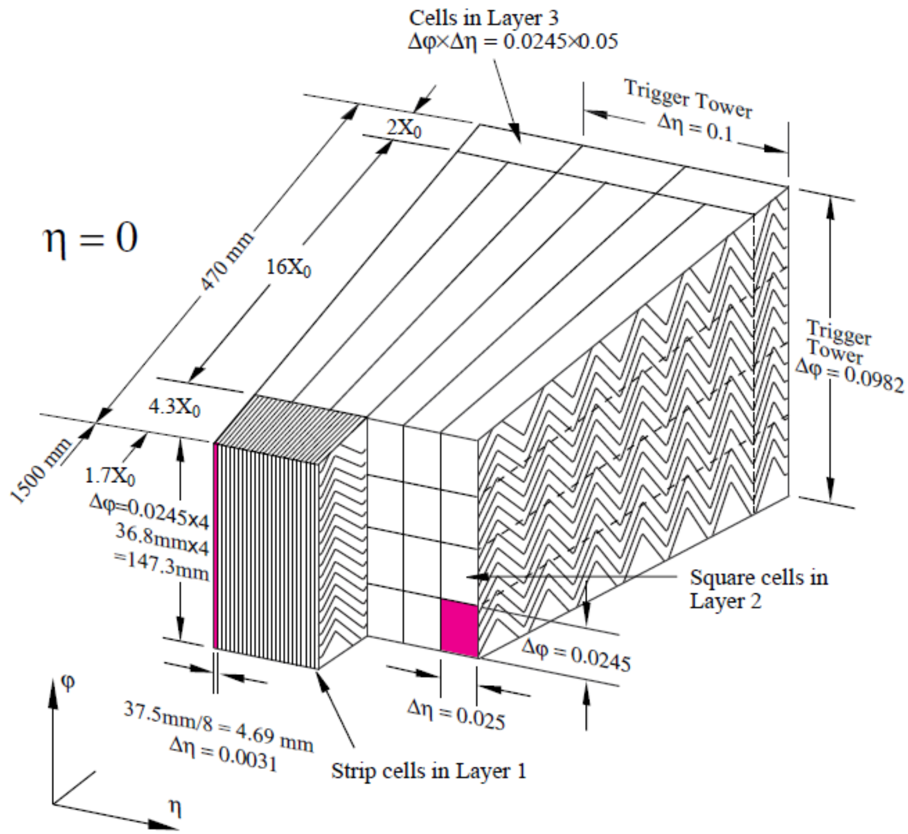
ATLAS

Calorimeter Electron ID

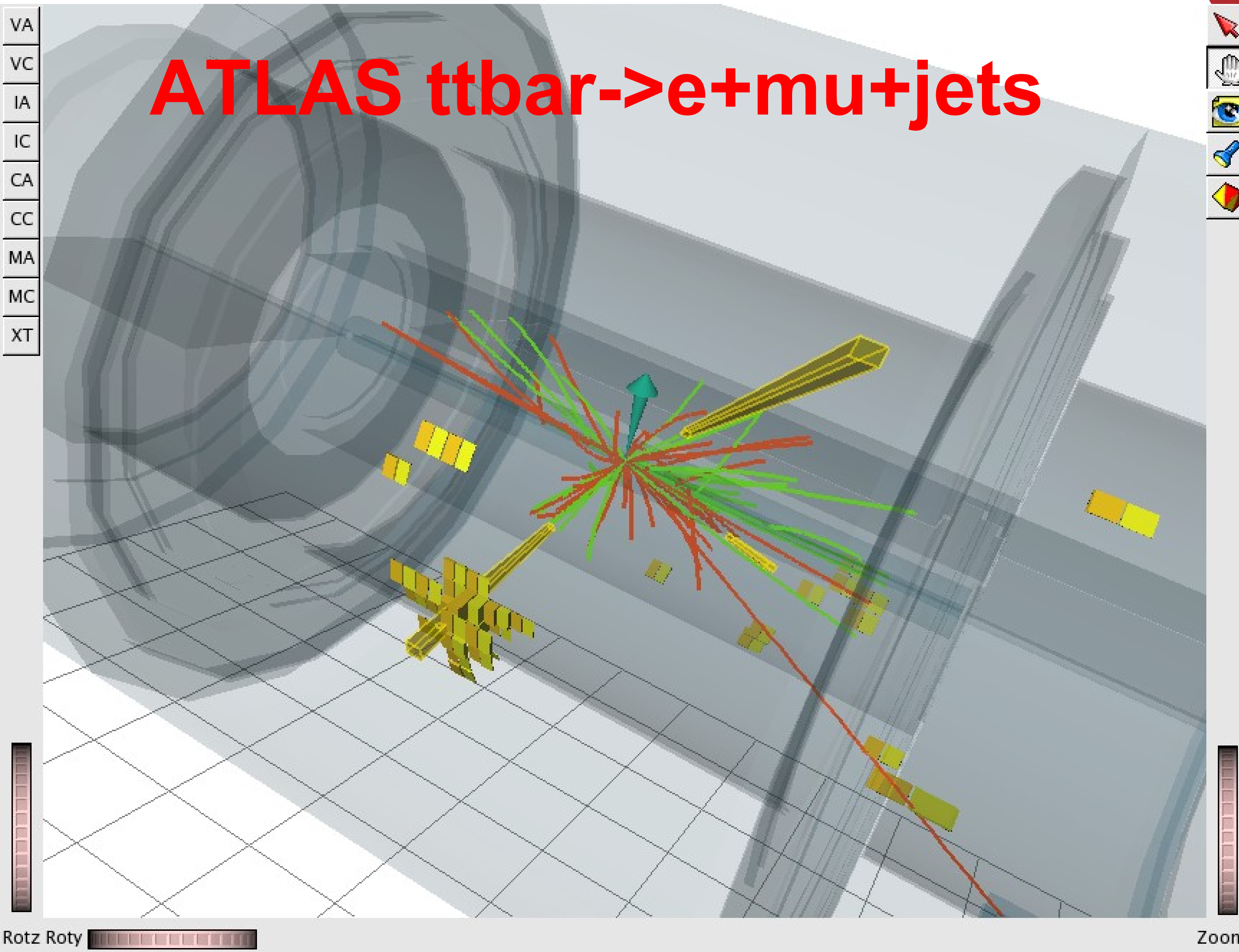
- Lateral and longitudinal profiles help reject pion backgrounds.
- Easy to reject 1/100 pions, many times need better than 1/1000 rejection.
- Other handles include track P to calorimeter E match, and transition radiation detectors.



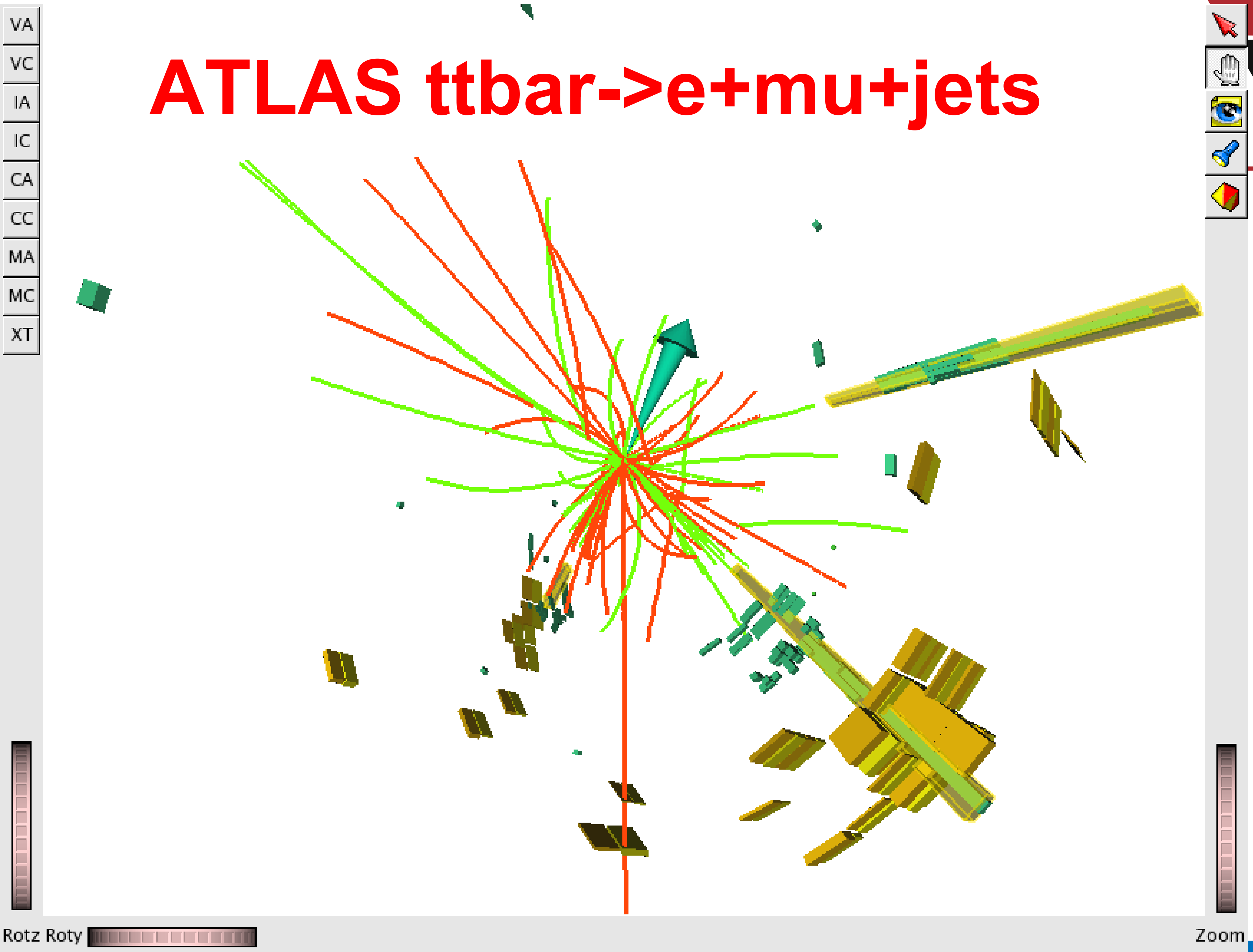
ATLAS Barrel Lead/Liquid Argon EM Calorimeter



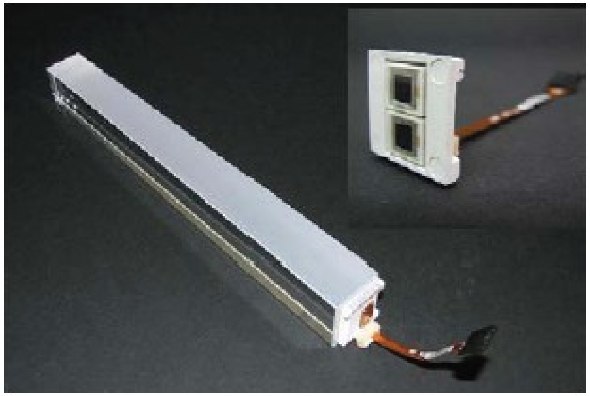
ATLAS ttbar->e+mu+jets

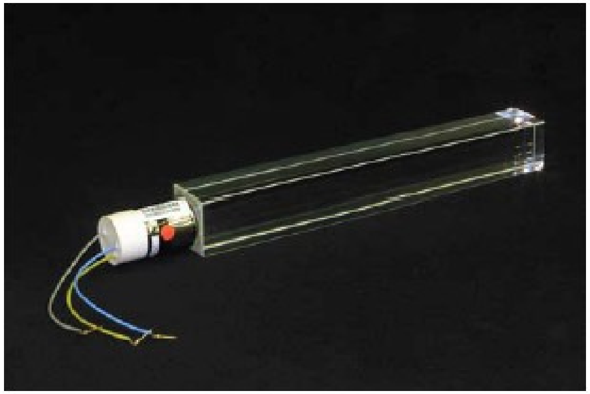


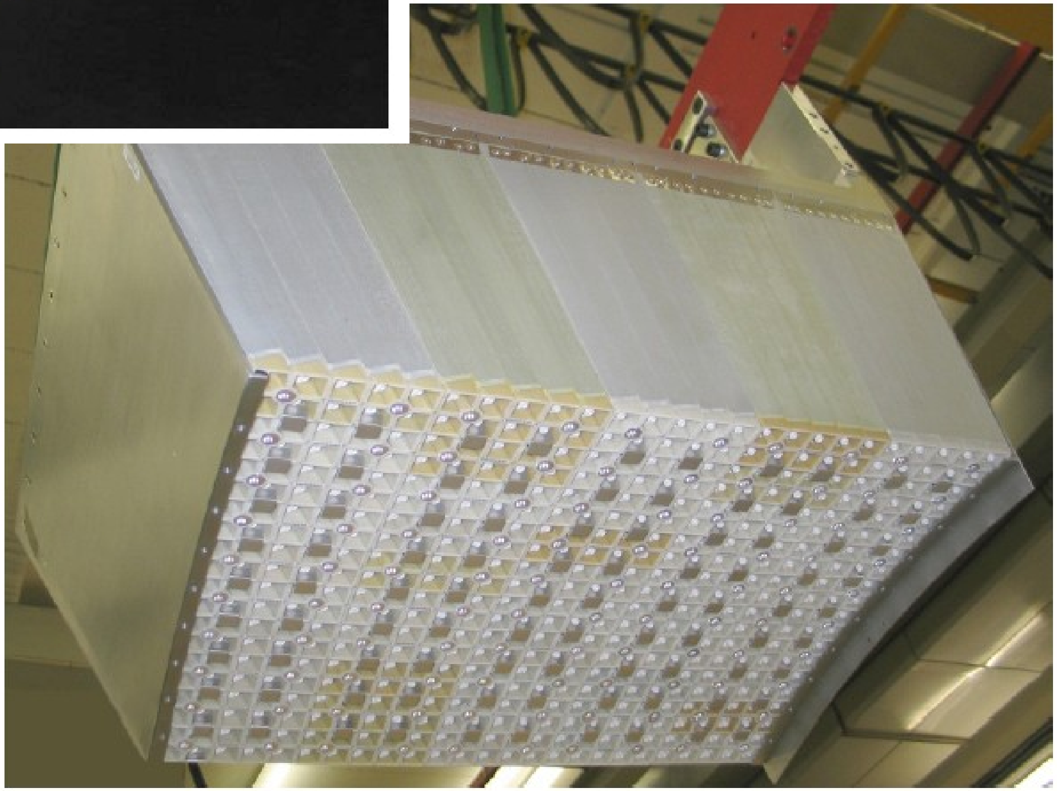
ATLAS ttbar->e+mu+jets



CMS EM Calorimeter



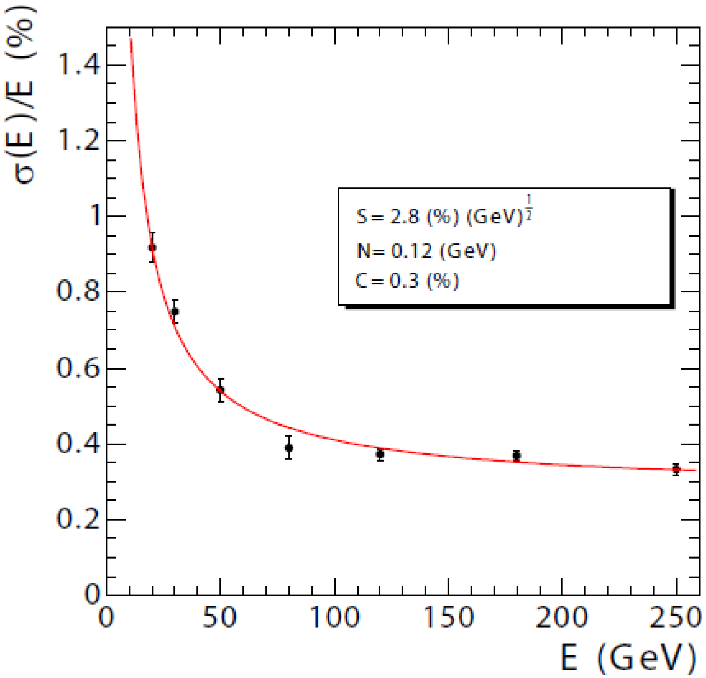




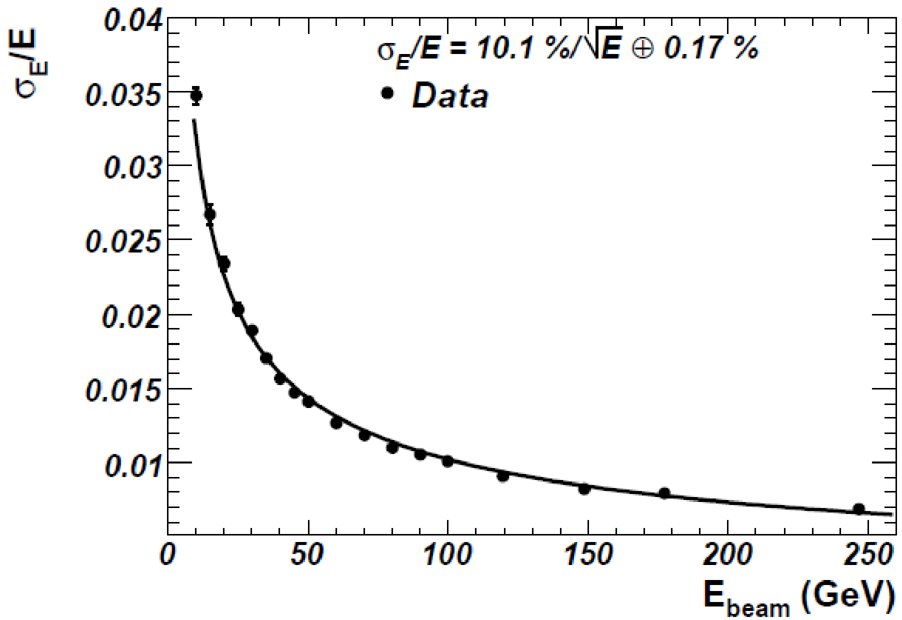
CMS Lead Tungstate Crystals

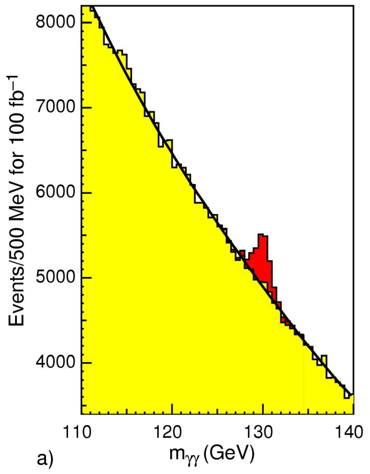
Greatly reduce fluctuations due to losses in dead layers in conventional sampling calorimeter.

EM Resolution



CMS





ATLAS

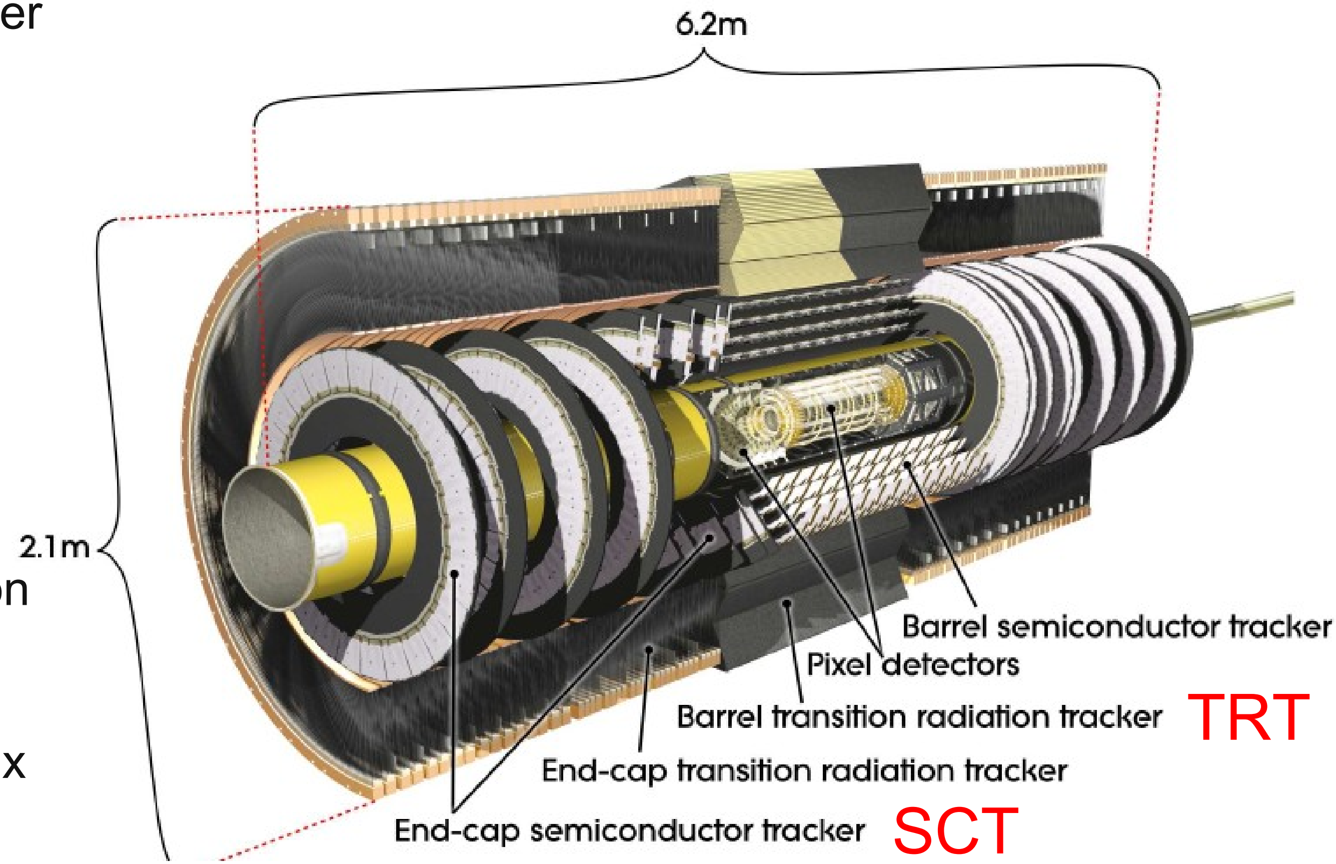
ATLAS Inner Tracking Detectors

- Inner half silicon, outer half straws.

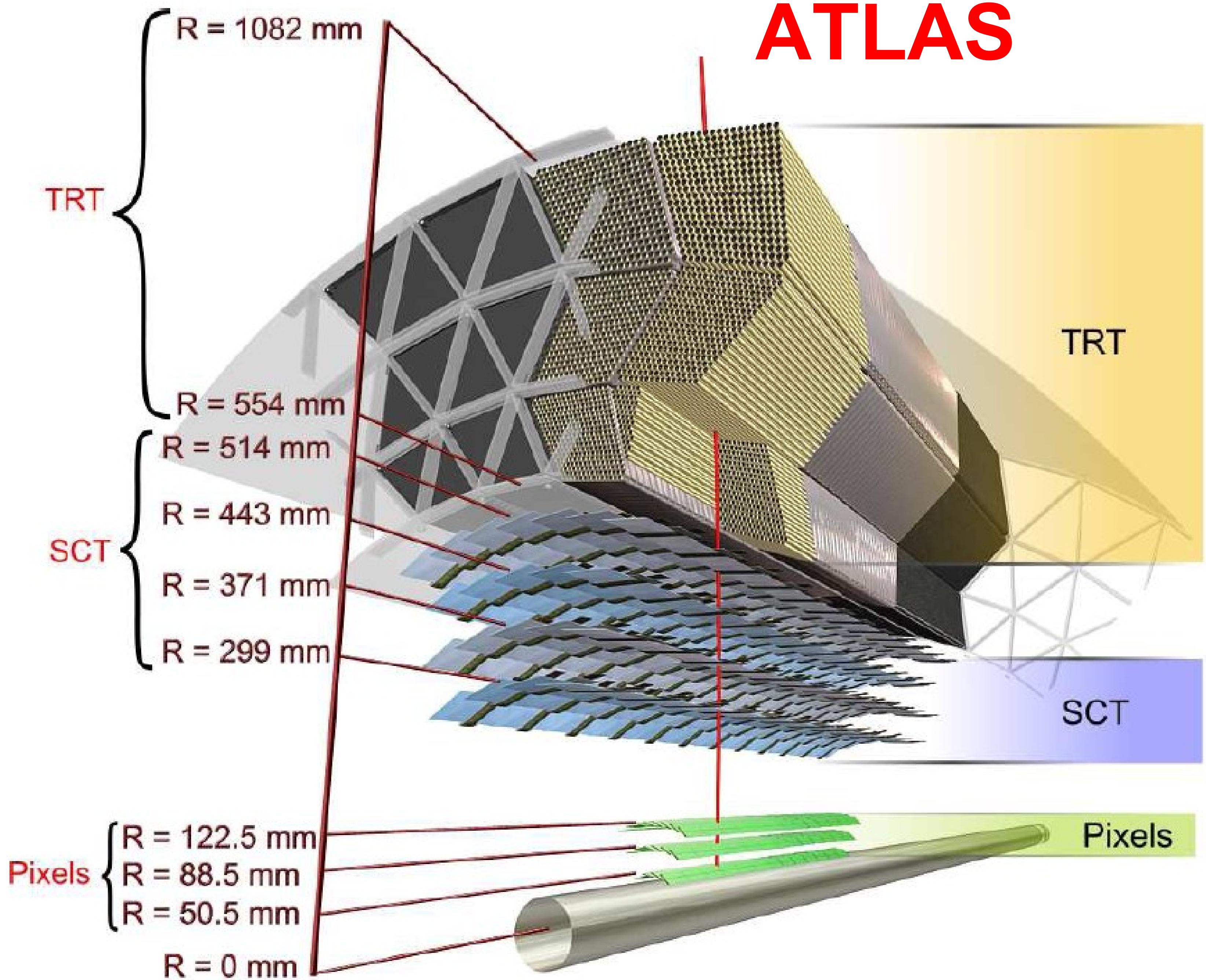
- Straws 4mm tubes with wire and gas.

- Interspersed with straws is material (polypropylene) to provide dielectric difference and transition radiation for electrons.

- Xenon gas part of mix to absorb TR and increase signal.



ATLAS


R = 1082 mm
TRT
R = 554 mm
R = 514 mm
R = 443 mm
SCT
R = 371 mm
R = 299 mm
R = 122.5 mm
Pixels
R = 88.5 mm
R = 50.5 mm
R = 0 mm
TRT
SCT
Pixels

ATLAS

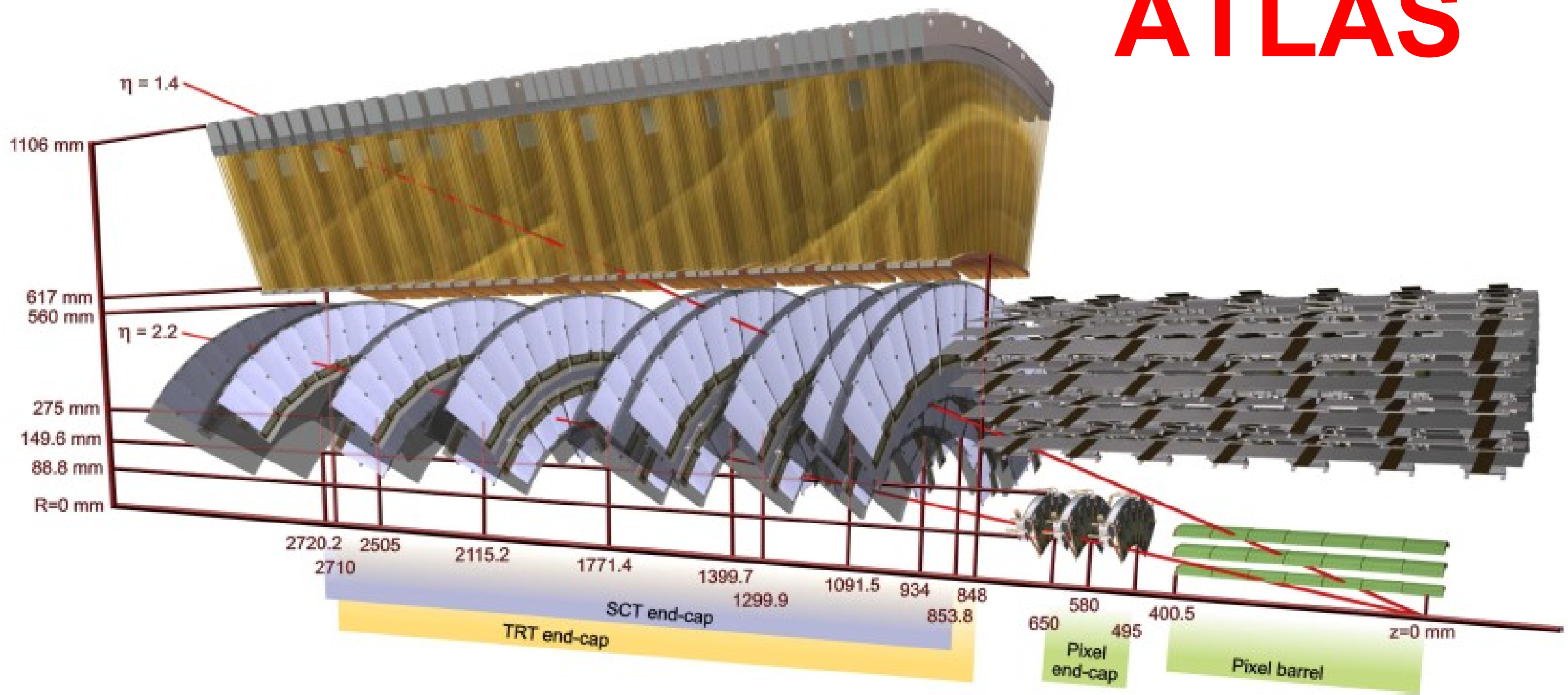
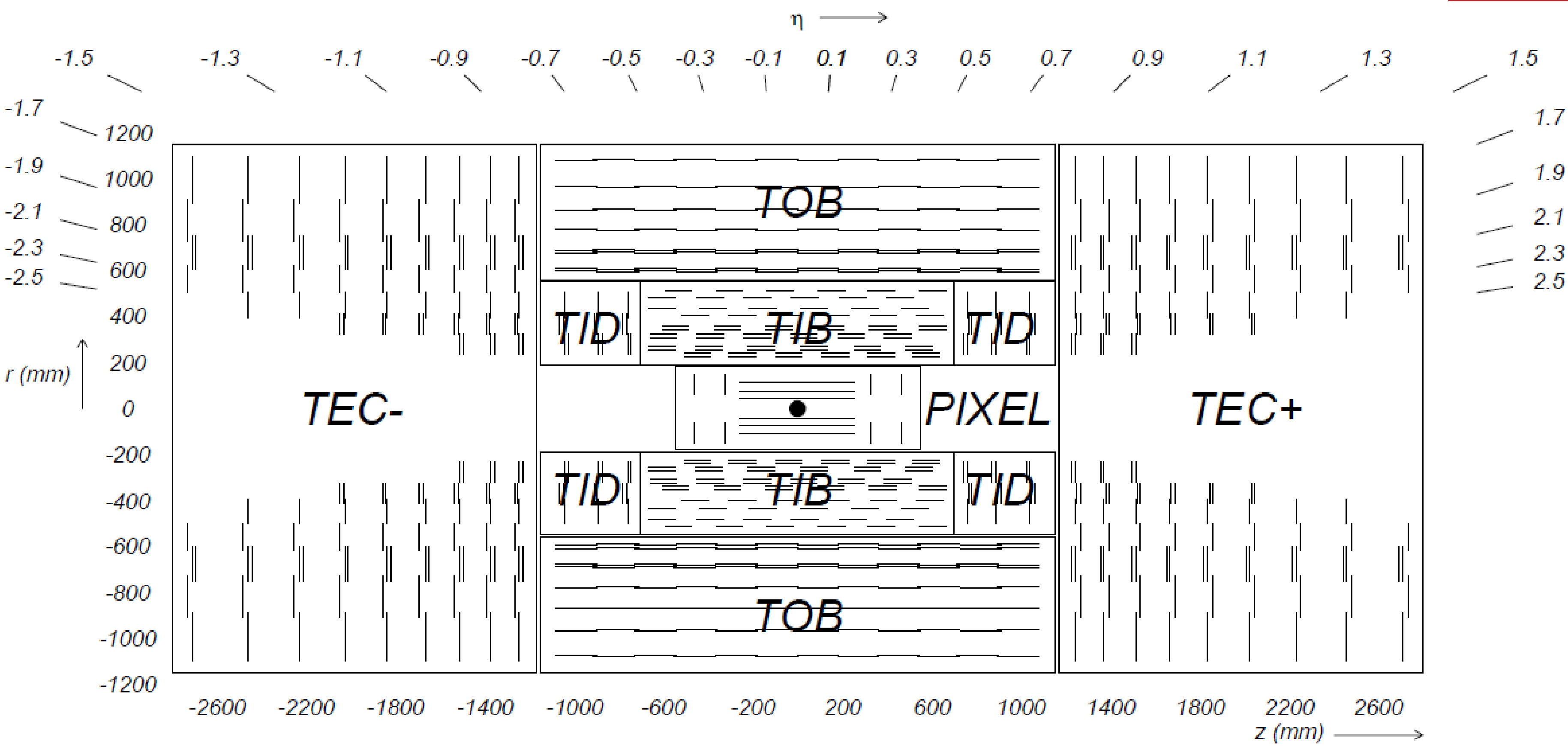
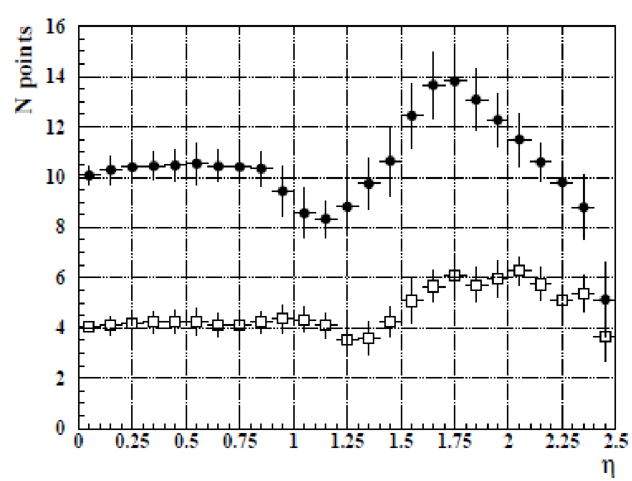


Figure 4.3: Drawing showing the sensors and structural elements traversed by two charged tracks of 10 GeV p_T in the end-cap inner detector (η = 1.4 and 2.2). The end-cap track at η = 1.4 traverses successively the beryllium beam-pipe, the three cylindrical silicon-pixel layers with individual sensor elements of $50 \times 400\ \mu m^2$, four of the disks with double layers (one radial and one with a stereo angle of 40 mrad) of end-cap silicon-microstrip sensors (SCT) of pitch $\sim 80\ \mu m$, and approximately 40 straws of 4 mm diameter contained in the end-cap transition radiation tracker wheels. In contrast, the end-cap track at η = 2.2 traverses successively the beryllium beam-pipe, only the first of the cylindrical silicon-pixel layers, two end-cap pixel disks and the last four disks of the end-cap SCT. The coverage of the end-cap TRT does not extend beyond $|\eta| = 2$.



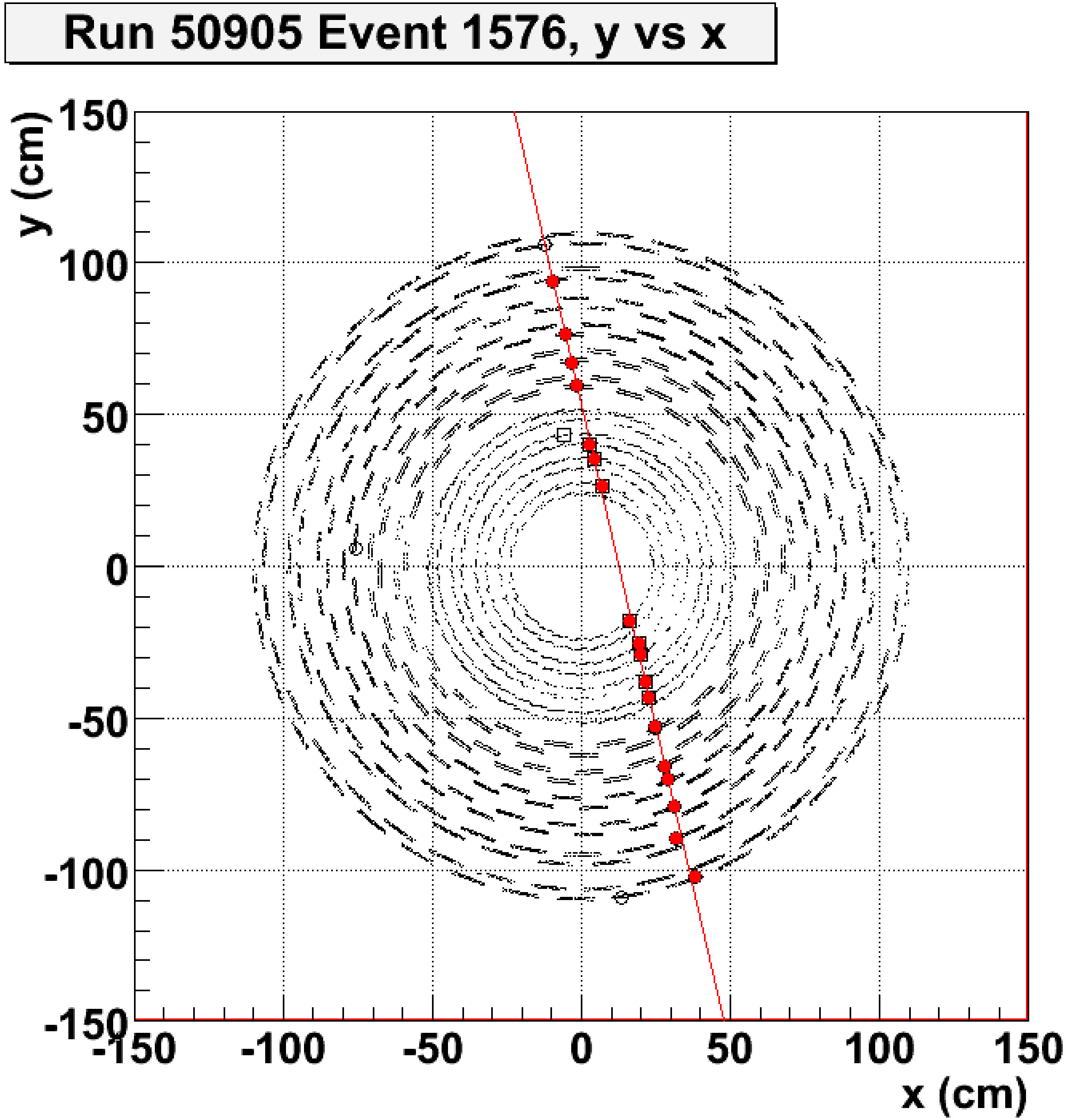
CMS Inner Silicon Trackers, and expected number of measurements per track.

(TOB = Tracker Outer Barrel, etc)



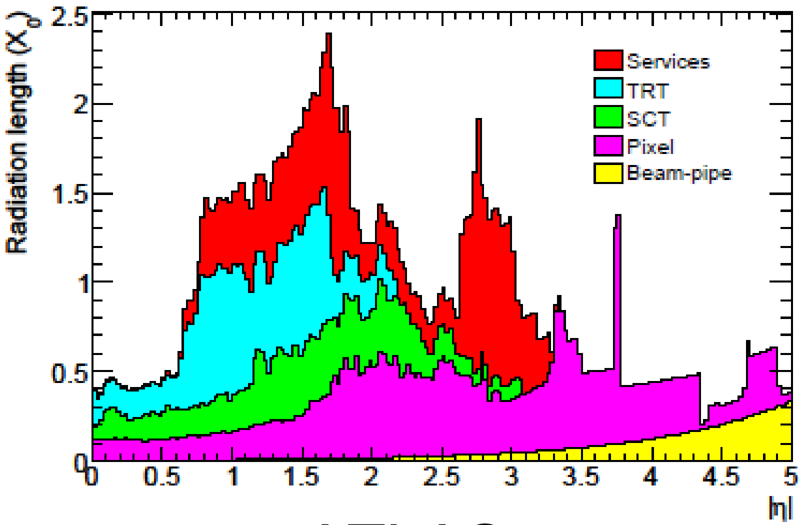
CMS Outer Barrel Support Structure

CMS Cosmics in Inner Detector

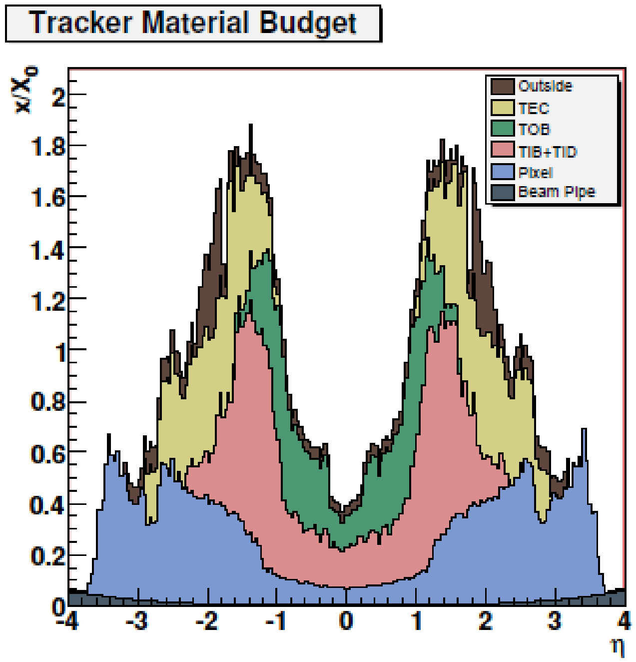


Inner Detector Material

Significant material in inner detectors, causes electron energy loss due to bremsstrahlung, photon conversions before calorimeter, and pion interactions.



ATLAS

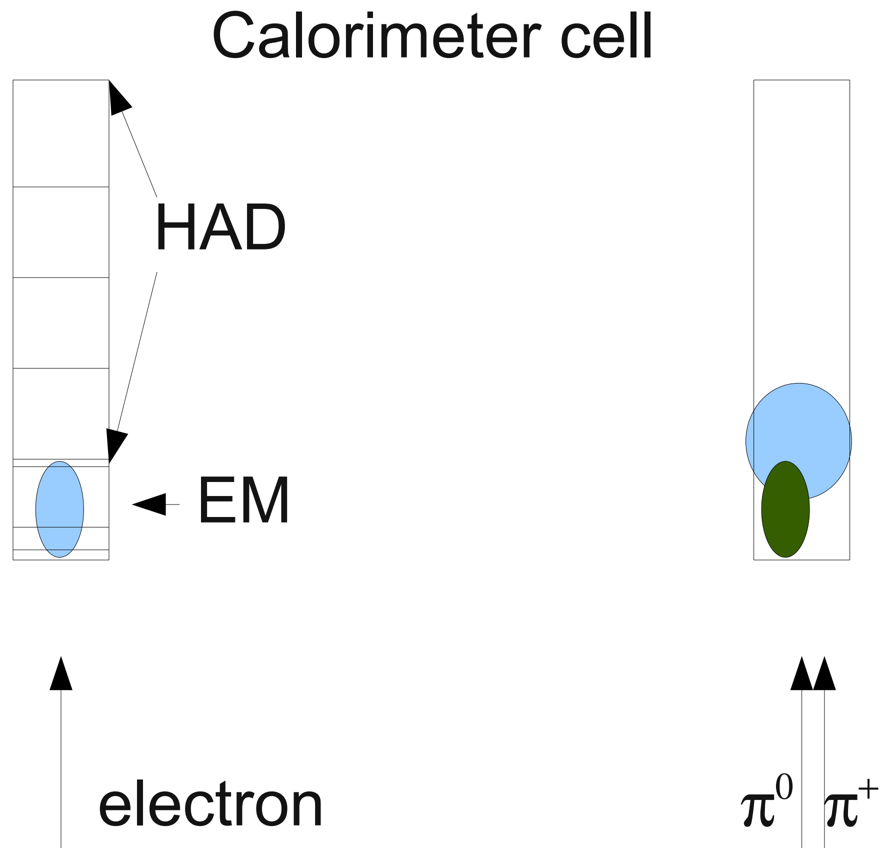


CMS

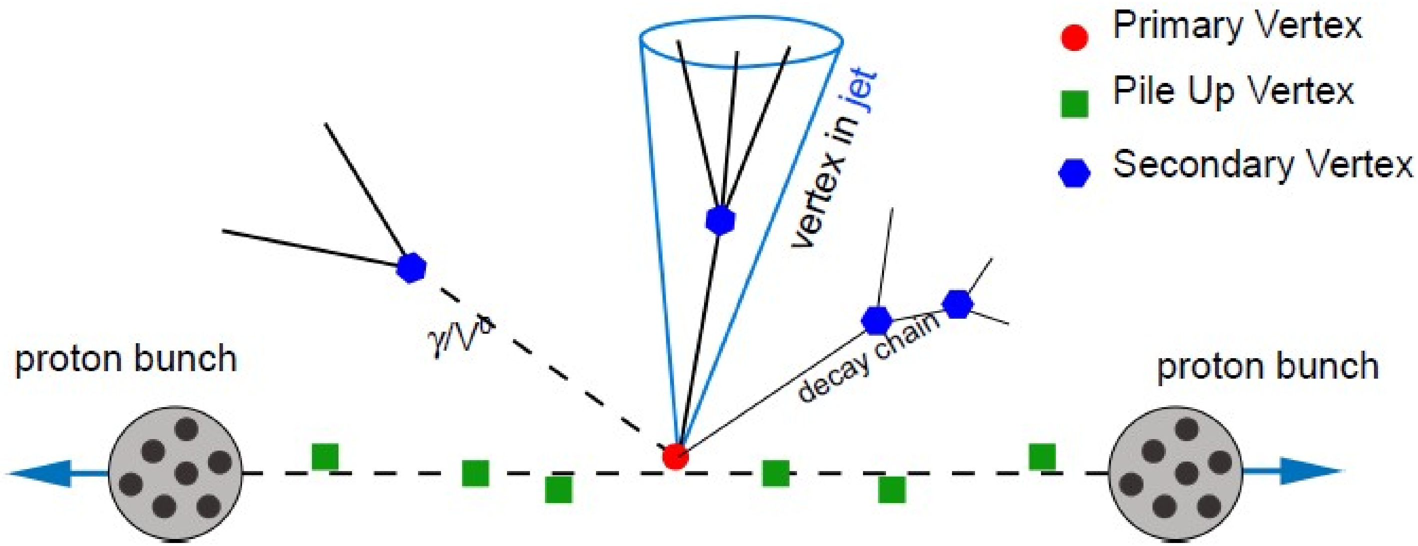
Typical for these material estimates to increase with time...

Calorimeter Electron ID II

- Large electron bremsstrahlung makes it more difficult to reject π^0 overlaps.



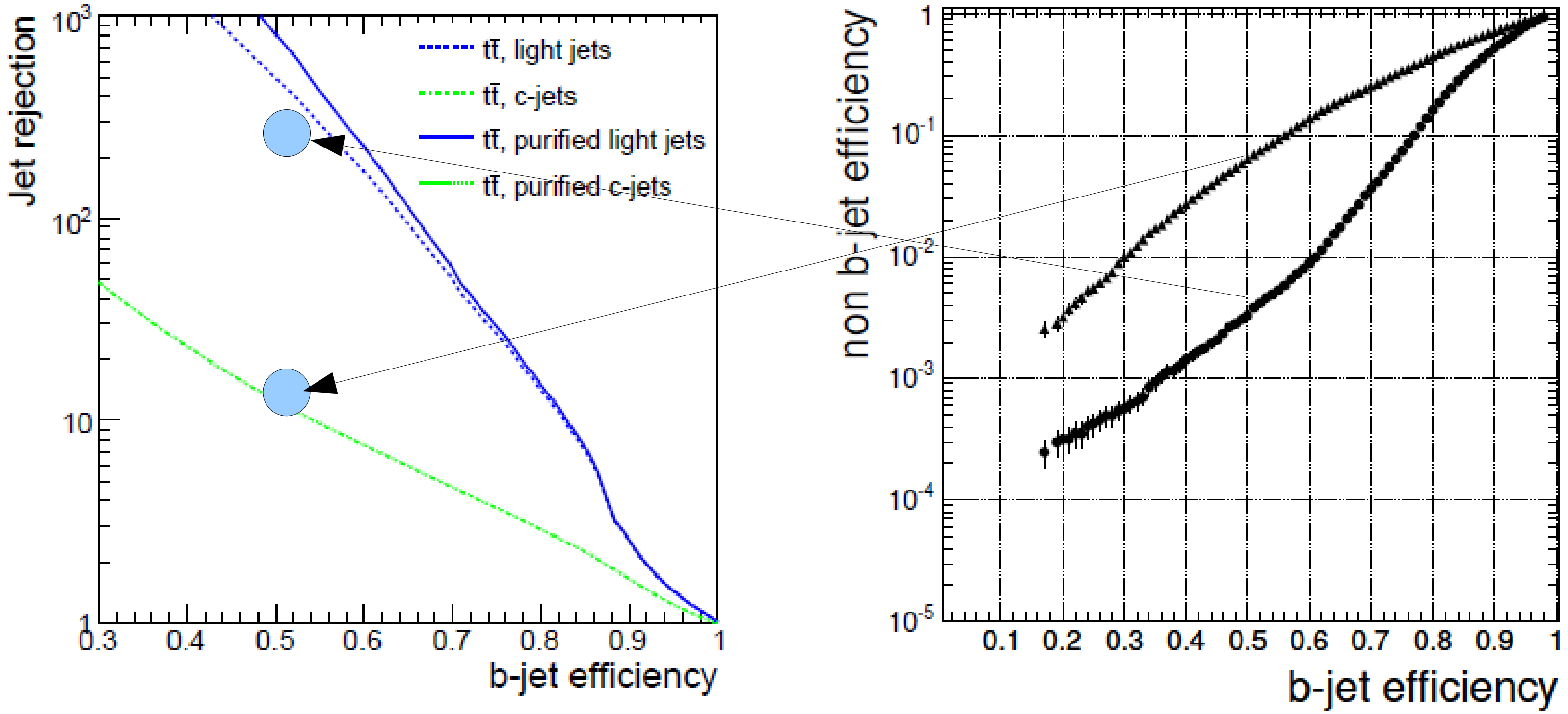
Vertexing



A. Wildauer

Tagging Efficiency

(similar to jets, very algorithm dependent)



ATLAS

CMS

Very similar results

Conclusions

The End. Thanks...